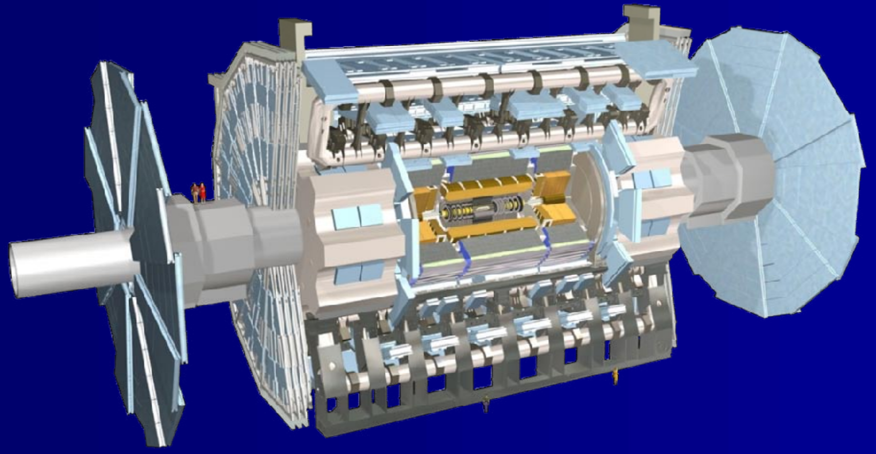
Quarkonium Measurements in Pb+Pb Collisions at LHC with the ATLAS Detector

Marzia Rosati
Iowa State University
for
the ATLAS Collaboration



Quarkonium and Deconfined Matter in the LHC era
Martina Franca, Italy
June 16- 18th, 2010

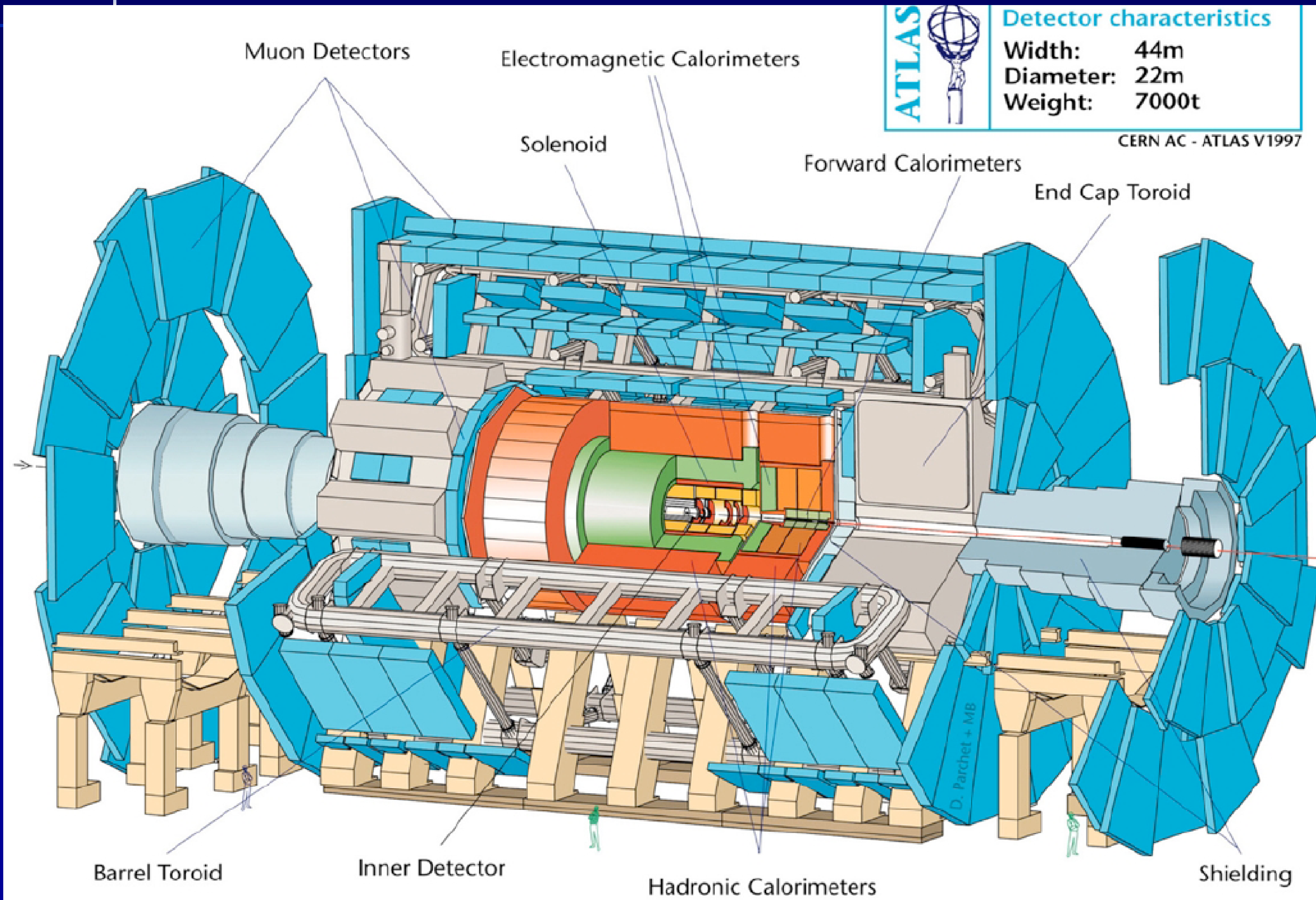
Outline

- ATLAS Detector
  - Muon Spectrometer
- Quarkonia capabilities
  - J/Ψ's
  - Upsilon's
- Z boson measurement
- First 7 TeV data at LHC and measurement of quarkonia in ATLAS

Lessons learned from RHIC

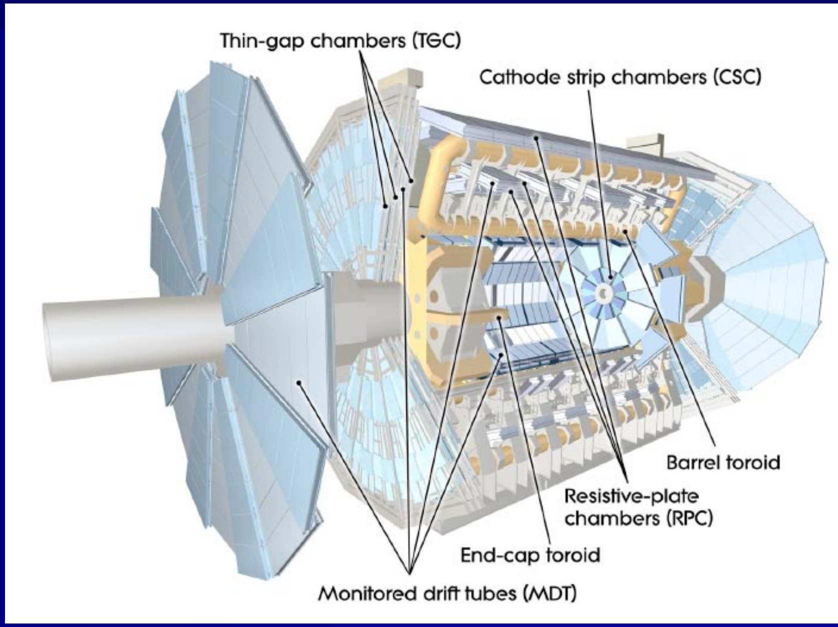
- We are still far from understanding quarkonium production in media
- Interplay between cold nuclear matter effects, quark gluon plasma screening, and possible production through regeneration, needs to be untangled by measuring production rates of:
  - A variety of charmonium and bottomonium states
  - Z bosons to probe gluon shadowing effects in nuclear matter
- ATLAS has excellent capabilities of performing all these measurements through dimuon decays

The ATLAS Detector



The ATLAS Muon Spectrometer

- toroidal magnetic field: <B> = 4 Tm
  $\Rightarrow$ high p_T resolution independent of the polar angle



