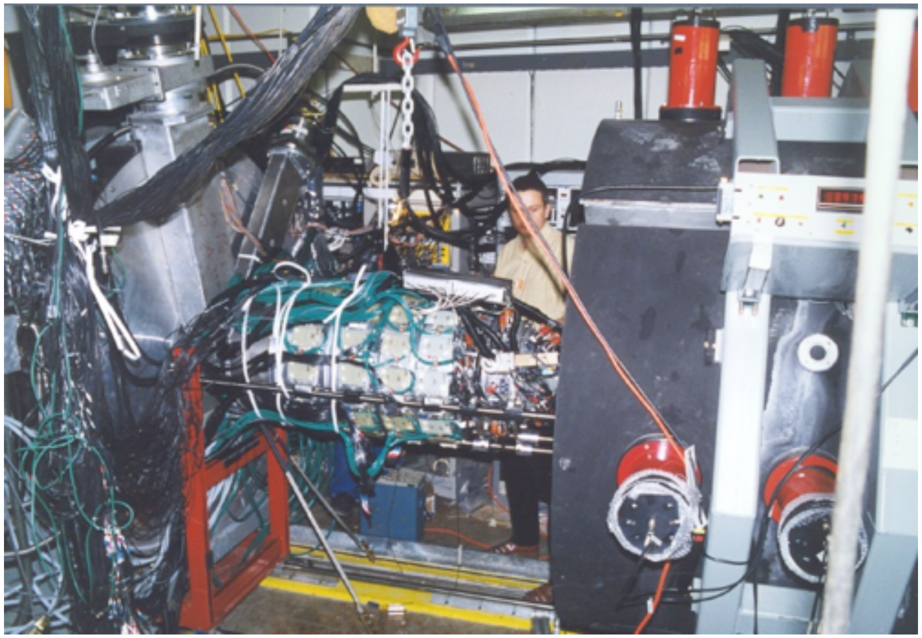
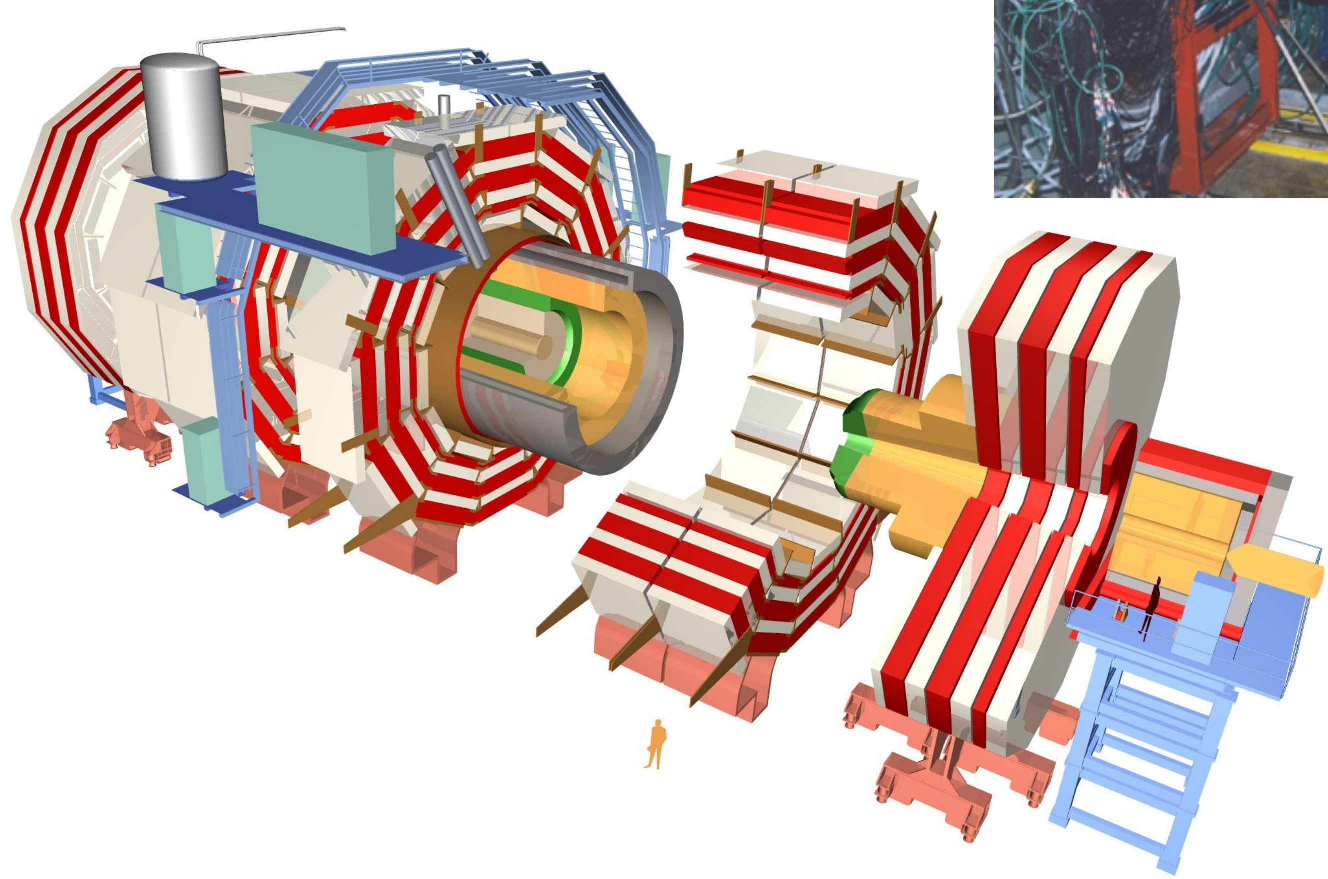
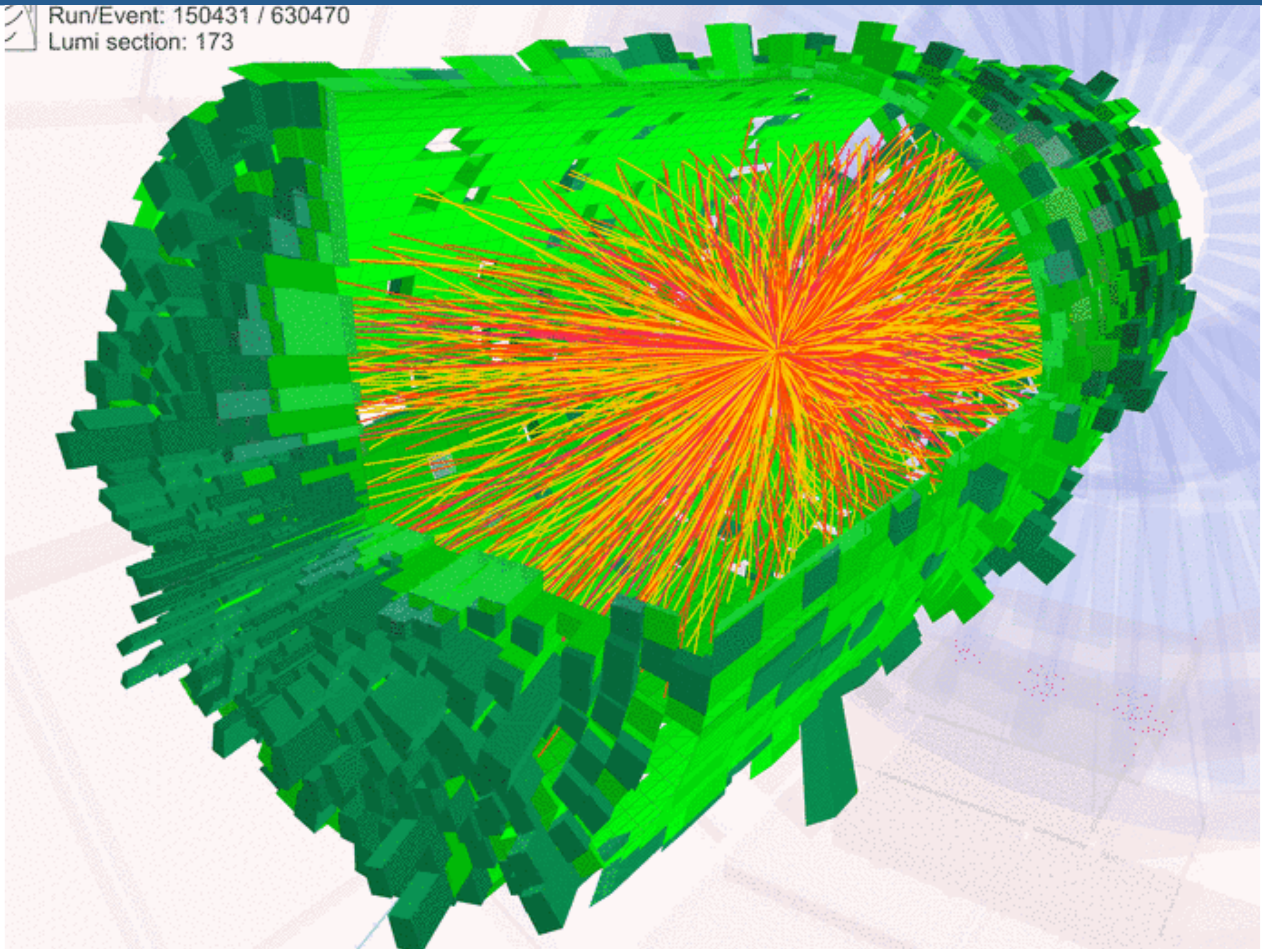
CMS Heavy Ion Results



