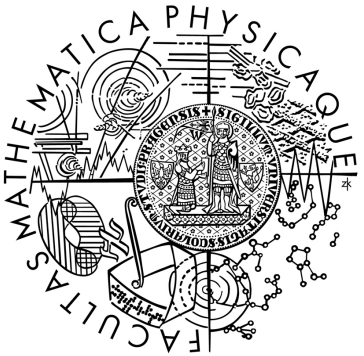
Jet measurements in Pb+Pb and p+Pb with the ATLAS Experiment at the LHC

Petr Balek

for the ATLAS collaboration

29 April 2015

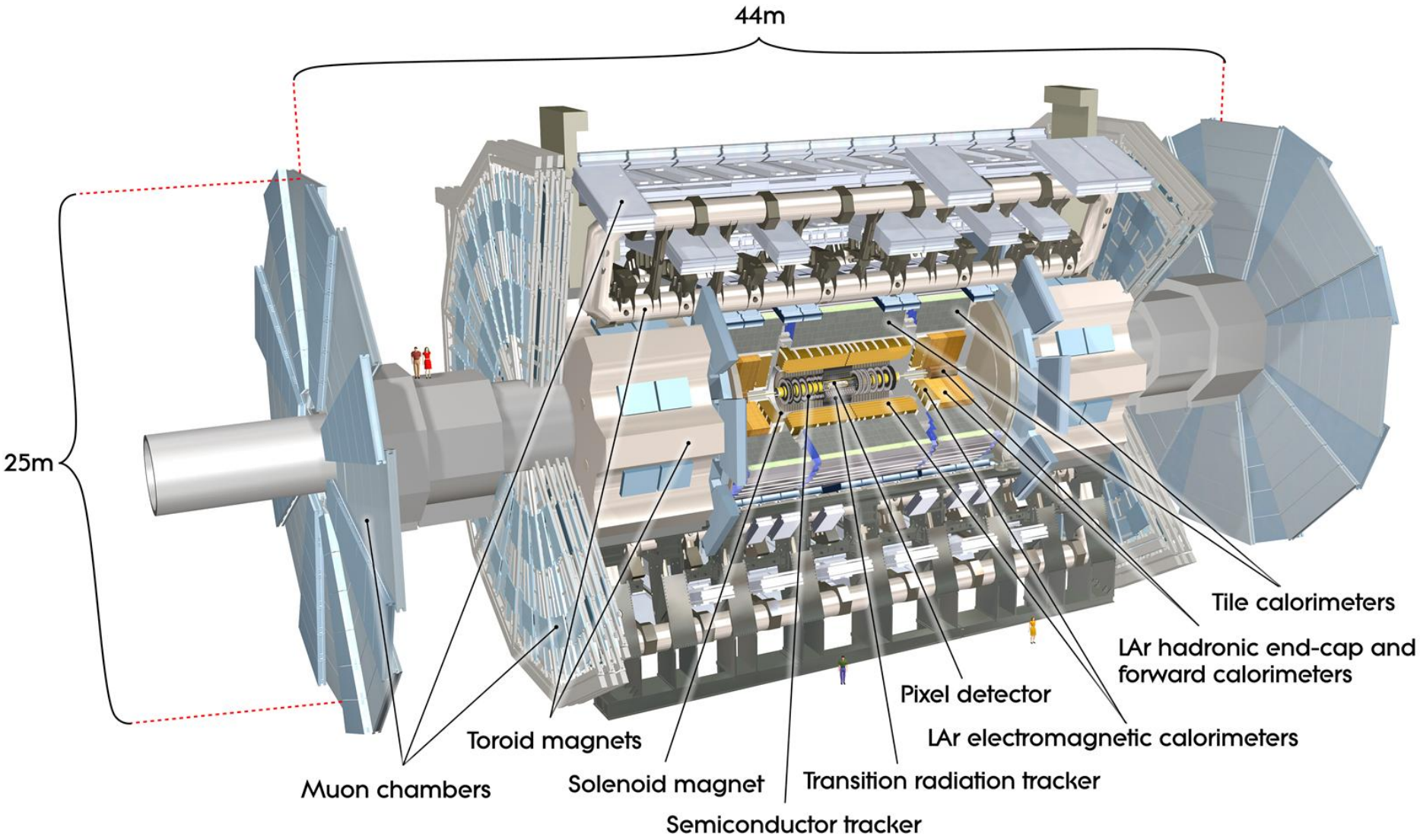


IPNP, Charles University in Prague

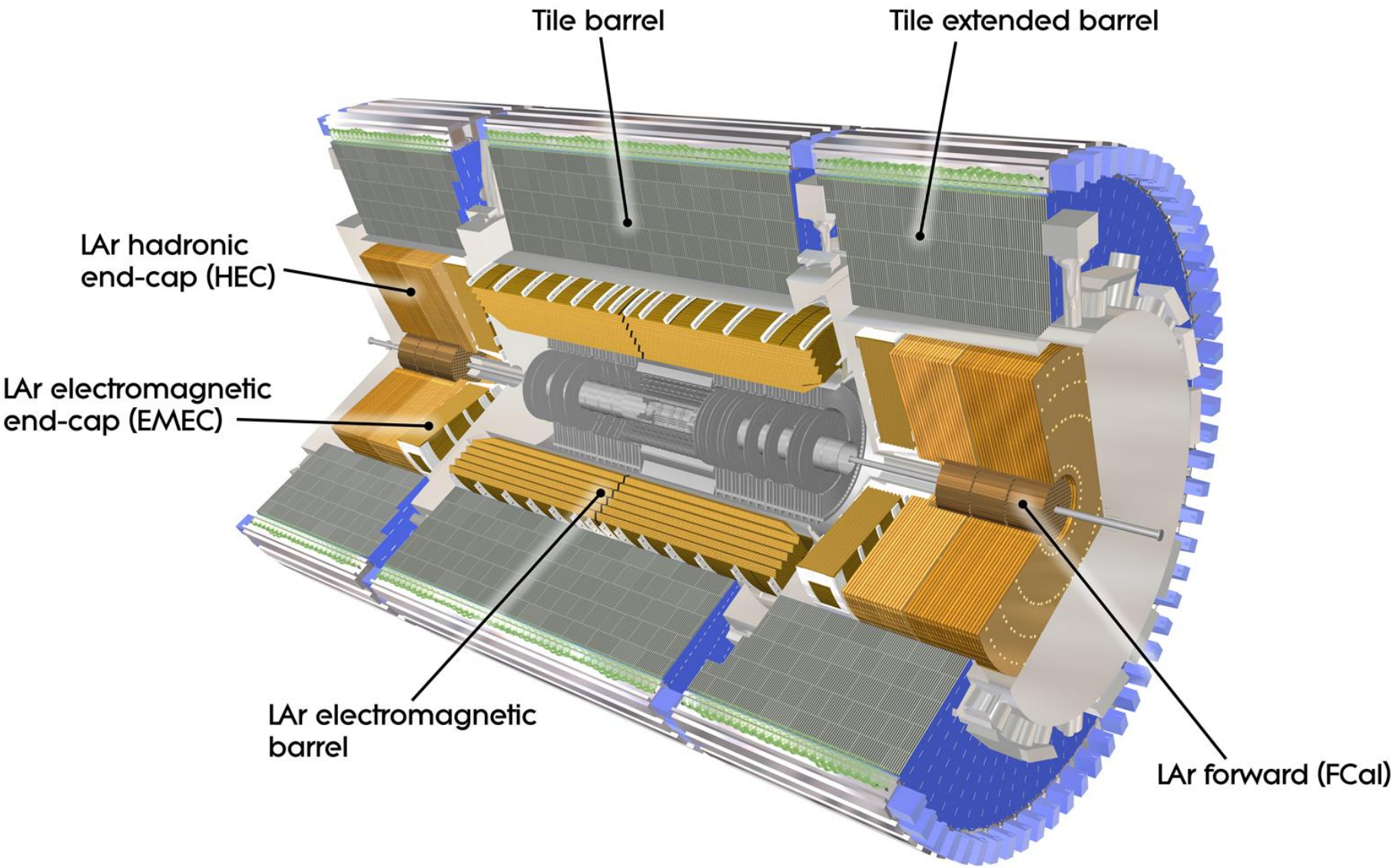
introduction

- apart from the pp collisions, the ATLAS detector has a promising capabilities regarding heavy ion collisions
- the ATLAS detector is well-suited to measure jets, as well as charged tracks, muons, electrons, photons
- we have measurements in three colliding systems (pp, p+Pb, Pb+Pb)
  - not the same center-of-mass energy, thus an interpolation is necessary
- as jets interact with the medium created in HI collisions, they provide insight on structure of it at short-length scale

