The 15th International Conference on Strangeness in Quark Matter

Charged particle production in Pb-Pb and p-Pb collisions measured by the ATLAS detector

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for the ATLAS Collaboration

Introduction

- why to study charged particle spectra?
  - to understand properties of hot dense matter created in HI collisions (Pb+Pb) and contribution of "cold" effects (p+Pb)
  - to understand the mechanism of energy loss of partons

- Pb+Pb 2011 ATLAS data allow to extend previous measurements

- p+Pb 2013 ATLAS data allow to check high p_T CMS results

- nuclear modification factor:

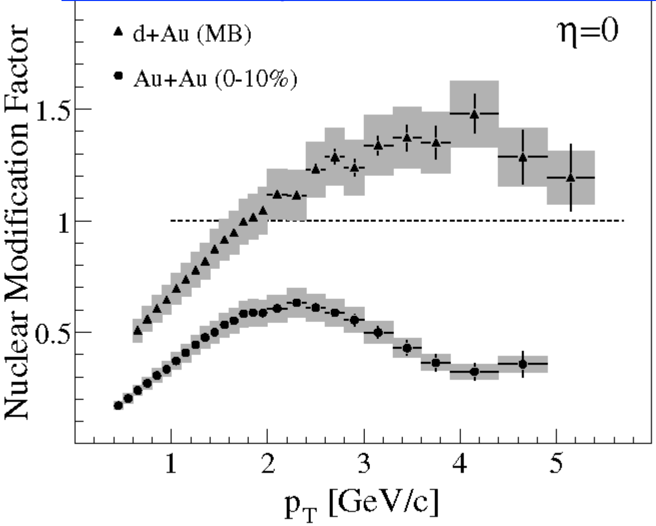
$$R_{\mathrm{AA}} = \frac{1}{\langle T_{\mathrm{AA}} \rangle} \frac{1/N_{\mathrm{evt}}\ \mathrm{d}^2 N_{\mathrm{Pb+Pb}}/\mathrm{d}\eta \mathrm{d}p_{\mathrm{T}}}{\mathrm{d}^2 \sigma_{pp}/\mathrm{d}\eta \mathrm{d}p_{\mathrm{T}}}$$

$$R_{\mathrm{pPb}\,(\mathrm{pA})} = \frac{\mathrm{d}^2 N_{\mathrm{Pb}}/\mathrm{d}y \mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{Pb}} \rangle\ \mathrm{d}^2 \sigma_{pp}/\mathrm{d}y \mathrm{d}p_{\mathrm{T}}}$$

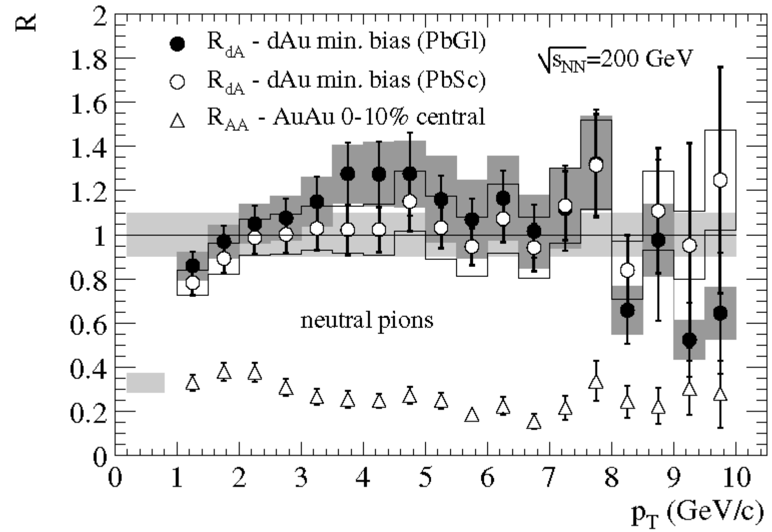
Results with RHIC energy

STAR [Nuclear Physics A Volume 757, Issues 1-2 , 8 August 2005, Pages 102-183]

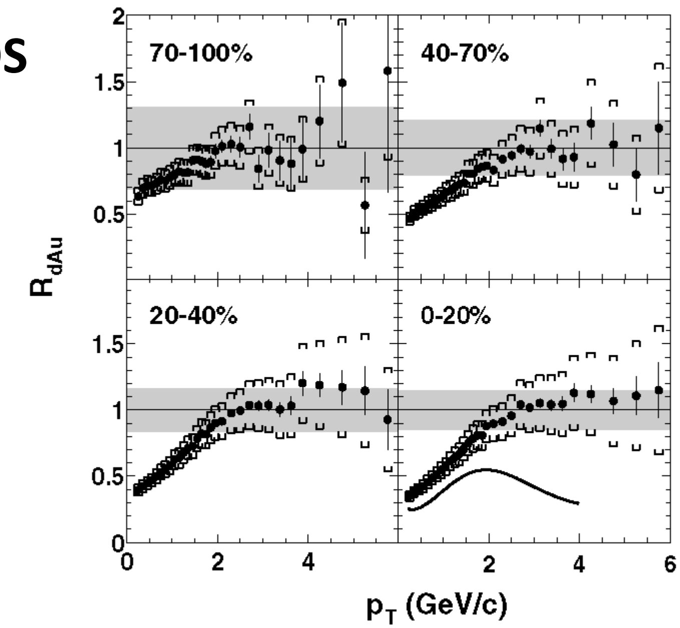
BRAHMS



PHENIX



PHOBOS
d+Au



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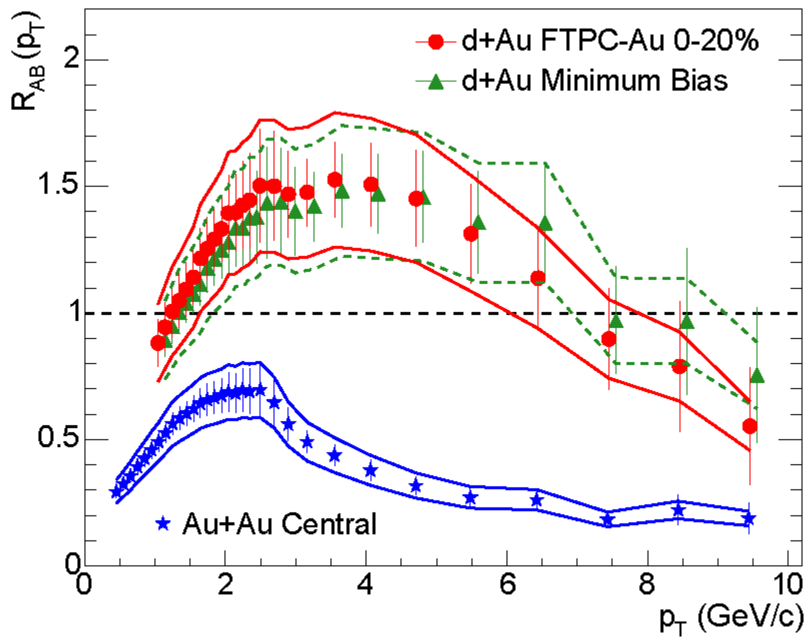
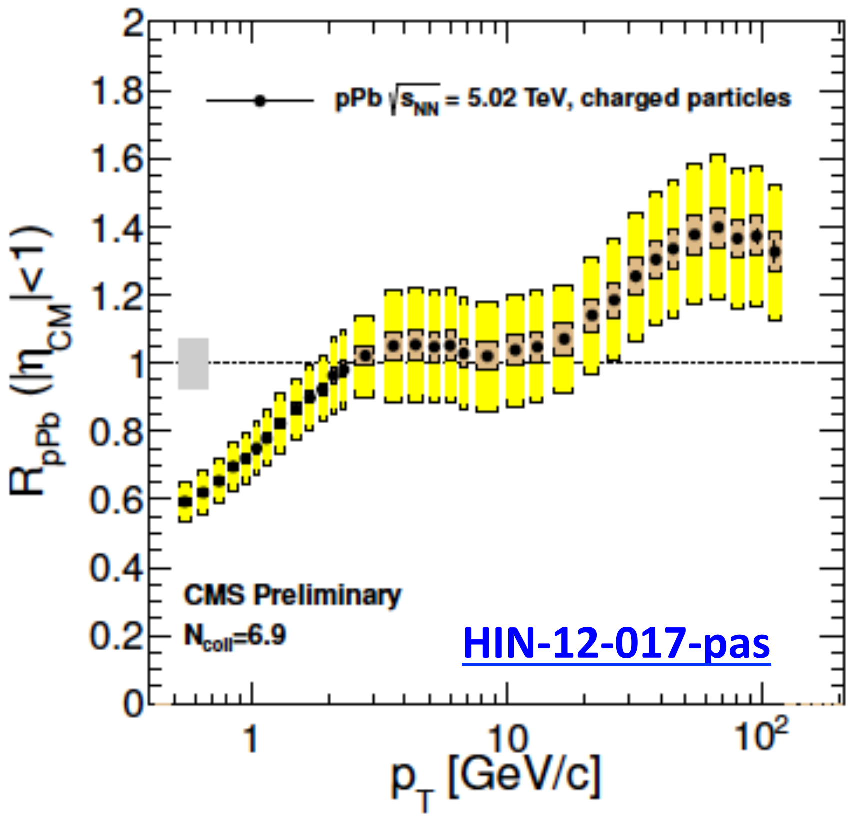
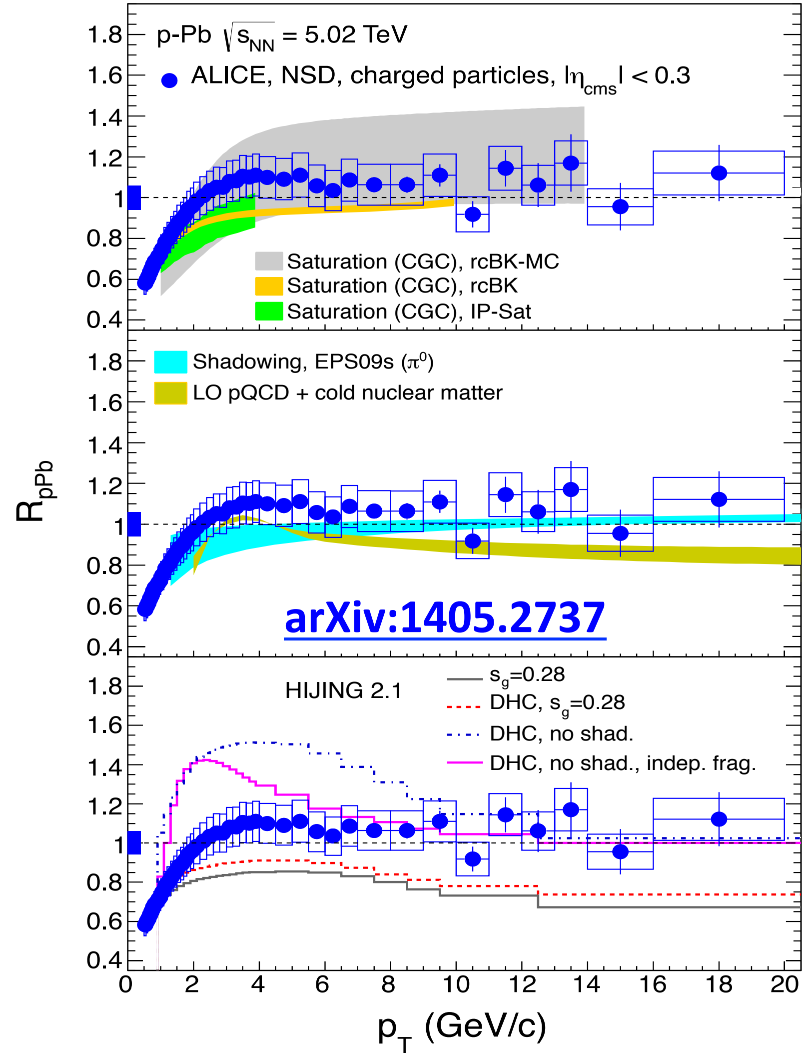


