Quark Matter 2012

Washington D.C.

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Charged-particle multiplicity in Pb-Pb at 2.76 TeV with the displaced vertex technique with ALICE at LHC

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On behalf of the ALICE collaboration

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- **Overview**
- Motivations
- The ALICE experiment
- Analysis technique
- Results
- Conclusion

Motivations

- Global observable which reflects the initial conditions
- Investigate final-state distribution of available energy and underlying dynamics of particle production mechanisms
- dN/dη , over a wide pseudo-rapidity coverage, allows one to access the longitudinal scaling:
  - Violation vs conservation:

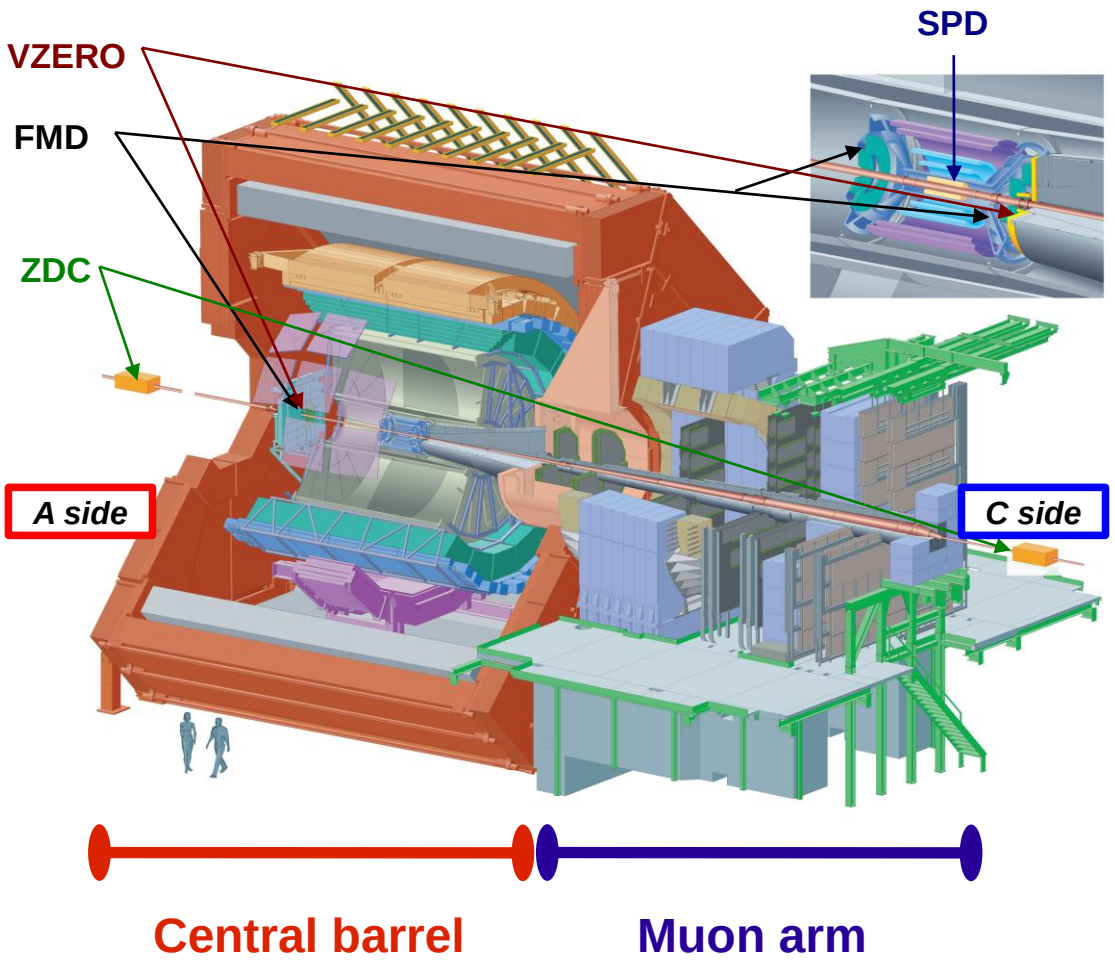
VIOLATION	CONSERVATION
• P. Brigueira, J. Dias de Deus, C.Pajares, Phys. Rev. C 75, 054908 (2007) • J. Cleymans, J. Strumpfer, L.Turko, Phys. Rev. C 78, 01901 (2008)	• W. Busza, J. Phys. G 35, 044040 (2008) • A. Bialas, A. Bzdak, R. Peschanski, Phys. Lett. B 665, 35 (2008)

- dN/dη is related to:
  - Density of the system
  - Initial conditions, energy, entropy production in the early stage of heavy ion (HI) collisions
  - Background for hard-probes signals

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)
  - 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

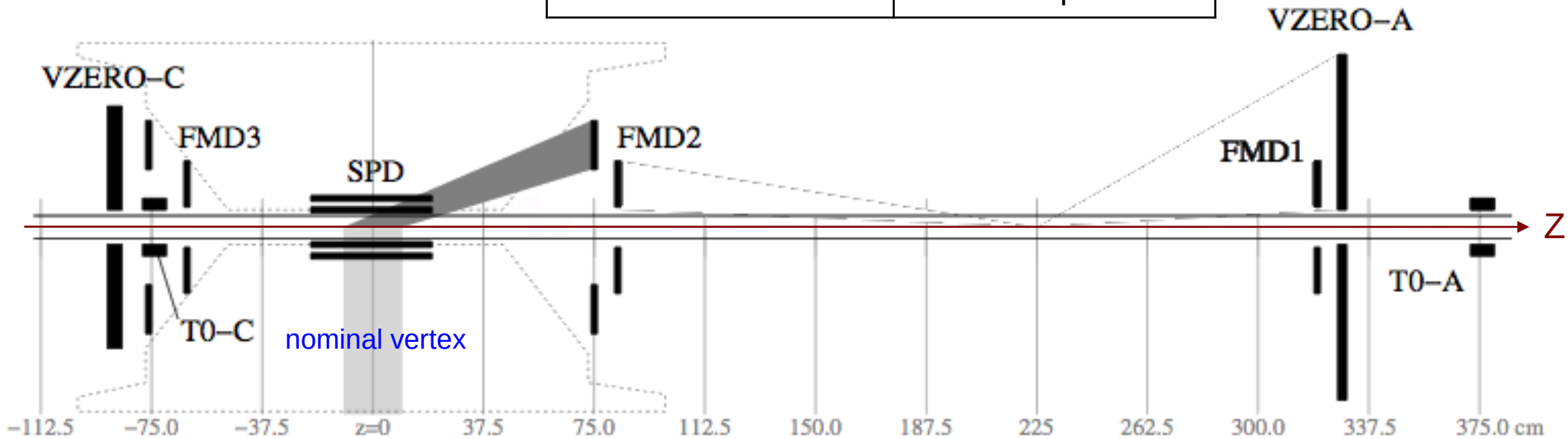


Analysis technique

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 ALICE published results *PRL 106, 032301 (2011)*
  - To reach this pseudo-rapidity range, the analysis was performed in 3 bins along Z axis to enlarge the acceptance of SPD:

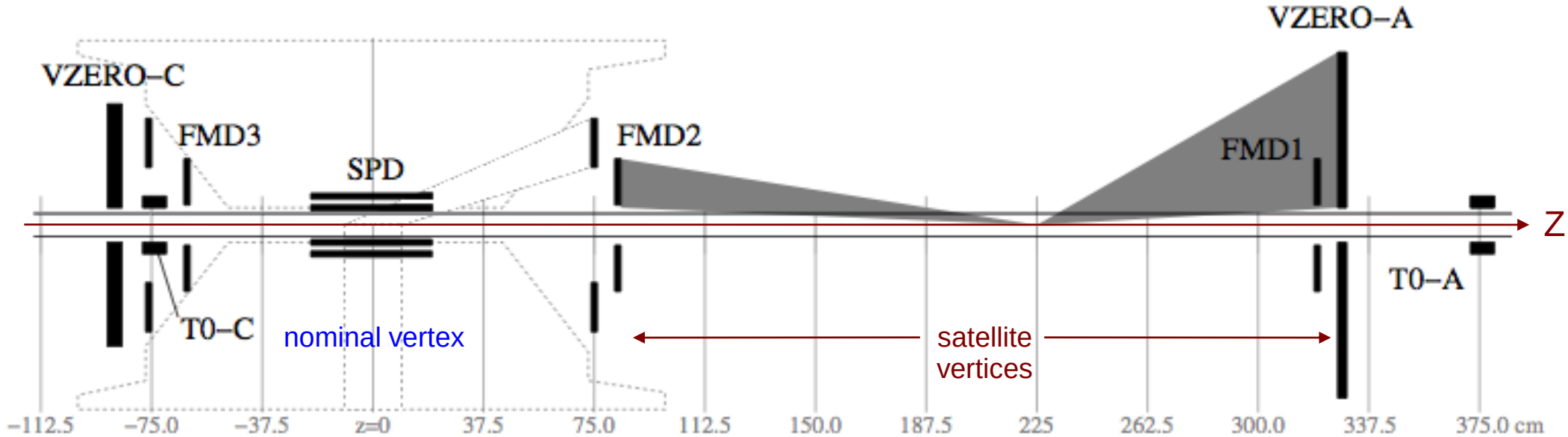
-13 cm < Zv < -6 cm	-2.00 < η < -0.75
-7 cm < Zv < 7 cm	-0.75 < η < 0.75
6 cm < Zv < 13 cm	0.75 < η < 2.00