the ATLAS detector

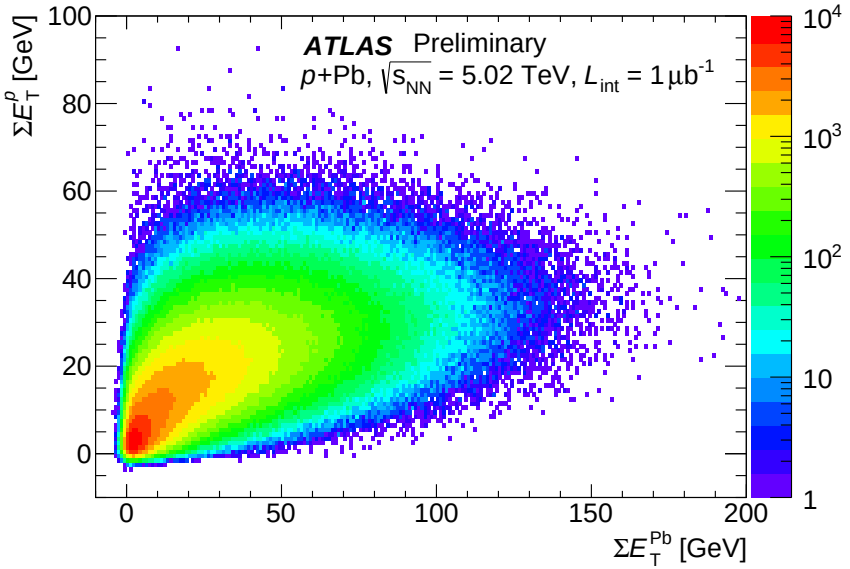


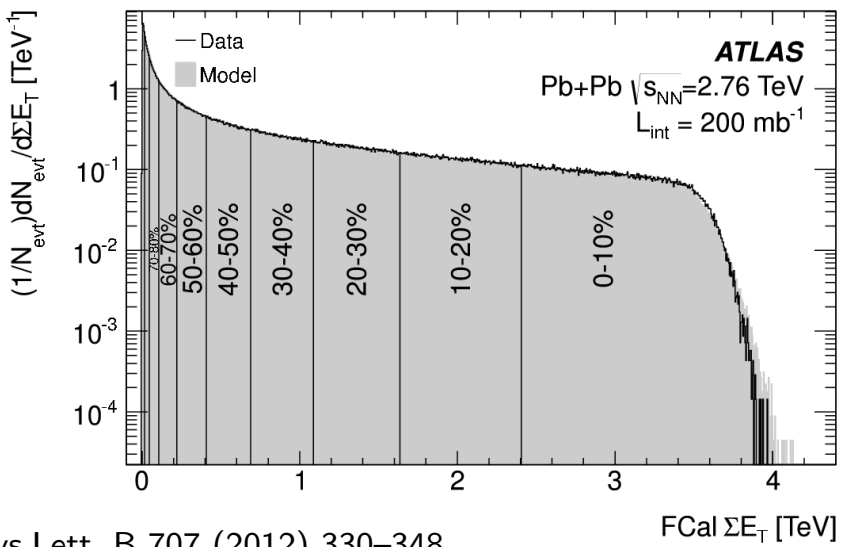
the calorimeters



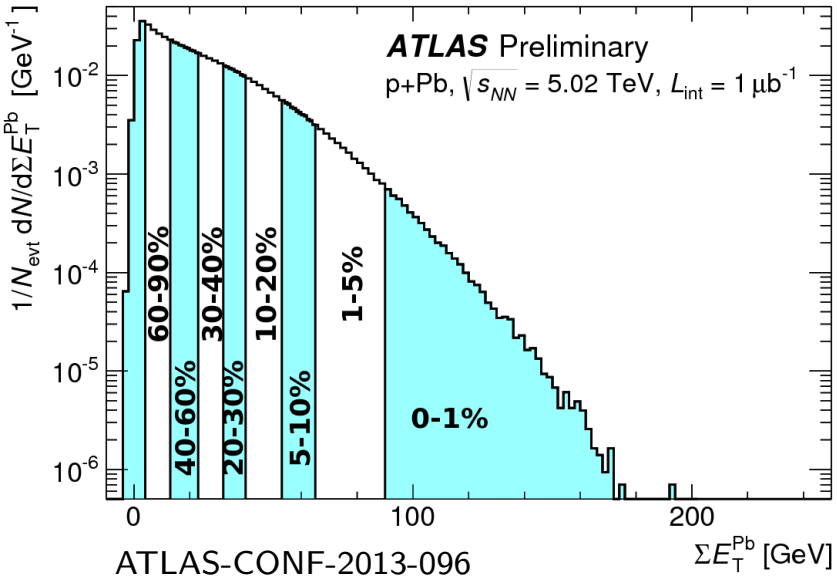
centrality

- centrality based on energy deposited in Forward Calorimeter ($3.1 < |\eta| < 4.9$)
  - in Pb+Pb, in both sides
  - in p+Pb, only in the Pb-going side, as p-going side saturates much faster
- model based on Glauber ($\Omega = 0$)
- nuclear thickness function $\langle T_{\mathrm{AA}} \rangle$ or $\langle T_{\mathrm{pPb}} \rangle = \langle N_{\mathrm{coll}} \rangle / \sigma_{\mathrm{nn}}$





