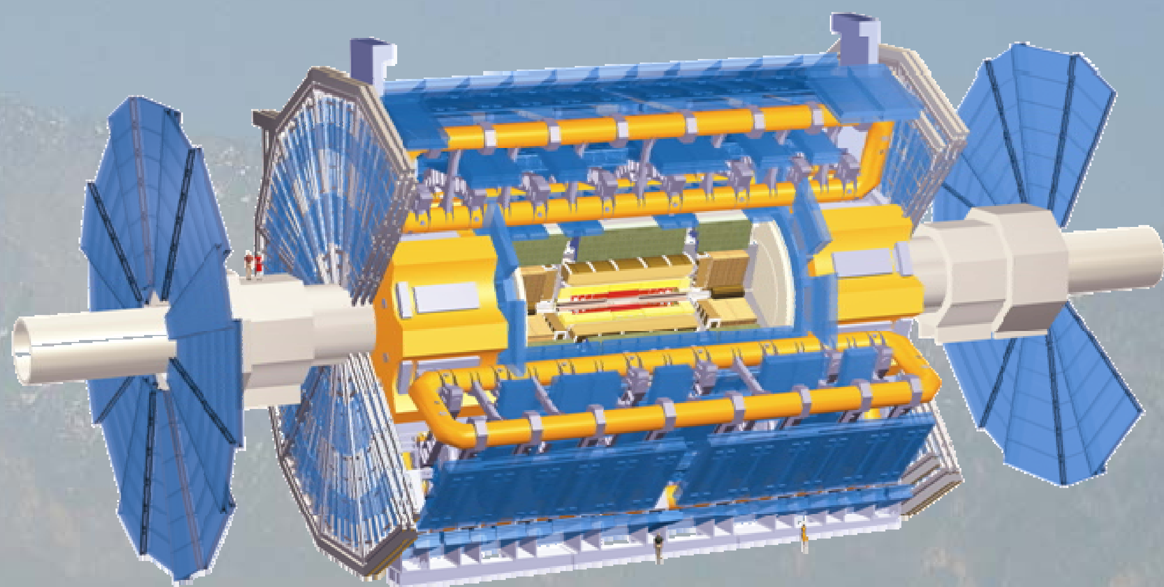
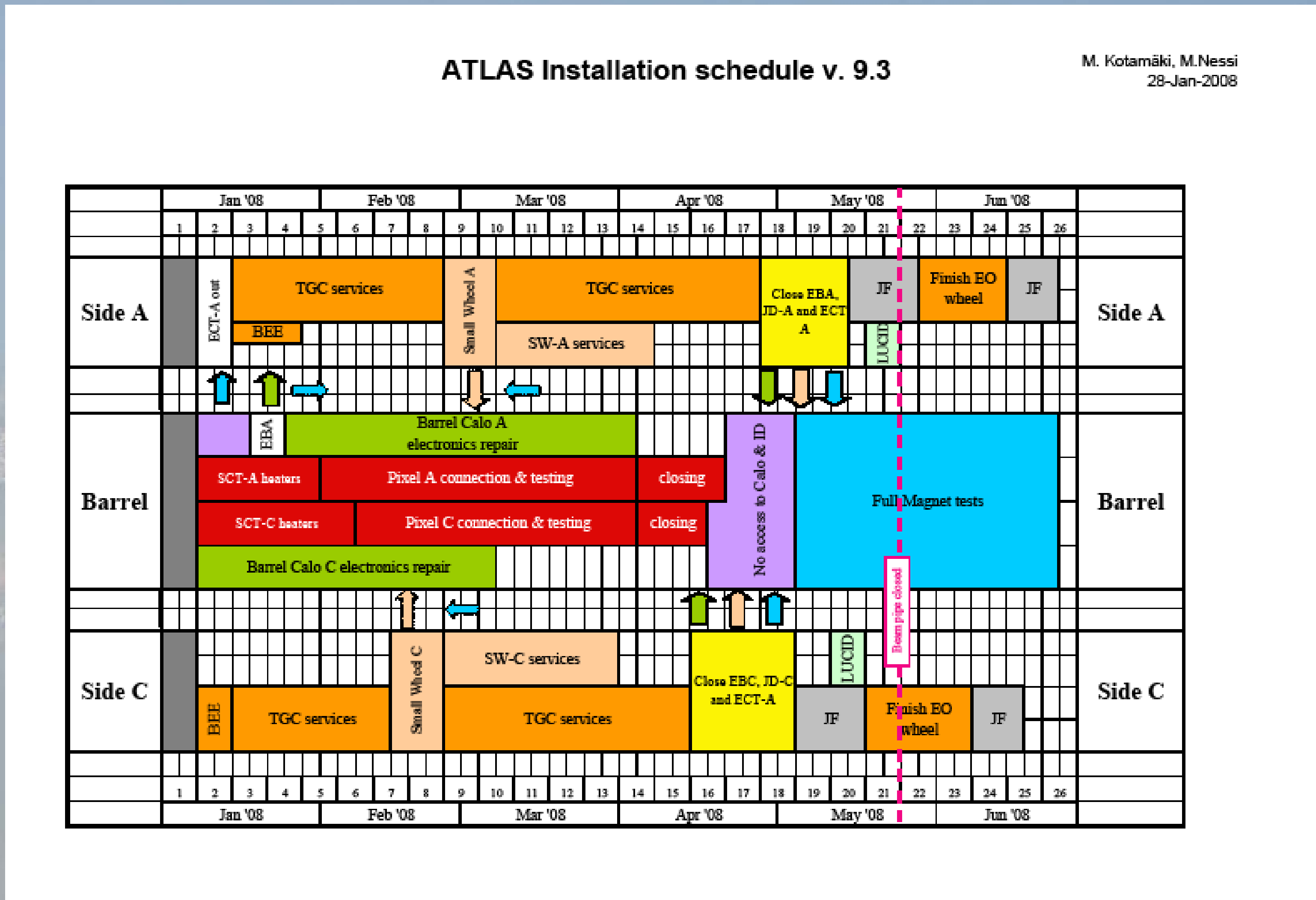
Parton fragmentation studies in ATLAS



Jiri Dolejsi (Charles University Prague)
for ATLAS collaboration

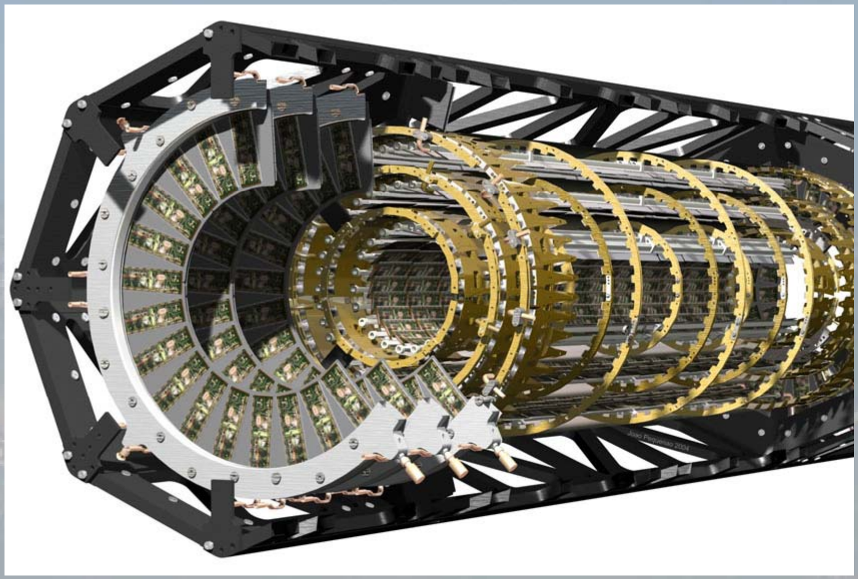
ECT* Trento, 28 February 2008

Progress in installation



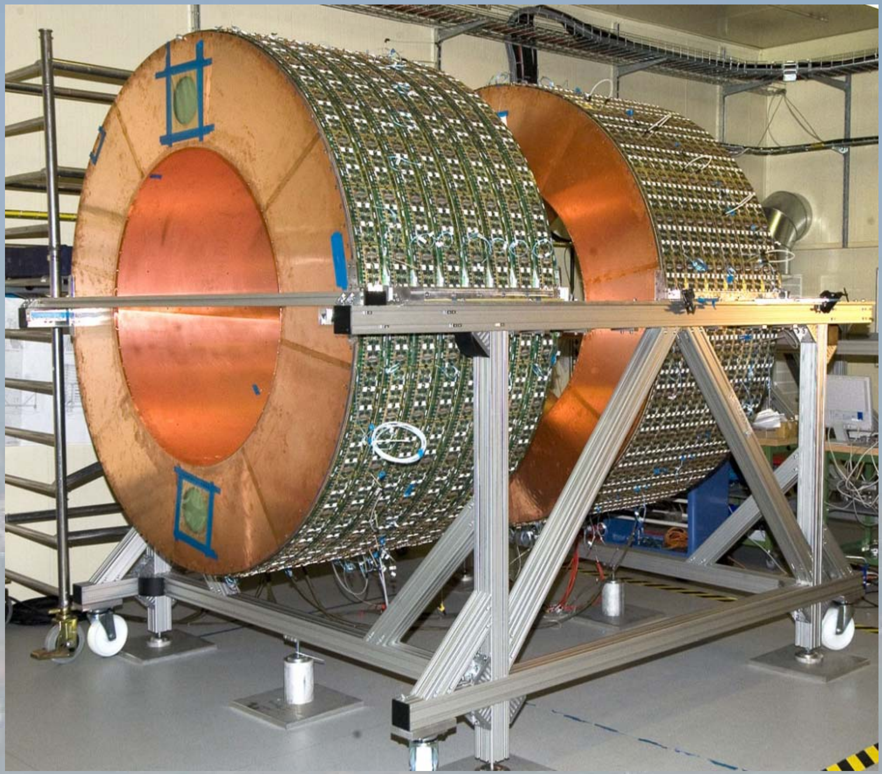
Progress in installation

The **inner detector** will trace the individual tracks, count and measure them, cooperate with outer shells to measure flow, quarkonia, particle content of jets and much more.

