Charm and beauty physics at ATLAS

On behalf of ATLAS Collaboration

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Outline

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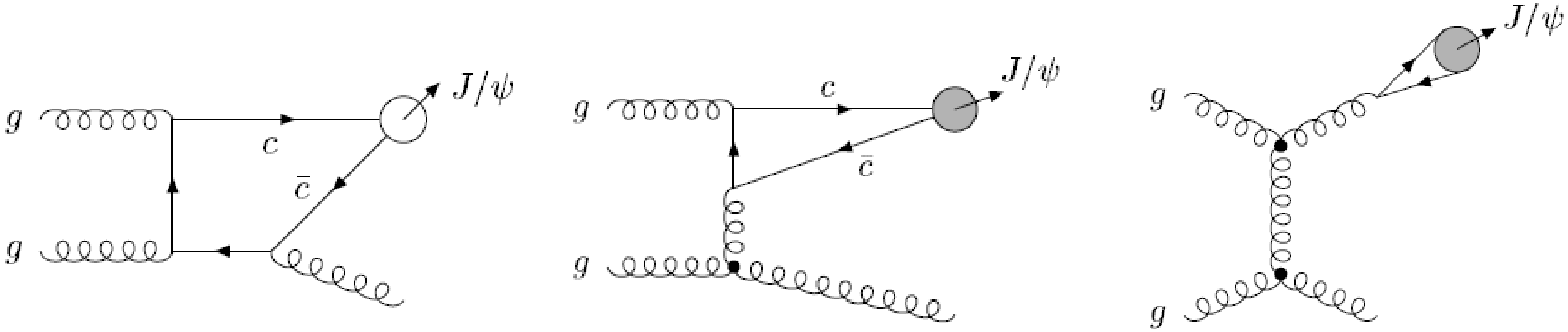
  - B-physics program for early data
- ATLAS detector
  - di-muon trigger
  - muon reconstruction
- Performance with 900 GeV collision data
  - tracking
  - muon reconstruction
- Expected results
  - Quarkonium
  - B-decay
- Summary

Quarkonium physics

- J/Ψ and Υ production cross-sections are predicted to be large at the LHC
  - Study of production mechanism of quarkonium and tests of QCD

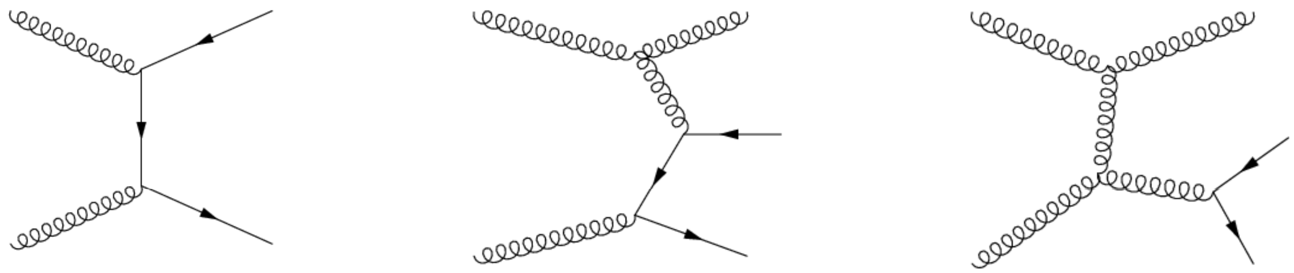


  - Prompt quarkonia production is important background for many other b-physics processes at LHC

  - J/Ψ → μμ and Υ → μμ are important channels to understand the performance of the ATLAS detector
    - Efficiency determination of muon reconstruction and muon trigger, alignment, magnetic field mapping, material distribution

B-physics program for early data

- Large production cross section through flavour creation, flavour excitation and gluon splitting



