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2263-35

Beyond the Standard Model: Results with the 7 TeV LHC Collision Data

19 - 23 September 2011

Results from the ALICE experiment

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Beyond the Standard Model: Results with the 7 TeV LHC Collision Data
19-23 September 2011, Trieste, Italy

LATEST RESULTS WITH THE ALICE EXPERIMENT AT LHC

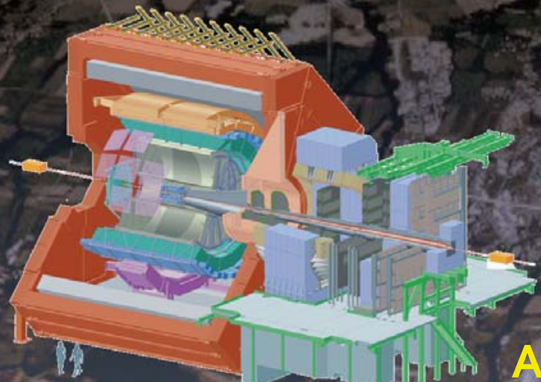
C. Zampolli for the ALICE Collaboration

Outline

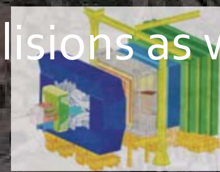
- The ALICE experiment
- pp collisions @ 7 TeV
  - Results
- PbPb collisions @ 2.76 TeV
  - Centrality
  - Results
- Summary and conclusions

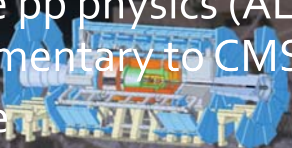
The ALICE Experiment at LHC

- A Large Ion Collider Experiment is the general-purpose experiment at the CERN Large Hadron Collider (LHC) designed for heavy-ion physics.
- **The ultimate goal is the study of the QGP**
- Very rich Heavy-ion physics program spanning from the global charateristics of the event (multiplicities, η distributions…), to the properties of the system produced in the collisions (hadrochemistry, temperature, energy density, HBT, elliptic flow, jet…)
  - Precise tracking (low B field, low material budget) and performant Particle Identification required



- ALICE has interest in pp collisions as well
  - Provide reference for PbPb
  - Genuine pp physics (ALICE complementary to CMS and ATLAS)
  - MC tune
  - …





A Large Ion Collider Experiment

ALICE Detectors - requirements

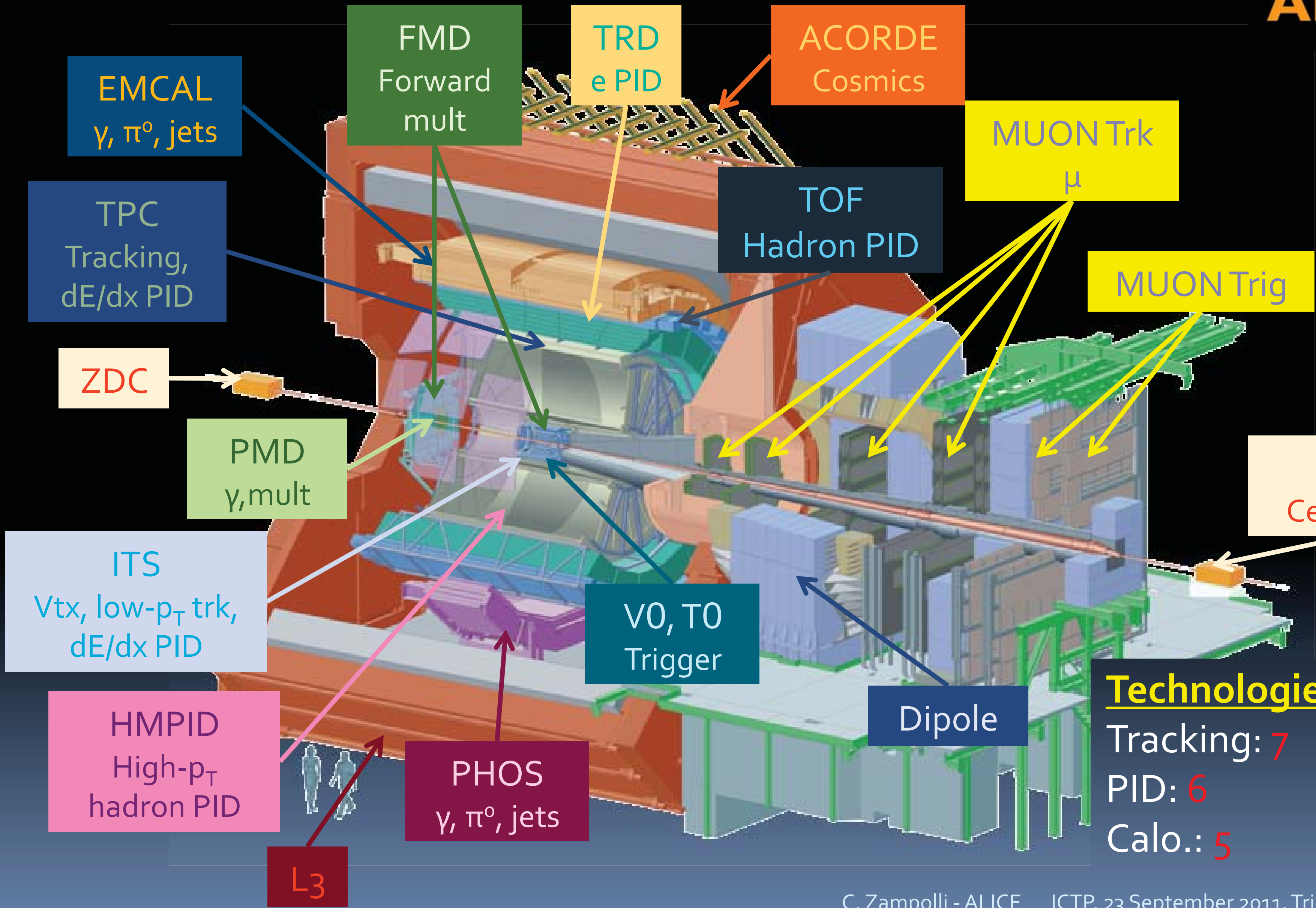
- Dedicated to HI physics
  - Must be comprehensive and able to cover all the interesting observables
  - Very robust tracking from 0.1 to 100 GeV/c
    - High-granularity 3D detectors (TPC, ITS)
    - Low material budget
  - PID over a very wide momentum range
    - Use all known technologies
  - Hadrons, leptons, photons
  - Excellent vertexing

→ Drawbacks:

→slow detectors

→Limited η acceptance

ALICE Detectors - Setup



Technologies: 18

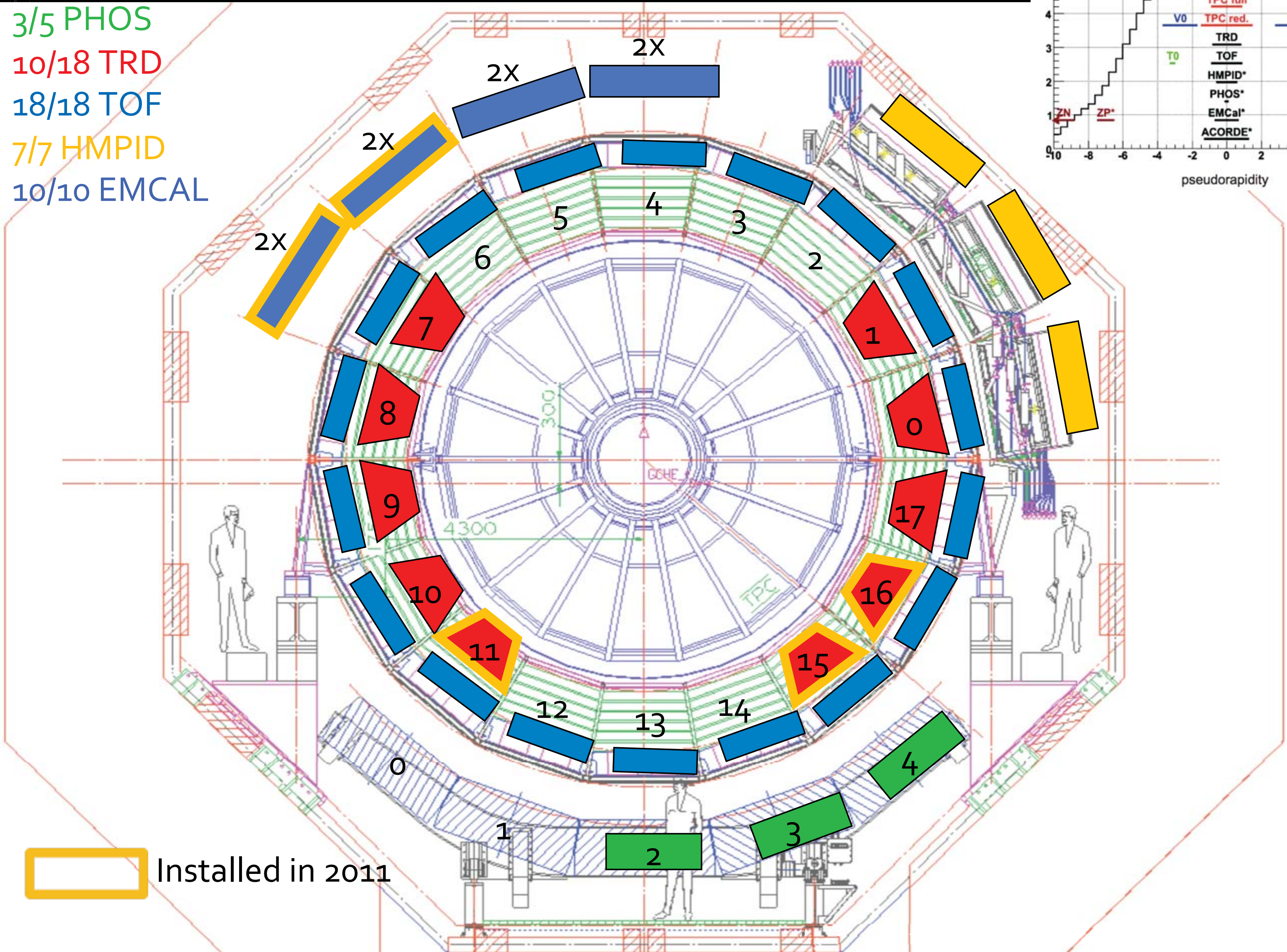
Tracking: 7

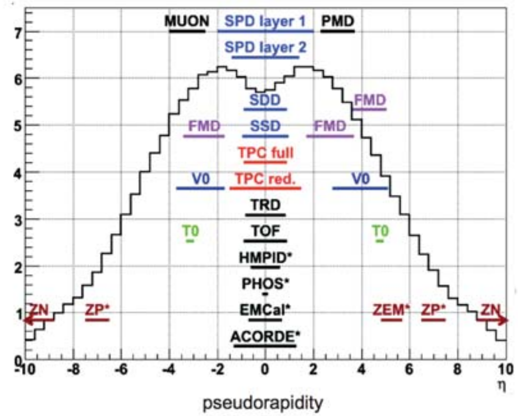
PID: 6

Calo.: 5

ALICE Configuration

3/5 PHOS
10/18 TRD
18/18 TOF
7/7 HMPID
10/10 EMCAL





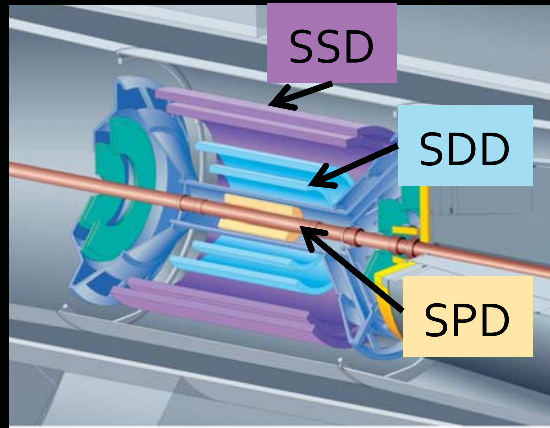
Installed in 2011

ALICE Data Taking

Year of Data Taking	Collision System	Energy	N. of Events, trigger
2009	pp	900 GeV	300K, MB
2009	pp	2.36 TeV	~40K, MB
2010	pp	900 GeV	~8M, MB
2010	pp	7 TeV	~980M, MB
			~50M, μ trigger
			~16M, high mult
2010	PbPb	2.76 TeV/N	>50M, MB
2011	pp	2.76 TeV	~40M, MB
			~9M, μ trigger
			~1.5M, high mult
		7 TeV	>700M, MB (*)
			~200M, μ trigger (*)

(*) being processed

Trigger and Event Selection



- Minimum Bias Trigger
  - Coincidence among (in OR for pp):
    - SPD Fast-Or trigger (≥ 1-2 hits (pp-PbPb))
    - VZERO-A
    - VZERO-C

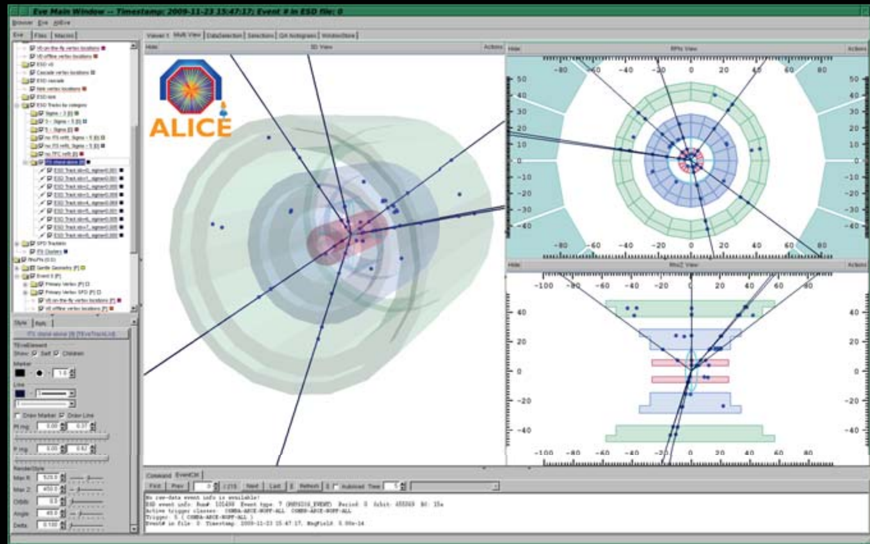
    → High efficiency wrt hadronic cross section (PbPb)

    → Requirements changed during PbPb data taking period
- Ultra-peripheral trigger (PbPb)
  - ≥ 3 TOF maxi-pads
- Single-muon and di-muon (2011) trigger
- Zero bias trigger
- Offline event selection
  - Background rejection
    - Beam background: VZERO and TPC tracks vs SPD tracklets info
    - EM processes (PbPb): ZDC

pp @ 7 TeV

23/11/2009, P2: When and Where Everything Began

- pp
  - Reference to PbPb
  - Soft and semi-hard QCD
  - High-mult pp events
- Starting @ 900 GeV…

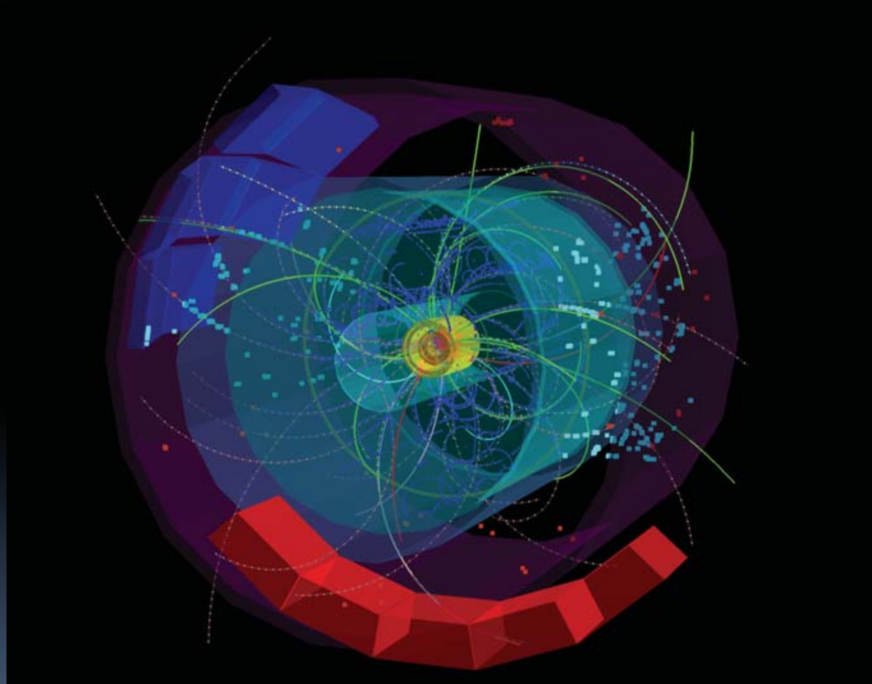


First publication "*First proton–proton collisions at the LHC as observed with the ALICE detector: measurement of the charged-particle pseudorapidity density at $\sqrt{s}$=900 GeV*", Eur. Phys. J. C (2010) 65: 111-125 (January 2010)
with 284 events (and 1056 authors!)

23/11/2009, P2: When and Where Everything Began

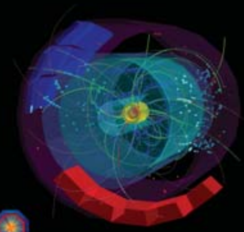
- pp
  - Reference to PbPb
  - Soft and semi-hard QCD
  - High-mult pp events
- Starting @ 900 GeV…

…to 7 TeV



ALICE event display of a 7 TeV collision in the central barrel

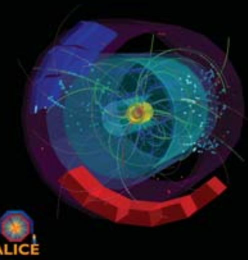
ALICE pp publications



▪ N_{ch} multiplicity & distributions:	
▫ 900 GeV	EPJC: Vol. 65 (2010) 111
▫ 900 GeV, 2.36 TeV	EPJC: Vol. 68 (2010) 89
▫ 7 TeV	EPJC: Vol. 68 (2010) 345
▪ $\bar{p}/p$ ratio (900 GeV & 7 TeV)	PRL: Vol. 105 (2010) 072002
▪ Momentum distributions (900 GeV)	PLB: Vol. 693 (2010) 53
▪ Bose-Einstein correlations (900 GeV)	PRD: Vol. 82 (2010) 052001
▪ Strangeness (K^o, Λ, Ξ, Ω, ϕ) (900 GeV)	EPJC Vol. 71 (2011) 1594
▪ Id charged particle spectra (900 GeV)	EPJC Vol. 71 (2011) 1655
▪ Pion B-E correlations (900 GeV & 7 TeV)	Sub. to PRD, arXiv 1101.3665
▪ y and p_T of inclusive J/ψ -> μμ, e^+e- (7 TeV)	Acc. by PLB, arXiv 1105.0380

- Under final collab. Review
  - Multistrange
- Advanced
  - 7 TeV event properties (spectra, Id particles..)
  - D mesons
  - Di-hadron correlations
  - Event topology, underlying event
  - π^o
  - …

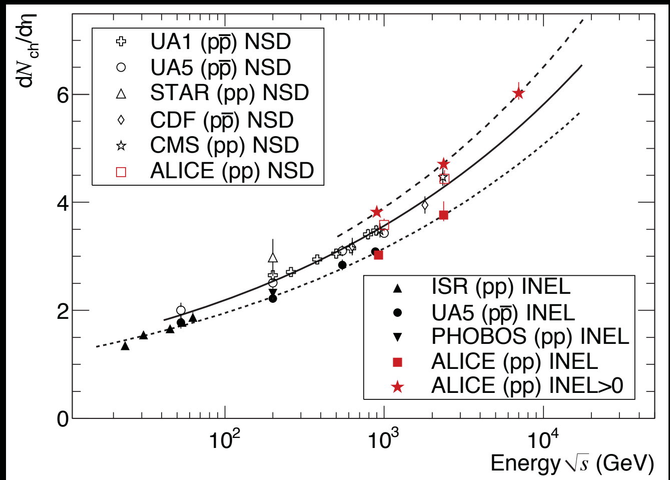
- Some well-ongoing analyses
  - Jet fragmentation
  - Photon multiplicity
  - Anti-nuclei production
  - …



$dN_{ch}/d\eta$

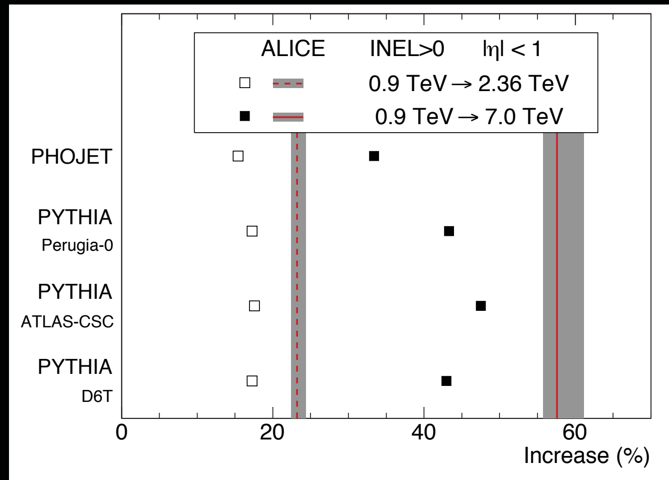
Energy dependence

Eur.Phys.J.C68:345-354,2010



Relative increase

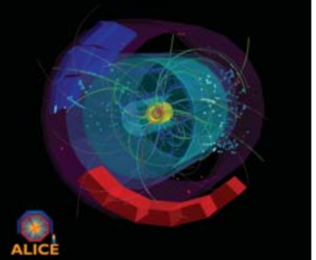
Eur.Phys.J.C68:345-354,2010



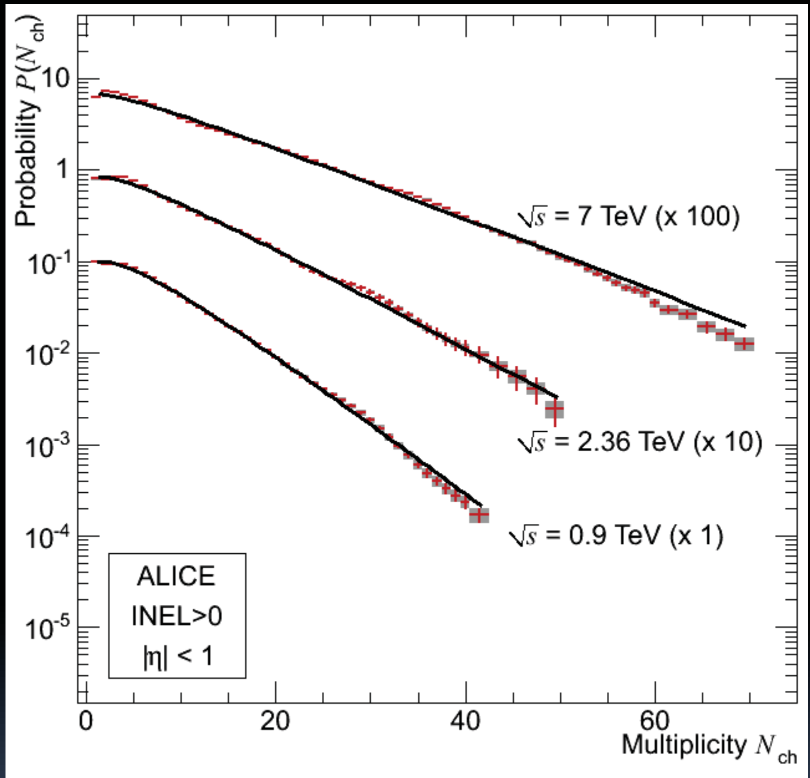
- Hadron- level definition used (INEL>0)
- Model dependent corrections and systematic error minimized
- $dN_{ch}/d\eta \sim \sqrt{s}^{0.2}$

