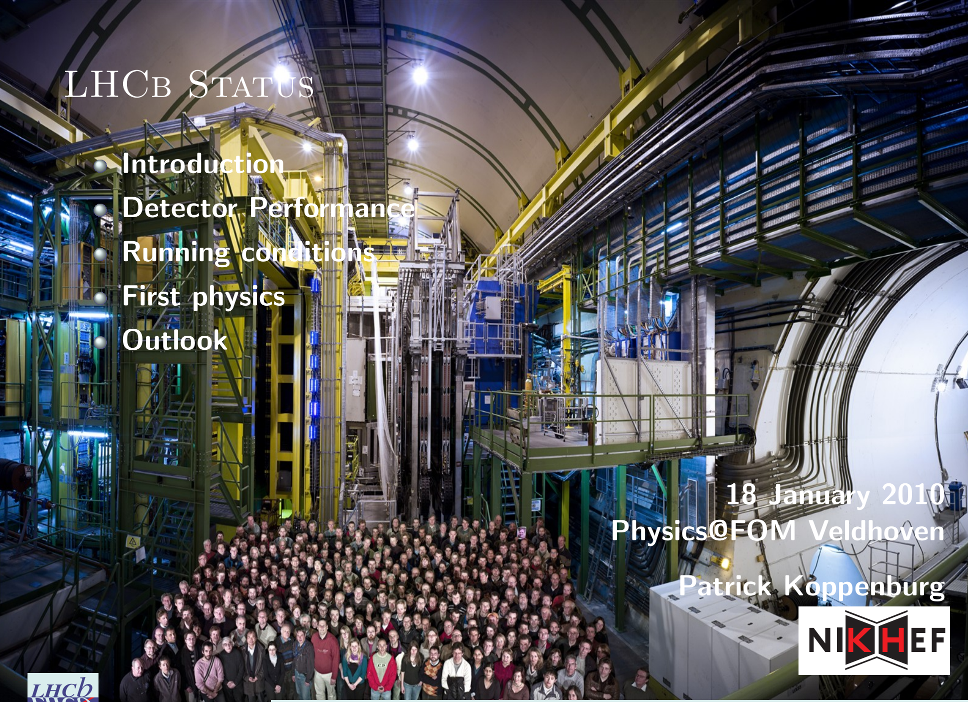
LHCb Status



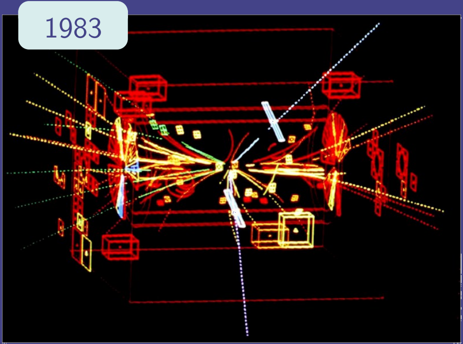
- Introduction
- Detector Performance
- Running conditions
- First physics
- Outlook

18 January 2010
Physics@FOM Veldhoven

Patrick Koppenburg
NIKHEF

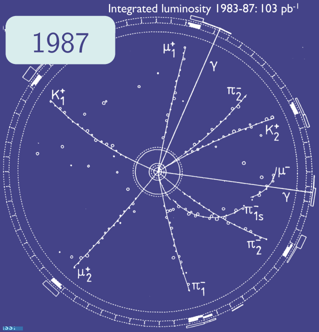
Indirect Searches

- Sensitive to New Physics effects
  - When was the Z discovered?
    - 1973 from $N\nu \to N\nu$?
    - 1983 at SpS collider?
  - c quark postulated by GIM, third family by Kobayashi & Maskawa



Indirect Searches

- Sensitive to New Physics effects
  - When was the Z discovered?
    - 1973 from $N\nu \to N\nu$?
    - 1983 at SpS collider?
  - c quark postulated by GIM, third family by Kobayashi & Maskawa
- ✔ Estimate masses
  - t quark from $B\overline{B}$ mixing
  - ✔ Much larger mass coverage than $\sqrt{s}$
- ✔ Get phases of couplings
  - Half of new parameters
  - Needed for a full understanding
- Look in lepton and **flavour** sectors
  - ➜ CP asymmetry in the Universe



Indirect Searches

The b quark is the best laboratory for this programme (see Fleischer's talk)

Hot channels for the near future:

$B_s \to \mu\mu$: Is there susy? $\mathcal{B} \propto \frac{\tan^6 \beta}{m_A^4}$.

