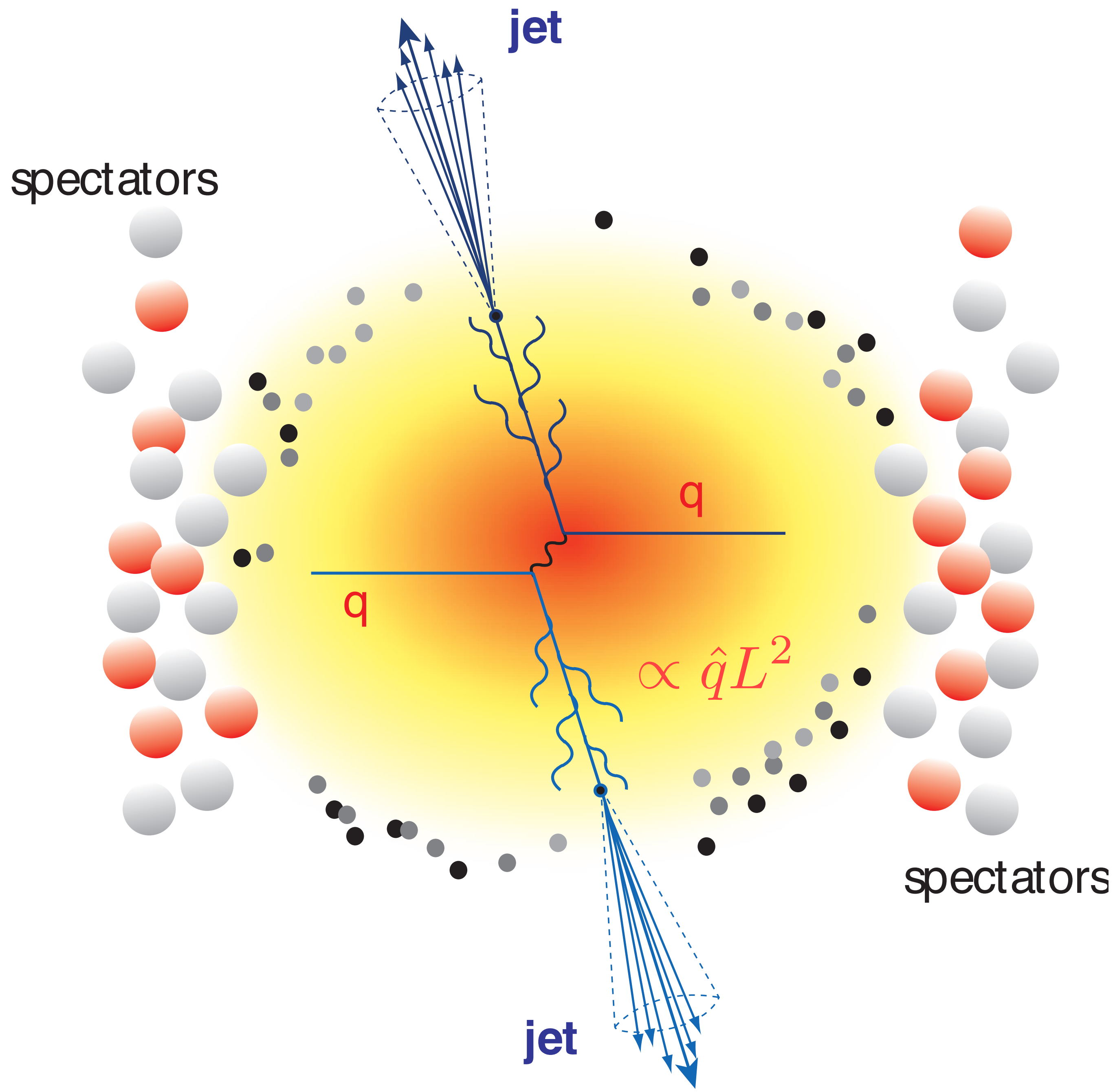
ATLAS Experiment Capabilities and Status

Helio Takai
Brookhaven National Laboratory

(for the ATLAS collaboration)

BROOKHAVEN NATIONAL LABORATORY

Physics Case was already made



"Quenching" = induced gluon radiation

LHC heavy ion collisions are expected to produce a hotter, denser and longer lived QGP.

The increase in hard process cross section make them a good tool to explore the hot QCD matter.

The energy loss of hard scattered partons provides a direct probe of color charge density of medium.

Upsilon states and J/ψ can serve as thermometers of the hot QCD matter.

Yes, ATLAS!!

ATLAS *has a hermetic and highly segmented calorimeter both longitudinally (in* R *) and transversely (in* η *and* Φ*).*

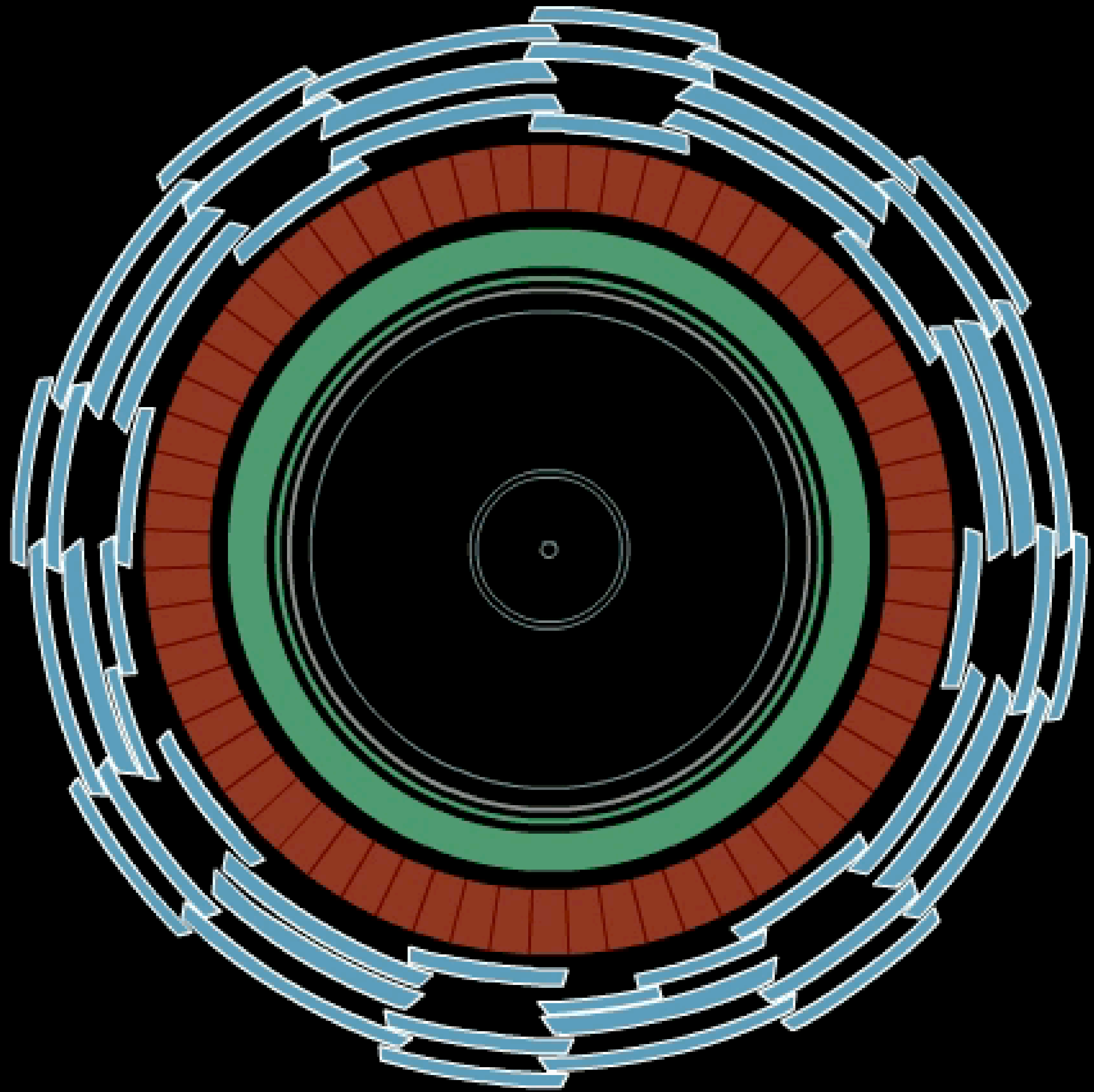
ATLAS *has tracking that operates in the heavy ion environment.*

ATLAS *can study jets at moderate* p_T *where quenching is still strong and at very high* p_T *where quenching is expected to disappear.*

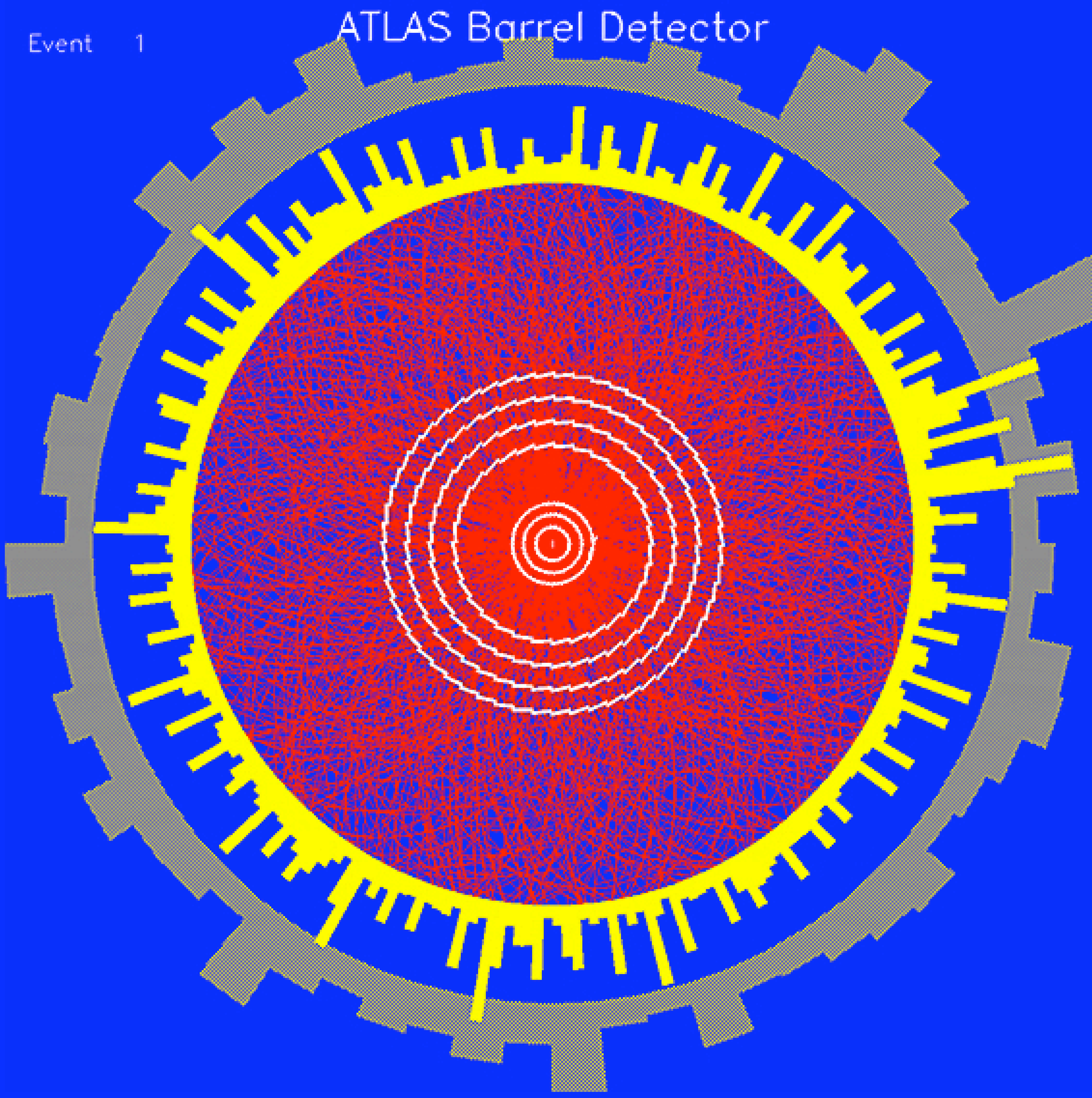
Strong Interaction with the ATLAS *QCD group!*

... closer to the Cafeteria and T-shirts by Alan Alda!

