

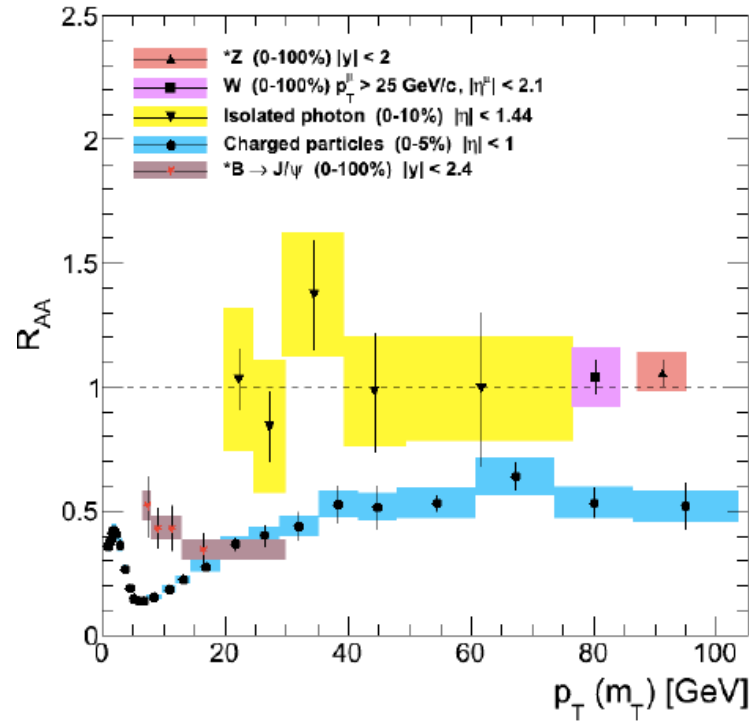
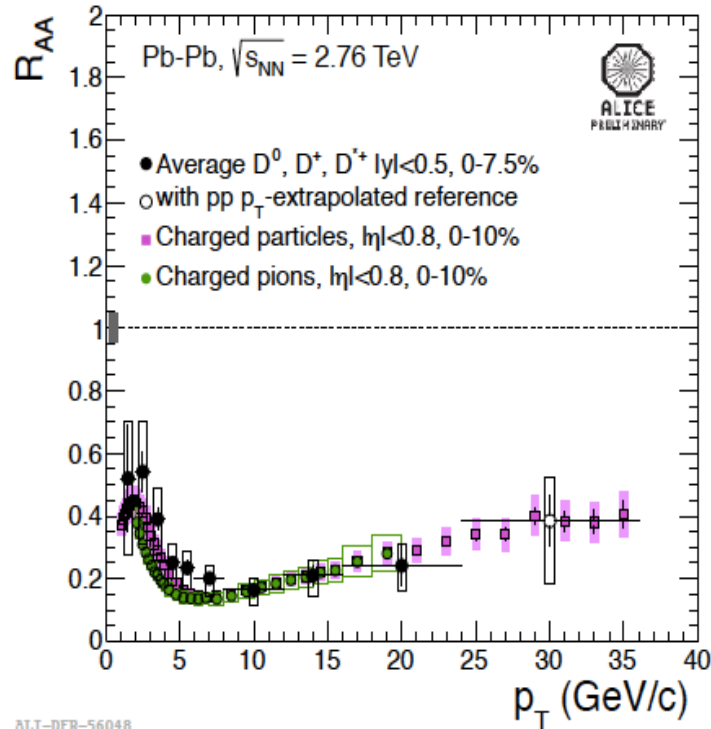
Jet from QM2014

Shingo Sakai @ LNF-INFN

At the beginning ...

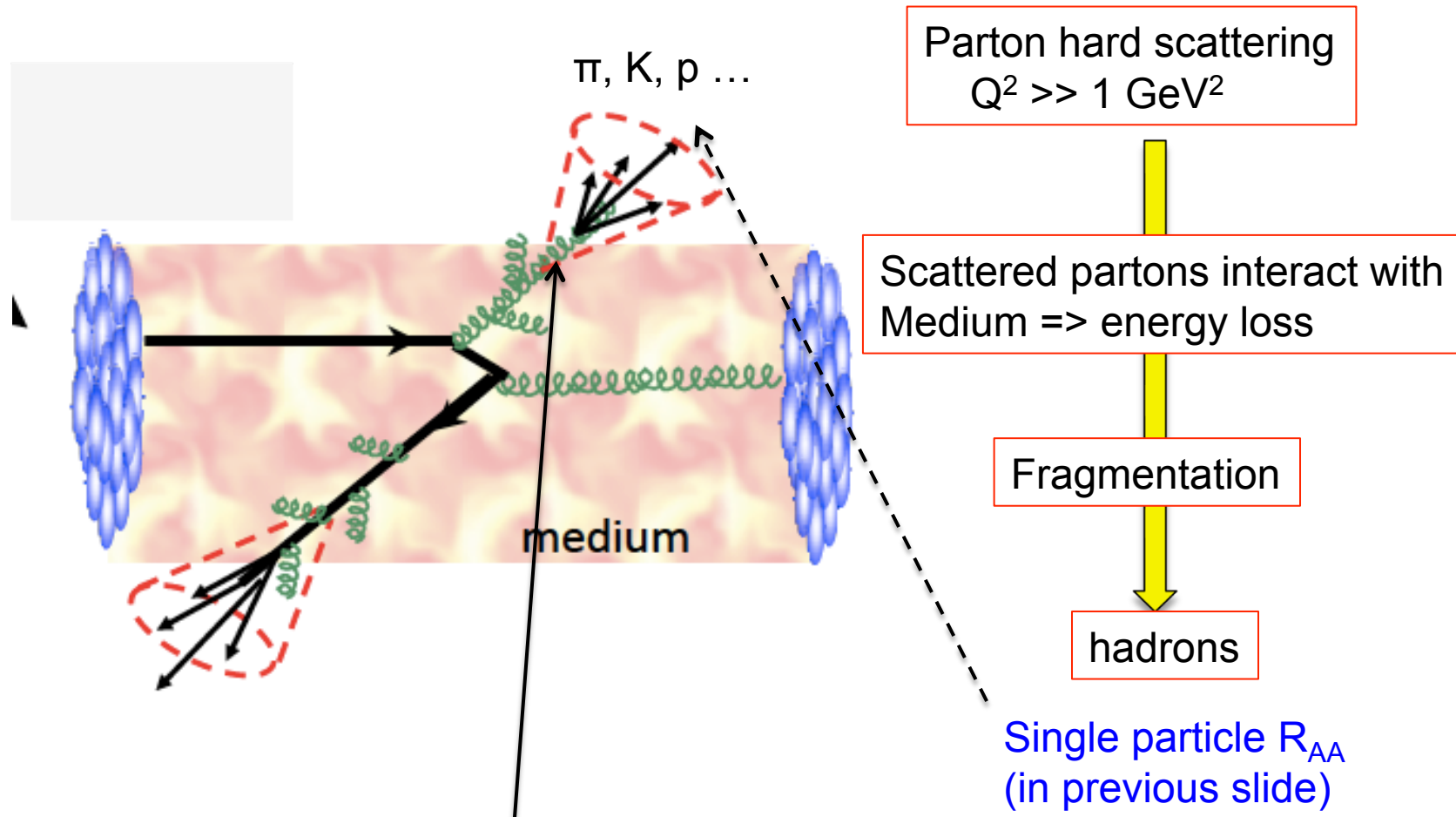
- ▶ This presentation is based on QM 2014
 - ▶ *Measurement of jets in Pb-Pb collisions with ALICE*
 - ▶ S. Aiola for ALICE collaboration
 - ▶ *Measurements of jet suppression with ATLAS*
 - ▶ A. Angerami for ATLAS collaboration
 - ▶ *Centrality and rapidity dependence of inclusive jet production in $\sqrt{s_{NN}}=5.02$ TeV p+pB with ATLAS*
 - ▶ D. V. Perepelitsa for ATLAS collaboration
 - ▶ *B-jet RAA in Heavy-ion collisions with CMS*
 - ▶ K. Jung for ATLAS collaboration
 - ▶ *Jet and charged hadron RAA in pPb collisions with CMS*
 - ▶ E. Appelt
 - ▶ *Studies of dijet & photon-jet properties in pp, pPb, & PbPb collisions with CMS*
 - ▶ R. Alex for CMS collaboration
 - ▶ *Measurement of momentum flow relative to the dijet system in PbPb & pp collisions*
 - ▶ D. Gulhan for CMS collaboration
 - ▶ *Experimental results on jets in ultra-relativistic nuclear collisions*
 - ▶ Y. J. Lee

Introduction (I)



