J/Ψ Physics at ATLAS

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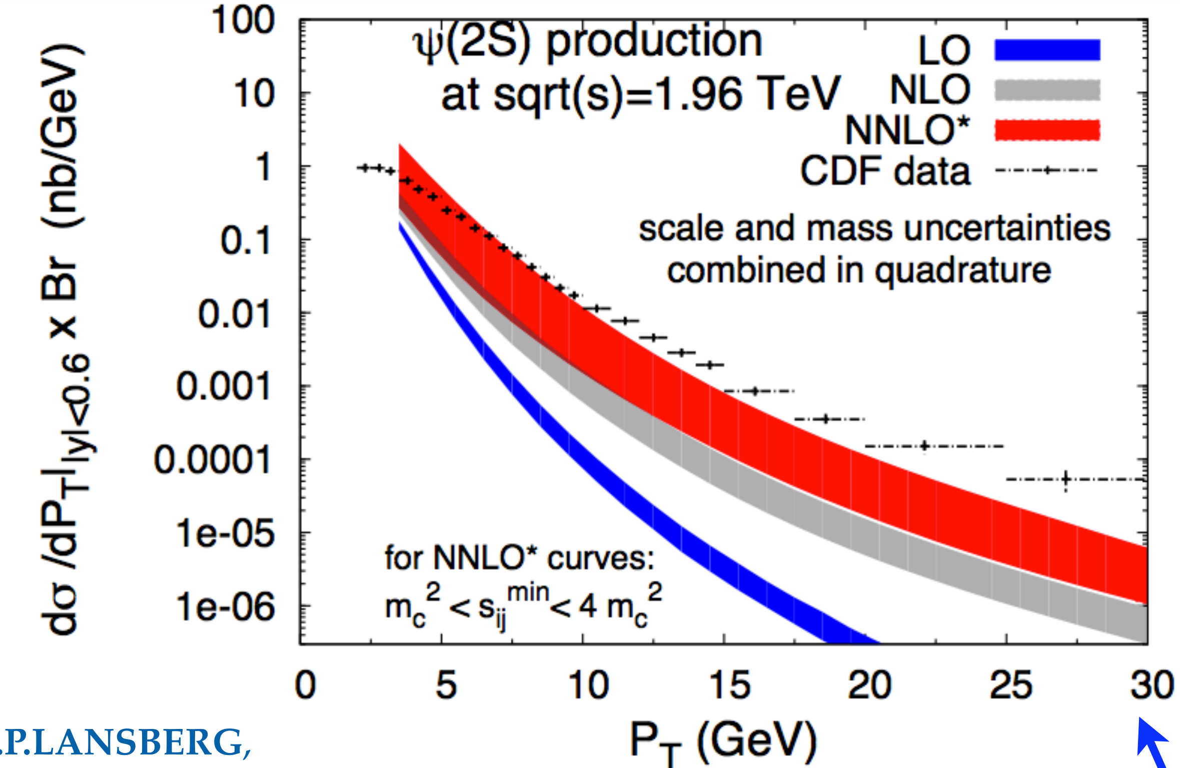
on behalf of the ATLAS Collaboration

General Motivations for J/Ψ and quarkonia studies at LHC

- Three main motivations for quarkonia studies at LHC:
- i: QCD physics of prompt onia production
  - uncertain hadron-production mechanism
  - unknown quarkonia polarization state
- ii: precise measurement of onia production allows to correctly subtract background for rare / interesting processes with onia indirect production
- detector/trigger calibration and performance (in the low p_T regime) measurement from data using a candle physics process
- *both i: and ii: need prompt to non-prompt separation capability*
  - in the following prompt-production definition includes:
    - J/Ψ emerging from the hard parton scattering
    - J/Ψ from radiative decays of the C-even states ($\chi_{ci} \rightarrow J/\psi\gamma$)

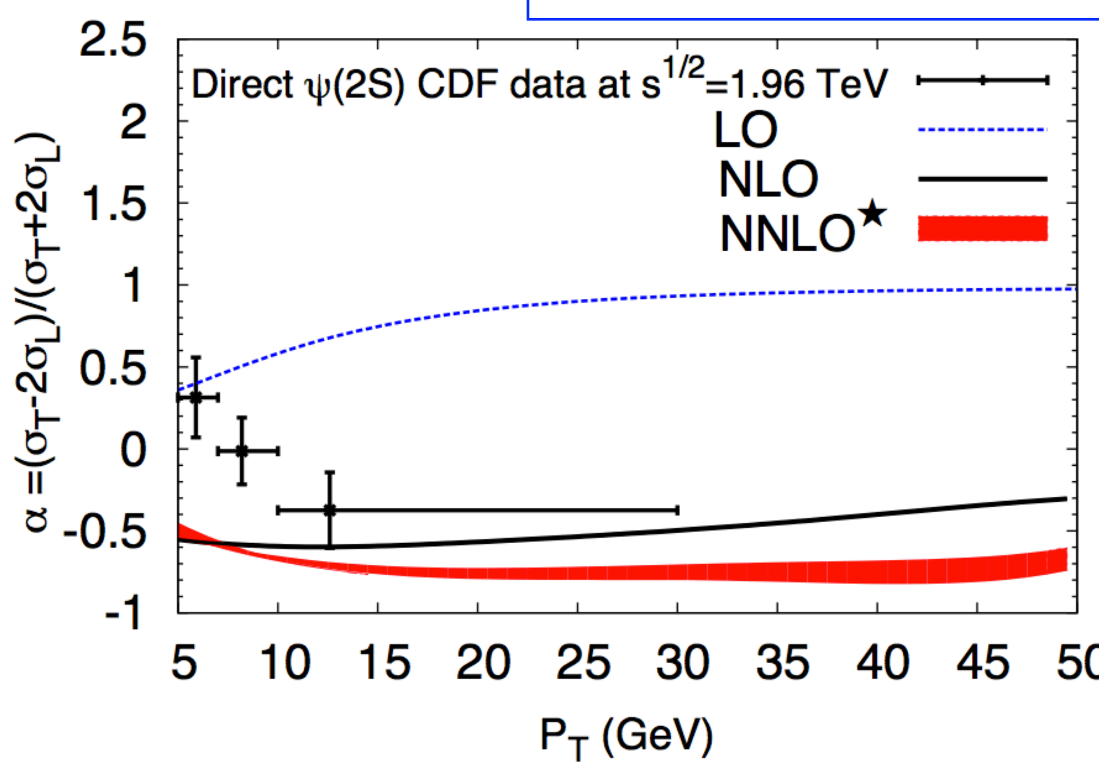
Problems in past and present quarkonia measurements

- Color Singlet Model (quarkonium quantum numbers = final meson quantum numbers) + pQCD at improved NLO (NNLO*) describes the p_T trend of the production cross section at low and intermediate transverse momenta
  - still room for Color Octet Model at very high p_T?
    - gluon splitting would enhance the production at high p_T
- Color Octet Model (allows for gluon content of the quarkonium) challenged by
  - NLO $d\sigma/dp_T$ predictions at low p_T overshoot data
  - e+e-→J/ψ+X at B-factories ➠ full consistency with CSM at NLO leaves no room for COM
- Quarkonia polarization measurements until now statistically limited and not well described by theory
  - CSM + pQCD NLO predictions wildly different w.r.t. LO prediction
  - COM predicts generally high polarization values



J.P.LANSBERG, "Perspectives for quarkonium production at the LHC", ICHEP-2010 and references therein

Ψ(2S) does not suffer from feed-down from Chi states



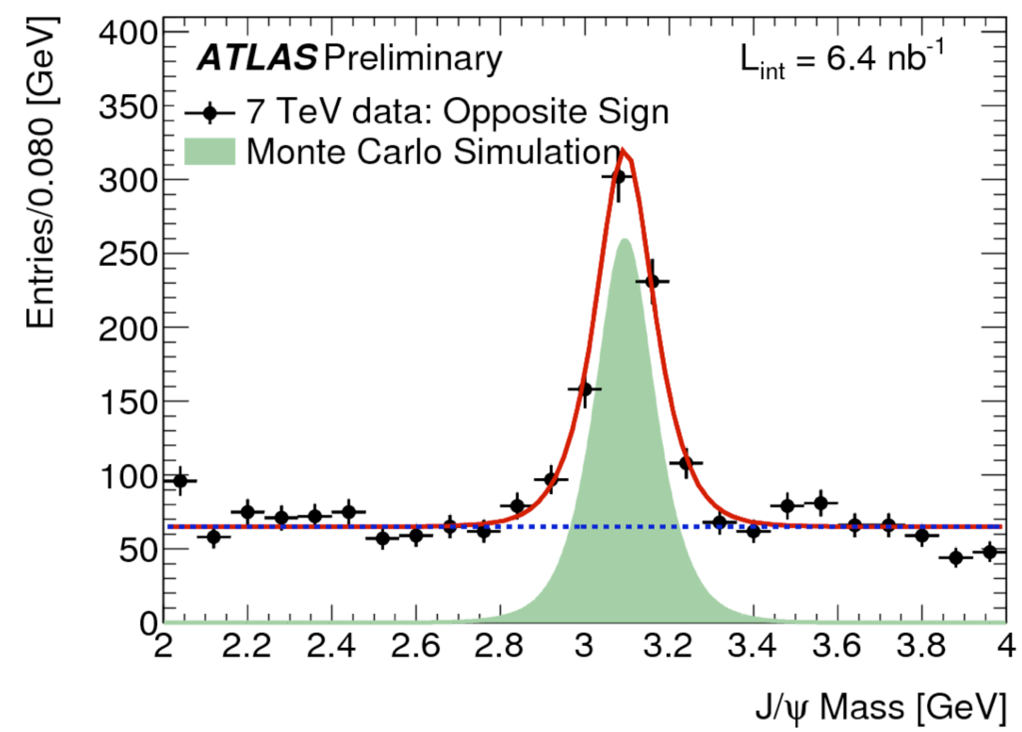
Quarkonia observation in ATLAS

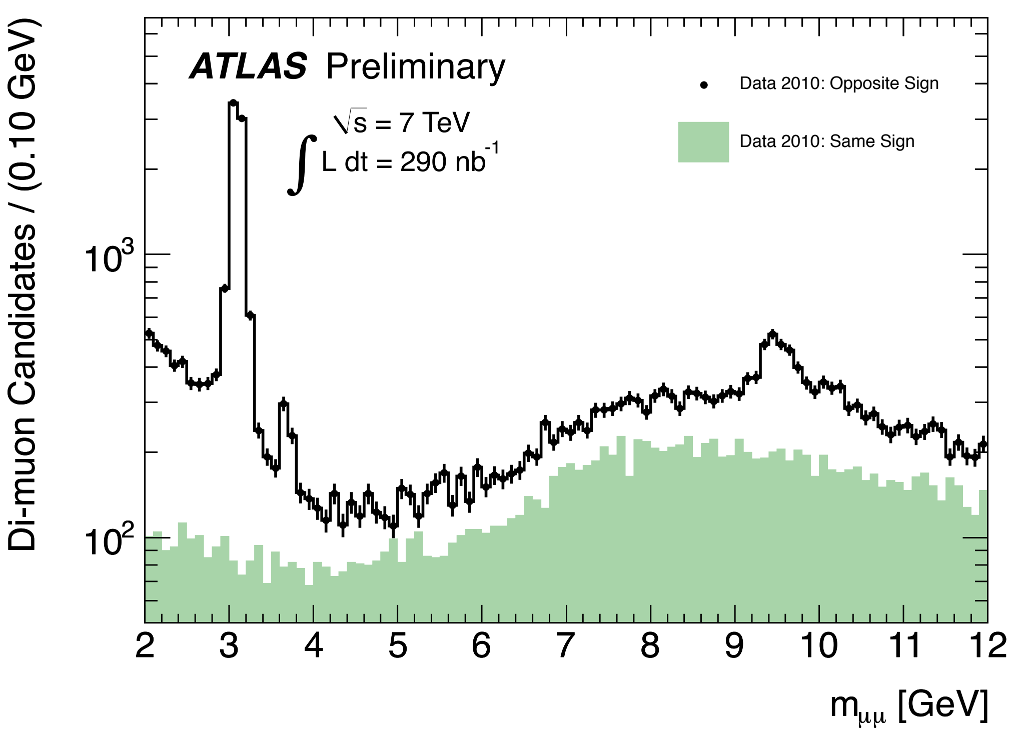
J/ψ first observation:

μ+μ- channel

measured mass and width in agreement with MC

$M_{J/\Psi}$ = 3.095 ± 0.001 GeV
$\sigma_{m(J/\Psi)}$ = 70 ± 1 GeV with Lint=290nb[-1]



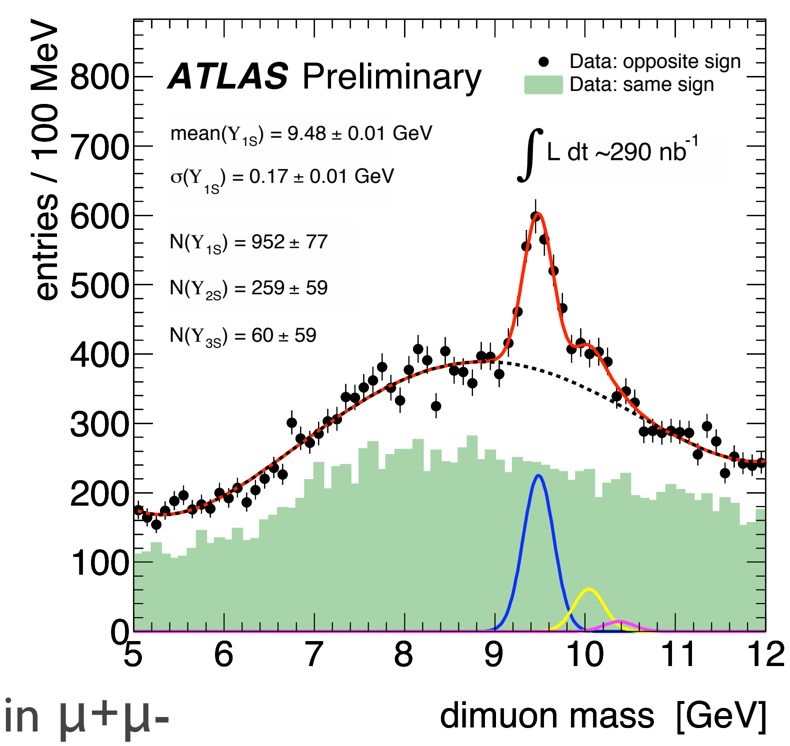


On a larger data set

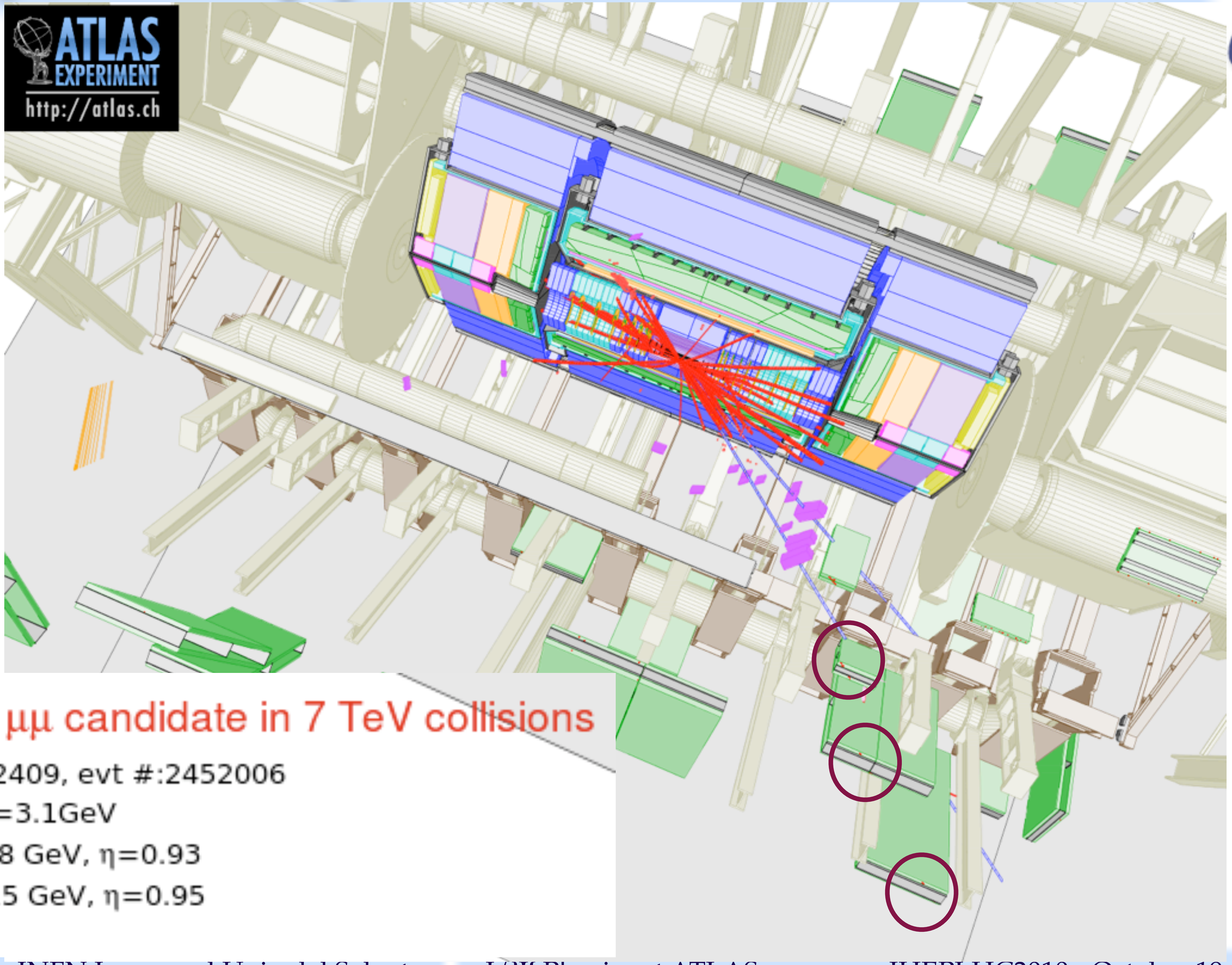
the quarkonia spectrum emerges clearly
from the ATLAS data

