Elucidating Jet Energy Loss Using Jets: Prospects from ATLAS

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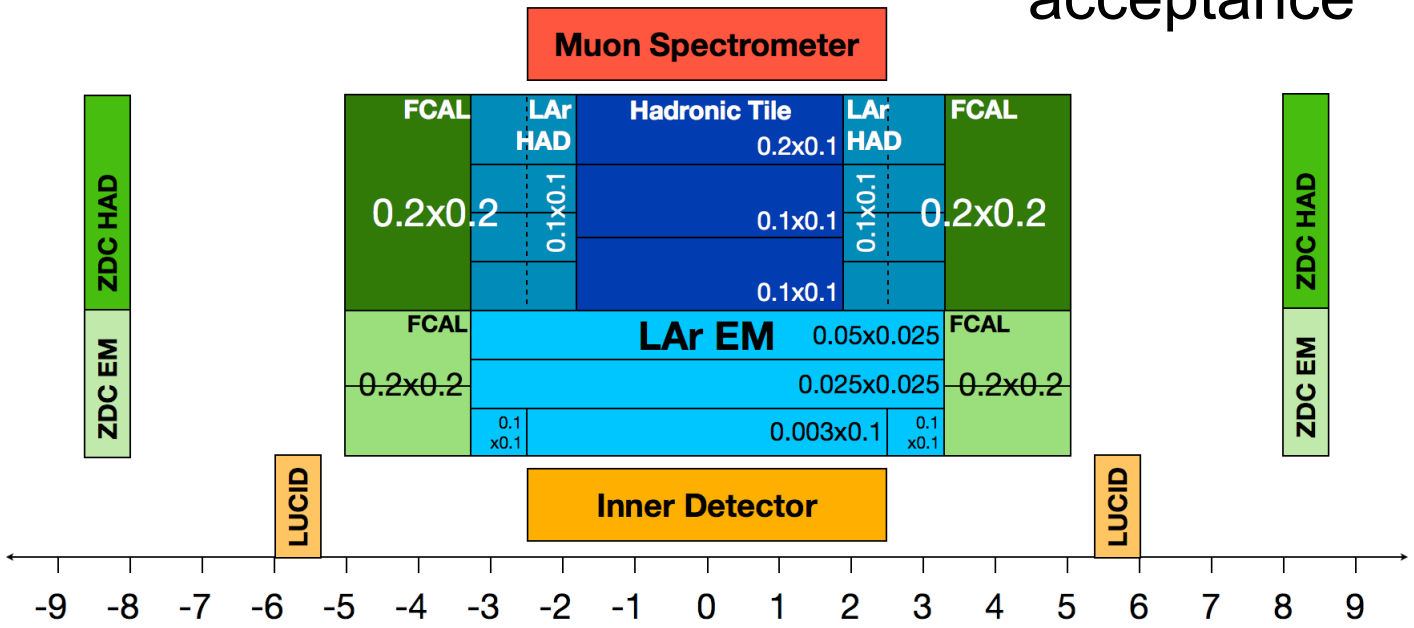
On Behalf of the ATLAS Collaboration

Outline:

- With full electromagnetic and hadronic calorimetery ATLAS will directly measure jets event-by-event.
- Jets offer new handles to reduce energy-loss bias.
- New variables using full jet measurements have sensitivity to unexplored aspects of energy loss.

The ATLAS Detector

Full azimuthal acceptance



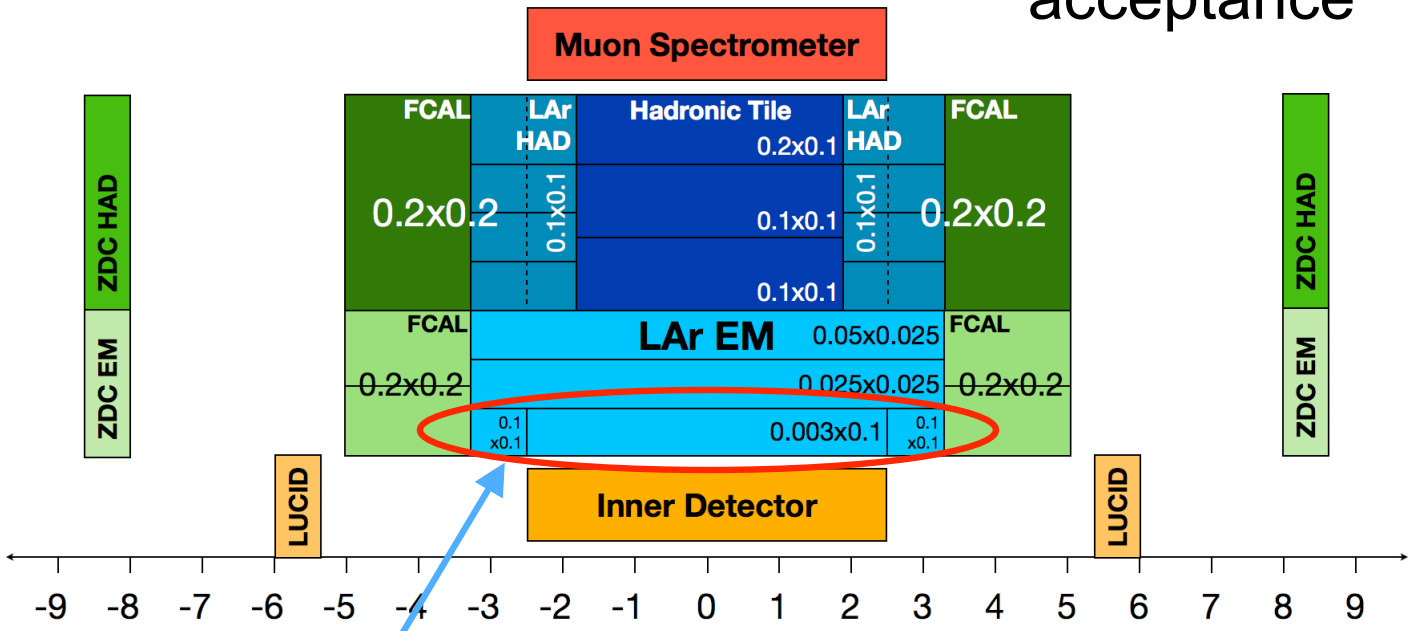
M. Rosati 4A #1

Tracking in 2T solenoid

Muon ID

The ATLAS Detector

Full azimuthal acceptance



M. Rosati 4A #1

M. Baker 3C #5

Photons

Tracking in 2T solenoid

Muon ID

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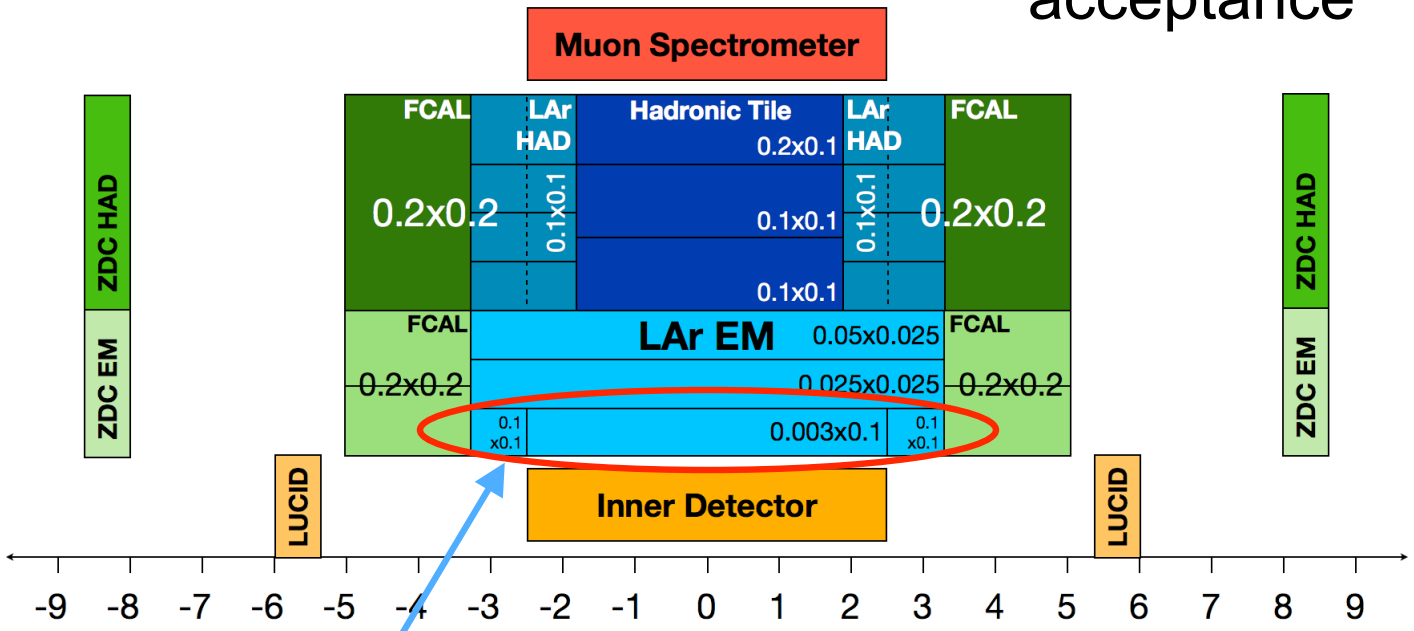
Full azimuthal acceptance