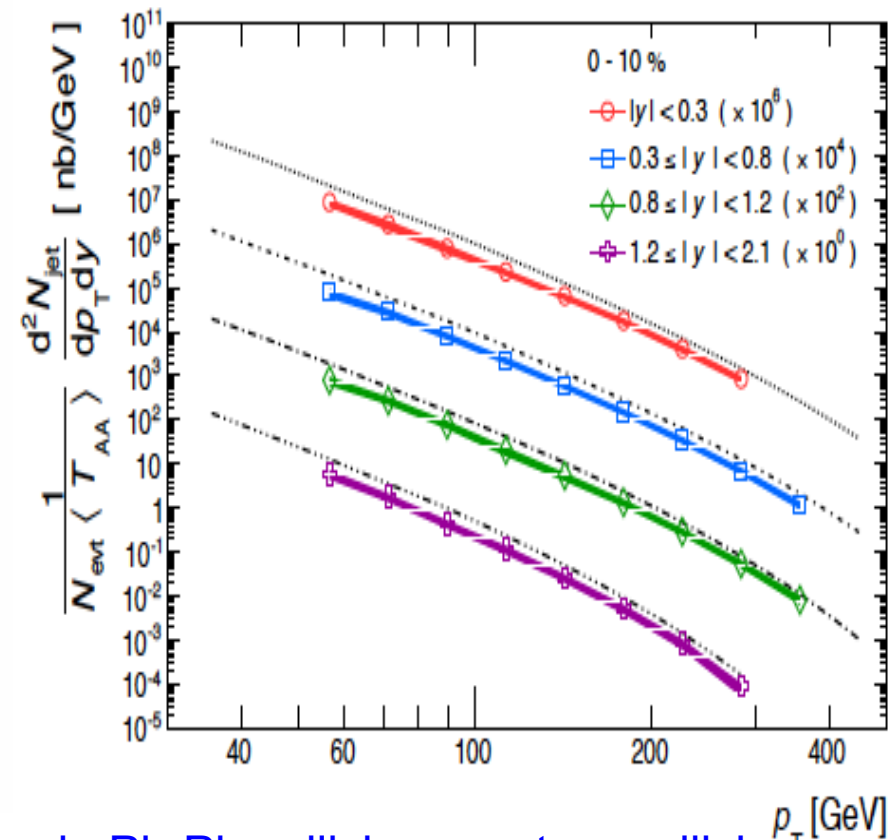
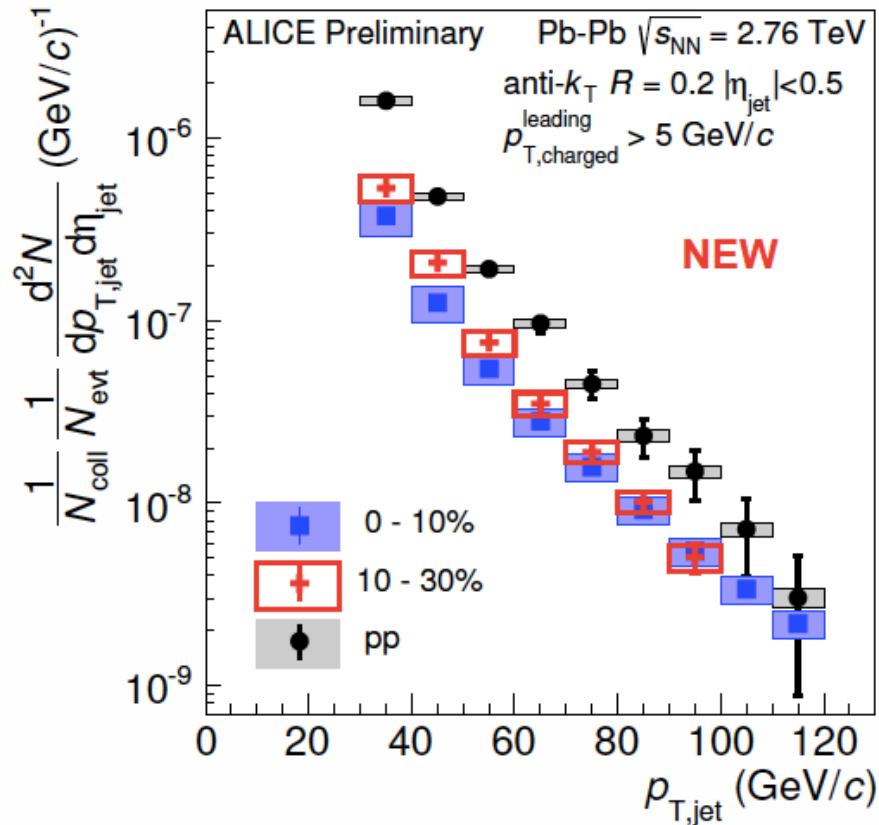
- A strong suppression of particle production in H.I.C was observed at RHIC (0.2 TeV)
- Particle productions in H.I.C at LHC (2.76 TeV)
 - strong suppression up to 100 GeV/c (charged particle)
 - heavy flavours (charm & beauty) productions are strongly suppressed
 - photon, Z and W productions are scaled binary collisions of pp

Introduction (2)



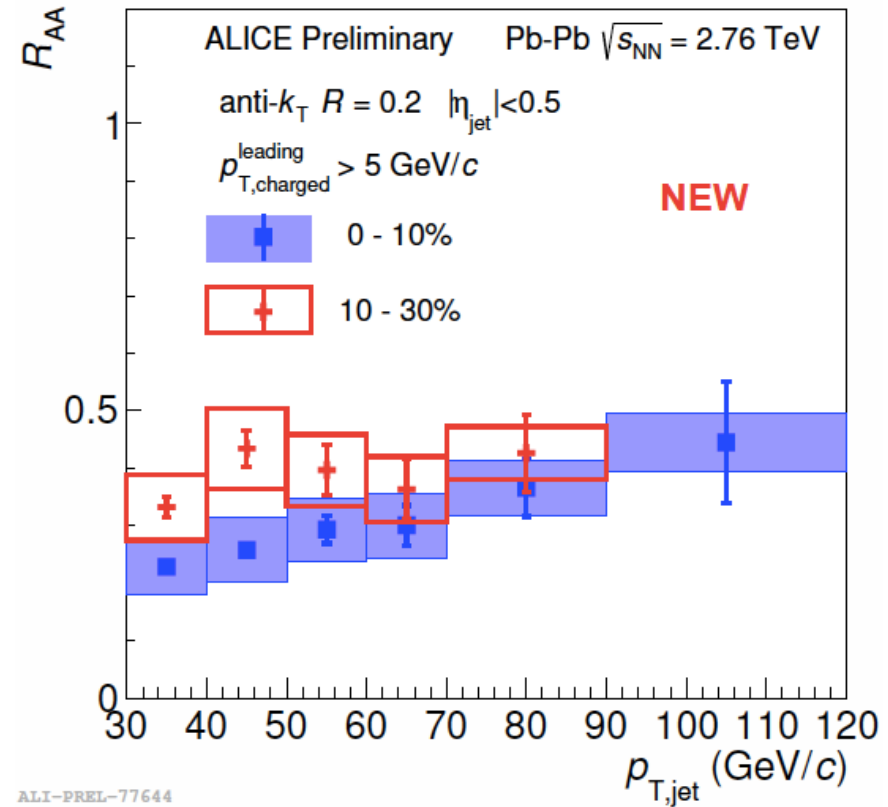
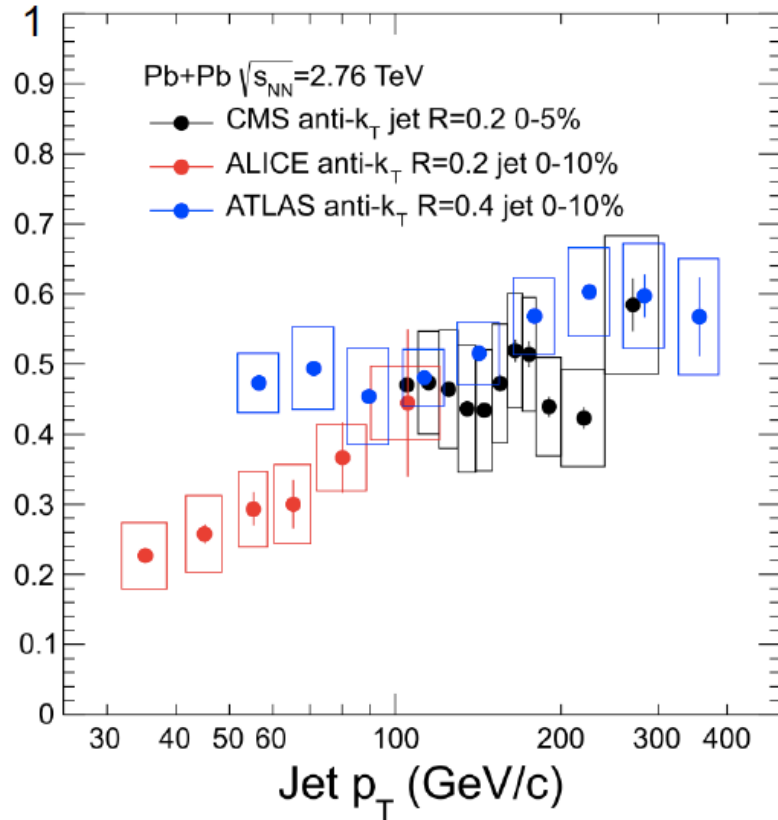
Jet measurement allow to access parton level