Υ family

observation in μ+μ-



A J/Ψ→μμ candidate view



J/psi -> μμ candidate in 7 TeV collisions

run #: 152409, evt #:2452006

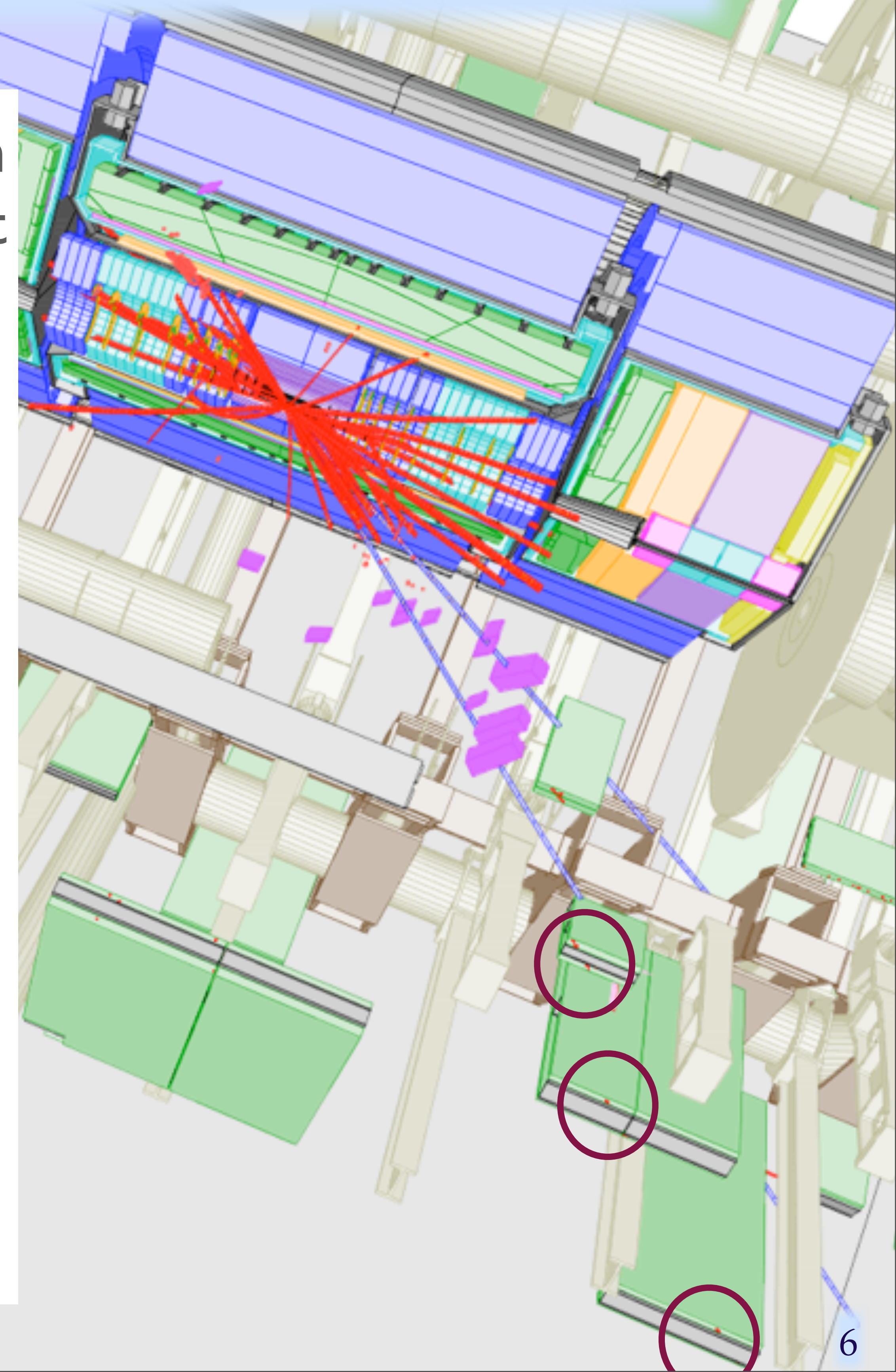
Inv. Mass=3.1GeV

P(μ+) = 28 GeV, η=0.93

P(μ-) = 15 GeV, η=0.95

Muon reconstruction in ATLAS

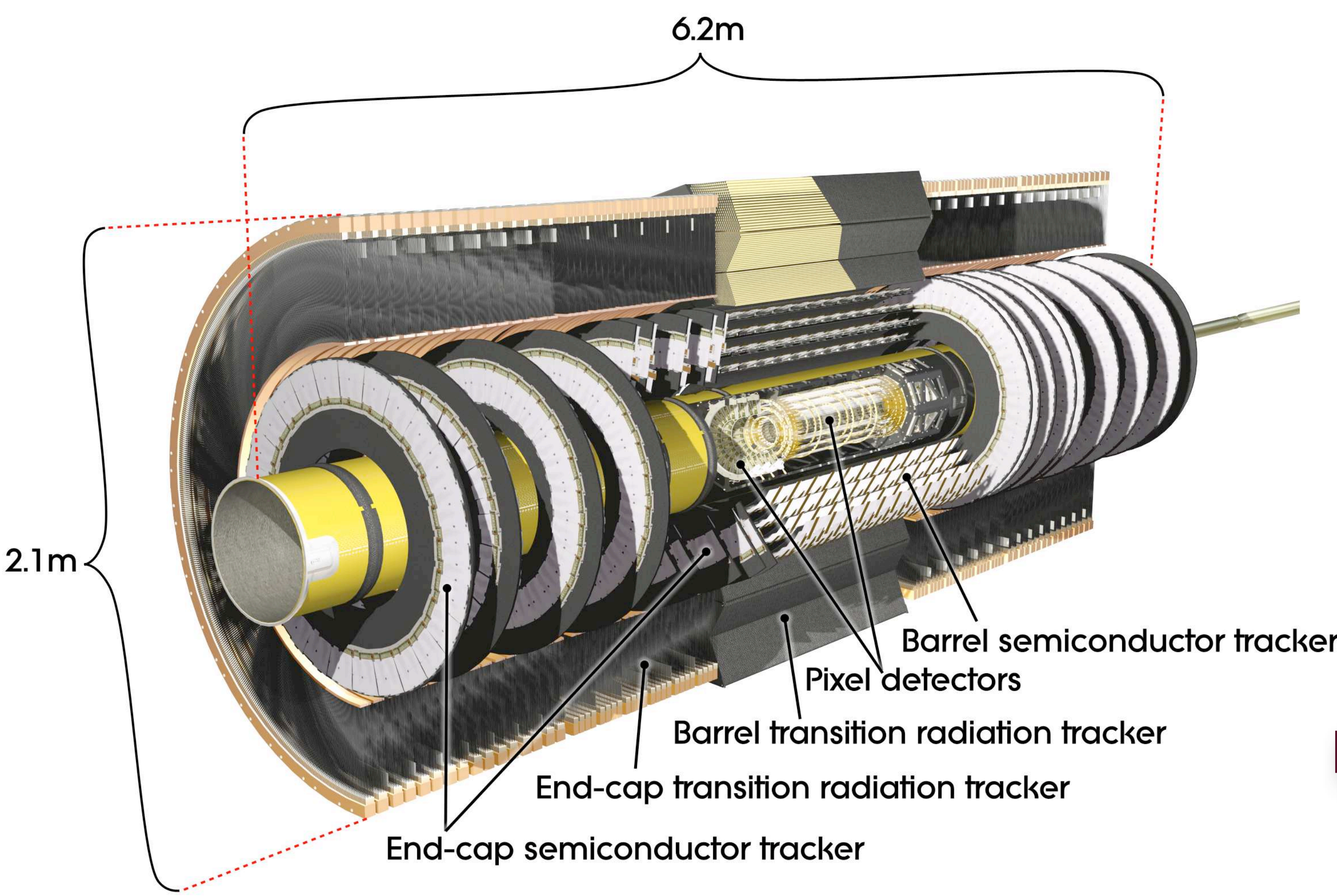
- Muon Reconstruction in ATLAS starts from local segments in 3 (typically) measurement stations of the **Muon Spectrometer** (MS) fitting to a common track
  - **Rel. sagitta resolution <10% for p_T<1 TeV**
  - **coverage |η| <2.7**
- extrapolated to IP, if matching an Inner Detector (ID) track the statistical combination of the ID and MS extrapolated tracks is a *Combined Muon [CB] (typical muon reconstruction mode for intermediate-high p_T)*
- an ID track extrapolated to the MS and matching one or more muon segments is a *Segment Tagged Muon [ST] (low p_T muons are reconstructed with higher efficiency as ST Muons if |η|<2)*



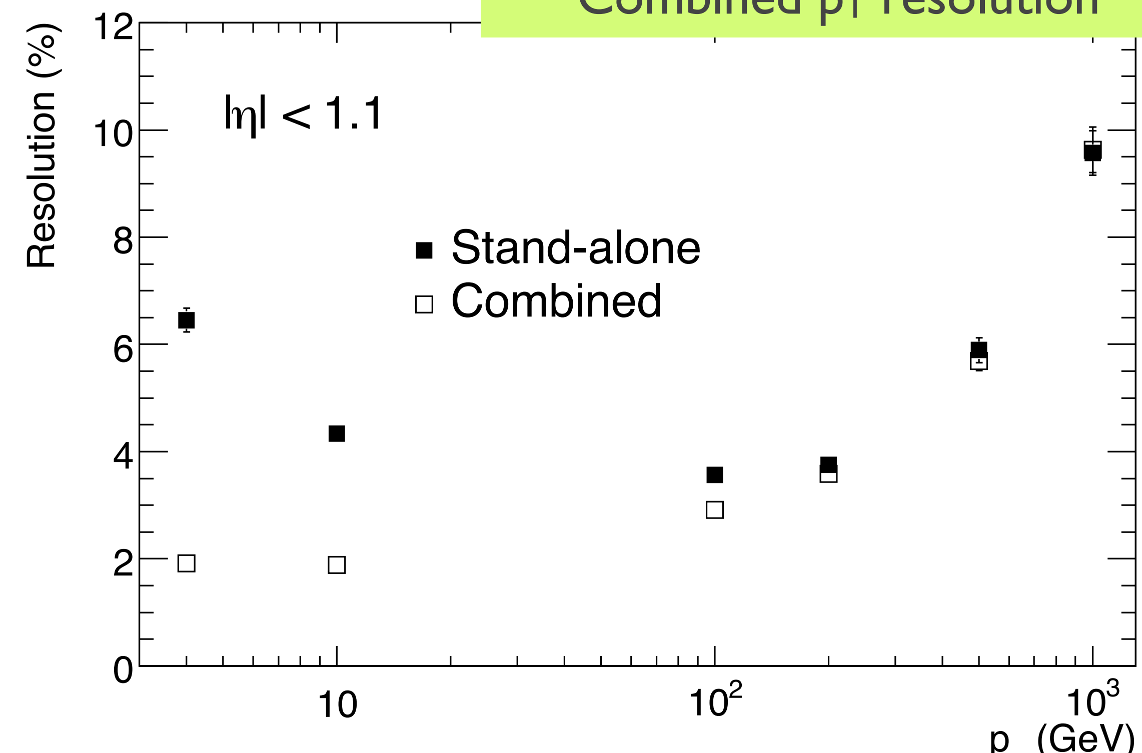
ATLAS detector features relevant to J/Ψ physics

The Inner Detector

- Coverage |η|<2.5, Solenoid B=2 T
- Pixel detectors (PI), Silicon Strips (SCT), straw tubes Transition Radiation Tracker (TRT)
- a high p_T track is typically measured in 3 Pixel detectors, 4 SCT paired modules (for phi and eta measurement) and, for |η|<2 produces ~40 TRT hits (giving e/π separation power)
- **relative p_T resolution 0.035% x p_T[GeV]+1.5%**



Expected Muon Standalone and Combined p_T resolution

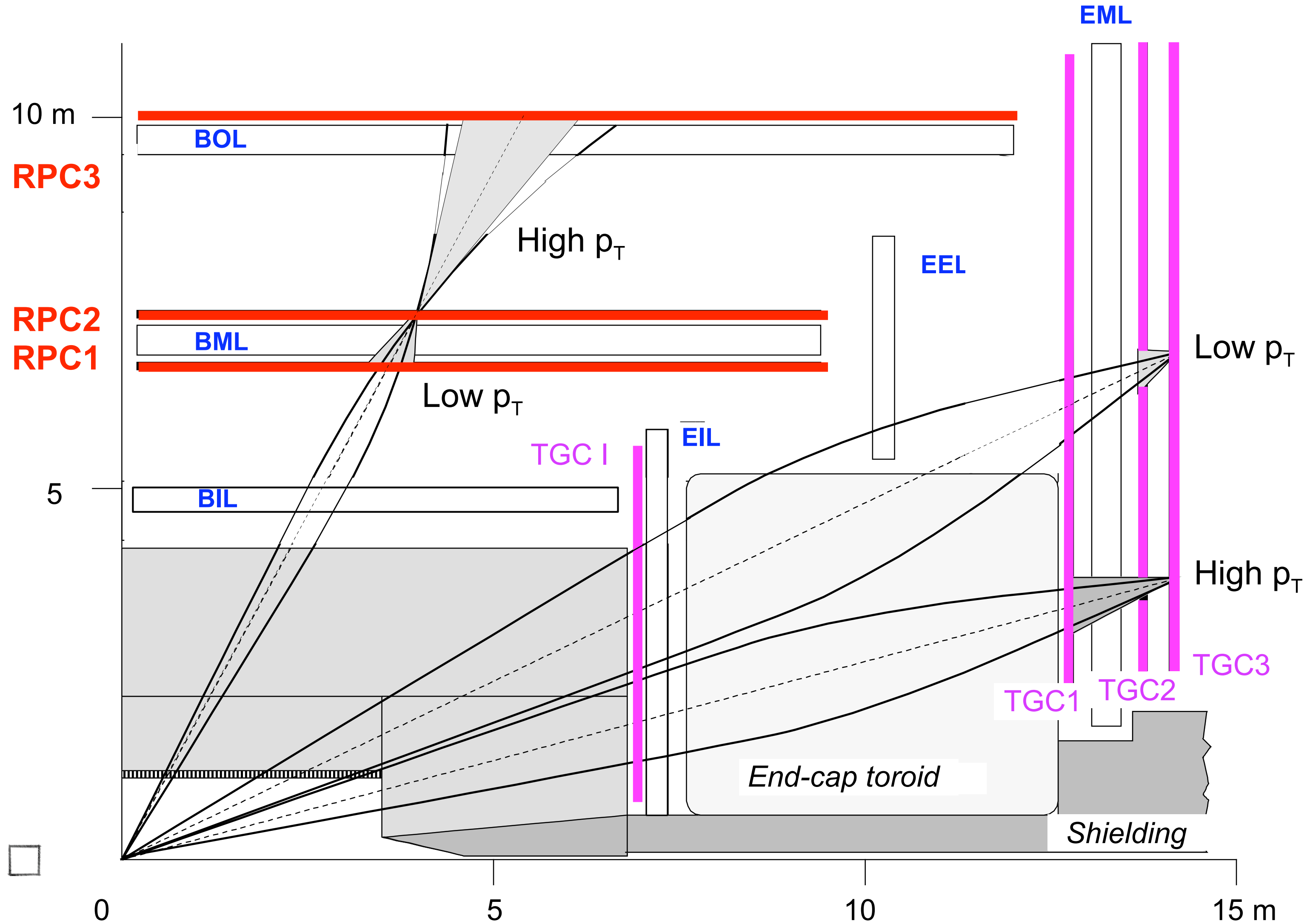


Muon Reconstruction performance in the J/Ψ momentum regime is dominated by the ID

