First results of the ALICE experiment in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

Raphaelle Bailhache
on behalf of the ALICE collaboration

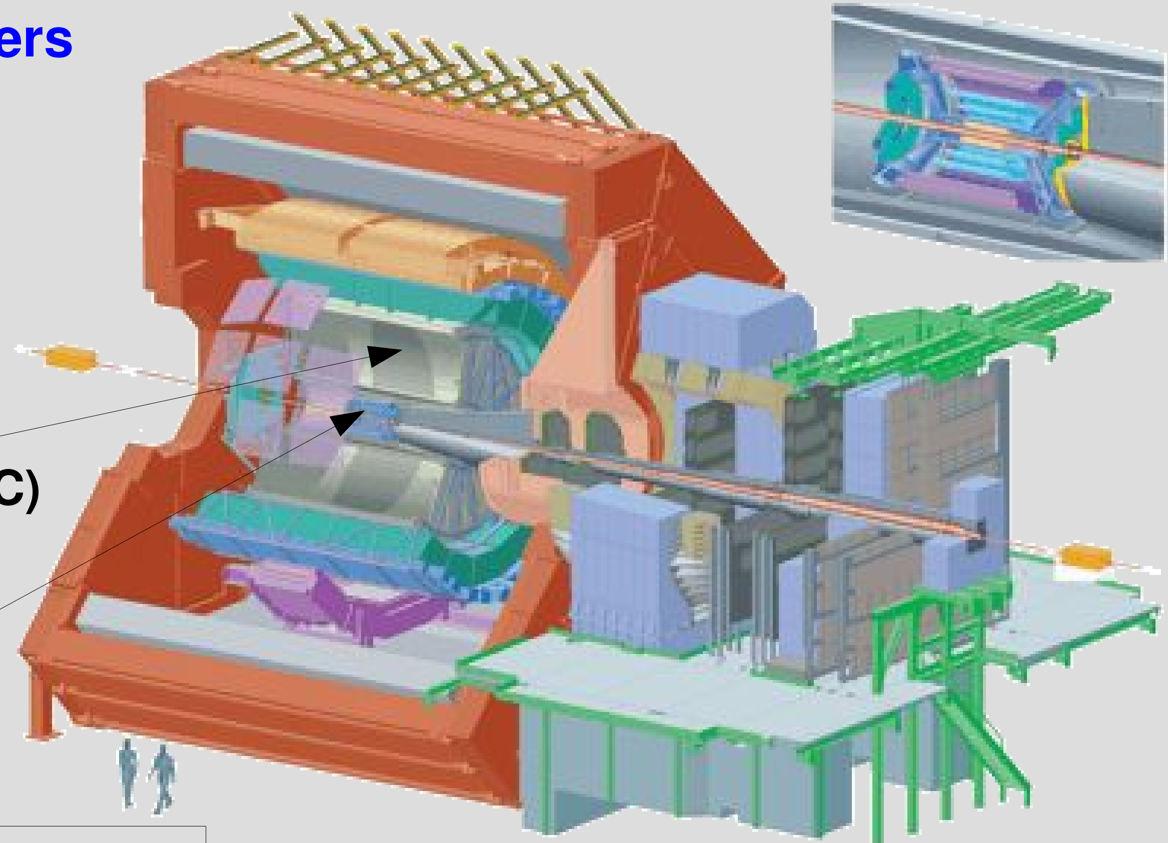
Outline

- The ALICE experiment
- First results in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
  - Charged-particle multiplicity density at mid-rapidity
    - dN/dη in most-central: PRL 105, 252301 (2010)
    - dN/dη vs. centrality: arXiv:1012.1657v1 [nucl-ex]
  - Bose-Einstein correlations
    - Two pion HBT: PL.B 696:328-337,2011
  - Elliptic flow:
    - v_2 vs. centrality and p_T: PRL105,252302 (2010)
  - High p_T charged-particle suppression:
    - R_{AA} nuclear modification factor: PL B 696 (2011) 30-39
- Summary and Outlook

ALICE Experiment

Trigger detectors:

•**VZERO scintillator counters**
(z = 3.3 m and z = - 0.9 m)
•**2 pixel layers (ITS)**
(r = 3.9 cm and r = 7.6 cm)



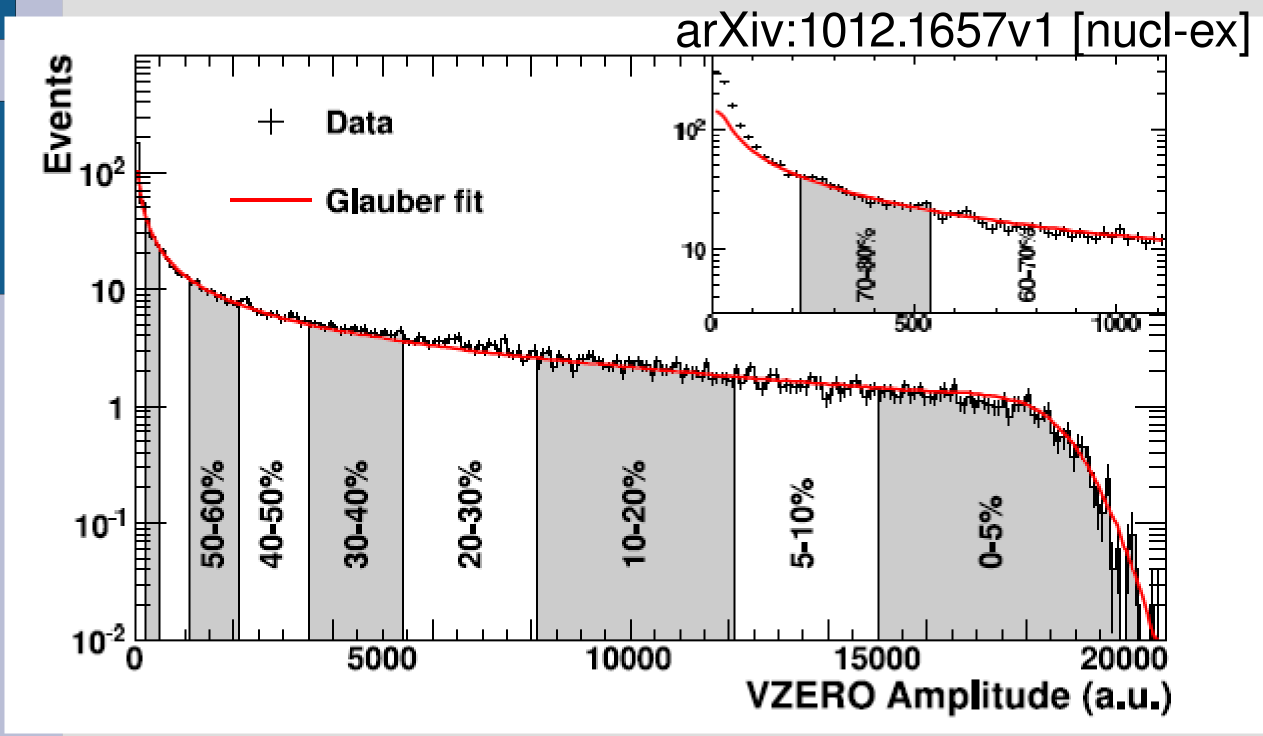
Time Projection Chamber (TPC)