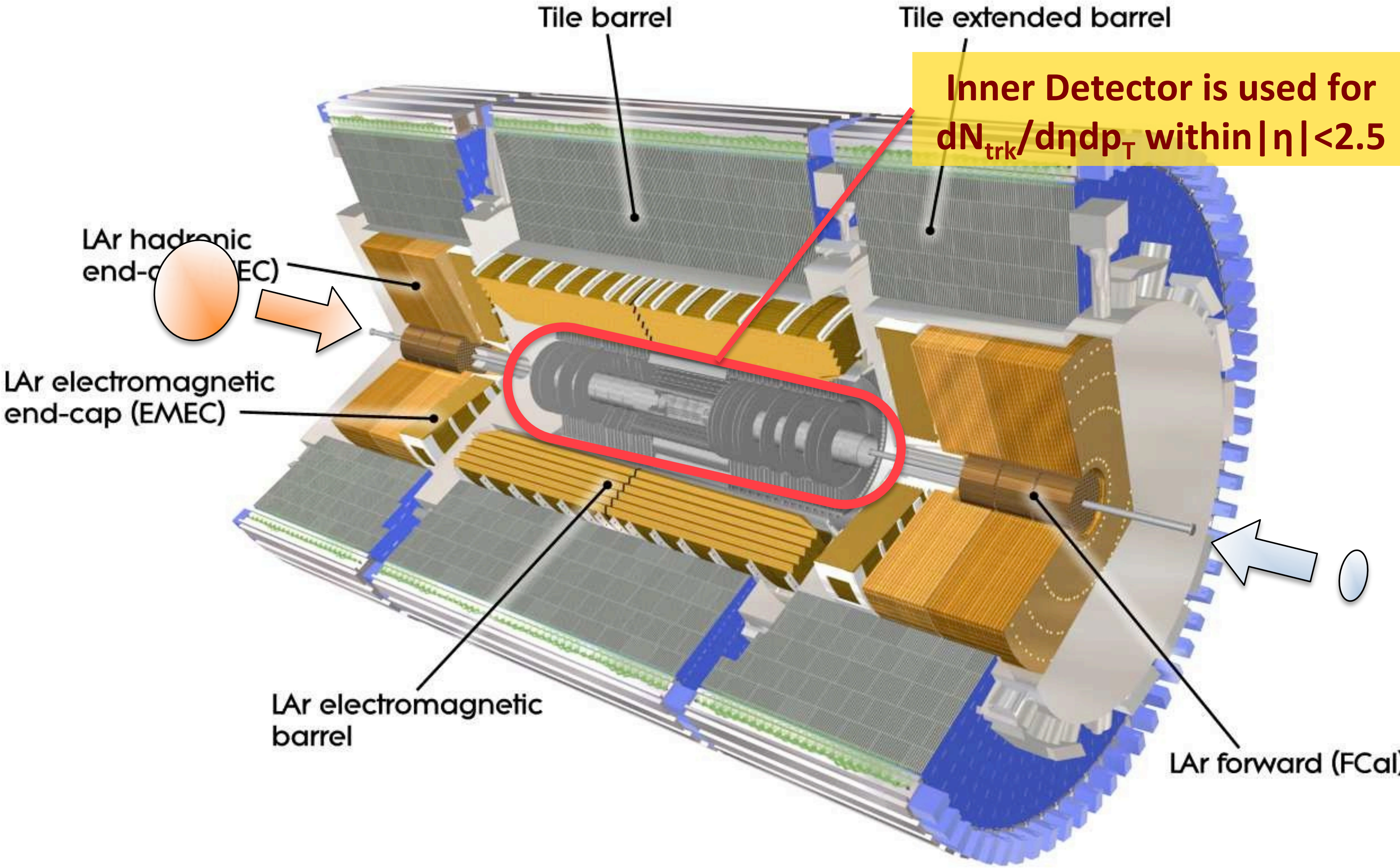
Recent LHC results





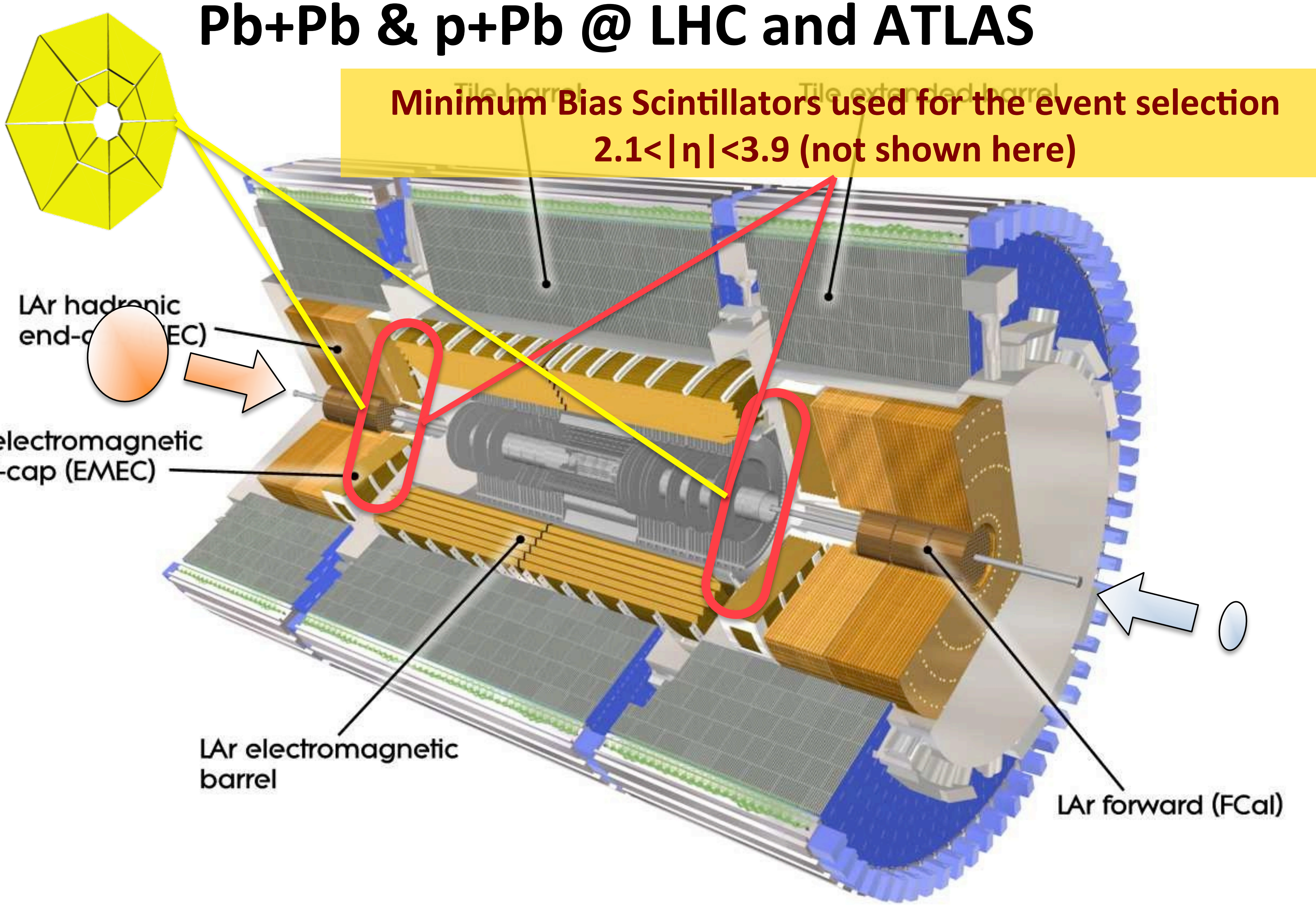
- There is no precise description for the dynamics of the peak
- Centrality dependence have been shown by the ALICE experiment

Pb+Pb & p+Pb @ LHC and ATLAS

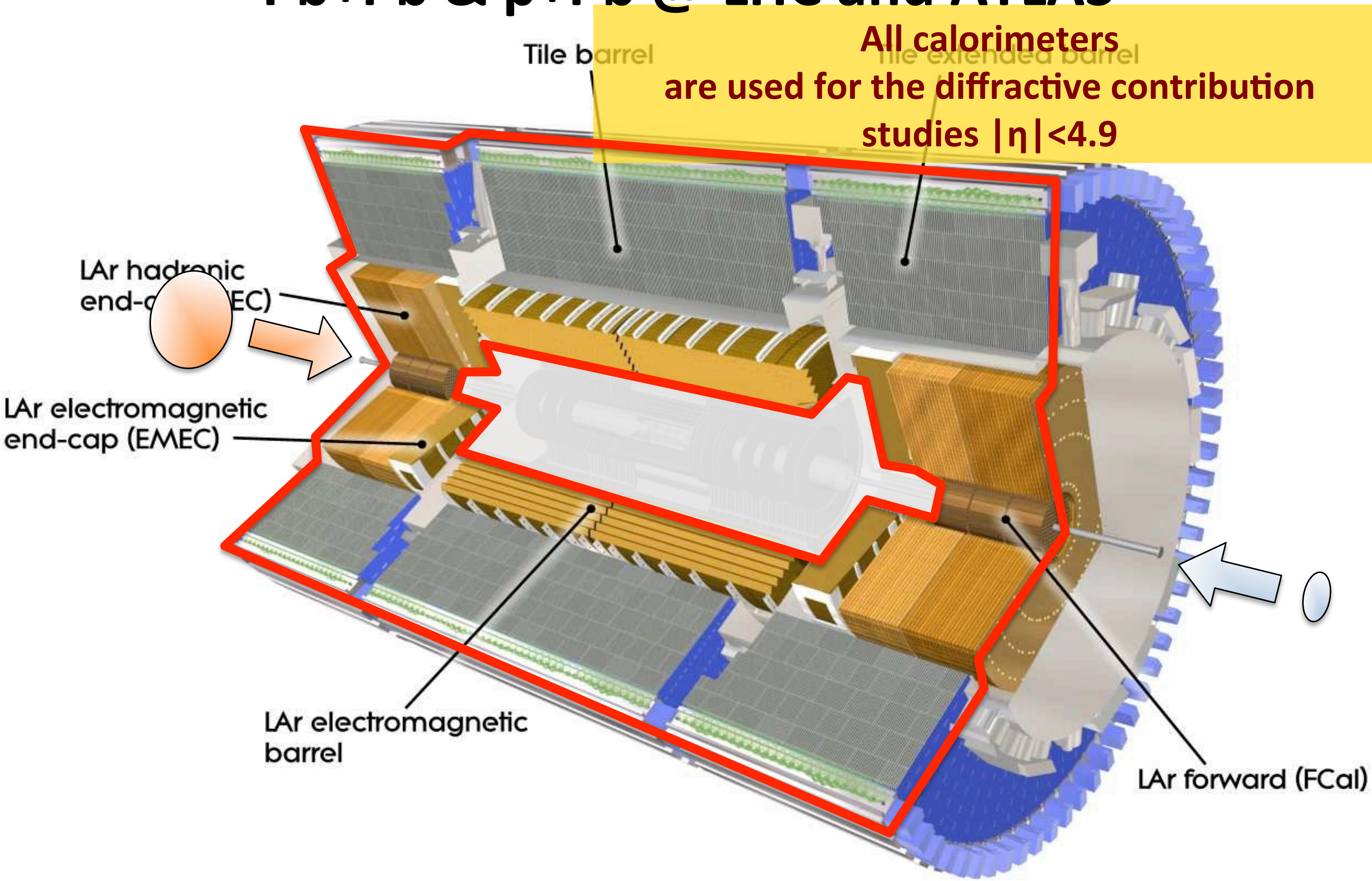


Pb+Pb & p+Pb @ LHC and ATLAS

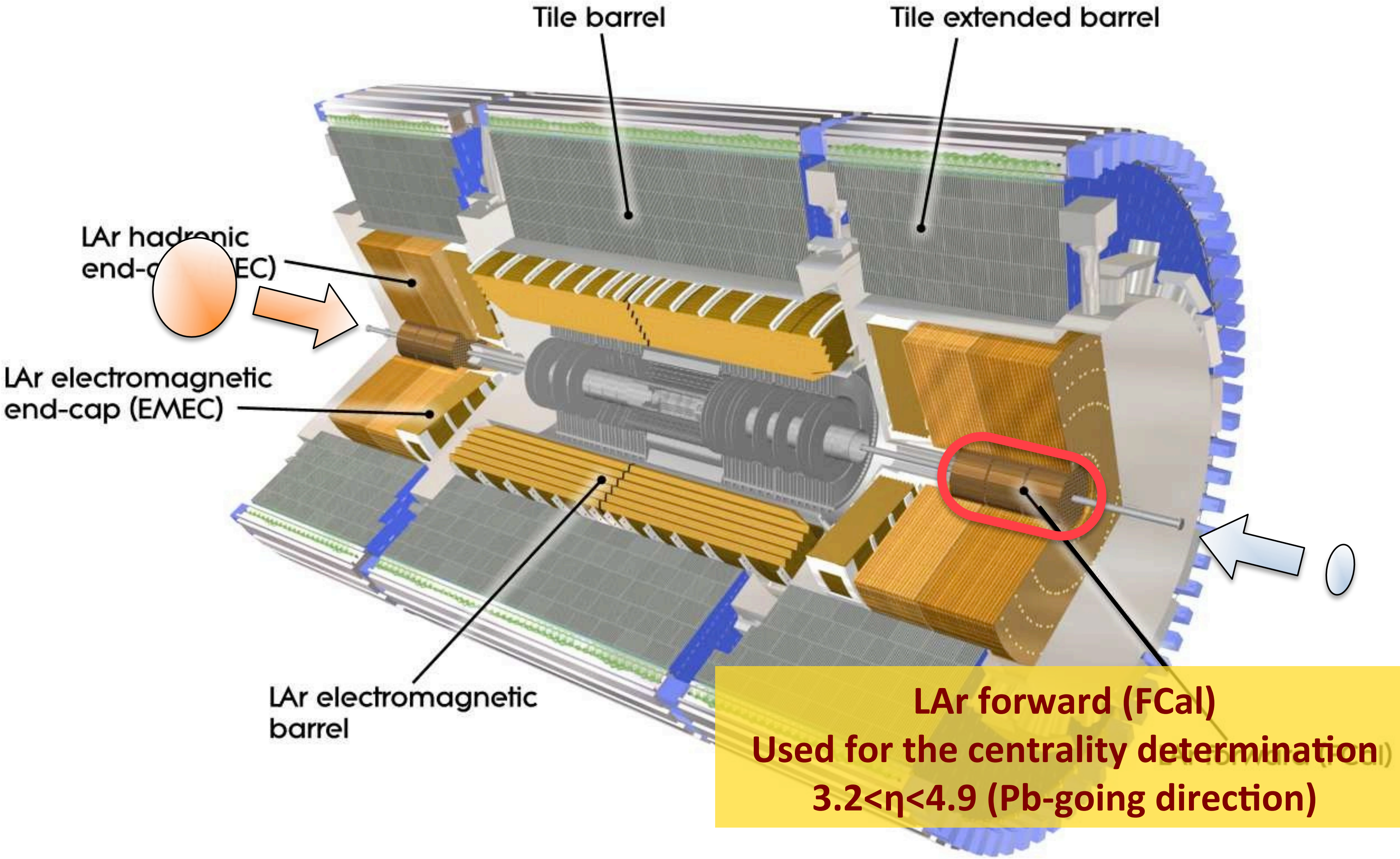
Minimum Bias Scintillators used for the event selection $2.1<|\eta|<3.9$ (not shown here)



