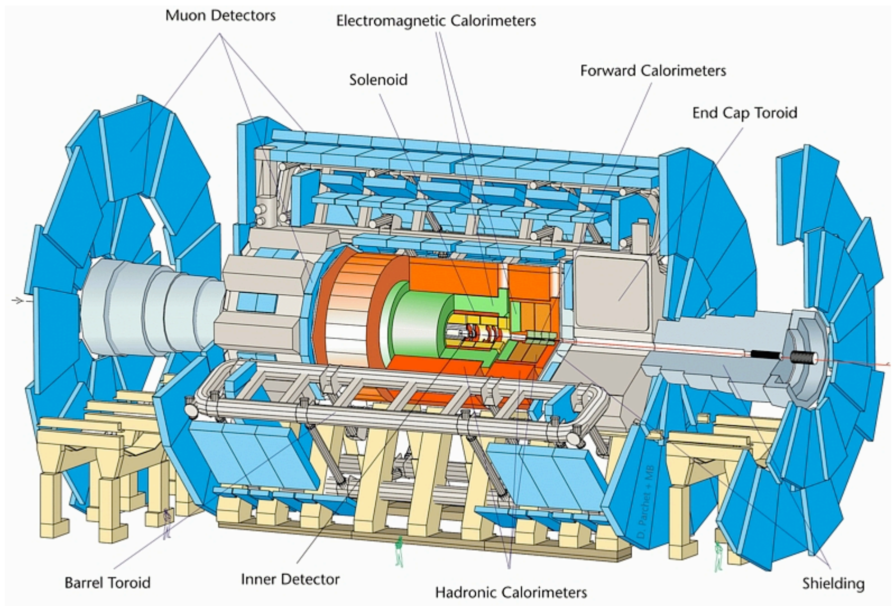
ATLAS expected measurements of Heavy Quarkonia in Pb+Pb collisions

