Heavy Ion Physics with the ATLAS Detector

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CERN, University of Colorado
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Lawrence Berkeley National Laboratory
Lebedev Institute of Physics ,INFN
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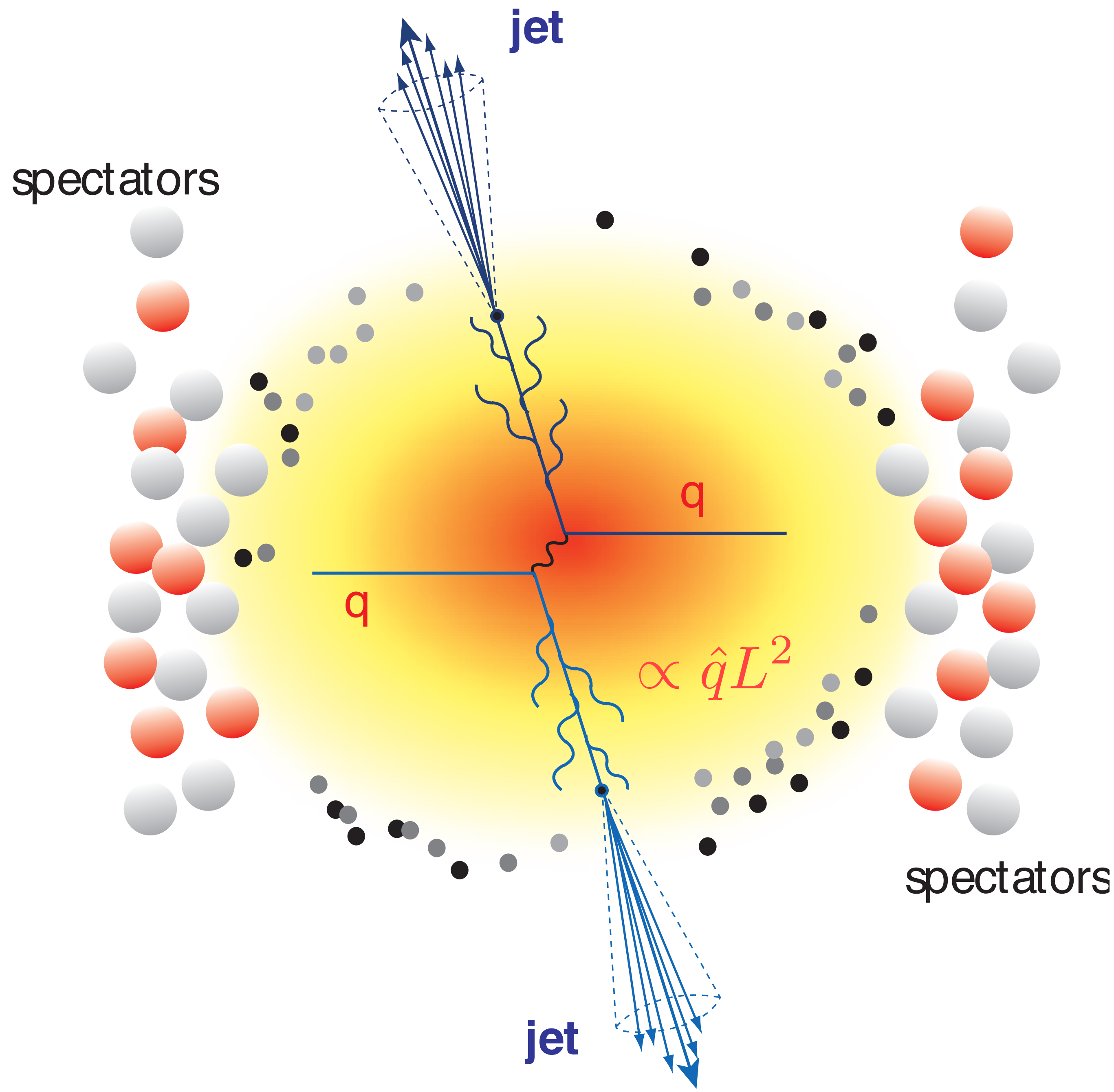
Universidade Federal do Rio de Janeiro, University of Geneva
Institute of Nuclear Physics, Cracow

The Artist's view



"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.

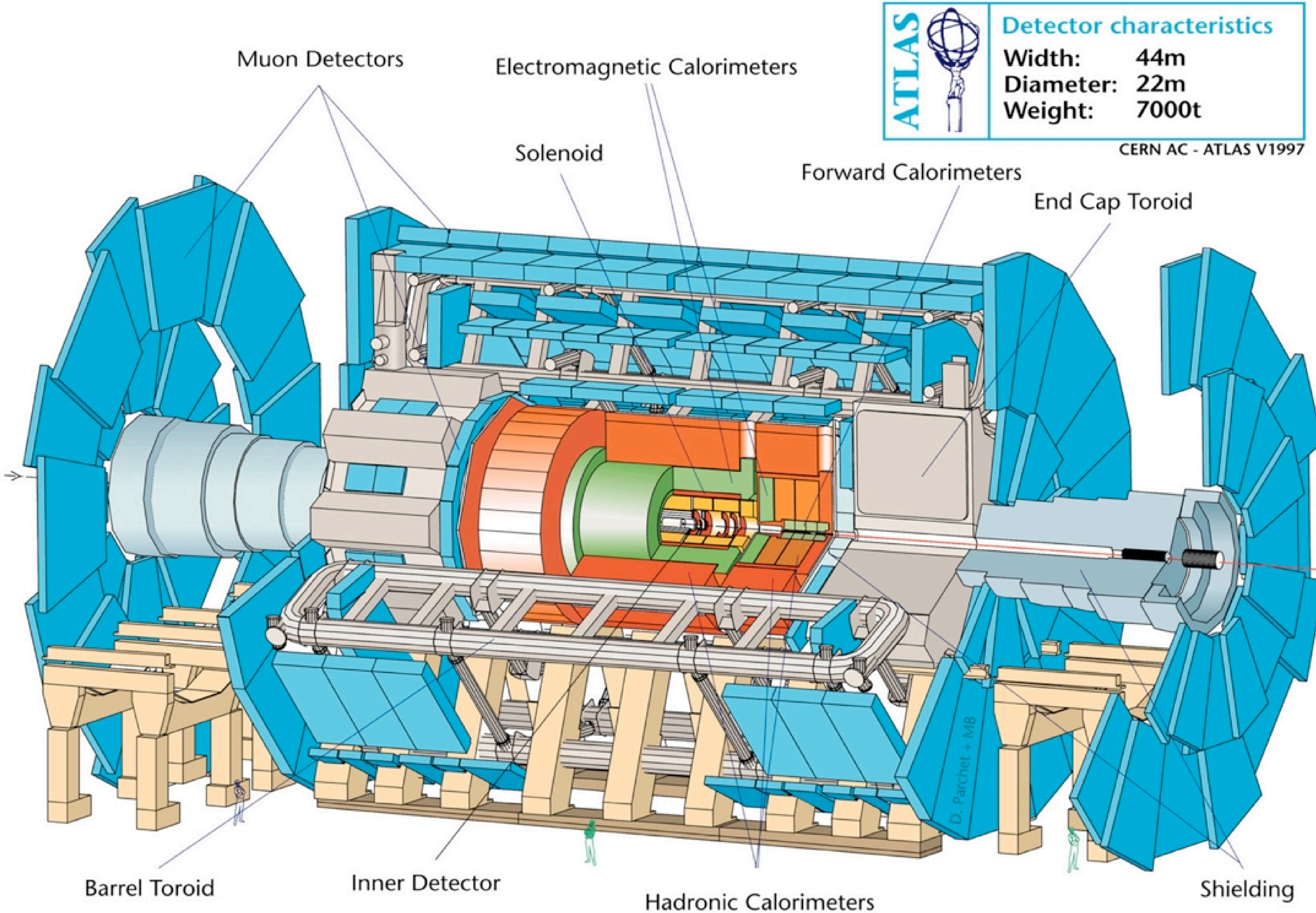
Why ATLAS?

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.

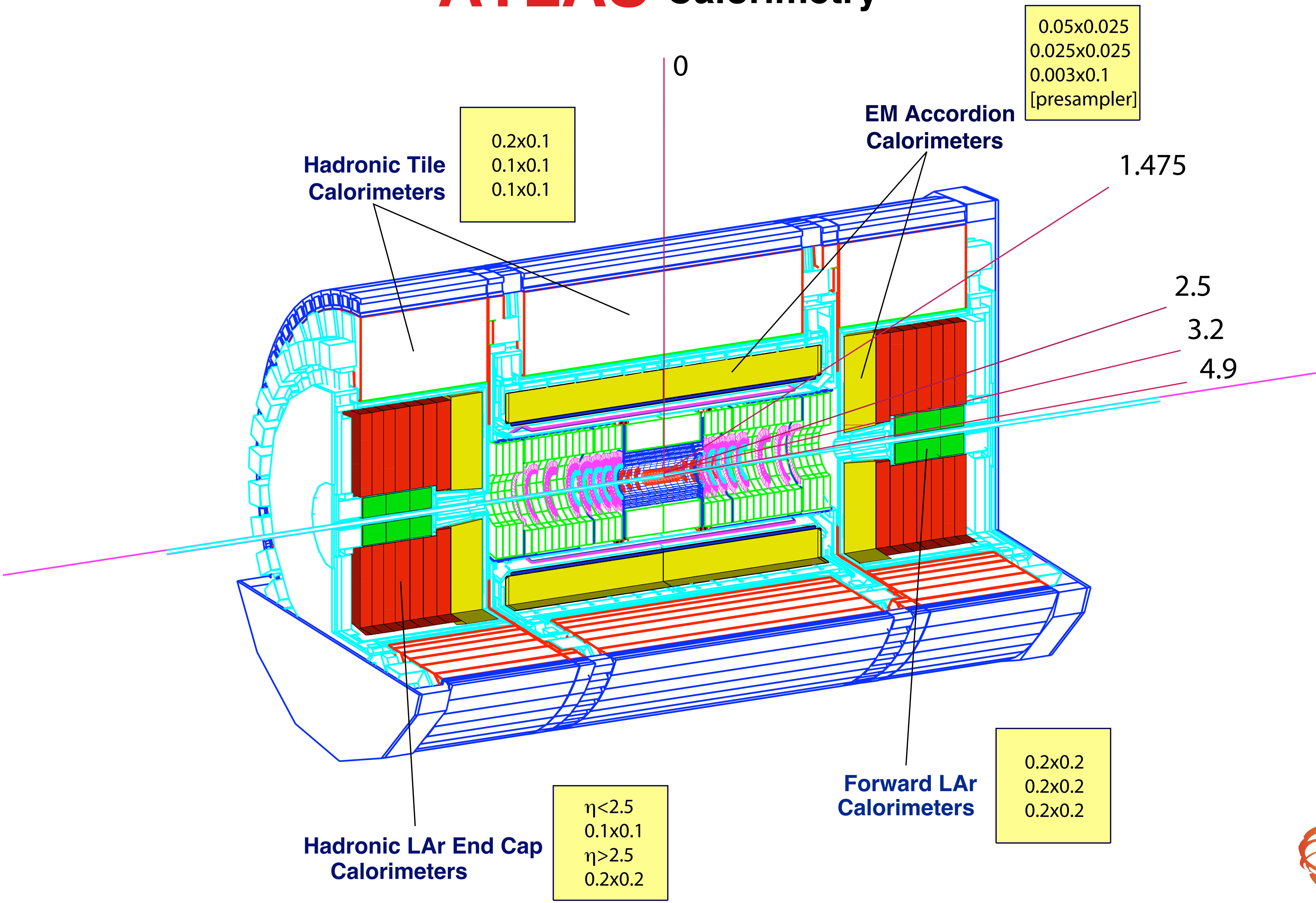
ATLAS has submitted and presented a Letter of Intent to pursue heavy ion physics to the LHCC.



