Институт ядерной физики и технологий
Кафедра №40 «Физика элементарных частиц»

Моделирование процесса ассоциативного рождения бозона Хиггса с одиночным топ-кварком на БАК

Научный руководитель: Солдатов Е.Ю., к.ф.-м.н.

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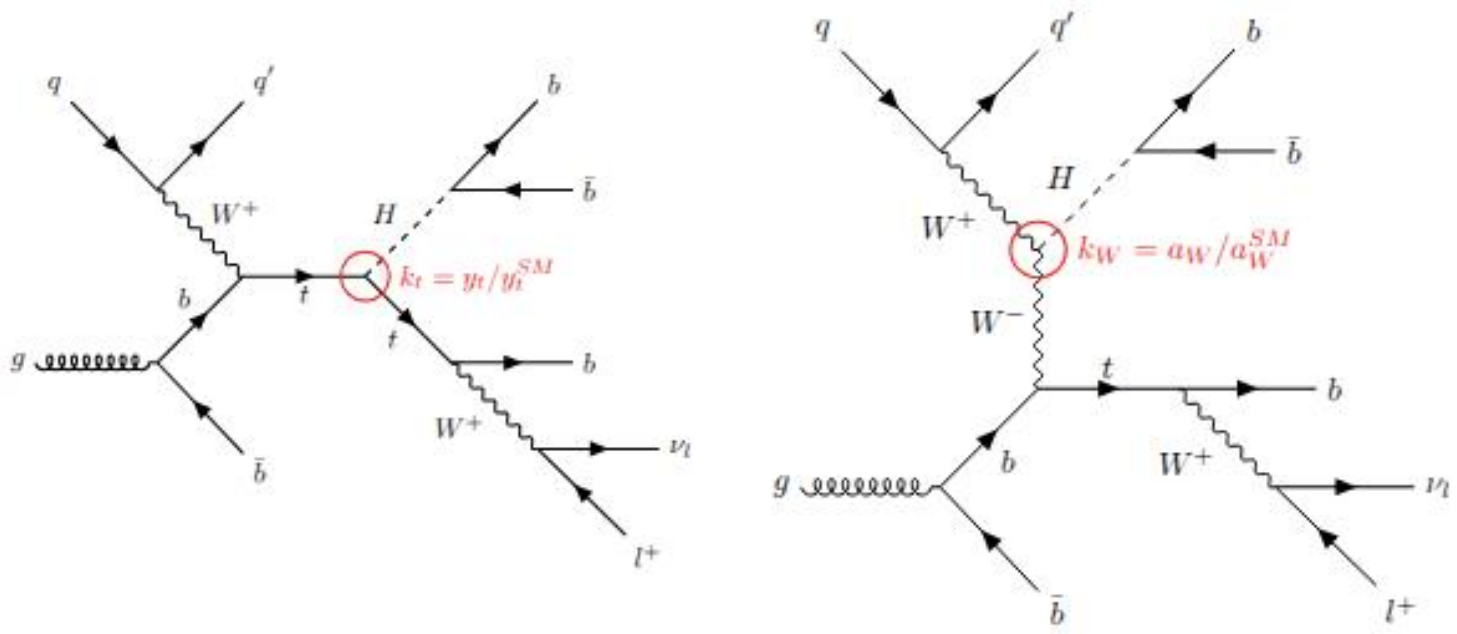
Студент: Дадашова А.Э.

Москва 2026

Мотивация и цели

Цель: исследование методом Монте-Карло событий ассоциативного рождения бозона Хиггса с одиночным топ-кварком и соответствующих фоновых процессов.

Мотивация: поиск редкого процесса $pp \to tH$ на БАК с целью измерения комплексной фазы константы взаимодействия бозона Хиггса с топ-кварком и ее сравнение с теоретическими предсказаниями Стандартной Модели.



Диаграммы Фейнмана для процесса $pp \to tH$

Информация о генерации событий (NLO)

m(b) = 4.2 GeV
m(t) = 172.5 GeV
Y_b*m(b) = 4.2 GeV
Y_t*m(t) = 172.5 GeV

Генерация: MadGraph5_aMC@NLO (tHbq; ttH), POWHEG (ttbar)
Адронизация: PYTHIA 8 (tHbq; ttH), Herwig7 (ttbar)
Реконструкция струй: FastJet
Framework: Rivet

Jets:
anti-KT
p_T^{min} = 20.0 GeV
$|\eta|^{max}$ = 5.0
R = 0.5

Отбор событий: $p_T^{lead} > 27$ GeV;
$p_T^{\nu,reco} \geq 10$ GeV; $|\eta|^{lead} \leq 2.7$; $3 \leq N^{b\text{-jets}} \leq 4$;
$|\eta|^{b\text{-jet}} < 2.4$

Информация о сгенерированных событиях

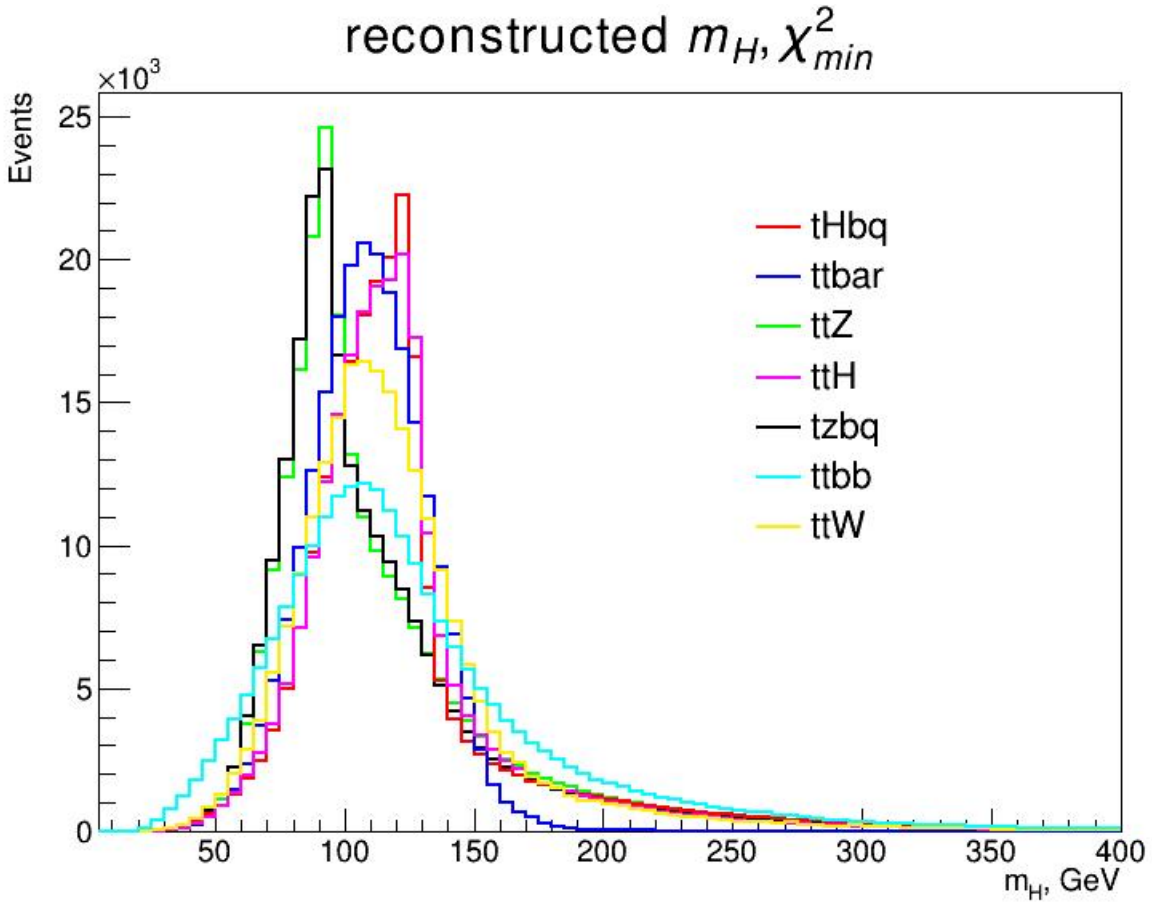
Process	Events generated	$p_T^{lead} > 27$ GeV $3 \leq N^{b\text{-jets}} \leq 4$	$p_T^{\nu,reco} \geq 10$ GeV $\|\eta\|^{lead} \leq 2.7$ $\|\eta\|^{b\text{-jet}} < 2.4$	PDF
tHbq	8 782 291	1 777 571	1 077 004	NNPDF30_nlo_as_0118_nf_4
ttbar	2 750 000	676 834	559 135	NNPDF30_nlo_as_0118
ttH	30 000 000	230 807	174 976	NNPDF30_nlo_as_0118_nf_4

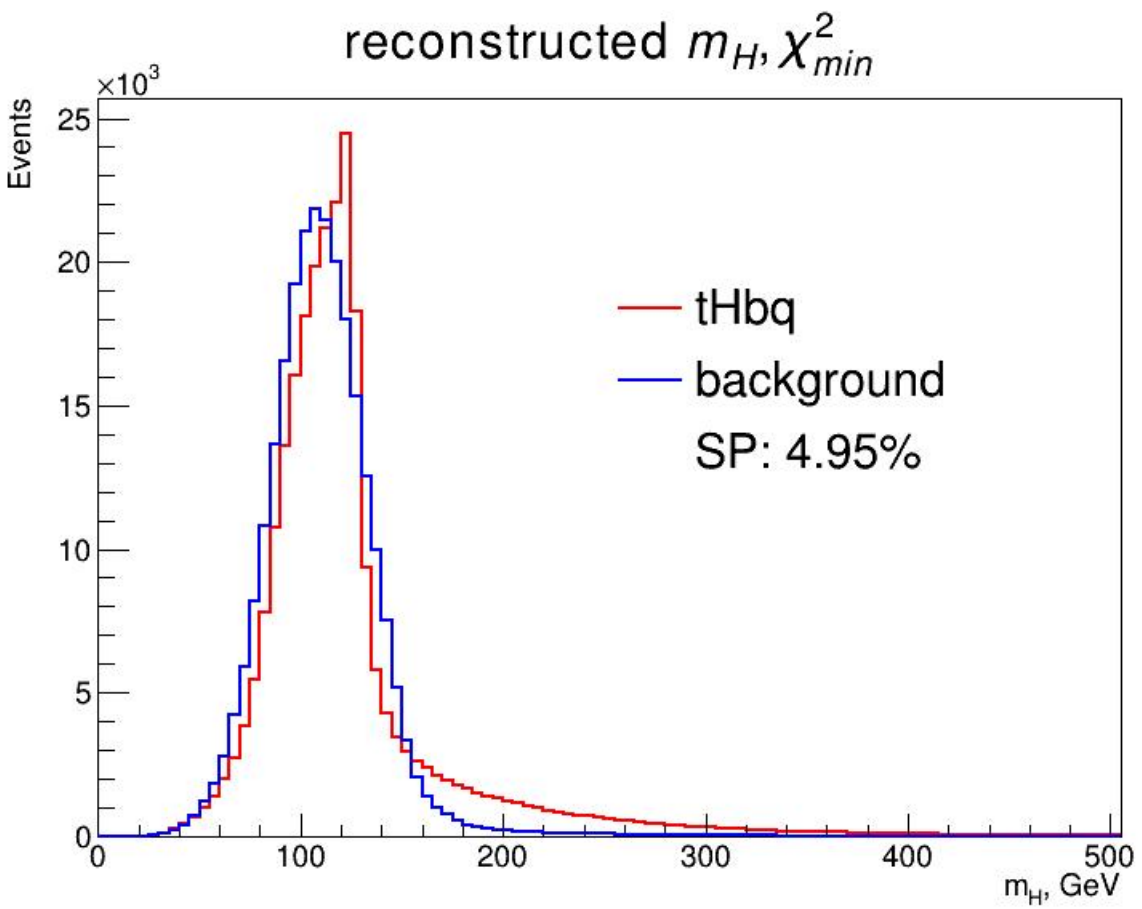
Реконструкция события

- Все события реконструируются как события сигнального процесса: $pp \to tHbq(H \to bb, t \to bl\nu)$.
- Струи реконструируются из адронов конечного состояния.
- Поперечный импульс нейтрино реконструируется как недостающий поперечный импульс струй.
- Продольная компонента импульса нейтрино восстанавливается из решения уравнения : $m_{l\nu} = m_W$.
- b-струи приписываются распаду топ-кварка или бозона Хиггса путем перебора всех комбинаций и выбора той из них, что дает массы m_t и m_H, ближайшие к номинальным.

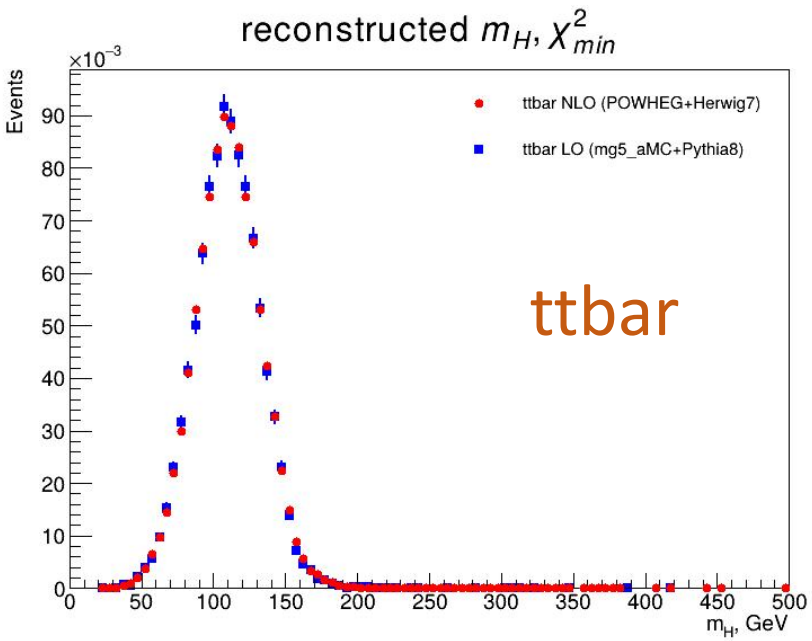
В рамках гипотезы о том, что все события соответсвуют сигнальному процессу, реконструированы 52 кинематических переменных.

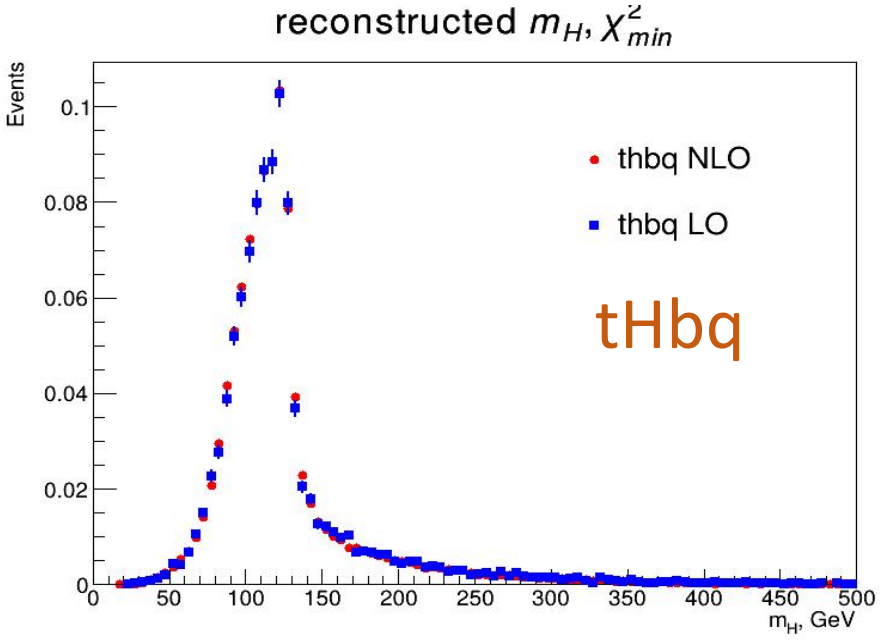
Инвариантная масса реконструированного бозона Хиггса для сигнального и фоновых процессов (LO)

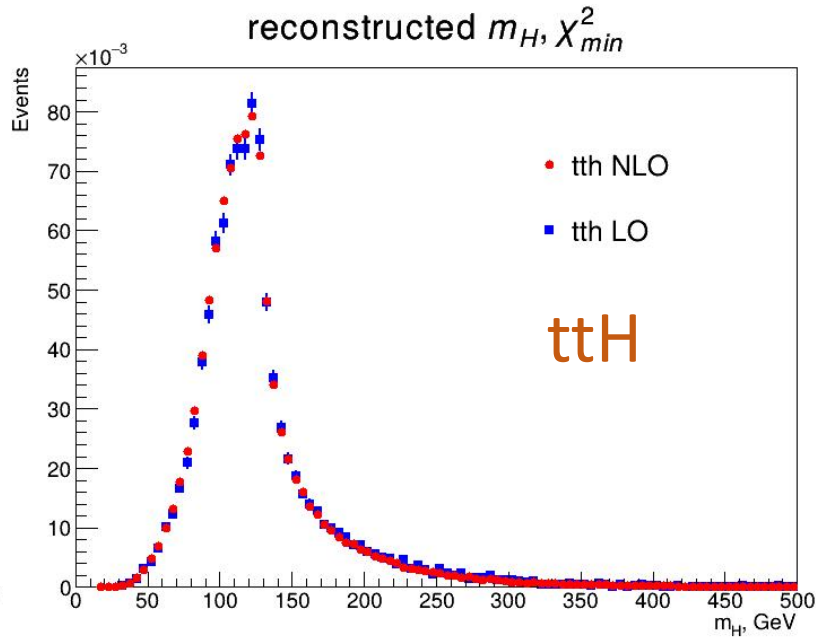




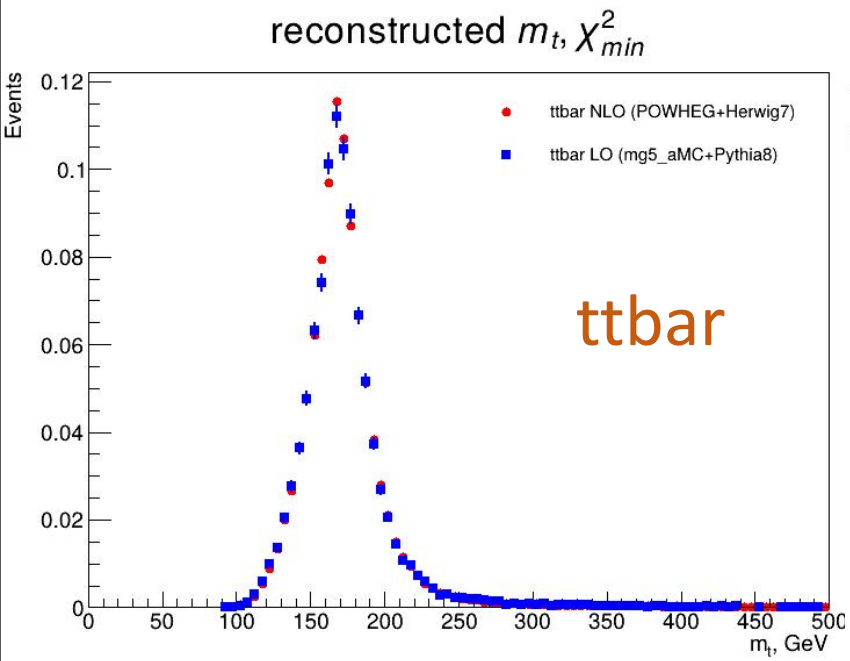
Инвариантная масса реконструированного бозона Хиггса для сигнального и фоновых процессов

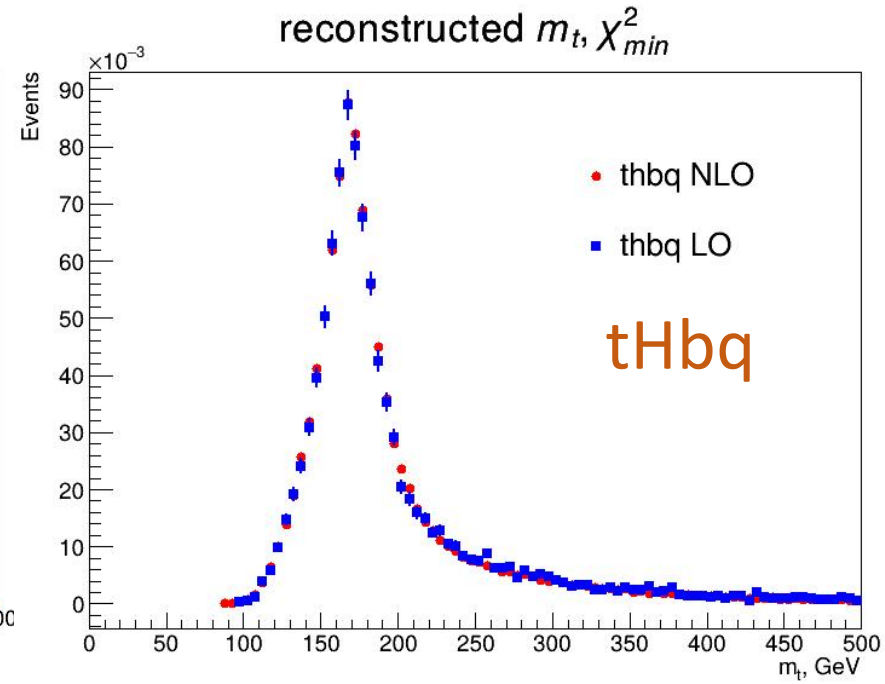


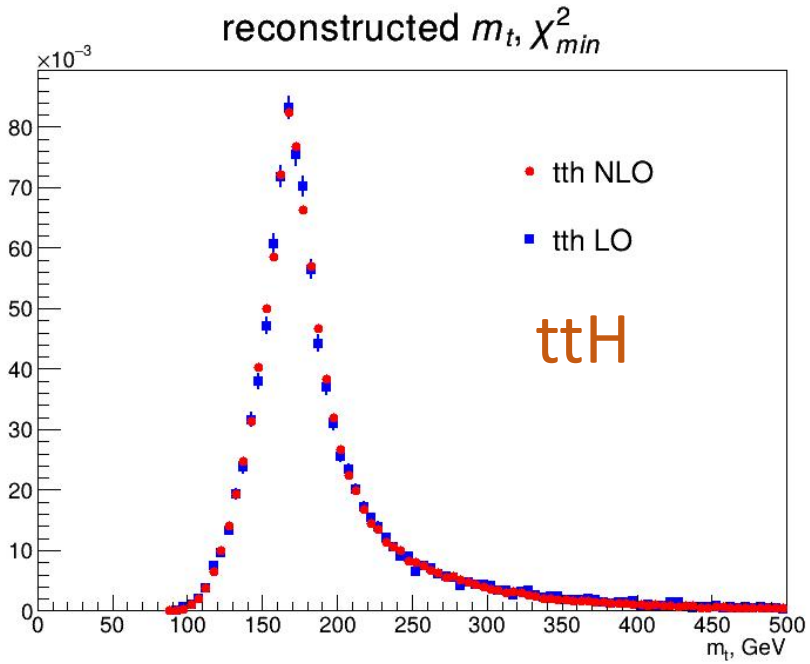




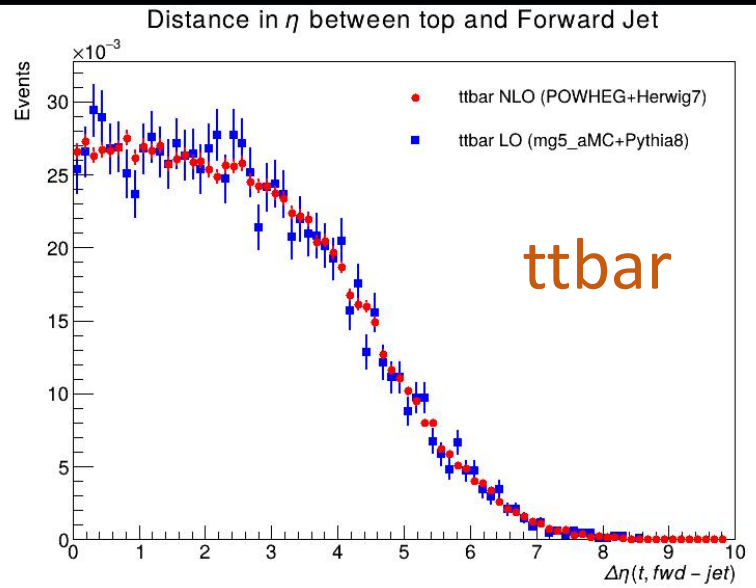
Инвариантная масса реконструированного топ-кварка для сигнального и фоновых процессов

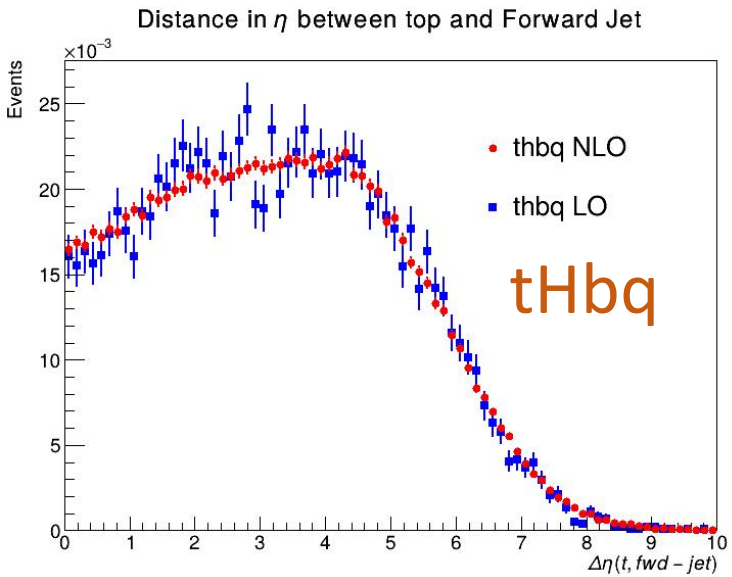


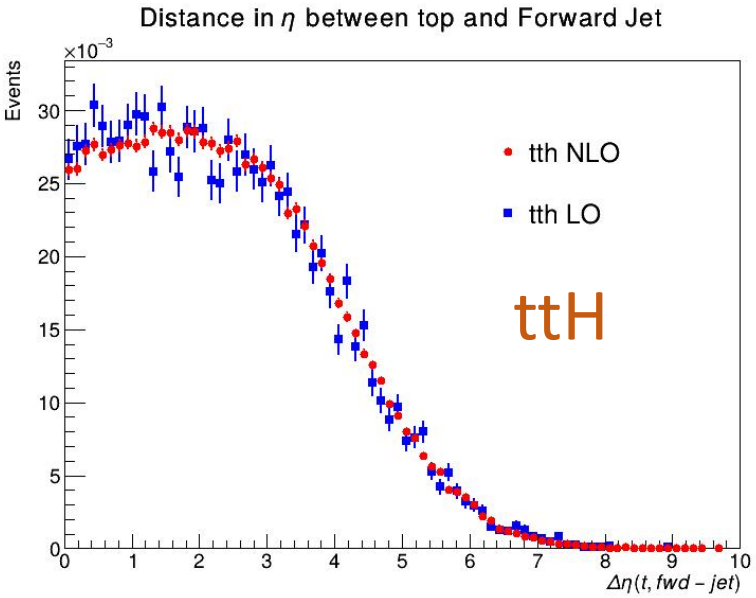


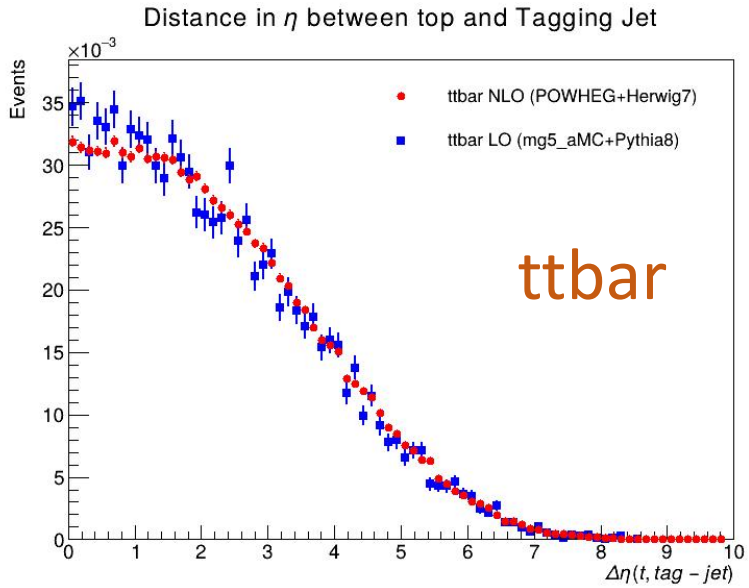


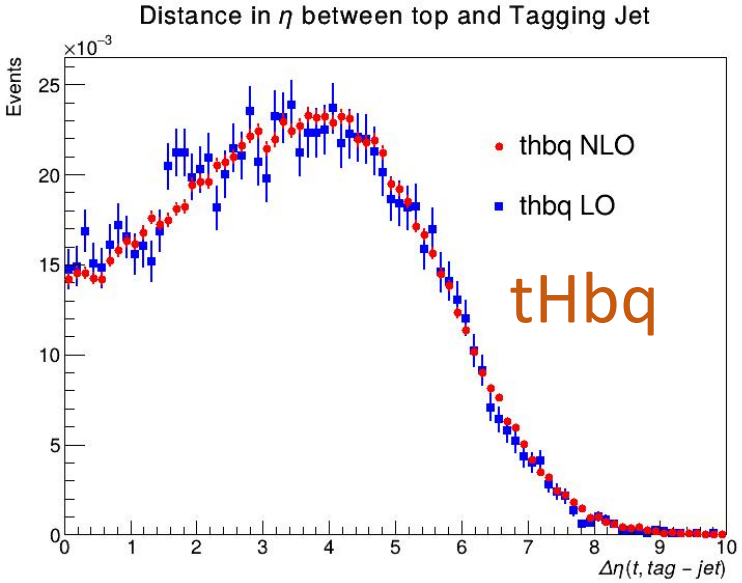
$|\Delta\eta|$ между реконструированным топ-кварком и передней (тагирующей) струей для сигнального и фоновых процессов

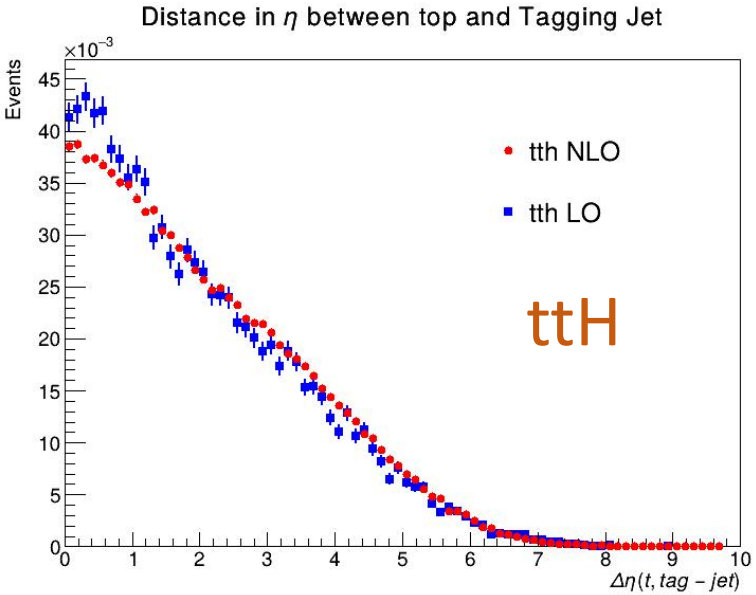




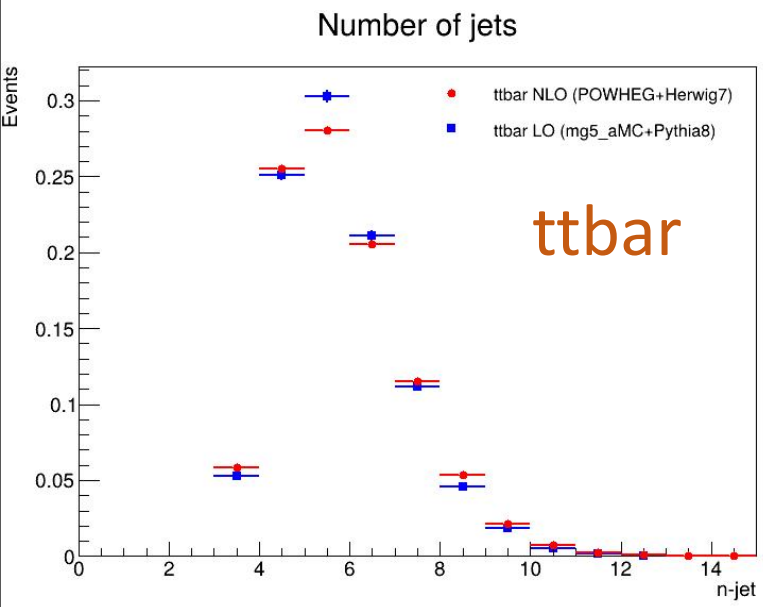


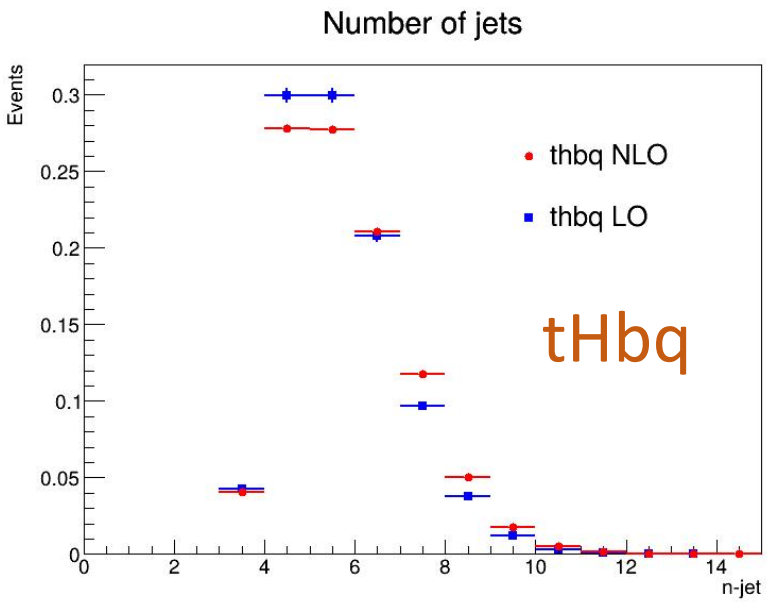


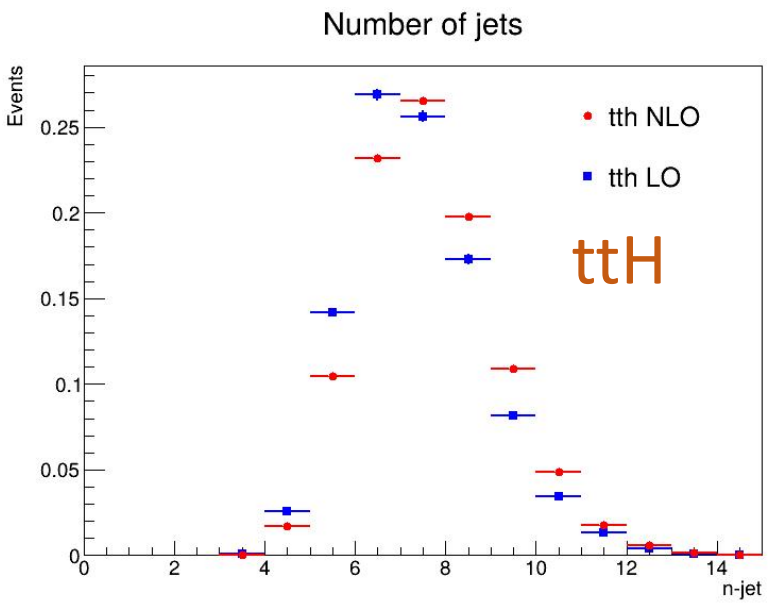


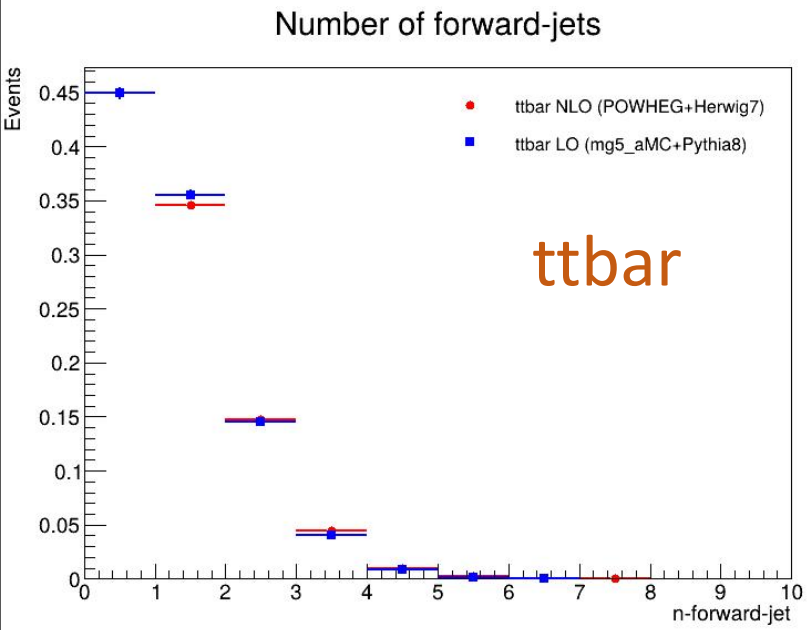


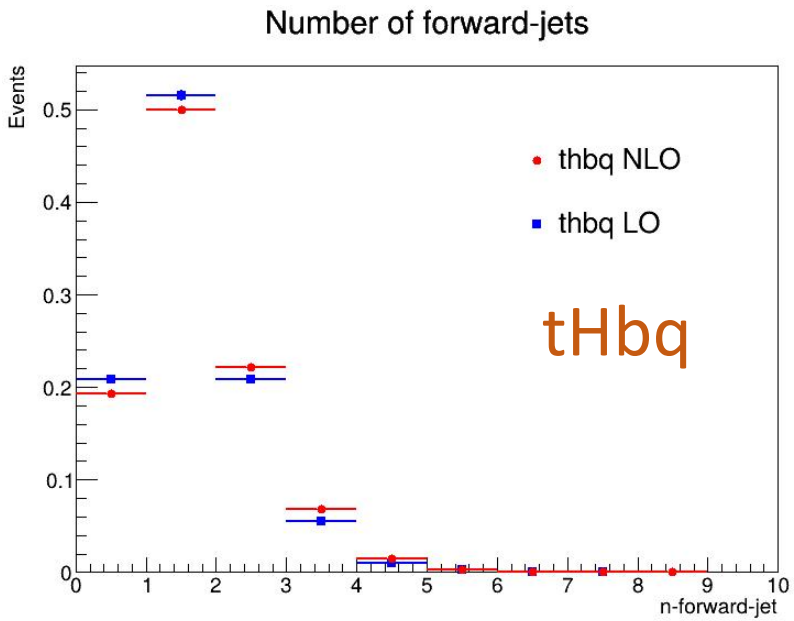
Число струй

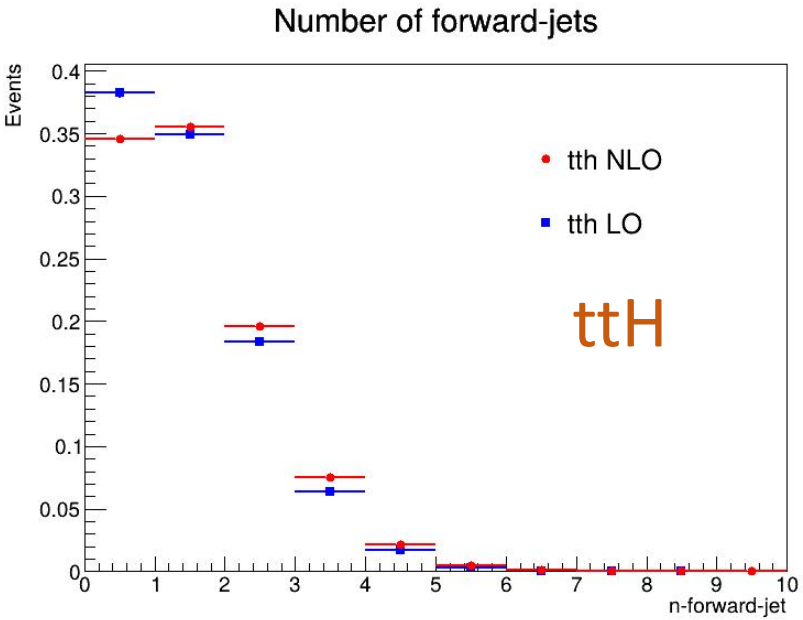

Number of jets
Events
ttbar NLO (POWHEG+Herwig7)
ttbar LO (mg5_aMC+Pythia8)
ttbar
n-jet


Number of jets
Events
thbq NLO
thbq LO
tHbq
n-jet

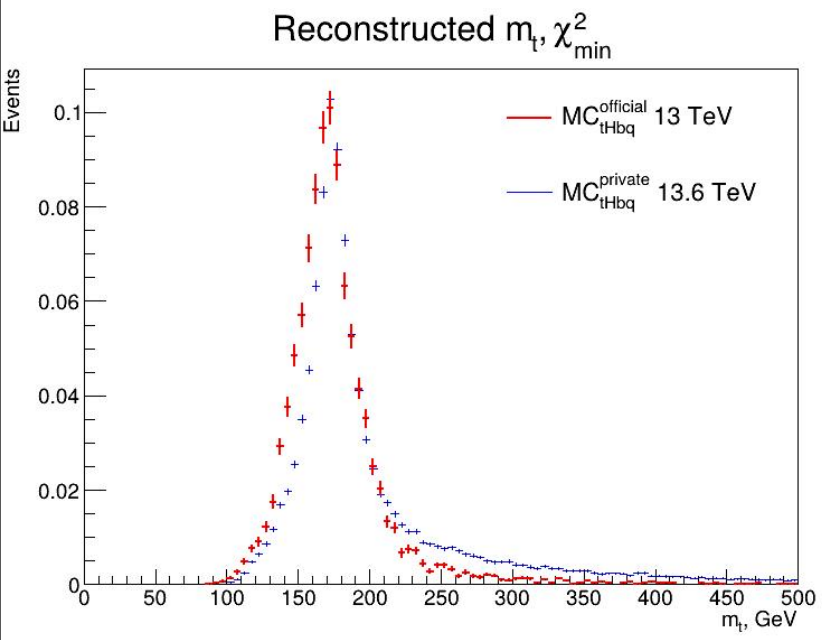

Number of jets
Events
tth NLO
tth LO
ttH
n-jet

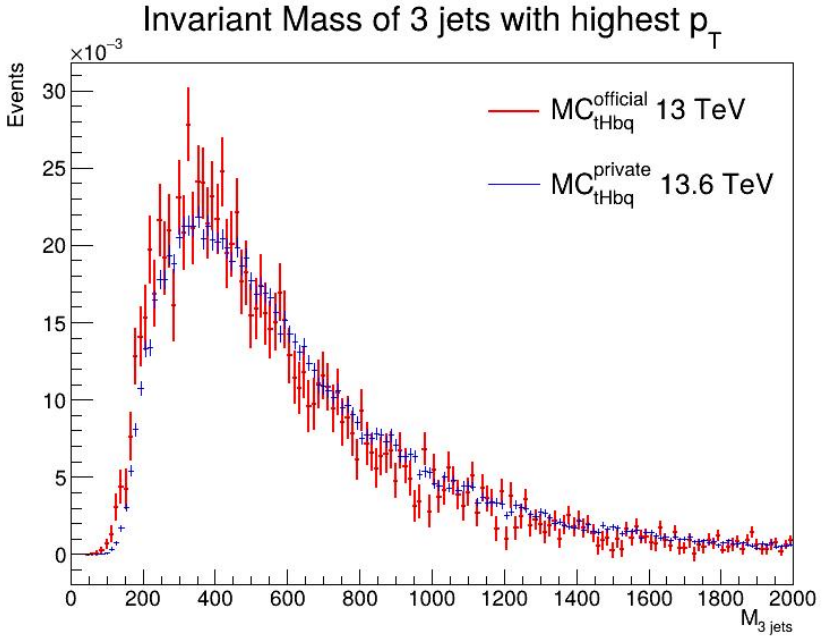

Number of forward-jets
Events
ttbar NLO (POWHEG+Herwig7)
ttbar LO (mg5_aMC+Pythia8)
ttbar
n-forward-jet

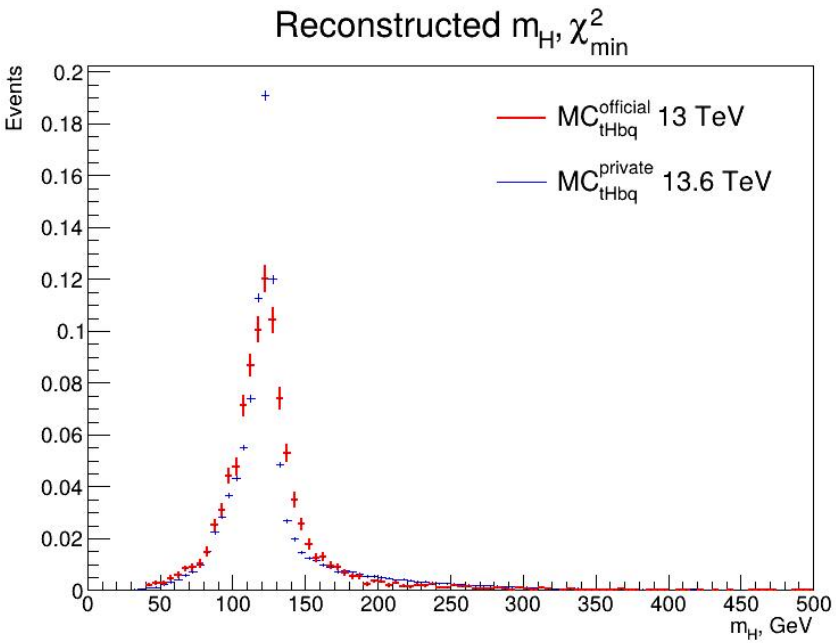

Number of forward-jets
Events
thbq NLO
thbq LO
tHbq
n-forward-jet


Number of forward-jets
Events
tth NLO
tth LO
ttH
n-forward-jet

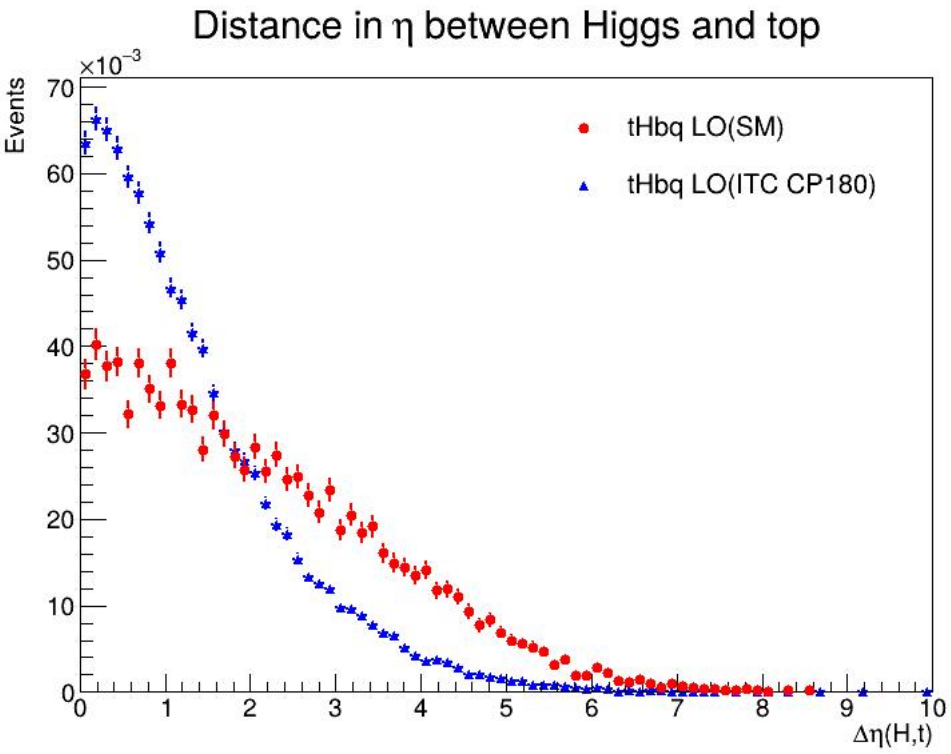
Валидация сигнального процесса



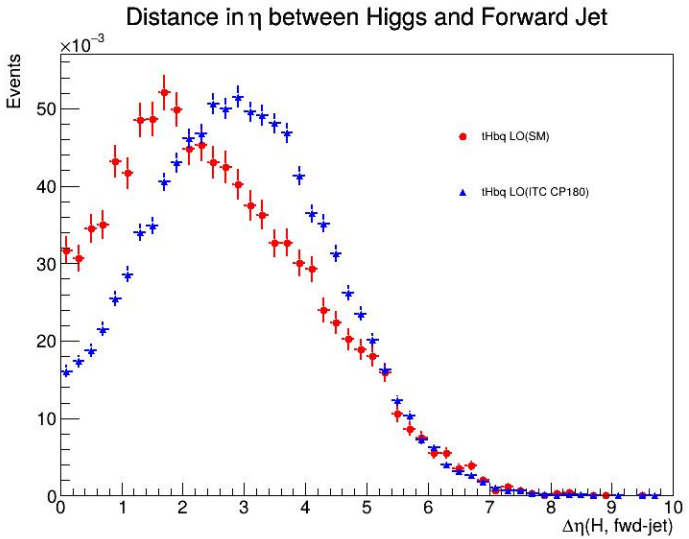


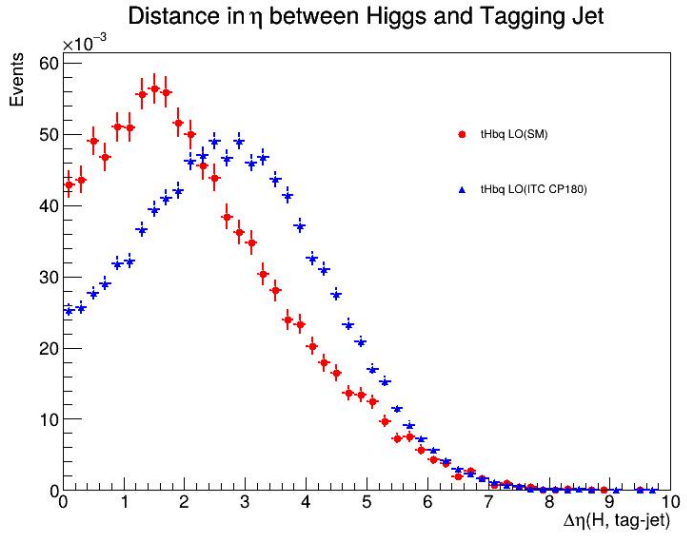


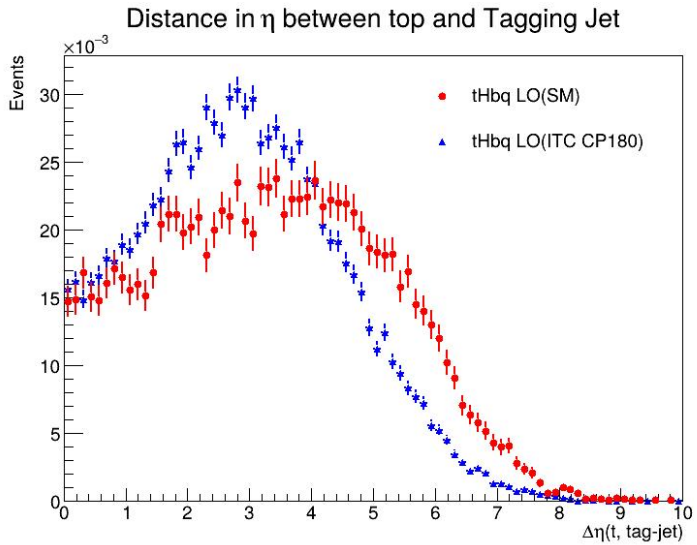
Inverted Top Coupling (ITC)

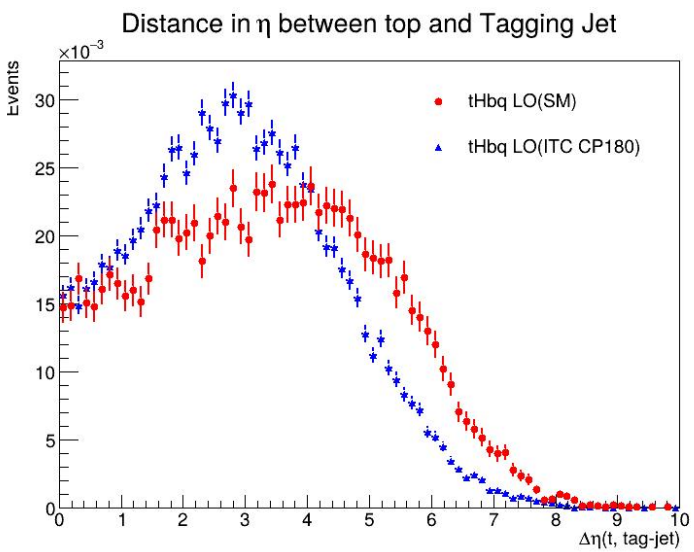


https://arxiv.org/pdf/1306.6464

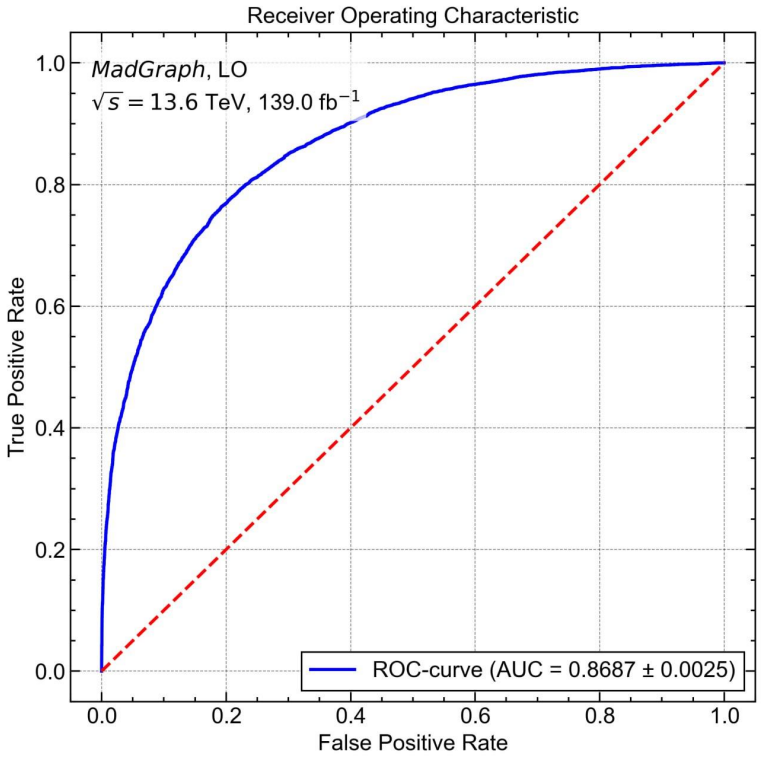


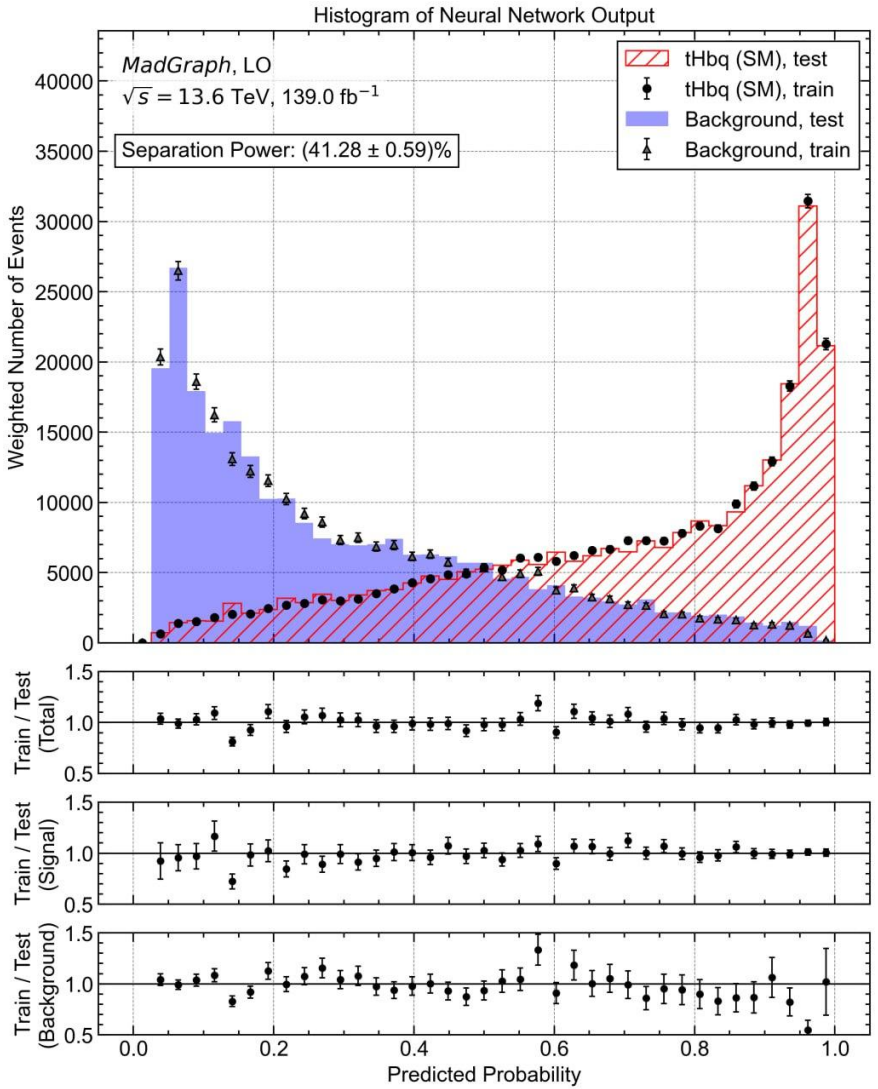






Оценка чувствительности экпериментов на БАК к процессу tHbq





Значимость сигнального процесса:
$(2.3 \pm 0.3)\sigma$ для Run2+Run3;
$(6.5 \pm 0.8)\sigma$ для Run2+Run3+Run4
(High Luminosity)

$$Z = \frac{S}{\sqrt{S + B}}$$

Заключение

- Сгенерирован сигнальный процесс ассоциативного рождения бозона Хиггса с одиночным t-кварком (процесс tHqb), а также соответствующие фоновые процессы в приближениях LO и NLO для энергии столкновений 13.6 ТэВ в системе центра масс.
- Построены и проанализированы распределения кинематических переменных, наиболее важных для выделения сигнального процесса на фоне фоновых процессов.
- Начато производство и анализ ntuple для сигнального процесса в рамках модели ITC.
- Начата валидация с официальными Монте-Карло данными эксперимента ATLAS.
- Проведена оценка чувствительности экспериментов БАК к сигнальному процессу (tHbq)

Спасибо за внимание!

BACK-UP

Предыдущий анализ (Run2)

Исследование рождения бозона Хиггса совместно с одиночным топ-кварком методом Монте-Карло

И.Р.Бойко[1], Н.А.Гусейнов[1,2], and О.А.Коваль[1]

[1]Объединенный институт ядерных исследований, Дубна
[2]Институт физики НАНА, Баку

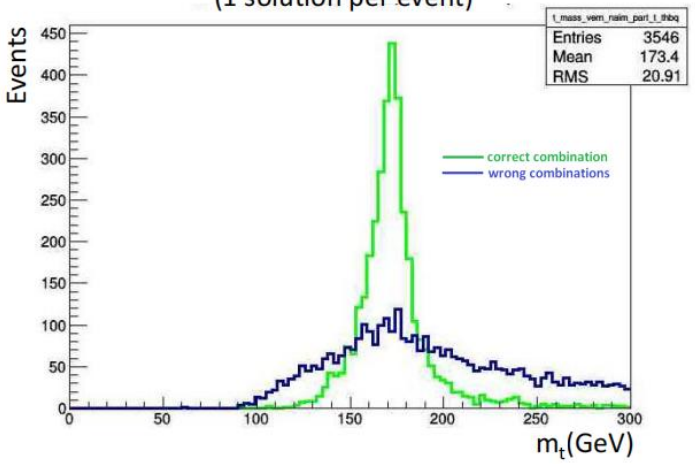
5 сентября 2021 г.

- MadGraph MG5_aMC_v2_6_3_2 (last version)
- LHAPDF-6.1.6 (last version)
- ExRootAnalysis: A package to convert the various output (LHE) in a ROOT format.
- Pythia 8.2: A package containing Pythia6 and PGS. Pythia6 is able to shower and to hadronize your events and is able to perform the matching for multi-jet production. PGS is a fast detector simulation package. or Pythia 8.
- Delphes: A package allowing to have a fast detector simulation, in replacement of PGS.

