Heavy Ion Physics at the LHC with ATLAS

Peter Steinberg

May 22, 2007

PHENIX Focus

for the ATLAS Collaboration

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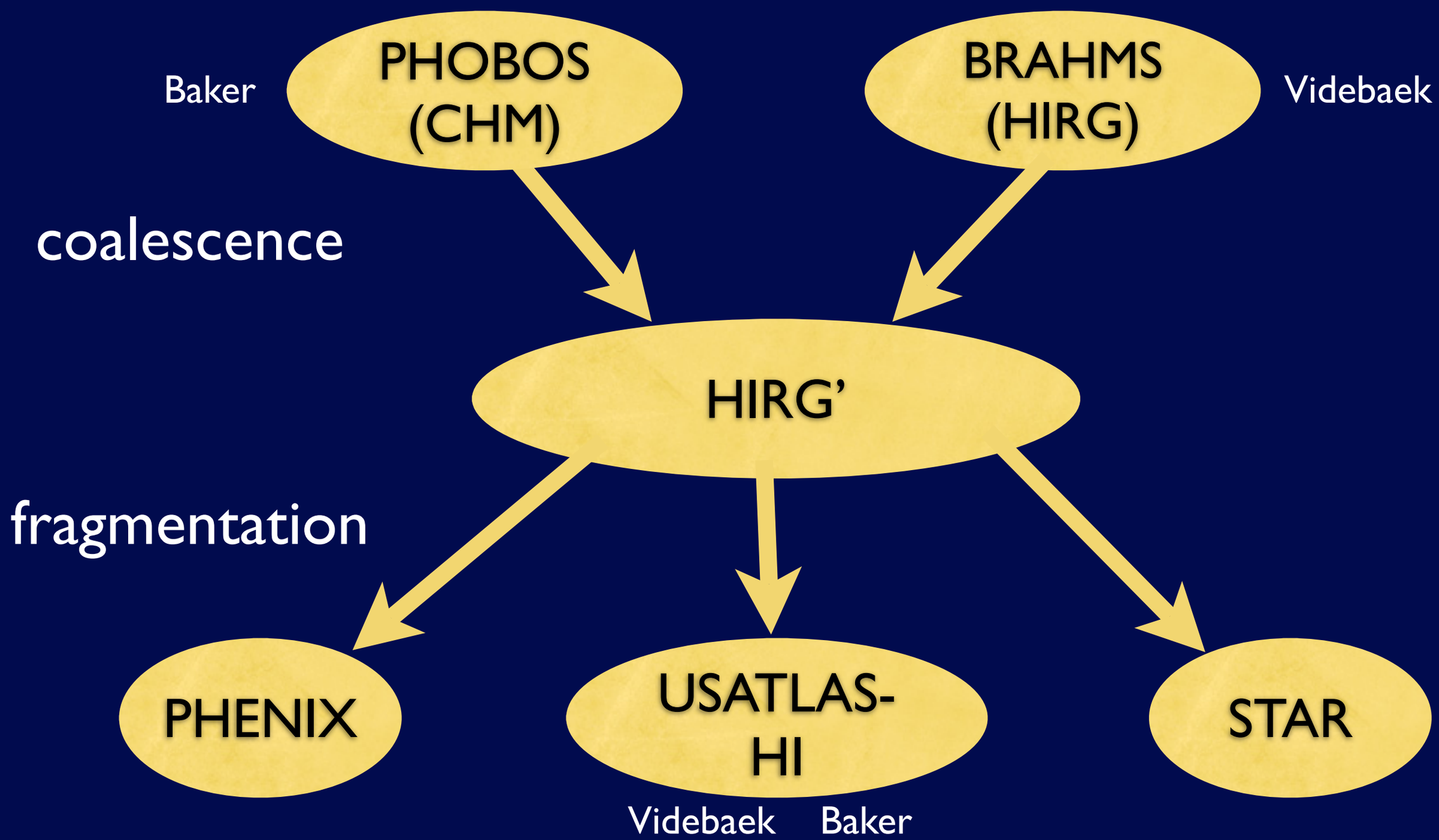
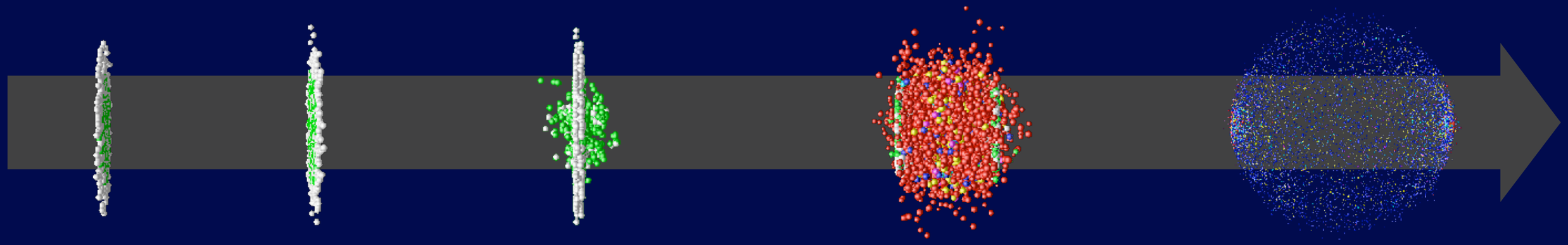
ATLAS-HI @ BNL

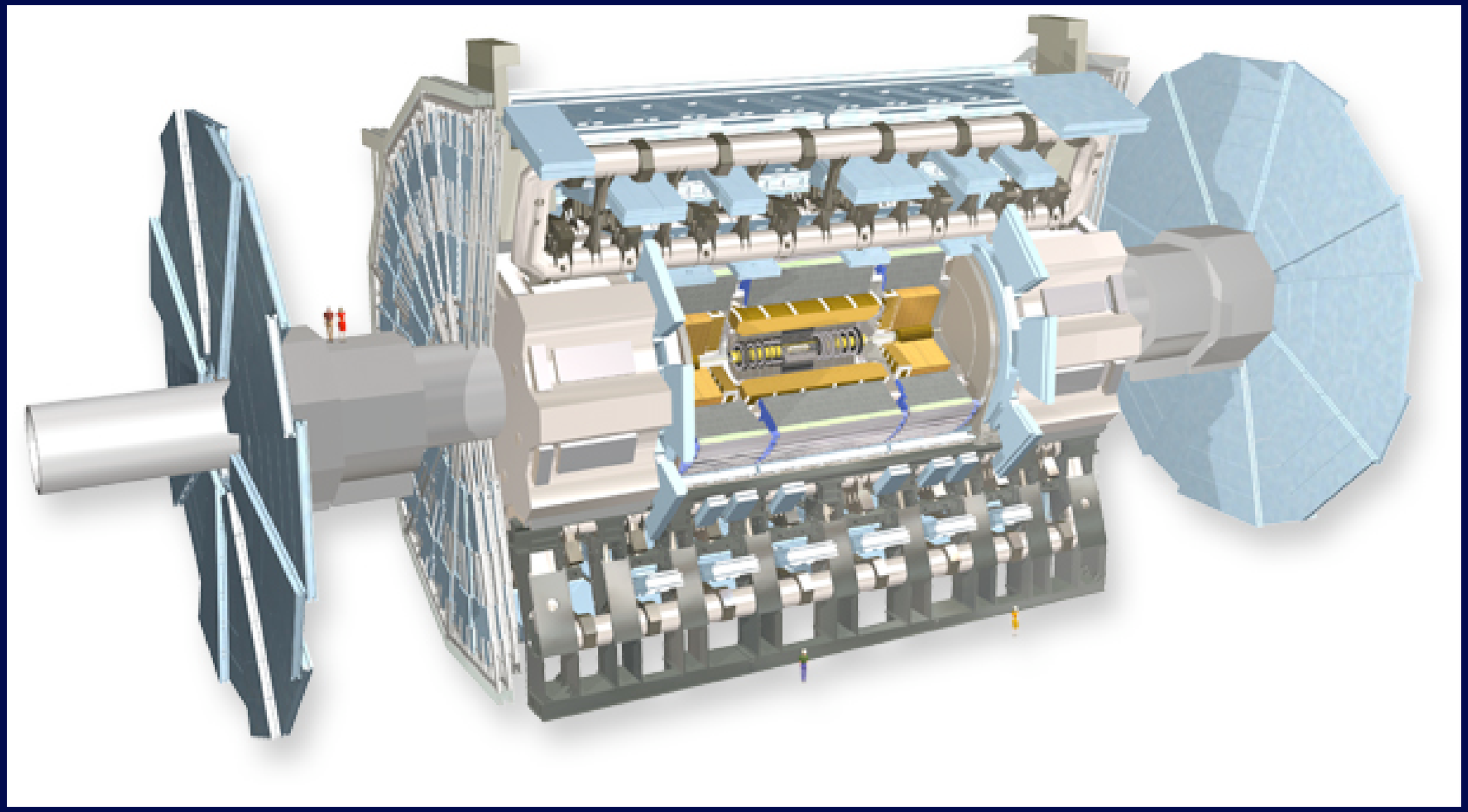

Baker
PHOBOS
(CHM)
BRAHMS
(HIRG)
Videbaek
coalescence
HIRG'
fragmentation
PHENIX
USATLAS-
HI
Videbaek
Baker
STAR

Why LHC?

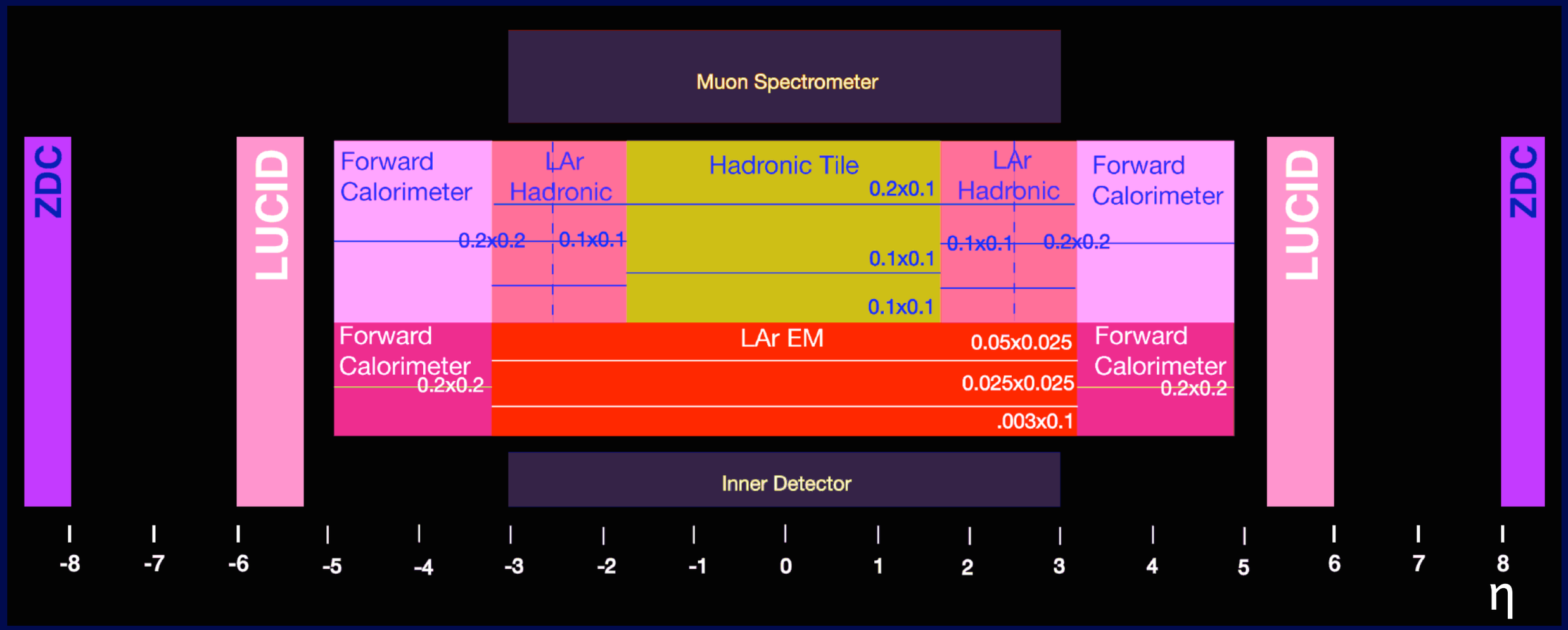


	Experimental Observable	Theoretical Tools	Physics
Nuclear PDFs	Particle multiplicities, monojets	Color Glass Condensate (Parton Saturation)	**High-density pQCD**
Hard Processes	Jets, Photons, Heavy Quarks & Onia, Z&W	pQCD	**QCD in medium**
(non-) Ideal Hydrodynamics	$\frac{d^3N}{d\eta d\phi dp_T}$	3+1D Hydro Initial conditions	**Equation of State (Degrees of Freedom)**
Hadron Freezeout	Particle yields, correlations, fluctuations	Statistical models, Cluster models	**Hadronization**

ATLAS Detector

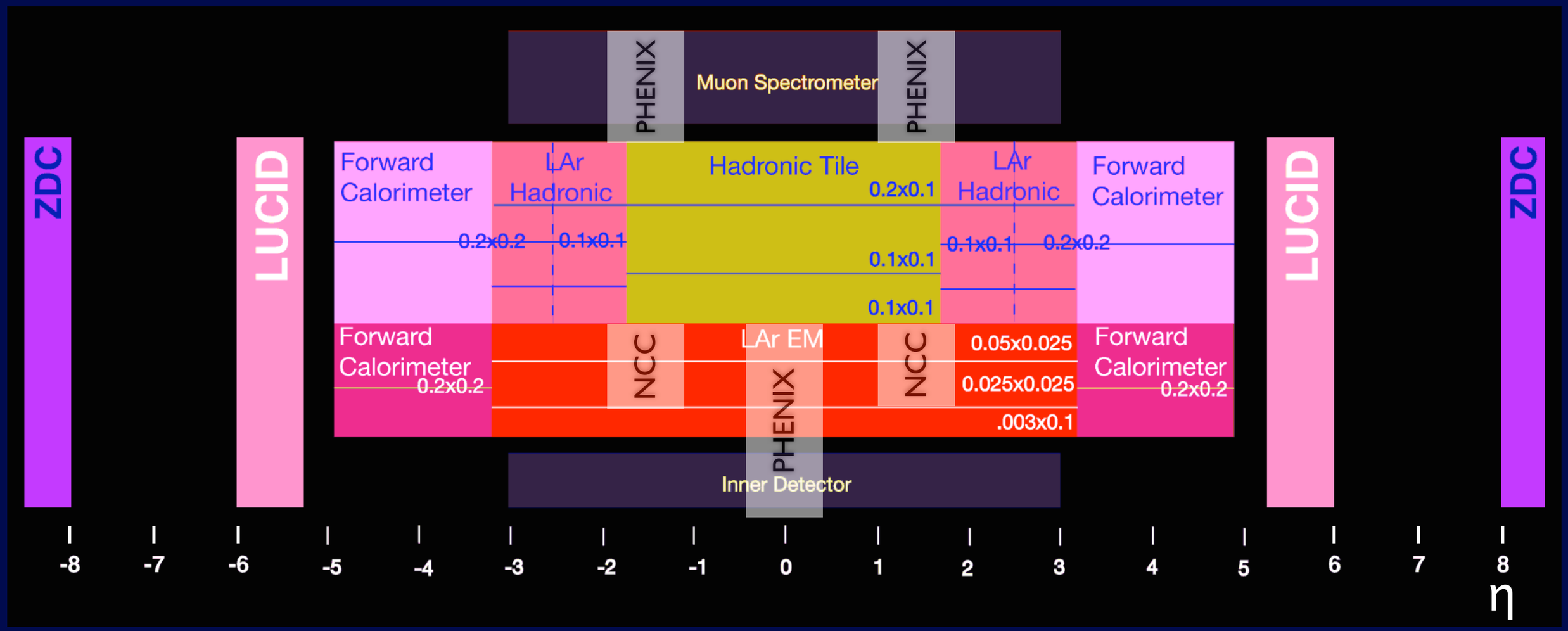


ATLAS Acceptance



Unprecedented acceptance for A+A physics both in p_T and rapidity, with full azimuthal coverage: Tracking, EM & Hadronic calorimetry, Muons

ATLAS Acceptance



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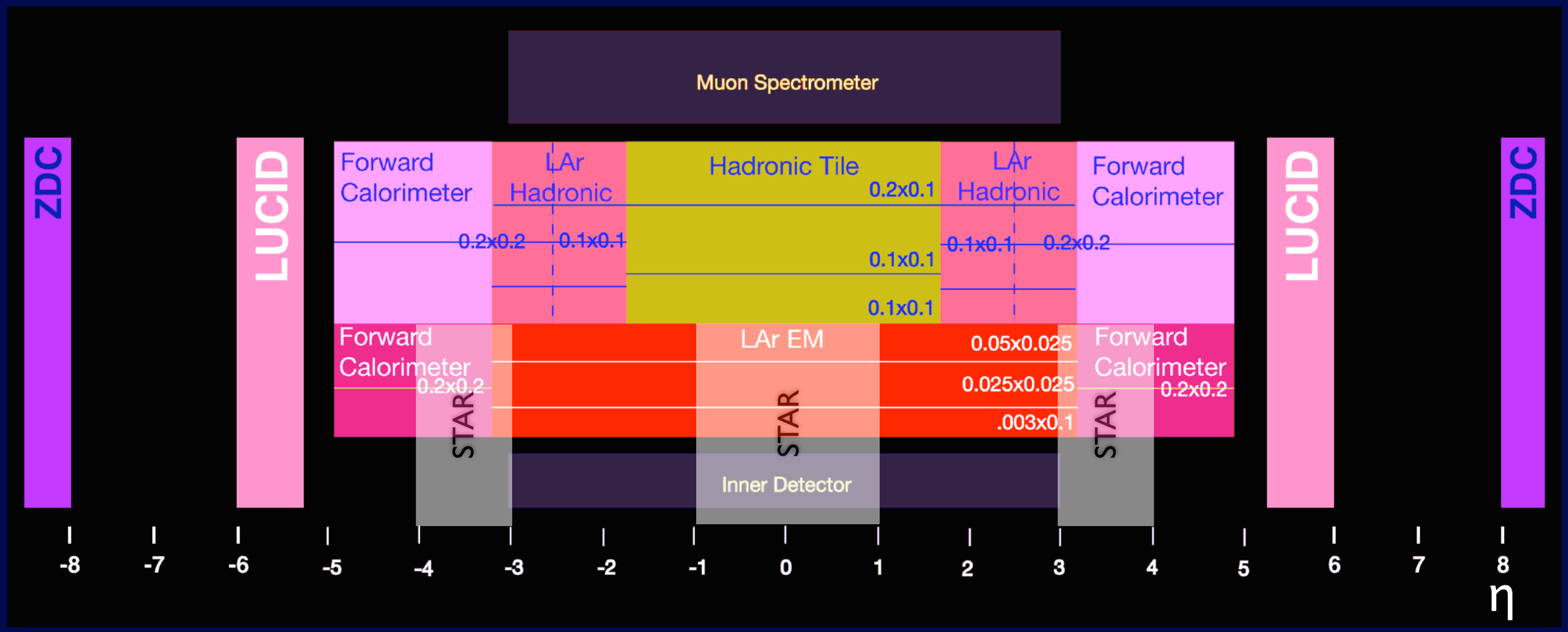
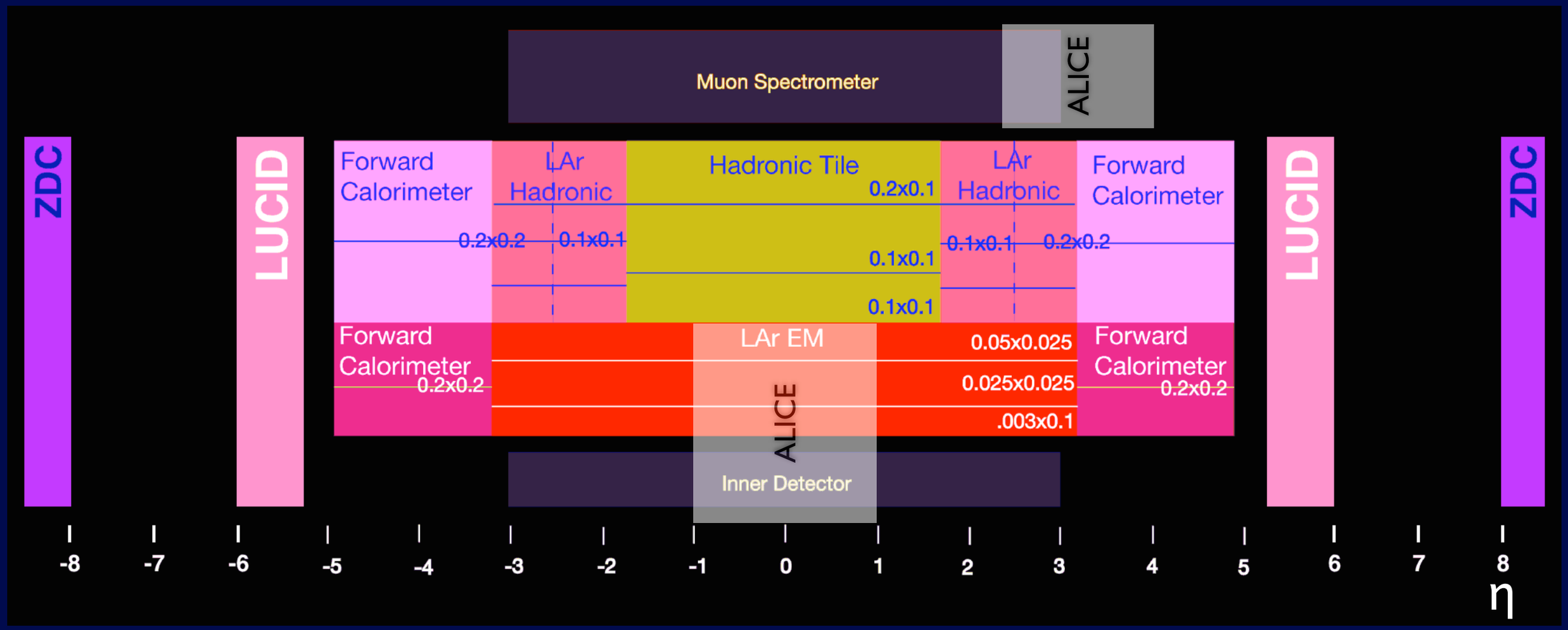


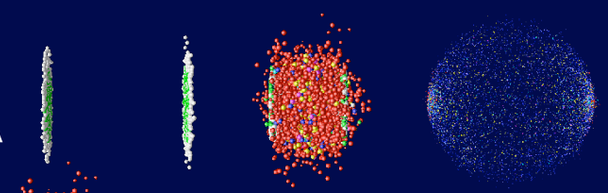
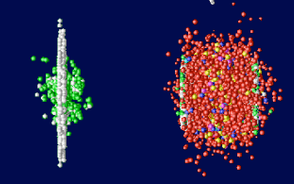
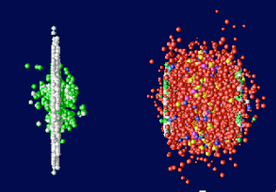
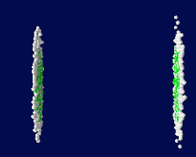
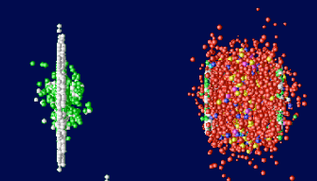
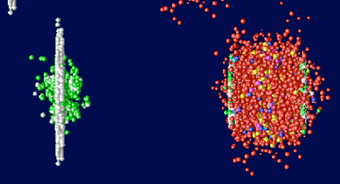
Unprecedented acceptance for A+A physics both in p_T and rapidity, with full azimuthal coverage: Tracking, EM & Hadronic calorimetry, Muons