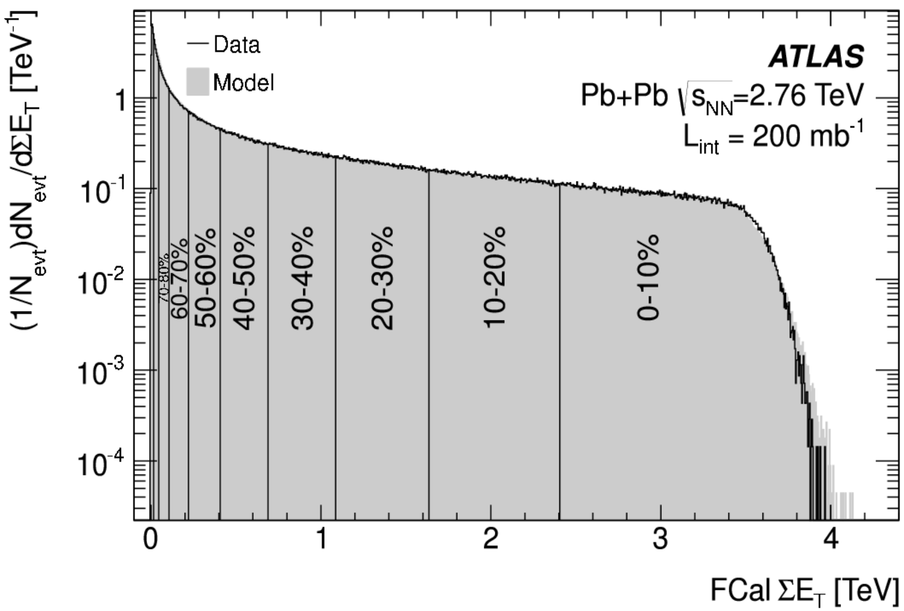
Pb+Pb & p+Pb @ LHC and ATLAS

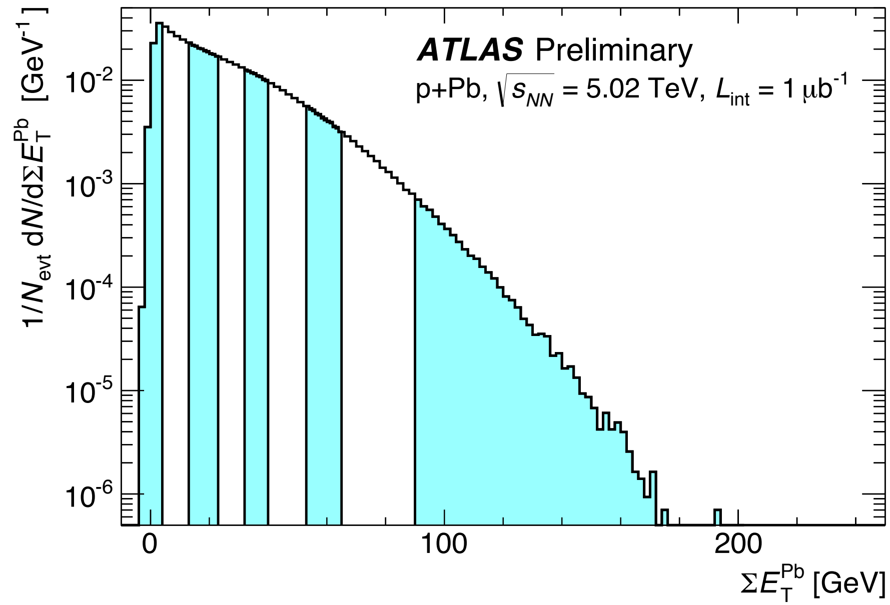


Pb+Pb & p+Pb @ LHC and ATLAS



Centrality definition





- Centrality based on energy deposited in Forward Calorimeter – $3.1 < |\eta| < 4.9$
- Model – based on Glauber calculation convoluted with p+p data

For p+Pb:

- Pb-going FCal (side "A") is used to characterize event centrality, it is more sensitive to nuclear geometry in p+Pb
- Gribov extension is evaluated for the centrality estimations

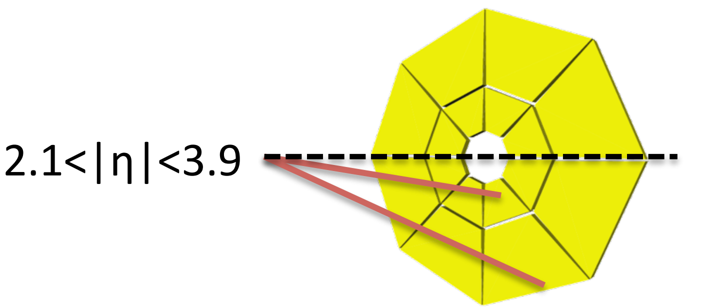
Pb+Pb event selection

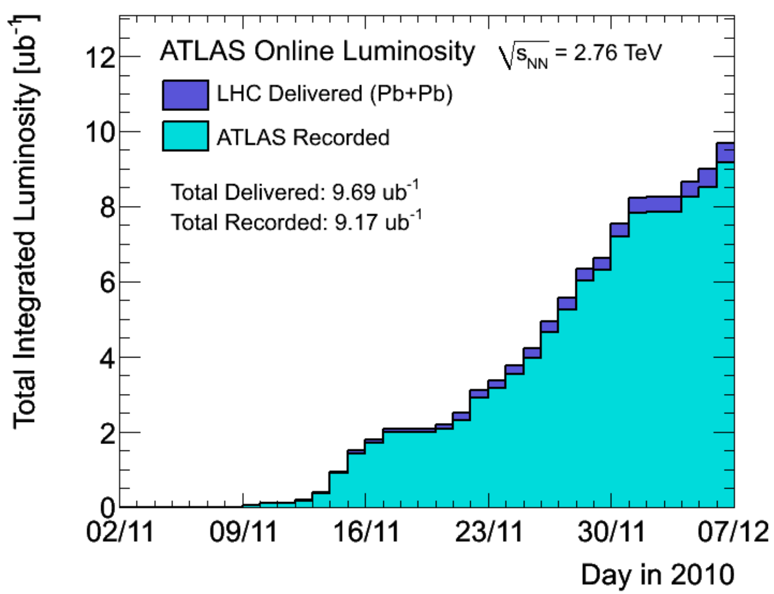
Data 2010 and 2011 are used:

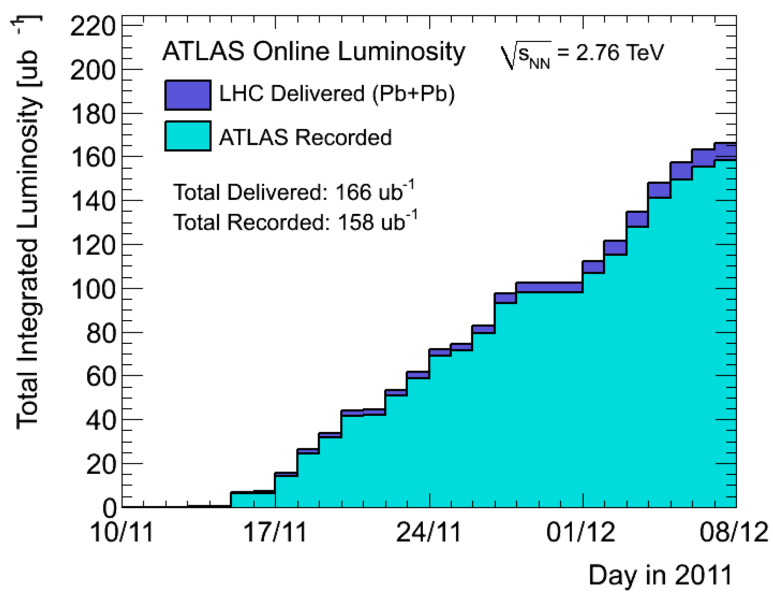
- minimum bias 2010 – 7μb^{-1}, 50.7M events
  - MBTS or ZDC
- minimum bias 2011 – 7μb^{-1}, 50.7M events
  - total energy > 50 GeV
  - or signal from ZDC+track
- to reconstruct high p_T part of the spectrum,

