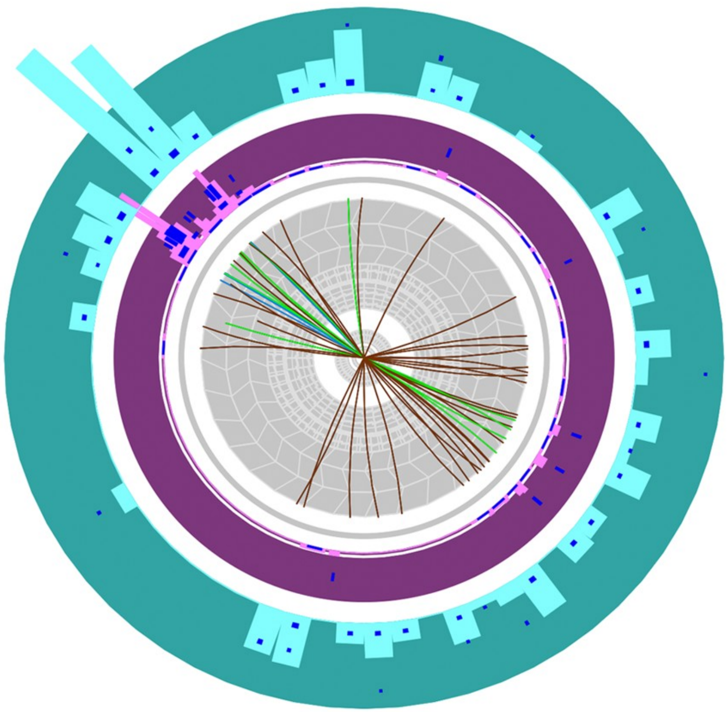
Jet production in Pb-Pb collisions in ATLAS



Martin Rybář

for the ATLAS collaboration

Winter Workshop on Recent QCD Advances at the LHC

Les Houches, Feb 13 -18th, 2011

Heavy Ions at the LHC

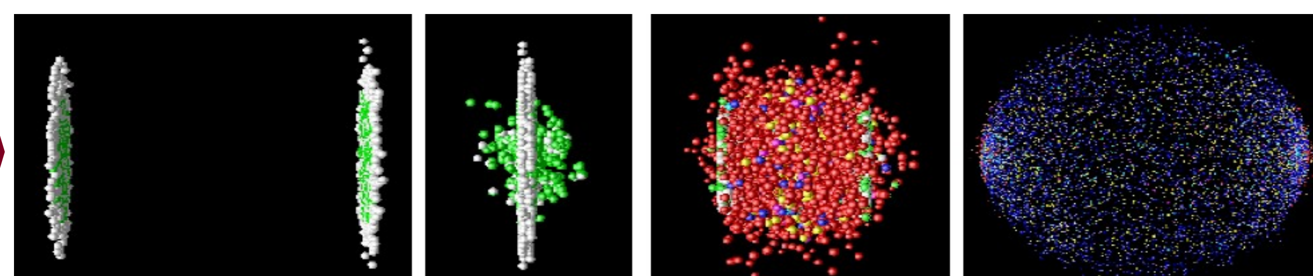
- the heavy ion programme at the LHC started on Nov 4th 2010

RHIC - $\sqrt{s_{NN}} = 200$ **GeV**

⬇

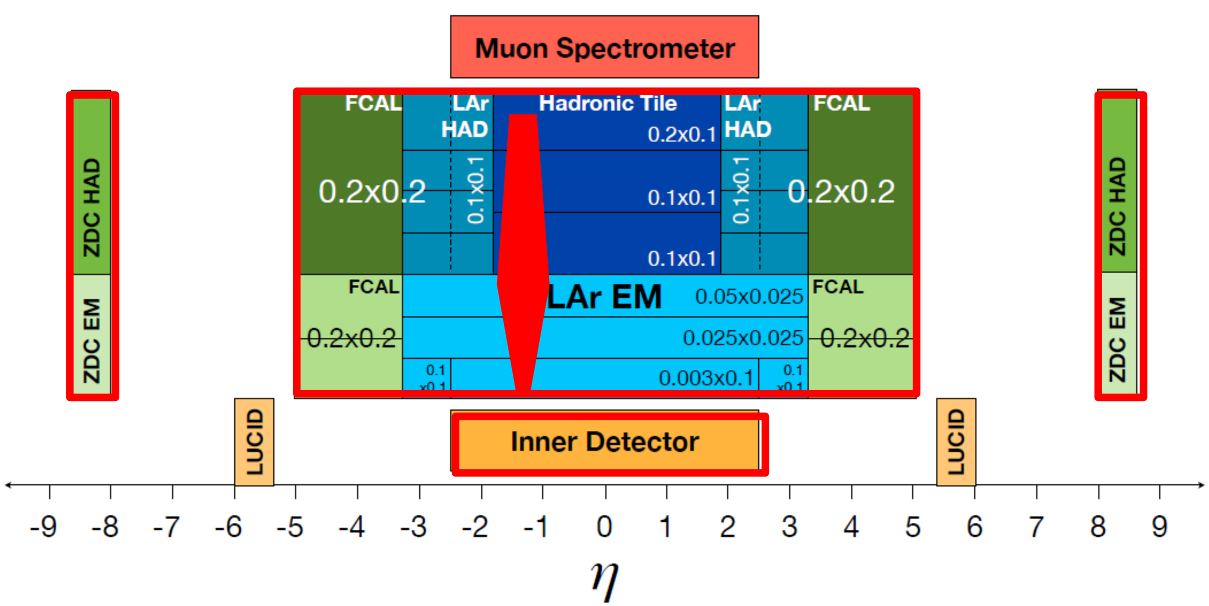
LHC - $\sqrt{s_{NN}} = 2.76$ **TeV**

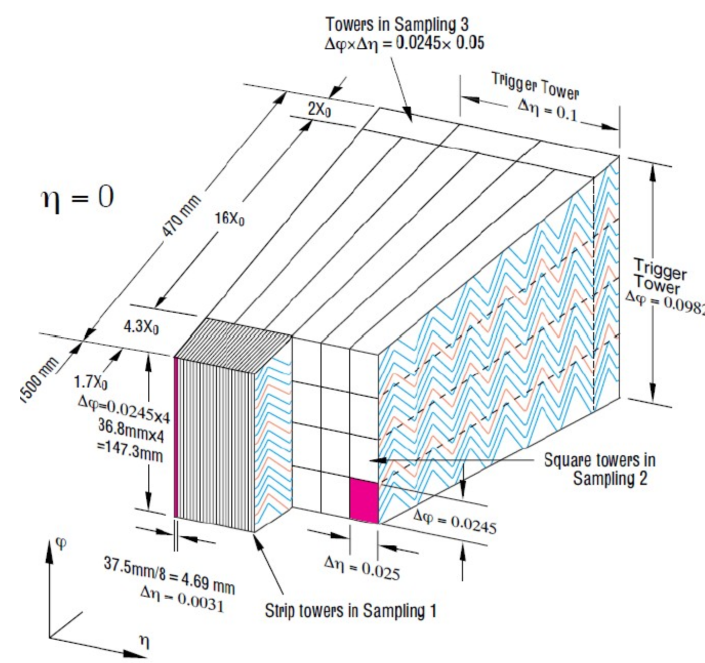
- 13 times larger energy ➡ a new regime in HI physics
- the highest energy density ever achieved
- new probes like Z bosons and **jets** – topic of this talk
- full jet reconstruction possible



The ATLAS Detector

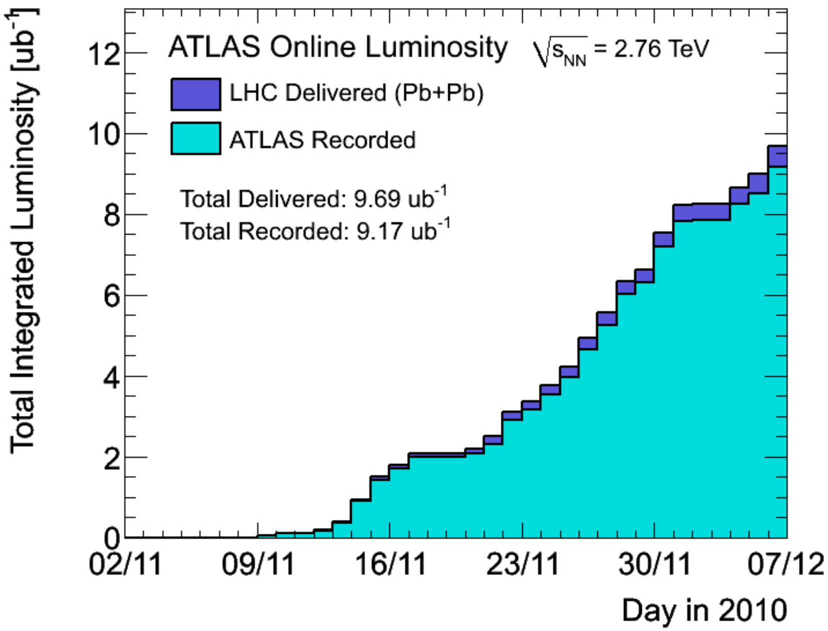
- ATLAS is a general-purpose p-p experiment, but the detector can be very well used for heavy ion physics!
- large pseudorapidity coverage and full azimuthal acceptance
- fine granularity and longitudinal segmentation
- precise inner detector in a 2T field
- extensive system of muon chambers placed inside a 1T field

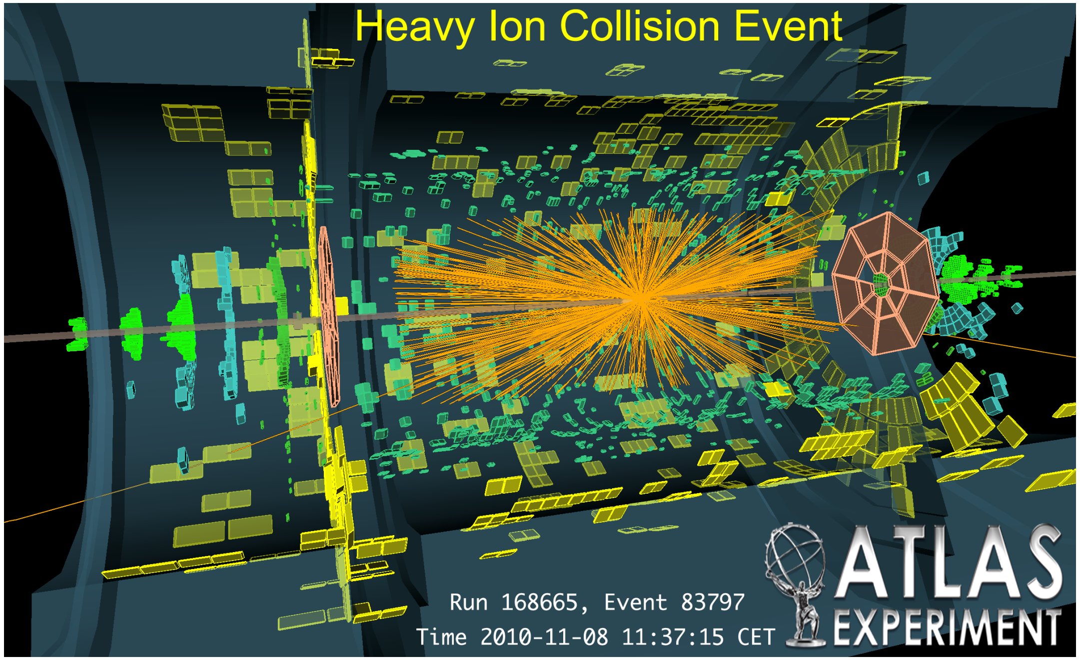




ATLAS Detector Status during HI Run

- ATLAS detector was fully operational
- 9.17 μb^{-1} of Pb-Pb were recorded
- data recording efficiency > 95%
- fraction of good quality data > 99%



