Heavy Ion Physics with the ATLAS Detector

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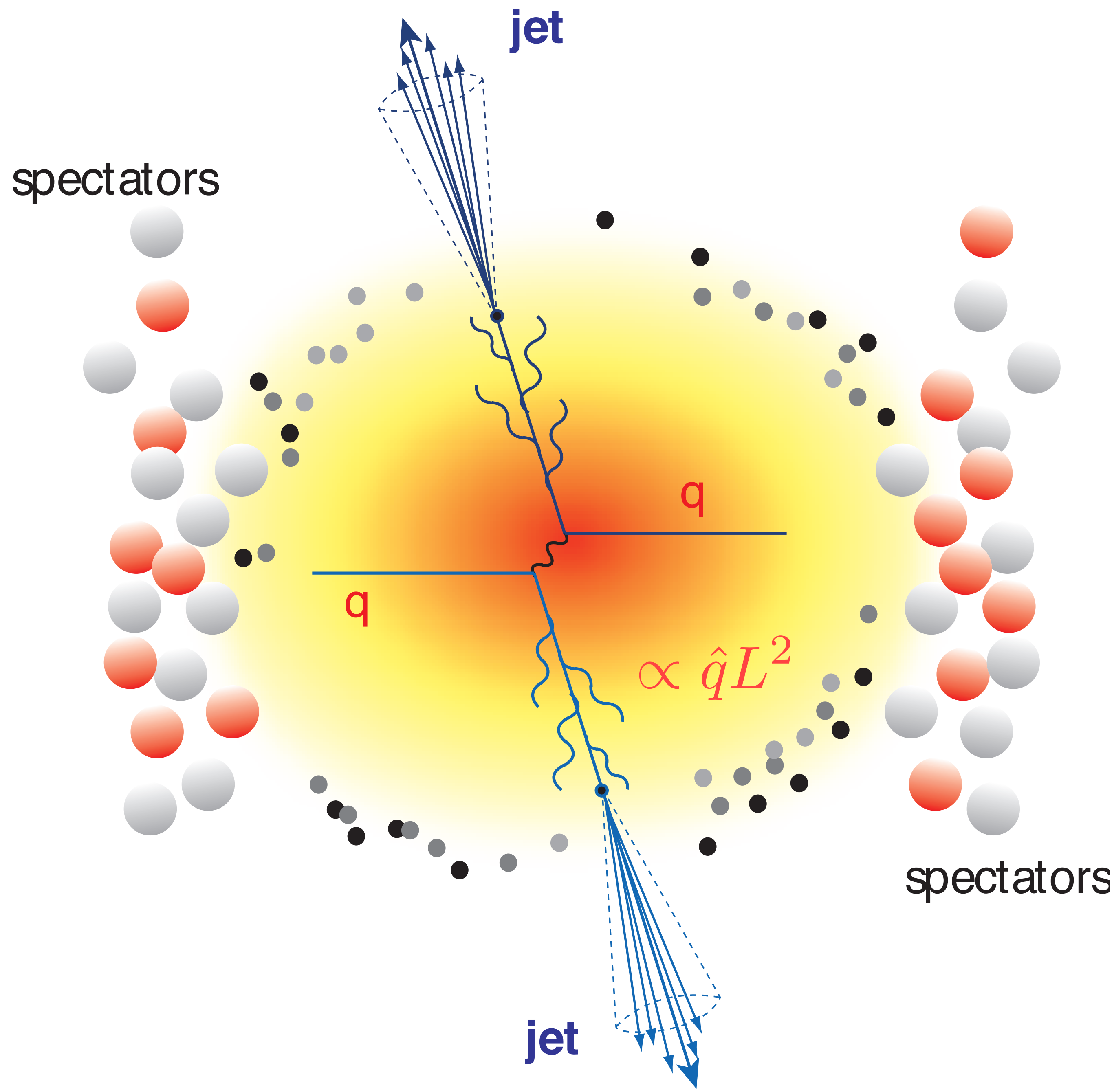
The Artist's view



"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?
(one might ask...)

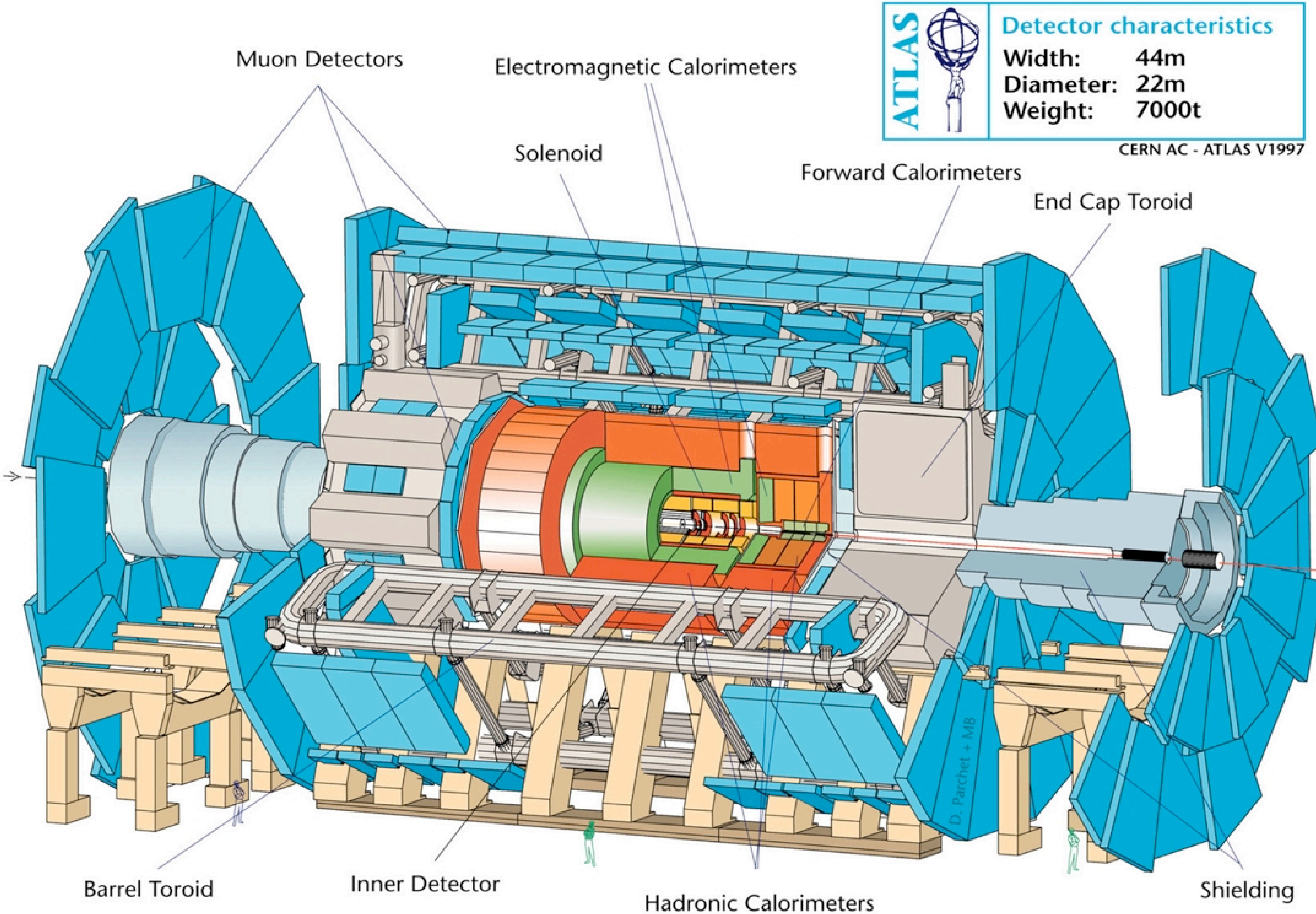
ATLAS *has a hermetic and highly segmented calorimeter both longitudinally (in* R *) and transversely (in* η *and* Φ).

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.*

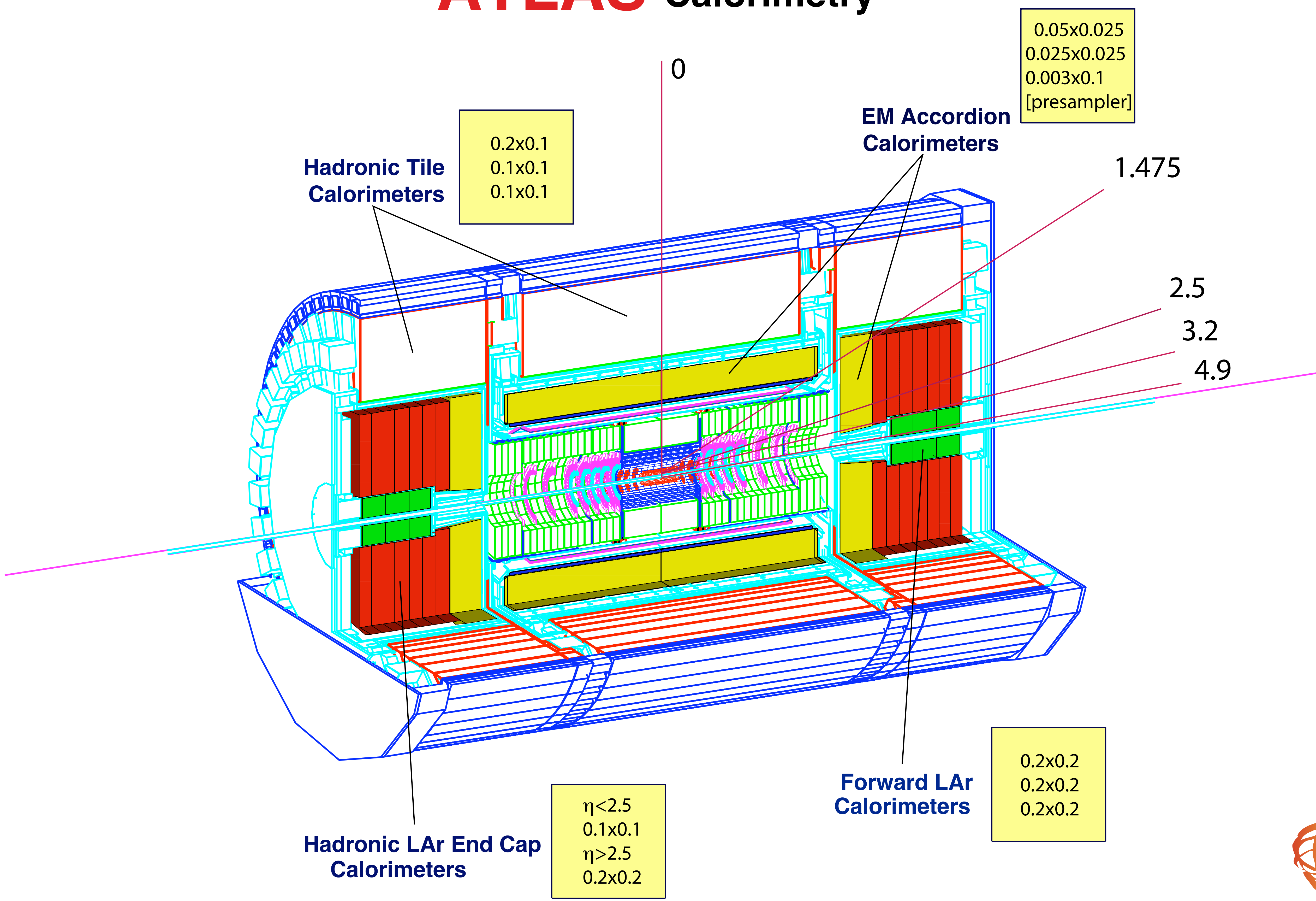
... closer to the Cafeteria and T-shirts by Alan Alda!