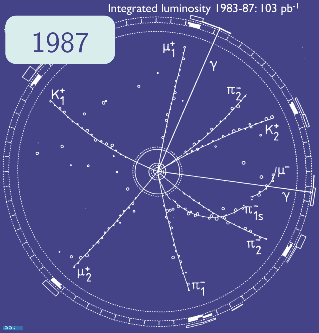
$B_s \to J/\psi\phi$: Beyond-SM CPV?

$B_d \to \mu\mu K^*$: Right-handed currents?

γ (ϕ_3): Is the CKM matrix sufficient?

y_{cp} in D^0: Beyond-SM CPV?

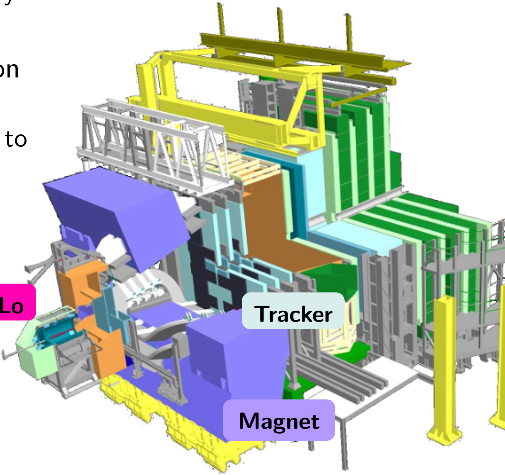
The LHC beauty experiment for precise measurements of CP violation and rare decays



LHCb Detector

Forward detector (b-hadrons produced forward at LHC)

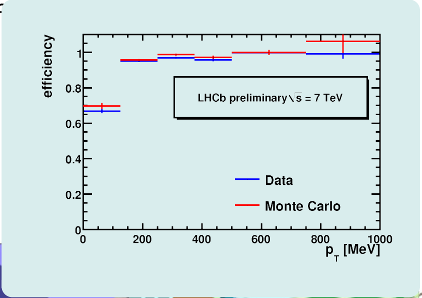
- Warm dipole magnet. Polarity can be reversed.
- ✔ >99% of channels working
- ✔ Good momentum and position resolution
  - Vertex detector gets 8mm to the beam

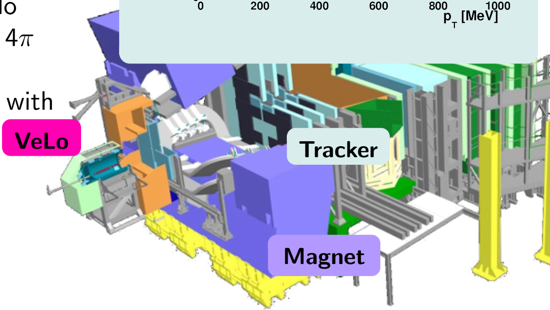


LHCb Detector performance

Forward detector (b-hadrons produced f

- Warm dipole magnet. Polarity can
- ✔ $>$99% of channels working
- ✔ Good momentum and position resolution, high efficiency
  - Low-P efficiency from K_S^0 tag-and-probe with calo
  - Medium P from $D \to 4\pi$ and $D \to 2\pi$
  - High-P from $Z \to \mu\mu$ with muon detector

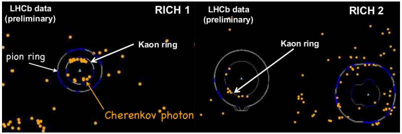


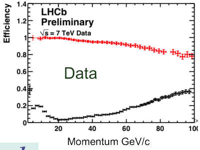


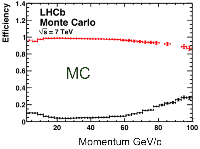
LHCb Detector performance

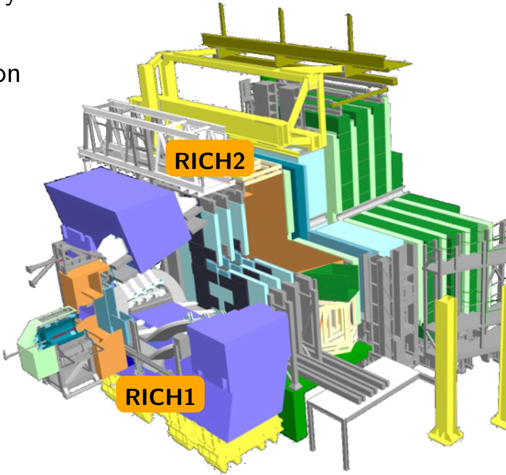
Forward detector (b-hadrons produced forward at LHC)