hard probes 2011 is used – 0.14nb^{-1}, 998M sampled events

  - unprescalled jet trigger: anti-k_T , E_T > 20 GeV

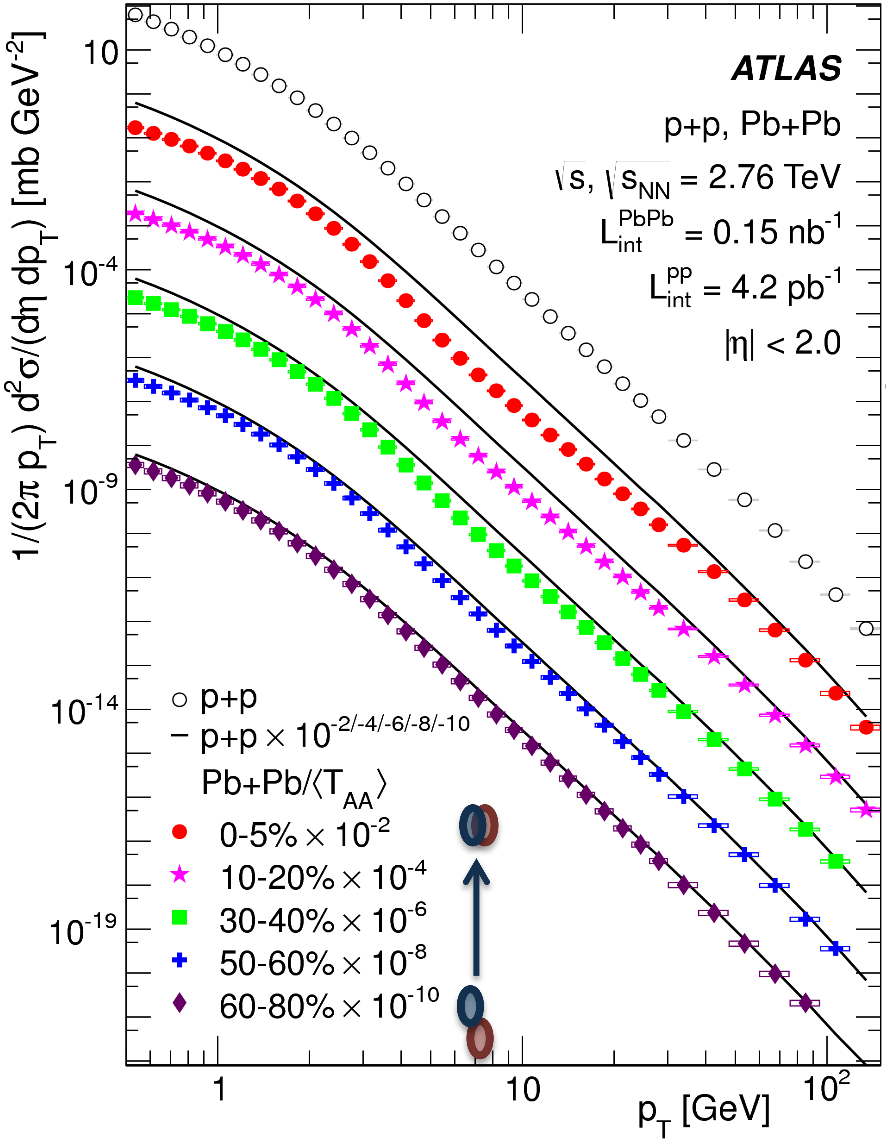


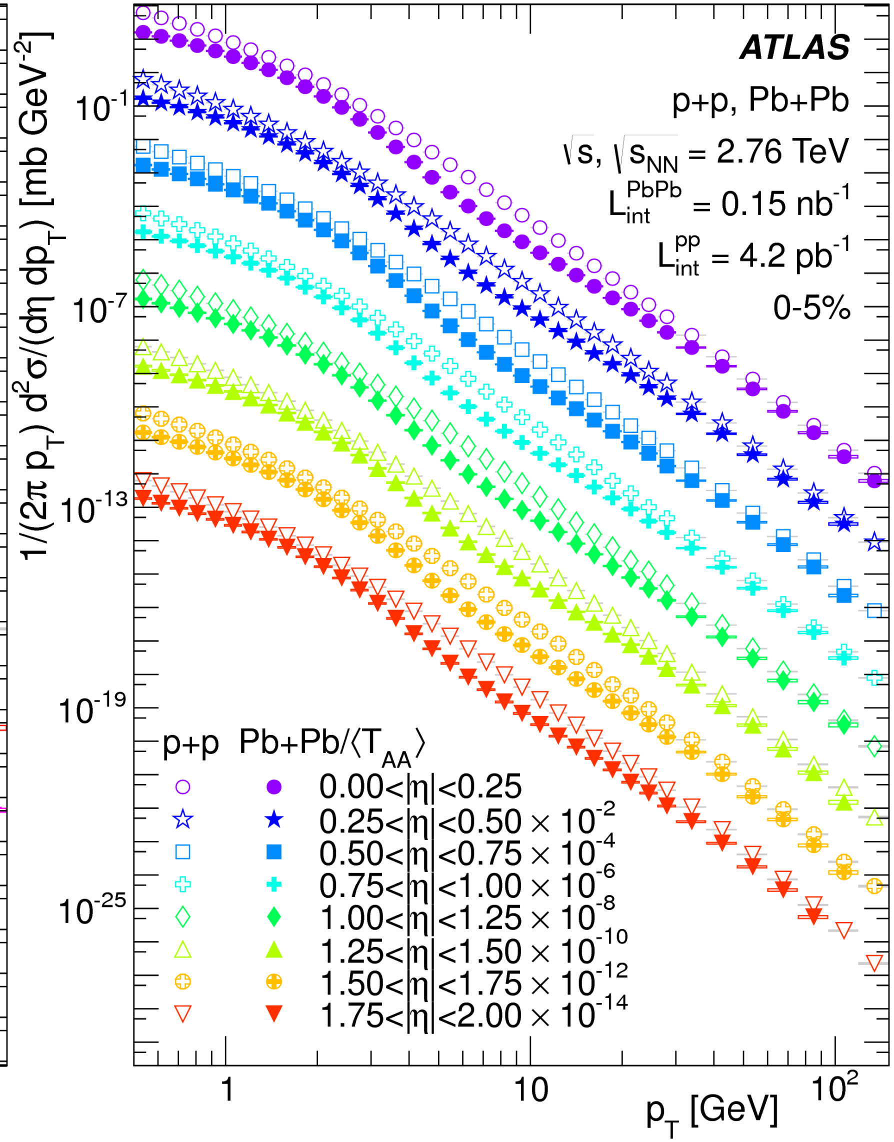




Charged particle spectra: Pb+Pb

arXiv:1504.04337v1

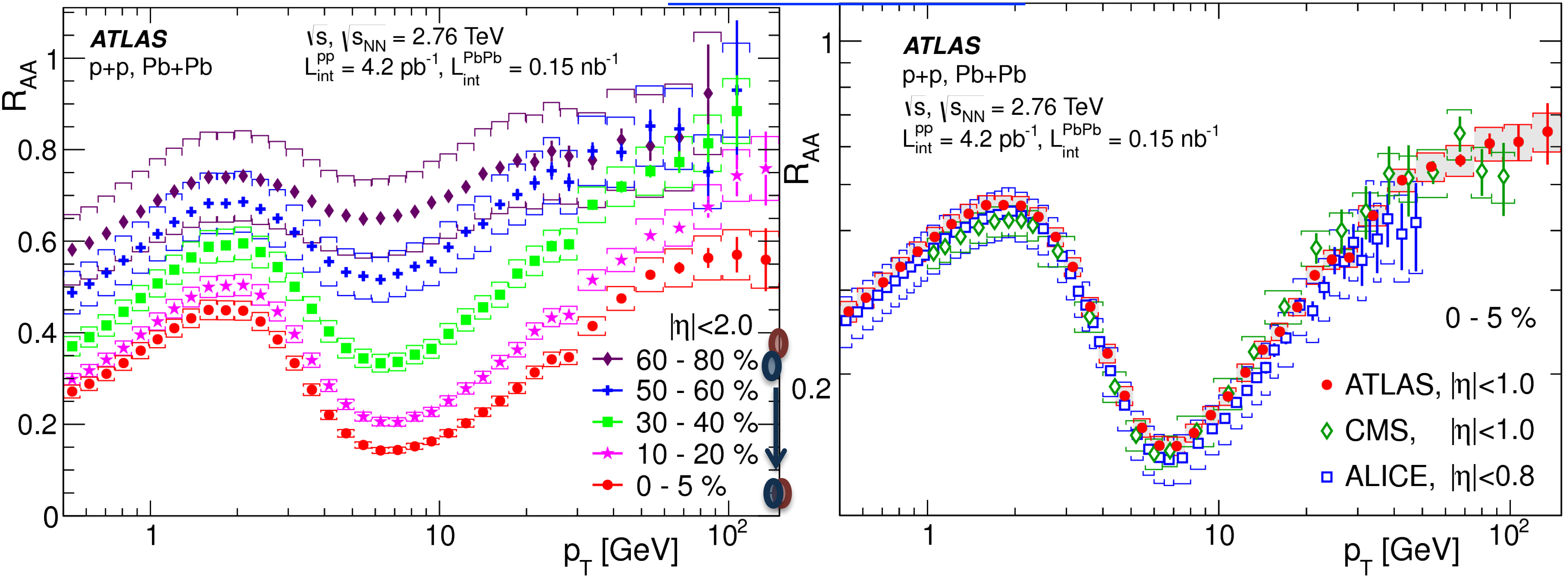




- Significant difference is visible

R_{AA} ($0.5<p_T<150$ GeV): Pb+Pb

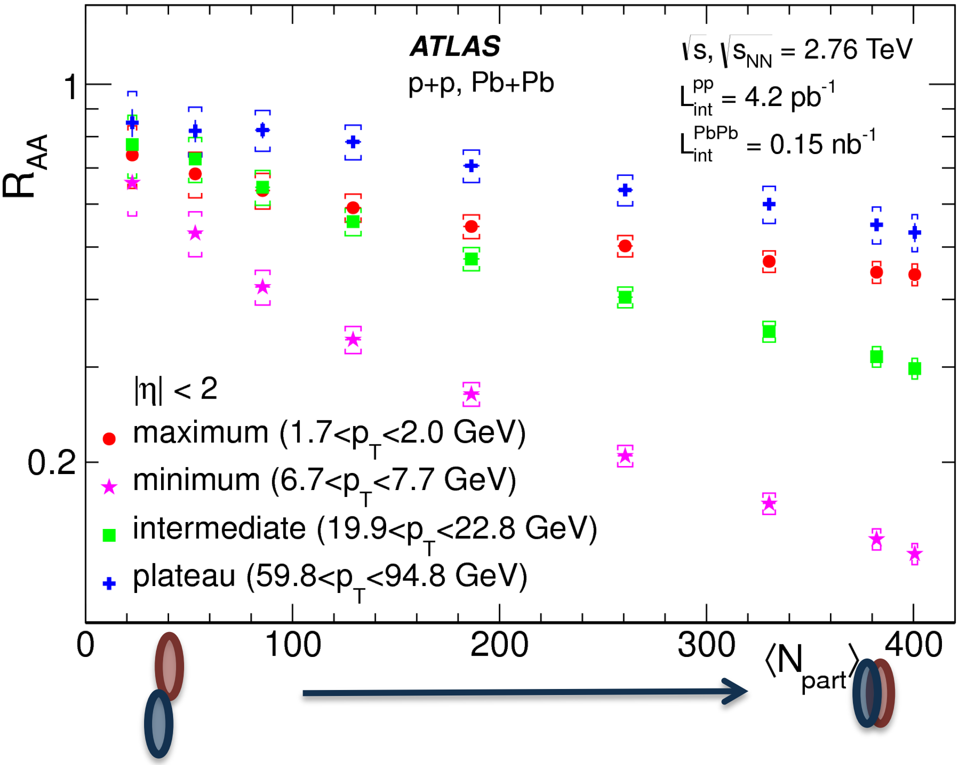
arXiv:1504.04337v1

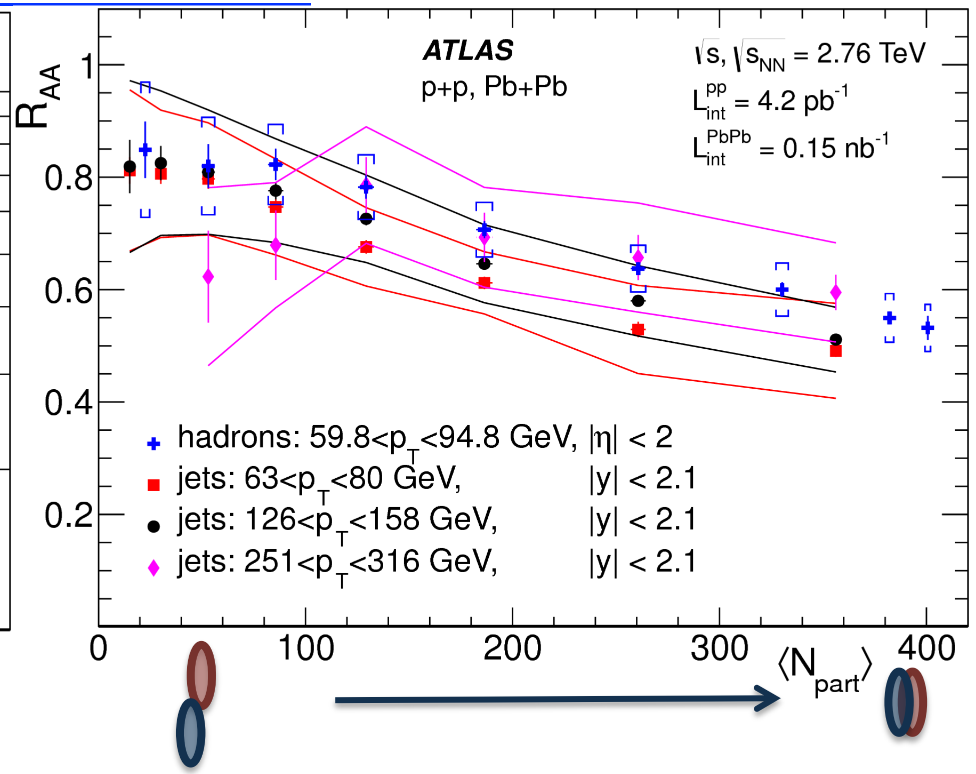


- The measurement is extended up to 150 GeV with better statistics
- R_{AA} shows strong p_T dependence
- R_{AA} decreases with higher p_T reaching a minimum at $p_T \approx 7$ GeV, where the charged-particle suppression is strongest
- R_{AA} shows good agreement with other experiments

R_{AA}: Pb+Pb

arXiv:1504.04337v1

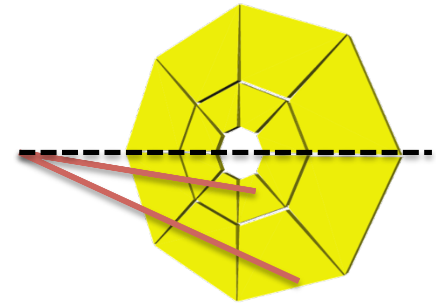




- In all momentum intervals R_{AA} decreases with $\langle N_{part} \rangle$
- The decrease is strongest for the minimum ($6.7<p_T<7.7$ GeV) interval and weakest in the plateau region
- In the more central collisions the jet R_{AA} reaches lower values

p+Pb event selection

2012 p+Pb pilot run is used for the measurements
Integrated Luminosity: $1\mu b^{-1}$



1. Two scintillator signals in the MBTS:
2. Good timing $|\Delta t|<10$ns

3. Reconstructed vertex with at least two tracks of $p_T>100$ MeV.

4. Pileup during data taking was at the level of 10^{-3}
5. Events with two good vertices were rejected, residual pile-up 10^{-4}

6. A pseudorapidity gap on the lead going side of $\Delta\eta^{Pb}\leq2.0$

Sample used in the analysis: 2,131,219 events.
This sample corresponds to 98±2% of the inelastic events.

Charged particle spectra: p+Pb

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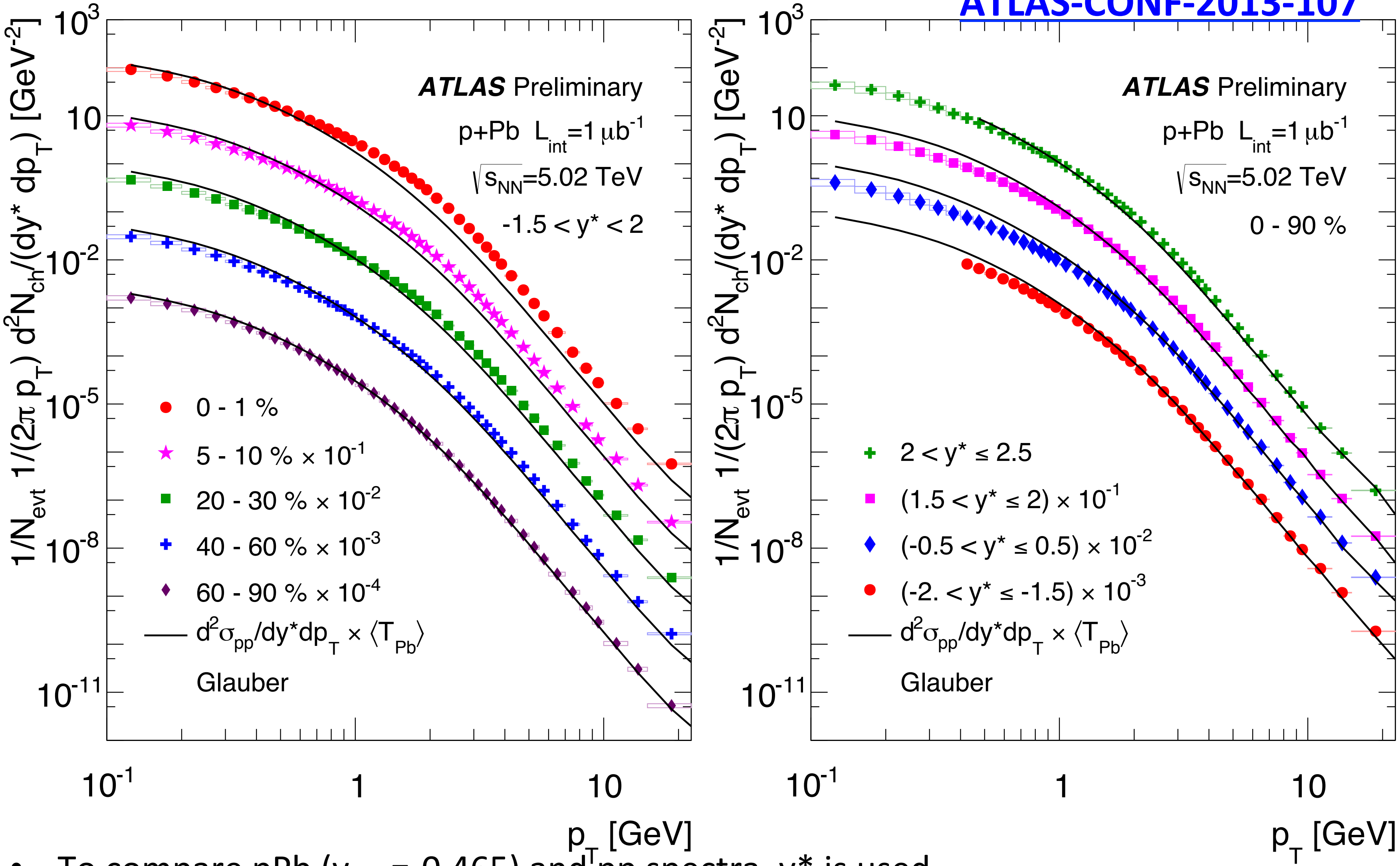

- To compare pPb (y_{cms}=-0.465) and pp spectra, y* is used
- Significant difference is observed

