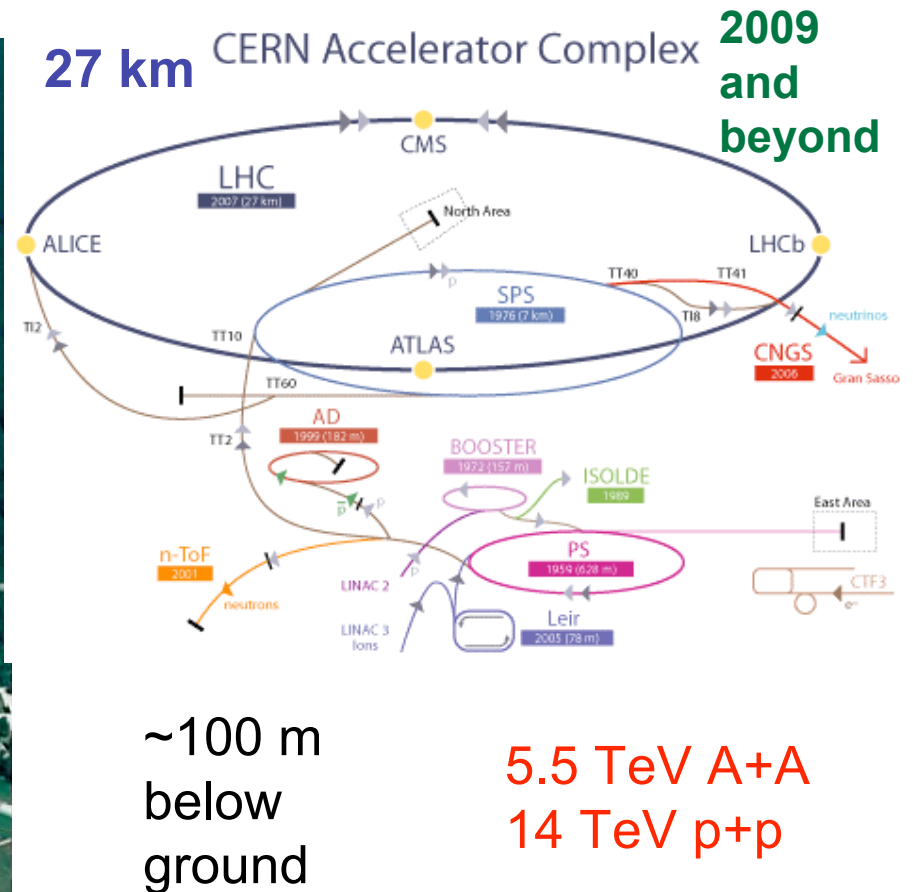
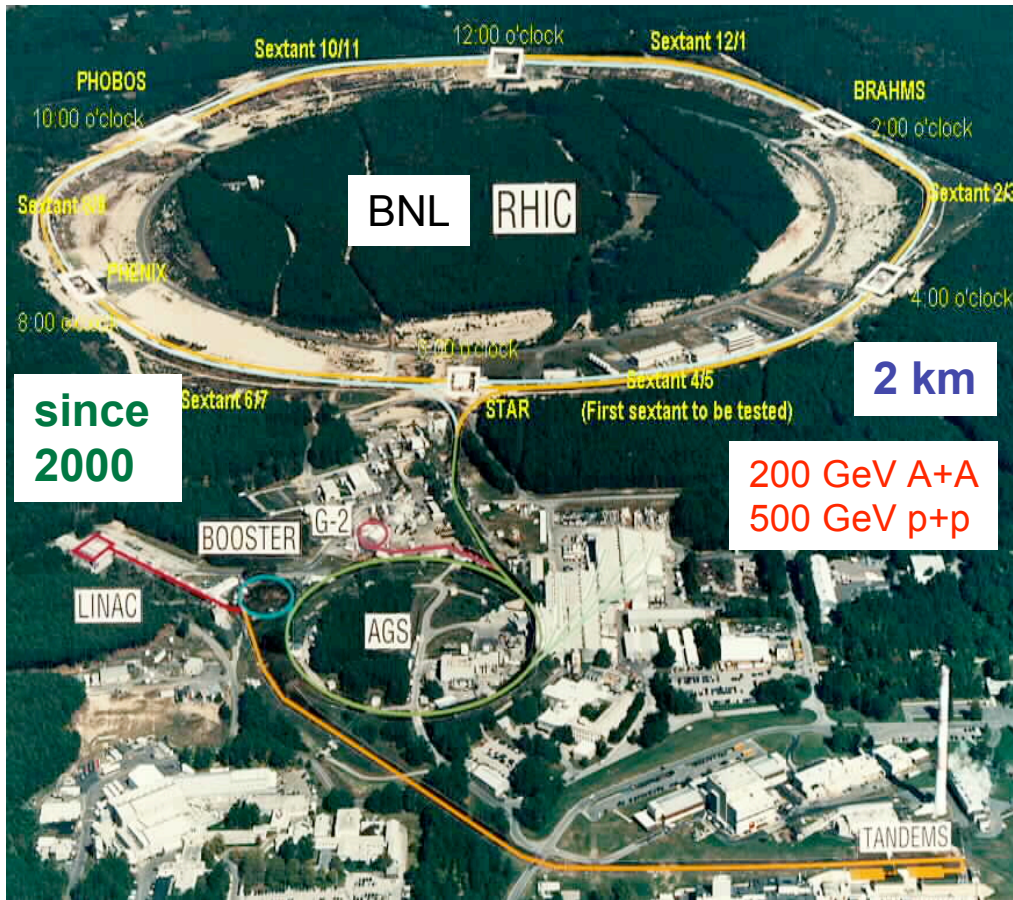

ATLAS Heavy Ion Physics Program

Nathan Grau,
Columbia University, Nevis Labs
for the ATLAS Collaboration




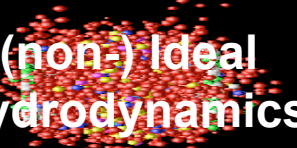



From the Present to the Future of Relativistic Heavy Ion Collisions



Heavy Ion Collision Evolution



	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	$\frac{d^3 N}{d\eta d\phi dp_T}$	3+1D Hydro Initial conditions	Equation of State (Degrees of Freedom)
 Hadron Freezeout	Particle yields, correlations, fluctuations	Statistical models, Cluster models	Hadronization



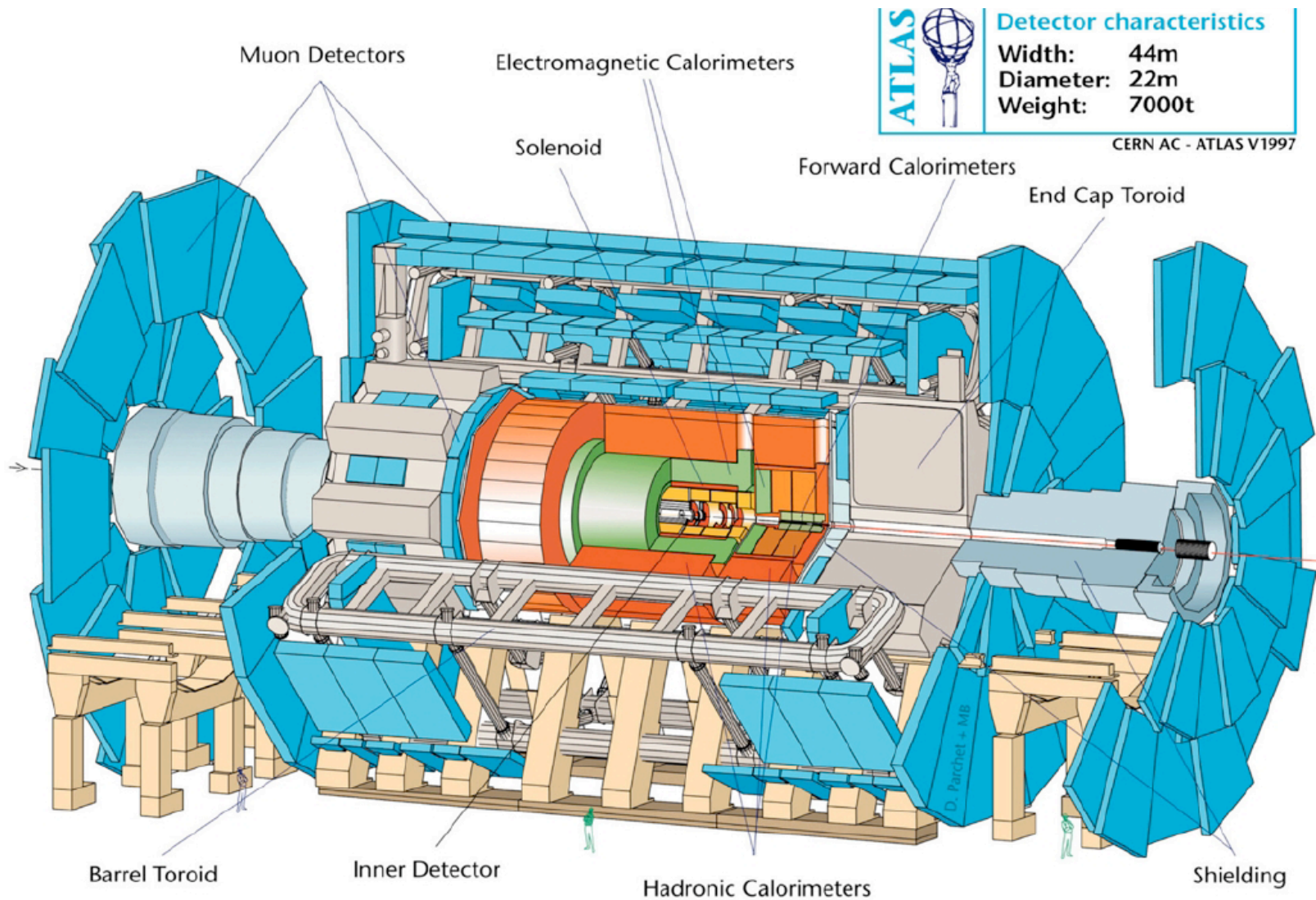
Heavy Ion Collision Evolution



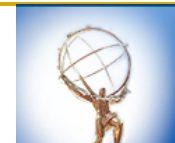
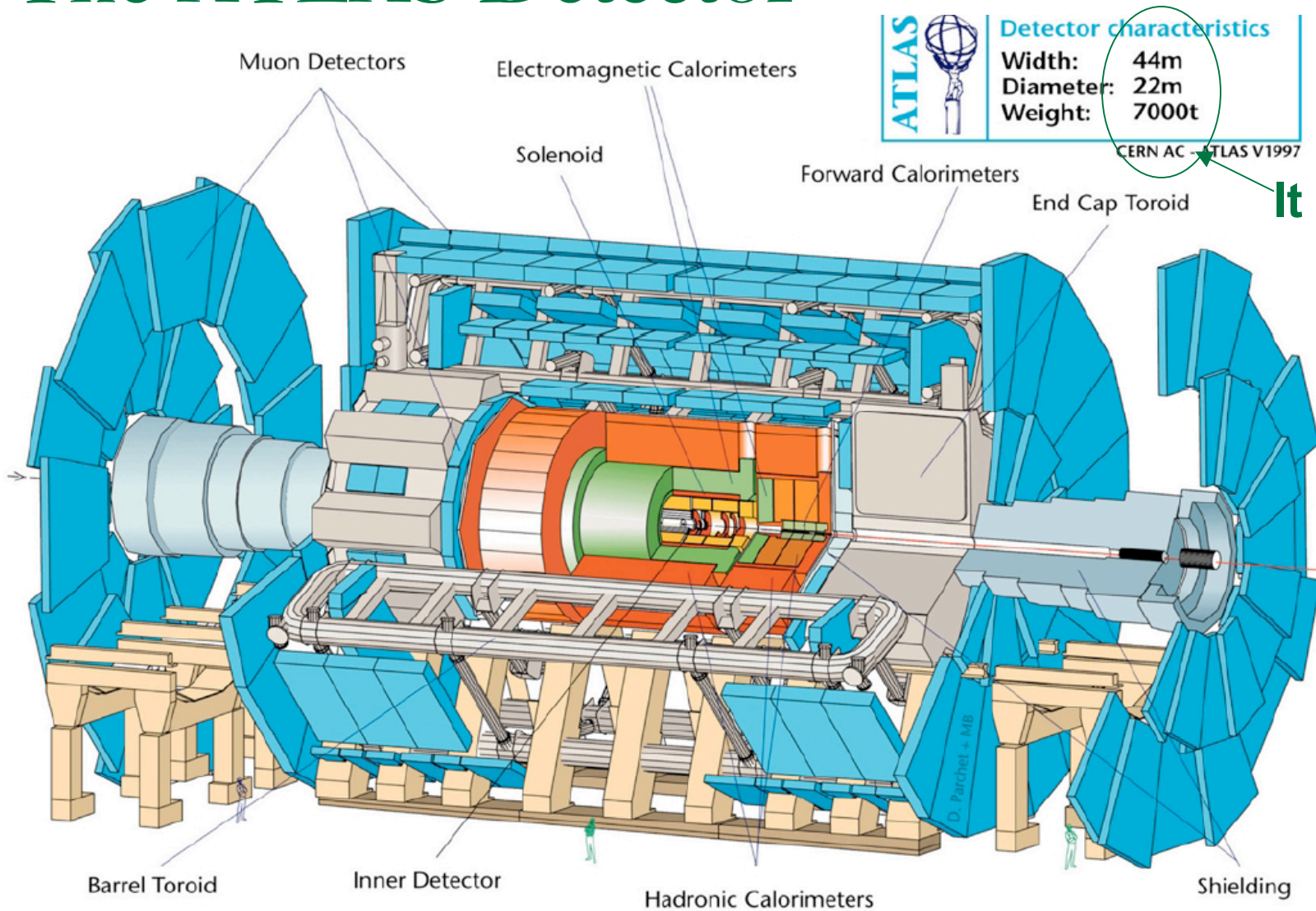
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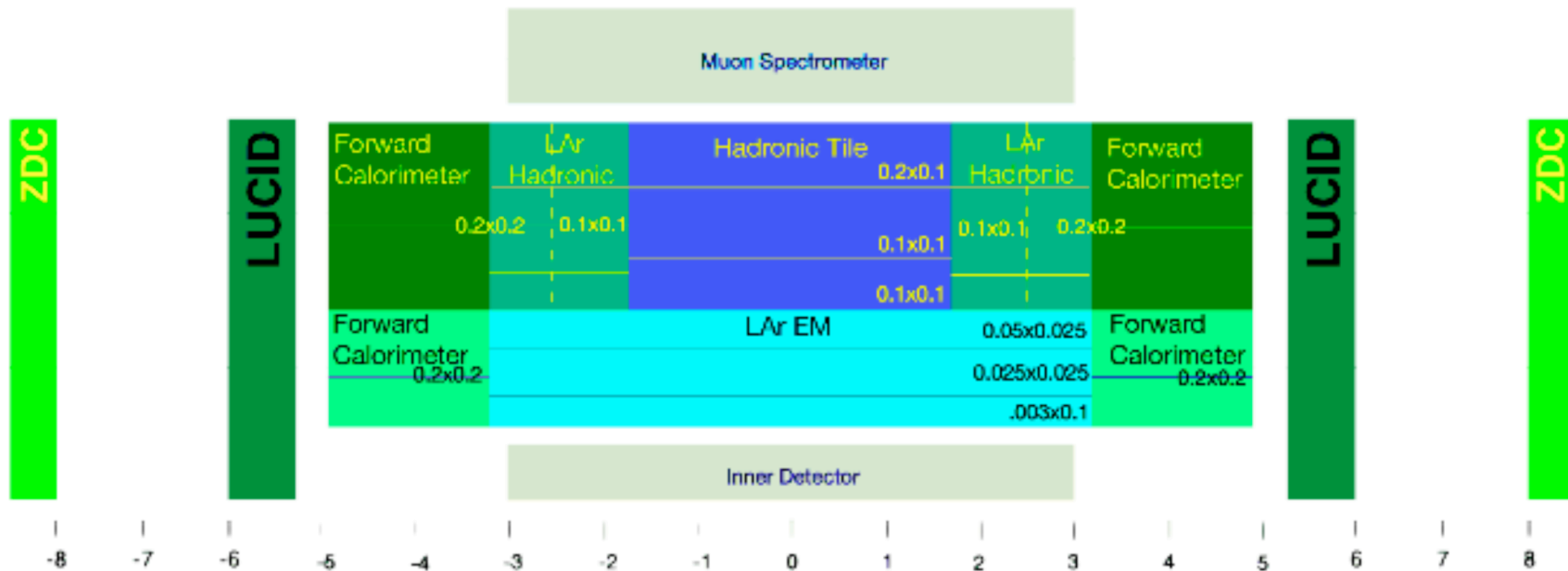
The ATLAS Detector



