Измерение спектров анти-$\bar{\Sigma}^{\pm}$-гиперонов с помощью электромагнитного калориметра PHOS эксперимента ALICE

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Статус работы

Изменения с предыдущего доклада:

- Увеличение статистики в 2 раза в данных и MC – переход от wSDD к woSDD+FAST
- Добавлено новое MC для pp 5 TeV (LHC18j2). Статистика возросла с 25% до 100%
- Пересчитаны спектры, добавлено сравнение с различными MC моделями. Для оценки фона, помимо pol1, была добавлена exp
- Посчитаны систематические погрешности
- Посчитано отношение $\bar{\Sigma}^{+}/\bar{\Sigma}^{-}$
- Пересчитан RpPb

Event selection

$\Sigma^+ = \mathrm{uus}$

$m = 1189.37 \pm 0.07\ \mathrm{MeV}/c^2$

$\Sigma^+ \to p\pi^0 (51.57 \pm 0.30)\ \%$

$\Sigma^+ \to n\pi^+ (48.31 \pm 0.30)\ \%$

$\bar{\Sigma}^- \to \bar{n}\pi^-$

$\Sigma^- = \mathrm{dds}$

$m = 1197.449 \pm 0.030\ \mathrm{MeV}/c^2$

$\Sigma^- \to n\pi^- (98.848 \pm 0.005)\ \%$

$\bar{\Sigma}^+ \to \bar{n}\pi^+$

- p-Pb collisions at $\sqrt{s} = 5.023$ TeV
- pp collisions at $\sqrt{s} = 5.02$ TeV
- Data:

Data sets	Trigger events	Selected events	
LHC16(q,t)_CENT_woSDD	$1.65 \cdot 10^8$	$1.40 \cdot 10^8$	p-Pb
LHC16(q,t)_FAST	$1.53 \cdot 10^8$	$1.30 \cdot 10^8$	p-Pb
LHC17(p,q)_CENT_woSDD	$1.77 \cdot 10^8$	$1.50 \cdot 10^8$	pp
LHC17(p,q)_FAST	$1.95 \cdot 10^8$	$1.65 \cdot 10^8$	pp

- MC:

MC sets	Total events	Selected events	
LHC18f3_cent_woSDD_(1,2)	$1.24 \cdot 10^8$	$1.05 \cdot 10^8$	p-Pb
LHC18f3_fast_(1,2)	$1.15 \cdot 10^8$	$9.83 \cdot 10^7$	p-Pb
LHC17l3(b)_cent_woSDD	$5.66 \cdot 10^7$	$4.29 \cdot 10^7$	pp
LHC17l3(b)_fast	$7.31 \cdot 10^7$	$5.53 \cdot 10^7$	pp
LHC18j2_cent_woSDD	$1.64 \cdot 10^8$	$1.24 \cdot 10^8$	pp
LHC18j2_fast	$2.41 \cdot 10^8$	$1.82 \cdot 10^8$	pp

- Event selection:
- |Vertex z position| ≤ 10 cm
- Pile-up rejection
- INEL>0 and NSD events selection *AliMultSelectionTask::IsINELgtZERO(ev)*
- Minimum Bias trigger

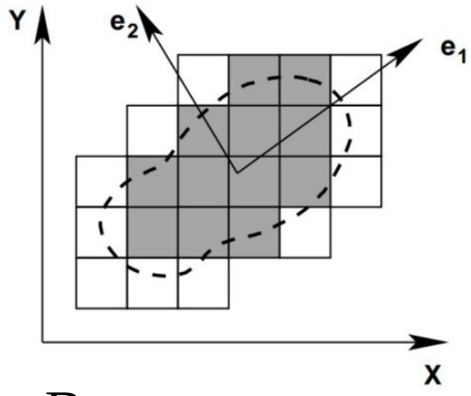
New! Увеличение статистики в 2 раза

Antineutron identification in PHOS

Напоминание

How we can identify $\bar{n}$:

- Deposited energy of annihilation
- Neutrality (Charged Particle Veto)
- Dispersion of cluster
- Number of cells

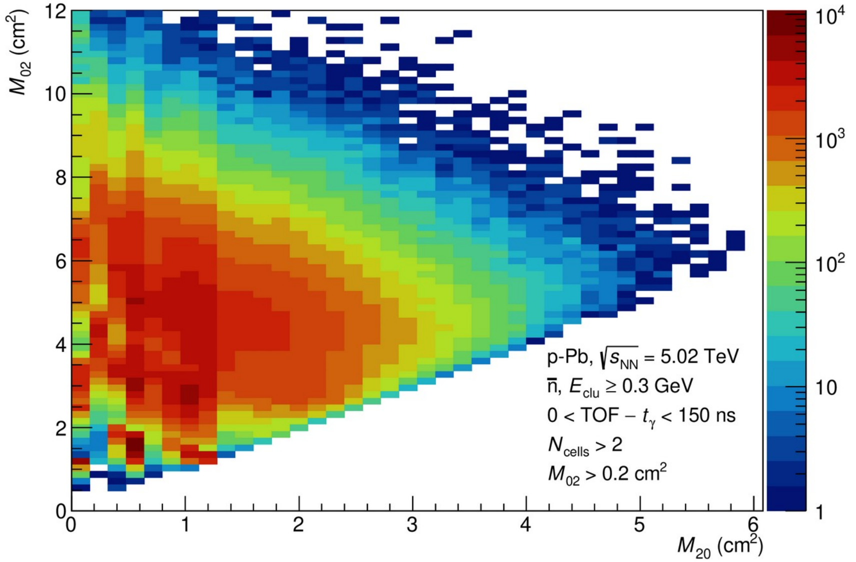


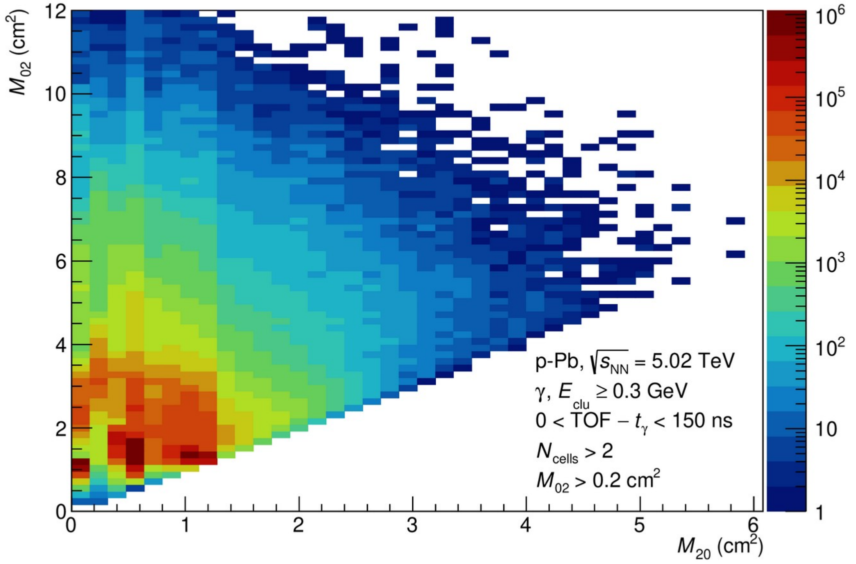
$$S = \begin{pmatrix} s_{xx} & s_{xz} \\ s_{zx} & s_{zz} \end{pmatrix}$$

$$s_{xx} = \langle (x - \bar{x})^2 \rangle$$

$$s_{xz} = \langle (x - \bar{x})(z - \bar{z}) \rangle$$

- But:
- We cannot measure momentum directly
- Use Time-of-Flight to reconstruct antineutron momentum





Default set of cuts for clusters

Напоминание

- Obtained as a result of a variation of different cuts, as the version with the greatest **purity times efficiency**

$$\mathrm{M02} > 0.2\ \mathrm{cm}^2$$

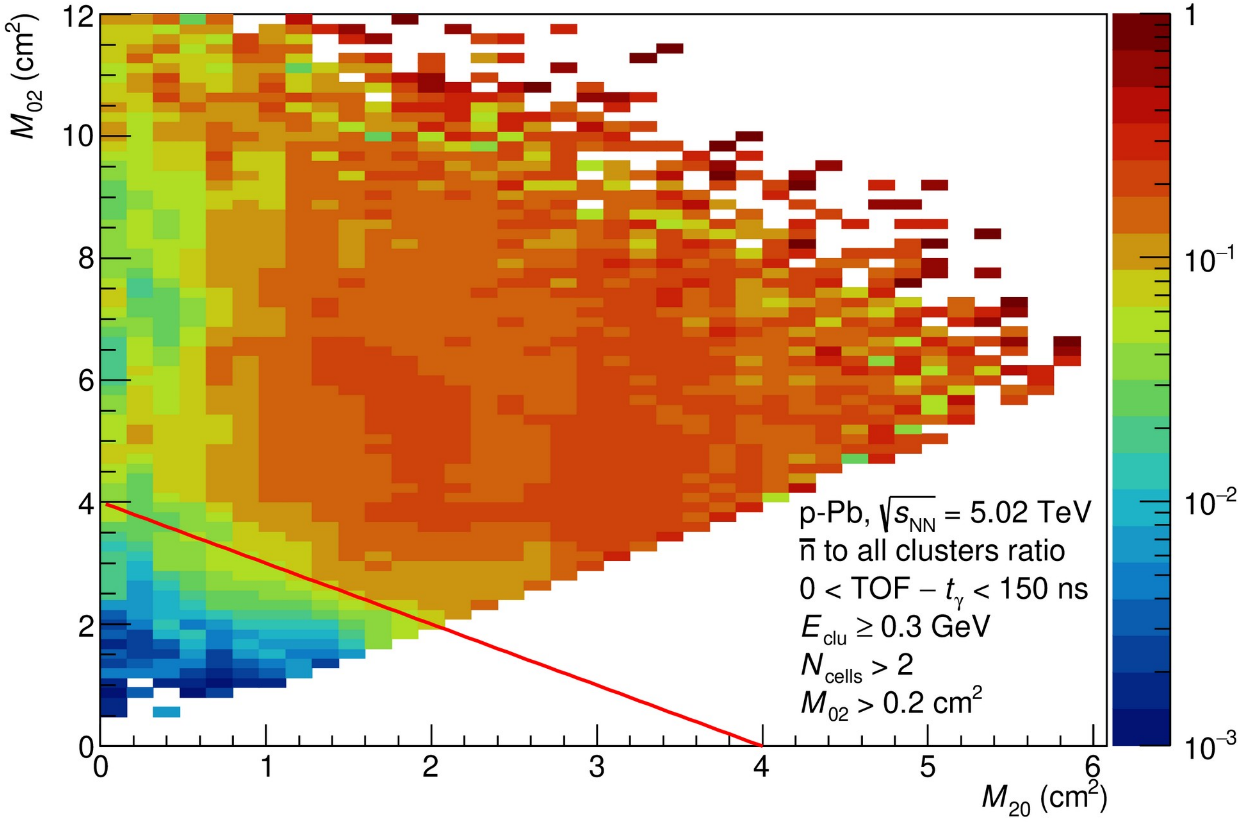
$$E_{\mathrm{clu}} \geq 0.6\ \mathrm{GeV}$$

$$N_{\mathrm{cells}} \geq 7$$

$$\mathrm{CPV} > 10\sigma$$

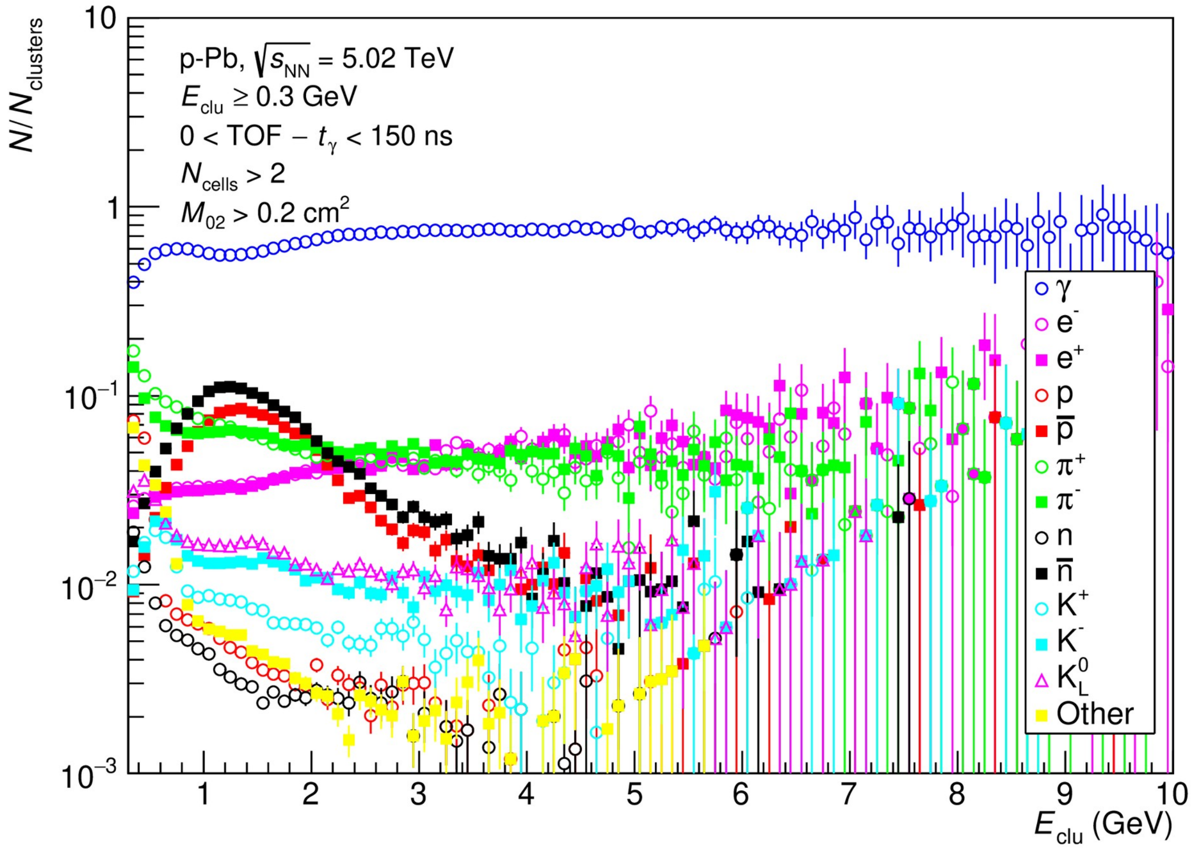
$$\mathrm{M20} \geq -\mathrm{M02} + 4$$

$$0 < \mathrm{TOF} - t_\gamma < 150\ \mathrm{ns}$$

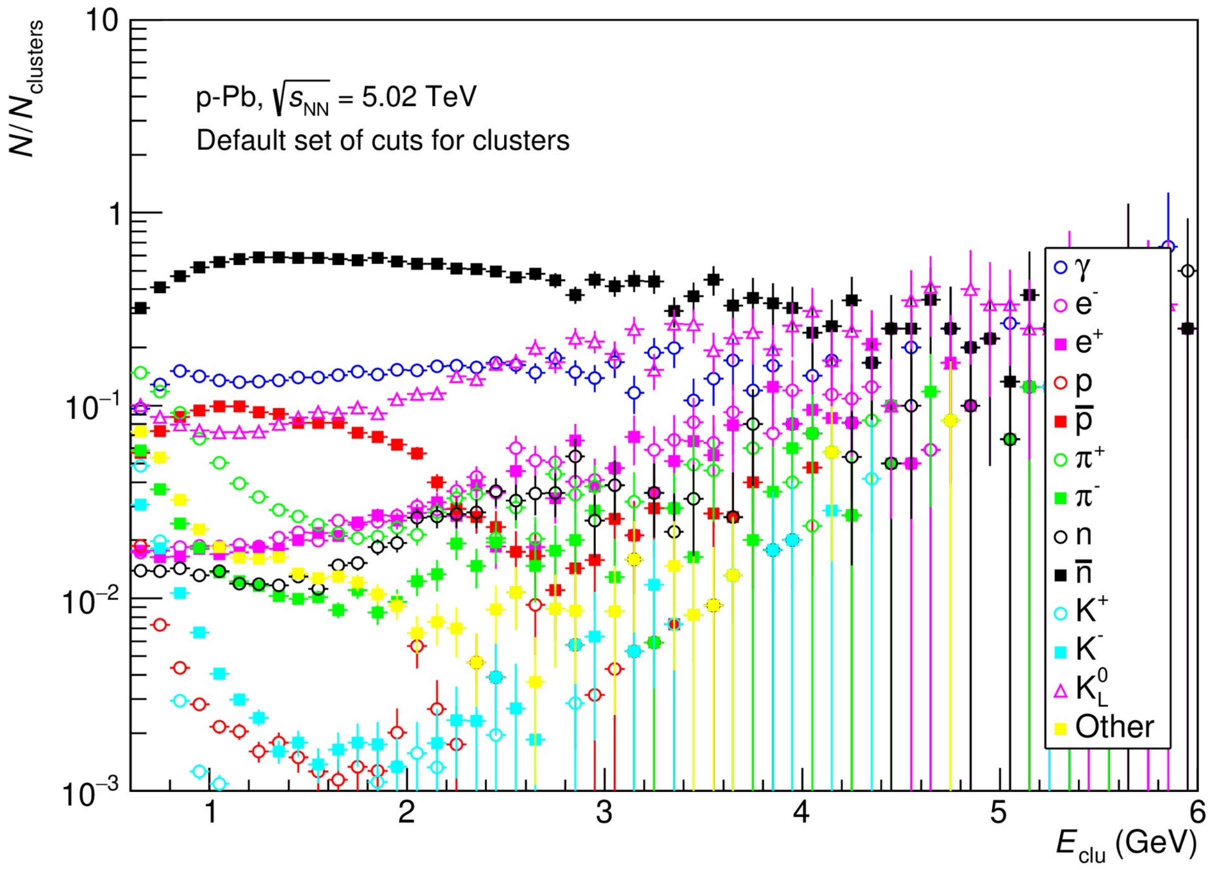


Fraction of different type of clusters

Напоминание



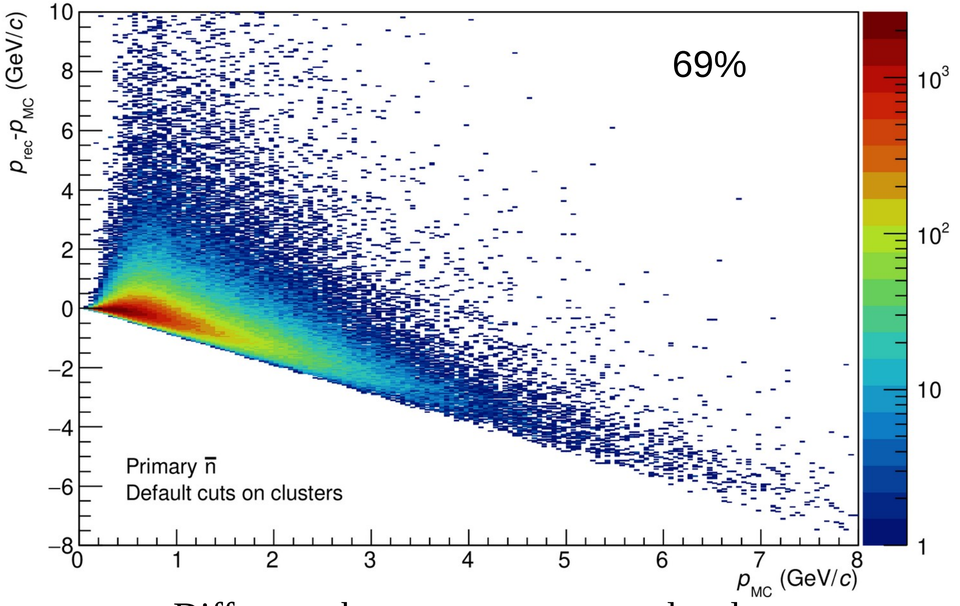
Before cuts



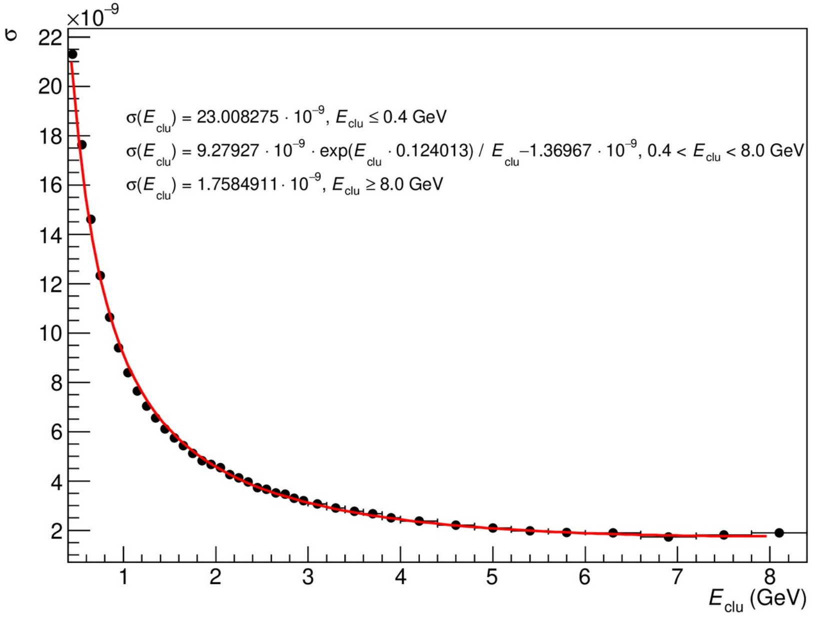
After default set of cuts, show on previous slide