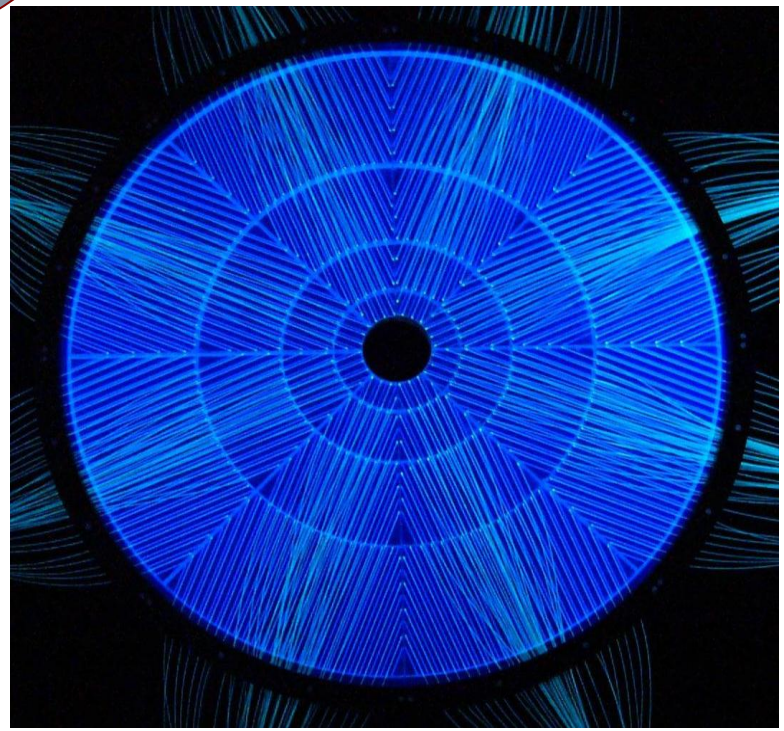
Analysis technique

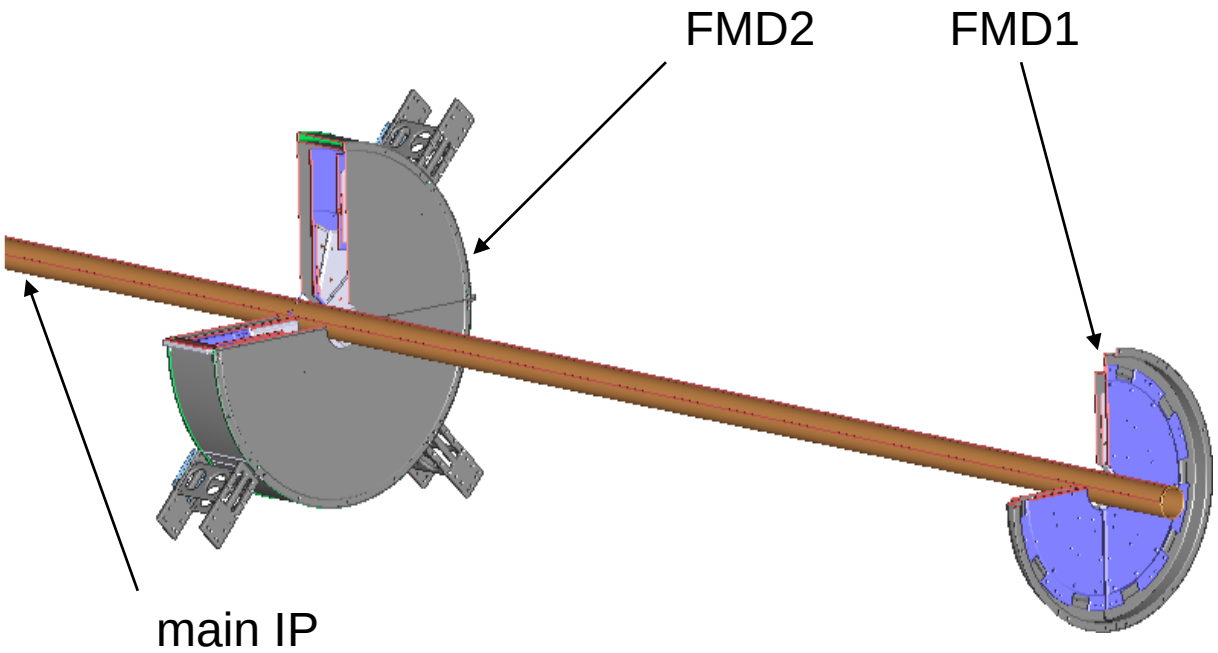
Satellite collisions:

- 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**
- Due to zero crossing angle, a large amount of satellite collisions was 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





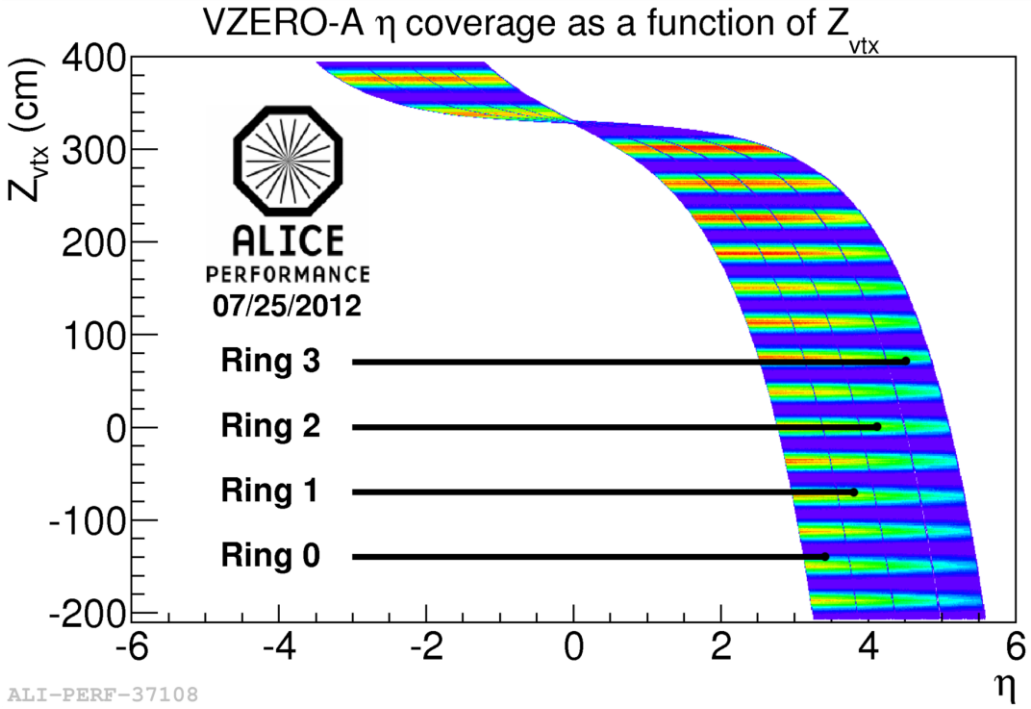
- VZERO-A η coverage for collisions at main IP:

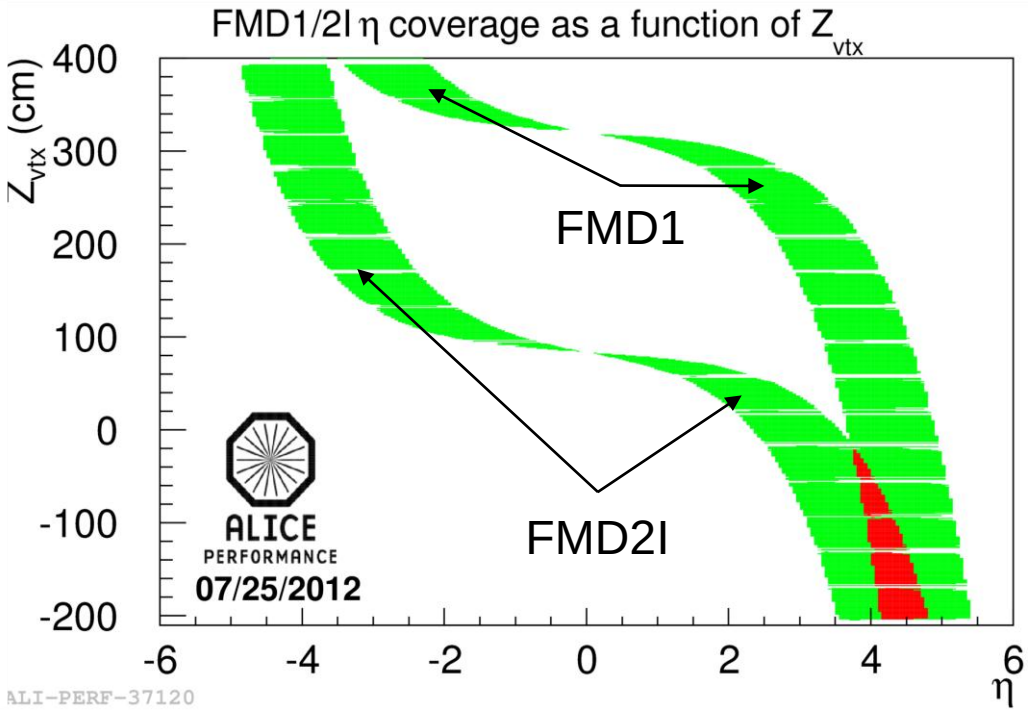
Ring	0	4.5<η<**5.1**
	1	3.9<η<4.5
	2	3.4<η<3.9
	3	**2.8**<η<3.4

- FMD1 & FMD2 η coverage at main IP:

FMD1	3.7<η<**5.0**
FMD2	**1.7**<η<3.7

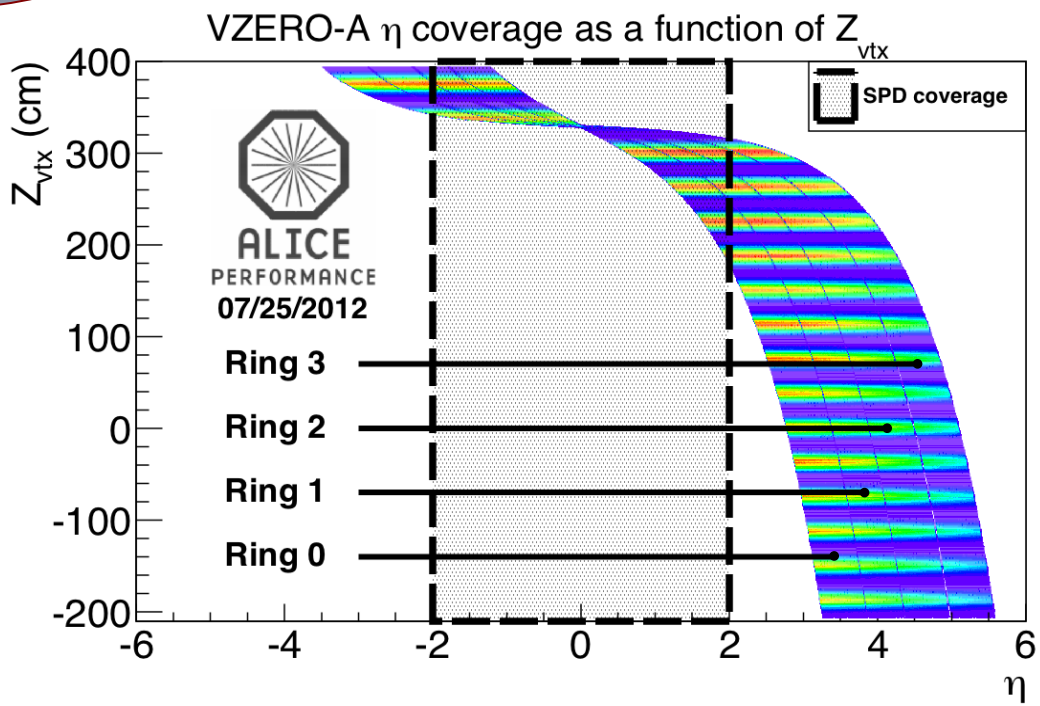
Analysis technique: η coverage





- 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: VZERO



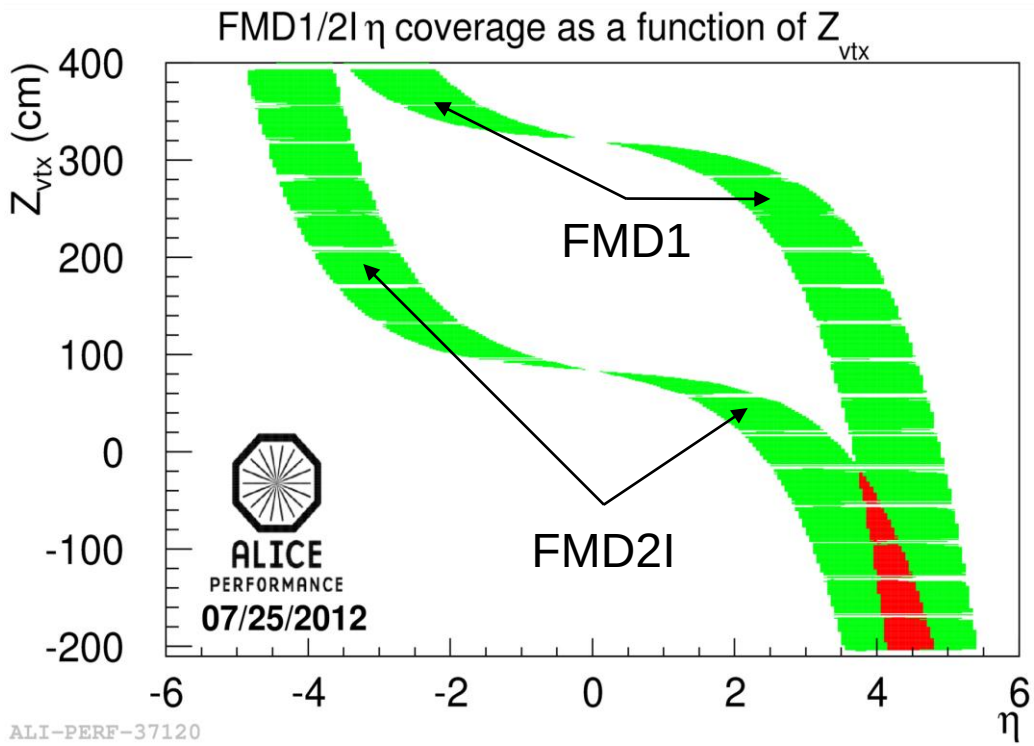
- VZERO & SPD coverage overlap for several vertices
  - VZERO signal calibrated on SPD measurement
  - Charged-particle multiplicity is computed with:

$$\frac{dN}{d\eta}(Z_m,i) = \frac{dN}{d\eta}(SPD,i).\frac{\alpha_\eta(Z_r,i).A_{VZERO}(Z_m,i)}{\alpha_\eta(Z_m,i).A_{VZERO}(Z_r,i)}$$

- $A_{VZERO}(Z_{r/m},i)$:
  - Signal amplitude for a given ring at a given vertex
- α_η are extracted from MC
  - HIJING + GEANT3 simulations with satellite vertices
  - Ratio between signal amplitude and the number of primary charged-particle generated at the collision
  - This ratio is given for each ring and each vertex
- Method features
  - Detector response, secondaries contribution are cancelled out in the ratio
  - Weakly MC dependent
  - Relative measurement

Analysis technique: FMD

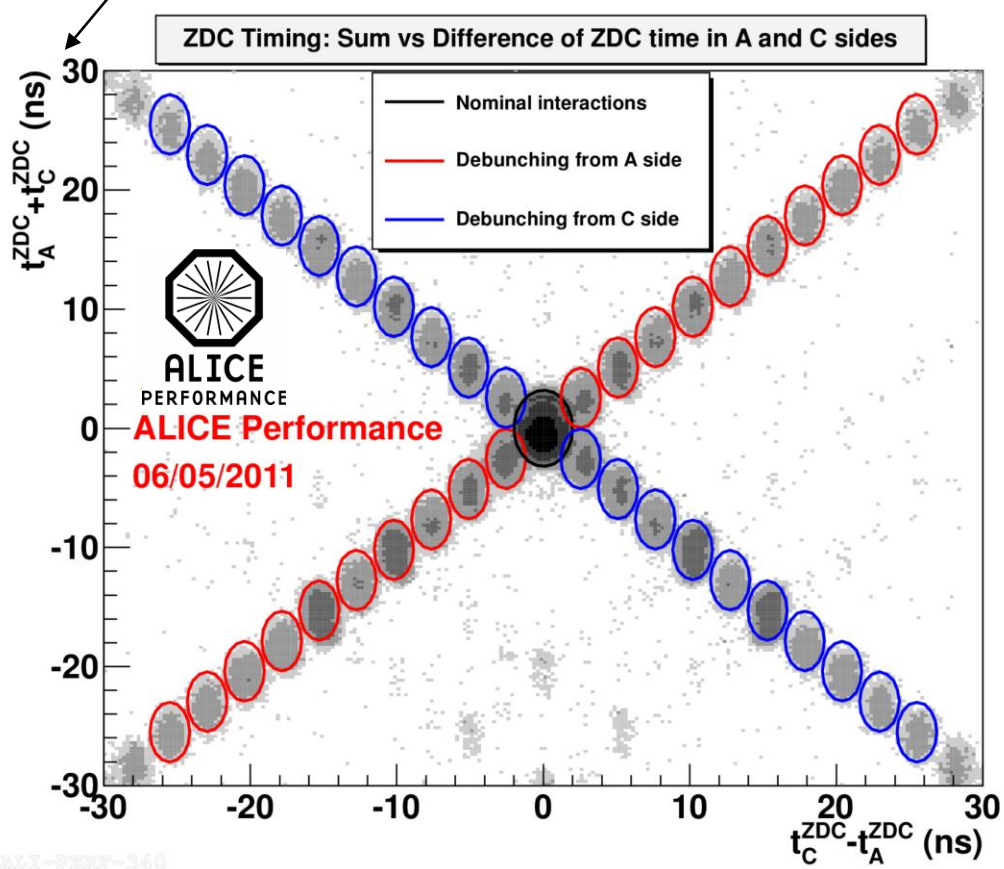
- FMD measurement was also performed with displaced vertex technique
- Method features
  - Absolute measurement
  - Symmetrical coverage: symmetry check
  - Corrections from secondaries are MC dependent
- MC:
  - HIJING + GEANT3 simulation with satellite vertices
- Low material density between 112.5 cm & 375 cm
  - Lower secondary particle contribution to the signal
  - Smaller syst. uncertainties



Analysis technique: Event selection

- Satellite collisions every 2.5 ns
- ZDC time resolution allows to separate 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)

