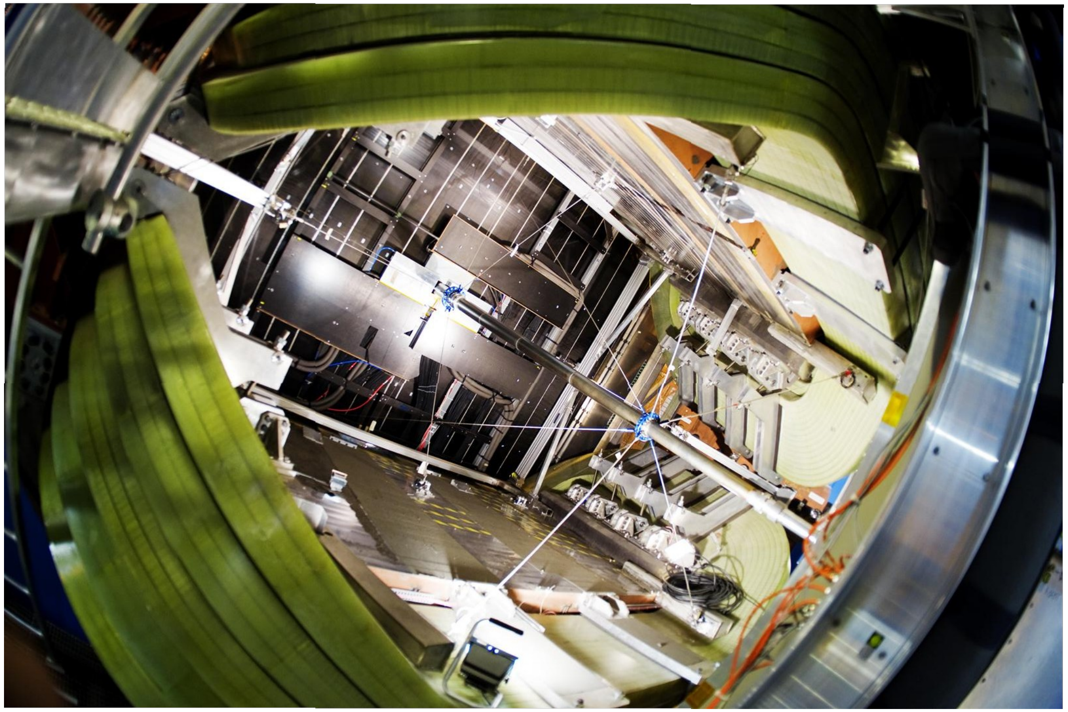
Towards the measurement of the J/ψ production cross section at LHCb



Julien Cogan on behalf of the LHCb collaboration

INTRODUCTION

Introduction

J/ψ produced in abundance at LHC

- expect :
  - → $\sigma(pp \to X + J/\psi) \approx O(0.1)\ mb^{-1}$
- typical mode studied in LHCb :
  - → $\sigma(pp \to X + B_s,\ B_s \to J/\psi\ \Phi) \approx O(0.1)\ \mu b^{-1}$

3 main sources of J/ψ :

- direct production at pp collisions
- feed down from heavier charmonium states (ψ(2S), $\chi_{c0,1,2}$)

  } prompt J/ψ

- J/ψ from b-hadron decay chains

  } J/ψ from b

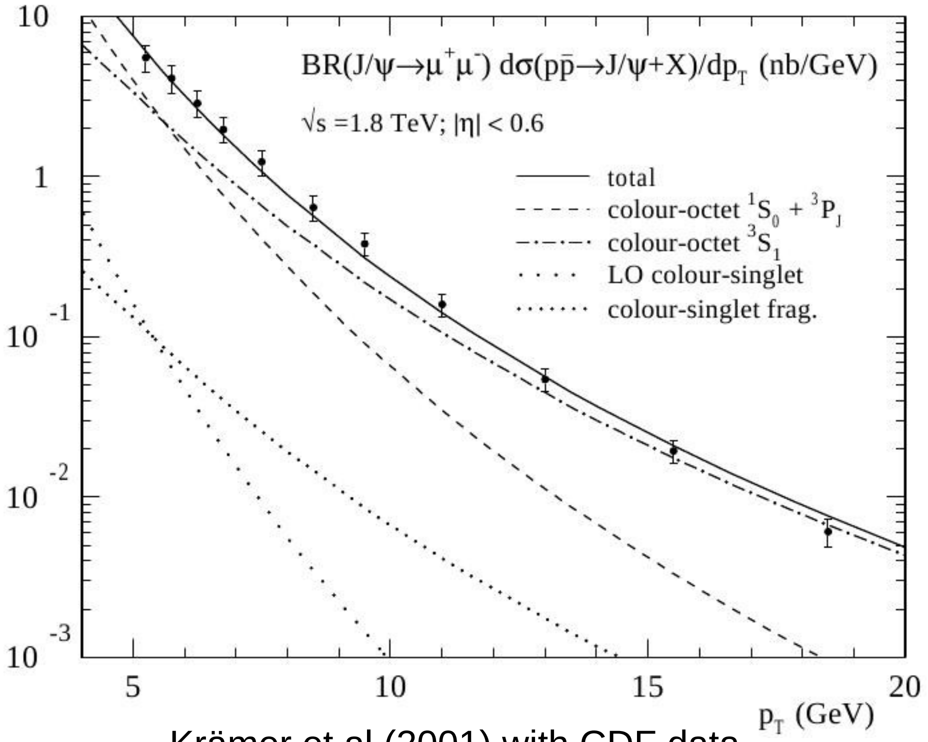
We want to measure

- the cross section as a function of
  - → transverse momentum (p_T)
  - → rapidity (y)
- both for prompt J/ψ and J/ψ from b

Motivations (1/2)

J/ψ production mechanism is not well understood

- colour-singlet model failed to reproduce CDF data (1997)
- colour-octet model introduced to explain the production rate but failed to reproduce the polarization