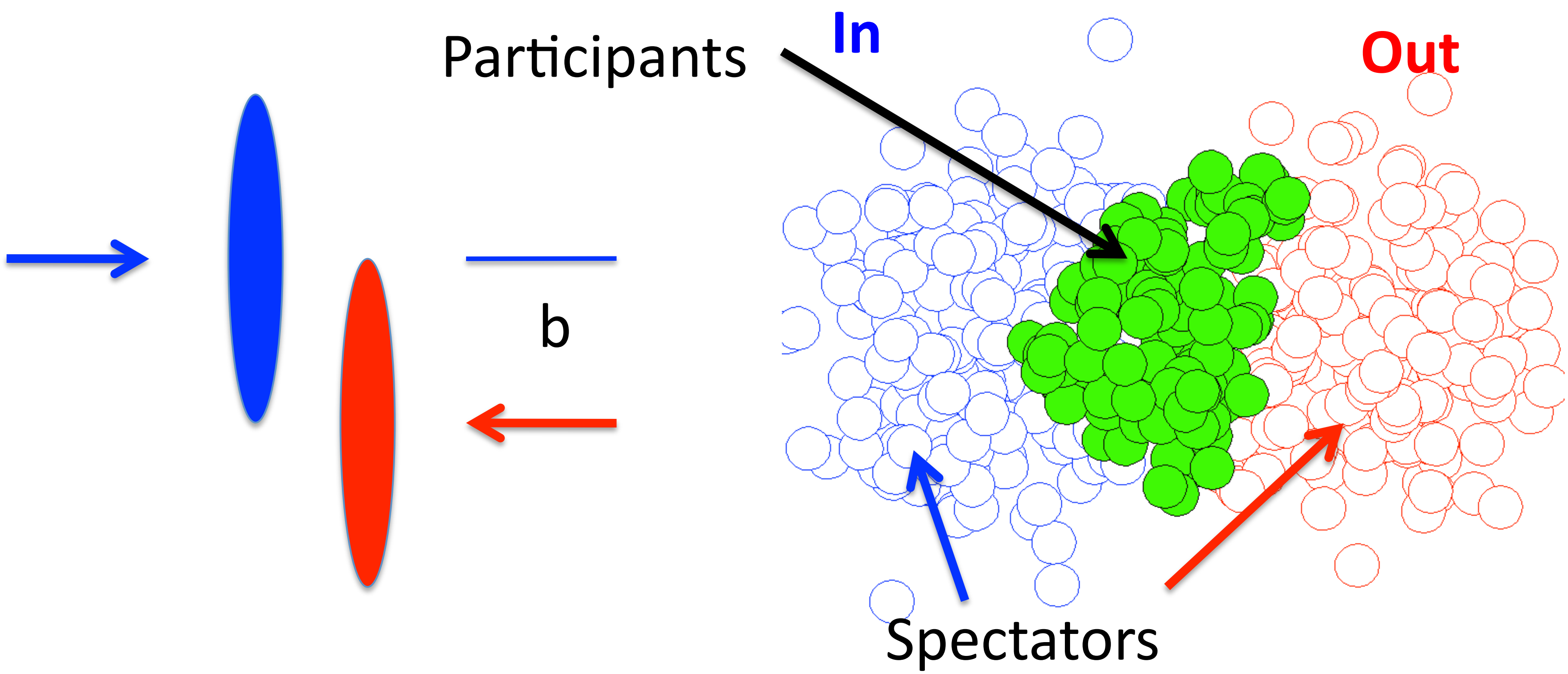


Michael Murray, College Station 21st August 2013

A PbPb event

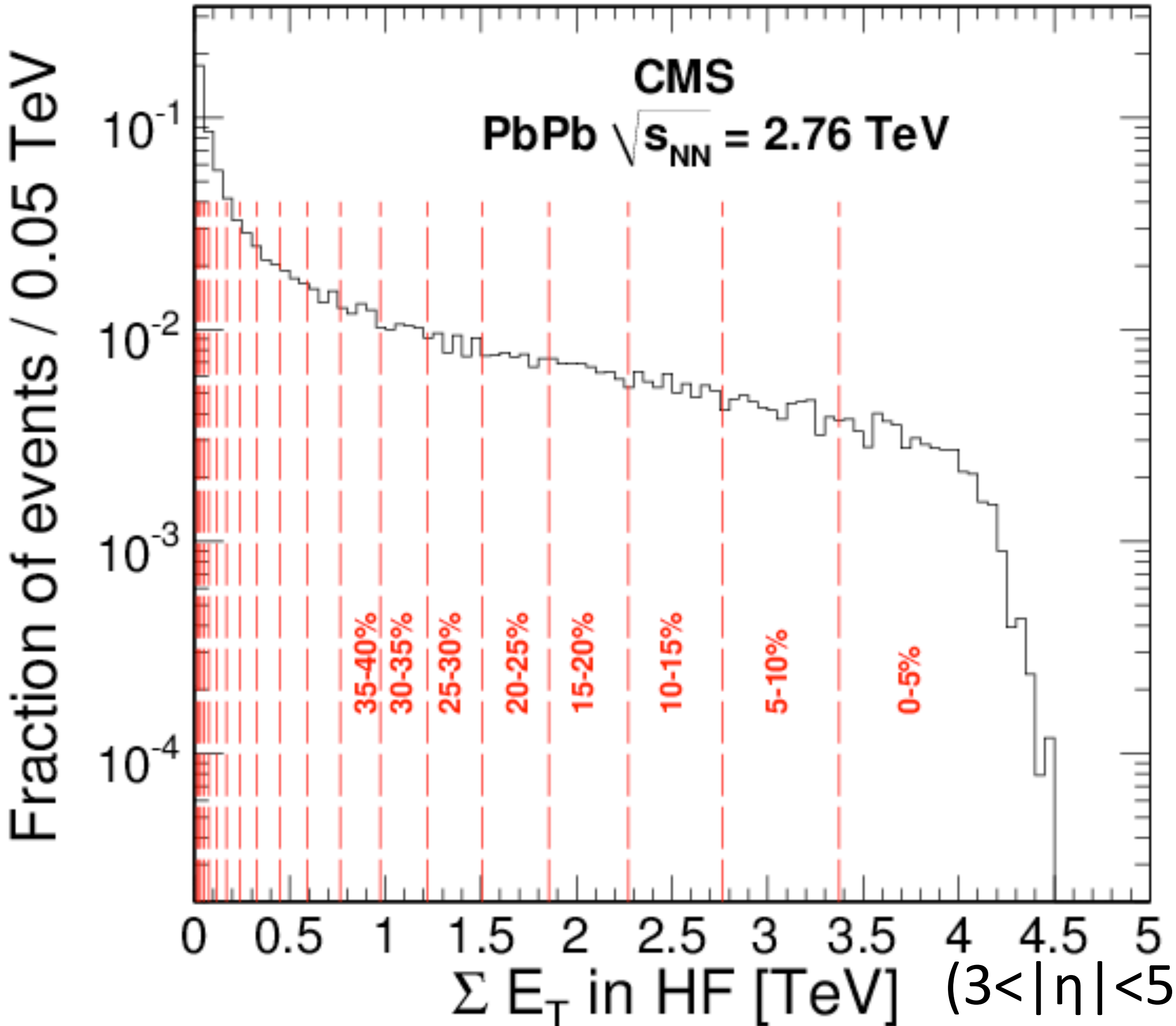


Centrality: Geometry of ion collisions



Centrality is percentage of events with impact parameter b smaller than a given value. In CMS centrality normally measured with HF ,ie $3<|\eta|<5$

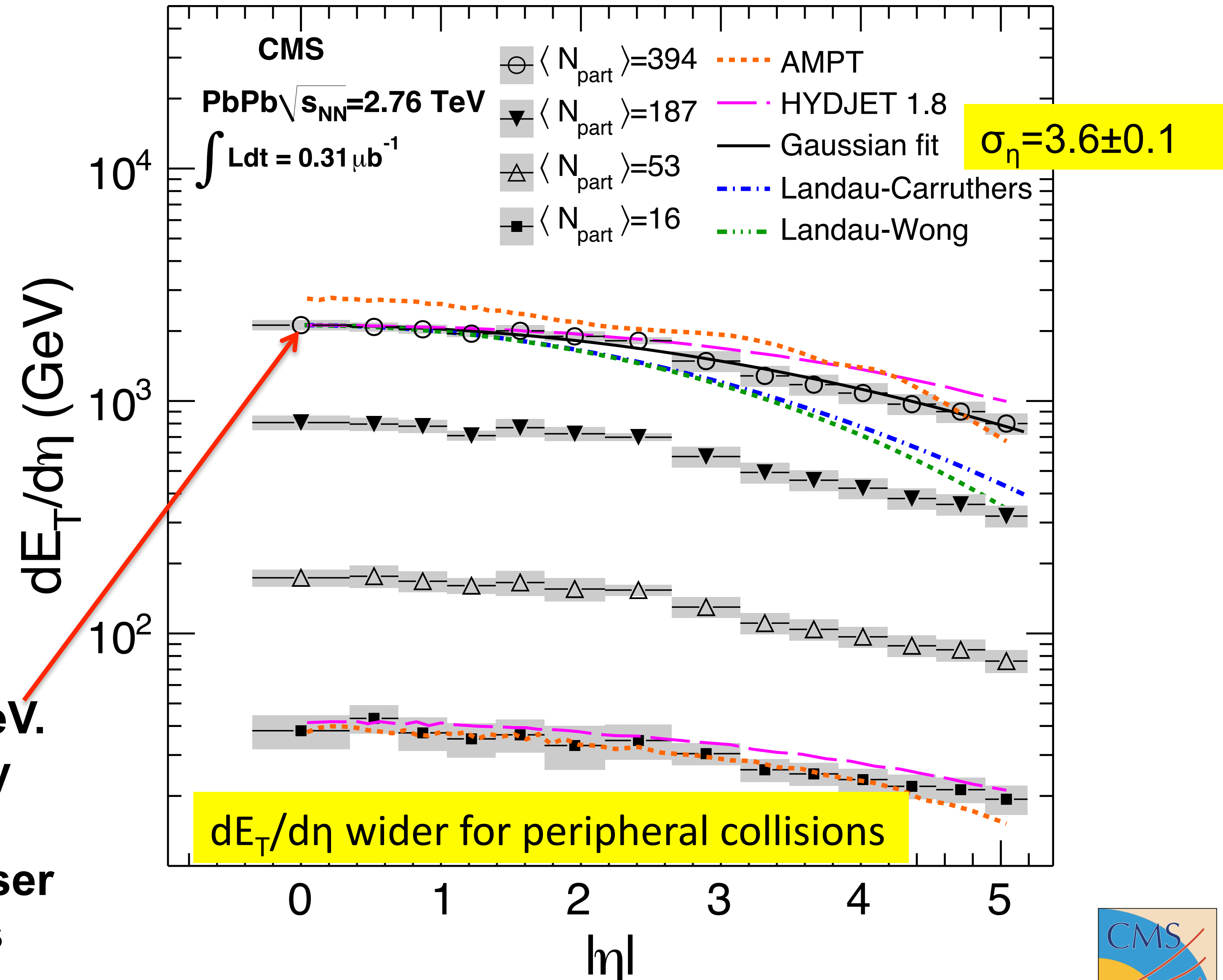
Centrality defined by forward calorimeters



(3<|η|<5)

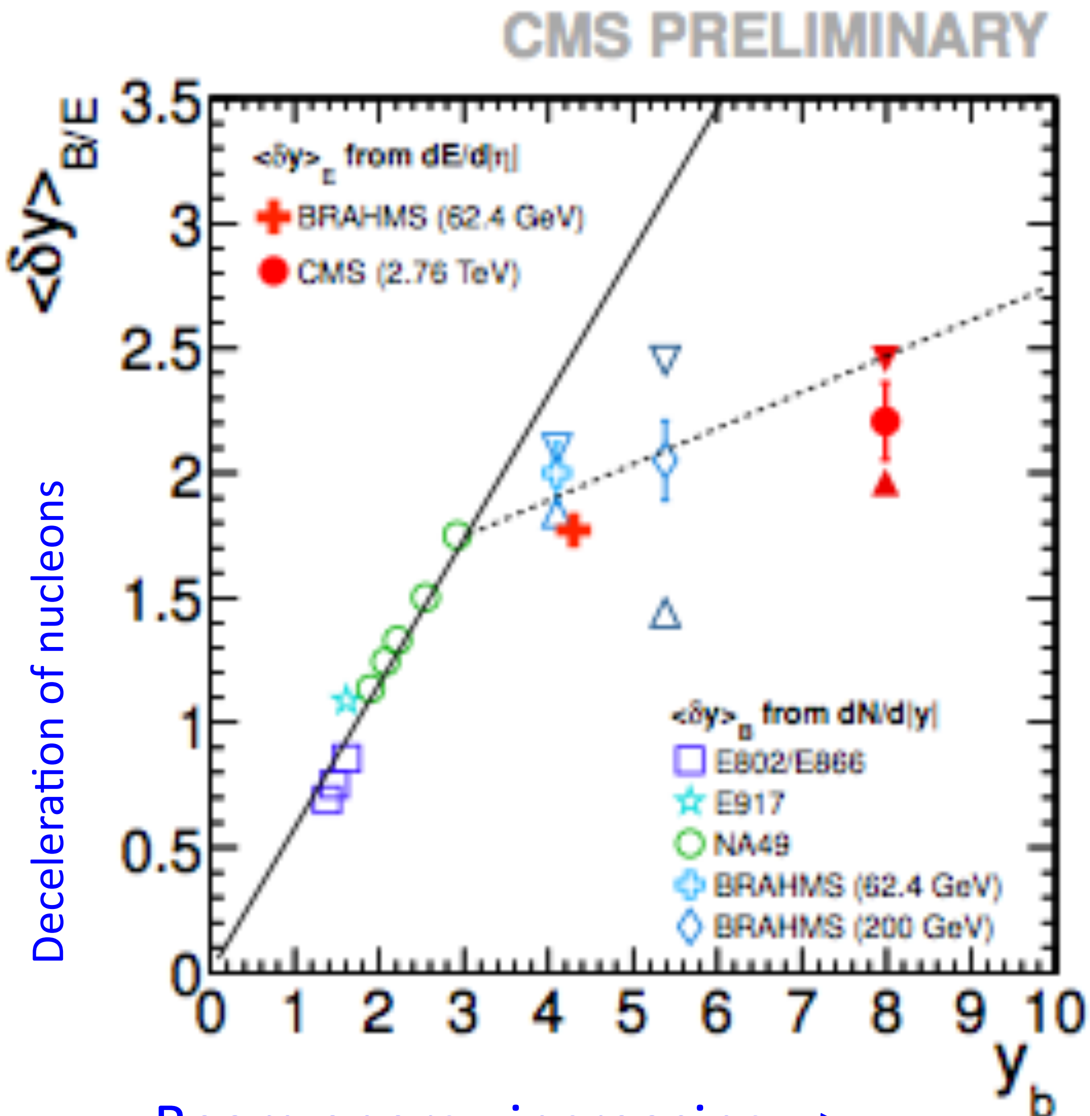
Need to go home and fit with a gamma distribution

Making a hot system: $dE_T/d\eta$ vs η



$dE_T/d\eta$ = 2.1 TeV.
Energy density
ε ≈15 GeV/fm³
100 times denser than a nucleus

Do the lead nuclei stop each other?



