

Search for $B_s \rightarrow \mu\mu$ and the Reference
Channel $B^+ \rightarrow J/\psi K^+$ in ATLAS

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Federal Ministry
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and Research

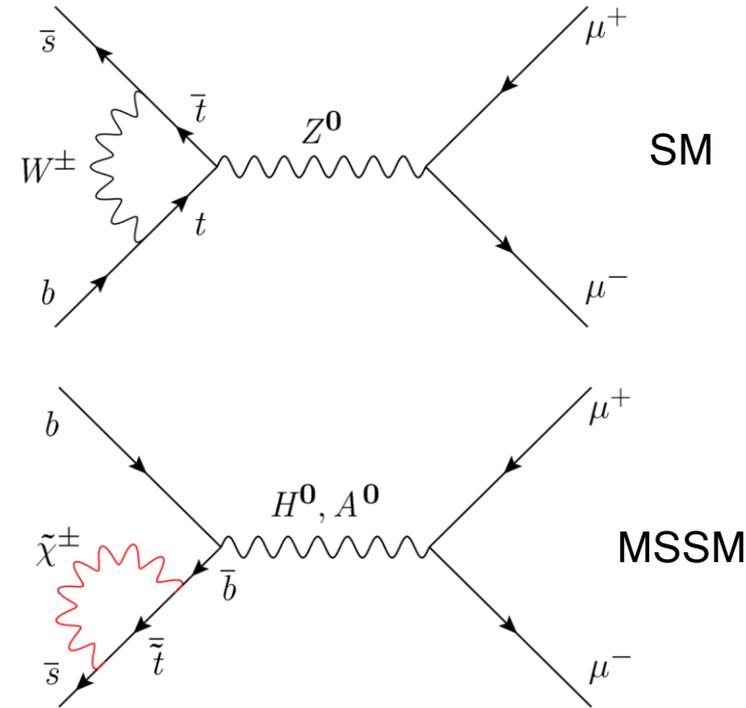
FSP 101

ATLAS



- Overview of rare B -decays
 - Motivation
 - B -physics trigger
 - $B_s \rightarrow \mu^+ \mu^-$ decays
 - $B^+ \rightarrow J/\psi(\mu^+ \mu^-) K^+$ (the reference channel)
- First studies of $B^+ \rightarrow J/\psi(\mu^+ \mu^-) K^+$
 - Datasets & event selection
 - B^\pm invariant mass

- Standard Model
 - $B_s \rightarrow \mu^+ \mu^-$ forbidden at tree level
 - Lowest order contributions are CKM suppressed
 - $\mathcal{B}(B_s \rightarrow \mu^+ \mu^-)$ is small
- Standard Model extensions
 - $\mathcal{B}(B_s \rightarrow \mu^+ \mu^-)$ **enhanced** by several orders of magnitude
- Best upper limits so far by CDF and DØ:



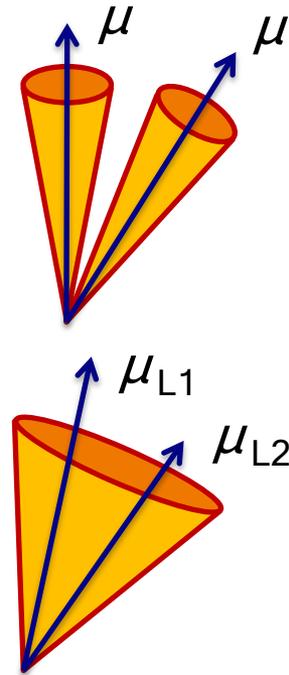
| | $\mathcal{B}(B_s \rightarrow \mu^+ \mu^-)$ |
|----------------|--|
| SM expectation | $(3.6 \pm 0.3) \cdot 10^{-9}$ |
| DØ limit | $5.3 \cdot 10^{-8}$ @ 95% CL |
| CDF limit | $4.3 \cdot 10^{-8}$ @ 95% CL |

[AJ Buras, Prog. Theor. Phys. 122 (2009) 145]

[ICHEP2010]

[ICHEP2010]