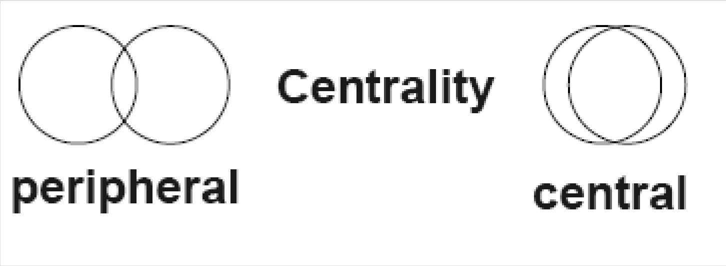
Inner Tracking System (ITS)

Central Barrel |η| < 0.9

ALICE Experiment

Centrality selection





- Summed amplitudes in VZERO scintillator tiles
- Uncorrected charged multiplicity in $|\eta| < 0.8$ (TPC)
- Zero Degree Calorimeters (Energy of spectator nucleons)

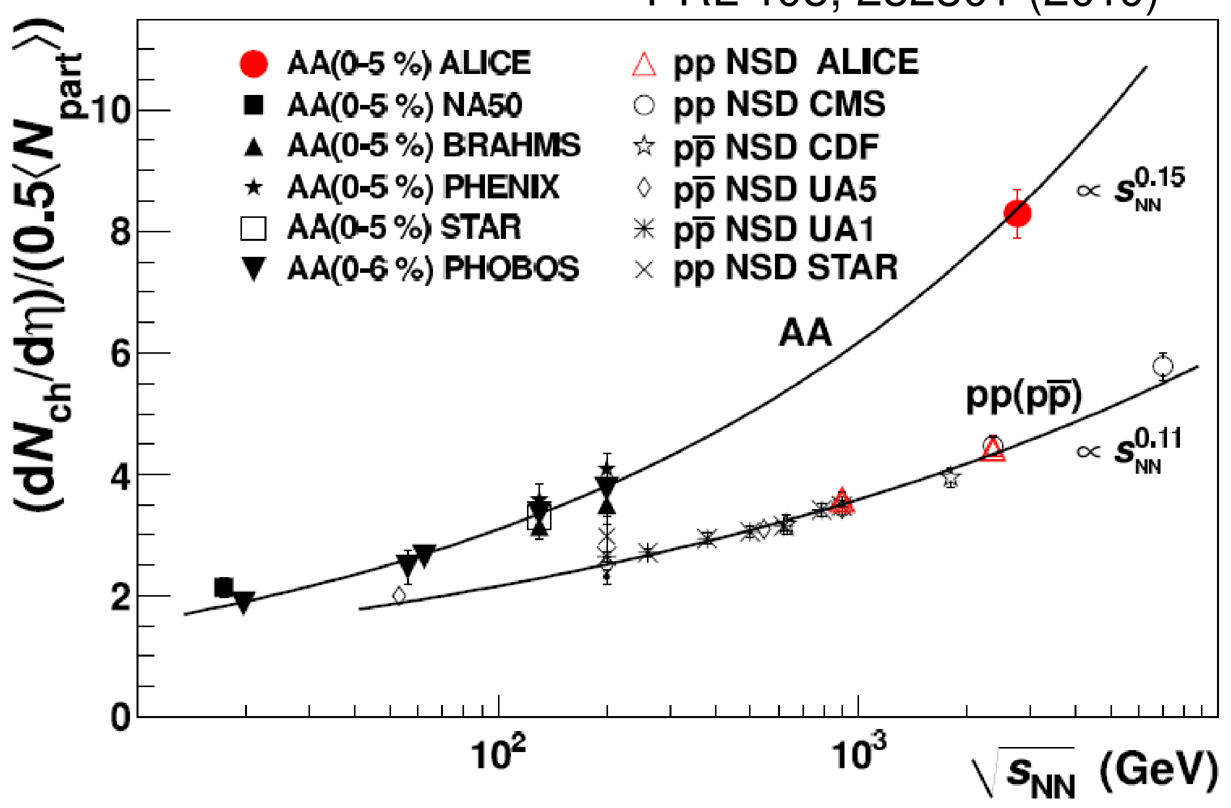
From Glauber model fit extract from VZERO:

- N_{part} number of participating nucleons
- N_{col} number of binary NN collisions

Charged-particle multiplicity density at mid-rapidity

Charged-particle multiplicity vs collision energy

PRL 105, 252301 (2010)



$2/N_{part}\,(dN_{ch}/d\eta)$ = 8.3 ±0.4 (sys.)

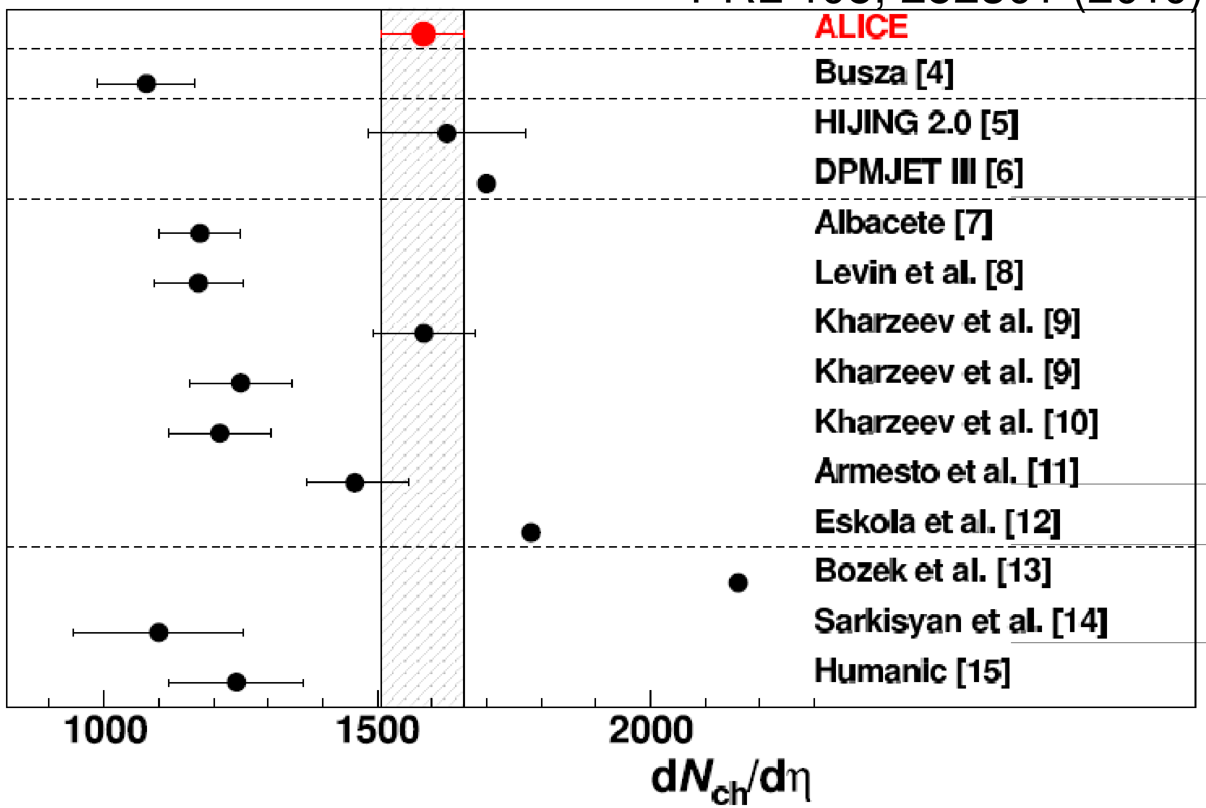
- x 2.2 increase from Au-Au at $\sqrt{s_{NN}}$=0.2 TeV
- x 1.9 increase from pp at similar energies