Phys.Lett. B 707 (2012) 330–348

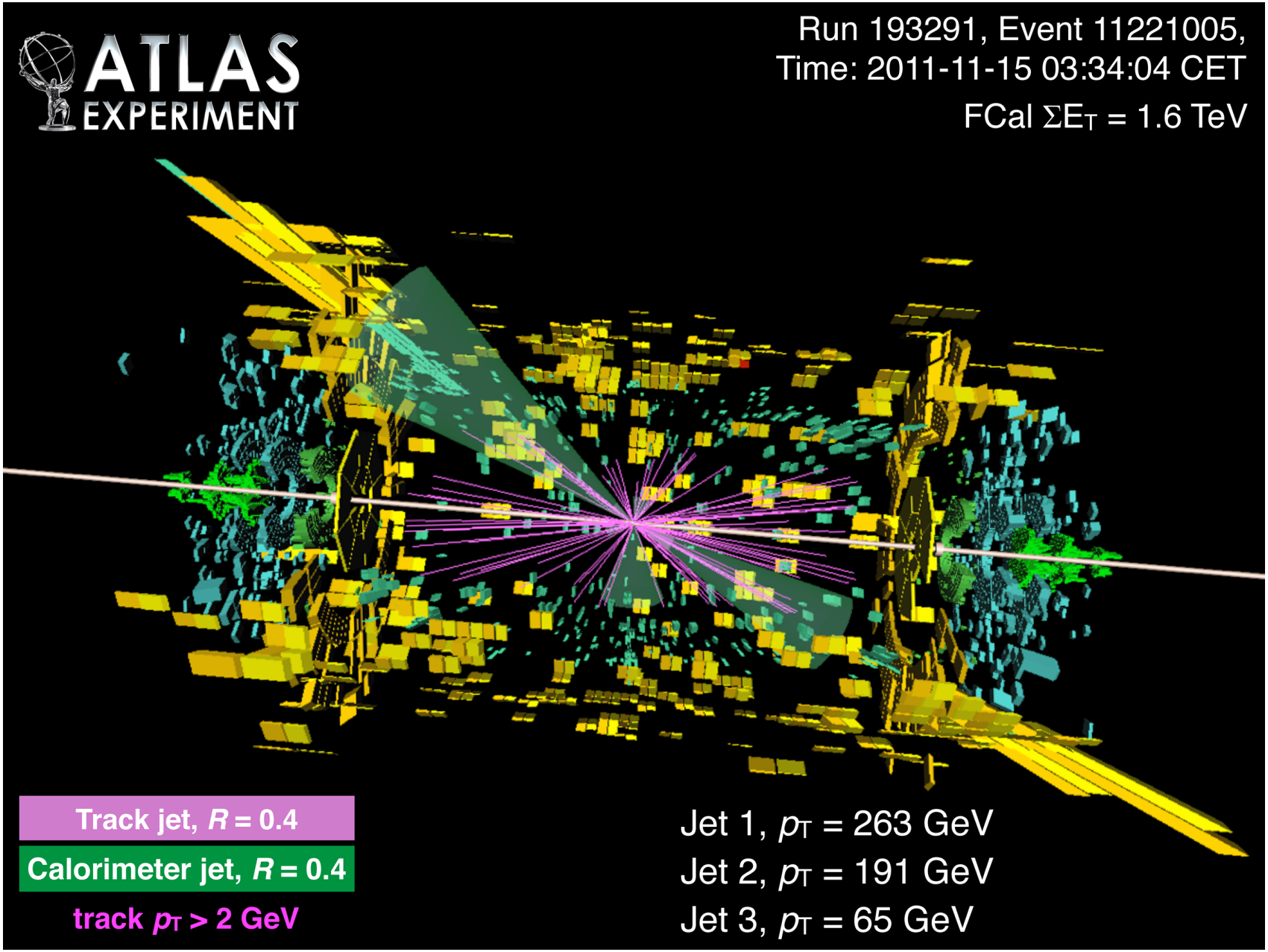


ATLAS-CONF-2013-096

jets

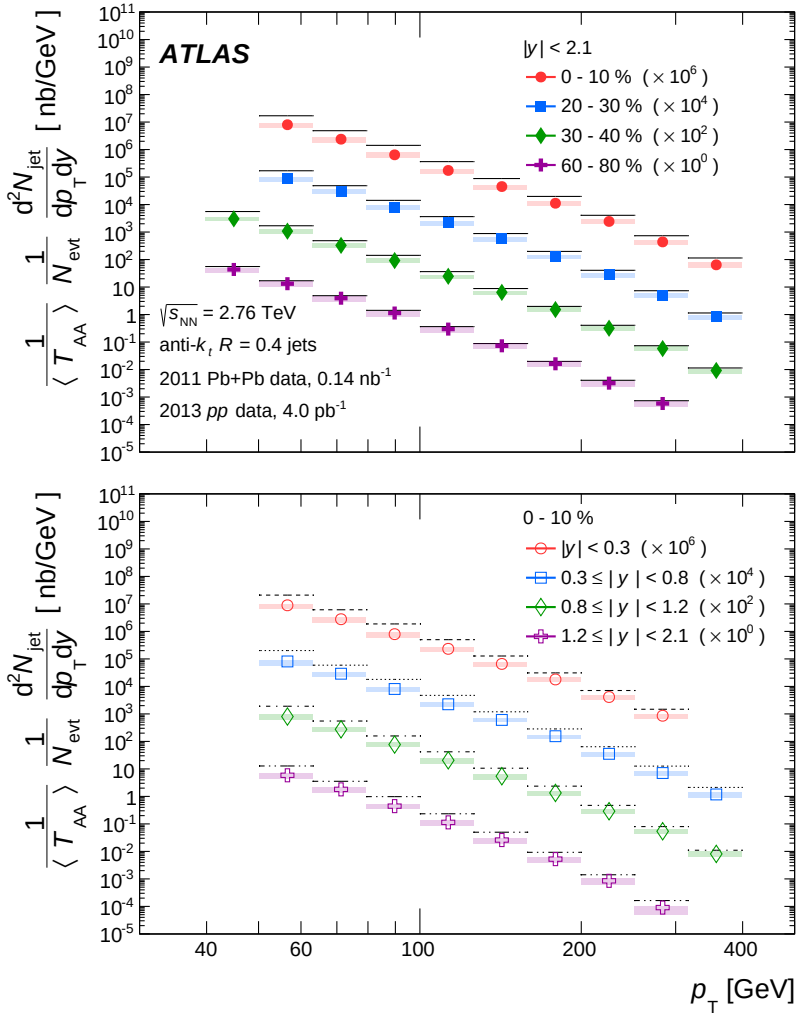
- PbPb @ 2.76 TeV:
  - 2011 Pb+Pb run, 140 μb^{-1}
  - anti-k$_t$ jets with R=0.4, 0.3 and 0.2
  - iterative subtraction of underlying event, correction for flow
- pPb @ 5.02 TeV:
  - 2013 p+Pb run, 28 nb^{-1}
  - anti-k$_t$ jets with R=0.4
  - iterative subtraction of underlying event
  - $y^\star = y - y_{CM}$; $y_{CM} = -0.465$
- pp @ 2.76 TeV:
  - 2013 pp run, 4.0 pb^{-1}
  - anti-k$_t$ jets with R=0.4
  - subtraction of contribution from in-time pile-up

Pb+Pb


ATLAS
EXPERIMENT
Run 193291, Event 11221005,
Time: 2011-11-15 03:34:04 CET
FCal ΣE_T = 1.6 TeV
Track jet, R = 0.4
Calorimeter jet, R = 0.4
track p_T > 2 GeV
Jet 1, p_T = 263 GeV
Jet 2, p_T = 191 GeV
Jet 3, p_T = 65 GeV