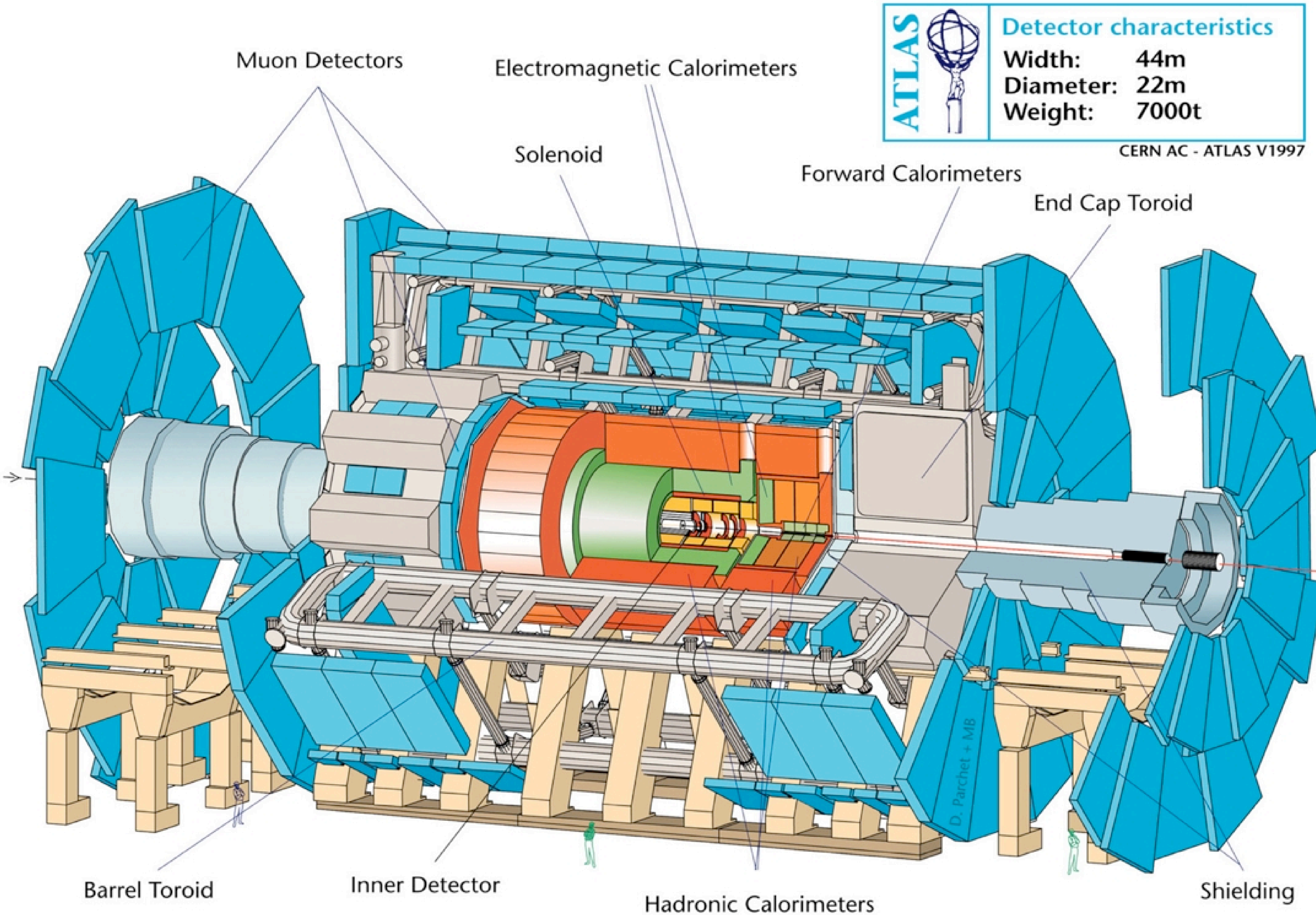
ATLAS Design



One Pb+Pb event in ATLAS

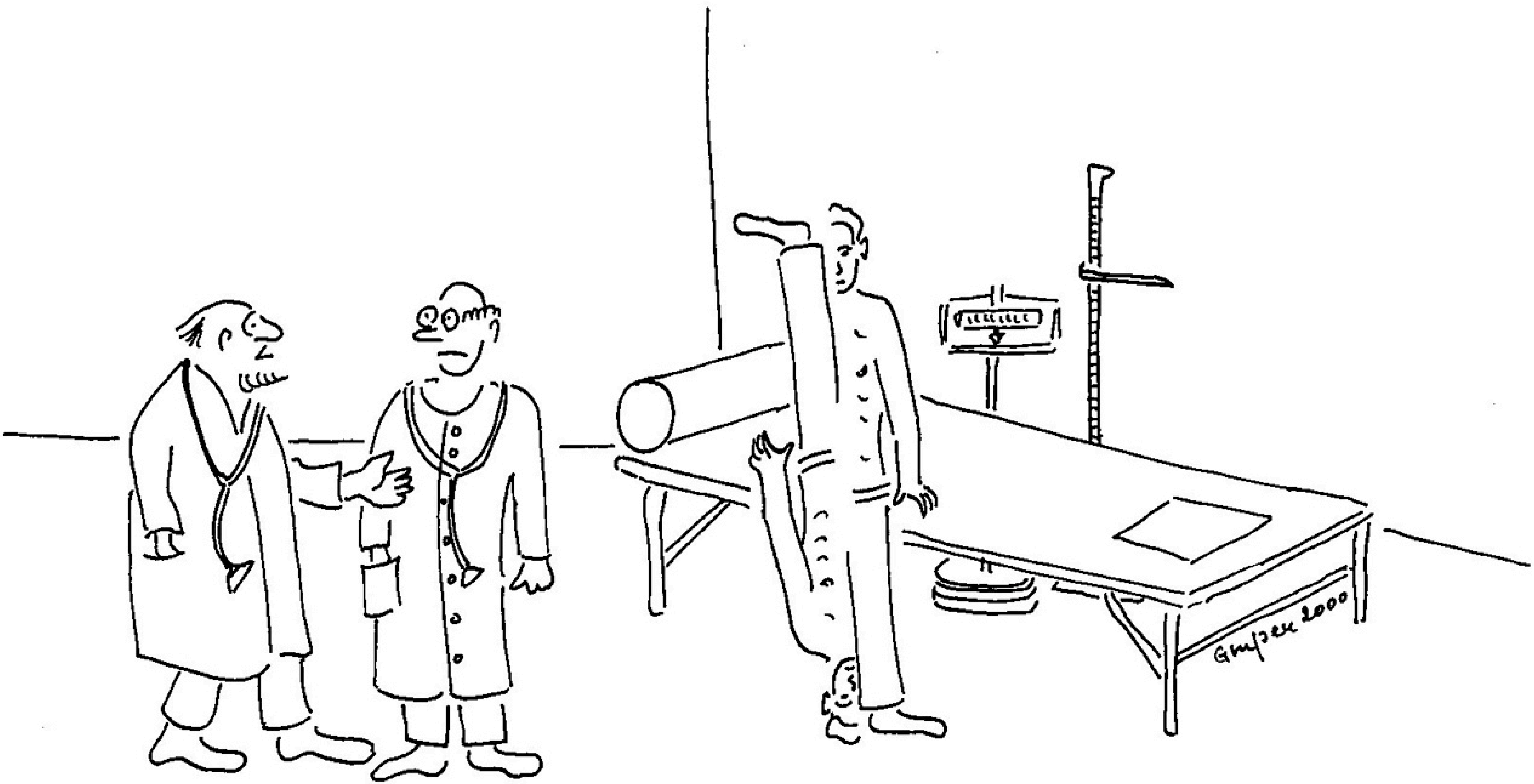


Δη=0.5 at η=0

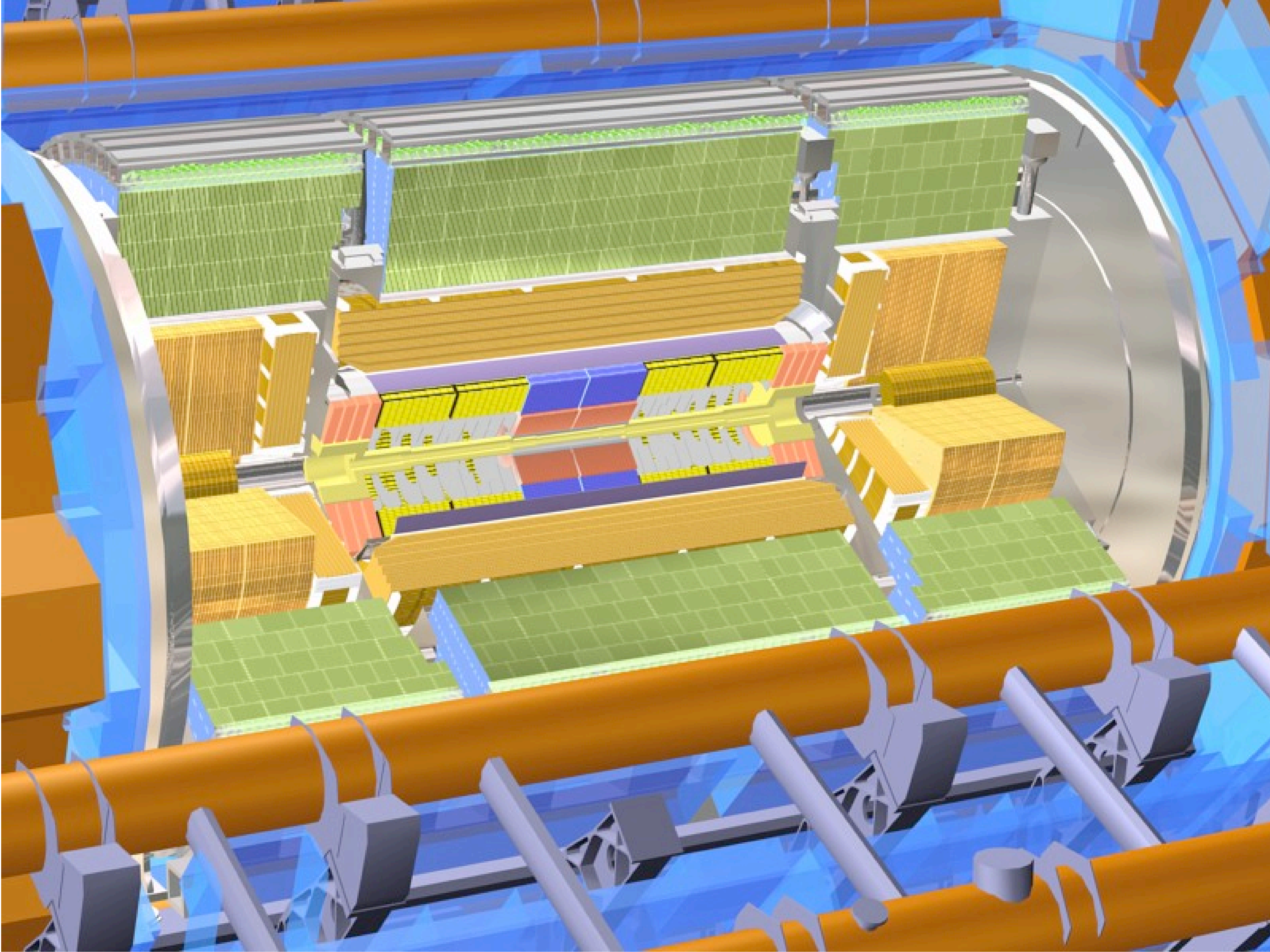


1900 physicists, 154 institutions, 35 countries

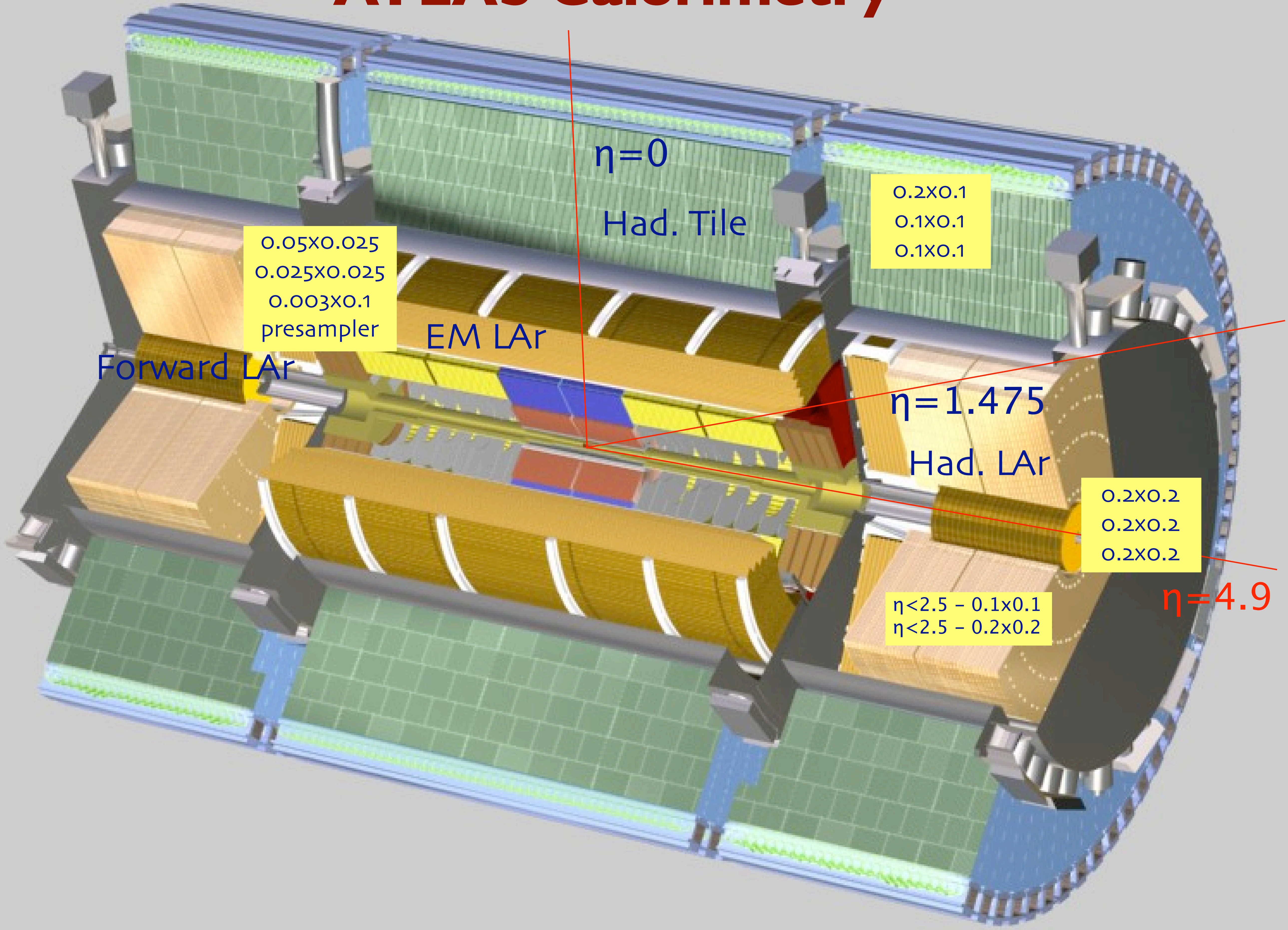
Designed for high p_T physics in pp collisions



"A severe case of symmetry breaking!"



ATLAS Calorimetry



ATLAS Calorimeter Performance

EM Energy Resolution

$$\frac{\sigma_E}{E} = \frac{10\%}{\sqrt{E}} \oplus 0.3\%$$

Hadronic Energy Resolution

$$\frac{\sigma_E(\pi)}{E} = \frac{50\%}{\sqrt{E}} \quad 3\%$$

EM Calorimeter Timing Resolution

$$\sigma_t = \frac{4 \cdot ns.GeV}{E}$$

EM Calorimeter Angular Resolution

$$\sigma_\theta = \frac{60\ mrad}{\sqrt{E}}$$

The above performance was achieved with test beam modules

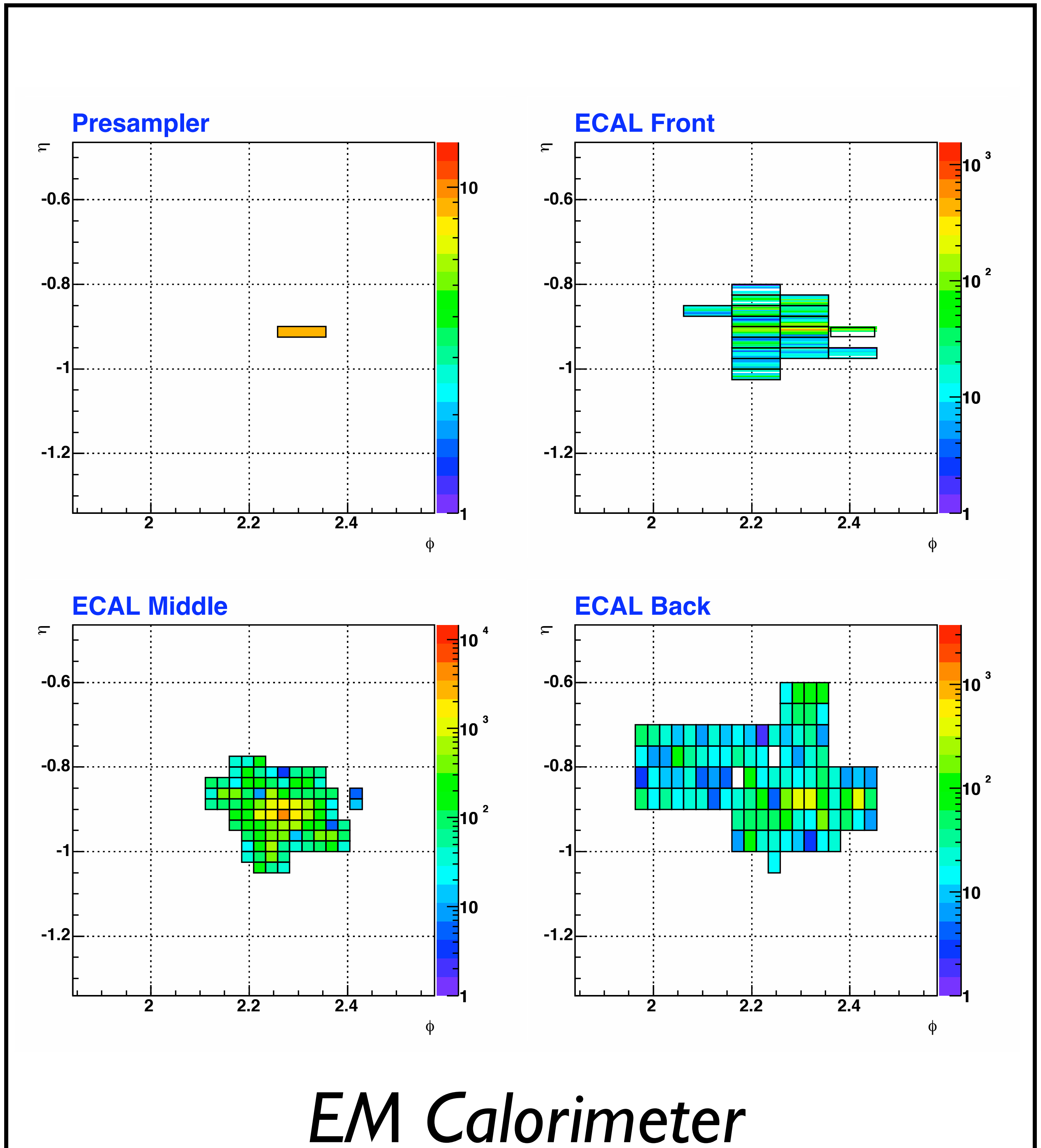
Jets in 3D!

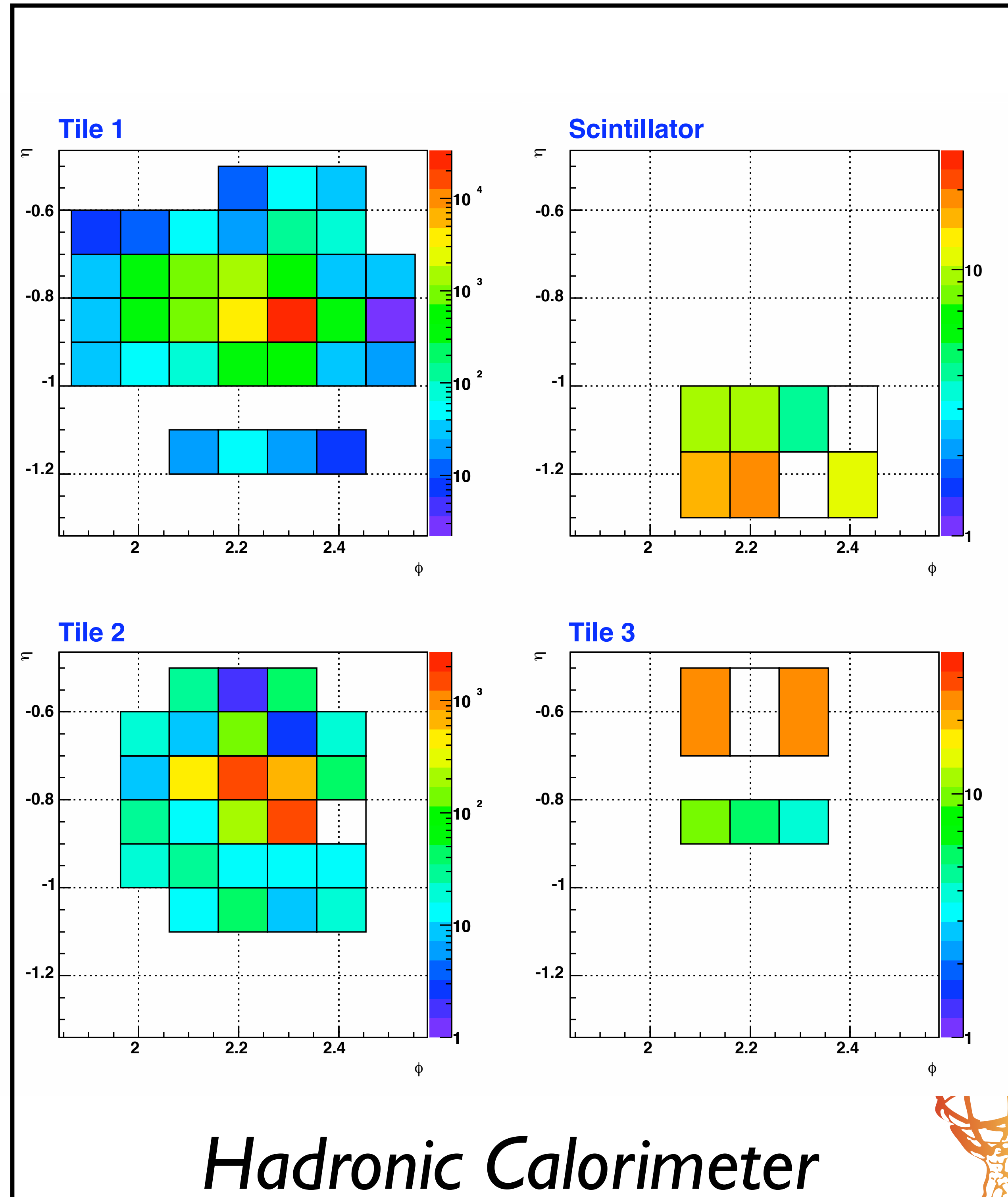
(and in color)

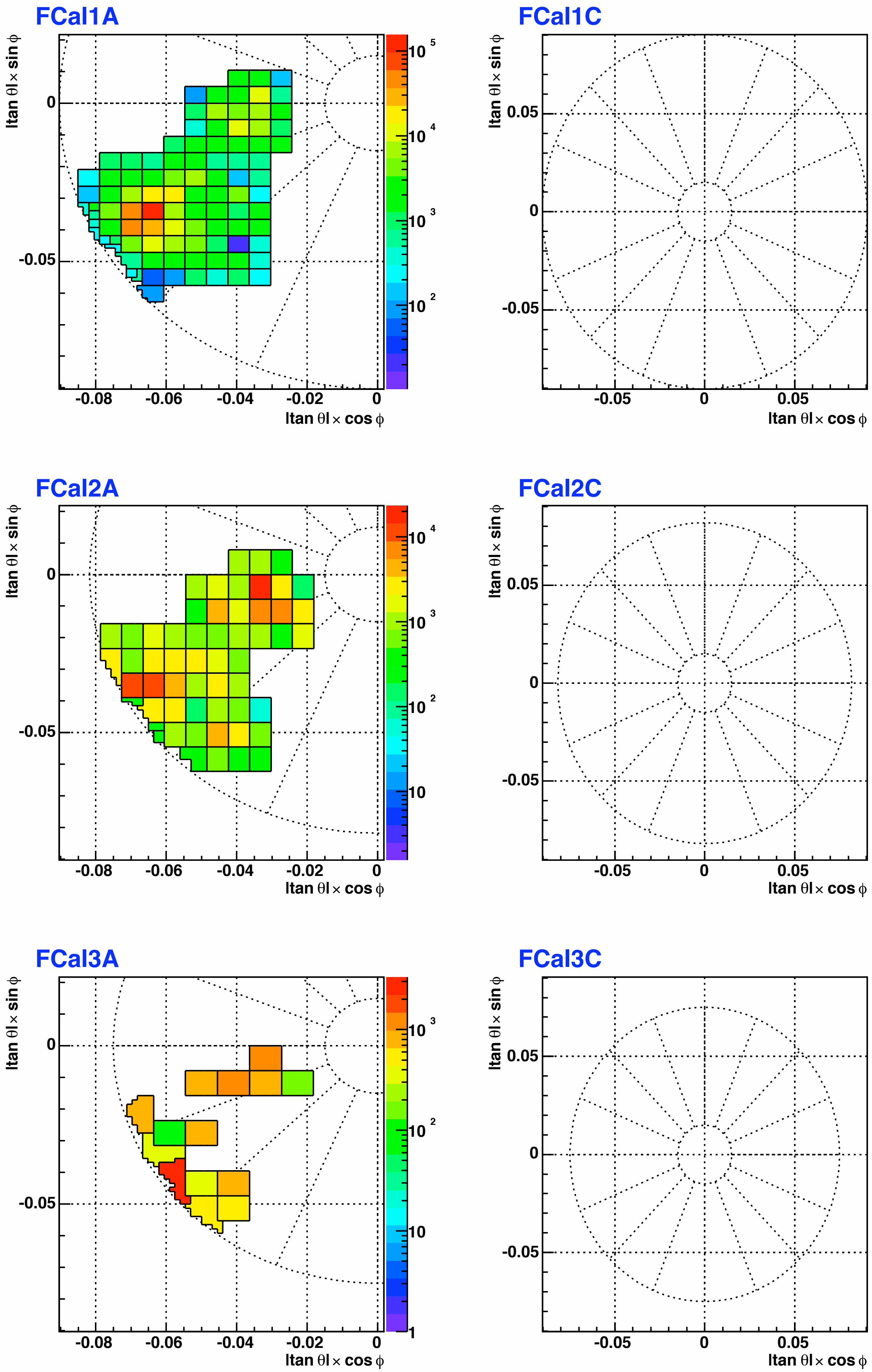
Contains 60% of soft background energy!

E_T=100 GeV (jet only)

$\Delta\eta \times \Delta\Phi = 0.8 \times 0.8$







Jets in 3D!

(Forward Calorimeter-only)

100 GeV (E_T) jet in forward calorimeter. (~3.0<η<4.9)

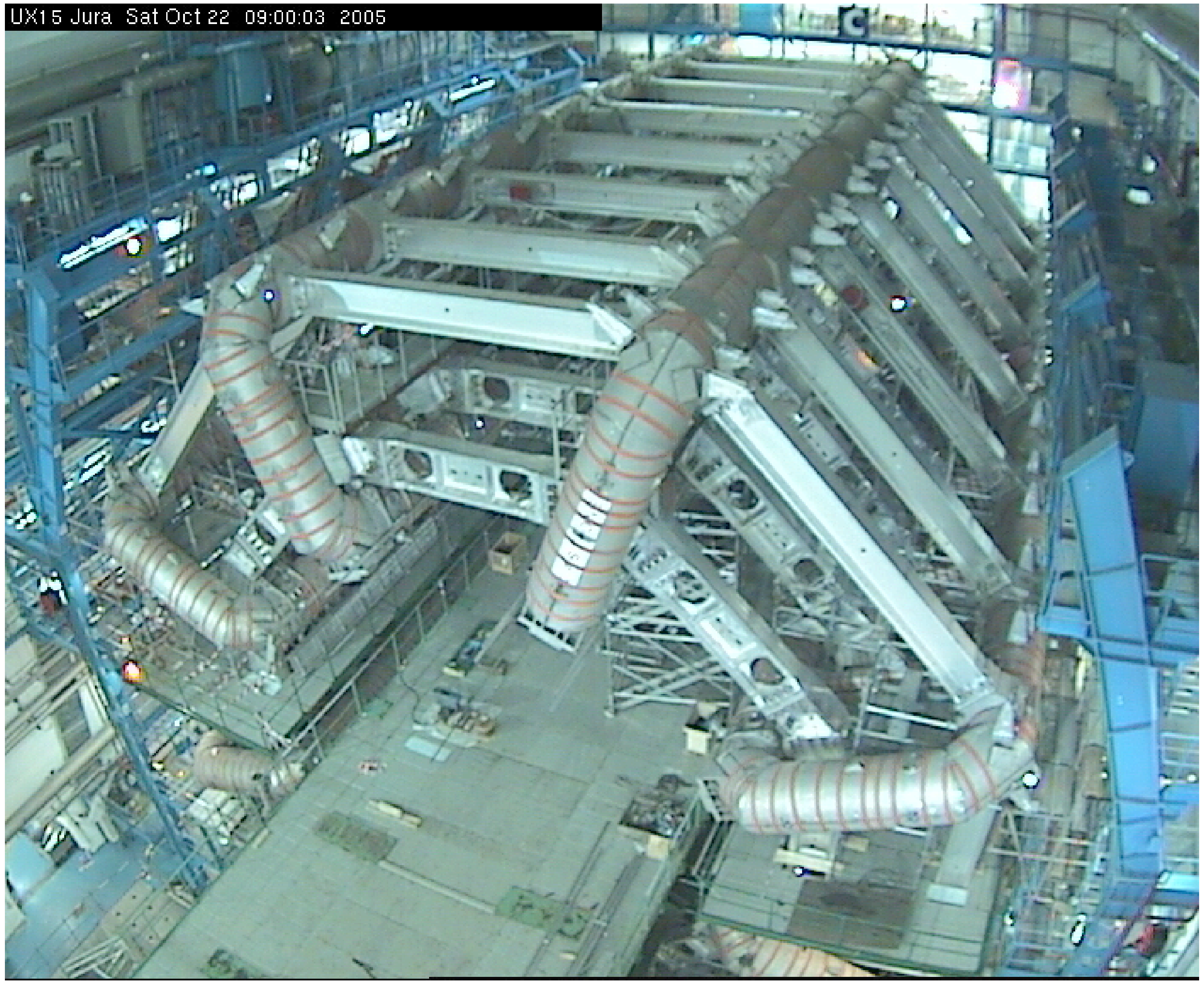
Important for pA physics down to $x \sim 10^{-5}$

Performance in AA needs to be evaluated but expect jets ~ 50 GeV.

