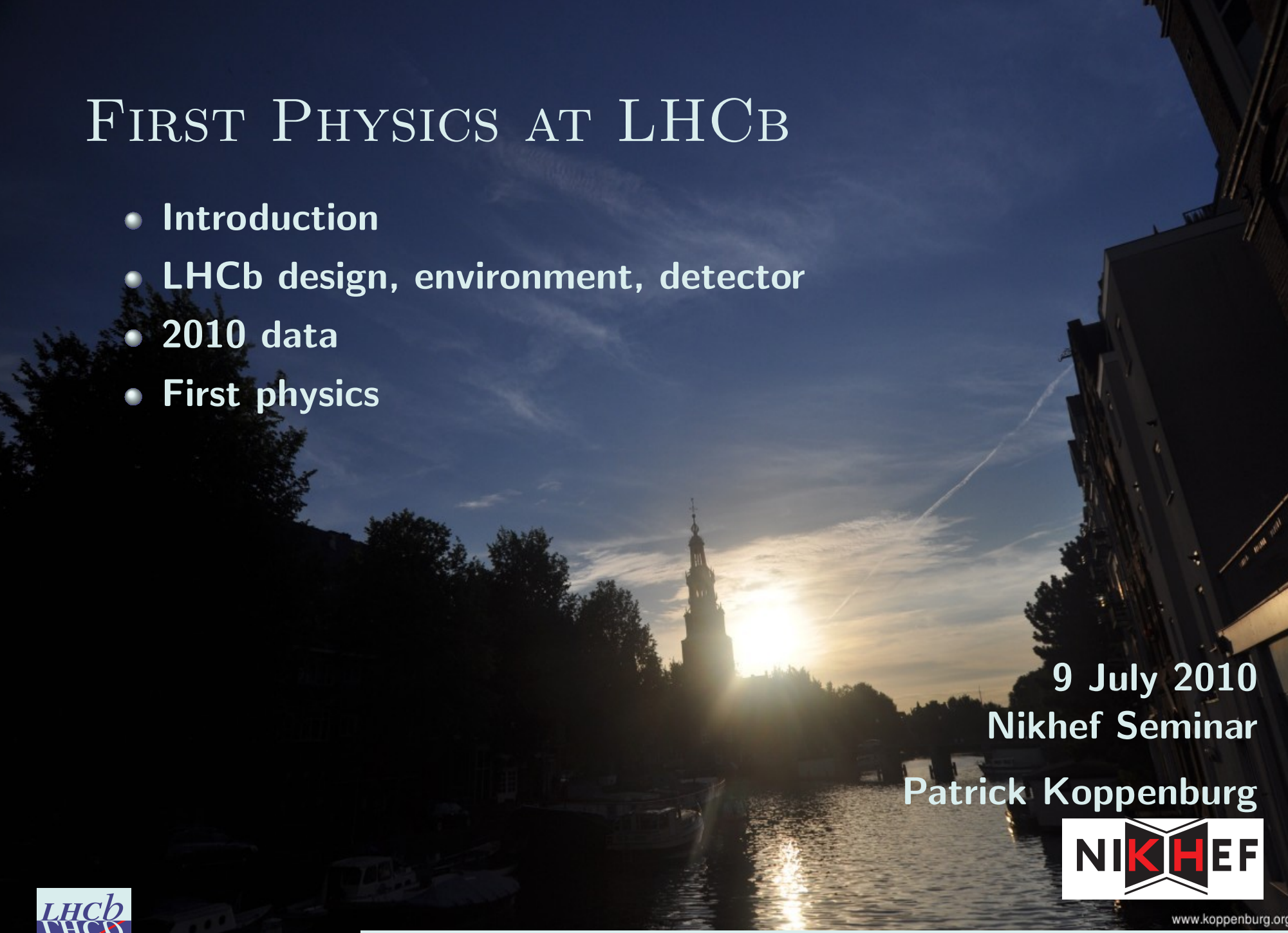
First Physics at LHCb

- Introduction
- LHCb design, environment, detector
- 2010 data
- First physics

9 July 2010
Nikhef Seminar

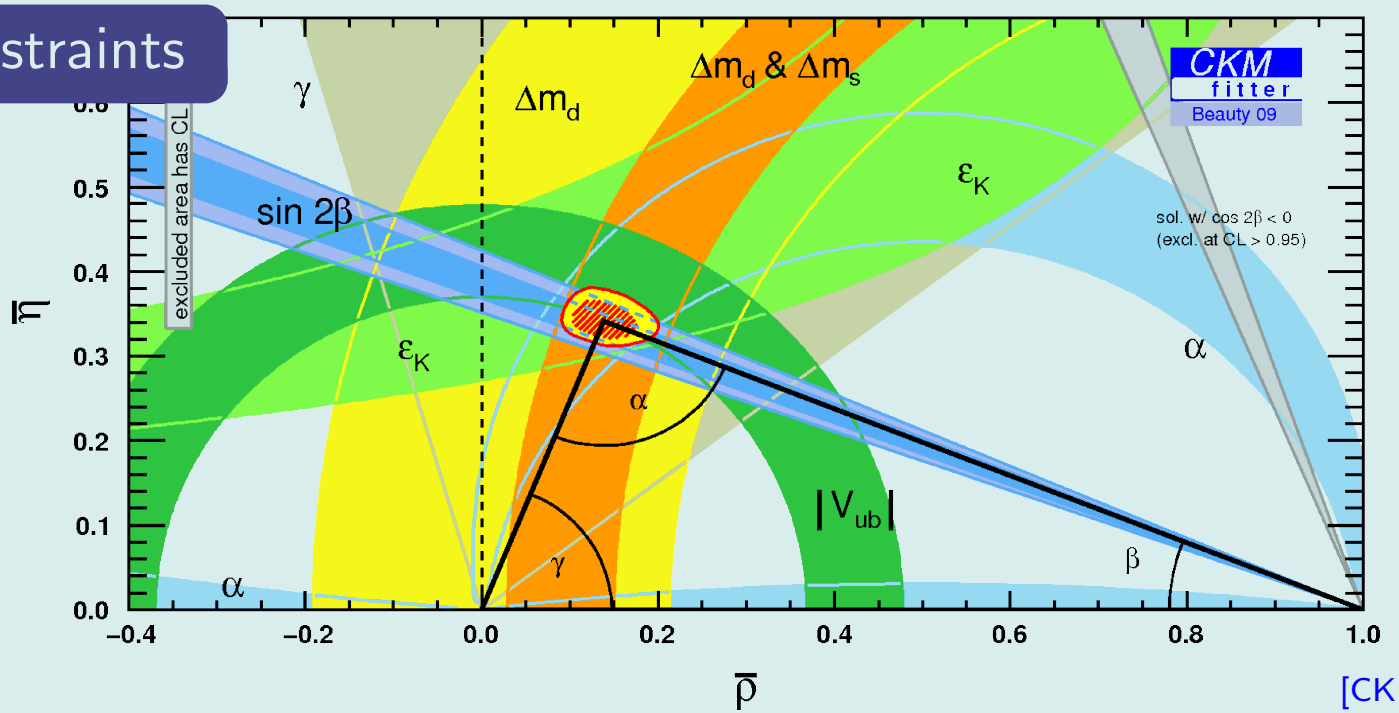
Patrick Koppenburg



Unitarity Triangle

- Changed focus: No longer seeking to verify the CKM picture
- Instead look for signs of New Physics
  - ➜ Discrepancies in measurements or unitarity triangle