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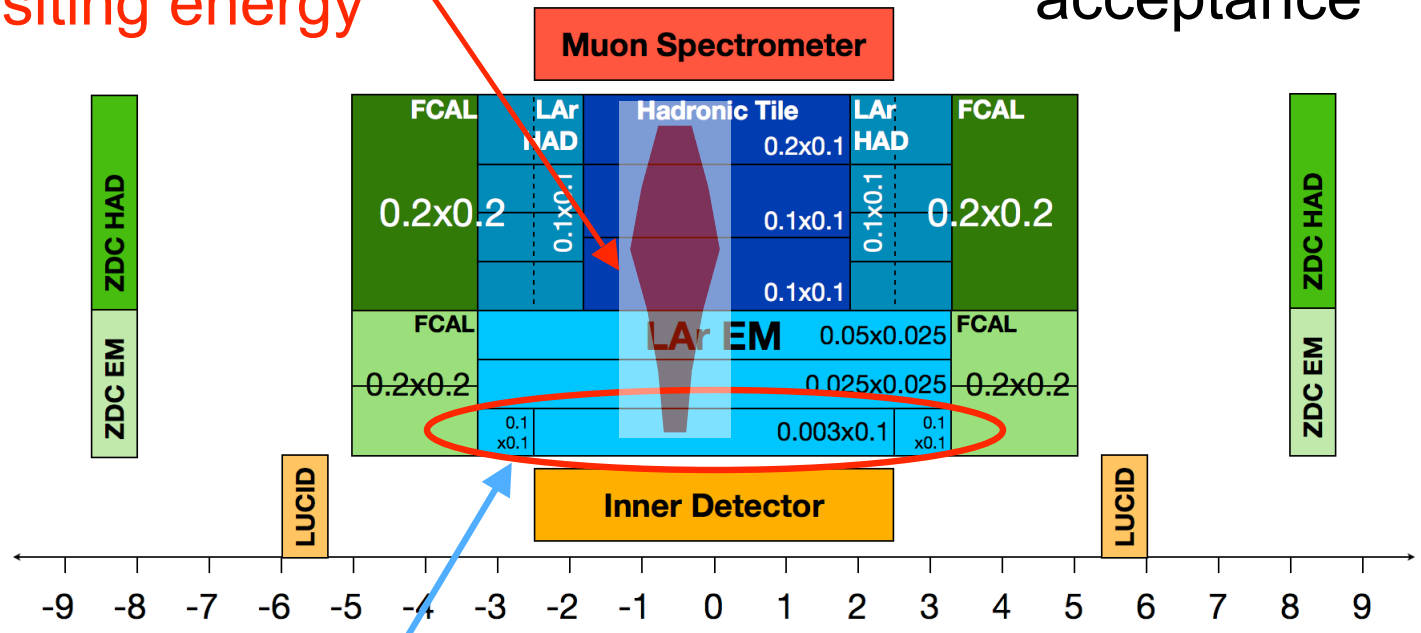
Jets

The ATLAS Detector

100 GeV jet depositing energy

Full azimuthal acceptance



M. Rosati 4A #1

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Tracking in 2T solenoid

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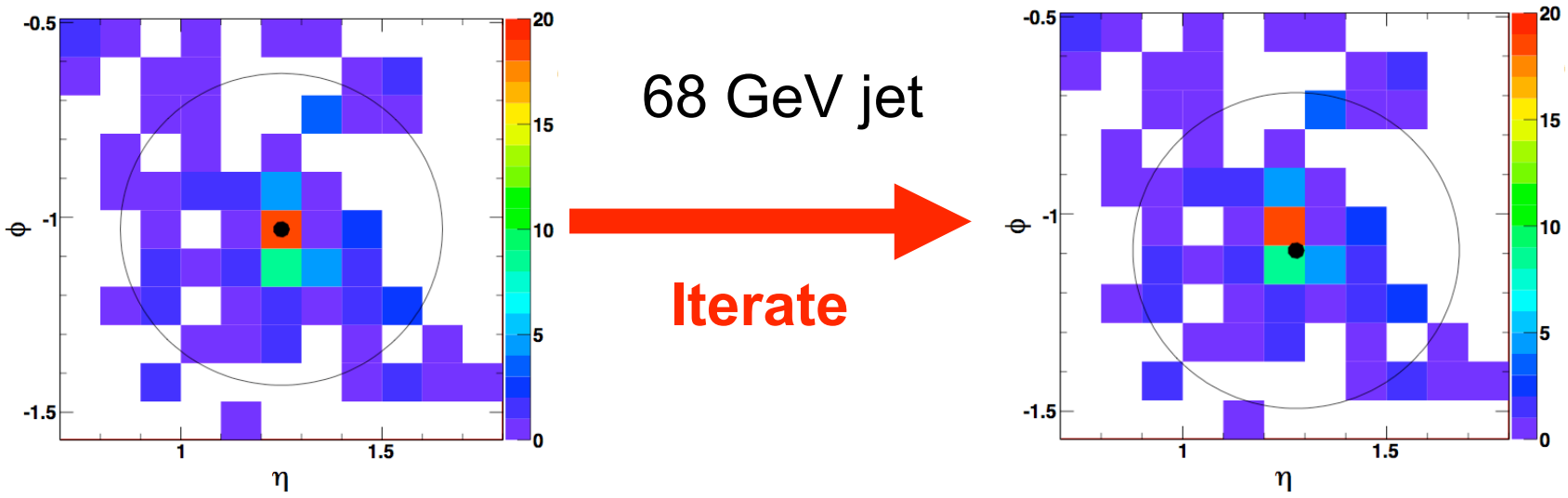
Jets

Cone Jet Reconstruction: Overview

General features of a cone algorithm

1. Choose a position
2. Sum 4-momentum of particles/towers in a fixed cone in $\eta-\phi$
3. Repeat step 2 with the 4-momentum sum as new position.
   Iterate until convergence.
4. Split or merge jets based on fraction of cone overlap



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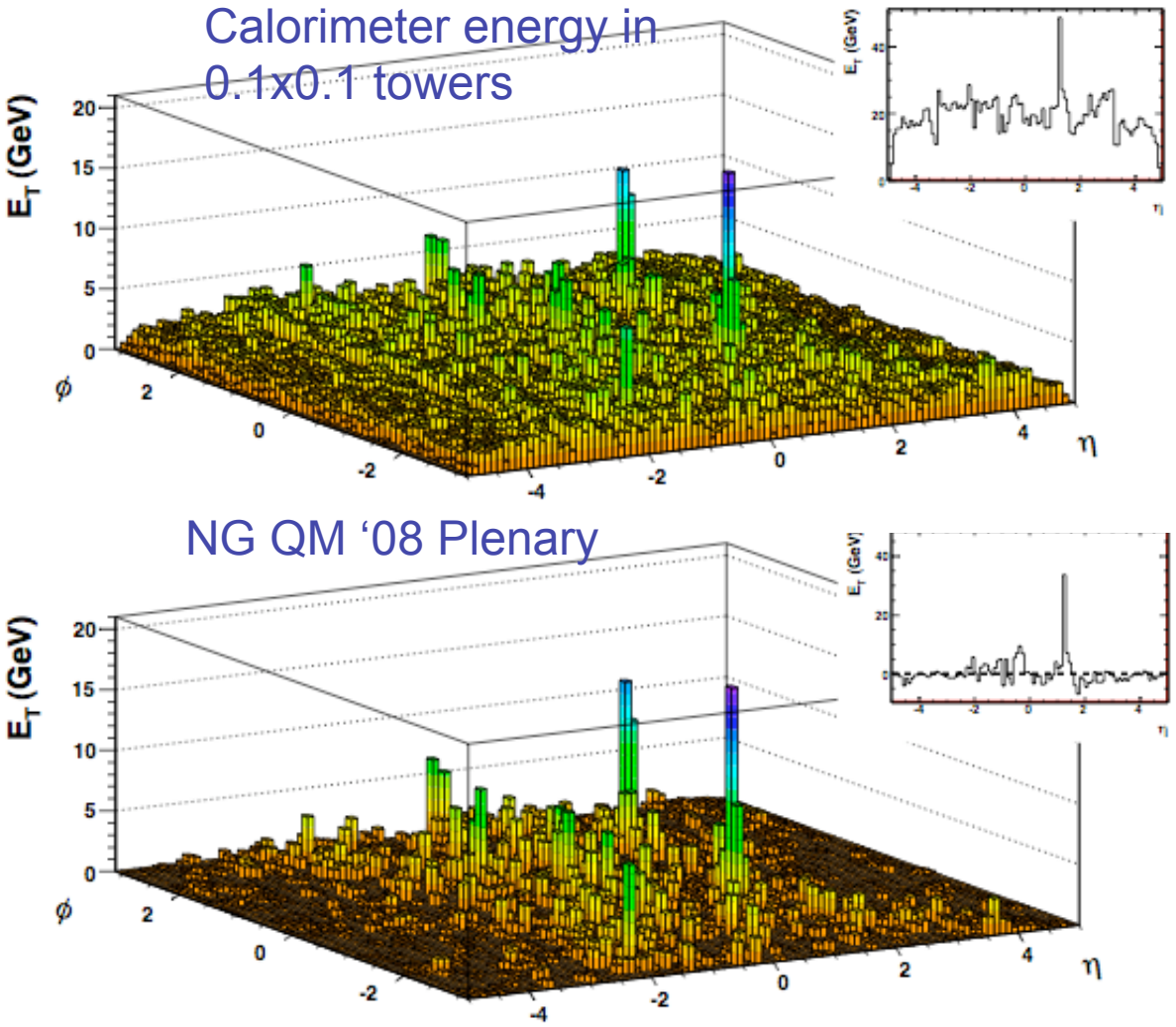
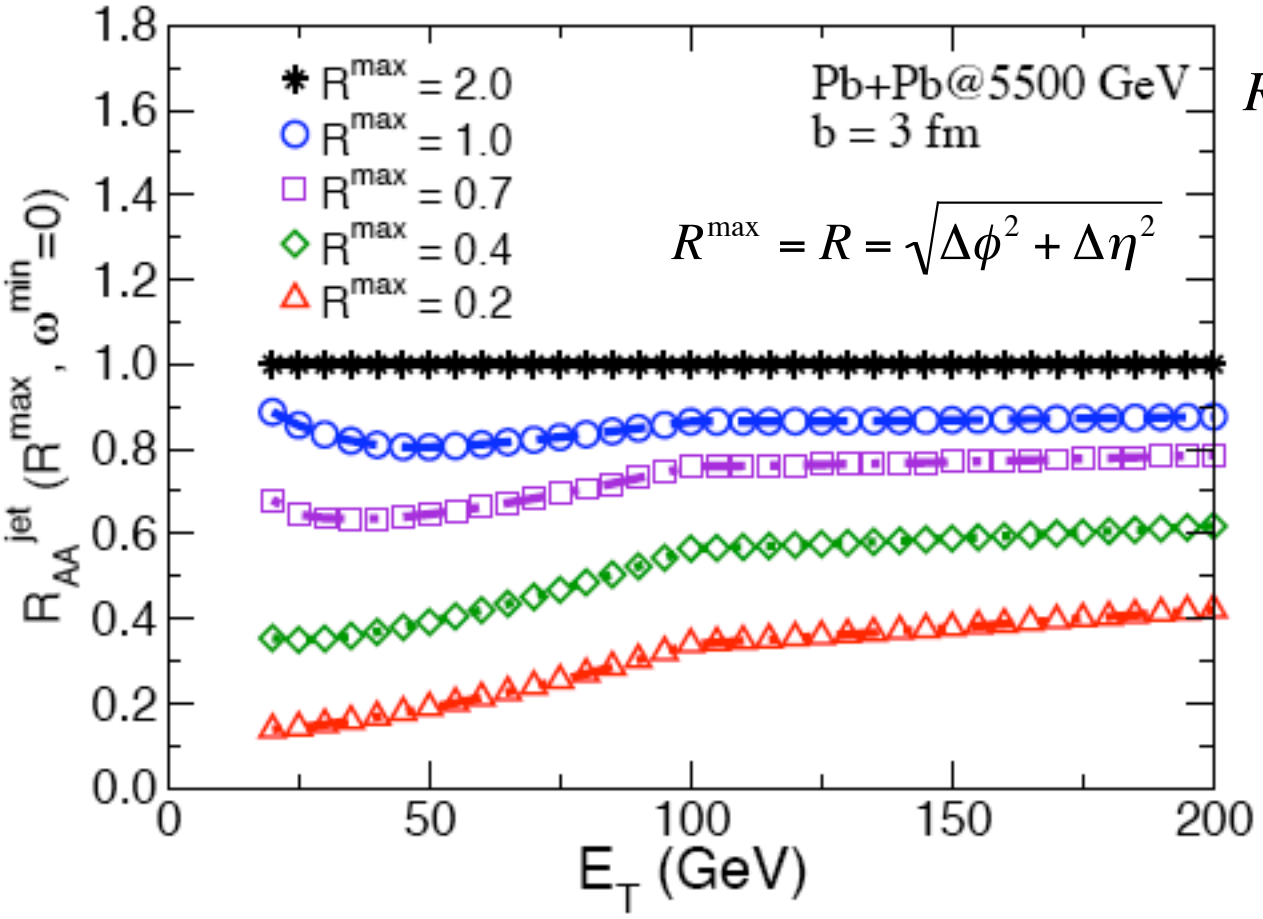
Parameters	Potential Bias
• Seed p_T - initial positions	• Leading particle bias a la RHIC
• R - cone radius	• Out of cone radiation
• Convergence/Overlap	• Non-cone structures, hard radiation