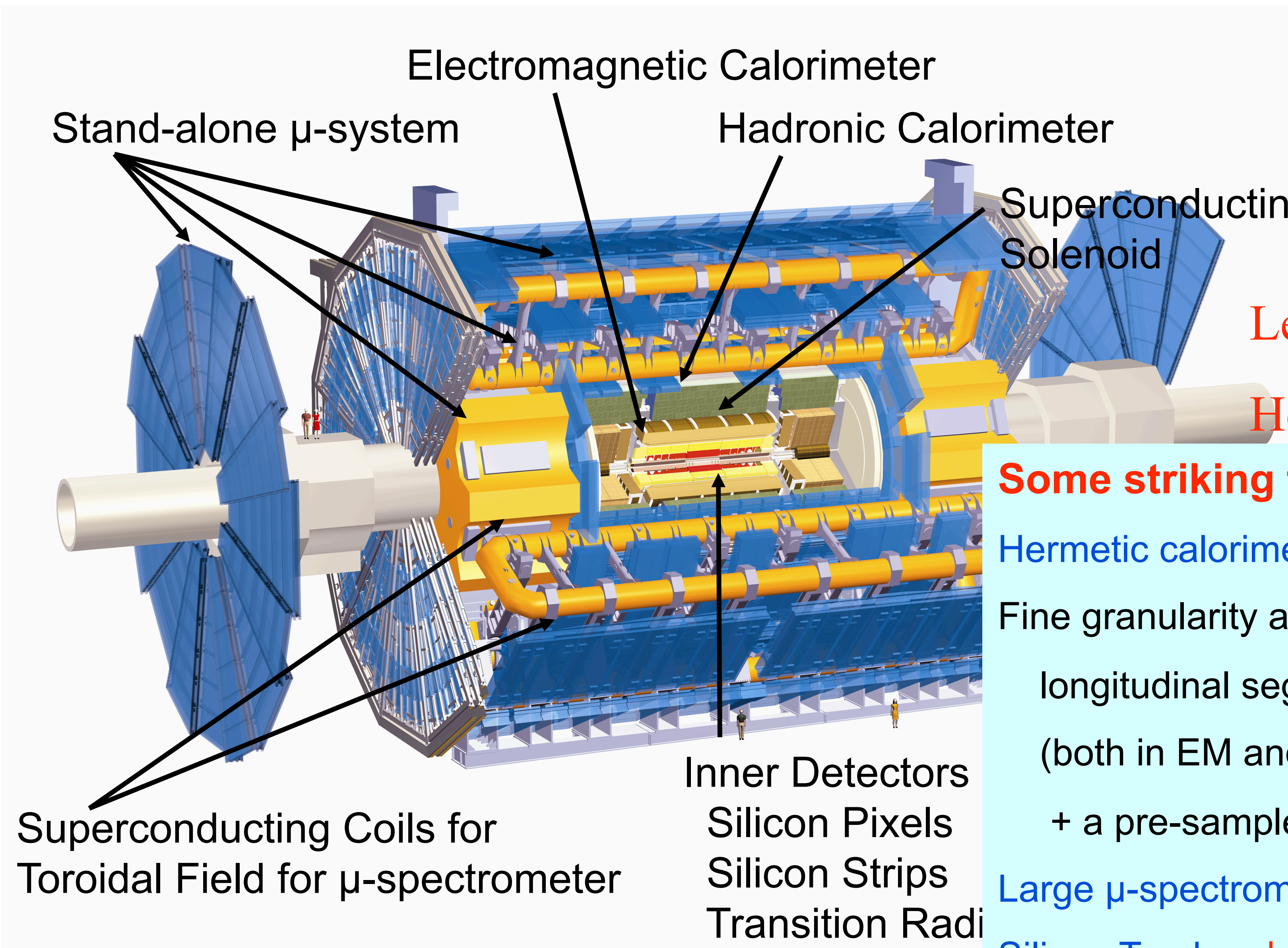


Laurent Rosselet

for the ATLAS Collaboration

International Workshop on Heavy Quarkonia, May 18-21 2010

The ATLAS detector



Length 44m

Height 22m

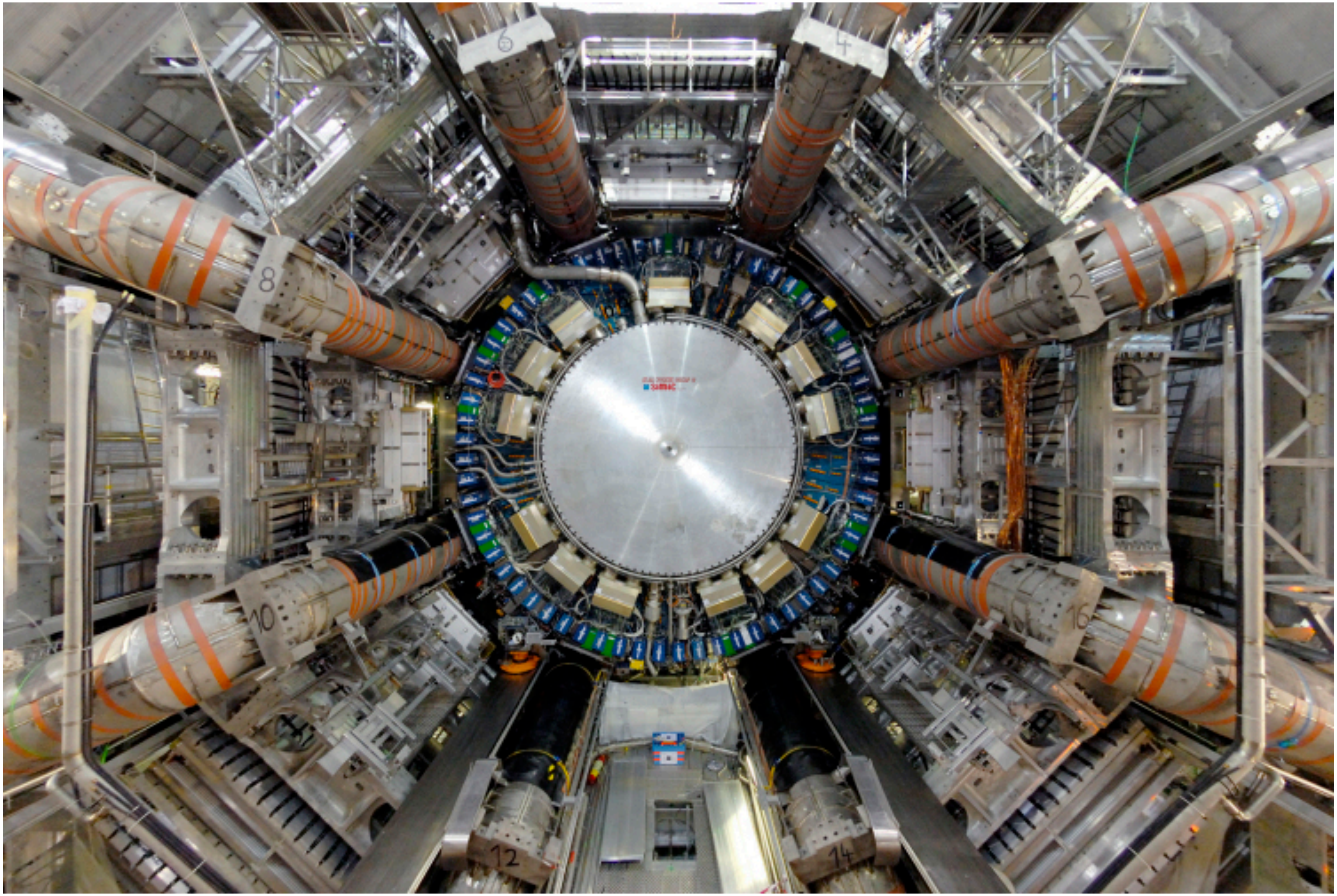
Some striking features:

Hermetic calorimeter $|\eta|<4.9$

Fine granularity and 3 longitudinal segmentations (both in EM and hadronic) + a pre-sampler

Large μ-spectrometer $|\eta|<2.7$

Silicon Tracker $|\eta|<2.5$

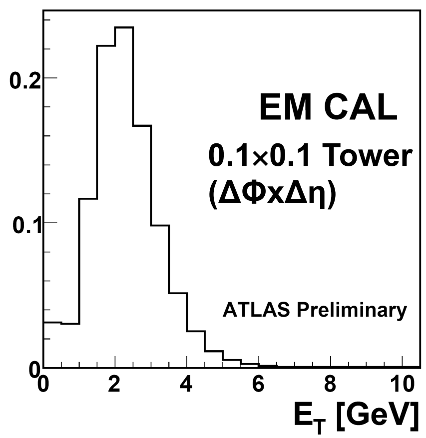

6
4
8
2
10
16
12
14

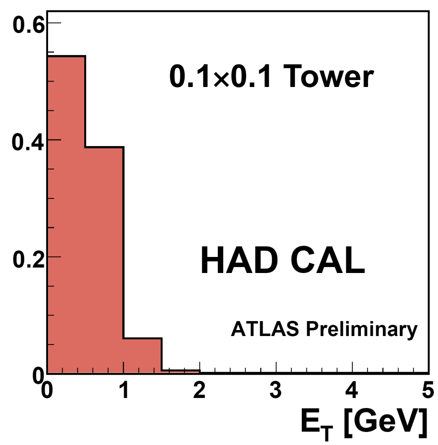
Central Pb-Pb collisions

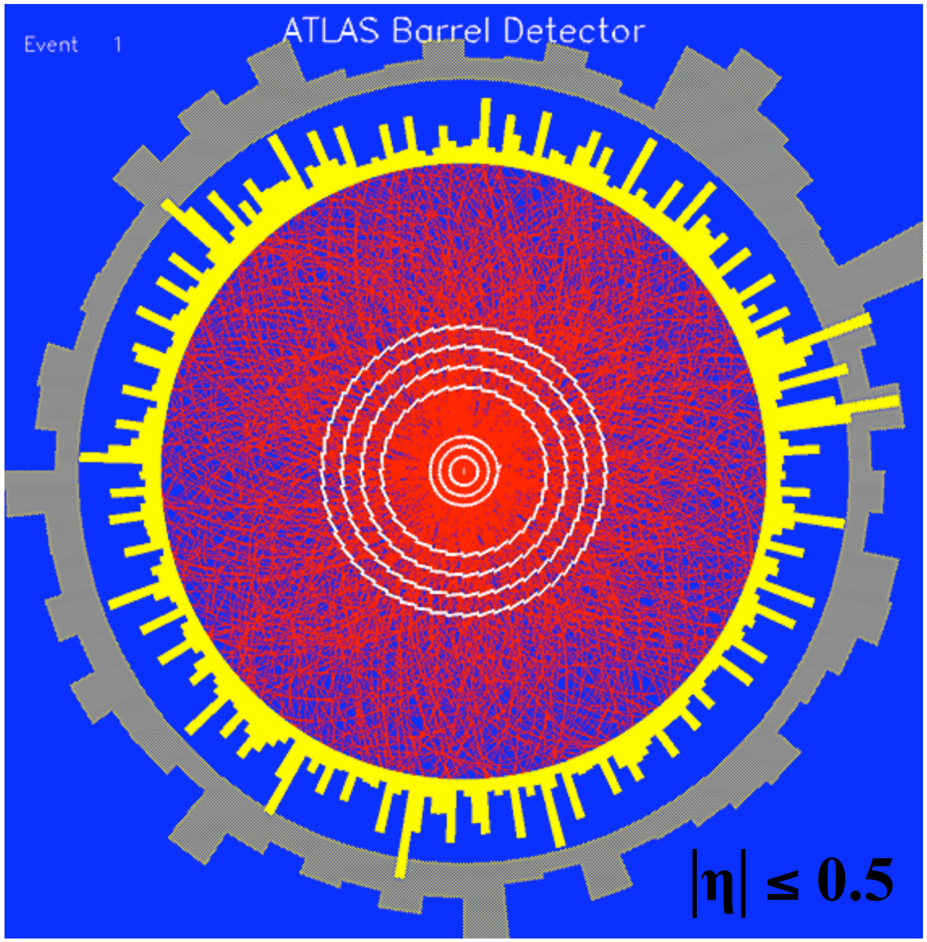
- Simulation: HIJING+GEANT

  $dN_{ch}/d\eta|_{max} \sim 3200$ in central Pb-Pb

  c.f. 1200 from RHIC log extrapol.



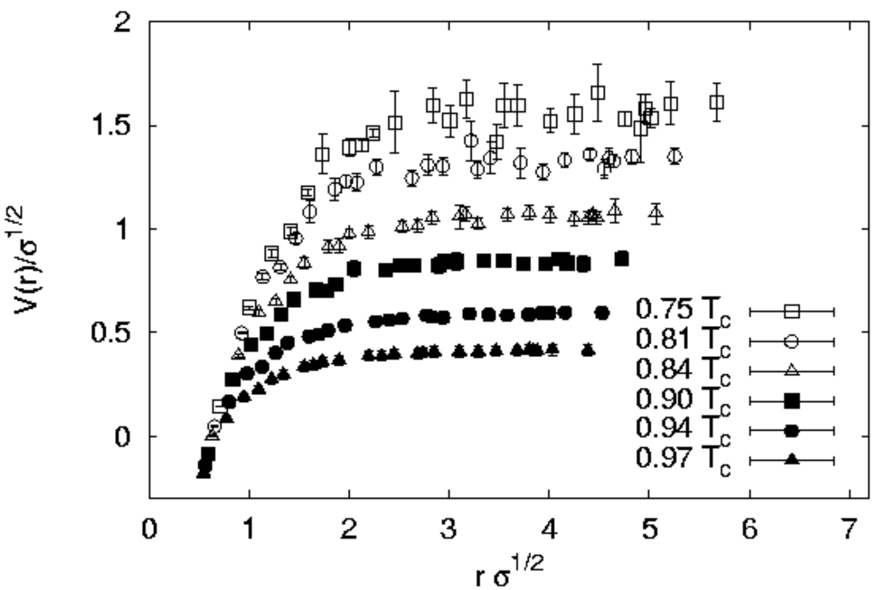




- Large bulk of low p_T particles is stopped in the first layer of the EM calorimeter (60% of energy)