The ATLAS Detector



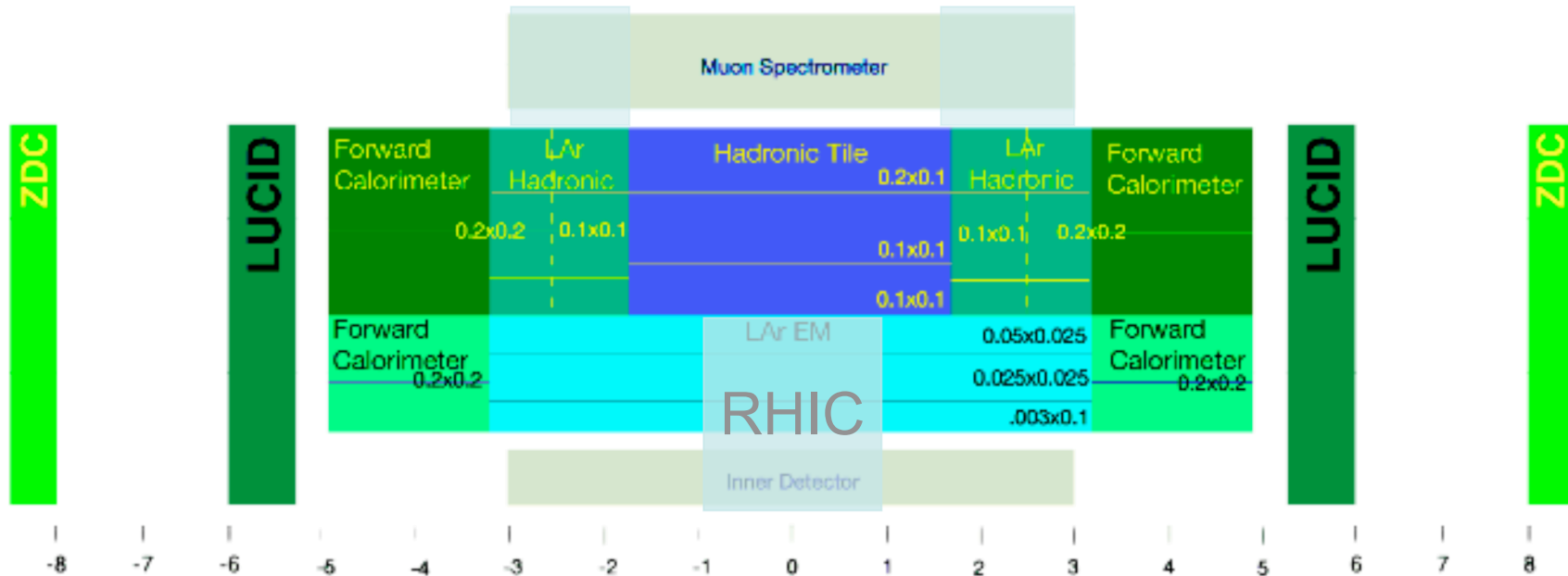
The ATLAS Detector: Coverage



- Unprecedented coverage for RHI
 - ❑ Tracking: 5 units ($|\eta| < 2.5$)
 - ❑ Hadronic and Electromagnetic Calorimetry: 10 units ($|\eta| < 5$)
 - ❑ Muons: 5 units ($|\eta| < 2.5$)
 - ❑ ZDC: at $|\eta| > 8$ units



The ATLAS Detector: Coverage

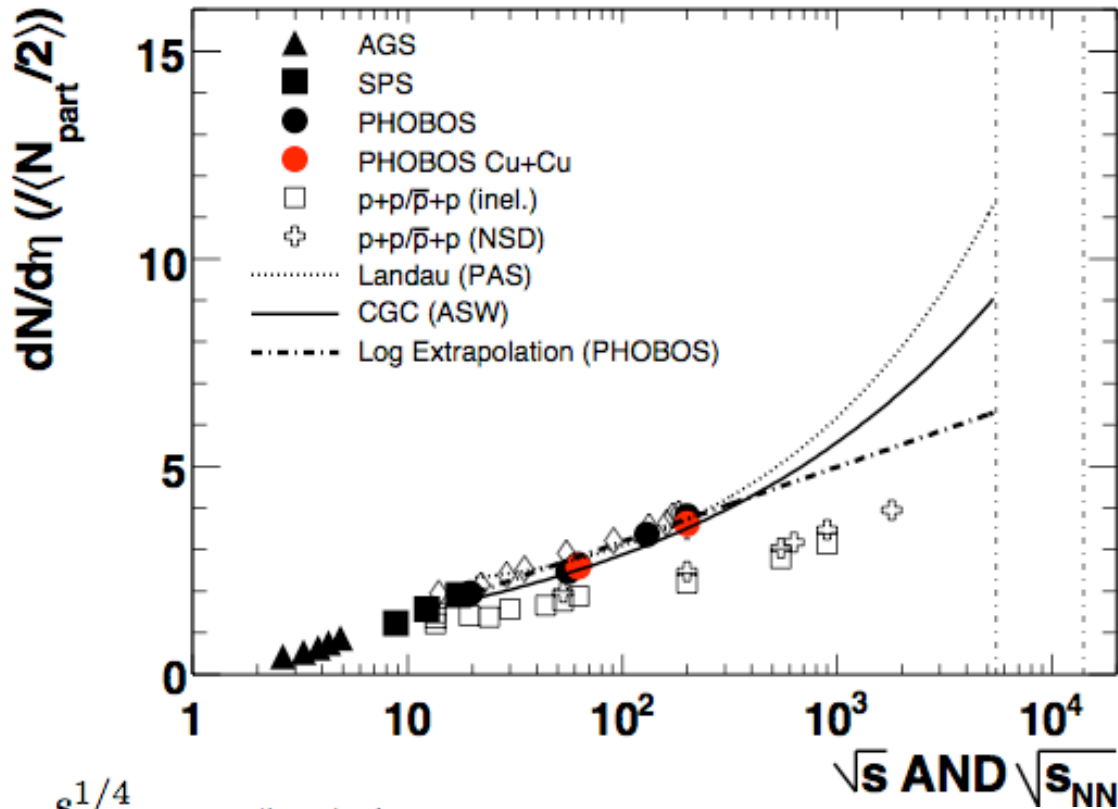


- Unprecedented coverage for RHI

- Tracking: 5 units ($|\eta| < 2.5$)
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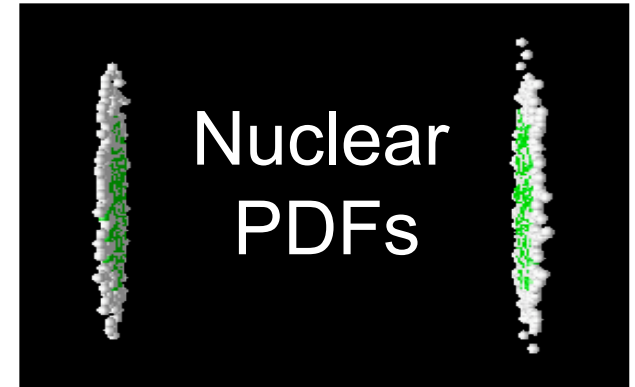
Global Physics: Particle Multiplicity



$s^{1/4}$
 $\frac{s^{1/4}}{\sqrt{\ln s}}$ 'Landau'
 (Carruthers 1974)

$\ln s$ Busza/PHOBOS:
 PRC 74 021901

$s^{0.144}$ CGC:
 arXiv:0707.0564



- Particle multiplicity sensitive to gluon saturation at low x
- Will add a data point at 5.5 TeV with ~few days of running