- increase from 0.9 to 7 TeV ~ 57% (NSD) – but models predict ~35-45%

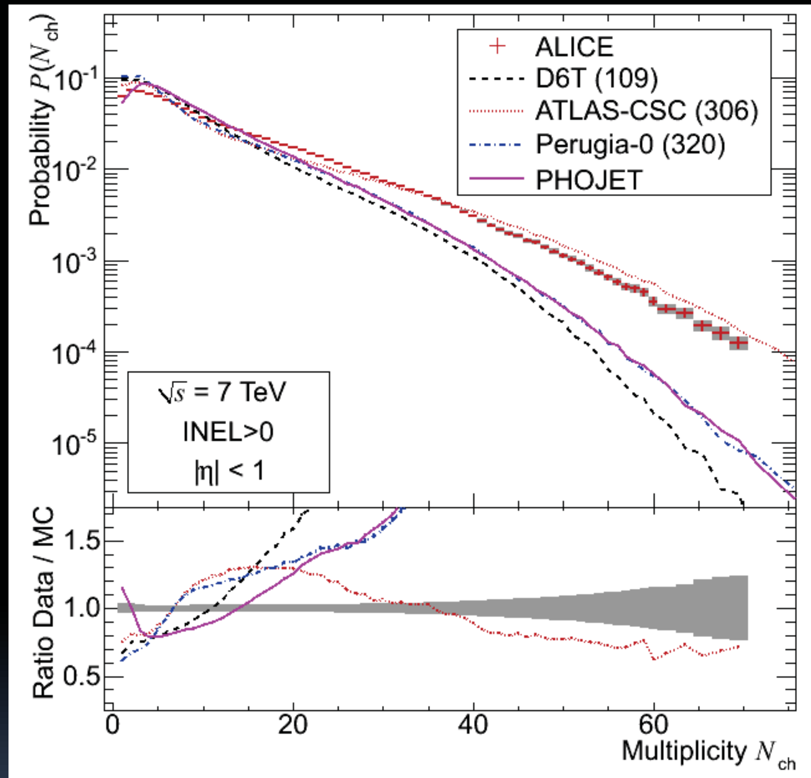
Multiplicity Distributions



Energy dependence



Model comparison

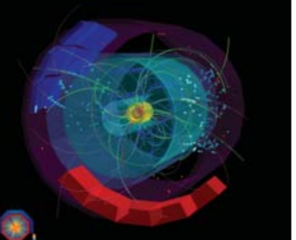


Eur.Phys.J.C68:345-354,2010

- Good description from NBD for all three energies

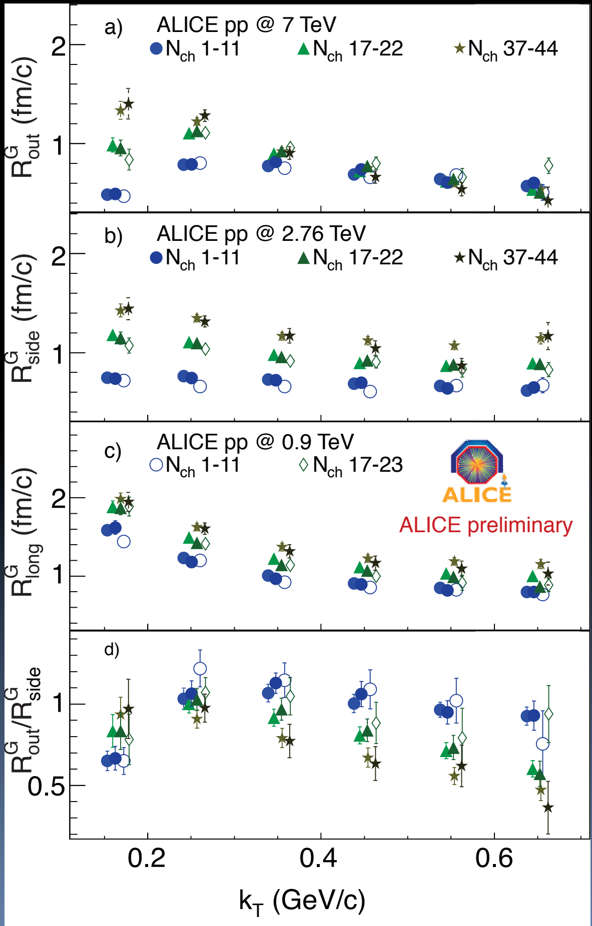
- Comparison with different MC models not satisfactory – increase at high multiplicity not reproduced

Femtoscopy

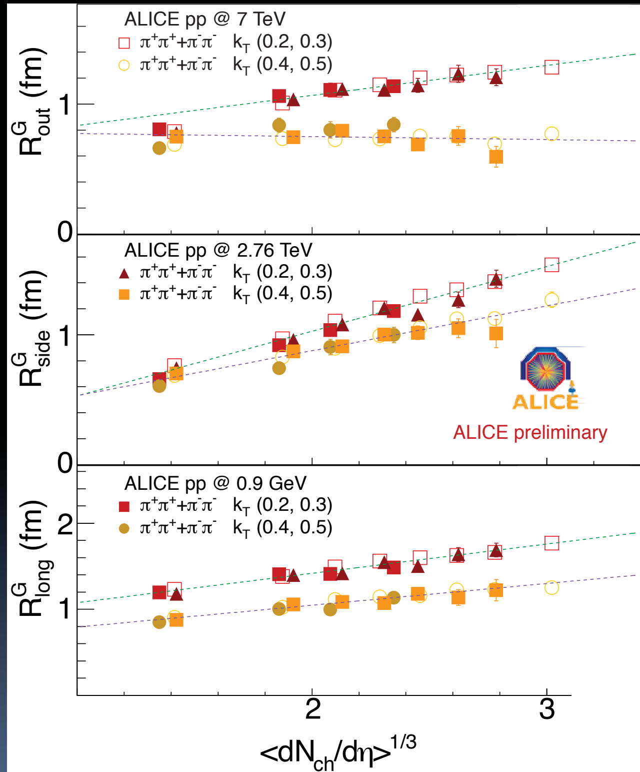


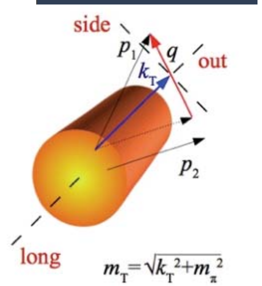
- To measure the size and the shape of the source

Energy independence of the 3 femtoscopic radii as a function of k_T

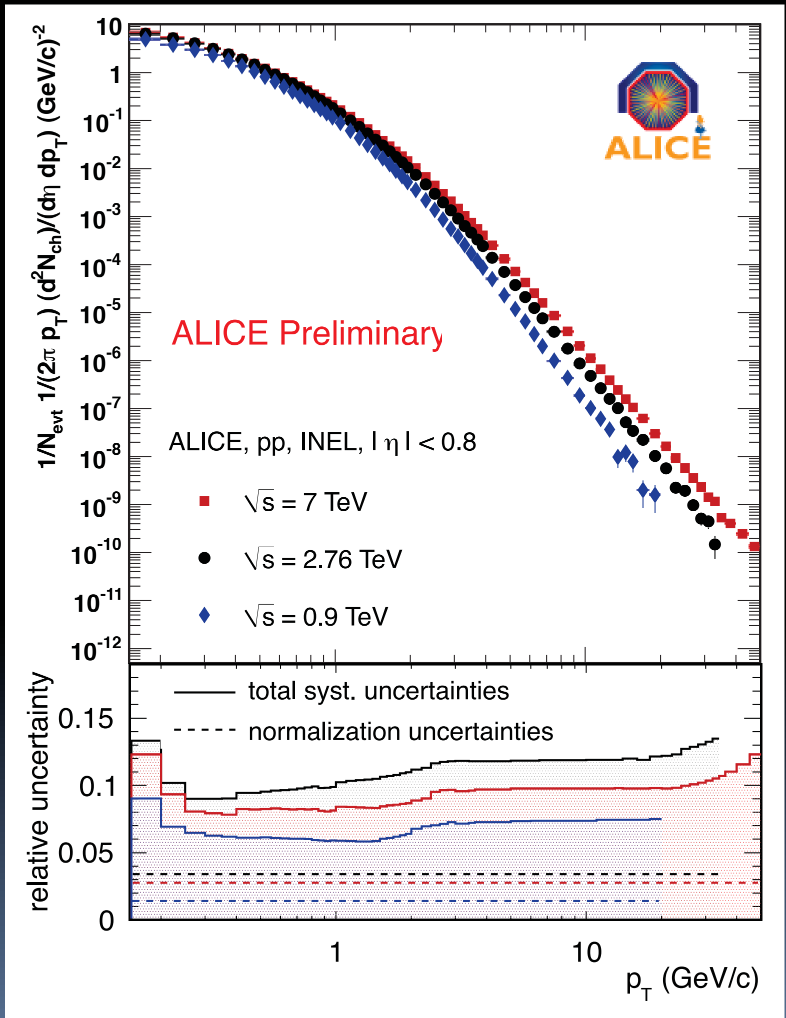


Linear scaling for the 3 femtoscopic radii, for every k_T, same for the 3 energies



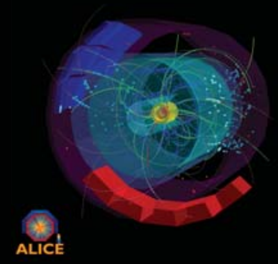


p_T Spectra of Charged Particles

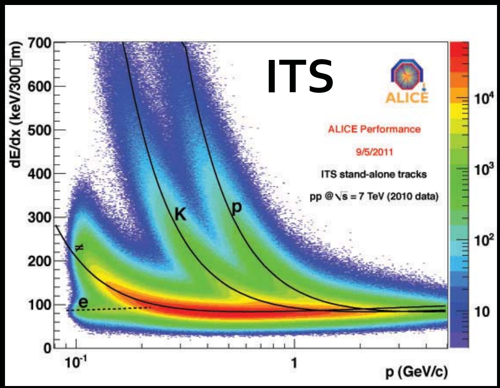


- pp p_T spectra measured up to 50 GeV/c (100 GeV/c with more statistics)
- pp reference for PbPb R_{AA} (see next slides) built from
  - pp data at 2.76 TeV, extrapolated at p_T > 30 GeV/c
  - Interpolation from 0.9 and 7 TeV data
  - NLO scaling of 0.9 and 7 TeV data

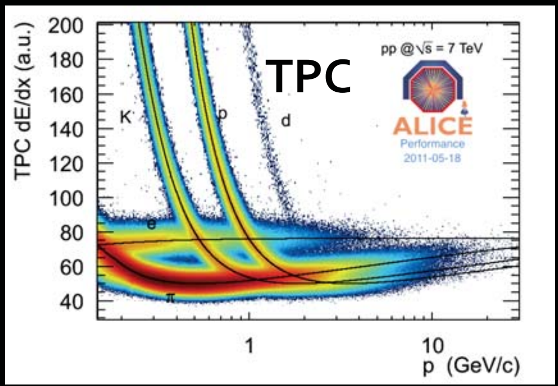
Identified Particle Spectra



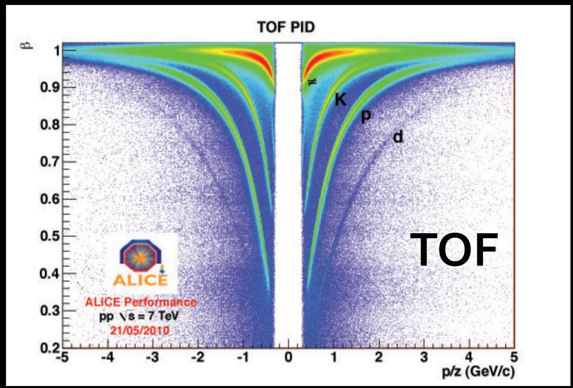
- 4 analyses combined, using the ALICE PID techniques in the central barrel



dE/dx at low momentum

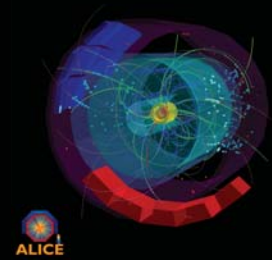


dE/dx up to ~50 GeV/c



TOF up to a few GeV/c

Identified Particle Spectra



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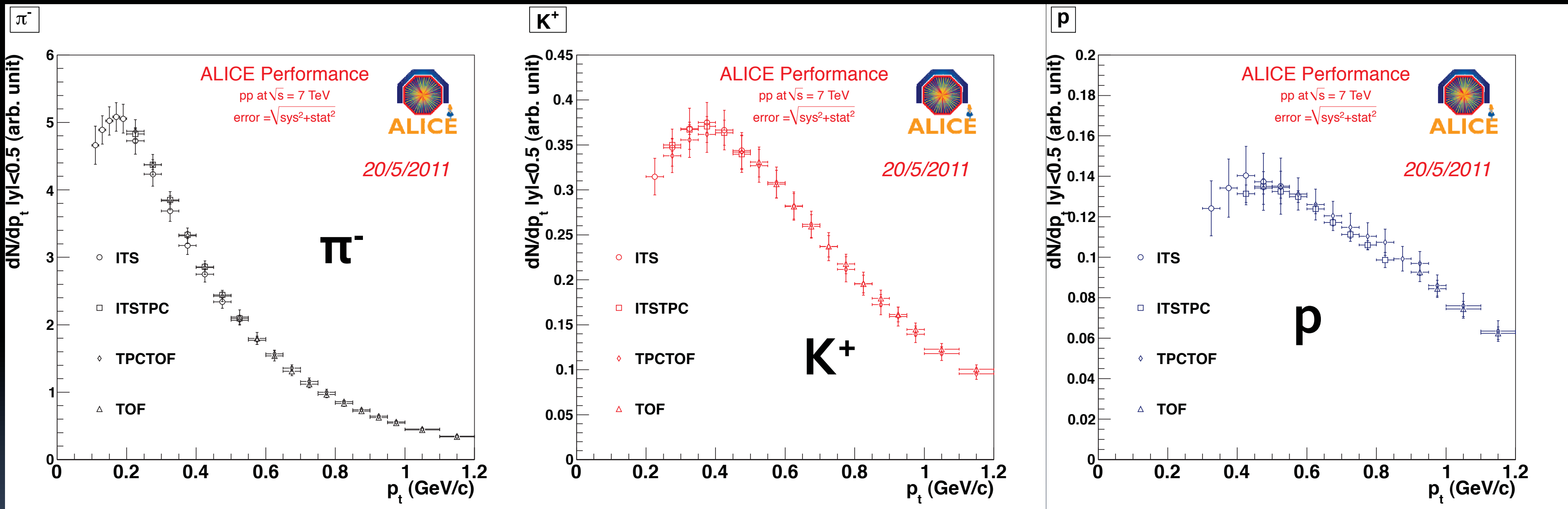
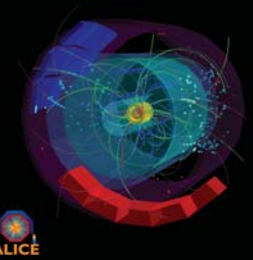


Very good agreement within uncertainties among the 4 methods for the three particle species

The same holds true for the opposite charges

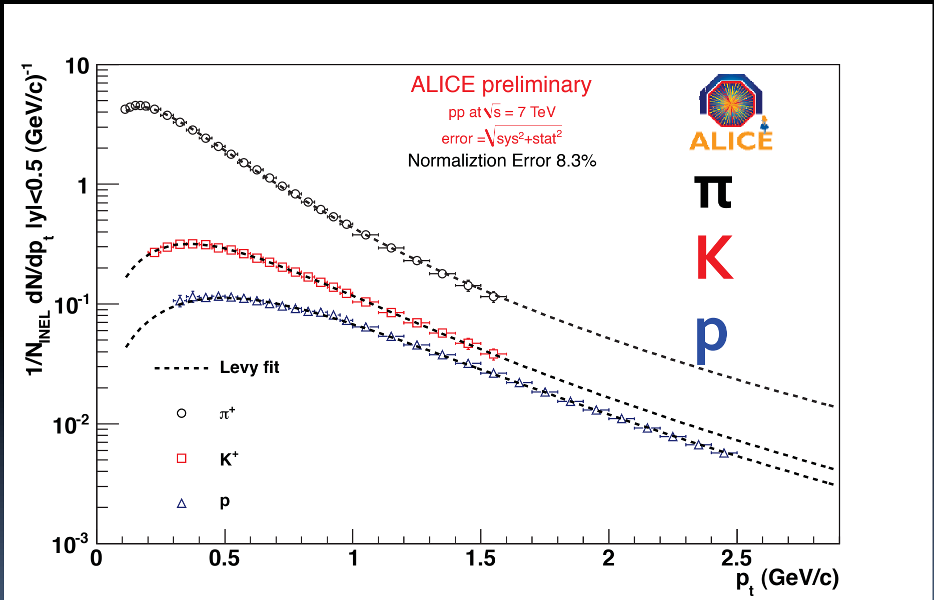
Identified Particle Spectra

results

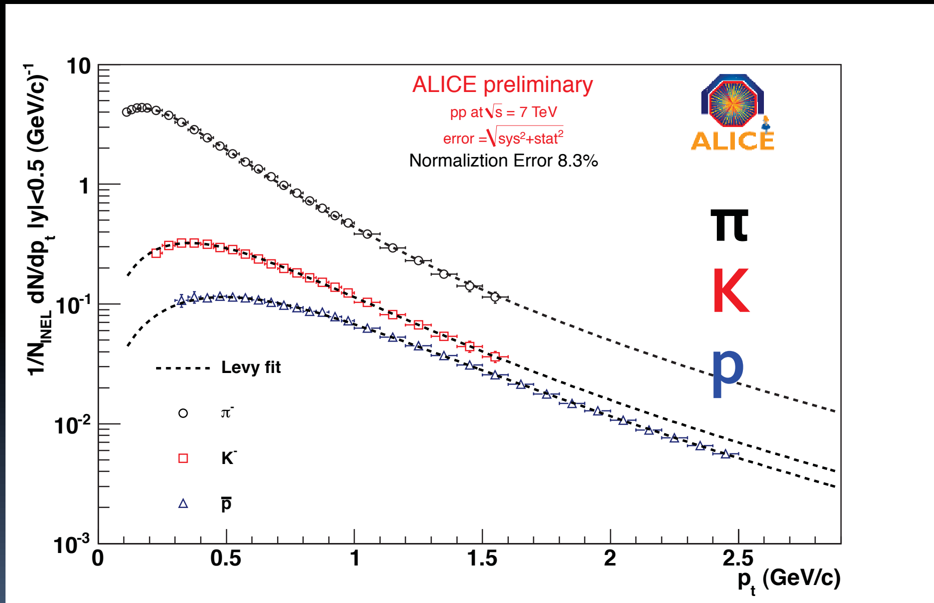


- 4 analyses combined, using the ALICE PID techniques in the central barrel
  - Minimum p_T = 0.1 (π), 0.2 (K), 0.3 (p) GeV/c

positive



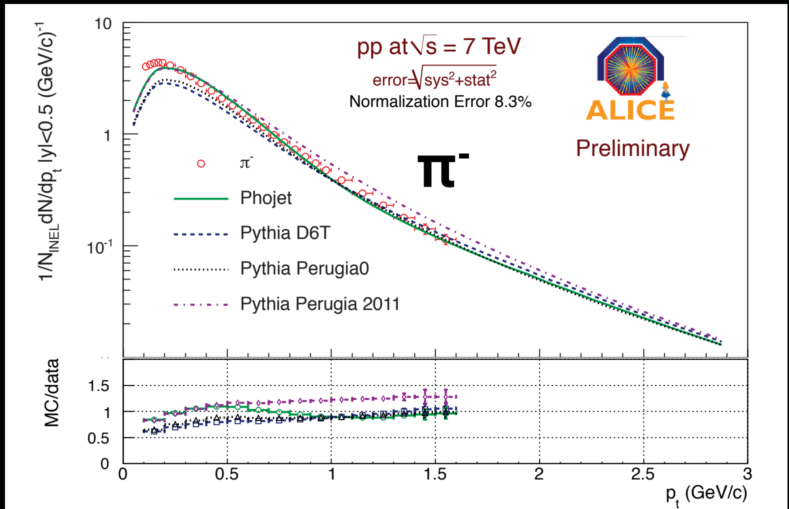
negative

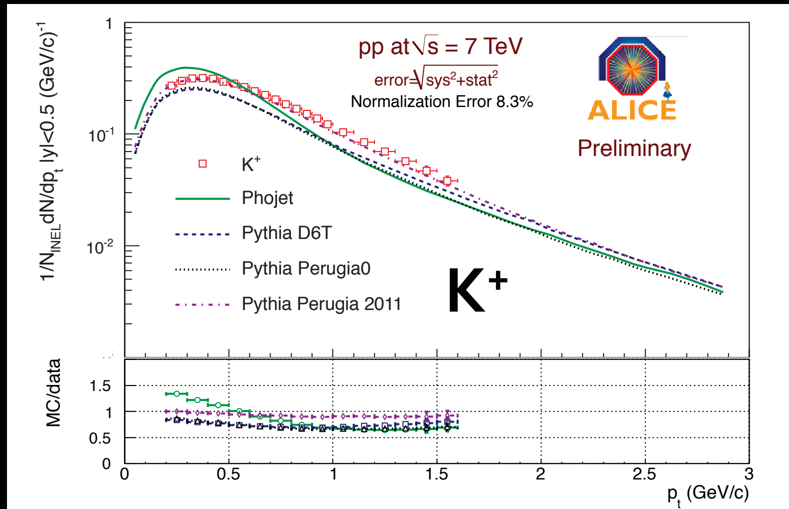


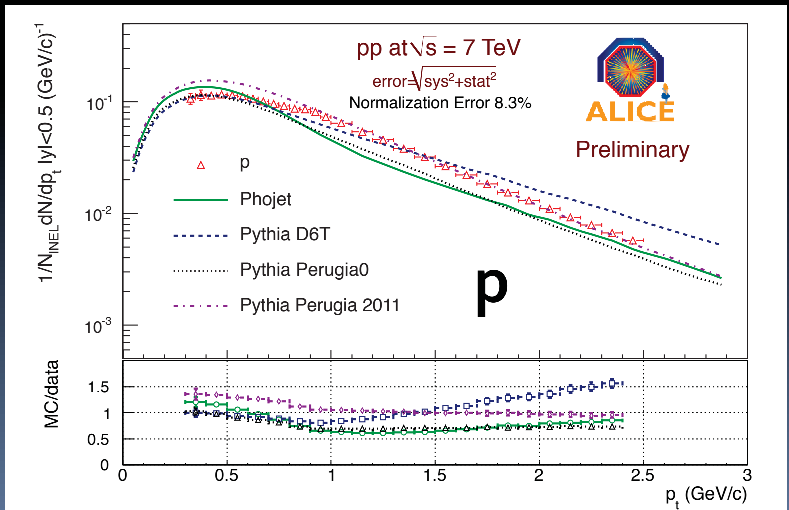
Lévi fit superimposed, used to extract the total yield and the <p_T>

Identified Particle Spectra

comparison to models







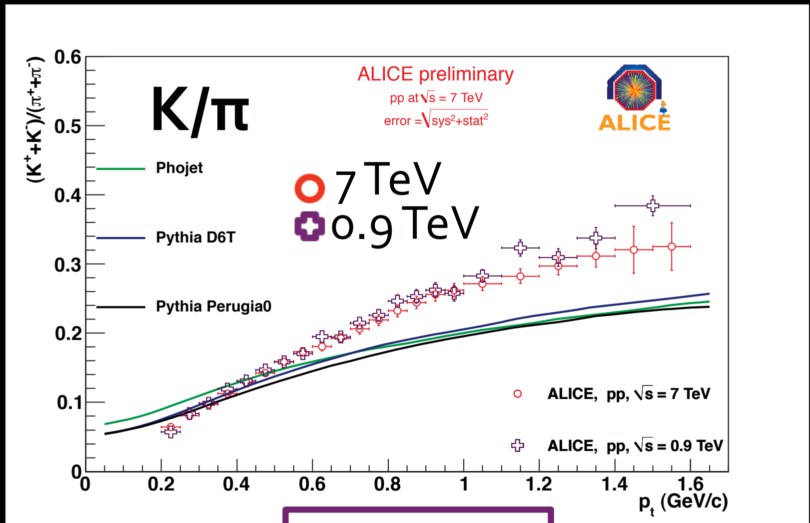
No satisfactory description of data from current MC models

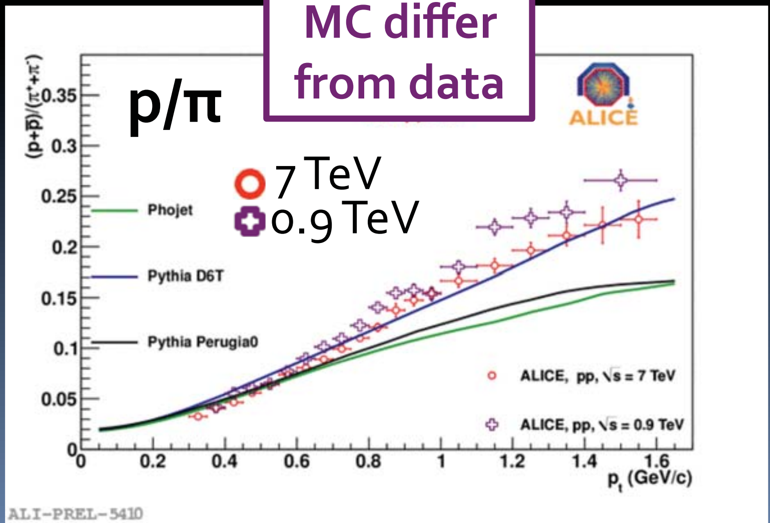
- Perugia 2011: ok for K (full range) and p (from p_T ~ 0.7) but overestimates π at high p_T

