Progress with the Nuons model

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May 8 2015

A NUON based particle zoo

heresy?, joke?,

ATLAS meeting 27 January 2012

René Brun

Talk overview

- Quick summary of the model
- Particle masses: better and better
- Magnetic moment
- Elastic Scattering: p-p & p-pbar
- Collisions at LHC
  - Particles kinematics
  - Jets
  - Multiple “Parton” Interactions
- Next steps

The model in 3 words

Particles masses and Magnetic Moment

Programs findall.C, showmass.C, drawmass.C

Decays

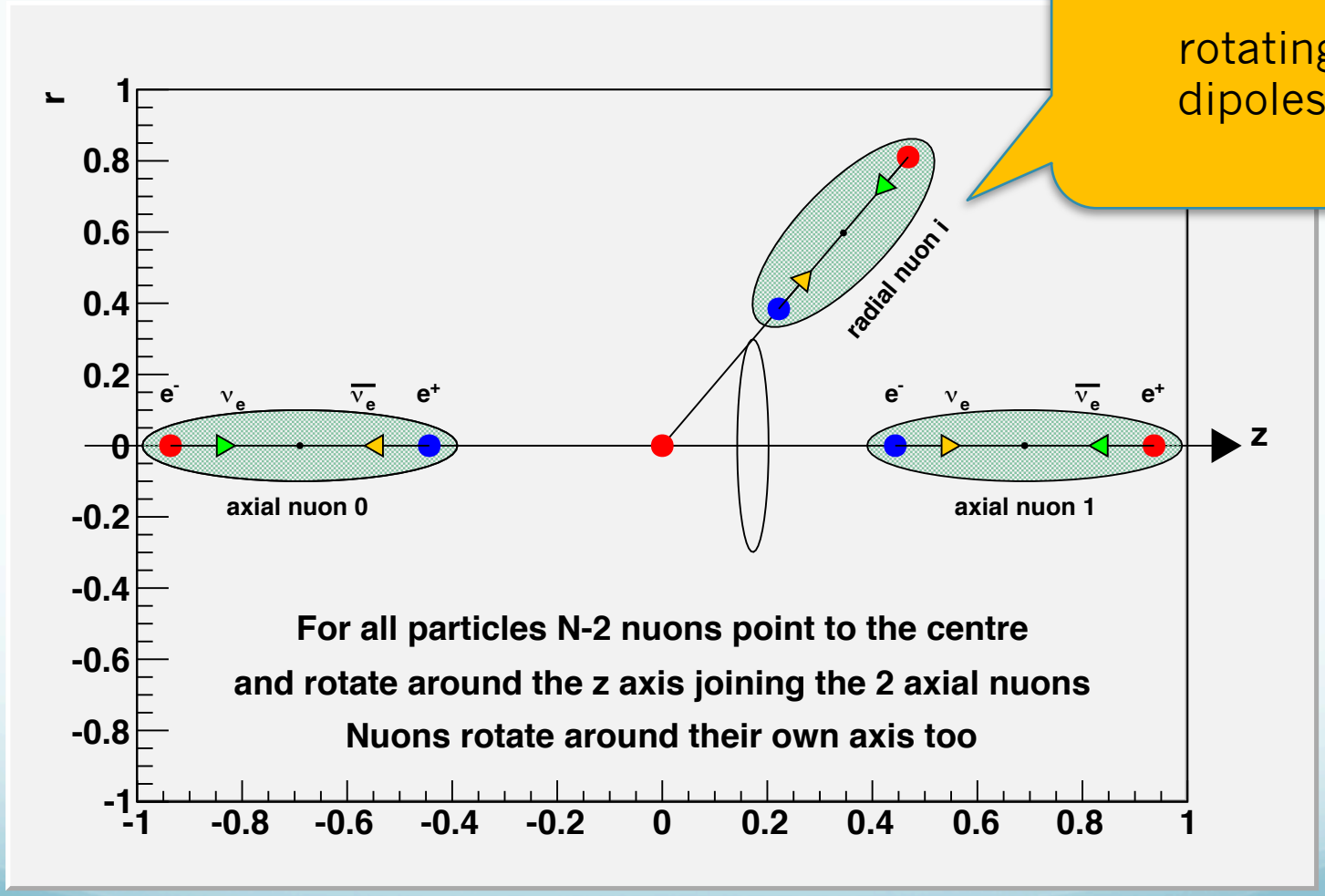
μ^- DECAY MODES		Fraction (Γ_j/Γ)	Co
$e^-\,\overline{\nu}_e\,\nu_\mu$		$\approx 100\%$	
$e^-\,\nu_e\,\nu_\mu\,\gamma$	[d]	$(1.4\pm0.4)\,\%$	
$e^-\,\nu_e\,\nu_\mu\,e^+\,e^-$	[e]	$(3.4\pm0.4)\times10^{-5}$	

π^+ DECAY MODES		Fraction (Γ_j/Γ)	Confidence
$\mu^+\,\nu_\mu$	[b]	$(99.98770\pm0.00004)\,\%$	
$\mu^+\,\nu_\mu\,\gamma$	[c]	$(\ 2.00\ \pm0.25\ )\times10^{-4}$	
$e^+\,\nu_e$	[b]	$(\ 1.230\ \pm0.004\ )\times10^{-4}$	
$e^+\,\nu_e\,\gamma$	[c]	$(\ 1.61\ \pm0.23\ )\times10^{-7}$	
$e^+\,\nu_e\,\pi^0$		$(\ 1.036\ \pm0.006\ )\times10^{-8}$	
$e^+\,\nu_e\,e^+\,e^-$		$(\ 3.2\ \pm0.5\ )\times10^{-9}$	
$e^+\,\nu_e\,\nu\,\overline{\nu}$		$<\ 5$ $\times10^{-6}$	
γ positronium		$(\ 1.82\ \pm0.29\ )\times10^{-9}$	
$e^+\,e^+\,e^-\,e^-$		$(\ 3.14\ \pm0.30\ )\times10^{-5}$	
$e^+\,e^-$		$(\ 6.2\ \pm0.5\ )\times10^{-8}$	
4γ		$<\ 2$ $\times10^{-8}$	CL=90%
$\nu\,\overline{\nu}$	[e]	$<\ 2.7$ $\times10^{-7}$	CL=90%
$\nu_e\,\overline{\nu}_e$		$<\ 1.7$ $\times10^{-6}$	CL=90%
$\nu_\mu\,\overline{\nu}_\mu$		$<\ 1.6$ $\times10^{-6}$	CL=90%
$\nu_\tau\,\overline{\nu}_\tau$		$<\ 2.1$ $\times10^{-6}$	CL=90%
$\gamma\,\nu\,\overline{\nu}$		$<\ 6$ $\times10^{-4}$	CL=90%

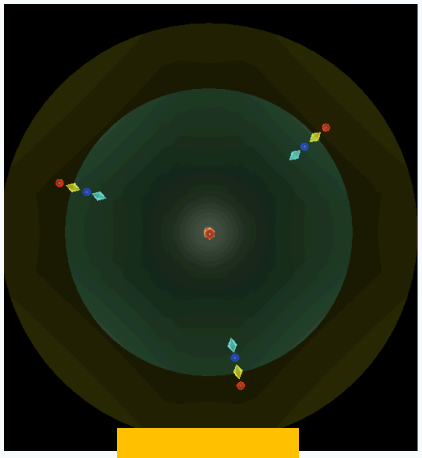
π^0 DECAY MODES		Fraction (Γ_j/Γ)	Confidence level	(M
2γ		$(98.798\pm0.032)\,\%$	S=1.1	
$e^+\,e^-\,\gamma$		$(\ 1.198\pm0.032)\,\%$	S=1.1	
γ positronium		$(\ 1.82\ \pm0.29\ )\times10^{-9}$		
$e^+\,e^+\,e^-\,e^-$		$(\ 3.14\ \pm0.30\ )\times10^{-5}$		
$e^+\,e^-$		$(\ 6.2\ \pm0.5\ )\times10^{-8}$		
4γ		$<\ 2$ $\times10^{-8}$	CL=90%	
$\nu\,\overline{\nu}$	[e]	$<\ 2.7$ $\times10^{-7}$	CL=90%	
$\nu_e\,\overline{\nu}_e$		$<\ 1.7$ $\times10^{-6}$	CL=90%	
$\nu_\mu\,\nu_\mu$		$<\ 1.6$ $\times10^{-6}$	CL=90%	
$\nu_\tau\,\nu_\tau$		$<\ 2.1$ $\times10^{-6}$	CL=90%	
$\gamma\,\nu\,\overline{\nu}$		$<\ 6$ $\times10^{-4}$	CL=90%	

Confidence level	(MeV/c)
2) % S=1.1	67
2) % S=1.1	67
	67
	67
	67
CL=90%	67
CL=90%	67
CL=90%	67
CL=90%	67
CL=90%	67
CL=90%	67