Isolated photons?

ATLAS Today


UX15 Geneva Sat Oct 22 09:00:02 2005
Palan auxiliaire 2 5 t


UX15 Jura Sat Oct 22 09:00:03 2005

The Physics Program

“Jet physics”, Quarkonia and Minimum Bias

Global variables, Flow, multiplicity, $dN/d\eta$, $dE_T/d\eta$

Inclusive jet cross section (E_T>40 GeV)

Multi jet events (e.g. three jet events)

Heavy quarks - b-jets

“Calibrated” jets - γ+j, Z^0+j, γ^*+j and others

Measurement of jet fragmentation properties

“Energy Loss” vs reaction plane

Quarkonia - Υ and J/ψ

proton-nucleus collisions

ultra-peripheral collisions

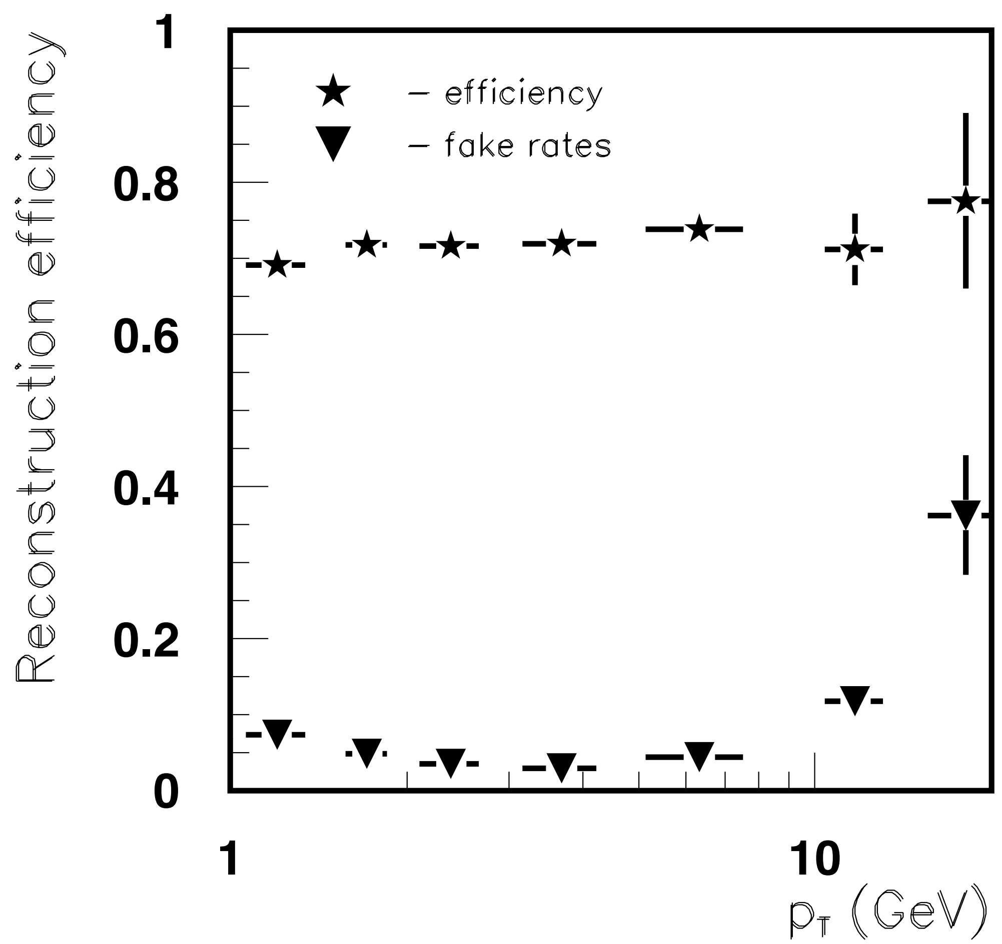
Light ions

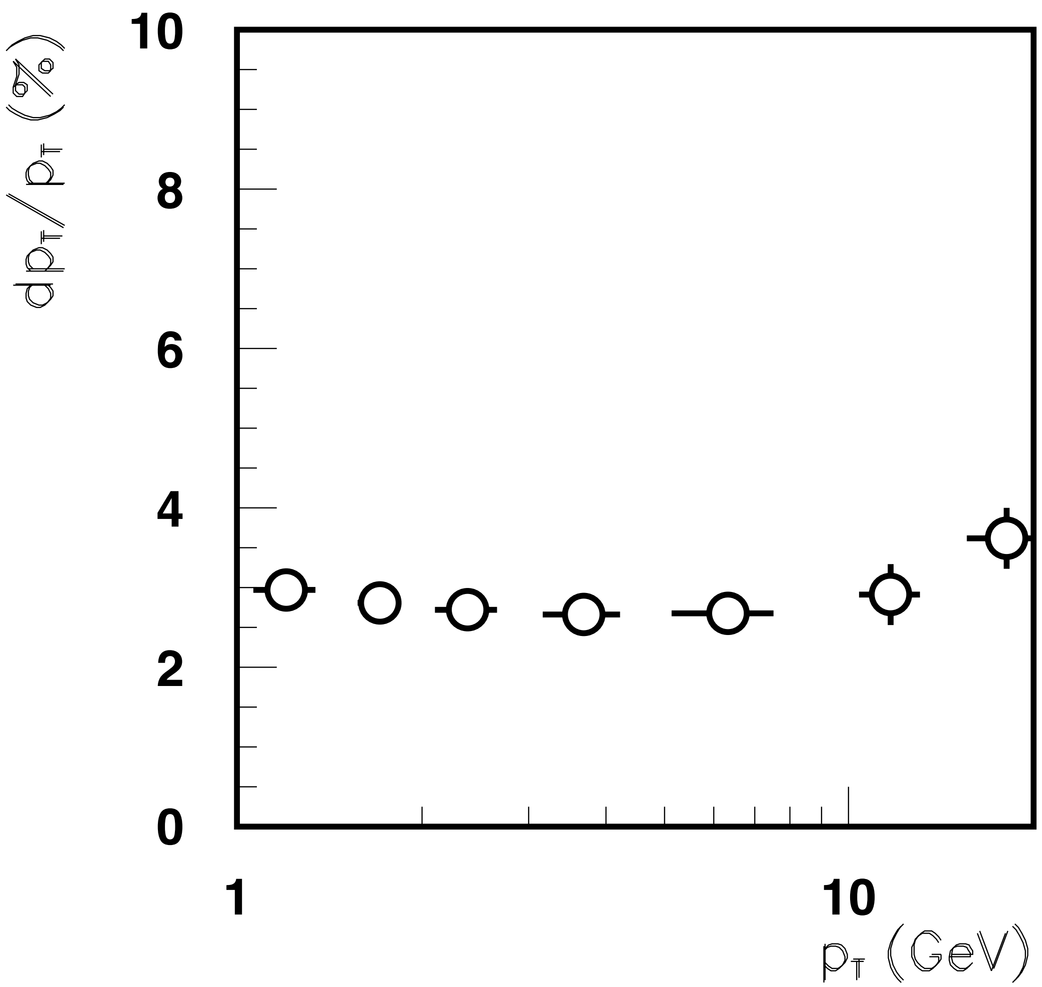
A first study of the detector response using full detector simulations was performed and these studies use the standard ATLAS software.

Tracking

Standard ATLAS reconstruction for pp is used and not optimised for PbPb.

Uses Pixel and SCT, not TRT
P_T threshold is 0.5 GeV
Uses 10 hits out of 11 available





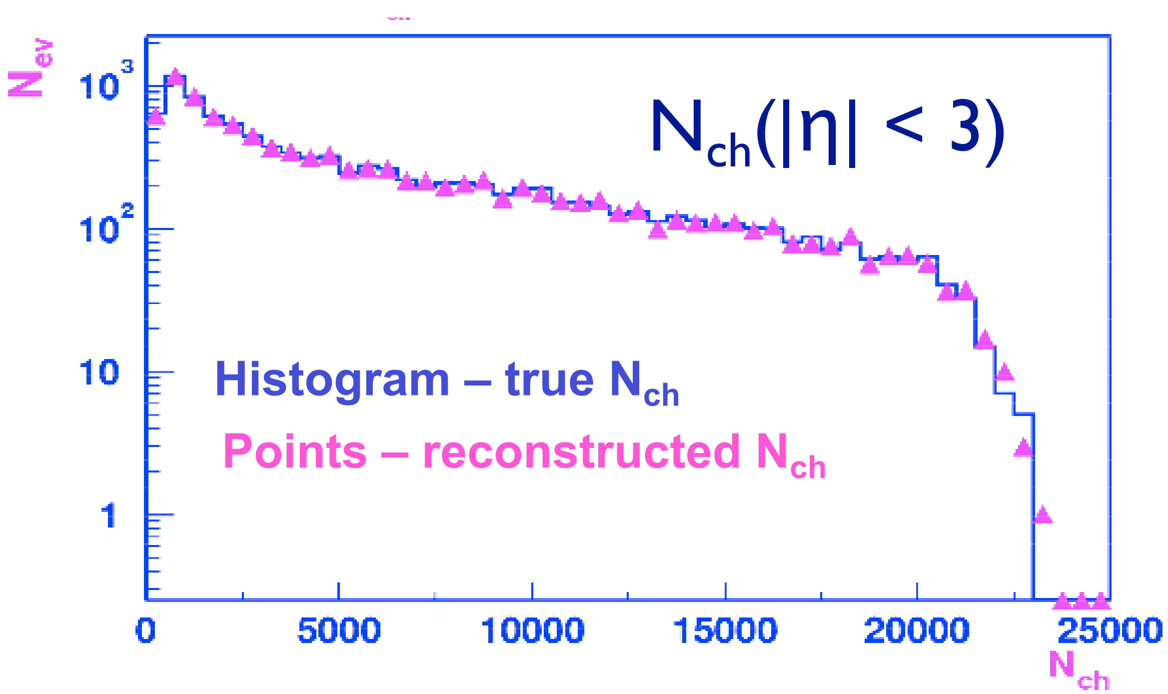
For p_T ~1 - 10 GeV ϵ=70%, fake~5%

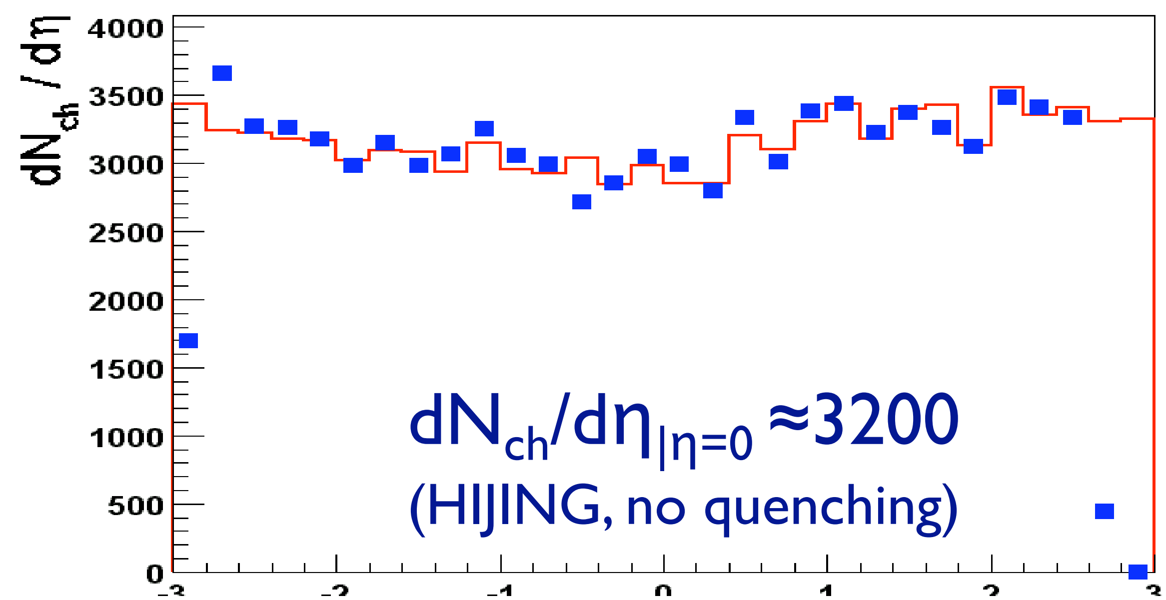
Momentum resolution is ~3%
(2% in barrel and 4-5% in end caps)

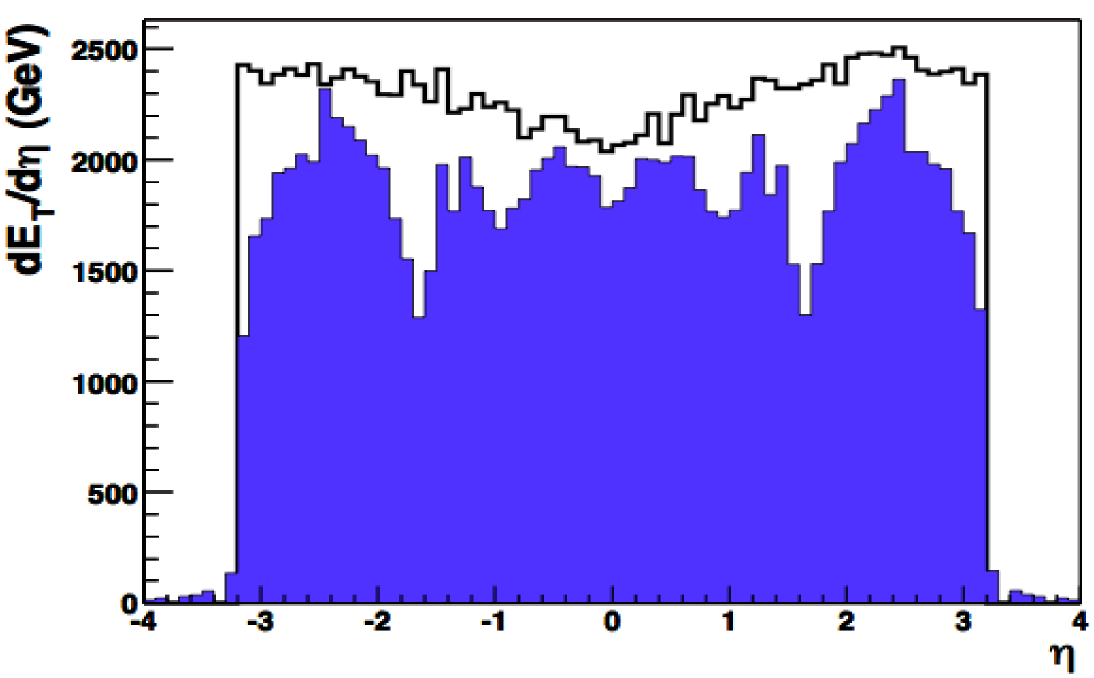
Global Event Characterization

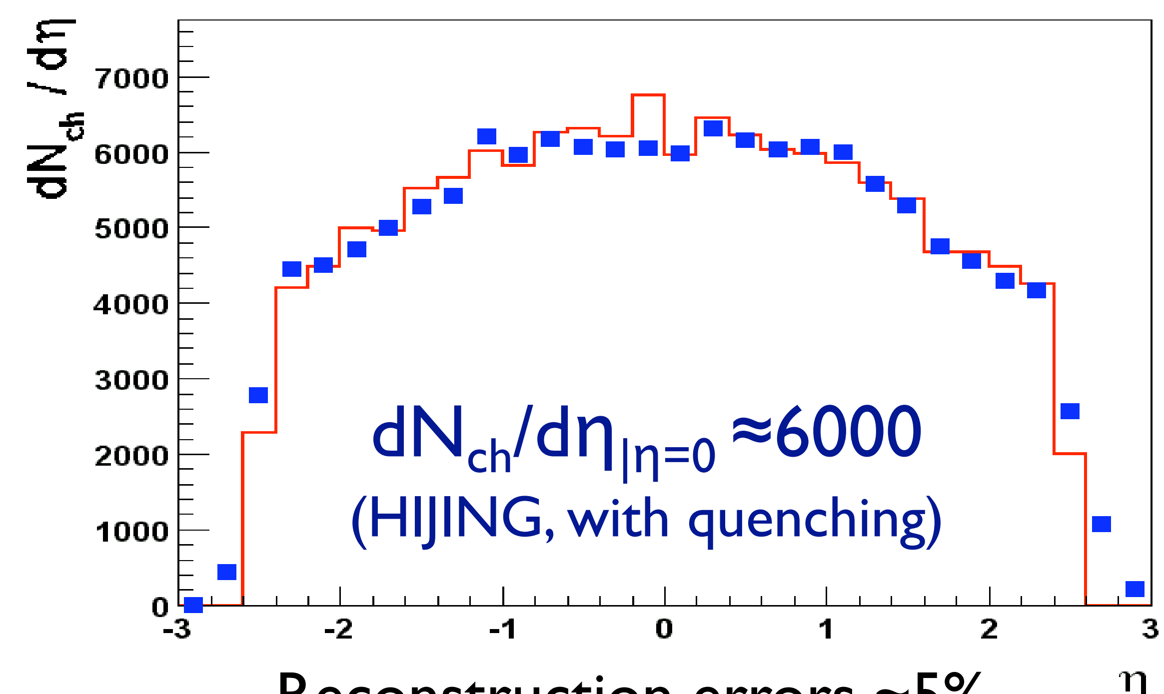
Day One Measurements: N_{ch}, $dN_{ch}/d\eta$, E_T, $dE_T/d\eta$, b

Single Pb+Pb event, b =0-1fm







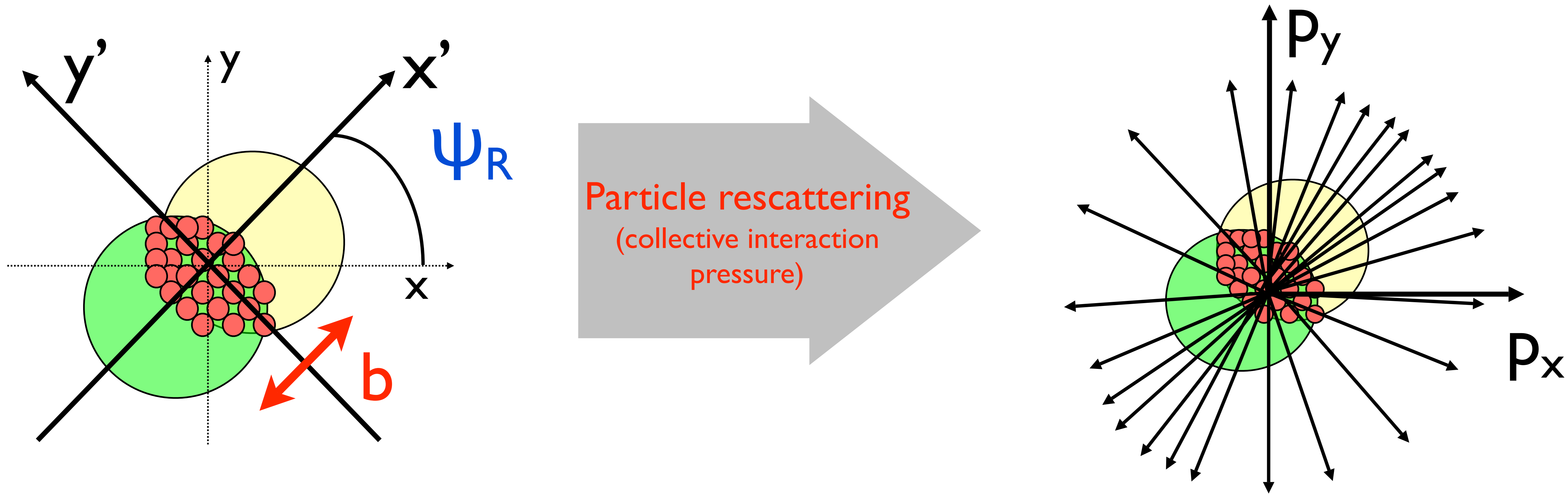


Reconstruction errors ~5%

Elliptic Flow in AA Collisions

Initial deformation in the coordinate system

Final momentum space azimuthal asymmetry



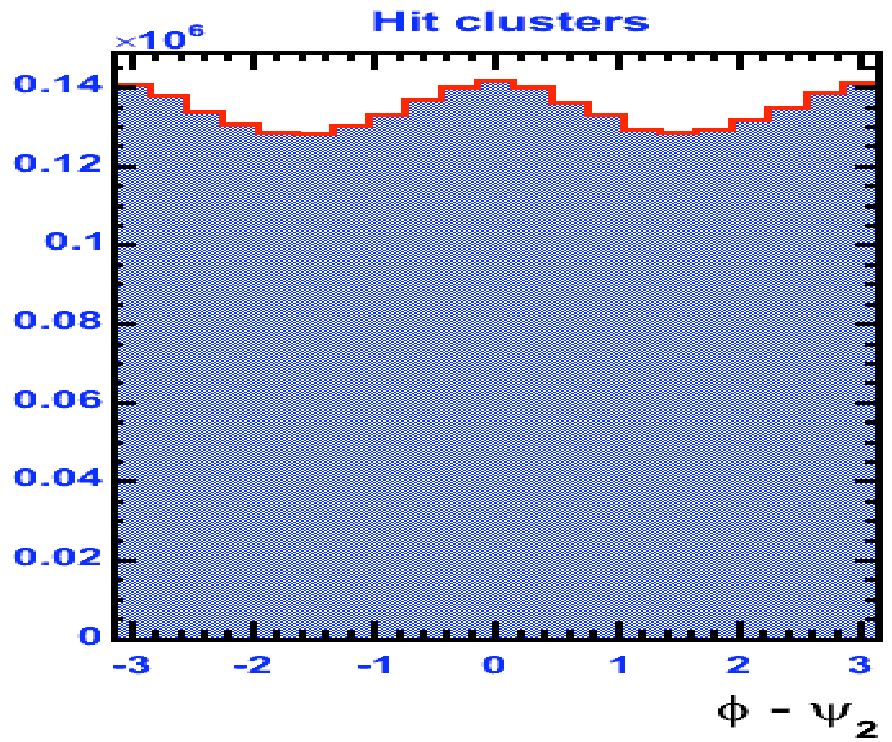
ψ_R - azimuthal angle of the reaction plane