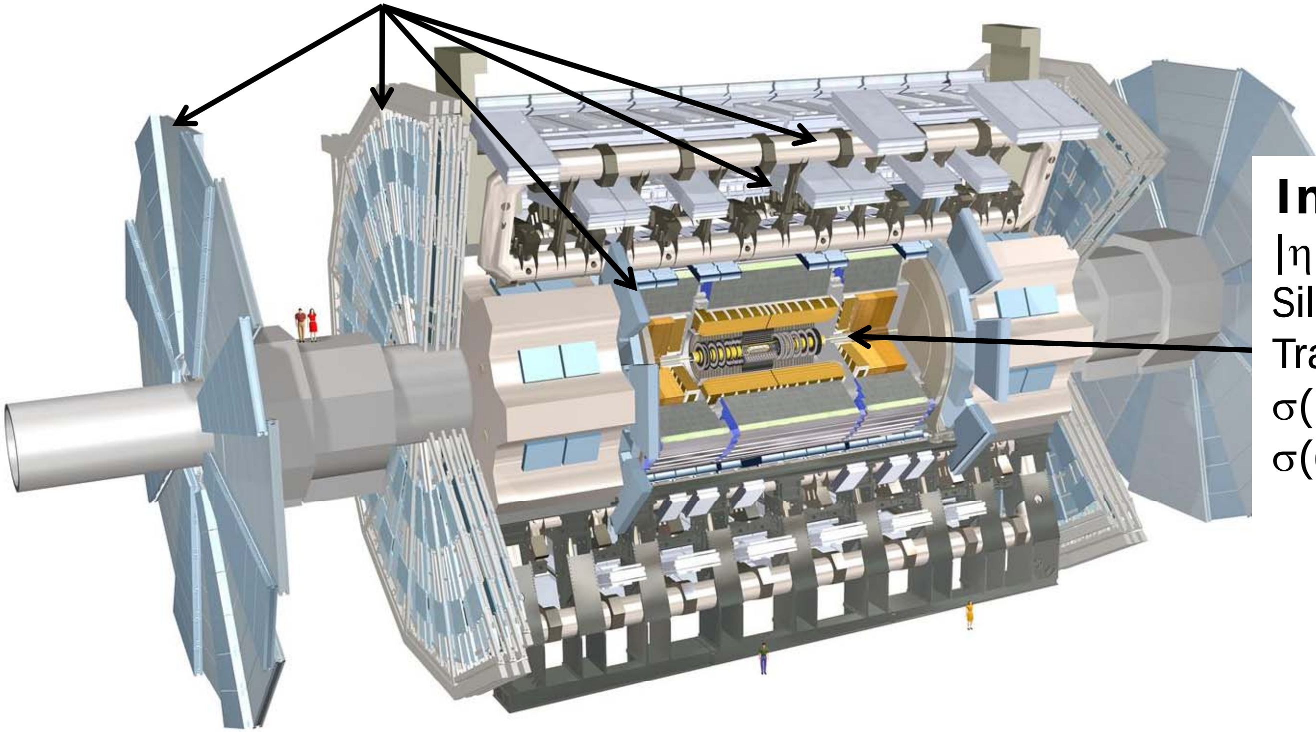
- Exclusive production cross-section measurement possible at early stage
  - $B^+ \rightarrow J/\Psi\ K^+$
    - Clear event topology
    - Reference channel for rare B decay searches

- Suitable for initial detector performance study through masses and proper lifetimes measurements
  - $B^+ \rightarrow J/\Psi\ K^+$
  - $B_d^0 \rightarrow J/\Psi\ K^{0*}$
  - $B_s^0 \rightarrow J/\Psi\ \phi$

ATLAS detector

Muon spectrometer
precision tracking chamber $|\eta| < 2.7$
trigger chamber $|\eta| < 2.4$
$\sigma(p_T)/p_T \sim 10\%\ p_T$ for 1 TeV muon

length: ~46m
radius: ~22m
weight: ~7000 tons
$\sim 10^8$ electronic channels

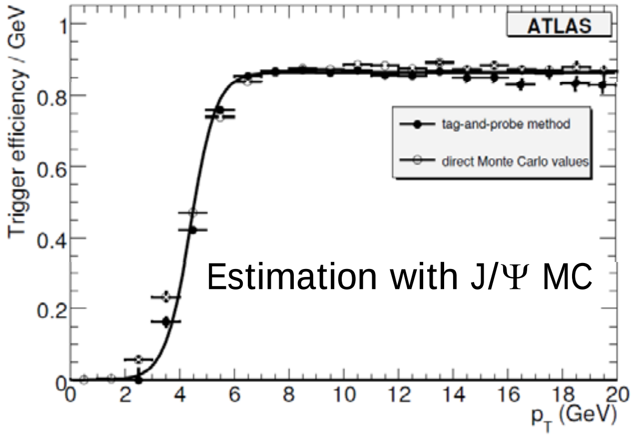


Inner detector
$|\eta| < 2.5$, B = 2T
Silicon: pixels, strips
Transition Radiation Tracker
$\sigma(p_T)/p_T \sim 3.4 \times 10^{-4}\ p_T \oplus 0.015$
$\sigma(d_0) \sim 10 \oplus 140 / p_T\ \mu m$
(p_T in GeV)

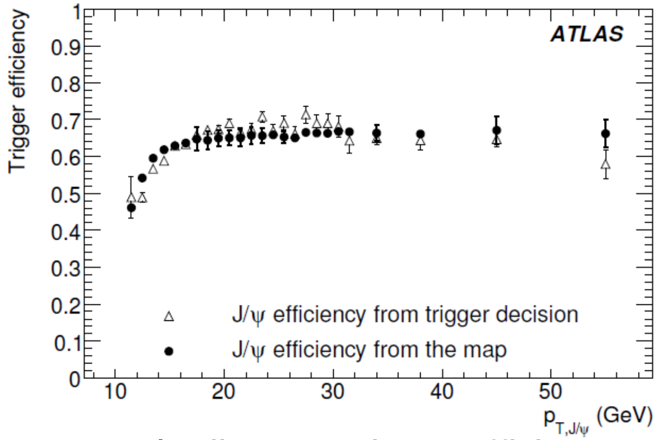
Three level trigger system
Level1: hardware trigger from muon and calorimeter information (40 MHz → 75 kHz)
Level2: software trigger to confirm level1 trigger decision (→ 2 kHz)
Event Filter: performs event selection using more complex algorithms (→ 200 Hz)

Di-muon trigger

- Muon pairs can be a clear signature of b-hadrons decaying inclusively to J/Ψ or to di-muons
- Needs efficient di-muon trigger for low-p_T muons to perform Quarkonium and B-physics studies