- air-core coils to minimize the multiple scattering

- 3 detector stations
  - cylindrical in barrel
  - wheels in end caps

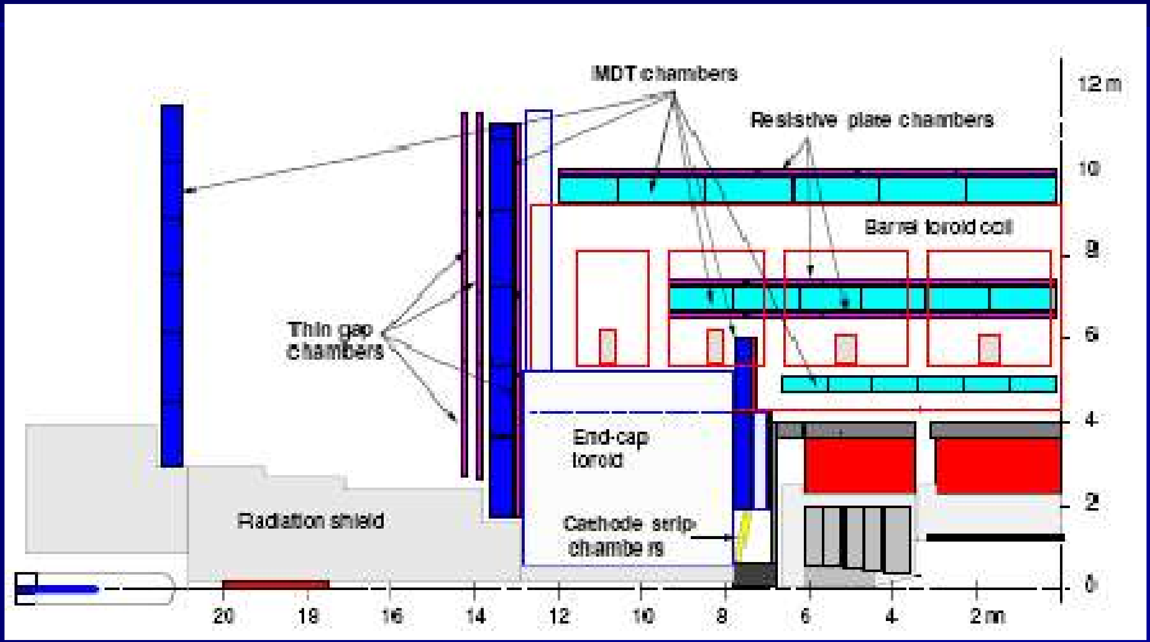
- Clean in Pb+Pb central collisions

ATLAS Muon Spectrometer

Coverage:

$|\eta| < 2.7$

p>3GeV/c



Muon Chambers:

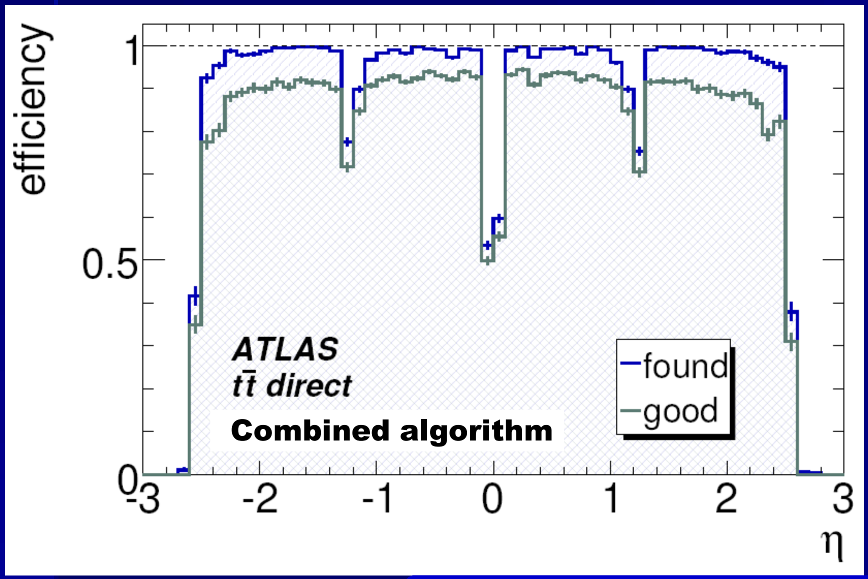
- Trigger Chambers
  - Resistive Plate Chambers (RPC) in Barrel
  - Thin Gap Chambers (TGC) in the Endcaps
- Momentum measurement chambers
  - Monitored Drift tubes (MDT) in most of the solid angle
  - Cathode Strip Chambers (CSC) in the forward Endcap region

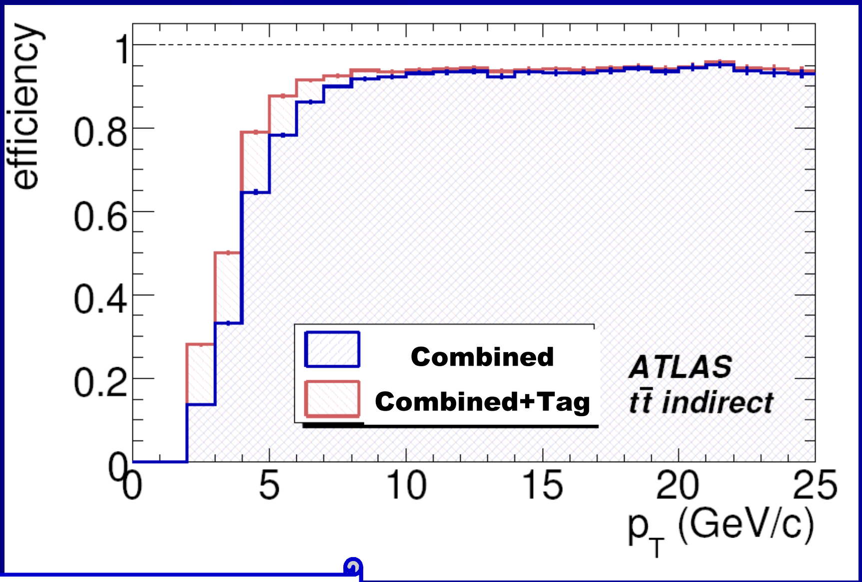
Muon Reconstruction Algorithms

- Muon reconstruction and identification combines the Muon Spectrometer information with the information from the Inner Detectors (Si pixels and microstrips covering $|\eta|<2.5$)
  - Combined Algorithms:
    I. Reconstruct standalone muons by finding tracks in the muon spectrometer and then extrapolating these to the beam line.
    II. Muons are found by matching standalone muons to nearby inner detector tracks and then combining the measurements from the two systems.
  - Tagging Algorithms:
    Inner detector tracks are tagged as muons if a matching track segment in the first stations of the muon spectrometer is found.

Single Muon Performance in p+p Collisions

- Reconstruction efficiency >90% for p_T>6GeV/c

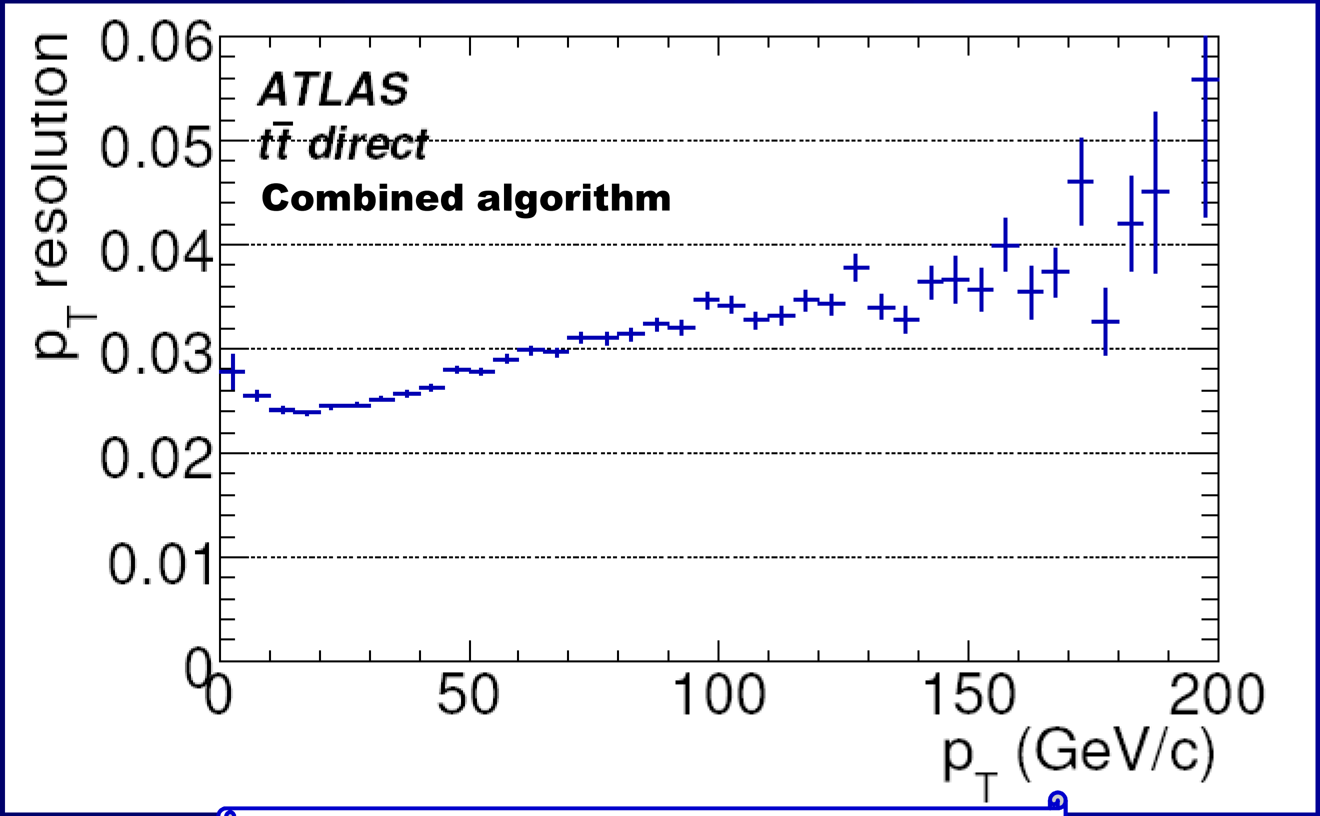




Expected Performance of the ATLAS Experiment
arXiv:0901.0512

Single Muon Performance in p+p Collisions (II)