- Constrain the dominant particle production mechanisms
- Estimate the initial energy density
- Reflect interplay between parton-parton scattering and soft processes

LHC multiplicity density vs models tuned for RHIC/SPS

$dN_{ch}/d\eta$=1584 ±4 (stat.)±76 (sys.) , 0-5%

PRL 105, 252301 (2010)



Empirical extrapolation

pQCD-inspired MC

Models with initial-state gluon density saturation

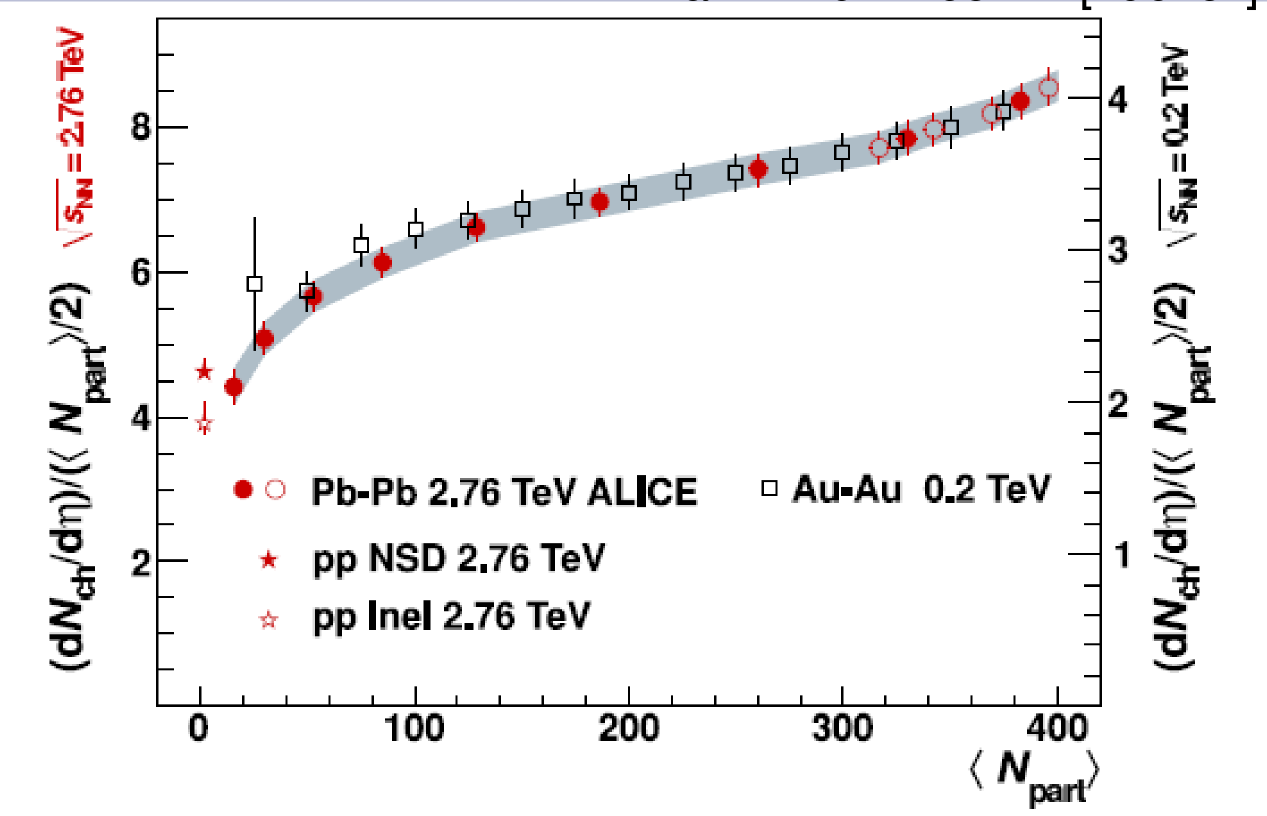
Hydro + final-state saturation

Models incorporating hydro

PYTHIA + hadronic rescattering

Charged-particle multiplicity vs centrality comparison with lower energy data

arXiv:1012.1657v1 [nucl-ex]



