Results from ALICE

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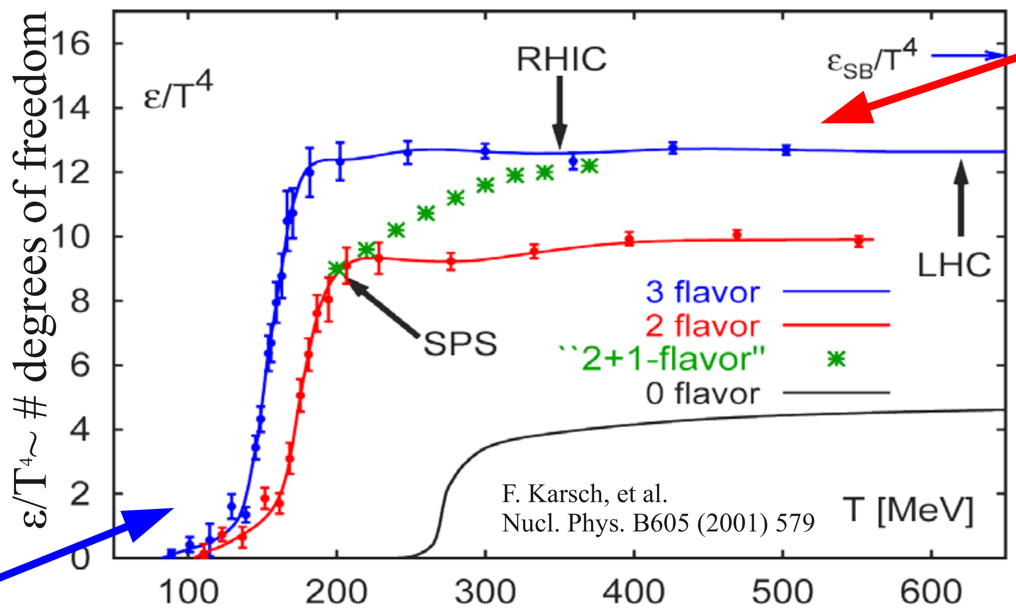
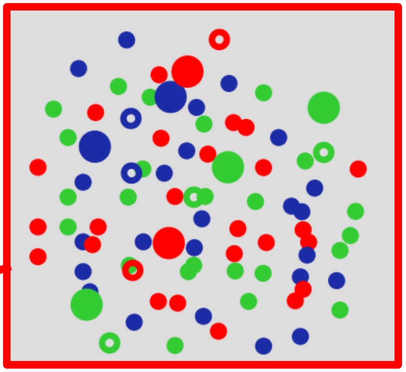
for the ALICE collaboration
University of Tennessee at Knoxville

Exploring QCD at high temperatures

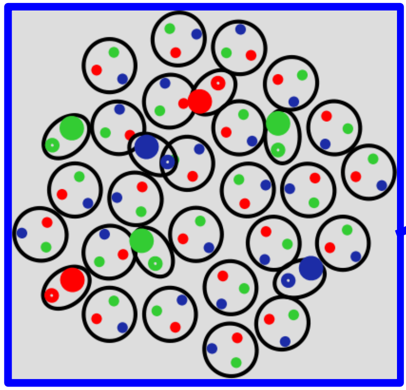
$T_c \sim 175 \pm 8$ MeV $\rightarrow \varepsilon_c \sim 0.3$ -1 GeV/fm^3



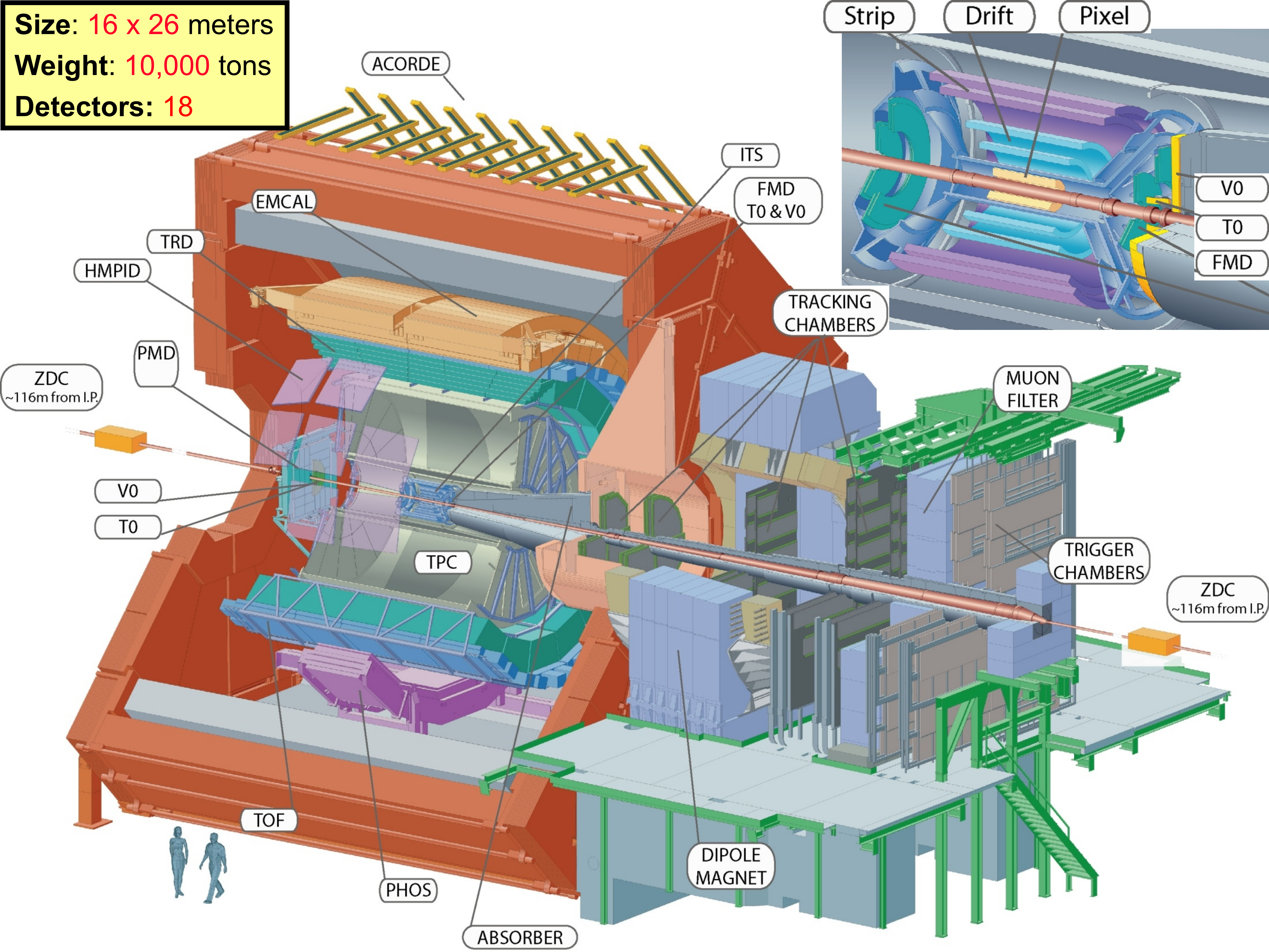
Quark-gluon plasma



Deconfined - more degrees of freedom



Confined - fewer degrees of freedom



Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18
ACORDE
Strip
Drift
Pixel
V0
T0
FMD
ITS
FMD
T0 & V0
EMCAL
TRD
HMPID
PMD
ZDC
~116m from I.P.
TRACKING CHAMBERS
MUON FILTER
V0
T0
TPC
TRIGGER CHAMBERS
ZDC
~116m from I.P.
TOF
DIPOLE MAGNET
PHOS
ABSORBER

Bulk properties

Bulk properties

Collision system on the slide

pp

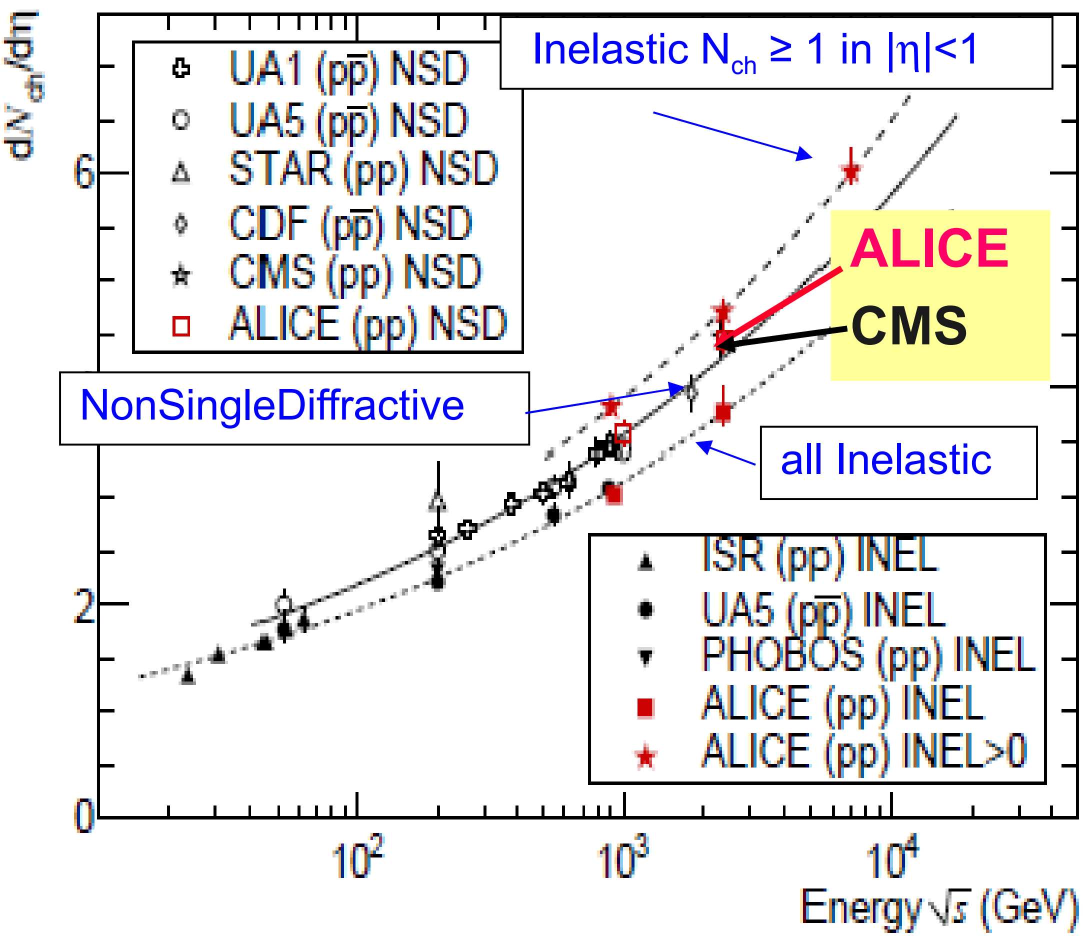
Bulk properties

Collision system on the slide

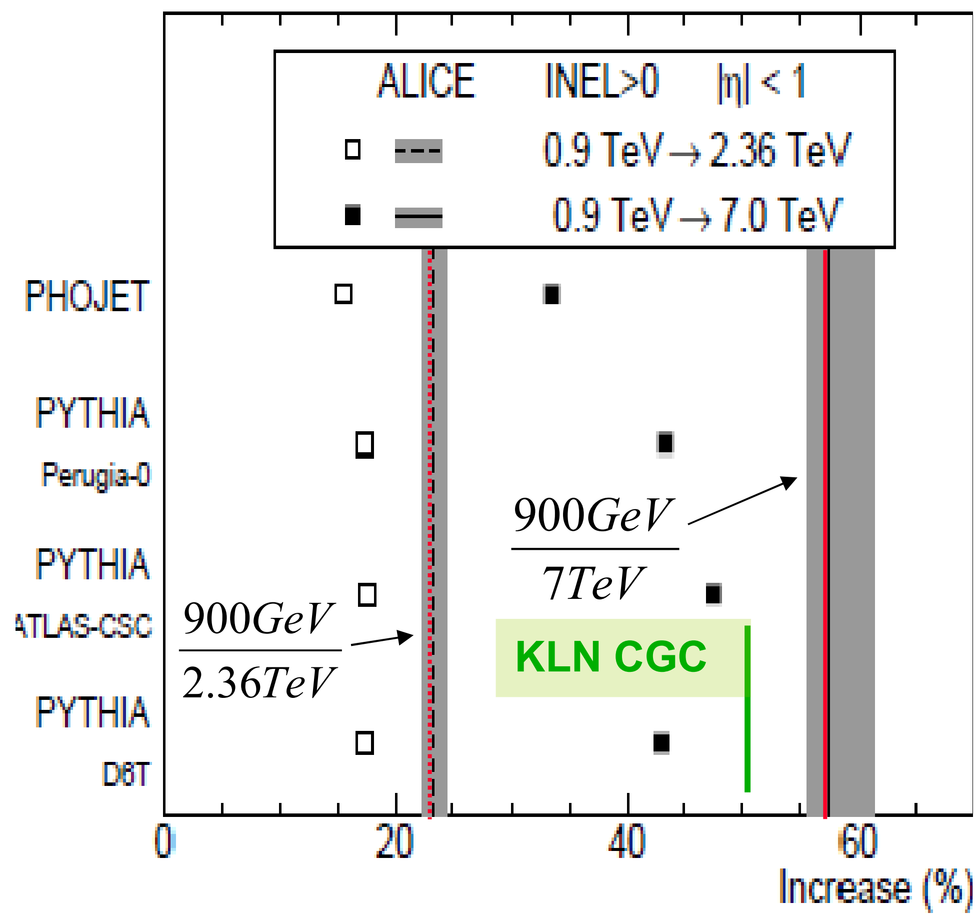
Pb+Pb

$dN_{ch}/d\eta$ versus $\sqrt{s}$

$dN_{ch}/d\eta$ versus $\sqrt{s}$



Relative increase in $dN_{ch}/d\eta$



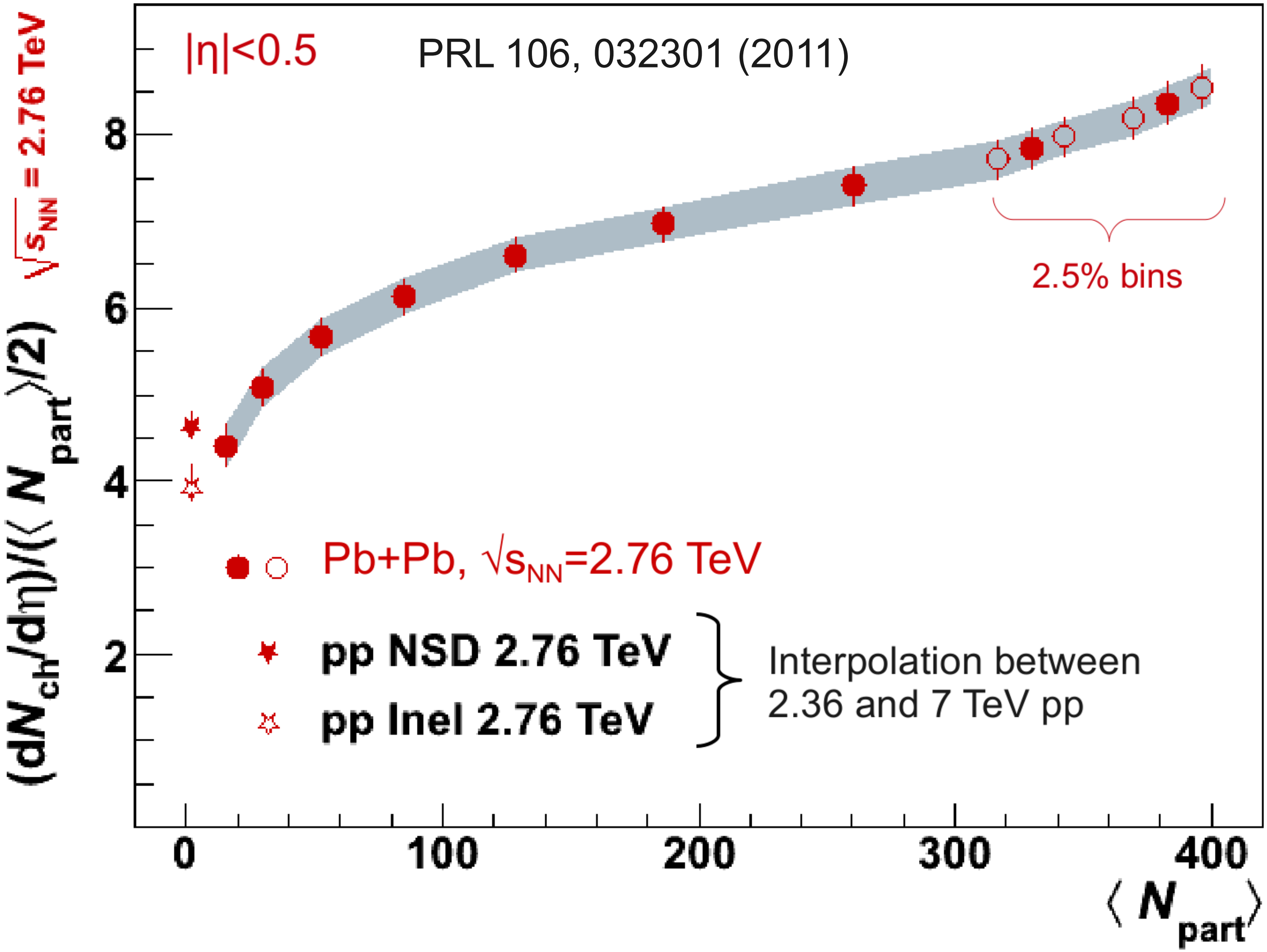
Eur. Phys. J. C (2010) 68: 345–354
Eur. Phys. J. C (2010) 68: 89–108
Eur. Phys. J. C (2010) 65: 111-125