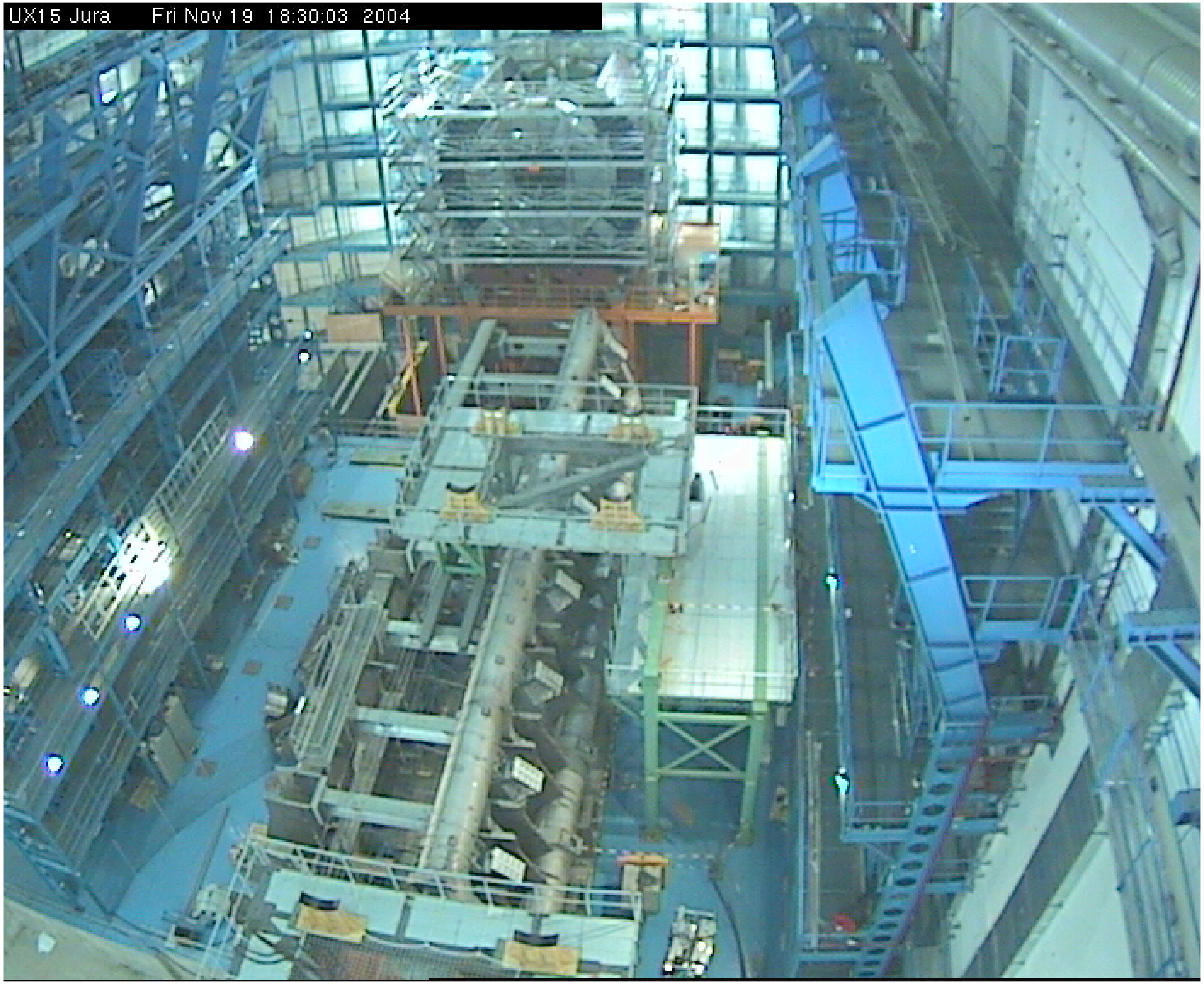
1900 physicists, 154 institutions, 35 countries

