Heavy flavour physics in ATLAS

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On behalf of ATLAS collaboration

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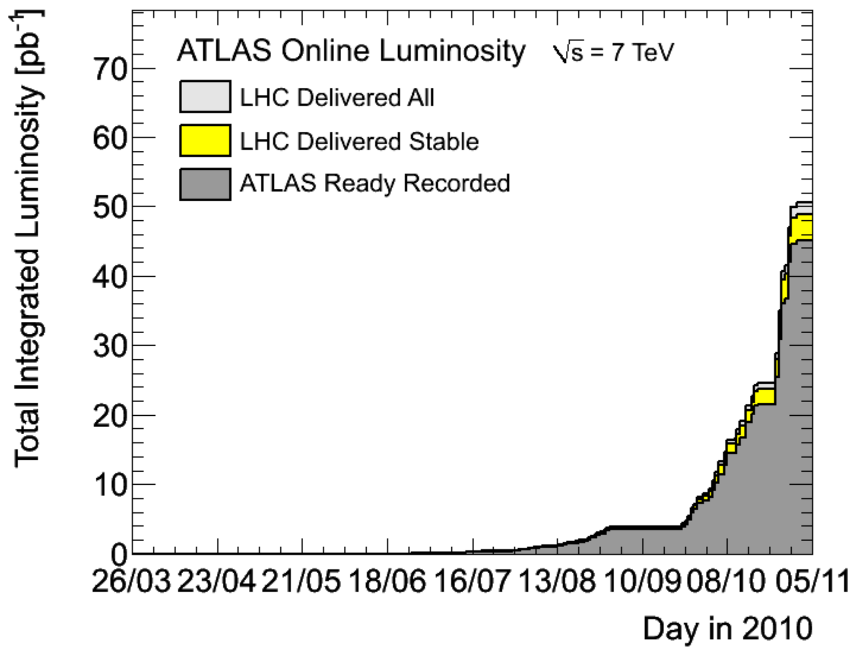
Outline

- ATLAS detector status
- Initial results on B-physics
  - Observation of J/ψ
  - Measurements of inclusive J/ψ production and non-prompt to prompt ratio
  - Observation of Υ system
  - Observation of $B^{\pm} \rightarrow J/\psi K^{\pm}$
  - Observation of D^*, D^+, D_s
- Planned ATLAS B-physics measurements

ATLAS detector status & online luminosity

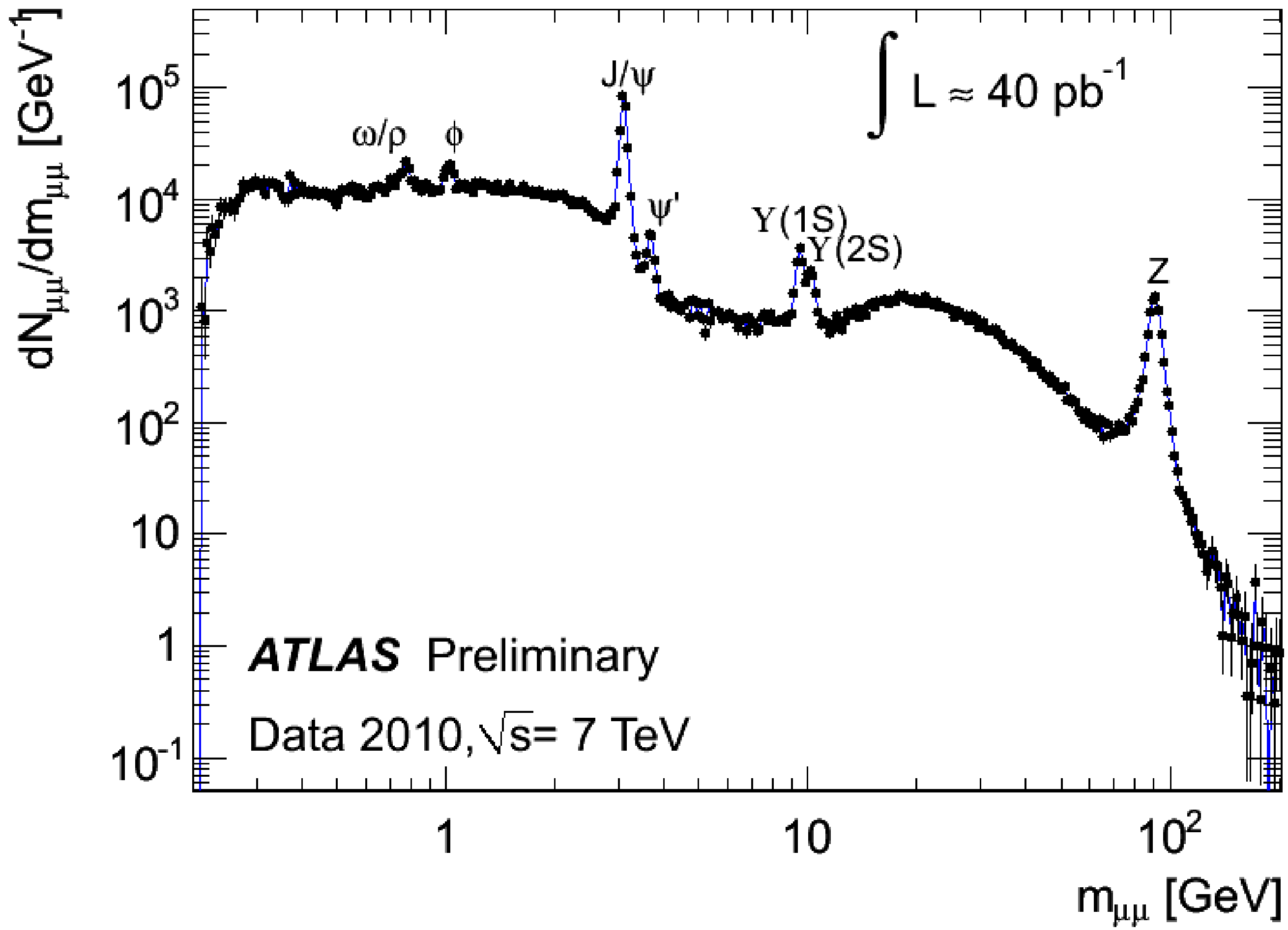
The detector operated with high efficiency

Subdetector	# Channels	% operational
Pixels	80 M	97.3%
SCT Silicon Strips	6.3 M	99.2%
TRT	350 k	97.1%
LAr EM Calorimeter	170 k	98.1%
Tile calorimeter	9800	96.9%
Hadr. endcap LAr cal.	5600	99.9%
Forward LAr cal.	3500	100%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trig.	370 k	99.5%
LVL1 Muon TGC trig.	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Ch.	31 k	98.5%
RPC Barrel Muon Ch.	370 k	97.0%
TGC Endcap Muon Ch.	320 k	98.6%



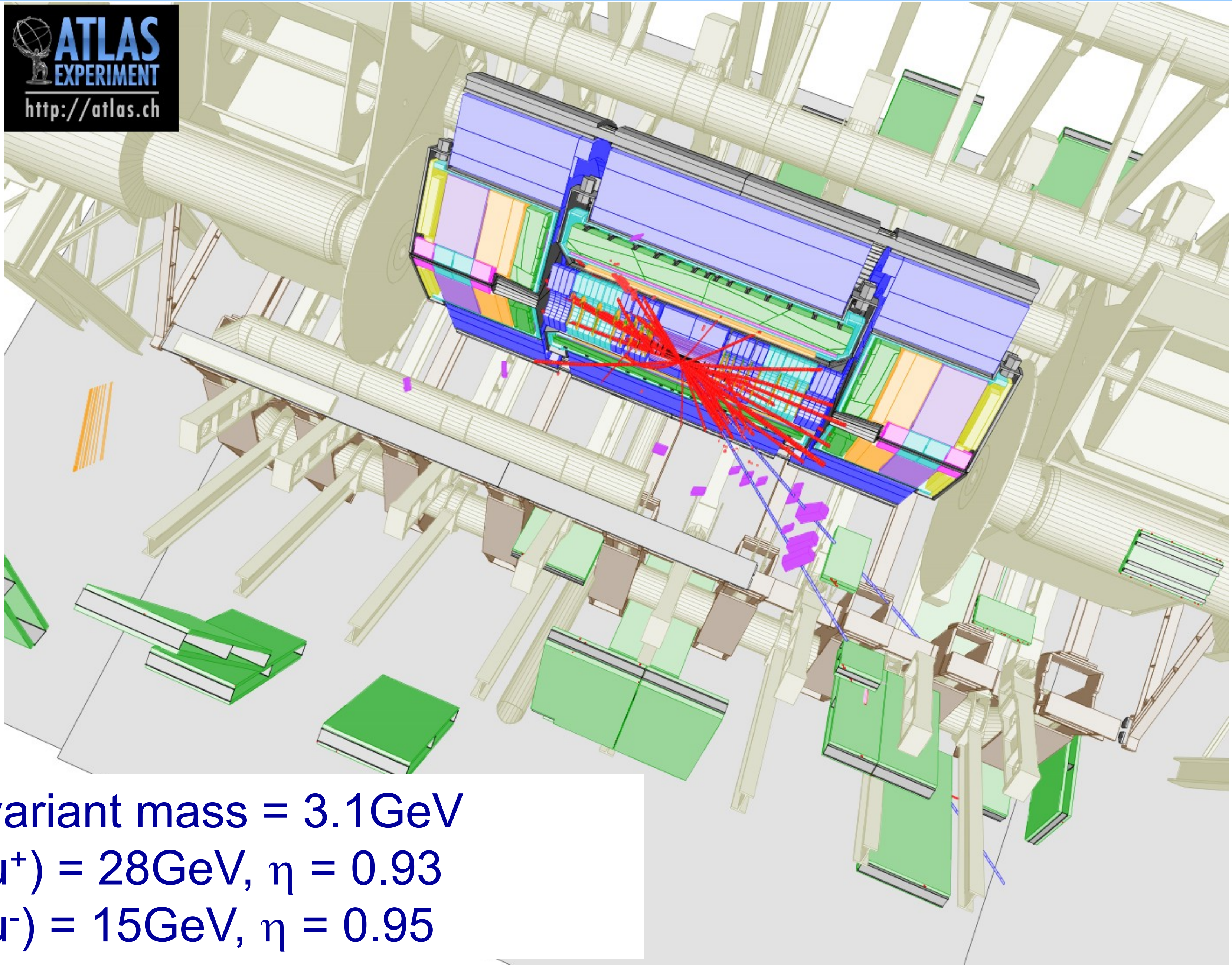
Peak luminosity	$2.07 \times 10^{32} cm^{-2} s^{-1}$
LHC delivered	$48.1 pb^{-1}$
ATLAS recorded	$45\ pb^{-1}$
Systematic uncertainty	11%

