Open Charm and Charmonium Production at the LHCb Experiment

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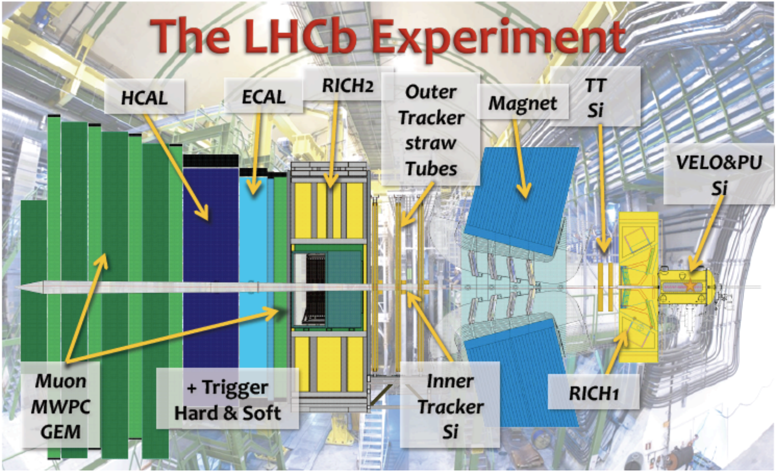
Outline

LHCb Experiment



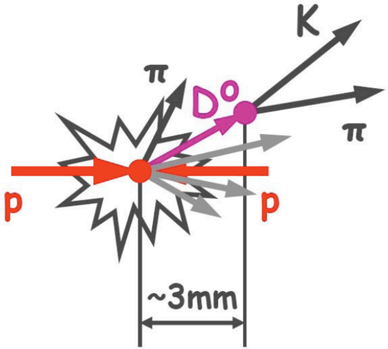
Large Hadron Collider beauty *& charm* experiment
for CPV and rare decays measurements

LHCb Status

- First Run in 2009 at $\sqrt{s}$ =900 GeV
  - 6.8±0.1 μb^{-1} accumulated *(more details on D. Moran's talk today)*
  - Detector and trigger commissioning, alignment, calibration
  - π^0, K_s, ϕ and Λ signals *(details given on M. Schiller's talk yesterday)*
- 2010 Run at $\sqrt{s} = 7$ TeV
  - Very successfull start !
  - $\sim$ 176 μb^{-1} accumulated up to last Friday
  - VELO fully closed (8 mm from the beam)
  - First K*, Ξ, D and J/Ψ evidences
  - and perhaps already our first fully reconstructed B !

Open Charm Production

Analysis focused on prompt charm production



- high cross-section ($\sigma_{c\bar{c}} \sim 7\sigma_{b\bar{b}}$)
- trigger optimization for charm and beauty
- potentially large backgrounds

Charm Physics in LHCb: many interesting topics

- Ratios of D mesons rates in early data $\left(\frac{\#\bar{D}^0 \to K^+\pi^-}{\#D^0 \to K^-\pi^+} \text{ and } \frac{\#D^+ \to K^-\pi^+\pi^+}{\#D^- \to K^+\pi^-\pi^-}\right)$
- Measurement of $\sigma_{c\bar{c}}$ and/or $\sigma_{c\bar{c}}/\sigma_{b\bar{b}}$
- $D^0\bar{D}^0$ mixing (evidences reported by BaBar, Belle and CDF[1])
- SM predictions for CPV asymmetries in charm are small; NP effects enhancements can be easier detected
  - CPV using $D^0 \to KK, K\pi, \pi\pi$ decays
  - Direct CPV in $D \to hhh$ (Dalitz Plot - search for anisotropy[2] and full amplitude analysis)
- Rare D decays ($D \to \mu^+\mu^-$) and semileptonic decays
- Expect to reconstruct 4×10^6 prompt $D^* \to D(KK)\pi$ in 100 pb^{-1} (BaBar reported $\sim 3 \times 10^5$)[3]

We will soon have the world largest sample of D mesons!

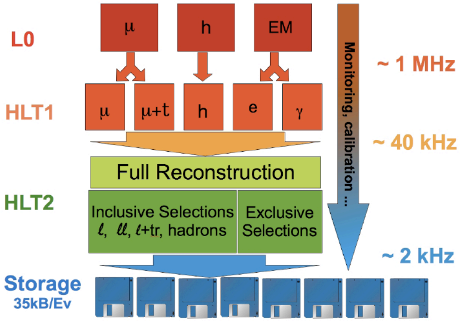
[1] BaBar: Phys.Rev.Lett 98(2007)211802; Belle: Phys.Rev.Lett. 98(2007)211803; CDF: Phys.Rev.Lett. 100(2008)121802

[2] DOI:10.1103/PhysRevD.80.096006.