- Warm dipole magnet. Polarity can be reversed.
- ✔ >99% of channels working
- ✔ Good momentum and position resolution
- ✔ Good Particle Identification





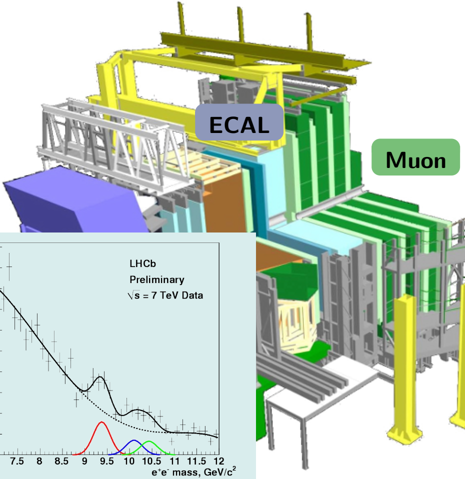


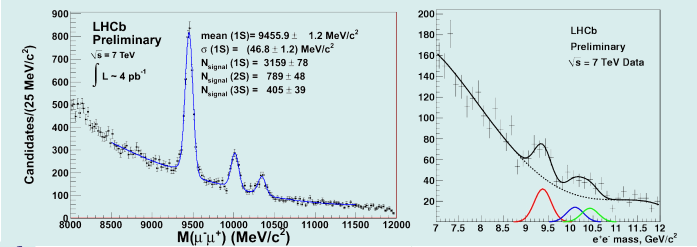


LHCb Detector performance

Forward detector (b-hadrons produced forward at LHC)

- Warm dipole magnet. Polarity can be reversed.
- ✔ >99% of channels working
- ✔ Good momentum and position resolution
- ✔ Good Particle Identification
  - Υ resonances are there ➜ ECAL and Muon works well





LHCb Trigger

Forward detector (*b*-hadrons produced forward at LHC)

- Warm dipole magnet. Polarity can be reversed.

