The latest results from ALICE

(with focus on Heavy Ions)

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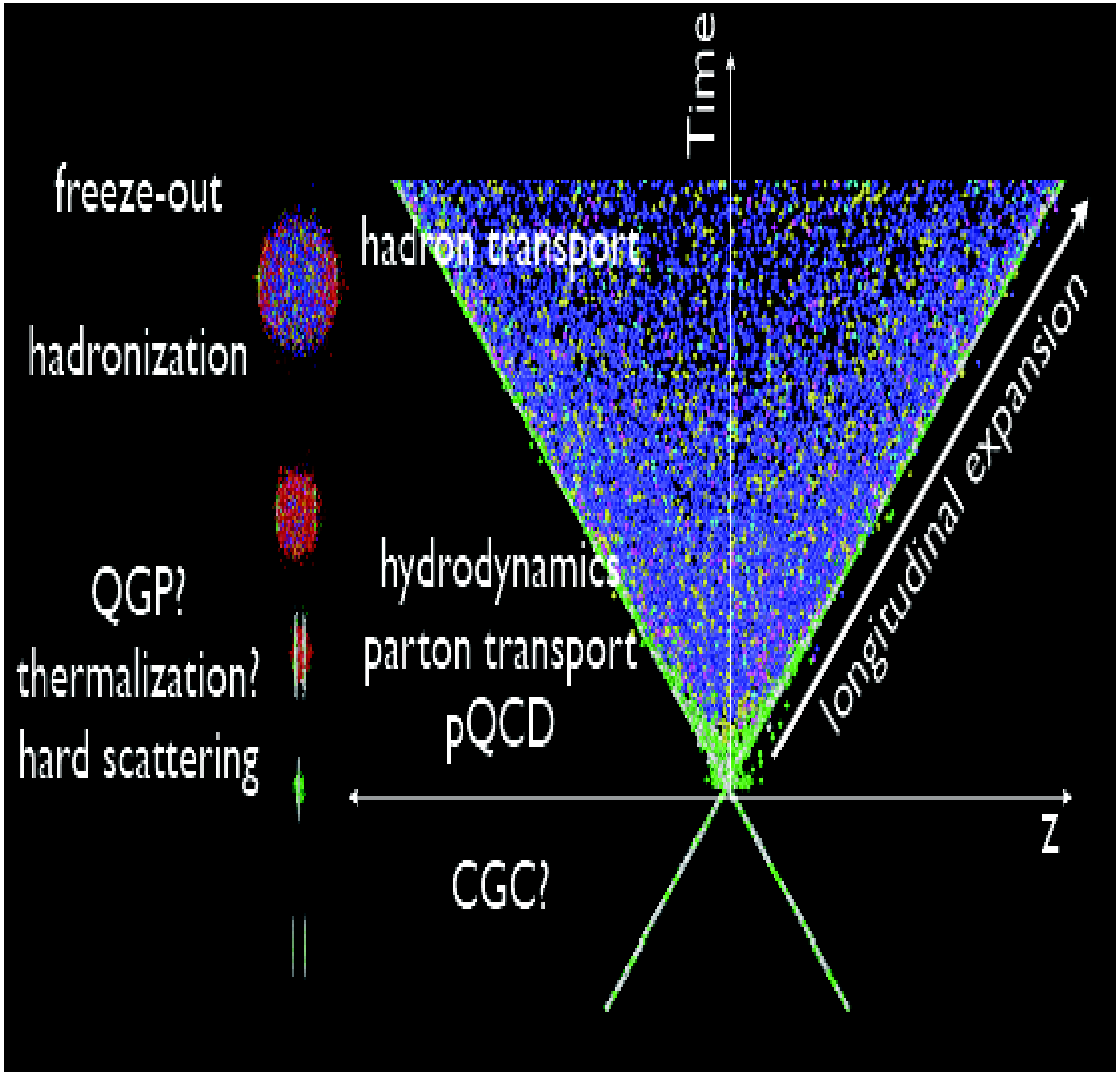
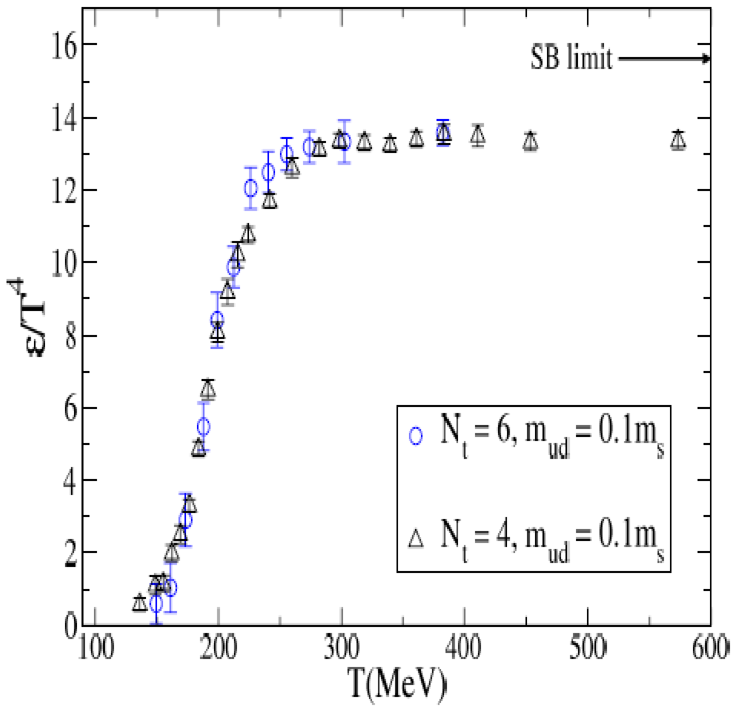
XL International Meeting on IMFP 2012, Benasque, May 2012