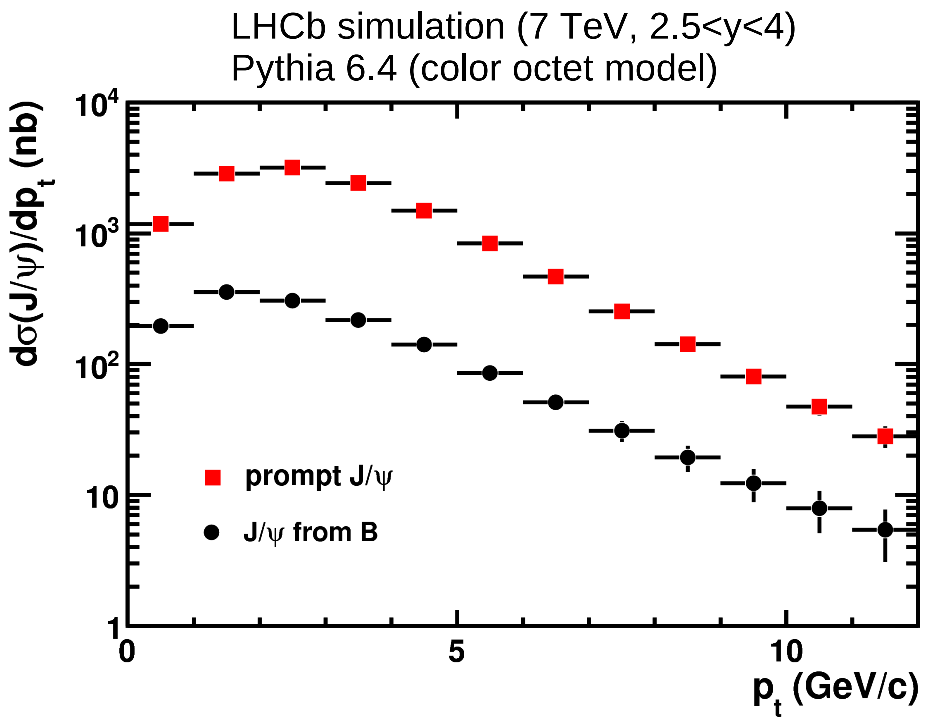
Krämer et al (2001) with CDF data

Measurement of this observable at higher energy will help in understanding the charmonium production mechanism.

Motivations (2/2)

Important measurement for later LHCb analysis steps

- open the road to B-physics with J/ψ or di-muon modes
- tune b-hadron spectra in simulation
- input for absolute branching fraction measurements



This is what we want to measure and re-inject in the simulation

Goal and reach

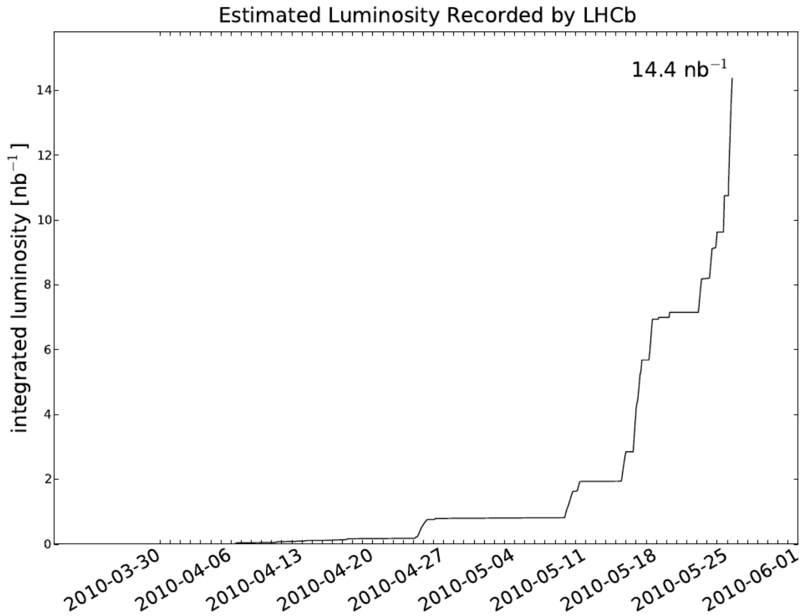
We aim at measuring the production cross section :

- using $J/\psi \rightarrow \mu^+\mu^-$ mode
- independently for prompt J/ψ and J/ψ from b
- in bins of :
  - → rapidity : 2 < y < 4.5 (5 bins)
  - → transverse momentum : 0 < pT < 12 GeV/c (12 bins)
- with 0(10%) accuracy in each bins
- based on ~10^6 reconstructed J/ψ (~ 10-20 pb^{-1})

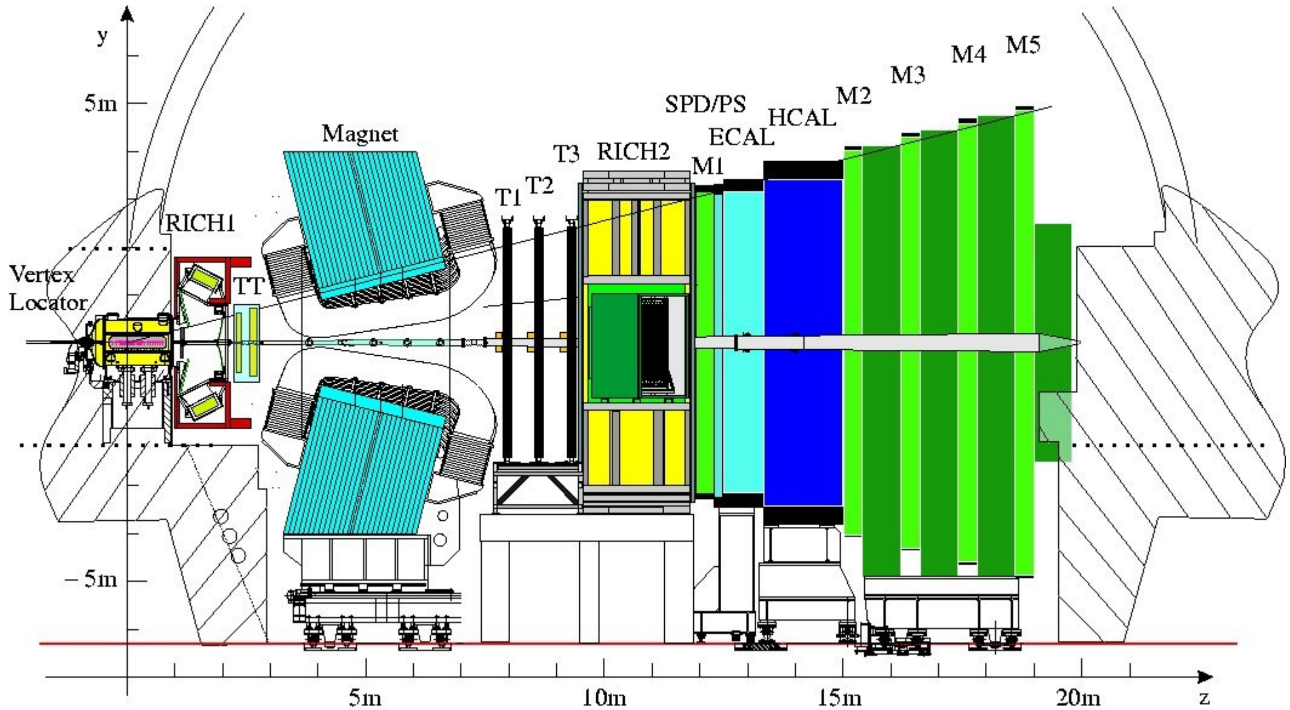
Today :