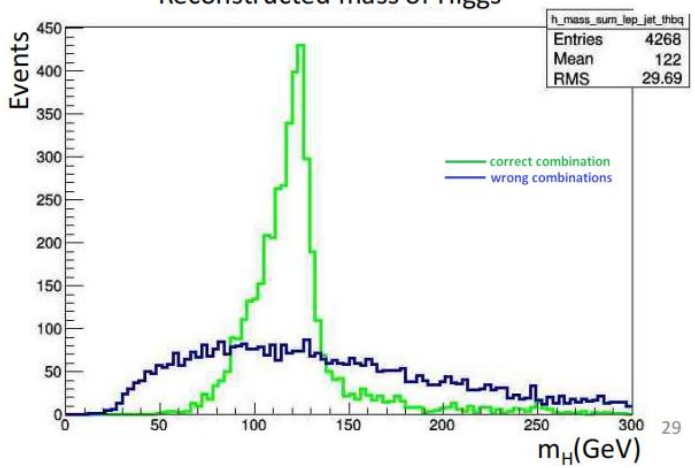
- PDF set: CT10; m(b): 4.2 GeV; m(t): 172.5 GeV
- m(H): 125 GeV; Y_b *m(b): 4.2 GeV; Y_t *m(t): (+1) * 172.5 GeV (SM) and (-1)* 172.5 GeV (BSM)
- Number of generator events = 34119 (as in ATLAS Ntuples)
- p p > tt h bb q, h > b b~, (t > w+ b, w+ > all all), (t~ > w- b~, w- > all all)

	Cross Section MadGraph, pb	Cross Section ATLAS MC (for Nevents 300k), pb
SM	0.03205 ± 6.9e-05	0.031216
BSM	0.4135 ± 0.00078	0.422364

Reconstructed mass of top-quark
(1 solution per event)



Reconstructed mass of Higgs



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Информация о генерации событий (LO)

PDF set: CT10
m(b) = 4.2 GeV
m(t) = 172.5 GeV
Y_b*m(b) = 4.2 GeV
Y_t*m(t) = 172.5 GeV

Генерация: MadGraph5_aMC@NLO 3.5.7
Адронизация: PYTHIA 8.313
Реконструкция струй: FastJet 3.4.3
Framework: Rivet 4.0.3

Отбор событий: $p_T^{lead} > 27$ GeV;
$p_T^{\nu,reco} \geq 10$ GeV; $|\eta|^{lead} \leq 2.7$; $3 \leq N^{b\text{-jets}} \leq 4$;
$|\eta|^{b\text{-jet}} < 2.4$

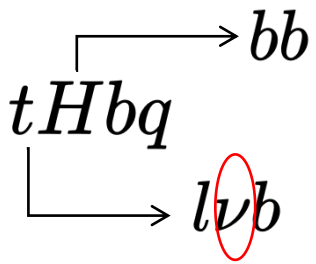
Jets:
anti-KT
$p_T^{min} = 20.0$ GeV
$|\eta|^{max} = 5.0$
R = 0.5

Информация о сгенерированных событиях

Процесс	N^{events}	Сечение (фб)	N^{sel}	N^{weght}
tHbq	22 000 000	12.45	2 567 765	202.08
tt	220 000 000	194 600.00	986 383	228 729.39
ttbb	65 979 470	4807.00	1 941 358	19 670.26
ttZ	22 000 000	34.10	2 532 704	545.80
ttH	22 000 000	103.40	2 948 179	1926.04
tZbq	22 000 000	31.37	2 336 142	463.02
ttW	22 000 000	212.20	157 993	211.82

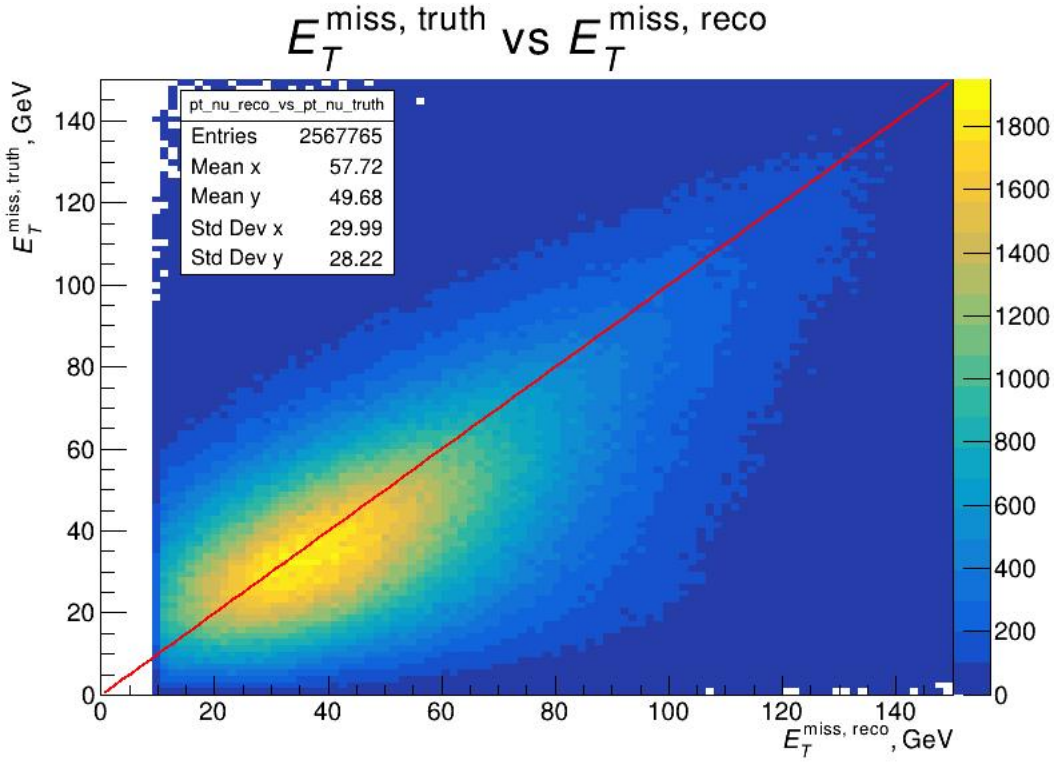
N^{events} - число сгенерированных событий
N^{sel} - число событий, прошедших отбор
N^{weight} - число взвешенных событий

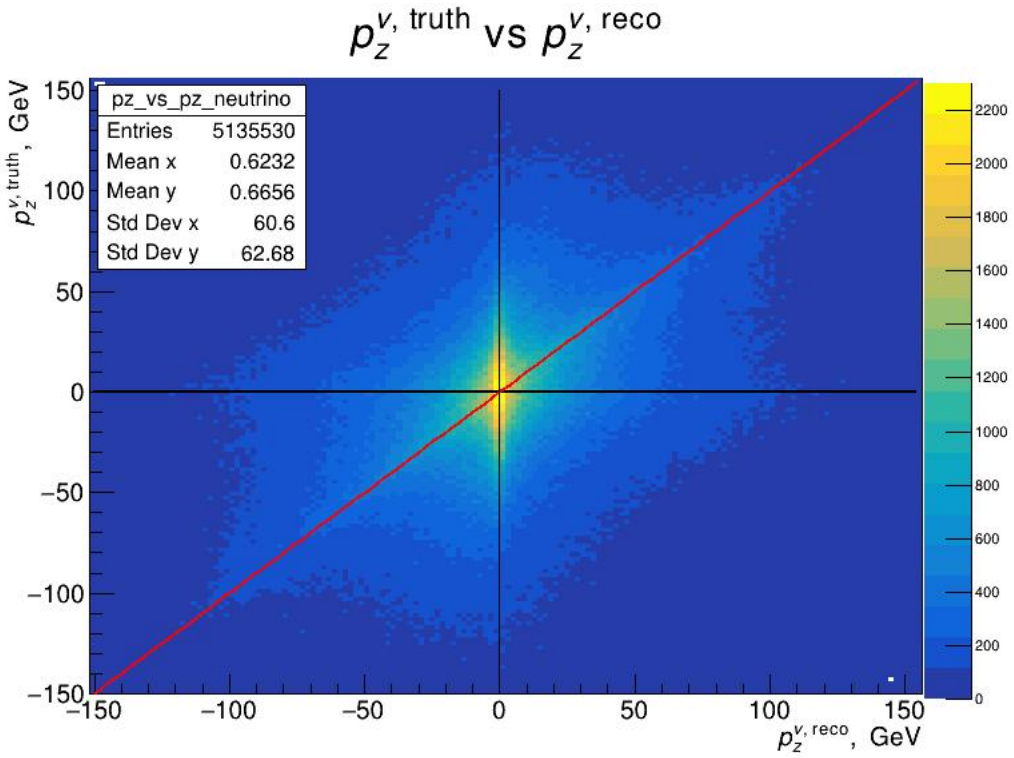
Neutrino reconstruction



Formula for calculating the z-component of neutrino momentum: $$P^{\pm}_{Z,\nu} = \frac{1}{P^2_{T,l}}\left(\mu P_{Z,l} \pm E_l\sqrt{\mu^2 - P^2_{T,l}(E^{miss}_T)^2}\right),$$

where $$\mu = \frac{m^2_W}{2} + P_{X,l}E^{miss,x}_T + P_{Y,l}E^{miss,y}_T;\ m_W = 80.35\ \text{GeV}$$





each event gives 2 entries: correct solution and wrong solution

$$m_W^2 = (p_{lead} + p_\nu)^2$$ ← the four-momentum conservation law of the W-boson

$$P_{Z,\nu}^{\pm} = \frac{1}{P_{T,l}^2}\left(\mu P_{Z,l} \pm E_l\sqrt{\mu^2 - P_{T,l}^2 (E_T^{miss})^2}\right)$$

$$\mu = \frac{m_W^2}{2} + P_{X,l}E_T^{miss,x} + P_{Y,l}E_T^{miss,y};\ m_W = 80.35\ \mathrm{GeV}$$

$$E_T^{miss,x} = -\sum p^x_{\text{charged lepton}} - \sum p^x_{\text{jet}} \qquad E_T^{miss,y} = -\sum p^y_{\text{charged lepton}} - \sum p^y_{\text{jet}}$$

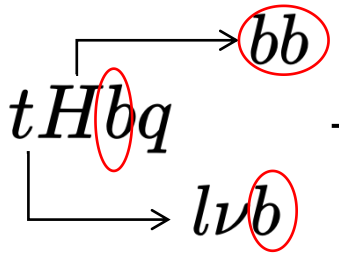
$$E_T^{miss} = \sqrt{E_T^{miss,x2} + E_T^{miss,y2}}$$ ← neutrino momentum

$$p_{\nu,1} = Vec4(E_T^{miss,x}, E_T^{miss,y}, p_{z,\nu}^{+}, \sqrt{E_T^{miss2} + p_{z,\nu}^{+2}})$$

$$p_{\nu,2} = Vec4(E_T^{miss,x}, E_T^{miss,y}, p_{z,\nu}^{-}, \sqrt{E_T^{miss2} + p_{z,\nu}^{-2}})$$

} two solutions for the neutrino momentum

Algorithm of top-quark and Higgs boson mass reconstruction



$$\longrightarrow \quad b_1^{jet}, b_2^{jet}, b_3^{jet} \quad \longrightarrow \quad \left[\begin{array}{ll} H^{reco} = b_i^{jet} + b_j^{jet} & i,j,k = 1,3 \\ t^{reco} = l + \nu^{reco,\pm} + b_k^{jet} & i \neq j \neq k \end{array} \right]$$

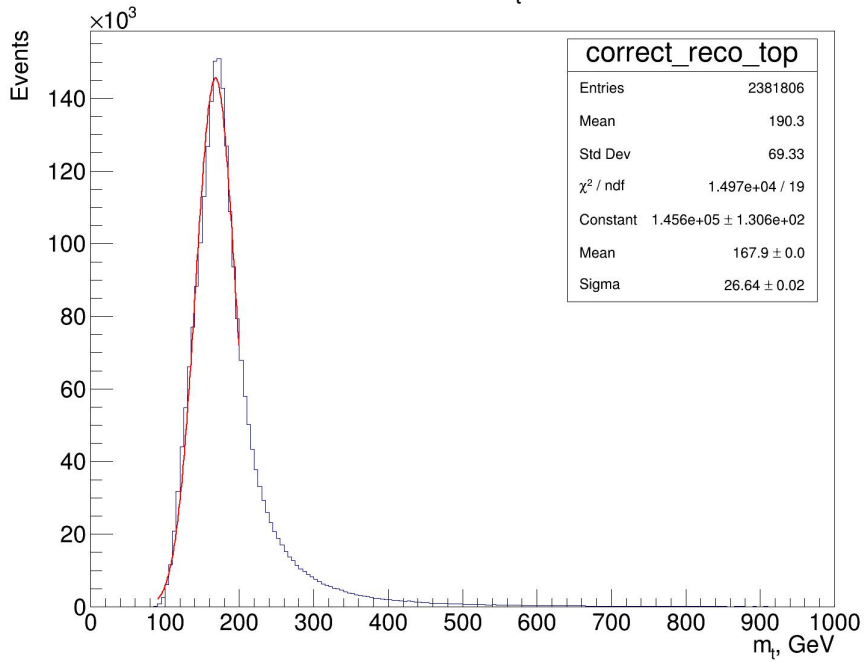
six combinations taking into account two solutions for neutrinos

If the number of b-jets is four, the three with the largest p_T are selected

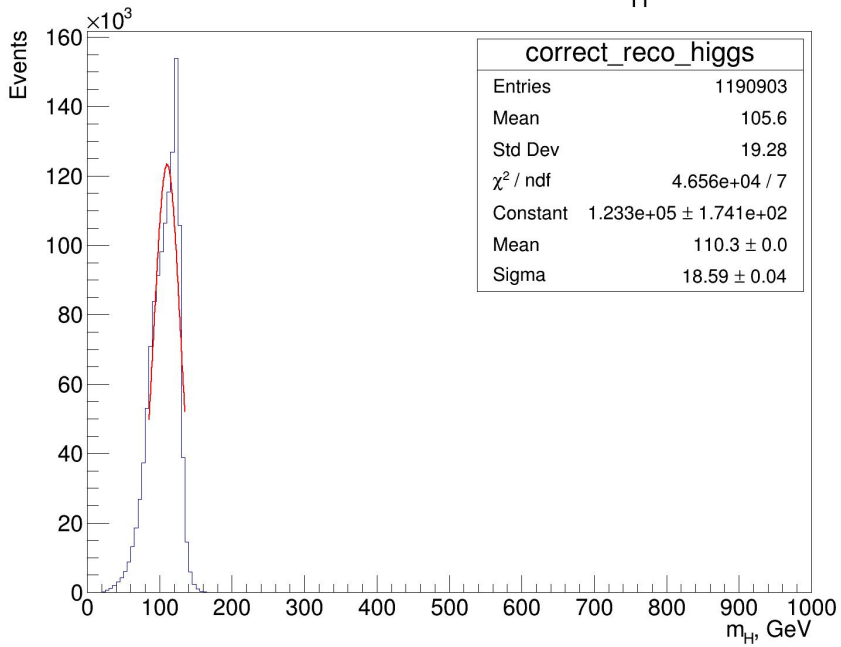
Selecting the best combination: $\chi^2 = \left(\frac{m_{bb} - m_H}{\sigma_H} \right)^2 + \left(\frac{m_{bl\nu} - m_t}{\sigma_t} \right)^2 \rightarrow min$

The parameters $m_H, m_t, \sigma_H, \sigma_t$ are taken from the fit of the correct combination

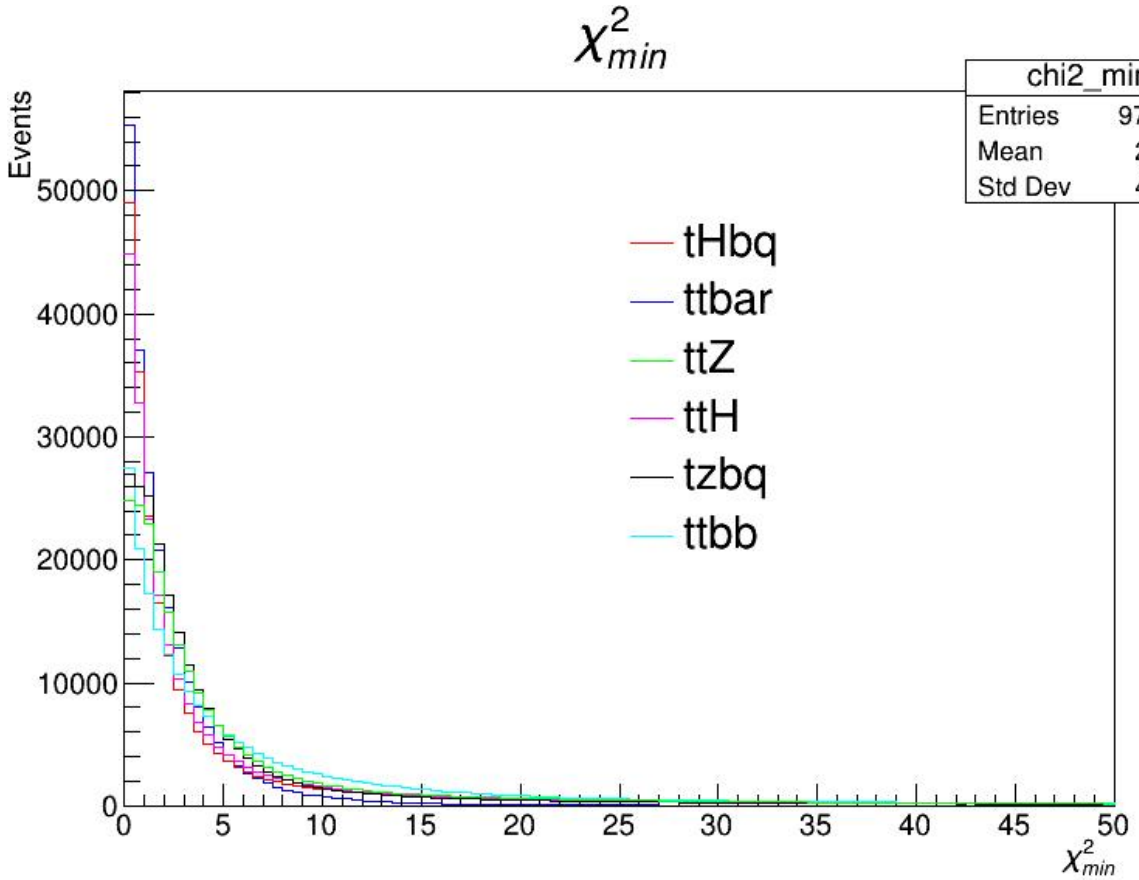
correct reconstructed m_t, all combination

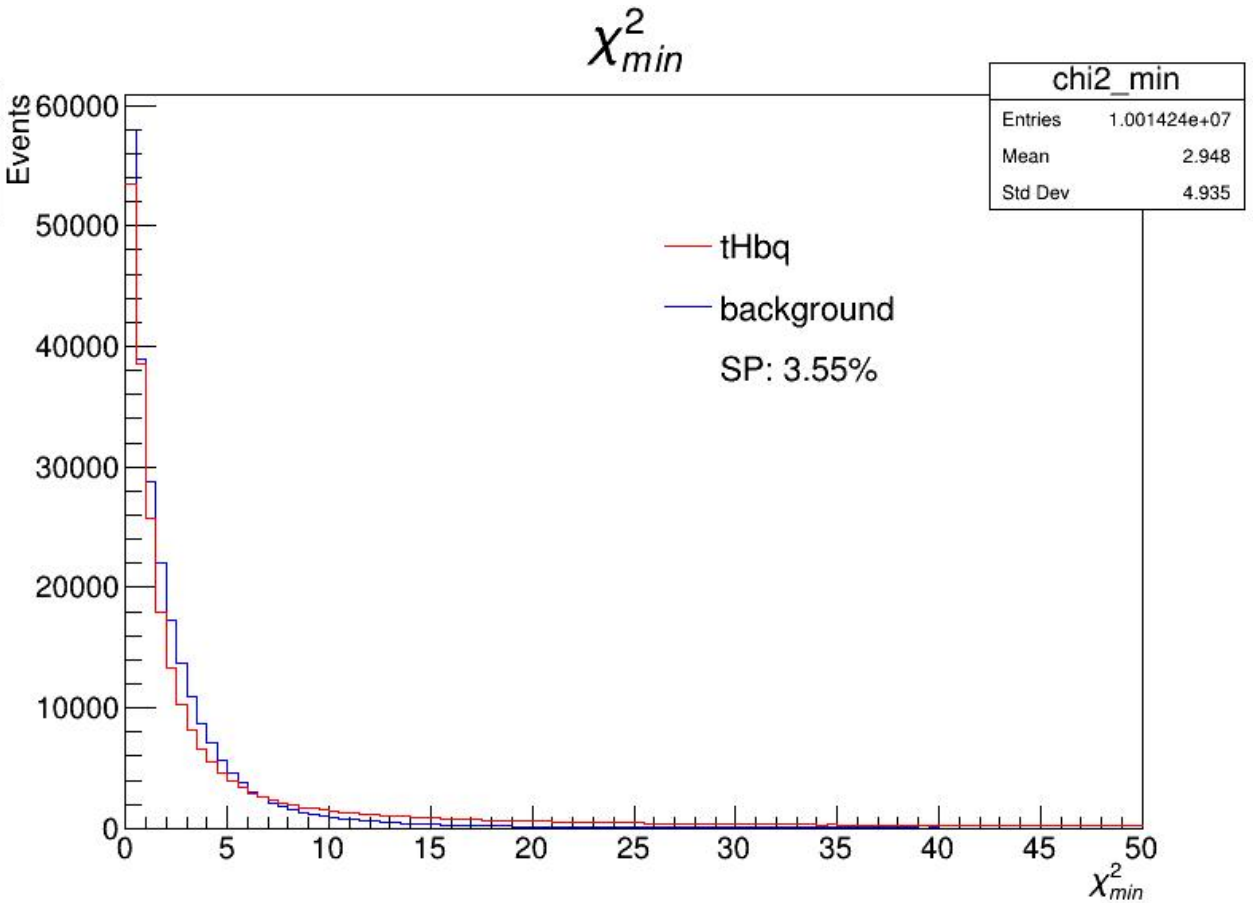


correct reconstructed m_H

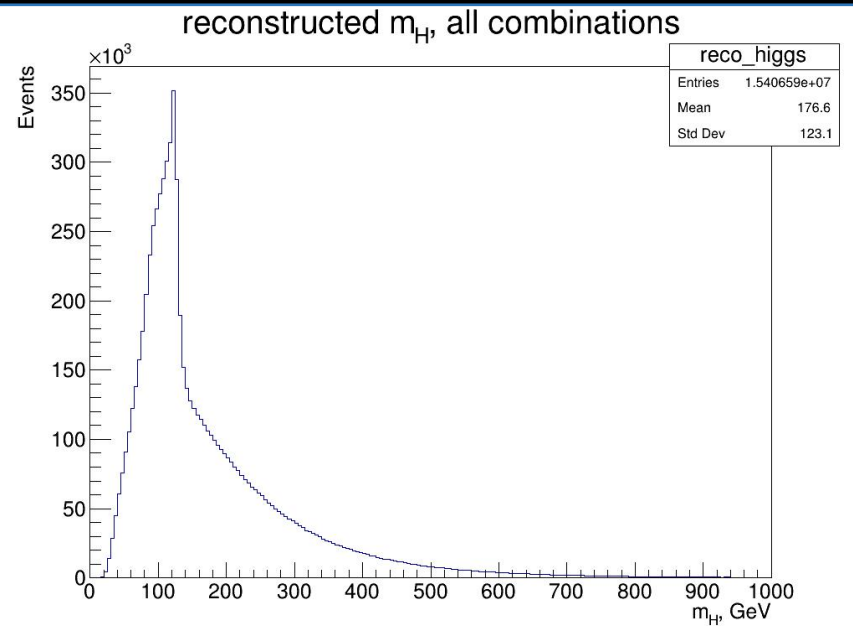


χ^2 for the signal and background processes

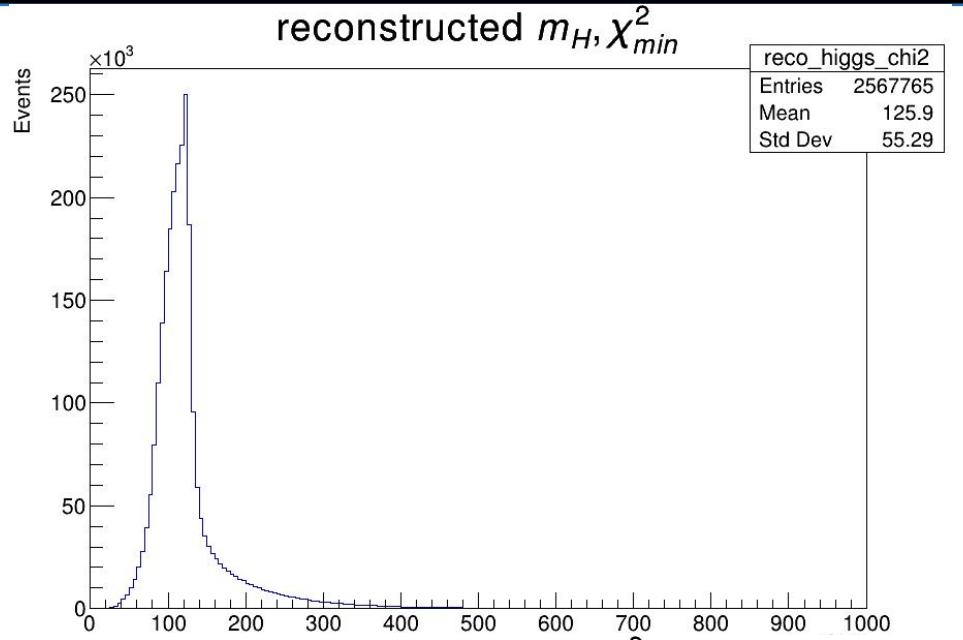


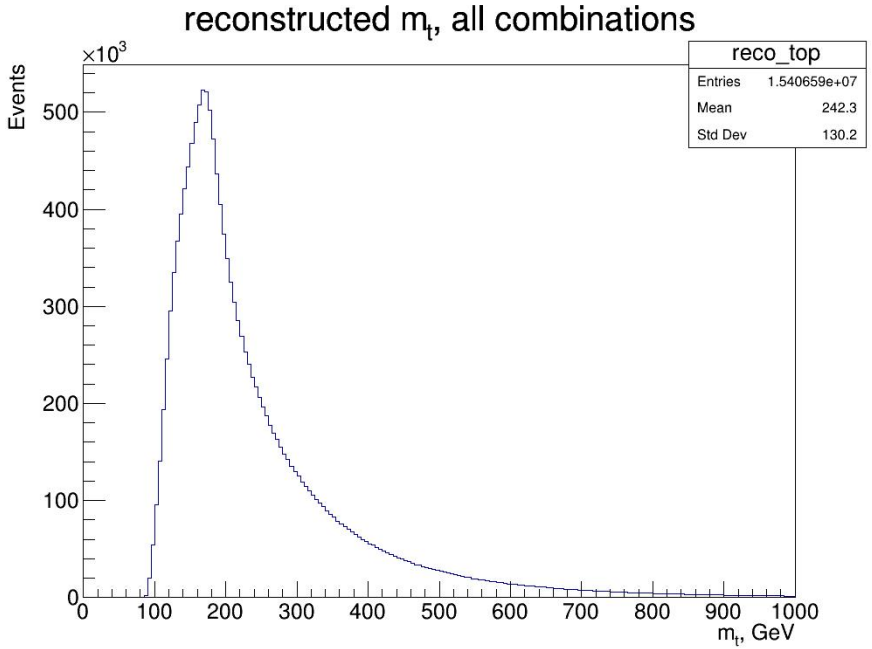


Reconstructed masses of the top quark and Higgs boson for the signal process

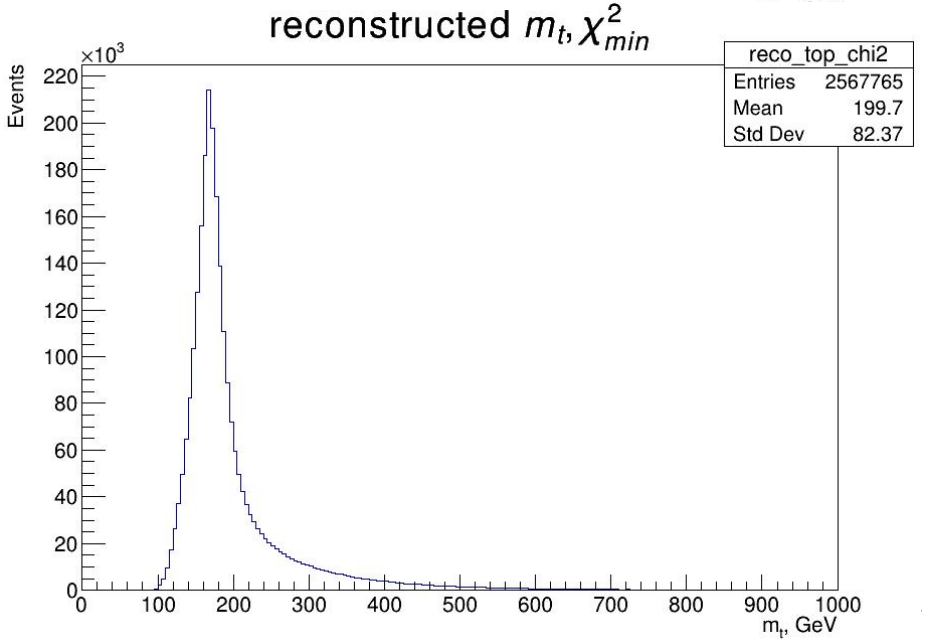


χ^2_{min}

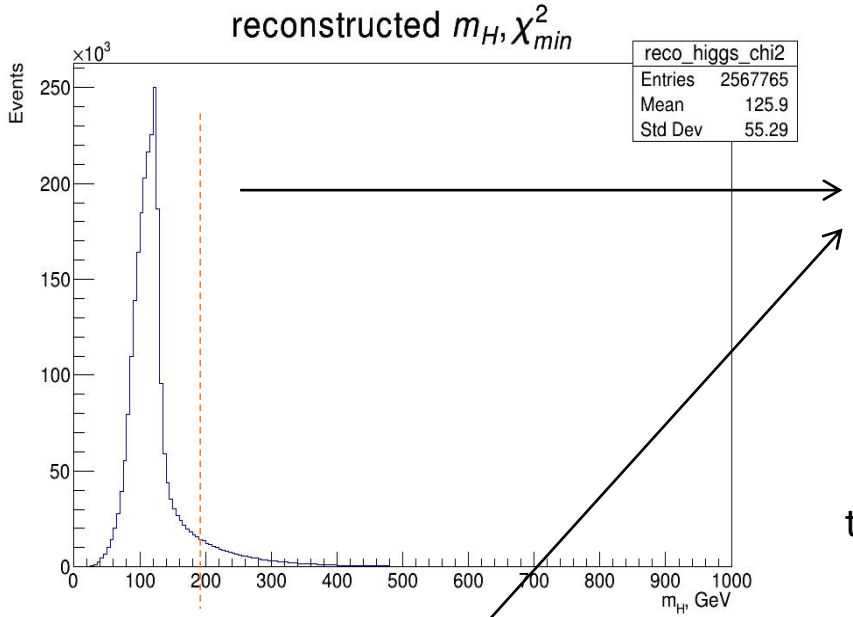


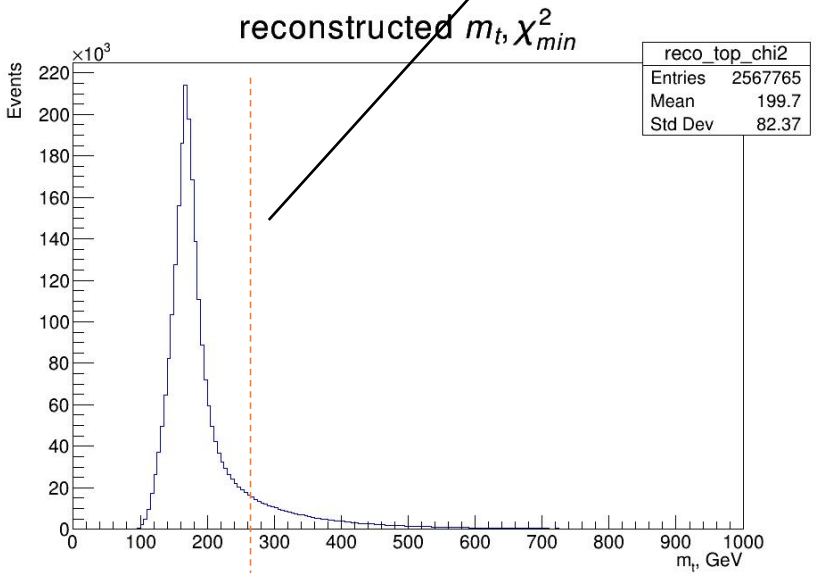


χ^2_{min}



Tails in distributions of reconstructed Higgs boson and top-quark masses for the signal process

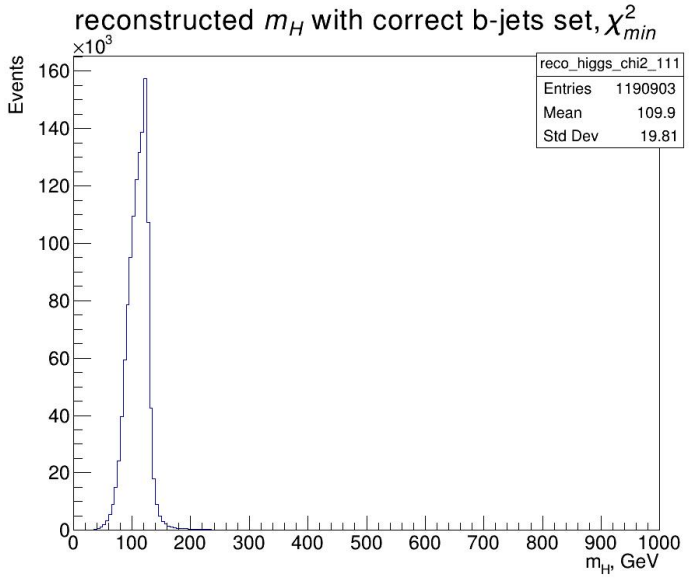


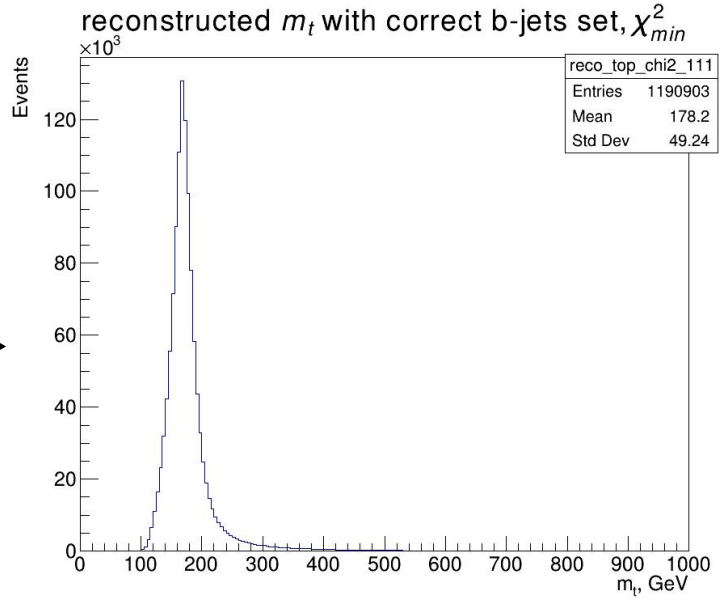


Where are the tails from?

In about half of the sampled events, the set of three b-jets, from which the Higgs boson and top-quark masses are recovered, contain a b-jet from the spectator quark

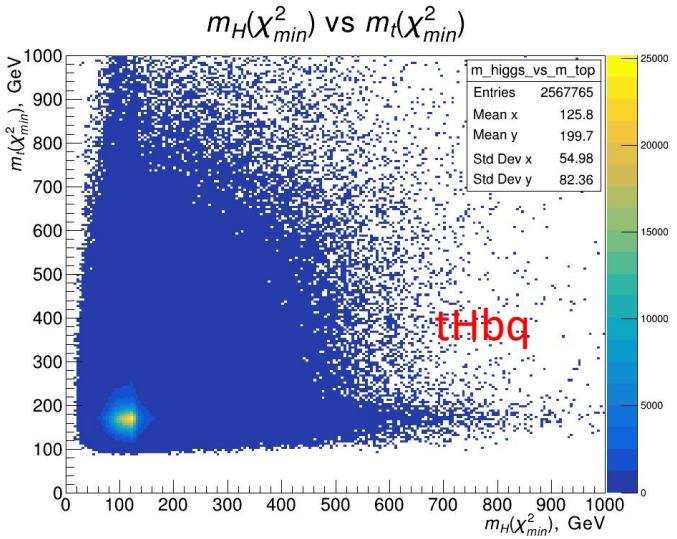
What happens if we consider only events with a valid set of b-strings?

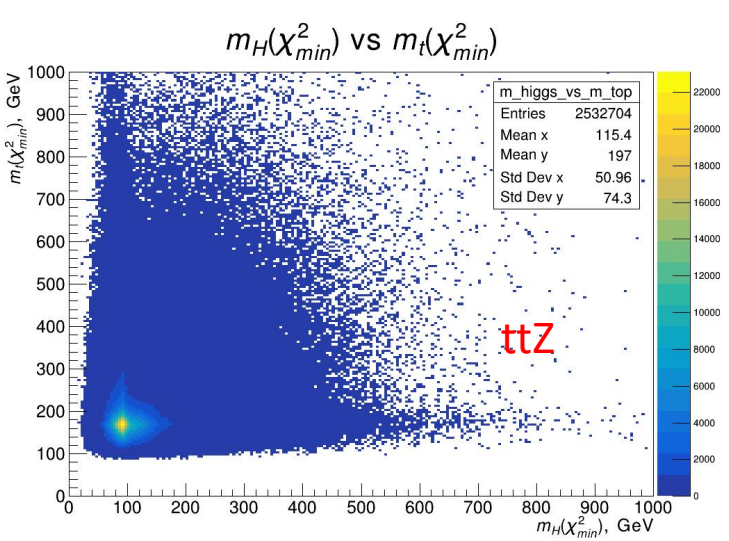


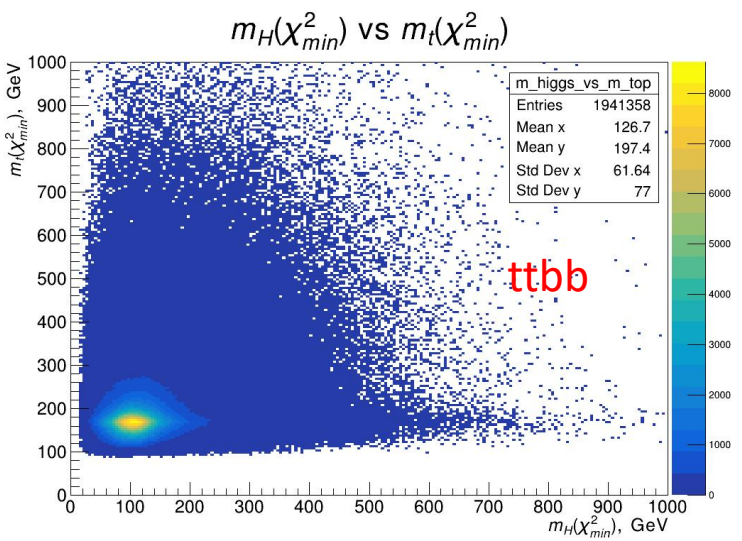


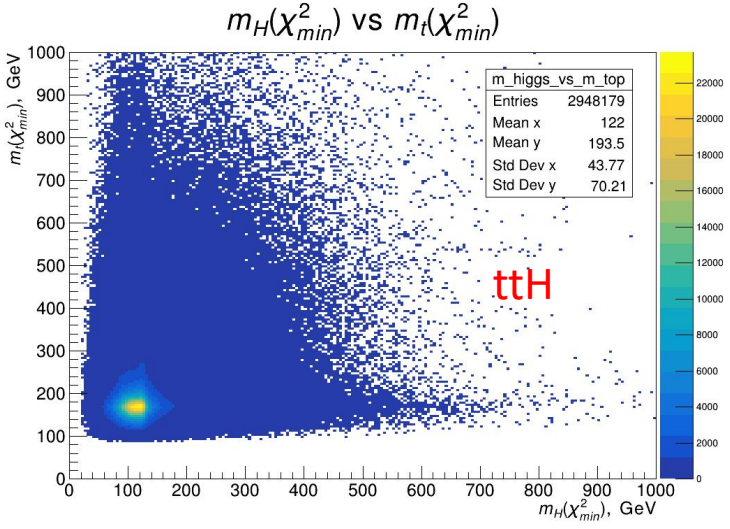
The χ^2 criterion does not select incorrect masses in this case

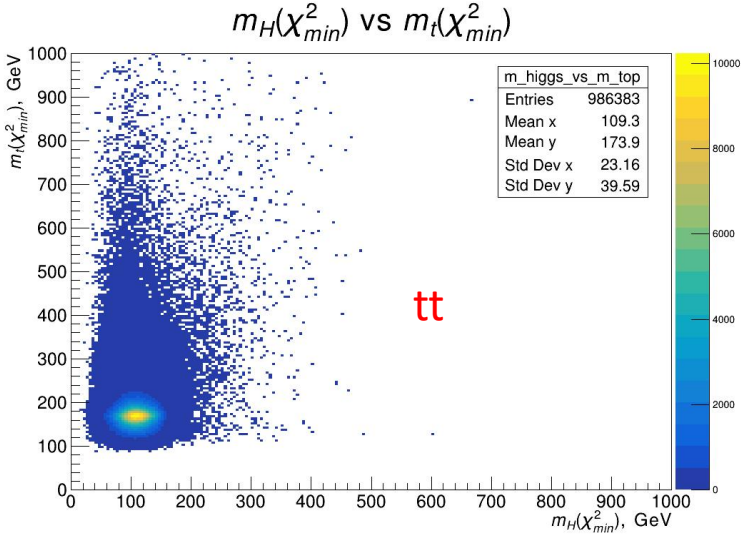
Two-dimensional distributions on the reconstructed Higgs boson and top-quark masses

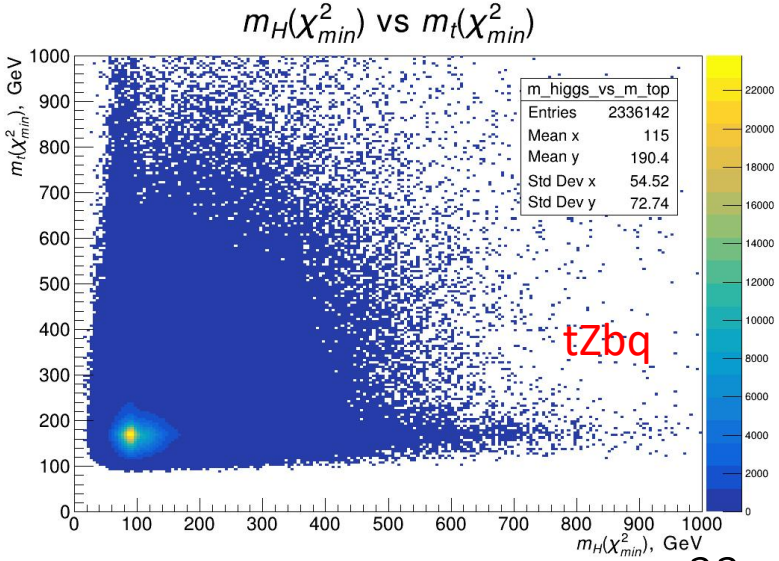




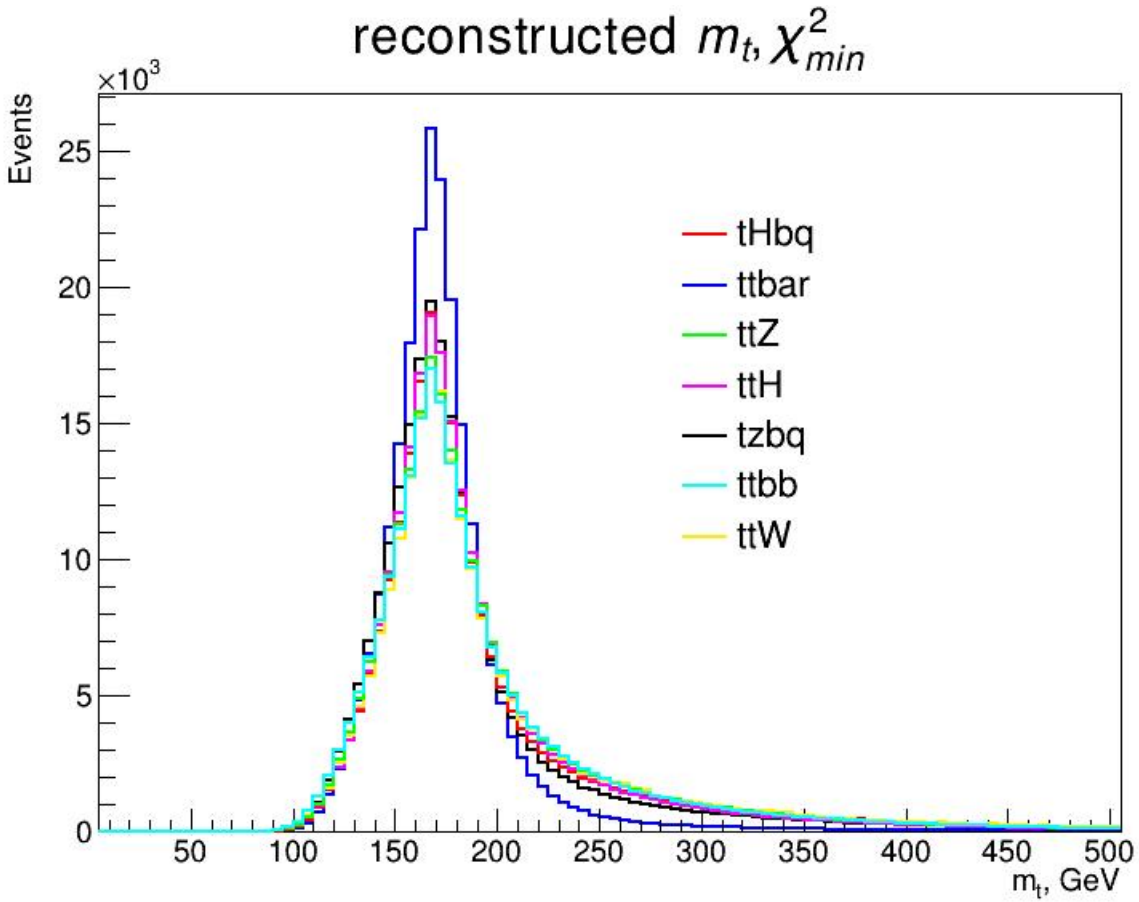


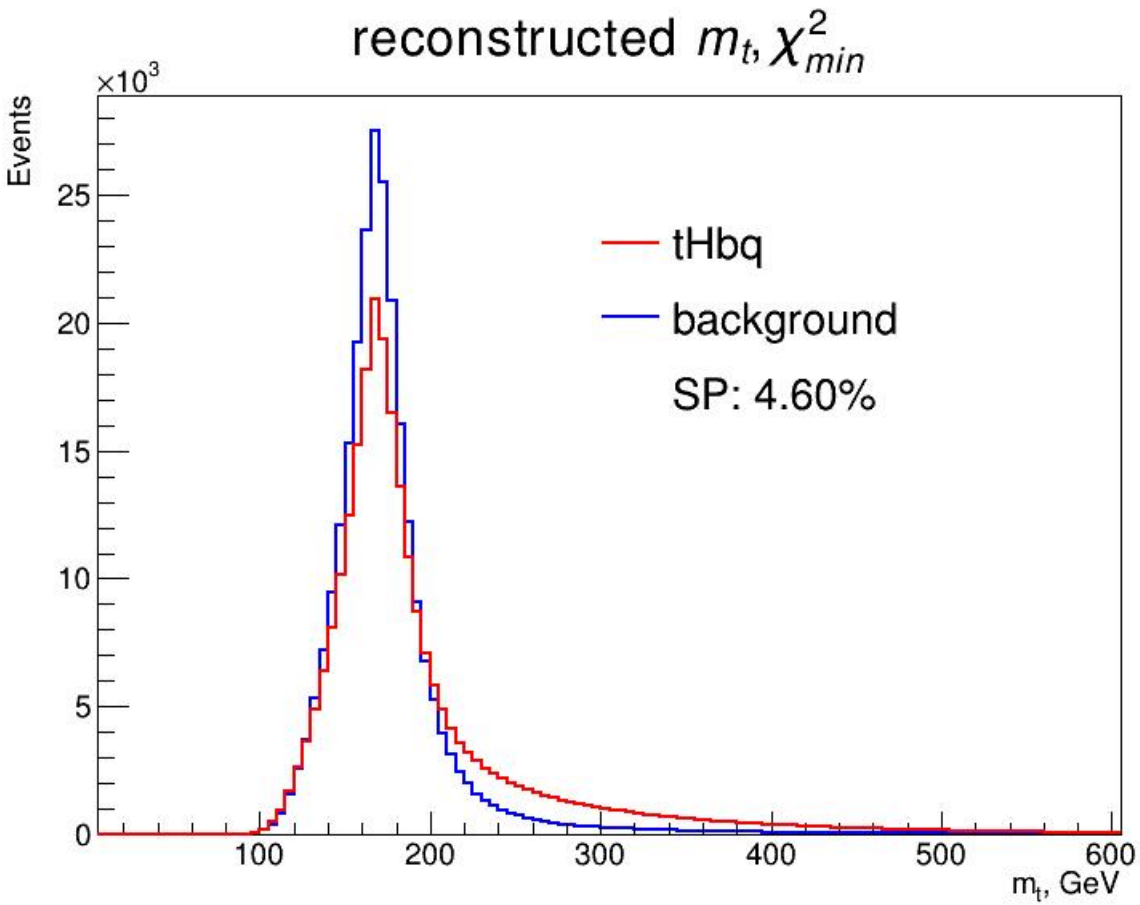




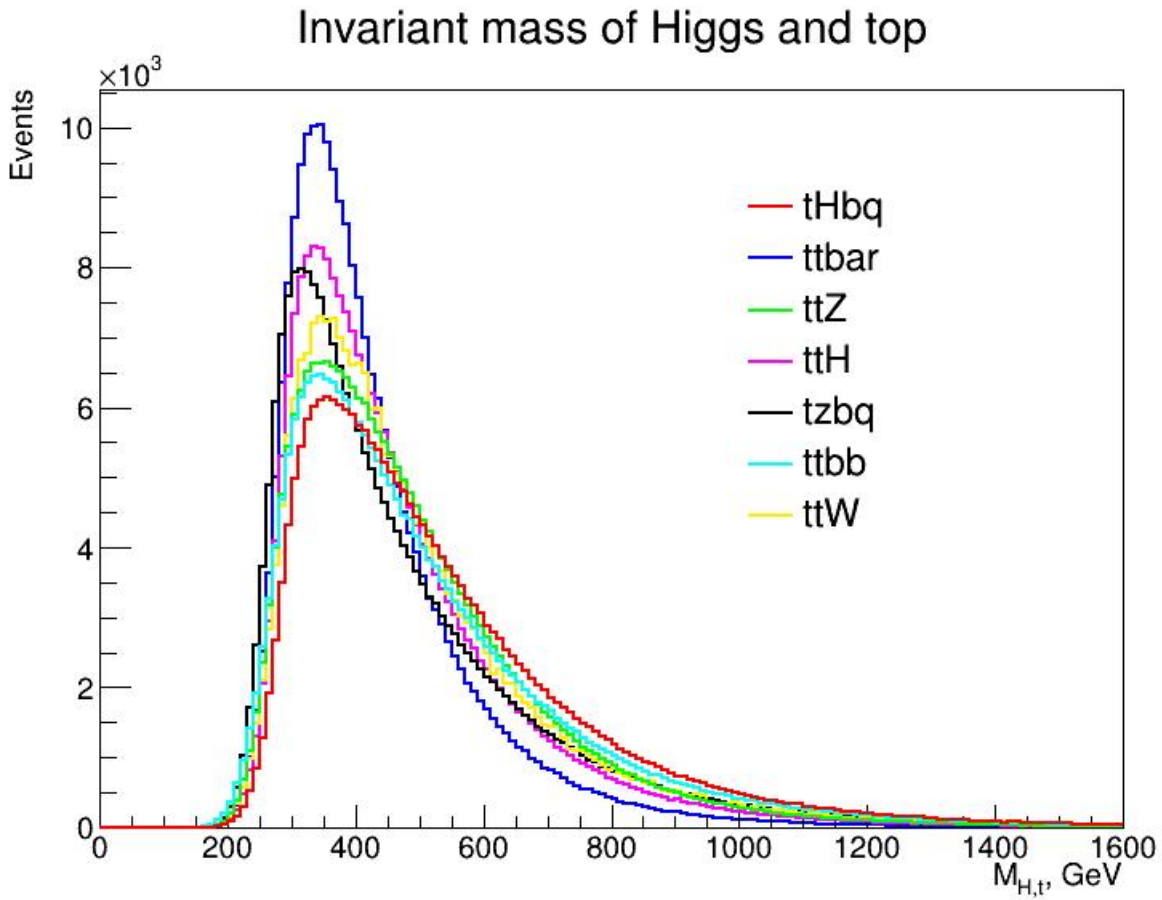


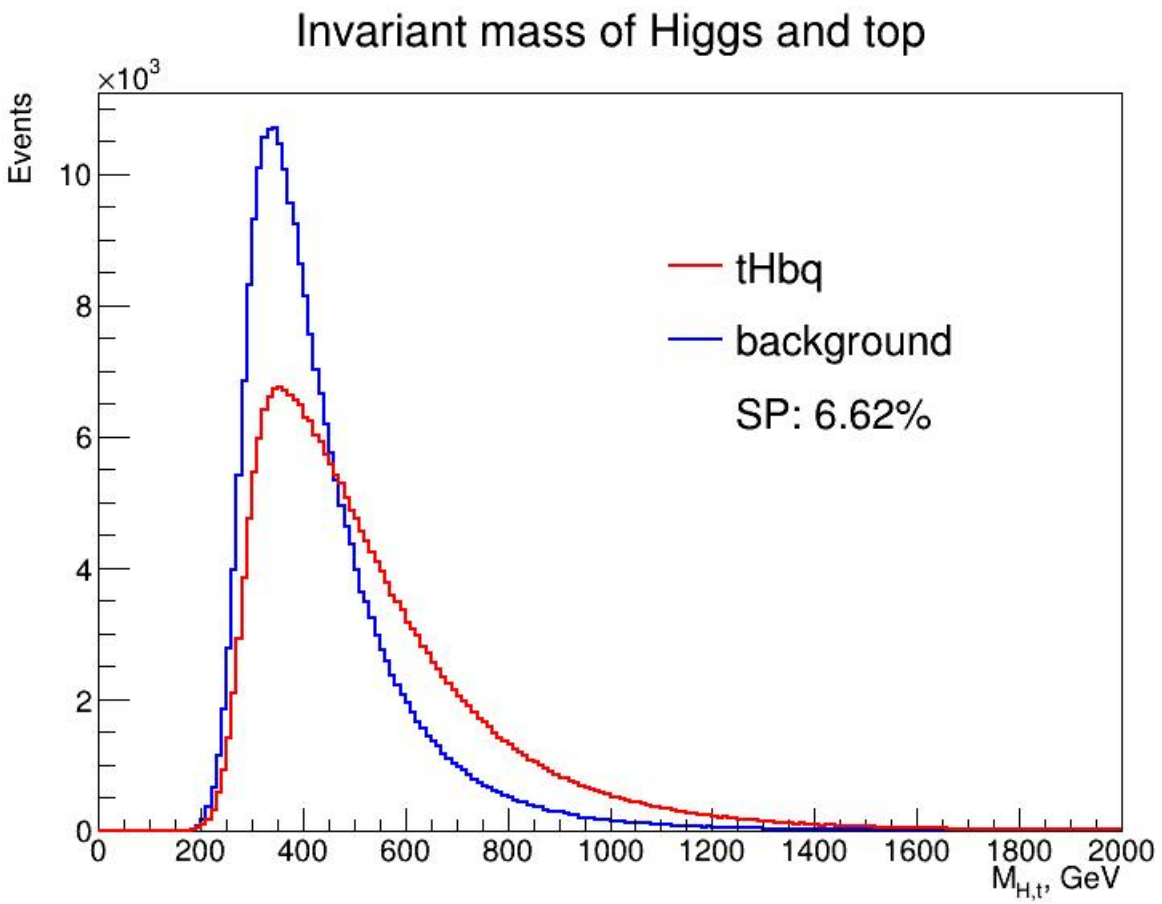
Reconstructed masses of the top quark for the signal and background processes



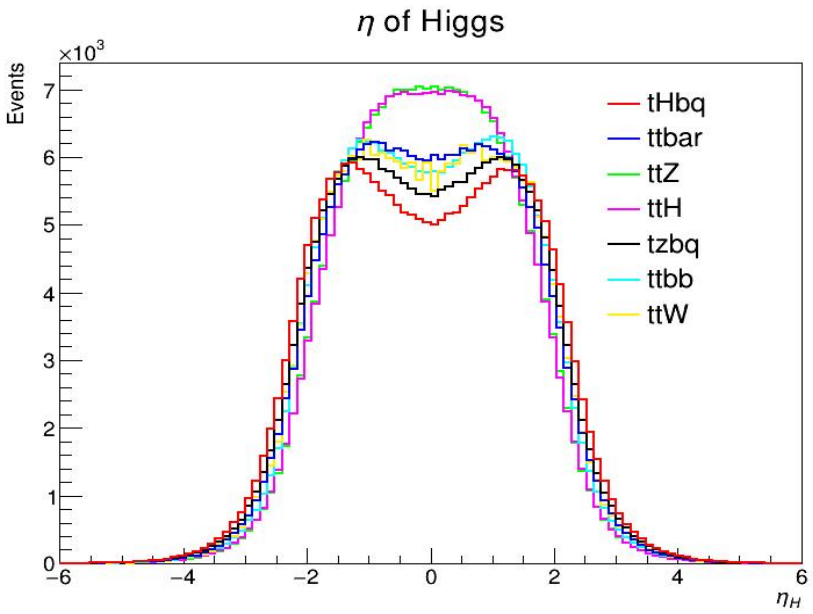


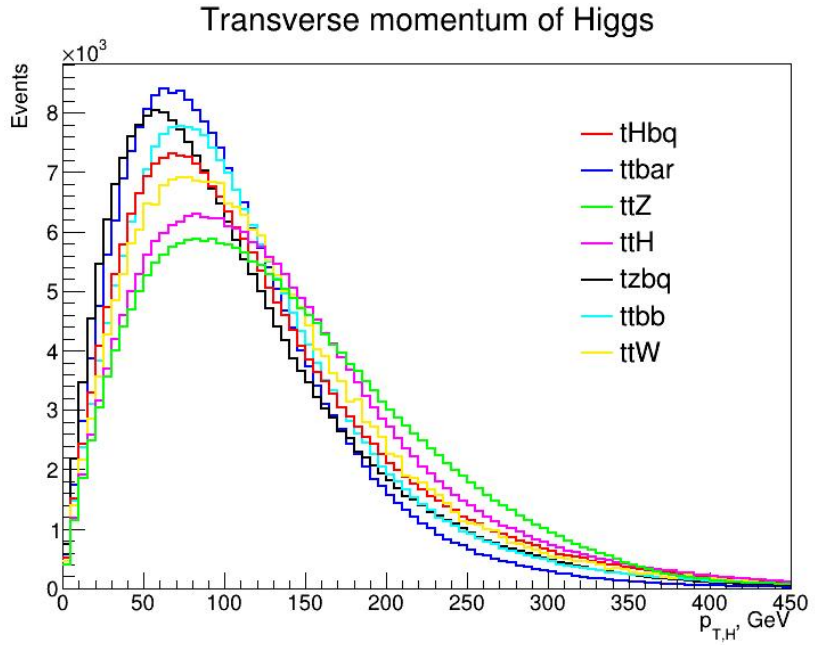
Invariant mass of the top quark and Higgs boson system for the signal and background processes

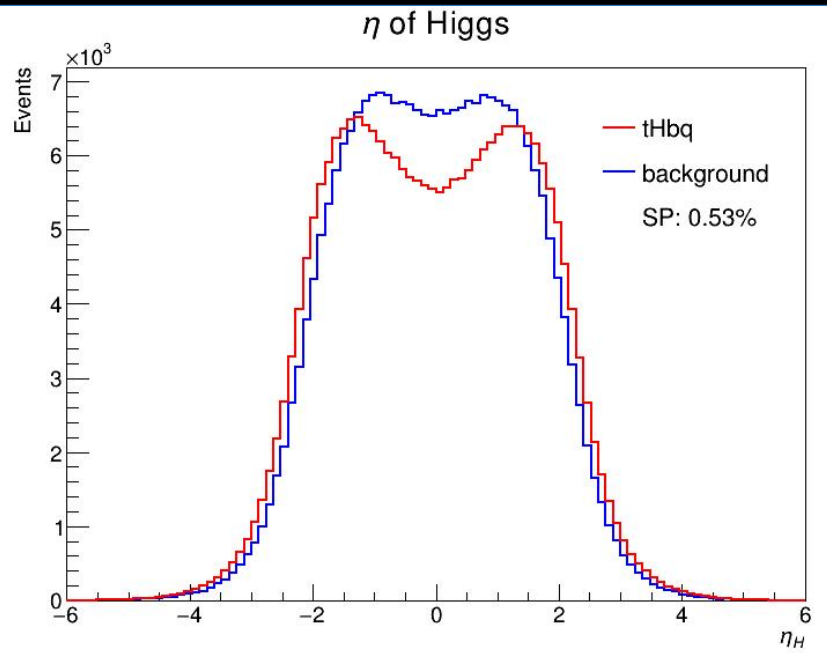


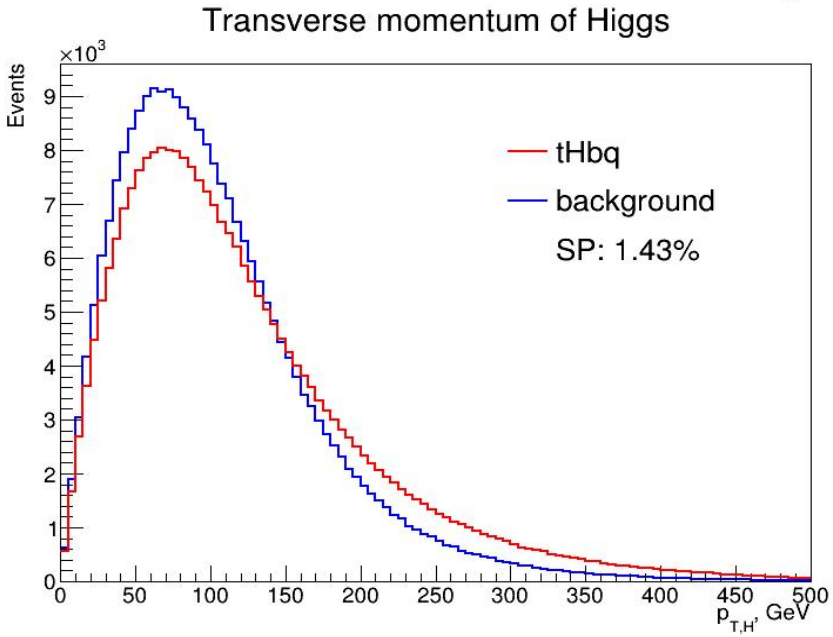


η and p_T Higgs boson for the signal and background processes

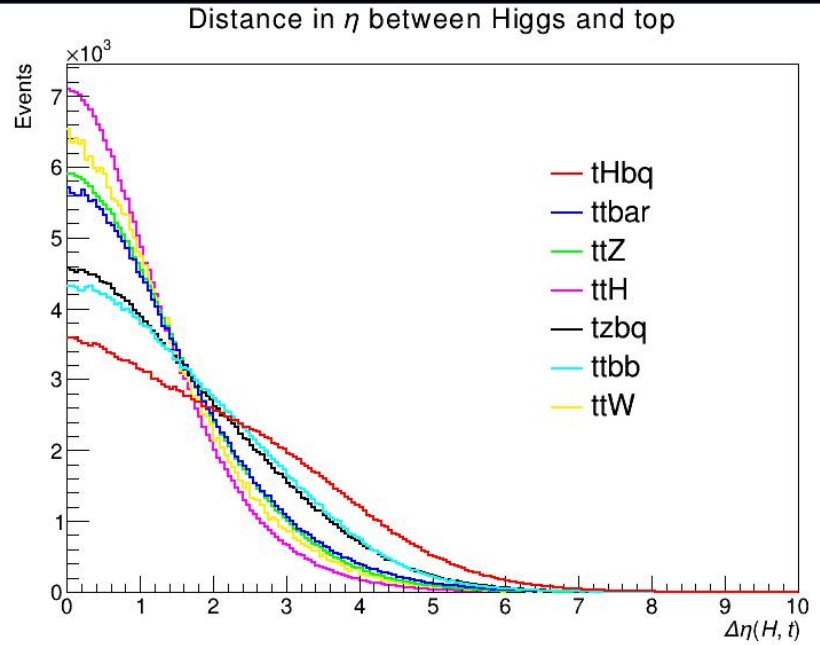


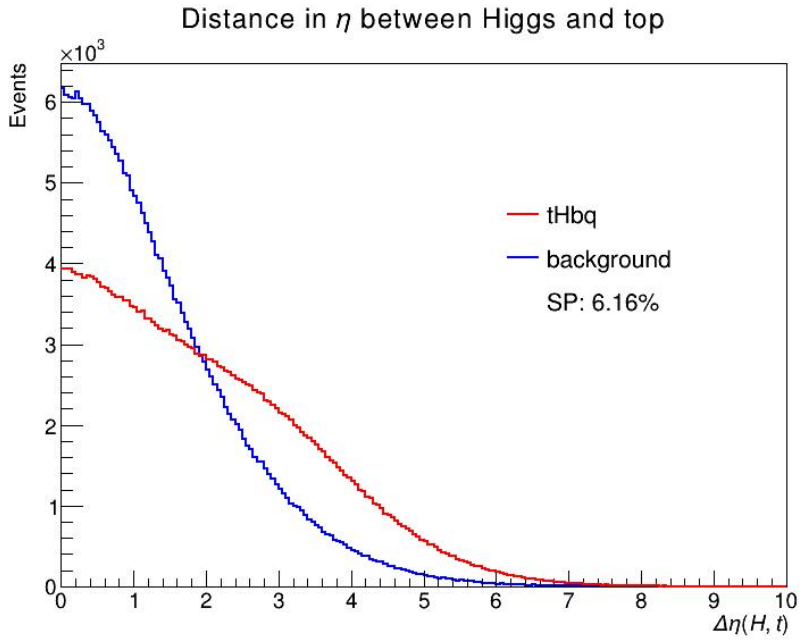


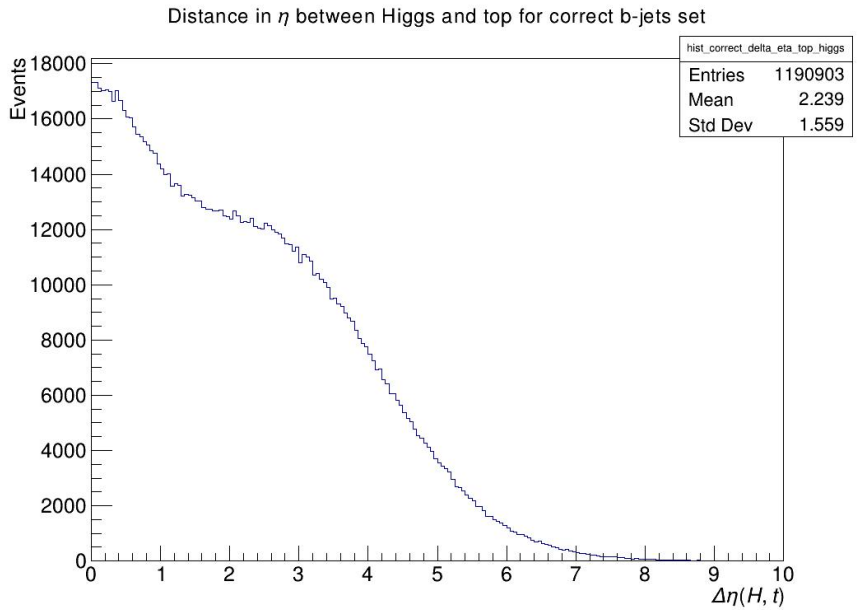




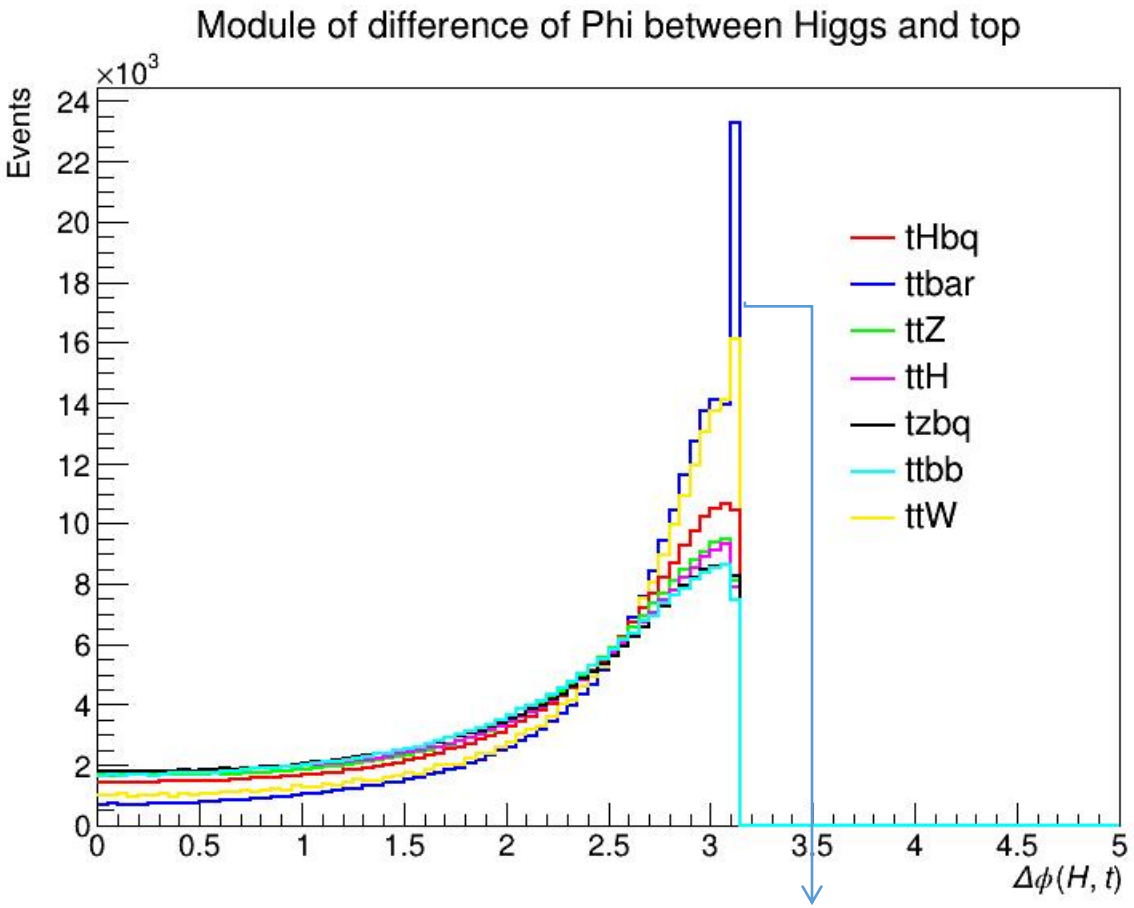
Distance η between top quark and Higgs boson for the signal and background processes