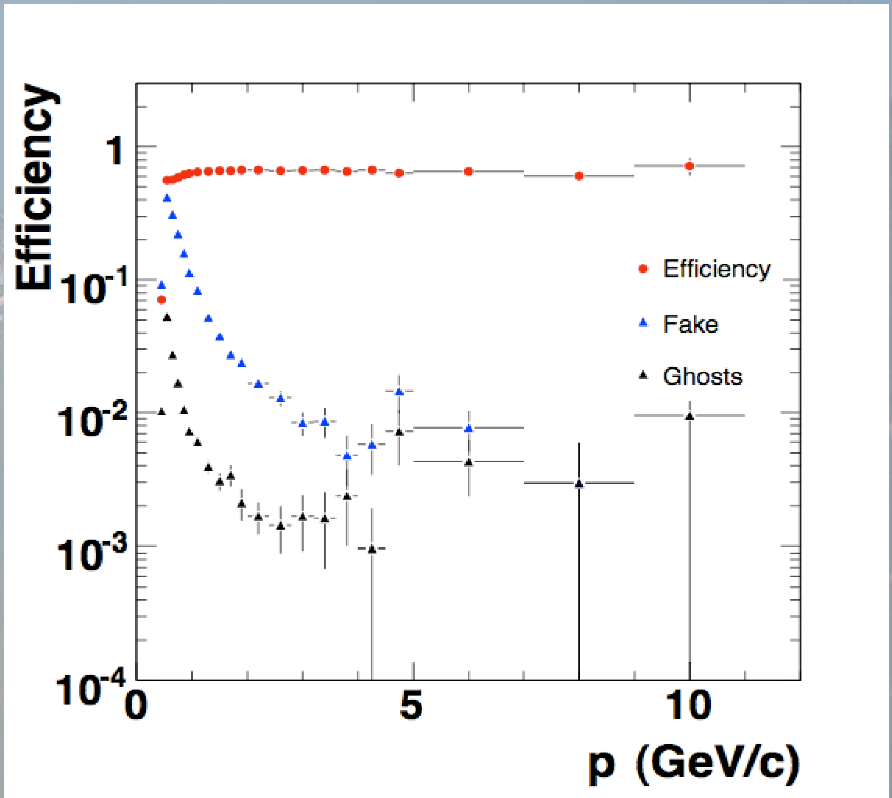


Pixel detector −3 layers
with less than 2% occupancy and **SCT** with 4 double-sided strip layers (and 9 wheels on each side) with less than 20% occupancy (@ $dN/d\eta \approx 3000$) are well capable of tracking.

Progress in installation



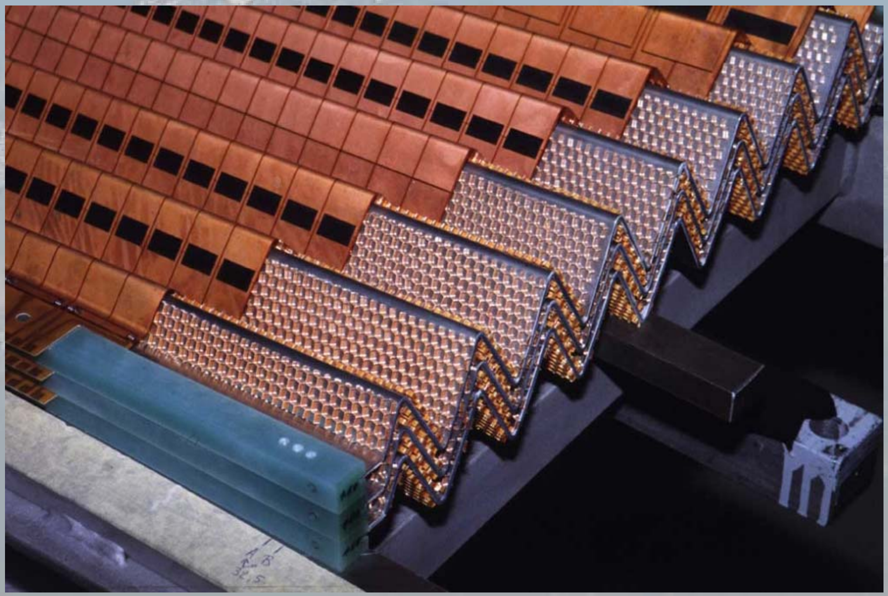
Simulations show reasonable tracking performance even in difficult heavy ion collision.



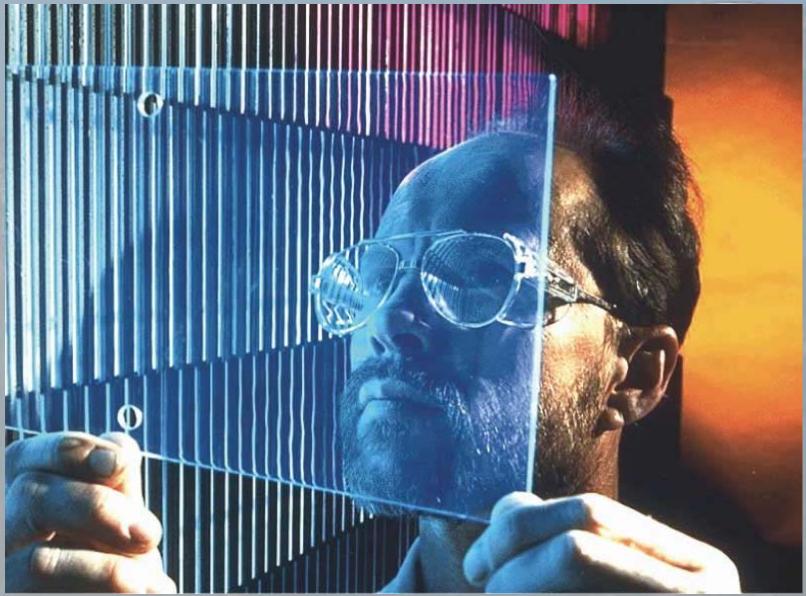
The Transition Radiation Tracker (**TRT**) will be overcrowded in central PbPb collisions but will be probably usable in peripheral ones.

Progress in installation

Electromagnetic and hadronic calorimeters will catch the intensive flow of particles/energy from PbPb collisions and can record high E_T jets. (estimated "background" is 3−4 GeV for high multiplicities per calorimeter tower $\Delta\eta\times\Delta\phi$ = 0.1×0.1, cells have finer granularity)



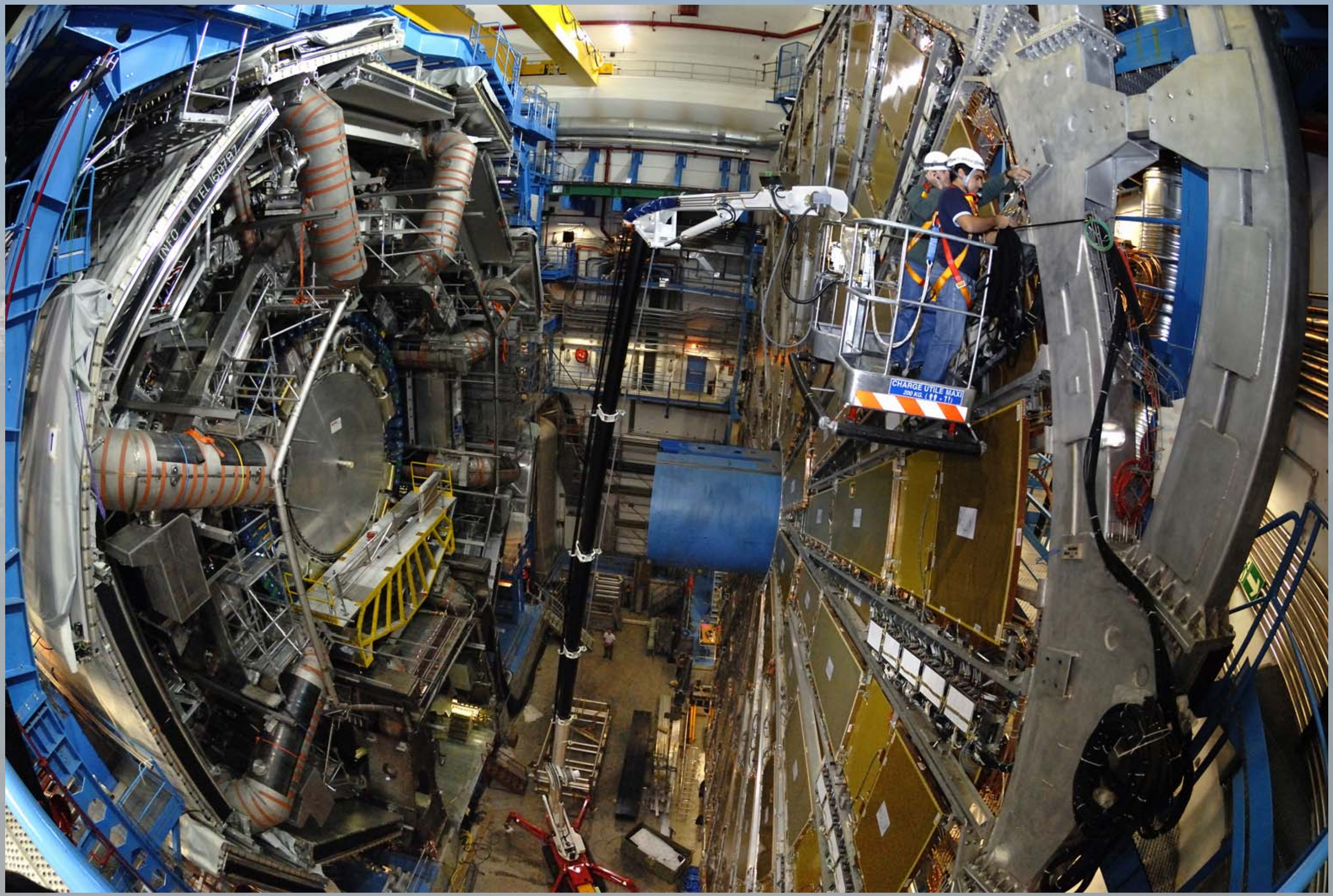
Accordion structure of the barrel liquid argon EM calorimeter



Scintillating tile of the barrel hadronic calorimeter

Progress in installation

The muon system (in cooperation with inner detector)
can identify muons from onia decays, detect muons from b-jets etc.