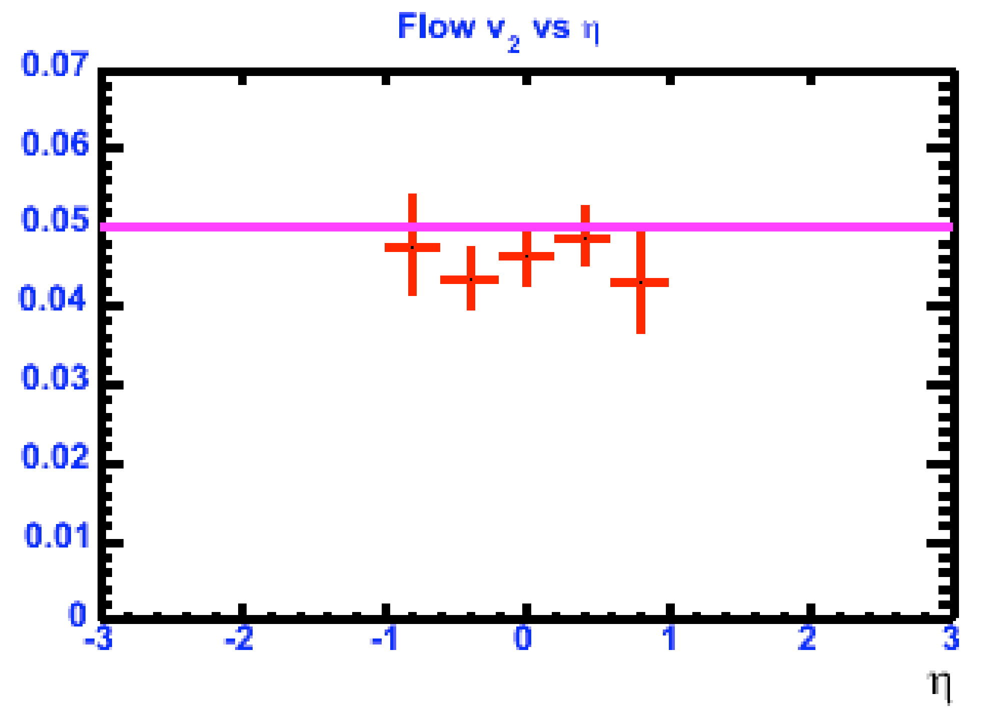
View of a A+A Collision with impact parameter b ≠0
in the plane transverse to the Reaction Plane (x≡b, z ≡ beam axis):

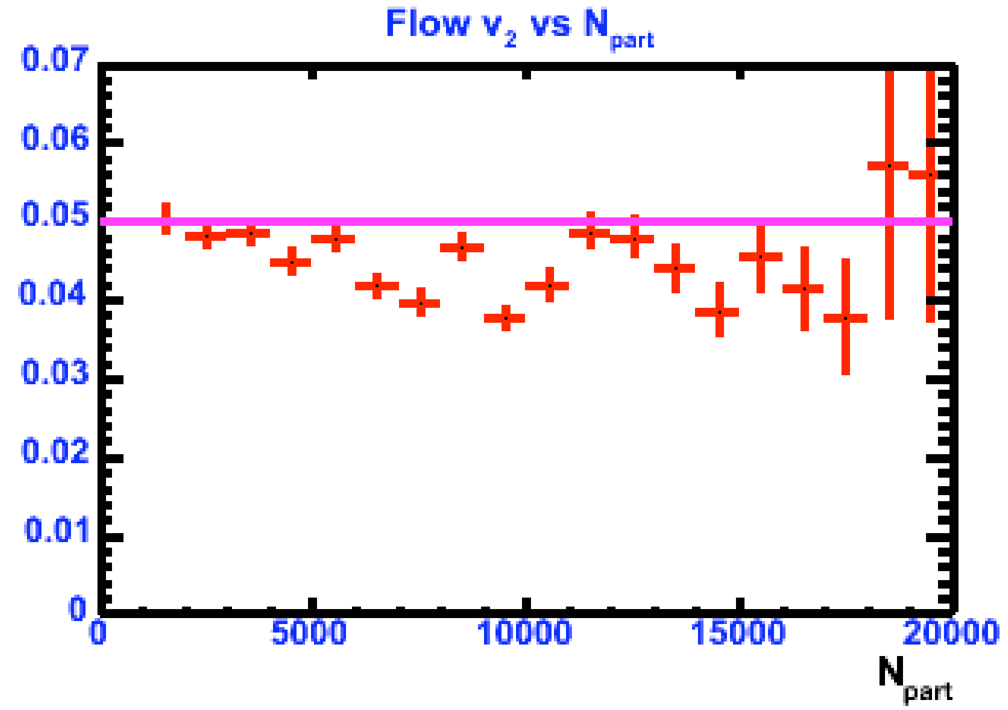
Elliptic Flow

v_2 measurable using Pixel (barrel) and Forward Calorimeter (reaction plane reconstruction)

Generation of HIJING events with flow with v_2 = 0.05; const(N_{ch}, η, y, p_T) by modification of azimuthal angle ϕ





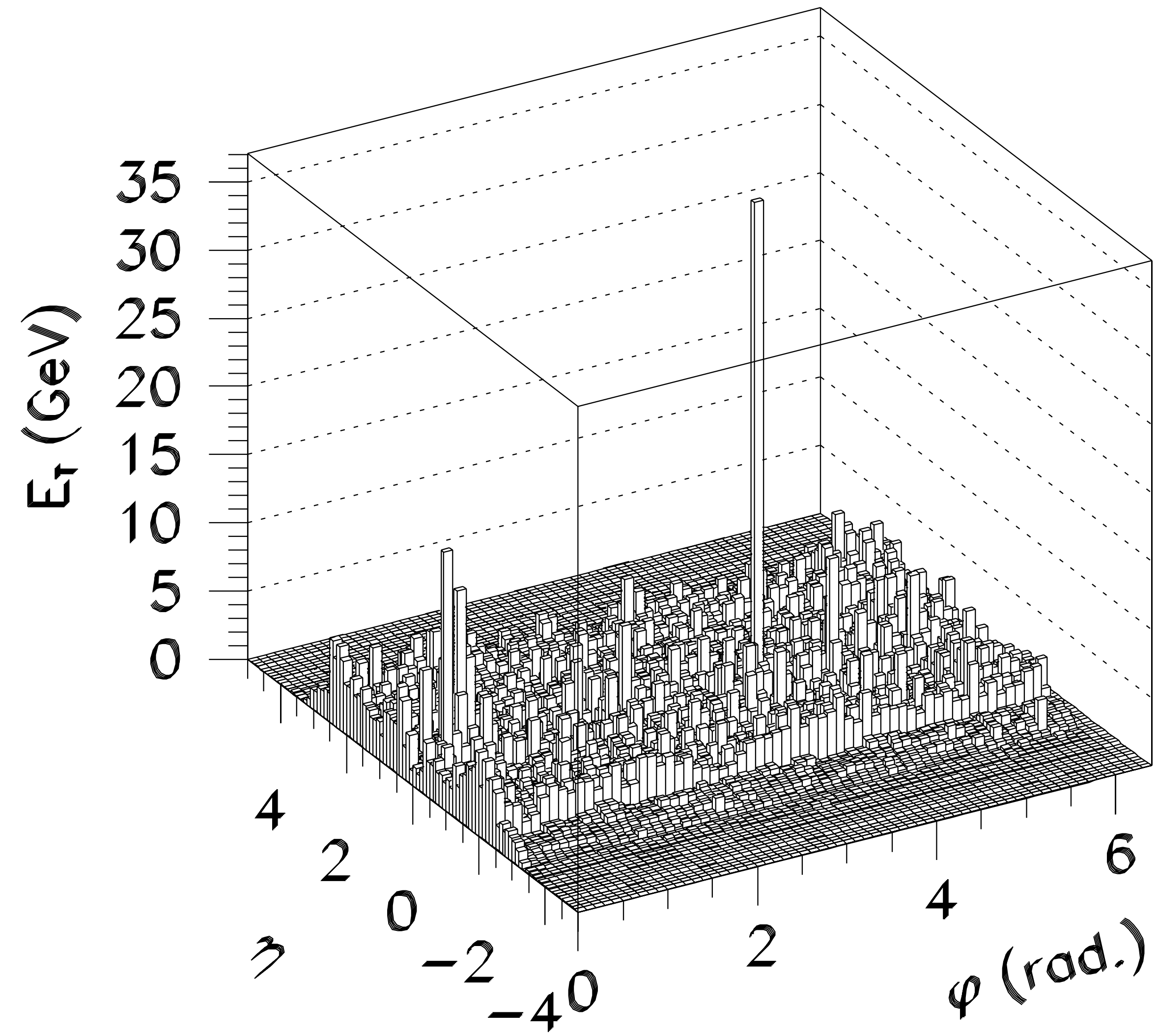


Reconstruction:

~10% is due to non-flow correl. and will be accounted for by MC correction

Jets

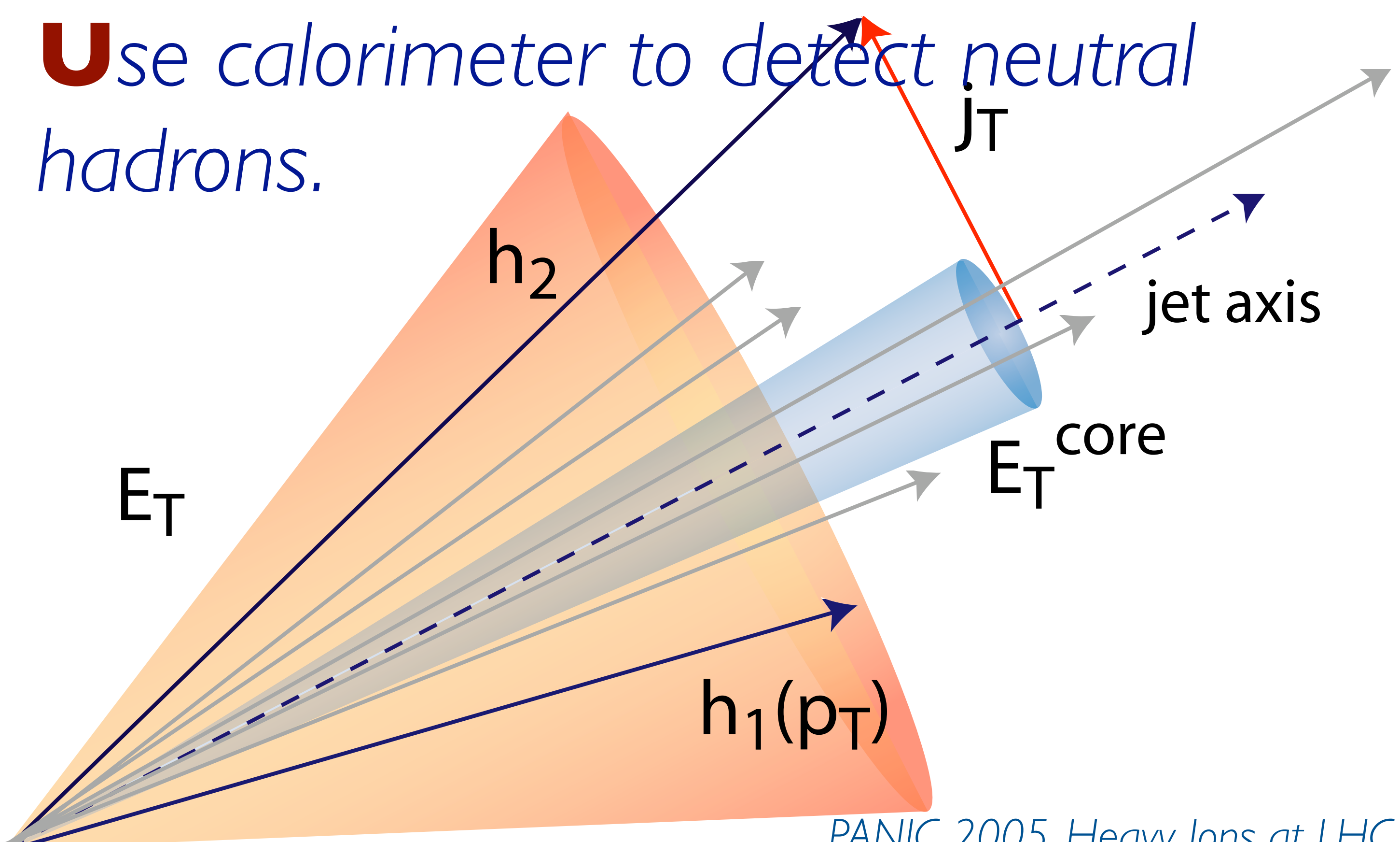
F*ind jets (after background subtraction) and measure their E_T*



U*se calorimeter do measure jet profile*

U*se calorimeters to measure core ET*

U*se calorimeter to detect neutral hadrons.*

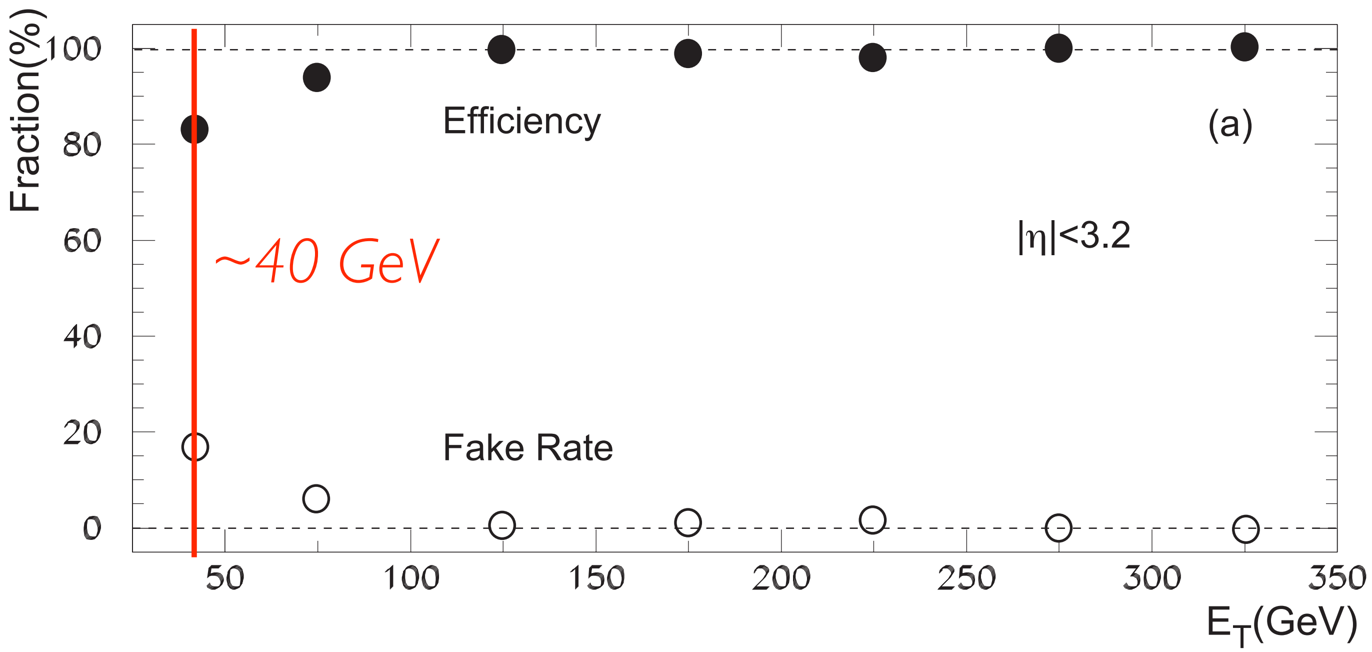


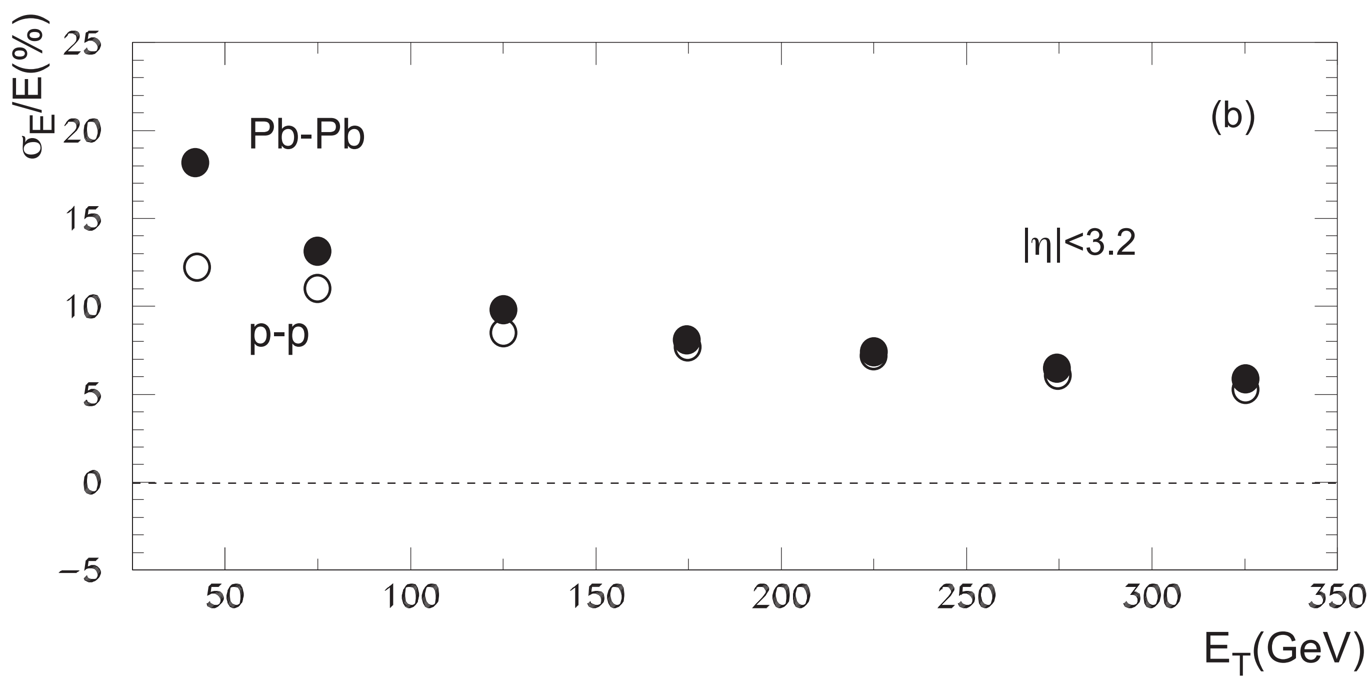
U*se tracking to measure fragmentation function D(z) and j_T via charged particles.*

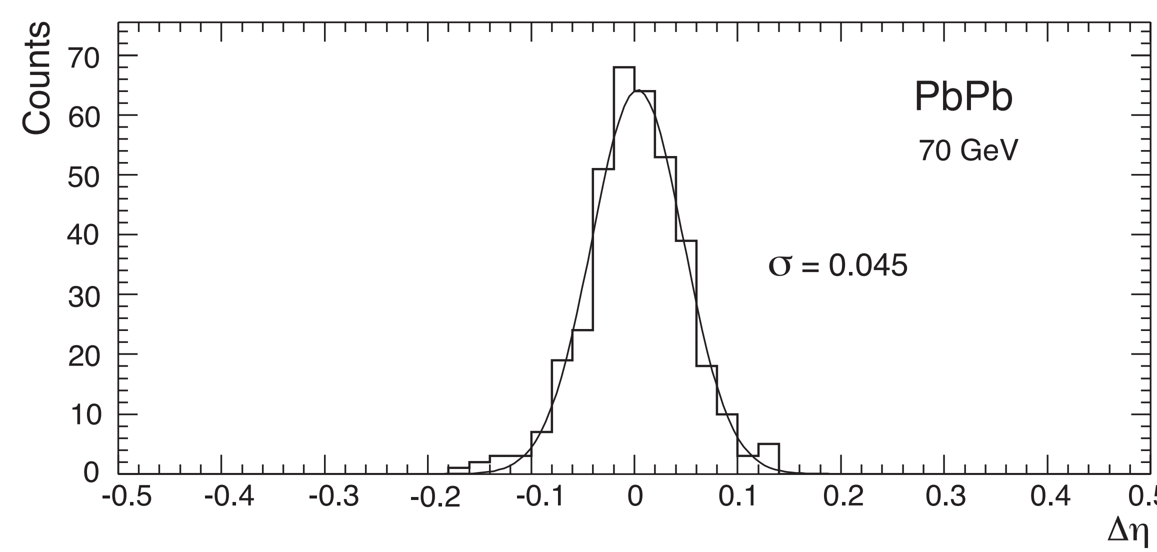
Performance

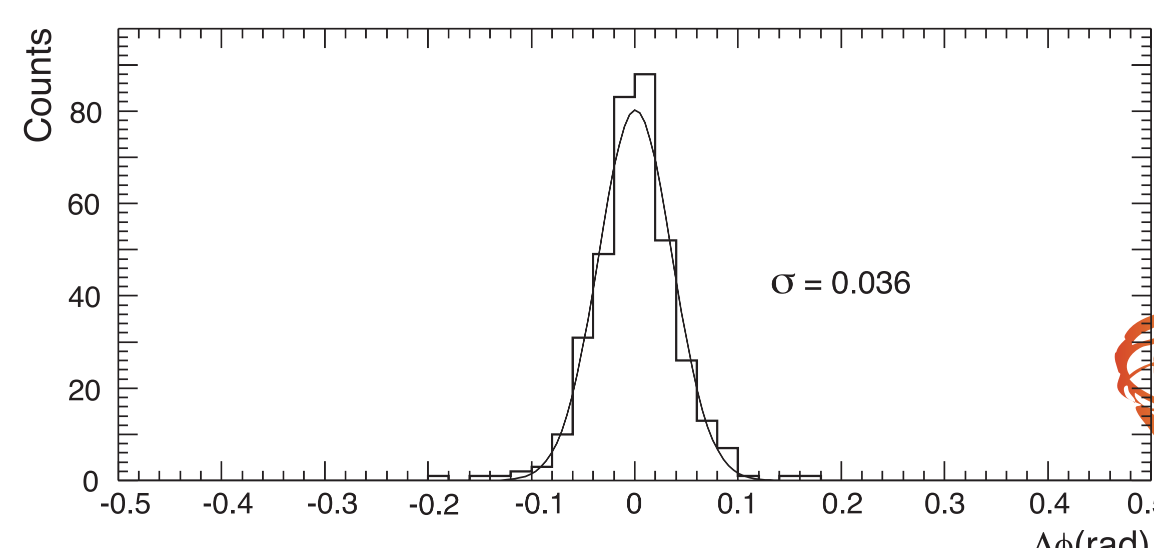
Window algorithm, with average pedestal subtraction.