✔ >99% of channels working

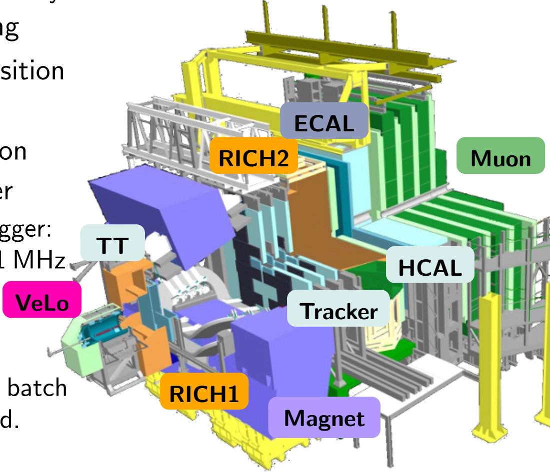
✔ Good momentum and position resolution

✔ Good Particle Identification

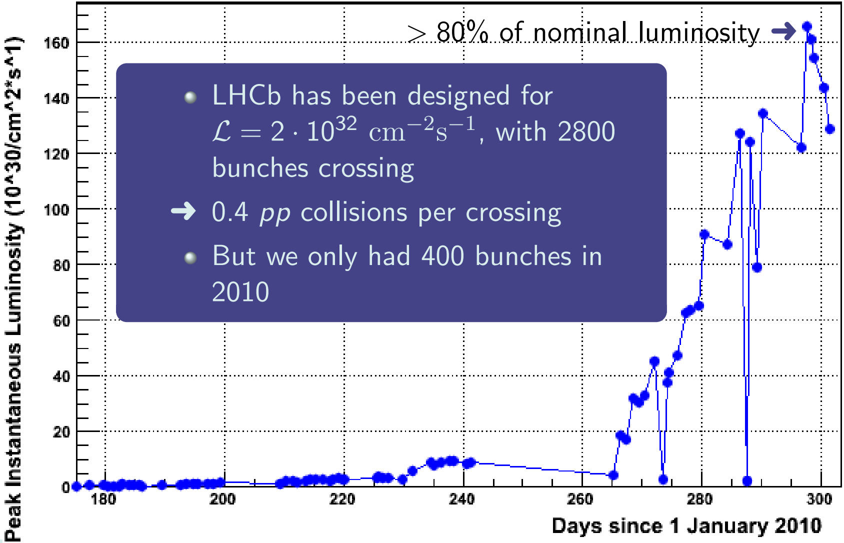
✔ Versatile two stage trigger

  - Hardware-based L0 trigger: moderate p_T cuts ➜ 1 MHz
  - The whole data sent to $\mathcal{O}(2000)$ servers
  - 2 kHz output rate

  ➜ fully operational. Last batch of CPUs being installed.



Instantaneous Luminosity at 3.5 TeV

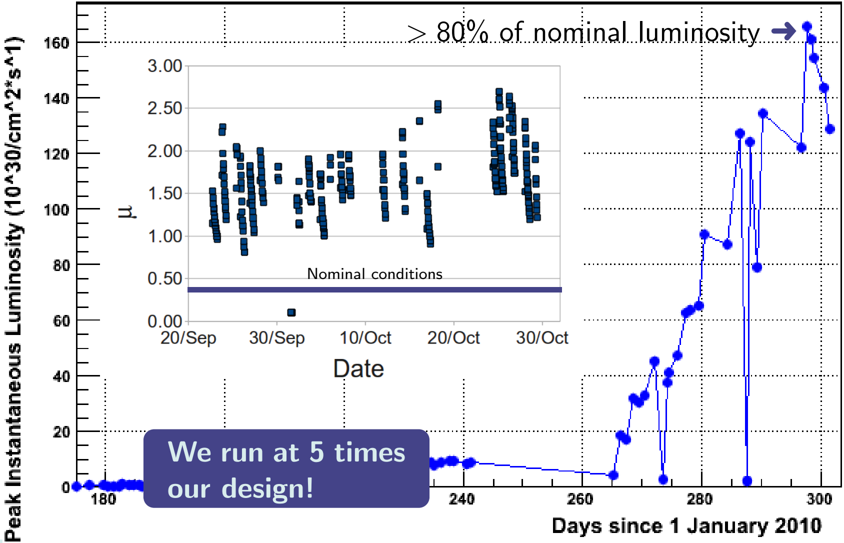


- LHCb has been designed for $\mathcal{L} = 2 \cdot 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, with 2800 bunches crossing

➜ 0.4 *pp* collisions per crossing

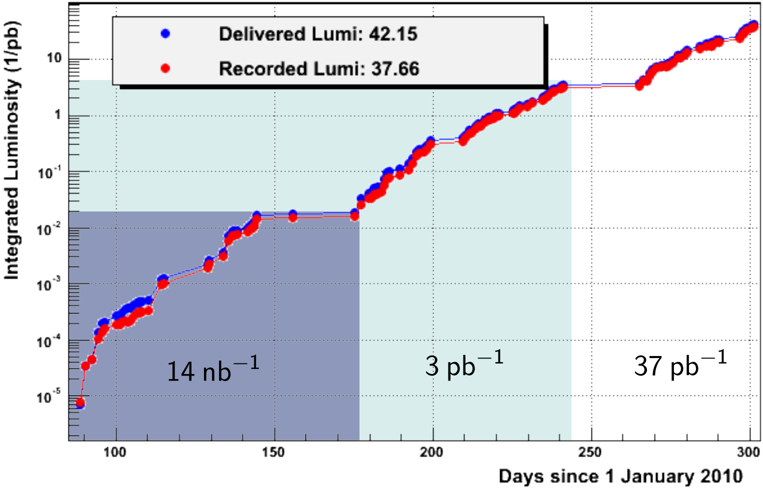
- But we only had 400 bunches in 2010

Instantaneous Luminosity at 3.5 TeV



We run at 5 times our design!