Most of the space between barrel toroids (left) is equipped with muon chambers, here "Big Wheels" with muon detectors are assembled.

Common objections

The ATLAS detector will burn when irradiated by heavy ions and by products of their collision.

NO! Although *PbPb* collisions will produce significantly more particles than *pp* (maybe about 3000 charged particles per unit rapidity at central region and very central events compared to about 200 in *pp* with the pileup), lead ions will be collided with much lower luminosity (10^{27} or about 4×10^{26} with all three experiments instead of 10^{34} for *pp*).
The *PbPb* event rate will be about 8 kHz instead of 40 MHz with pileup of more than 20 *pp* events, which makes life easier.

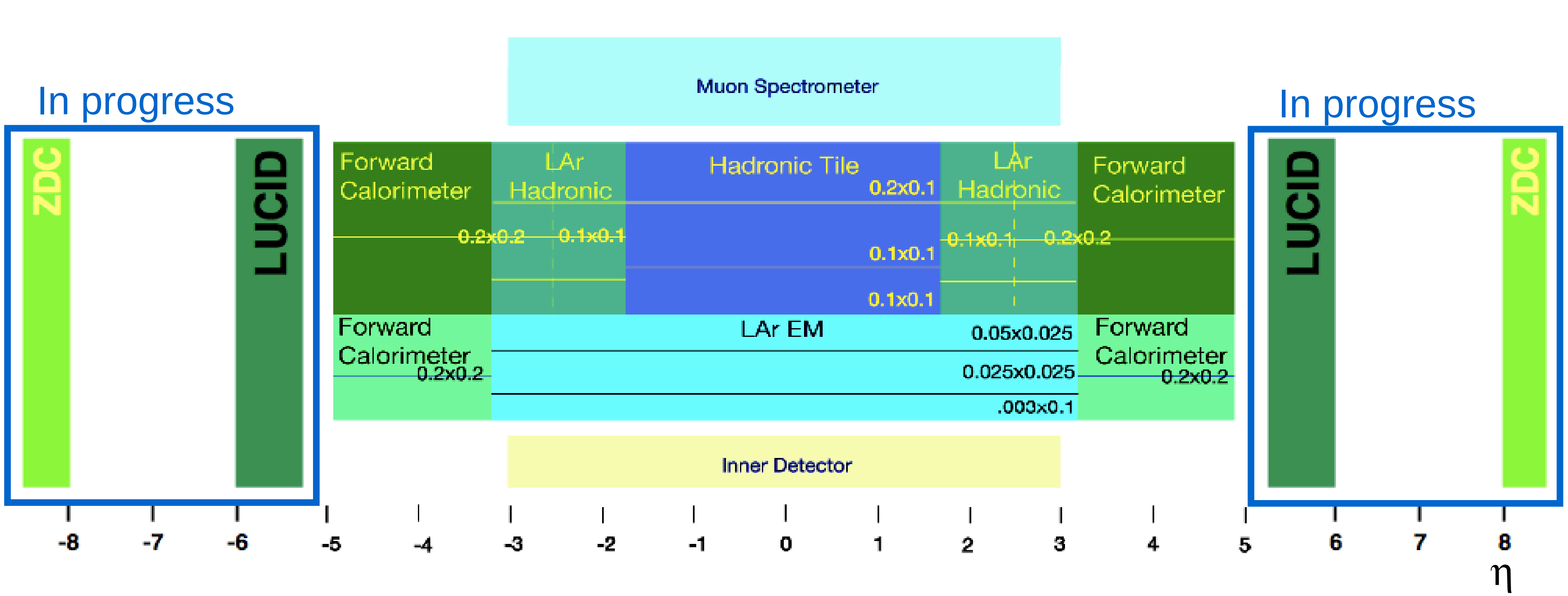
There is ALICE – dedicated heavy ion experiment, why CMS and ATLAS? They will only eat the luminosity!

NO! All experiments are different, with their strong and weak points. The field of heavy ions is crucially dependent on rich and reliable experimental data. What could be better than the fair scientific competition? The gain is worth the luminosity loss for ALICE alone.