Charged particle spectra high p_T: p+Pb

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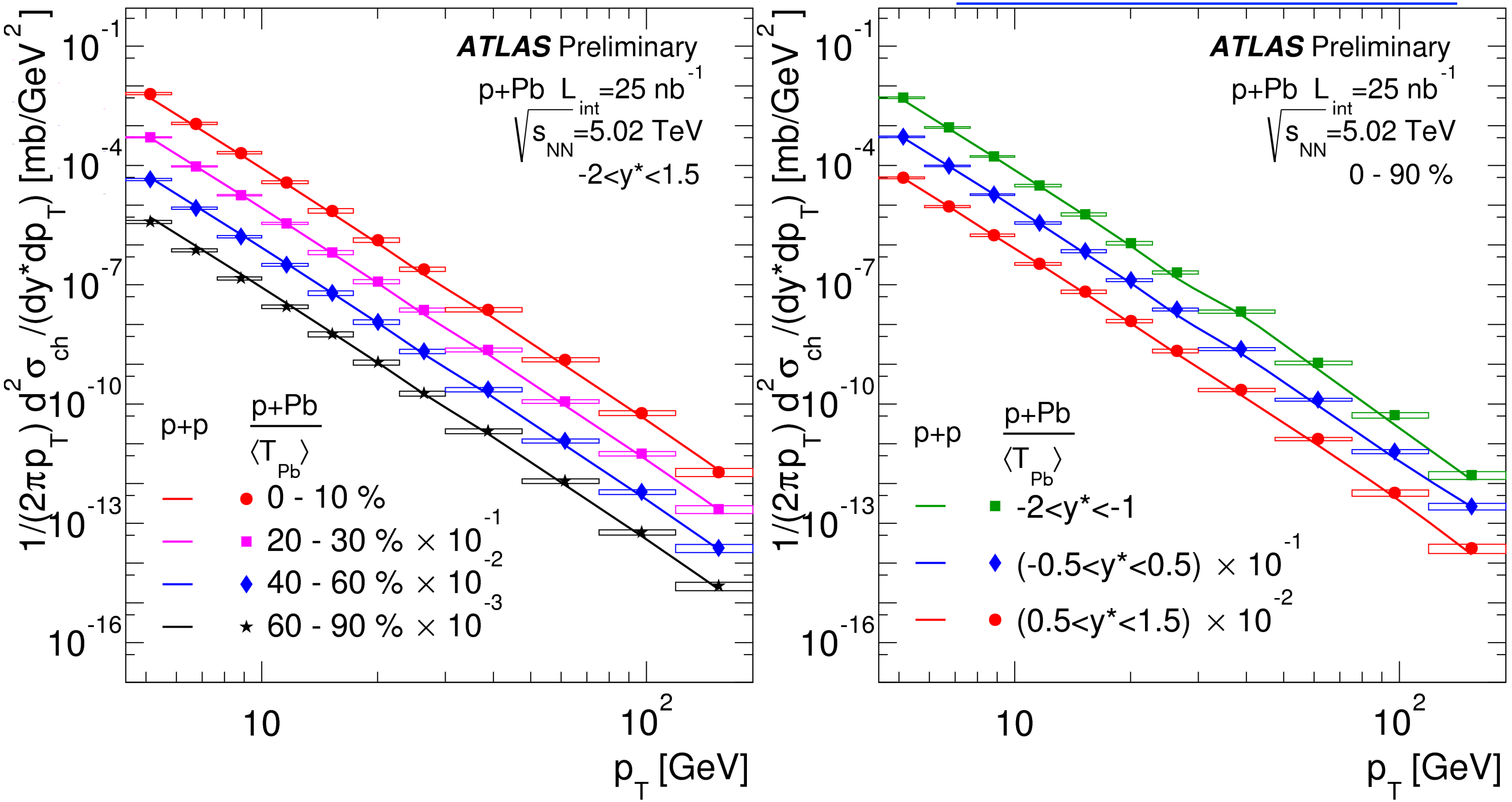

- Spectra are used for R_{pPb}

ATLAS R_{pPb}

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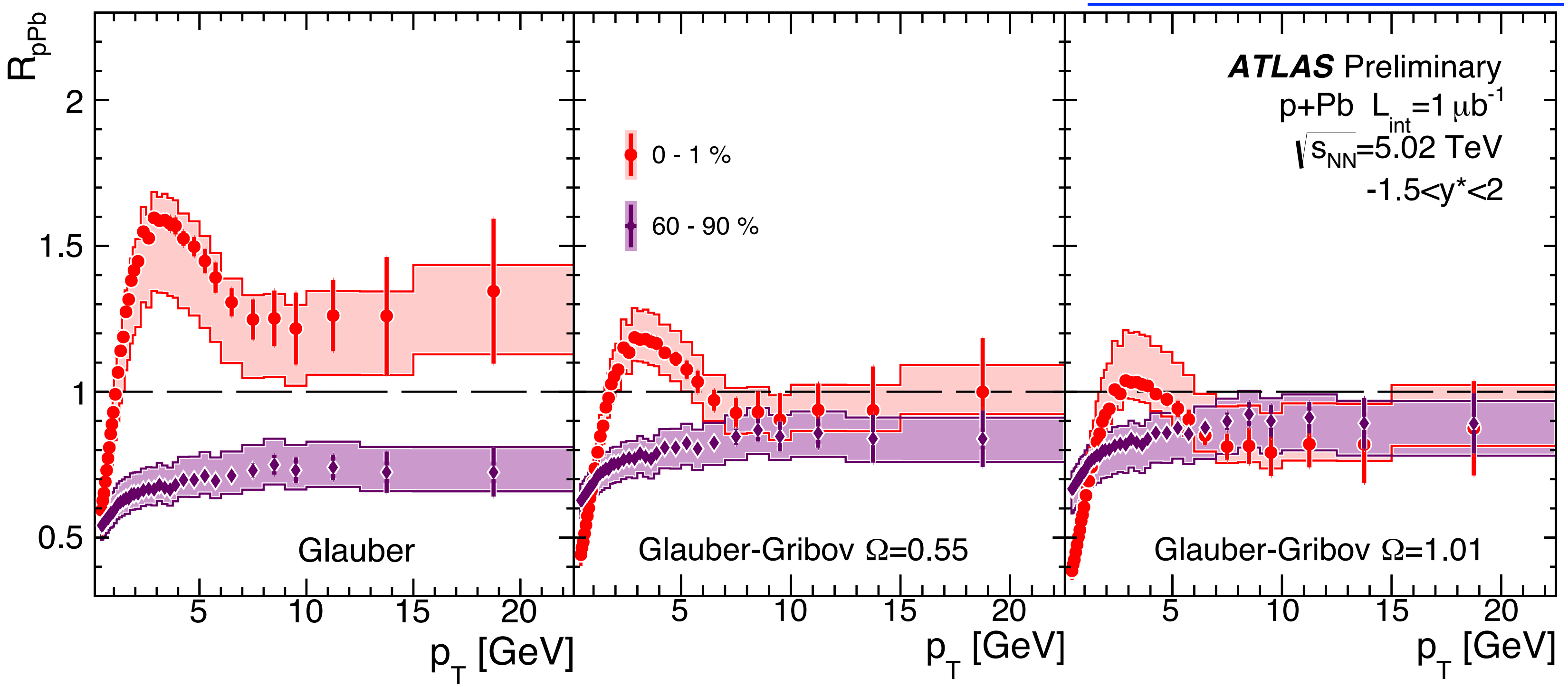

- Shows pronounced so-called Cronin peak
- R_{pPb} at low p_T shows strong variation with p_T
- Significant change in the interpretation with different centrality models

ATLAS R_{pPb}

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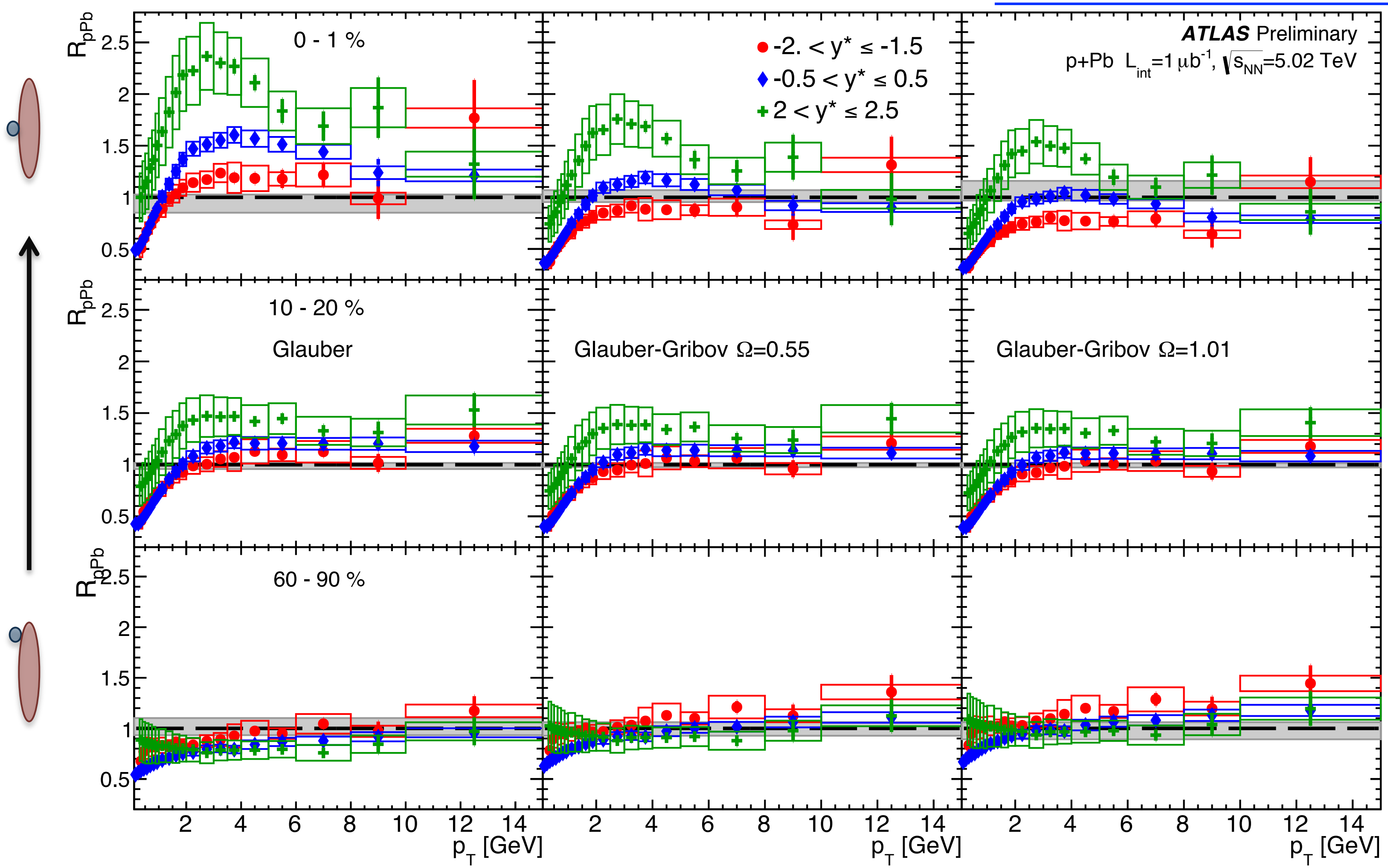
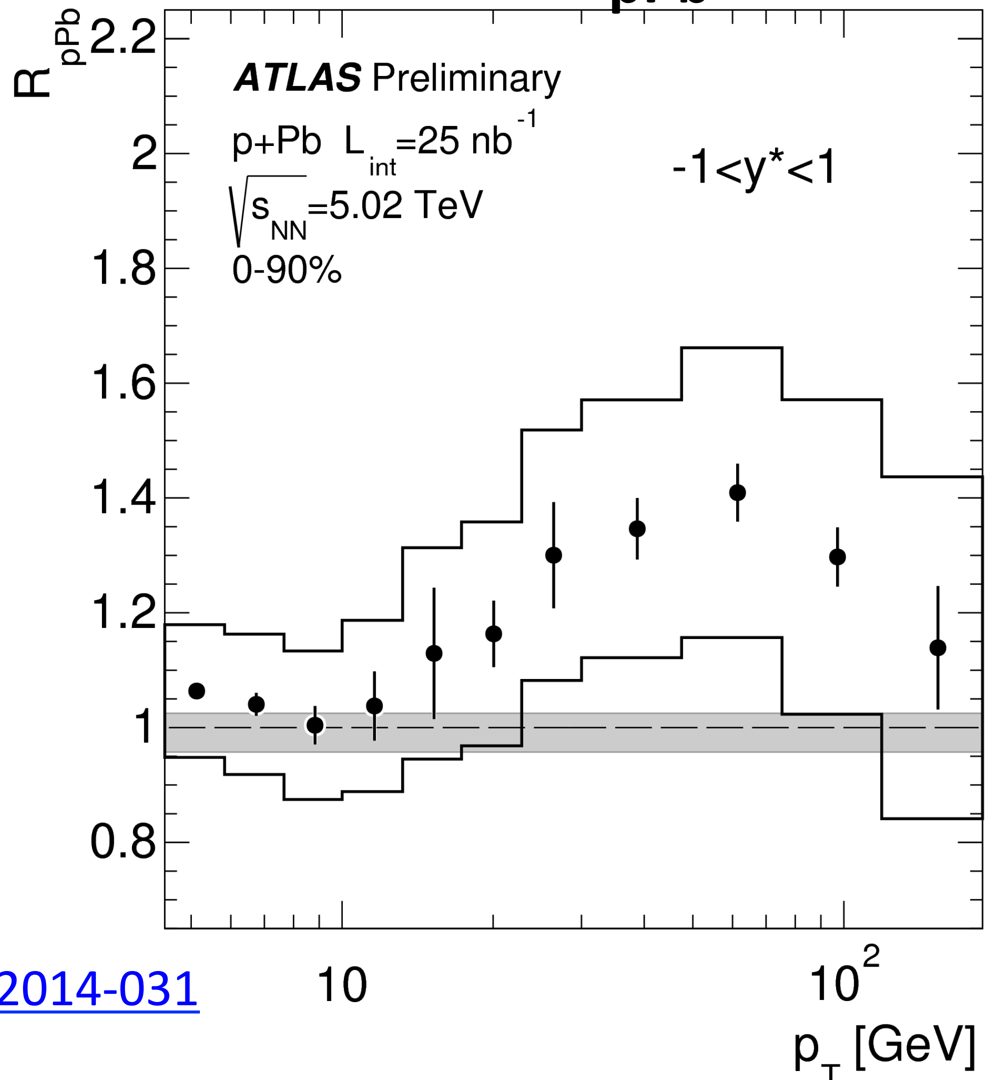