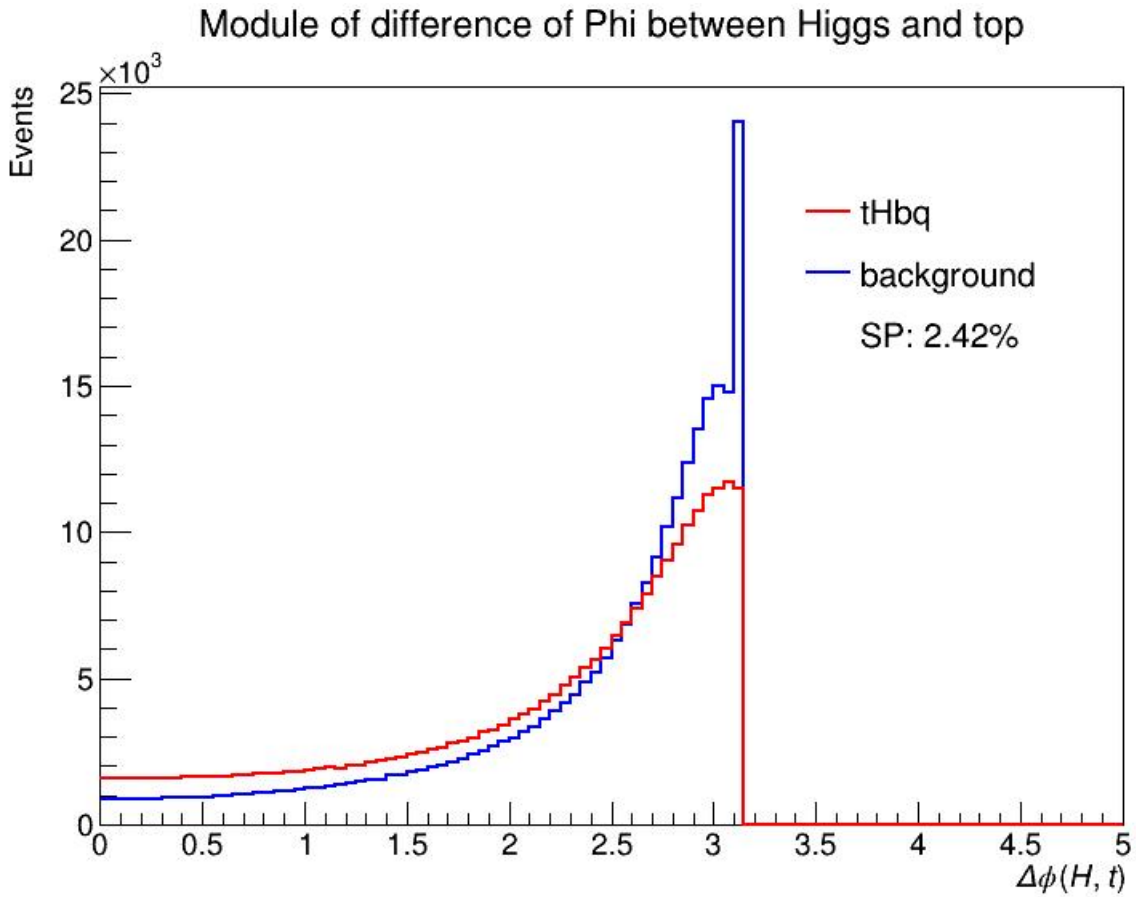






$|\Delta\phi|$ between top quark and Higgs boson for the signal and background processes





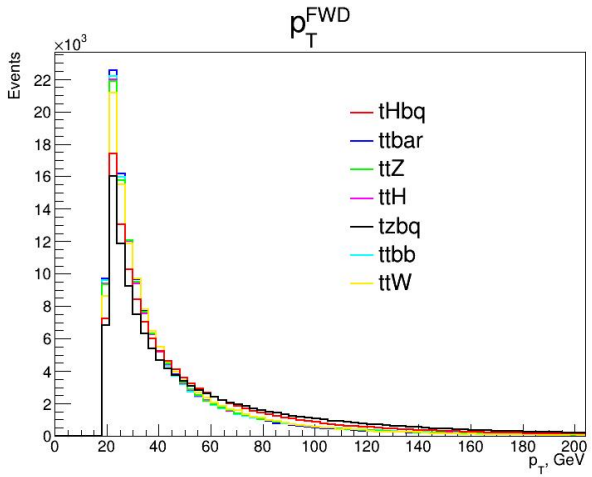
events with no non-b jets

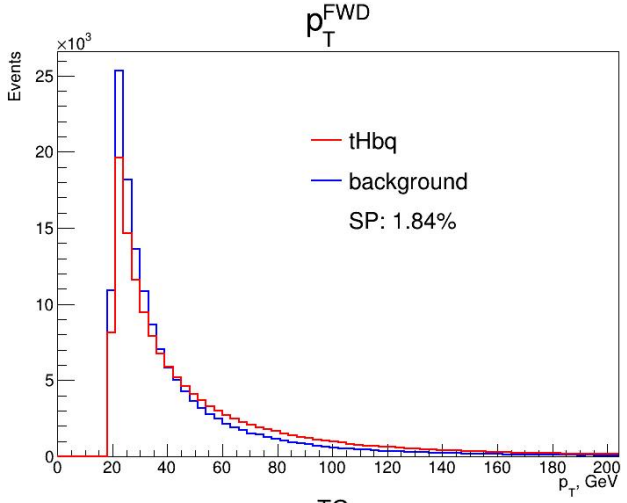
Forward and Tagging jet

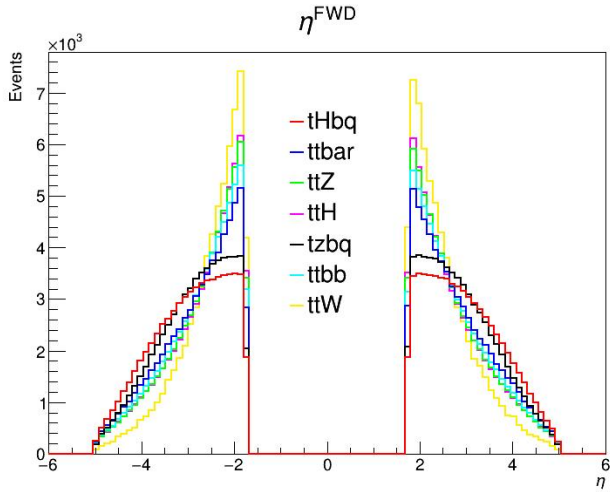
$tHbq$ → The jet generated by the quark-spectator can be used to extract the signalling process

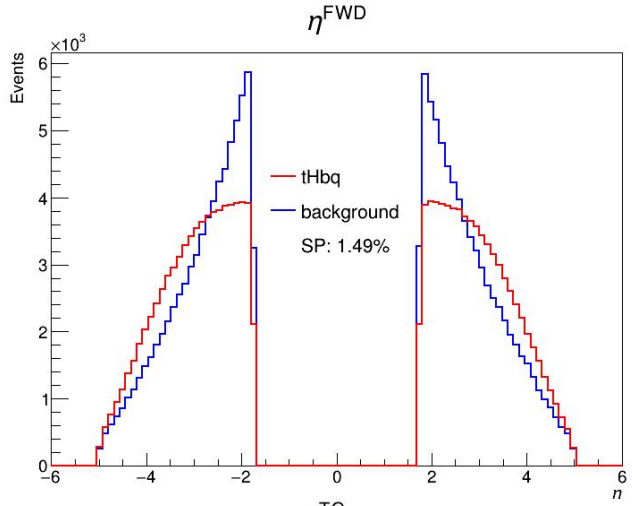
1) $p_T^{FWD} > 30\ \text{GeV}, |\eta^{FWD}| > 1.74$ ← Classical search algorithm (Forward Jet)

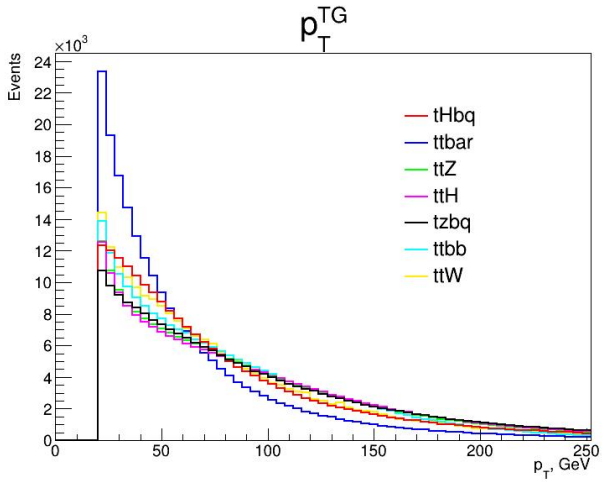
2) $m(bjet^{lep.\ top}, non\text{-}bjet)^{max}$ ← Alternative search algorithm (Tagging jet)

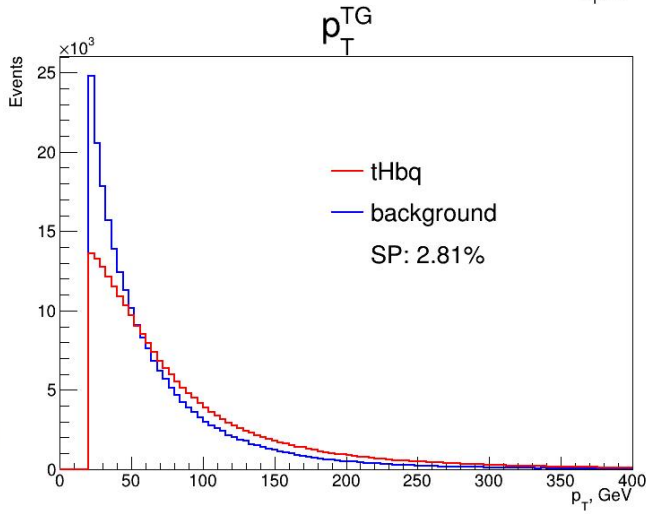


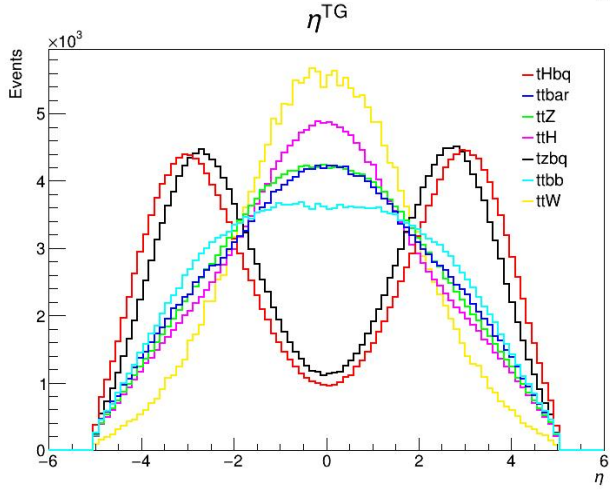


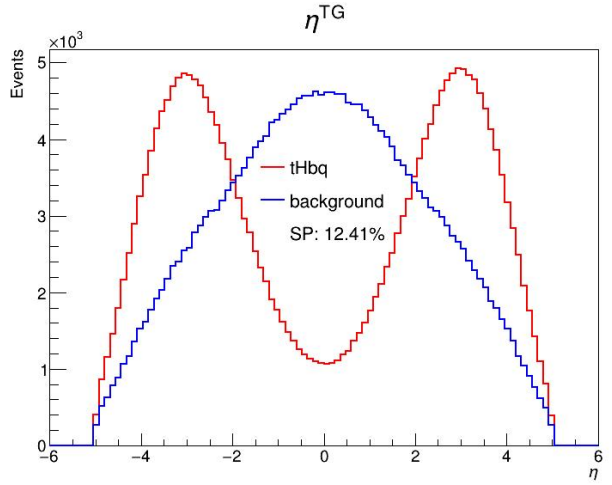




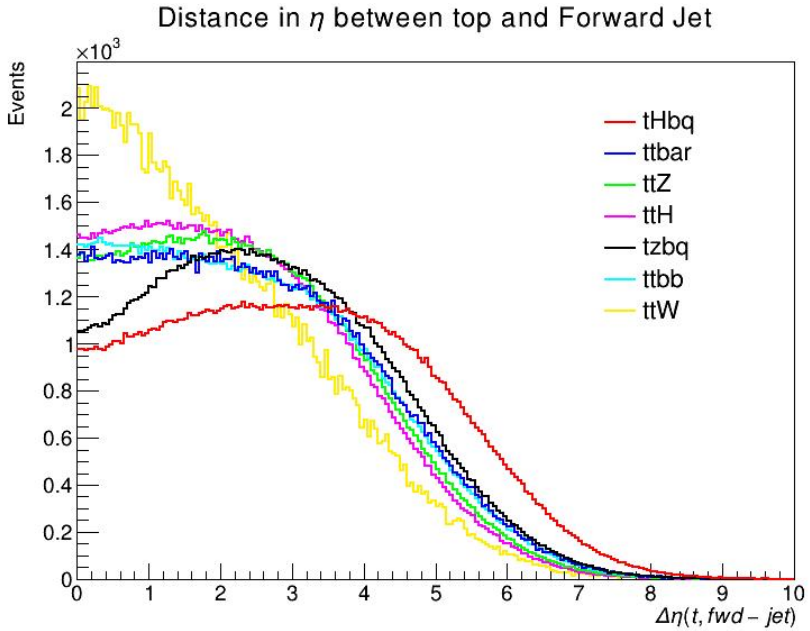


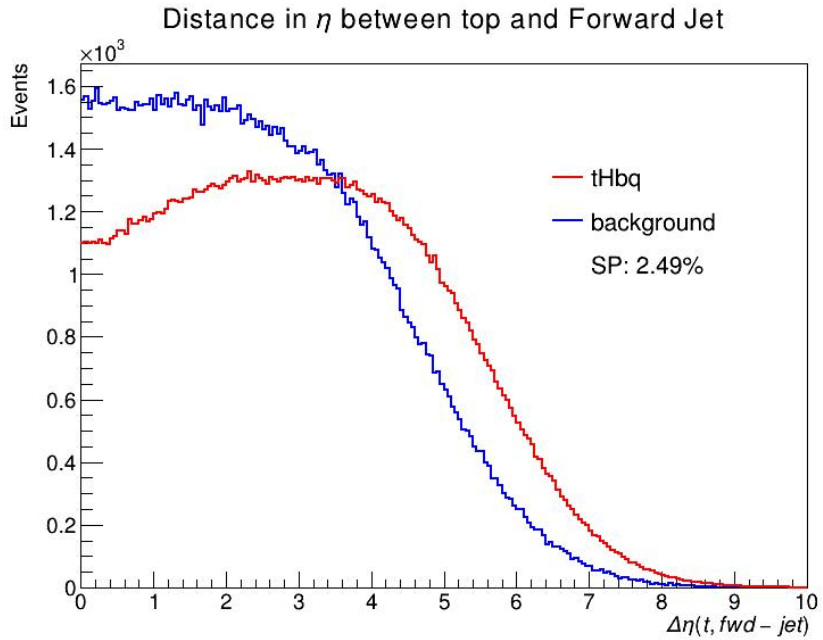


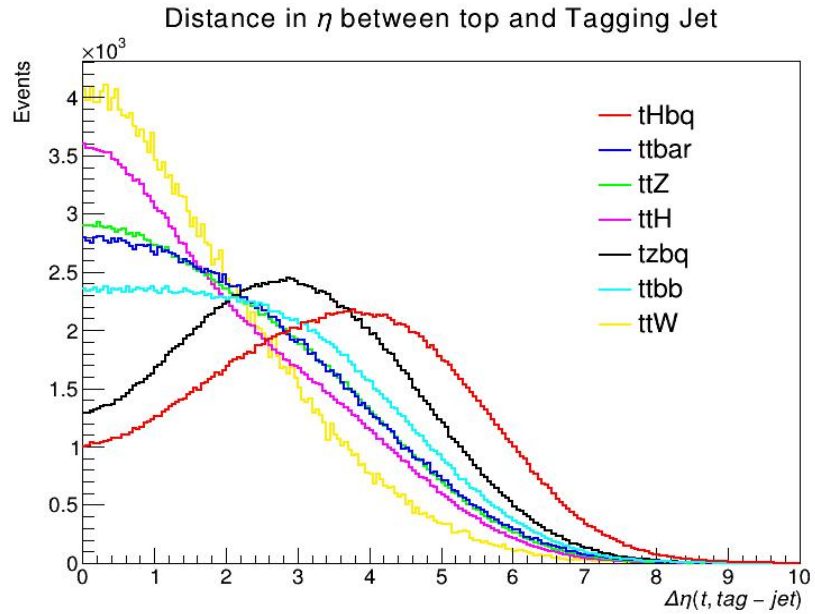


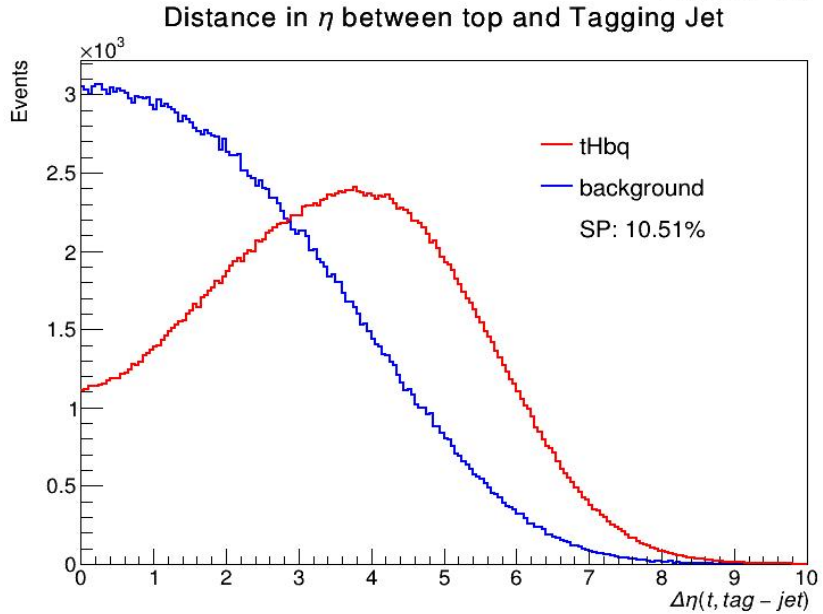


$|\Delta\eta|$ between top quark and Forward (Tagging) Jet for the signal and background processes

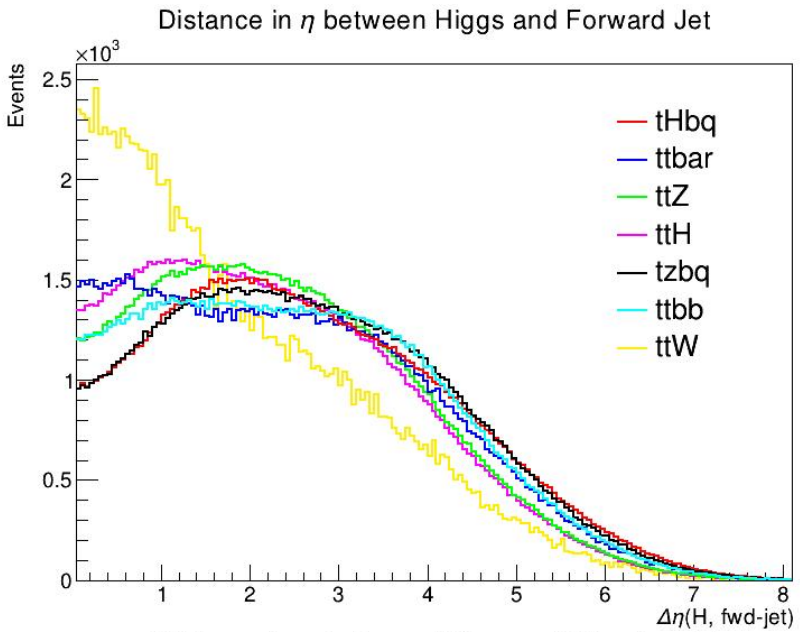


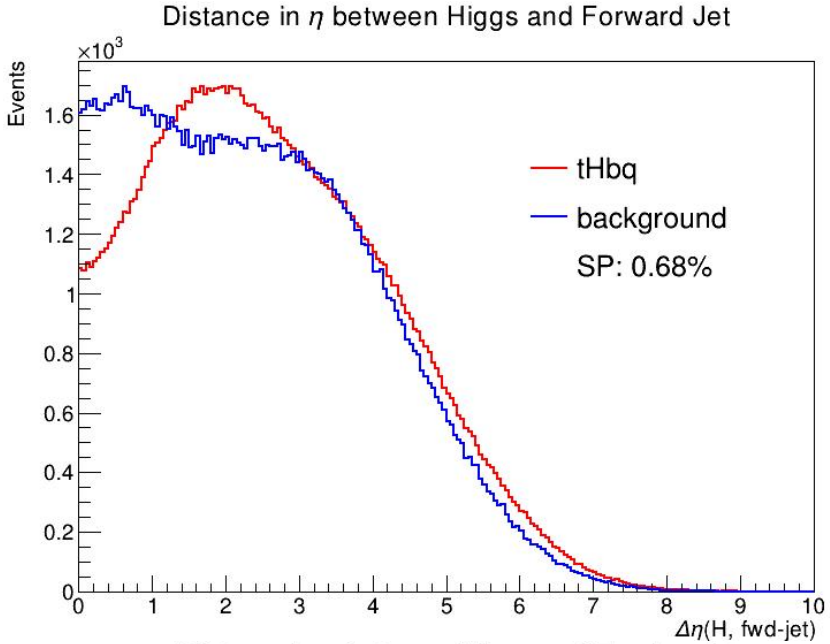


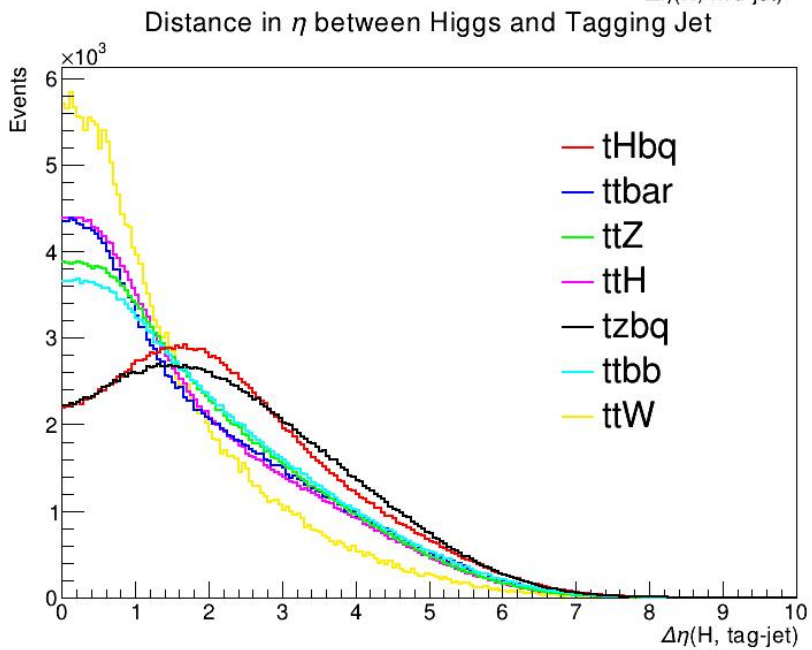


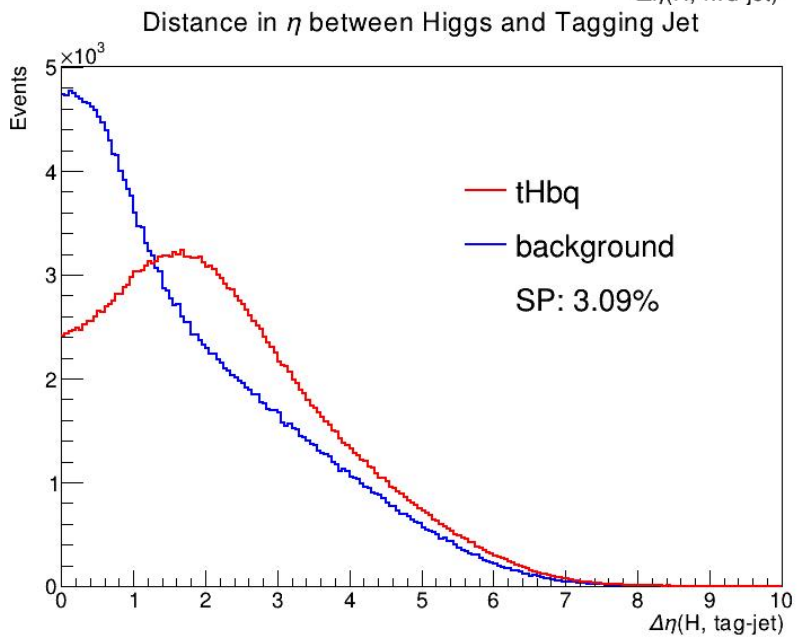


Distance in η between Higgs and Forward (Tagging) Jet for the signal and background processes

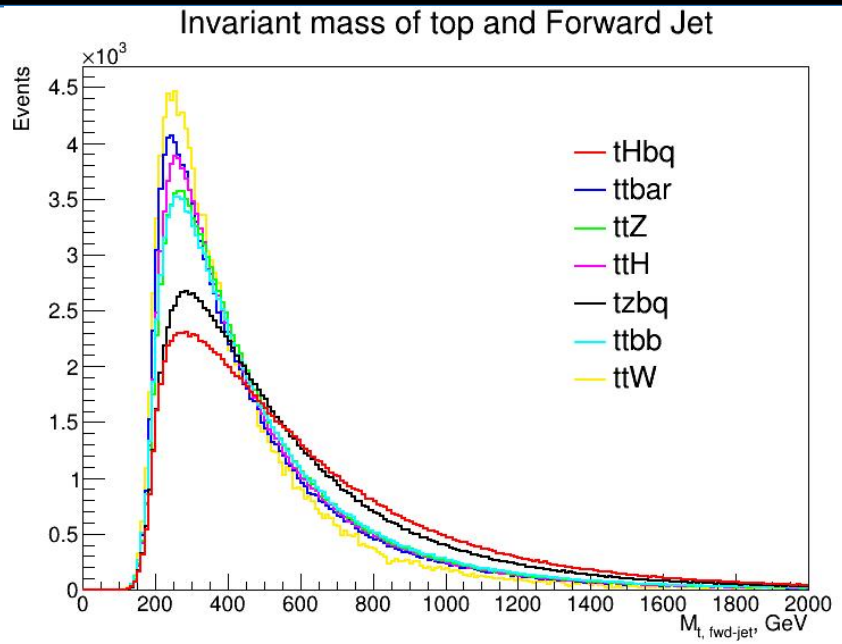


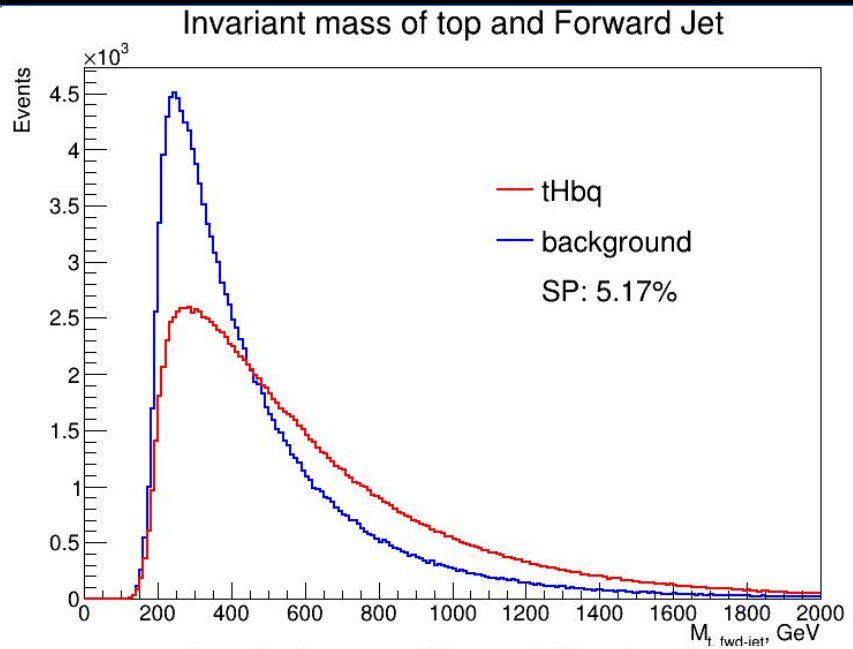


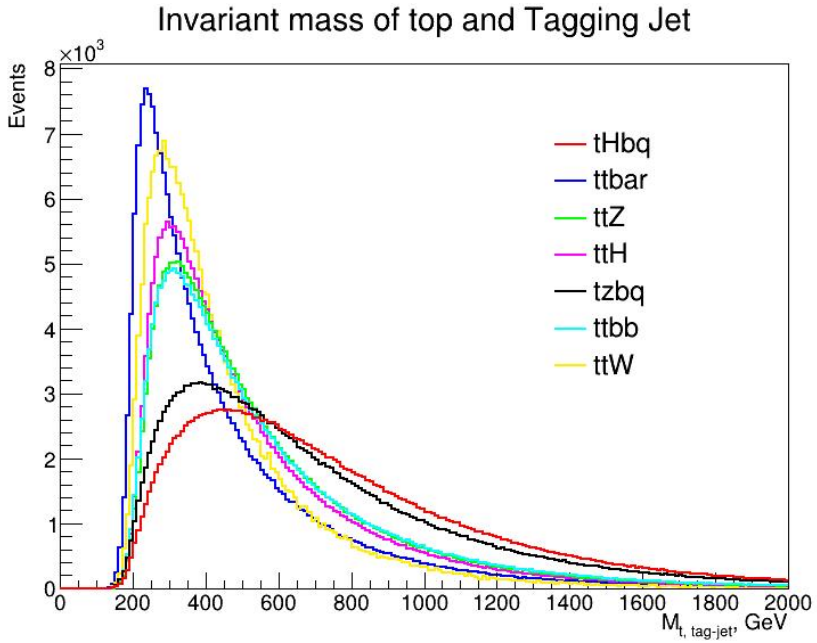


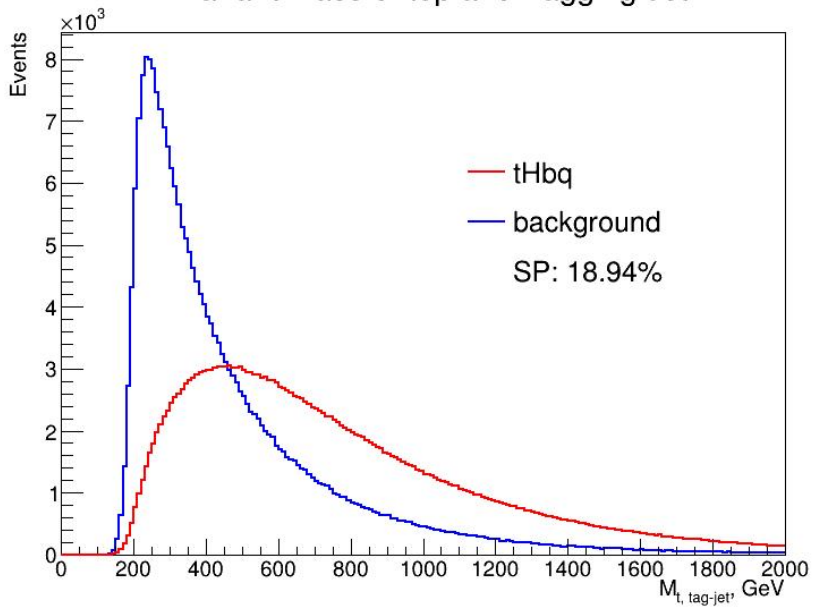


Invariant mass of Top-quark and Forward (Tagging) Jet for the signal and background processes

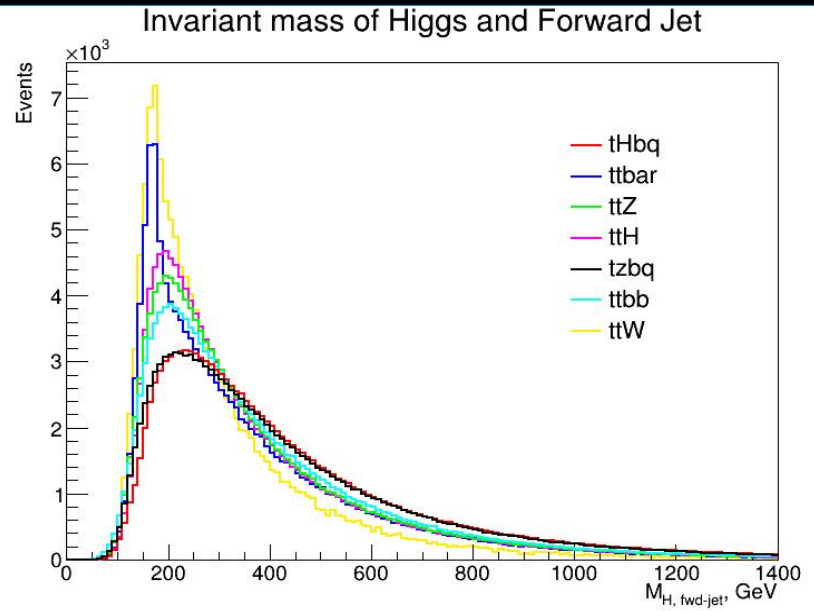


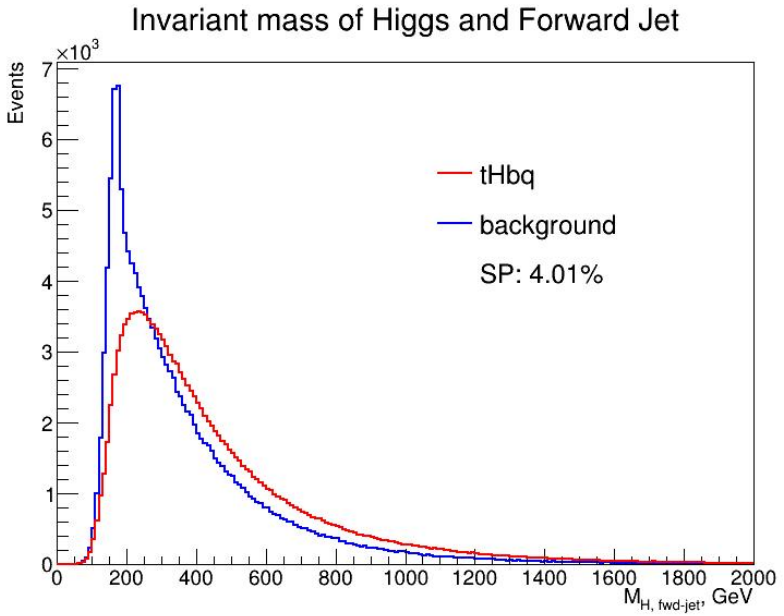


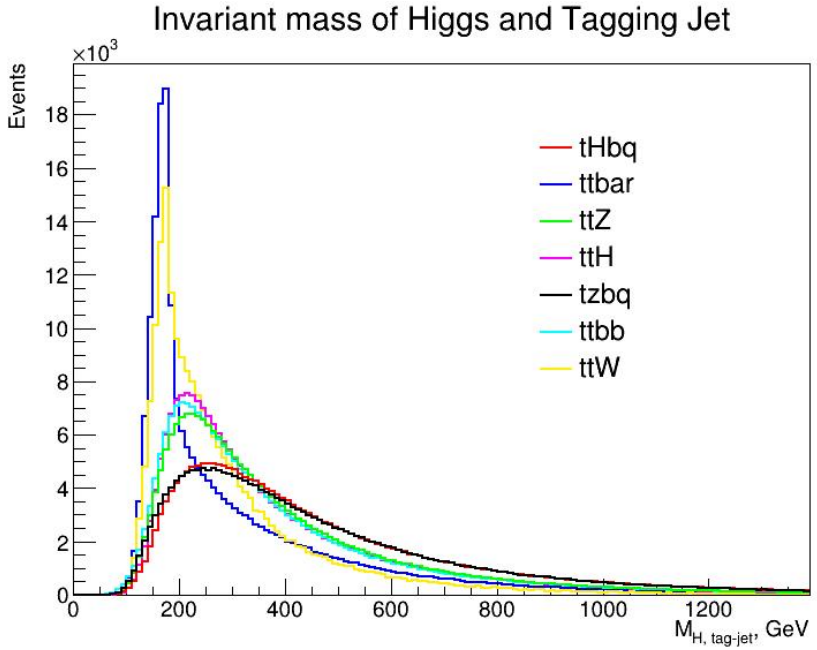


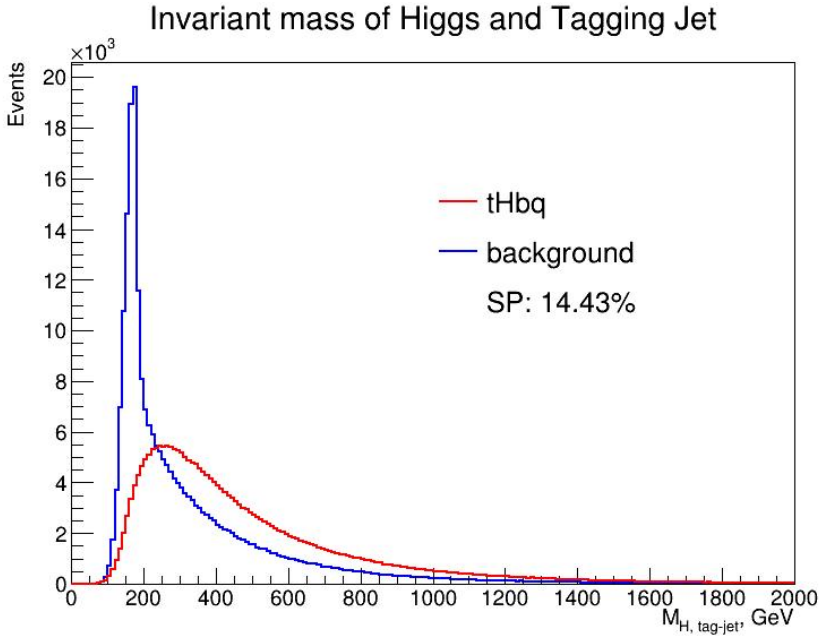


Invariant mass of Higgs and Forward (Tagging) Jet for the signal and background processes

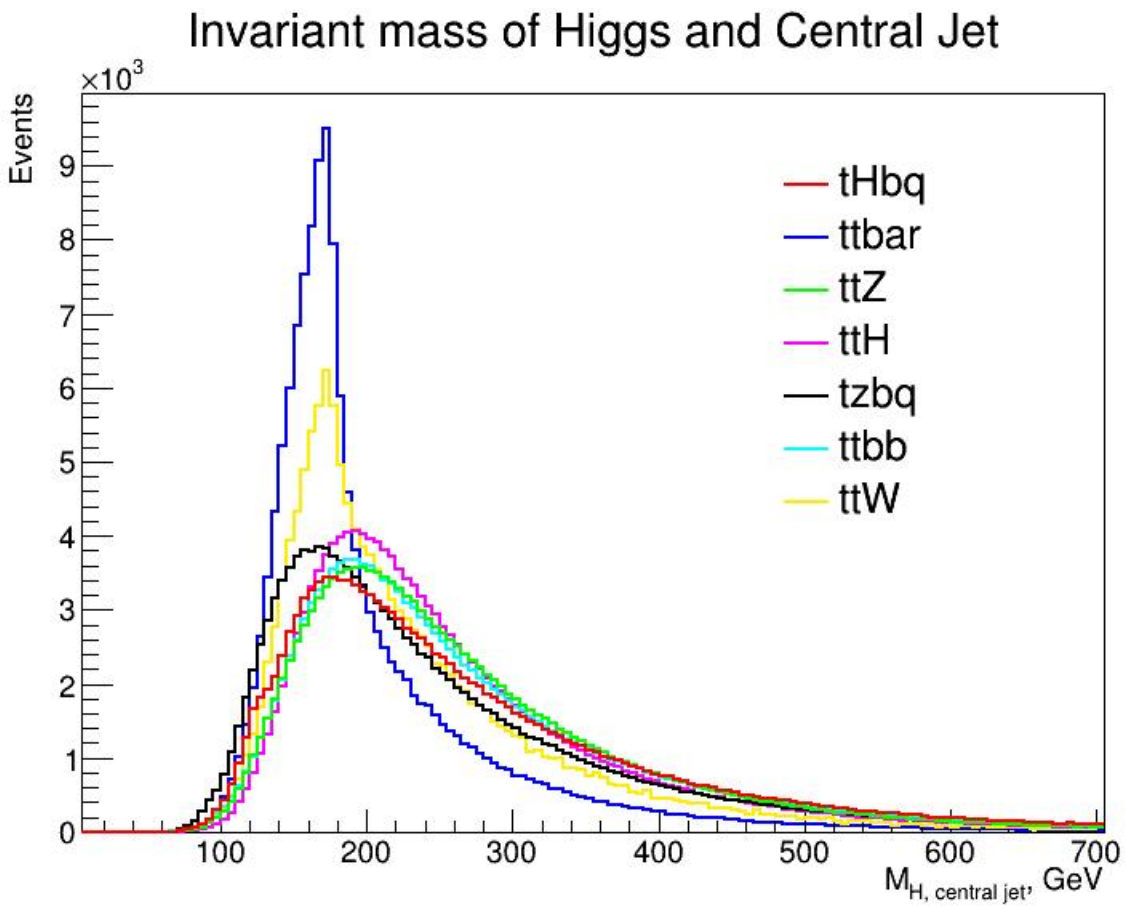


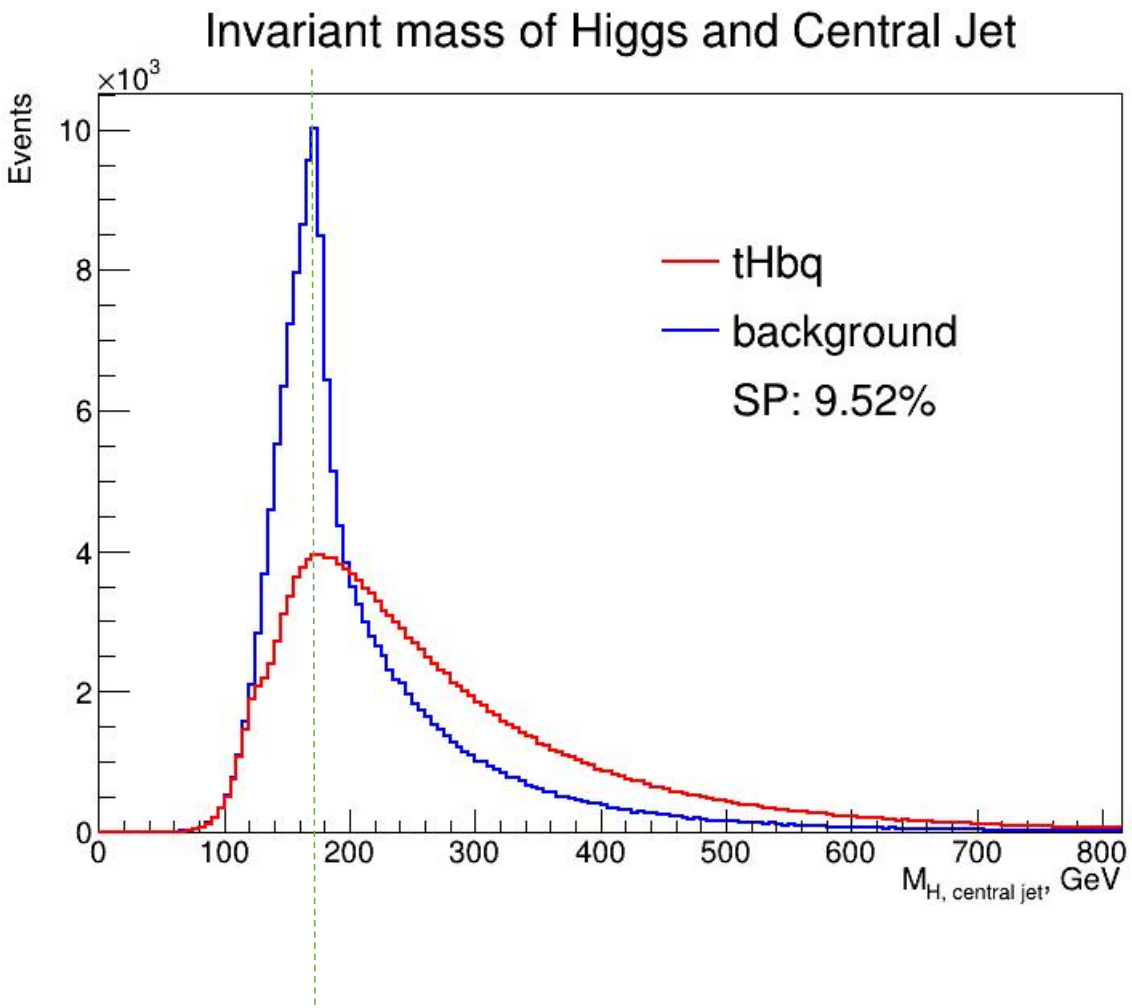






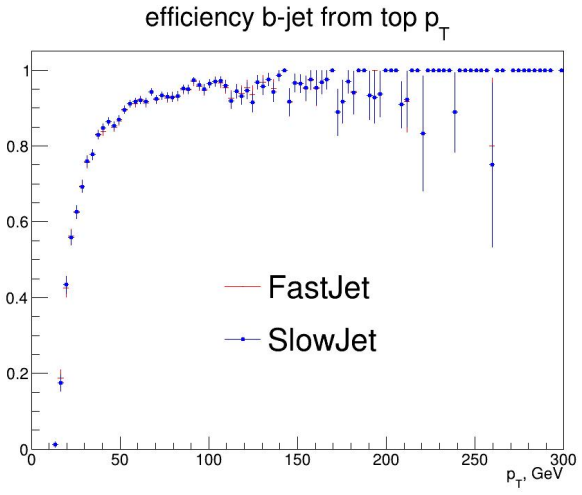
Invariant mass Higgs and Central Jet for the signal and background processes

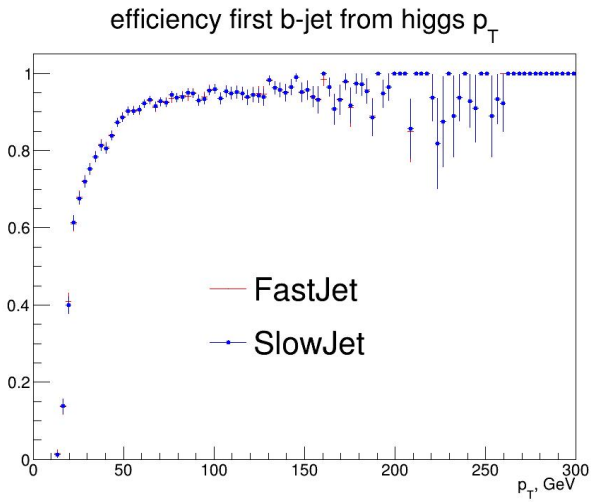


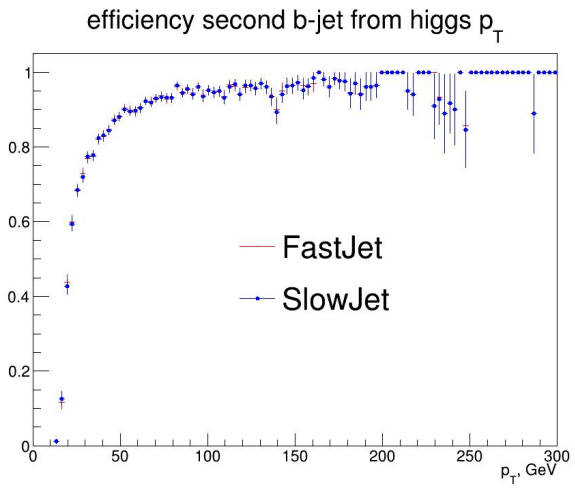


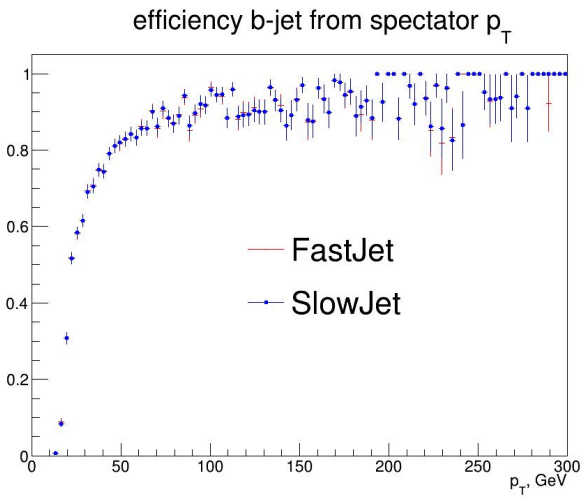
3) $|\eta^{\text{central jet}}| \leq 1.74$ with max p_T

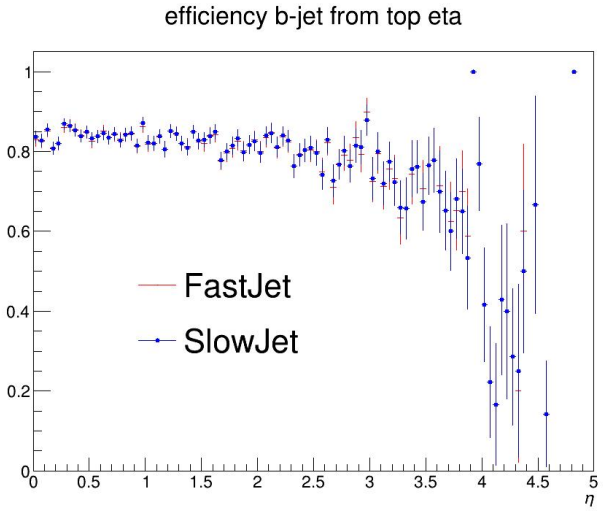
FastJet vs SlowJet

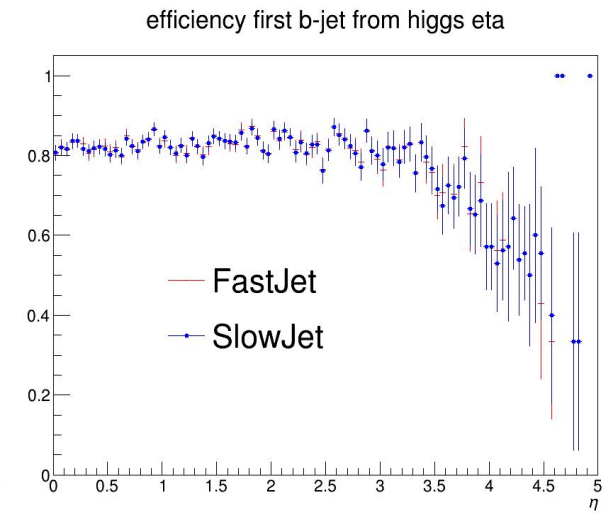


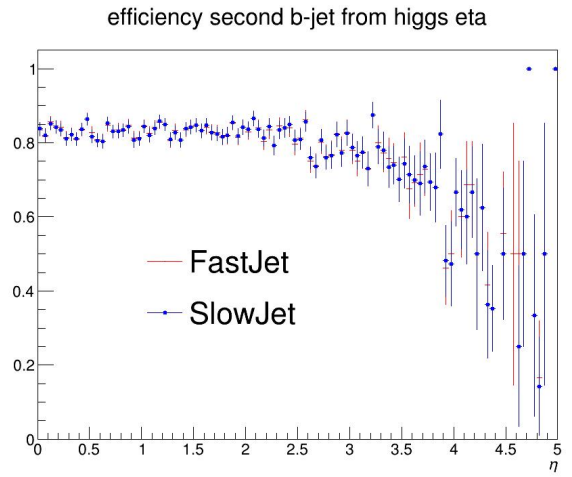


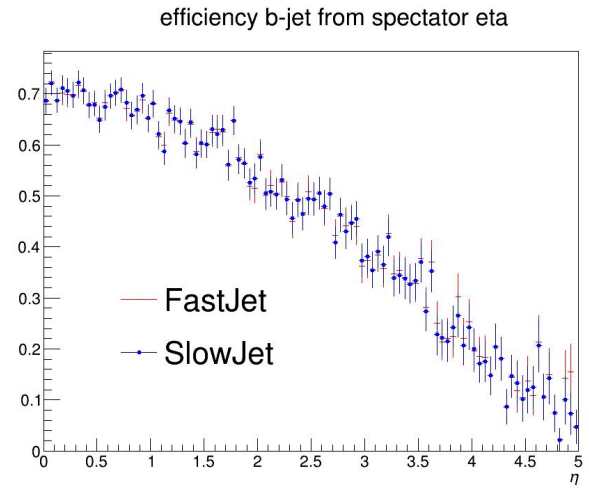












Aplanarity, spherisity and Fox-Wolfram Moments

$$M_{xyz} = \begin{pmatrix} p_{xi}^2 & p_{xi}p_{yi} & p_{xi}p_{zi} \\ p_{yi}p_{xi} & p_{yi}^2 & p_{yi}p_{zi} \\ p_{zi}p_{xi} & p_{zi}p_{yi} & p_{zi}^2 \end{pmatrix}$$

full momentum tensor

The individual eigenvalues are normalized and ordered such that

$$\lambda_1 > \lambda_2 > \lambda_3$$

$$\sum_i \lambda_i = 1$$

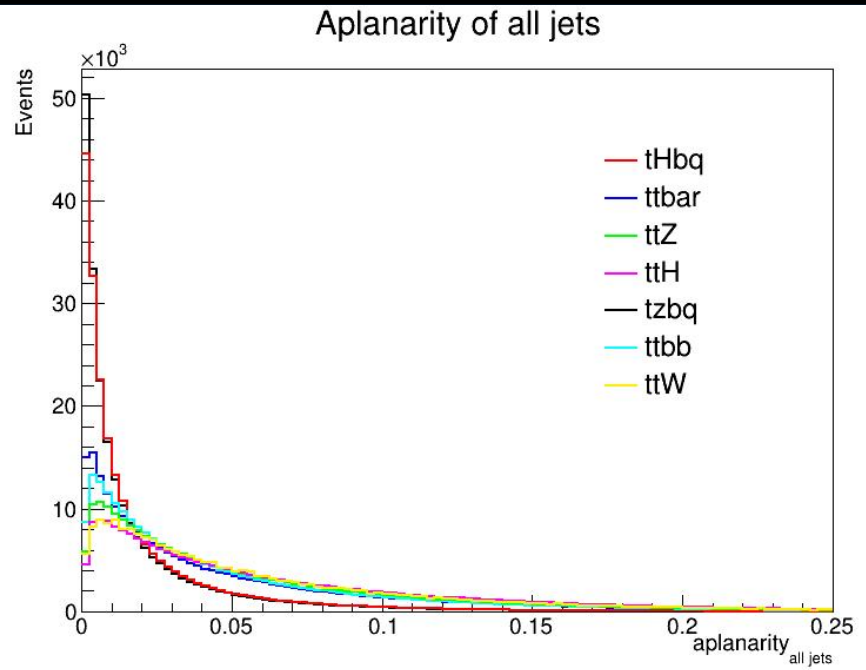
Spherisity: $S = \frac{3}{2}(\lambda_2 + \lambda_3)$

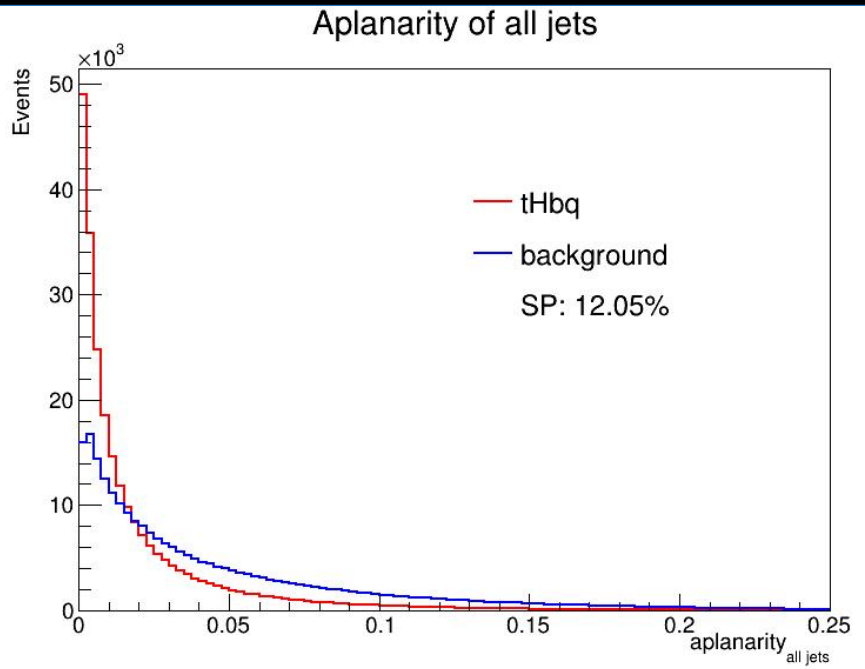
Aplanarity: $A = \frac{3}{2}\lambda_3$

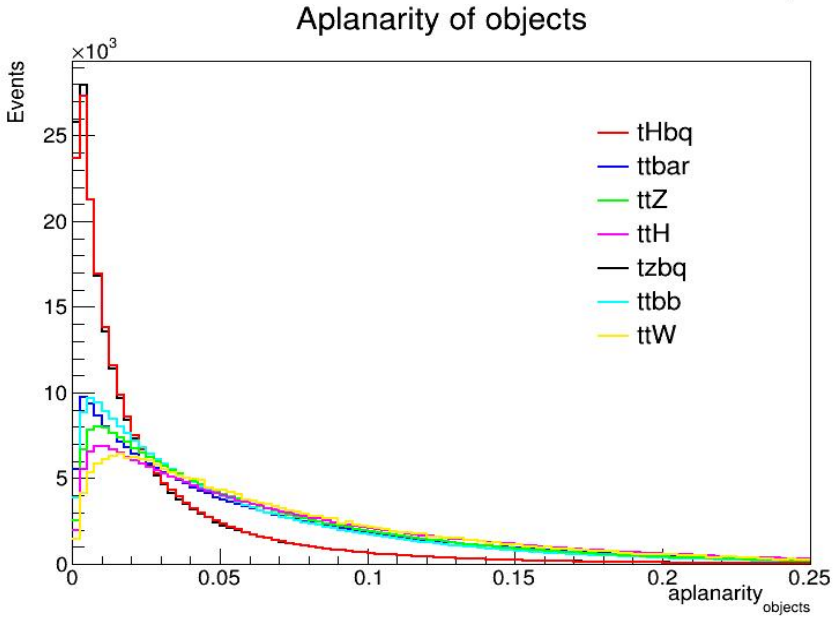
Fox-Wolfram Moments:

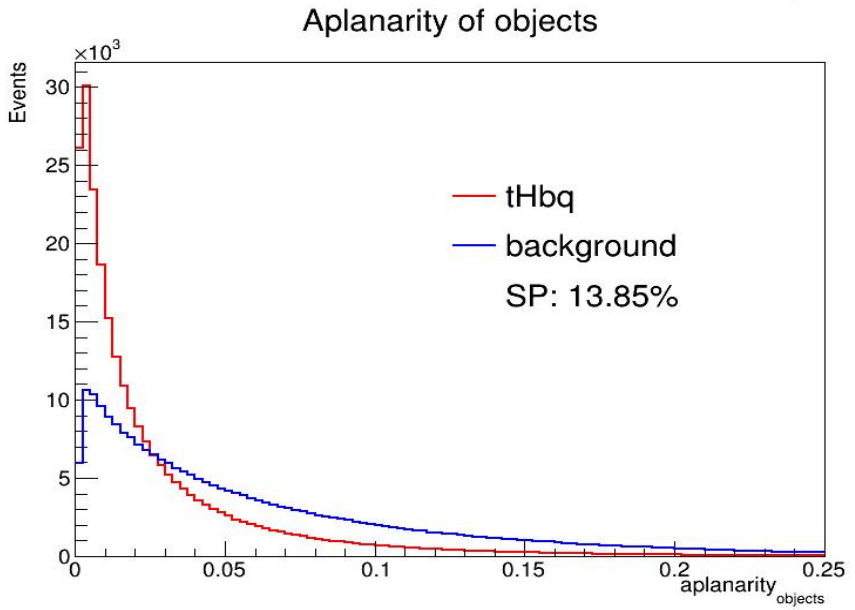
$$H_l = \frac{\sum_{ij} p_T^i p_T^j P_l(\cos\theta_{ij})}{(\sum_i p_T^i)^2}$$