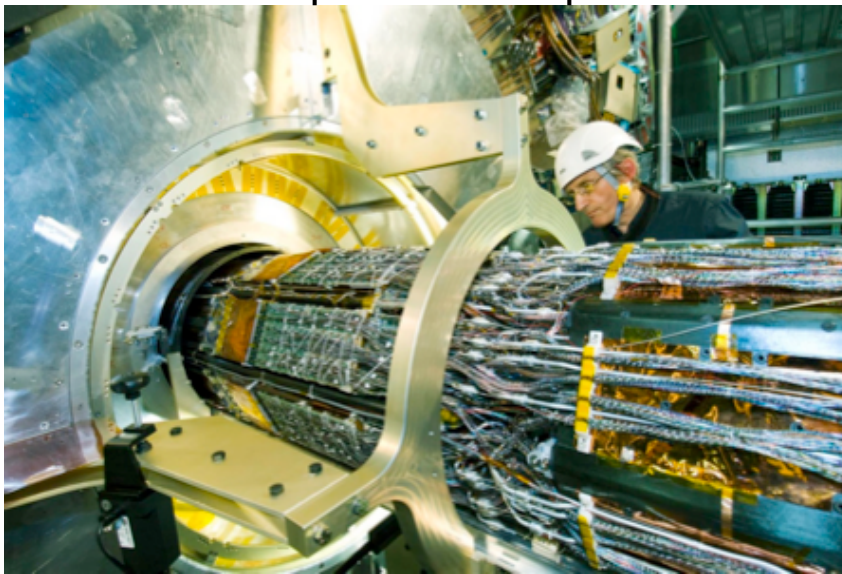


Inner Tracking

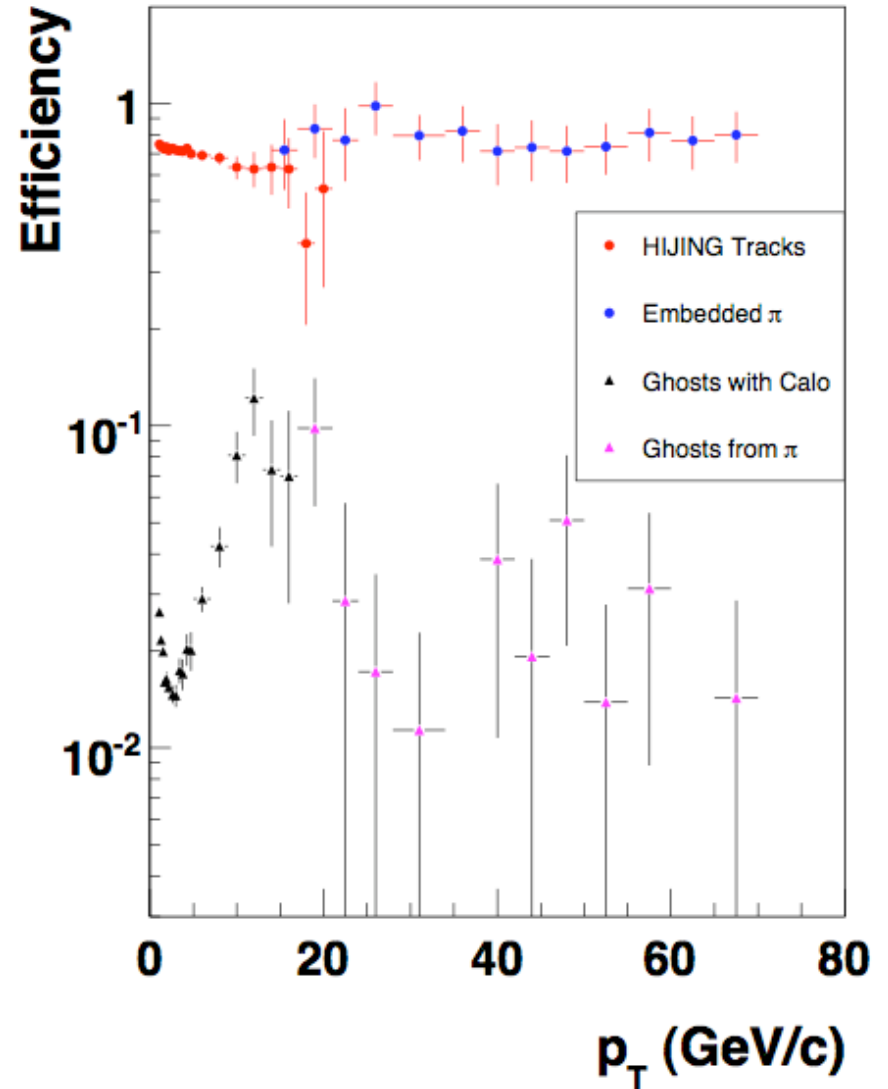
■ Tracking

- 3 pixel layers
- 4 double-sided strips
- 2 T solenoidal field

pixel and strip installation

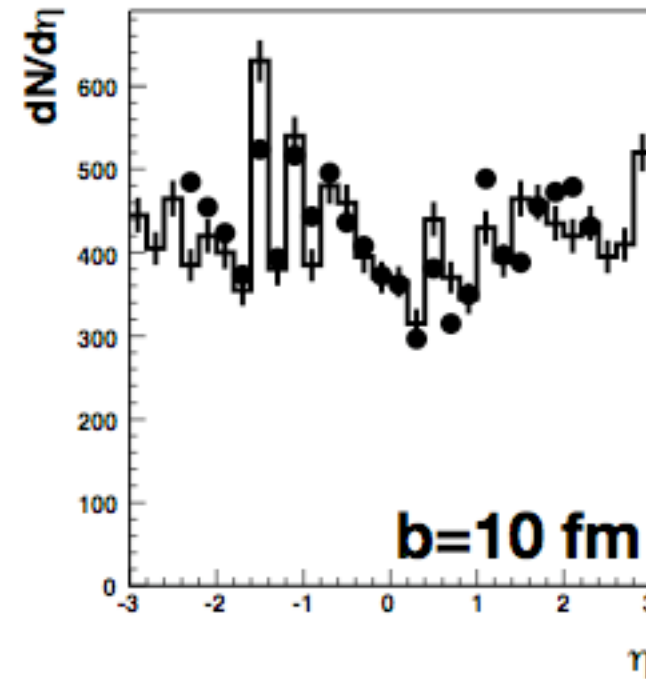
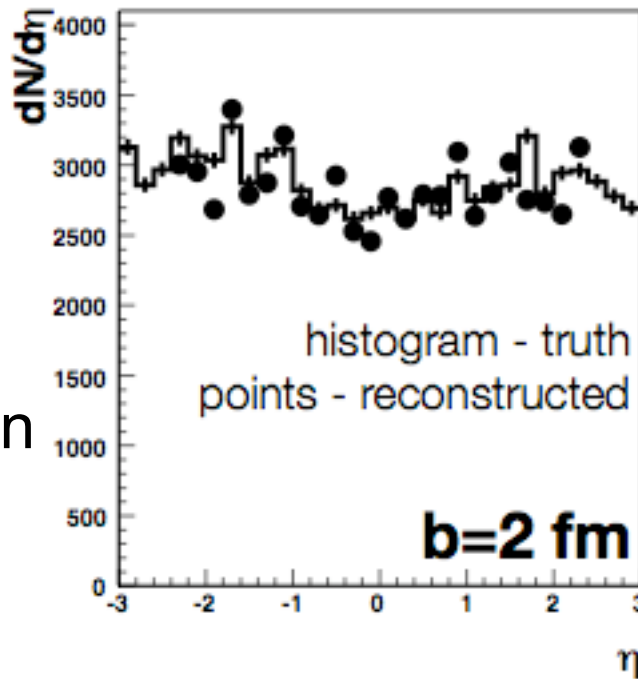


Track Reconstruction



Reconstructing Simulated Multiplicity

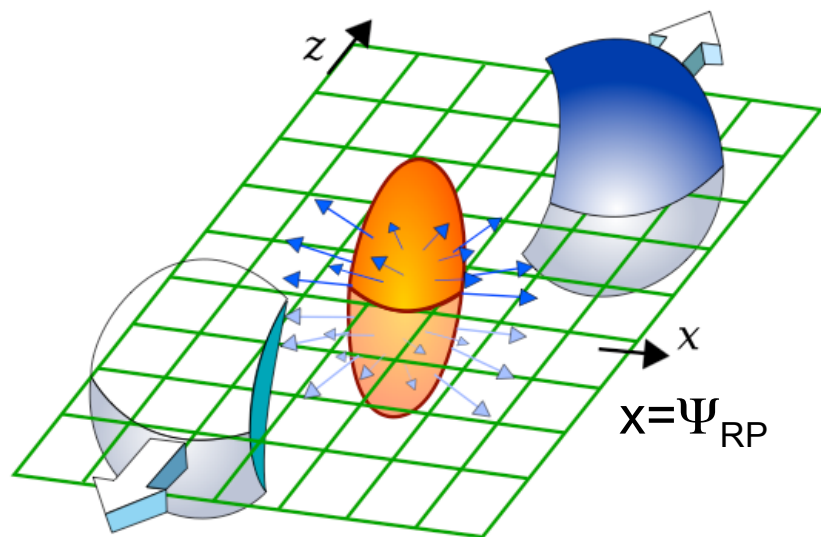
Single
event
HIJING
simulation



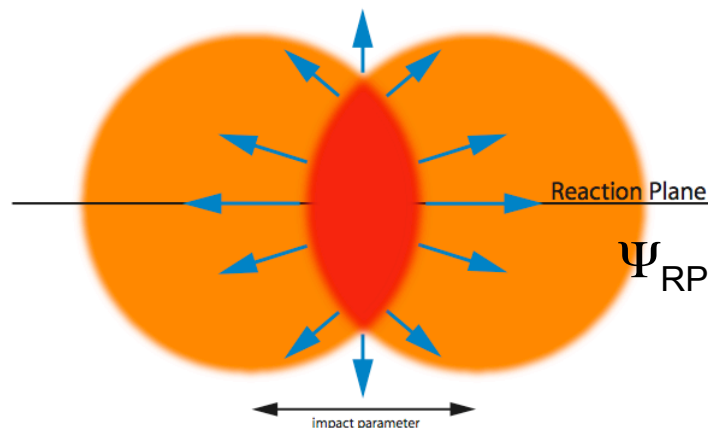
- Using η -dependent corrections from simulation obtain $dN/d\eta$ event-by-event!



Global Physics: Anisotropic Flow

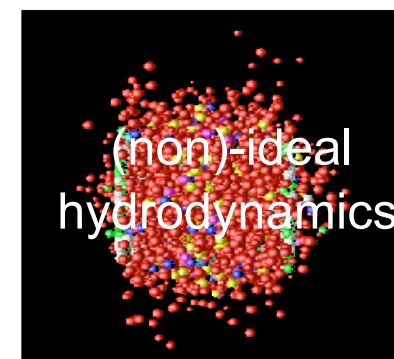


Pressure
gradient:
spatial \longrightarrow
momentum
anisotropy

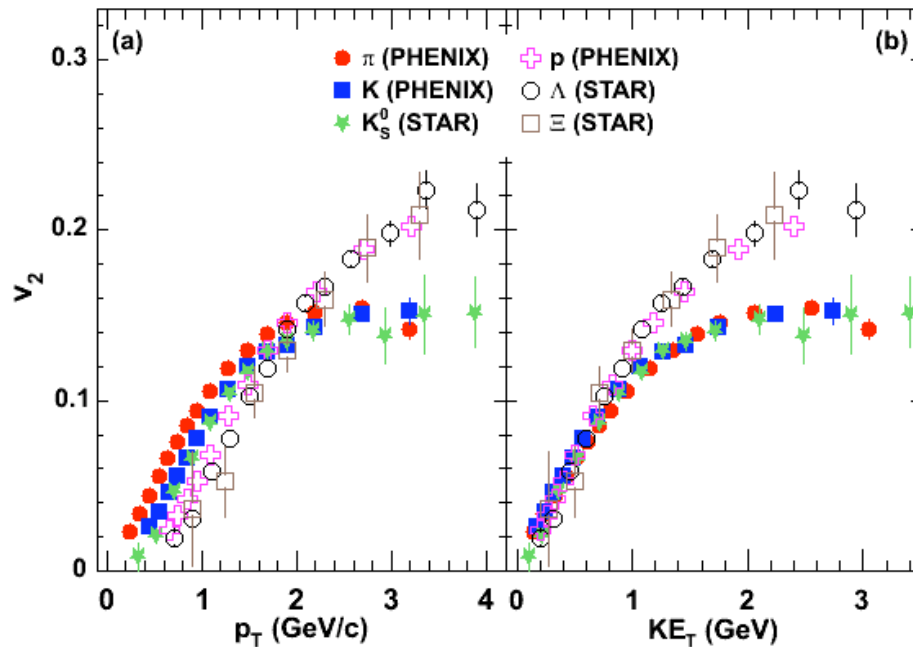


$$\frac{d^2 N}{dp_T d\phi} = \frac{1}{2\pi} \frac{dN}{dp_T} \left(1 + 2v_2(p_T) \cos[2(\phi - \Psi_{RP})] + \dots \right)$$

v_2 related to equation of state



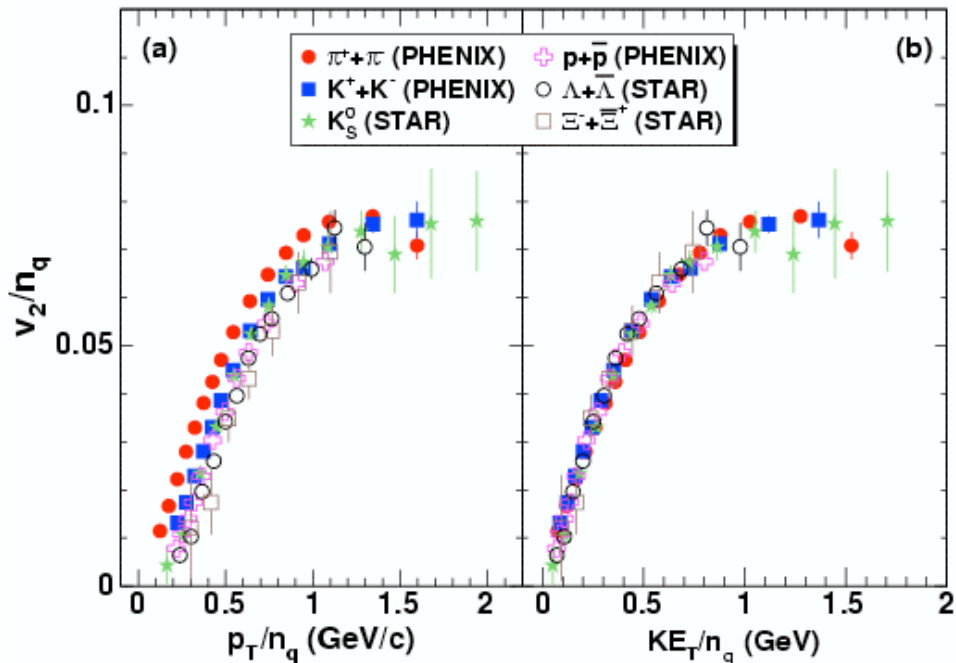
Flow at RHIC: Perfect Fluid



- Hydrodynamic (with 0 viscosity) scaling observed for **all** identified particles at RHIC



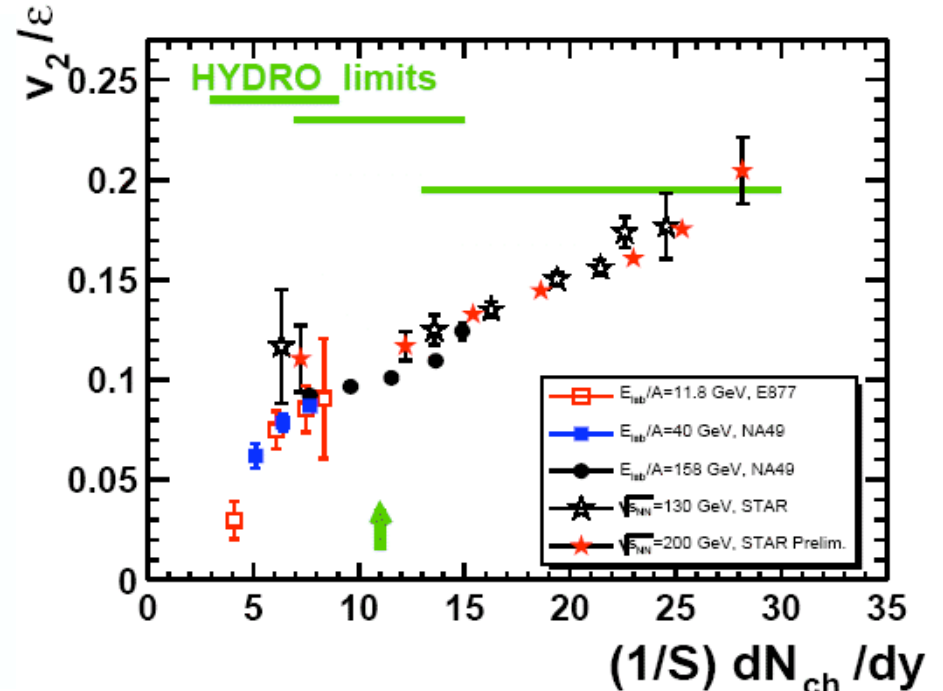
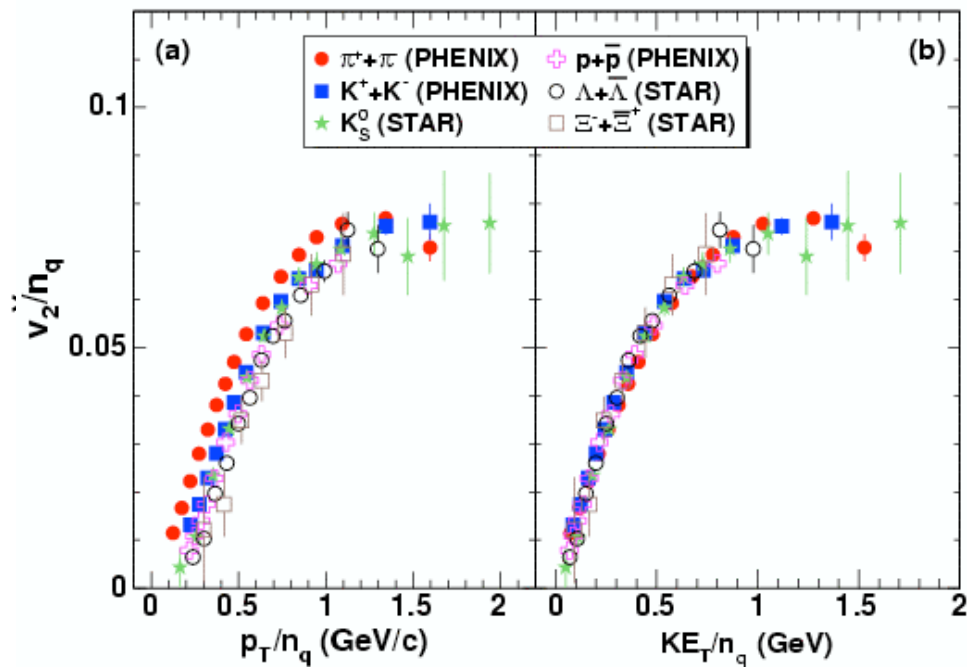
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- Hydrodynamic (with 0 viscosity) scaling observed for **all** identified particles at RHIC
- Quark constituent scaling implies a single quark-level flow