jets in Pb+Pb – spectra

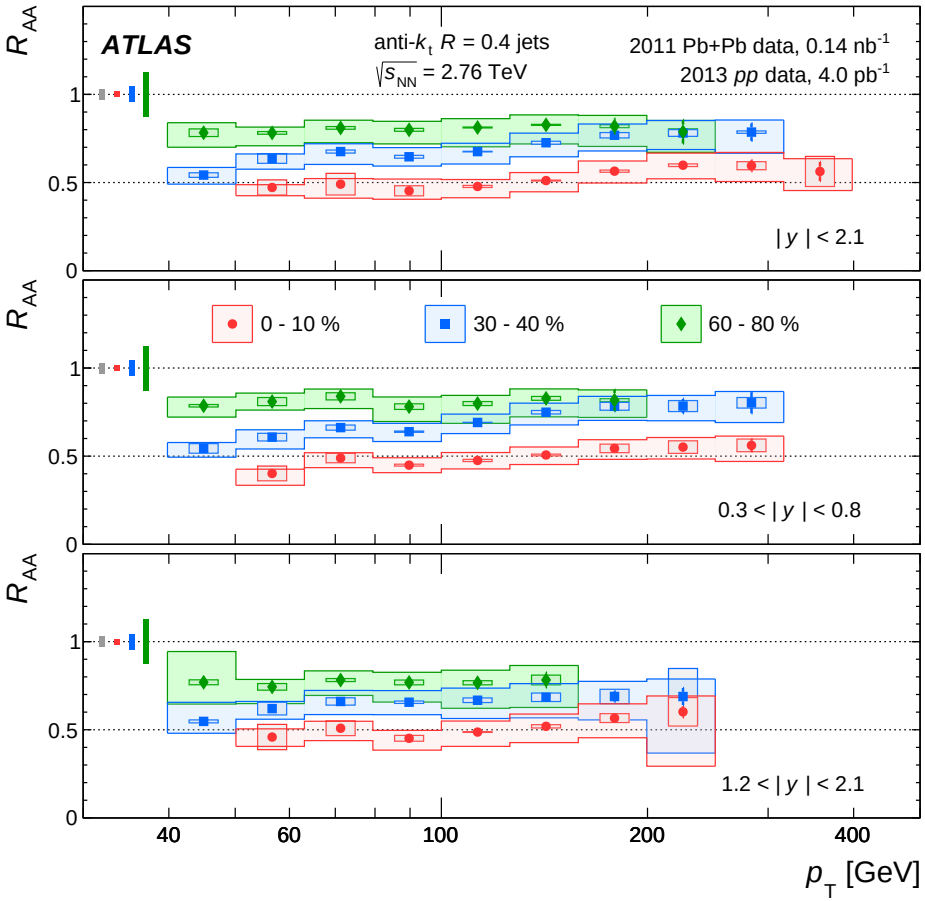
- jets were corrected for jet energy resolution (JER) by SVD (singular value decomposition) unfolding and for jet reconstruction inefficiency
- per-event jet yield scaled by $1/T_{\mathrm{AA}}$
  - HI results **in colors**
  - for different centrality (upper plot)
  - and rapidity (lower plot)
- pp reference with the same $\sqrt{s}$ denoted by **black** line



Phys. Rev. Lett. 114 (2015) 072302

jets in Pb+Pb – R_{AA}

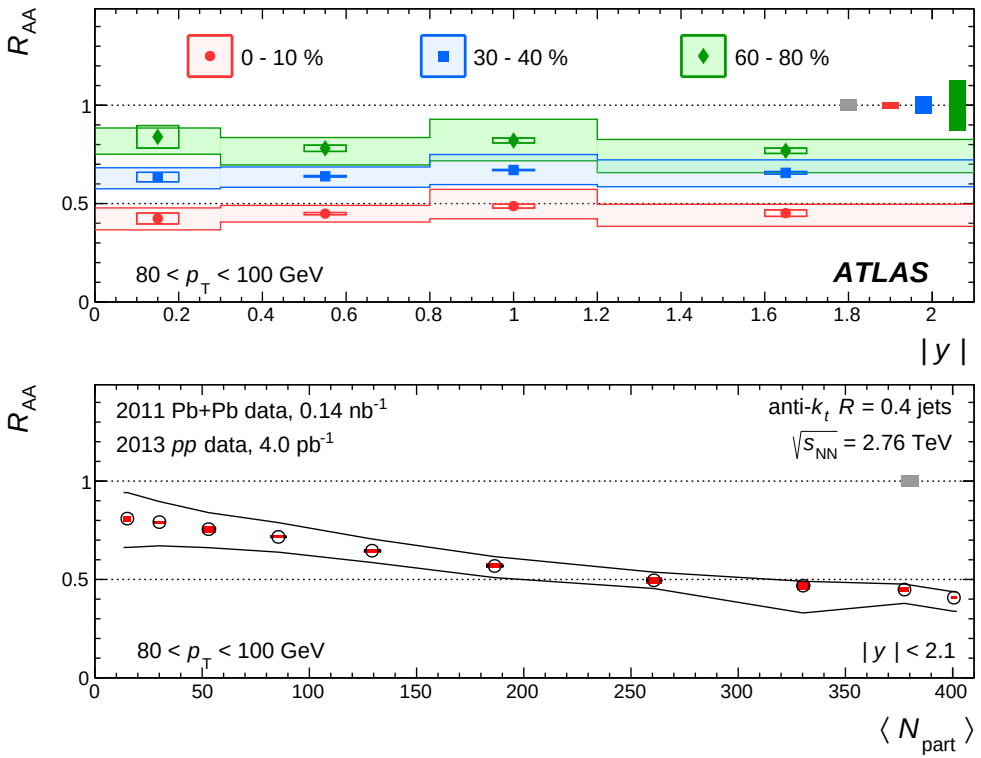
- comparison of HI yields to the pp yield
- $R_{\mathrm{AA}} = \dfrac{\frac{1}{N_{evt}} \frac{1}{\langle T_{\mathrm{AA}} \rangle} \frac{\mathrm{d}^2 N_{jet}}{\mathrm{d}p_{\mathrm{T}} \mathrm{d}y} \Big|_{central}}{\frac{\mathrm{d}^2 \sigma^{pp}_{jet}}{\mathrm{d}p_{\mathrm{T}} \mathrm{d}y}}$
- slight increase in p_{T} for all centralities

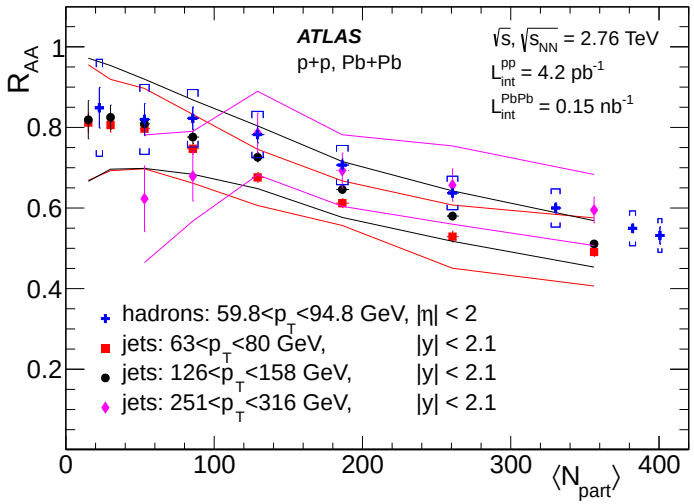


Phys. Rev. Lett. 114 (2015) 072302

jets in Pb+Pb – R_{AA}

- flat in rapidity for all centralities
- R_{AA} is decreasing with increasing centrality
  - similar behaviour also seen in the charge hadron spectra