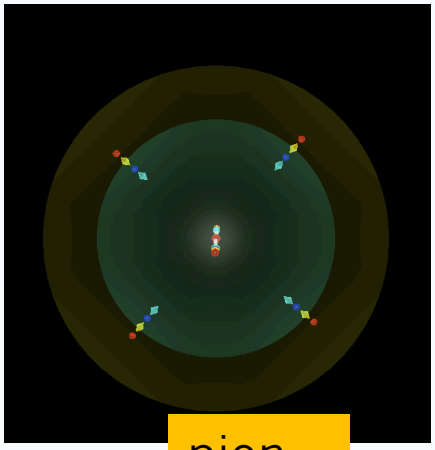
Nuon : a building block



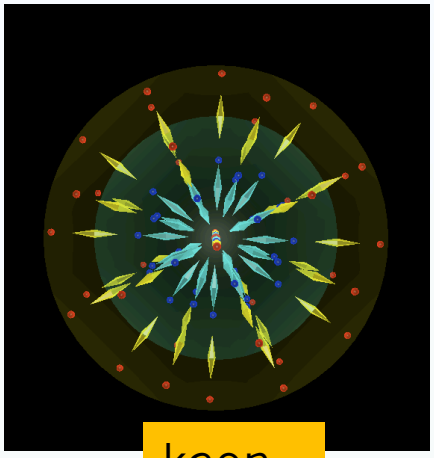
some particles



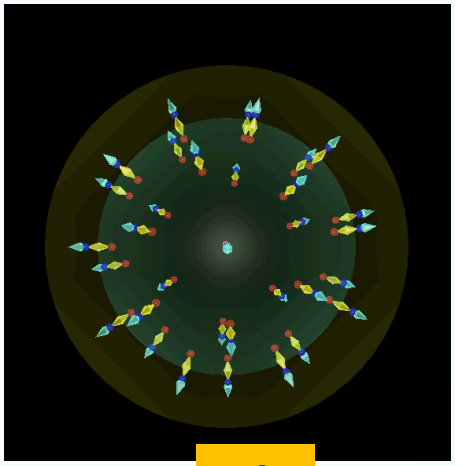
muon



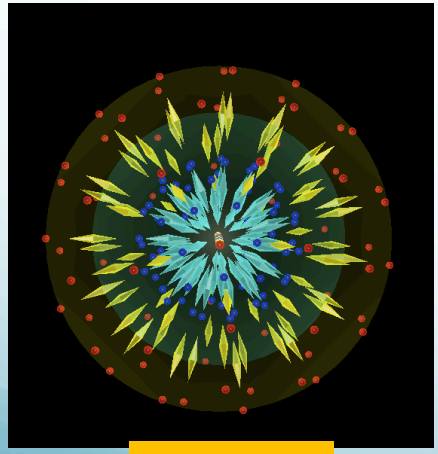
pion



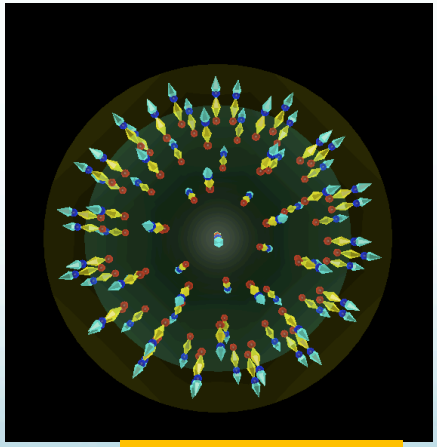
kaon



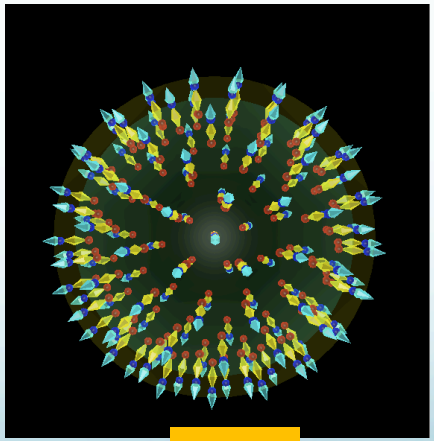
K0



proton



Lambda

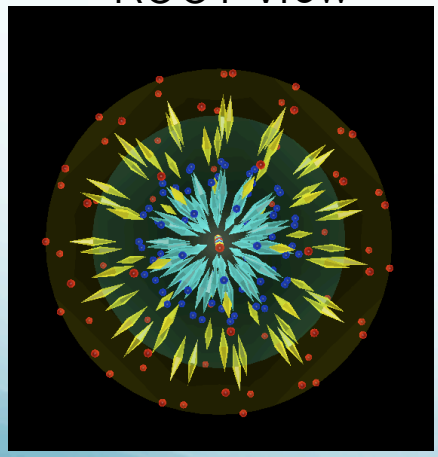


D0

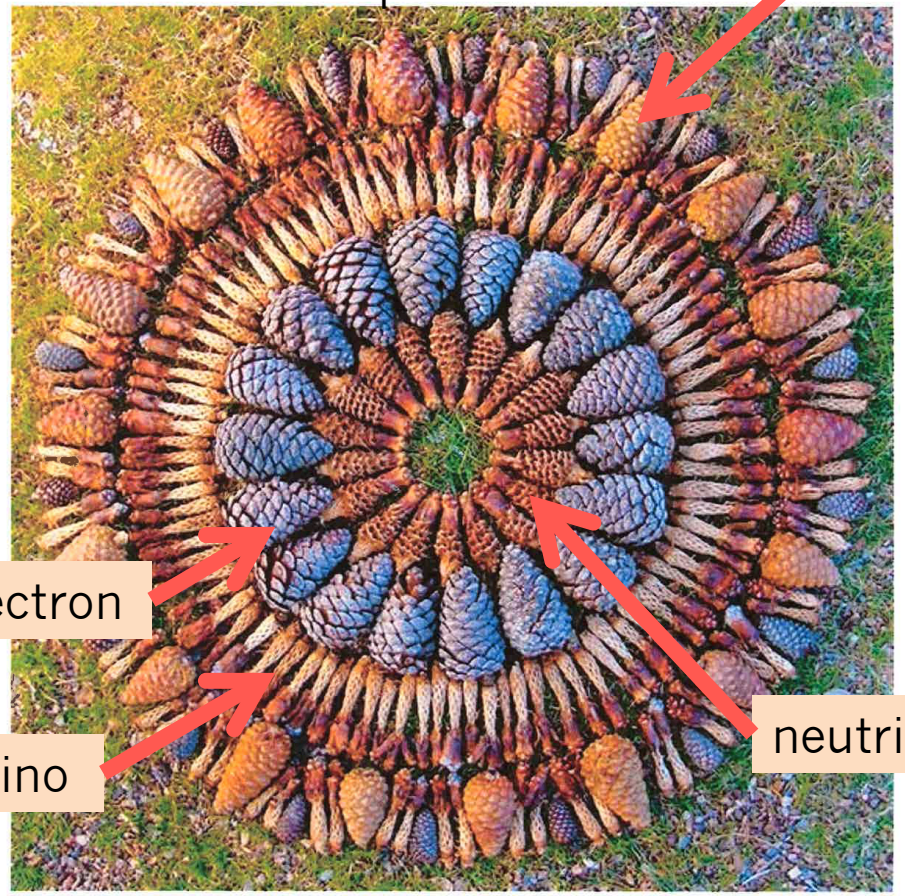
Proton Views

Engineer view

ROOT view



Artist/spiritual view



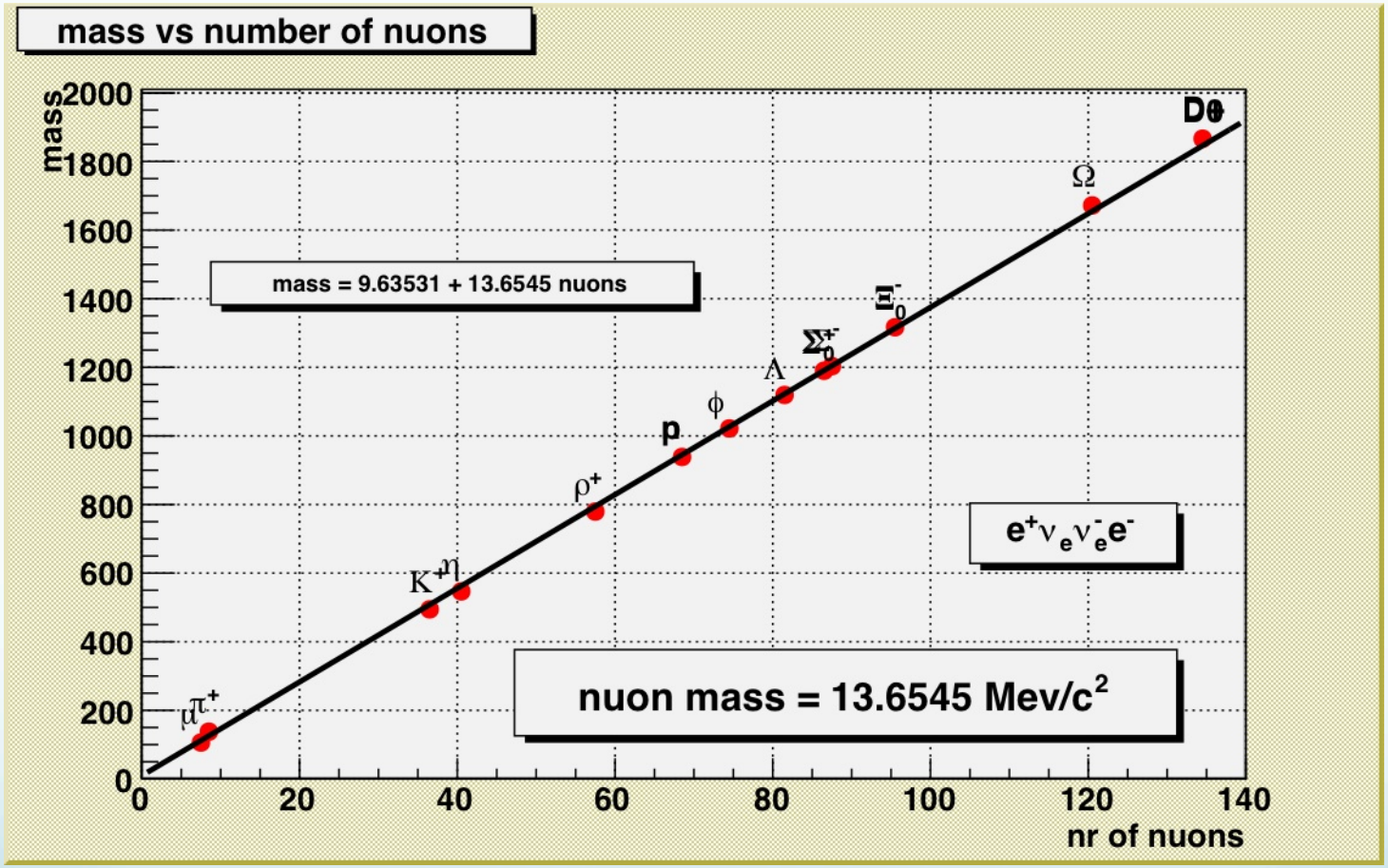
mass

Magnetic moment

keep_findall_5473.root with 7326 events Thu May 7 10:20:28 2015

nuons	quarks	spin	rings	PDG mass (MeV)	nuons model (MeV)	PDG-nuons PDG	mmexp/mmq (μn)	mm_nuons (μn)	life time (seconds)
μ^+ 3		1/2	1	105.658	105.585	-0.000691 (6886)	8.89/?? -5.37e-08	8.900 -1211.2 0.02	2.2e-06
π^+ 4	$u\bar{d}$	0	1	139.57 R = 0.663	139.928 R = 0.628147	0.00257 (6771)	?? -3.2e-08	0.013 -1452.9 0.08	2.6e-08
π_0 4	$(u\bar{u}-d\bar{d})/\sqrt{2}$	0	1	134.976	134.893	-0.000617 (7037)	-?? -0.0294	0.100 -4911.4 4e+05	8.4e-17
K^+ 32	$u\bar{s}$	0	2	493.677	493.604	-0.000149 (6374)	?? -1.29e-05	1.744 351.4 0.005	1.24e-08
K_0 32	$d\bar{s}$	0	2	497.614	497.184	-0.000864 (6622)	-?? -0.225	0.053 -2597.8 0.001	5.11e-08
η 36	$(u\bar{u}+d\bar{d}-2s\bar{s})/\sqrt{6}$	0	2	547.853	548.177	0.000591 (3436)	-?? -0.253	0.051 -3083.7 1e+03	3.5e-08
ρ^+ 52	$u\bar{d}$	1	3	770	767.863	-0.00278 (3088)	2±0.5/? 2.63e-05	3.007 1085.4 0.01	4.5e-24
ω_0 53	$(\bar{u}u+d\bar{d})/\sqrt{2}$	1	3	782	781.195	-0.00103 (3312)	-?? -0.371	-2.359 -5276.8 9e+02	7.8e-23
p 64	uud	1/2	3	938.272 R = 0.8768	938.304 R = 0.876071	3.41e-05 (5802)	2.793/2.79 -4.31e-05	2.793 1710.1 0.02	1e+40
n 64	udd	1/2	3	939.565	939.386	-0.00019 (5870)	-1.913/1.86 -0.447	-1.958 -6865 6e+02	885.7
ϕ 70	$s\bar{s}$	1	5	1019.45	1020.95	0.00148 (1584)	-?? -0.488	-1.800 -7789.7 8e+02	1.55e-22
Λ 77	uds	1/2	3.5	1115.7	1118.01	0.00207 (1560)	-0.613/0.61 -0.535	-1.642 -8874.8 0.05	2.63e-10
Σ^+ 82	uus	1/2	3.5	1189.37	1191.52	0.00181 (1370)	2.458/2.69 -9.47e-05	2.592 2900 0.02	8.02e-11
Σ_0 82	uds	1/2	3.5	1192.64	1188.7	-0.0033 (1588)	-0.61/0.82 -0.568	-1.543 -9686.3 5	7.4e-20
Σ^- 83	dds	1/2	3.5	1197.45	1205.54	0.00676 (1401)	-1.16/1.04 2.31e-05	-2.583 2974.8 0.02	1.48e-10
Ξ^- 91	dss	1/2	4	1321.7	1319.74	-0.00148 (1313)	-0.651/0.51 -3.46e-05	-2.520 3605.8 0.03	1.64e-10
Ξ_0 91	uss	1/2	4	1314.8	1314.37	-0.000325 (1631)	-1.25/1.44 -0.628	-1.393 -11189 0.1	2.9e-10
Ω^- 116	sss	3/2	4.5	1672.45	1676.55	0.00245 (1346)	-2.02/1.83 0.00019	-2.383 5940.3 0.06	8.21e-11
D+ 130	$c\bar{d}$	0	5.5	1869.6	1877.81	0.00439 (1287)	?? -7.08e-05	1.833 7478.5 0.2	1.04e-18
D0 130	$c\bar{u}$	0	5.5	1864.8	1859.79	-0.00269 (1493)	-?? -0.876	0.030 -18171 0.7	4.1e-17

fnorm = 4000 0.0018133

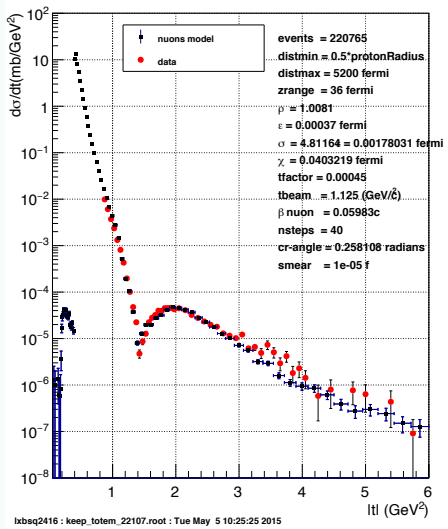

mass vs number of nuons
mass
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
140
nr of nuons
mass = 9.63531 + 13.6545 nuons
nuon mass = 13.6545 Mev/c2
e+νeν-ee-
μπ+
K+η
ρ+
p
ϕ
Λ
Σ0
Ξ-0
Ω
Dθ

Elastic Scattering

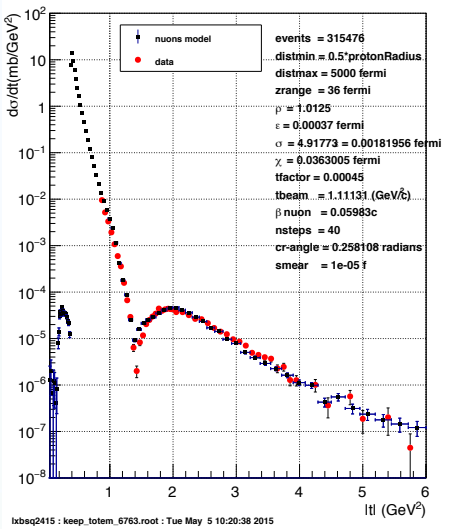
No time to explain the simulator Totem.C.
The program computes the sum of all Coulomb forces when traveling and spinning protons cross each other with a crossing angle.

