LHC France 2013

Annecy

04/04/2013

ALICE

Charged-particle multiplicity in Pb-Pb at 2.76 TeV and p-Pb at 5.02 TeV with ALICE at the LHC

Maxime GUILBAUD

On behalf of the ALICE collaboration

ipnl

ED 52 - PHAST

Physique & Astrophysique de Lyon

Ecole doctorale

UNIVERSITÉ DE LYON

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ALICE

Overview

- Motivations
- The ALICE experiment
- Pb-Pb results
- p-Pb results
- Conclusion

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Motivations

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  - Entropy production in the early stage of heavy ion (HI) collisions
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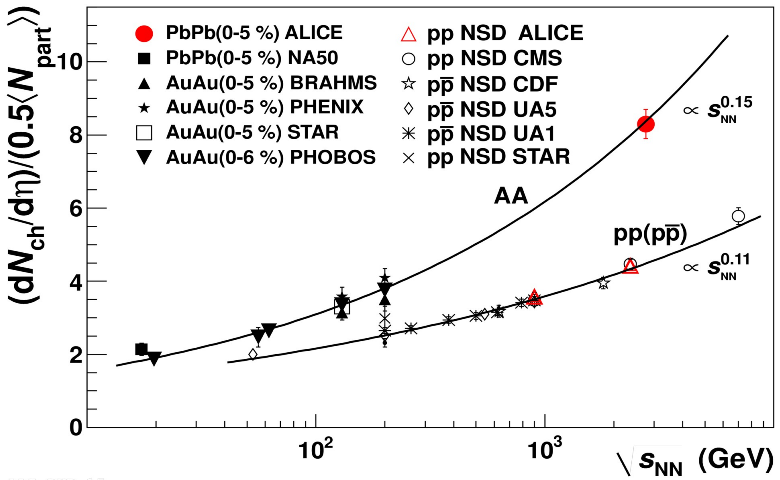
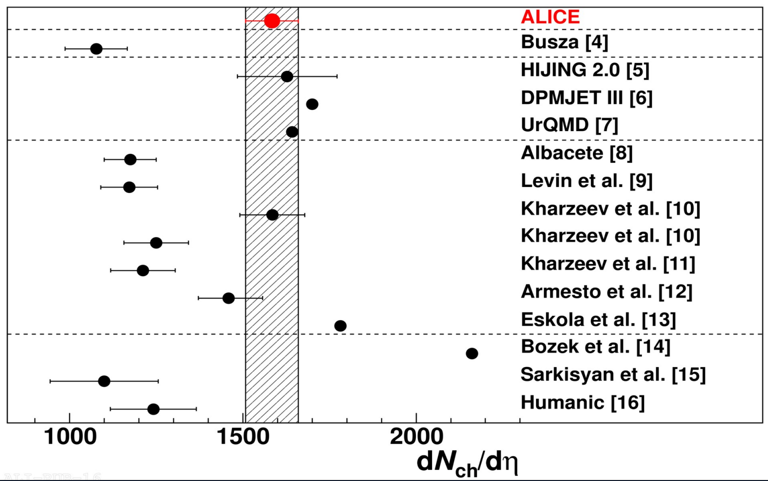
- dN/dη, provides constraints on theoretical models and, with lower energy data, reveals evolution of particle production with available energy





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VIOLATION

- **P. Brigueira, J. Dias de Deus, C.Pajares, Phys. Rev. C 75, 054908 (2007)**
- **J. Cleymans, J. Strumpfer, L.Turko, Phys. Rev. C 78, 01901 (2008)**

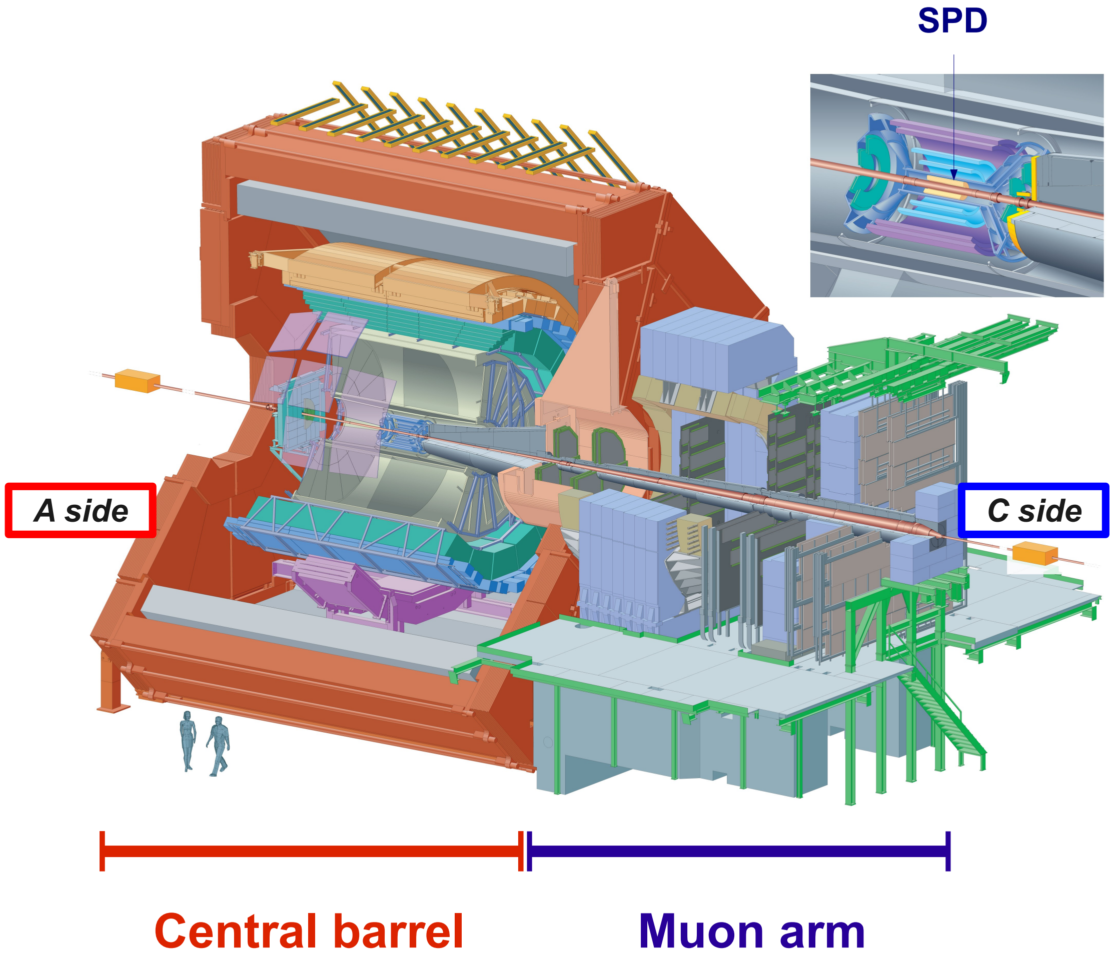
CONSERVATION

- **W. Busza, J. Phys. G 35, 044040 (2008)**
- **A. Bialas, A. Bzdak, R. Peschanski, Phys. Lett. B 665, 35 (2008)**

The ALICE experiment

The ALICE detectors:

- The relevant detectors for this talk are:
  - The Silicon Pixel Detector (SPD): 2 first layers of the Inner Tracking System (ITS)



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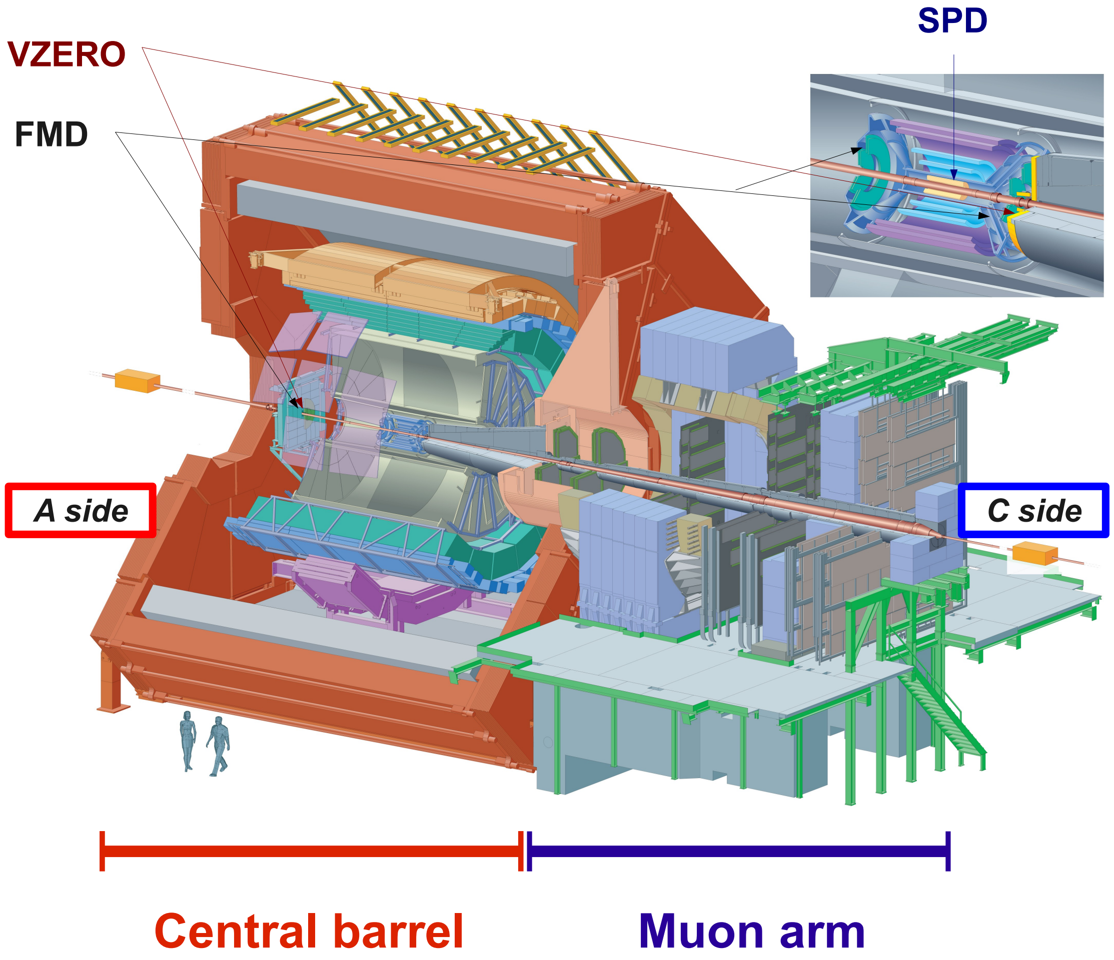

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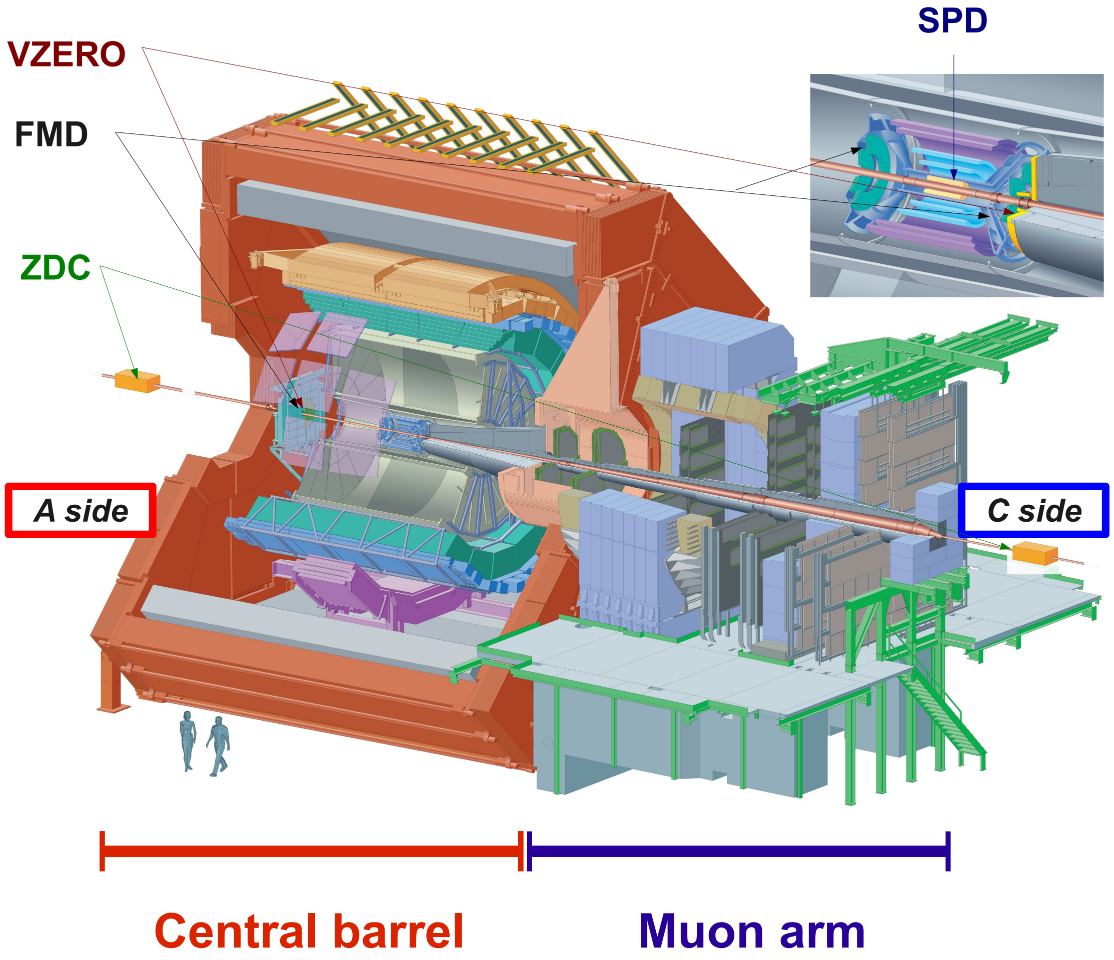
  - The VZERO & The Forward Multiplicity Detector (FMD)
  - The Zero Degree Calorimeter (ZDC)
    - ZNs (neutrons)+ZPs (protons) at 114m on both sides of the Interaction Point (IP)
    - Electromagnetic calorimeter (ZEM) on A side at 7.5m from the IP

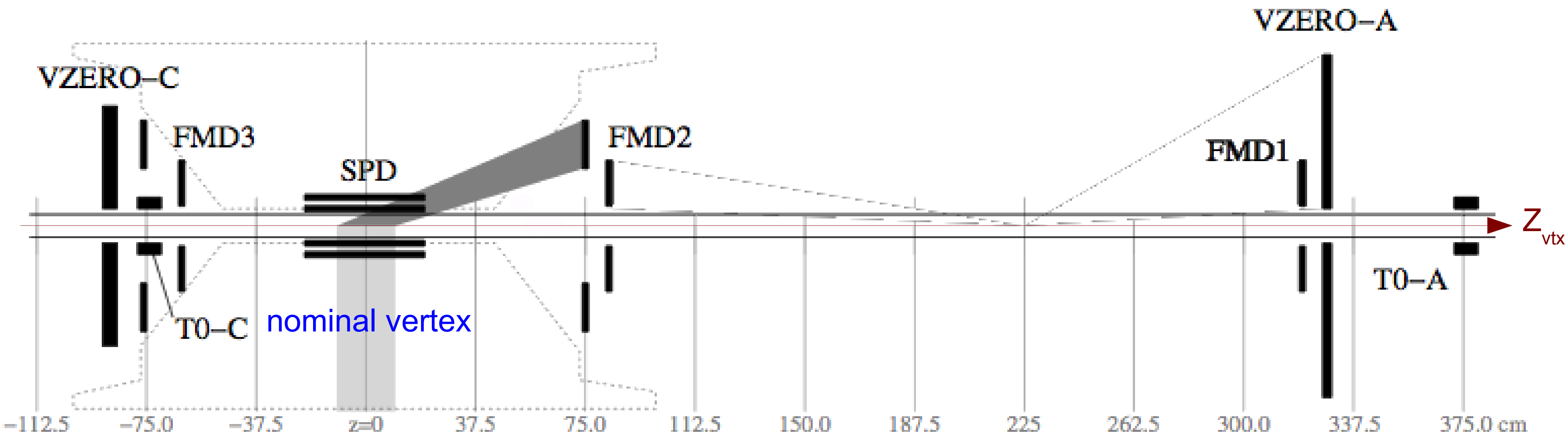


Pb-Pb results

Analysis technique

Nominal collisions:

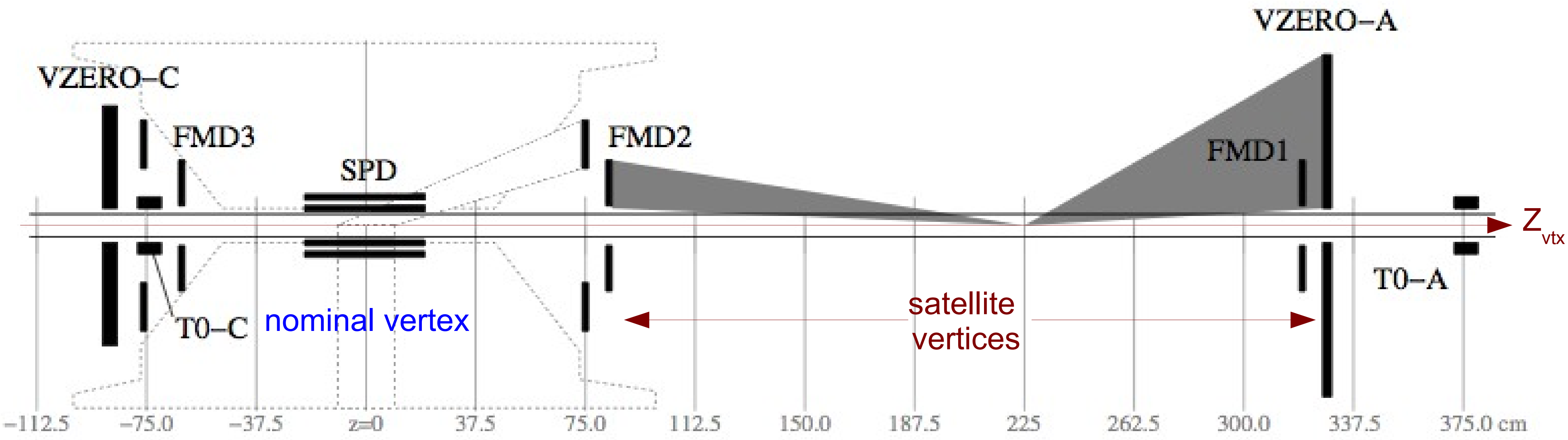
- SPD results using collisions at nominal vertex (light gray band)
  - dN/dη SPD tracklet results are given in an extended range in η (|η|<2) with respect to first ALICE published paper *PRL 106, 032301 (2011)* on this measurement.
  - To reach this pseudo-rapidity range, the analysis was performed in 3 bins along Z axis to enlarge the acceptance of SPD ($|Z_{vtx}|<13$)



Analysis technique

Satellite collisions:

- The LHC RF is 400 MHz → RF bucket separated by 2.5 ns
  - **Nominally**, beam bunches filled in one out of ten buckets (separation by a multiple of 25 ns)
  - Small fraction of the beam captured in unwanted RF buckets → **satellite bunches**
  - Satellite bunches give satellite collisions by crossing nominal bunch every **37.5 cm**