Pedestal subtraction requires more study, especially if background is asymmetric.



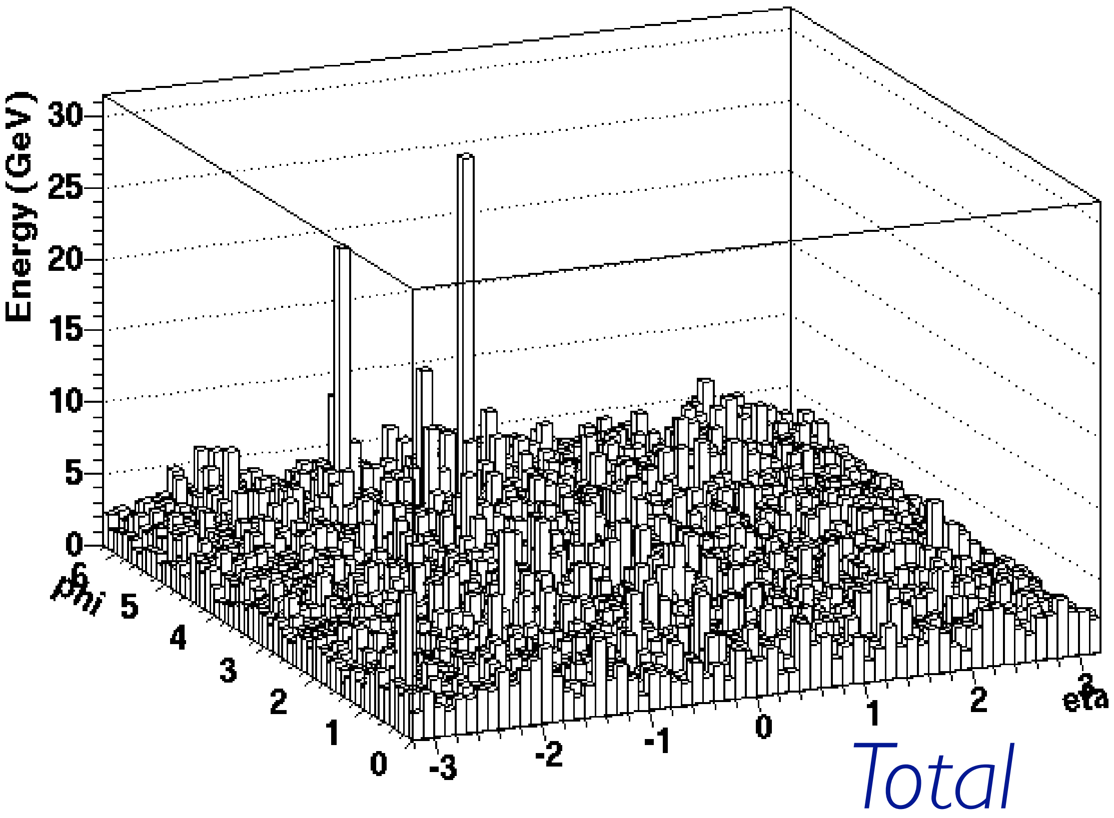


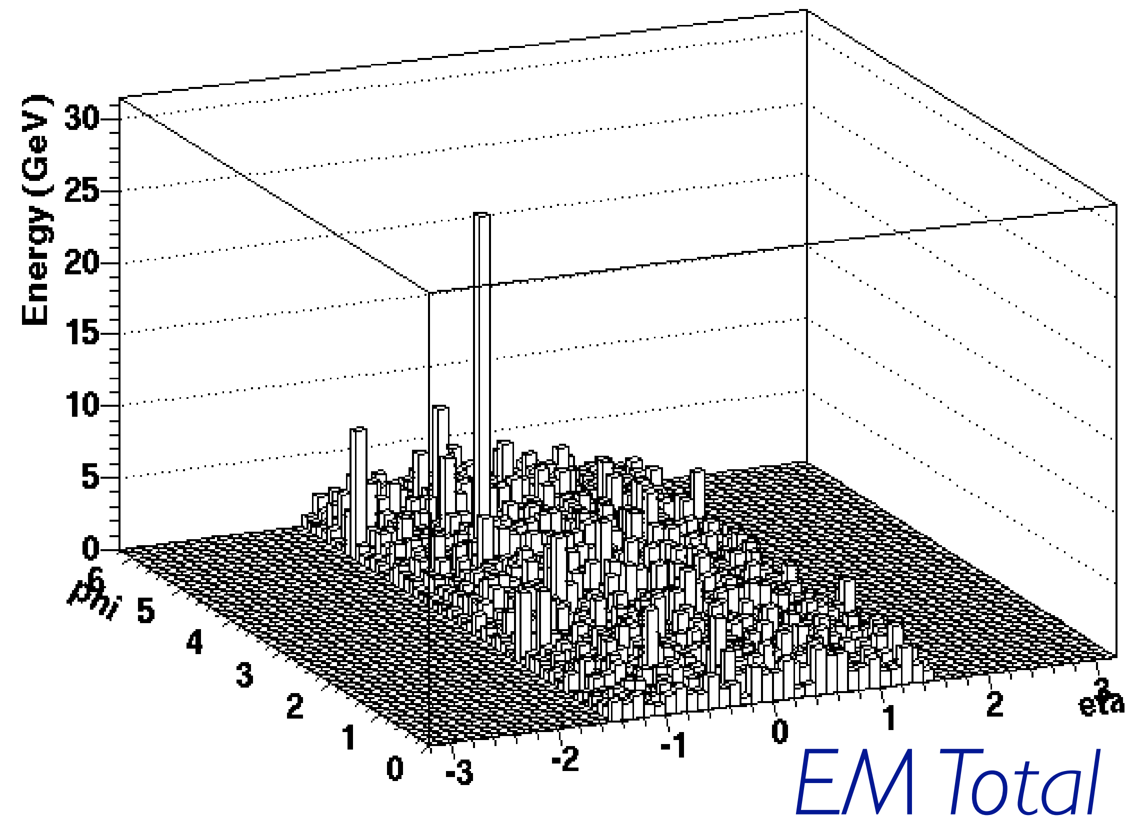


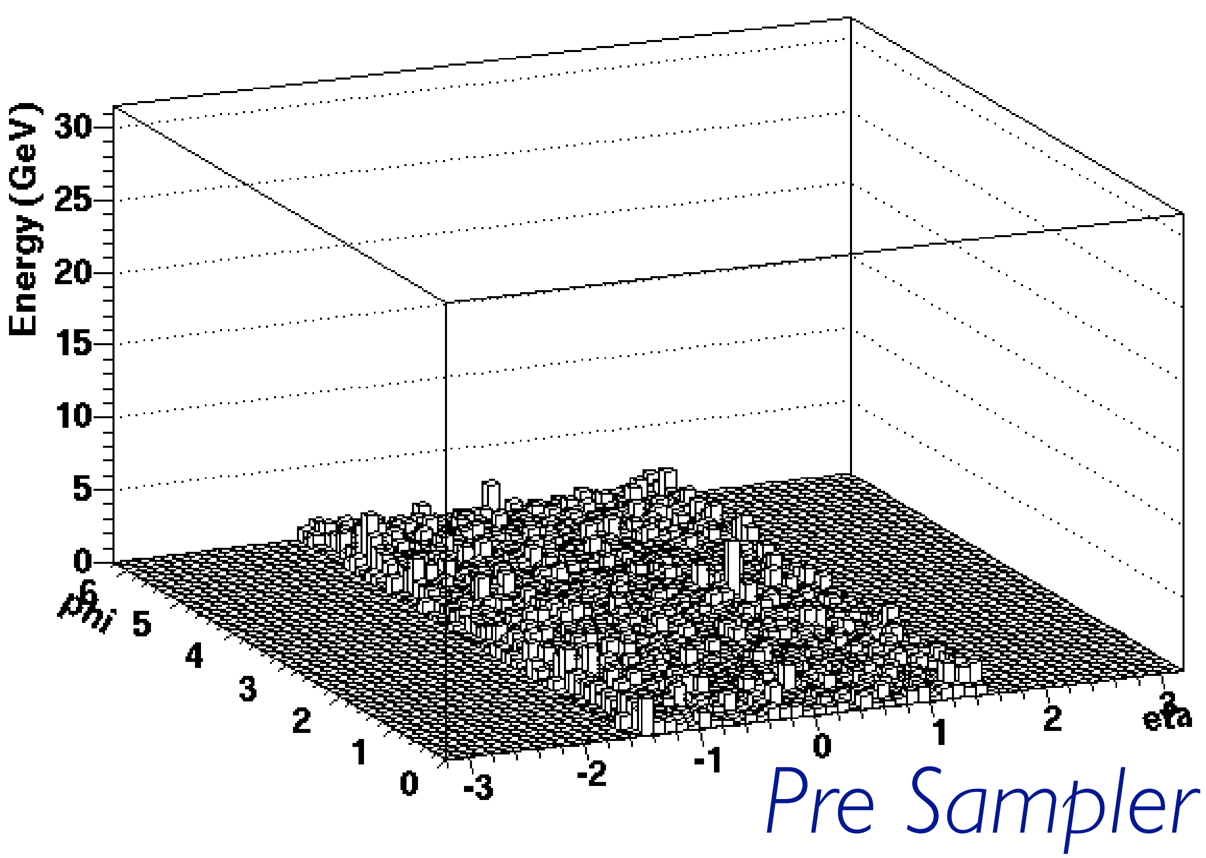


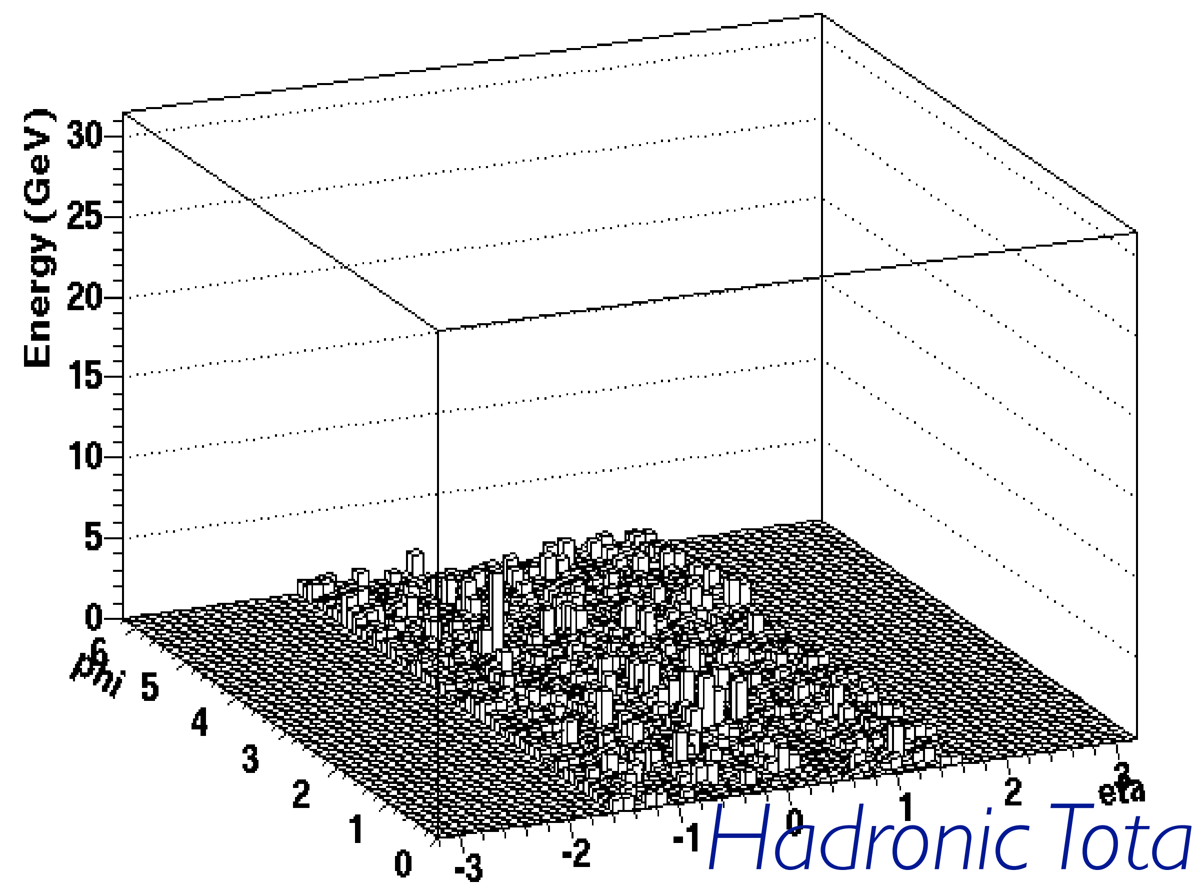
jet axis definition is important for measurement of j_T. At the moment it is about a factor of 2 worst than in pp

Calorimeter Layers



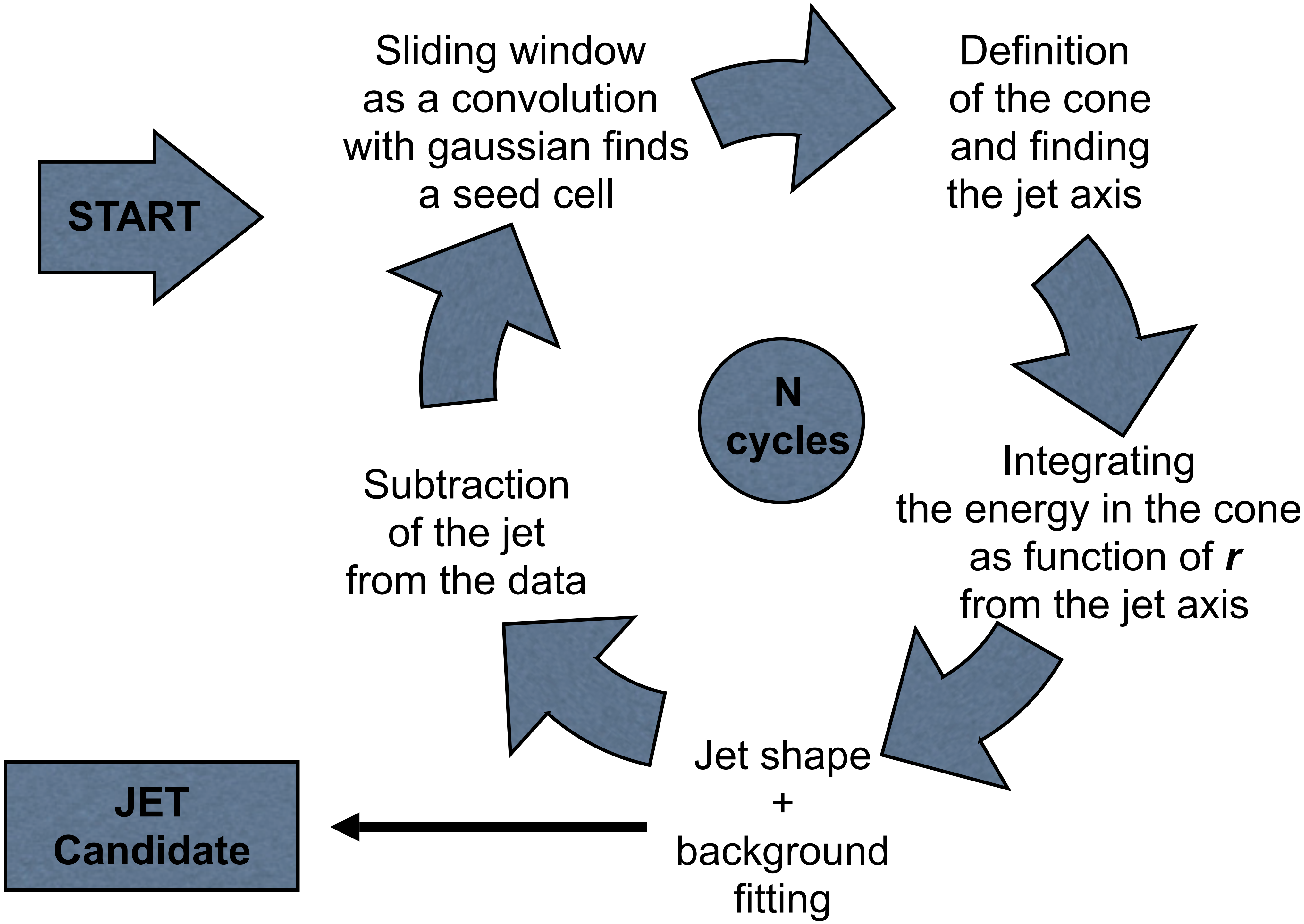




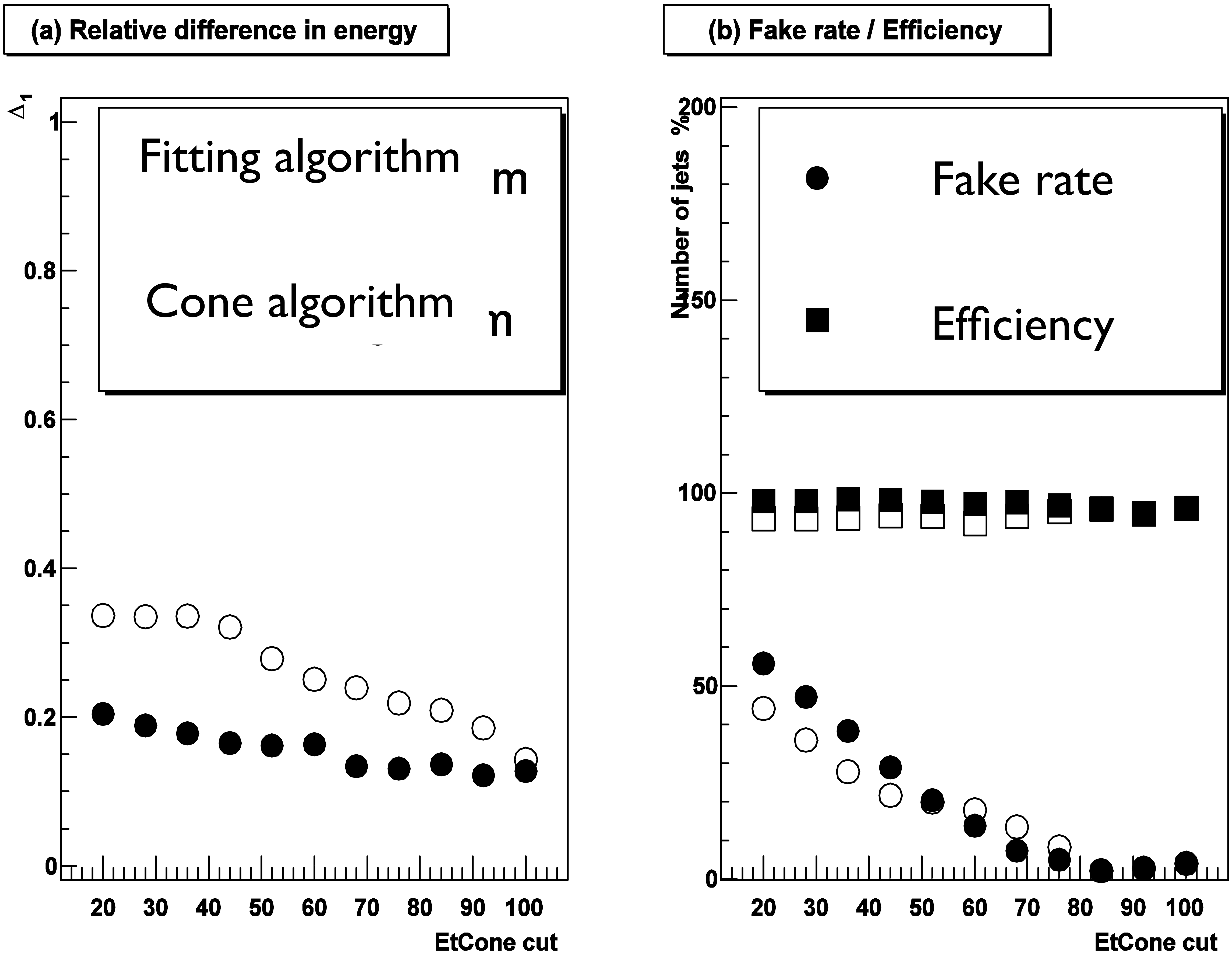


On going Study

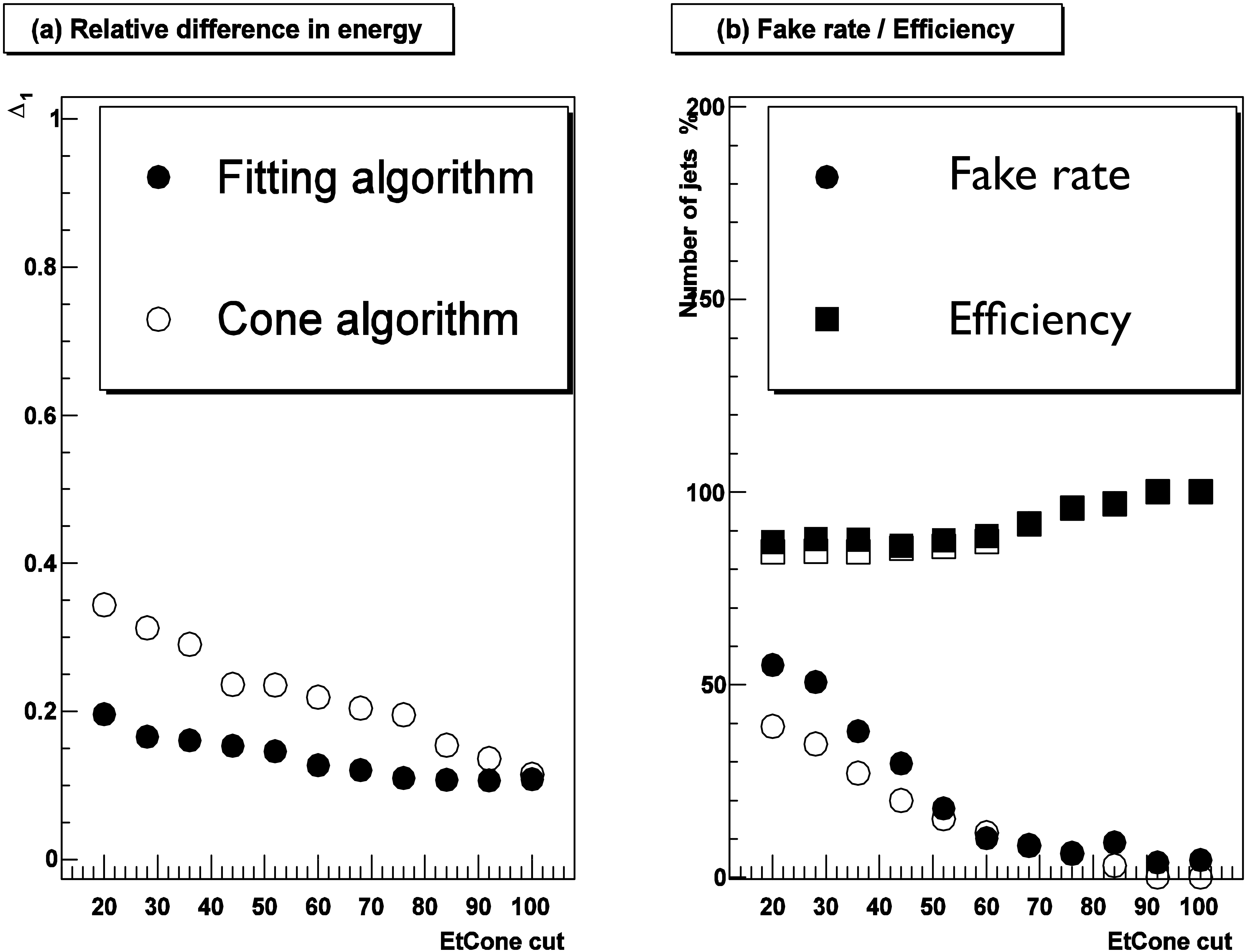
"Fit" a jet profile around the jet axis determined with the sliding window algorithm