1900 physicists, 154 institutions, 35 countries

Designed for high p_T physics in pp collisions

ATLAS Calorimetry



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

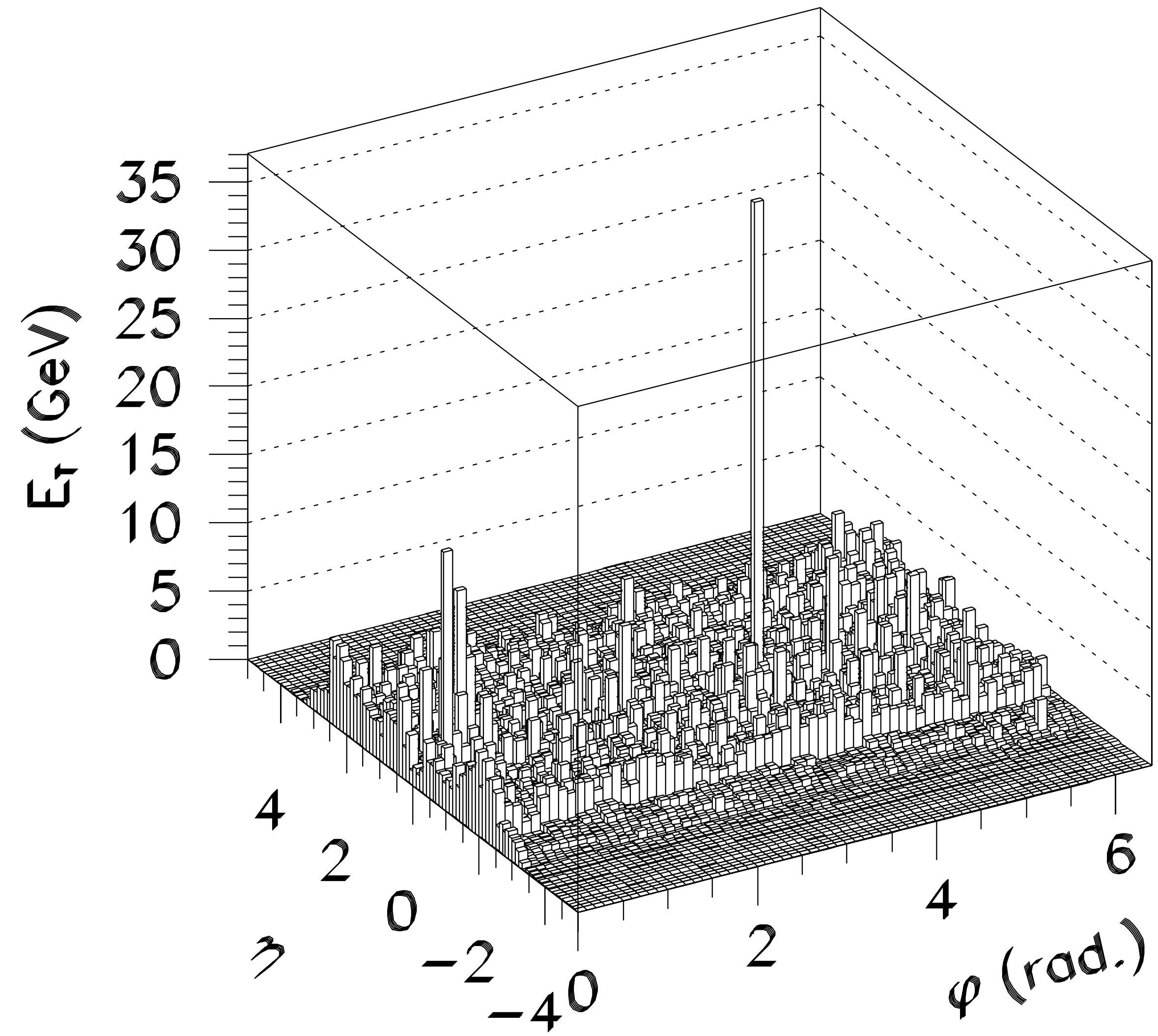
ultra-peripheral collisions

Light ions

A first study of the detector response using full detector simulations was performed and it is reported in the LoI. For these studies the standard ATLAS software was used.

Jets

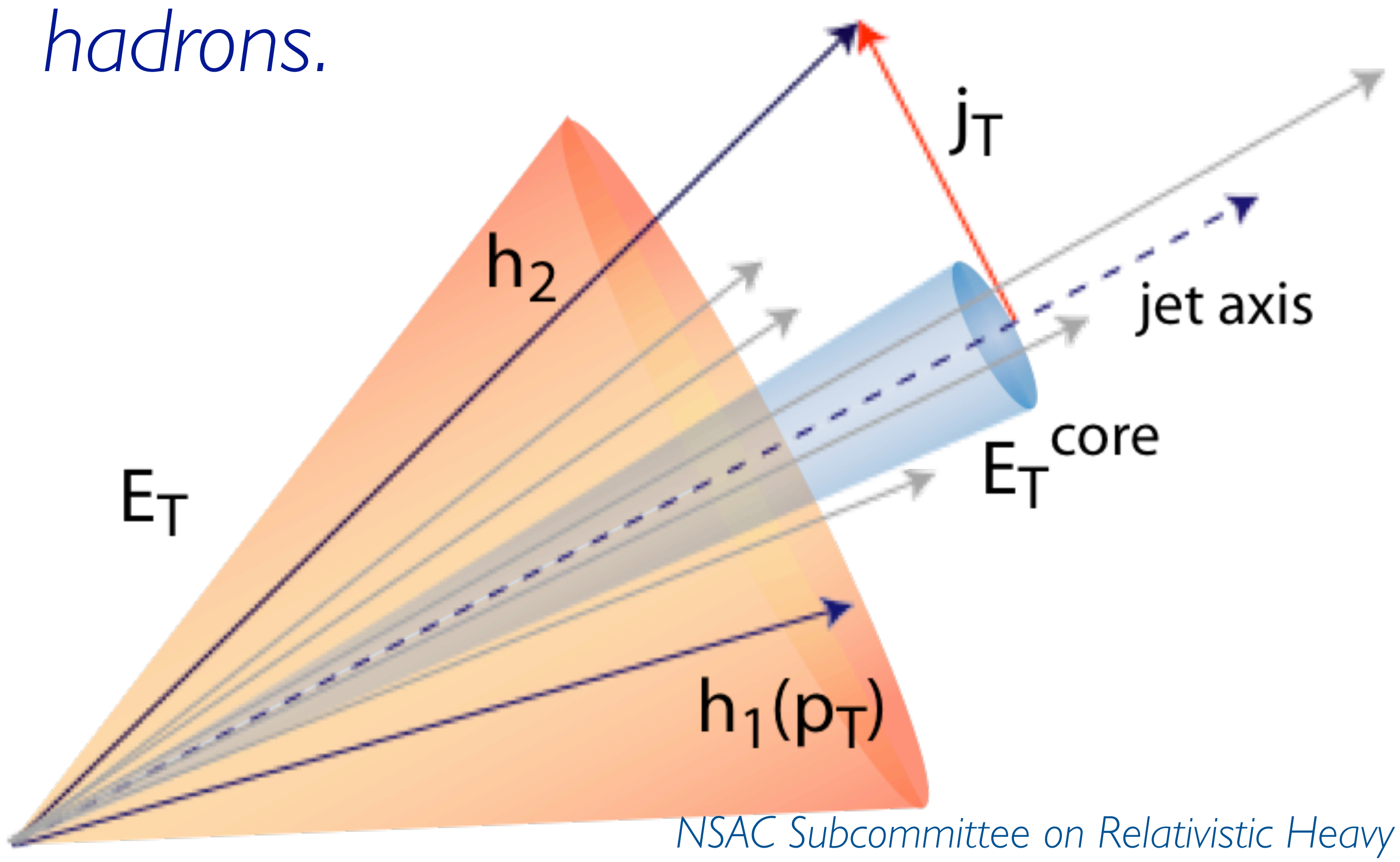
F*ind jets (after background subtraction) and measure their* E_T