Heavy quarkonia suppression

Original idea: color screening prevents various ψ, ϒ, χ states to be formed when $T \rightarrow T_c$, the T_{trans} to QGP (color screening length < size of resonance)



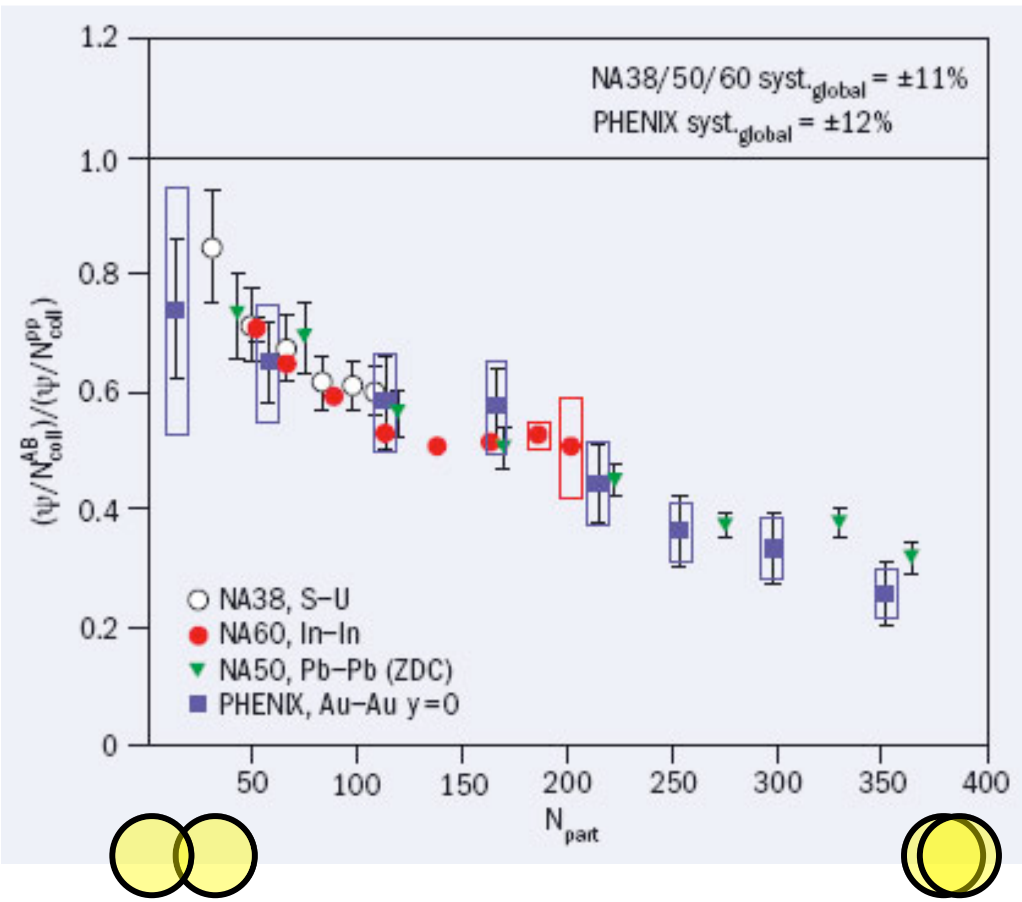
Modification of the potential can be studied by a systematic measurement of heavy quarkonia states characterized by different binding energies and dissociation temperatures

~thermometer for the plasma

state	J/Ψ	χ_c	ψ'	ϒ(1s)	χ_b	ϒ(2s)	χ_b'	ϒ(3s)
Mass [GeV}	3.096	3.415	3.686	9.46	9.859	10.023	10.232	10.355
B.E. [GeV]	0.64	0.2	0.05	1.1	0.67	0.54	0.31	0.2
T_d/T_c	1.10	0.74	0.15	2.31	1.13	0.93	0.83	0.74

In fact: complex interplay between suppression and regeneration

Identical J/ψ suppression at SPS and RHIC



Whereas medium is expected much denser and hotter at RHIC

Recent lattice data: J/ψ may survive to T twice T_c => only χ_c and Ψ' states are dissolved at SPS and RHIC (a lack of feed-down contribution is observed)

Or: the recombination of $c\bar{c}$ compensates the extra suppression at RHIC

=> Crucial to go to higher energy (LHC) and to study the ϒ family

Upsilon reconstruction

Study the $\Upsilon \rightarrow \mu^+ \mu^-$ in a full simulation (GEANT+reconstruction)

Upsilon family	Υ(1s)	Υ(2s)	Υ(3s)
Mass (GeV)	**9.460**	**10.023**	**10.355**
Binding energies (GeV)	**1.1**	**0.54**	**0.2**
Dissociation at the temperature	**$\sim 2.3T_c$**	**$\sim 0.9T_c$**	**$\sim 0.7T_c$**

=>Important to separate Υ(1s) and Υ(2s)

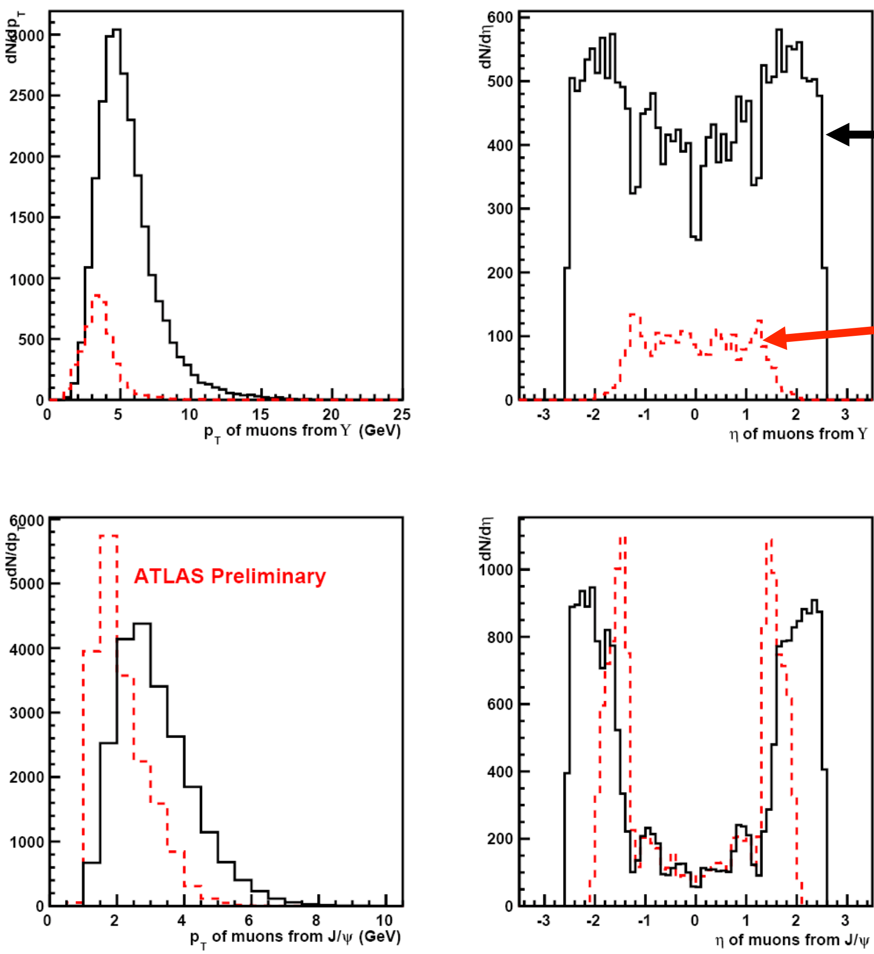
- $\mu^+ \mu^-$ mass resolution is 460 MeV at Υ peak in the μ-spectrometer

=> uses combined info from μ-spectrometer and ID (Pixels + Strips, not yet from the **T**ransition **R**adiation **T**racker)

Strategies to measure quarkonia $\rightarrow\mu^+\mu^-$

"Combined μ"≡ both μ's are fully reconstructed in the μ-spectrometer & ID

"Combined+tag"≡ at least one μ is fully reconstructed, the other one may be partially reconstructed (tag) inside $|\eta|<2$, to increase statistics without loss of mass resolution at low p_T.