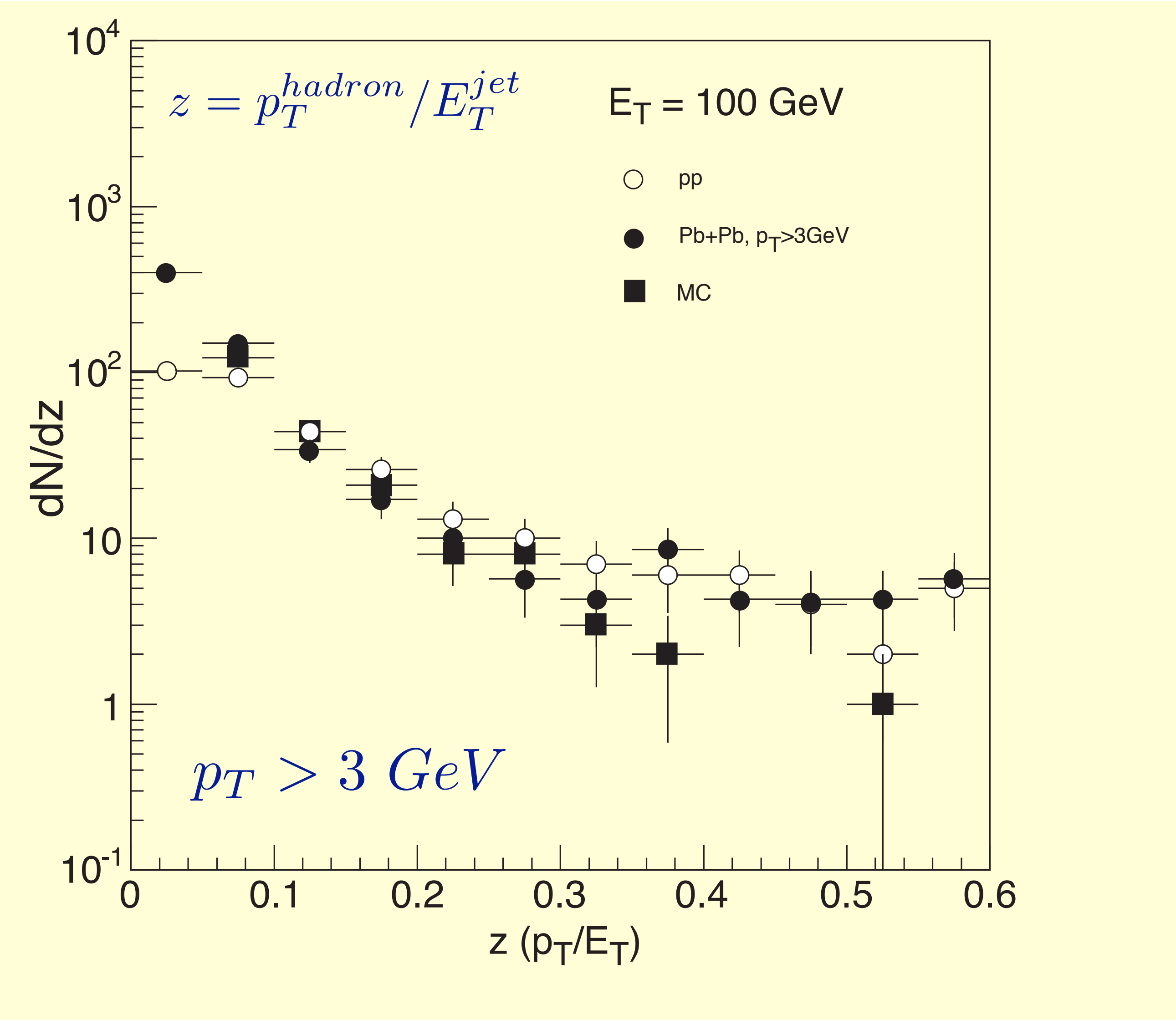
$$qq \to WH(120) \to \mu\nu_\mu uu$$

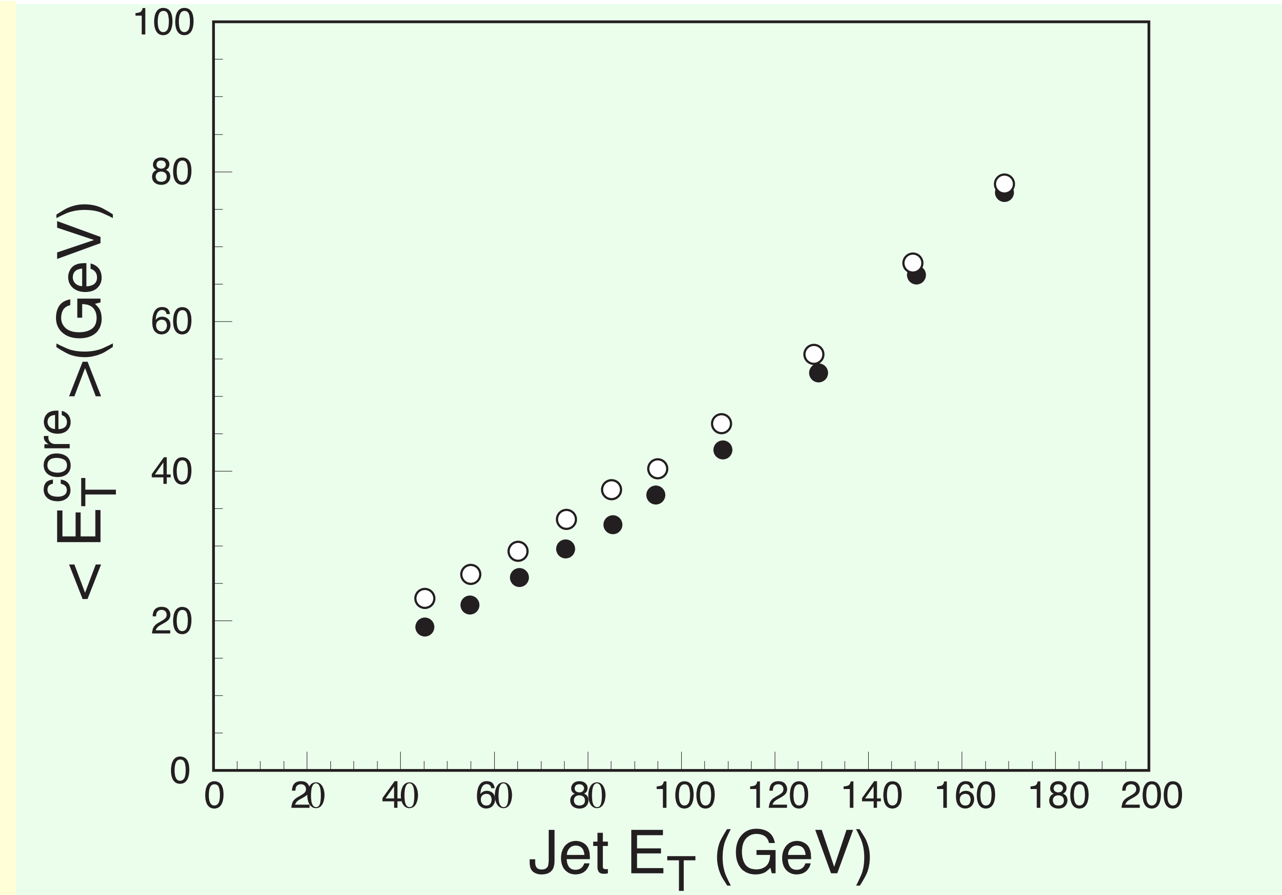


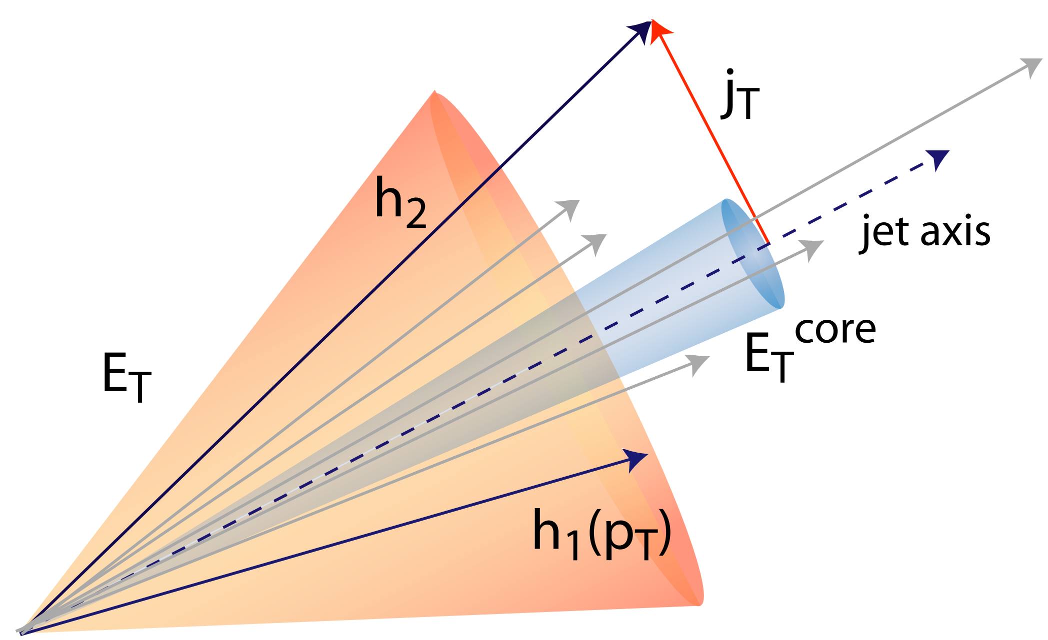
$$qq \to WH(120) \to \mu\nu_\mu bb$$

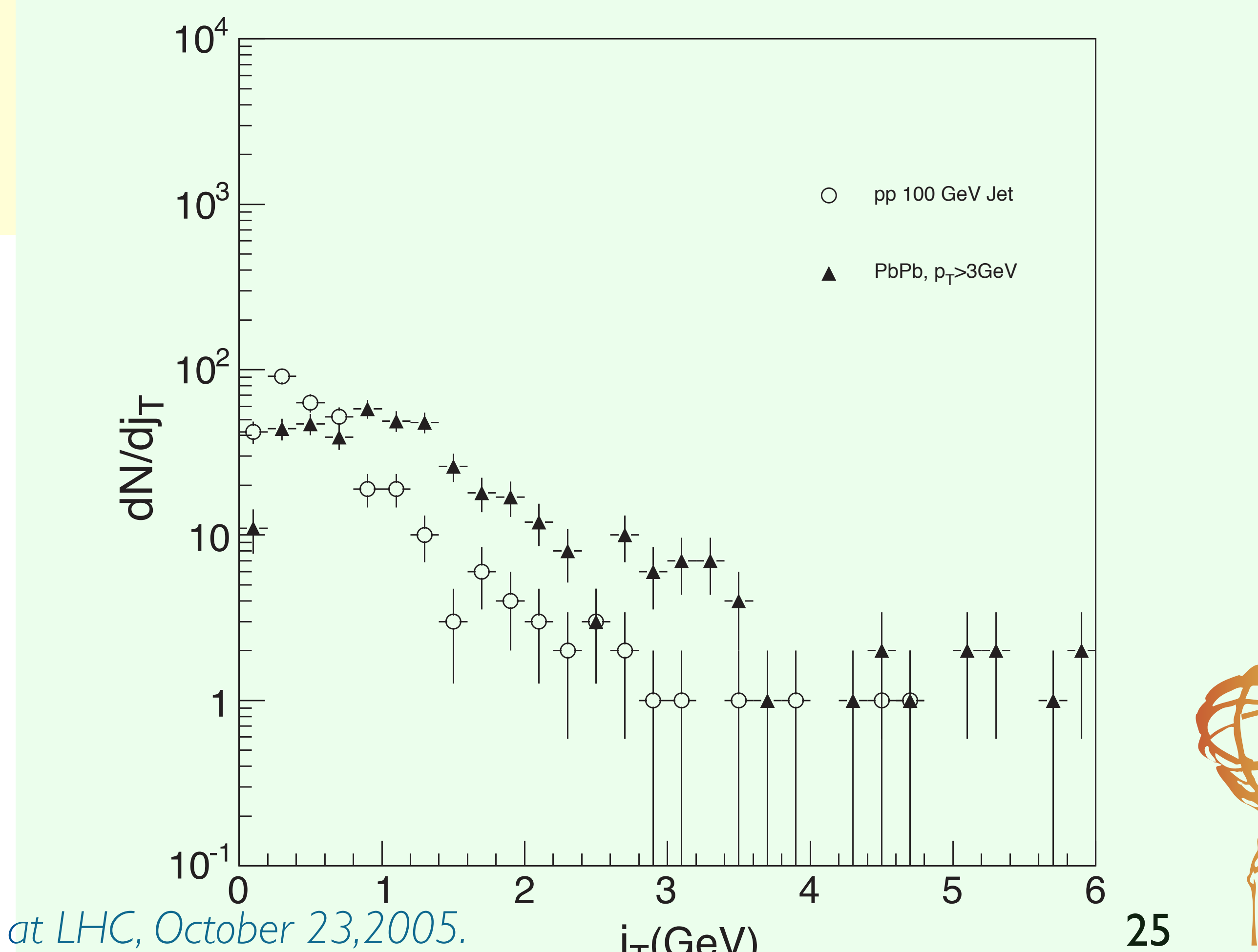


Fragmentation function, j_T and E_T^{core}





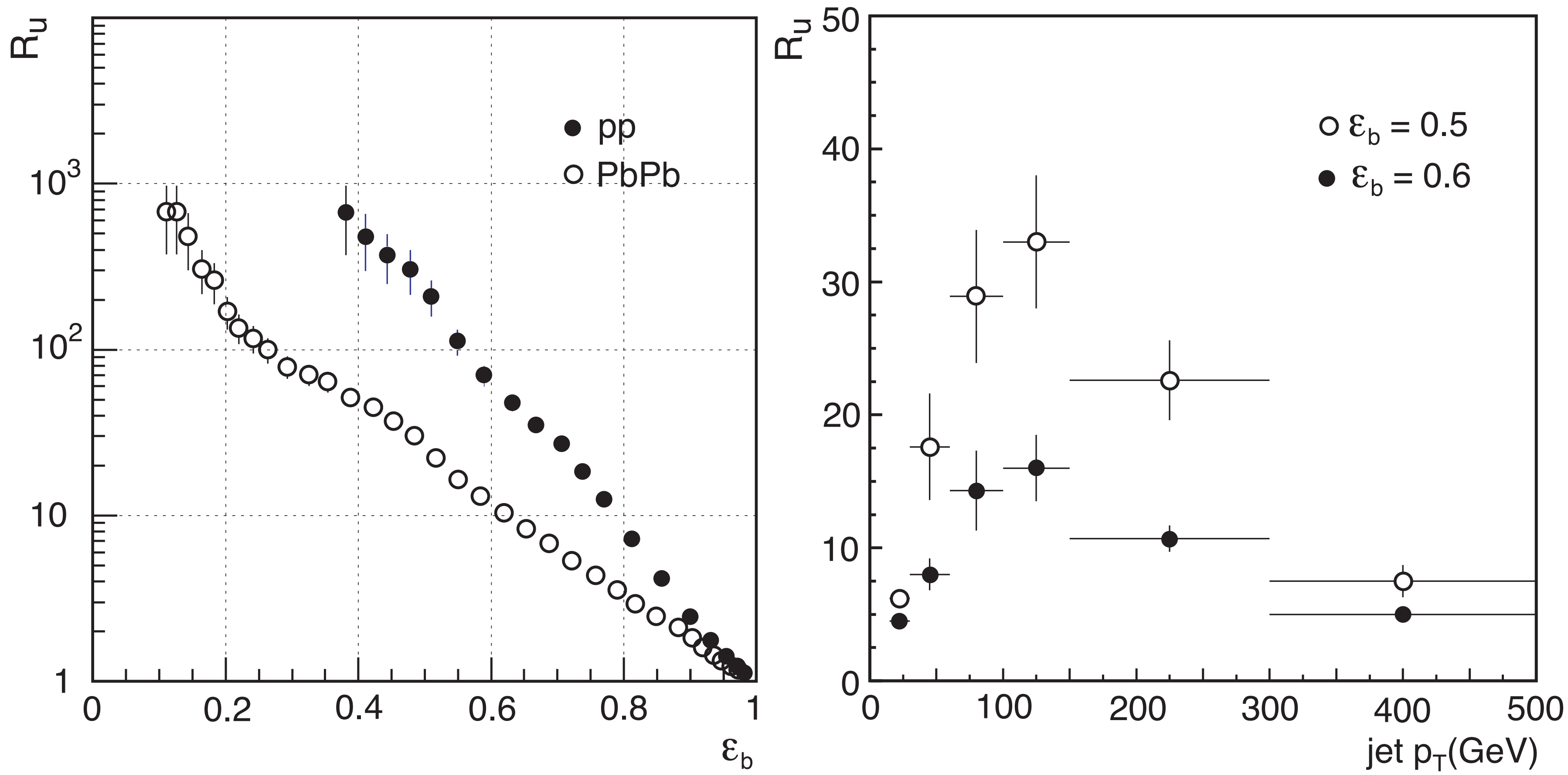




b- tagging

Motivation - *Heavy quarks may radiate less than light quarks in the hot QCD matter.*

A *first study of the b-tagging capability in the heavy ion environment was performed by overlapping WH events on HIJING background.*



A muon tag *will also be used by matching a muon in the spectrometer to the jet axis.*

How to track low p_T muons?