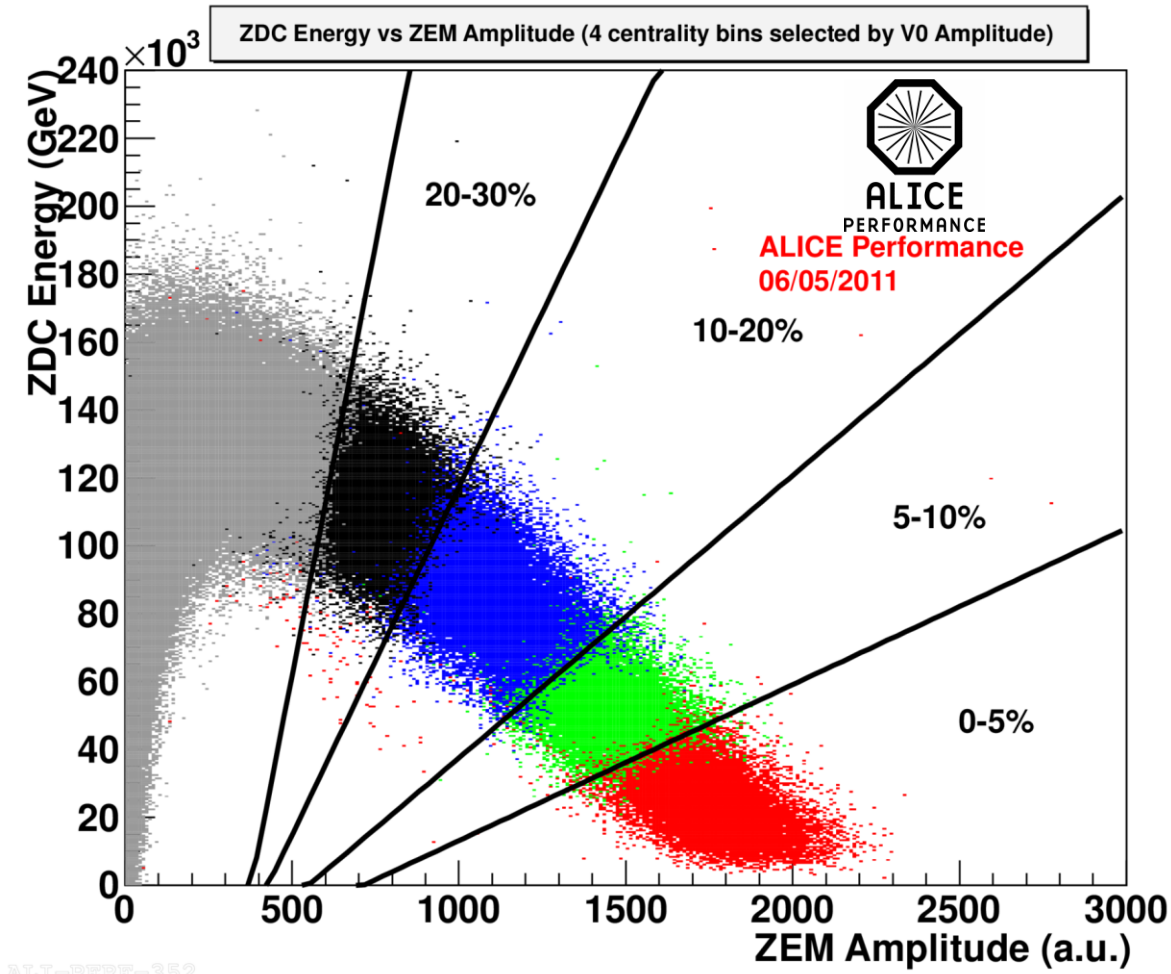
Collision time



IP position along the Z axis

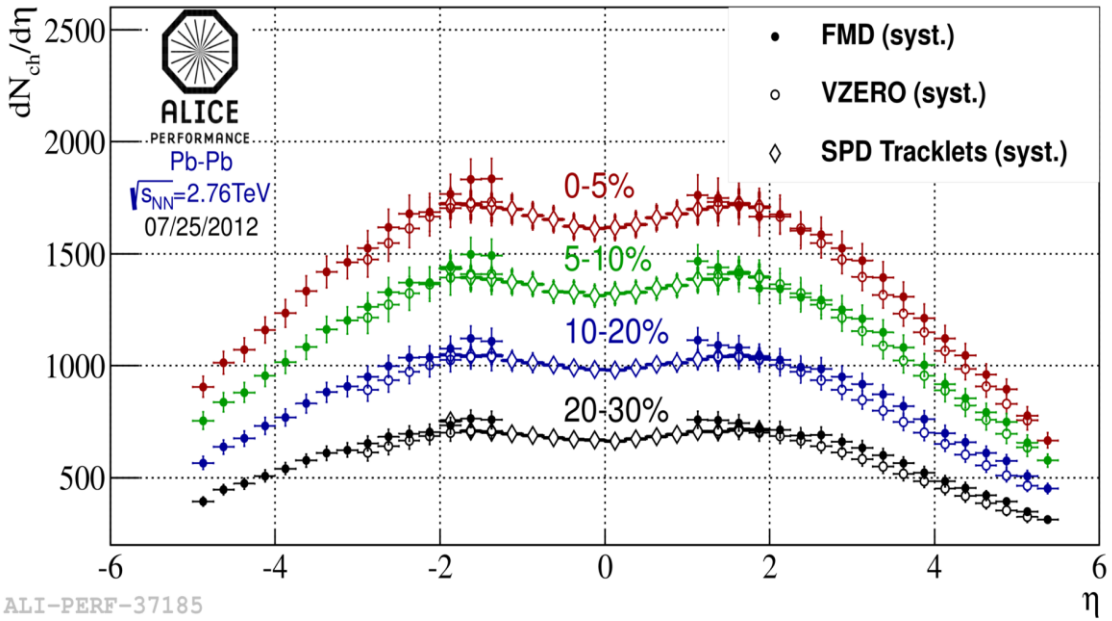
Analysis technique: Centrality selection

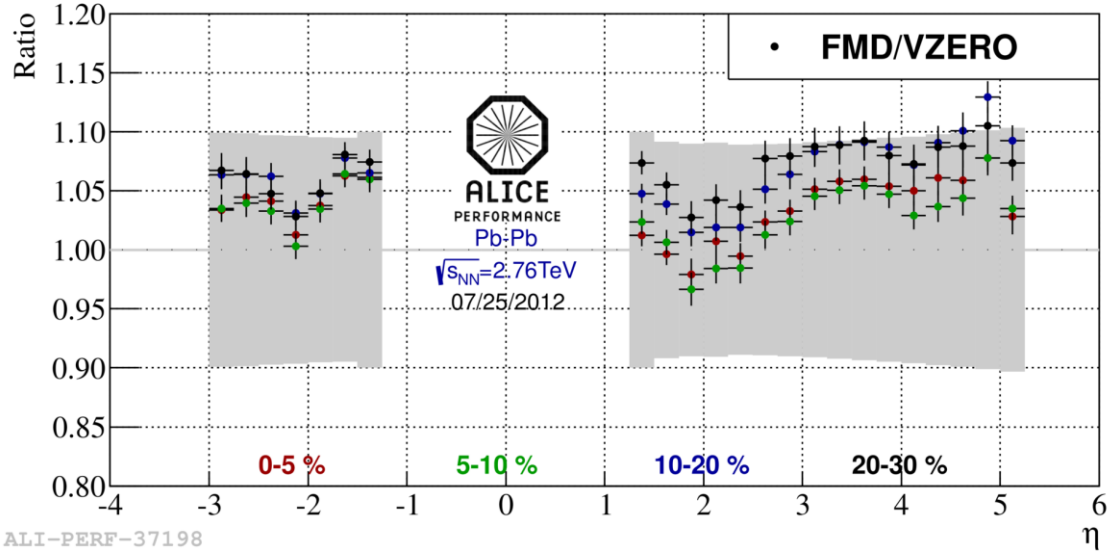
- ZDC energy ~ < N_{spect} >
- ZEM amplitude ~ < N_{part} >
- Estimator calibrated on VZERO at nominal IP
  - ZDC response weakly dependent on the vertex position (far from the IP) with respect to VZERO
  - This estimator works only for the most central events (0-30%) due to nuclear fragment production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



Results: FMD and VZERO comparison

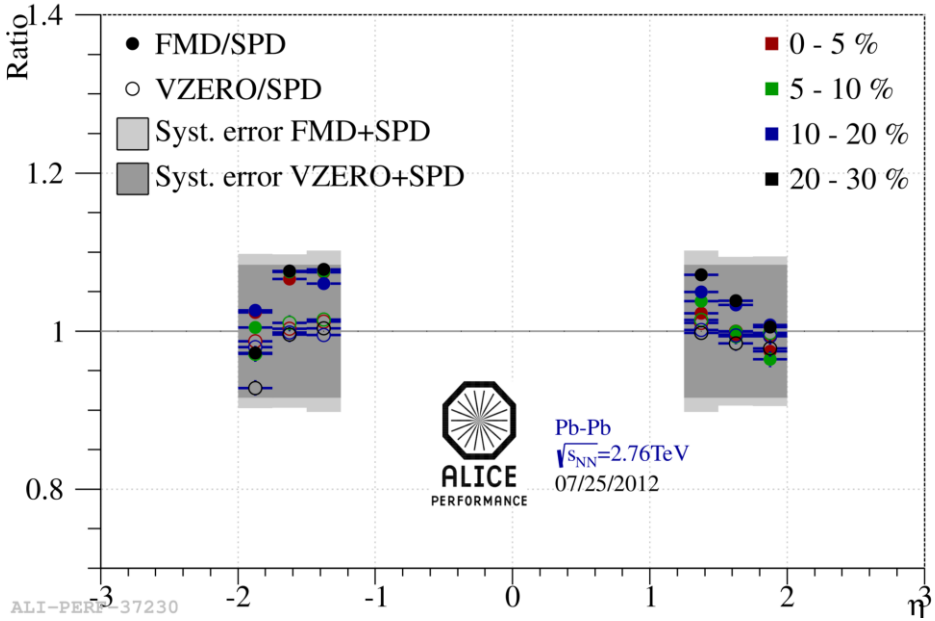
- Comparison between SPD, FMD and VZERO:
  - SPD: $-2 < \eta < 2$
  - FMD: $-5 < \eta < 5.5$
  - VZERO: $-3 < \eta < 5.25$
- Good agreement between FMD and VZERO

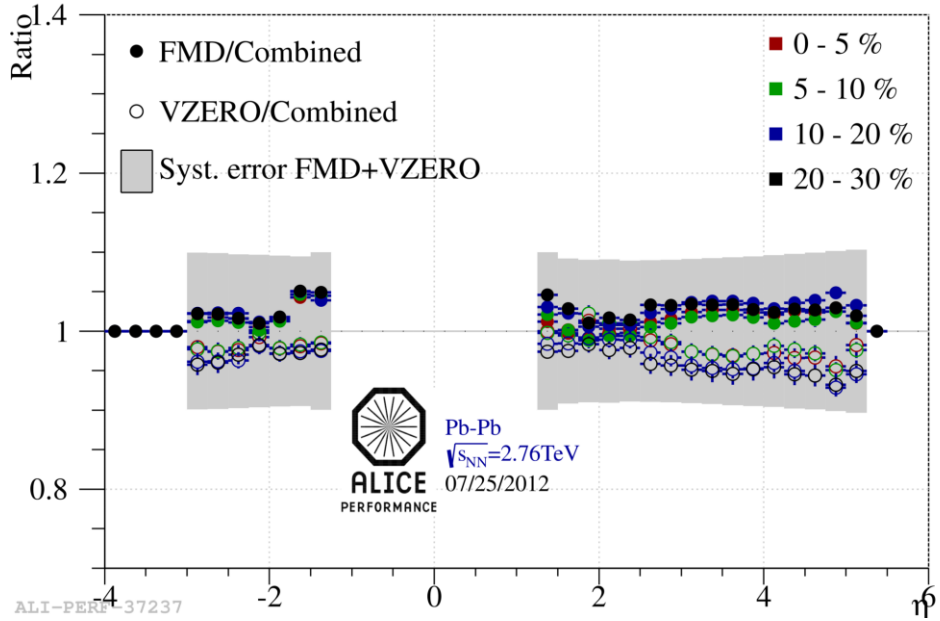




Results: Combining results

- Both FMD & VZERO are consistent with SPD in the overlapping region
- Results are combined:
  - Mean weighted by each detectors syst. errors
  - Common sources of syst. errors are then summed in quadrature
- The ratio shows a stronger contribution from FMD to the mean due to its smaller error