pp elastic ISR

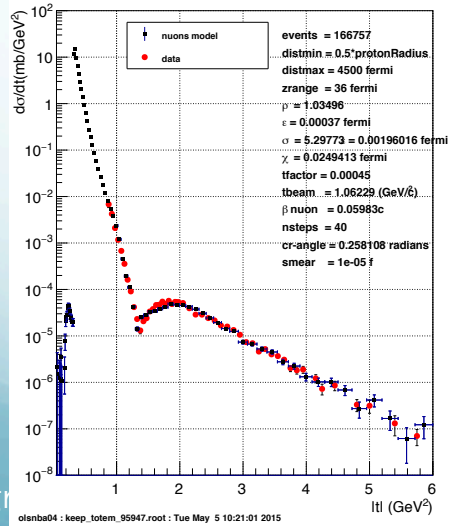
p-p elastic: ISR/SFM√s = 27.43 GeV/c



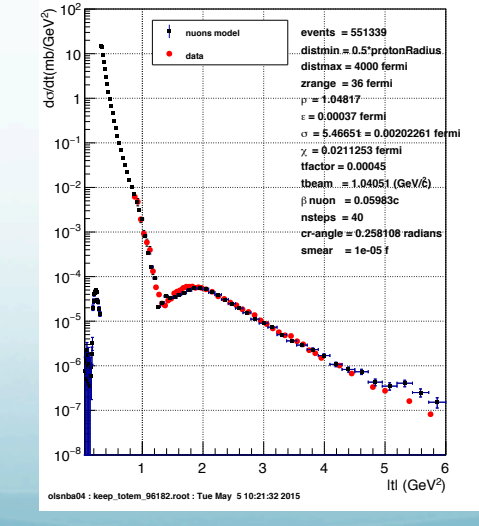
p-p elastic: ISR/SFM √s = 30.5 GeV/c



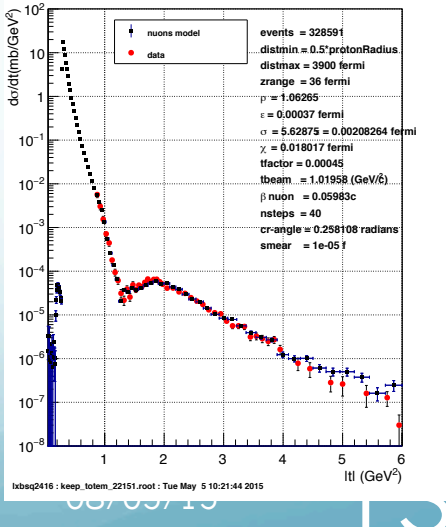
p-p elastic: ISR/SFM √s = 44.6 GeV/c



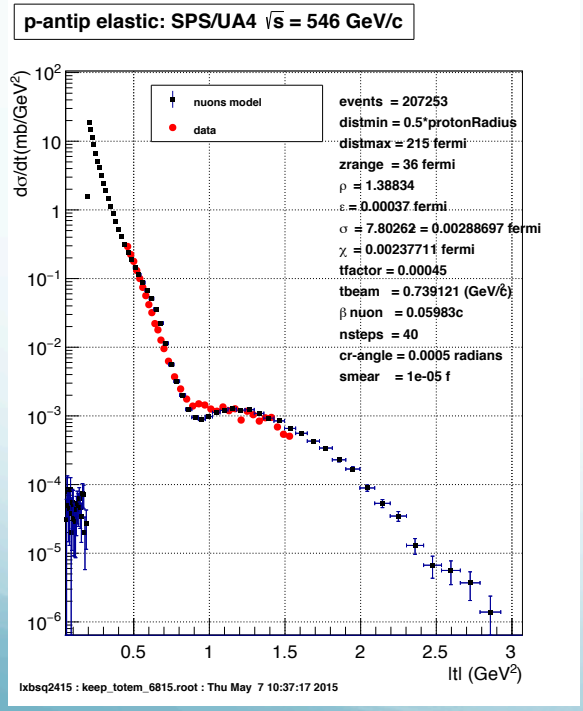
p-p elastic: ISR/SFM √s = 52.8 GeV/c

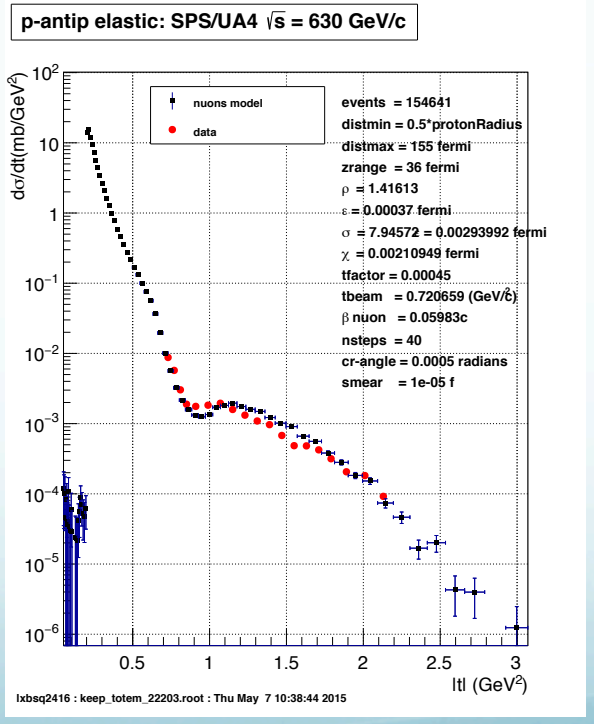


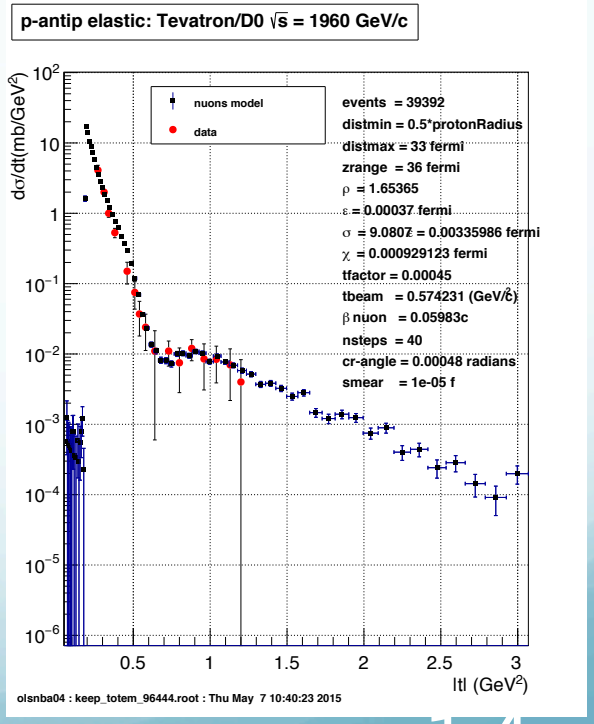
p-p elastic: ISR/SFM √s = 62.1 GeV/c



p-pbar elastic

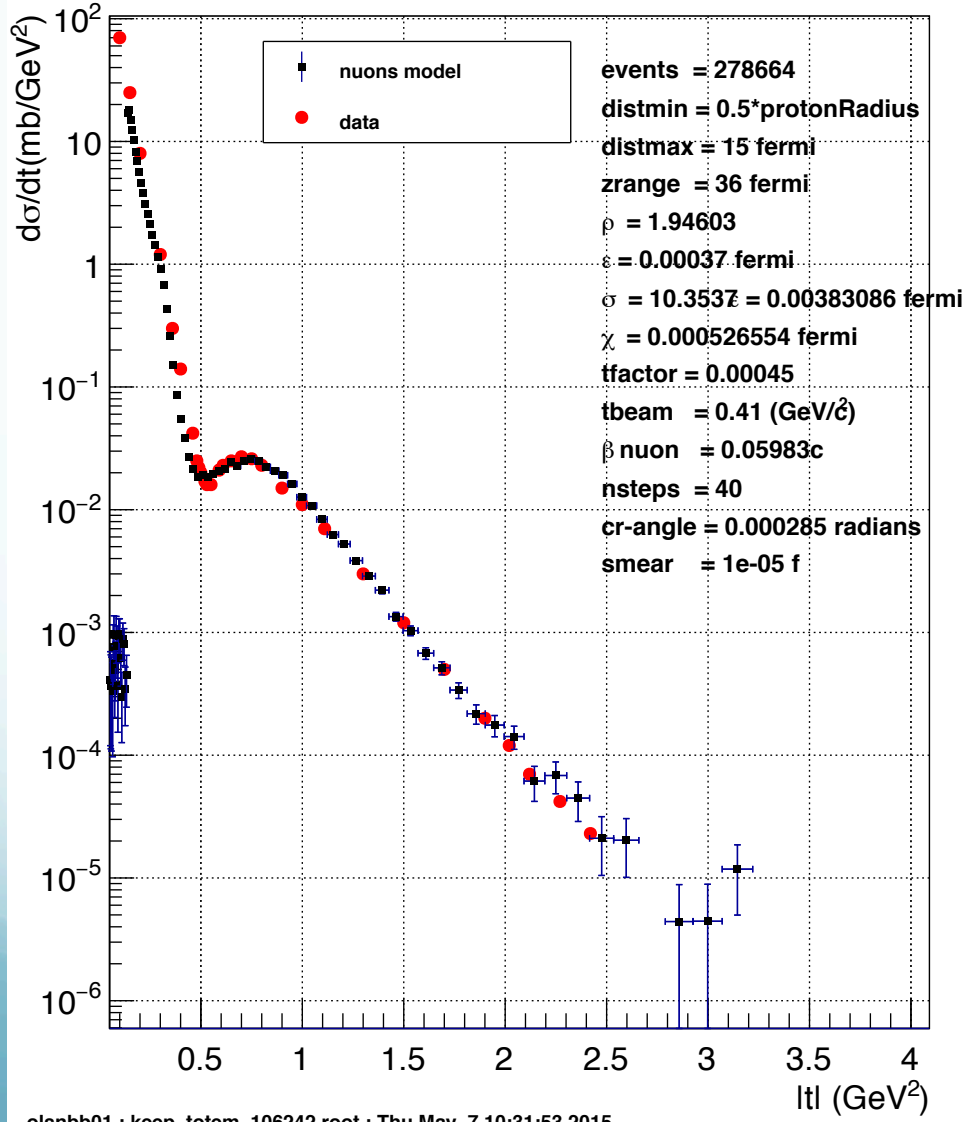






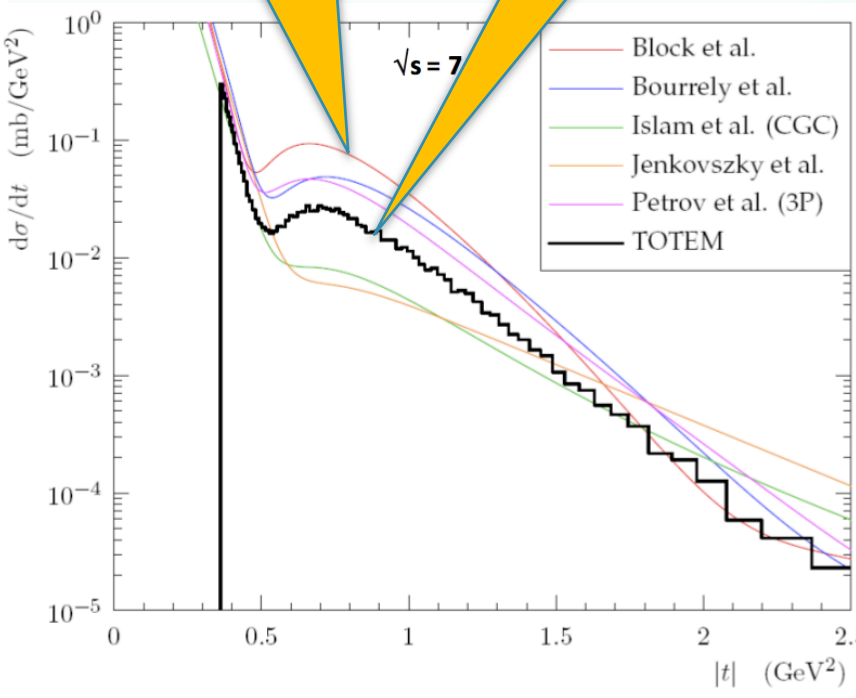
pp elastic at 7 TeV

p-p elastic: $\sqrt{s}$ = 7000 GeV/c

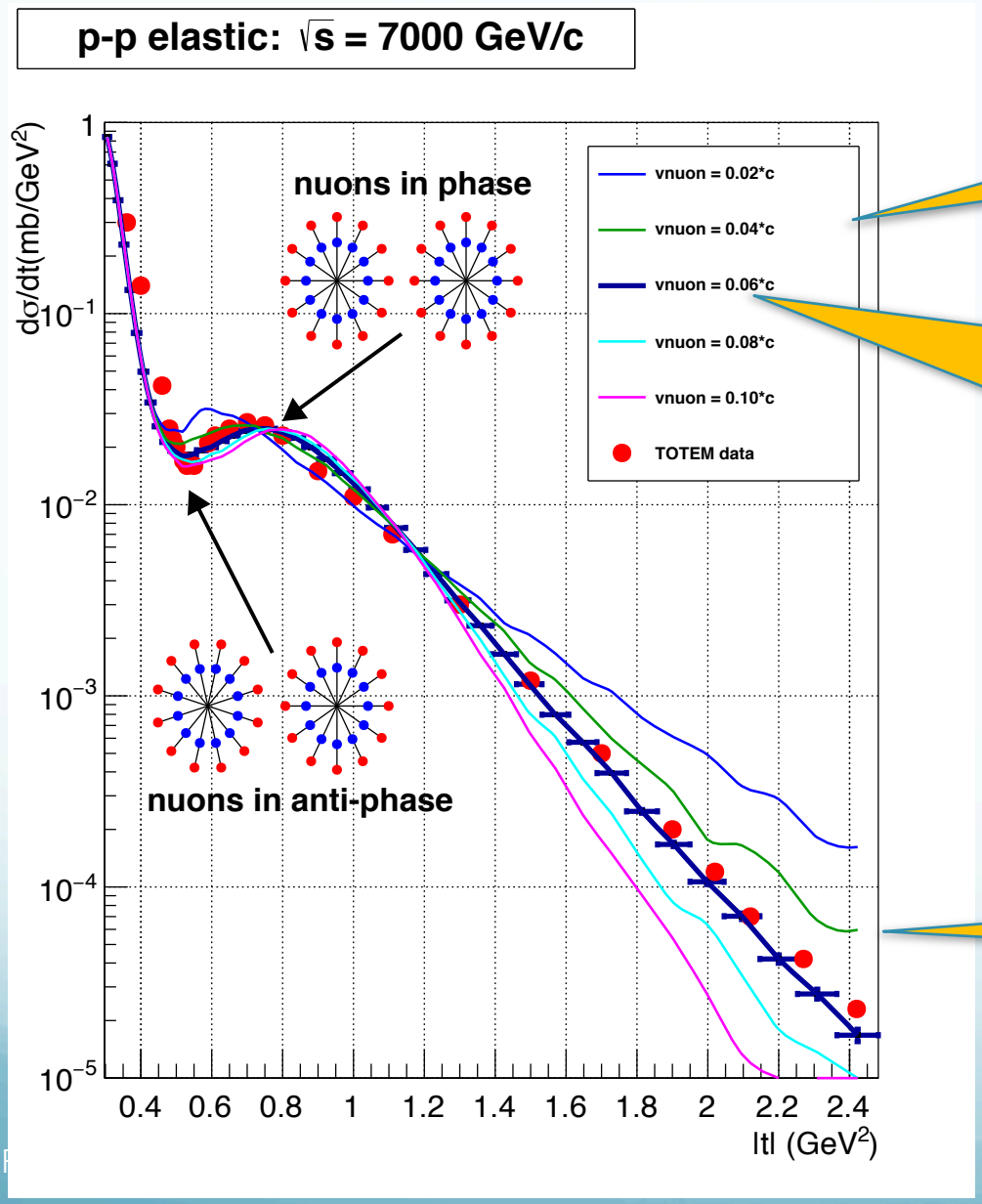


Theoretical predictions from various models

TOTEM results at 7 TeV



Dip and maximum



Vnuon = orbital speed of the positrons

The best value Vnuon=0.06 is in perfect agreement with Vnuon=0.0598 for magnetic moments

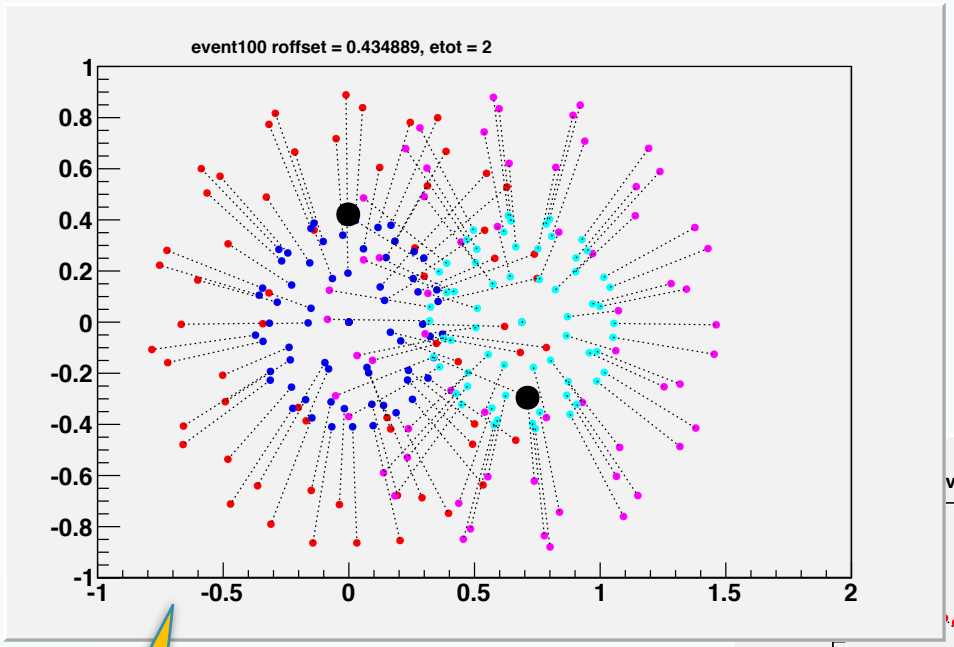
Vnuon effect is only visible above 1 TeV