- ATLAS trigger system: **3-level** selection
- B-physics triggers **based on muons**
- Level 1 (L1) trigger
 - For $L \geq 10^{33} \text{ cm}^{-2}\text{s}^{-1}$, **di-muon signature** required at L1 ($p_T > 6 - 8 \text{ GeV}$ for both)
 - For $L \leq 10^{32} \text{ cm}^{-2}\text{s}^{-1}$, **single-muon** required at L1
- Level 2 (L2) trigger
 - Software trigger, **partial event information**, fast algorithms
 - Confirms L1 muons
 - Selects $m_{\mu\mu}$ range, e.g. for $B^+ \rightarrow J/\psi (\mu^+\mu^-) K^+$ and $B_s \rightarrow \mu^+\mu^-$

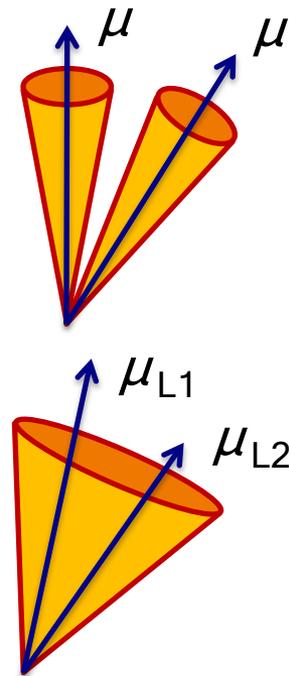


14 TeV MC

- Event Filter (EF)
 - Software trigger, **full event information**, offline-like algorithms
 - Further rejection of events
- Trigger efficiencies for $B_s \rightarrow \mu^+\mu^-$:

| L1 * L2 efficiency | EF w.r.t. L2 | Overall efficiency |
|--------------------|--------------|--------------------|
| 0.52 | 0.88 | 0.46 |

[CERN-OPEN-2008-020]



$B_s \rightarrow \mu^+ \mu^-$ Decays

- Branching ratio calculated relative to **reference channel**

$B^+ \rightarrow J/\psi(\mu^+ \mu^-) K^+$:

$$\mathcal{B}(B_s \rightarrow \mu^+ \mu^-) = \frac{N_{B_s}}{N_{B^+}} \frac{\alpha_{B^+}}{\alpha_{B_s}} \frac{\epsilon_{B^+}}{\epsilon_{B_s}} \frac{1}{\epsilon_N} \frac{f_u}{f_s} \mathcal{B}(B^+ \rightarrow J/\psi K^+) \cdot \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-)$$