Deceleration of nucleons

Beam energy increasing =>

Rapidity

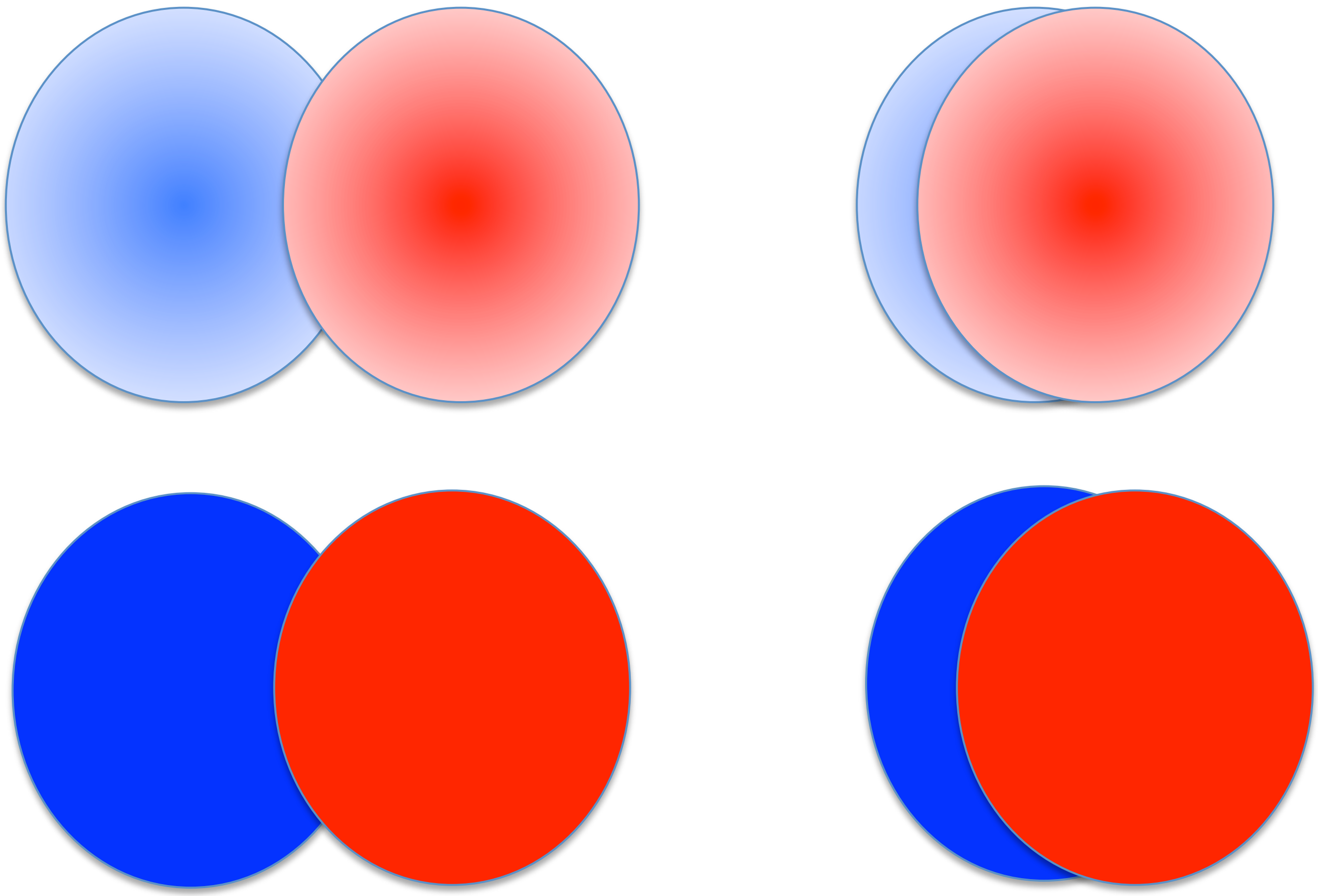
$y = \tanh^{-1}(v/c)$

Incoming nucleons lose all but $e^{-2.2}$ = 11% of their momentum

Scanning the Pb density profile

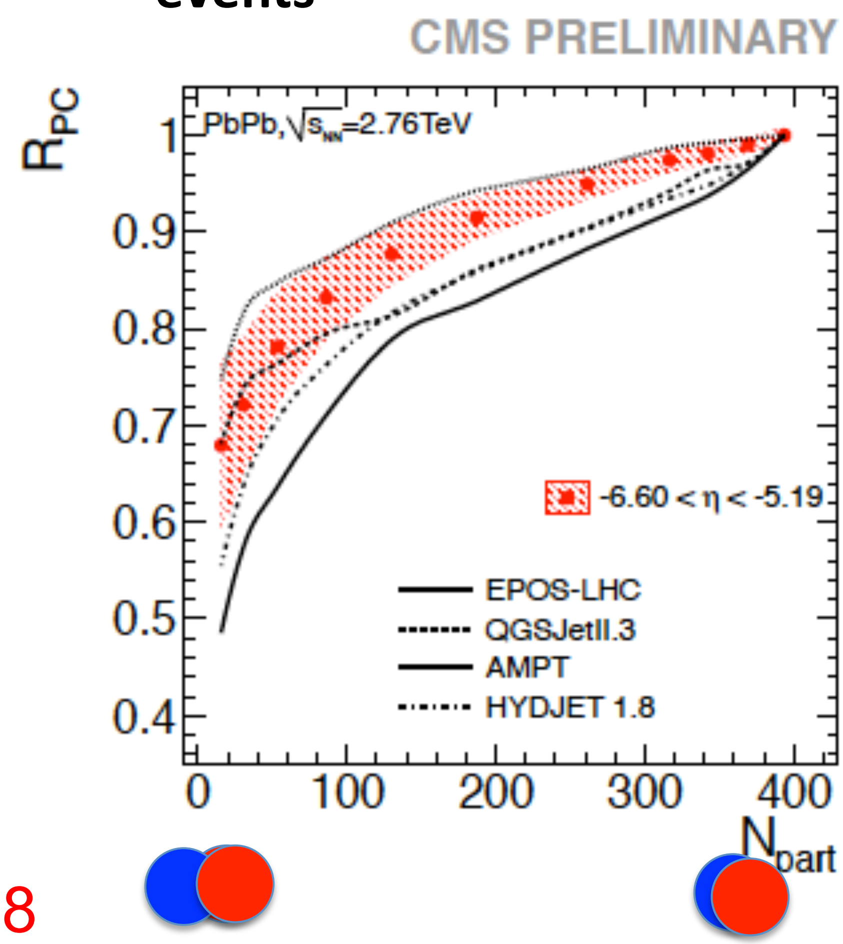
Unsaturated nucleus

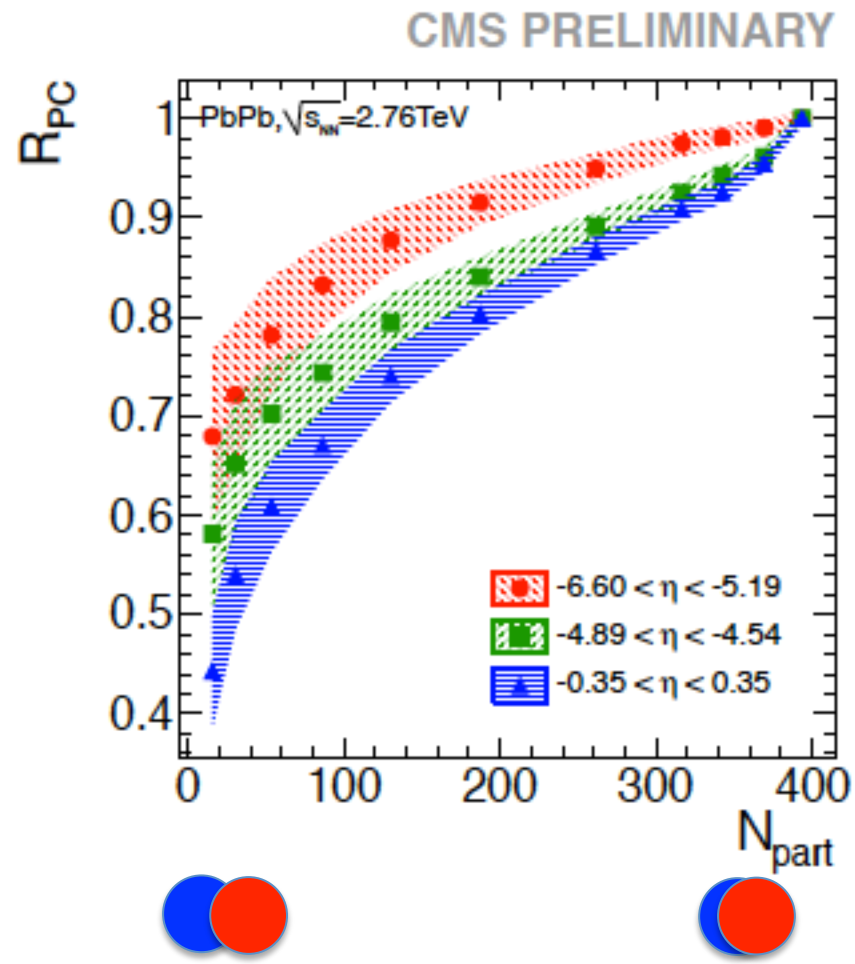
Saturated nucleus



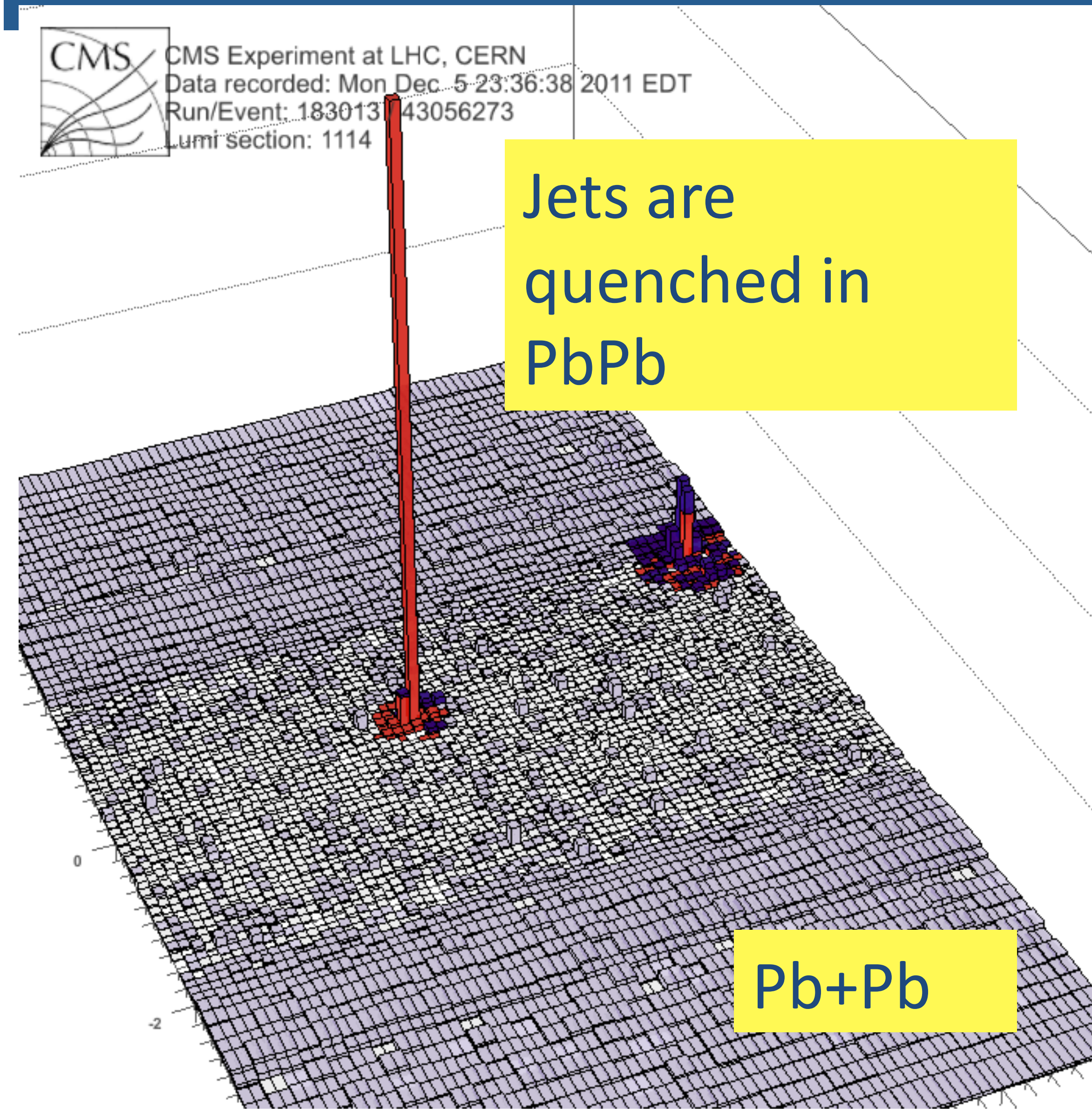
Centrality dependence of dE/dη

R_{pc} ratio of dE/dη in peripheral to central events



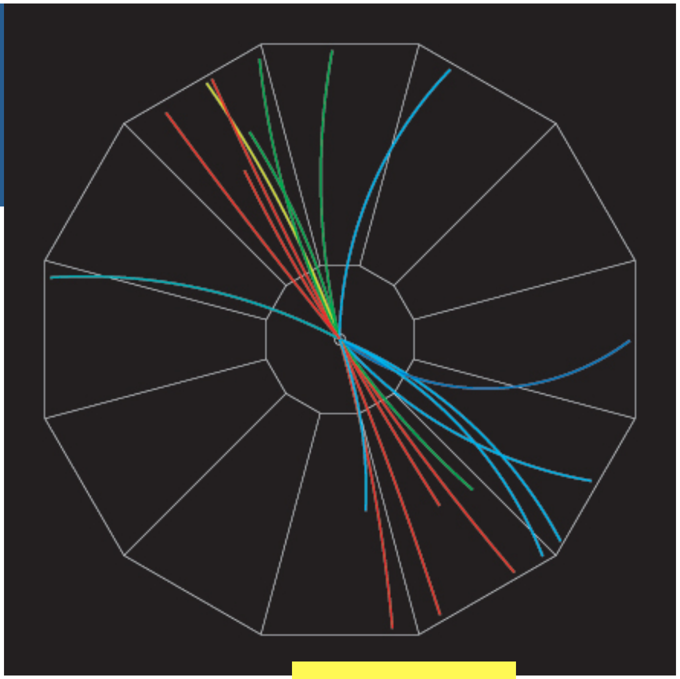


Jets in pp and PbPb



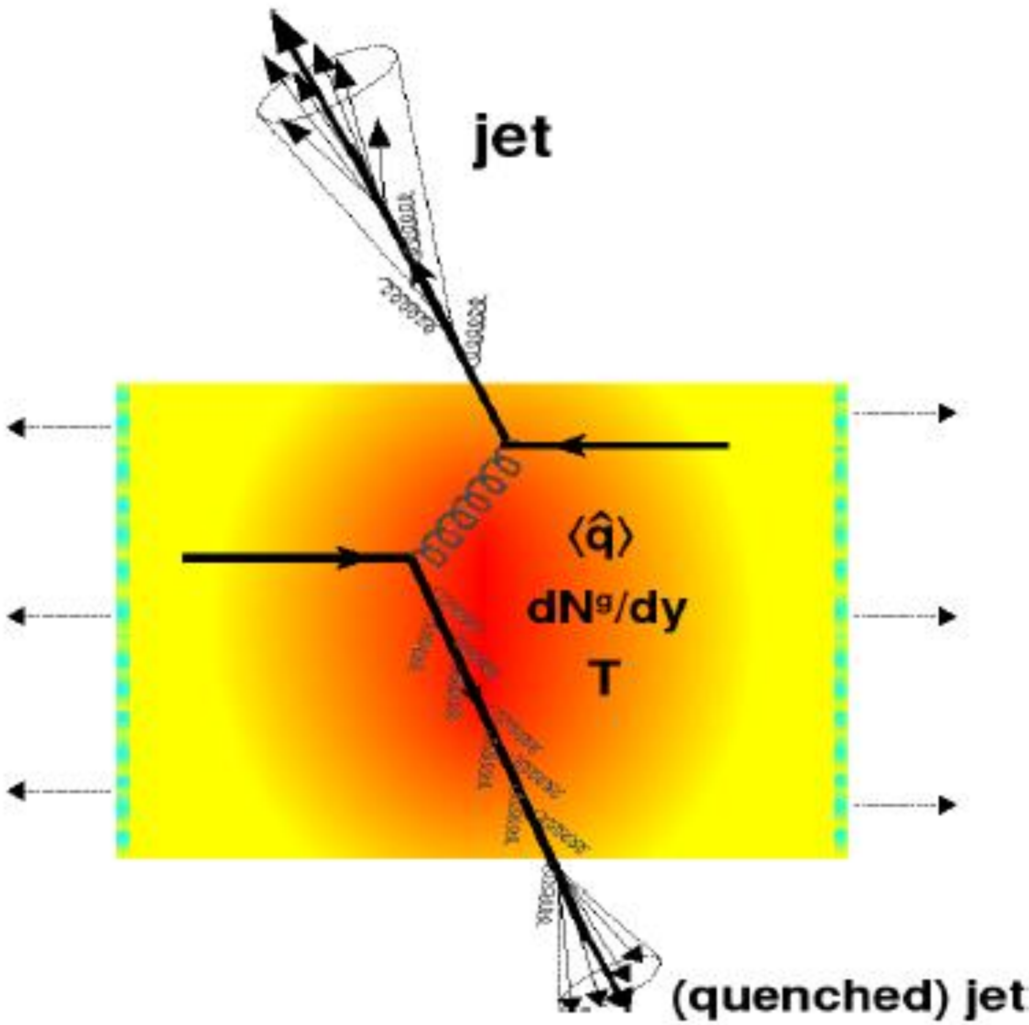