The “standard model” for the space-time picture of a Heavy Ion Collision



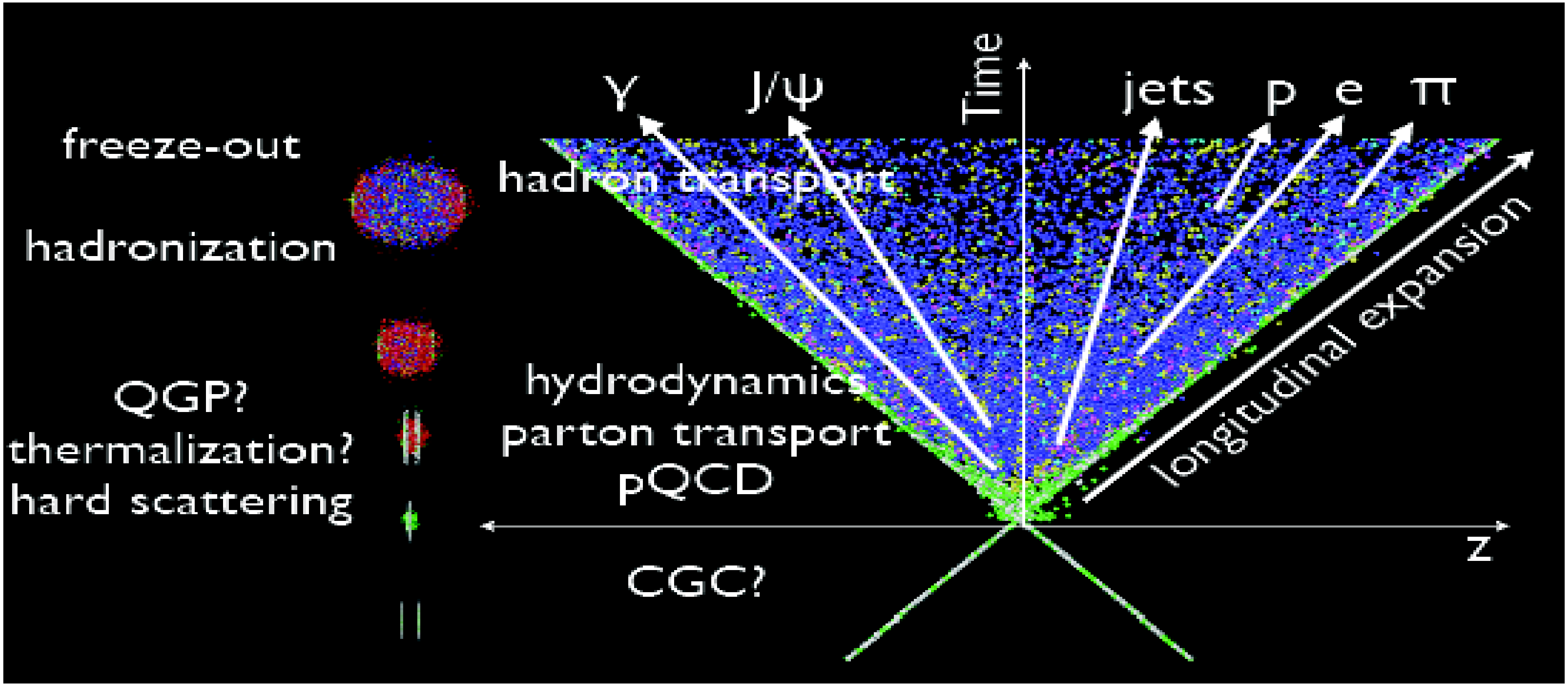


ε_c~1 GeV/fm3

T_c~170 MeV

from Lattice QCD

Probing the "standard model" of Heavy Ion Collisions

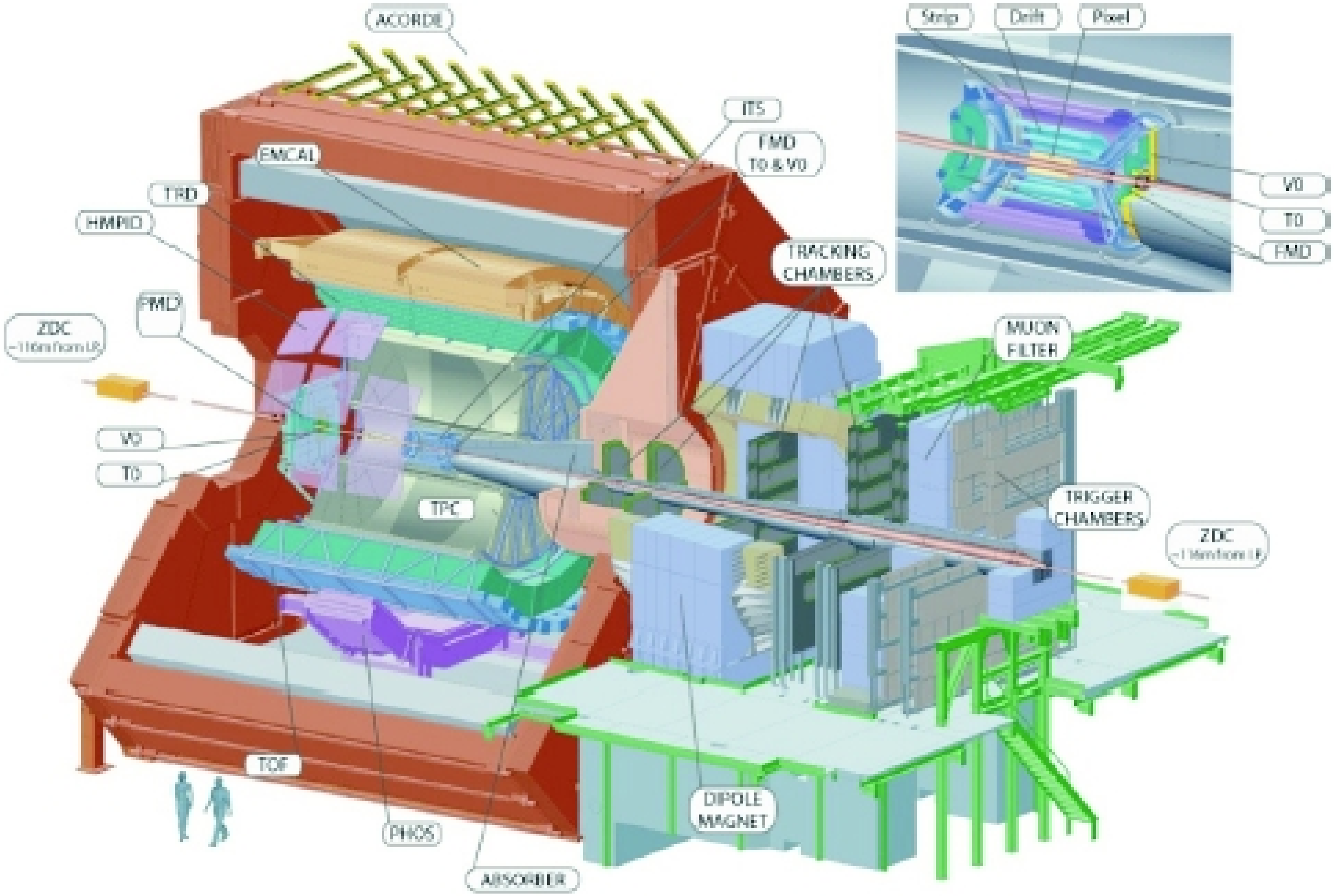


Probes

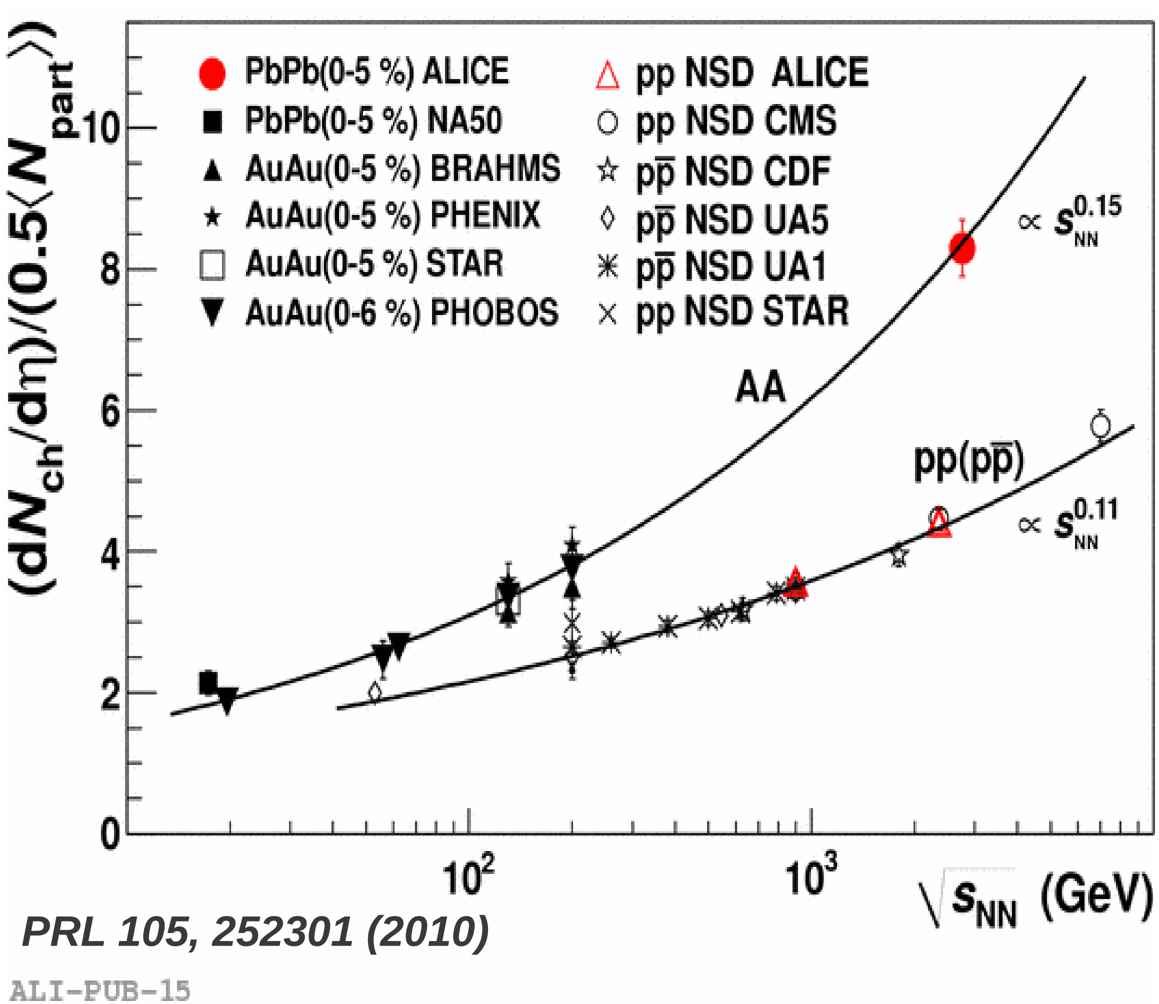
-**Collective Motion: radial, elliptic (higher orders) flow**
-**Critical fluctuations**
-**Thermal electromagnetic radiation**
-**Hard probes**

...

The ALICE experiment



The bulk: multiplicity



PRL 105, 252301 (2010)

5% most central events:

$dN_{ch}/d\eta$ = 1584±4(stat)±76 (sys)

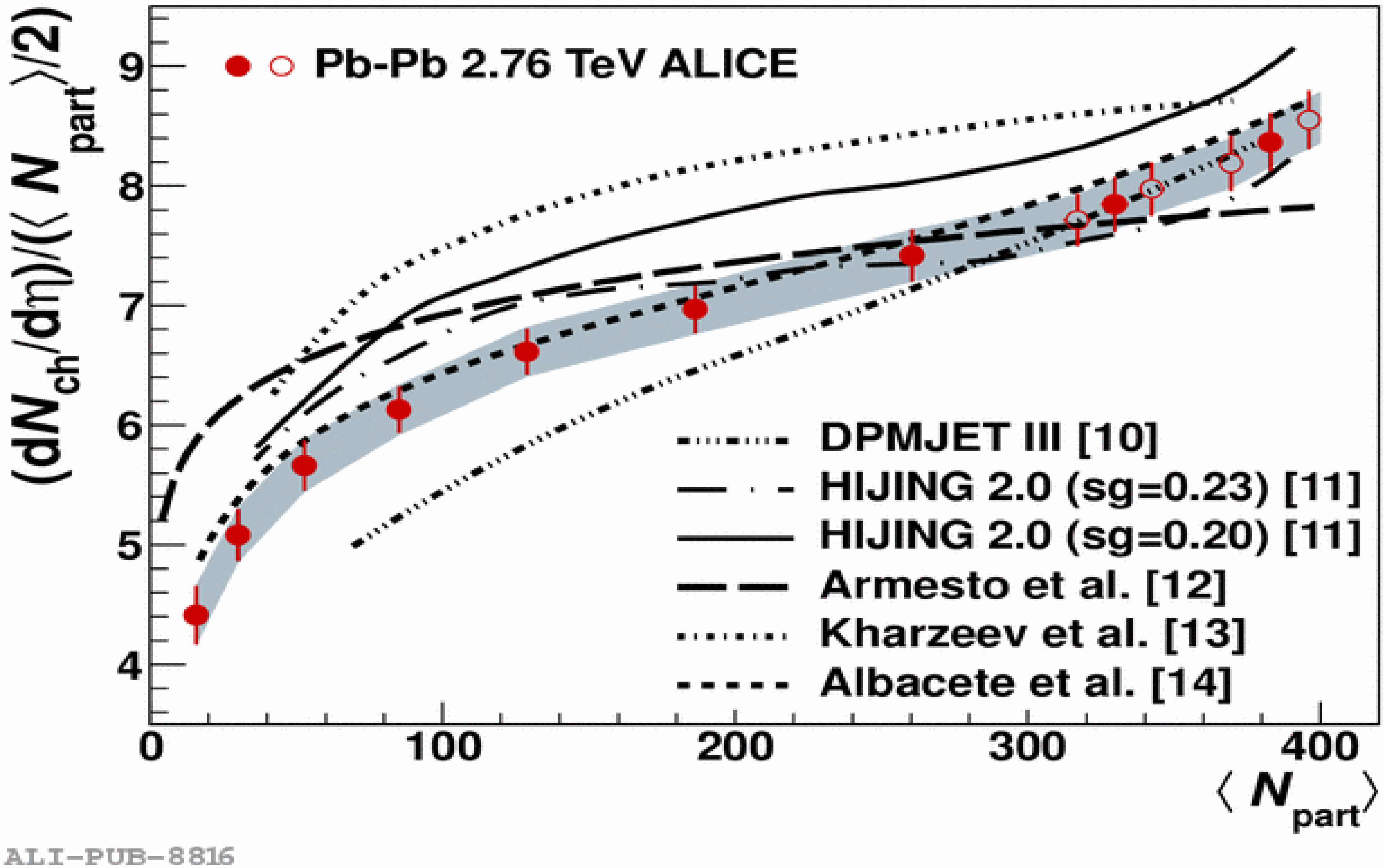
Multiplicity grows with √s

Nuclear amplification:

PbPb(√sNN=2.76 TeV) ~1.9 pp(√s=2.36TeV)

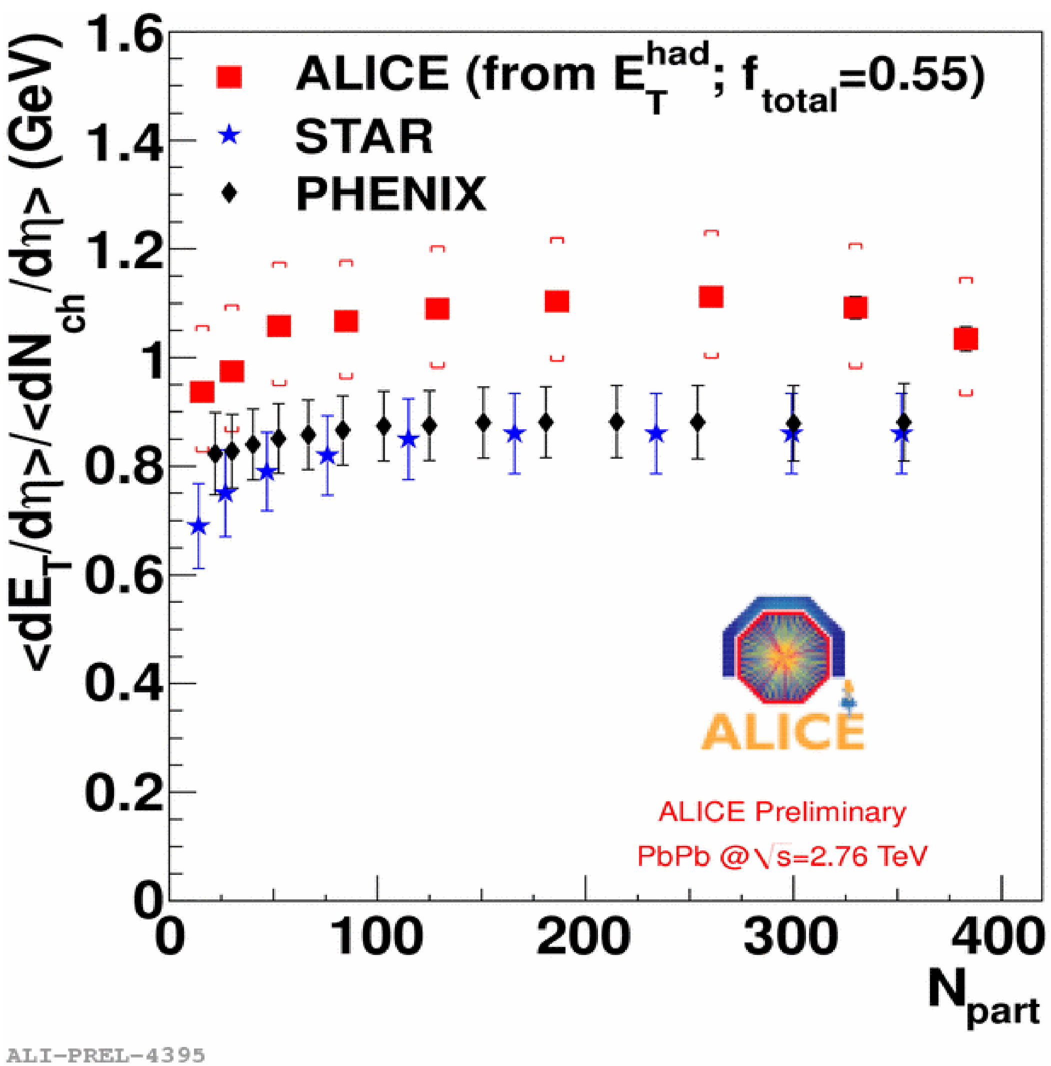
The bulk: multiplicity

PRL 106 (2011) 032301



The centrality dependence of particle multiplicity puts strong constraints on theoretical models.

The bulk: transverse energy density



Bjorken energy density estimate:

$$\varepsilon_{Bj} = \frac{1}{\tau \pi R^2} \frac{dE_T}{d\eta}$$

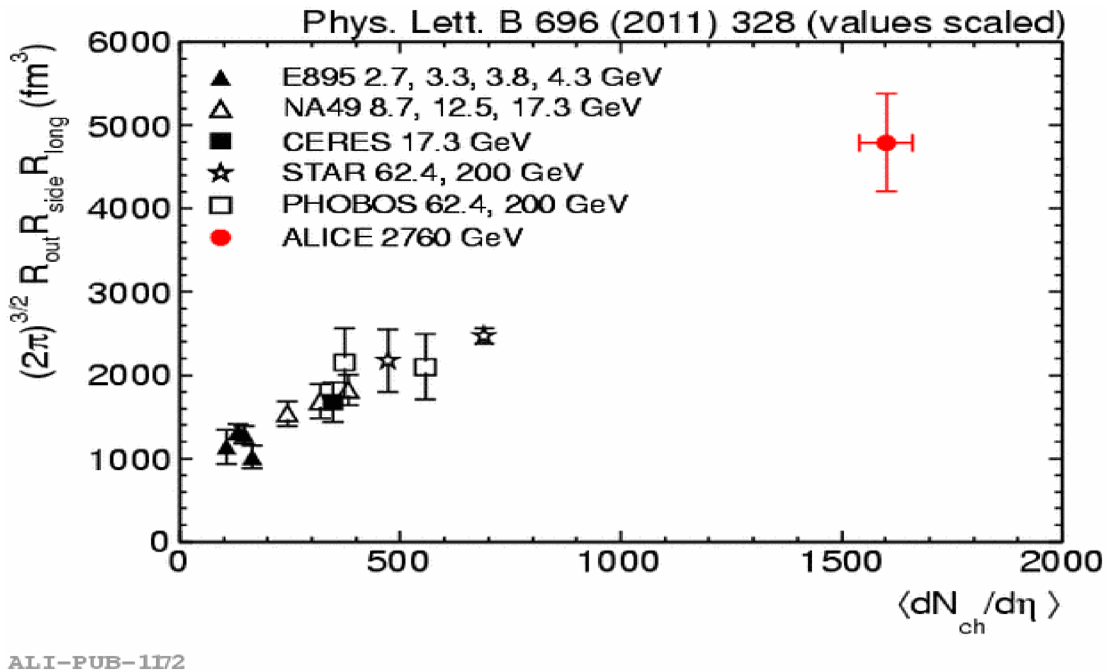
$\pi R2$->area of the overlapping region