ATLAS detector features relevant to J/Ψ physics

Muon Trigger

- 3 level trigger: LVL1 hardware + LVL2 and EF software
- regional approach: the trigger candidate identified in a Region Of Interest (RoI) at a given level is processed in the next level
- Full event scan at EF possible at low luminosity or for low rate LVL1-LVL2 seeding signatures



- LVL1 muon trigger is based on RPC (barrel) and TGC (endcap)
- one pivot plane and two confirm planes
- hits in the confirm planes are searched in roads open from the pivot hit with a p_T dependent width
  - 6 programmable thresholds
- lowest p_T threshold (L1_MU0) corresponds to connectivity limit of the trigger detectors
  - should be efficient in all regions for p_T >4 GeV

ATLAS results with J/Ψ

- ATLAS detector performance with J/ψ
  - mass scale and resolution from the ID tracking performance with J/ψ in $78 nb^{-1}$
    - ATL-CONF-2010-078
  - Electron performance of the ATLAS detector using J/ψ➛e+e- decays in $78 nb^{-1}$
    - ATL-COM-PHYS-2010-518
- **Results on J/ψ physics $\sqrt{s}$ = 7 TeV**
- Inclusive double differential J/ψ➛μμ production cross section in bins of J/ψ transverse momentum and rapidity with $\mathcal{L}_{int}$ =$9.5 nb^{-1}$
  - ATL-CONF-2010-062
- ratio of B→J/ψ to prompt J/ψ production as a function of the J/ψ p_T with $\mathcal{L}_{int}$ =$17.5 nb^{-1}$
  - ATL-CONF-2010-062

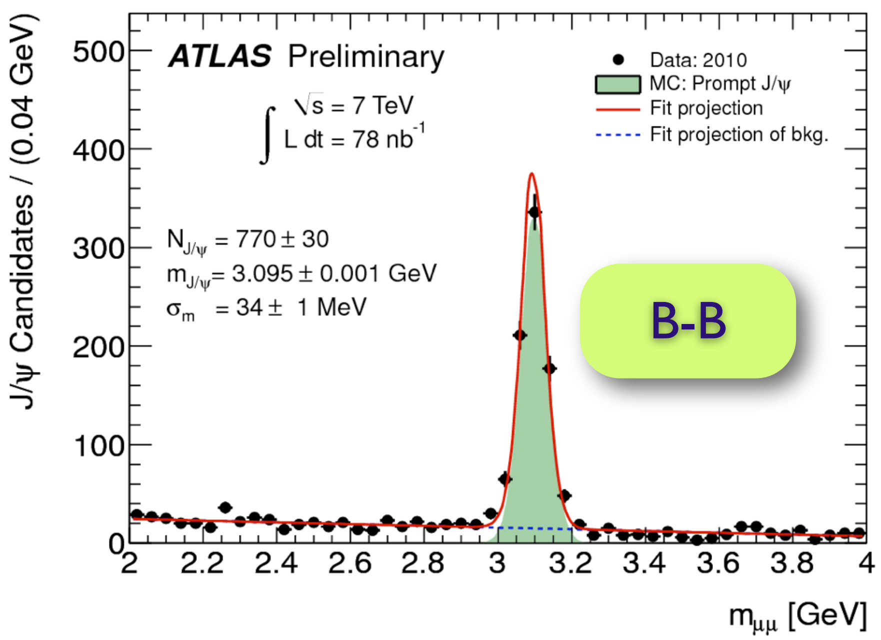
ATLAS results with J/Ψ

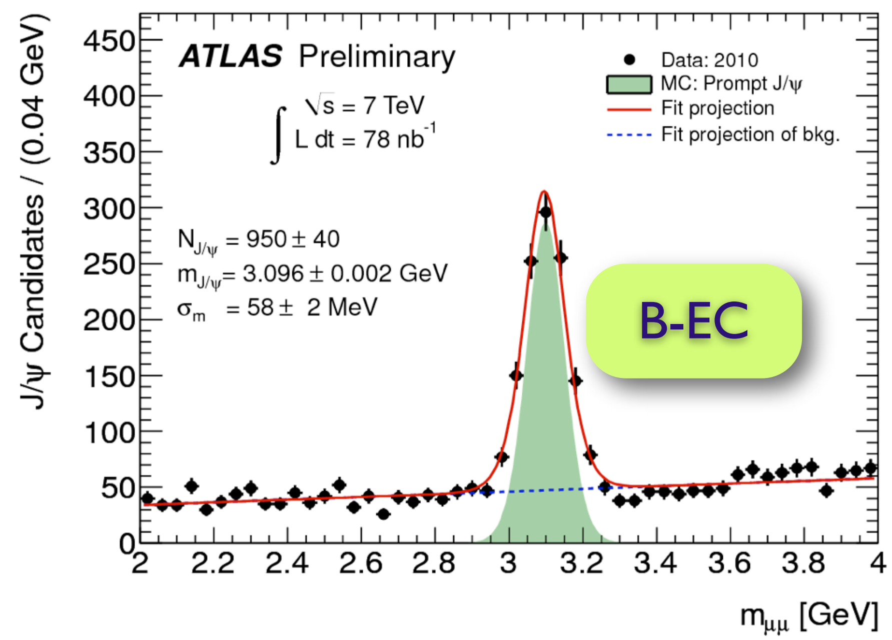
- ATLAS detector performance with J/ψ
  - mass scale and resolution from the ID tracking performance with J/ψ in $\mathcal{L}_{int}$ =78nb^{-1}
    - ATL-CONF-2010-078

ID tracking performance study with a J/Ψ➛μμ sample

- Event and J/ψ candidate selection
  - muon pairs can be **CB-CB, CB-ST or ST-ST**
  - **muon kinematic parameters from ID reconstruction used**
    - cut on p<3 GeV (no explicit p_T cut but ID reconstruction starts for p_T >0.5GeV)
- same analysis applied to MC
  - Pythia (MC09 ATLAS tune and MRST LO parton pdf's) with J/ψ prompt production implemented according to NRQCD Color Octet Model
- mass and mass resolutions are derived from an unbinned maximum likelihood fit to the candidate invariant mass (signal is modeled with a gaussian and background by a first order polynomial)
  - results are compared with MC in different detector regions

ID tracking performance study with a J/Ψ➛μμ sample

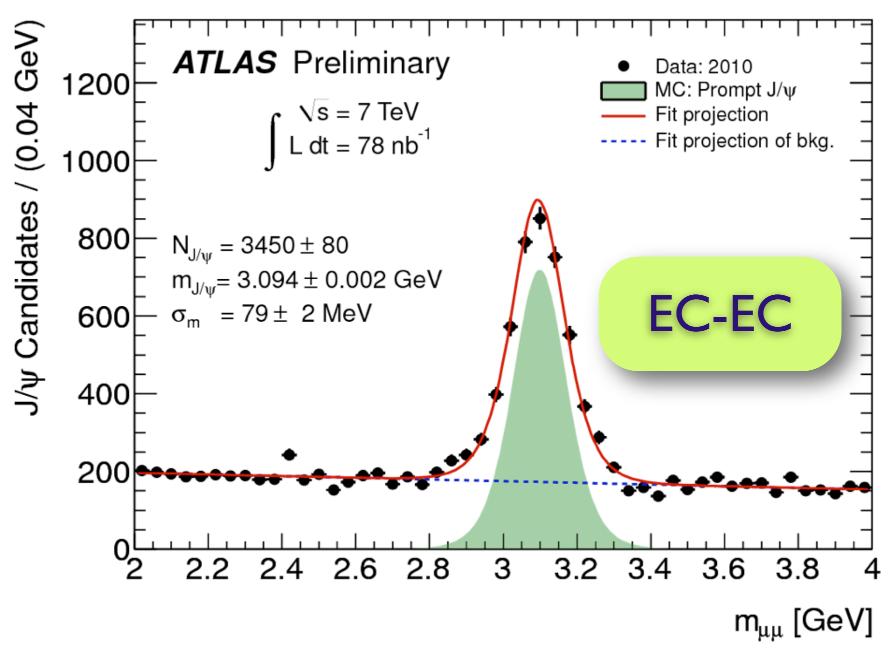




Separate samples with both muons are reconstructed in the barrel (B), or in the endcaps (EC) or one muon falls in the barrel and one in the endcap

B=barrel: $|\eta|<1.05$

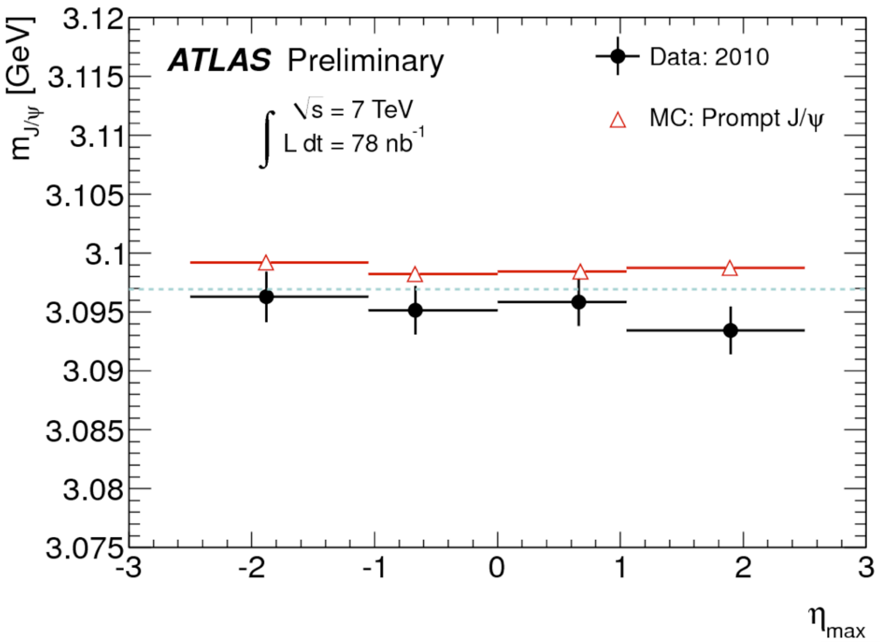
EC=endcap: $1.05<|\eta|<2.5$

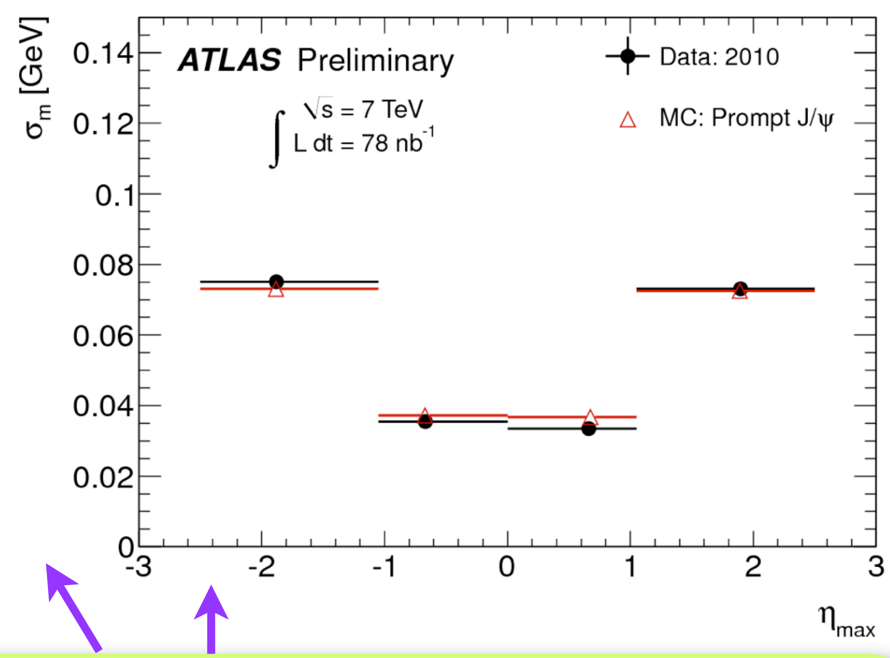


mass resolution in the endcap is worse due to larger amount of traversed material and lower (in average) field bending power seen by the track

Narrow resonance: allows to control **absolute mass scale and mass resolution** ➟ B field knowledge, material mapping, calibration and alignment

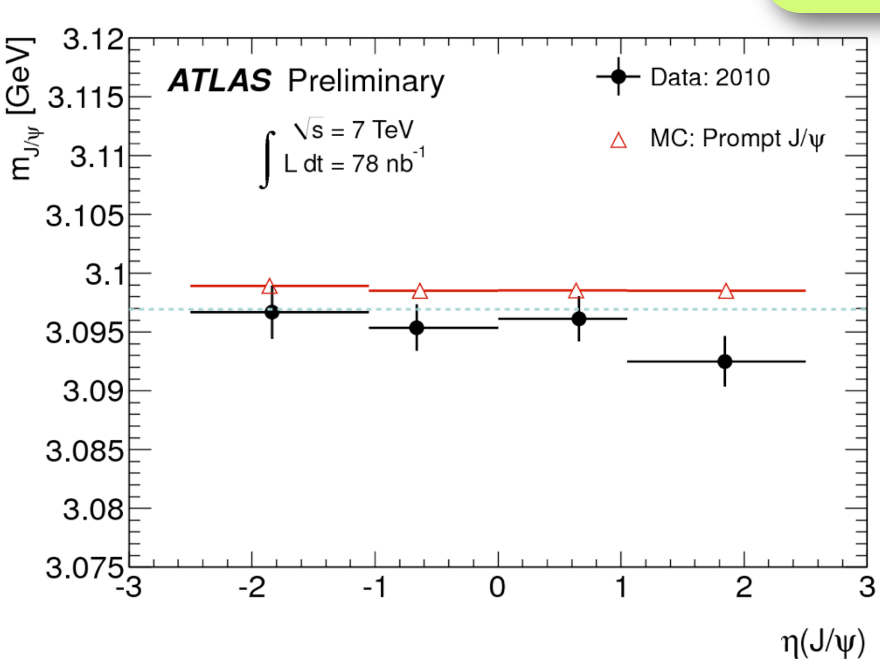
ID tracking performance study with a J/Ψ➤μμ sample