$2/N_{part}\,(dN_{ch}/d\eta)$

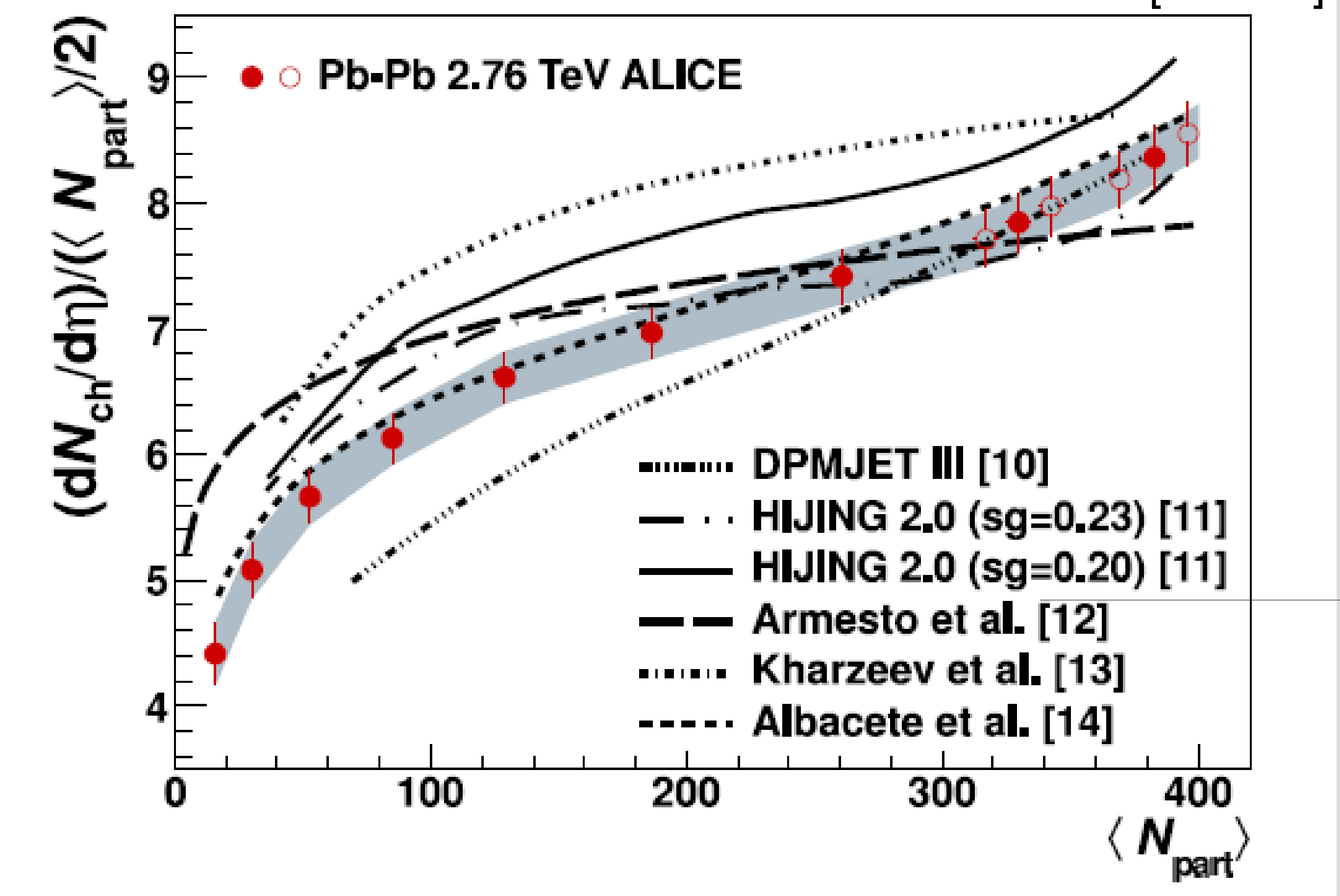
- Increase from 4.4±0.4 to 8.4±0.3 from peripheral to central

- Au-Au RHIC data scaled down by a factor 2.2
-> **centrality dependence very similar to RHIC**

- Error bars: point-to-point uncorrelated uncertainties
- Grey band: correlated uncertainties

Charged-particle multiplicity vs centrality
comparison with models

arXiv:1012.1657v1 [nucl-ex]



Challenge for theoretical models

pQCD (jets + mini-jets) + soft interactions

Models with initial state gluon saturation

Bose-Einstein correlations

Two pion Hanbury Brown-Twiss (HBT) analysis

HBT correlations

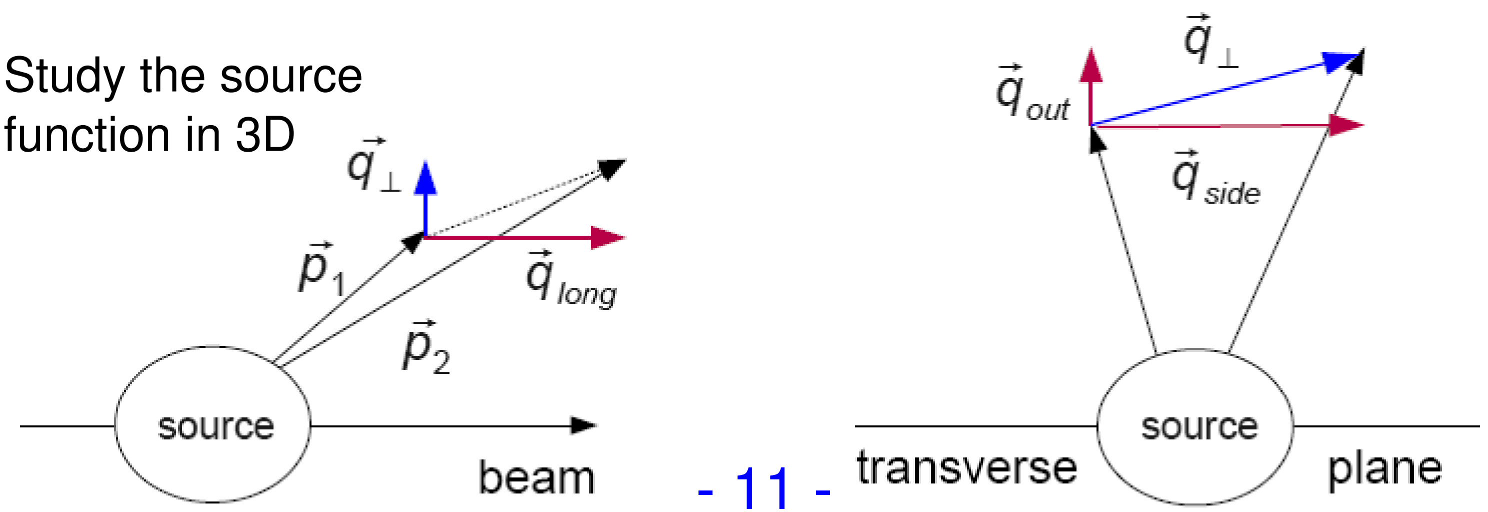
Momentum-space two particle correlations of identical bosons

$$C(q) = \frac{A(q)}{B(q)}$$

- $A(q)$: distribution of the difference $q = p_2 - p_1$ of the three-momenta
- $B(q)$: same function but for particles from two different events

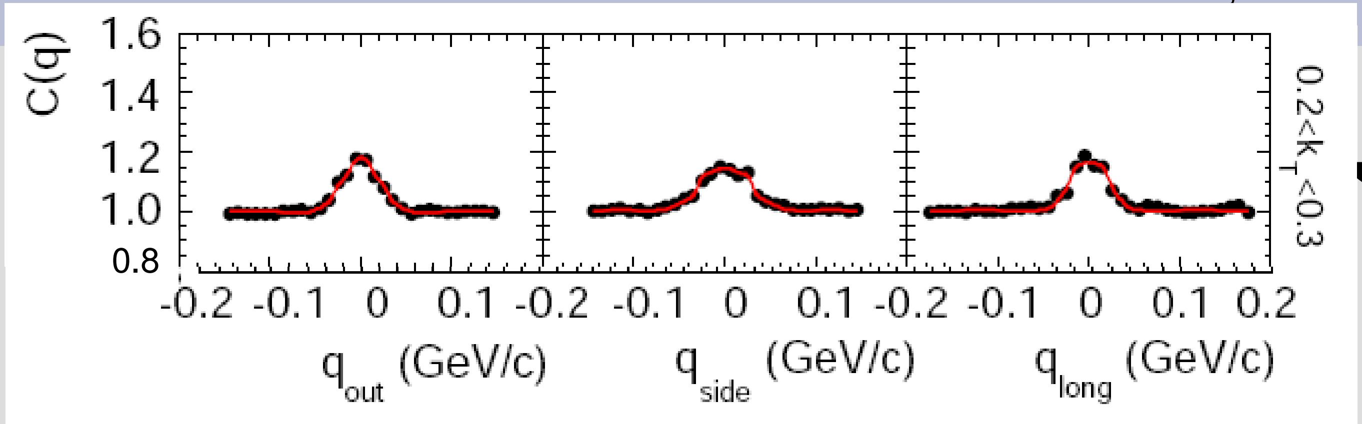
Correlation width in momentum space inversely proportional to the homogeneity volume

Study the source function in 3D



3D fit of the like-sign two-pion correlation

PL.B 696:328-337,2011



as function of $k_T = |p_{T,1} + p_{T,2}|/2$.