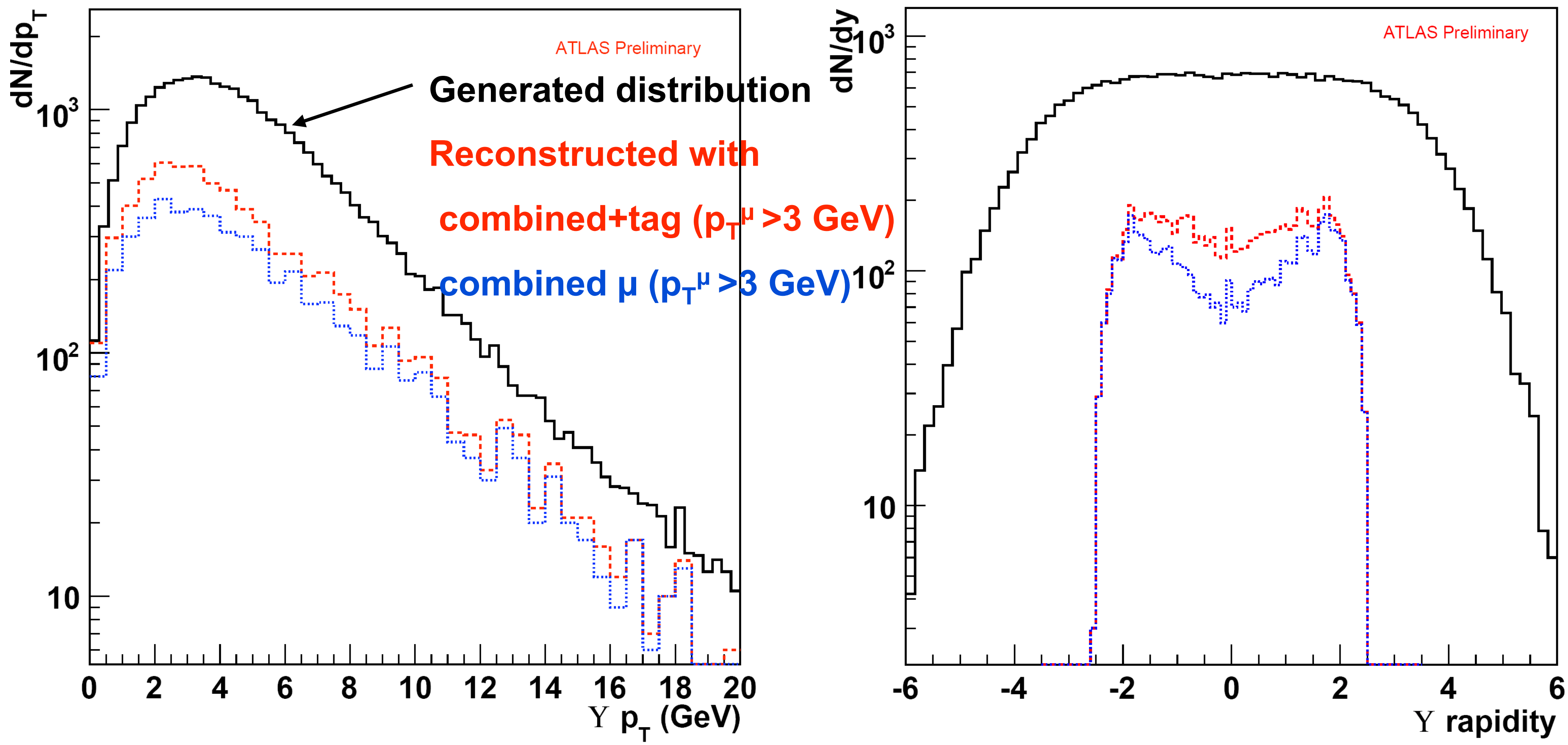
ordinary combined μ's from Υ's

additional μ's obtained by tagging

=> large gain for J/ψ

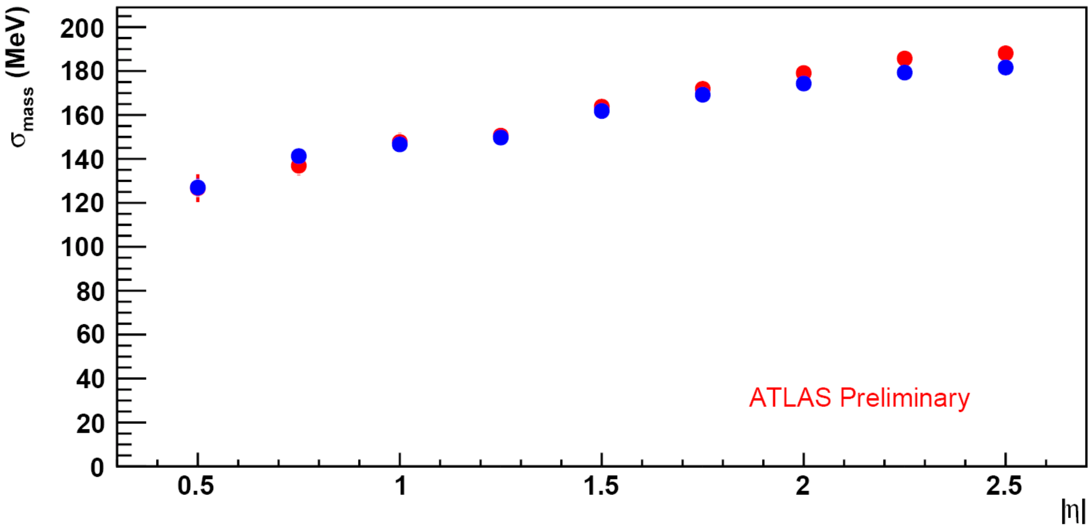
Additional way to increase acceptance is to reduce the toroidal field of the μ-spectrometer, e.g. of a factor 2 , see CERN-ATL-PHYS-PUB-2008-003