ATLAS Acceptance



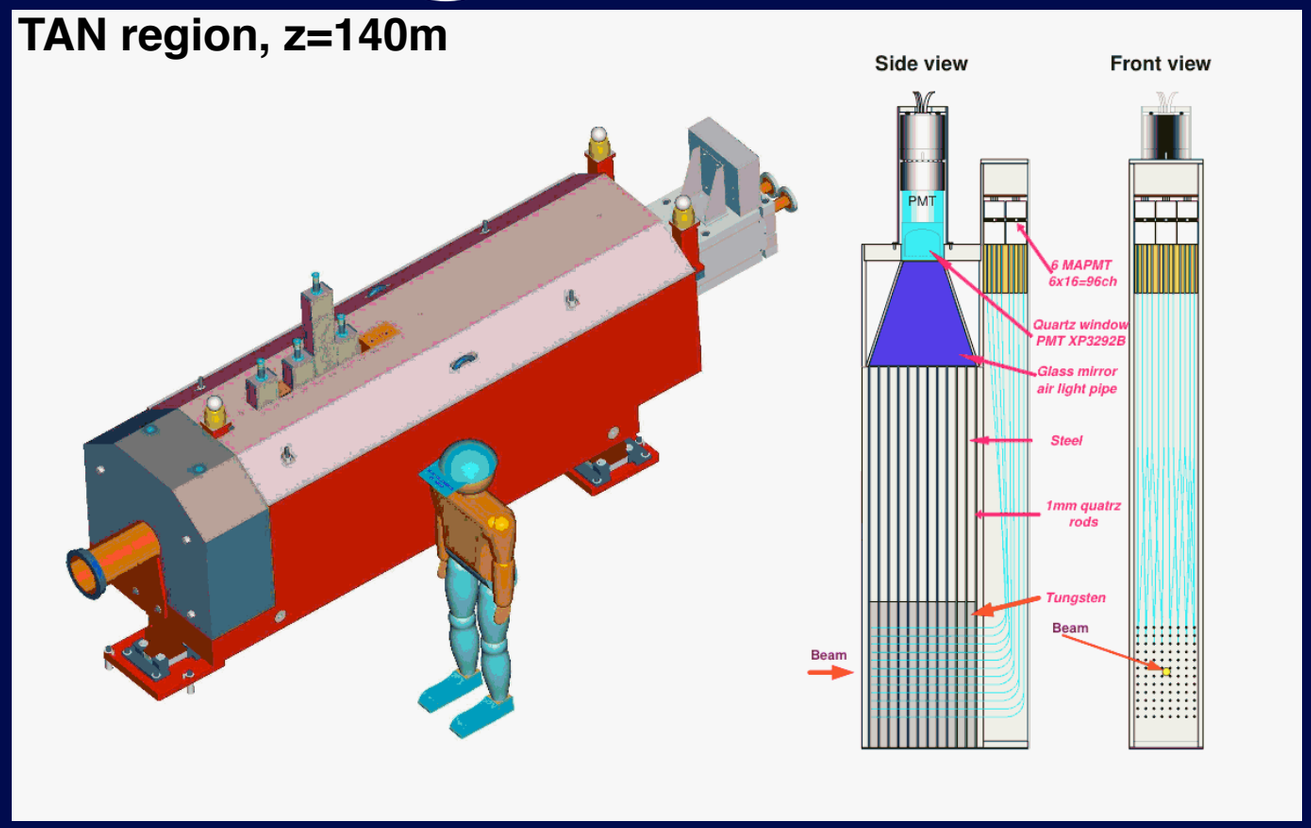
Unprecedented acceptance for A+A physics both in p_T and rapidity, with full azimuthal coverage: Tracking, EM & Hadronic calorimetry, Muons

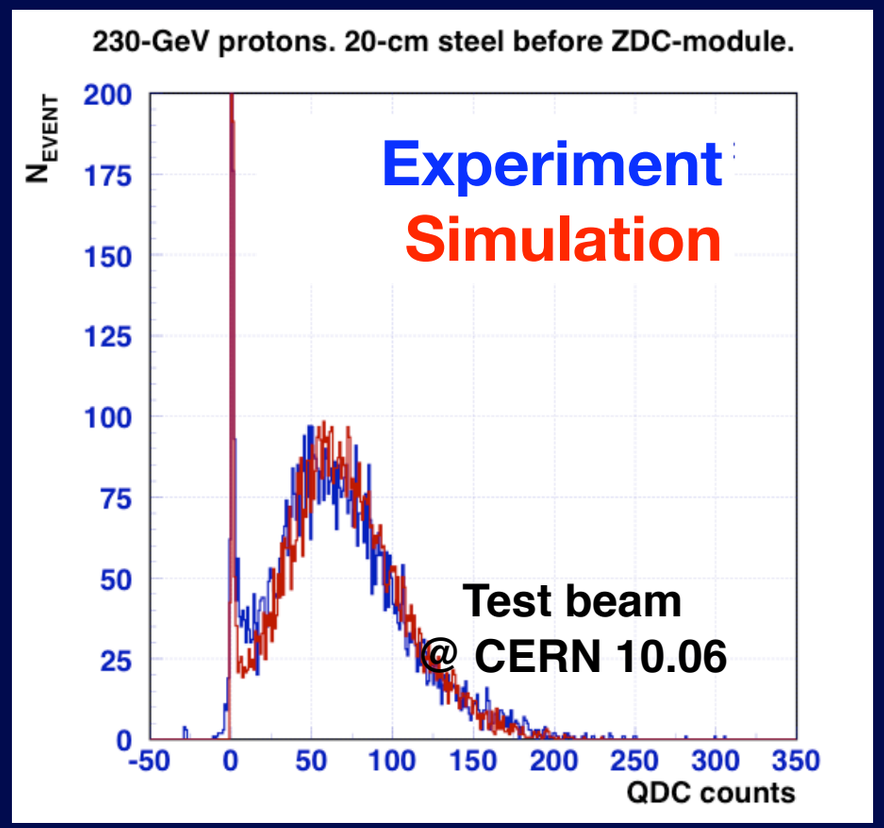
Major Interests

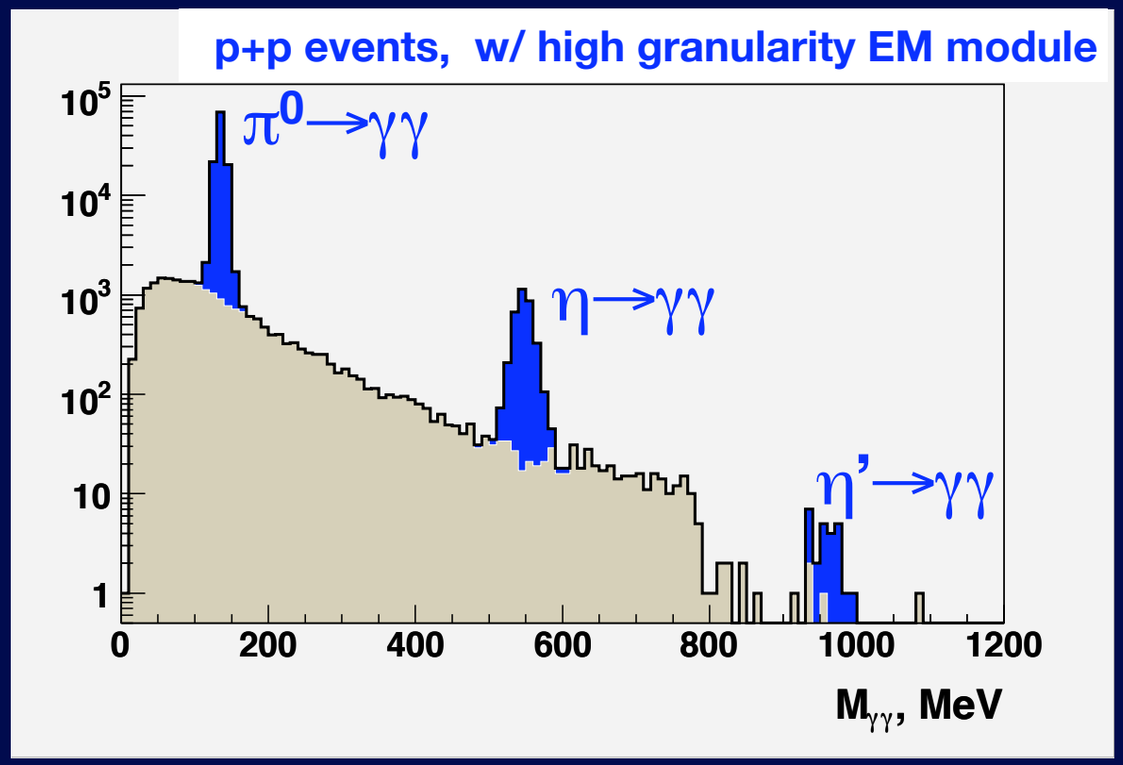
- **The ATLAS experiment will cover a full range of topics in Pb+Pb**
  - Bulk observables in p+p and A+A 
  - Inclusive jets in p+p and A+A 
  - Quarkonia (ϒ and ψ) 
  - Low-x physics & Ultra-peripheral collisions 
  - Heavy quarks (esp. b physics) 
  - <u>Z+jet, γ+jet, jet-jet correlations</u> 

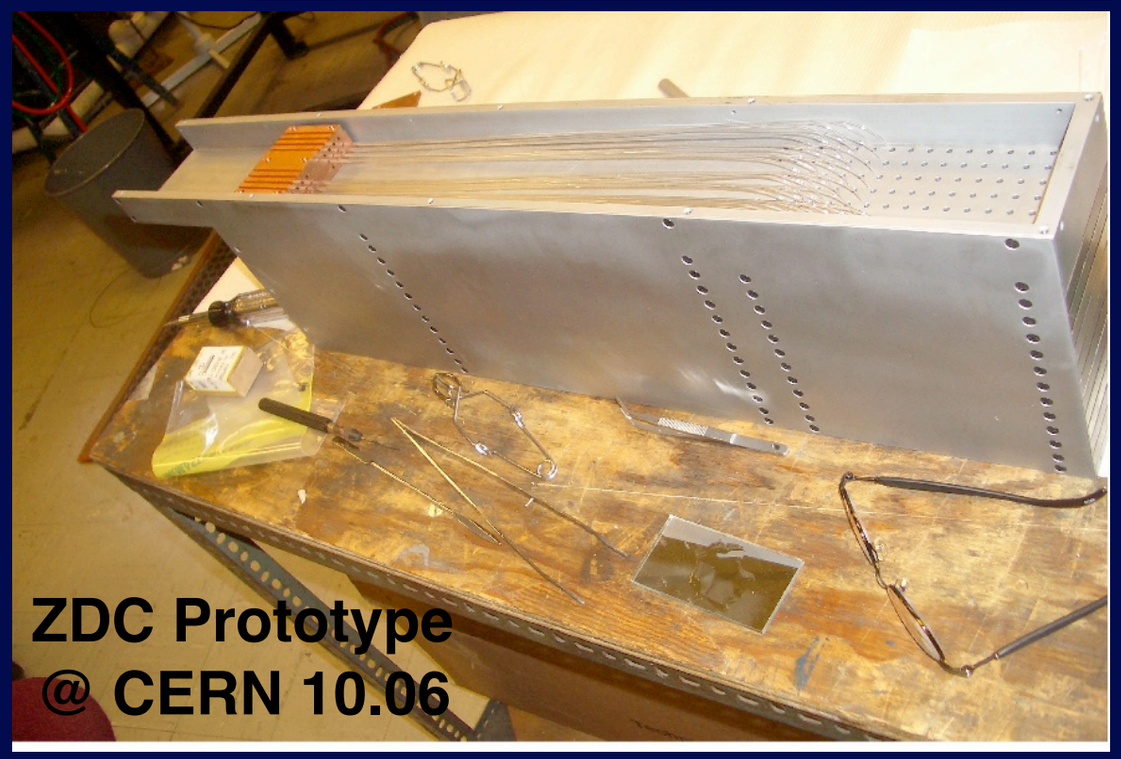
high energies, large rates for hard probes:
inclusive & correlations!

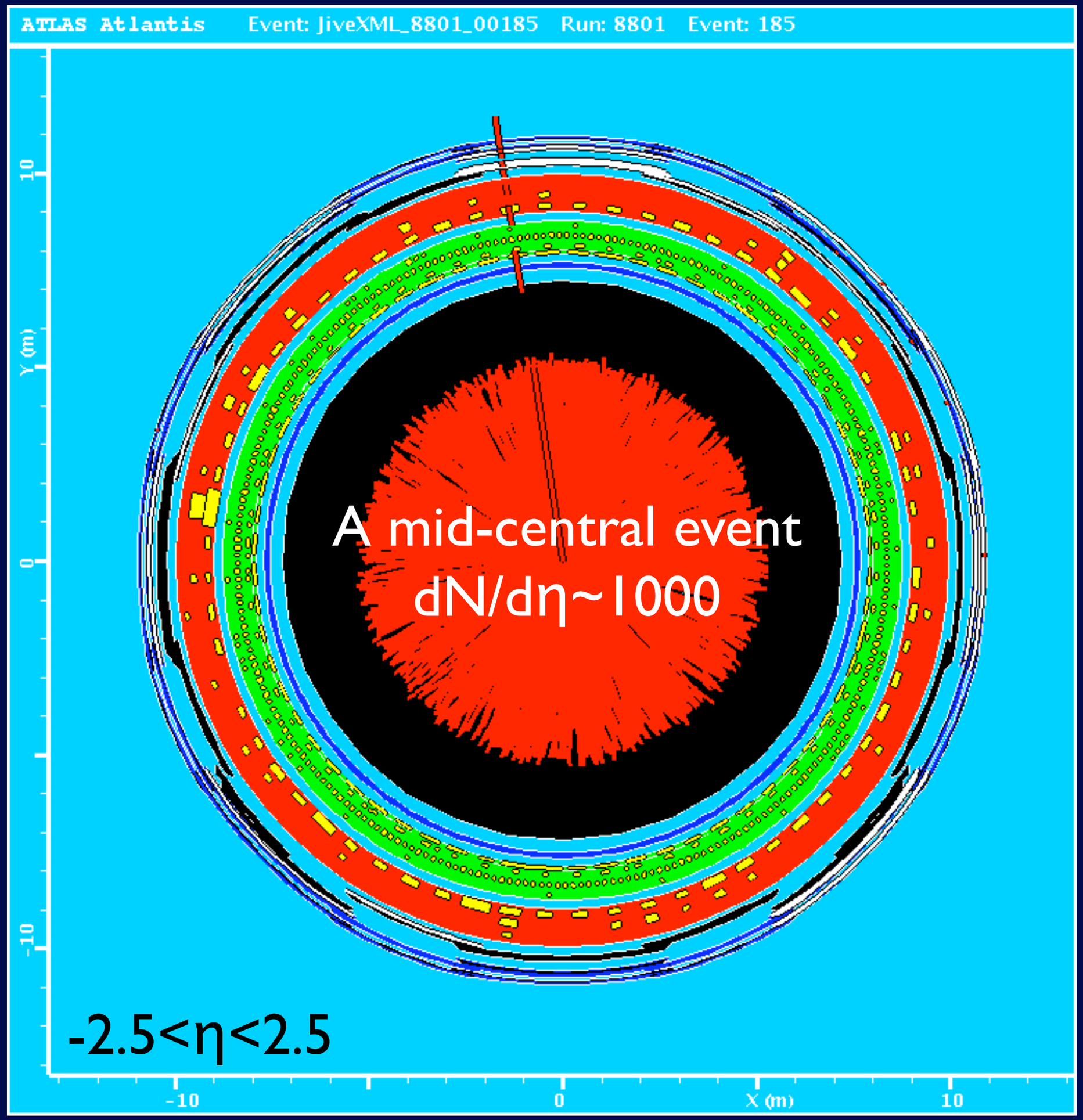
Progress on ATLAS ZDC

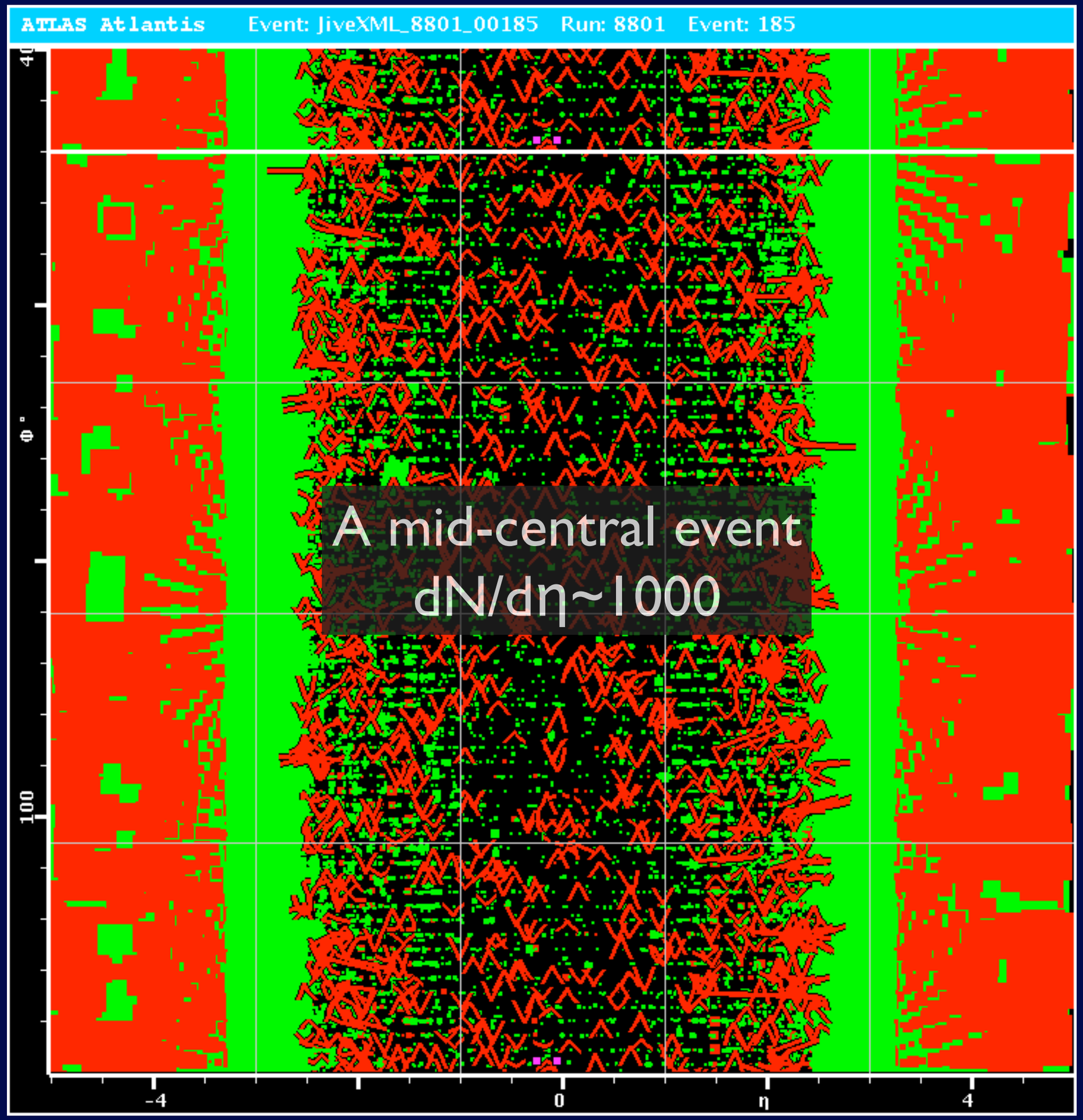






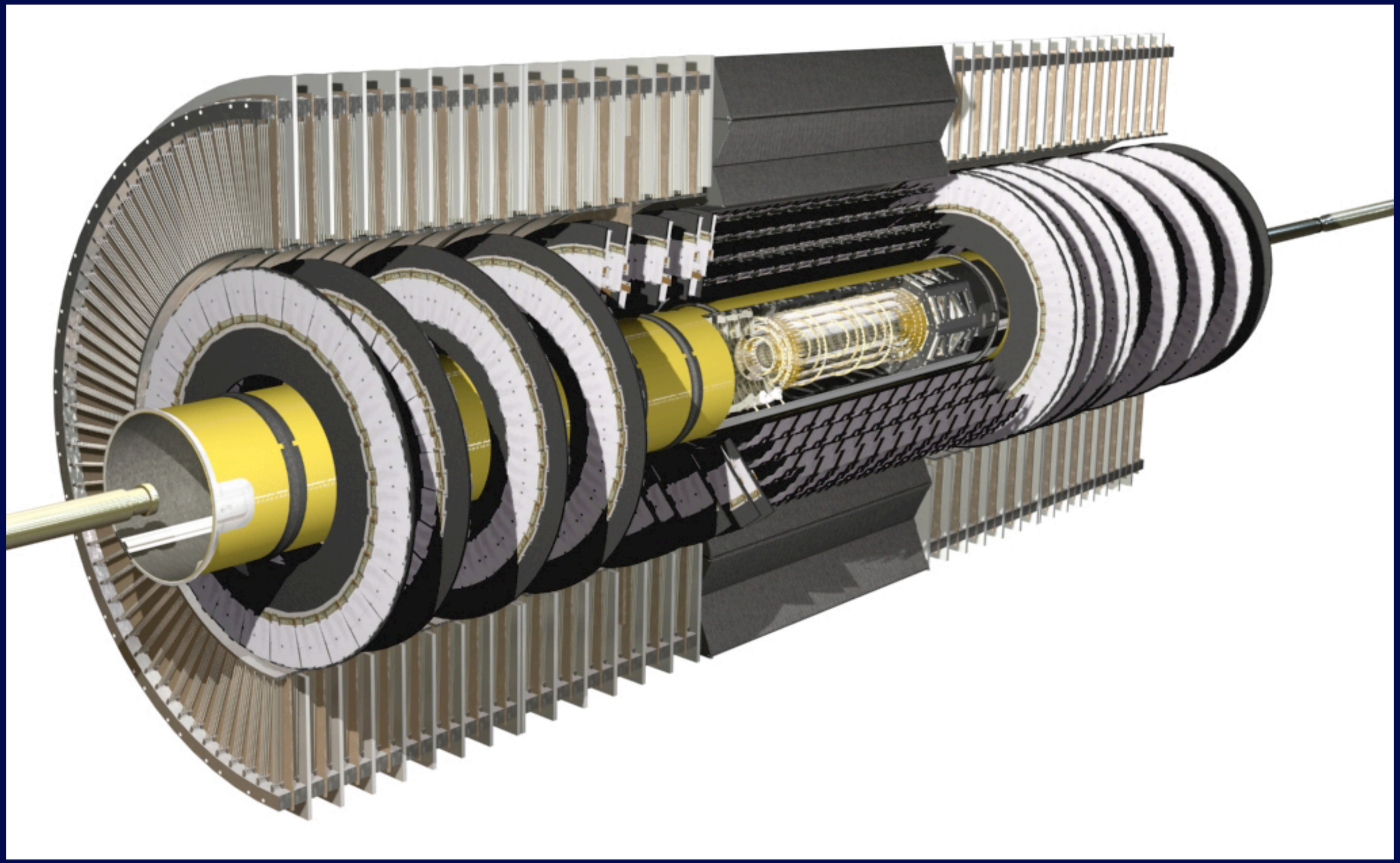



ATLAS Atlantis
Event: JiveXML_8801_00185
Run: 8801
Event: 185
Y (m)
X (m)
10
0
-10
-10
0
10
A mid-central event
dN/dη~1000
-2.5<η<2.5