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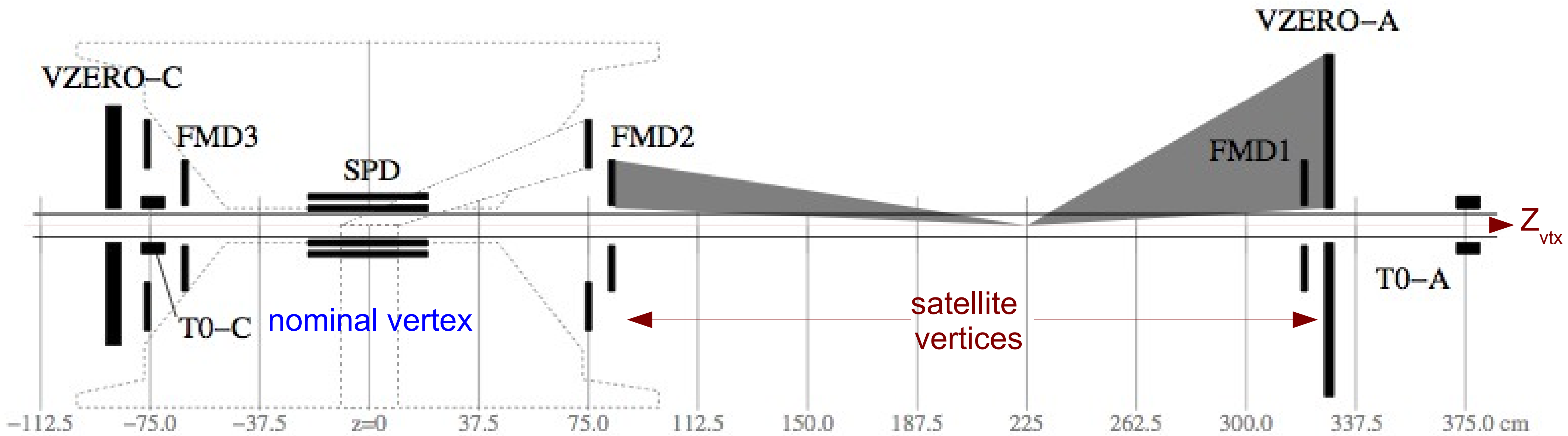
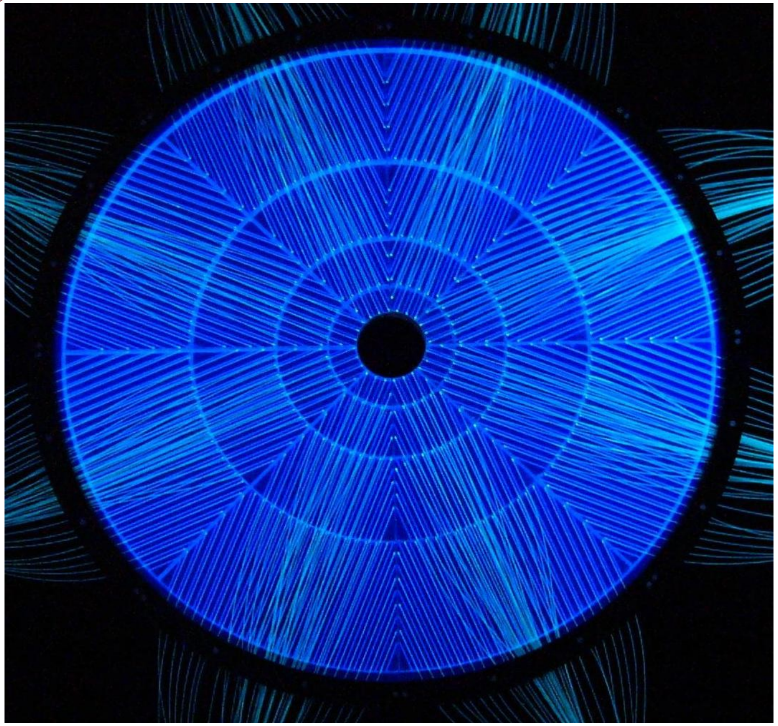
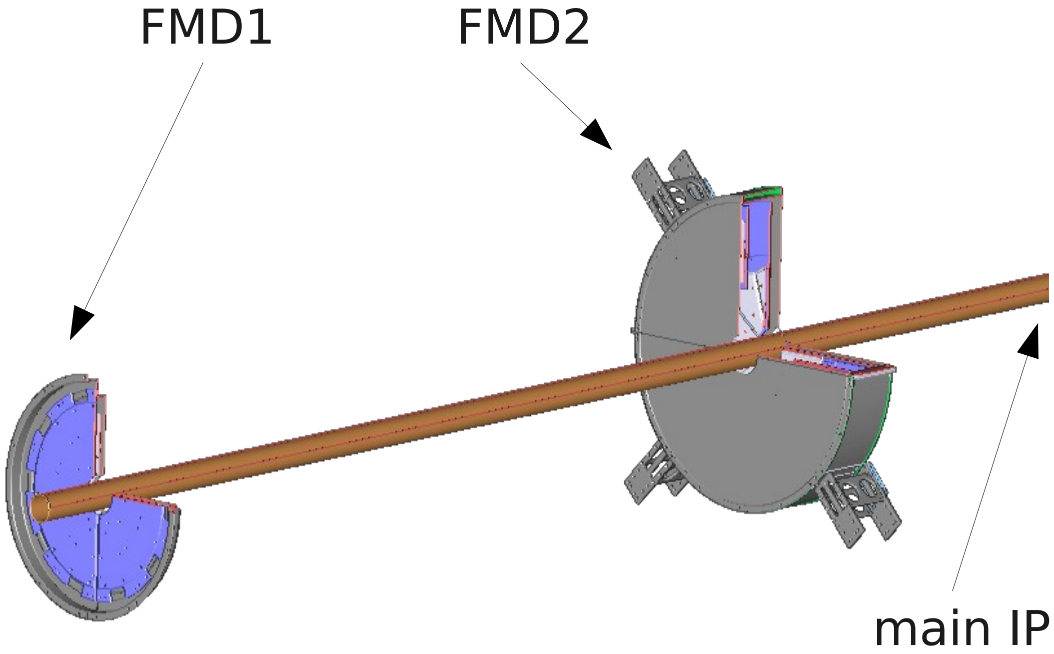
- Due to zero crossing angle, data from a significant number of satellite collisions were recorded by the ALICE experiment in 2010
  - Low material budget between 75 to 337.5 cm
  - The pseudo-rapidity coverage of each detector changes with every vertex



Analysis technique: η coverage





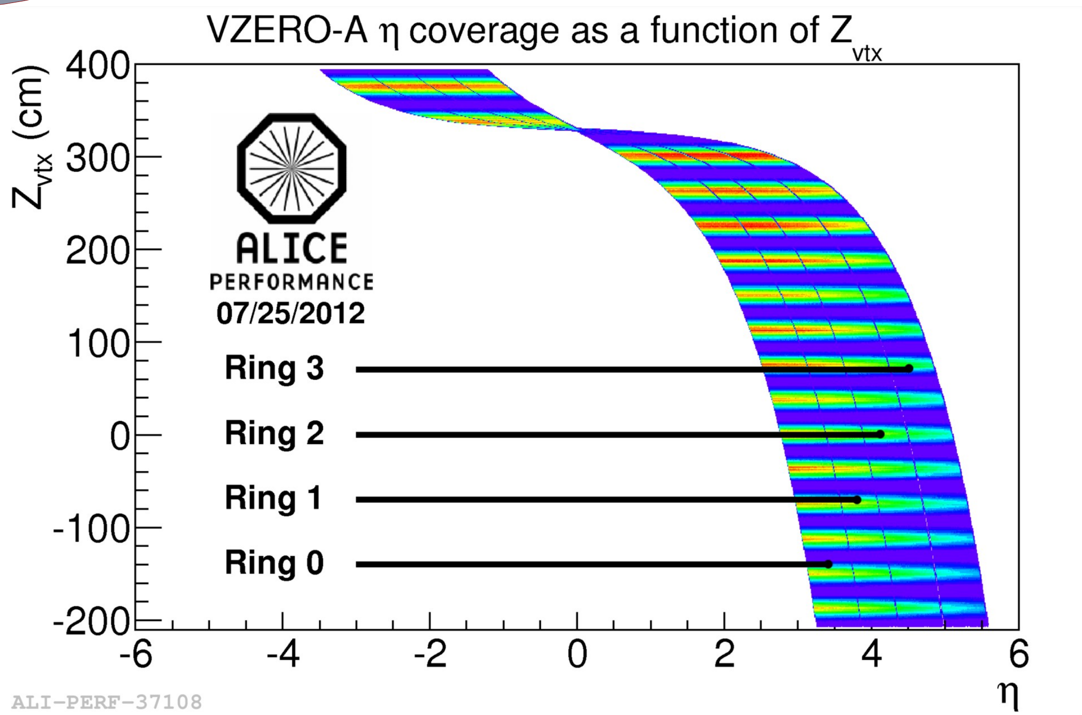
- VZERO-A η coverage for collisions at main IP:

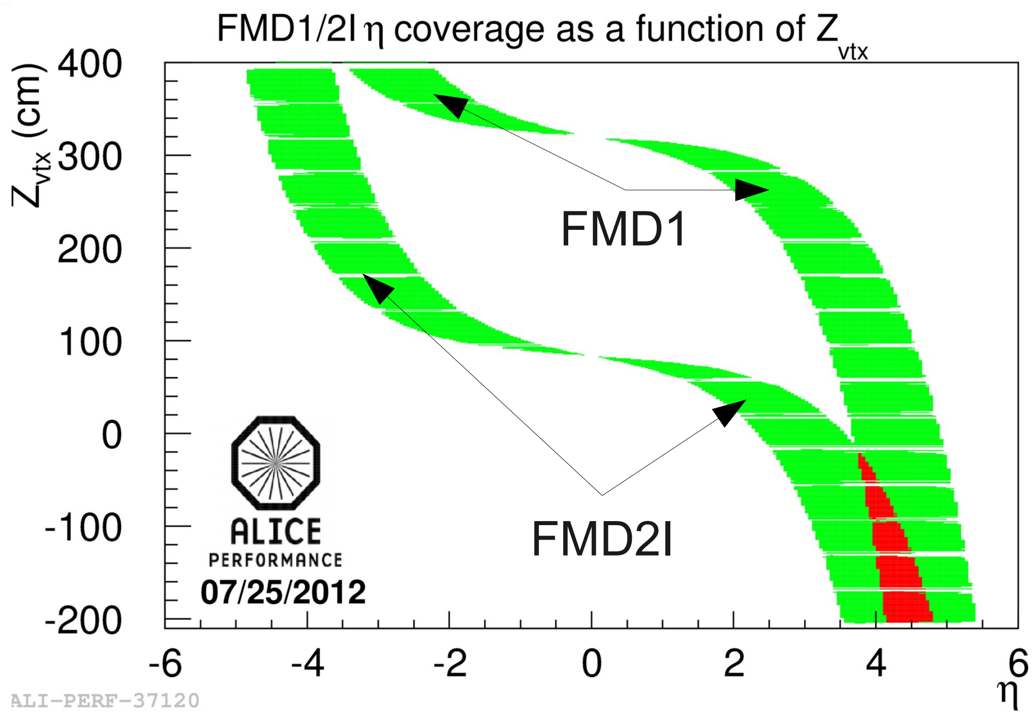
Ring	0	4.5<η<**5.1**
	1	3.9<η<4.5
	2	3.4<η<3.9
	3	**2.8**<η<3.4

- FMD1 & FMD2 η coverage at main IP:

FMD1	3.7<η<**5.0**
FMD2	**1.7**<η<3.7

Analysis technique: η coverage





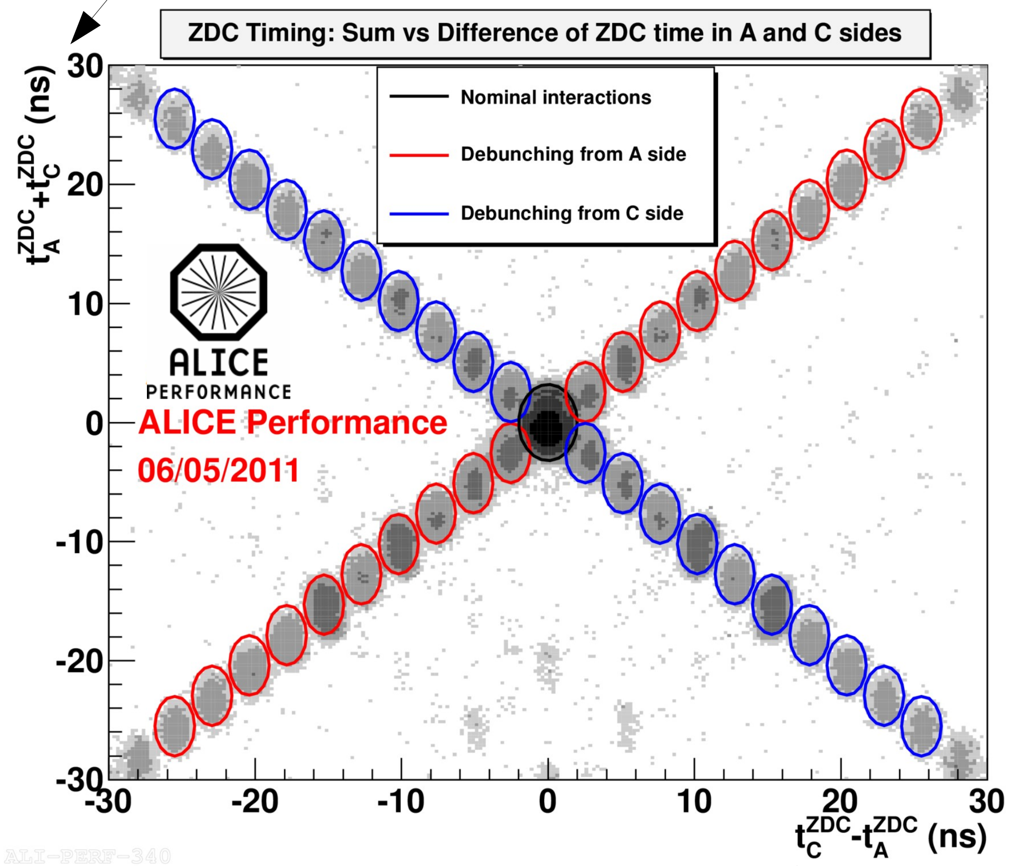
Large pseudo-rapidity coverage for both detectors thanks to satellite collisions:

- VZERO: $-3.0 < \eta < 5.25$
- FMD: $-5.0 < \eta < 5.5$

Analysis technique: Event selection

- Satellite collisions every 2.5 ns
- ZDC time resolution allows to discriminate collisions coming from different satellite bunches:
  - Collision between nominal bunches (black circle)
  - Satellite bunch from A side + nominal bunch from C side (red circles)
  - Satellite bunch from C side + nominal bunch from A side (blue circles)

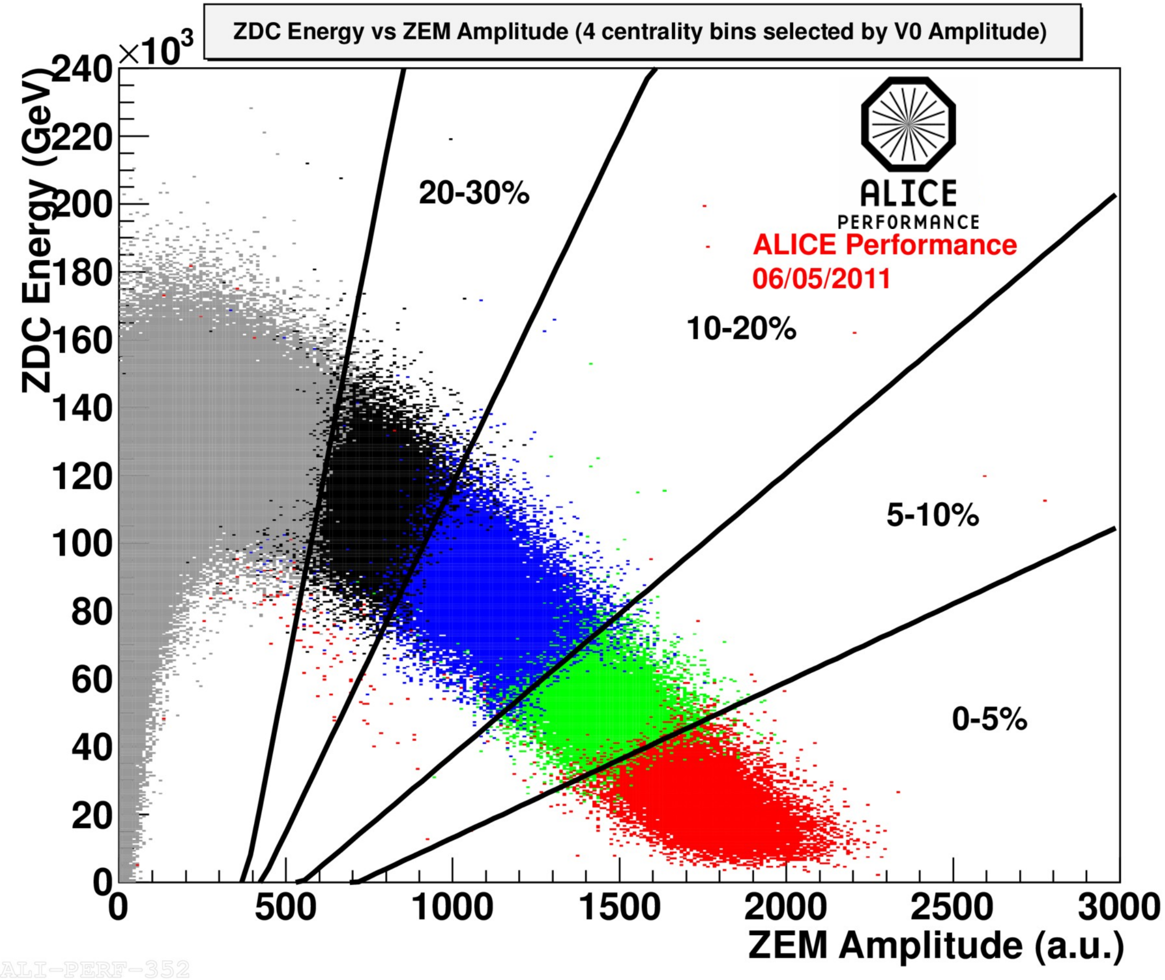
Collision time



IP position along the Z axis

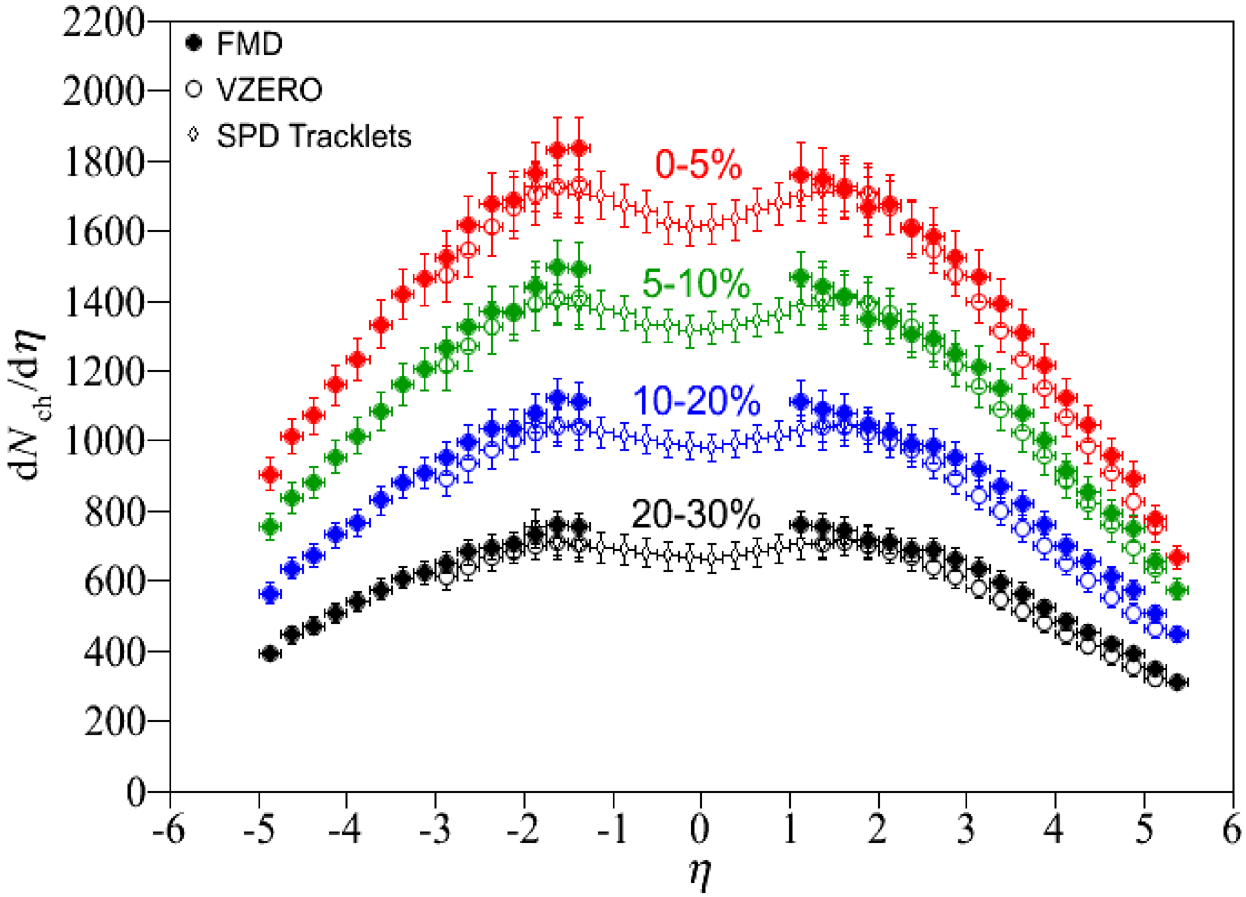
Analysis technique: Centrality selection

- Glauber model was used to determine the number of participants
  - ZDC energy ~ < N_{spect} >
  - ZEM amplitude ~ < N_{part} >
- Estimator calibrated on VZERO at nominal IP
  - ZDC response weakly dependent on the vertex position (far from the IP) with respect to VZERO
  - This estimator works only for the most central events (0-30%) due to nuclear fragment production in peripheral events



Results: FMD and VZERO comparison

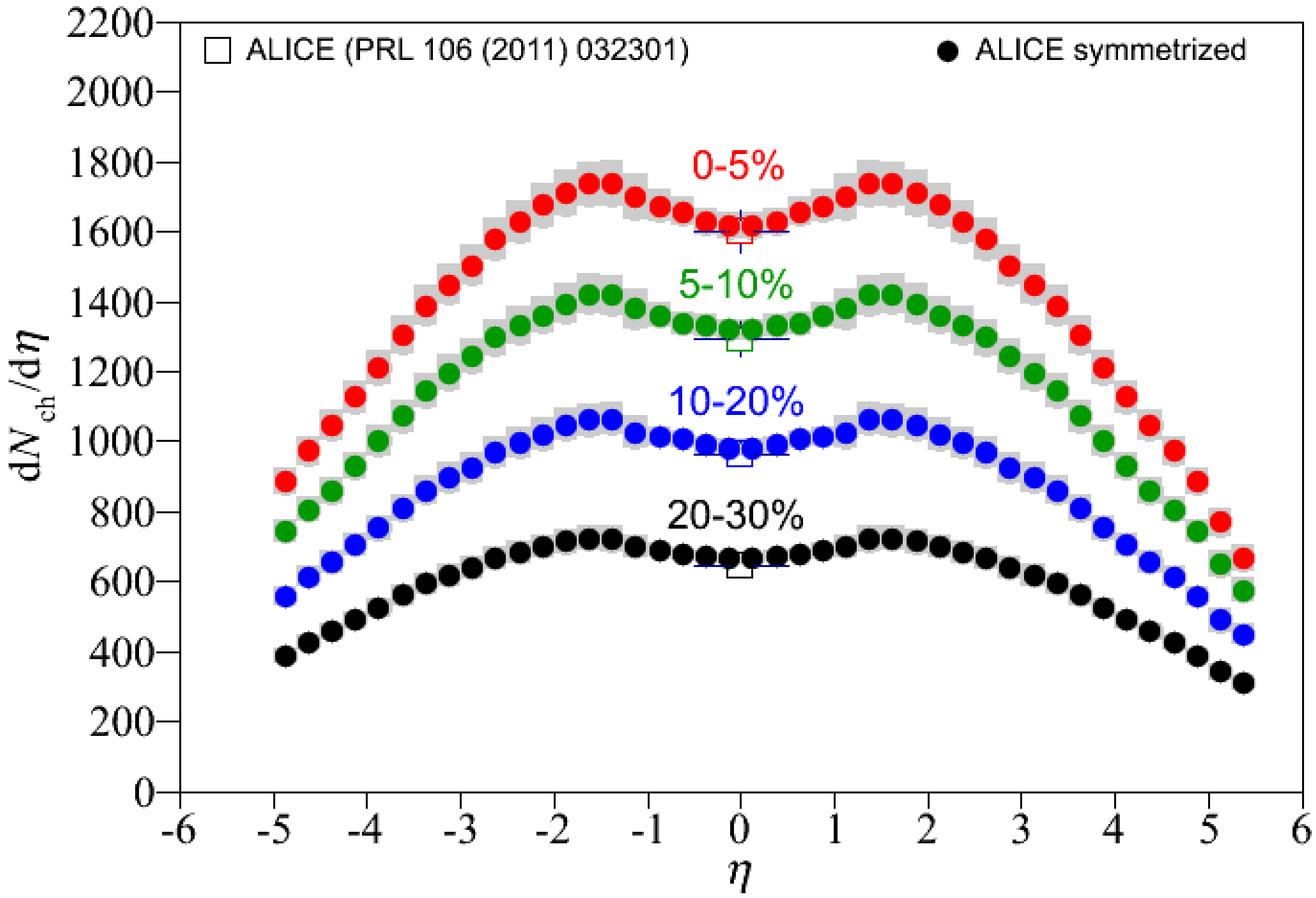
- Comparison between SPD, FMD and VZERO*
  - SPD: $-2 < \eta < 2$
  - FMD: $-5 < \eta < 5.5$
  - VZERO: $-3 < \eta < 5.25$
- Good agreement between FMD and VZERO