Jets are quenched in PbPb

Pb+Pb



p+p

Jets seem to be losing energy in plasma



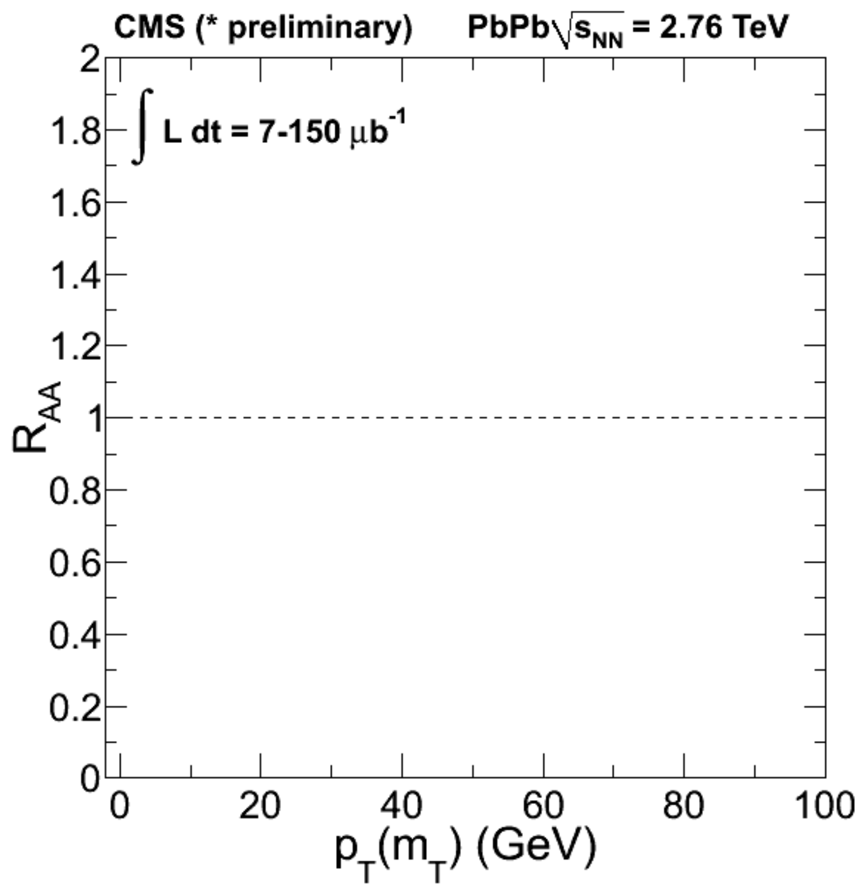
Energy loss per unit path length <q> probably depends upon the density of colored objects and the temperature

How can we quantify the suppression?

$$R_{AA} = \frac{\text{Number of particles from a PbPb event}}{N_{collisions} * \text{Number of particles from a pp event}}$$

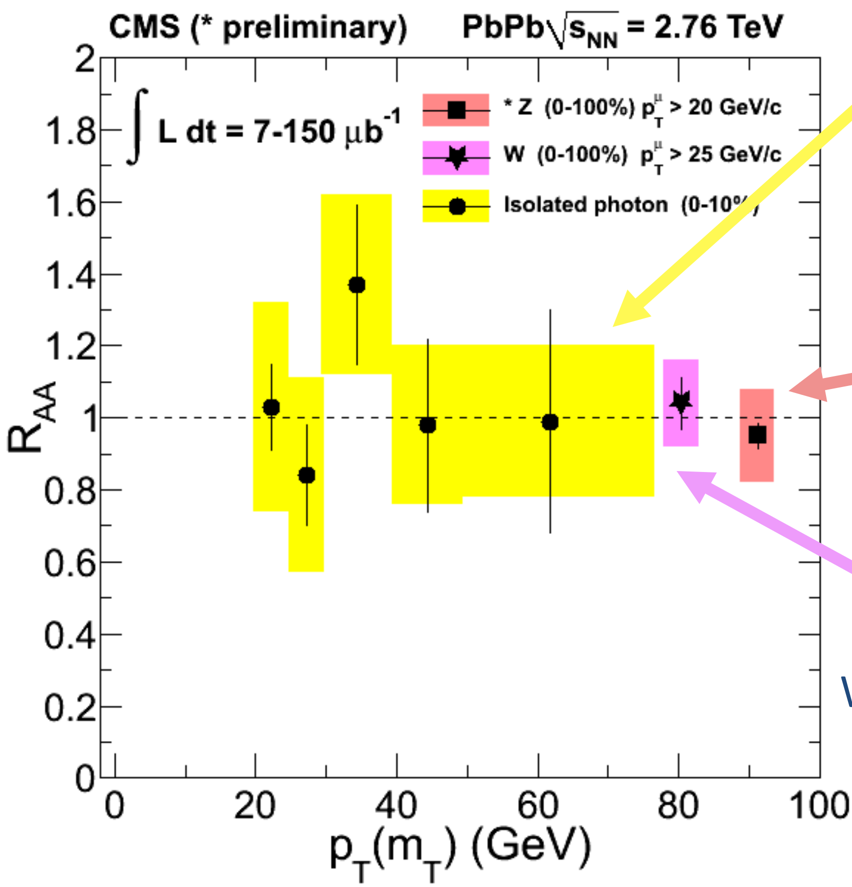
$N_{collisions}$ = number of individual pp collisions in a PbPb event

Does jet quenching depend on momentum?