Collisions at LHC

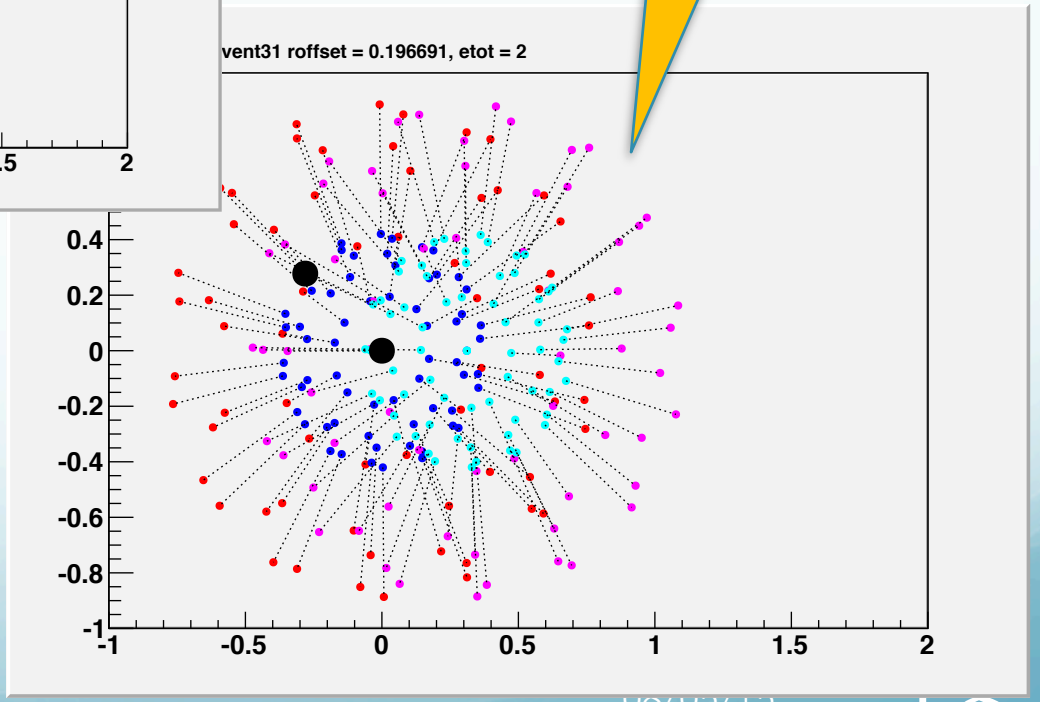
Particles Kinematics, Jets, MPI

Program collide.C

Collisions

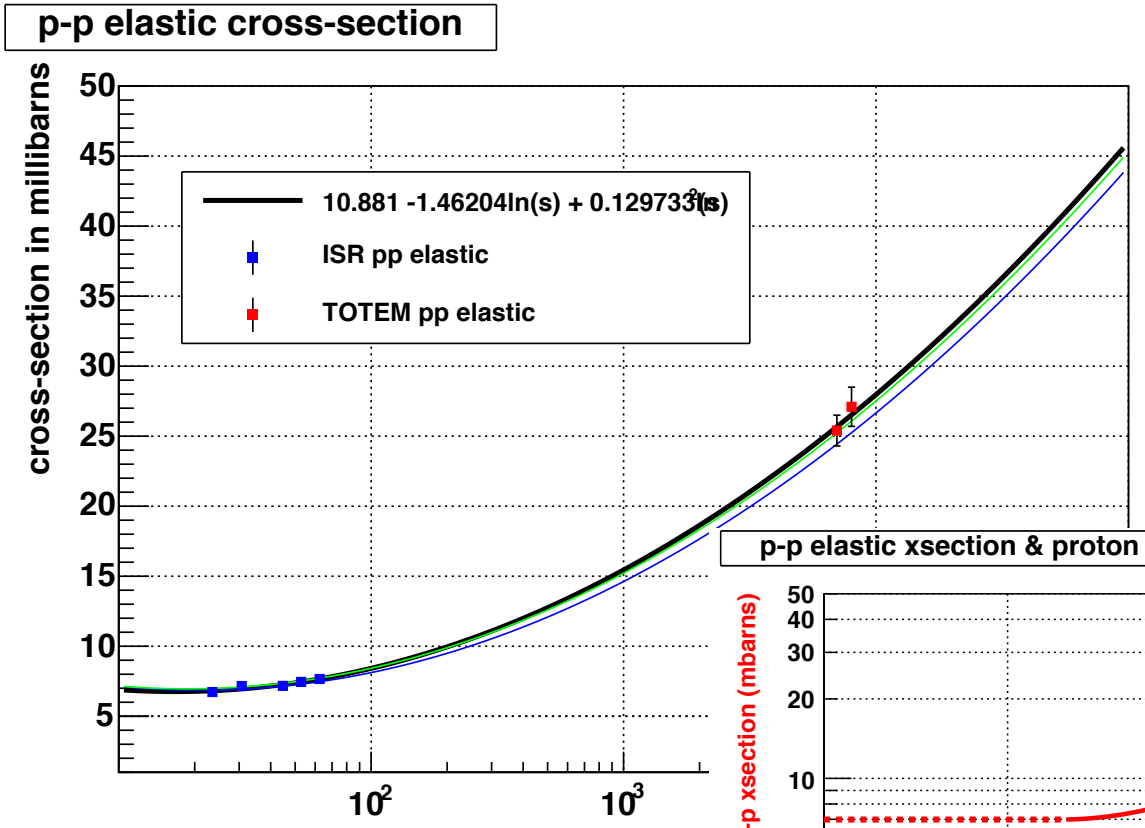


Axial-radial and radial-radial collisions

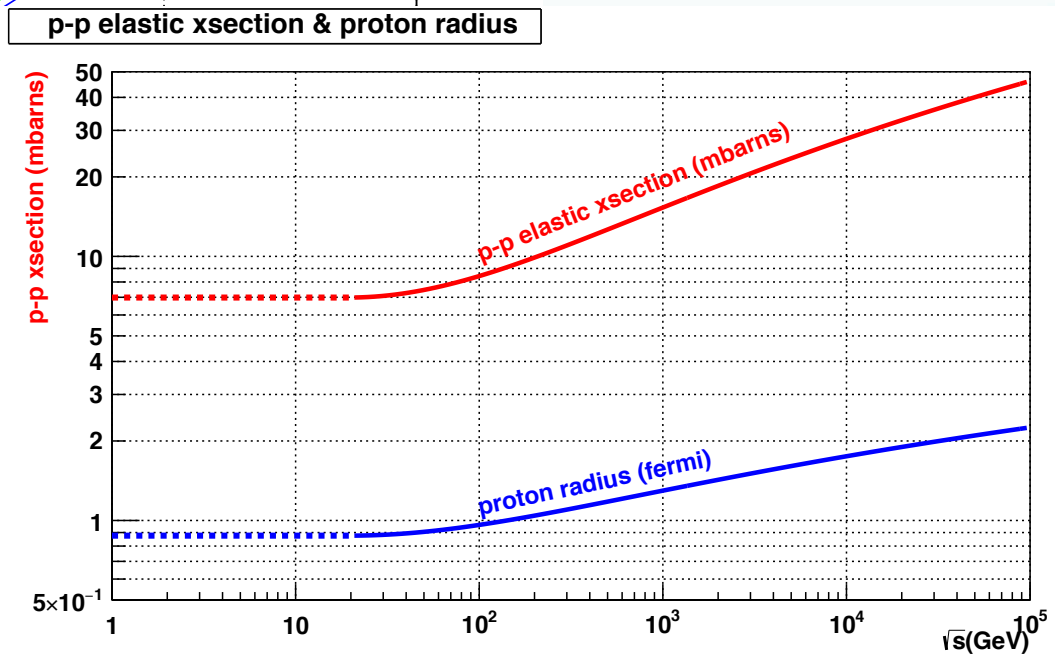


radial-radial collisions

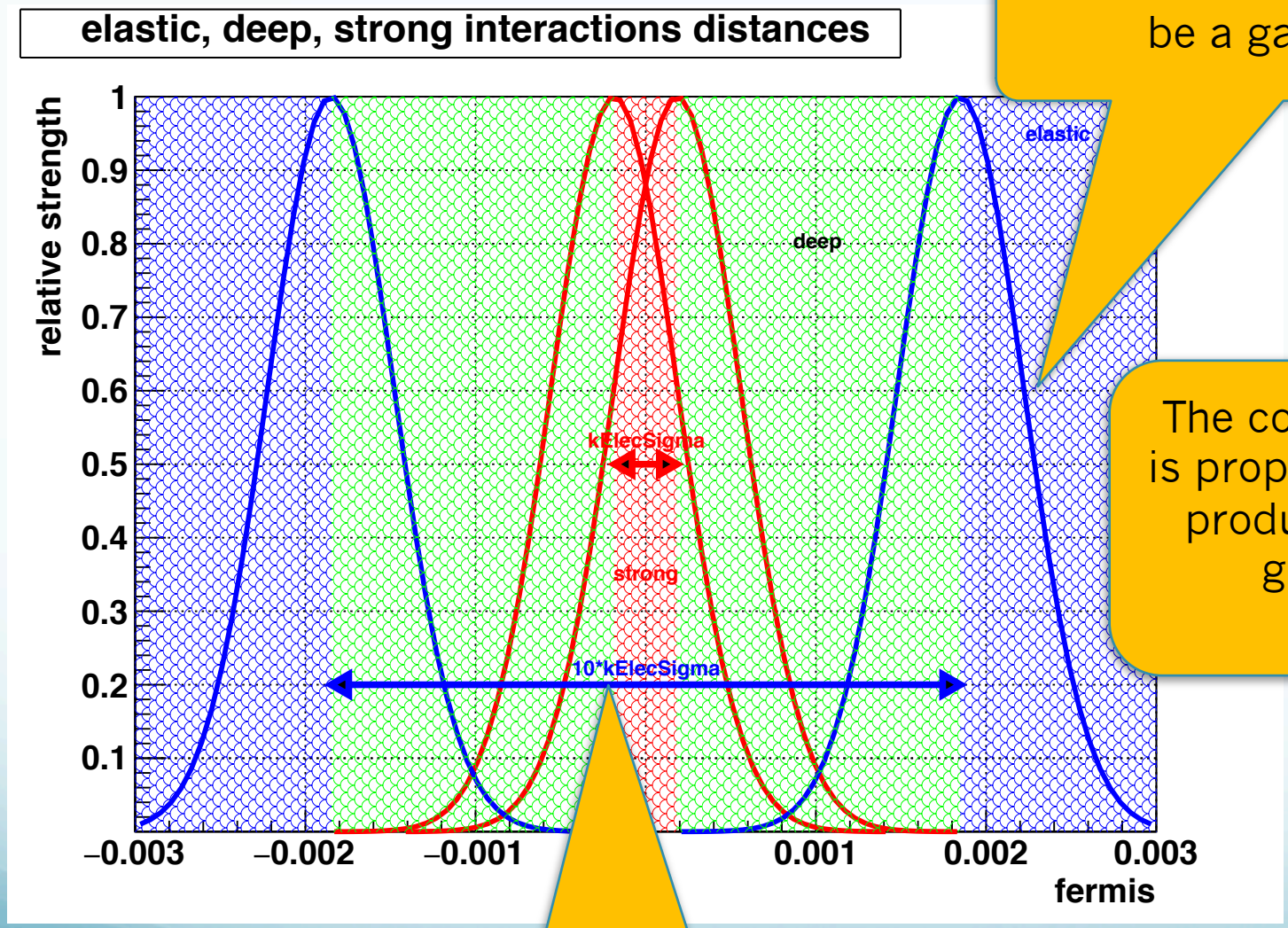
Proton Radius



The proton radius is taken as the sqrt(elastic cross-section) normalized to proton radius at rest