All constraints

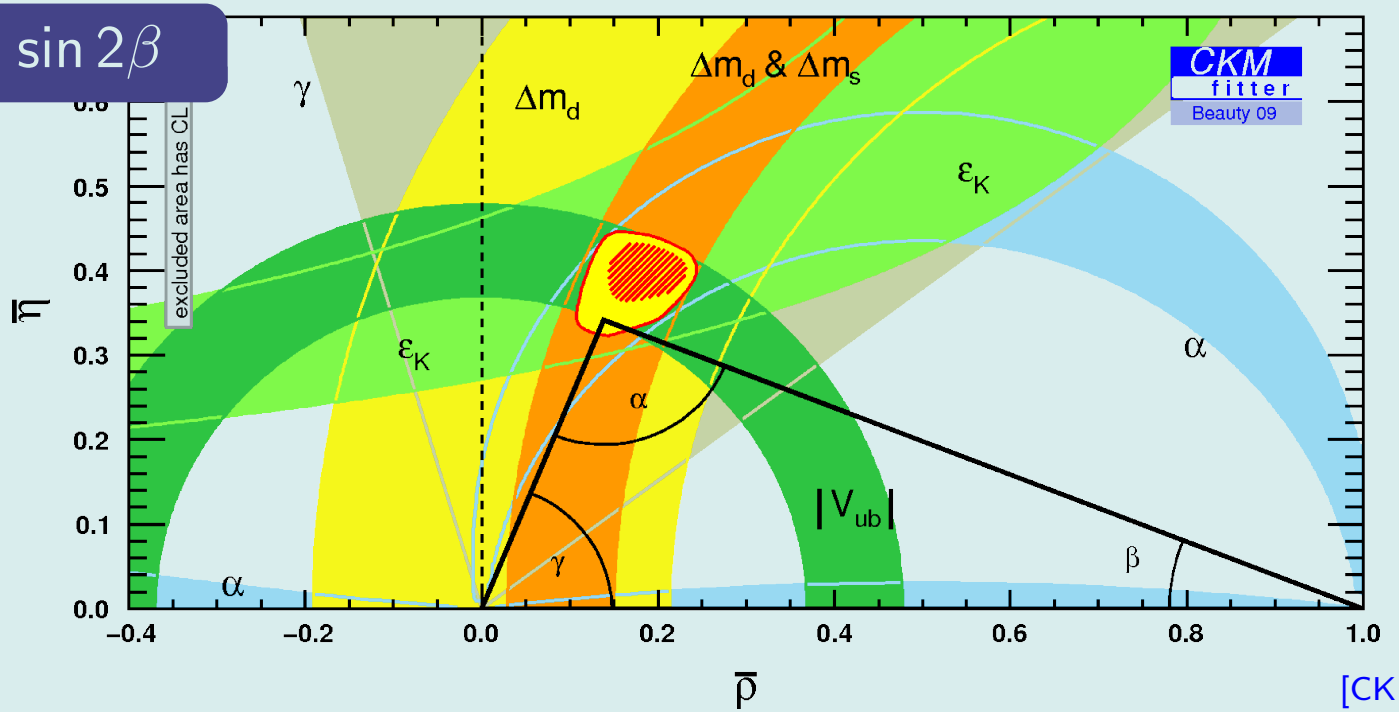


[CKMfitter 09/09]

Unitarity Triangle

- Changed focus: No longer seeking to verify the CKM picture
- Instead look for signs of New Physics
  - ➜ Discrepancies in measurements or unitarity triangle
- $(\bar{\rho}, \bar{\eta})$ fit is dominated by $\sin 2\beta$

All but $\sin 2\beta$



[CKMfitter 09/09]

Unitarity Triangle

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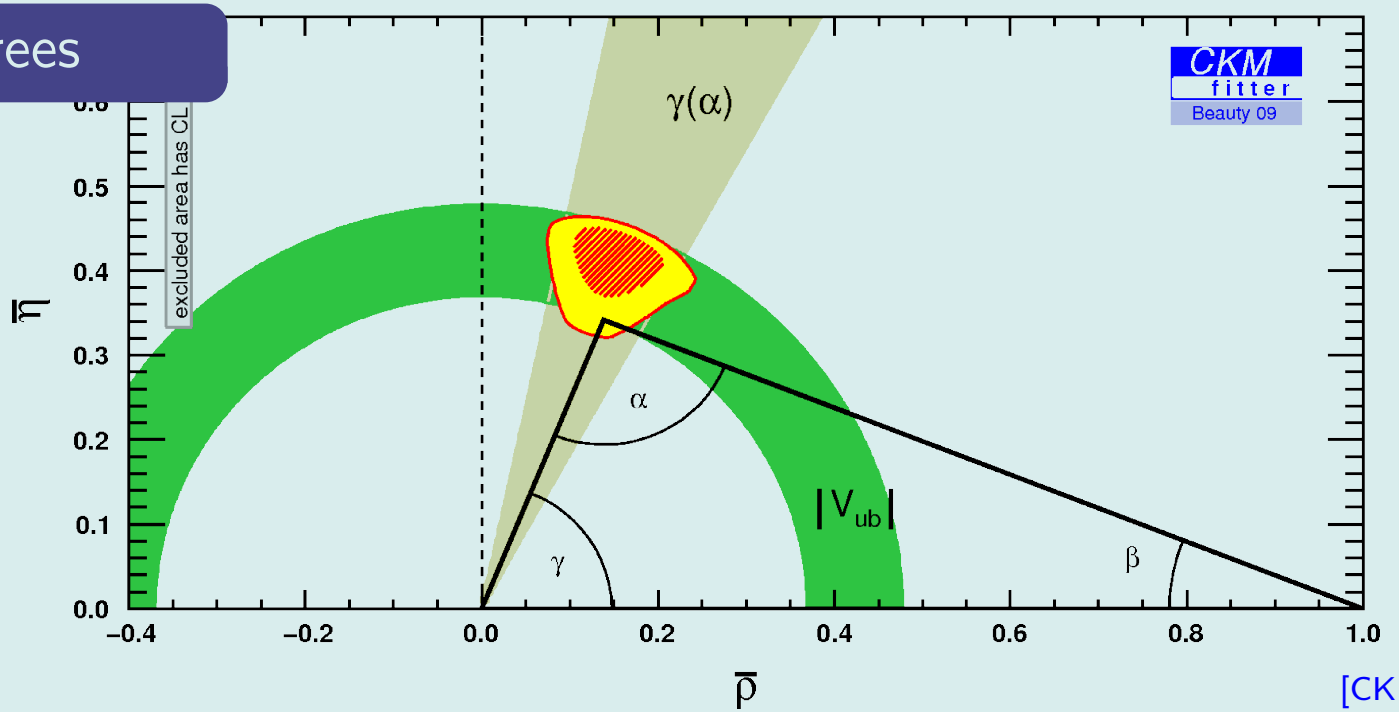
- Instead look for signs of New Physics
  - ➜ Discrepancies in measurements or unitarity triangle
- We don't know much about constraints from trees

Only trees



[CKMfitter 09/09]

Unitarity Triangle

- Changed focus: No longer seeking to verify the CKM picture
- Instead look for signs of New Physics
  - ➜ Discrepancies in measurements or unitarity triangle

✔ Look for rare B & D decays (and K as well)

➜ **Need a lot of data and a good precision**

✔ Need very good precision on all angles and sides.