Aplanarity for the signal and background processes

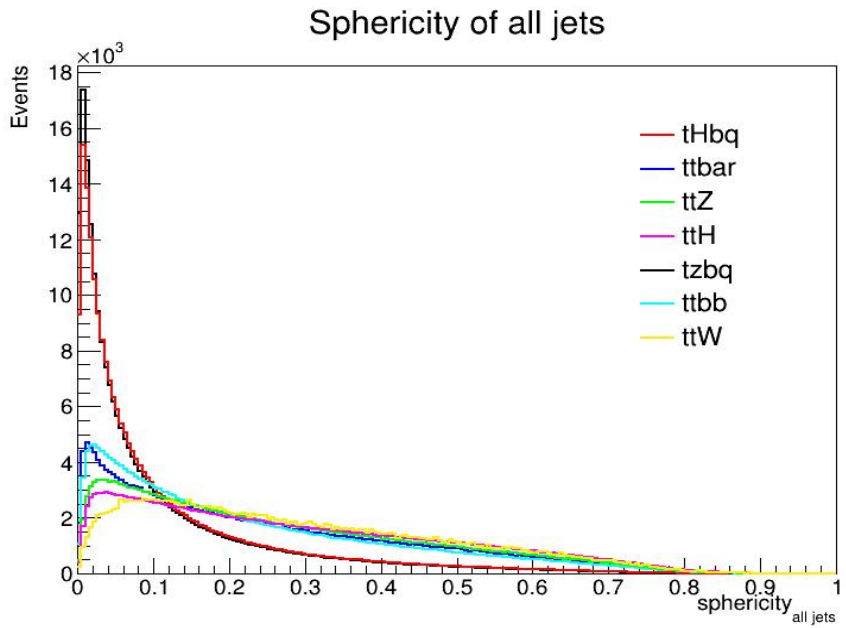


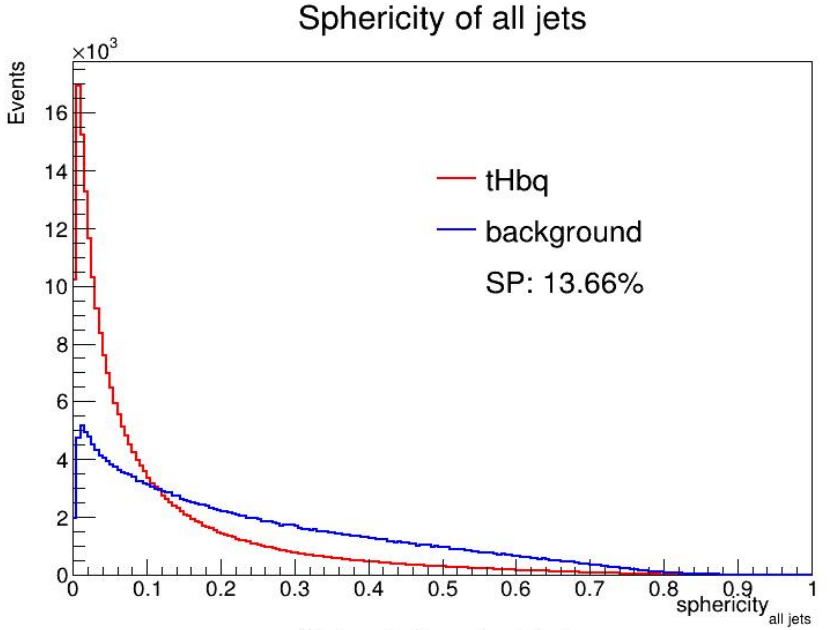


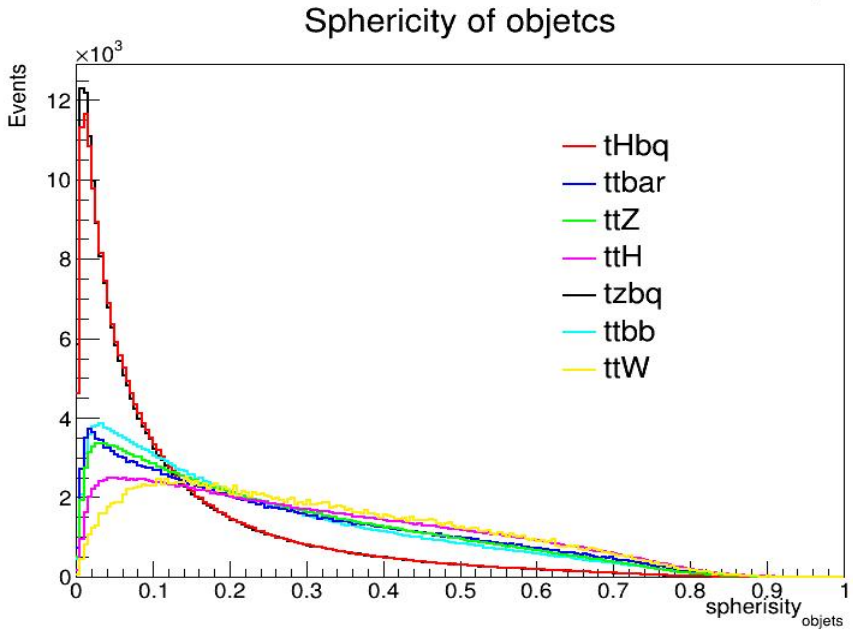


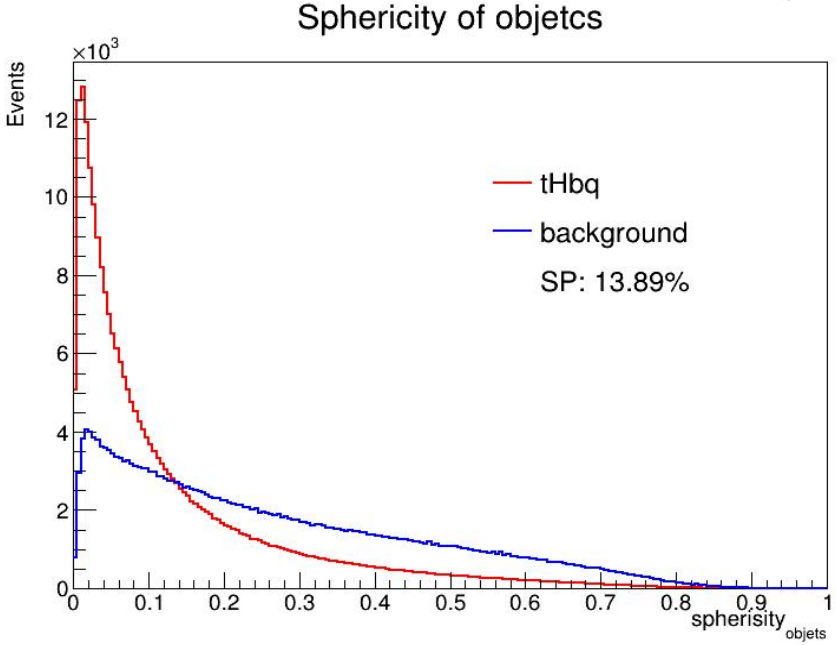


Sphericity for the signal and background processes

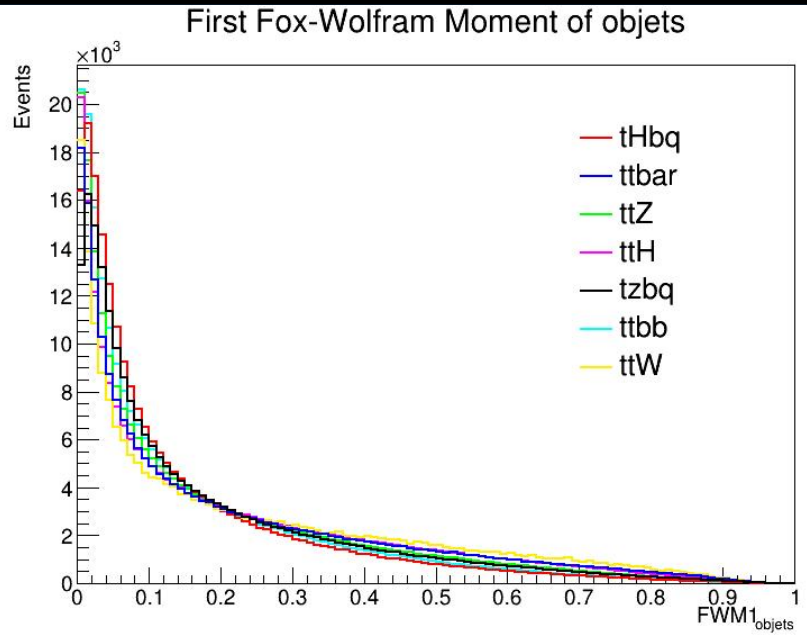


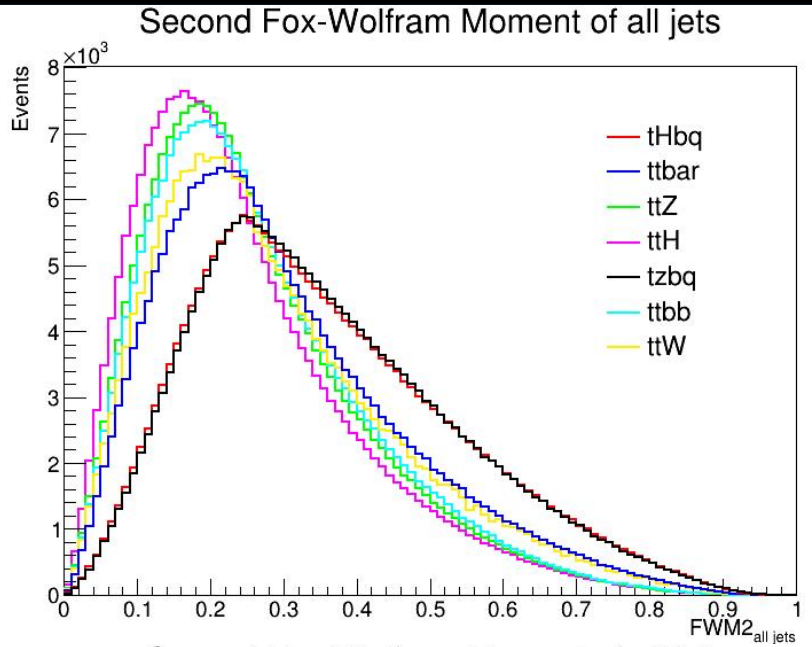


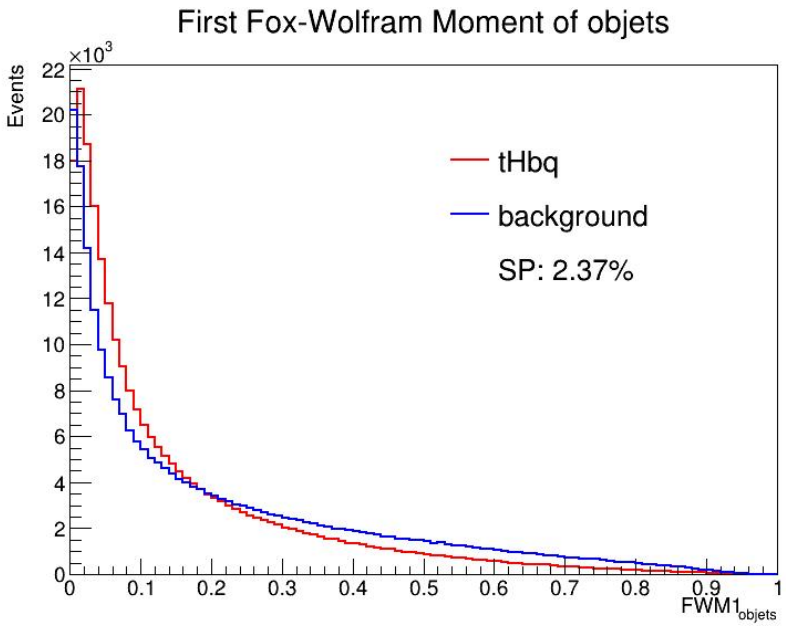


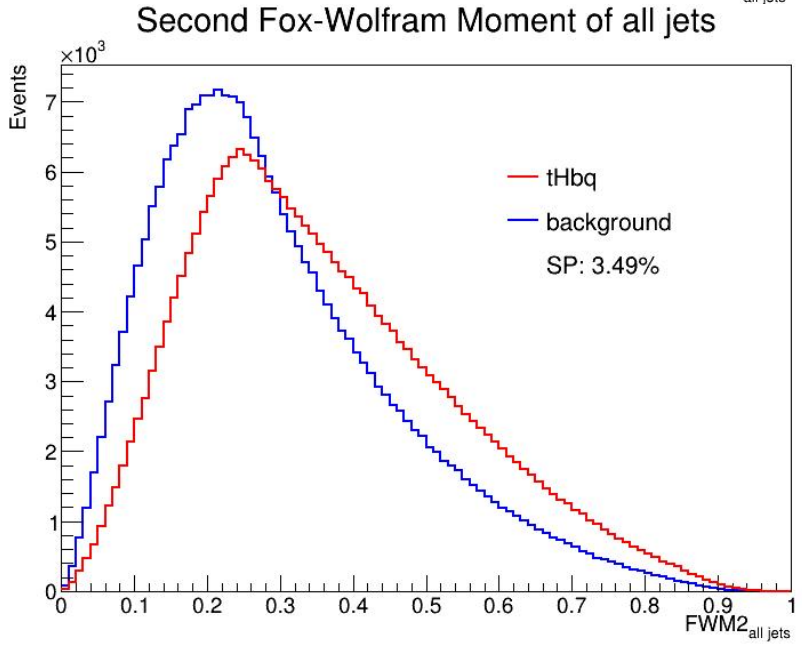


First and Second Fox-Wolfram moment for the signal and background processes

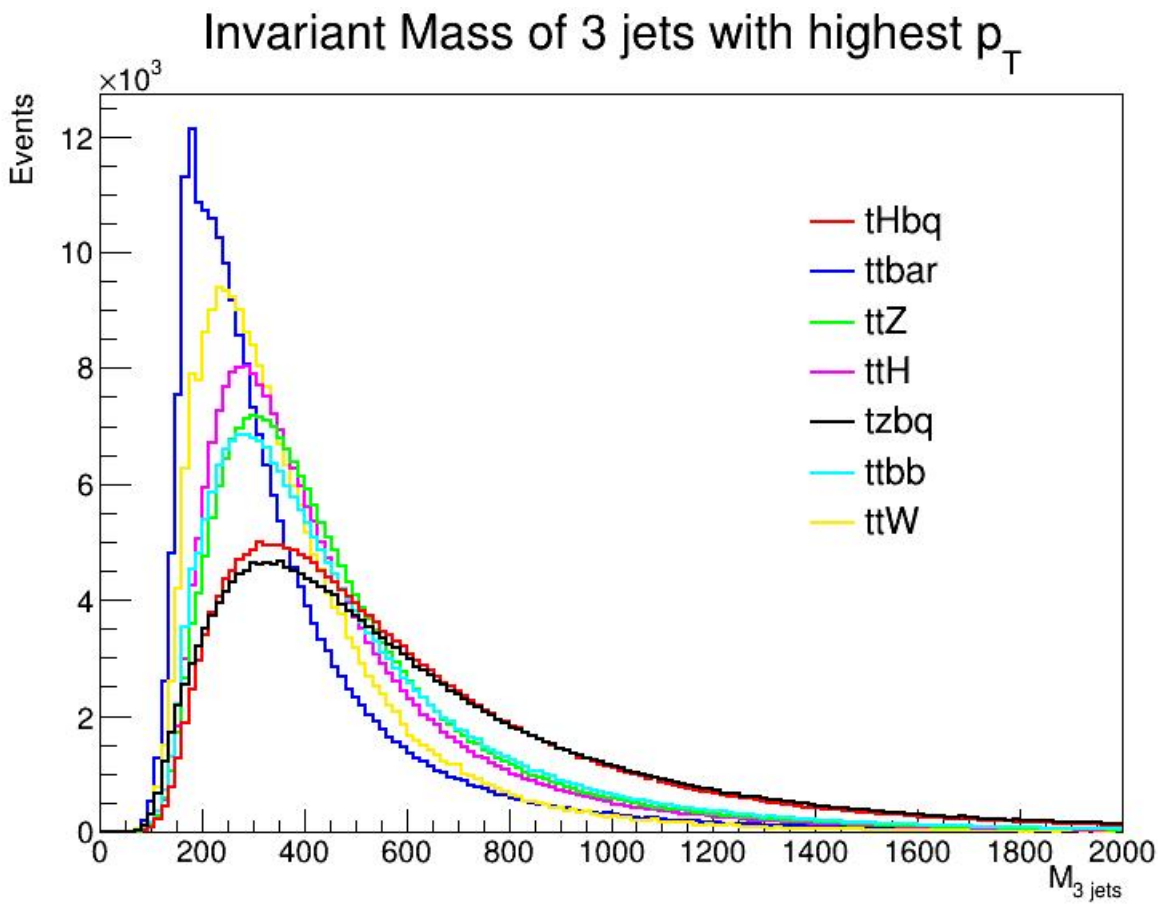


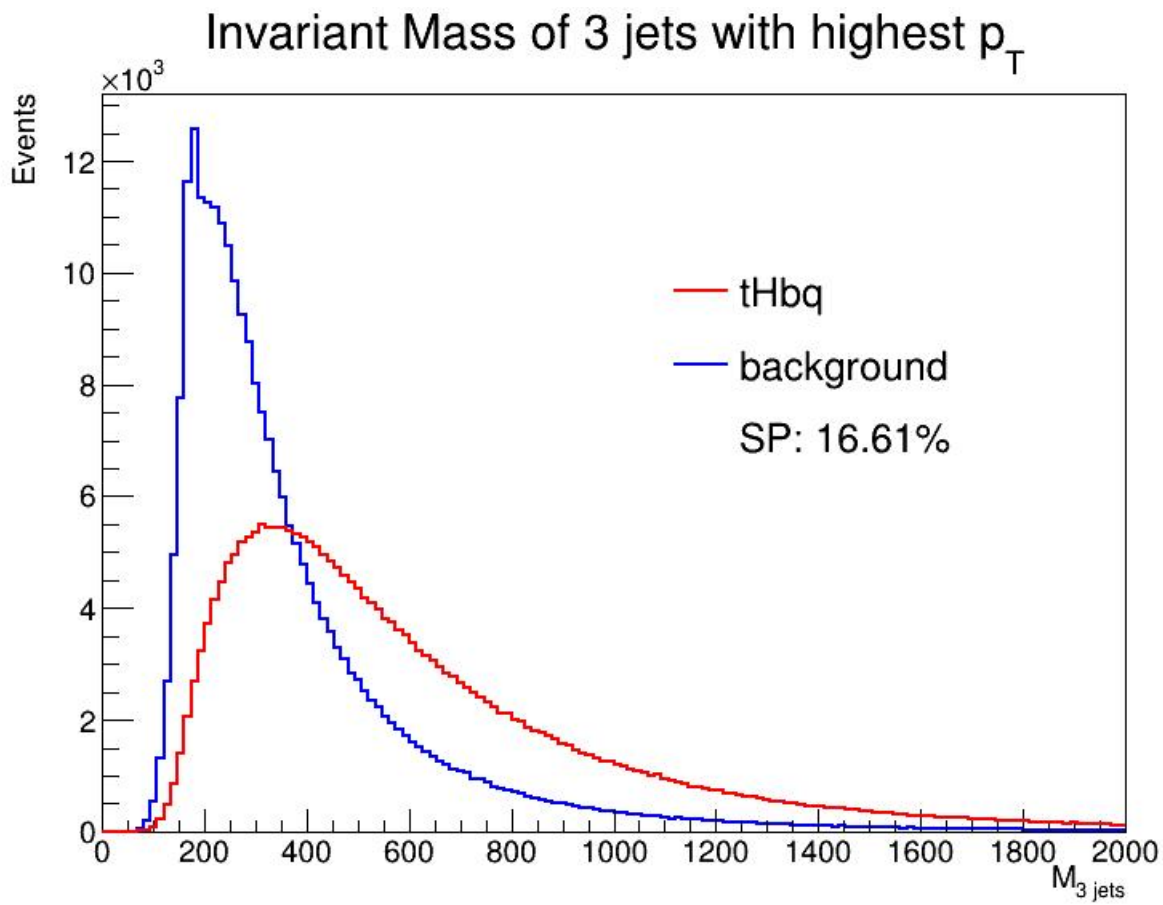




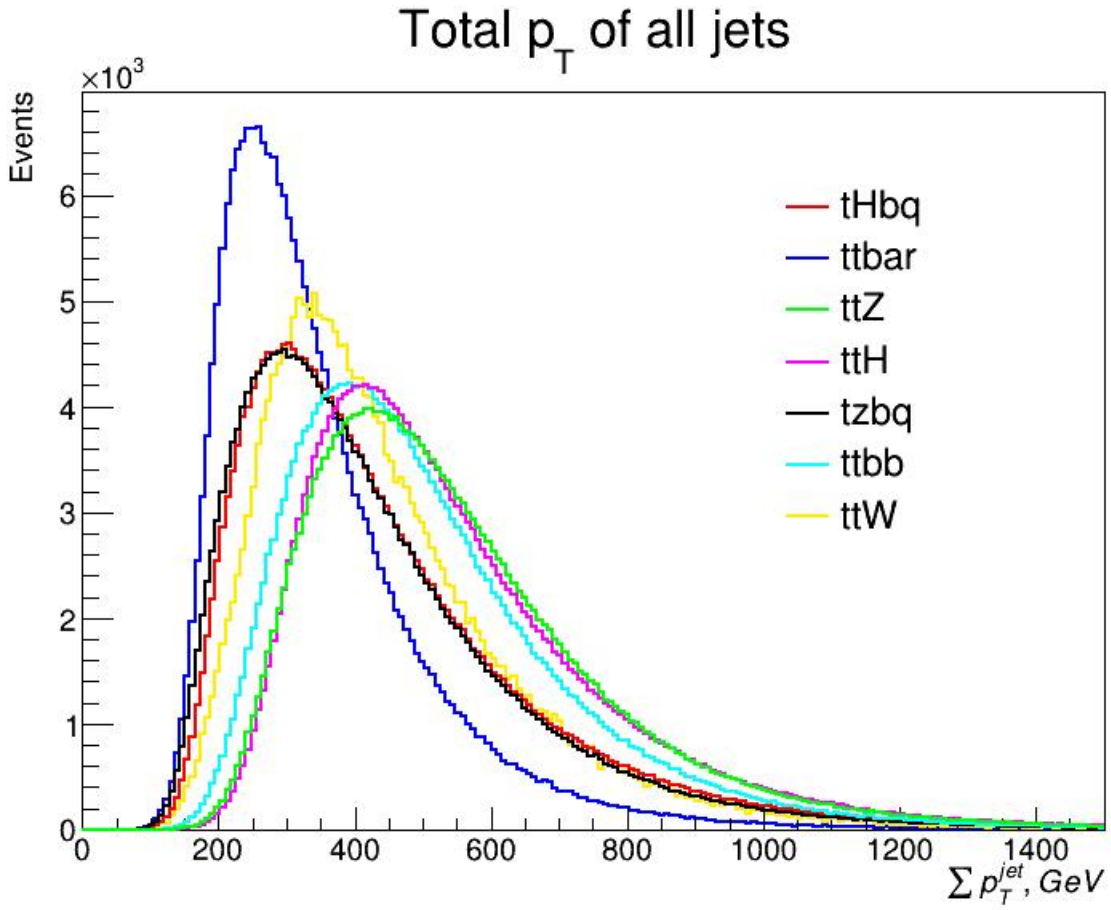


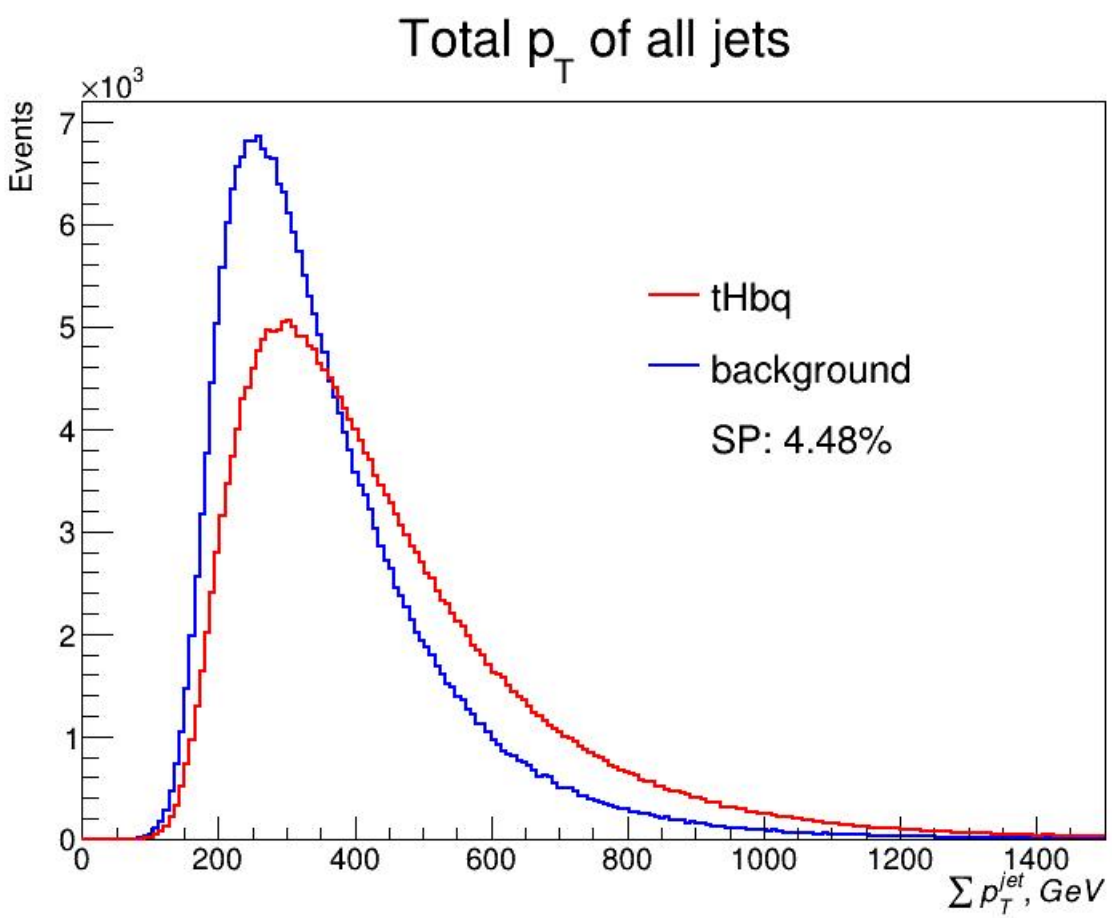
Invariant mass of 3 jets with highest p_T for the signal and background processes



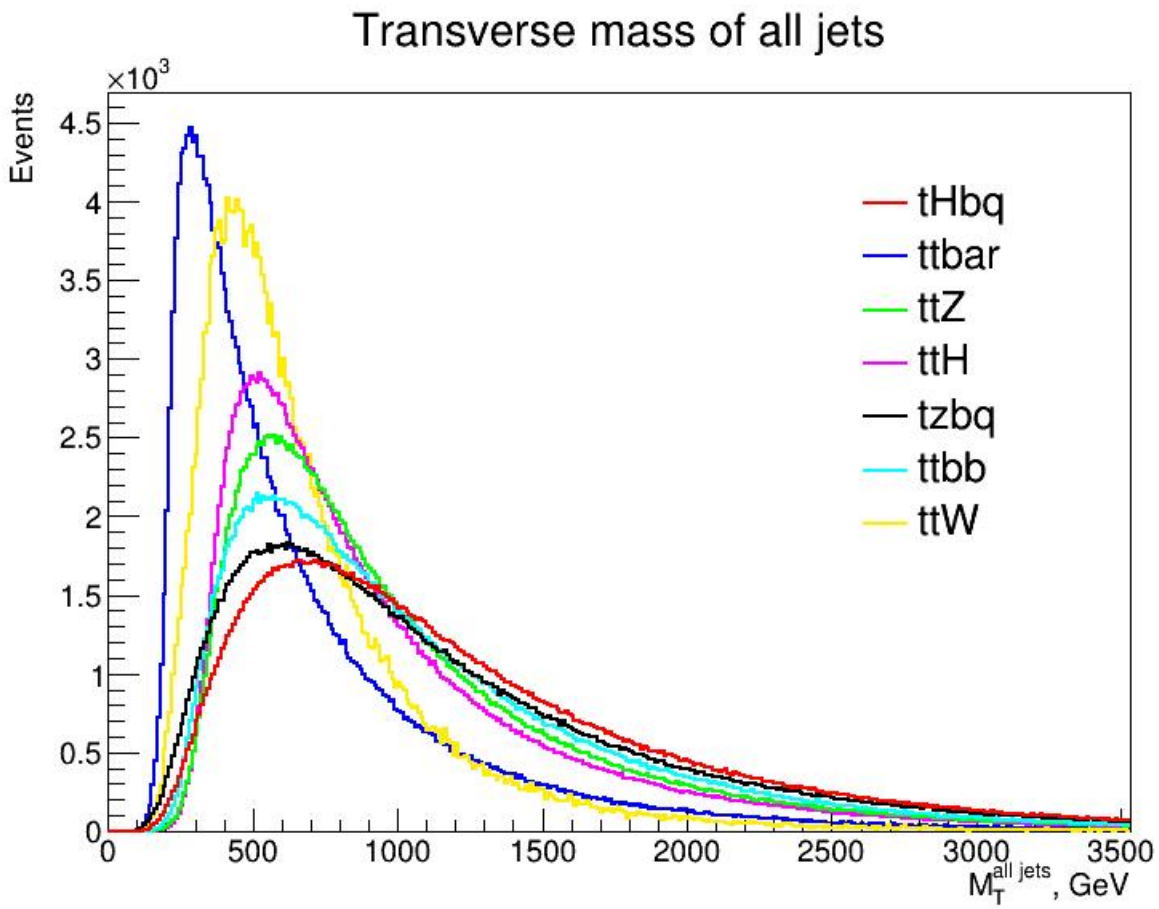


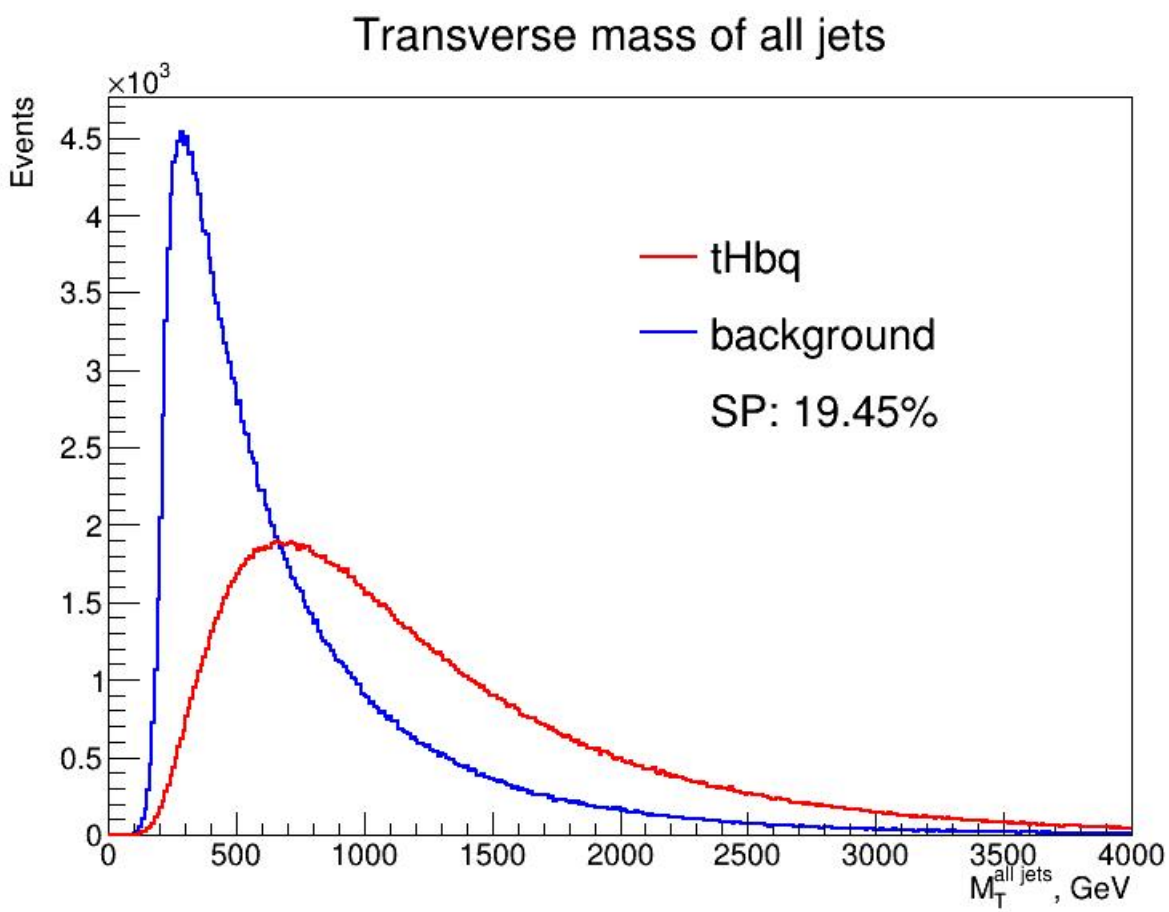
Total p_T of all jets for the signal and background processes



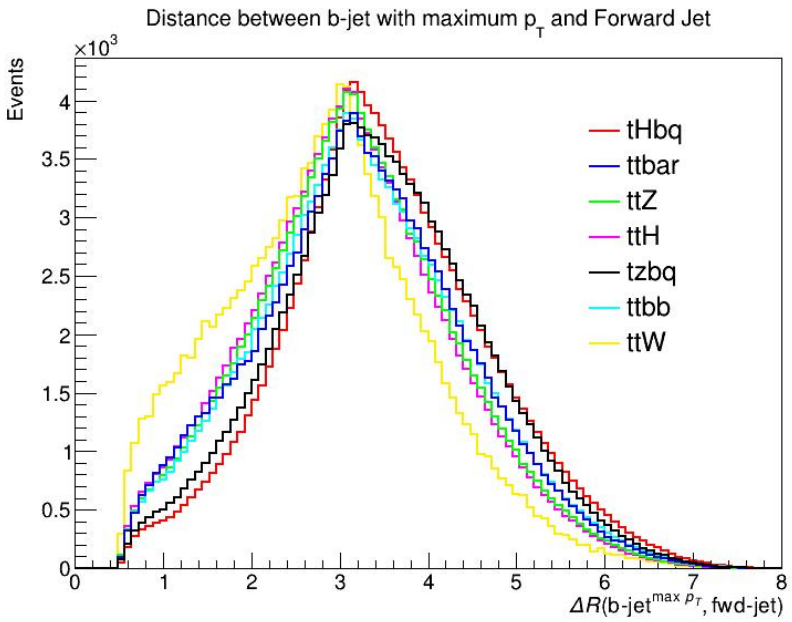


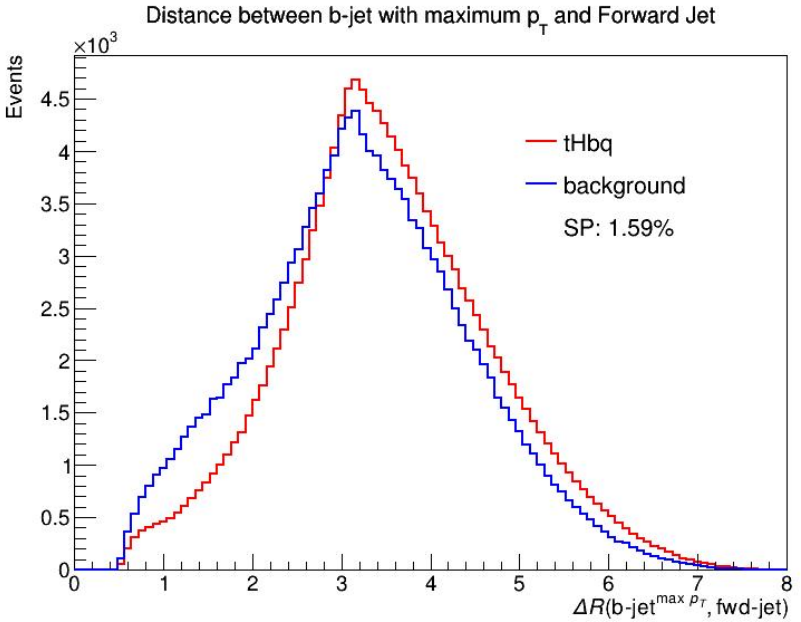
Transverse mass of all jets for the signal and background processes

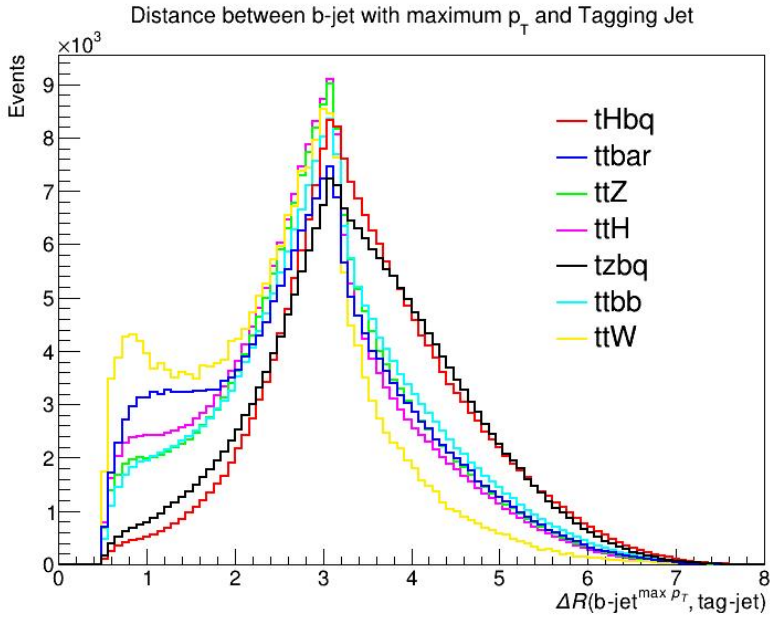


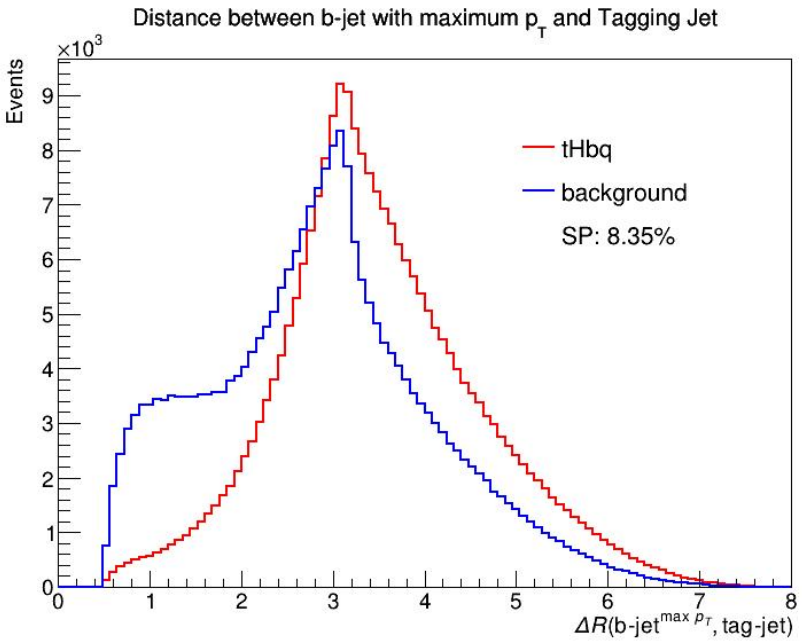


Distance between b-jet with maximum p_T and Forward (Tagging) Jet for the signal and background processes

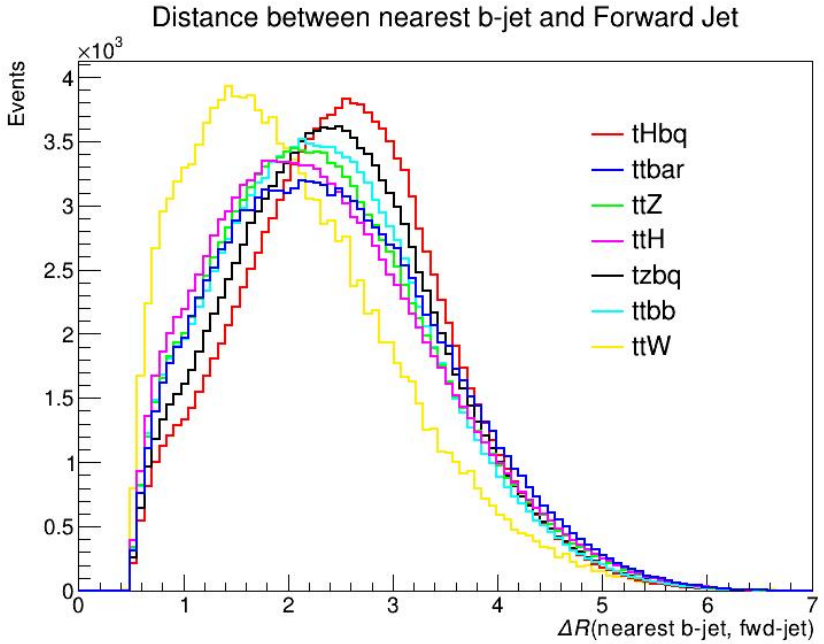


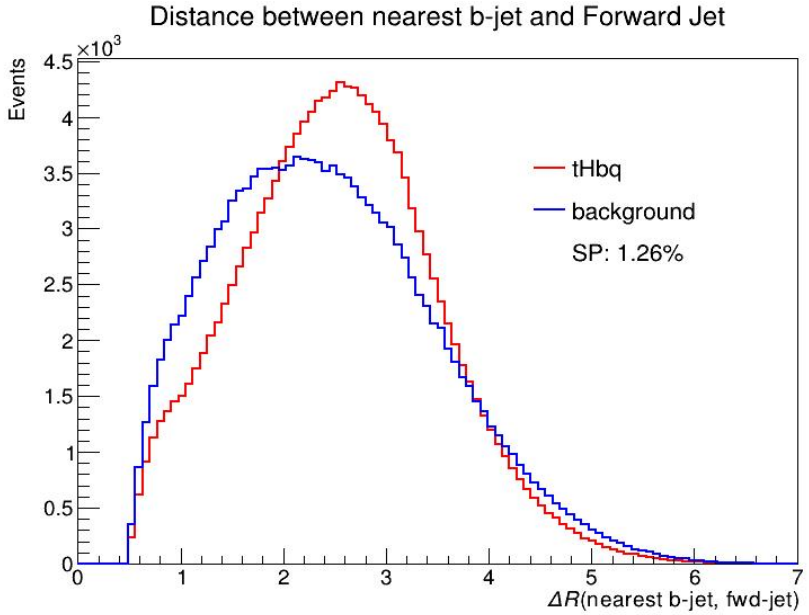


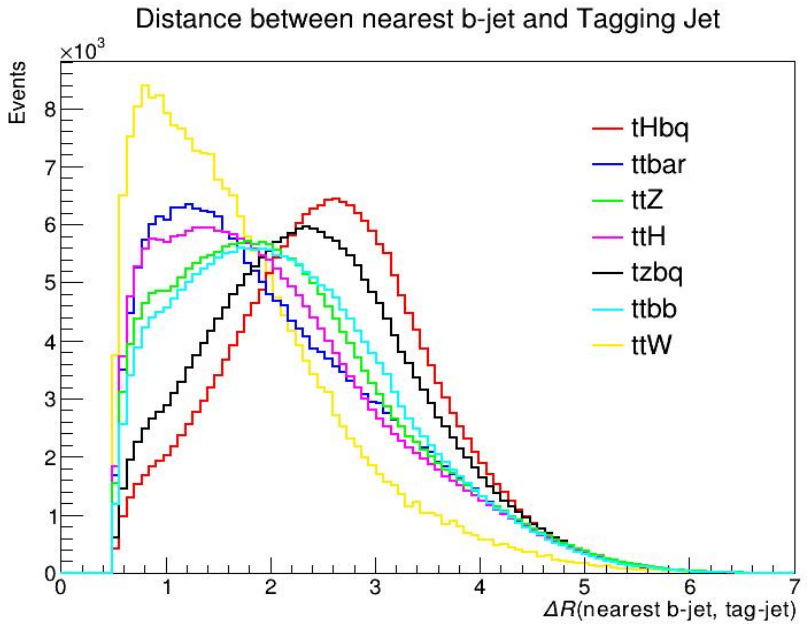


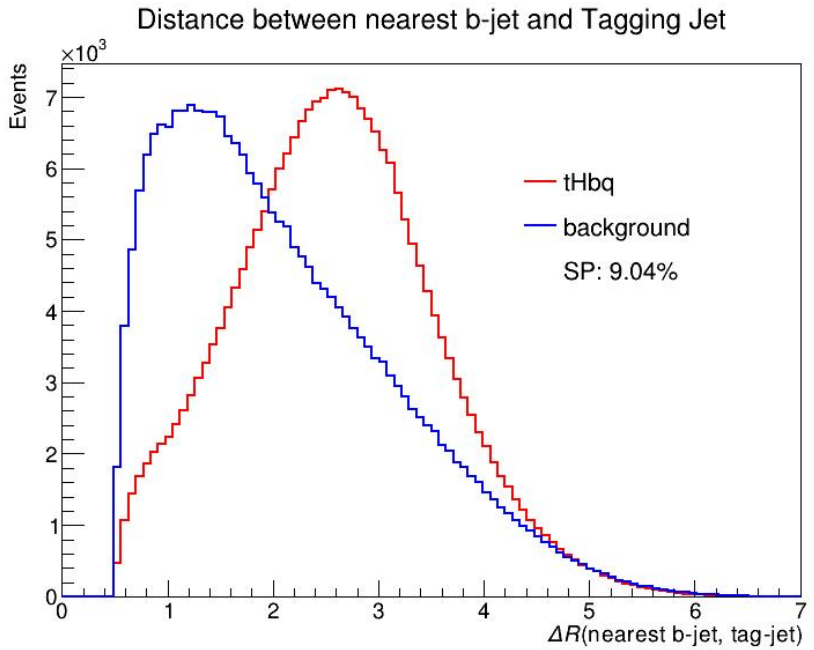


Distance between nearest b-jet and Forward (Tagging) Jet for the signal and background processes

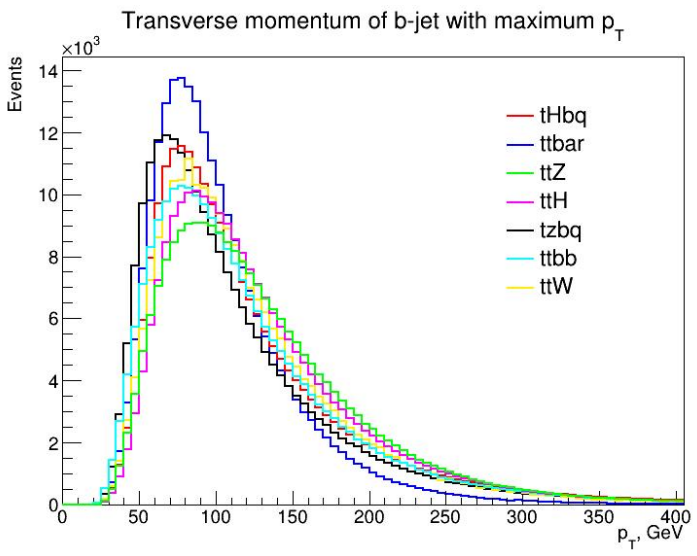


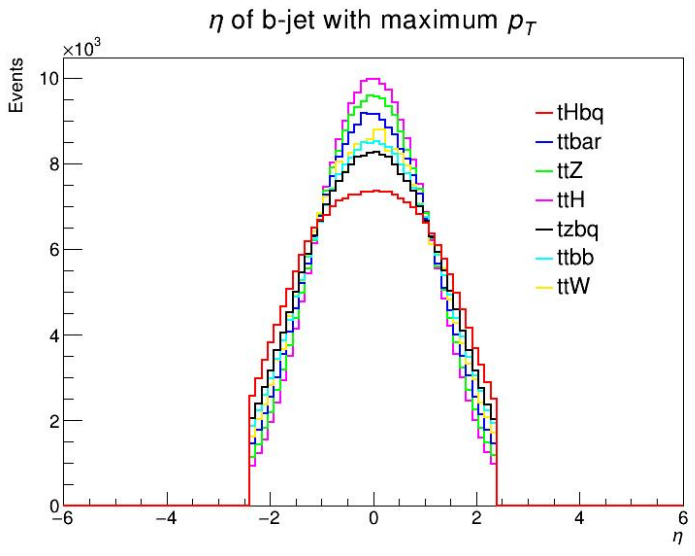


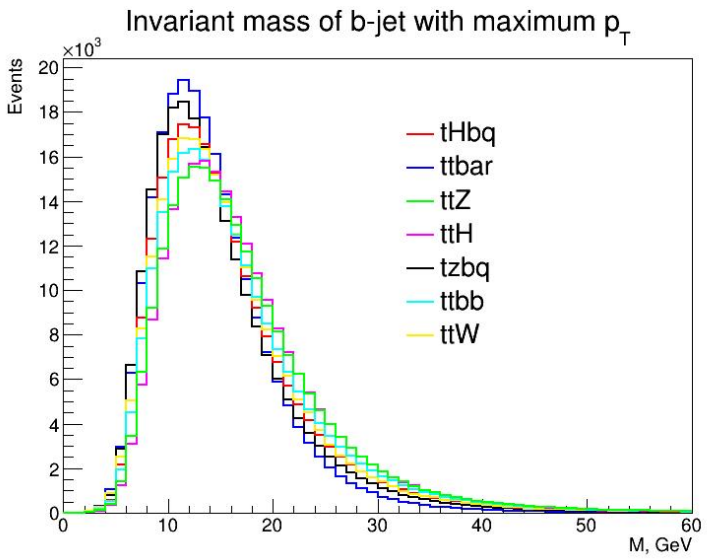


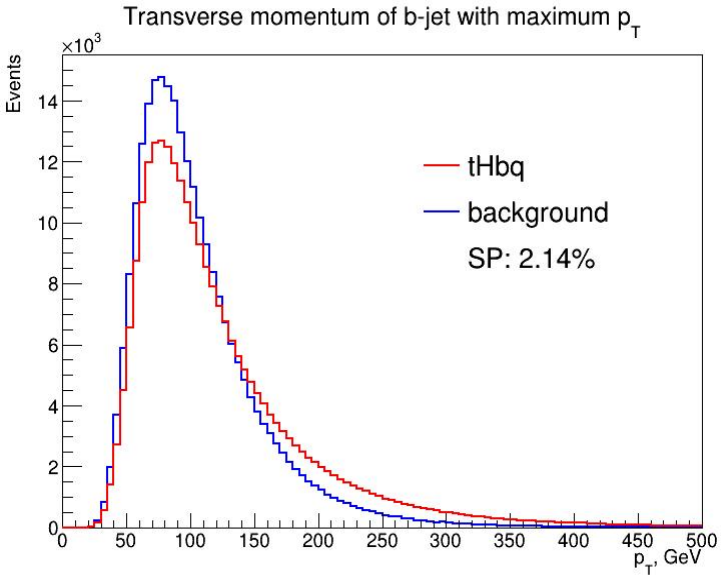


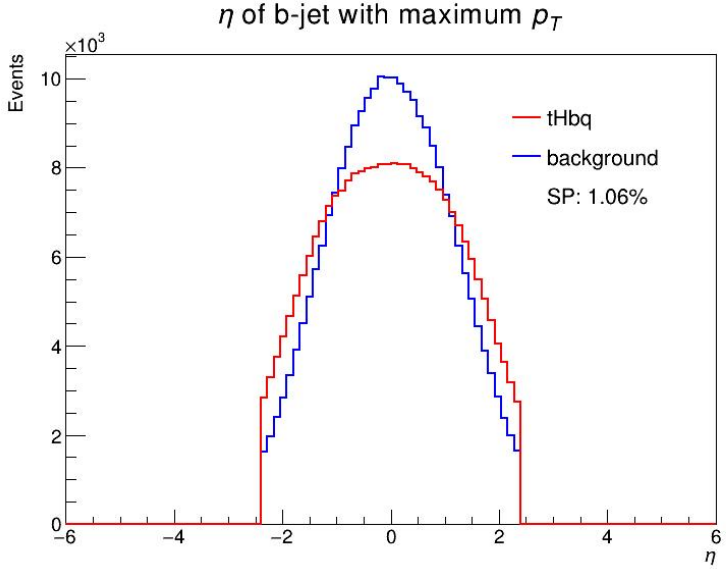
Characteristics b-jet with maximum p_T for the signal and background processes

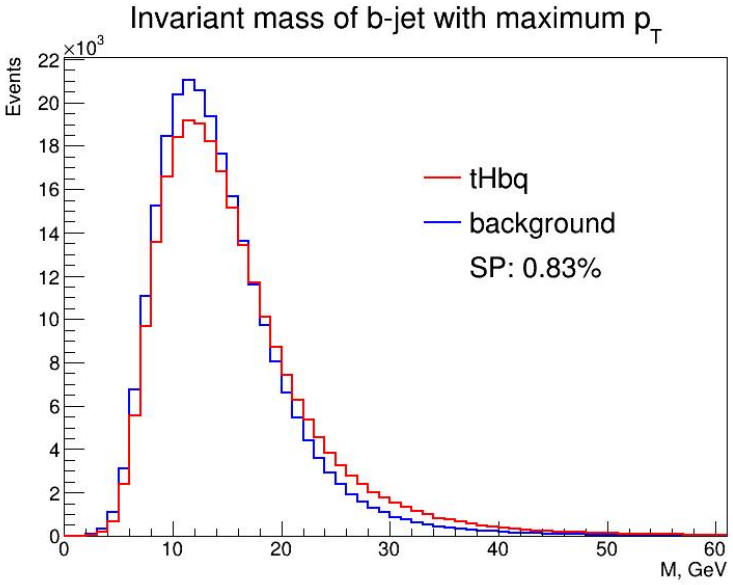




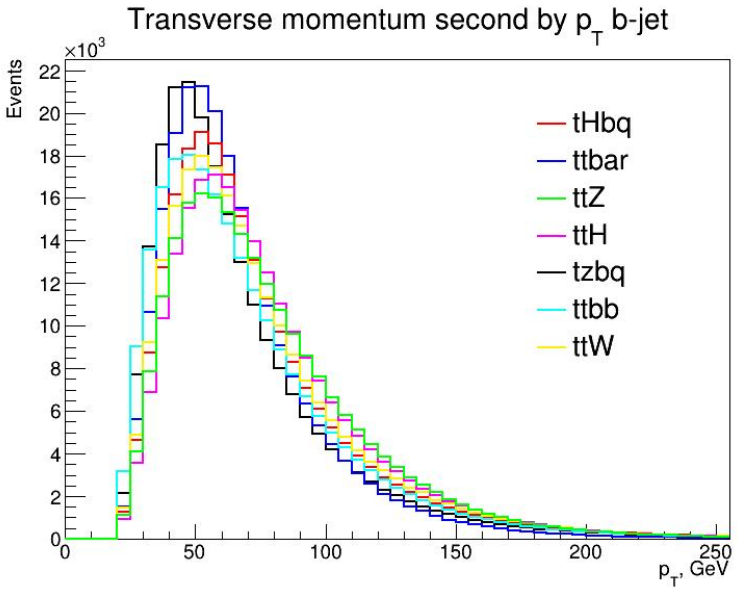


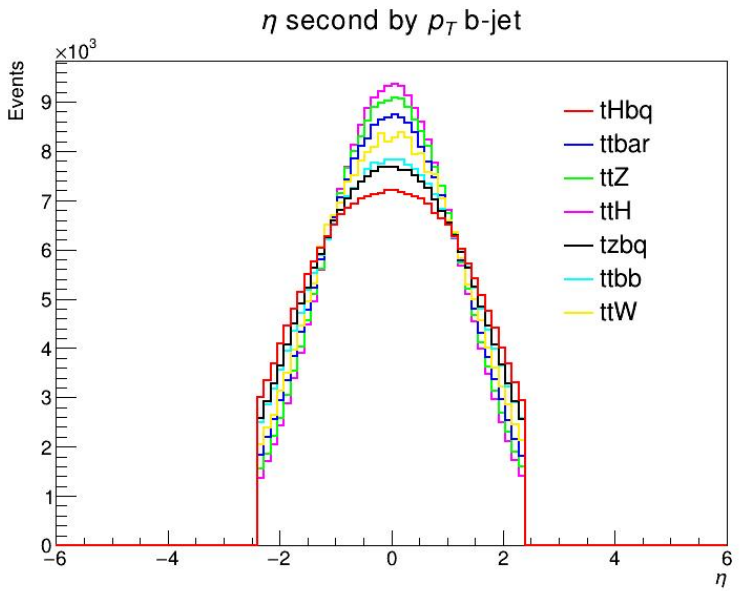


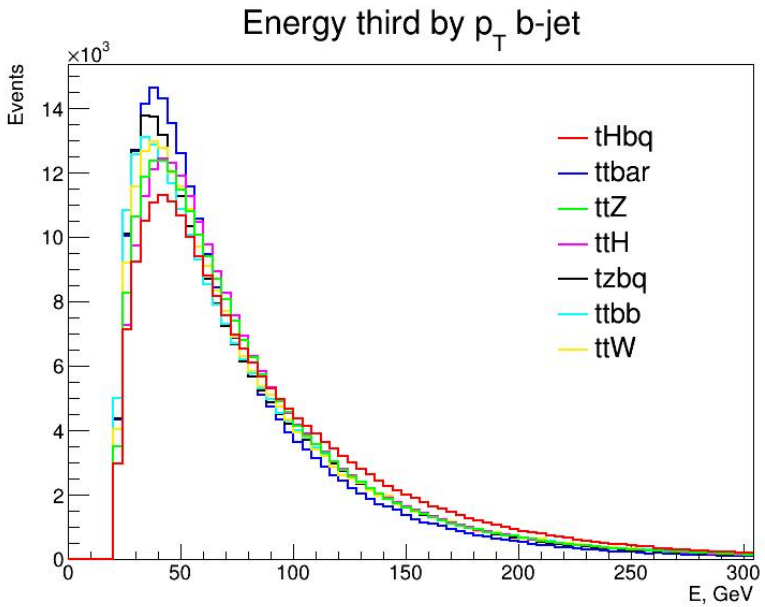


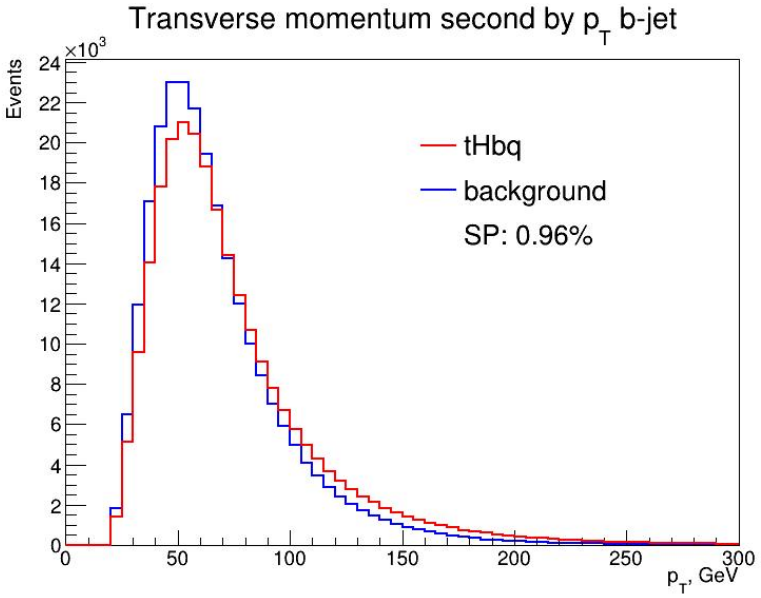


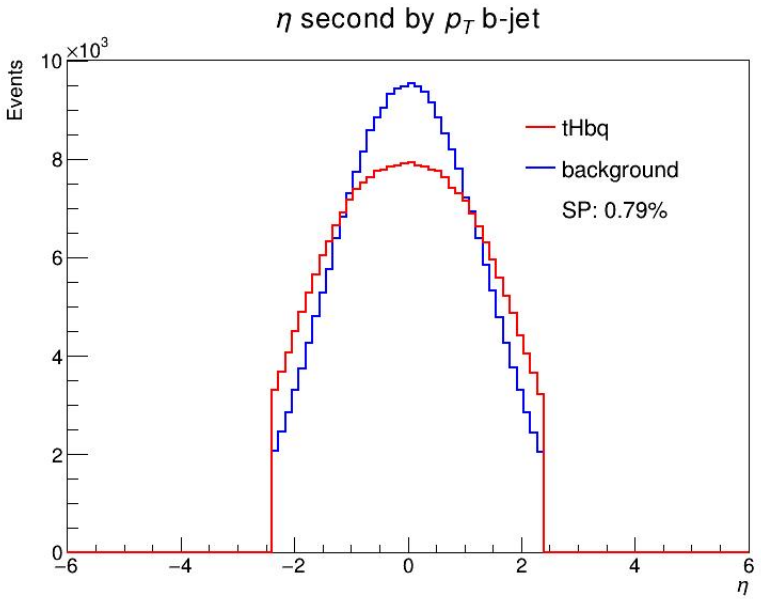
Characteristics other b-jets for the signal and background processes