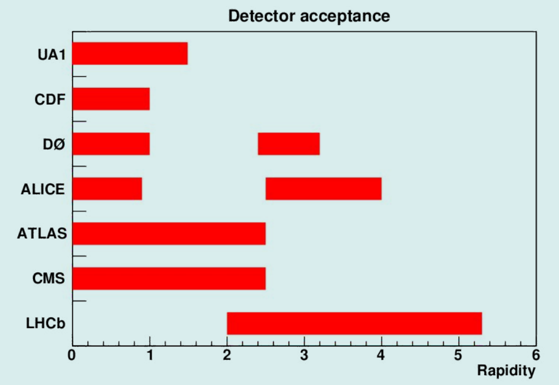
Integrated Luminosity at 3.5 TeV



Earlier data has less biasing trigger ➜ better for cross sections

Physics

- LHCb is the forward detector at the LHC
  - ✔ Unique rapidity coverage
- K_S^0 cross section (PLB 693 (2010) 69-80)
- $\Lambda/\overline{\Lambda}$ and $p/\overline{p}$
- Open charm (see next talk)
- J/ψ
- B
- Z, W …



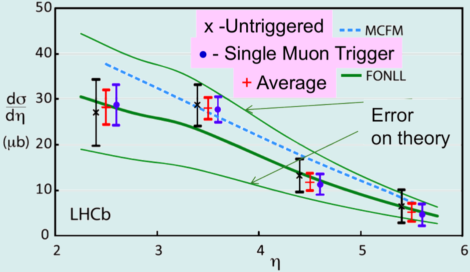
This is the tracking acceptance.
For composites we get even higher.

B Cross Section ($14\ \mathrm{nb}^{-1}$)

This time keep only the non-prompt part

- Start from non-prompt $D^0 \to K^-\pi^+$
- Add a non-prompt muon : $B^- \to D^0\mu^-\nu$
- Get $b\bar{b}$ cross section from $\mathcal{B}(b\to D^0 X) = (6.82 \pm 0.35)\%$
- $\sigma_{b\bar{b}} = (75.3 \pm 5.4 \pm 13.0)\ \mu\mathrm{b}$ (in acc.) using LEP fragmentation
  - 89.6 with Tevatron fragmentation
  - $\sigma_{b\bar{b}}(4\pi) = (284 \pm 20 \pm 49)\ \mu\mathrm{b}$
- Charm ➜ See next talk

[PLB 694 (2010) 209]



B Fragmentation $(3\ \mathrm{pb}^{-1})$

- This time separate between D_s, D^0 and D^+ (and also Λ_c)

→ Get hadronisation fractions

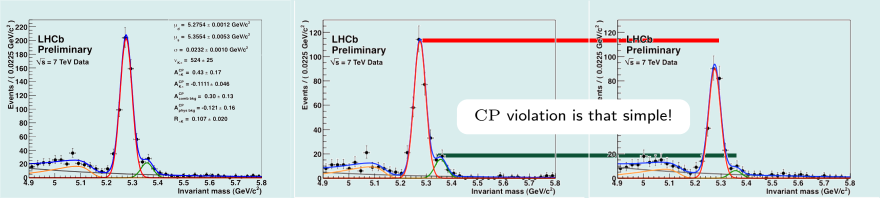
$$\frac{f_s}{f_d + f_u} = 0.130 \pm 0.004 \pm 0.013 \qquad \text{(Preliminary)}$$

  - LEP : 0.129 ± 0.012
  - Tevatron: 0.18 ± 0.03 : different p_T spectrum

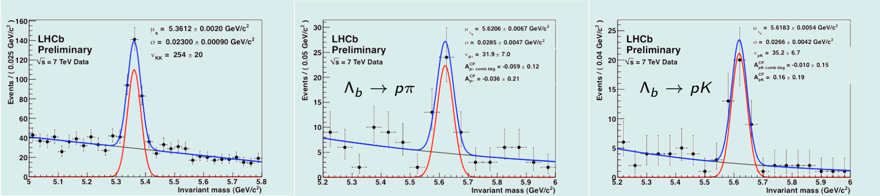
  → LHCb more like LEP than CDF

- This ratio is very important to normalise branching fractions, like $B_s \to \mu\mu$
- Other methods might be more precise, as using $B \to Dh$ decays [Fleischer et. al, 1012.2784]

Charmless B Decays : Direct CPV is seen!