Reconstruction of $\bar{n}$ momentum

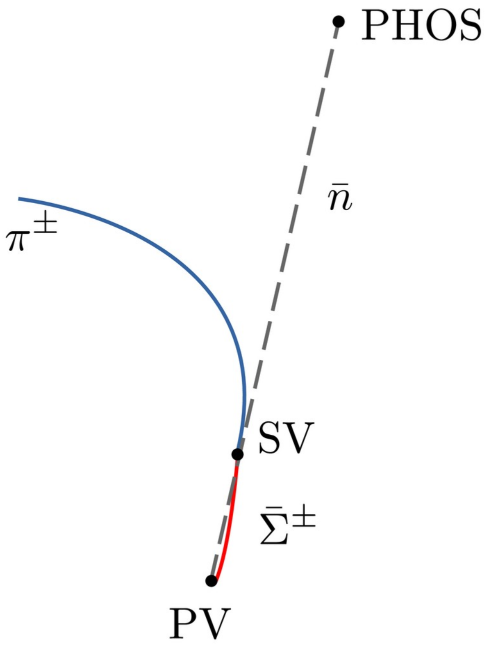
Напоминание



Difference between reconstructed and MC momentum



Time resolution of PHOS



$$p_{\text{rec}} = \frac{m_{\bar{n}}}{\sqrt{\left(\frac{t_{\text{TOF}} \cdot c}{L}\right)^2 - 1}}$$

L - distance between primary vertex and PHOS surface, m

$m_{\bar{n}}$ - antineutron mass, $0.939485\ \text{GeV}/c^2$

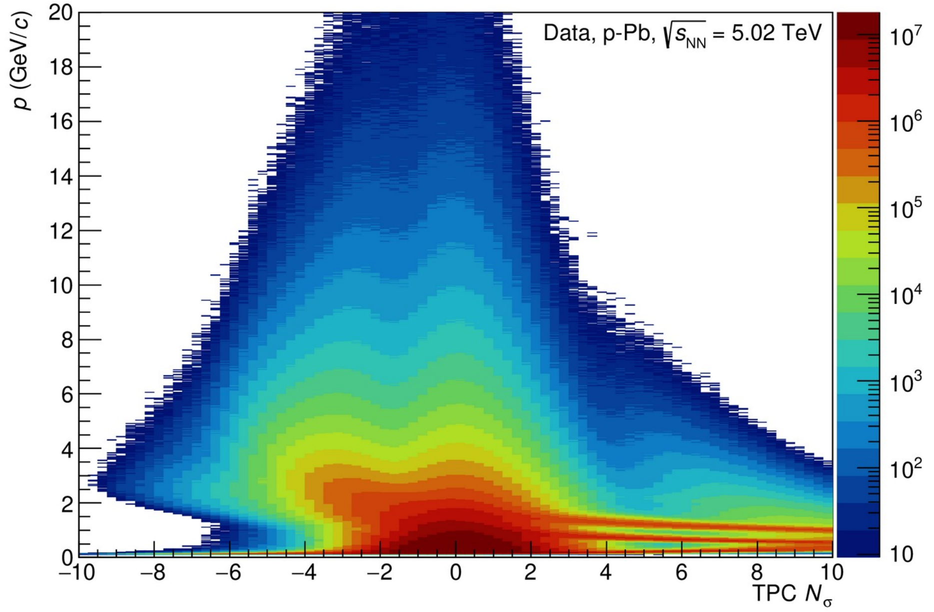
t_{TOF} - time of flight, s

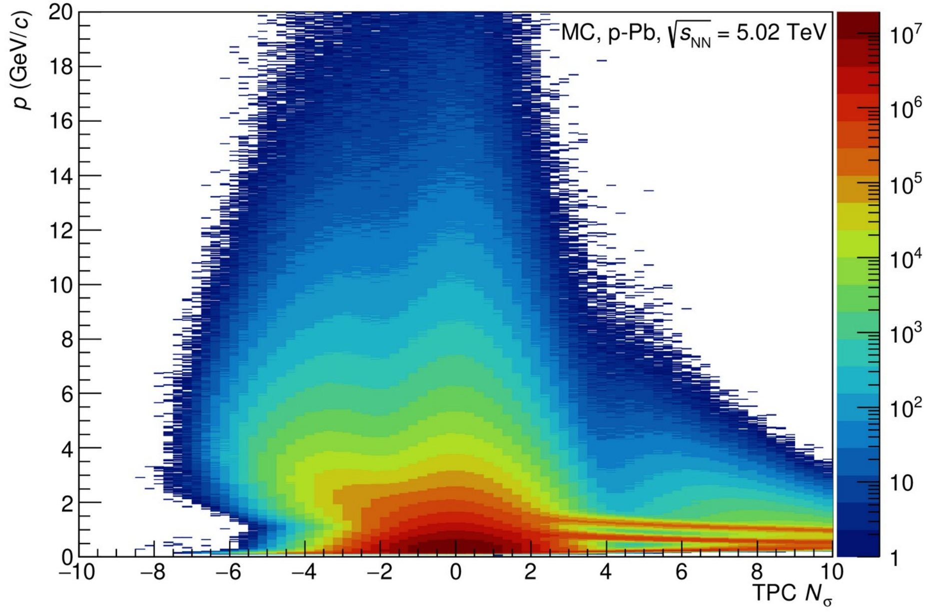
Track selection

Напоминание

- TPC dE/dx: 3σ band around π line
- $|\eta| < 0.8$
- Track FilterBit 4 (ITS-TPC tracks)
- Number of TPC clusters more than 60

TPC calibration in Data and MC





Topological selections

Напоминание

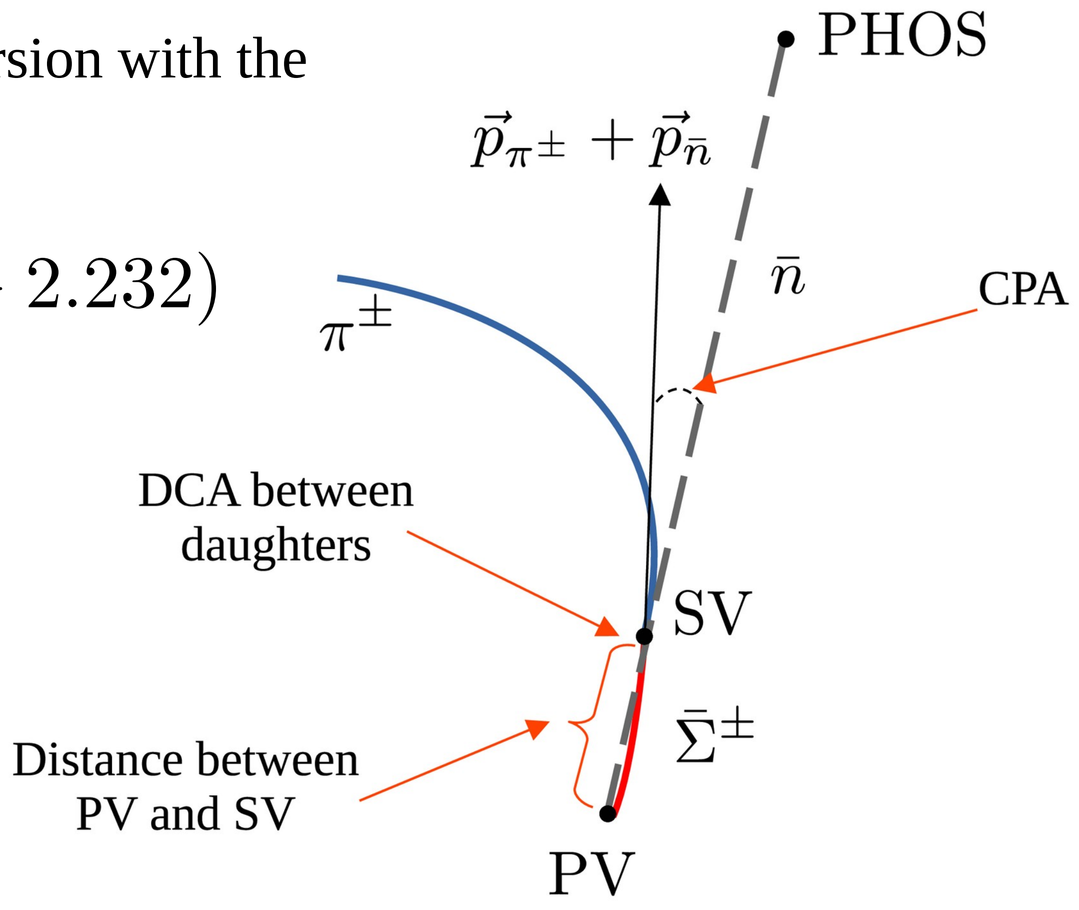
- Obtained default cuts is a result of a variation, the version with the greatest **purity times significance** was selected

$$\mathrm{DCA_{daug}} < \boxed{0.06} - \exp(-1.381 \cdot p^{\Sigma}_{\mathrm{T,\ rec}} - 2.232)$$

$$\mathrm{CPA} \geq \boxed{0.3}$$

$$\mathrm{PV\ to\ SV} > 0.193 \cdot p^{\Sigma}_{\mathrm{T,\ rec}} + \boxed{0.25}$$

	DCA	CPA	PV to SV
$\bar{\Sigma}^{+}$	0.06	0.3	0.25
$\bar{\Sigma}^{-}$	0.06	0.3	0.15



Signal extraction

Напоминание

- Applying all the obtained cuts, the distribution of the invariant mass for pairs of a track (pi-meson) and a cluster in the calorimeter (antineutron) is constructed
- Mixing of 100 events according to Z vertex coordinate and centrality bin

Signal extraction procedure:

- Same Event to Mixed Event ratios are constructed
- Fit SE/ME ratio with signal+background fuction
- From SE subtract normalized ME to obtain Signal distribution
- Obtain the RY from Signal distribution

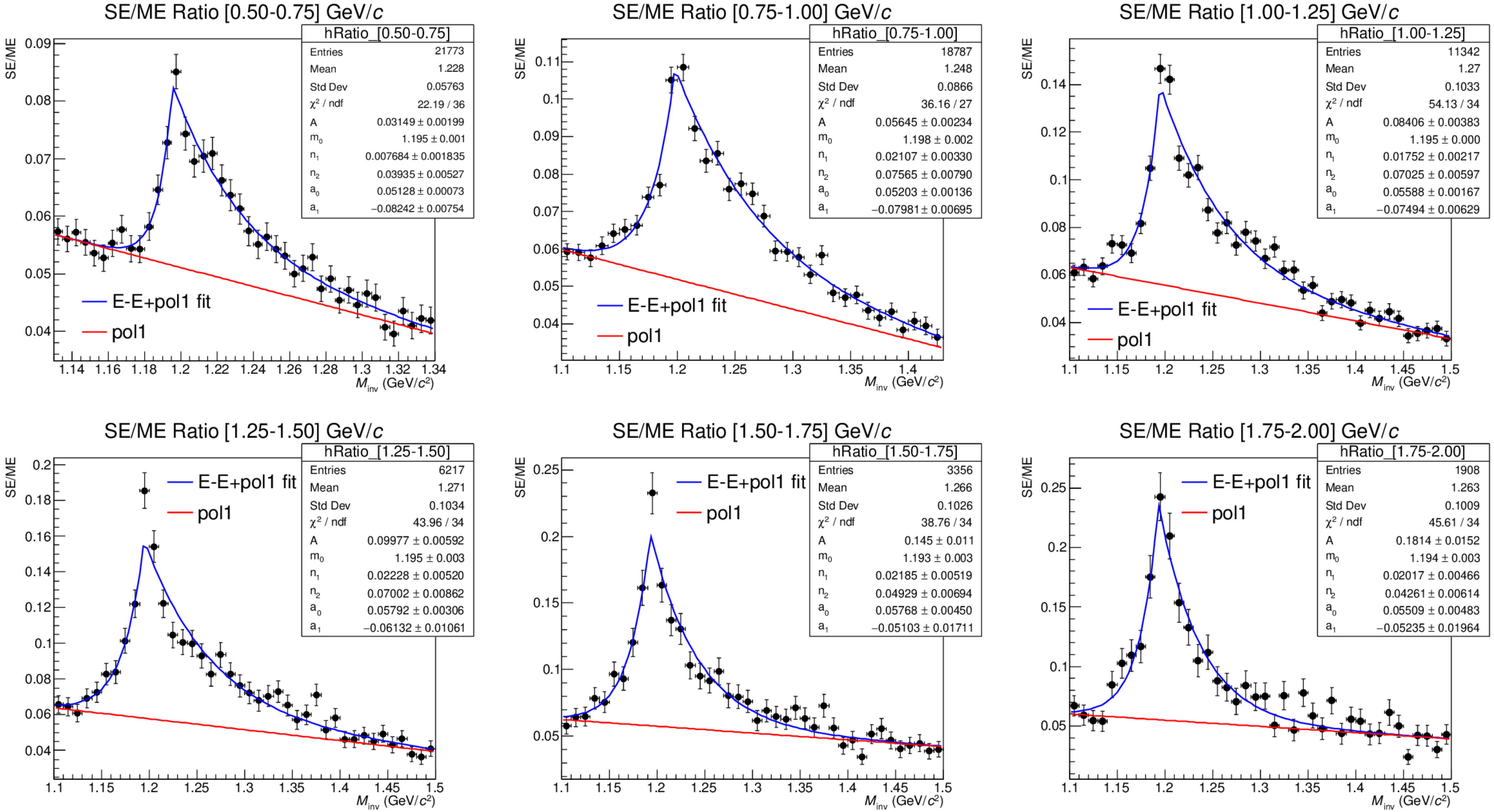
- Signal function:

$$f(x, m, w_1, w_2) = \begin{cases} c_0 \cdot \exp\left(-\frac{-x+m}{w_1}\right), x-m<0 \\ c_0 \cdot \exp\left(-\frac{x-m}{w_2}\right), x-m \geq 0 \end{cases}$$

- Crystal Ball function have negligible width of the gaussian core → use only tails to describe signal

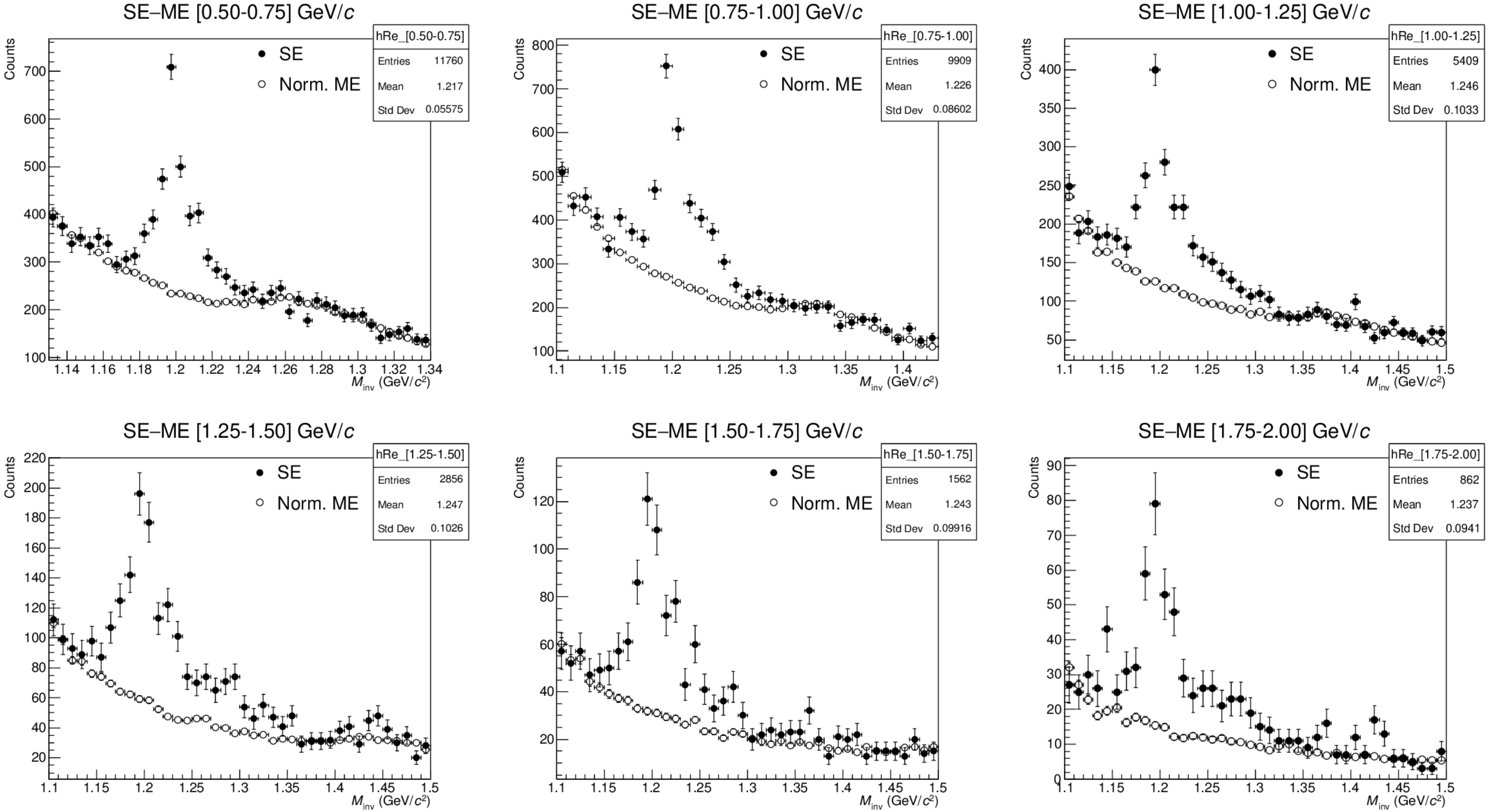
SE/ME fit. Data

Новое!