Acceptance ratio

Trigger, reconstruction and selection efficiencies

Ratio of $b \rightarrow B^+$ to $b \rightarrow B_s$

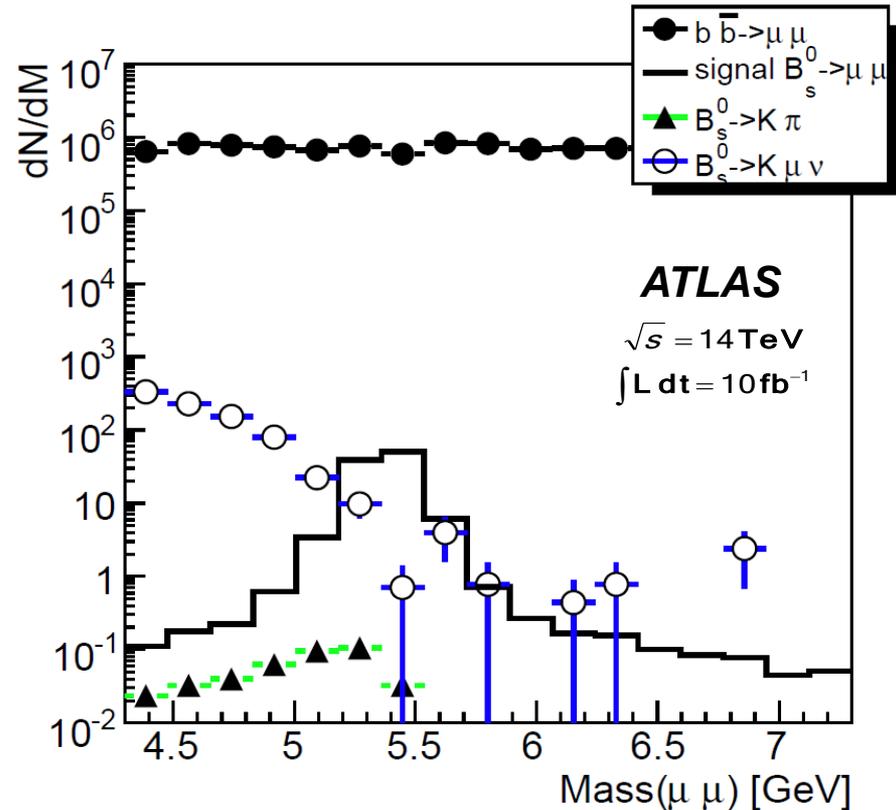
Final signal selection efficiency

- Cancels out systematic uncertainties

$B_s \rightarrow \mu^+ \mu^-$ Decays

Selection of the B_s

- Pre-selection cuts:
 - $\mu^+ \mu^-$ pairs:
 - $p_{T,\mu 1} \geq 6.0$ GeV,
 - $p_{T,\mu 2} \geq 4.0$ GeV,
 - $|\eta| < 2.5$
 - Vertex fit $\chi^2/\text{NDF} < 10$
 - Transverse decay length $L_{xy} < 20$ mm
 - $4 \text{ GeV} < m_{\mu\mu} < 7.3 \text{ GeV}$



[CERN-OPEN-2008-020]

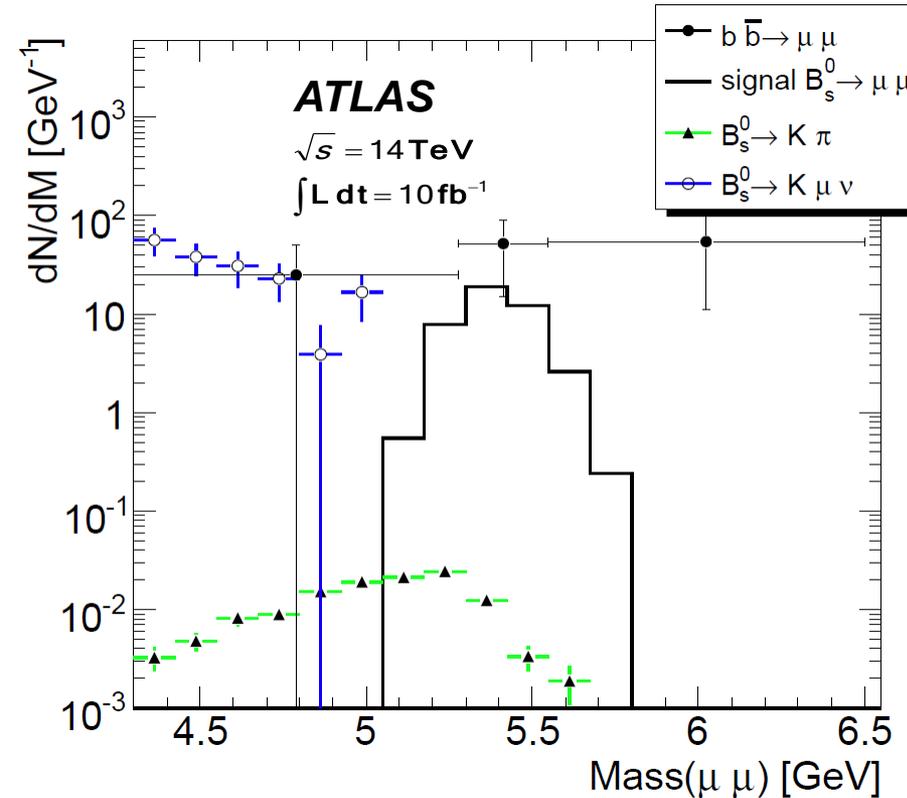
$B_s \rightarrow \mu^+ \mu^-$ Decays

Selection of the B_s

- Selection cuts:
 - $I_{\mu\mu} > 0.9$
 - $L_{xy} > 0.5$ mm
 - $\alpha < 0.017$ rad
 - Mass in $[-\sigma, 2\sigma]$, $\sigma = 90$ MeV