Flow at RHIC: Perfect Fluid

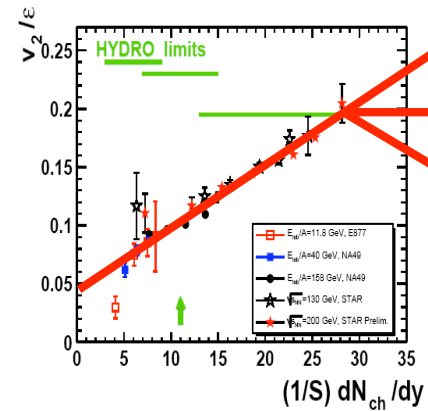


- Hydrodynamic (with 0 viscosity) scaling observed for **all** identified particles at RHIC
- Quark constituent scaling implies a single quark-level flow

- Hydrodynamic (with 0 viscosity) limit observed at RHIC?
- 0 viscosity == “Perfect fluid”



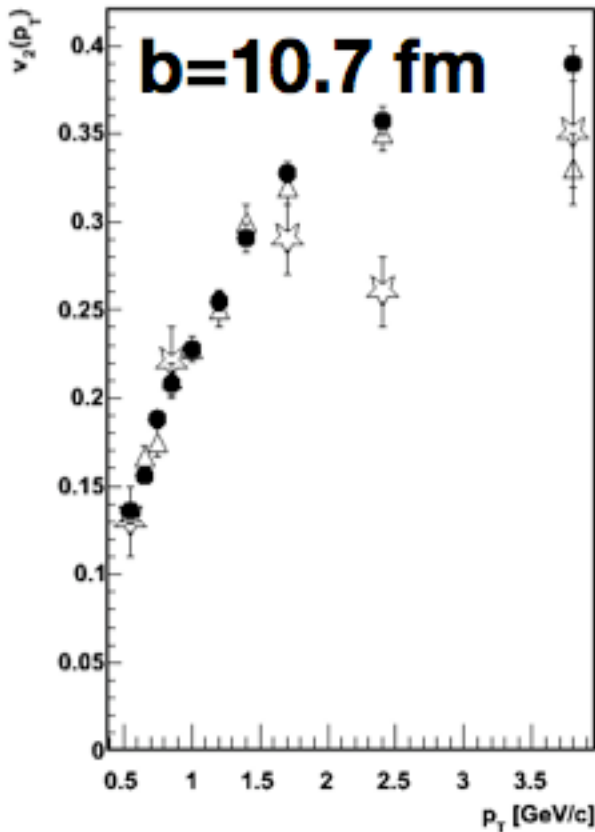
Flow at the LHC: More Perfect Fluid?



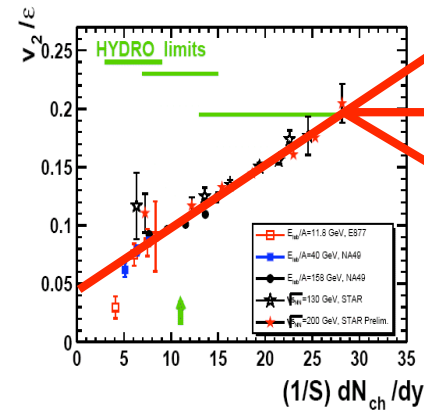
- At LHC does v_2
 - Rise like the data?
 - Flatten like the hydro limit?
 - Decrease because viscosity or hydro limit decrease?



Flow at the LHC: More Perfect Fluid?



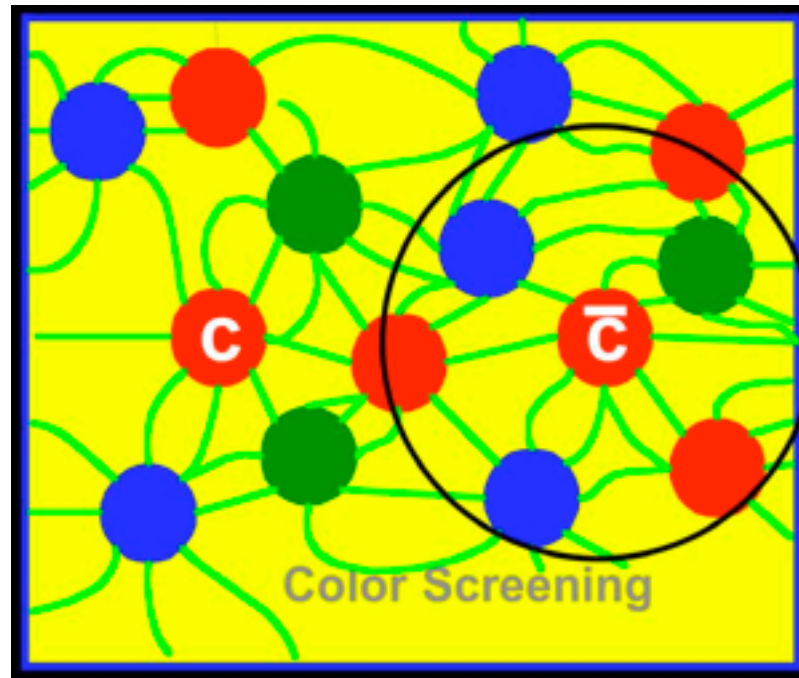
← modified HIJING
 ← v_2 from 2P corr.
 ← v_2 from RP method



- At LHC does v_2
 - Rise like the data?
 - Flatten like the hydro limit?
 - Decrease because viscosity or hydro limit decrease?



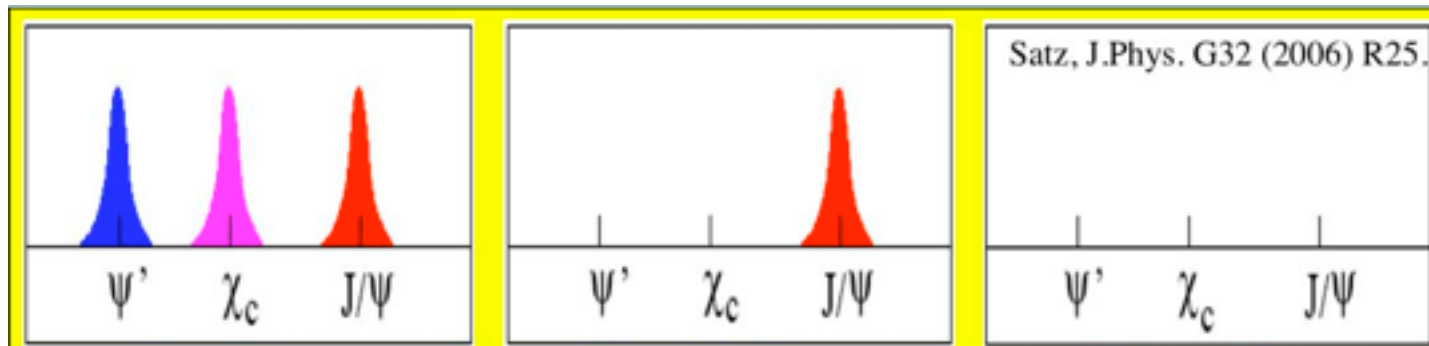
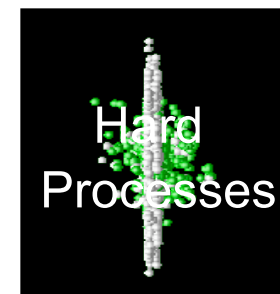
Hard Processes: Quarkonia



- J/Ψ suppression because of color screening in deconfined medium



Quarkonia Melting

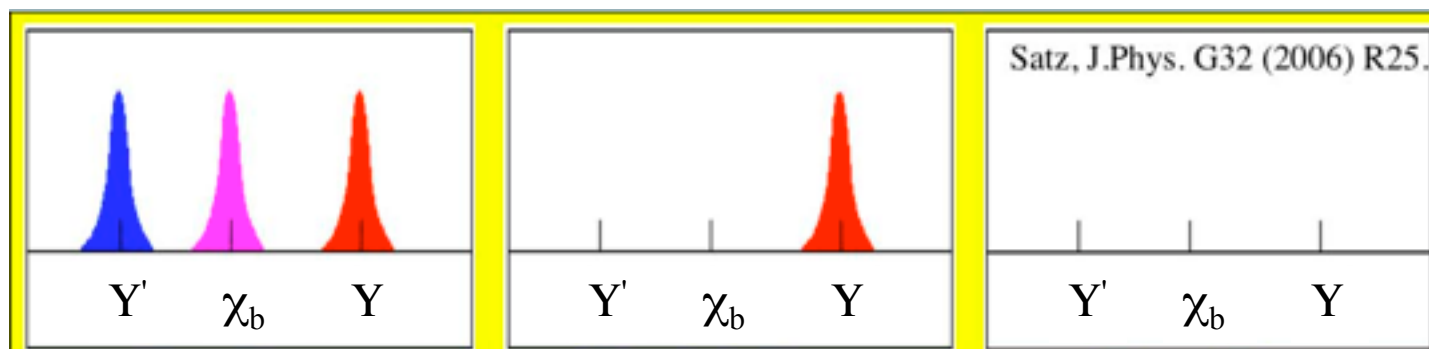


$$T < T_C$$

$$T \sim T_C$$

$$T > 1.2 T_C$$

- Sequence of states melt at different temperatures
- Bottom melts later than charm



$$T < T_C$$

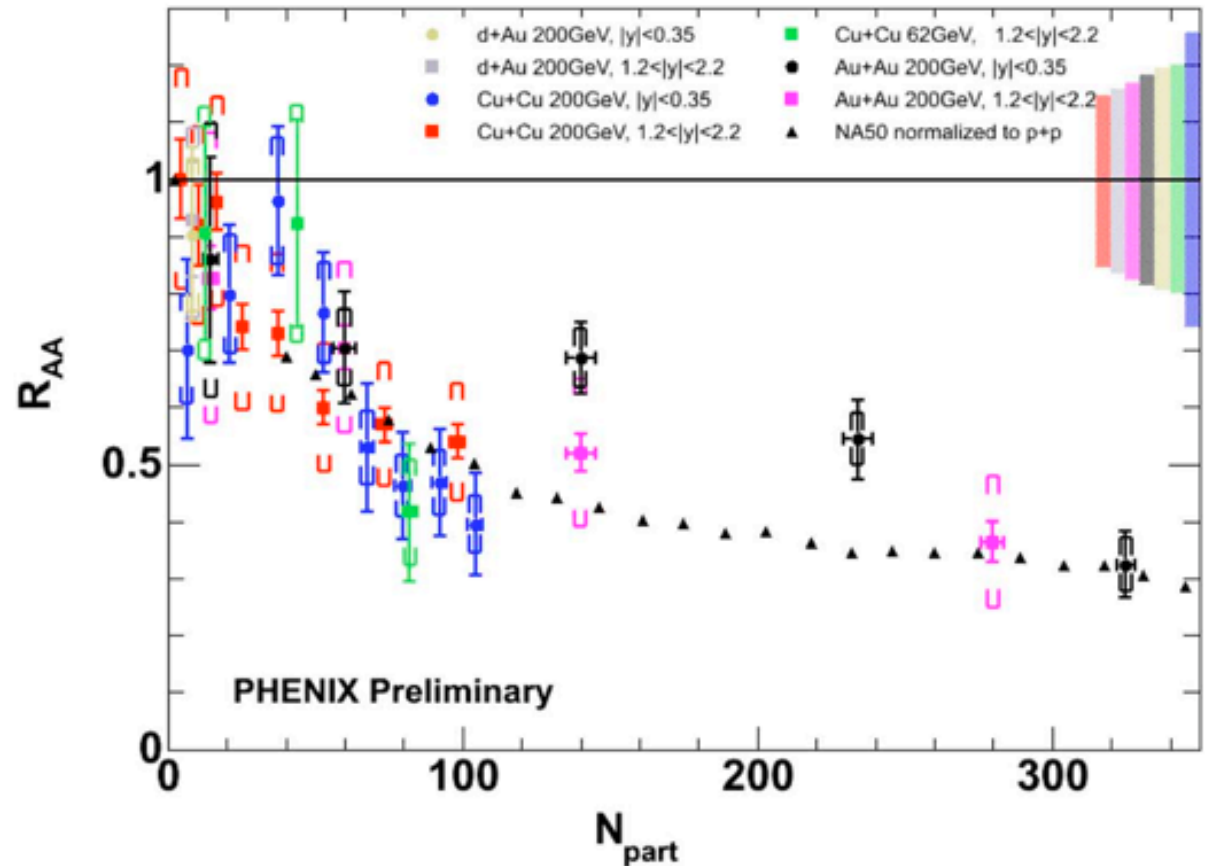
$$T \sim 1.3 T_C$$

$$T > 2 T_C$$



Quarkonia at RHIC

- J/ψ suppression RHIC ~ SPS
 - Regeneration?
 - Not color screening?
 - Need χ_C or bottomonium measurements
 - ...