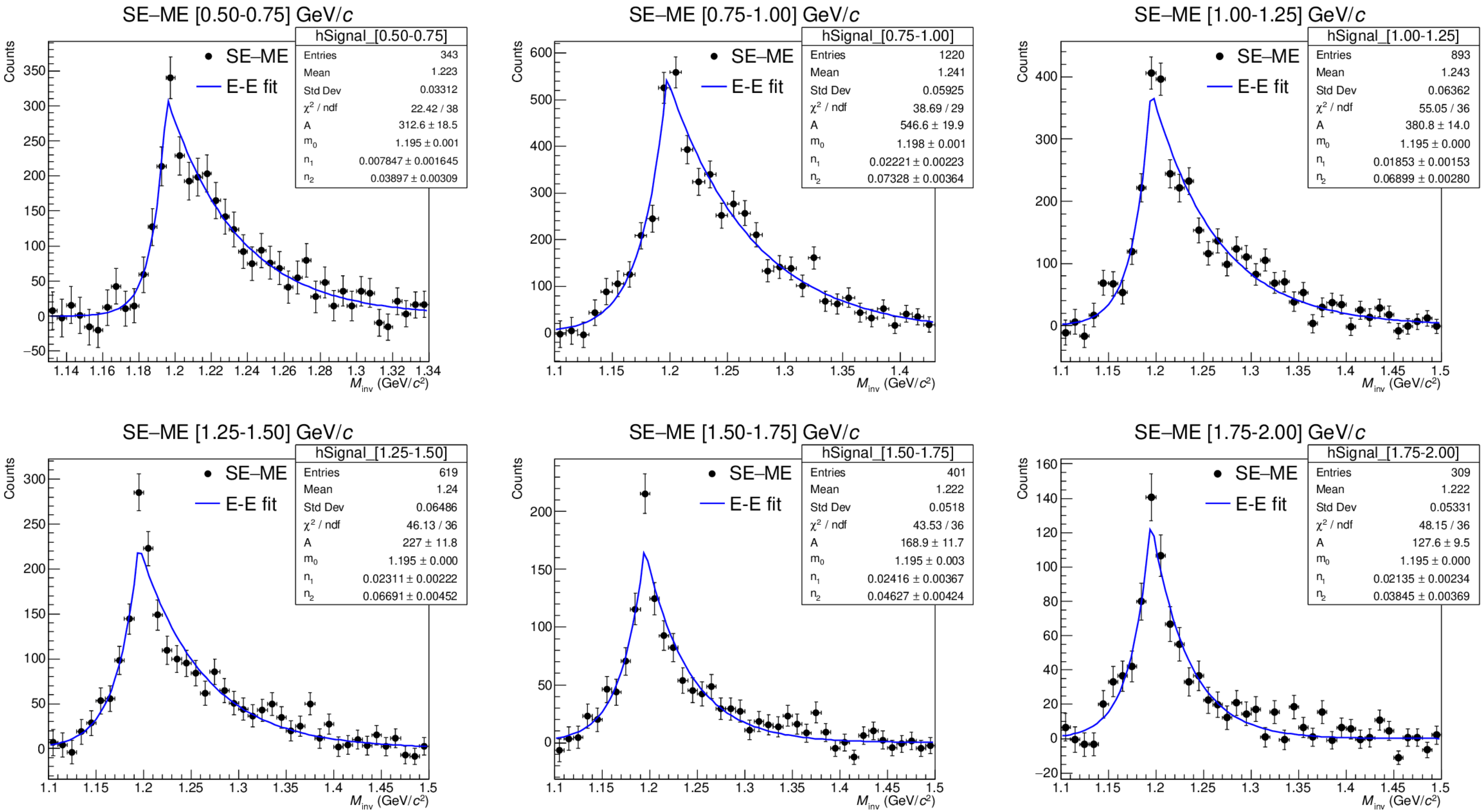
SE and norm. ME. Data

Новое!



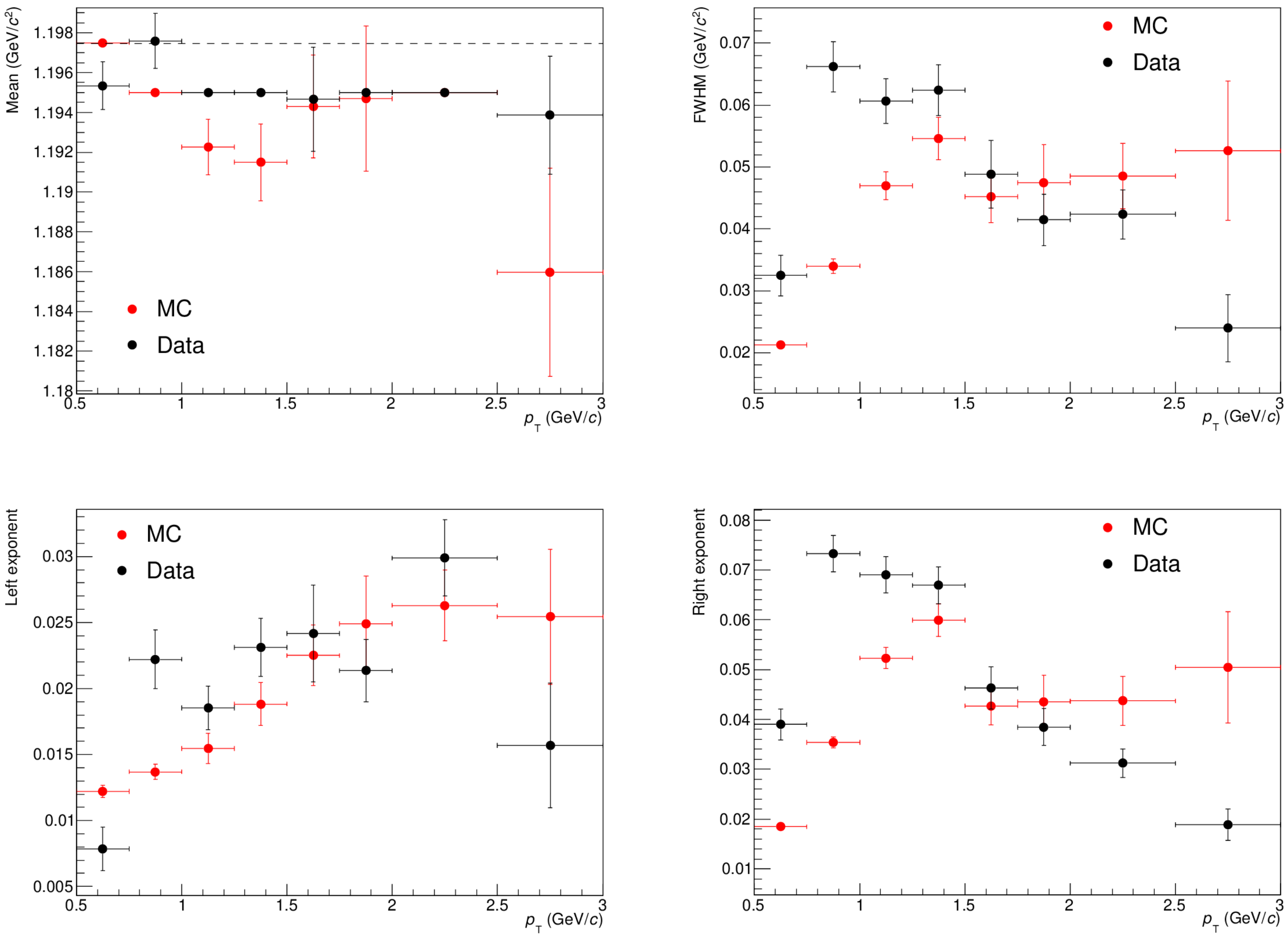
Signal fit. Data

Новое!



Compare fit parameters. Data and MC

Новое!



Systematic uncertainties. Sources

Новое!

- RY extraction: pol1/exp, 2 integration ranges, 4 fit ranges, num. integration
- ITS-TPC track matching efficiency: 3%
- Material budget: 4.5%
- Anti-neutron cross section uncertainty (the same as for p-bar): $0.00327 \cdot p_{\mathrm{T}}^{0.19716}$ %

- Ncells and Dispersion are considered correlated → simultaneous variation
- All Topological selections are considered correlated → simultaneous variation

Group	Cut	Minimum	Default	Maximum
Clusters	Minimum E_{clu}	> 0.5	> 0.6	> 0.7
	N_{cells}	> 6	> 7	> 8
	Dispersion	$M_{02} \geq -M_{20} + 3.5$	$M_{02} \geq -M_{20} + 4$	$M_{02} \geq -M_{20} + 4.5$
	CPV n_{σ}	9	10	11
	TOF	100 ns	150 ns	–
Tracks	$\lvert\eta\rvert$	<0.7	<0.8	<0.9
	Pion TPC n_{σ}	<2.5	<3	<3.5
	TPC clusters	50	60	70
Topological selections	DCA between daughters	$< 0.05 + \exp(-1.381 \cdot p_{\mathrm{T}} - 2.232)$	$< 0.06 + \exp(-1.381 \cdot p_{\mathrm{T}} - 2.232)$	$< 0.07 + \exp(-1.381 \cdot p_{\mathrm{T}} - 2.232)$
	Distance between PV and SV $\bar{\Sigma}^{+}$	$> 0.193 \cdot p_{\mathrm{T}} + 0.2$	$> 0.193 \cdot p_{\mathrm{T}} + 0.25$	$> 0.193 \cdot p_{\mathrm{T}} + 0.3$
	Distance between PV and SV $\bar{\Sigma}^{-}$	$> 0.193 \cdot p_{\mathrm{T}} + 0.1$	$> 0.193 \cdot p_{\mathrm{T}} + 0.15$	$> 0.193 \cdot p_{\mathrm{T}} + 0.2$
	CPA	>0	>0.3	>0.5

Systematic uncertainties

Новое!

- The mean spectrum is calculated using equation (av. only by RY extraction variation):

$$N_{\text{mean}} = \frac{\sum_i^n N_i/\sigma^2_{i,\text{stat}}}{\sum_i^n 1/\sigma^2_{i,\text{stat}}}$$

- The average stat. deviation:

$$\sigma_{\text{mean}} = \sqrt{\frac{n}{\sum_i^n 1/\sigma^2_{i,\text{stat}}}}$$

- For all variations to calculate systematic uncertainties we use RMS (except TOF cut):

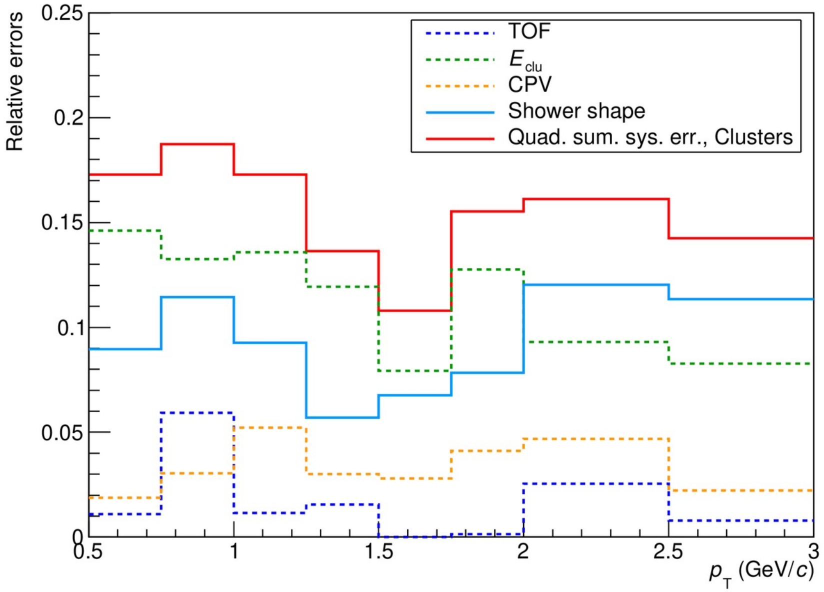
$$\sigma_{\text{syst}} = \sqrt{\frac{\sum_i^n N_i^2/\sigma^2_{i,\text{stat}}}{\sum_i^n 1/\sigma^2_{i,\text{stat}}} - \left(\frac{\sum_i^n N_i/\sigma^2_{i,\text{stat}}}{\sum_i^n 1/\sigma^2_{i,\text{stat}}}\right)^2}$$

- TOF systematic uncertainty (only 1 variation):

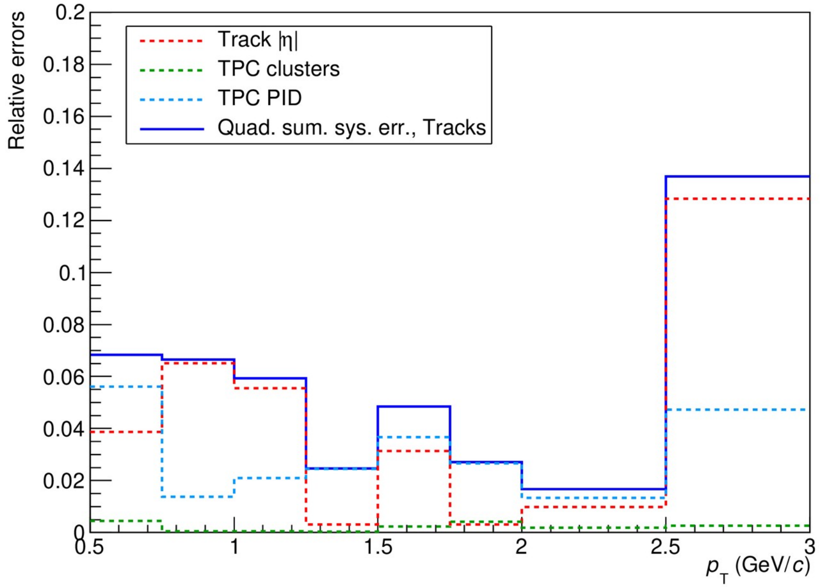
$$\sigma_{\text{syst,TOF}} = \frac{|a-b|}{\sqrt{12}}$$

Systematic uncertainties. p-Pb. $\bar{\Sigma}^{+}$

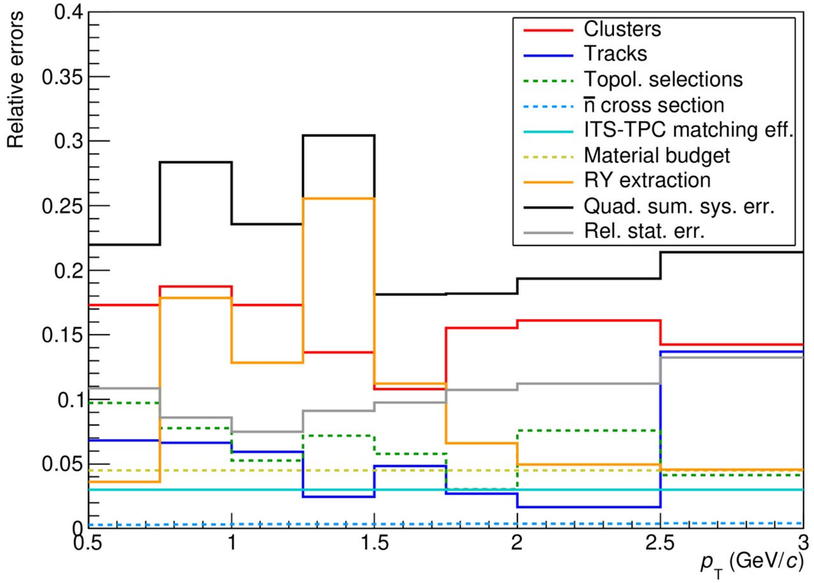
Новое!