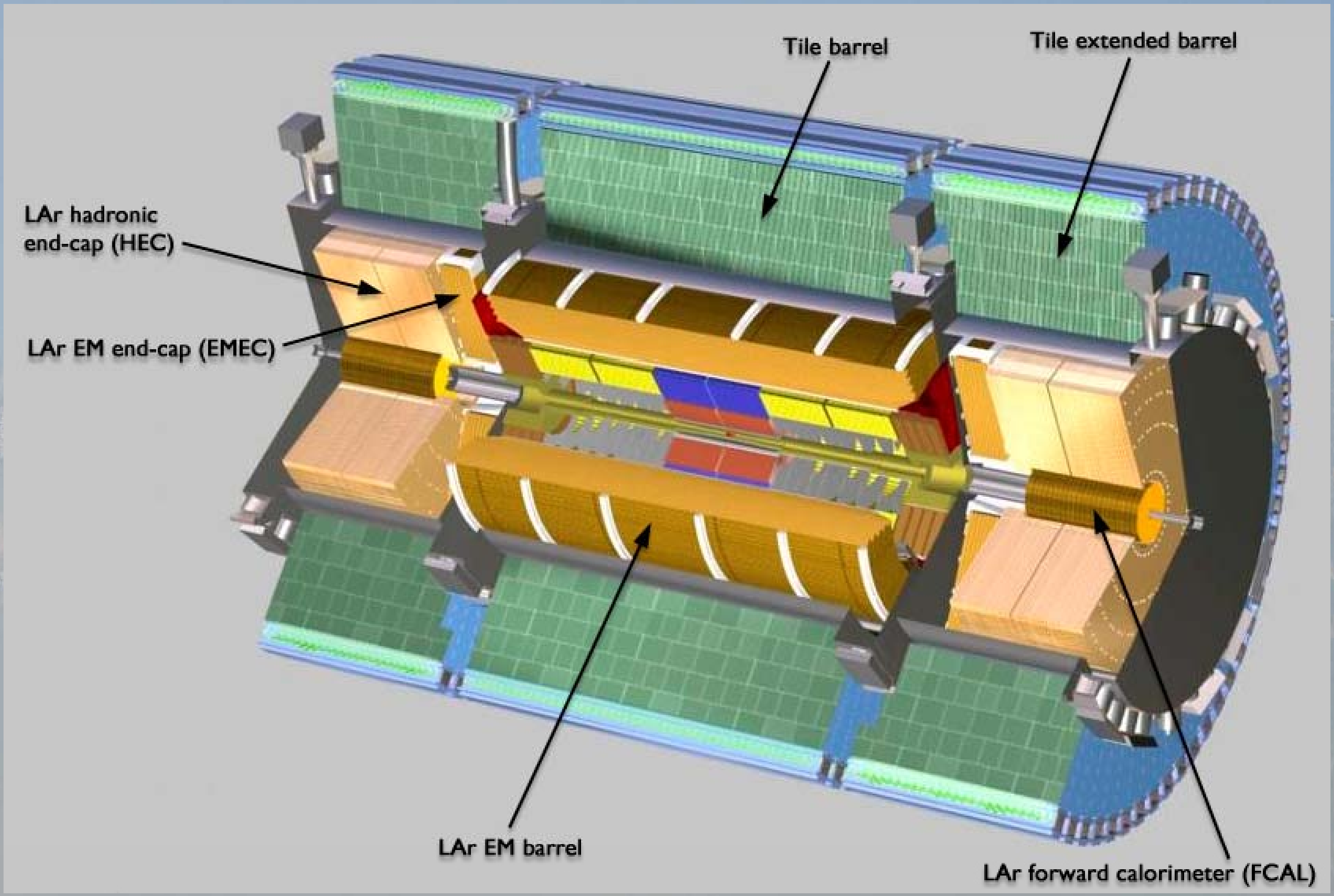
Common objections

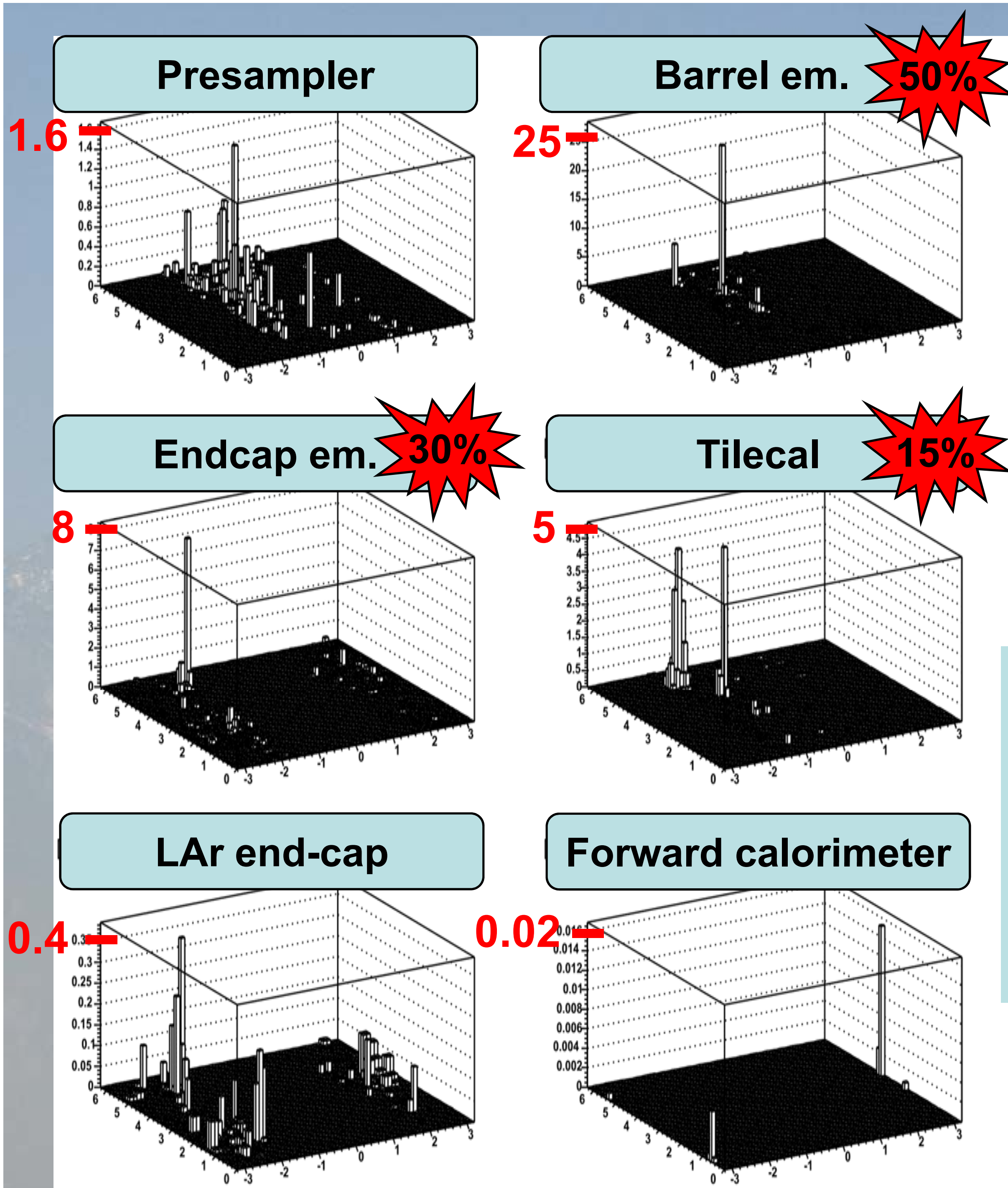
ATLAS is constructed as a sophisticated *pp* experiment. Its qualification for heavy ions is poor.

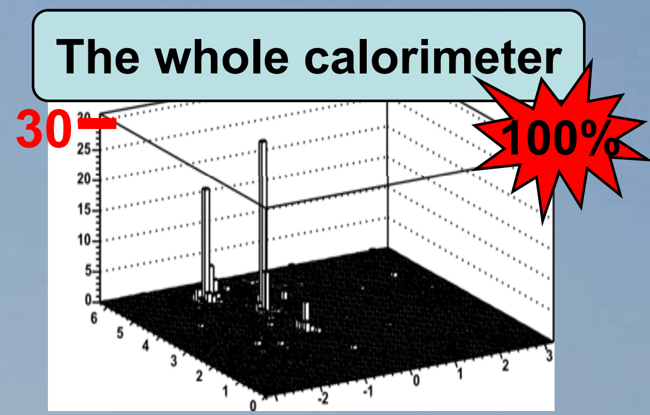
NO! Most features developed for pp physics could be used and will be used for heavy ion physics. E.g. calorimeters offering large coverage, fine granularity and longitudinal segmentation (3+3 layers).



Calorimeters at closer view







Population of different calorimeter layers from first ATLSIM studies.

Jets from Pythia simulated data from DC1 sample

$qq \rightarrow WH(120) \rightarrow \mu\, \nu_{\mu}\ uu$

ATLAS heavy ion working group

A. Ajitanand[10], A. Angerami[3], G. Atoian[11], M. Baker[1], P. Chung[10], B. Cole[3], R. Debbe[1], A. Denisov[5], J. Dolejsi[2], N. Grau[3], J. Hill[7], W. Holzmann[3], V. Issakov[11], J. Jia[10], H. Kasper[11], R. Lacey[10], A. Lebedev[7], M. Leltchouk[3], P. Nevski[1], R. Nouicer[1], A. Olszewski[6], A. Poblaguev[11], V. Pozdnyakov[8], M. Rosati[7], L. Rosselet[4], M. Spousta[2], P. Steinberg[1], H. Takai[1], S. Timoshenko[9], B. Toczek[6], A. Trzupek[6], F. Videbaek[1], S. White[1], B. Wosiek[6], K. Wozniak[6], M. Zeller[11]

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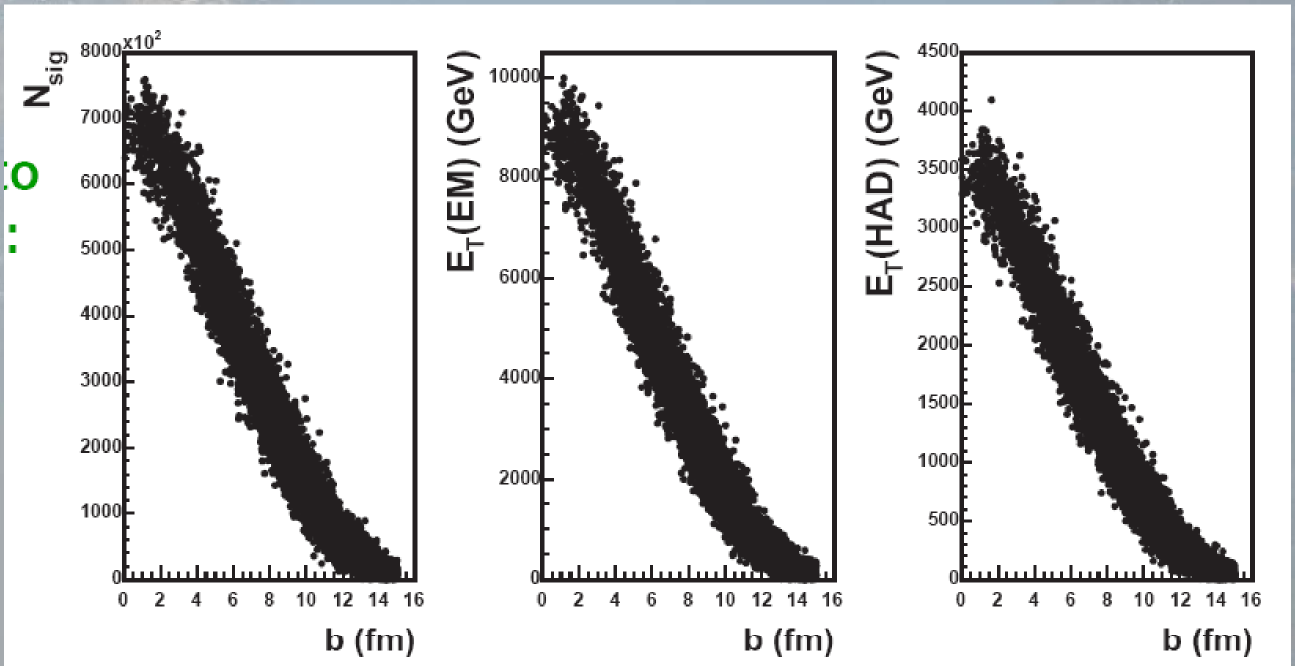
11 Yale University, USA

Illustration of physics tasks:

Global Event Variables

will represent the first-day measurements of $\mathbf{N_{ch}}$, $\mathbf{dN_{ch}/d\eta}$, $\mathbf{\Sigma E_T}$, $\mathbf{dE_T/d\eta}$, **b** and further will serve for studies of more subtle collisions features like the collective flow. Moreover, these variables are indispensable for almost all physics analyses.

Resolution of the estimated impact parameter ~1fm for all three considered systems – pixels and SCT, EM calorimeter and hadronic calorimeter.



Fragmentation …

Jets

There are theoretical predictions concerning the jet modifications in heavy ions collision, there is some kind of a summary … from the CERN workshop **Heavy Ion Collisions at the LHC Last Call for Predictions** (ArXiv 0711.0974v1),

but in my opinion **this area is driven by EXPERIMENTAL RESULTS,** see the RHIC story.

Our task:
To be ready to look for jets and their modifications …

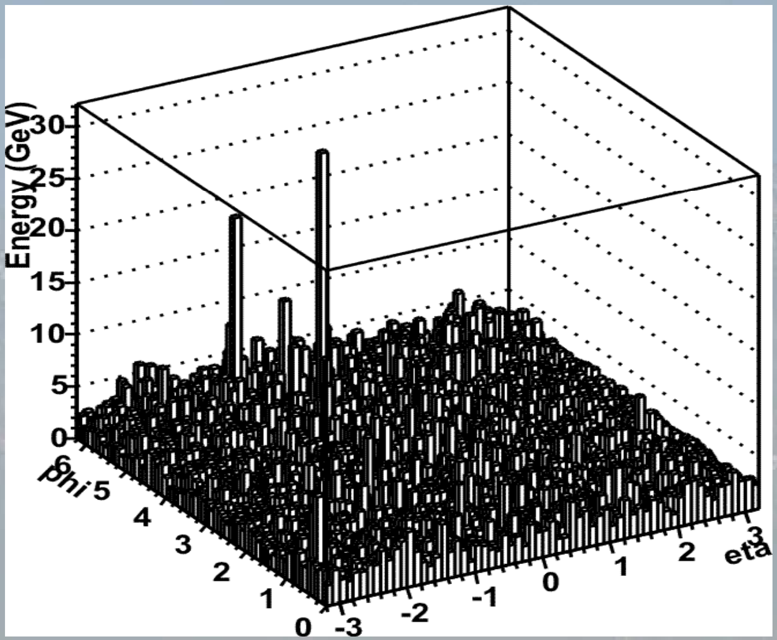
One more urgent question from RHIC:
What happens to the energy lost by partons?