[3] PRD.80.071103

Triggering D mesons

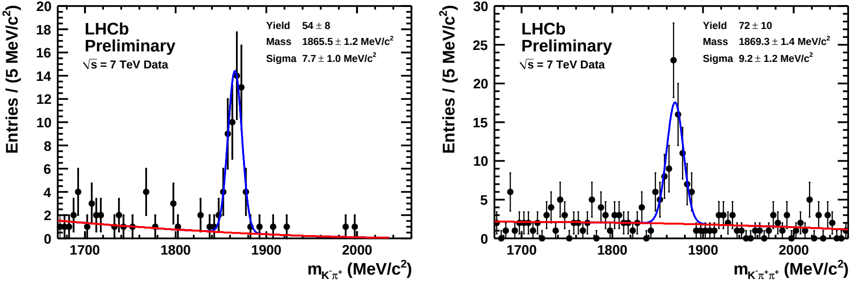
- trigger is a key ingredient



- retuned for low luminosity (lower thresholds)
- prompt charm yields improved by a factor 4 compared to trigger settings optimised for B physics ($\epsilon_{L0xHLT1}$ for prompt D^* $\sim$ 70%)
- results shown here: L0 only with even lower thresholds (Rate$\sim$ 100 Hz)

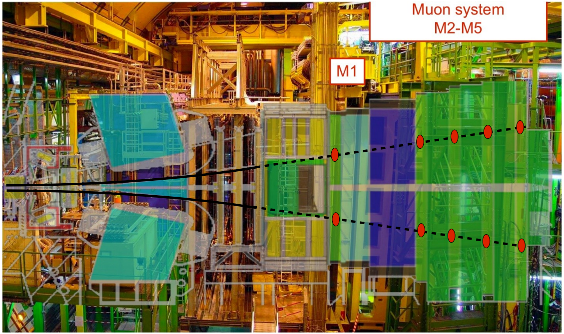
D mesons reconstruction

- selection based on flight distance, vertex quality, impact parameter and particle ID
- no evidence in 2009 Collisions at $\sqrt{s} = 900$ GeV (due to the low statistics)
- first signal peaks seen in 2010 Collisions at $\sqrt{s} = 7000$ GeV



masses and widths compatible with expectation
selection not optimized (corresponds to $\sim 110\ \mu b^{-1}$)

Muon Identification: the basic strategy



1. Look for hits in the MS within Fields of Interest (FOI) around the track extrapolation
2. Select muon candidate requiring a minimum number of stations with hits within FOI
3. Build likelihood for Muon and Non-muon hypotheses

Both local and global alignment are important

Fields of Interest

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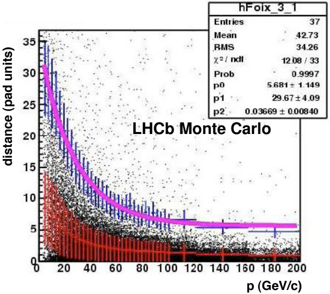


FOI: function of p and Muon System position

Loosest Muon Candidate requirement

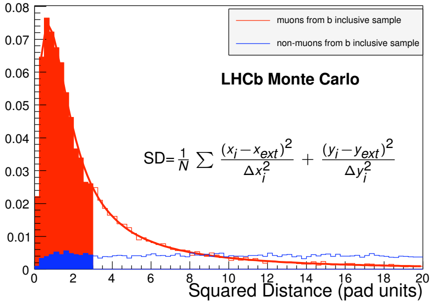
1. Look for hits in the MS within Fields of Interest (FOI) around the track extrapolation
2. Select muon candidate requiring a minimum number of stations with hits within FOI
3. Build likelihood for Muon and Non-muon hypotheses