Phys. Rev. Lett. 114 (2015) 072302

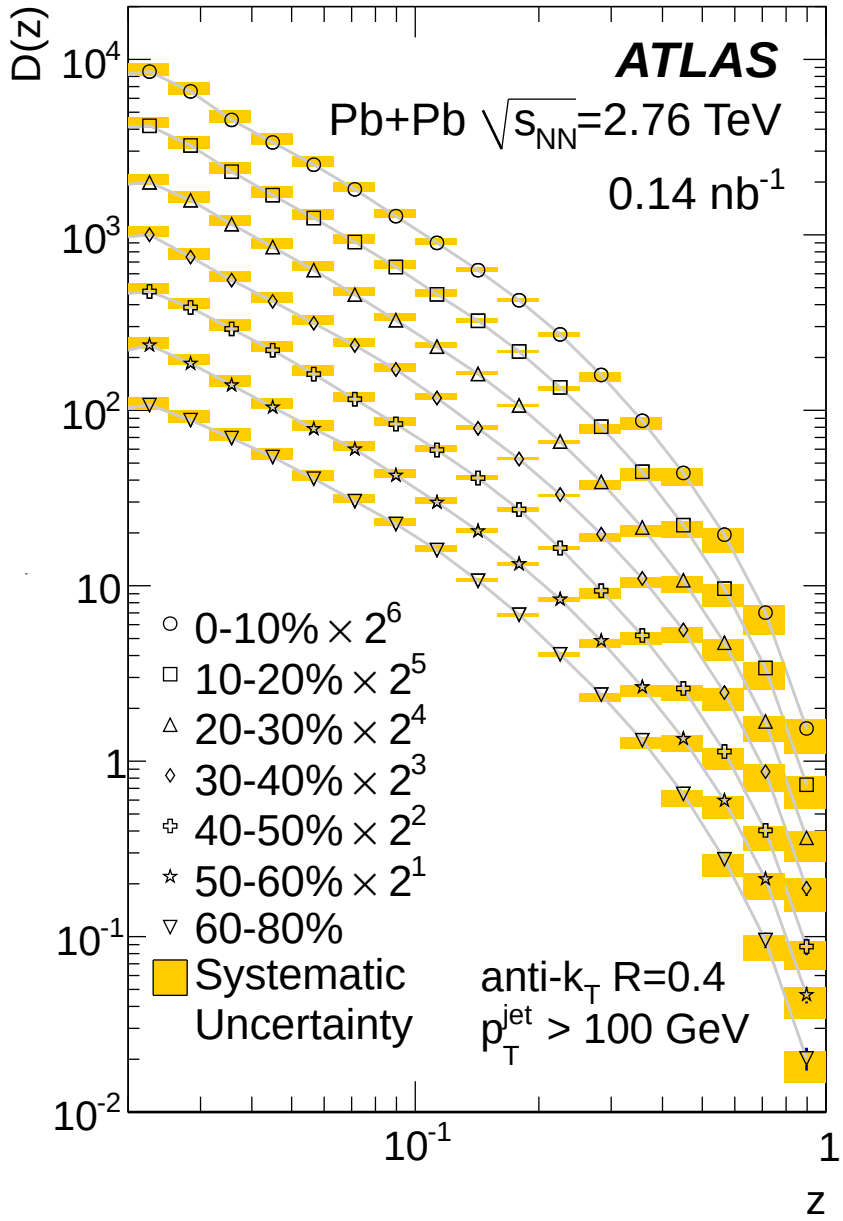
arXiv:1504.04337,
submitted to JHEP

jet fragmentation functions in Pb+Pb

- $z = p_{\mathrm{T,ch}}/p_{\mathrm{T,jet}} \cos \Delta R$
- longitudinal charged particle fragmentation functions D(z):

$$D(z) = \frac{1}{N_{\mathrm{jet}}} \frac{\Delta N_{\mathrm{ch}}(z)}{\Delta z}$$

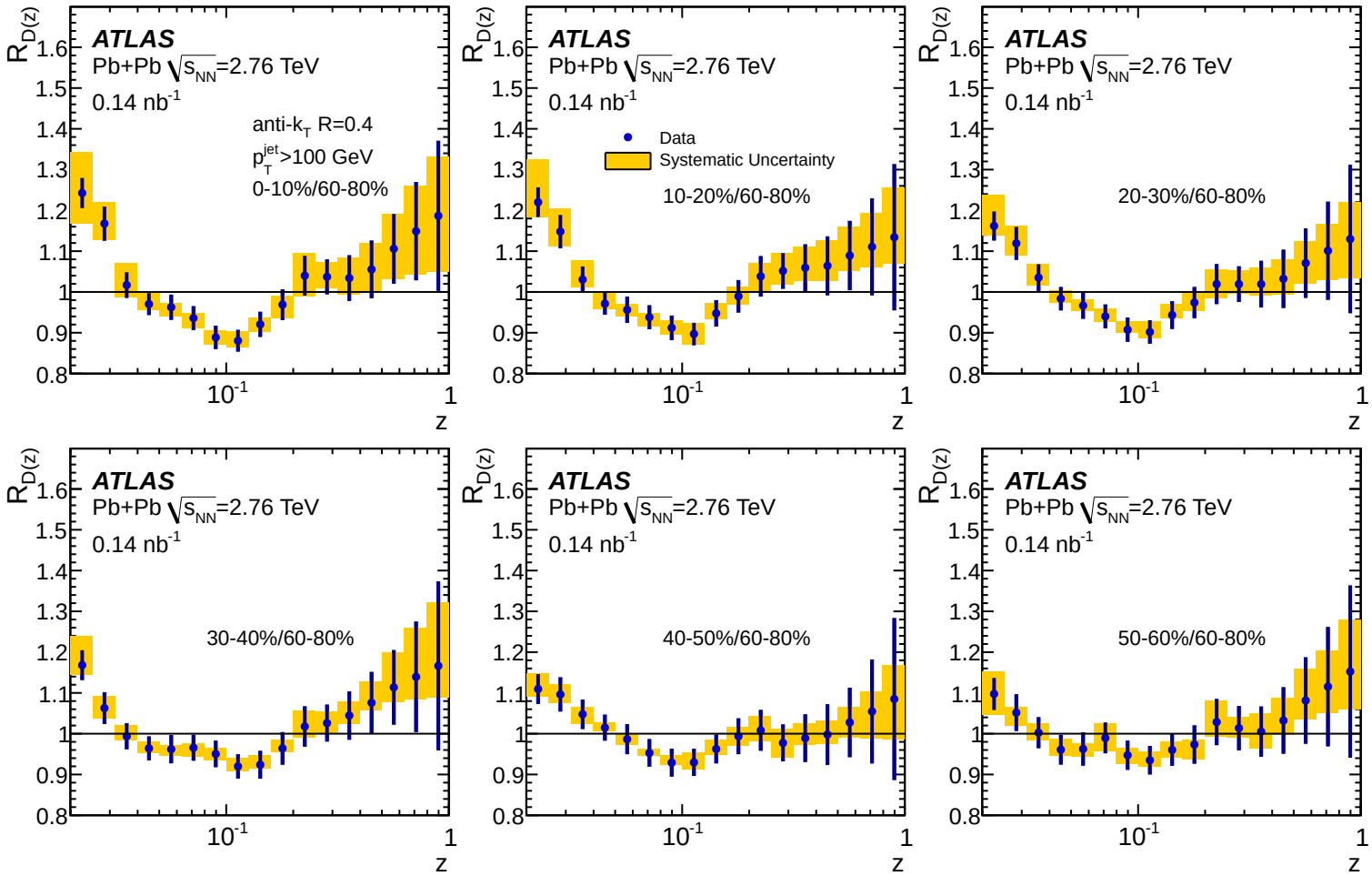
- ΔN_{ch} – number of charged tracks within $\Delta R = 0.4$
- distributions are corrected using SVD unfolding



