
# Charmonia and beauty production measurements with J/ψ events at LHCb

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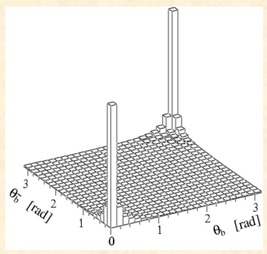
***Abstract*** **-We report on the possibilities of measuring charmonia and beauty production with the LHCb experiment. Using reconstructed J/ψ decays to $\mu^+\mu^-$, both the prompt J/ψ and the *b* →J/ψ production cross-sections in p-p collisions at LHC energies will be determined in the J/ψ eta range 2-5. Due to the very large statistics, this analysis will be possible very early after the LHC start. Other charmonia related measurements will also be discussed, such as that of the J/ψ polarization at production or of the production of some of the new X, Y and Z states.**

## The LHCb experiment

LHCb is an experiment at the LHC (Large Hadron Collider) dedicated to precise measurements of CP violating and rare decays of *b*-hadrons. LHCb will operate at a luminosity of $2\cdot10^{32}$ $cm^{-2}s^{-1}$ exploiting the high number of $b\bar{b}$ pairs produced by the LHC proton-proton collisions: the expected number of $b\bar{b}$ pairs produced at the LHCb interaction point is $N_{b\bar{b}}\sim10^{12}$/year.




The $b\bar{b}$ quarks produced at LHC are strongly correlated and both with small polar angle. As a consequence the outgoing *b*-hadrons will be forward(backward) produced: they fly and decay within a cone of small angular aperture.

## J/ψ production at LHCb

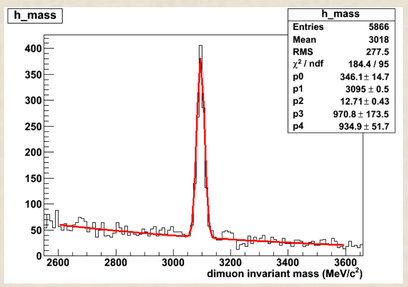
At LHCb large J/ψ→$\mu^+\mu^-$ samples, with a unique coverage in η and $p_t$ will be collected by muon trigger.

These samples will allow to study both the J/ψ prompt and non-prompt production (pp→*b*-hadron( J/ψ+X )+X').

The charmonium production mechanisms are not yet well understood. Although the prompt cross-sections measured at the Tevatron are predicted by the so-called Non-Relativistic QCD theories, the same fail dramatically in the prediction of the polarization. Other models have been proposed but further measurements and studies are needed to clarify the situation.

## J/ψ Selection

- Pair of good quality tracks, identified as muons
  - the muon likelihood is obtained combining the likelihood informations from the various PID subdetectors: $DLL_{\mu\pi}>-3$
- $P_t^{\mu+}\cdot P_t^{\mu-} > 10^6\,(MeV/c)^2$ to reduce the combinatorial background
- Fitted common vertex $\chi^2<10$, for the quality of the vertex
- Mass window cut around the J/ψ



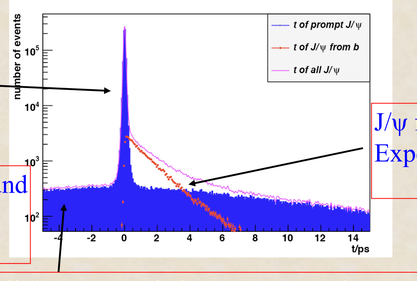

**_ 2.2 M mb events stripped by L0**
**_ σ~12 MeV**
**_ S/B~3.3**

Several sources of J/ψ
- pp→[ψ(2S), $\chi_{c0,1,2}$ → J/ψ +...] +X
- pp→J/ψ +X
- pp→b-hadron + X→ J/ψ + X' (~ 8%)

To separate prompt J/ψ from those from *b* decays the variable

$$t = \frac{dz}{p_z^{J/\psi}} m_{J/\psi}$$

is used, *dz* being the projection on the beam axis of the flight distance. Such variable is a good approximation of the *b*-hadron proper time