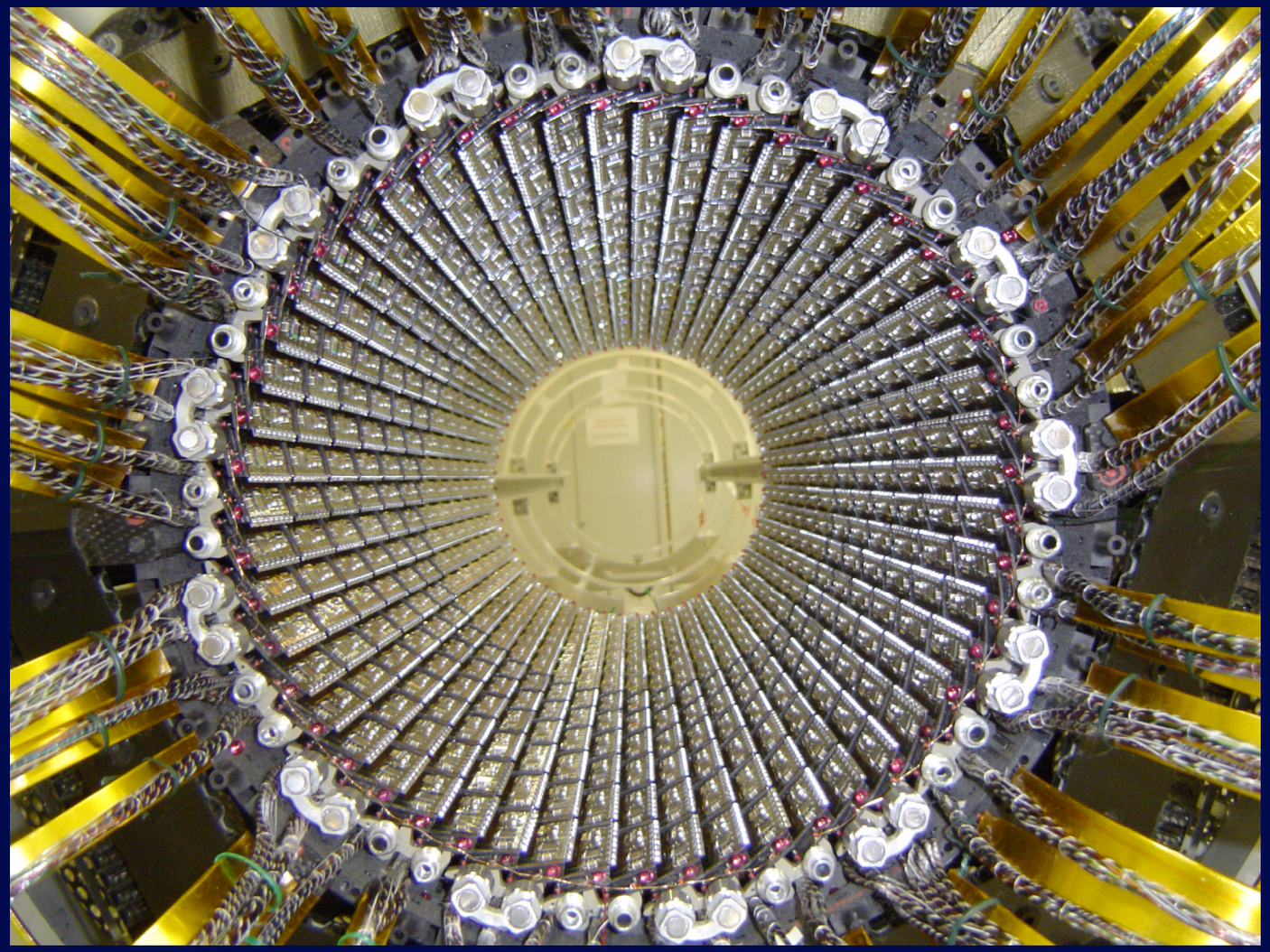


A mid-central event
dN/dη~1000

ATLAS Inner Detector

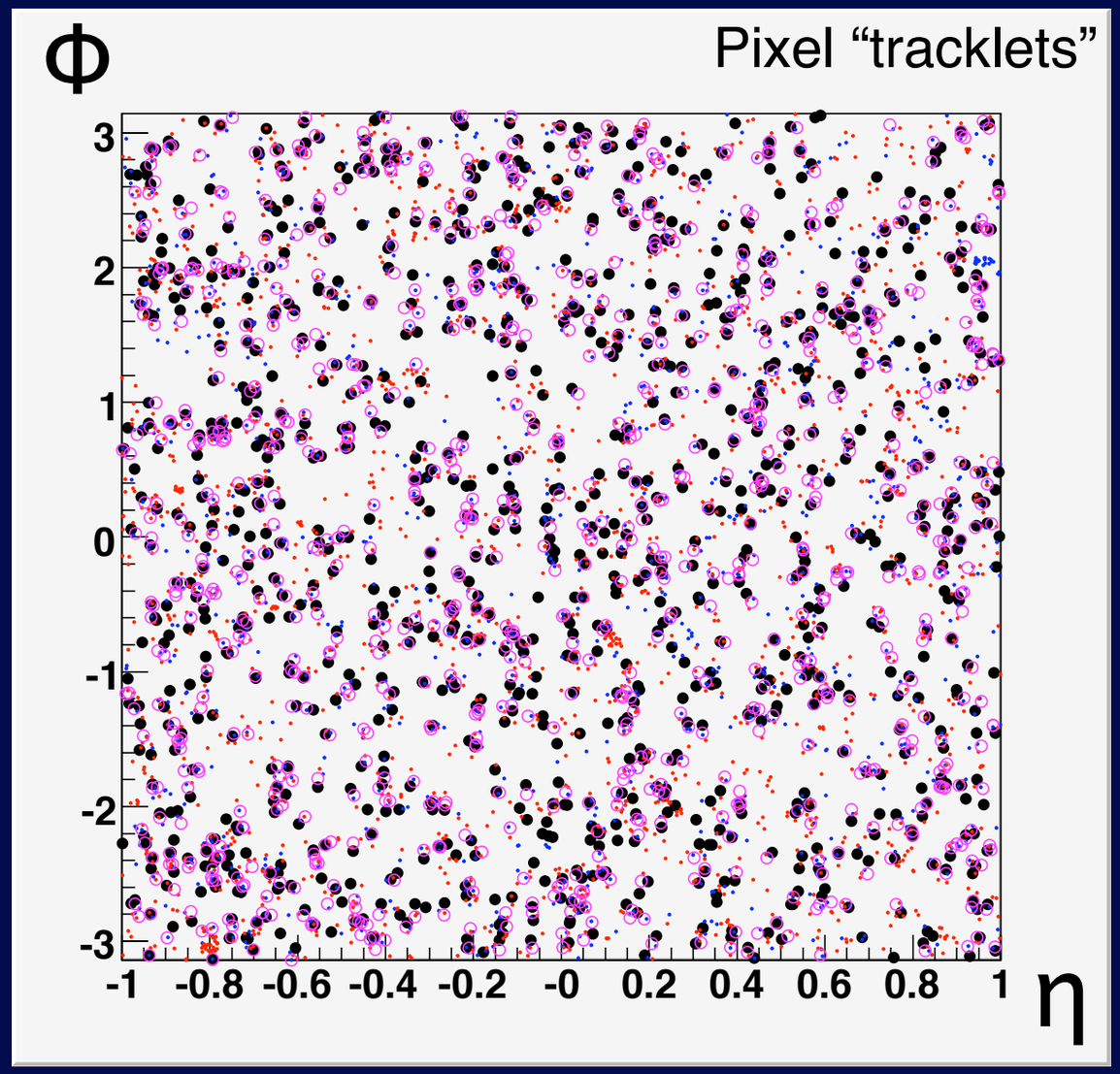


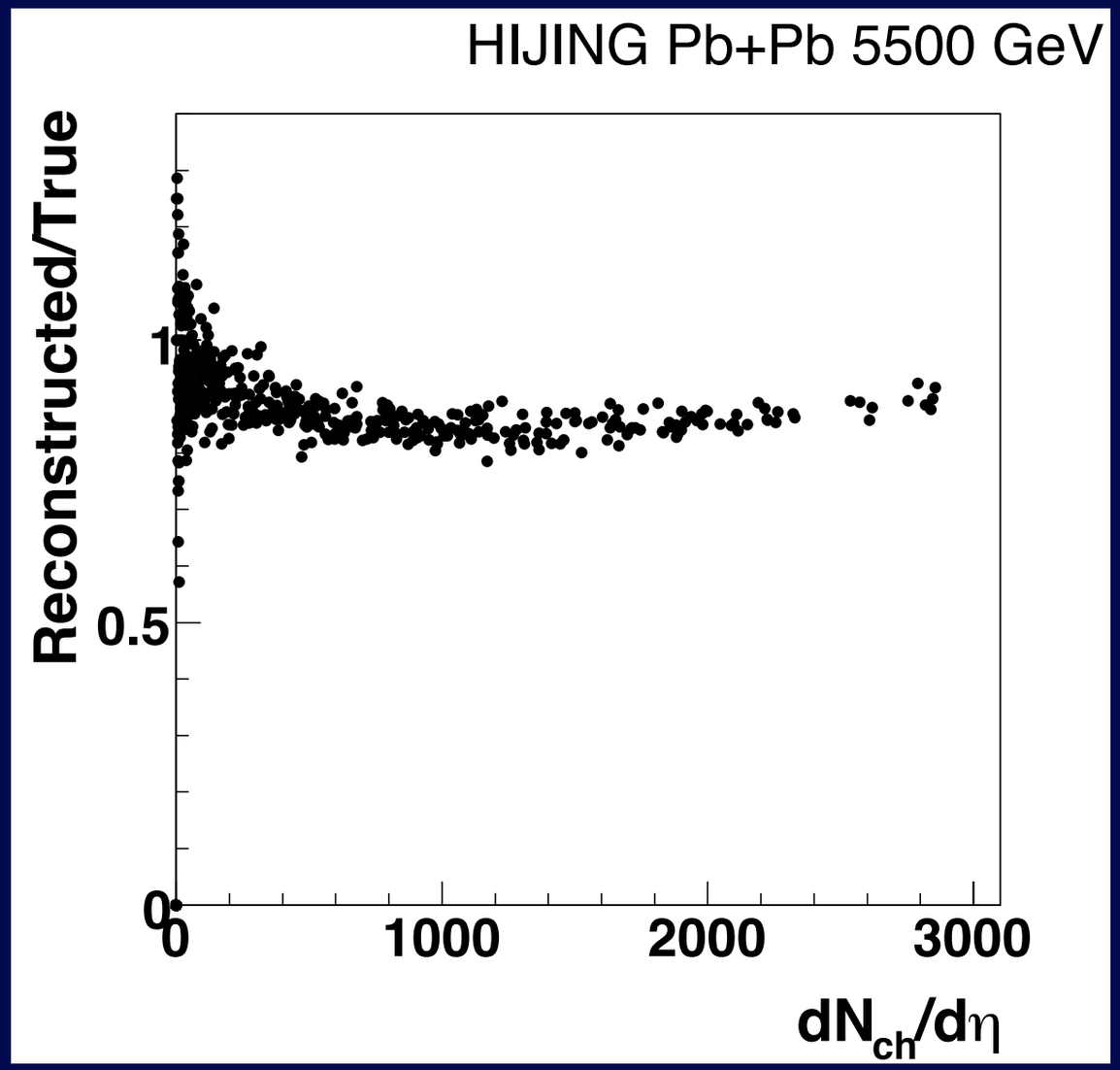
ATLAS Inner Detector



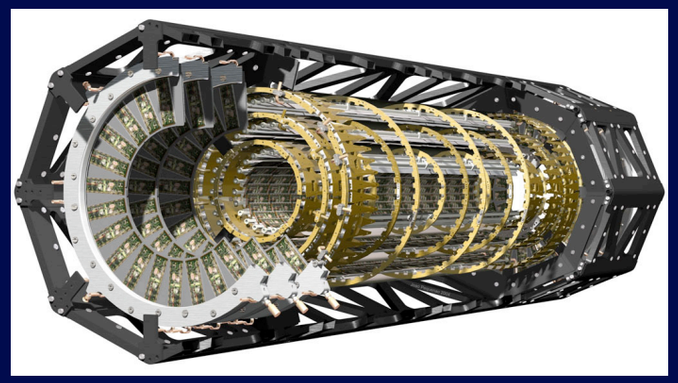
3 Pixel layers (80m channels!)
4 Double-sided strip layers (SCT)
Transition Radiation Tracker (TRT)

Inclusive Charged Multiplicity



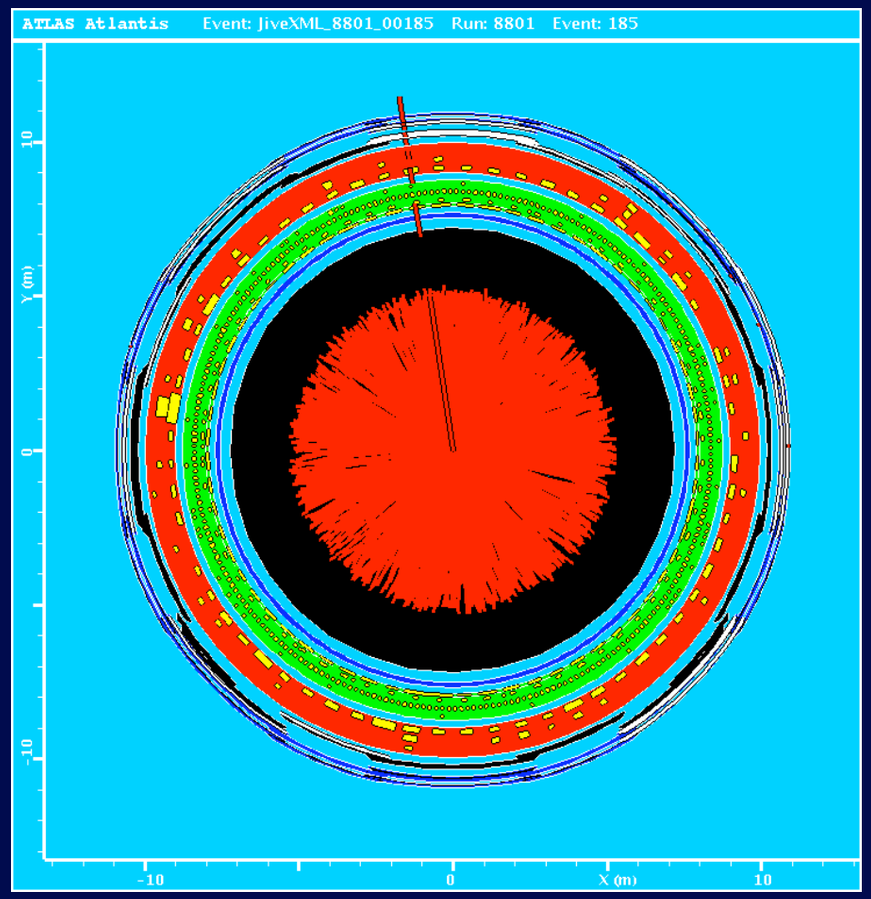


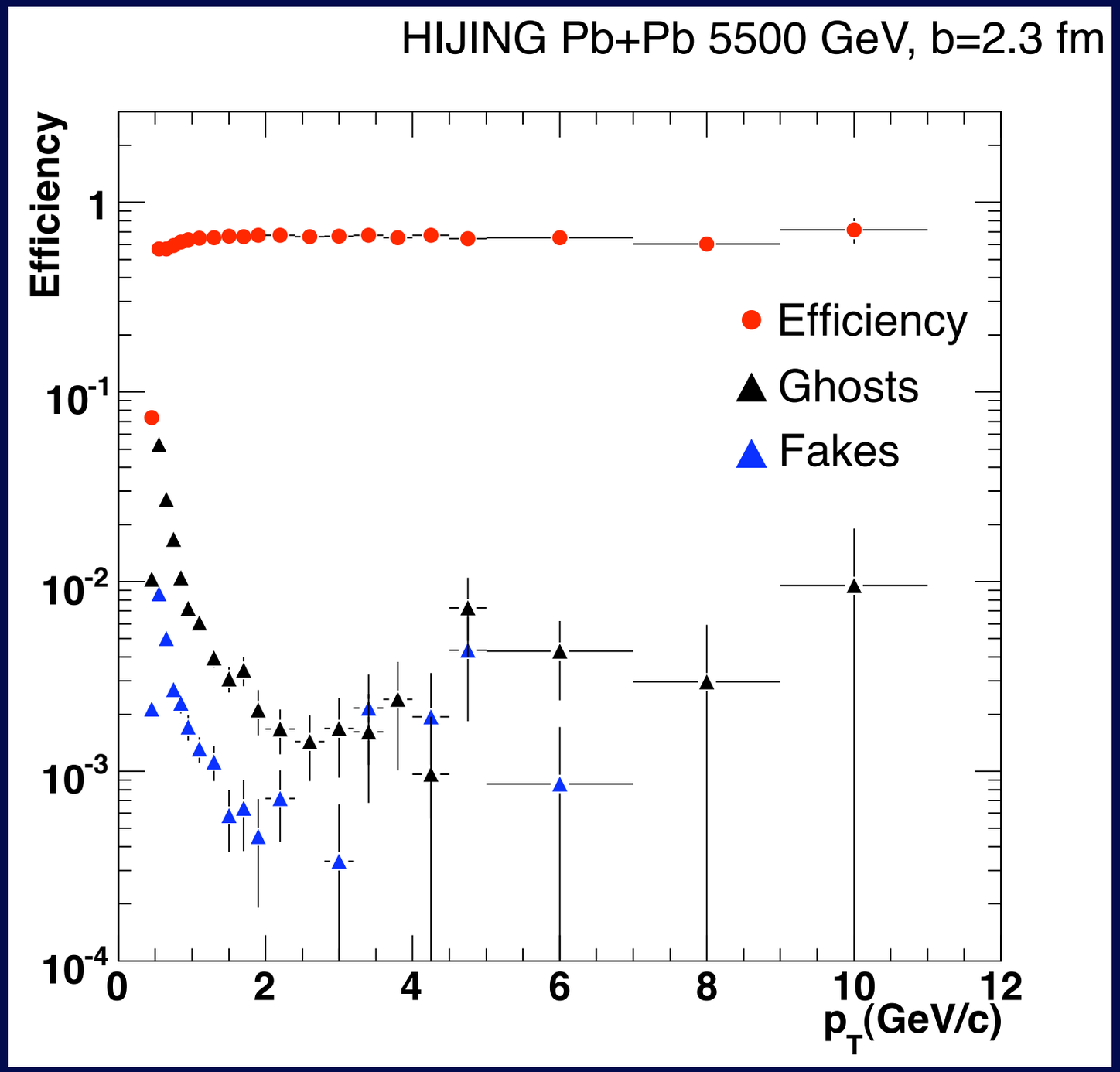
1. Truth tracks (black)
2. "B-Layer" Hits
3. Layer 1 Hits
4. Matched Tracklets



Good estimate of particle densities with subset of full detector

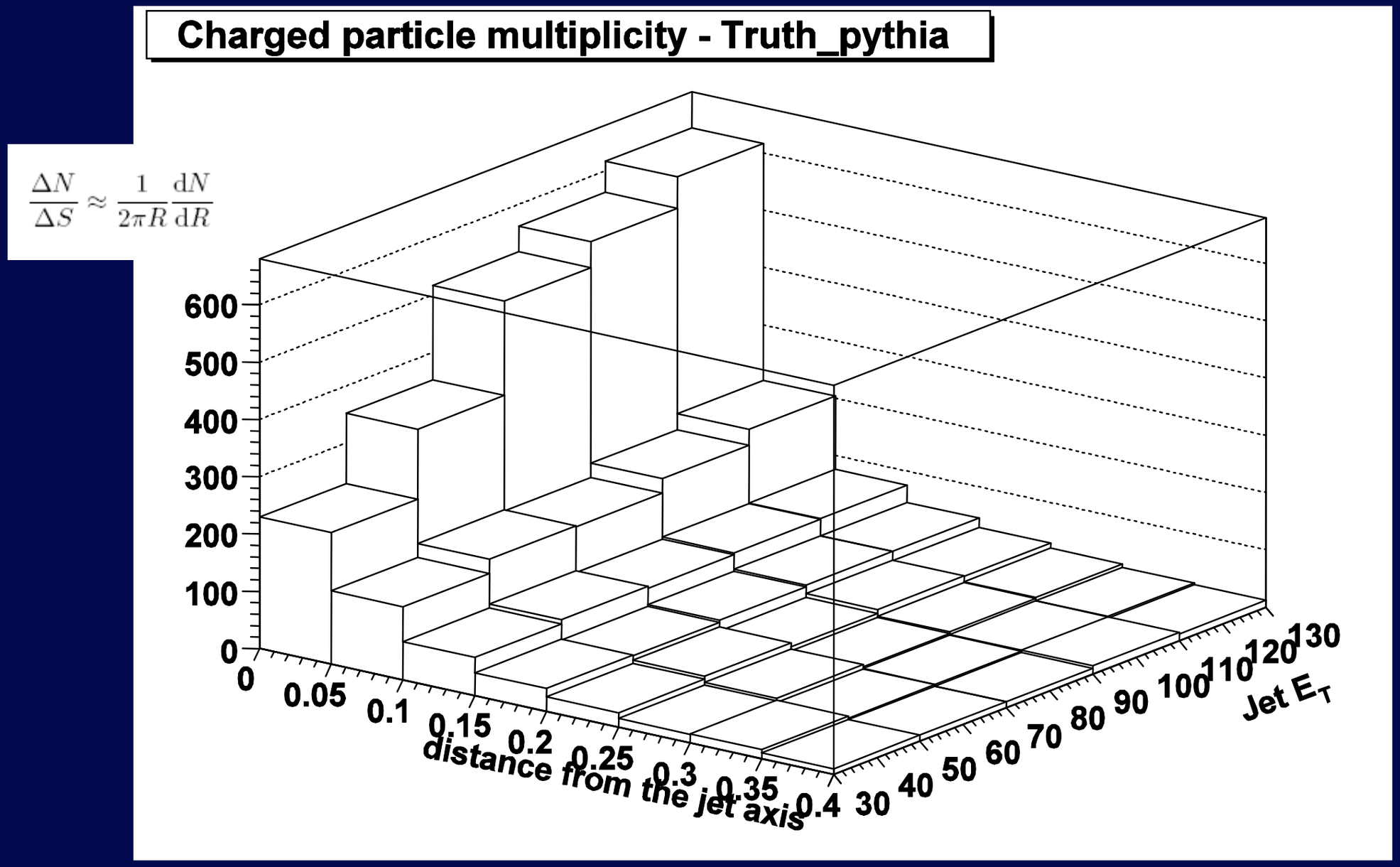
Tracking Performance in A+A





A+A is a challenging environment. Intense work on optimizing tracking performance

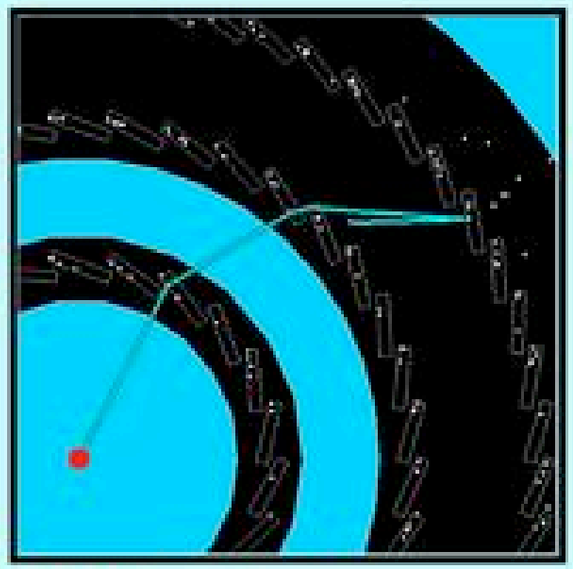
Multiplicity in Jets



Martin Spousta (Prague @ BNL)

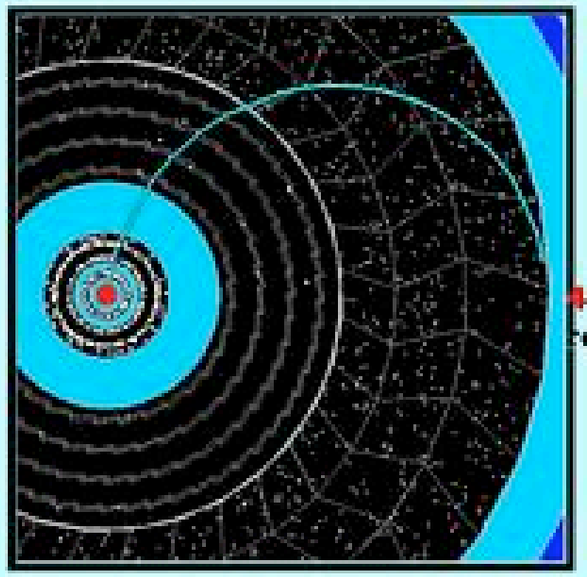
Motivates tracking optimizations:
this is extra density in vicinity of jets - performance impact