Clusters



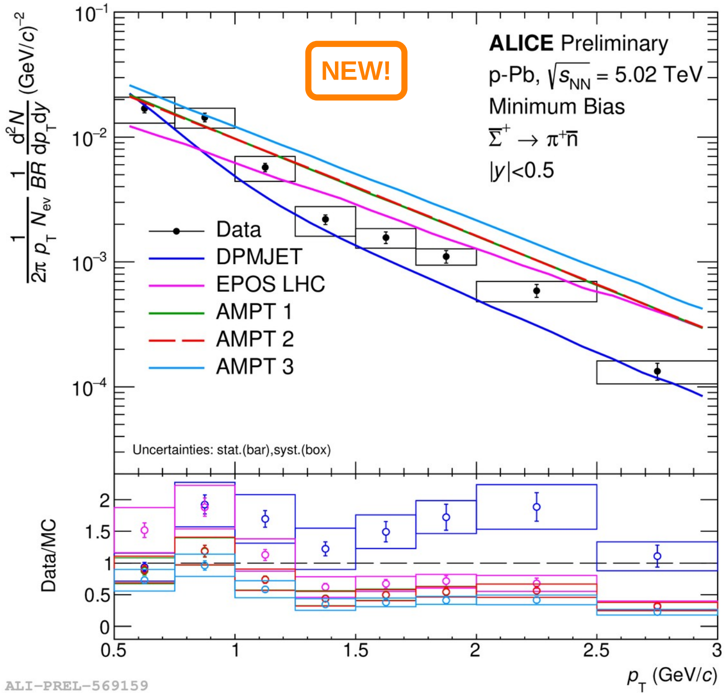
Tracks

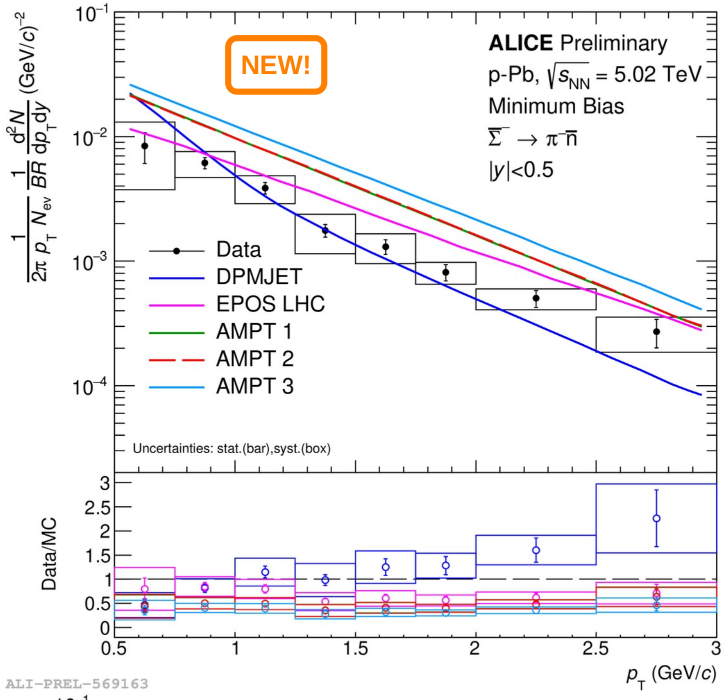


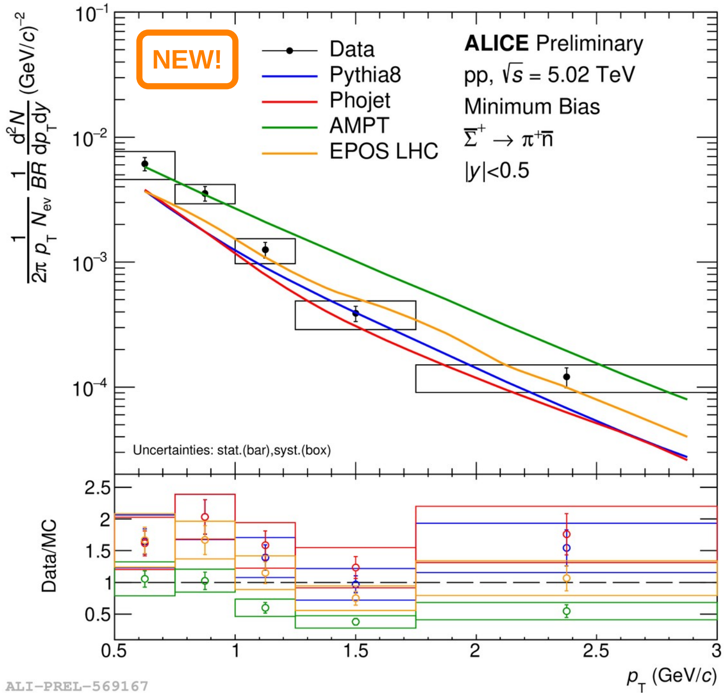
All

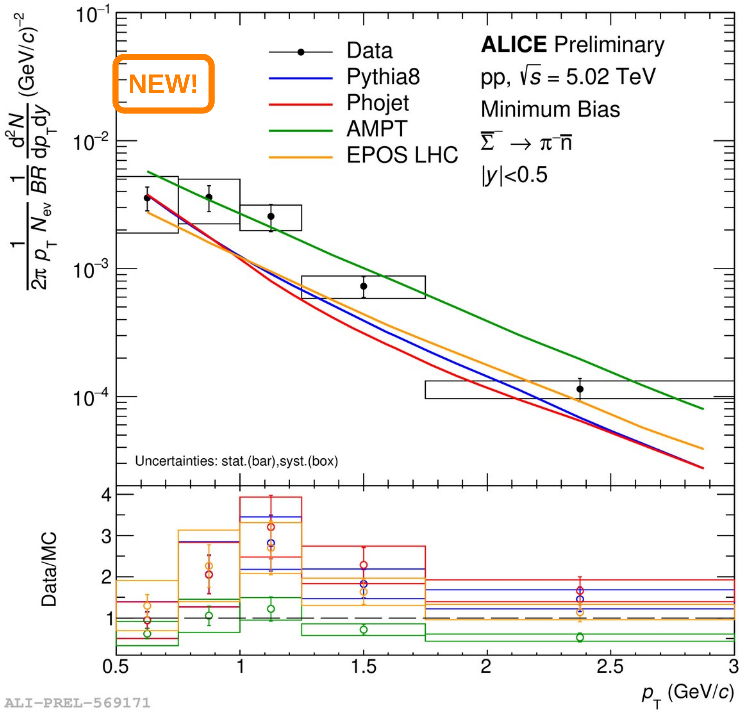
Spectrum of $\bar{\Sigma}$

- All syst. uncertainties are shown with box
- DPMJET shows good agreement at high pT but have a rise at low pT, which is not common to other models
- EPOS LHC works slightly better for the whole pT range within large uncertainties
- EPOS LHC , PYTHIA8 Monash13 and Phojet show good agreement with data points within large uncertainties



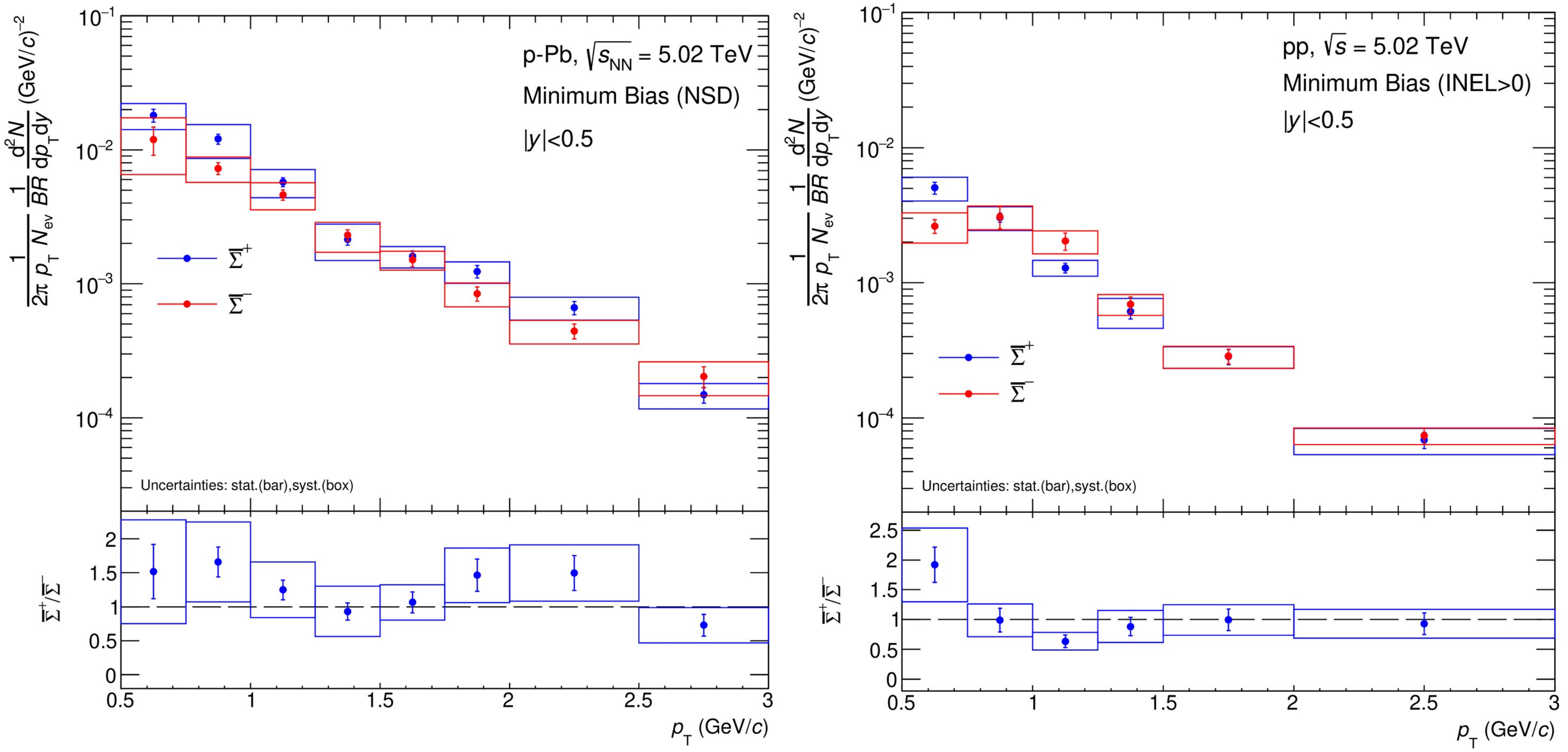






Spectrum of $\bar{\Sigma}$

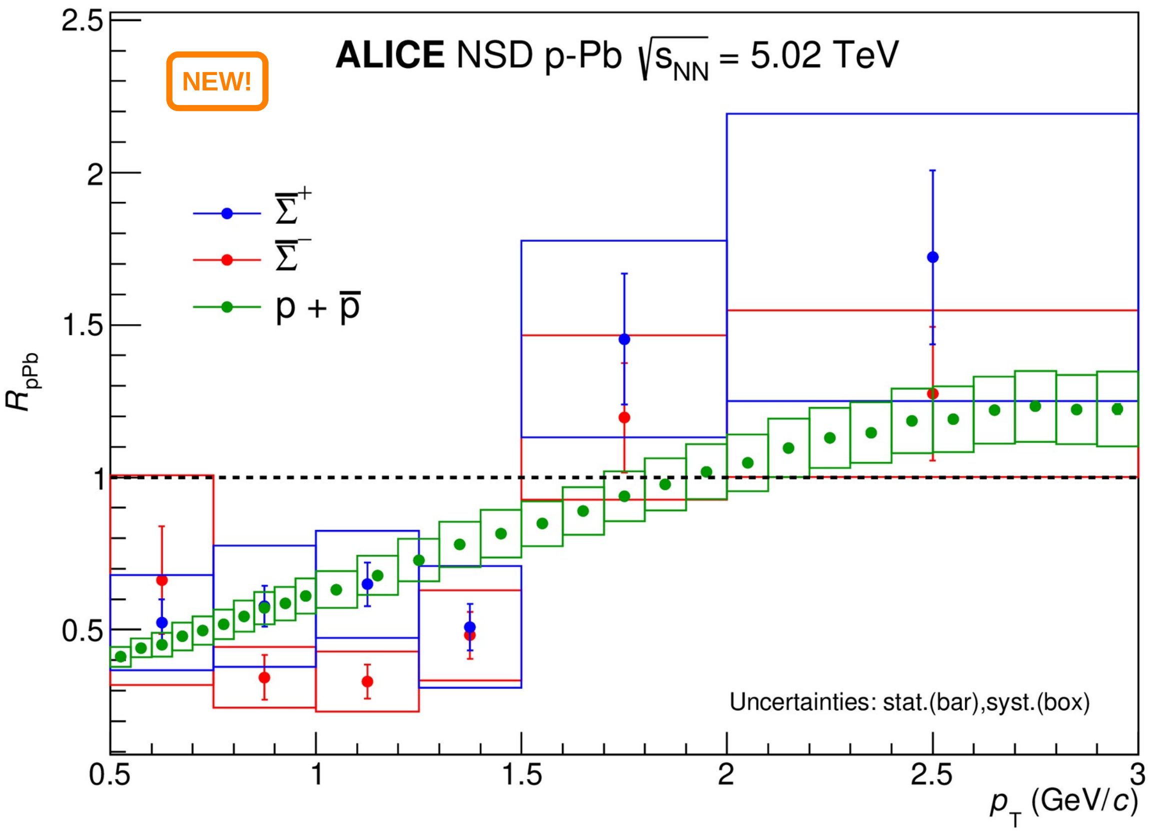
- Comparison between two Antisigma can be made
- As expected, the ratio is close to unity



RpPb for $\bar{\Sigma}$

- RpPb can be obtained from resulting spectra in p-Pb and pp, and compared to published one for p+pbar
- Where $\langle N_{\mathrm{coll}} \rangle$ - 6.87 for V0M 0-100%

$$R_{\mathrm{pPb}} = \frac{dN_{\mathrm{pPb}}/dp_{\mathrm{T}}}{\langle N_{\mathrm{coll}} \rangle \cdot dN_{\mathrm{pp}}/dp_{\mathrm{T}}}$$



Заключение

- Получены спектры анти-Сигма-гиперонов, оценены систематические погрешности
- Пройдена коллаорационная процедура по одобрению результатов: от Analysis Note (подробный отчет) до получения статуса Preliminary для спектров
- Одобрена коллаборационная статья
- Полученные результаты представлены на международной конференции QM 2023 в составе постера и доклада; представлен доклад на международной конференции SQM 2023, Strasbourg, France

Дальнейшие планы:

- Написание коллаборационной статьи
- Более тщательная проверка результатов

Suggestions and comments are welcome!

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Motivation

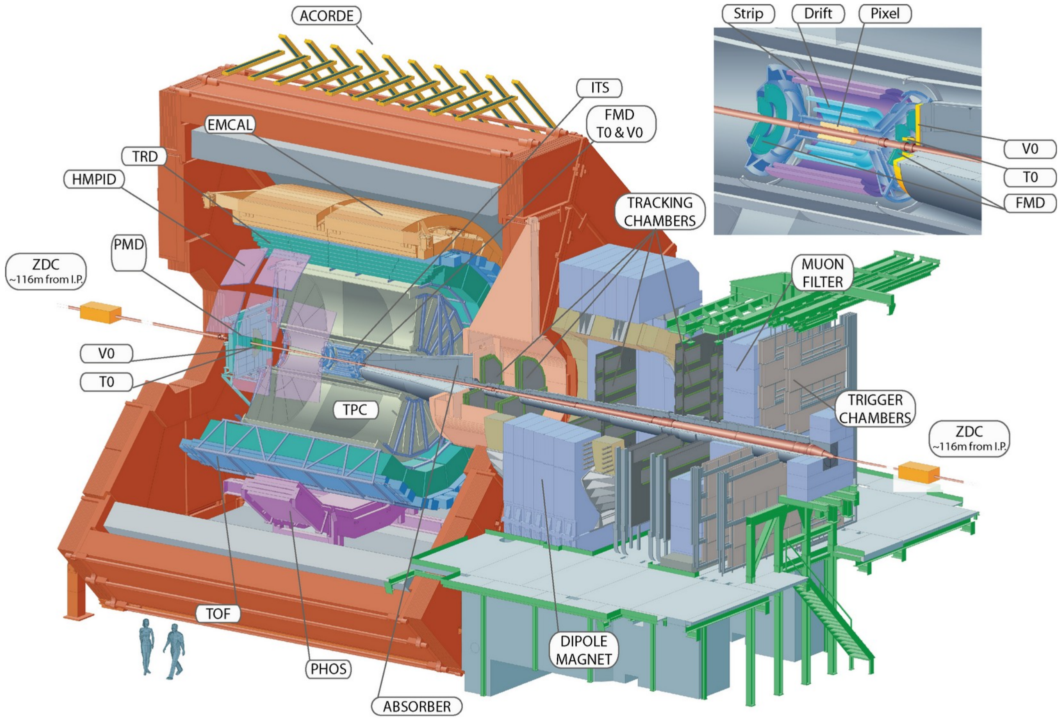
Measurement of antineutron

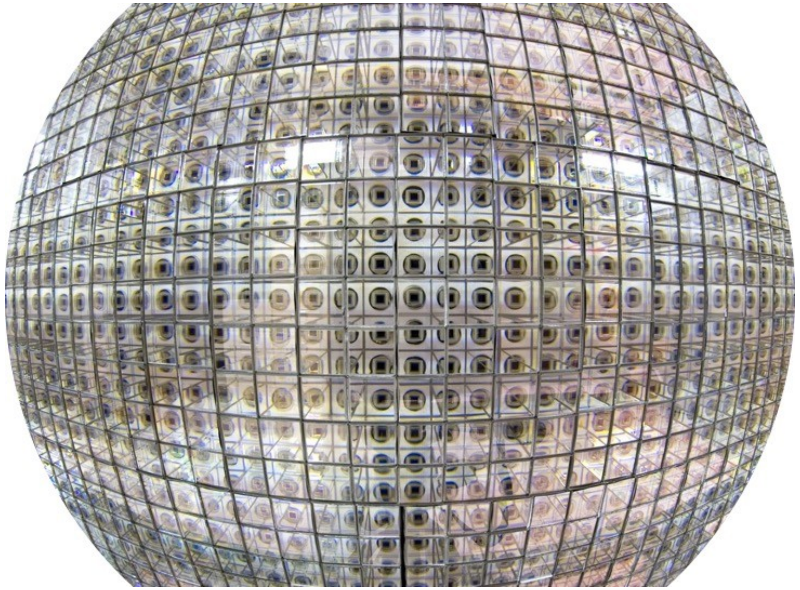
- Measurement of antineutron-hadron interaction and antineutron correlations
- Measurement of antineutron spectrum

- Measurement of $\bar{\Sigma}$ to validate method of antineutron identification and get insight into hyperon production mechanisms
- Measurement of the p-$\bar{\Sigma}$ interaction via the femtoscopic method to understand the hyperon-nucleon interaction (important for astrophysics)
- Measurement of particles that decays into antineutrons