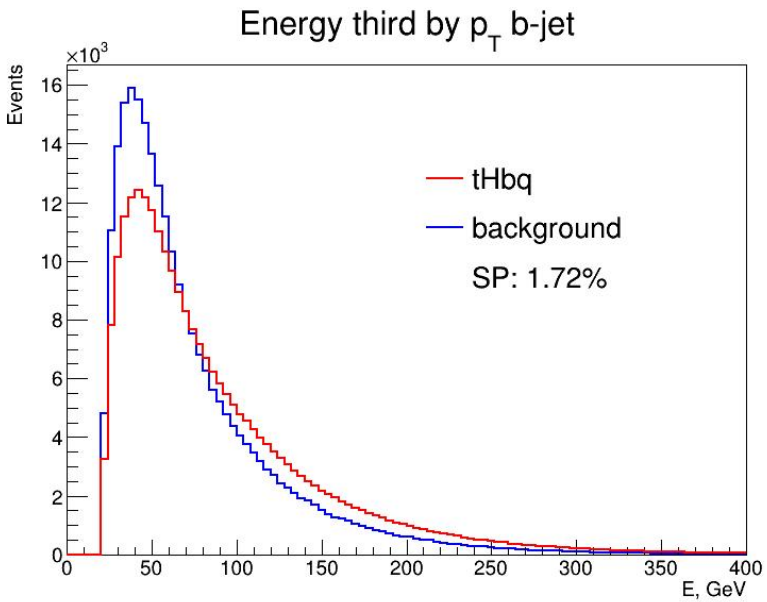




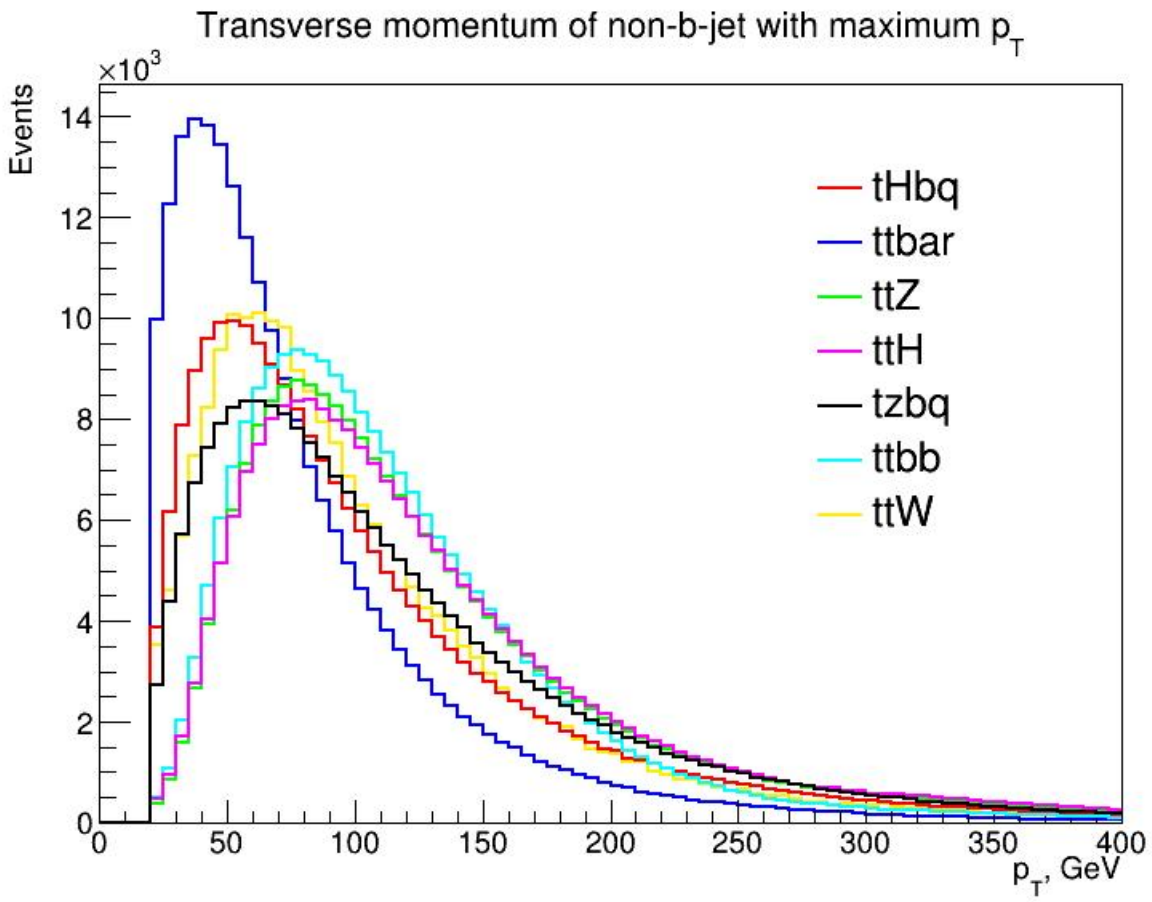


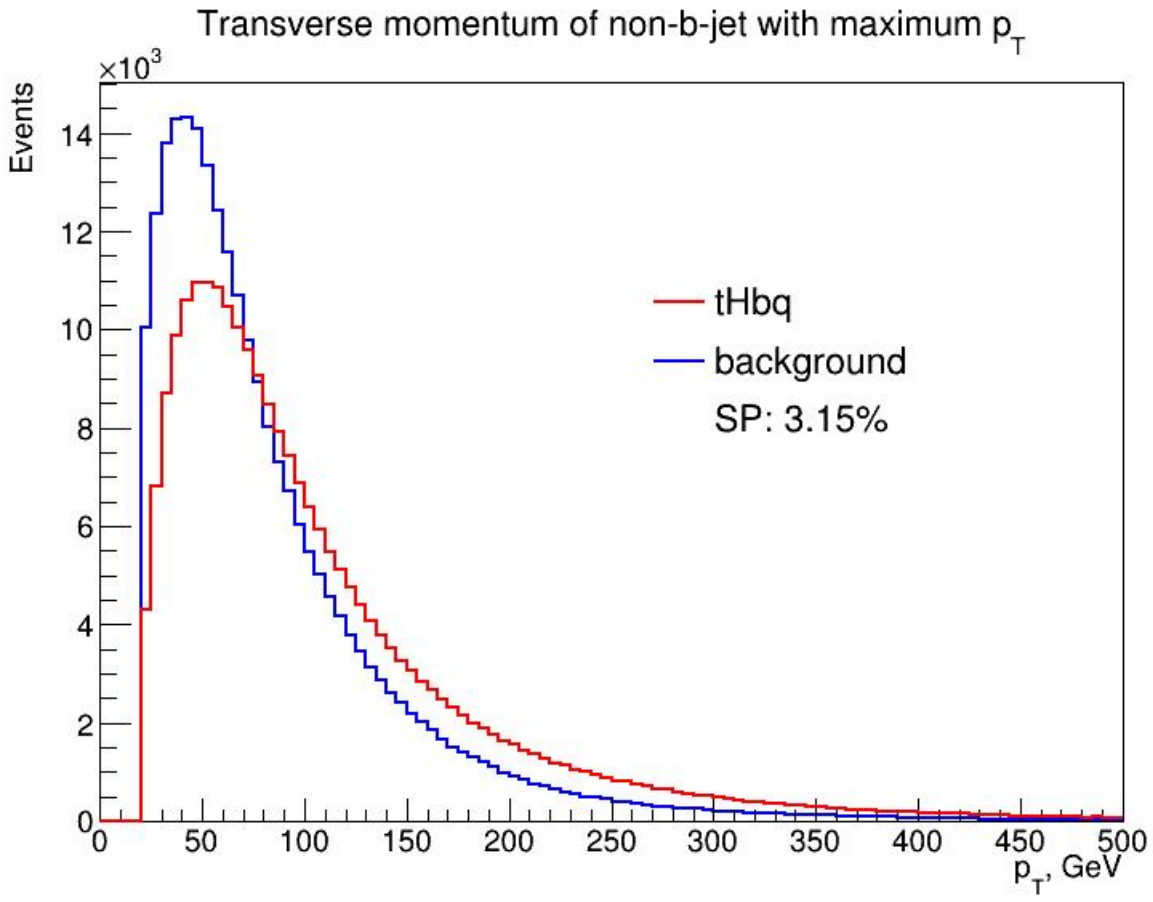






Transverse momentum non-b-jet with maximum p_T for the signal and background processes





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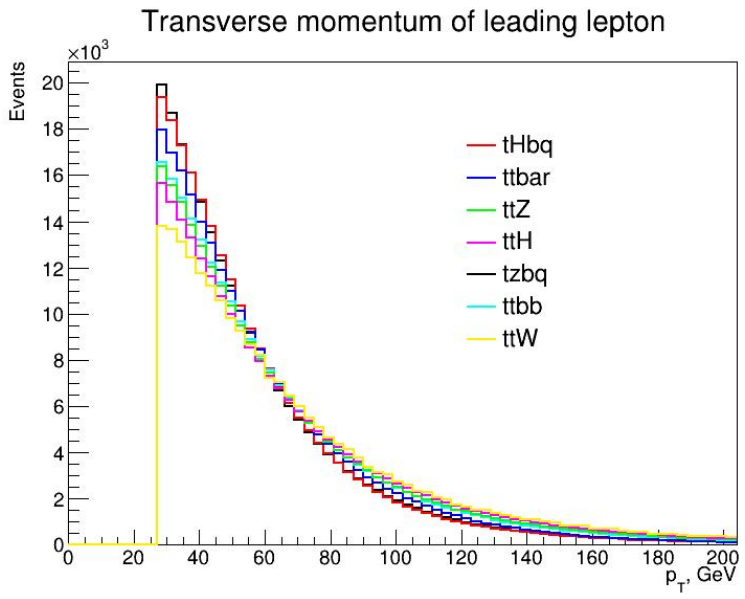
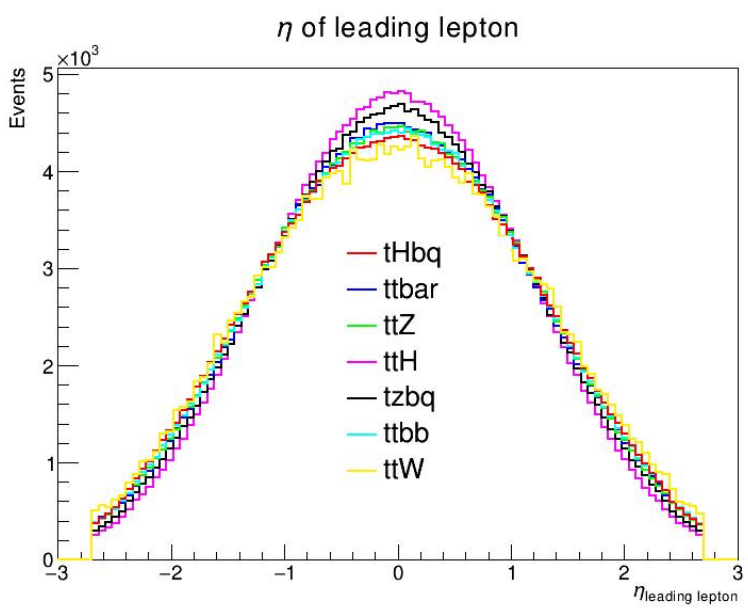
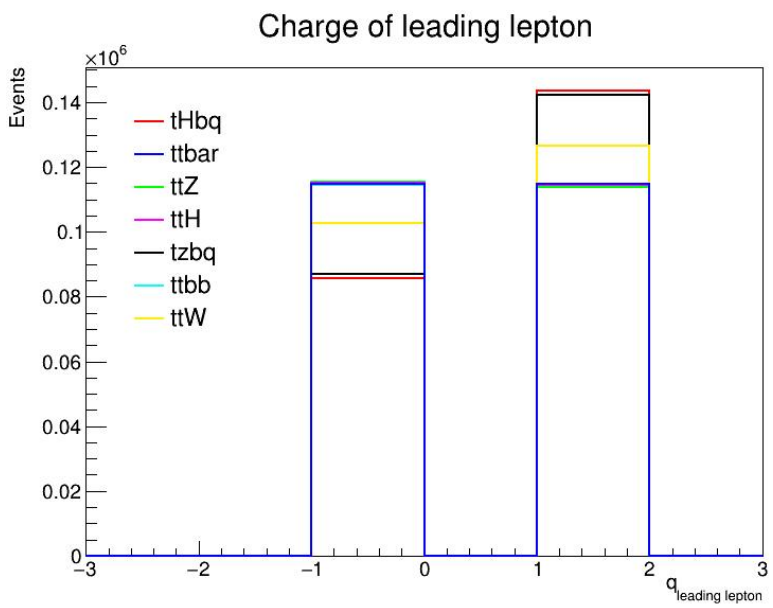
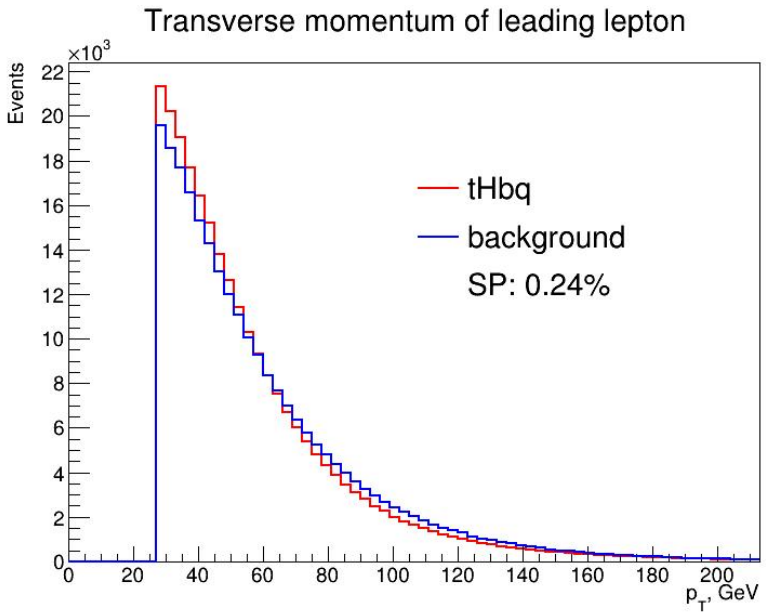
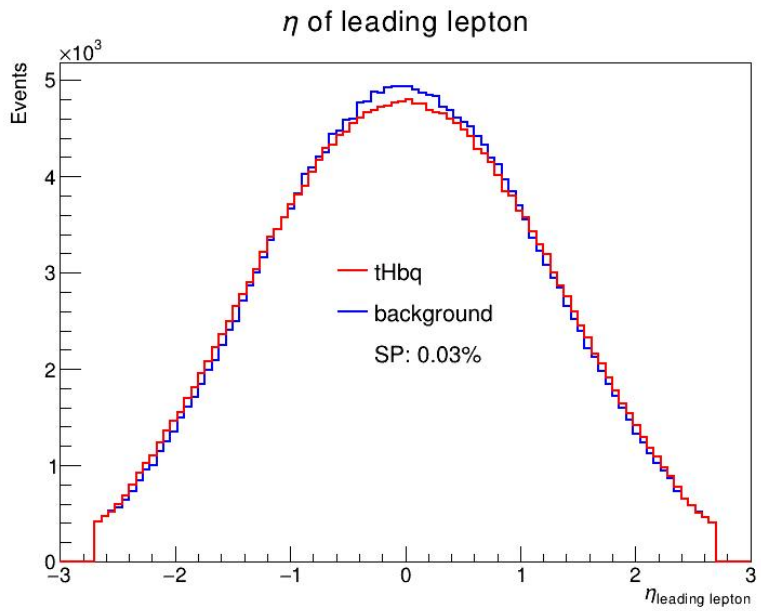
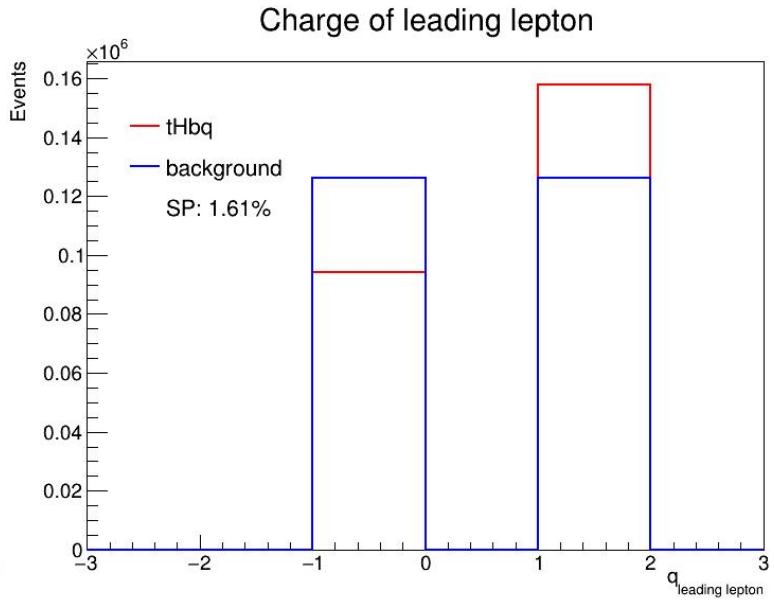




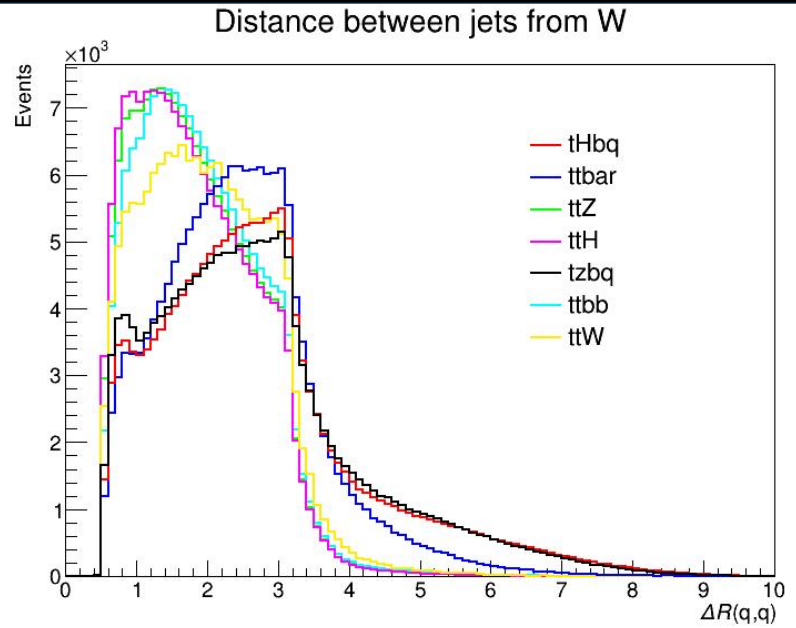


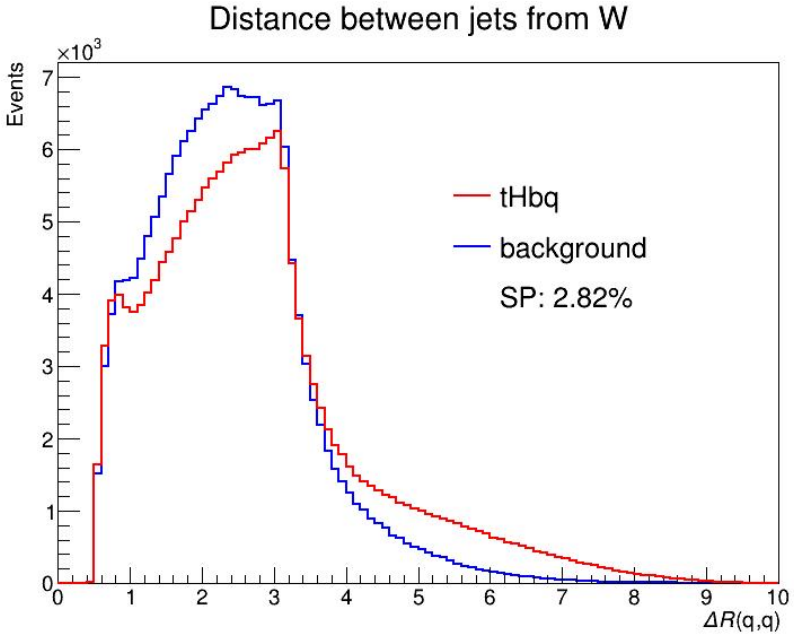






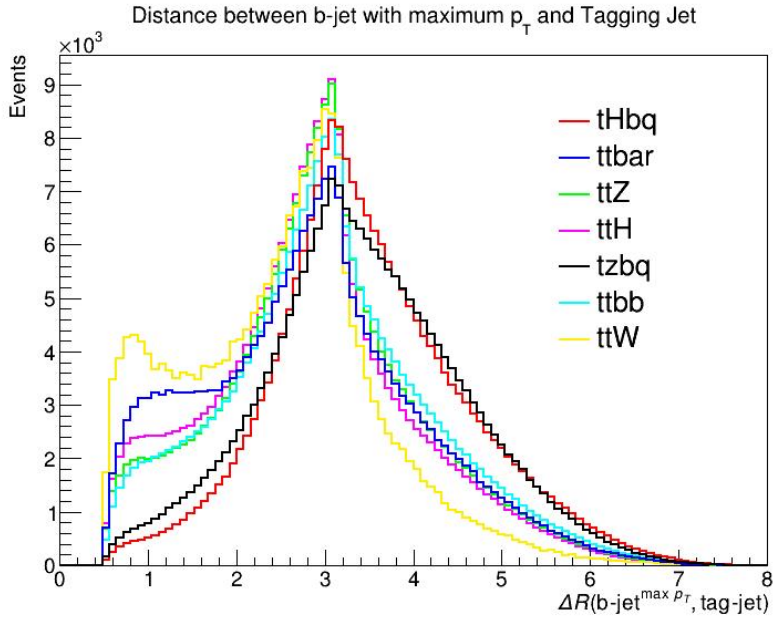
Distance between jets from W-bozon for the signal and background processes

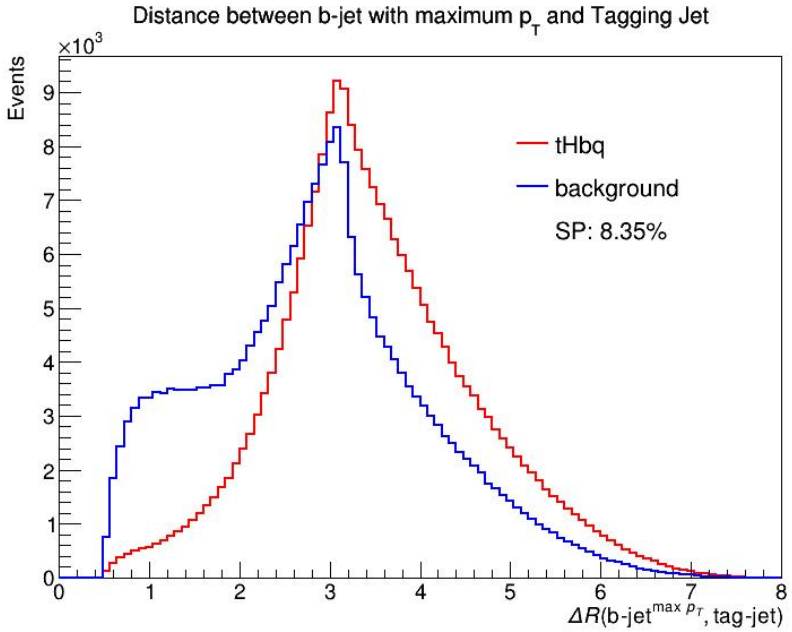




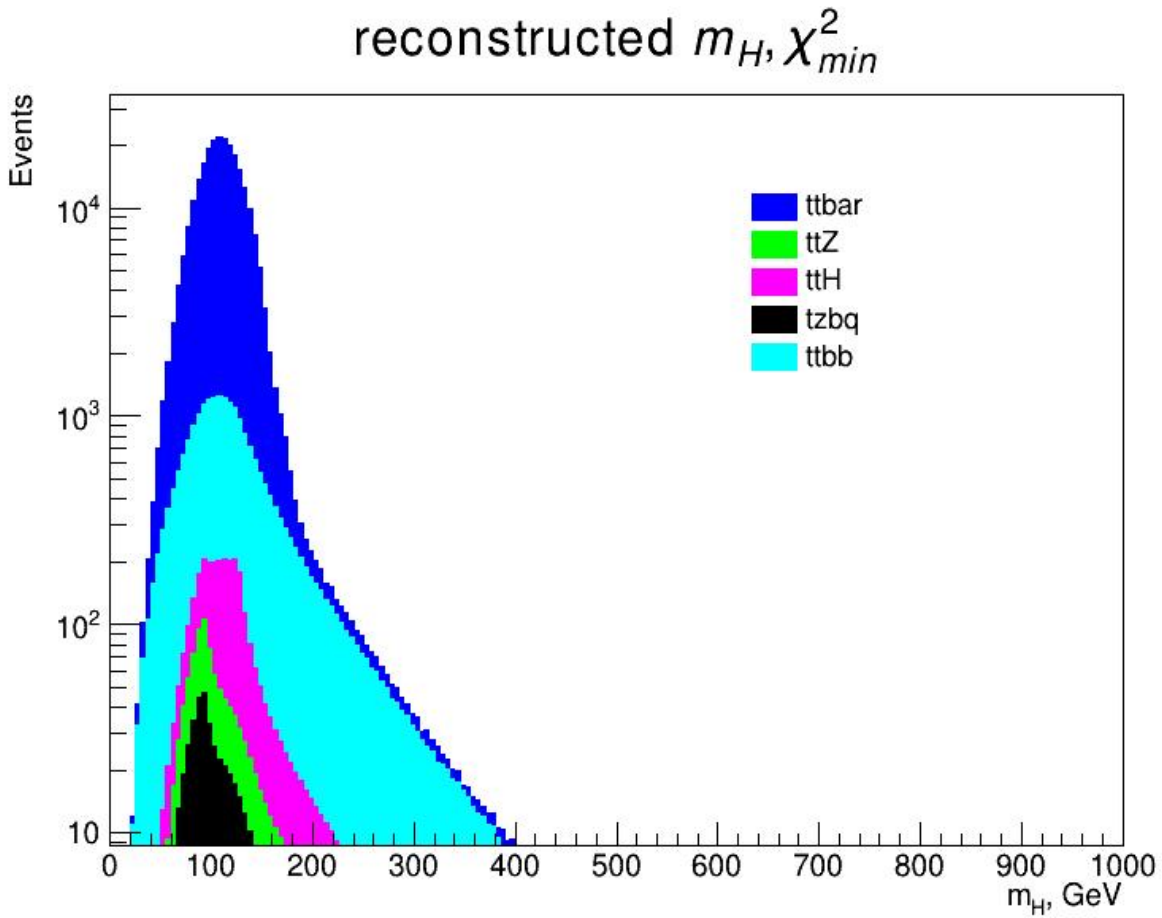
$p_T^{max}\ (non-bjet)$

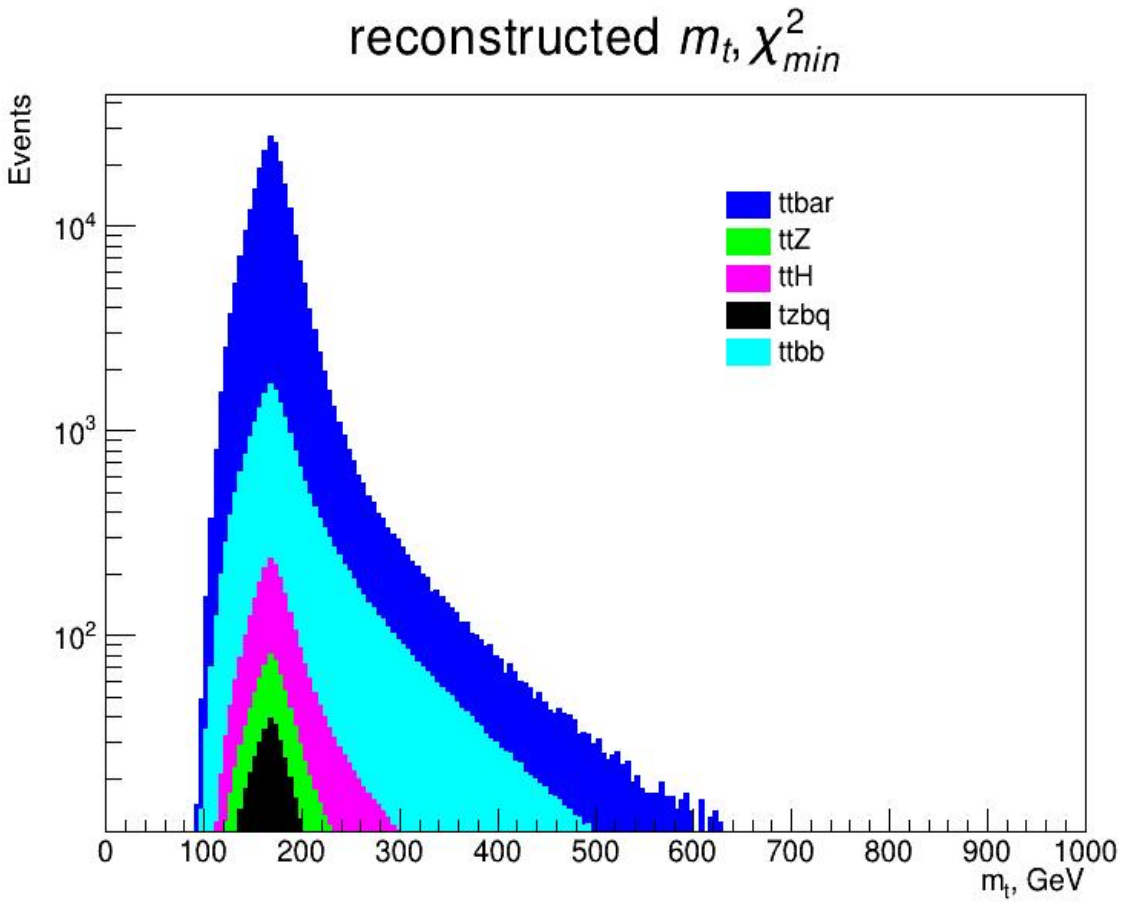
$m^{non-bjets} \sim 80.4\ GeV$





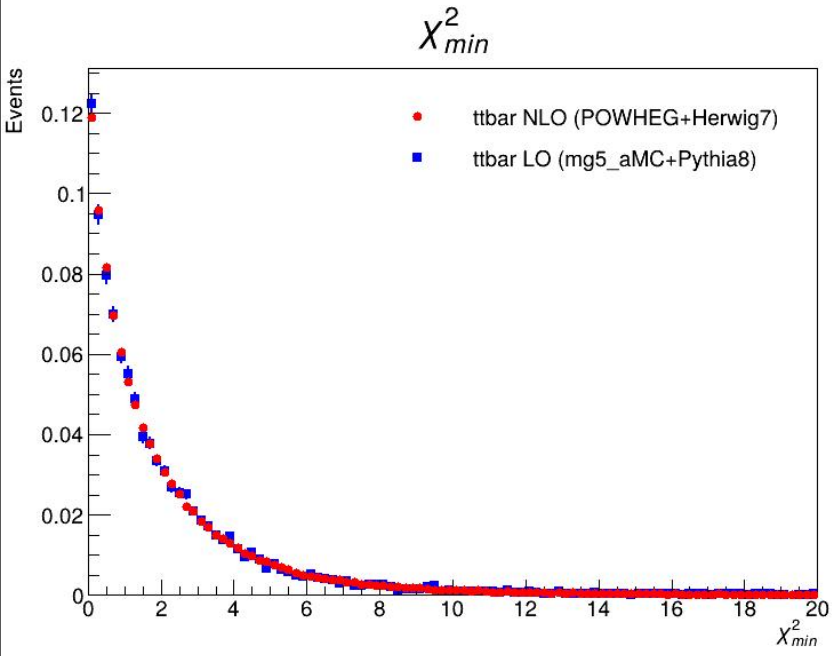
Reconstructed masses of the top quark and Higgs boson for background processes

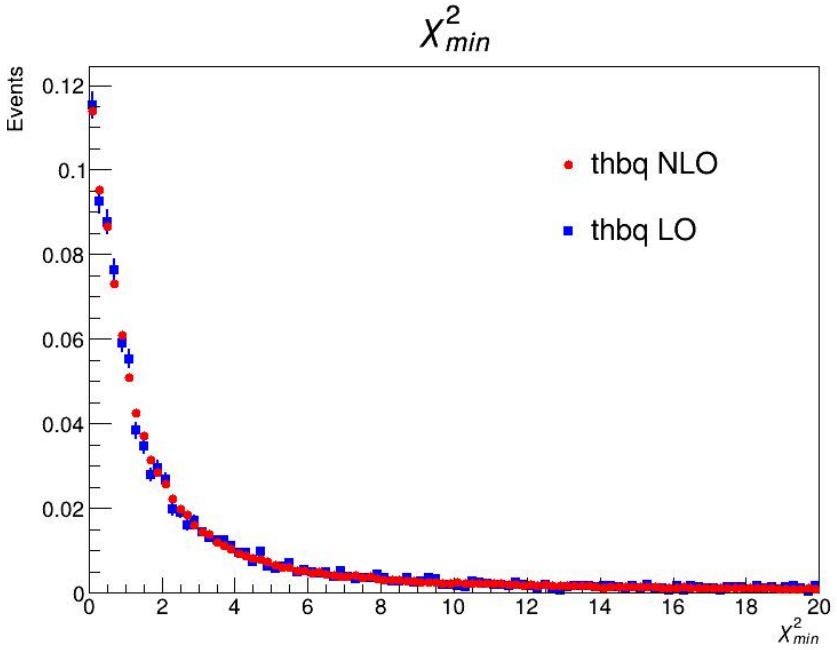


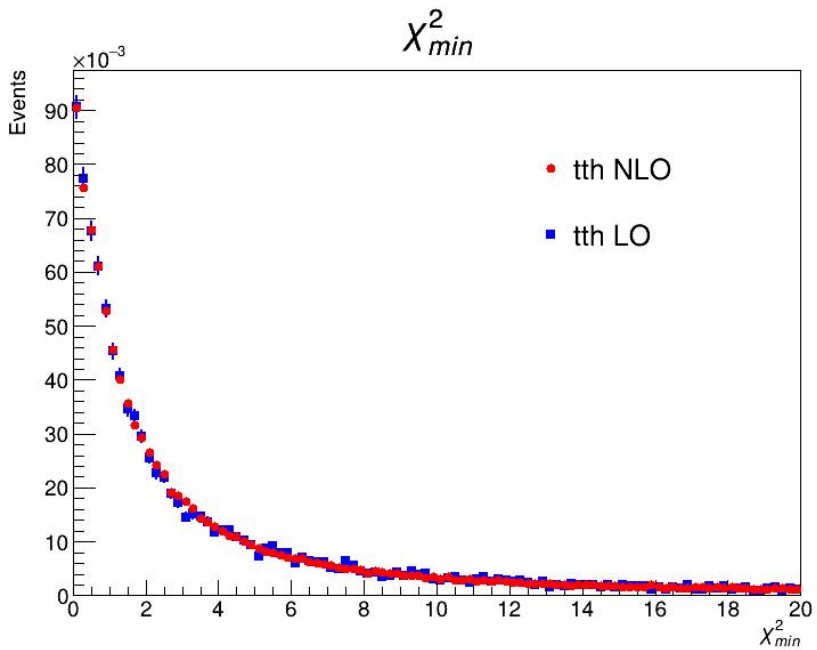


NLO vs LO

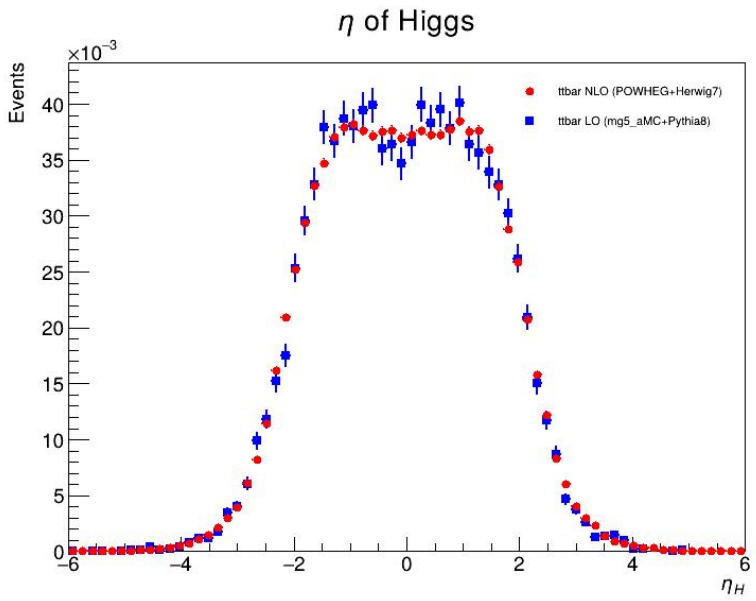
χ^2 for the signal and background processes

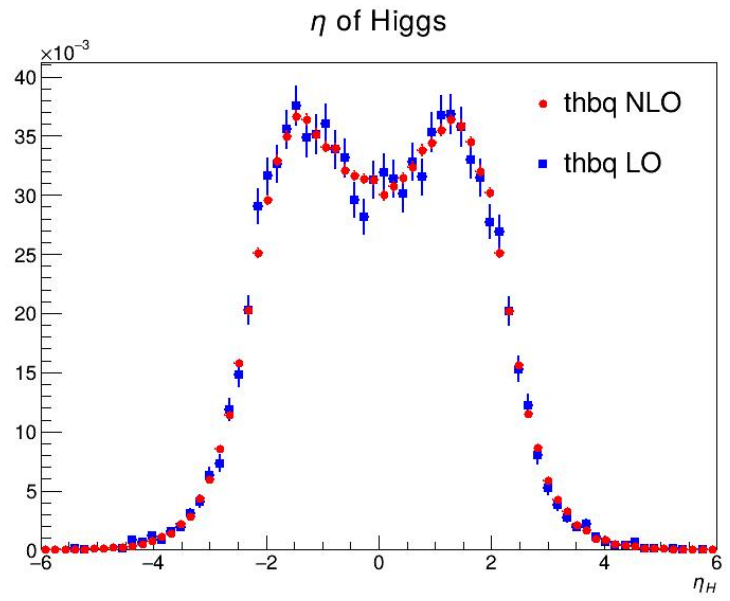


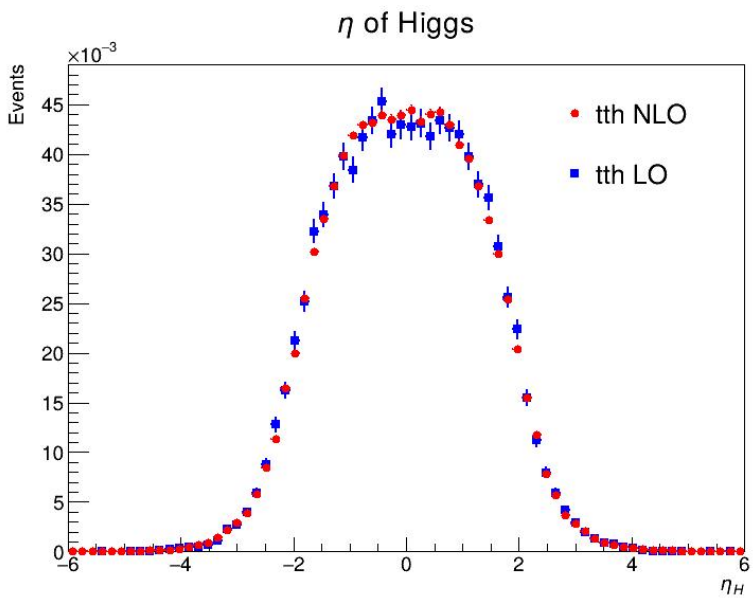


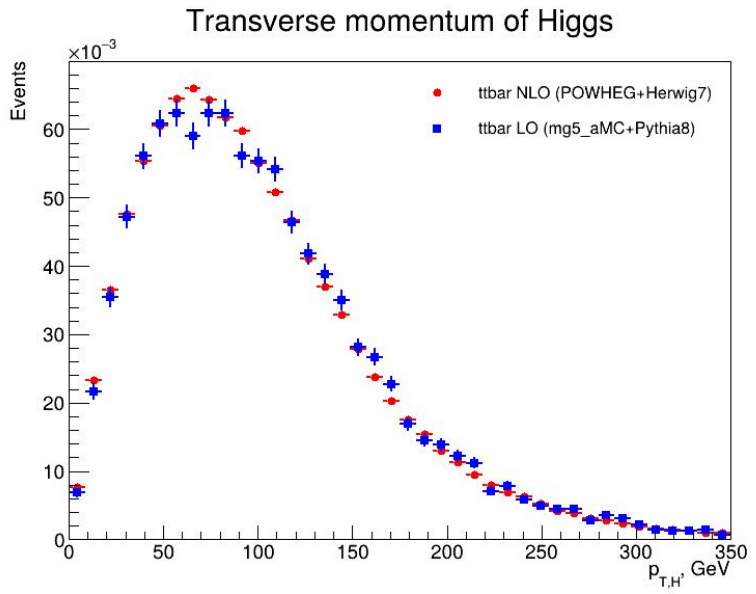


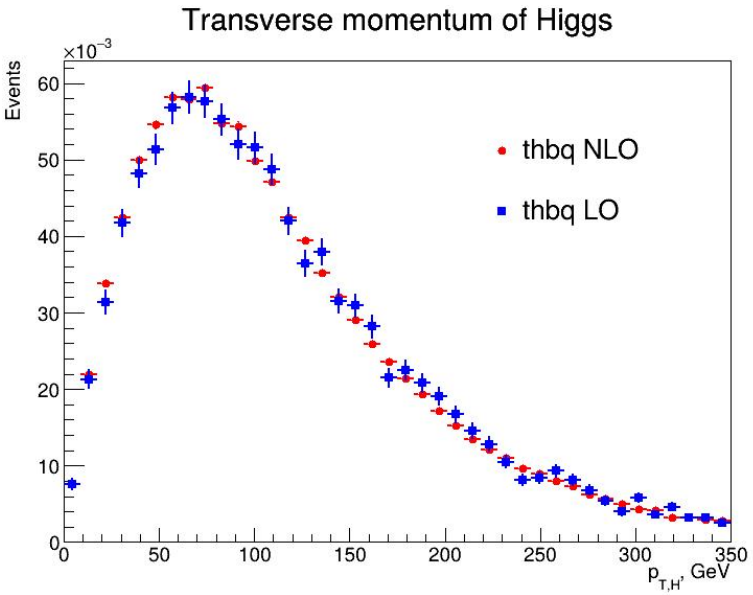
η and p_T Higgs boson for the signal and background processes

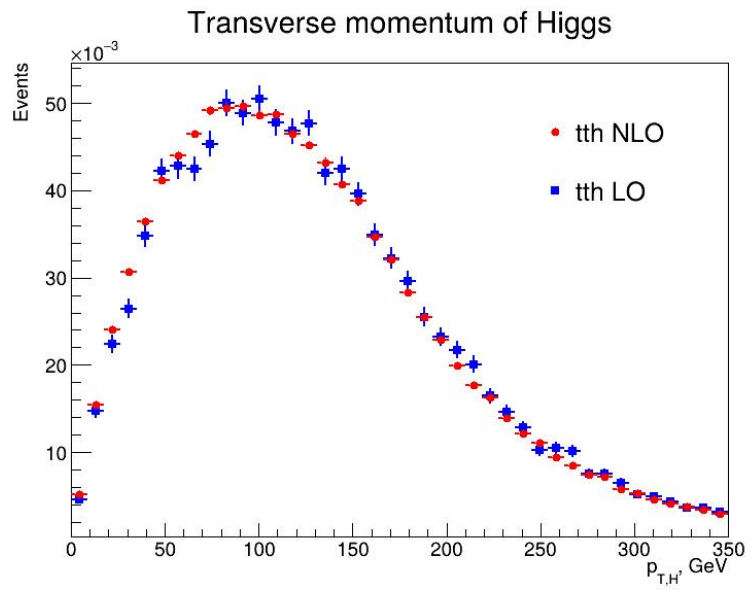




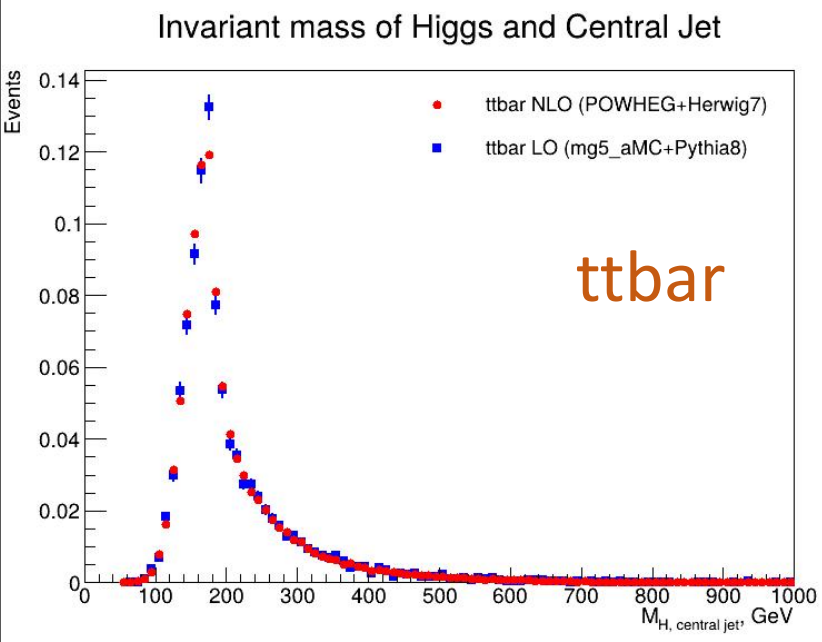


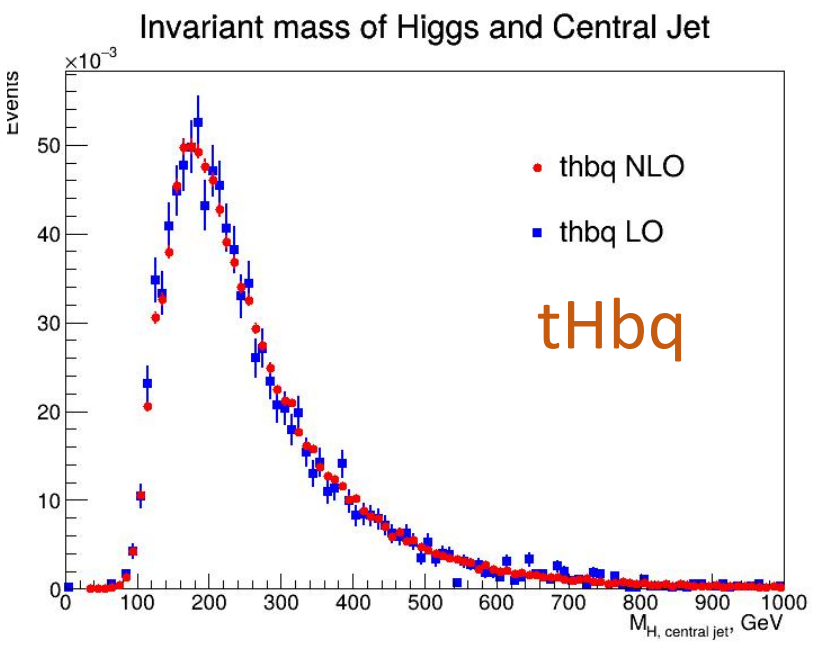


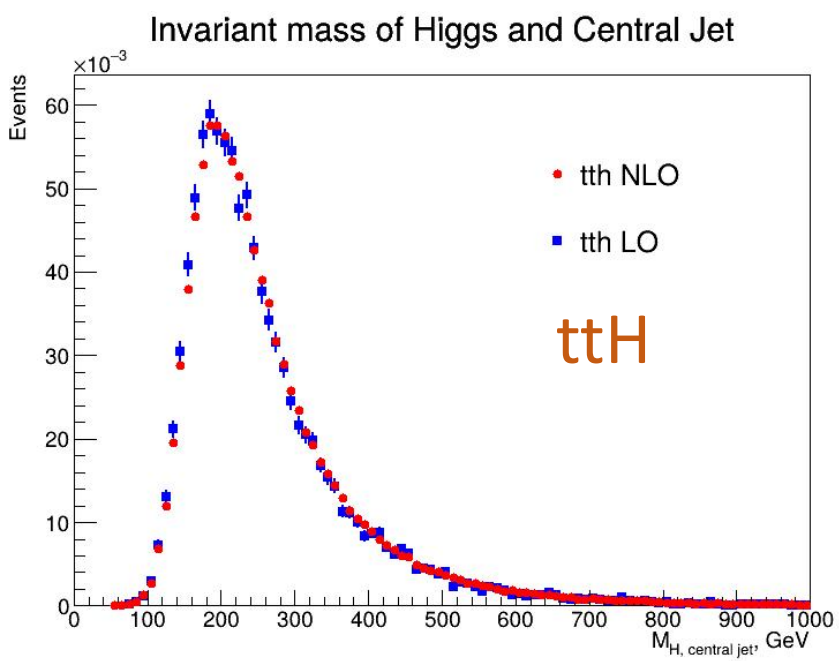




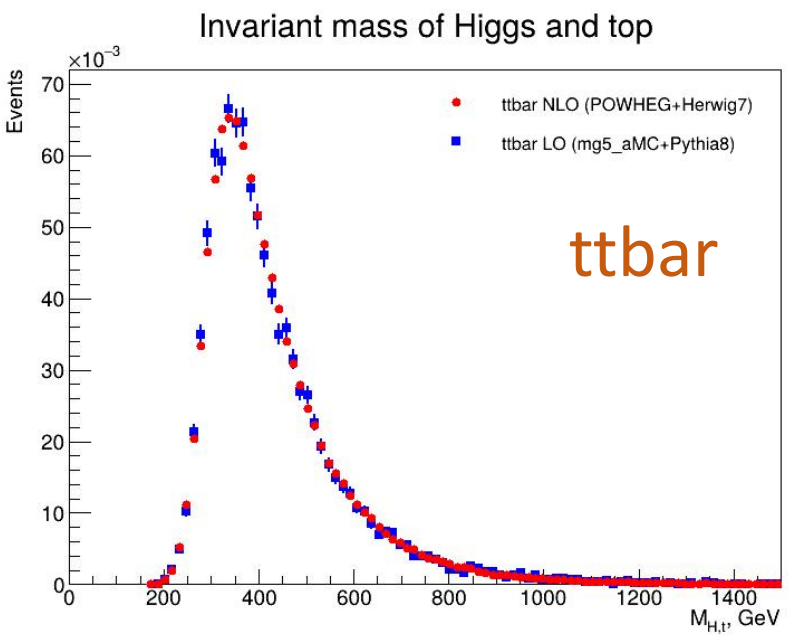
Invariant mass Higgs and Central Jet for the signal and background processes

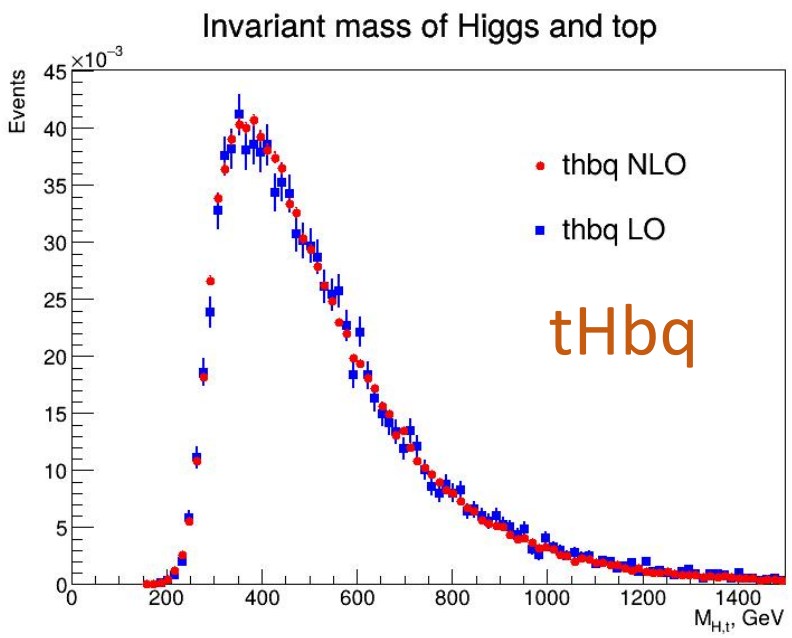


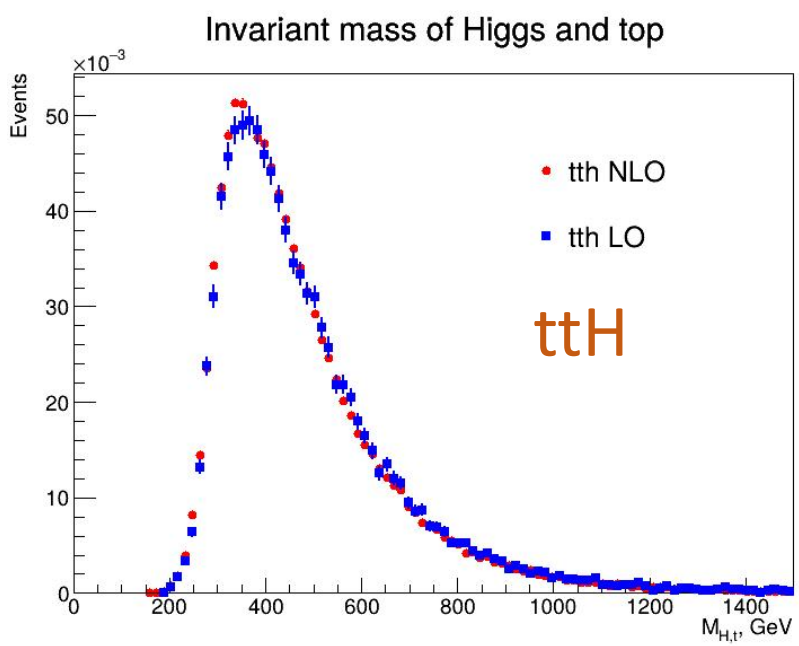




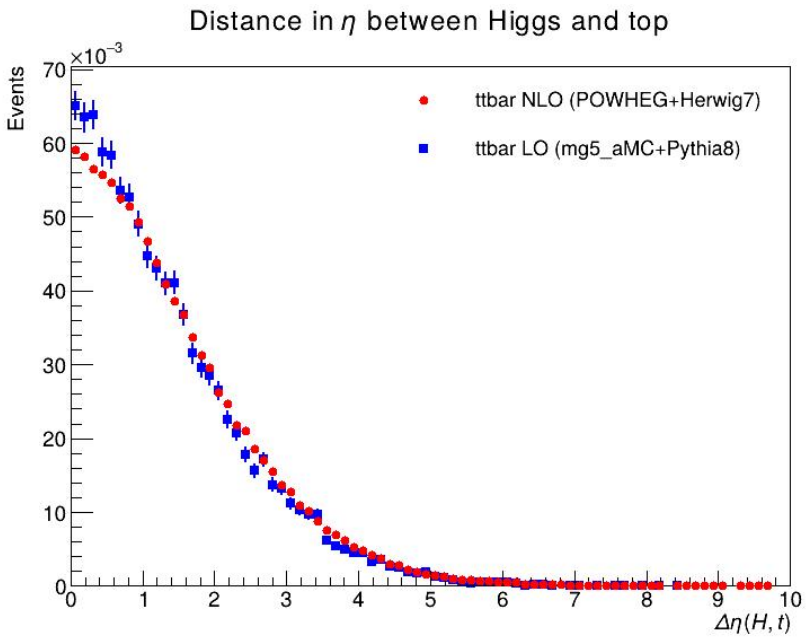
Invariant mass of the top quark and Higgs boson system for the signal and background processes

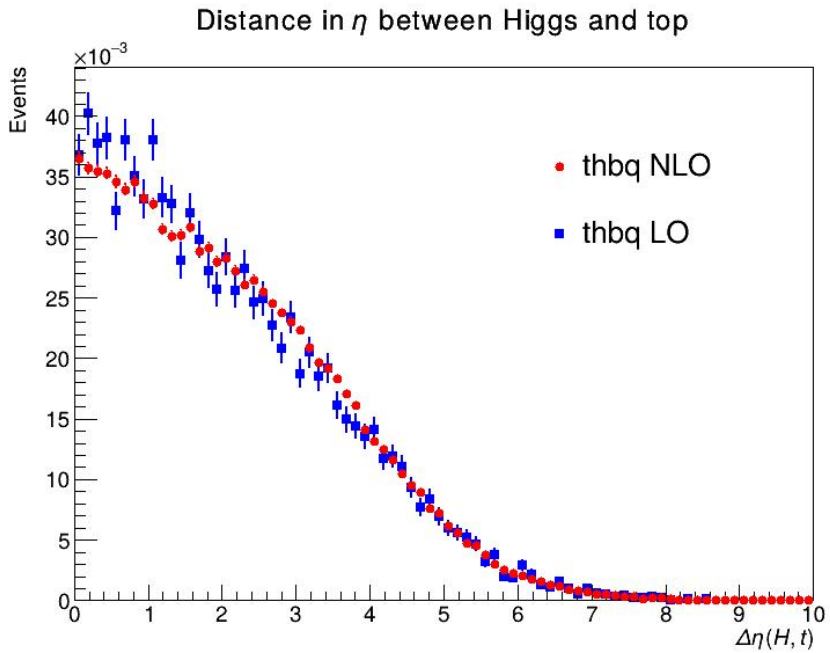


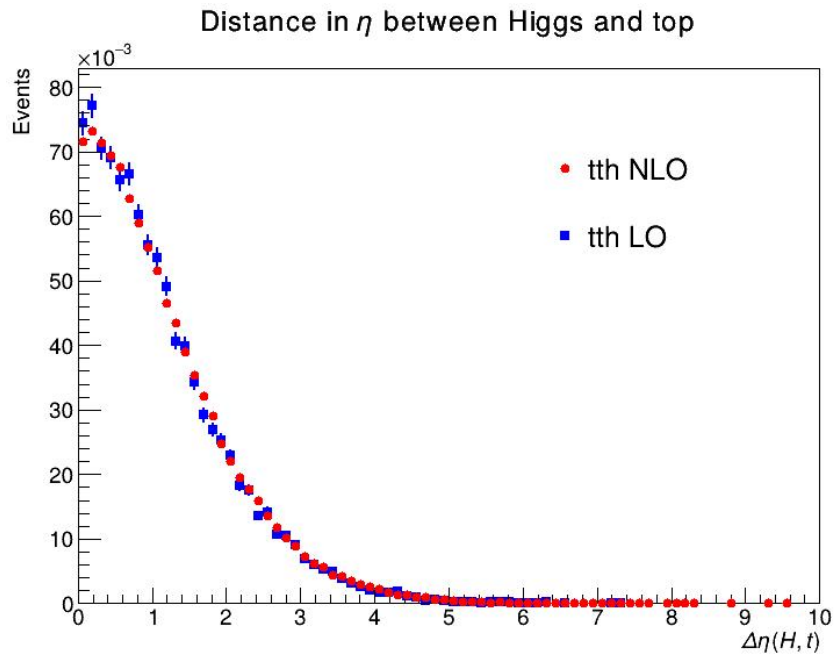




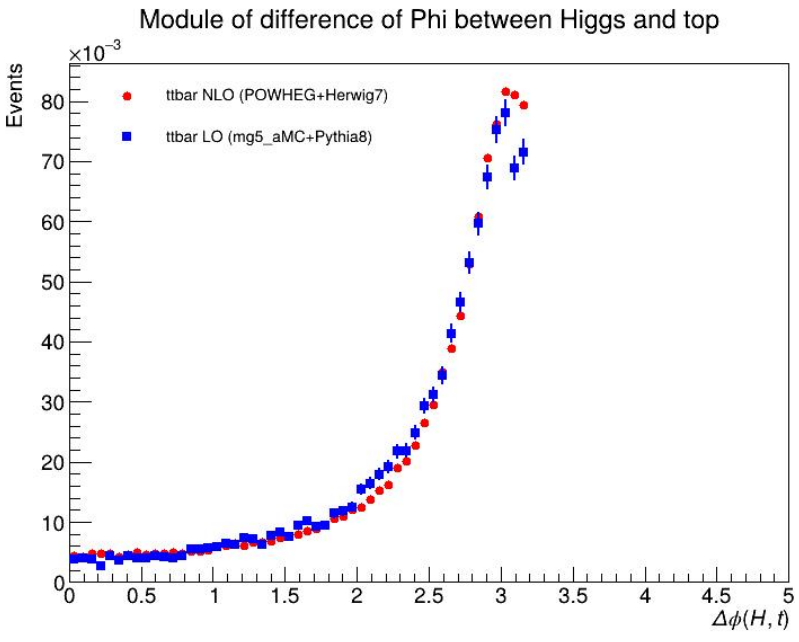
Distance η between top quark and Higgs boson for the signal and background processes

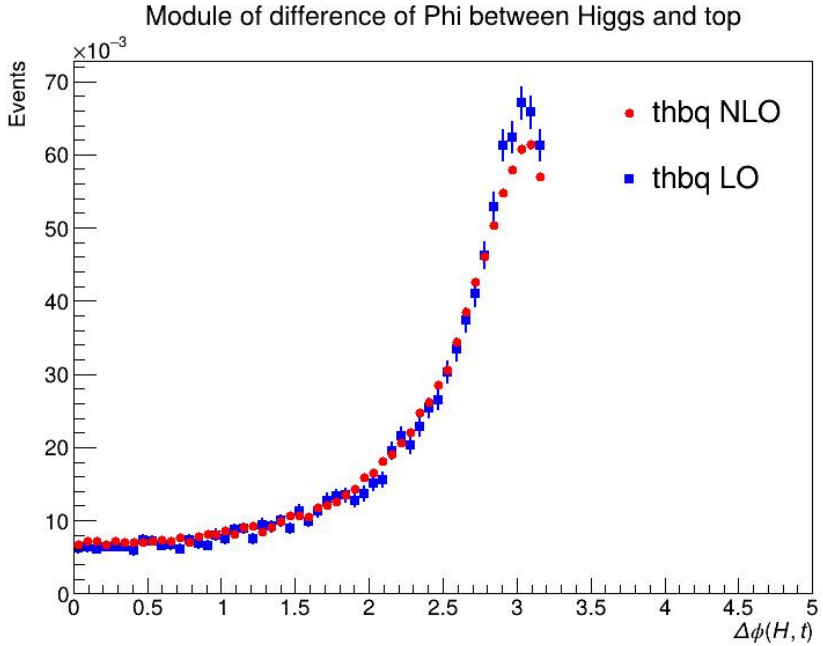


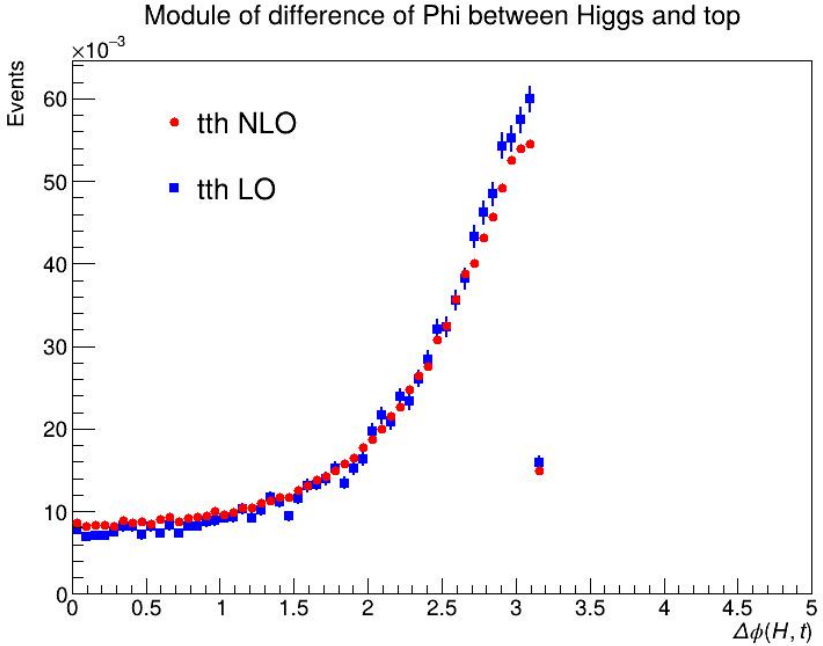




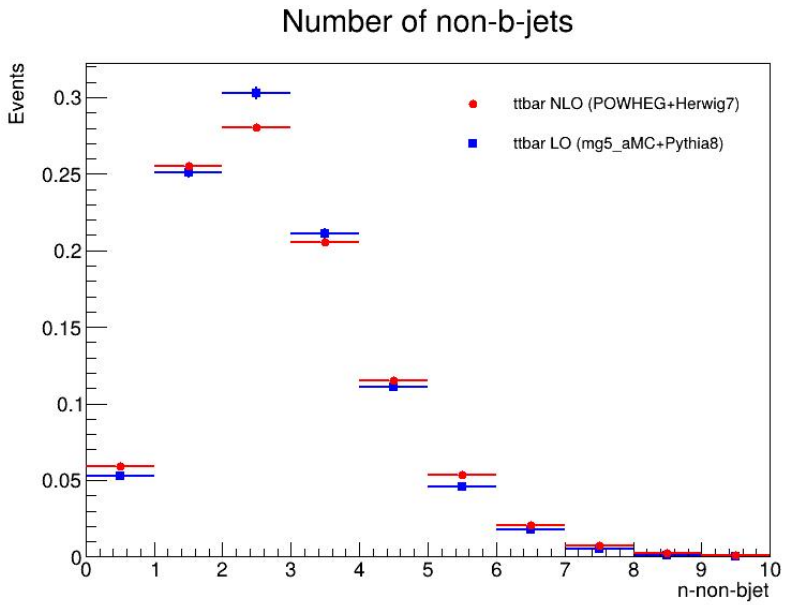
$|\Delta\phi|$ between top quark and Higgs boson for the signal and background processes