  ✔ Precise measurement of ϕ_3

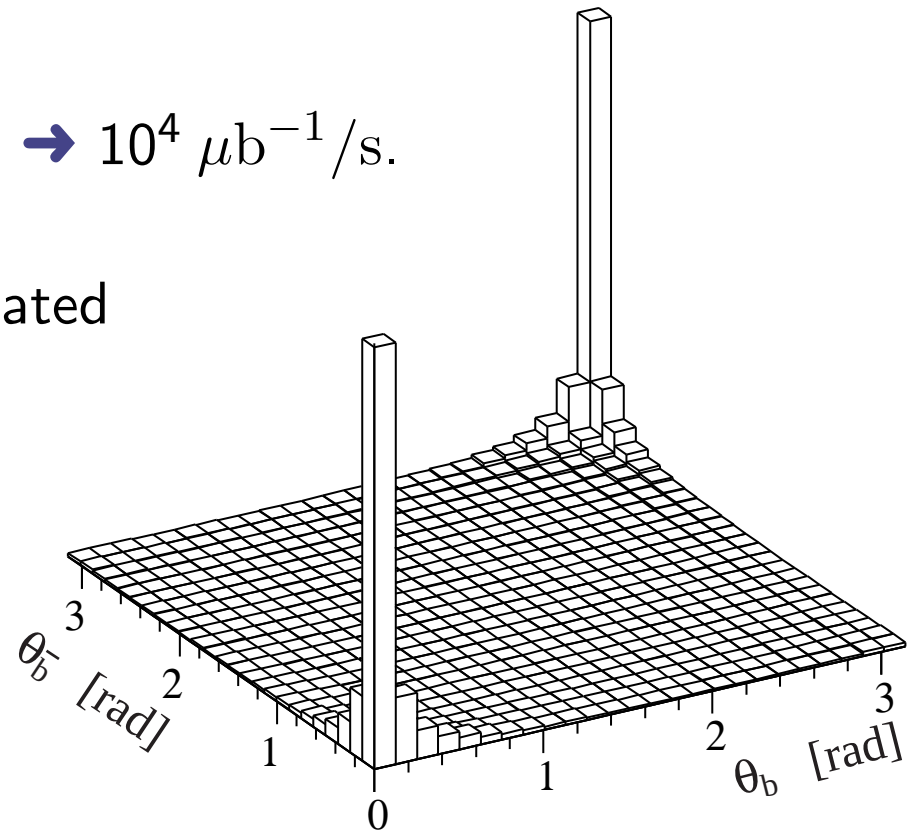
✔ Need B_s as well ➜ β_s and more

The Large Hadron Collider beauty experiment for precise measurements of CP violation and rare decays

LHC

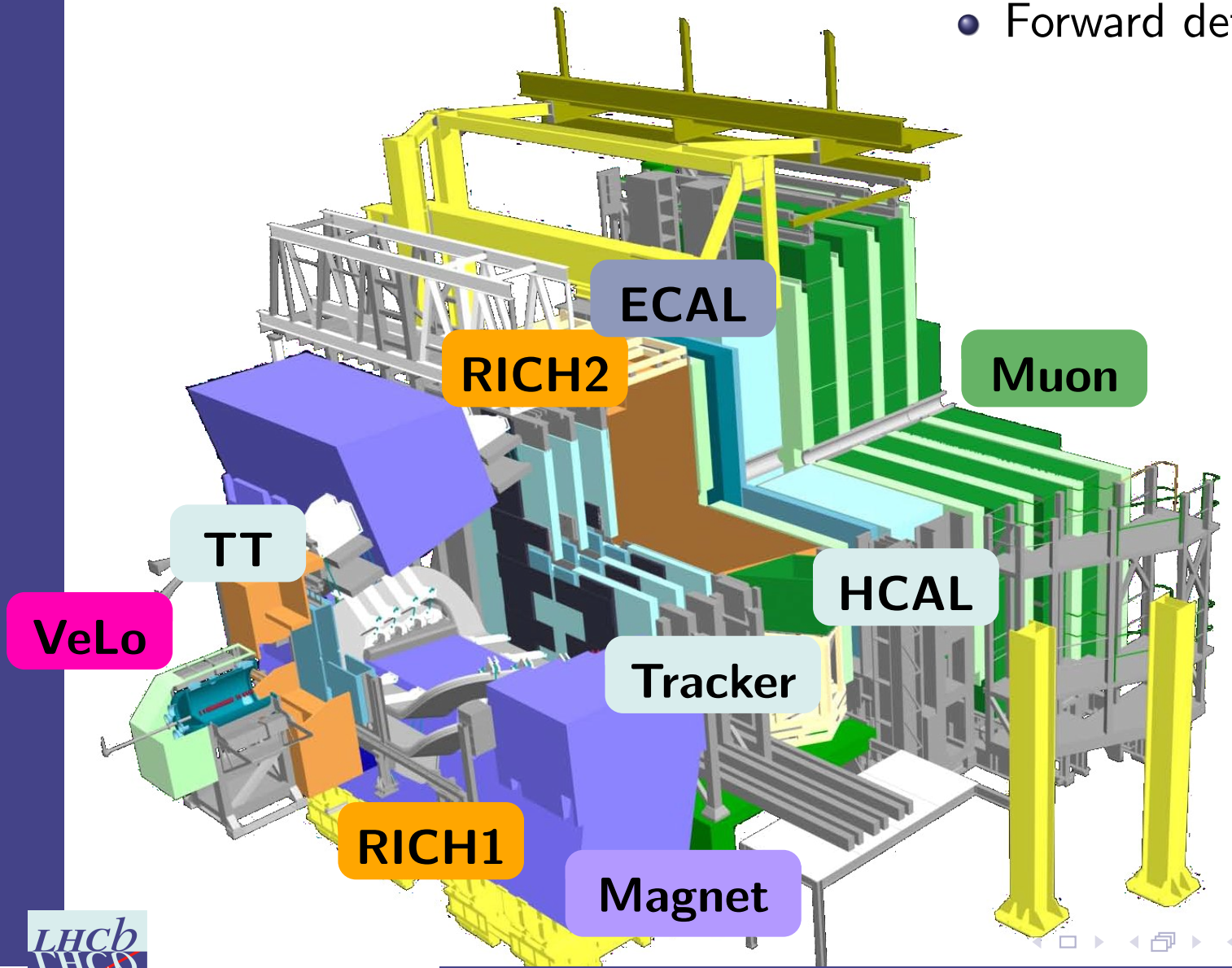
Nominal LHC Environment

- pp collider at 14 TeV (7 TeV in 2010–12)
  - Inelastic cross-section about 60 mb
  - Assumed $b\bar{b}$ cross-section about 500 $\mu\mathrm{b}$ (one every 120)
  - Our `Pythia` tuning predicts more than 1 mb at 14 TeV
- Bunch crossings at 40 MHz
- Luminosity up to $10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ ➜ $10^{4}\,\mu\mathrm{b}^{-1}/\mathrm{s}$.
  - ➜ $5 \cdot 10^{6}$ $b\bar{b}$ pairs per second
- Direction of b and $\bar{b}$ very correlated
  - ➜ A 4π coverage not optimal
  - ➜ Build a forward spectrometer
- The choice of the LHCb collaboration