Dimuon spectrum – 40pb^{-1}



- Combined opposite sign muons with: $p_T(\mu) > 2.5$ GeV
- High Level Trigger (EF) with p_T threshold of 15 GeV

J/ψ candidate

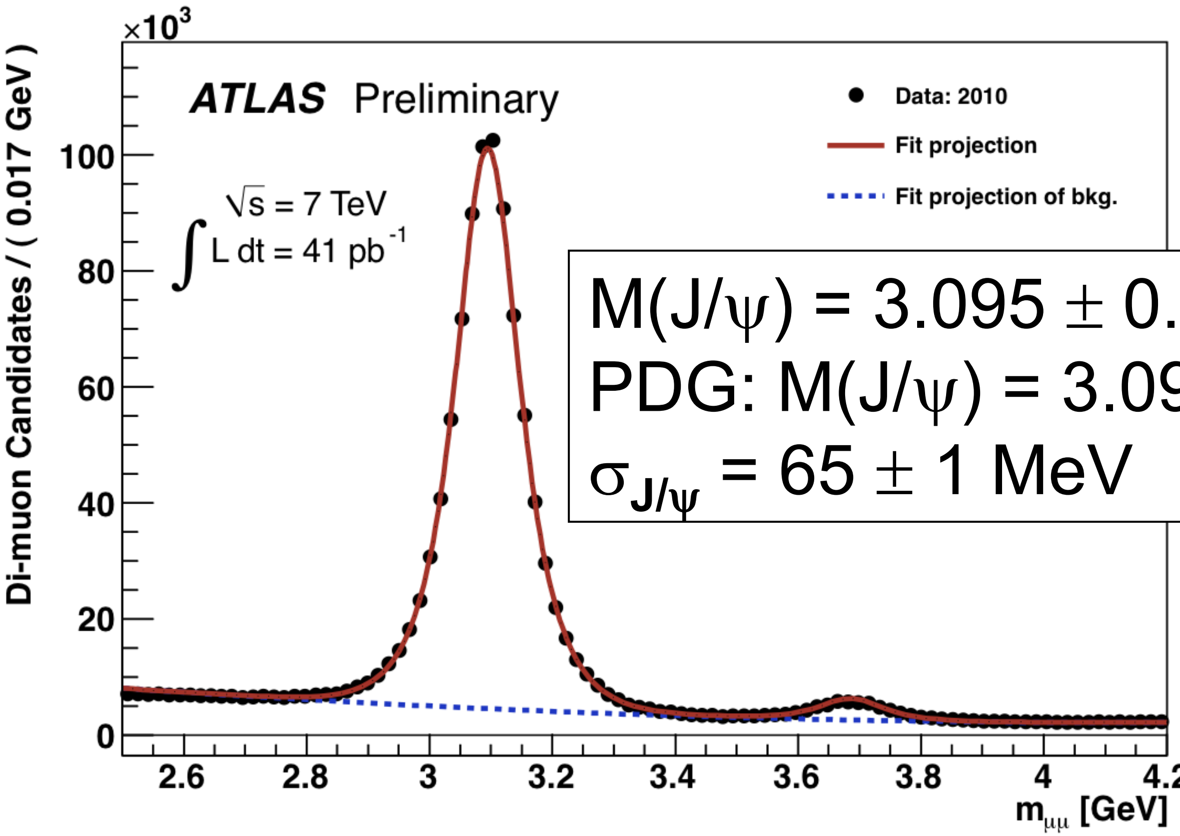


Invariant mass = 3.1GeV

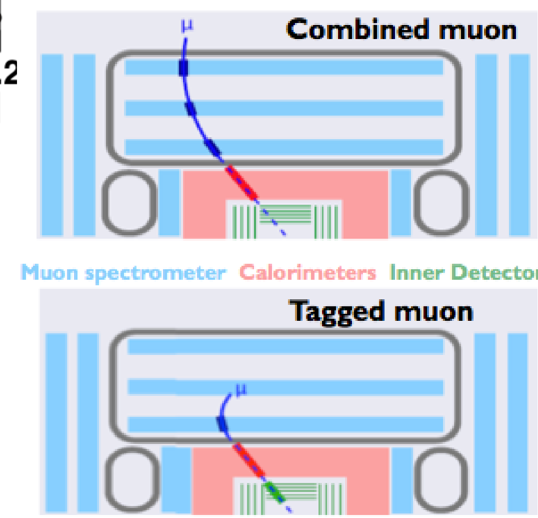
$p(\mu^+)$ = 28GeV, η = 0.93

$p(\mu^-)$ = 15GeV, η = 0.95

J/ψ observation with 41pb^{-1}



$M(J/\psi) = 3.095 \pm 0.003$ GeV
PDG: $M(J/\psi) = 3.09692$ GeV
$\sigma_{J/\psi} = 65 \pm 1$ MeV



- At least one primary vertex with 3 tracks associated
- Quality cuts on the ID tracks to remove the badly measured muons
- Opposite charge muon pairs with successful vertex fit
- One of the muon candidates needs to be combined

First B physics measurements

- Differential J/ψ production cross section in bins of p_T and rapidity (9.5 nb^{-1})
- Ratio of non-prompt to prompt production cross-section vs. p_T (17.5 nb^{-1})

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Differential J/ψ production cross-section

Each $J/\psi \to \mu^+\mu^-$ candidate is multiplied by weight to recover true number of J/ψ

$$w^{-1} = \mathcal{A}(p_T, y, \lambda_i) \times \mathcal{E}_\mu(\vec{p}_1) \times \mathcal{E}_\mu(\vec{p}_2) \times \mathcal{E}_{\text{trig}}(\vec{p}_1, \vec{p}_2)$$

J/ψ kinematic acceptance:

1) detector acceptance
2) spin alignment

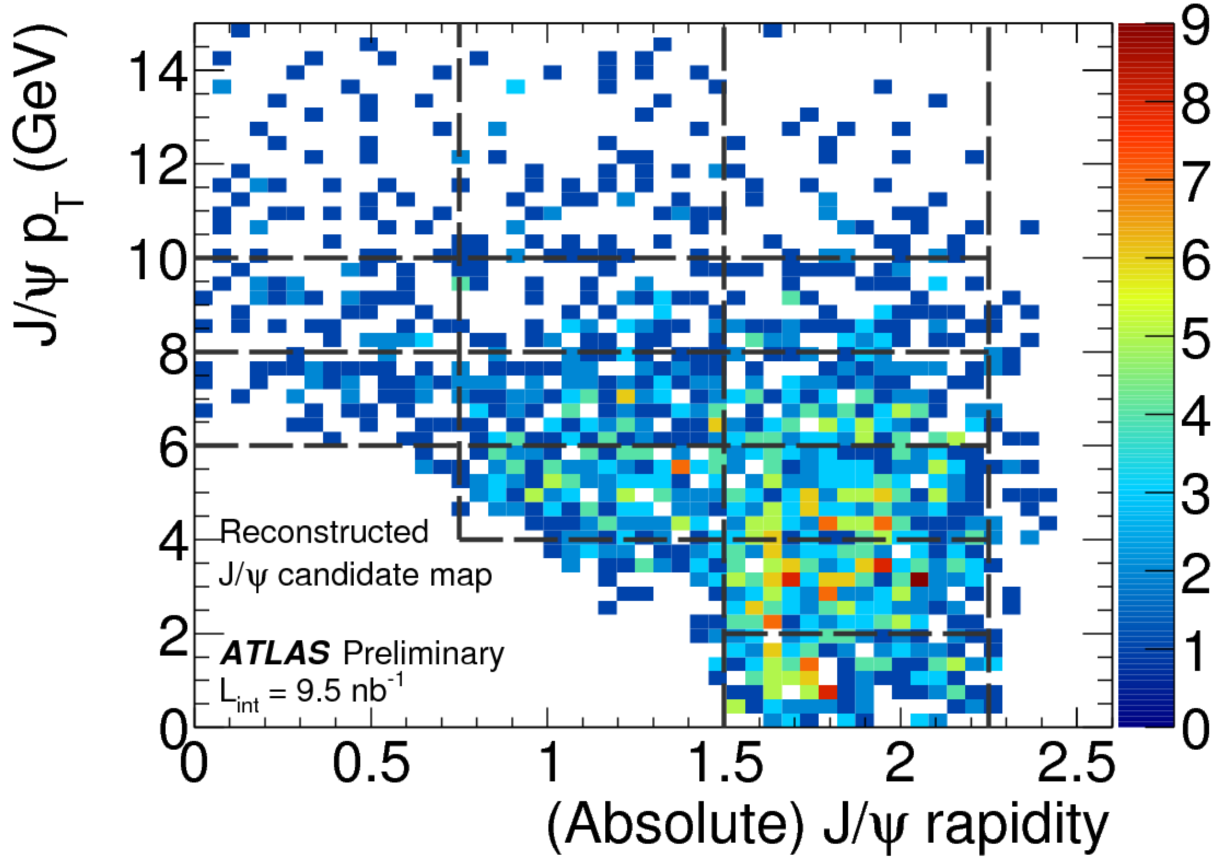
The muon reconstruction efficiency in bins of p_T, η, φ