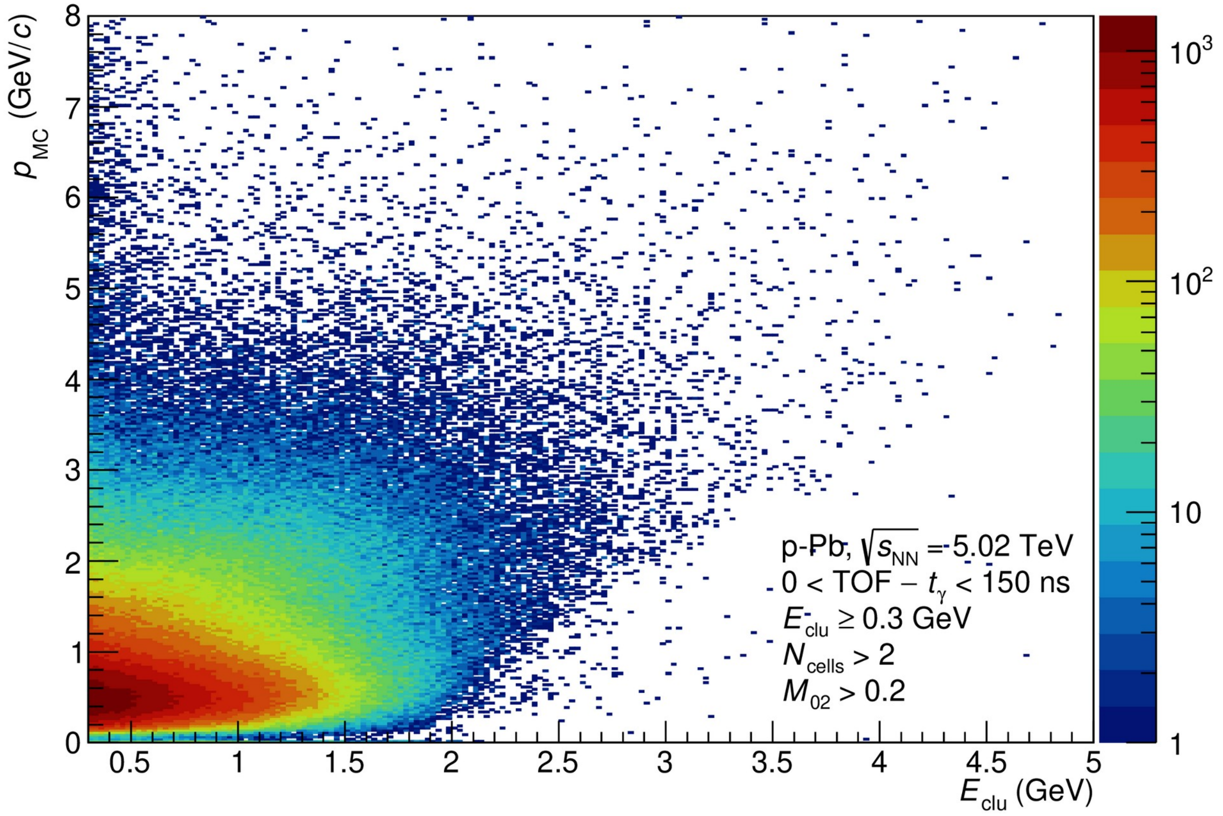
PHOS

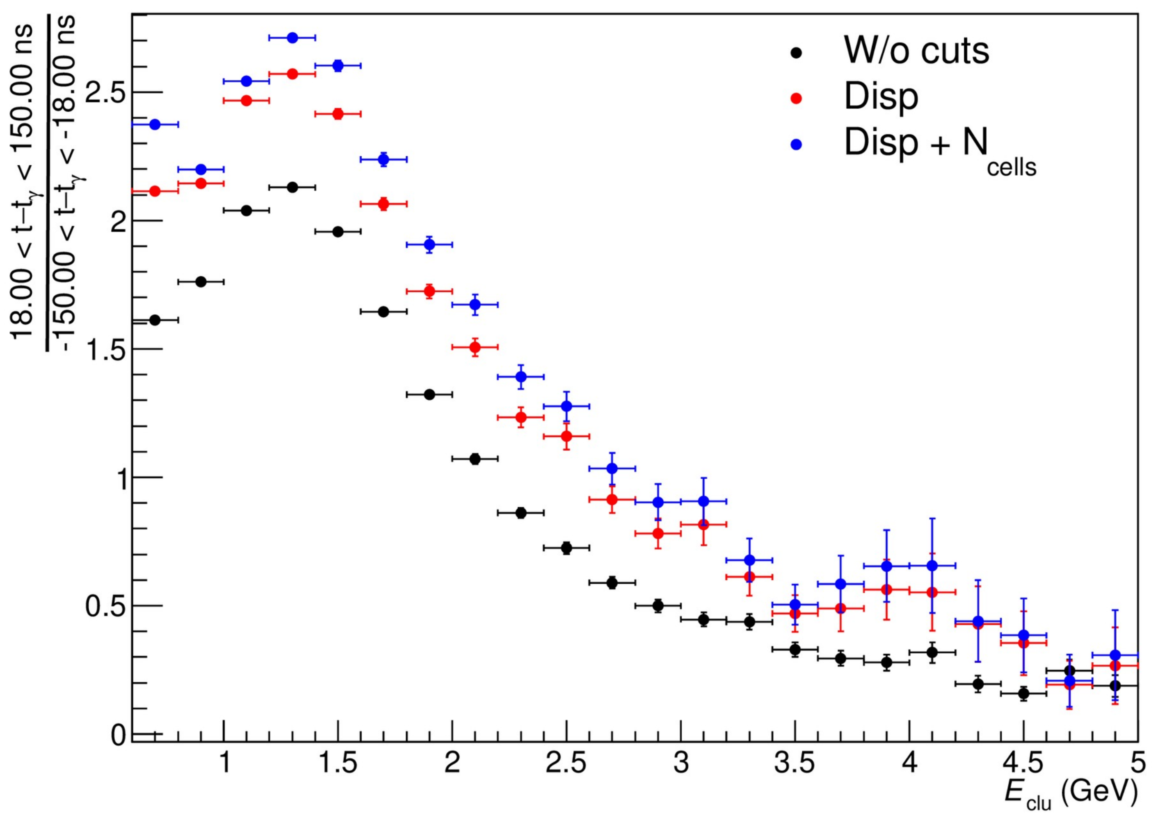
- PHOS – high granularity photon spectrometer based on PbWO4 crystals, located at the bottom of ALICE
- The PHOS is dedicated to the search for electromagnetic radiation from the hot strongly interacting matter in nucleus-nucleus interactions at high energies, as well as for measurements of meson spectra via their decays on photons
- Distance to IP = 4.6 m





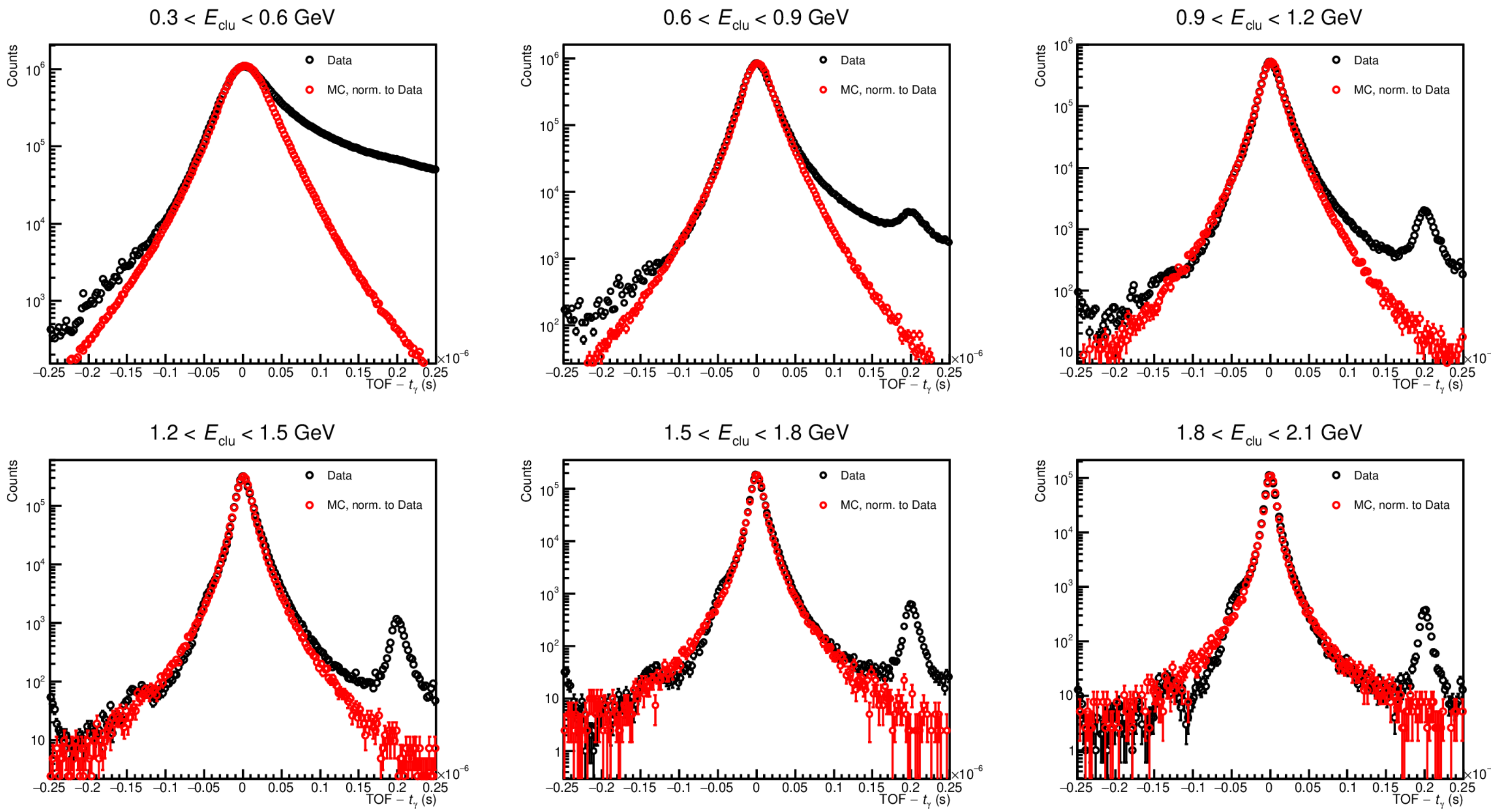
Eclu vs MC momentum. p-Pb





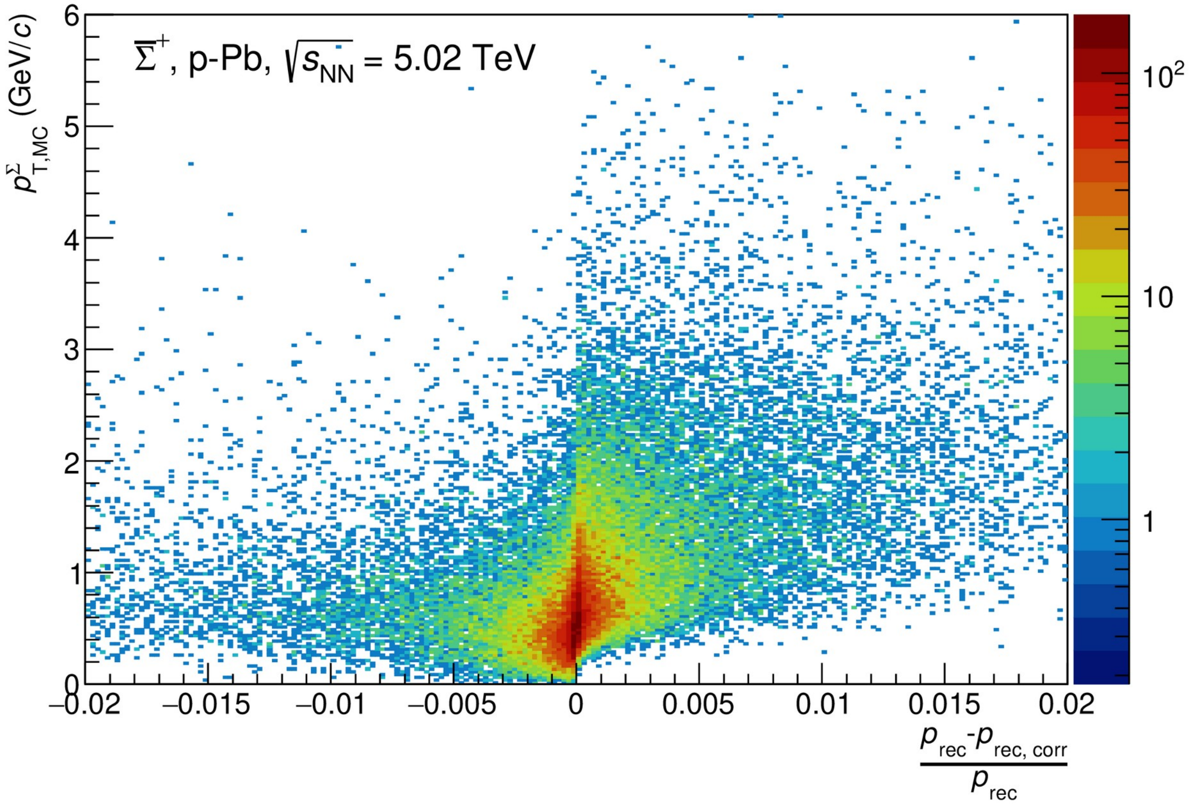
PHOS time resolution in MC

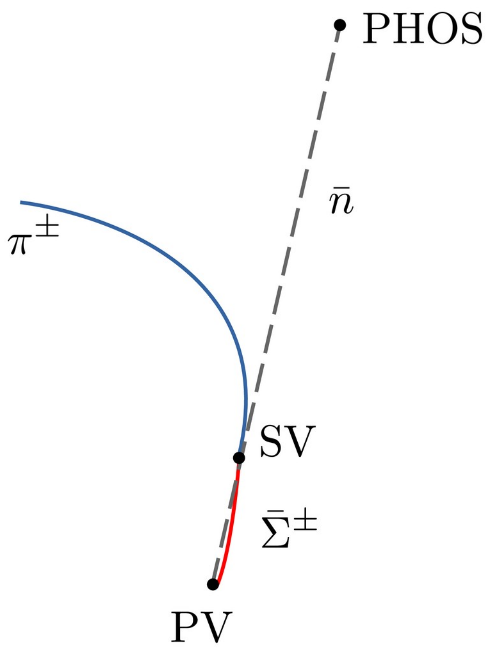
- PHOS measures time with respect to BC time (LHC clock)
- MC does not reproduce PHOS time resolution → needs to be implemented by hand
- Left part of distribution – PHOS time resolution
- Right part – particles that MC does not describe, pile-ups



Assumption about the trajectory. $\bar{\Sigma}$

- The time of flight for Antisigma and antineutron is compared
- The distance is compared taking into account the secondary vertex
- $p_{\mathrm{rec,\ corr}}$ is calculated taking account Antisigma TOF and SV





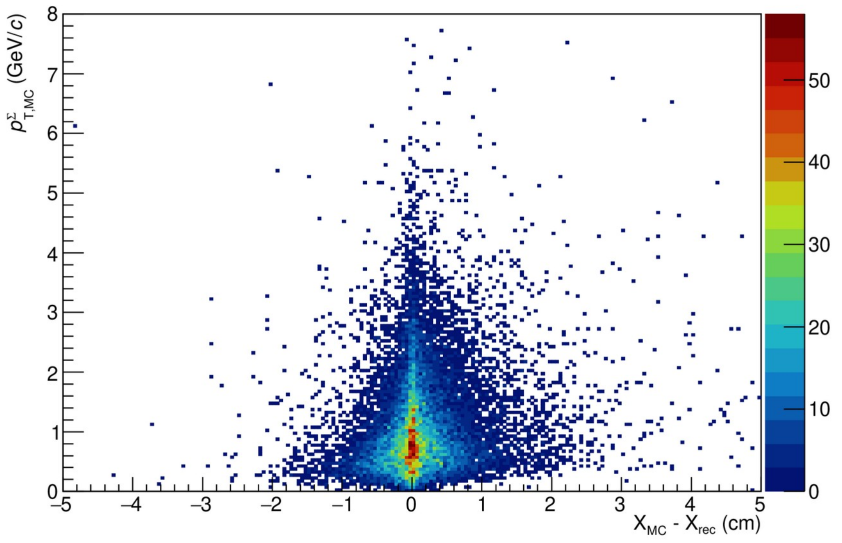
Sigma decay vertex reconstruction

- AliCascadeVertexer::PropagateToDCACurvedBachelor(AliESDv0 *v, AliExternalTrackParam *t, Double_t b)
- AliESDv0 → AliCaloPhoton

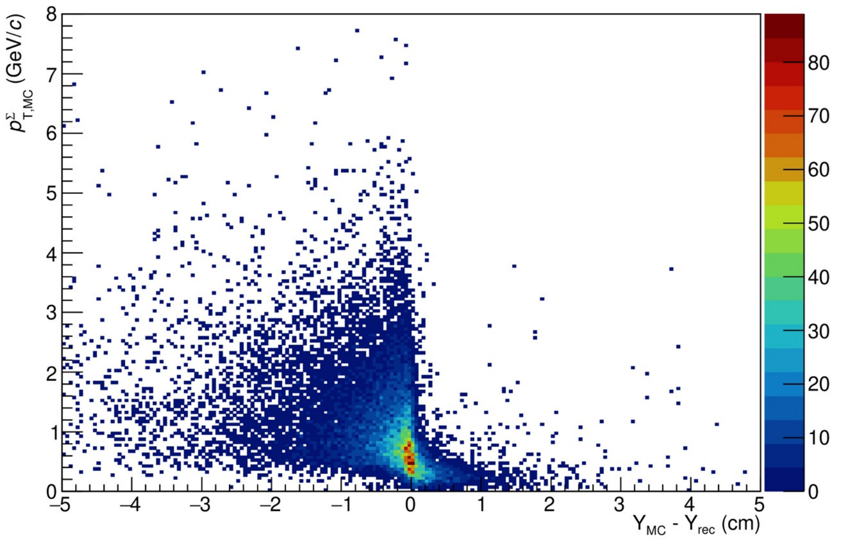
- DCA between daughters
- CPA
- Distance between PV and SV

Precision of SV reconstruction

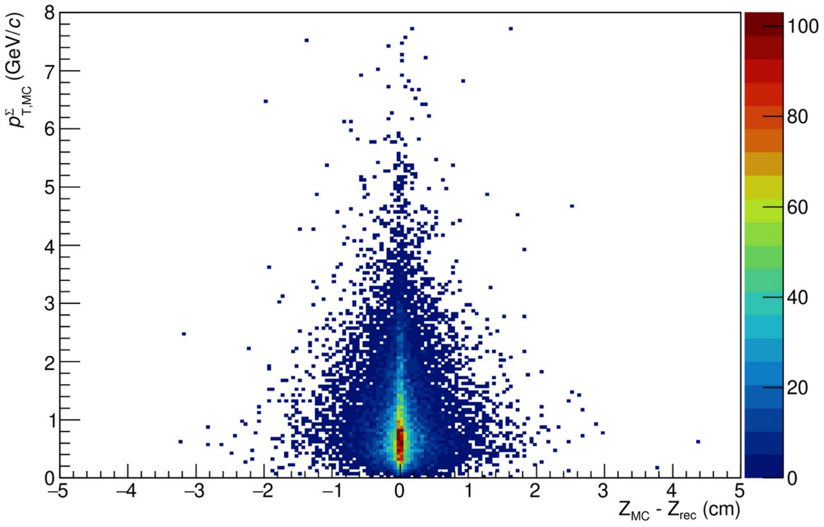
- The difference between MC and Rec. vertex position of AntiSigma is calculated for each coordinate