Results:

increase with energy significantly stronger in data than MC's

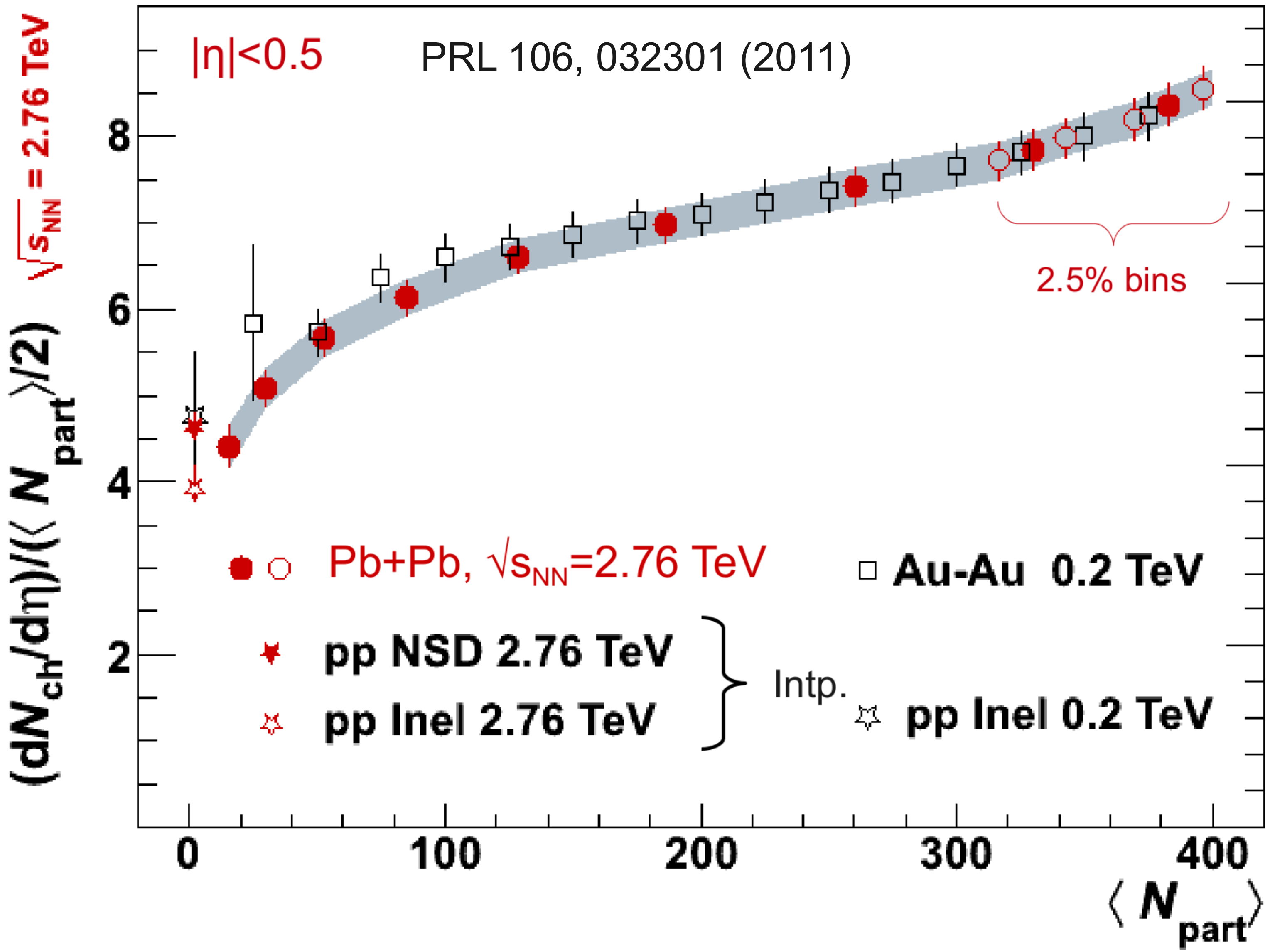
- ALICE & CMS agree to within 1 σ (< 3%)

Centrality dependence of $dN_{ch}/d\eta$



Pb+Pb

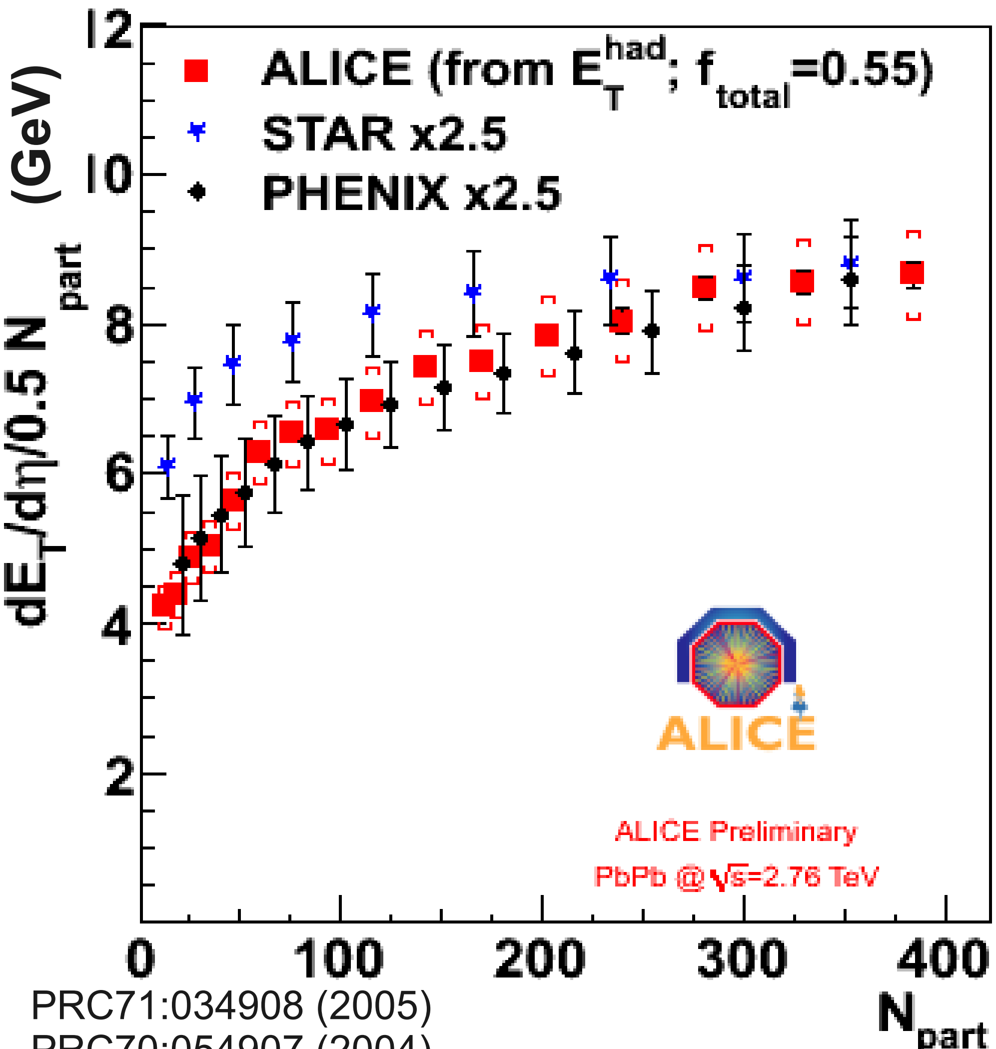
Centrality dependence of $dN_{ch}/d\eta$



RHIC data scaled by 2.1

PHENIX
PRC 71, 034908 (2005)

Transverse Energy



PRC71:034908 (2005)
PRC70:054907 (2004)

Centrality dependence similar to RHIC (PHENIX)

- E_T^{had} from charged hadrons directly measured by the tracking detectors
- f_{total} from MC to convert into total E_T
- From RHIC to LHC
  - ~2.5 increase $dE_T/d\eta/(0.5*N_{part})$
- Energy density (Bjorken)

$$\varepsilon = \frac{1}{\pi R^2 \tau} \frac{dE_t}{dy} \qquad R = 1.12\, A^{1/3} fm$$

- $\varepsilon\tau \sim 16$ GeV/(fm^{2}c)
  RHIC: $\varepsilon\tau = 5.4 \pm 0.6$ GeV/(fm^{2}c)

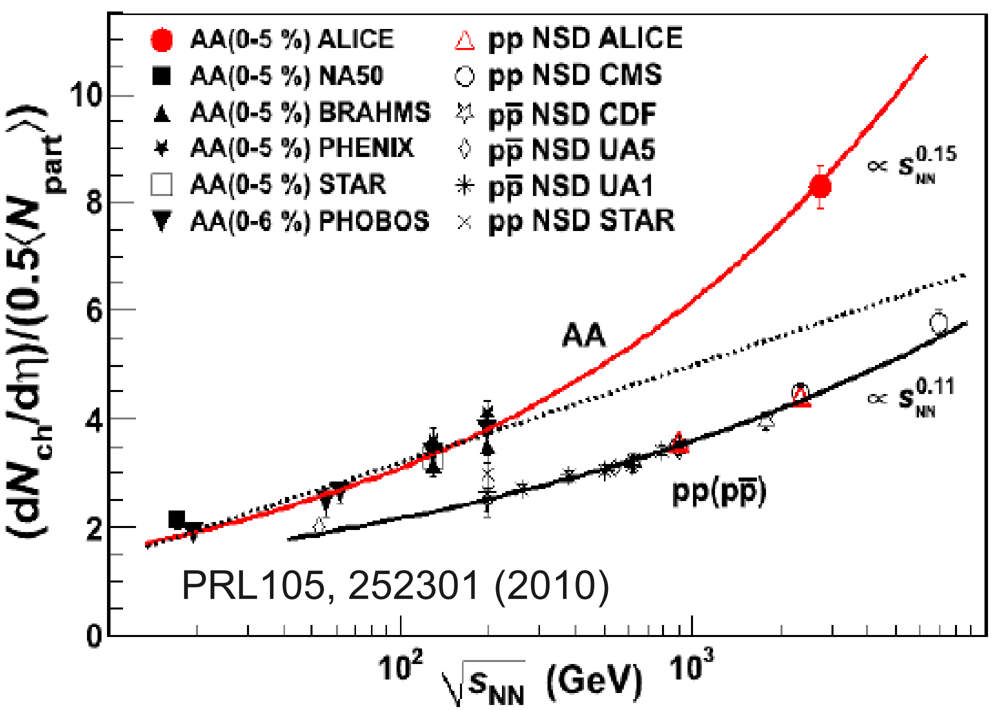
Pb+Pb

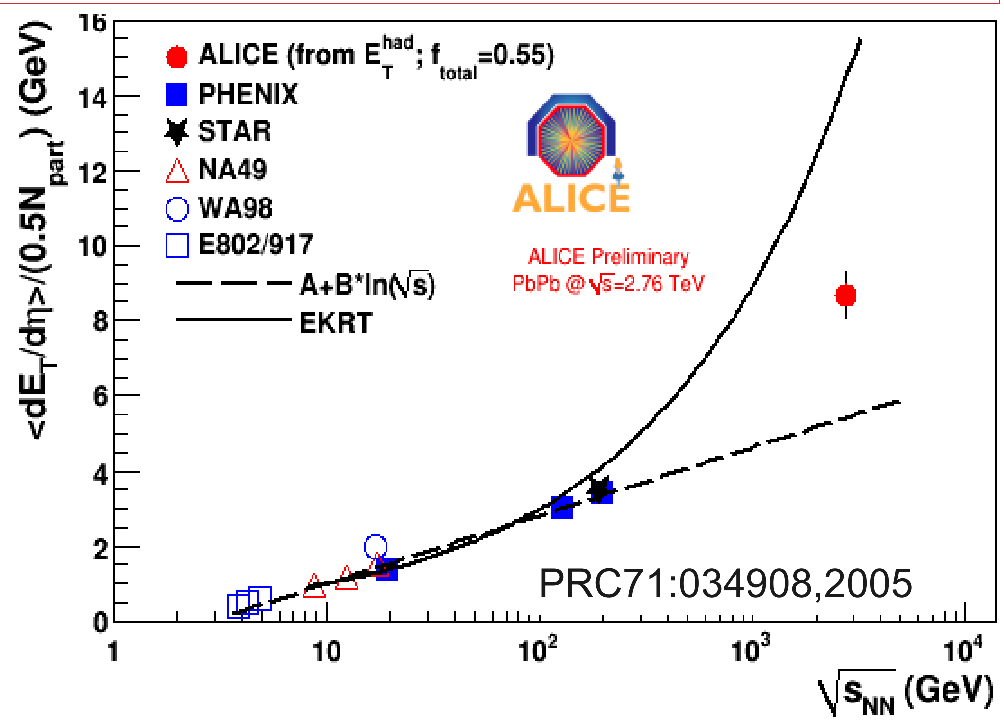
$\sqrt{s}_{NN}$ dependence

- $dN_{ch}/d\eta/(0.5*N_{part}) \sim 8$
- **2.1 x RHIC**
  1.9 x pp (NSD) at 2.36 TeV
- growth with $\sqrt{s}$ faster in AA than pp

- $dE_T/d\eta/(0.5*N_{part}) \sim 9$ in 0-5%
- ~5% increase of N_{part} (353 → 383)
  → **2.7 x RHIC**
  (consistent with 20% increase of $\langle p_T \rangle$)

Grows faster than simple logarithmic scaling extrapolated from lower energy

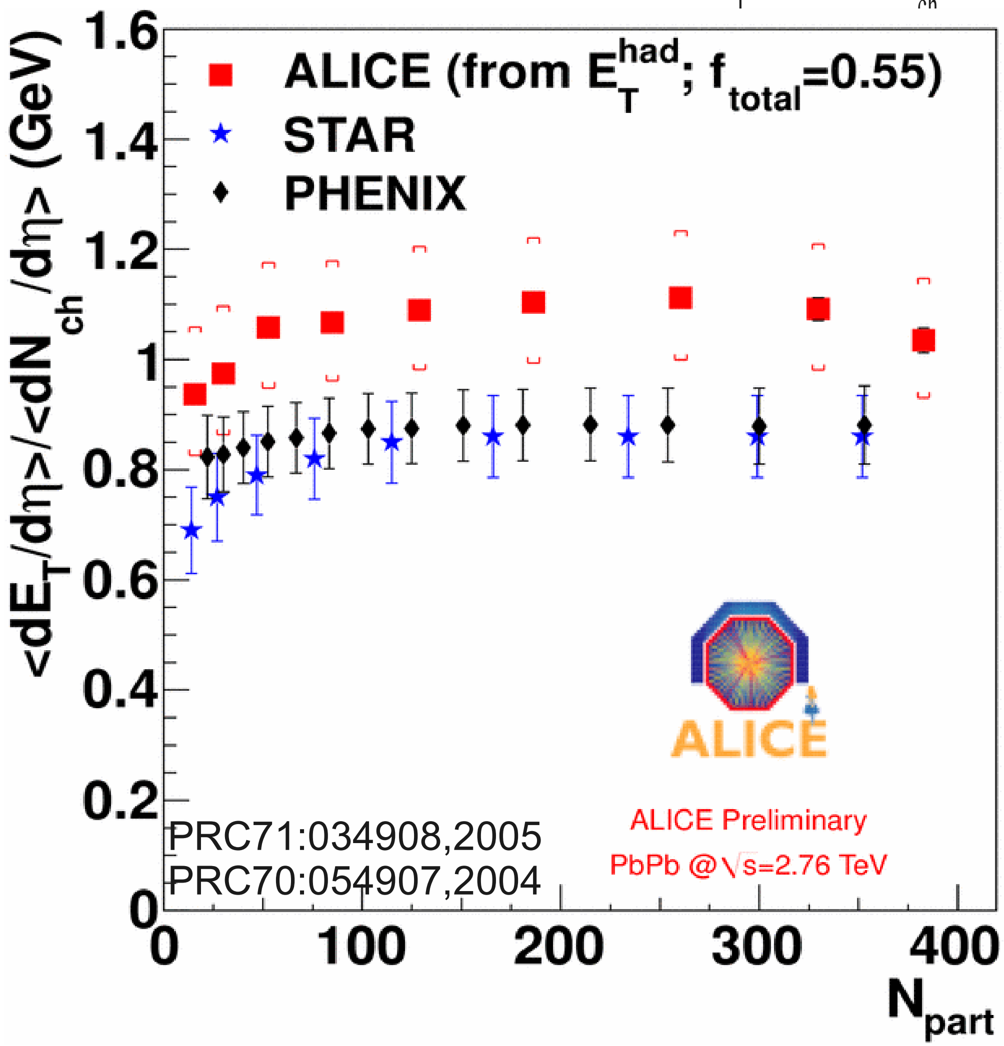




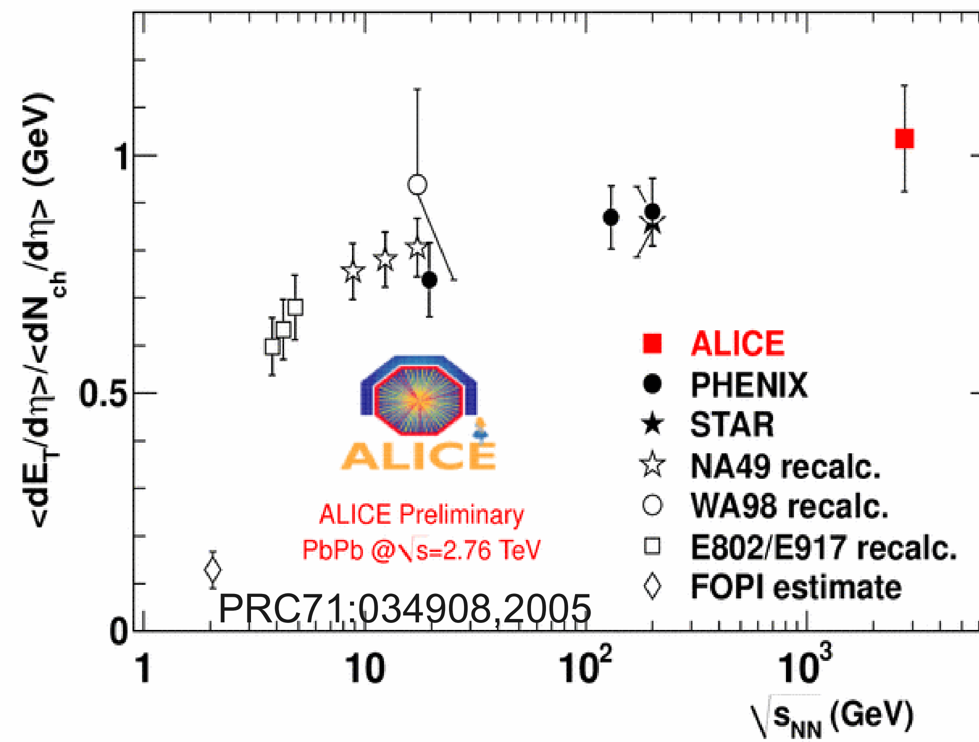
Pb+Pb

E_T/N_{ch}

- Consistent behavior for E_T and N_{ch}



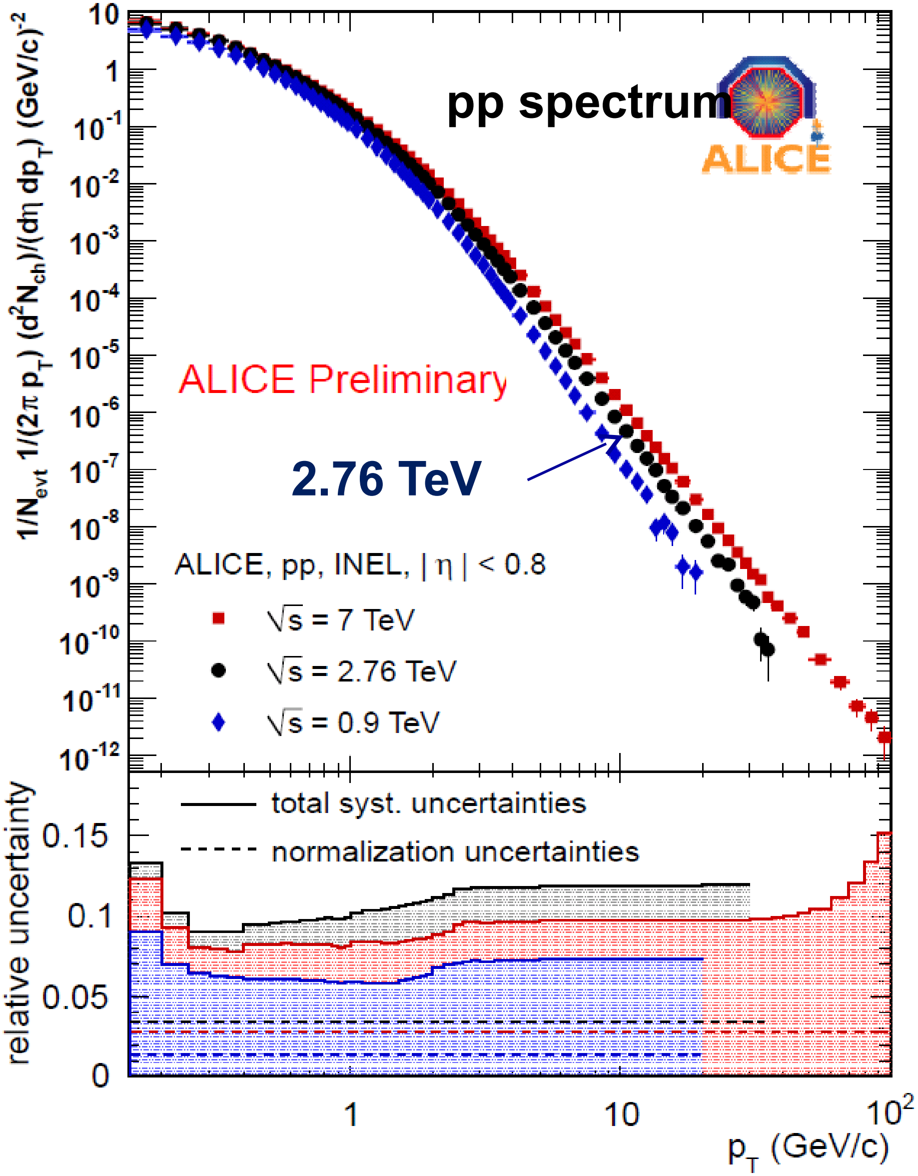
- Both increase with energy
- Both show steady rise from peripheral to central
- E_T/N_{ch} independent of centrality
- E_T/N_{ch} slightly increases with energy