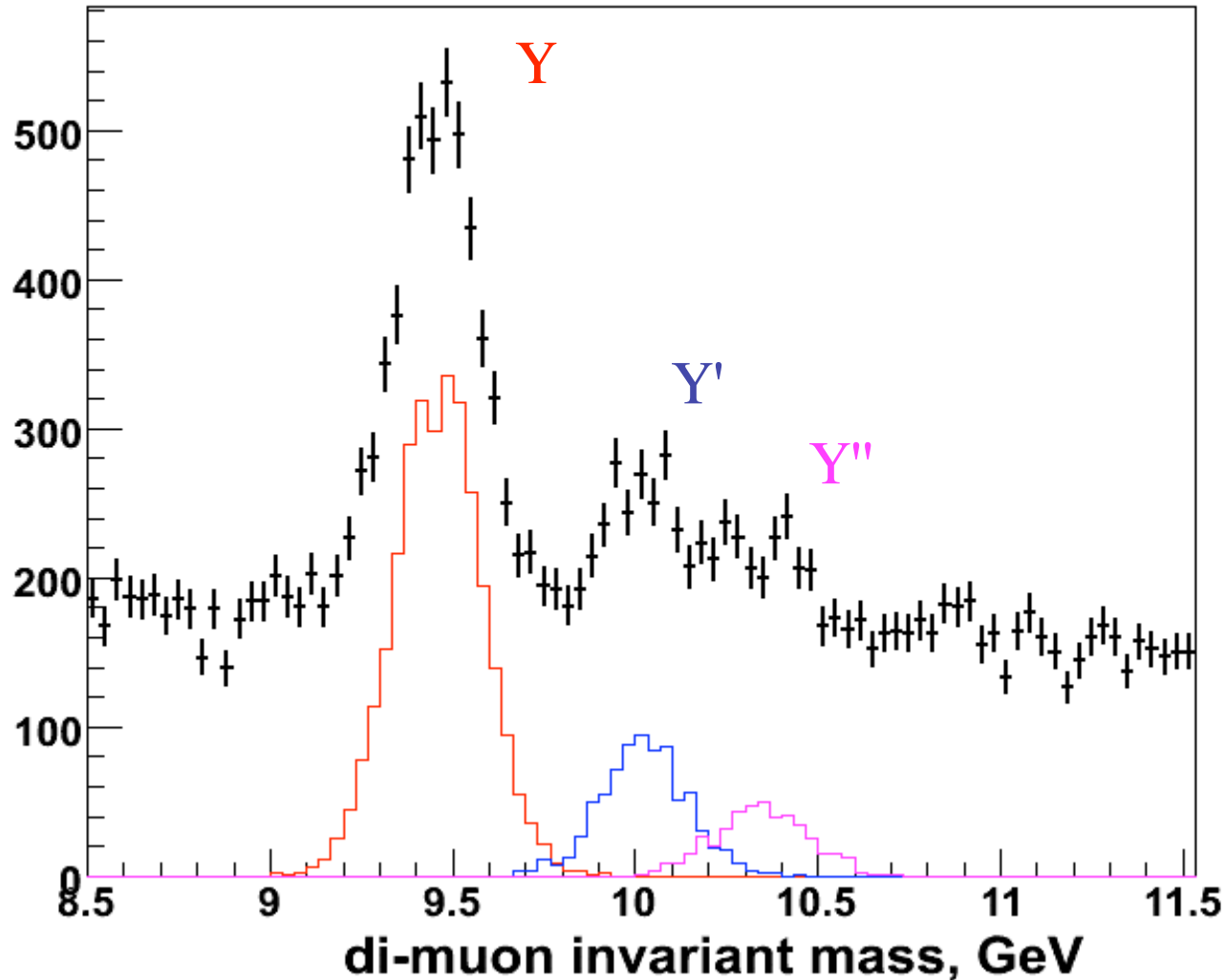
$$R_{AA} = \frac{A + A \text{ Yield}}{\langle N_{coll} \rangle p + p \text{ Yield}}$$



Quarkonia from Muons in ATLAS



Quarkonia from Muons in ATLAS

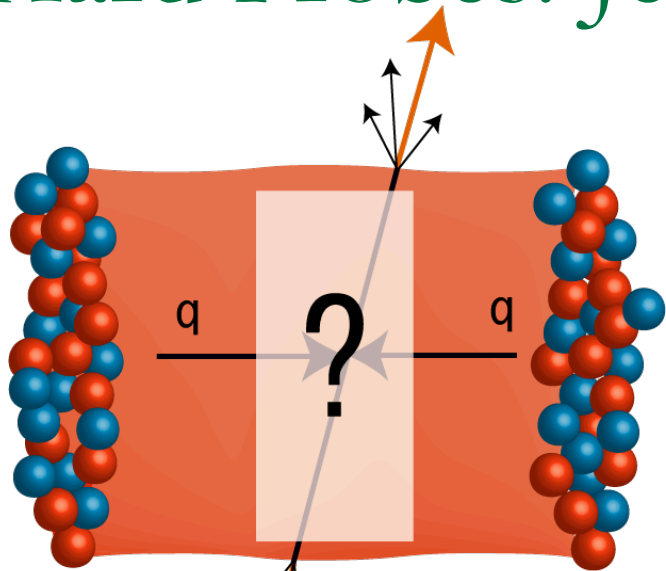


- Estimate of signal and background for Y states for typical LHC year
- With judicious cuts all 3 states accessible!

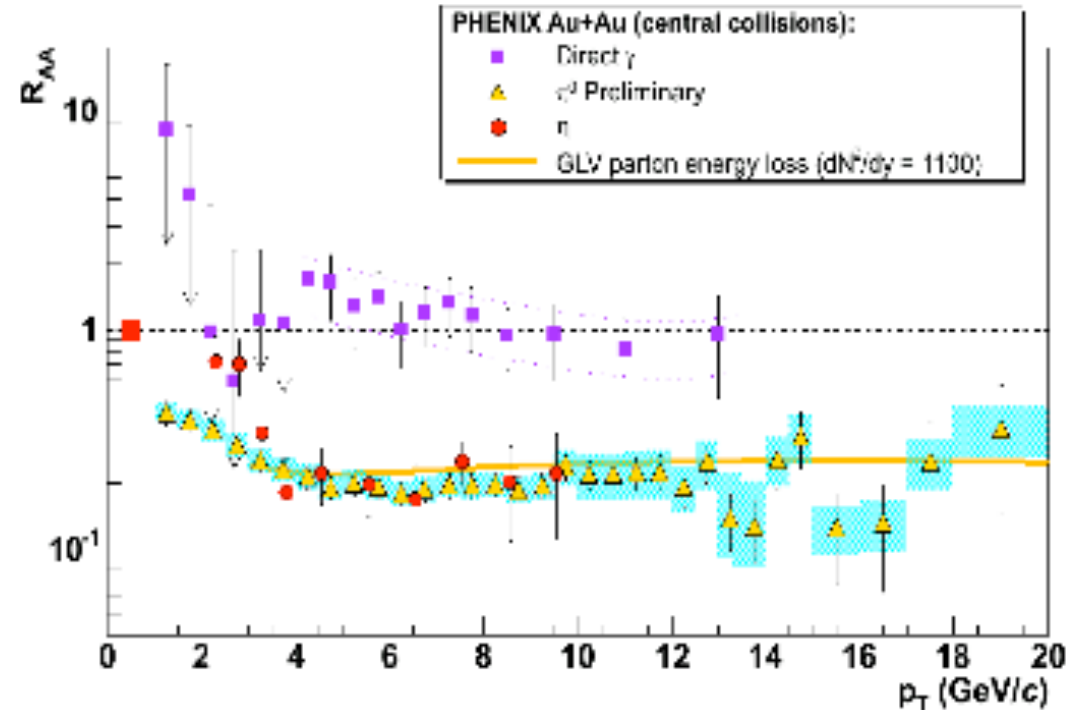


Hard Probes: Jets and Photons

Hard Processes



$$R_{AA} = \frac{A + A \text{ Yield}}{\langle N_{coll} \rangle p + p \text{ Yield}}$$

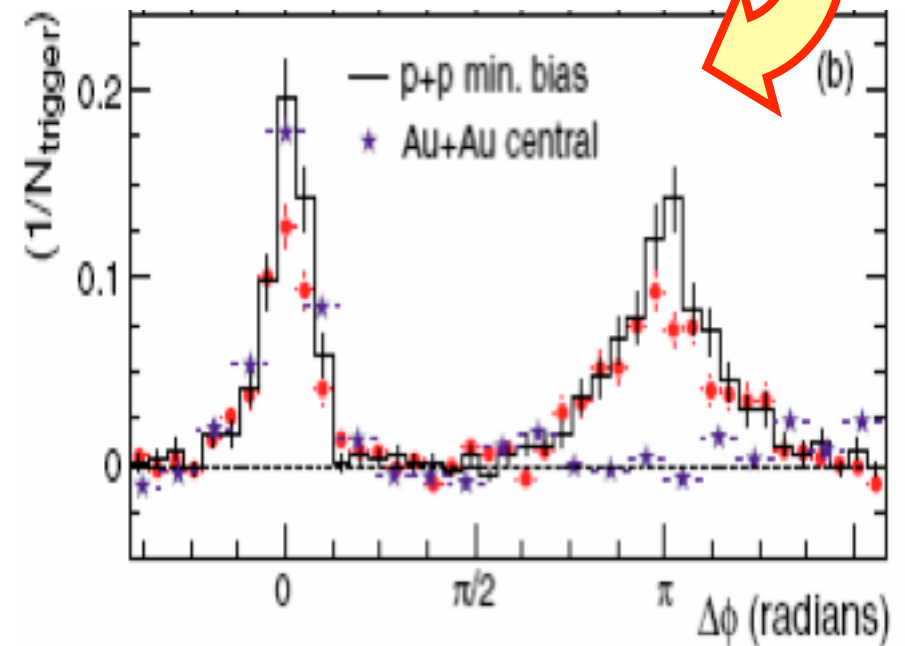
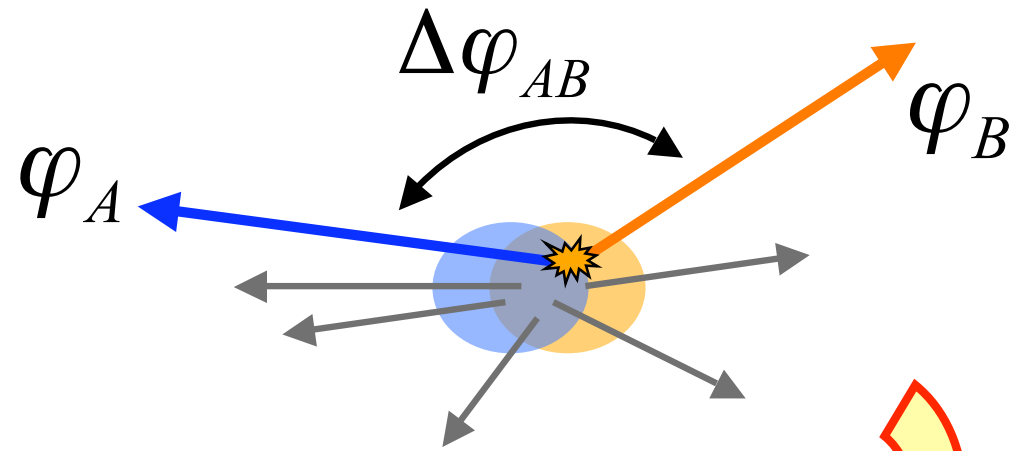


- Photons not suppressed, not strongly interacting
- Single high- p_T highly suppressed: jet quenching

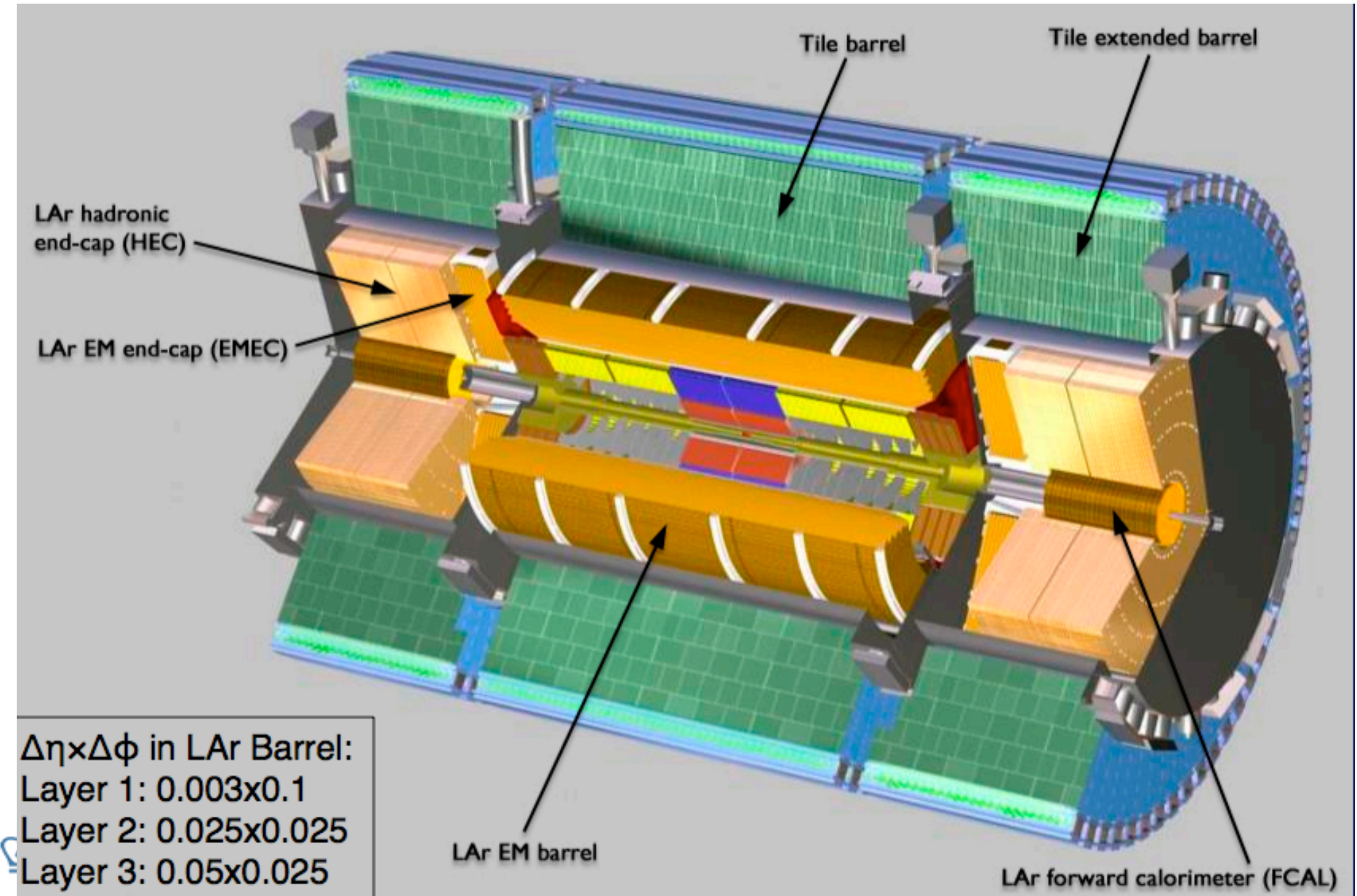


Jets at RHIC

- Direct jet reconstruction not currently possible
- Perform 2-particle correlations at high- p_T
- Recoil jet ($\Delta\phi \sim \pi$) suppressed
- But ΔE biased
 - Surface biased, punch-through, tangential emission