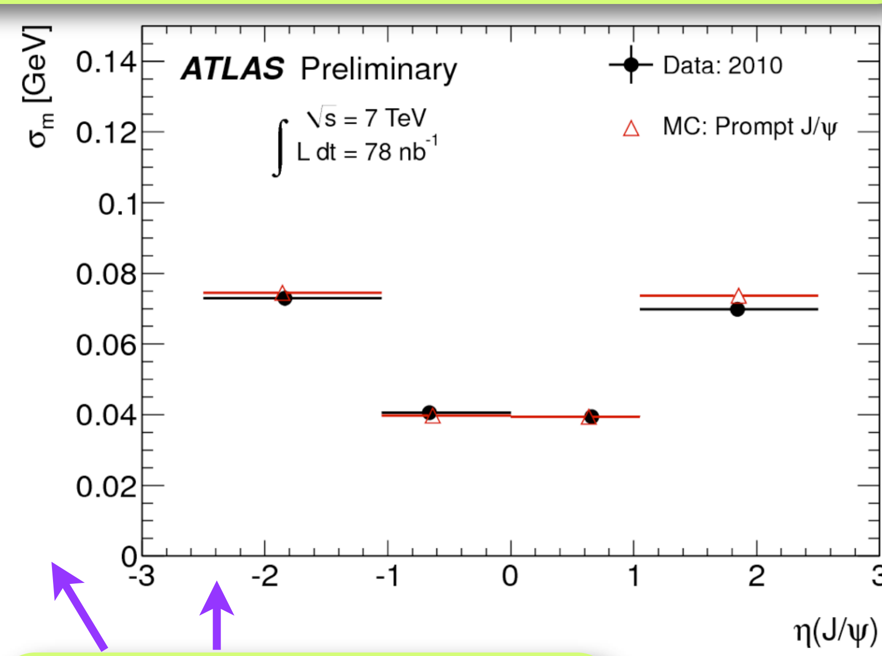




pseudo-rapidity of the most forward muon

Mass in agreement with PDG in all regions of pseudo-rapidity





J/ψ pseudo-rapidity

Scale and resolution in data well described by the simulation

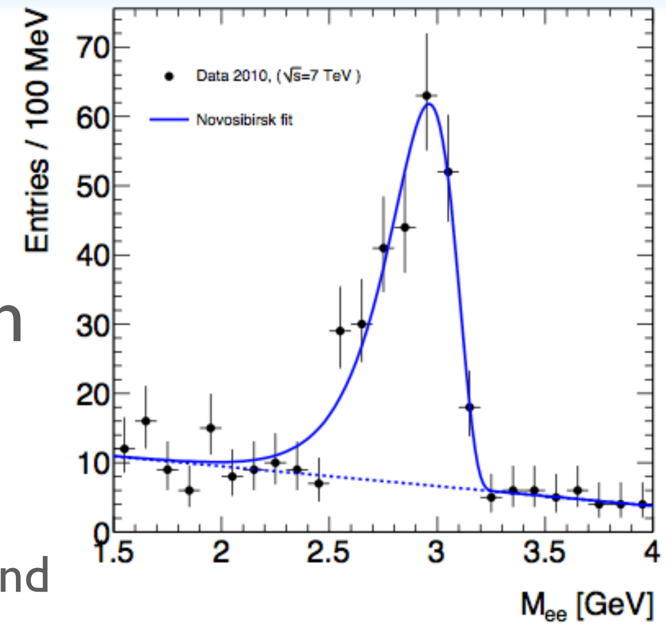
mass scale max. deviation (0.2±0.1)%

Electron performance with J/Ψ➛e+e-

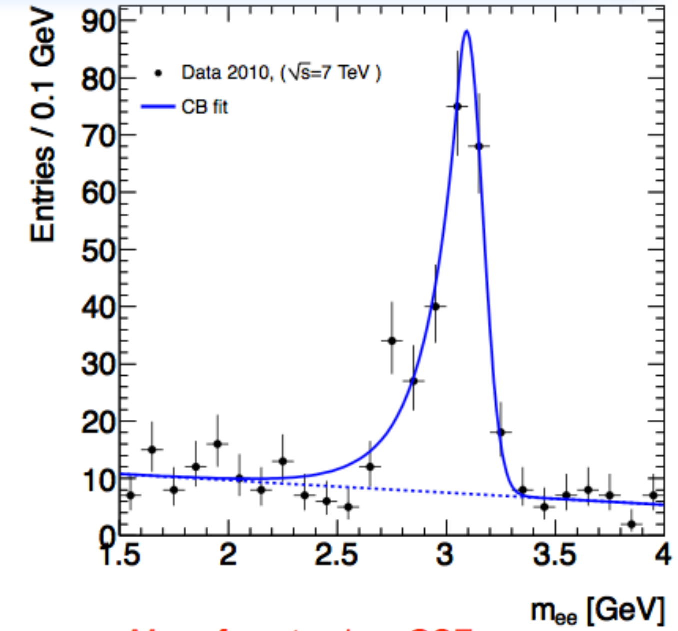
- Electron performance of the ATLAS detector using J/ψ➛e+e- decays
  - ATL-COM-PHYS-2010-518 based on $\mathcal{L}_{int}$ =78nb^{-1}
- calorimeter momentum scale (and uniformity) through J/ψ reconstructed mass
- performance of bremsstrahlung recovery in track refit

Electron performance with J/Ψ➤e+e- bremsstrahlung recovery, calorimeter mass scale and uniformity

- electron selection for e+e- invariant mass reconstruction
  - Calorimeter discriminants
    - Lateral containment in η in the 2nd LAr layer: R_η < 0.85(0.9) for |η| <1.5(>1.5)
    - fraction of EM energy in the 1st compartment w.r.t. total: f1 > 0.15
    - Eratio > 0.07,
  - Tracking variables:
    - fraction of TRT highThr hits > 0.12,
    - track p_T> 2 GeV, 1 b-layer hit (removes γ conversions), 1 pixel hit, 7 SCT hits, unbiased d0 significance w.r.t. primary vertex < 5

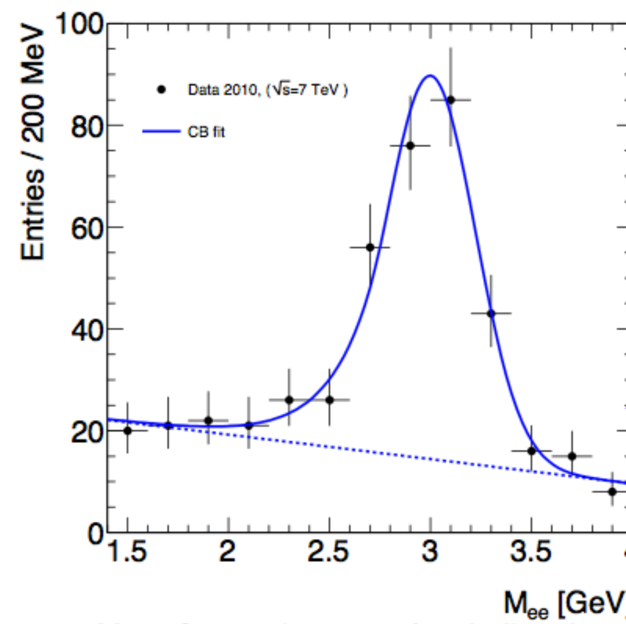


Mass from tracks
mean = 2.96 +/- 0.01
sigma = 0.16 +/- 0.01
signal = 234 +/- 20
bkg = 57 +/- 18



Mass from tracks - GSF
mean = 3.09 +/- 0.01
sigma = 0.07 +/- 0.01
signal = 222 +/- 11
bkg = 28 +/- 2

Gaussian Sum Filter for bremsstrahlung recovery



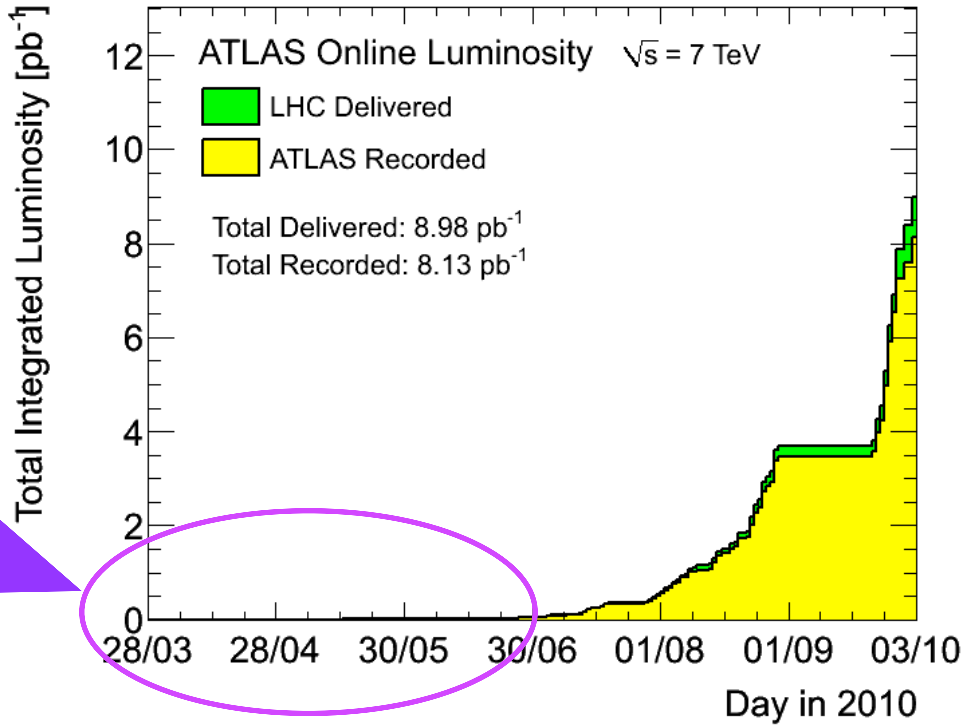
Mass from calo energy/track direction
mean = 3.00 +/- 0.03
sigma = 0.22 +/- 0.03
signal = 229 +/- 24
bkg = 96 +/- 22

by measuring the mass from the calorimeter energy as a function of Energy & η the uniformity can be probed

ATLAS results on J/Ψ physics

- Results on J/ψ physics $\sqrt{s}$ = 7 TeV
  - ATL-CONF-2010-062
  - Inclusive double differential J/ψ➛μμ production cross section in bins of J/ψ transverse momentum and rapidity with $\mathcal{L}_{int}$ =9.5nb^{-1}
  - ratio of B→J/ψ to prompt J/ψ production as a function of J/ψ p_T with $\mathcal{L}_{int}$ =17.5nb^{-1}

data in this corner are used for results discussed here



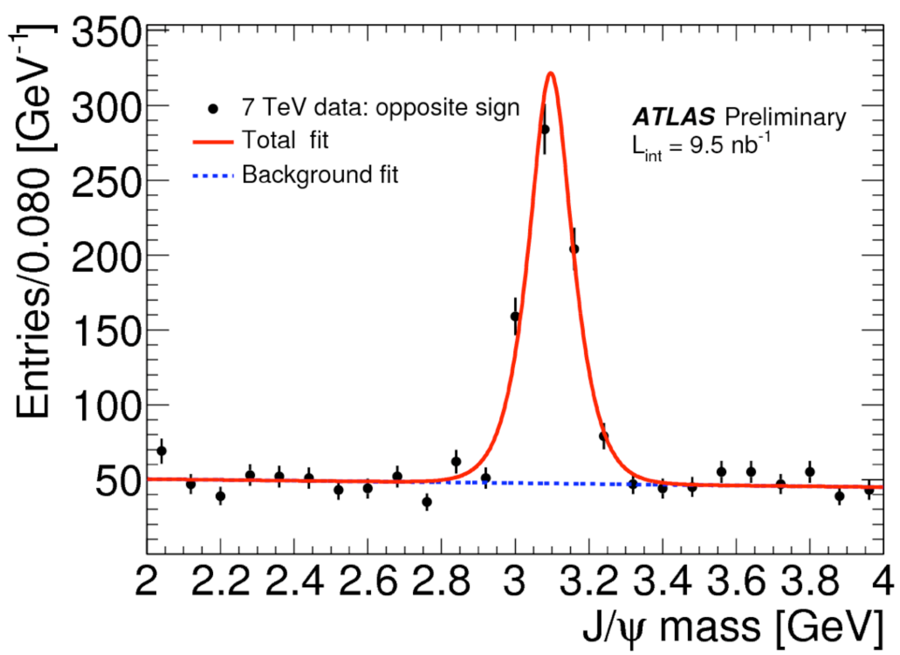
Results on J/Ψ physics $\sqrt{s} = 7$ TeV: event selection

- Muon trigger request in preselection:
  - Lowest threshold Lvl1 muon trigger: not-prescaled but efficiency not well know initially
    - can be used for indirect to prompt production cross section ratio where efficiencies cancel out ➠17.5 nb-1
  - loose standalone muon (MS detectors only) reconstructed at EF in full event scan after a LVL1 minimum bias trigger; pre-scaled after some time; efficiency (relative to offline reconstruction) measured in minimum bias data and close to 100% for $p_T > 4$ GeV
    - used for inclusive double differential cross section ➠9.5 nb-1
- 2 opposite sign muons (at least one CB) with associated ID tracks (with ≥1 Pixel and ≥6 SCT hits) are requested
  - the associated ID tracks are used to measure the 4-momenta and for any subsequent computation
- must come from a common vertex
  - unconstrained mass and distance from the primary vertex
- invariant mass after vertex fit must be in the range 2-4 GeV (large range for statistical background subtraction)

Double Differential $J/\Psi \to \mu\mu$ production cross section

- observed J/ψ yield must be corrected for
  - acceptance $\mathcal{A}\,(p_T,y)$
    - defined as the fraction of $J/\psi \to \mu\mu$ decays that have both μ's in the detector fiducial volume
    - estimated with MC for prompt $J/\psi \to \mu\mu$ production by requiring for each muon $p_\mu > 3.5$ GeV for $|\eta|<2$ and $p_\mu > 8$ GeV for $2<|\eta|<2.5$
  - μ recontruction efficiency $\varepsilon(p_{T\mu+},\eta_{\mu+}) \times \varepsilon(p_{T\mu-},\eta_{\mu-})$
    - $\varepsilon(p_{T\mu},\eta_\mu)$ defined in the μ fiducial volume
    - estimated from large statistics MC for prompt $J/\psi \to \mu\mu$ and validated with first low statistic efficiency determination from data
  - trigger efficiency $\varepsilon_{trg}(p_T,y)$
    - single μ $\varepsilon_{trg}(p_{T\mu},\eta_\mu)$ measured for reconstructed muons on minimum bias events; ➠ μ^+ORμ^- trigger efficiency averaged over expected $\mu^+\mu^-$ kinematics in the J/Ψ p_T,y bin, using prompt J/ψ MC events.
- per event weight: $w_i^{-1} = \mathcal{A}\,(p_T,y) \times \varepsilon(p_{T\mu+},\eta_{\mu+}) \times \varepsilon(p_{T\mu-},\eta_{\mu-}) \times \varepsilon_{trg}(p_T,y)$

Double Differential J/Ψ➛μμ production cross section



- the selection retains some irreducible background (mainly from c/b➛μ+X and π/K decays in flight)

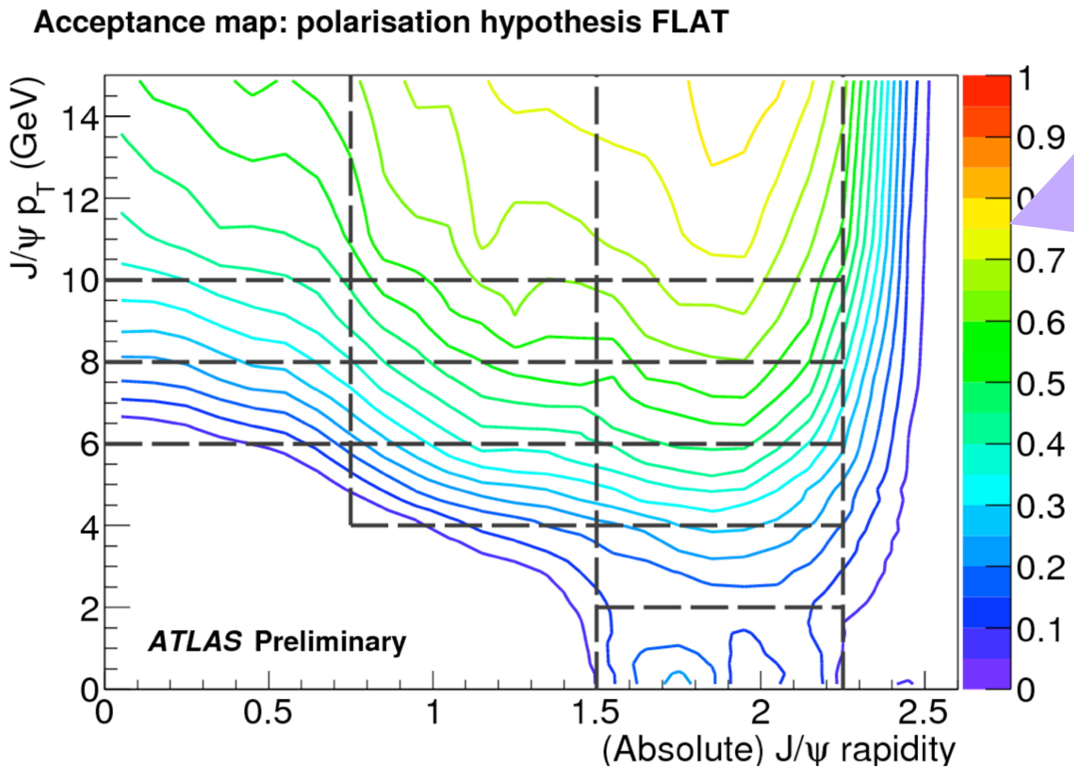
- ➠ $\mathcal{N}_{J/\psi}$ is derived from un-binned maximum likelihood fit to the invariant mass distribution of all candidates ($m_{\mu\mu}$ and $\delta m_{\mu\mu}$ from dimuon vertex fit)

$$\ln \mathcal{L} = \sum_{i=1}^{N} w_i \cdot \ln \left[f_{signal}(m^i_{\mu\mu}) + f_{bkg}(m^i_{\mu\mu}) \right]$$

  - with Signal and Background PDFs
  - $$f_{signal}(m_{\mu\mu}, \delta m_{\mu\mu}) \equiv a_0 \frac{1}{\sqrt{2\pi}\, S\, \delta m_{\mu\mu}} e^{\frac{-(m_{\mu\mu}-m_{J/\psi})^2}{2(S\,\delta m_{\mu\mu})^2}} \qquad f_{bkg}(m_{\mu\mu}) \equiv (1-a_0) + b_0 m_{\mu\mu}$$