$\varepsilon_{Bj}\,\tau \sim 16\ \mathrm{GeV/fm^2}$

τ-->formation time, unknown, τ<1fm/c

Bjorken estimate well above lattice critical density

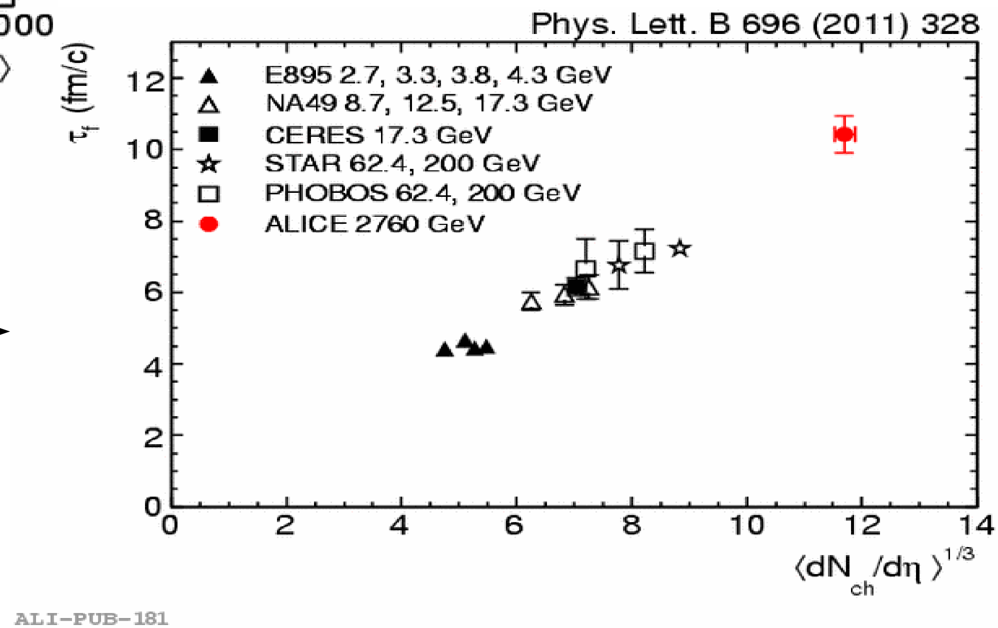
The size & lifetime of the source: pion interferometry



Two pion interferometry/
Bose Einsten correlations-->
particle source volume and lifetime

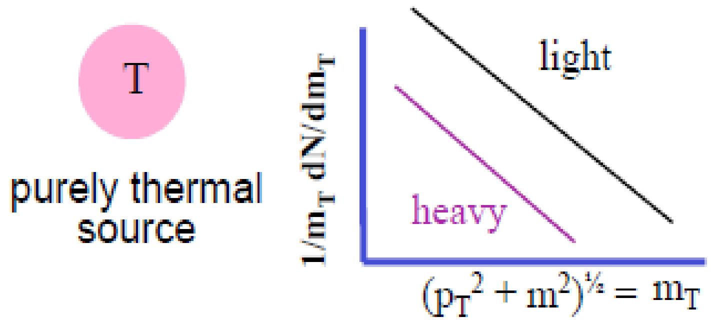
V=5000 fm^3

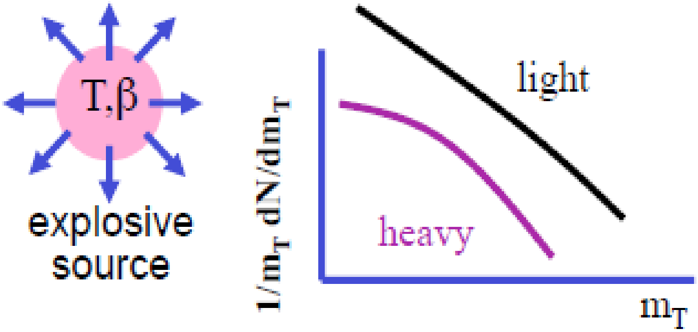
R_{long}~t_f=11 fm/c



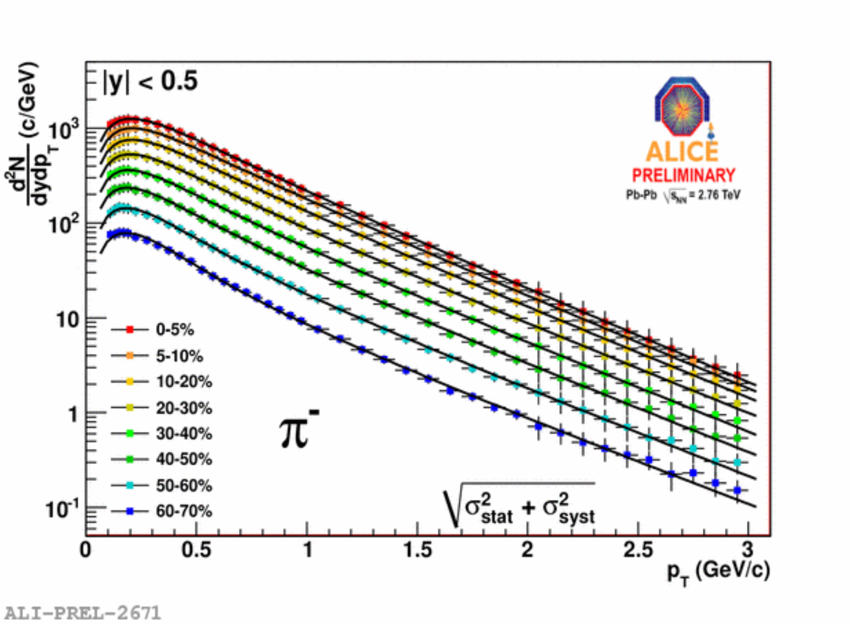
Larger and longer living source than at RHIC

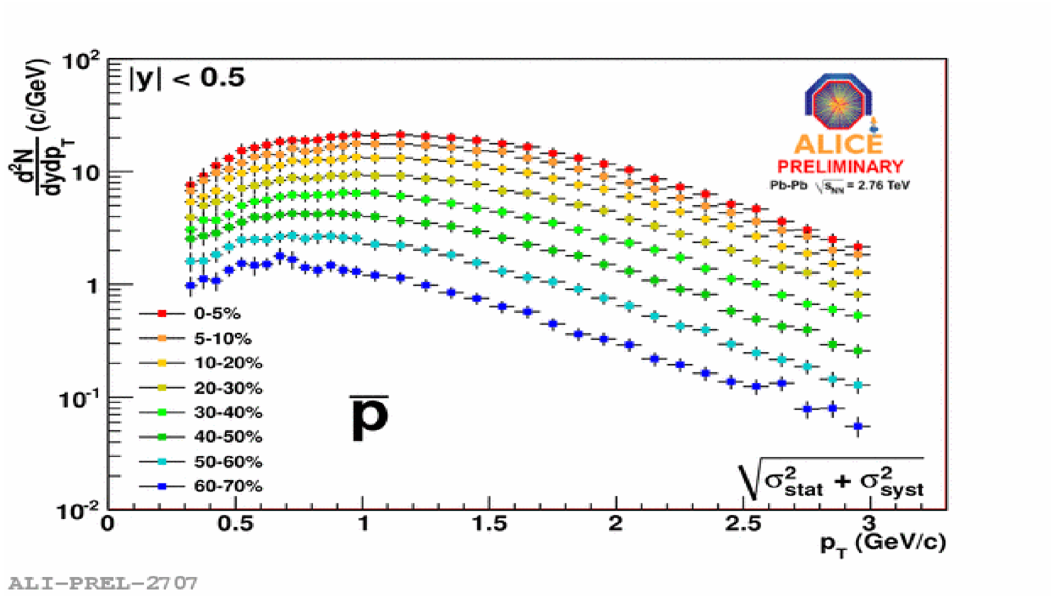
The radial flow: collective transverse expansion



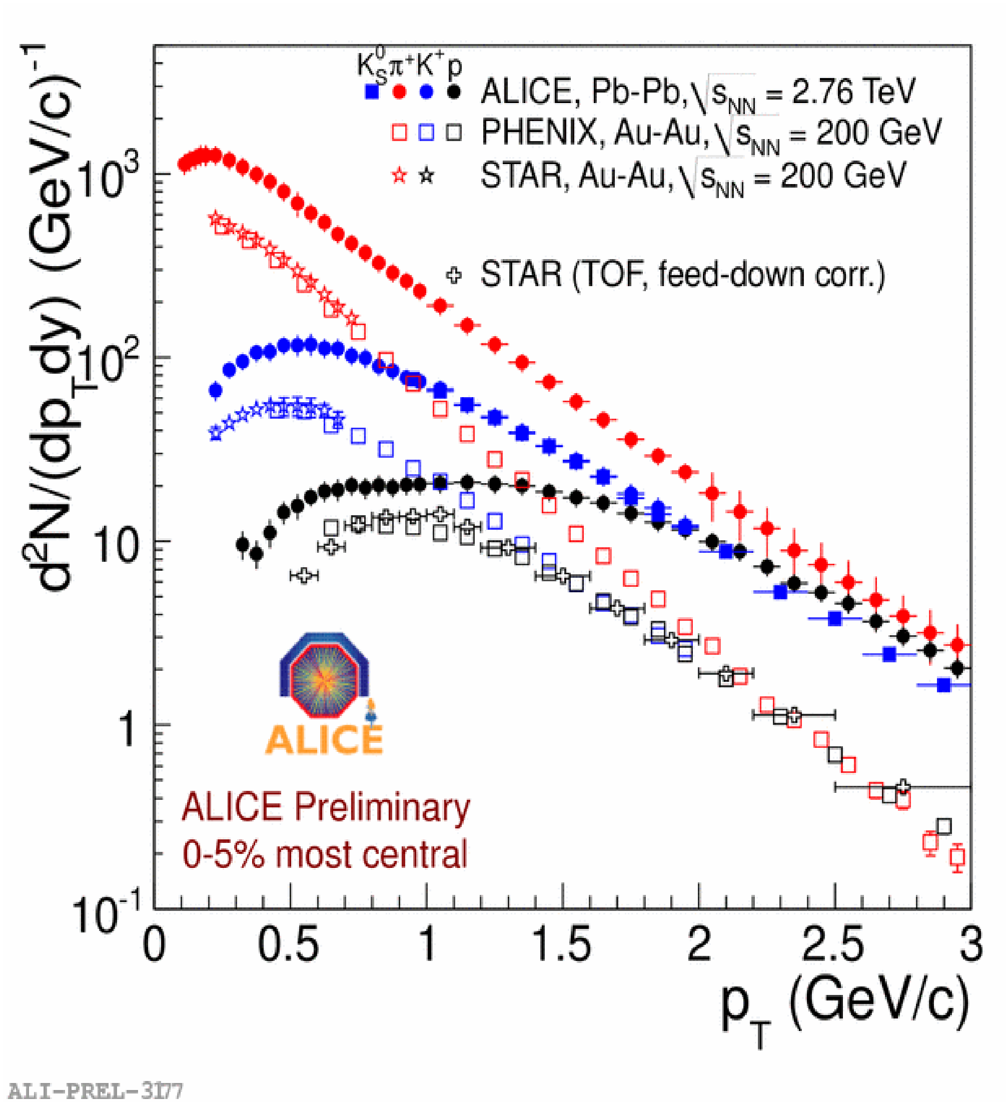


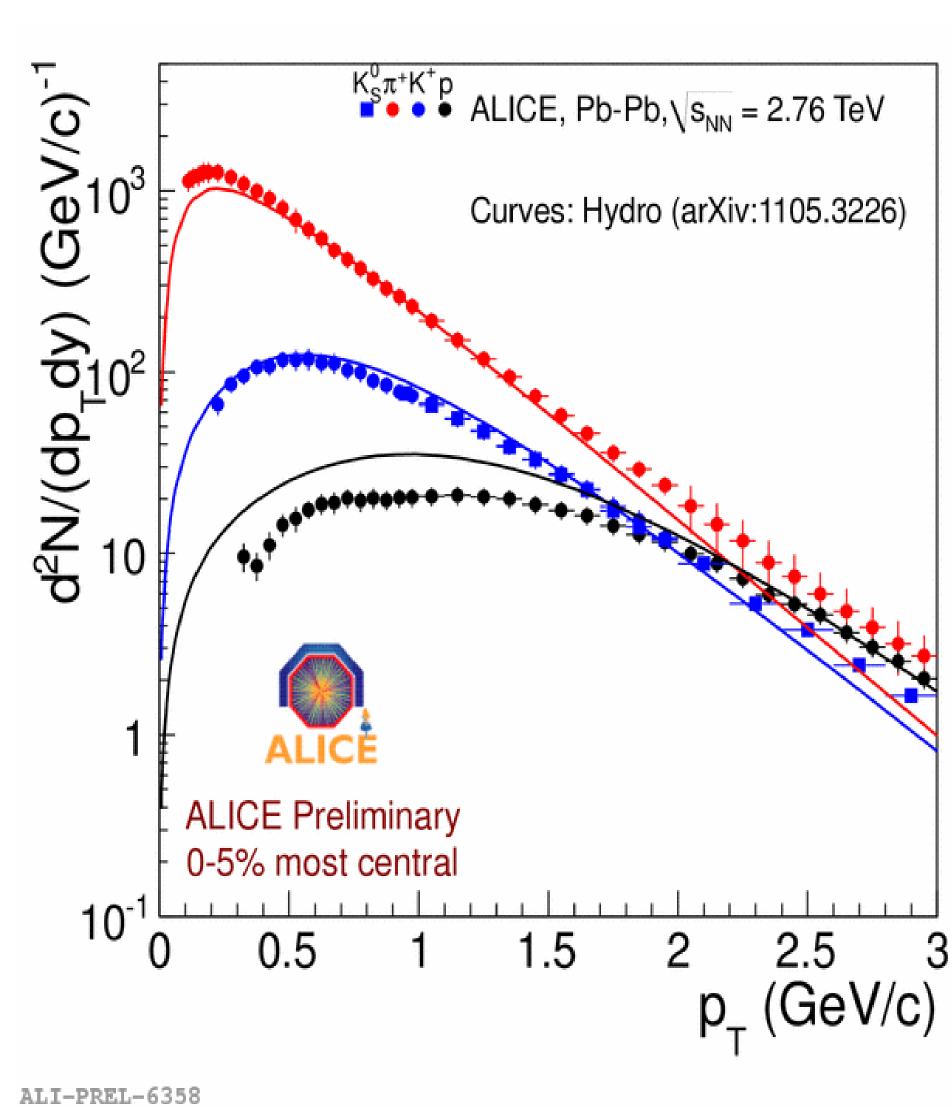
Different spectral shapes for particles of different mass