Low p_T Tracking



50 MeV tracks:
reach all Pixel layers

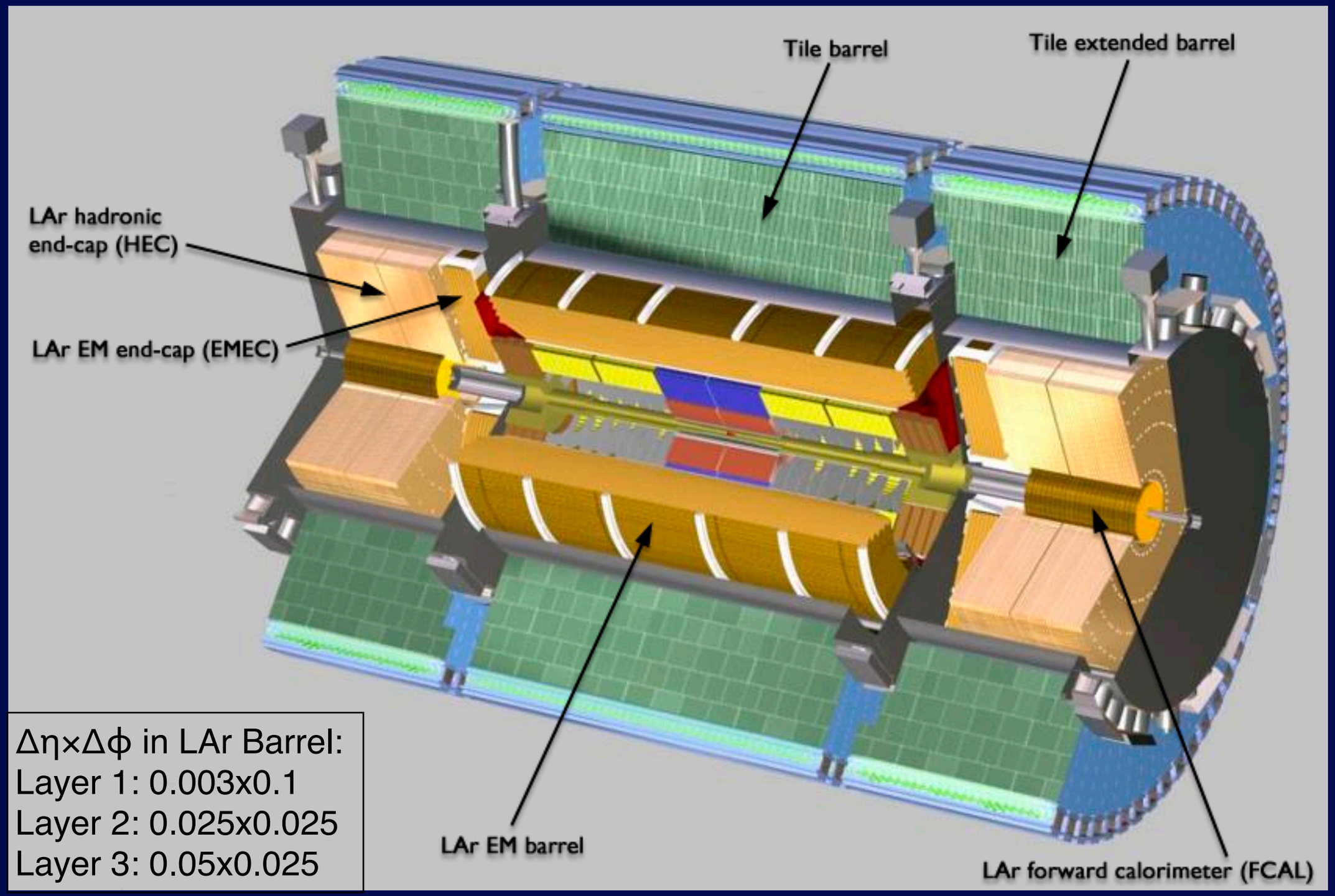
150 MeV tracks:
reach last SCT layer



400 MeV tracks:
reach end of TRT

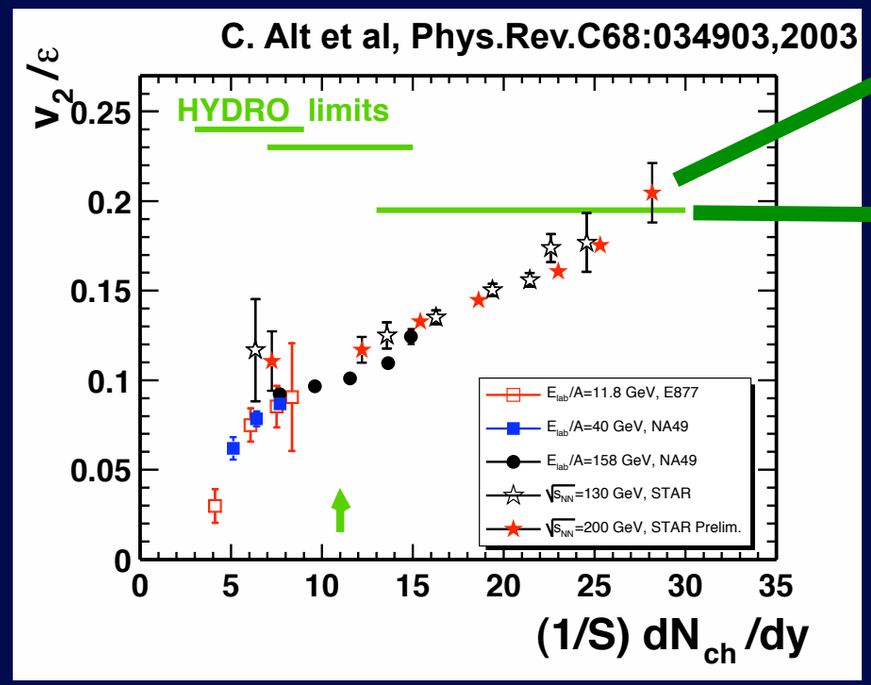
ATLAS <u>can</u> track down to low p_T
Tracking studies already pushing down to
$p_T \sim 100$ MeV in p+p → A+A is next

ATLAS Calorimeters



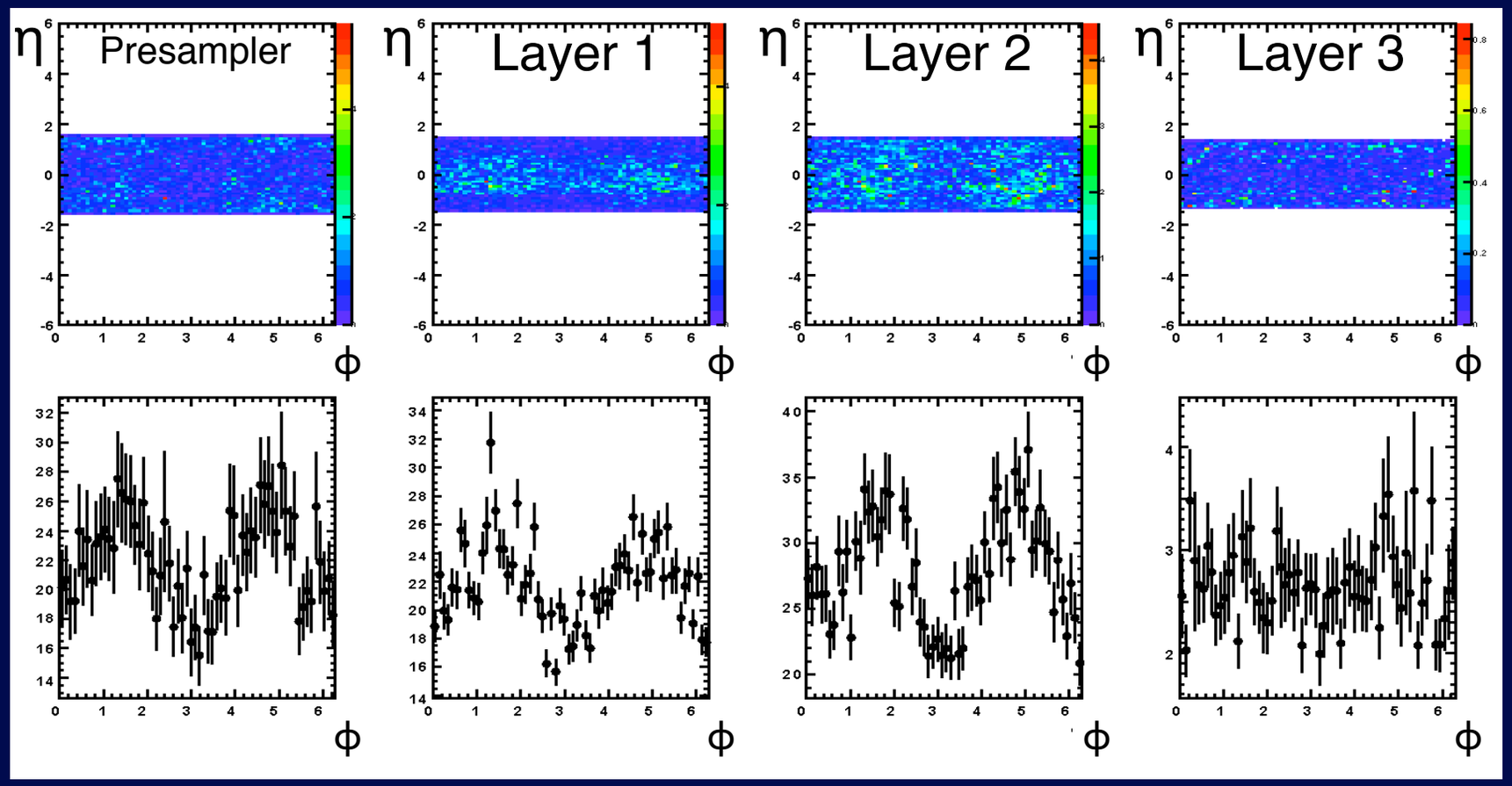
$\Delta\eta \times \Delta\phi$ in LAr Barrel:
Layer 1: 0.003x0.1
Layer 2: 0.025x0.025
Layer 3: 0.05x0.025

Flow from Calorimeters

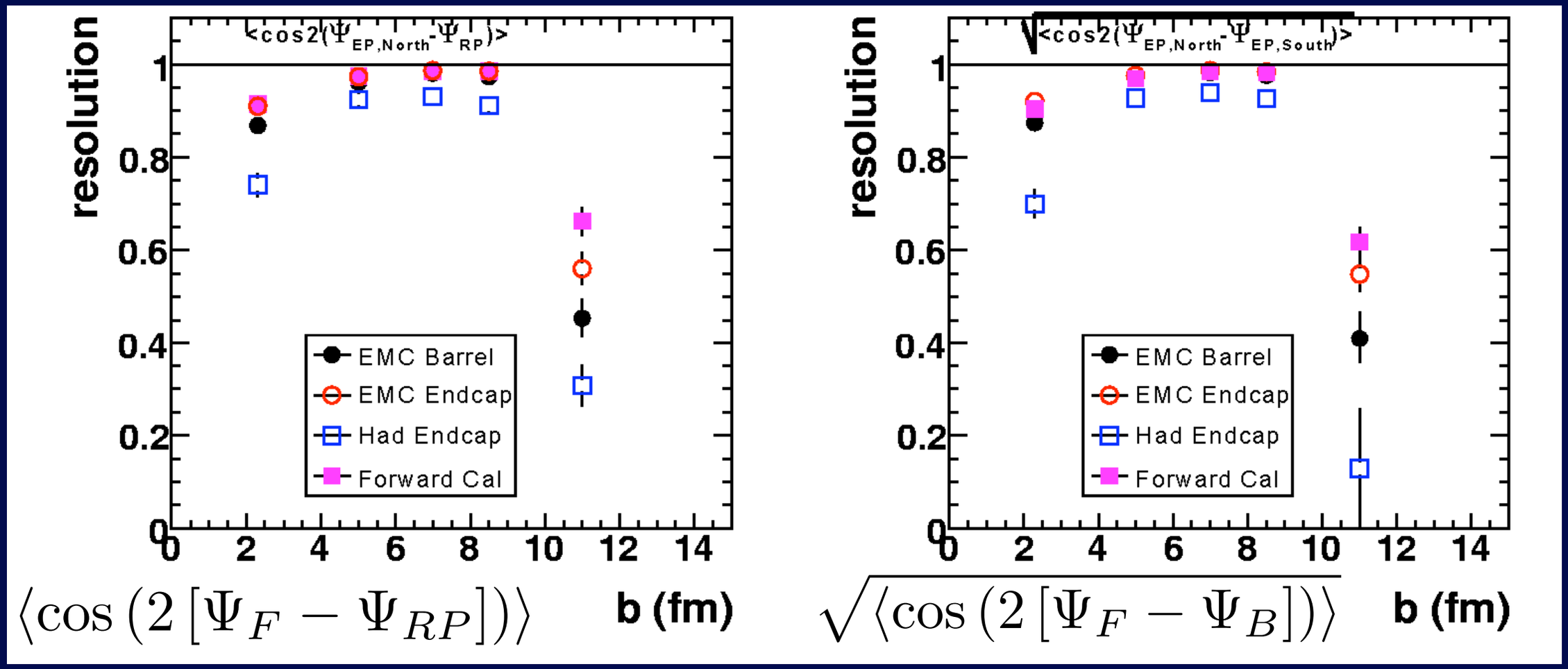


Has RHIC really reached the "hydro limit"?
LHC could extend densities by x2 or more

Can measure dN/dϕ in different layers & in different sections (rapidity dependence), e.g. EM Barrel

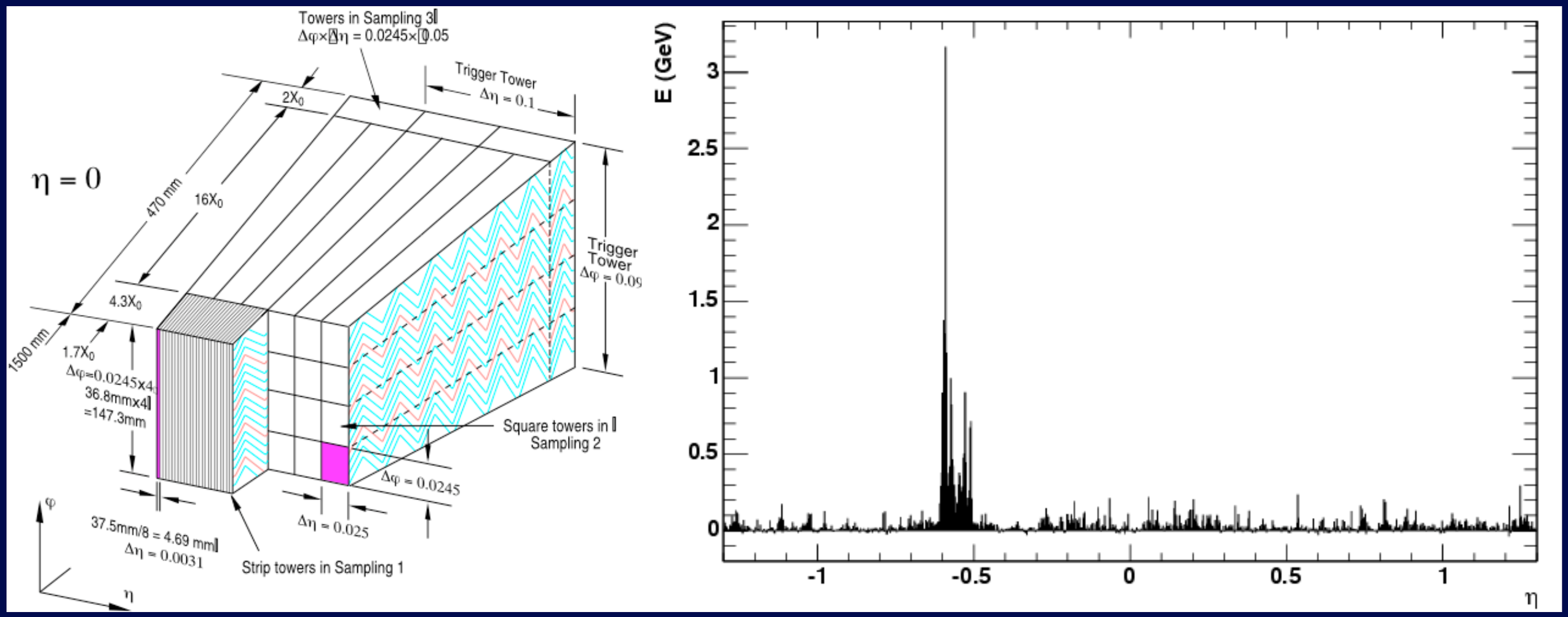


Flow from Calorimeters



Excellent reaction plane resolution (for v_2=10%)
vs. collision centrality and rapidity (η=0-5):
- relative to true reaction plane (RP) &
- derived from symmetric subevents (F,B)

Longitudinal Segmentation

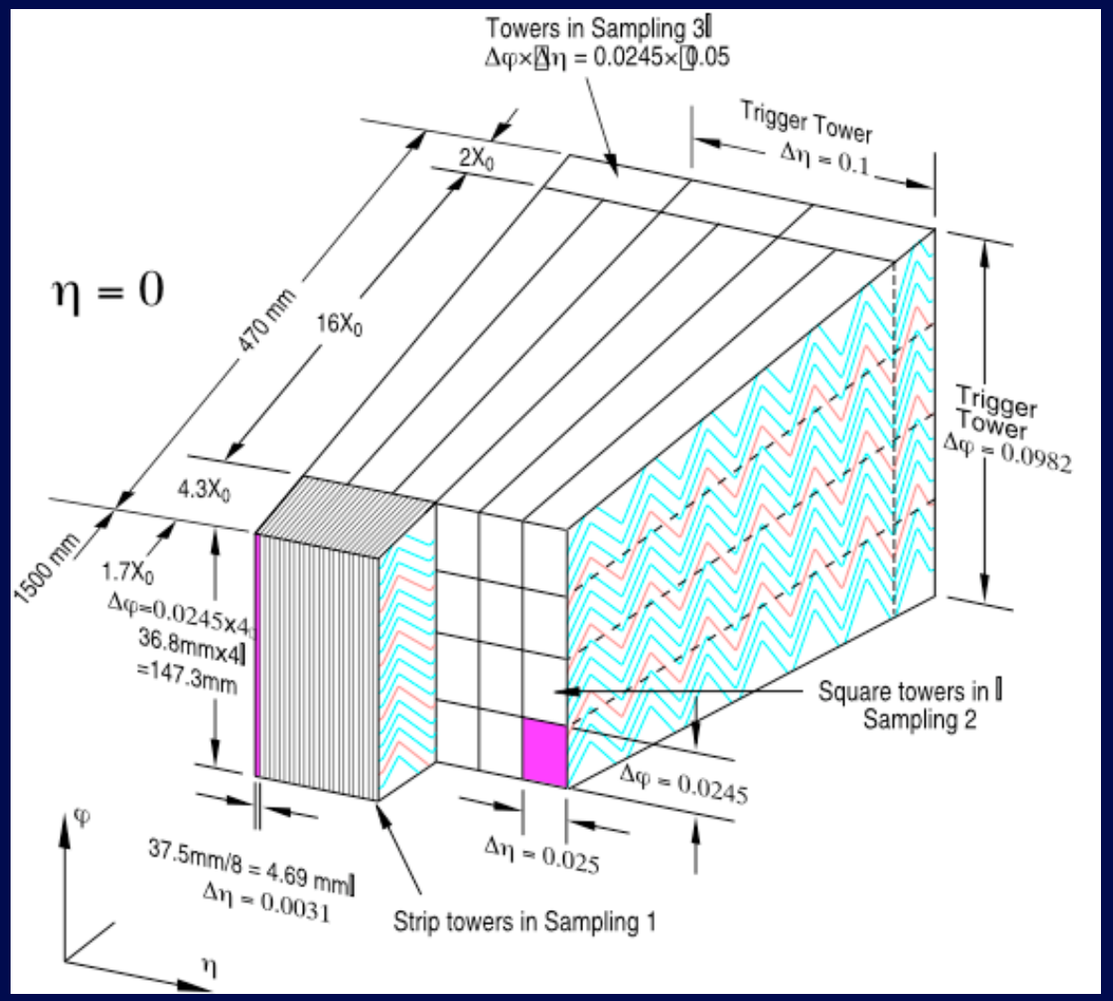


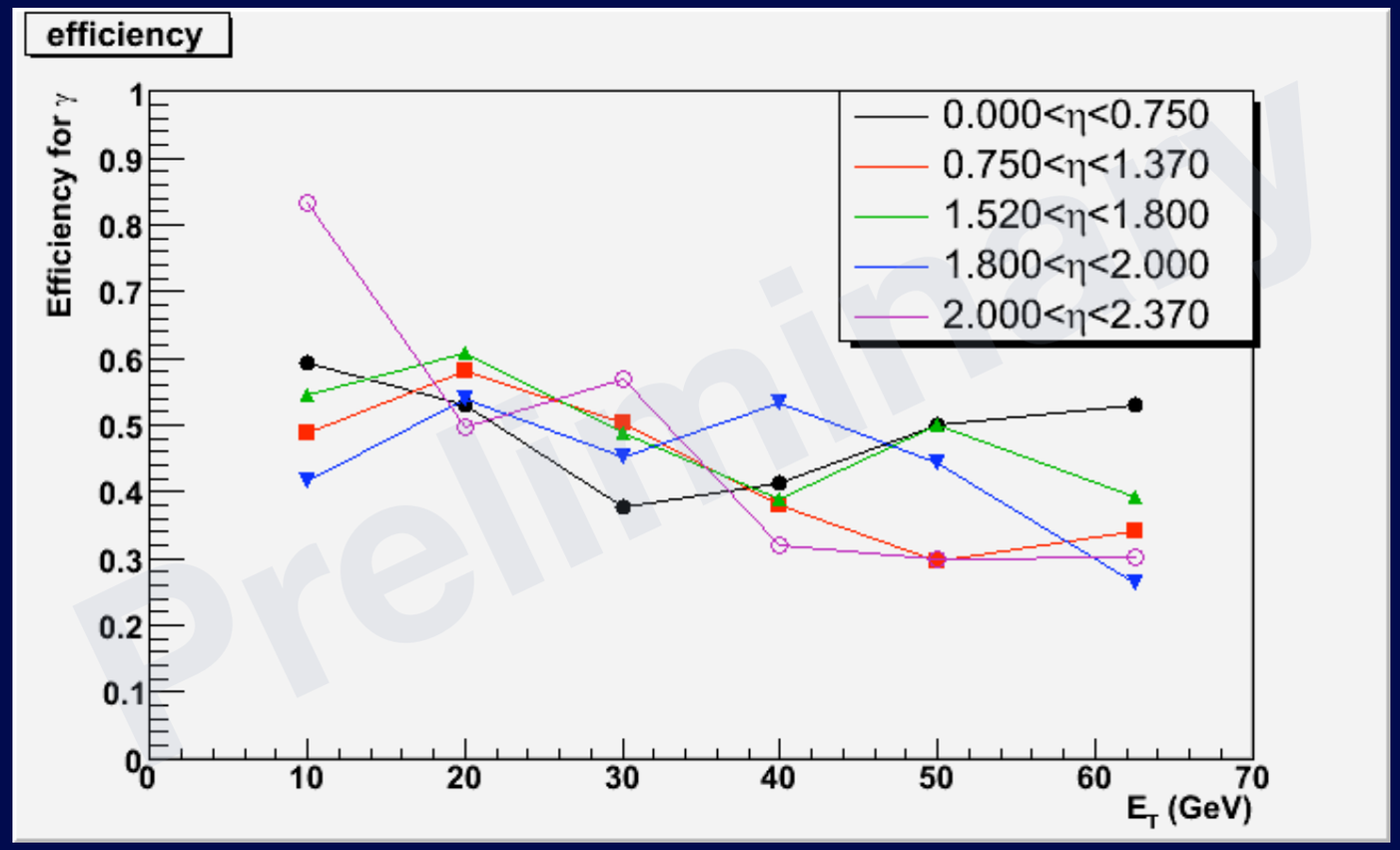
Longitudinally-segmented EMCAL unique at LHC

Photons in 1st LAr layer truly “stick out” above HI background (central event shown): under study