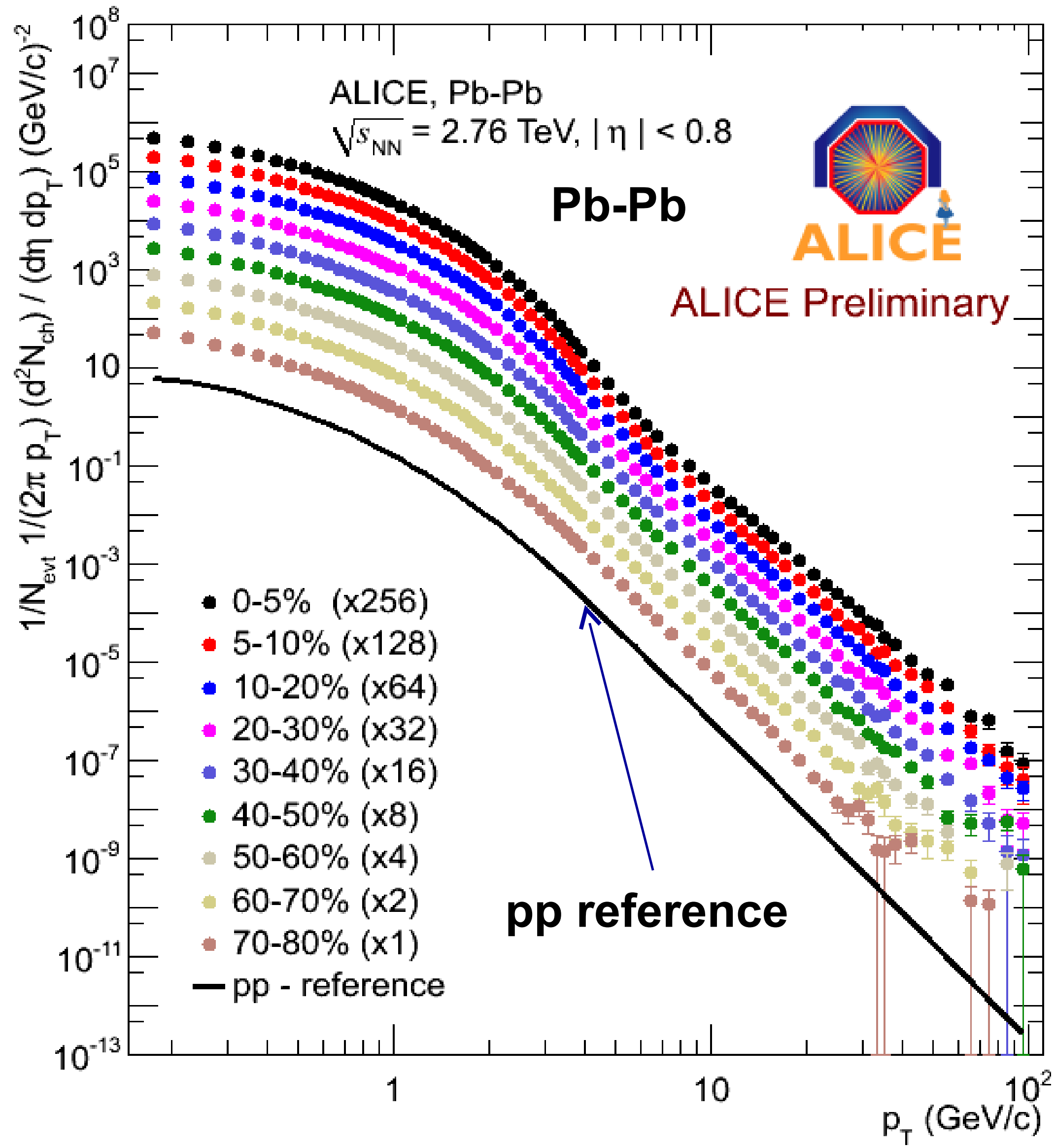


Pb+Pb

Charged particle spectra

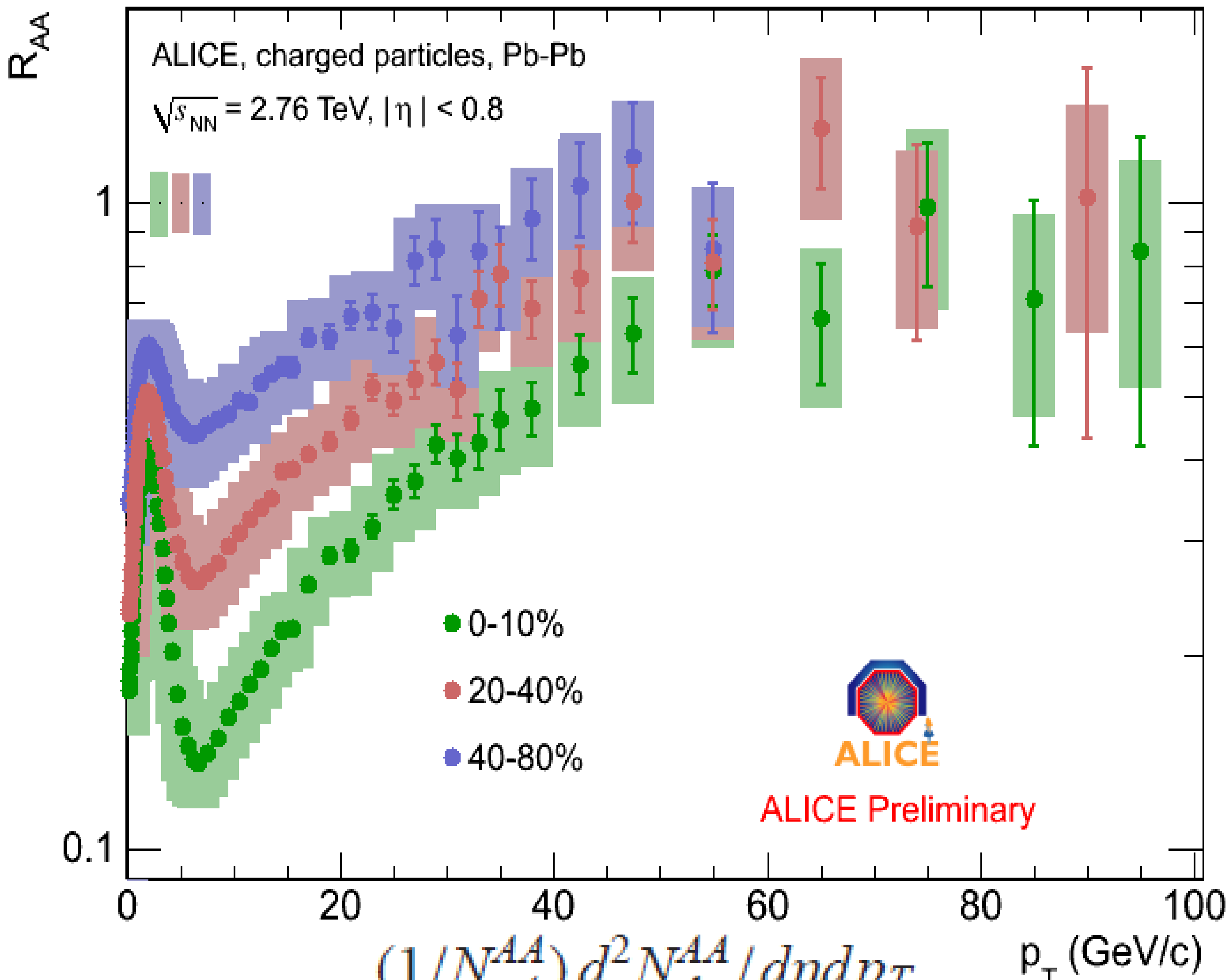
Charged particle spectra





Pb+Pb

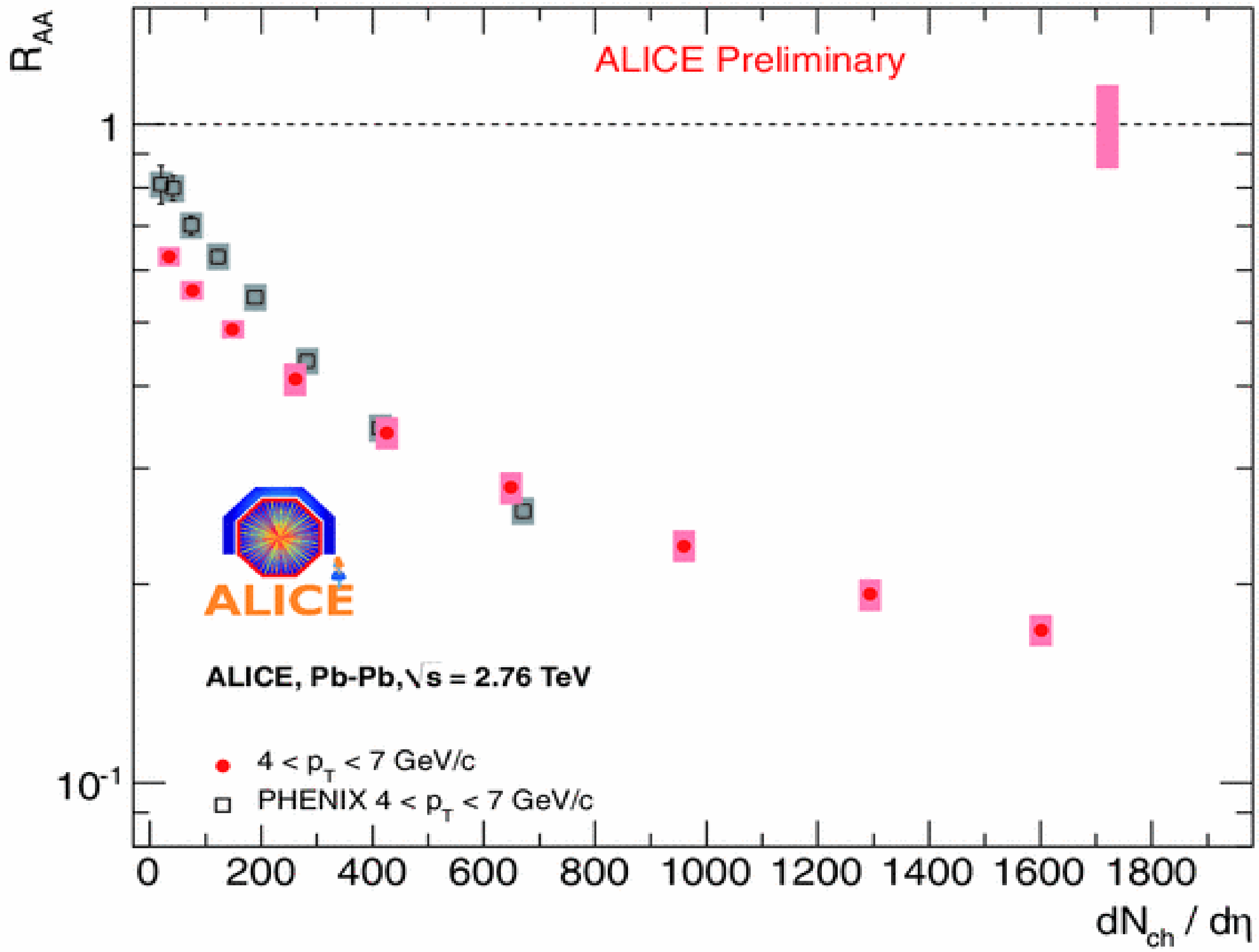
Nuclear modification factor (R_{AA})



$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$

Pb+Pb

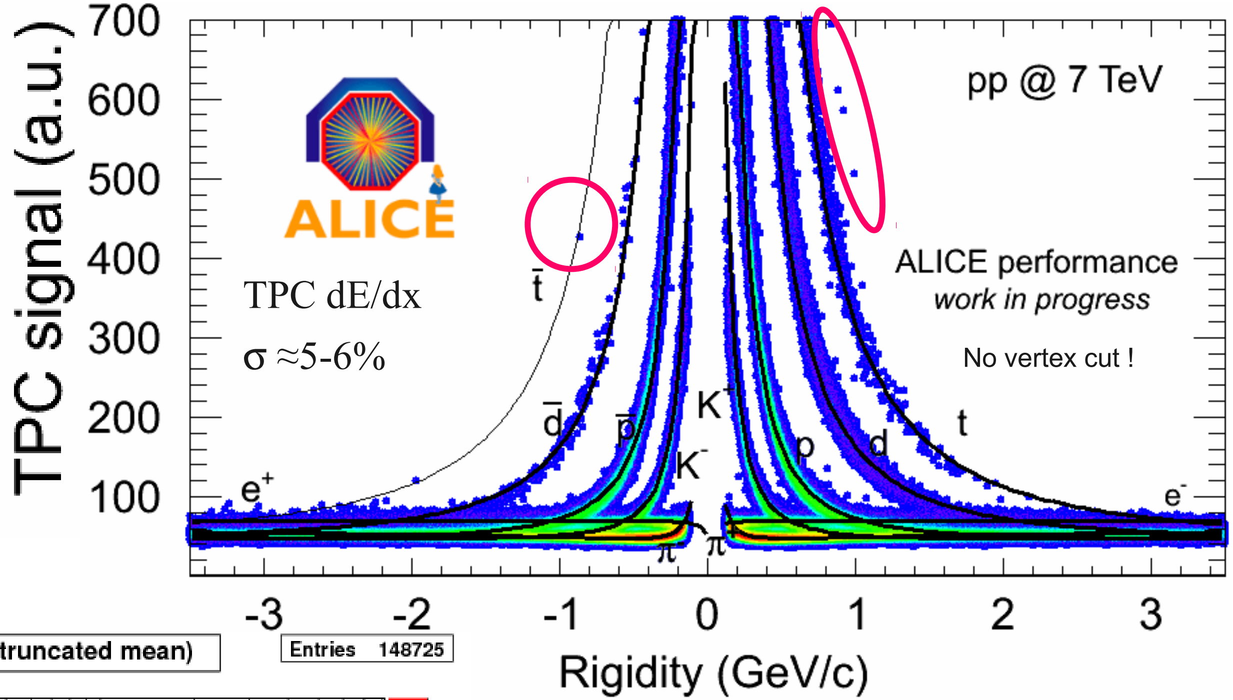
Nuclear modification factor (R_{AA})

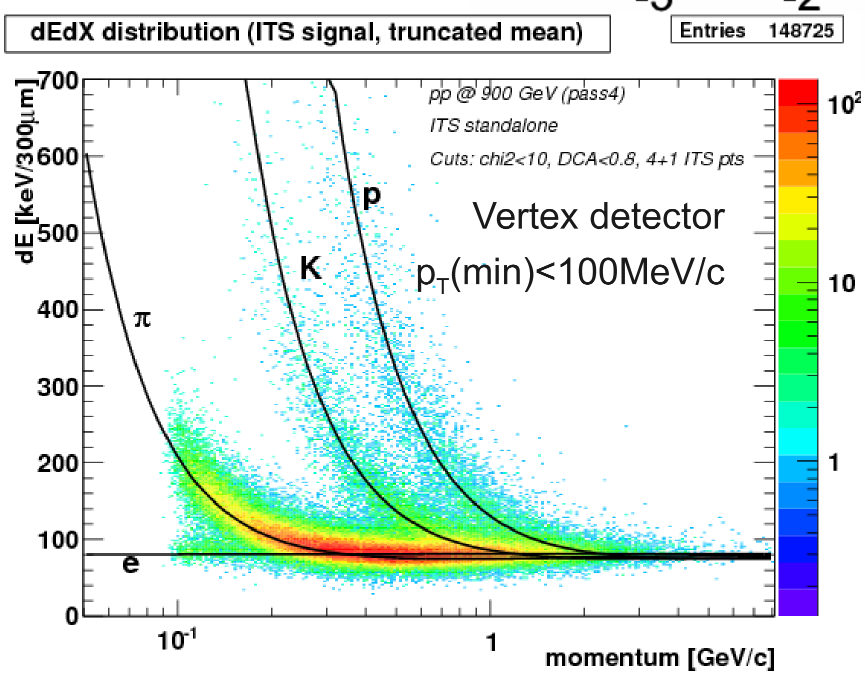


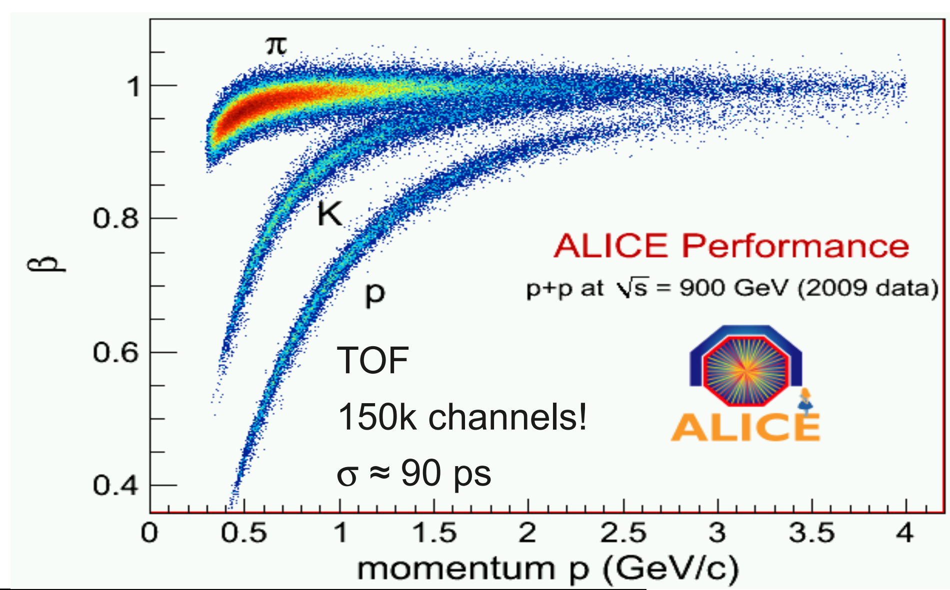
$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{\mathrm{ch}}^{AA}/d\eta dp_T}{\langle N_{\mathrm{coll}}\rangle\,(1/N_{evt}^{pp})\, d^2N_{\mathrm{ch}}^{pp}/d\eta dp_T}$$