- where we stand

  using all available data ≈ 14 nb^{-1}
- main steps towards the measurement
  - → acceptances and efficiencies
  - → prompt J/ψ and J/ψ from b
  - → luminosity



The LHCb unique angular acceptance

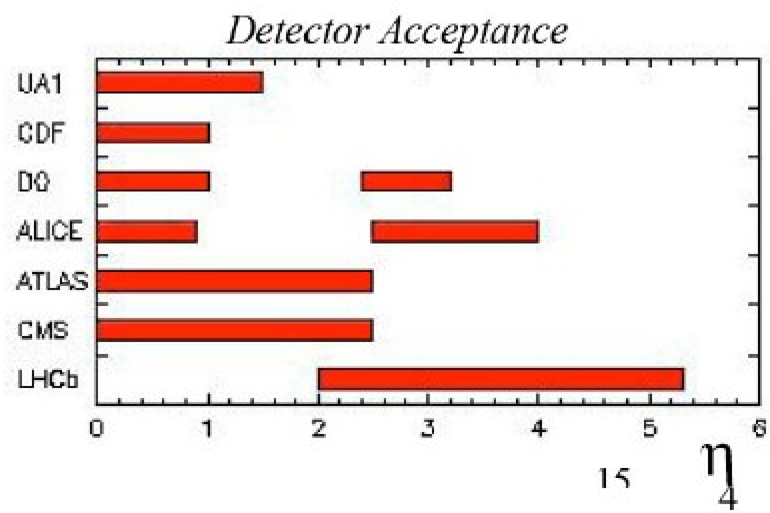


Forward spectrometer

– angular acceptance :

  $15 < \theta < 300$ mrad

– Special coverage of LHCb experiment, where theoretical predictions are less accurate.



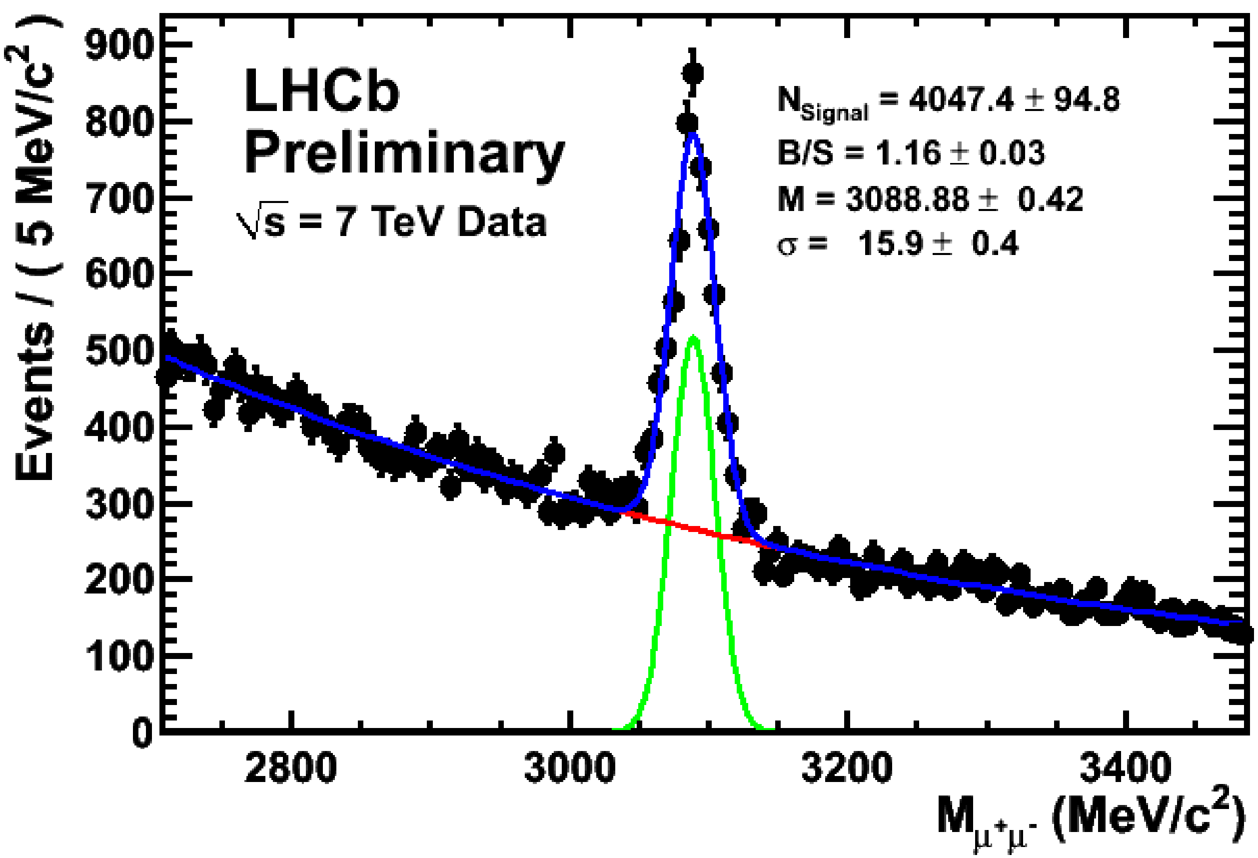
See talks from A. Golutvin (Status of and news from LHCb)