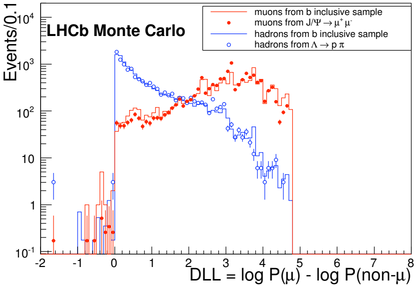
p range	Stations
3-6 GeV/c	2 out of M2-M4
>6 GeV/c	3 out M2-M5

minimum requirement, robust against possible innefficiencies

Likelihoods

1. Look for hits in the MS within Fields of Interest (FOI) around the track extrapolation
2. Select muon candidate requiring a minimum number of stations with hits within FOI
3. Build likelihood for Muon and Non-muon hypotheses

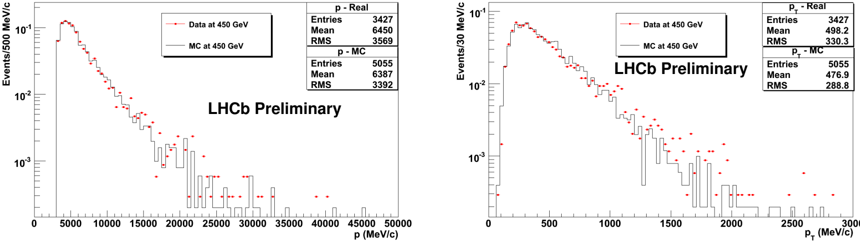




Calibration and Monitoring using Data

- Calibration of FOI and muon likelihood & monitoring of efficiency
  - ➟ *probe muons* in a pure sample of J/Ψ
  - ➟ two tracks in the MS acceptance making a good vertex
  - ➟ invariant mass within J/Ψ mass
  - ➟ one *tag muon* selected using MS information
  - ➟ one *probe muon* compatible with MIP in Ecal/Hcal
- Calibration of non-muon likelihood & monitoring of misidentification rate
  - ➟ protons and pions from $\Lambda \rightarrow p\pi$
  - ➟ pions from K_s
  - ➟ pions and kaons from $D \rightarrow K\pi$

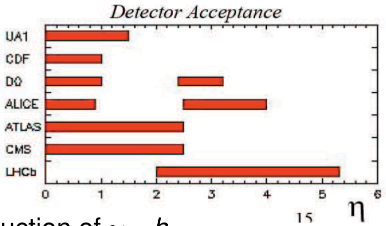
First Look at 2009 Data



Good Data/MC agreement for the spectra

Charmonium Production

- J/Ψ production cross-section and polarization measurement
  - ✔ Color Octect Mechanism can reproduce well the cross-section and P_T spectrum measured at Tevatron
  - ✘ but predicts predominance of transverse polarization in disagreement with CDF data[4]
  - ✘ higher order corrections to Color Singlet Model[5] have better agreement with data, but still room for improvements
  - ➥ LHCb provides η coverage where theoretical predictions are less accurate and can help in the comprehension of the underlying production mechanism of charmonium states



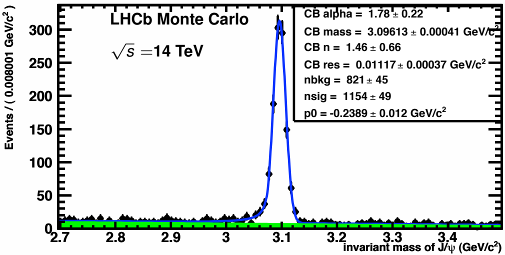
- similar measurements with $\Psi(2S)$, production of χ_c, h_c
- J/Ψ is also essential for detector and PID calibration

[4] Phys.Rev.Lett.79 (1997)572,578;Phys.Rev.Lett.(2007)132001

[5] Phys. Rev. Lett. 98 (2007) 252002 [arXiv:hep-ph/0703113] & JHEP 0802 (2008) 102 [arXiv:0712.2770 [hep-ph]].

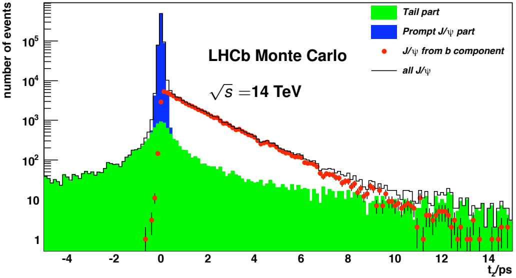
$J/\Psi \to \mu^+\mu^-$ Reconstruction

- Long tracks matching hits in the Muon System
- $0.7 GeV/c < p_T < 7 GeV/c$
- $3 < \eta < 5$
- good quality $\mu^+\mu^-$ vertex
- From MC studies at 14 TeV:
  - $\sim$11 MeV/c^2 mass resolution
  - S/B$\sim$18
  - 1×10^9 J/Ψ after L0 (1 fb^{-1})