The trigger efficiency

Detector Acceptance

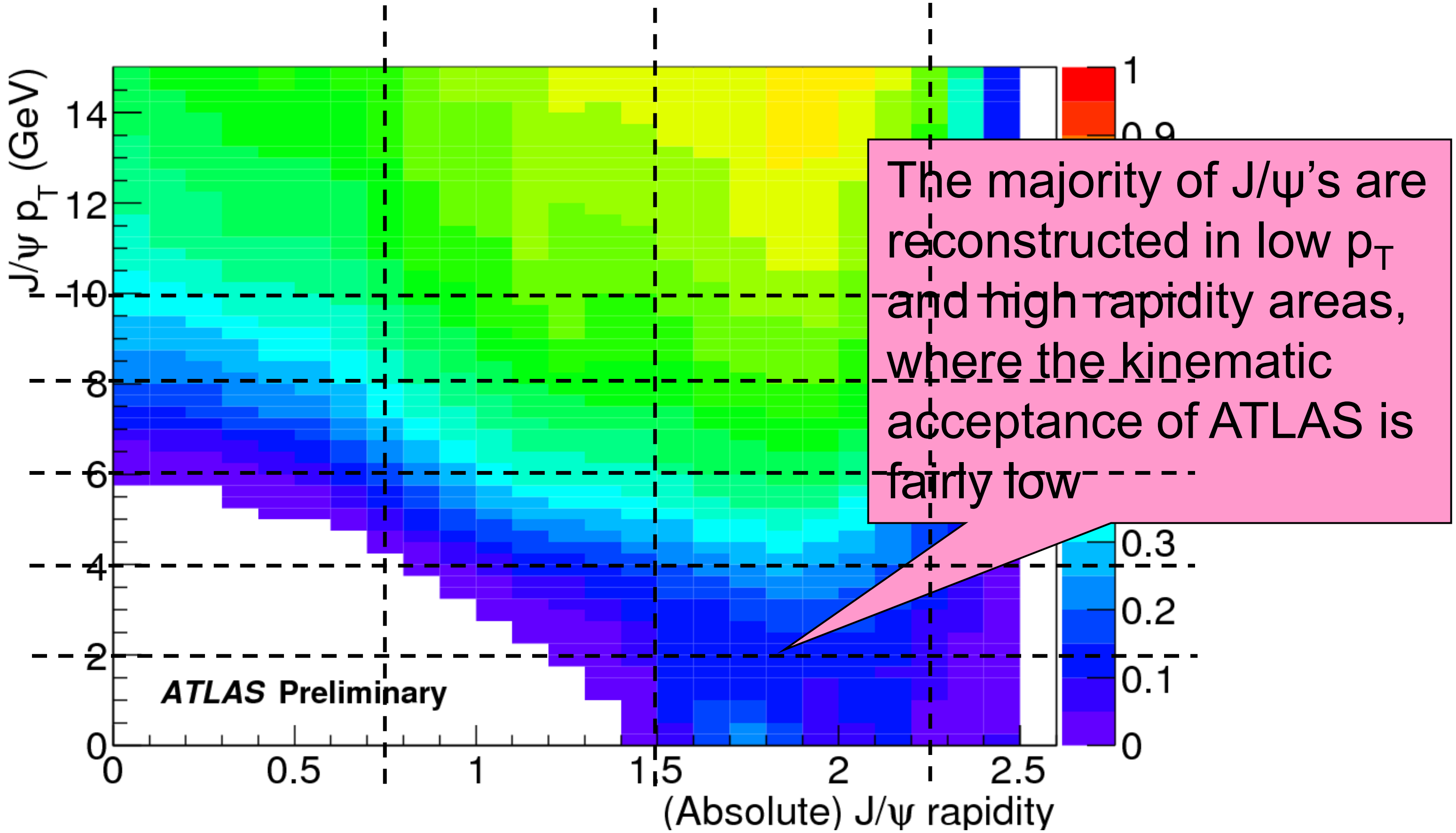
Detector Acceptance is defined as the probability to have both μ from J/ψ in the detector volume

Map of reconstructed J/ψ



Detector Acceptance

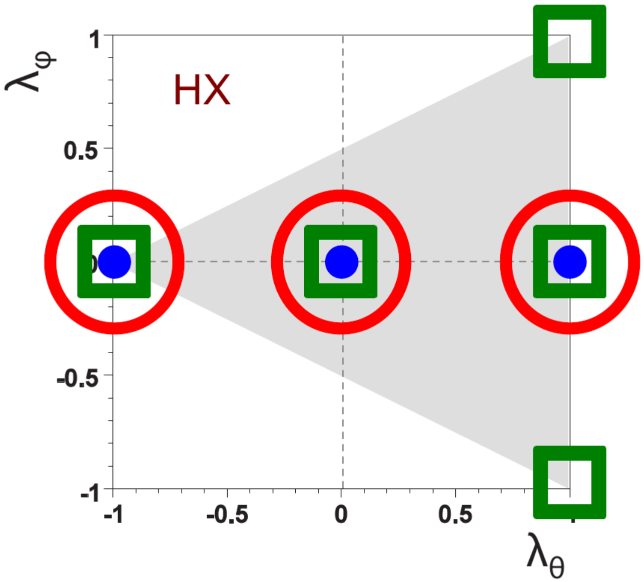
Acceptance map is determined by MC events with generator level cuts: $p(\mu) > 3.5$GeV for $|\eta|<2$, $p(\mu) > 8$GeV for $2<|\eta|<2.5$



- MC simulated with 0 polarization

Kinematic Acceptance - Spin Alignment

- Polarization is unknown
  - How to take into account the polarization effect?
- Perform the measurement under the assumption of a different spin alignment scenario: a flat, one longitudinal and three 3 transverse orientations
  - use extremes to determine the “envelope” of possible values (**ATLAS**, **CMS**, **ALICE**)
- Assign an appropriate systematic uncertainties

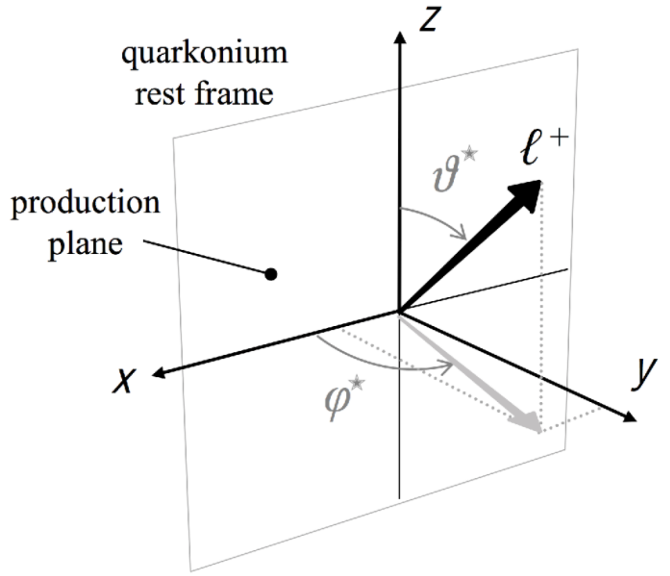


Reminder

- J/ψ acceptance ∝ φ*, θ*

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

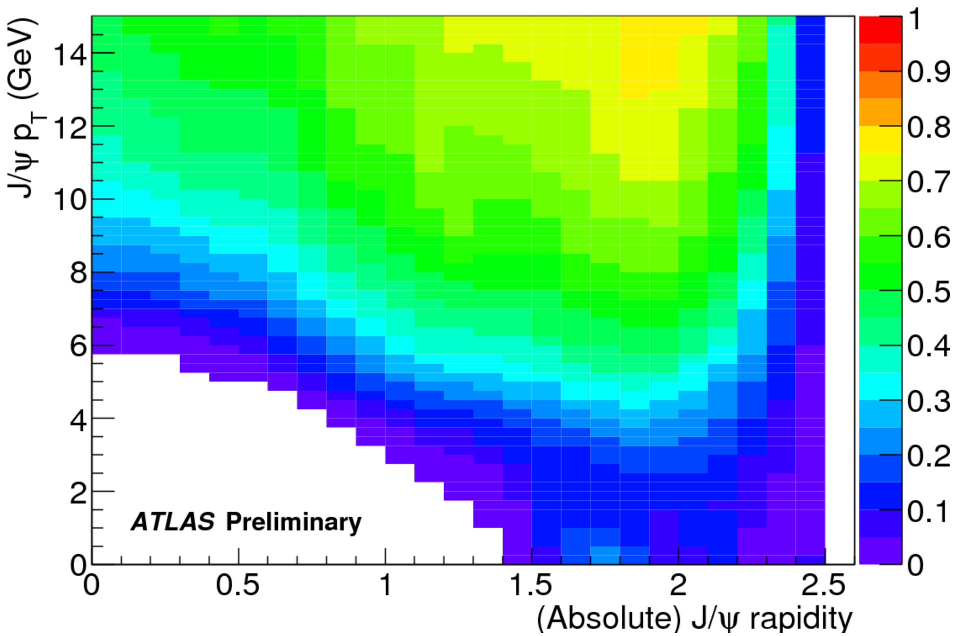
- φ*, θ* ∝ the spin alignment of J/ψ
- Spin alignment of J/ψ depends on the production mechanism