U*se calorimeter do measure jet profile*

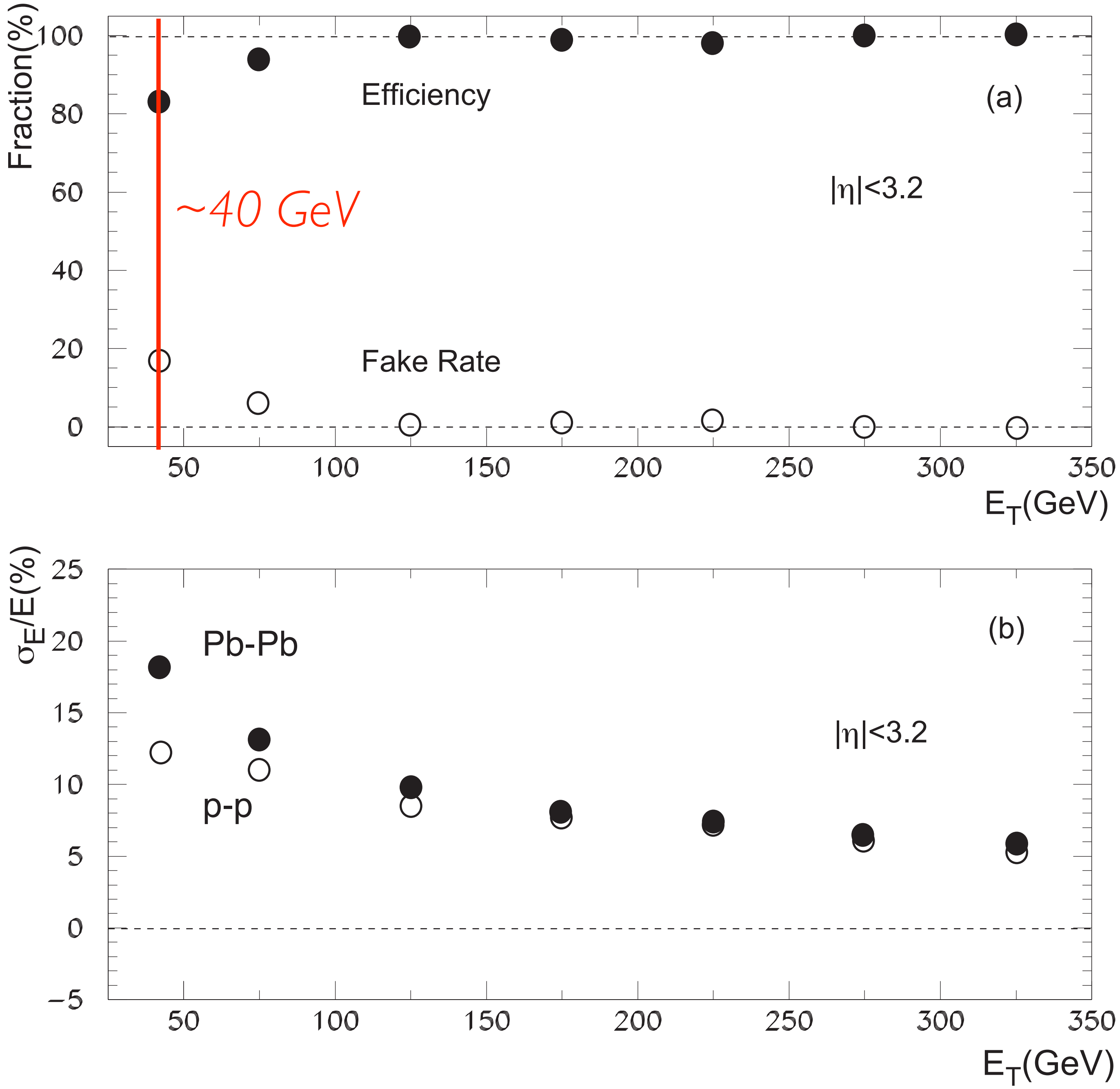
U*se calorimeters to measure core* E_T

U*se calorimeter to detect neutral hadrons.*



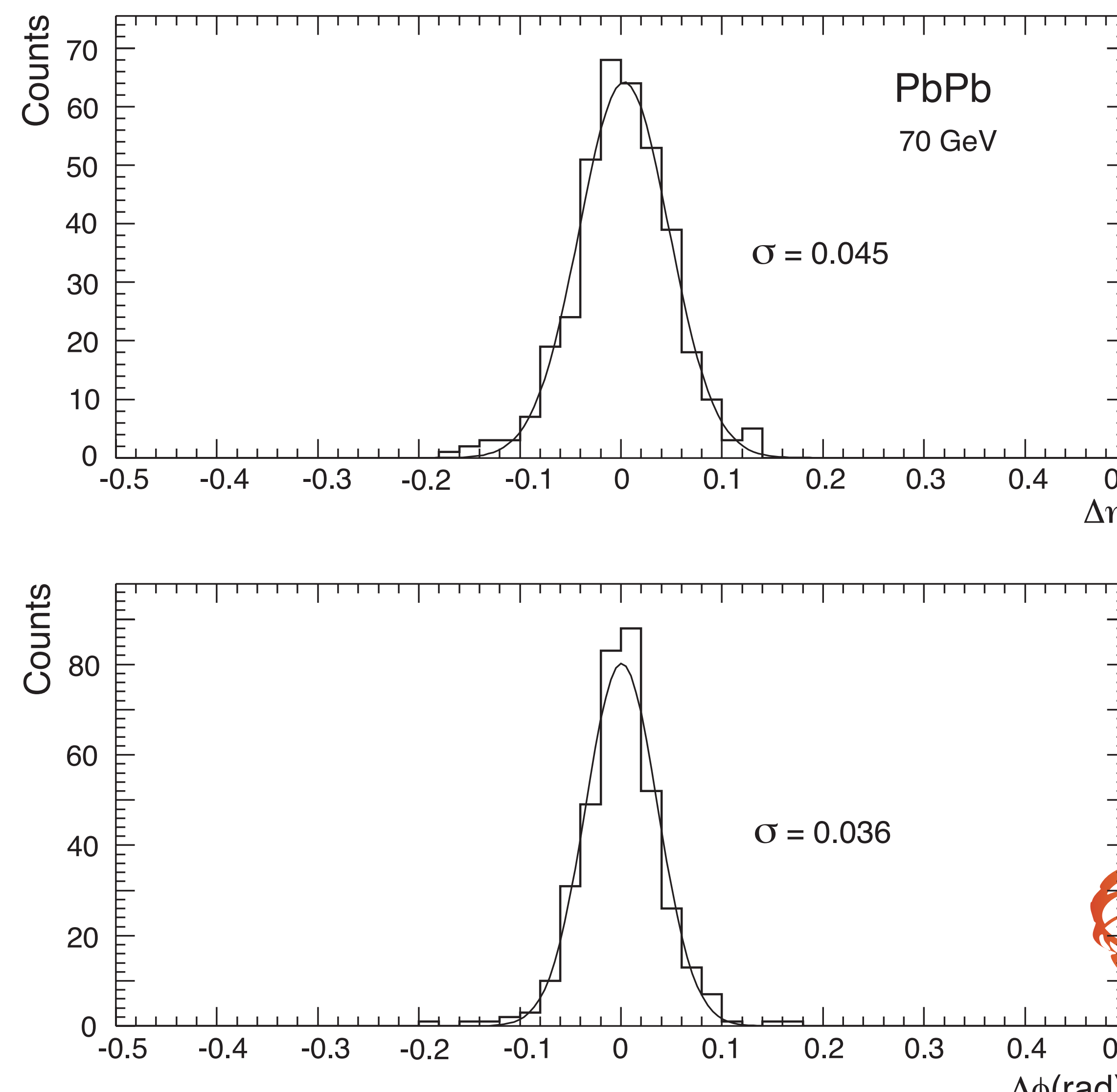
U*se tracking to measure fragmentation function D(z) and* j_T *via charged particles.*

Performance



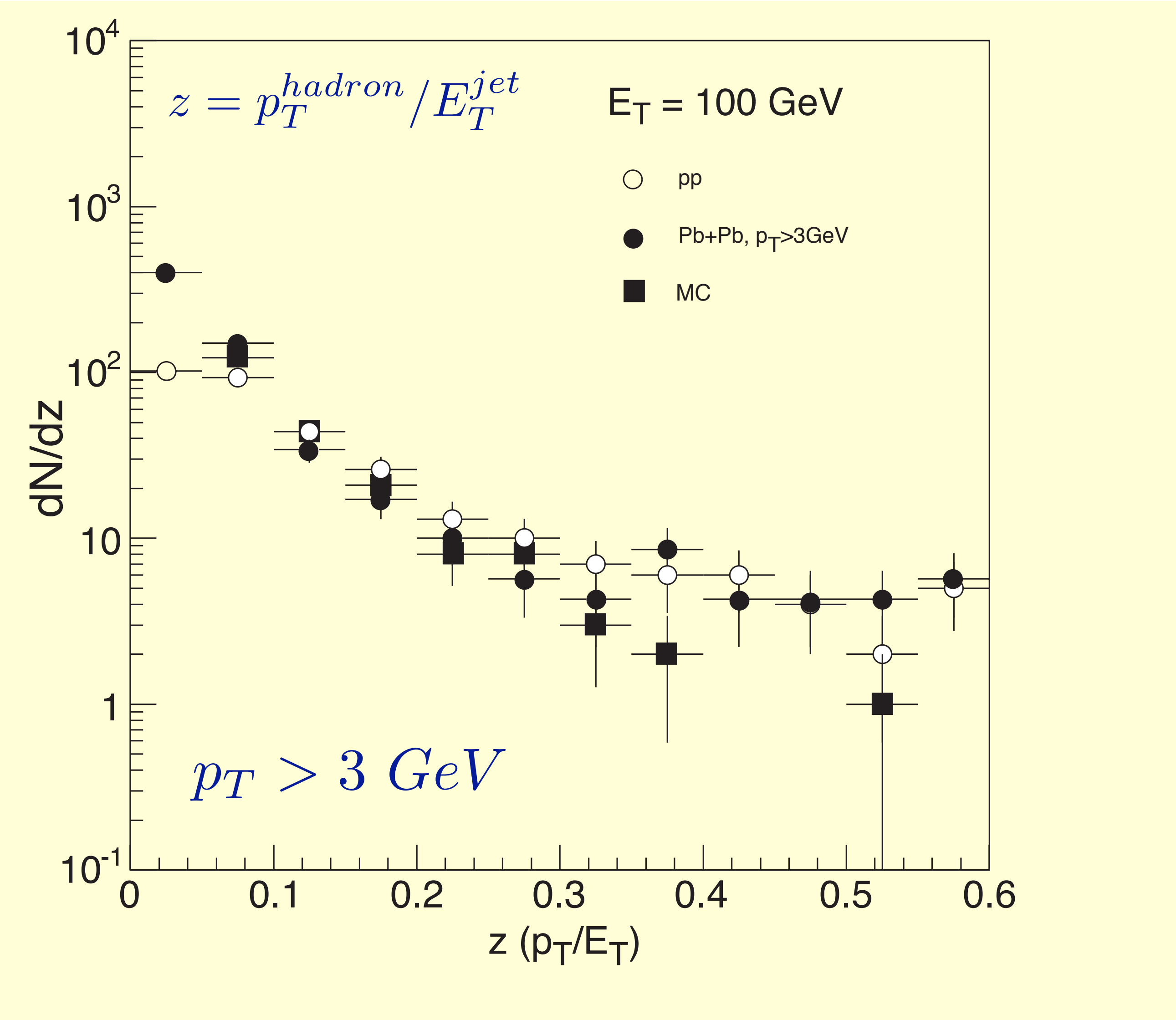
Window algorithm, with average pedestal subtraction.

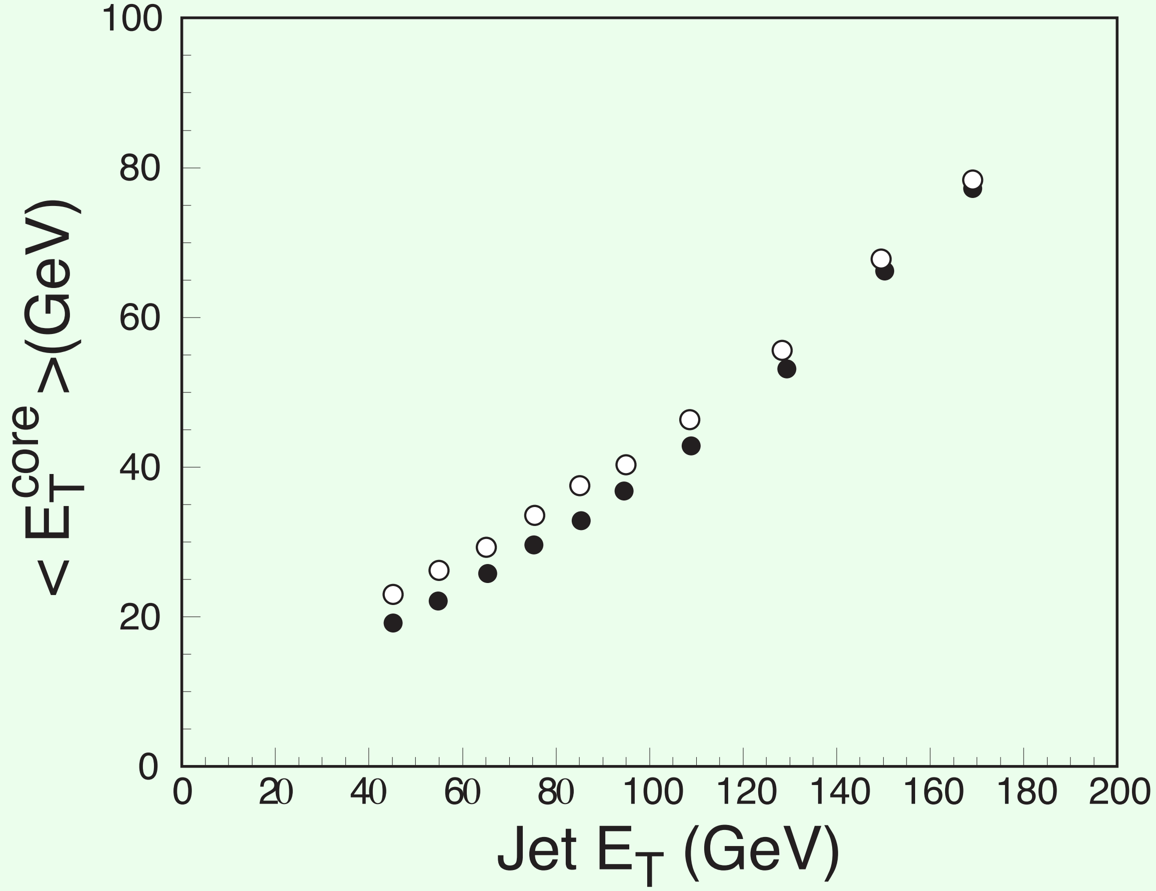
Pedestal subtraction requires more study, especially if background is asymmetric.