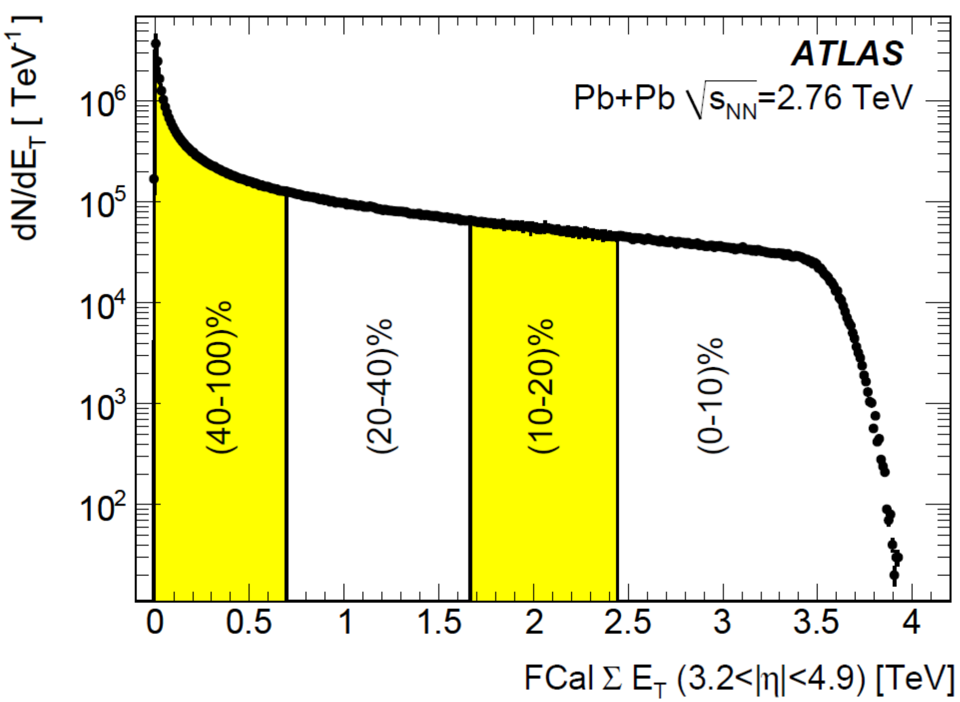


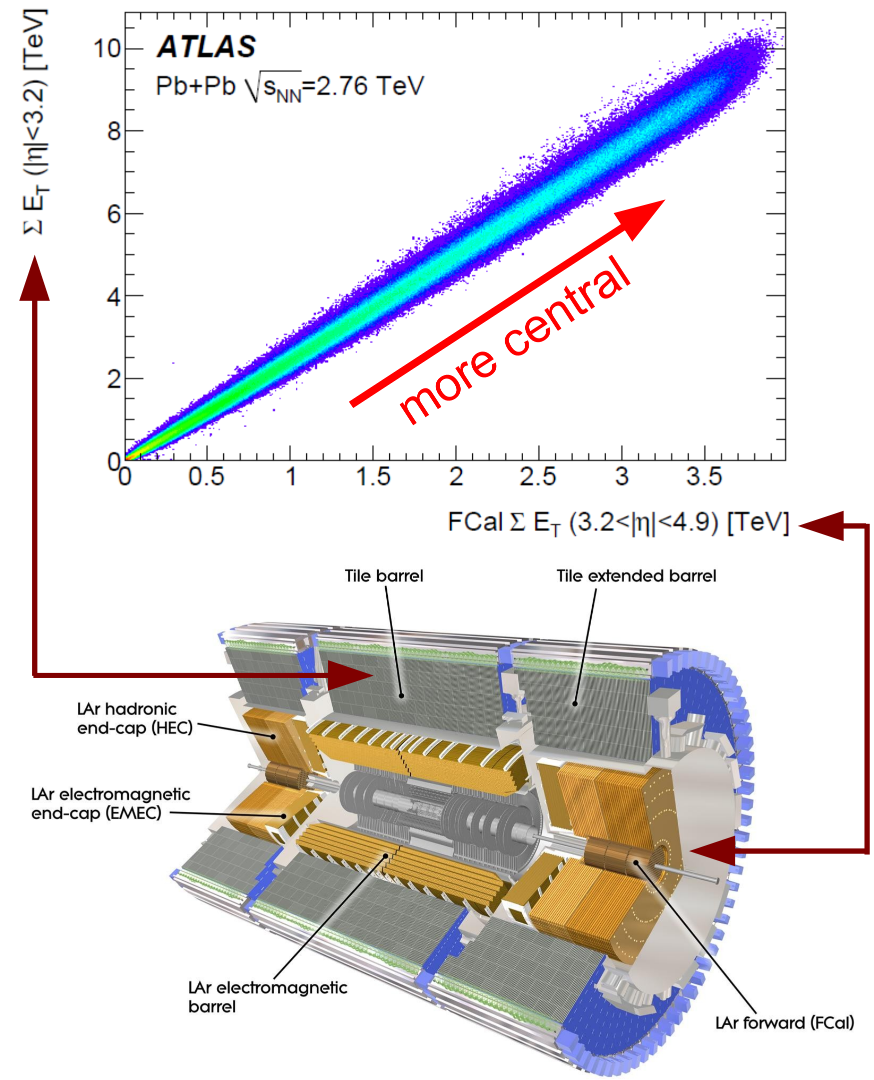
Excellent data quality during first HI run!

Centrality

total E_T measurement ➡ impact parameter
number of collisions and participants

- characterize centrality by percentile of total cross-section using total E_T measured in forward calorimeter (3.2<|η|<4.9)

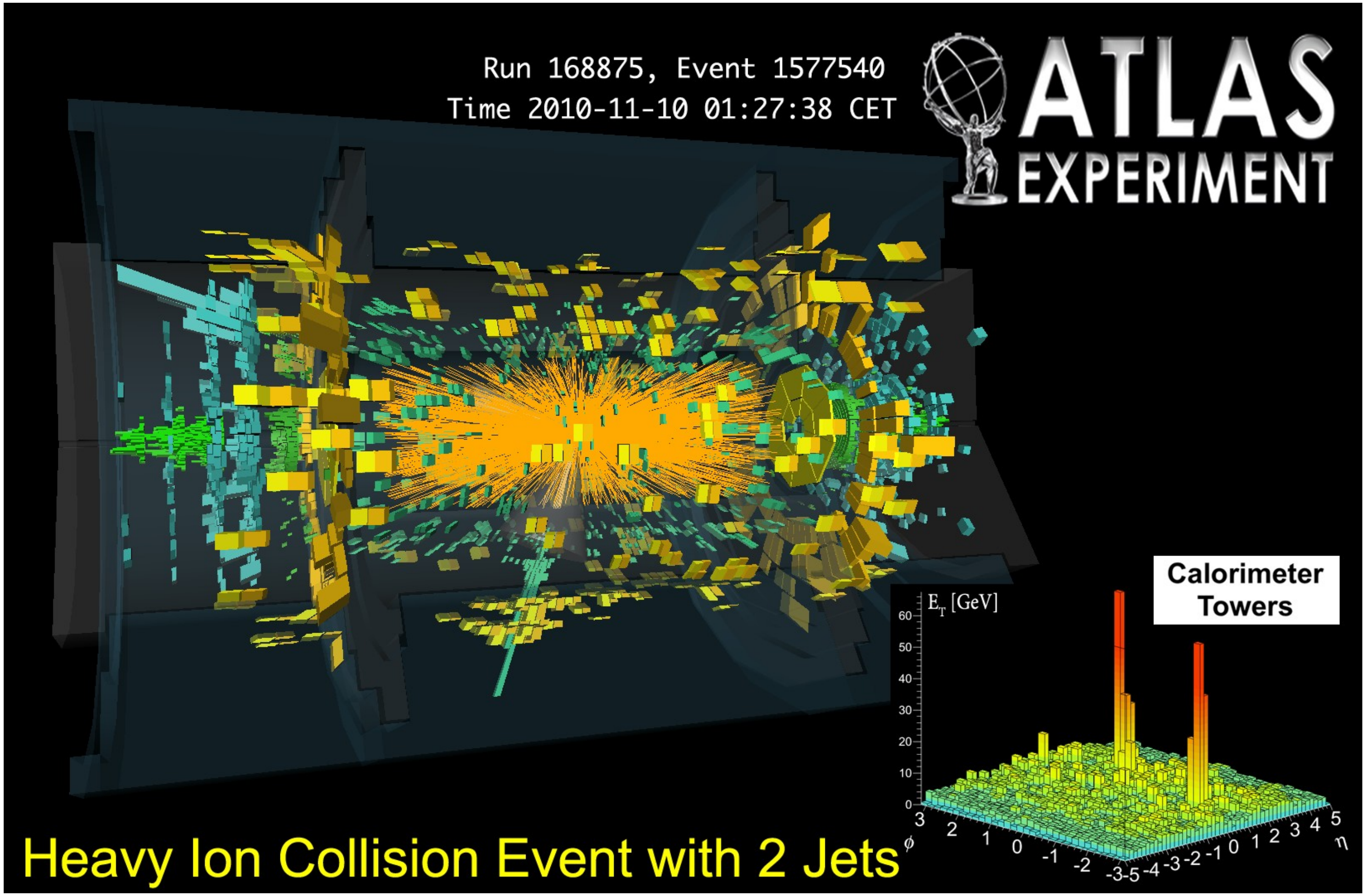




Jets in ATLAS

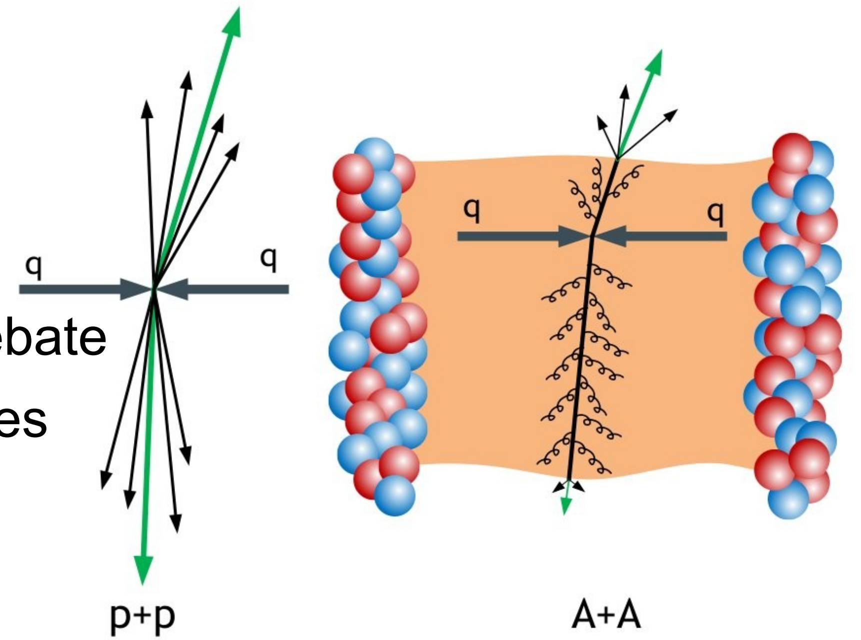
- jet production well described by a NLO pQCD
- ATLAS has already measured jets in p-p collisions