Start from blank slate

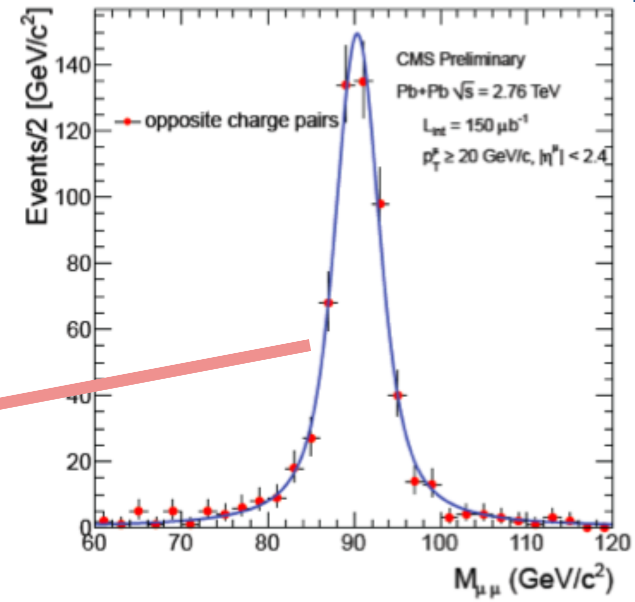
(Non-) Suppression of colorless probes

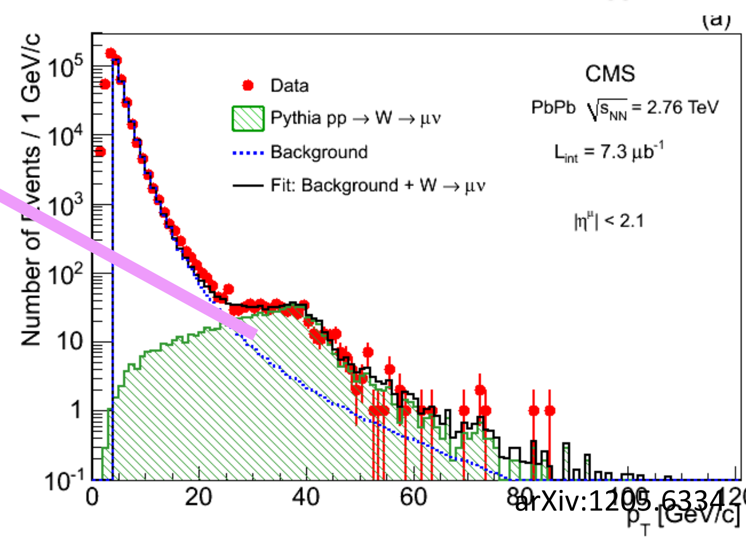


Isolated photons

Z^0 $\mu^+\mu^-$

W => $\mu\nu$

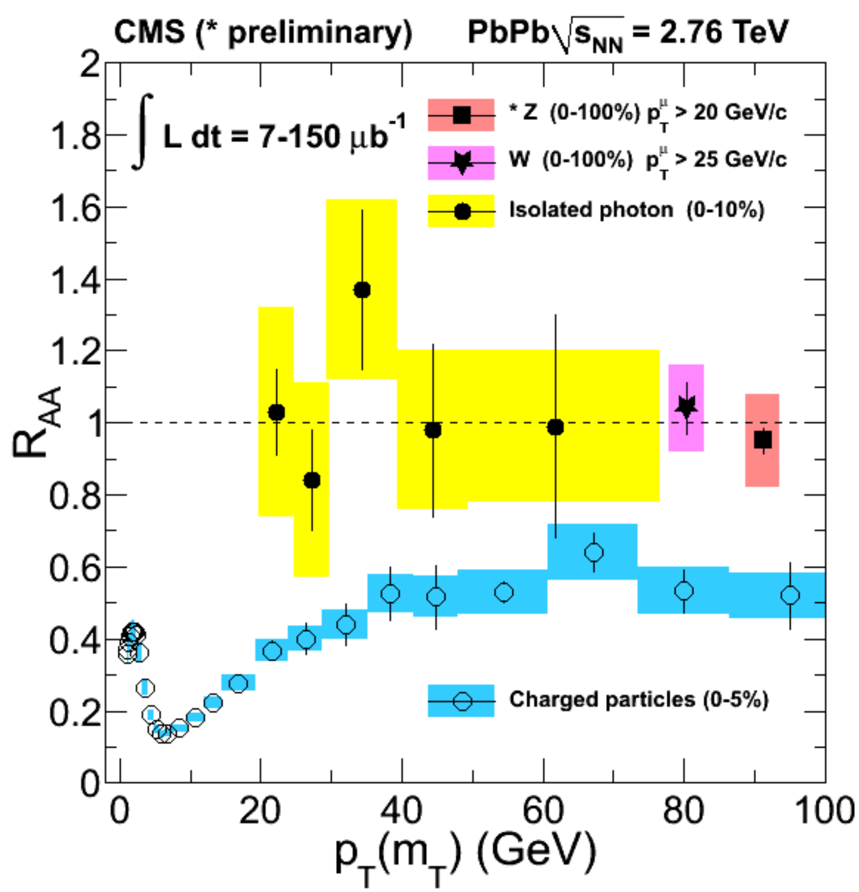




arXiv:1205.6334

N_{coll} scaling confirmed

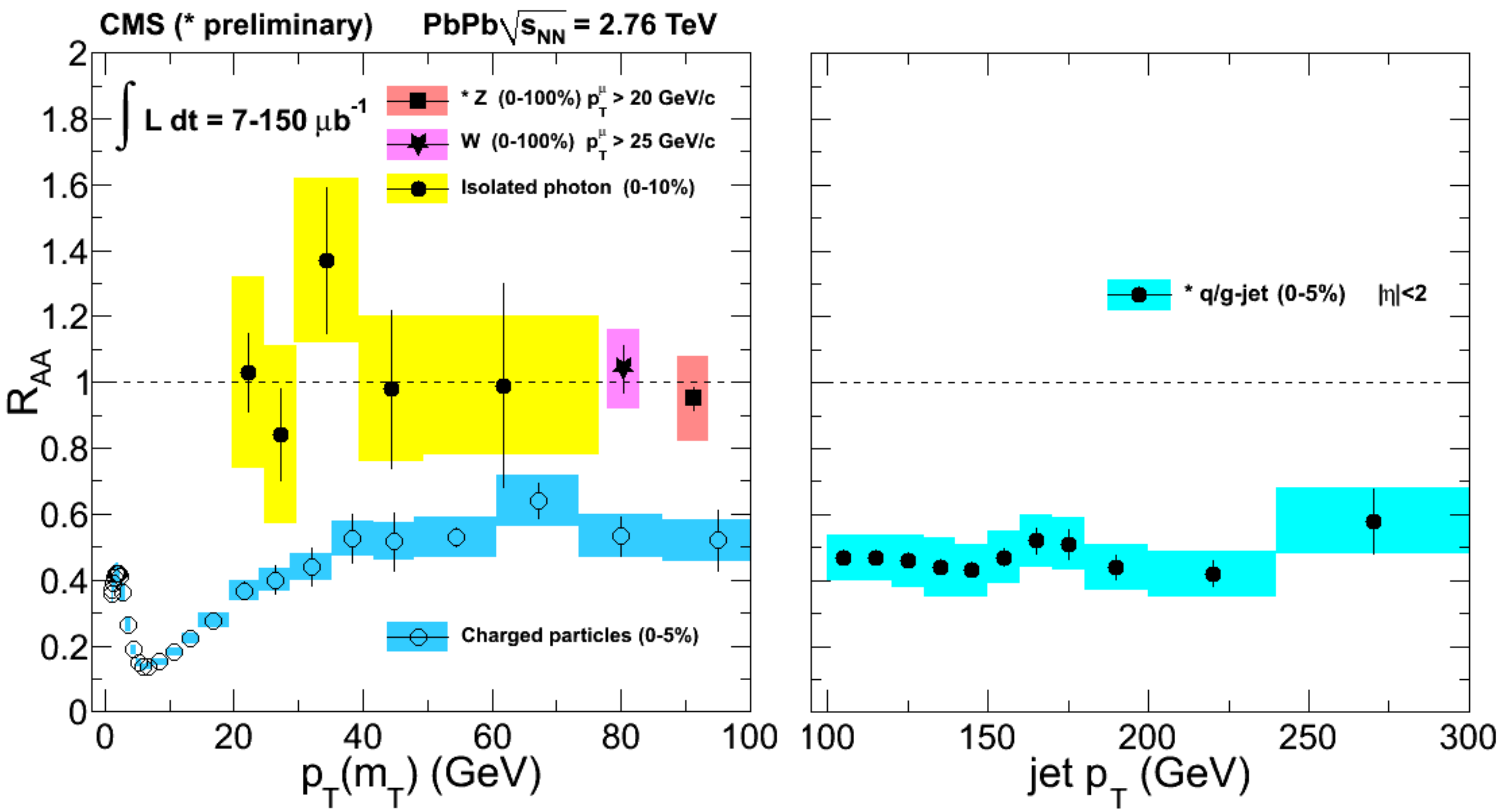
Suppression of charged particles



EPJC 72 (2012) 1945

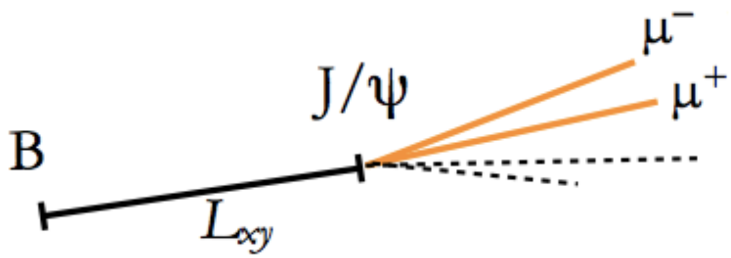
Charged hadron R_{AA} flat from $p_T = 30 - 100$GeV

Suppression of inclusive jets

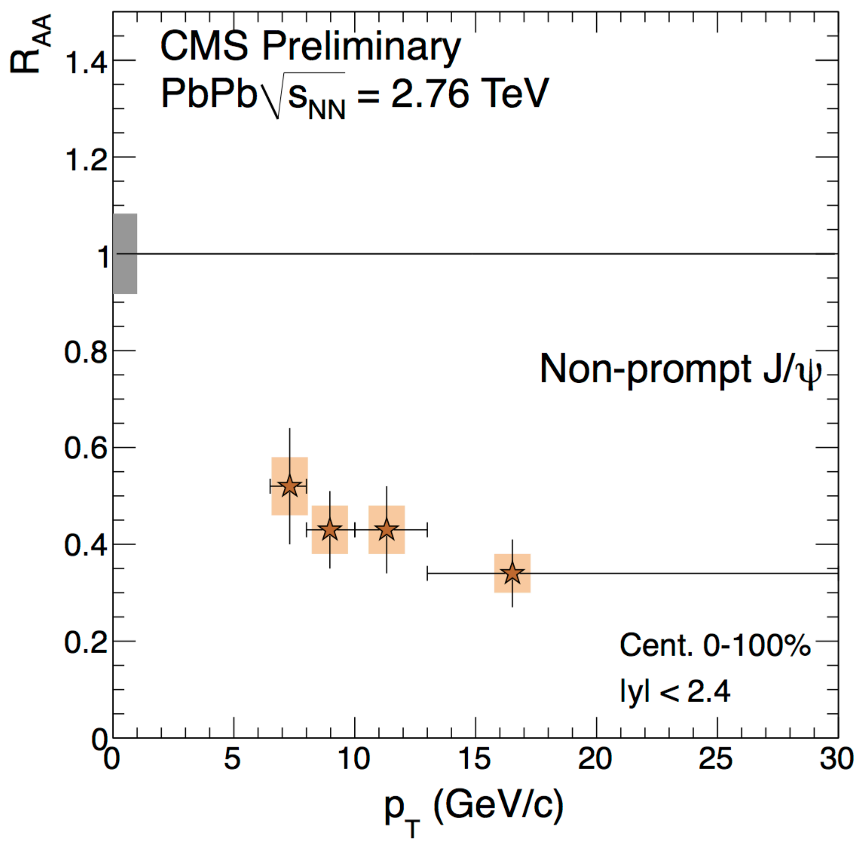


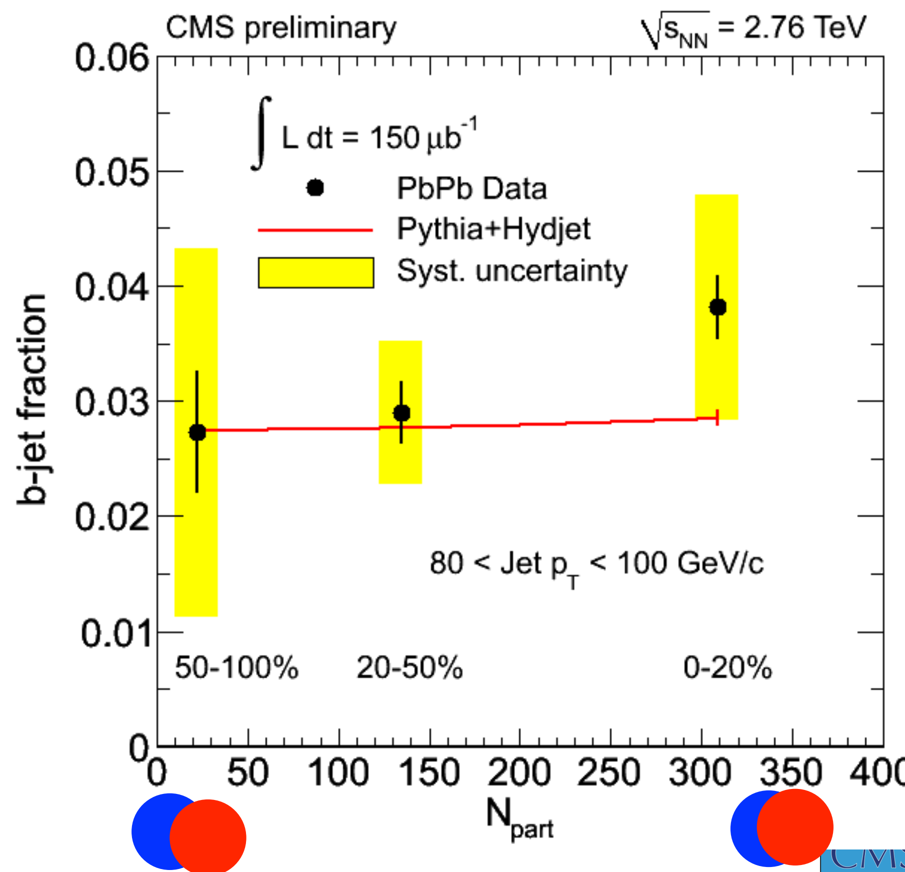
Jet R_{AA} looks similar to charge particles, flat at ≈ 0.5n