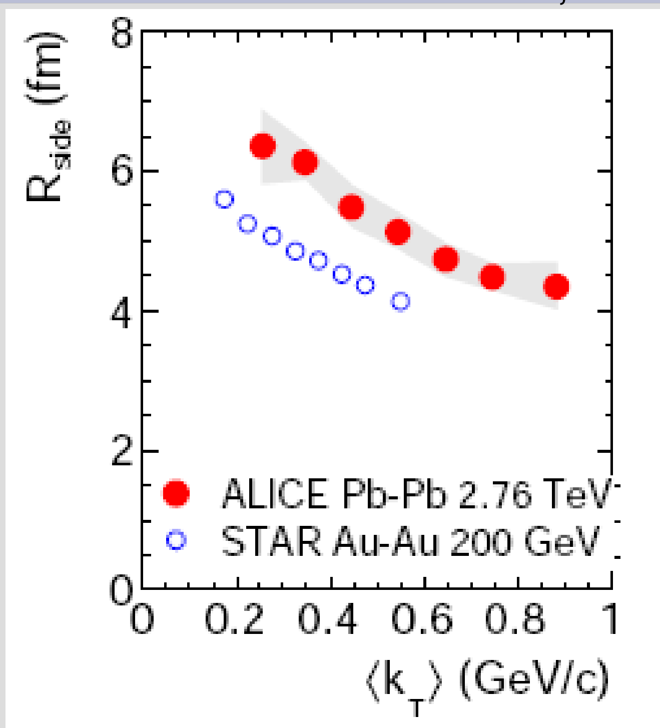
Fit parametrization: $C(\vec{q}) \sim 1 + \lambda K(q_{inv})[1 + G(\vec{q})]$

$$G(\vec{q}) = \exp\left(-(R^2_{out} q^2_{out} + R^2_{side} q^2_{side} + R^2_{long} q^2_{long})\right)$$ Bose-Einstein enhancement

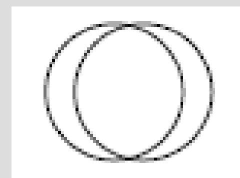
$K(q_{inv})$ Coulomb correction

Radii vs. transverse momentum

PL.B 696:328-337,2011



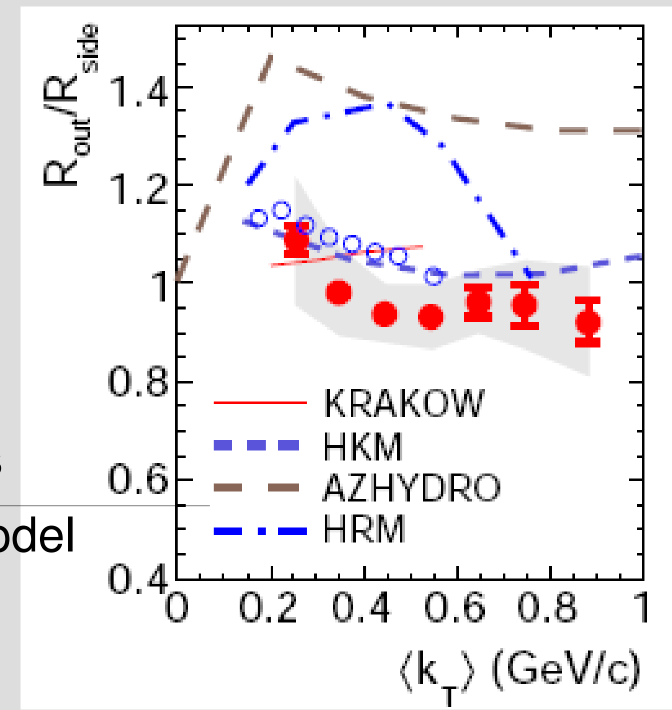
0-5% centrality



hydrodynamic approaches

hadronic-kinematics-based model

PL.B 696:328-337,2011



- Radii **10-35% larger** than at RHIC (roughly reproduced by calculations)
- Decrease as function of k_T-> **expanding particle sources**

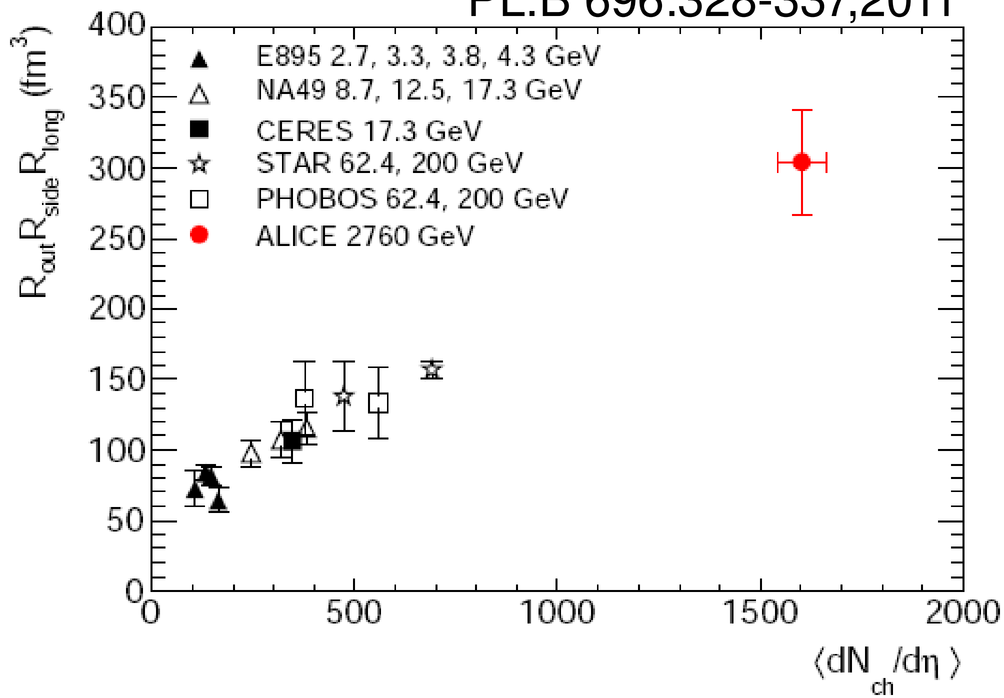
-> homogeneity length rather than overall size of particle-emitting system