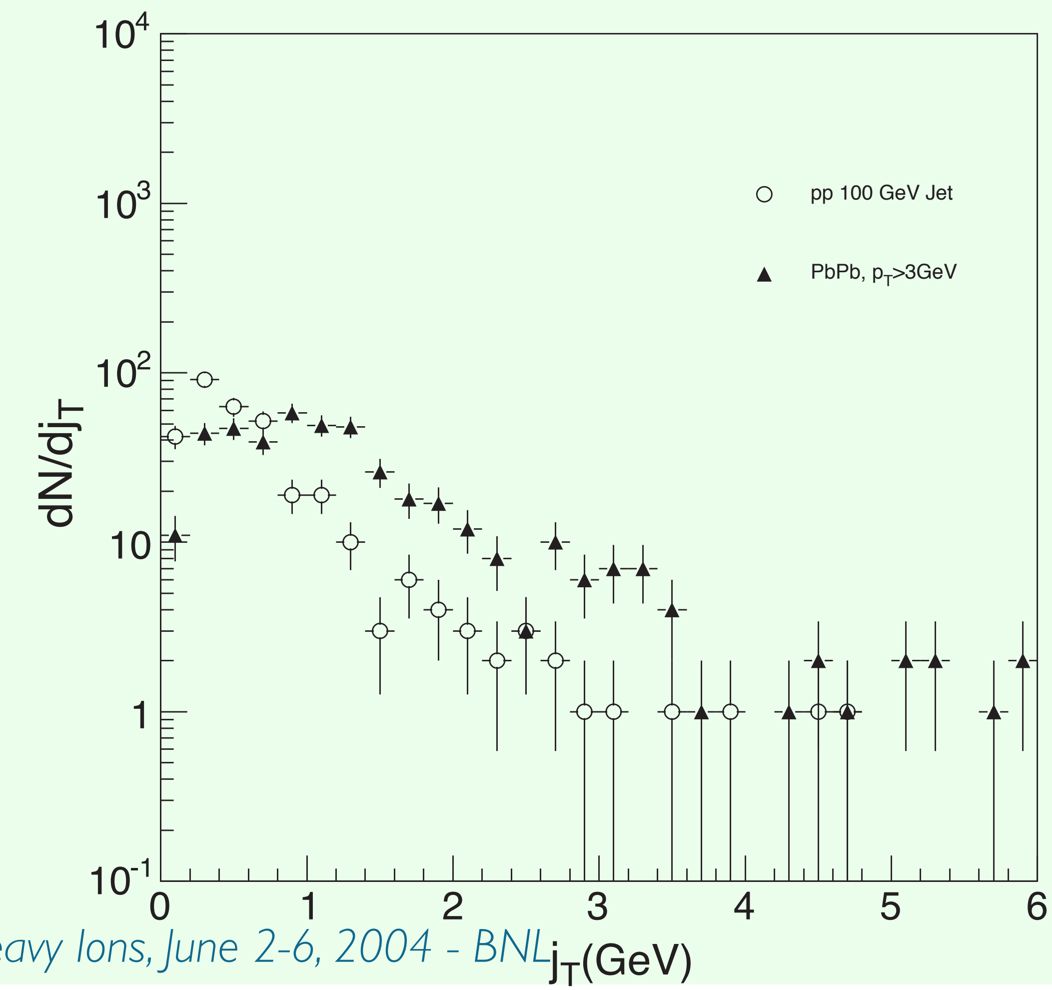


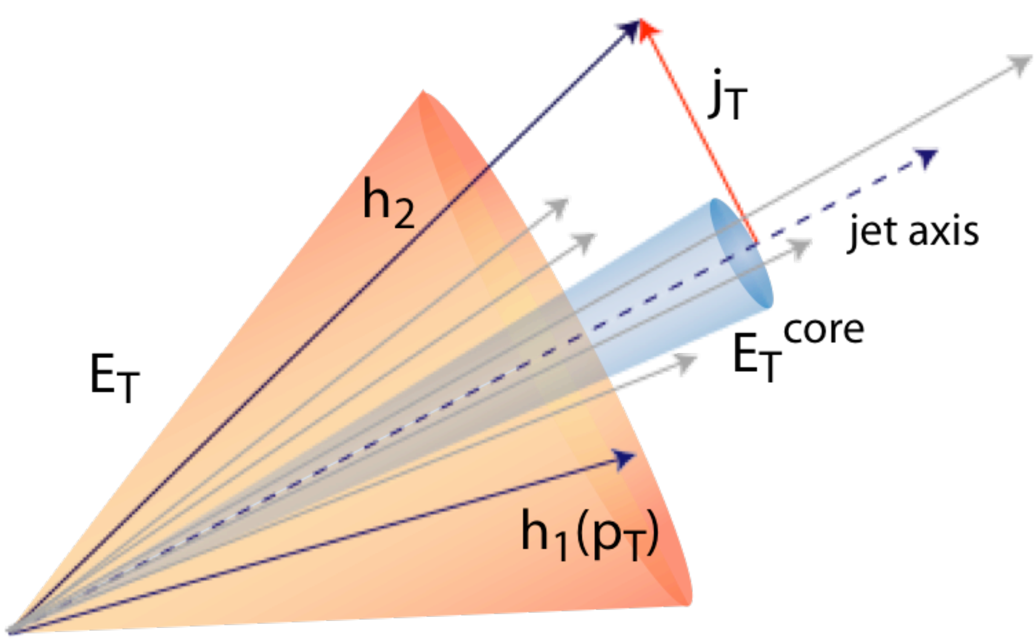
jet axis definition is important for measurement of j_T. At the moment it is about a factor of 2 worst than in pp

Fragmentation function, j_T and E_T^{core}





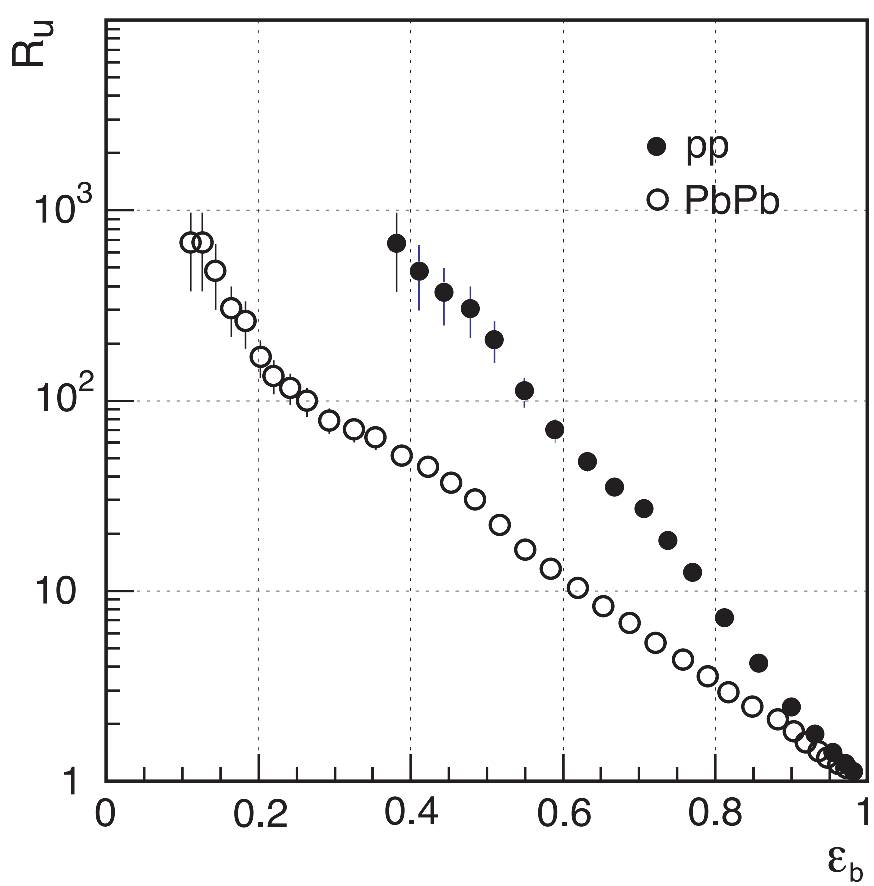


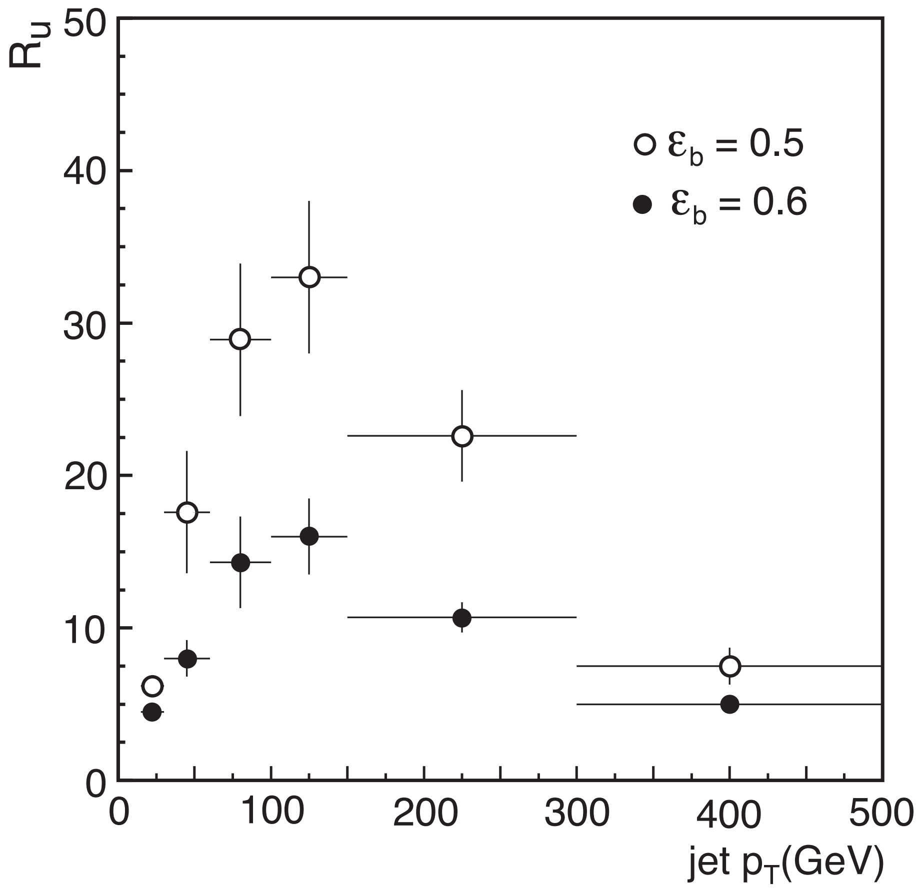


b- tagging

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.*

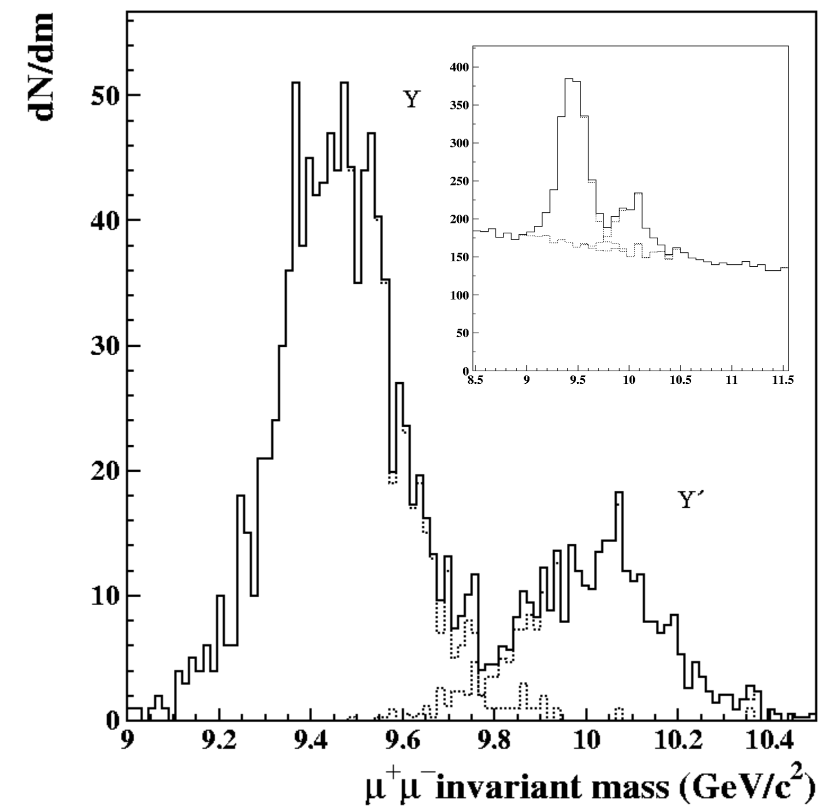




A muon tag *will also be used by matching a muon in the spectrometer to the jet axis.*