Designed for high p_T physics in pp collisions

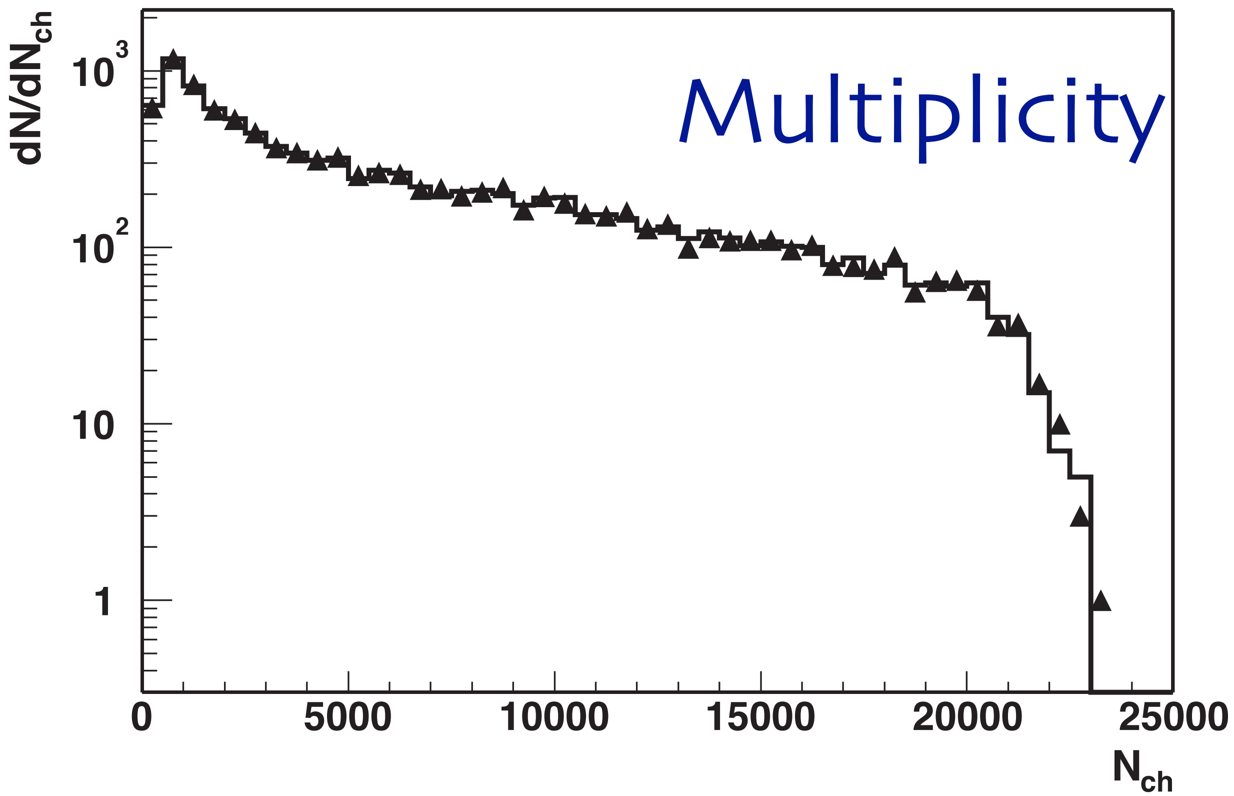
ATLAS Calorimetry



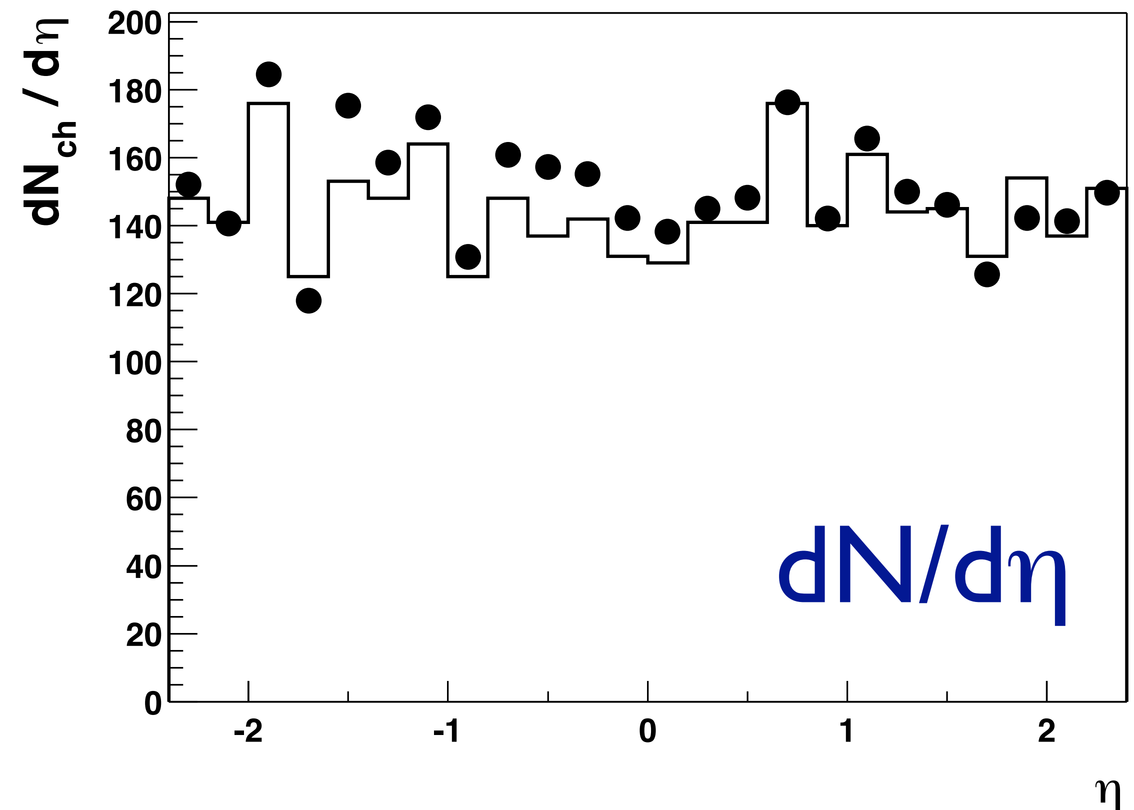
ATLAS today



Global Variables

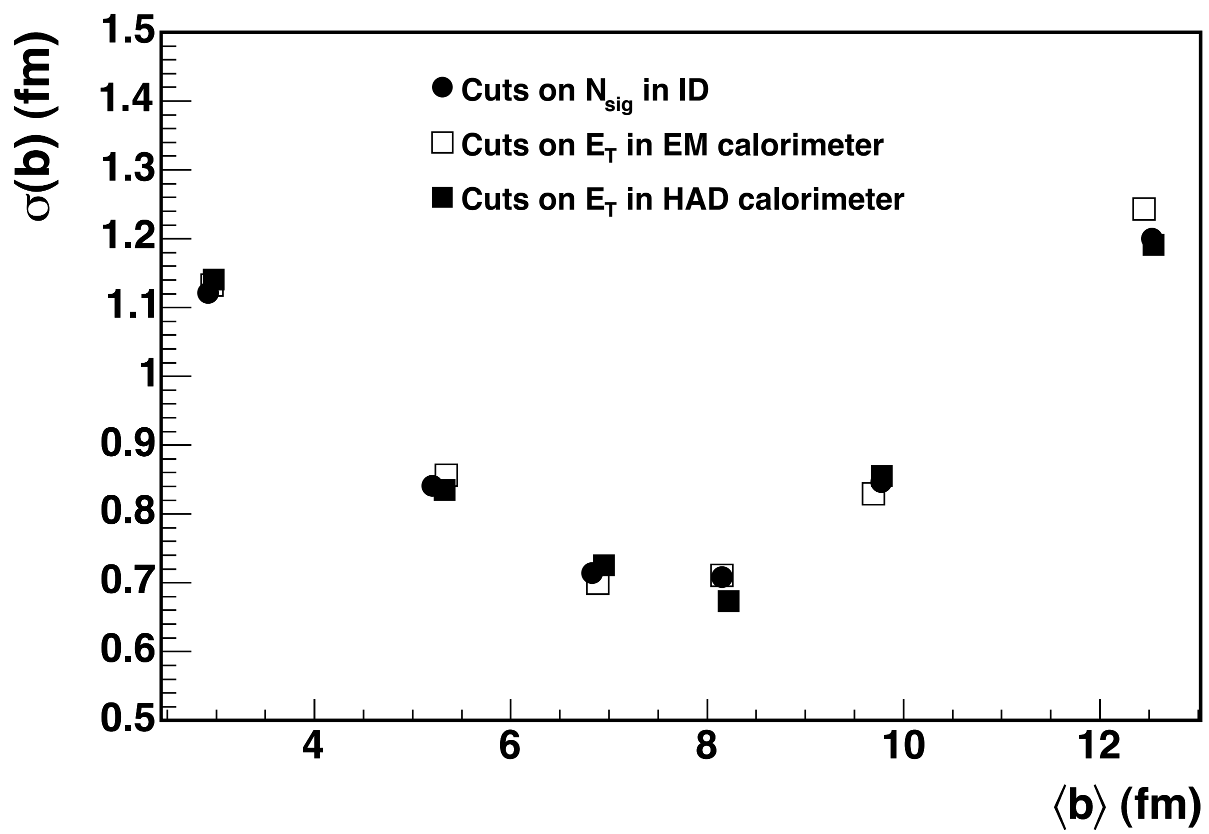


Multiplicity



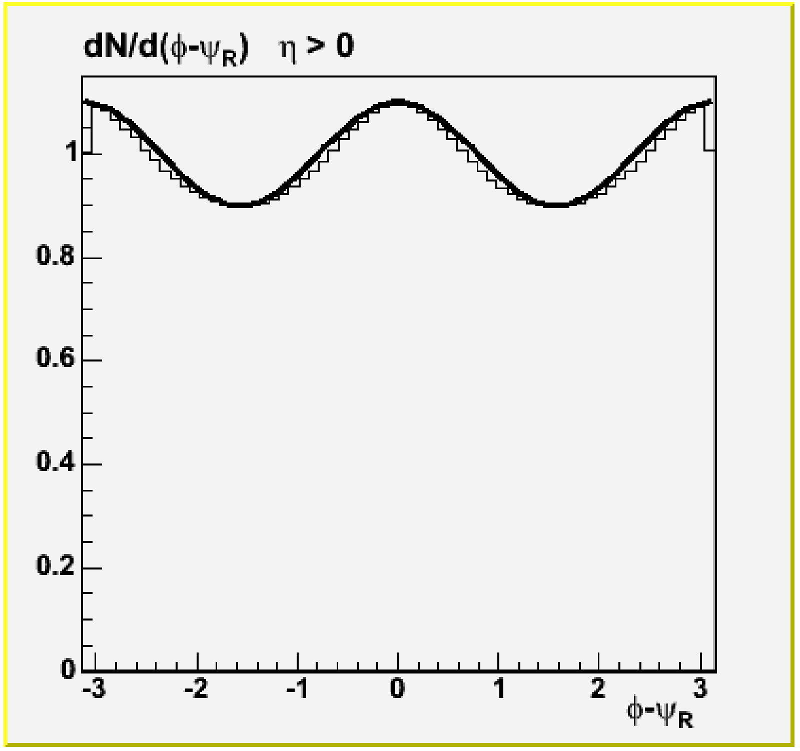
dN/dη

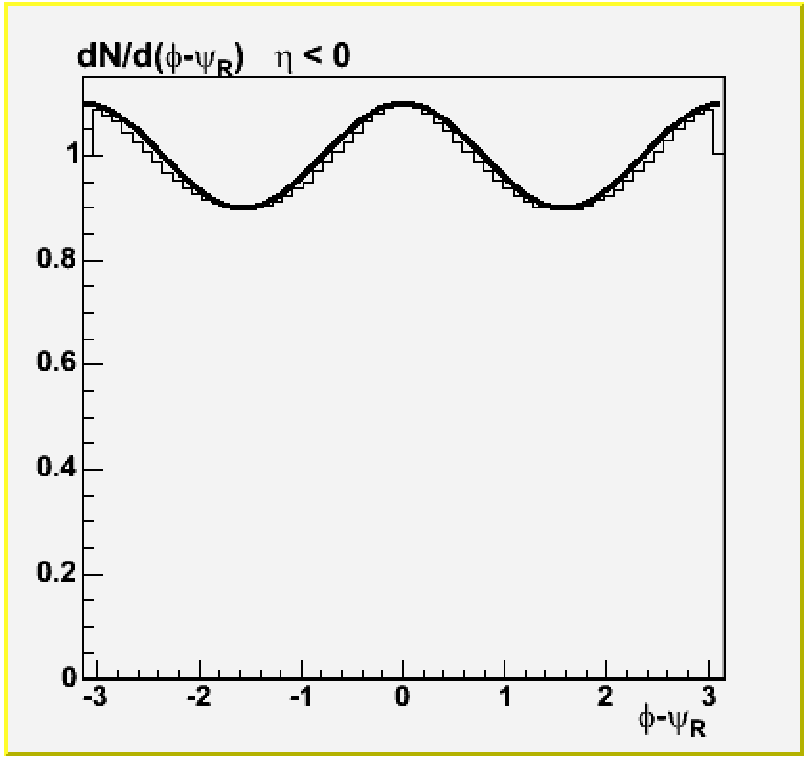
impact parameter resolution



Simulation for Elliptical Flow

Heavily based on RHIC results, it will use HIJING with an afterburner to generate events.





Input Flow: $v_1 = 0$

$v_2 = 0.05$ const(N_{ch}, η, y, p_T)

A. Olszewski, B. Wosiek

Jets

ATLAS is well suited for jet physics because of the high resolution and high granularity calorimeter system

- Measurement of jet inclusive cross section
- Multi-jet events - 3 jet events
- Heavy Quarks (b-jets)
- "Calibrated" jets

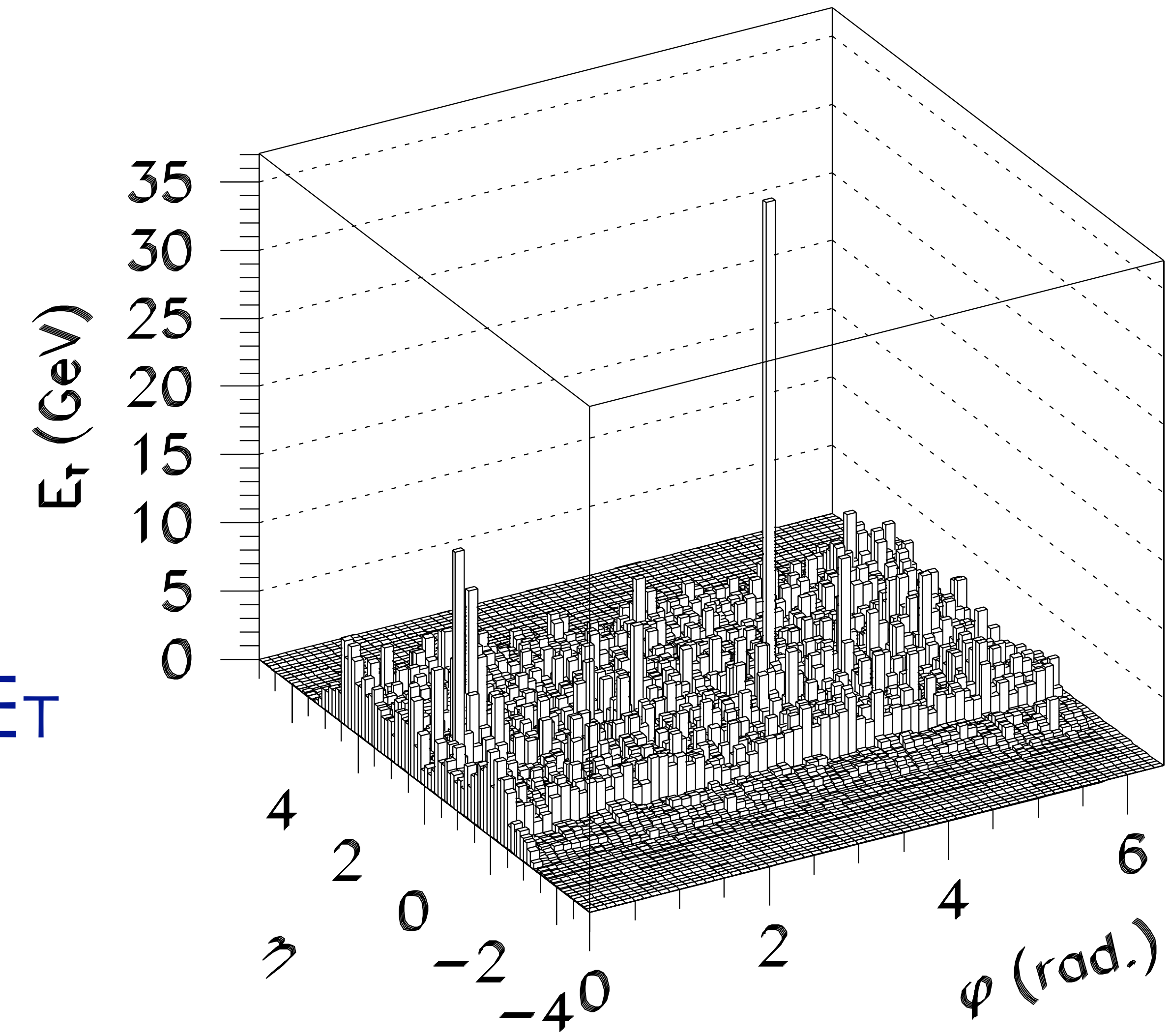
Jets

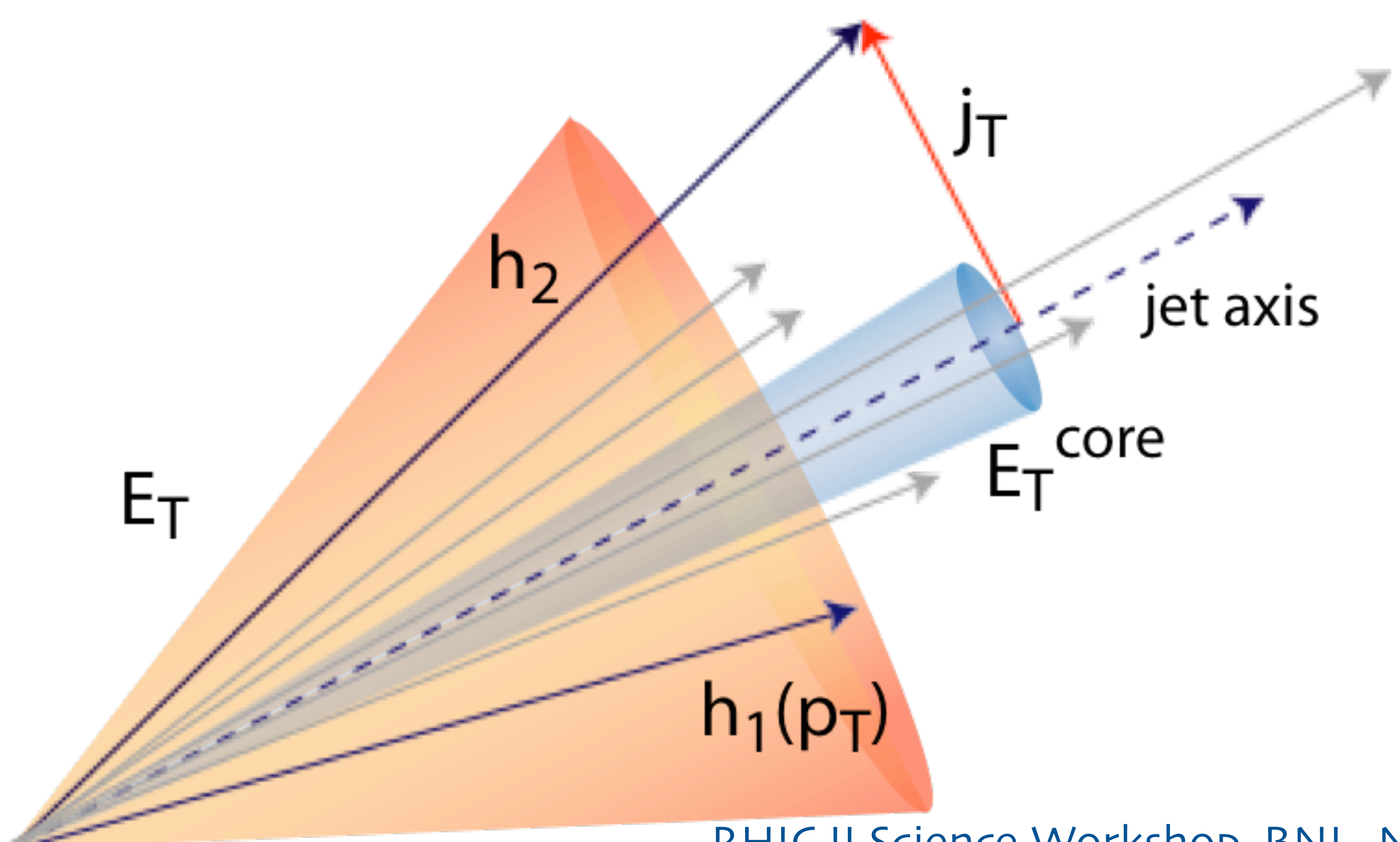
Find jets (after background subtraction) and measure their E_T

Use calorimeter do measure jet profile

Use calorimeters to measure core E_T

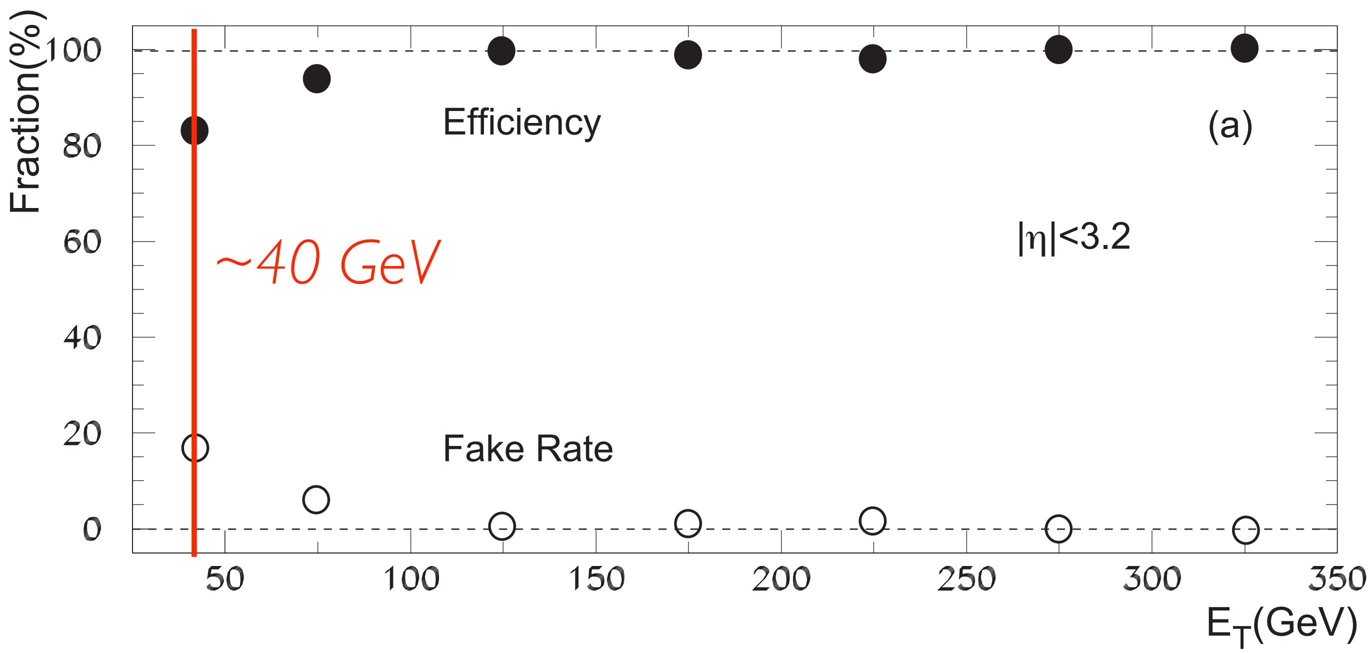
Use calorimeter to detect neutral hadrons.