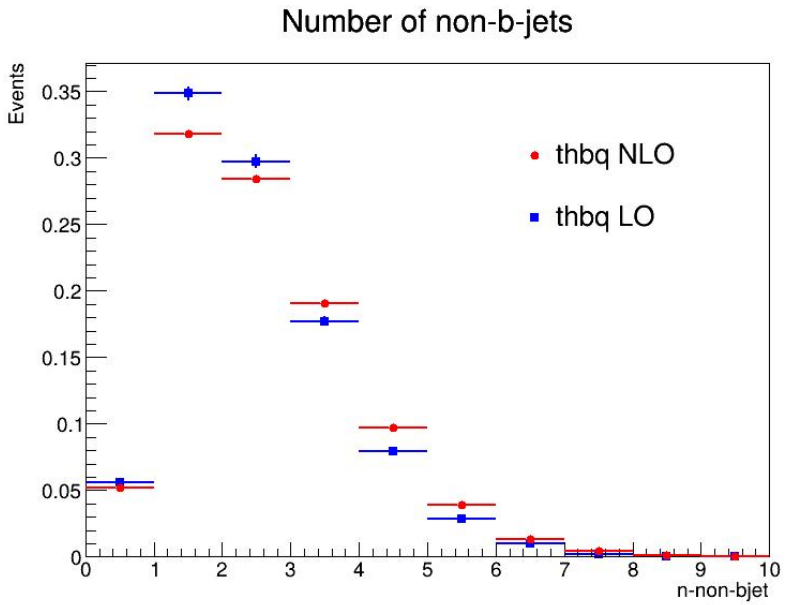


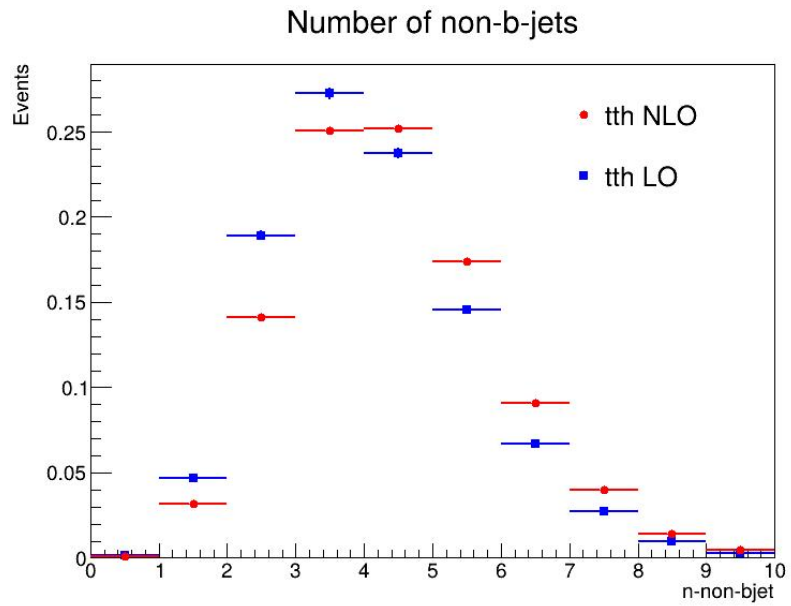


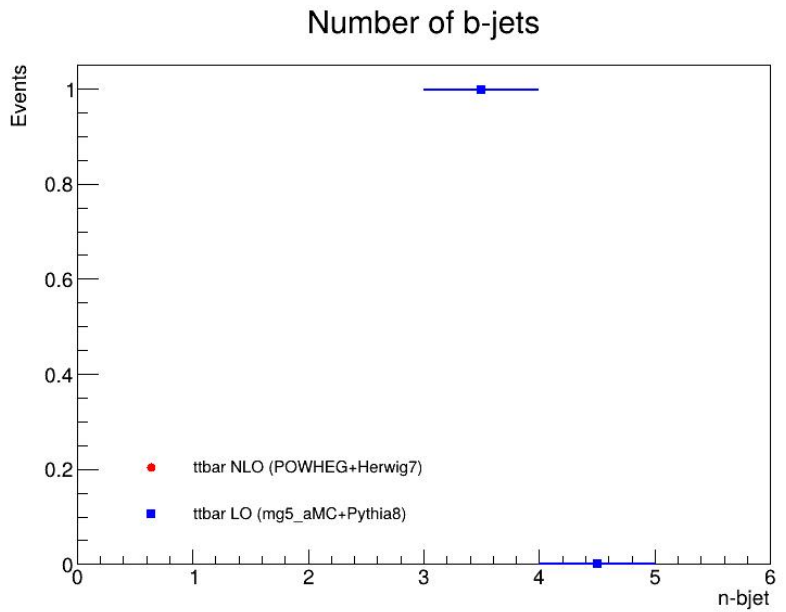


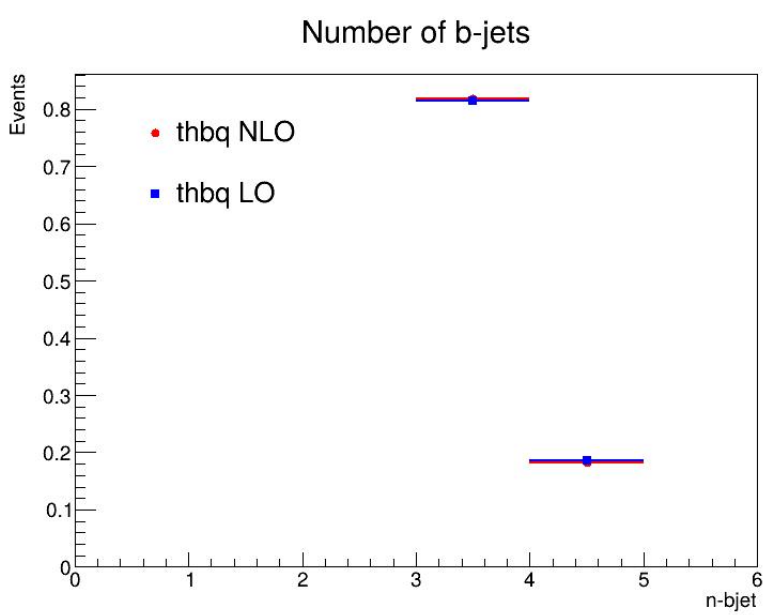
Number of b-jets and non-b-jets

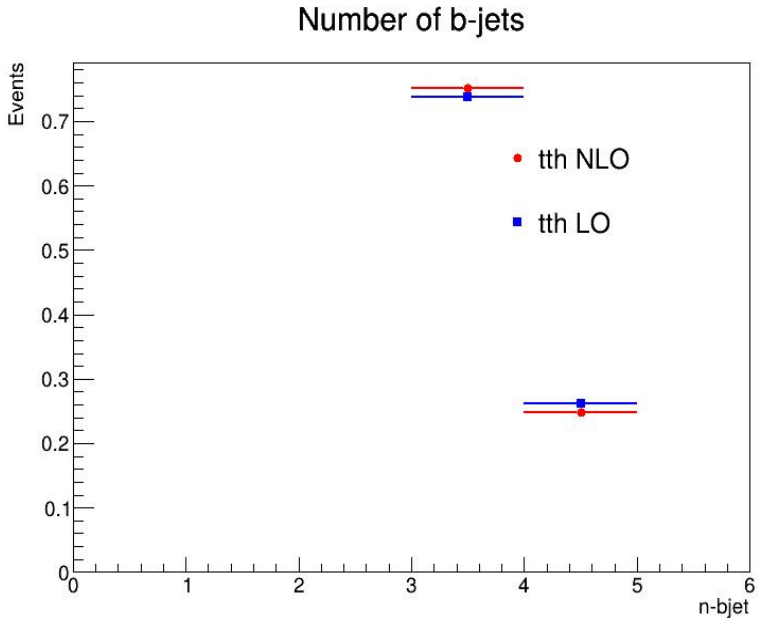




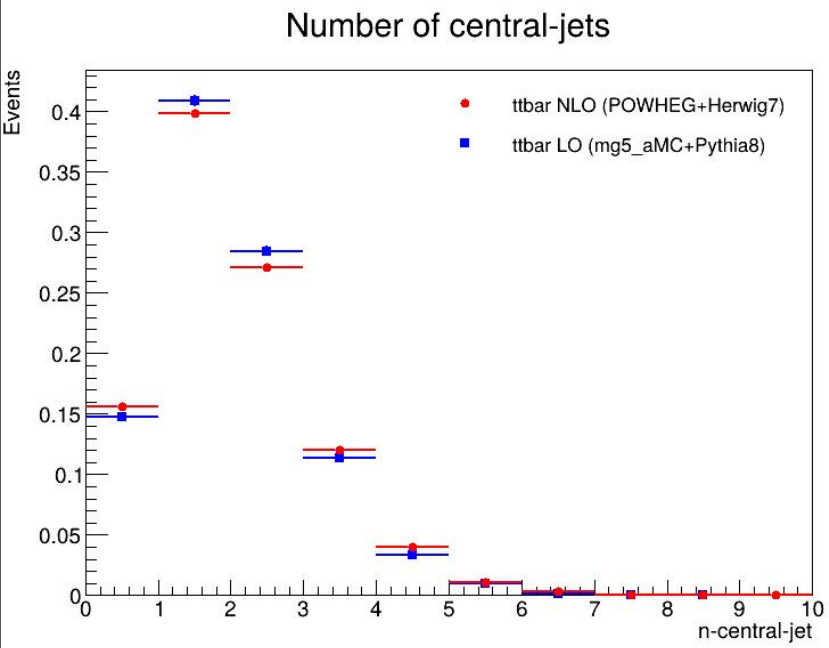


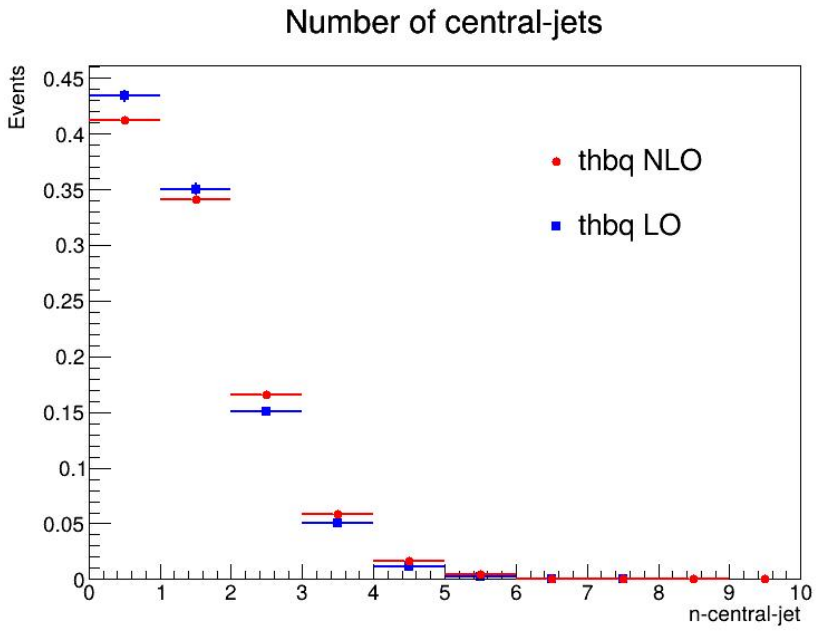


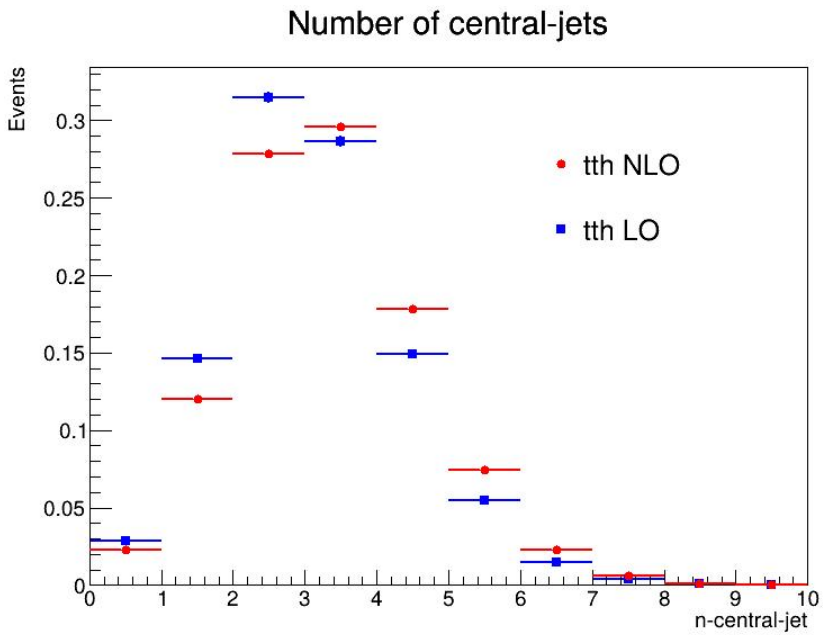




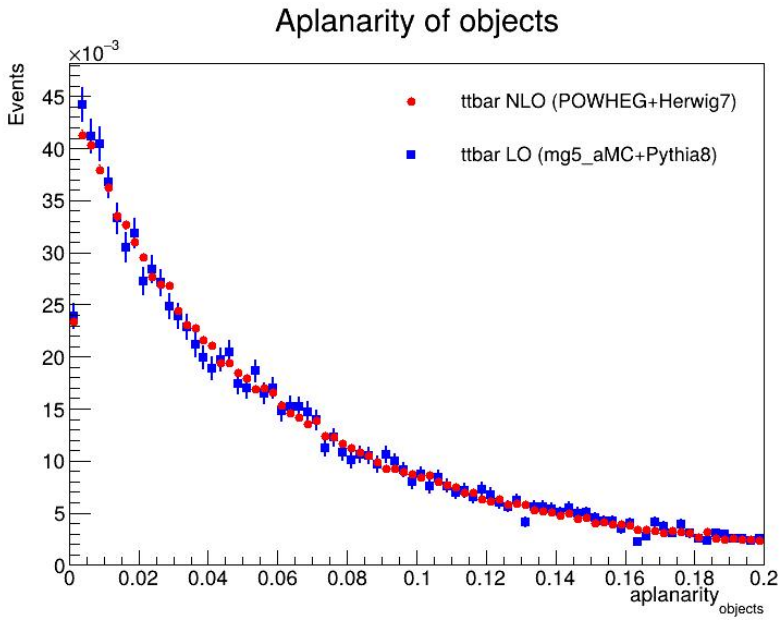
Number of central jets

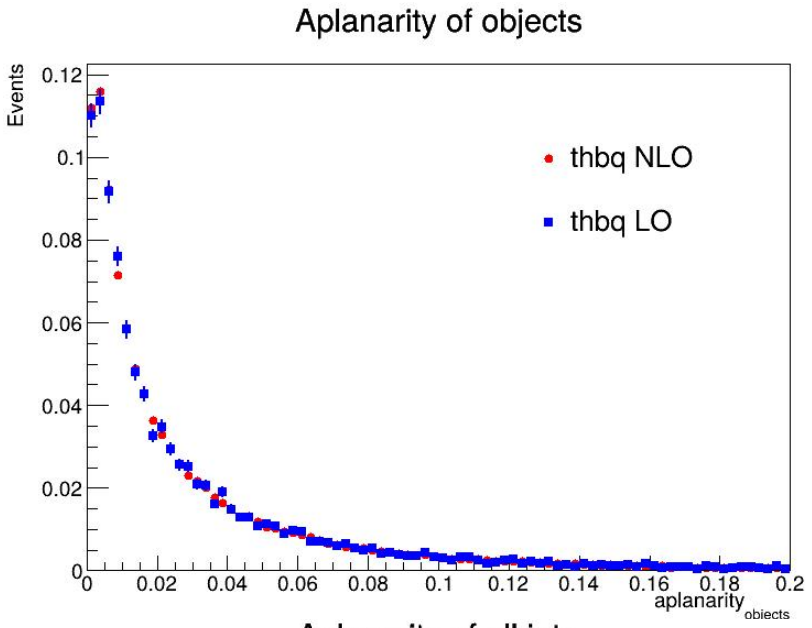


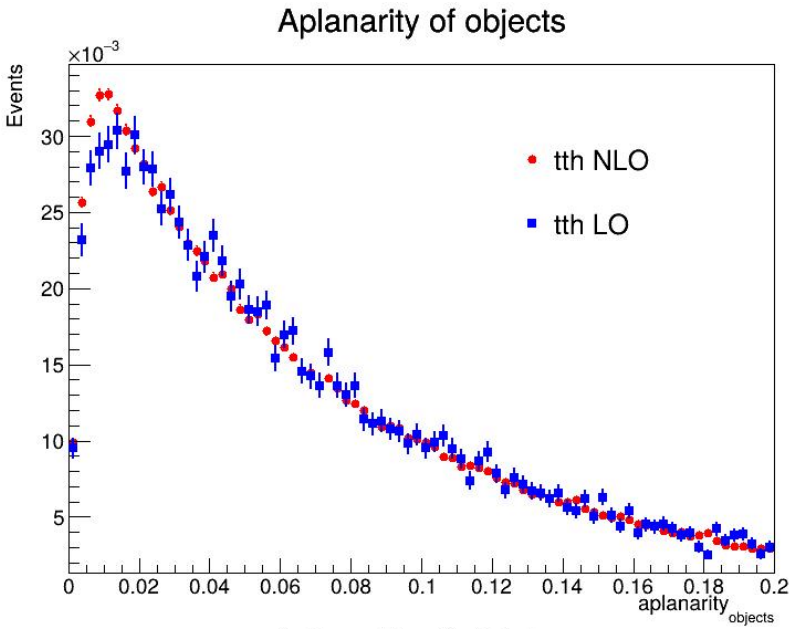


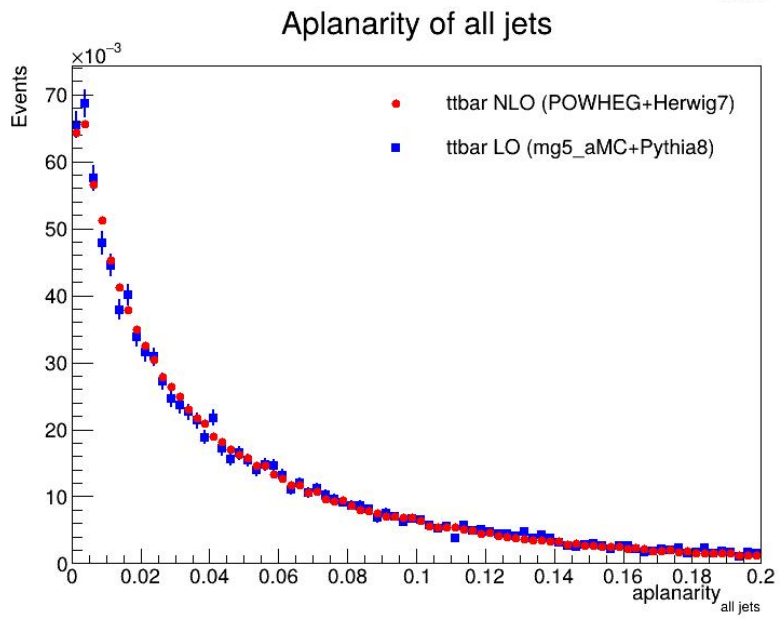


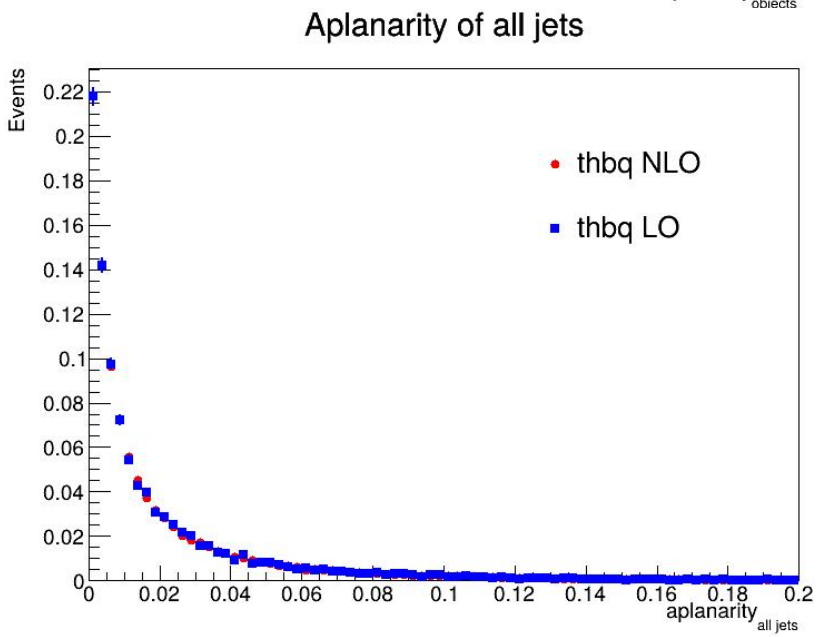
Aplanarity for the signal and background processes

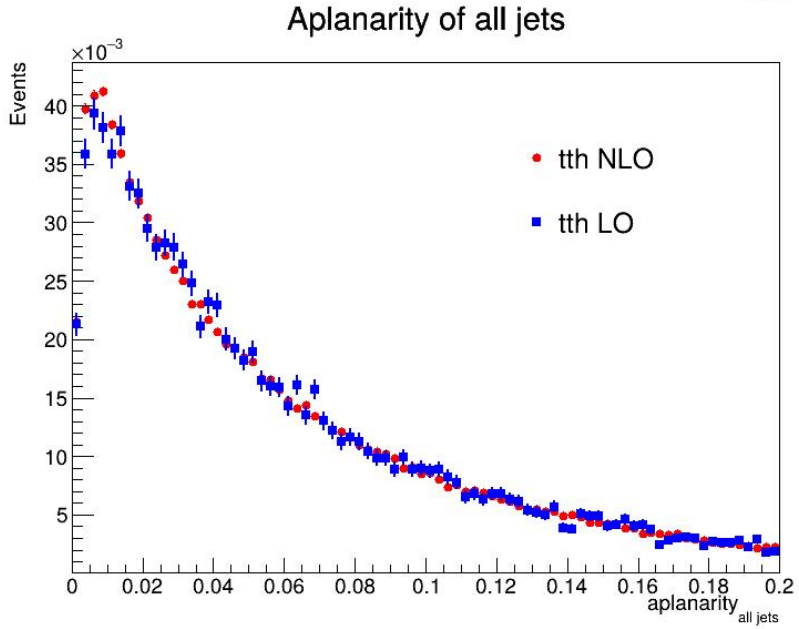




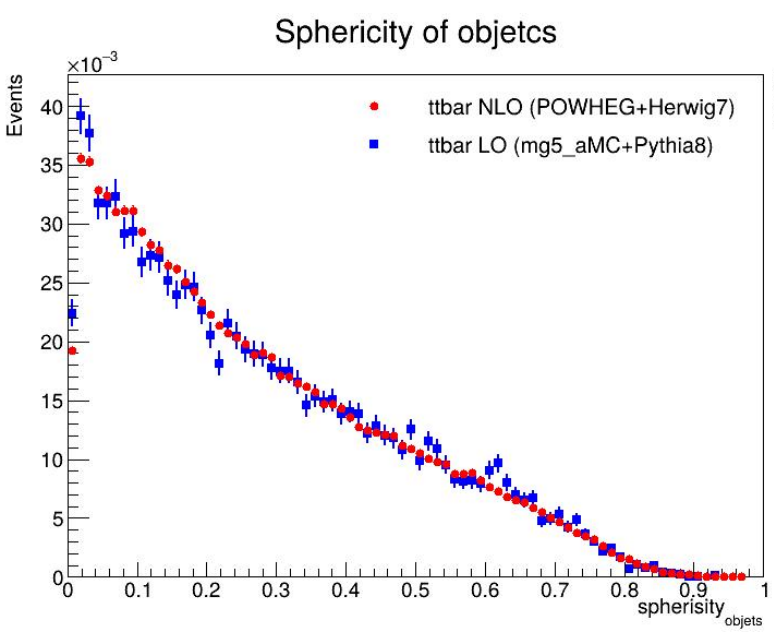


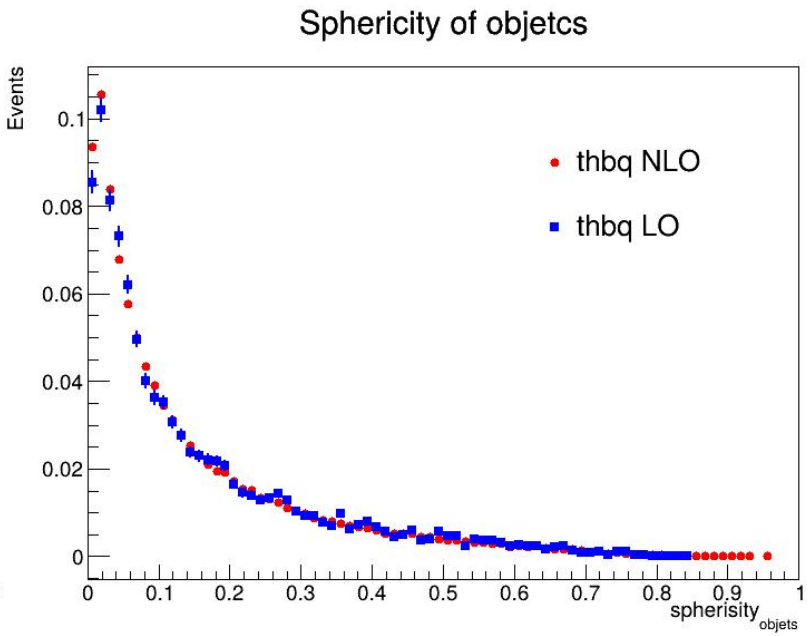


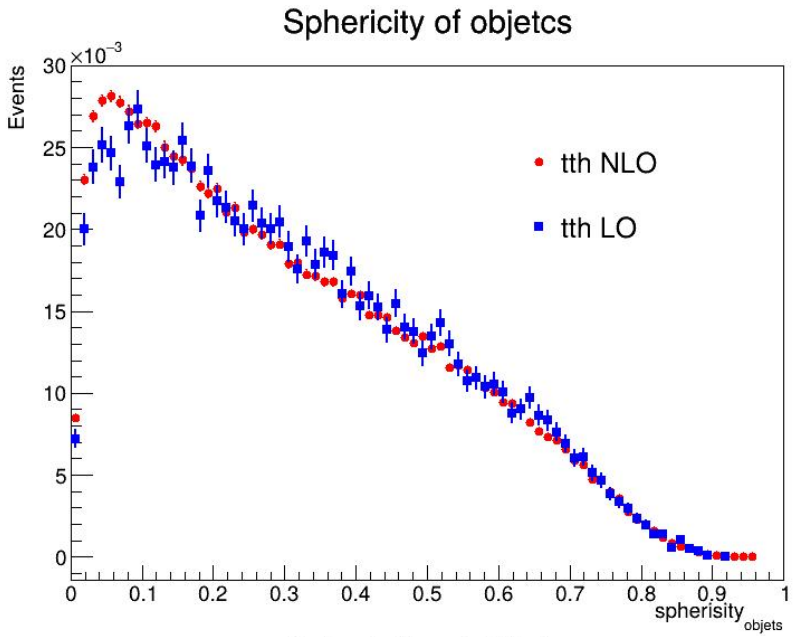


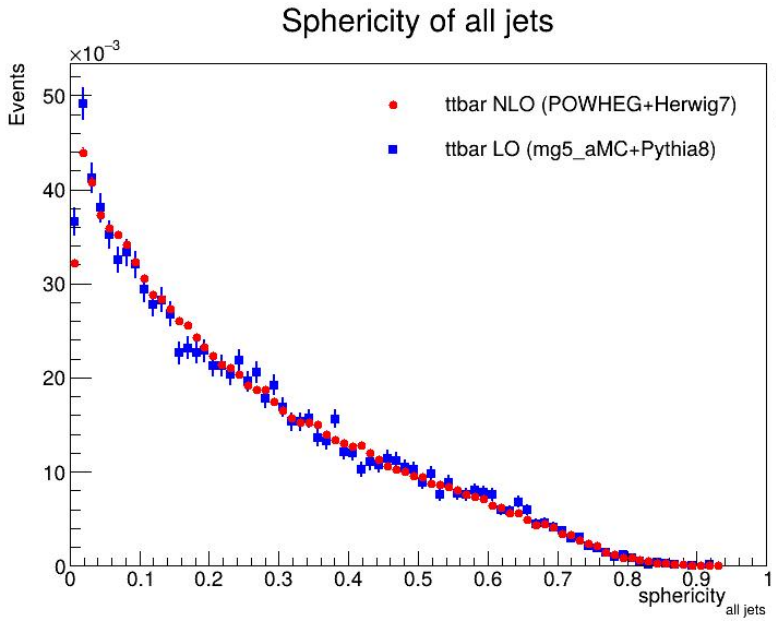


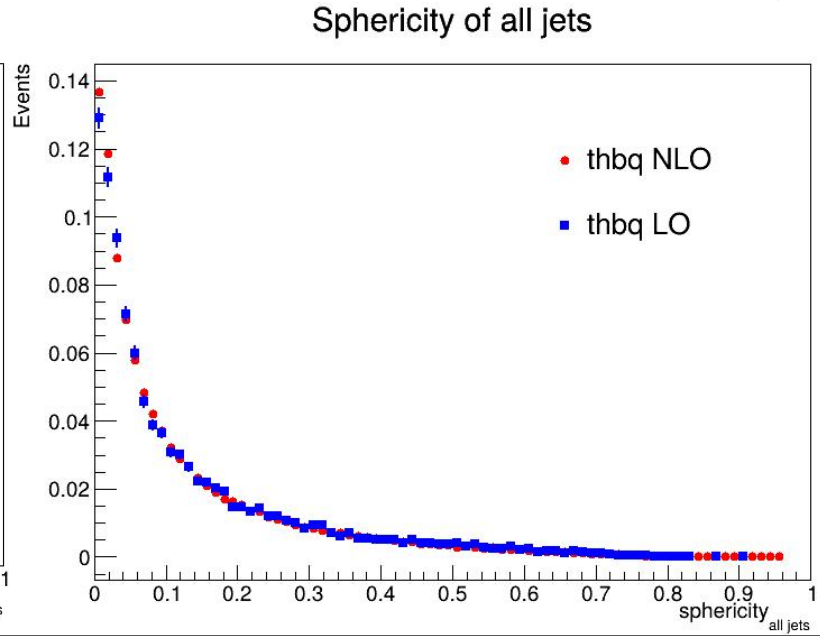
Sphericity for the signal and background processes

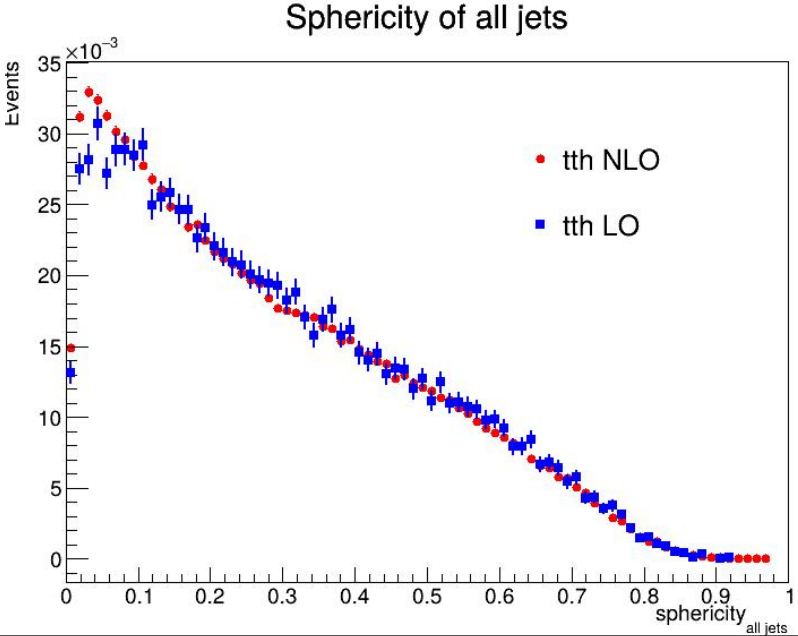




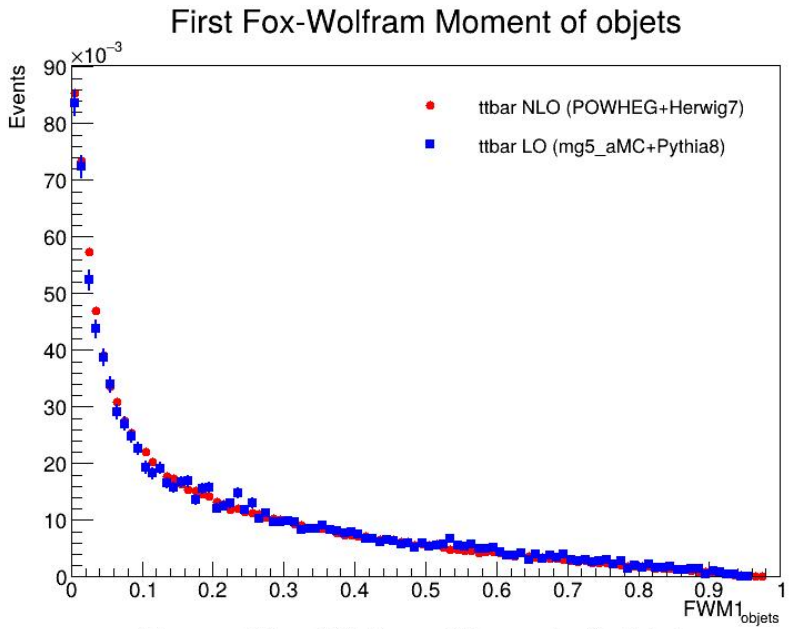


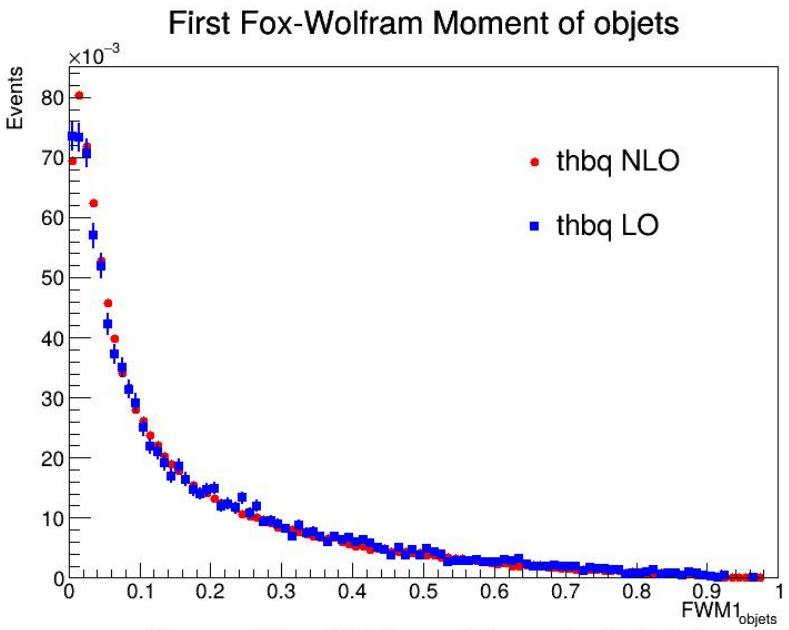


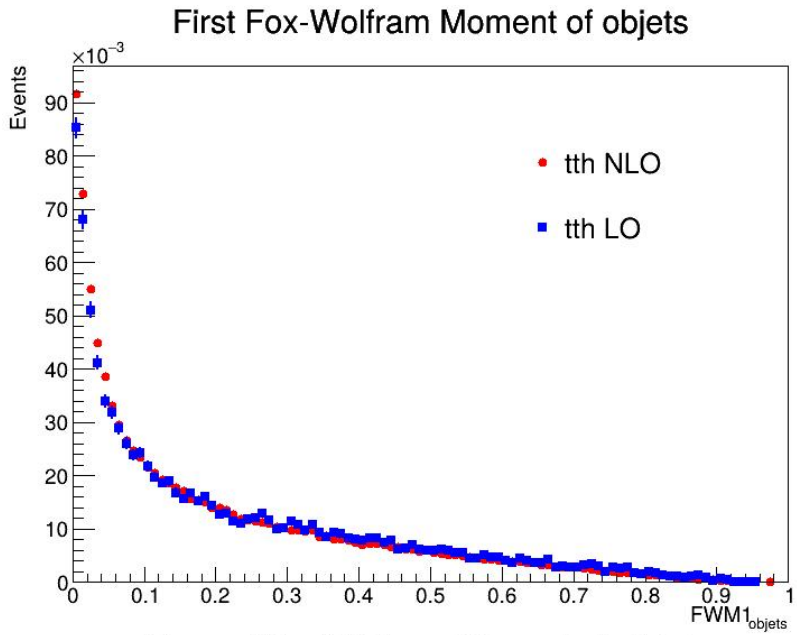


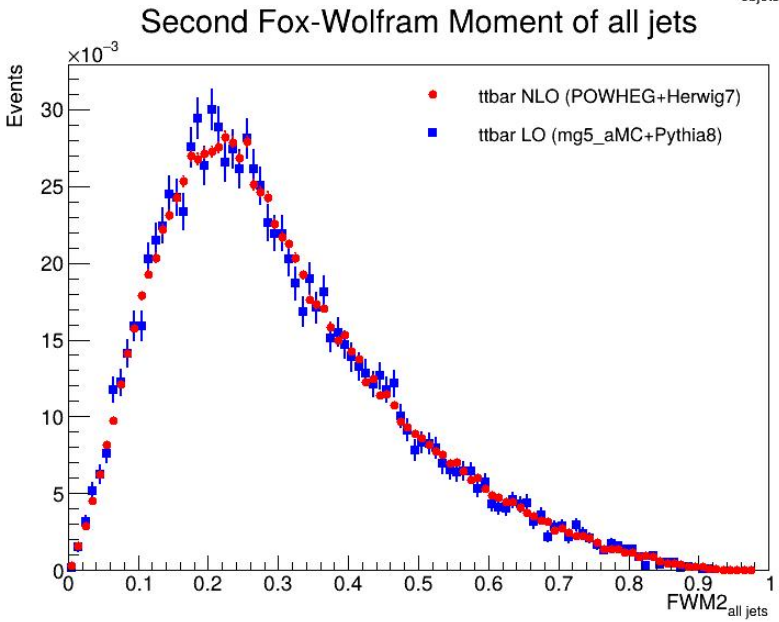


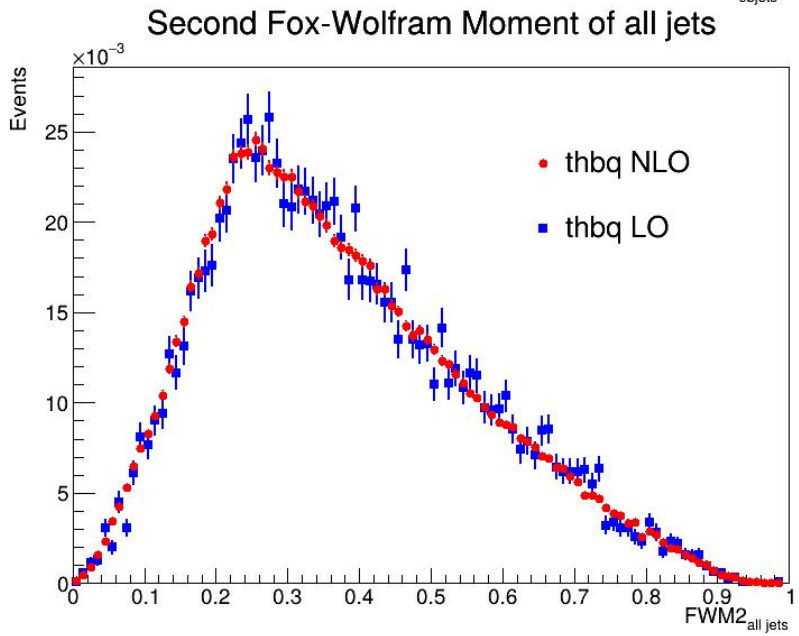
First and Second Fox-Wolfram moment for the signal and background processes

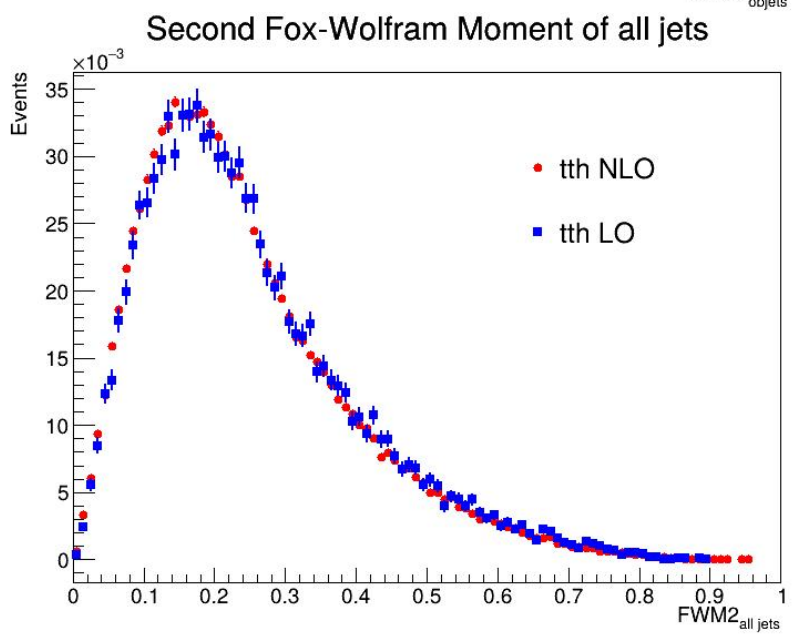




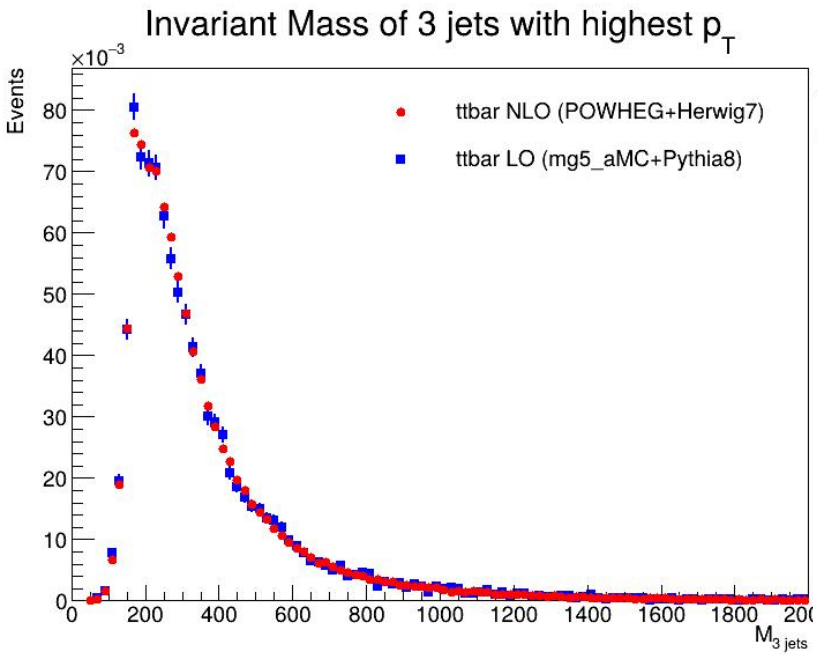


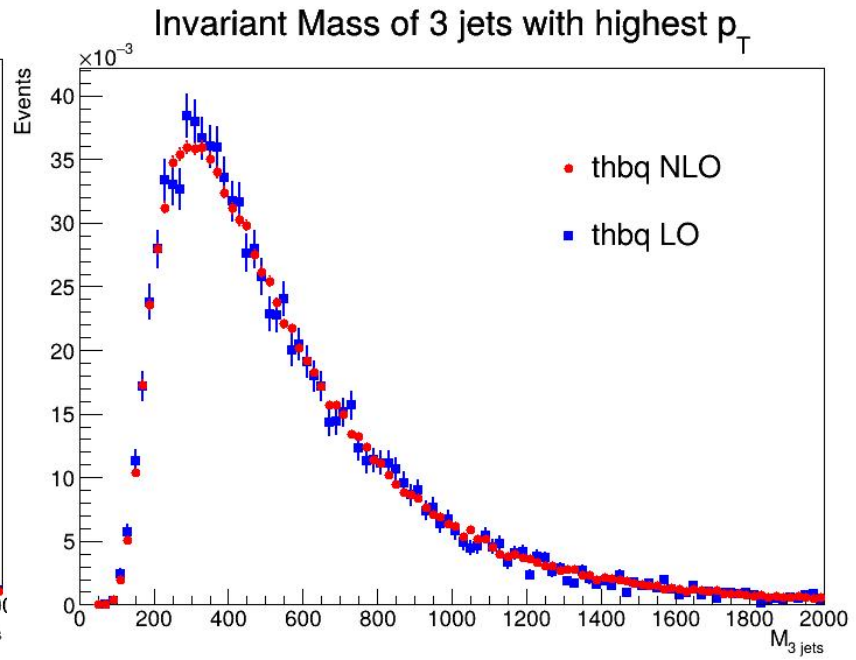


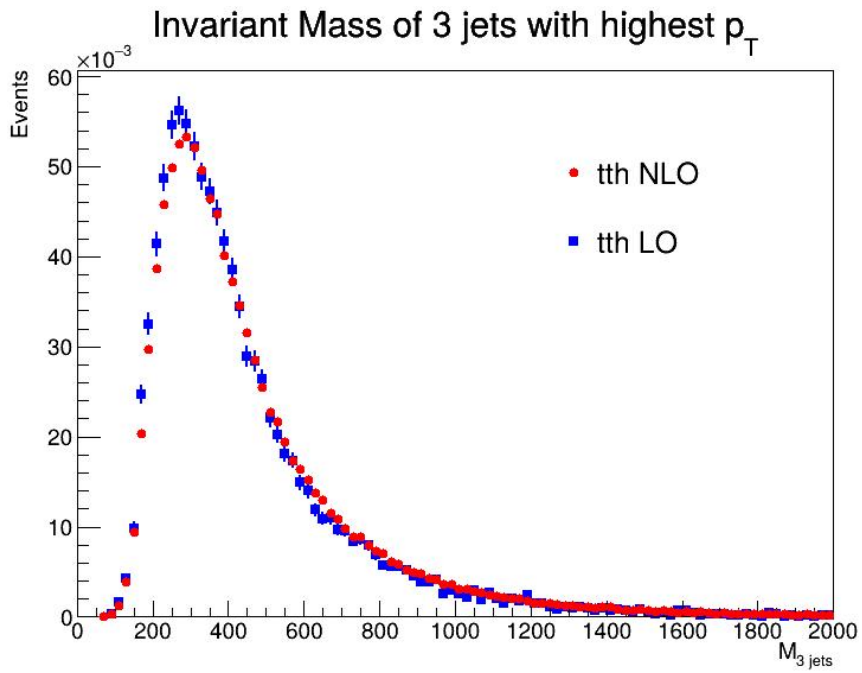




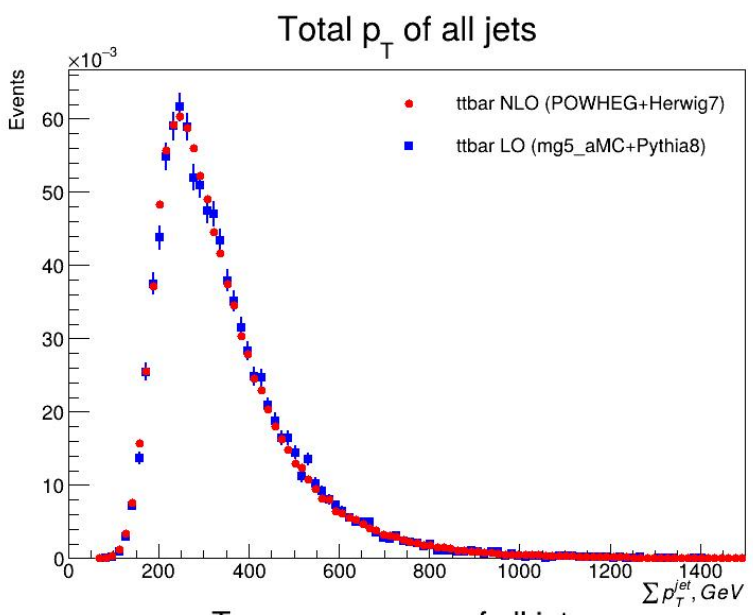
Invariant mass of 3 jets with highest p_T for the signal and background processes

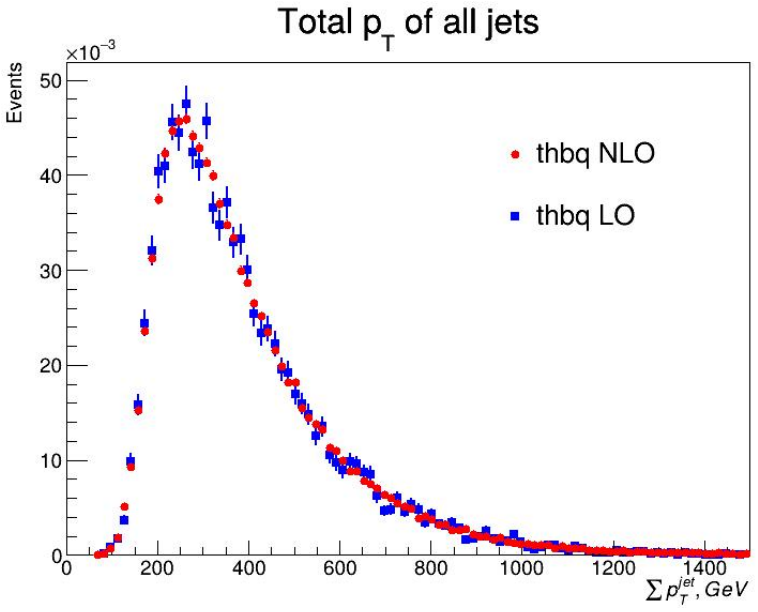


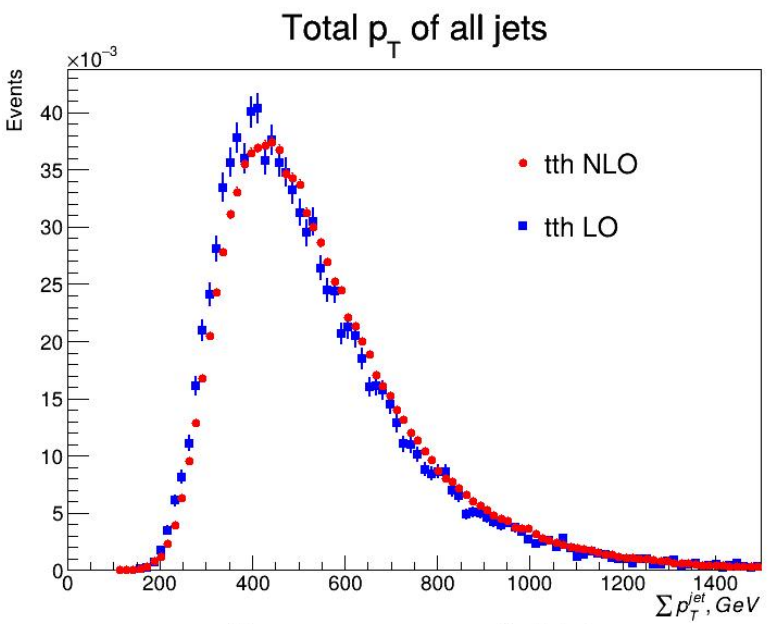


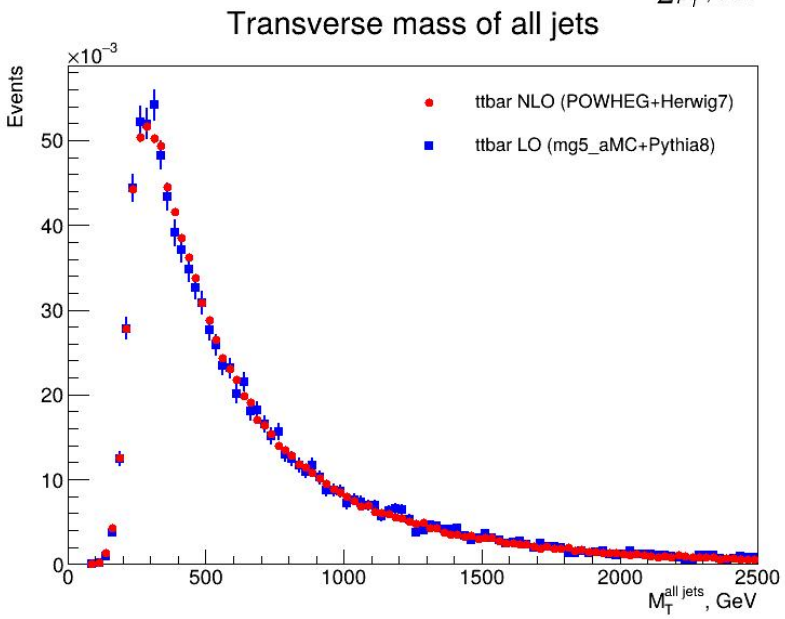


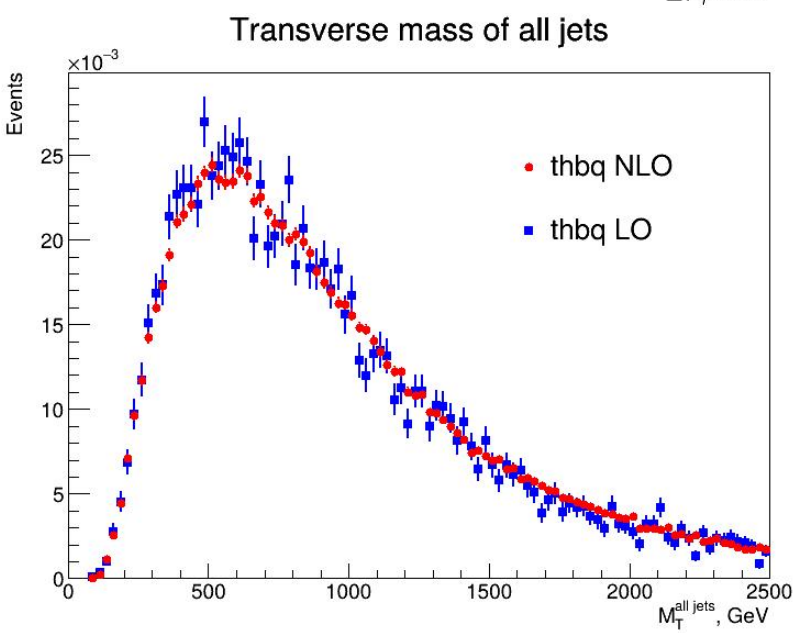
Total p_T and transverse mass of all jets for the signal and background processes