$X_{\mathrm{MC}} - X_{\mathrm{rec}}$

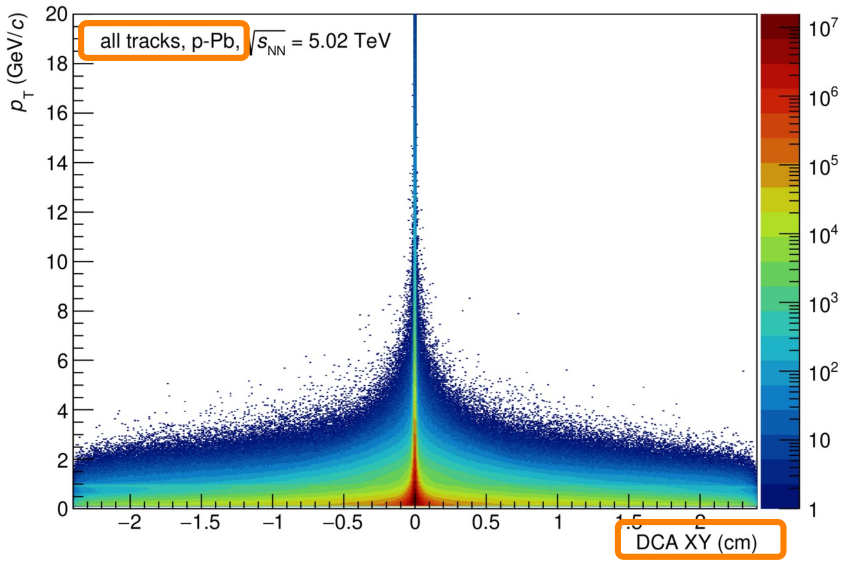


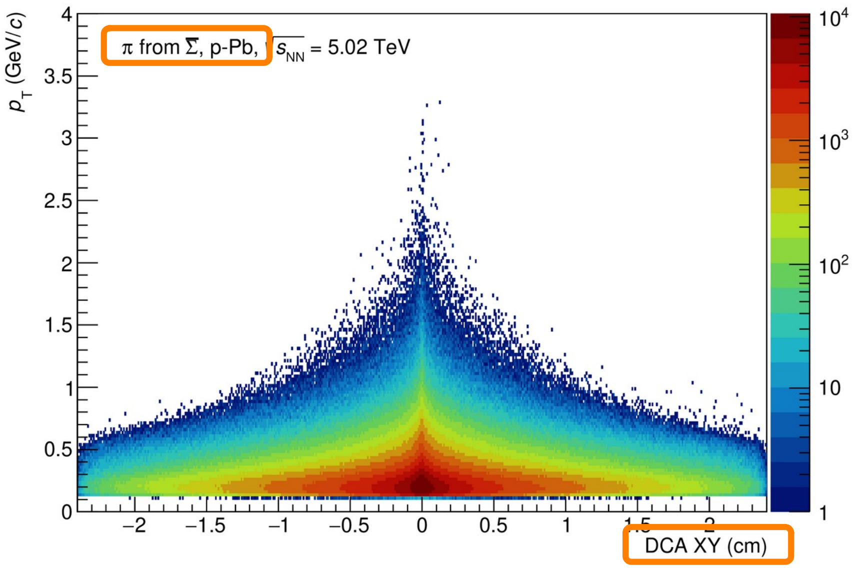
$Y_{\mathrm{MC}} - Y_{\mathrm{rec}}$

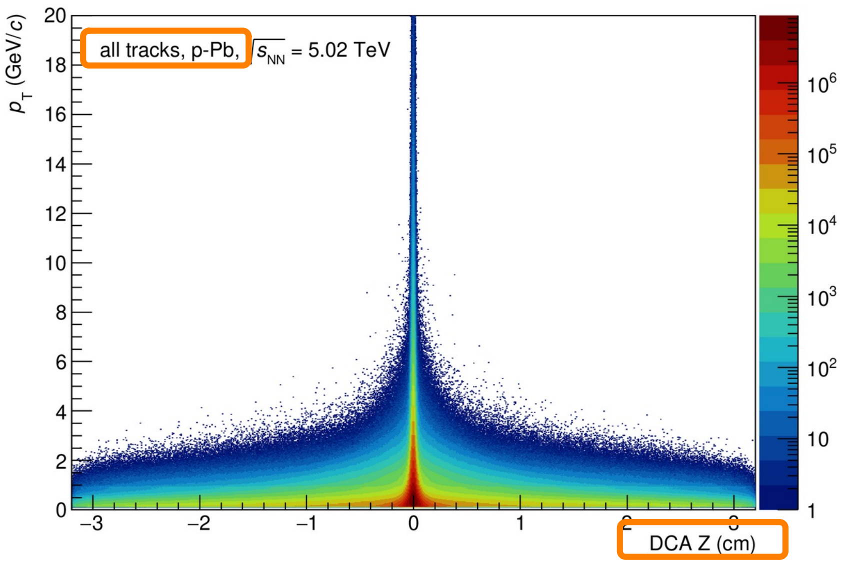


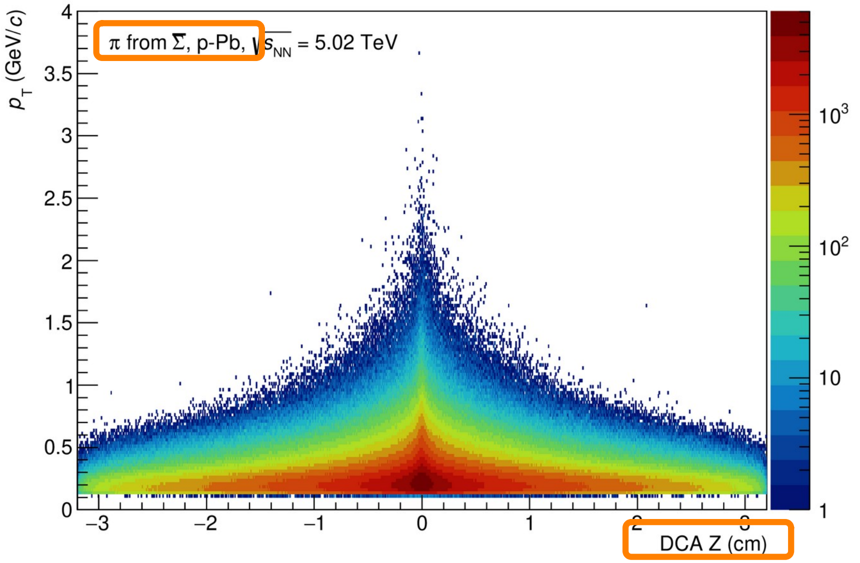
$Z_{\mathrm{MC}} - Z_{\mathrm{rec}}$

Topological selections. DCA. p-Pb

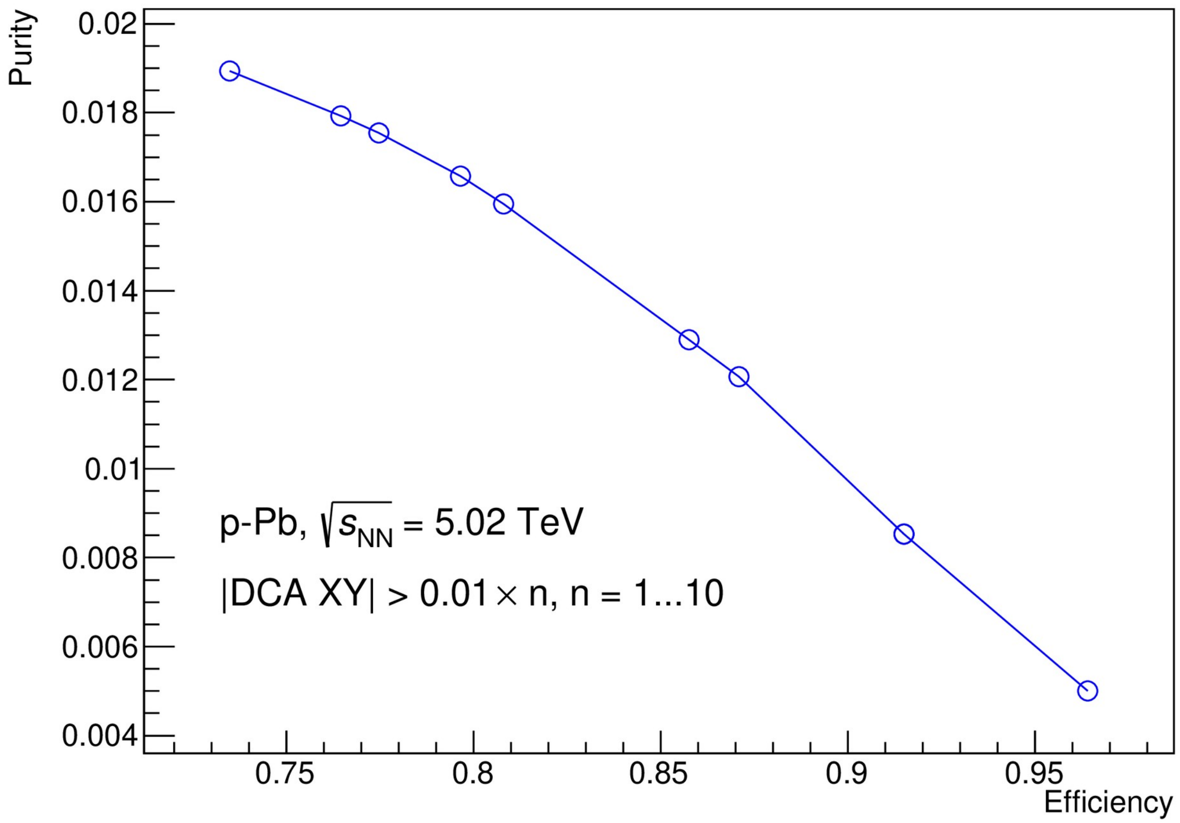


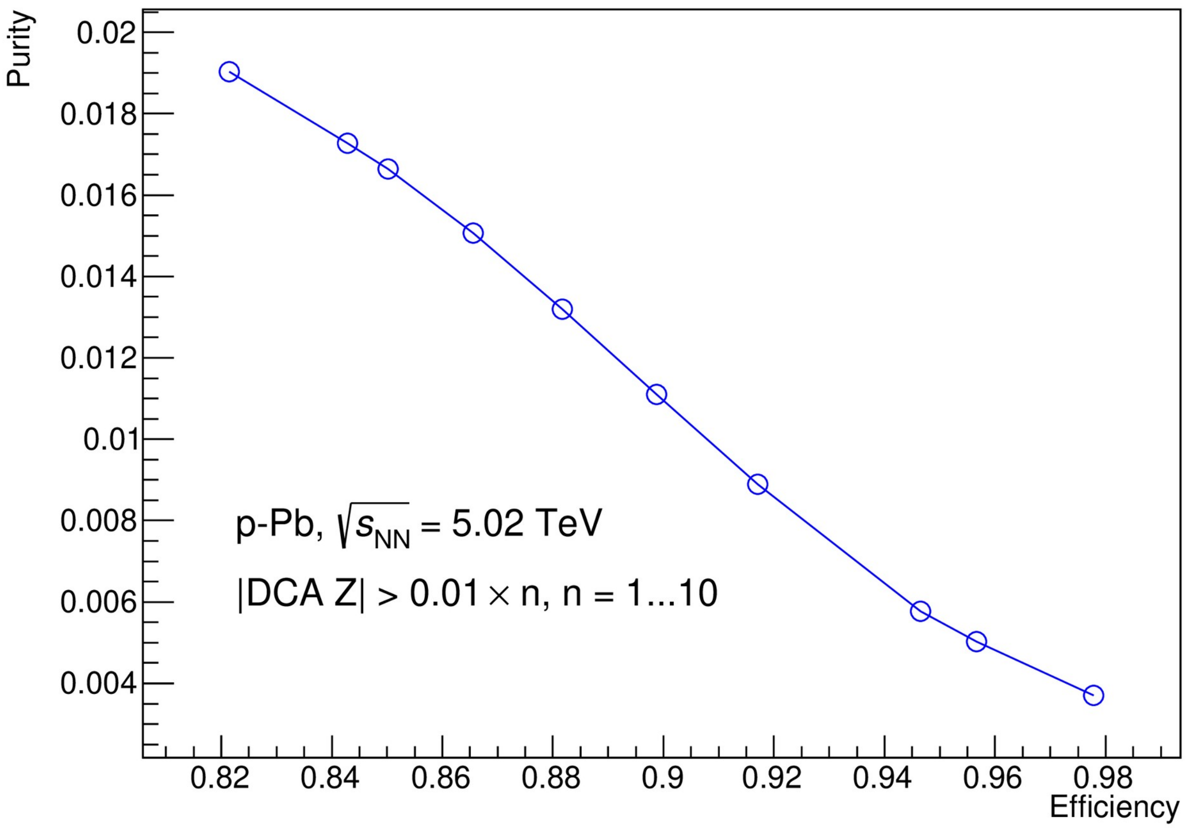




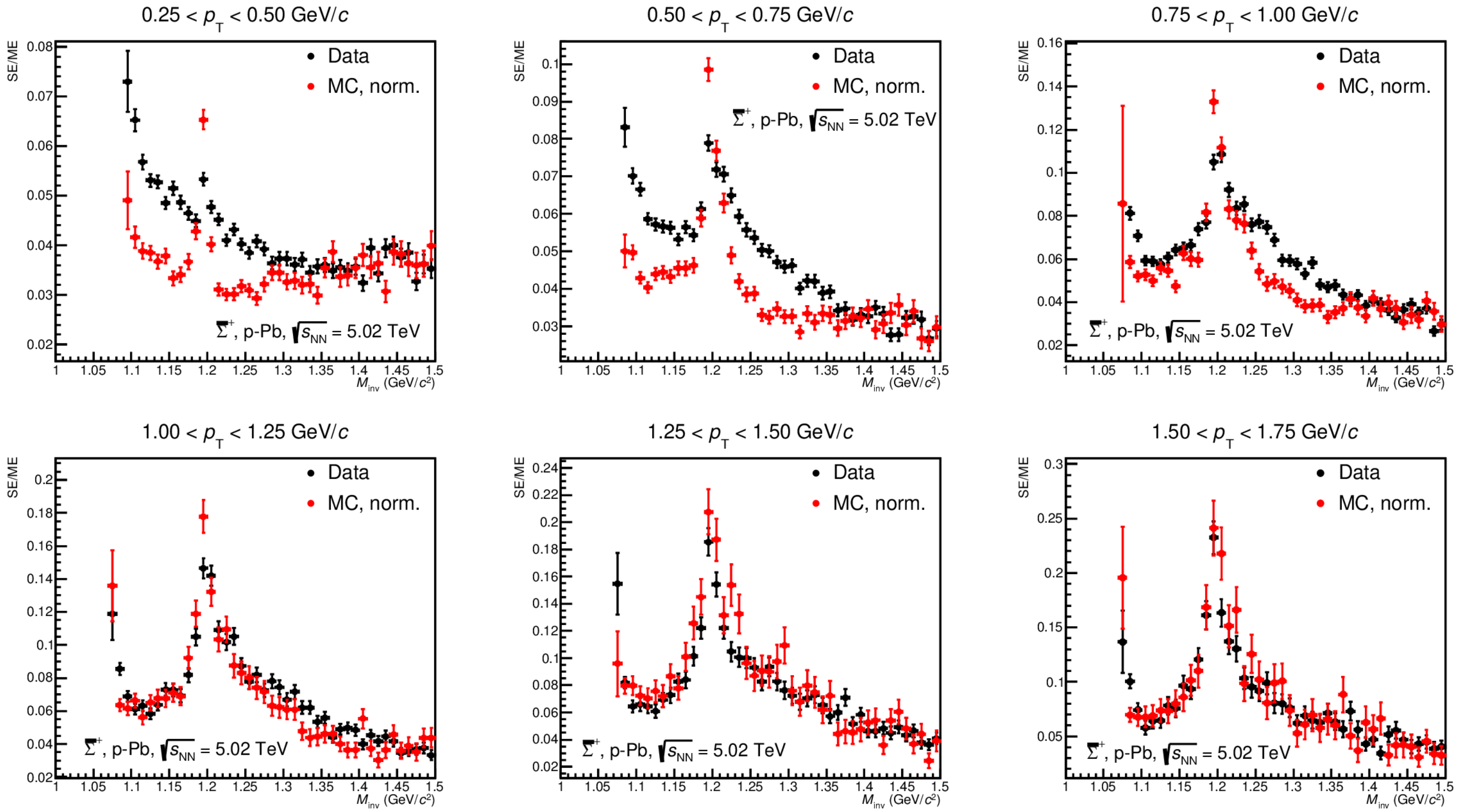


Topological selections. Eff vs Pur. p-Pb

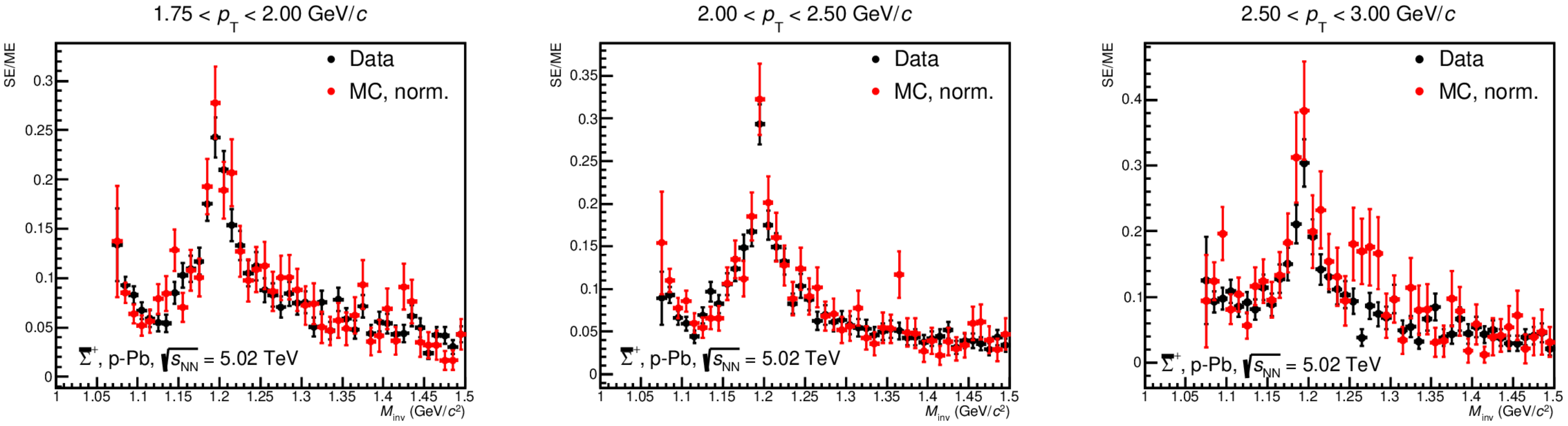




Compare SE/ME. Data and MC



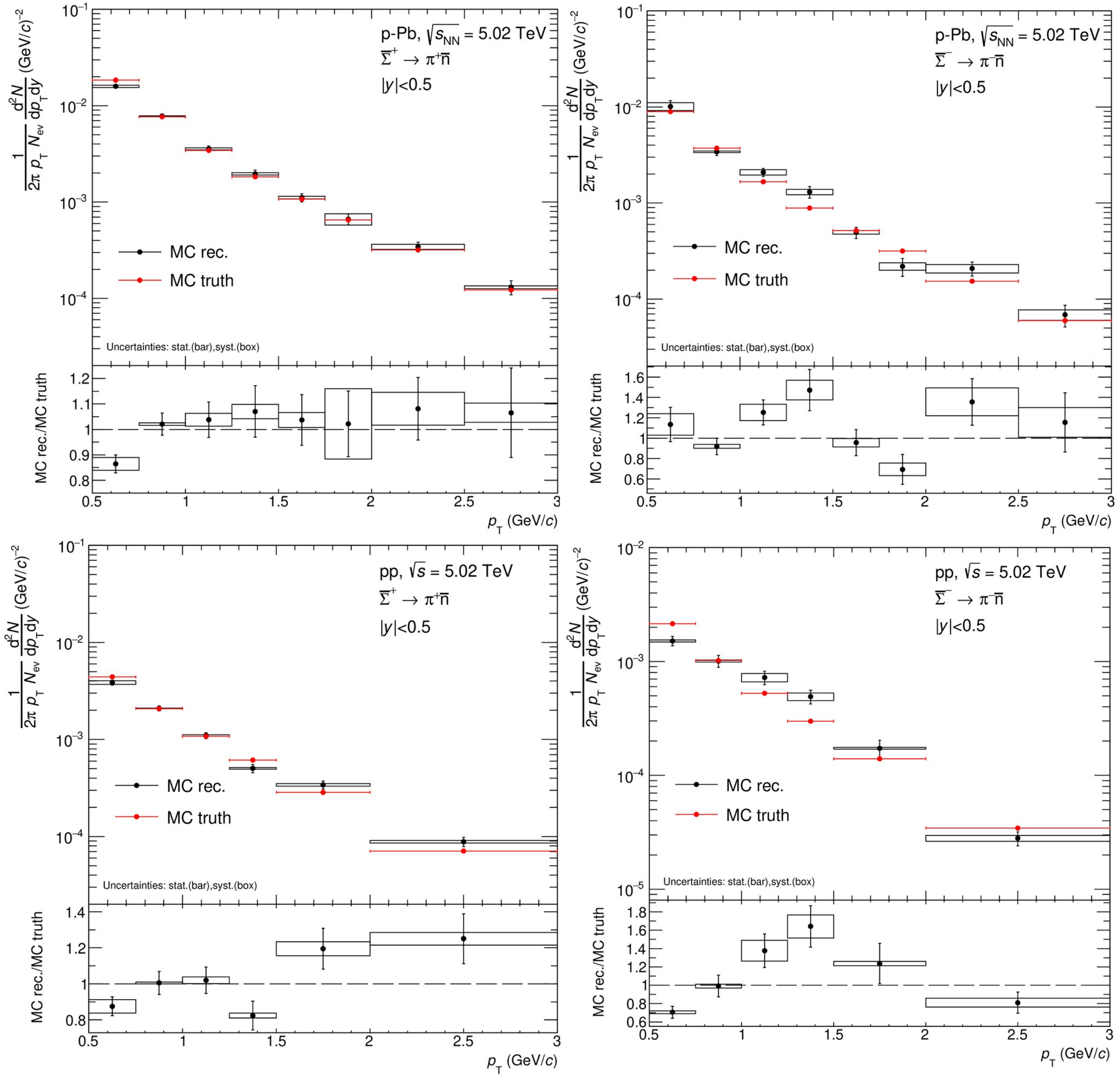
Compare SE/ME. Data and MC

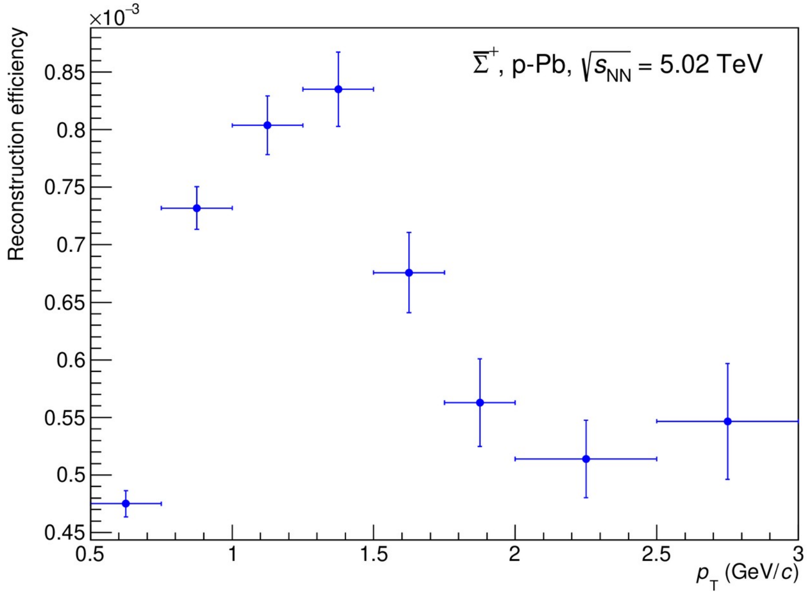


- For low pT S/Bg ratio is not consistent between Data and MC
- It results in large systematic uncertainties
- Here and below plots only for $\bar{\Sigma}^+$ are shown. The rest can be found in AN

MC closure test

- MC treated as Data and signal extraction procedure was performed