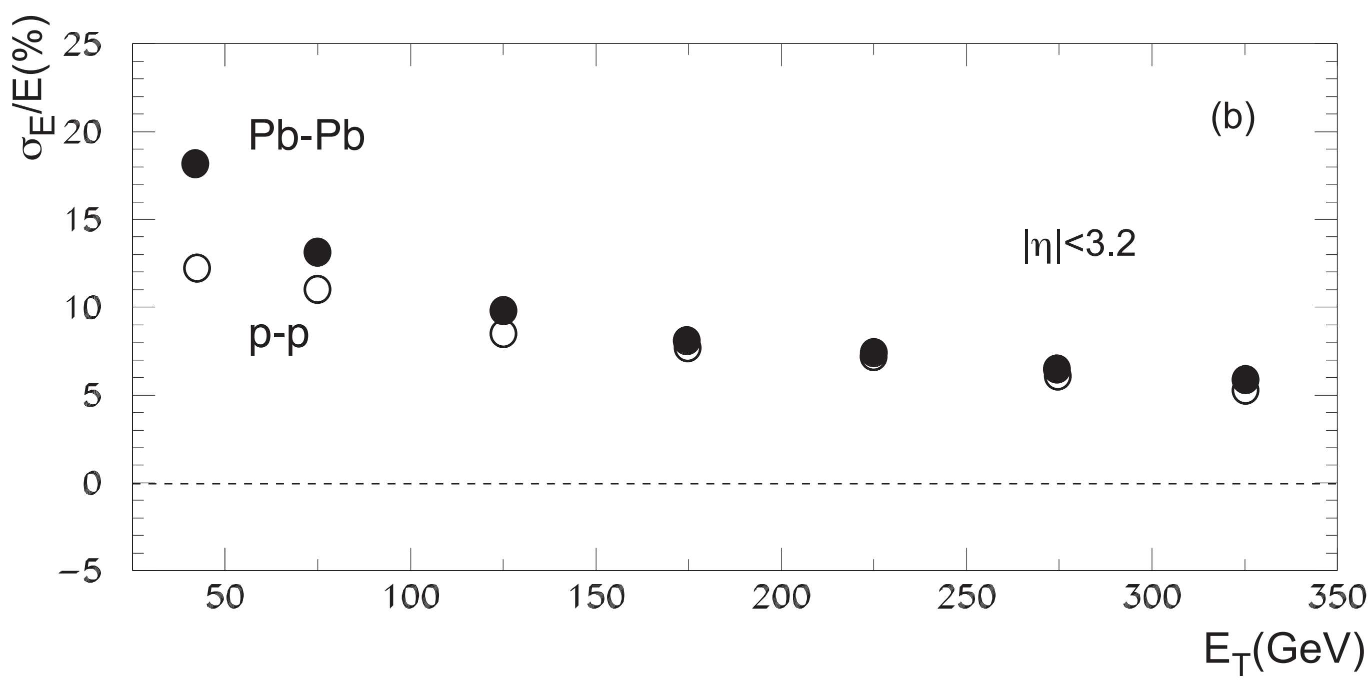
Use *tracking to measure fragmentation function D(z) and j_T via charged particles.*

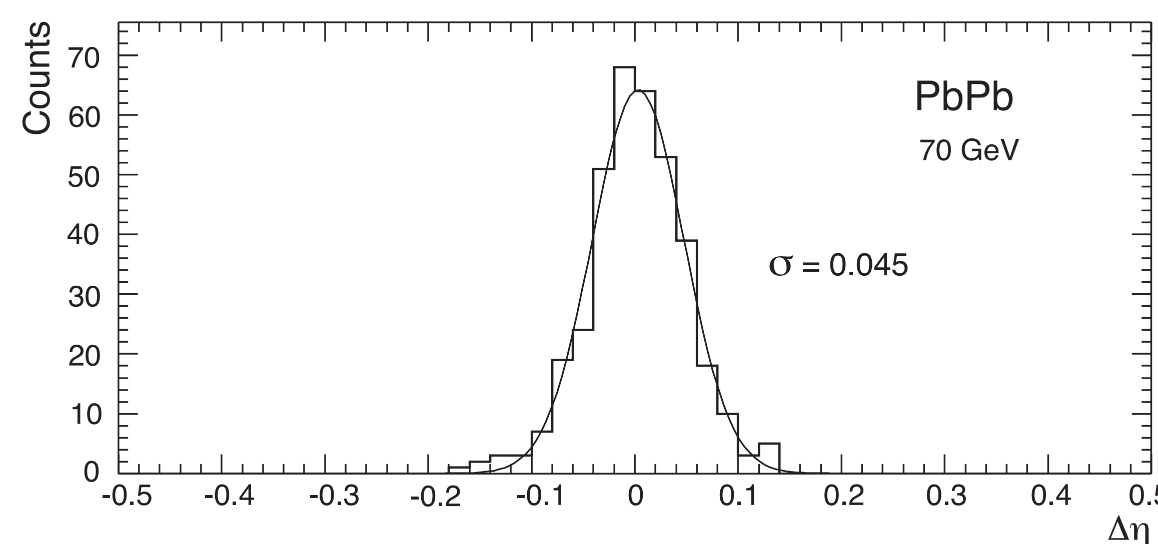
Performance

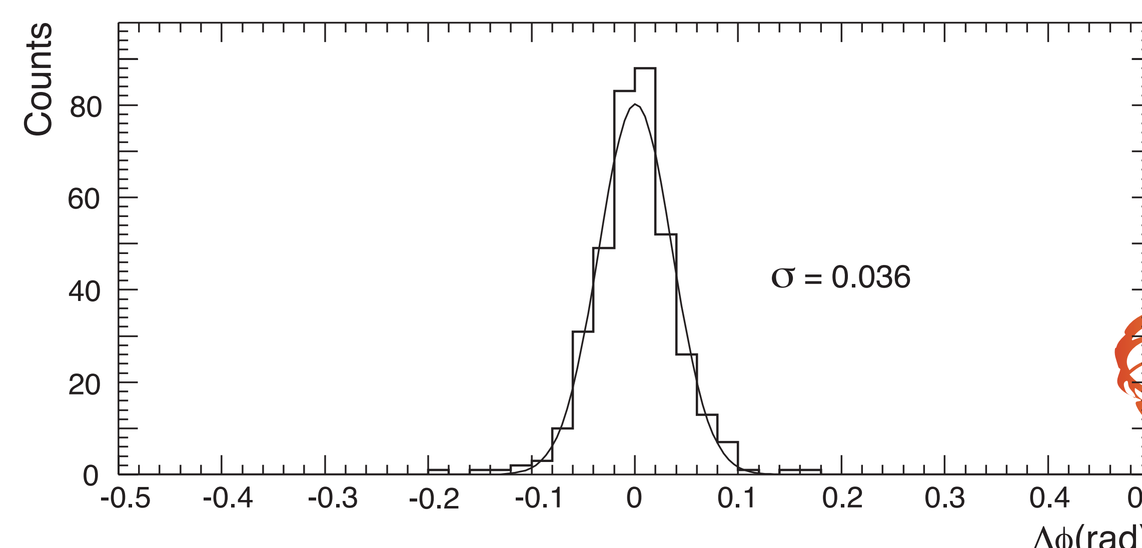


Window algorithm, with average pedestal subtraction.