Quarkonia

***A**TLAS will measure upsilon in the rapidity range |η|<2.5 using the muon spectrometer and inner detector (not including the TRT).*



	|η|<1	|η|<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.*

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

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

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 $\mathcal{L} = 4\times10^{26}\ cm^{-2}s^{-1}$ *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

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

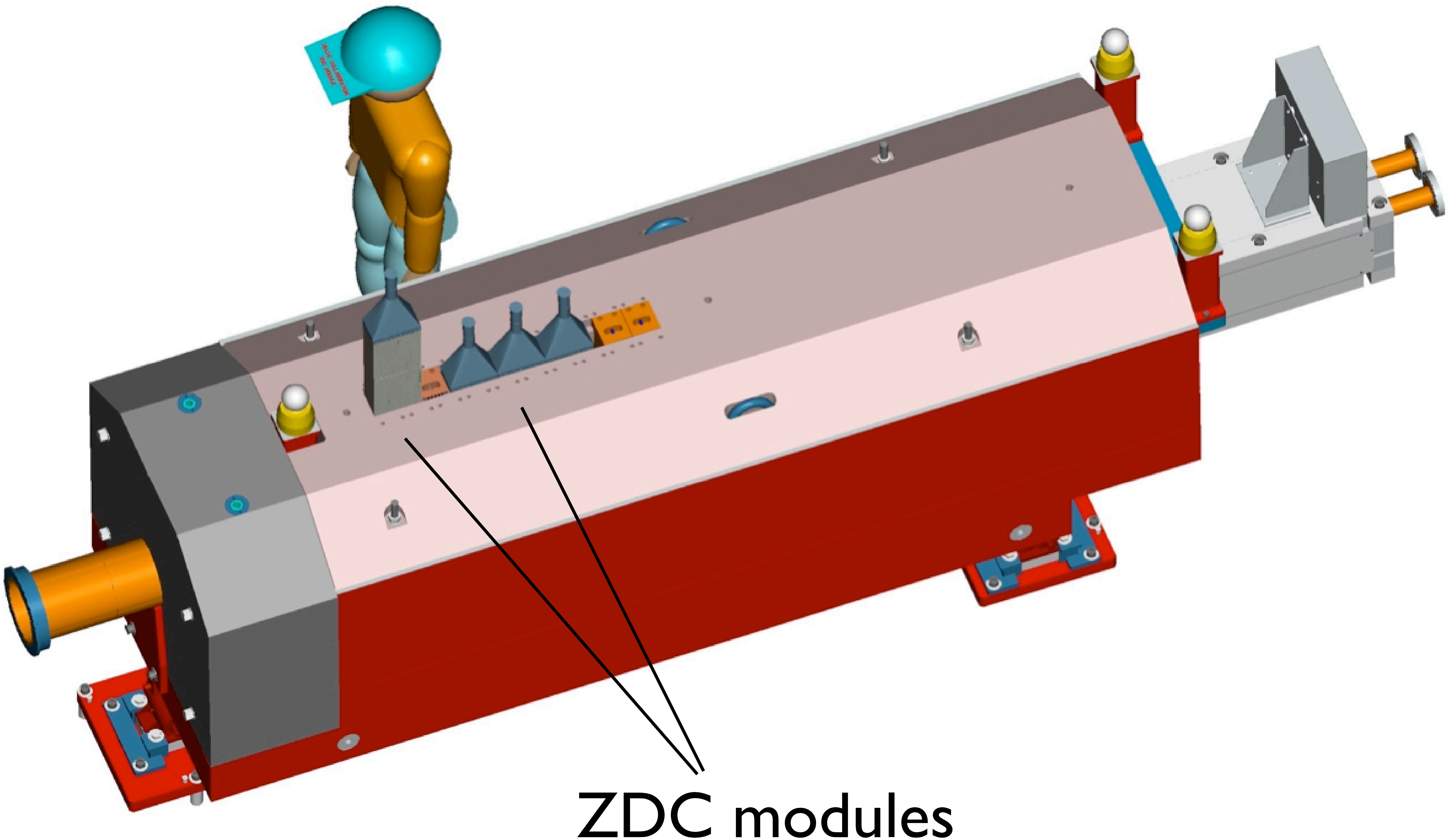
H*igh energy γ-γ and γ-nucleon collisions*

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.*

ZDC



ATLAS and Heavy Ions

The *ATLAS collaboration has prepared and submitted a letter of intent to the LHCC (May 10-12).*

The *collaboration has a strong interest in pursuing heavy ion physics.*

The *heavy ion working group has been formed and participates in the physics coordination.(H. Takai and L. Rosselet, conveners)*

Many *of us have keen interest in the pp program as well, especially in QCD.*

Life Post-LoI

Heavy Ion Specific Algorithms

So far most simulations use "standard" ATLAS software. We are now moving towards the development of heavy ion specific algorithms for jet reconstruction and tracking. (man power needed!)

Level 3 trigger

Reprogramming of level 3 trigger will be required. The level 3 processor farm can handle the data volume.

Physics Performance Report

Our next step is the preparation of a document describing in much more detail the capabilities of the detector in the heavy ion environment.

Rescuing the TRT (may open doors to electrons).

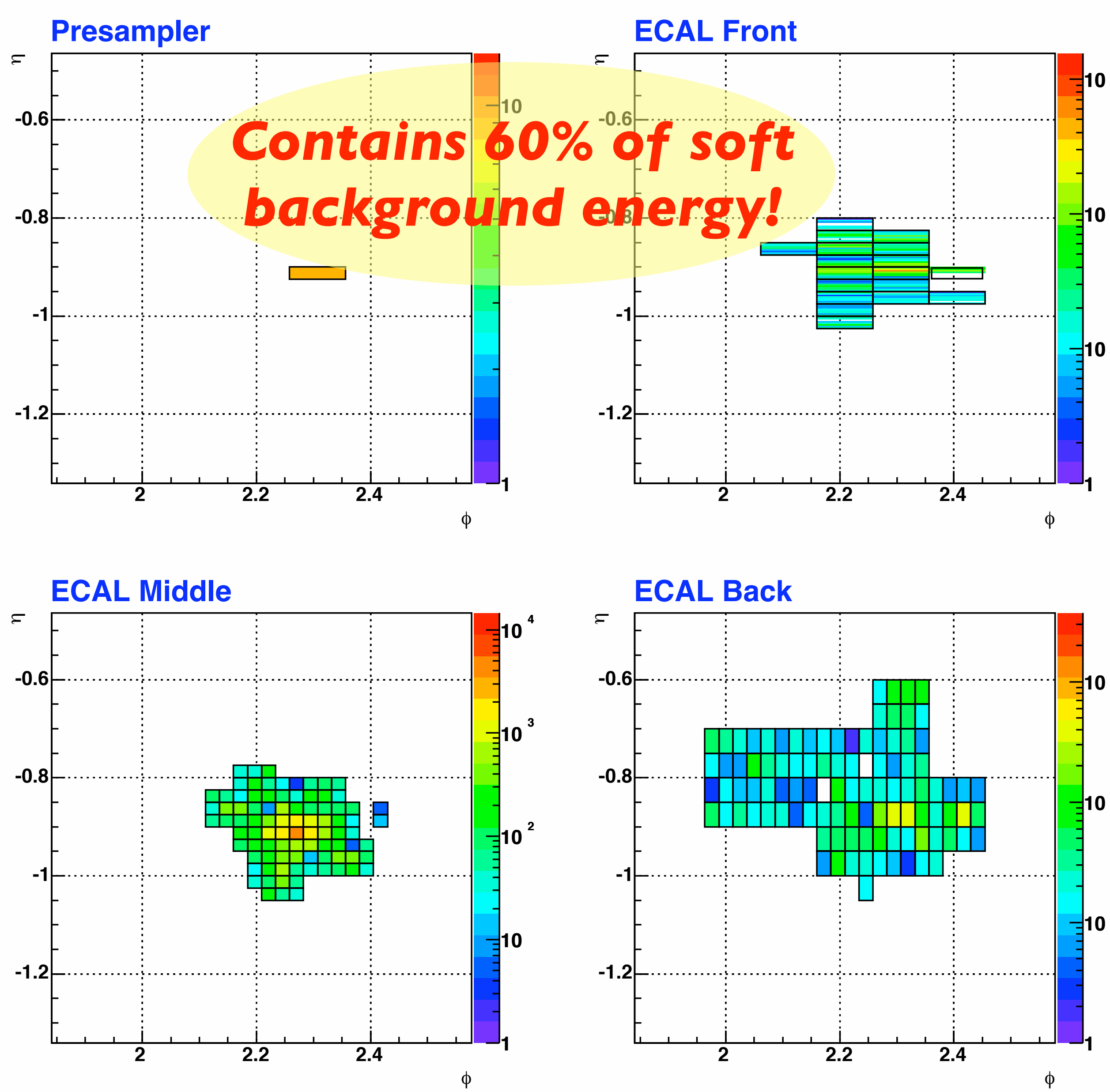
Jet energy calibration in the heavy ion environment.

Jets in 3D!