Selection efficiencies:

| | $B_s \rightarrow \mu^+ \mu^-$ | $b\bar{b} \rightarrow \mu^+ \mu^- X$ (background) |
|------------------|-------------------------------|---|
| Total efficiency | 0.04 | $(2.0 \pm 1.4) \cdot 10^{-6}$ |
| Events yield | 5.7 | 14^{+13}_{-10} |



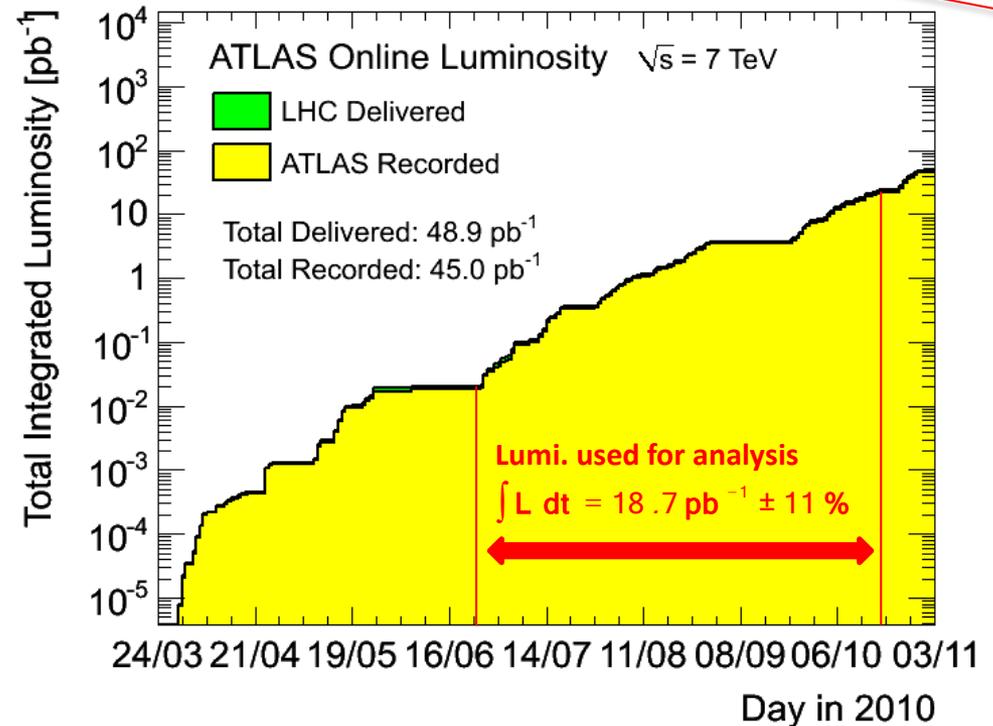
[CERN-OPEN-2008-020]

First Studies of the Reference Channel $B^+ \rightarrow J/\psi K^+$

with ATLAS Data @ 7 TeV

Dataset:

- pp collisions data
@ $\sqrt{s} = 7$ TeV
- Jun 24 – Oct 18, 2010

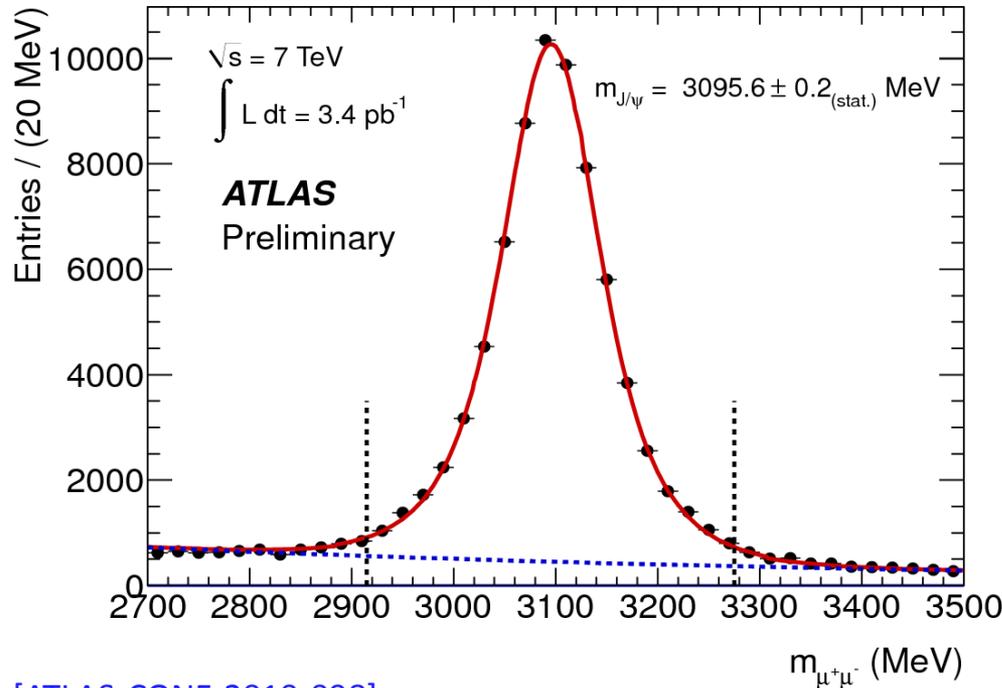


Event selection summary:

1. Good runs are selected based on data quality flags
2. Events are selected that passed the L1 muon trigger (open window)