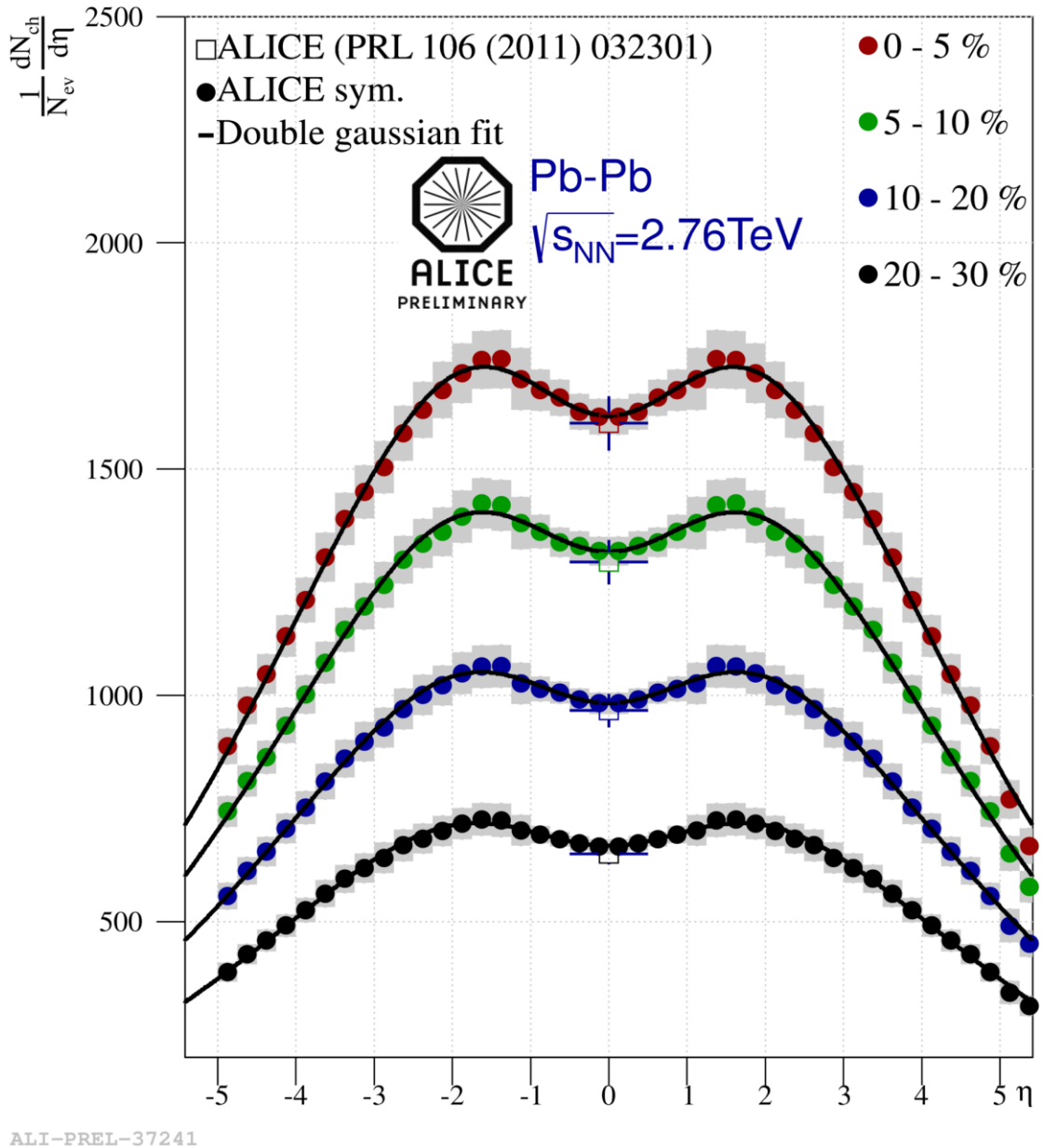




Results: Combined results

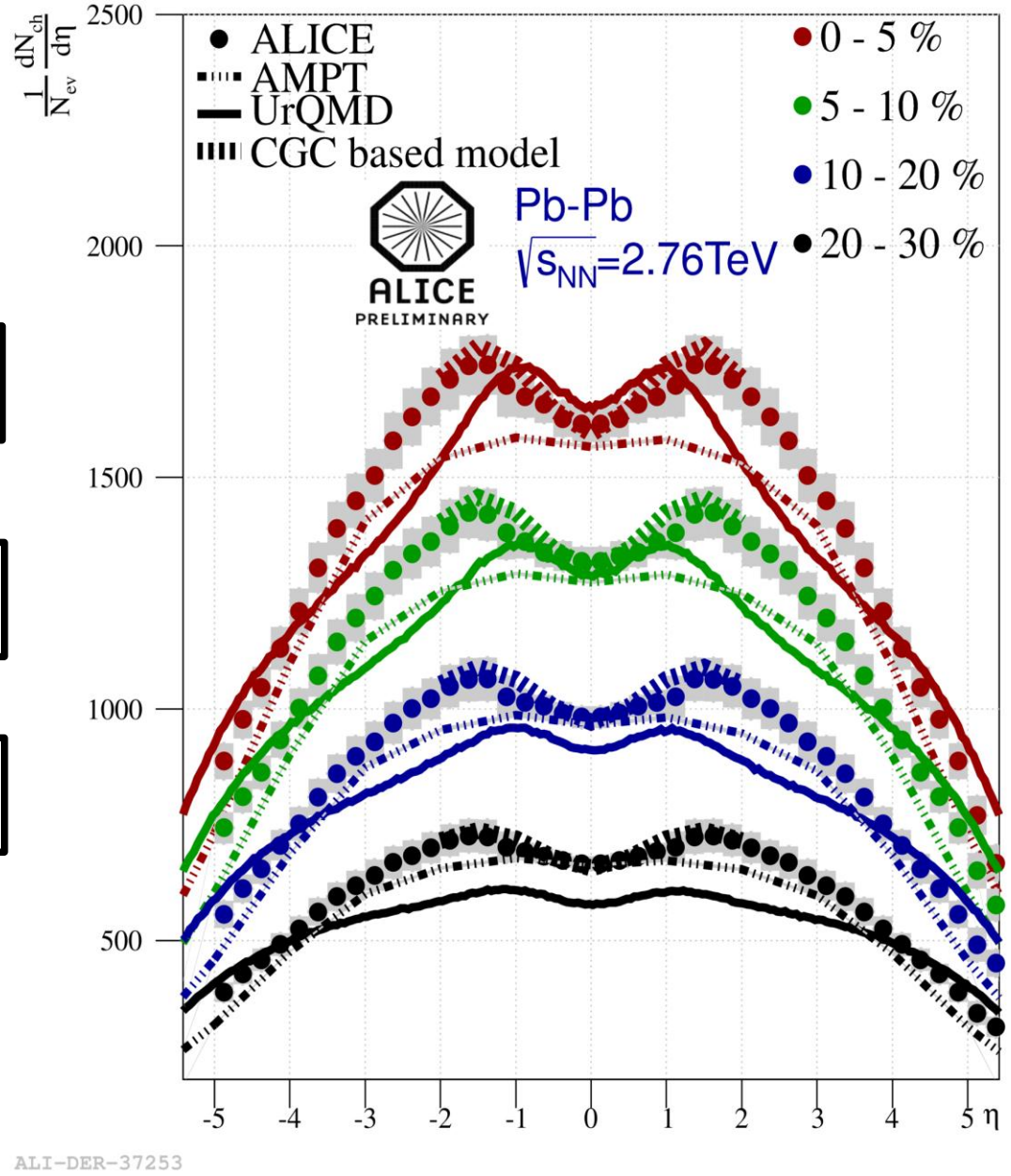
- The ALICE combined distribution is given in 4 centrality bins
  - Stat. error smaller than marker size
  - Syst. error: 2-6%
- Each distribution is symmetrized
- A double gaussian function fits well the data:

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



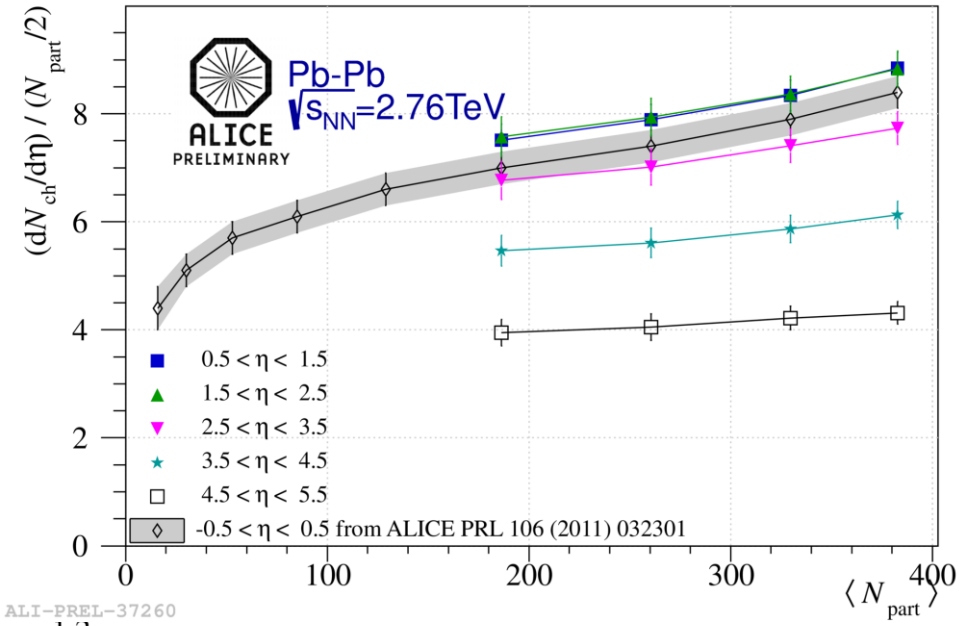
Results: Comparison with models

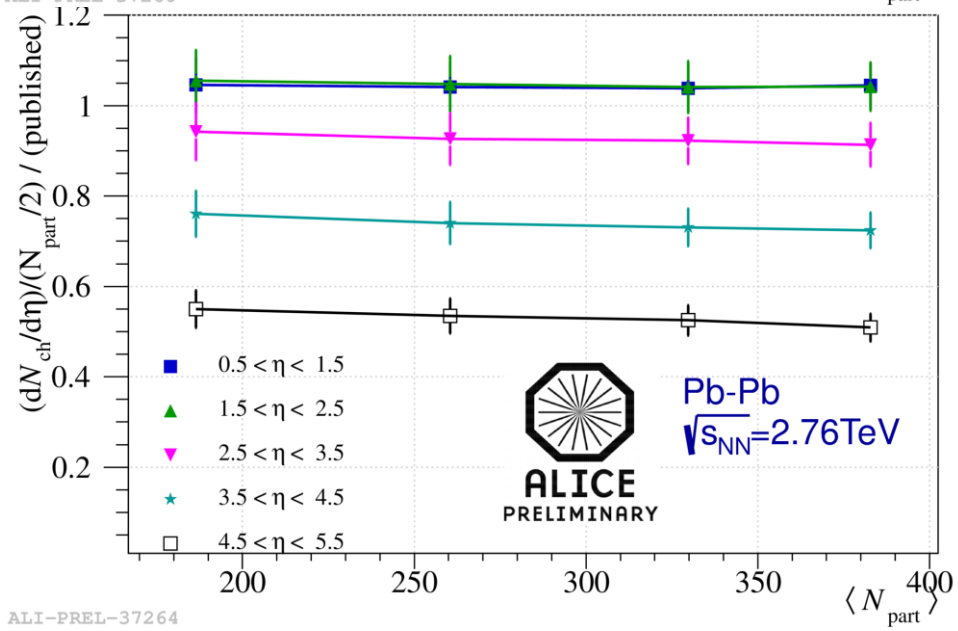
- Three models are compared with ALICE results
  - Color Glass Condensate (CGC) based model
    - **J. L. Albacete, A. Dumitru, Y.Nara arXiv:1106.0978v1 (2010)**
  - UrQMD model
    - **M. Mitrovski, T. Schuster, G. Graf, H. Petersen, M. Bleicher, Phys.Rev. C 79, 044901 (2009)**
  - AMPT
    - **Jun Xu, Che Ming Ko, Phys.Rev. C 83, 034904 (2011)**
- CGC: reproduces the shape & the amplitude, but for a restricted η range
- UrQMD/AMPT: fails to reproduce the overall amplitude and shape of the pseudo-rapidity density



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

- The d*N*/dη scaling as a function of $\langle N_{part} \rangle$ is given in 5 pseudo-rapidity bins:
  - Complementary results to those published
  - The primary charged particle density normalized by the number of participant pairs increases for the most central events
- The trend in each pseudo-rapidity bin is the same:
  - These results are compared to the ALICE published* results in the central region
  - The ratio is flat for all centrality bins