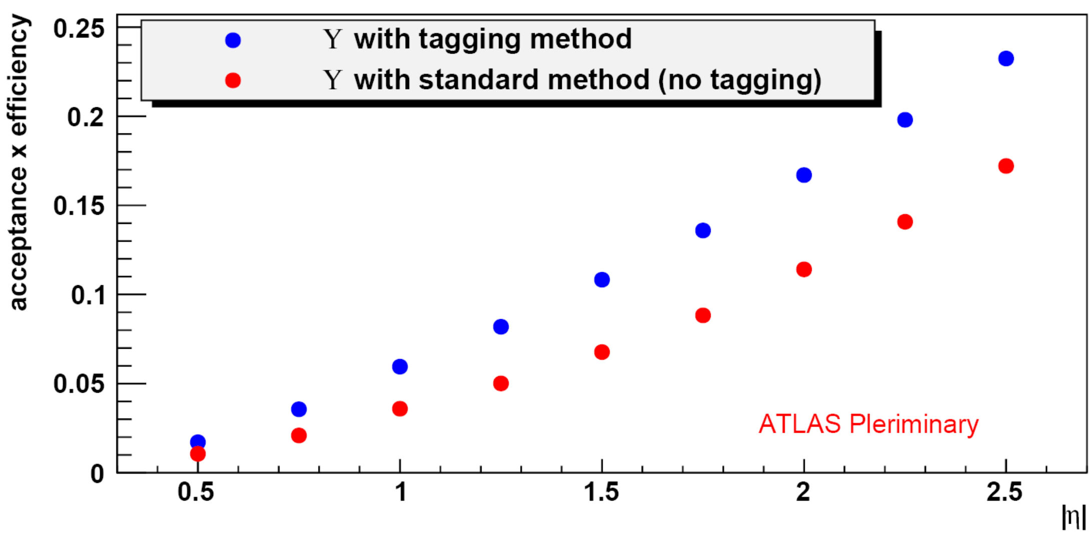
Acceptance/efficiency for the Υ



Full p_T coverage even if the p_T of the muons > 4 GeV

Mass resolution and acceptance for $\Upsilon \rightarrow \mu^+\mu^-$





Pseudo-rapidity upper cut on the decay μ's

A compromise has to be found between acceptance and resolution to clearly separate Υ states with maximum statistics (e.g. |η| < 1.5)

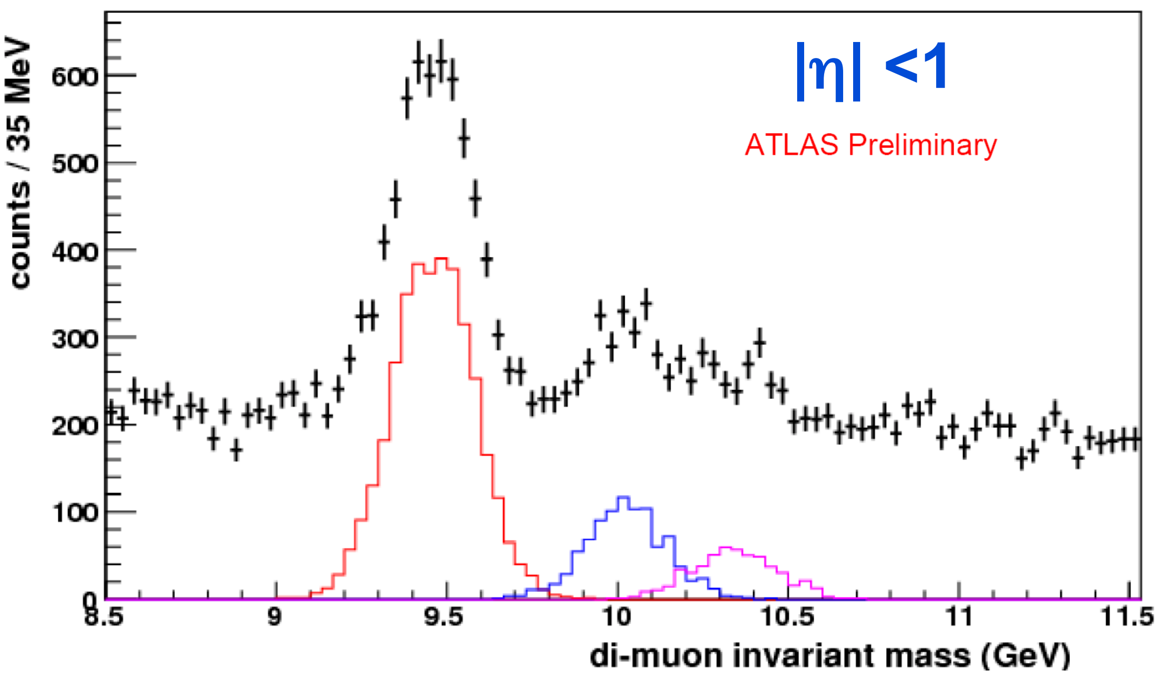
$\Upsilon \rightarrow \mu^+\mu^-$ reconstruction

combined+tag p_T^μ >3 GeV

combined μ	$\lvert\eta\rvert$ <1	$\lvert\eta\rvert$ <1.5	$\lvert\eta\rvert$ <2.5
Acceptance xefficiency	6.0% 3.6%	10.8% 6.8%	23.2% 17.2%
Resolution	147 MeV	162 MeV	182 MeV
Rate/month	9100 5500	16400 10300	35200 26100

For the full η range, we expect 35K $\Upsilon \rightarrow \mu^+\mu^-$ /month of 0.5 nb^{-1}

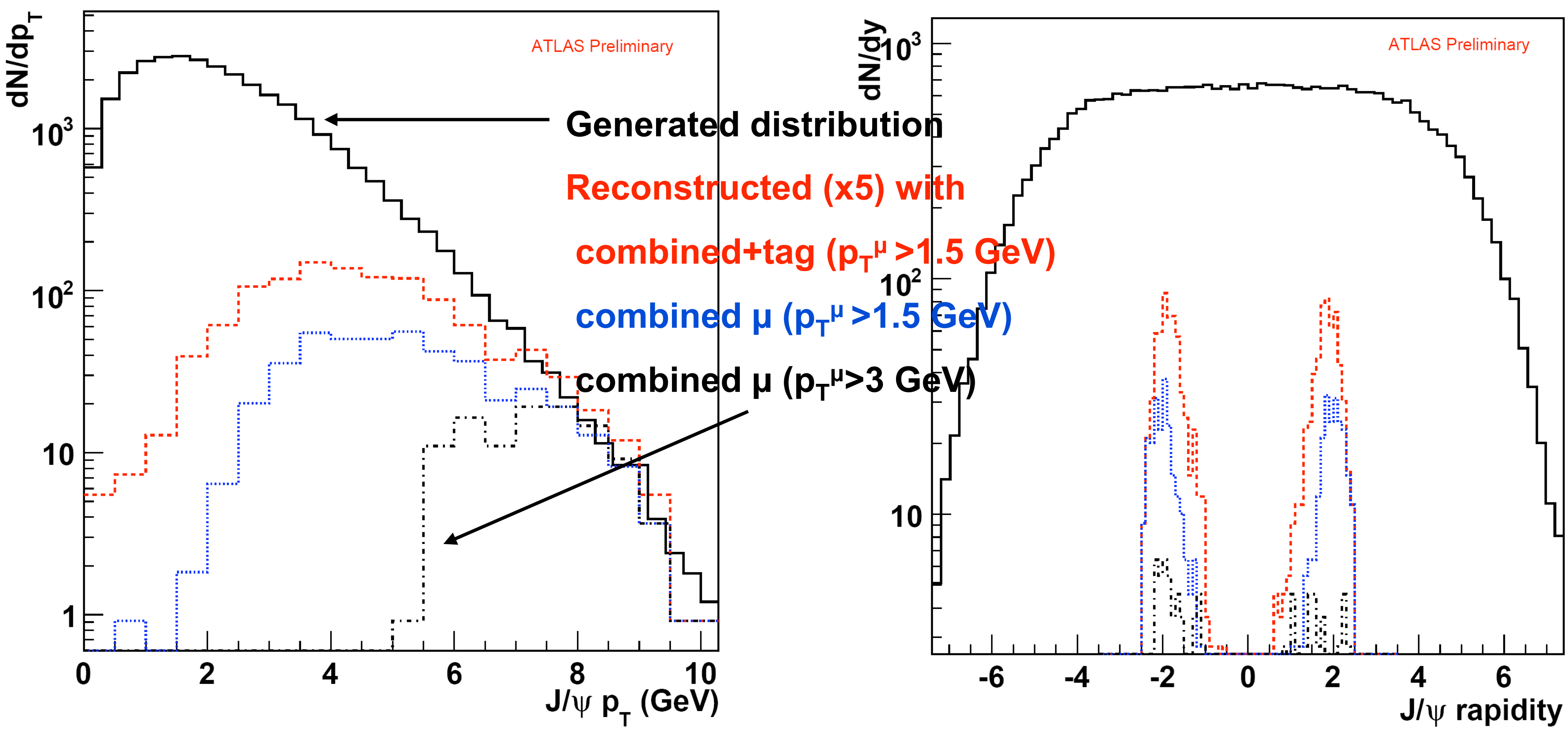
S/B ranges between 0.8 and 1



The Transition Radiation Tracker has not been considered for this study. When N_{ch} allows its use, the mass resolution can be improved.