TOWARD THE MEASUREMENT

Selected J/ψ

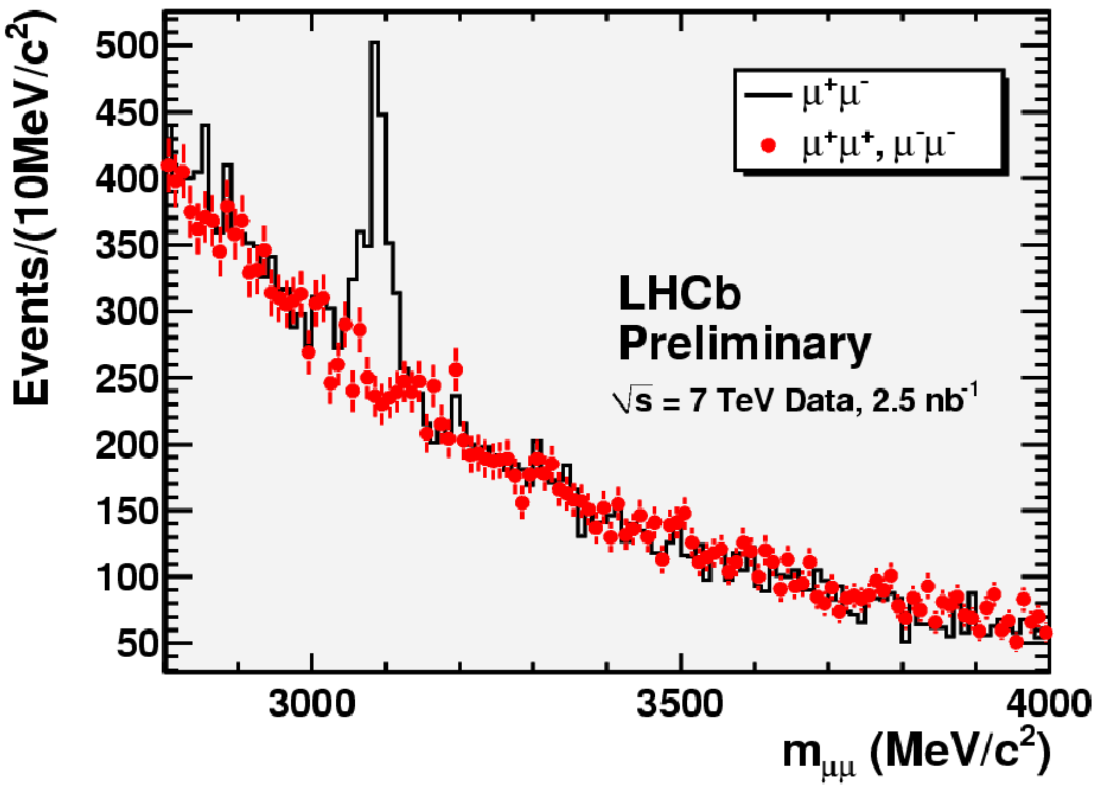
2 muons :

- fully reconstructed tracks (VELO + Tracker)
- with $p_T > 700$ MeV/c
- identified as muon by the muon system (hits in muon stations inside fields of interest)
- making a good vertex



Background

On going promising study : combinatoric contribution to background estimated from same sign muons



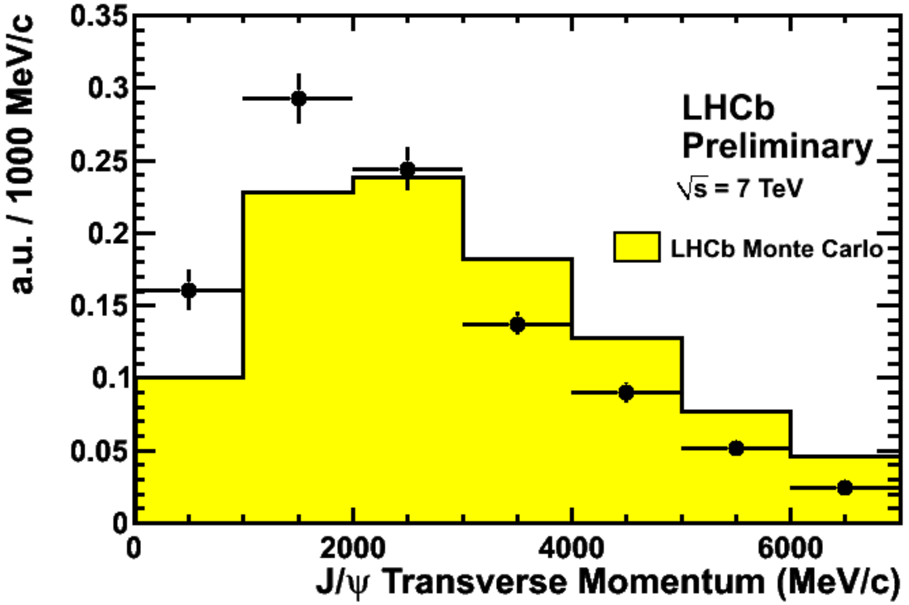
Background shape very well reproduced

J/ψ raw spectra

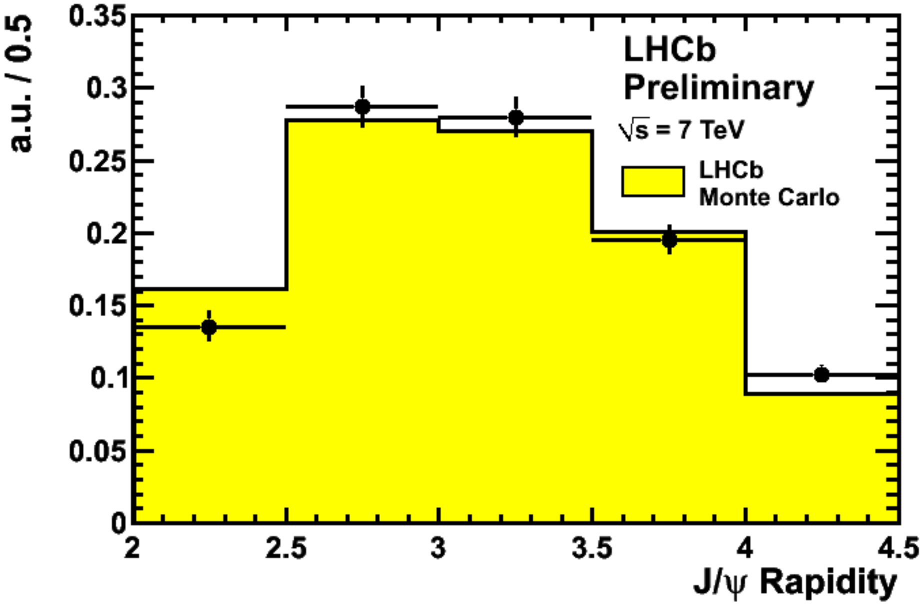
In each bin, yield extracted from mass distribution