Identifying bottom quarks

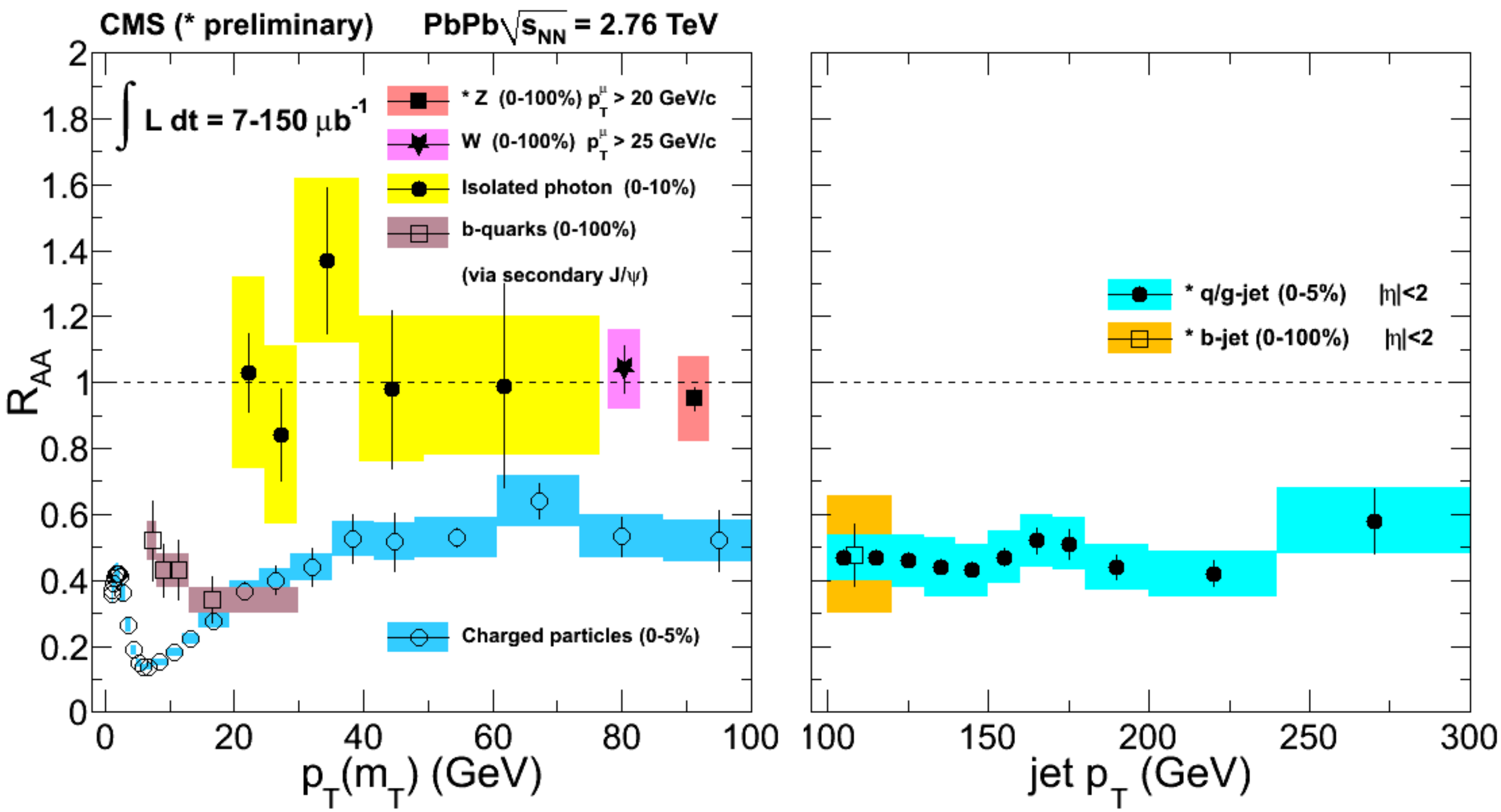


Look for jets with a high mass secondary vertex from a b quark





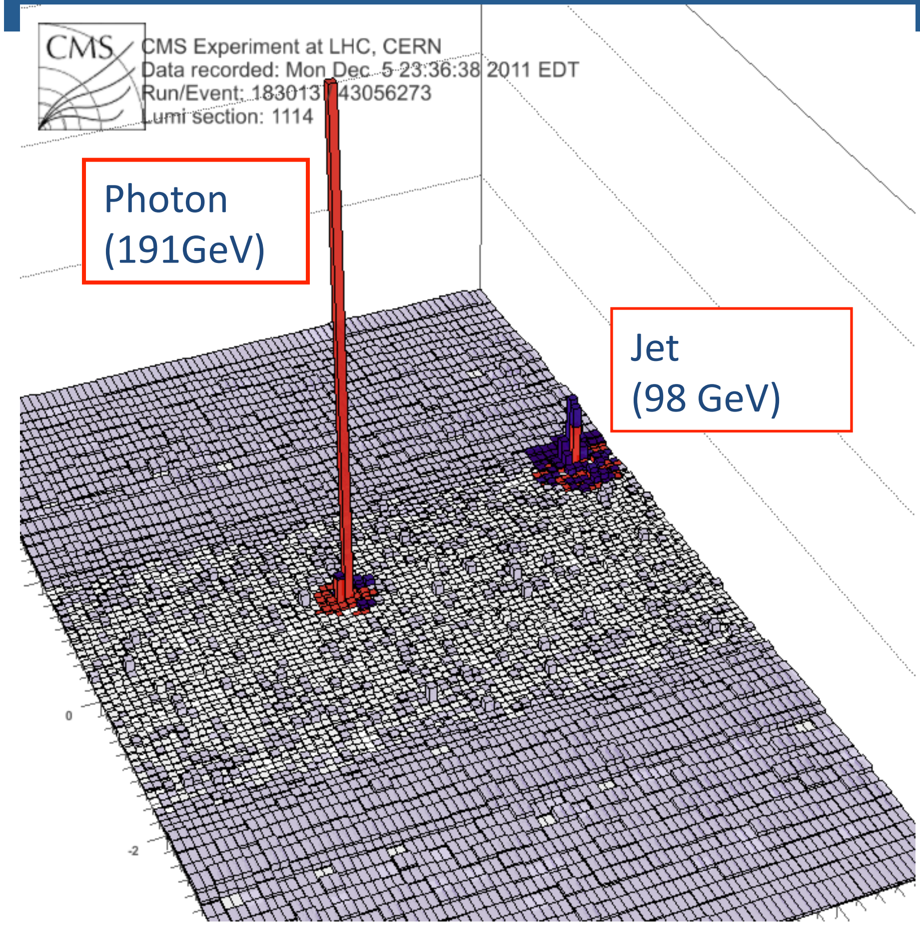
Suppression of b-quarks

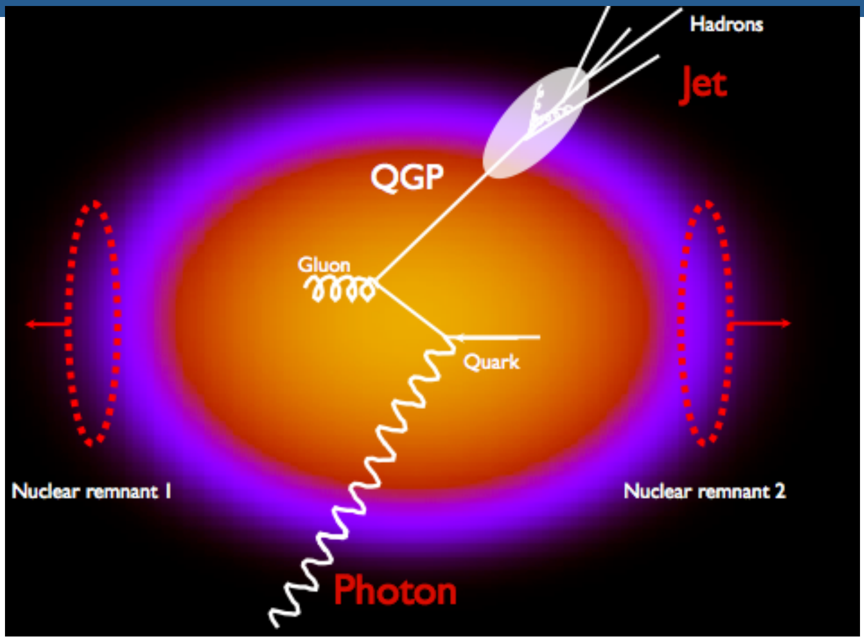


Distinct b-quark suppression pattern at low p_T

First observation of b-jet suppression at high p_T

γ+jet: u,d quark energy loss





Photon tag:

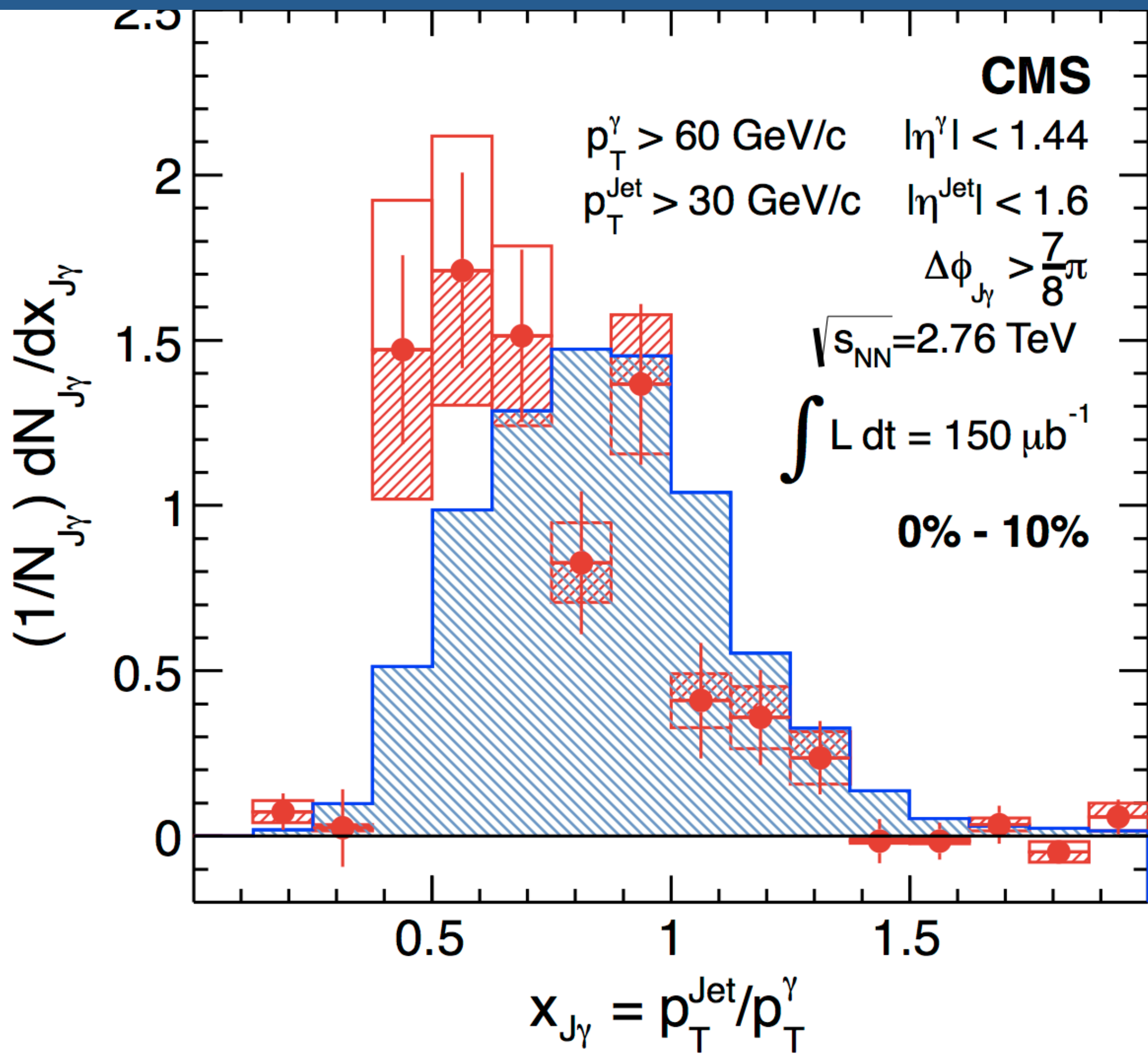
- Identifies jet as u,d quark jet
- Provides initial quark direction
- Provides initial quark p_T