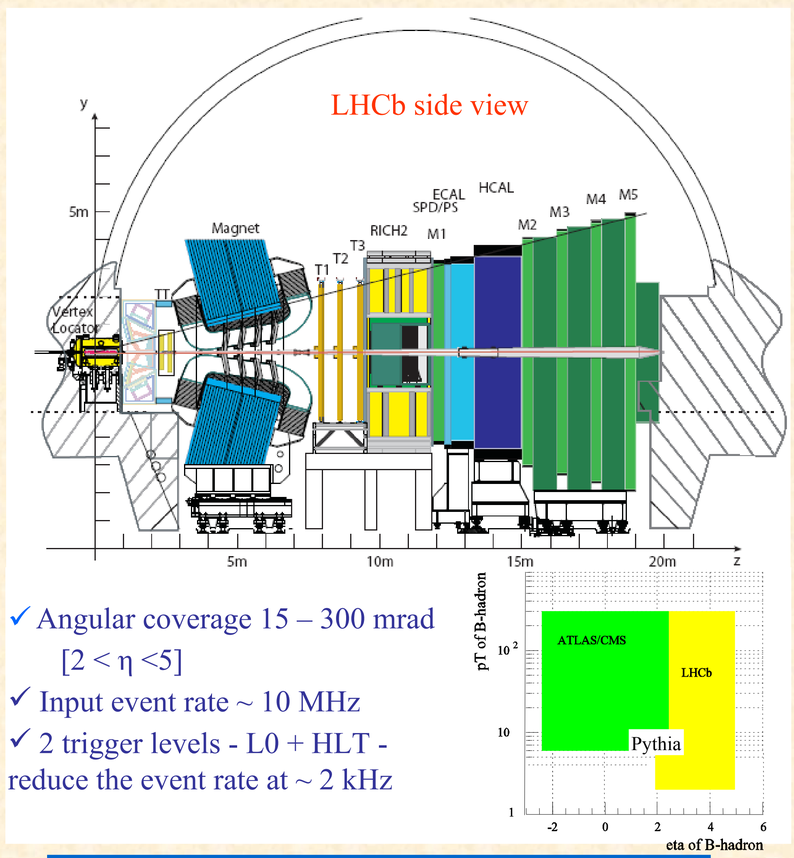



Prompt component Gaussian

Prompt background [extracted from mass sidebands]

J/ψ from b Exponential

Long tail due to association to wrong primary vertex

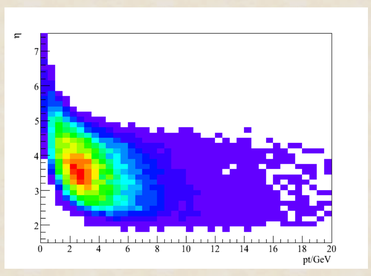



✓ Angular coverage 15 – 300 mrad [2 < η <5]
✓ Input event rate ~ 10 MHz
✓ 2 trigger levels - L0 + HLT - reduce the event rate at ~ 2 kHz




## J/ψ cross-section measurement

- To separate prompt J/ψ's from those from *b* decays means that the measurement of the prompt J/ψ cross-section will also lead to a determination of the *b* cross section
- Measurement in bin of η and $p_t$




Color Octet model, 5 $pb^{-1}$, $2<\eta<3$ :

→ 380k events in $2<p_t<4$ GeV

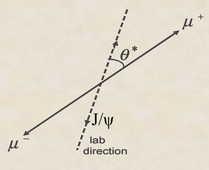
→ 40k events with $p_t>10$ GeV

- The high number of J/ψ available will reduce the statistic uncertainty
- Need to correct the number of J/ψ by the detector acceptance and efficiency (trigger · reconstruction · offline selection): large use of Monte Carlo to evaluate the total efficiency in each bin

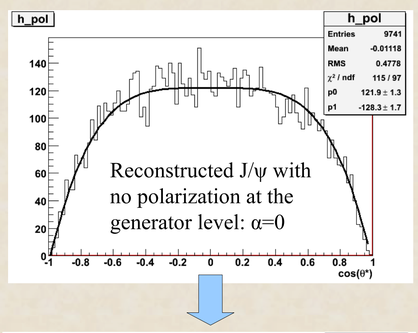
## Systematic sources

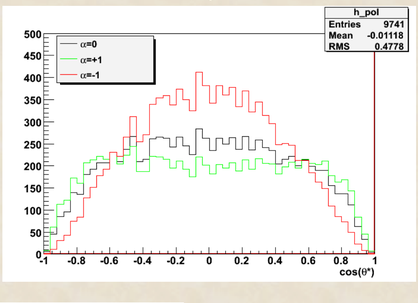
- Knowledge of the integrated luminosity
- Acceptance and efficiency: modelling in the Monte Carlo
- Uncertainty in *b*-fraction determination: choice of appropriate PDFs to fit *t*
- Uncertainty in *b*-hadron→J/ψ + X branching ratio
- Cross-section measurement needs to account for polarization

$$\frac{dN}{d\cos\theta^*} \propto 1+\alpha\cos^2\theta^*$$




The number of reconstructed events, and therefore the efficiency, depends on polarization




| $\alpha_{«data»}$ | Measured cross-section, assuming α=0 | Input $\sigma_{«data»}$ |
|---|---|---|
| 0 | 4337.3 nb ± 7.7 nb | 4340 nb |
| +1 | 4305.4 nb ± 7.7 nb | 4909 nb |
| -1 | 4383.0 nb ± 7.9 nb | 3518 nb |