*: The *ALICE Collaboration, arXiv:1304.0347 [nucl-ex]*

Results: Combined results

- Results are combined*
  - Mean weighted by each detector's syst. error
  - Common sources of syst. errors are then added in quadrature
  - Stat. error smaller than marker size
  - Syst. error: 2-6%



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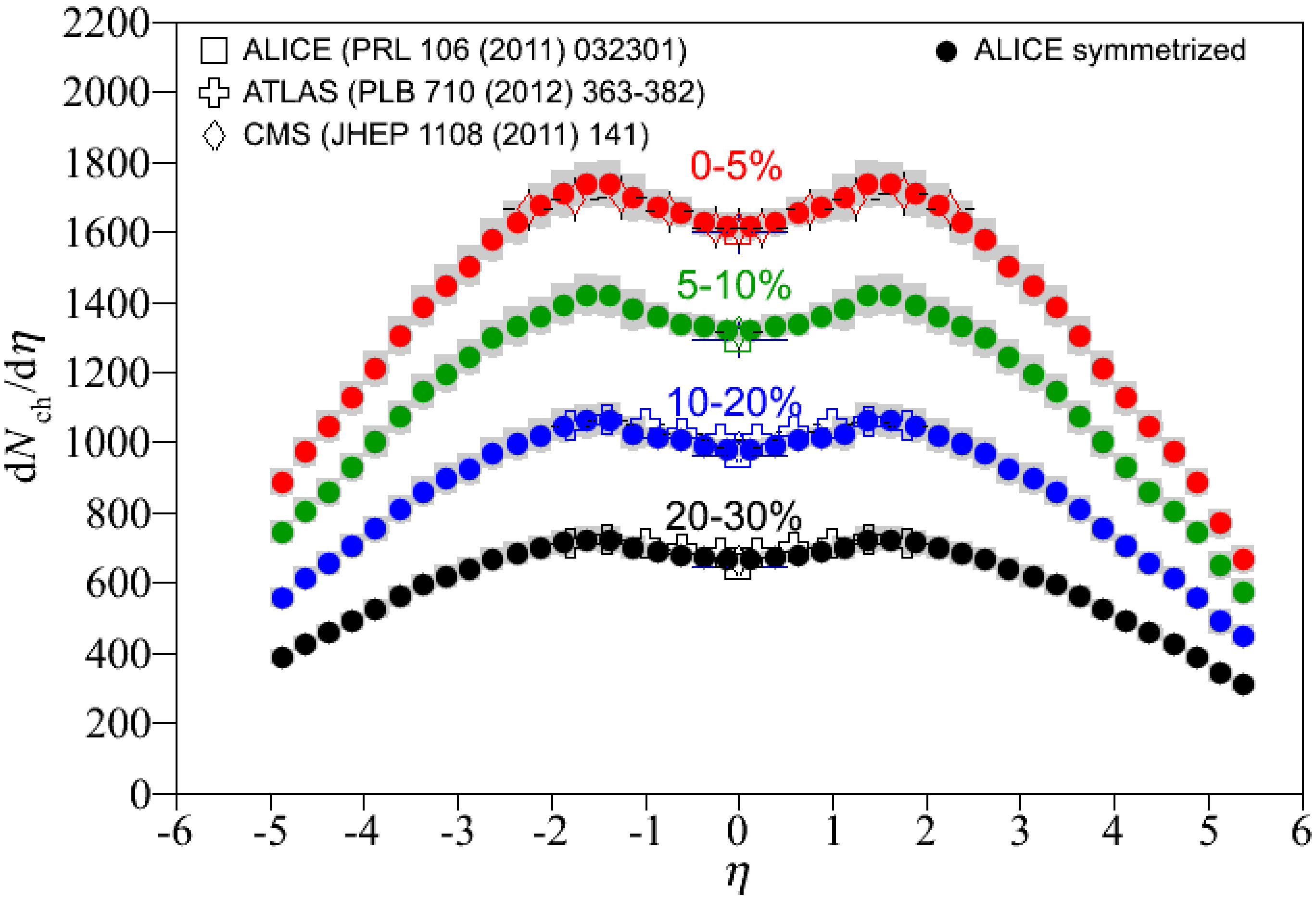

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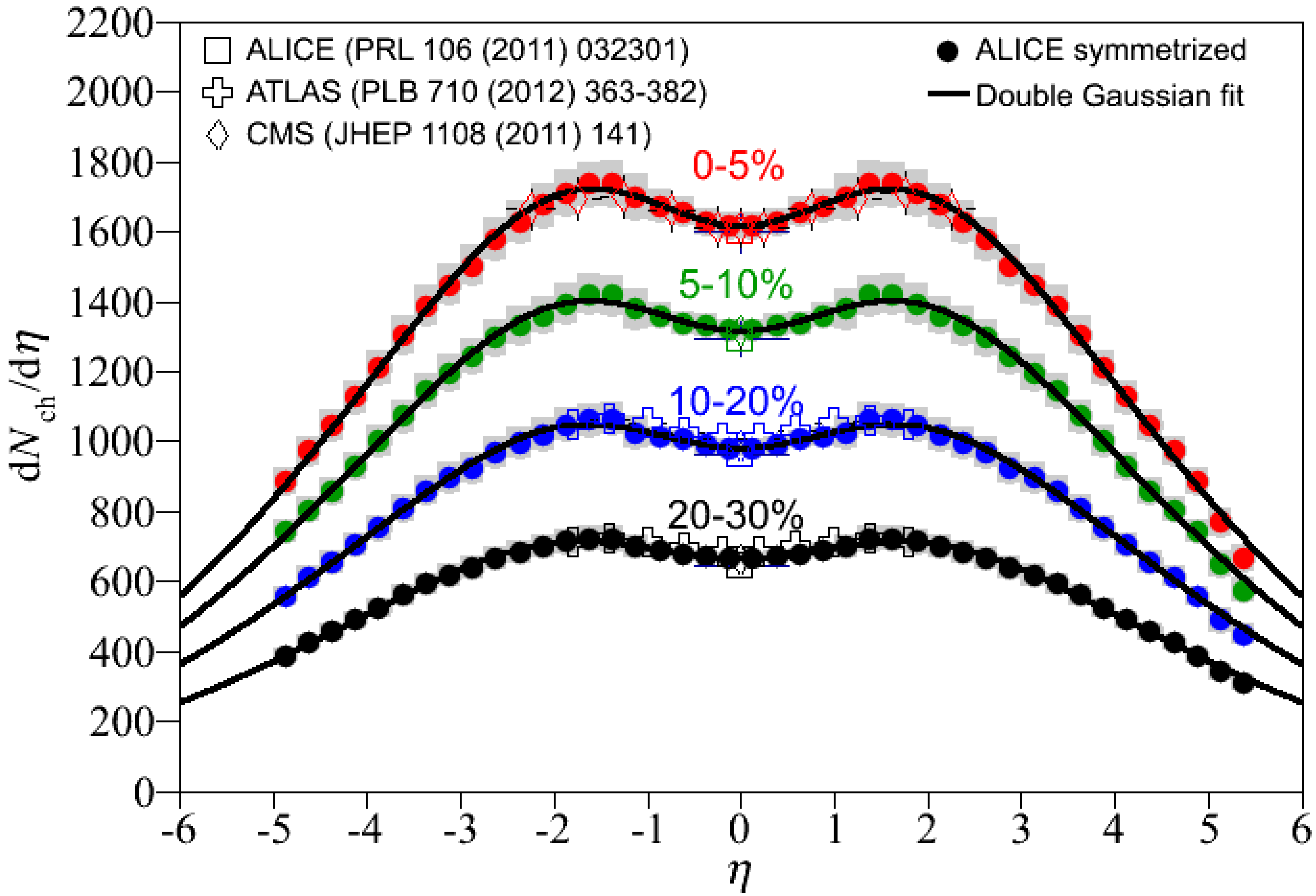
- A double gaussian function fits well the data



$$\frac{dN_{ch}}{d\eta} = A_1 e^{-\frac{\eta^2}{2\sigma_1^2}} - A_2 e^{-\frac{\eta^2}{2\sigma_2^2}}$$

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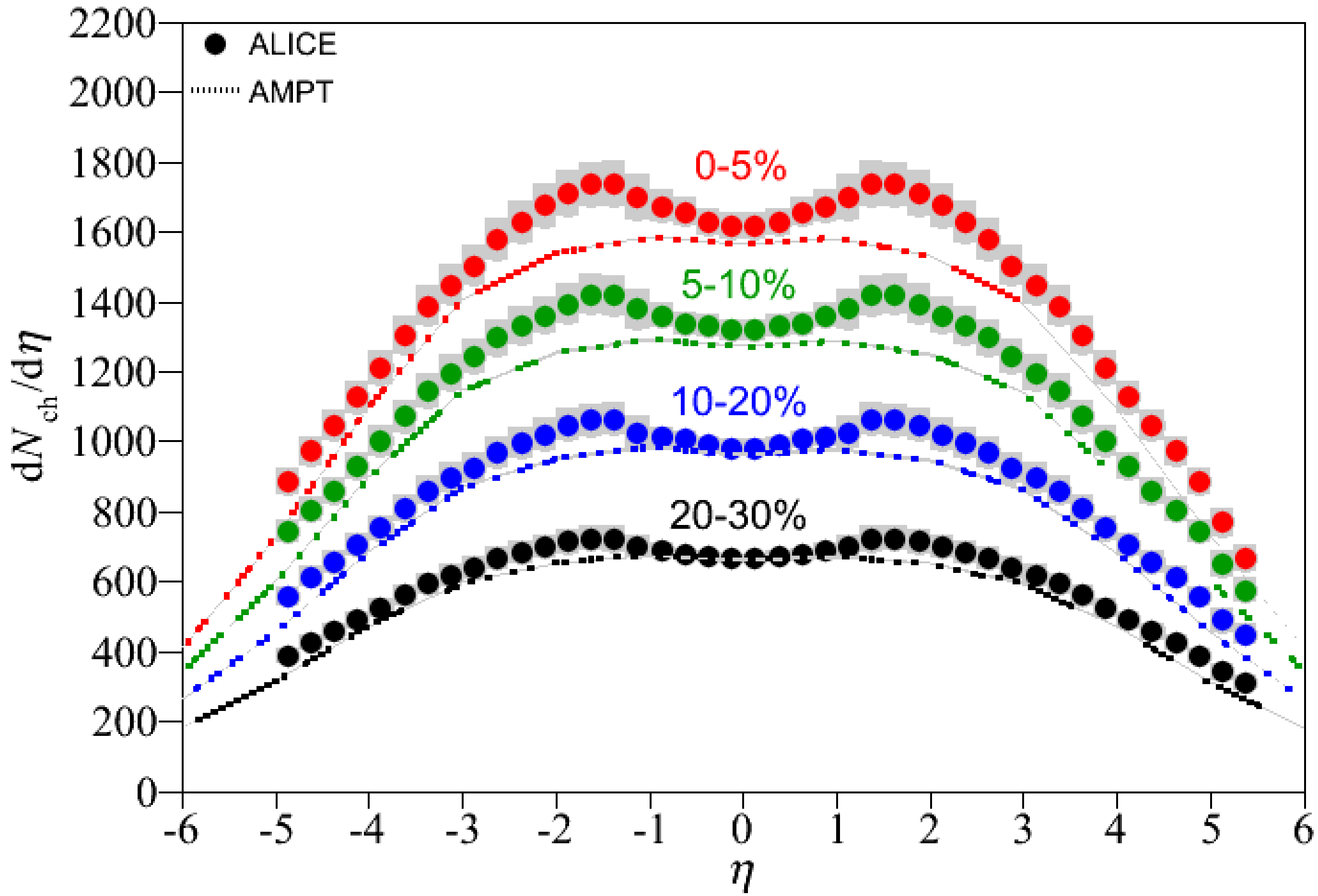
Results: Comparison with models

- Three MC based models are compared with ALICE results
  - **AMPT**



- **Jun Xu, Che Ming Ko, Phys.Rev. C 83, 034904 (2011)**

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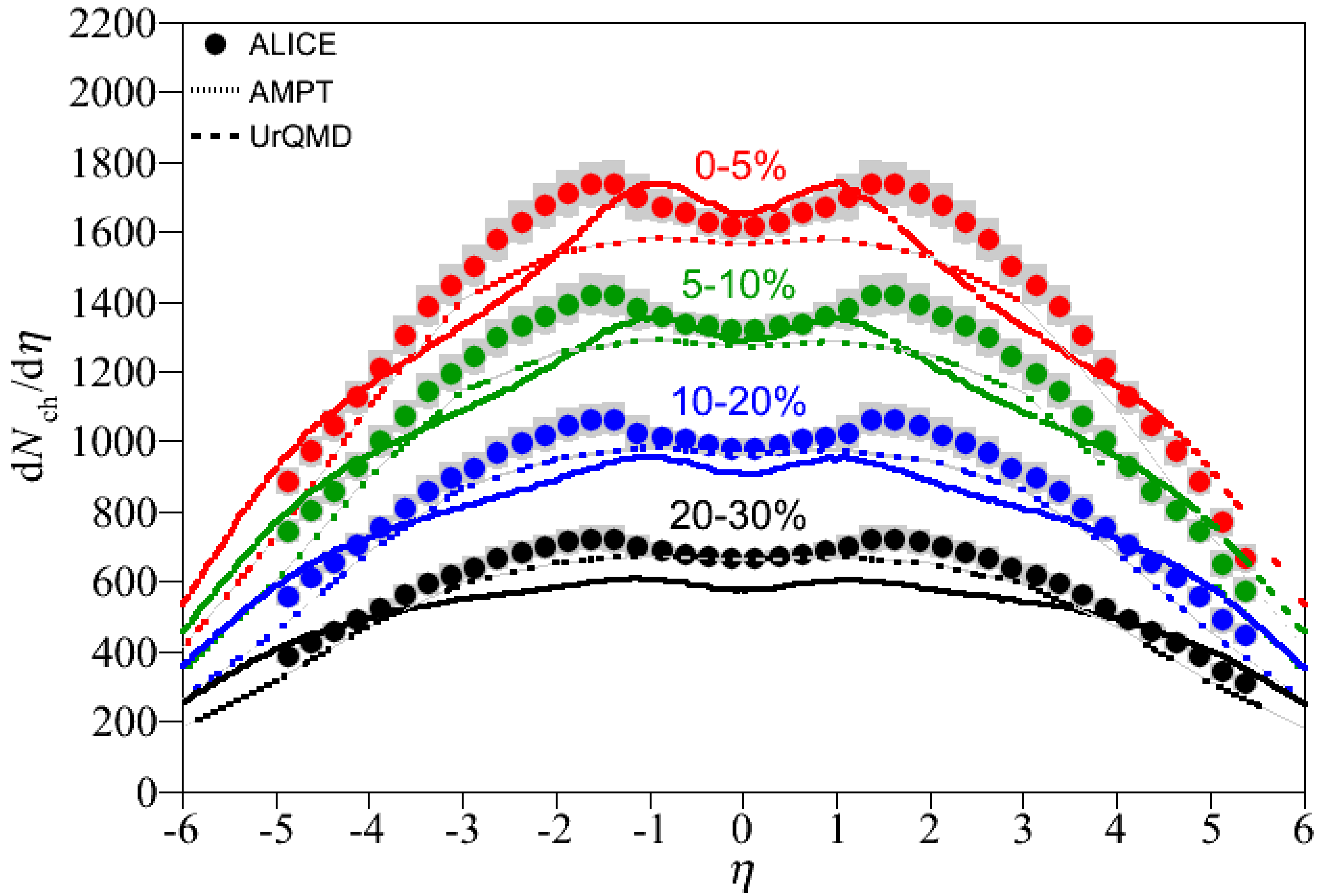
  - **UrQMD model**
- UrQMD/**AMPT**: fails to reproduce the overall amplitude and shape of the pseudo-rapidity density



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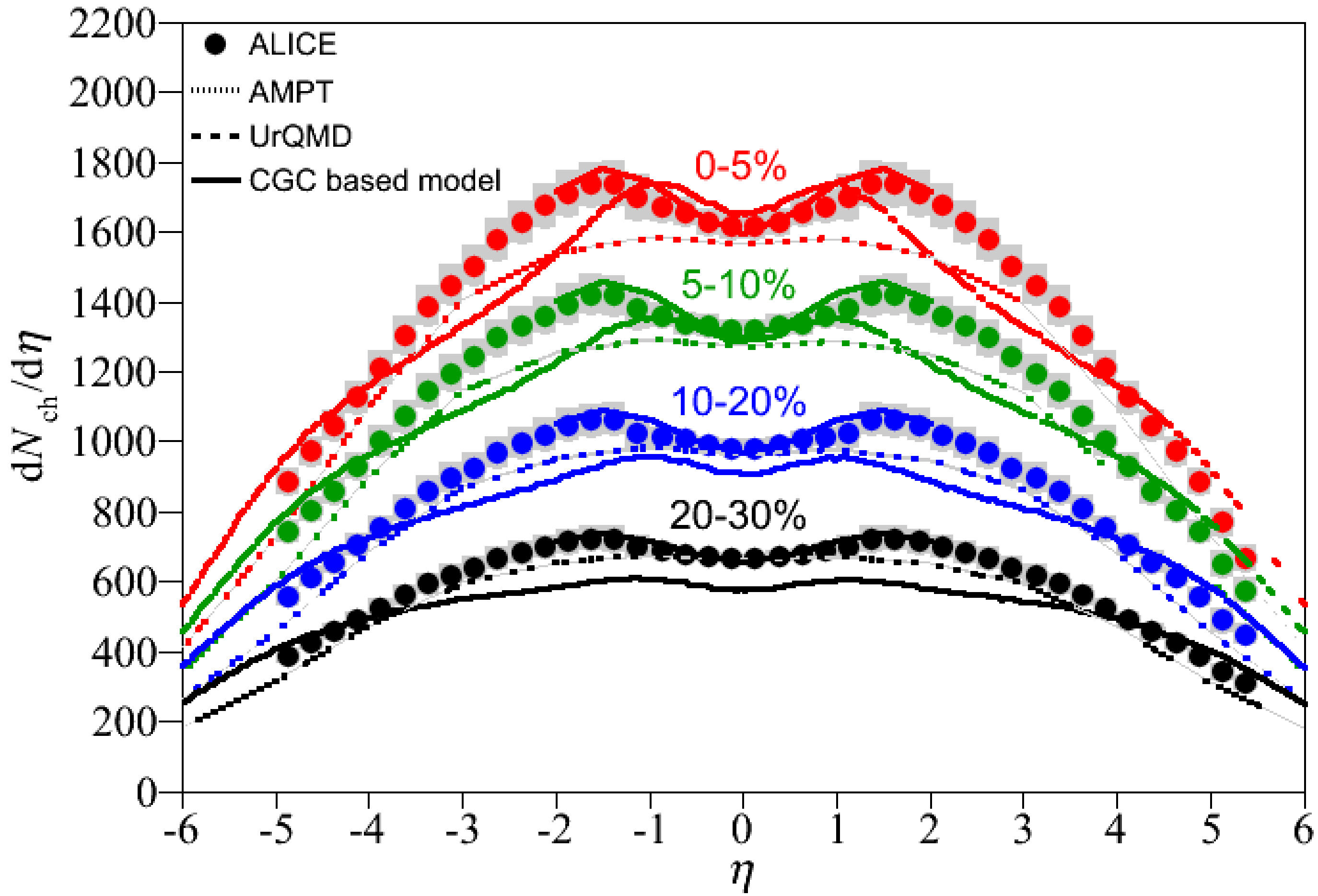