No correction

p_T spectrum



rapidity spectrum

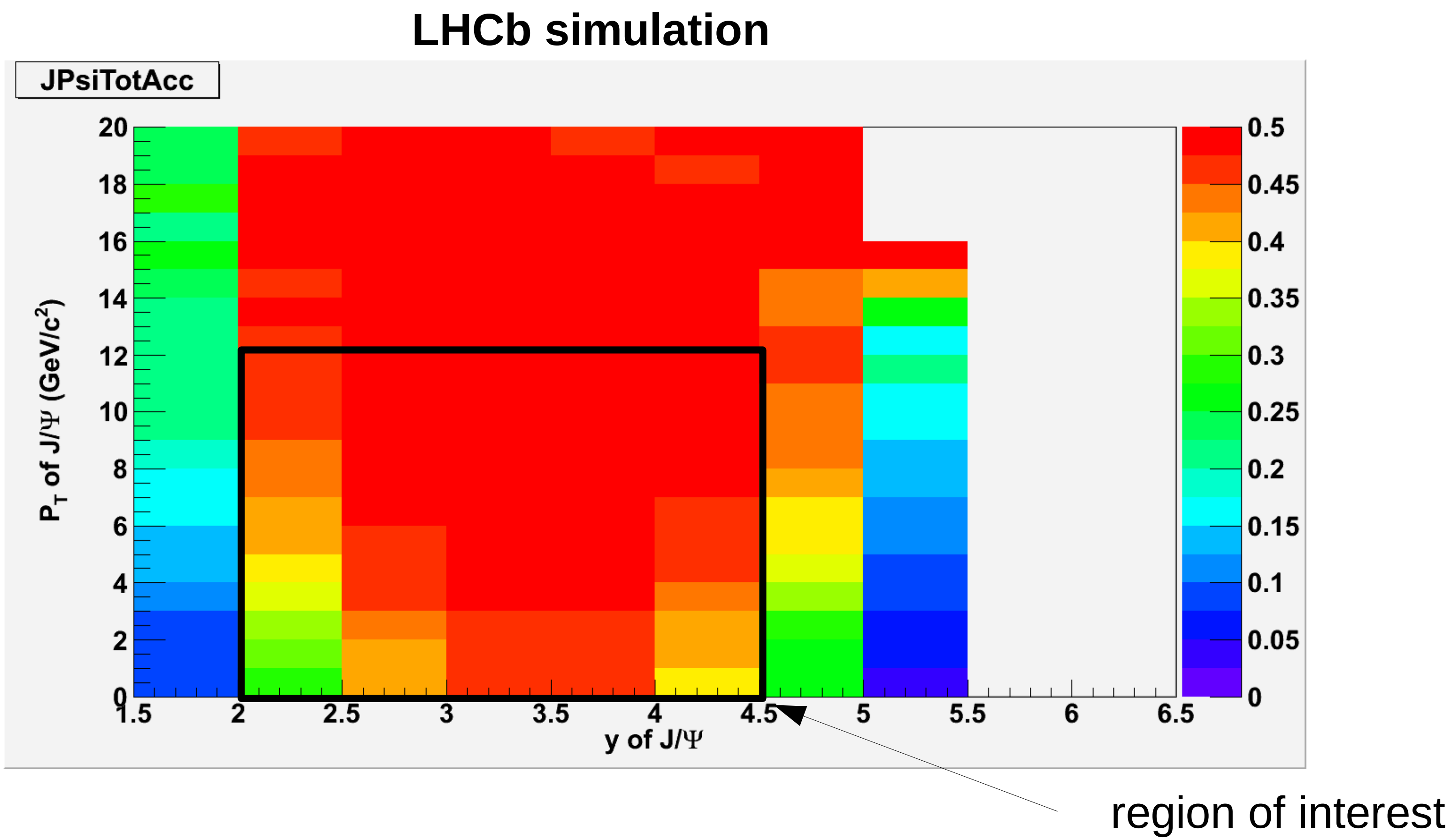


To turn these distributions into cross section measurement, still need :

- efficiencies determination
- prompt and from b separation
- luminosity

Detector acceptance

Extracted from simulation



Acceptance in region of interest : ~ 85 %

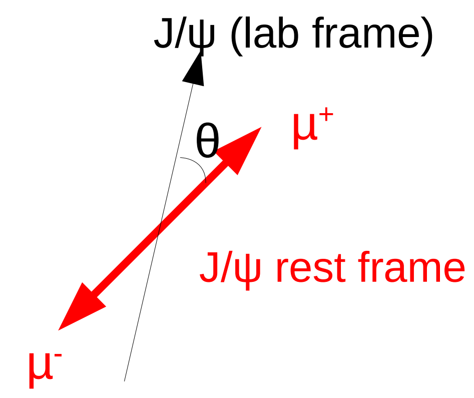
Warning strong effect of J/ψ polarization !

Polarization effect

J/ψ polarization is unknown

Angular distribution strongly dependant on polarization

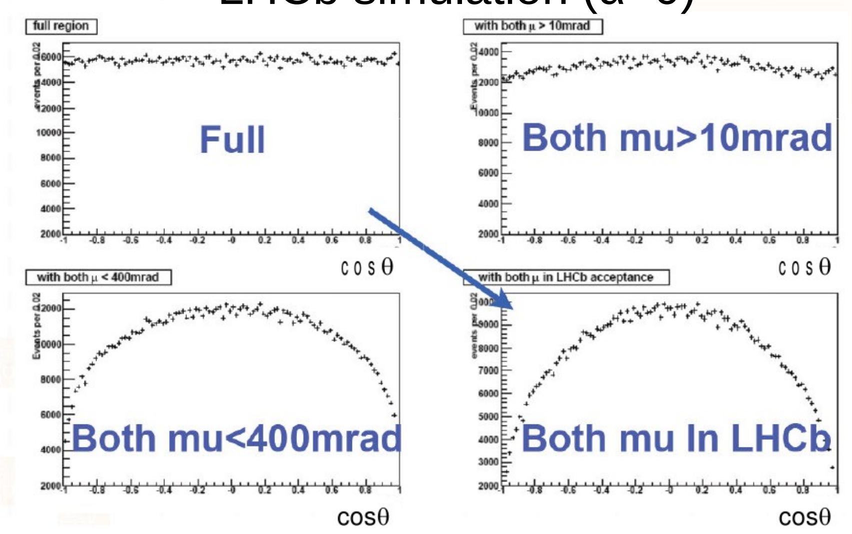
$$\frac{dN}{d\cos\theta}=\frac{1+\alpha\cos^2\theta}{2+2\times\alpha/3}, \quad \alpha=\begin{Bmatrix} +1: \textit{fully transverse} \\ -1: \textit{fully longitudinal} \\ 0: \textit{no polarization} \end{Bmatrix}$$



LHCb angular acceptance is not trivial

– detector creates artificial polarization

LHCb simulation (α=0)



Polarization modifies the acceptance up to 20% in some (p_T,y) bins

– 1st step : measure the cross section for 3 values of α (to be agreed among LHC experiments)