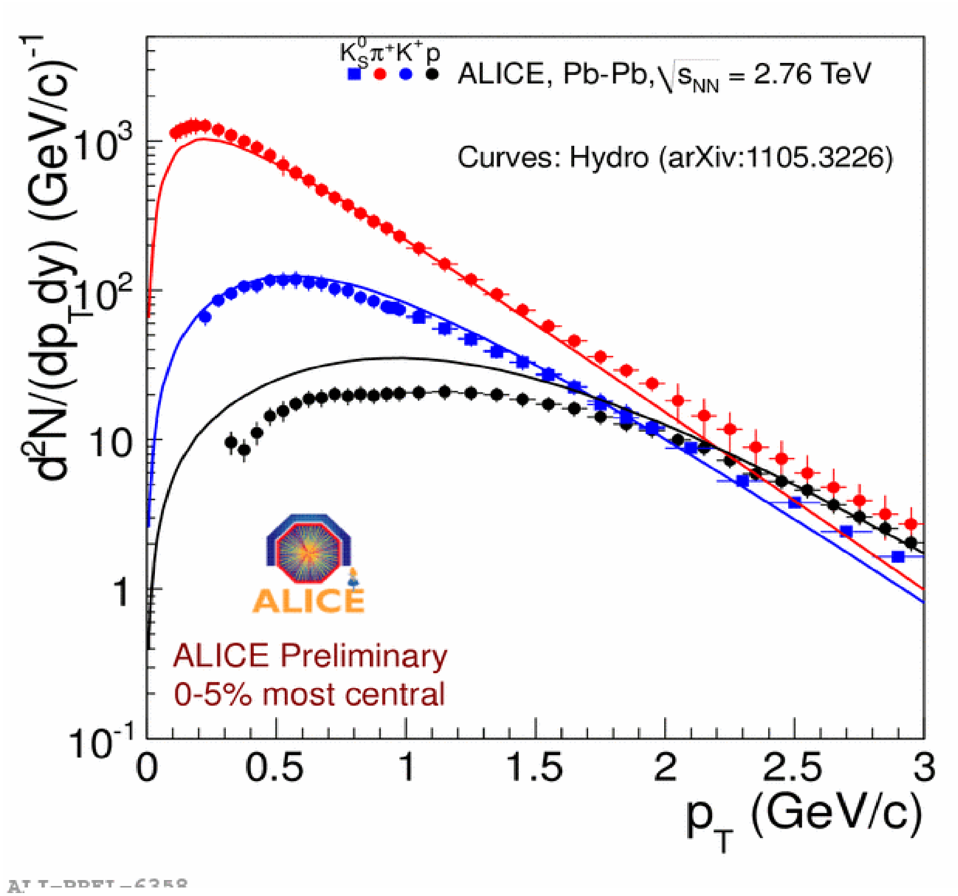
The radial flow:collective transverse expansion





Note much harder yields comparing to RHIC energies

The radial flow:collective transverse expansion



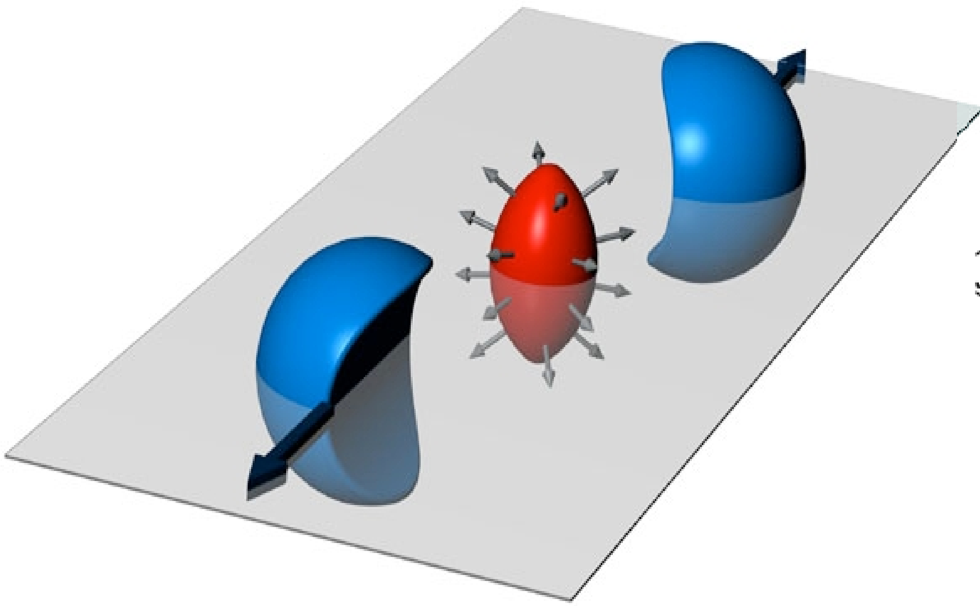
Boosted thermal spectra give a very good description of the particle distributions measured in PbPb:

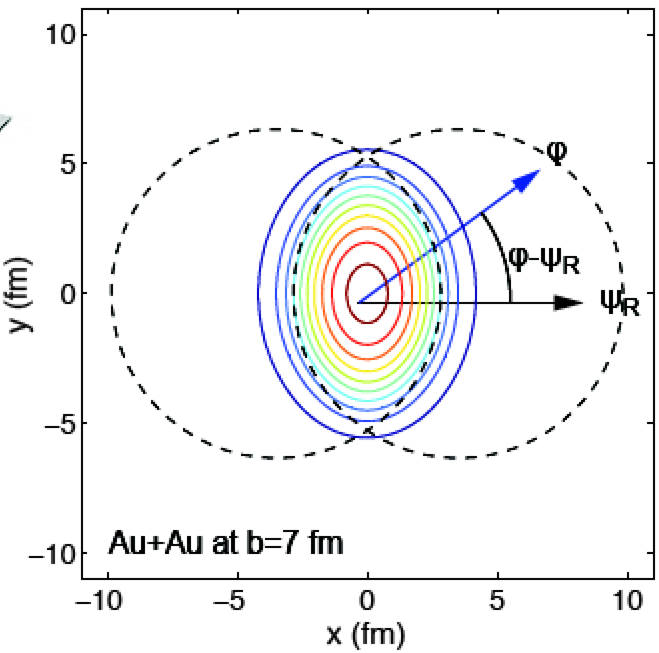
βc=0.66c
T_{KIN}~80 MeV

$$\frac{d^2N_j}{m_T dy dm_T} = \int_0^{R_0} A_j m_T \cdot K_1\left(\frac{m_T \cosh\rho}{T}\right) \cdot I_0\left(\frac{p_T \sinh\rho}{T}\right) r dr$$

$$\rho(r) = \tanh^{-1}\beta_\perp(r)$$

The elliptic flow: early thermalization





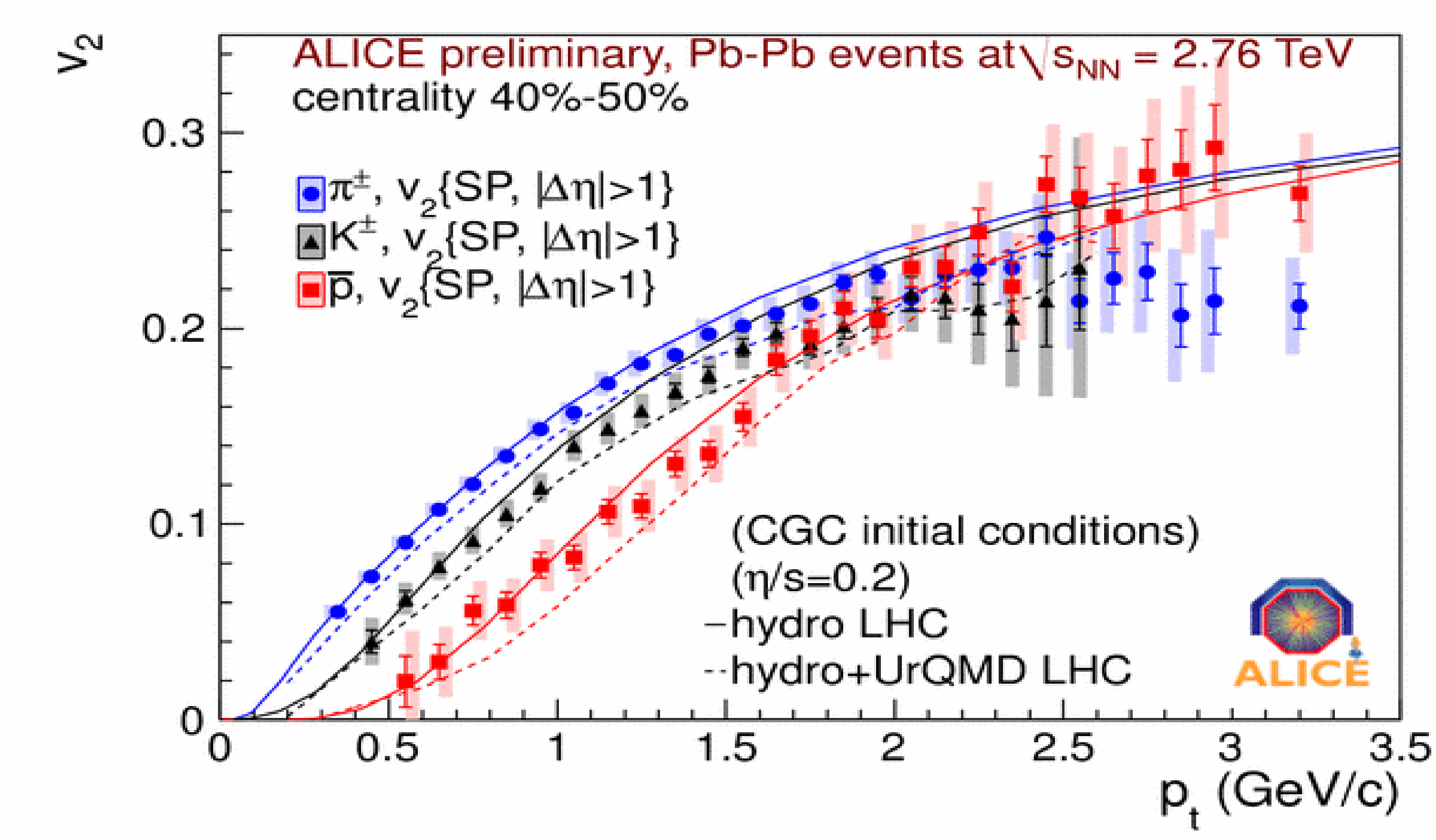
Almond shape overlapping region in coordinate space → Interactions generate pressure gradients → anisotropy in momentum space