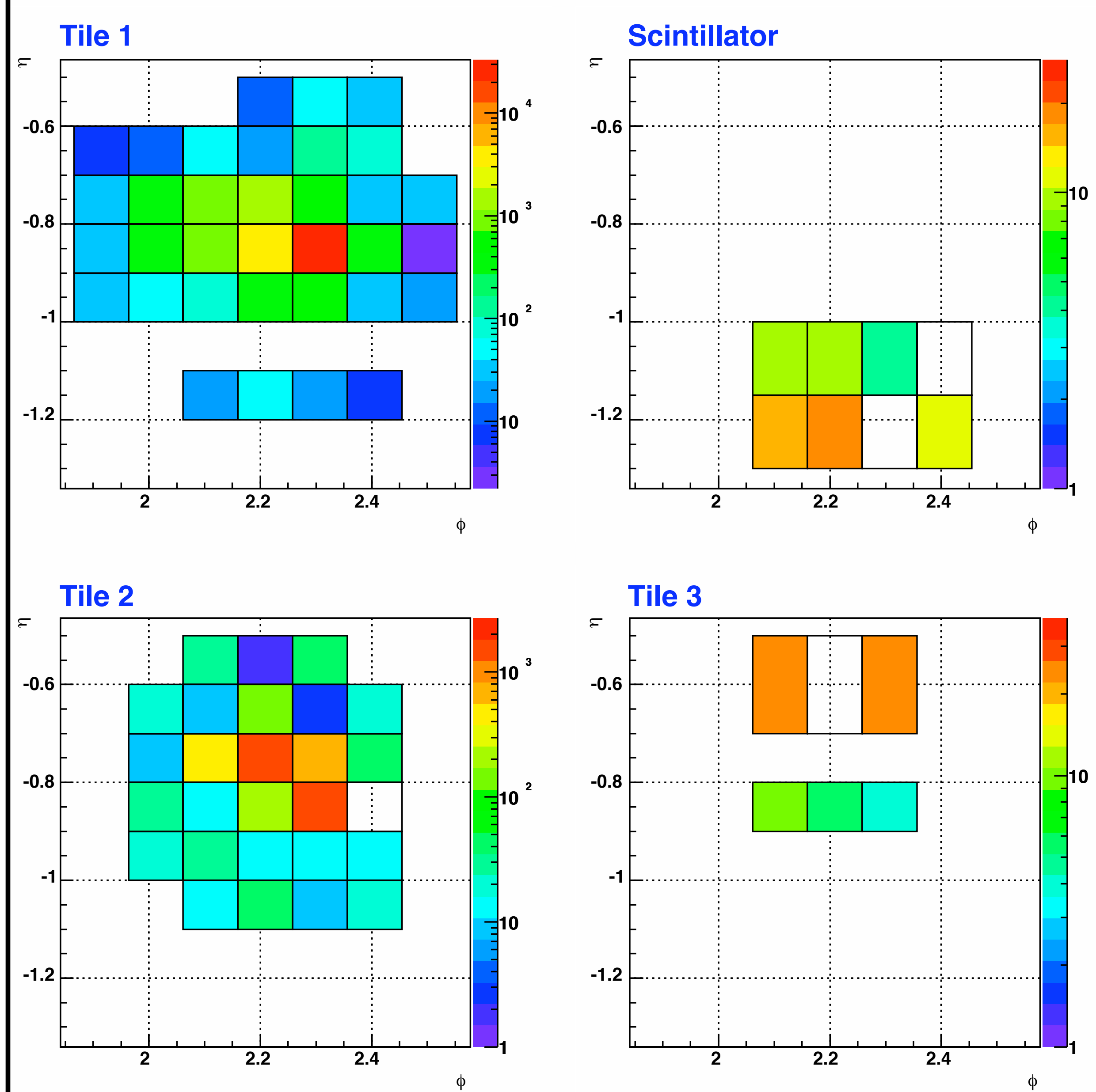
(and in color)

E_T=100 GeV (jet only)

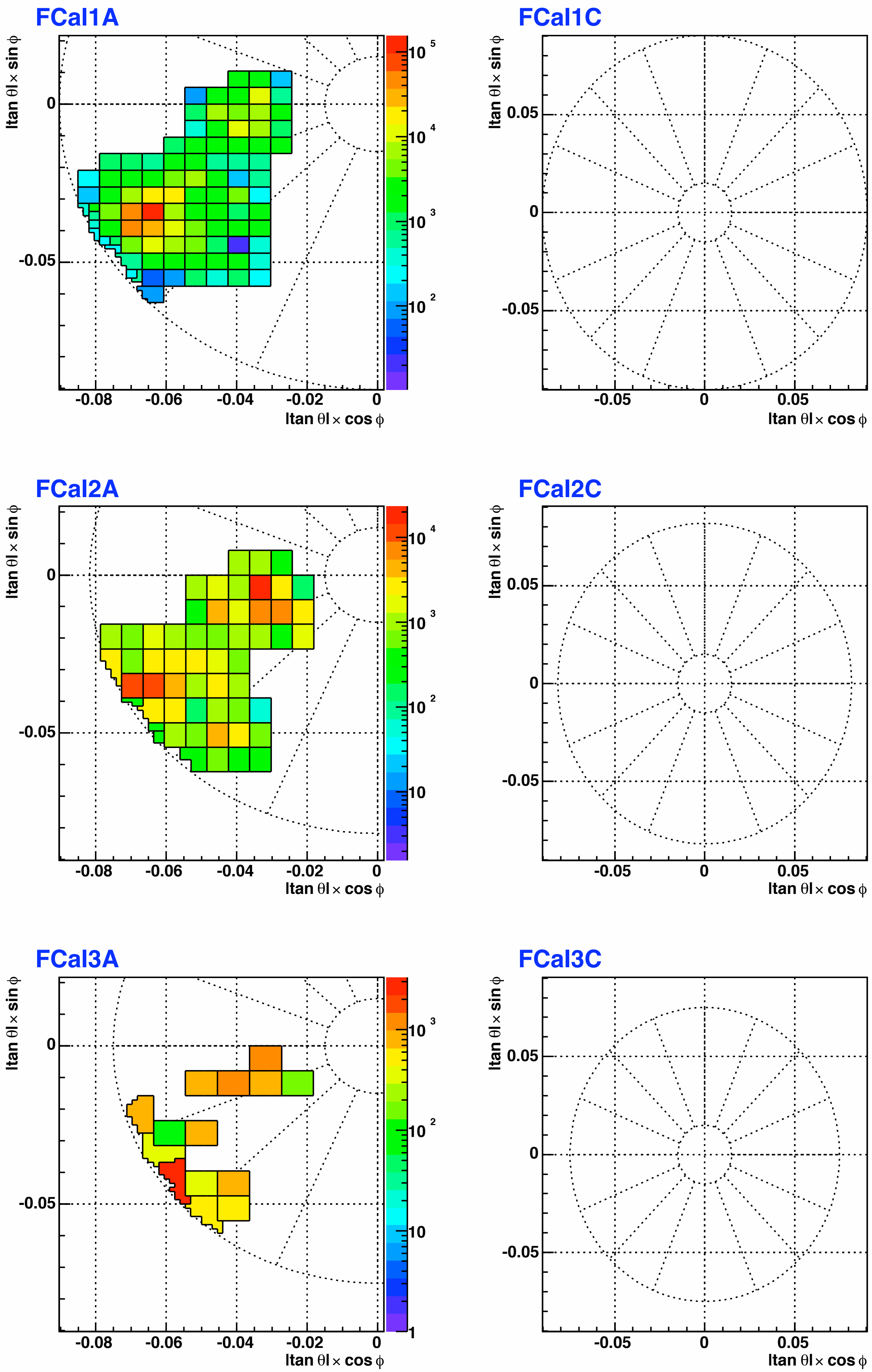
$\Delta\eta \times \Delta\Phi = 0.8 \times 0.8$



EM Calorimeter



Hadronic Calorimeter



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~10^{-5}

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

Isolated photons?

People

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

LHEP, University of Bern, Brookhaven National Laboratory
CERN, University of Colorado
Columbia University, Nevis Laboratories
Lawrence Berkeley National Laboratory
Lebedev Institute of Physics ,INFN
Intsitute of Particle and Nuclear Physics, Prague
Universidade Federal do Rio de Janeiro, University of Geneva
Institute of Nuclear Physics, Cracow

Expression of interest from institutions that are already in US-ATLAS

Estimated Cost

(Model dependent)

ZDC Calorimeter Construction

Constant FY 05 $k

	FY 05	FY06	FY07	Total
Pre-R&D				
R&D	50			50
CDR				
PED/EDIA	25	50		75
Construction		300	75	375
Preops				
TEC	25	350	75	450
TPC	75	350	75	500
Planned redirect				
Needed New Funds (TPC-redirect)	75	350	75	500

Heavy Ion Physics with the ATLAS Detector - Operations

Constant FY 05 $k

	FY05	FY06	FY07	FY08	Total
Cost Components					
Labor	450	900	1,200	1,500	4,050
MST	150	225	300	375	1,050
Computing	50	110	133	326	619
M&O Cat.A	30	43	70	95	238
Total	680	1,278	1,703	2,296	5,957
Staffing					
U.S. Authors	10	15	20	25	
FTE's	3	6	8	10	

Conclusions

The Letter of Intent (LoI) represent a first look into a heavy ion physics program with the ATLAS detector.

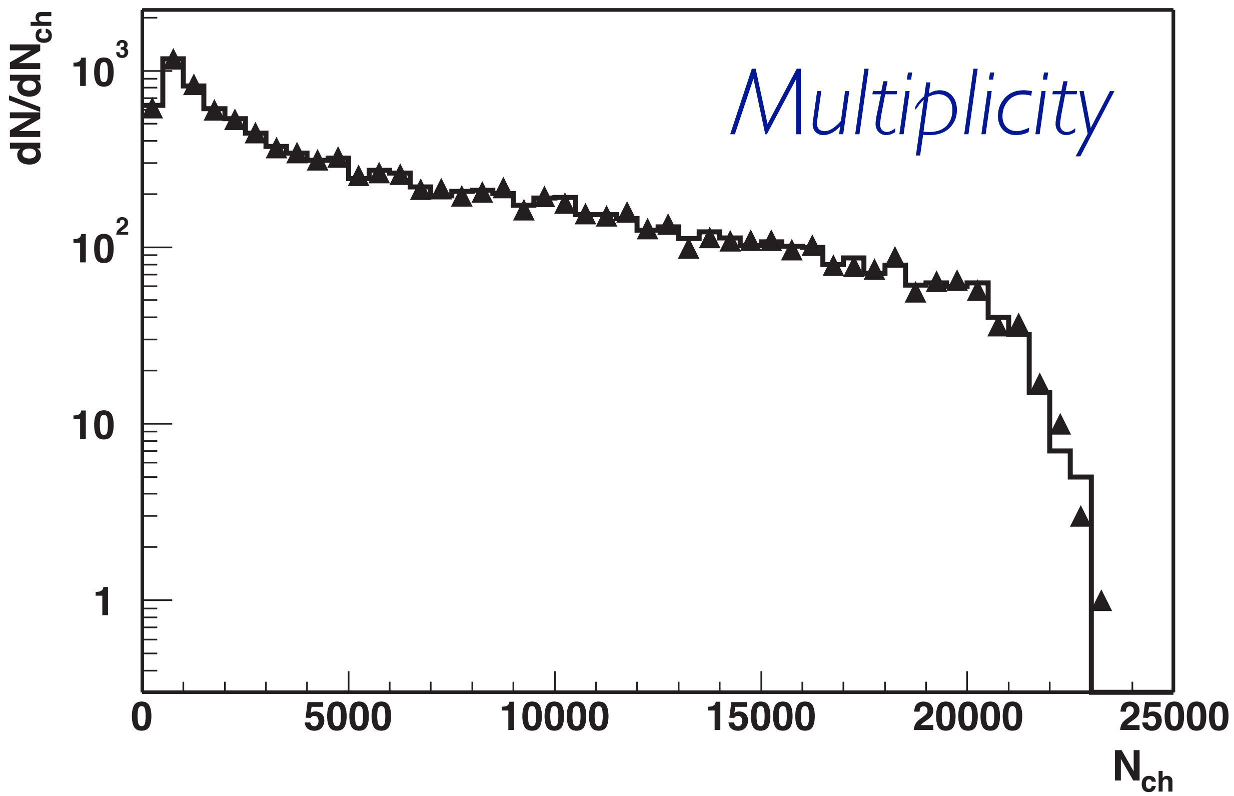
The high granularity of the calorimeter system, external muon spectrometer and tracking capabilities in the high multiplicity environment makes ATLAS ideal for the study of jets and quarkonia in heavy ion collisions.