– 2nd step : measure the polarization

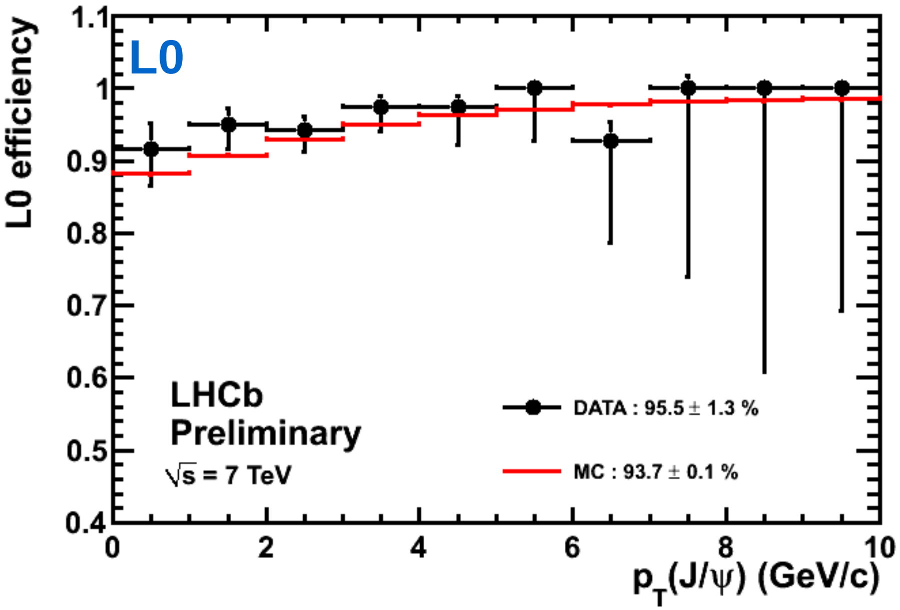
Trigger efficiency

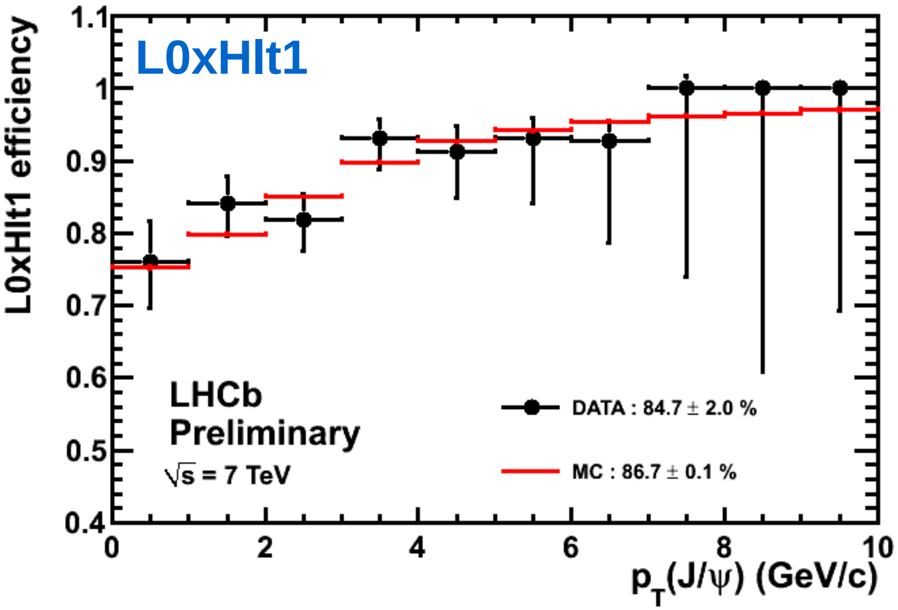
Main J/ψ trigger :

- → L0: μ candidate from aligned hits in the muon stations + p_T cut (320 MeV/c)
- → Hlt1 : confirm the L0 candidate adding tracking information + p_T cut (1300 MeV/c)

Efficiency measured using independent trigger

- → use the large fraction of minimum bias events that are still recorded





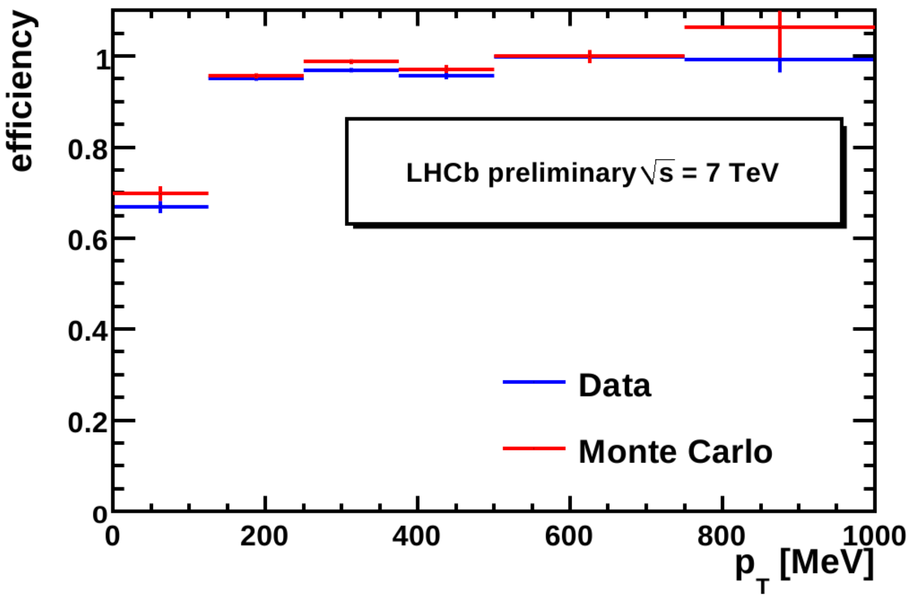
Good agreement between data and simulation, overall efficiency ~ 85 %

Additional di-muon lines available with lower pt cut (add ~4% efficiency)