Pb+Pb

Particle identification

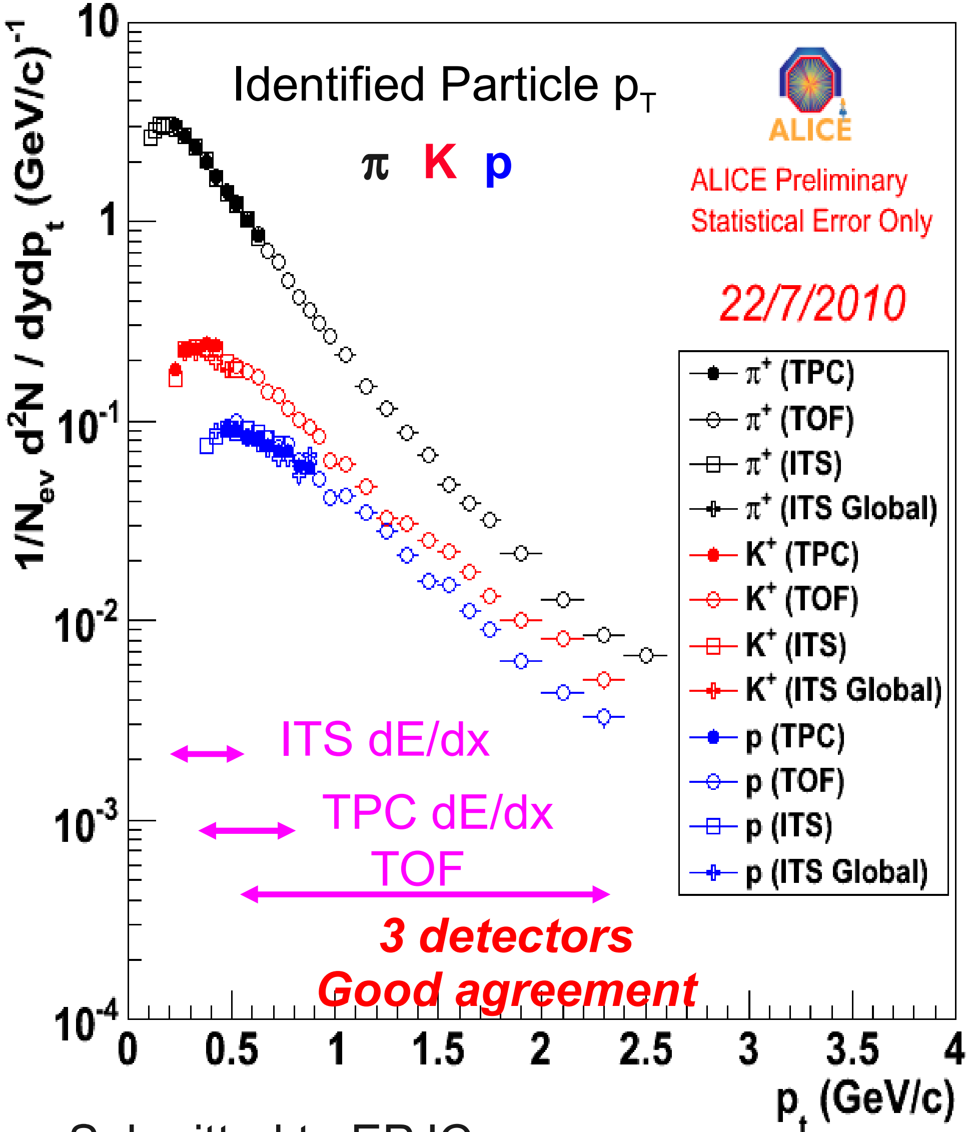




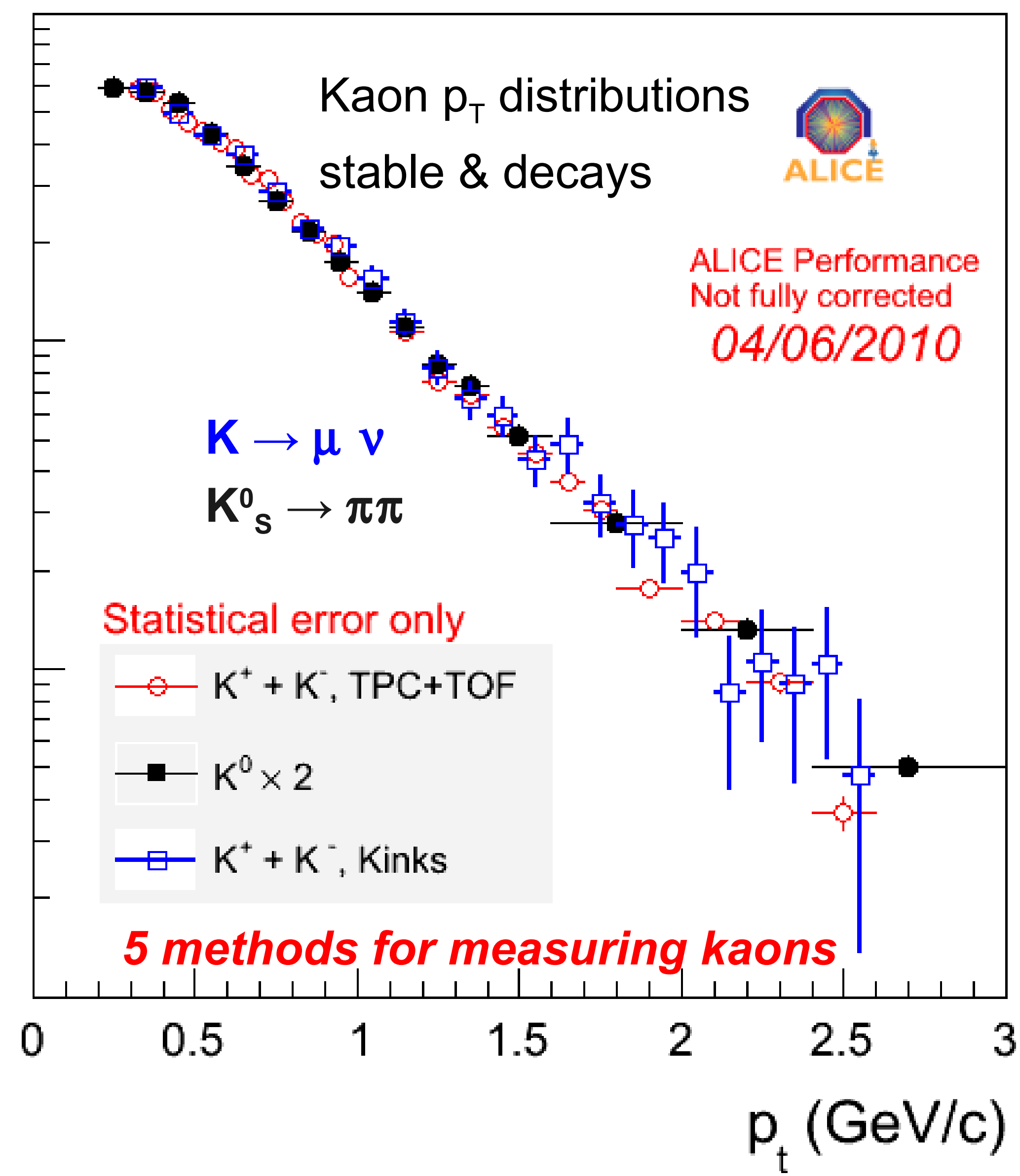


pp

Identified particle spectra

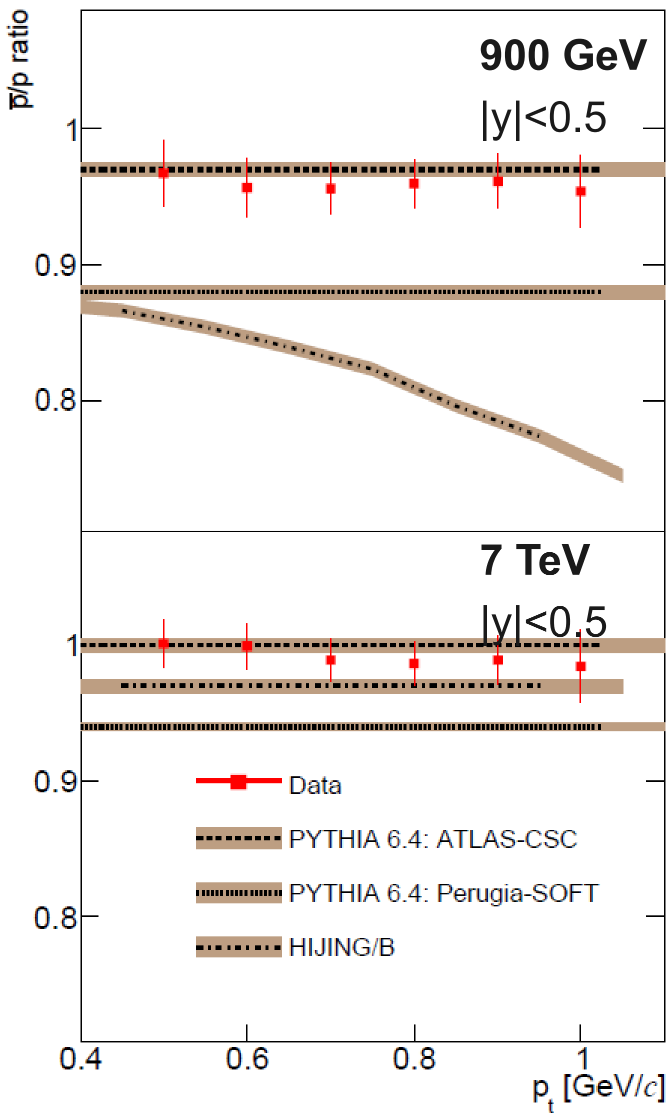


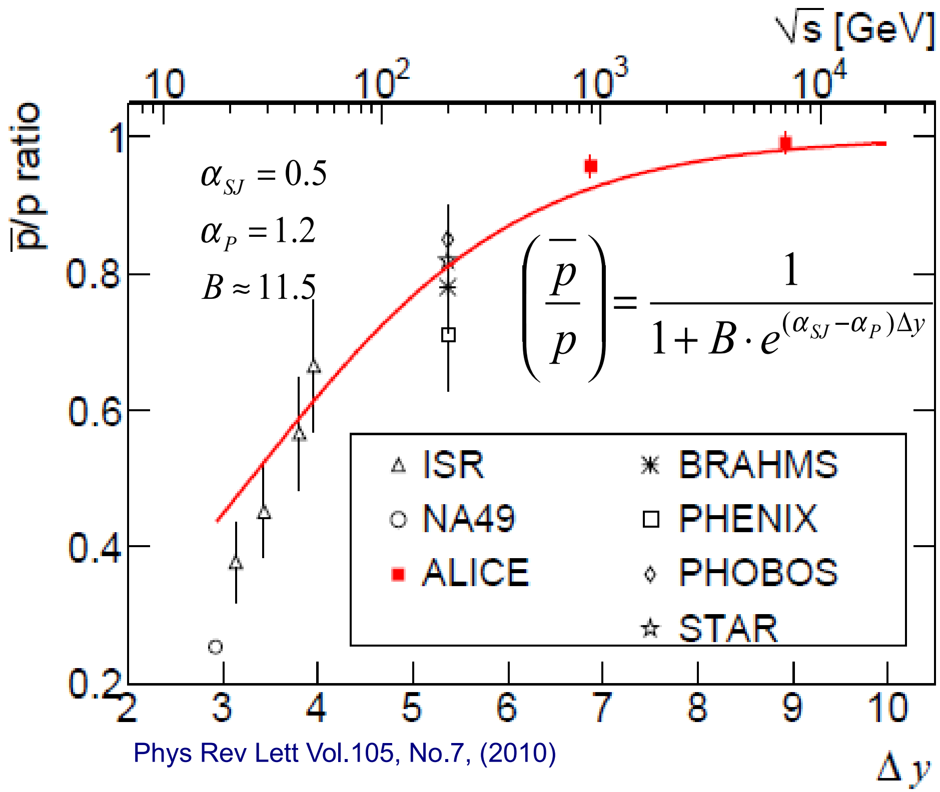
Submitted to EPJC



pp

$\bar{p}/p$ ratio in p+p collisions





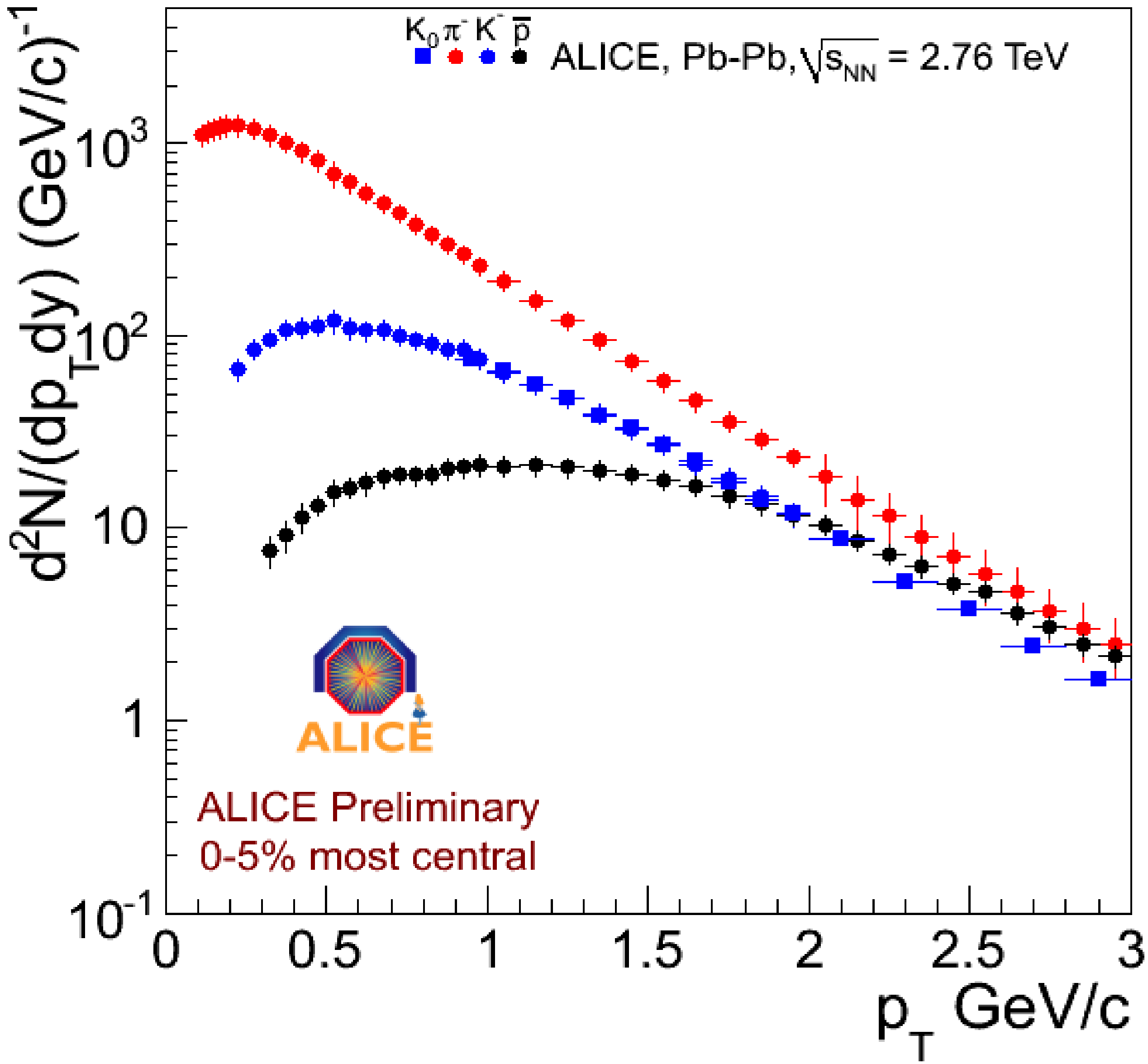
$$\left(\frac{\bar{p}}{p}\right) = \frac{1}{1 + B \cdot e^{(\alpha_{SJ} - \alpha_P)\Delta y}}$$

Phys Rev Lett Vol.105, No.7, (2010)

0.9 TeV: $\bar{p}/p$ = **0.957**±0.006(stat) ±0.014(syst)

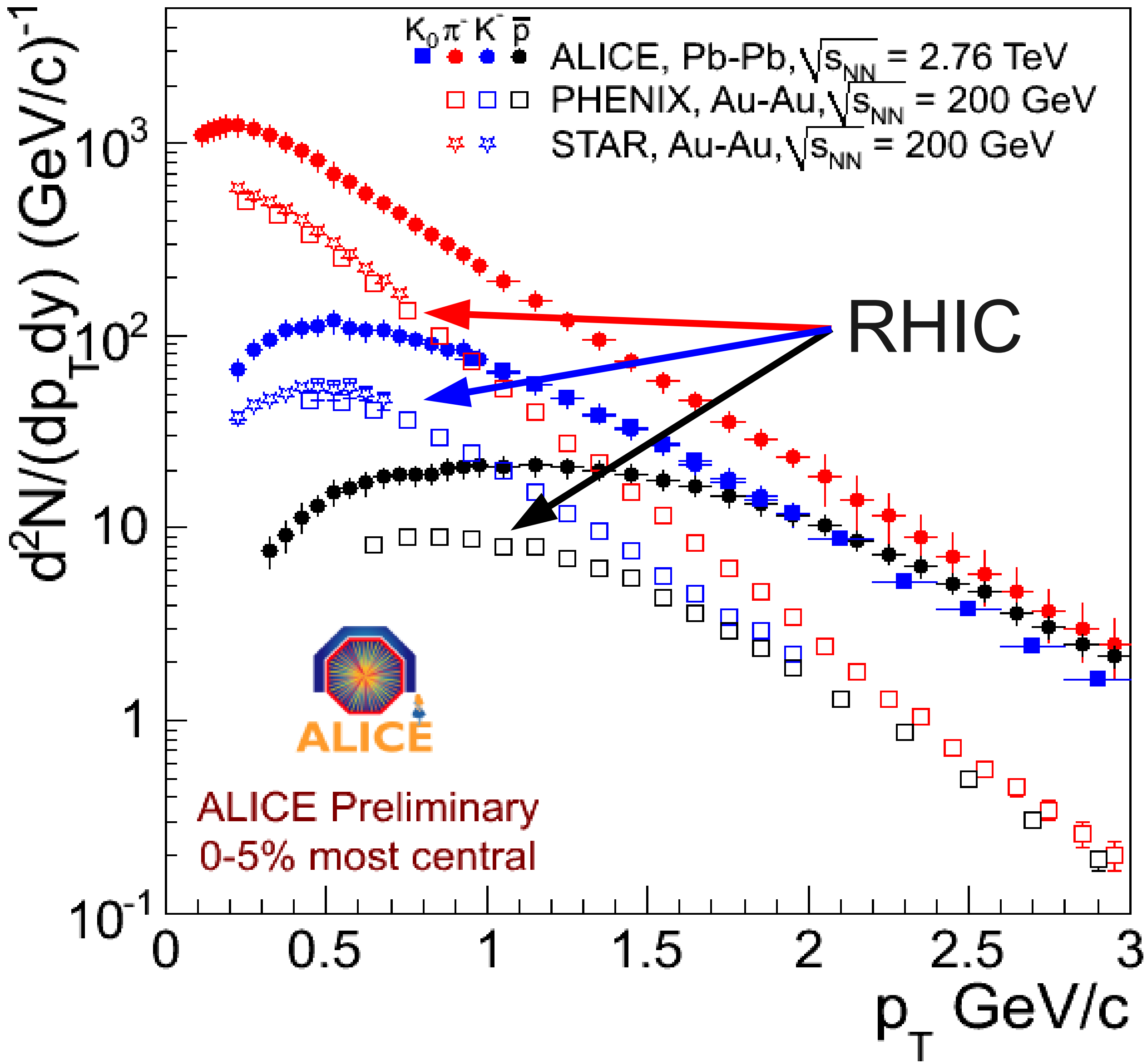
7 TeV: $\bar{p}/p$ = **0.990**±0.006(stat) ±0.014(syst)