Fourier expansion to describe angular dependence of particle density wrt reaction plane →

$$\frac{dN}{d\varphi} \propto 1 + 2v_2 \cos[2(\varphi - \psi_R)] + ...$$

$$v_2 = \langle \cos[2(\varphi - \psi_R)] \rangle$$

The elliptic flow: the perfect liquid



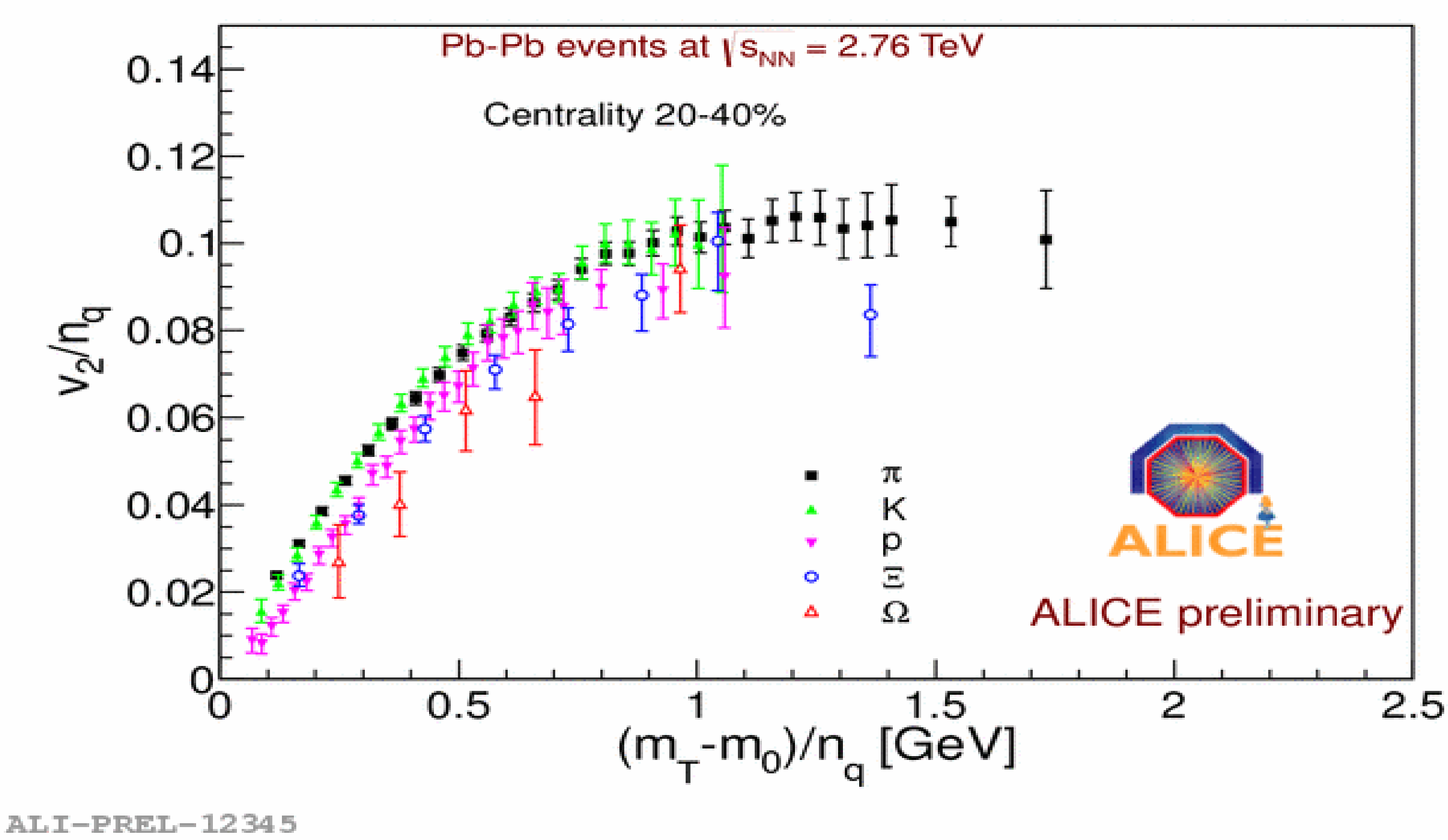
ALI-PREL-10622

Mass ordering at low pT expected from radial flow

Well described with hydrodynamical calculations using a shear viscosity close to the lower bound   (AdS/CFT lower bound=0.08)

--> the system behaves almost as a perfect liquid!

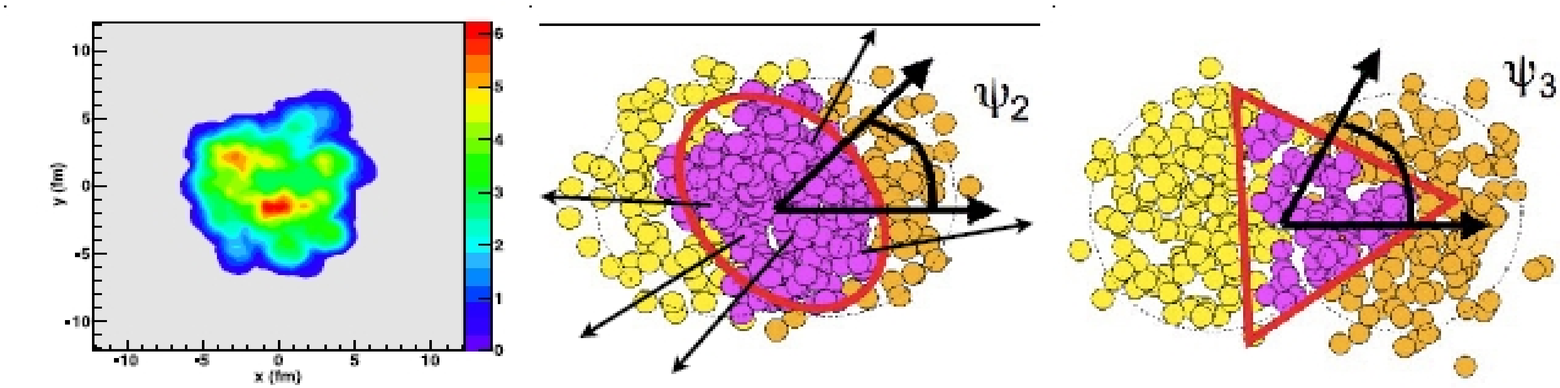
The elliptic flow: what is flowing



Scaling with the number of valence quarks nq

---> partonic collectivity

The initial conditions:event-by-event fluctuations



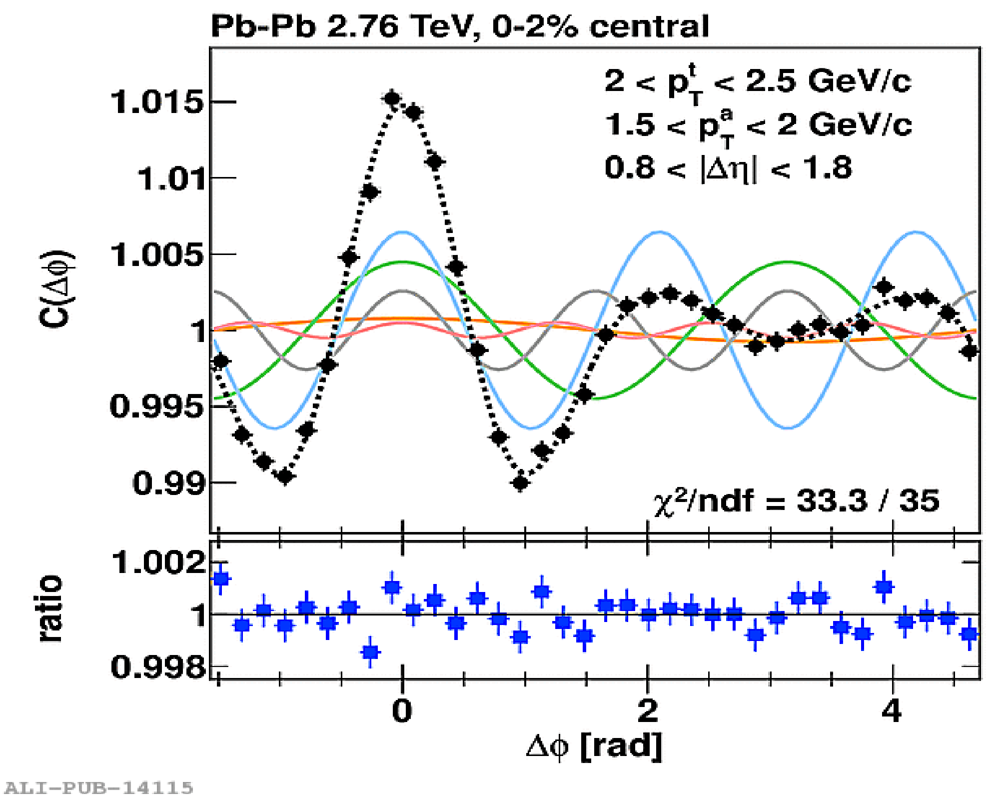
Angular dependence of particle density can't be described only with v2

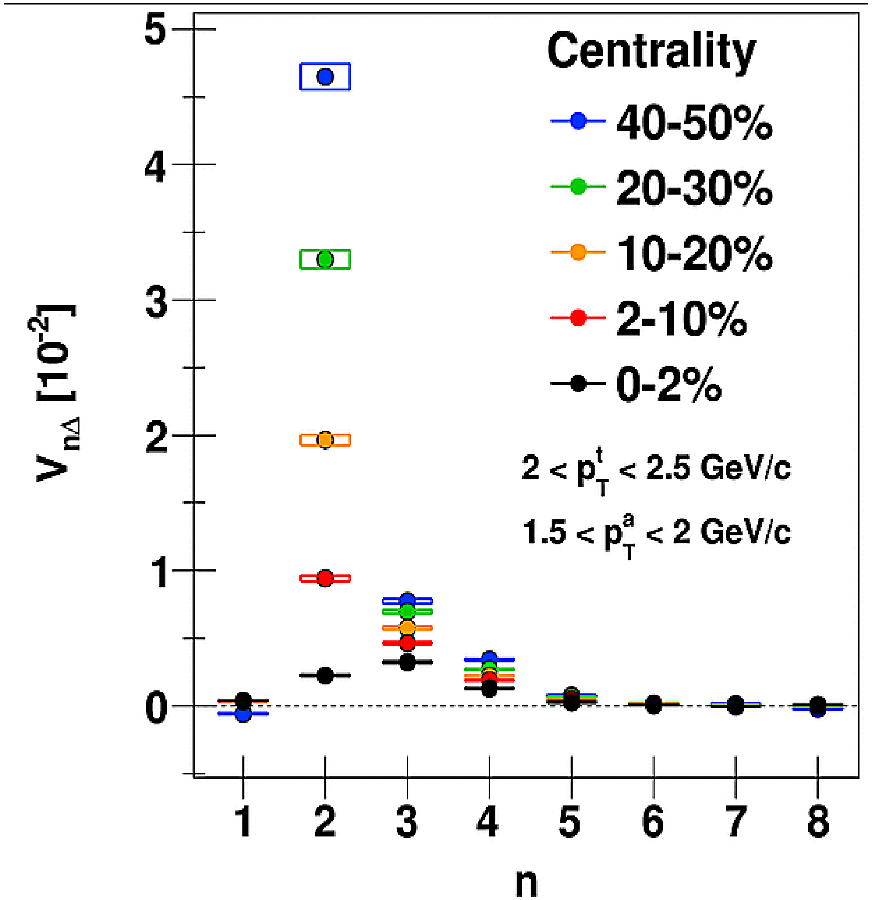
Each event has a different initial shape and density:
different symmetry planes and flow coefficients vn are present

Event-by-event hydrodynamical calculations need to account for fluctuations

The initial conditions: higher harmonics

Phys.Lett.B 708 (2012)





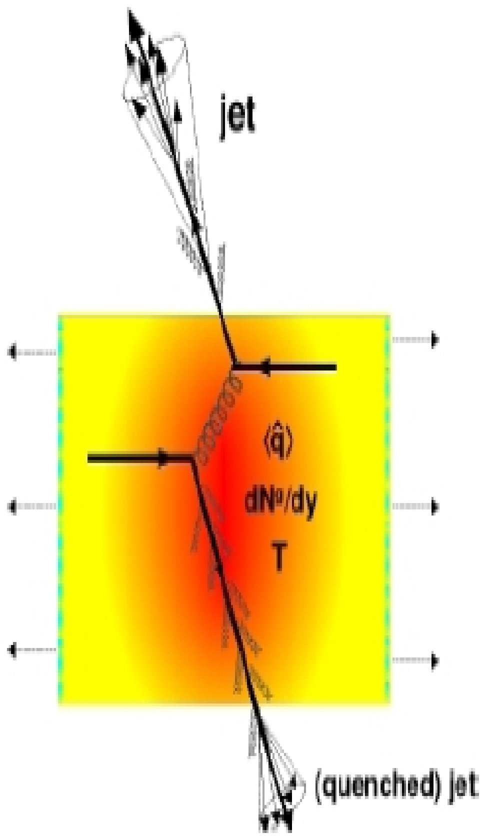
Up to n=5 seems to be all we need to describe particle correlations

In the most central collisions all vn have similar strength

Different sensitivity of v2 and v3 to viscosity can be used to constrain initial state conditions needed for hydro calculations.