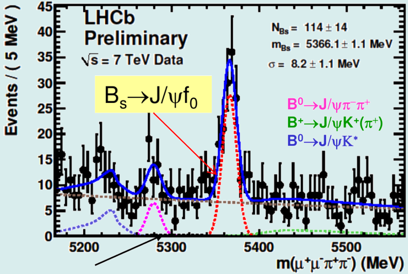
$B \to K\pi \quad = \quad B \to K^+\pi^- \quad + \quad B \to K^-\pi^+$

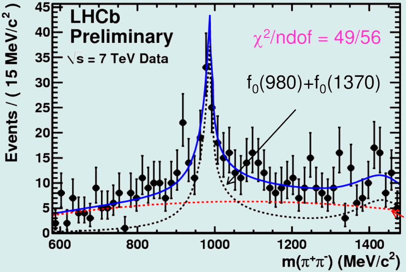


$B_s \to KK$

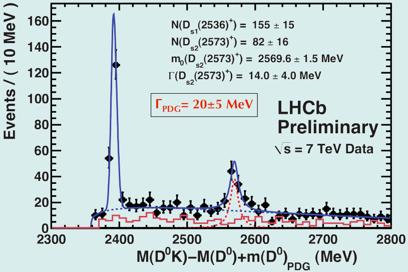
$B \to$ 2-body works: ready for $B_s \to \mu\mu$!

First observations ($\mathcal{O}(30)$ pb^{-1})

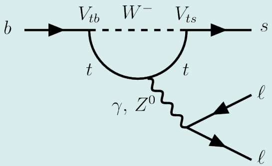


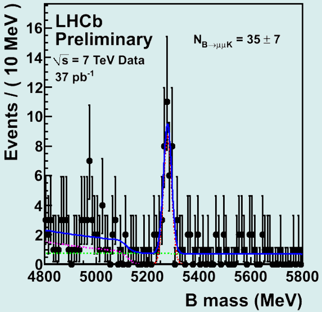


- ✔ First observation of $B_s \to J/\psi f_0(980)$ ($f_0(980) \to \pi\pi$)
- ✔ First observation of $B_s \to D^*_{s2}(2573)^+ \mu^- \nu$ (first time seen in a decay)

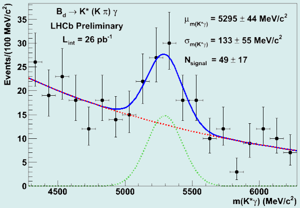


We see penguin decays

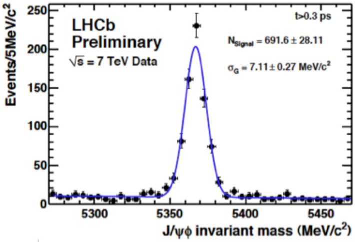




- ✔ 35 $B_u \to \mu\mu K$ events in 37 pb^{-1}
  - Interesting for axial currents and minimal flavour violation ($\mathcal{B} = 5 \cdot 10^{-7}$)
- ➜ Looking for $B \to \mu\mu K^*$
  - Will soon have the best measurement of the forward-backward-asymmetry
- ✔ And $B \to K^*\gamma$
  - ➜ Waiting for $B_s \to \phi\gamma$ to constrain right-handed currents



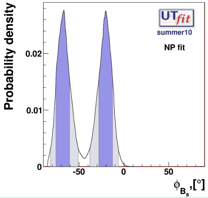
Will there the first signs of new physics?



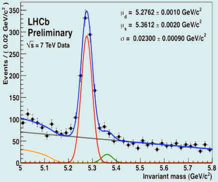
✔ Very clean $B_s \to J/\psi\phi$ sample

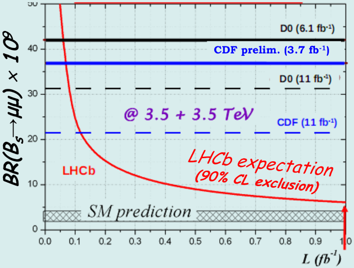
➜ Ready to measure $\phi_s^{J/\psi\phi}$ (= 0 in SM)