Cone Jet Reconstruction: HI Events



- Embed full PYTHIA di-jet events into HIJING events at 5.5 TeV
- Subtract underlying event pedestal
  - event-by-event
  - layer-by-layer
  - η dependent

Differential Studies of Jet R_{AA}

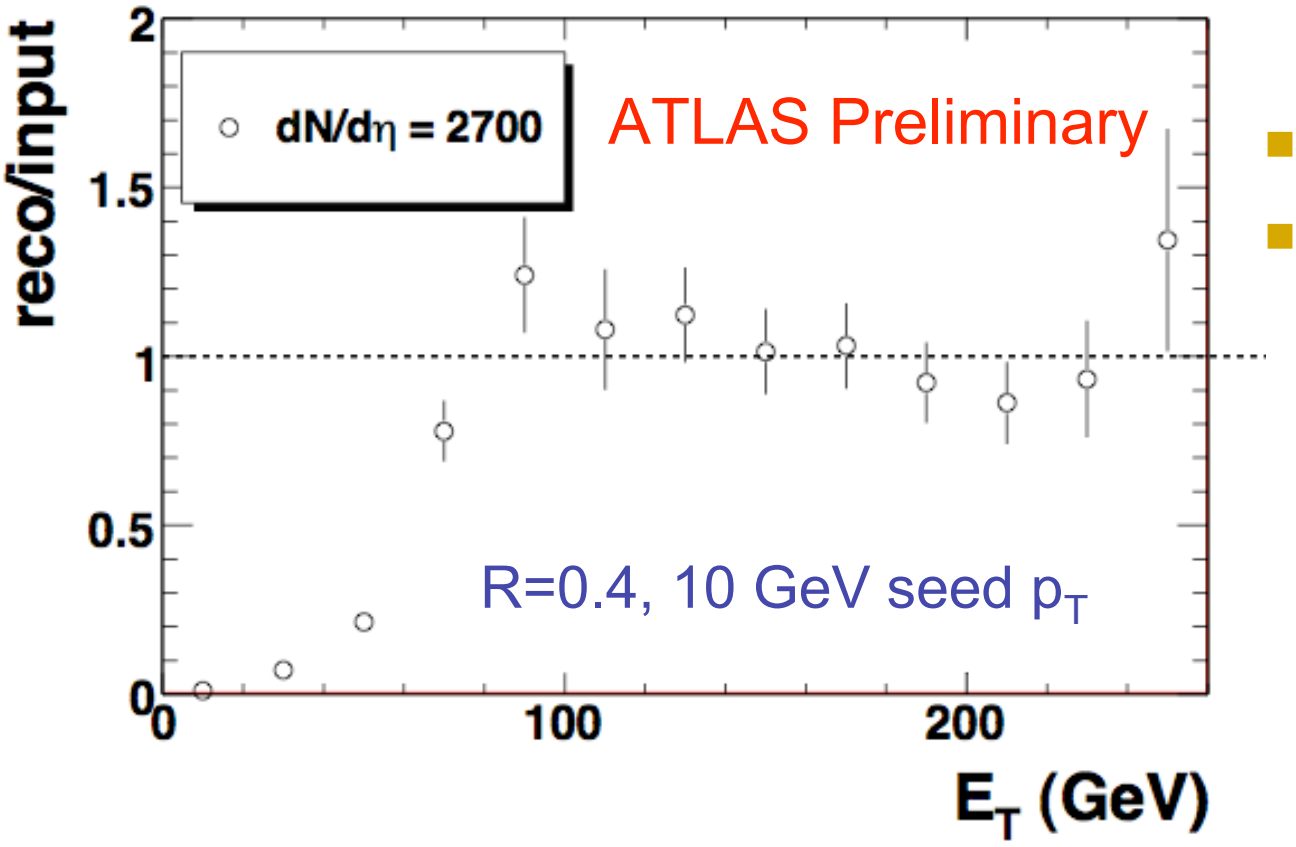


$$R_{AA}^{jet} = \frac{Pb + Pb \text{ Jet Yield}}{\langle N_{coll} \rangle p + p \text{ Jet Yield}}$$

- All energy lost is recovered: $R_{AA}^{jet} = 1$
- Out of cone radiation will reduce R_{AA}^{jet}
- Measurable by measuring jets with different R

Vitev, Wicks, and Zhang JHEP **11** (2008) 093

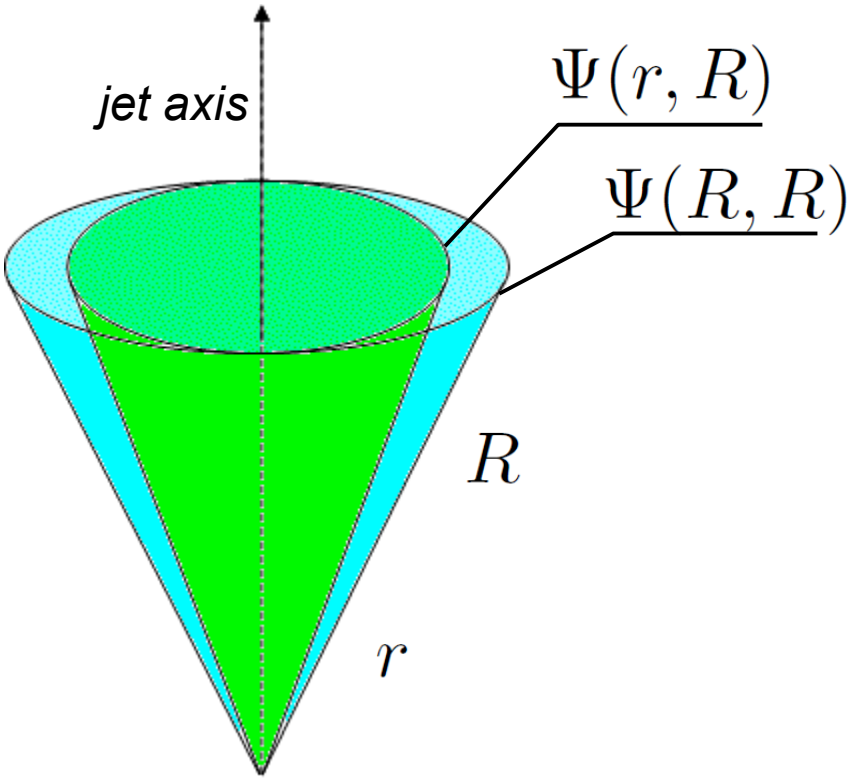
ATLAS Sensitivity for Jet R_{AA}



- Ratio ~20%
- Will be sensitive to this level of effects from perturbative energy loss on R_{AA}^{jet}