Jets spectrum in Pb-Pb



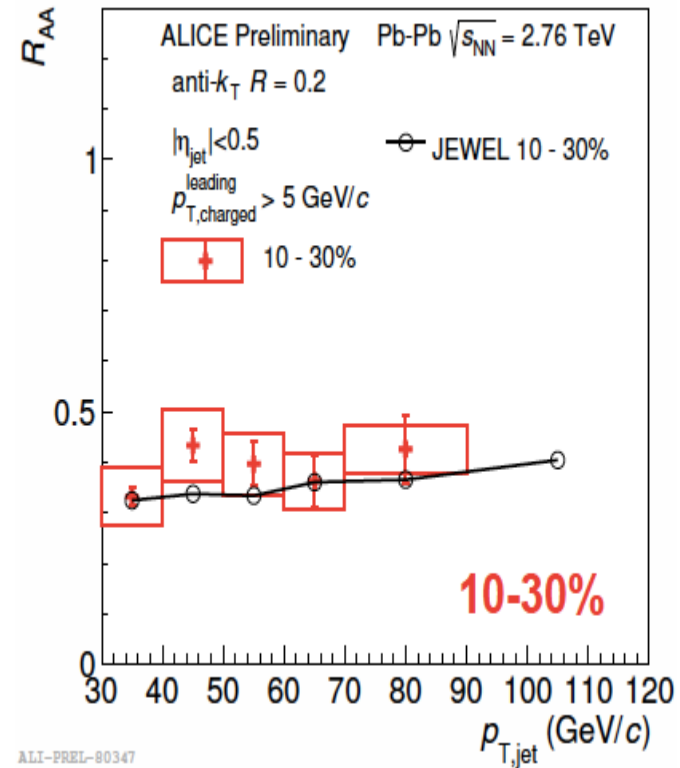
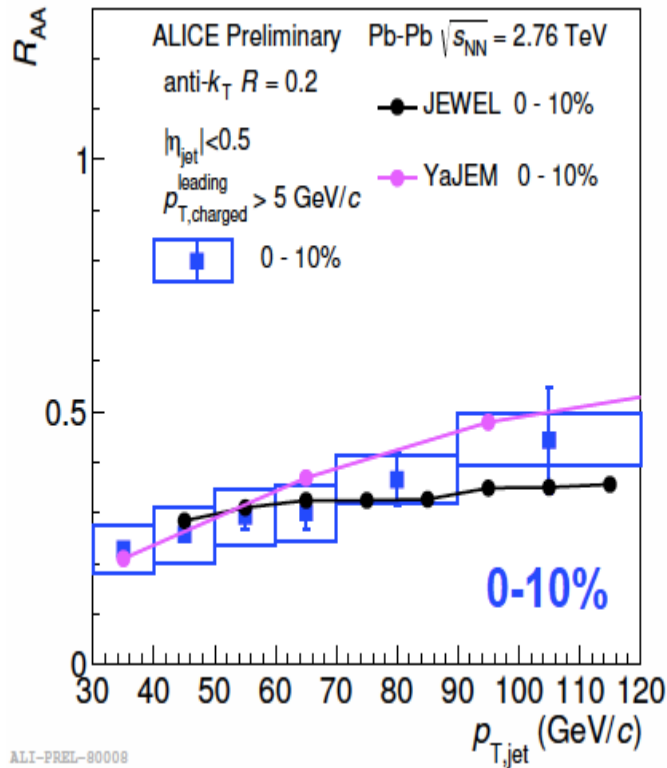
- Suppression of Jet in Pb-Pb collisions in Pb-Pb collisions w.r.t pp collisions
- y dependence of jet production
 - forward rapidity, the spectrum becomes steeper
 - dominated by hard scattering with outgoing quarks (different parton shower)

Jets in Pb-Pb



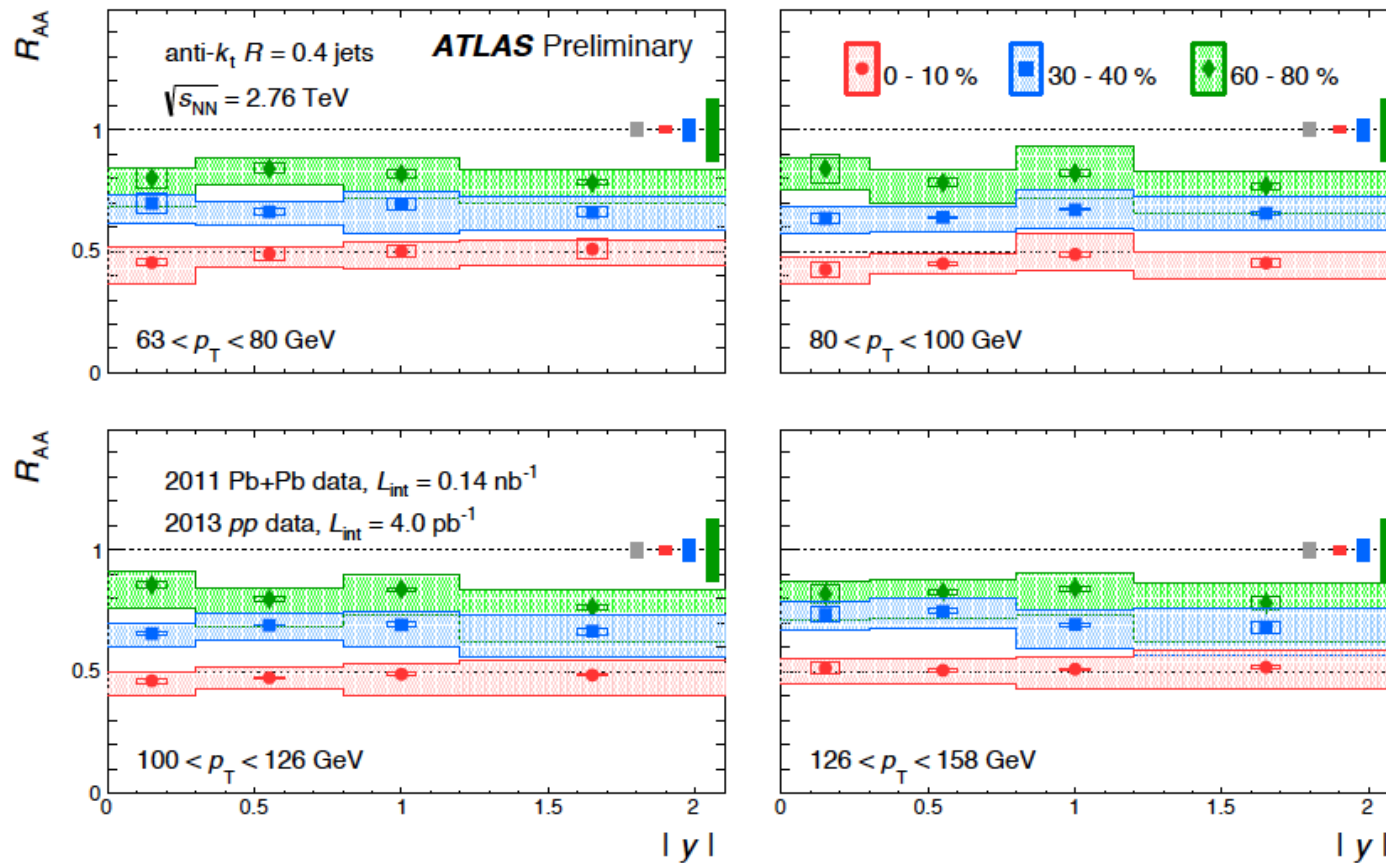
- Strong suppression up to 400 GeV in most central (0-5%, 0-10%)
- Indication of centrality dependence of R_{AA} : $R_{AA}(0-10\%) < R_{AA}(10-30\%)$
- Indication of energy recover in large R: $R_{AA}(R=0.2) < R_{AA}(R=0.4)$:

Comparison with models



- Models: realistic geometry, initial state conditions, hadronization
 - are in good agreement with measurements (0-10% & 10-30%)
- detail of models
 - JEWEL: arXiv: 1212.1599
 - YaJEM: PRC78,034908, PRC84,067902

y dependence of Jet production

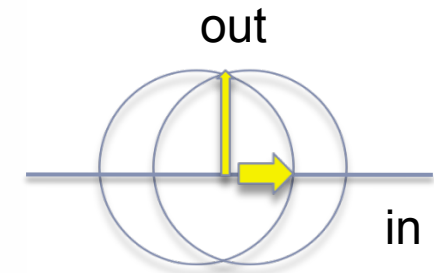
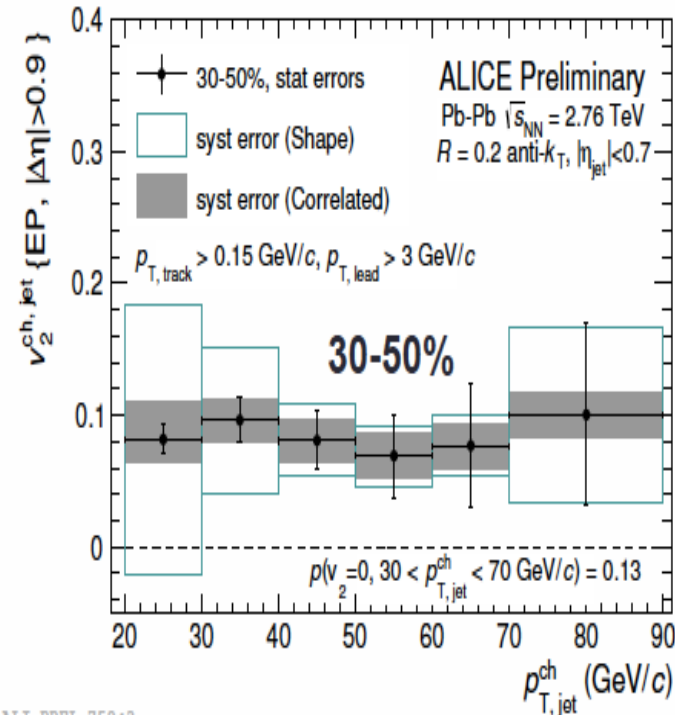
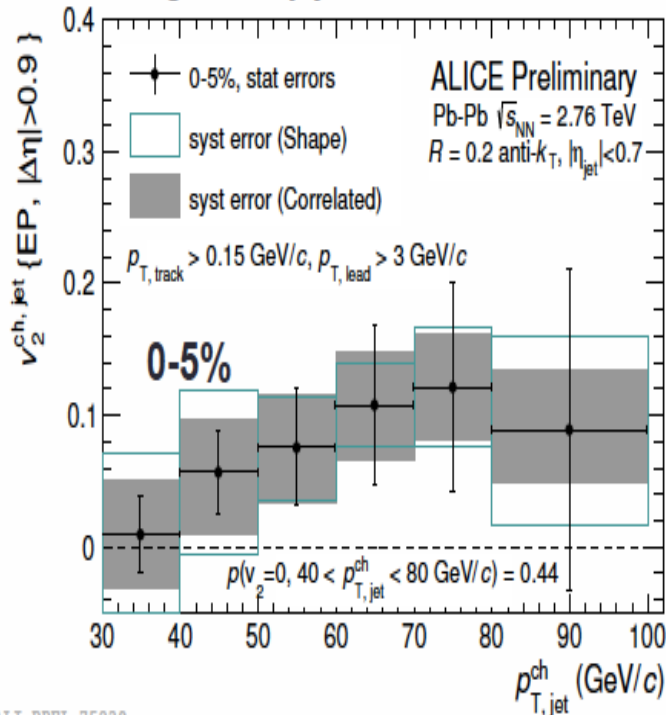