$B_s \to J/\psi\phi$



$B_s \to \mu\mu$





✔ Good mass resolution on $B \to K\pi$

➜ Expect the same for $B_s \to \mu\mu$

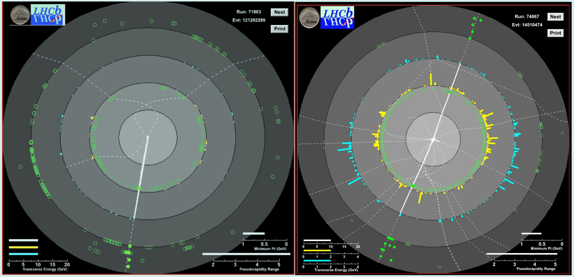
Conclusion

- Detector works very well
- We are far above our nominal conditions, but we cope
- With 37 pb^{-1} we are already competing with the Tevatron!
- Measured cross sections and made first observations
- We are ready for the flagship analyses $B_s \to \mu\mu$ and $B_s \to J/\psi\phi$
- Waiting for more luminosity : we are getting our nominal luminosity already now

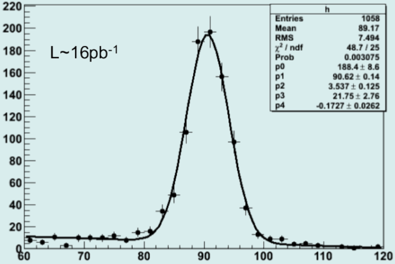
We can find new physics with 2011 data!

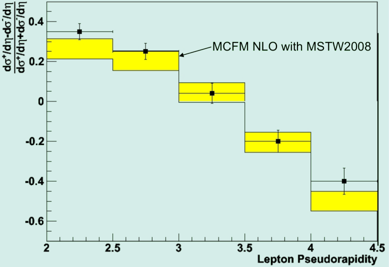
Backup

BEYOND THE B (16 pb^{-1})



- We see forward Z ($\mu\mu$ and ee) and W
- ➜ Shown in unorthodox z-ϕ view
- Will measure cross section and asymmetries





Why "only" 37 pb^{-1}?

ATLAS 45.0 of 48.2 (94%)

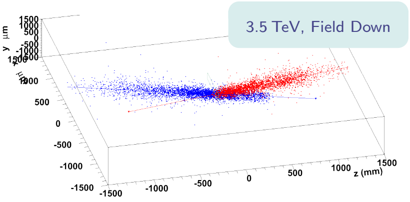
CMS 43.2 of 47.0 (92%)

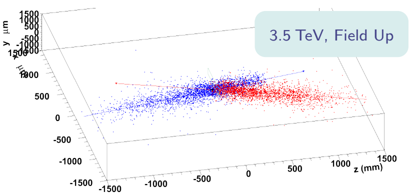
LHCb 37.7 of 42.1 (90%)

Dipole magnet ➜ crossing angle

- added or subtracted from external angle
- Most data taken with polarity that gives the highest angle ➜ lower $\mathcal{L}$

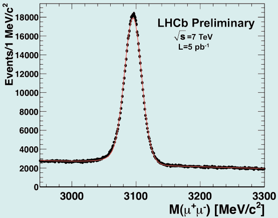
Will not be an issue any more in 2011, when we won't follow in $\mathcal{L}$

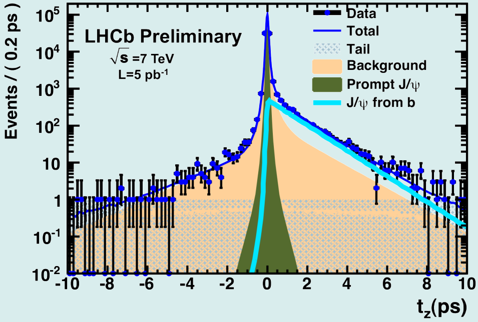




J/ψ AT $\sqrt{s} = 7$ TeV ($5\ \mathrm{pb}^{-1}$)

- $0.56 \cdot 10^6$ candidates in $5\ \mathrm{pb}^{-1}$
- Separate prompt and non-prompt components