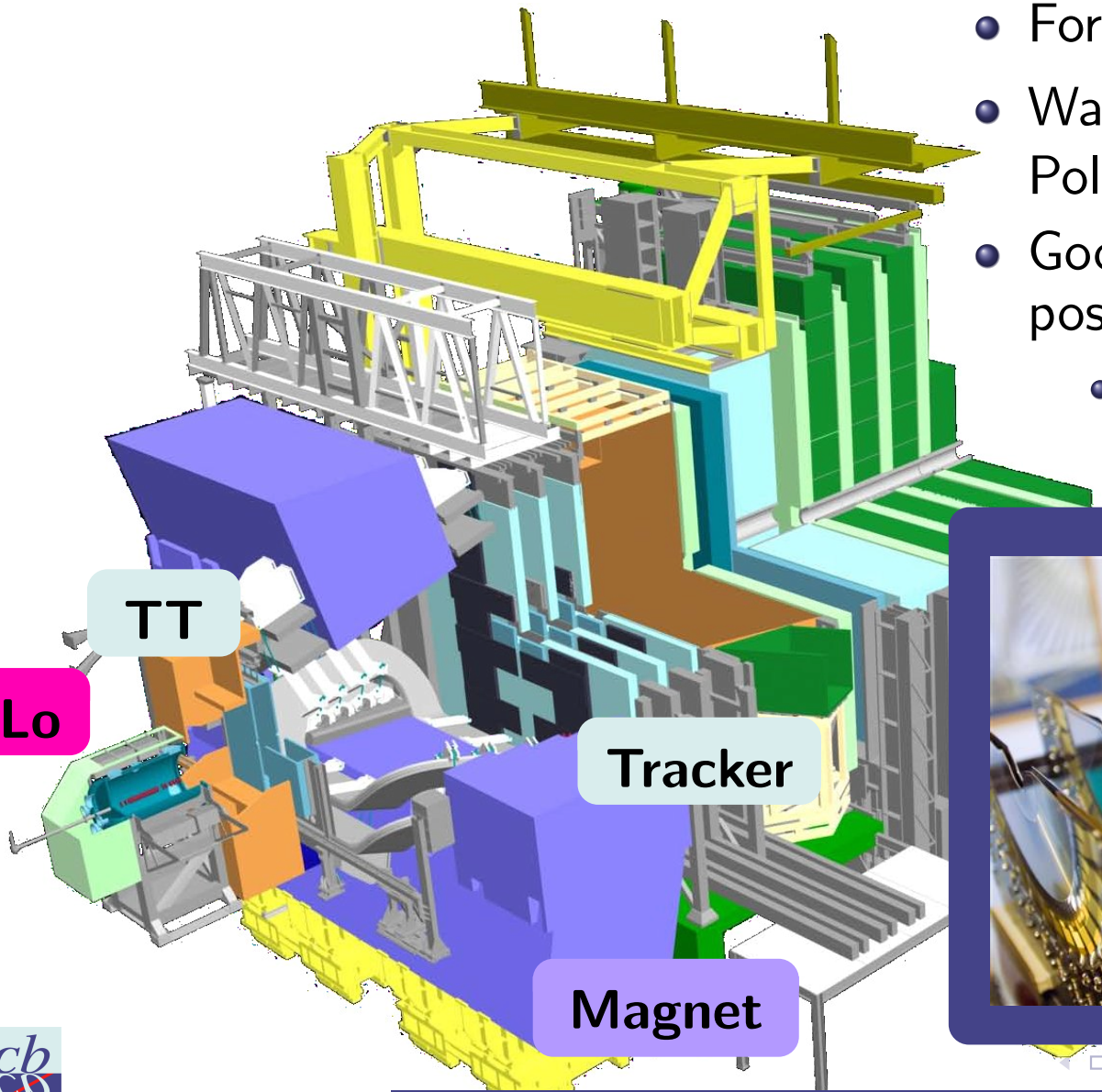


LHCb

- Forward detector

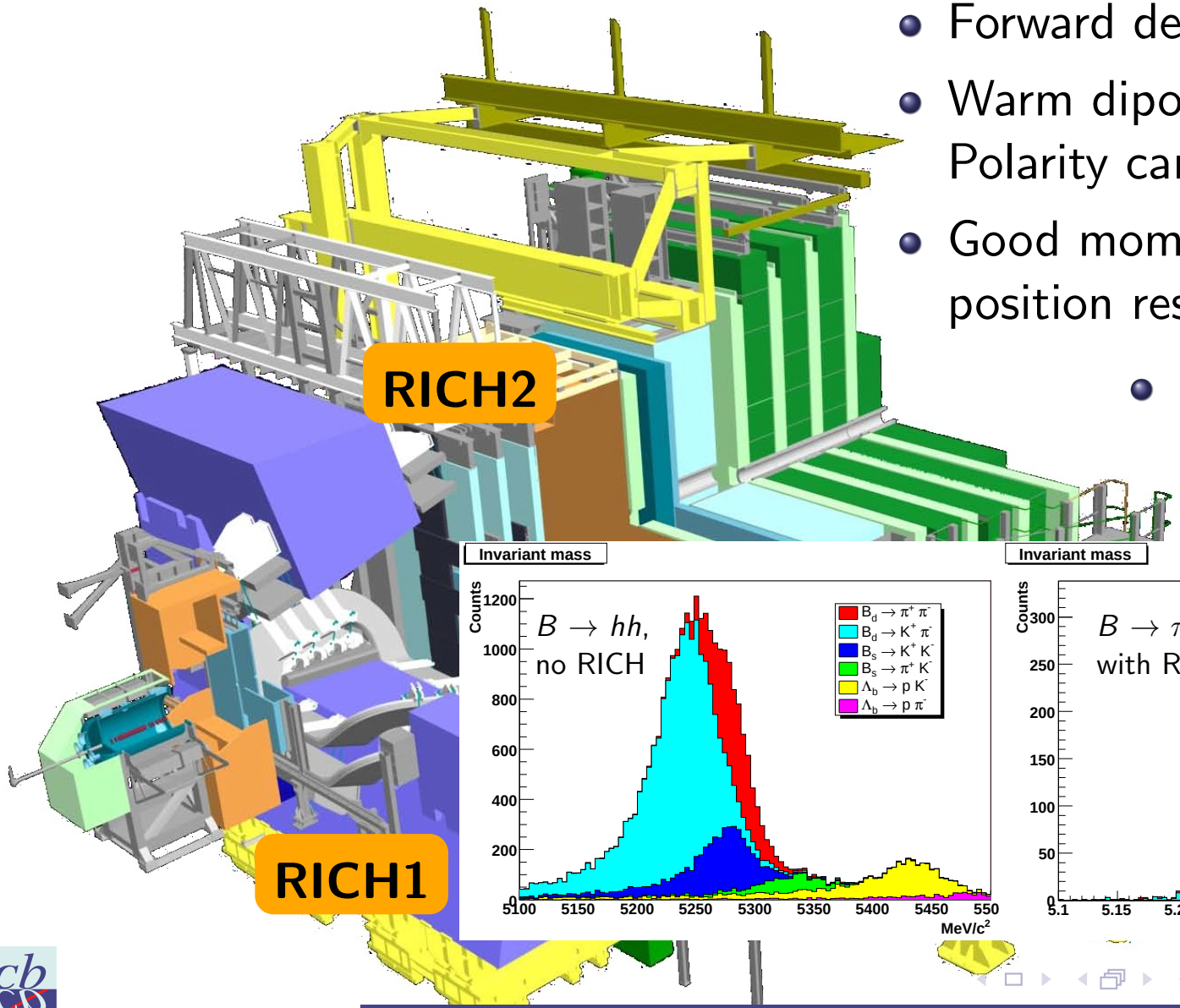


LHCb

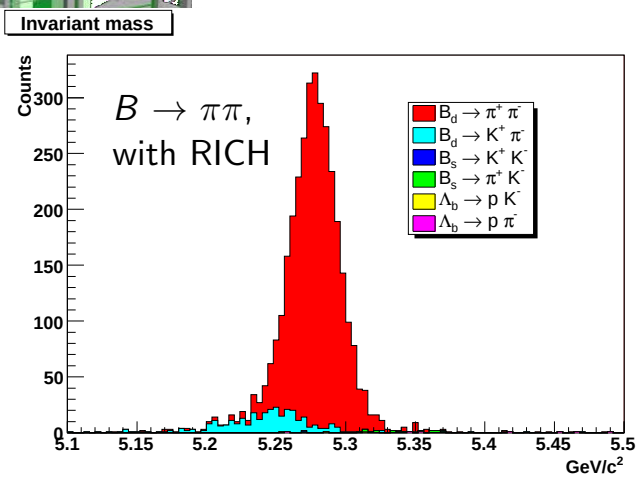


- Forward detector
- Warm dipole magnet. Polarity can be reversed
- Good momentum and position resolution
  - Vertex detector gets 8mm to the beam