- free parameters are
  - $m_{J/\psi}$, S scaling factor for the mass resolution, a_0 fraction of signal events, background slope

Double Differential J/Ψ➛μμ production cross section - Acceptance and Data Binning



Constant Acceptance Contours for the flat polarization hypothesis used as baseline for the cross section measurement

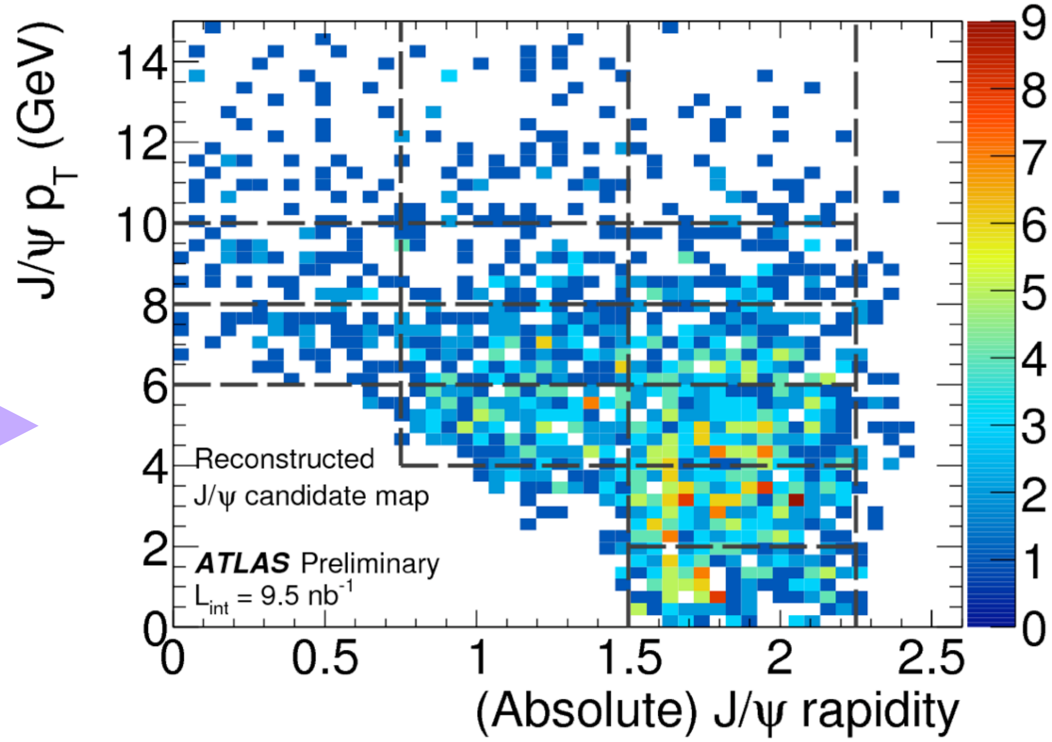
MC: Pythia (MC09 ATLAS tune and MRST LO parton pdf's) with

- J/ψ prompt production implemented according to NRQCD Color Octet Model
- Xc➛J/ψγ included in prompt component

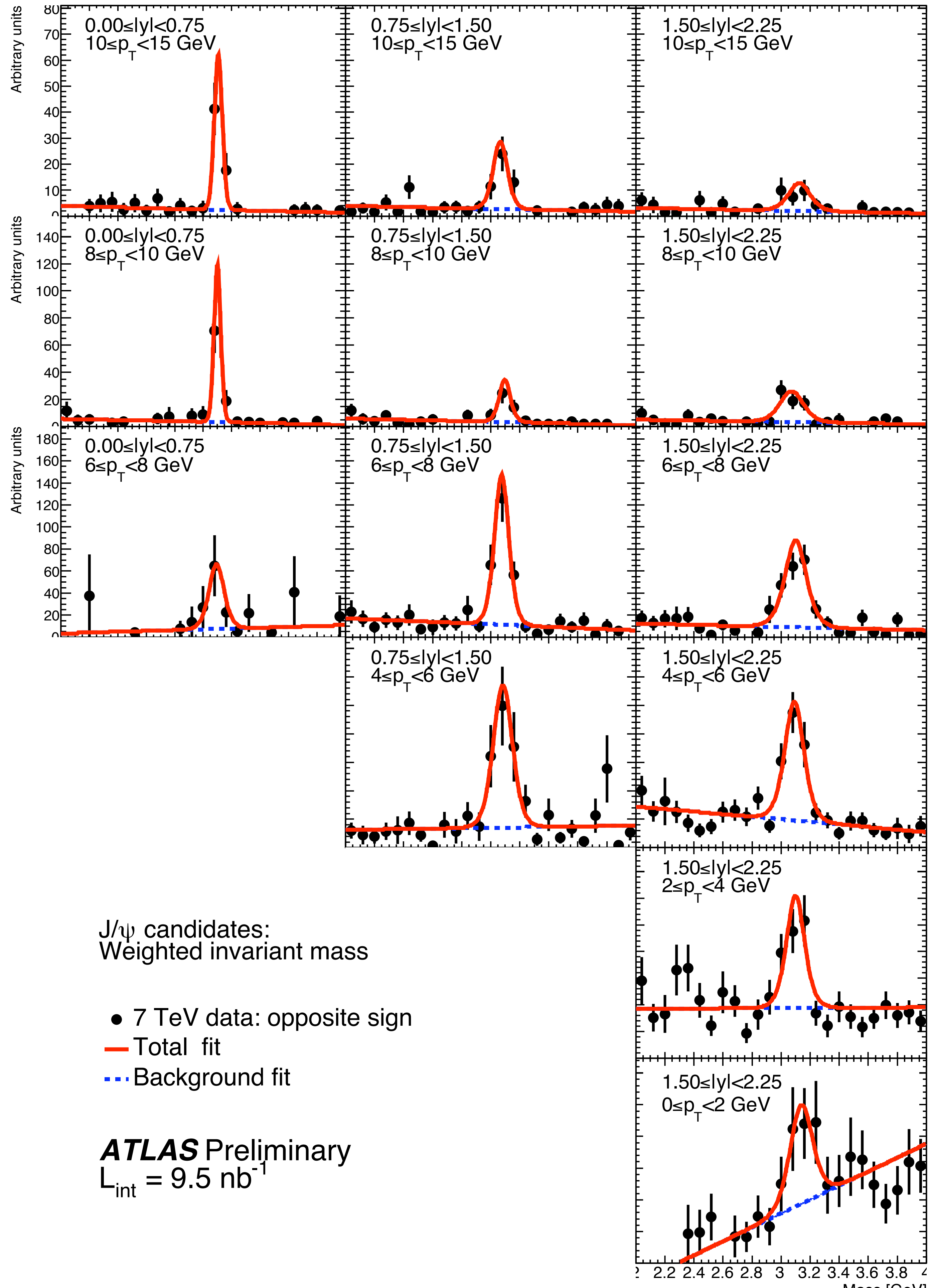
Data binning:

3 y regions (from 0 to 2.25) and 3÷6 p_T regions (from 0 to15 GeV)

J/ψ candidates in the $m_{J/\psi} \pm 3\sigma$ overlaid to the grid defined for the differential cross measurement



Double Differential inclusive J/Ψ→μμ production cross section



Acceptance and efficiency corrected J/ψ yield in the 13 p_T,y bins

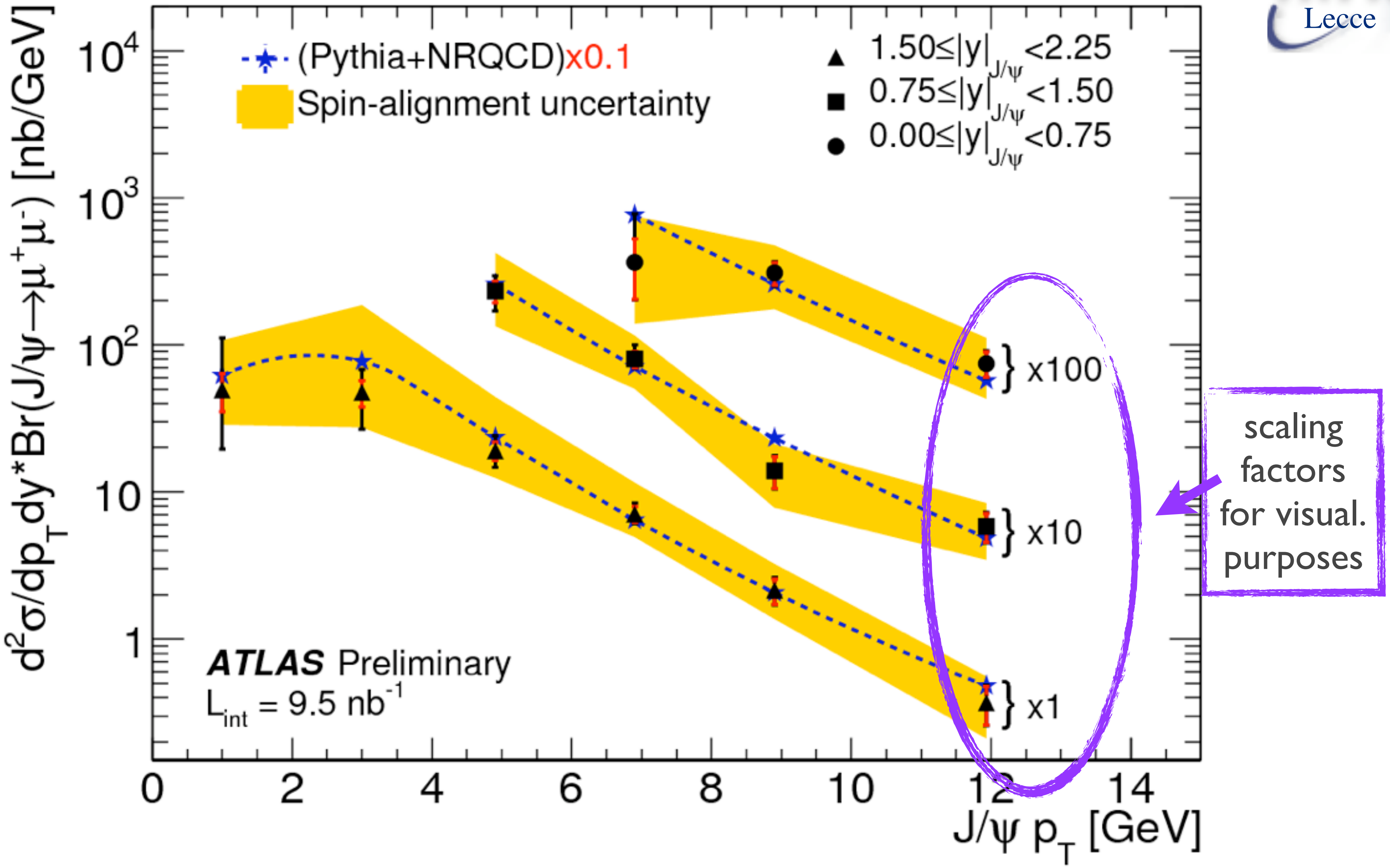
Double Differential J/Ψ➤μμ production cross section - Results

Errors are stat⊕syst

Systematic theoretical error due to spin alignment (via acceptance) shown separately (yellow band)

Dominant experim. systematics: *trigger efficiency* (low p_T and high y) *reconstruction efficiency* (7% absolute error from MC-data low stat. comparison) and *muon selection* (ST-ST pairs allowed in the analysis vs baseline selection) expected to decrease with integrated luminosity

11% systematics from luminosity not shown



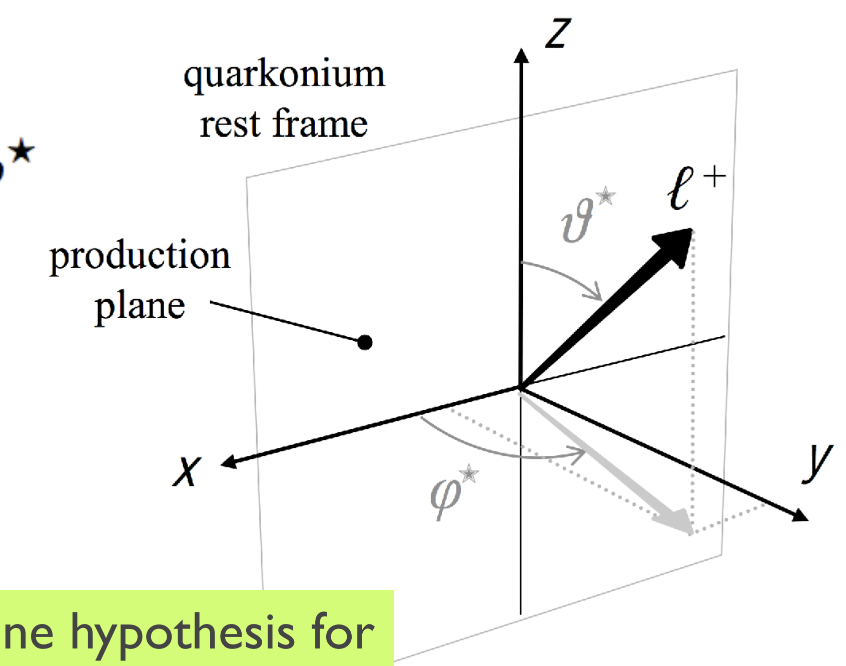
Pythia predictions give a good representation of the shape

The factor10 between data and Pythia predictions is traced to ATLAS tune and PDF's used

Double Differential J/Ψ➝μμ production cross section - Acceptance Uncertainty

- the uncertainty on the J/ψ production mechanism reflects into the the spin-alignment of the J/ψ wave function and, hence, the angular distribution of the muon pairs
  - the determination of the acceptance is affected by the unknown polarization
- parameters describing the polarization dependence of the cross section are θ★ (angle between μ+ momentum in the J/ψ rest frame and J/ψ momentum) and φ★ (angle between J/ψ production and decay planes)

$$\frac{d^2N}{d\cos\theta^\star d\phi^\star} \propto 1 + \lambda_\theta \cos^2\theta^\star + \lambda_\phi \sin^2\theta^\star \cos 2\phi^\star + \lambda_{\theta\phi} \sin 2\theta^\star \cos\phi^\star$$



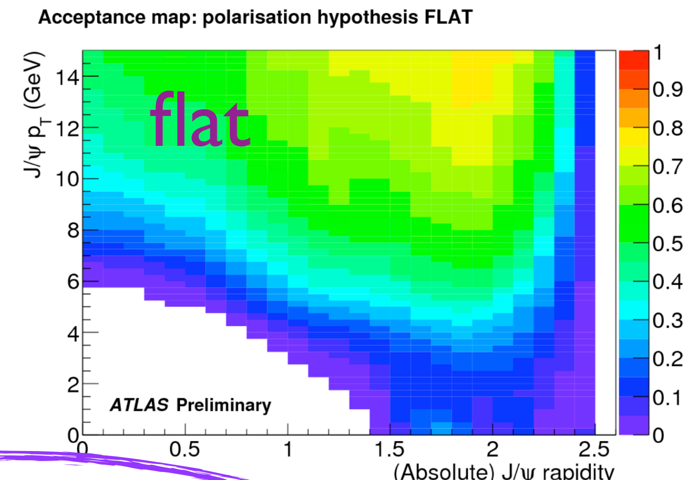
- $\lambda_\theta=0$, $\lambda_\varphi=0$, $\lambda_{\theta\varphi}=0$ flat distribution, no polarization
- $\lambda_\theta=-1$, $\lambda_\varphi=0$, $\lambda_{\theta\varphi}=0$ longitudinal pol. ←→
- $\lambda_\theta=+1$, $\lambda_\varphi=0$, $\lambda_{\theta\varphi}=0$ transverse pol. ↓↓ or ↑↑
- $\lambda_\theta=+1$, $\lambda_\varphi=+1$, $\lambda_{\theta\varphi}=0$ transverse pol. ↓↓ + ↑↑
- $\lambda_\theta=+1$, $\lambda_\varphi=-1$, $\lambda_{\theta\varphi}=0$ transverse pol. ↓↓ − ↑↑