Identified Particle Spectra

ratios

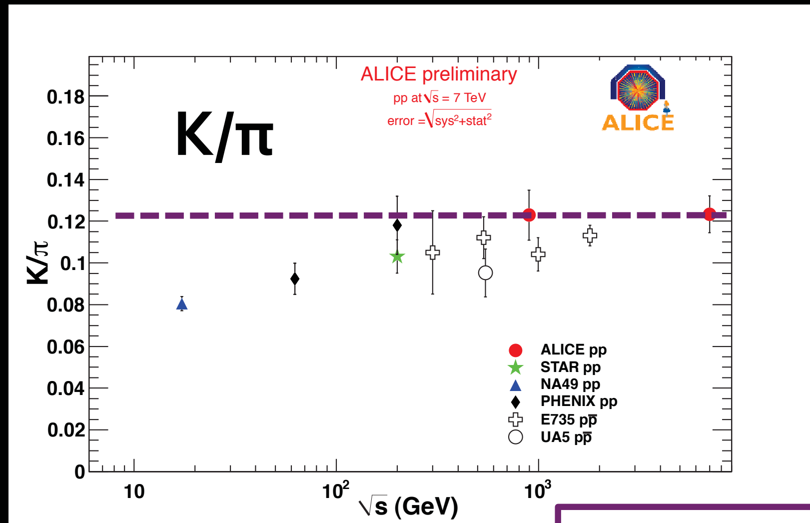
p_T dependence

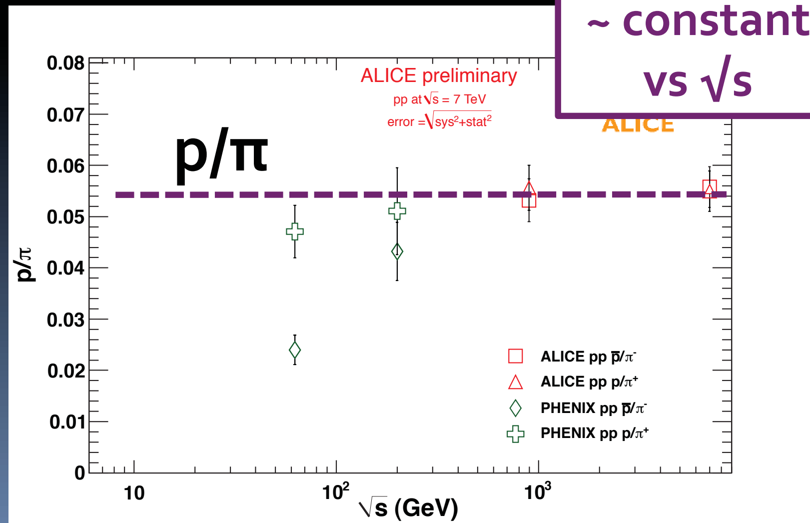




MC differ from data

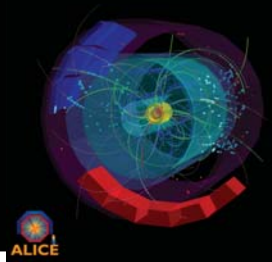
Energy dependence



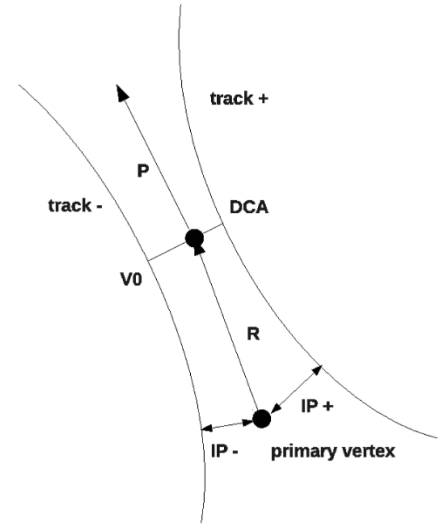


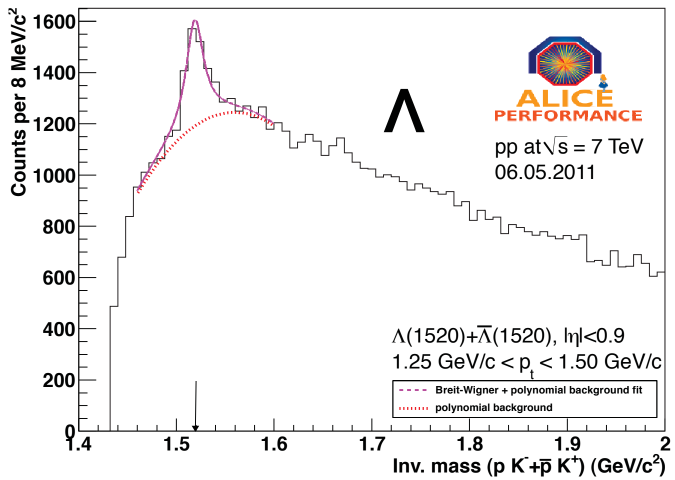
~ constant vs √s

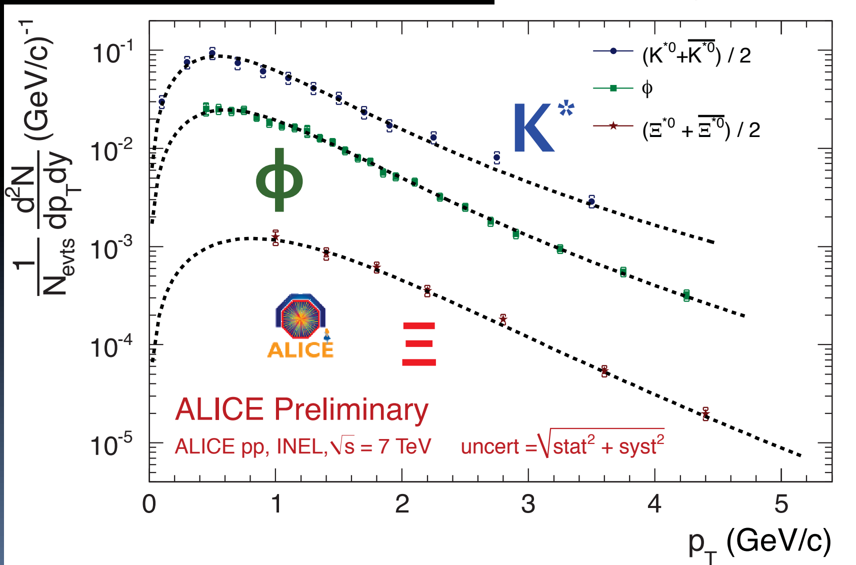
Strangeness

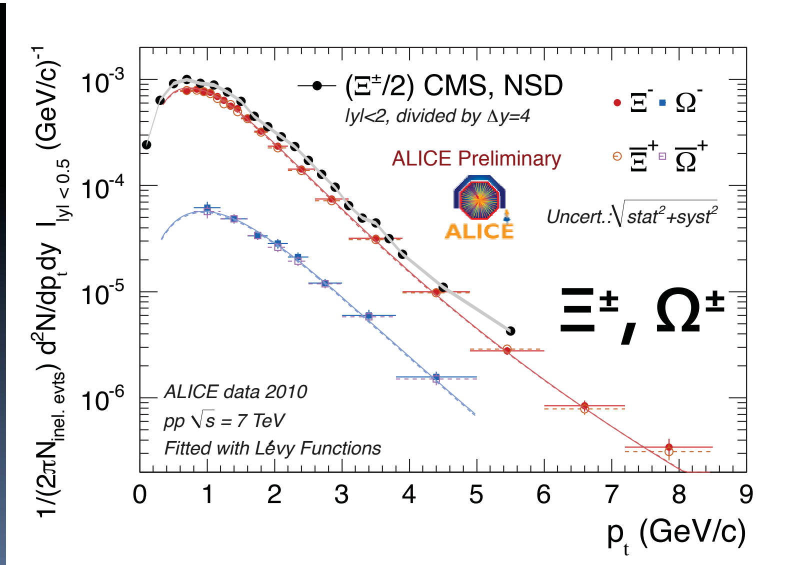


- Topological reconstruction
  - K^0_s, Λ, Ω, Ξ
- Resonances
  - K^*, ϕ, Σ

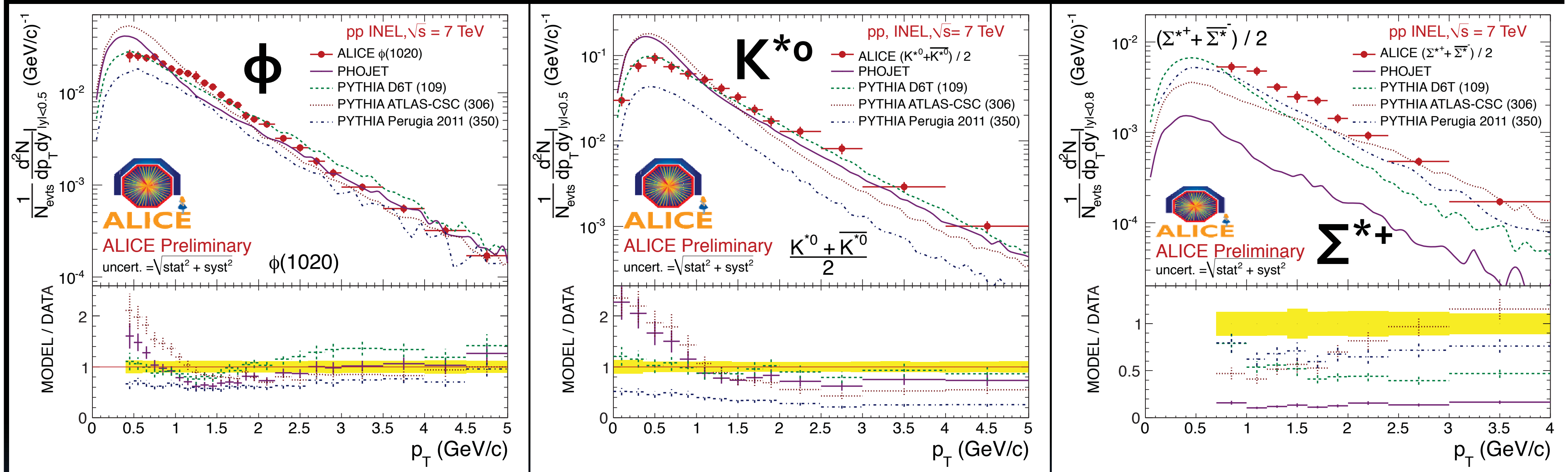








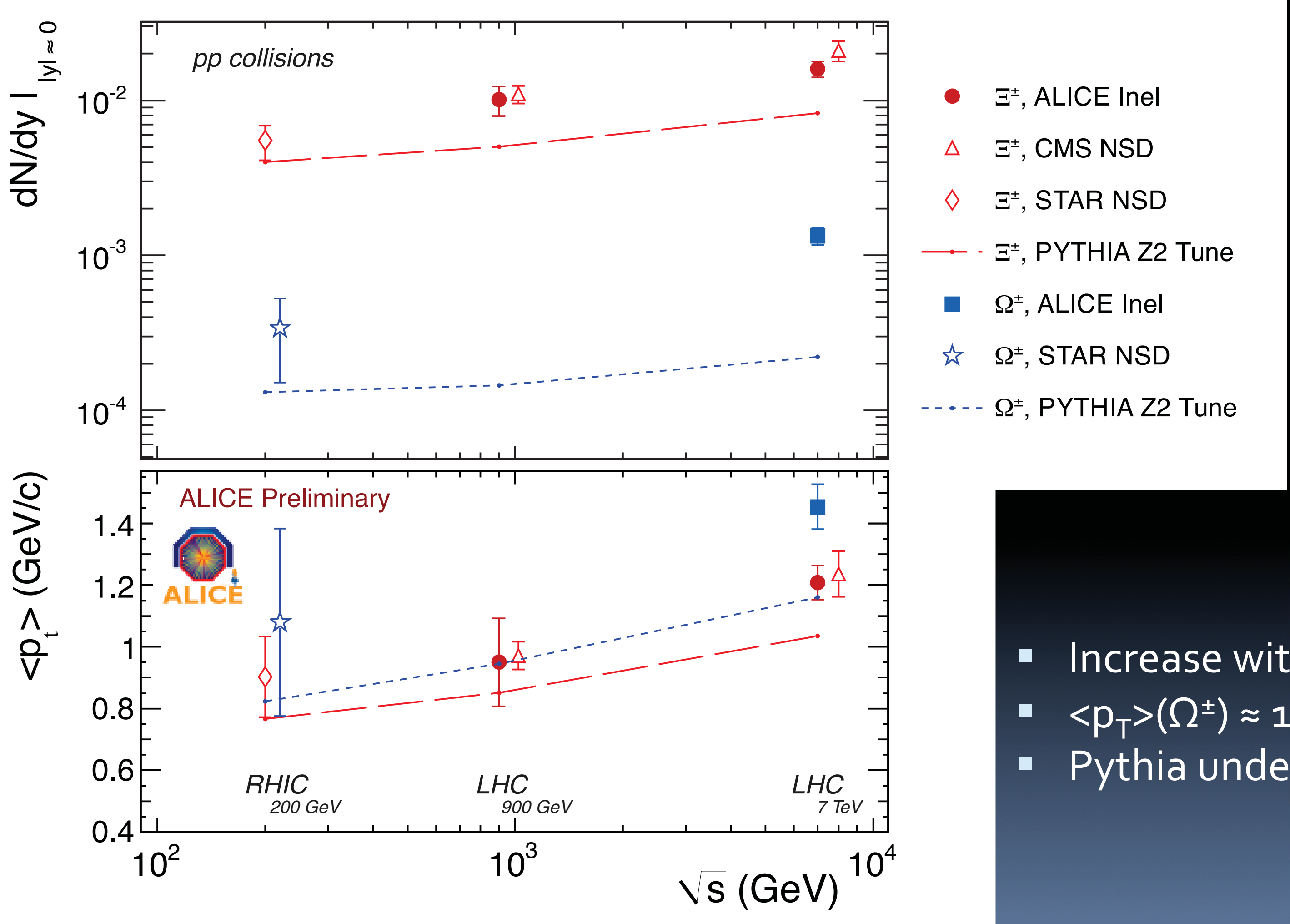
Strangeness
comparison to models



- Meson resonances quite well described by PYTHIA D6T tune
- Perugia 2011 – good for charged K, see before – underestimates resonances
- Baryon resonances always badly described by MC

Strangeness

comparison to other experiments

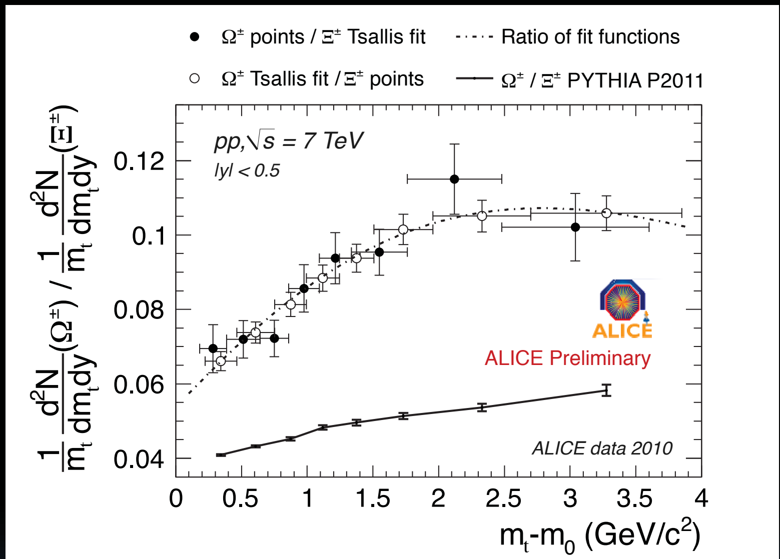


CMS:
JHEP 05 (2011) 164
STAR:
PRC 75: 064901 (2007)
→ BUT different normalizations wrt ALICE

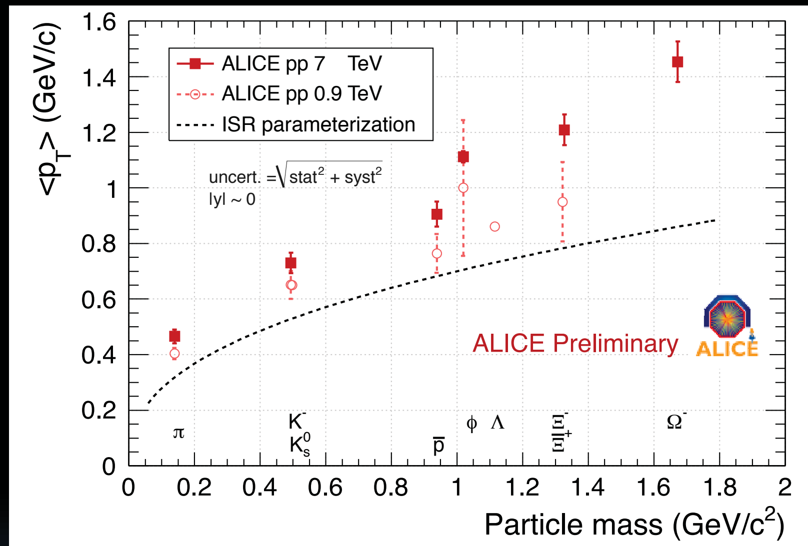
- Increase with $\sqrt{s}$
- $\langle p_T \rangle(\Omega^{\pm}) \approx 120\% \langle p_T \rangle(\Xi^{\pm})$
- Pythia understimates the data

Comparisons between particles

$\Omega^{\pm} / \Xi^{\pm}$



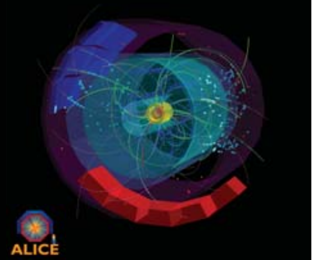
$\langle p_T \rangle$ vs mass

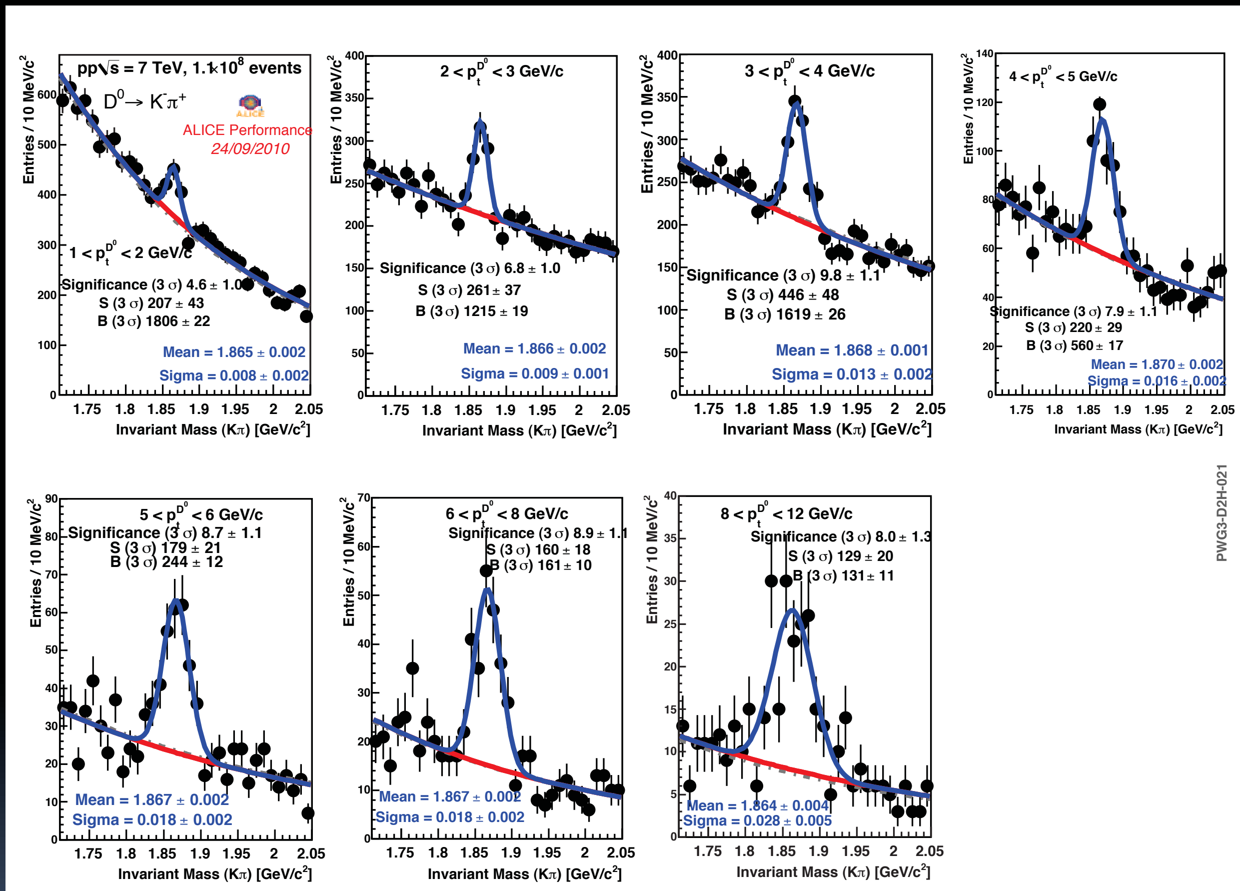


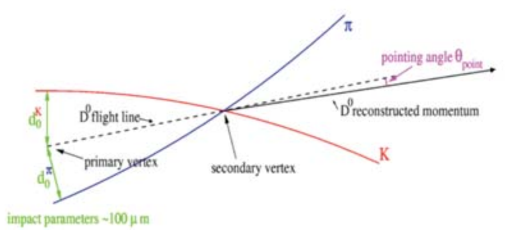
- Easier to add a strange quark at high pt?
- MC completely out…

- IRS parametrization out…

D mesons – open charm

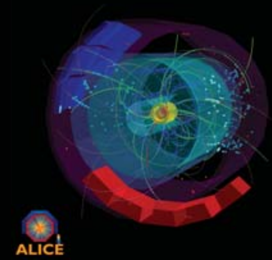


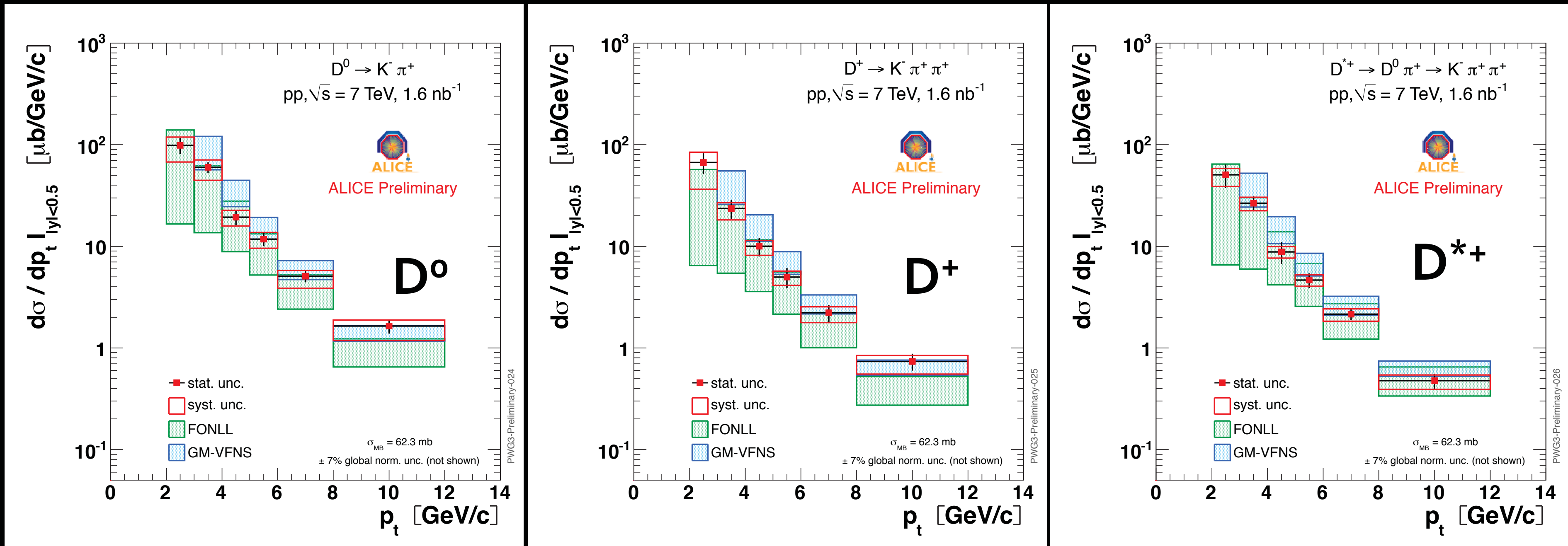




- $D^0 \rightarrow K\,\pi$; 7 p_t bins
- $D^+ \rightarrow K\,\pi\,\pi$; 6 p_t bins
- $D^* \rightarrow D^0\,\pi$; 6 p_t bins
- $D_s \rightarrow K\,K\,\pi$; 4 p_t bins
- $\Lambda_c \rightarrow p\,K\,\pi$

D meson cross section



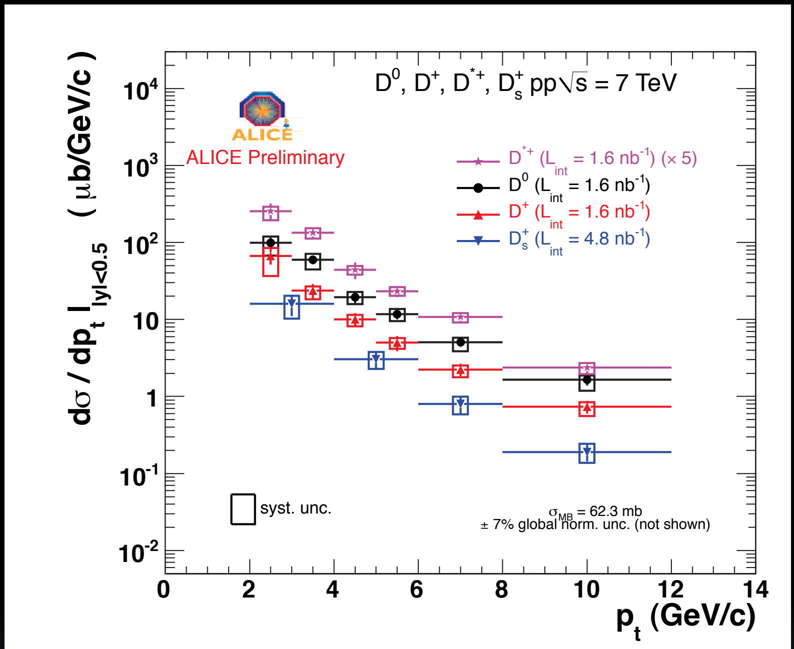


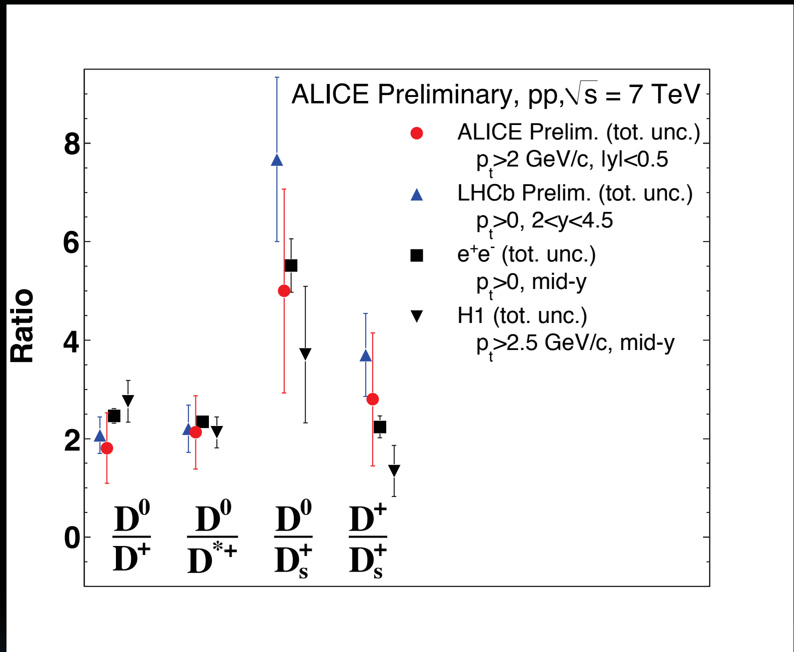
- Raw yields corrected for efficiency and acceptance
- B feed-down corrections using FONLL calculations
  - Evaluation from D meson impact parameter distributions (à la CDF) ongoing