Hard probes

$$\sigma^{pp\to h} = \underbrace{f_p(x_1,Q^2)}_{\text{LHC}} \otimes \underbrace{f_p(x_2,Q^2)}_{\text{LHC}} \otimes \underbrace{\sigma(x_1,x_2,Q^2)}_{\text{RHIC}} \otimes \underbrace{D(z,Q^2)}_{\text{LHC}} + \underbrace{\left(\frac{1}{Q^2}\right)^n}_{\text{SPS}}$$



Early production of the hard scattering
t~1/Q:

Long distance terms in the factorized Xsection above can be **directly modified by the dense medium** created in HIC

The probe production rate is the same as in vacuum -->**well calibrated probes**

Look for attenuation/absorption of the probe

RAA for light hadrons

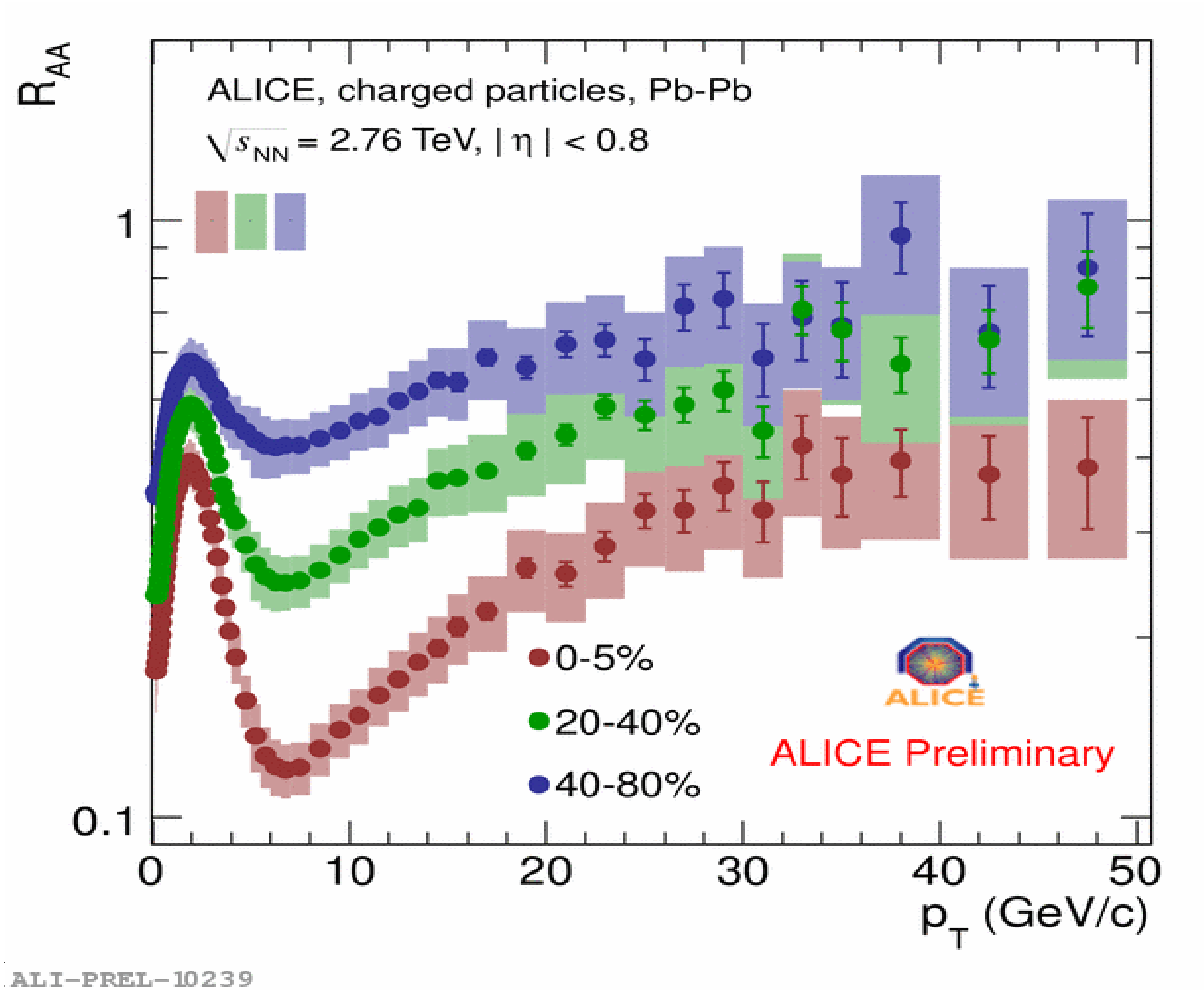
Nuclear Modification Factor (RAA):

Measures the suppression of the yiedl in PbPb collisions with respect to the scaled yield in pp.

$$R_{AA}(p_T) = \frac{Yield(A+A)}{Yield(p+p) \times \langle N_{coll} \rangle}$$

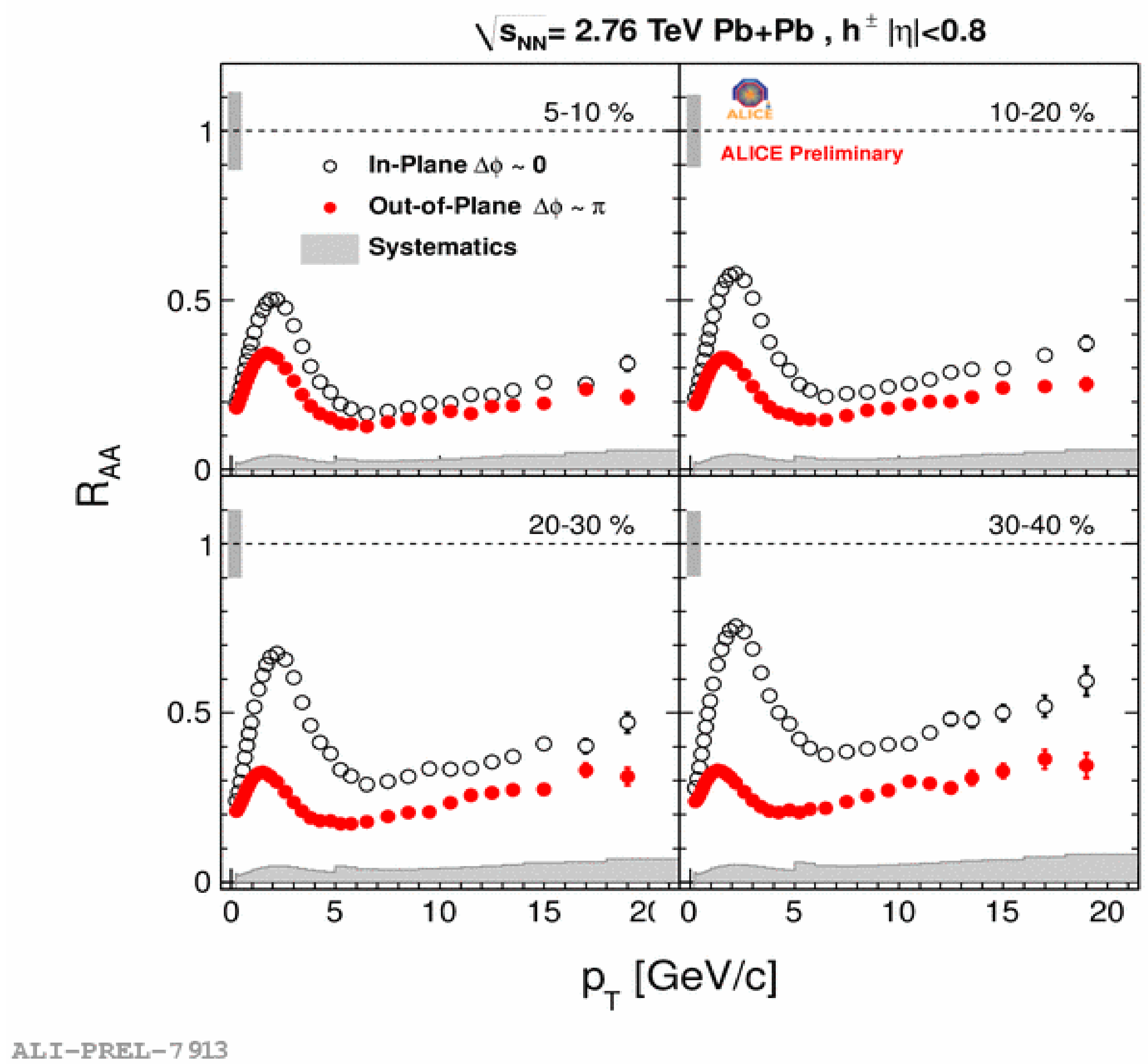
Peripherals: RAA-->1

Centrals:
~1/5 suppression factor. Larger in-medium path encountered by the hard parton.



XL

RAA vs reaction plane



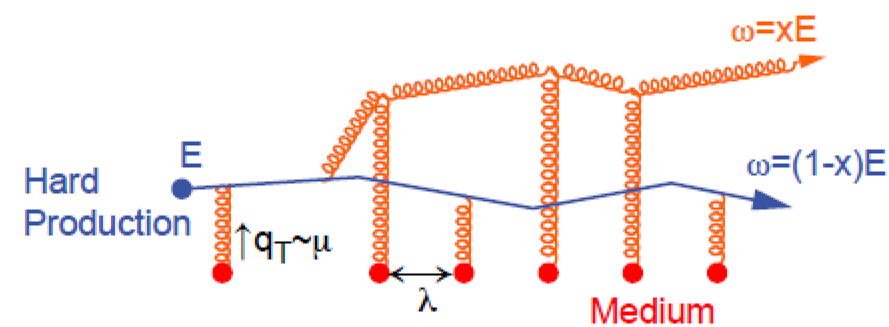
Hadrons exiting out of plane are more suppressed--> longer average in-medium path length

Towards quantitative understanding of path length dependence of energy loss

ie. BDMPS formalism predicts a ΔE~L² in a static medium due to LPM effect.

The mechanisms of energy loss in medium

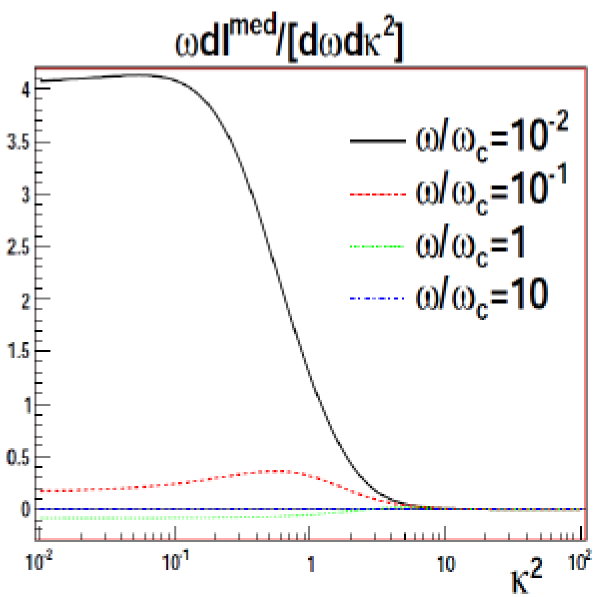
Medium-induced gluon radiation, dominant mechanism of energy loss for a high energy parton traversing a colored medium.



Energy loss & transverse broadening of the jet shower dynamically related by:

$\Delta E \sim \text{qhat}\ \Delta k_T$

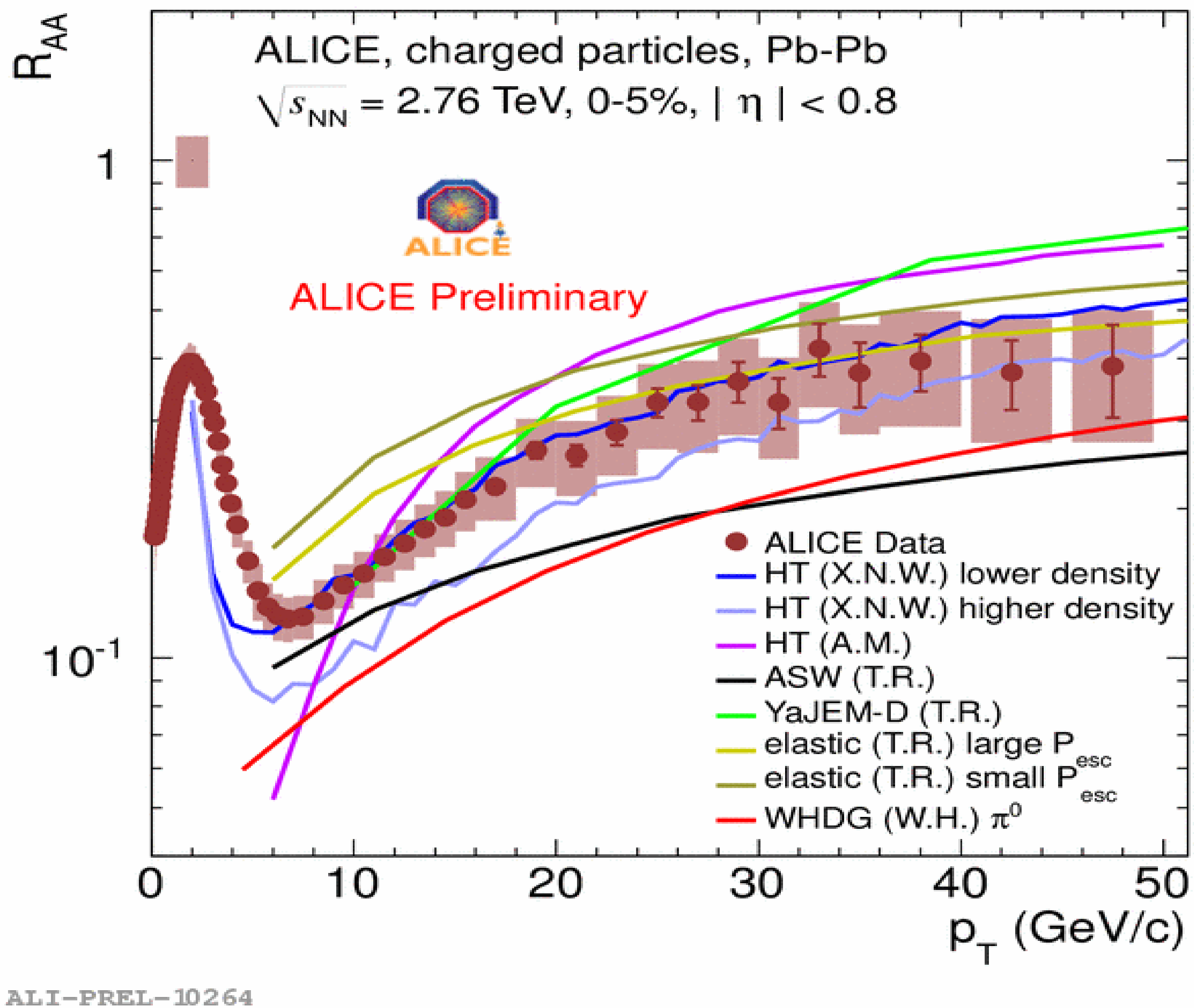
$\omega_c = 1/2\ \text{qhat}\ L^2$



qhat characterizes the medium (encodes the info about the colored potential):
$<k_T>$ given by the medium to the projectile per unit path length λ.