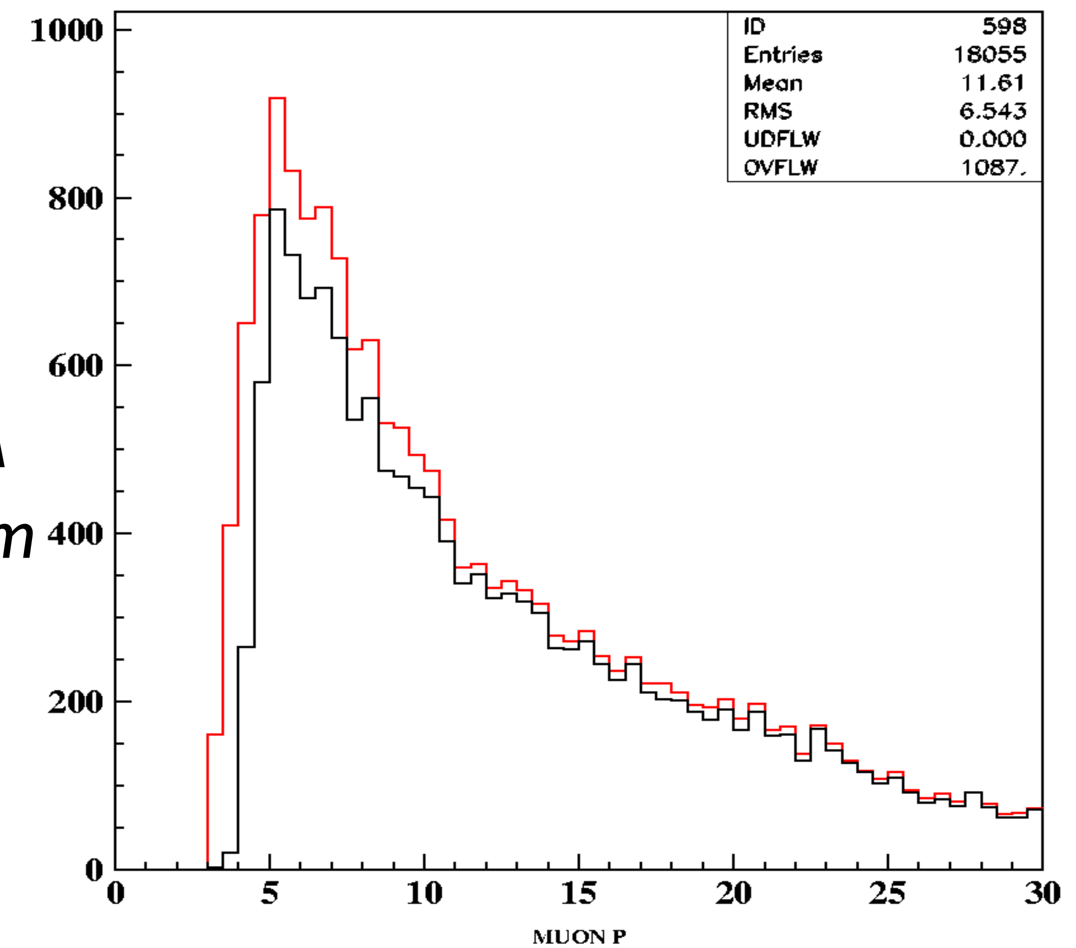
Global method (A): use tracks fully traversing the μ-spectrometer, which allows momentum measurement in the standalone μ-spectrometer, then associate with ID tracks through a global fit.

Tagging method (B): select ID tracks whose extrapolation coincide with a track segment in the μ-spectrometer.

Advantage of A over B: better p measurement (true for Z^0,not J/ψ, ϒ), better purity.

Advantage of B over A: lower p threshold => better acceptance (3 GeV instead of 4).

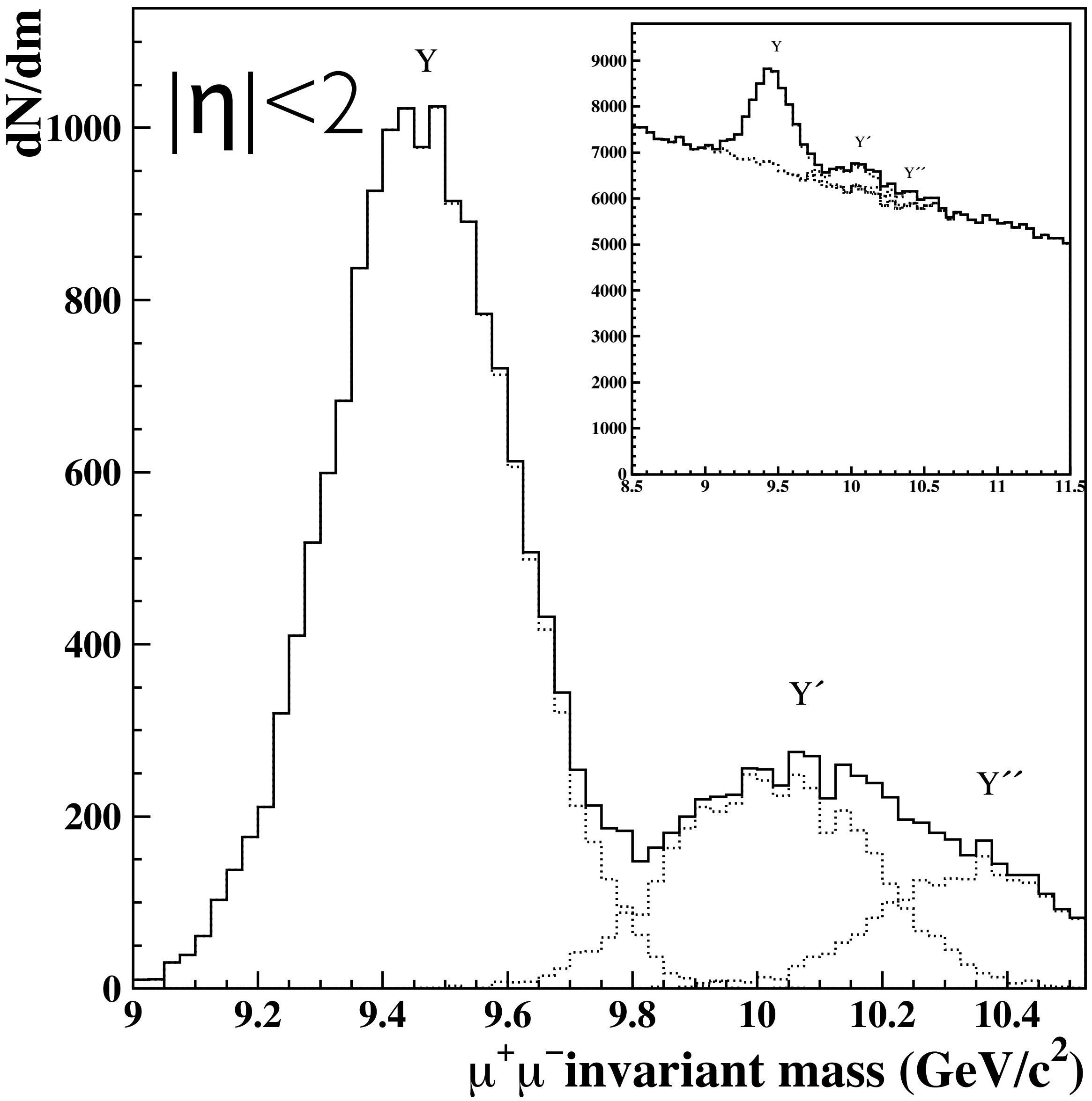
For this study, A+B are used, with a priority to method A when possible. Selection of pairs with at least one μ from method A.



$\Upsilon \to \mu^+\mu^-$ Reconstruction

	$p_T(\mu) > 3$ GeV		
	$\|\eta\|<1$	$\|\eta\|<2$	$\|\eta\|<2.5$
Acceptance and Efficiency	2.6% 4.7%	8.1% 12.5%	12.0% 17.5%
Resolution	123 MeV	145 MeV	159 MeV
S/B	0.4 0.3	0.3 0.2	0.3 0.2
$S/(S+B)^{1/2}$	31 37	45 46	55 55

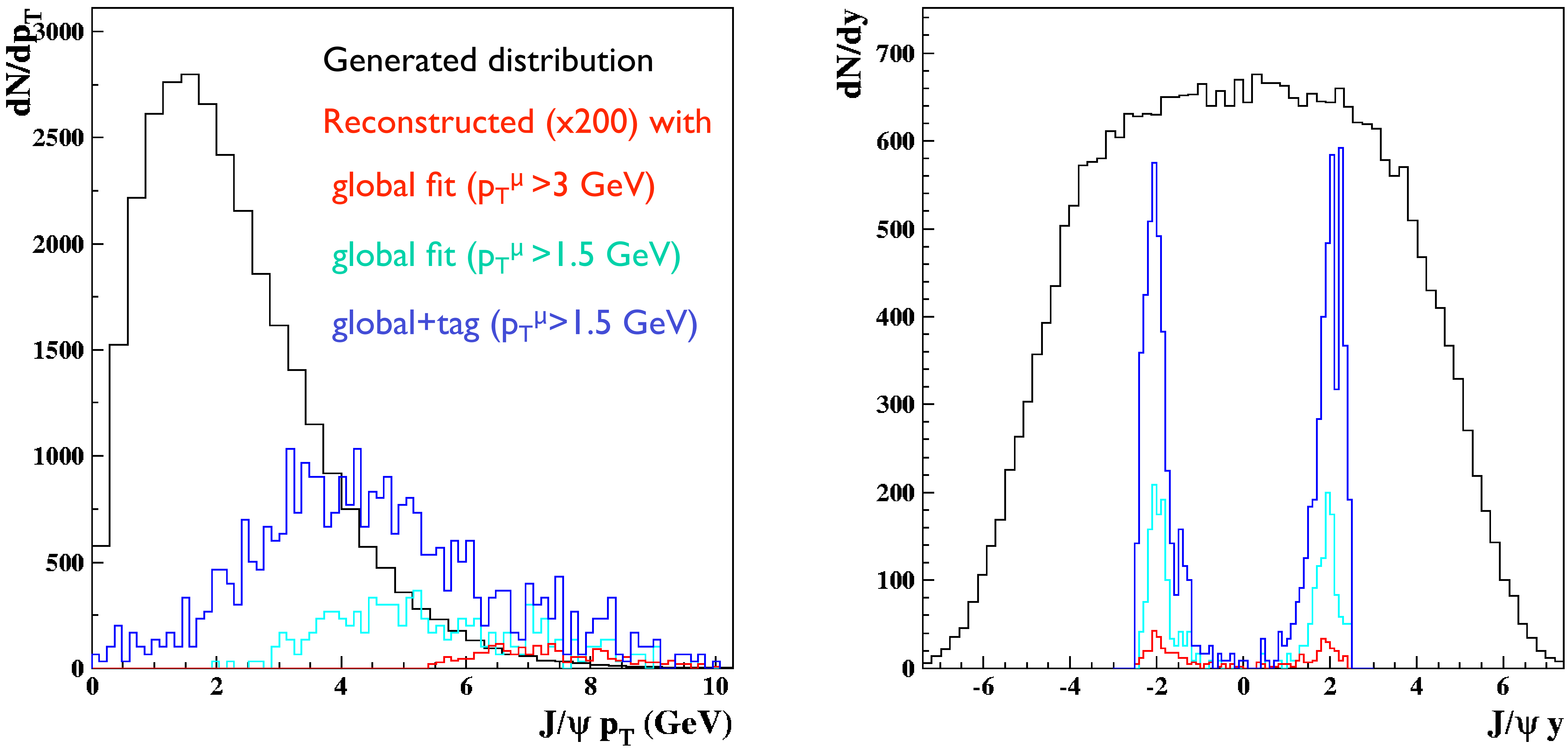
Global Fit (upper values) **Global+Tag** (lower values)



For $|\eta| < 2$ (12.5% acceptance+efficiency) we expect 15,000 Υ per month (10^6s) at $\mathcal{L}=4\times10^{26}$ cm^{-2} s^{-1}

The TRT has not been considered for this study. If N_{ch} allows for its use, the mass resolution will be improved by 25%

Acceptance and efficiency for J/ψ

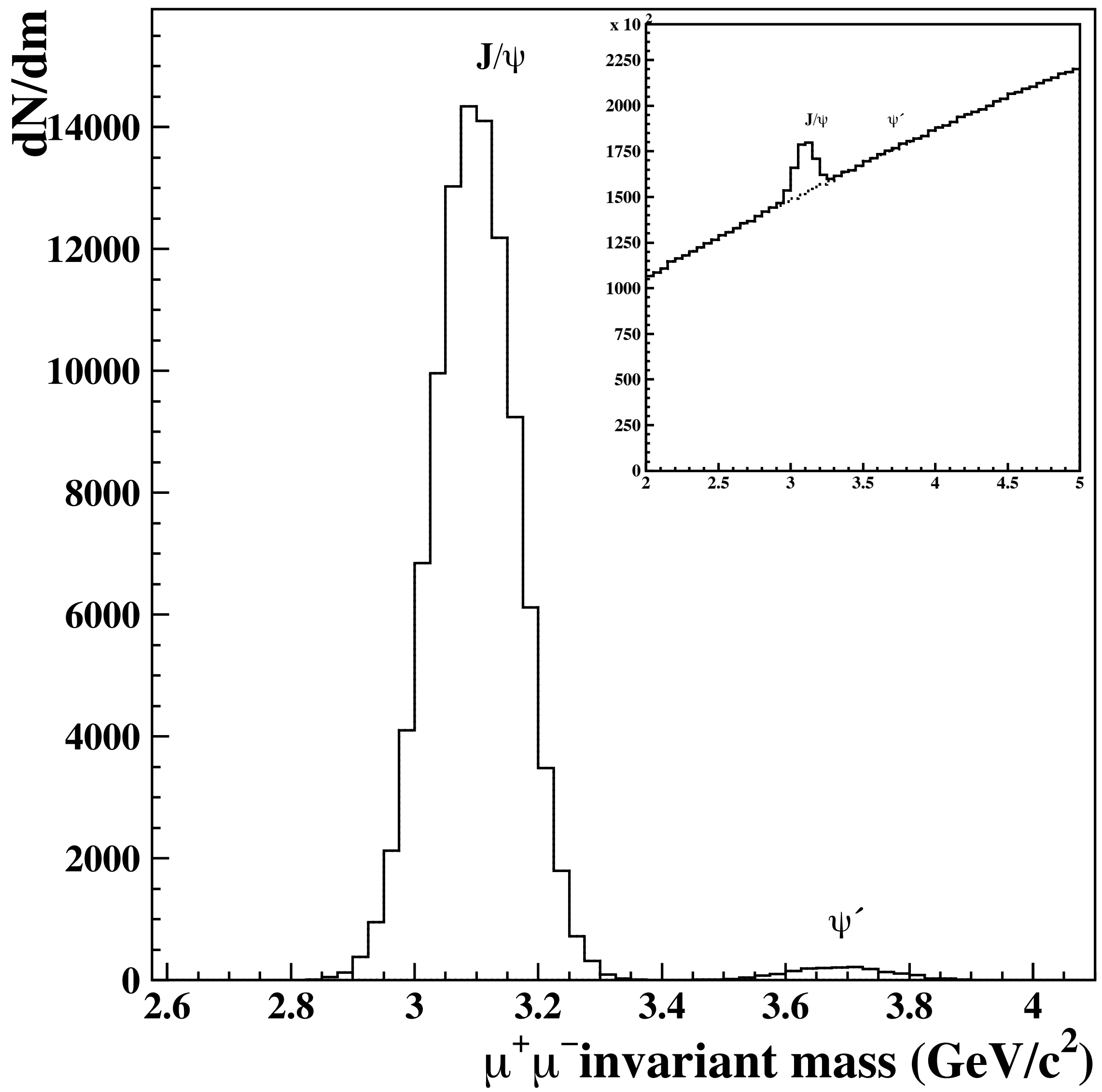


The full p_T range of the J/ψ is not accessible for $p_T^{\mu} > 3$ GeV, but is accessible for $p_T^{\mu} > 1.5$ GeV. Acceptance is forward and backward.

$J/\Psi \rightarrow \mu^+\mu^-$ Reconstruction

	$\lvert\eta\rvert<2.5$ pT(μ)>3 GeV	$\lvert\eta\rvert<2.5$ pT(μ)>1.5 GeV
Acceptance and Efficiency	0.039% 0.055%	0.151% 0.530%
Resolution	68 MeV	68 MeV
S/B	0.5 0.4	0.2 0.15
$S/(S+B)^{1/2}$	52 56	72 113
Rate per Month	8000 11000	30000 100000

Global Fit (upper values) **Global+Tag** (lower values)

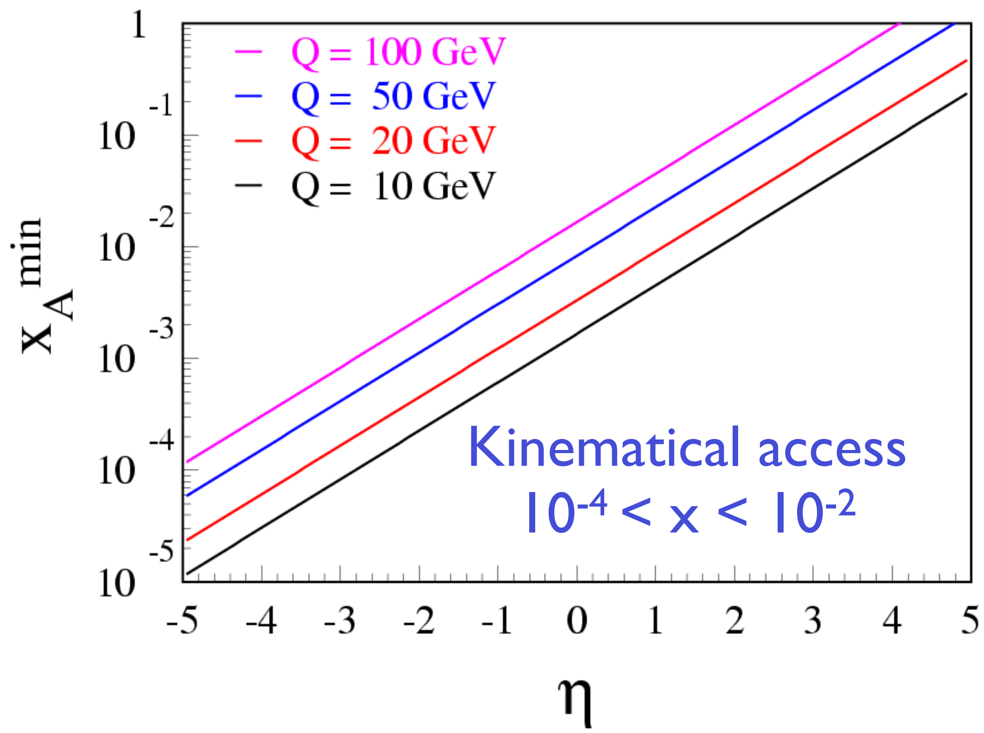


We expect 8,000 to 100,000 $J/\psi \rightarrow \mu^+\mu^-$ / month(10^6s) at $\mathcal{L}=4\times10^{26}$ cm^{-2} s^{-1}

If a trigger is possible forward with a muon p_T >1.5 GeV, we gain a factor 4 in statistics. A solution might be to reduce the toroidal field for HI runs

Global+tag method increases rate by 3.5 and decreases S/B by 1.5

proton-Nucleus in ATLAS



Study *of the modification of the gluon distribution and jet fragmentation function in the nucleus at low x, when gluon saturation occurs ("saturation physics")*

Probe *pQCD in nuclear environment*

Link *between p-p and A-A physics, baseline for HI*

p-Pb: *$\mathcal{L} \sim 10^{29}$ - 10^{30} cm^{-2} s^{-1} ,σ_{TOT}=2 b,$\sqrt{s}$=9 TeV, rapidity shift=0.5*

Soft *background and occupancy in p-Pb are lower than in p-p with 25 pile-up* events

Hermetic *calorimeter good for asymmetric collisions; ΔY=0.5*
*⇒**ATLAS** is an excellent detector for proton nucleus collisions.*

Trigger and DAQ

Assume a limiting bandwidth of 200 x 1.5 = 300 *MB.Hz*. *A central (b<1 fm) event size Pb-Pb collision is 5 MB.*

A luminosity of $\mathcal{L}$ = 4x10^{26} cm^{-2}s^{-1} *gives an int. rate of ~ 3.5 kHz.*

Interaction trigger *can be defined on the basis of the forward calo.*

E_T thresh.	centrality	rate(kHz)	% of σ_{tot}
5.6 TeV	b< 3 fm	0.3	3
4.3 TeV	b < 5 fm	0.8	10
1.7 TeV	b < 9 fm	2.4	30
0.3 TeV	b < 13 fm	5.6	70
1 GeV	unbiased	6.8	85
0.25 GeV	unbiased	7.9	99
$1<E_T<30$ GeV	b > 15 fm	0.9	11

Ultra Peripheral Nuclear Collisions

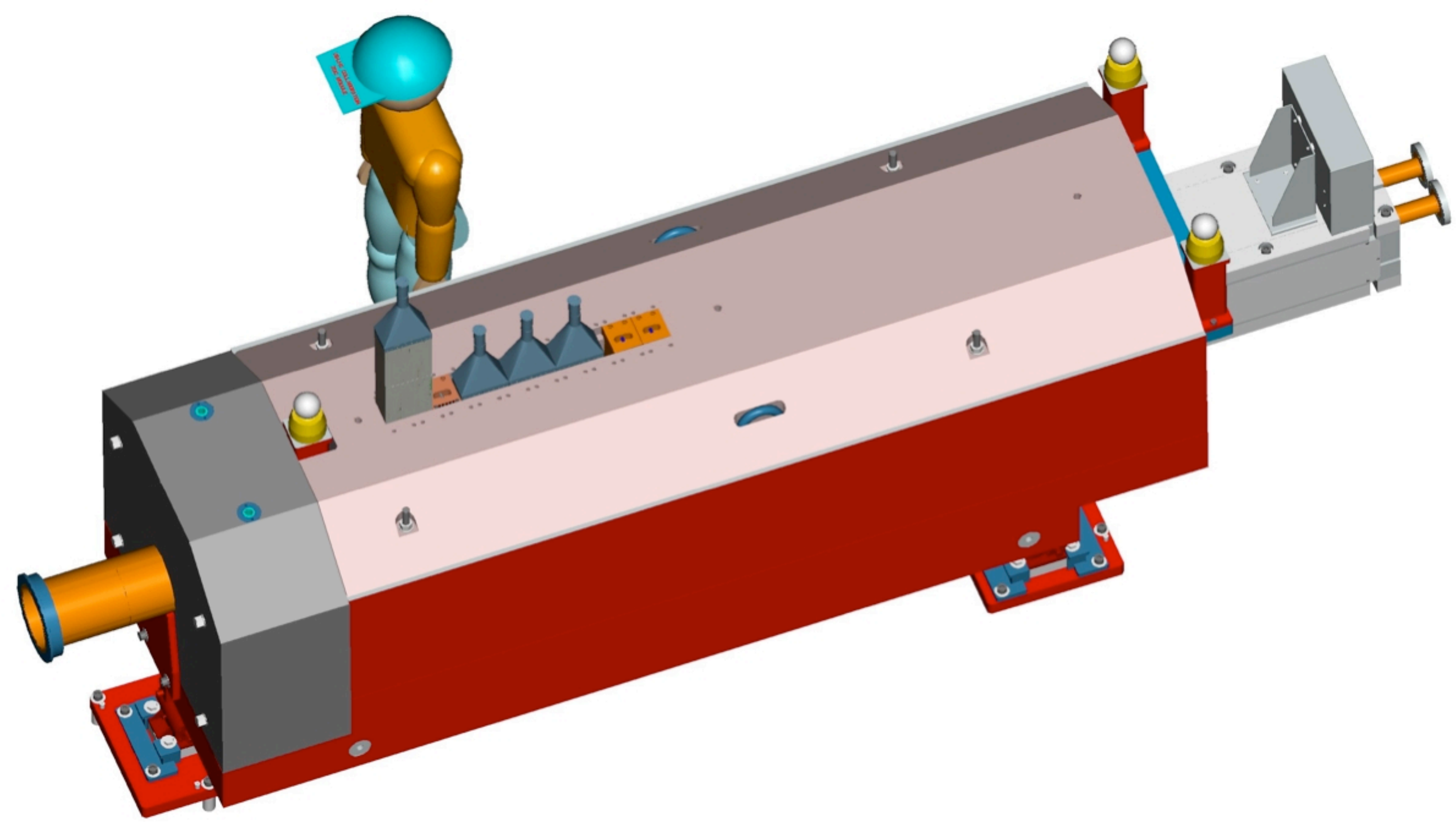
***H**igh energy γ-γ and γ-nucleon collisions*

***M**easurements of hadron structure at high energies above HERA*

di-Jet and heavy quark production

***T**agging of UPC requires a Zero Degree Calorimeter*

***O**n going work on ZDC design and integration with the accelerator instrumentation.*



People

S. Aronson, K. Assamagan, M. Baker, B. Cole, A. Denisov M. Dobbs, J. Dolejsi, H. Gordon, F. Gianotti, I. Gavrilenko, V. Kostyukhin, M. Levine, F. Marroquim, A. Moraes, J. Nagle, P. Nevski, A. Olszewski, M. Rosati, L. Rosselet, M. Spousta, P. Steinberg, H. Takai, S. Tapprogge, A. Trzupek, M.A.B. Vale, S. White, B. Wosiek and K. Wozniak.