Jet/Photon momentum balance

arXiv:1205.0206

PbPb

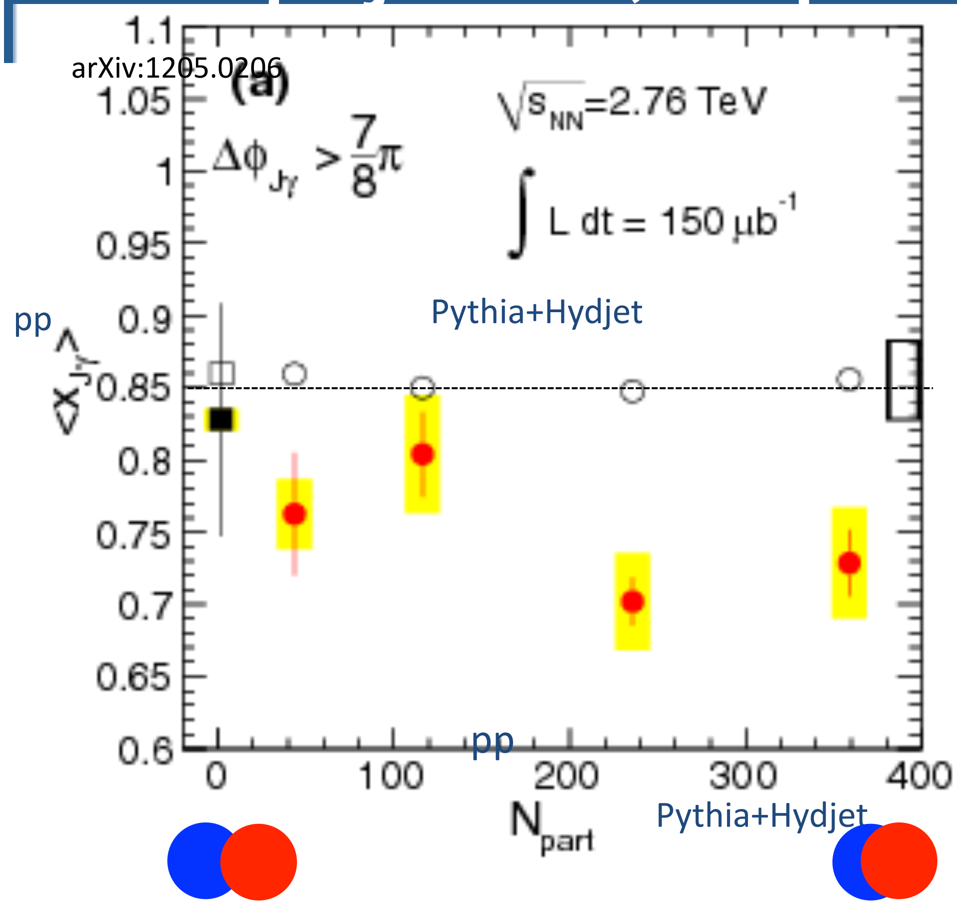
Pythia+Hydjet



Area normalized to unity

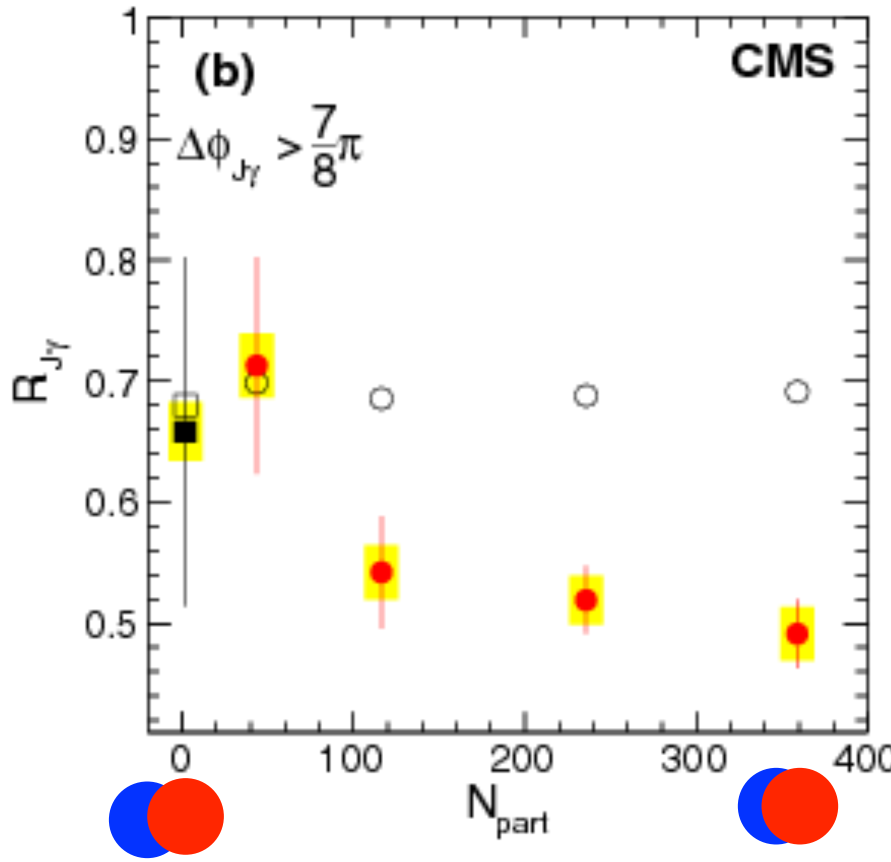
γ+jet: u,d quark energy loss

arXiv:1205.0206

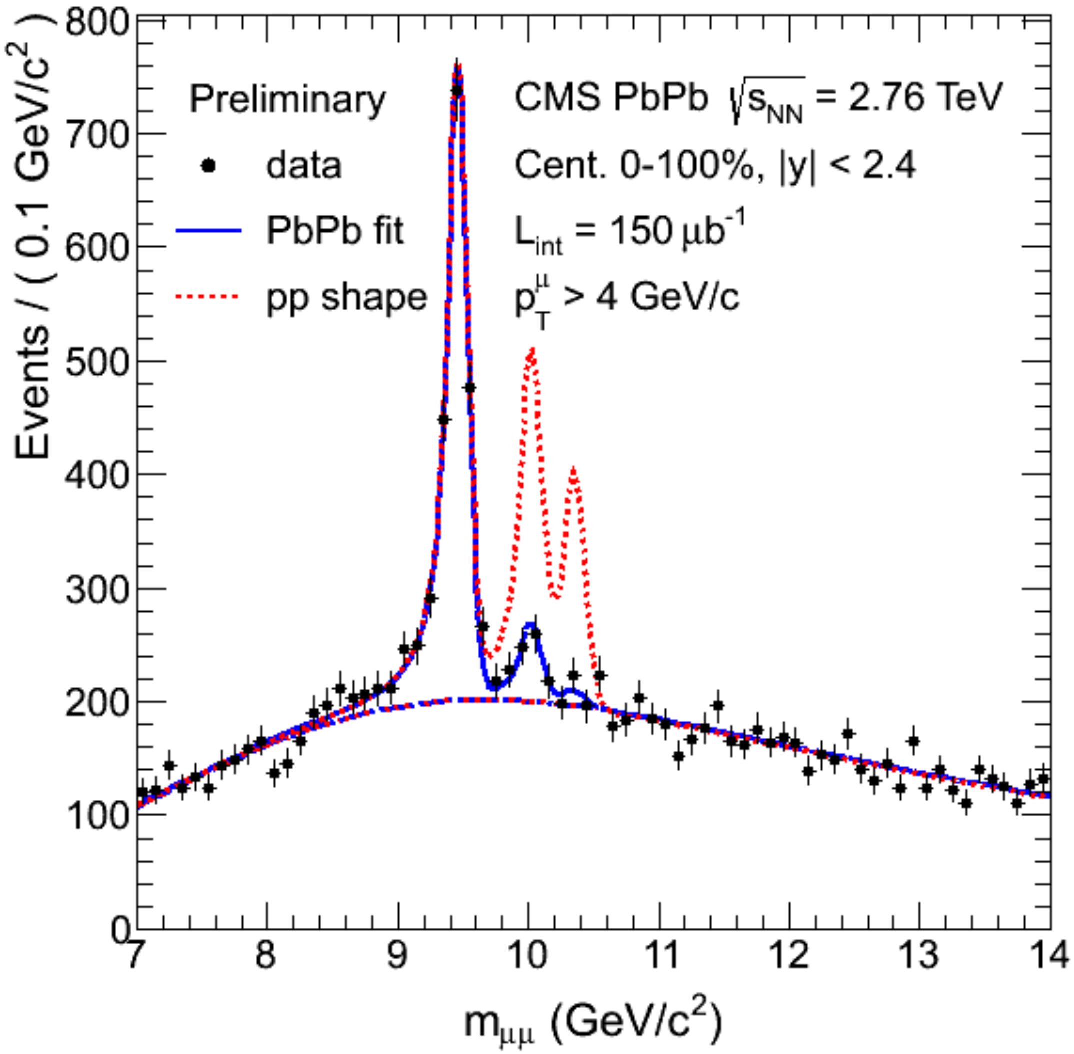


Ration of jet/photon p_T drops by 14%

20% of photons lose jet partner



Sequential Upsilon suppression

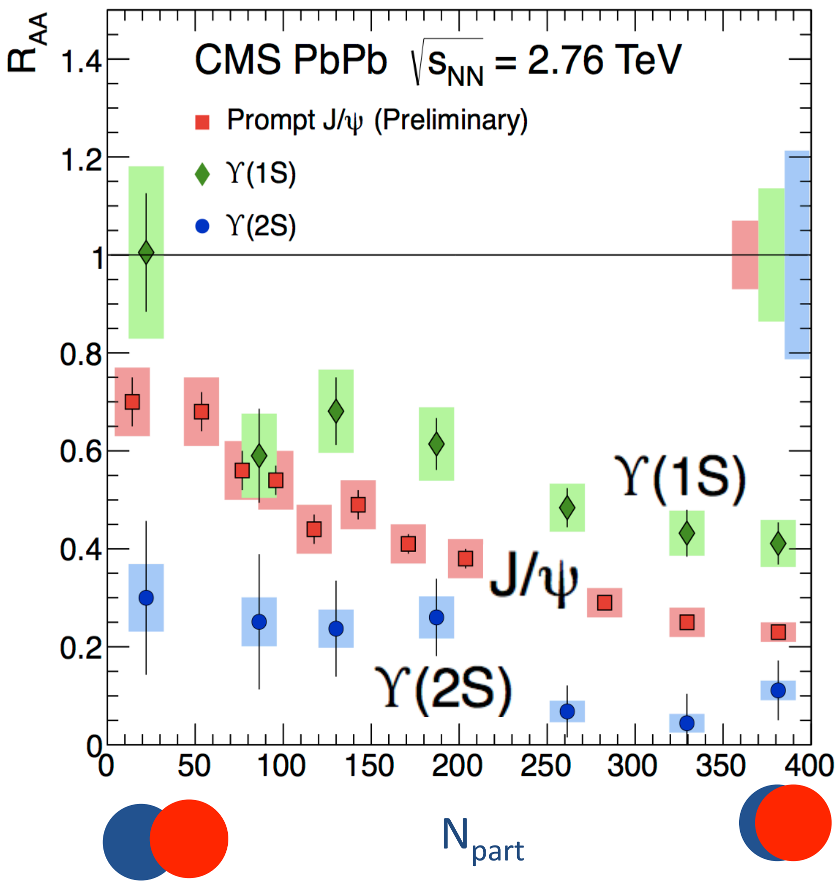


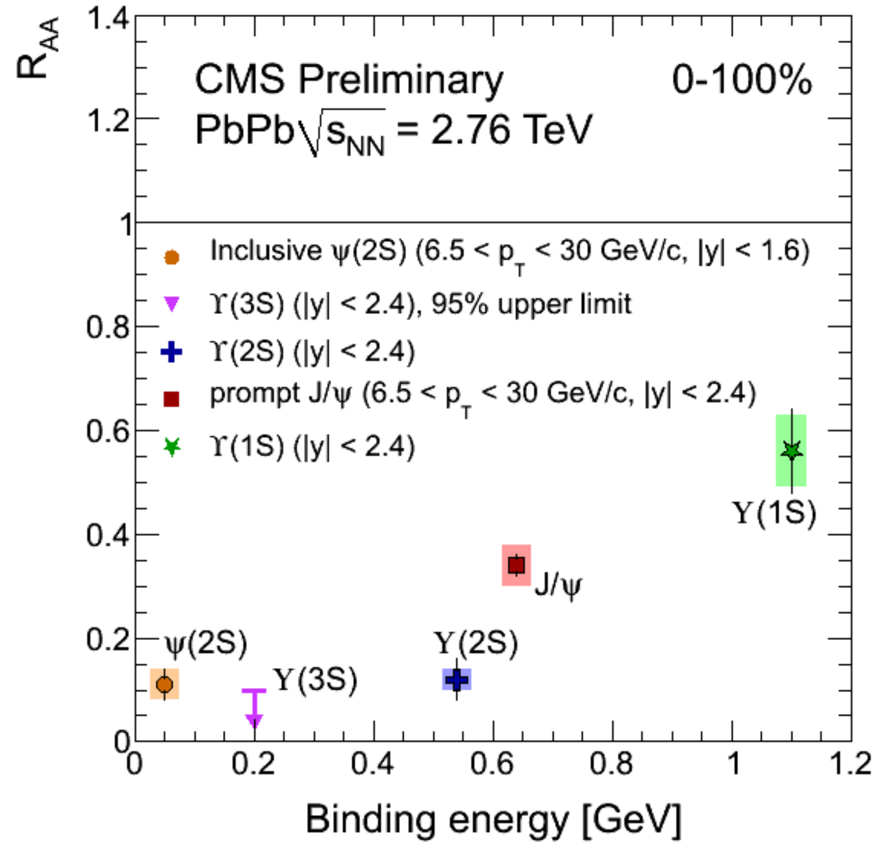
Sequential suppression of Υ family, the least bound member is suppressed the most in PbPb collisions

Building a quarkonium-thermometer

CMS-PAS HIN-11-011

Note: $6.5<p_T<30$ GeV for J/ψ and ψ(2s)





Clear hierarchy in R_{AA} of different quarkonium states

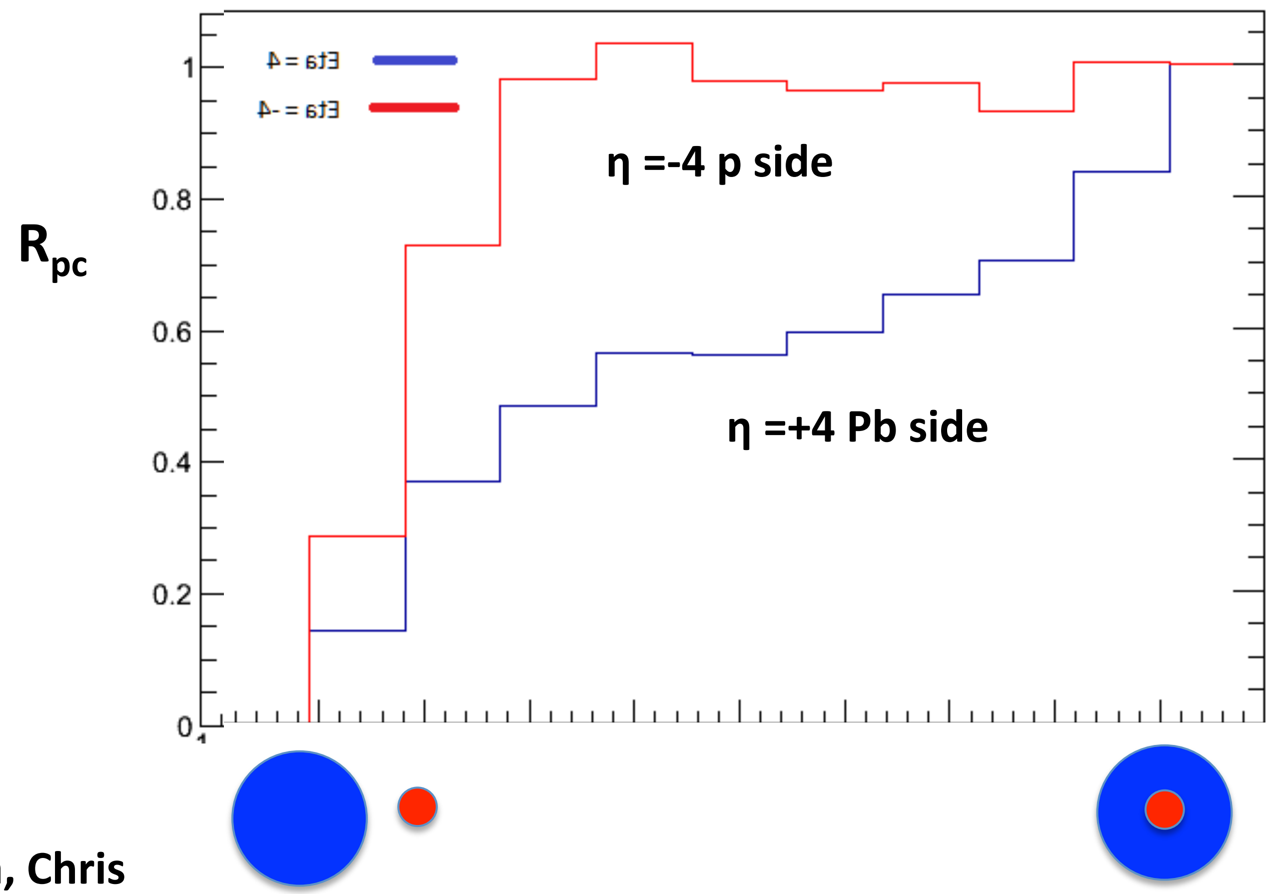
Expected in terms of binding energy

Summary

- System is extremely dense, ~ 100 time more than normal nuclei,
- Longitudinal flow not described by simple Landau Hydrodynamics
- We see a strong suppression of high momentum objects.
- As jets punch through medium they are many low momentum particles spray our to large radii.
- Systems of bound quarks like Y and J/ψ show a characteristic melting with weakly bound systems being the most suppressed
- **Thank you Joe for all you did for me & my family**