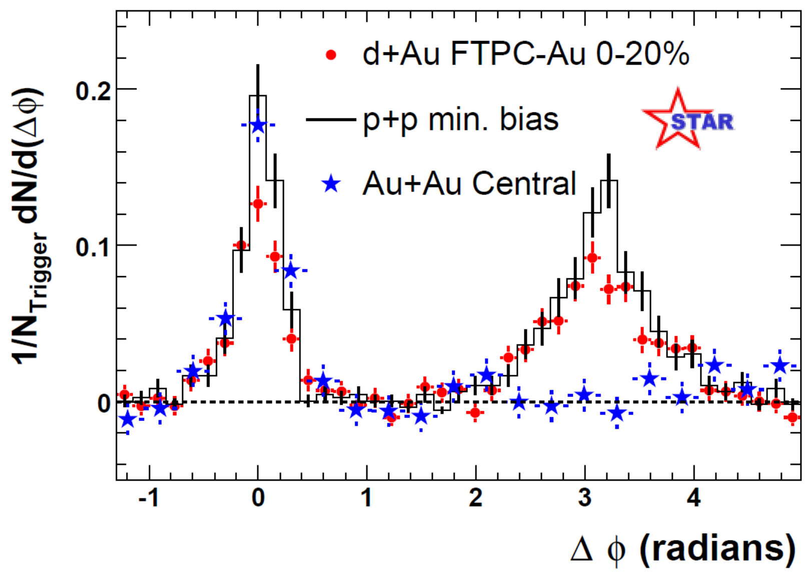
→ jets are ideal for tomography of medium



Jets in HI Collisions

- partons are expected to lose energy in dense coloured medium
  - ➡ jet quenching
  - ➡ medium properties
  - ➡ mechanisms of quenching still under debate
- RHIC's measurements of high p_T particles
  - ➡ first evidence for jet quenching





arXiv:nucl-ex/0306024v3
18 Aug 2003

- ATLAS has a very good ability to perform the full jet reconstruction

Jet Reconstruction at ATLAS

- two reconstruction strategies: cone and anti-k_t algorithm (0.2, 0.4, 0.6)

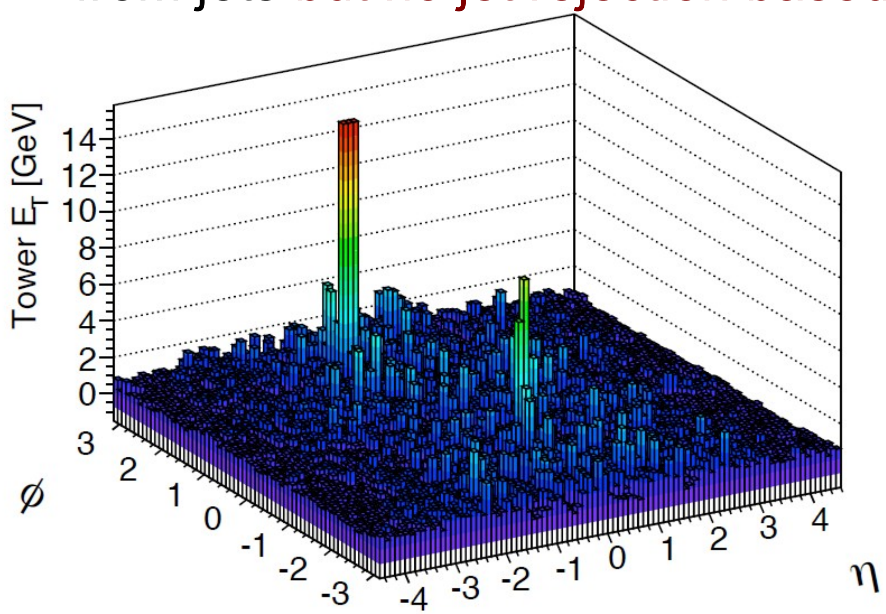
➡ anti-k_t with R=0.4 for main analysis

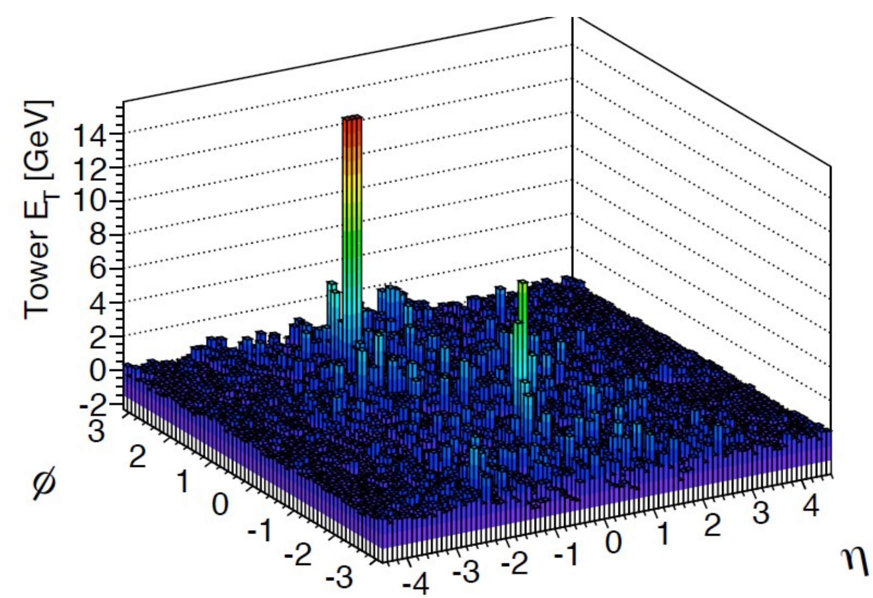
- input: calorimeter towers 0.1 x 0.1 (η x φ)
- event-by-event background subtraction:

➡ anti-k_t reconstruction prior to a background subtraction

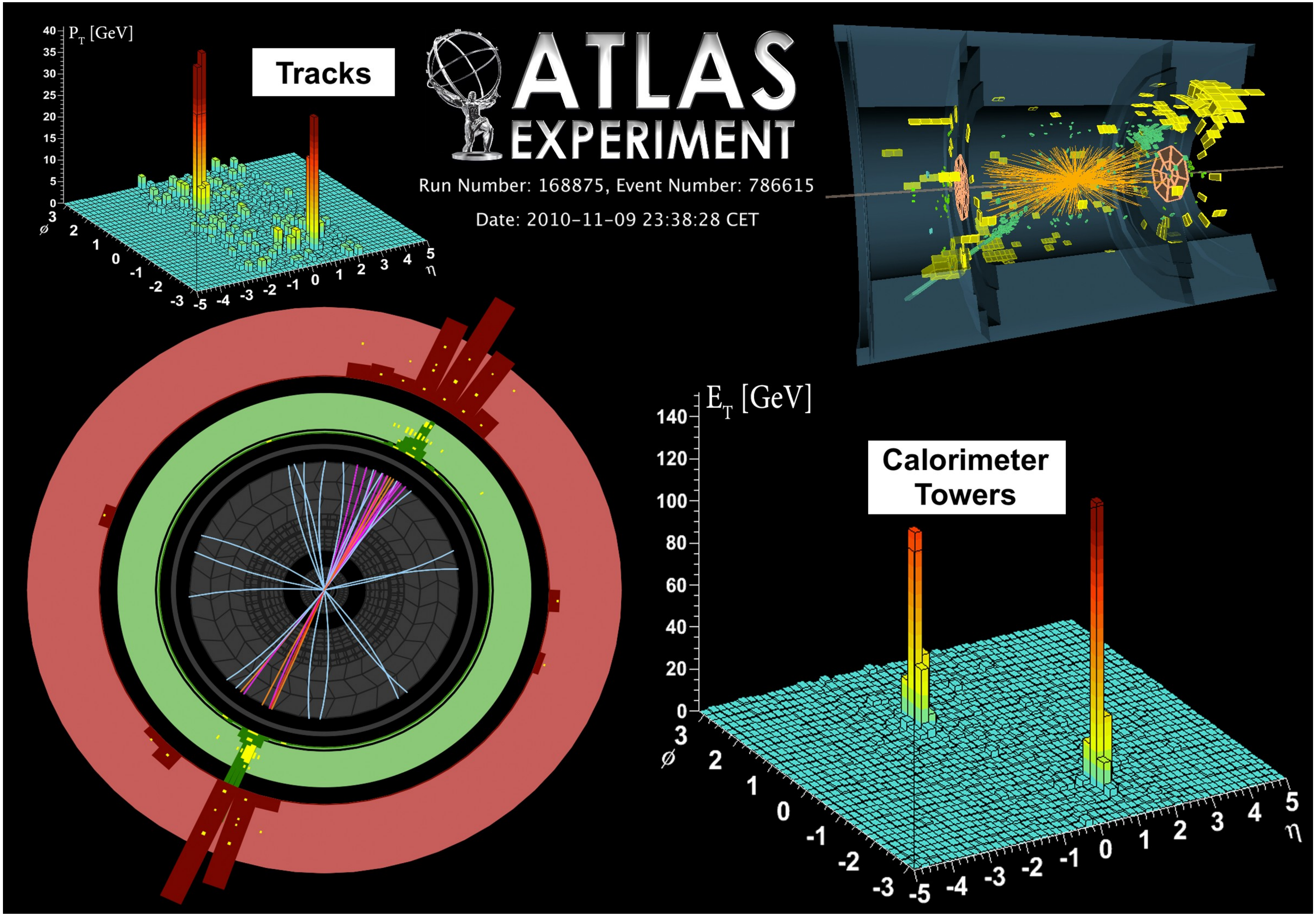
➡ underlying event estimated for each longitudinal layer and η slice separately

- we exclude jets with $D = E_{T\,tower}^{max} / \langle E_{T\,tower} \rangle > 5$ to avoid biasing subtraction from jets but no jet rejection based on *D*