- "Standalone" Momentum resolution ~5% at p_T=10GeV/c
- "Combined" Momentum resolution ~2.5% at p_T=10GeV/c



Expected Performance of the ATLAS Experiment
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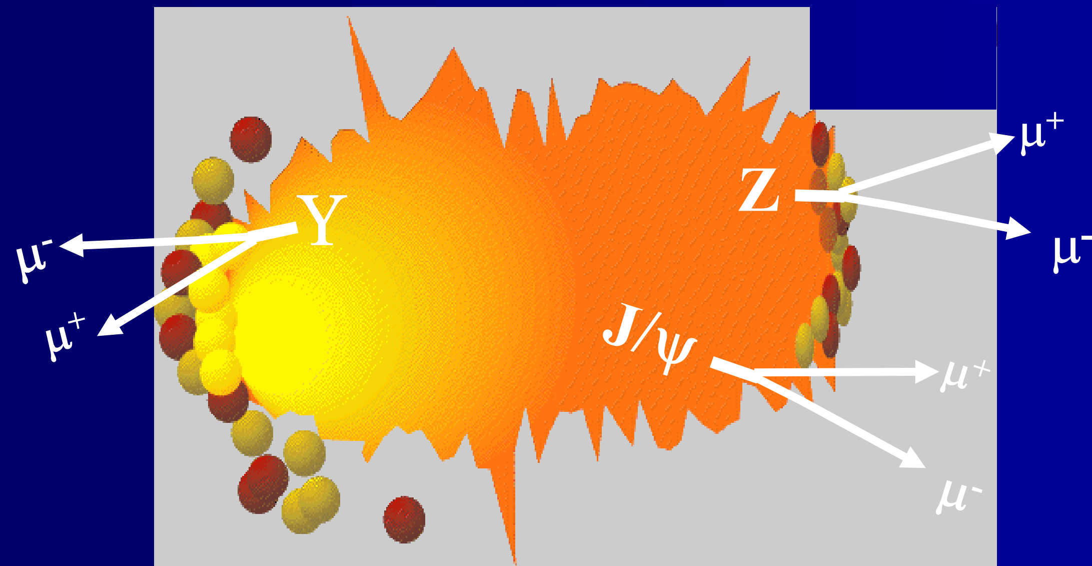
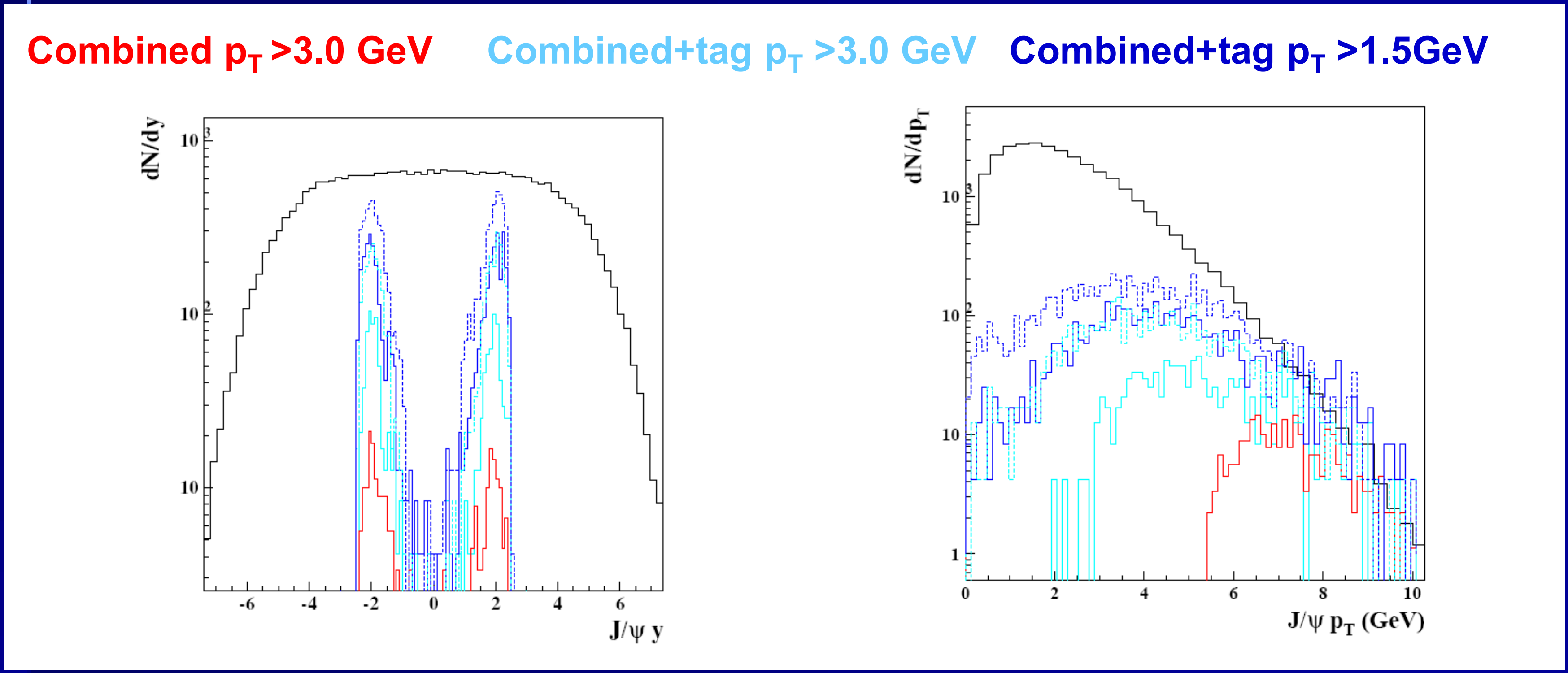
Using Dimuons to Probe Nuclear Matter



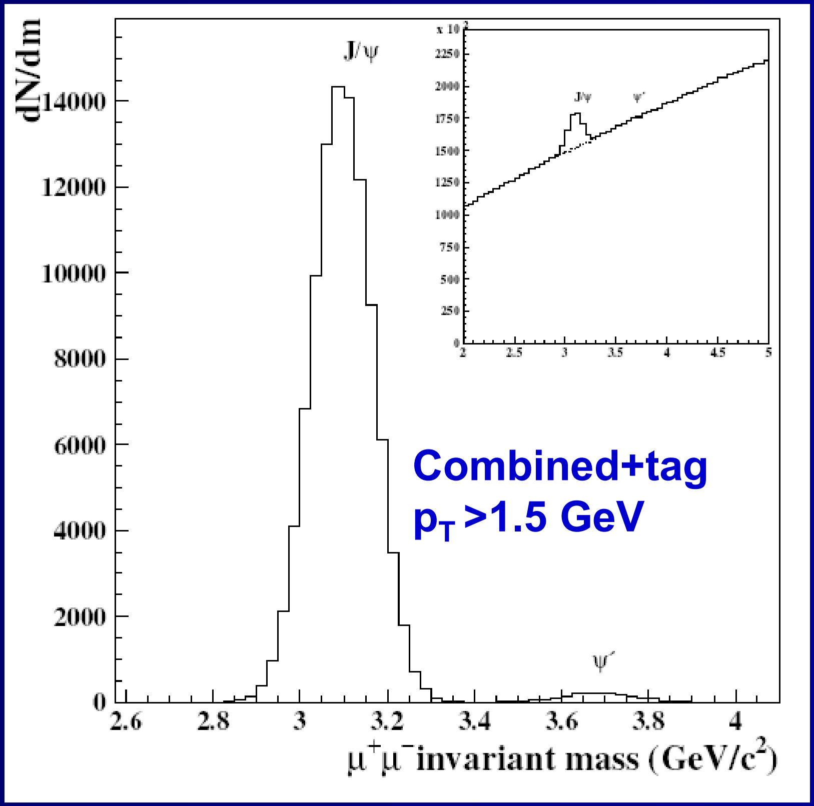
- ATLAS performance in Pb+Pb collisions to measure quarkonium and Z via di-muon channel was studied by merging single J/ψ, Υ and Z into Hijing Pb+Pb collisions at 5.5 TeV energy.