Rejecting π^0 & η

BAKER, Cole, Grau, Holzmann, Leltchouk, Steinberg

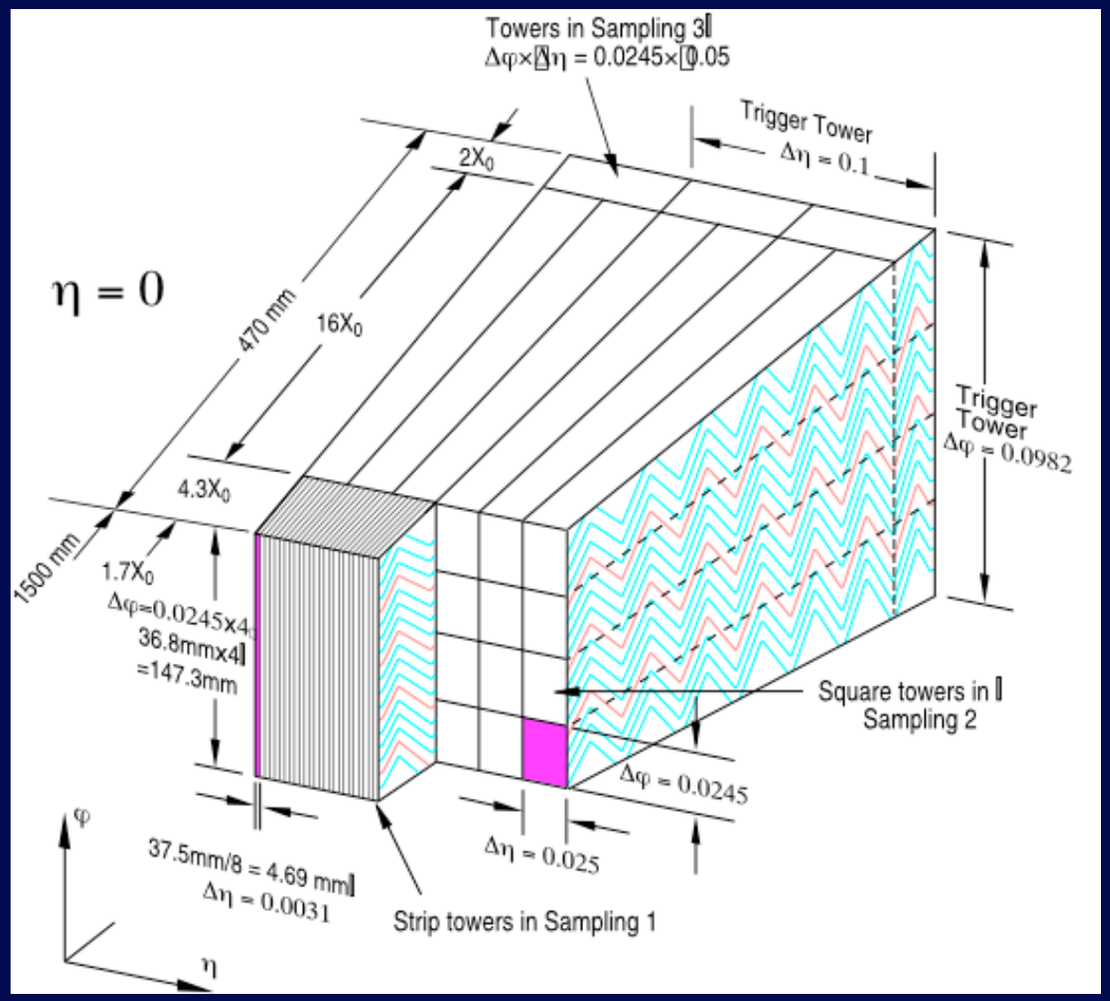


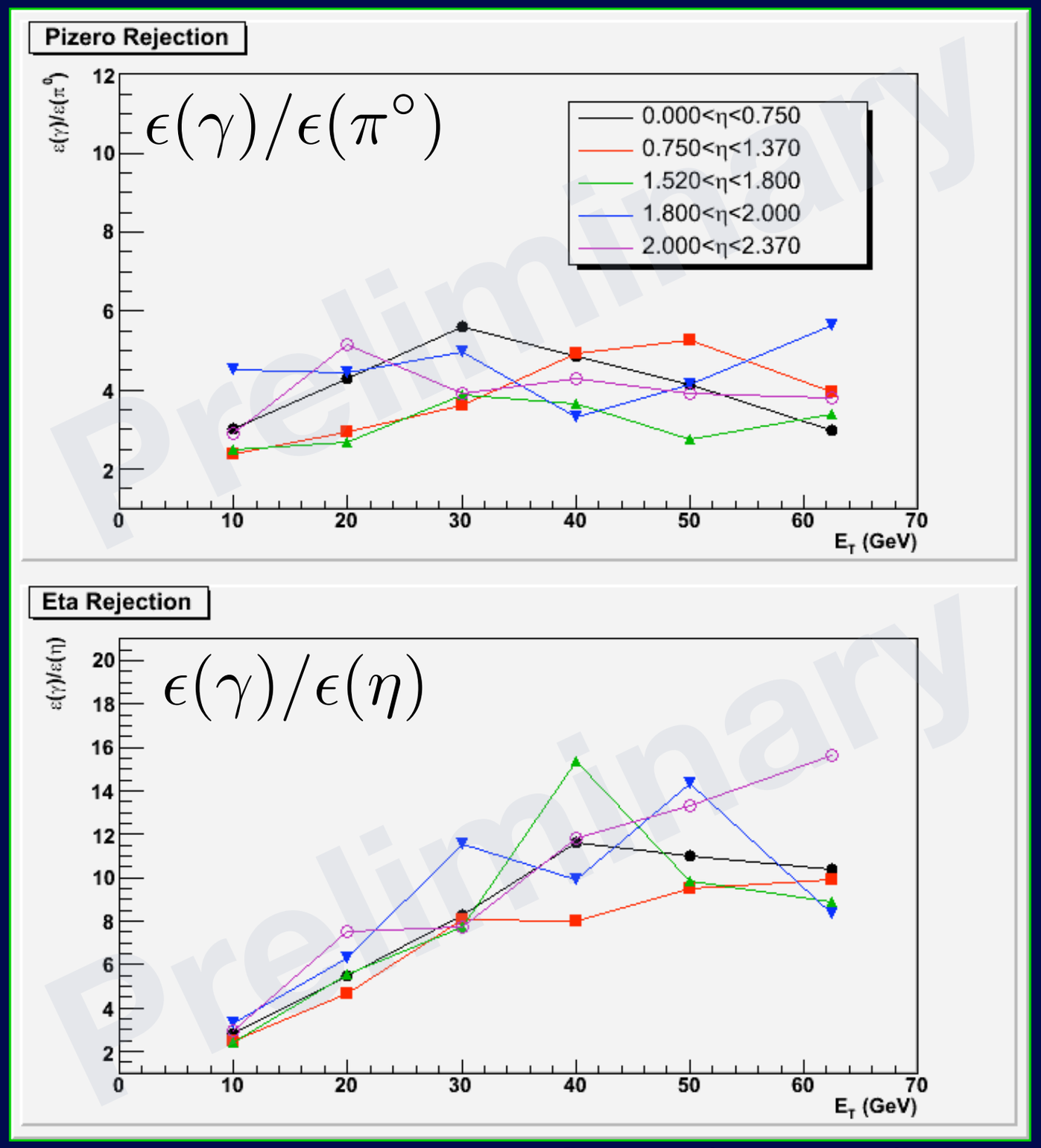


first result: very preliminary

<u>Preliminary</u> studies on single-particle events in ATLAS
"Tight" cuts based on topology of signals in strips
(optimizes rejection at cost of efficiency)
Good direct (isolated) photon efficiency

Rejecting π^0 & η

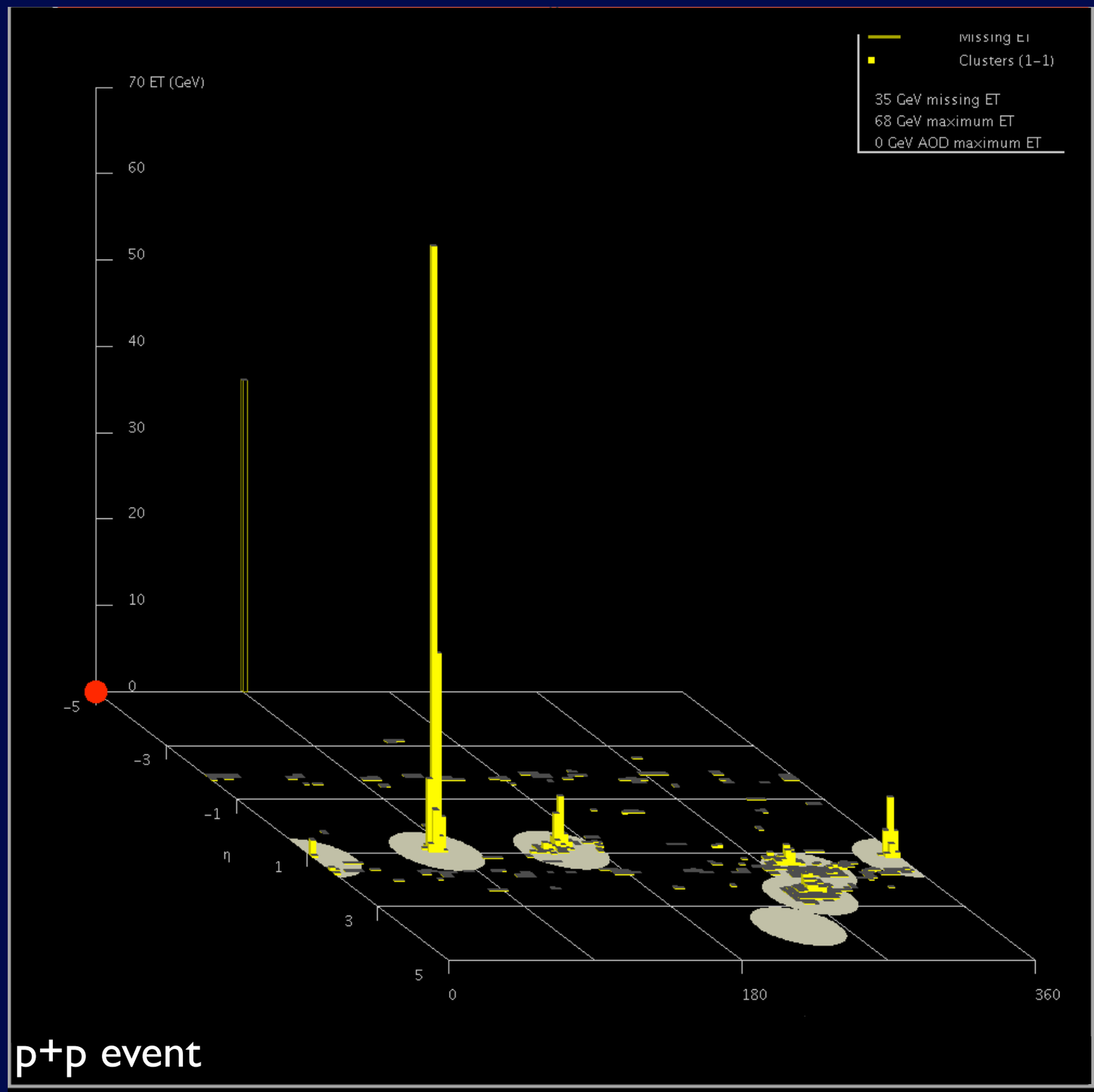




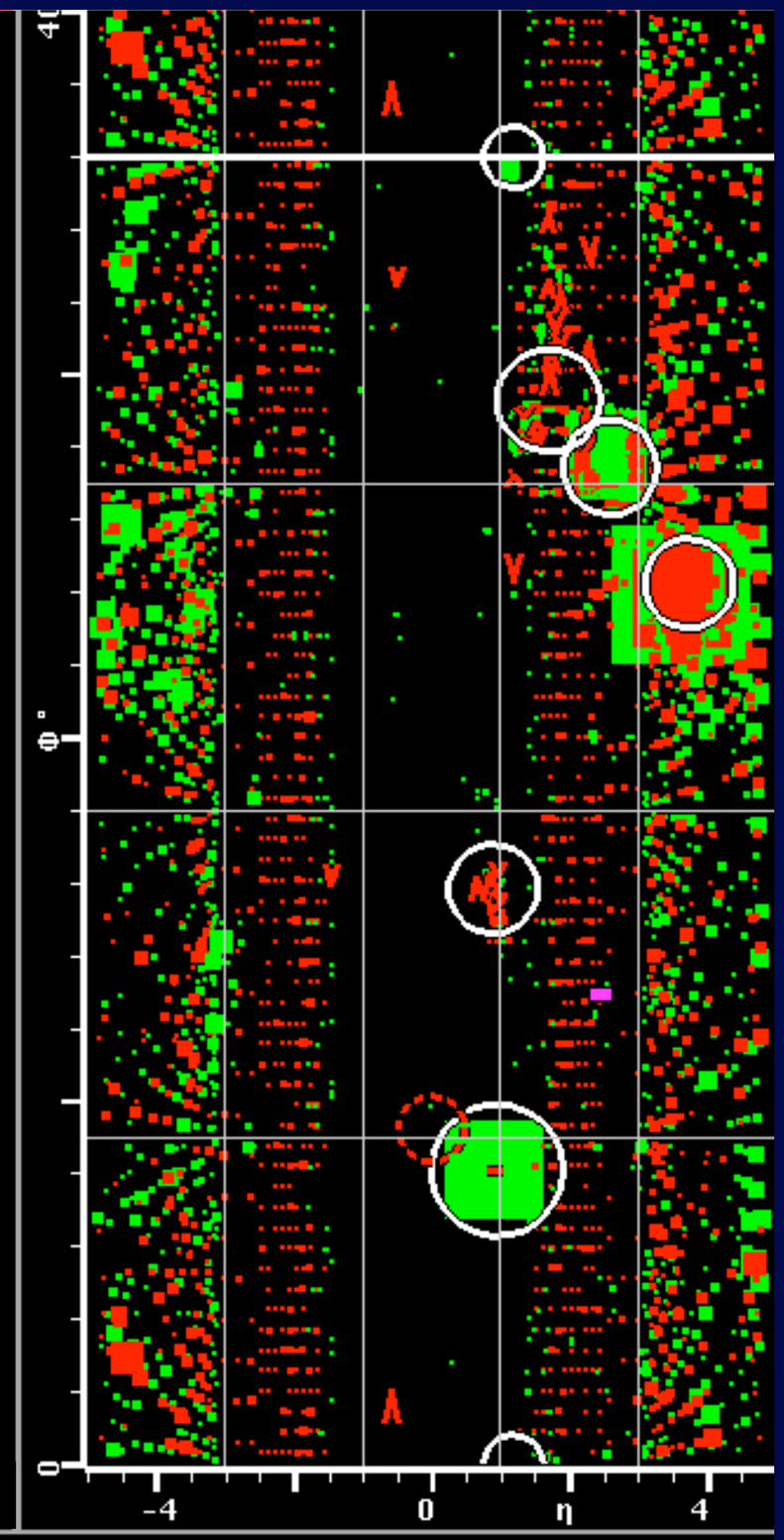
Good <u>rejection</u> at very high E_T - embedding studies w/ HIJING next