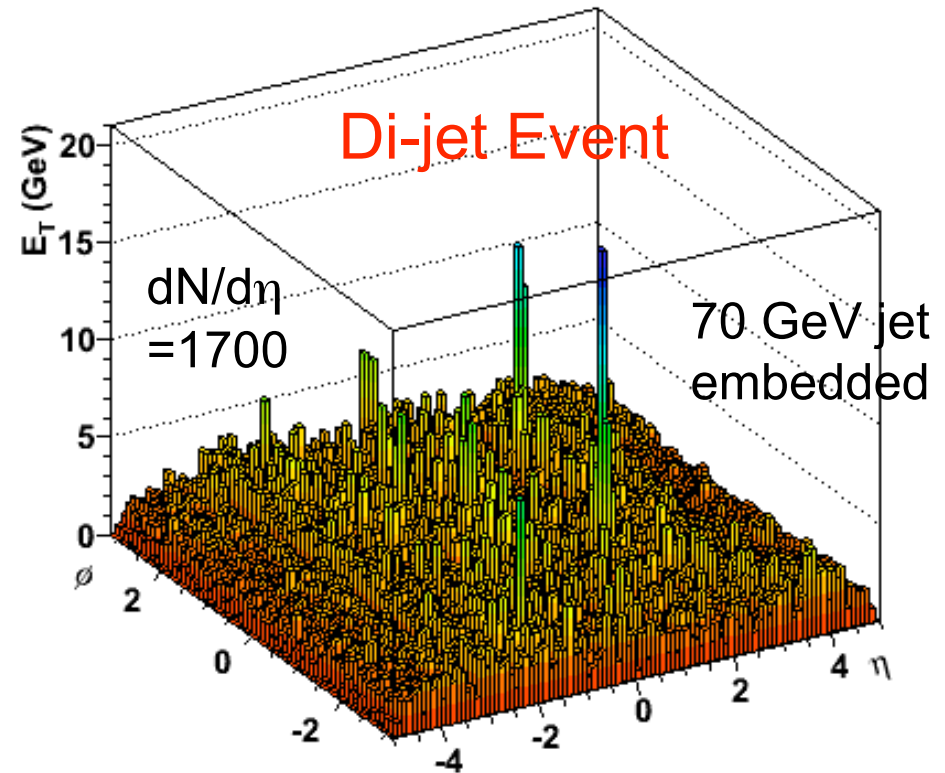


ATLAS Calorimeters



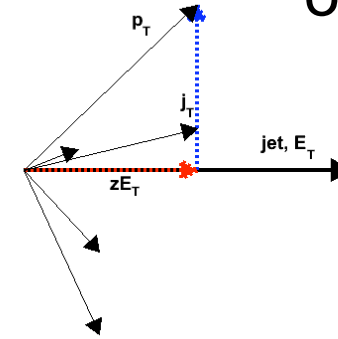
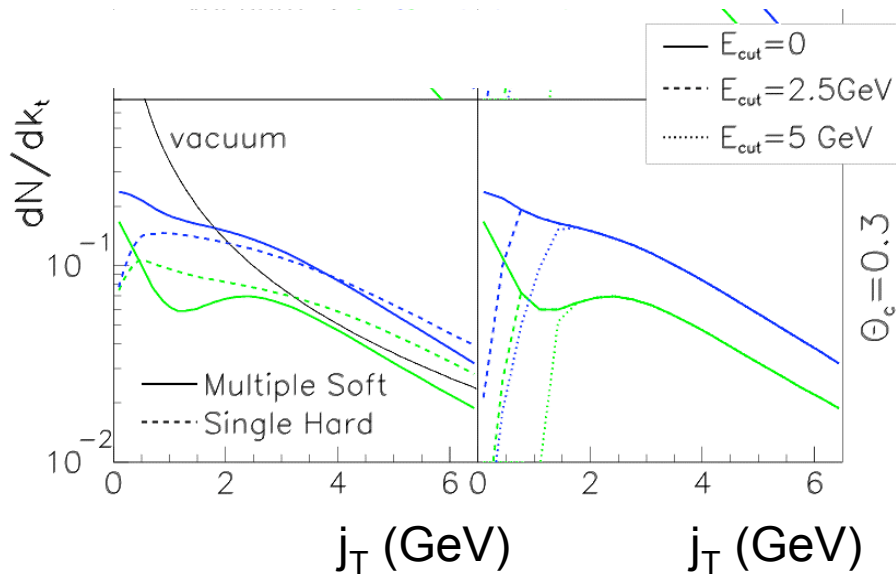
Jets at the LHC

- Large rates of jets at the LHC
 - Expect few 10^7 jets/year with $E_T > 50$ GeV
- High- E_T jets stick out above the background
- Full jet reconstruction less susceptible to ΔE bias

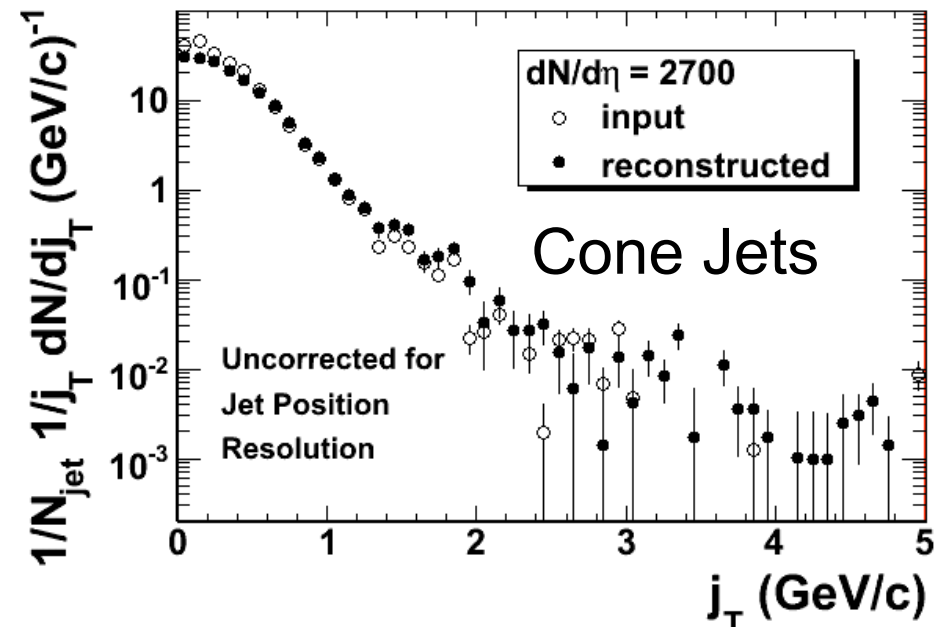


Studying Energy Loss: j_T

Fragmentation of a jet

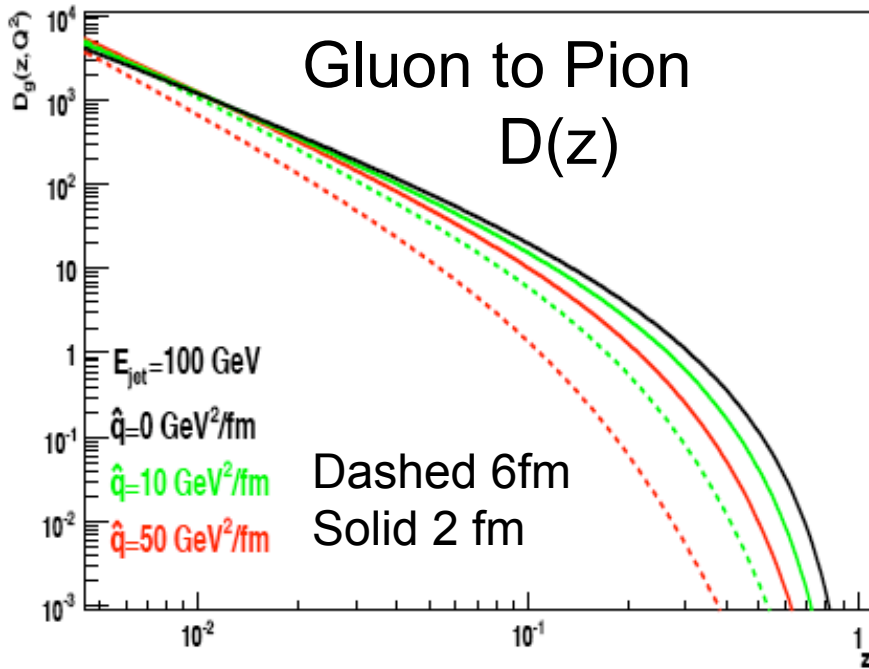


- j_T shape sensitive to energy loss of the jet

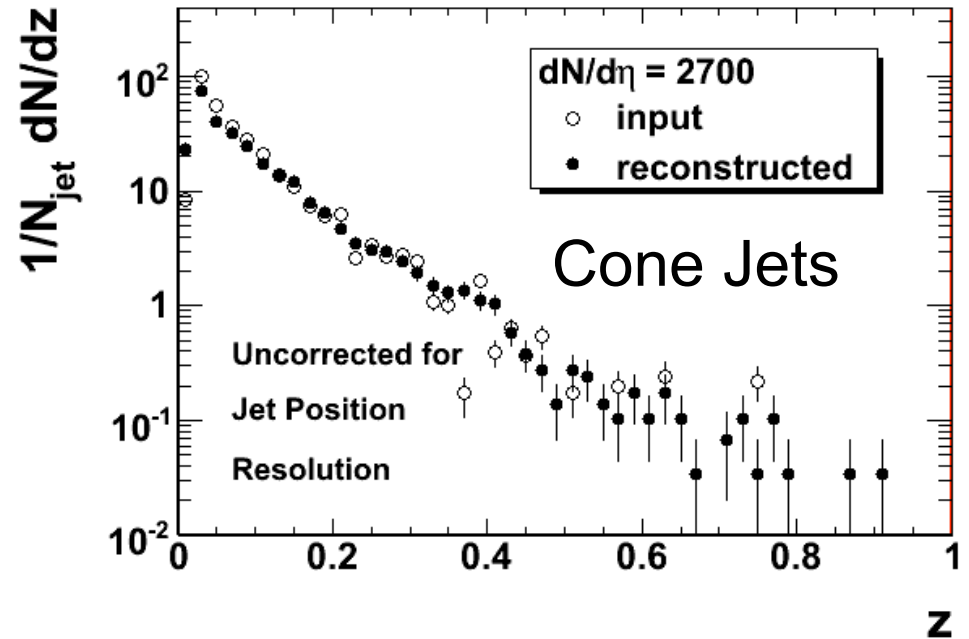
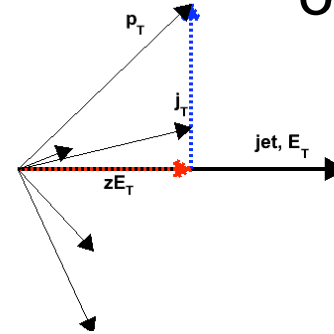