Collision Probability

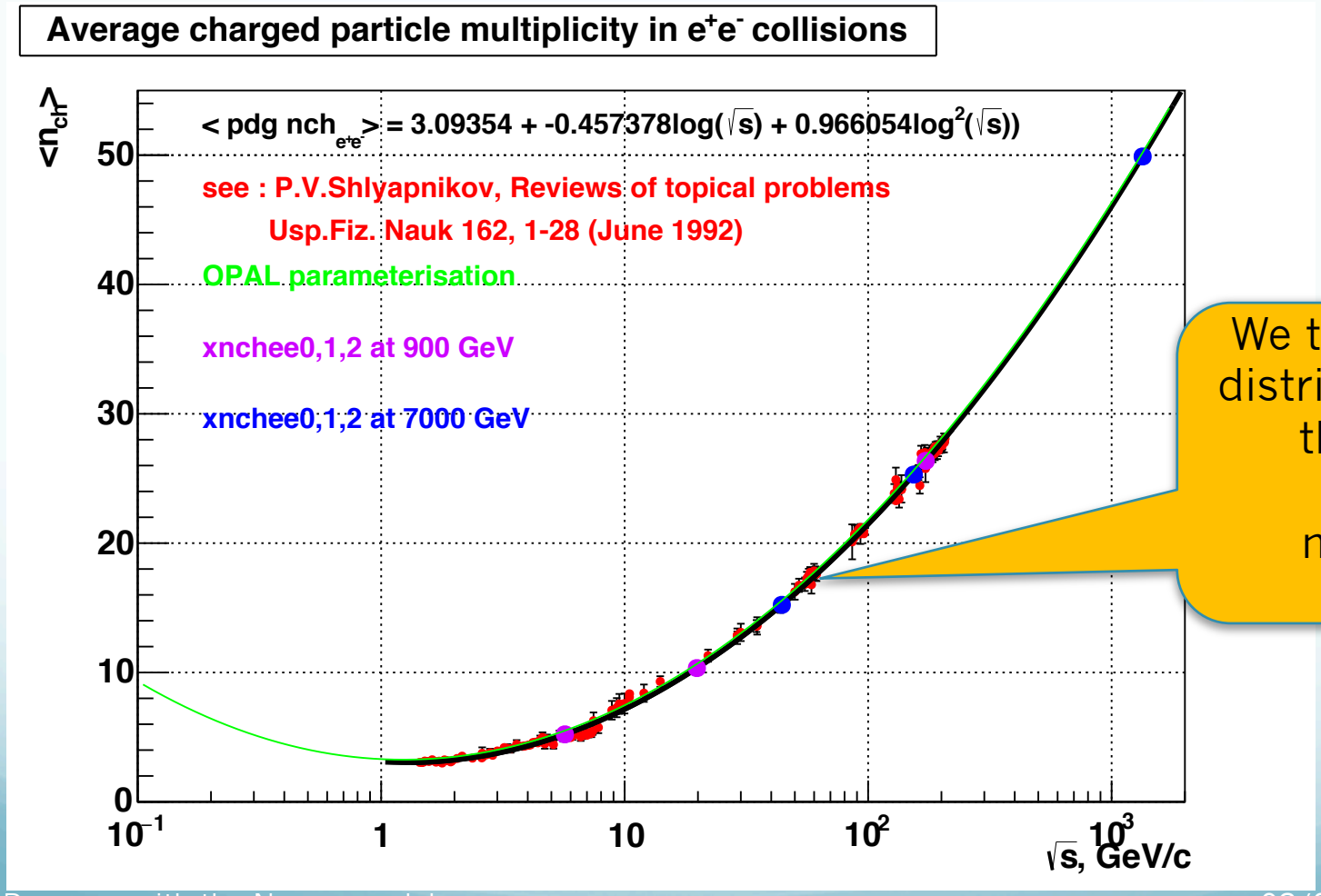


The electrons are assumed to be a gaussian wave

The collision energy is proportional to the products of the 2 gaussians

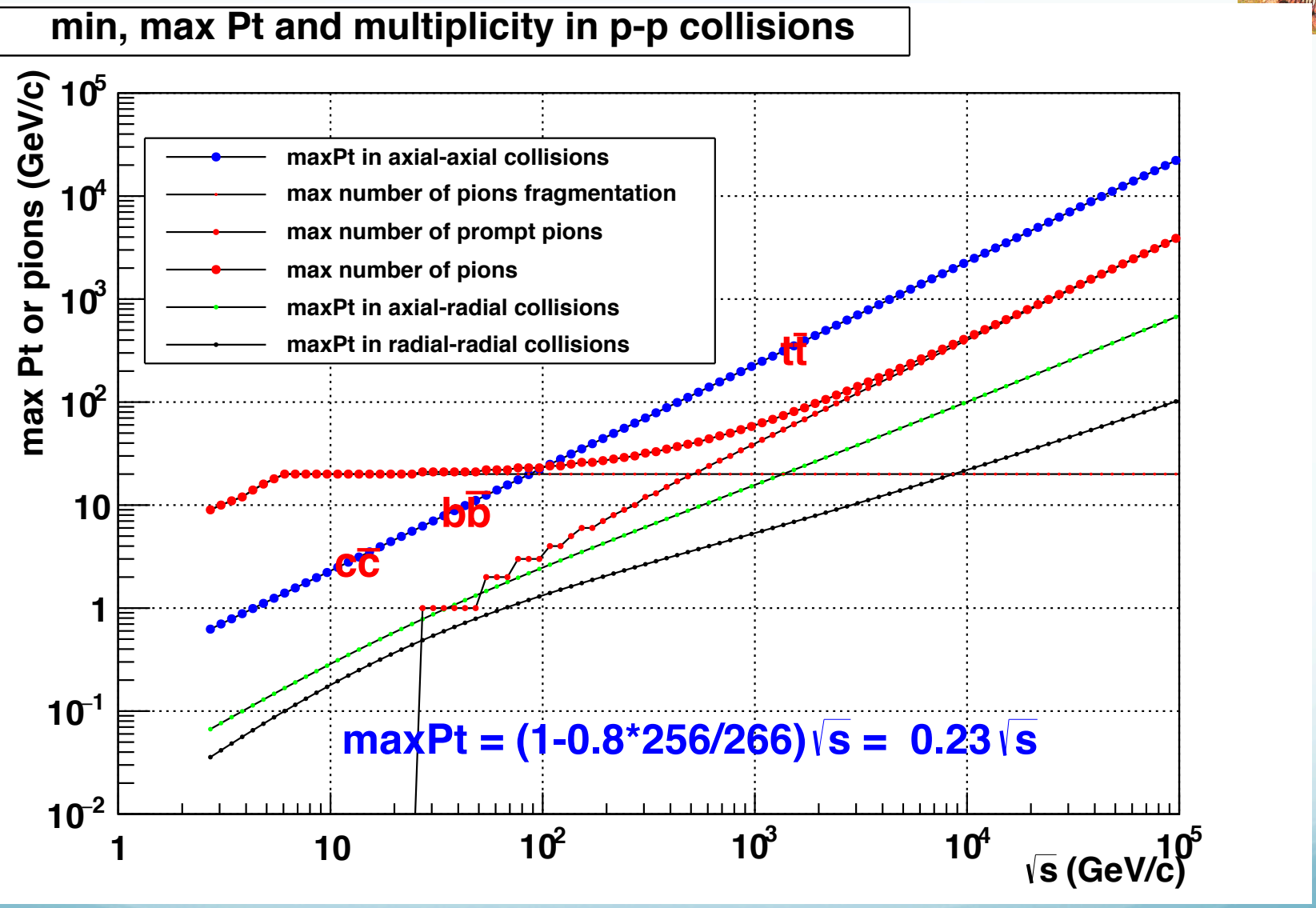
kElecSigma = 0.00037 fermi

Collision products

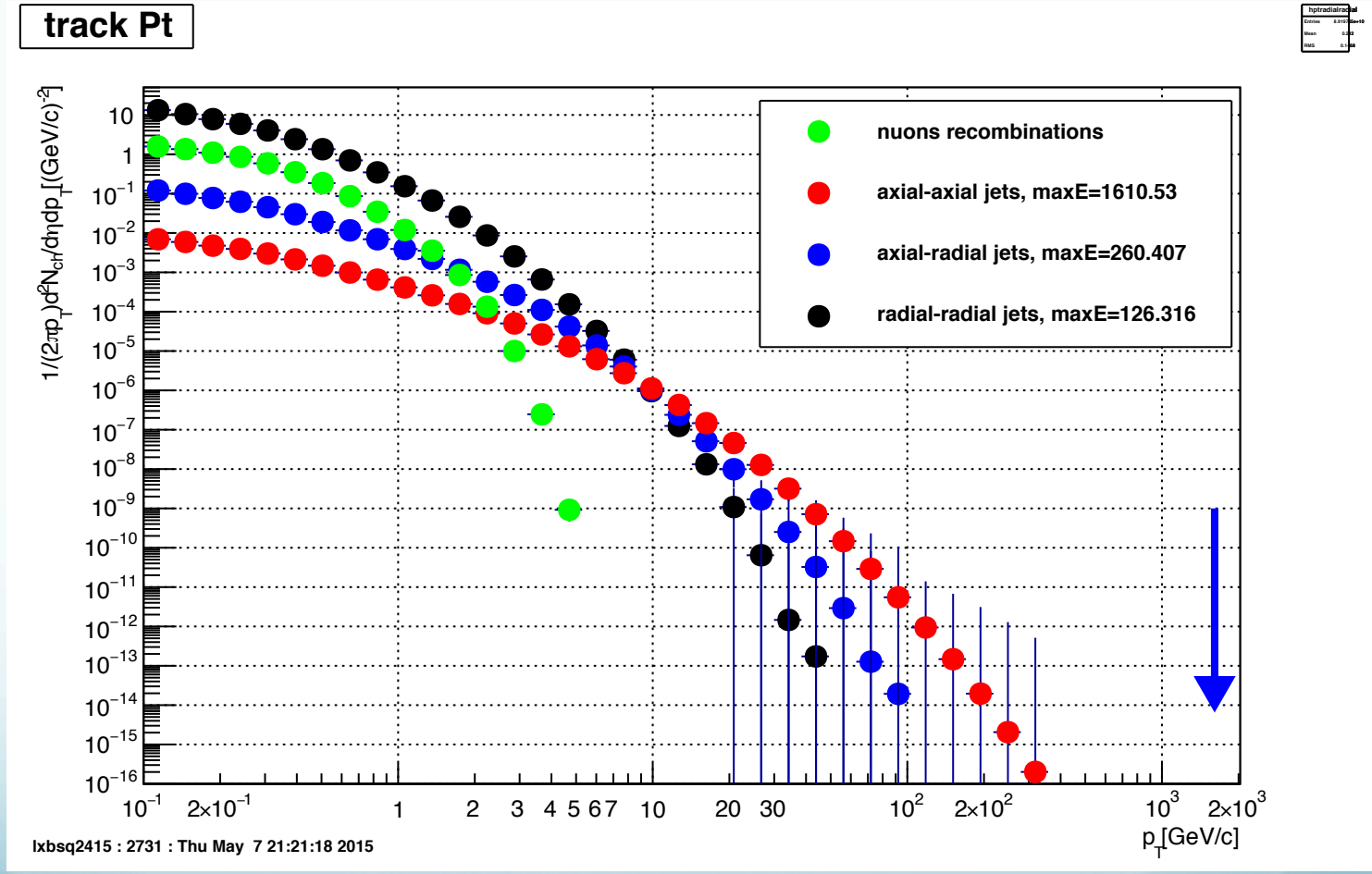


We take a Poisson distribution around the average particles multiplicity

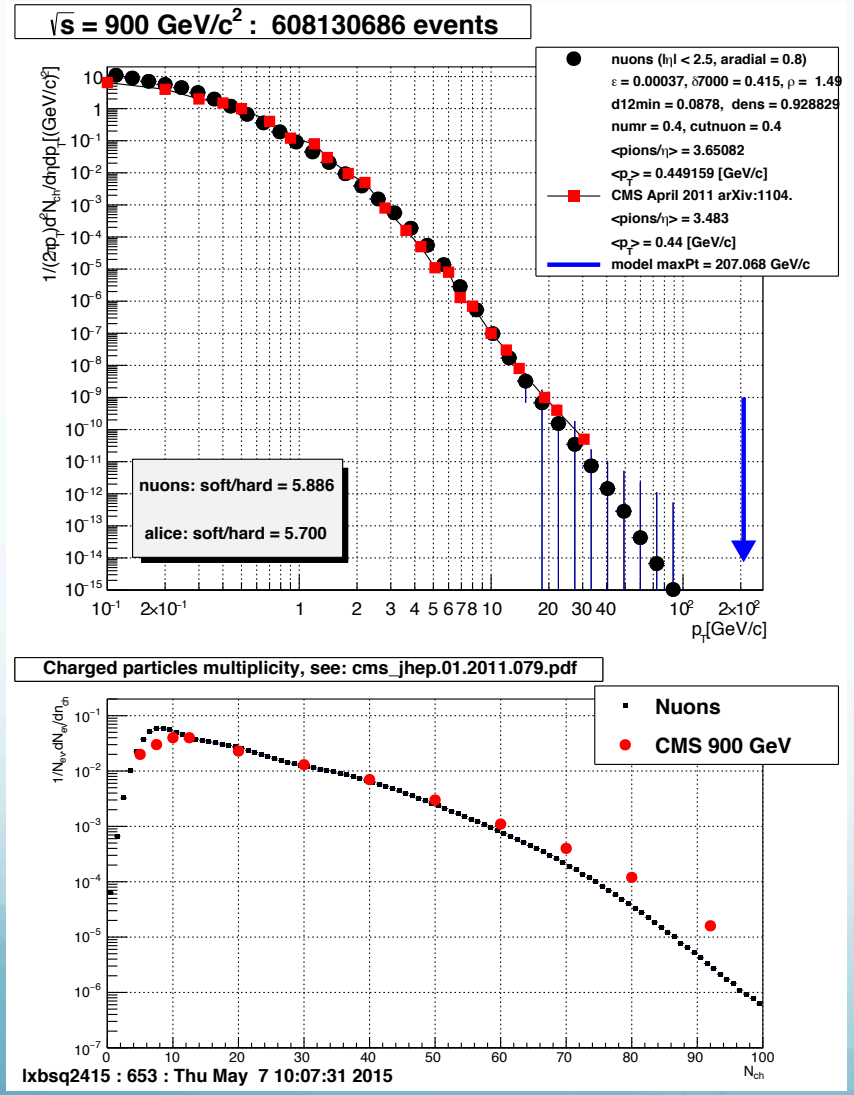
Some simple estimators

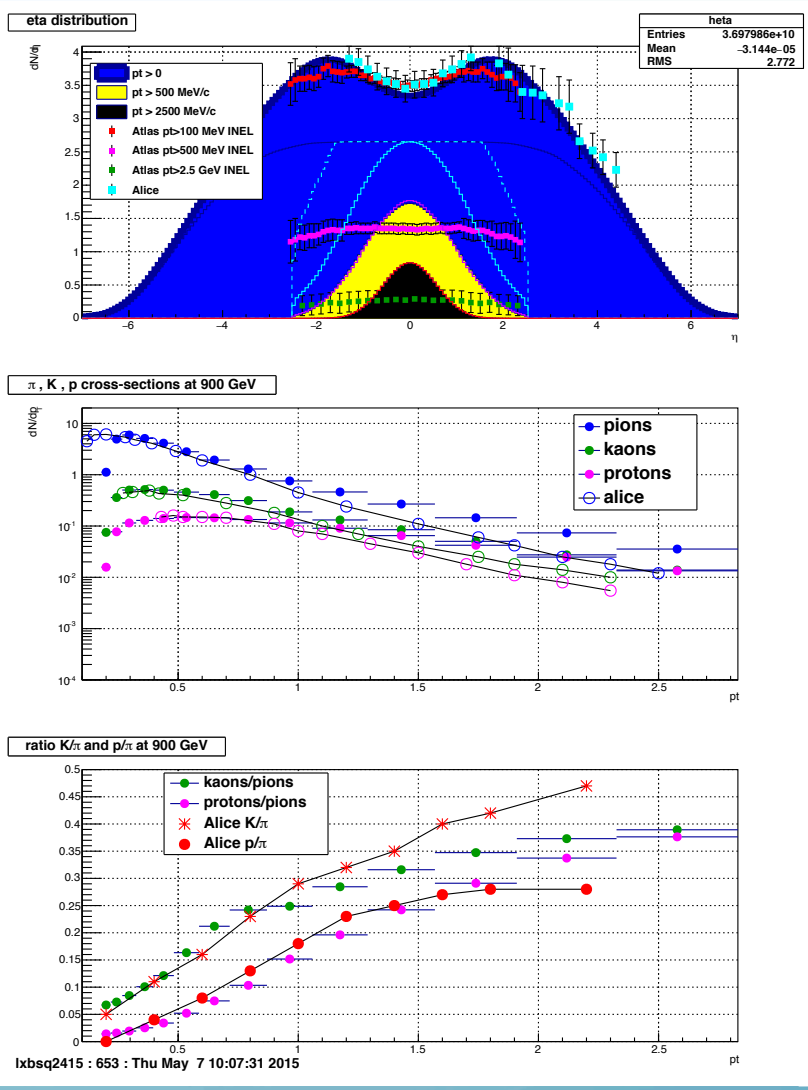


Collision types and Pt

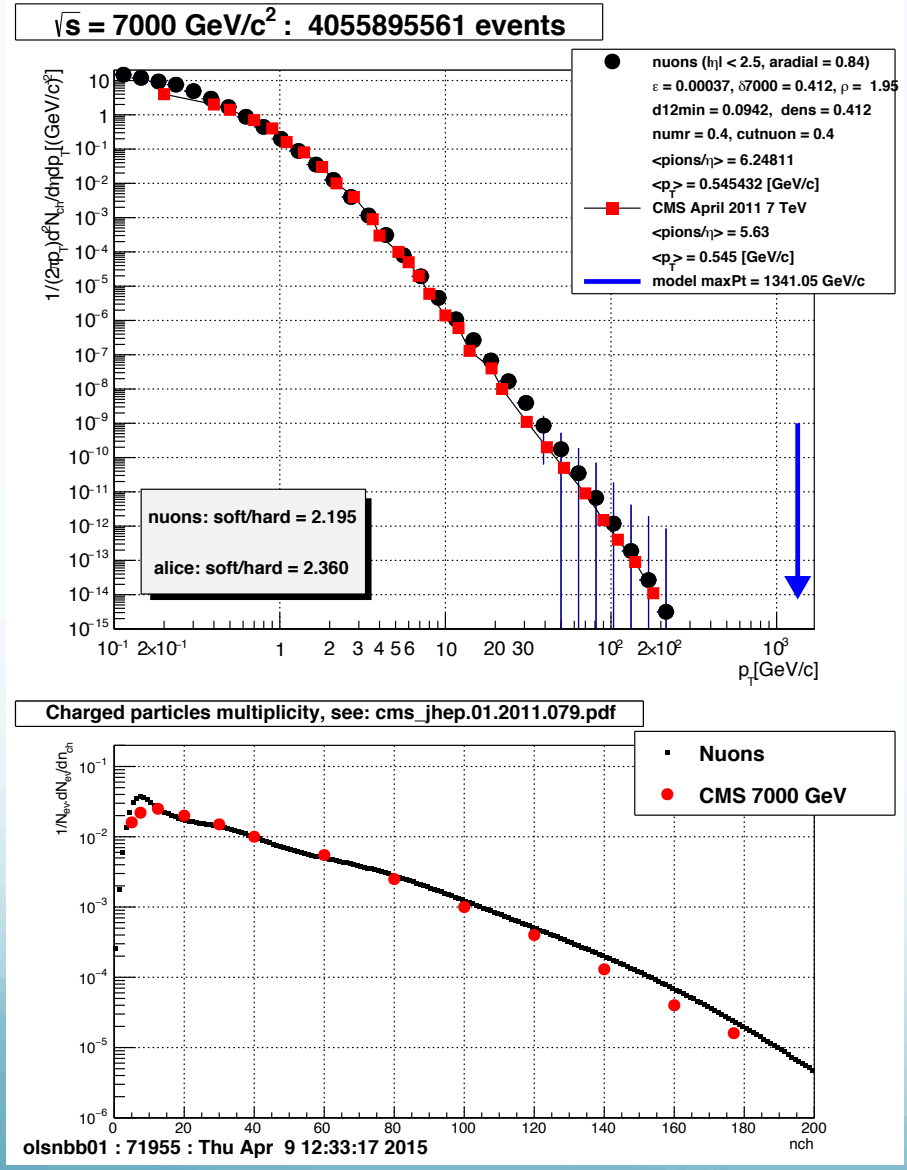


900 GeV

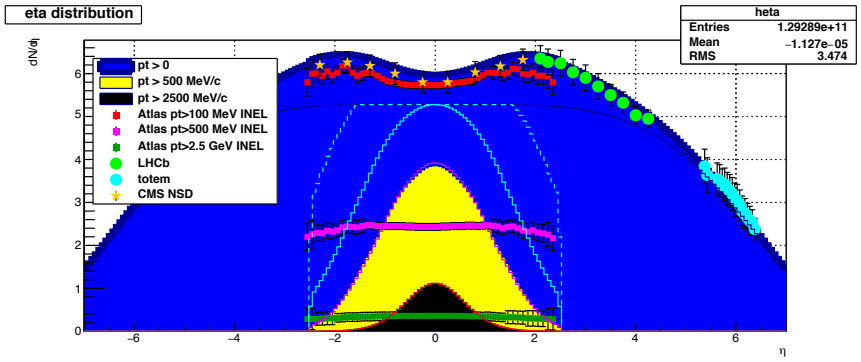

√s = 900 GeV/c² : 608130686 events
nuons (|η| < 2.5, aradial = 0.8)
ε = 0.00037, δ7000 = 0.415, ρ = 1.49
d12min = 0.0878, dens = 0.928829
numr = 0.4, cutnuon = 0.4
<pions/η> = 3.65082
<p_T> = 0.449159 [GeV/c]
CMS April 2011 arXiv:1104.
<pions/η> = 3.483
<p_T> = 0.44 [GeV/c]
model maxPt = 207.068 GeV/c
nuons: soft/hard = 5.886
alice: soft/hard = 5.700
1/(2πp_T)d²N_ch/dηdp_T[(GeV/c)²]
p_T[GeV/c]
Charged particles multiplicity, see: cms_jhep.01.2011.079.pdf
Nuons
CMS 900 GeV
1/N_ev dN_ev/dn_ch
N_ch
lxbsq2415 : 653 : Thu May 7 10:07:31 2015

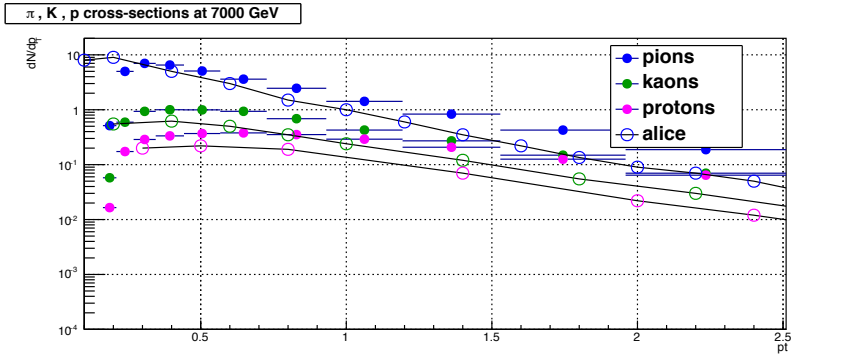

eta distribution
heta
Entries 3.697986e+10
Mean -3.144e-05
RMS 2.772
pt > 0
pt > 500 MeV/c
pt > 2500 MeV/c
Atlas pt>100 MeV INEL
Atlas pt>500 MeV INEL
Atlas pt>2.5 GeV INEL
Alice
dN/dη
η
π , K , p cross-sections at 900 GeV
pions
kaons
protons
alice
dN/dp_t
pt
ratio K/π and p/π at 900 GeV
kaons/pions
protons/pions
Alice K/π
Alice p/π
lxbsq2415 : 653 : Thu May 7 10:07:31 2015

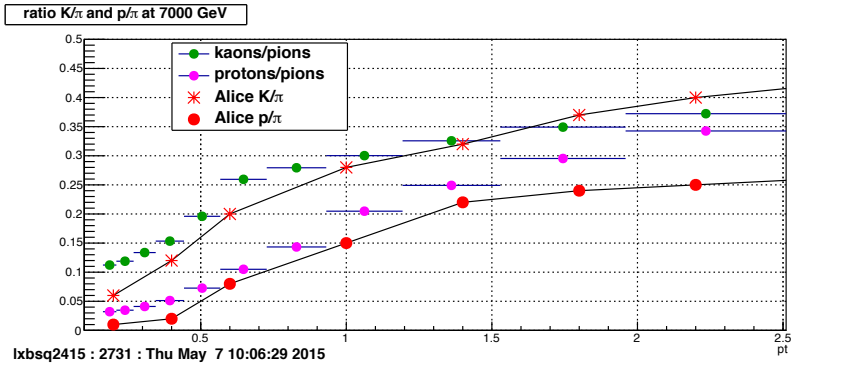
7 TeV


√s = 7000 GeV/c² : 4055895561 events
nuons (|η| < 2.5, aradial = 0.84)
ε = 0.00037, δ7000 = 0.412, ρ = 1.95
d12min = 0.0942, dens = 0.412
numr = 0.4, cutnuon = 0.4
<pions/η> = 6.24811
<p_T> = 0.545432 [GeV/c]
CMS April 2011 7 TeV
<pions/η> = 5.63
<p_T> = 0.545 [GeV/c]
model maxPt = 1341.05 GeV/c
nuons: soft/hard = 2.195
alice: soft/hard = 2.360
1/(2πp_T)d²N_ch/dηdp_T [(GeV/c)⁻²]
p_T [GeV/c]

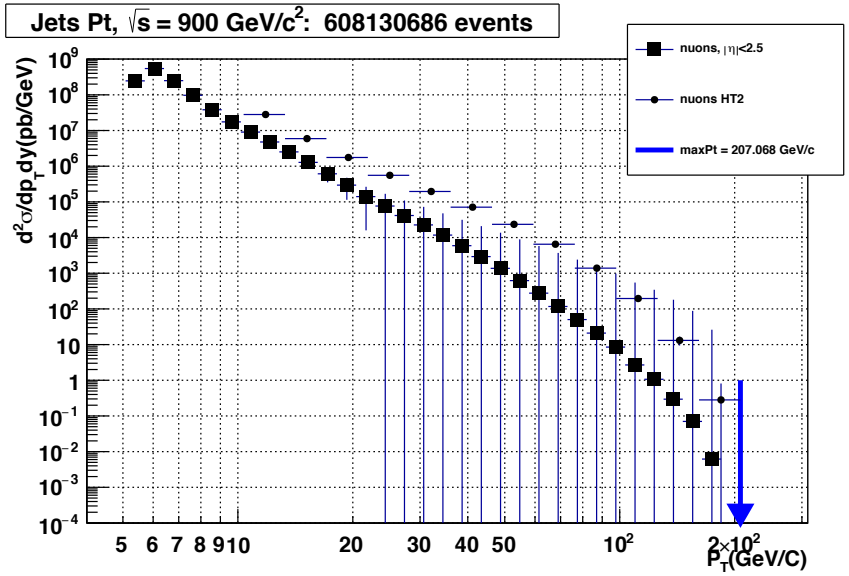
Charged particles multiplicity, see: cms_jhep.01.2011.079.pdf
Nuons
CMS 7000 GeV
1/N_ev dN_ev/dn_ch
nch
olsnbb01 : 71955 : Thu Apr 9 12:33:17 2015

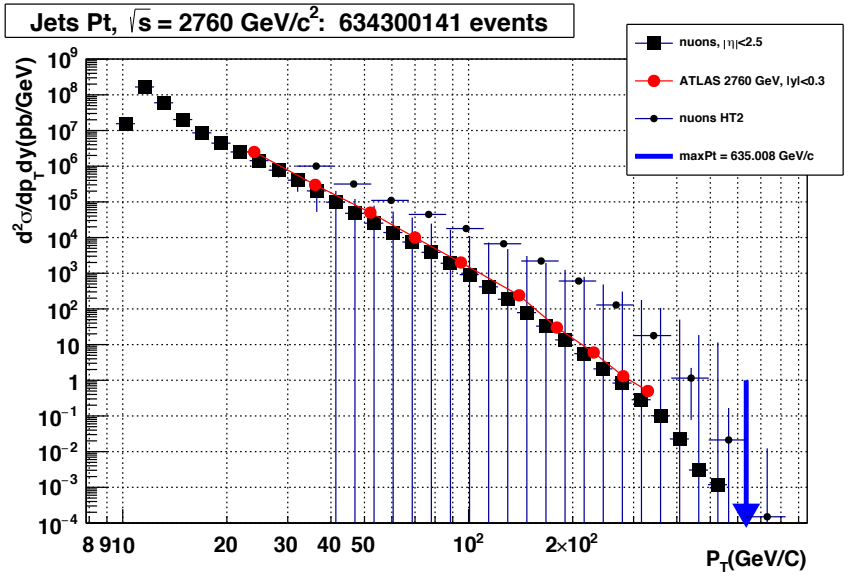

eta distribution
heta
Entries 1.29289e+11
Mean -1.127e-05
RMS 3.474
pt > 0
pt > 500 MeV/c
pt > 2500 MeV/c
Atlas pt>100 MeV INEL
Atlas pt>500 MeV INEL
Atlas pt>2.5 GeV INEL
LHCb
totem
CMS NSD
dN/dη
η