Phys. Lett. B 739 (2014) 320–342

jet fragmentation functions in Pb+Pb – ratio

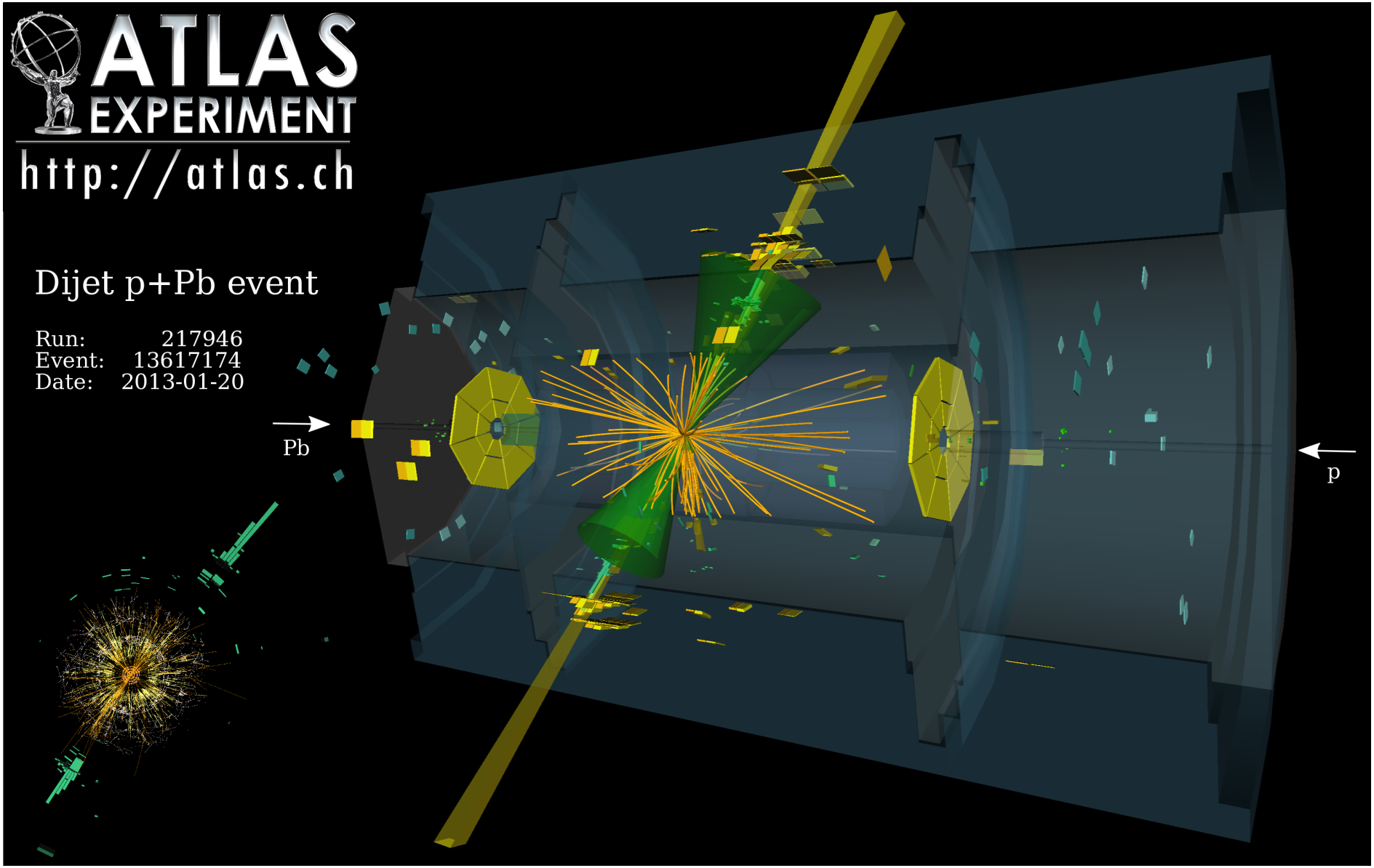
- ratios of $D(z)_{\mathrm{central}}/D(z)_{60-80\%}$



- ∼10% suppression at intermediate z (∼0.1), 25% enhancement at low z (∼0.2) and smaller enhancement at large z

Phys. Lett. B 739 (2014) 320–342

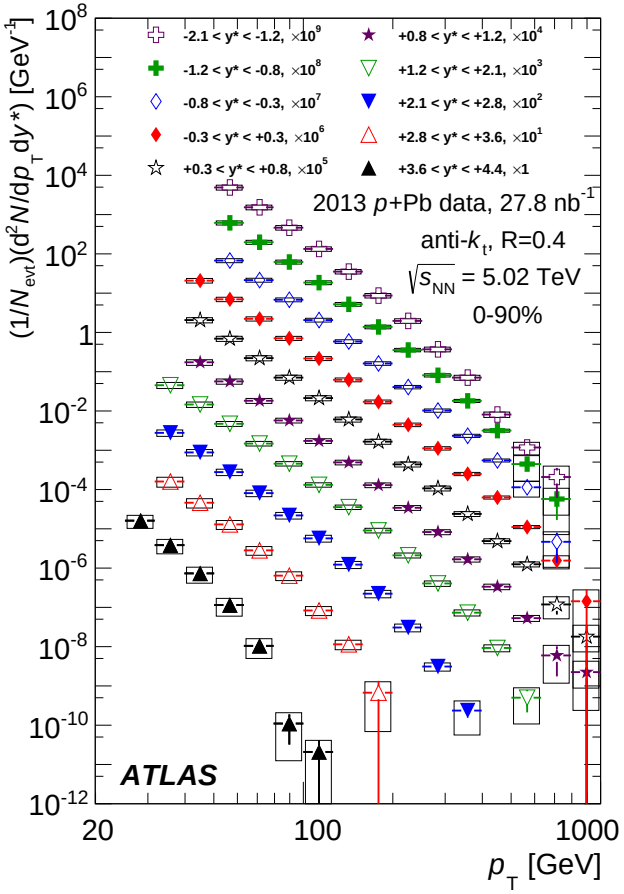
p+Pb

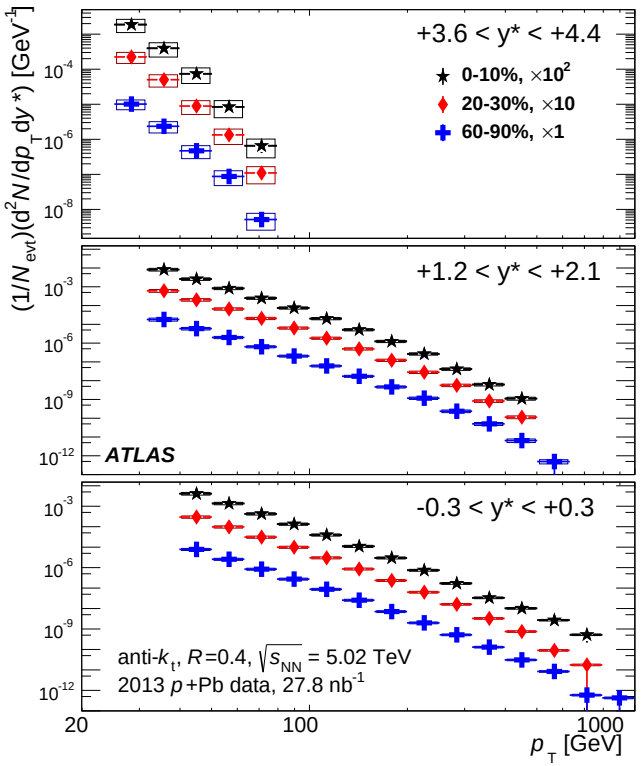


← positive $y^\star$ negative $y^\star$ →

jets in p+Pb – spectra

- jets corrected for JER and for jet reconstruction inefficiency by bin-by-bin unfolding
- pp reference obtained from pp data at $\sqrt{s} = 2.76\,\text{TeV}$ and $7\,\text{TeV}$ by interpolation