Reconstructed spectrum uncorrected for efficiency and energy resolution

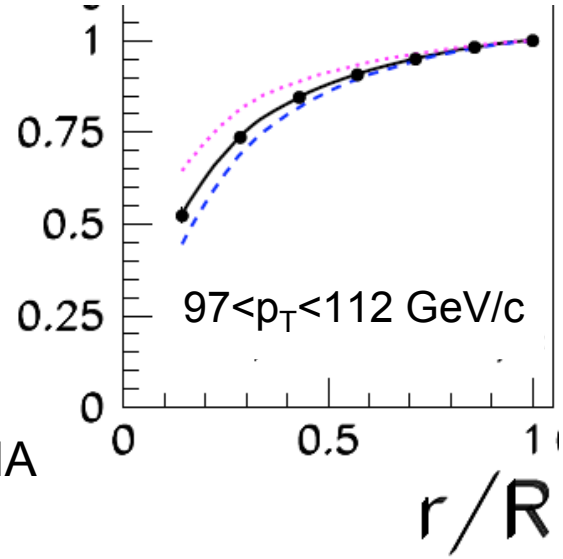
Jet Shapes



Fractional Energy contained within a radius r

Integral

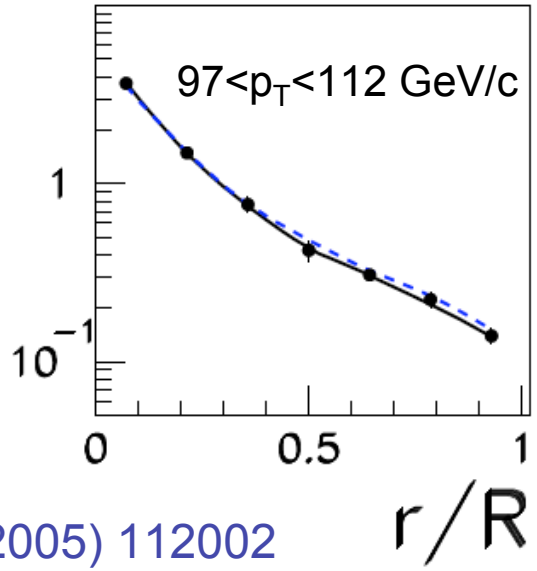
$$\Psi(r,R) = \frac{\int_0^r \frac{dE_T}{d\rho} d\rho}{\int_0^R \frac{dE_T}{d\rho} d\rho}$$



Comparison to PYTHIA
Red dotted - gluon
Blue dashed - quark

Differential

$$\psi(r,R) = \frac{d\Psi}{dr}$$

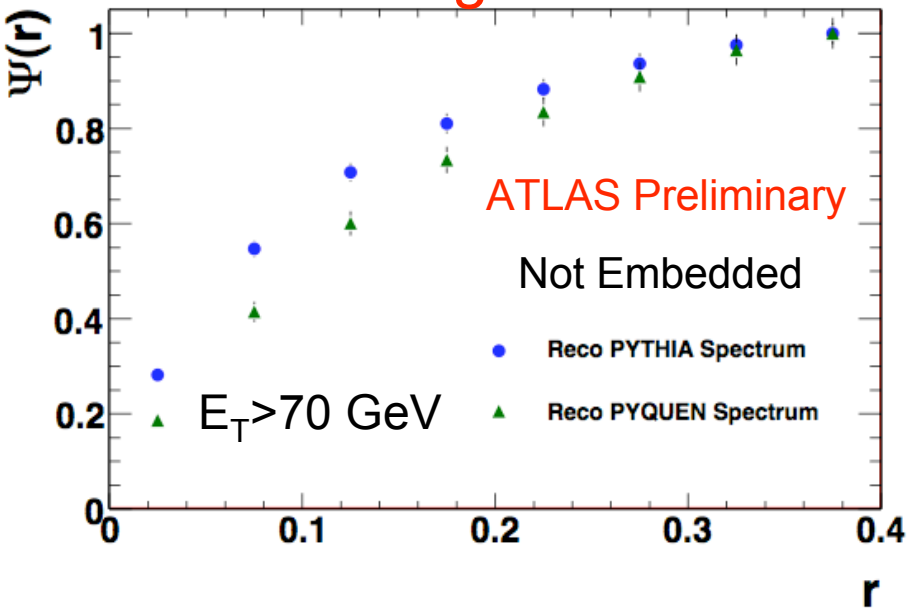


CDF Collaboration PRD 71 (2005) 112002

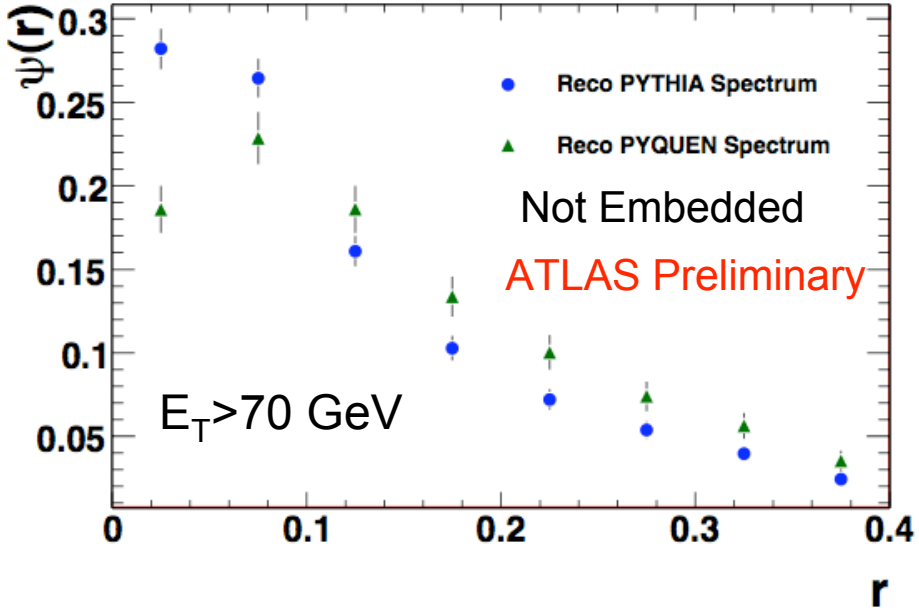
Jet Shapes in ATLAS

M. Spousta High p_T @ LHC '09

Integral

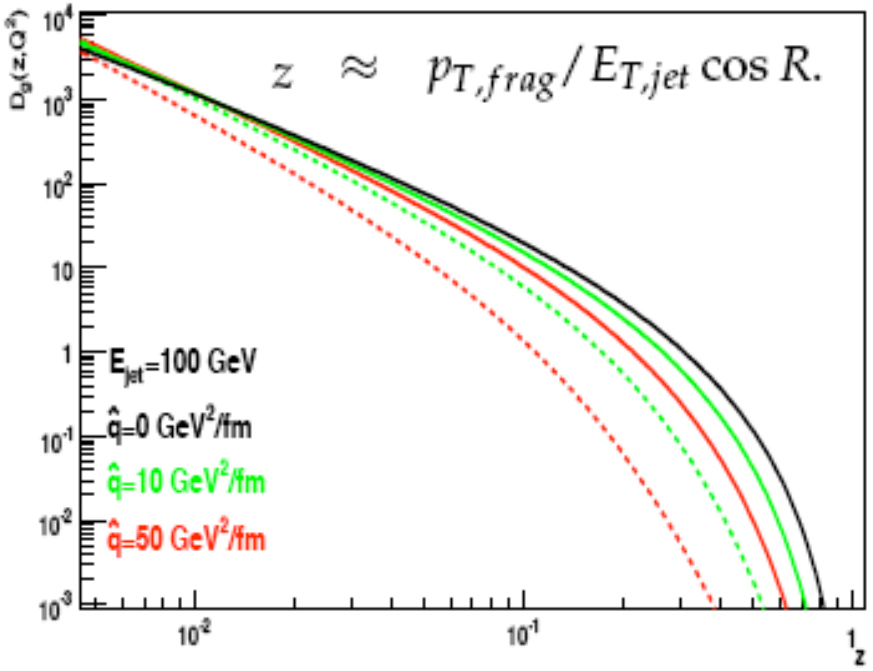


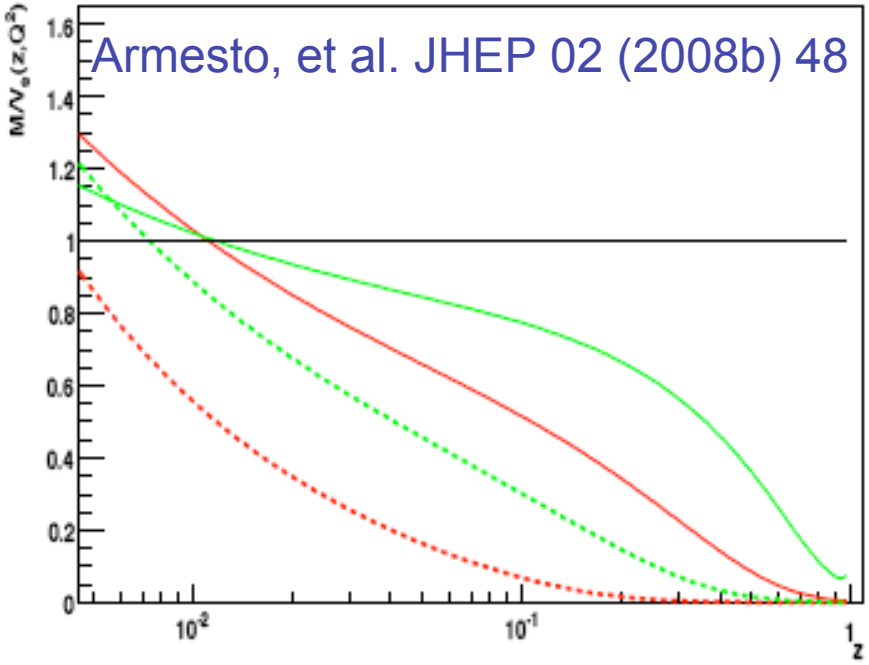
Differential



- Integral and Differential jet shapes in PYTHIA and PYQUEN
- Energy loss modifies these distributions
  - Energy transferred from center to periphery of the jet