J/Ψ Acceptance



- Muons from J/ψ decays can be reconstructed at forward and backward rapidities
- Using the Combined+tag algorithms with p_T>1.5 GeV:
  - Acceptance x Reconstruction Efficiency= 0.78%

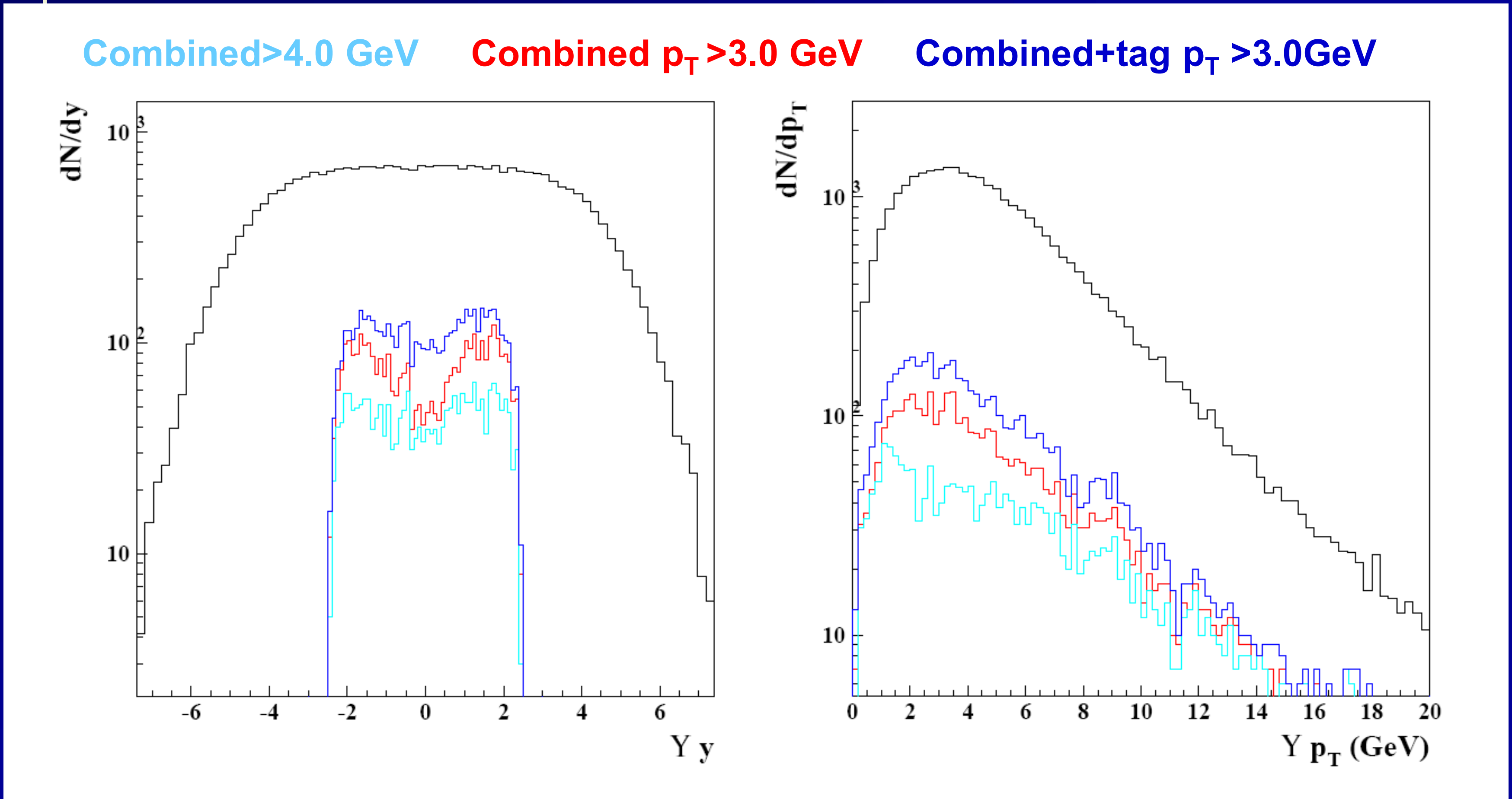
Invariant Mass Distribution



Using the Combined+tag algorithms with p_T>1.5 GeV:

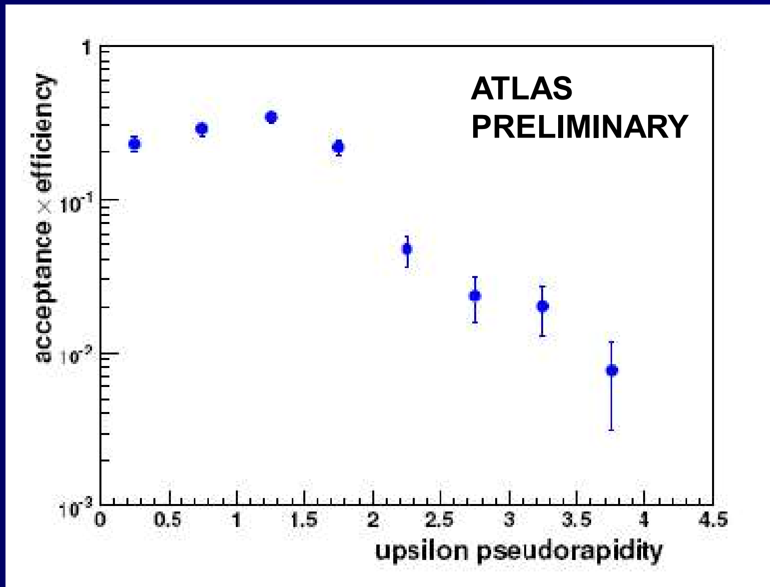
- J/ψ mass resolution ~ 80 MeV
- Signal/Background ~1:6

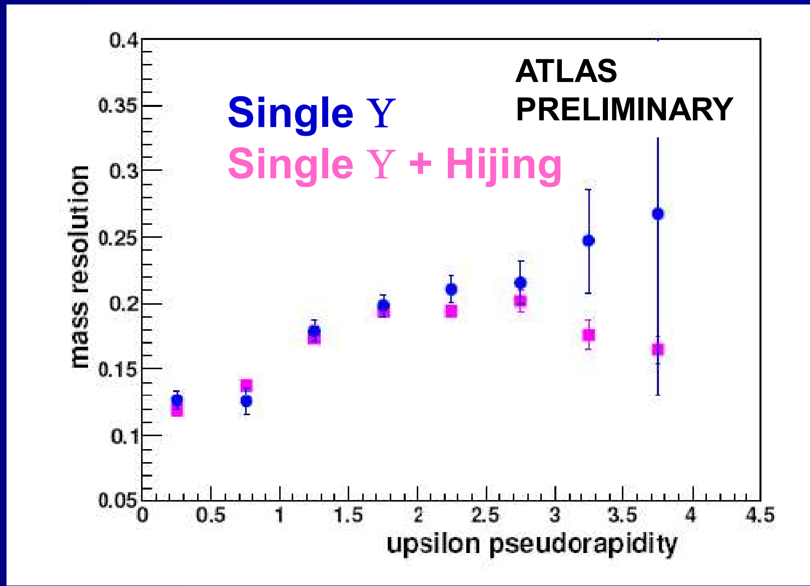
Υ Acceptance



- Muons from Υ decays are more energetic and they can be reconstructed over a large Υ kinematic range

Υ Acceptance and Mass Resolution

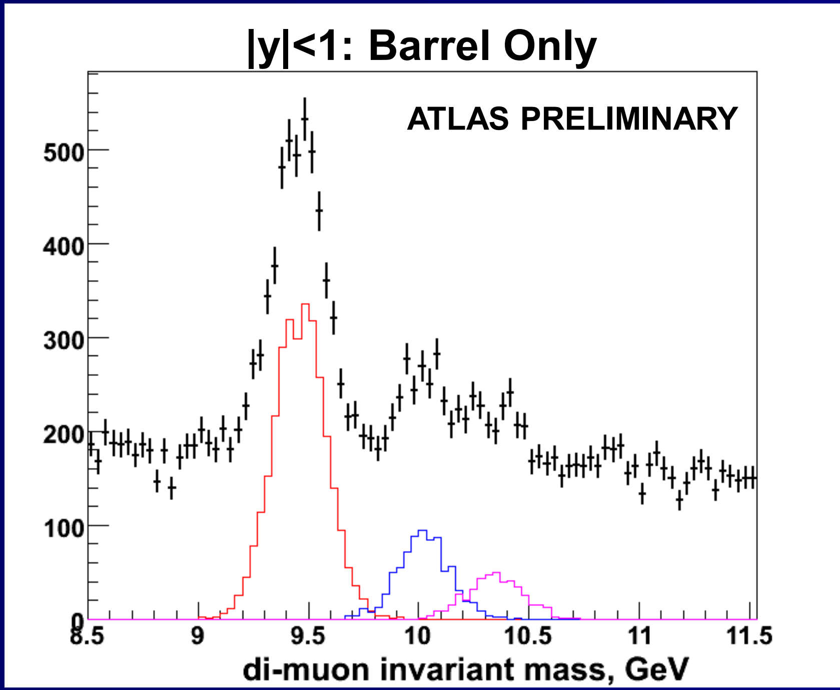




- Muons from Υ decays are more energetic and they can be reconstructed over a large Υ kinematic range
- Acceptance x Reconstruction Efficiency=23%
- Υ mass resolution 140-180 MeV

Upsilon Reconstruction in Pb+Pb

- Invariant Mass Spectra are calculated assuming that both high p_T muons and Υ scale with number of binary collisions :
  - Use PYTHIA to get muons from charm/beauty leptonic decays
  - Run full simulation on single pions and kaons to extract muon spectrum from hadron decays/punch-throughs
  - Add Υ's