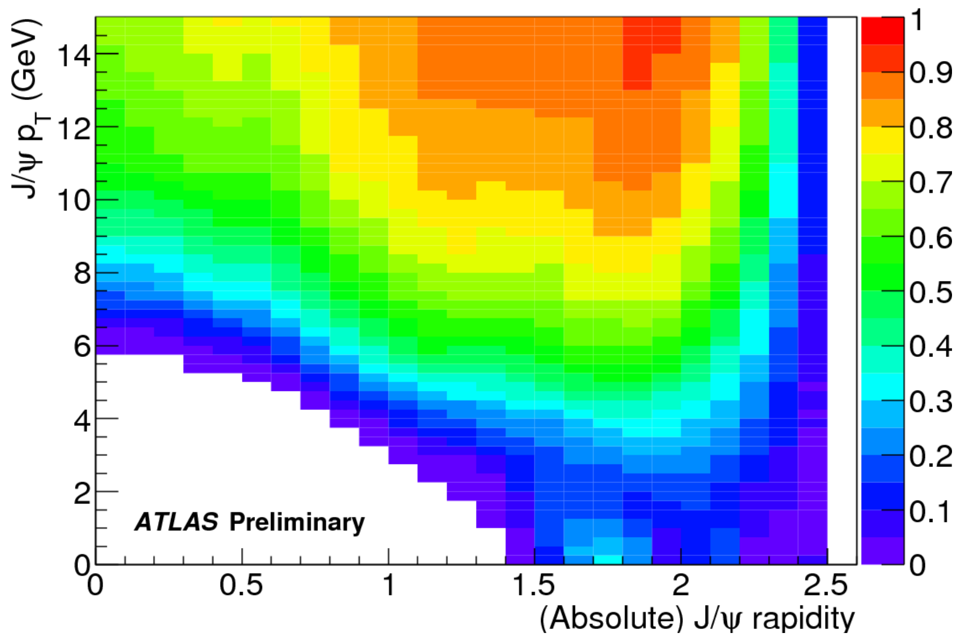


Kinematic Acceptance - Spin Alignment

Difference in the acceptance depending on the different spin alignment scenario

Acceptance maps with
Flat & **Longitudinal** hypothesis





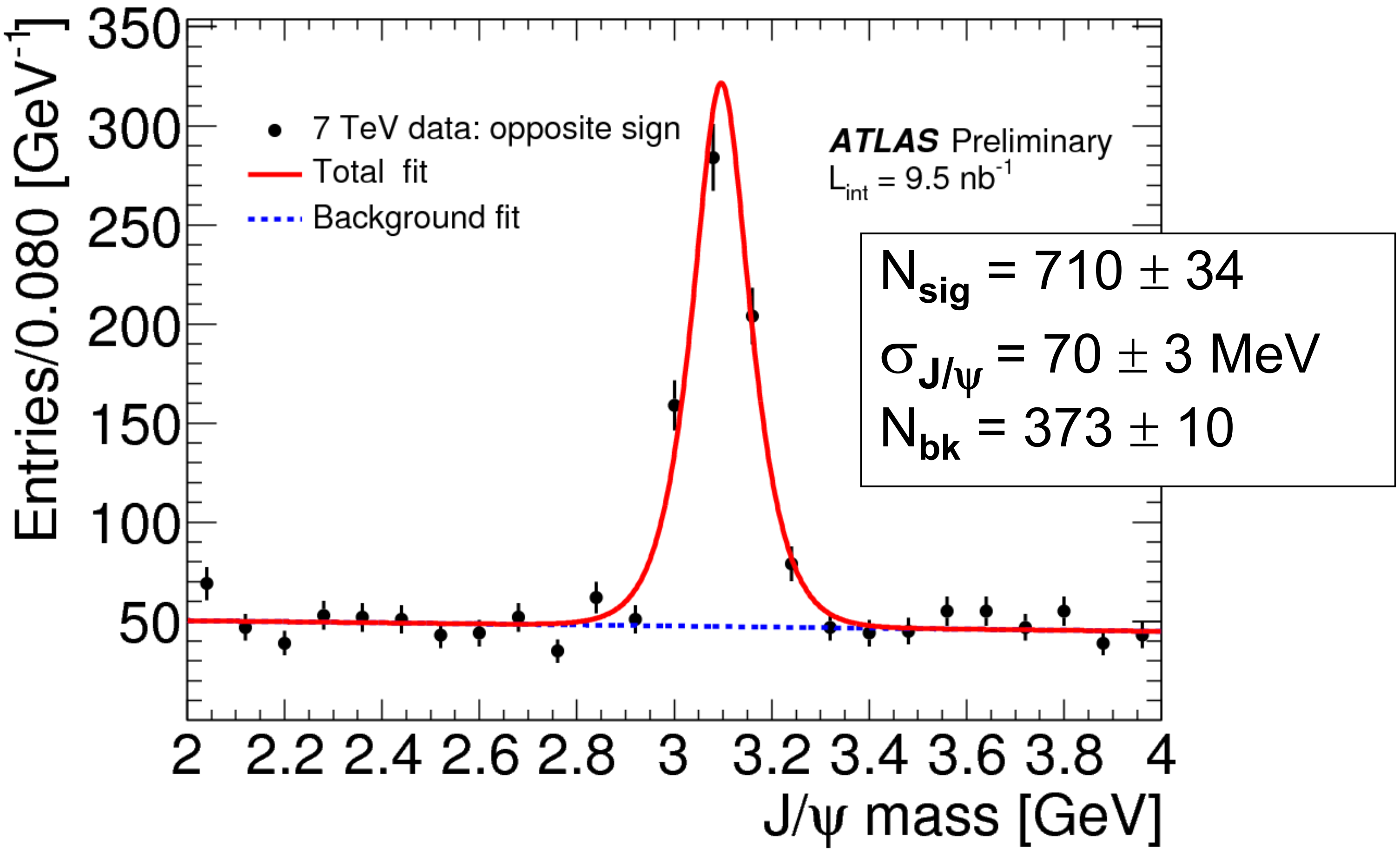
Trigger & muon reconstruction efficiencies

- The trigger efficiency is calculated relative to the offline reconstruction efficiency
  - using minimum bias data the **p_T - η** map of the single muon efficiencies for the EF trigger is constructed
  - the average efficiency for the EF trigger is calculated for each of the analysis bins by populating the bins with MC prompt $J/\psi \rightarrow \mu^+\mu^-$ simulated events

$p_T(J/\psi)$ [GeV]	**efficiency (%)**
> 6	**95**
< 6	**57 – 63**

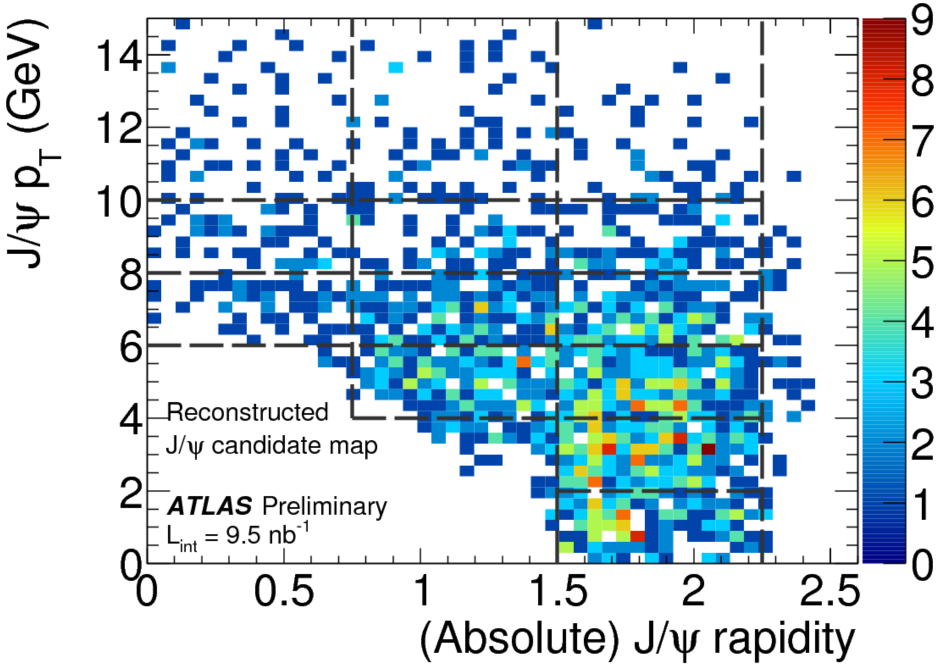
- The muon reconstruction efficiency
  - Determined by the fully simulated prompt $J/\psi \rightarrow \mu\mu$ MC events