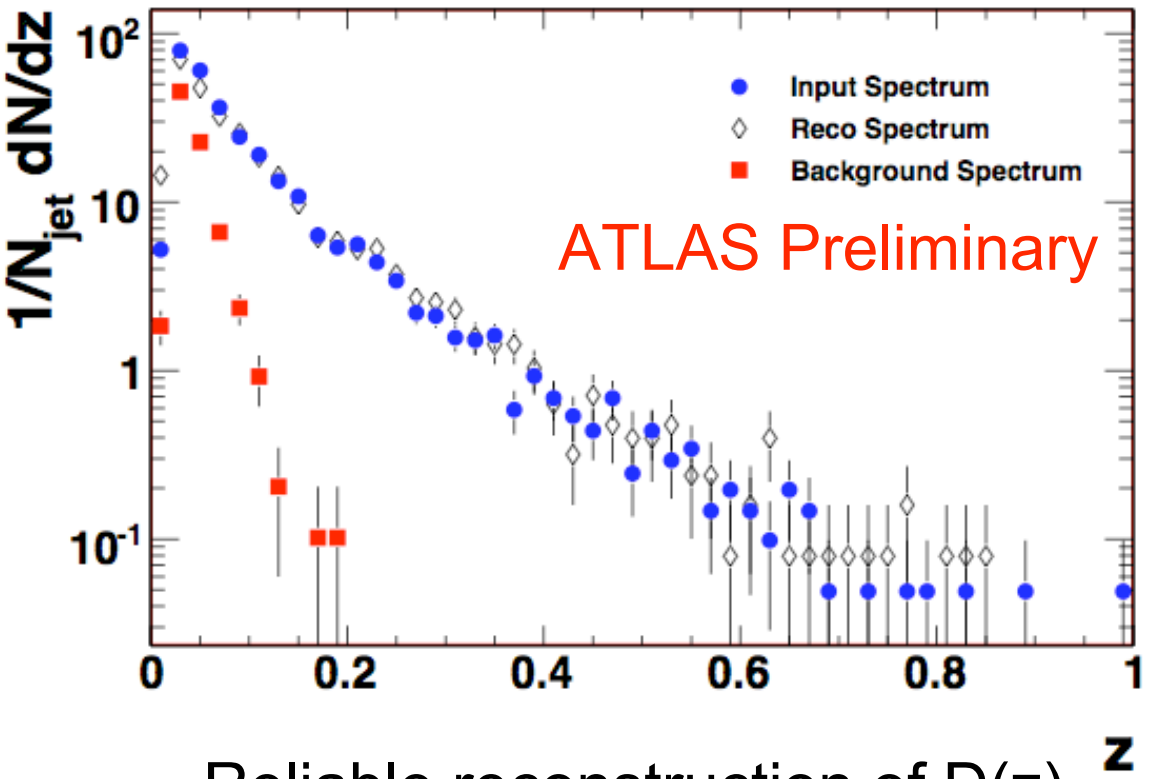
Fragmentation Functions: D(z)





- High momentum fragments lose energy and are measured at low z.

Fragmentation Functions: D(z)

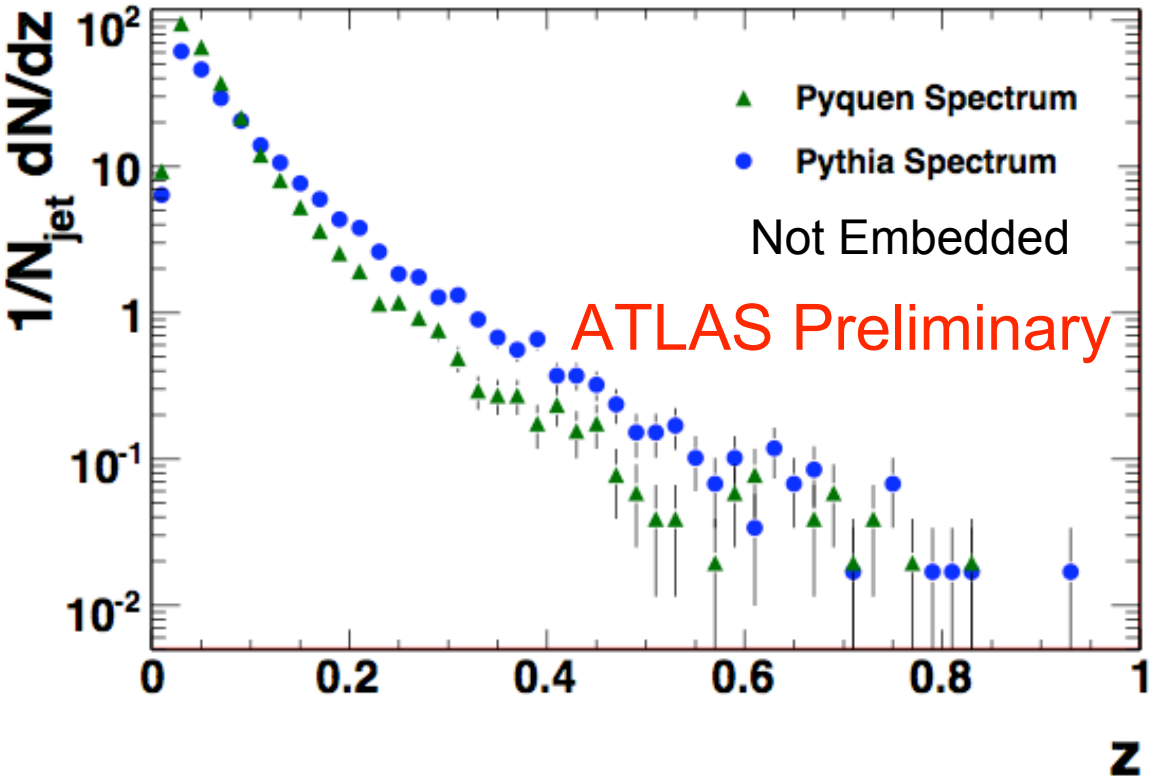


Reliable reconstruction of D(z) **before any corrections** to the reconstructed spectrum.

NG QM '08 Plenary

- Extrapolate reconstructed tracks to match jets in the calorimeter
- Cut on p_T>2 GeV
- Lower p_T cut sensitive to recovered energy but has more background.
- Background from tracks in underlying HIJING event not associated with the jet.

ATLAS Sensitivity to D(z) Modification



- Compare reconstructed PYTHIA and PYQUEN jets
- Modification from PYQUEN is apparent
- Well within ATLAS ability to measure before corrections.

Recall: Embedding doesn't modify fragmentation function appreciably

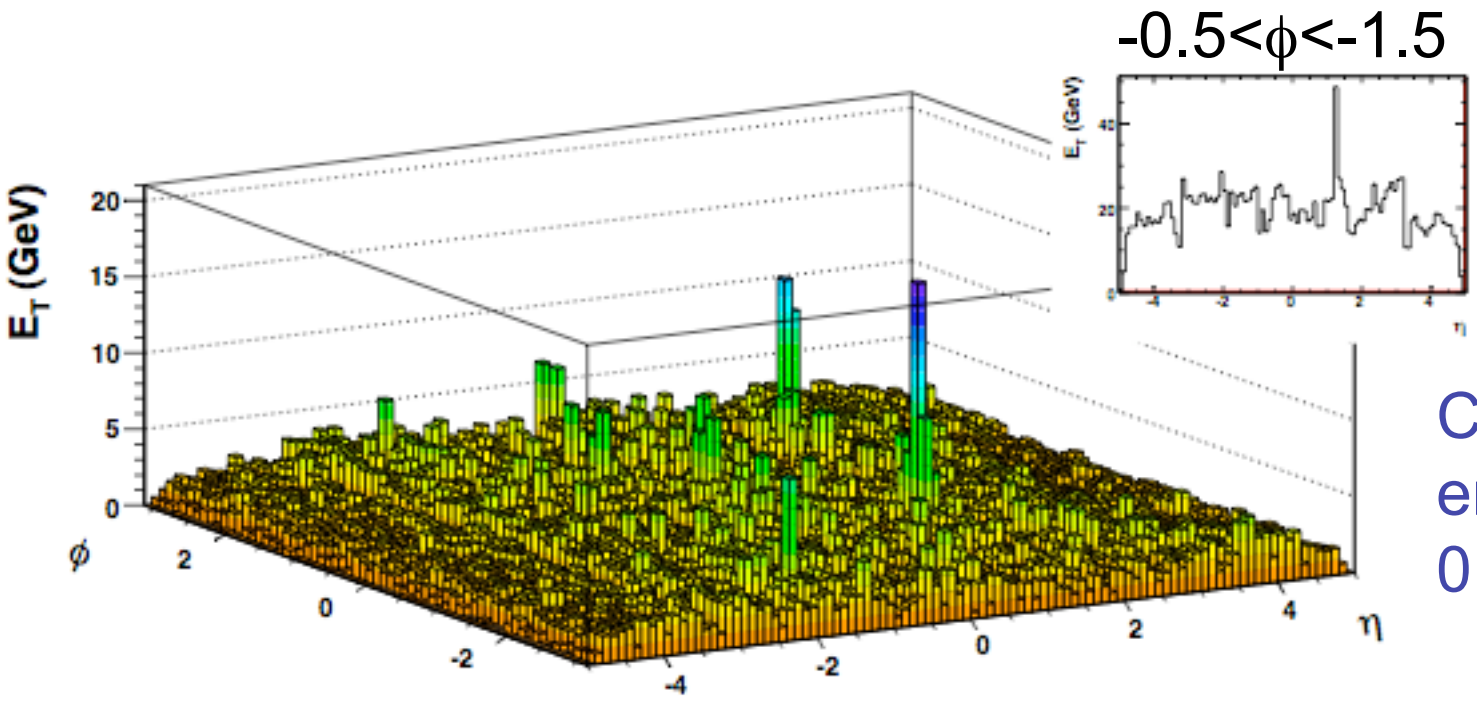
M. Spousta High p_T @ LHC '09

Summary

- Jets offer more handles and variables to study energy loss than single and di-hadron measurements
- Differential studies of jet R_{AA}, jet shapes, D(z) (and many others) will be sensitive to different aspects of energy loss
- Energy loss models will be rigorously tested when required to reproduce these various results.