Identified Particle spectra in Pb-Pb collisions



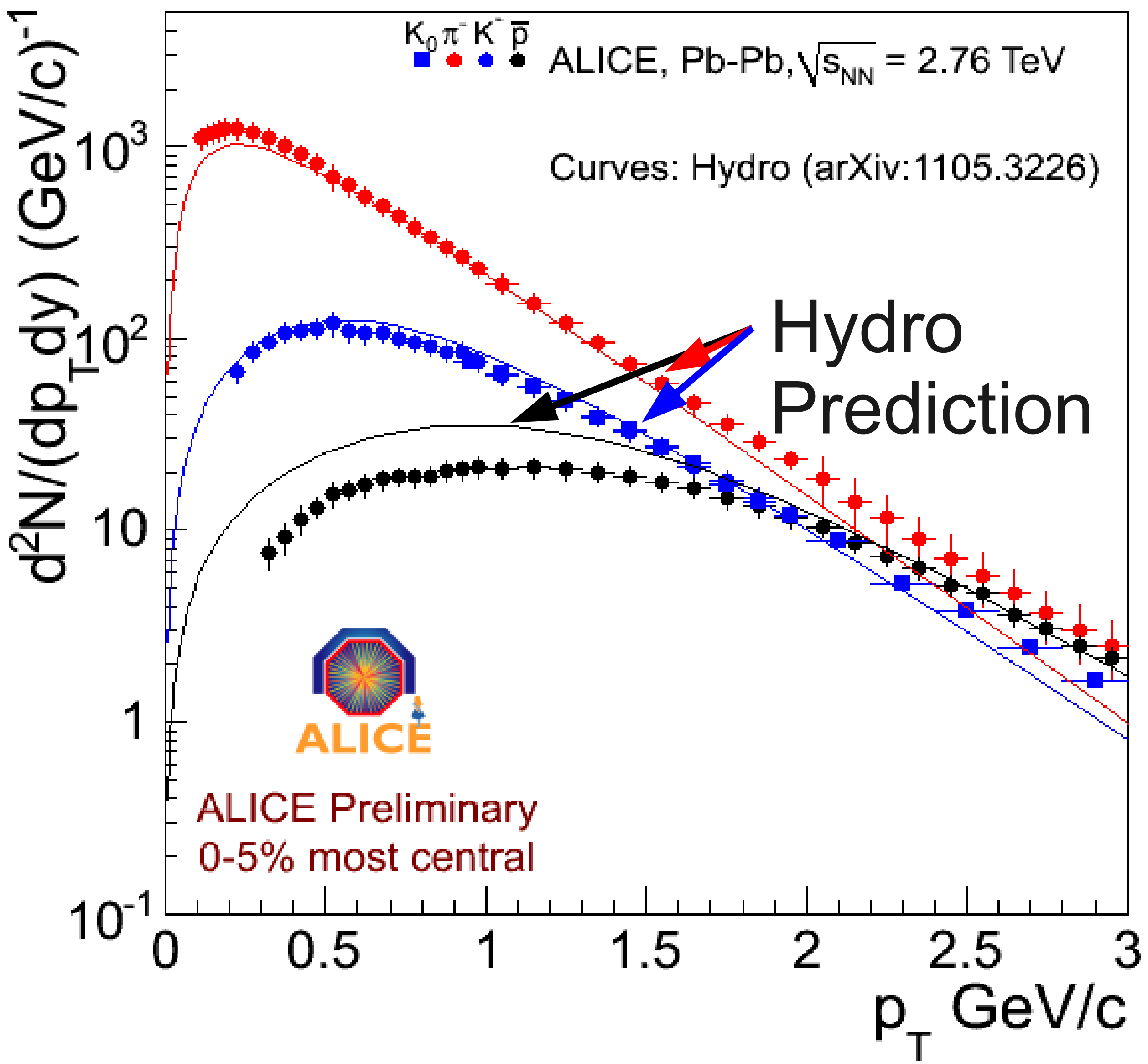
Pb+Pb

Identified Particle spectra in Pb-Pb collisions



Pb+Pb

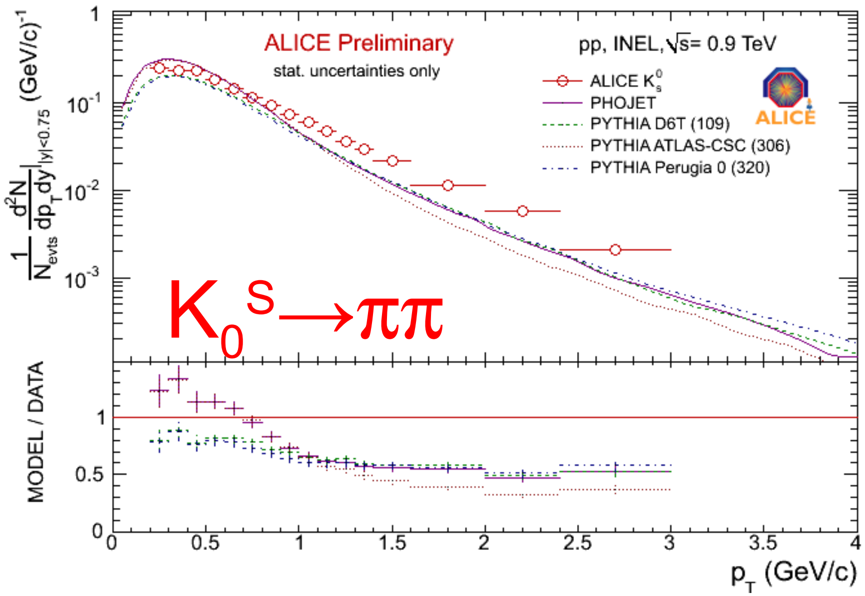
Identified Particle spectra in Pb-Pb collisions

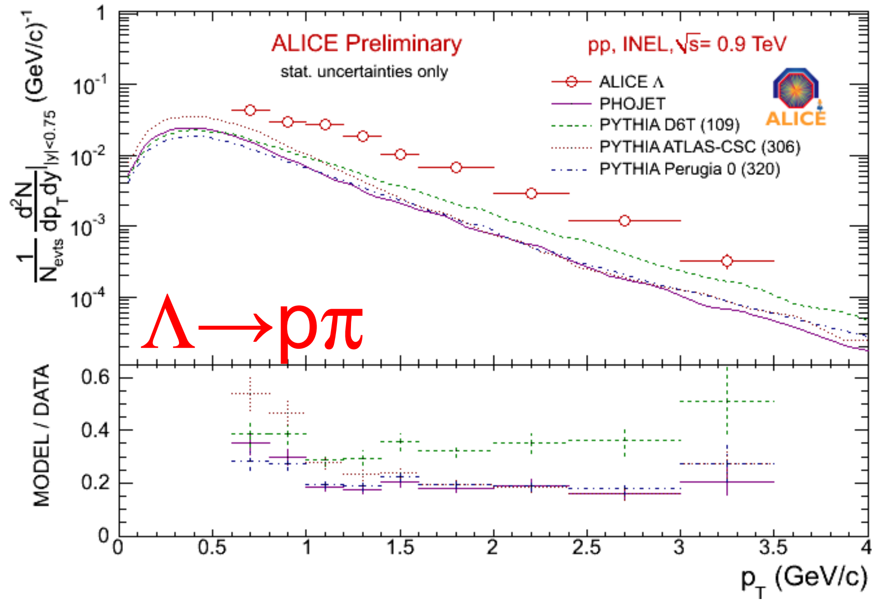


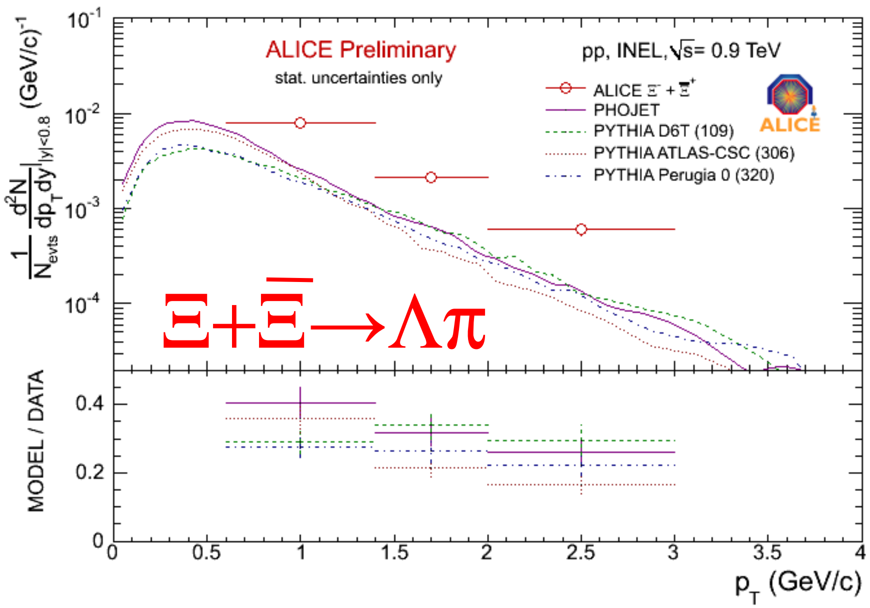
Pb+Pb

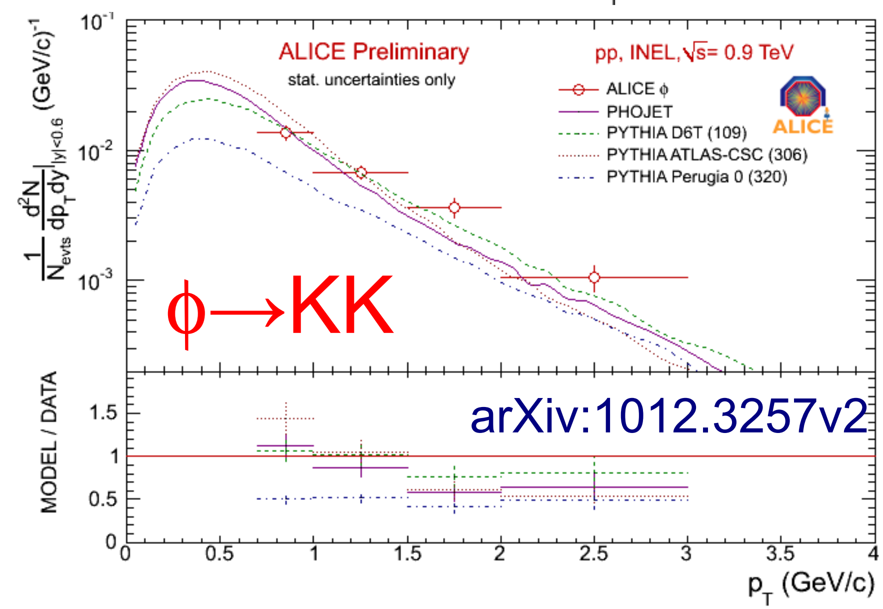
Strange particle spectra

Strange particles in pp collisions





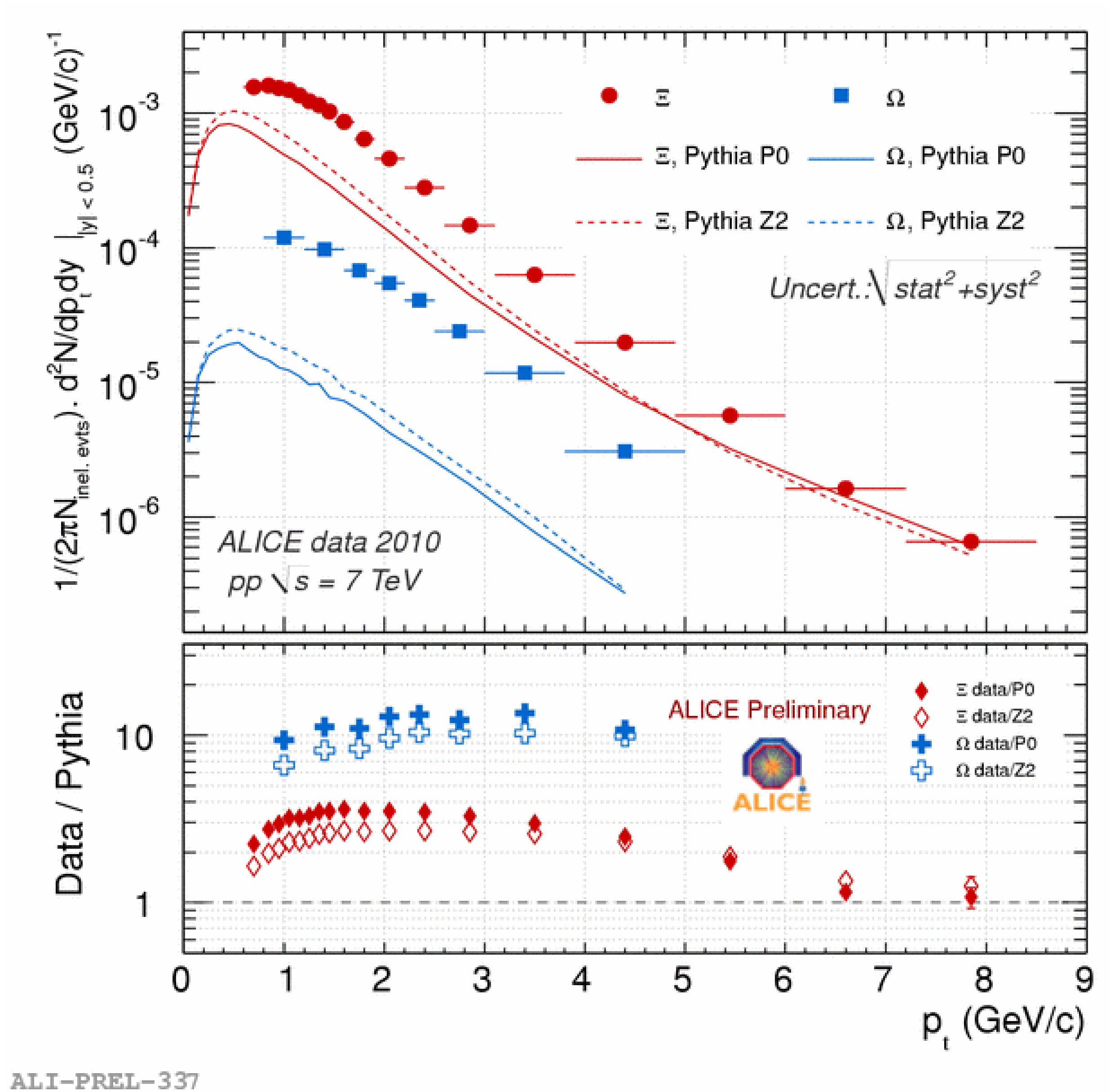




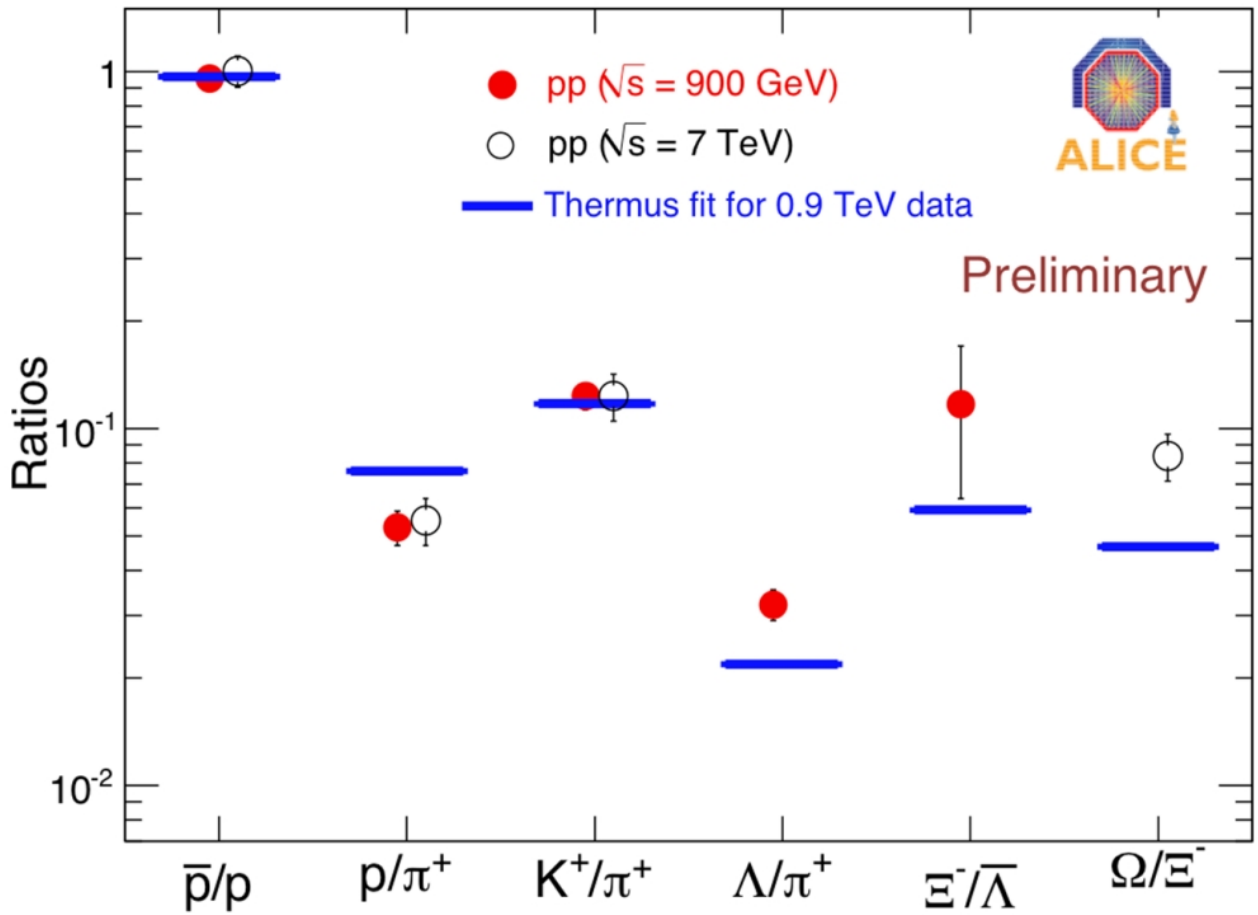
- PYTHIA and PHOJET consistently below data