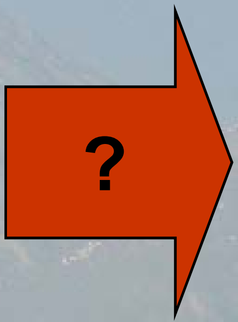
Methods …

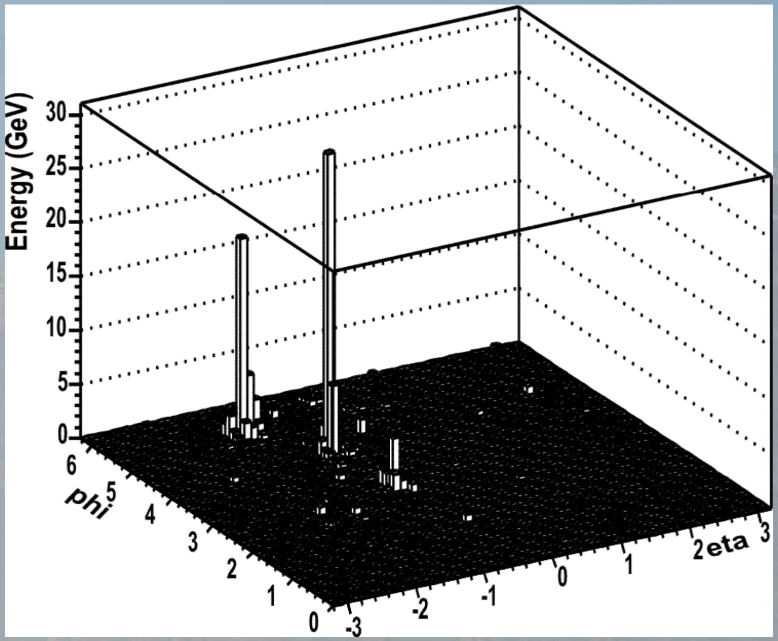
Jets

Pythia jets superimposed onto
a Hijing *PbPb* event, full reconstruction

True Pythia jets
after reconstruction

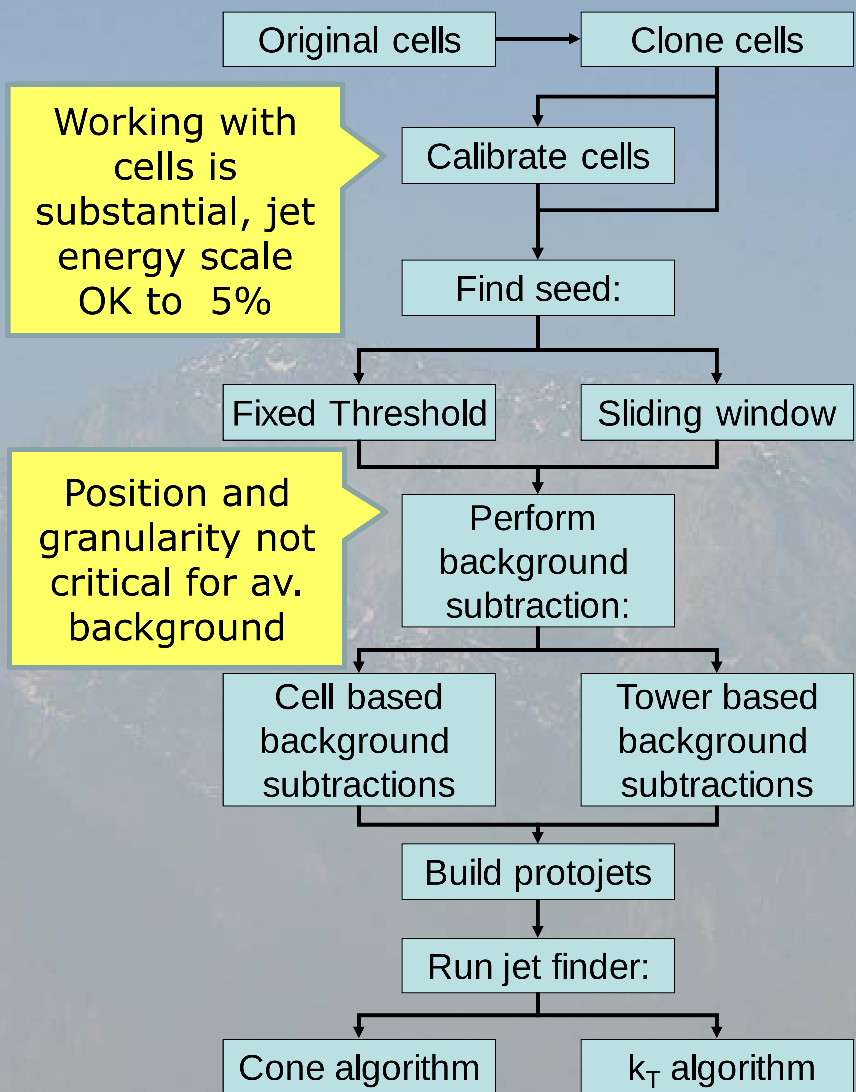






What to do with the “background“ … interesting by itself,
but quite difficult underlying *PbPb* event.

Jet reconstruction



Jet reconstruction algorithms are implemented as an independent reconstruction package within the official ATLAS software environment (ATHENA), generated events are a mixture of Pythia jets with Hijing events.

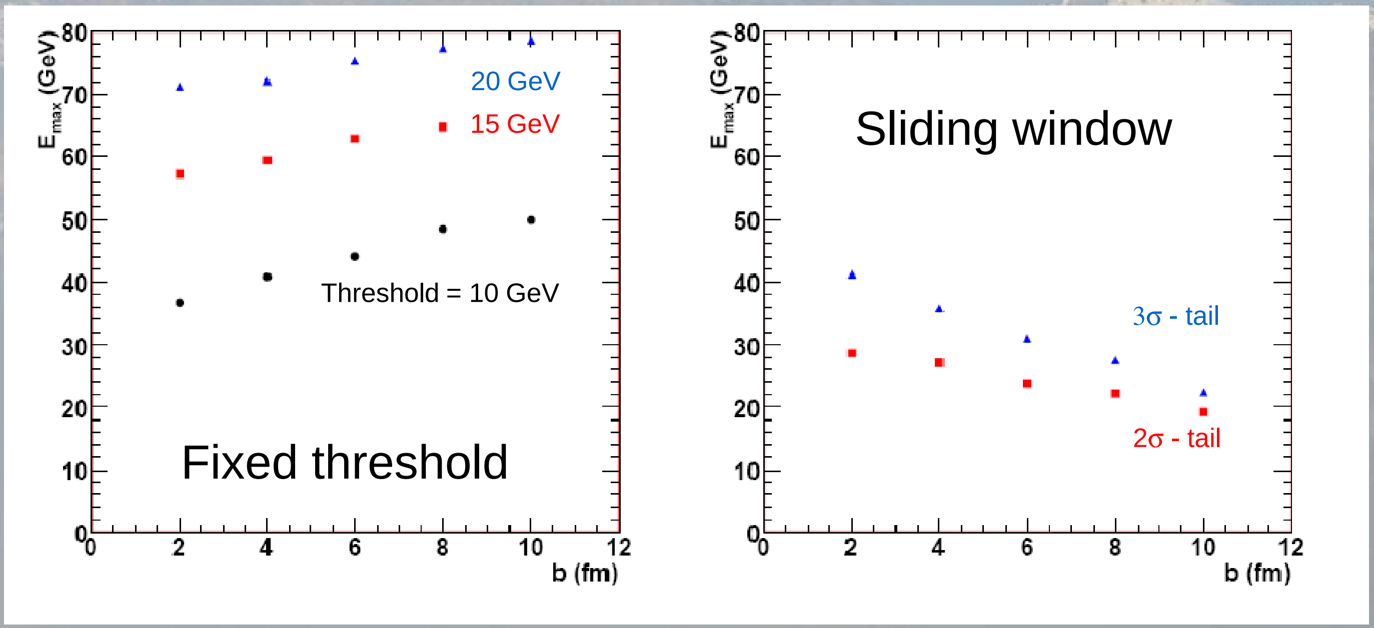
Candidate jets positions (“seeds”) will be used just for background subtraction: Area (over ϕ) outside of these regions determins the back-ground (either using cells or 0.1x0.1 towers). This background energy is then subtracted from all cells (or towers).

Protojets are simple four-momenta that enter any standard jet finding algorithm with iteration.

Jet reconstruction

Illustration of the seed finding efficiency:

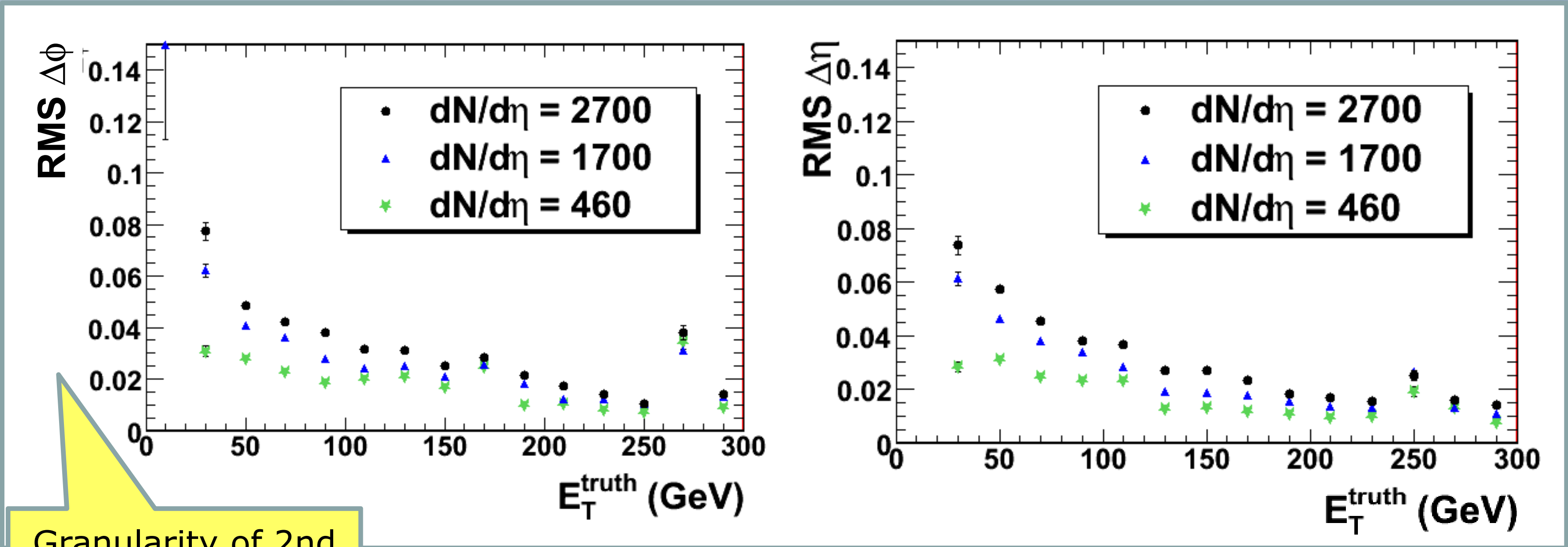
“Seeds” mean the cells or towers which are excluded from background averaging (together with the circle around them). Fixed threshold algorithm looks for 0.1x0.1 towers with E_T above some threshold, while sliding window algorithm uses the sum over square 0.3x0.3 and looks for high E_T tail of the distribution of sums. Figures show the E_T of the truth jet, which is found with 62% efficiency.