Systematic up to 25 %

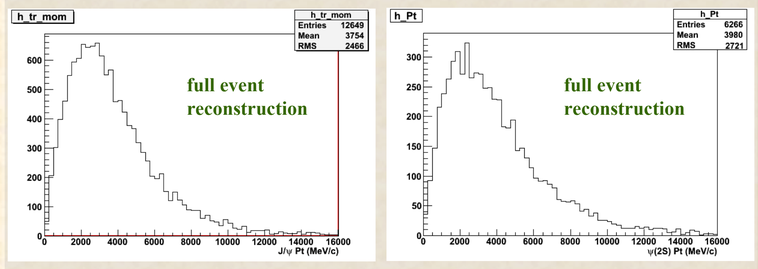
## The Detector

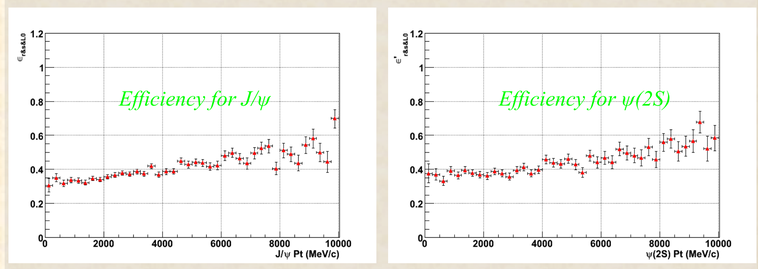
- VErtex LOcator to measure vertex positions with a resolution ~ 50-150 μm. LHCb will measure the *b*-hadron proper time with 40 fs resolution.
- A Tracking System, composed of four stations TT-T1-T2-T3 (using silicon microstrips and straw tubes), and the Magnet, that produces an integrated B field of ~ 4Tm, allow momentum measurement with a resolution $\sigma(p)/p$ = 0.3%-0.5%.
- Two RICH detectors to identify particles in a wide momentum range: [2, 100] GeV.
- Calorimeter System, ECAL and HCAL, used in the L0 trigger and to measure the energy of $e^{\pm}$, γ, hadrons. A preshower detector is placed just before them.
- Muon System used in the L0 trigger and for muon identification, is composed of five stations (M1-M5). It uses MWPC and GEM detectors in the inner part of M1.

**The LHCb experiment is installed and will start data taking at the end of 2009.**

## Measurement of the ratio σ(ψ′)/σ(J/ψ)

A large number of ψ′ will also be collected at LHCb: ~2-4 % of the J/ψ's number. ψ′ can be selected using a similar offline selection as J/ψ, with a ratio S/B ≈ 1-2. Since the $(M_{\psi'}-M_{J/\psi}) \approx 600$ MeV, from the point of view of the reconstruction and acceptance, their efficiencies are very similar.




$$\frac{\varepsilon}{\varepsilon'} = 1.01 \pm 0.07(stat)$$

In the measurement of the prompt cross-sections ratio, the main systematic effects cancel out. Important informations on the charmonium production mechanisms can be obtained even with a 10% precision measurement.

## Other charmonium measurements

- ~ 30% of J/ψ come from $\chi_{c1,2}$→J/ψ γ: an important observable is $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ whose value is useful to distinguish between several proposed models (e.g. Color Evaporation Model, NRQCD). Exclusive reconstruction is possible due to low $p_t$ detection capabilities of ECAL

- Studies of exotic XYZ states: the potential and sensitivity of LHCb are being investigated

$B^+$→X(3872) (→J/ψρ) $K^+$. Angular analysis to disentangle $J^{PC} = 1^{++}$ from $2^{-+}$

- The aim is to measure the X(3872) $J^{PC}$ quantum numbers. Simulation studies show differences in the expected angular distributions in the hypotheses $1^{++}$ or $2^{-+}$