pp

Stranger particles

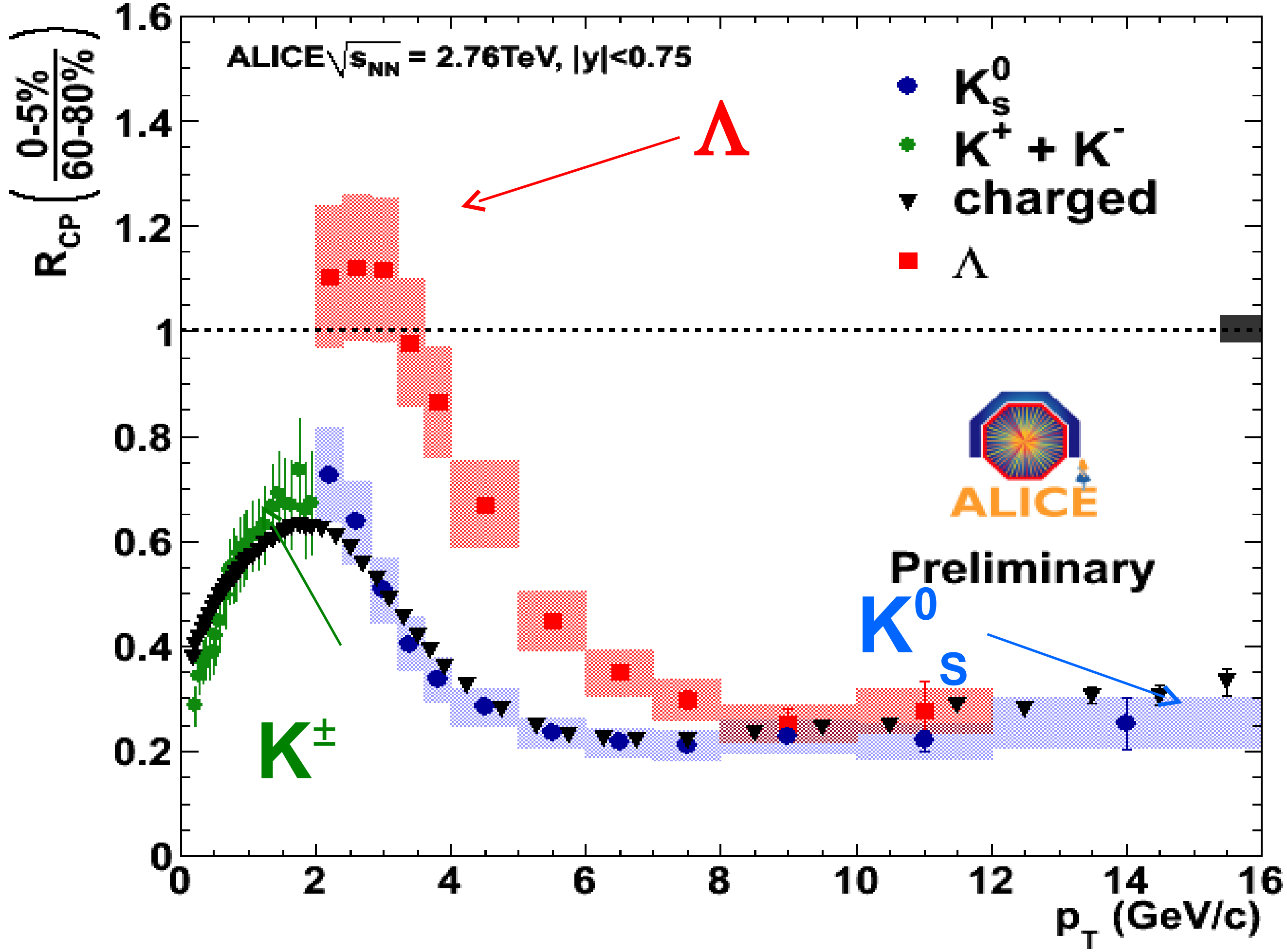


Particle ratios in pp collisions



Thermus fit fails – worked better at lower energies

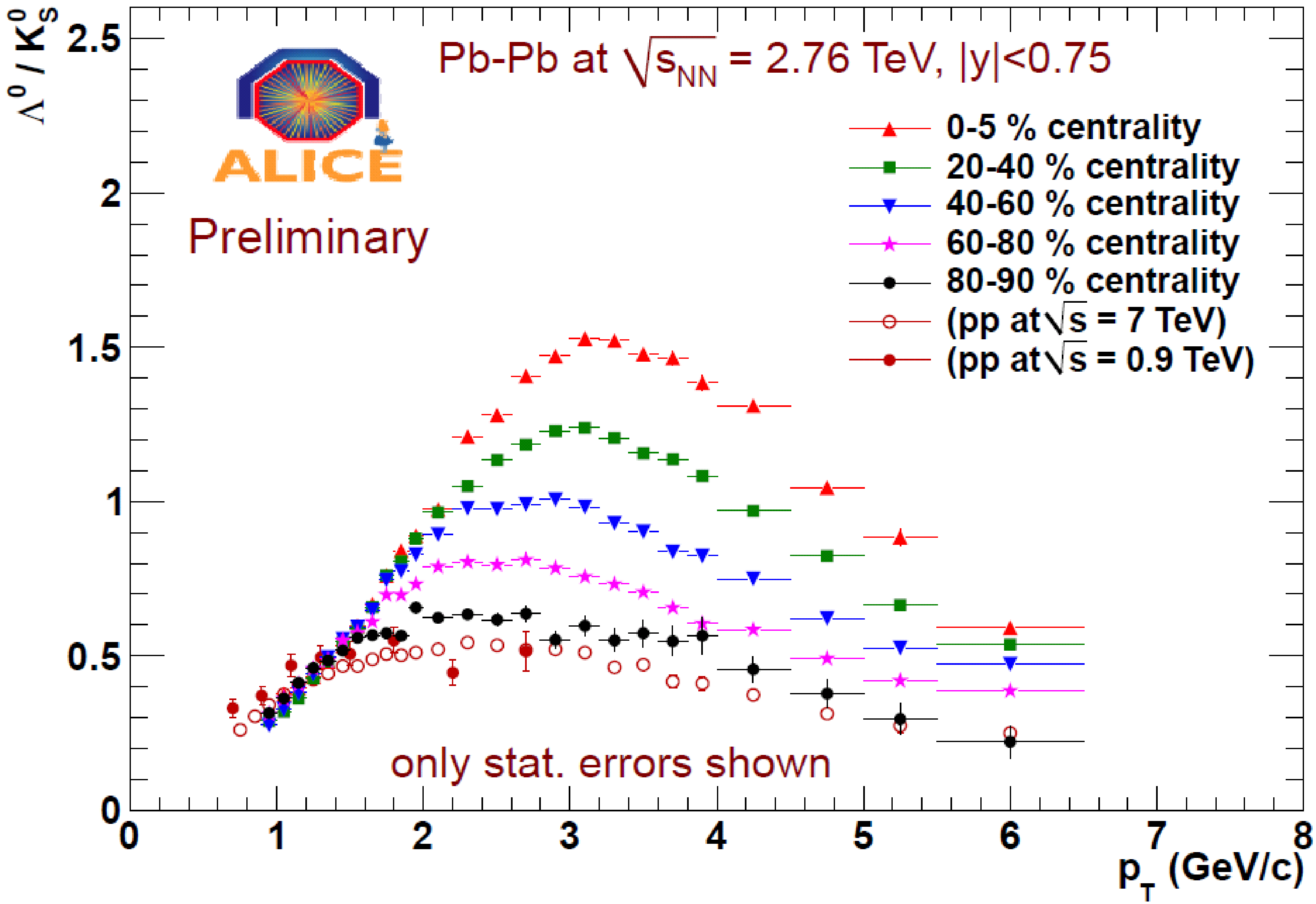
Nuclear modification factor (R_{AA})



$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle\,(1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$