Υ Mass Resolution 140 MeV
Signal/Background 4:10

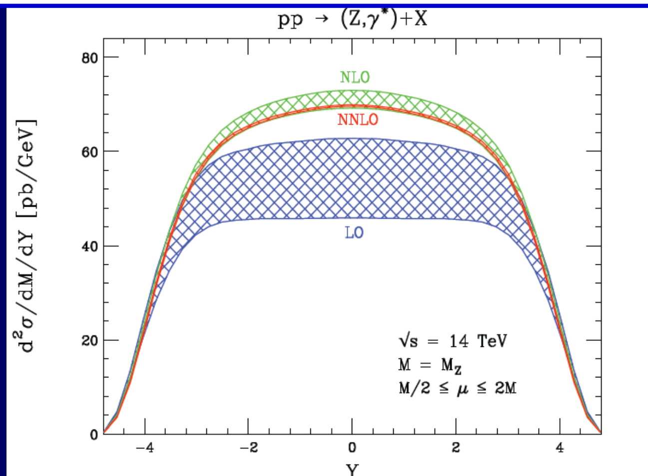
Quarkonia Performace and Rates

	J/ψ	Υ	$\Upsilon(\|y\|<1)$
Acceptance x Efficiency	0.78%	23. %	6.0%
Mass Resolution (MeV)	80	180	140
Signal:Background	3:20	3:10	4:10
Rate/month	190,000	35,000	9,100

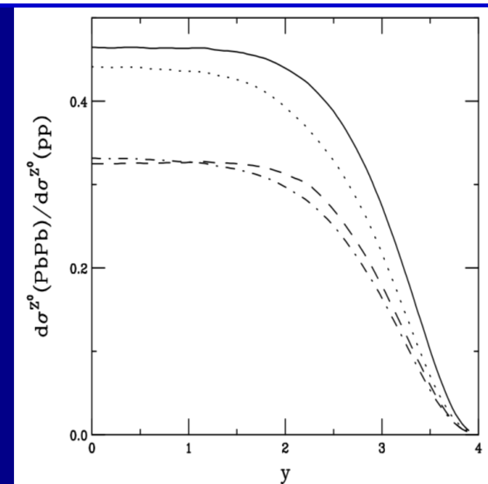
- Rates calculated for one month running at nominal luminosity with 50% machine+experiment efficiency equivalent to an integrated luminosity of $0.5 nb^{-1}$.

Probing PDF's with Z Boson

C. Anastasiou et al., Phys.Rev.D69:094008,2004



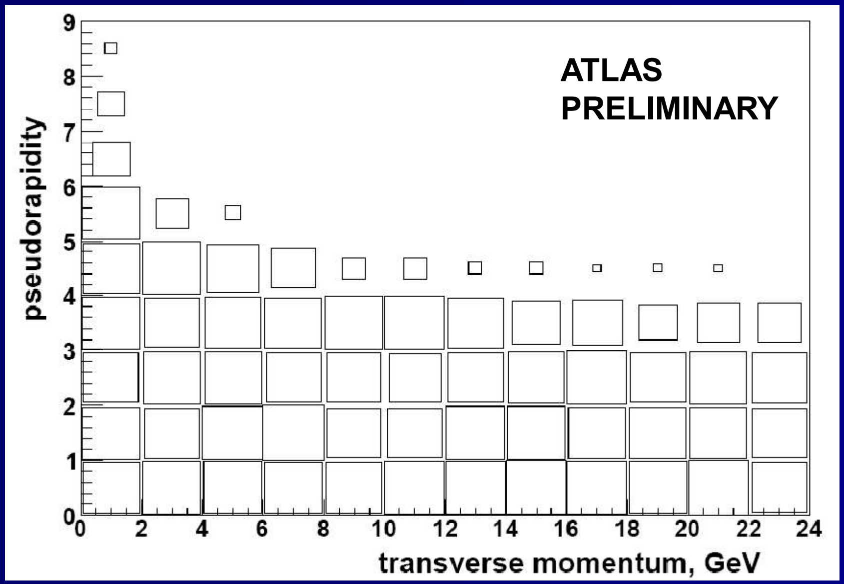
R.Vogt, Phys.Rev.C64:044901,2001

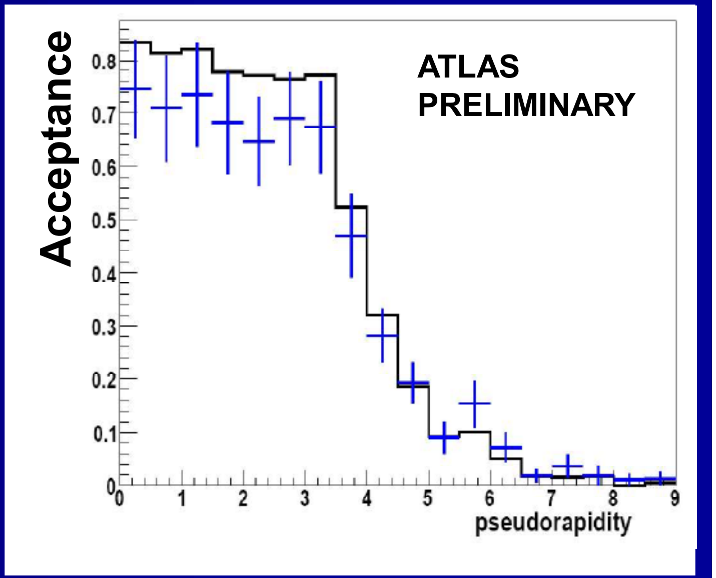


- Z production rate in p+p can be accurately calculated in NNLO pQCD therefore measuring production in Pb+Pb will provide a precise measurement of PDF's
  - We can determine x dependence of shadowing while measuring Z as a function of rapidity
  - Study centrality dependence while dividing into rapidity bins to restrict the x coverage
- Use Z as a reference for quarkonium suppression

Z Boson Acceptance

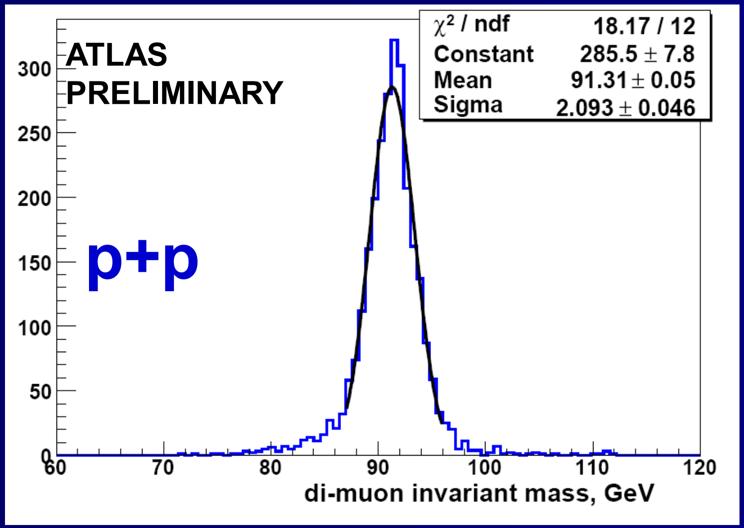
- Acceptance for Z boson was estimated by generating Z's with flat rapidity and transverse momentum distributions

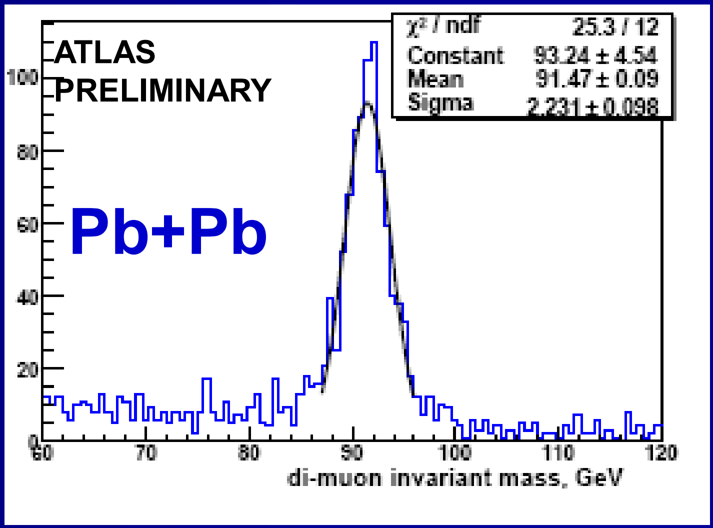




- Weighting the calculated acceptance with kinematic distributions predicted by NLO we derive:
  - Acceptance x Reconstruction Efficiency=60%

Z Mass Resolution



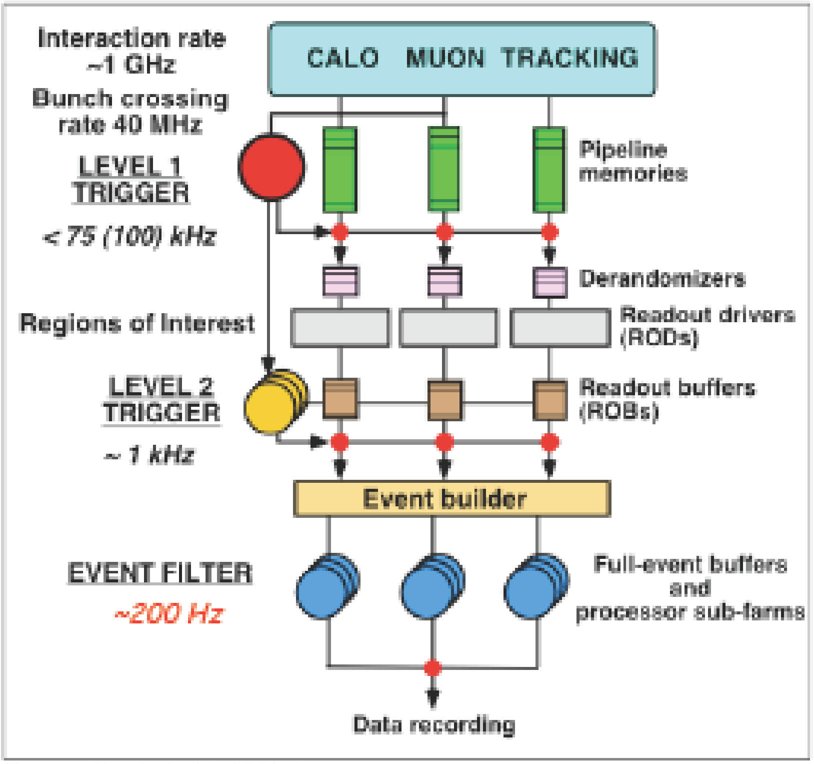


Acceptance x Efficiency	60%
Mass Resolution	2.2 GeV
Rate/year	8,000

- Rates calculated for one month running at nominal luminosity with 50% machine+experiment efficiency equivalent to an integrated luminosity of 0.5nb^{-1}, using NLO kinematic distributions.