- forward rapidity: different production in mid-rapidity
 - spectrum is steeper in large y
- not significant y dependence of suppression up to $y=2$

Path length dependence of Jet R_{AA}

NEW

Charged-only jets



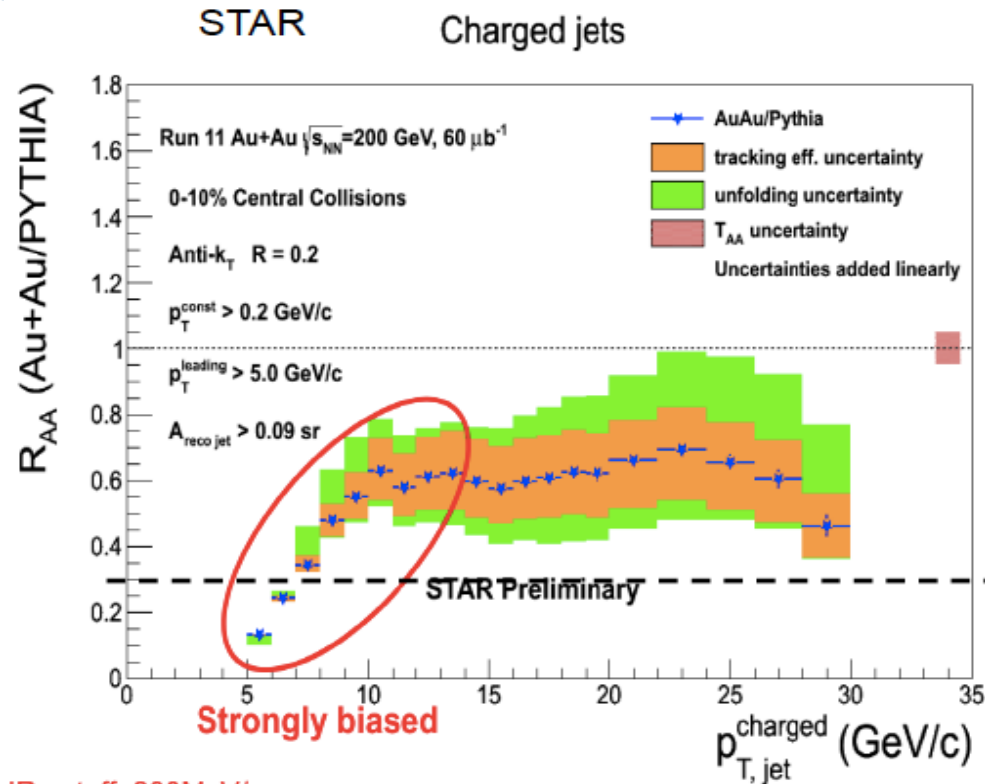
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- energy loss: expect path length dependence
 - out-plane: longer length
- 0-5%: zero v_2 ? path length almost same in-out plane
- 30-50%: indication non-zero v_2

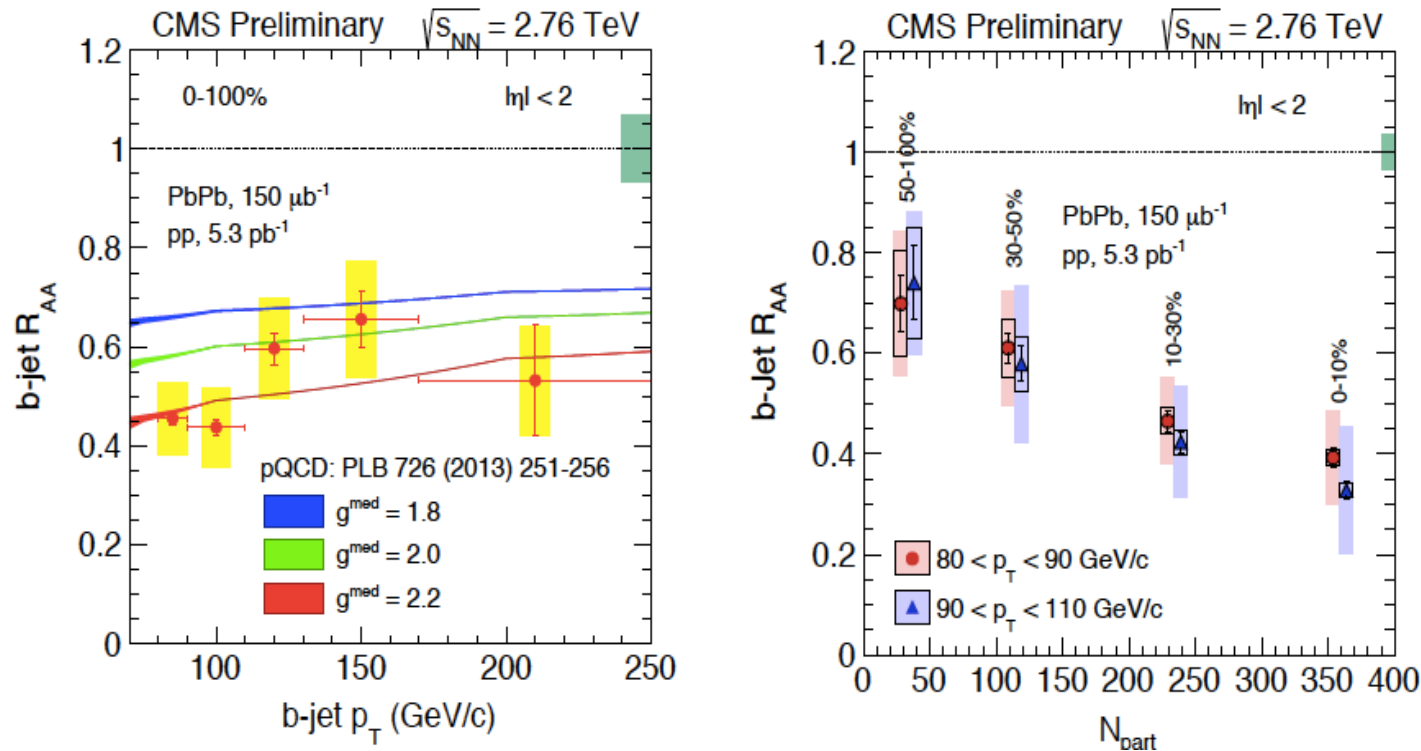
$$v_2^{\text{jet}} = \frac{1}{R_{EP}} \frac{\pi}{4} \frac{N_{in} - N_{out}}{N_{in} + N_{out}}$$