Pb+Pb

Baryon anomaly: Λ/K^0_S

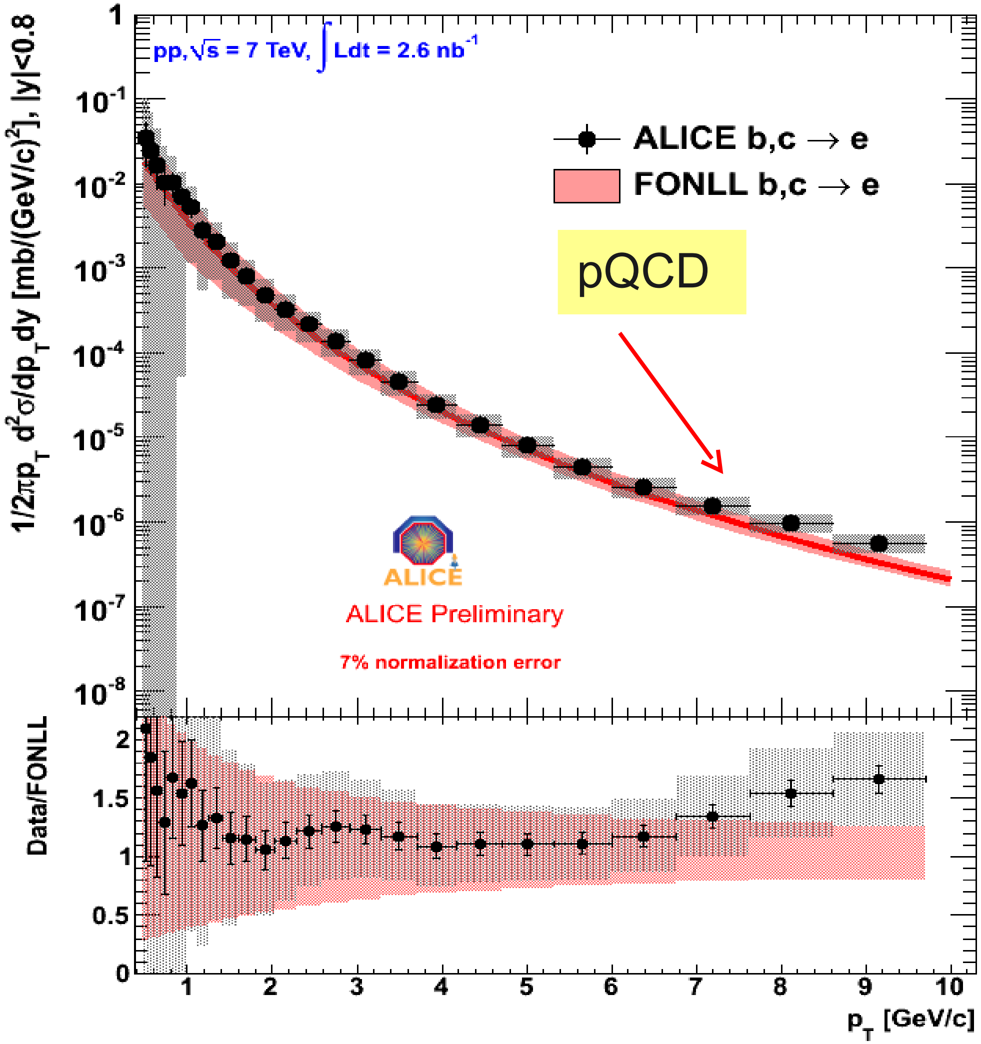


Pb+Pb

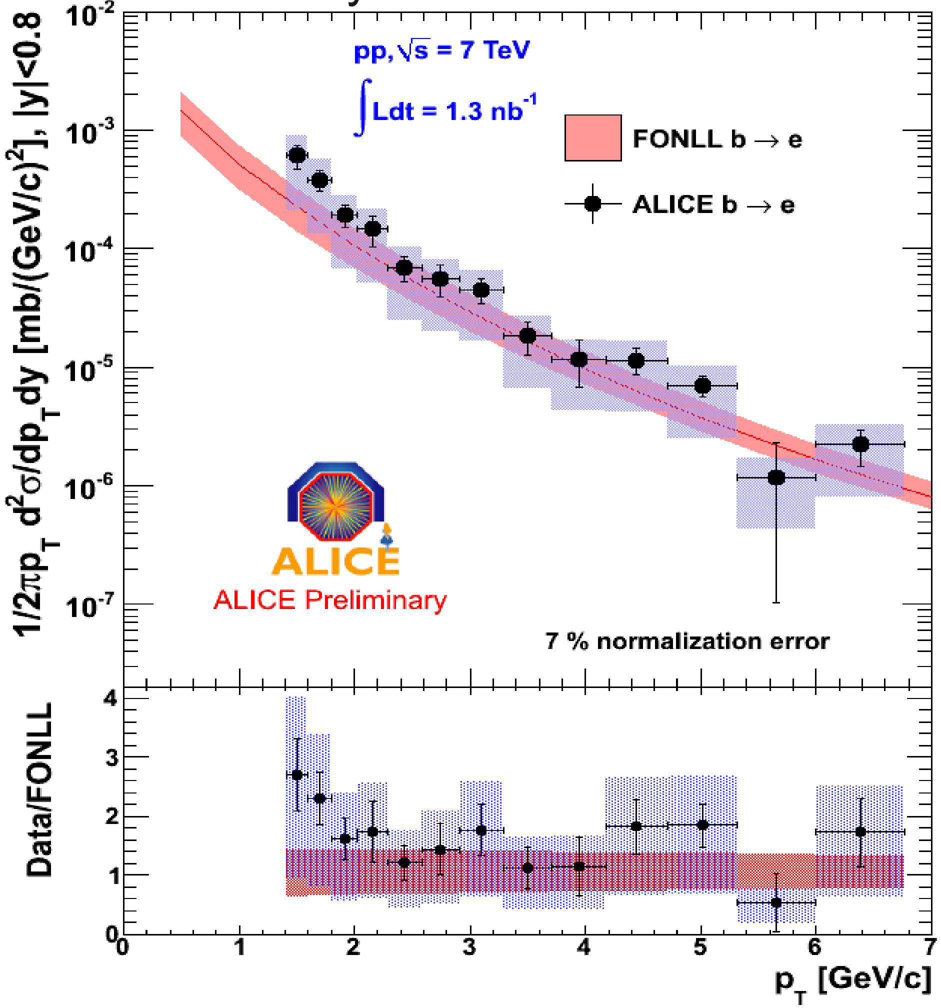
Heavy flavor spectra

Non-photonic electrons

Beauty + Charm

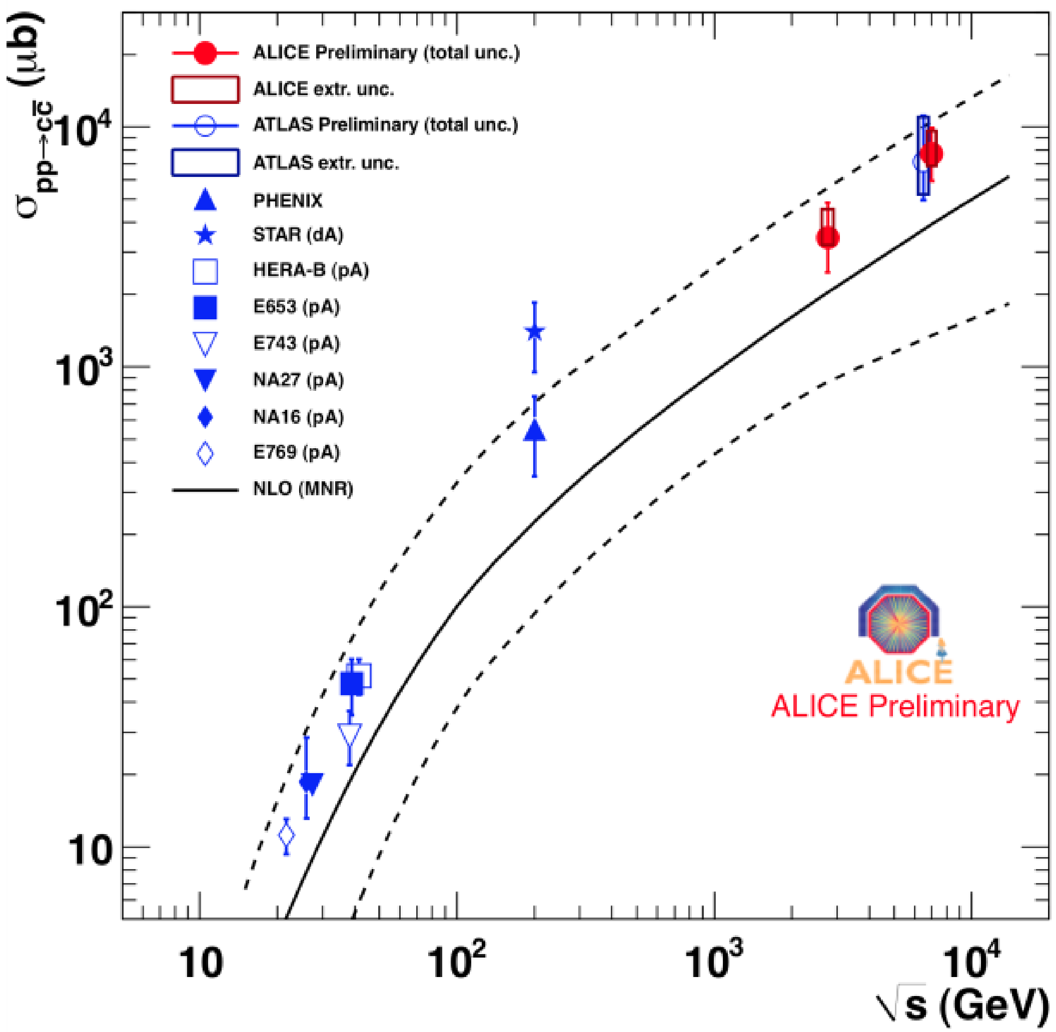


Beauty Electrons

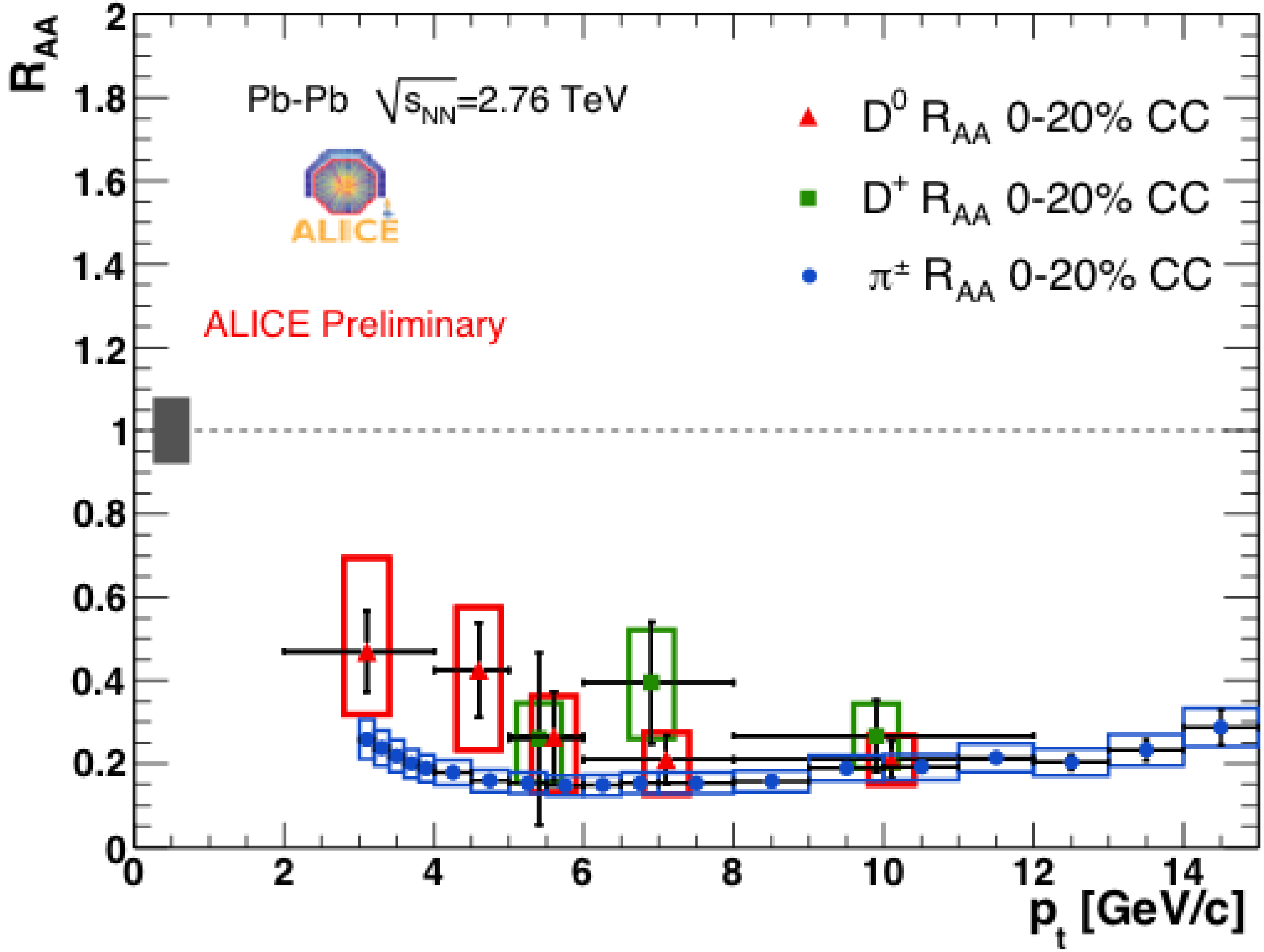


pp

Charm cross section



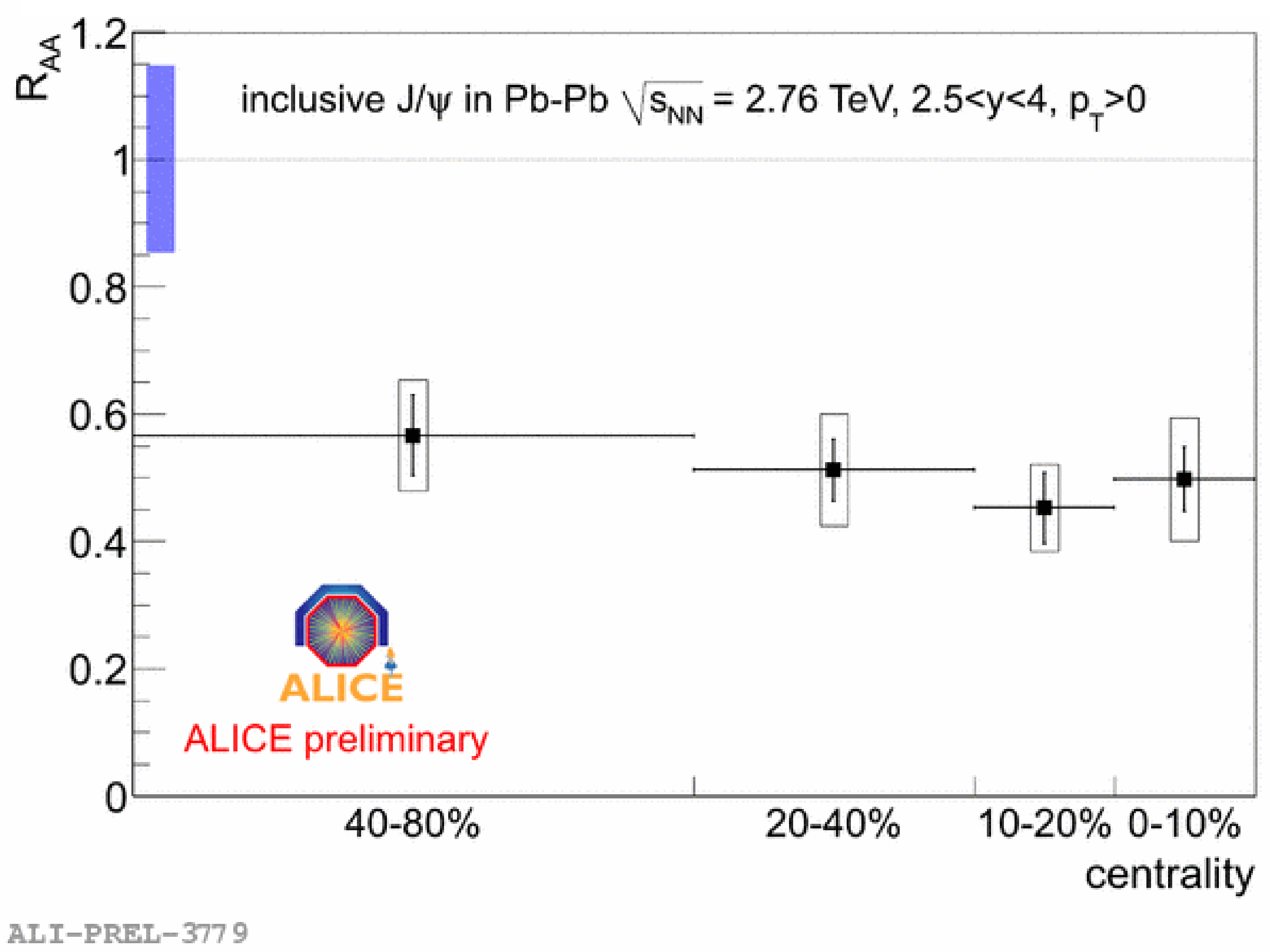
Charm nuclear modification factor



Pb+Pb

J/Ψ nuclear modification factor

Inclusive J/ψ $R_{AA}^{0\text{-}80\%} = 0.49 \pm 0.03$ (stat.) ± 0.08 (sys.)



Conclusions

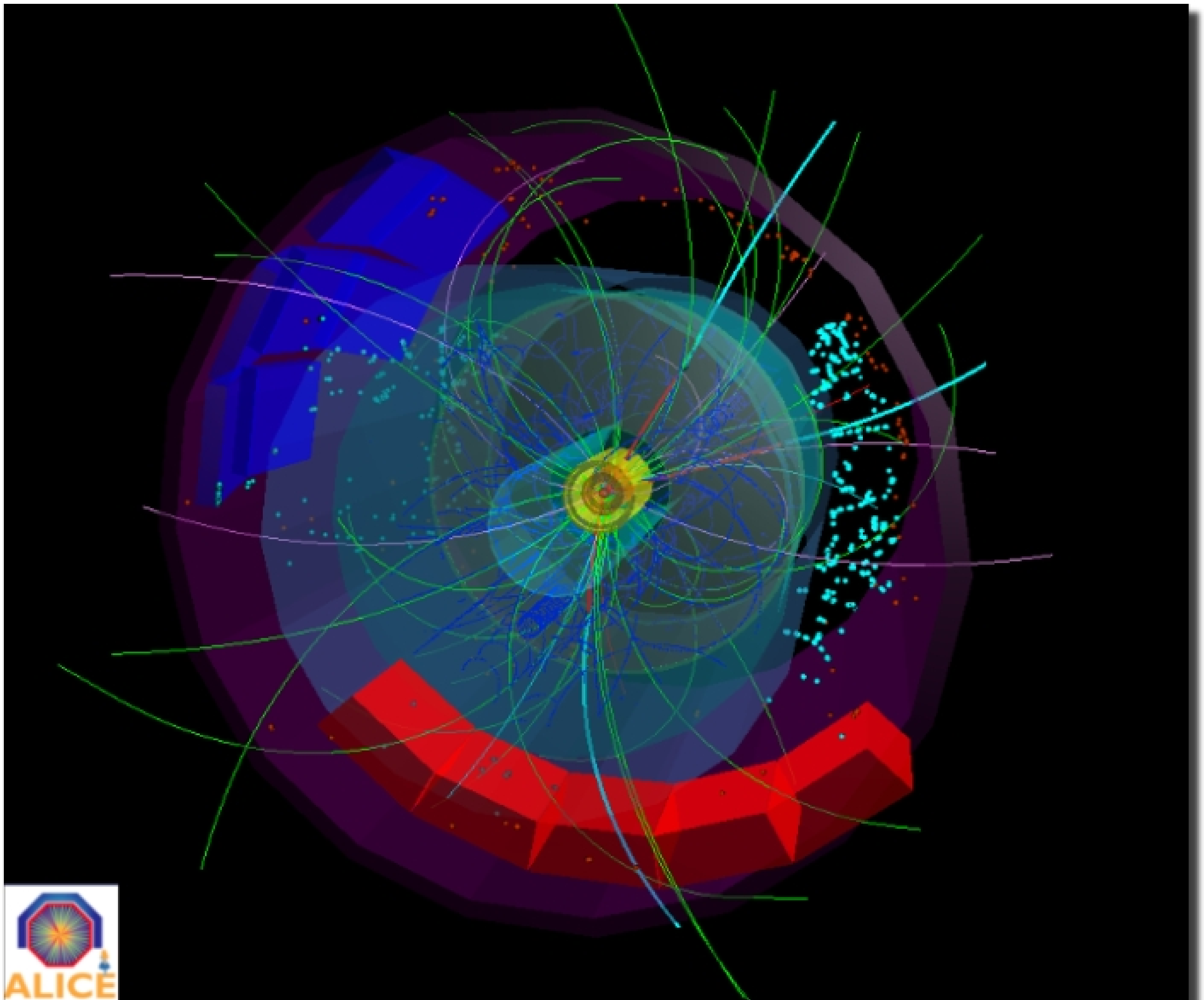
- Charged particle multiplicities and transverse energy
  - pp: higher than model predictions
  - Pb-Pb: higher than model predictions, centrality dependence similar to RHIC
- Charged particle spectra
  - pp: excellent PID measurements to low p_T, measurements of $\bar{p}/p$ ratio, failure of statistical models
  - Pb+Pb: suppression greater than RHIC, comparable suppression to RHIC at same $dN_{ch}/d\eta$, failure of hydro models to describe protons
- Strange particles
  - pp: models fail significantly
  - Pb+Pb: baryon enhancement, Λ & K^0_S suppression similar
- Heavy flavor
  - pp: charm cross sections measured, separation of charm & beauty
  - Pb+Pb: suppression of heavy flavor similar to charged particles

Many results not covered

- HBT correlations
- Hydrodynamical flow
- Di-hadron correlations
- Charged track jets
- Neutral mesons
- Resonances
- Diffraction in pp
- Ultraperipheral Pb+Pb collisions
- CP violation
- p_T fluctuations

Backup slides

p+p collisions



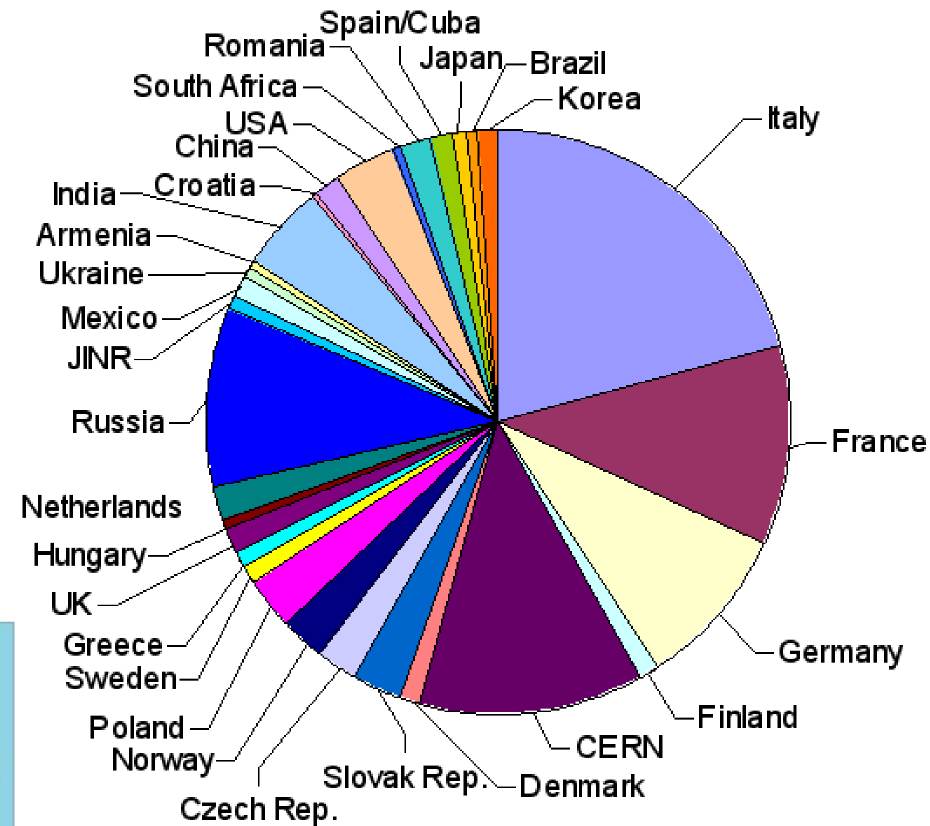
The ALICE Collaboration

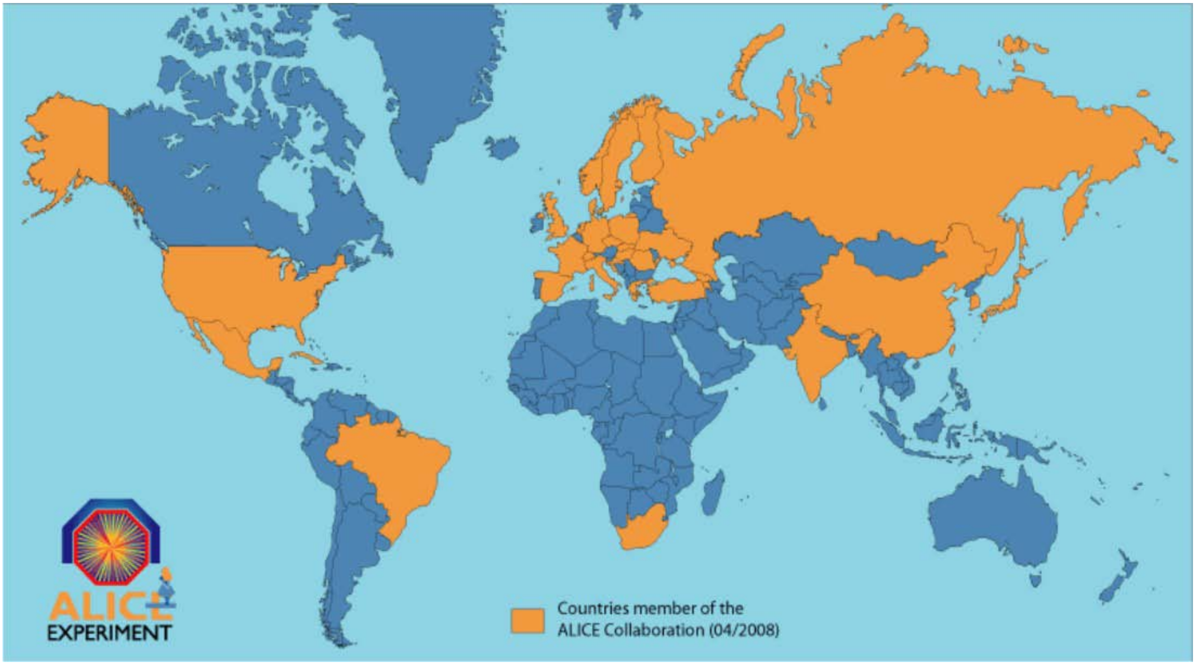
~1000 Members
63% from CERN member states

~30 Countries

~100 Institutes

~150 MCHF capital cost (+magnet)



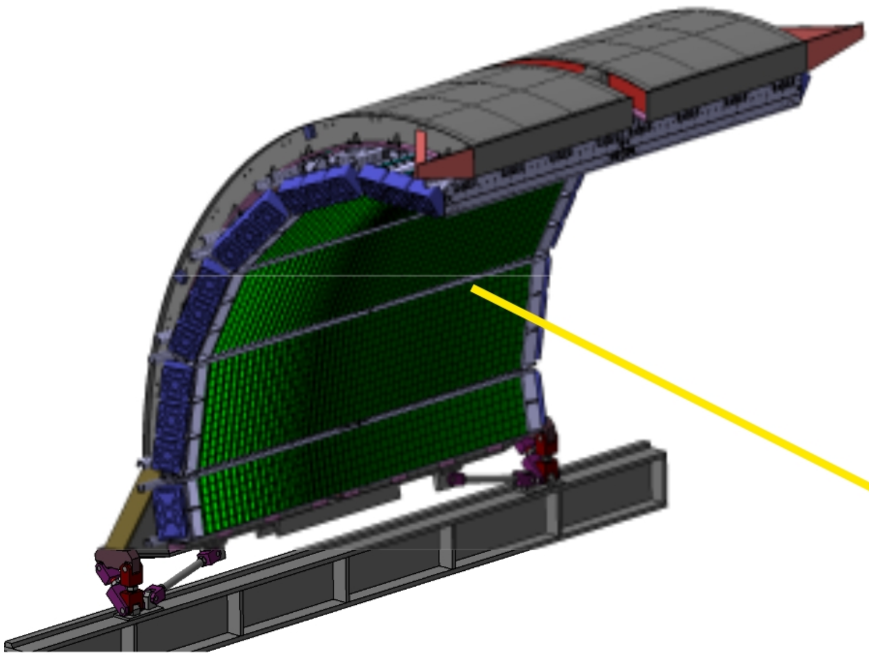


US ALICE

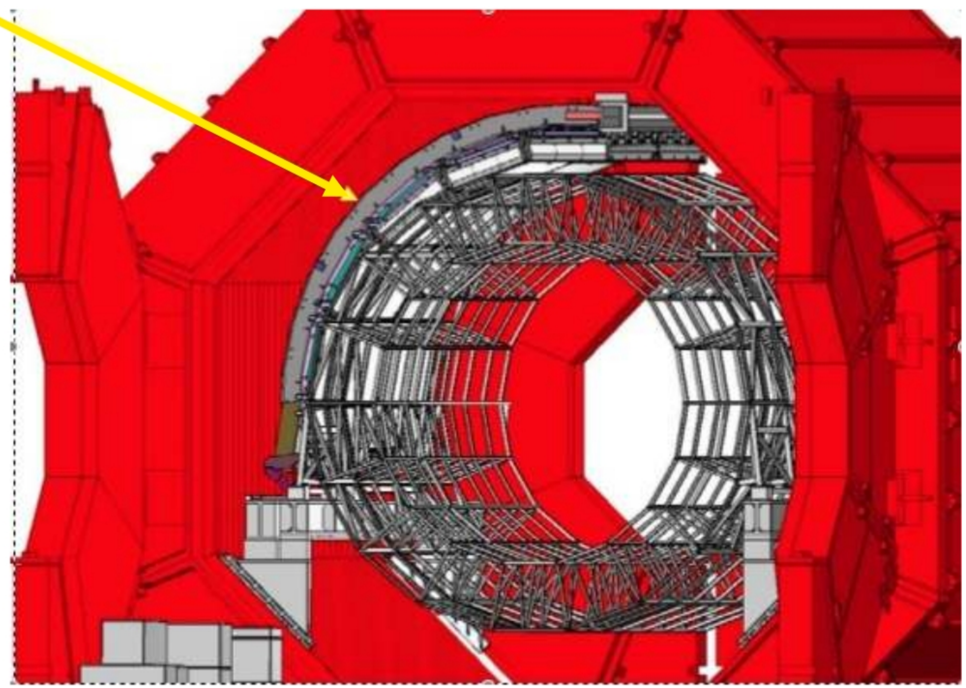
11 Institutions53 members (inc. 12 grad. Students)

Cal. St. U. –San Luis Obispo, Creighton University,University of Houston, Lawrence Berkeley Nat. Lab,Lawrence Livermore Nat. Lab, Oak Ridge Nat. Lab,Ohio State University, Purdue University, University of Tennessee, Wayne State University,Yale University

EMCal



Current coverage:
$\Delta\eta=1.4, \Delta\varphi=39^{\circ}$ ($R\approx0.3$ max)
Full calorimeter installation scheduled for 2012