- Reconstruction efficiency – ratio of true AntiSigma that passes all selection to MC truth generated spectrum of AntiSigma in |y|<0.5



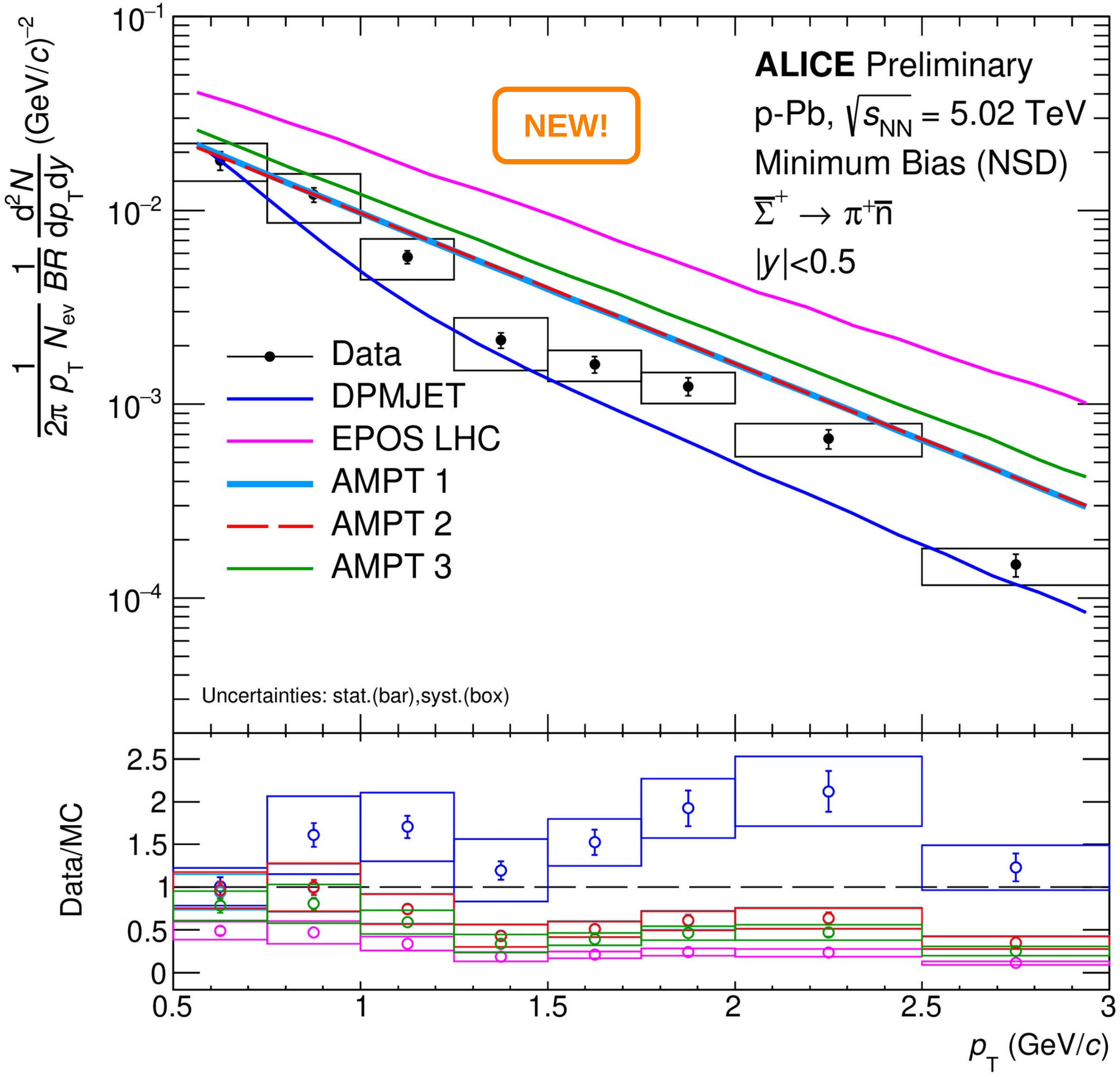


Spectrum of $\bar{\Sigma}$

- All syst. uncertainties are shown with box
- NSD and INEL>0 corrections are introduced for p-Pb and pp respectively
- NSD correction factor

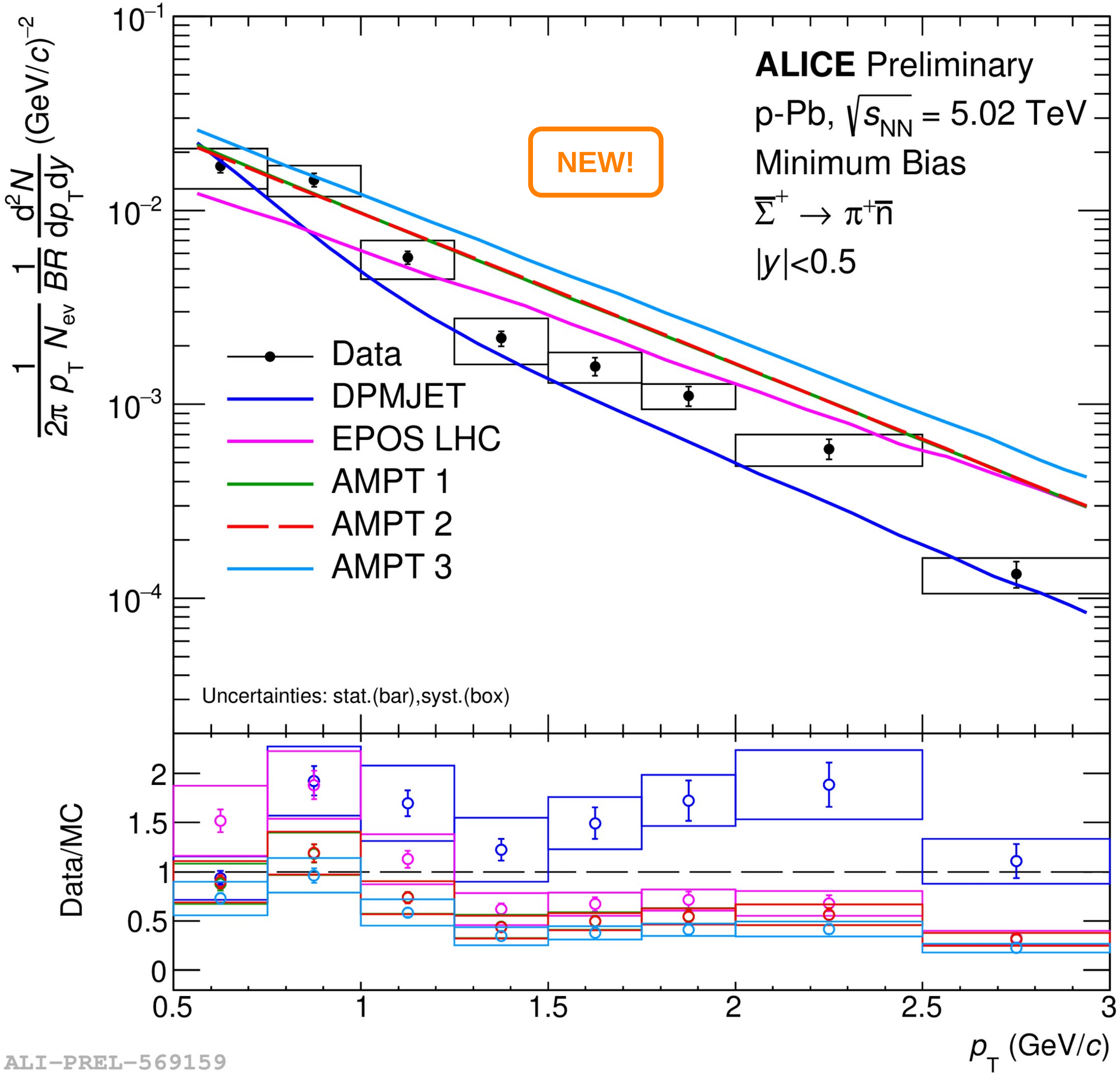
  0.964 ± 0.031
- INEL>0 correction factor

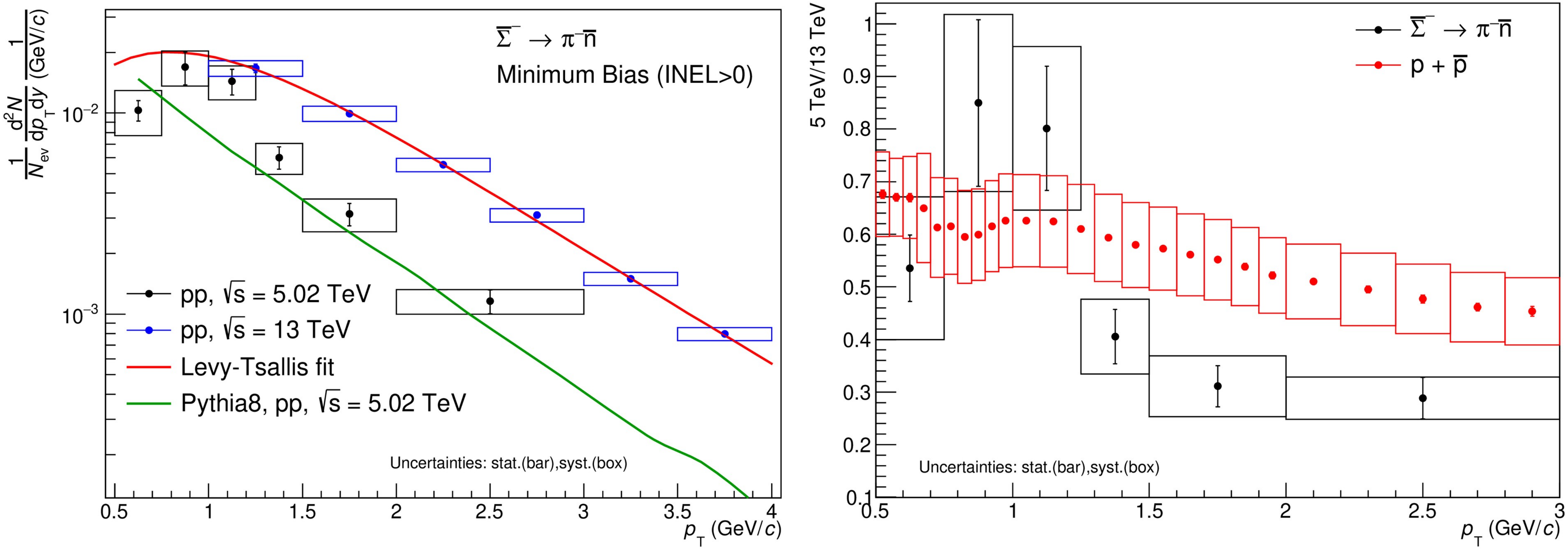
  0.7574 ± 0.0190



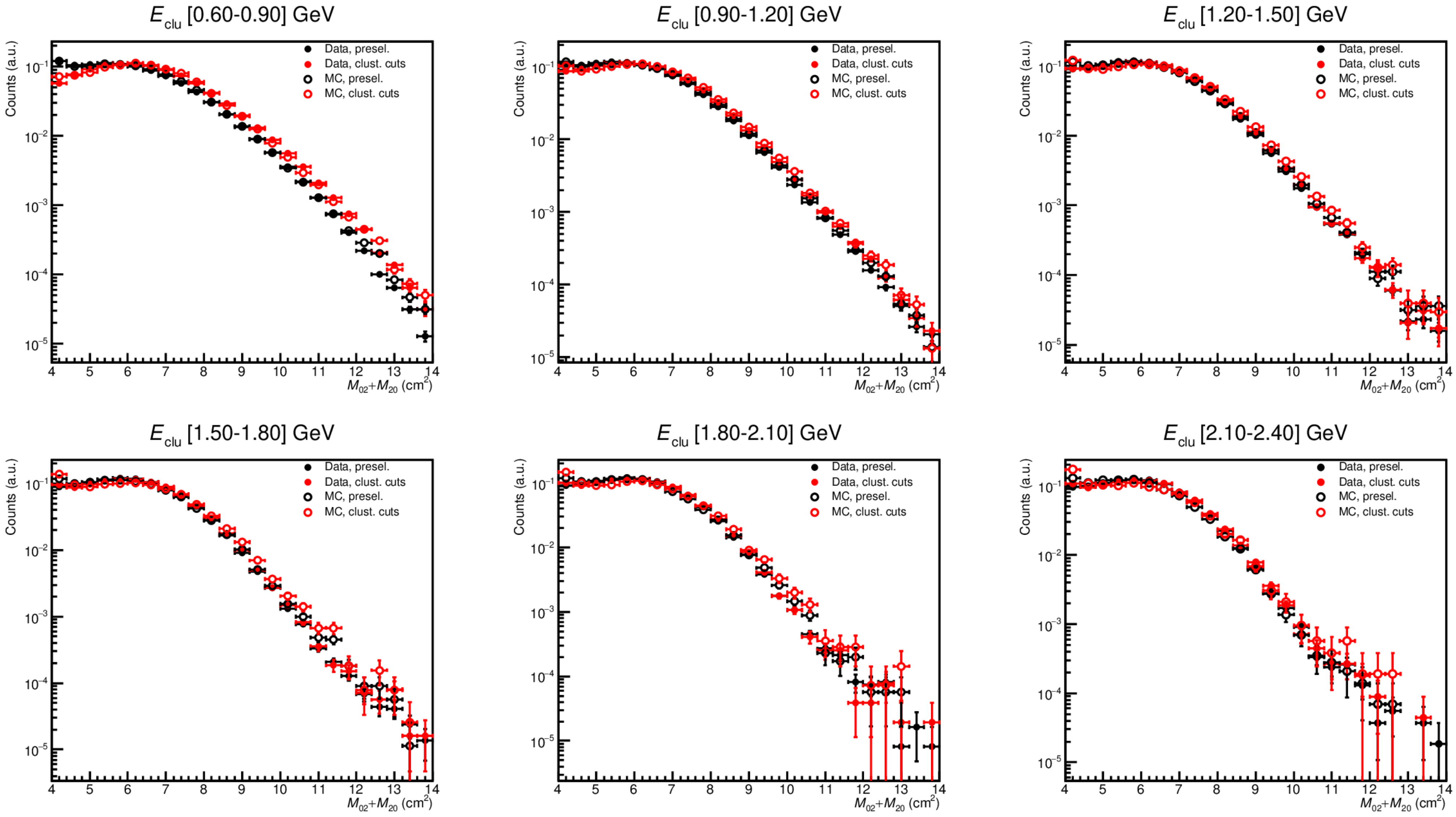
Spectrum of $\bar{\Sigma}$

- All syst. uncertainties are shown with box
- AMPT_1 - the hadron rescattering is switched off and the String melting is switched on. With shadowing
- AMPT_2 - the hadron rescattering is switched on and the String melting is switched on
- AMPT_3 - the hadron rescattering is switched off and the String melting is switched on. Without shadowing