Brookhaven National Laboratory
CERN, University of Colorado
Columbia University
Iowa State
Lebedev Institute of Physics
Intsitute of Particle and Nuclear Physics, Prague
Universidade Federal do Rio de Janeiro, University of Geneva
Institute of Nuclear Physics, Cracow

Brief Status

Jets - Energy Calibration.

Use Layers to reconstruct jet energy and pointing.

Tracking - The use of TRT. While occupancy is high, higher threshold (TR signal) show lower occupancy.

Trigger - Common interest with Super LHC studies.

Conclusions

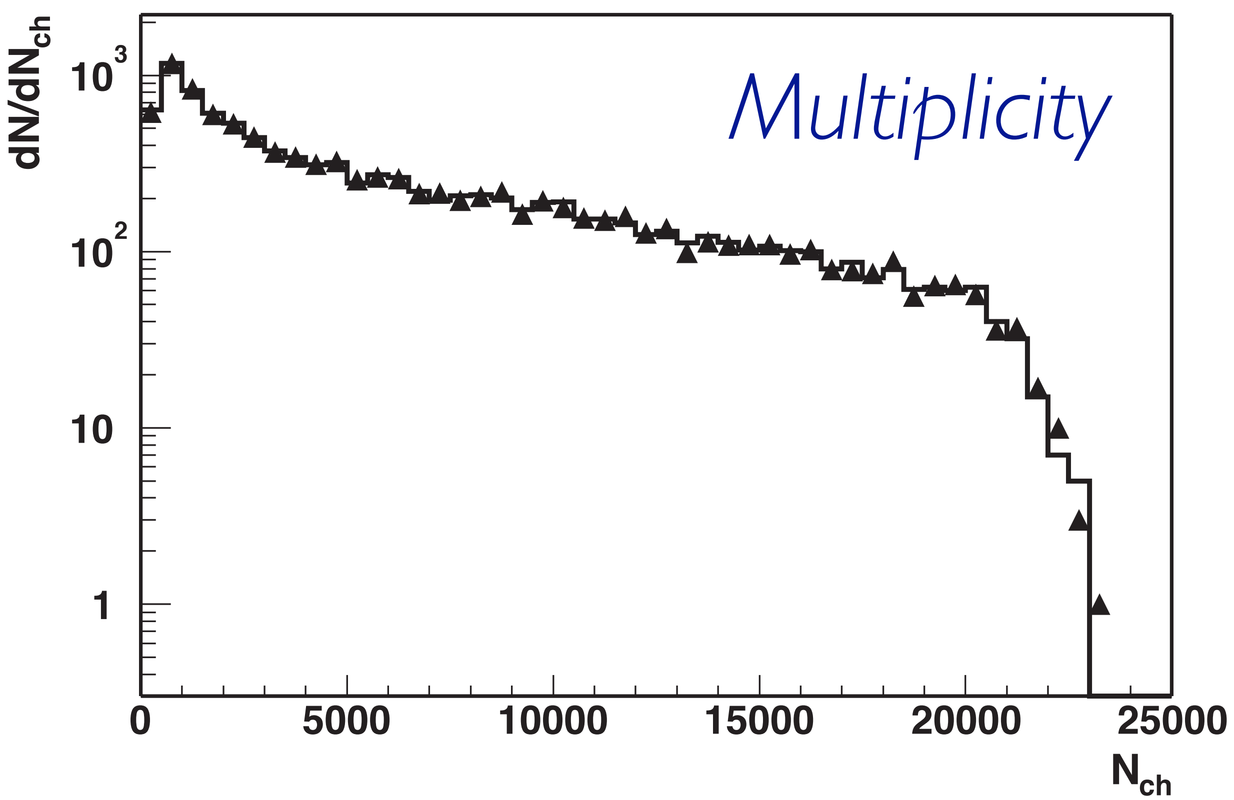
The high granularity of the calorimeter system, external muon spectrometer and tracking capabilities in the high multiplicity environment makes ATLAS ideal for the study of jet physics, quarkonia and minimum bias events in heavy ion collisions.

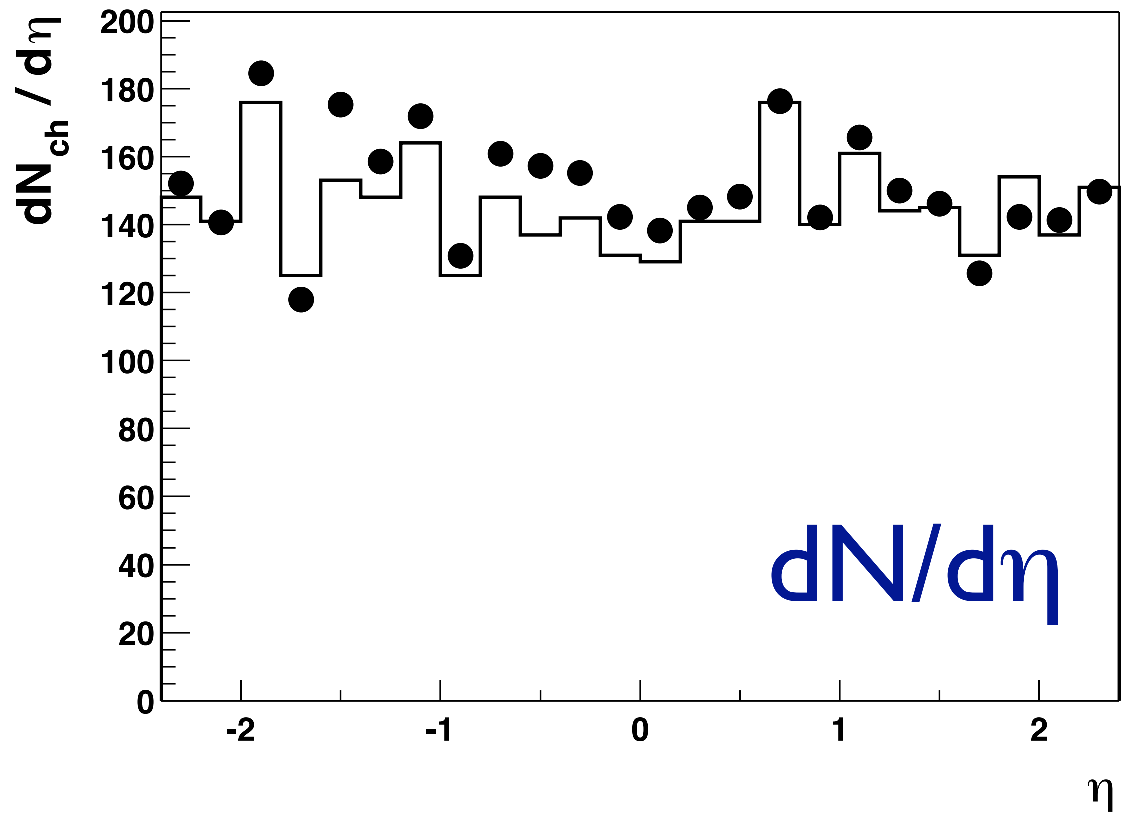
The study of pp and pA collisions in the same environment will allow for the definition of a solid baseline. Hence the interest in jet physics in pp and pA runs.

Studies of detector performance is continuing. Algorithms tailored to the high multiplicity environment need to be developed within the ATLAS ATHENA software framework.

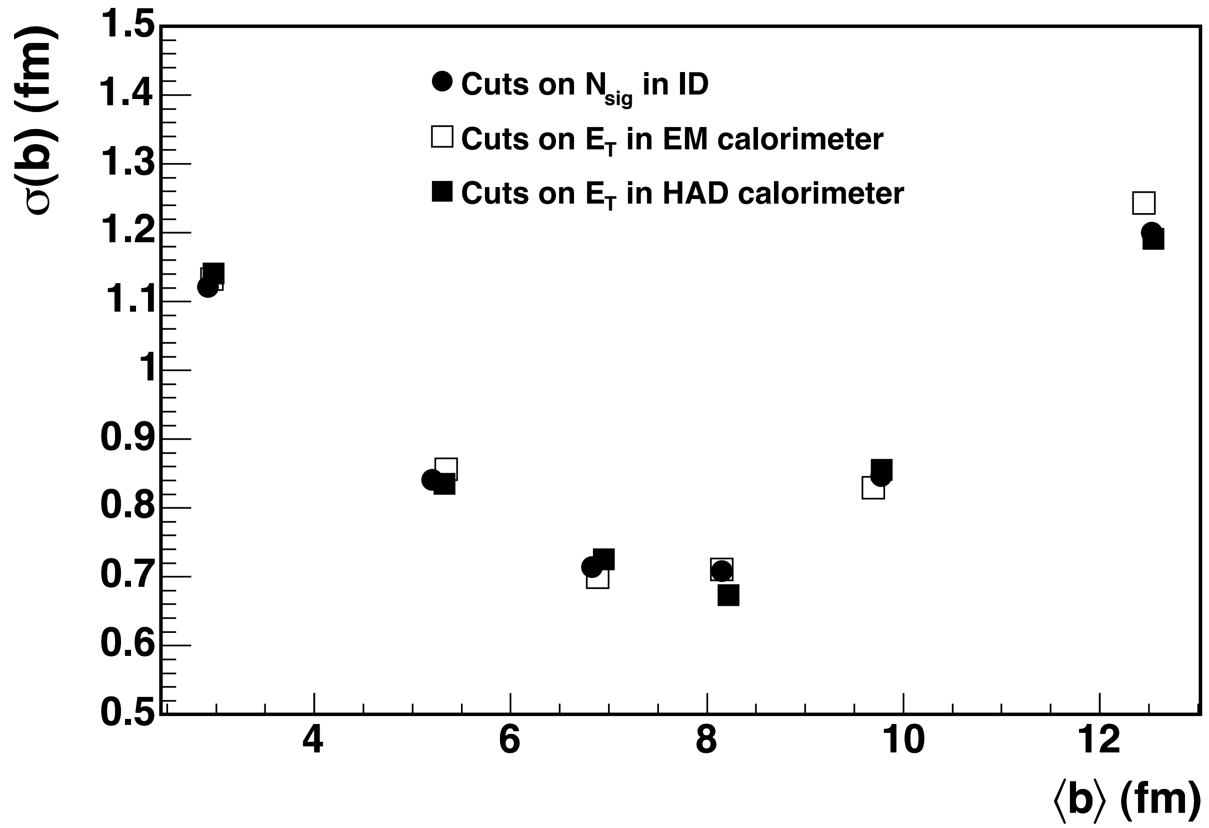
Supplemental Slides

Global Variables



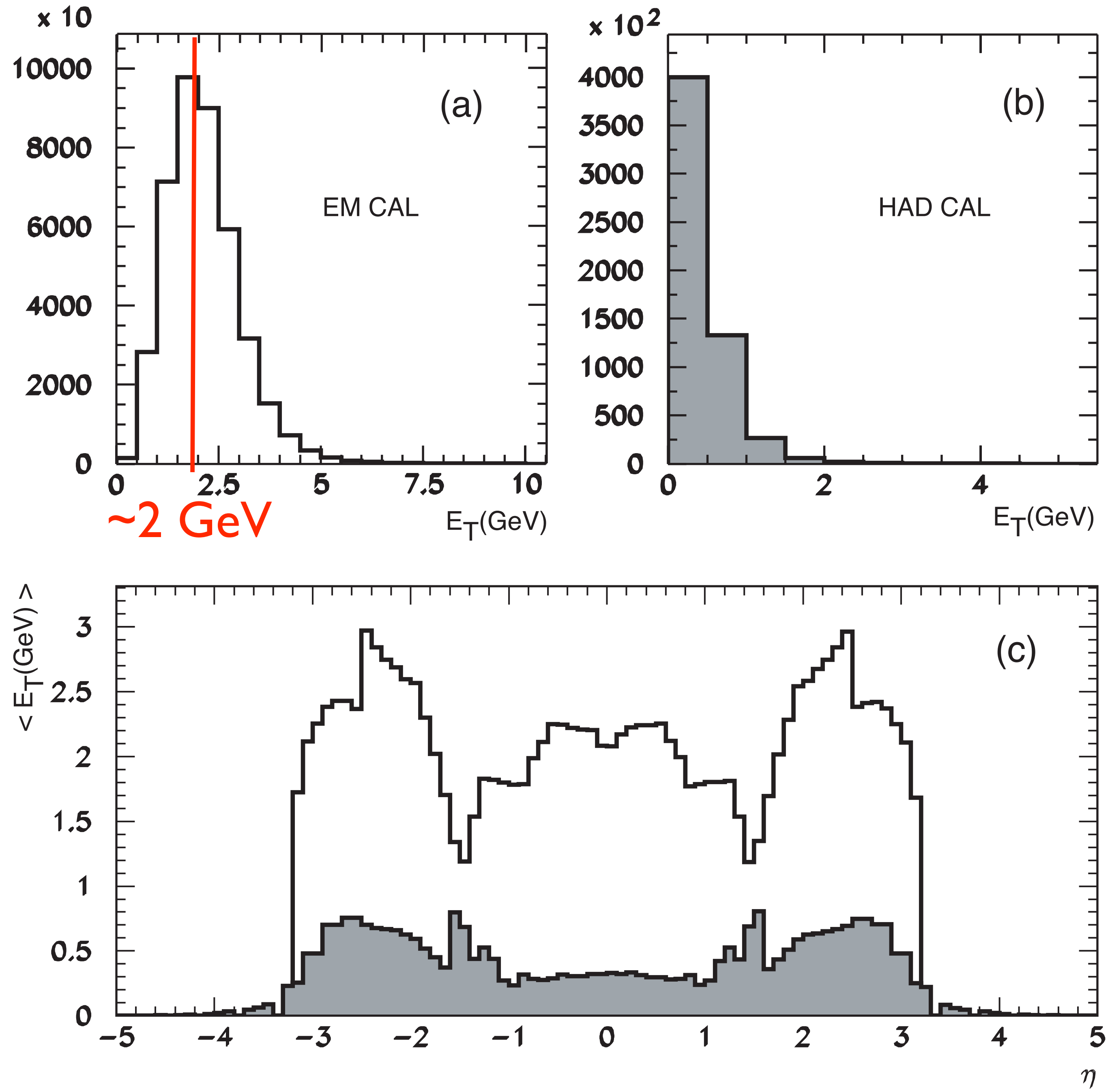


impact parameter resolution



Average Energy in Calorimeters

(in 0.1x0.1 cell)



b<1 fm

E*nergy deposition by soft particles in heavy ion collisions (b<1)*

M*ost energy is absorbed by the electromagnetic calorimeter!!!*

Jets *will ride on top of an average pedestal of (50±11) GeV (ΔR=0.4)*

Rates

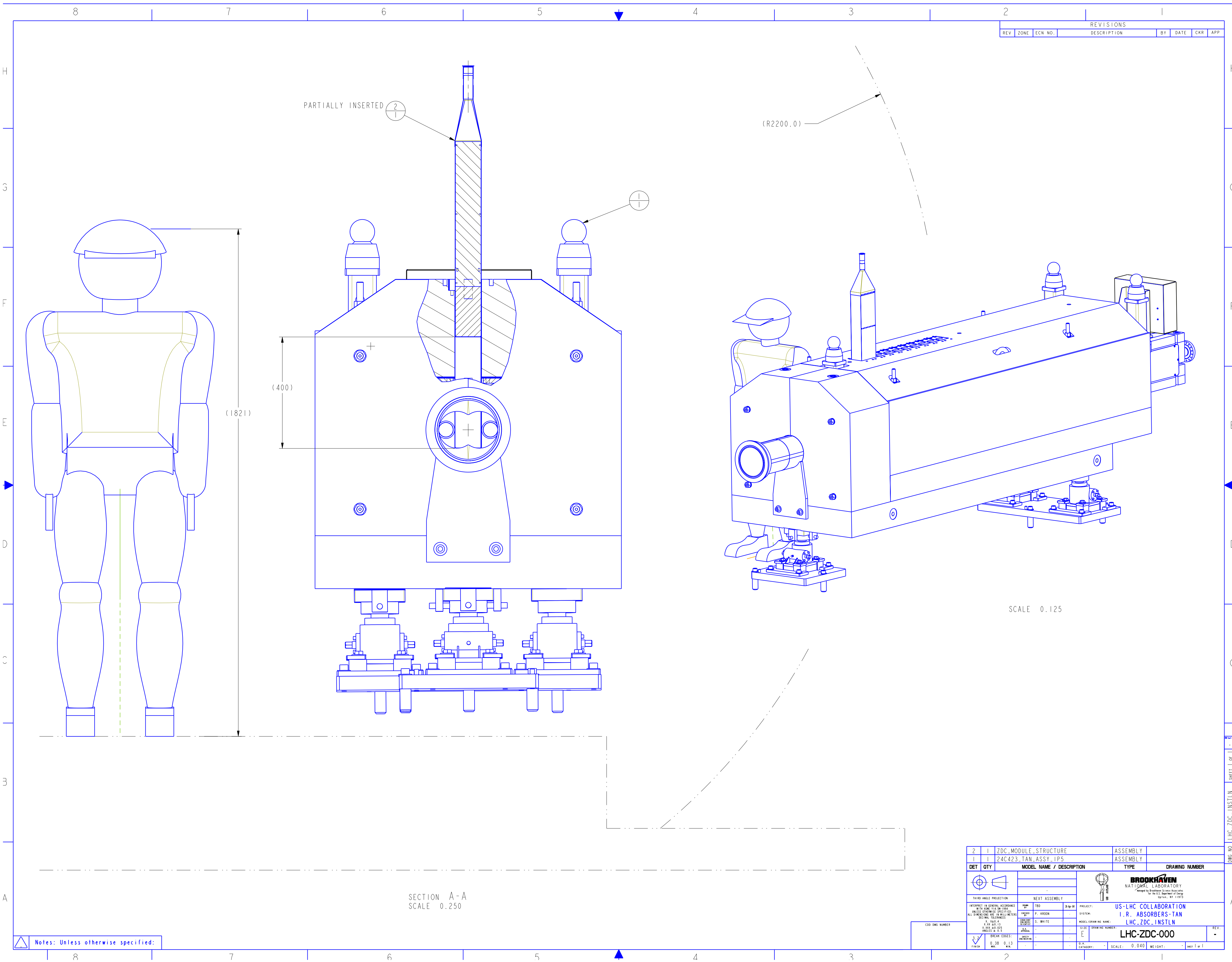
PbPb collisions will produce large amounts of jets!!!! Each collision will produce **1** (one) E_T=20 GeV jet. In each 10^6s run at nominal luminosity of $4\text{x}10^{26}$ we expect:

p_T threshold	jets
50 GeV	$40\text{x}10^6$
100 GeV	$1.0\text{x}10^5$
200 GeV	$2.0\text{x}10^4$

$(|\eta|<2.5)$, *A. Accardi, N. Armesto and I.P. Lokhtin, hep-ph/0211314*

We also expect ~1000 γ+jet events in a 1 GeV bin at E_T= 60 GeV

~ 500 $Z^0(\mu^+\mu^-)$+jets total



PARTIALLY INSERTED
(R2200.0)
(400)
(1821)
SCALE 0.125
SECTION A-A
SCALE 0.250
REVISIONS
Notes: Unless otherwise specified:
ZDC_MODULE_STRUCTURE
24C423_TAN_ASSY_IP5
ASSEMBLY
BROOKHAVEN NATIONAL LABORATORY
US-LHC COLLABORATION
I.R. ABSORBERS-TAN
LHC_ZDC_INSTLN
LHC-ZDC-000