Lower energy & lower p_T



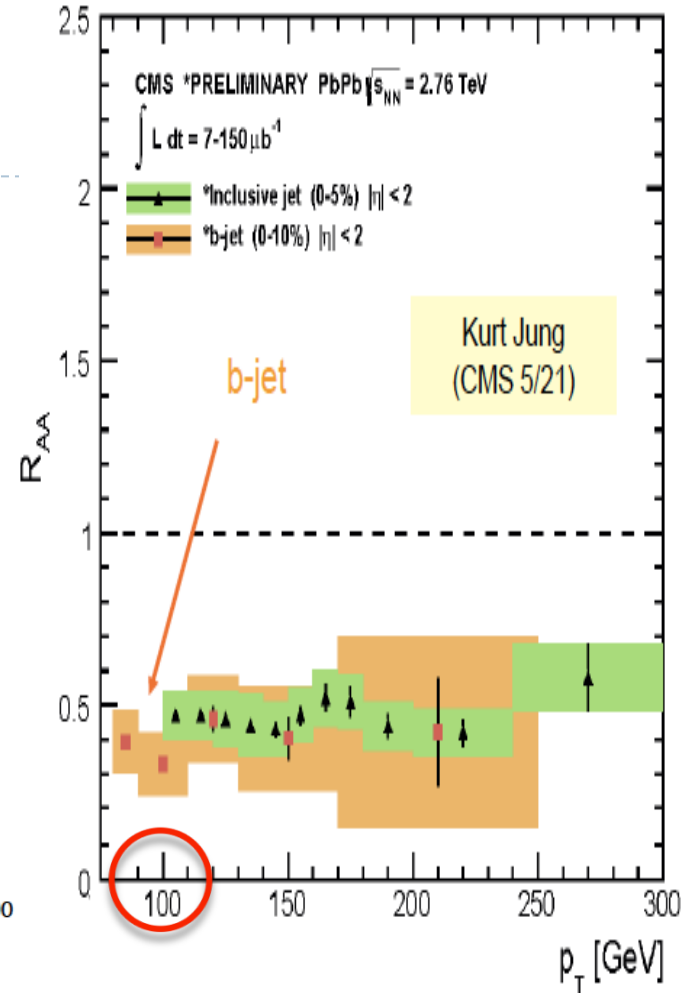
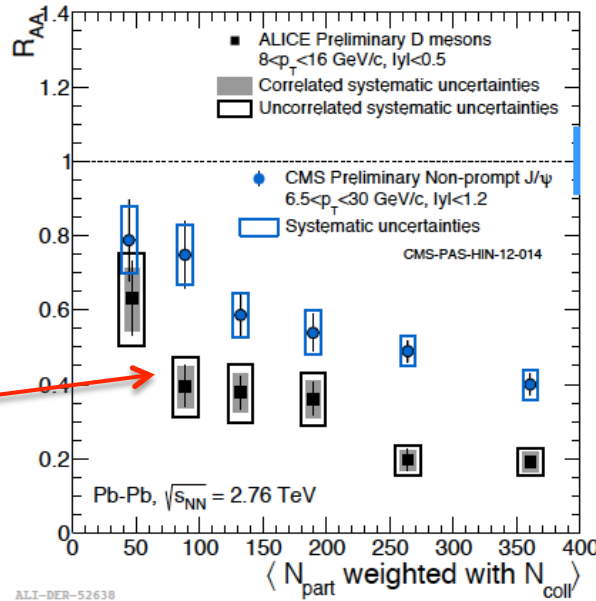
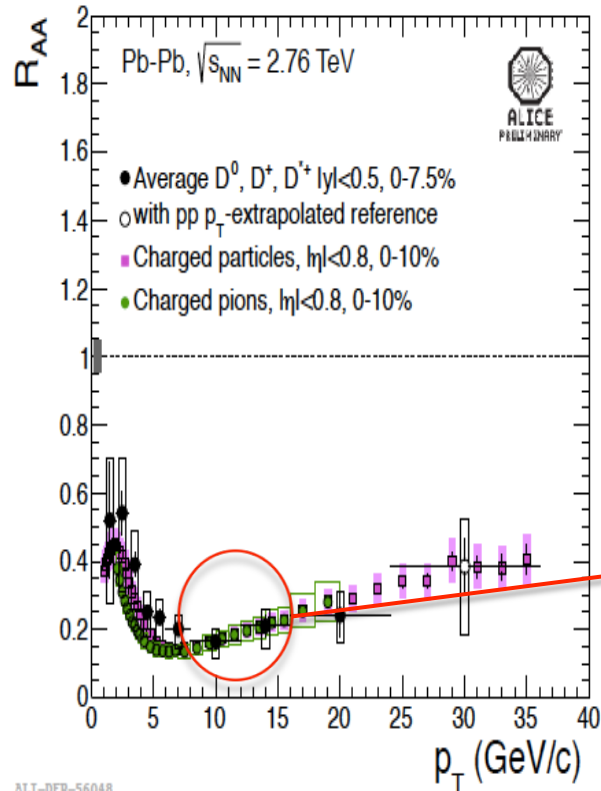
- Strong suppression of jets at $p_T > 30$ GeV/c at 2.76 TeV Pb-Pb
- Jets in 0.2 TeV Au-Au collisions
- observed suppression at low p_T (<30 GeV/c)
 - note: $R = 0.4$
 - ATLAS R_{AA} ($R=0.4$) ~ 0.5 at $p_T > 50$ GeV/c

b jet production in Pb-Pb collisions



- heavy flavour production: mainly initial hard scattering
 - good probe to study the medium
- production is understood by pQCD
 - NLO: Flavor creation, Flavour excitation & Gluon splitting
- Strong suppression of b jet in most central (0-10%) collisions
 - indication of beauty energy loss in Pb-Pb collisions

Flavour dependence ?



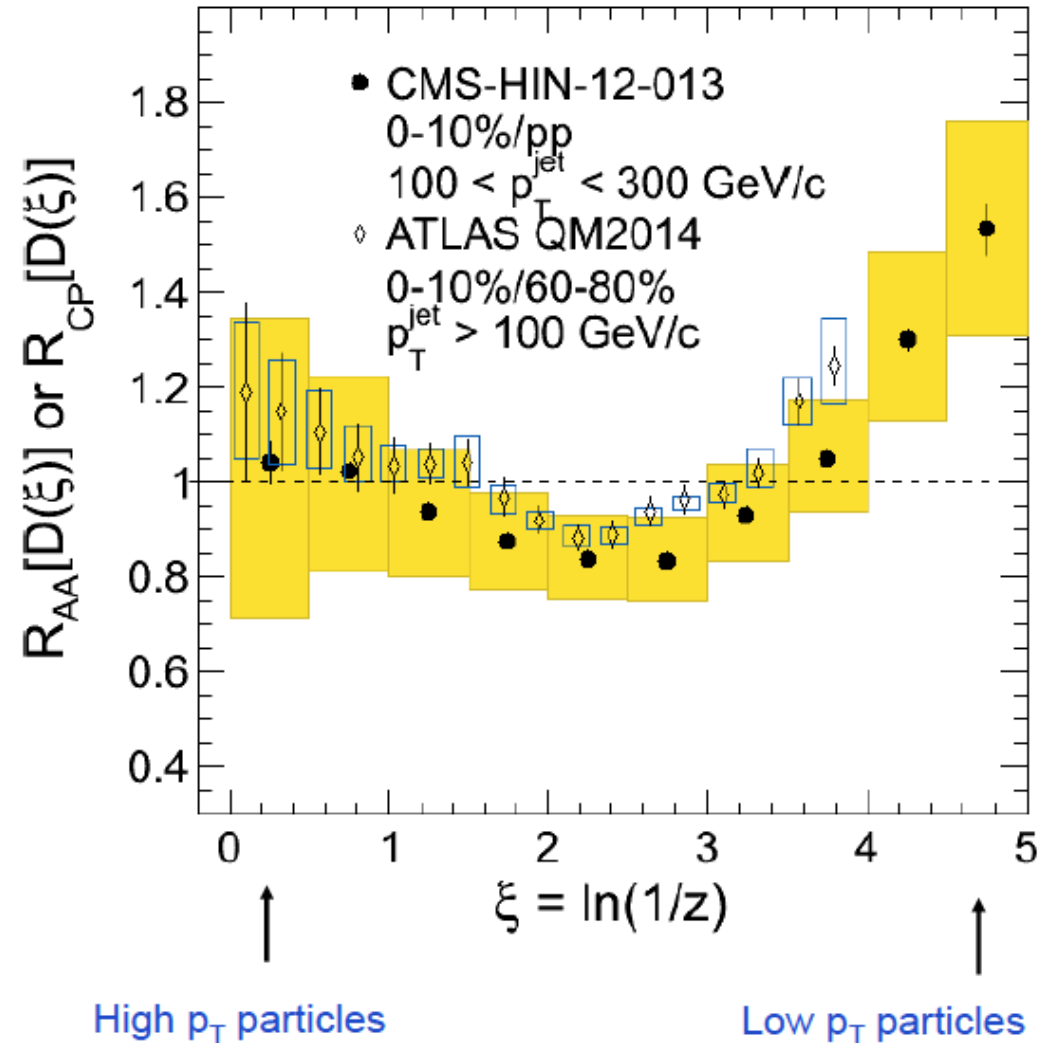
- no mass order of energy loss at high p_T of jets (> 80 GeV/c)
- comparison D meson & non-prompt J/ψ ($p_T \sim 10$ GeV/c) indicates mass dependence of energy loss
- measurement of low p_T heavy-flavour jets is important

Jet Fragmentation at LHC

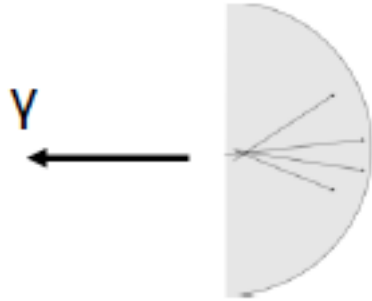
- Fragmentation function of jet ($100 < p_T < 300 \text{ GeV}/c$)