- Experimental ratio R_{out}/R_{side} well described by two calculations only

Homogeneity volume and decoupling time vs. collision energy

Homogeneity volume

PL.B 696:328-337,2011



Decoupling time

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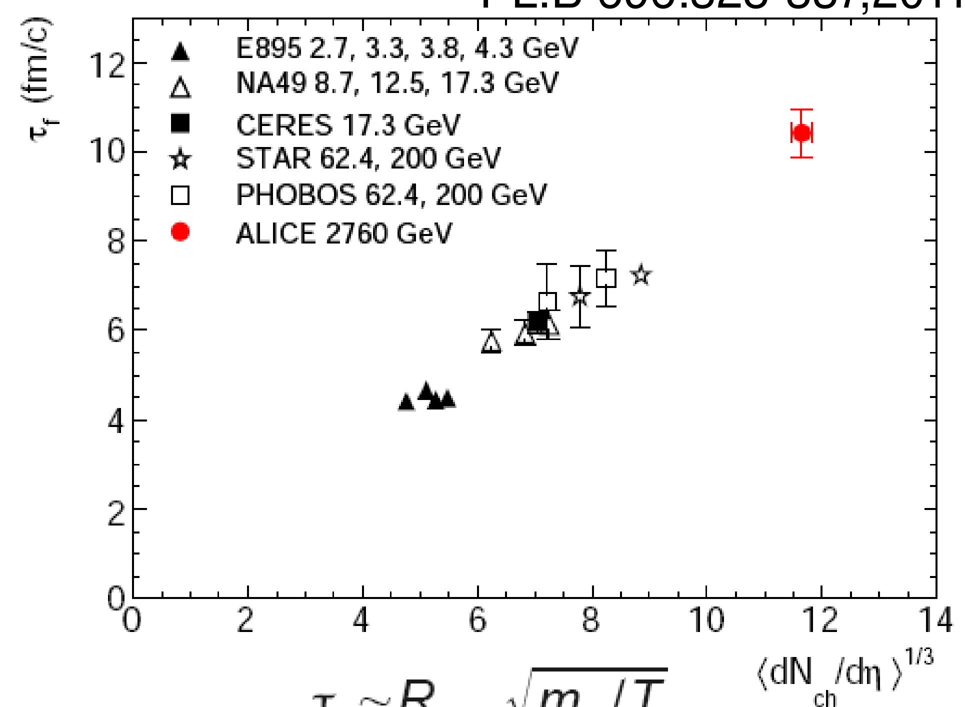


$$\tau_f \sim R_{long}\sqrt{m_T/T}$$

- Linear dependence on the charged-particle pseudorapidity density
- Twice as large at the LHC than at RHIC

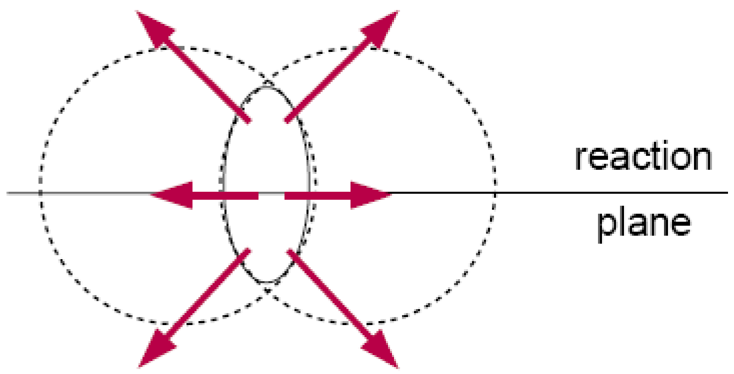
T, kinetic freeze-out temperature (0.12GeV)

30% longer emission time

Elliptic flow
v_2 vs centrality and p_T

Experimental determination of the transverse flow

Elliptic flow: $v_2 = \langle \cos(2[\phi - \Psi_{RP}]) \rangle$



- Almond shape of the overlap region
-> pressure gradient
- Evolves into momentum space via multiple collisions
->measured experimentally

- Probes/scans the medium
- Reveals particle collectivity

Fourier decomposition of particle azimuthal distribution wrt. the reaction plane

$$\frac{dN}{d\phi} \sim 1 + 2\sum_{n=1} v_n(p_T, \eta) \cos(n[\phi - \Psi_{RP}])$$

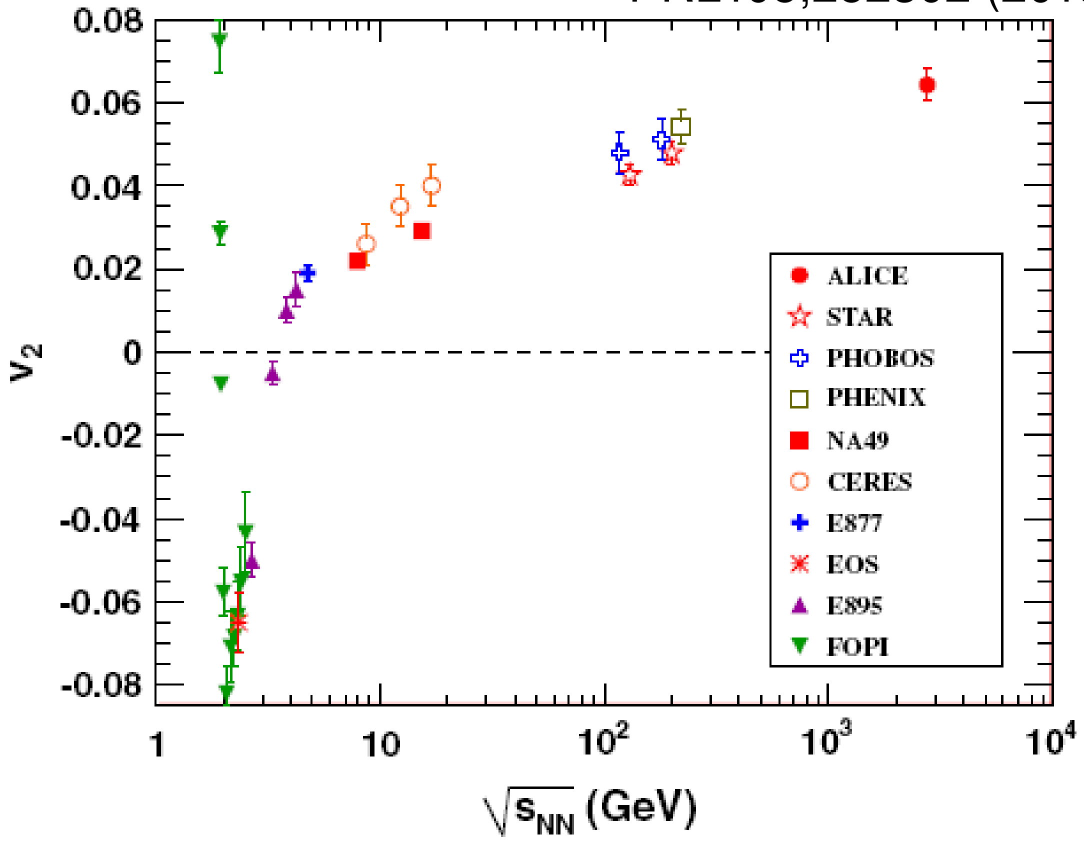
v_1 direct flow
v_2 elliptic flow

particle azimuthal angle

reaction plane (RP) angle

Integrated elliptic flow vs. collision energy

PRL105,252302 (2010)