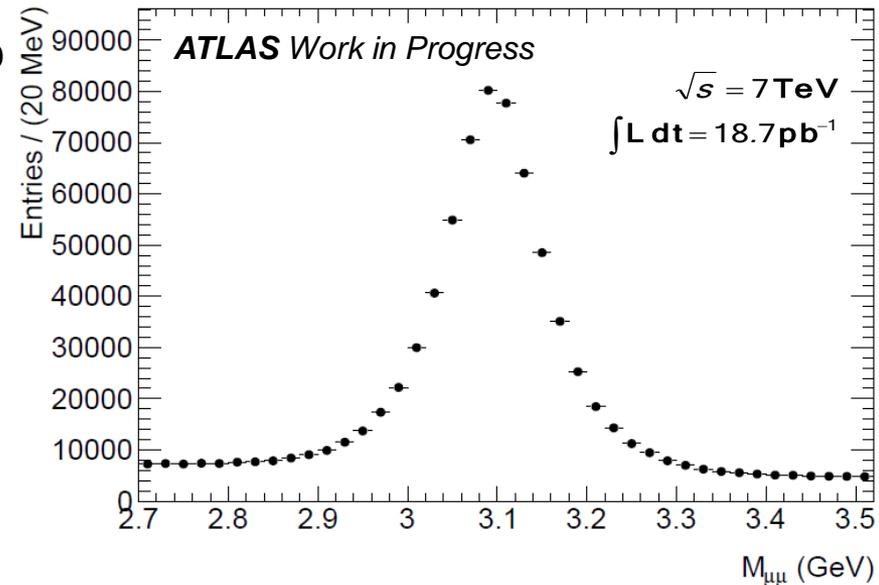
J/ψ Candidates used for B Selection

7 TeV Data

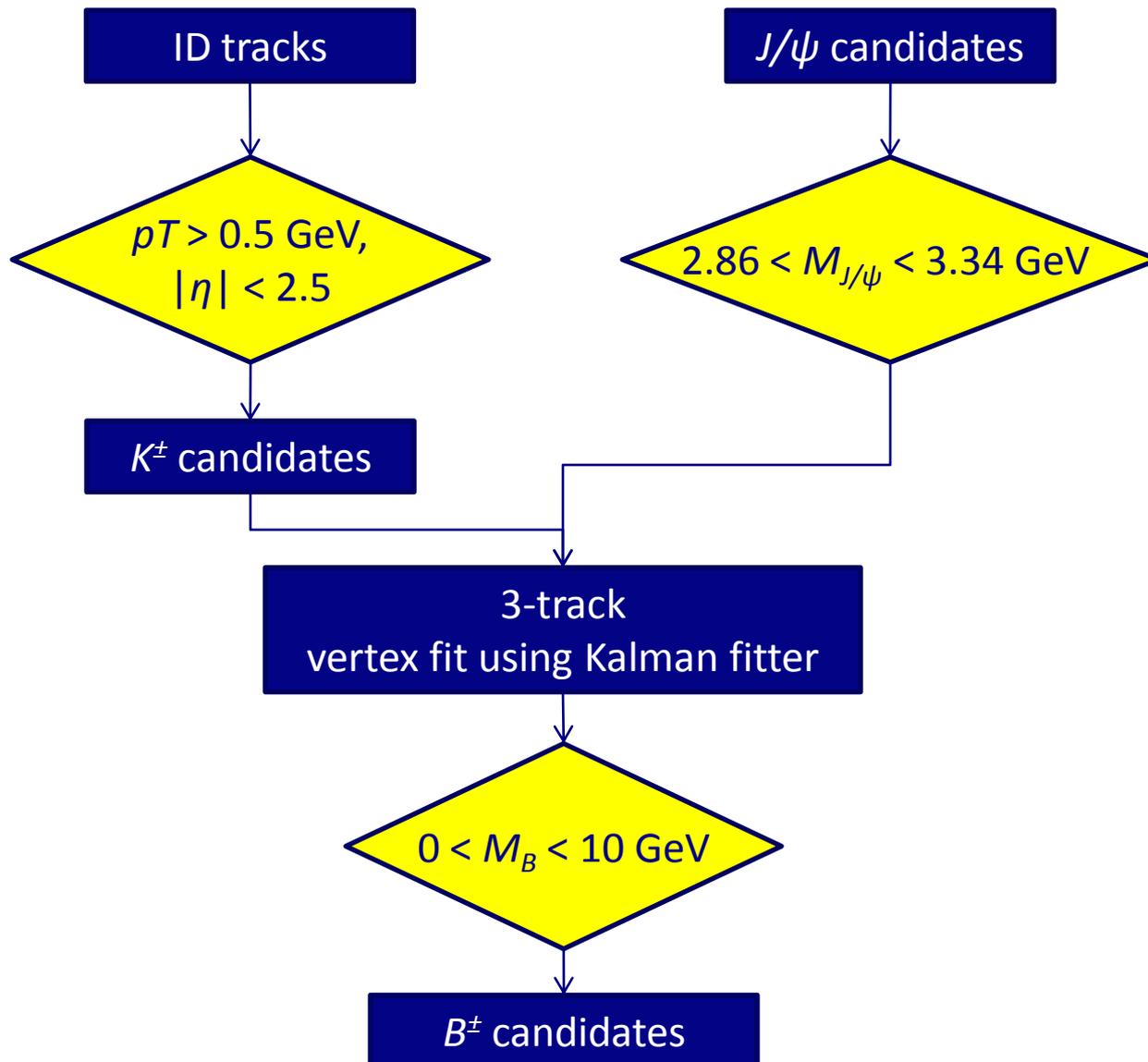


[ATLAS-CONF-2010-098]

- Pre-selection cuts:
 - All combinations of $\mu^+\mu^-$ tracks
 - Vertex fit $\chi^2/\text{NDF} < 200$



Pre-selection of B^\pm Candidates



Selection of B^\pm Candidates

- J/ψ selection

- $p_{T,\mu 1} > 4.0$ GeV,
 $p_{T,\mu 2} > 2.5$ GeV
- Vertex $\chi^2/NDF < 10$
- $2.9 < M_{J/\psi} < 3.2$ GeV