Trigger/DAQ

For Pb-Pb collisions the interaction rate is 8 kHz,
a factor of 10 smaller than LVL 1 bandwidth (75 kHz).



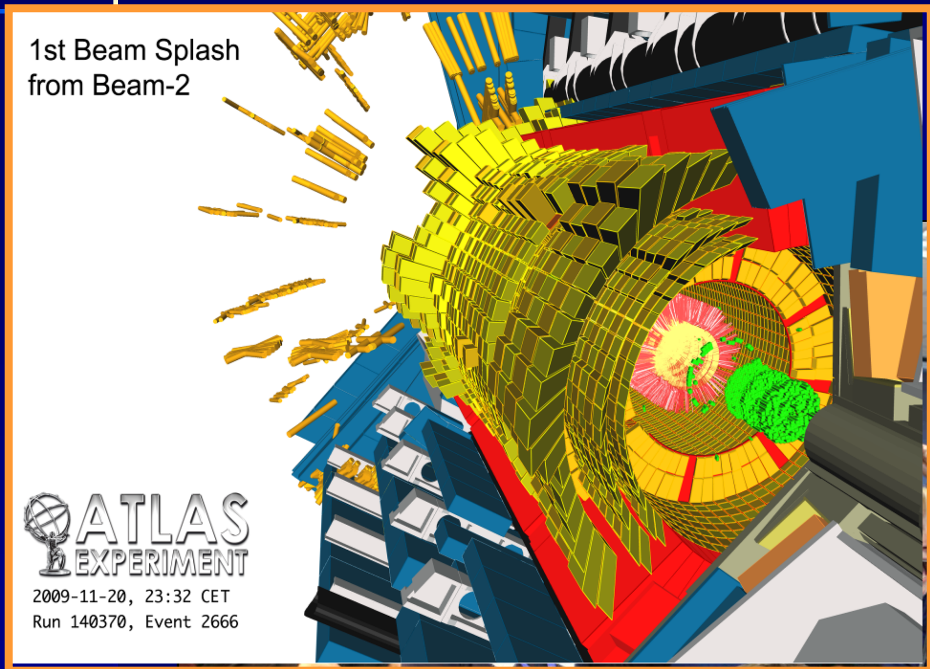
LVL 1 di-μ trigger can be based on ϕ information from μ-trigger chambers for a low p_T cut (toroidal B bending is in η), and defines Regions of Interest.

LVL 2 & 3 are based on reconstruction in the Regions of Interest.

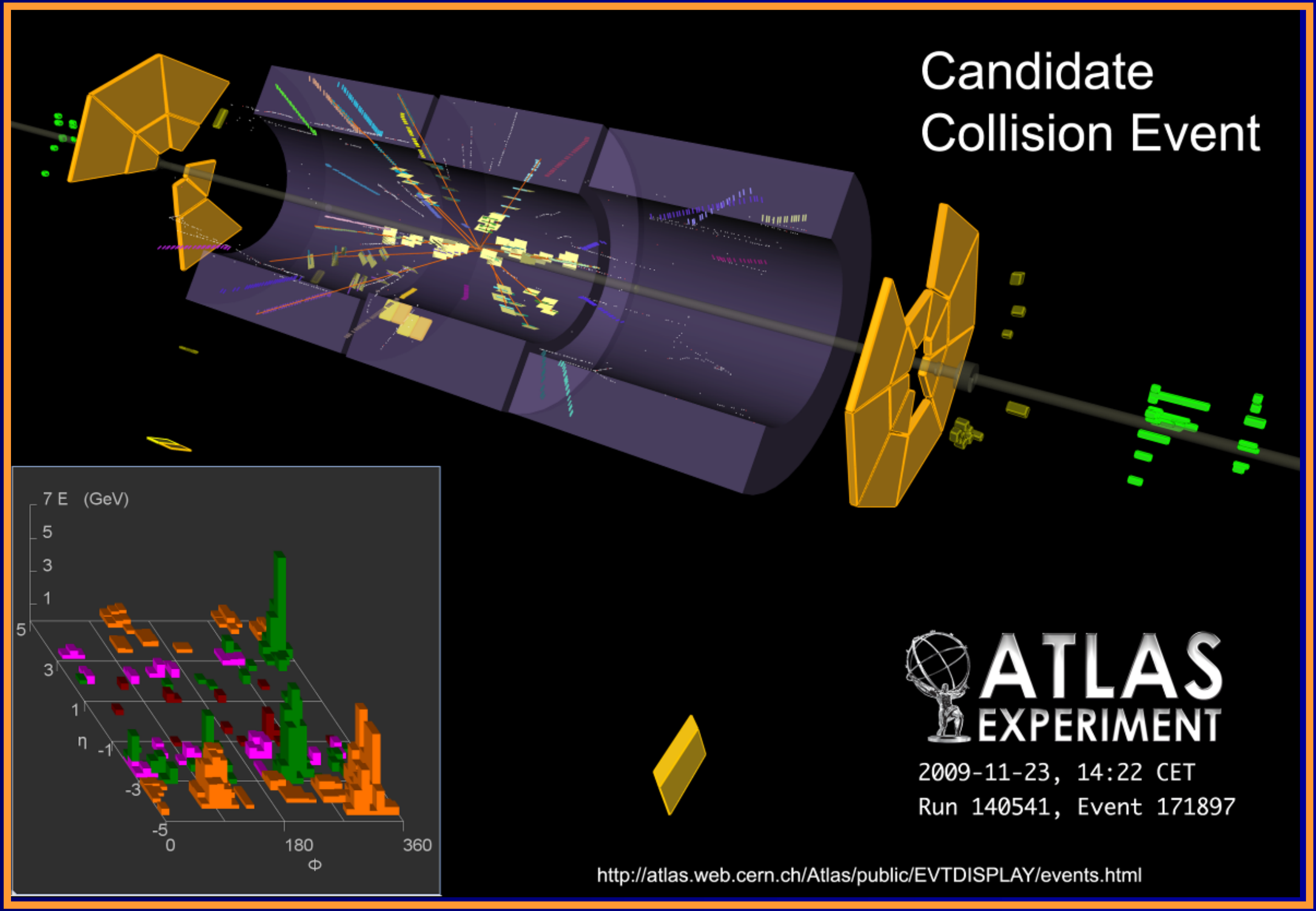
Under study.

The event size for a central collision is ~ 5 Mbytes.
Similar bandwidth to storage as pp implies ~ 50 Hz data recording.