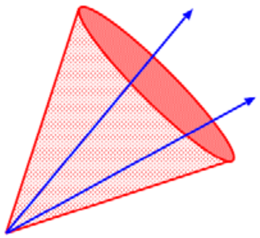


Level1 single muon trigger efficiency

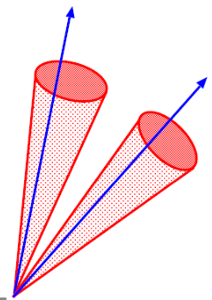


Level2 di-muon trigger efficiency

- Higher level triggers for di-muon seeded by level1 single muon trigger or level1 di-muon trigger



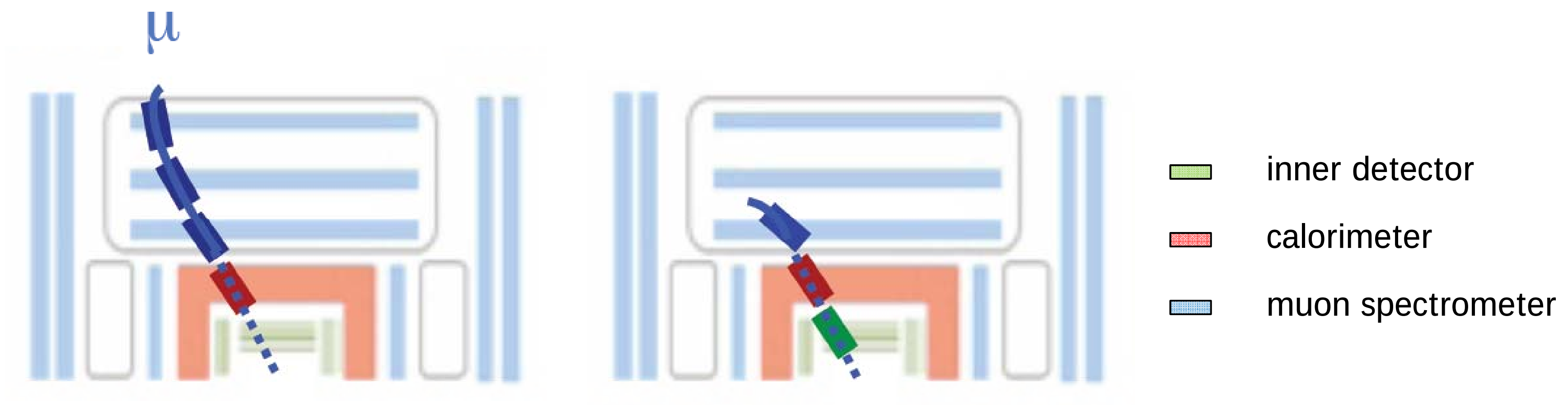
- Search for two muons in a wider η and ϕ region than seeded by level1
- efficient for J/Ψ searches