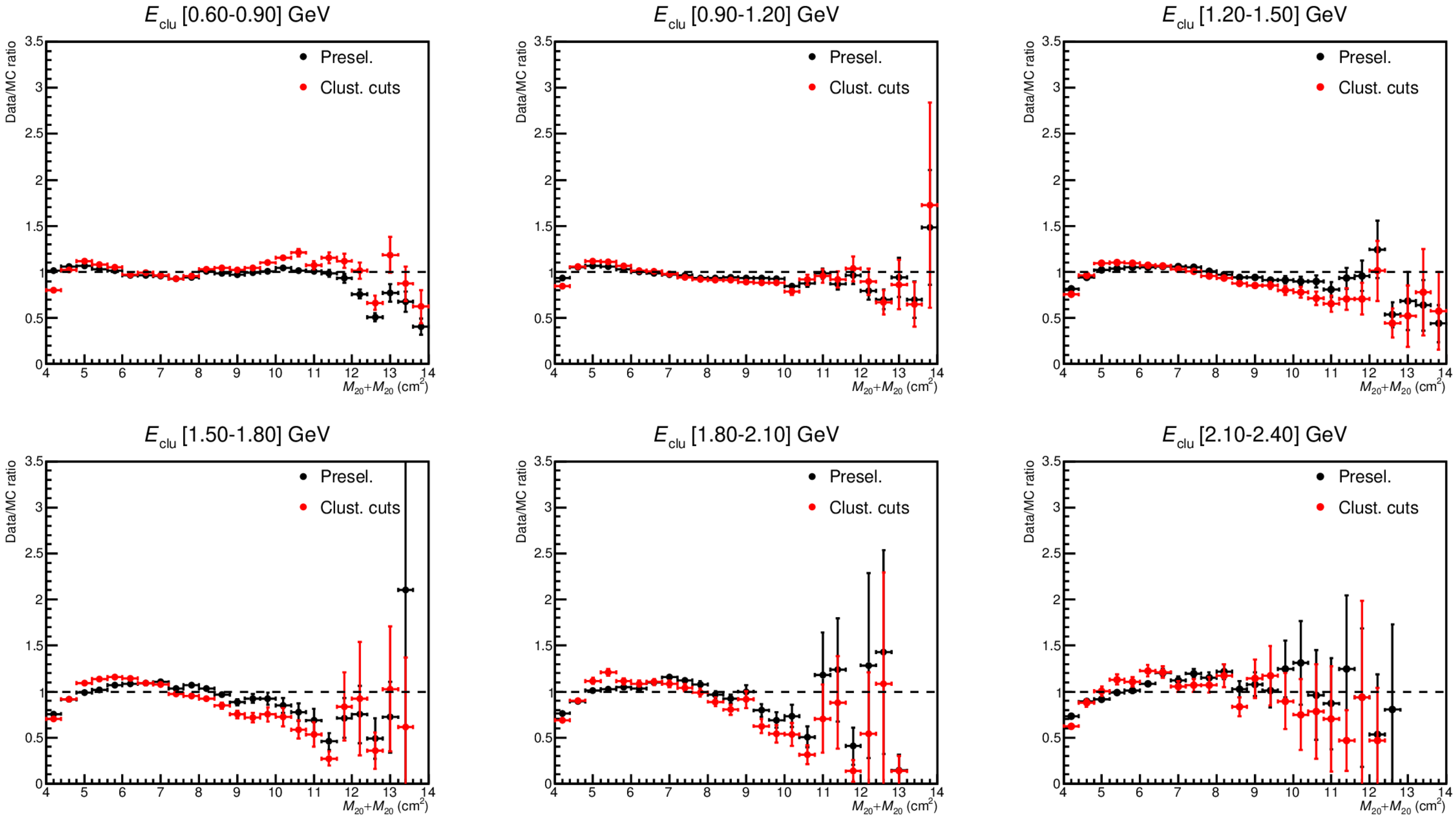



$\overline{\Sigma}^{-} \to \pi^{-}\overline{n}$
Minimum Bias (INEL>0)
$\frac{1}{N_{ev}} \frac{d^2N}{dp_T dy} \frac{1}{(GeV/c)}$
pp, √s = 5.02 TeV
pp, √s = 13 TeV
Levy-Tsallis fit
Pythia8, pp, √s = 5.02 TeV
Uncertainties: stat.(bar),syst.(box)
p_T (GeV/c)
5 TeV/13 TeV
$\overline{\Sigma}^{-} \to \pi^{-}\overline{n}$
p + $\overline{p}$
Uncertainties: stat.(bar),syst.(box)
p_T (GeV/c)

Dispersion parameters. MC closure. p-Pb



Dispersion parameters. MC closure. p-Pb



Pbar and Nbar spectra

Steps:

- We correct the measured spectrum in the data by Purity
- Then, correct the spectrum by Efficiency

- No feed-down correction. The results are not final and demonstrate the possibility of measuring nbar and pbar spectrum using PHOS (in current analysis)

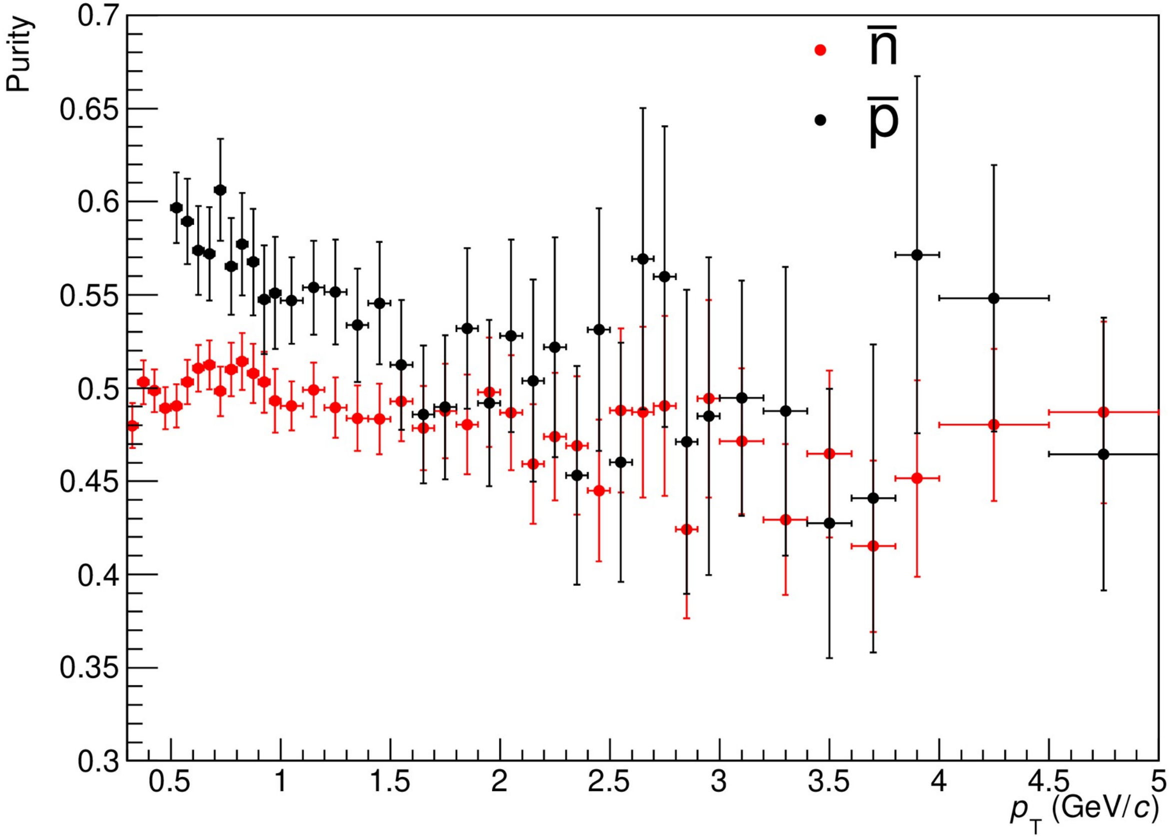
$$\text{Purity} = \frac{dN_{\text{nbar truth,all cuts, in PHOS}}/dp_T}{dN_{\text{nbar candidate,all cuts, in PHOS}}/dp_T}$$

$$\text{Efficiency} = \frac{dN_{\text{nbar truth, all cuts, in PHOS}}/dp_T}{dN_{\text{gen},|y|<0.5}/dp_T}$$

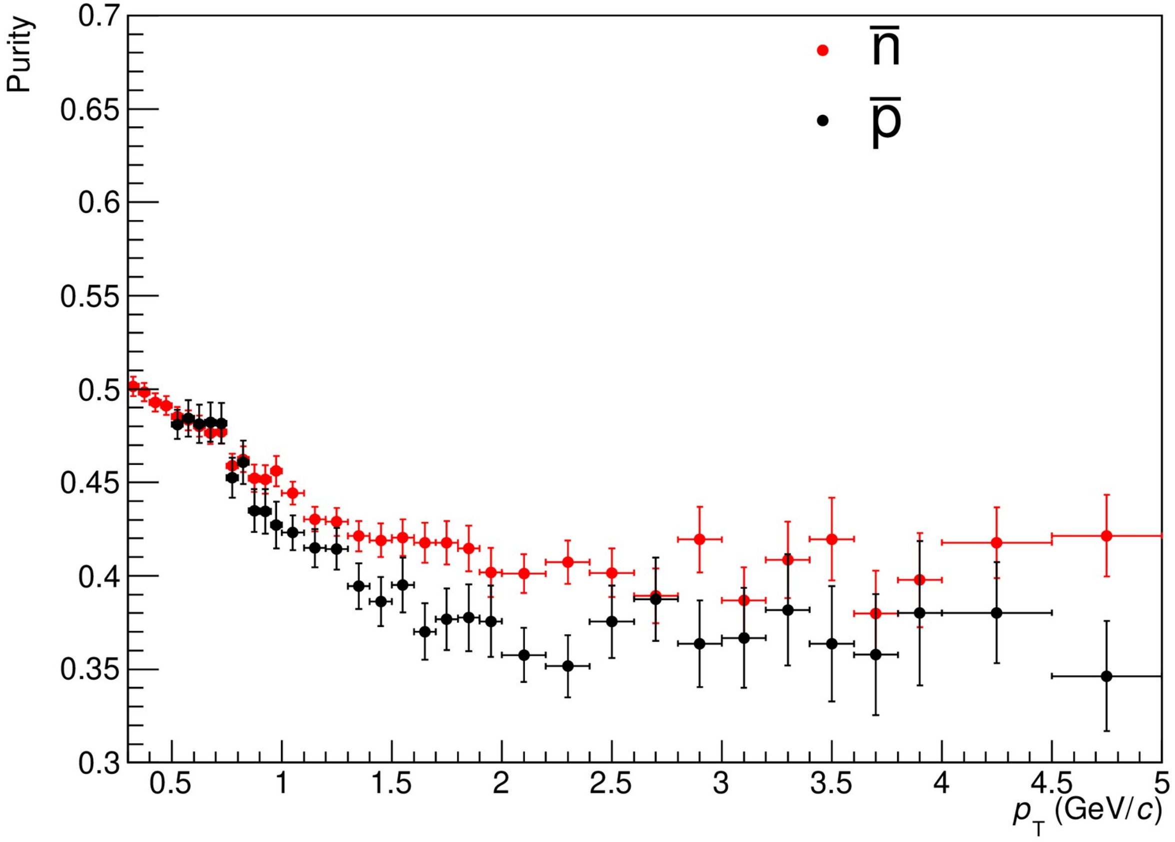
$\bar{n}$	$\bar{p}$
$\text{M02} > 0.2\ \text{cm}^2$	$\text{M02} > 0.2\ \text{cm}^2$
$E_{\text{clu}} \geq 0.6\ \text{GeV}$	$E_{\text{clu}} \geq 0.6\ \text{GeV}$
$N_{\text{cells}} \geq 7$	$N_{\text{cells}} \geq 7$
$\text{CPV} > 10\sigma$	$\text{CPV} < 2\sigma$
$\text{M20} \geq -\text{M02} + 4$	$\text{M20} \geq -\text{M02} + 4$
$0 < \text{TOF} - t_\gamma < 150\ \text{ns}$	$0 < \text{TOF} - t_\gamma < 150\ \text{ns}$

- Associated track: TPC dE/dx PID: 3σ
- Taking into account the curvature of the track

Purity

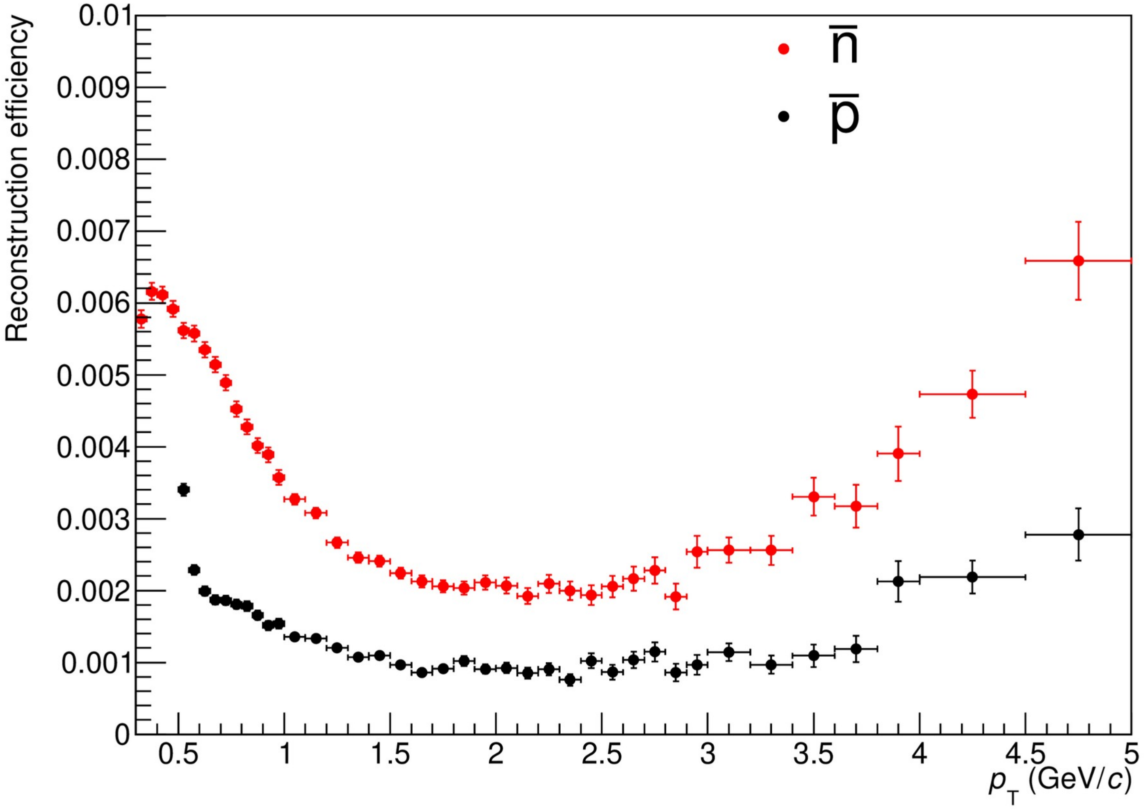


p-Pb

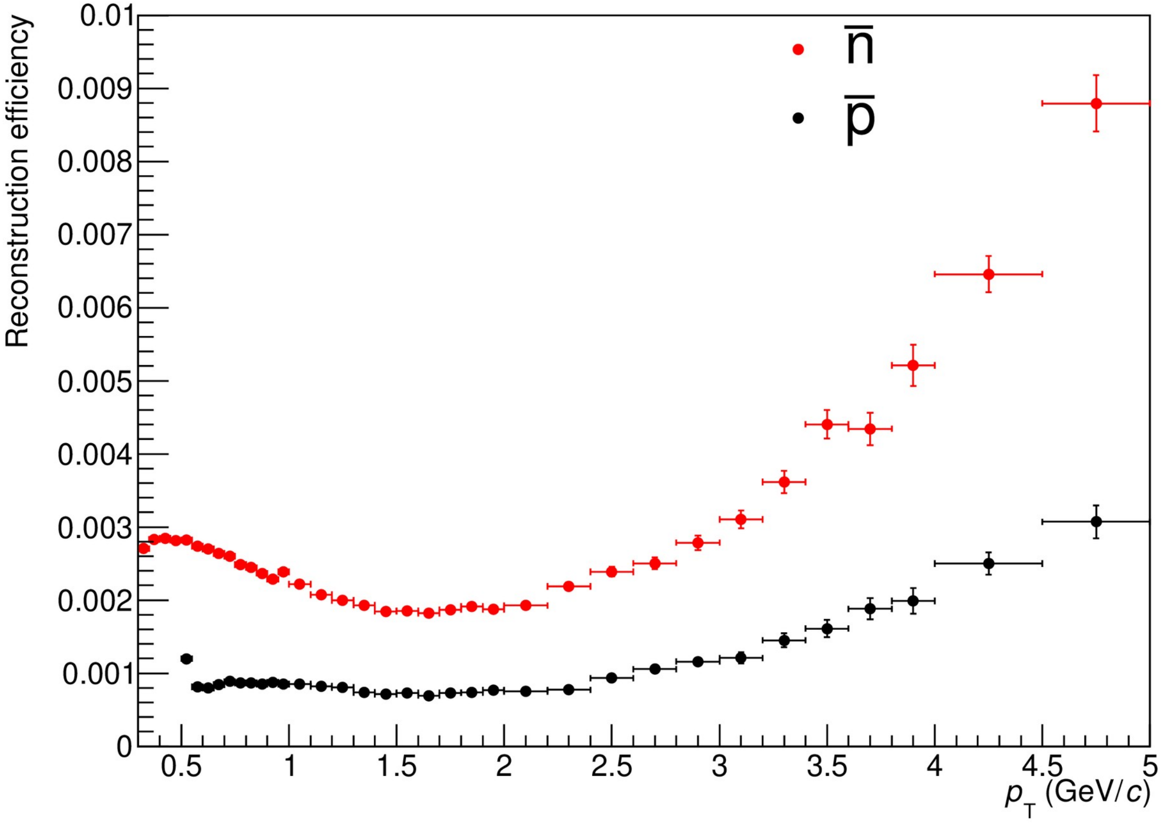


pp

Efficiency



p-Pb



pp

Comparison with published results