Backup

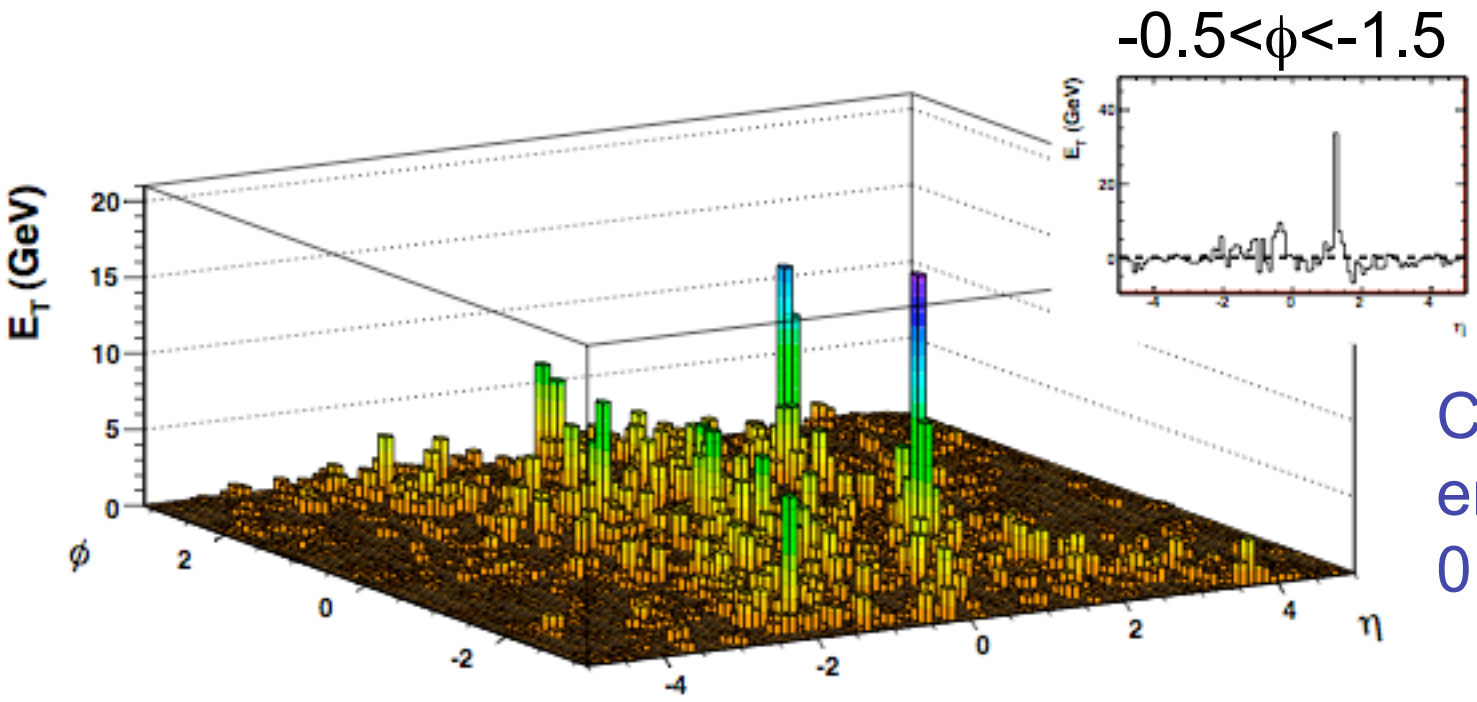
Cone Jet Reconstruction: Embedding



Calorimeter energy in 0.1x0.1 towers

- Pythia di-jets embedded in unquenched HIJING
  - Lots of correlations: Mini-jets, c-cbar, b-bbar, longitudinal strings, etc.