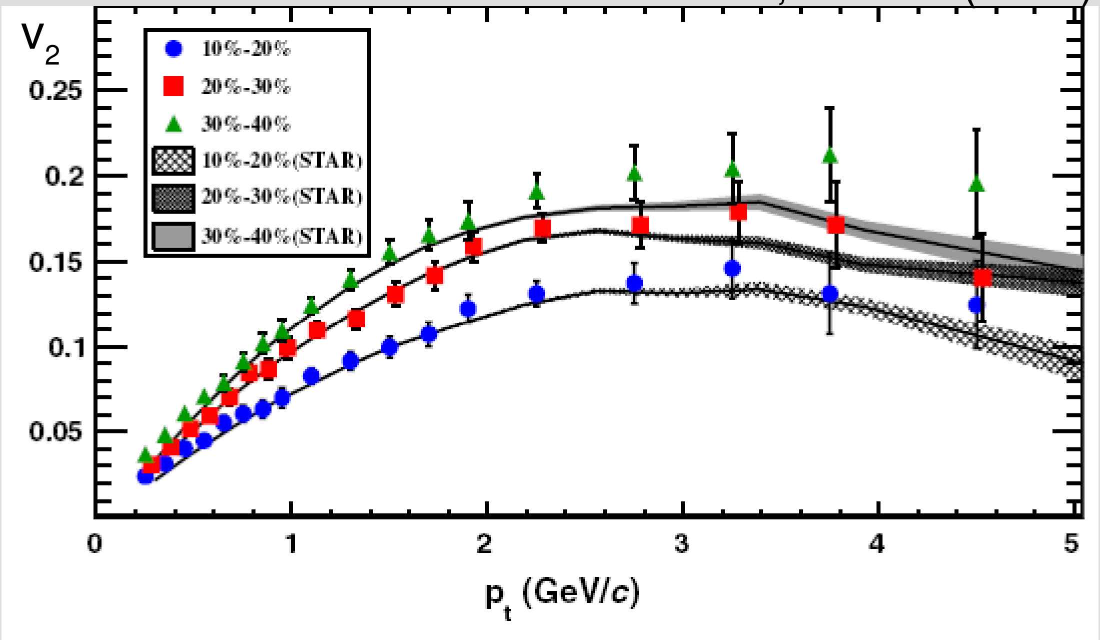
20-30% centrality class

- •30% increase compared to Au-Au collisions at $\sqrt{s_{NN}}$ = 0.2 TeV

Stronger collectivity at LHC?

Elliptic flow vs. momentum and centrality

PRL105,252302 (2010)



- Similar flow at RHIC and LHC
- p_T-integrated flow increases due to rise in average p_T

  ->stronger radial flow

In agreement with hydrodynamic model predictions including viscous corrections (predict also a decrease of v_2 at low p_T mostly for heavy-particles)

Outlook: v_2 from identified particles

High p_T charged-particle suppression R_{AA} nuclear modification factor

R_{AA} nuclear modification factor

Quantify medium effects in heavy ion collisions by deviation from particle production in pp interactions

$$R_{AA}(p_T) = \frac{1}{N_{coll}} \frac{Y_{AA}(p_T)}{Y_{pp}(p_T)}$$

Normalized to N_{col} number of binary NN collisions

$$Y(p_T) = \frac{1}{N_{evt}} \frac{d^2 N_{ch}}{d\eta \, dp_T}$$

p_T charged-particle distribution at mid-rapidity

R_{AA}=1 no medium effect

R_{AA} ingredients: p_T spectrum in Pb-Pb and pp reference

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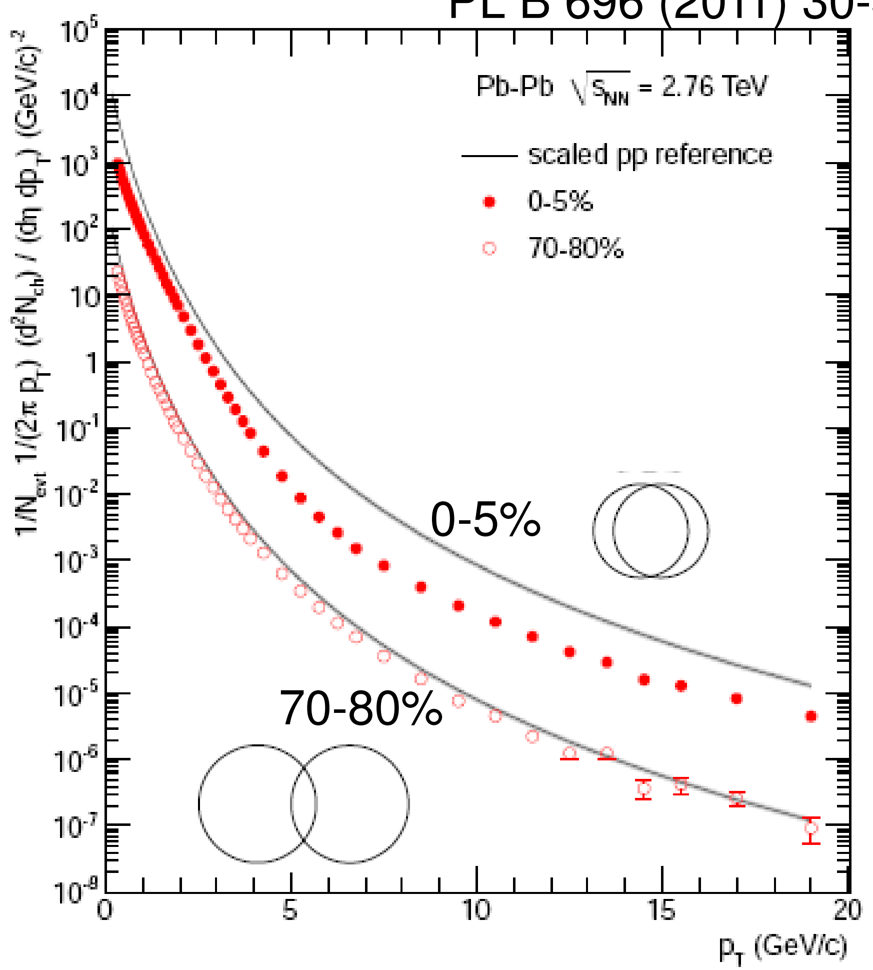

- Measured p_T spectrum in Pb-Pb: Very good statistics: go up to p_T=20 GeV/c
- No pp reference measured at √s=2.76 TeV
  - Interpolate between 0.9 TeV and 7 TeV
  - Additional uncertainties in R_{AA}
- **peripheral: pp and Pb-Pb similar**
- **0-5% central: strong modification**