first result: very preliminary

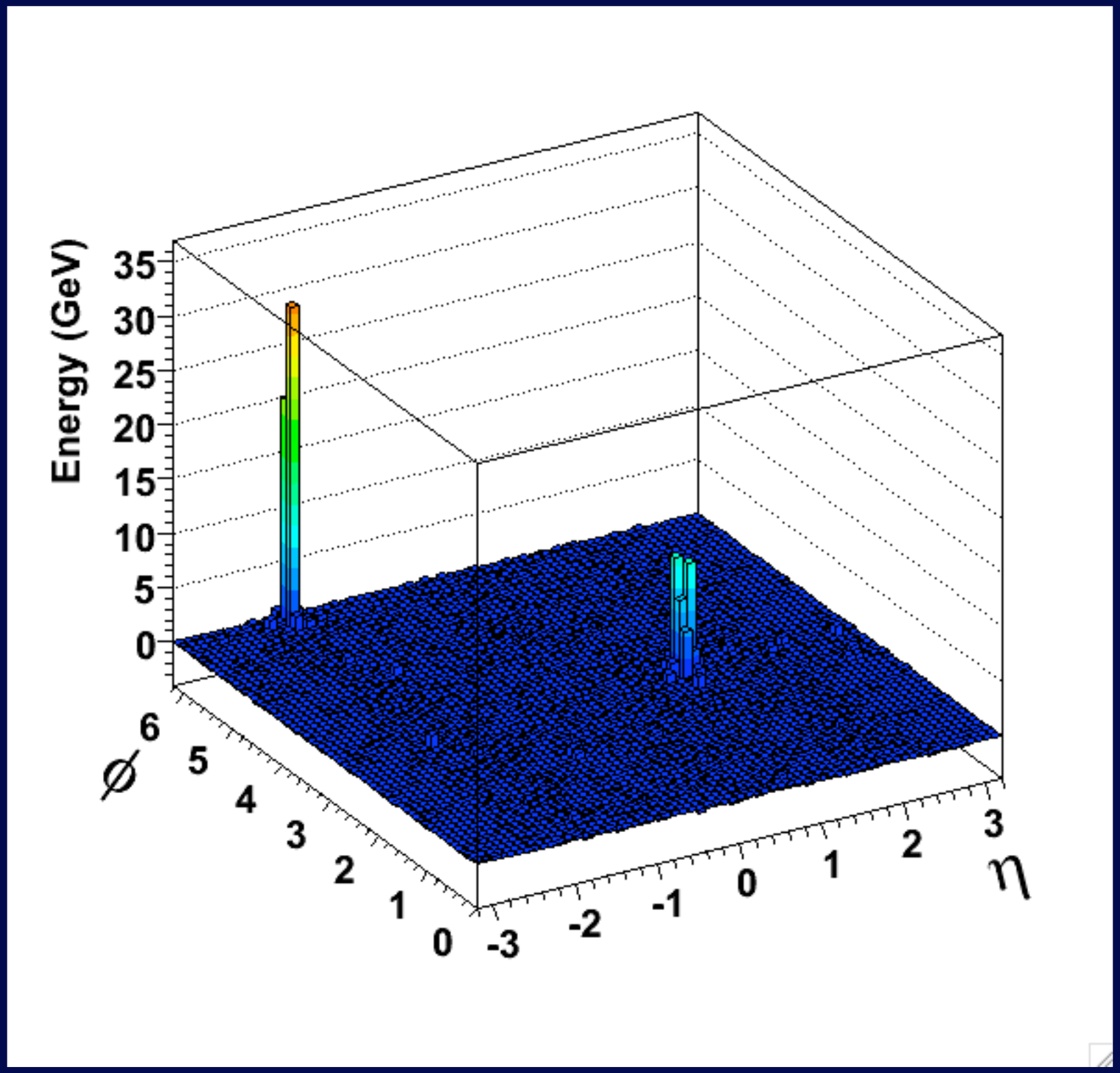
Jets with ATLAS



p+p event

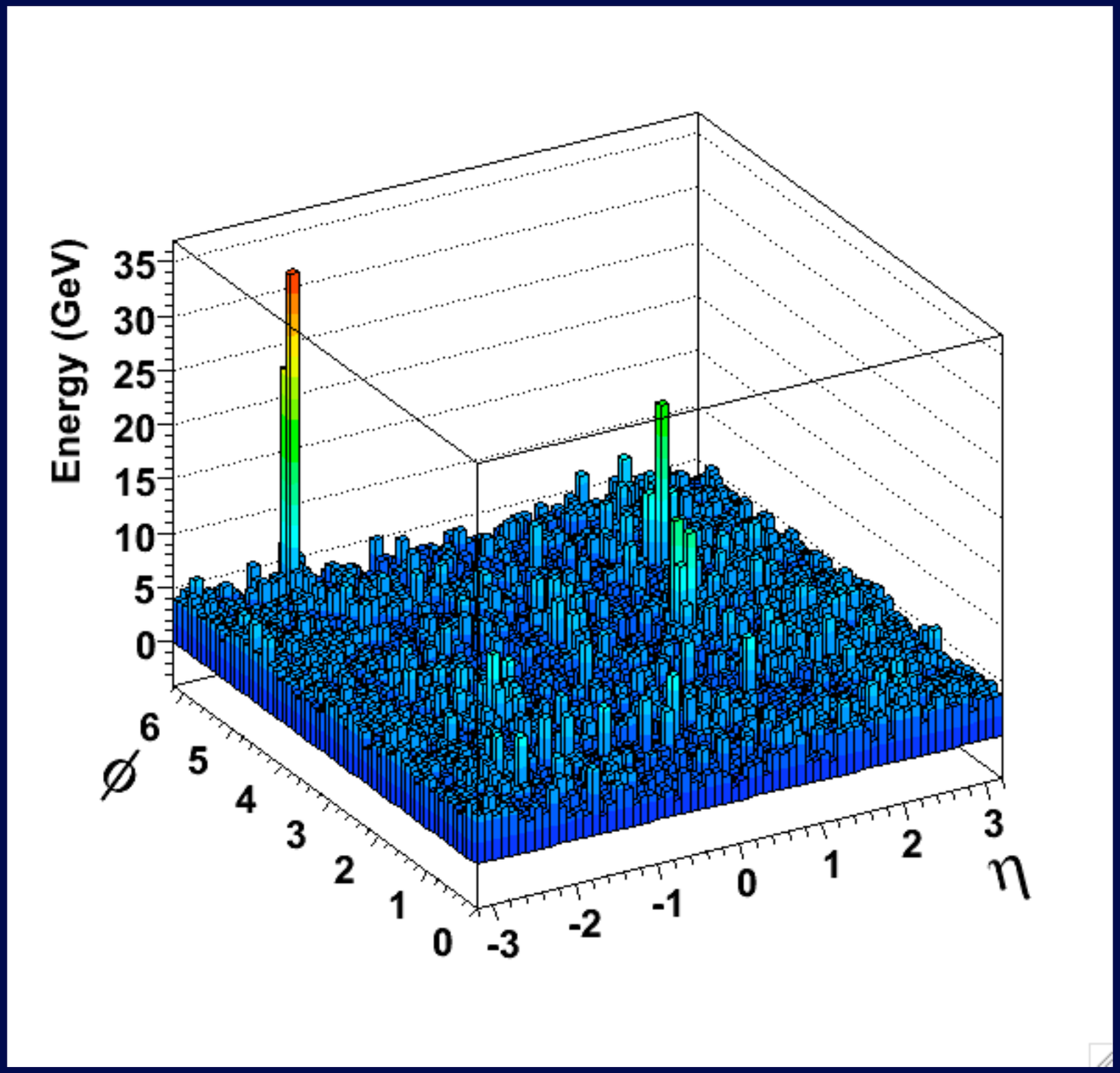


Jets in A+A



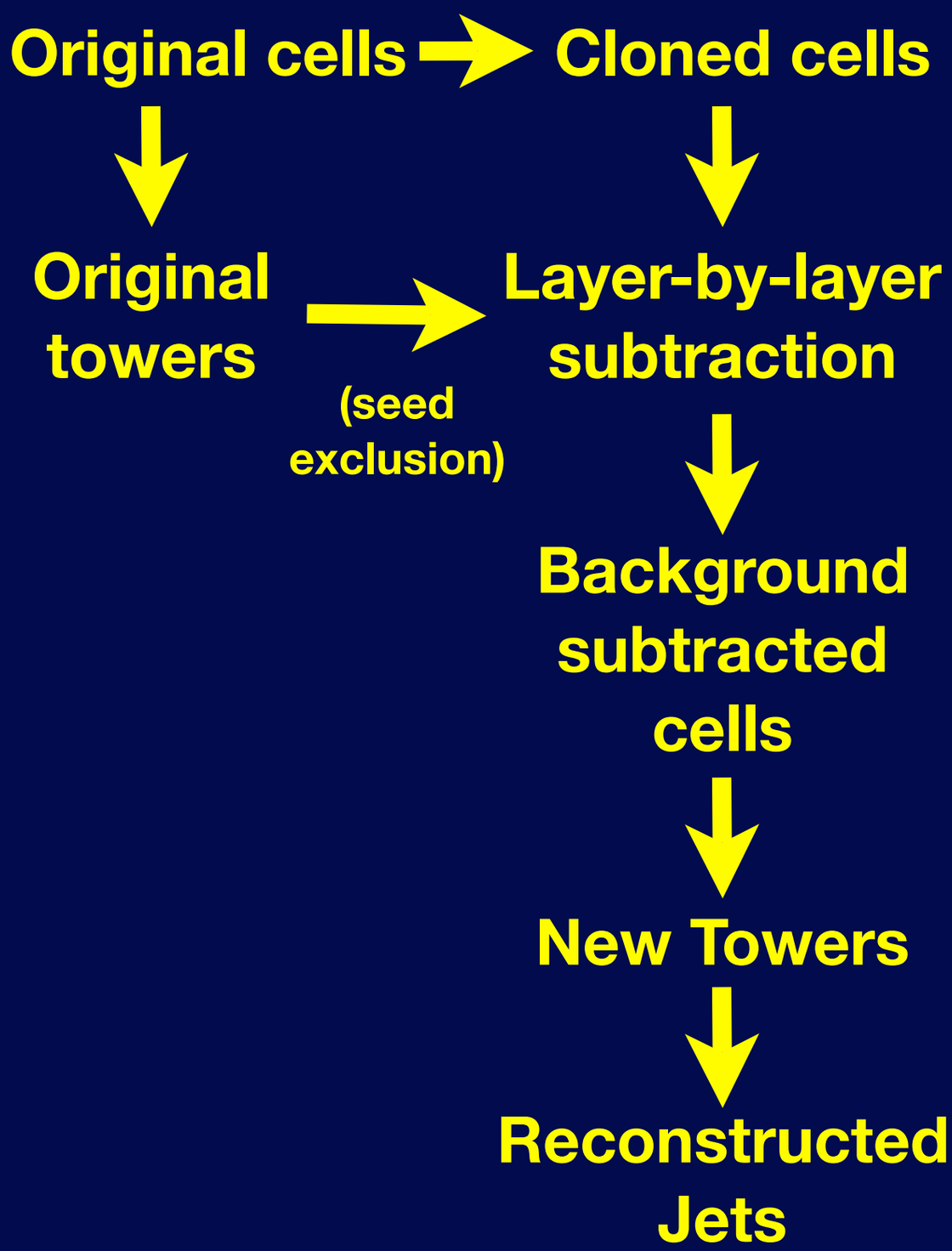
Jets from PYTHIA in Calorimeter Towers

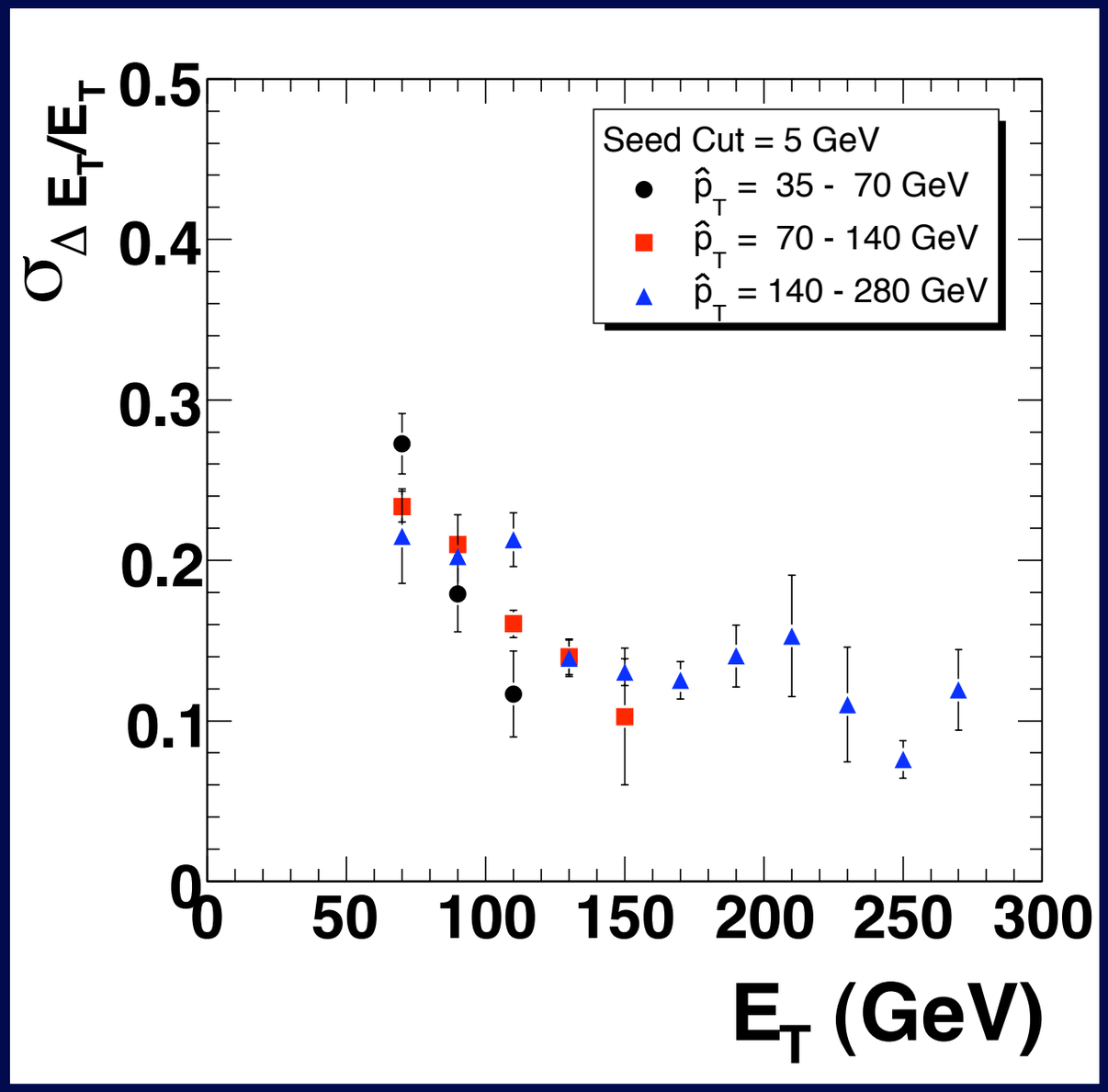
Jets in A+A



Jets from PYTHIA in Calorimeter Towers merged with HIJING

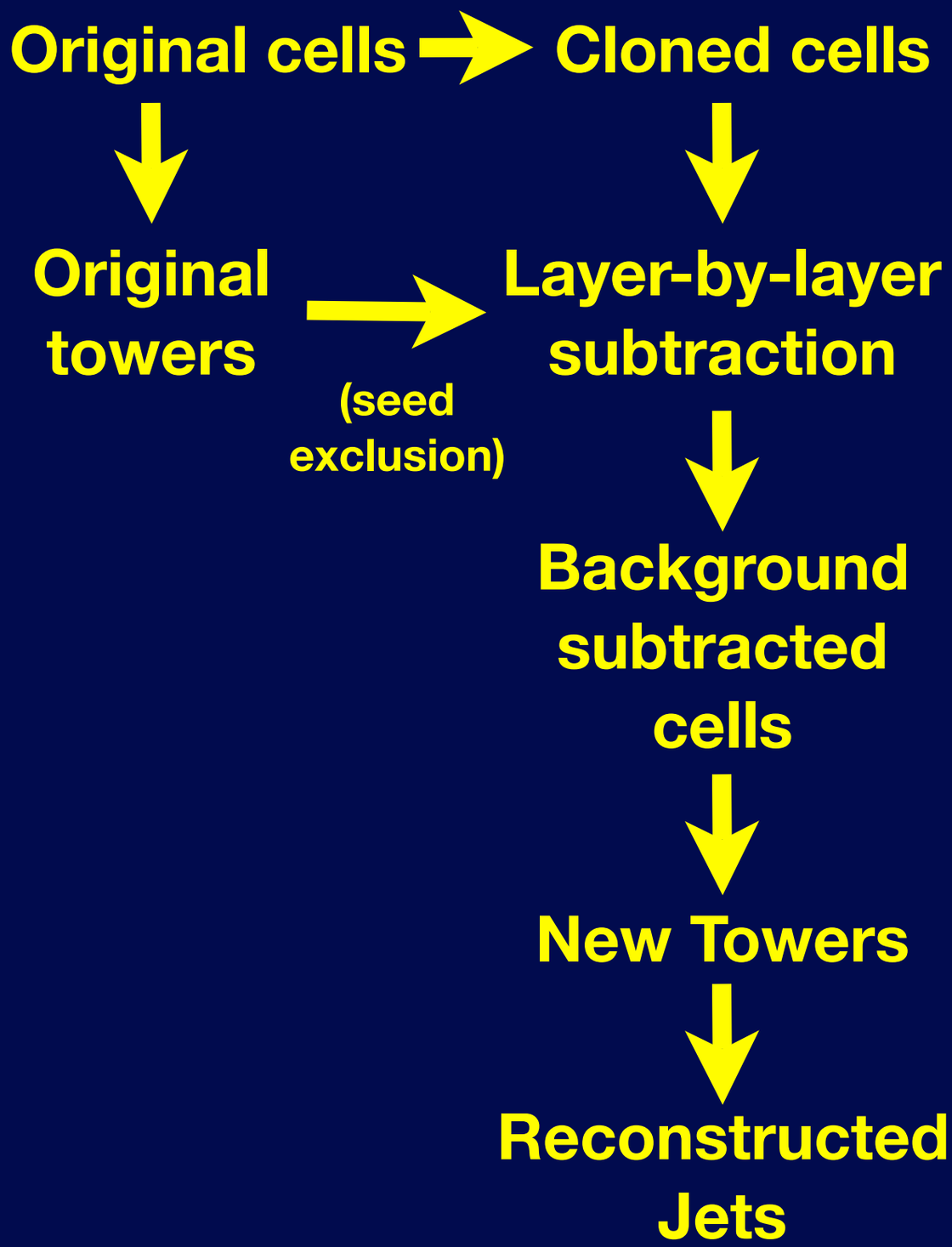
Jet Energy Resolution

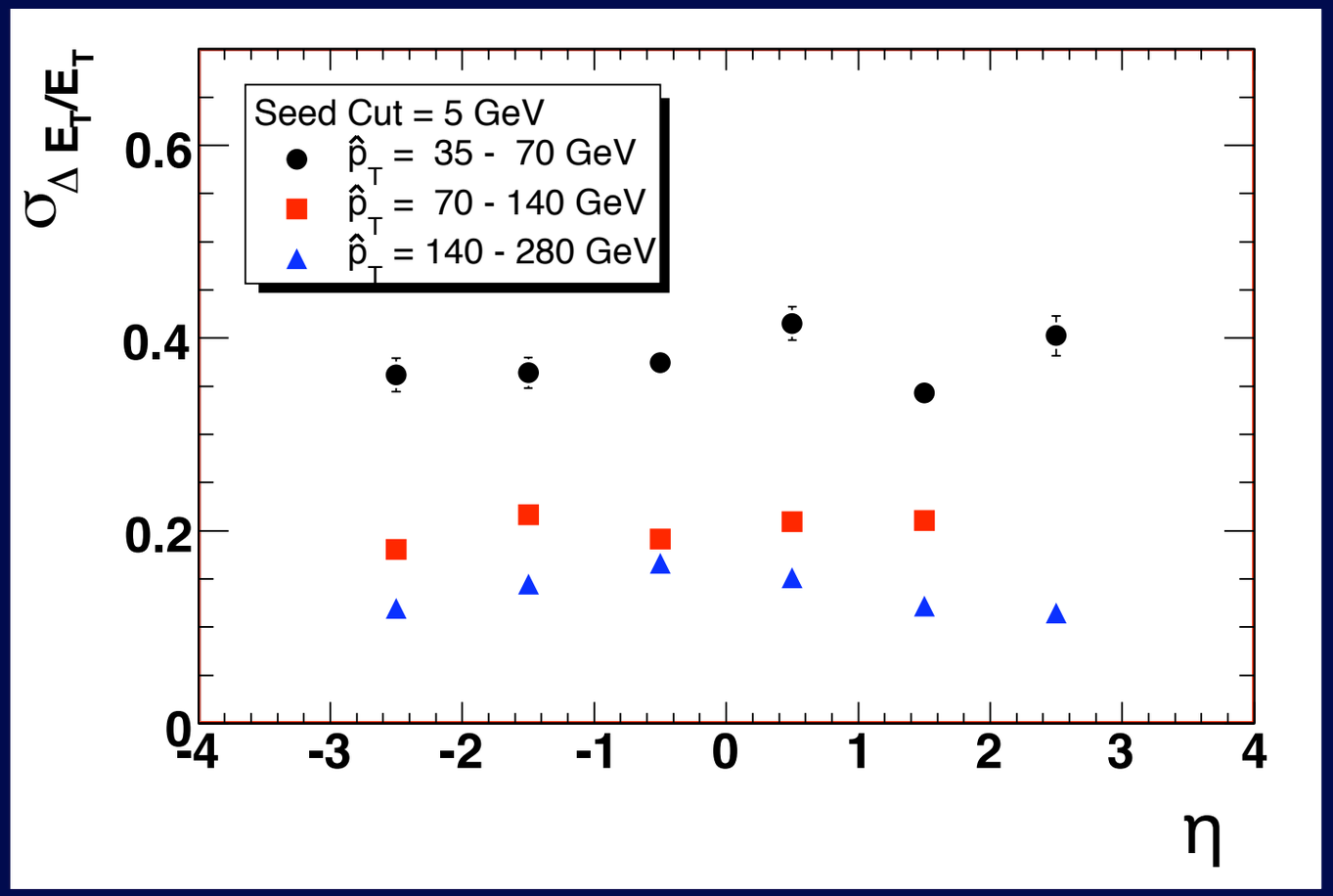




Study of different event samples embedded into central Pb+Pb HIJING (b=0-2 fm)

Jet Energy Resolution

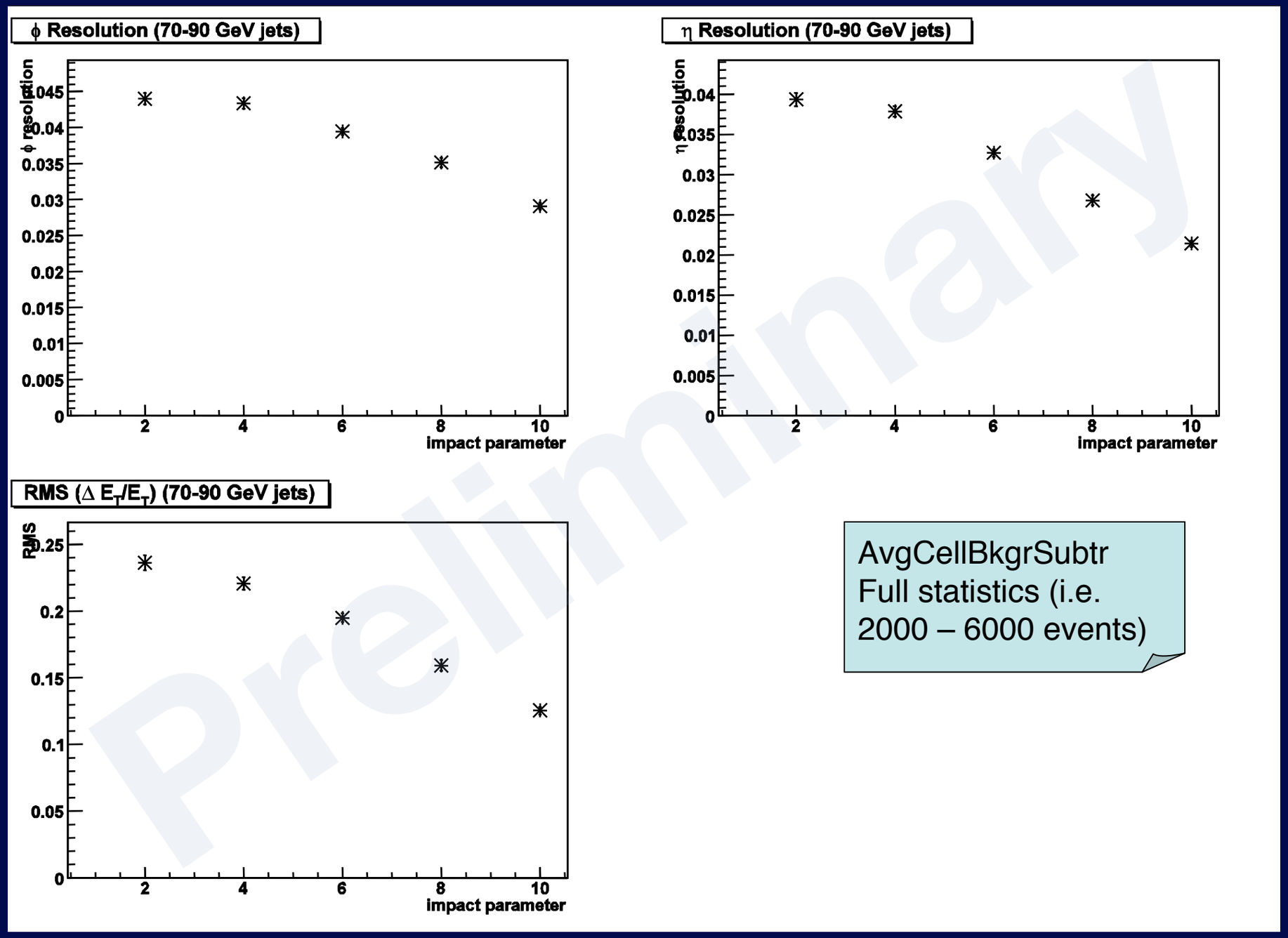




Good resolution out to |η|=3, will extend out to |η|=5 (Δη=10)

Study of different event samples embedded into central Pb+Pb HIJING (b=0-2 fm)

Centrality Dependence



Spousta
Grau
Holzmann
Cole
Leltchouk
Ajitanand
Lee

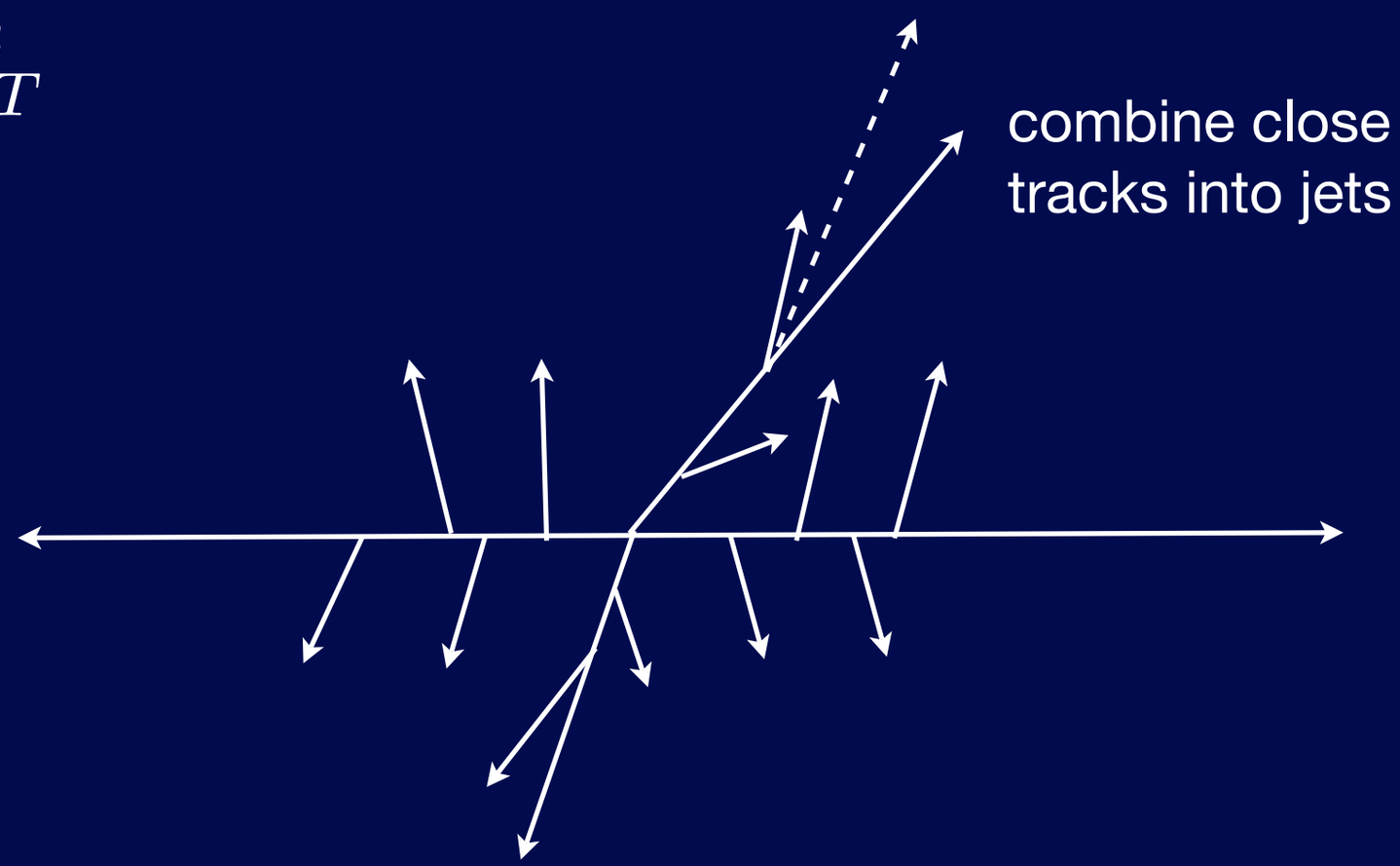
first result: very preliminary!

Studies developing rapidly since QM2006: now have full characterization of Jet reco vs. b

The "Fast k_T" Algorithm

$$d_{ij} = \min(k_{iT}, k_{jT})R^2 \quad R^2 = (\phi_i - \phi_j)^2 + (\eta_i - \eta_j)^2$$

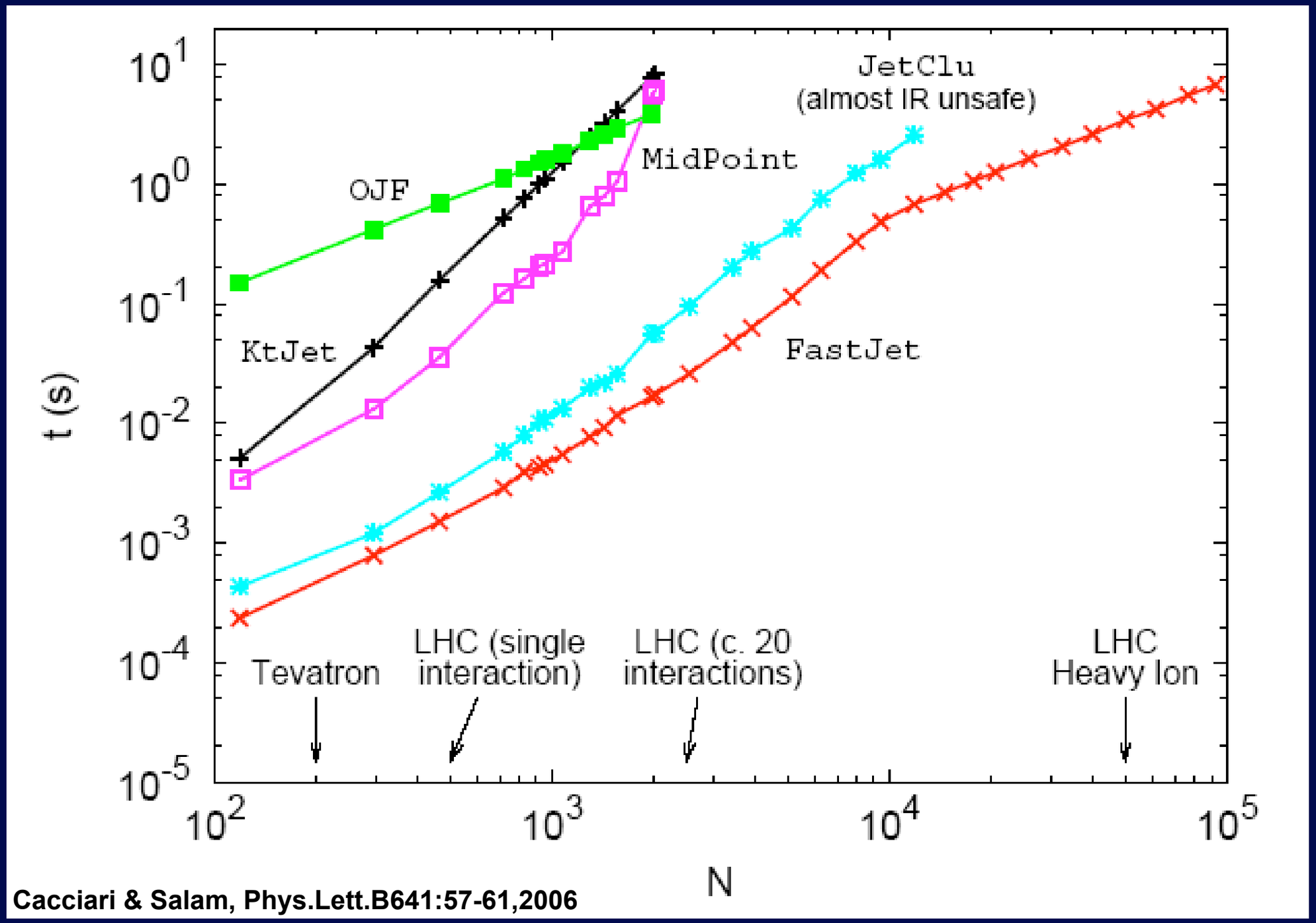
$$d_{iB} = k_{iT}^2$$



Reconstructs jet backwards along fragmentation chain.