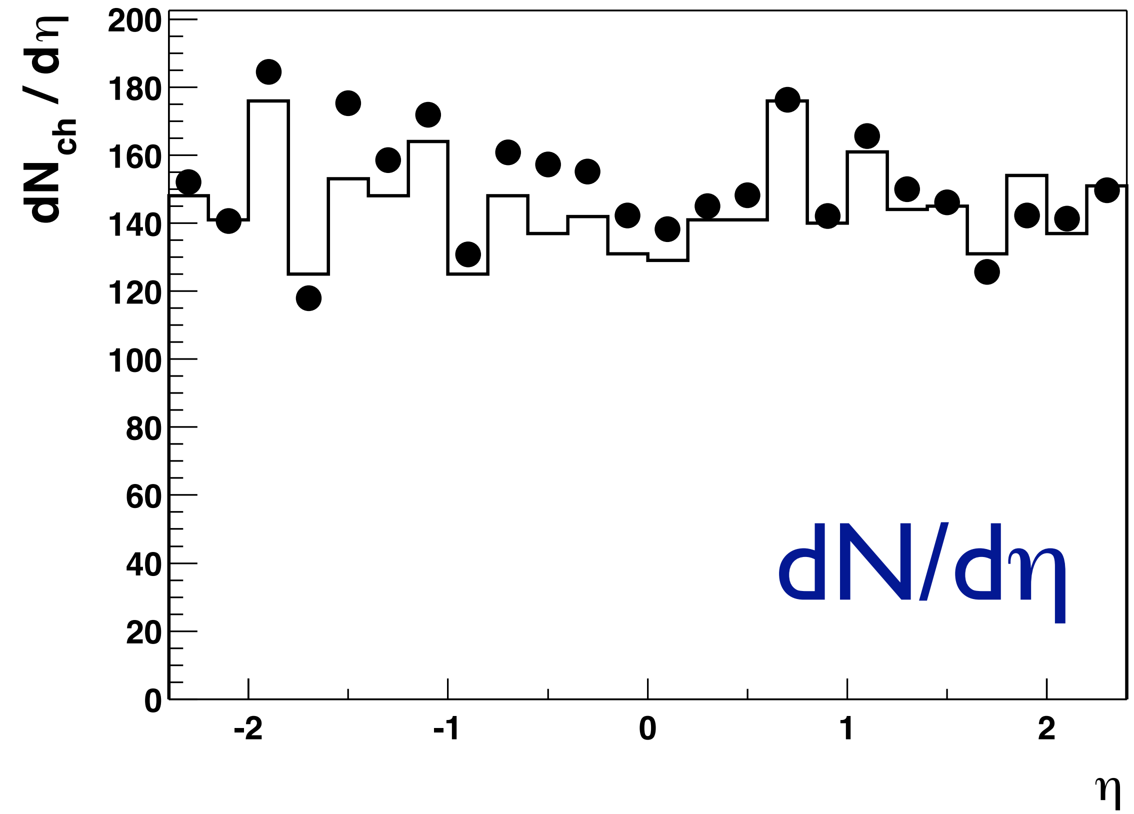
The study of pp and pA collisions in the same environment will allow for the definition of a solid baseline. Hence the interest in jet physics in pp and pA runs.

Studies of detector performance will continue. Algorithms tailored to the high multiplicity environment need to be developed. Much work is ahead but prospects of successful and interesting physics program is ahead of us.

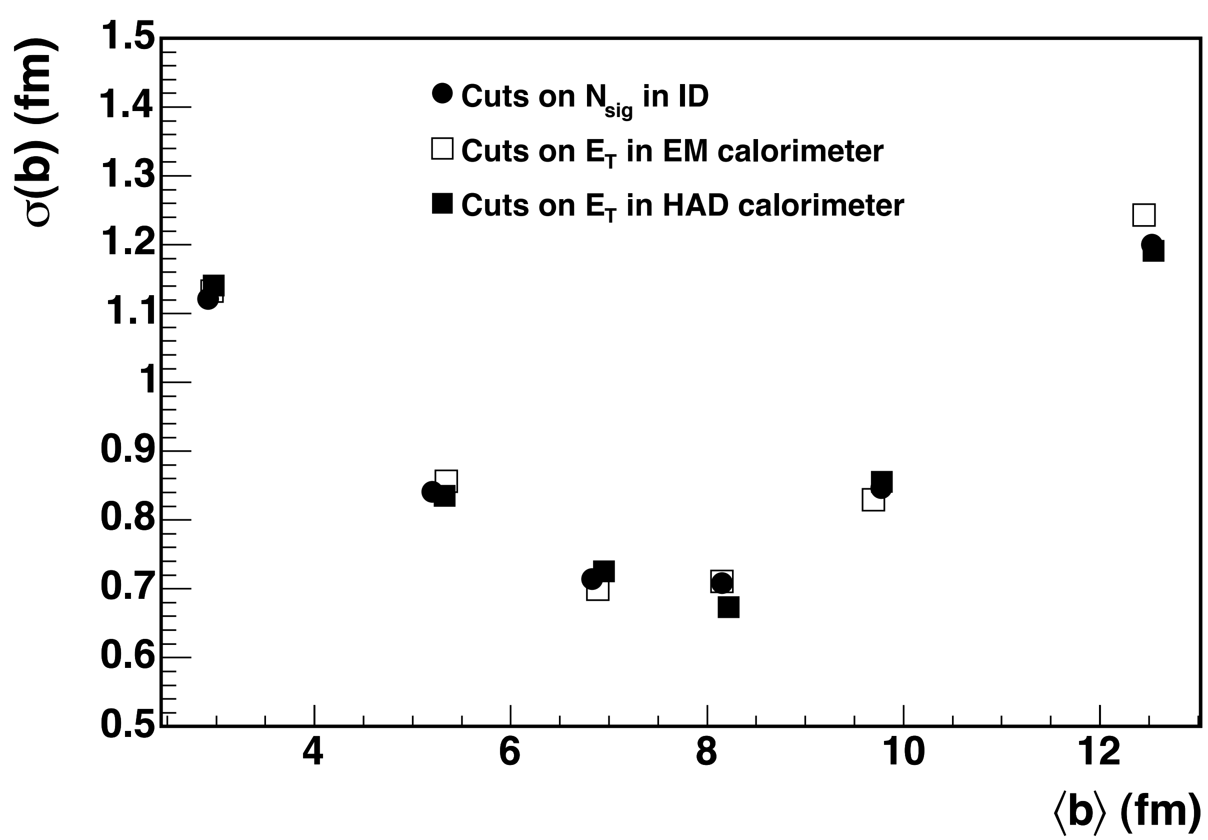
Supplemental Slides

Global Variables



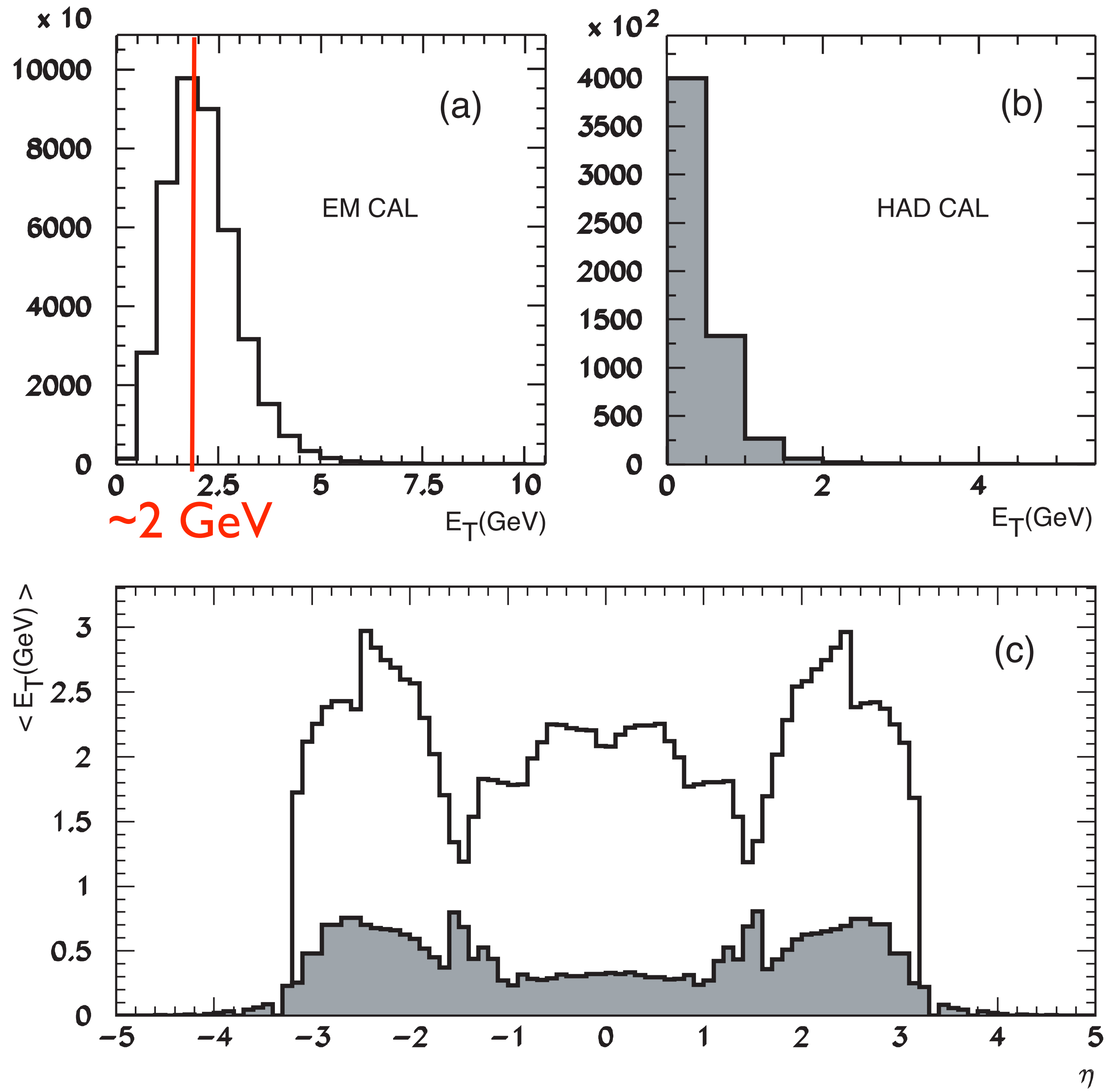


impact parameter resolution



Average Energy in Calorimeters

(in 0.1x0.1 cell)