LHCb

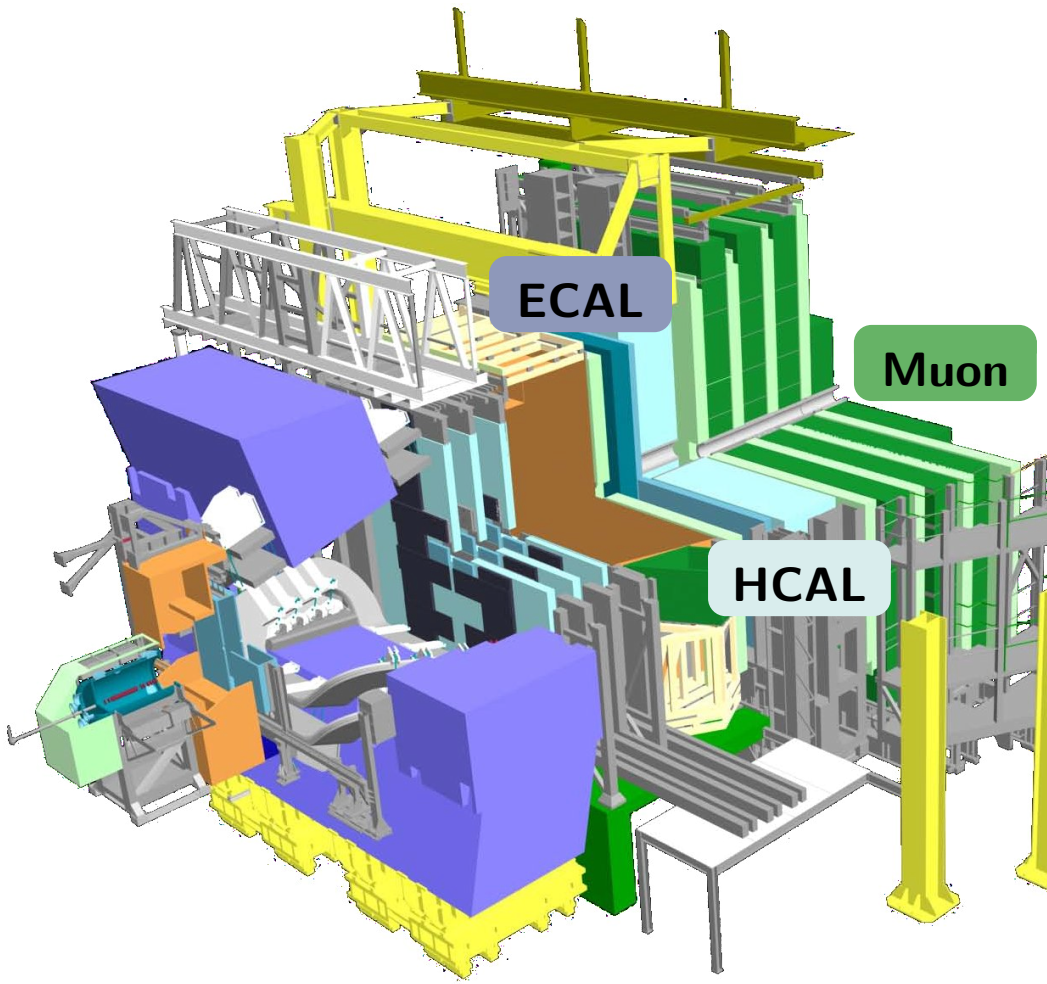


- Forward detector
- Warm dipole magnet. Polarity can be reversed
- Good momentum and position resolution
  - Good Particle Identification



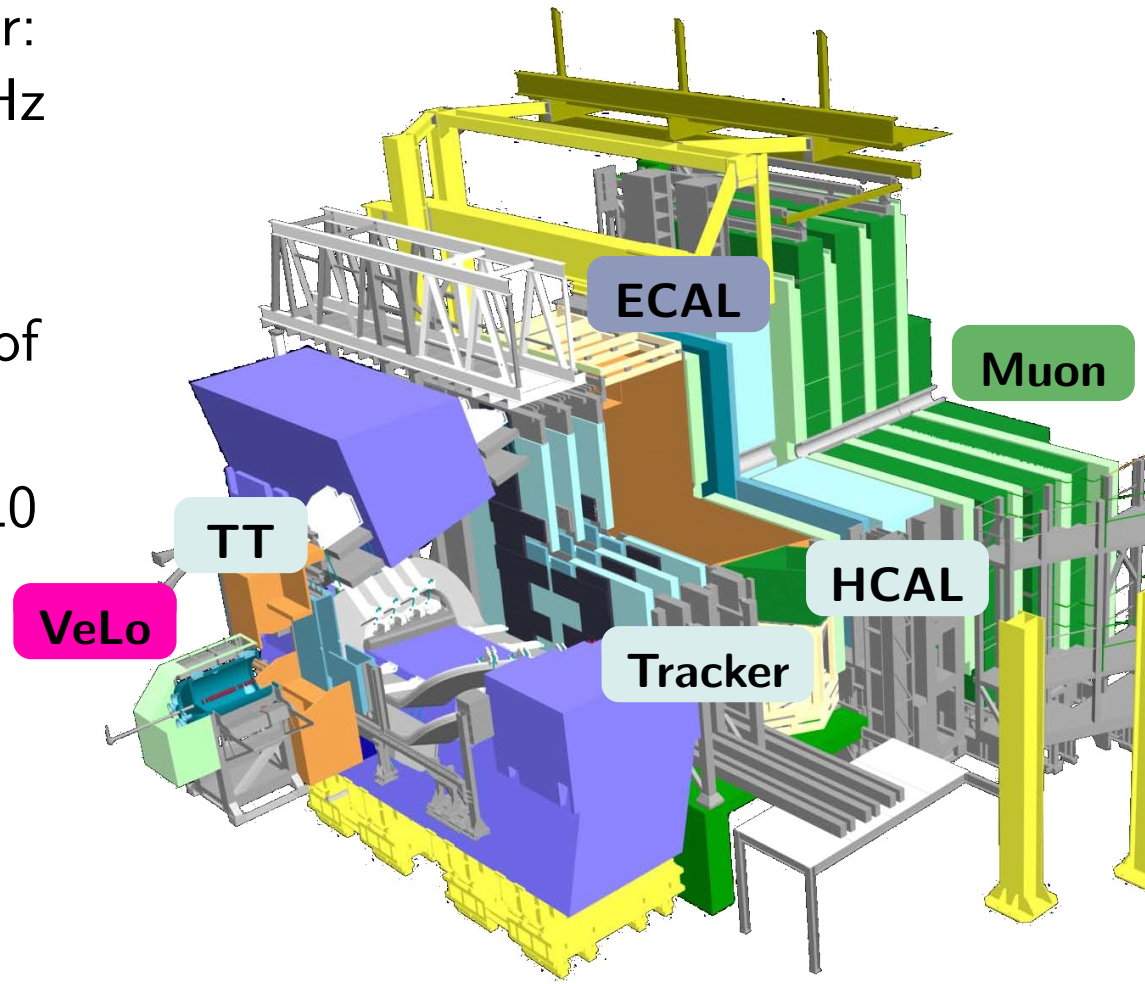
LHCb Trigger

- Hardware-based L0 trigger:
  moderate p_T cuts: 40 MHz
  ➜ 1 MHz



LHCb Trigger

- Hardware-based L0 trigger: moderate p_T cuts: 40 MHz ➜ 1 MHz
- The whole data is then sent at 1 MHz to a farm of $\mathcal{O}(2000)$ CPUs
- HLT1 tries to confirm a L0 decision by matching the L0 candidates to tracks. ➜ $\sim$ 30 kHz