$$Z = p_{T}^{\text{Trk}} / p_{T}^{\text{Jet}}$$

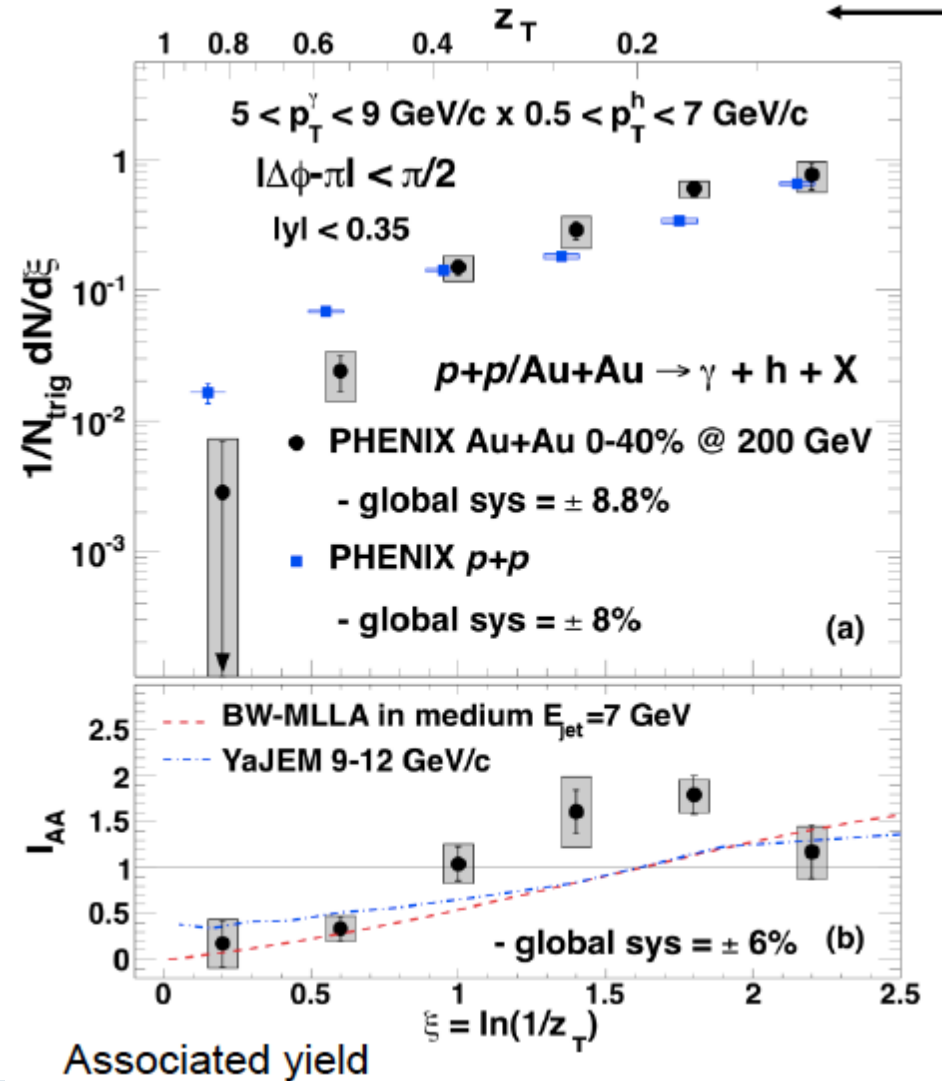
- ratio between central (0-10%) and peripheral (60-80%) / or pp collisions
- low p_T particles are enhanced in central collisions



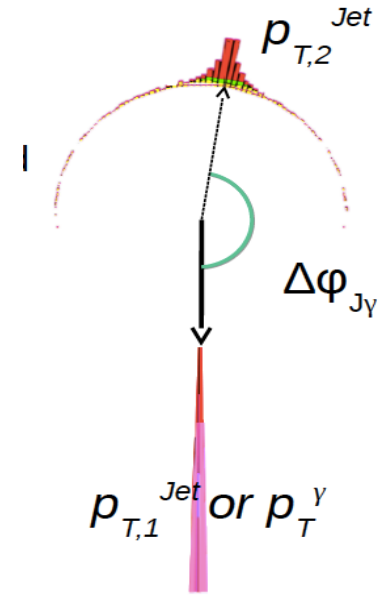
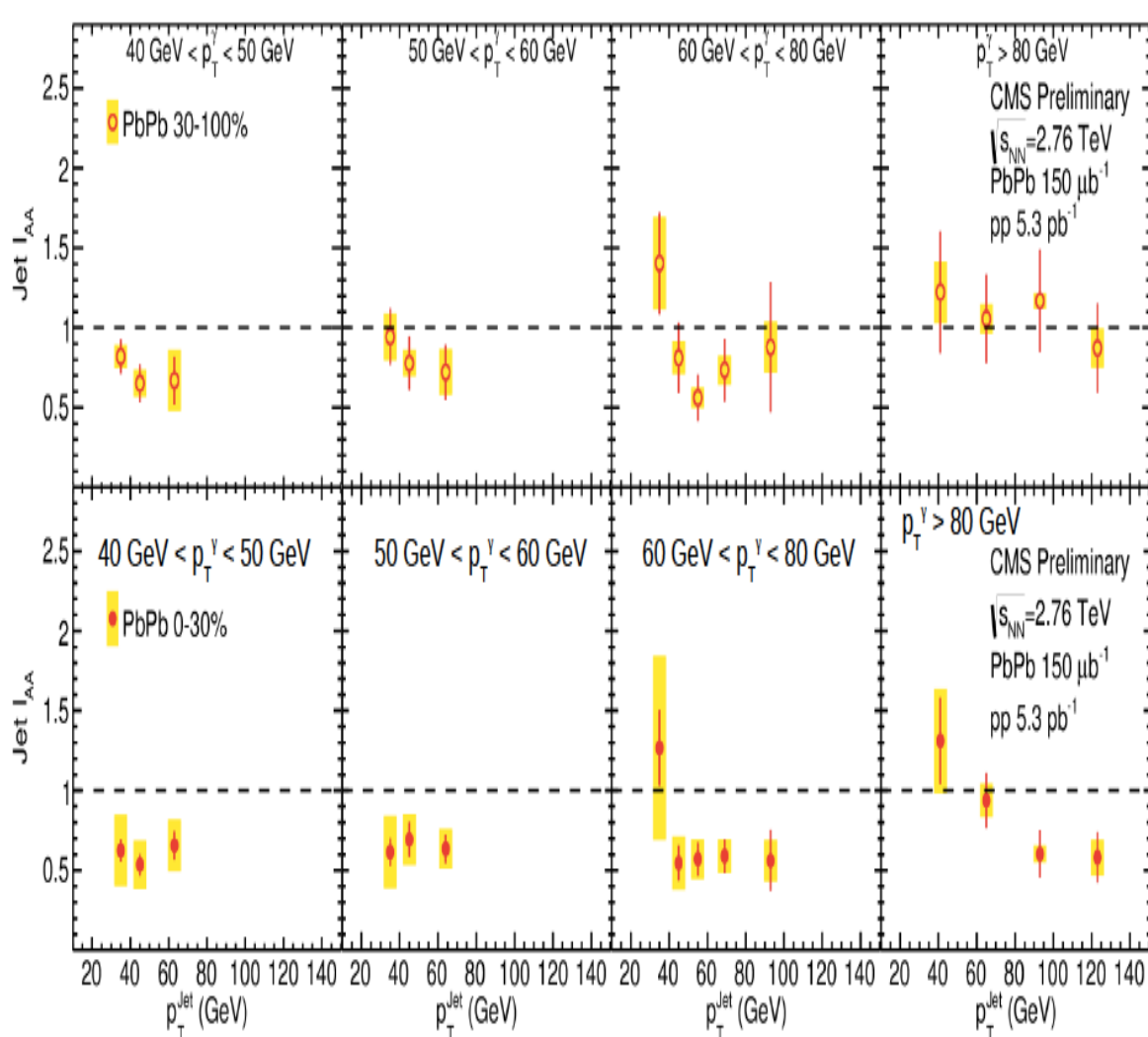
Photon-h correlations in Au-Au



- high p_T associate hadrons (small ξ) are suppressed w.r.t pp
- low p_T associate hadrons (large ξ) are enhanced w.r.t. pp
- lost energy goes to low p_T particle

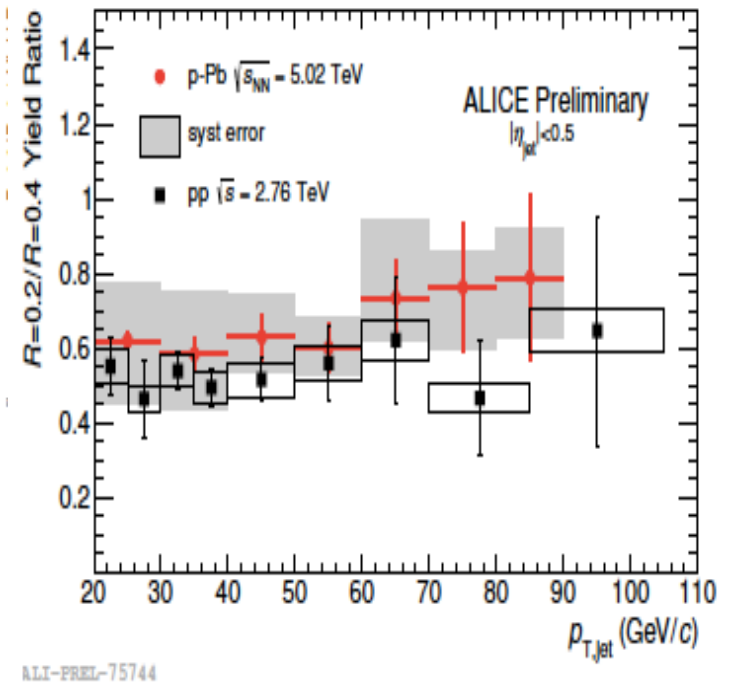
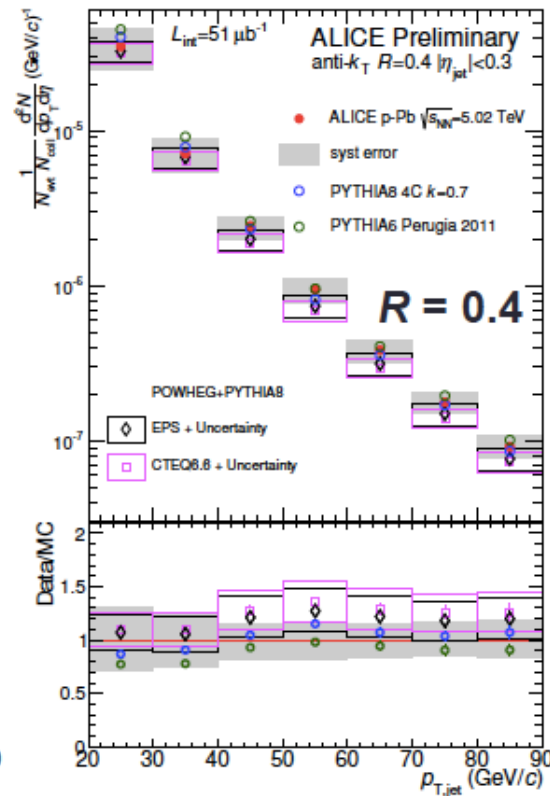
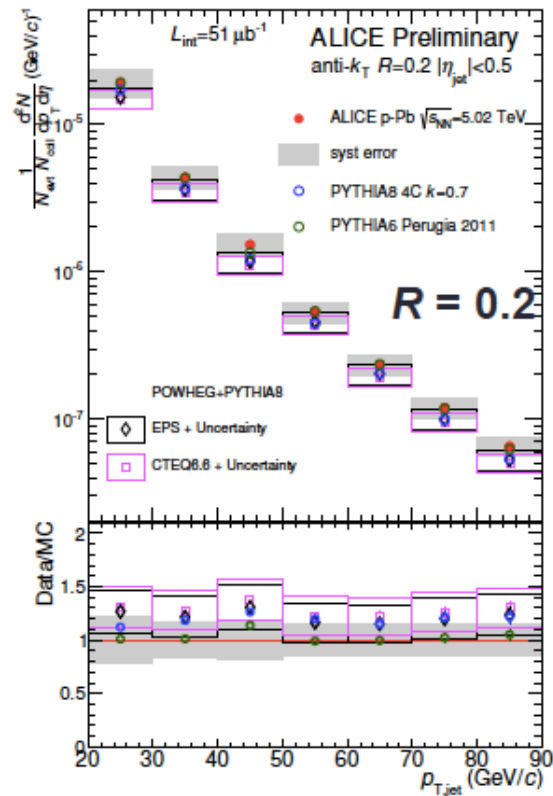