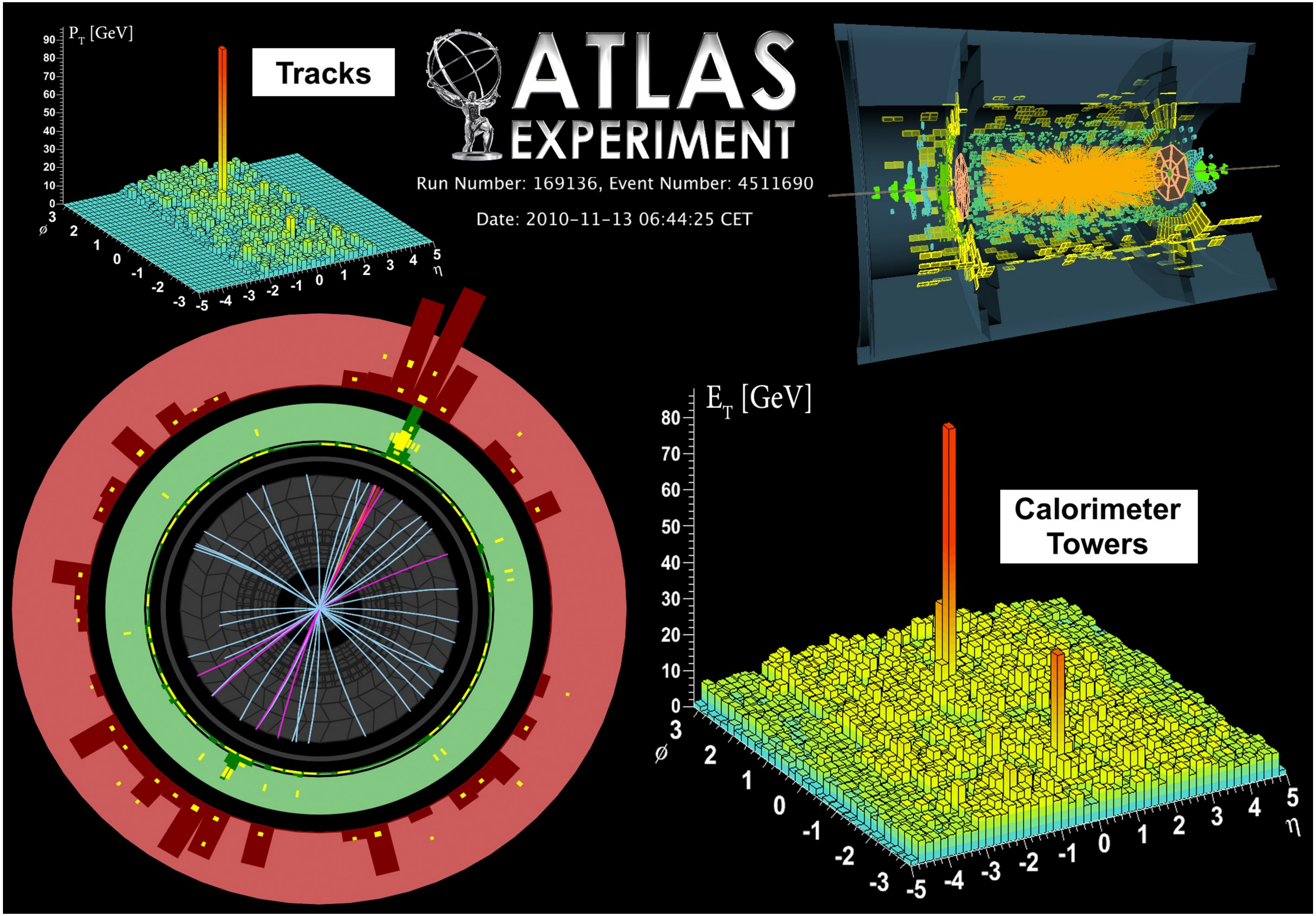




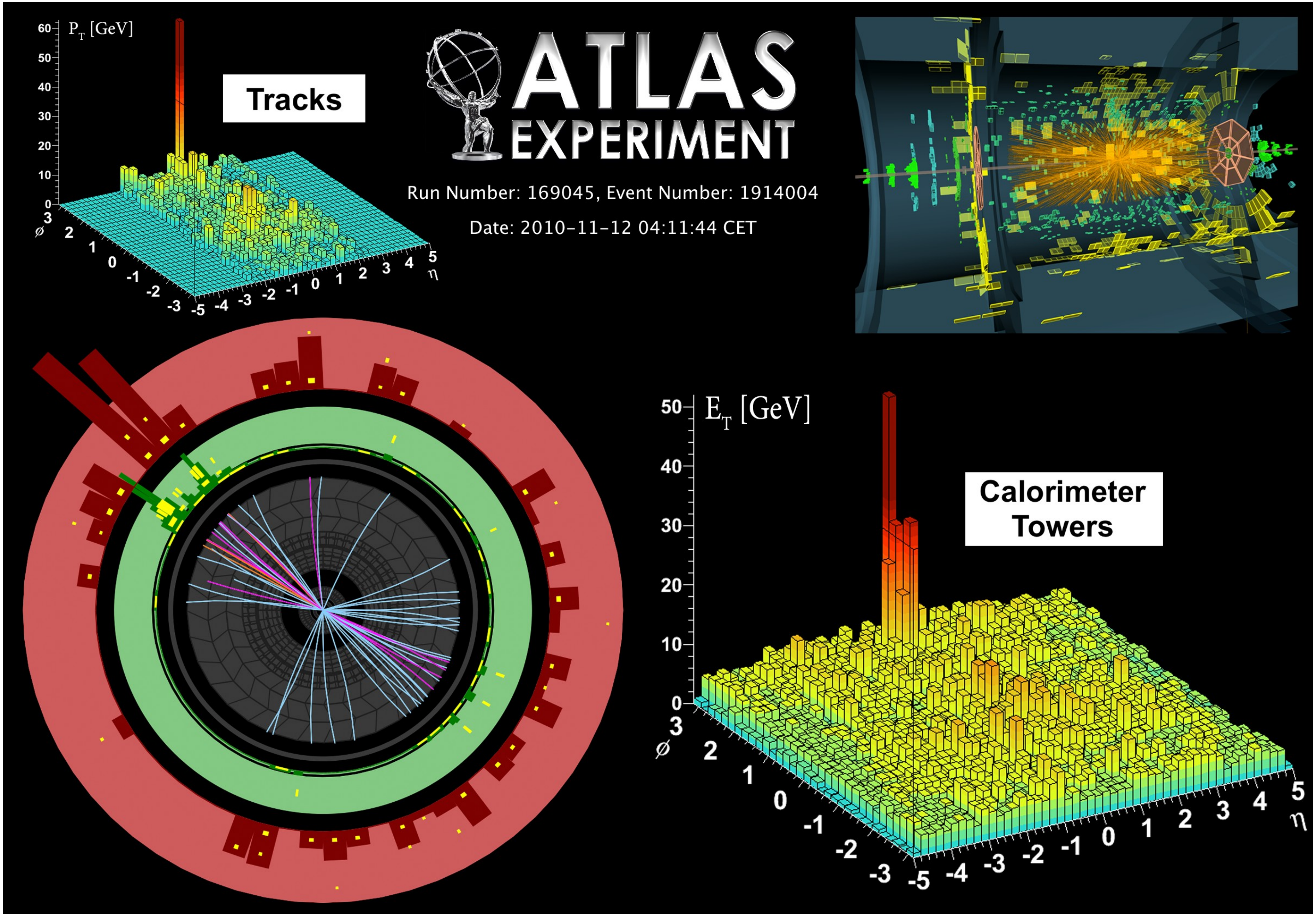
Jets in Peripheral HI Collisions



Jets in Central HI Collisions



Jets in Central HI Collisions



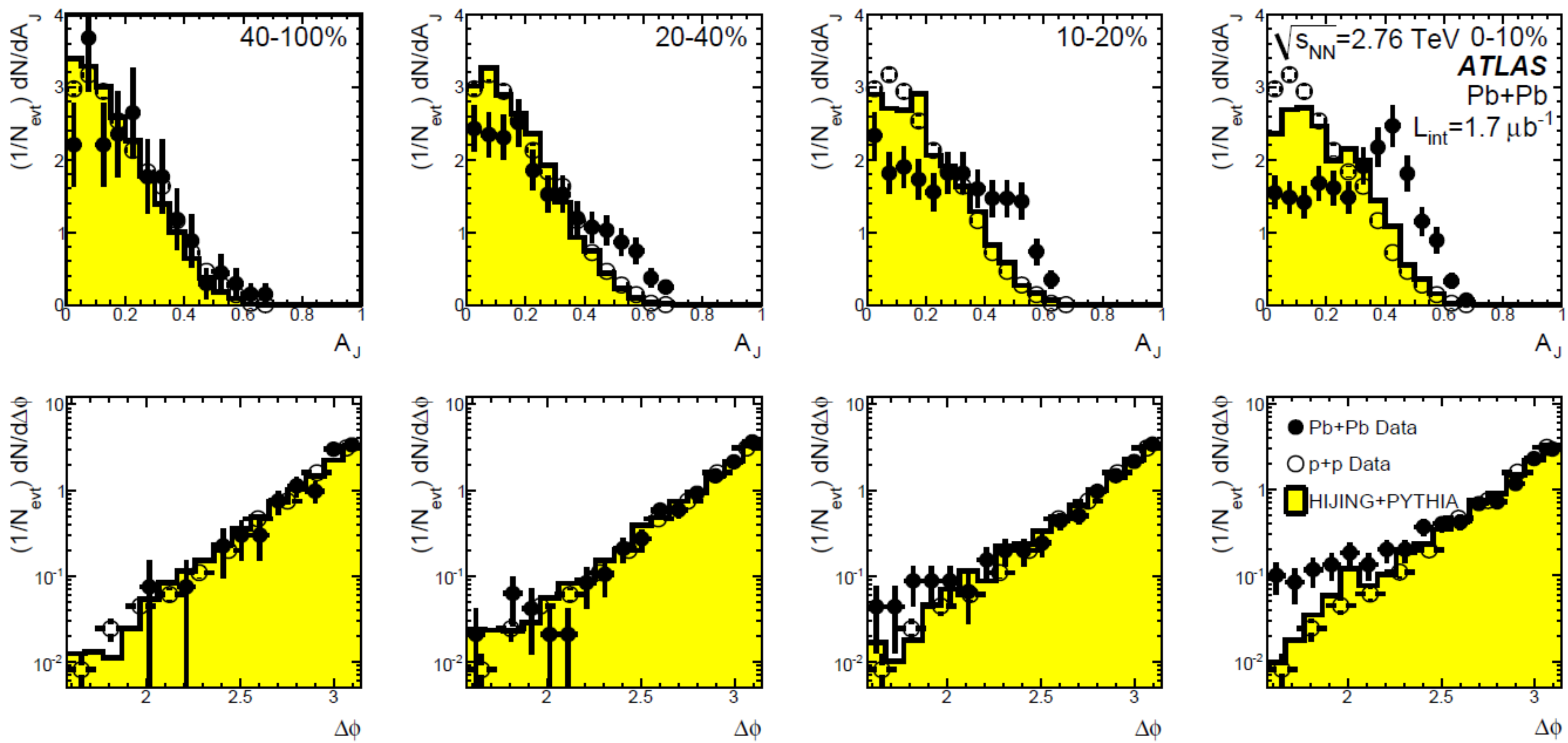
Dijet analysis

- events selected with minimum bias trigger (MBTS and ZDC)
- anti-k_t with R=0.4
- jets calibrated to the hadronic energy scale using H1-style cell weighting
- measurement of an azimuthal angle separation $\Delta\varphi$
- Selection criteria:
  - leading jet: E_{T1}>100 GeV, $|\eta|<2.8$ ➡ 1693 events in 1.7 μb^{-1}
  - sub-leading jet: highest E_T jet in opposite hemisphere: $\Delta\varphi_{12}>\pi/2$, E_{T2}>25 GeV, $|\eta|<2.8$ ➡ 5% of selected events without sub-leading jet
- dijet imbalance quantified by asymmetry variable:

$$A_J \equiv \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$$

Dijet asymmetry in Pb+Pb collisions

- comparison of Pb-Pb data, p-p data and MC Hijing+Pythia (Hijing without quenching, Pythia dijets at $\sqrt{s}=7$ TeV)