baseline hypothesis for acceptance calculation

acceptance systematic error

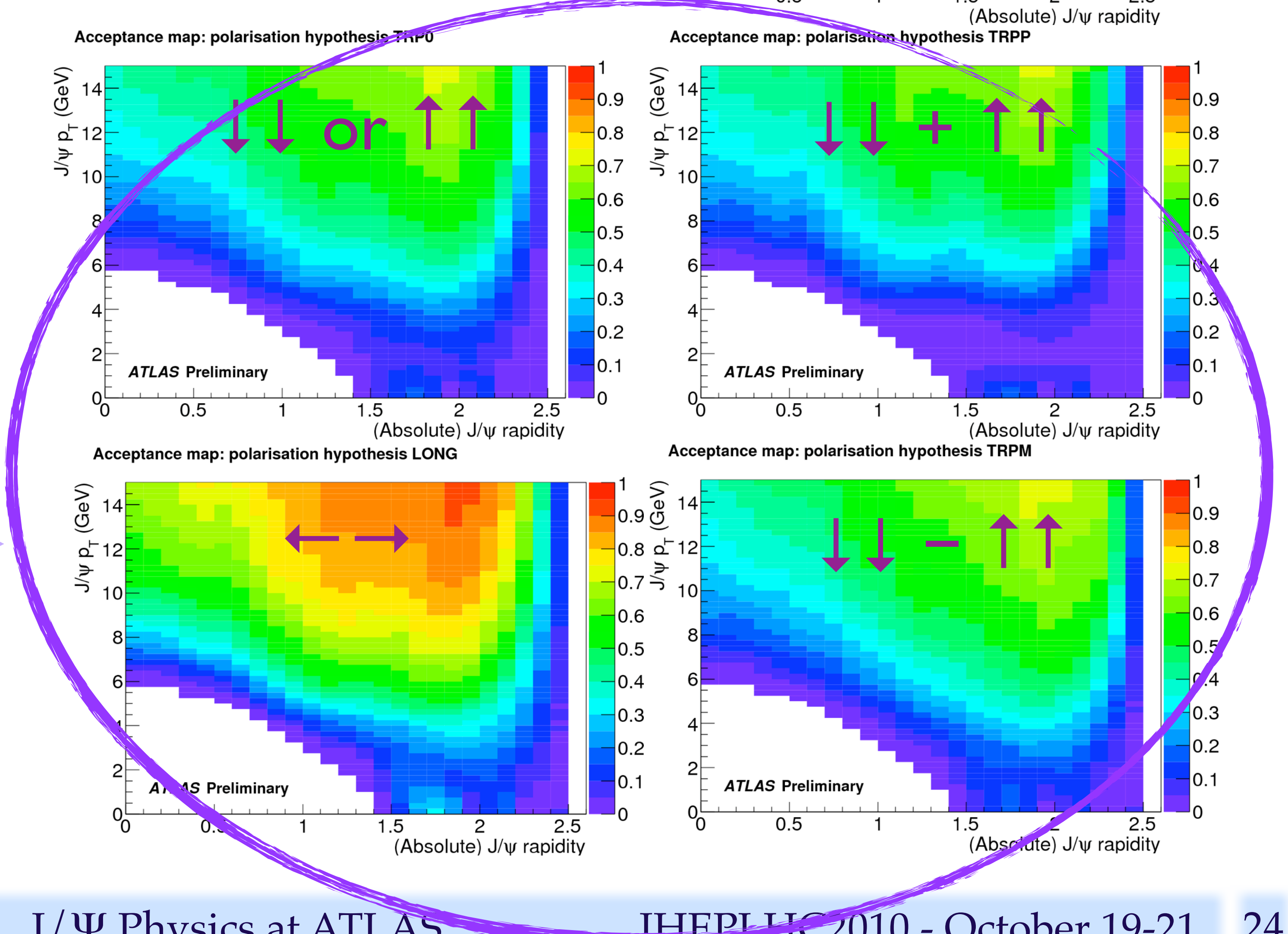
Double Differential J/Ψ➛μμ production cross section - Acceptance Uncertainty

- obtained from Pythia J/ψ prompt production implementation based on NRQCD Color Octet Model
  - fraction of μμ in the fiducial volume



- MC with FLAT polarization hypothesis re-weighted according to the double differential cross sections in 4 extreme polarization scenarios

$$\frac{d^2N}{d\cos\theta^\star d\phi^\star}$$



- range of overall acceptance scaling factors in the p_T, y bins 0.7 ÷ 3.4

Double Differential J/Ψ→μμ production cross section - Results

$p_T(J/\psi)$ GeV	Mean p_T GeV	$\frac{d\sigma}{dp_T dy} \cdot \mathrm{Br}[J/\psi \to \mu^+\mu^-]$ (nb/GeV) Data	Pythia
		$0.0 \le \lvert y \rvert < 0.75$	
6 – 8	6.9	3.6 ± 1.6 (stat) $^{+3.9}_{-0.3}$ (syst) $^{+3.9}_{-2.3}$ (theory)	76.5 ± 1.5
8 – 10	8.9	3.08 ± 0.66 (stat) $^{+0.40}_{-0.22}$ (syst) $^{+1.7}_{-1.4}$ (theory)	26 ± 1
10 – 15	11.9	0.75 ± 0.18 (stat) $^{+0.11}_{-0.05}$ (syst) $^{+0.37}_{-0.32}$ (theory)	5.7 ± 0.3
		$0.75 \le \lvert y \rvert < 1.50$	
4 – 6	4.9	23.2 ± 4.0 (stat) $^{+5.2}_{-4.9}$ (syst) $^{+18.9}_{-9.9}$ (theory)	260 ± 3
6 – 8	6.9	8.0 ± 1.0 (stat) $^{+1.9}_{-0.6}$ (syst) $^{+3.6}_{-3.0}$ (theory)	72 ± 2
8 – 10	8.9	1.40 ± 0.34 (stat) $^{+0.18}_{-0.09}$ (syst) $^{+0.73}_{-0.62}$ (theory)	23.3 ± 0.9
10 – 15	11.9	0.58 ± 0.13 (stat) $^{+0.06}_{-0.04}$ (syst) $^{+0.26}_{-0.24}$ (theory)	4.9 ± 0.3
		$1.50 \le \lvert y \rvert < 2.25$	
0 – 2	1.0	49 ± 20 (stat) $^{+61}_{-26}$ (syst) $^{+58}_{-21}$ (theory)	621 ± 3
2 – 4	3.0	48 ± 10 (stat) $^{+18}_{-18}$ (syst) $^{+139}_{-20}$ (theory)	773 ± 3
4 – 6	4.9	19.1 ± 2.7 (stat) $^{+5.1}_{-3.5}$ (syst) $^{+25.1}_{-6.6}$ (theory)	235 ± 2
6 – 8	6.9	7.10 ± 0.88 (stat) $^{+1.32}_{-0.57}$ (syst) $^{+4.5}_{-2.2}$ (theory)	64 ± 1
8 – 10	8.9	2.14 ± 0.43 (stat) $^{+0.33}_{-0.10}$ (syst) $^{+1.1}_{-0.8}$ (theory)	20.7 ± 0.9
10 – 15	11.9	0.37 ± 0.11 (stat) $^{+0.06}_{-0.03}$ (syst) $^{+0.19}_{-0.16}$ (theory)	4.8 ± 0.3

80% of the cross section is in the 1.5-2.25 y bin

based on that bin

$$d\sigma/dy \times \mathrm{Br}(J/\psi \to \mu\mu)|_{\langle y\rangle \simeq 1.85} = \left(250^{+130}_{-80}\right)\,\mathrm{nb}$$

includes luminosity error

does not include spin-alignment error

Current theory predictions are in the range on 140-250 nb with uncertainties as large as 3 x prediction in either direction

Lansberg, arXiv:1006.2750 [hep-ph]

Brodsky, Lansberg PRD81(2010)051502

Khoze et al, EPJC39(2005)163

Bedjidian et al, arXiv:03110478 [hep-ph]

Non-prompt to prompt J/Ψ production ratio

$$\mathcal{R} \equiv \frac{\sigma(pp \to b\bar{b}X \to J/\psi\, X')}{\sigma(pp \to J/\psi\, X'')_{\mathrm{prompt}}}$$

J/ψ candidate selection as in the case of the cross section measurement in events with a Lvl1 muon trigger (any threshold)

- extracted from an un-binned maximum likelihood fit in the 2D space of pseudo-proper-time and invariant mass of the unweighted J/ψ yield in p_T bins
  - bins: 1-4, 4-6, 6-8, 8-10,10-15 GeV
  - free parameters: f_B (J/ψ from B decay fraction), τ_{eff} decay time of the B➛J/ψ+X component, pseudo-proper-time resolution scaling factors for signal and effective parameters for background, parameters of the probability distribution functions for signal and background (as for the cross section measurement)

acceptance and muon reco/trg efficiency cancel in the ratio

$$\tau = \frac{L_{xy}\, m(J/\psi)}{p_T(J/\psi)} \cong \frac{L_{xy}\, m_B}{p_T(B)} \propto e^{-\tau/\tau(B)}$$

B meson life-time

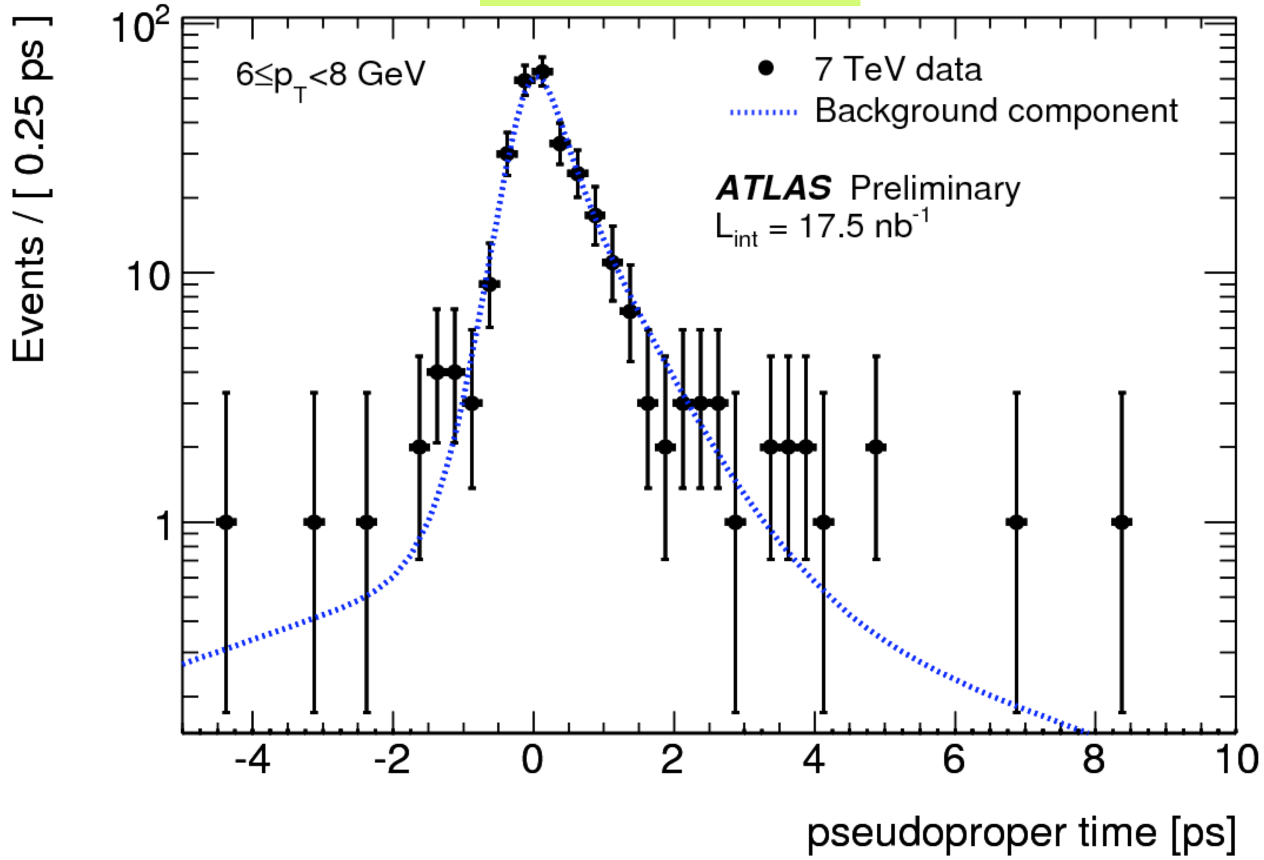
B meson proper decay time

pdf's as in the cross section analysis

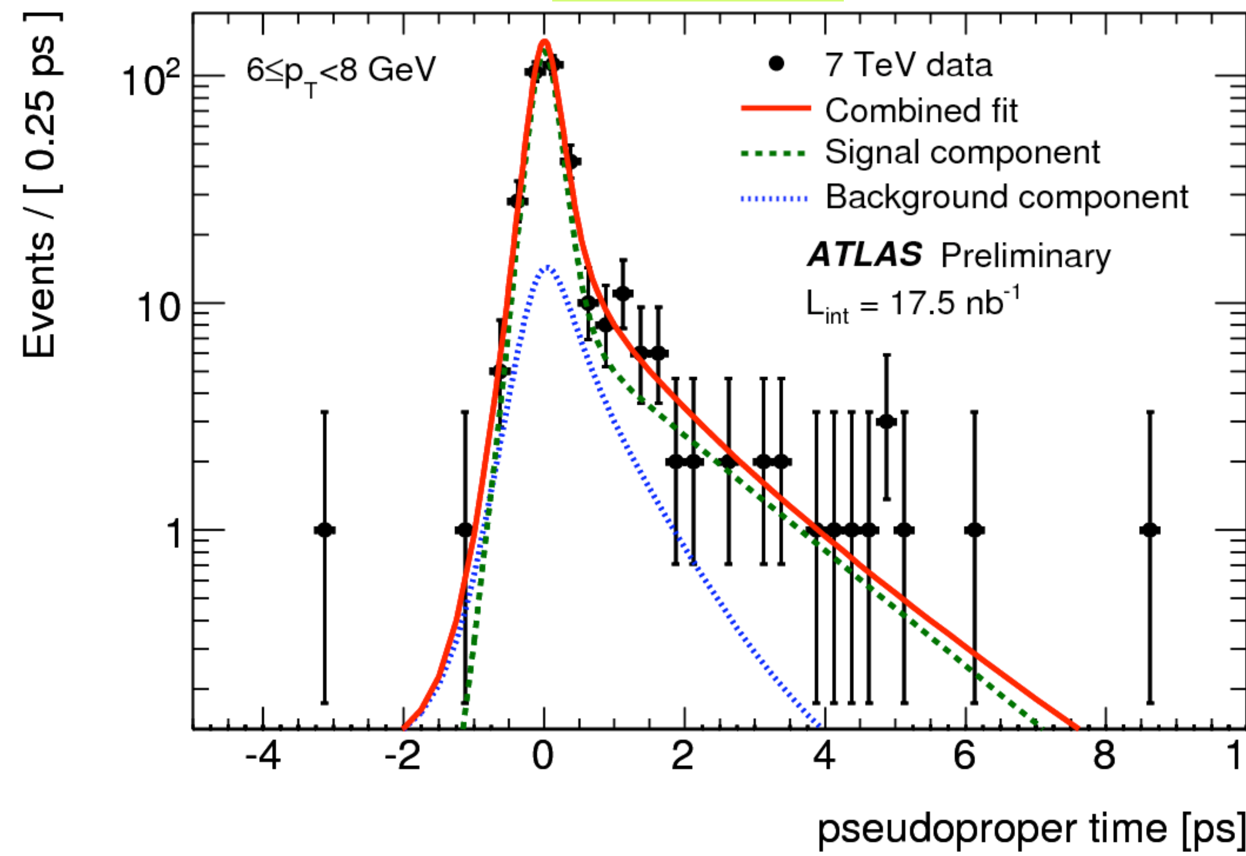
Lxy distance of J/ψ decay vertex from primary vertex in the transverse plane projected on the J/ψ p_T direction

Non-prompt to prompt J/Ψ production ratio the p_T bin 6-8 GeV

side-band region



signal region



Data and projection of the background component of the fit result in the "side bands"