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

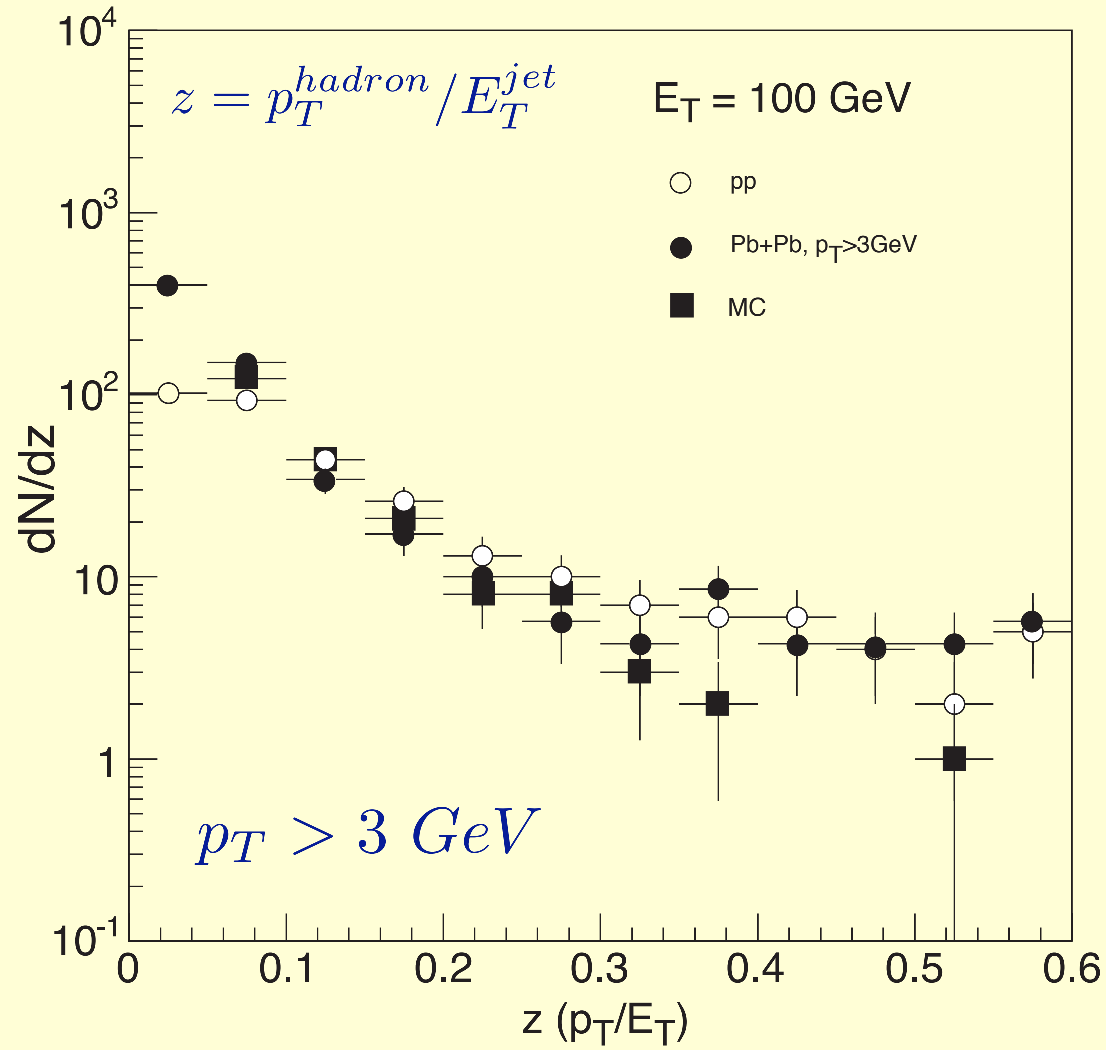


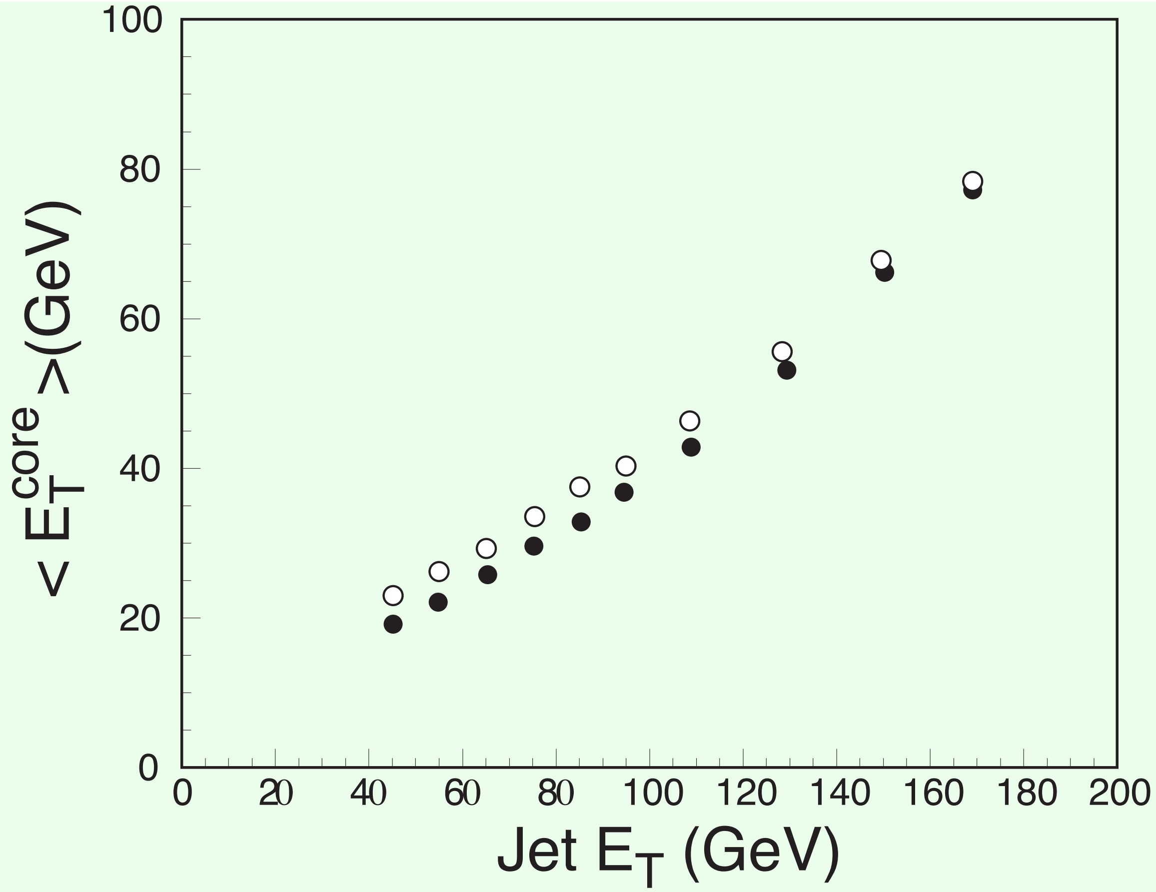


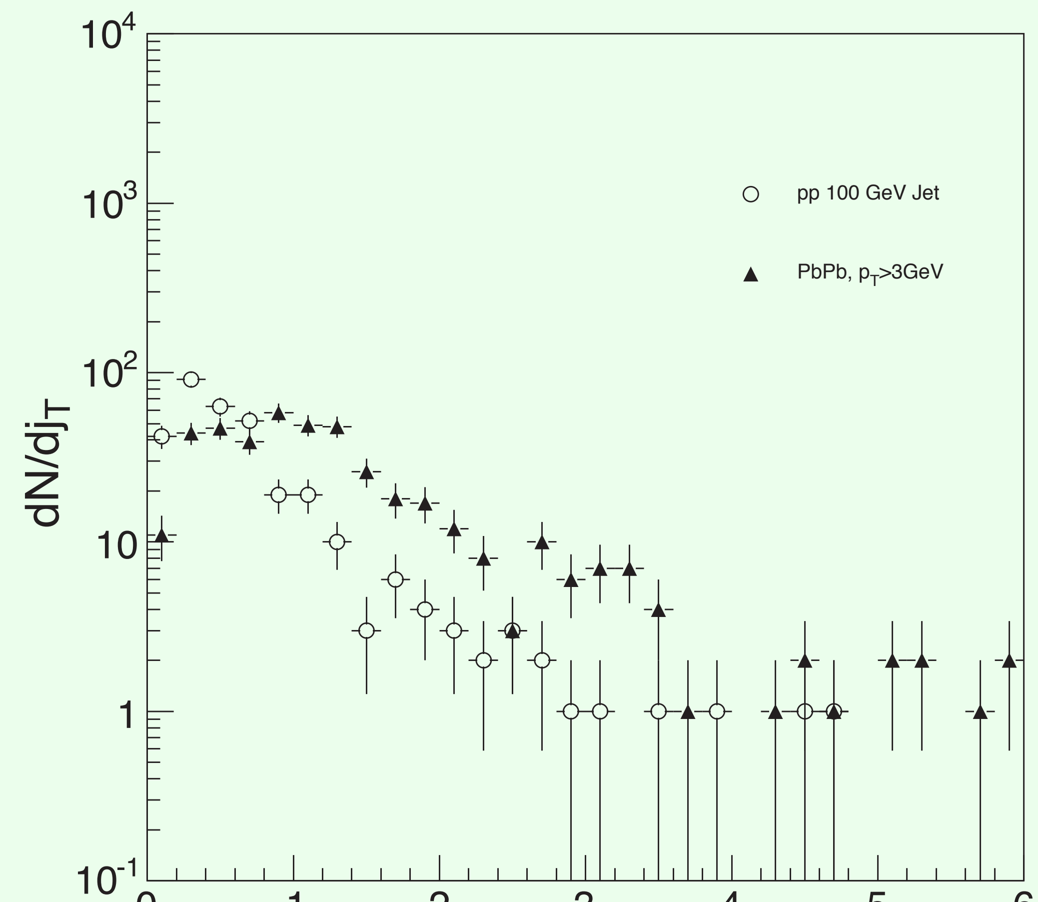


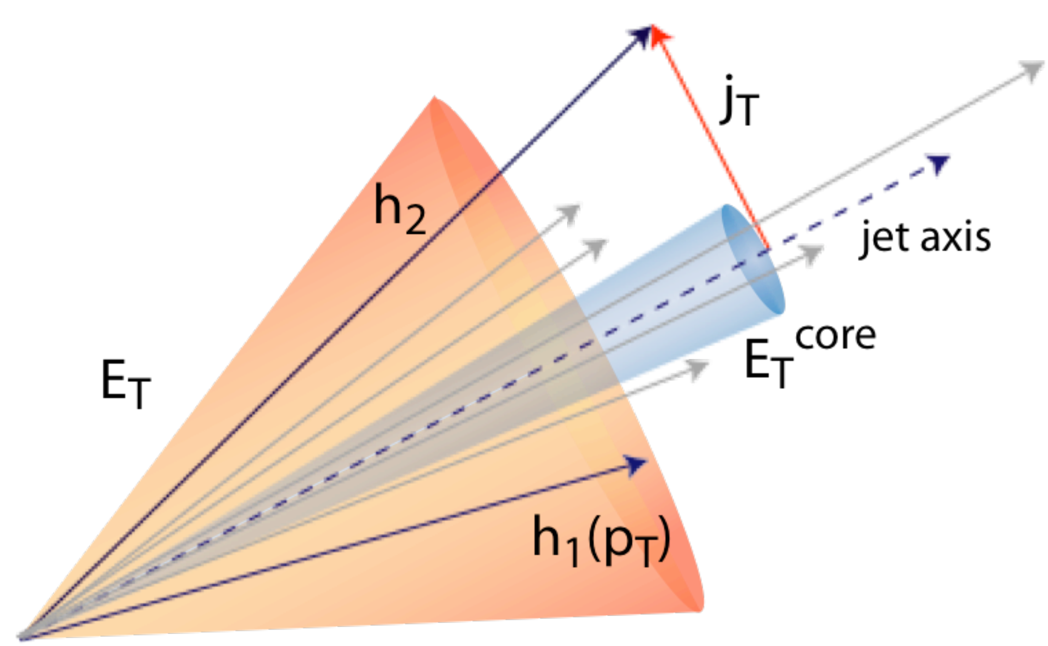
jet axis definition is important for measurement of j_T. At the moment it is about a factor of 2 worst than in pp

Fragmentation function, j_T and E_T^{core}





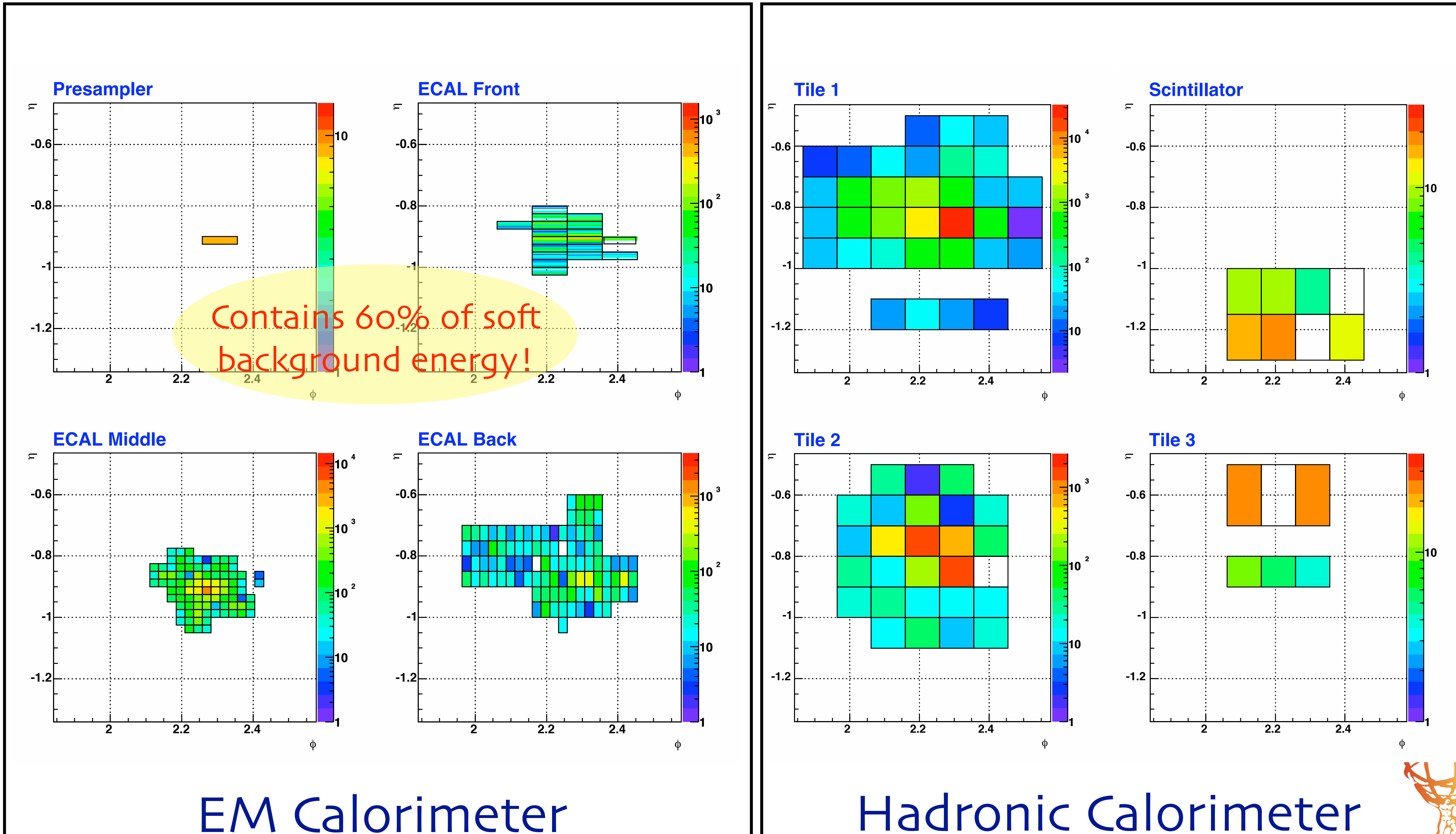




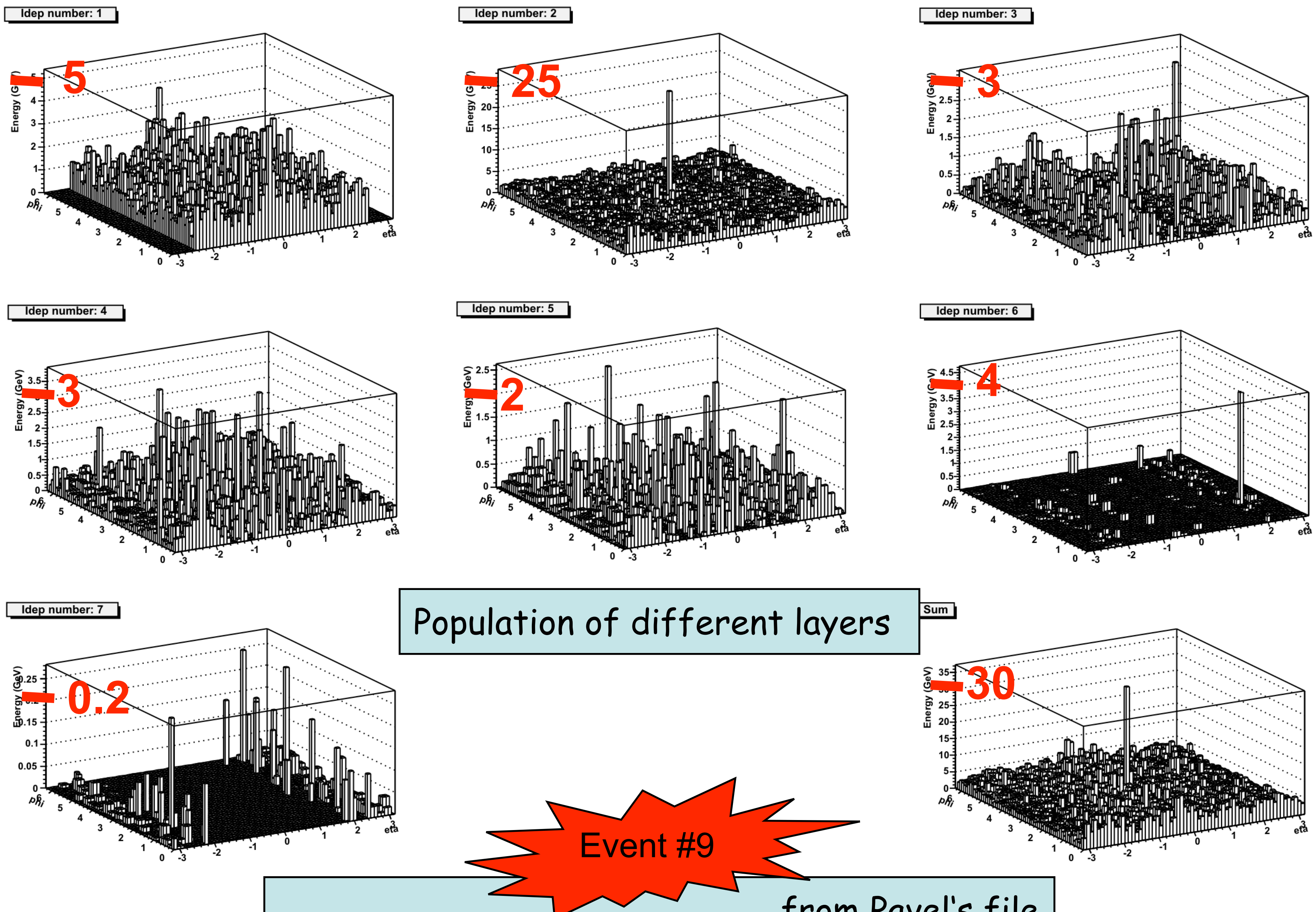
Jets in 3D!