Prompt and Secondary $J/\Psi \rightarrow \mu^+\mu^-$ Separation

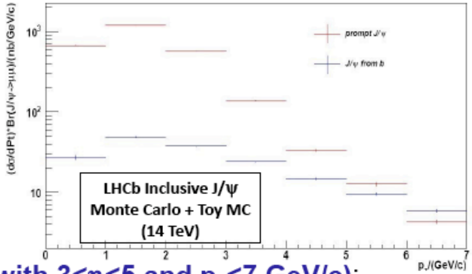
- based on pseudo-propertime $t_z = \frac{dz}{p_z} \times m_{J/\Psi}$
- prompt component: peak at 0
- secondary component: exponential decay
- wrong PV association: long tail (got from a different event PV)



combined mass and pseudo-proper time fit: cross-sections in

- 4 η bins $3 < \eta < 5$
- 7 p_T bins $p_T < 7$ GeV/c

Monte Carlo example of cross-section measurement



Results (J/ψ with 3<η<5 and p_T<7 GeV/c):

- σ(prompt J/ψ) x Br(J/ψ → $\mu^+ \mu^-$) = 2597 ± 12 (stat) ± 24 (eff) nb [Input: 2667 nb]
- σ(J/ψ from b) x Br(J/ψ → $\mu^+ \mu^-$) = 161 ± 4 (stat) ± 2 (eff) nb [Input: 153 nb]

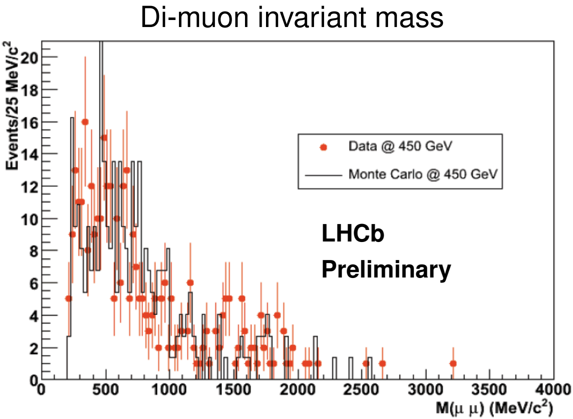
➜ expect $\sim 3 \times 10^6$ reconstructed J/Ψ for 5 pb^{-1} at $\sqrt{s} = 7$ TeV:

➜ maximum 10% statistical error in each bin

➜ systematic uncertainties up to 25% when ignoring polarization

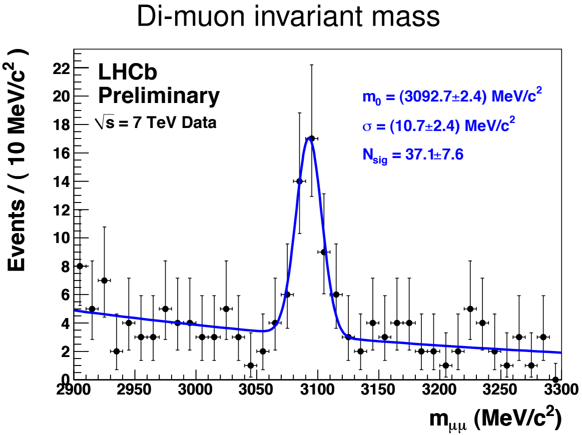
➜ polarization will be measured in bins of η and p_T with full angular analysis

2009 Data: J/Psi hunting



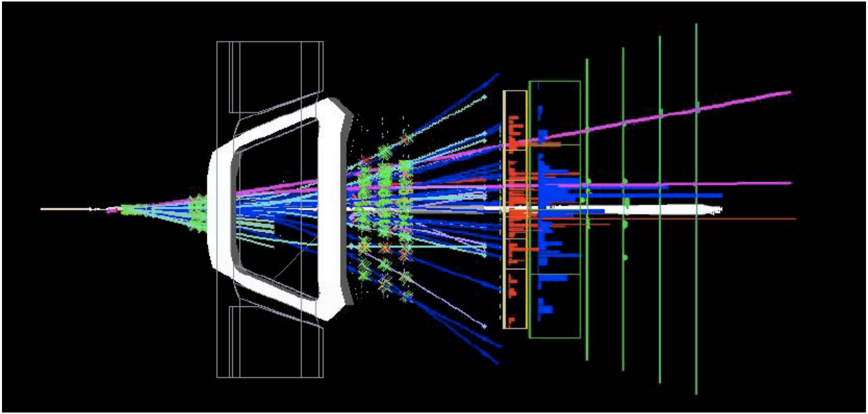
- loose selection based on vertex quality, muon ID and high p_T
- no signal evidence in 2009 data (6.8 ± 0.1 μb^{-1})