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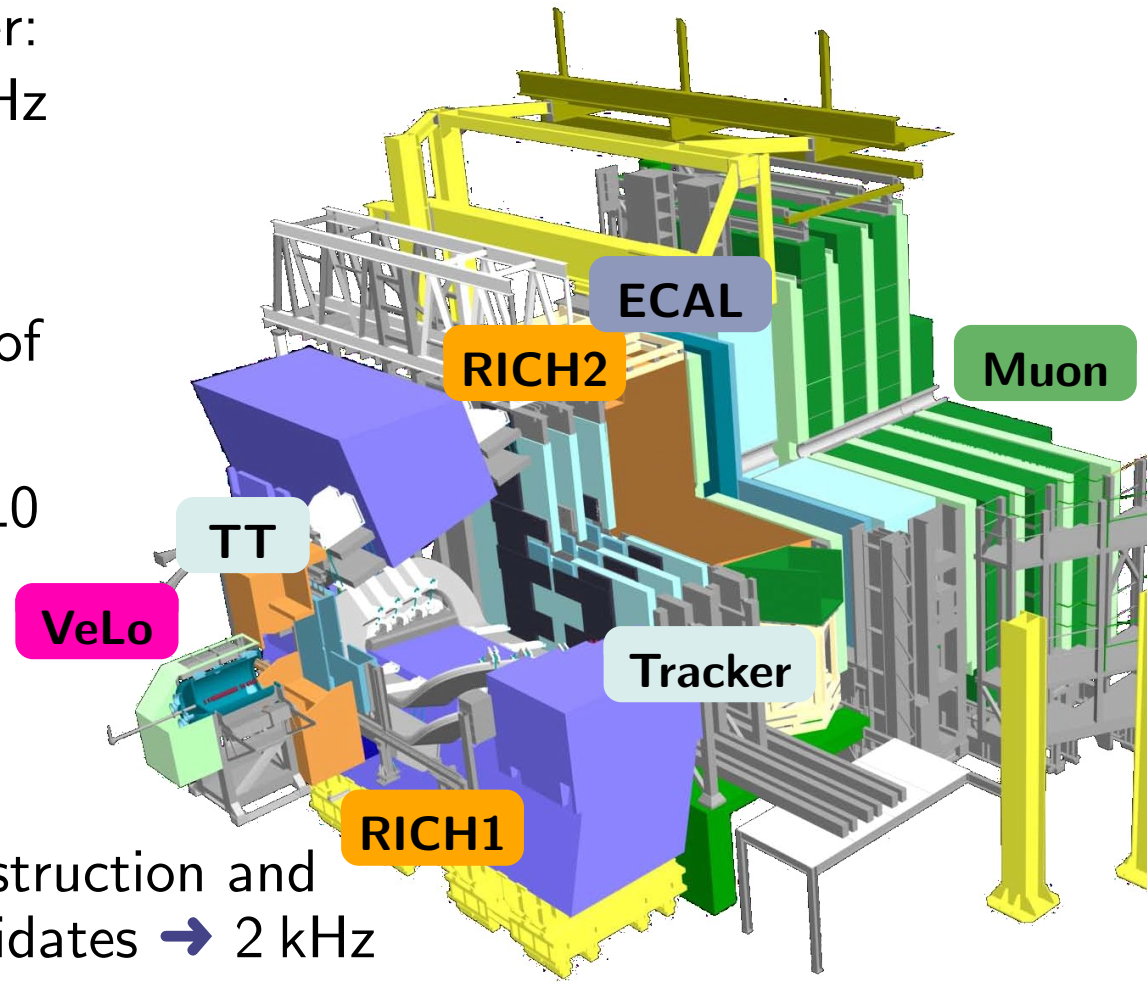
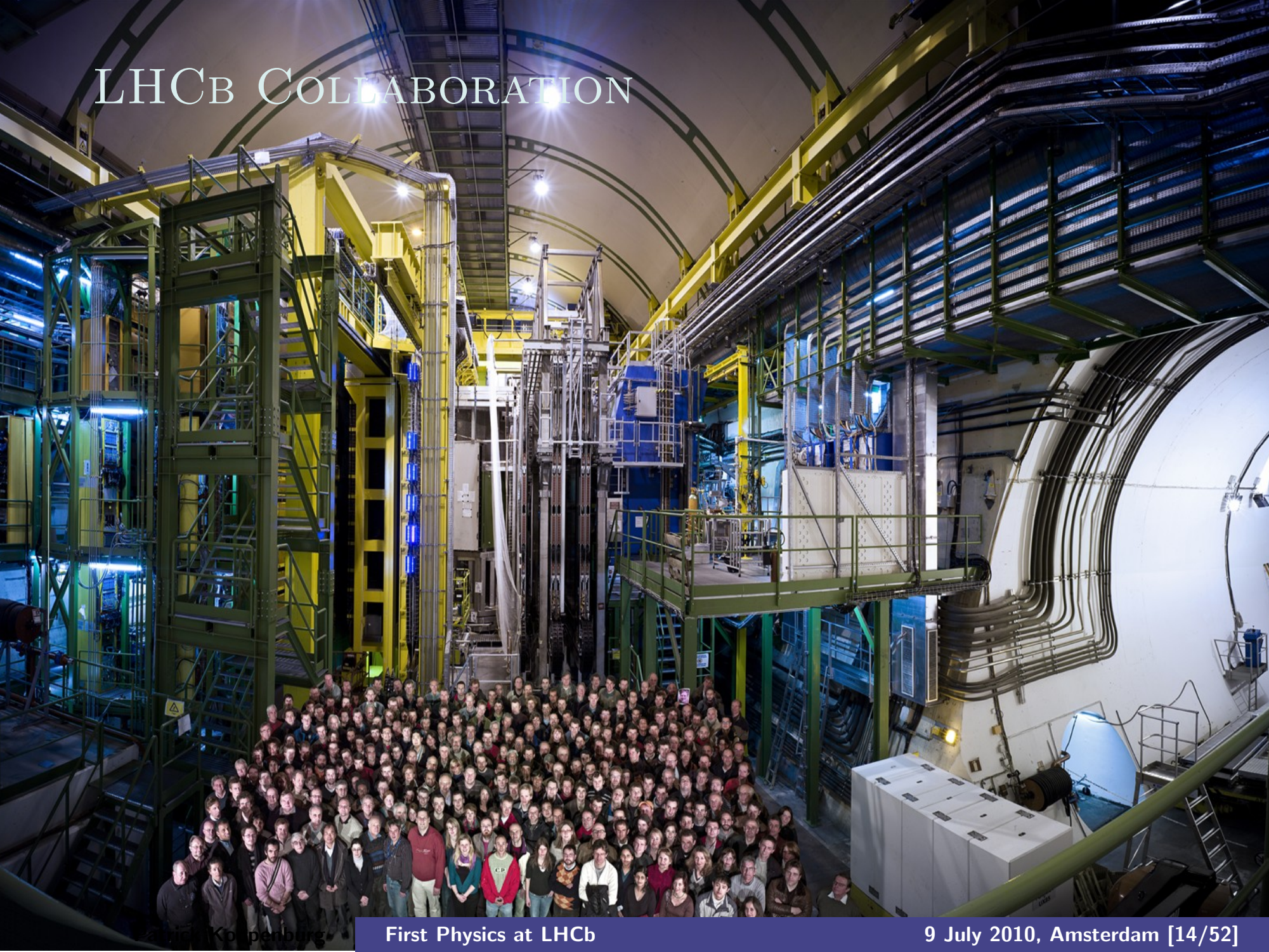