- Shows shift to the positive y* with increasing centrality
- So-called Cronin peak is more pronounced when centrality is higher

ATLAS R_{pPb}

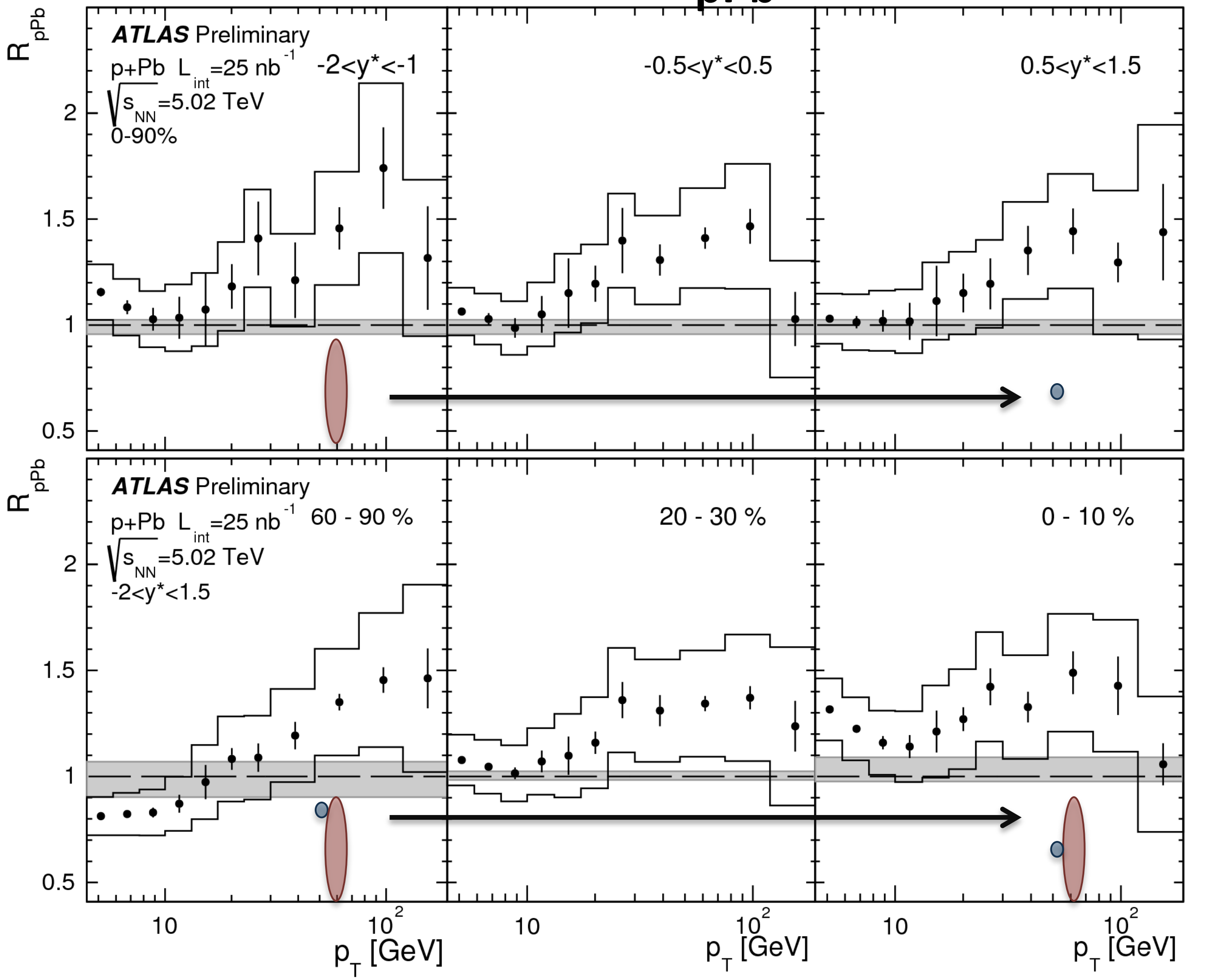


[ATLAS-COM-CONF-2014-031]

- ATLAS have provided close to CMS results with higher enhancement then it is expected for parton anti-shadowing

ATLAS R_{pPb}

ATLAS-COM-CONF-2014-031



- For low p_T values R_{pPb} strongly correlate with y* & centrality
- For higher p_T values enhancement is present

Conclusion

- Pb-Pb and p-Pb spectra are measured within $|\eta| < 2.5$ and $0.1\text{GeV} < p_T < 150\text{GeV}$
- For PbPb:
  - The measurement is extended up to 150 GeV with better precision
  - Minimum seen at around 7 GeV, above show rise up to high p_T for the Pb+Pb measurement
  - R_{AA} agrees with level of suppression measured in jets

- For pPb:
  - R_{pPb} at low p_T shows strong variation with p_T, rapidity and centrality with a pronounced so-called Cronin peak
  - An enhancement at higher p_T is observed
  - p+Pb high p_T measurement agrees with CMS result

- Obtained results show strong influence of hot & cold matter effects on the charged particle production with indication of needs to improve centrality calculation models for future results

Thank You !

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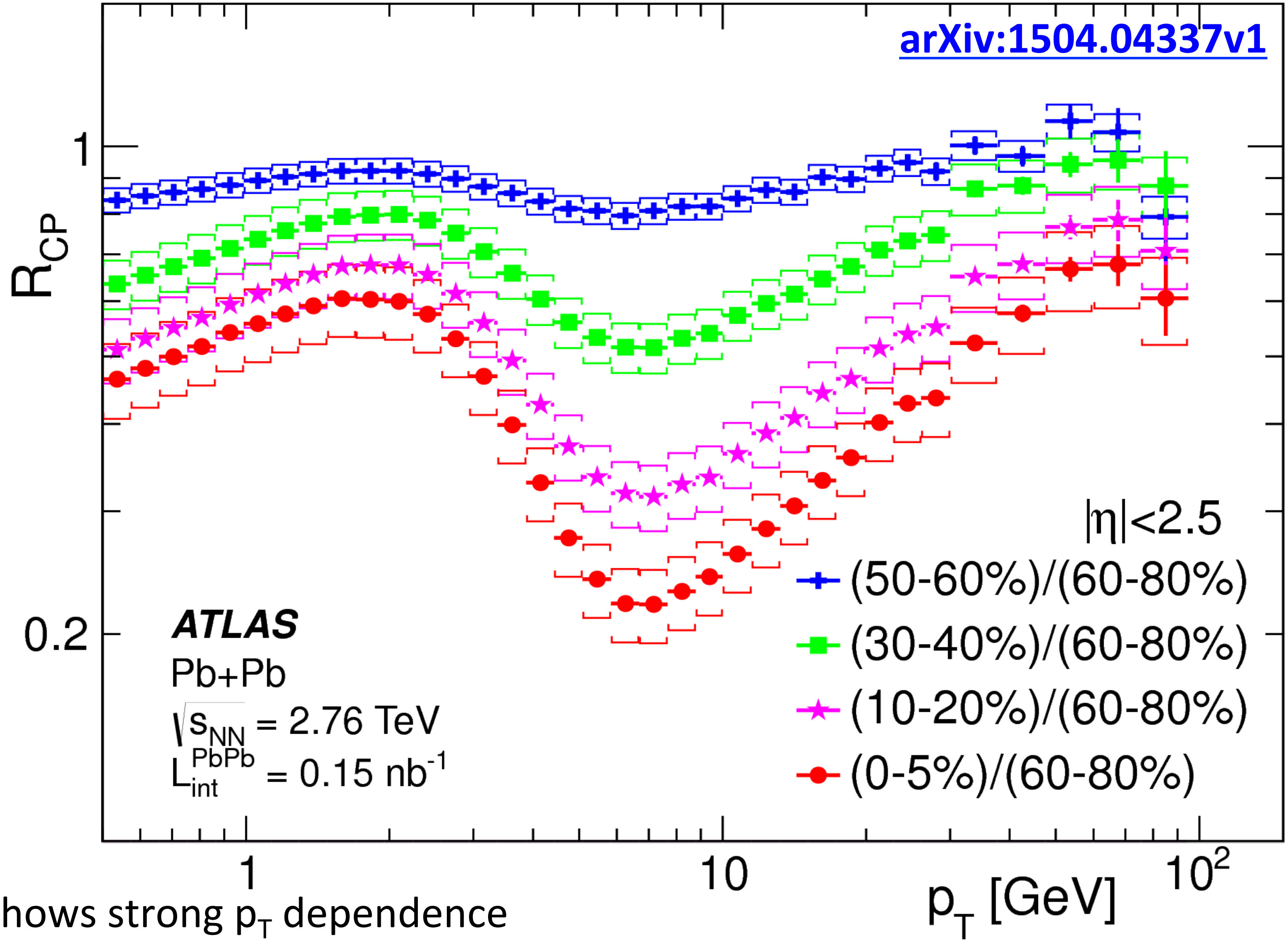
Systematics: Pb+Pb

arXiv:1504.04337v1

Systematic uncertainties [%]					
	Spectra		R_{CP}	R_{AA}	Strongest
Source	Pb+Pb	pp			variation
Luminosity		3		3	
$\langle T_{\mathrm{AA}} \rangle$				1.5–13	centrality
$\langle T_{\mathrm{AA}} \rangle / \langle T_{\mathrm{AA}}^{60-80\%} \rangle$			3.8–12		centrality
Jet trigger efficiency	1	3	1	3	p_{T}
Track selection	10	4	10	10	p_{T}
Fake and secondary tracks	5	0.5	5	5	p_{T}, centrality
Matching gen – rec	20	15	15	13	p_{T}
Unfolding	8	2	4	2	p_{T}
p_{T} resolution	20	7	14	12	p_{T}
Efficiency correction	5	1	4	4	p_{T}, η
Detector material	2–6	2–6			η

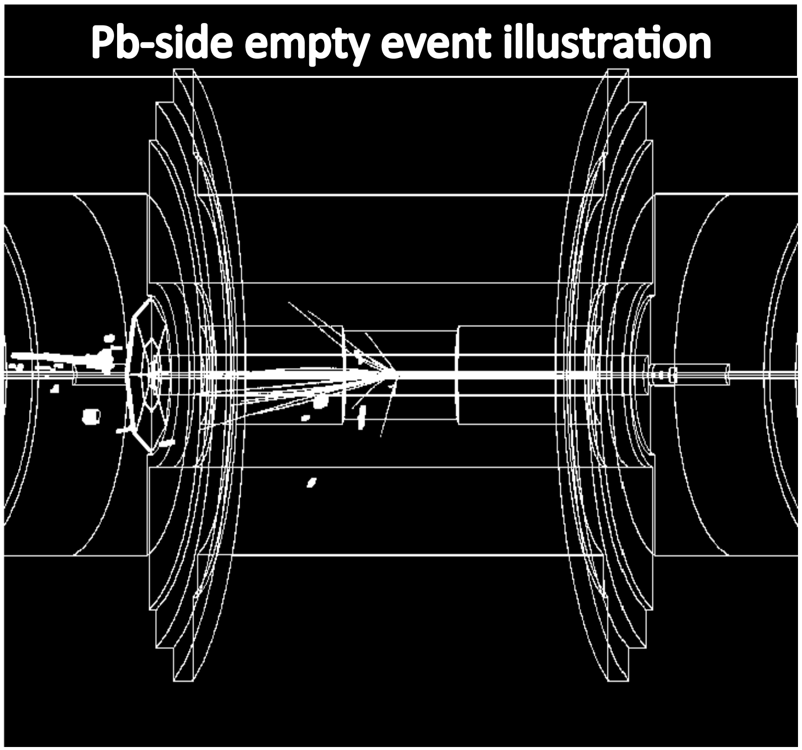
R_{CP}: Pb+Pb



- R_{CP} shows strong p_T dependence
- R_{CP} decreases with higher pT reaching a minimum at $p_T \approx 7$ GeV, where the charged-particle suppression is stronger

Removal of events with large η gaps

- pPb interactions produce an additional coherent and photo-nuclear component of events consistent with the excitation of the proton



- Full coverage $|\eta| < 4.9$ divided into $\Delta\eta = 0.2$ intervals
- Occupied interval , contains reconstructed tracks or calorimeter clusters with $p_T > 200$ MeV
- $\Delta\eta^{Pb}_{gap} = \Sigma\Delta\eta^{Pb}_{Empty\ interval}$
- Electromagnetic or diffractive excitation of the proton typically produce $\Delta\eta^{Pb}_{gap} > 2$ ($f_{gap} = 6\%$)

Glauber and Glauber-Gribov models

To model Npart distribution we used:

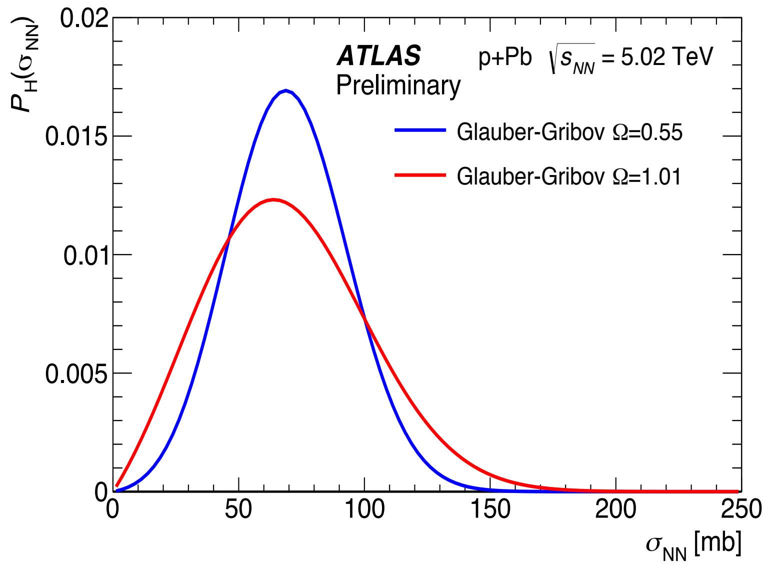
- standard Glauber with σ_{NN} cross section = 70±5mb
- Glauber-Gribov color fluctuation models, with $\langle\sigma_{NN}\rangle$ cross section = 70±5mb