b<1 fm

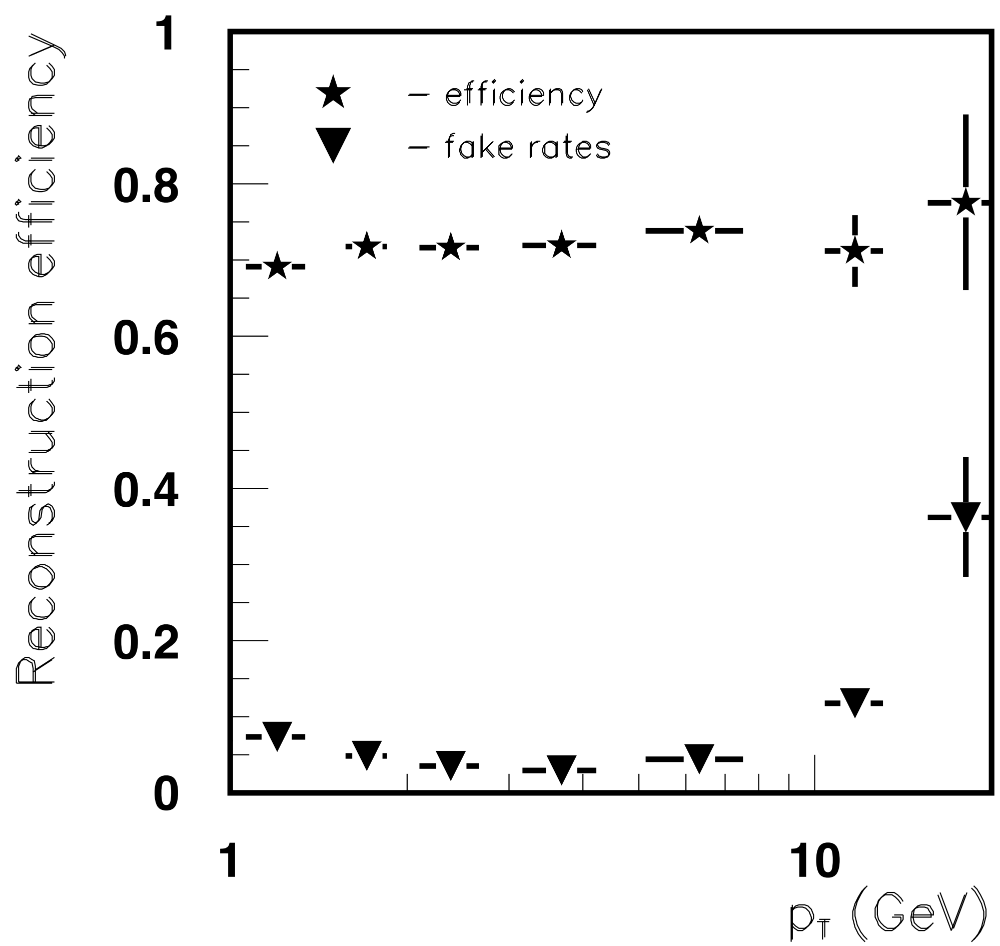
E*nergy deposition by soft particles in heavy ion collisions (b<1)*

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

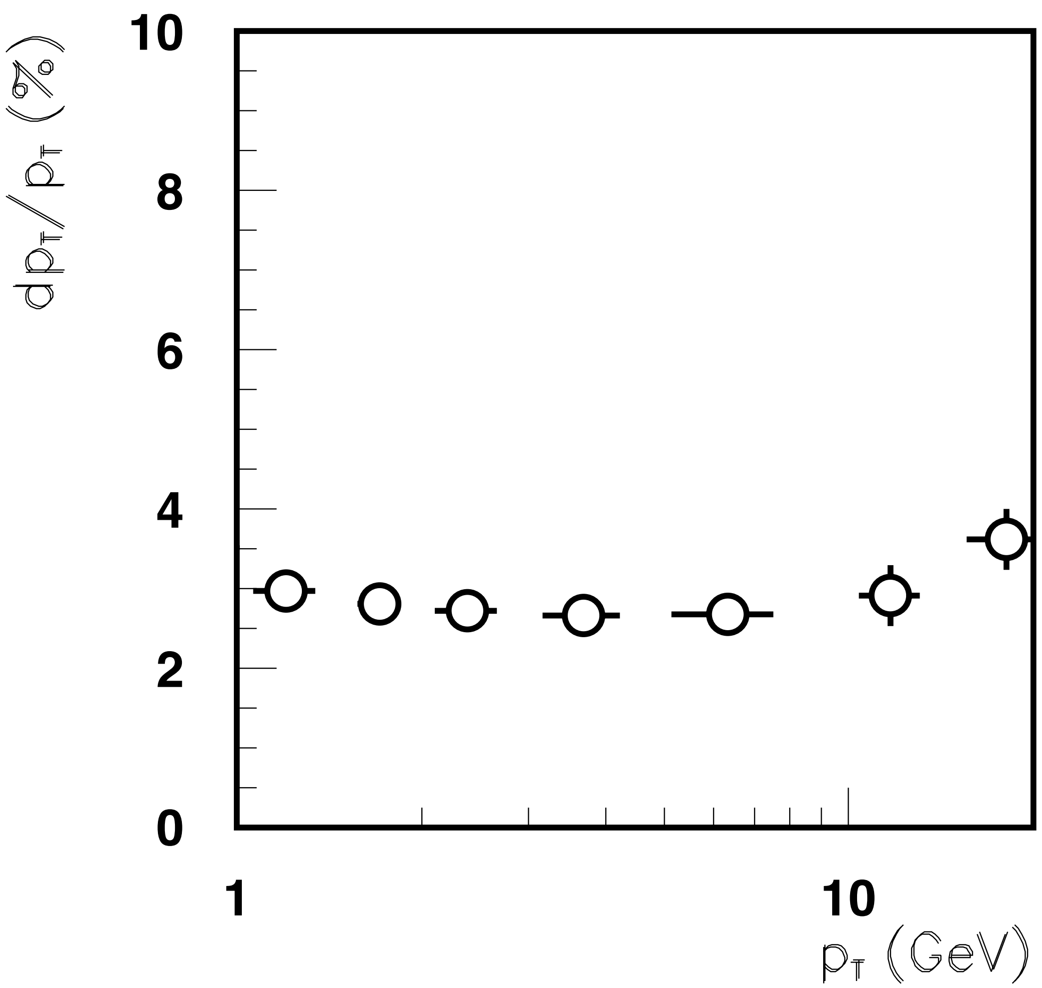
Jets *will ride on top of an average pedestal of (50±11) GeV (ΔR=0.4)*

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)

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

DRAFT
CERN/LHCC 2004-016
LHCC 70
13 May 2004

DRAFT

LARGE HADRON COLLIDER COMMITTEE

Minutes of the seventieth meeting held on
Wednesday and Thursday, 12-13 May 2004

OPEN SESSION:

1. LHC Status Report: Lyn Evans
2. Letter of Intent – Measurement of Photons and Neutral Pions in the Very Forward Region of the LHC: Yasushi Muraki
3. ATLAS Status Report: Peter Jenni
4. Letter of Intent – ATLAS Forward Detectors for Luminosity Measurement and Monitoring: Per Grafström
5. Letter of Intent – Heavy Ion Physics with the ATLAS Detector: Barbara Wosiek

CLOSED SESSION:

Present: S. Bertolucci, K. Borras, M. Calvetti (Chairman), A. Ceccucci, J. Engelen, J. Feltesse, F. Ferroni*, M. Hauschild, M. Jaffre, Y. Karyotakis, V. Kekelidze, Y.-K. Kim, J. Knobloch, M. Mangano, J. Martin, P. McBride, K. Potter*, P. Seyboth, H. Tiecke, E. Tsesmelis (Secretary), C. Vallée, T. Wyatt

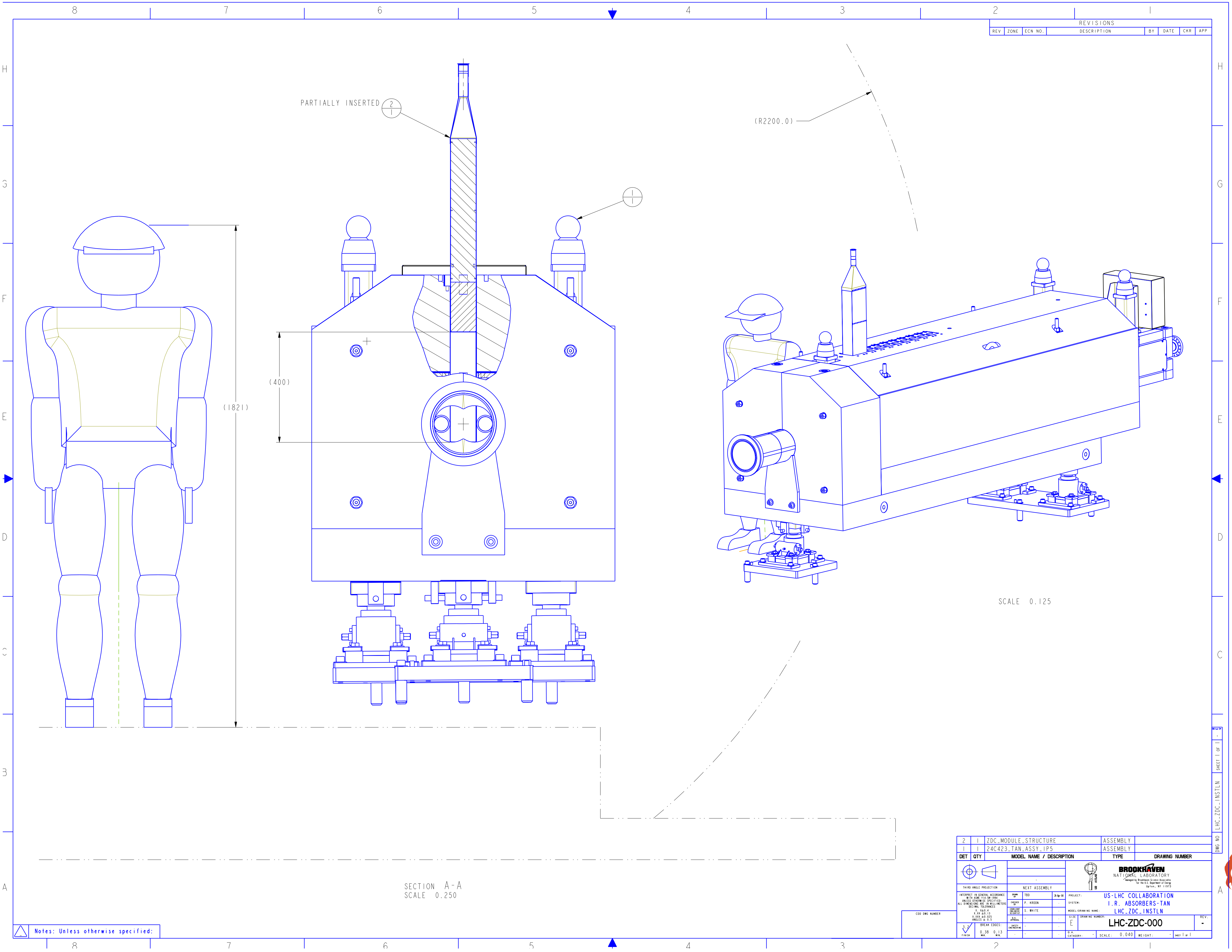
*) Part time

1. REPORT FROM THE ATLAS REFEREES

The LHCC heard a report from the ATLAS referees, concentrating on general progress in the detector construction, and reports on the Inner Detector and the Letters of Intent on the Forward Detectors for Luminosity Measurement and Monitoring and for Heavy Ion Physics with the ATLAS Detector.

…..

The referees also reported on the ATLAS Letter of Intent on Heavy Ion Physics with the ATLAS Detector (LHCC 2004-009 / I-013). The Letter of Intent details first and preliminary studies to establish the performance of the baseline ATLAS experiment, as described in the approved Technical Design Reports, in the field of heavy-ion physics and the experiment's capability to provide measurements to constrain the underlying physics. The accent of the studies is on high-p_T signatures, which are better matched to the ATLAS design concept than the soft final states. No changes to the detector under construction, except for the possibility of the addition of a Zero Degree Calorimeter in the very forward regions to improve studies of ultra-peripheral collisions, are assumed. The LHCC encourages the ATLAS Collaboration to continue their studies for heavy ion physics with a view to submitting a Physics Performance Report.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ASSEMBLY
BROOKHAVEN NATIONAL LABORATORY
US-LHC COLLABORATION
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