First LHC beam in 2009-2010



p+p Collisions at 900 GeV



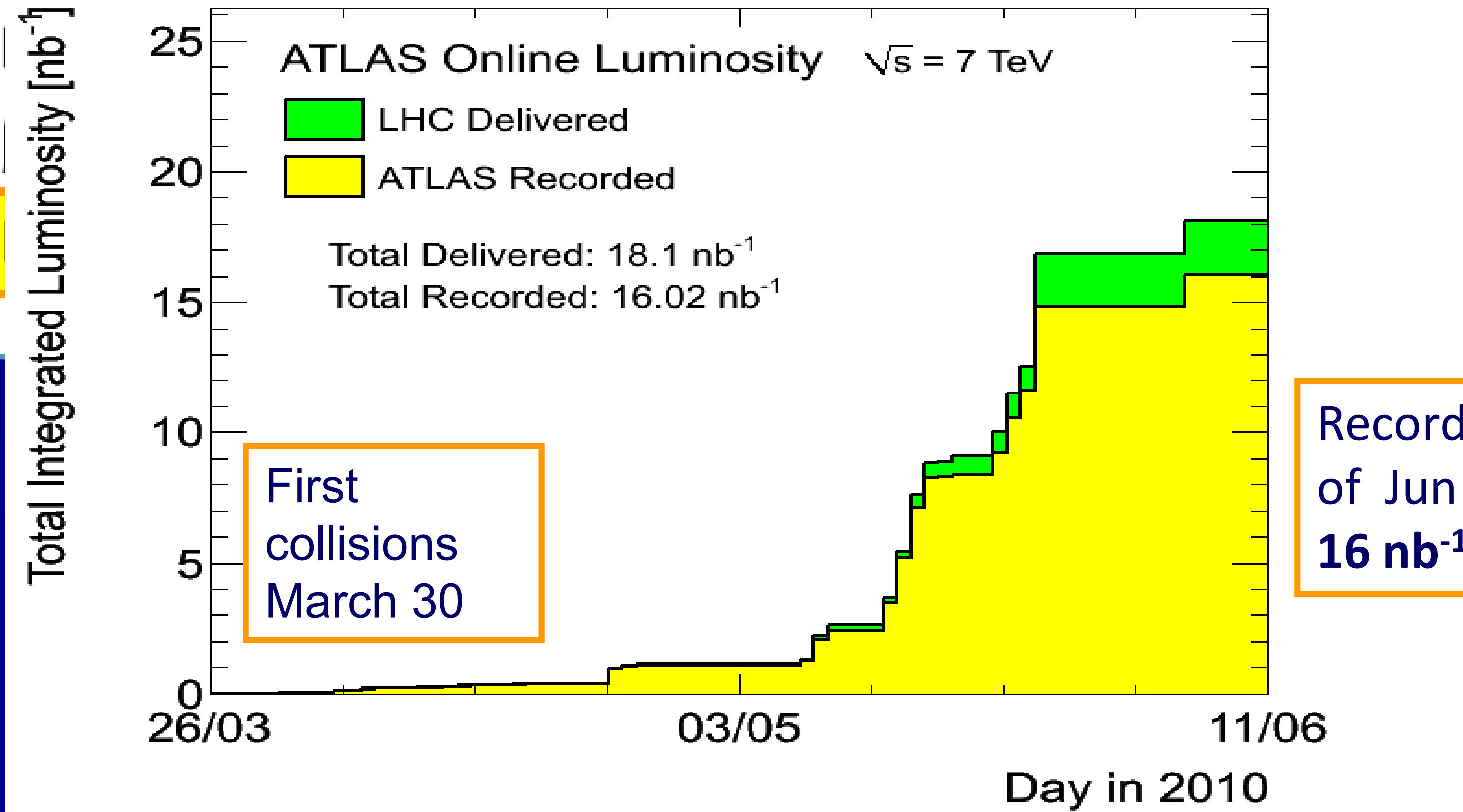
Operational Fraction (June 2010)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.8%
LVL1 Muon RPC trigger	370 k	99.7%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.3%
TGC Endcap Muon Chambers	320 k	98.8%

- All subsystems > 97%

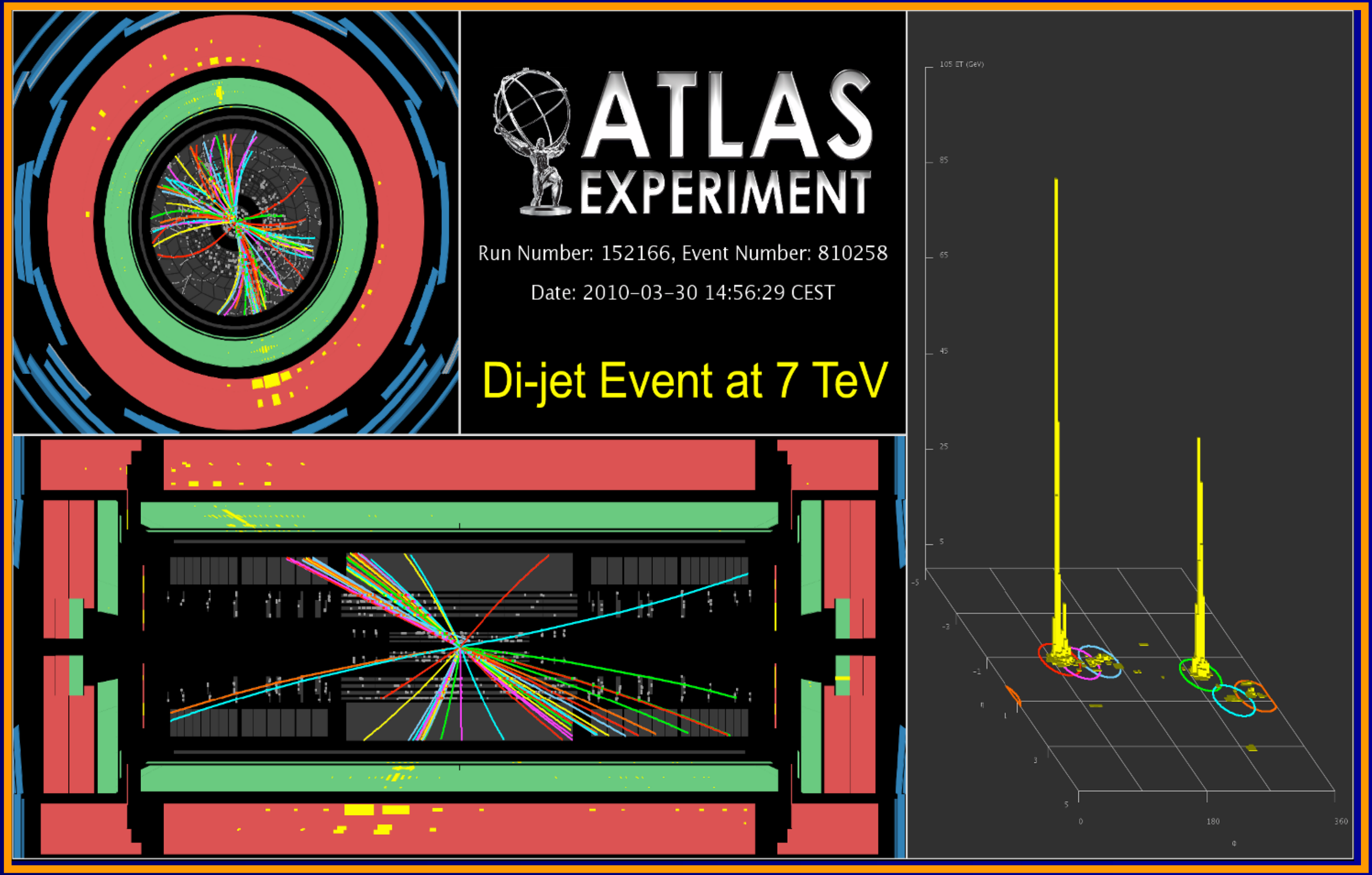
2010 Run Summary

	Initial	Current	2011	Nominal
Beam Energy	3.5 TeV	3.5 TeV	**3.5 TeV**	7 TeV
Coll. bunches	1	3	~700	2808
				$1 \cdot 10^{11}$
				1 m
				10^{34}