Studying Energy Loss: $D(z)$

Fragmentation
of a jet

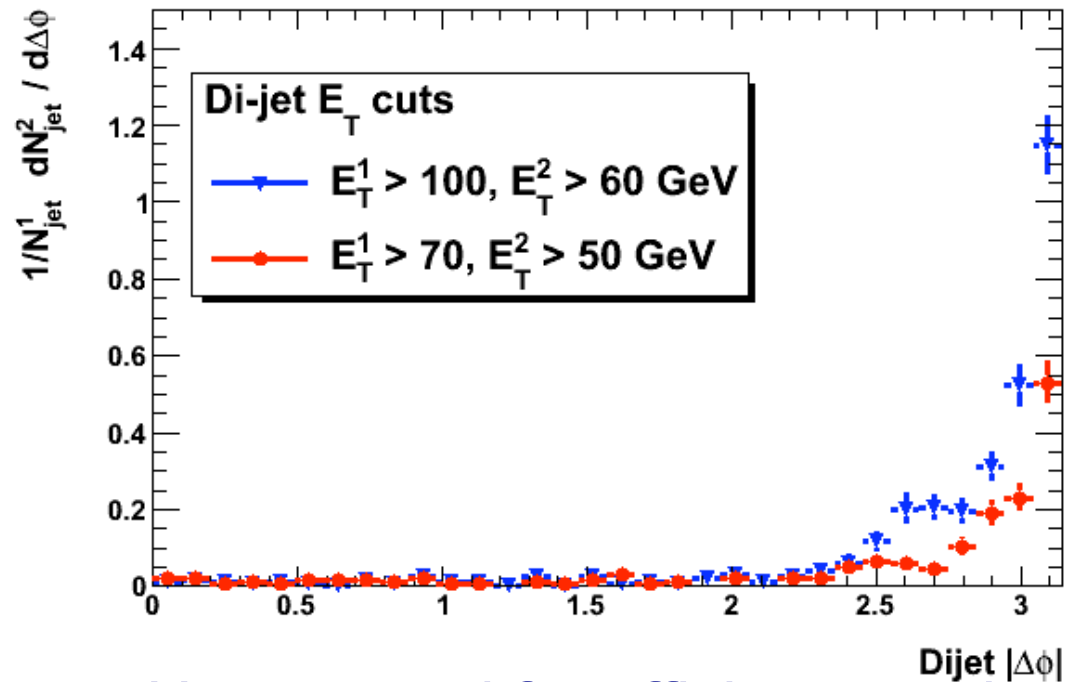


- $D(z)$ shape sensitive to energy loss



Studying Energy Loss: Di-jet Correlations

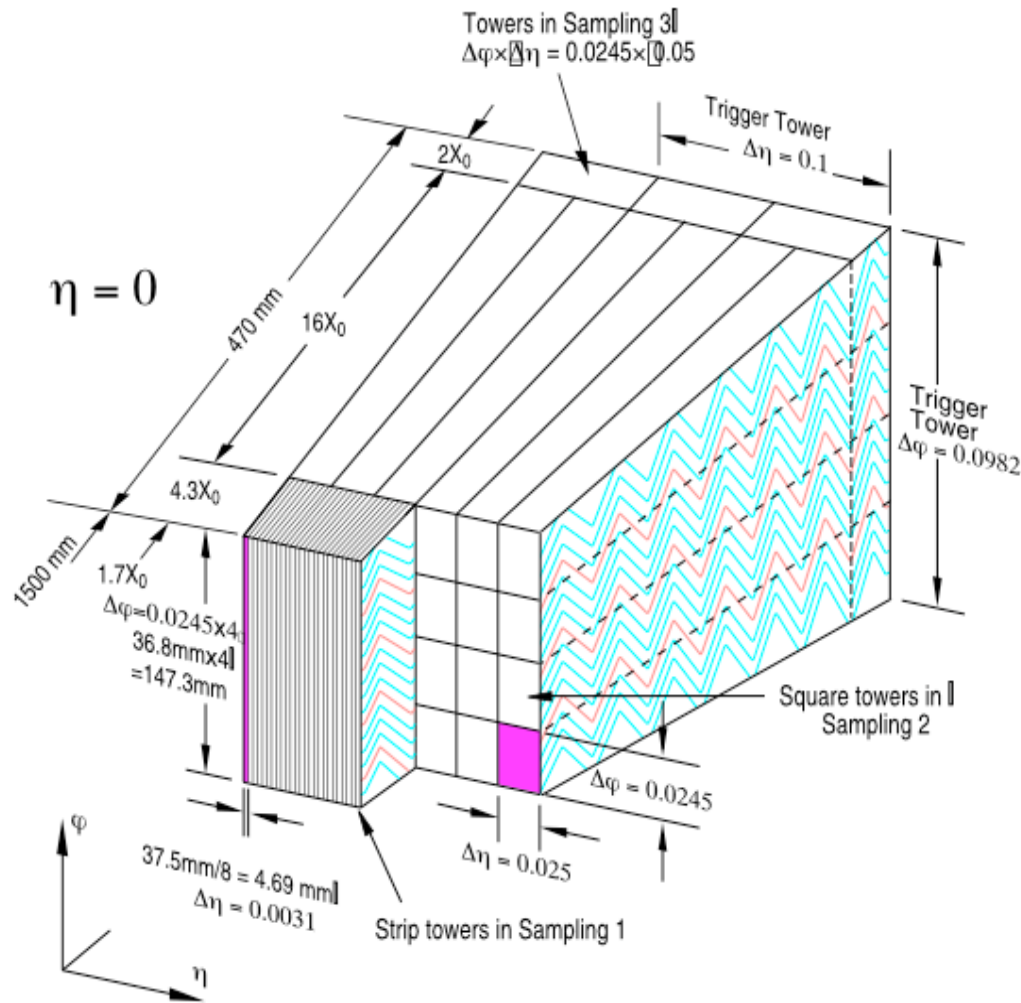
- Large acceptance + high resolution = di-jet studies
- Multiple scattering induces broader $|\Delta\phi|$ distribution



Uncorrected for efficiency and resolution



Detecting Direct Photons



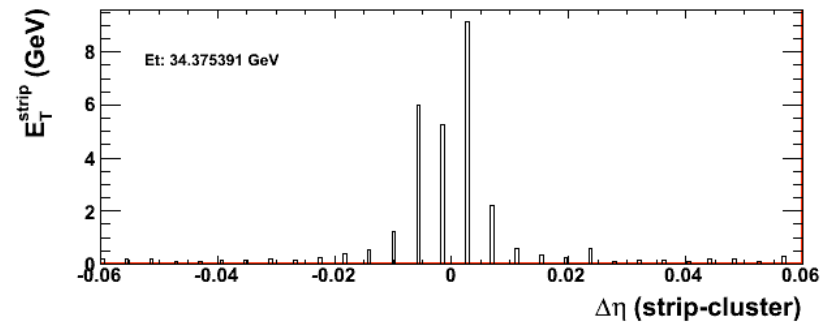
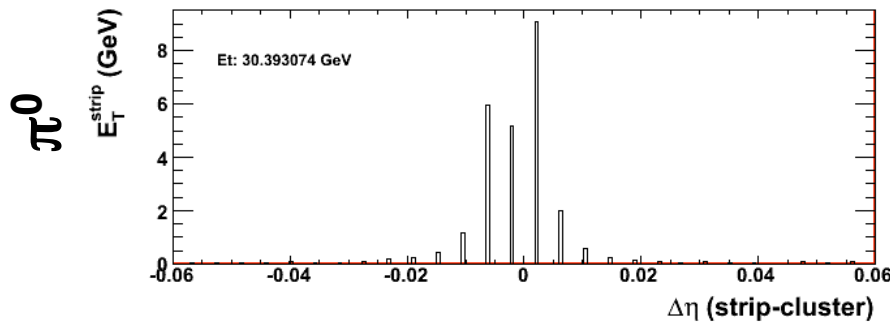
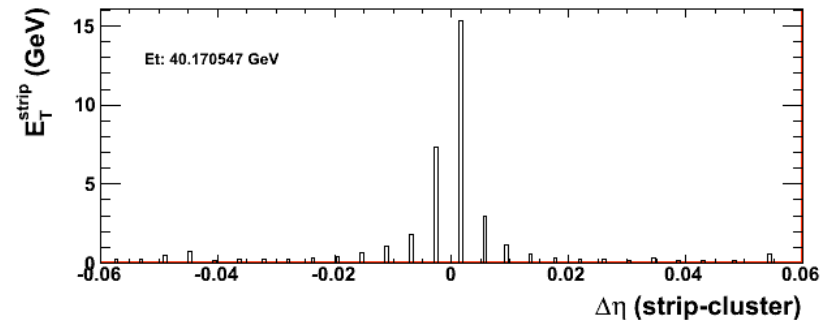
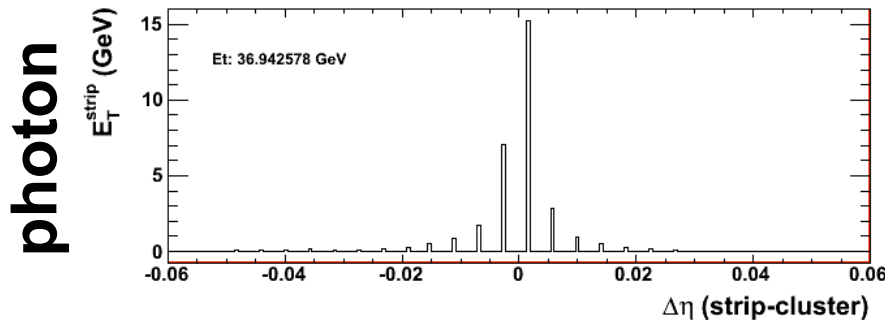
- Direct photons swamped by light meson decay
S/B ~ 0.01 at 100 GeV
- Design: Reject di-jets from $H \rightarrow \gamma\gamma$
- Front layer: strips
 - Typically 0.003×0.1 in $\Delta\eta \times \Delta\phi$
 - Over $|\eta| < 2.5$



Single Particles Detection with Strips

Single particle

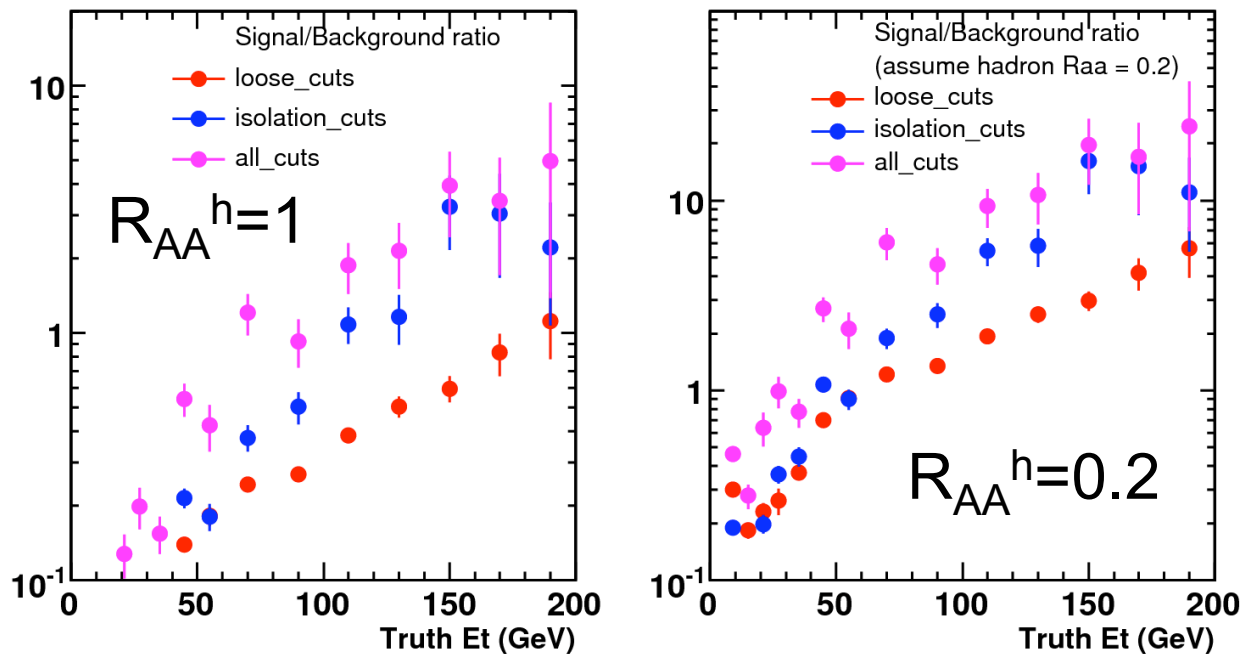
Embedded



- Excellent γ - π^0 separation
- Extremely low occupancy due to underlying event: energy in strips not disturbed.



γ S/B

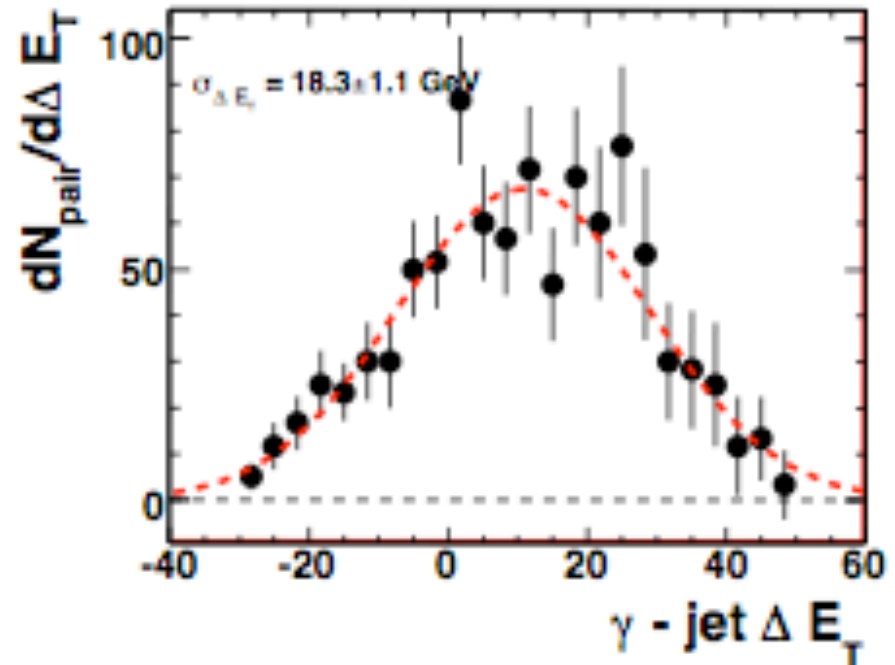
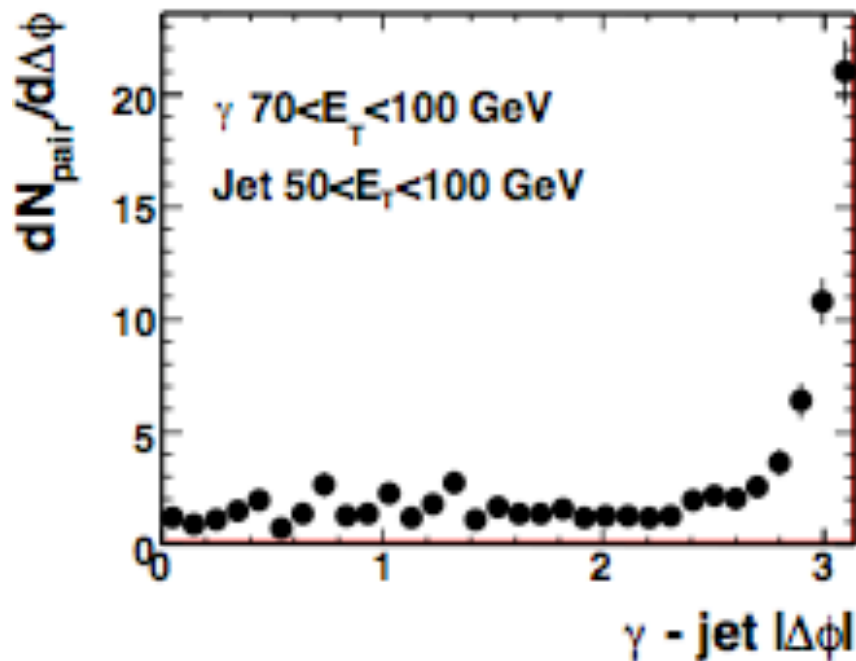


- Apply shower shape cuts from strip layer and isolation cuts using energy and tracks
- With highest efficiency cuts
 - $S/B > 1$ for 30 GeV assuming suppressed hadrons
 - Expect xxx photons in 1 LHC year above 30 GeV



γ -Jet Correlations

- Tag a jet correlated with a direct photon
- Remove fragmentation and strong interaction from one of the pair.