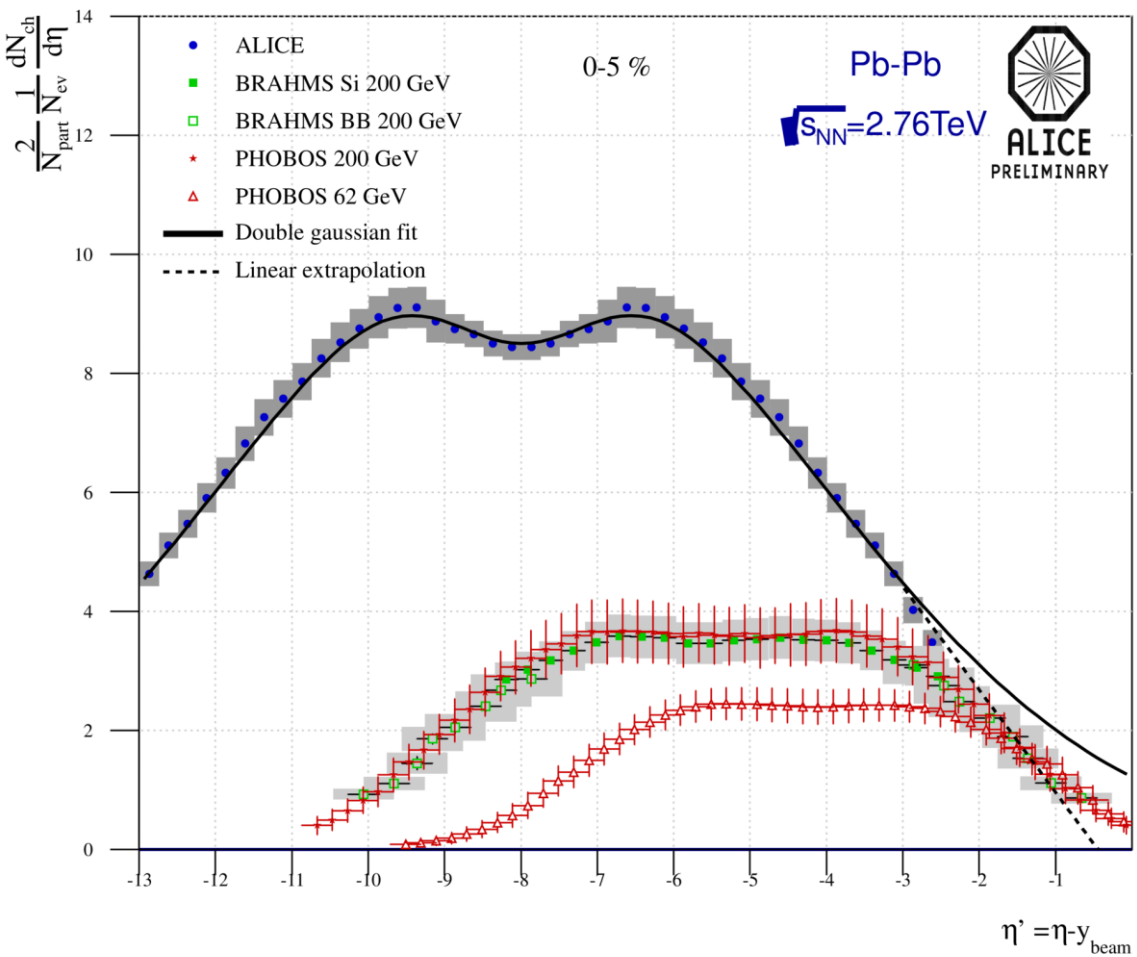




*: *ALICE Collaboration, Phys. Rev. Lett. 106 (2011) 032301*

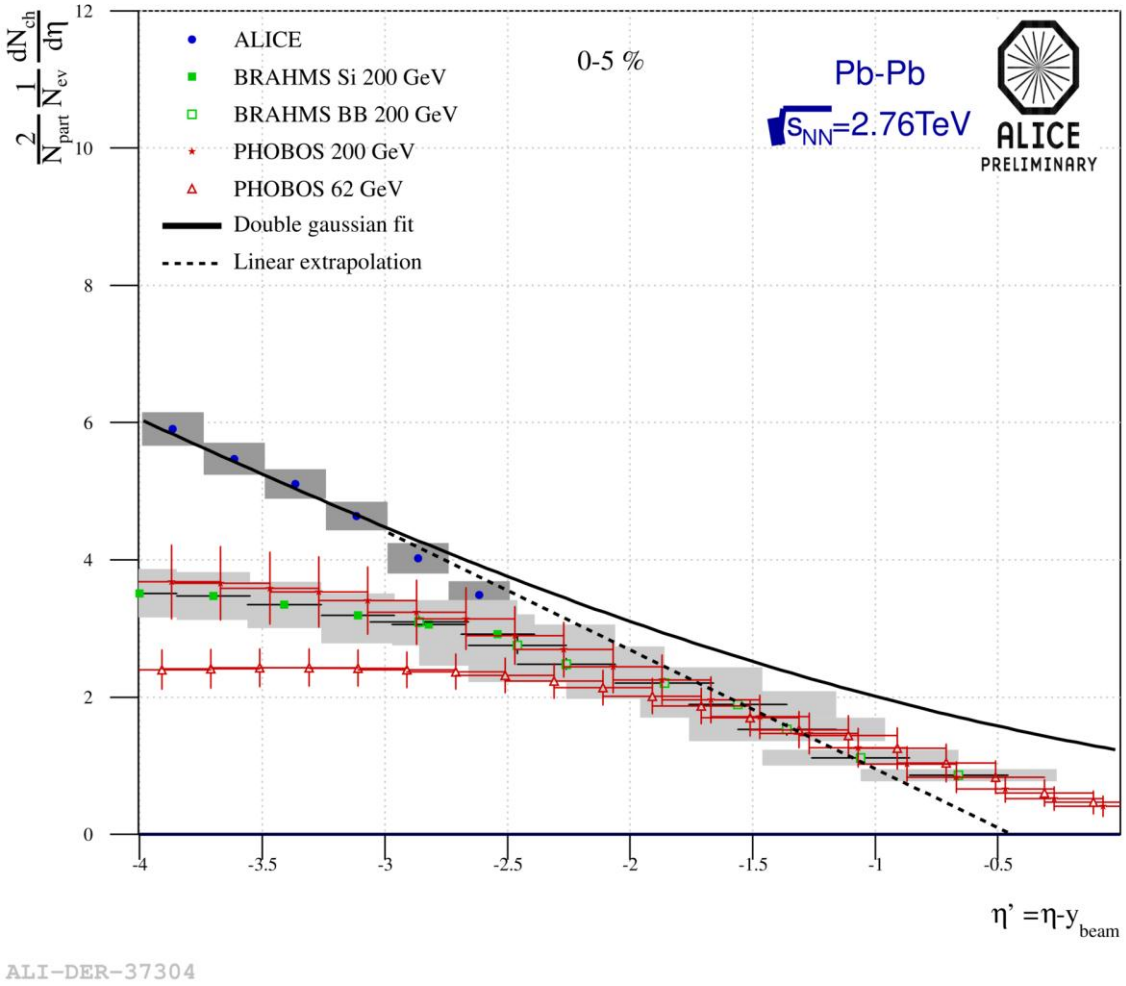
Results: Longitudinal scaling

- The longitudinal scaling is given for the most central bin:
  - dN/dη distribution is normalized by the number of participant pairs & shifted by the beam rapidity
  - Results are compared to BRAHMS & PHOBOS Au-Au data at 62 and 200 GeV at RHIC
  - Tail not expected to be gaussian and the very high rapidity region is extrapolated with a linear function



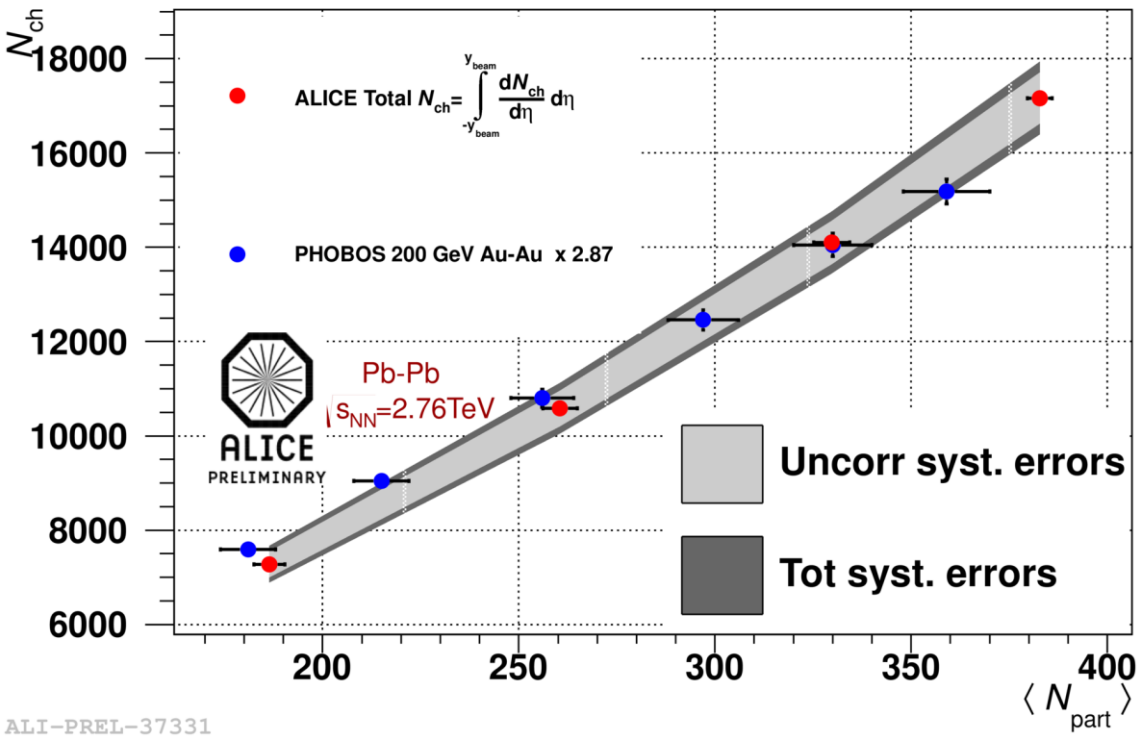
Results: Longitudinal scaling

- The linear extrapolation shows that ALICE, BRAHMS and PHOBOS data are consistent
- Scaling validity is confirmed within the errors at LHC
- Also seen for v_2 longitudinal scaling:
  - See Alexander Hansen's talk (**#417**) on Friday:
    - Pseudo-rapidity dependence of the anisotropic flow with ALICE at LHC



Results: Total number of charged particles N_{ch}

- N_{ch} is estimated with the 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 included the uncertainty on the extrapolation: 2-3 %
- The total number of charged particles increases with the number of participants:
  - Fraction of extrapolation: 13%