Search for two muons in η and ϕ regions seeded by level1

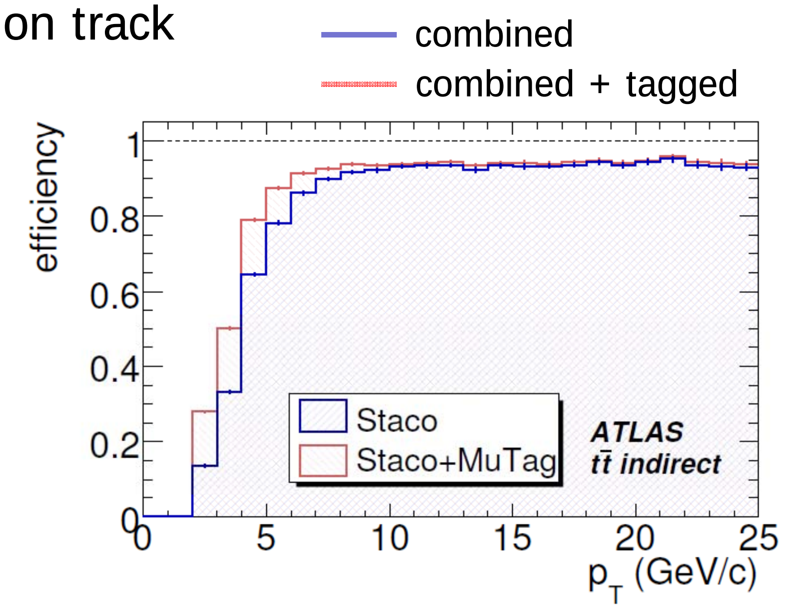
Low p_T muon reconstruction

- Excellent tracking and muon system for muon reconstruction

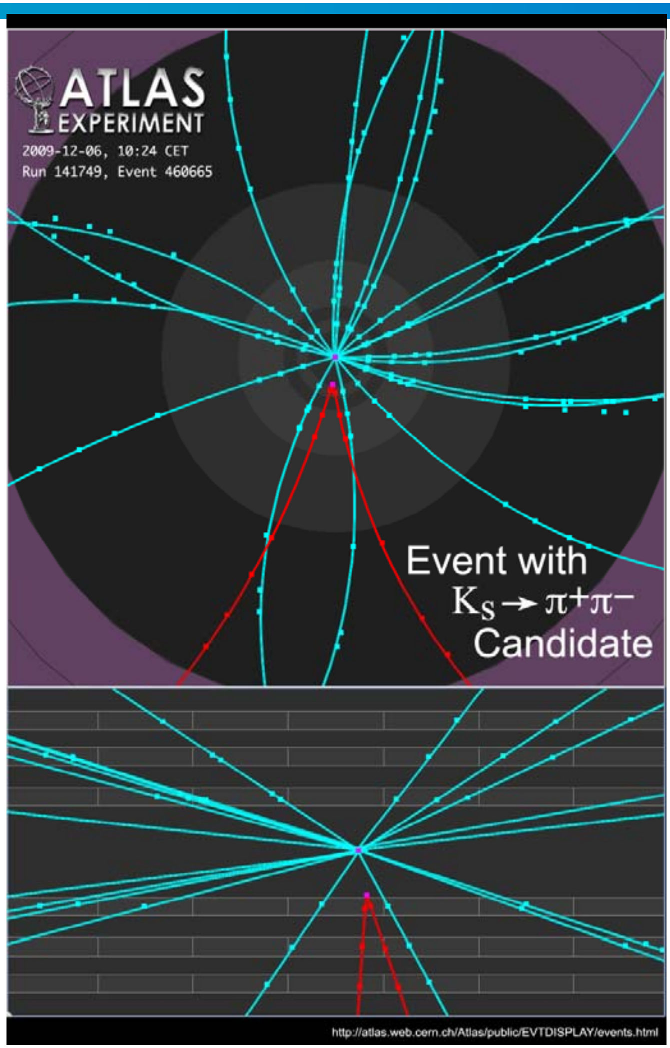


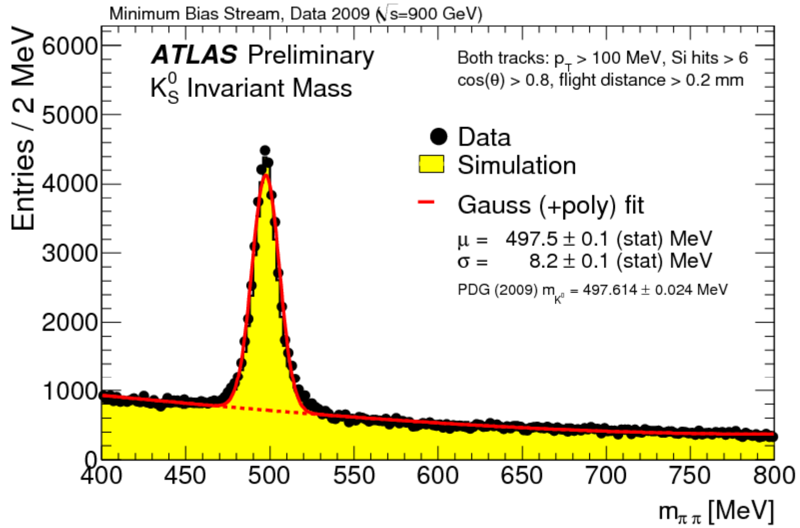
combined muon track　　tagged muon track

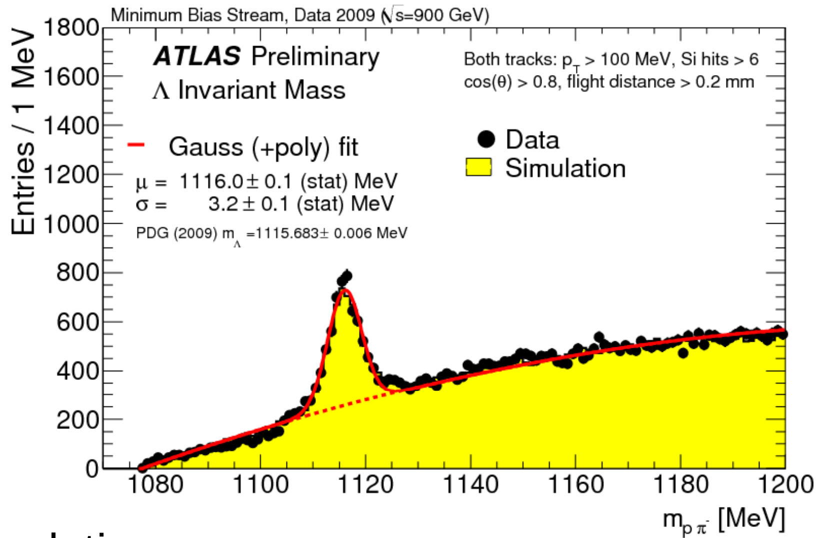
- Significant efficiency improvement for p_T < 10 GeV by using tagged muon track
  - Fake rate for J/Ψ sample < 1%