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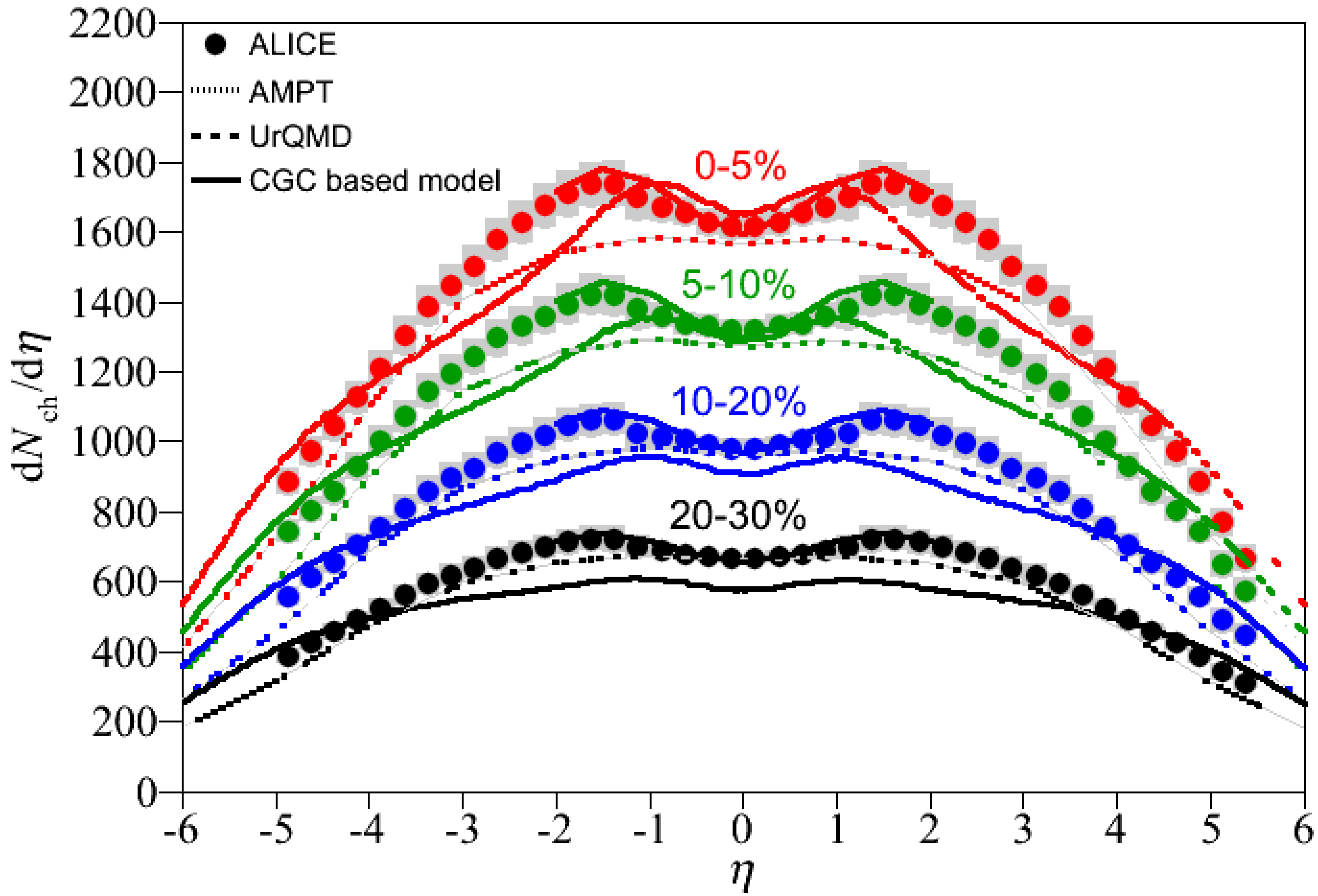

- UrQMD/**AMPT**: fails to reproduce the overall amplitude and shape of the pseudo-rapidity density
- **CGC**: reproduces the shape & the amplitude, but for a restricted η range

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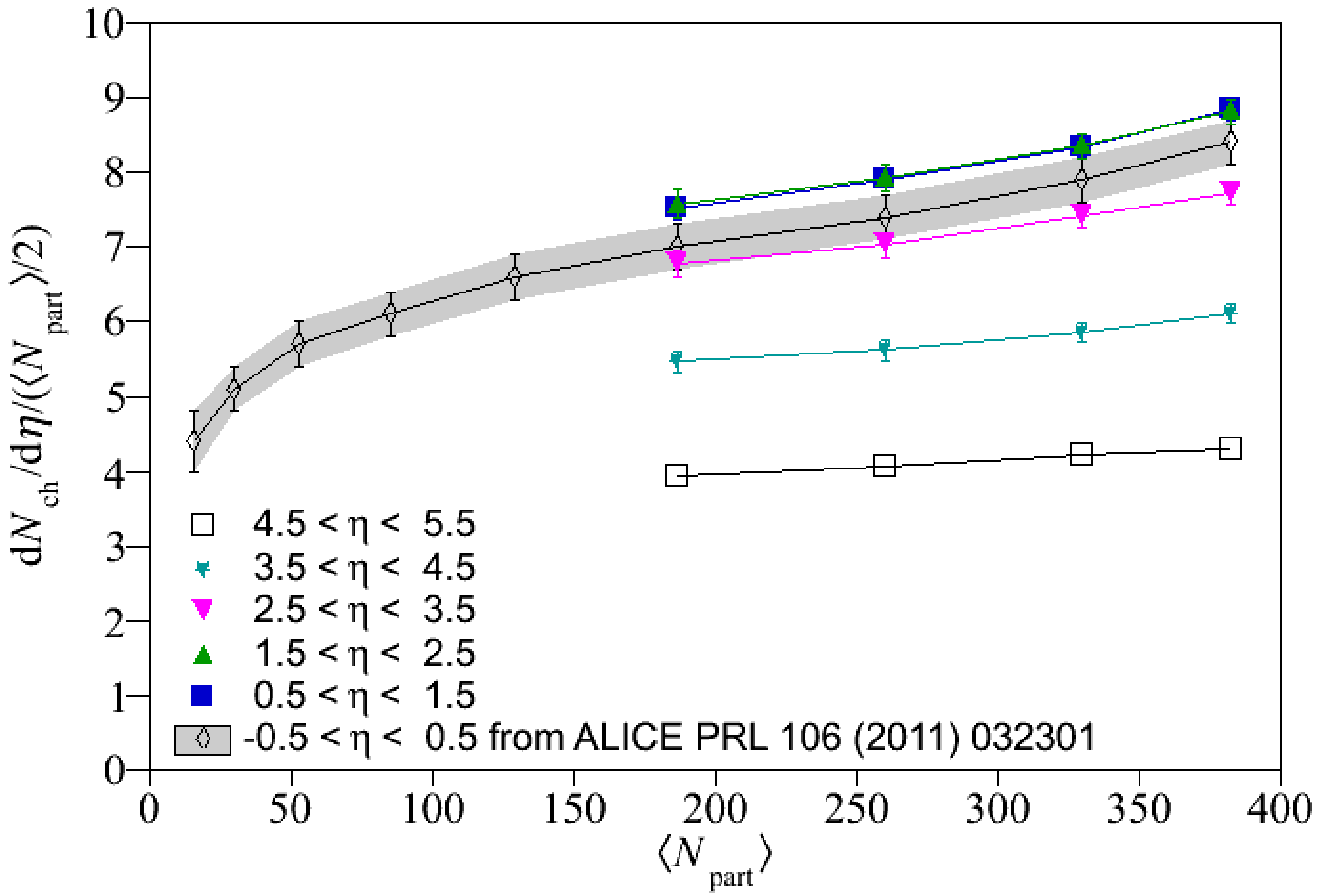
Results: $dN/d\eta$ scaling as a function of $\langle N_{part} \rangle$

- The $dN/d\eta$ scaling as a function of $\langle N_{part} \rangle$ is given in 5 pseudo-rapidity bins
  - Complementary results to those previously published by the ALICE Collaboration*
  - The primary charged particle density per participant pair for the most central events



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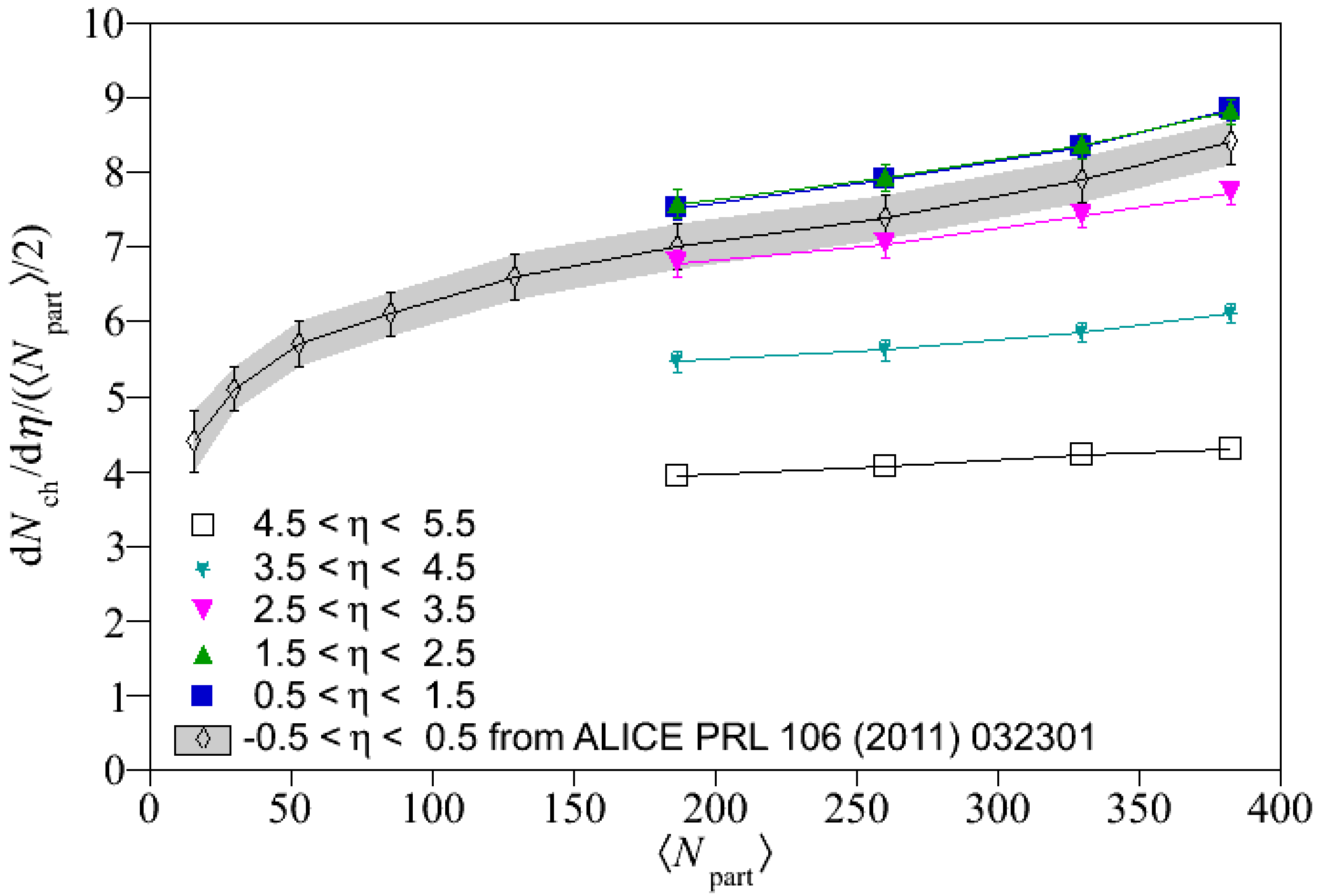
  - The primary charged particle density per participant pair for the most central events
- Related to the entropy production at the collision

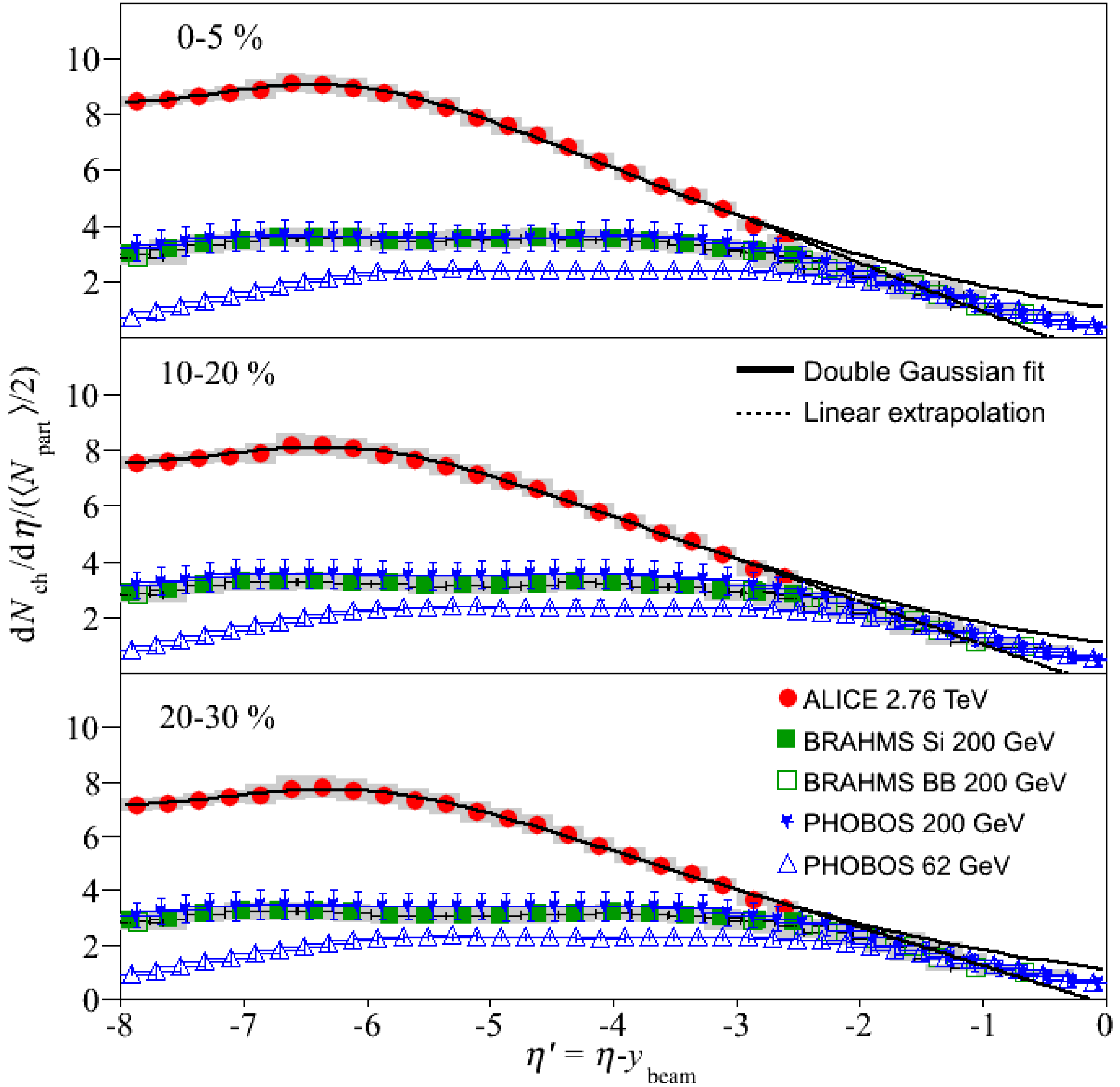


➔ **same trend in each bin, no clear η dependence**

*: *ALICE Collaboration, Phys. Rev. Lett. 106 (2011) 032301*

Results: Longitudinal scaling

- Results compared to BRAHMS & PHOBOS Au-Au data at 62 and 200 GeV at RHIC
  - dN/dη distributions normalized by $\langle N_{part} \rangle /2$
  - dN/dη distributions shifted by y_{beam}
  - Very high rapidity region is extrapolated with a linear function



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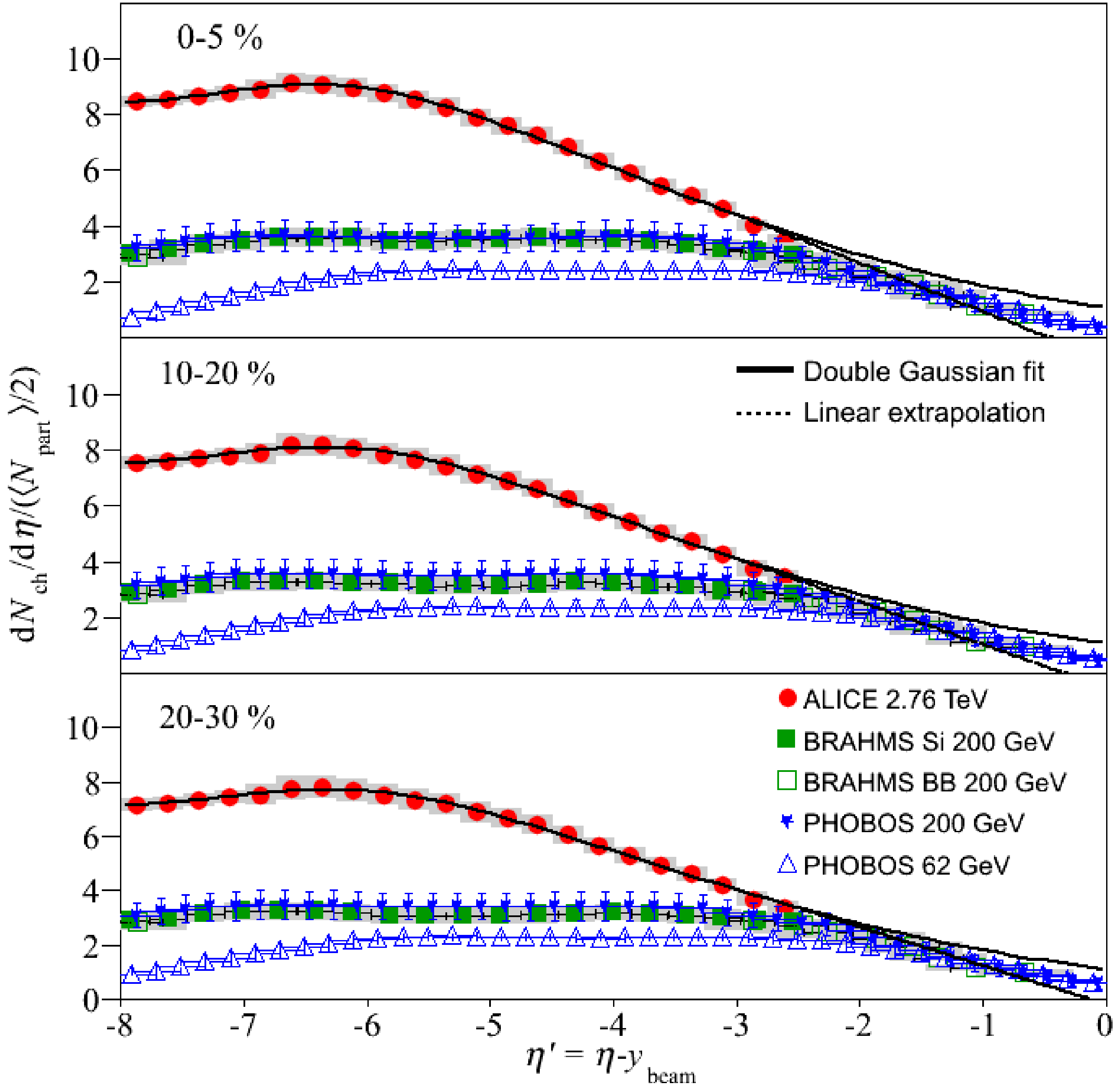
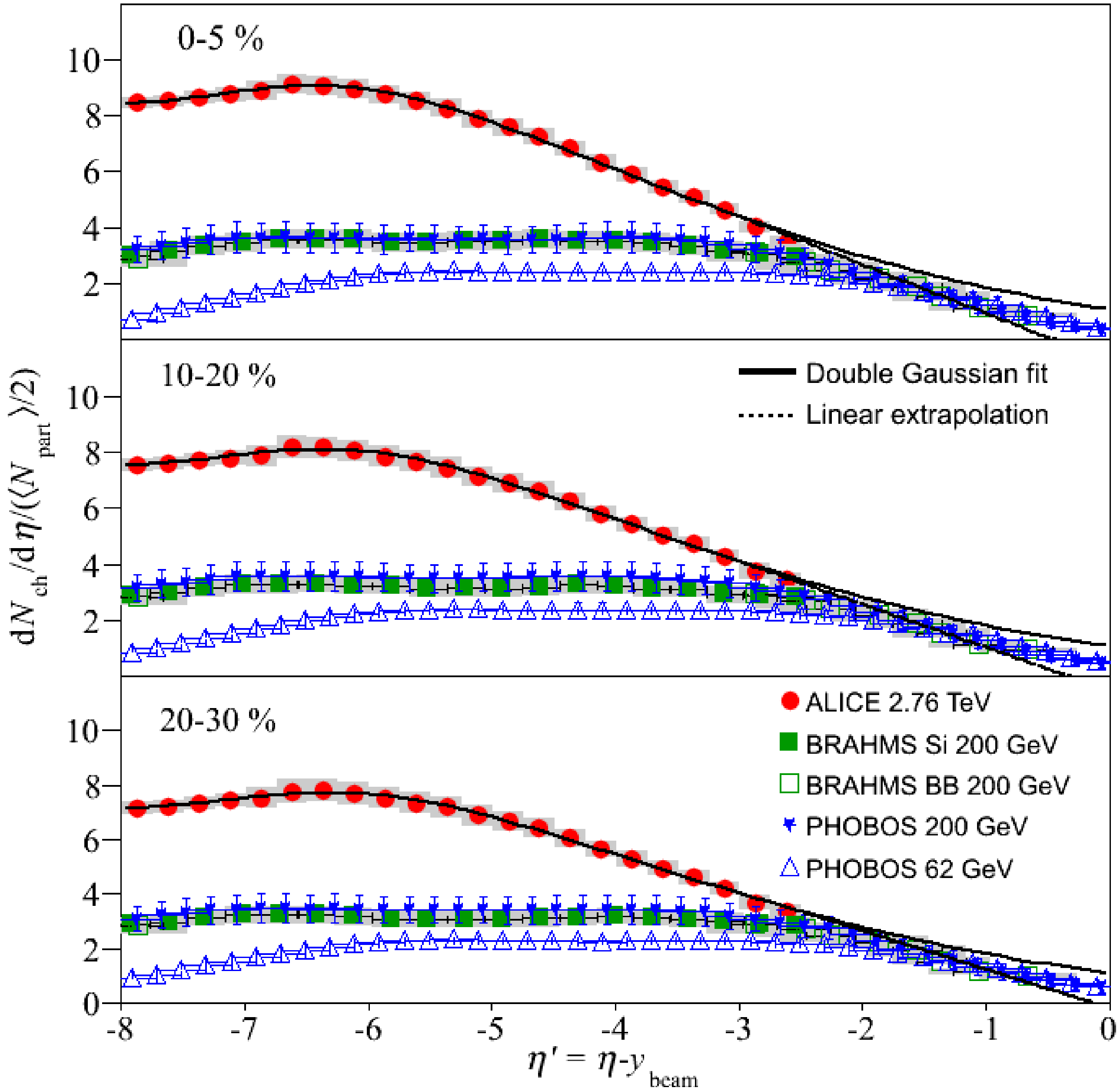
- The linear extrapolation shows that ALICE, BRAHMS and PHOBOS data are consistent