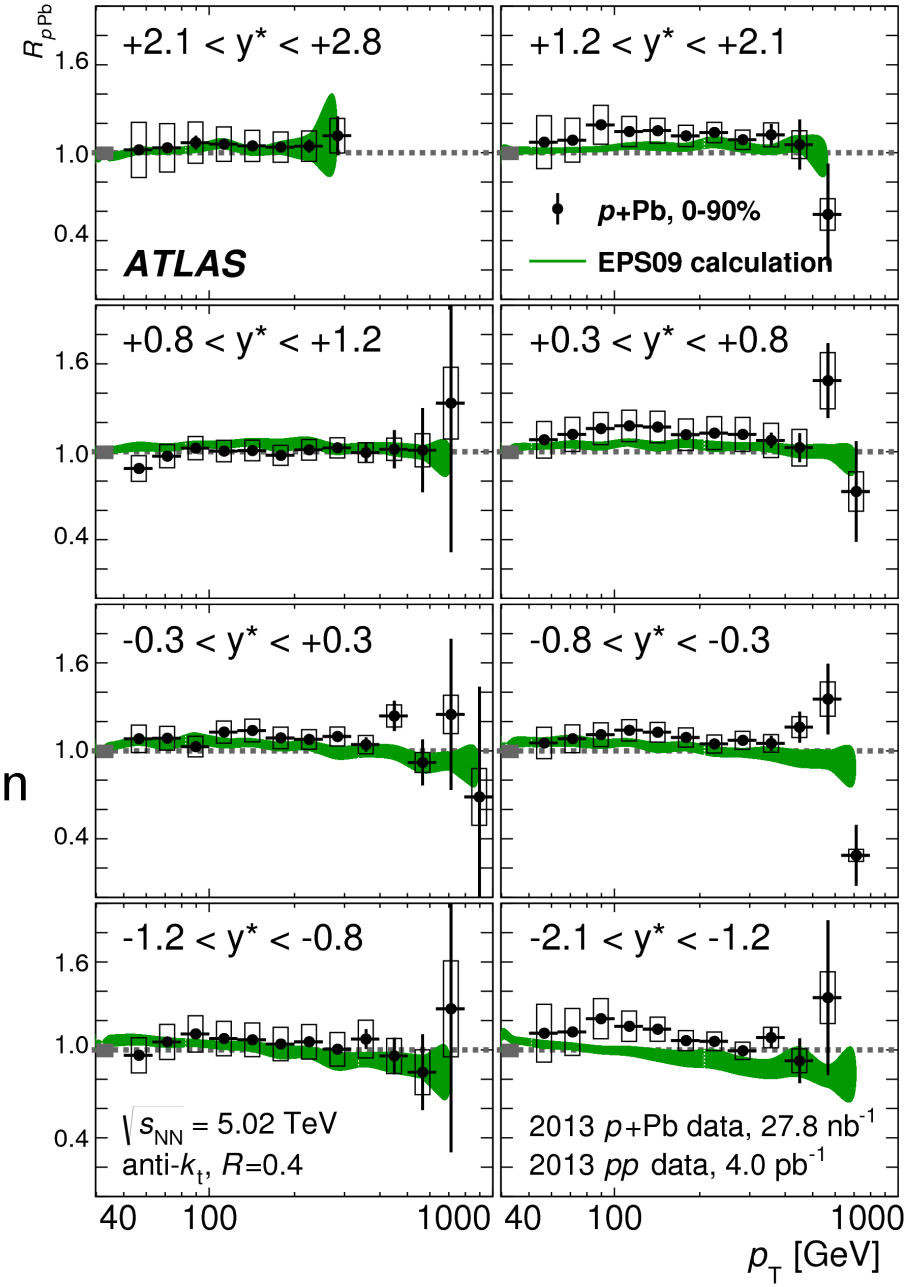




arXiv:1412.4092, submitted to PLB

jets in p+Pb – R_{pPb} in 0–90%

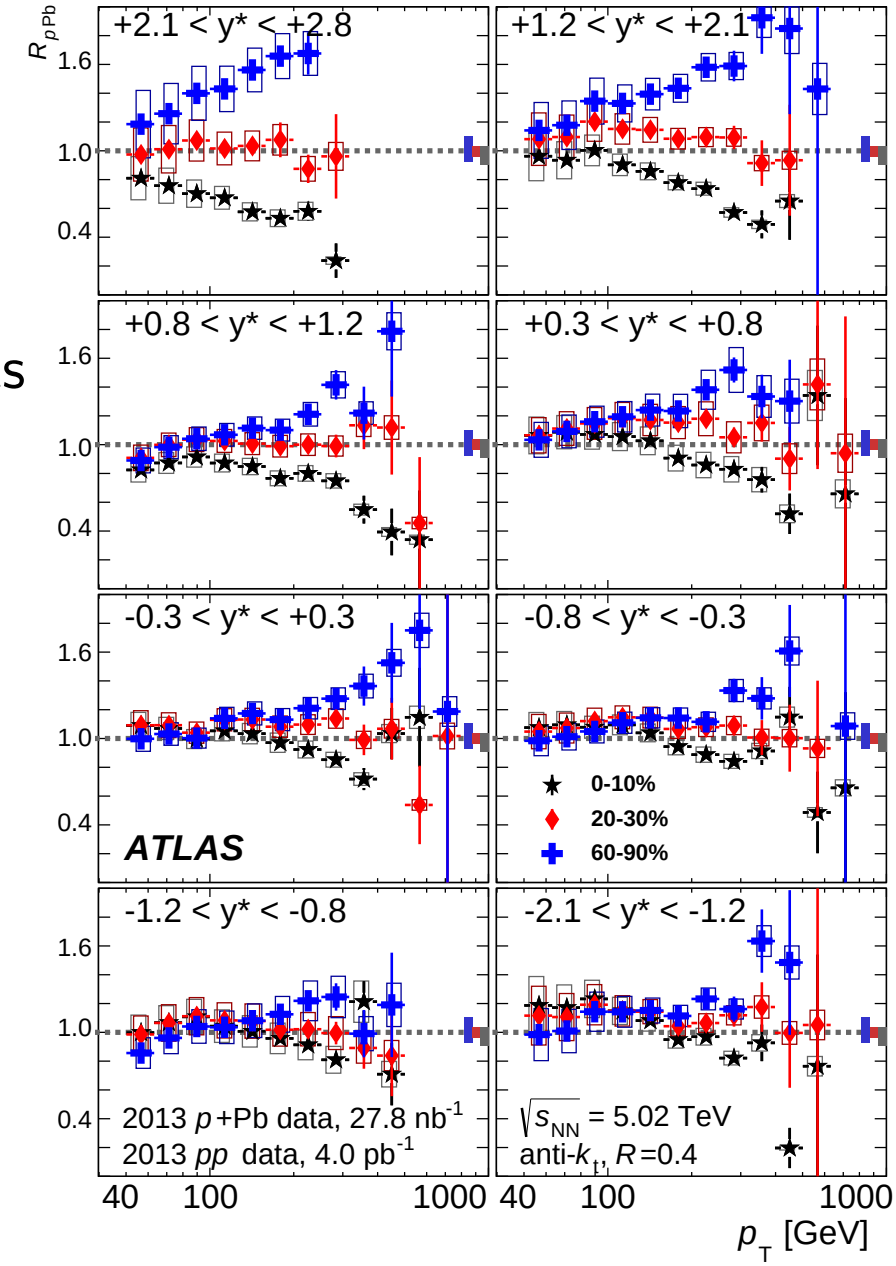
- comparison of HI yields to the pp yield
- $R_{\mathrm{pPb}} = \dfrac{\frac{1}{N_{evt}}\frac{1}{\langle T_{\mathrm{pPb}}\rangle}\frac{\mathrm{d}^2 N_{jet}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^{\star}}}{\frac{\mathrm{d}^2\sigma^{pp}_{jet}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}}$
- R_{pPb} has a weak p_{T} dependence
- consistent with next-to-leading order perturbative QCD calculation