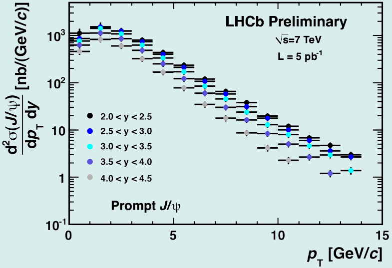


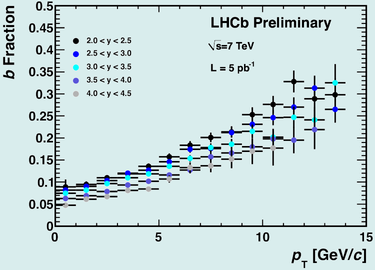


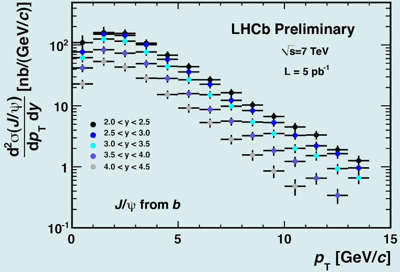
J/ψ at $\sqrt{s} = 7$ TeV $(5\ \text{pb}^{-1})$

- $0.56 \cdot 10^6$ candidates in 5 pb^{-1}
- Separate prompt and non-prompt components
- Get $\sigma_{J/\psi}$ in bins of p_T and y for prompt and from b

$$\sigma_{b\bar{b}} = 2.95 \pm 4 \pm 48\ \mu\text{b}$$





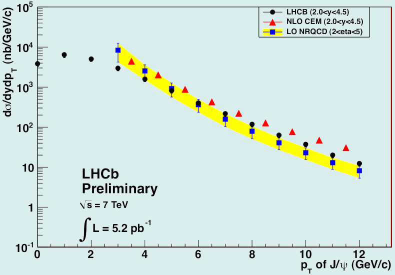


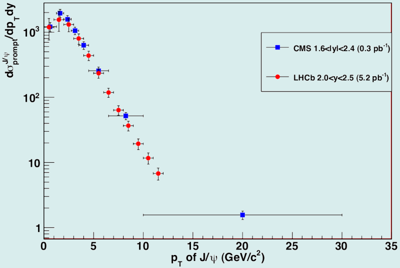
J/ψ AT $\sqrt{s} = 7$ TEV ($5\ \mathrm{pb}^{-1}$)

- $0.56 \cdot 10^6$ candidates in $5\ \mathrm{pb}^{-1}$
- Separate prompt and non-prompt components
- Get $\sigma_{J/\psi}$ in bins of p_T and y for prompt and from b

$$\sigma_{b\bar{b}} = 2.95 \pm 4 \pm 48\ \mu\mathrm{b}$$

- Compare with theory
- Compare with CMS

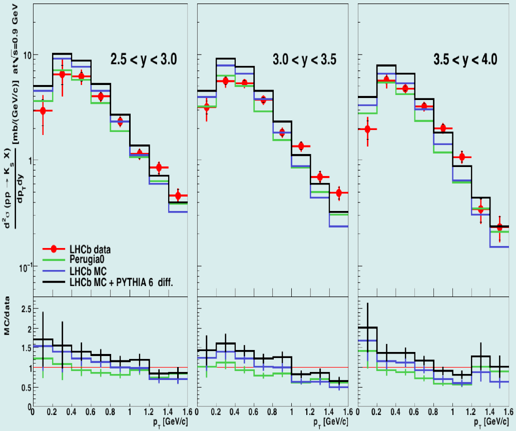




K_S^0 Cross Section at $\sqrt{s} = 900$ GeV

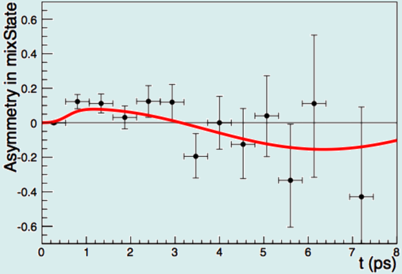
- Two independent analyses (one with and one without VeLo)
  - Large overlap ➜ no attempt to average. We take best bin of each.
- Errors:
  - 10% statistical
  - 13% luminosity
  - 10% tracking
- Data seems to favour higher p_T than MC

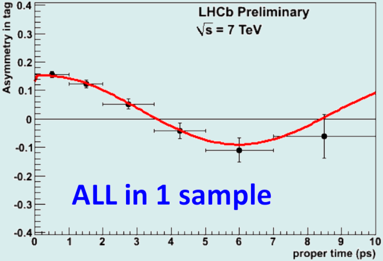
➜ First LHCb paper



p_T spectrum in bins of y.

Oscillations





- Tagging is working
  - We see oscillations in $B_d \to J/\psi K^*$
  - and $d \to D^* \mu\nu$
- Retuning to $\mu \sim 2$ ongoing.