2010 Data: J/Psi hunting



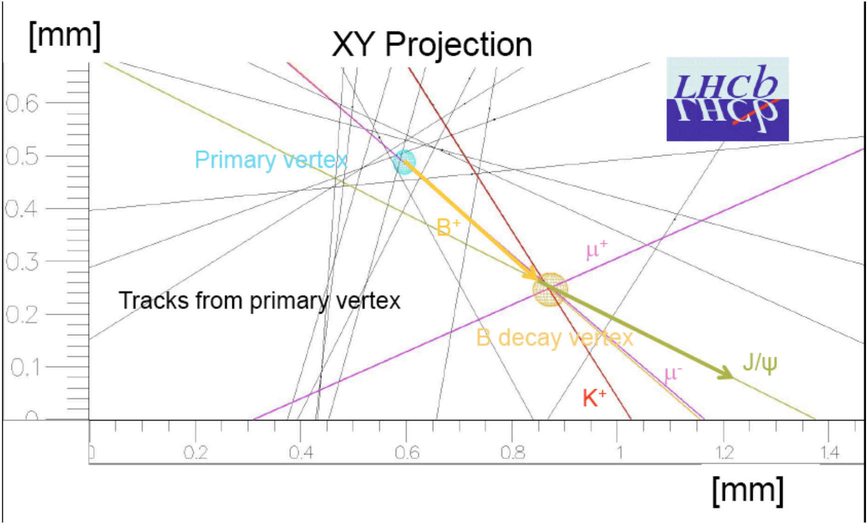
- selection based on vertex quality, muon ID, p and p_T
- corresponding to $\sim 160\mu b^{-1}$

Our first $B^+ \to J/\Psi K^+$ candidate



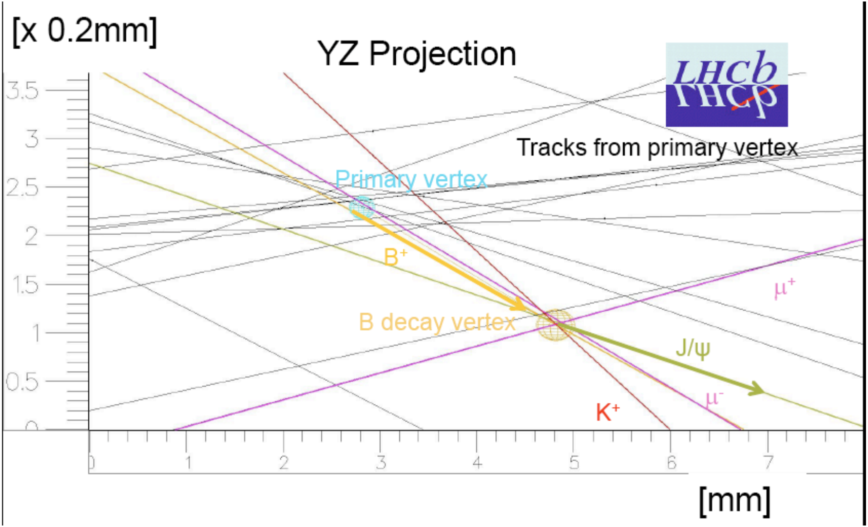
LHCb 2010 Preliminary

Our first $B^+ \to J/\psi K^+$ candidate: zoom in y-x view



LHCb 2010 Preliminary

Our first $B^+ \to J/\psi K^+$ candidate: zoom in y-z view



LHCb 2010 Preliminary

Summary and final comments

- many interesting physics topics with open charm
- LHCb will measure J/Ψ cross-section and polarization
- similar studies for $\Psi(2S)$ and measurements of other charmonium states (χ_c, $h_c(1P)$,...)
- D and J/Ψ decays also important for detector and particle ID software calibration, MC tuning, ...
- we have just started hard and interesting work
- first evidences of D and J/Ψ produced at $p-p$ collisions at $\sqrt{s}$ =7 TeV in the LHCb experiment !