Jet reconstruction

Performance of the cone algorithm:

Position resolution in ϕ and η

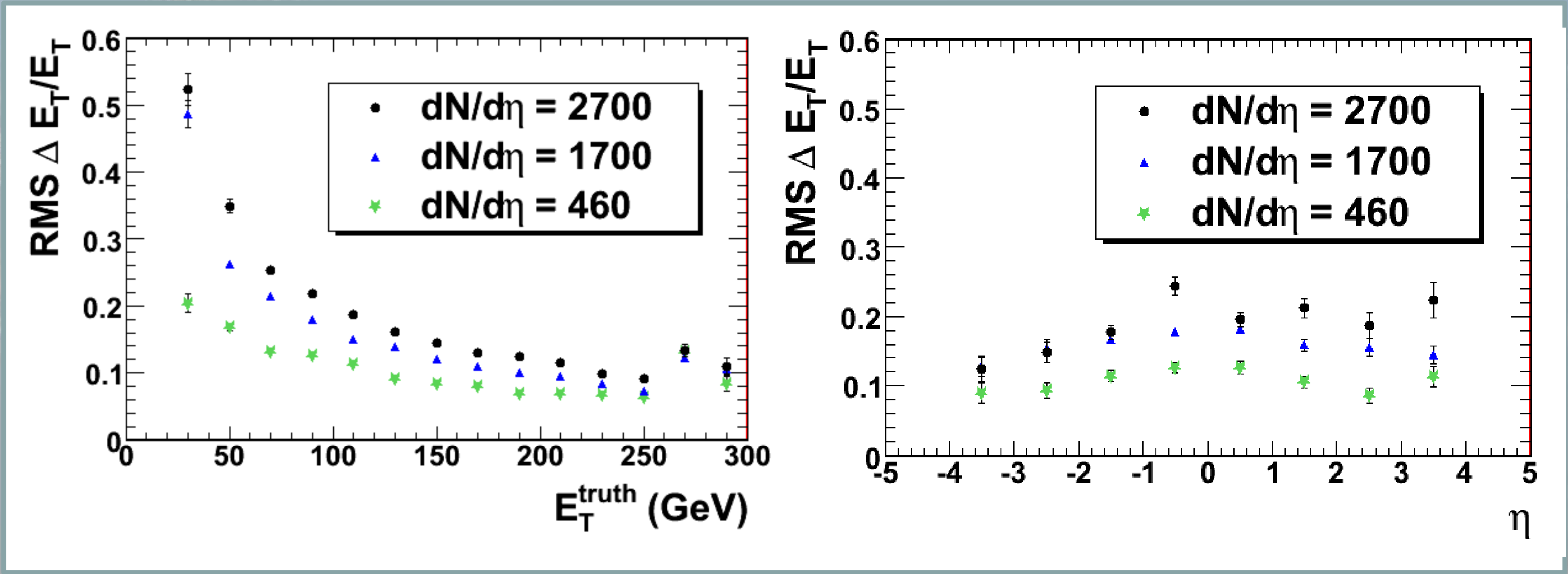


Granularity of 2nd layer of EM calo is 0.025× 0.025

Jet reconstruction

Performance of the cone algorithm:

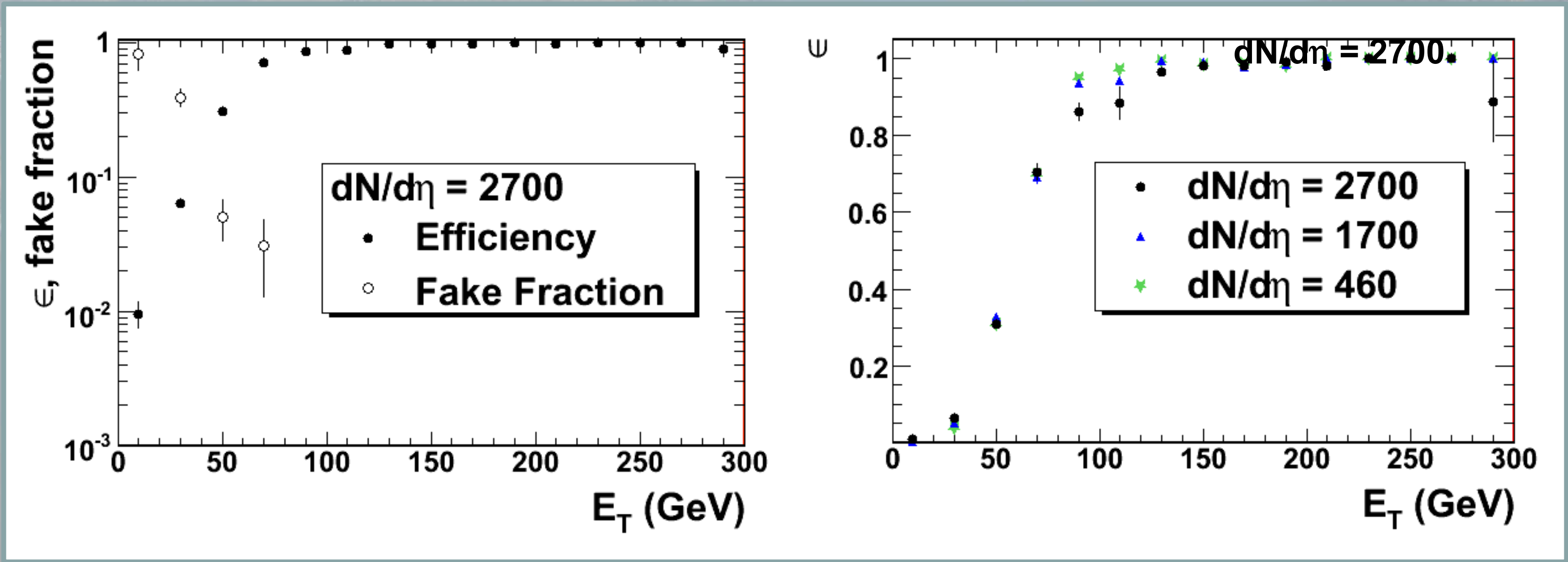
Energy resolution as a function of truth Pythia jet E_T (left figure) and as a function of η (right figure).
All plots are combination of "J2" (35-70 GeV initial partons), "J3" (70-140 GeV) and "J4" (140-280 GeV) Pythia jets.



Jet reconstruction

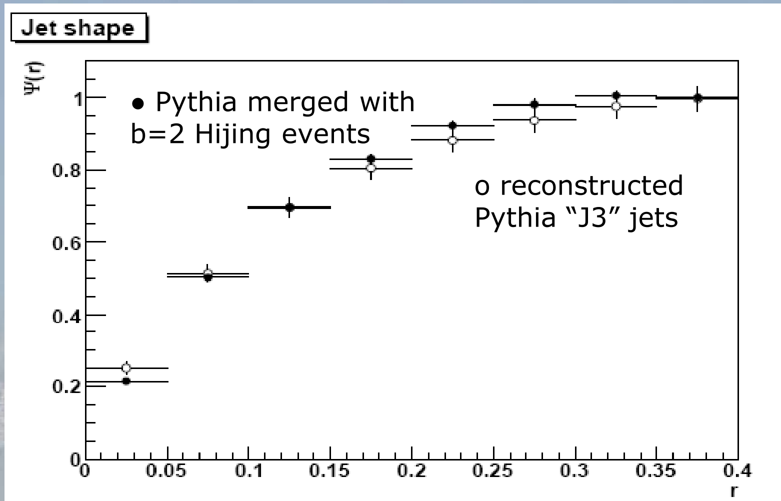
Performance of the cone algorithm:

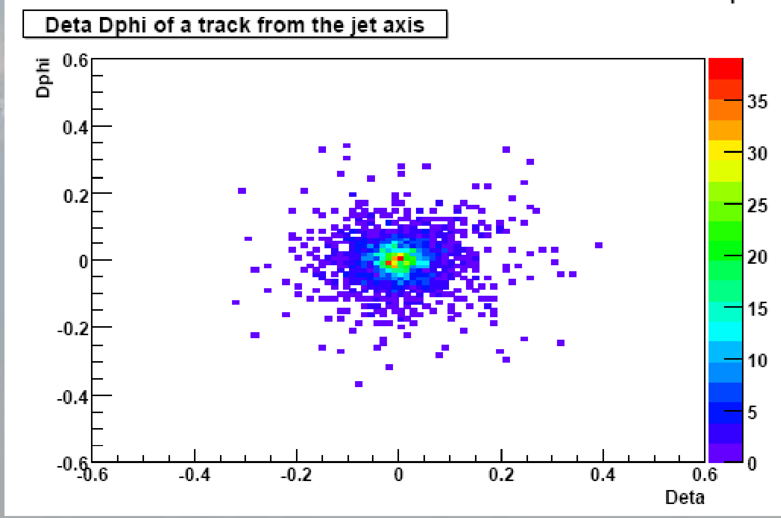
Fake jets & efficiency: Fake jets coming from the background can be identified using measurement of sum of j_T of cells with respect to the jet axis. Above ~80 GeV practically no fakes are present.