E_T=100 GeV (jet only)

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



Energy by layers of calorimeter



Population of different layers

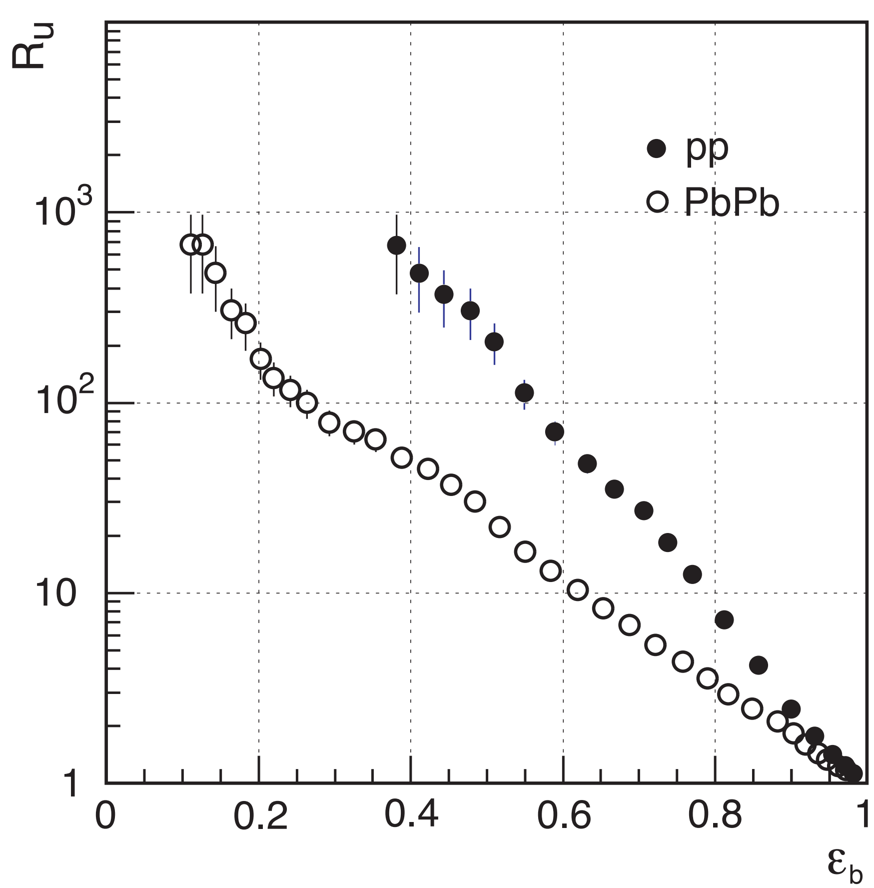
... from Pavel's file
hjet.002056.reco.0001.pyt_WH120_munuuu.fz

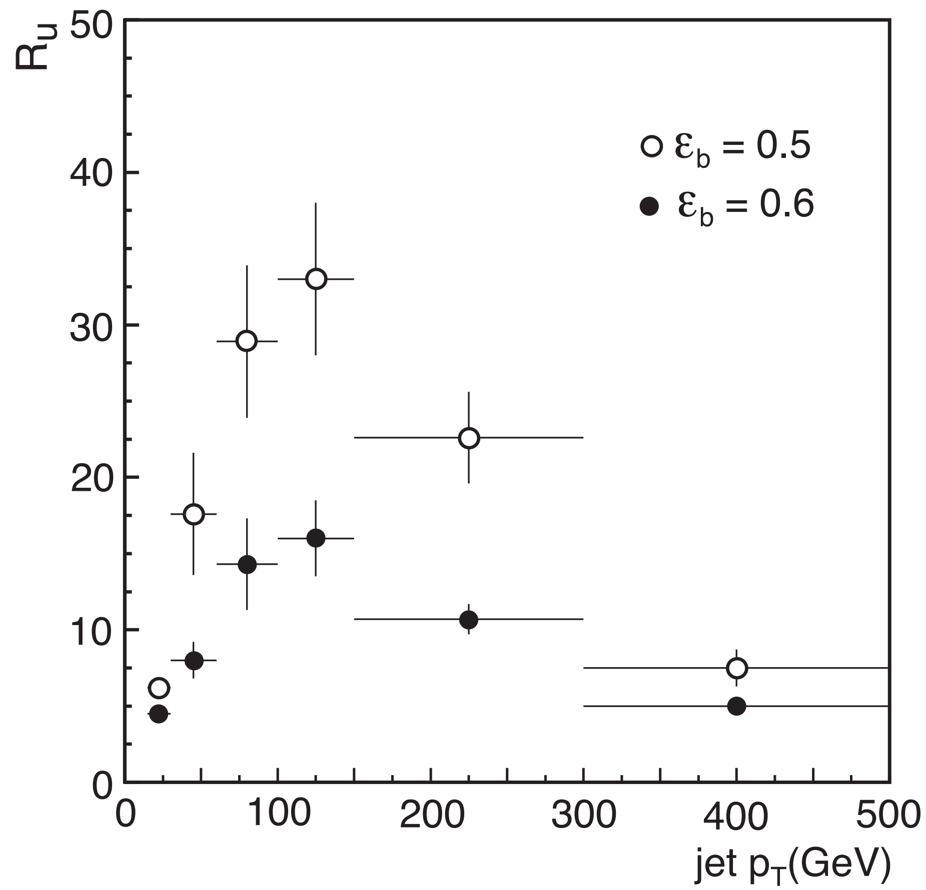
J. Dolesji and Martin Spousta

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.



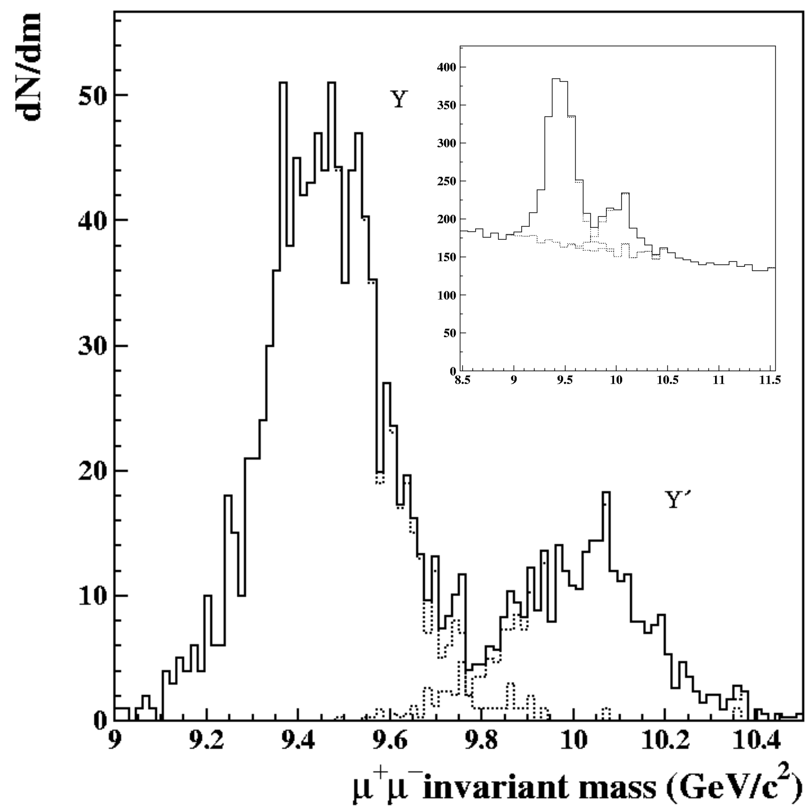


A muon tag will also be used by matching a muon in the spectrometer to the jet axis.

Quarkonia

ATLAS will measure upsilon in the rapidity range $|\eta|<2.5$ using the muon spectrometer and inner detector (not including the TRT).

	$\|\eta\|<1$	$\|\eta\|<2.5$
Accept+efficiency	4.9%	14.1%
Resolution	123 MeV	147 MeV
S/B	1.3	0.5



A compromise has to be found between acceptance and mass resolution to clearly separate upsilon states.

For a 10^6s run with Pb+Pb at $\mathcal{L}=4\times10^{26}$ cm^{-2}s^{-1} we expect 10^4 events in $|\eta|<1.2$, with $p_T>0$.

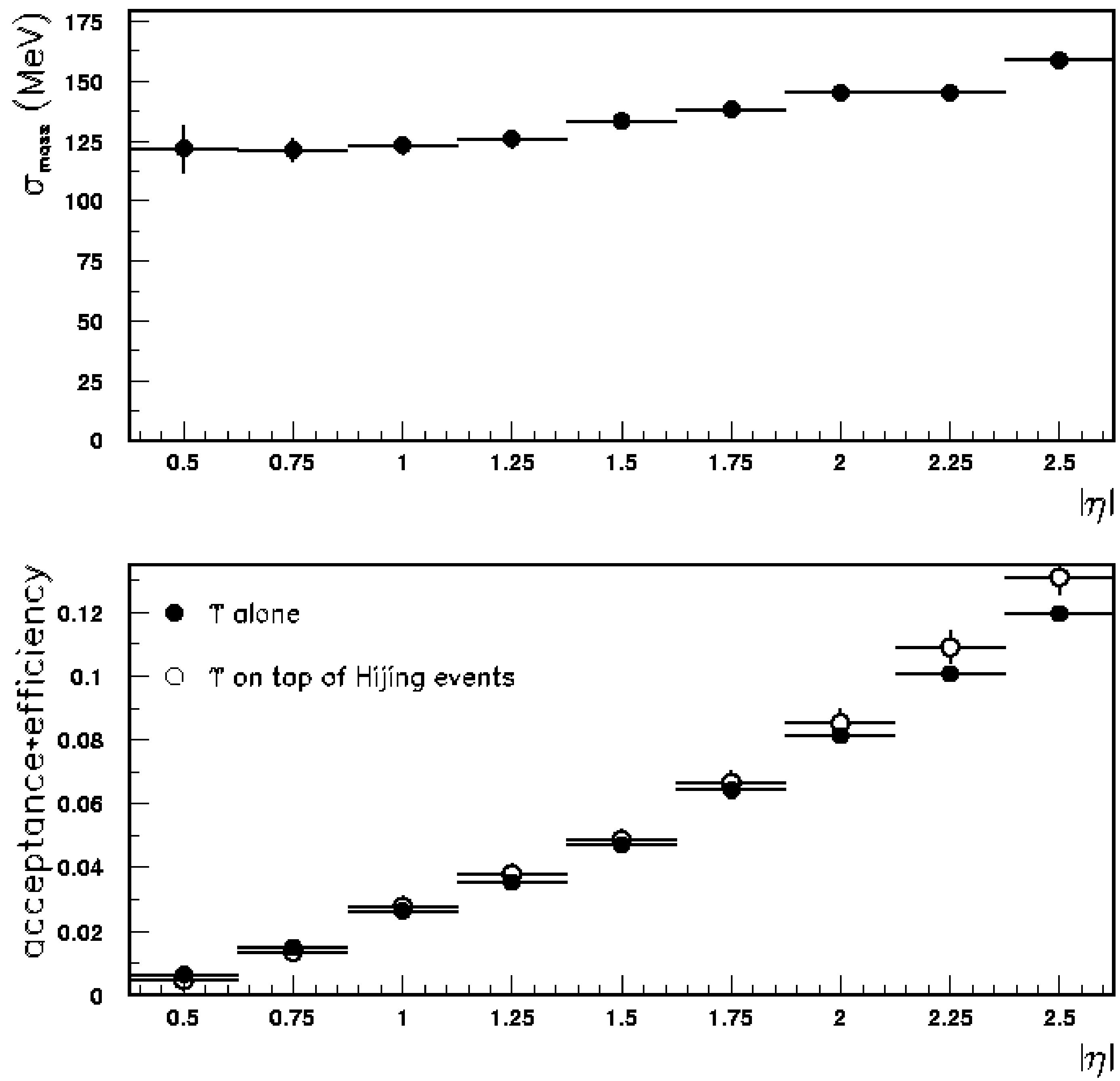
A study is under way for $J/\psi\rightarrow\mu^+\mu^-$, $\sigma_M=53$ MeV, $p_T>4$-5 GeV