Normalization using σ_{MB} from VdM scan

COMPATIBLE WITH pQCD (FONLL AND GM-VFNS) PREDICTIONS

D meson comparisons



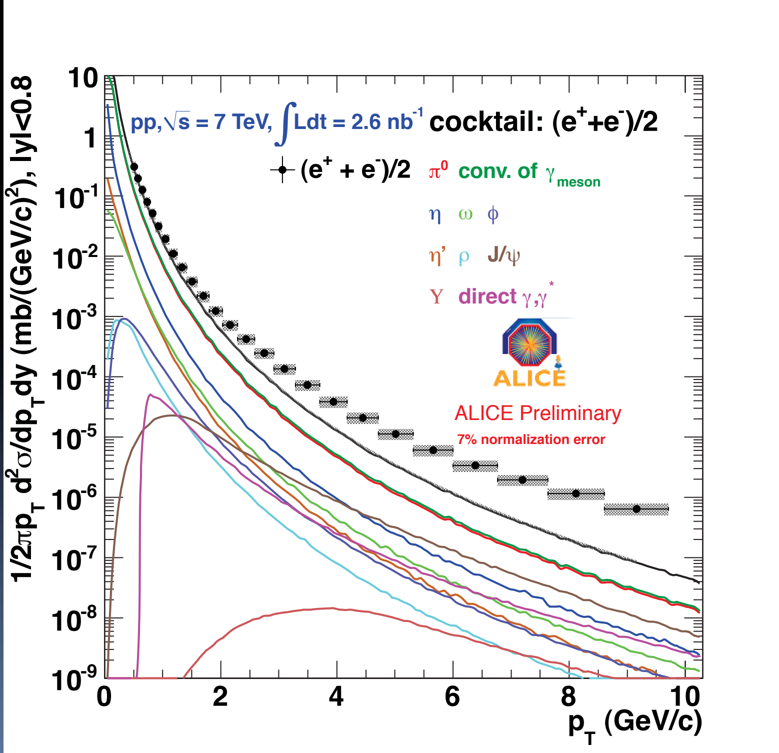


D^{*+} scaled by 5 not to overlap with D^+_s

Ratios in good agreement with the other experiments

Heavy Flavor Electrons

- Heavy Flavor (HF) Single Electron spectrum extracted from
  a) "Cocktail" of background electrons sources (à la RHIC)
     - Photonic, dielectron decays of mesons, direct radiation, J/ψ, Υ
  b) Cut on impact parameter to select electrons, especially efficient for those from B



Ingredients:

- Measured π⁰ spectrum
- m_T scaling for the other mesons
- J/ψ and Υ from ALICE and CMS measurements
- Ratio conversion/Dalitz from the known material budget

Heavy Flavor Electrons

- Heavy Flavor (HF) Single Electron spectrum extracted from
  a) "Cocktail" of background electrons sources (à la RHIC)
     - Photonic, dielectron decays of mesons, direct radiation, J/ψ, Υ

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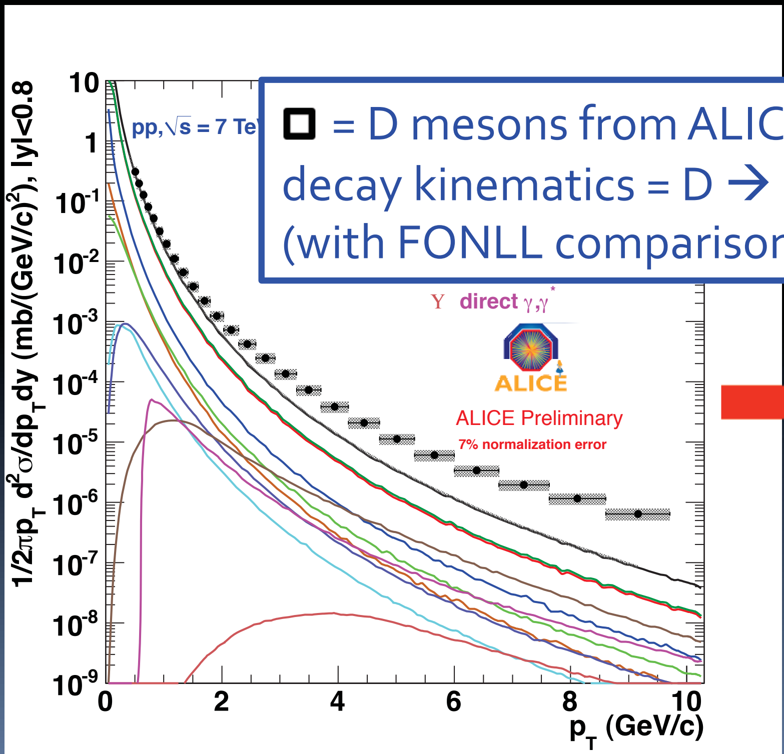
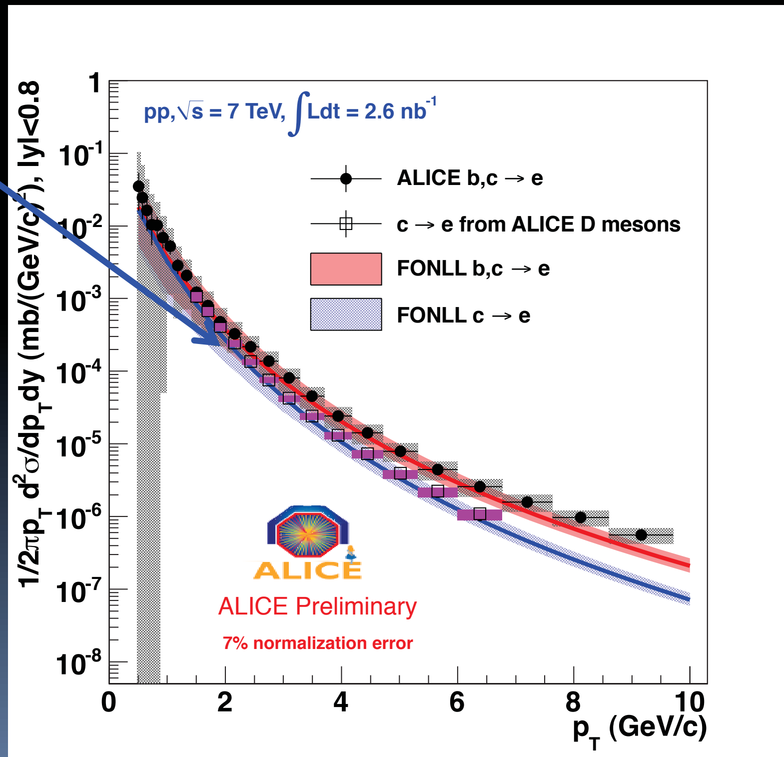
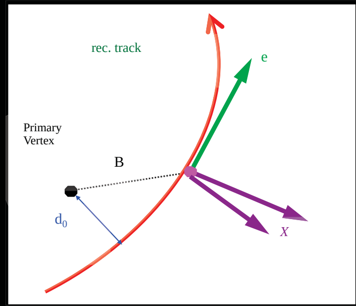


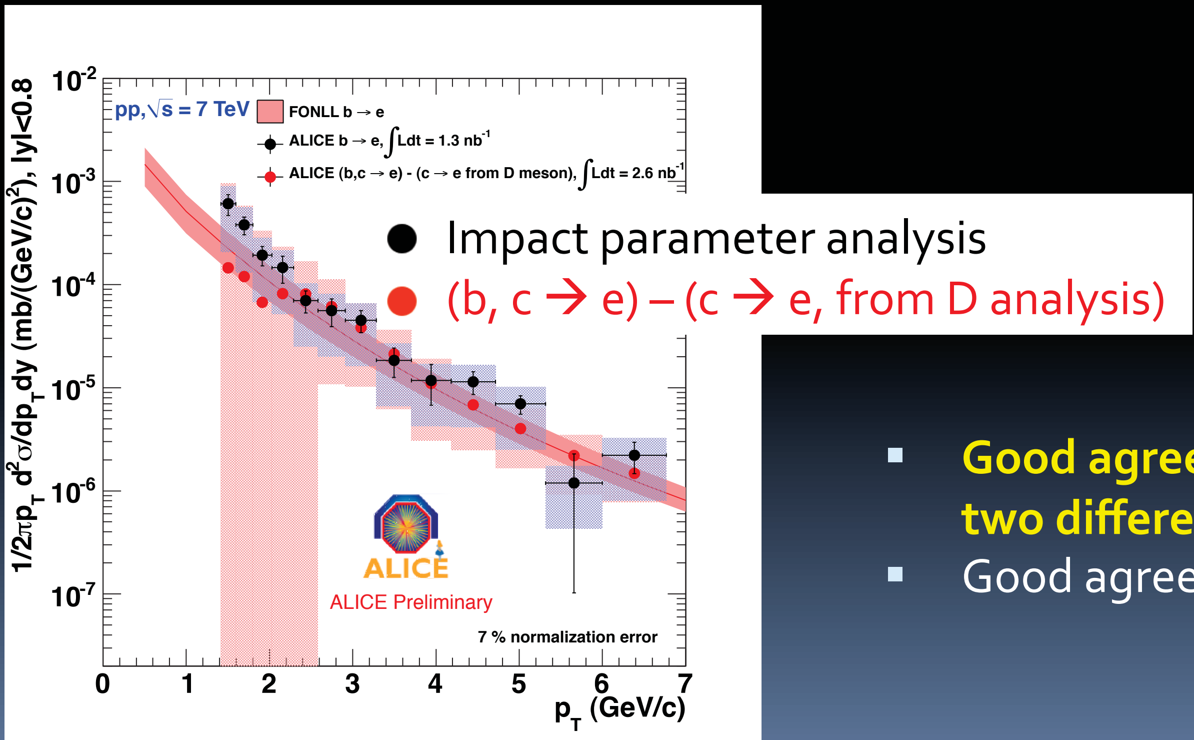
□ = D mesons from ALICE + decay kinematics = D → e+X (with FONLL comparison)



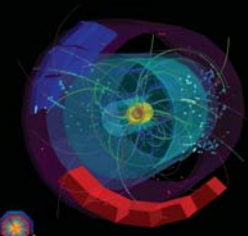
Heavy Flavor Electrons from B

- Exploiting the very large impact parameter (cτ ≈ 500 μm, m ≈ 5 GeV/c^2)
- Comparing with results combining cocktail analysis and D meson measurements





- **Good agreement between the two different analyses**
- Good agreement with FONLL

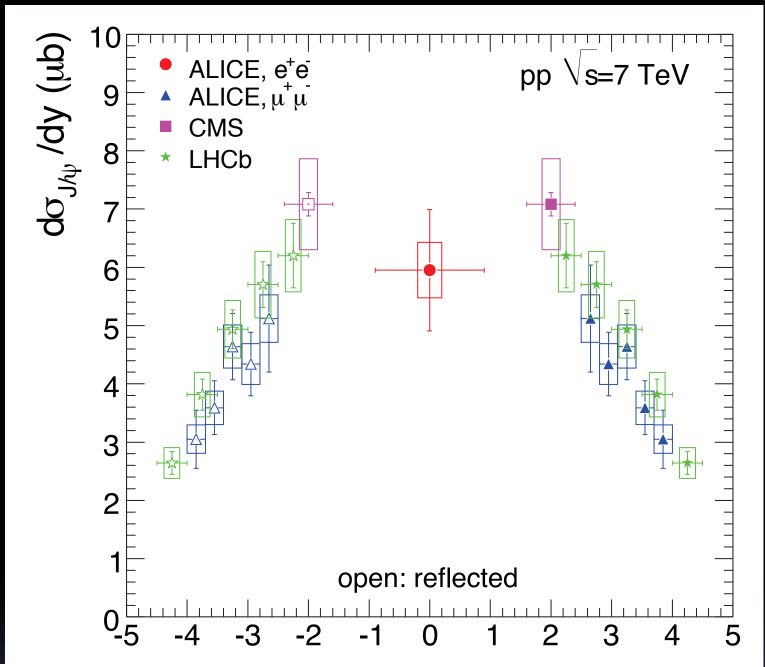


J/ψ

- $J/\psi \rightarrow e^+e^-$
  - at midrapidity (ITS+TPC) , $|\eta| < 0.9$
  - Signal extraction: bin counting
  - Background: like-sign technique
- $J/\psi \rightarrow \mu^+\mu^-$
  - forward rapidity (MUON) , $-4 < \eta < -2.5$
  - Signal extraction: crystal ball
  - Background: double exponential

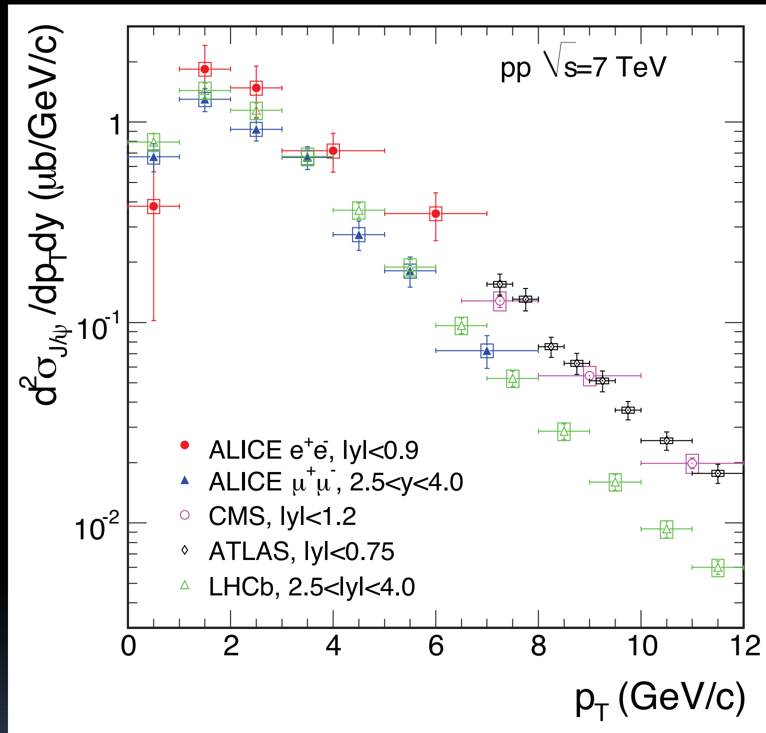
J/ψ

- $J/\psi \rightarrow e^+e^-$



Comparison in the rapidity range where the p_T coverage goes down to 0

- $J/\psi \rightarrow \mu^+\mu^-$

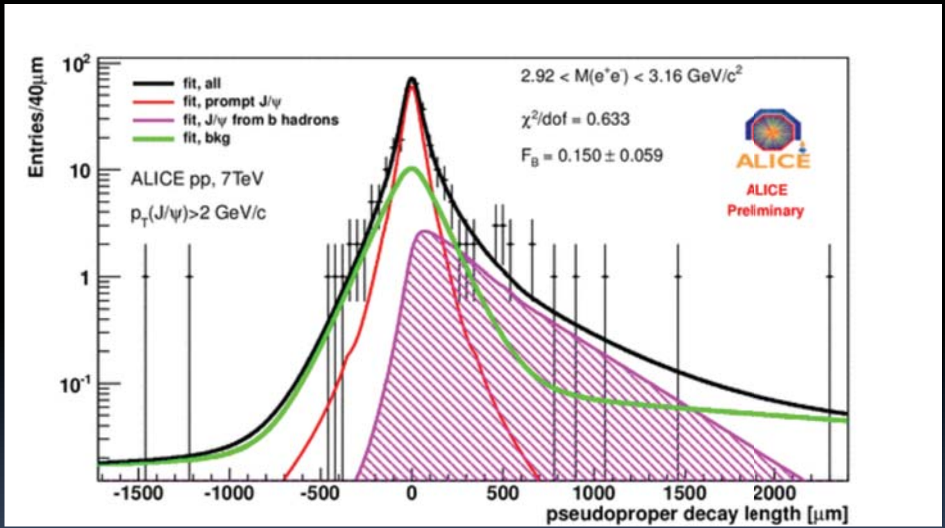


ALICE: arXiv:1105.0380v1 (2011), ATLAS: Nucl. Phys. B850 (2011) 387, CMS Phys. J. C71, (2011) 1575, LHCb Eur. Phys. J. C71 (2011) 1645

- Good agreement with LHCb at forward rapidity
- Broad rapidity coverage, down to p_T = 0 GeV/c

J/ψ
more results

- J/ψ from B
  - Based on the pseudo-proper decay length



J/ψ
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- J/ψ from B
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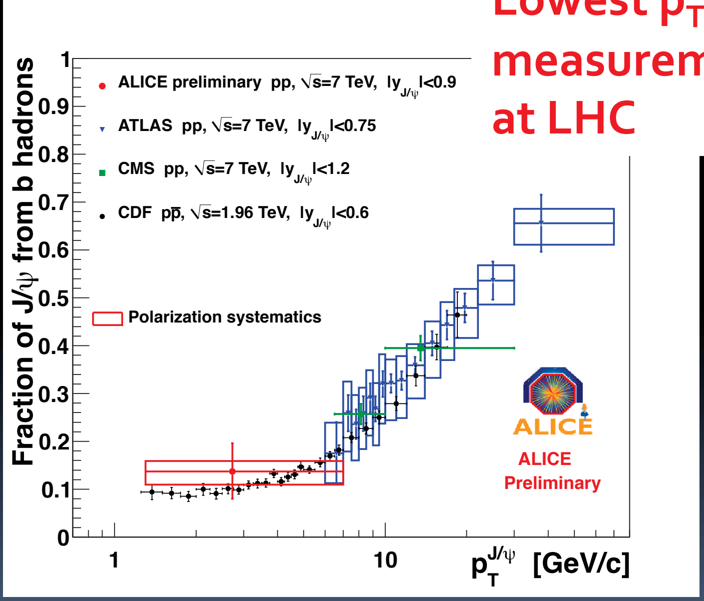
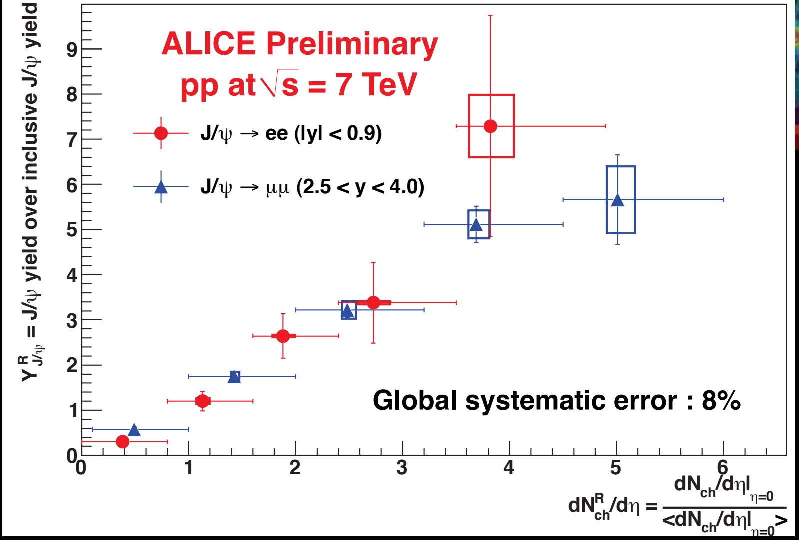


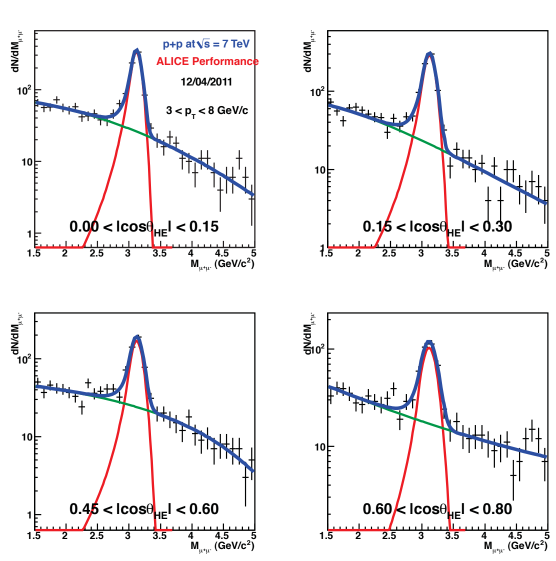
Lowest p_T measurement at LHC

- ALICE
- ATLAS: Nucl. Phys. B850 (2011) 387,
- CMS Phys. J. C71, (2011) 1575,
- CDF (pp @ 1.96 TeV, PRD 71 032011

- Multiplicity dependence



- J/ψ polarization
  - Well ongoing

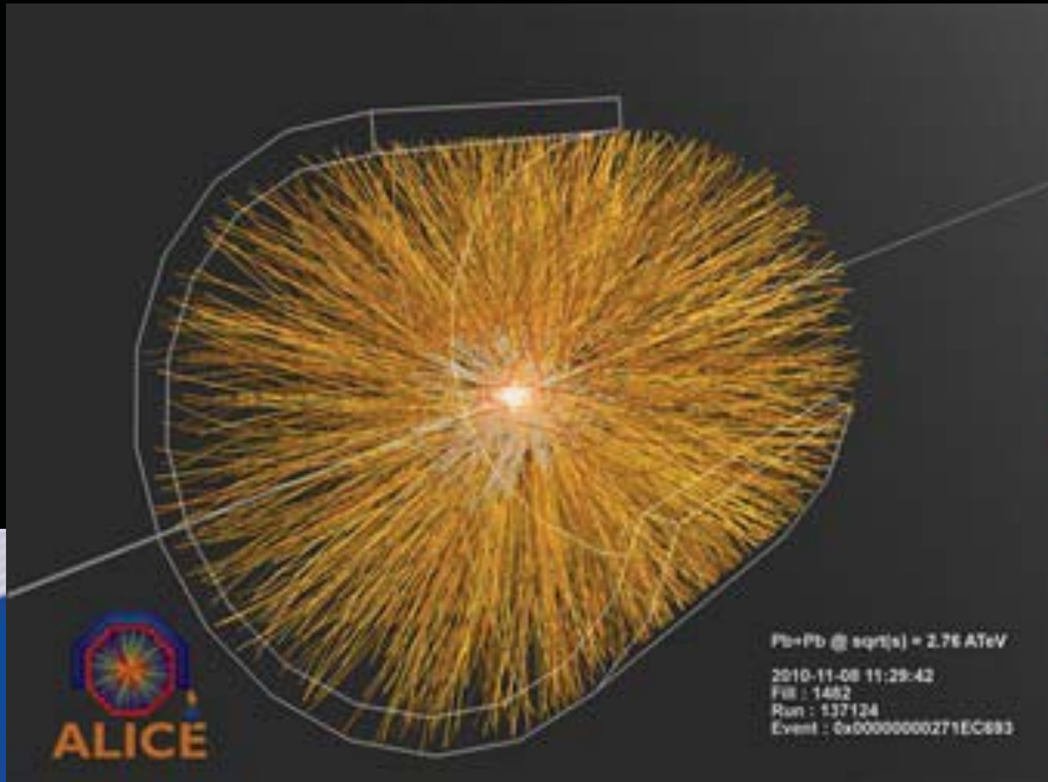


Invariant mass fit in $\cos\theta_{HE}$ bins

Pb-Pb @ 2.76 TeV

05/11/2010, P2: Let’s enter Wonderland!