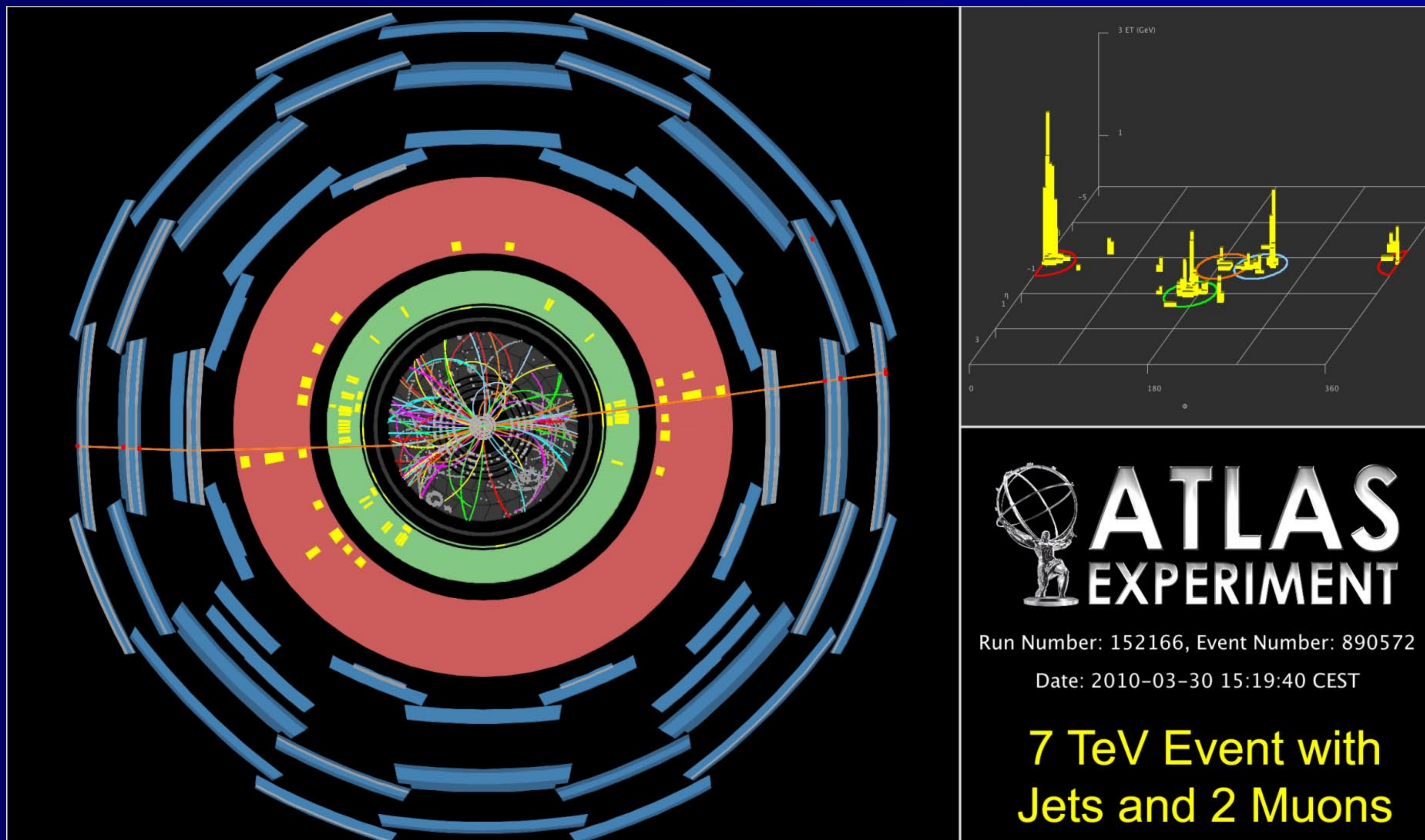
Recorded as of Jun 11: **16 nb^{-1}**

p+p collisions at 7 TeV



- ATLAS ready for data taking

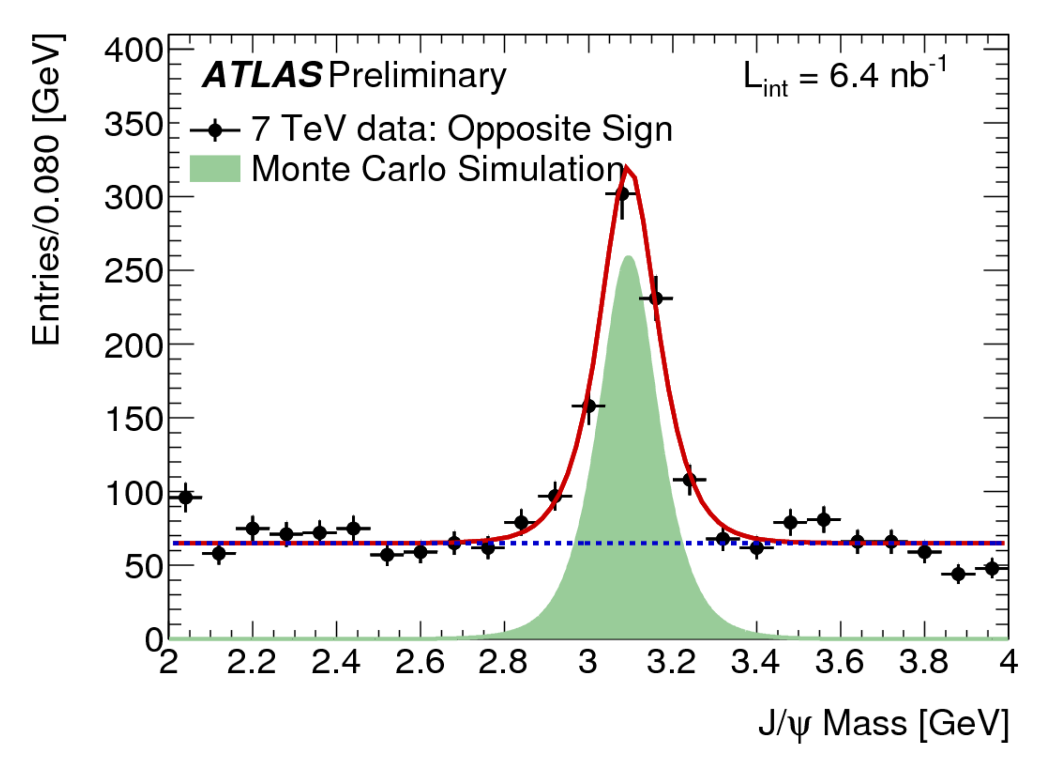
Jets and 2 Muons event candidate



- Muon spectrometer “clean”

First J/ψ measurement

- **$J/\psi \rightarrow \mu^+\mu^-$ Reconstruction:**
  - Require $E(\mu) > 3$ GeV
  - at least one muon combined with tracker



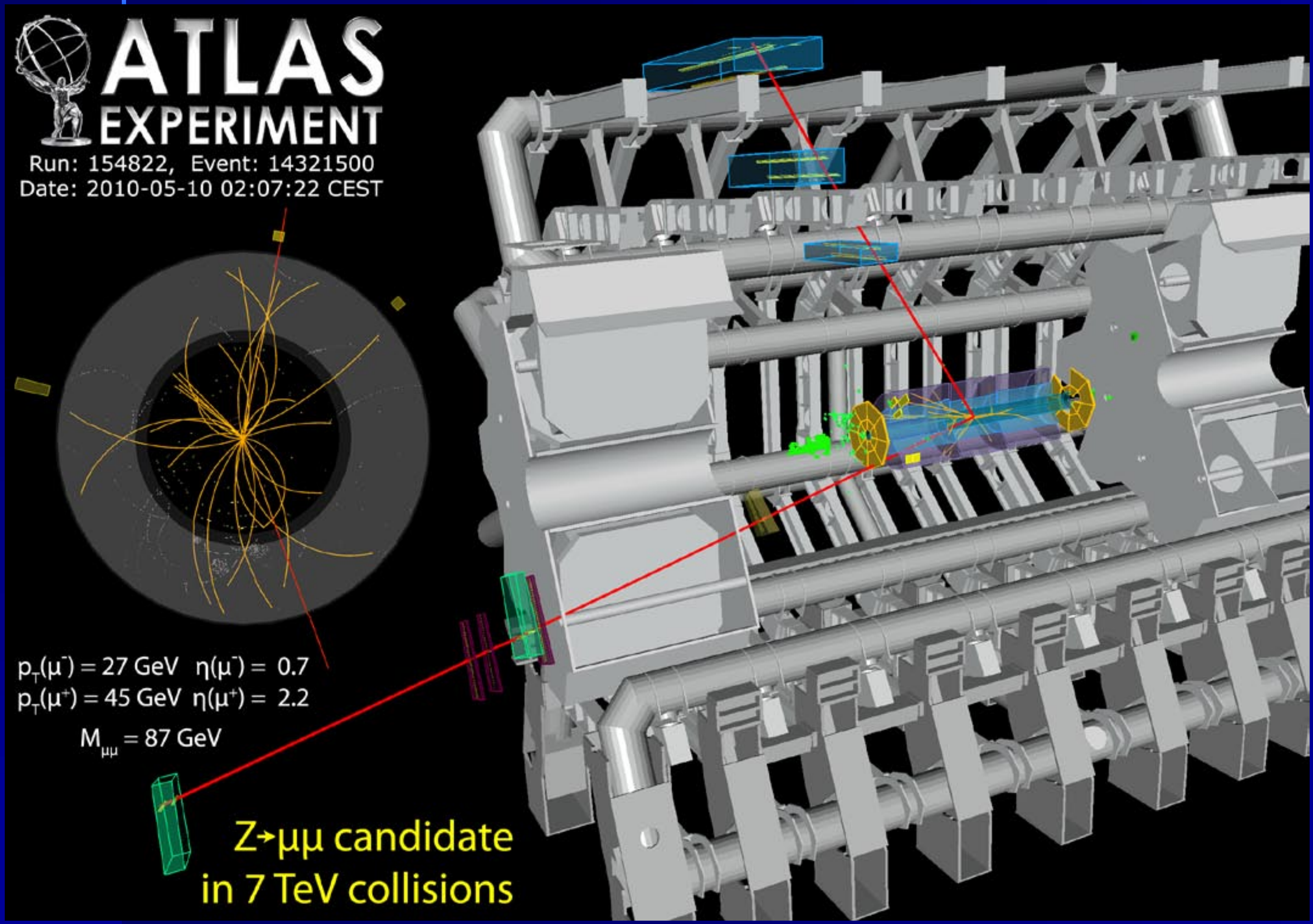
$m(J/\psi) = 3.095 \pm 0.004$ GeV

$\sigma = 82 \pm 7$ MeV

$N_{sig} = 612 \pm 34$
$N_{bkg} = 332 \pm 9$

ATLAS-CONF-2010-045

$Z \rightarrow \mu^+\mu^-$ event candidate



Candidate collected on 10 May 2010

Event properties:

$p_T(\mu^+)$ = 45 GeV
$p_T(\mu^-)$ = 27 GeV

$m_{\mu\mu}$ = 87 GeV

Conclusions

- ATLAS will make interesting measurements in dimuon channel probing Hot and Cold Nuclear Matter effects in Pb+Pb Collisions
- Excellent capability to measure
  1. J/ψ's
  2. Υ's
  3. Z^0's
  - Mass resolution is almost unaffected in PbPb collisions
  - Mass resolution is good enough to separate different Υ states in the barrel region
  - We should be able to see Υ and J/ψ peaks in a few weeks of running

- First J/ψ peak already observed in 7TeV p+p collisions!

END

Contributions to Muon Momentum Resolution