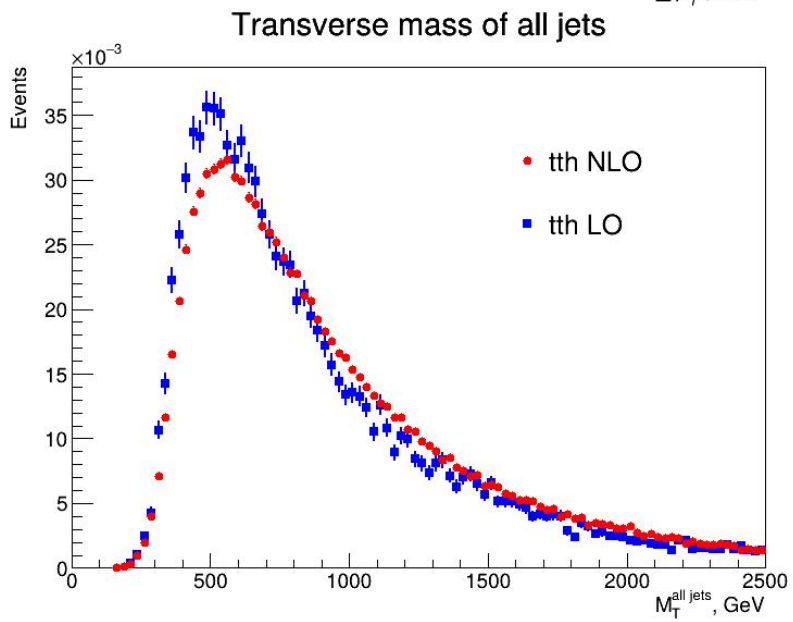




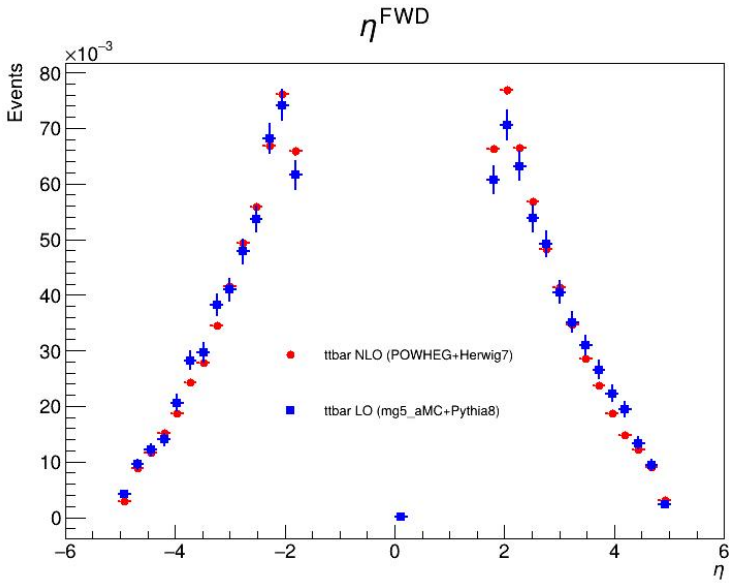


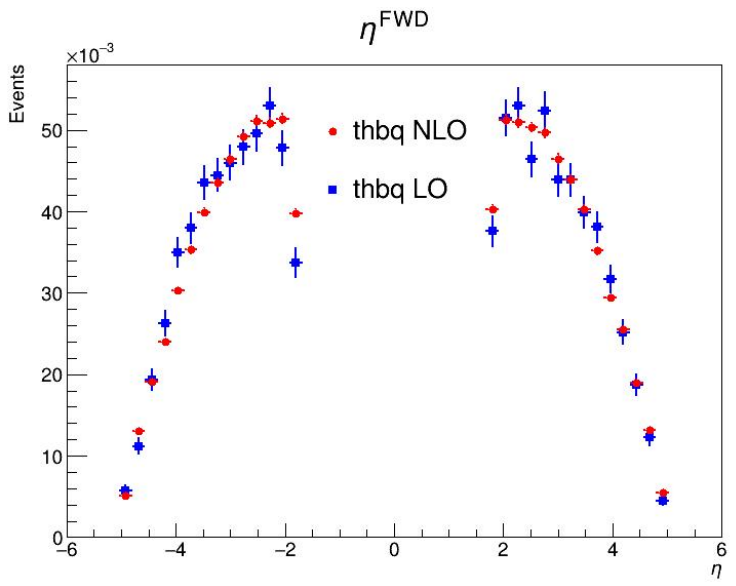


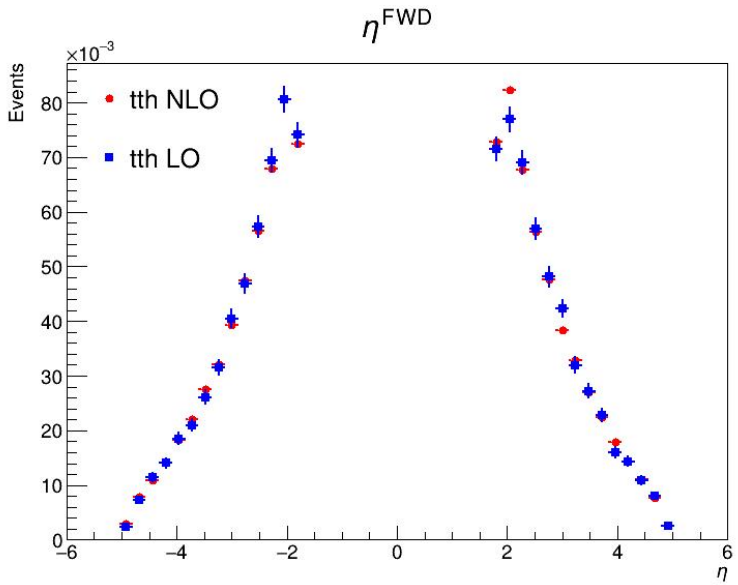


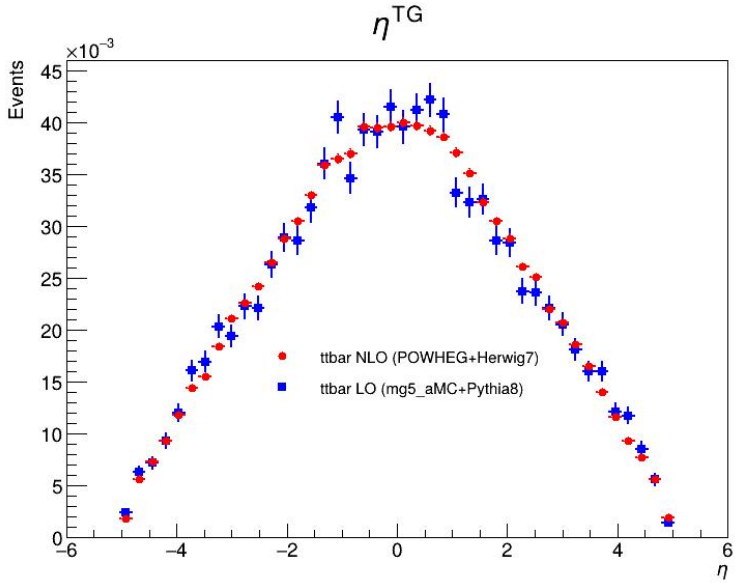


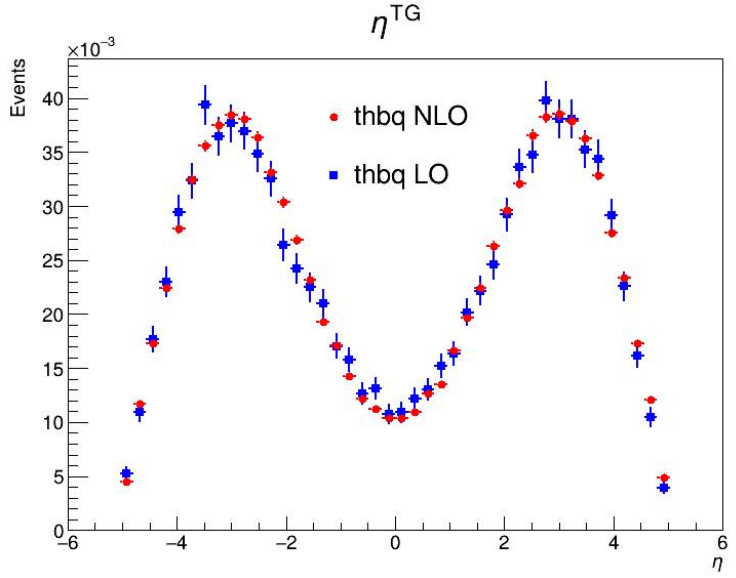
Forward and Tagging jet

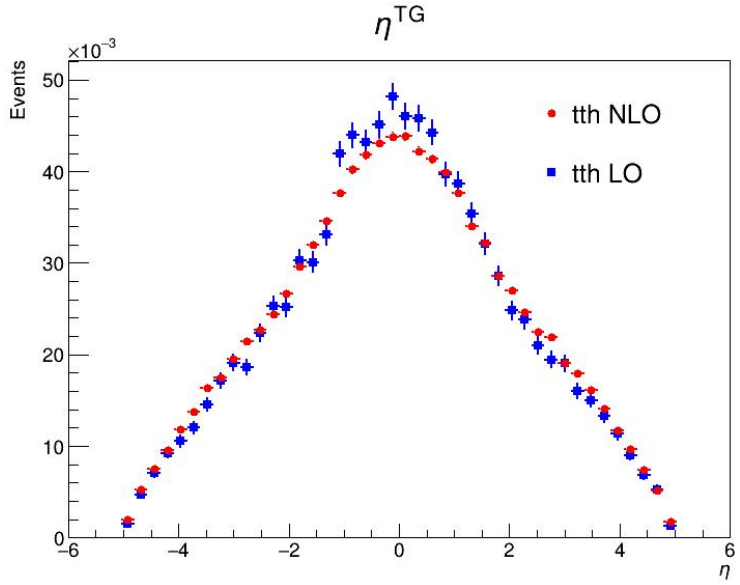




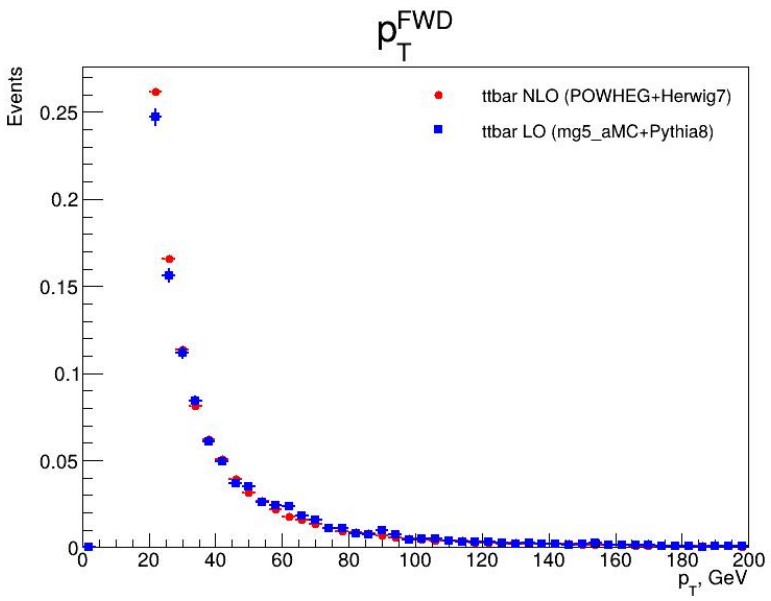


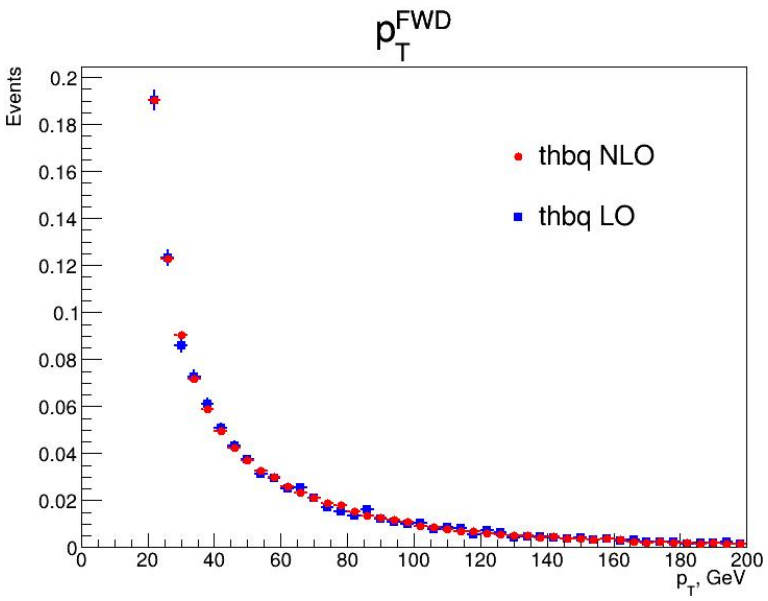


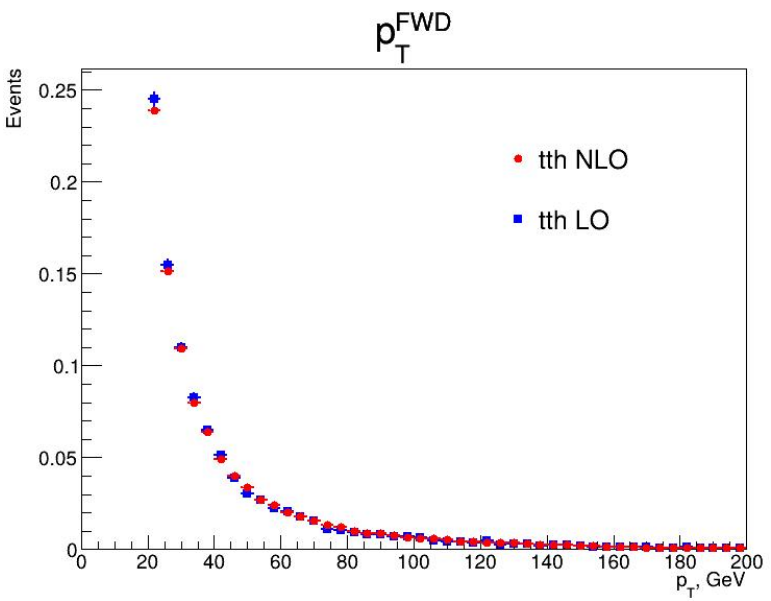


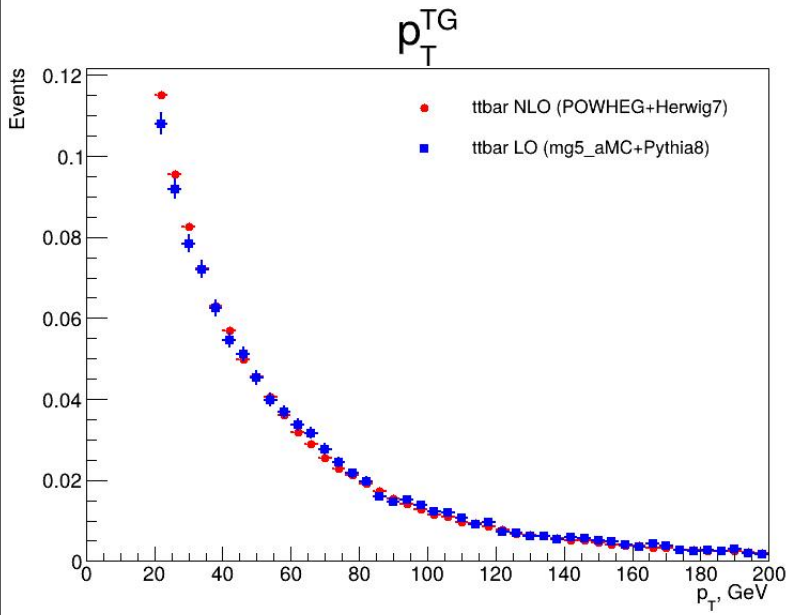


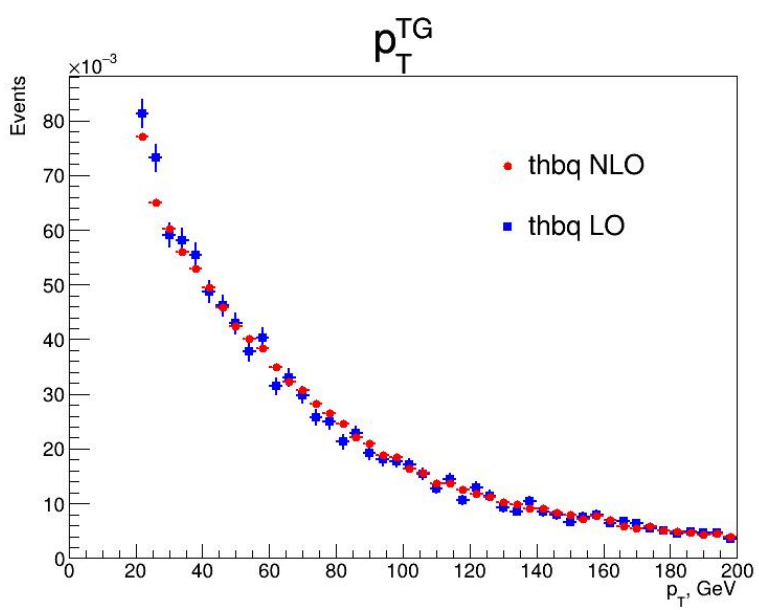
Forward and Tagging jet

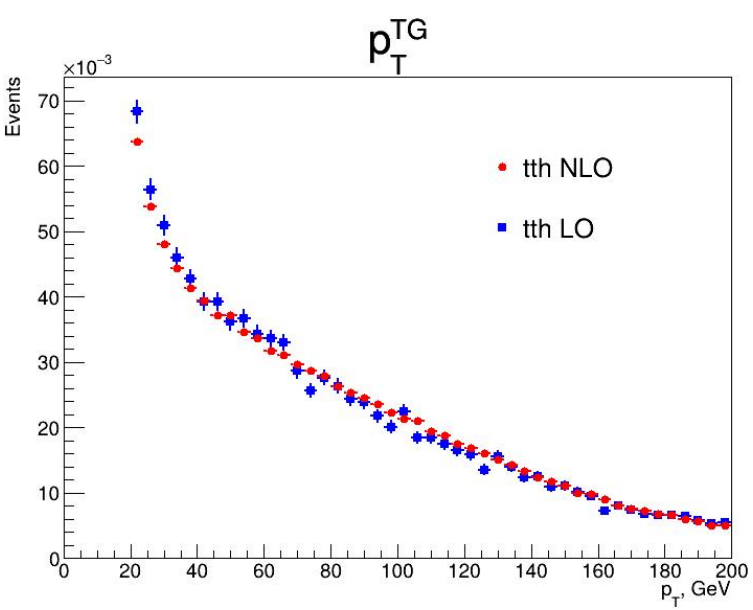




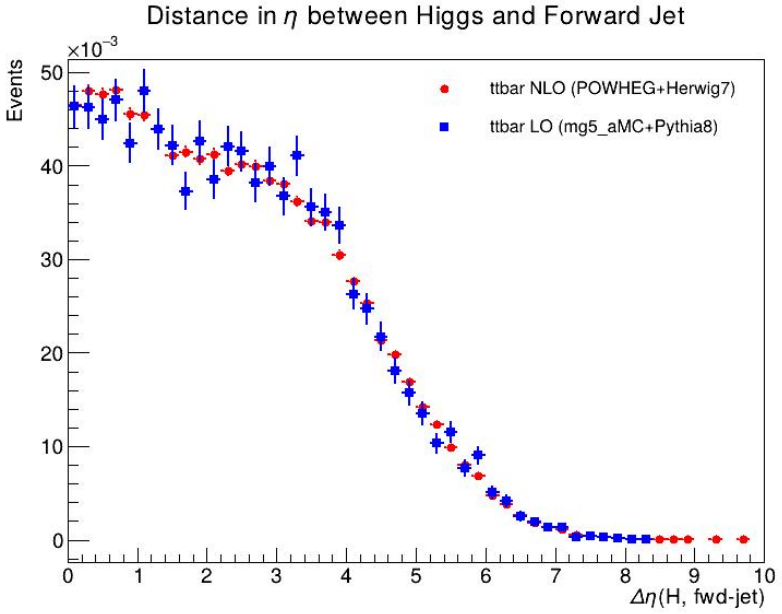


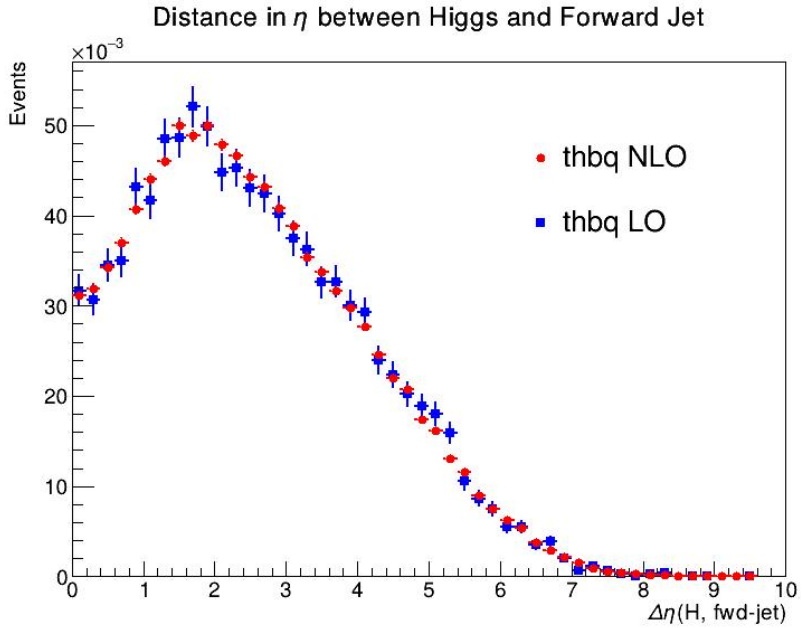


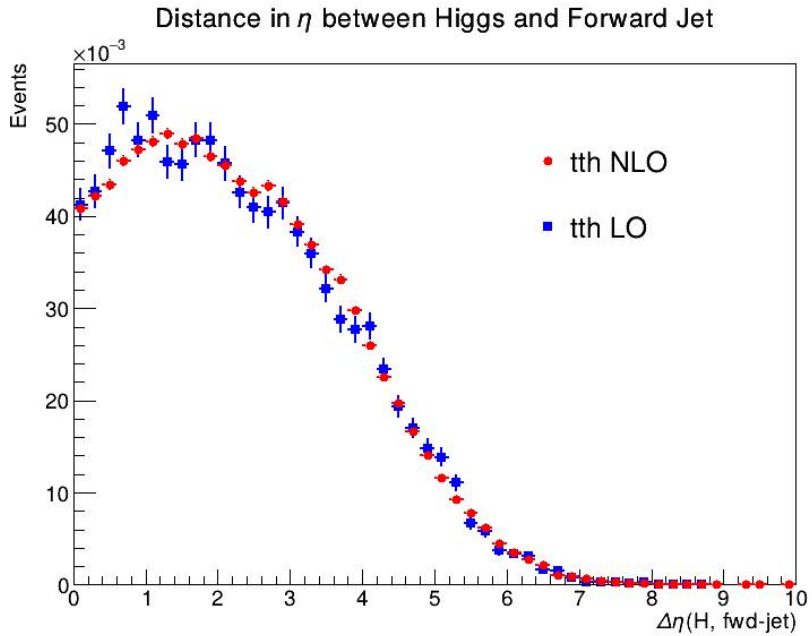


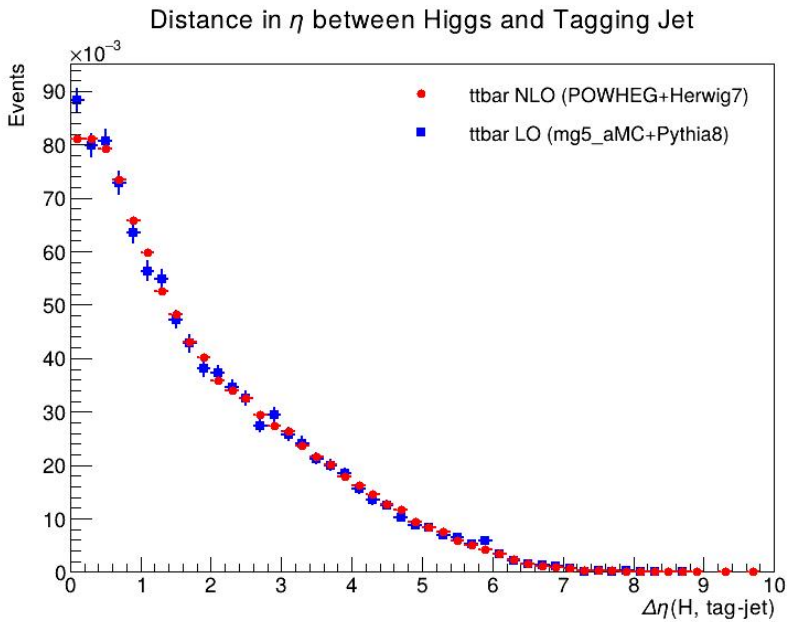


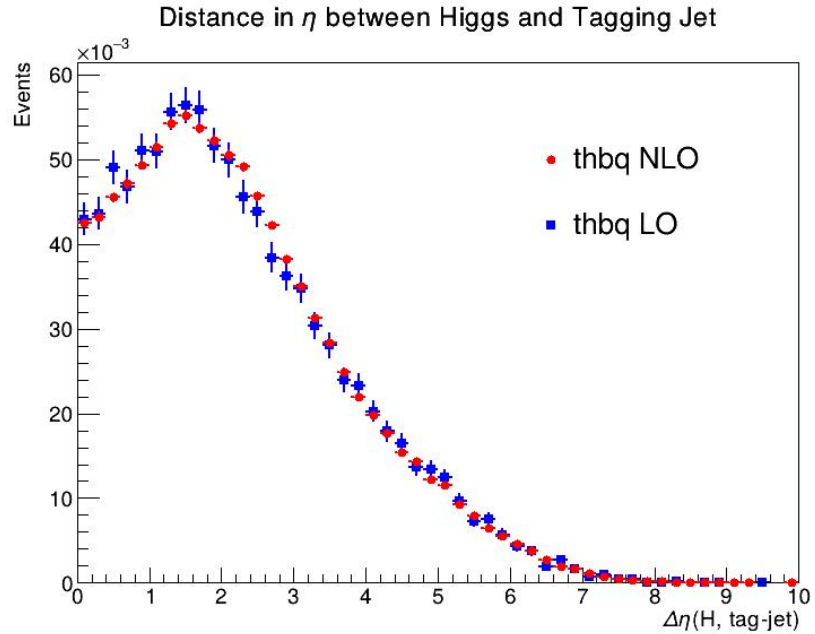
Distance in η between Higgs and Forward (Tagging) Jet for the signal and background processes

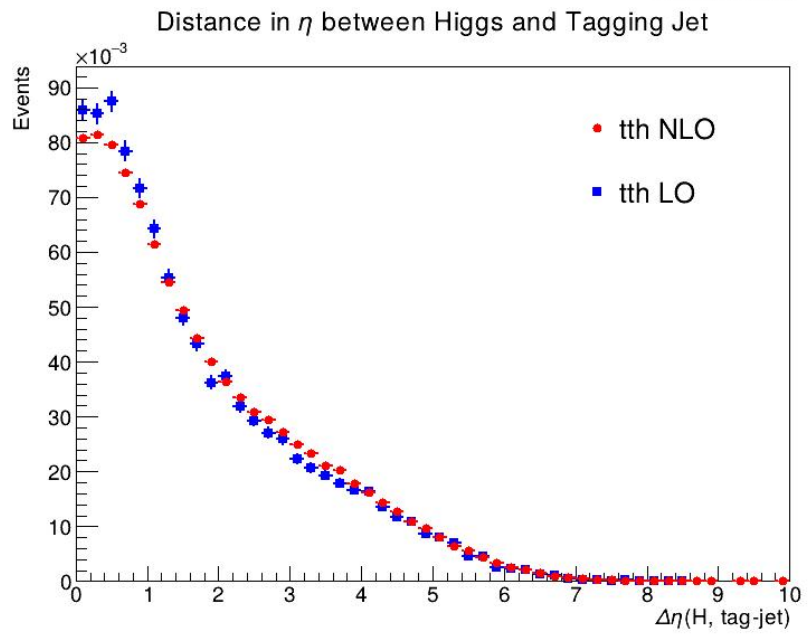




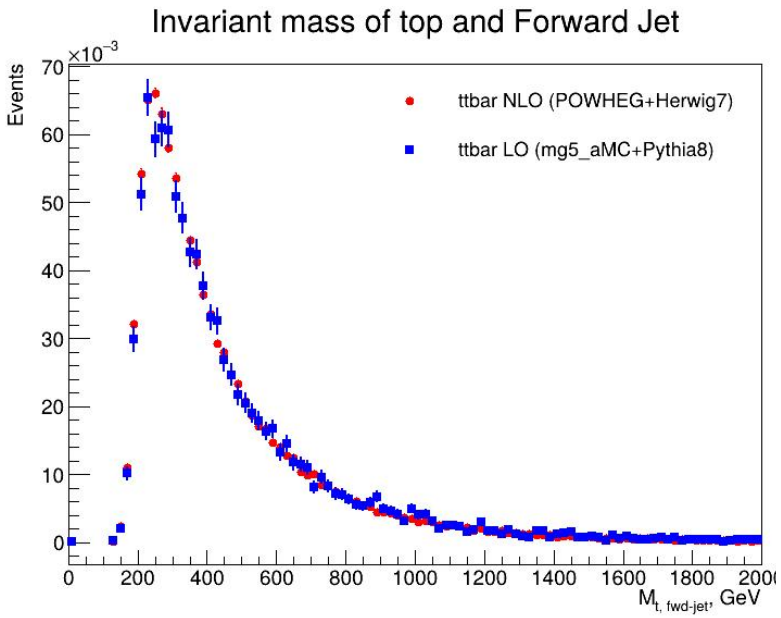


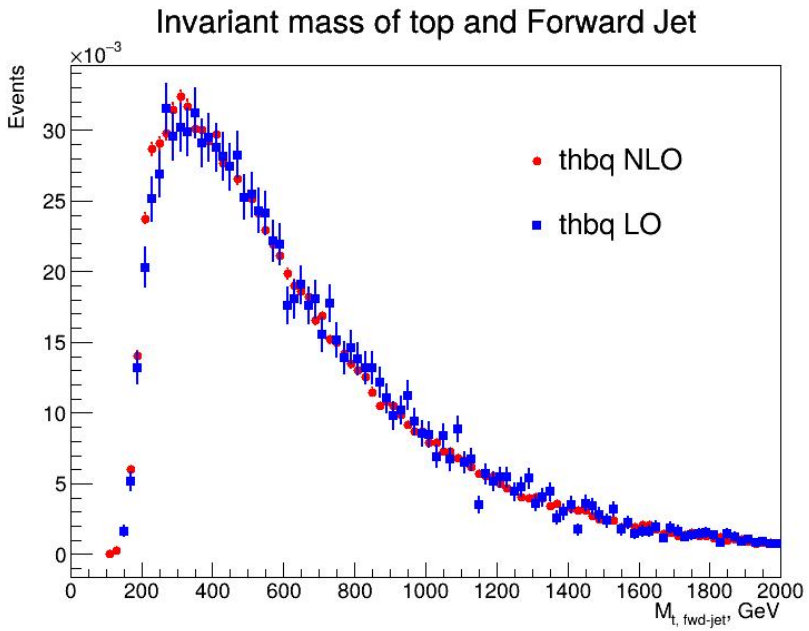


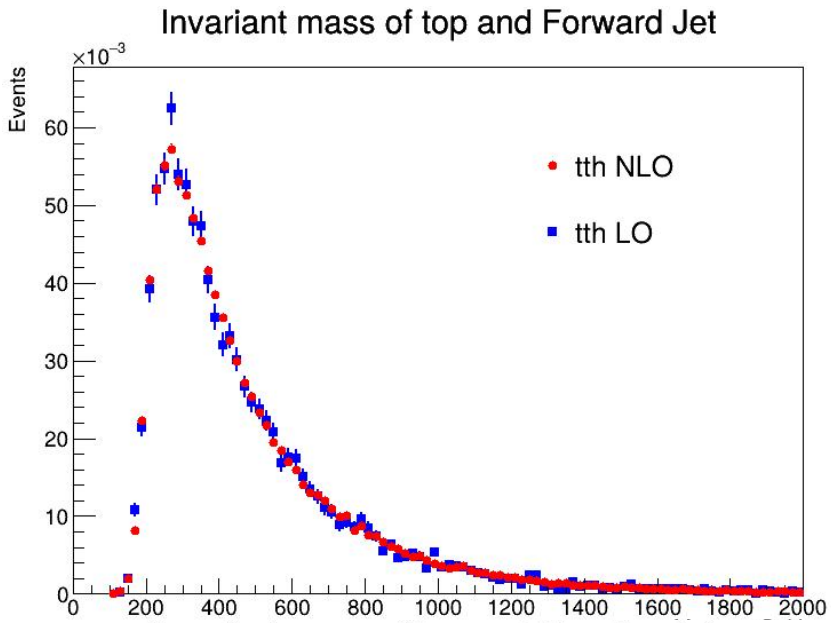


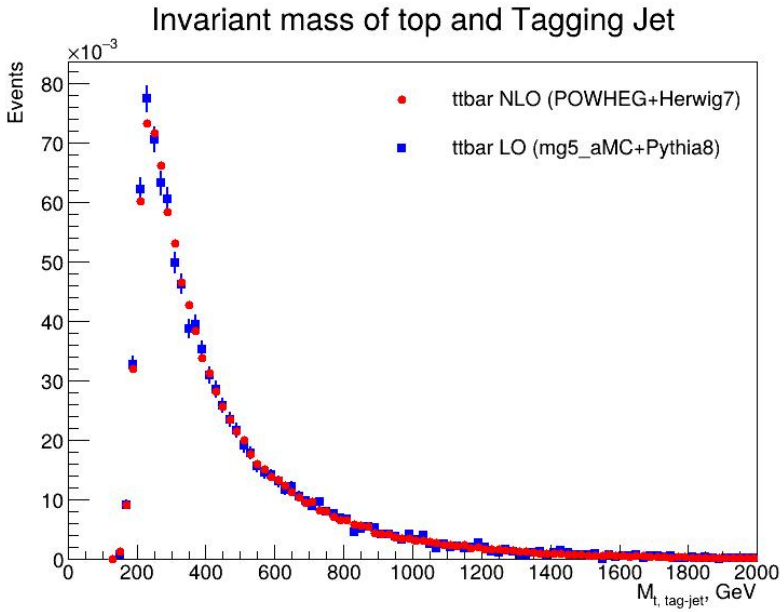


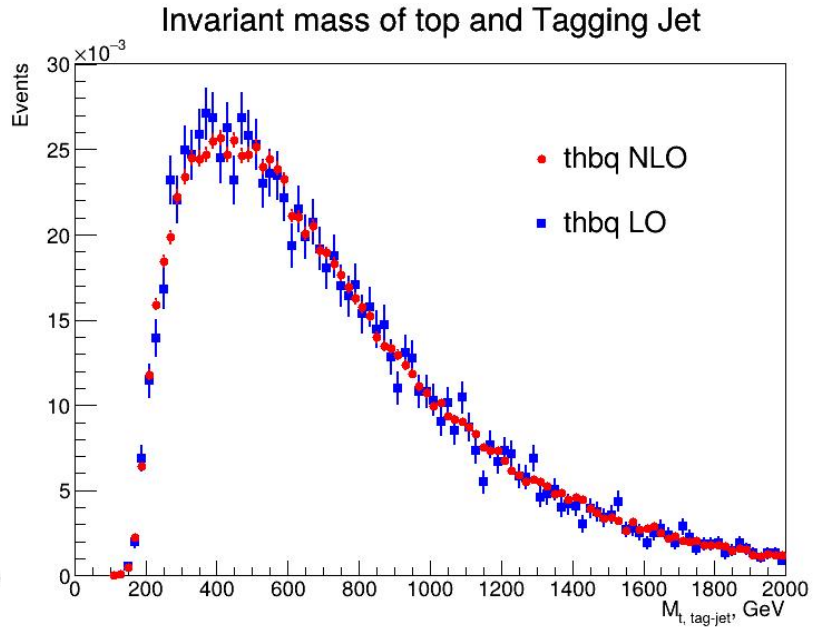
Invariant mass of Top-quark and Forward (Tagging) Jet for the signal and background processes

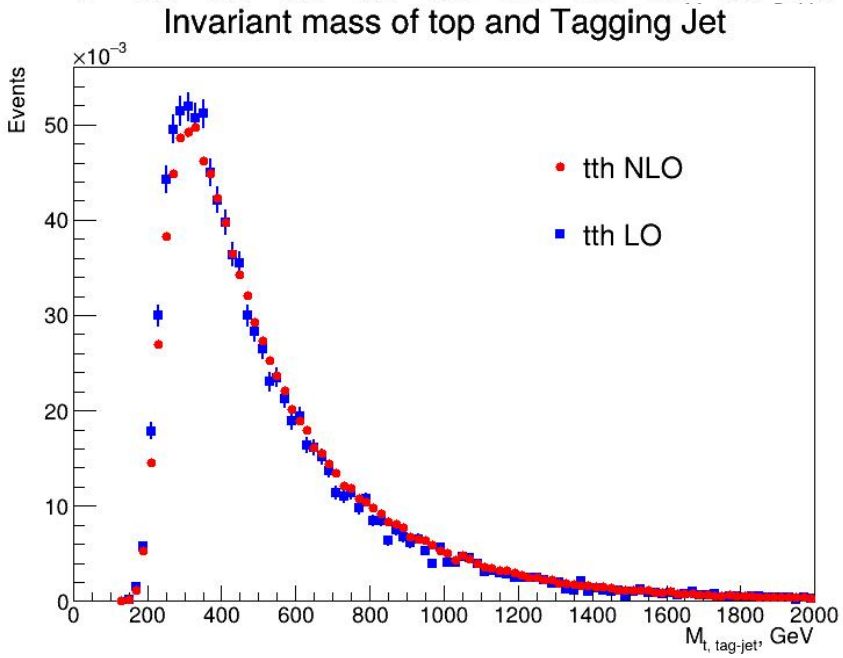




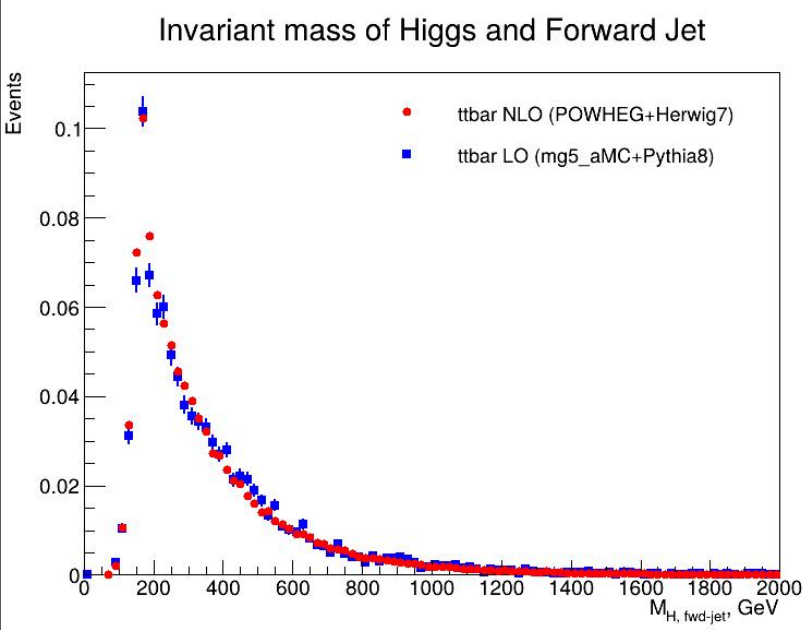


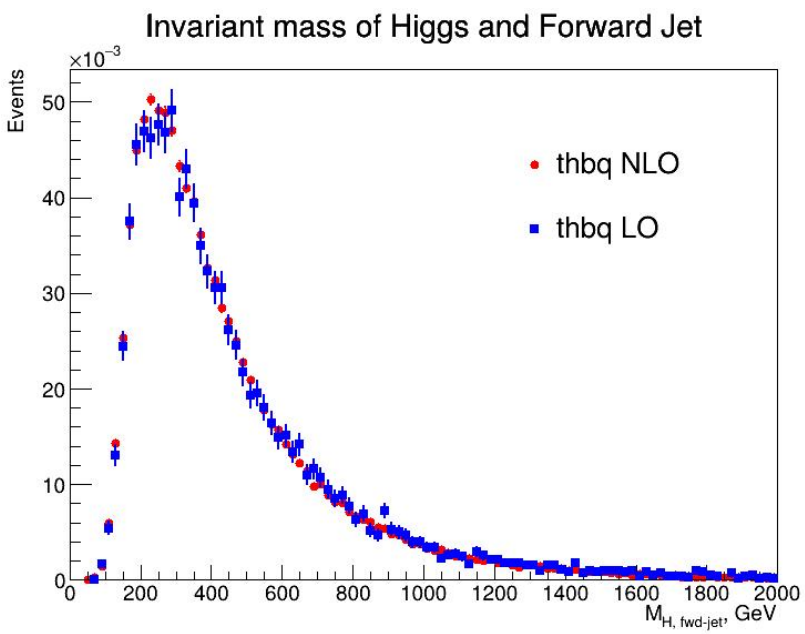


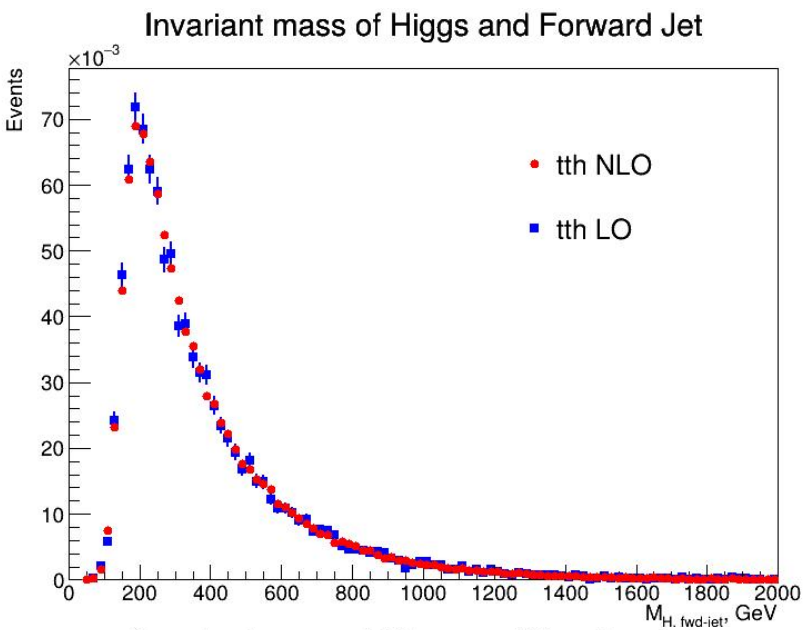


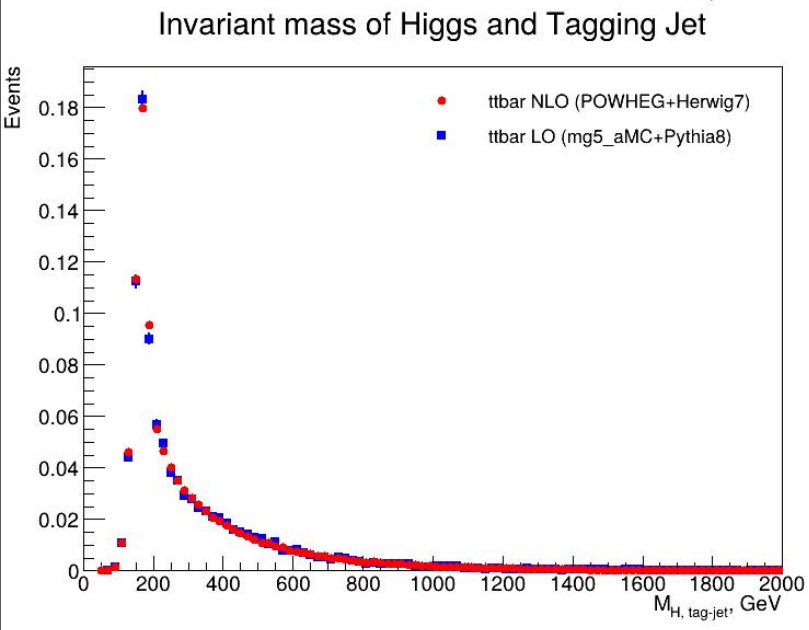


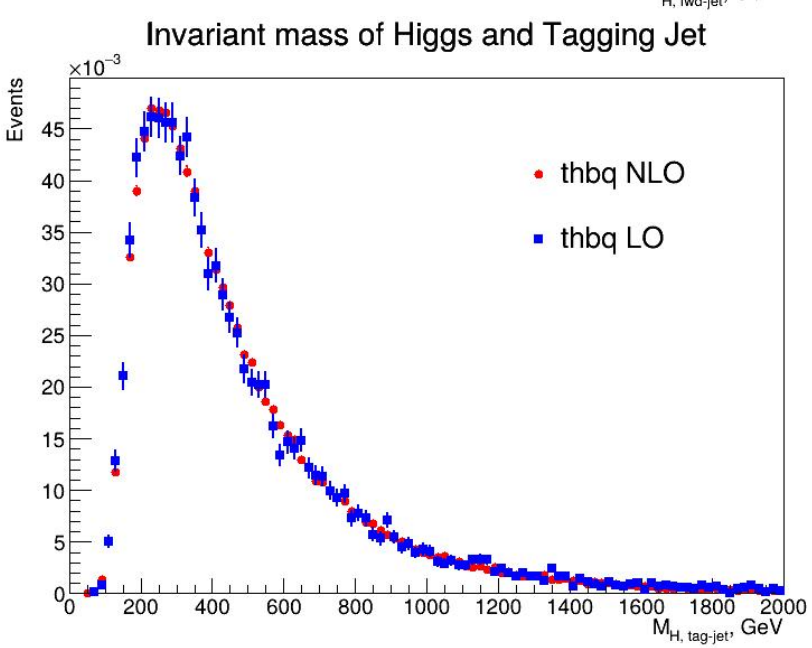
Invariant mass of Higgs and Forward (Tagging) Jet for the signal and background processes

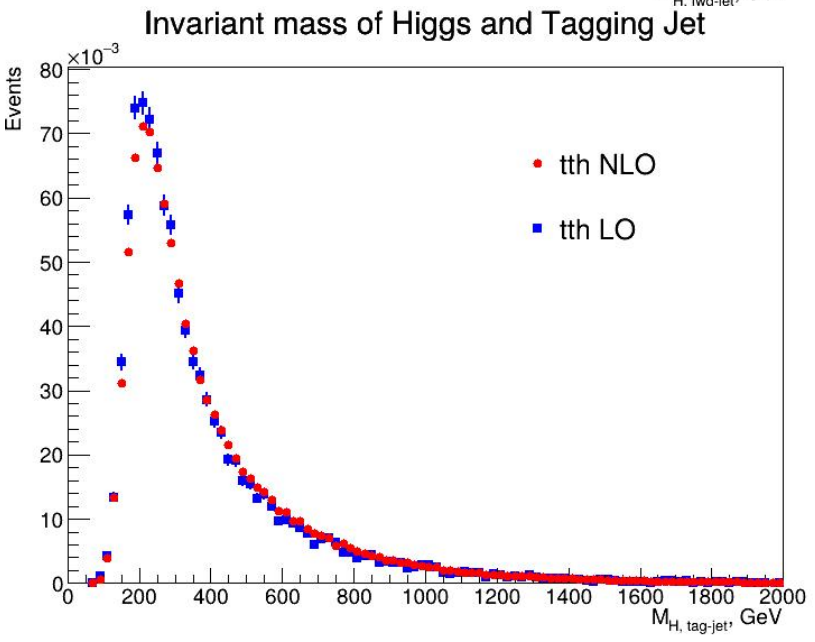




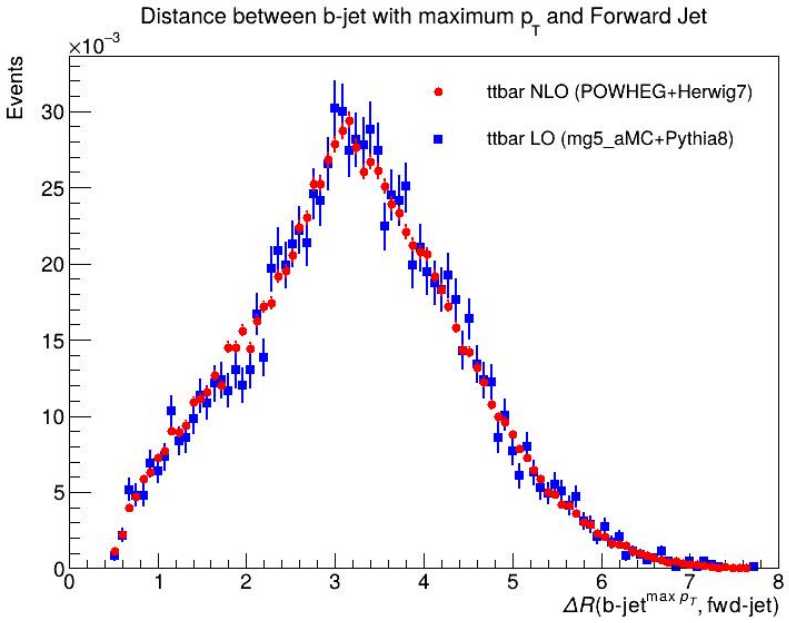


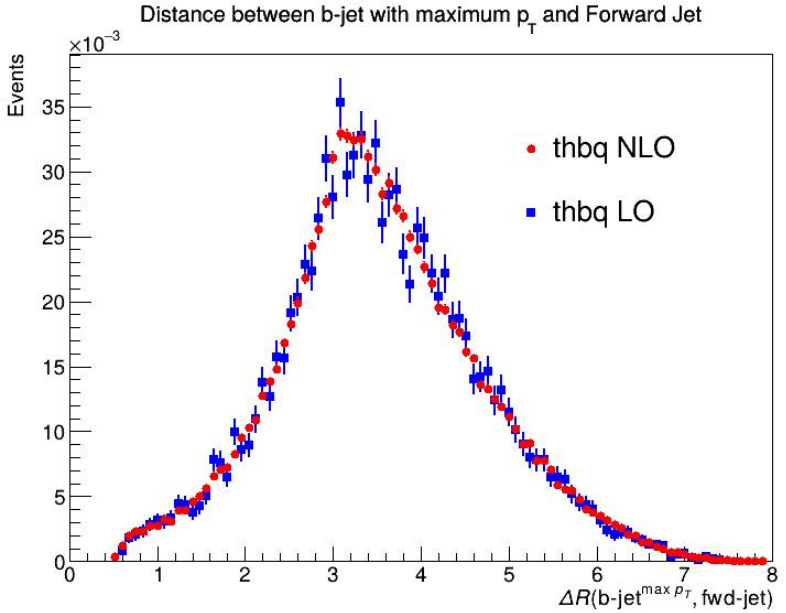


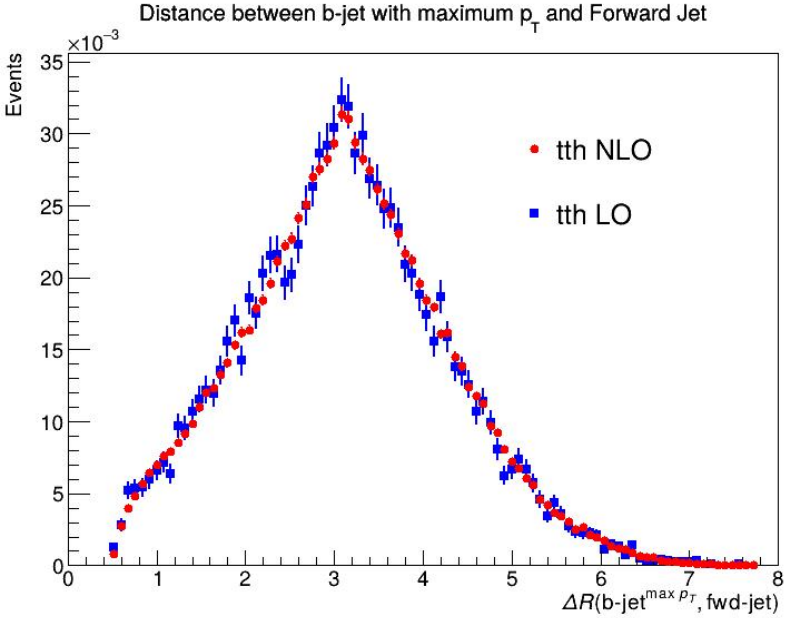


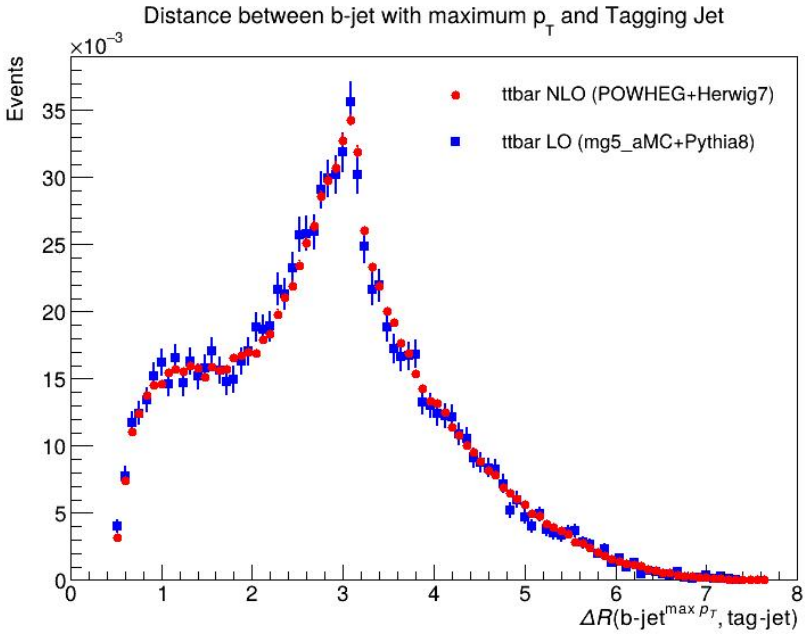


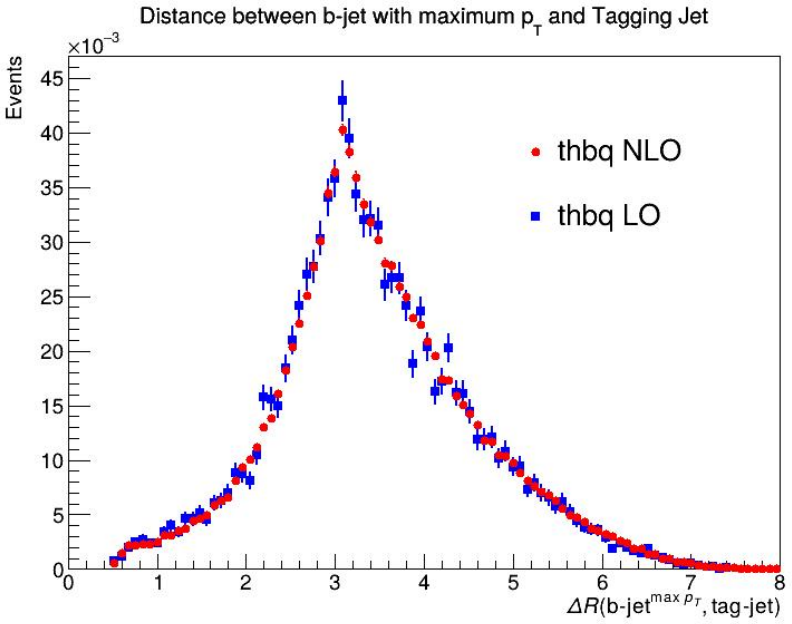
Distance between b-jet with maximum p_T and Forward (Tagging) Jet for the signal and background processes

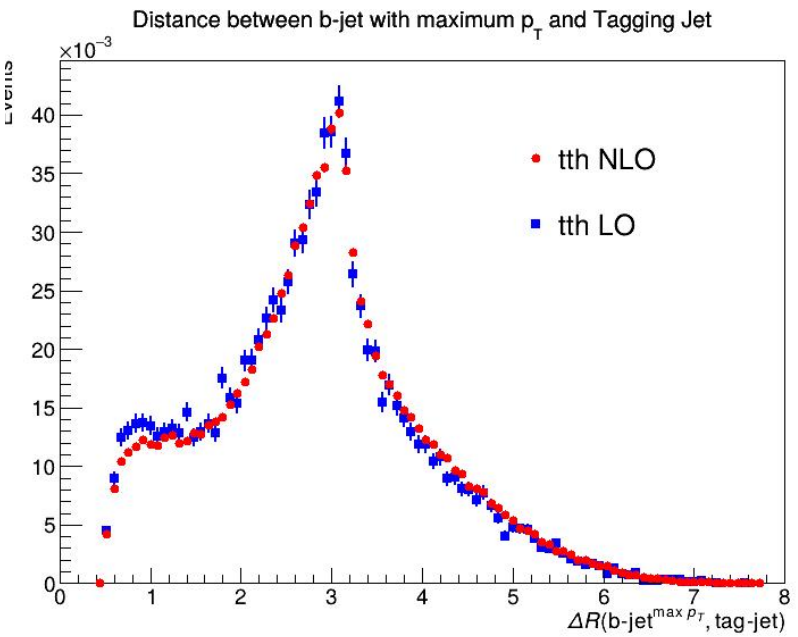




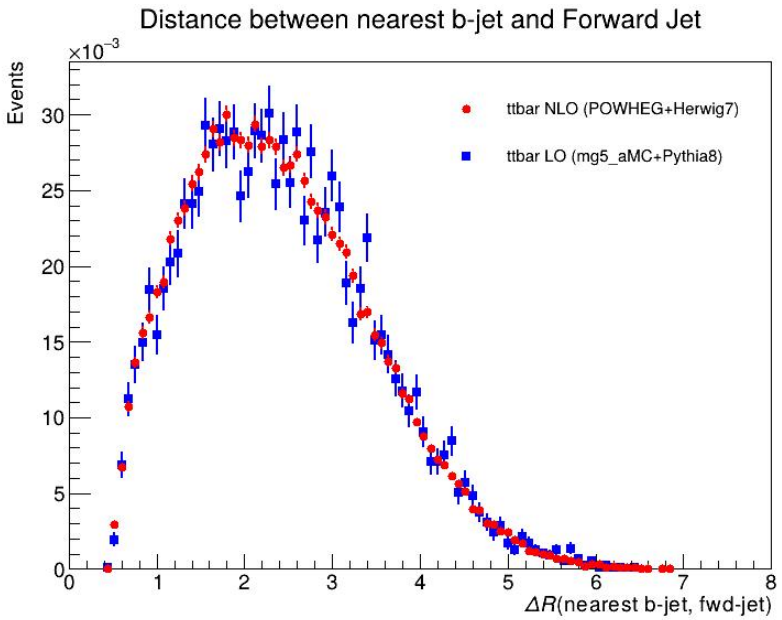


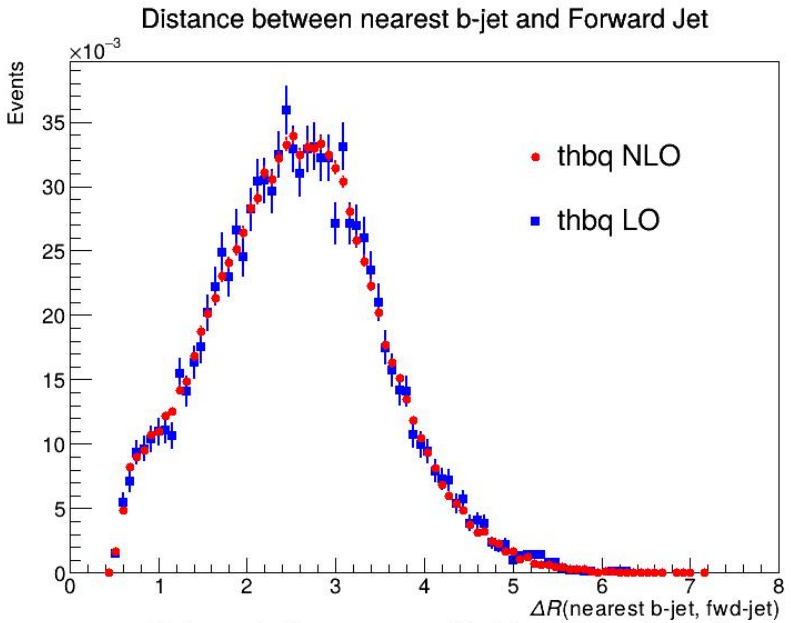


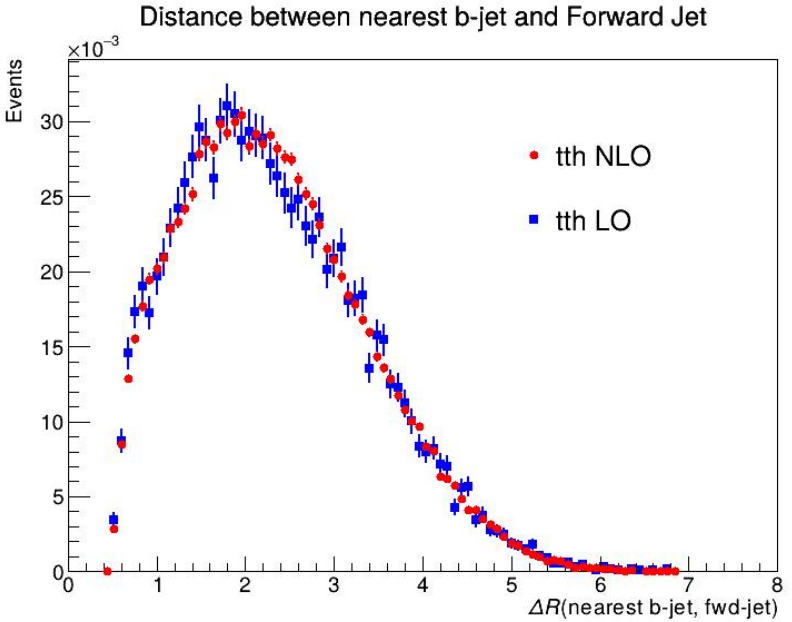


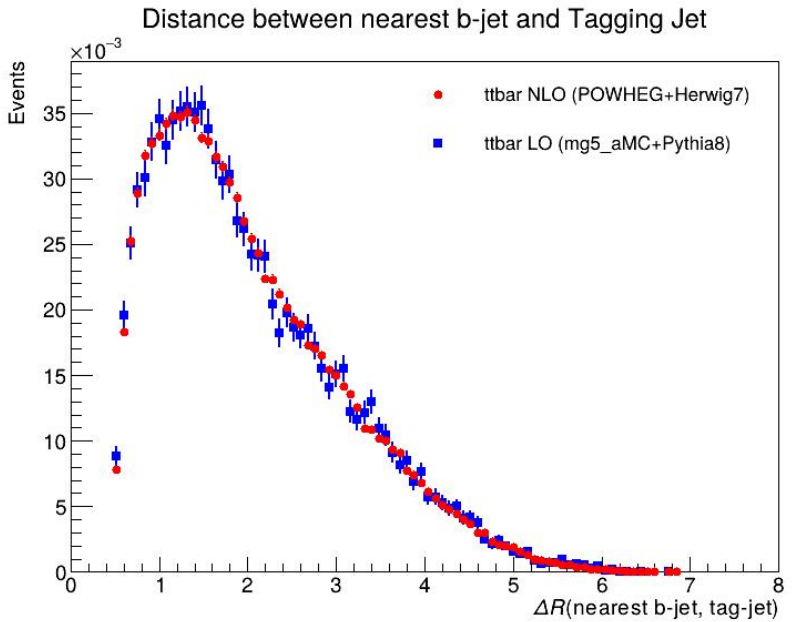


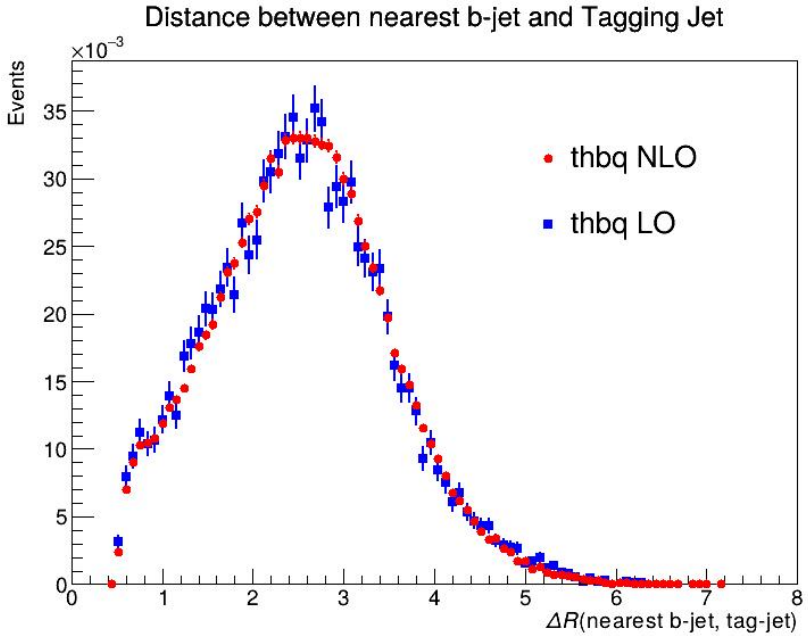
Distance between nearest b-jet and Forward (Tagging) Jet for the signal and background processes

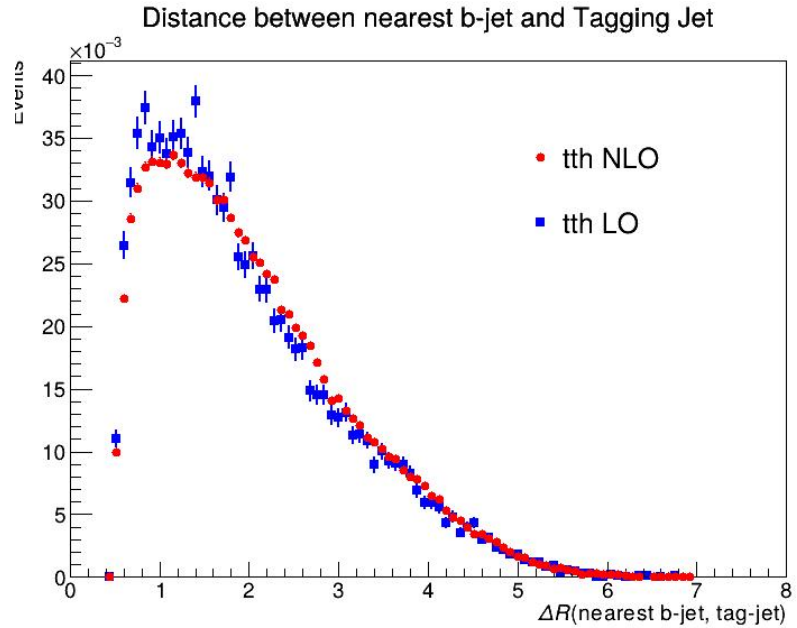




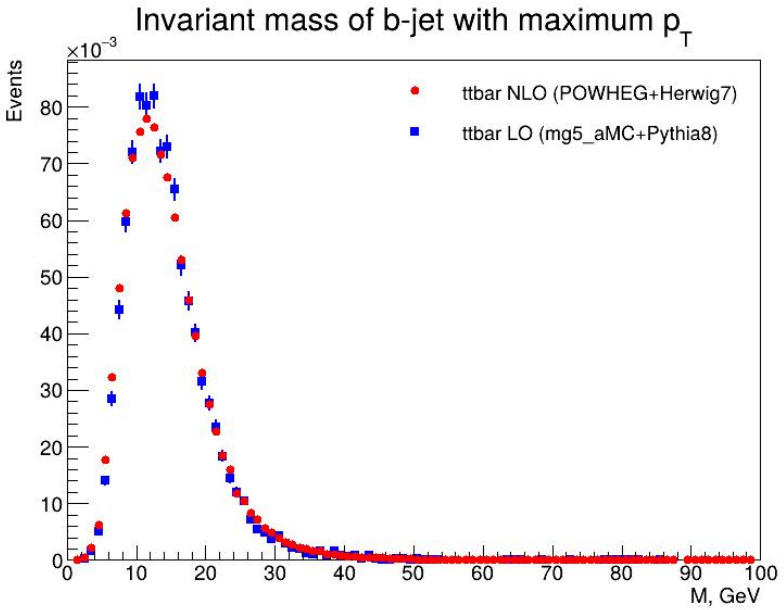


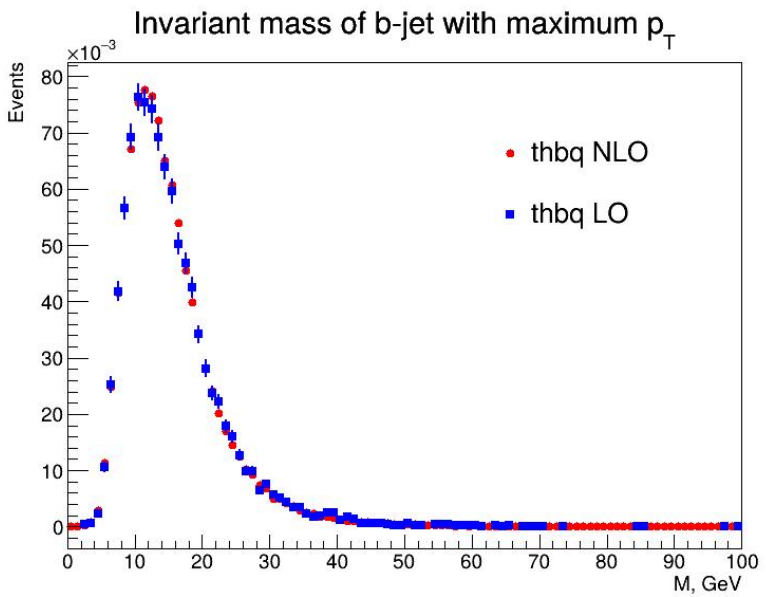


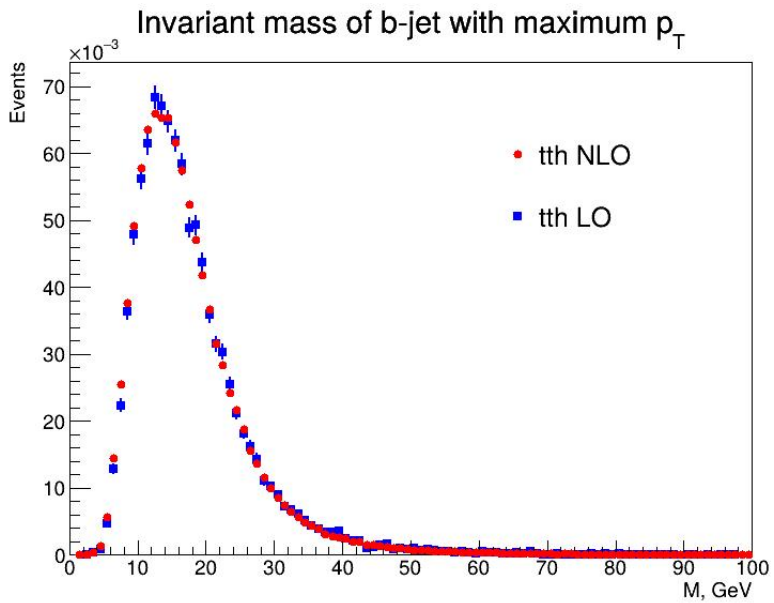


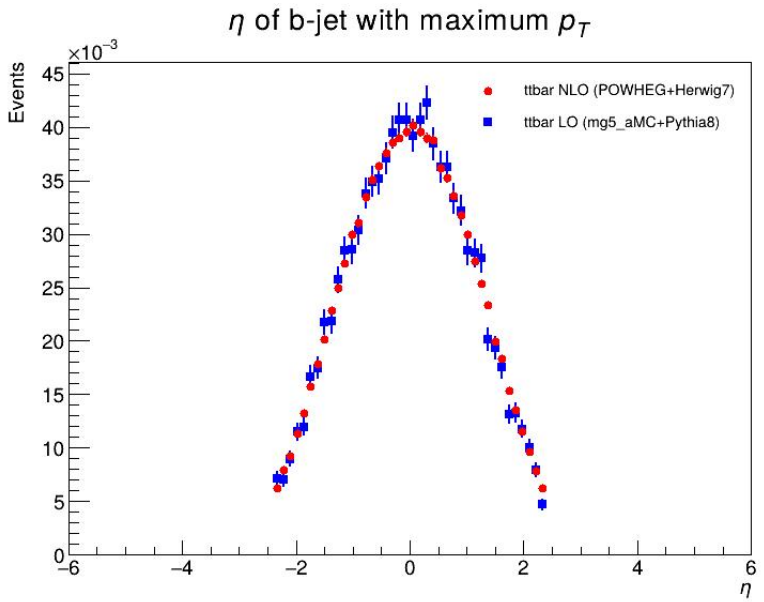


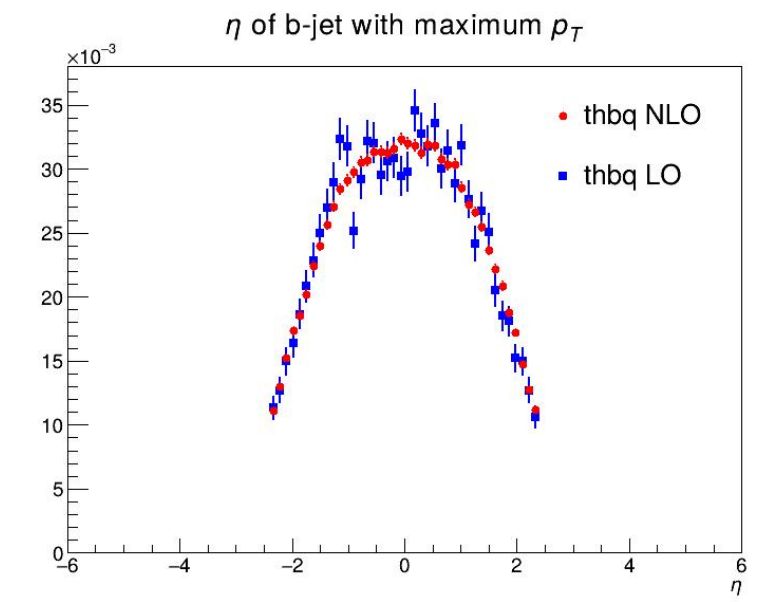
Characteristics b-jet with maximum p_T for the signal and background processes