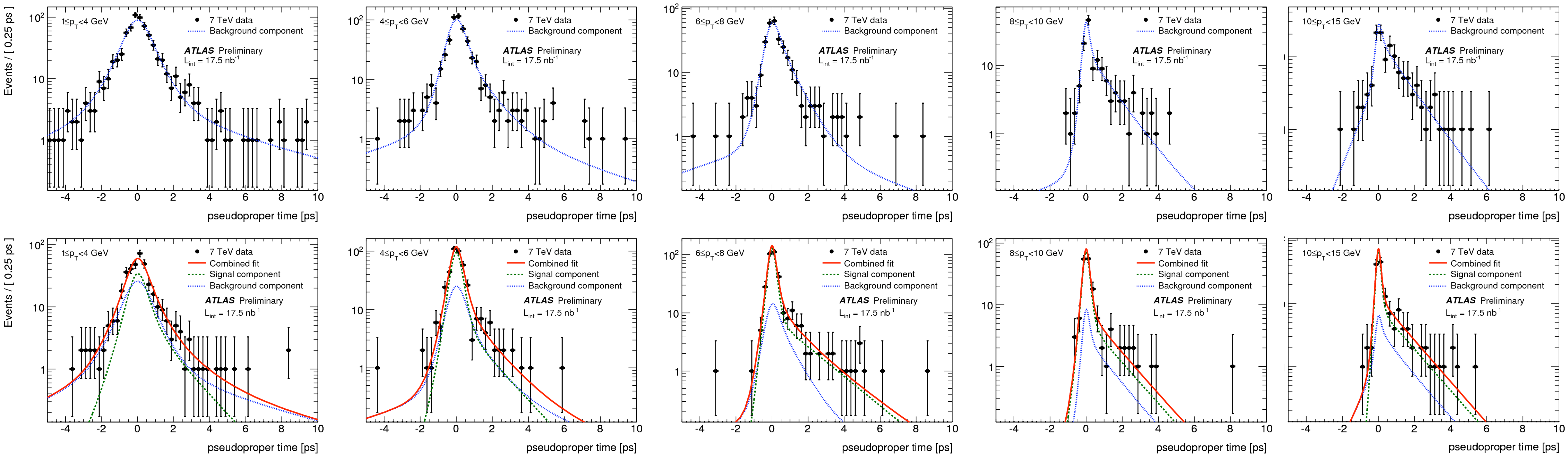
Data and projection of the fit results in the $m_{\mu\mu}$ range 2.9 ÷3.3 GeV with the signal and background components overlaid

Pseudopropertime pdf for the **background**: effective parameterization chosen by studying the sidebands (dominated by a gaussian resolution term with mean at 0)

The **signal** component is clearly described by a gaussian (resolution dominated) distribution for the prompt J/ψ component + an exponential distribution for the B➛J/ψ+X component

Non-prompt to prompt J/Ψ production ratio

1÷4 GeV | 4÷6 GeV | 6÷8 GeV | 8÷10 GeV | 10÷15 GeV



$$\ln \mathcal{L} = \sum_{i=1}^{N} \ln \left[\mathcal{F}_{\mathrm{sig}}(\tau,\delta_\tau) f_{signal}(m_{\mu\mu},\delta m_{\mu\mu}) + \mathcal{F}_{\mathrm{bkg}}(\tau,\delta_\tau) f_{bkg}(m_{\mu\mu})\right]$$

$$\mathcal{F}_{\mathrm{sig}}(\tau,\delta_\tau) = f_B \mathcal{F}_B(\tau,\delta_\tau) + (1-f_B)\mathcal{F}_P(\tau,\delta_\tau)$$

$$R(\tau'-\tau,\delta_\tau) \times e^{-\tau'/\tau_{eff}}$$

Non-prompt to prompt J/Ψ production ratio: Results

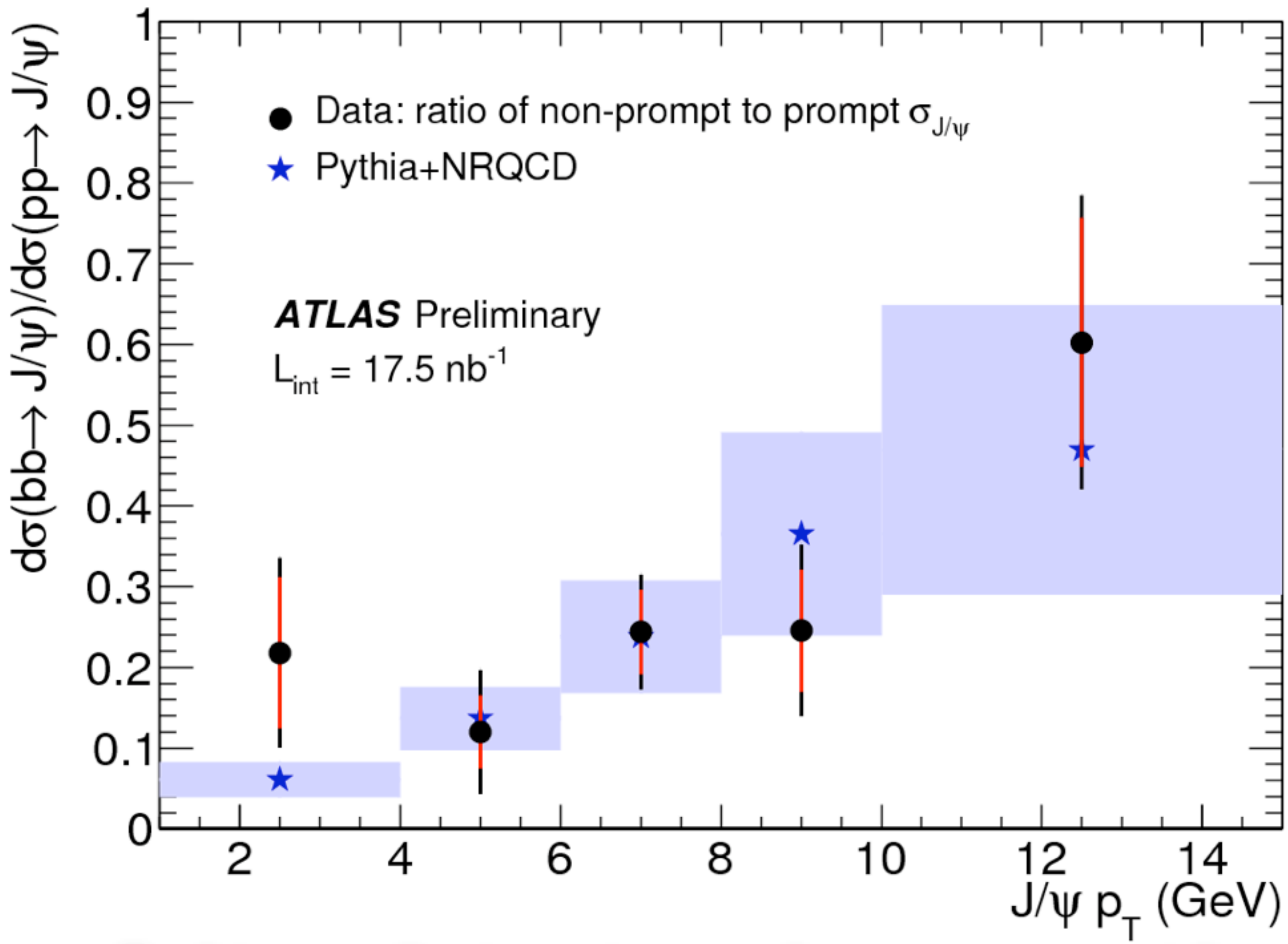
Systematics estimated from f_B stability vs various fit options

different τ resolution model (double gaussian)

polynomial background model vs linear

background τ pdf parameters fixed from side-band fit vs simultaneous fit with signal τ pdf

No assessment yet of uncertainty due to spin-alignment differences for non-prompt and prompt J/Ψ



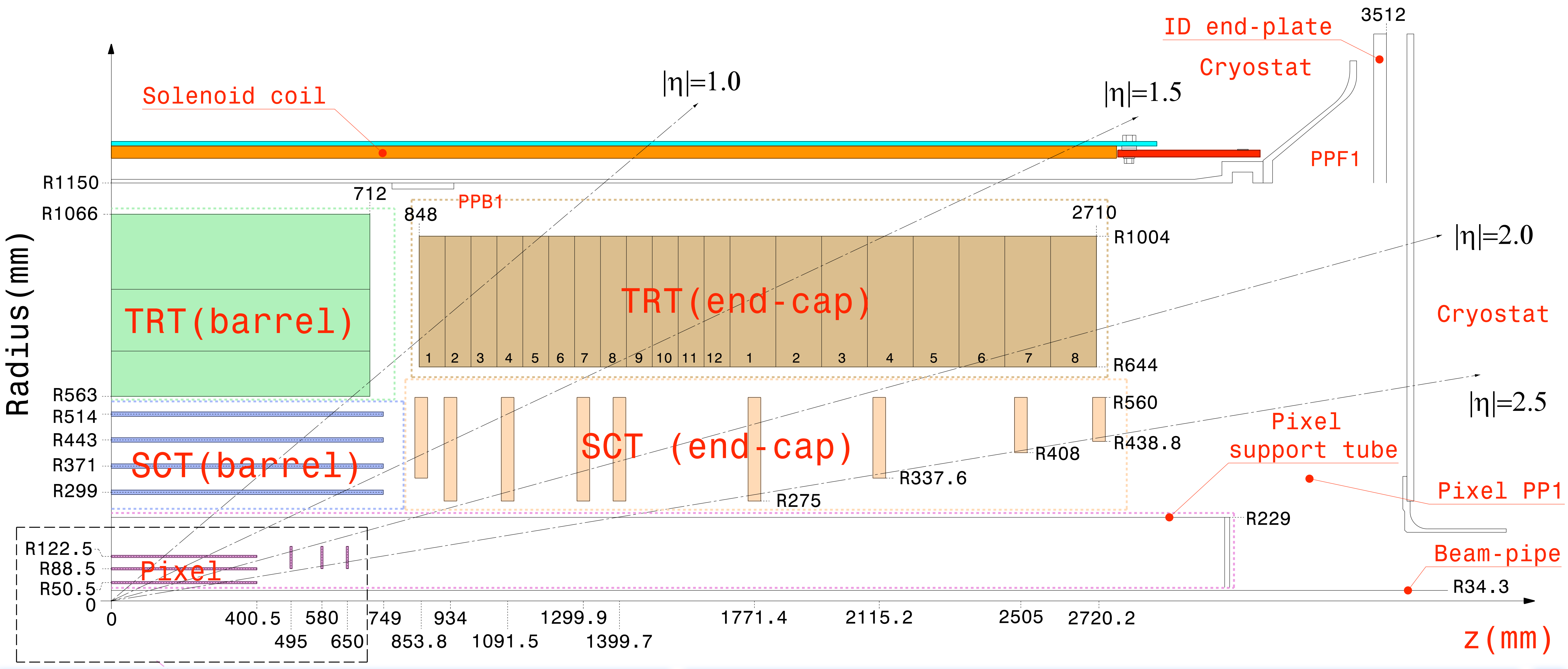
Pythia predictions in good agreement with ATLAS data ➠ normalization discrepancy equally affecting prompt and indirect J/Ψ production

Conclusion and Outlooks

- J/ψ observation has been used to calibrate and control the ATLAS detector performance
- First results on J/ψ production cross section and non-prompt to prompt ratio in ATLAS have been presented based on early LHC running periods ($\mathcal{L}_{int}$ <20 nb^{-1}) but loose muon trigger requirements (high acceptance for quarkonia physics)
  - ATLAS quarkonia results are in the process of being updated with the much higher statistics available
  - a large program of quarkonia physics investigation is open
    - it will require dedicated B-physics triggers
      - already under commissioning, performance and strategy carefully estimated with simulations in the past

backup slides

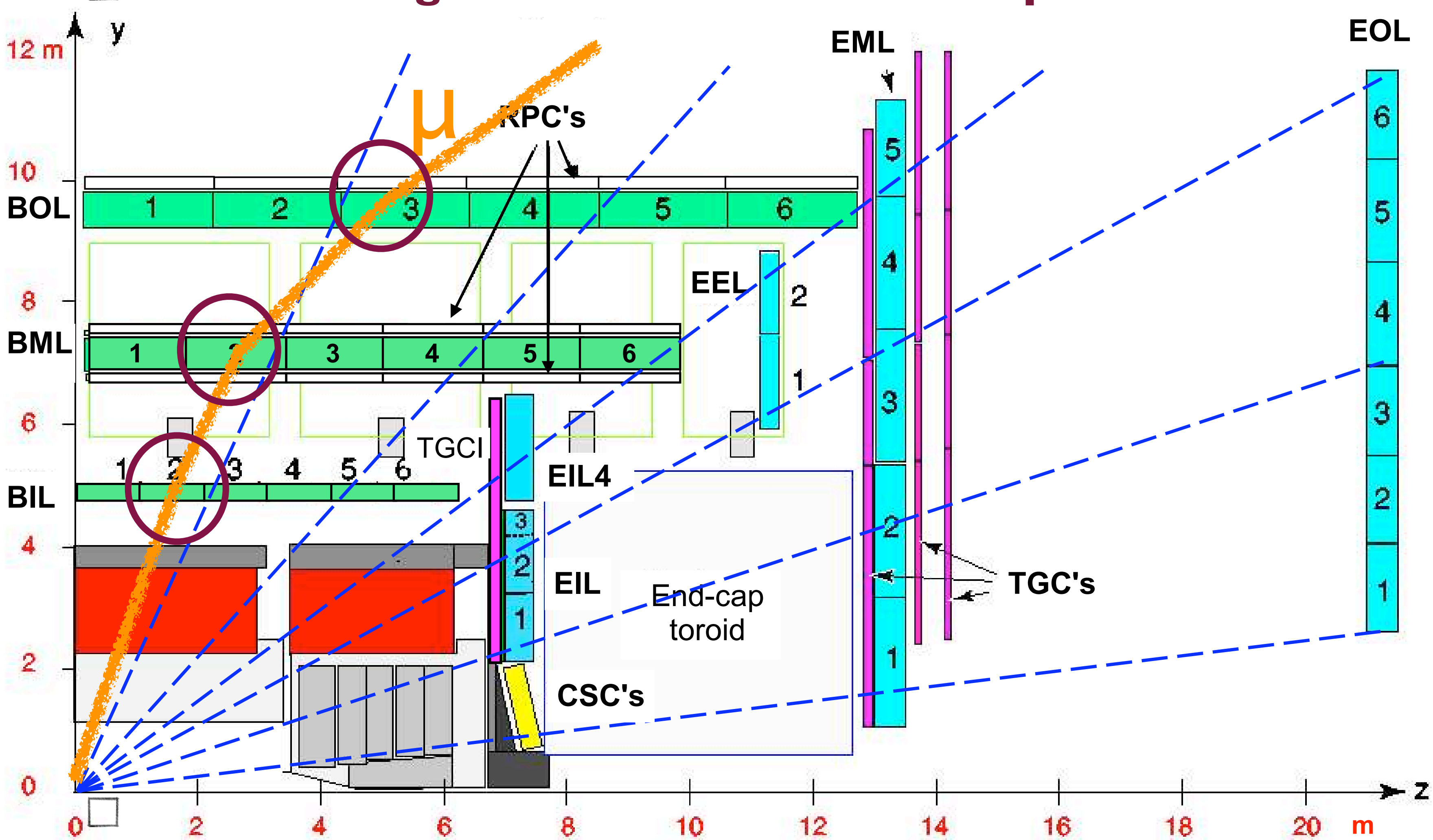
ATLAS detector features relevant to J/Ψ physics