$J/\psi \rightarrow \mu^+\mu^-$

Acceptance/efficiency for the J/ψ:



The full p_T range of the J/ψ is not accessible for $p_T^{\mu} > 3$ GeV, but is accessible for $p_T^{\mu} > 1.5$ GeV. **Acceptance is forward and backward.**

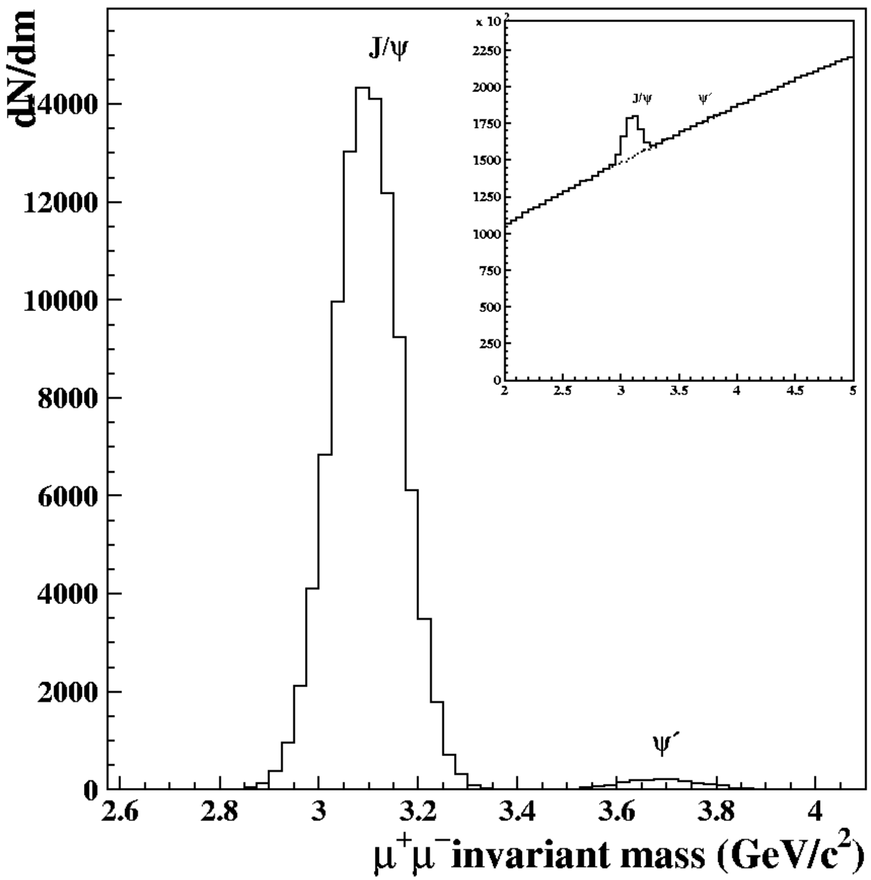
$J/\psi \rightarrow \mu^+\mu^-$ reconstruction

combined+tag

combined μ	$p_T^\mu > 3$	$p_T^\mu > 1.5$
Acceptance xefficiency	0.075% 0.051%	0.785% 0.301%
Resolution	69 MeV	81 MeV
S/B	0.4 0.5	0.15 0.2
$S/\sqrt{S+B}$	74 66	158 111
Rate/month	19000 13000	192000 74000

We expect 19K to 192K $J/\psi \rightarrow \mu^+\mu^-$ per month of 0.5 nb^{-1}

$|\eta| < 2.5$, $p_T^\mu > 1.5$ GeV

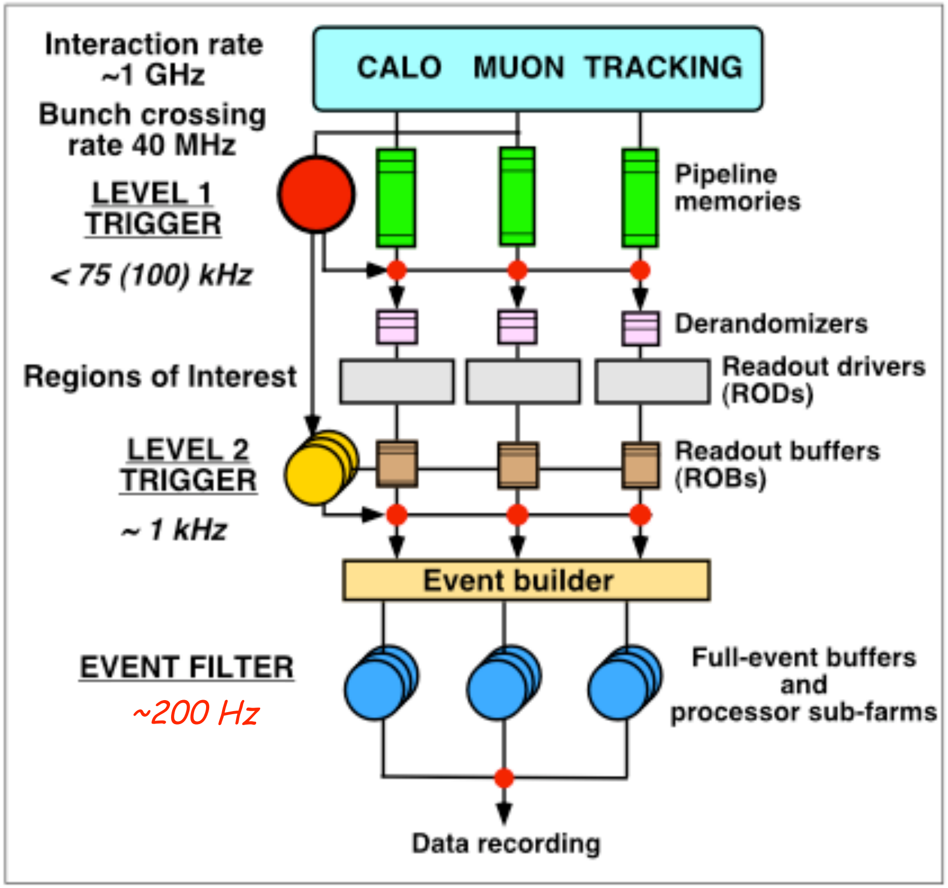


A low p_T trigger is under study (worse backgr., better rate & significance).

Possibility of measuring χ_c decaying into J/ψ.

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.