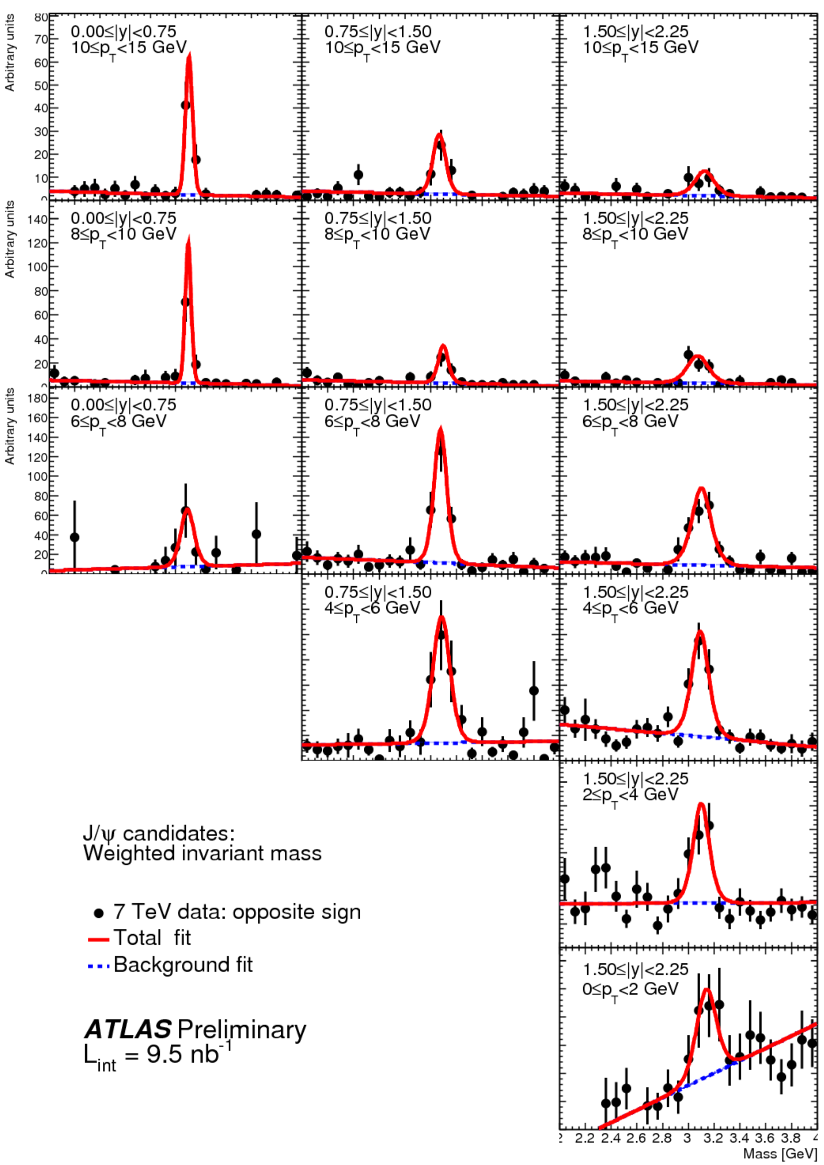
J/ψ candidates



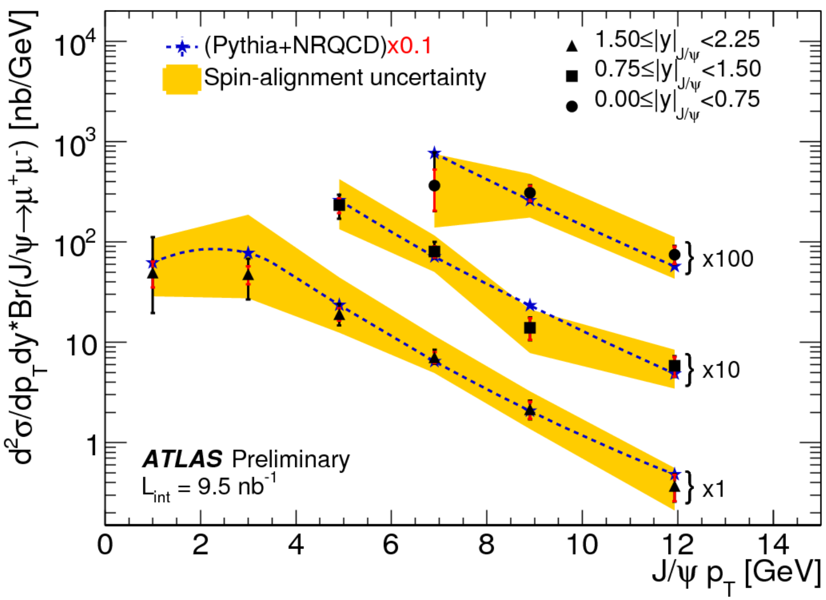
Perform the ML unbinned fit to derive N of J/ψ candidates

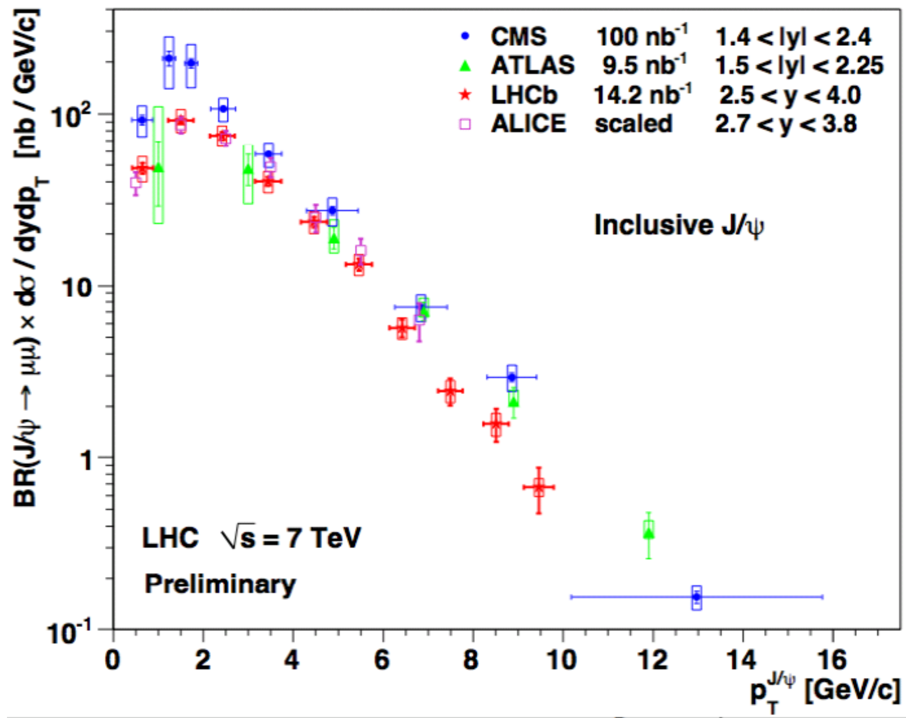
J/ψ candidates: reweighted invariant mass





Differential J/ψ production cross-section





- Shape of distribution is in good agreement
- ATLAS Pythia retuning ongoing to correct the factor 10 discrepancy

ATLAS preliminary results compatible with other LHC experiments

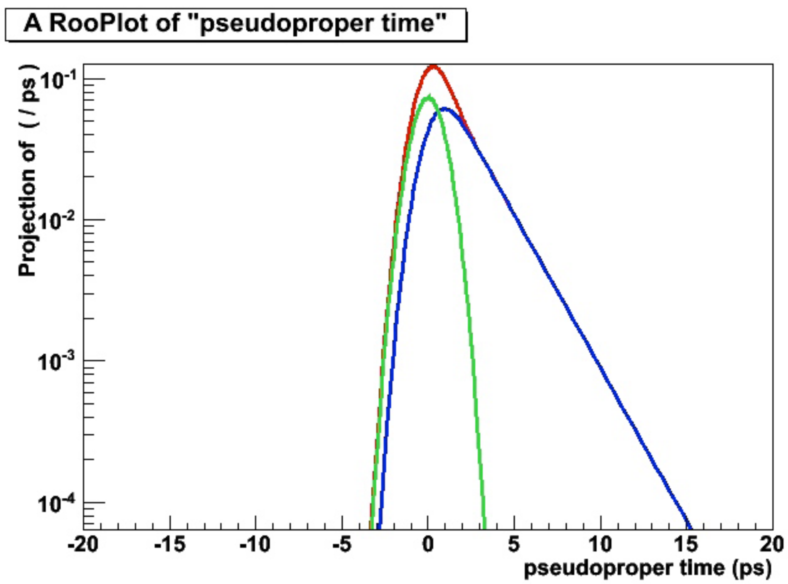
Forward rapidities:

ALICE ATLAS CMS LHCb

Non-prompt to prompt J/ψ cross-section ratio

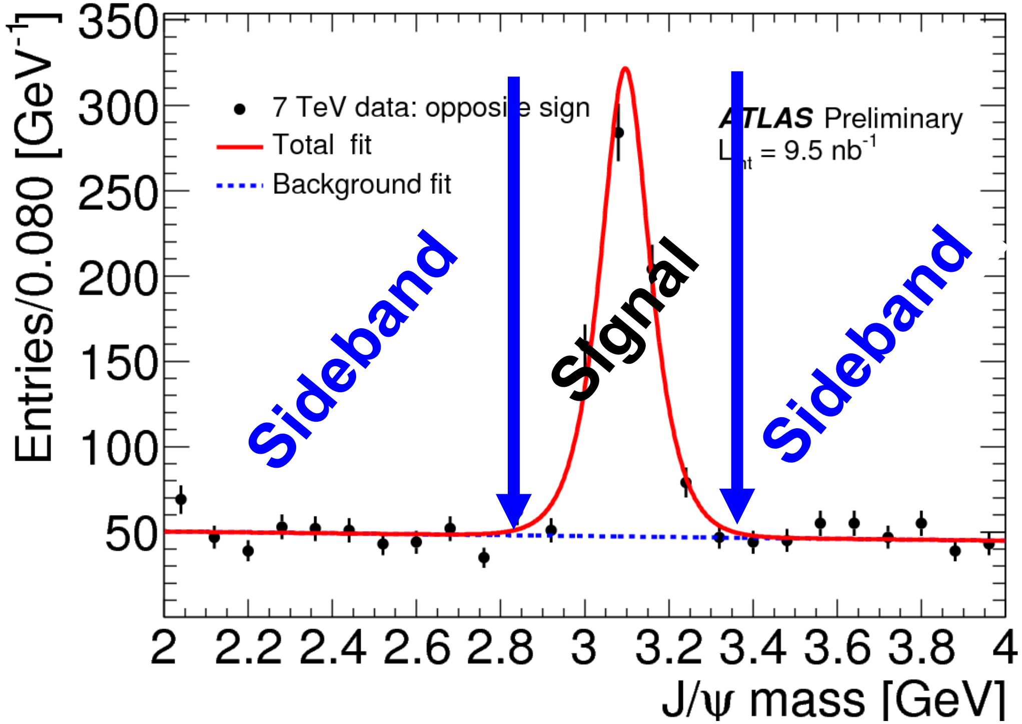
$$\mathcal{R} \equiv \frac{\sigma(pp \to b\bar{b}X \to J/\psi\, X')}{\sigma(pp \to J/\psi\, X'')_{\text{prompt}}}$$

- The pseudo-proper decay time separates prompt from non-prompt candidates: $\tau = L_{xy}M(J/\psi)/p_T(J/\psi)$
  L_{xy} – projection of the flight distance of the J/ψ onto its p_T

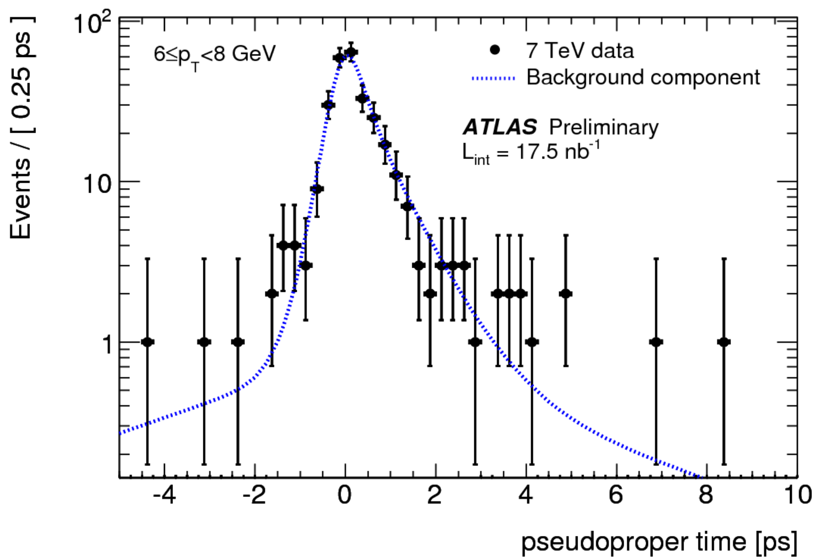


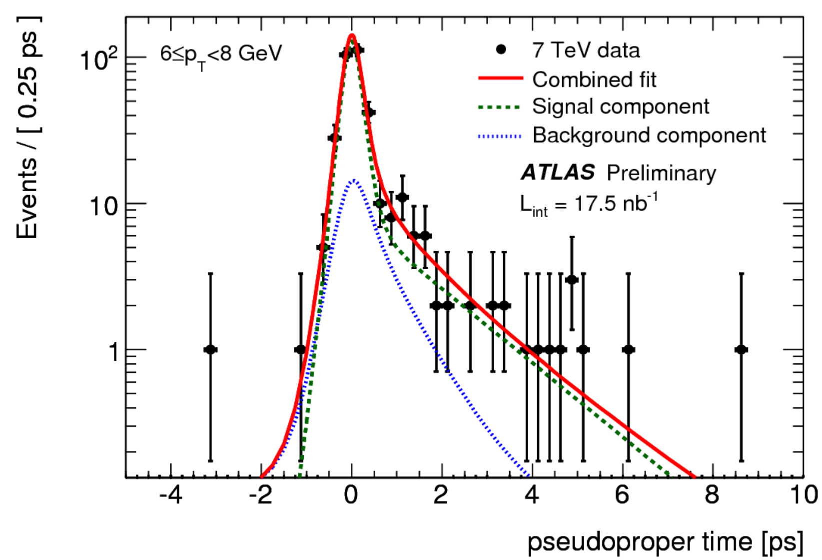
- Simultaneous fit
  - **Invariant mass**
    - Signal: Gaussian function
    - Background: Linear function
  - **Proper time**
    - Signal: resolution + exponential function ⊗ resolution
    - Background: resolution + positive and negative exponential function ⊗ resolution

Fit models



From Sideband





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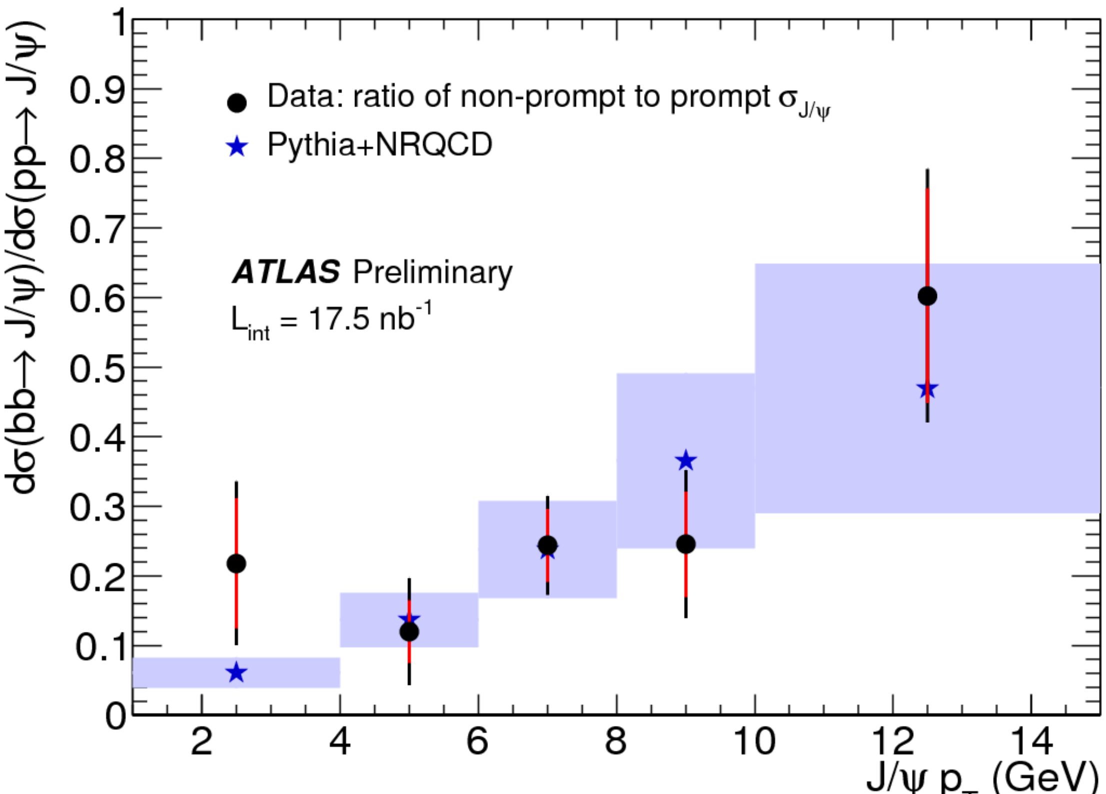
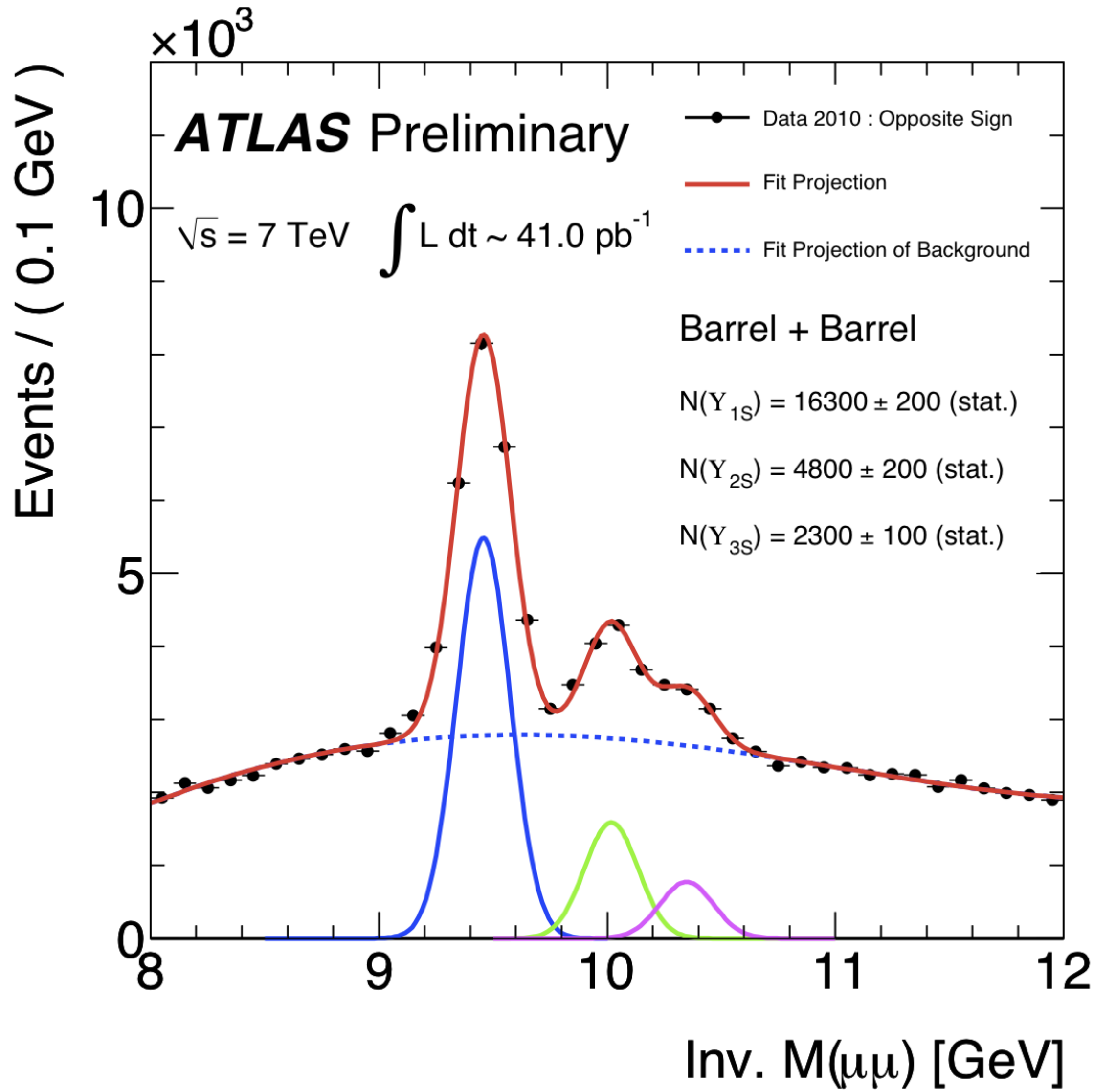
Non-prompt to prompt J/ψ cross-section ratio