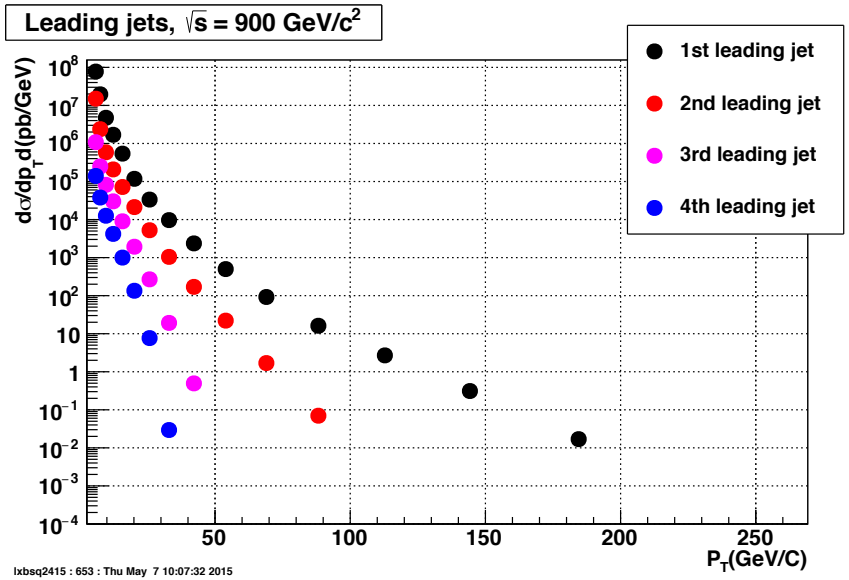

π , K , p cross-sections at 7000 GeV
pions
kaons
protons
alice
dN/dp_t
pt

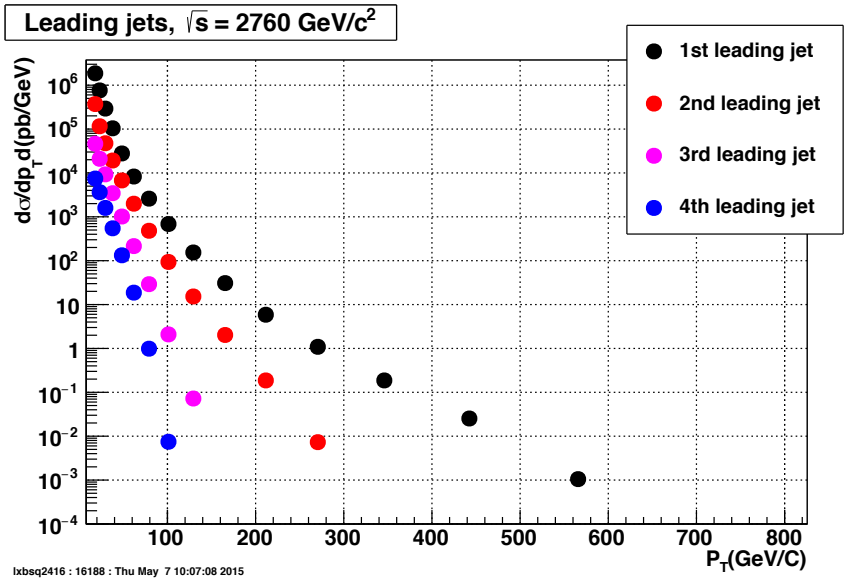

ratio K/π and p/π at 7000 GeV
kaons/pions
protons/pions
Alice K/π
Alice p/π
pt
lxbsq2415 : 2731 : Thu May 7 10:06:29 2015

Jets 0.9, 2.76 TeV

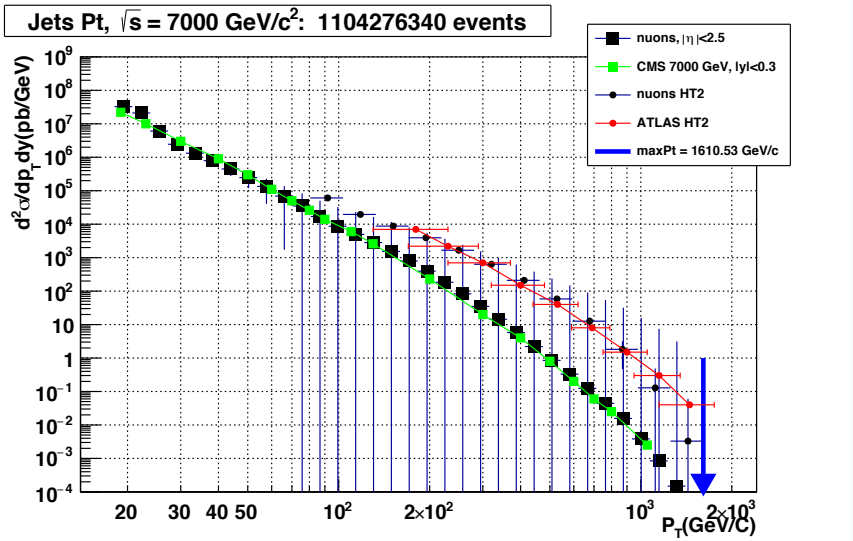


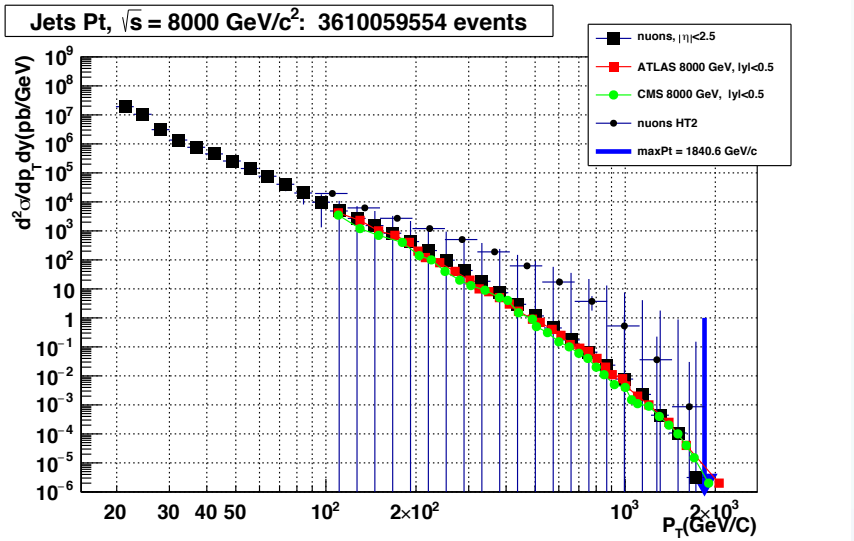


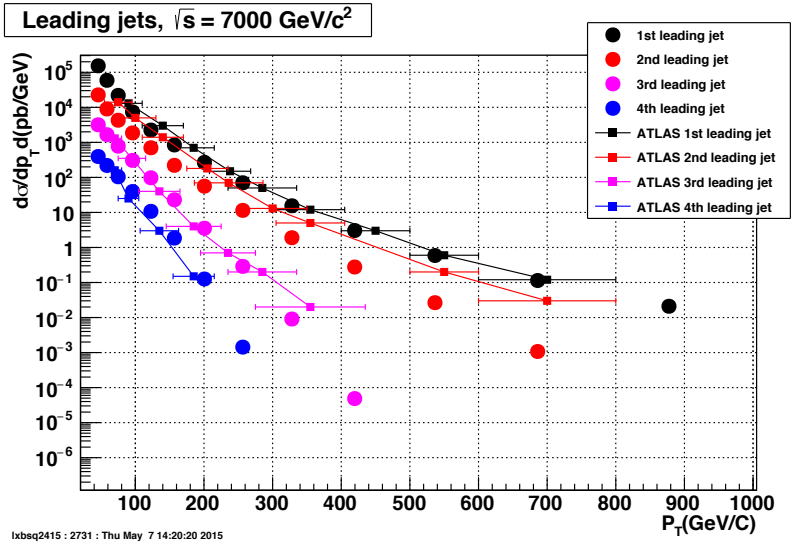


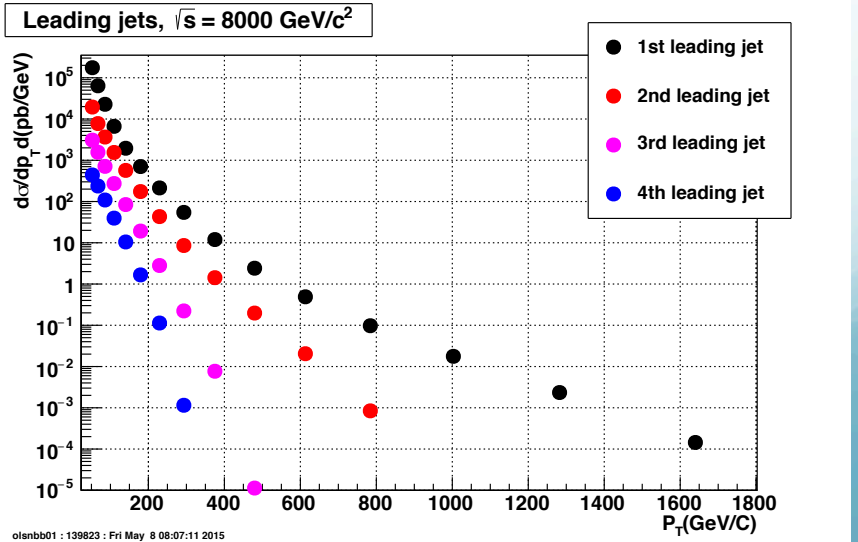


Jets 7, 8 TeV

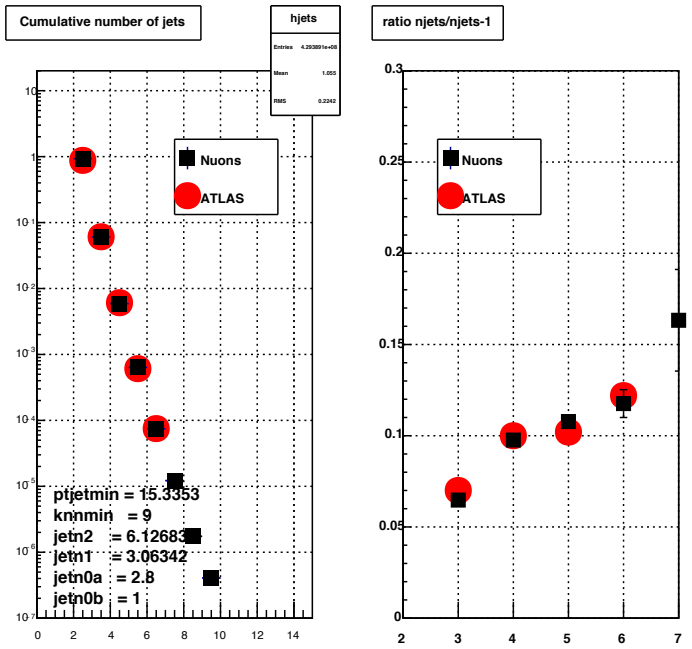

Jets Pt, √s = 7000 GeV/c²: 1104276340 events
nuons, |η|<2.5
CMS 7000 GeV, |y|<0.3
nuons HT2
ATLAS HT2
maxPt = 1610.53 GeV/c
d²σ/dp_T dy(pb/GeV)
P_T(GeV/C)

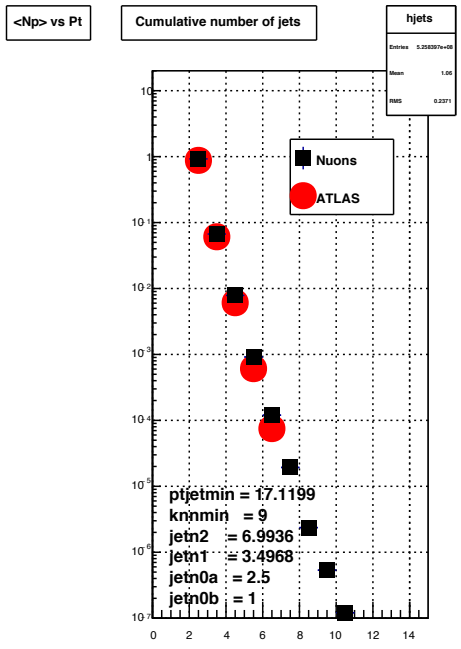

Jets Pt, √s = 8000 GeV/c²: 3610059554 events
nuons, |η|<2.5
ATLAS 8000 GeV, |y|<0.5
CMS 8000 GeV, |y|<0.5
nuons HT2
maxPt = 1840.6 GeV/c
d²σ/dp_T dy(pb/GeV)
P_T(GeV/C)


Leading jets, √s = 7000 GeV/c²
1st leading jet
2nd leading jet
3rd leading jet
4th leading jet
ATLAS 1st leading jet
ATLAS 2nd leading jet
ATLAS 3rd leading jet
ATLAS 4th leading jet
dσ/dp_T d(pb/GeV)
P_T(GeV/C)
lxbsq2415 : 2731 : Thu May 7 14:20:20 2015

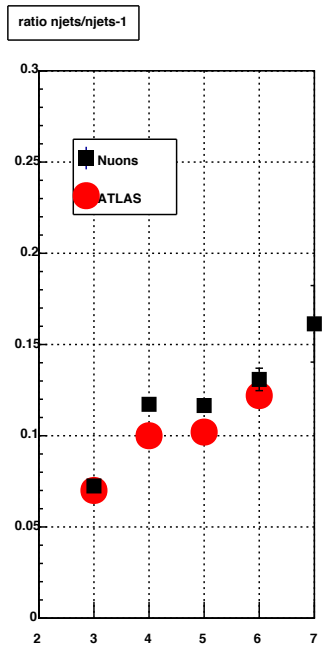

Leading jets, √s = 8000 GeV/c²
1st leading jet
2nd leading jet
3rd leading jet
4th leading jet
dσ/dp_T d(pb/GeV)
P_T(GeV/C)
olsnbb01 : 139823 : Fri May 8 08:07:11 2015

Inclusive Jets





7 TeV



8 TeV

Jets vs event Multiplicity

Jets compared to CMS data at $\sqrt{s}$ = 7000 GeV/c^2 : 821716887 events

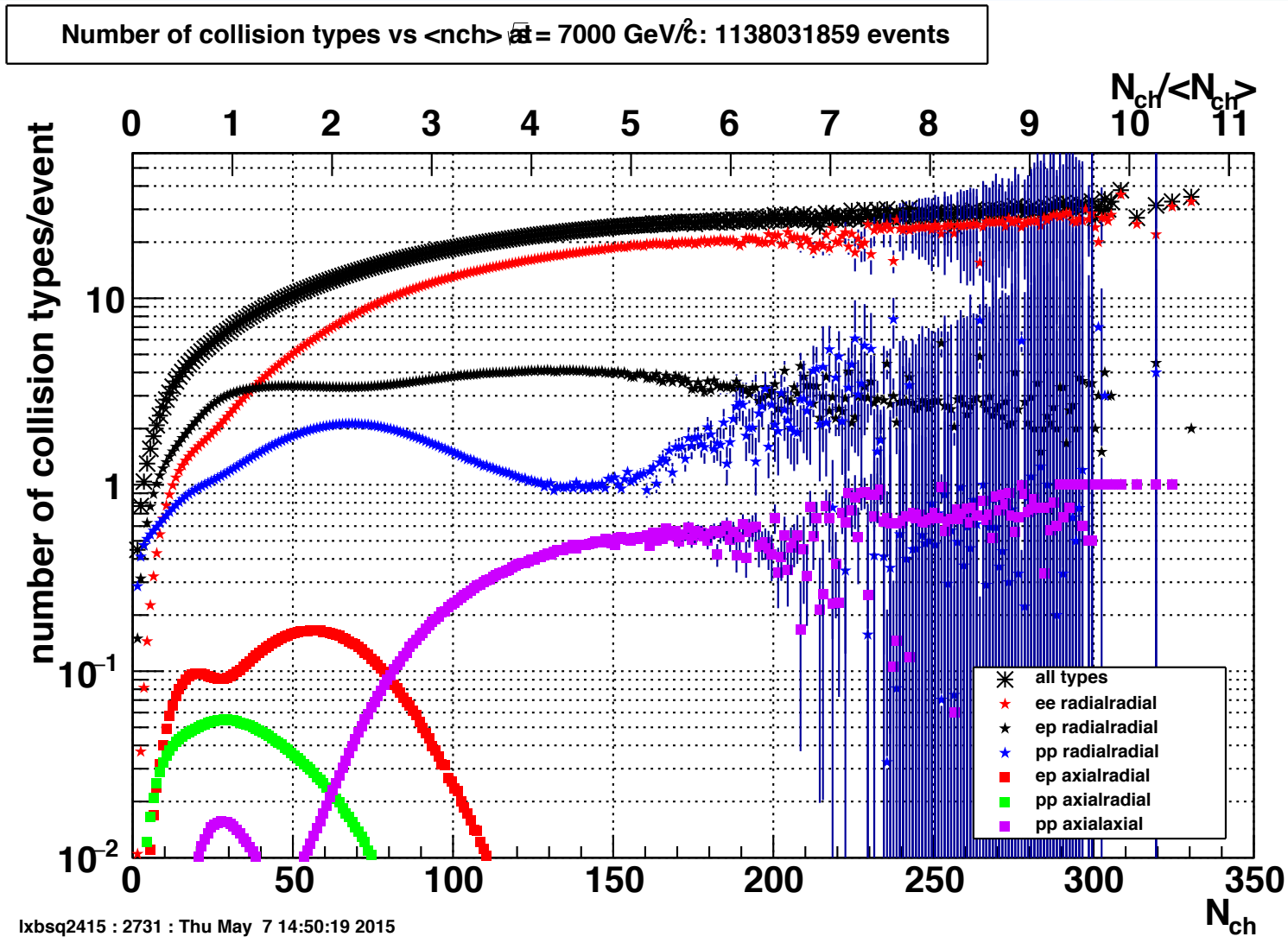
		$10< N_{ch}\leq 30$	$30< N_{ch}\leq 50$	$50< N_{ch}\leq 80$	$80< N_{ch}\leq 110$	$110< N_{ch}\leq 140$
events %	data	0.581	0.264	0.130	0.0219	0.0024
	nuon	0.581	0.264	0.135	0.0189	0.0019
p_T^{ch} particle	data	0.68 ± 0.01	0.75 ± 0.01	0.80 ± 0.01	0.85 ± 0.01	0.88 ± 0.01
	nuon	0.67	0.75	0.77	0.81	0.89
	p6Z2	0.67	0.74	0.80	0.85	0.90
p_T^{UE}	data	0.65 ± 0.01	0.71 ± 0.01	0.74 ± 0.01	0.76 ± 0.01	0.77 ± 0.01
	nuon	0.66	0.74	0.77	0.81	0.89
	p6Z2	0.65	0.70	0.74	0.76	0.77
p_T^{ij}	data	1.90 ± 0.02	1.64 ± 0.02	1.45 ± 0.01	1.32 ± 0.01	1.24 ± 0.01
	nuon	2.13	1.98	1.87	2.05	2.41
	p6Z2	1.86	1.62	1.44	1.33	1.29
p_T^{ijl}	data	3.65 ± 0.05	3.37 ± 0.04	3.15 ± 0.03	2.96 ± 0.03	2.86 ± 0.03
	nuon	3.51	3.32	3.17	3.41	3.93
	p6Z2	3.59	3.33	3.10	2.97	3.05
p_T^{ch} jet	data	6.85 ± 0.06	7.04 ± 0.09	7.18 ± 0.09	7.46 ± 0.11	7.81 ± 0.10
	nuon	6.97	6.90	6.81	7.33	8.31
	p6Z2	7.01	7.20	7.30	7.64	8.15
ch.jets/event pt>5	data	0.054 ± 0.004	0.287 ± 0.014	0.84 ± 0.03	2.13 ± 0.09	3.68 ± 0.15
	nuon	0.046	0.167	0.310	0.610	1.116
	p6Z2	0.067	0.304	0.87	2.12	3.95
ch.jets/event pt>30	data	$(3.2 \pm 0.5)10^{-5}$	$(3.4 \pm 0.4)10^{-4}$	$(1.5 \pm 0.1)10^{-3}$	$(4.3 \pm 0.4)10^{-3}$	$(1.0 \pm 0.1)10^{-2}$
	nuon	$(5.0 \pm 0.1)10^{-5}$	$(3.9 \pm 0.0)10^{-4}$	$(0.5 \pm 0.0)10^{-3}$	$(3.7 \pm 0.0)10^{-3}$	$(1.8 \pm 0.0)10^{-2}$
	p6Z2	$(2.7 \pm 0.3)10^{-5}$	$(3.5 \pm 0.2)10^{-4}$	$(1.4 \pm 0.2)10^{-3}$	$(5.7 \pm 0.4)10^{-3}$	$(2.1 \pm 0.1)10^{-2}$