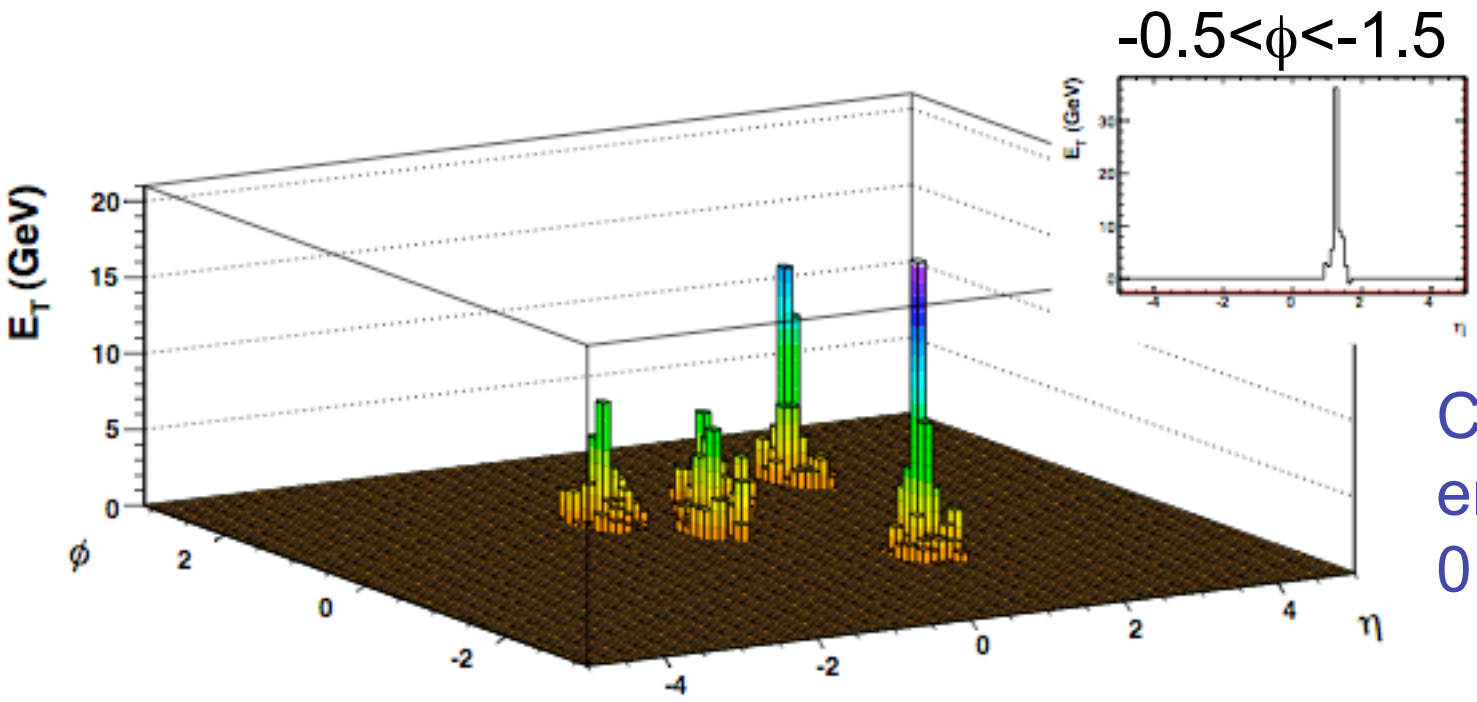
Cone Jet Reconstruction: Subtraction



Calorimeter energy in 0.1x0.1 towers

- Remove <E_T> layer-by-layer and vs. η

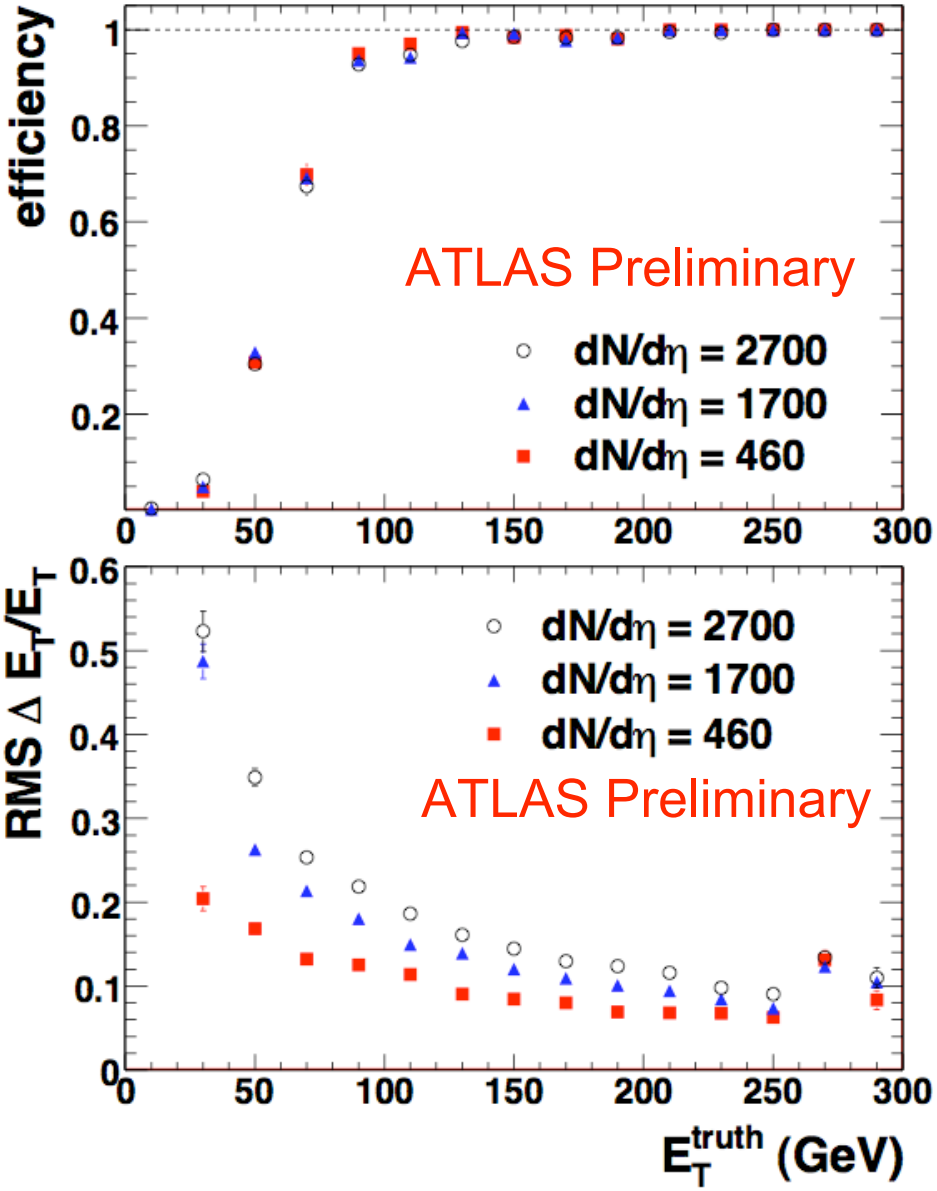
Cone Jet Reconstruction: Jets

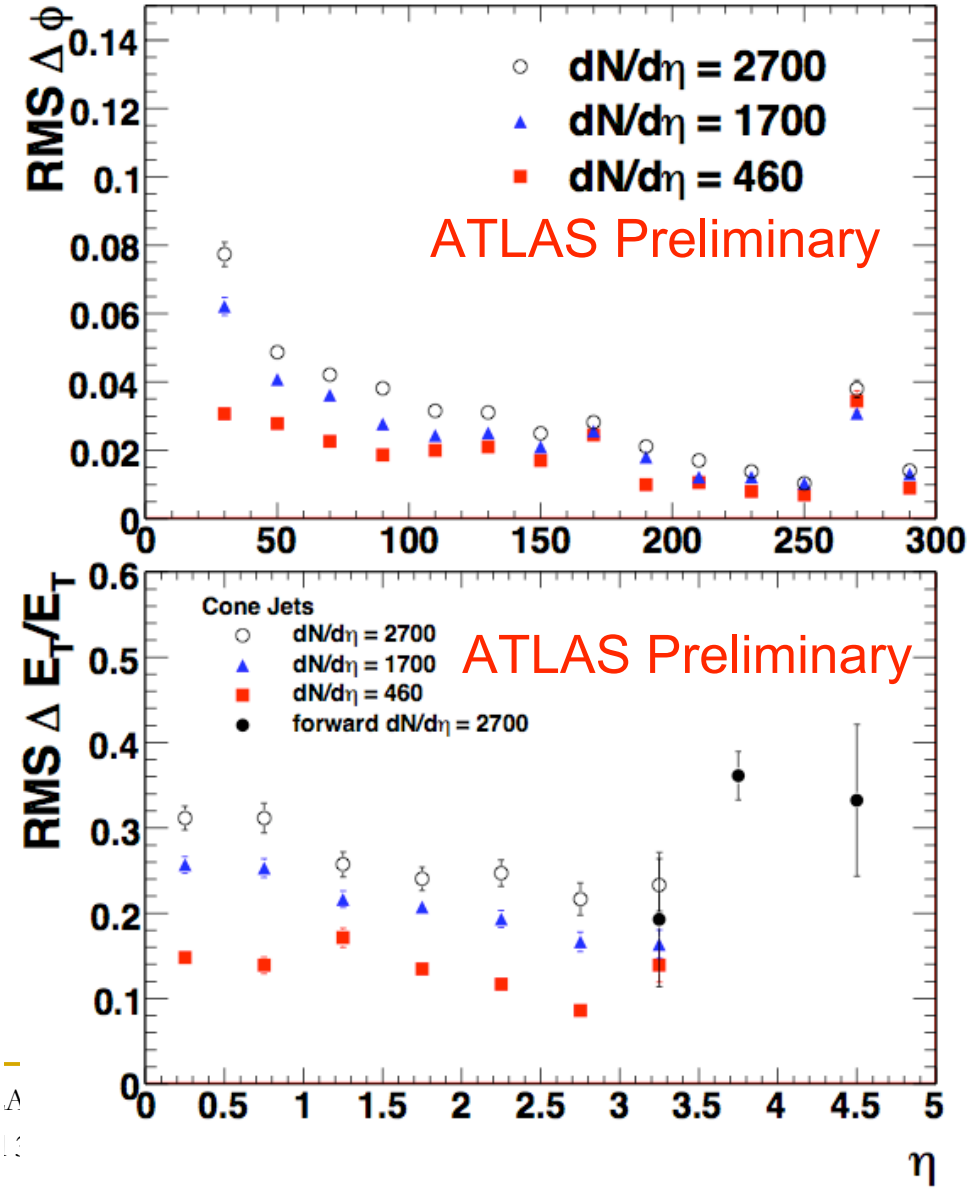


Calorimeter energy in 0.1x0.1 towers

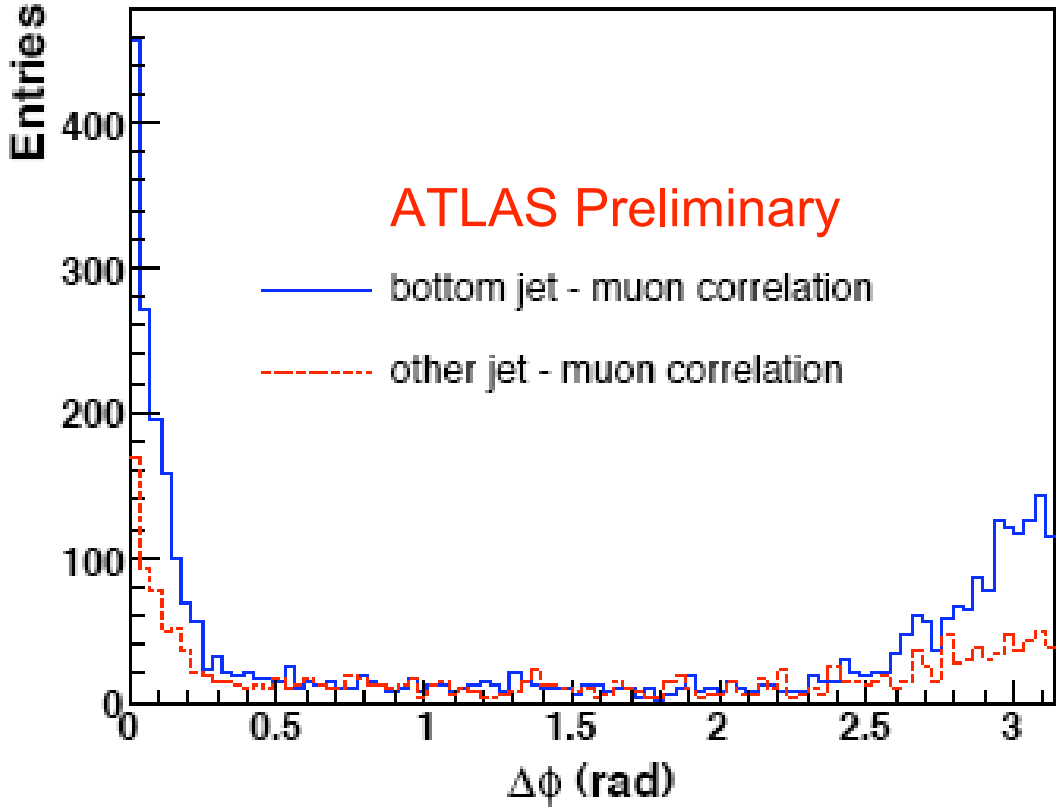
- Use Seed E_T = 5 GeV, R=0.4 split/merge fraction = 50%
- Reliably reconstruct the input jets

Cone Jet Reconstruction Performance



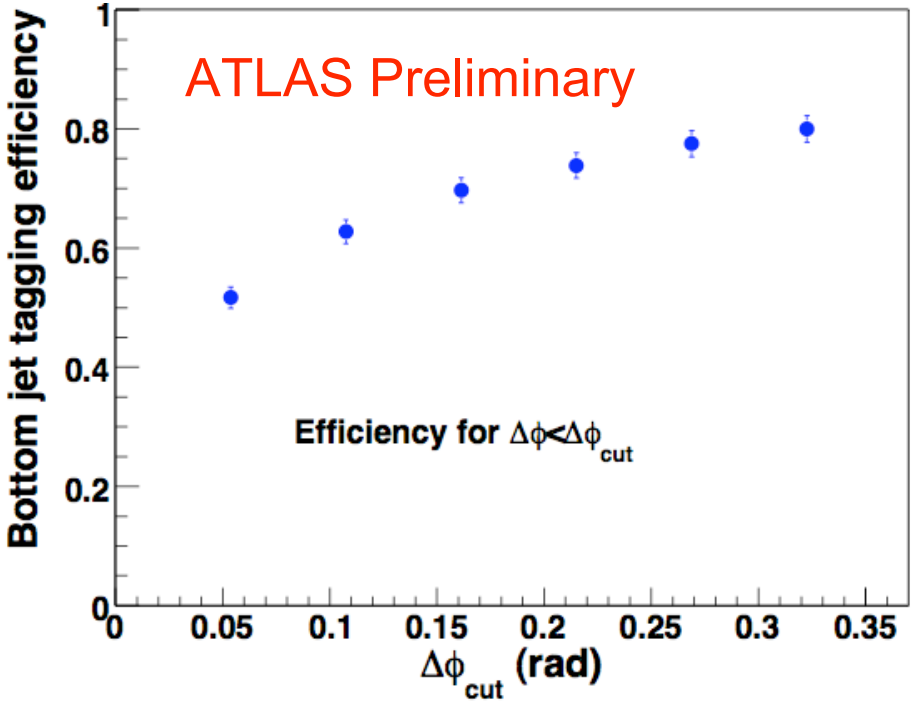


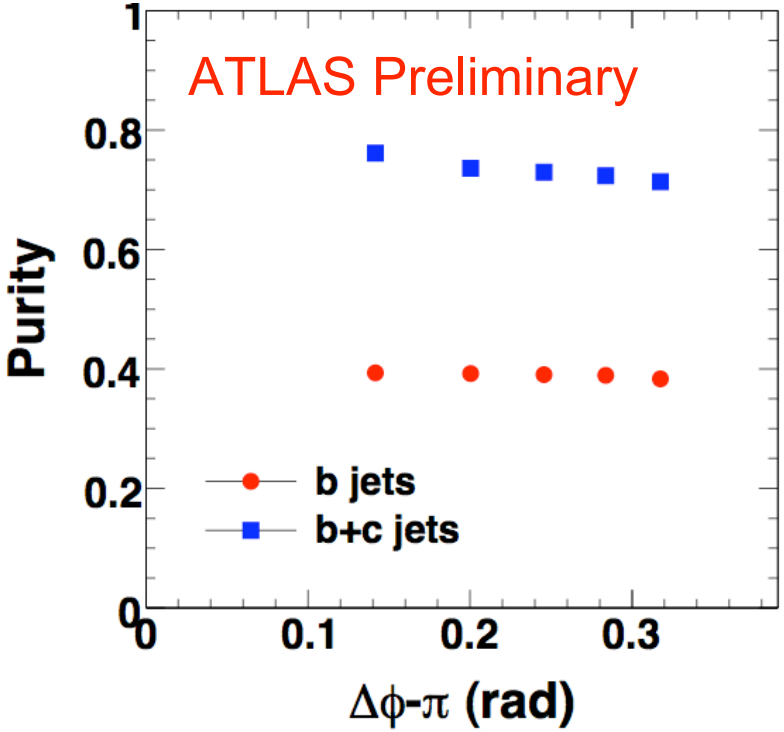
Heavy Flavor Tagging with Muons



- Correlate a high-p_T (5 GeV) muon with a reconstructed jet
- $\Delta\phi = 0$ tagged same jet
- $\Delta\phi \sim \pi$ tagged recoil jet