Jet reconstruction

Performance of the cone algorithm:





Jet shape defined as:

$$\Psi(r_n, R_{cone}) = \frac{\sum_{r \leq r_n} E_T(r)}{\sum_{r \leq R_{cone}} E_T(r)}$$

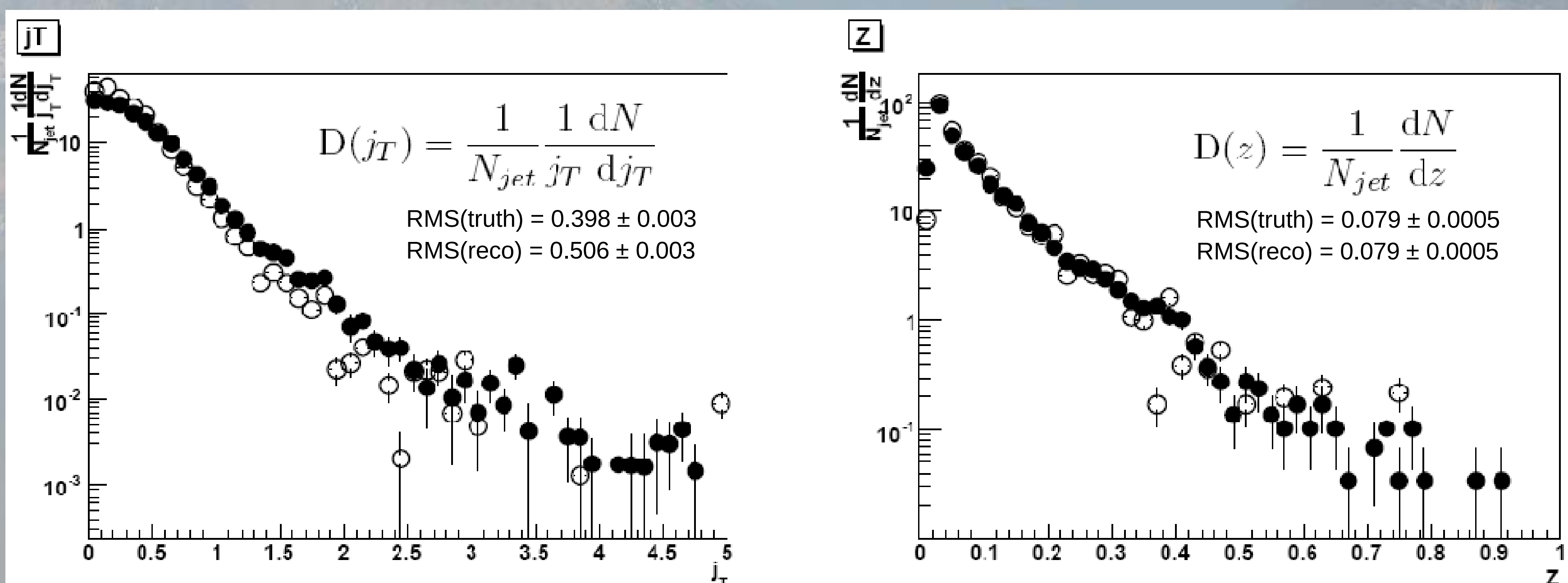
can be measured using very fine segmented cells of the ATLAS detector. In the top left figure open markers stand for the jet shape of reconstructed Pythia "J3" jets, full markers stand for the jet shape of reconstructed jets merged with the central (b=2) Hijing events.

Here is an average distribution of tracks within a Pythia "J3" jet (70-140 GeV).

Jet reconstruction

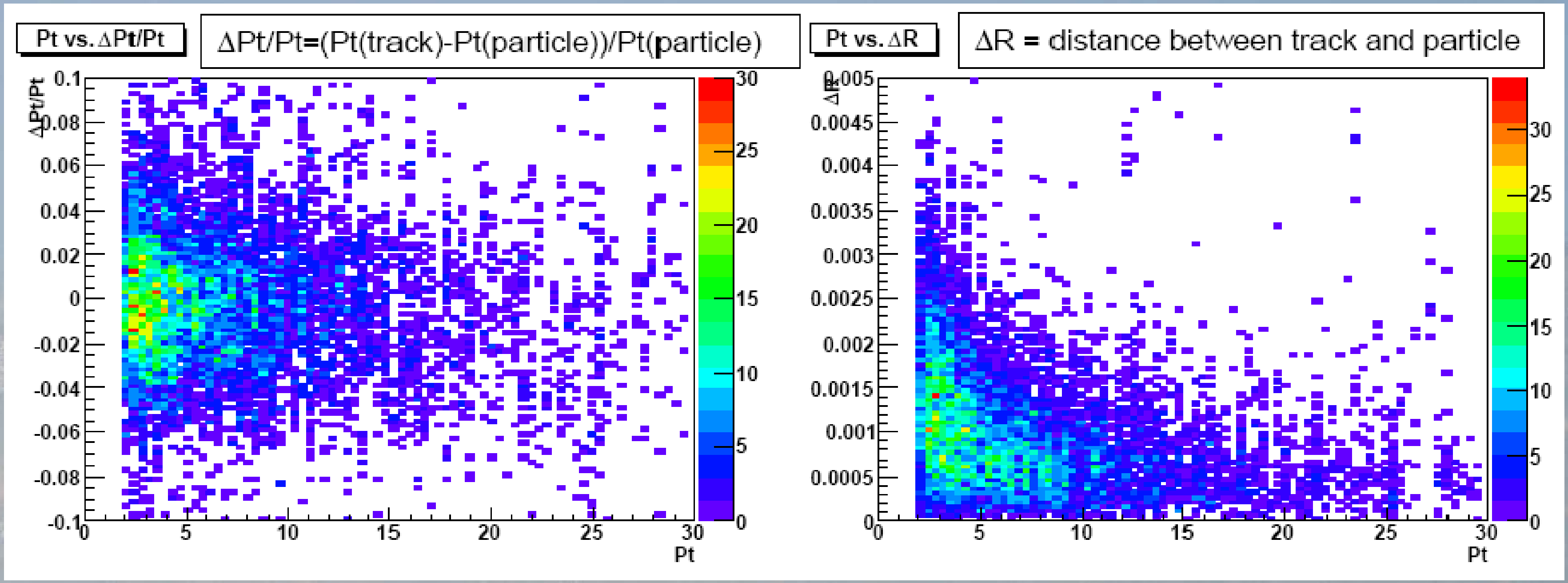
Performance of the cone algorithm together with tracking:

j_T (the track momentum transverse to jet axis) **distribution and fragmentation function** for “J3” jets in simulated most central (0,5%) *PbPb* events. Open markers stand for truth distribution (Pythia truth jets and stable charged particles), closed markers display reconstructed distribution (reconstructed jets and tracks). Distributions belonging to the underlying event are subtracted.