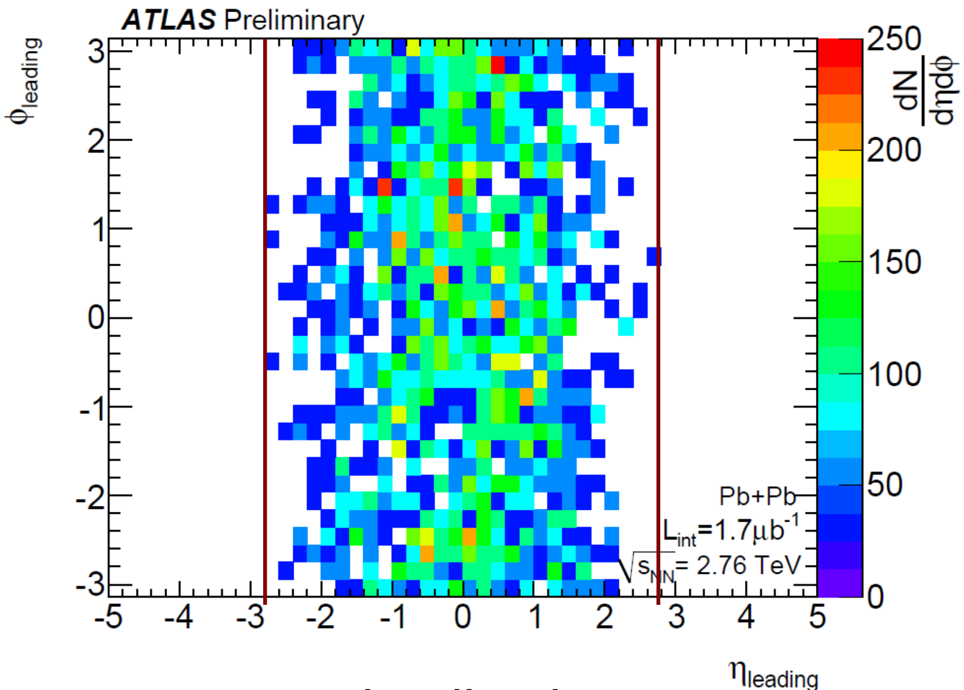


the first ATLAS HI data paper: arXiv:1011.6182, Phys. Rev. Let. 105, 252303

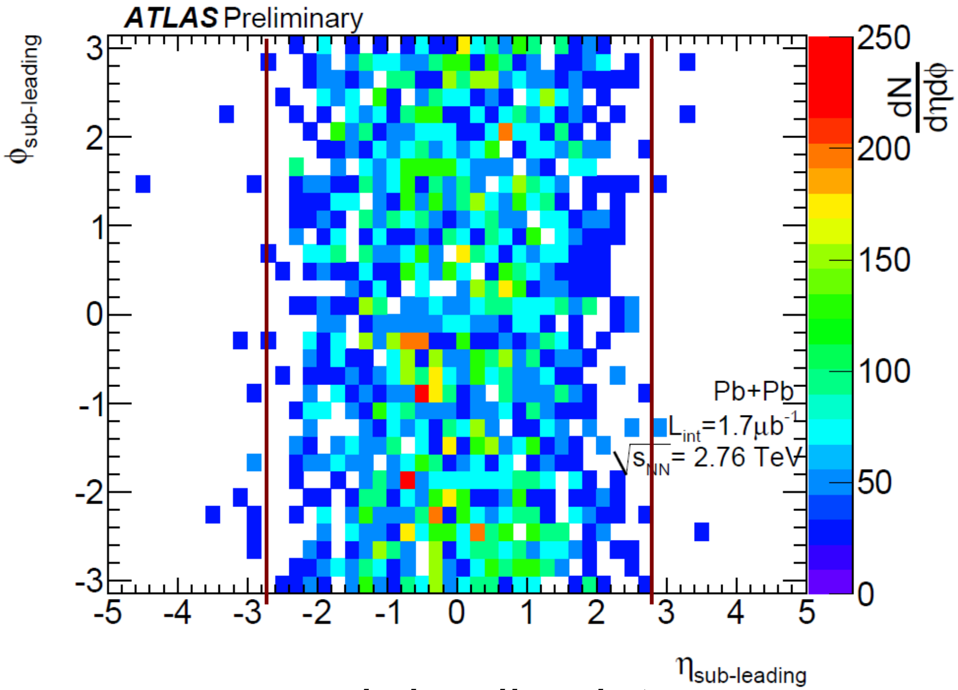
increasing centrality ➡ increasing fraction of dijets with large asymmetry

➡ $\Delta\varphi_{12}$ still peaked at π

Cross Checks: Jet Position



leading jet

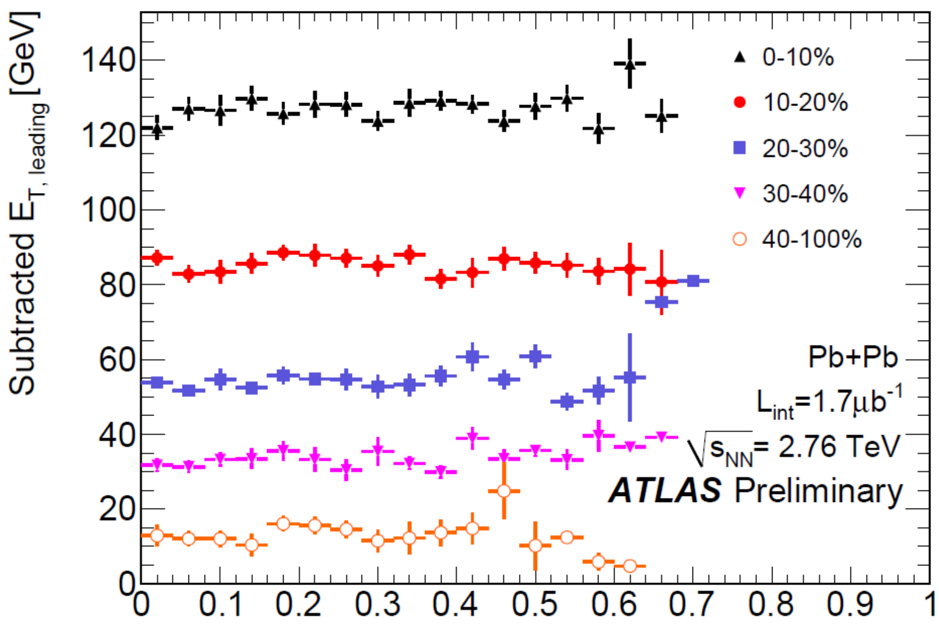


sub-leading jet

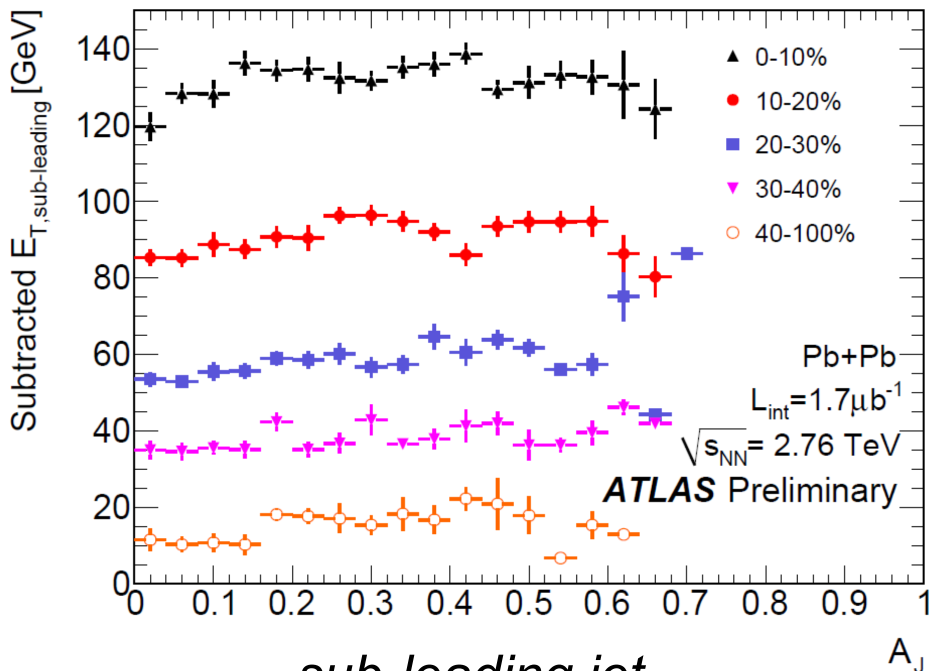
- no holes or hot spots in detector
- small impact of η cut —