lxbsq2415 : 2731 : Thu May 7 10:06:30 2015

see : CERN-PH-EP/2013-195 (arXiv:submit/0825507)

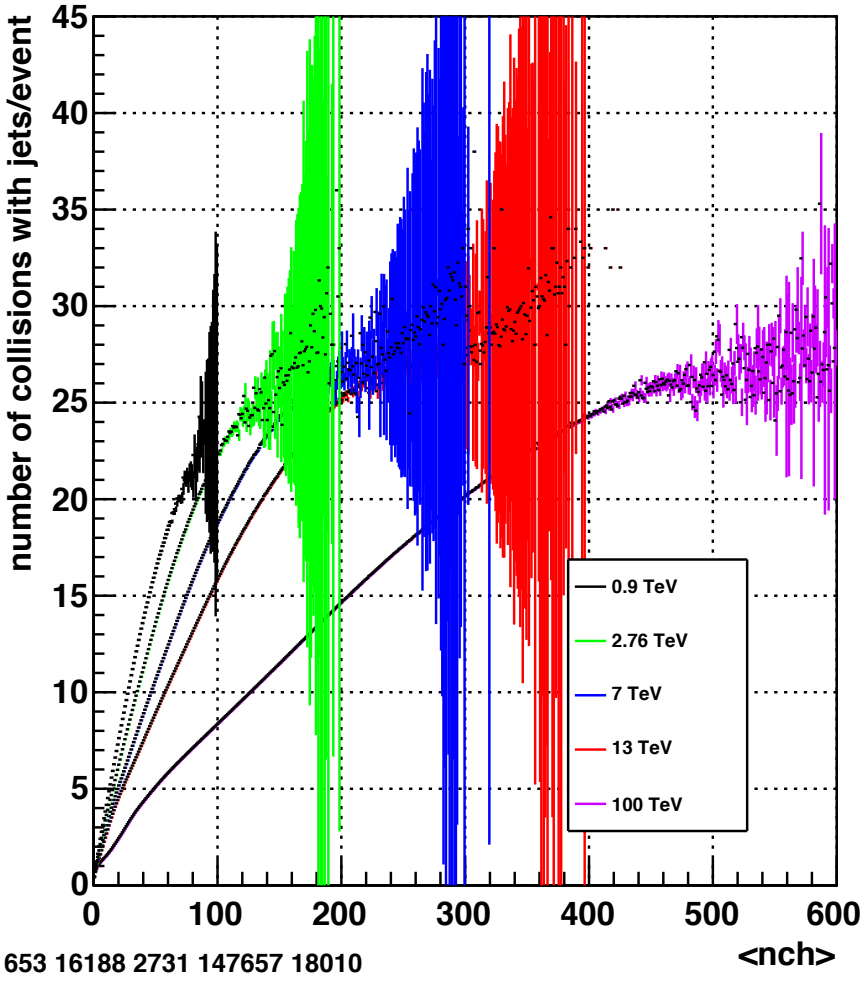
Multi Parton Interactions

Collision types vs multiplicity

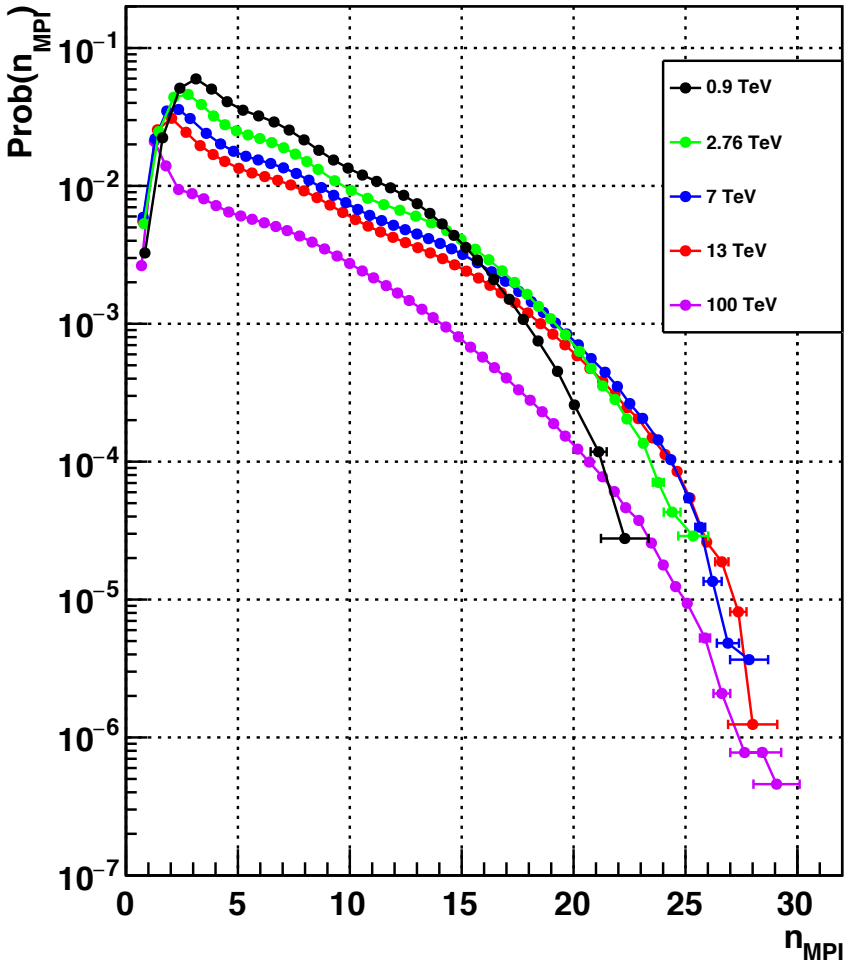


MPI vs Energy and multiplicity

number of collisions vs multiplicity



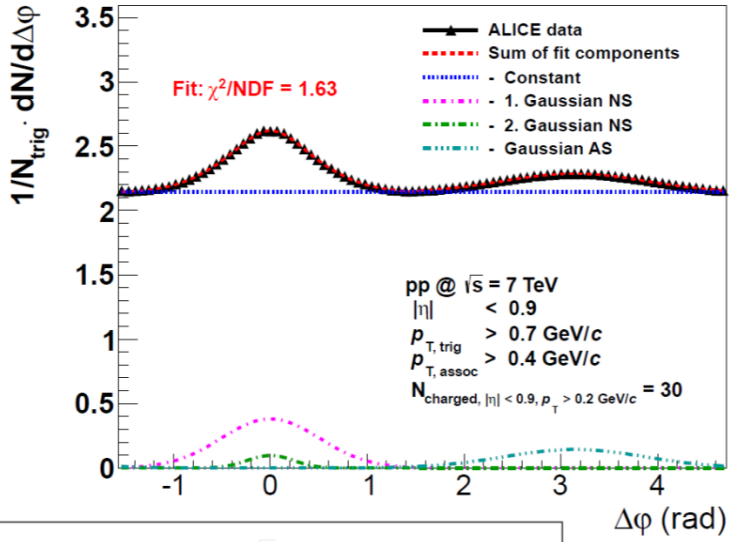
Probability of Multiple Interactions



Mini-jets in pp vs. multiplicity

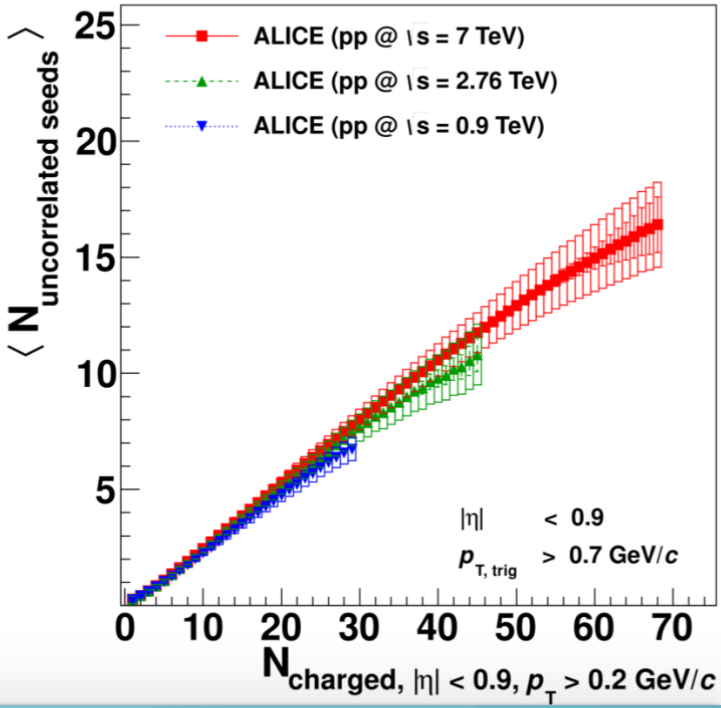
- **Mini-jets**: bundles of particles from semi-hard partonic scatterings
- **How**: from 2-particle correlations, associated yields in near and away sides

🕮 **ALICE, JHEP 09 (2013) 049**



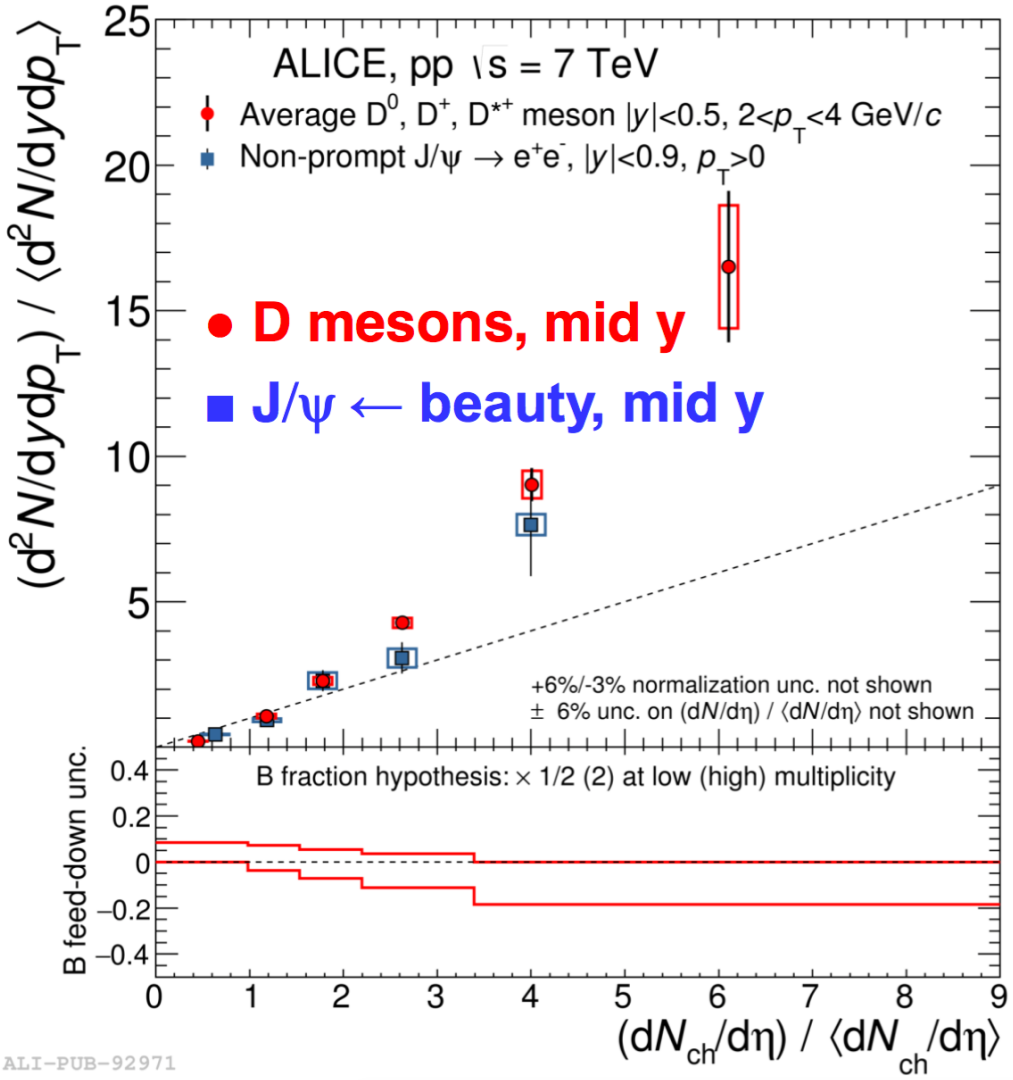
- Uncorrelated seeds = number of independent sources of particle production

$$< N_{\text{uncorrelated seeds}} >= \frac{< N_{\text{trigger}} >}{< 1 + N_{\text{assoc, near+away}} >}$$



- ⇨ In PYTHIA strongly correlated with number of MPIs
- ⇨ Linearly increasing with multiplicity at low multiplicity
- ⇨ Levels off at high multiplicities

Open charm vs. open beauty

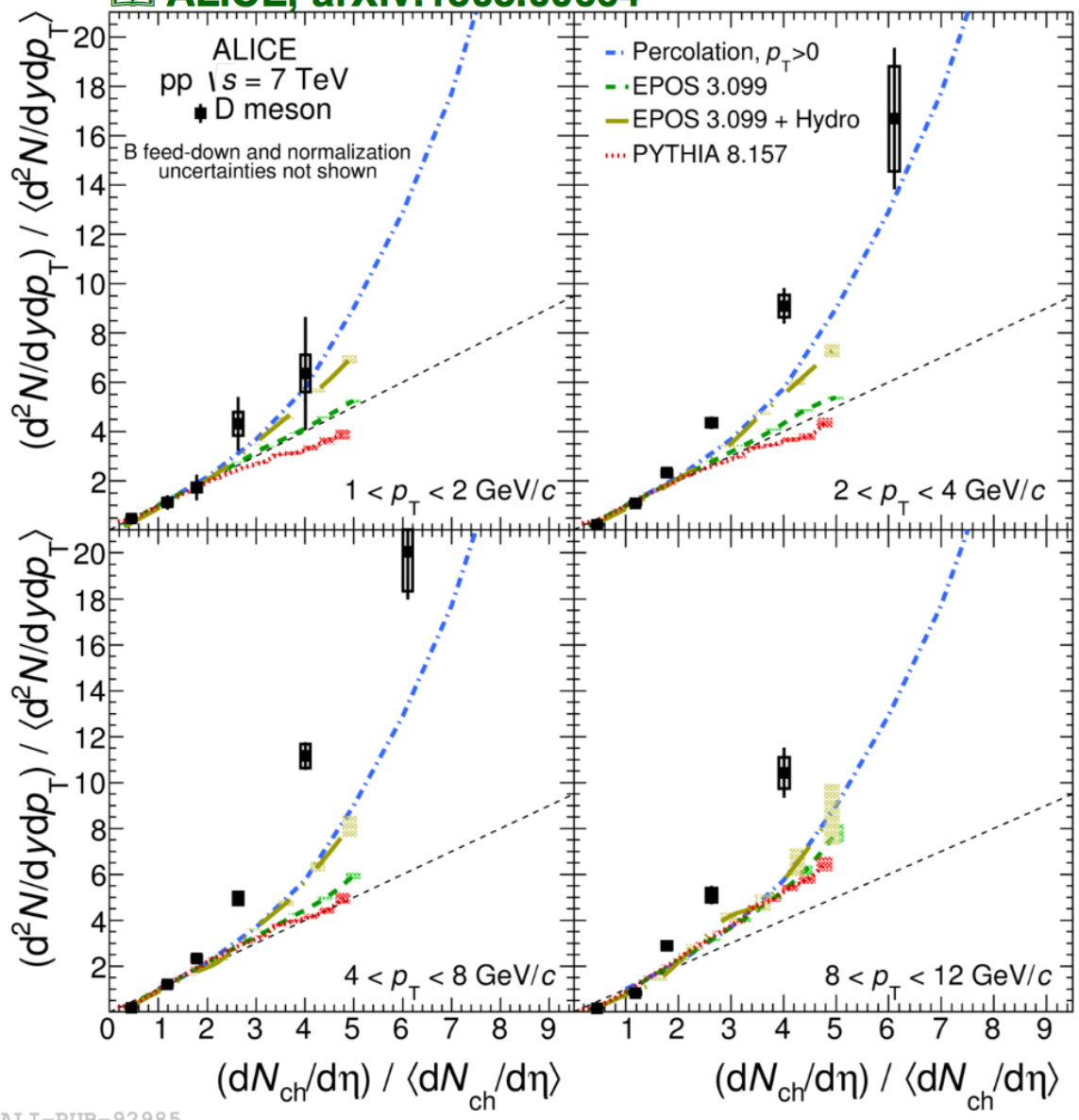


- Similar increase with multiplicity of per-event yield of open charm and beauty production