Tracking results from 900 GeV collisions



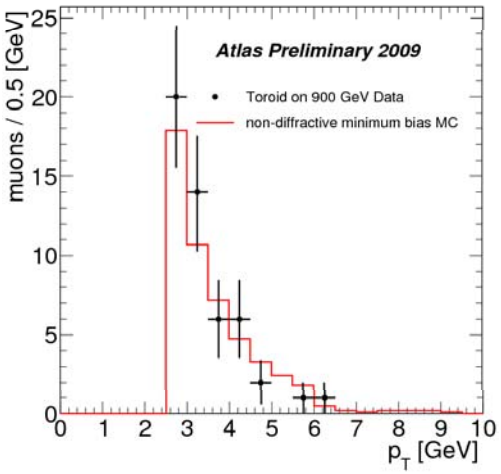


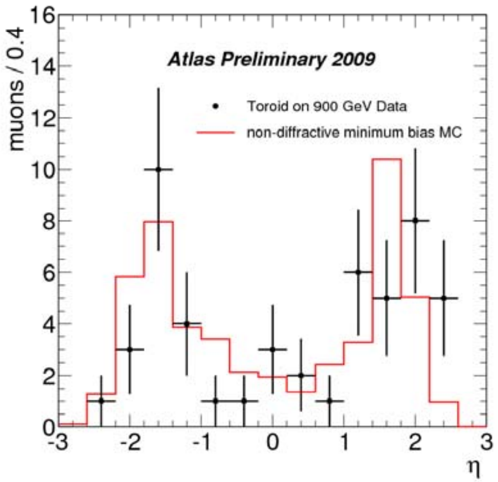


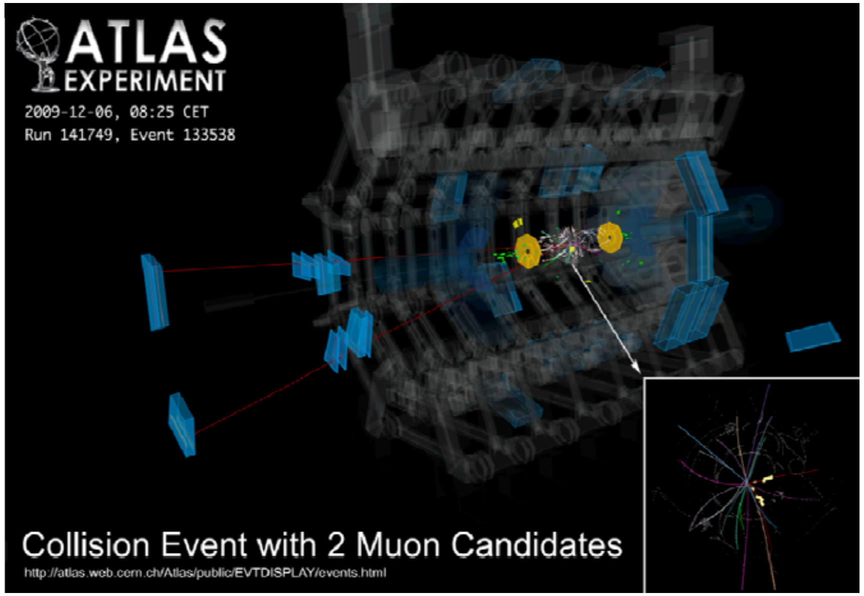
- Test of vertexing, momentum scale and resolution
  - Reconstructed K_s and Λ masses close to PDG values, width of the invariant mass peaks well reproduced by Monte Carlo

Muon results from 900 GeV collisions

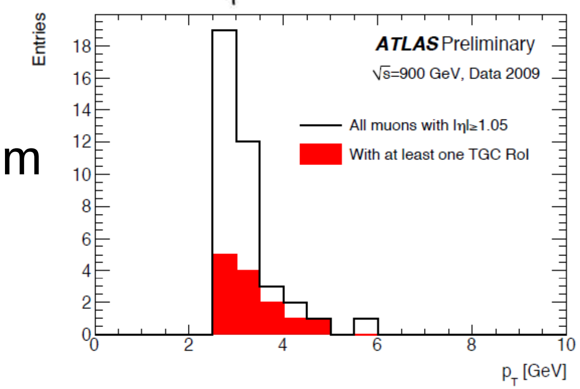
- Statistics limited, dominantly in the forward direction
  - $p > 4$ GeV, $p_T > 2.5$ GeV and $|\eta| < 2.5$
  - 50 candidates with $L = 6\ \mu b^{-1}$
- Data and Monte Carlo are consistent with available statistics

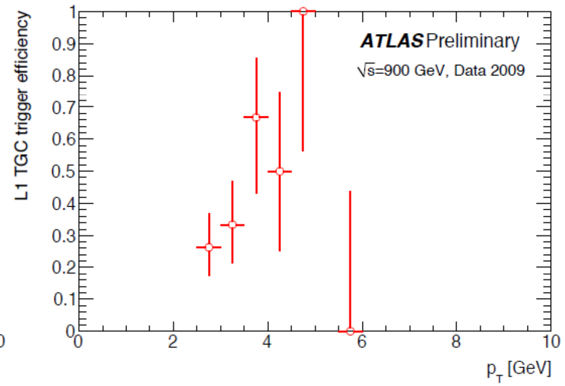






- Muon trigger is being commissioned with muon from collisions





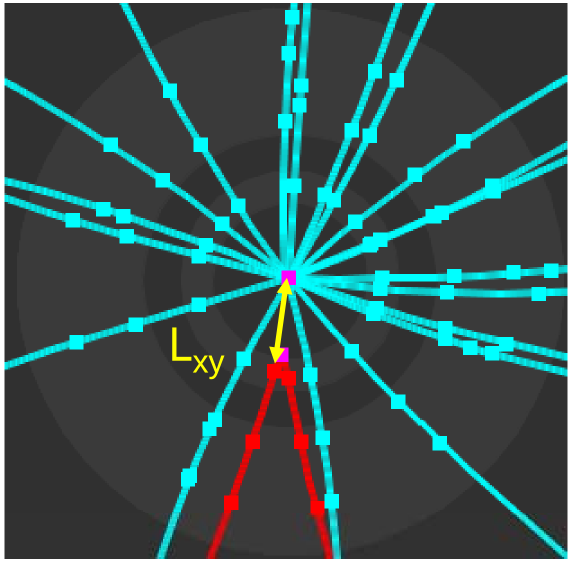
Expected results on quarkonium with Monte Carlo study