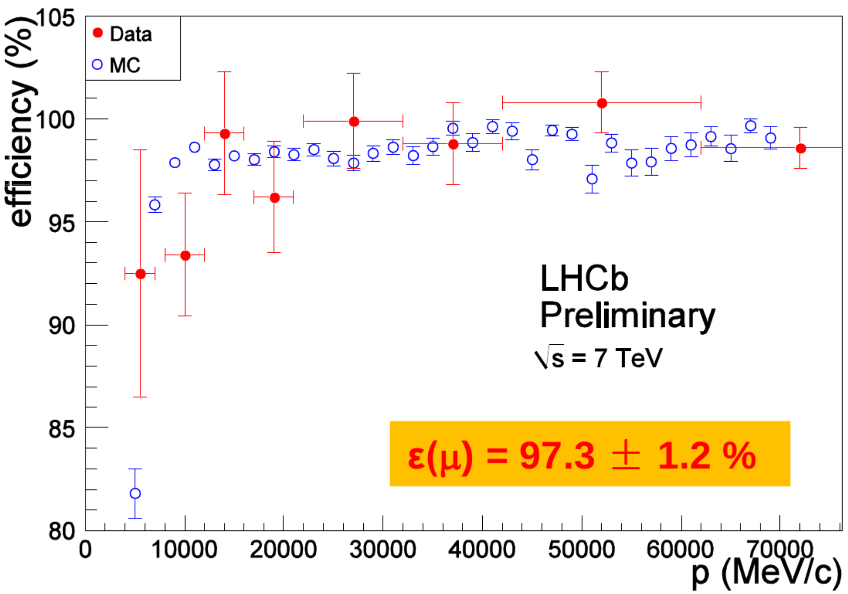
Reconstruction efficiency

Data driven methods :

– tracking efficiency using K_s sample



– muon ID using J/ψ



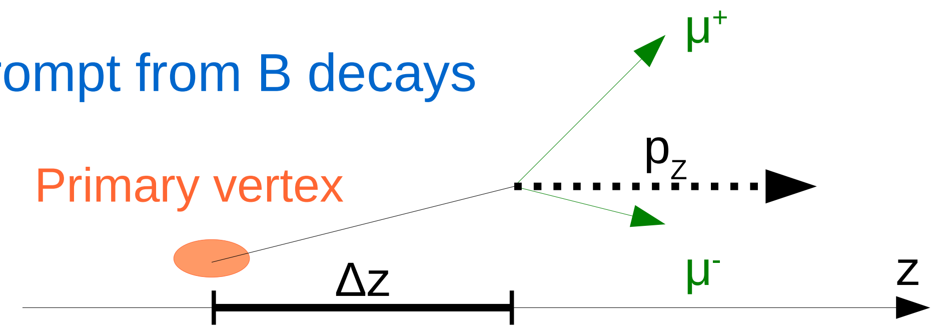
Good data/simulation agreement

See talks from F. Maciuc (Tracking and alignment in LHCb) and P. Xing (LHCb particle ID)

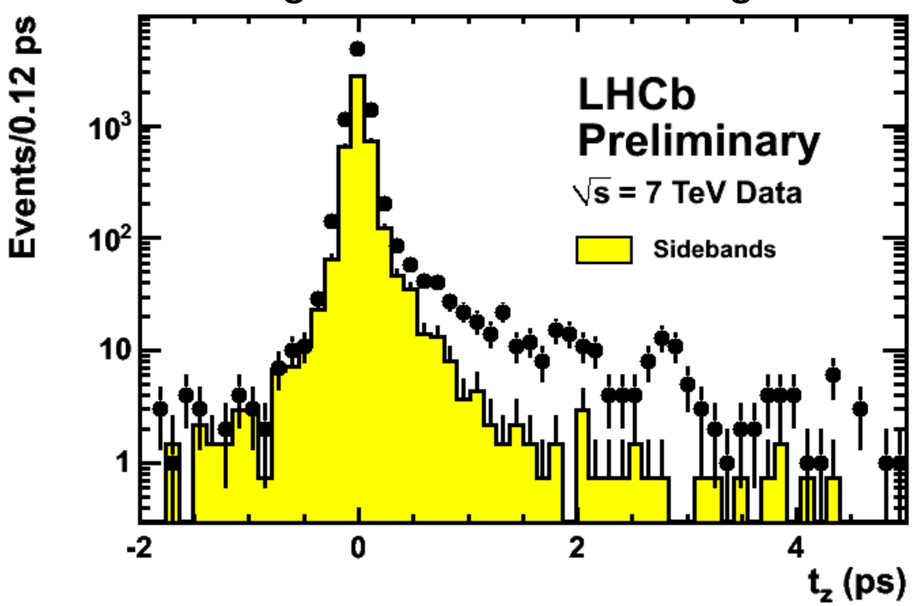
Prompt J/ψ -VS- J/ψ from b (1/2)

Use pseudo-proper time to distinguish prompt from B decays

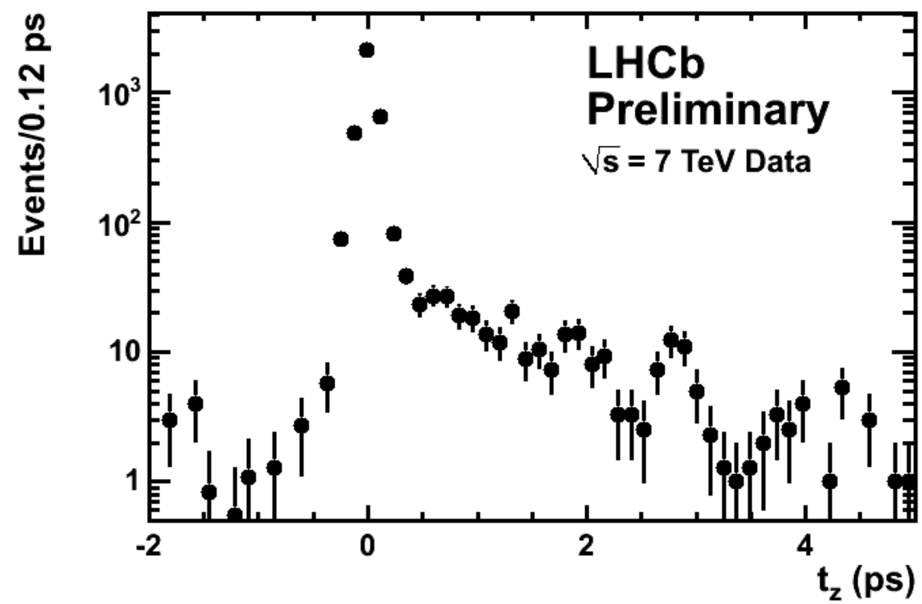
$$t_z = \Delta z \frac{M_{J/\psi}}{p_{zJ/\psi}}$$