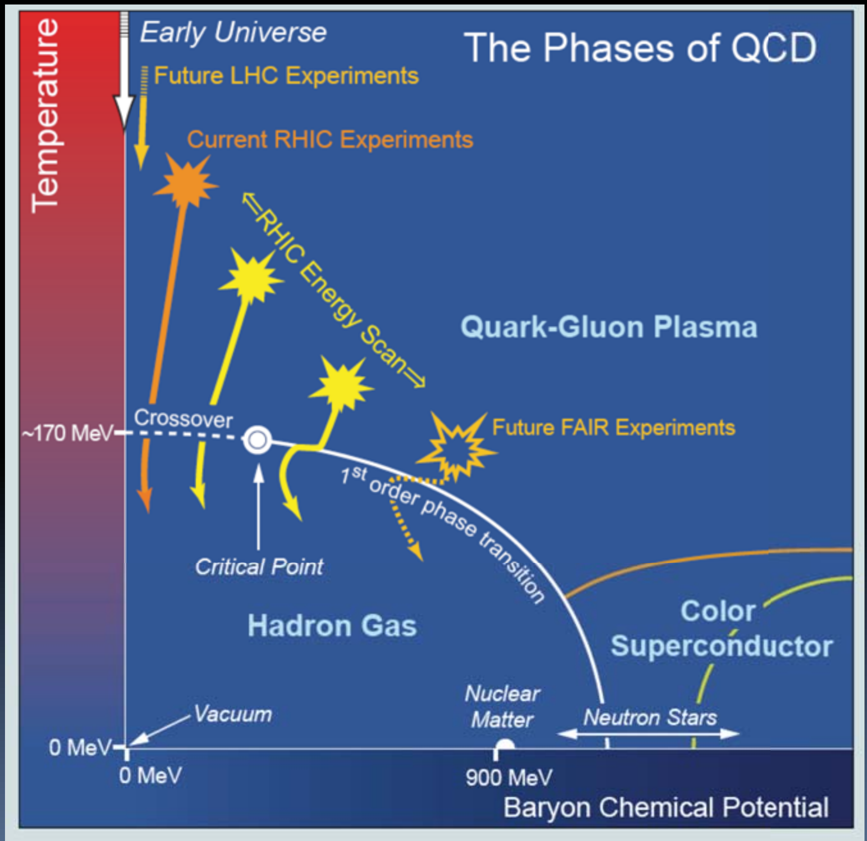
- PbPb:
  - ALICE’s Wonderland



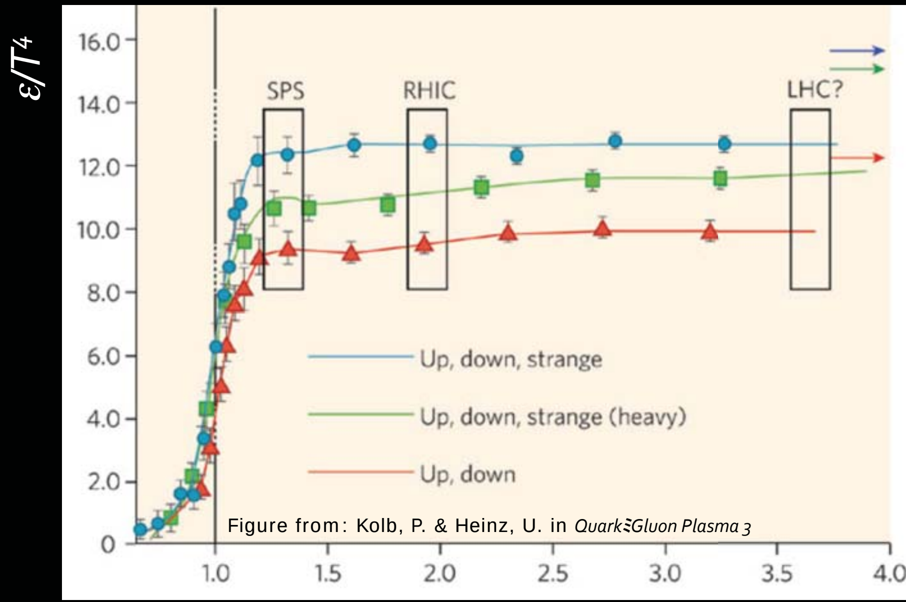
Main goal: to study the QGP

QCD Phase Diagram and QGP

- Lattice QCD predicts a transition from a hadronic to a QGP phase at T_c ~ 170 MeV for zero baryochemical potential

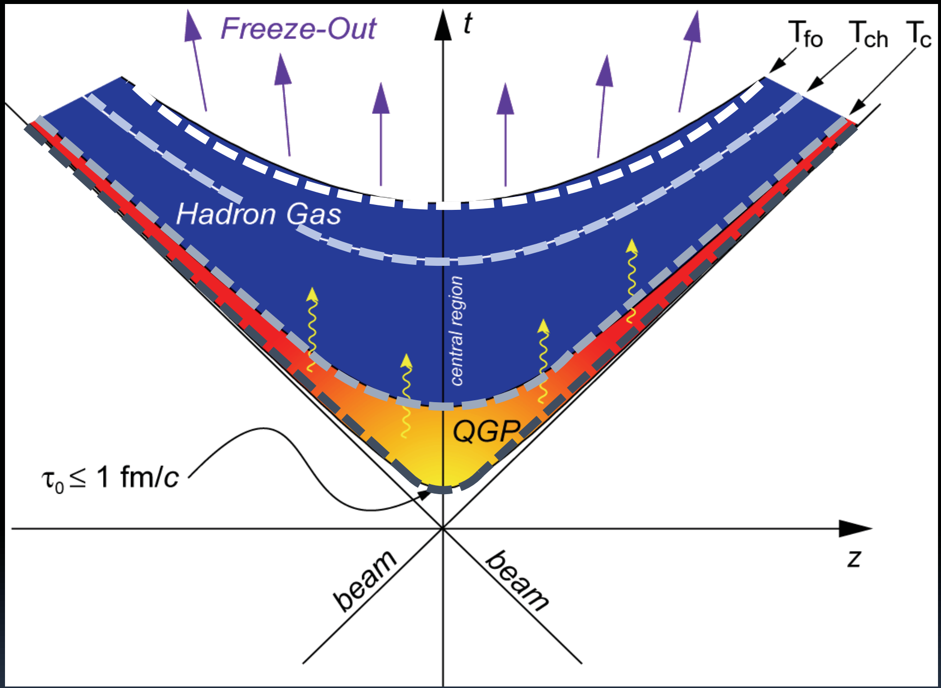


NSAC Long Range Plan 2007, The Frontiers of Nuclear Science



- Typical behavior of a phase transition
- The nature of the transition highly depends on the number of dynamical quark flavors included, and on the hypothesis for the quark masses

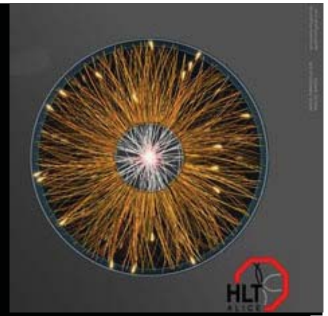
Space-Time Evolution of a Heavy-Ion Collision – a Closer Look



- Kinetic freeze-out (no more elastic processes)
- Chemical freeze-out (no more inelastic processes)
- QCD phase transition QGP → Hadronic Matter
- Local thermalization – QGP state

T_c – Critical temperature for transition to QGP
T_{ch} – Chemical freeze-out ($T_{ch} \leq T_c$)
T_{fo} – Kinetic freeze-out ($T_{fo} \leq T_{ch}$)

ALICE PbPb publications

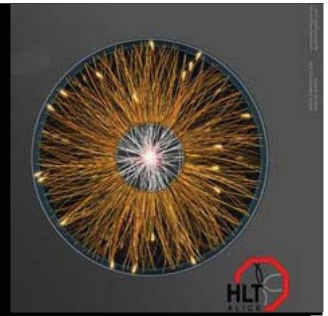


N_{ch} multiplicity	PRL: Vol. 105 (2010) 252301
Elliptic flow of charged particles	PRL: Vol. 105 (2010) 252302
R_{AA} of charged particles	PLB: Vol. 696 (2011) 30
Centrality dependence of $dN_{ch}/d\eta$	PRL: Vol. 106 (2011) 32301
Two π B-E correlations	PLB: Vol. 696 (2011) 328
Higher harmonic anisotropic flow	Sub. to PRL, arXiv 1105.3865v1
HBT	Acc. by PLB, arXiv 1012.4035
2-particle angular correlations	arXiv 1109.2501

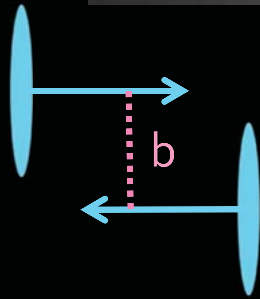
- Ready for submission
  - I_{AA} and I_{CP}
- Advanced
  - v_2 for id-particles
  - R_{AA} of D mesons
  - Strangeness
  - Charge fluctuations
  - …

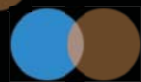
- Some well-ongoing analyses
  - Vector mesons
  - J/ψ
  - Heavy flavor electrons
  - Particle spectra
  - …

Centrality

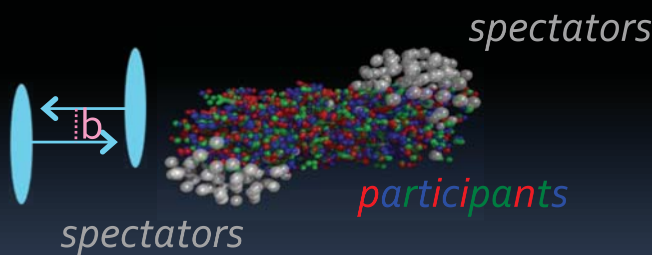


- Impact parameter of the collision, b
  - Distance between the centers of the colliding nuclei, perpendicular to the beam axis



    - Small b → central collisions; small cross-section 
    - Large b → peripheral collisions; large cross-section 

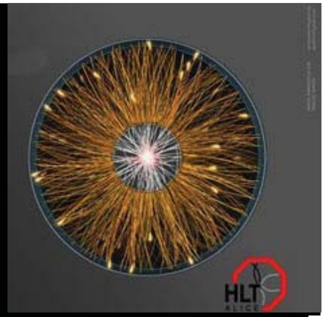
- The collision geometry (b) determines:
  - N_{part}: number of participant nucleons (soft)
  - N_{bin}: number of binary collisions (hard)
  - N_{spec} : number of spectators ($N_{spec} = 2A - N_{part}$)



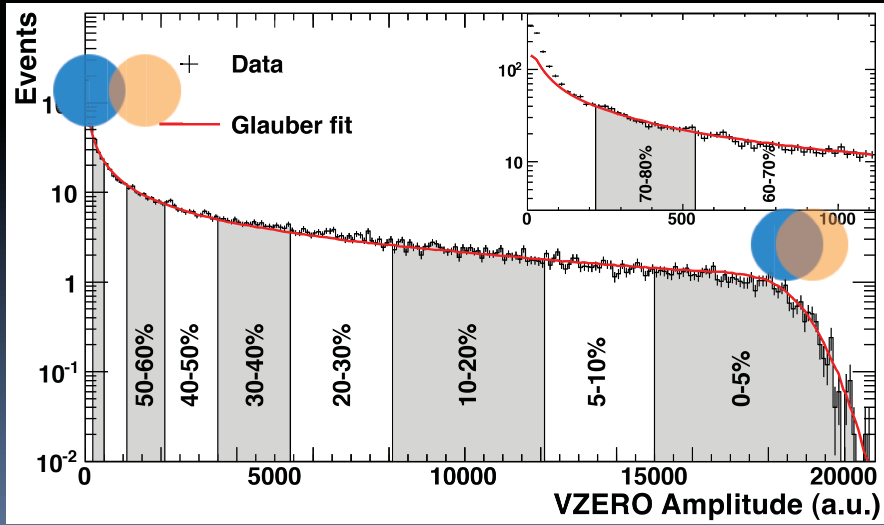
→ Use these to determine centrality

→Many observables scale with N_{part}

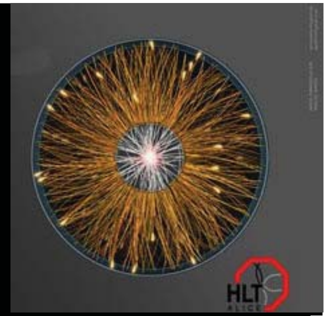
Centrality in ALICE



- VZERO amplitudes fitted with the Glauber supposing
  - $N_{ancestors} = \alpha N_{part} + (1-\alpha) N_{coll}$
  - Each ancestor emits particles following a NBD
- Fit above the anchor point 150 (~88% of the total hadronic cross-section) to have robust results (exclude EM background)
- Derive N_{part} and N_{coll} with the Glauber model
- Little dependence on the centrality estimator (ZDC, tracks, ZDC vs VZERO…)



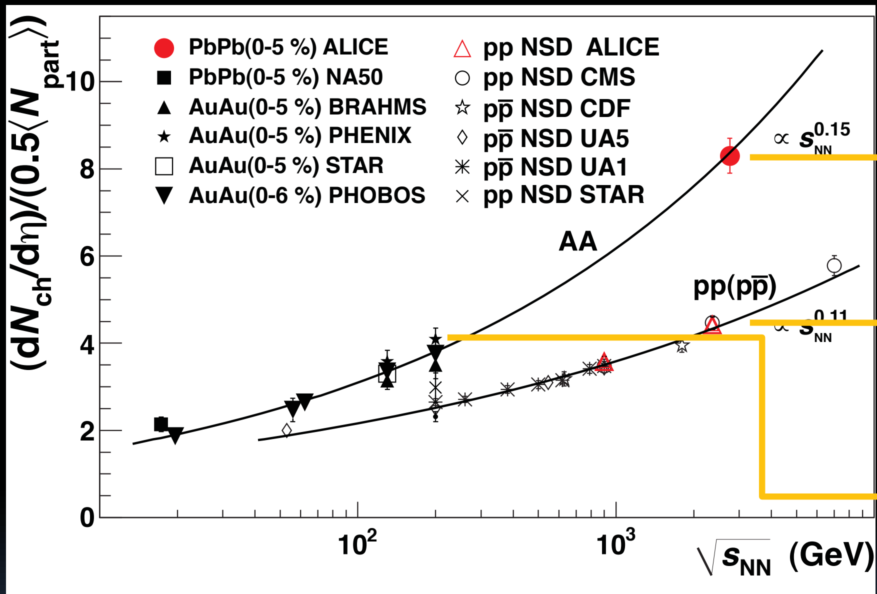
Particle Production



Energy dependence

PbPb, $\sqrt{s_{NN}}$ = 2.76 TeV, 0-5% central, $|\eta| < 0.5$

PRL 105, 25230 (2010)



PbPb: 8.3 ± 0.4 (sys.)

x 1.9 pp (NSD, $\sqrt{s}$ = 2.36 TeV)

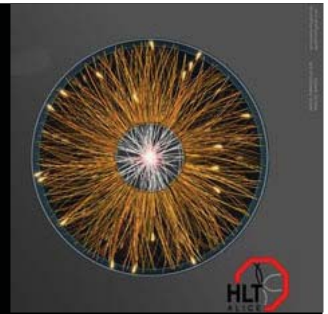
x 2.2 AuAu ($\sqrt{s_{NN}}$ = 0.2 TeV)

$dN_{ch}/d\eta$ = 1584 ± 76 (sys.)

pp: $\sim\sqrt{s_{NN}}^{0.11}$

PbPb: $\sim\sqrt{s_{NN}}^{0.15}$

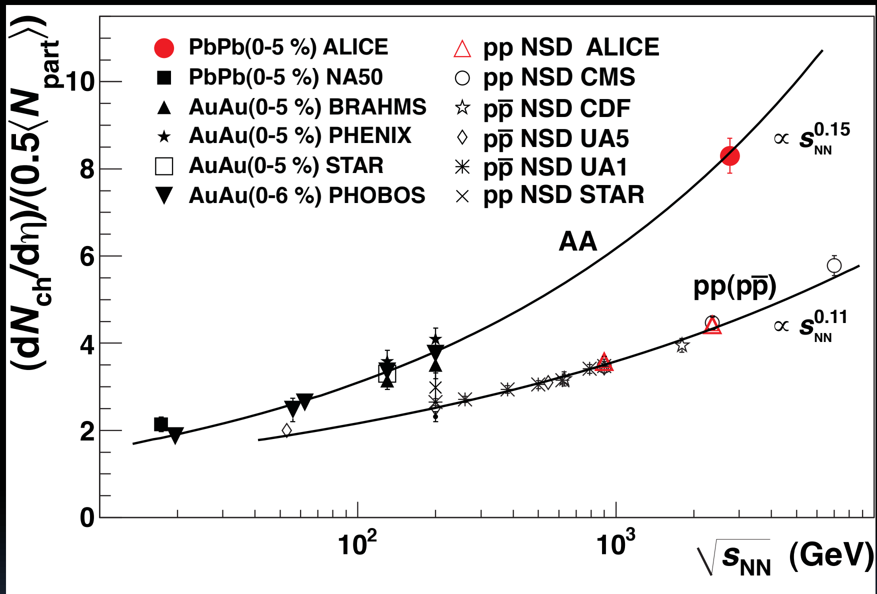
Particle Production



Energy dependence

PbPb, $\sqrt{s_{NN}}$ = 2.76 TeV, 0-5% central, |η| < 0.5

PRL 105, 25230 (2010)

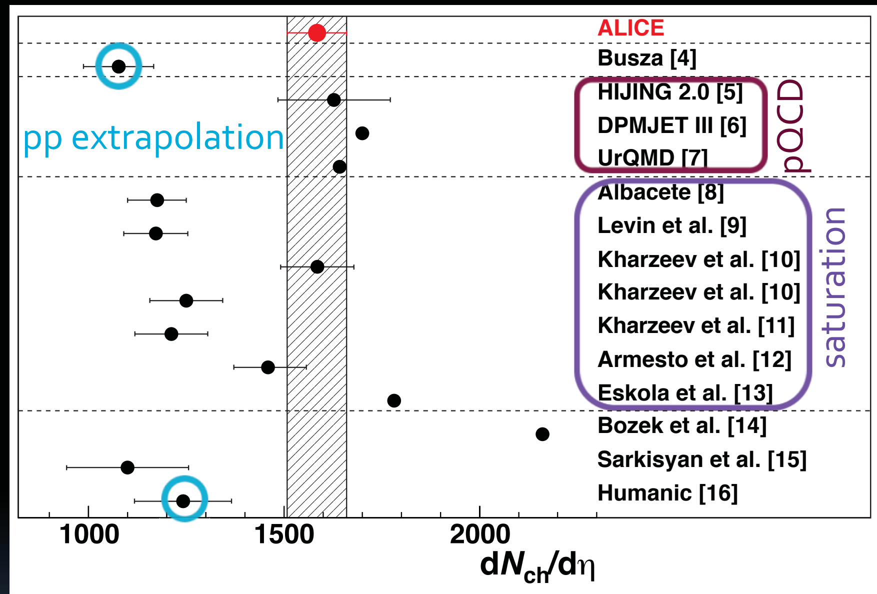


$dN_{ch}/d\eta$ = 1584 ± 76 (sys.)

pp: $\sim\sqrt{s_{NN}}^{0.11}$
PbPb: $\sim\sqrt{s_{NN}}^{0.15}$

Model Comparison

PbPb, $\sqrt{s_{NN}}$ = 2.76 TeV, 0-5% central, |η| < 0.5



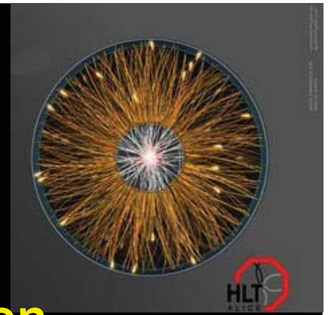
PRL 105, 25230 (2010)

Energy density estimate (Bjorken)

$$\varepsilon(\tau) = \frac{E}{V} = \frac{1}{A\tau}\frac{dN}{d\eta}\langle m_T \rangle$$

$$\varepsilon(\tau_0)_{LHC} \geq 3 \times \varepsilon(\tau_0)_{RHIC}$$

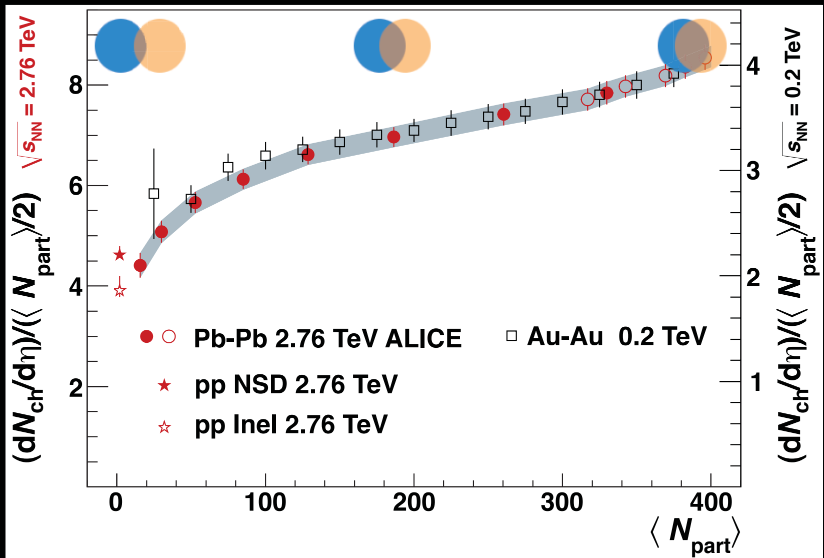
Centrality Dependence



Centrality dependence

PbPb, $\sqrt{s_{NN}}$ = 2.76 TeV, $|\eta|$ < 0.5

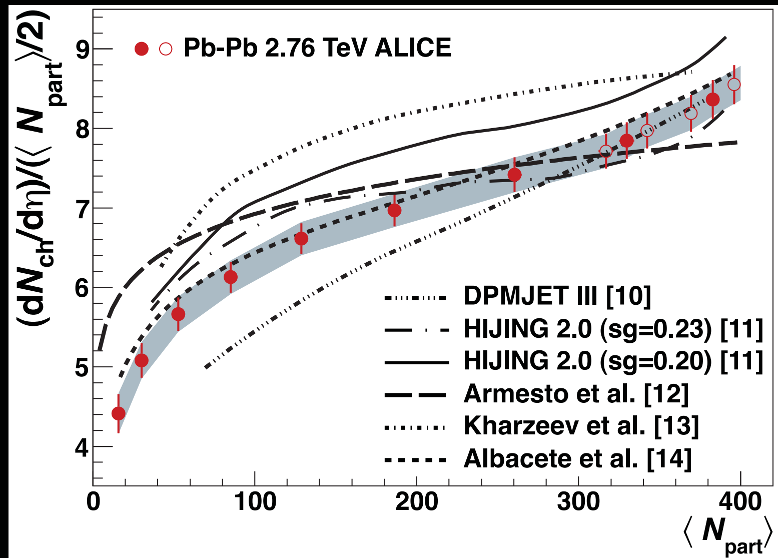
PRL 106, 032301 (2011)



Similar behavior as found at RHIC

Model Comparison

PbPb, $\sqrt{s_{NN}}$ = 2.76 TeV, $|\eta|$ < 0.5



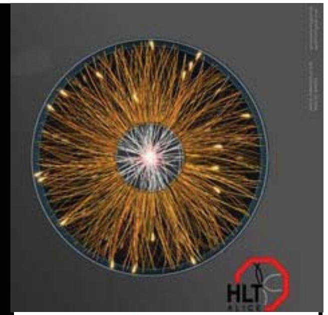
PRL 106, 032301 (2011)

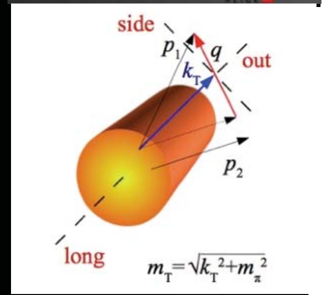
Comparison with models

- DPMJET (with string fusion)
- HIJING (no quenching)
- Saturation models [12-14]

→ models incorporating a moderation of the multiplicity
with centrality are favored by the data

Femptoscopy



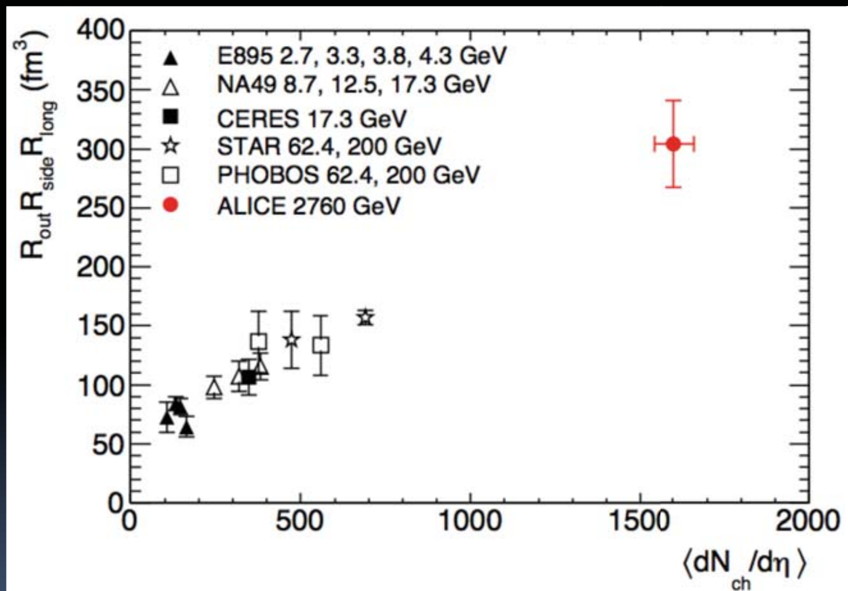


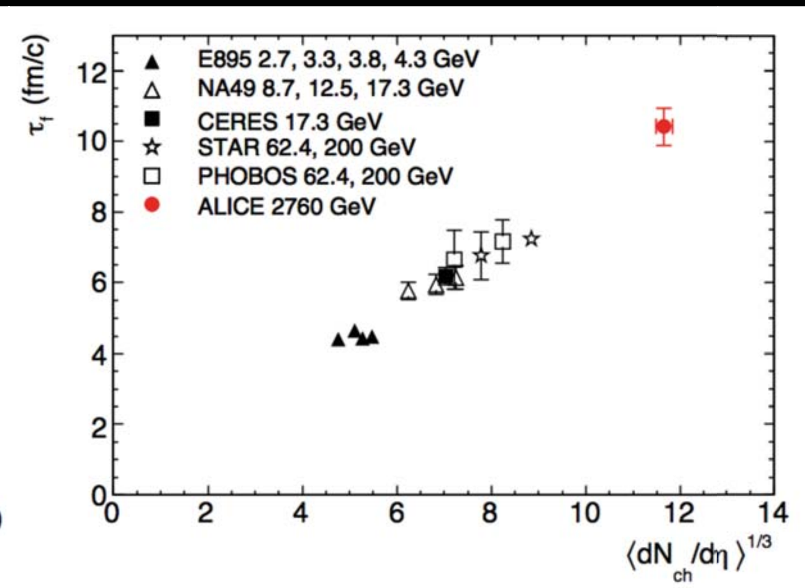
- Assess the space-time extension of the system that emits particles in PbPb collisions (homogeneity volume)