Update on Upsilon and J/Psi

"Realistic" model for upsilon production

Started to simulate J/psi

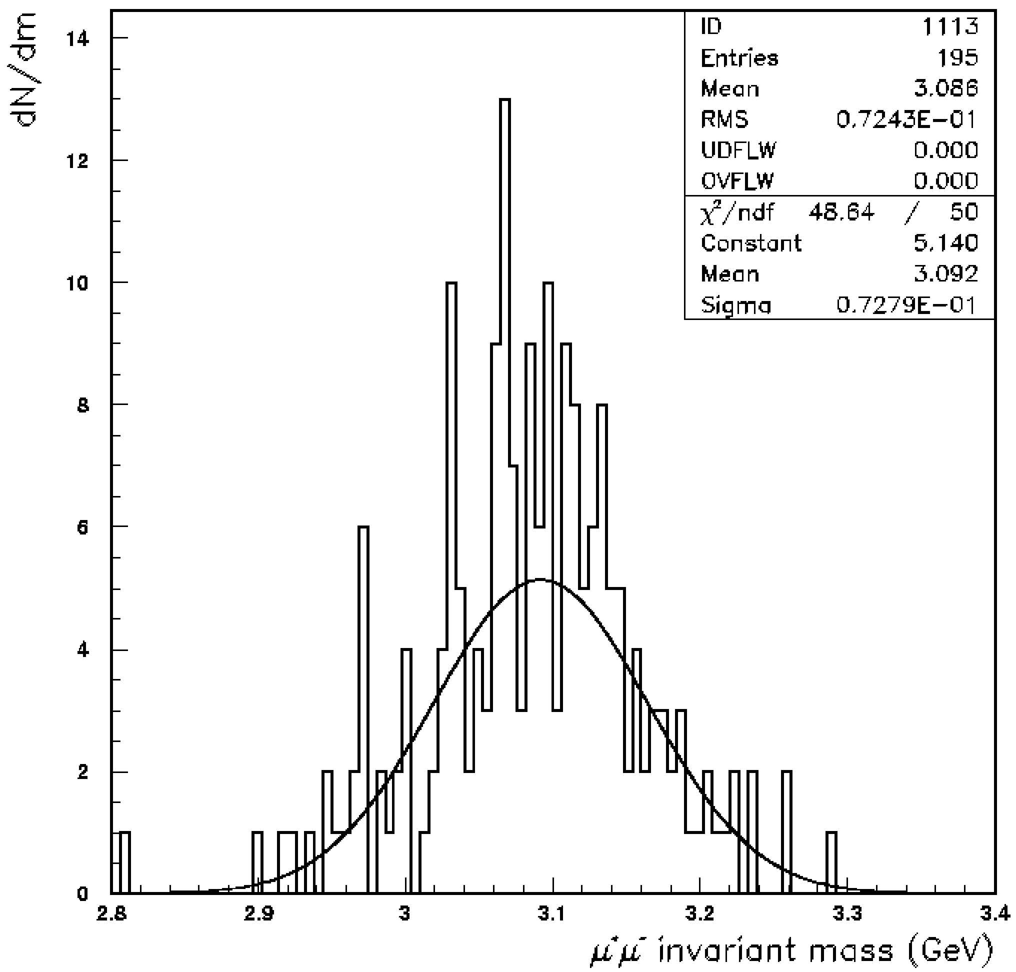
Problem: low p_T.



3500 ϒ inside central Pb-Pb events

L. Rosselet

Update on J/Psi



Mass resolution ~72±10 MeV

J/Ψ acceptance ~1/100 Υ acceptance

But:

J/ψ production ~ 100 the Υ production

=>expect similar statistics

muon p_T>3 GeV => J/Ψ p_T>5GeV

If a trigger is possible forward with a muon p_T>1.5 GeV , we gain a factor 5 in statistics

Or an e^+e^- trigger in the TRT with p_T>2 GeV …

L. Rosselet

The Physics Program

"Jet physics" and quarkonia

Global variables, 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

What I did not talk about

There is an on-going effort to instrument the forward region of the detector (led by M. Rijssenbeek and P. Gafstrom). Letter of Intent submitted and a proposal in the works.

On going effort on the construction of a zero degree calorimeter (S. White).

Participation in QCD working group ("Standard Model").

Simulation moving towards G4.

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 jets and quarkonia 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.

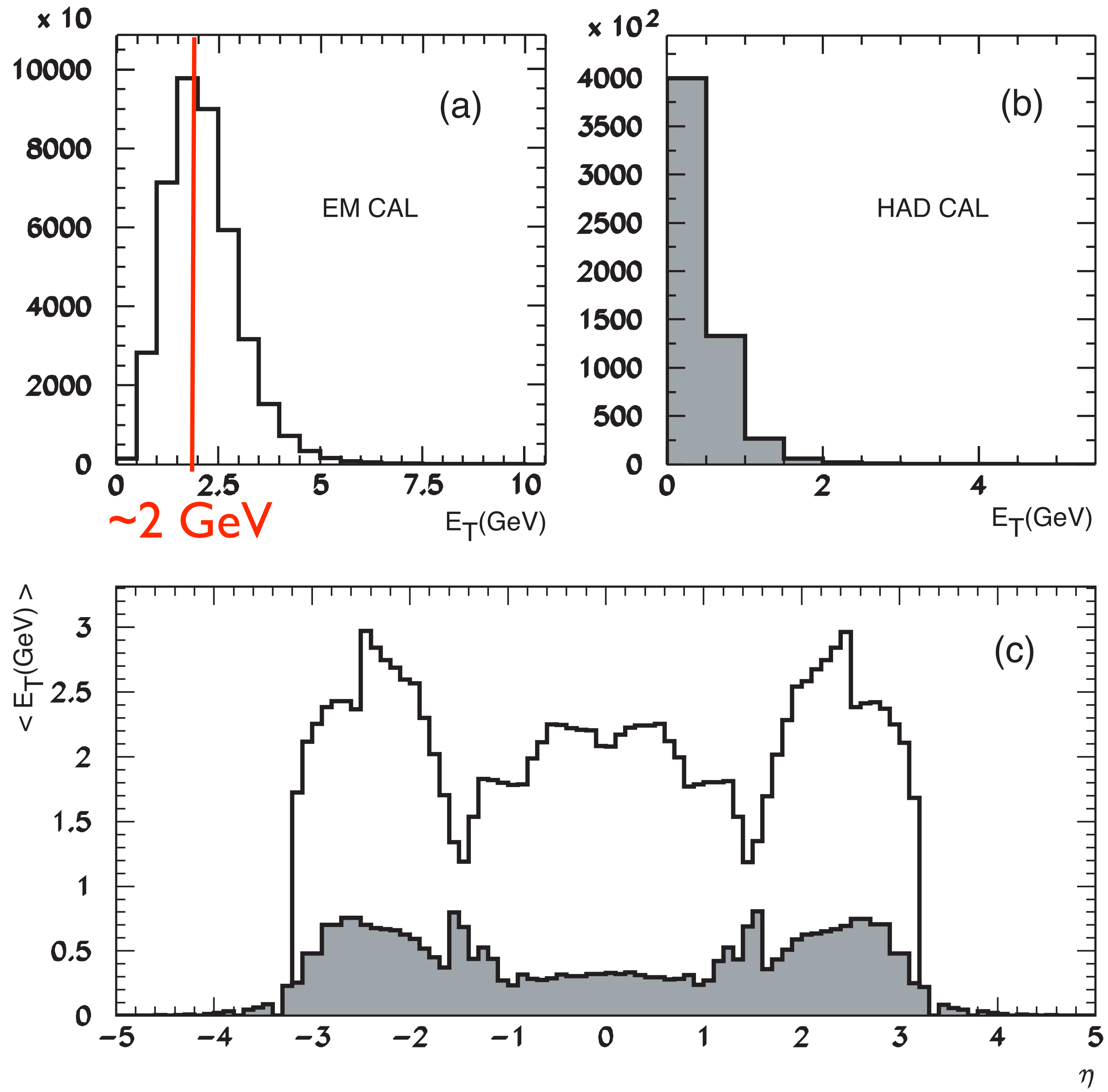
Studies of detector performance is continuing. Algorithms tailored to the high multiplicity environment is under development.

Much work is ahead. Prospects of successful and interesting physics program is ahead of us.

Supplemental Slides

Average Energy in Calorimeters

(in 0.1x0.1 cell)



b<1 fm

Energy deposition by soft particles in heavy ion collisions (b<1)

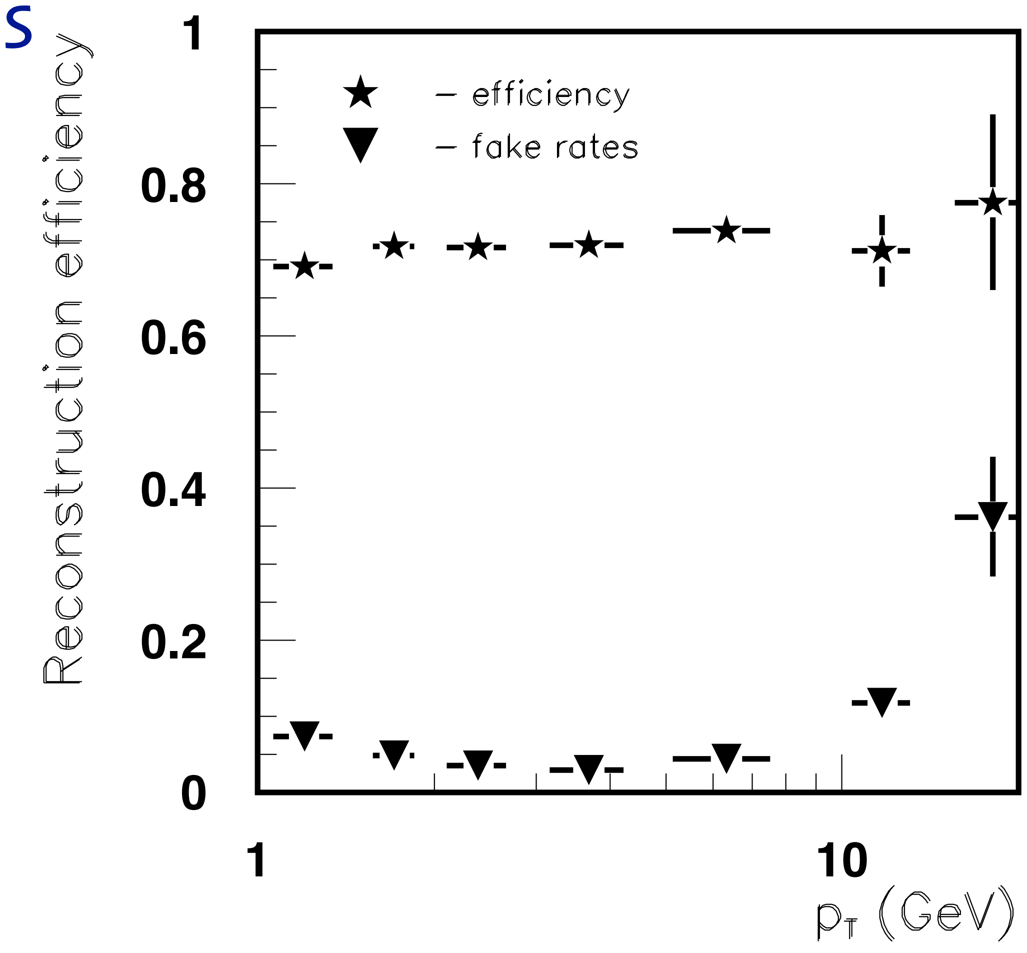
Most energy is absorbed by the electromagnetic calorimeter!!!

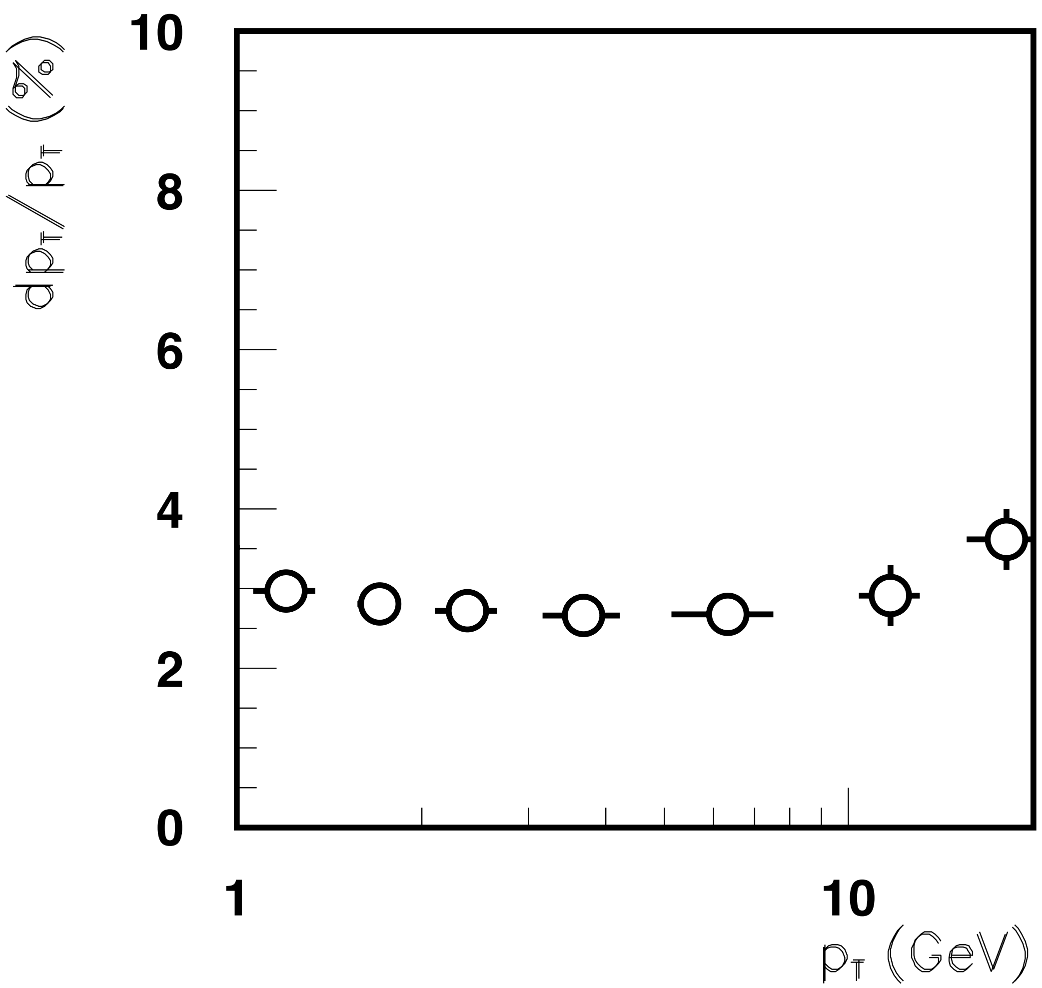
Jets will ride on top of an average pedestal of *(50±11)* GeV (ΔR=0.4)