Results: Longitudinal scaling

- Measurement consistent with longitudinal scaling within extrapolation errors at the LHC
  - The shape dN/dη distribution does not depend on the colliding energy at forward rapidity



Results: Longitudinal scaling

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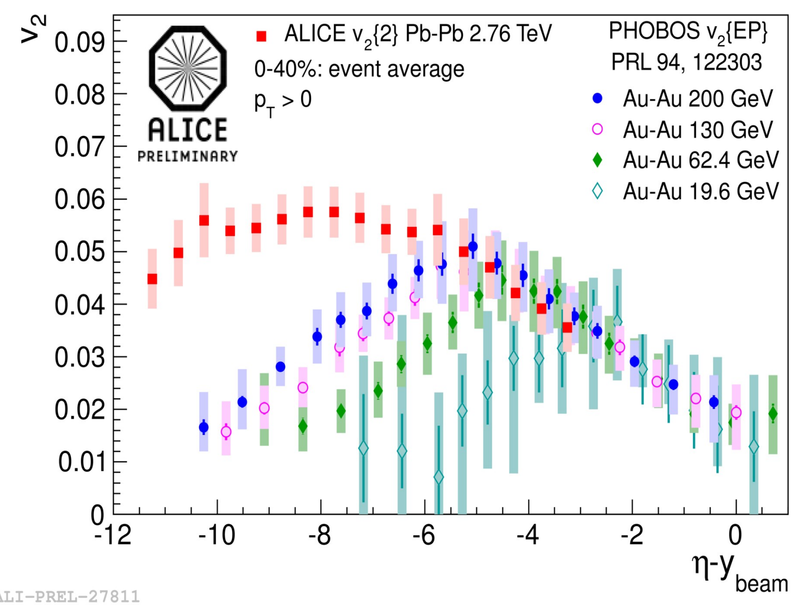
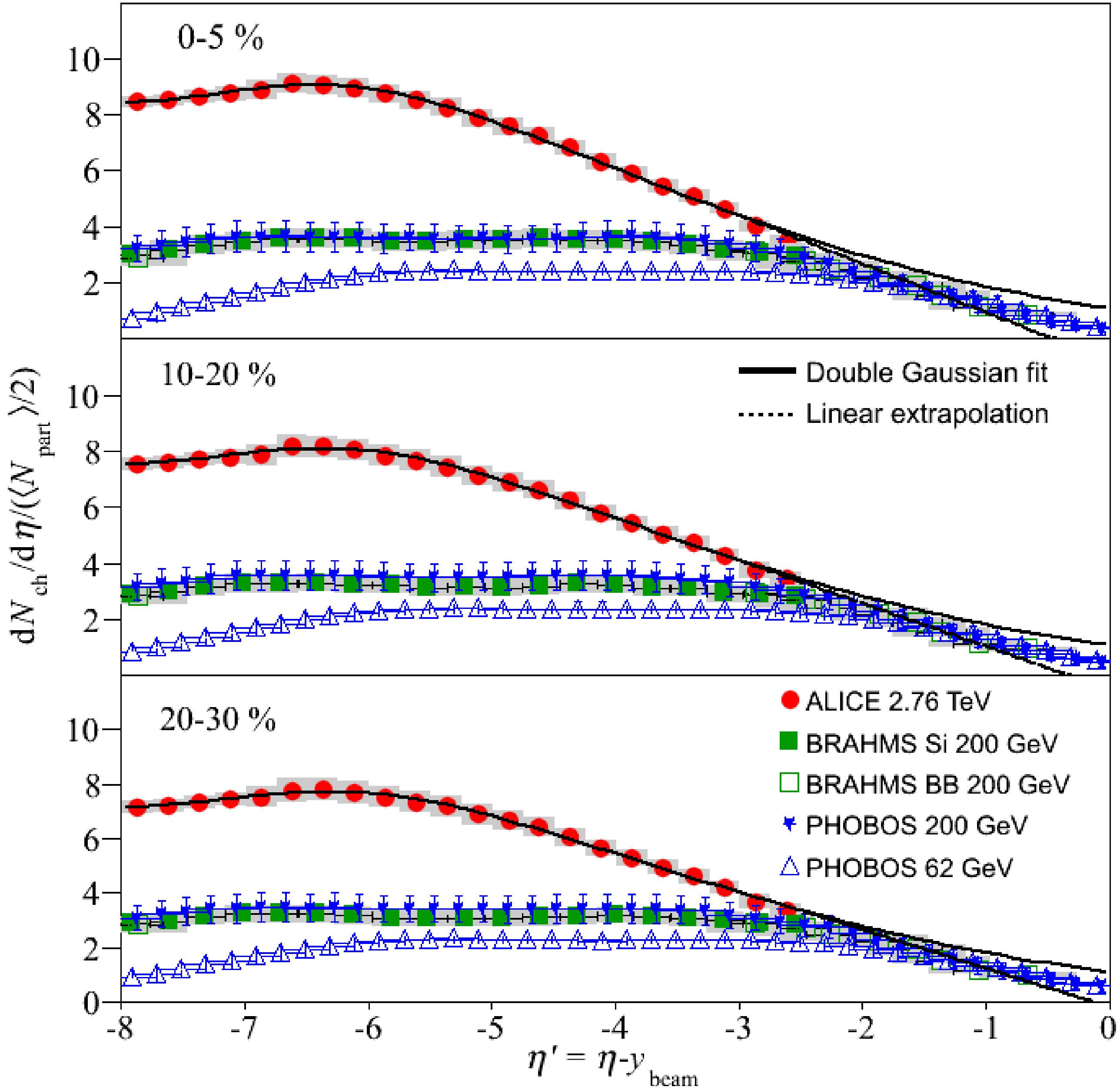
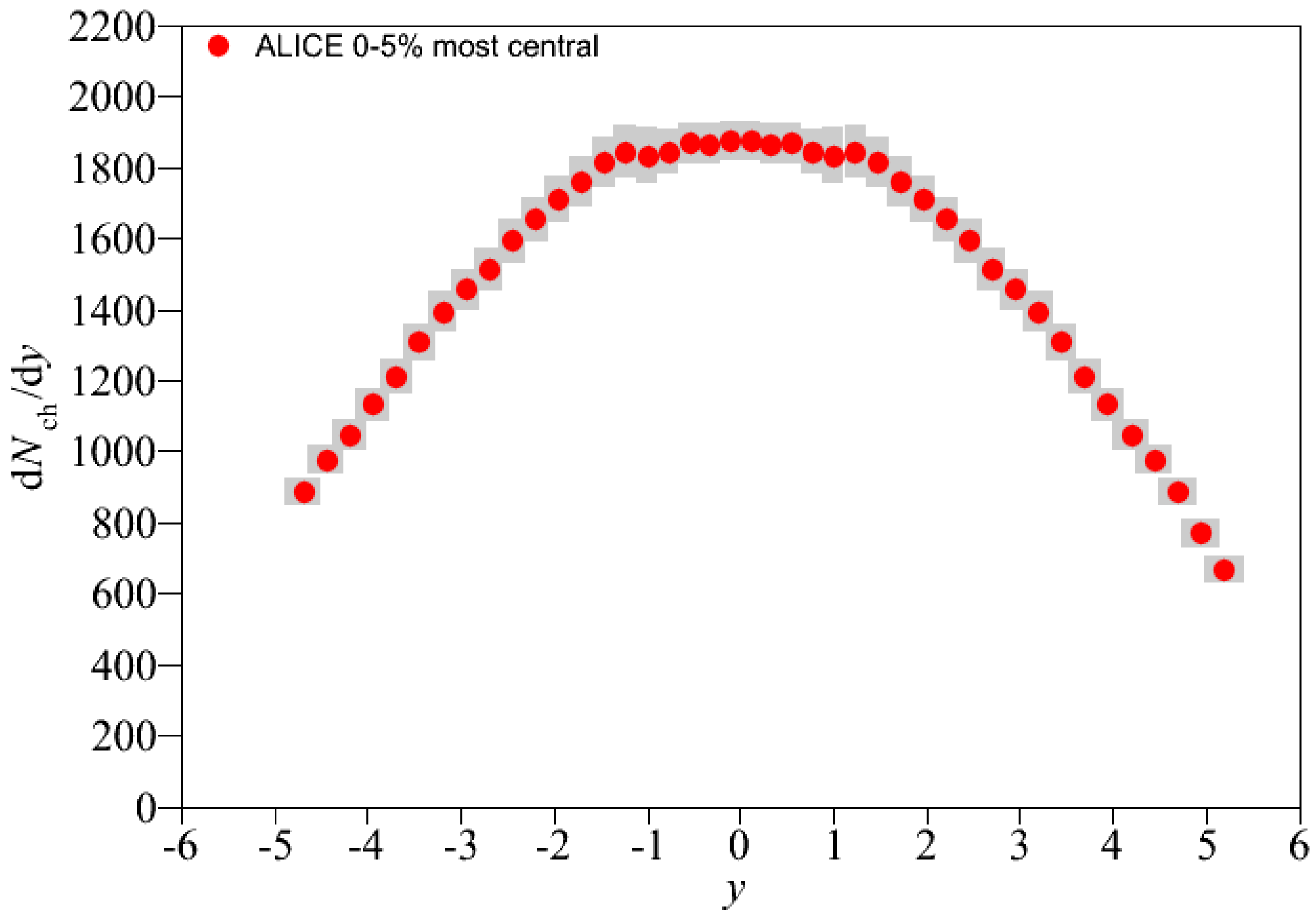
  - The shape dN/dη distribution does not depend on the colliding energy at forward rapidity
  - Also seen for v_2 longitudinal scaling





Results: dN/dy distribution

- dN/dy is extracted by performing a Jacobian transformation from η to y
  - $$\frac{dN}{dy} = \frac{1}{< J(\eta) >} \frac{dN}{d\eta}$$
  - Measured particle ratio and p_T distribution for $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ in ALICE* are used (|y|<0.5)
- Syst. errors included:
  - A linear softening of the p_T spectra with increasing |η|
  - Variations in the particle yields

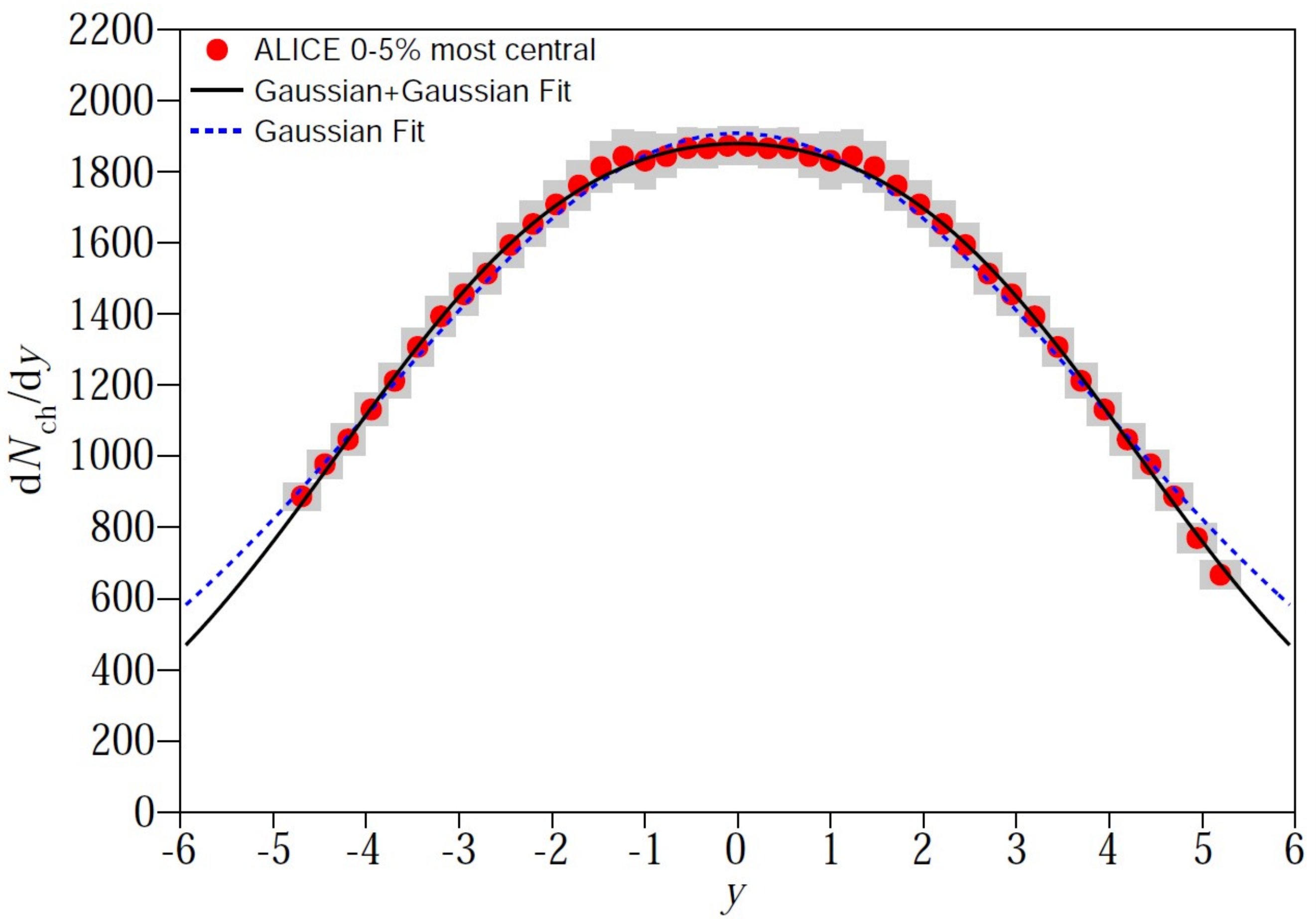


$$< J(\eta) >= \frac{N_{\pi^{\pm}} < J_{\pi^{\pm}}(\eta) > + N_{\kappa^{\pm}} < J_{\kappa^{\pm}}(\eta) > + N_{p/\bar{p}} < J_{p/\bar{p}}(\eta) >}{N_{\pi^{\pm}} + N_{\kappa^{\pm}} + N_{p/\bar{p}}}$$

*: B. Abelev et al. (ALICE Collaboration) Phys. Rev. Lett. 109, 252301 (2012)

Results: dN/dy distribution

- Results consistent with a plateau for within $|\eta|<1.5$
  - Favored by a Bjorken hydrodynamical picture → **boost invariance**
  - Results also well described by Gaussian fits



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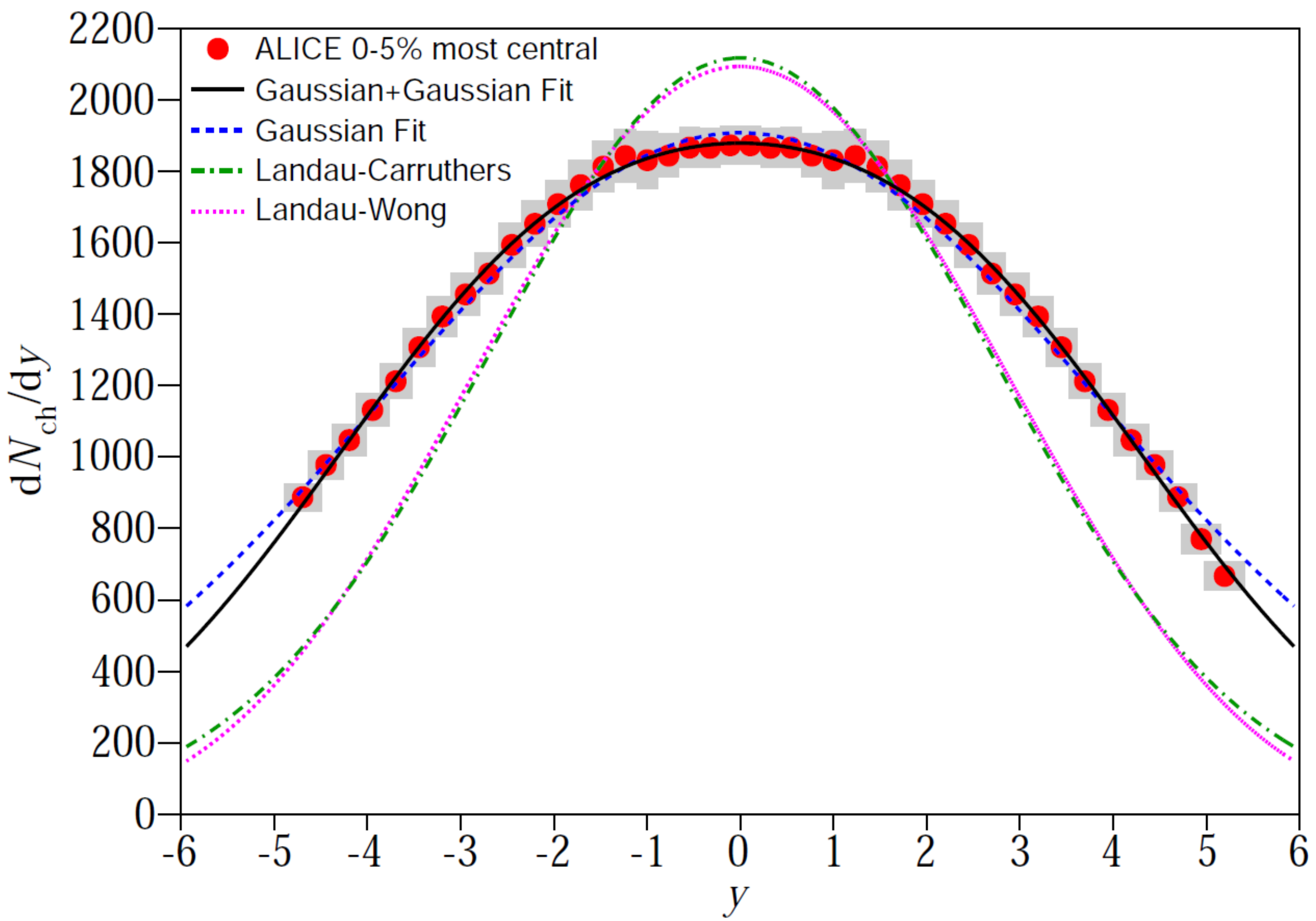