Photon-jet correlations in Pb-Pb



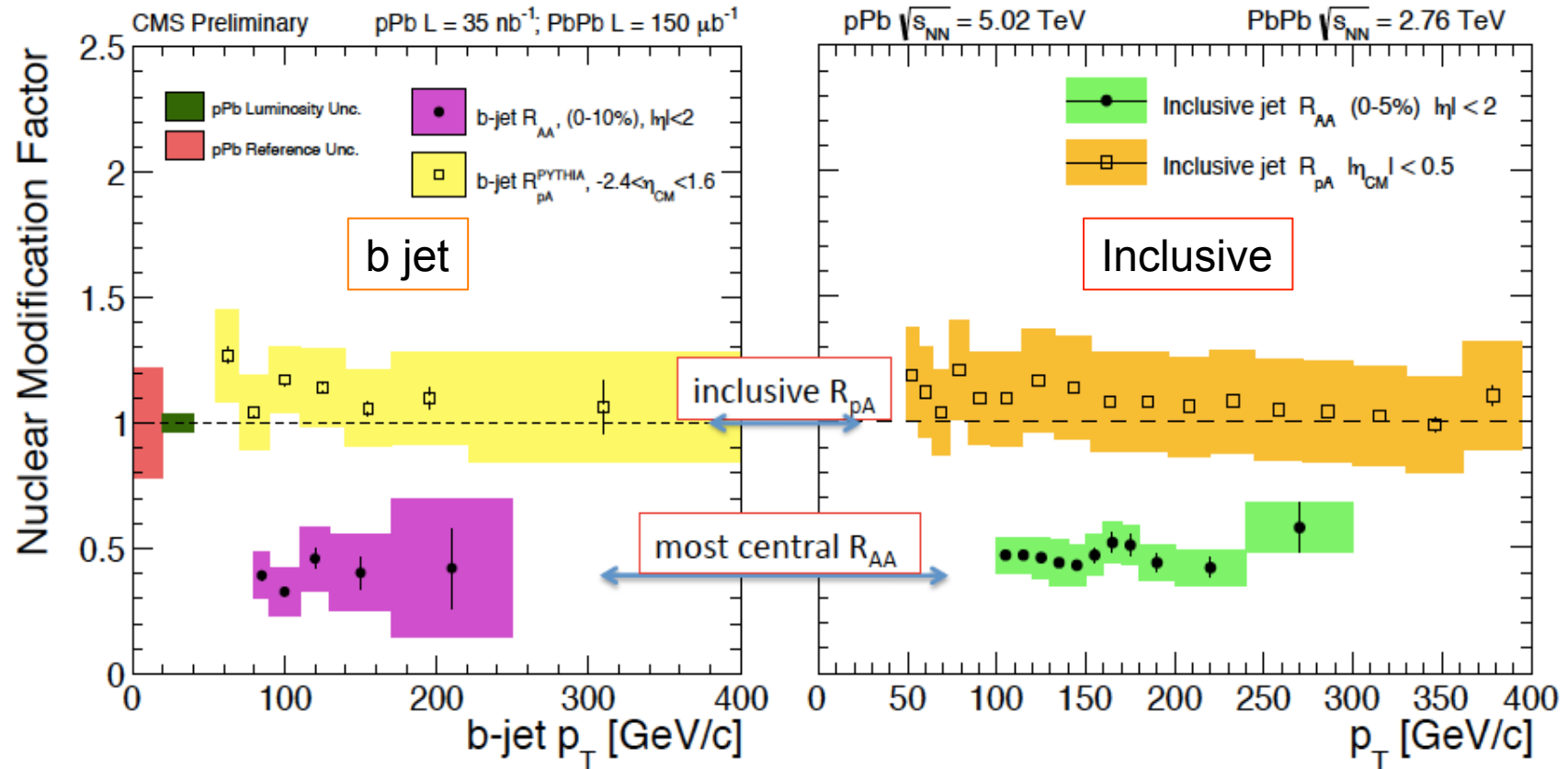
- photon
 - penetrate the matter
 - unbiased trigger
- low p_T jet enhanced especially triggered with high p_T γ

Jet production in p-Pb



- R_{pPb} of Jet is unity ($R = 0.2$ & $R = 0.4$)
 - no Cold Nuclear Matter effects
- No modification of jet shape: $R(0.2)/R(0.4)$ in pp & pPb are consistent

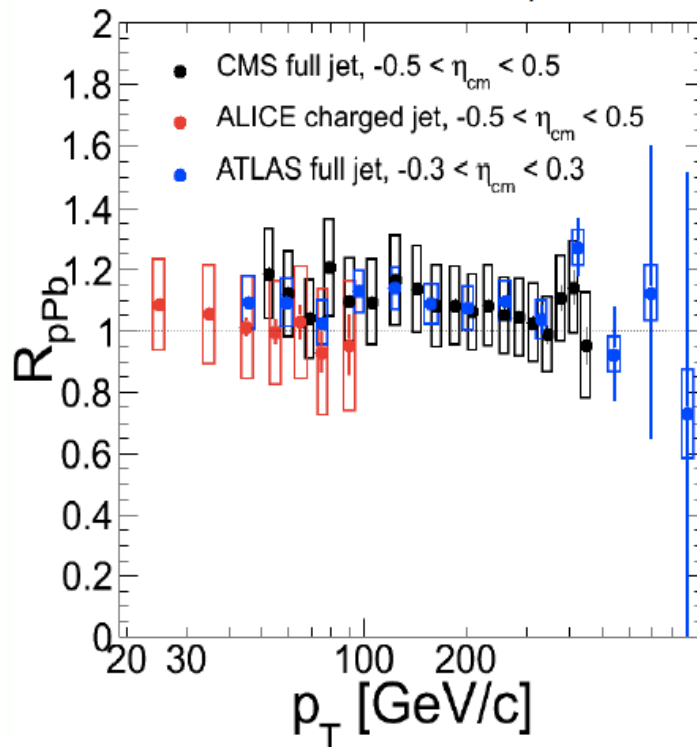
Jet production in p-Pb & Pb-Pb



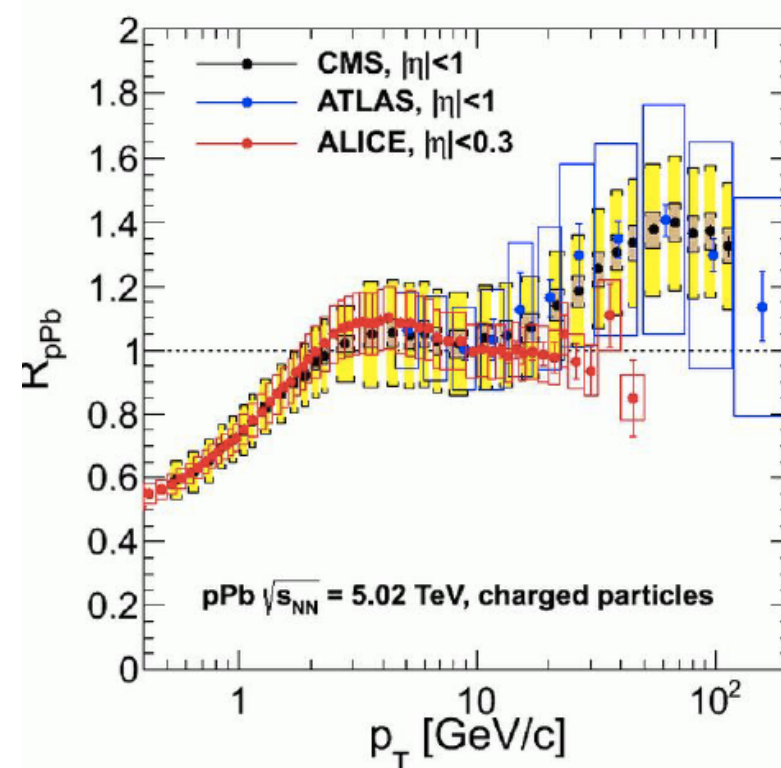
- R_{pPb} of Jet is unity up to 400 GeV/c: inclusive & b jets
- inclusive & b jet R_{AA} strongly suppress up to 250 – 300 GeV/c
 - strong suppression of jets in Pb-Pb is mainly due to final state interaction with medium