To varying extent, all the theories predict a softening of the fragmentation and a broadening of the jet shape

RAA vs theory models

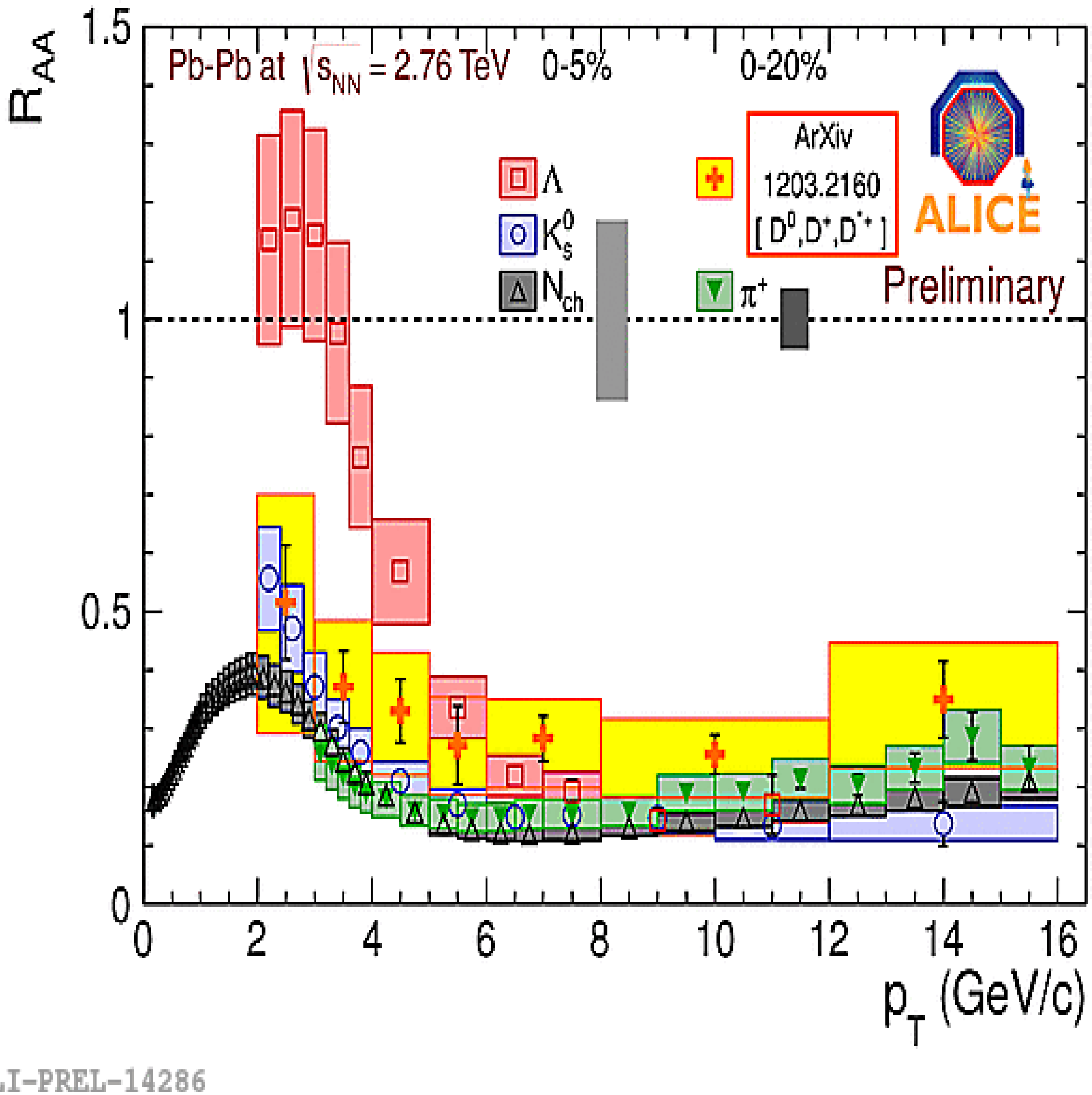


Different elementary kernel for the single gluon emission.

No energy conservation in the models!

RAA (in combination with more differential observables like di-hadron correlations) puts strong constraints on models.

PID RAA



Dead cone effect?

$$\omega \frac{dI}{dw}\bigg|_{\mathrm{HEAVY}} = \frac{\omega \frac{dI}{dw}\big|_{\mathrm{LIGHT}}}{\left(1+\left(\frac{m_Q}{E_Q}\right)^2 \frac{1}{\theta^2}\right)^2}$$

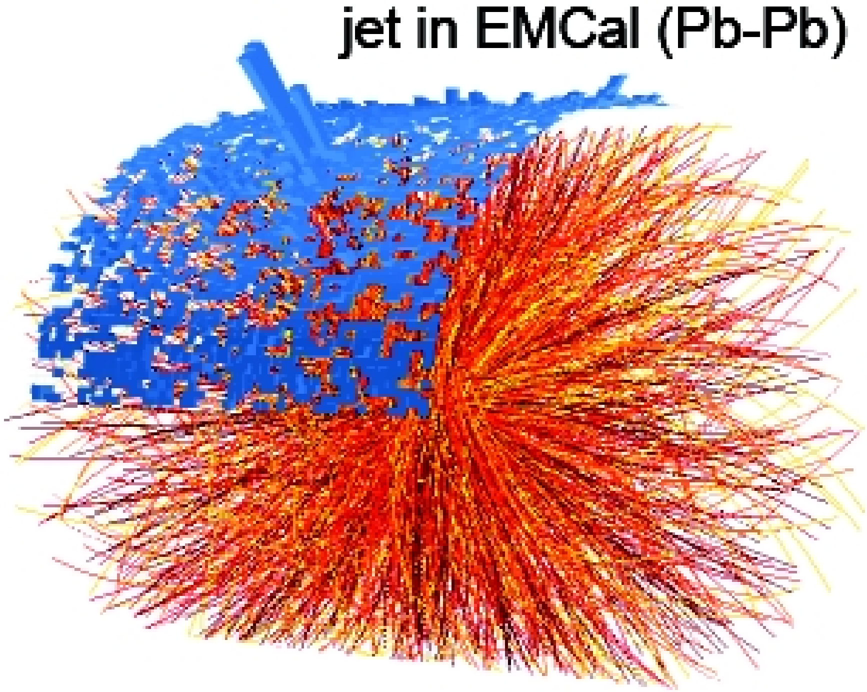
Implies lower heavy quark energy loss in matter

Dokshitzer PLB (2001) 519 199

Similar suppression at high p_T for all particle species, including charm.

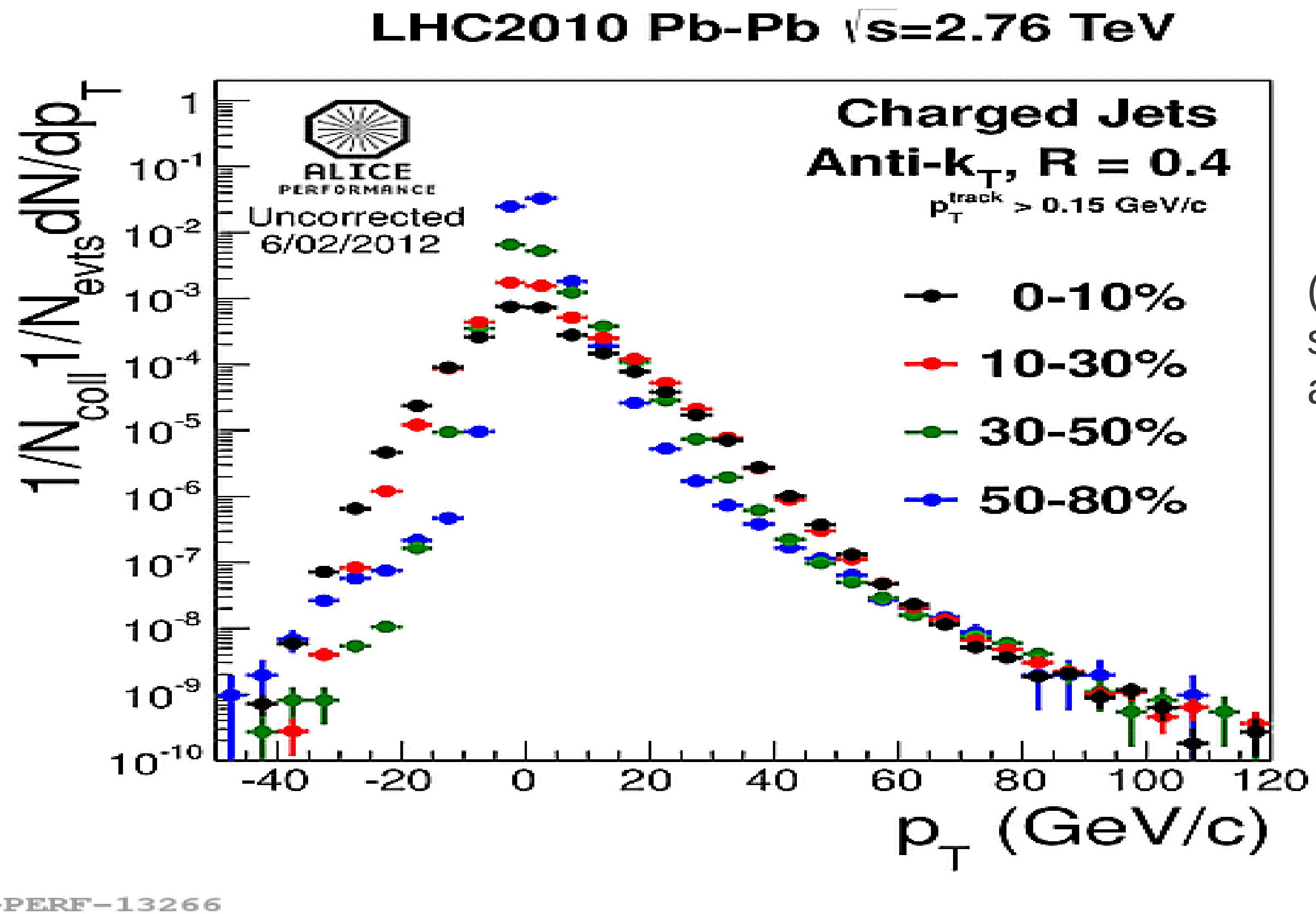
Jets

To capture the full dynamics of parton energy loss,
jet reconstruction is required.



Jets are complex objects:
intrincate interplay between jet finding, background fluctuations and quenching.

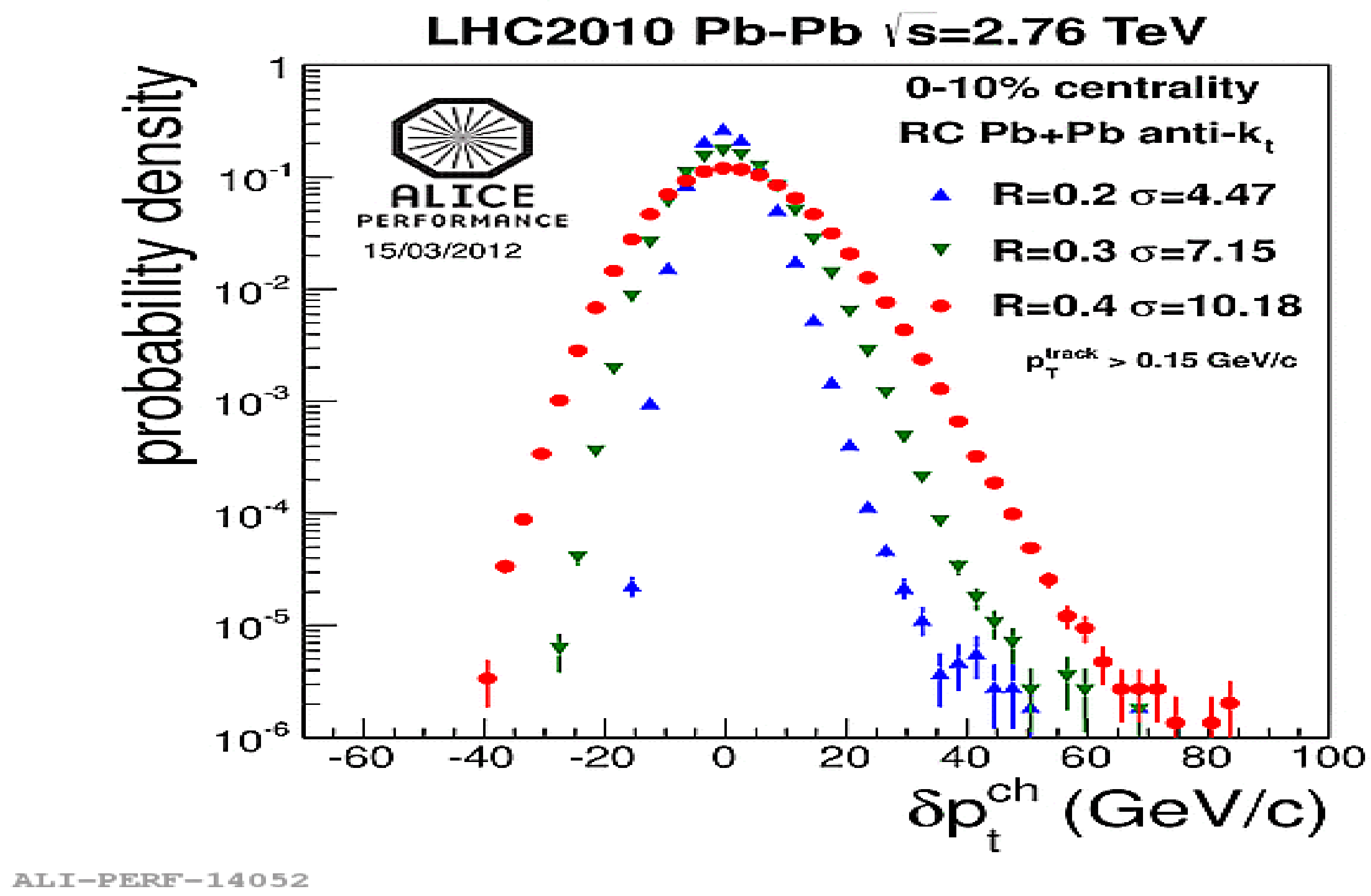
Jets: the inclusive uncorrected jet spectra