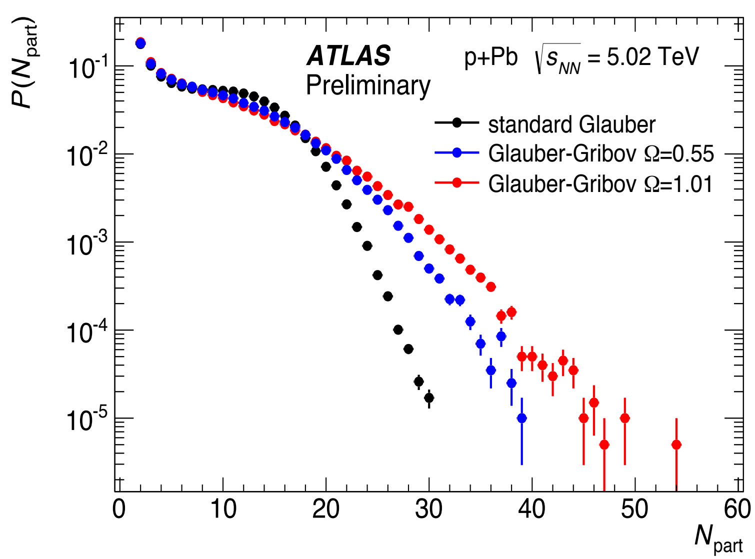
In Glauber-Gribov model:

- σ_{tot} is considered frozen for each event
- parameter Ω controls the amount of fluctuations
- Ω is extracted from experimental data: 0.55 [PLB633 (2006) 245–252] and 1.01 [PLB 722 (2013) 347–354]

$$P_h(\sigma_{\rm tot}) = \rho \frac{\sigma_{\rm tot}}{\sigma_{\rm tot}+\sigma_0} \exp\left\{-\frac{(\sigma_{\rm tot}/\sigma_0 - 1)^2}{\Omega^2}\right\}.$$

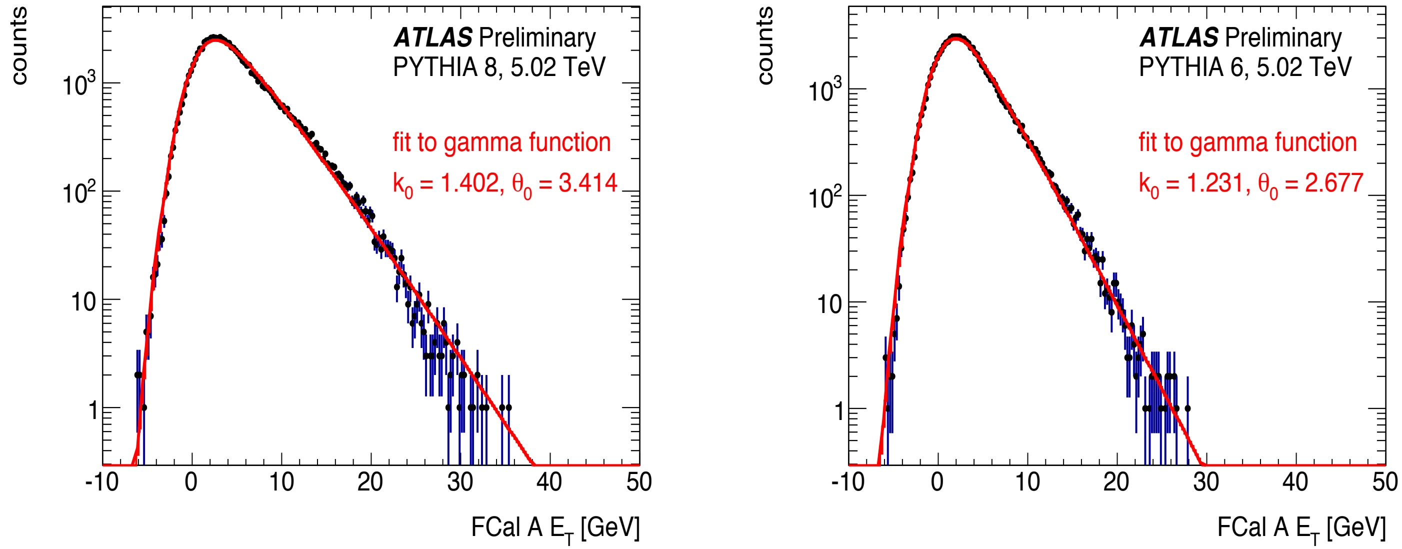
$$P_H(\sigma_{\rm NN}) = \frac{1}{\lambda} P(\sigma_{\rm NN}/\lambda)$$





Constructing FCal ΣE_T^{Pb} response

E_T distribution modeled by PYTHIA simulated taking into account FCal response in p +Pb configuration and were approximated by Gamma(k,θ) distributions



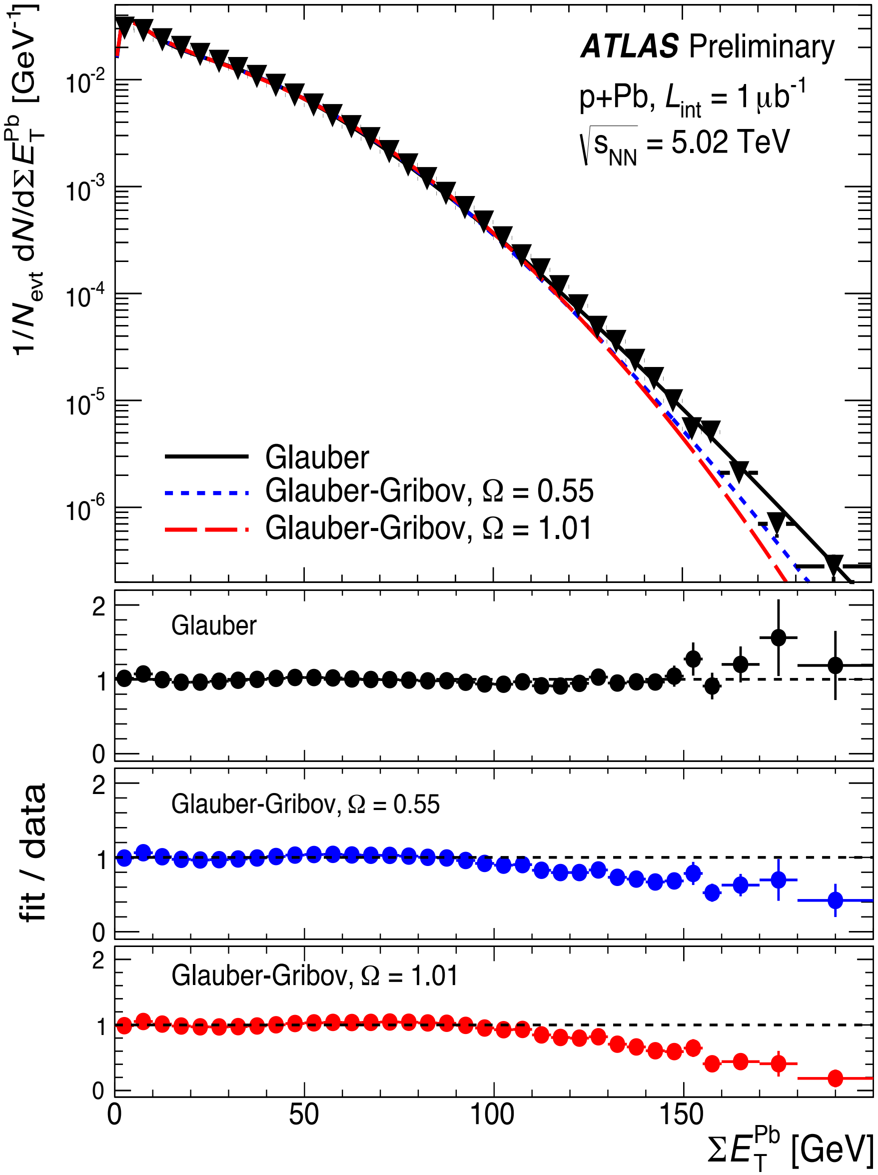
Convolution of N_{part} Gamma(k,θ) was taken as Gamma($k(N_{part})$,$\theta(N_{part})$)

We allowed: $k(N_{part}) = k_0+k_1*(N_{part}-2)$; $\theta(N_{part}) = \theta_0+\theta_1*(\log(N_{part}-1))$;

In WN : $k(N_{part}) = k*N_{part}$; $\theta(N_{part}) = \theta$;

E_T response for N_{part} was weigthed according to Glauber or Glauber-Gribov model and fitted to the data

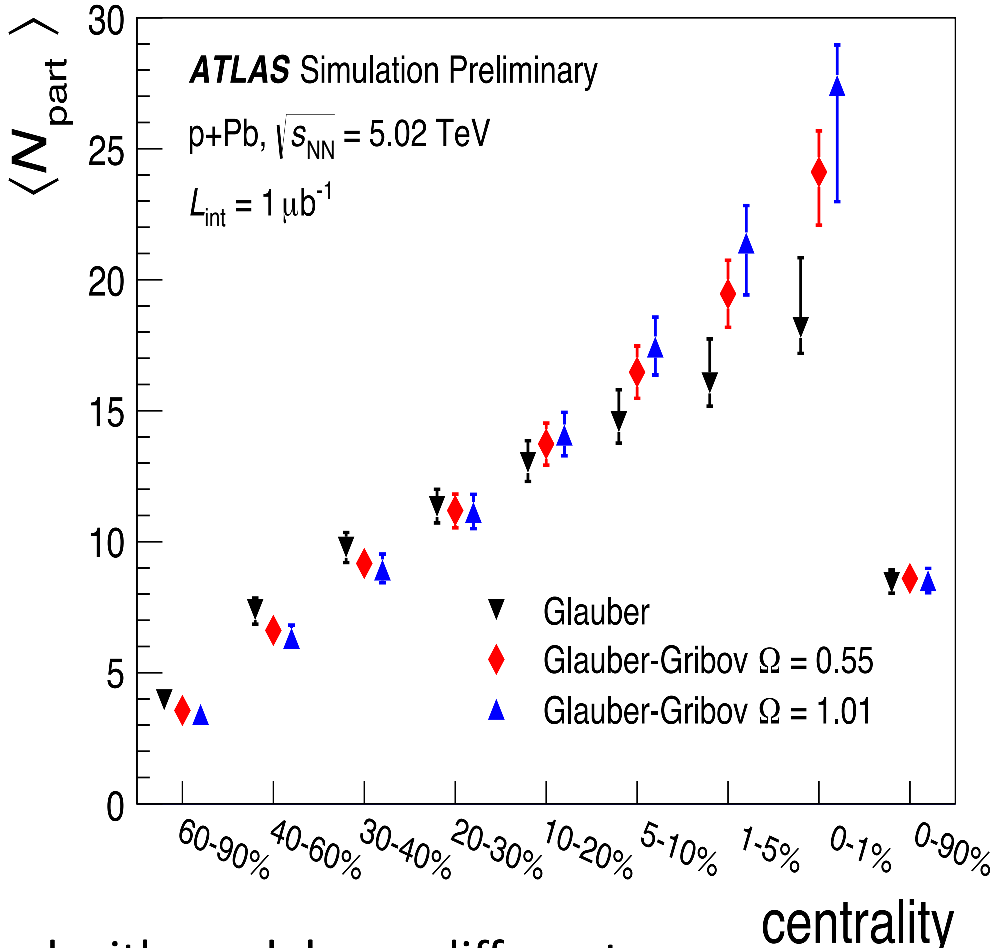
FCal E_T distribution fits



- dN_{evt}/dE_T obtained by summing the gamma distributions over different N_{part} values weighted by $P(N_{part})$

Fits to the measured E^{Pb}_T distributions show reasonable agreement over 3 orders of magnitude in E_T distribution.