Homogeneity Volume

Decoupling Time
from collision to hadron freeze-out

PLB 696, 328 (2011)





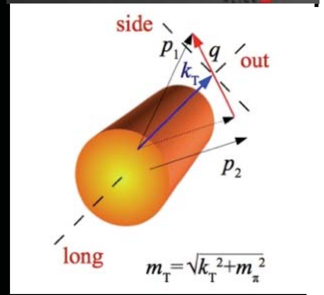
PLB 696, 328 (2011)

- Linear dependence on multiplicity
- V ~ 300 fm^3 ,x2 as at RHIC

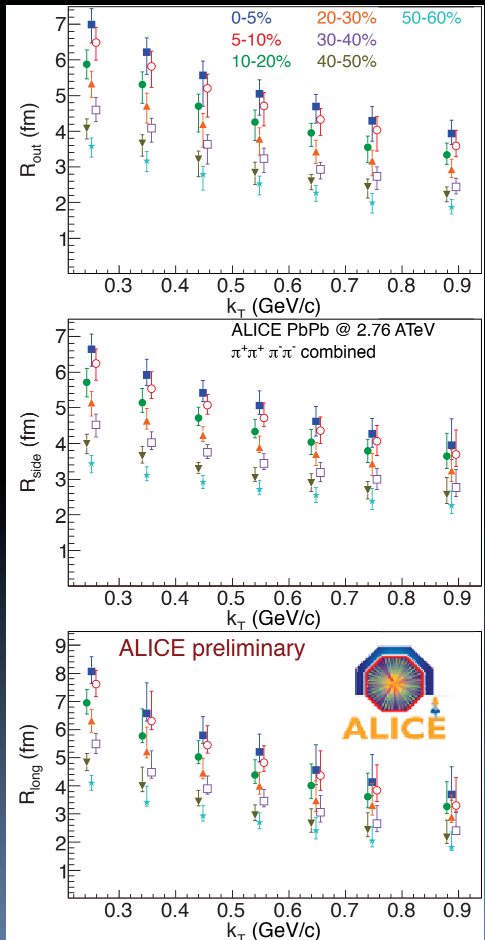
- τ ~ 10-11 fm/c ,x1.4 as at RHIC

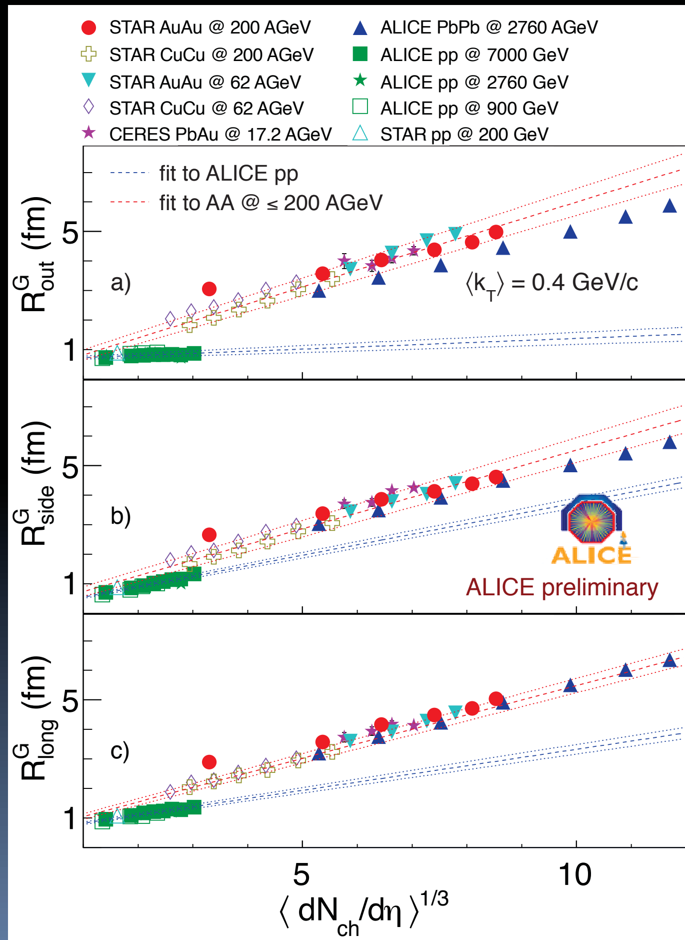
Femptoscopy

- Assess the space-time extension of the system that emits particles in PbPb collisions (homogeneity volume)



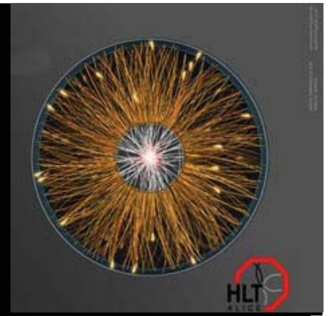
Centrality dependence of femptoscopic radii



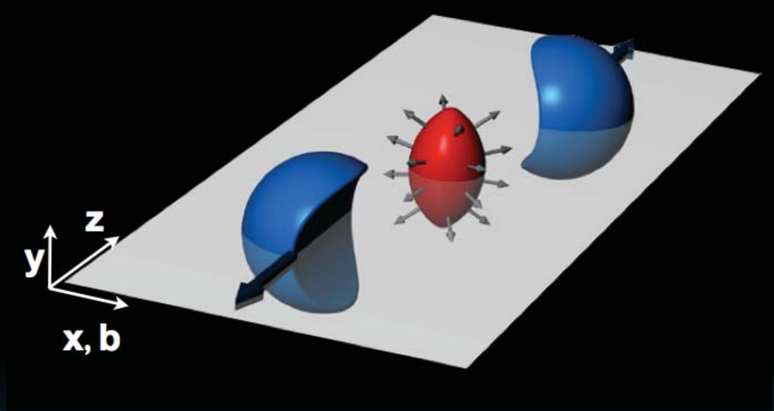


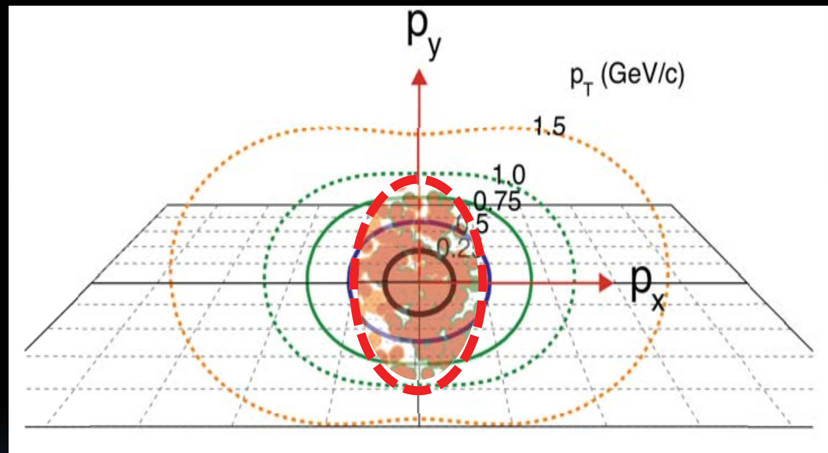
Comparison with existing data

Elliptic Flow



- Anisotropic distribution of matter in the overlap region leads to anisotropies in the observed final particle spectra → ***elliptic flow***
- It's magnitude depends on the initial conditions, the EOS, and the system lifetime



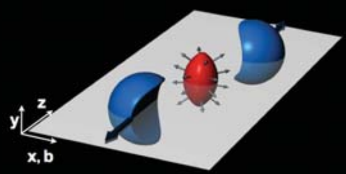


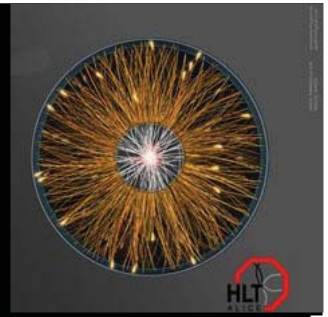
- Fourier expansion of the angular spectra relative to the event-by-event reaction plane
- The second component v2 measures the shape of the reaction zone and depends strongly on p_T

$$N(\phi) \propto 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi) + 2v_3 \cos(3\phi) + \ldots$$

Elliptic Flow

results

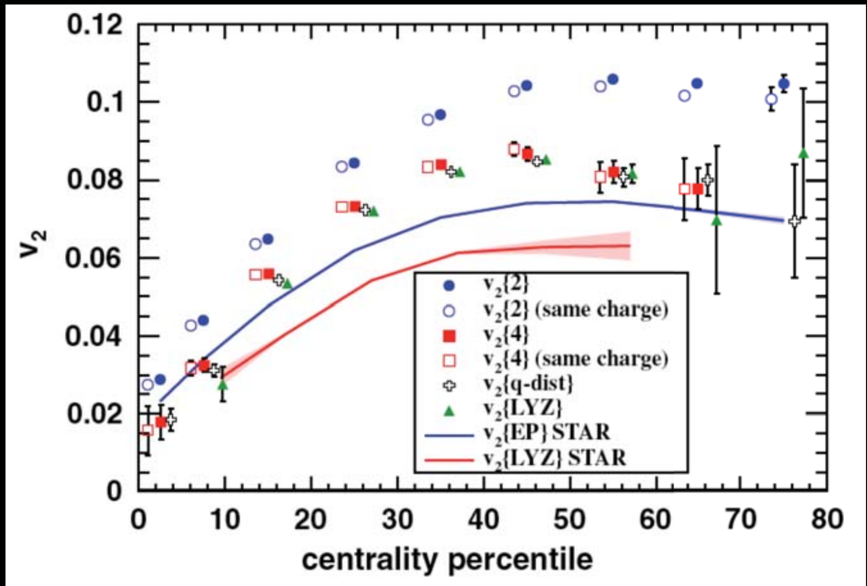




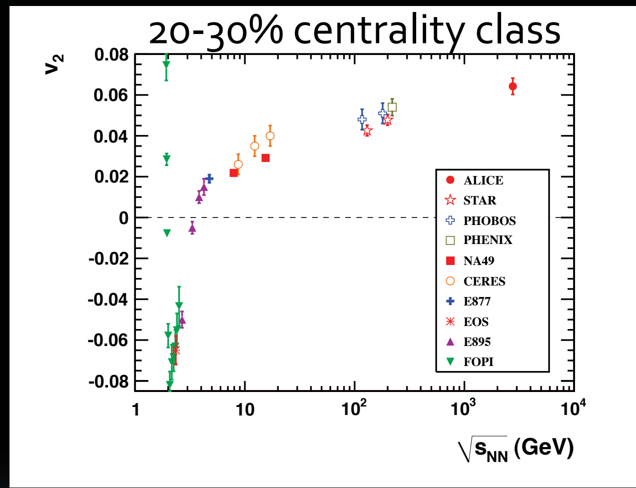
$$E\frac{d^3N}{d^3p}=\frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+\sum_{n=1}^{\infty}2v_n\cos\left[n(\phi-\Psi_R)\right]\right)$$

Centrality dependence

PRL 105, 252302 (2010)



Energy dependence



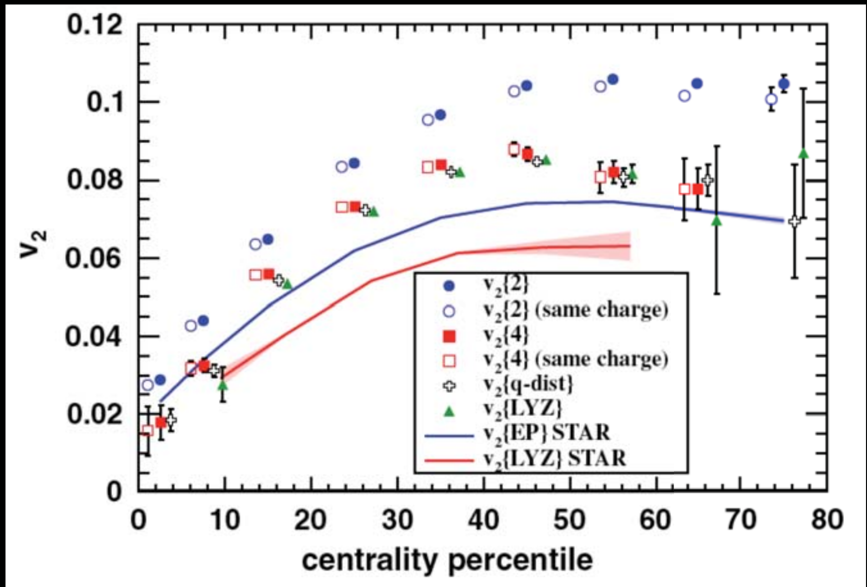
- 2 and multi-particle methods differ as expected
- multi-particle estimates agree within uncertainties as is expected for collective flow
- 30% increase of integrated v_2 from STAR ($\sqrt{s_{NN}}$ = 0.2 TeV) to ALICE ($\sqrt{s_{NN}}$ = 2.76 TeV)
  - Visible over all centralities
  - due to increased <p_T> (stronger radial flow at higher energies)
- Agreement with Hydro + viscous corrections

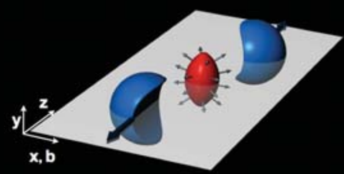
Elliptic Flow

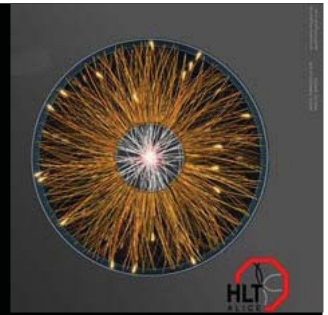
results

Centrality dependence

PRL 105, 252302 (2010)

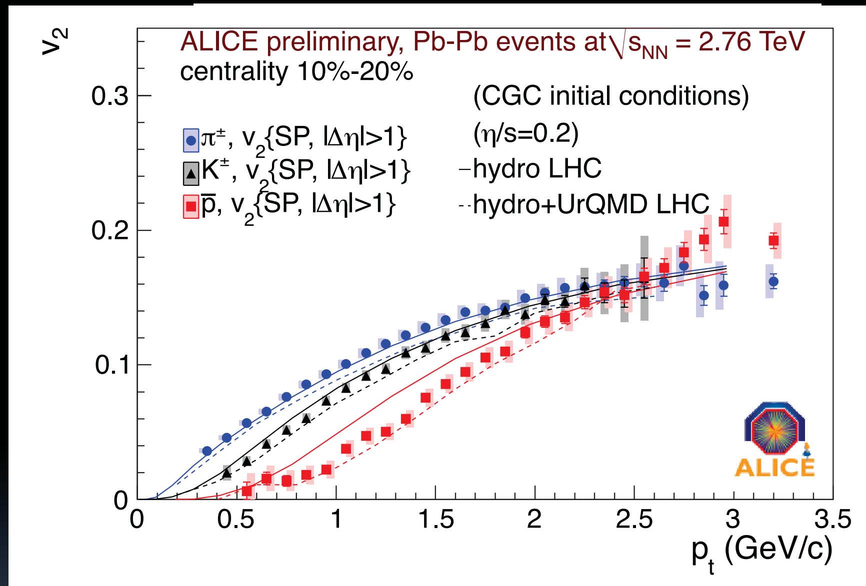






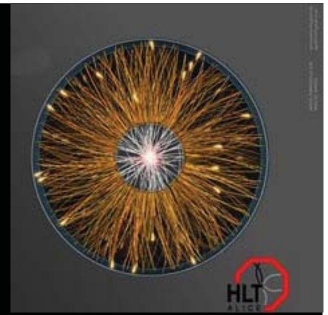
$$E\frac{d^3N}{d^3p}=\frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+\sum_{n=1}^{\infty}2v_n\cos\left[n(\phi-\Psi_R)\right]\right)$$

Flow of Identified Particles



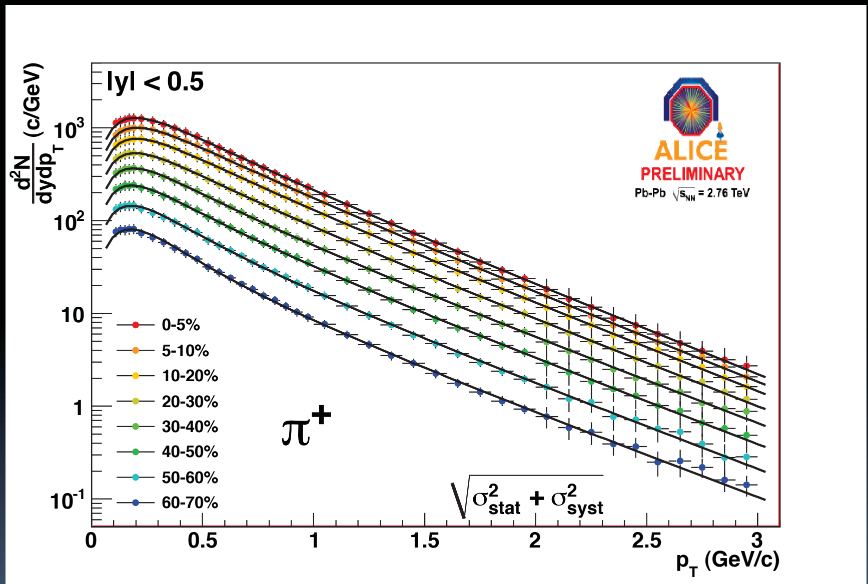
- Strong radial flow (mass dependence of v_2)
- Quite good agreement with hydro predictions for π and K, not true for $\overline{p}$ in semi-central events (better in peripheral)

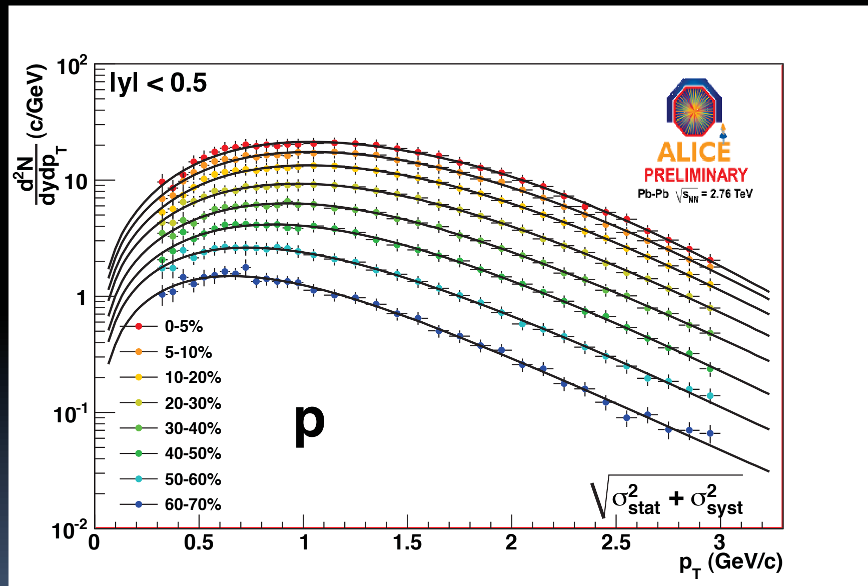
Identified Particle Spectra



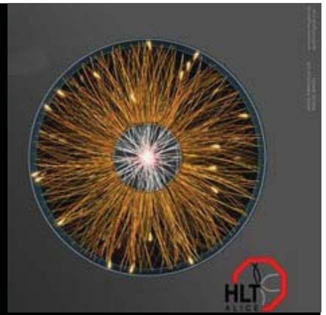
- Analysis performed combining ITS+TPC+TOF PID information in p_T ranges
  - [0.1, 3.0] → π   [0.2, 2.0] → K   [0.3, 3.0] → p
- Blast wave fit to extract yields and $\langle p_T \rangle$

Spectra for different centralities





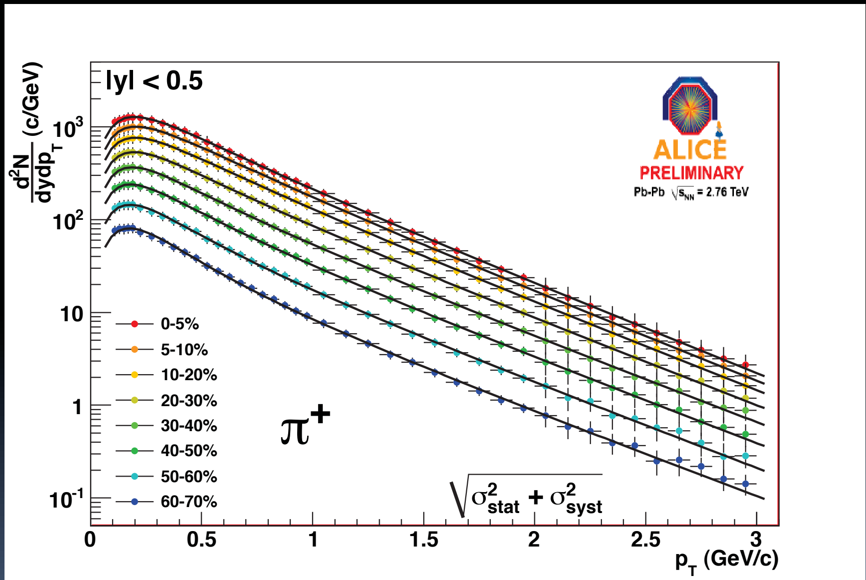
Identified Particle Spectra



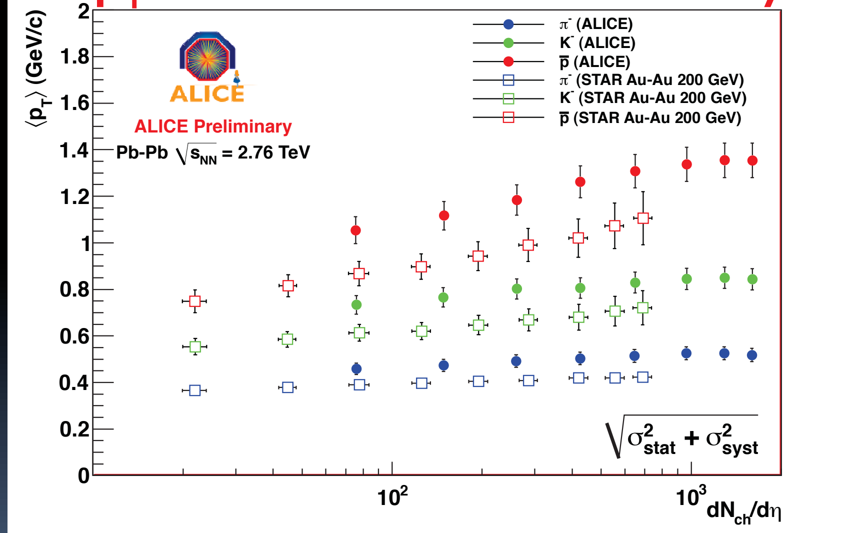
- Analysis performed combining ITS+TPC+TOF PID information in p_T ranges

  [0.1, 3.0] → π [0.2, 2.0] → K [0.3, 3.0] → p
- Blast wave fit to extract yields and $<p_T>$

Spectra for different centralities



$<p_T>$ as a function of centrality

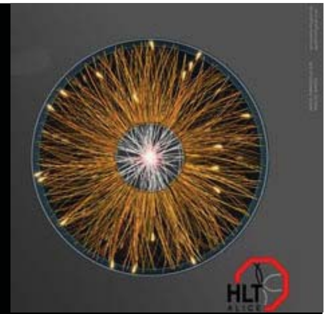


Harder spectra at LHC

Mean p_T increases with mass

- Stronger radial flow?