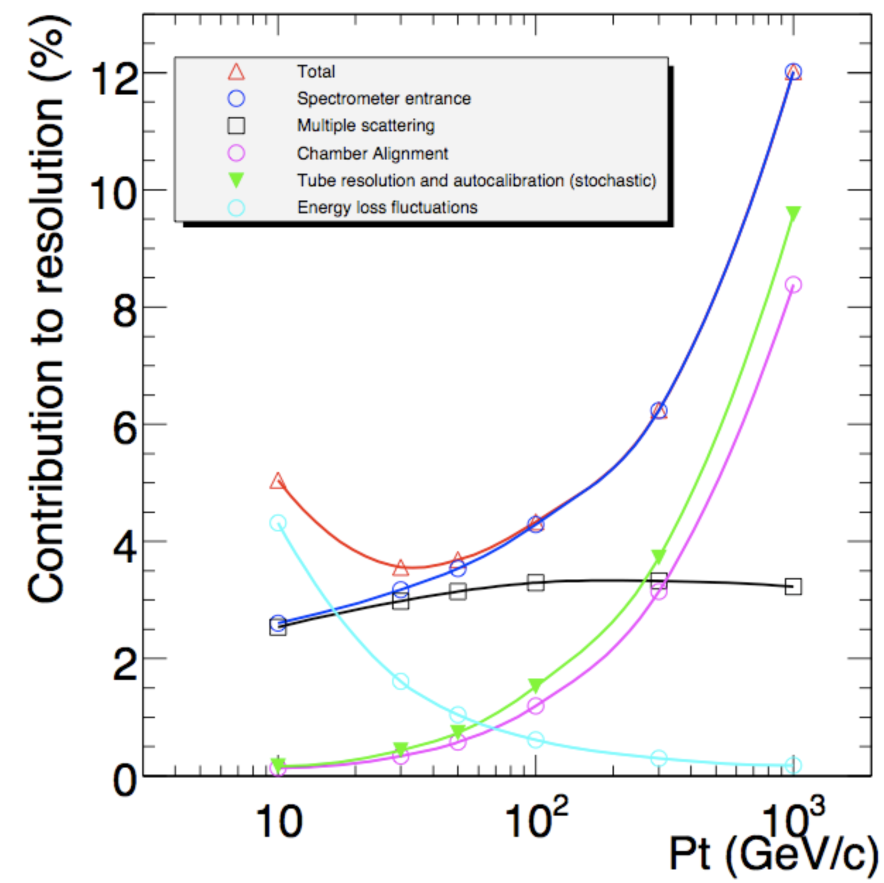


ATLAS detector features relevant to J/Ψ physics

The Muon Spectrometer

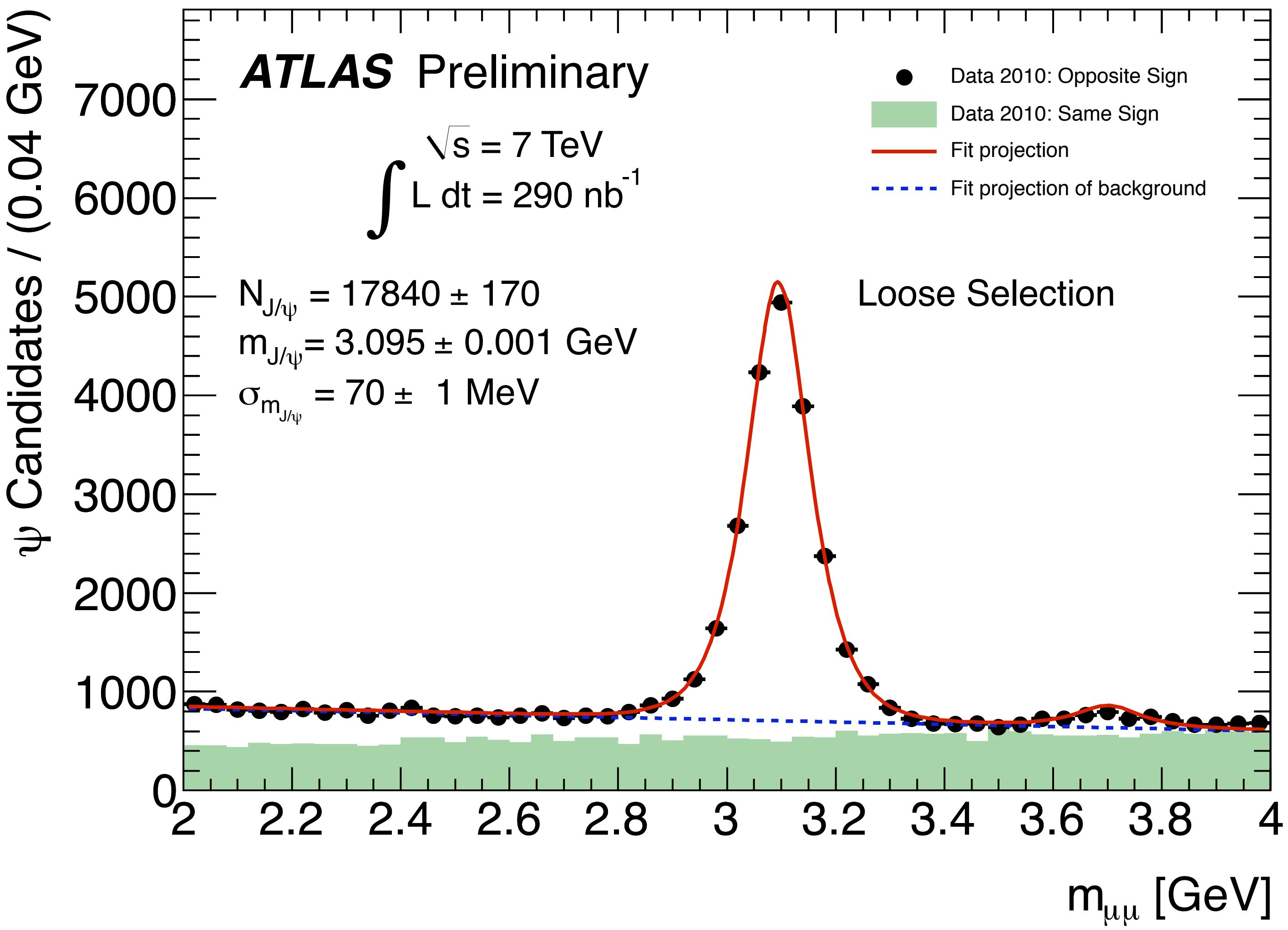
- for |η|<2: 3 stations of MDT tubes (80μm average resolutions per tube, 6 or 8 tube layers per station); for 2<|η|<2.7: 2 stations of MDT and 1 CSC station (50μm resolution in the precision coordinate); coarse second coordinate measurement by RPC and TGC
- Air core toroidal magnetic system ∫Bdl ~2-4 Tm for infinite momentum muons
- **relative sagitta resolution < 10% for p_T <1 TeV**





Muon Spectrometer expected relative p_T resolution

J/Ψ observation in ATLAS



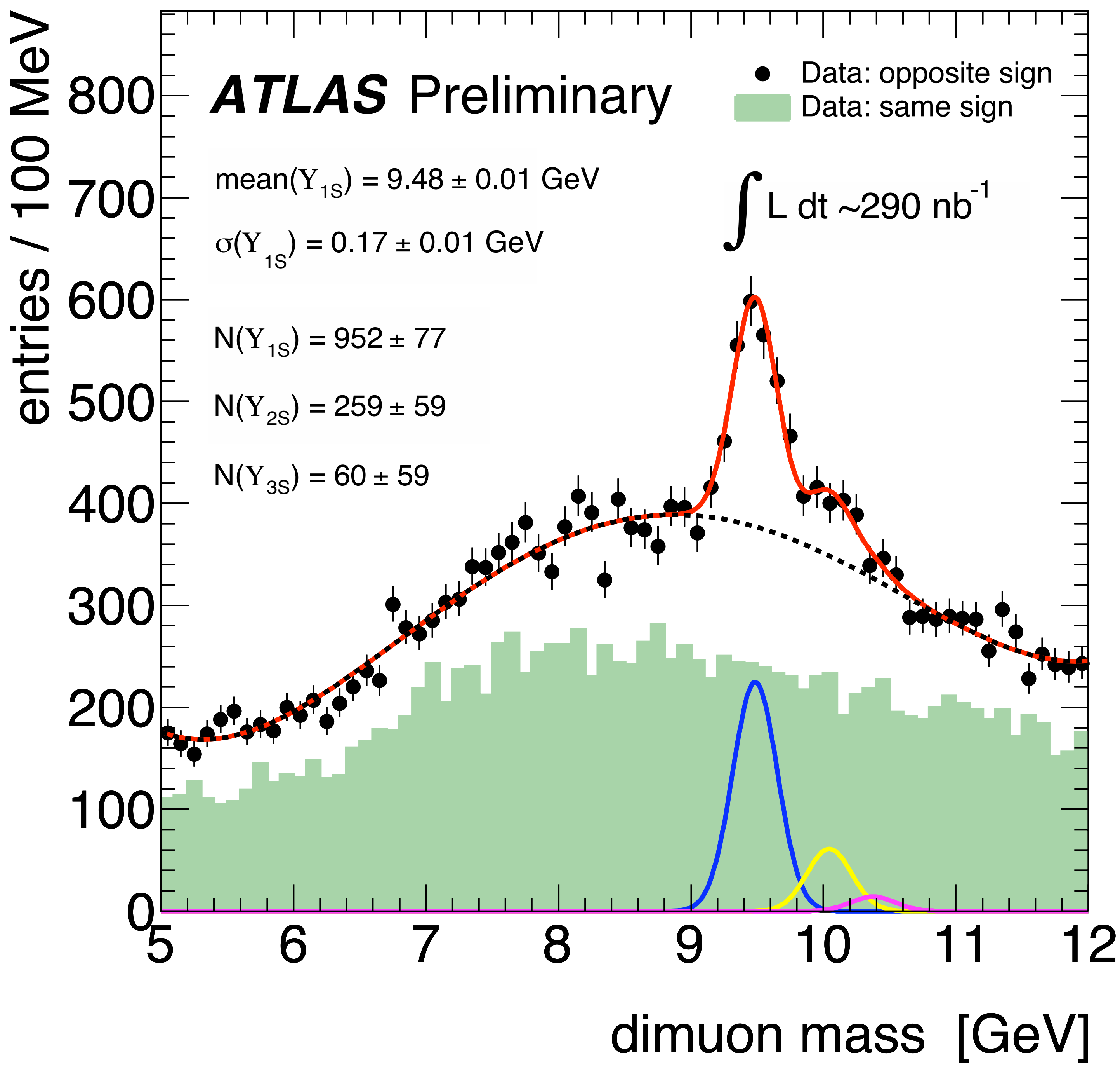
J/ψ and ψ(2s) candidates

$M_{J/\Psi}$ = 3.095 ± 0.001 GeV
$\sigma_{m(J/\Psi)}$ = 70 ± 1 GeV

- **J/Ψ selection**
- event preselection based on loose muon trigger requirements
  - L1_MU0 or Muon Standalone at EF in full event scan
- all opposite sign muon pairs with a successful vertex fit and invariant mass in the 2-4 GeV range are used
- all categories of reconstructed muons contribute: ST-ST pairs, CB-ST pairs and CB-CB pairs
  - ST = segment tagged muons
  - CB = combined muons
- Unbinned maximum likelihood fit
  - Gaussian signal lineshape + quadratic modeling of background

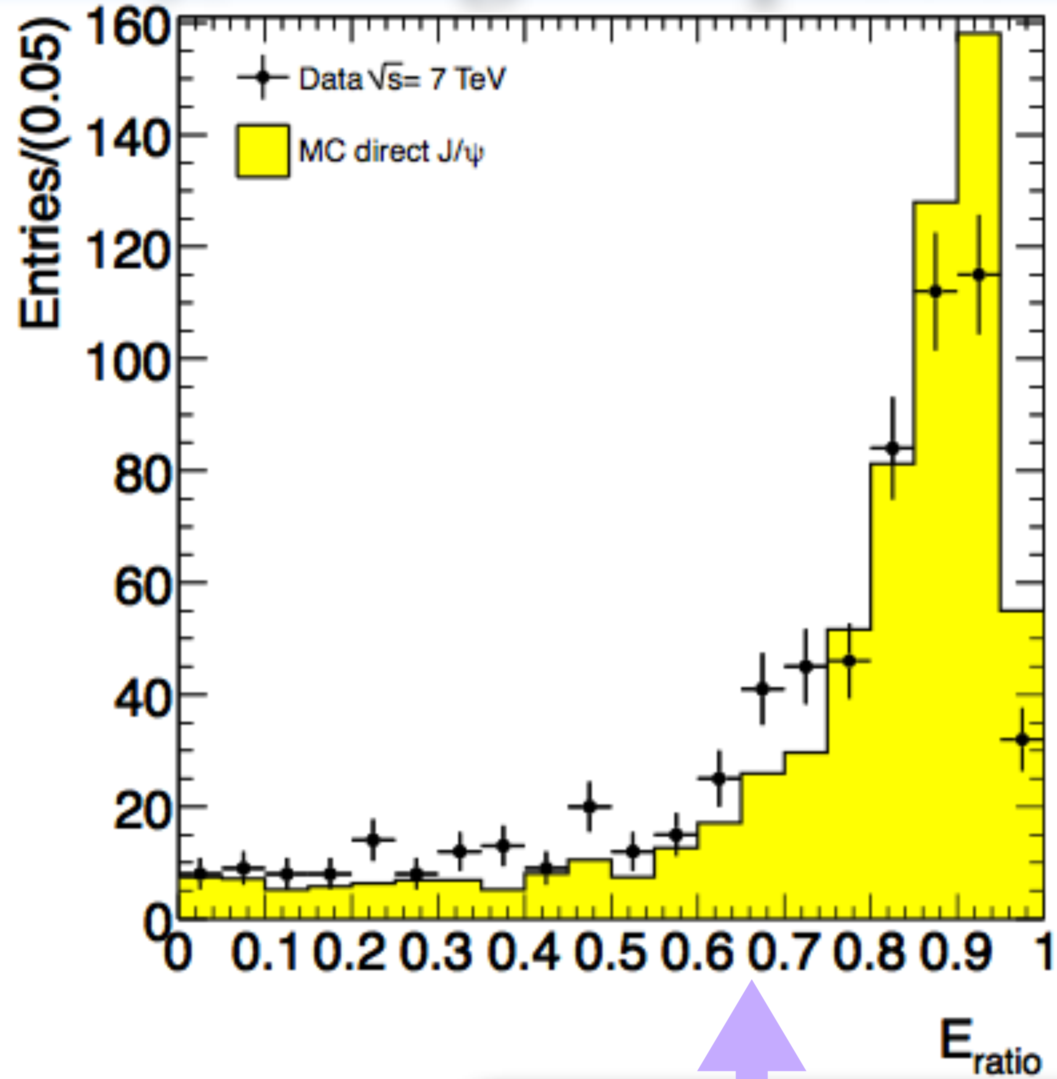
ATLAS observation of ϒ(1s,2s,3s)

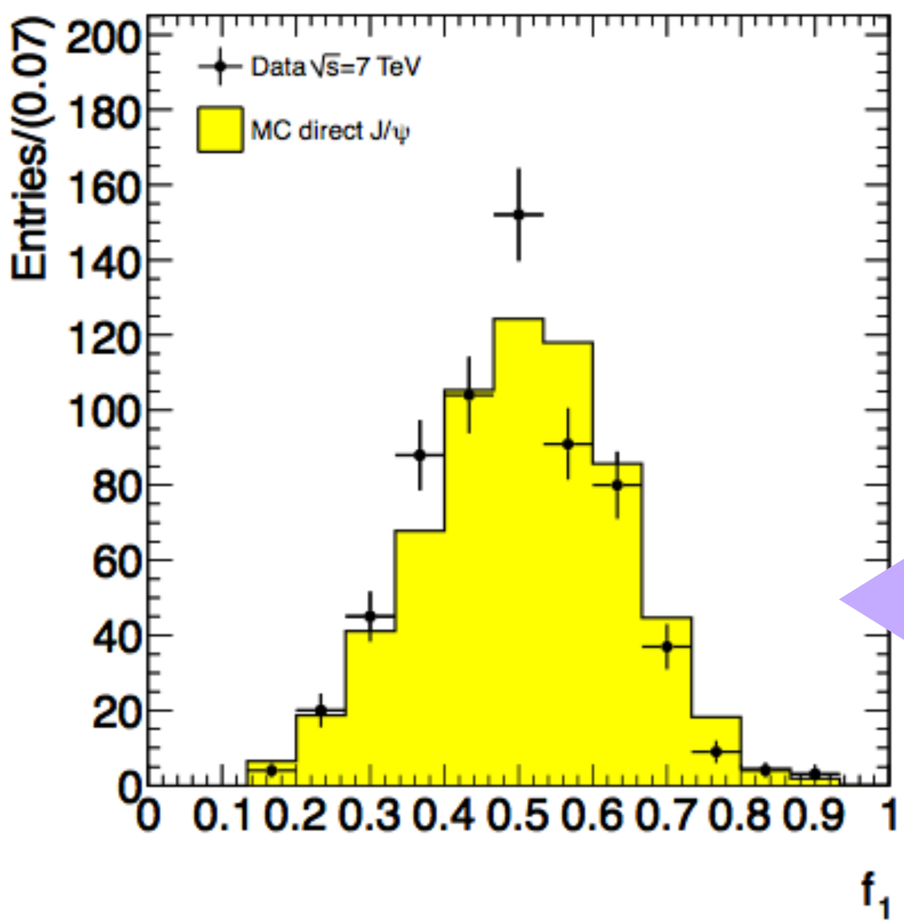
- A first look at bottonium in μ+μ-
  - observation of ϒ family with $\mathcal{L}_{int}$ =290nb^{-1}
  - muon trigger: L1MU0 or EF muon in full scan
  - muon p_T >2.5 and 4 GeV
  - CB-CB or CB-ST pairs only
  - Δm(ϒ2s-ϒ1s) and Δm(ϒ3s-ϒ2s) constrained to PDG value but overall mass scale free
  - 3 gaussians (signal) + 4th order Chebyshev polynomial (background)



Electron performance with J/Ψ➛e+e- shower shape at low E_T with J/Ψ tag and probe

- tighter electron selection for the tag
  - p_T > 4 GeV, fraction of TRT highThr hits > 0.18, raw cluster energy >2.5 GeV
- electron probe identification
  - Calorimeter discriminants cuts are fully released
  - Tracking variables as in standard J/ψ ➛ ee selection but fraction of TRT highThr hits > 0.15
- tag-and-probe selection: 2.7<Minv<3.2 GeV (15% bkg under the peek not subtracted)





Energy fraction in the first EM calo compartment **for electrons identified with tracking criteria + tag&probe**

Ratio of the energy difference between largest and second largest energy deposits over the sum of them in the 1st calo compartment **for electrons identified with tracking criteria + tag&probe**