Cross Checks: Subtraction

- Mean subtracted energy as a function of asymmetry



leading jet



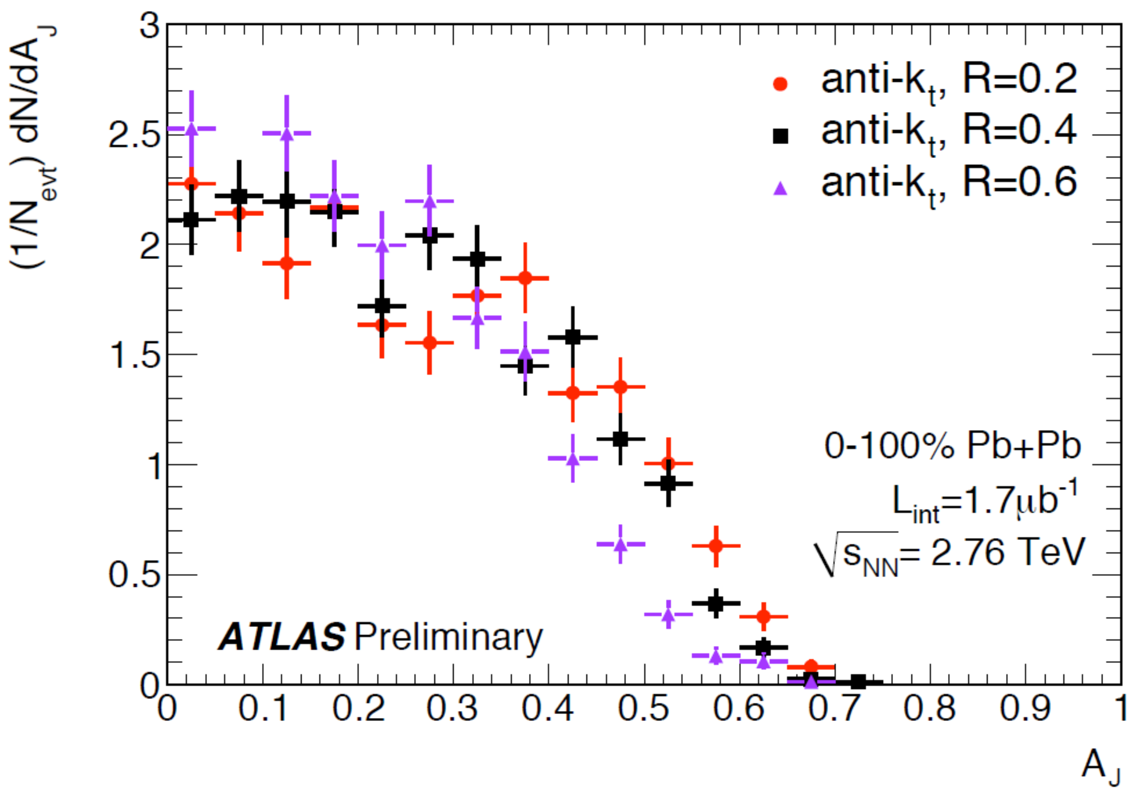
sub-leading jet

➡ no asymmetry dependence

➡ amount of subtracted energy for leading and sub-leading jet is comparable

Cross Checks: variation of cone size

- asymmetry distribution for 3 different cone sizes

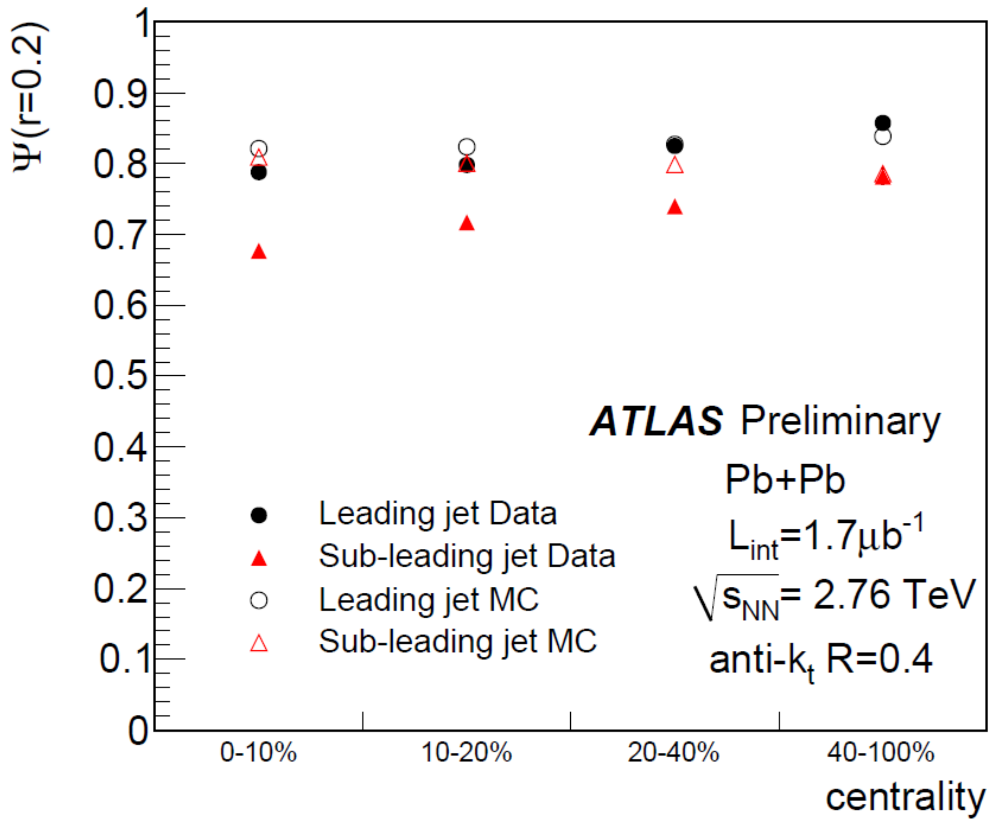


➡ increasing asymmetry with reducing cone size

➡ opposite effect expected if asymmetry develop due to a subtraction

Jet shapes

- core/total ratio for leading jet as a function of centrality



$$\psi(r=0.2)=\frac{\sum_{r<0.2} E_T}{E_T^{jet}}$$

➡ leading jet: agreement between data and MC for all centralities

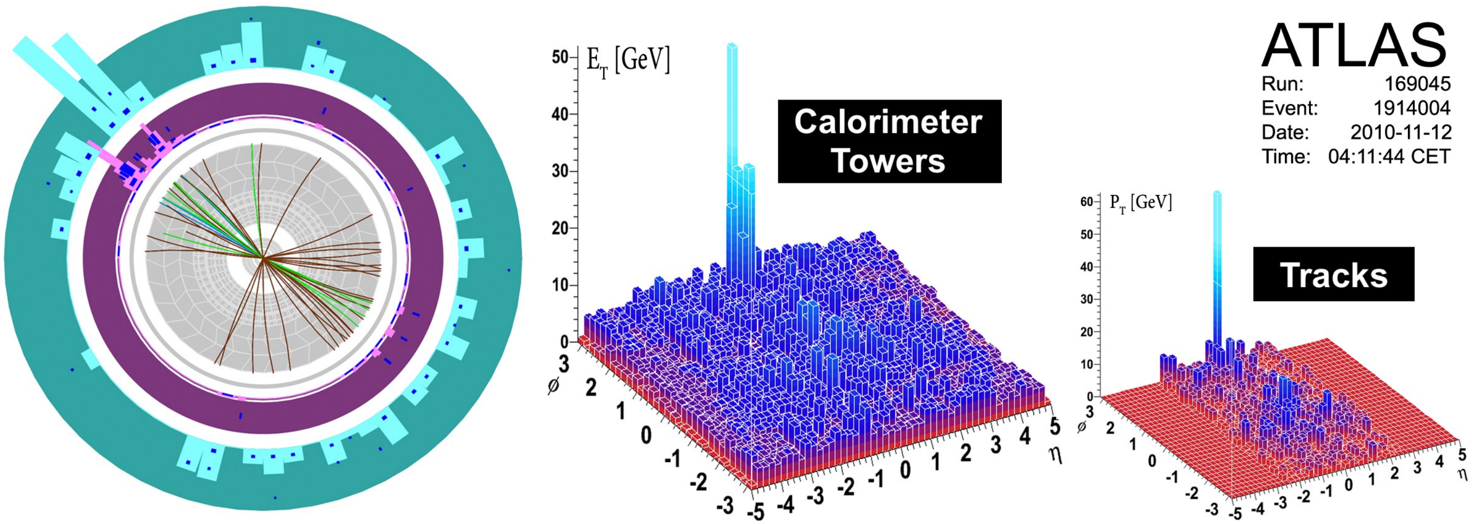
➡ sub-leading jet: agreement for peripheral events but broadening in more central collisions

Other Cross Checks

- event quality and calorimeter signal quality
- asymmetry visible also at unsubtraced and uncalibrated energy level and at the level of tracks
- no energetic muons in high asymmetry events
- no significant missing E_T in high asymmetry events
- different jet algorithms and subtraction methods
- and many others...

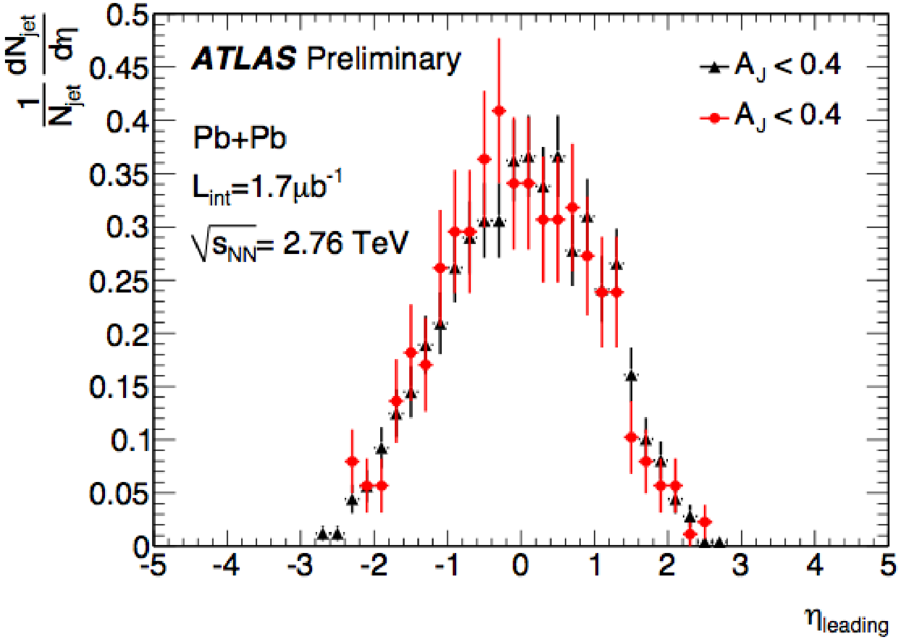
Conclusions

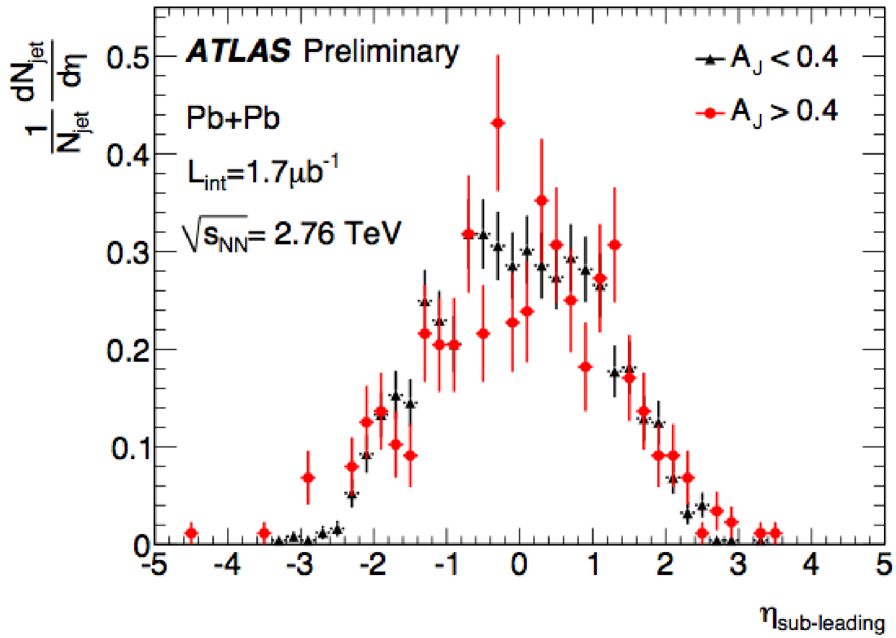
- heavy ion programme at LHC started in Nov 2010
- excellent performance of LHC and ATLAS!
- a lot of interesting results but analysis still ongoing
- ATLAS published first observation of large dijet asymmetry in heavy ion collisions
- explanation by jet quenching is natural but a lots of work needed to understand the effect
- many of cross checks have been done and the effect is still here...



Backup

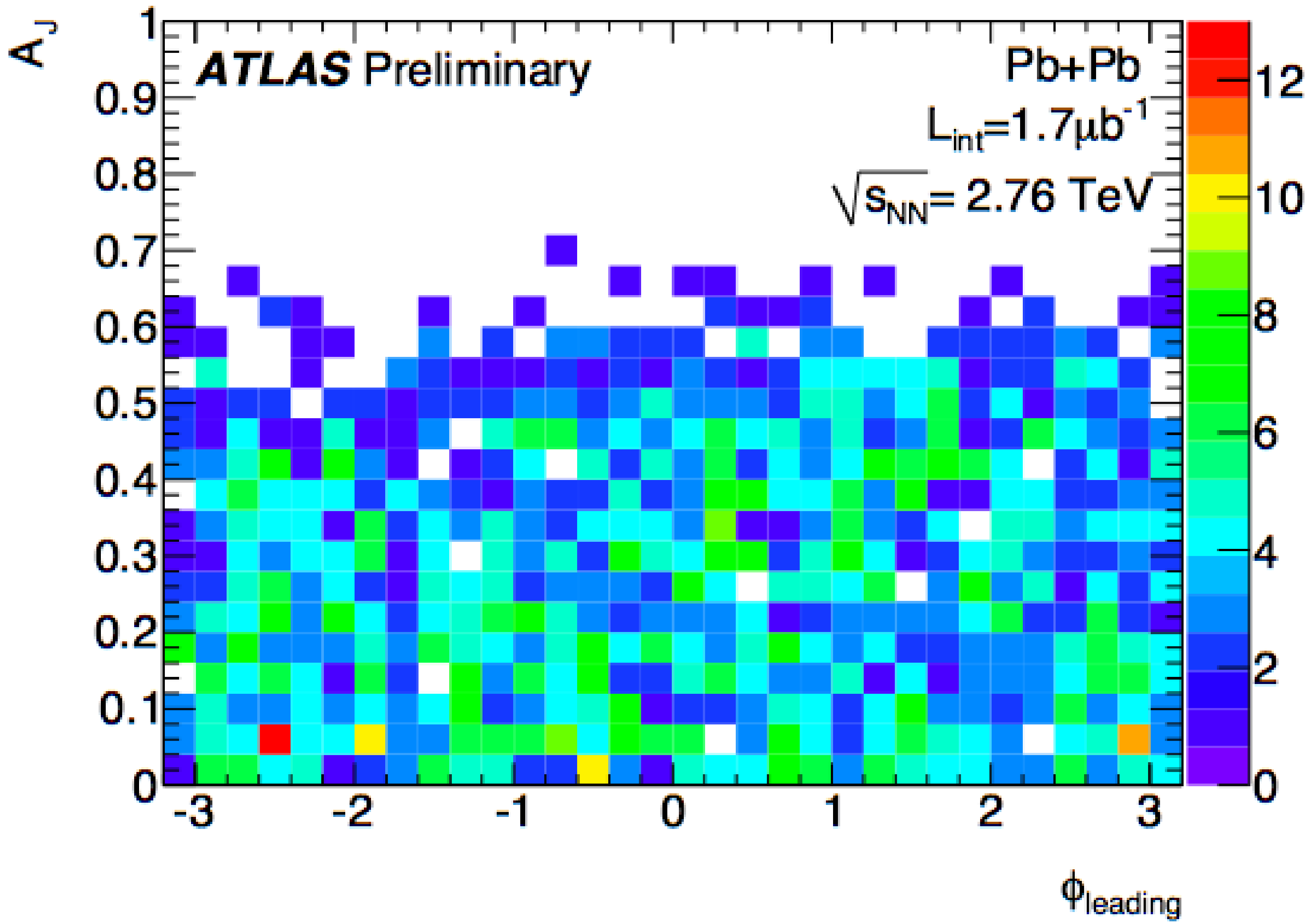
η distribution of leading and sub-leading jets