Jet production in p-Pb

(Charged) Jet R_{pPb}

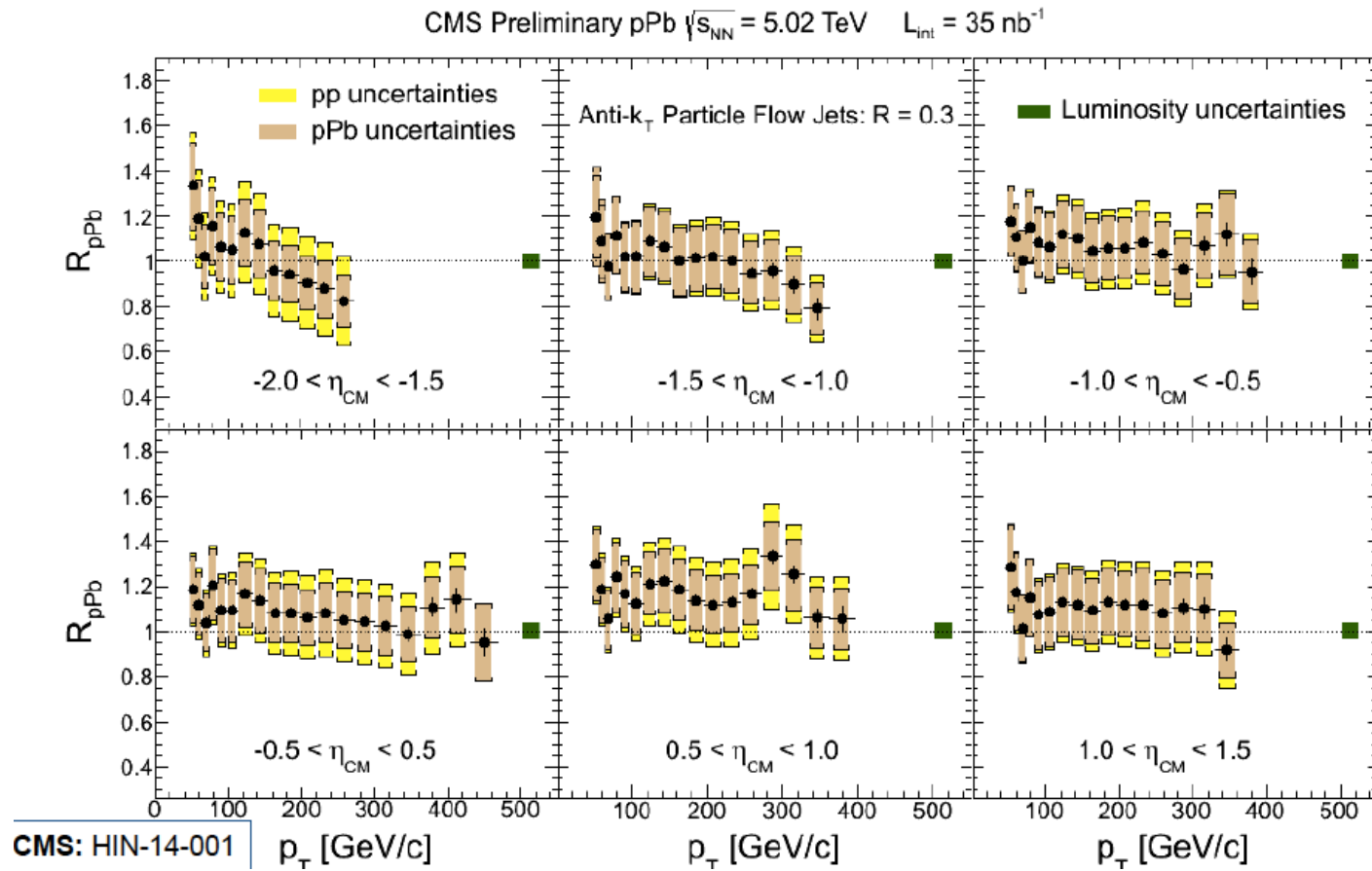


Charged particle R_{pPb}



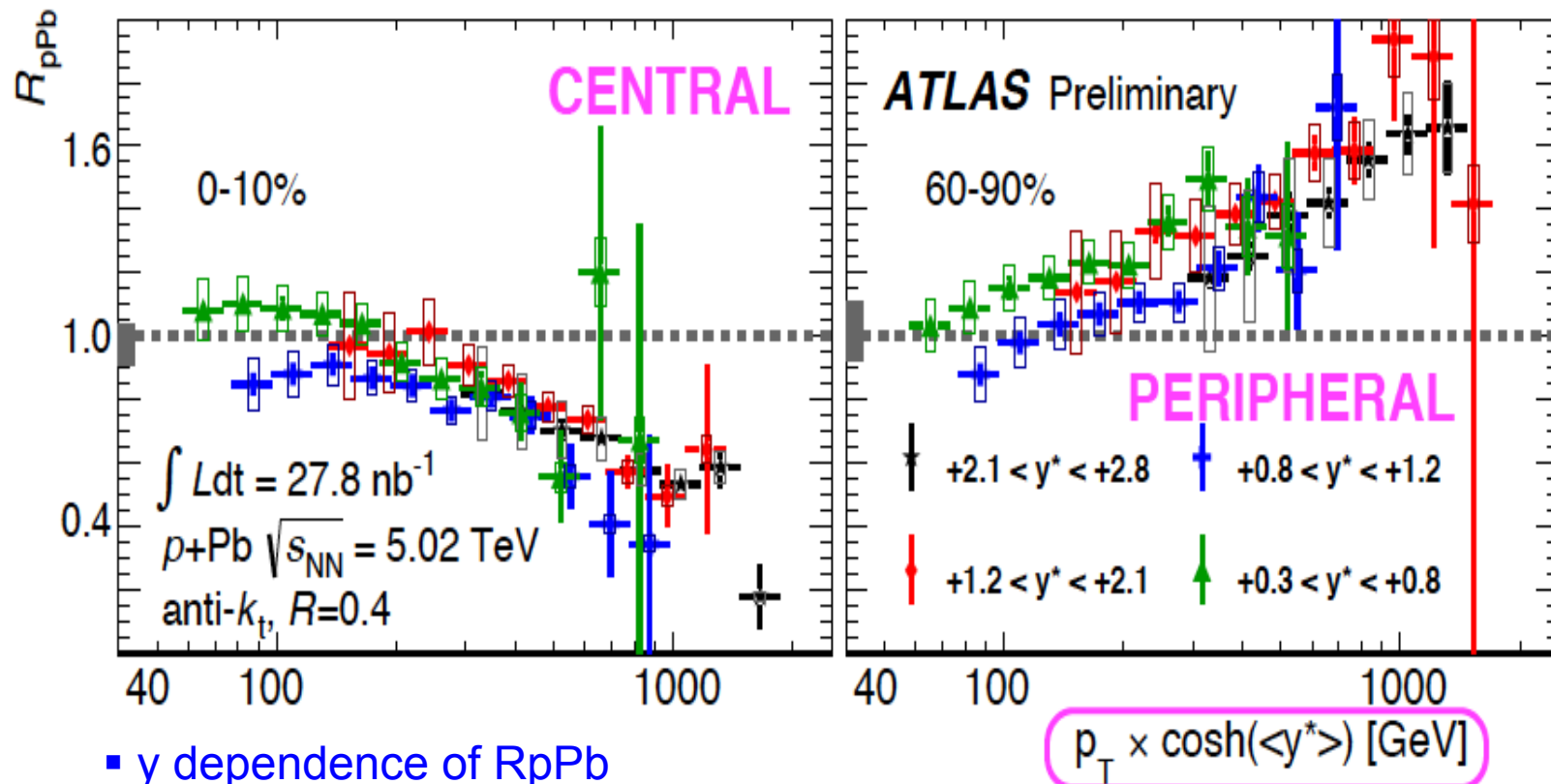
- R_{pPb} of Jet is unity in ALICE, ATLAS & CMS: good agreement
- However, charged particles R_{pPb} show enhancement at high p_T in CMS & ATLAS
 - high p_T charged particle: leading particle of jet => large fraction in jet
 - might be expected similar trend in Jet ?
 - pp references are different in ALICE & ATLAS (QM discussion)

y dependence

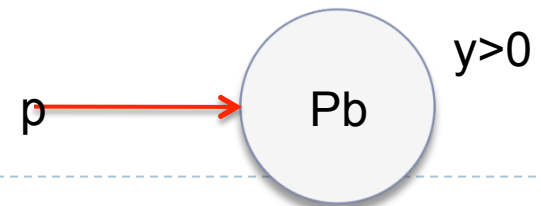


- R_{pPb} is unity in all rapidity range in MB

y dependence in different centrality



- y dependence of R_{pPb}
 - most central: looks like suppression
 - energy loss due to path length ?
 - peripheral: looks like enhancement



Summary

- ▶ **Strong suppression of jet production up to 400 GeV/c**
 - ▶ centrality dependence
 - ▶ Not observed y dependence
 - ▶ Path length dependence
 - ▶ b-jet also strongly suppress: same order of inclusive jet
 - ▶ Low pT particle / jet enhancement observe in FF & away-side
- ▶ **No modification of Jet in p-Pb ($R_{pPb} = 1$)**
 - ▶ No R dependence (R=0.2 vs. R=0.4)
 - ▶ In MB, $R_{pPb} = 1$ in rapidity
 - ▶ Centrality dependence
 - ▶ Most central: suppression at high pT
 - ▶ Peripheral: enhancement at high pT