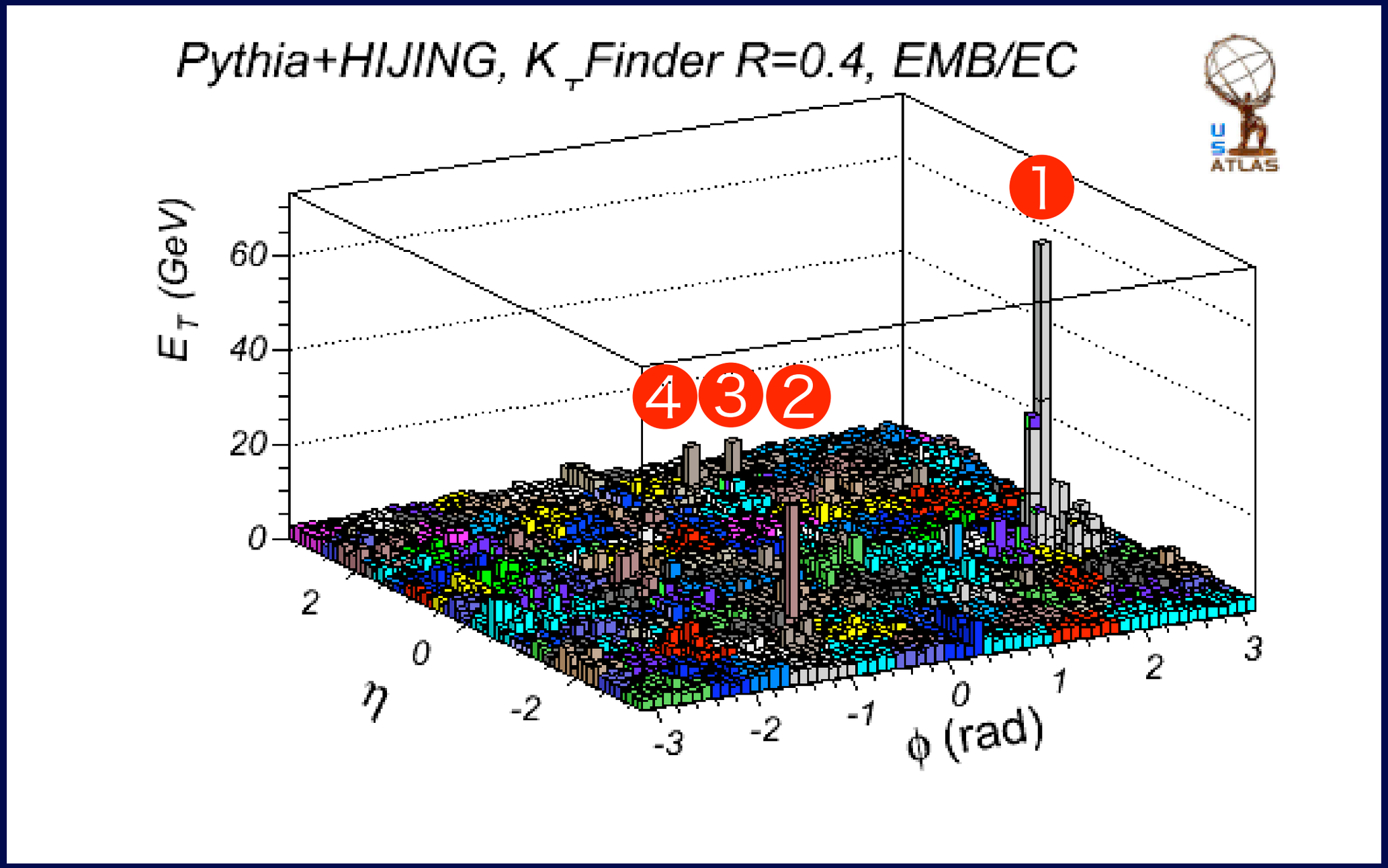
Typically scales as $O(N^3)$ → Cacciari & Salam (2005)'s "FastKt" has optimized problem down to O(N log N)!

The “Fast k_T” Algorithm

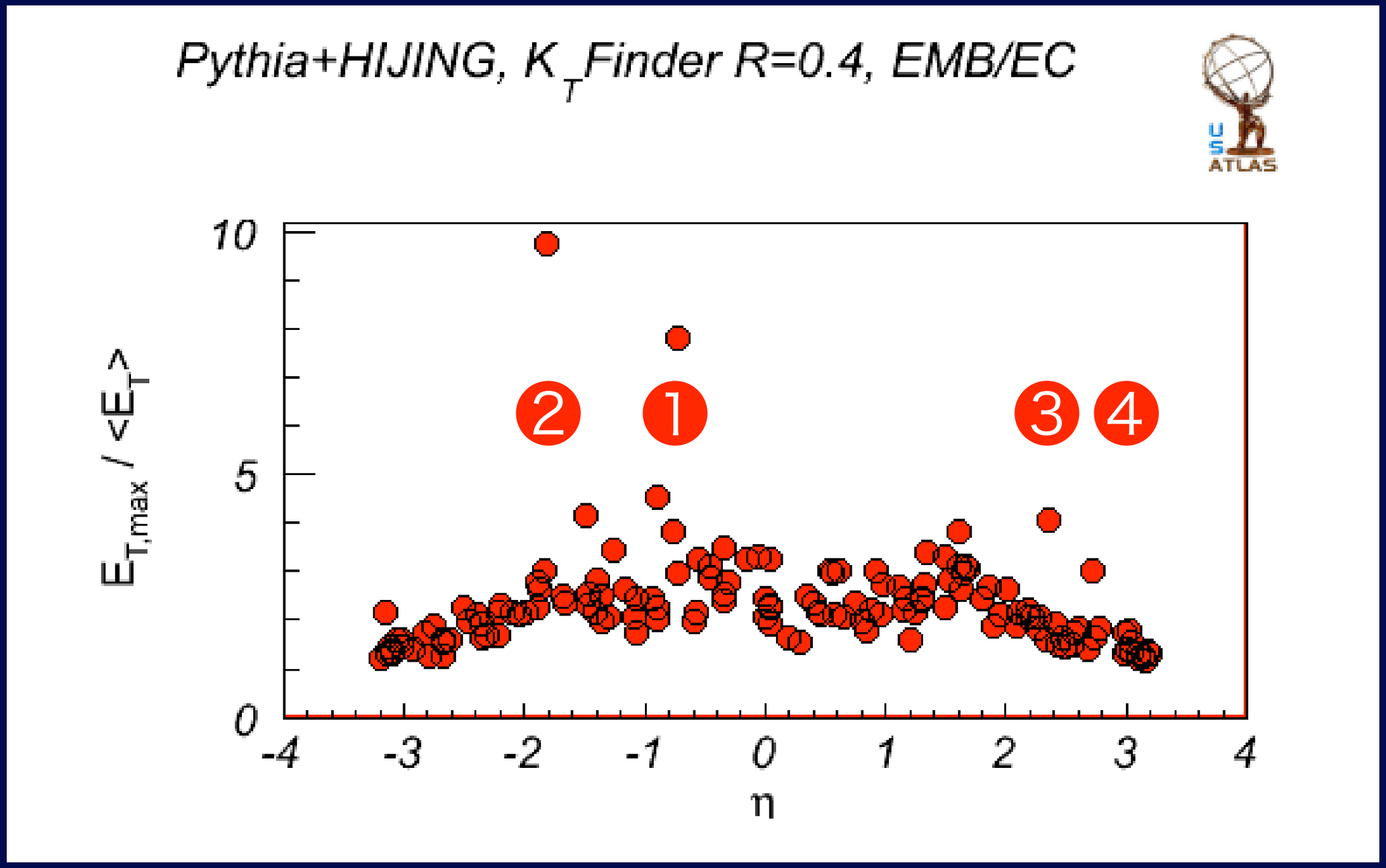


Cacciari & Salam, Phys.Lett.B641:57-61,2006

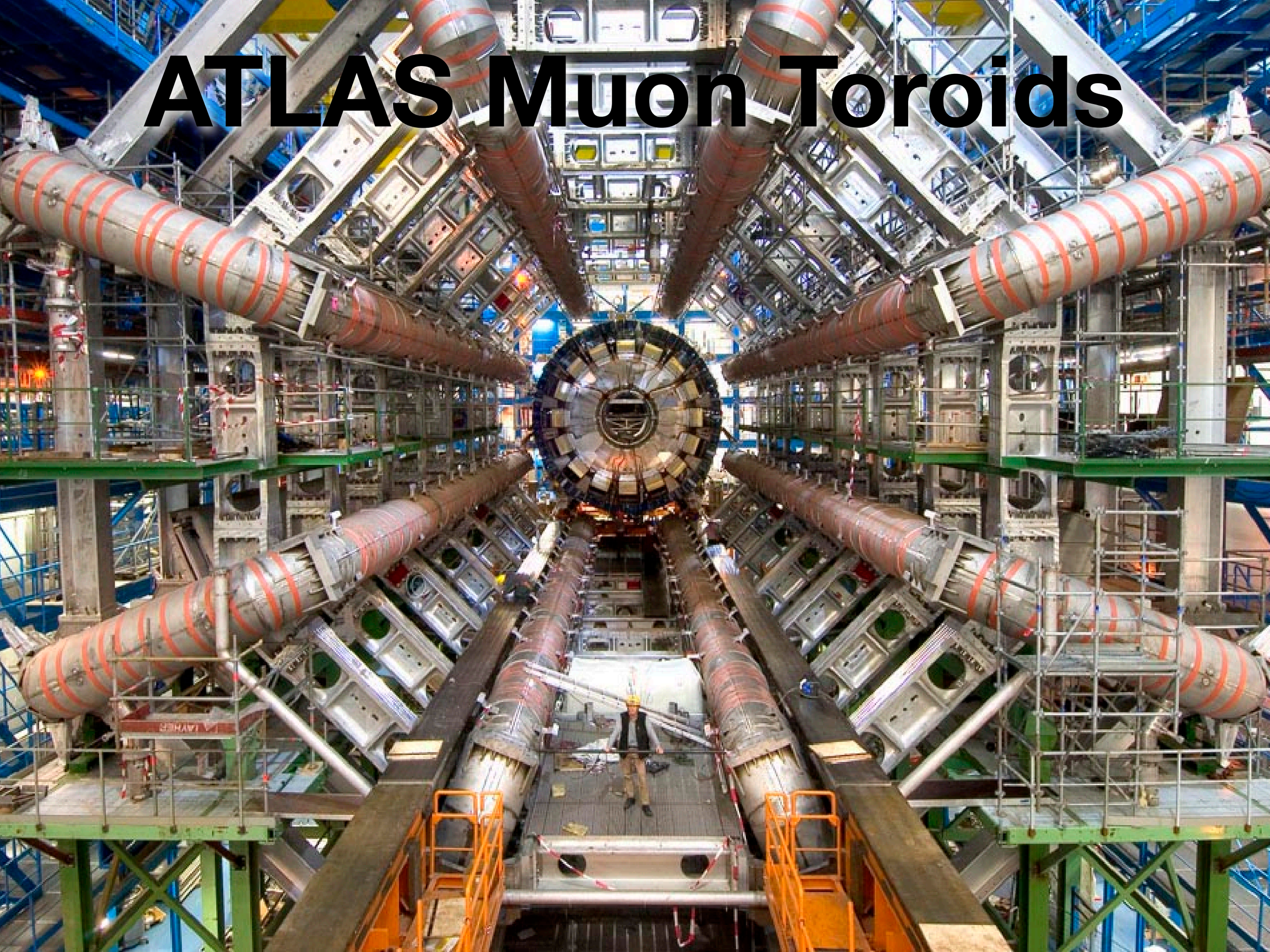
Fast k_T in ATLAS



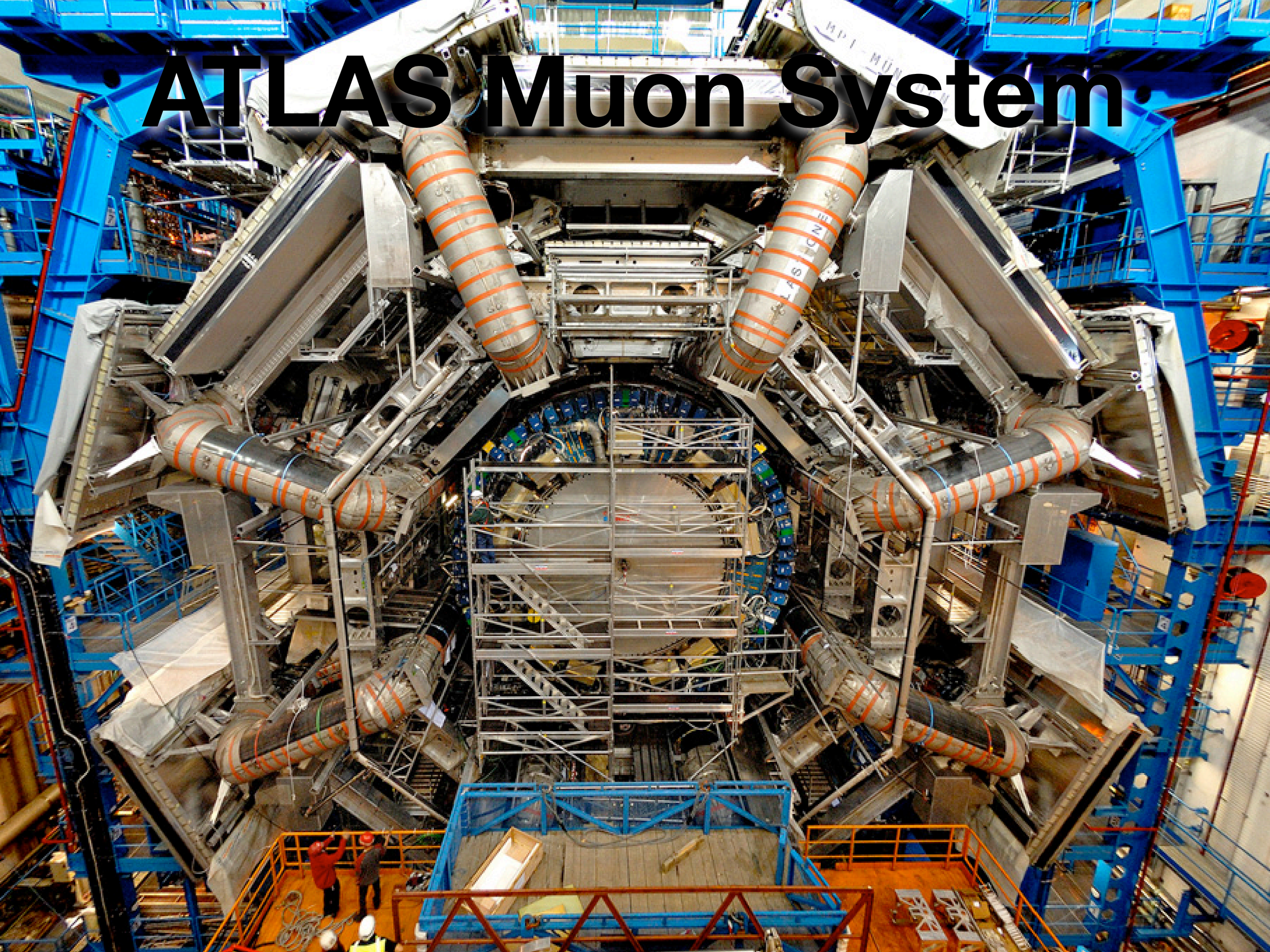
Fast k_T in ATLAS



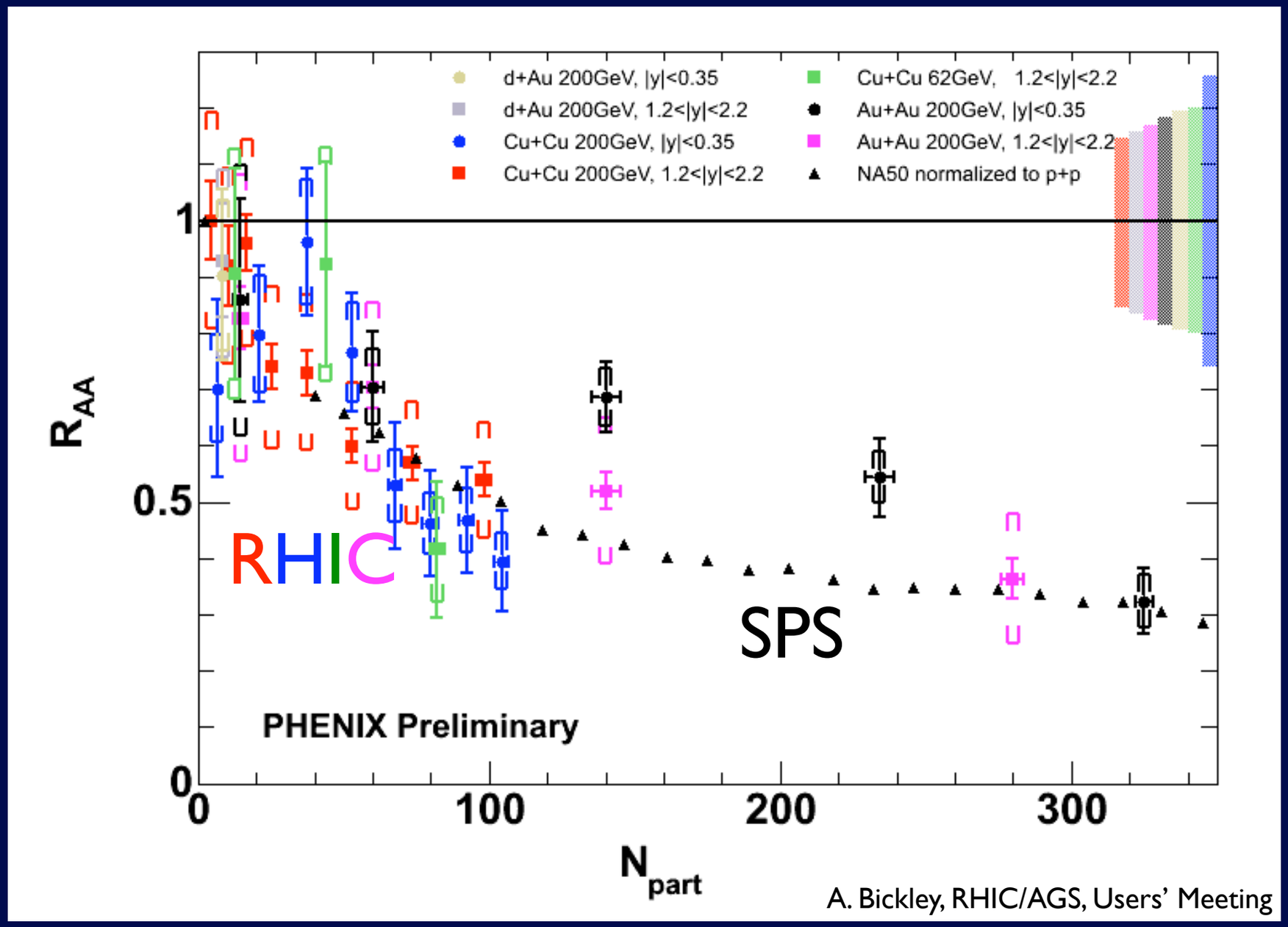
ATLAS Muon Toroids



ATLAS Muon System



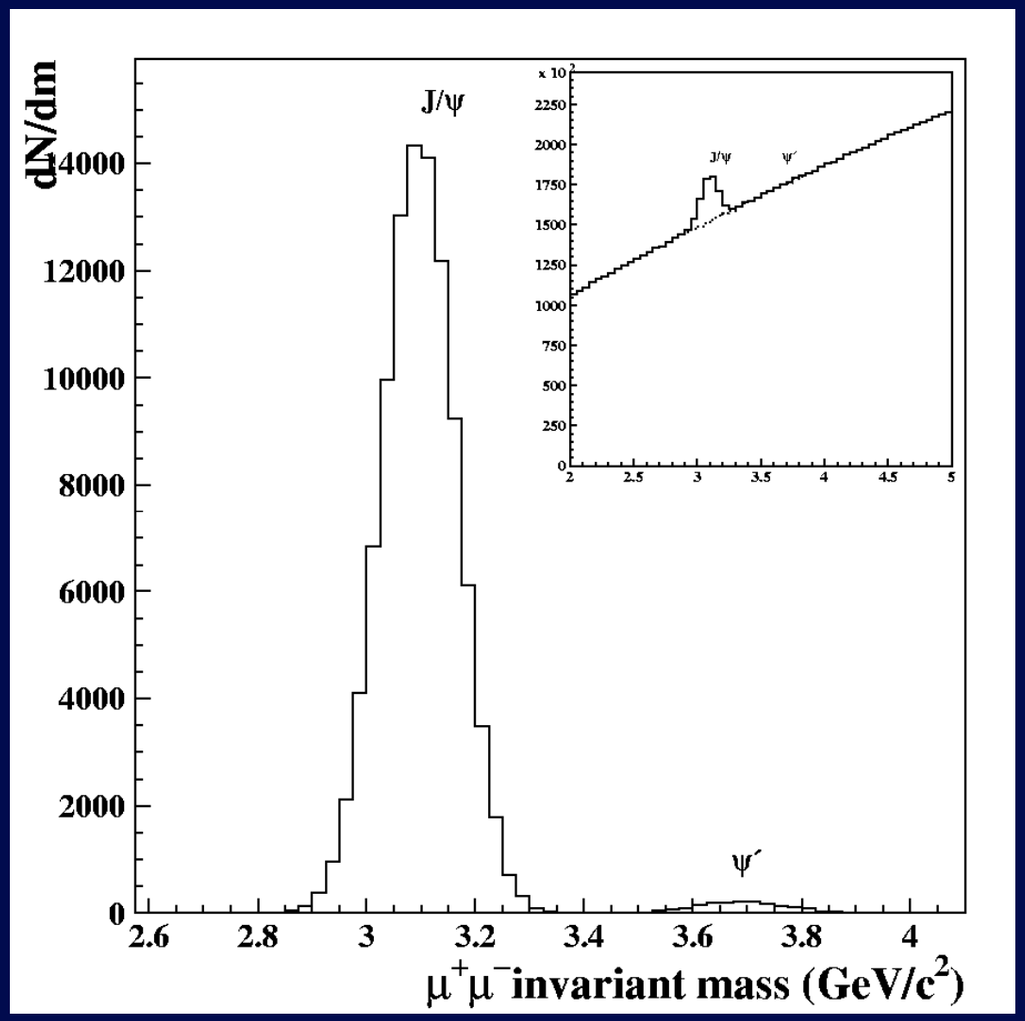
Quarkonia Suppression

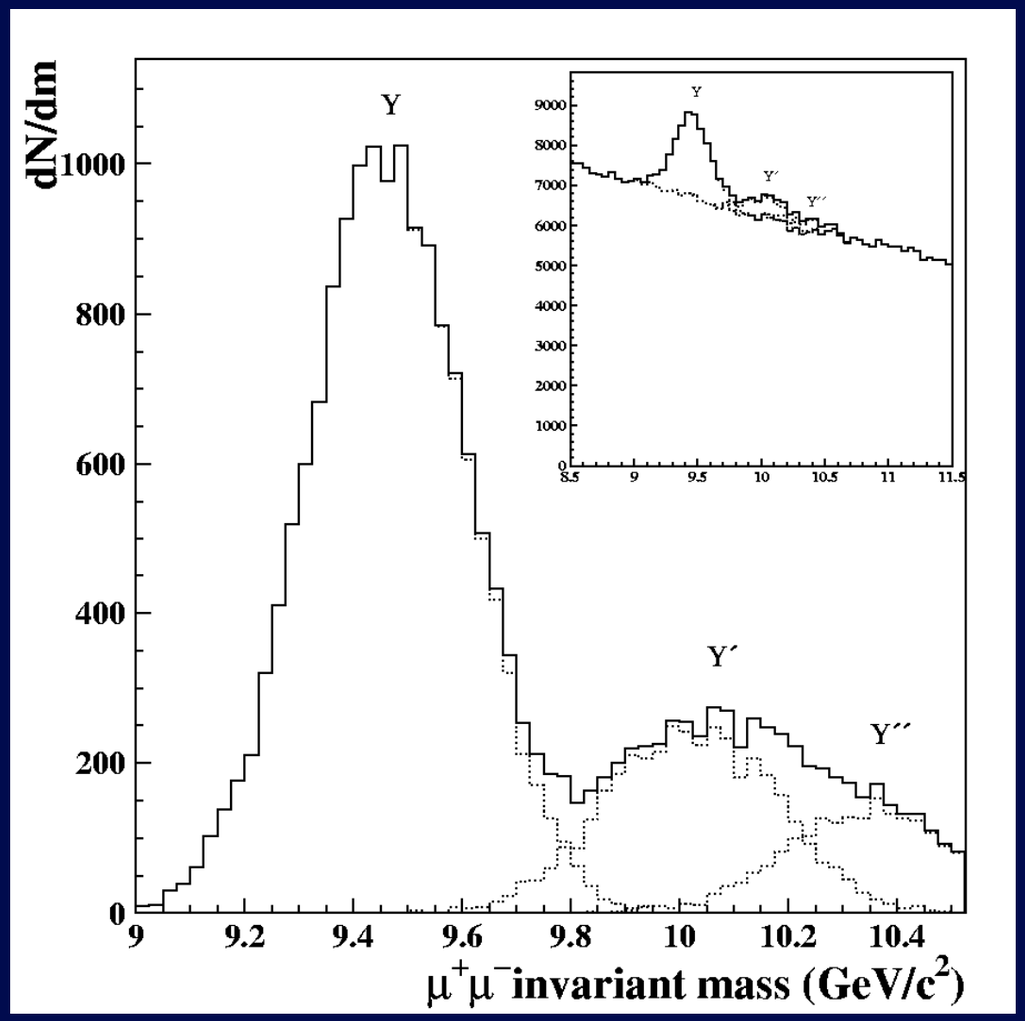


J/ψ shows similar suppression pattern at all available energies

Models unable to explain this naturally → **LHC**?