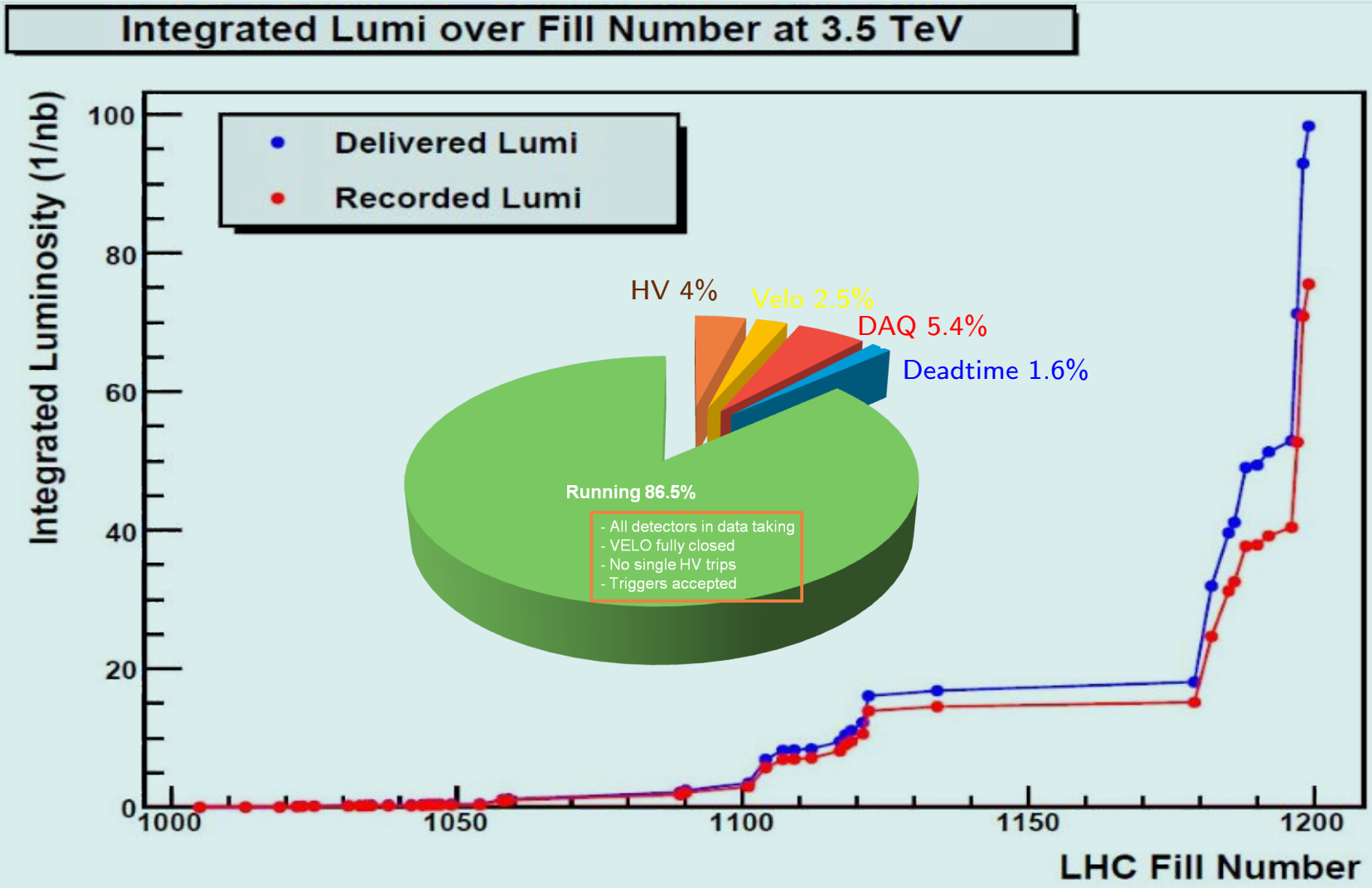
- HLT2 does the full reconstruction and loose selection of B candidates ➜ 2 kHz
  - This is much less than the 10^5 b events per second

LHCb Collaboration



2010 Data Taking

Luminosity at 3.5 TeV



Trigger Strategy

L0: Based on Calo, Muon and Pile-up

MB triggers: HCAL, SPD, CALO, MUON, Pile-Up ...

c,b triggers: Electron, Photon, Hadron, Muon, Di-Muon, π^0

Luminosity: Muon, Di-Muon, Beam-Gas

Readout Supervisor: Passes on L0 decision and adds random triggers

- Knows about bunch structure.

HLT: software based on "everything"

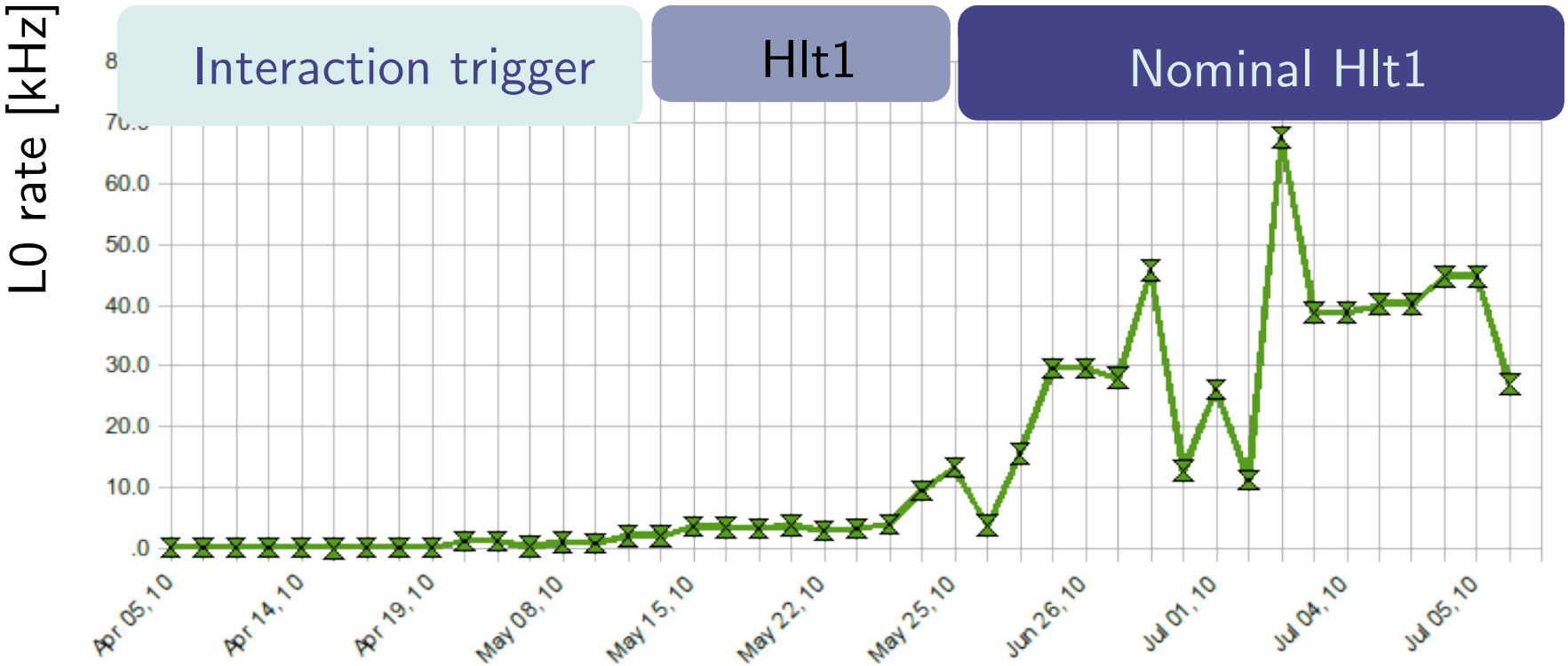
Hlt1: Confirmation of L0 objects ➜ $\sim$ 2kHz

Hlt2: All combinatorics. Presently still in pass-all mode.