- Measurements in agreement with the Pythia expected value within the statistical and systematic uncertainties
- Systematic uncertainties estimated modifying:
  - resolution model in the time fit (Gaussian → double - Gaussian)
  - background model in the mass fit (using a polynomial)
  - fitting procedure

Upsilon observation - Υ(1s,2s,3s)→μμ

Two muons in the barrel region



Observation of the $B^{\pm} \rightarrow J/\psi(\mu^+\mu^-)\, K$

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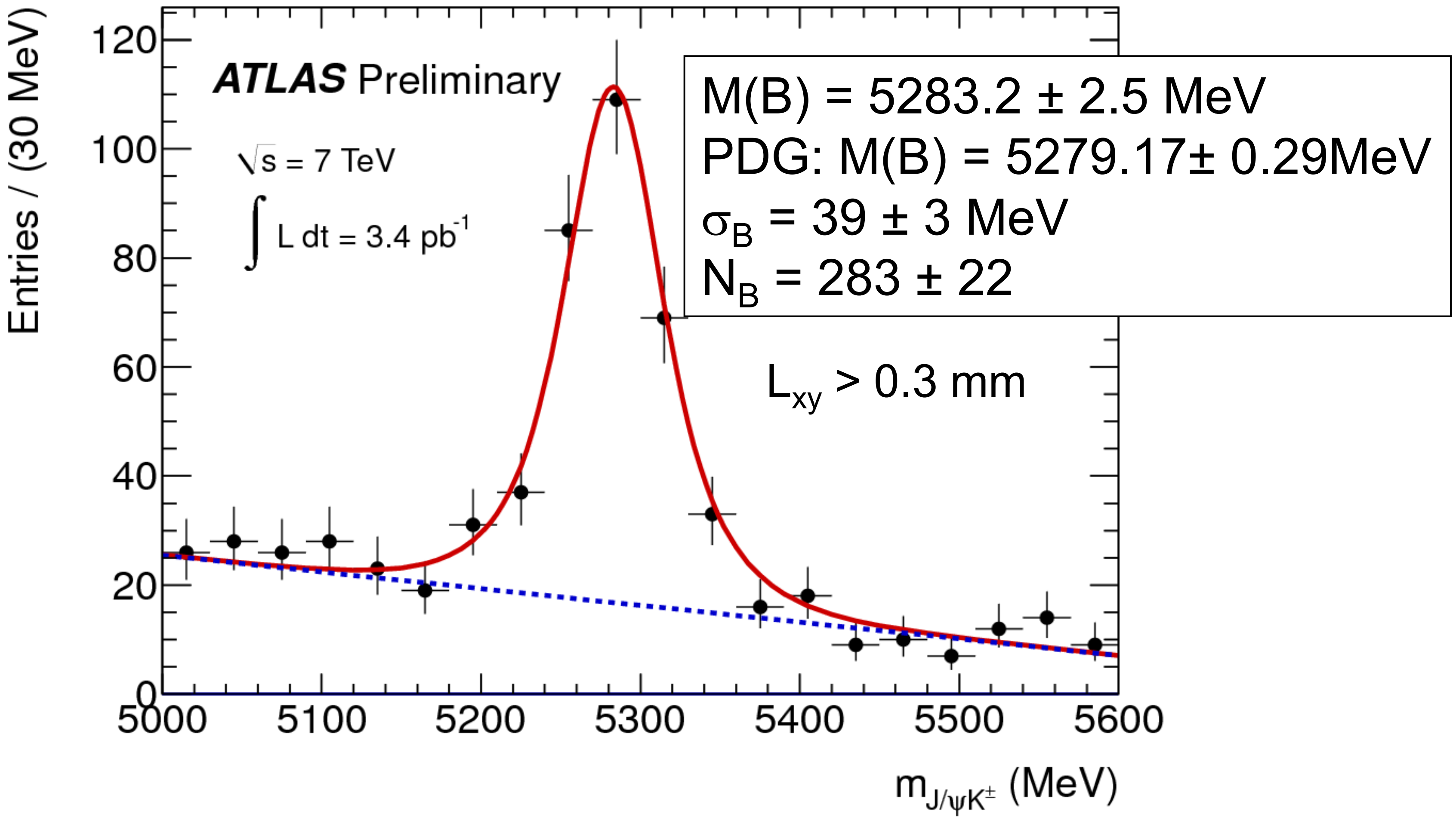


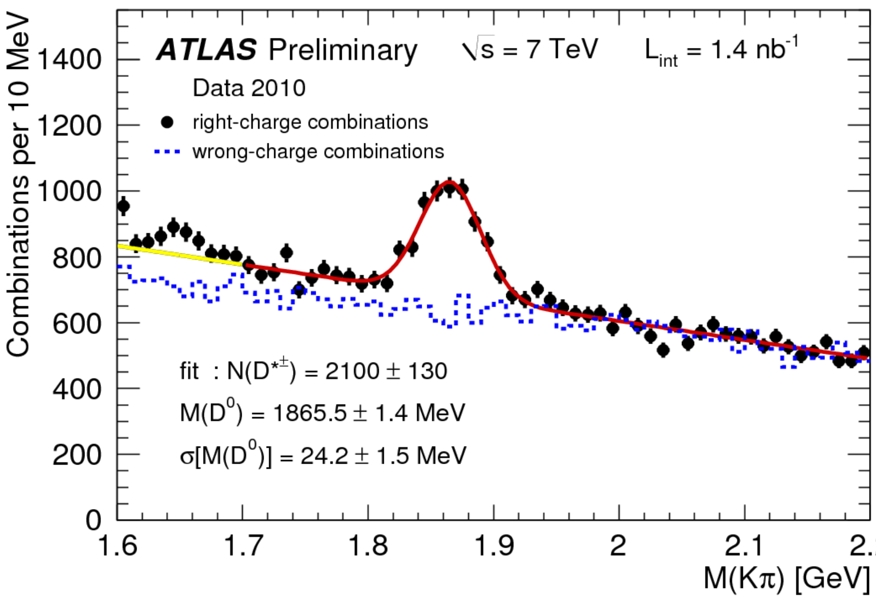
Dimuon in the J/ψ mass range combined with a third track (kaon mass assigned)

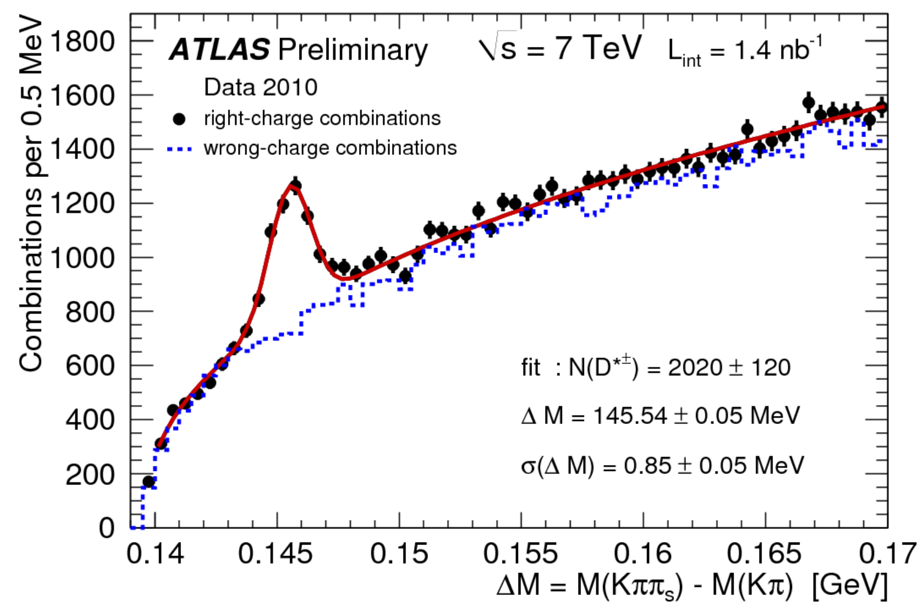
- Fitted to a common vertex, with J/ψ mass on dimuon
- Background suppression - transverse decay length