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)

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 $\mathcal{L}$ = 4×10^{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

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 4×10^{26} we expect:

p_T threshold	jets
50 GeV	40×10^6
100 GeV	1.0×10^5
200 GeV	2.0×10^4

$(|\eta|<2.5)$, 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

Proton Nucleus Collisions

S*tudy of the nuclear modification of the gluon distribution at low x*

S*tudy of the jet fragmentation function modification*

L*ink between pp and AA physics*

F*ull detector capabilities available due to low luminosity (1 MHz interaction rate, compared to 40 MHz in pp)*

Ultra Peripheral Nuclear Collisions

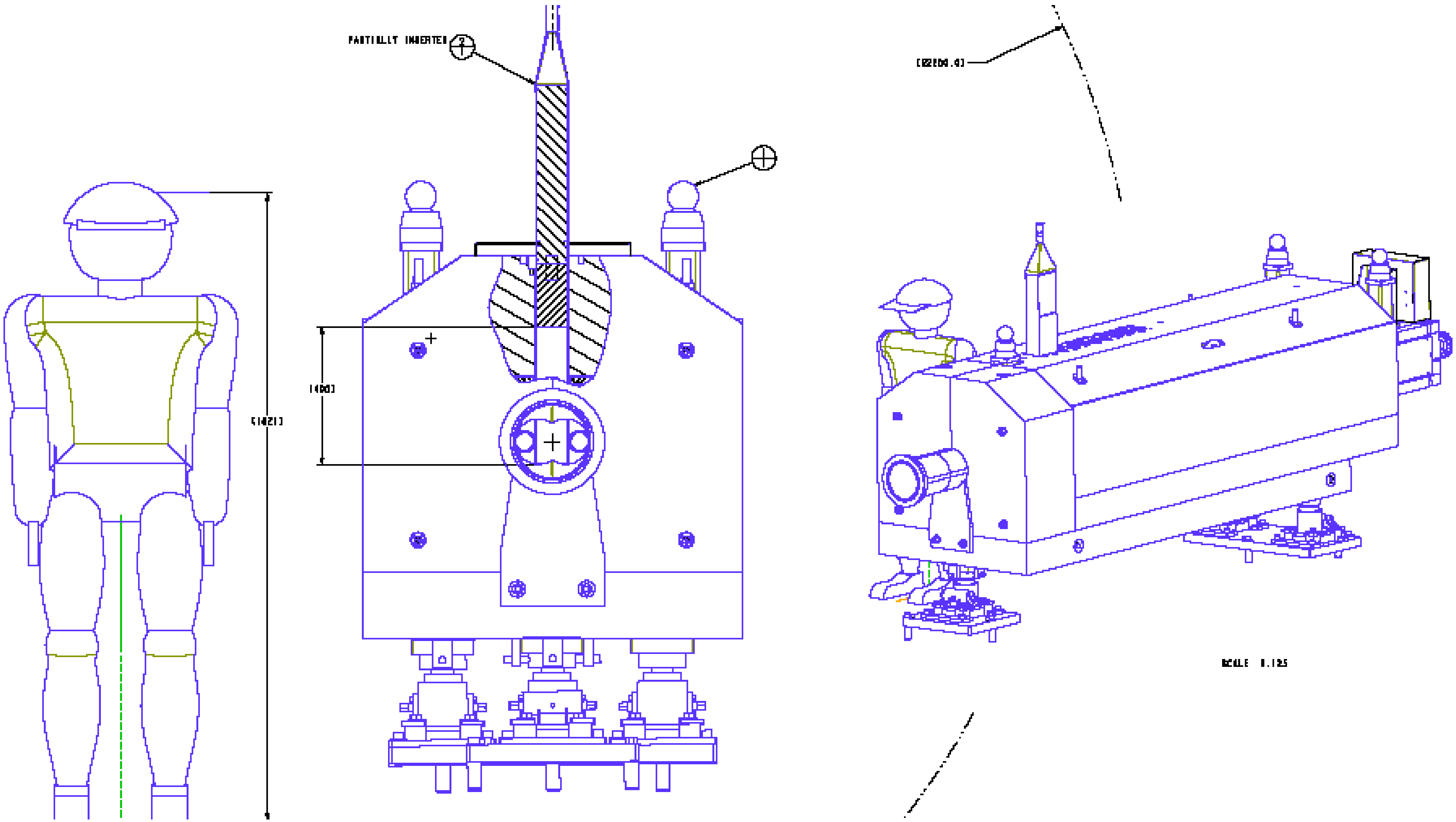
H*igh energy γ-γ and γ-nucleon collisions*

M*easurements of hadron structure at high energies above HERA di-Jet and heavy quark production*

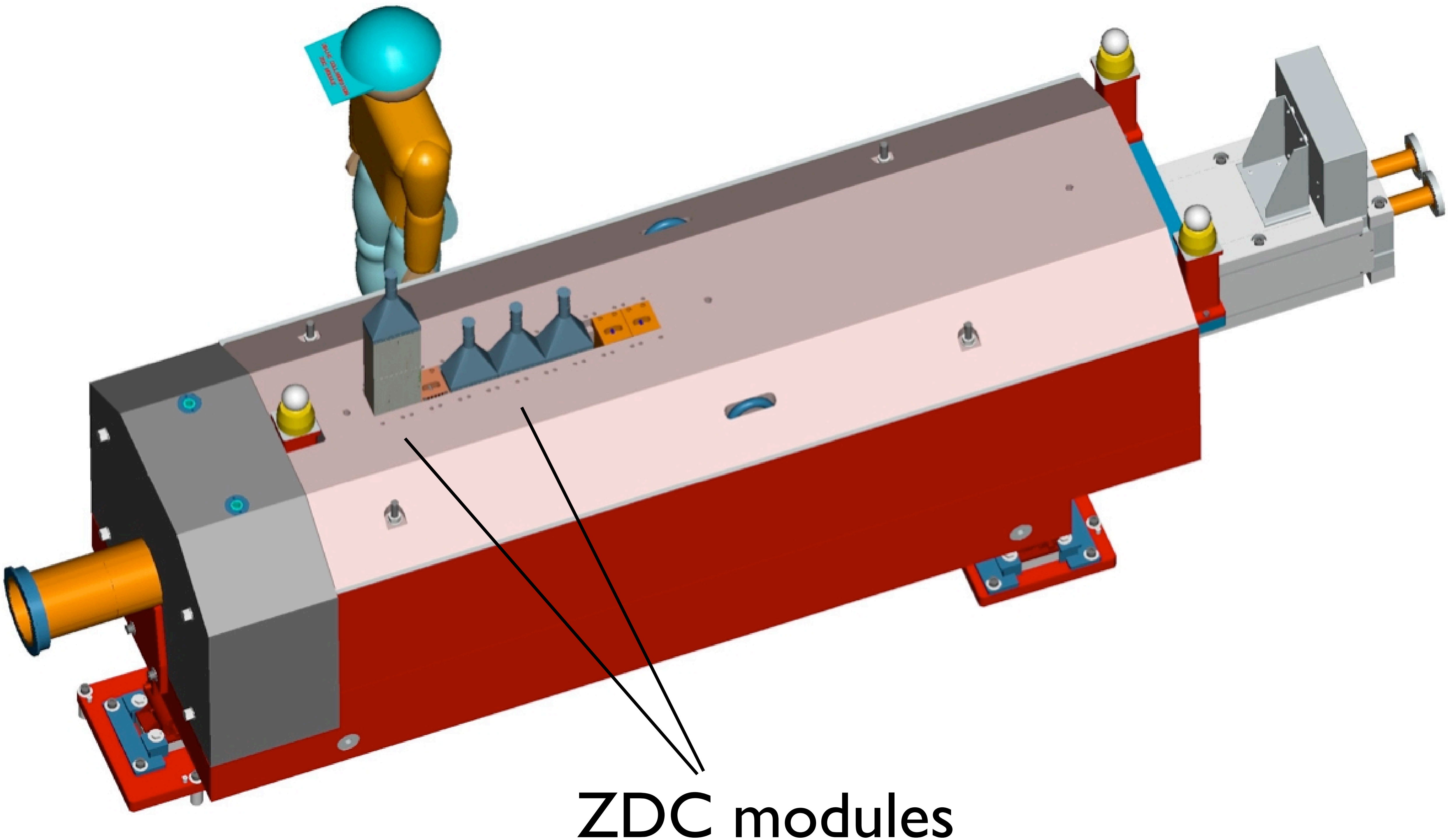
T*agging of UPC requires a Zero Degree Calorimeter*

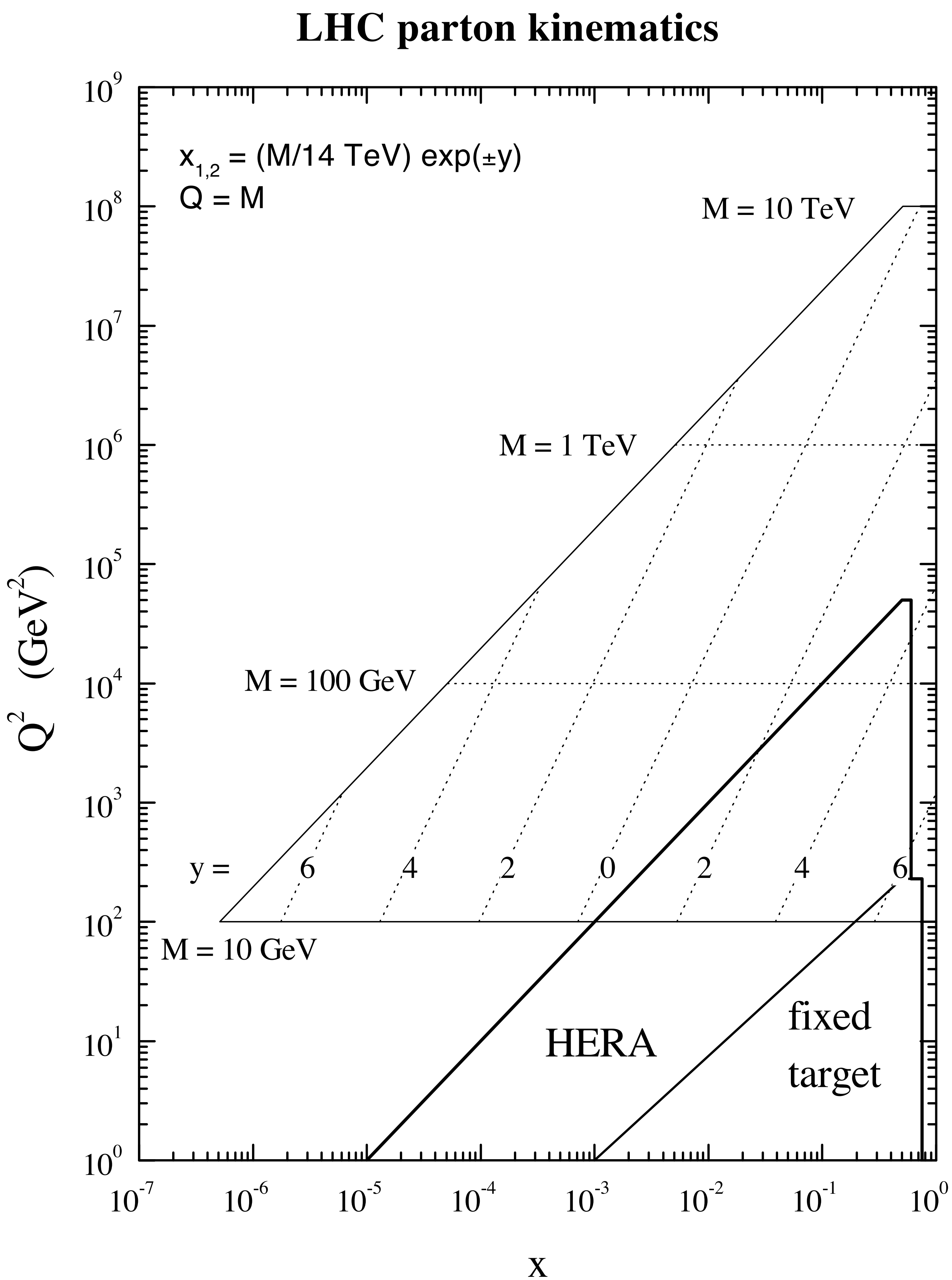
O*n going work on ZDC design and integration with the accelerator instrumentation.*

Installation, Integration issues partly dealt with



ZDC




LHC parton kinematics
$x_{1,2}$ = (M/14 TeV) exp(±y)
Q = M
M = 10 TeV
M = 1 TeV
M = 100 GeV
M = 10 GeV
y = 6 4 2 0 2 4 6
HERA
fixed target
Q^2 (GeV^2)
x
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9
10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^0