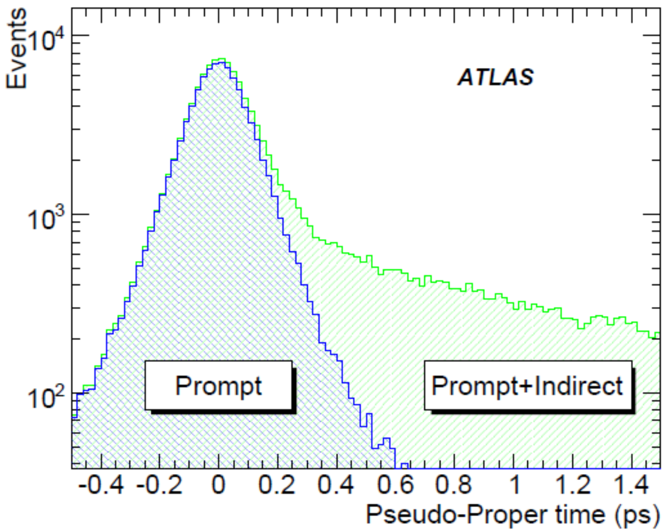
Prompt quarkonia: selection

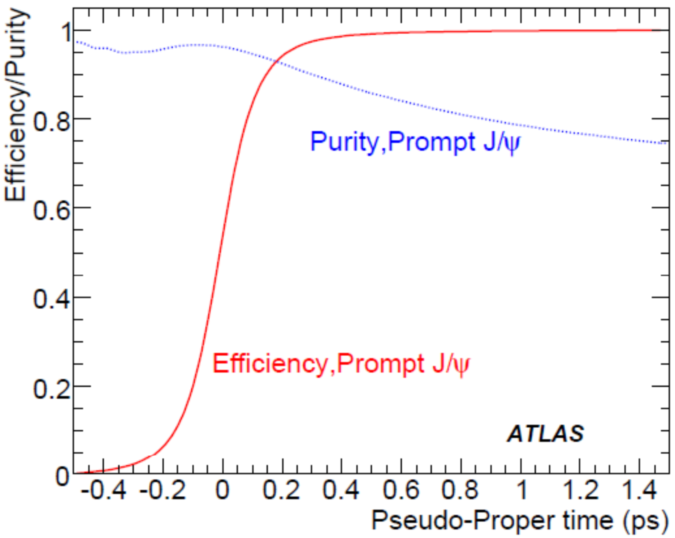
- J/Ψ from B-decays form significant background to prompt J/Ψ, in addition to muons from b-quark decays
- Measurement of prompt J/Ψ to indirect cross-section relies on separation (and understanding of separation) of these two processes

$$\text{Pseudo-proper time} = \frac{L_{xy} \cdot M_{J/\psi}}{p_T(J/\psi) \cdot c}$$

- Prompt J/Ψ typically have zero proper time while indirect J/Ψ have positive proper time
  - Use pseudo-proper time to separate indirect/prompt
  - Cut at 0.2 ps gives prompt J/Ψ efficiency of 93% with purity of 92%



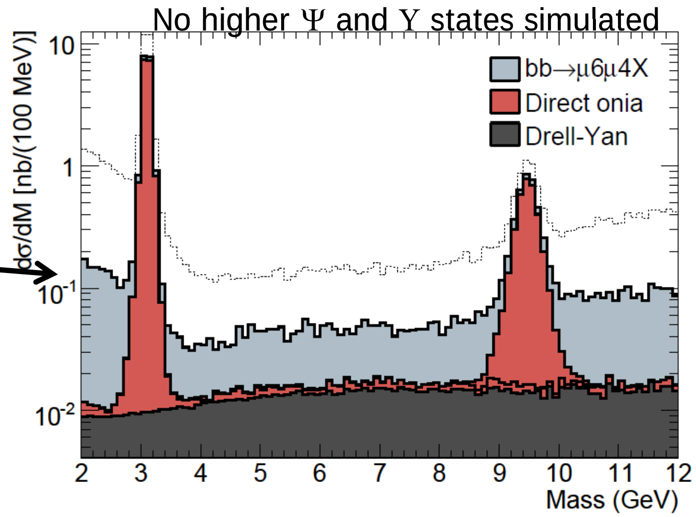




Results with 14 TeV MC

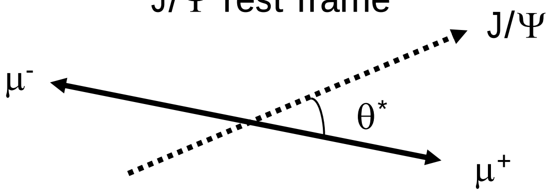
Prompt quarkonia

- Invariant mass distribution of di-muons
  - Seeded by level1 di-muon trigger
  - Muons from primary vertex
  - Pseudo-proper time cut at 0.2 ps