Identified Particle Spectra

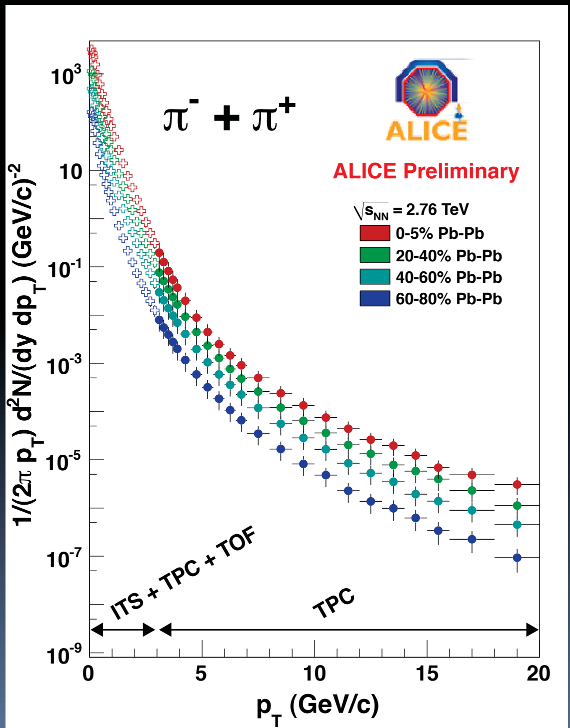


- Analysis performed combining ITS+TPC+TOF PID information in p_T ranges

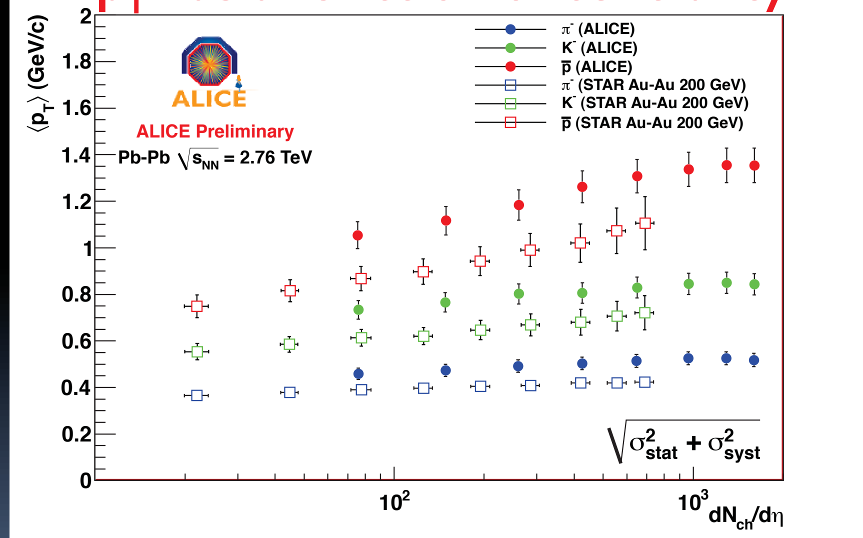
  [0.1, 3.0] → π   [0.2, 2.0] → K   [0.3, 3.0] → p

- Blast wave fit to extract yields and $\langle p_T \rangle$

Spectra for different centralities



$\langle p_T \rangle$ as a function of centrality



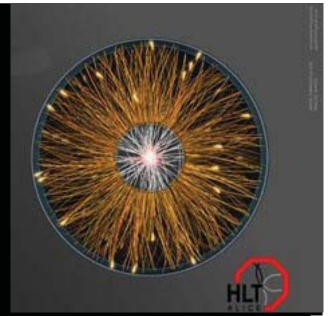
Harder spectra at LHC

Mean p_T increases with mass

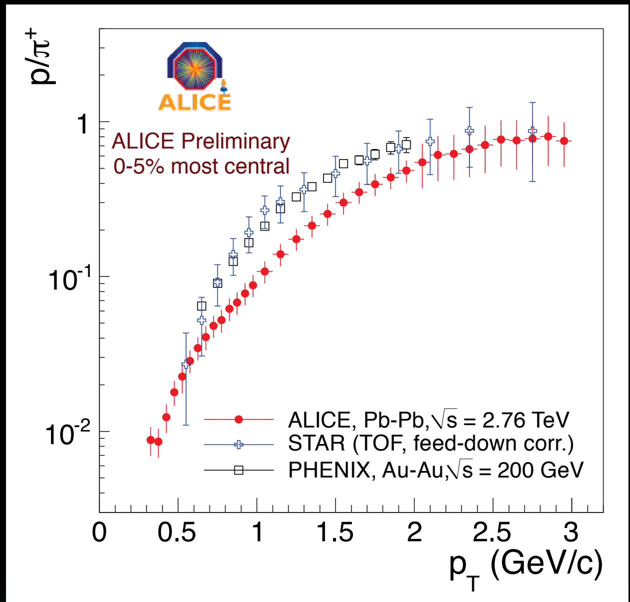
- Stronger radial flow?

Identified Particle Spectra

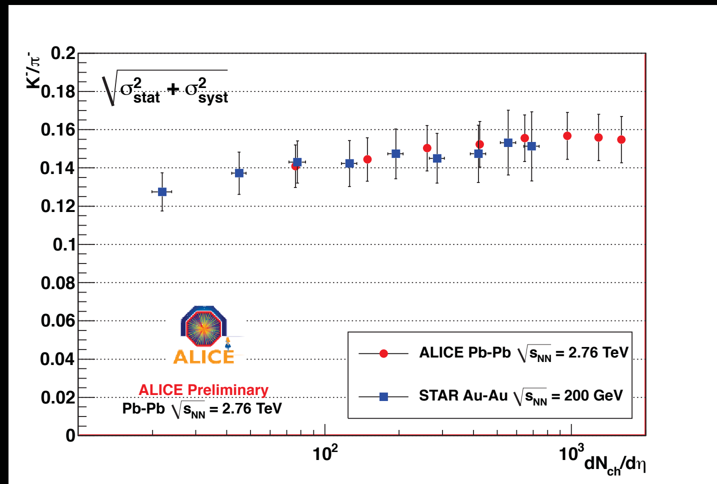
ratios



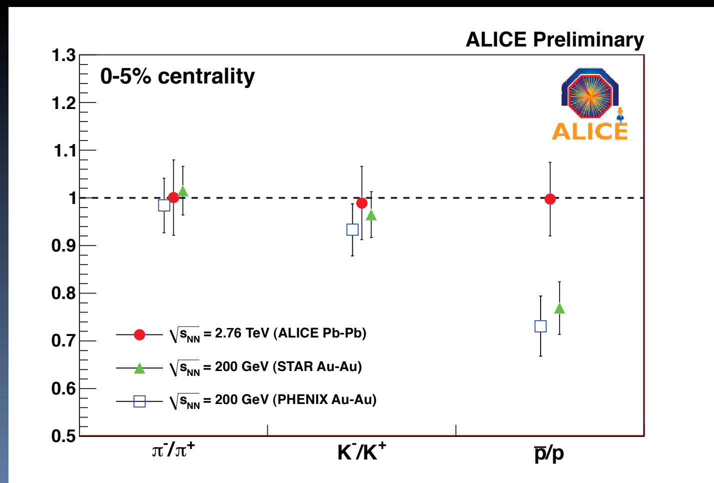
As a function of p_T



As a function of multiplicity



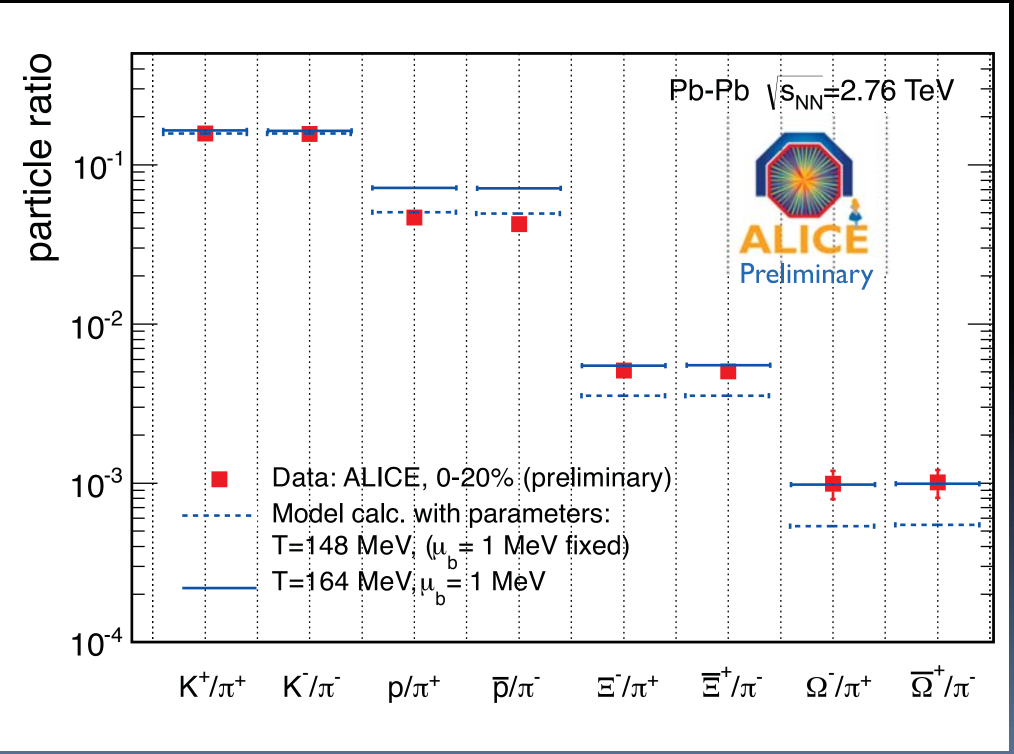
Comparison with RHIC

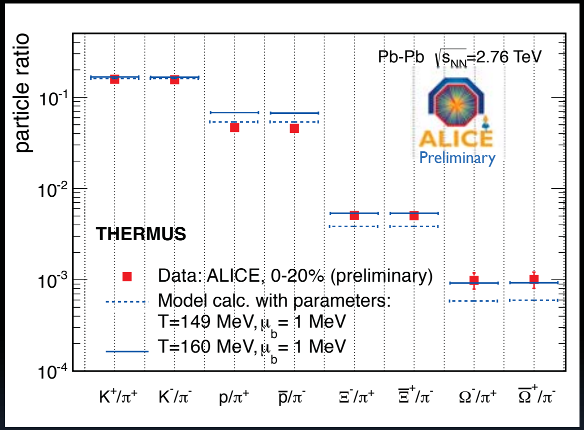


- Particle-antiparticle productions very similar
  - $\mu_B \approx 0$

Thermal Models

- All ratios containing strangeness on top of model expectations
  - Protons are an exception, below expectations → model tuned ad hoc with a T_{fo} = 148

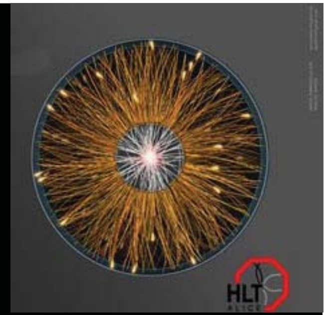


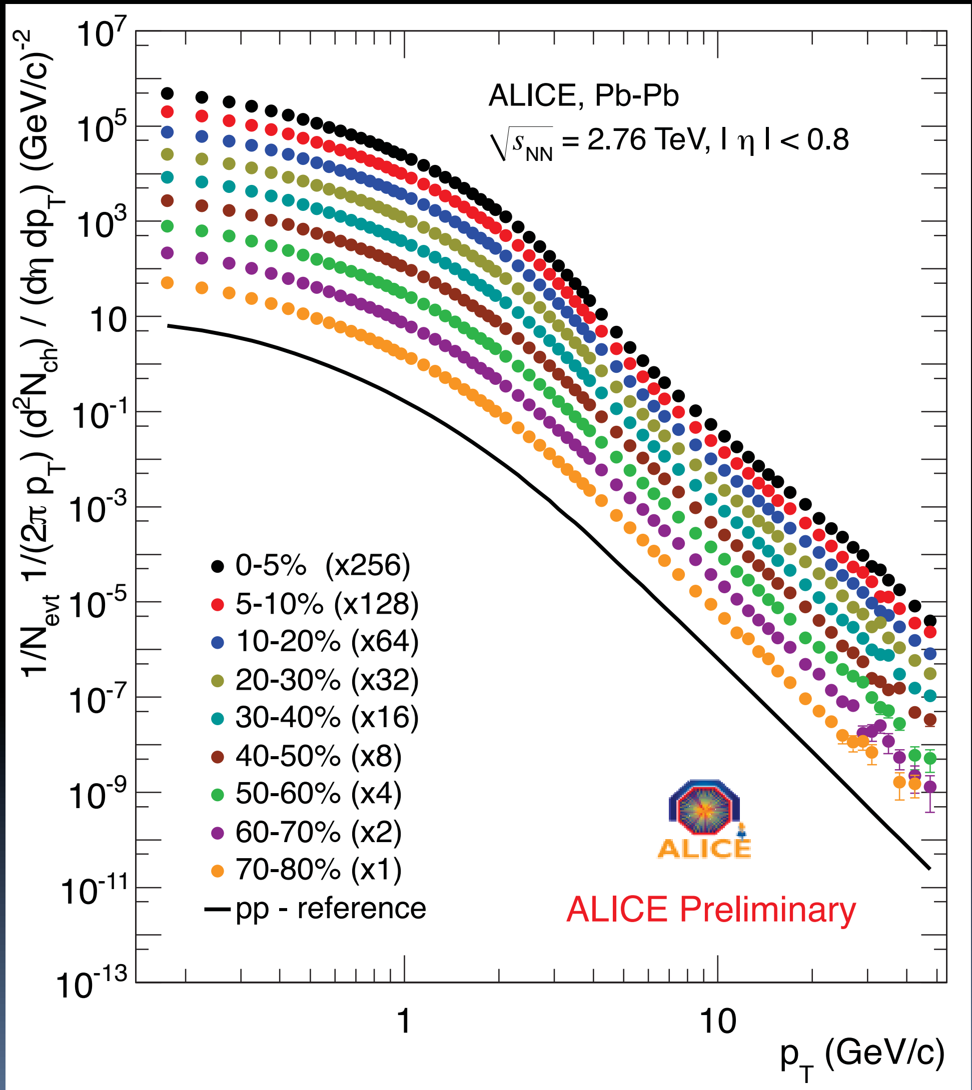


Same for THERMUS
S. Wheaton, J. Cleymans and M. Hauer, Comput. Phys. Commun. 180 (2009) 84-106

A. Andronic et al., PLB 673, 2009, 142

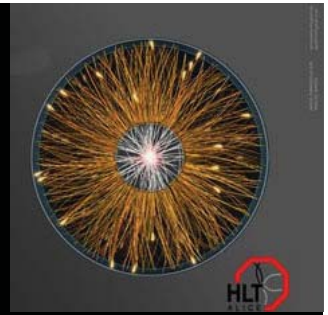
p_T Spectra of Charged Particles





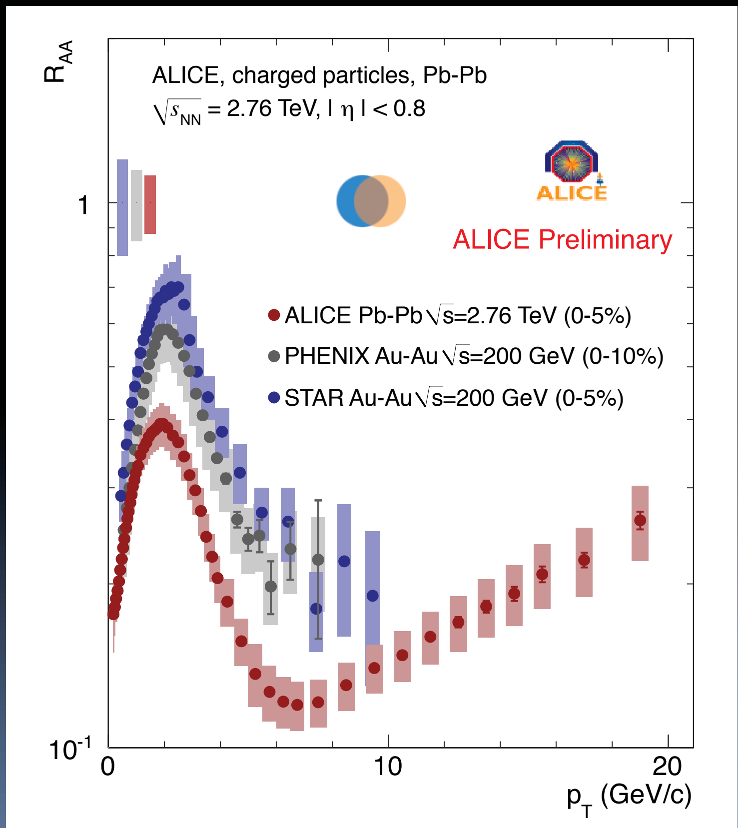
- p_T spectra up to 50 GeV/c for different centrality classes
  - Up to 100 GeV/c with increased statistics
- Shape changes with centrality

Nuclear Modification Factor



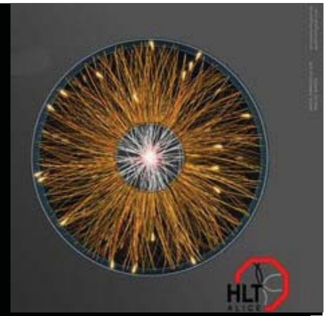
$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta\, dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta\, dp_T}$$

Comparison with RHIC



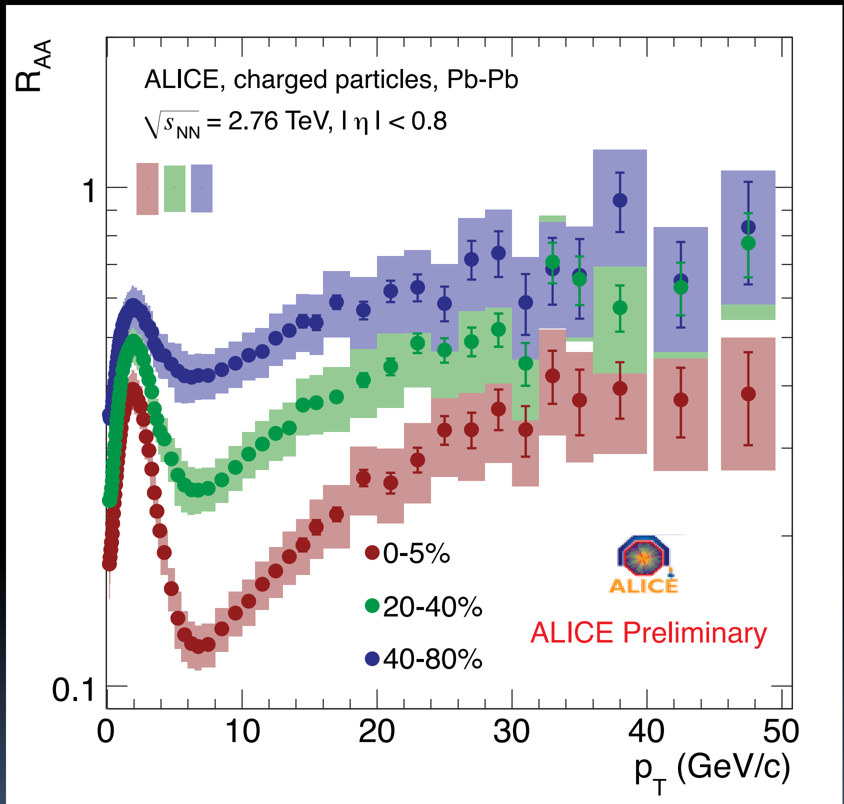
- p_T ~ 1 GeV/c: similar value
- Low-intermediate p_T: shape and maximum position (at 2 GeV/c) similar
- High p_T (6-7 GeV/c): ALICE R_{AA} smaller than at RHIC → more energy loss, denser medium

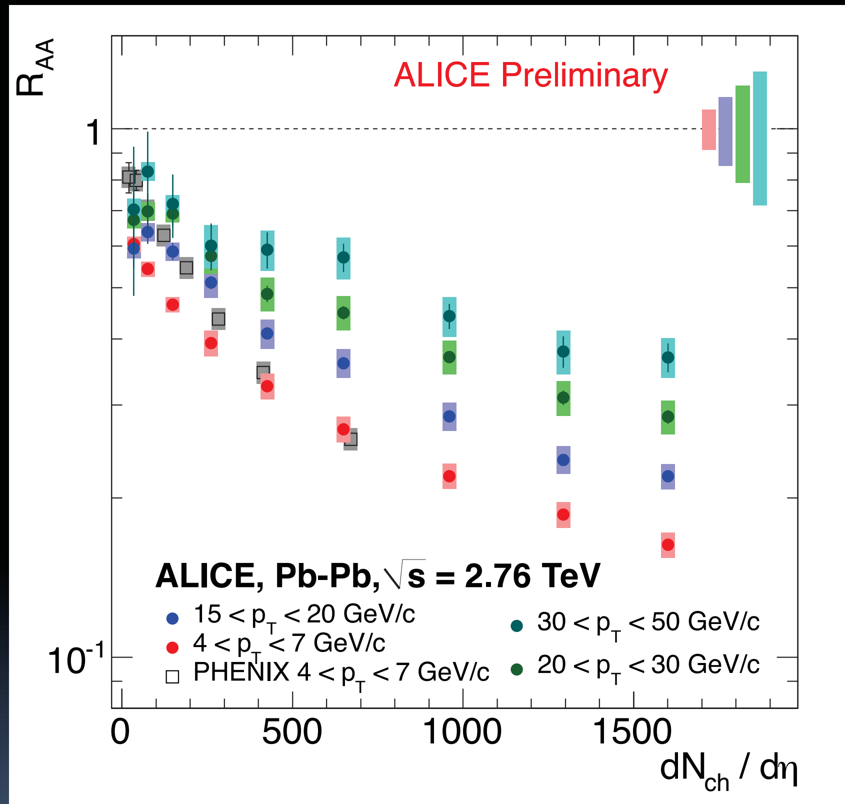
Nuclear Modification Factor



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

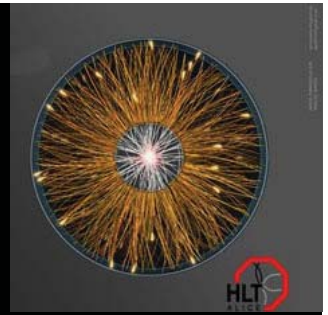
R_{AA} as a function of centrality





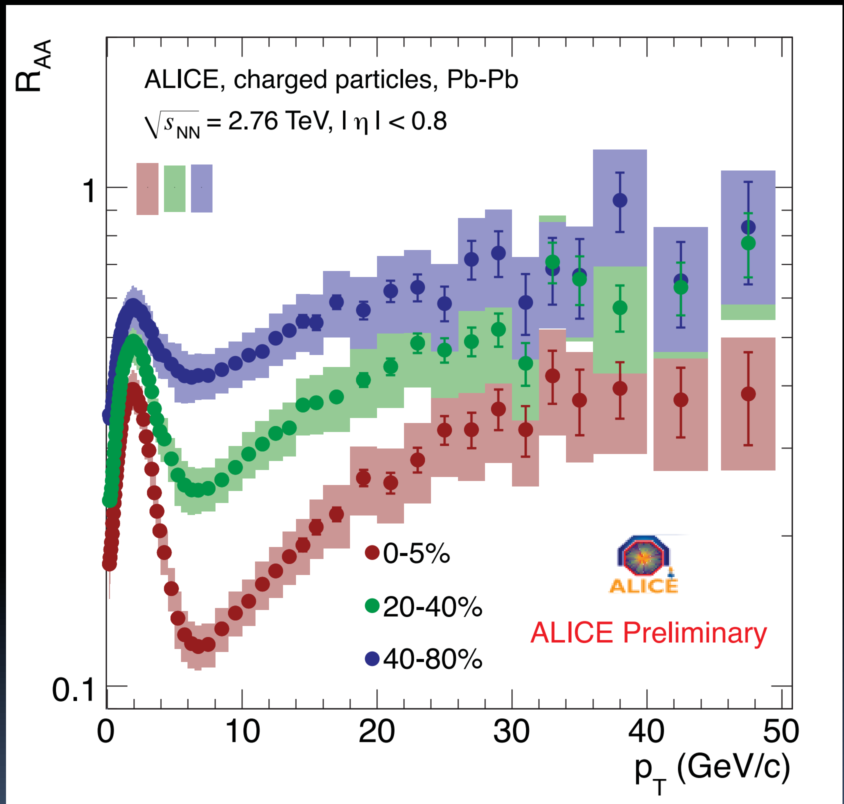
- Different suppression pattern vs centrality
- Minimum at ~ the same p_T
- Leveling at ~30 GeV/c in central collisions

Nuclear Modification Factor

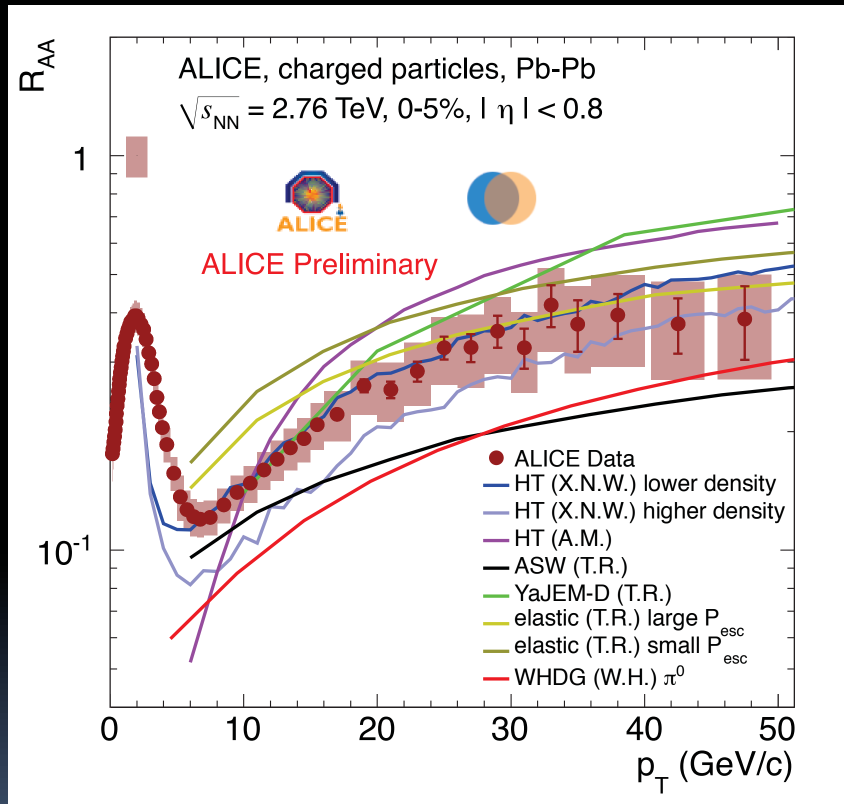


$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$

R_{AA} as a function of centrality



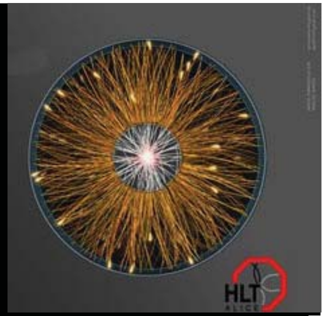
Comparison to models



- Different suppression pattern vs centrality
- Minimum at ~ the same p_T
- Leveling at ~30 GeV/c in central collisions