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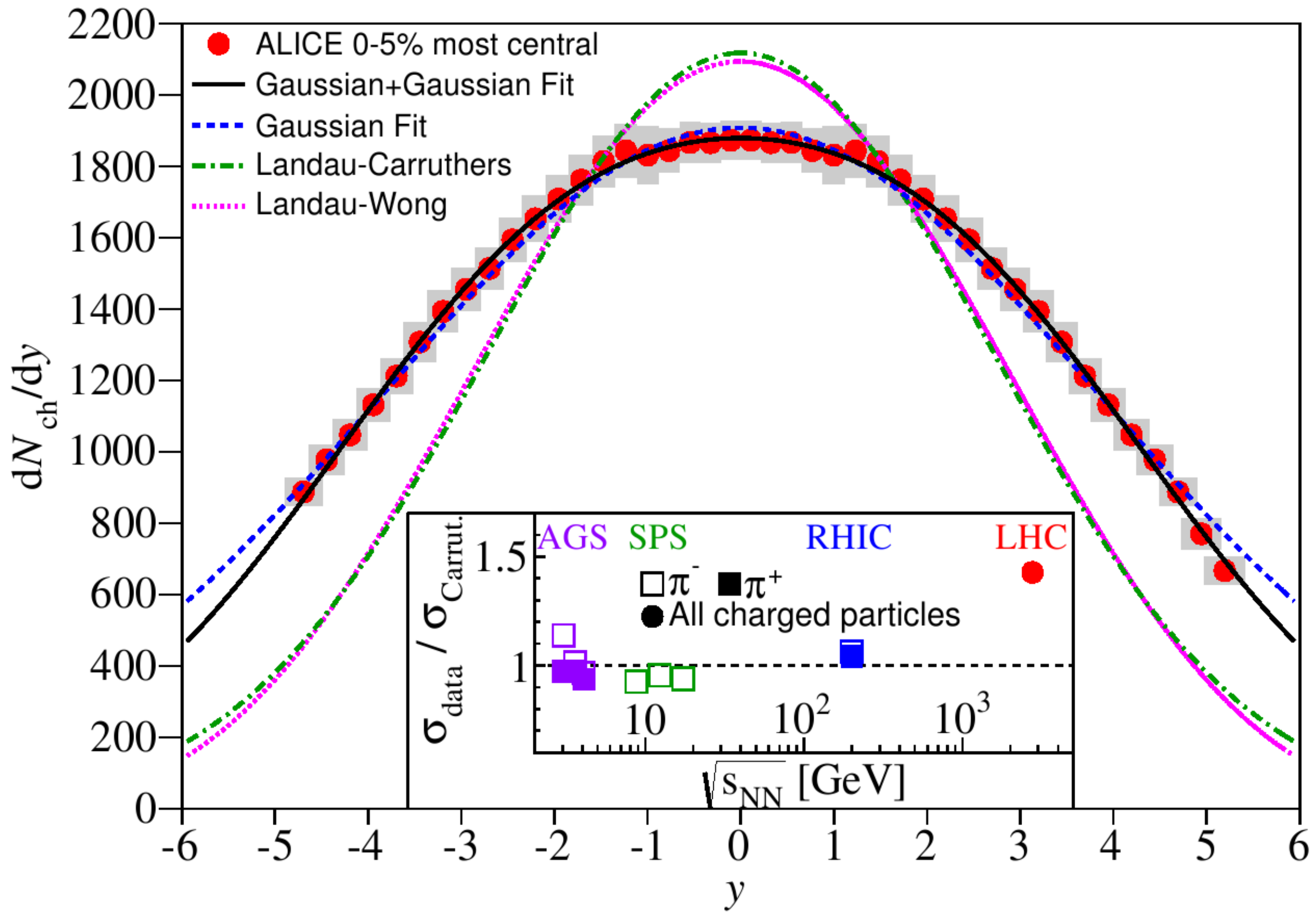
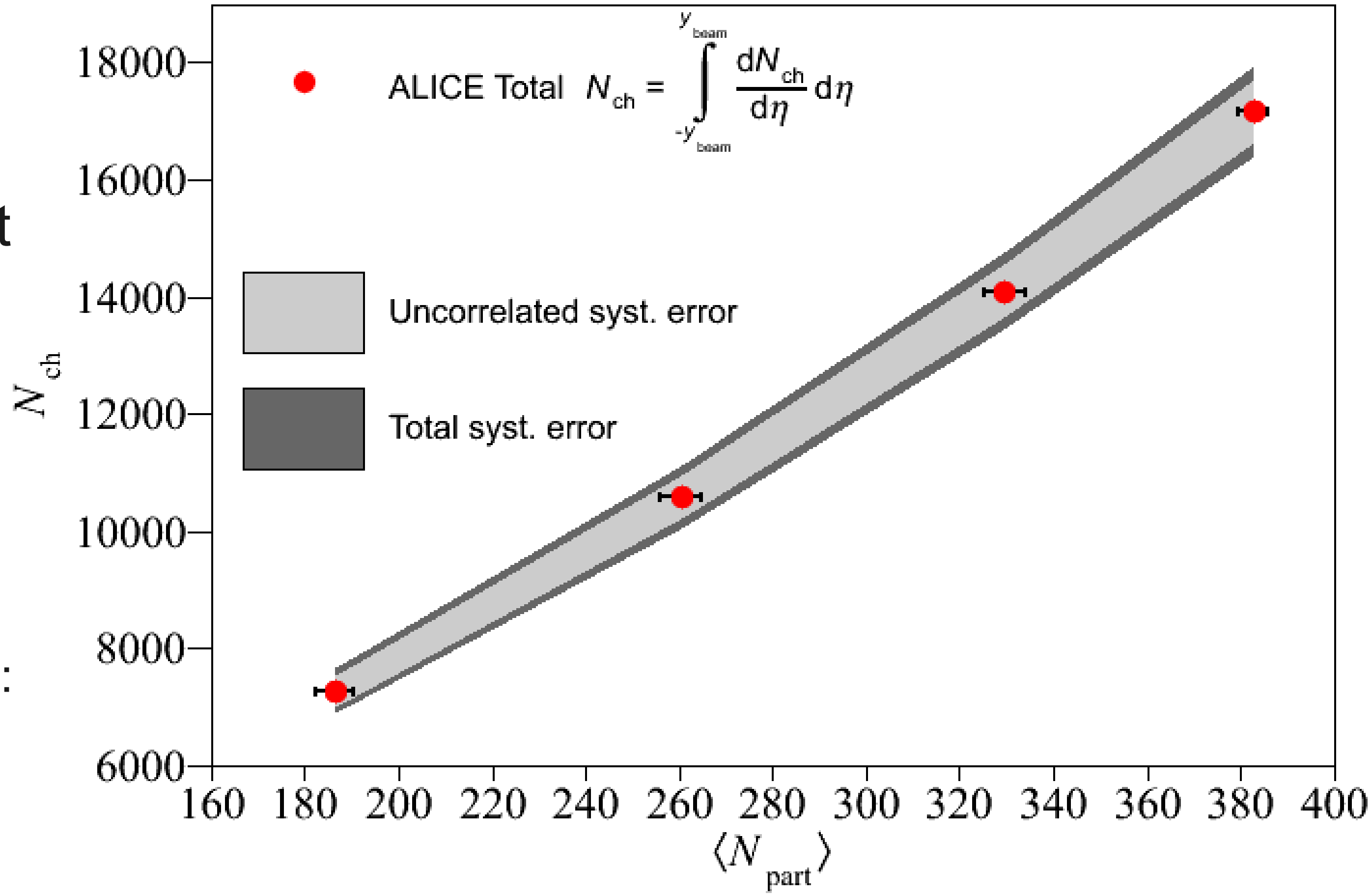
- Deviations with respect to lower energy suggest a significant change in dynamics at LHC energies



Results: Total number of charged particles N_{ch}

- N_{ch} is estimated with a double gaussian fit function and a linear extrapolation at high rapidity for each centrality bin
  - Stat. error is smaller than the marker size
  - Syst. errors includes the uncertainty on the extrapolation: 2-3 %



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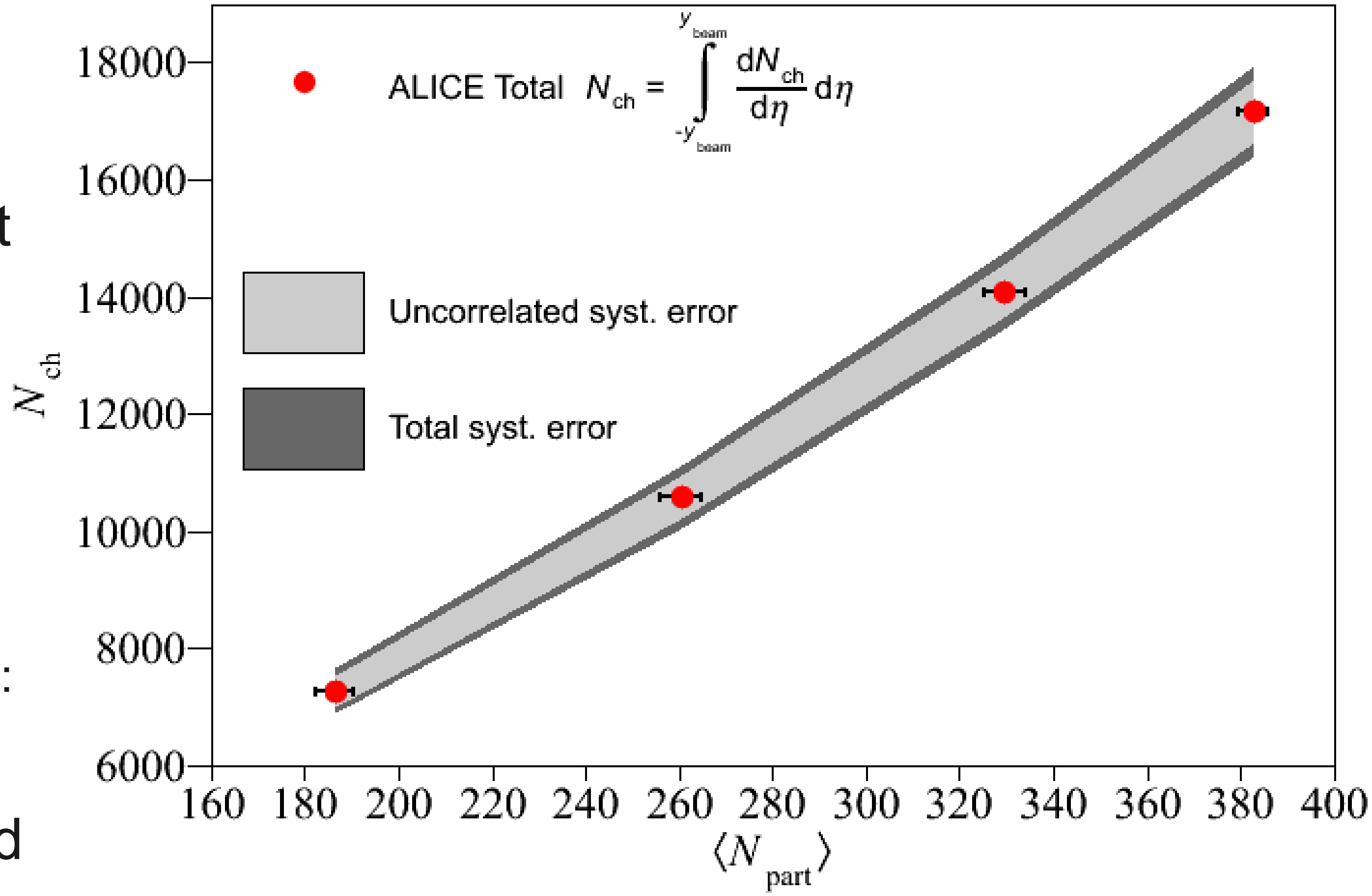
  - Fraction of particle in extrapolation: 13%



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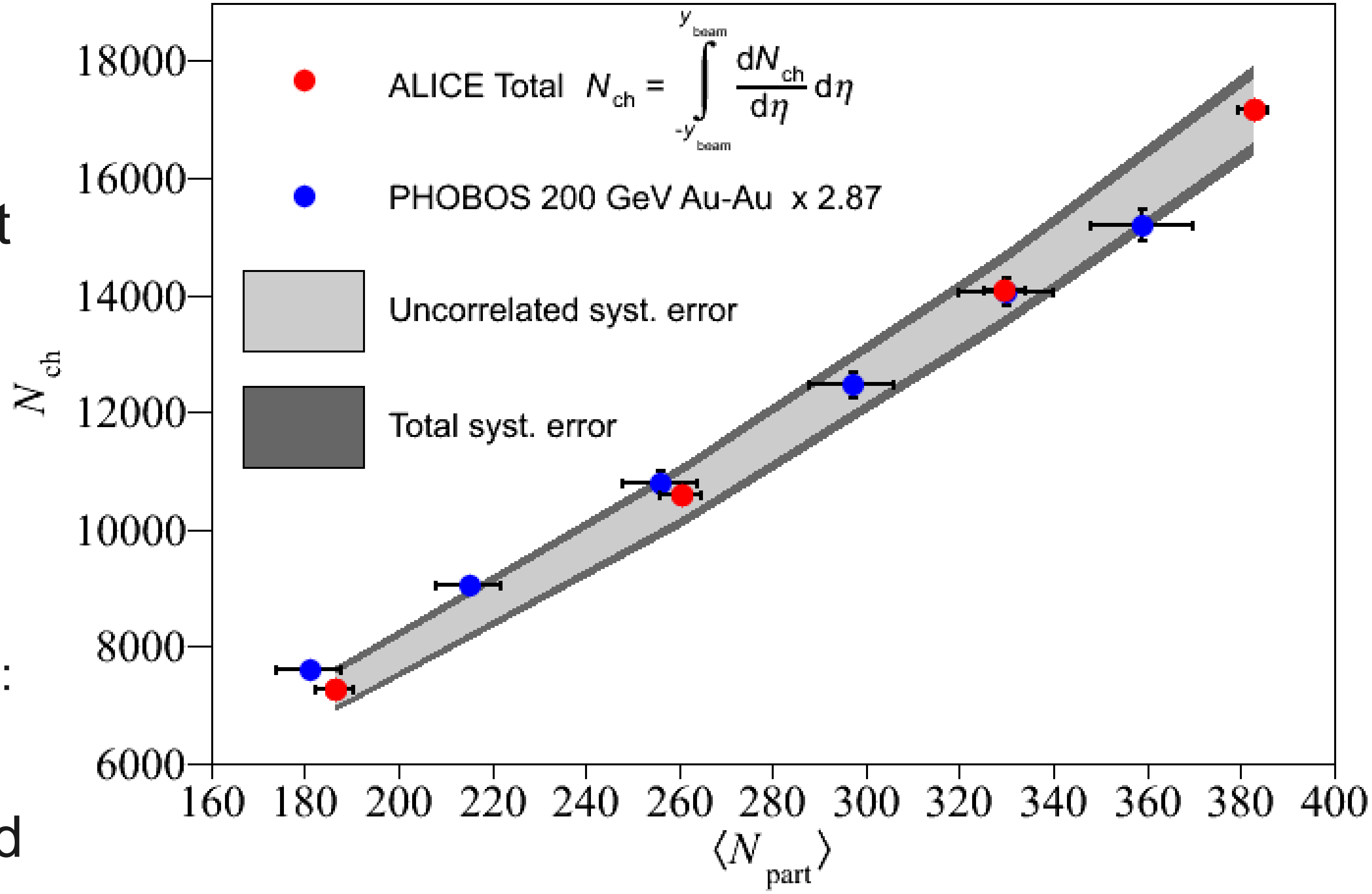
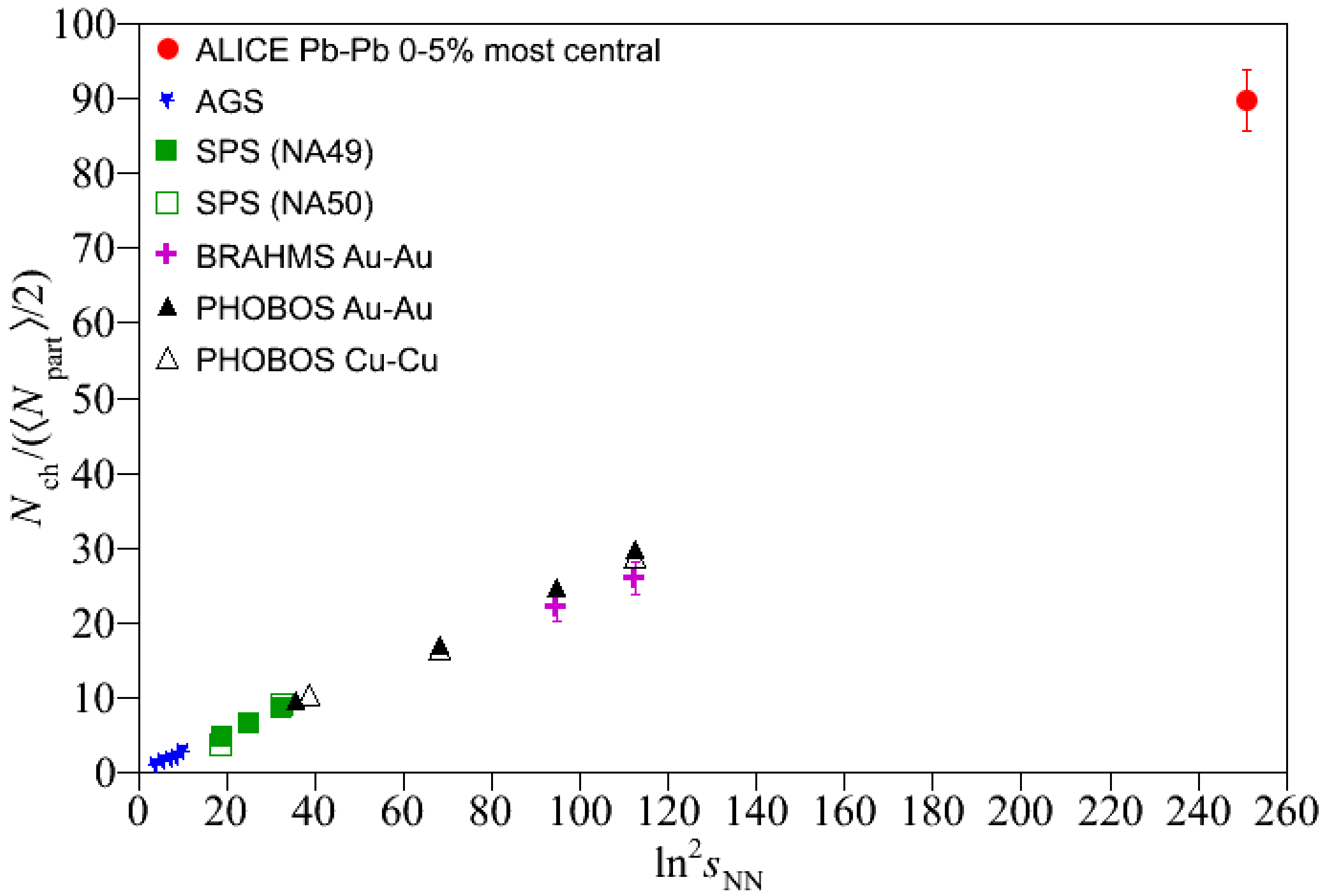


- Comparison with PHOBOS data:
  - PHOBOS data scaled by $\dfrac{\langle \frac{N_{ch}}{N_{part}} \rangle_{LHC}}{\langle \frac{N_{ch}}{N_{part}} \rangle_{RHIC}} = 2.87$

Results: N_{ch} scaling as a function of $\ln^2 s_{NN}$

- N_{ch} scaling is computed in ALICE and compared with other experiment result as a function of $\ln^2(s_{NN})$



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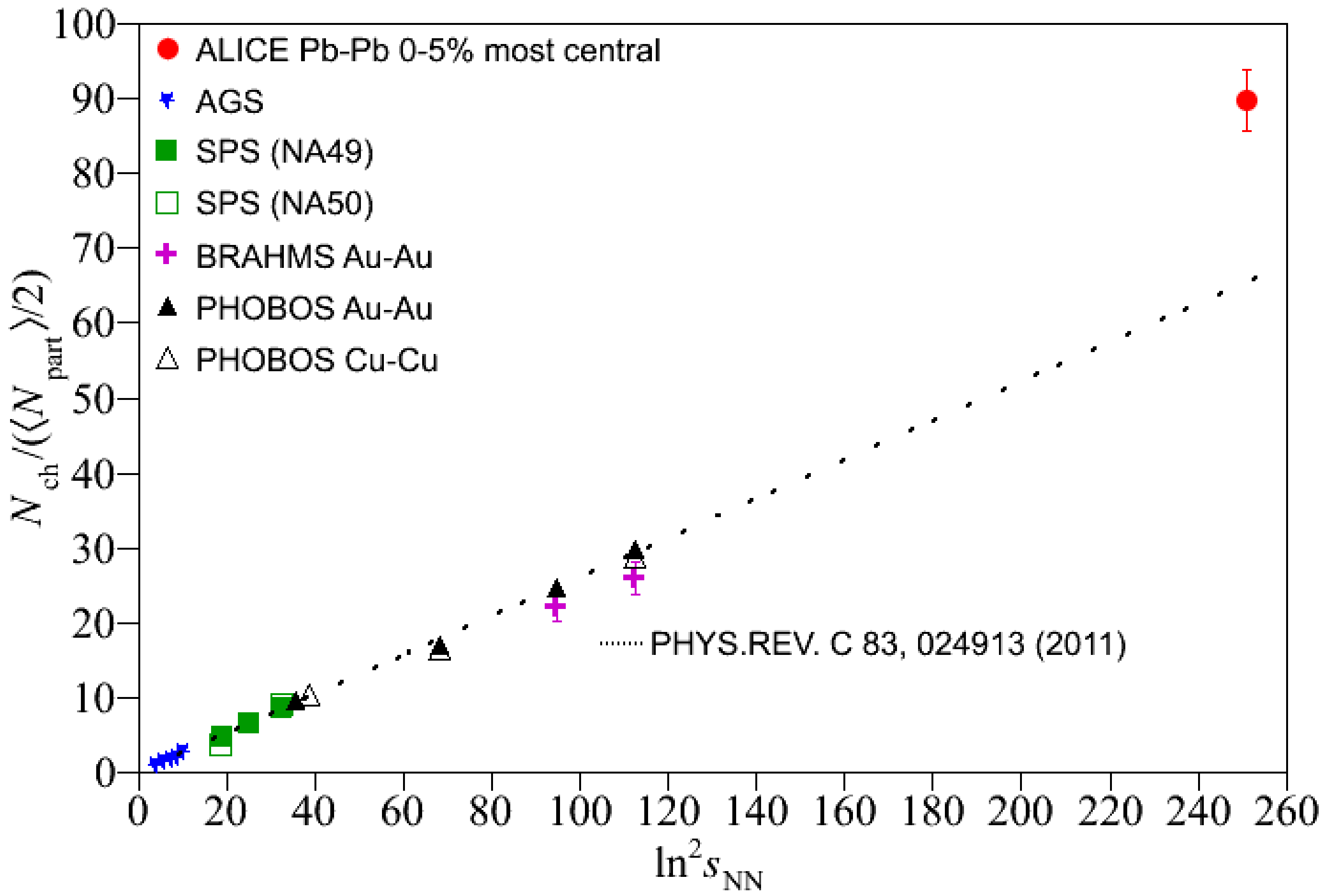
  - The trend was observed to be linear from AGS to RICH
    → **not valid at LHC energies**