Jet reconstruction

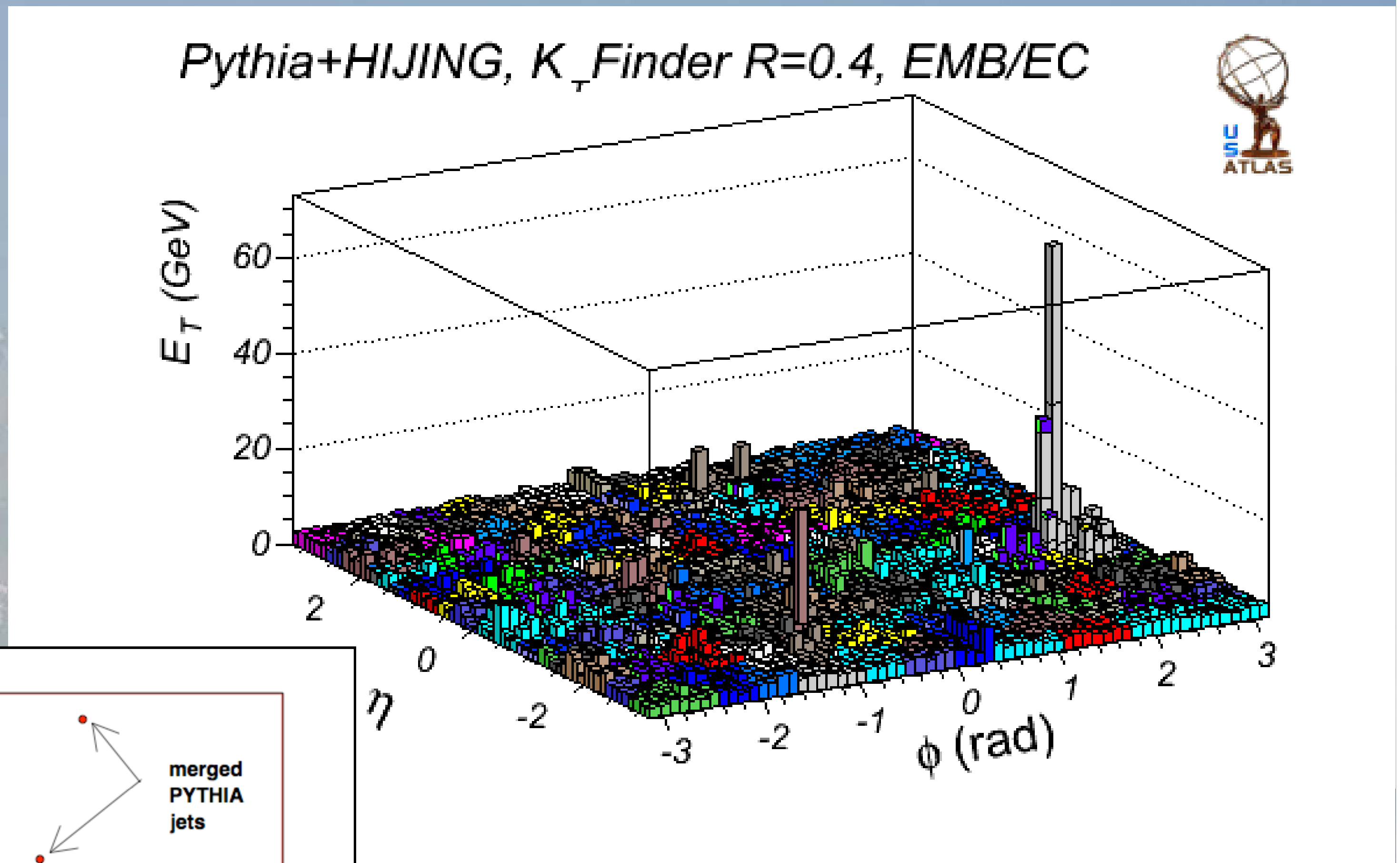
Illustration of tracking resolution

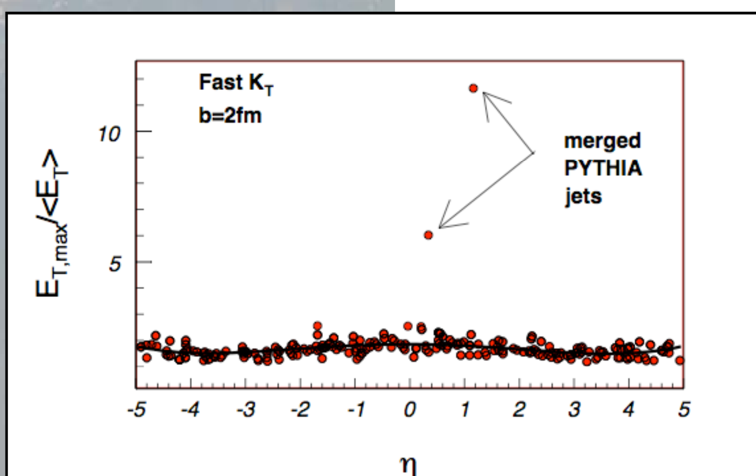


Jet reconstruction

Another possibility is studied – **Fast K_T**

The algorithm itself can offer criteria for background subtraction:

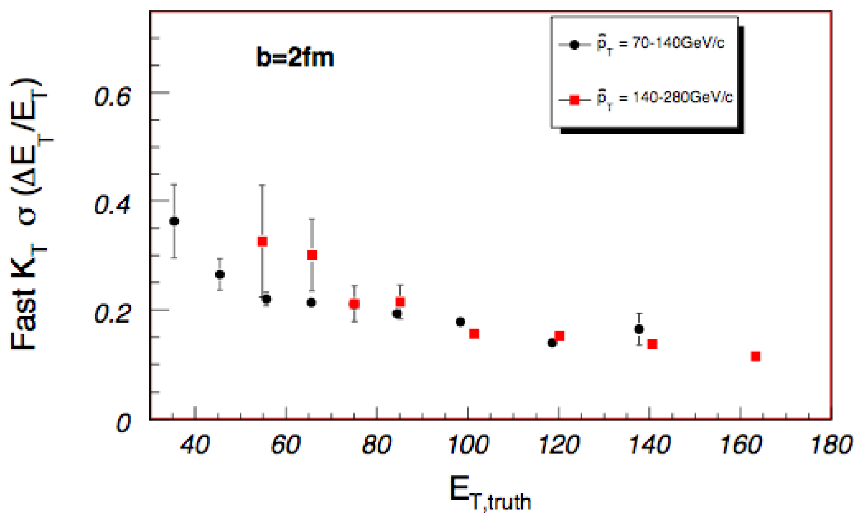


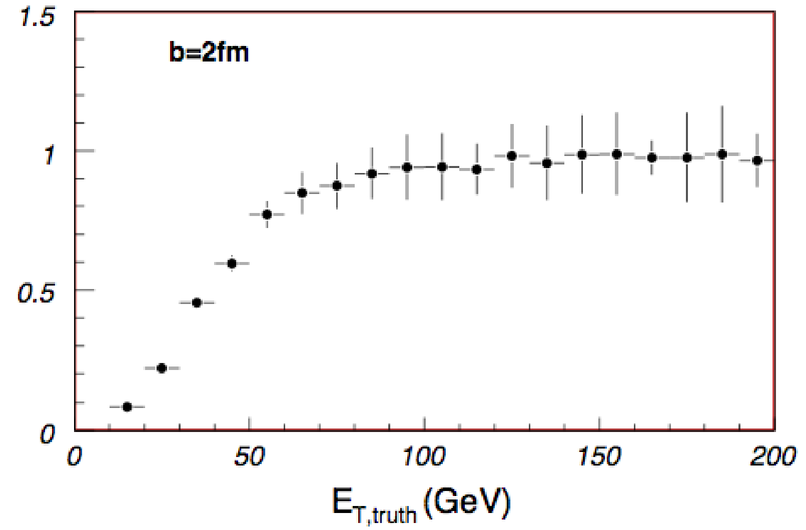


Jet reconstruction

Performance of the Fast K_T algorithm:

Energy resolution and efficiency:





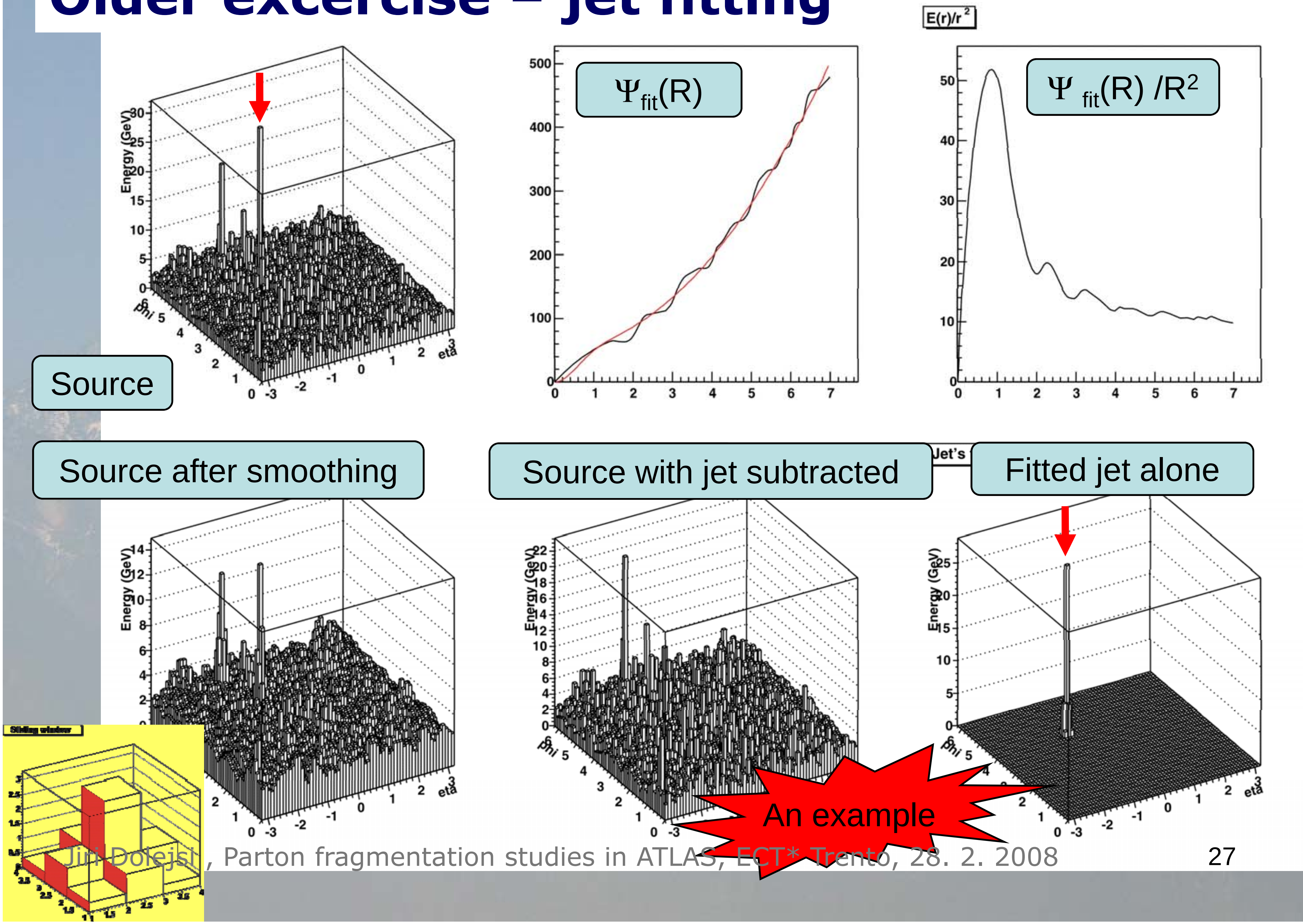
Not covered topics

- Current work on γ isolation (very good performance of EM calo thanks to optimization for H $\rightarrow \gamma\gamma$), γ – jet correlation, dijets …
- Trigger issues (developed in cooperation with pp minimum bias group)
- All other ATLAS HI activities (see e.g. N. Grau‛s plenary talk at QM2008)
- Jet shape and fragmentation (already mentioned in Physics TDR II), single photons, photon-jet,… for comparison with HI

Summary

- “Baseline‟ jet algorithm tested and tuned to heavy ion environment, alternatives studied
- Jet shapes, j_T disributions, fragmentation functions accessible
- Further studies ongoing

Older excercise – jet fitting



Jets

The goal of the studies is to be prepared to measure also the **modification of the jet profiles and particle content of jets** (fragmentation functions).

The sensitivity to the jet profile is illustrated on the the difference of the first radial moment of the jet energy distribution (measured from the jet axis) between u- and b-quarks.