- Lead-scintillator sampling calorimeter
- 13 k towers
- Each tower $\Delta\eta \times \Delta\varphi = 0.014 \times 0.014$
- Shashlik geometry
- Avalanche phototodiodes
- $\Delta\eta=1.4, \Delta\varphi=107^{\circ}$
- $\sigma(E)/E=0.12/\sqrt{E} + 0.02$

ALICE detectors and acceptance

Central barrel $-0.9 < \eta < 0.9$

- $\Delta\varphi = 2\pi$ tracking, PID (TPC/ITS/TRD/ToF)
- single arm RICH (HMPID)
- single arm e.m. cal (PHOS)
- jet calorimeter (EMCal)

Forward muon arm $-2.4 < \eta < -4$

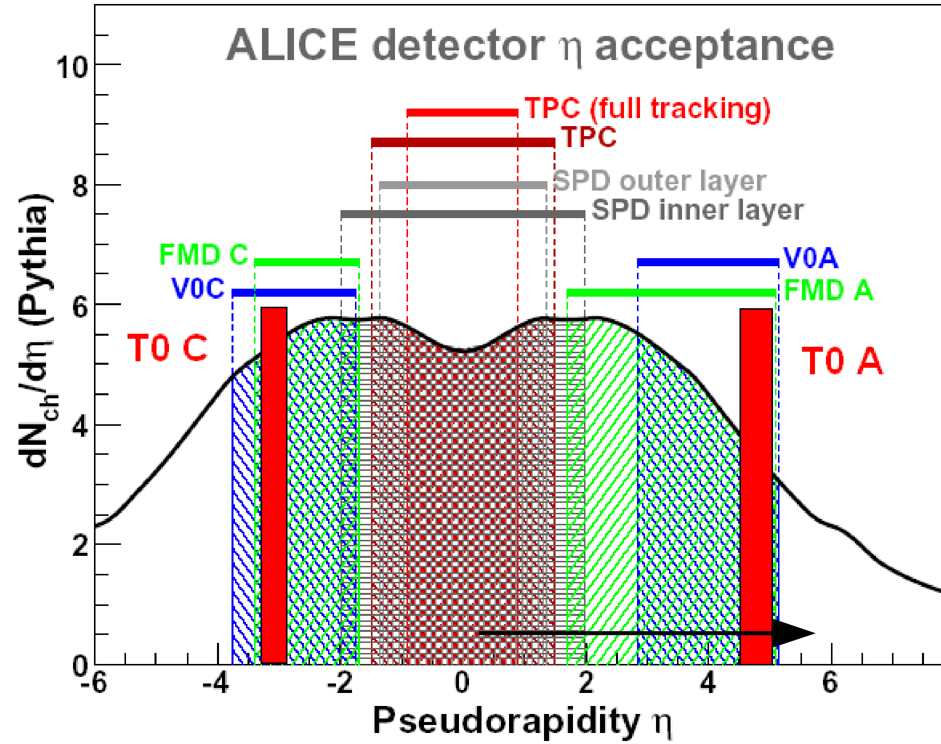
- absorber, 3 T-m dipole magnet
  5 tracking + 2 trigger planes

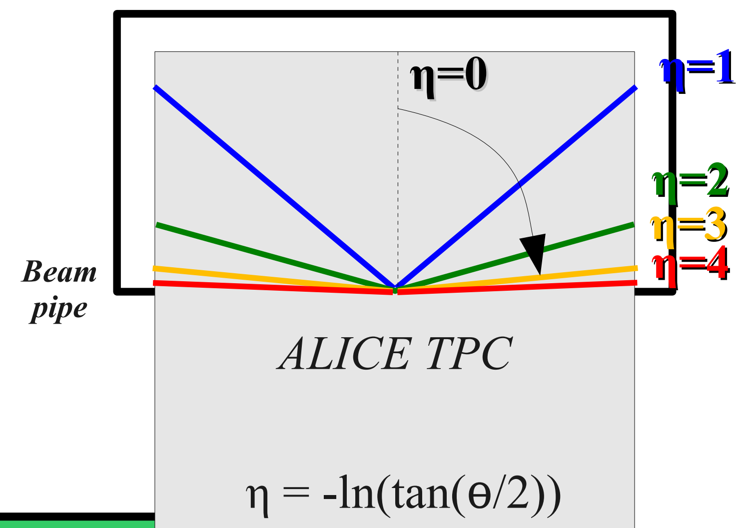
Multiplicity detectors $-3.4 < \eta < 5$

- including photon counting in PMD

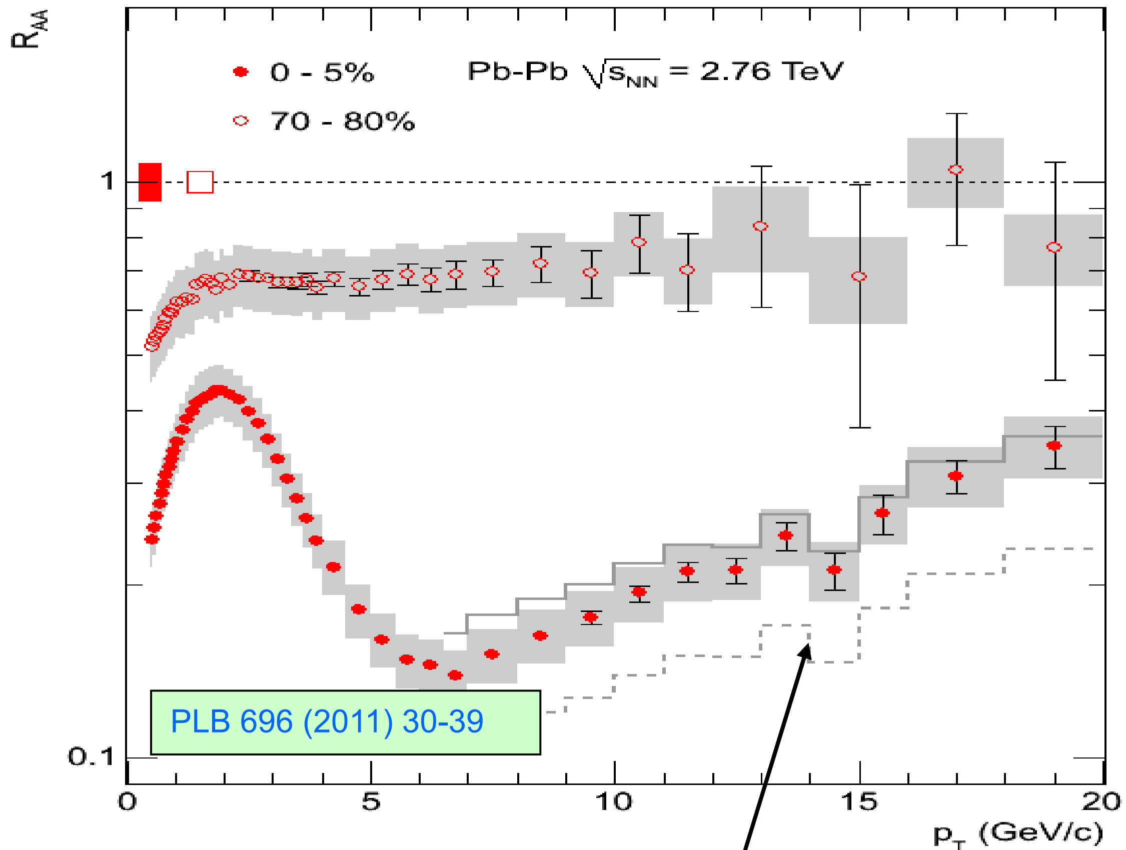
Trigger & timing detectors

- 6 Zero Degree Calorimeters
- T0:ring of quartz window PMT's
- V0:ring of scintillator Paddles





Charged Particle R_{AA}

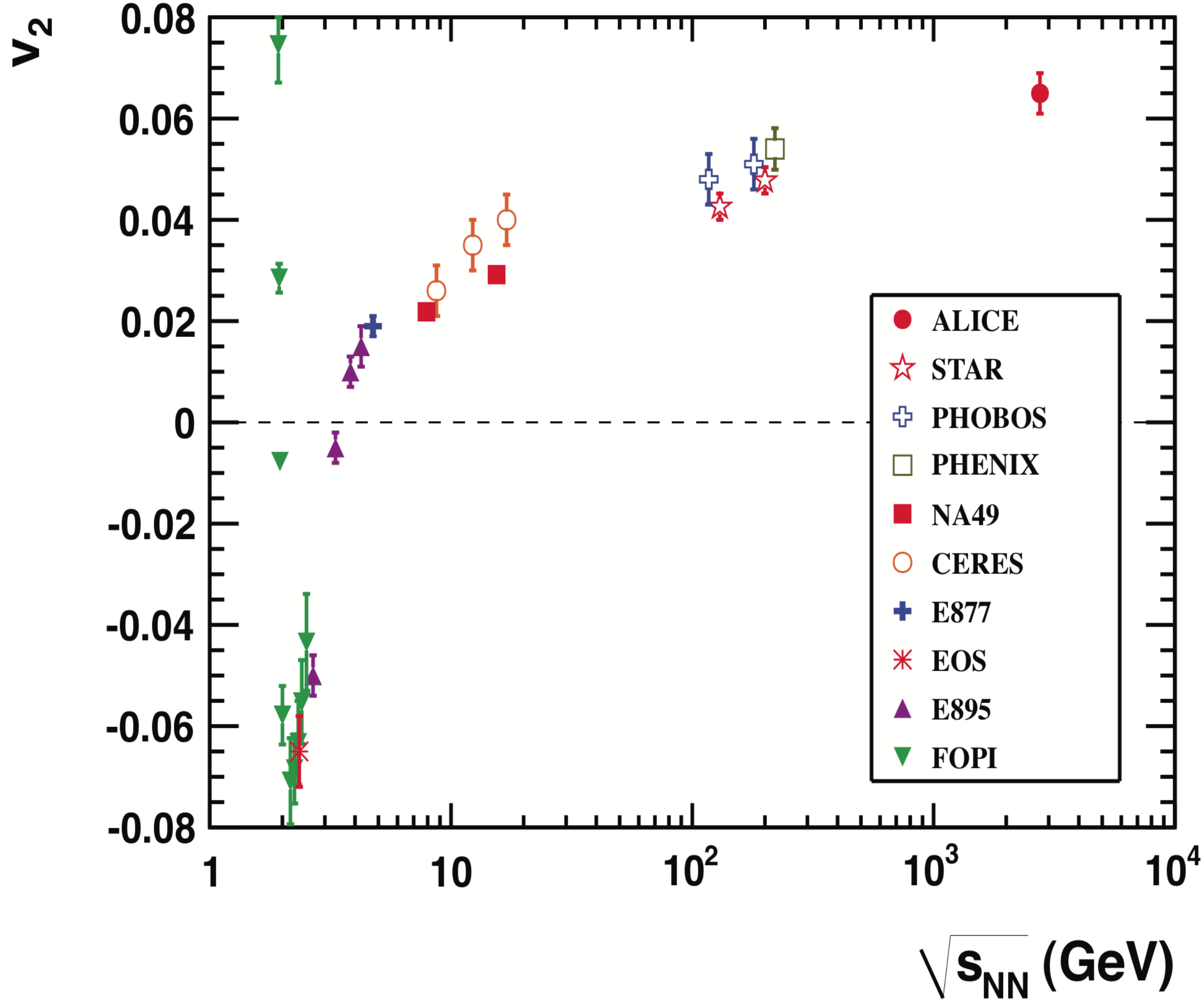


Extrapolated reference
=> large syst. error

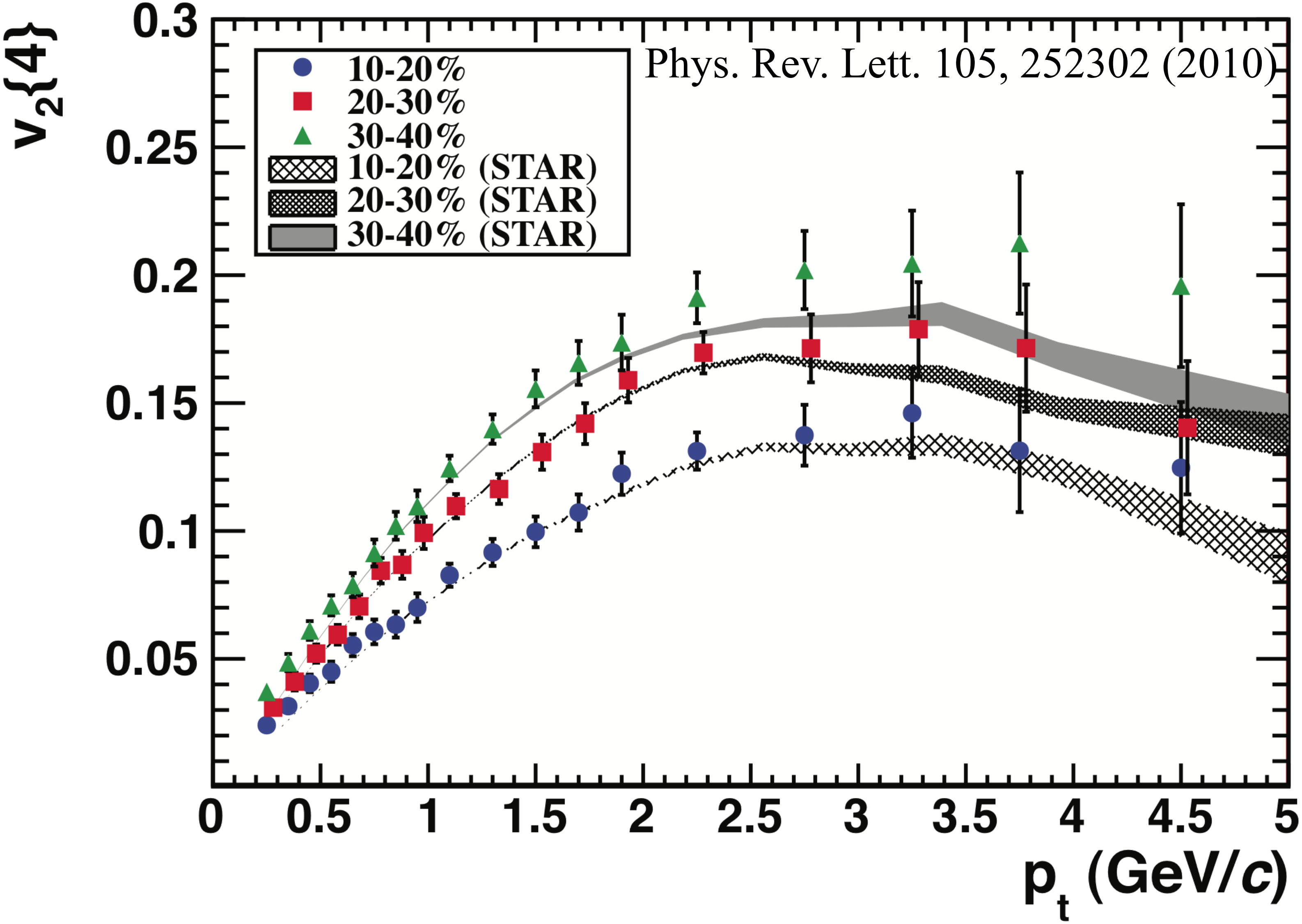
$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle\,(1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$

Elliptic flow at 2.76 TeV

Phys. Rev. Lett. 105, 252302 (2010)

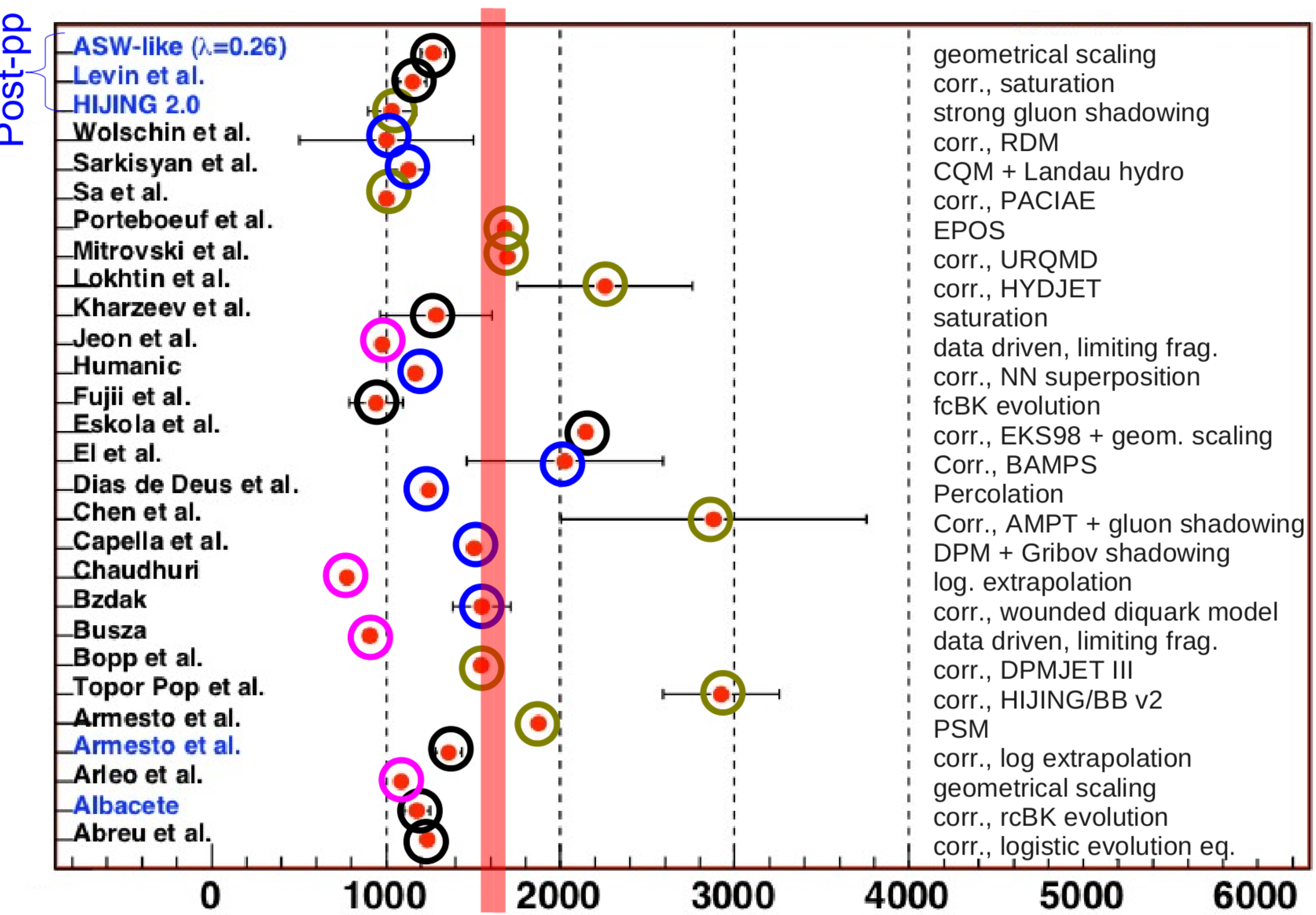


Elliptic flow at 2.76 TeV



$dN_{ch}/d\eta$ in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV

Measured dNch/dη = 1584 ± 76 (sys.) PRL, 105, 252301 (2010)



Compilation from N. Armesto

Monte Carlo, coherence via collectivity, strong gluon saturation

Saturation ideas

Data driven, limiting frag.

Miscellaneous: superposition, WNM, diffusion eqs., DPM + shadowing/ percolation

Pb+Pb