Signal and sideband regions



Sideband subtracted distribution



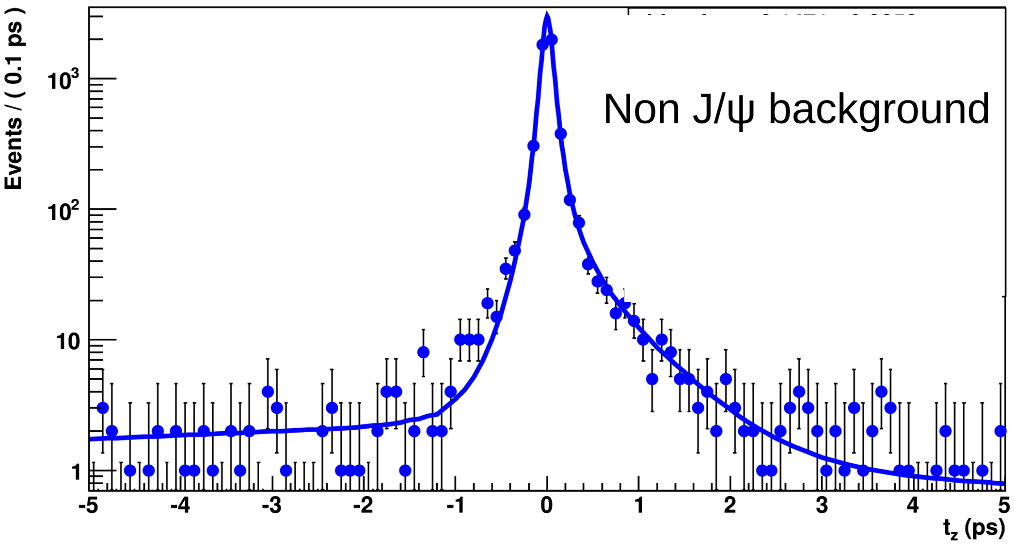
clear signal from B hadron decays

Prompt J/ψ -VS- J/ψ from b (2/2)

Non J/ψ background :

- asymmetric tails expected
- fake J/ψ using μ from B decays

Simulation : minimum bias sample

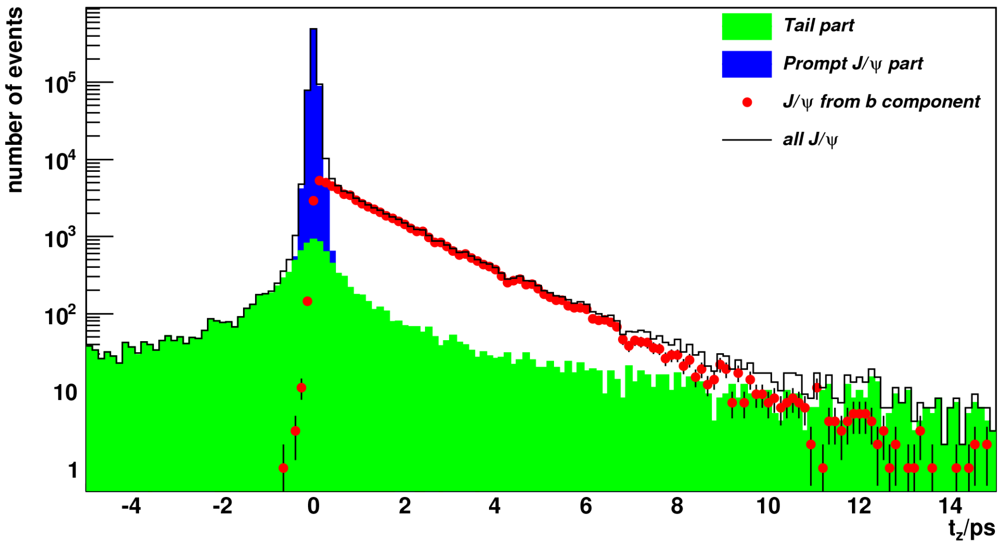


Signal :

3 components

- peak from prompt J/ψ
- exponential from J/ψ from b
- tails due to wrong choice of primary vertex

Simulation : inclusive J/ψ sample



Will use a combined fit to mass and pseudo-proper time in each (p_T, y) bin

Luminosity determination

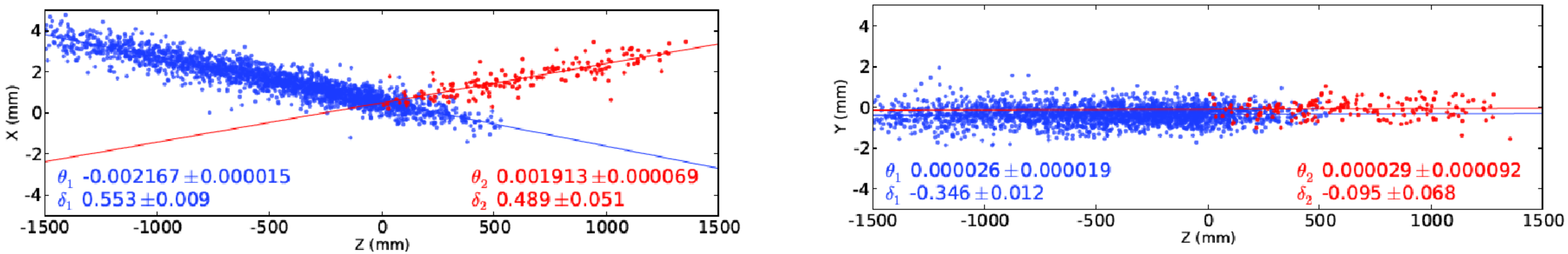
Luminosity will be estimated from beams properties :

$$L = f \sum_{i}^{N} \frac{n_{1i} n_{2i}}{4\pi \sigma_{xi} \sigma_{yi}}$$

n_{1i}, n_{2i} : nb of proton in bunches of collision I
σ_x, σ_y : transverse bunch size
f : frequency of collision
N : number of bunches

Beam properties extracted from beam-gas interactions:

LHCb preliminary 2009 data, $\sqrt{s} = 0.9\,TeV$



Determined with ~15% accuracy in 2009 (dominated by the uncertainty on the number of proton per bunch)

Expect 5-10 % precision by end of 2010

See talks from O. Schneider (Physics with first LHCb data) and W. Bonnivento (Minimum bias physics at LHCb)

CONCLUSION

Conclusion

Analysis of the first 14 nb^{-1} shows very good prospect for the J/ψ production cross section measurement

Aim at a measurement in 5 bins of y (2<y<4.5) and 12 bins of p_T (0.<p_T<12 GeV/c) with 10% accuracy in each bins (need ~10-20 pb^{-1})

Foresee early measurement for ICHEP (based on 100 nb^{-1} ?) :

- p_T bins only (integrated over y) :
  - → $d\sigma/dp_T$(all J/ψ)
- prompt J/ψ and J/ψ from B separation for the whole analysis region
  - → σ(prompt J/ψ)
  - → σ(J/ψ from B)