- Different predictions for polarisation depending on production model

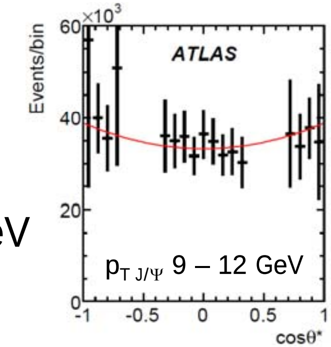
J/Ψ rest frame

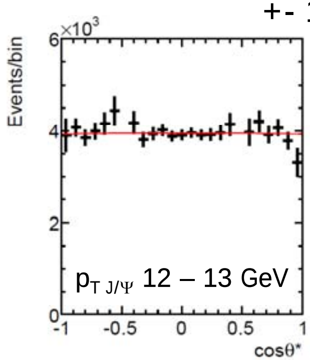


L =10 pb^{-1}	J/Ψ	Υ
# of signal	150k	25k
S/B at peak	60	10

Mass window: +- 300 MeV for J/Ψ
+- 1 GeV for Υ

  - Polarisation can be determined with θ^*
  - $\frac{dN}{d\cos\theta^*} \propto (1+\alpha\cos^2\theta^*)$
  - θ^* acceptance highly depends on trigger
  - Error on σ with 10 pb^{-1} : order of 1%
  - Error on α with 10 pb^{-1} :
    - 0.02 – 0.06 for $p_T(J/\Psi)$ ~ 10 – 20 GeV and above
    - ~ 0.2 for Υ





α (gen) = 0

Results with 14 TeV MC

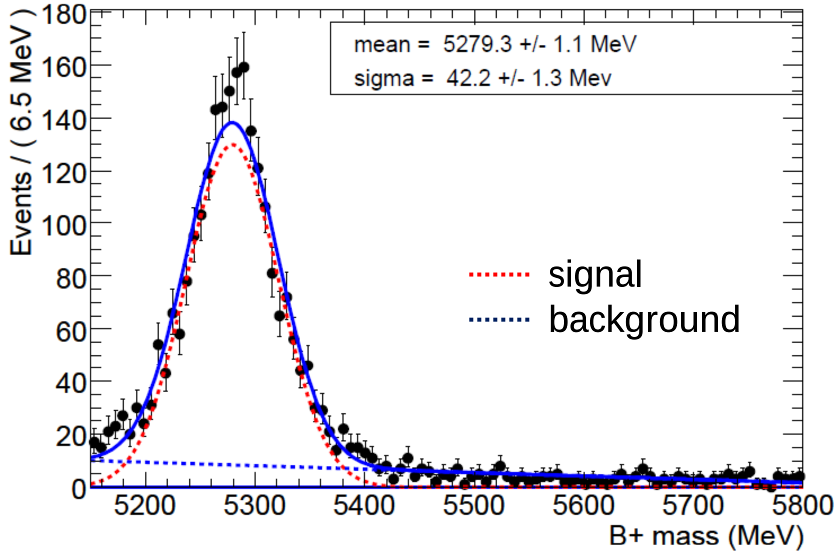
Expected results on B-decays

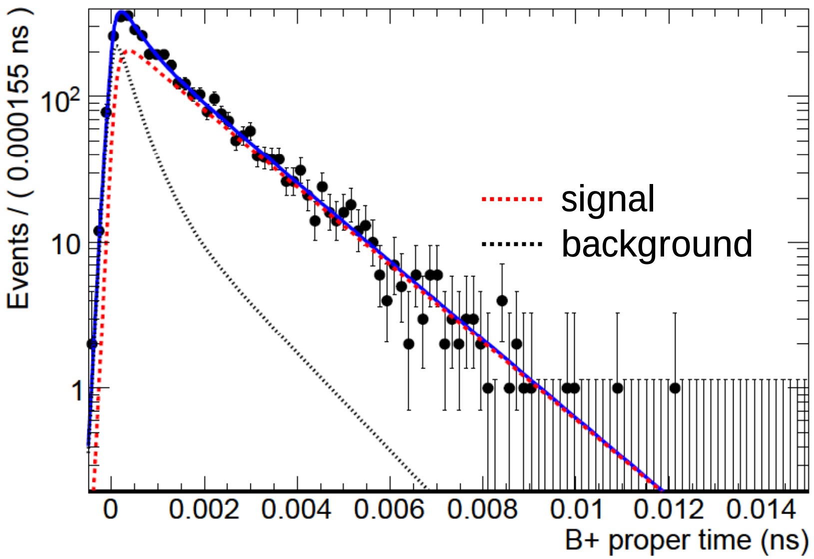
$B^+ \rightarrow J/\Psi K^+$

- Selection
  - J/Ψ reconstruction
    - mass window +- 120 MeV
    - proper decay length > 0.1 mm
  - Cuts on $\mu\mu K^+$ vertex
  - 1600 B^+ candidates with 10 pb^{-1}
- Mass fit