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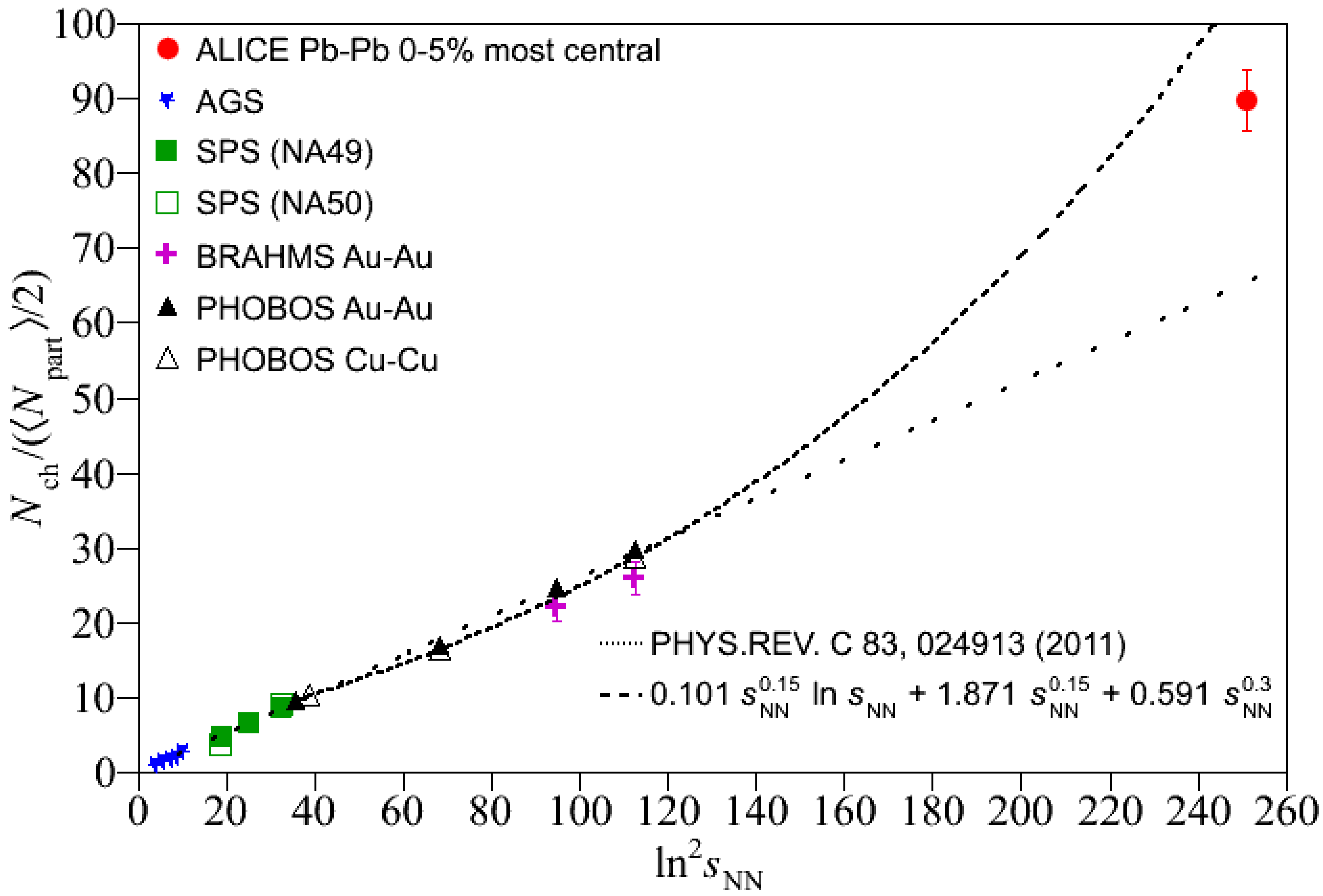
- 2 fit functions are tested
  - Adding a power law scaling of the dN/dη at midrapidity to the linear trend ➔ **overestimate**



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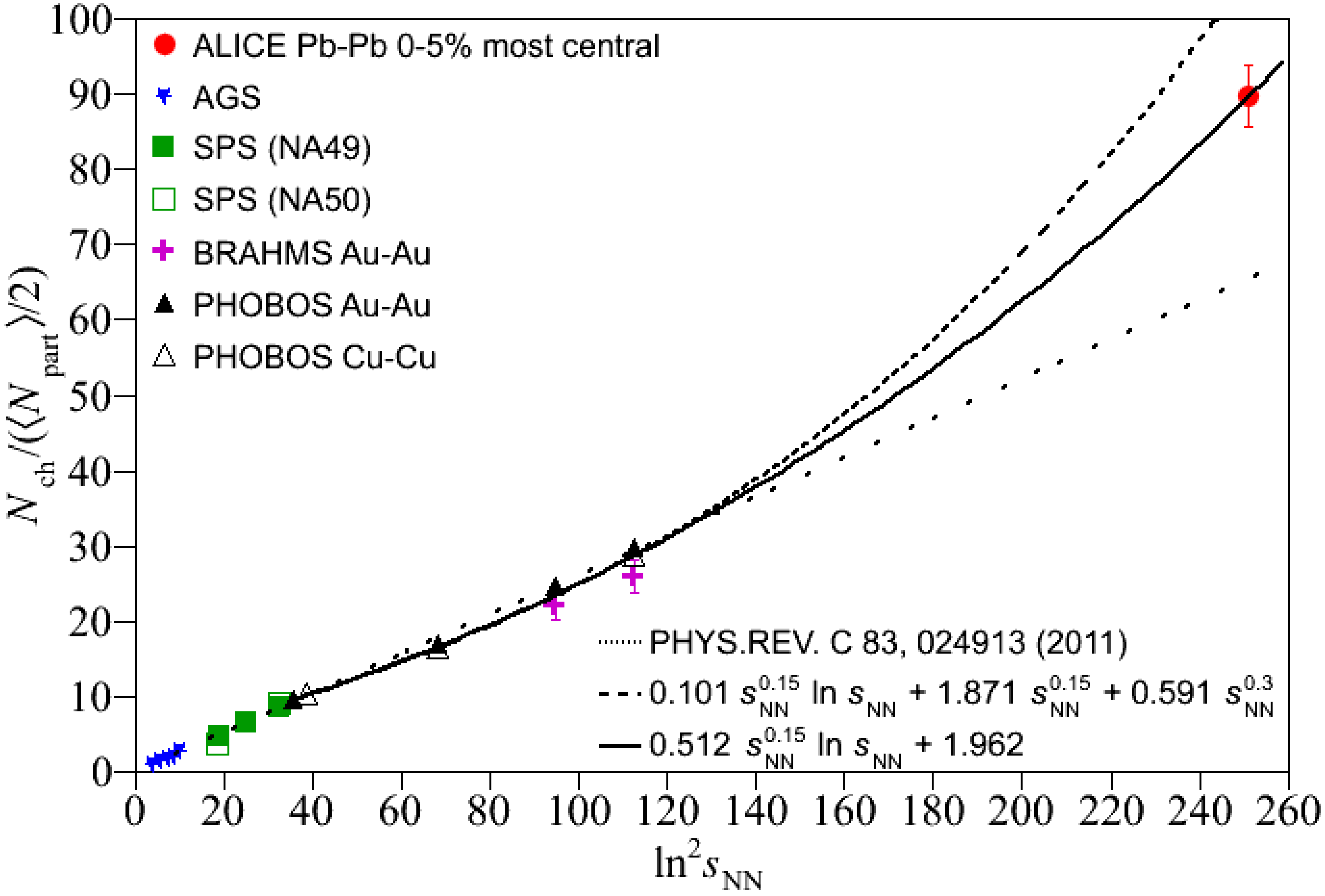
- 2 fit functions are tested
  - Adding a power law scaling of the dN/dη at midrapidity to the linear trend ➔ **overestimate**
  - Fit with a function where the dN/dη at midrapidity scales as a power law & extends over an η range growing as $\ln(s_{NN})$

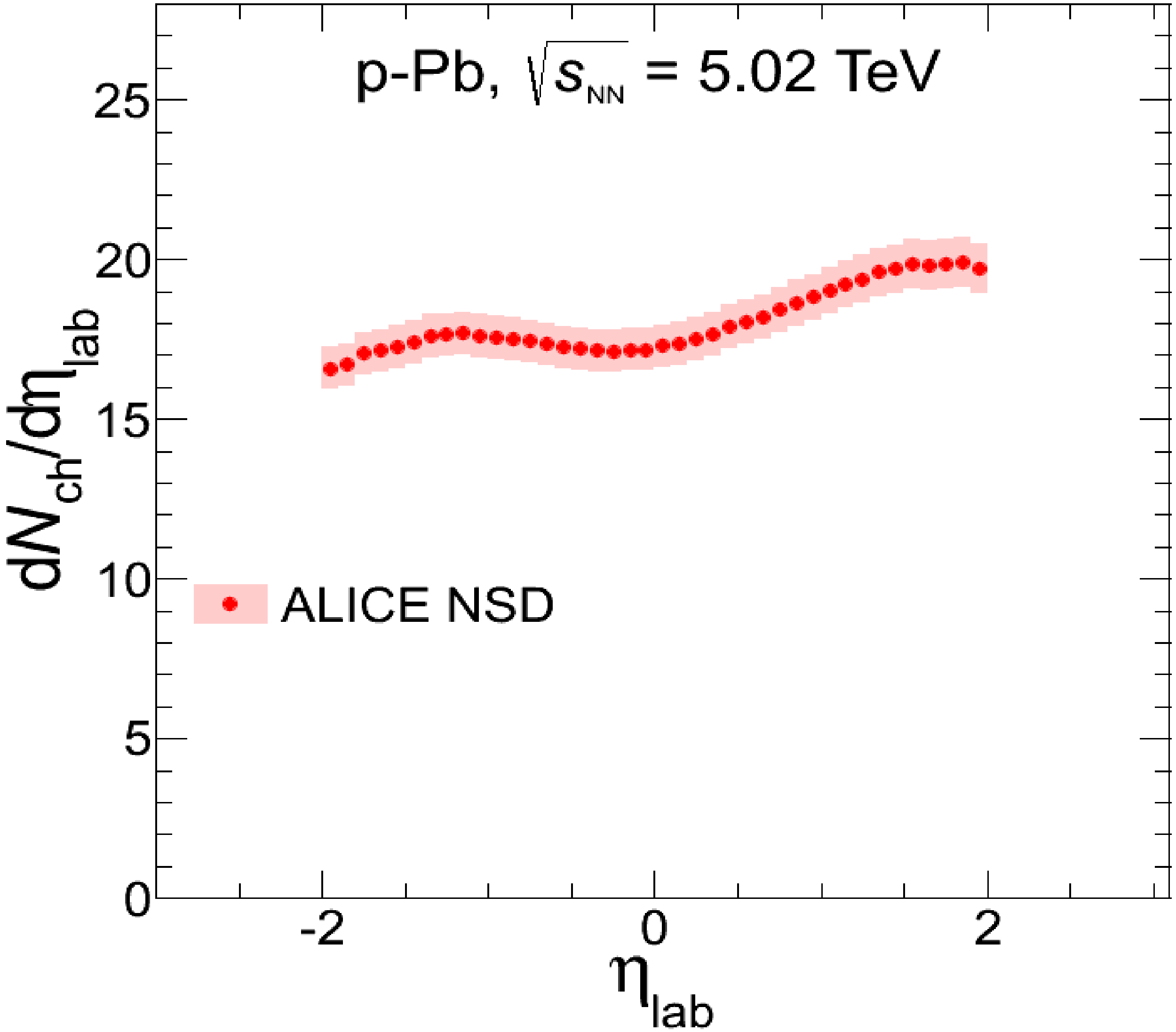


$$\mathbf{dN/d\eta|_{\eta=0} \sim s_{NN}^{0.15}\ \ \&\ \ \sigma(dN/d\eta) \sim \ln(s_{NN})}$$

p-Pb results

Results: $dN_{ch}/d\eta$ (NSD) as a function of η

- Analysis made with SPD*
  - Same as in Pb-Pb ➔ **tracklet analysis**
  - NSD event sample
  - Results shifted by Δy_{NN}=0.465 to take into account the boost due to different incident energy between p & Pb
  - Syst. Error ~ 3.8%



*: *ALICE Collaboration, Phys. Rev. Lett. 110, 032301 (2013)*

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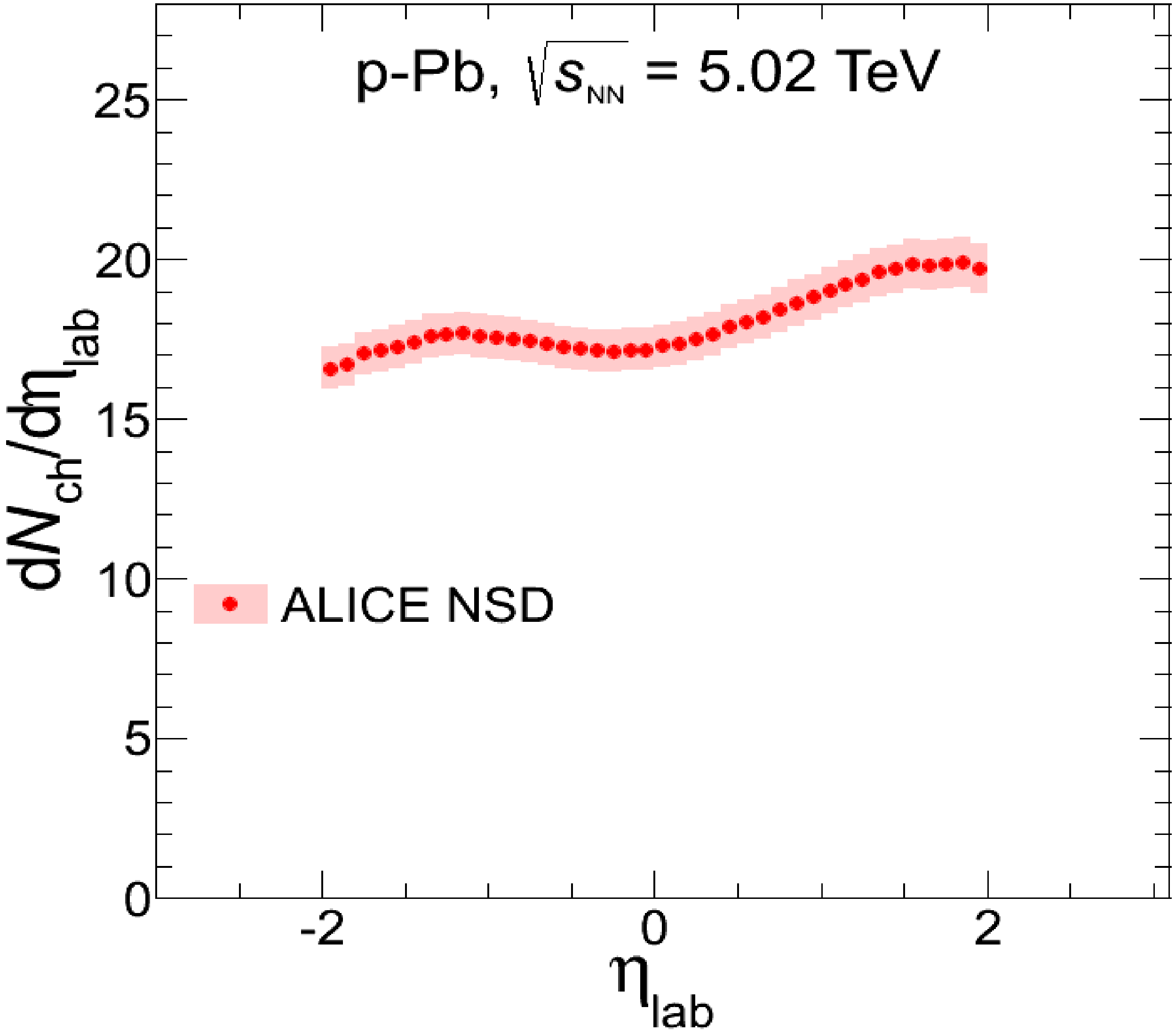
  - NSD event sample
  - Results shifted by Δy_{NN}=0.465 to take into account the boost due to different incident energy between p & Pb
  - Syst. Error ~ 3.8%
- Asymmetry between p & Pb hemispheres clearly visible
  - $dN/d\eta_{lab}|_{|\eta|<0.5}$ = 17.35 ± 0.67(syst.)
  - $dN/d\eta_{cms}$ = 16.81 ± 0.71(syst.)



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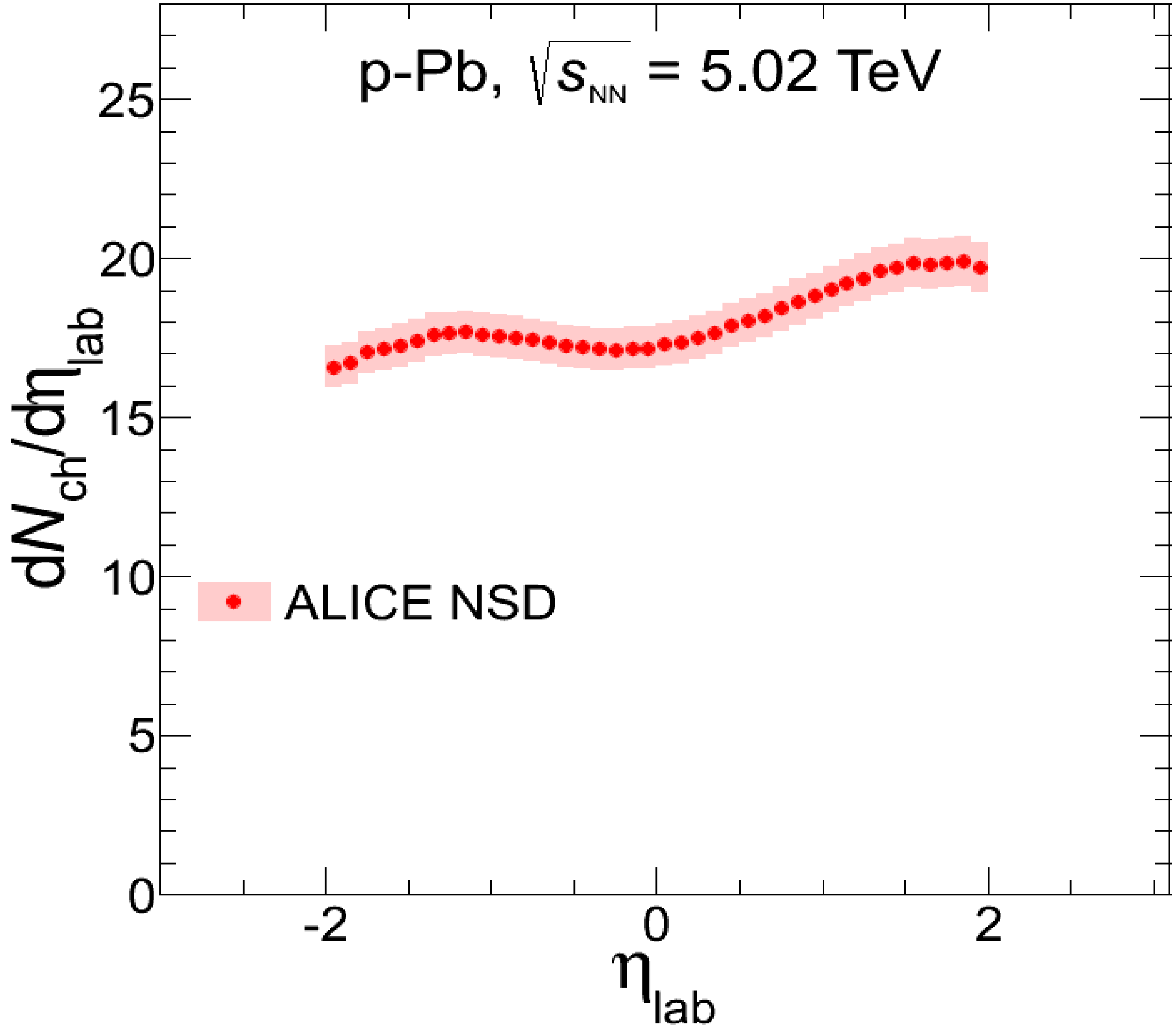
Results: $dN_{ch}/d\eta$ (NSD) as a function of η