➡ no dependence on η and on dijet asymmetry

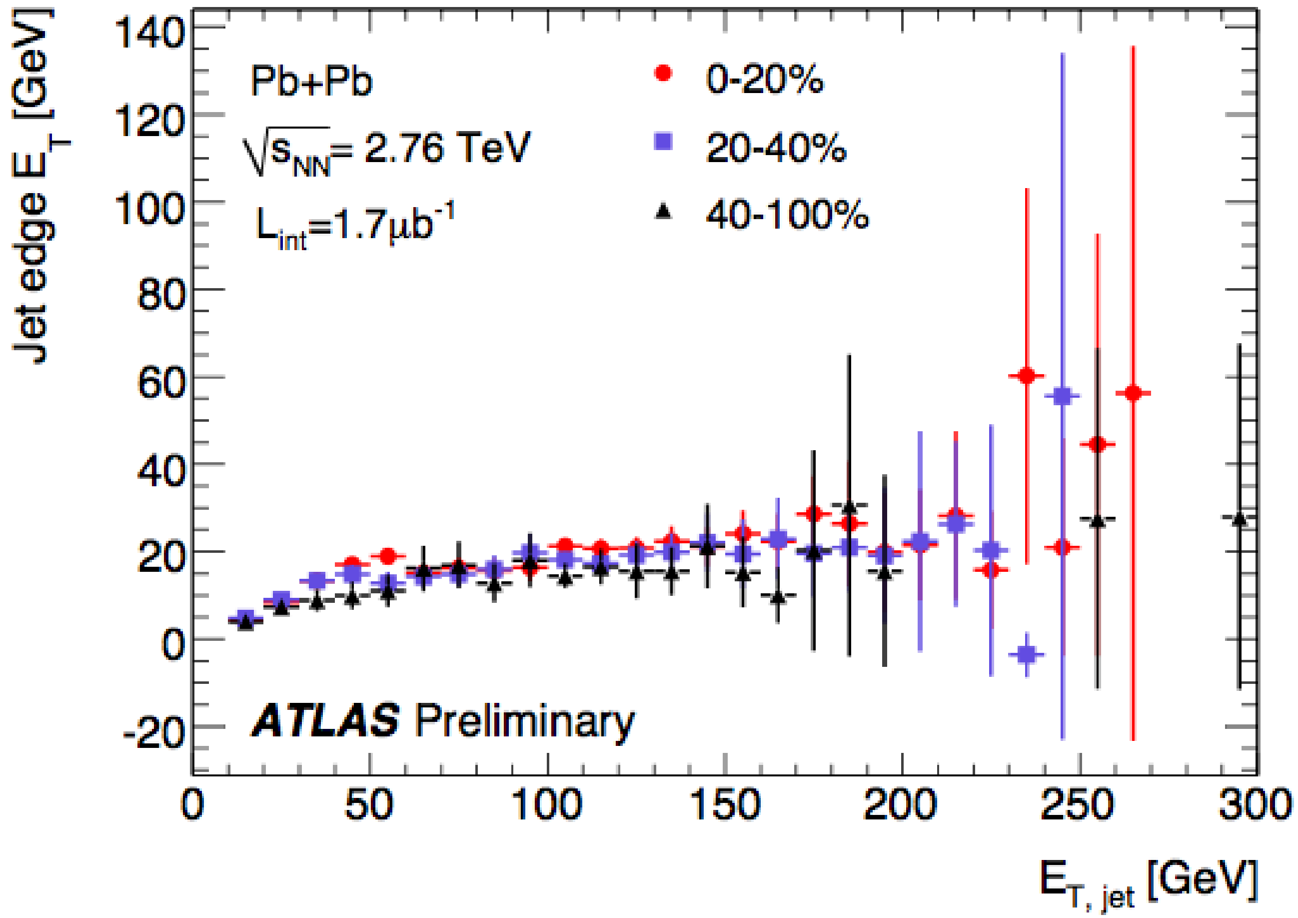
Asymmetry versus φ distribution for leading jet

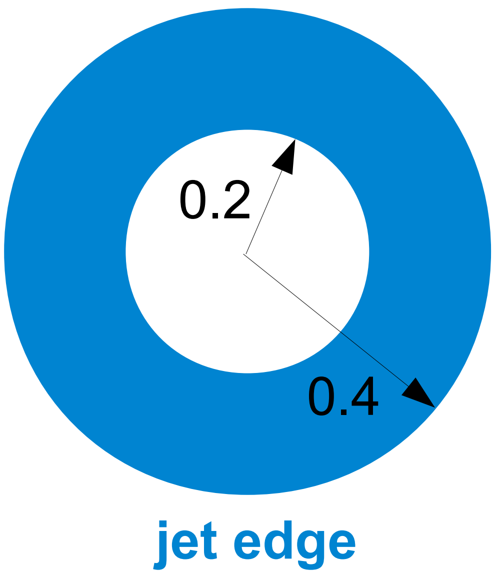


➡ no dependence on φ

Subtraction Cross Check: Jet Edge E_T

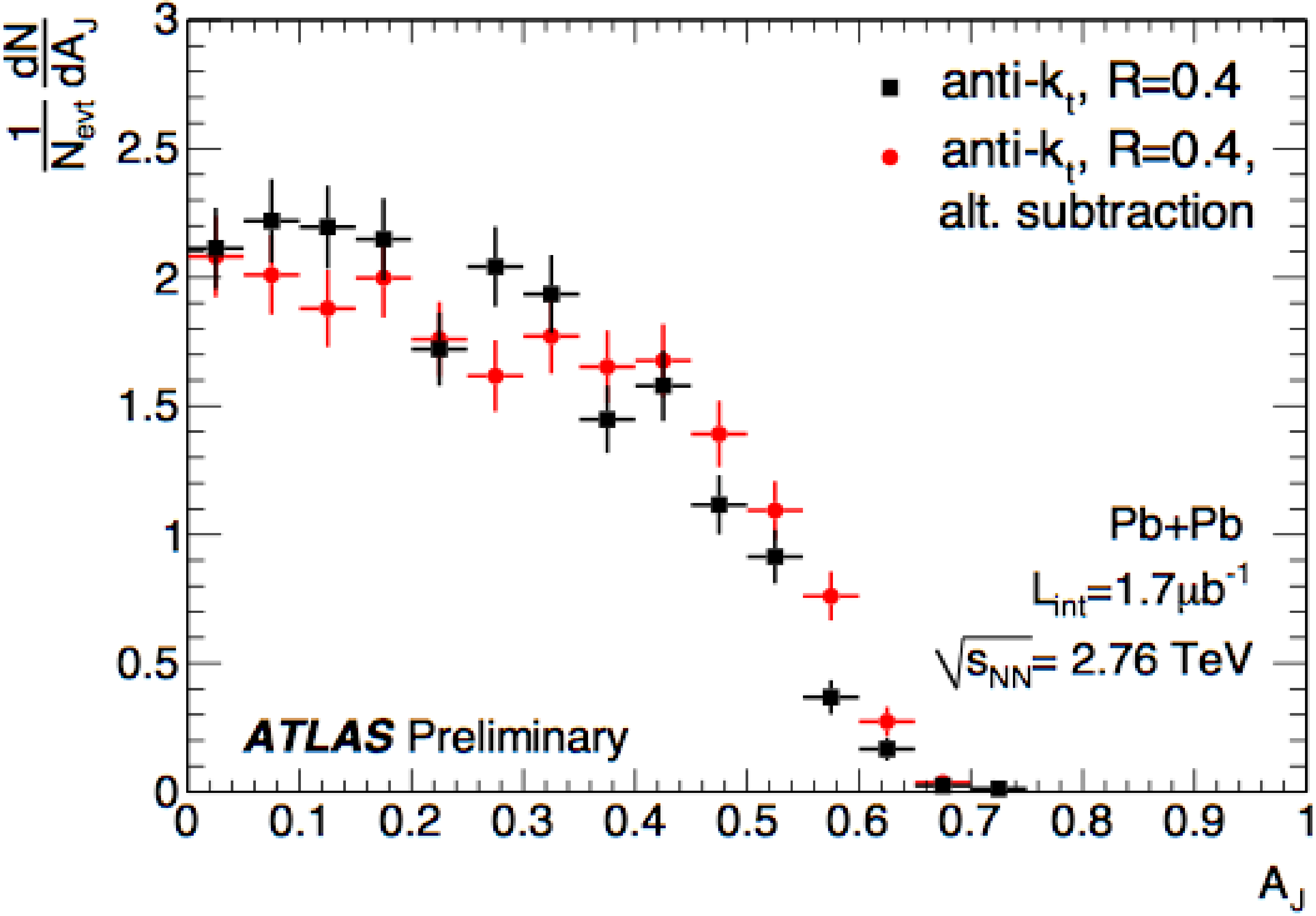
muon spectrum:





➡ no dependence on centrality

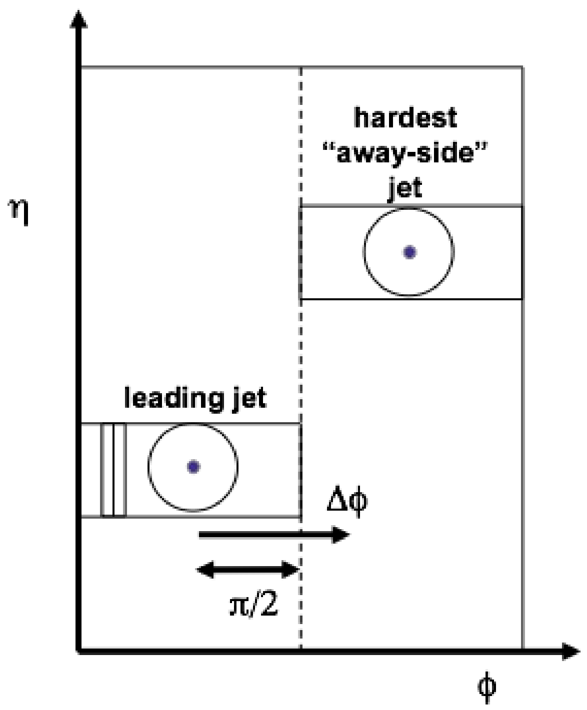
Subtraction Cross Check: different subtraction methods