(background subtracted on average)

The influence of region-to-region background fluctuations is apparent up to large values of jet p_T

Jets: precision measurements of the energy resolution



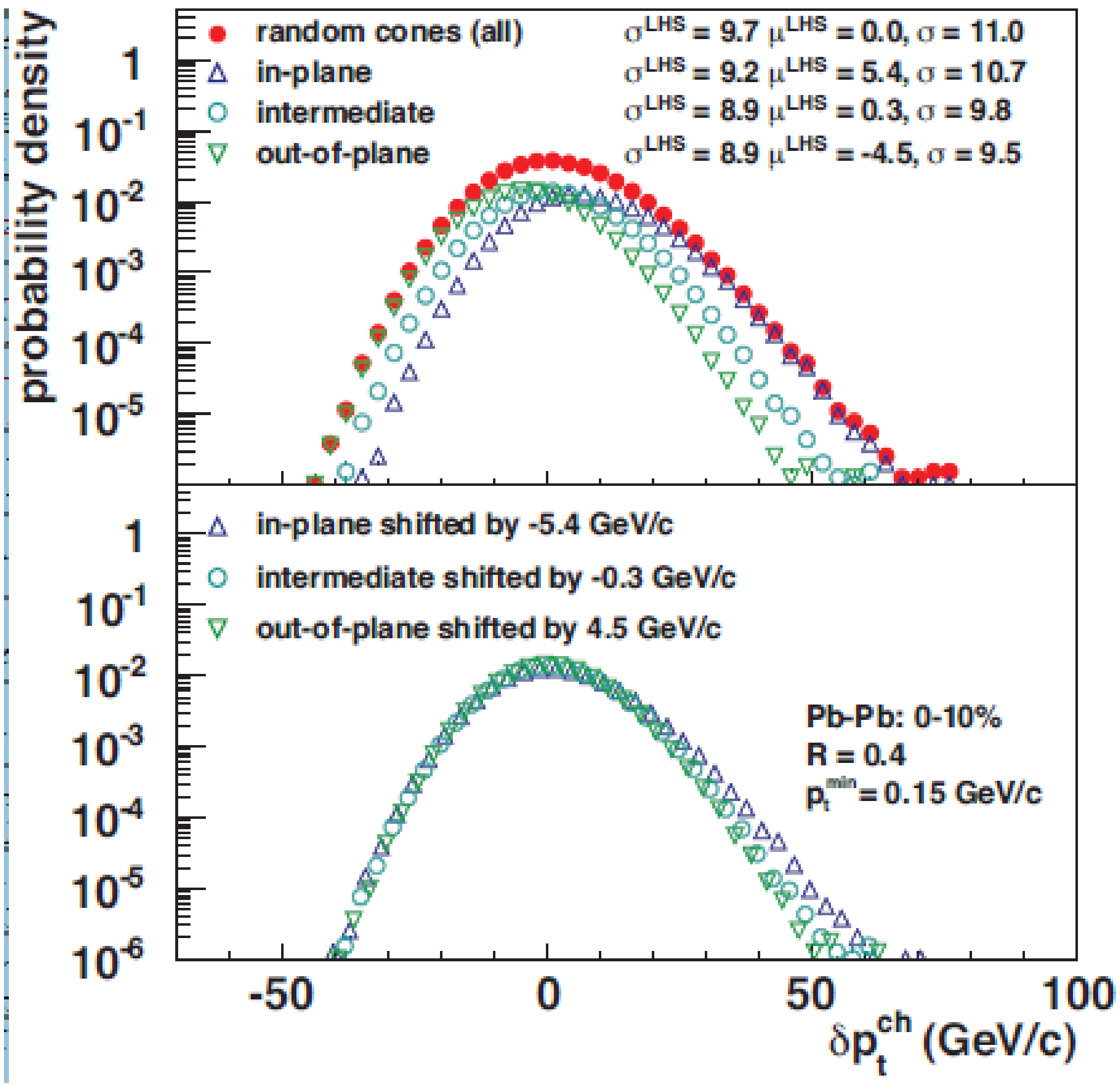
$\delta p_T^{ch} = p_T^{rec} - p_T^{probe} - \rho A$ measures the jet response to bakground

ρ=average bkg
A=jet area

Background fluctuations grow as~R

Jets: precision measurements of the energy resolution

JHEP 03 (2012) 053



~ 5GeV shift in the background density for in-out-of-plane
~v2<ρ>

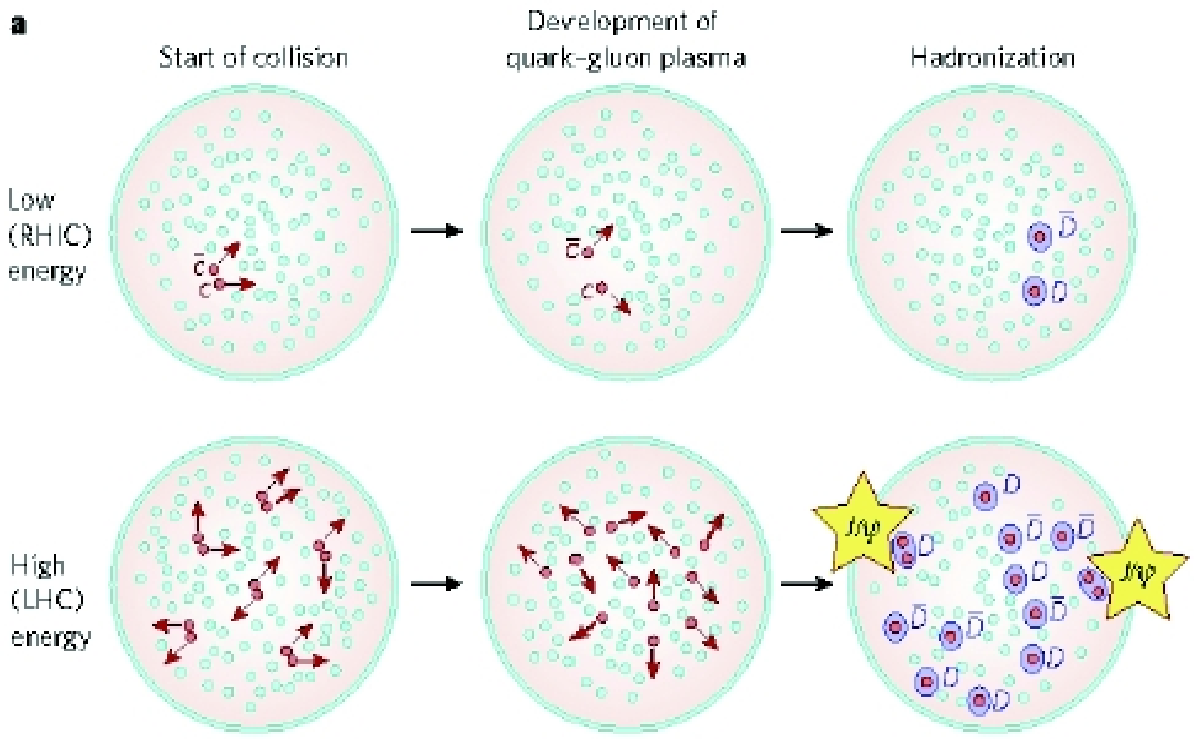
LHS narrower out of plane, qualitatively consistent with more particles out of plane

More pronounced tail on the RHS in plane:
--Jet spectrum &RP dependence?
--Autocorrelations?
--more systematic studies ongoing

Quarkonia

$$\sigma^{hh\to J/\Psi} = f_i(x_1,Q^2)\otimes f_j(x_2,Q^2)\otimes\sigma^{ij\to[c\bar{c}]}(x_1,x_2,Q^2)\langle\mathcal{O}([c\bar{c}]\to J/\Psi)\rangle$$

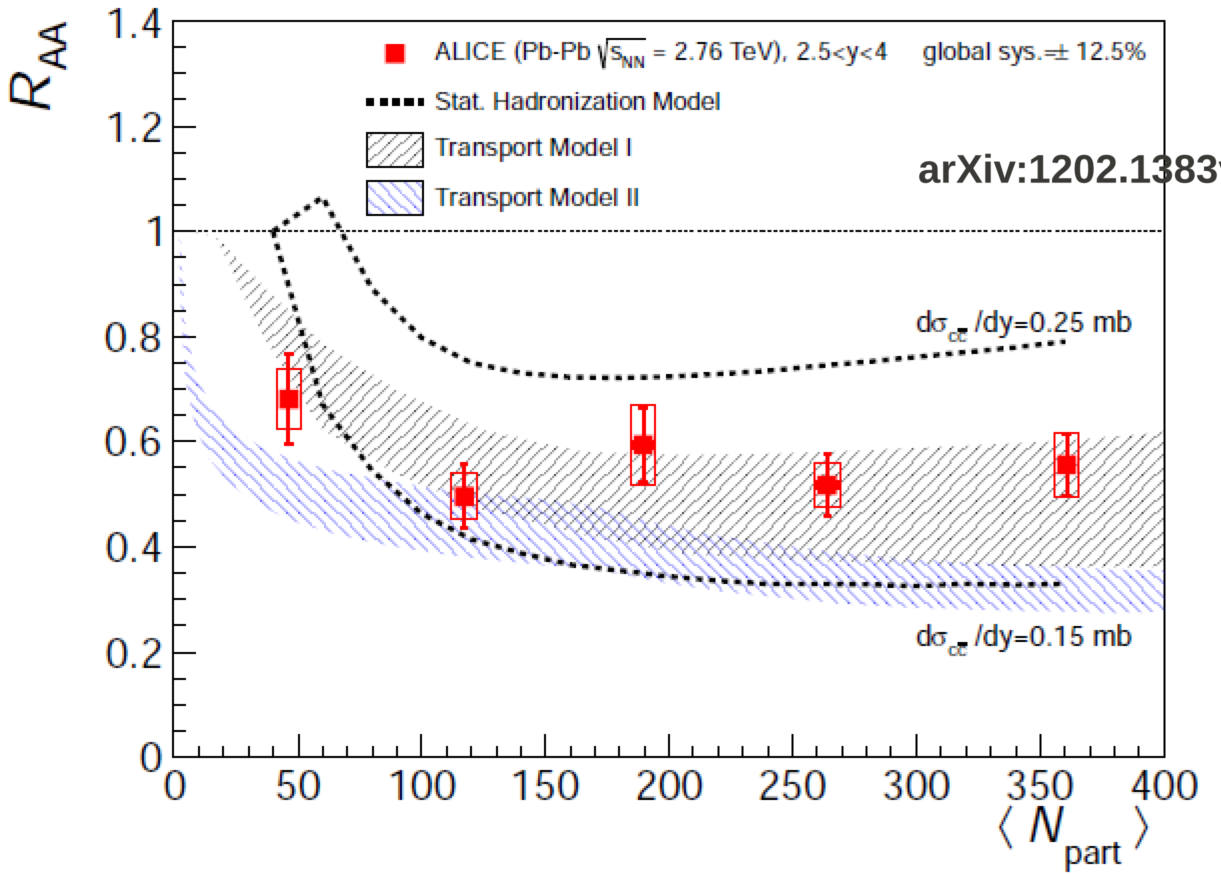
The large scale process encoded here $\longrightarrow$ $\langle\mathcal{O}([c\bar{c}]\to J/\Psi)\rangle$ can suffer modification in the presence of a deconfined medium



Color charge screening

Color charge recombination

Quarkonia



arXiv:1202.1383v1

The J/psi suppression is compared with theoretical models that include a regeneration component from deconfined charm quarks in the medium that contributes to about the 50% of the measured yield.

Summary and outlook

ALICE measures a larger,denser,longer lived and more opaque source than at RHIC

ALICE measurements of bulk properties confirm the great success of hydrodynamics in Heavy Ion Collisions.
-->precision measurements of shear viscosity η/s

-Precision tracking in ALICE down to very low p_T and PID capabilities will allow one to set strong constraints on models for energy loss.

Towards a quantitative characterization of the fundamental "transport" properties of the medium
qhat,η/s....