High p_T charged particle suppression at RHIC and LHC

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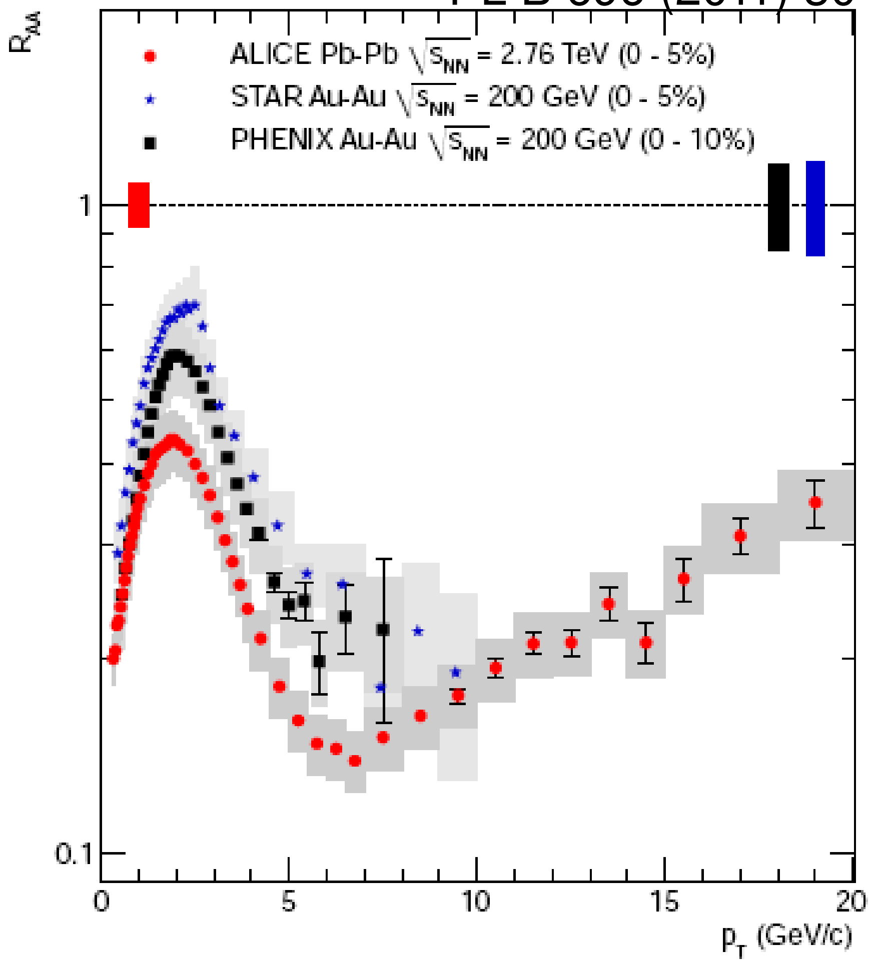


- Similar shape as at RHIC
- Maximum at 2 GeV/c: may reflect a variation of particle composition in heavy-ion collisions with respect to pp
- Increase at large p_T

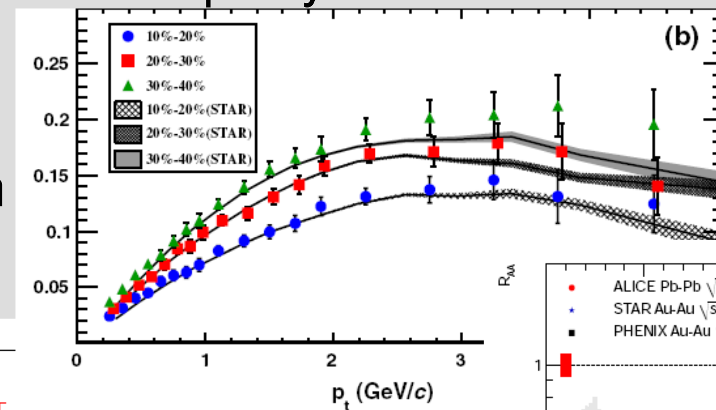
Much flatter p_T spectrum at LHC compared to RHIC
R_{AA} nevertheless smaller
-> enhanced parton energy loss
-> denser medium

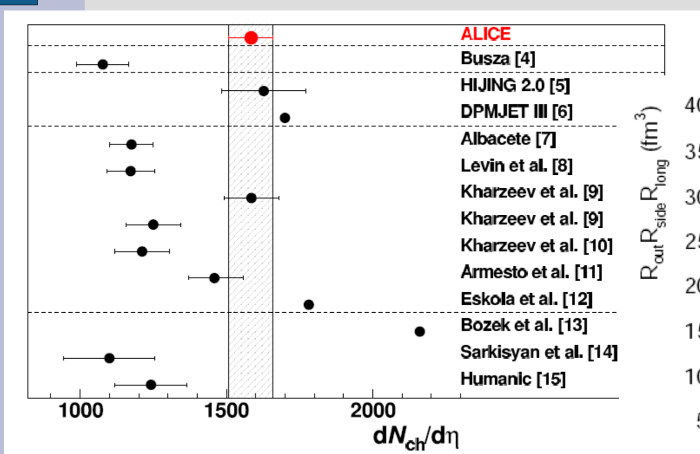
R_{AA} from identified particles...

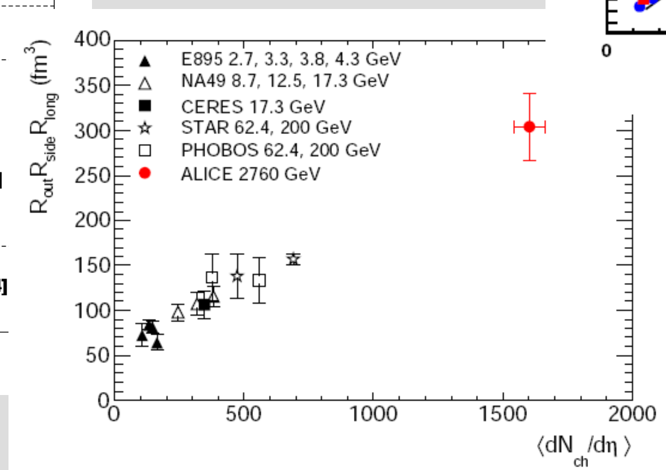
Summary

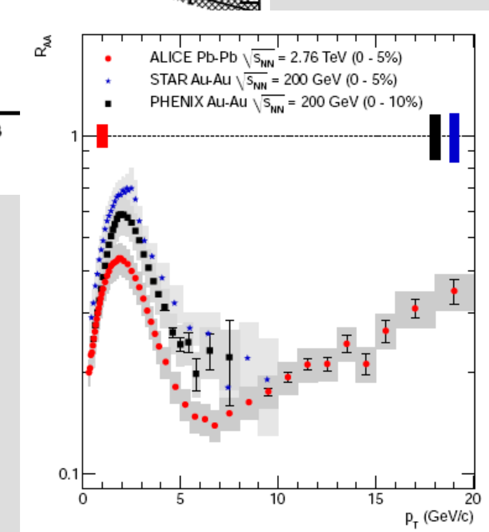
First results in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV

- Charged-particle multiplicity density at mid-rapidity
- Bose-Einstein correlations
- Elliptic flow v_2
- High p_T charged-particle suppression









Looking forward to further studies and upcoming results from LHC!

Thank you