N_{part} for different Glauber models



- Results produced with models are different
- Standard Glauber has highest fluctuations of produced E_T per participant
- Glauber-Gribov Ω=1.01 has less E_T fluctuation and therefore gives highest N_{part}

Systematics: p+Pb (2012)

ATLAS-CONF-2013-107

Uncertainty	p+Pb	pp	Variation
Track selection	1%	1%	decreases with p_{T}, increases with $\lvert\eta\rvert$
Particle composition	1-6%	2%	changes with p_{T}
Material budget	1-7%		decreases with p_{T}, increases with $\lvert\eta\rvert$
p_{T} reweighting	1%		flat in p_{T} and η
Rapidity transformation	0-8%		decreases with p_{T}
Centrality selection	1-6%	–	flat in p_{T} and η, increases with centrality
Trigger Efficiency	–	0.5%	
Luminosity	–	2.7% (2%)	$\sqrt{s}$=2.76 TeV (7 TeV)
$\sqrt{s}$ interpolation	–	3-9%	increases with p_{T} and flat in η
Vertex reconstruction	–	1%	

ATLAS R_{pPb}

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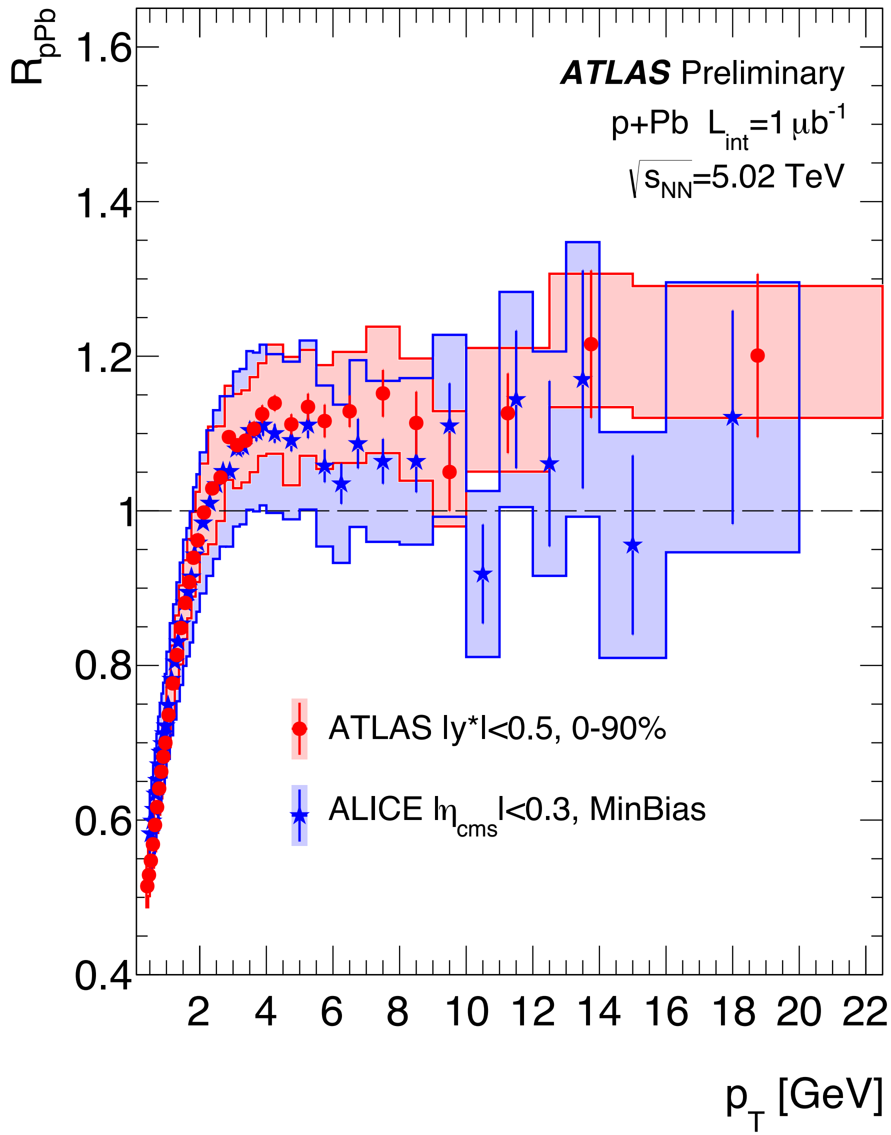
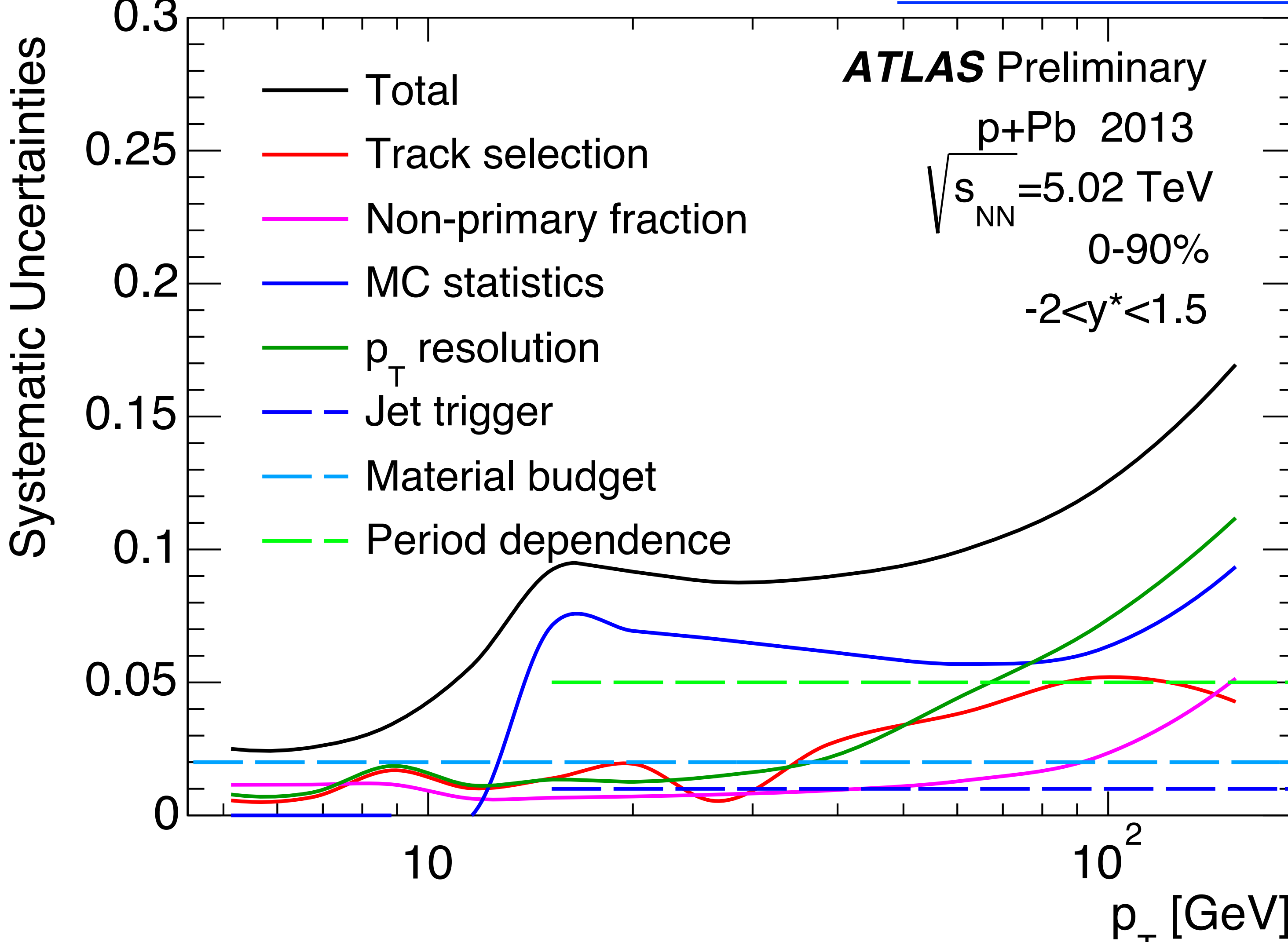


- ATLAS in a good agreement with initial ALICE results

Systematics: p+Pb (2013)

ATLAS-COM-CONF-2014-031



Ratios: p+p (2013)

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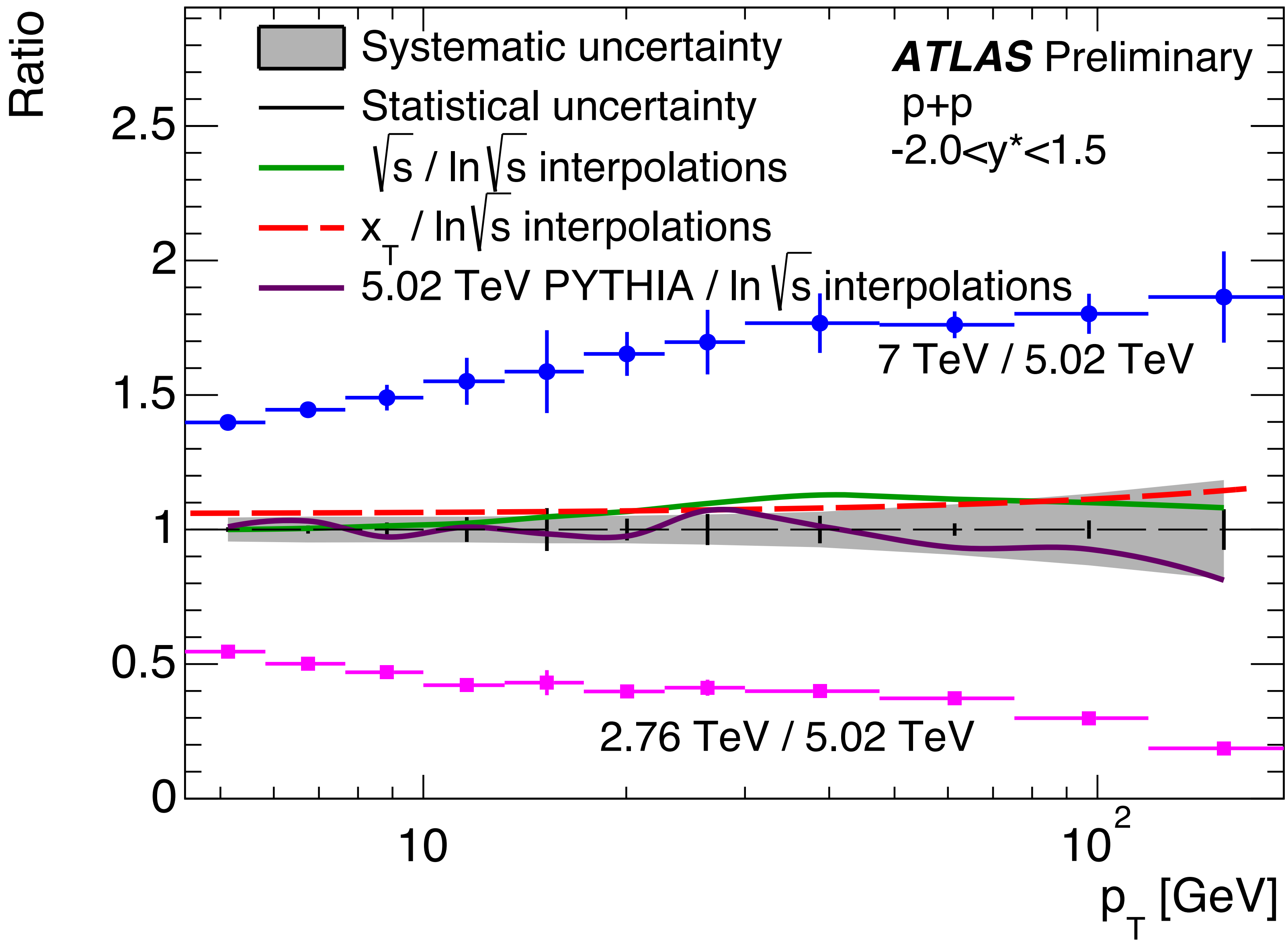

ATLAS R_{pPb}

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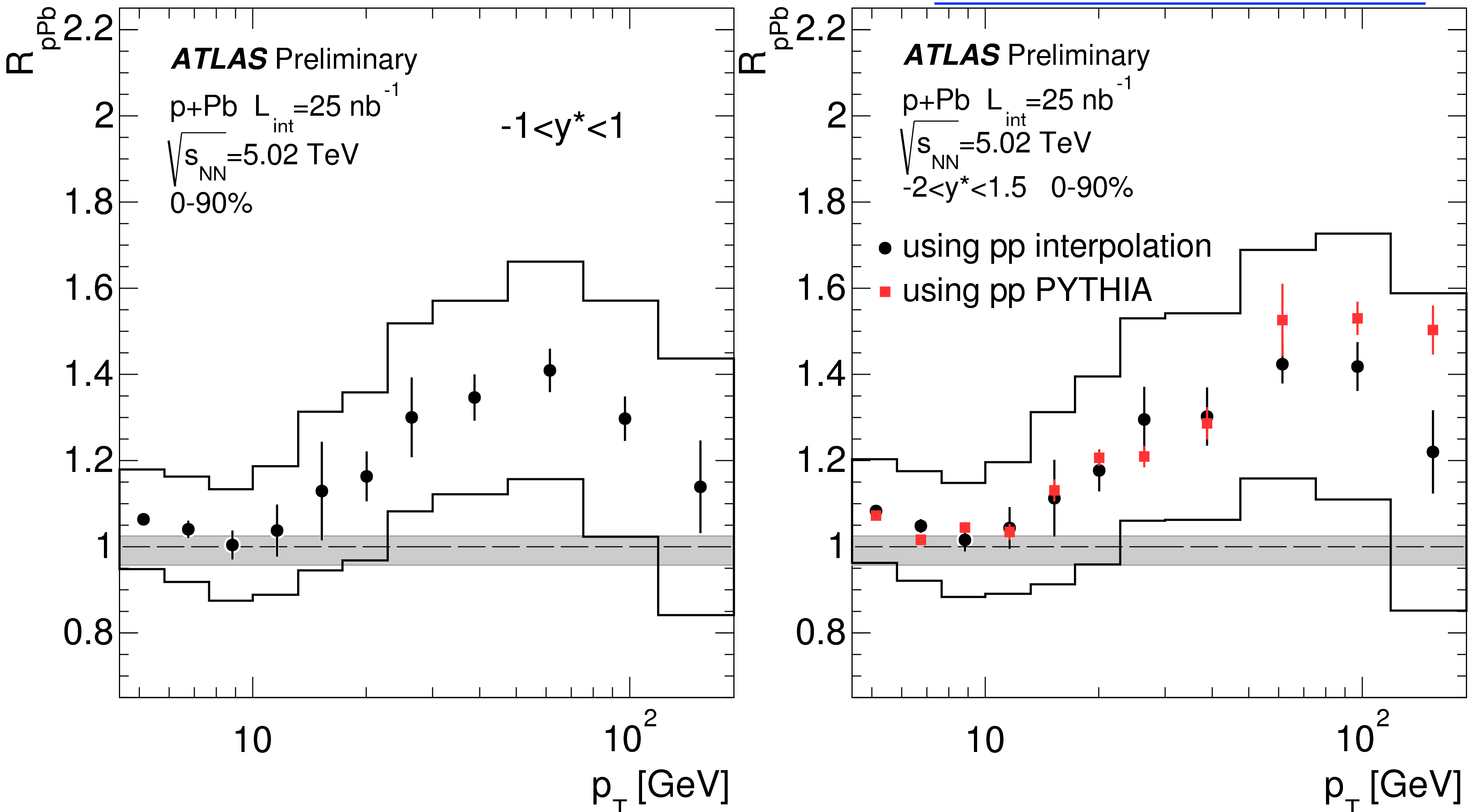

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