Backup

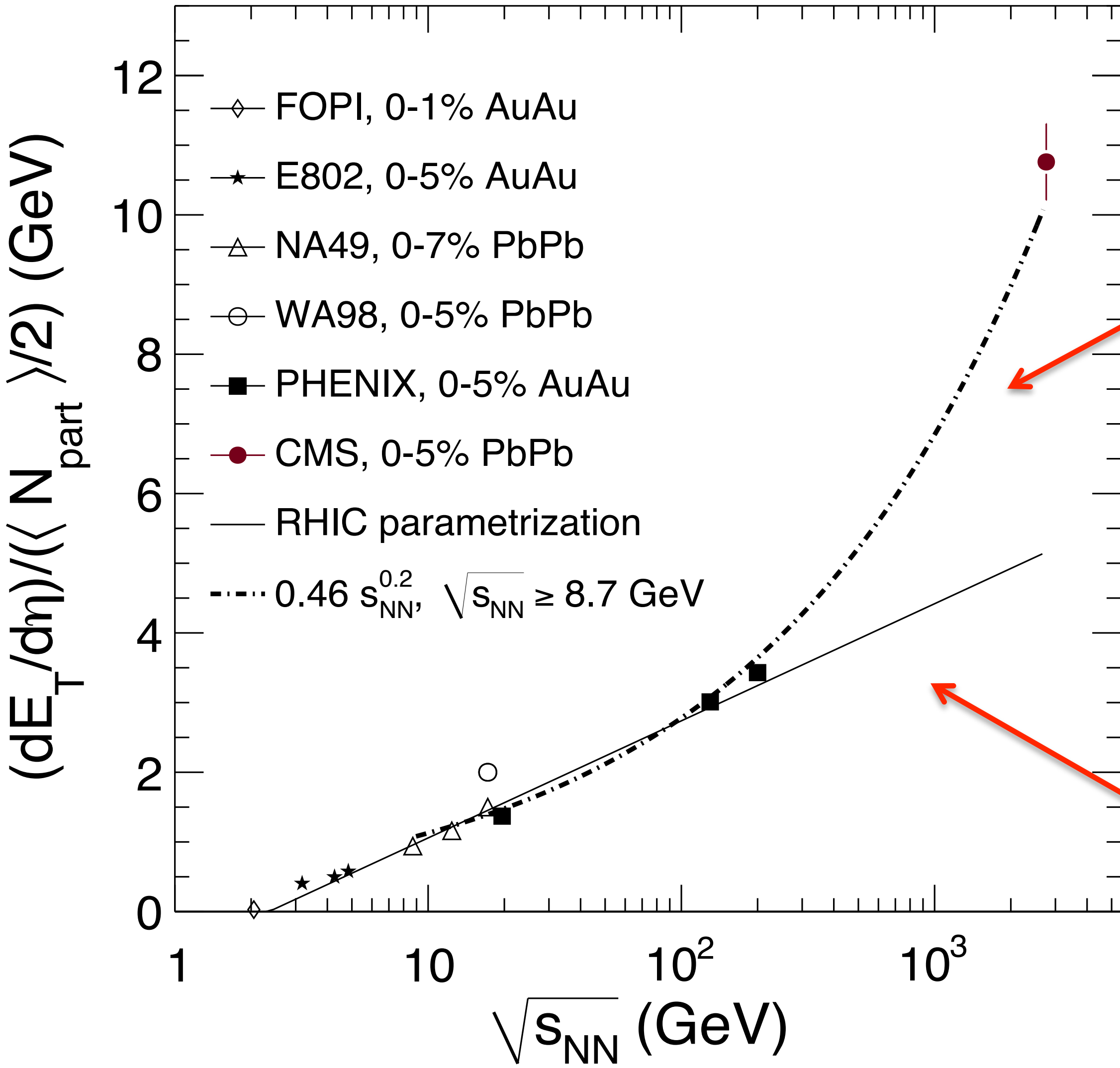
Ratio of energy in peripheral/central for pPb (proton going to positive rapidity)



Magdalena, Chris

So far only for HF, with CASTOR and barrel should have 13.5 units of rapidity

$dE_T/d\eta$ at η=0 versus $\sqrt{s}$

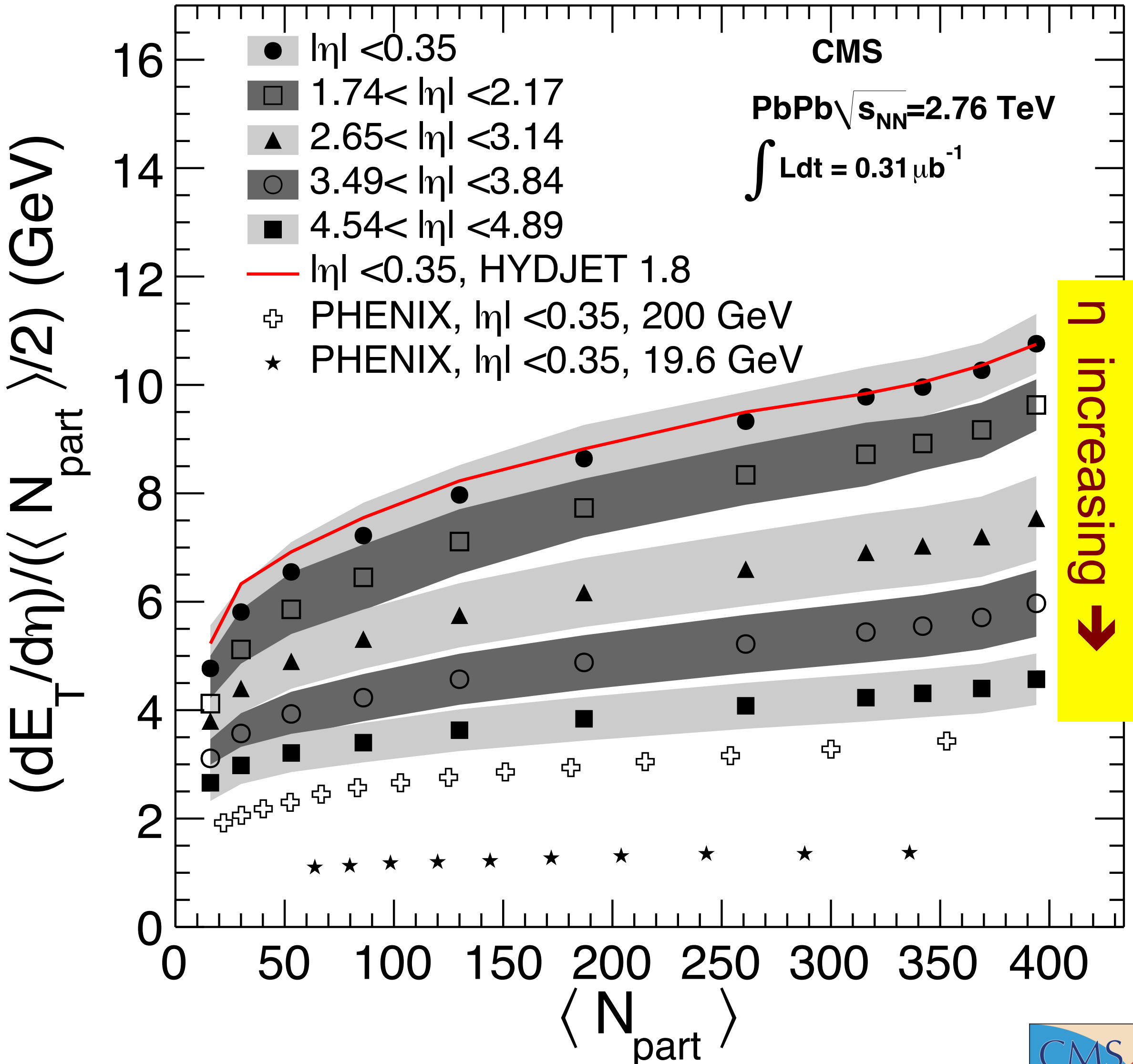


Power law works for $\sqrt{s_{nn}} \geq$ 8GeV

Logarithmic parameterization that worked from $\sqrt{s_{NN}}$ = 1.5 to 200 GeV breaks down for TeV energies

$dE_T/d\eta$ vs N_{part} and η

For all η the distribution rises rapidly at low N_{part} and then levels off



Magdalena

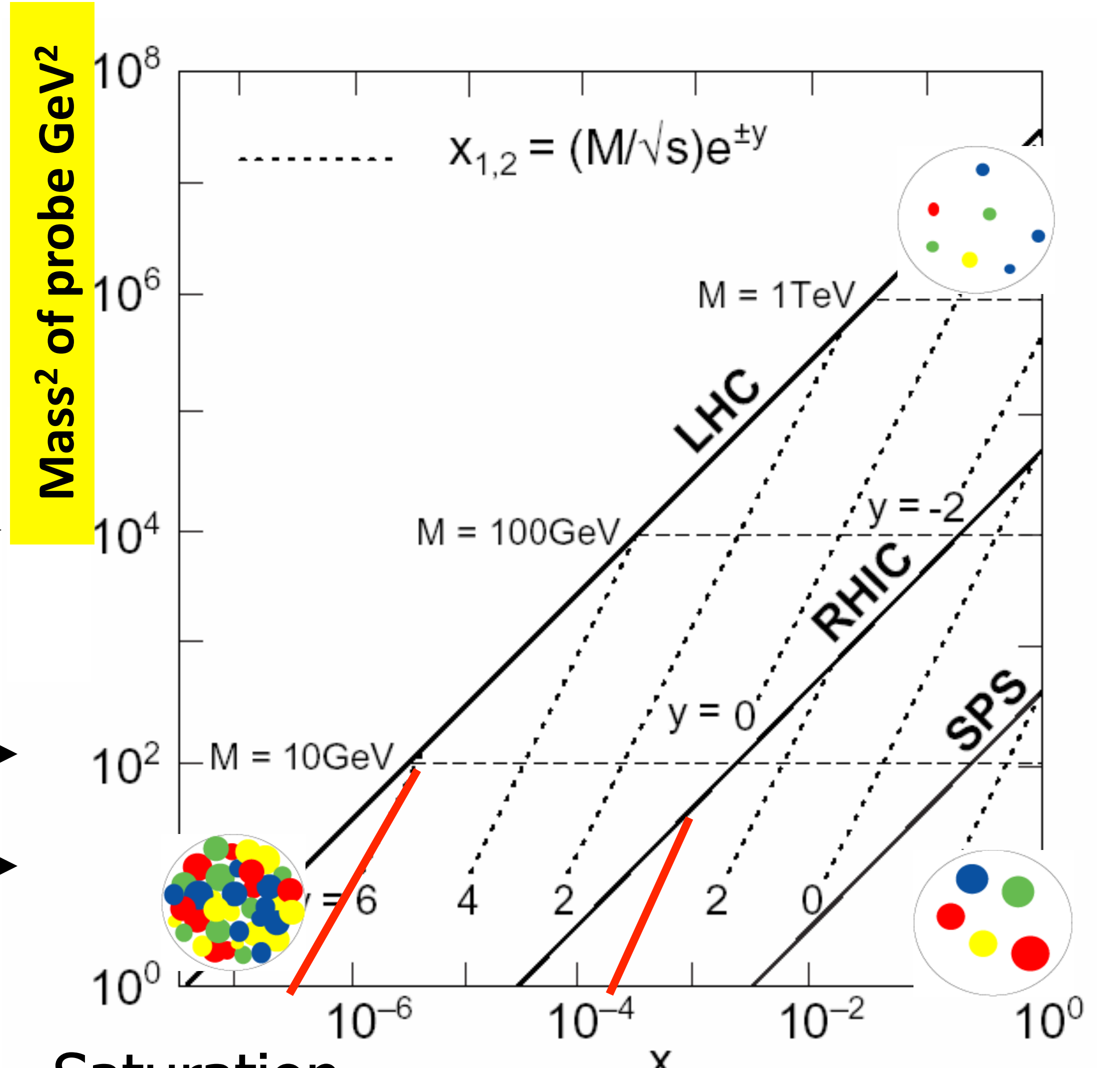
Searching for color glass

Access to widest range phase space

Z0 →

ϒ →

J/ψ →



Saturation

Fraction of momentum carried by parton

Gluon density has to saturate at low x