- Comparison with PHOBOS data:
  - PHOBOS data scaled by a factor 2.87

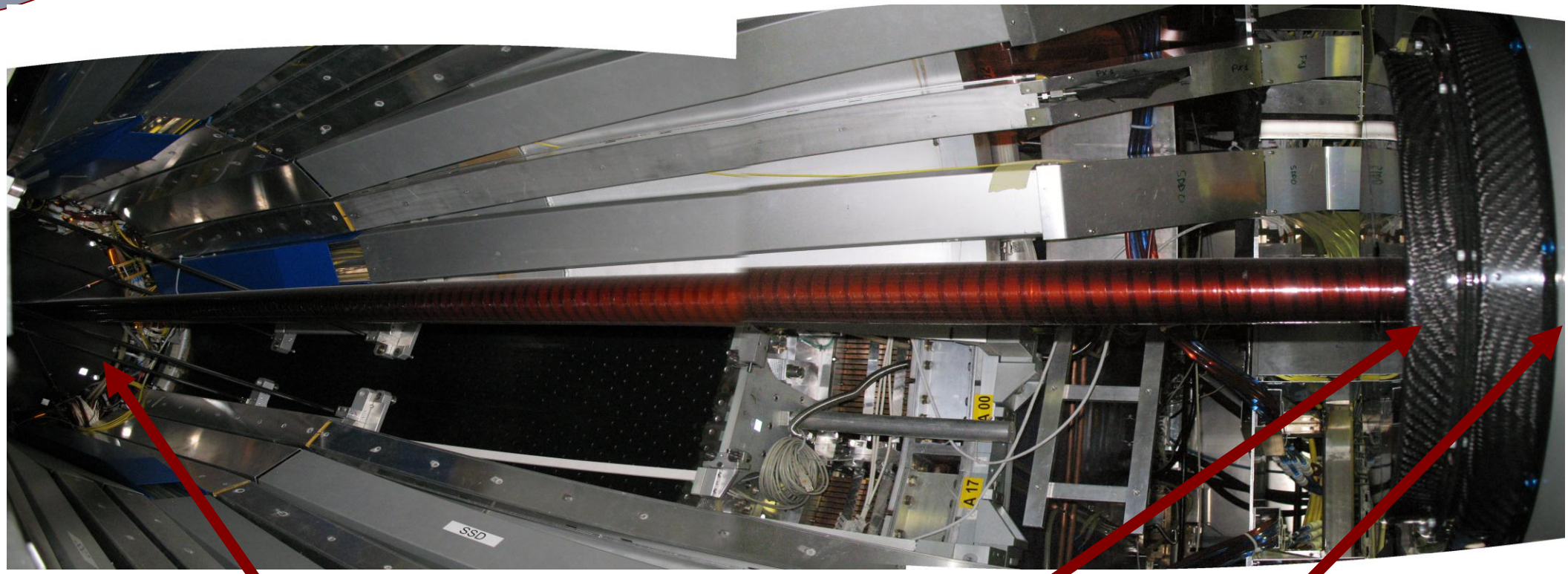
$$\frac{\langle \frac{N_{ch}}{N_{part}} \rangle_{LHC}}{\langle \frac{N_{ch}}{N_{part}} \rangle_{RHIC}} = 2.87$$

Conclusion

- The charged particle multiplicity was shown in 10 pseudo-rapidity units and 4 centrality bins (0-30%)
- The dN/dη distribution scaled by the number of participant pairs increases as a function of N_{part} with a similar trend in all pseudo-rapidity bins
- The longitudinal scaling shows that ALICE results are consistent with PHOBOS and BRAHMS ones over a large range of energies and confirm the scaling validity
- ALICE and PHOBOS (scaled) N_{ch} are consistent within errors even if the trend of ALICE data looks a bit different