D mesons

Production of charm mesons is one of the first hard processes to be measured at LHC

$D^{*+} \rightarrow D^0\pi^+ \rightarrow (K^-\pi^+)\pi^+$





Mesons	PDG Mass (MeV)	ATLAS Mass (MeV)
$D^* - D^0$	145.42 ± 0.01	145.54 ± 0.05
D^0	1864.83 ± 0.14	1865.5 ± 1.4

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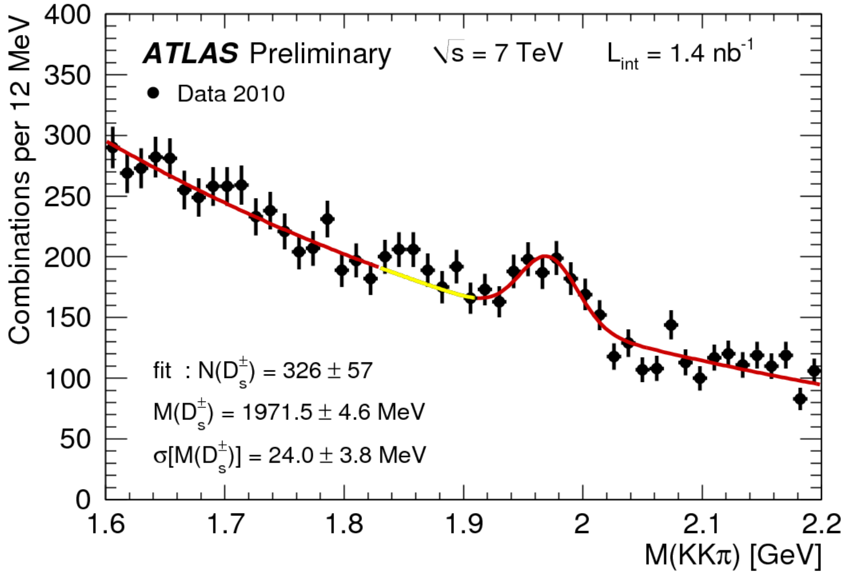
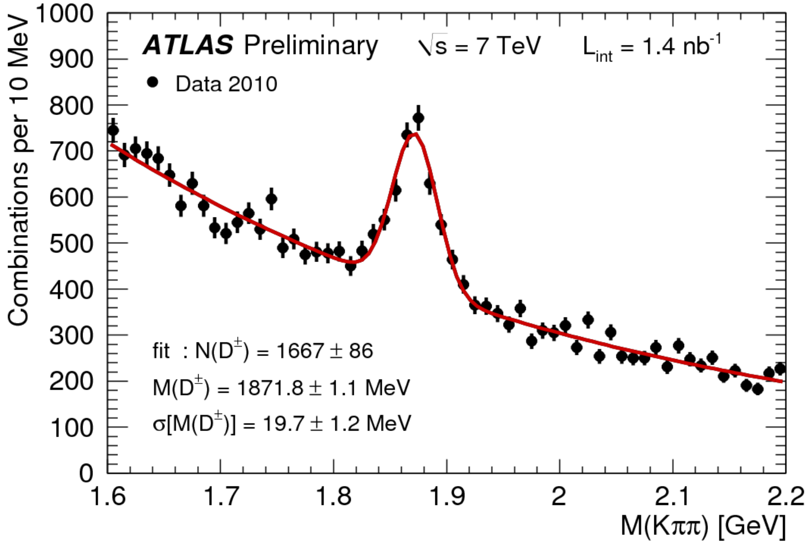
D mesons

$D_s^+ \rightarrow \Phi\pi^+ \rightarrow (K^-K^+)\pi^+$

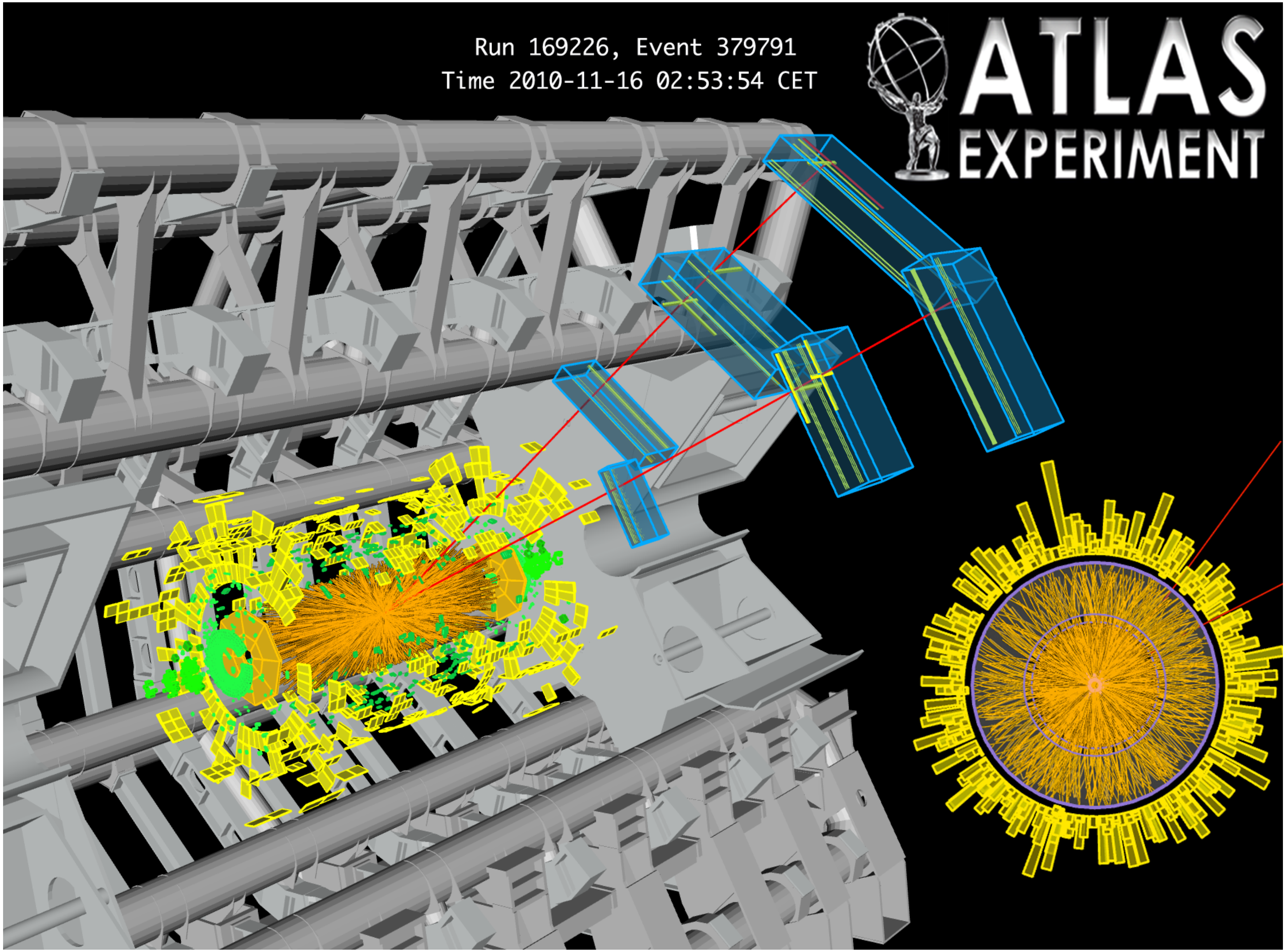


$D^+ \rightarrow K^-\pi^+\pi^+$



Mesons	PDG Mass (MeV)	ATLAS Mass (MeV)
$D^{\pm}$	1869.60 ± 0.16	1871.8 ± 1.1
$D_s^{\pm}$	1968.47 ±0.33	1971.5 ± 4.6

A heavy ion collision with a candidate $J/\psi \rightarrow \mu^+\mu^-$



Future Measurements 2011/2012

- Heavy quarkonia:
  - upsilon and ψ(2s) differential cross sections
  - J/ψ, ψ(2s) and Υ spin alignment
  - ψ(2S), χ_c, Υ → J/ψ $\pi^+\pi^-$ observation, cross sections
- B hadron physics
  - Differential production cross sections for B±, Bs, Bs through exclusive decays
  - Inclusive B-hadrons lifetime
  - Exclusive B-hadron lifetime
  - Bs mixing - double lifetime and helicity amplitudes
  - Search for additional sources of CP-violation with B_s→ J/ψ ϕ
  - Limits on branching ratios for rare B-decays: $B_s \rightarrow \mu\mu$ and $B_d \rightarrow \mu\mu X$