	$M(B^+)$	width of $\sigma(B^+)$
Relative error	0.02 %	3.5 %

- Lifetime measurement
  - relative error on $\sigma(\tau)$ 2.5%
- Cross section measurement
  - Statistical error ~ 10%
  - Systematic error ~ 15-20%
    - L ~ 10%, BR($B^+ \rightarrow J/\Psi K^+$) ~ 10%





Results with 14 TeV MC

$B_d^0 \rightarrow J/\Psi K^{0*}$ and $B_s^0 \rightarrow J/\Psi \phi$

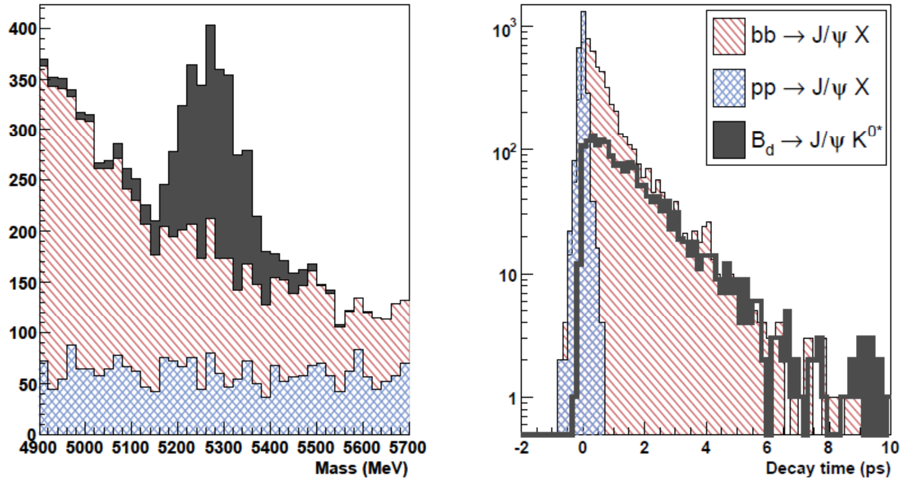
- Selection
  - J/Ψ reconstruction
    - mass window +- 180 MeV
  - m_{inv}(2 tracks) ~ K^{0*} [ϕ]
  - Cuts on vertex and p_T of B_d [B_s]
  - No decay length cut applied

$L = 10\ pb^{-1}$	signal	$pp \rightarrow J/\Psi X$	$bb \rightarrow J/\Psi X$
$B_d^0 \rightarrow J/\Psi K^{0*}$	1024	1419	3970
$B_s^0 \rightarrow J/\Psi \phi$	76	2449	1660

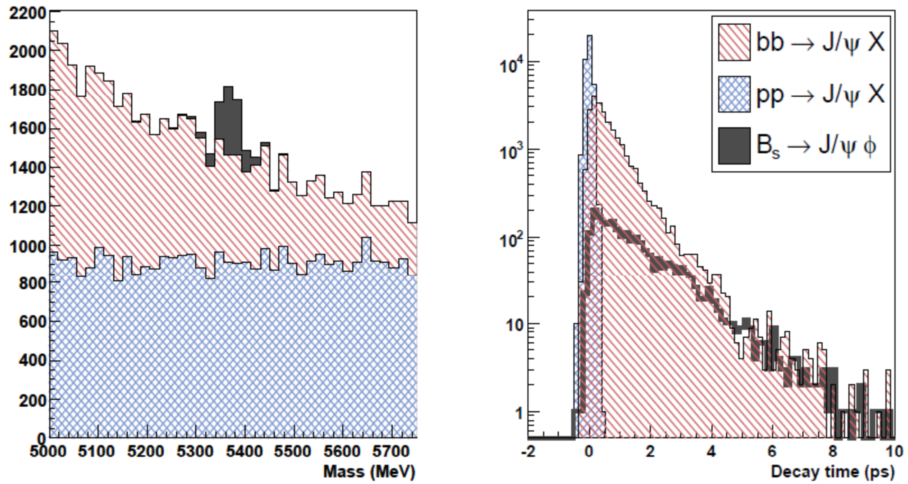
mass window +- 12 $\sigma(m_B)$

- Simultaneous fit to mass and decay time to extract mass and lifetime
  - Mass can be measured with a precision of ~ 10^{-3}
  - Lifetime can be measured with a precision of 10%

$B_d^0 \rightarrow J/\Psi K^{0*}$ with 10 pb^{-1}



$B_s^0 \rightarrow J/\Psi \phi$ with 150 pb^{-1}



Results with 14 TeV MC

Summary

- ATLAS is well prepared for charm and beauty physics
  - J/Ψ, Υ
    - At 7 TeV cross-section ratio of indirect to prompt J/Ψ will be measured with a few pb^{-1} and polarisation with order of 100 pb^{-1}
  - $B^+ \rightarrow J/\Psi\ K^+$, $B_d^0 \rightarrow J/\Psi\ K^{0*}$, $B_s^0 \rightarrow J/\Psi\ \phi$
    - cross-section, mass and lifetime measurements possible with 10 pb^{-1} – 150 pb^{-1}
  - All these samples are important for detector study as well
- ATLAS is now collecting p-p collision data at 7 TeV
  - Stay tuned for the results from ATLAS