- Comparison with models



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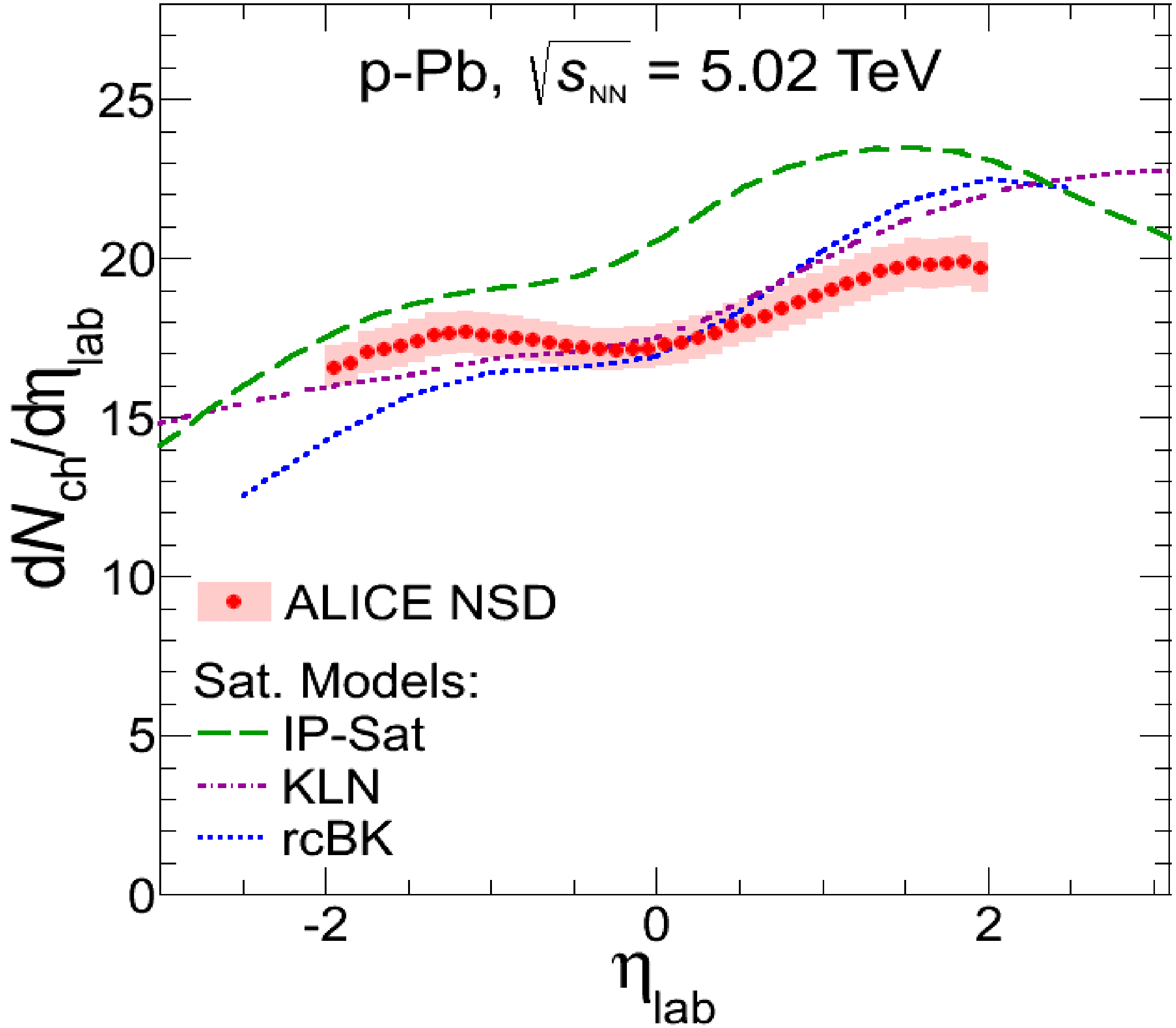
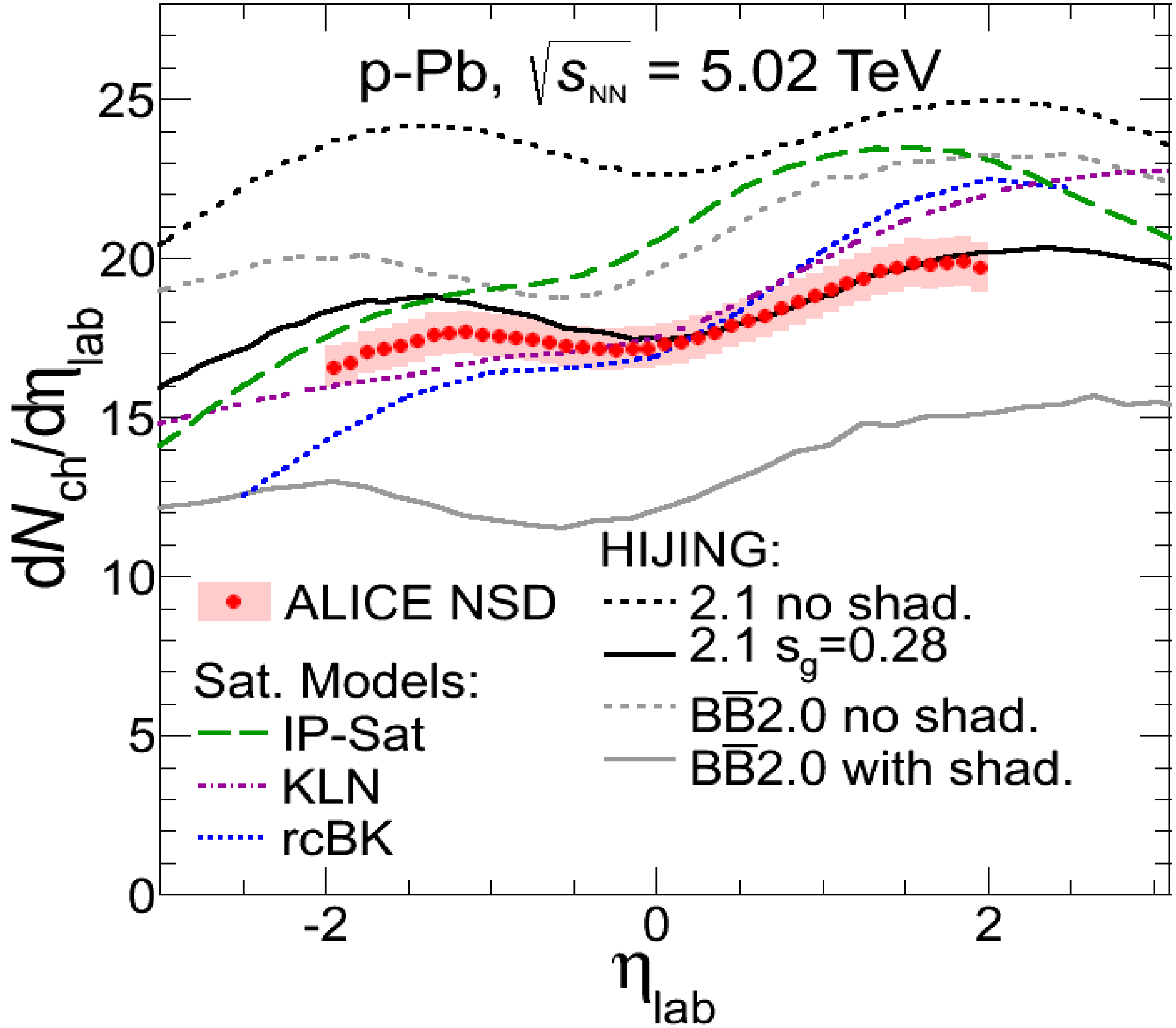
- Comparison with models
  - **Saturation models**



Results: $dN_{ch}/d\eta$ (NSD) as a function of η

- Comparison with models
  - **Saturation models**
  - HIJING models with/without shadowing or including a tune on the gluon shadowing parameter



Results: $dN_{ch}/d\eta$ (NSD) as a function of η

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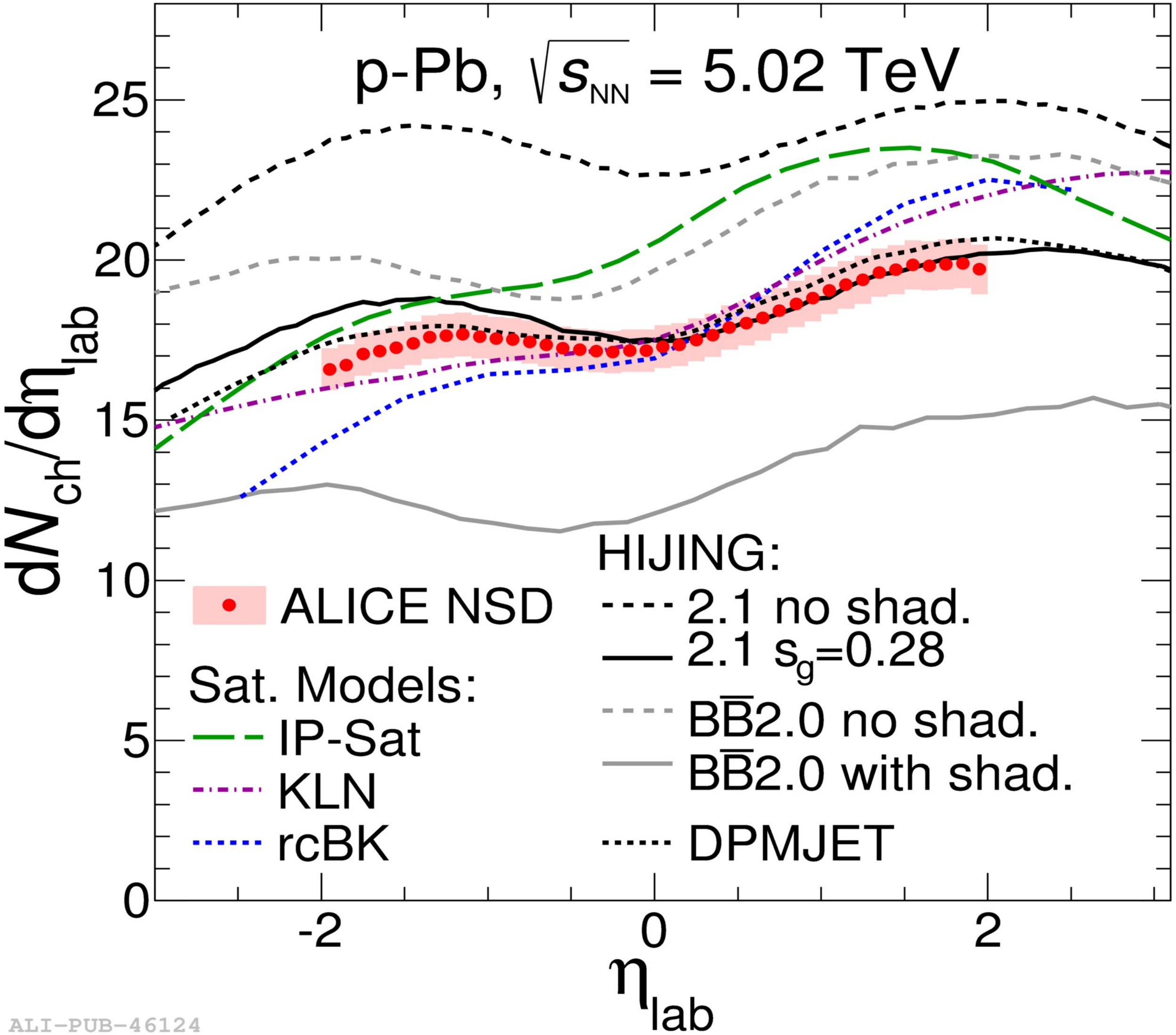
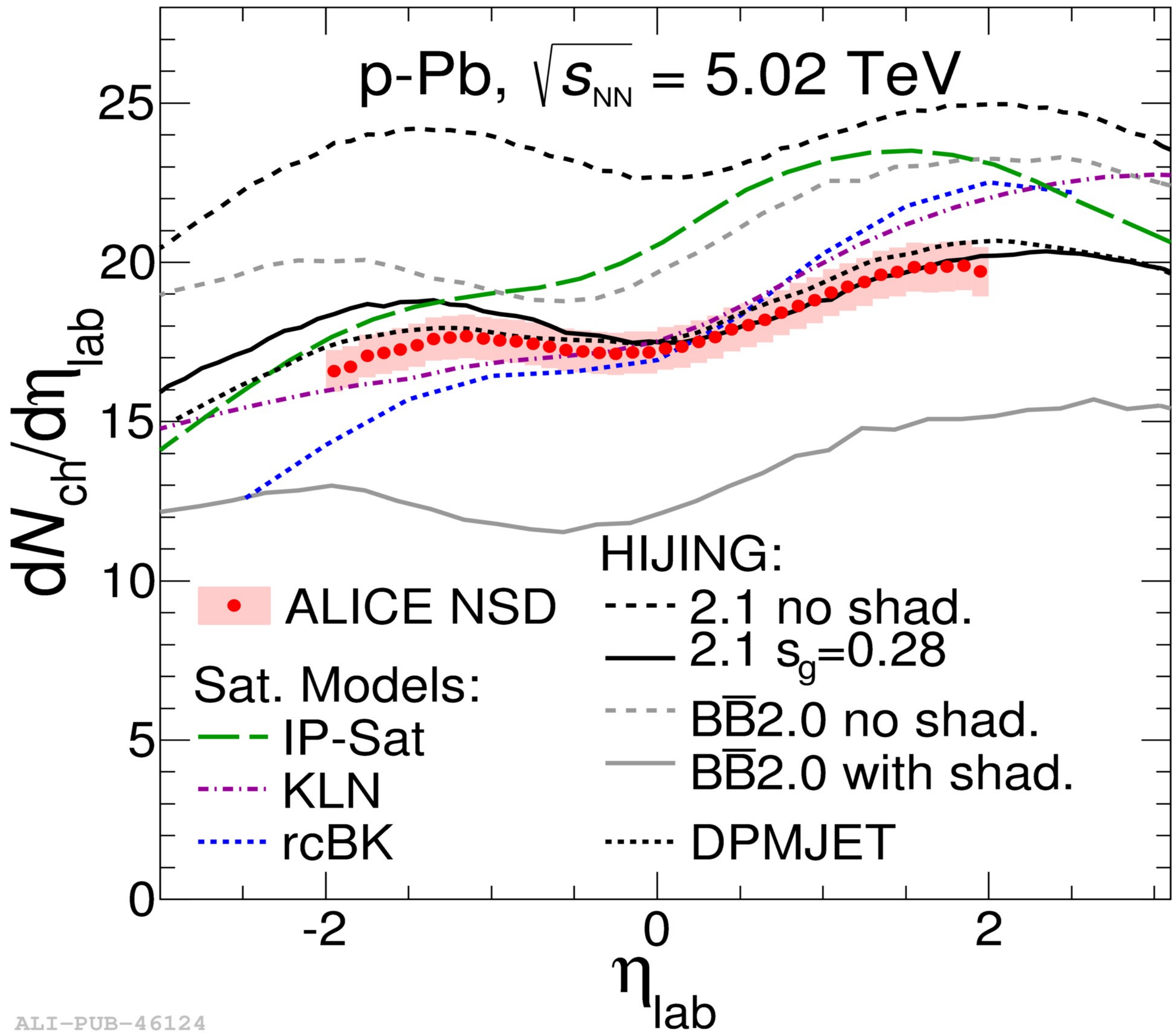


Results: $dN_{ch}/d\eta$ (NSD) as a function of η

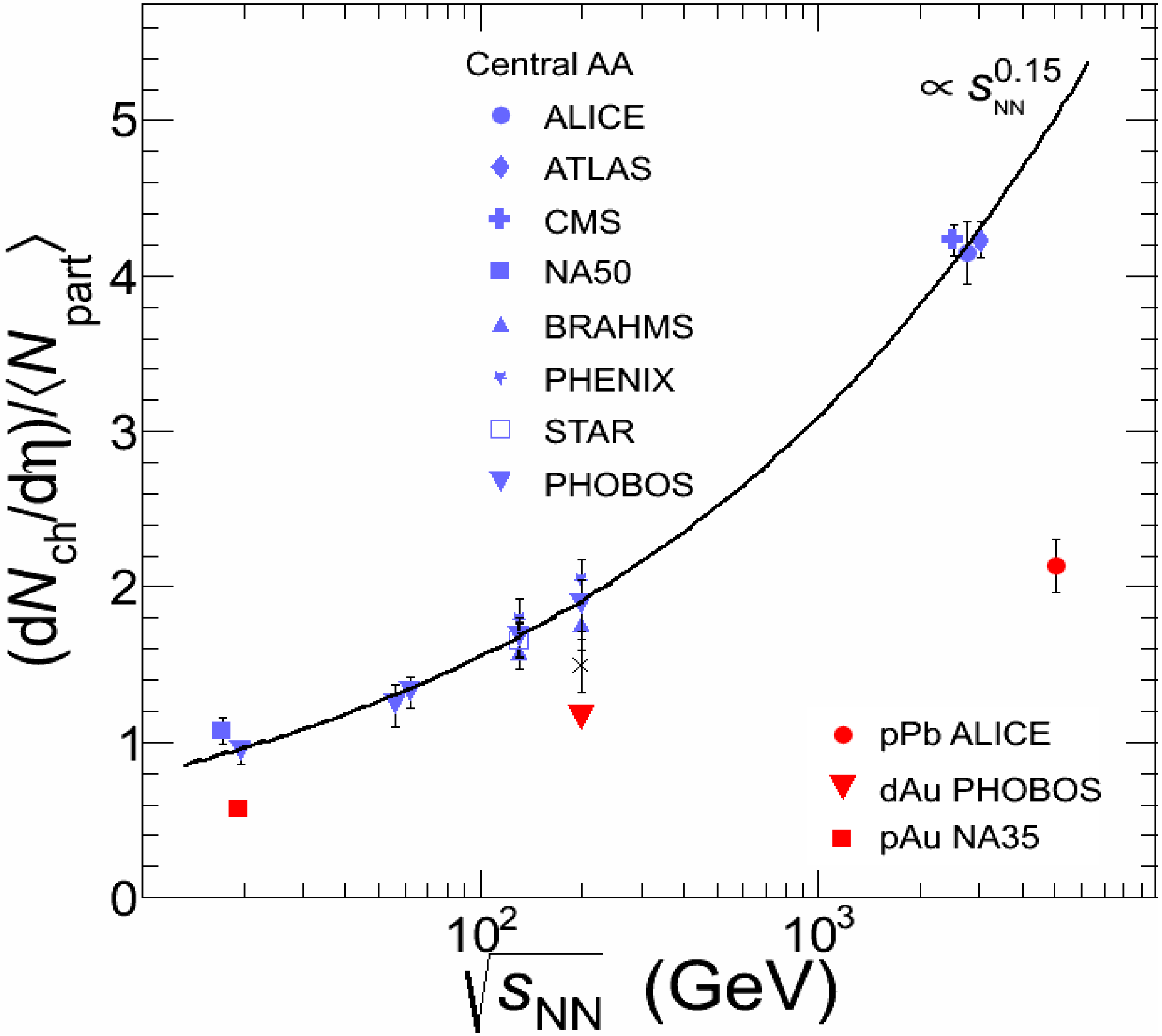
- Comparison with models
  - **Saturation models**
  - HIJING models with/without shadowing or including a tune on the gluon shadowing parameter
  - DMPJET normalized to NSD
- Most of the models which include saturation/shadowing reproduce the data within 20%
  - Saturation models exhibit difficulties to reproduce the shape
  - HJING 2.1 (s_g=0.28) & DMPJET give the closest values



ALI-PUB-46124

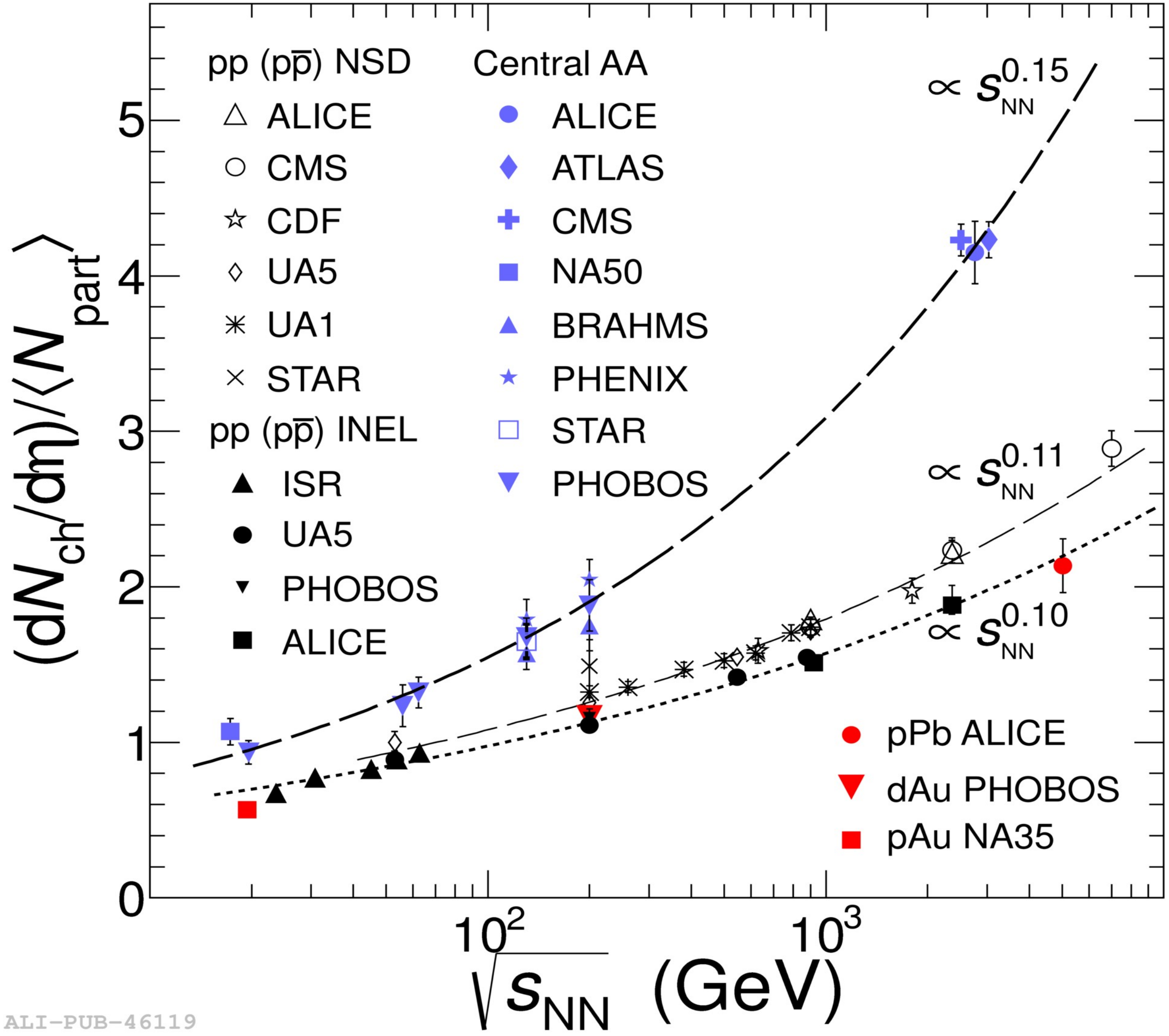
Results: $dN_{ch}/d\eta$ scaling as a function of $\sqrt{s_{NN}}$

- $dN/d\eta$ scaled by $<N_{part}>$
  - $<N_{part}> = 7.9 \pm 0.6$
  - $(dN_{ch}/d\eta_{cms})/<N_{part}> = 2.14 \pm 0.17$
  - 84% higher than in d-Au at $\sqrt{s_{NN}}$=0.2 TeV



Results: $dN_{ch}/d\eta$ scaling as a function of $\sqrt{s_{NN}}$

- $dN/d\eta$ scaled by $\langle N_{part} \rangle$
  - $\langle N_{part} \rangle = 7.9 \pm 0.6$
  - $(dN_{ch}/d\eta_{cms})/\langle N_{part} \rangle = 2.14 \pm 0.17$
  - 84% higher than in d-Au at $\sqrt{s_{NN}}$=0.2 TeV
- Comparison with other system
  - 16% lower than NSD pp collision interpolated to the same energy
  - Consistent with inelastic pp ($p\bar{p}$) interpolated to the same energy



Conclusion

Conclusion

- Pb-Pb @ 2.76 TeV
  - The charged particle multiplicity was computed in a large η range and 4 centrality bins (0-30%) thanks to the satellite vertex technique
  - The dN/dη per participant pair distribution increases as a function of $<N_{part}>$ with a similar trend in all pseudo-rapidity intervals.
  - The ALICE dN/dη distributions are consistent with the PHOBOS and BRAHMS distributions in the fragmentation region showing consistency with longitudinal scaling over a large energy range
  - The ALICE and PHOBOS (scaled) N_{ch} measurements are consistent
  - The dN/dy distribution is consistent with a plateau around $|\eta| < 1.5$ and the width of the distribution is wider than expected from Landau hydrodynamics
- p-Pb @ 5.02 TeV
  - The dN/dη is measured and most of the models which include saturation/shadowing reproduce the data within 20%
  - The dN/dη scaling is consistent with inelastic pp and 16 % lower than pp NSD data