Cross Check: energy and p_T flow

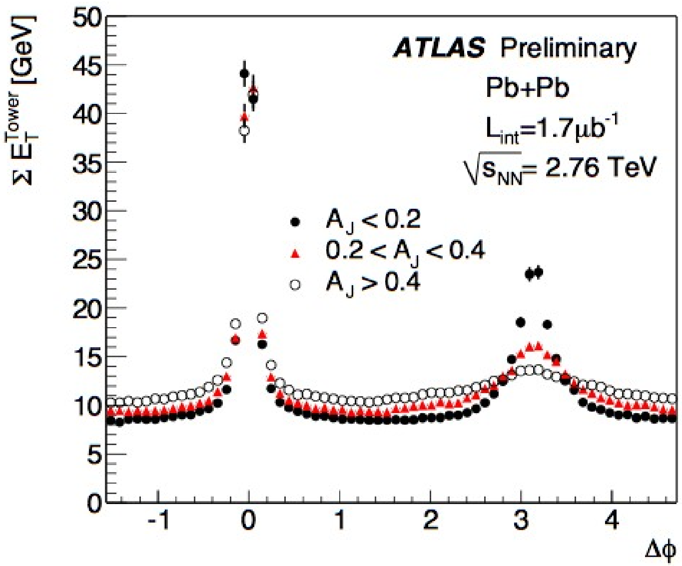
- no background subtraction!

confirmation of asymmetry in calorimeter

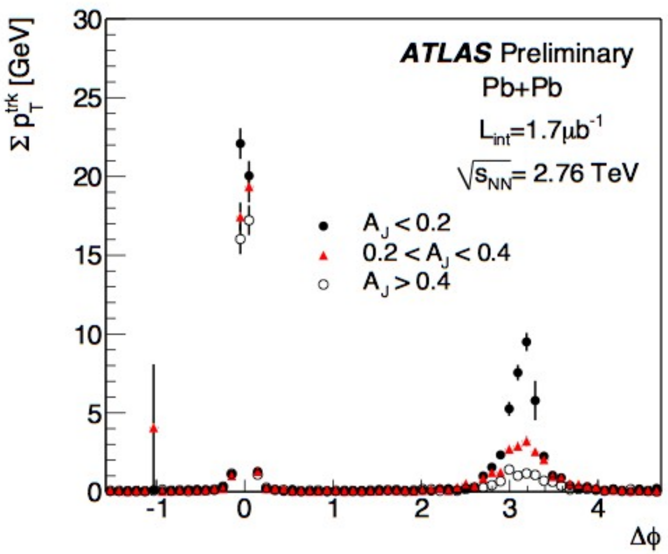


asymmetry also in tracks

energy flow from calorimeter towers:

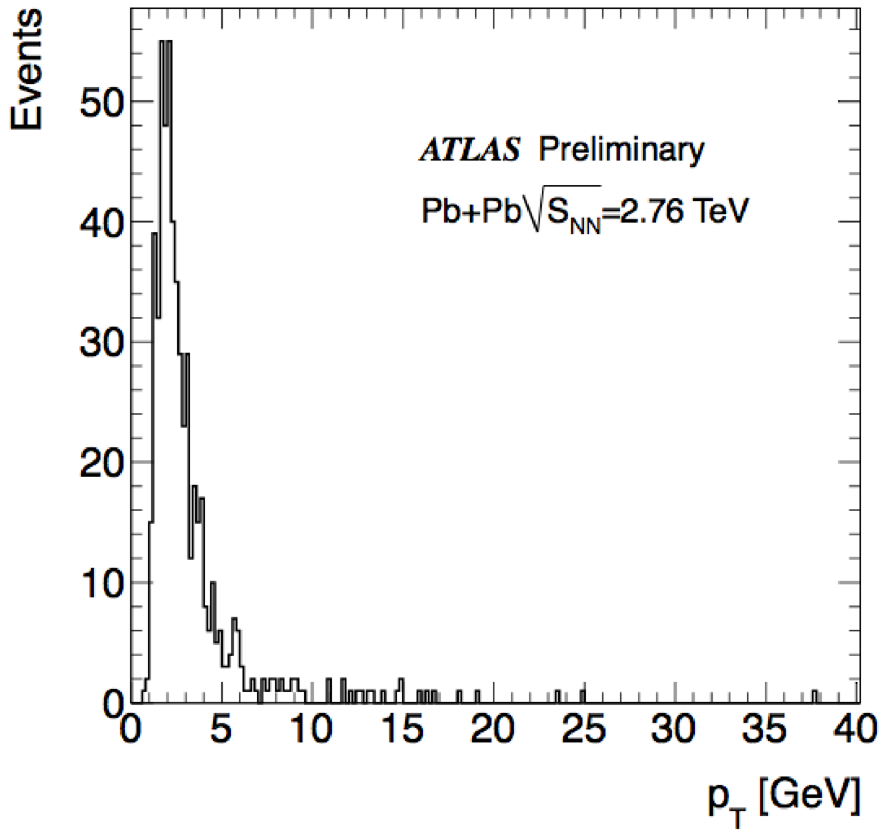


p_T flow from track > 4 GeV:

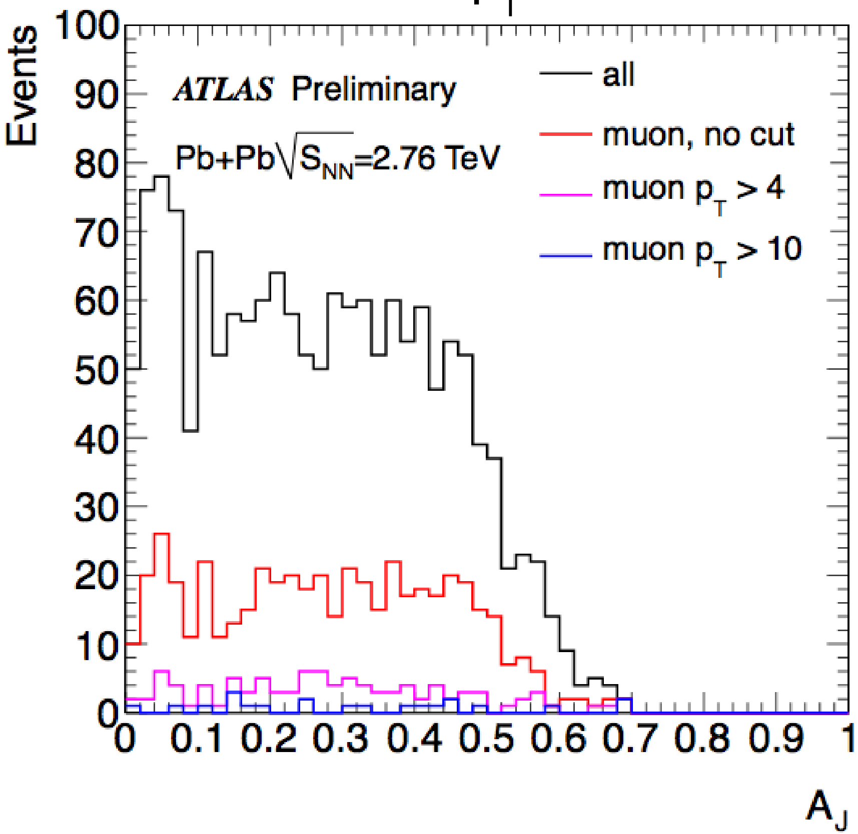


Cross Check: Muons

muon spectrum:



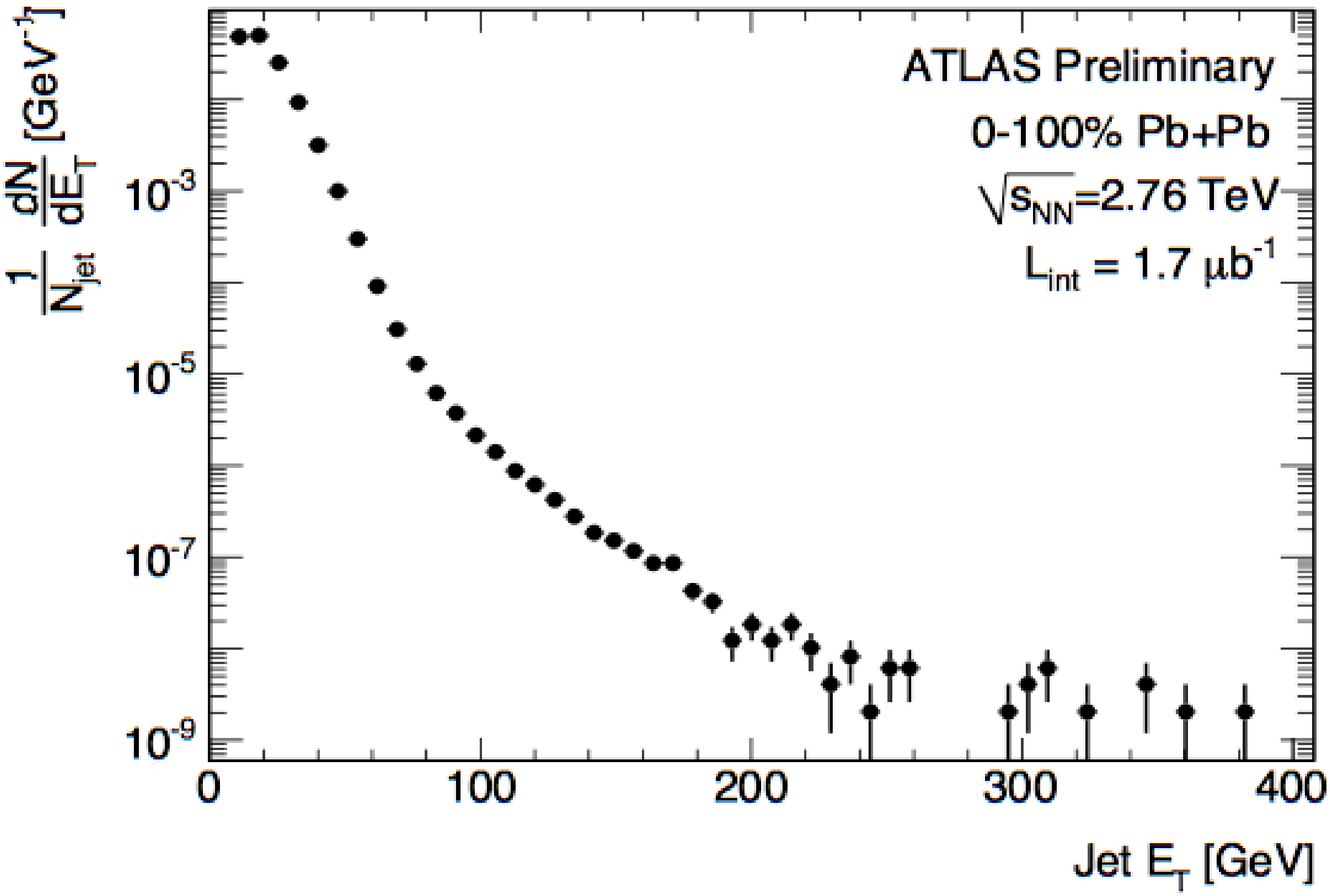
asymmetry distributions for different muon p_T:



➡ no correlation between high p_T muons and high asymmetry dijets

Inclusive jet spectrum

- uncorrected jet E_T spectrum in minimum-bias Pb+Pb, anti-k_T, R = 0.4



Jet Reconstruction Efficiency

- Pb+Pb, anti-k_T, R = 0.4, matching to truth jet: ΔR<0.2