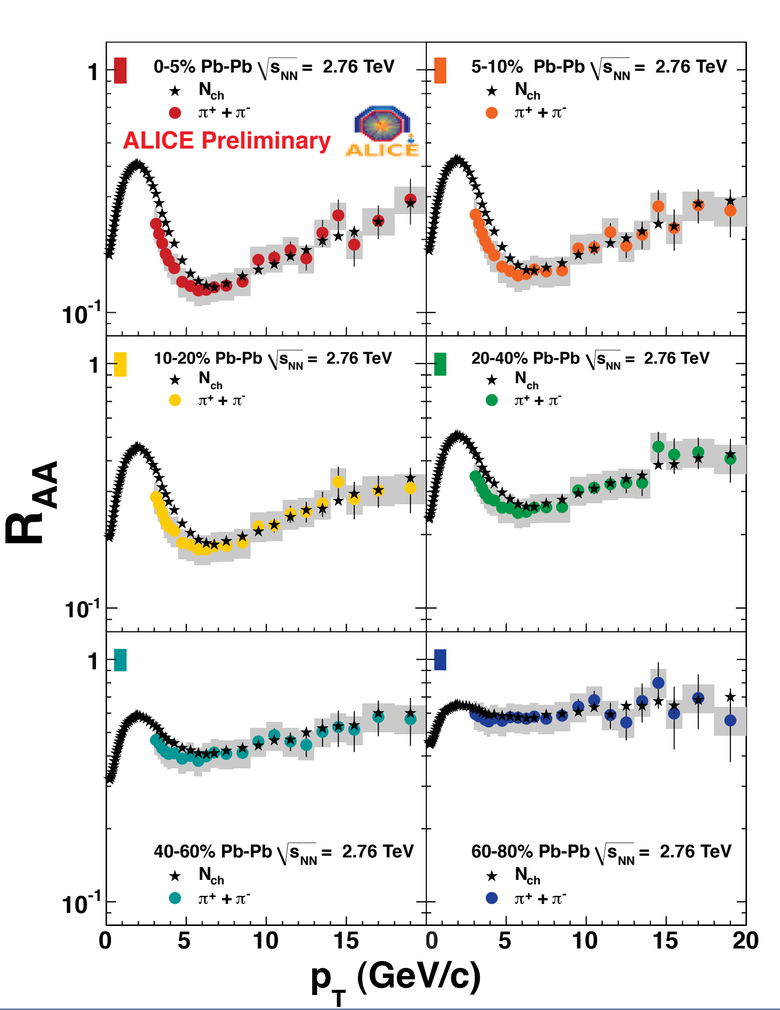
- Models tuned to RHIC

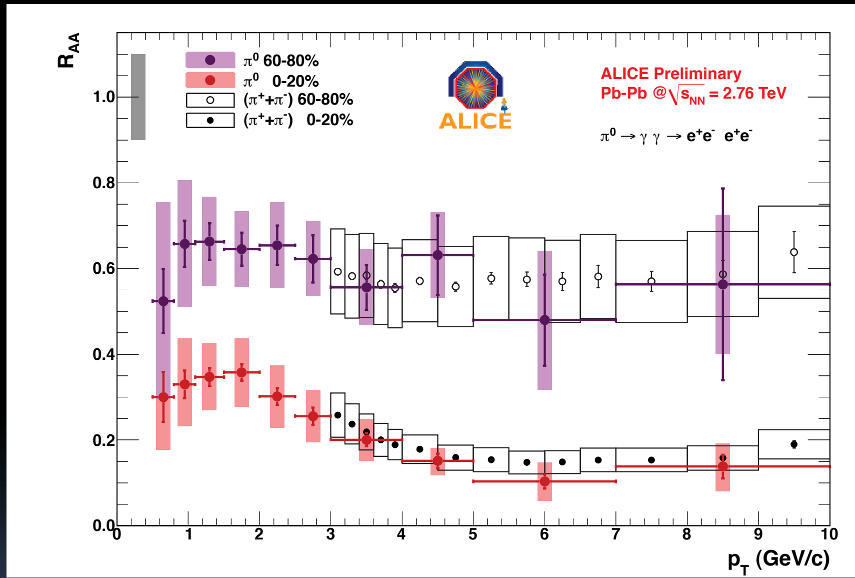
Nuclear Modification Factor



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

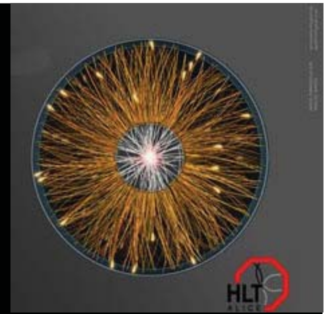
Charged and neutral pions





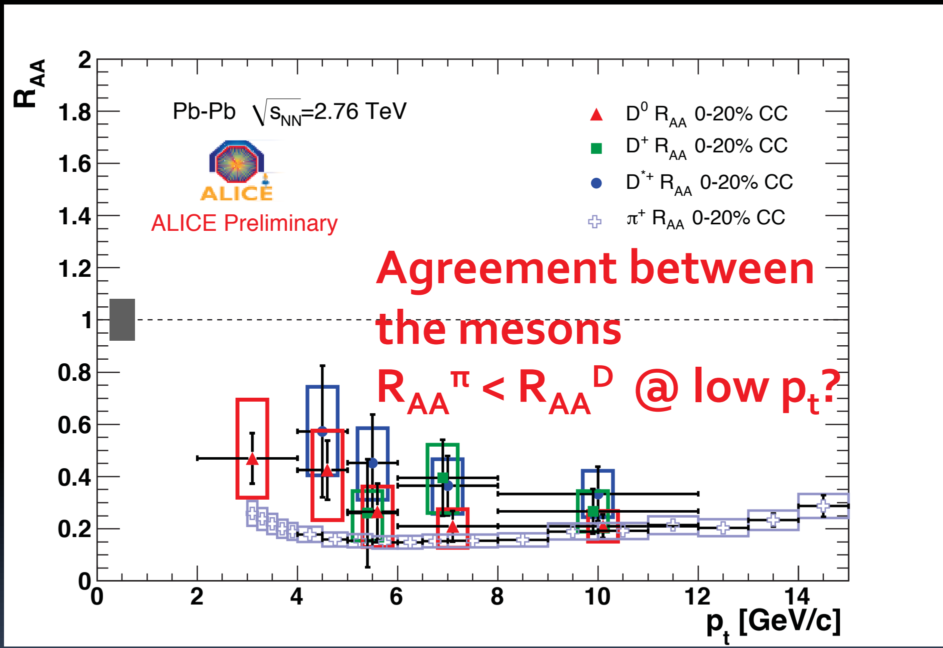
- Good agreement between charged and neutral π

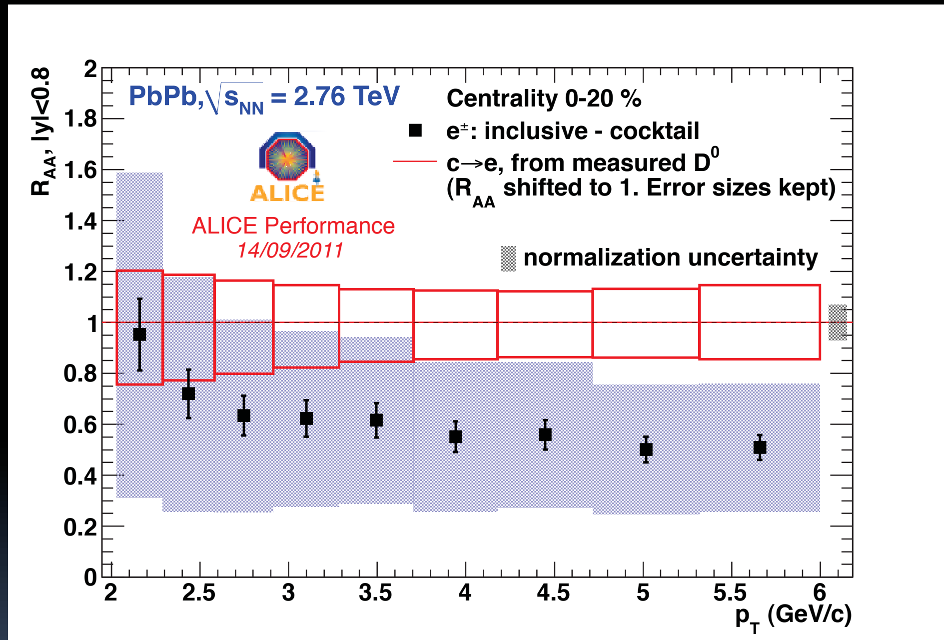
Open Heavy Flavor



- R_{AA} of open charm
  - Study energy loss mechanism (dead cone + Casmir effect):

    $\Delta E_g > \Delta E_{uds} > \Delta E_c > \Delta E_b \rightarrow R_{AA}^{\pi} < R_{AA}^{D} < R_{AA}^{B}$

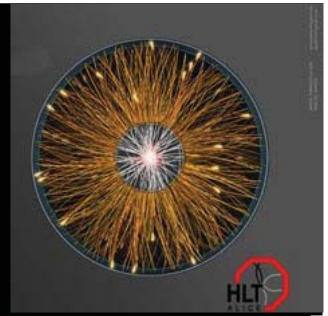




- Reference from scaled 7 TeV spectra
- Suppression ~5x at high p_T (~4 times larger in central events than in peripheral)

- c→e from Do measurement + decay kine

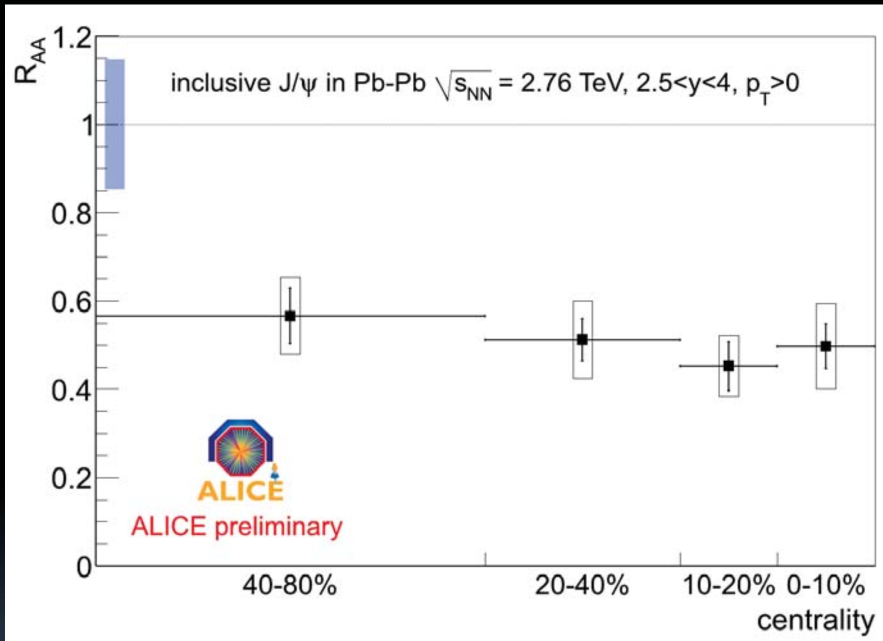
  Way to compare charm and beauty suppression @ midrapidity

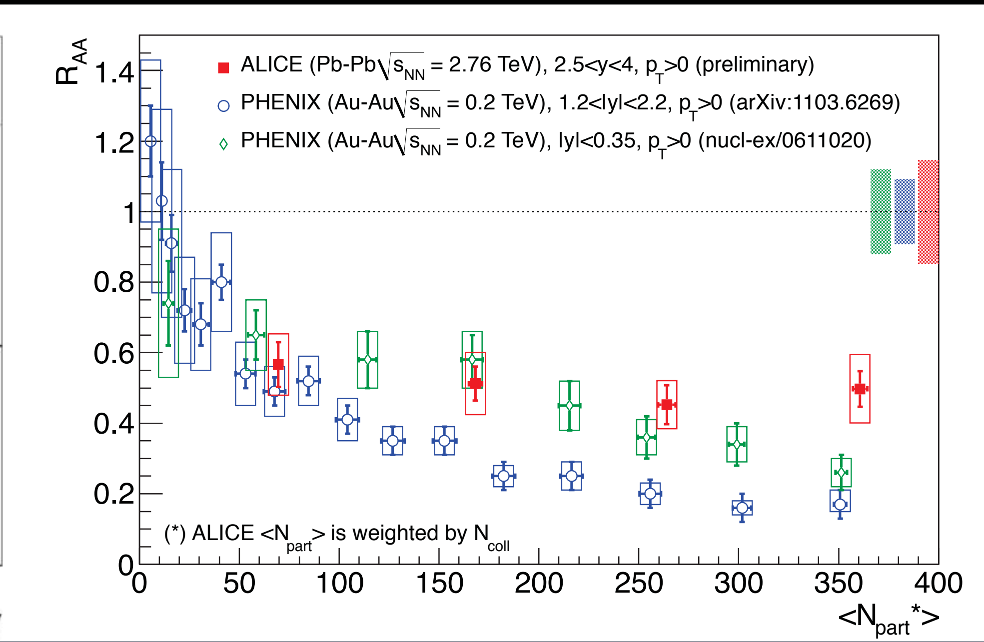


Quarkonia

R_{AA} as a function of centrality

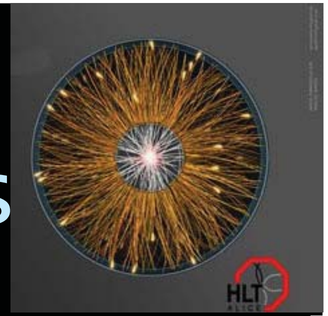
Comparison to RHIC





- Very little (almost no) dependence on centrality
- Comparison with model started
- Less suppression than at RHIC in most central events

Triggered Di-Hadron Correlations



- To further study the energy loss mechanism and to determine the p_T region where collective effects/jet-like correlations dominates
- Choose a particle from one p_T region ("trigger particle") and correlate with particles from another p_T region ("associated particles") where $p_{T,assoc} < p_{T,trig}$ in bins of $p_{T,trig}$ and $p_{T,assoc}$
- Define:

Per-trigger yield

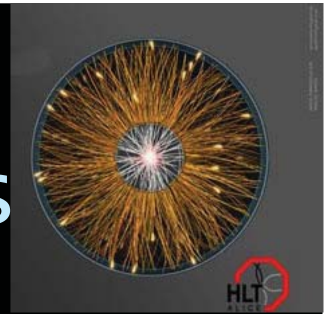
$$Y(\Delta\varphi) = \frac{1}{N_{trig}} \frac{dN_{assoc}}{d\Delta\varphi}$$

Correlation function

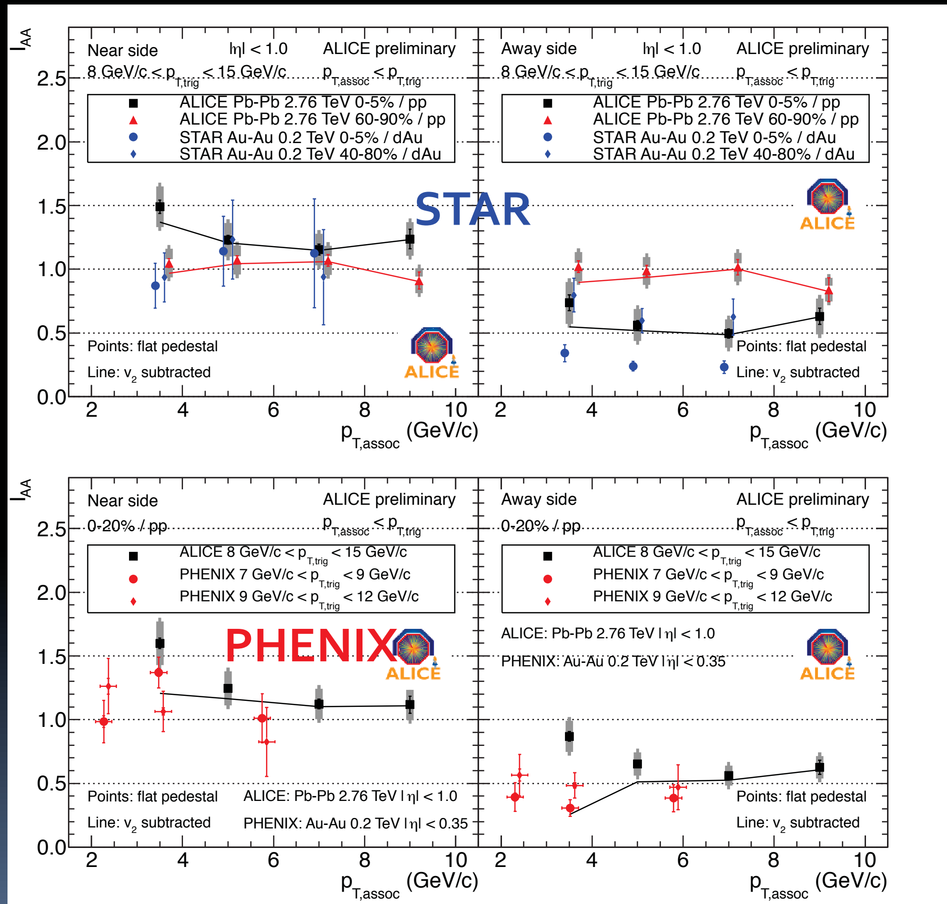
$$C(\Delta\varphi,\Delta\eta) = \left(\frac{1}{N_{pair}} \frac{d^2N_{assoc}}{d\Delta\varphi d\Delta\eta}\right)_{same} \Big/ \left(\frac{1}{N_{pair}} \frac{d^2N_{assoc}}{d\Delta\varphi d\Delta\eta}\right)_{mixed}$$

- Extract near and away-side jet yields from per-trigger yields
  - Compare Pb-Pb and pp → I_{AA}
  - Compare central and peripheral collisions → I_{CP}
- Analysis strategy: characterize the structures in the long-range correlation region with a Fourier decomposition

Triggered Di-Hadron Correlations results - I

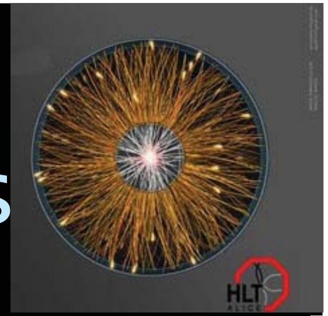


Comparison to RHIC

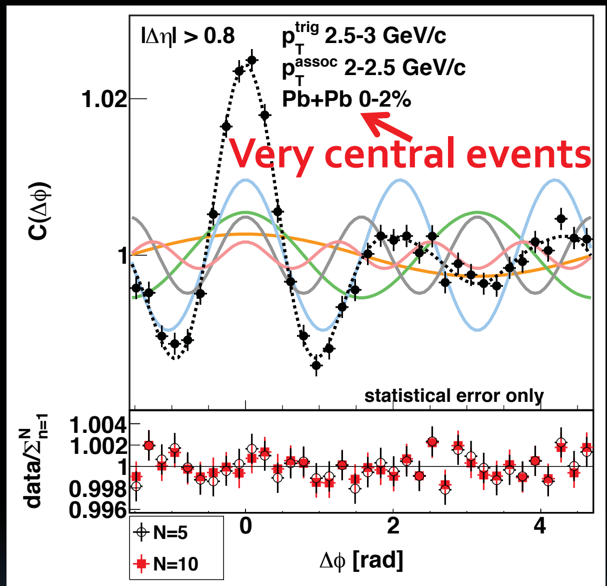


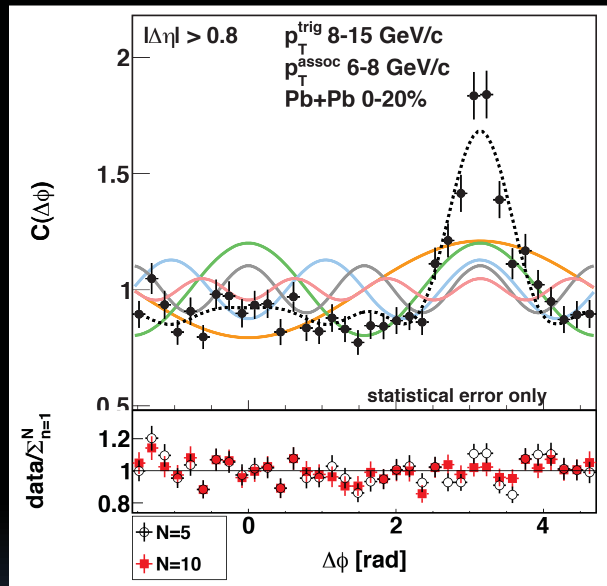
- Measurement in a region where collective effects are small
  - $p_{T,\,trig} > 8$ GeV/c
- Uncorrelated and v_2 background subtracted
- Comparison to models studied
- Caveat: same trigger p_T probes different parton p_T at different $\sqrt{s_{NN}}$
- STAR and PHENIX subtract v_2 → compare with ALICE line
  - STAR I_{AA} w.r.t. to dAu reference
  - STAR has different centrality for peripheral events
  - Away side larger than at STAR
  - PHENIX has (slightly) different $p_{T,trig}$ ranges
- No evidence for near-side $I_{AA} > 1$ at RHIC, but not excluded
- ALICE I_{CP} in agreement with I_{AA} (near-side enhancement + away-side suppresion)

Triggered Di-Hadron Correlations
results - II



- Fourier coefficients



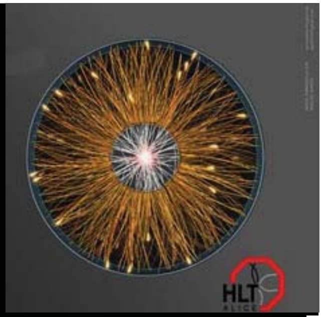


- Strong near-side ridge + double peak at away side
- 5 harmonics look enough to describe the correlation well

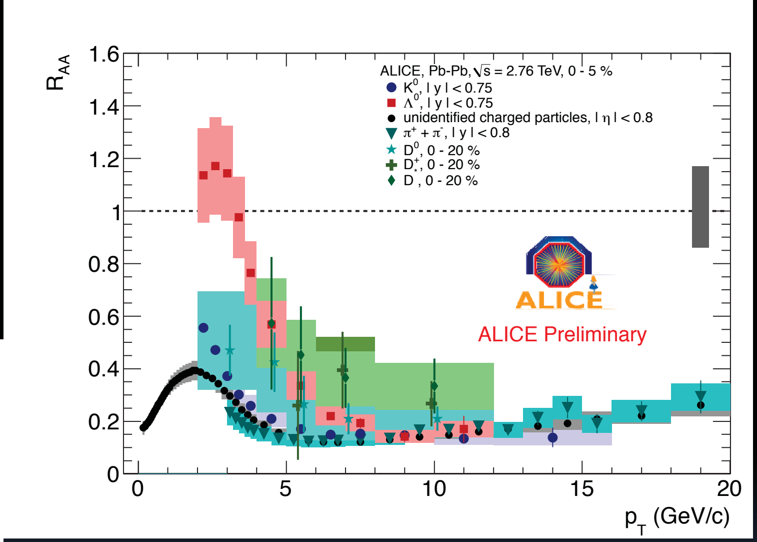
- Away-side peak dominates
- Higher harmonics improve the description of the correlations

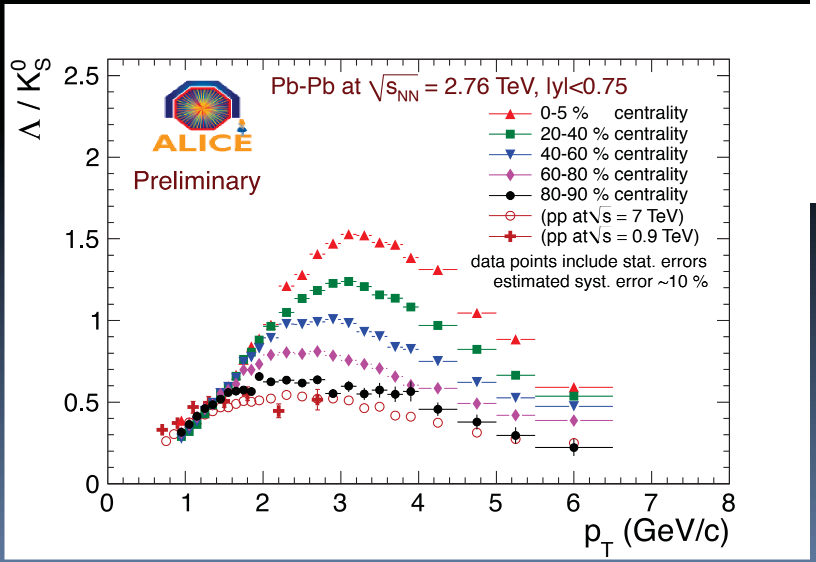
The flow factorization (not shown here) demonstrates that up to 3-4 GeV/c collectivity dominates, while at larger p_T jet-like correlations take over

…and much more…



- Higher harmonics in flow analysis
- Jets
- Hyperons
- Strangeness
- …





Summary and Conclusions

- The ALICE experiment has shown an excellent performance during pp and PbPb data taking, some highlights presented here
  - Many results already published and many analyses well ongoing
- pp collisions have shown challenging results for MC tuning…
- …and have allowed to start studying the medium created in PbPb collisions
- Wrt RHIC, ALICE has shown:
  - Similar dependence of multiplicity on centrality
  - An increased (by 30%) v_2 (mainly due to higher p_T)
  - Harder spectra (stronger radial flow?)
  - Stronger R_{AA}
  - Smaller J/ψ suppression
- Much more has been found not shown here…

Stay tuned, we're just at the doors of Wonderland

An Appropriate Citation

ALICE

"so many out-of-the-way things had happened lately, that Alice had begun to think that very few things indeed were really impossible."
L. Carrol, Alice's Adventures In Wonderland