📖 **ALICE, arXiv:1505.00664**

Model calculations

📖 ALICE, arXiv:1505.00664



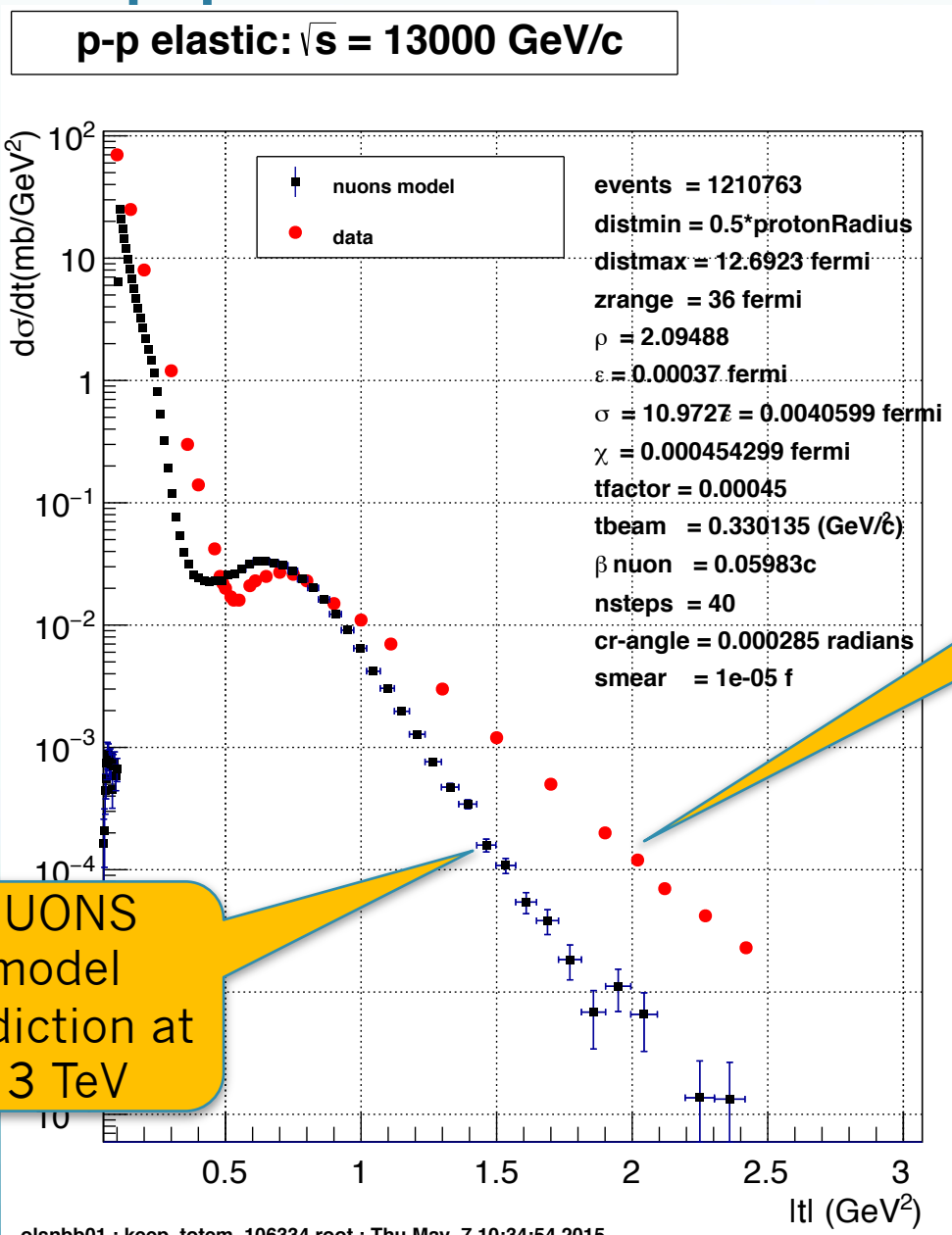
ALI-PUB-92985

- Percolation model
  - ⇨ Elementary sources of particle production: colour ropes/strings formed in parton-parton collisions
    - ✓ ***Close to MPI scenario***
  - ⇨ Colour strings have finite spatial extension and interact
    - ✓ ***At high densities: overlap among the sources -> reduction of their number***
    - ✓ ***Affects more soft sources (larger transverse size) and charged multiplicity***
  - ⇨ More than linear increase of D-meson yield with multiplicity

📖 Ferreiro, Pajares, PRC 86 (2012) 034903

Predictions for 13 TeV

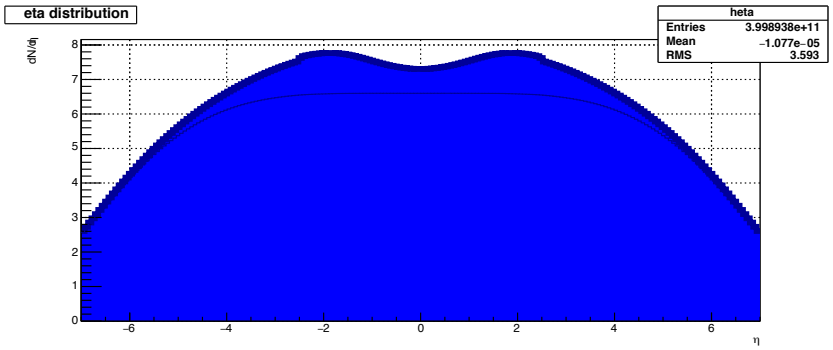
pp elastic at 13 TeV

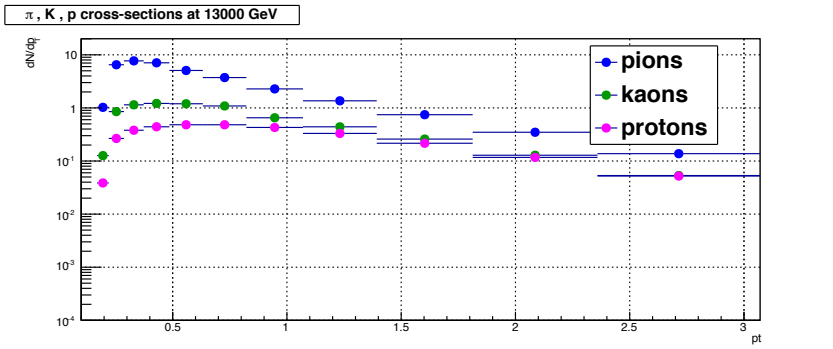


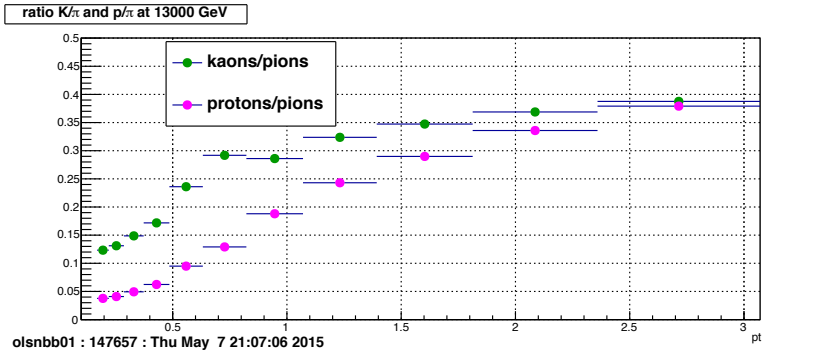
TOTEM results at 7 TeV

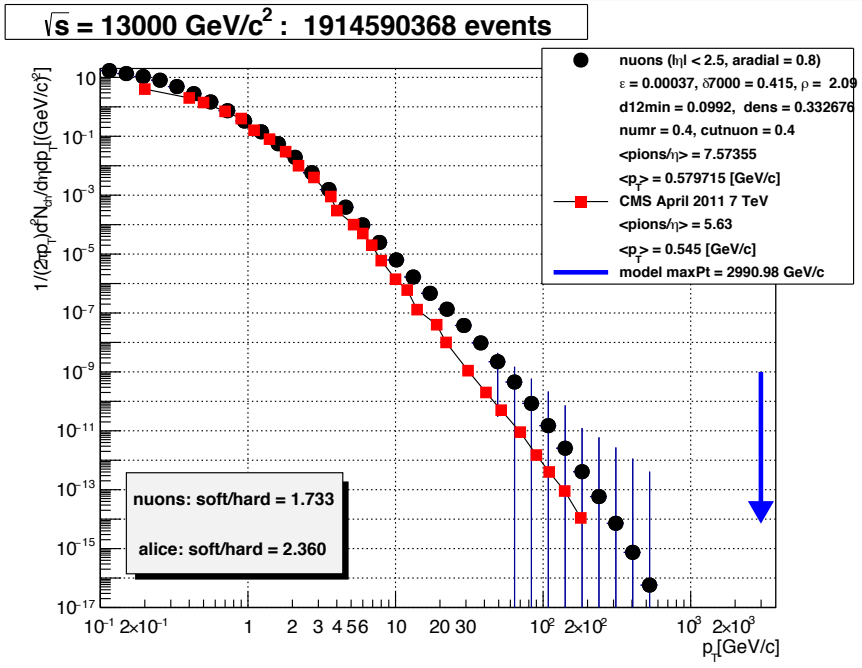
NUONS model prediction at 13 TeV

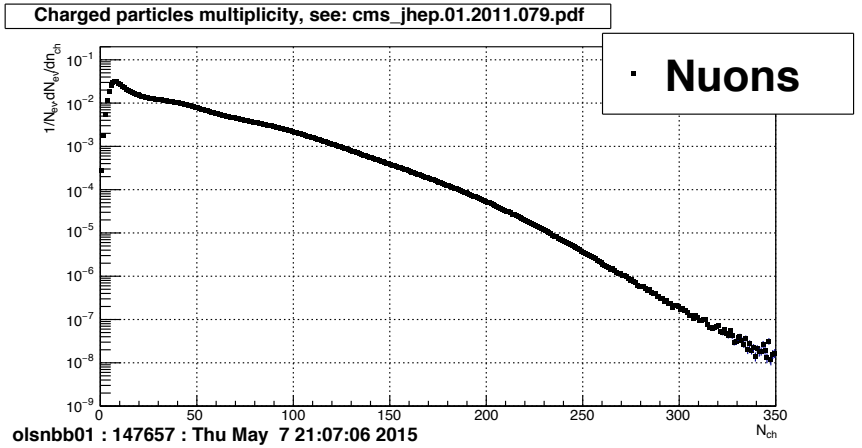
Particles kinematics at 13 TeV



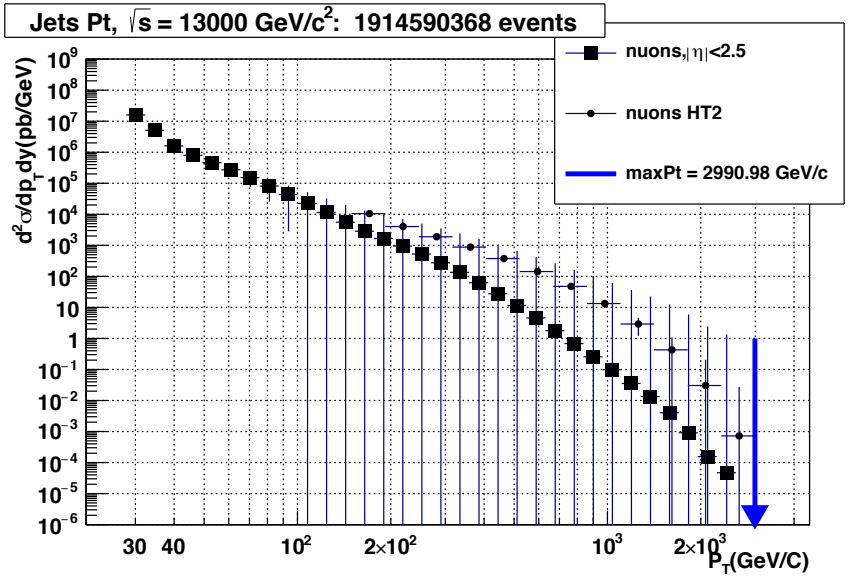


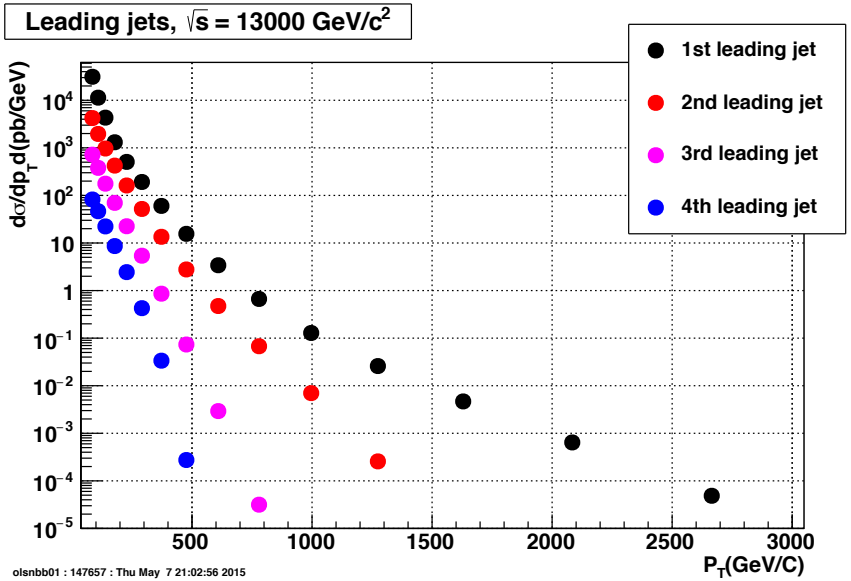


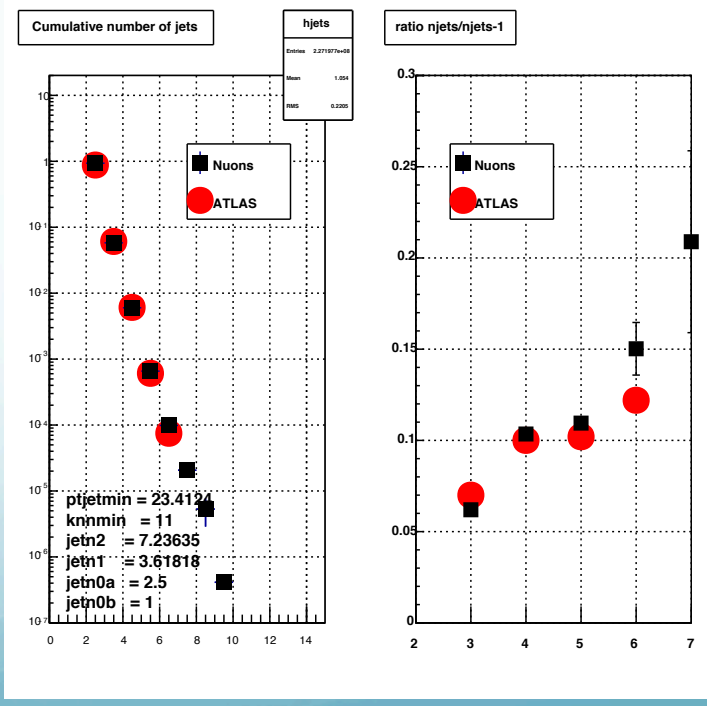




Jets at 13 TeV







Possible next steps

Improvements to findall.C, totem.C, collide.C

Deep Inelastic: deep.C

Binding energy, Life time