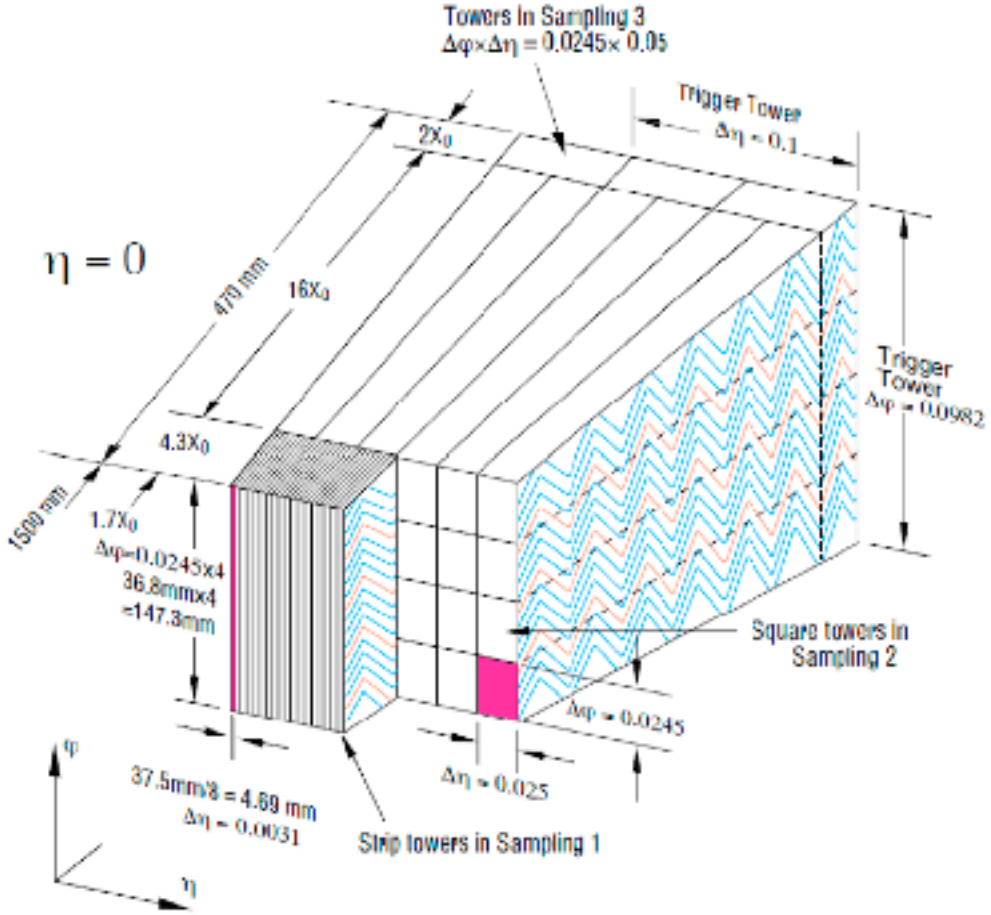
Heavy Flavor Tagging with Muons

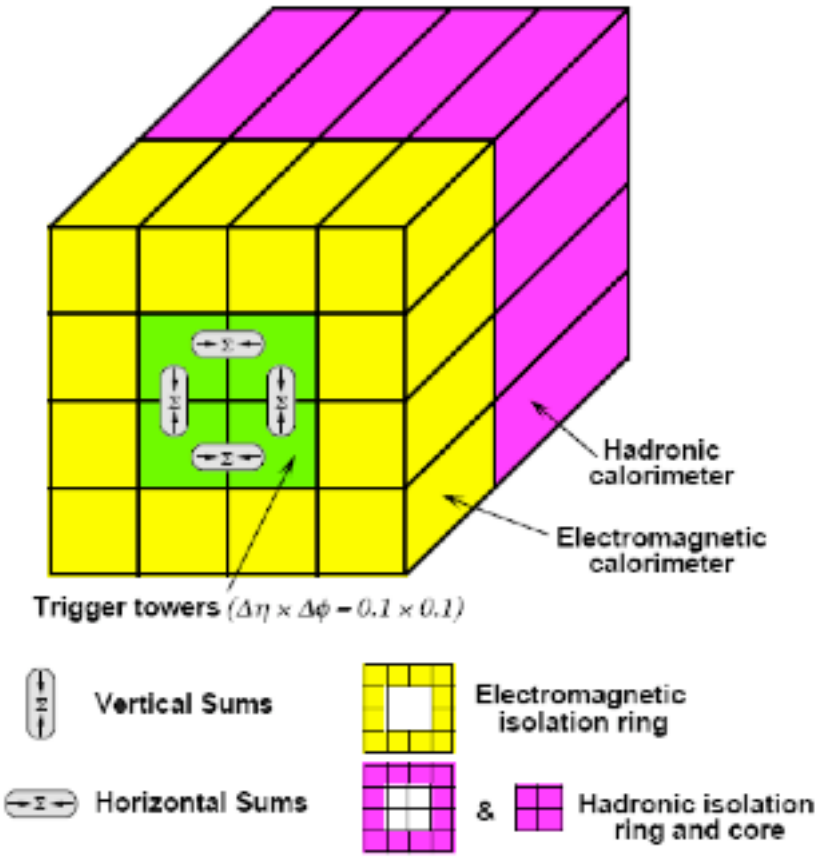




- Efficiency of tagging a bottom jet based on the $\Delta\phi$ between the jet and muon: 80%
- Purity of heavy flavors with a muon tag: 70%

ATLAS Level 1 Calorimeter Triggers



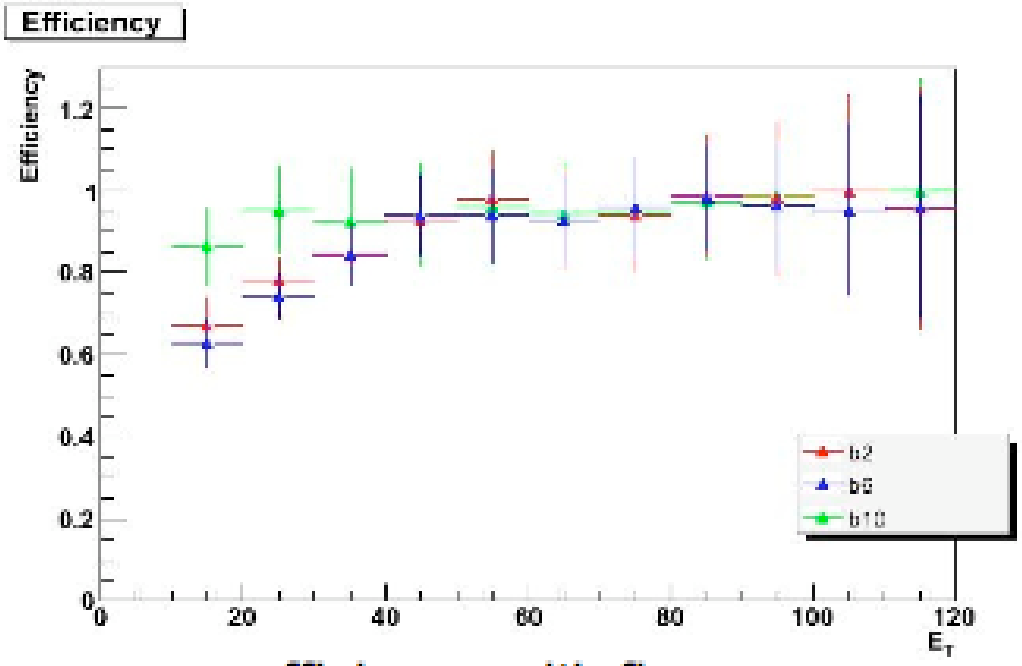


- HI rate doesn't require rejection at Level1
- ATLAS requires trigger at Level1 to define a Region of Interest (RoI) to be processed at Level2

ATLAS Level 1 Calorimeter Triggers

- eγ
  - 0.1x0.2($\Delta\eta$X$\Delta\phi$) EM > threshold
  - 0.2x0.2 hadronic core < threshold
- tau/hadron
  - 0.1x0.2 EM+hadronic > threshold
- Jet trigger
  - EM+hadronic 0.4x0.4 > threshold
  - 4 available thresholds
  - (No subtraction at Level1 is possible)

ATLAS HI Jet Trigger



efficiency with firmware modification - new redefined thresholds

- Set jet threshold based on total E_T at Level 1.
- Combine eγ+tau+jet
- Jet identification efficiency ~95% down to 40 GeV independent of centrality
- First attempt: improvement after further study is expected

M. Rybar High p_T @ LHC '09