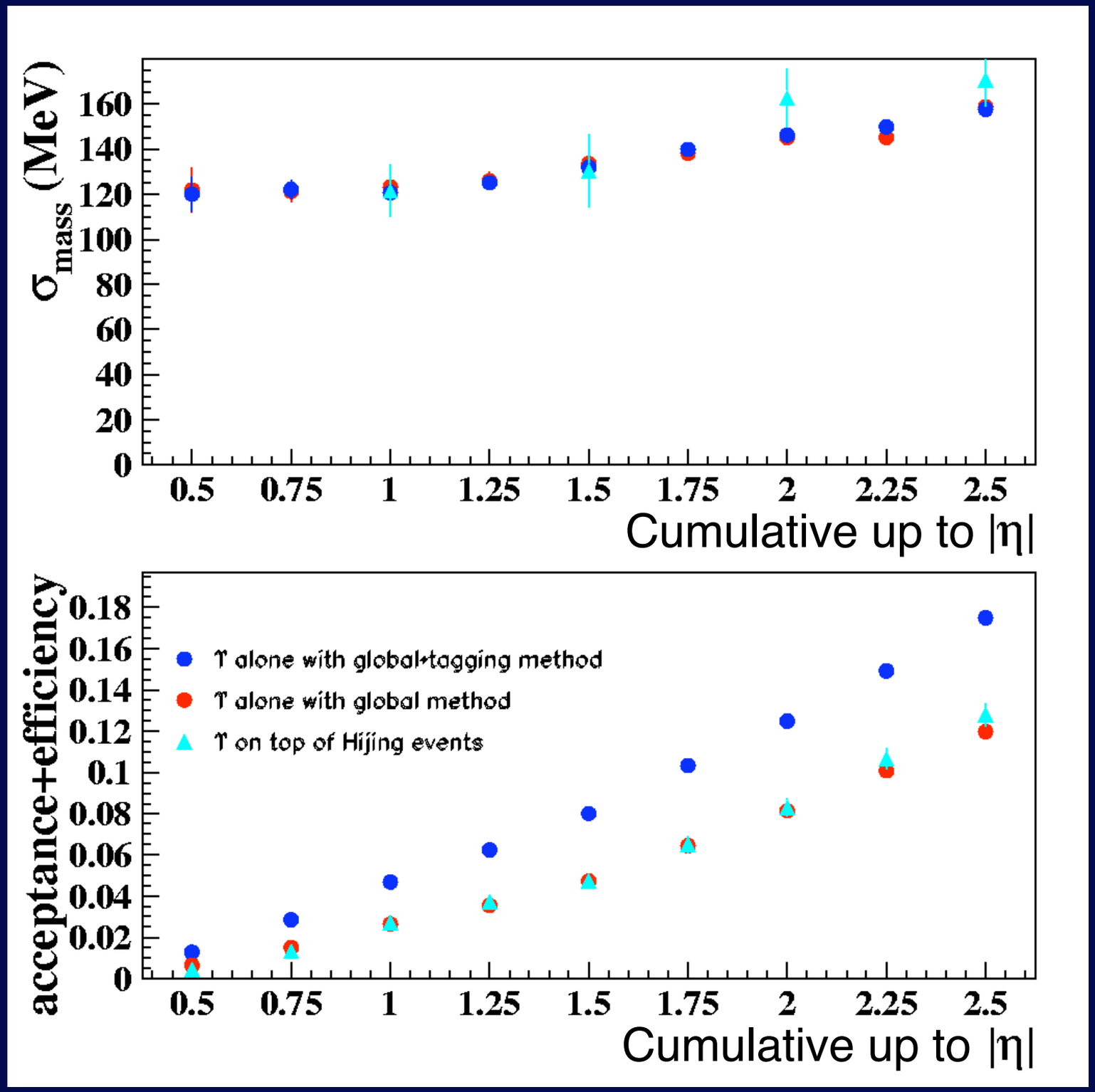
Quarkonia in ATLAS

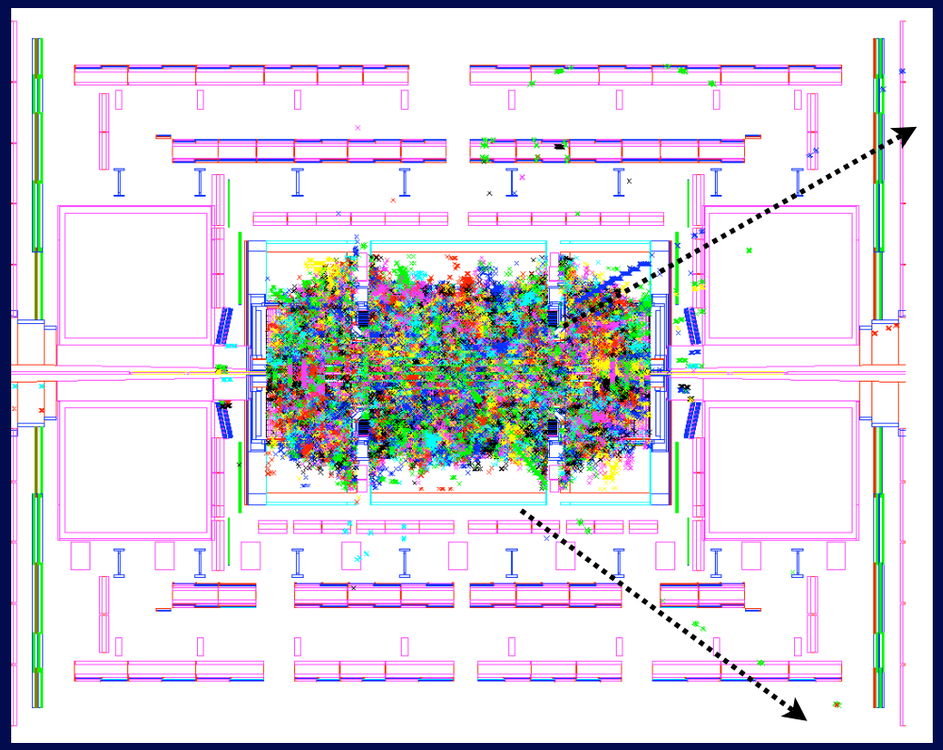




High statistics studies of acceptance, efficiency, resolution of single upsilons and J/ψ

Mass Resolution of ϒ

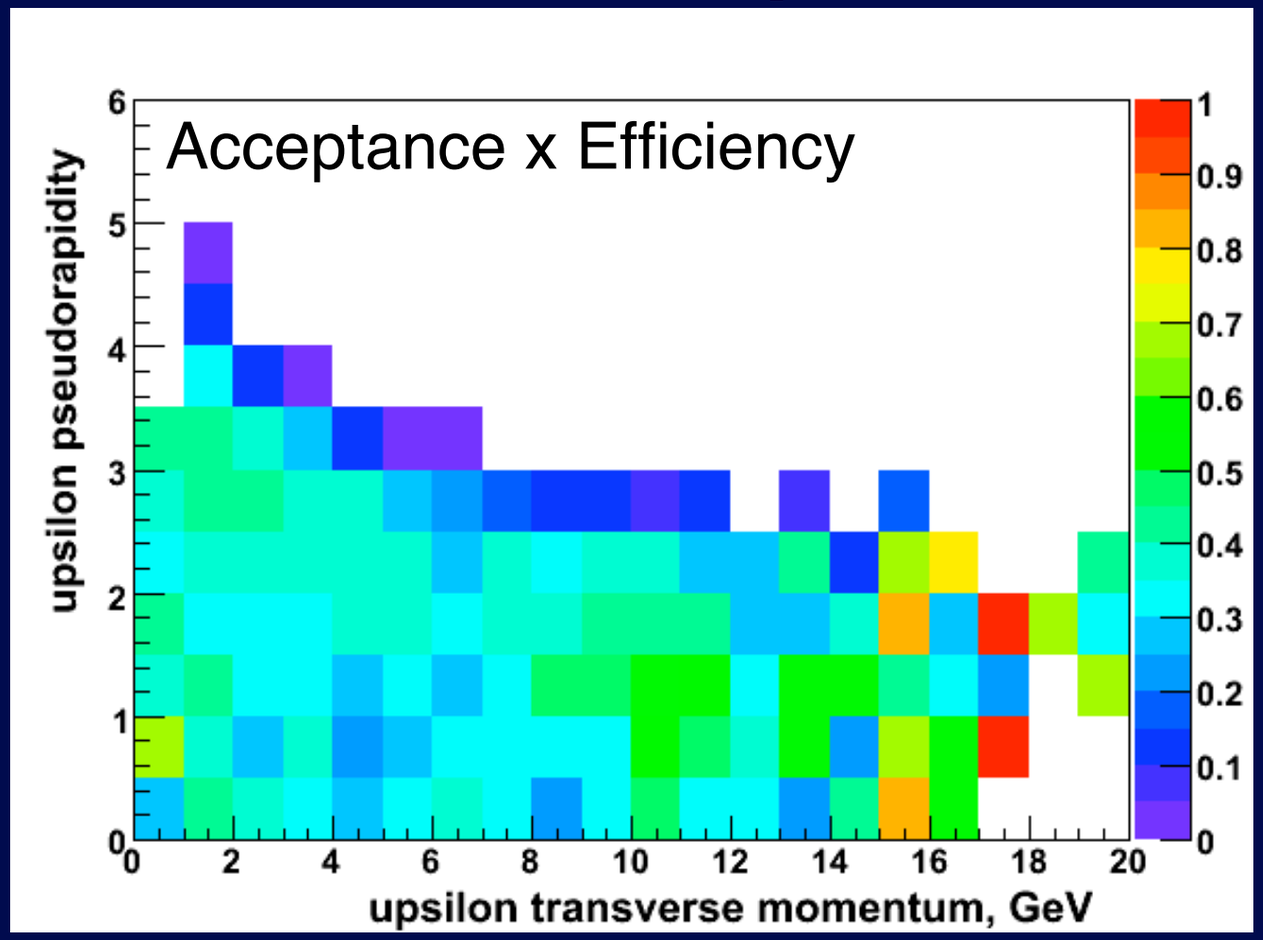


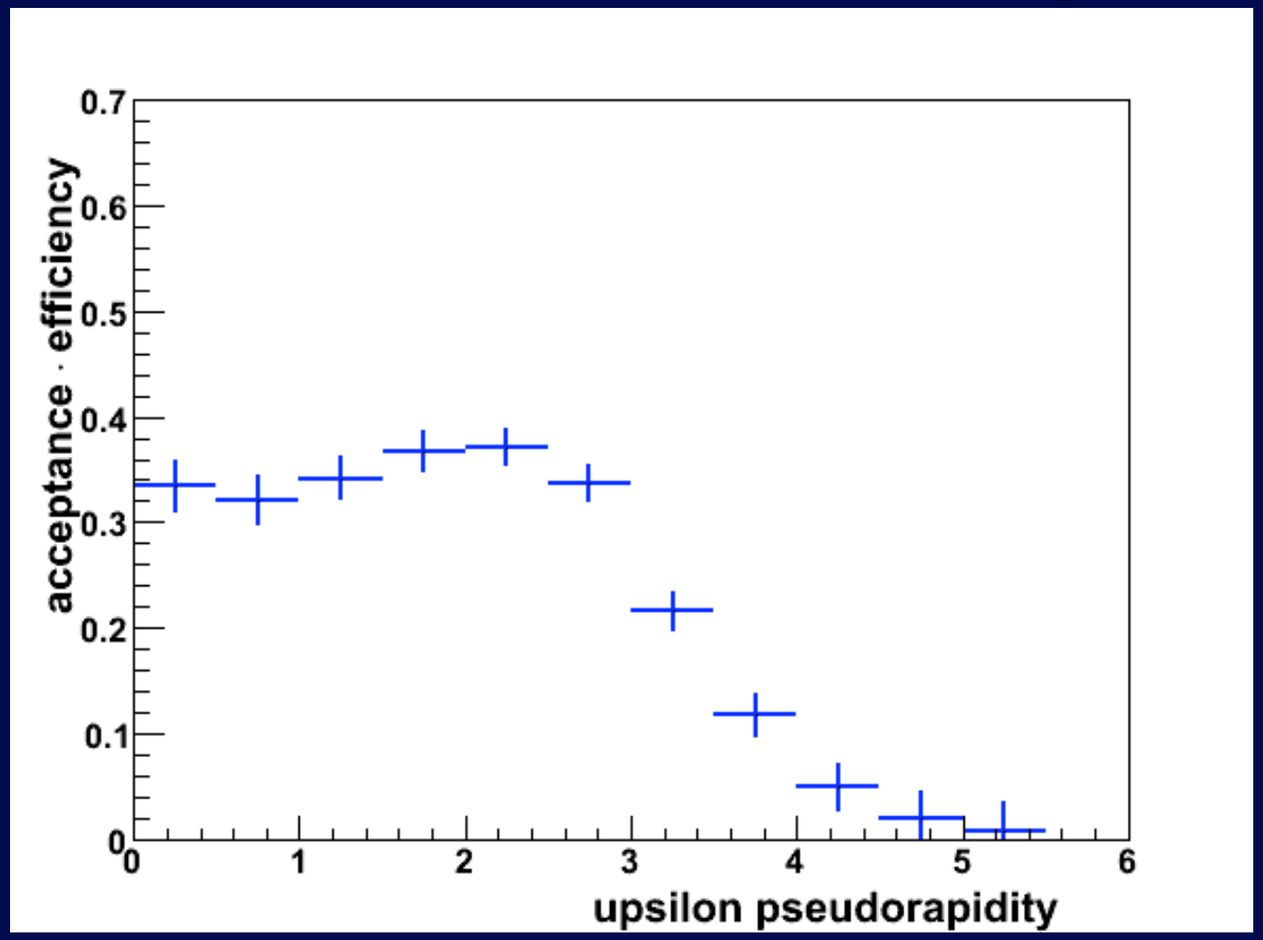


MuID algorithm
GEANT3 simulation

Good ϒ mass resolution, acceptance & efficiency, even embedded in HIJING

ϒ Acceptance & Efficiency

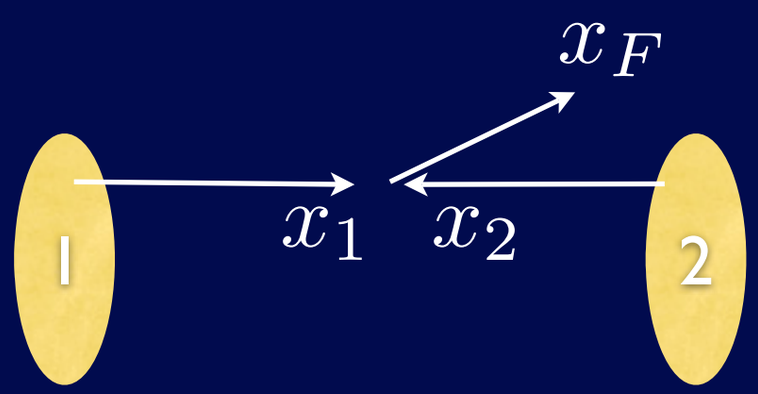




Pythia + ϒ events, GEANT 4 simulation, Staco algorithm

Broad acceptance with good efficiency in p_T and y
(Inefficiencies at midrapidity due to material)

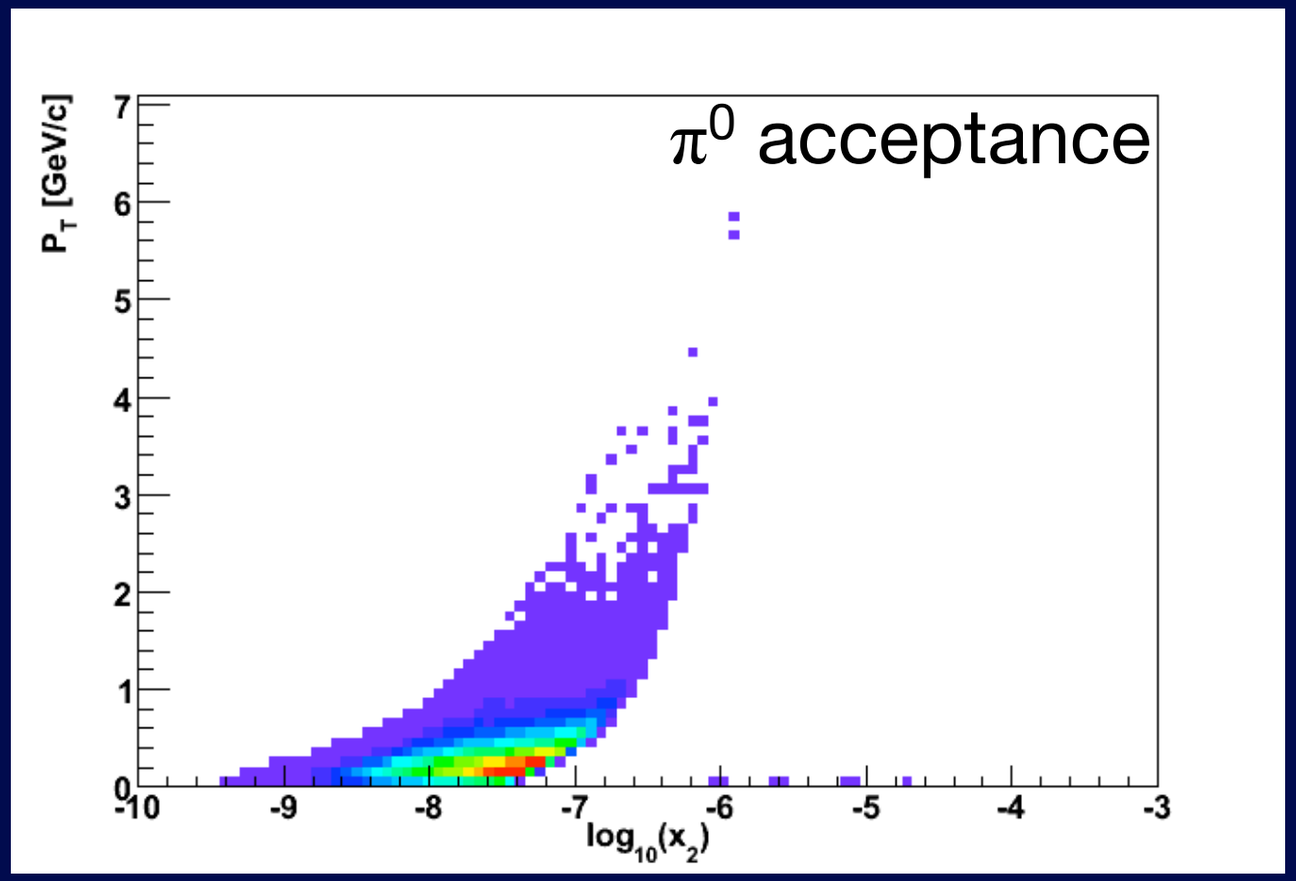
Low-x Physics w/ ZDC



$$x_F = x_1 - x_2$$

$$x_1 x_2 = \frac{m_T^2}{s}$$

$$x_1 \sim \frac{m_T}{\sqrt{s}} e^{y} \quad x_2 \sim \frac{m_T}{\sqrt{s}} e^{-y}$$

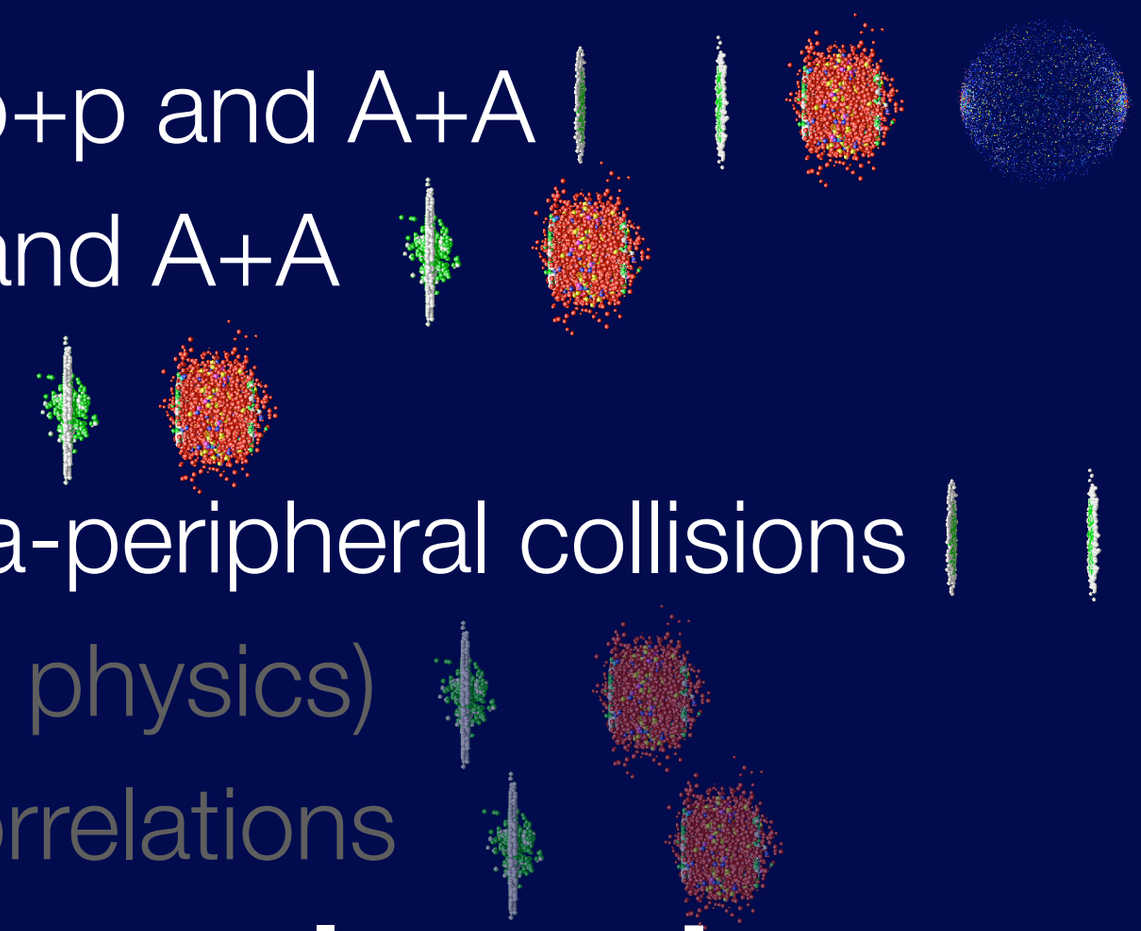


ZDC will be used for centrality and Ultraperipheral Pb+Pb

Also reconstructs neutral particles at very high rapidities: physics processes at <u>very</u> low x, e.g. Color Glass Condensate

Conclusions

- **ATLAS is preparing for heavy ions at the LHC in 2008+**
  - Bulk observables in p+p and A+A
  - Inclusive jets in p+p and A+A
  - Quarkonia (Υ and ψ)
  - Low-x physics & Ultra-peripheral collisions
  - Heavy quarks (esp. b physics)
  - Z+jet, γ+jet, jet-jet correlations
- **New collaborators welcome!**
  - Software, Analysis, Physics, Trigger



ATLAS