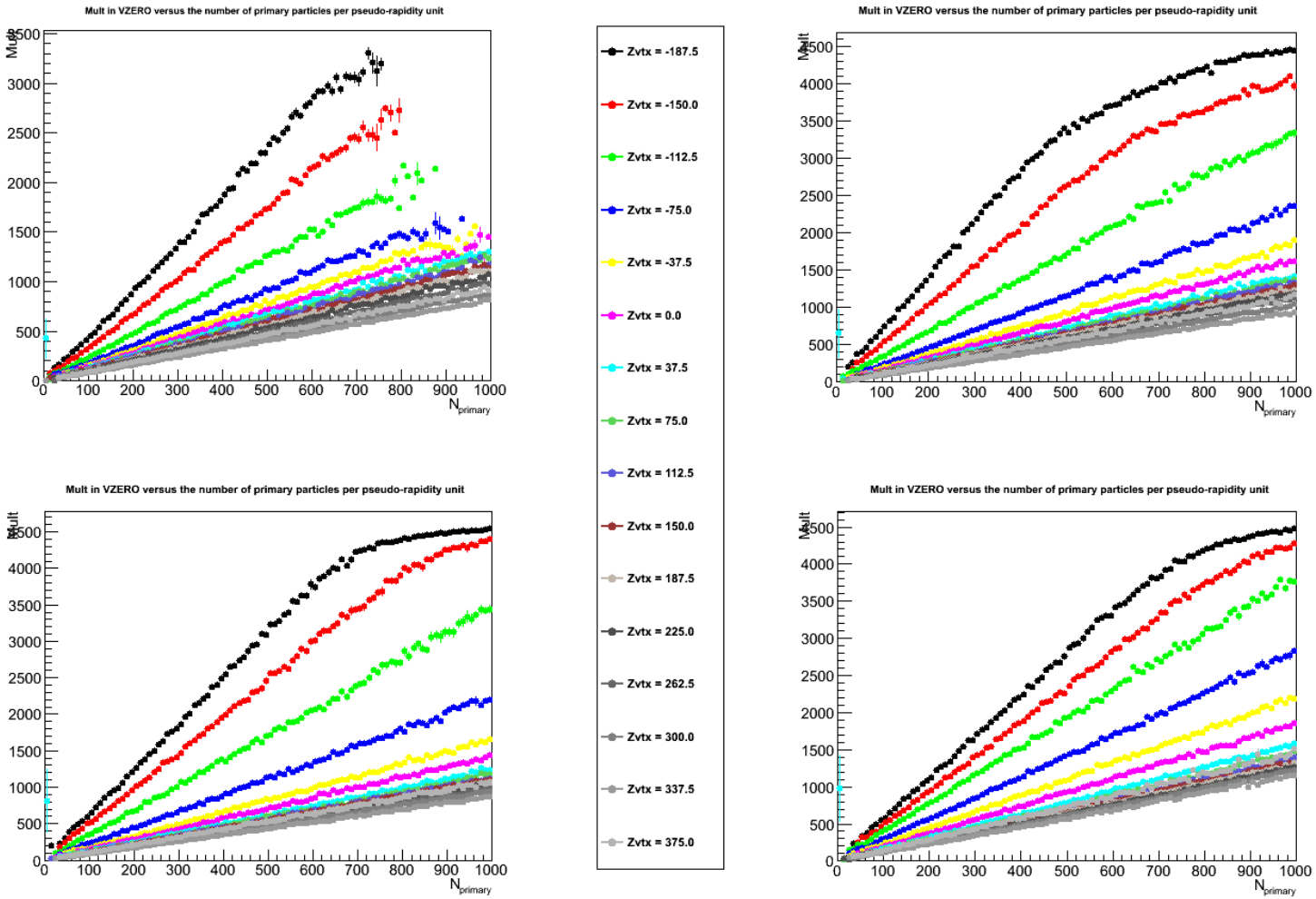
Back up

Analysis technique: Simple Material Budget



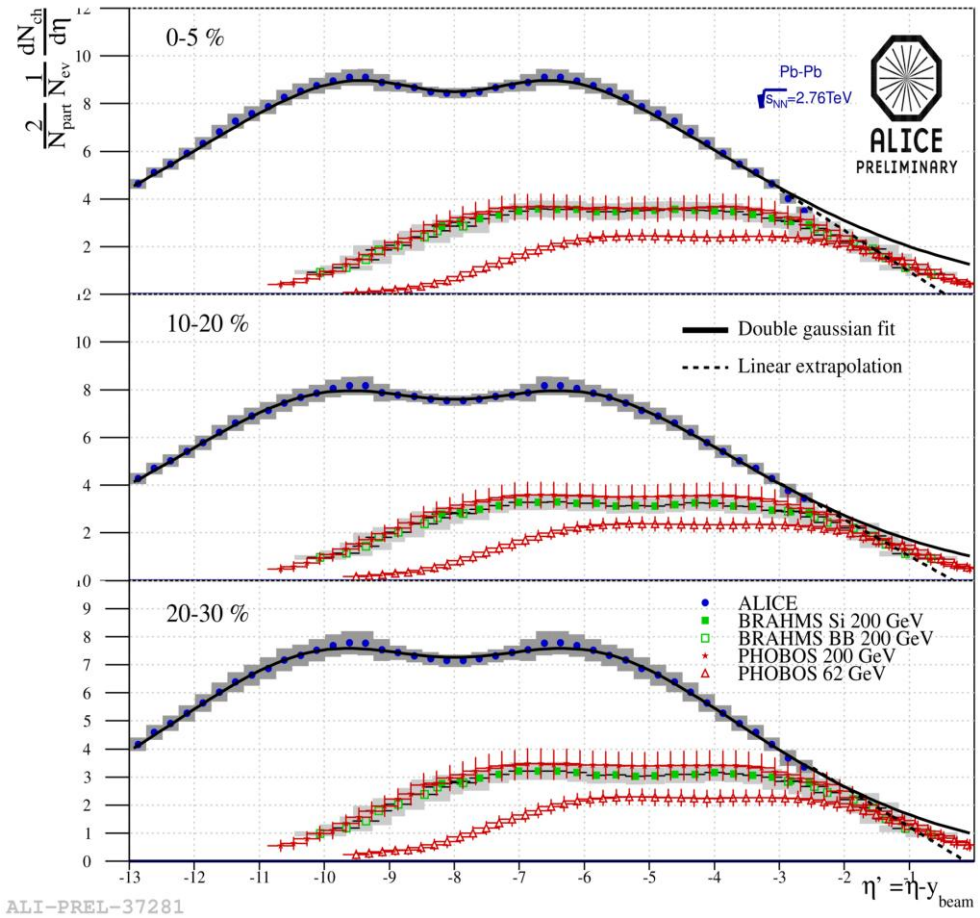
FMD2 FMD1 VZERO-A

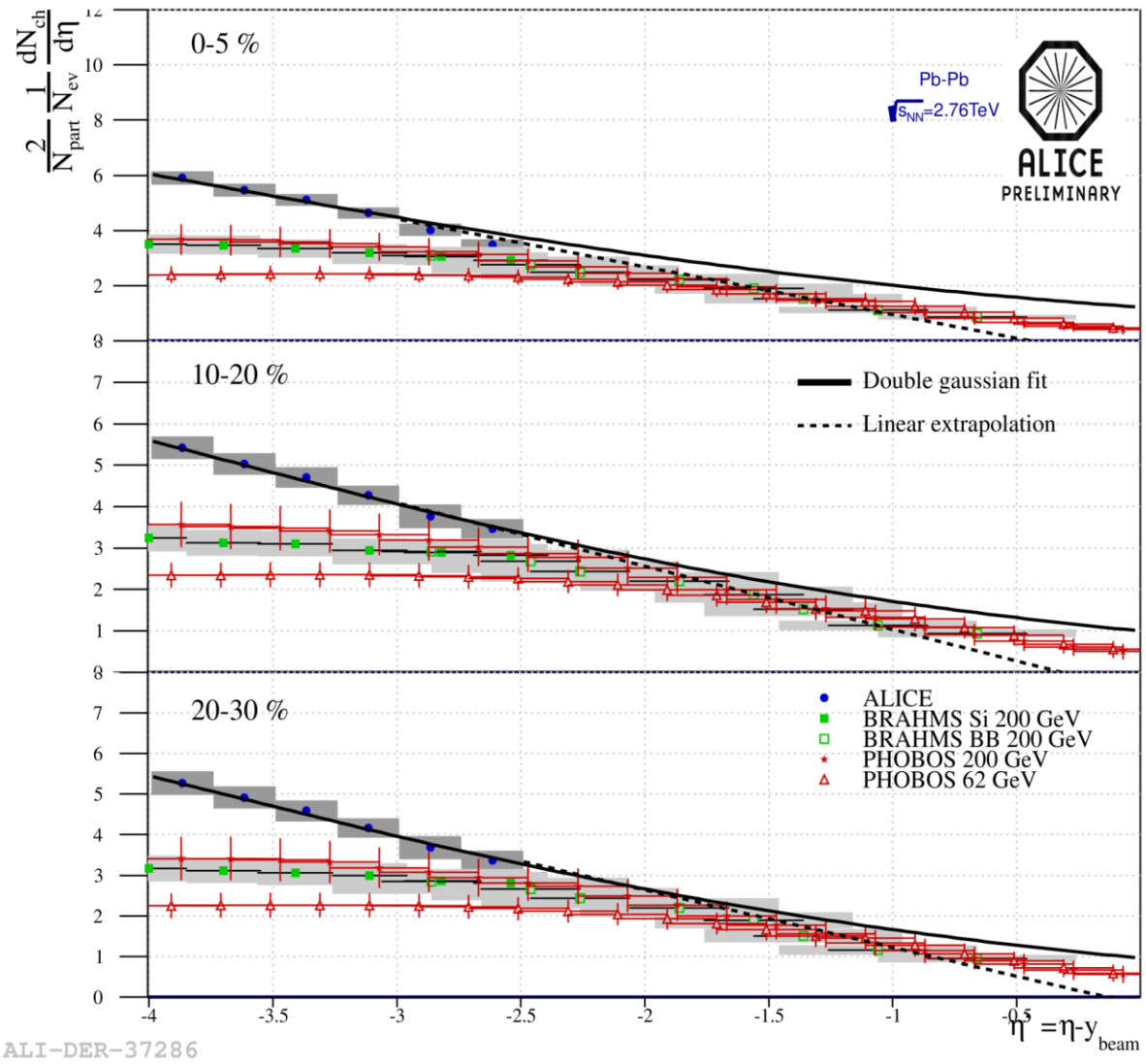
Analysis technique: VZERO, α extraction from MC



- These plots are fitted with a linear function for each rings and several vertices
- The resulting slopes give α_η values

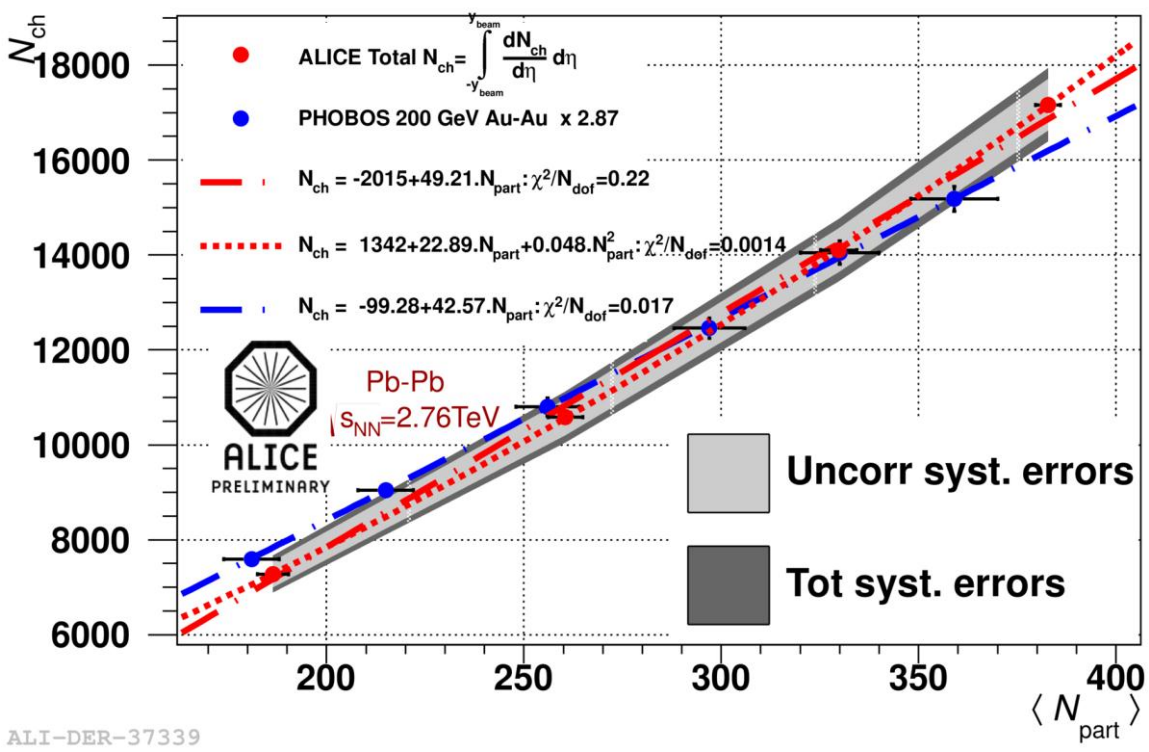
Results: Longitudinal scaling in several centrality bins



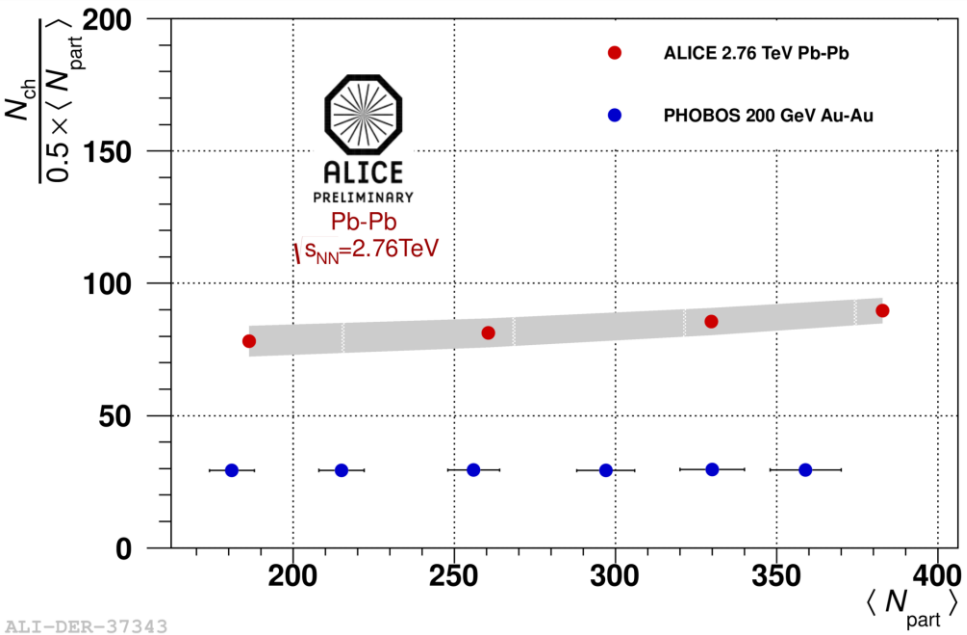


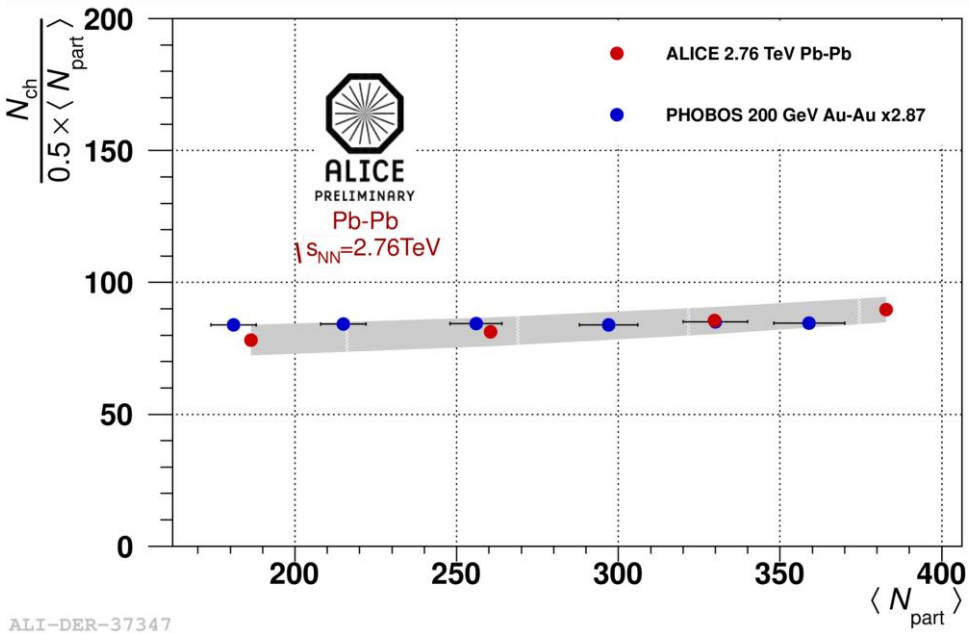
Results: Total number of charged particles N_{ch}

- N_{ch} is fitted with a linear and a 2nd order polynomial function
  - The χ^2 is better for the 2nd order polynomial function for ALICE data
  - PHOBOS are well fitted by a linear function



Results: Total number of charged particles N_{ch}





- The PHOBOS scaling factor is extracted from this plot:

$$\frac{\langle \frac{N_{ch}}{N_{part}} \rangle_{LHC}}{\langle \frac{N_{ch}}{N_{part}} \rangle_{RHIC}} = 2.87$$

- The ALICE and PHOBOS measurements are consistent within errors
- The trend between both measurements looks a bit different