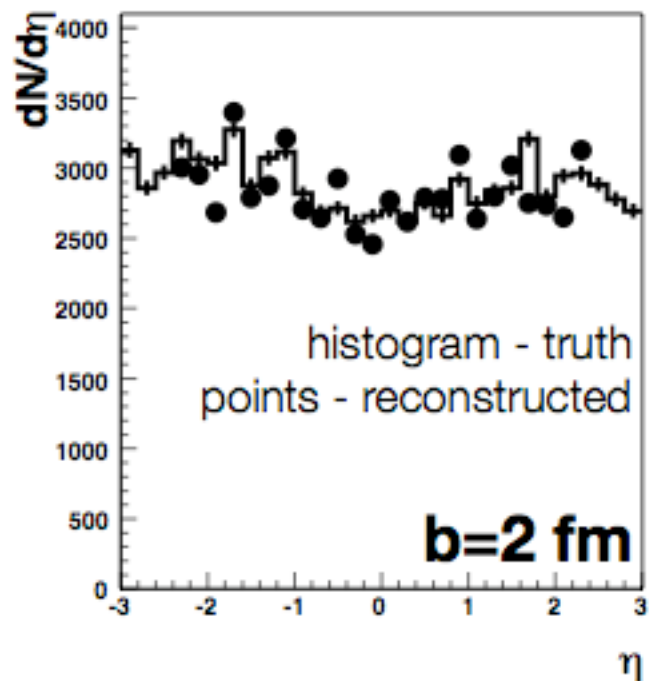
Summary



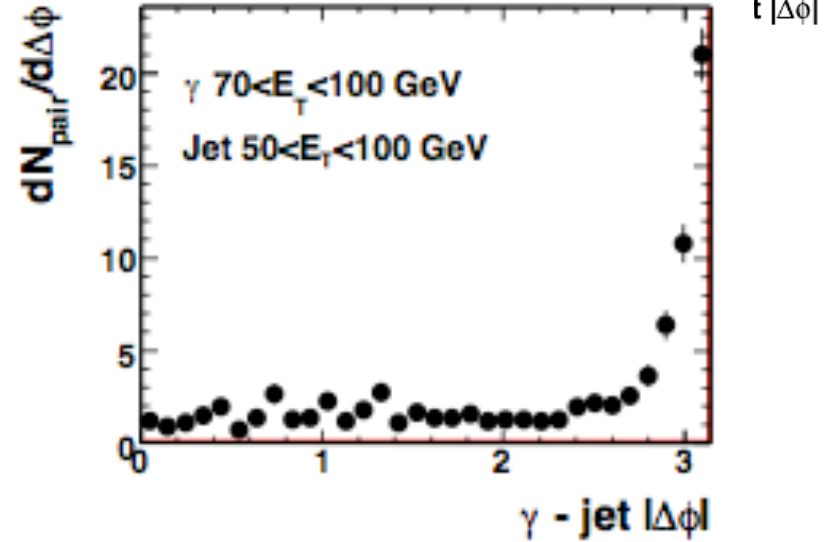
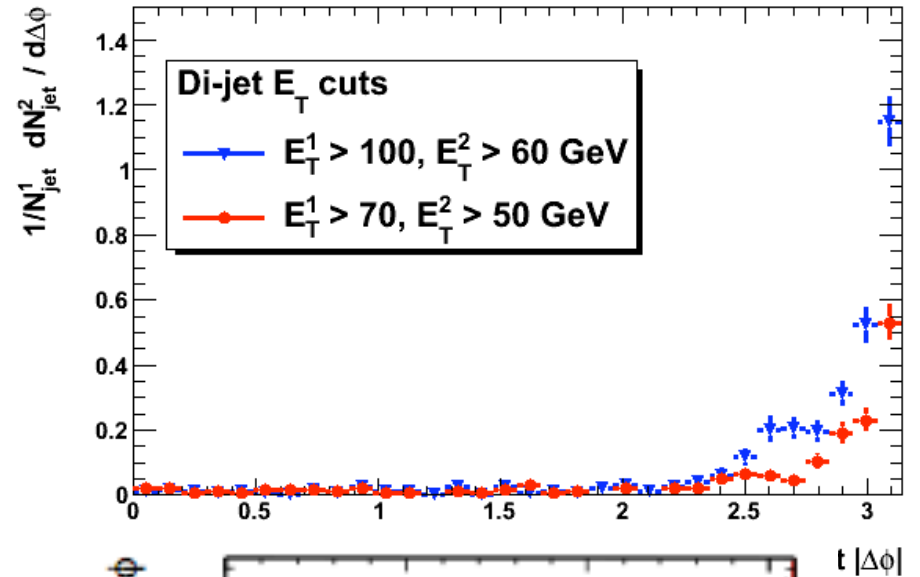
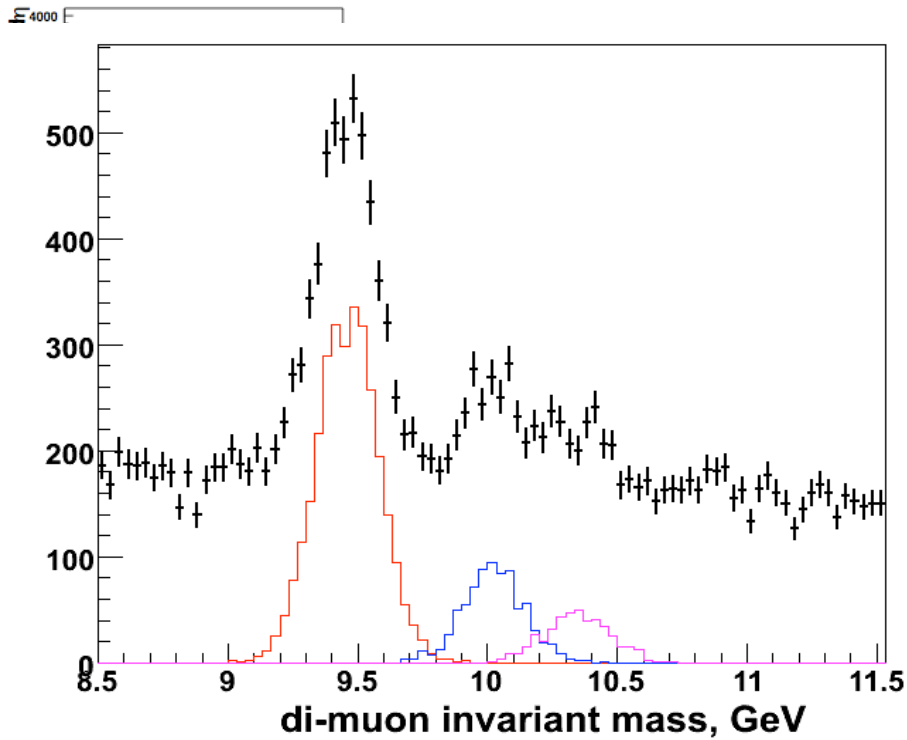
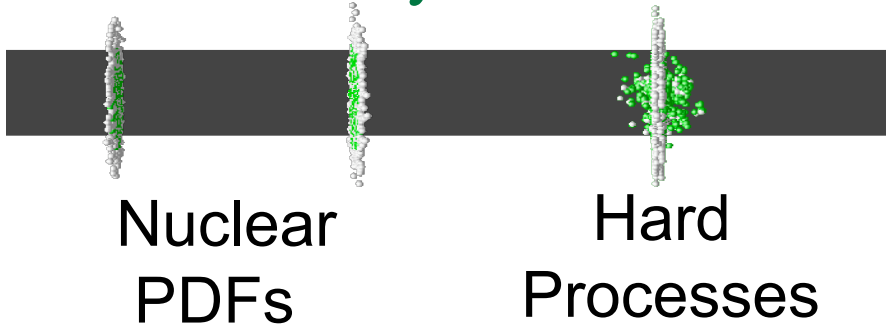
Summary



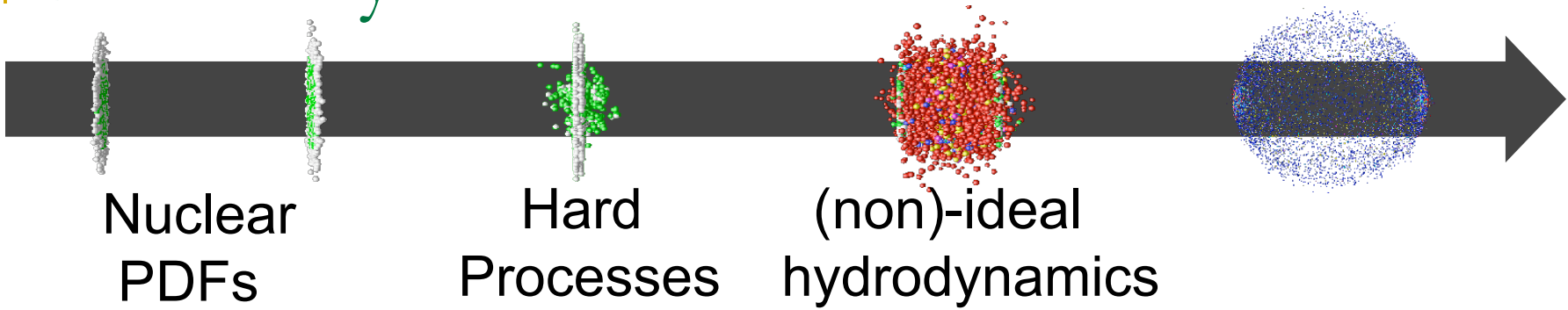
Nuclear
PDFs



Summary



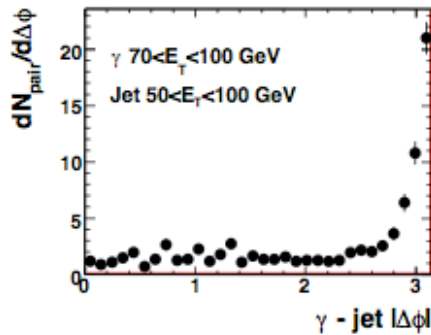
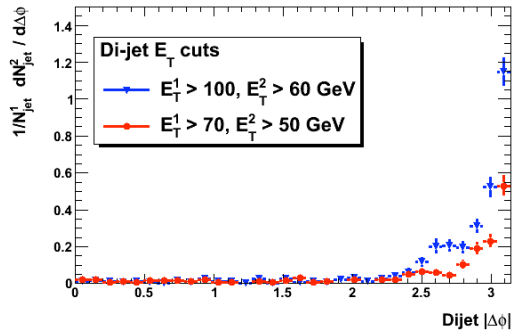
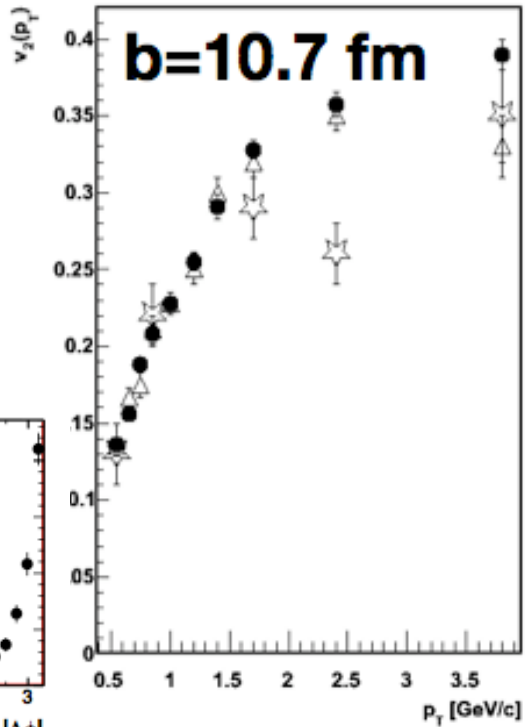
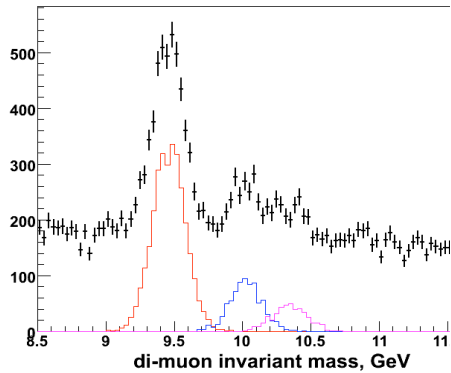
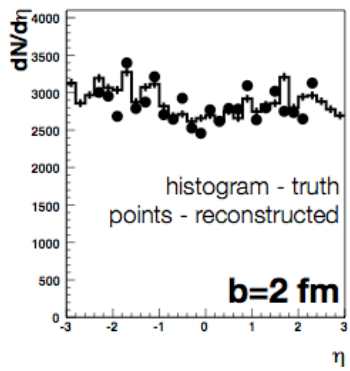
Summary



Nuclear
PDFs

Hard
Processes

(non)-ideal
hydrodynamics



Summary

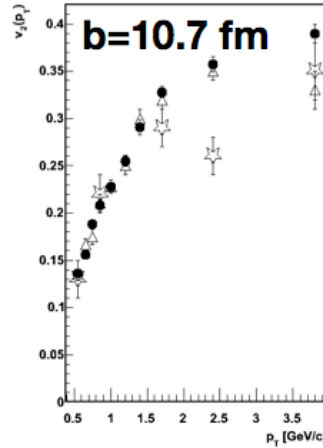
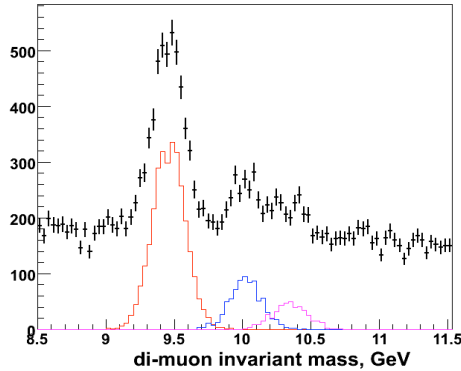
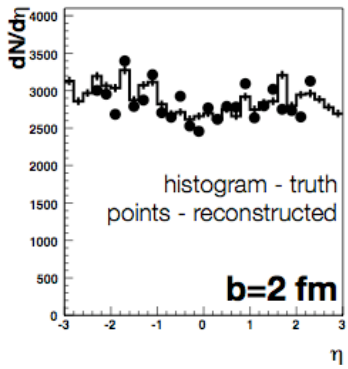


Nuclear
PDFs

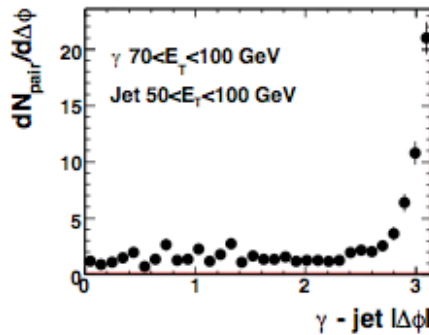
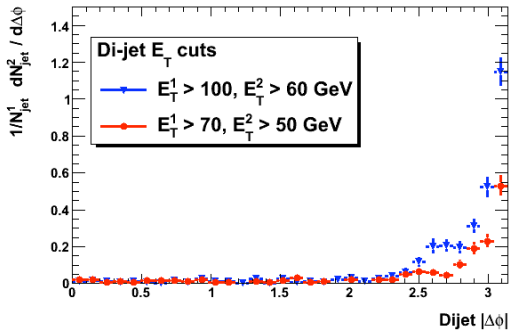
Hard
Processes

(non)-ideal
hydrodynamics

Hadron
Freezeout



All bases of
the RHI program
covered...



ATLAS Heavy Ion Working Group

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