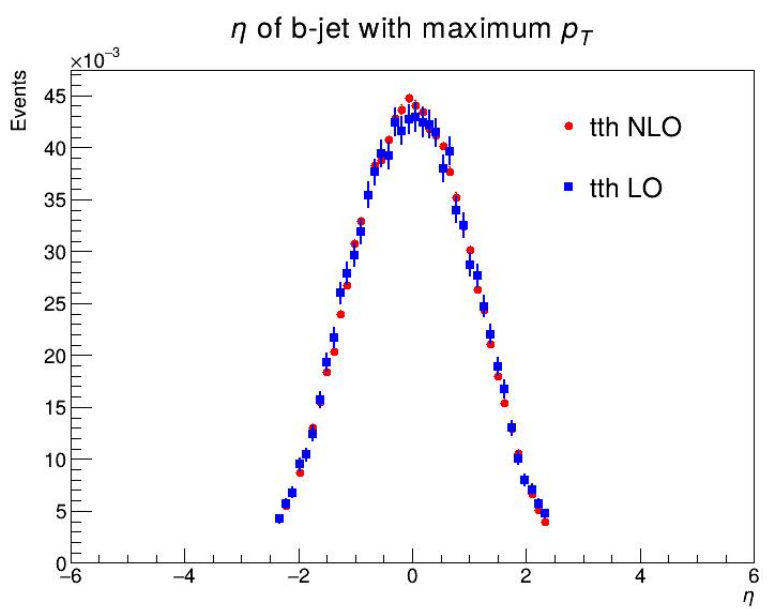




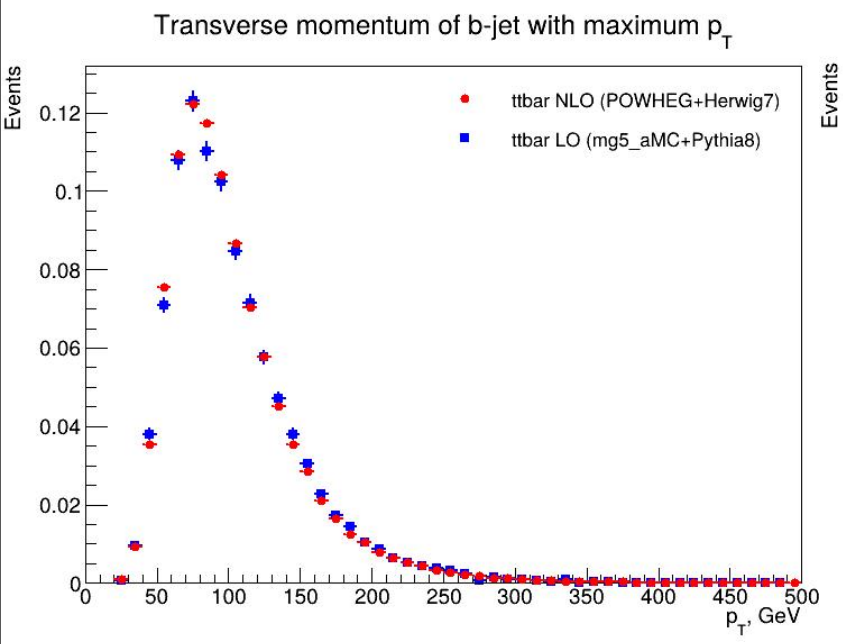


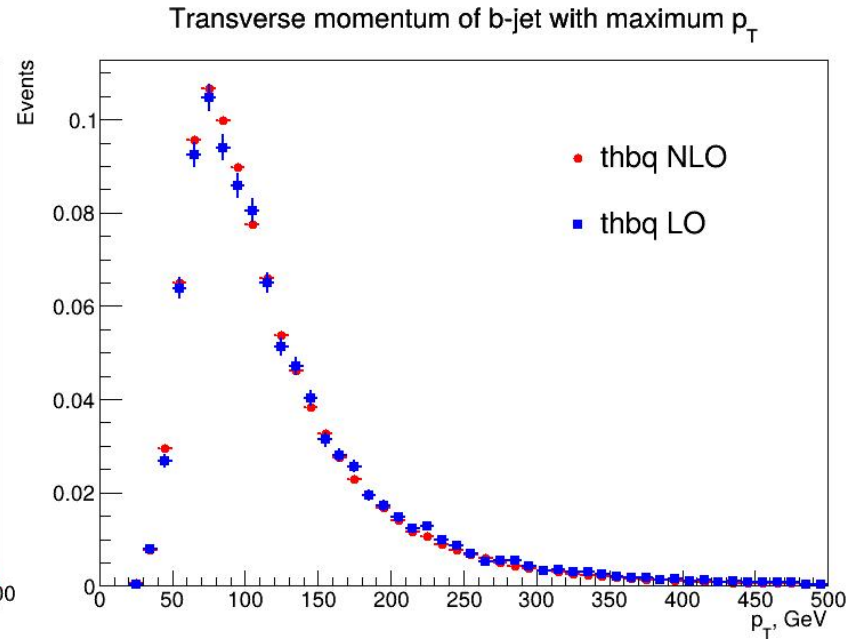


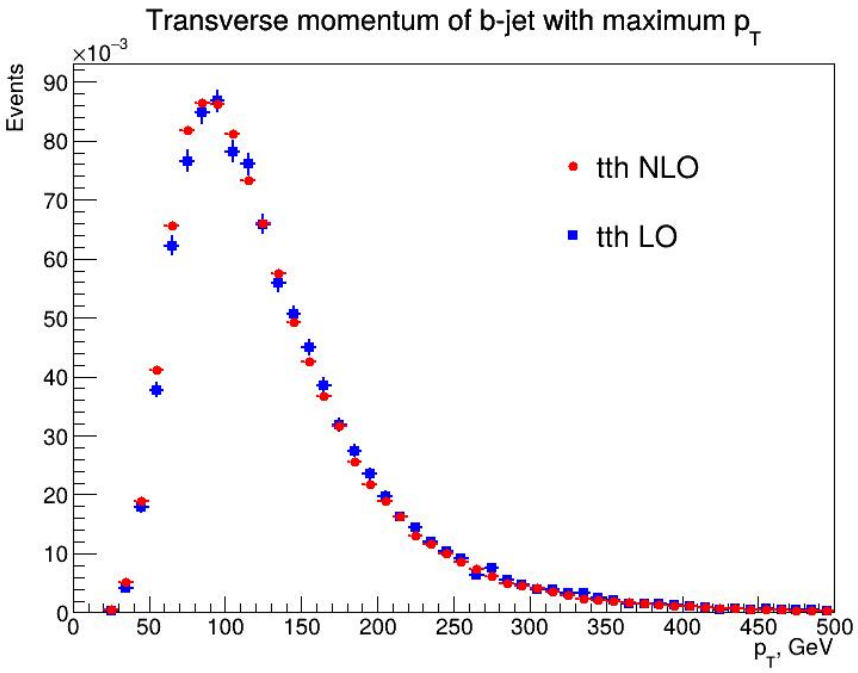




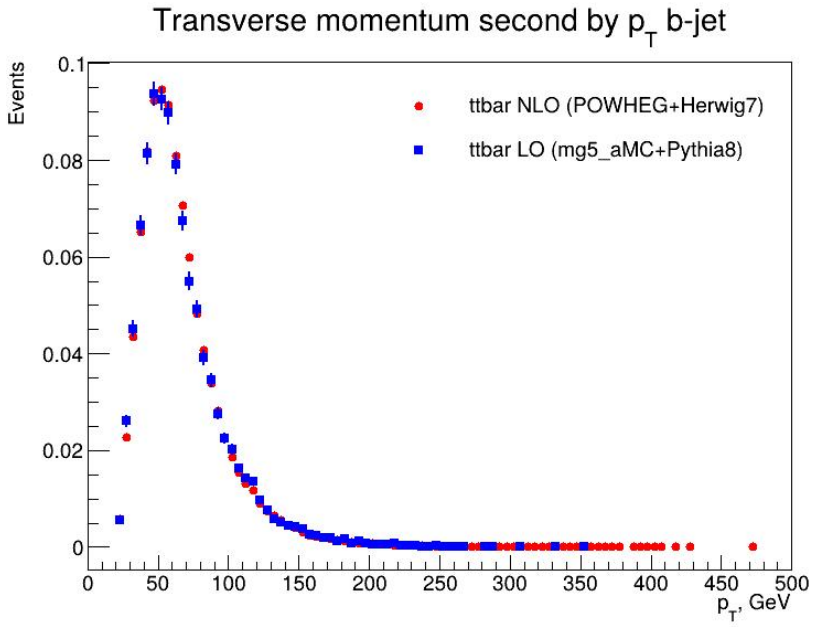
Characteristics b-jet with maximum p_T for the signal and background processes

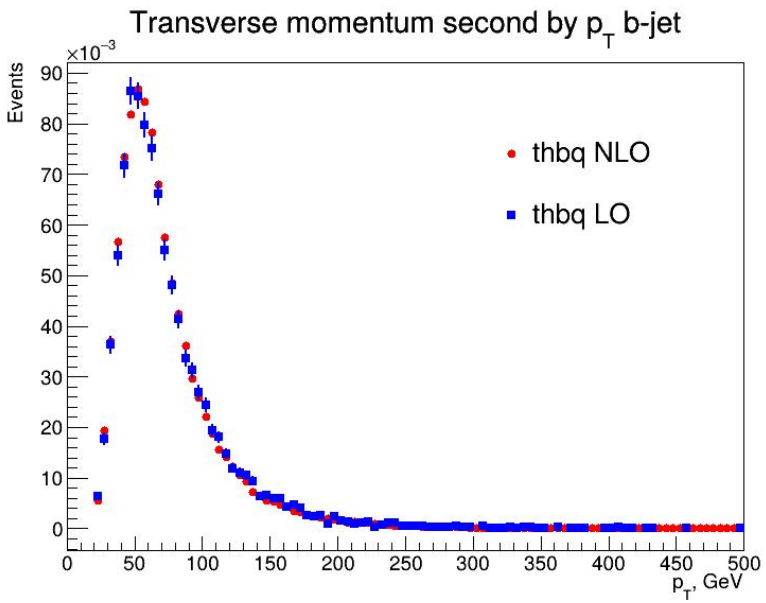


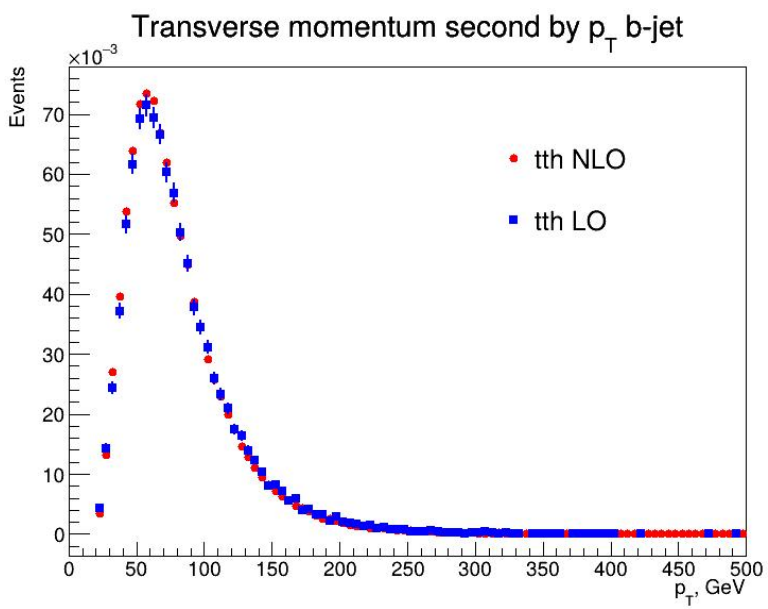


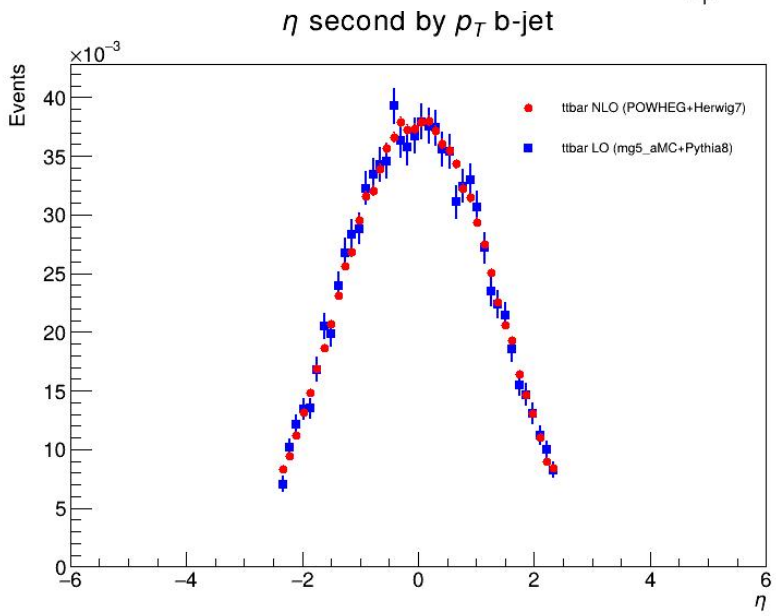


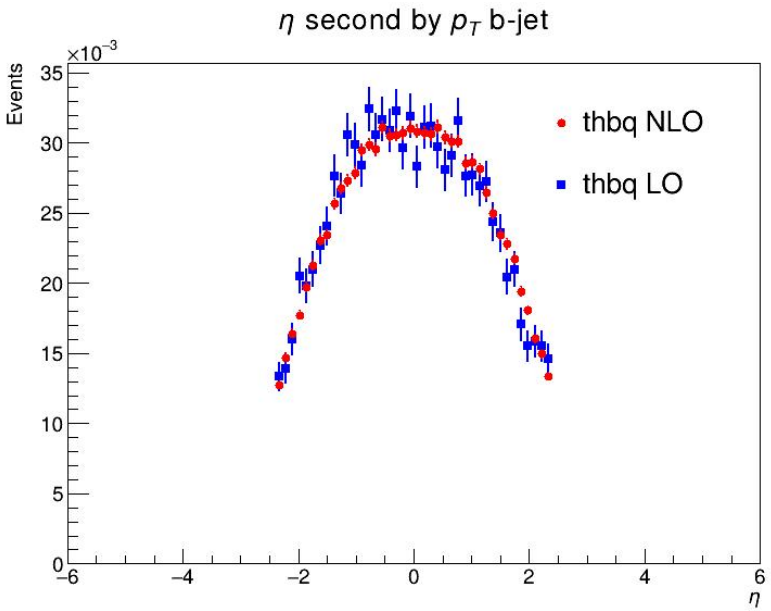
Characteristics other b-jets for the signal and background processes

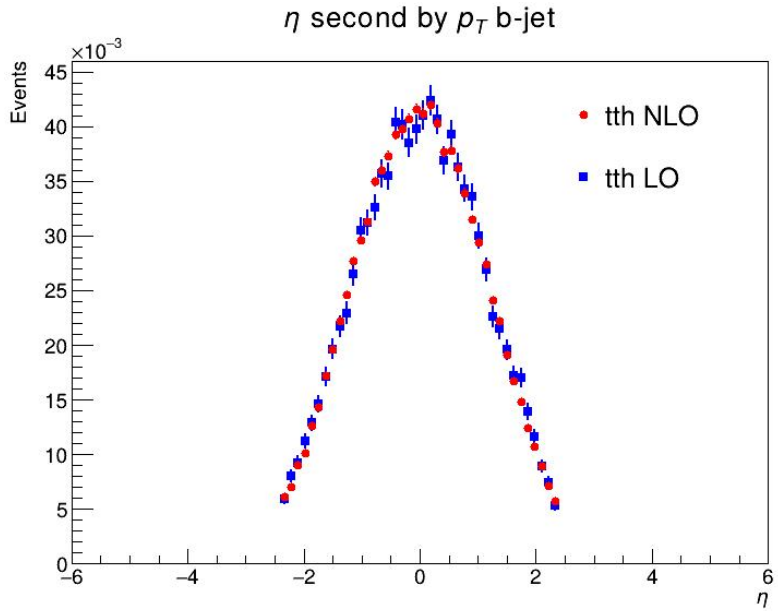




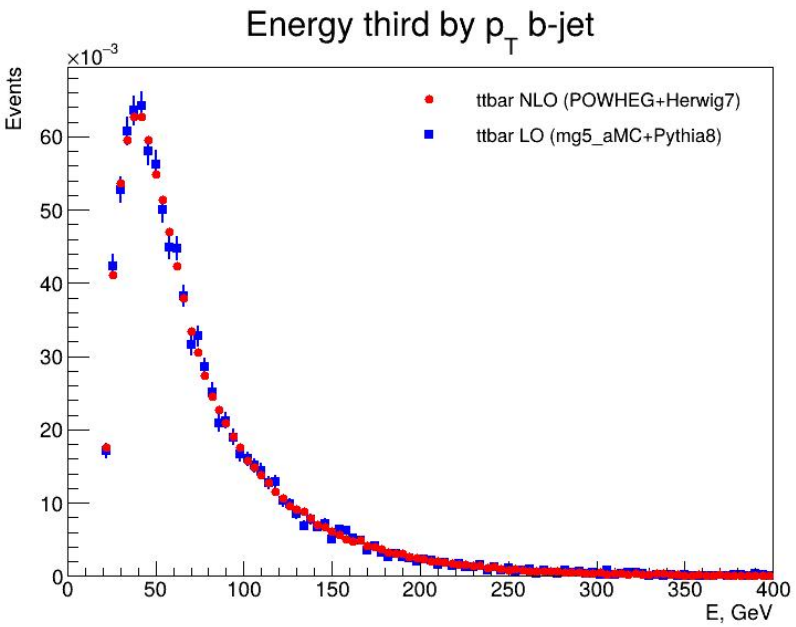


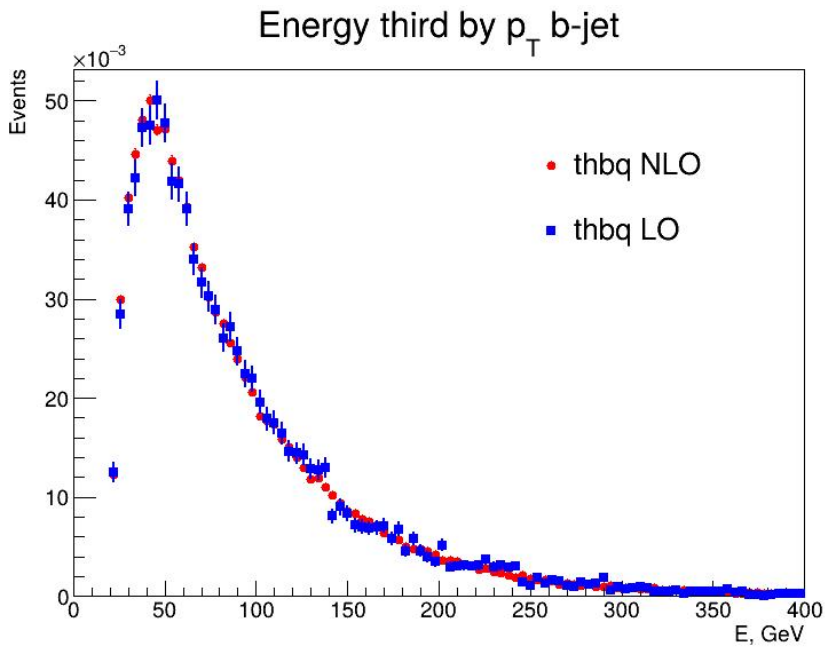


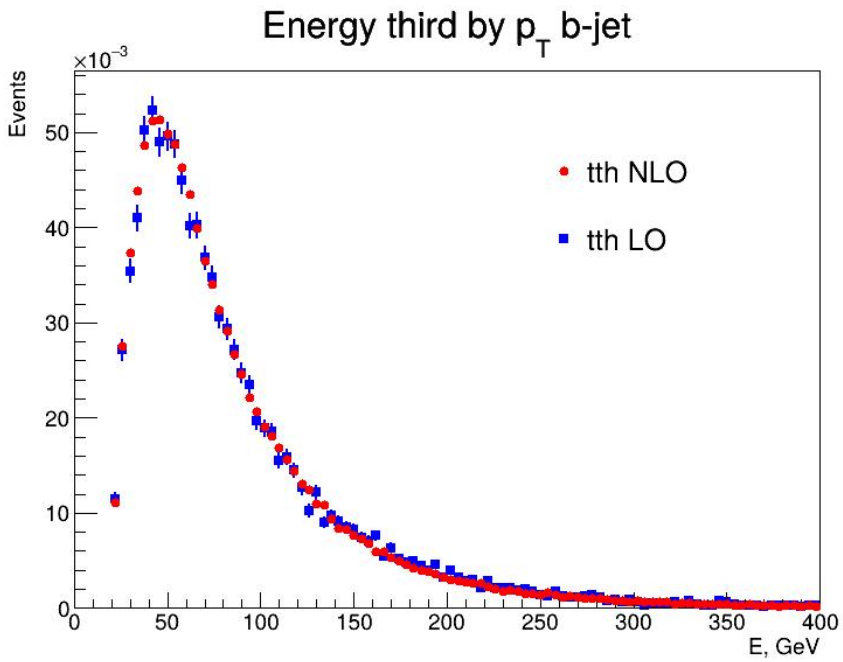




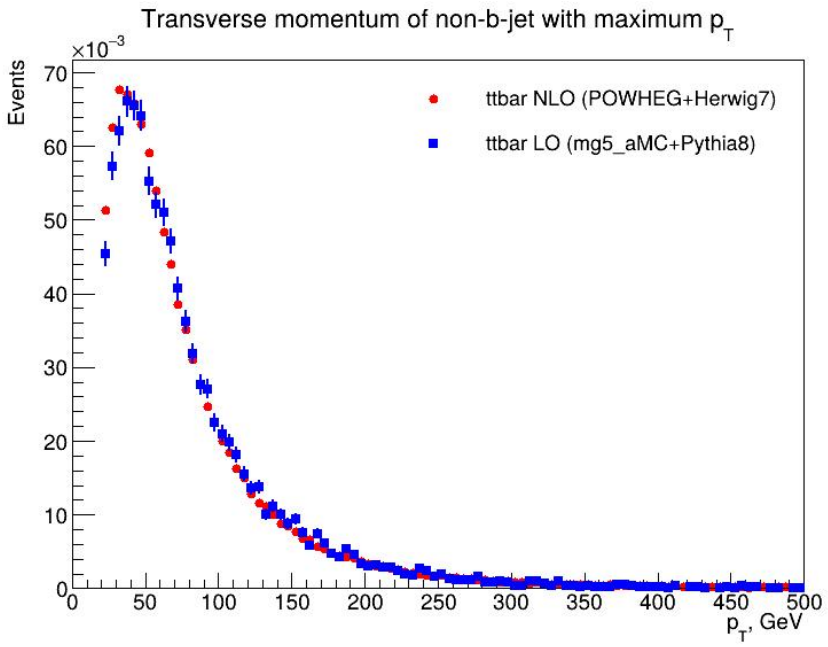
Characteristics other b-jets for the signal and background processes

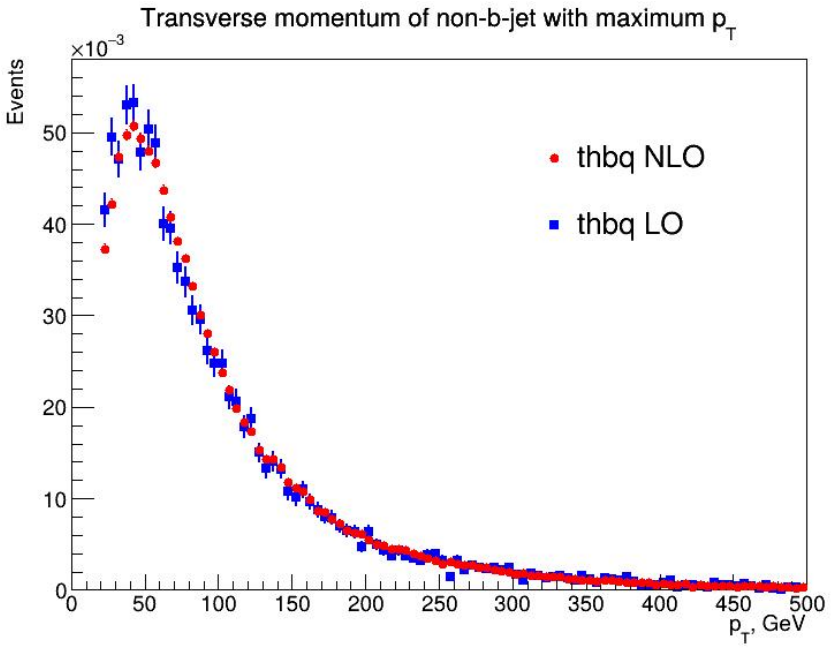


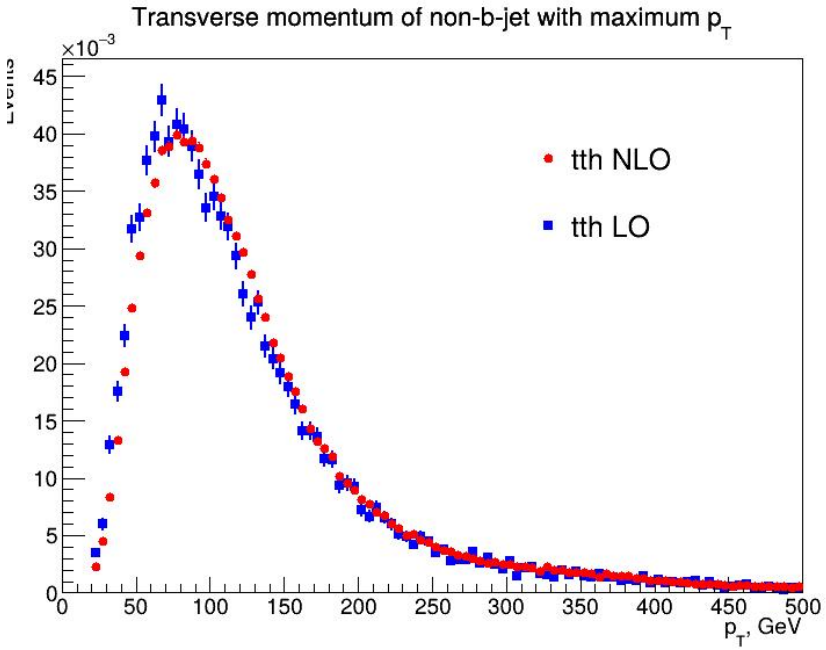




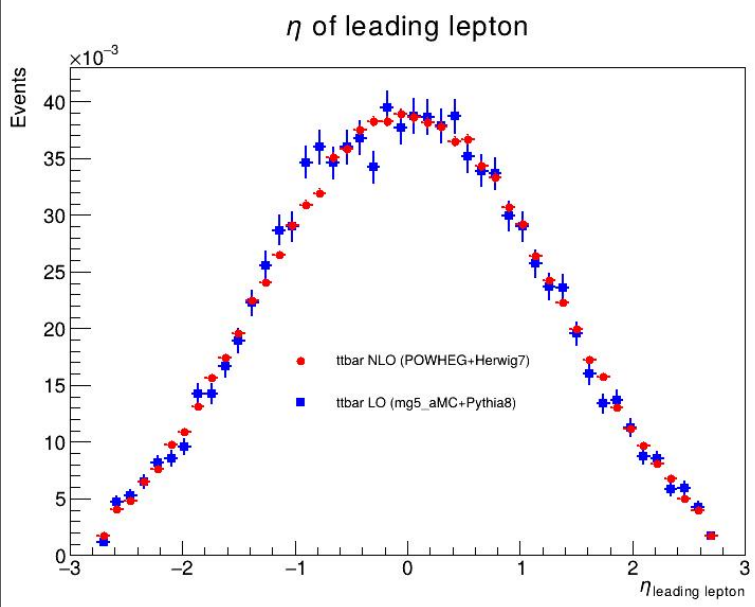
Transverse momentum non-b-jet with maximum p_T for the signal and background processes

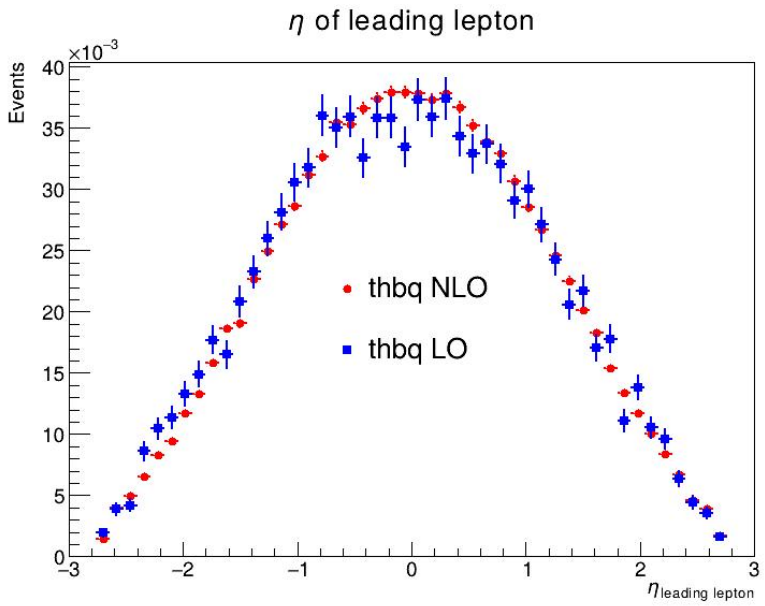


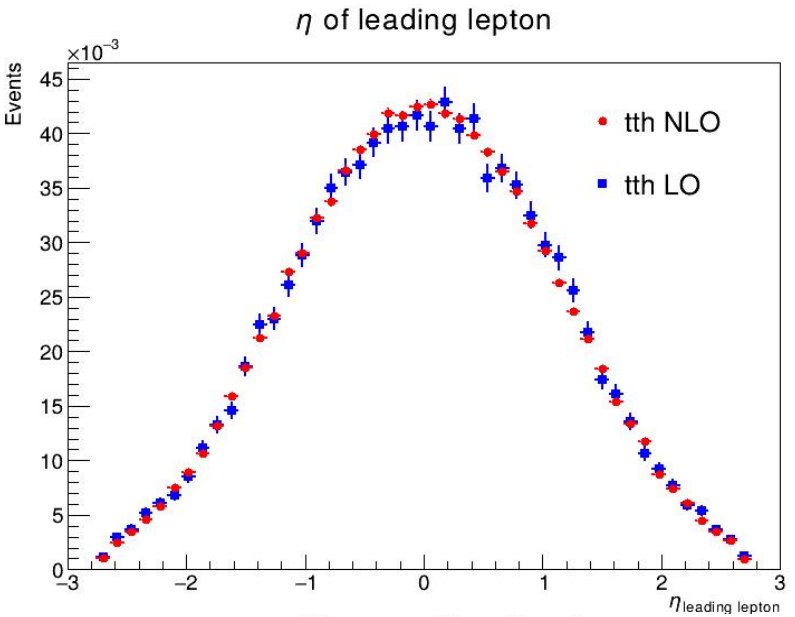


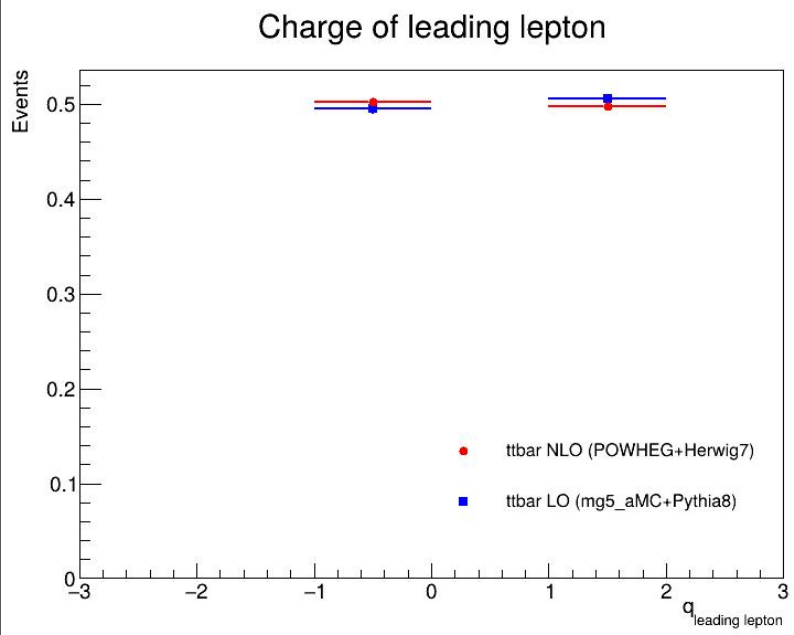


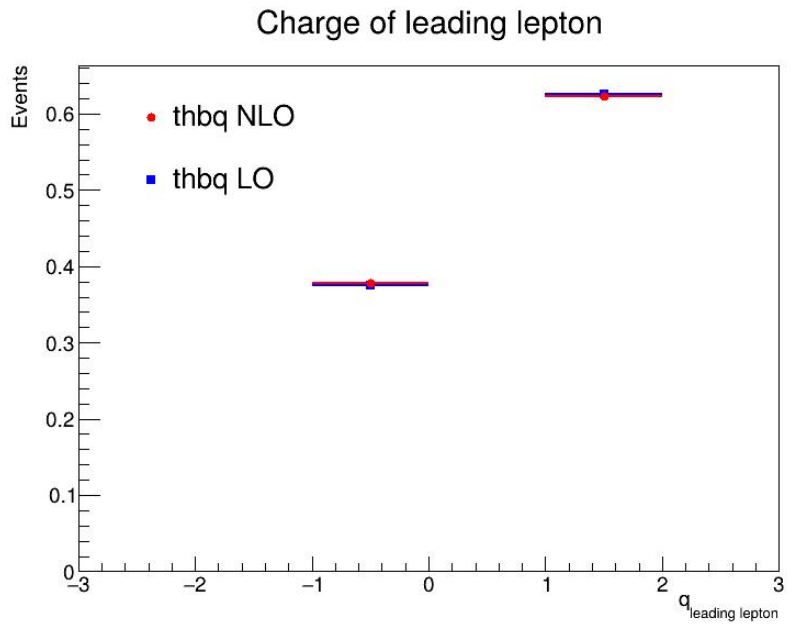
Leading leton

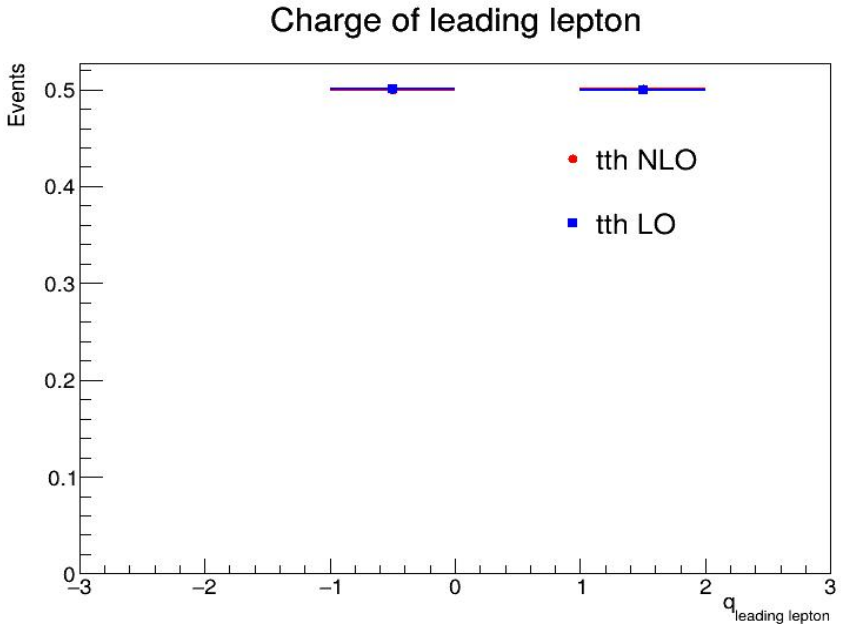












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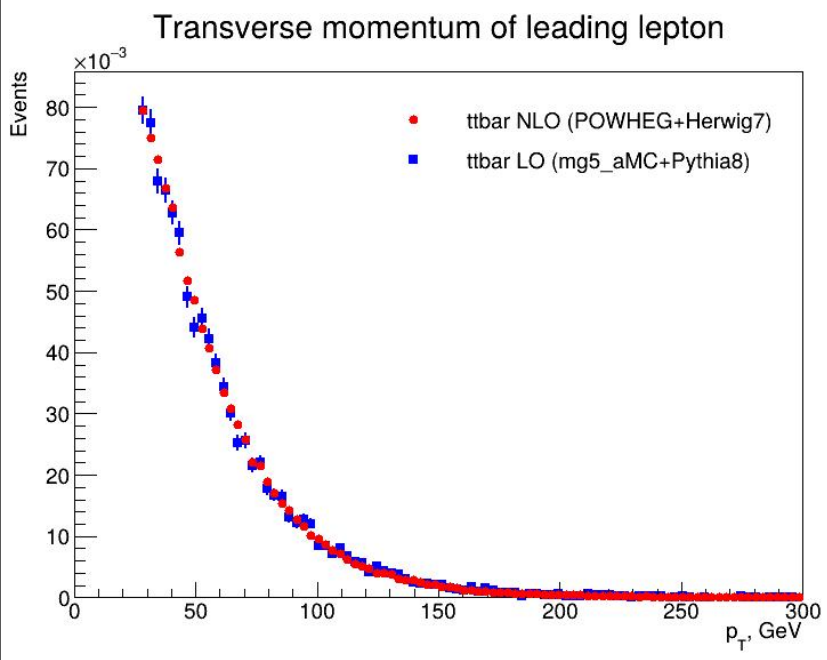
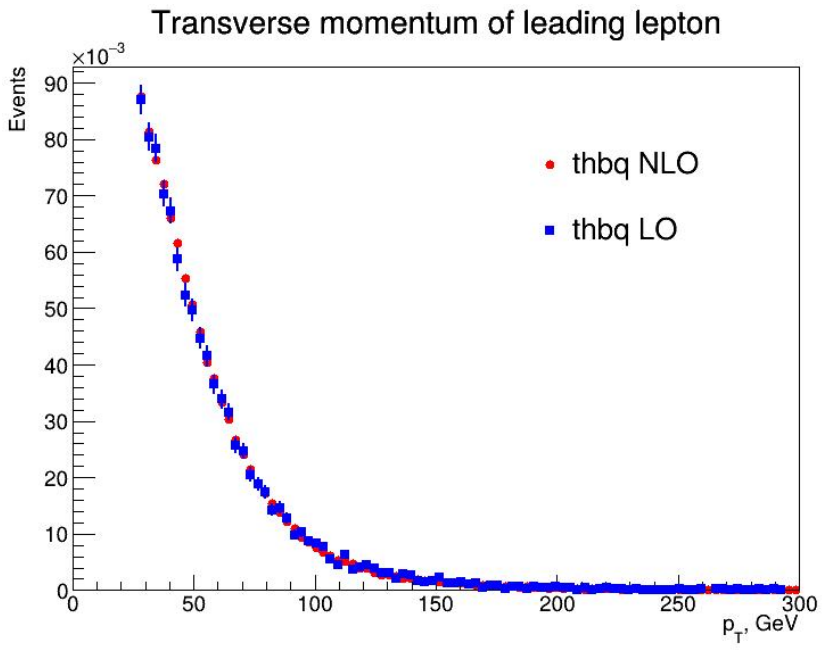
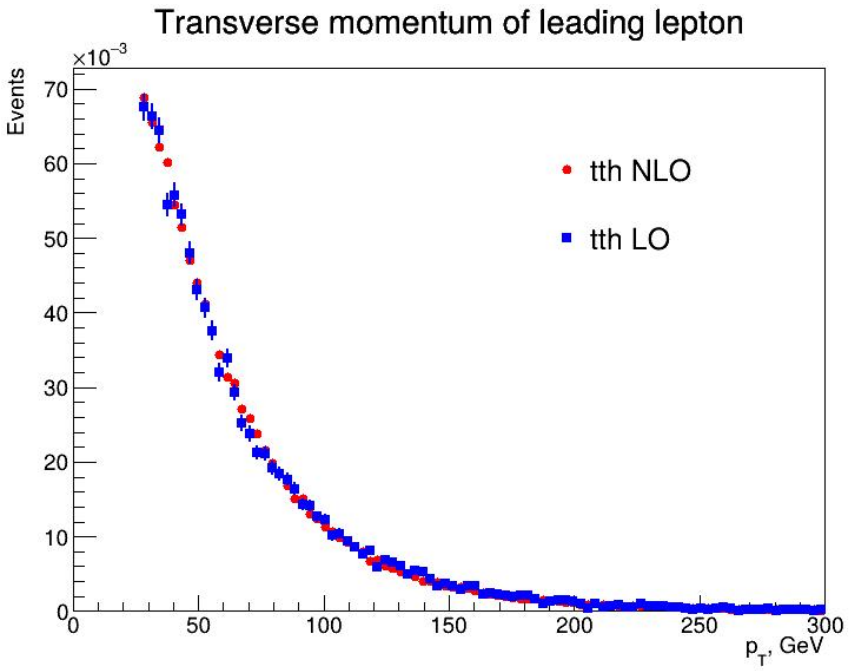
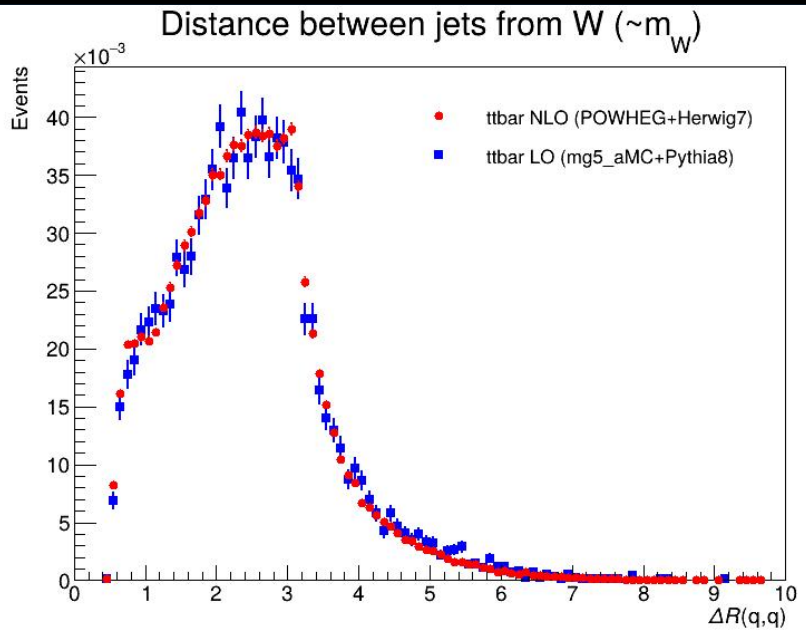
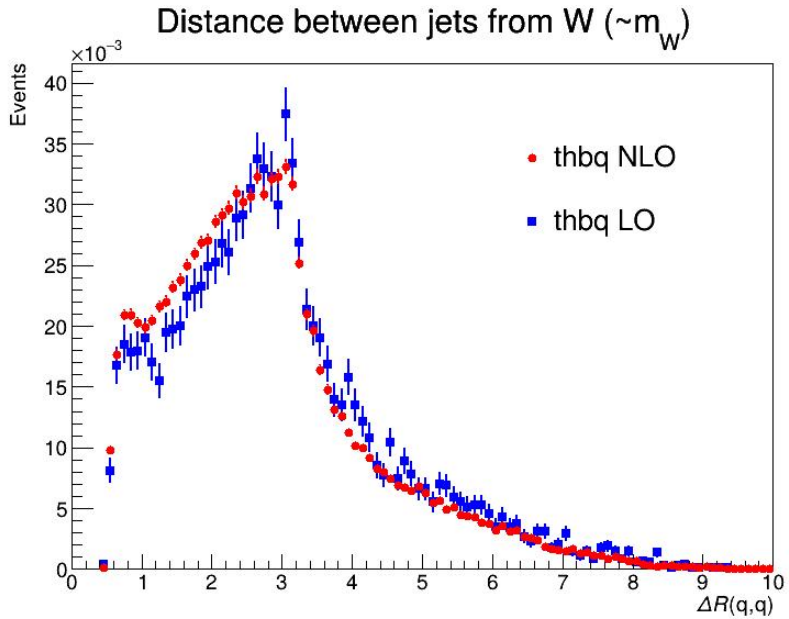


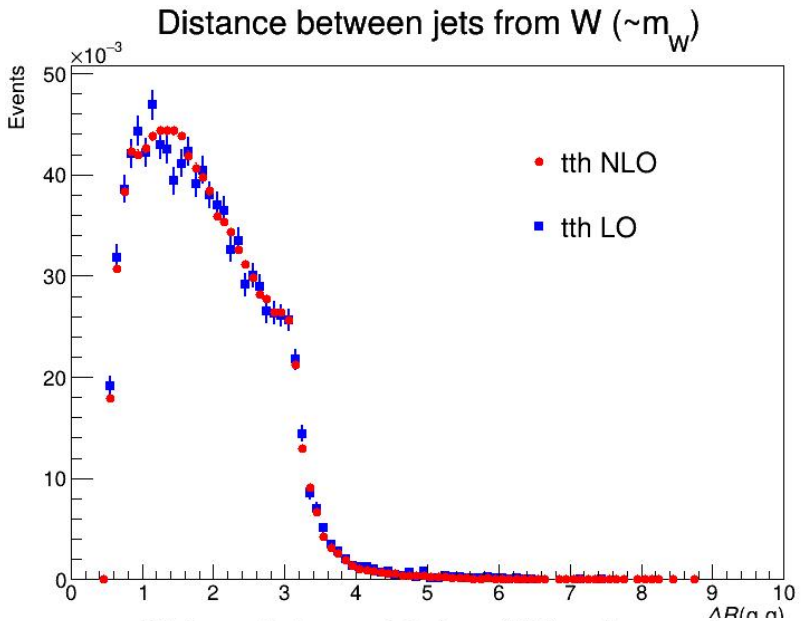


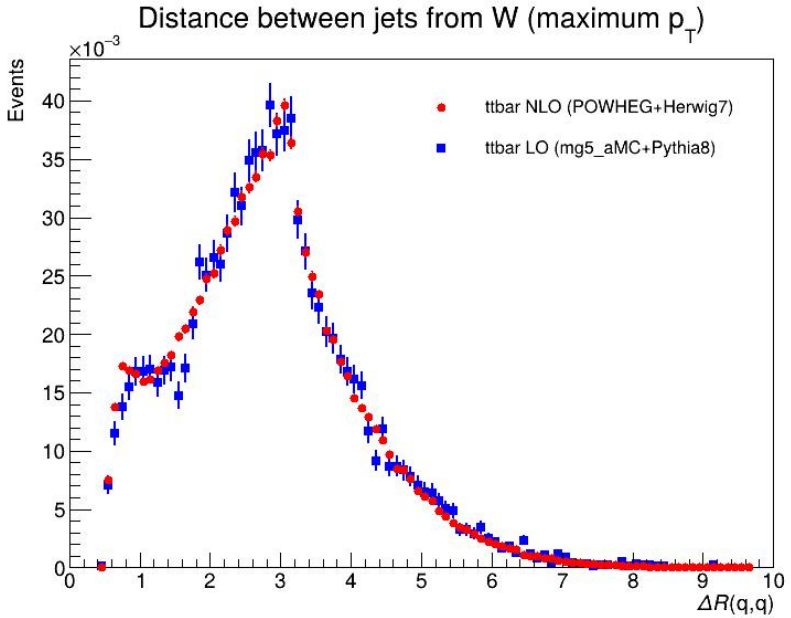


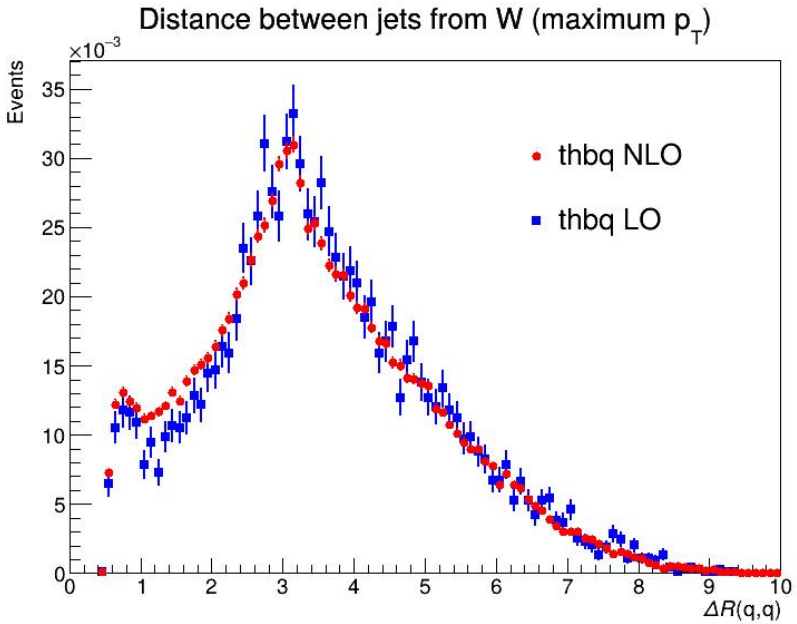
Distance between jets from W-bozon for the signal and background processes

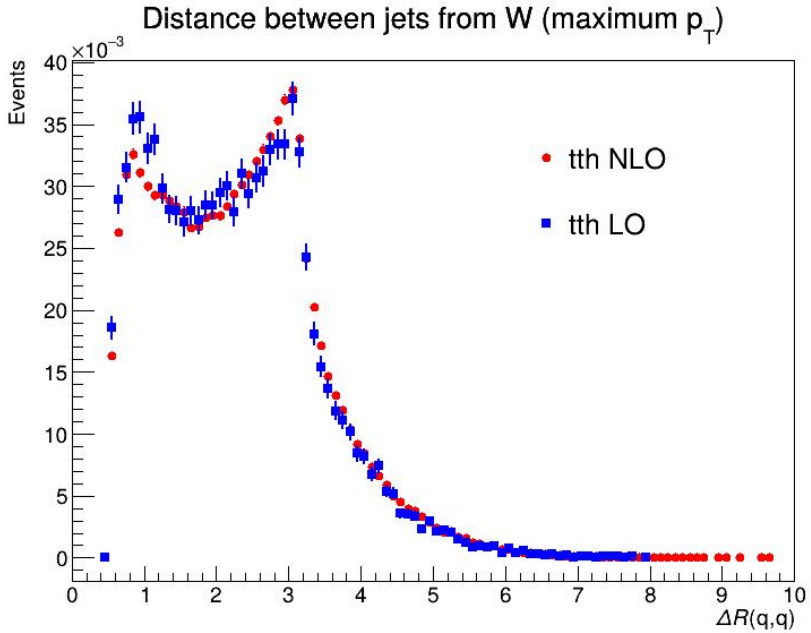




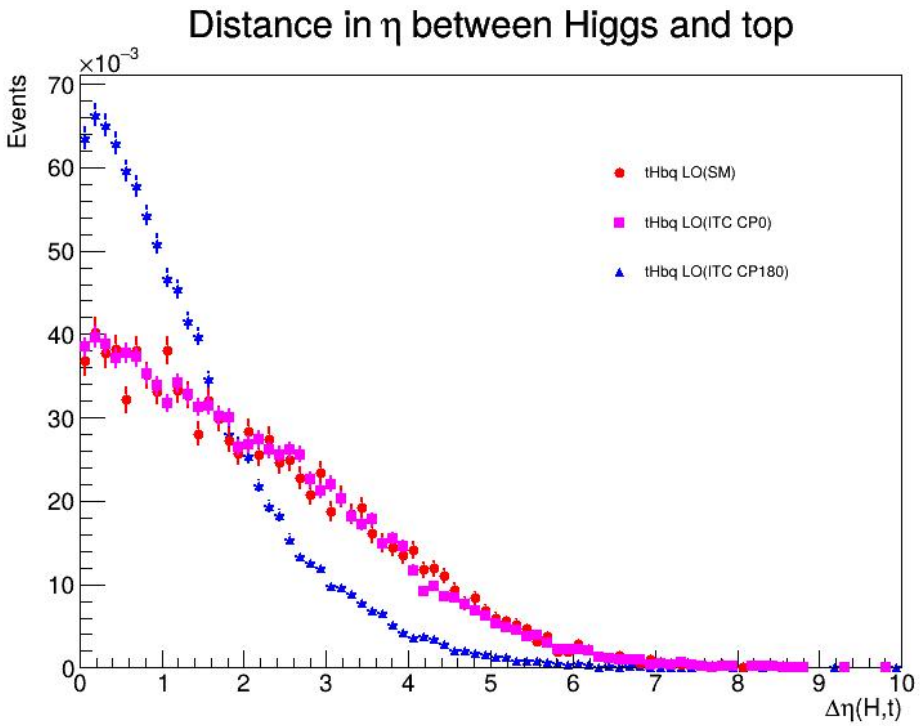


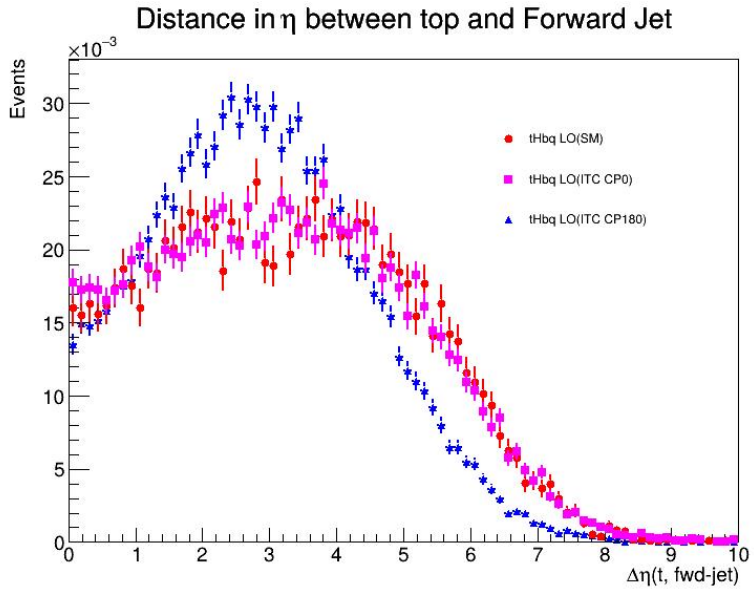


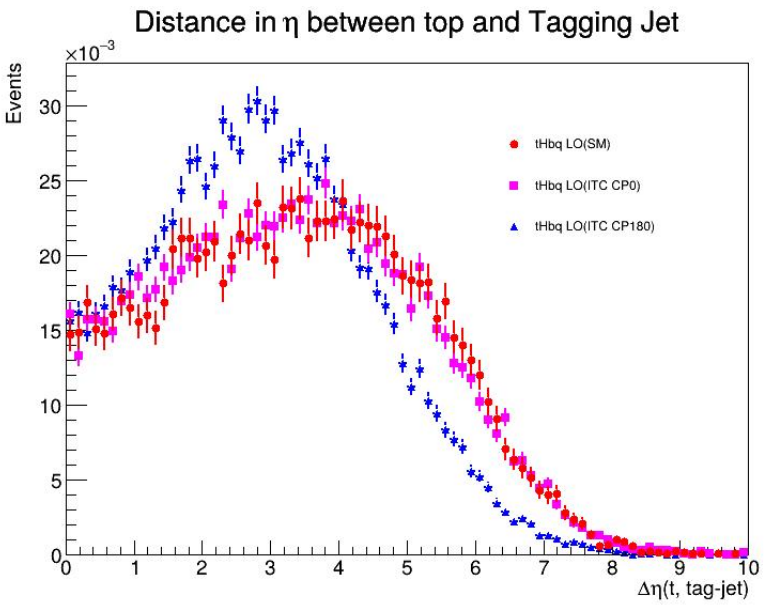


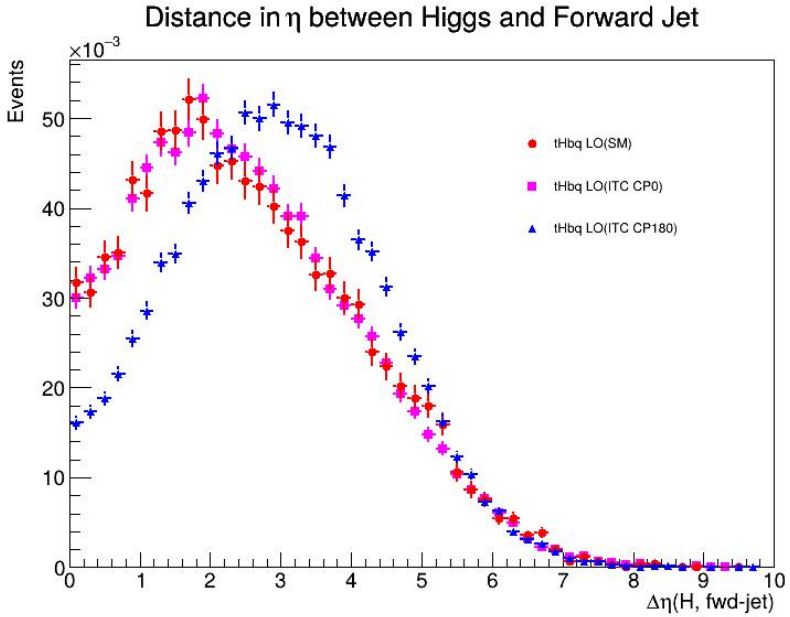


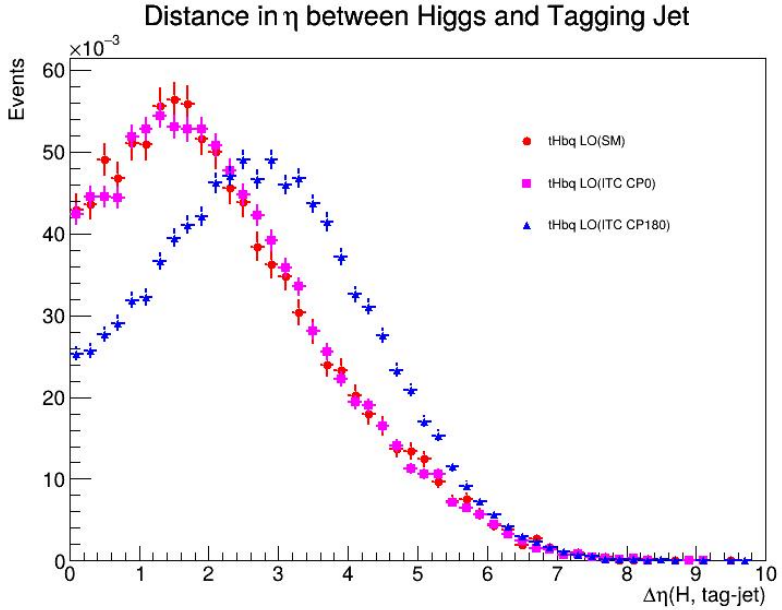
Inverted Top Coupling (ITC)











https://arxiv.org/pdf/1306.6464

A set of variables most sensitive to the selection of signalling process events

Название	Определение
M_{3J}	Инвариантная масса трех струй с наибольшим p_T
N_b	Количество струй, порожденных b-кварками
$Sphresity_{all\ jets}$	Мера равномерности распределения струй в пространстве
$Sphresity_{lnu}$	Мера равномерности распределения объектов в пространстве
$Aplanarity_{all\ jets}$	Мера отклонения струй от одной общей плоскости
$\Delta(\eta_{t,FWD})$	Разность псевдобыстрот топ-кварка и передней струи
$Aplanarity_{lnu}$	Мера отклонения объектов от одной общей плоскости
$\Delta(\eta_{t,H})$	Развность псевдобыстрот топ-кварка и бозона Хиггса
$M_{t,H}$	Восстановленная масса топ-кварка и бозона Хиггса
M_H	Восстановленная масса бозона Хиггса
fwmlnujet1	Первый момент Фокса-Вольфрама, составленный из импульсов объектов
P_t^{FWD}	Поперечный импульс передней стру
$M_{H,FWD}$	Инвариантная масса бозона Хиггса и передней струи
$M_{H,cen.jet}$	Инвариантная масса бозона Хиггса и центральной легкой струи
η^{FWD}	Псевдобыстрота передней струи
χ^{min}	Качество (критерий χ^2) определения масс бозона Хиггса и топ-кварка
M_t	Восстановленная масса топ-кварка

Q_{lep}	Заряд лептона с наибольшим p_T
$\Delta(R_{qqW})$	Угол между струями от адронного распада W-бозона
N_{nonb}	Количество струй, порожденных кварками, отличных от b-кварка
fwm2	Второй момент Фокса-Вольфрама, составленный из импульсов струй
RapGap_maxptb	Разность псевдобыстрот передней стру и b-струи с наибольшим p_T
RapGap_closetb	Разность псевдобыстрот передней струи и ближайшей к ней b-струи
$P^t_{nonb\_max}$	Наибольший поперечный импульс среди легких струй
W_T_m	Поперечная масса всех струй
M_{FWD}	Инвариатная масса передней струи и топ-кварка
η_{lep}	Псевдобыстрота лептона с наибольшим p_T
E_{b2}	Энергия третьей по поперечному импульсу b-струи
$\Delta(\phi_{t,H})$	Разность азимутальных углов топ-кварка и бозона Хиггса
HT_alljets	Алгебраическая сумма поперечных импульсов всех струй
$\Delta(\eta_{H,FWD})$	Разнвость псевдобыстрот бозона Хиггса и передней струи
P^t_H	Восстановленный поперечный импульс бозона Хиггса
P^t_{b0}	Поперечный импульс b-струи с наибольшим p_T
P^t_{b1}	Поперечный импульс второй по p_T b-струи
η_H	Восстановленная псевдобыстрота бозона Хиггса
η_{b1}	Псевдобыстрота второй по p_T b-струи
M_{b0}	Инвариантная масса передней струи и b-струи с наибольшим p_T

Additional information

Processes	Pre-selection
tH	73.80 ± 0.15
tWH	49.62 ± 0.04
tt + ≥1b	60170 ± 50
tt + ≥1c	33585 ± 29
tt + light	106290 ± 90
ttH	1676.9 ± 1.4
ttZ	891.0 ± 0.8
ttW	362.01 ± 0.31
tZq	170.54 ± 0.25
tWZ	2.2157 ± 0.0019
Wt channel	5849± 5
t channel	3223 ± 4
s channel	259.71 ± 0.22
W + jets	4072 ± 4
Z + jets	609.5 ± 0.6
VV	291.79 ± 0.26
other Higgs	25.054 ± 0.023
Rare top	8.936 ± 0.008
Fakes	8028 ± 7
Total	225640 ± 190
Data	244167

Process	Generator	Order (scheme)	PDF set	Partor shower	PDF set (tune)
		Signal			
tHq	MadGraph5_aMC@NLO 2.6.2	NLO (4FS)	NNPDF3.0nlo nf4	Pythia 8.230	NNPDF2.3lo (A14 tune)
		Backgrounds			
$t\bar{t}$	Powheg Box v2	NLO (5FS)	NNPDF3.0nlo	Pythia 8.230	NNPDF2.3lo (A14 tune)
V+jets	Sherpa 2.2.1	NLO+LO	NNPDF3.0nnlo	-	-
Diboson	Sherpa 2.2.1-2	NLO+LO	NNPDF3.0nnlo	-	-
Triboson	Sherpa 2.2.2	NLO+LO	NNPDF3.0nnlo	-	-
$t\bar{t}Z$	MadGraph5_aMC@NLO 2.3.3	NLO	NNPDF3.0nlo	Pythia 8.210	NNPDF2.3lo (A14 tune)
$t\bar{t}W$	Sherpa 2.2.10	NLO	NNPDF3.0nnlo	-	-
$t\bar{t}H$	Powheg Box v2	NLO (5FS)	NNPDF3.0nlo	Pythia 8.230	NNPDF2.3lo (A14 tune)
t-channel	Powheg Box v2	NLO (4FS)	NNPDF3.0nlo nf4	Pythia 8.230	NNPDF2.3lo (A14 tune)
tW	Powheg Box v2	NLO (5FS, DR)	NNPDF3.0nlo	Pythia 8.230	NNPDF2.3lo (A14 tune)
s-channel	Powheg Box v2	NLO	NNPDF3.0nlo	Pythia 8.230	NNPDF2.3lo (A14 tune)
tZq	MadGraph5_aMC@NLO 2.3.3	NLO	NNPDF3.0nlo	Pythia 8.230	NNPDF2.3lo (A14 tune)
tWH	MadGraph5_aMC@NLO 2.8.1	NLO (5FS, DR)	NNPDF3.0nlo	Pythia 8.245p3	NNPDF2.3lo (A14 tune)
tWZ	MadGraph5_aMC@NLO 2.3.3	NLO	NNPDF3.0nlo	Pythia 8.212	NNPDF2.3lo (A14 tune)
ttt	MadGraph5_aMC@NLO 2.2.2	NLO	NNPDF3.1nlo	Pythia 8.186	NNPDF2.3lo (A14 tune)
$t\bar{t}t\bar{t}$	MadGraph5_aMC@NLO 2.3.3	NLO	NNPDF3.1nlo	Pythia 8.230	NNPDF2.3lo (A14 tune)
ggH	Powheg Box v2	NLO	CT10	Pythia 8.210	CTEQ6L1 (AZNLO tune)
qqH	Powheg Box v1	NLO	CT10	Pythia 8.186	CTEQ6L1 (AZNLO tune)
WH	Pythia 8.186	LO	NNPDF2.3lo	-	-
ZH	Pythia 8.186	LO	NNPDF2.3lo	-	-