arXiv:1412.4092, submitted to PLB

jets in p+Pb – R_{pPb}

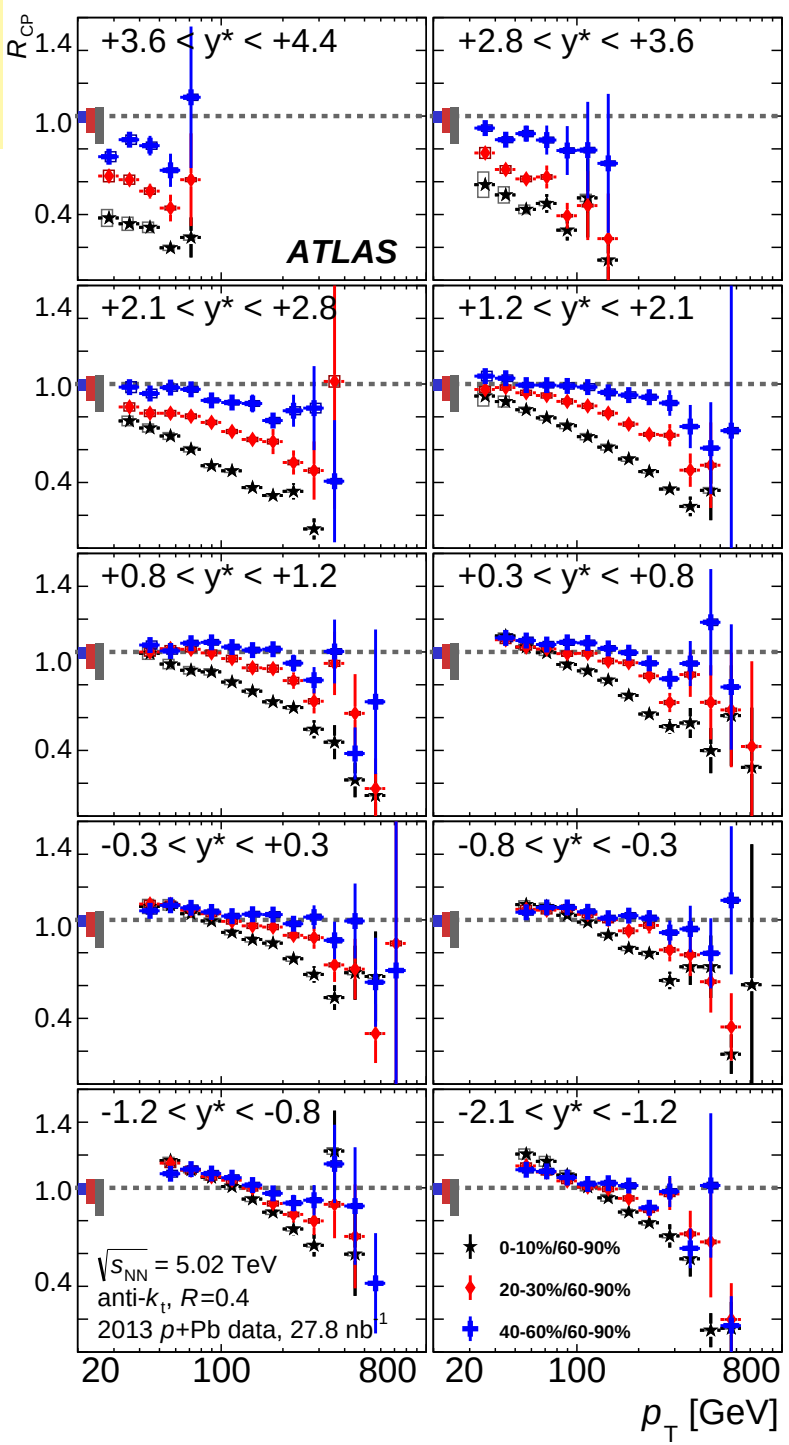
- suppression for **central** events
- near unity for **mid-central** events
- enhancement for **peripheral** events
- possible link between soft and hard processes?
- nevertheless, we have only small enhancement in 0-90% events



arXiv:1412.4092, submitted to PLB

jets in p+Pb – R_{CP}

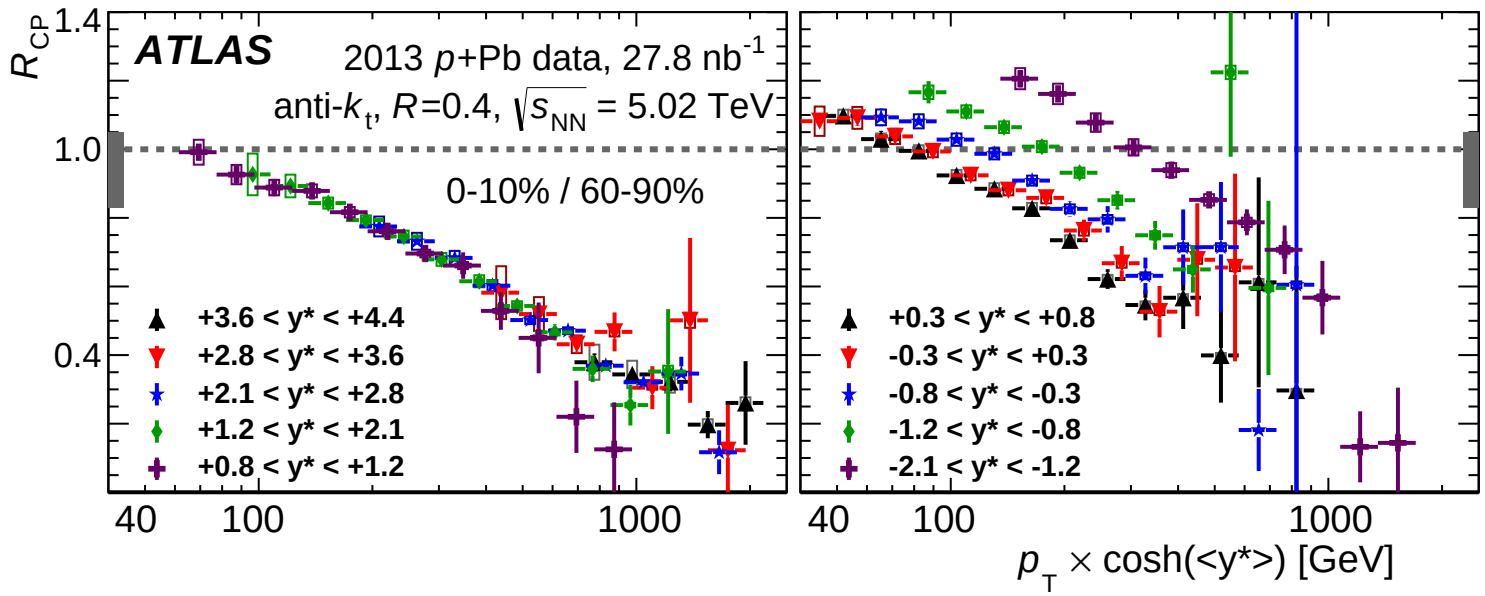
- comparison of HI central yields to the HI peripheral yield
- $$R_{\mathrm{CP}} = \frac{\frac{1}{\langle T_{\mathrm{pPb}} \rangle} \frac{1}{N_{evt}} \frac{\mathrm{d}^2 N_{jet}}{\mathrm{d}p_{\mathrm{T}} \mathrm{d}y^{\star}} \Big|_{central}}{\frac{1}{\langle T_{\mathrm{pPb}} \rangle} \frac{1}{N_{evt}} \frac{\mathrm{d}^2 N_{jet}}{\mathrm{d}p_{\mathrm{T}} \mathrm{d}y^{\star}} \Big|_{peripheral}}$$
- more suppression of **central** events; for negative rapidities, the difference between **central** and **mid-central** events diminishes
- at fixed p_{T}, R_{CP} is decreasing with more positive rapidities



arXiv:1412.4092, submitted to PLB

jets in p+Pb – R_{CP}

- $p_{\mathrm{T}} \times \cos(\langle y^{\star} \rangle) = p$ is total momentum of the jet
- for proton-going rapidities, R_{CP} follow the same pattern
  - the same is observed in other centralities, although with different slopes
  - dependence on initial parton kinematics?
    - ★ for proton-going rapidities, the jet production is dominated by a high-x parton in the proton?
    - ★ for lead-going rapidities, partons from both lead and proton are involved?
- for lead-going rapidities, R_{CP} increase



conclusion

- ATLAS has capabilities to measure jets in large p_{T} and rapidity region
- in Pb+Pb collisions, the suppression of jet production has small dependence on p_{T} and it is flat in rapidity
  - these measurements are in agreement with measurements of charged hadrons
- in p+Pb collisions, there is suppression for central events but enhancement for peripheral; there is also strong dependence on rapidity