$\Upsilon \to e^+e^-$, $J/\psi \to e^+e^-$

The Transition Radiation Tracker can be used fully if N_{ch} is low enough partially in central Pb+Pb

- **as tracker:**

simplest strategy for central Pb+Pb: keep the 2 first time steps (out of 13) of the drift tubes

=> occupancy of 30% as in pp

=> 4 to 6 additional hits for track reconstruction

=> improves mass resolution, reduces fake tracks

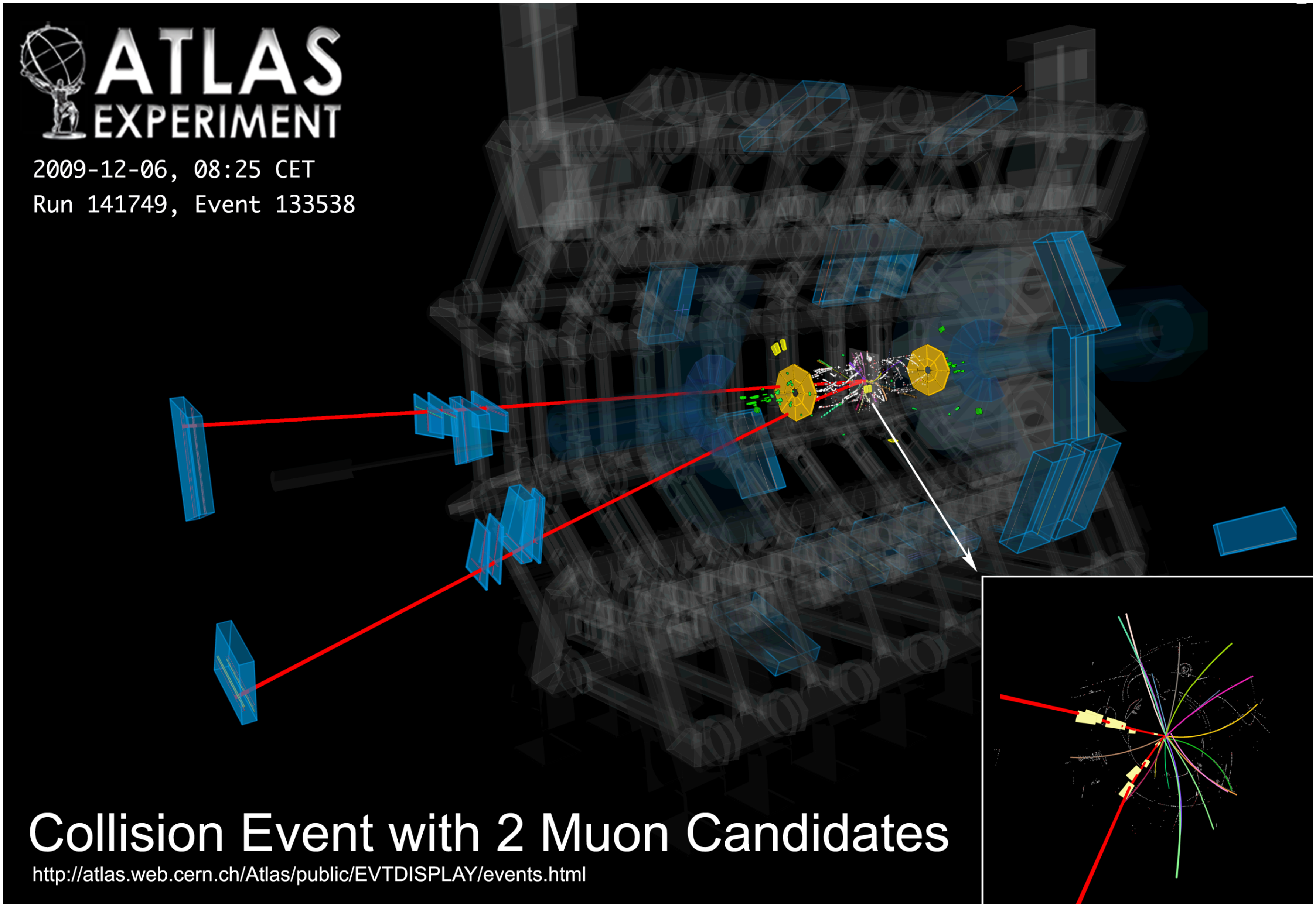
- **as electron detector:**

defines a road where to look for transition radiation to identify electrons & get Υ and $J/\psi \to e^+e^-$

A rejection factor of 30-100 against π can be achieved for an electron efficiency of 50% if $dN_{ch}/d\eta|_{max}$ =3200-1600 (ATL-PHYS-PUB-2008-003)

Scenario under evaluation

First di-muon candidate in √s=900 GeV pp data?



Summary

- **Heavy quarkonia physics (suppression in dense matter) well accessible,**
  capability to measure and separate Υ and Υ',
  to measure the J/ψ, ψ' using a specially developed μ tagging method,
  and to reduce background from π and K to an acceptable level.

- **A study of Υ, J/ψ $\rightarrow$ e^+e^- and of open heavy flavor production**
  are under way.

- **First Pb beams expected at the LHC this November with half energy**
  ($\sqrt{s_{NN}}$=2.76 TeV) and low luminosity (L_{max}=2x10^{25} cm^{-2} s^{-1} <=>160 Hz
  instead of 10^{27} nominal) .

Extra slides:

Machine parameters for Hi running

$$^{208}\mathrm{Pb}^{82+} \Rightarrow \quad \Leftarrow {}^{208}\mathrm{Pb}^{82+}$$

Parameter	Nominal	Early (2010)
Beam energy/nucleon [TeV]	2.76	1.38
Peak luminosity [$cm^{-2}s^{-1}$]	10^{27}	10^{25} - 2×10^{25}
No. of bunches	592	62
Bunch spacing [ns]	100	1350
Optics (β*) at IP1	0.55	3.0
No. of Pb ions per bunch	7×10^{7}	7×10^{7}
Luminosity half-time (3 expts)[h]	3	5.5