- K^\pm selection

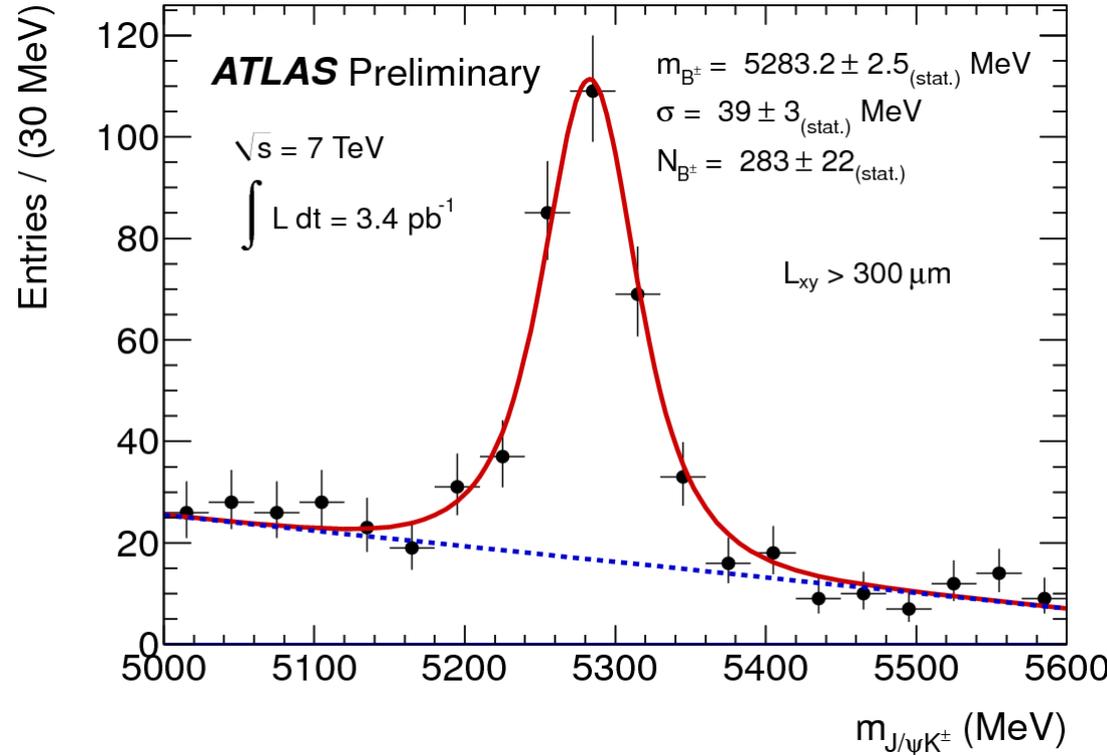
- $p_T > 2.5$ GeV

- Cuts on all three tracks

- Pixel hits > 1
- SCT hits > 6

- B^\pm selection

- $p_T > 10.0$ GeV
- Vertex $\chi^2/NDF < 6$
- $4.0 < M_B < 7.0$ GeV



[ATLAS-CONF-2010-098]

- ATLAS will measure $\mathcal{B}(B_s \rightarrow \mu^+ \mu^-)$ using $B^+ \rightarrow J/\psi K^+$ as the reference channel
- ATLAS trigger system will allow collection of data for rare decay searches also at $L = 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Monte Carlo studies show **good background rejection**: 5.7 signal events over 14 background events (in 10 fb^{-1} of data @ $\sqrt{s} = 14 \text{ TeV}$)
- Studies of the reference channel are on going
[\[ATLAS-CONF-2010-098 \(Nov. 16, 2010\)\]](#)
- Looking forward for additional data in 2011!



Extra Material

$$B_s \rightarrow \mu^+ \mu^-$$

Background Channels

- Combinatorics from $b\bar{b}$ pairs producing 2 muons in the final state
- 2- or 3-body decays producing the final state particles K^\pm, π^\pm, μ^\pm as in $B_s \rightarrow K^- \mu^+ \nu$
 - Expected contribution is lower than combinatorics type of background

| Channel | Branching fraction |
|-----------------------------------|---------------------------------|
| $B^0 \rightarrow K^+ \pi^-$ | $(1.82 \pm 0.08) \cdot 10^{-5}$ |
| $B^0 \rightarrow \pi^+ \pi^-$ | $(4.6 \pm 0.4) \cdot 10^{-6}$ |
| $B^0 \rightarrow K^+ K^-$ | $< 3.7 \cdot 10^{-7}$ @ 90% CL |
| $B_s \rightarrow \pi^+ \pi^-$ | $< 1.7 \cdot 10^{-4}$ @ 90% CL |
| $B_s \rightarrow \pi^+ K^-$ | $< 2.1 \cdot 10^{-4}$ @ 90% CL |
| $B_s \rightarrow K^+ K^-$ | $< 5.9 \cdot 10^{-5}$ @ 90% CL |
| $B_s \rightarrow K^- \mu^+ \nu$ | $\sim 1.36 \cdot 10^{-4}$ |
| $B^0 \rightarrow \pi^- \mu^+ \nu$ | $(1.36 \pm 0.15) \cdot 10^{-4}$ |

Pre-selection of J/ψ Candidates