J. Jowett QM2008, http://arxiv.org/abs/0807.1397v1
(meeting 25.02.2010)

Heavy-ion physics programme

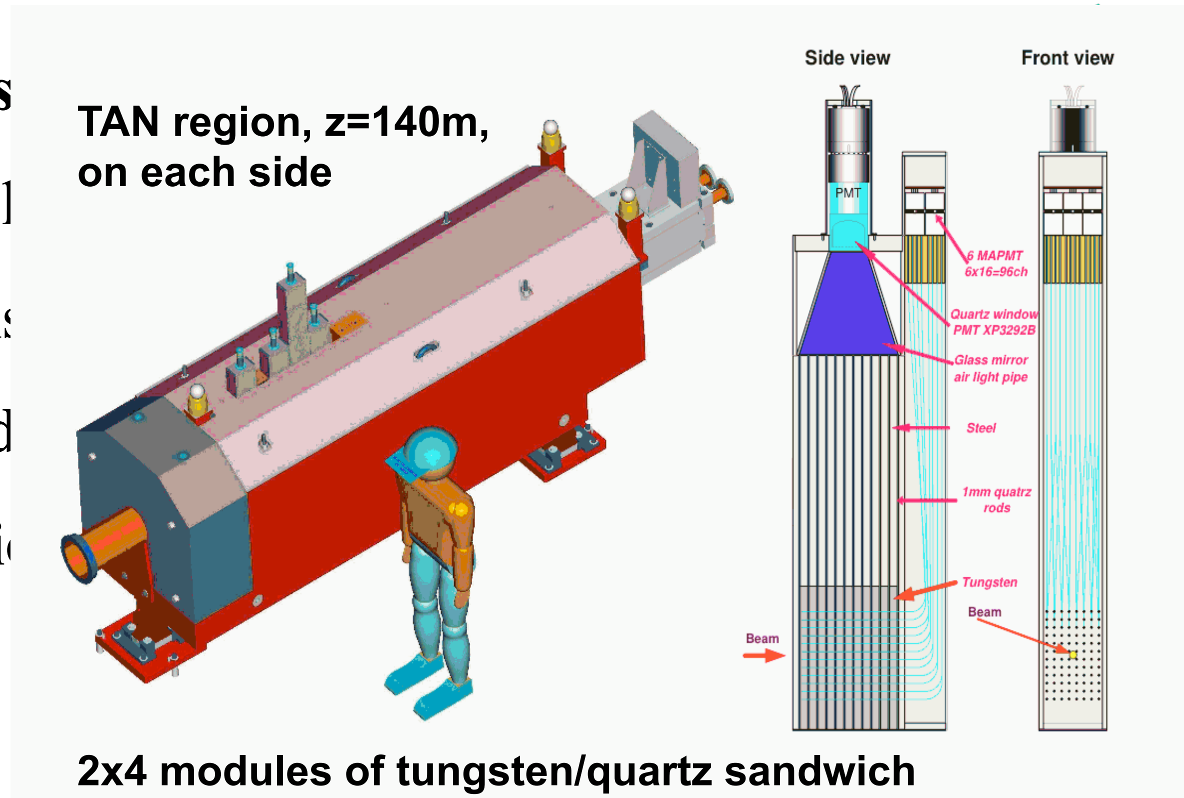
- **Global variable meas**

  dN/dη dE$_T$/dη el

  azimuthal distribution

- **Jet measurement and**
- **Quarkonia suppressi**

  Υ J/Ψ χ_c

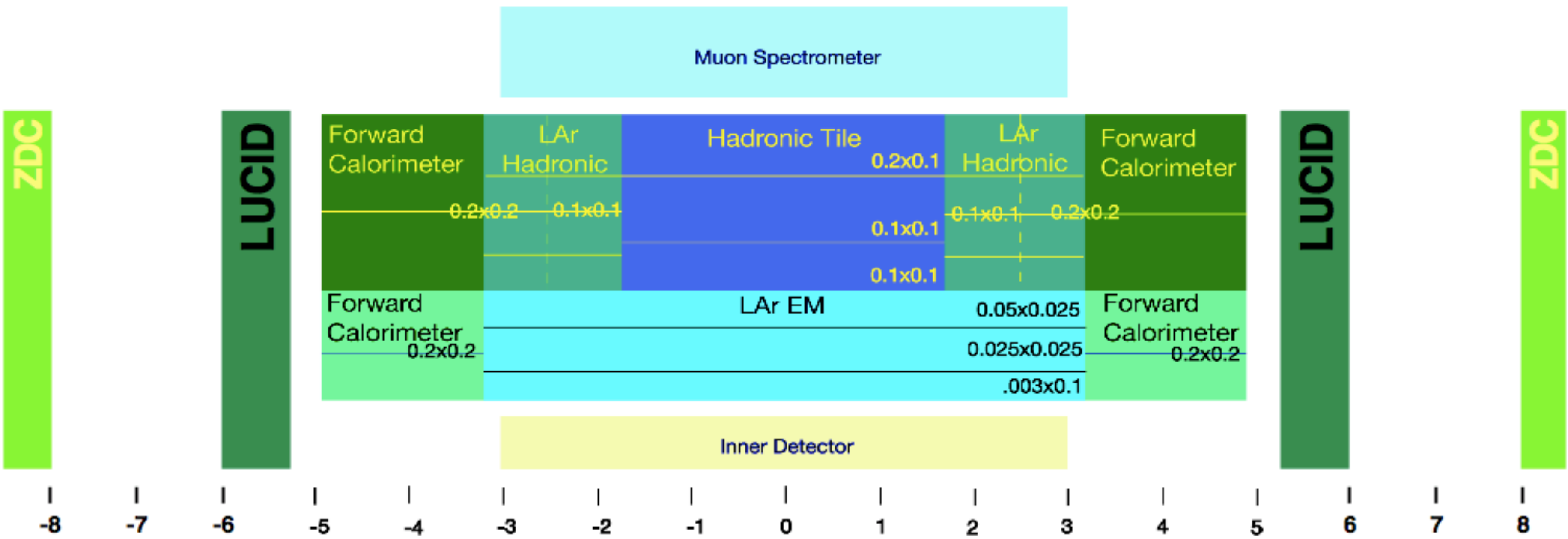


- **p-A physics**
- **Ultra-Peripheral Collisions (UPC)**

Idea: take full advantage of the large calorimeter and μ-spectrometer

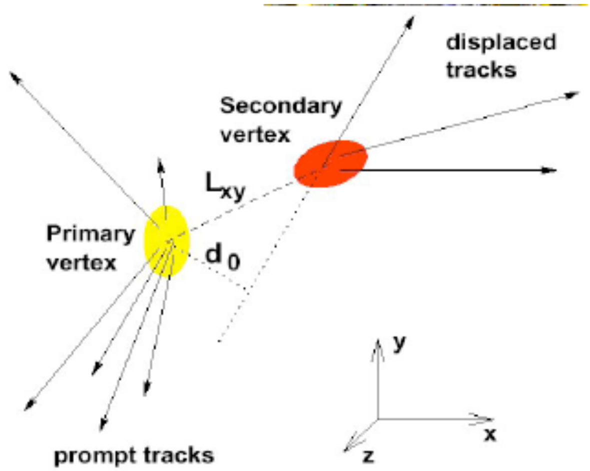
A **Z**ero **D**egree **C**alorimeter is being added for trigger and UPC tagging

Atlas acceptance



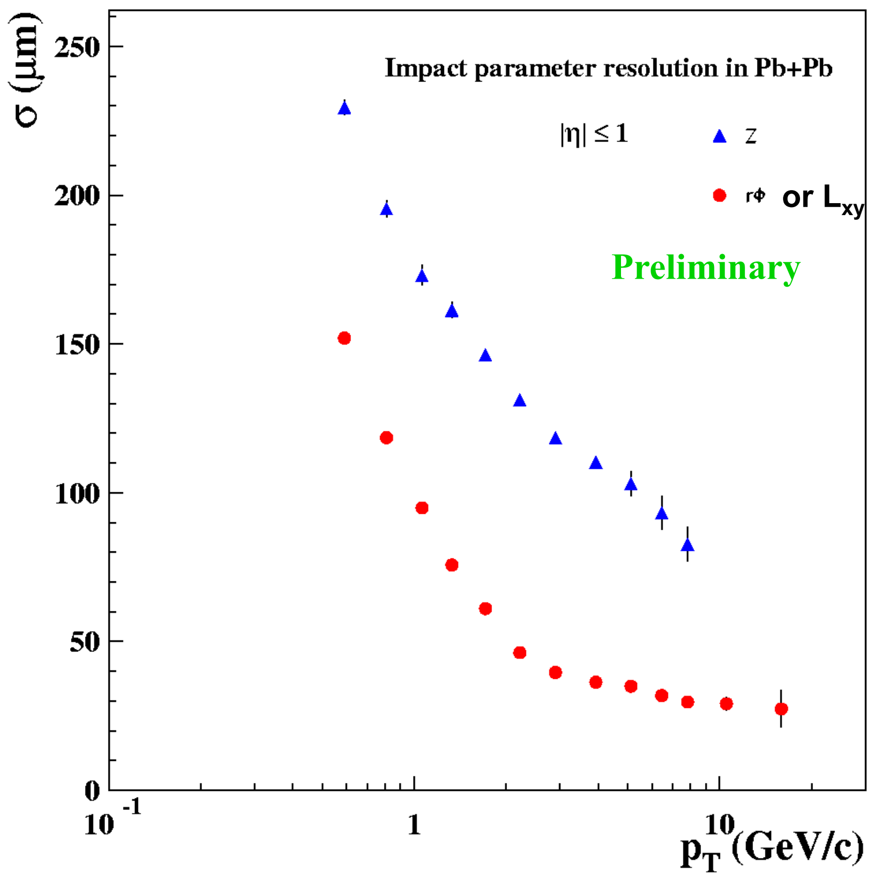
Open heavy flavors

B and D meson decays appear at secondary vertices, determined by lifetime and Lorentz boost.



Impact parameter resolution for reconstructed tracks from central Pb+Pb collisions:

=> semi-leptonic B, D decays and B-chain channel can be identified by displaced vertices via μμ, possibly μe and ee



under study