Micro-Bias: At least one track in velo (RZ), or T stations (no downscaled to 100 Hz)

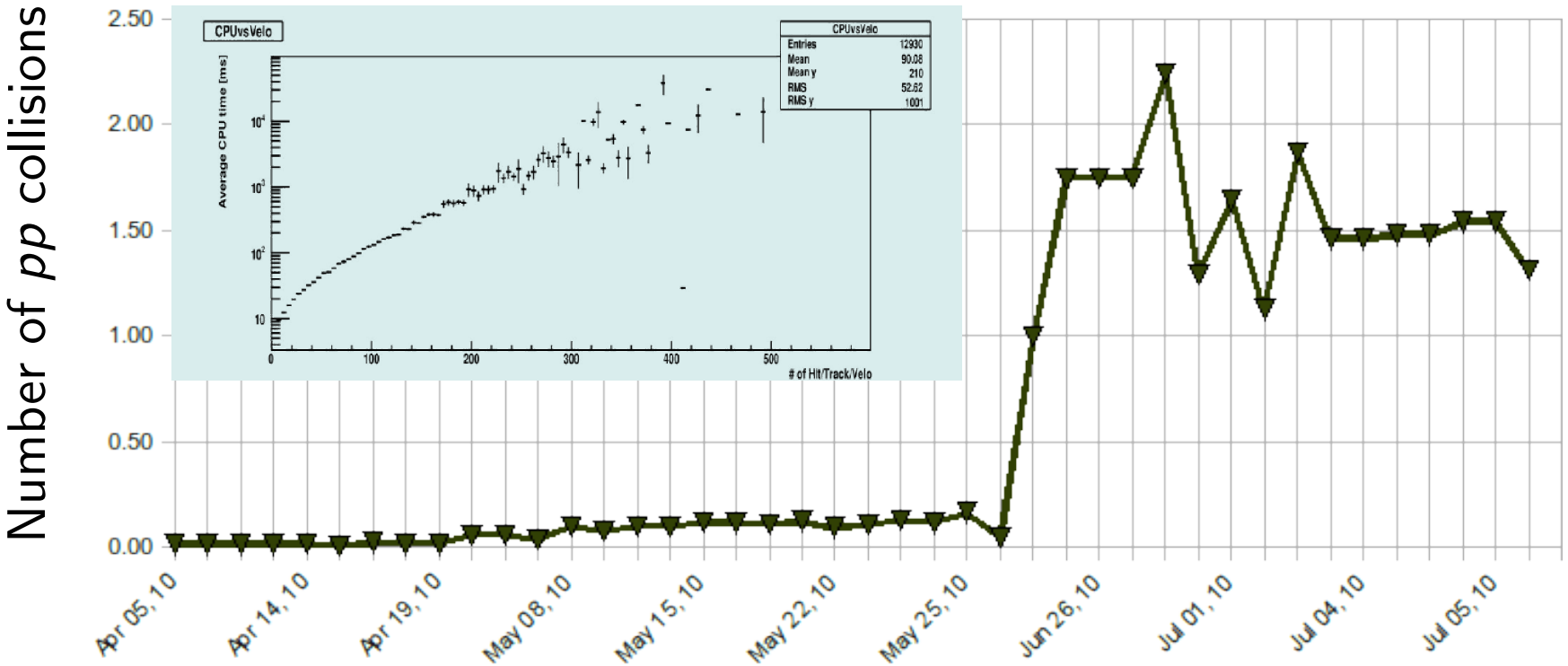
No-Bias: Downscaled random

Trigger Operations



L0 rate: Close to 11 kHz per pair of bunches

Trigger Operations

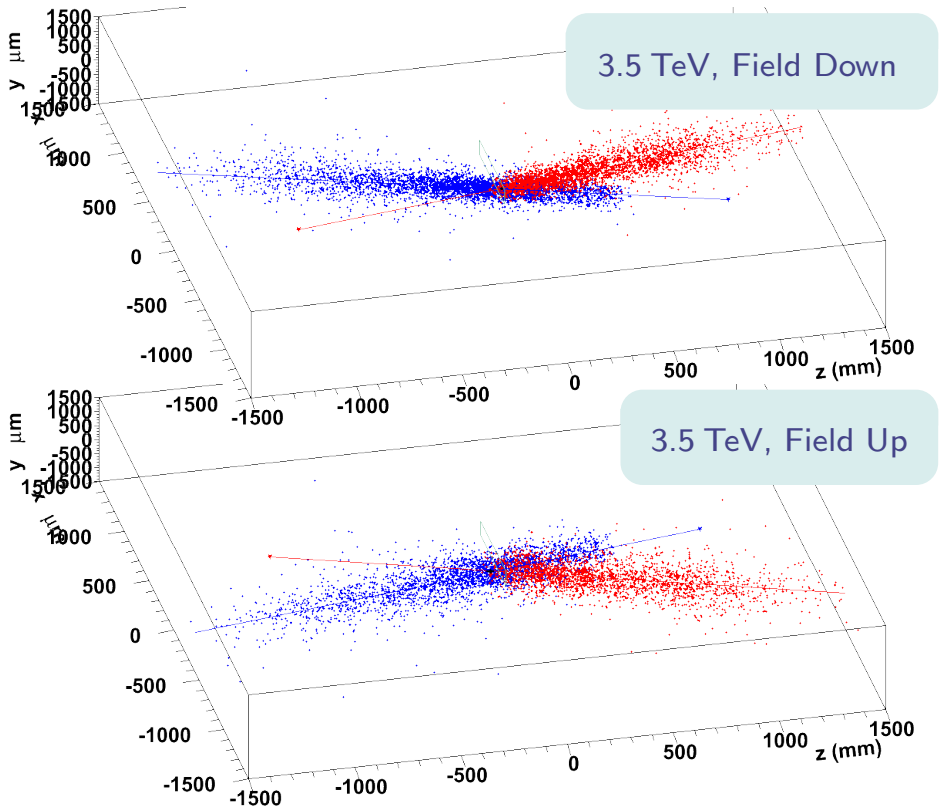


L0 rate: Close to 11 kHz per pair of bunches

Pile-up: The issue is the large pile-up: We are a factor 2–4 above nominal (like $8 \cdot 10^{32}$). CPU goes exponentially.

Magnet Polarity

- We can swap the magnet polarity
  - ➜ Important for systematic studies of CP effects
    - Trying to have 50% of each polarity for each trigger configuration.



- Primary vertex in Beam Gas events for Beam1 and Beam2
  - z coverage due to velo acceptance
  - Crossing angle due to B field
- Beam profiles used to determine luminous region
  - ➜ Luminosity

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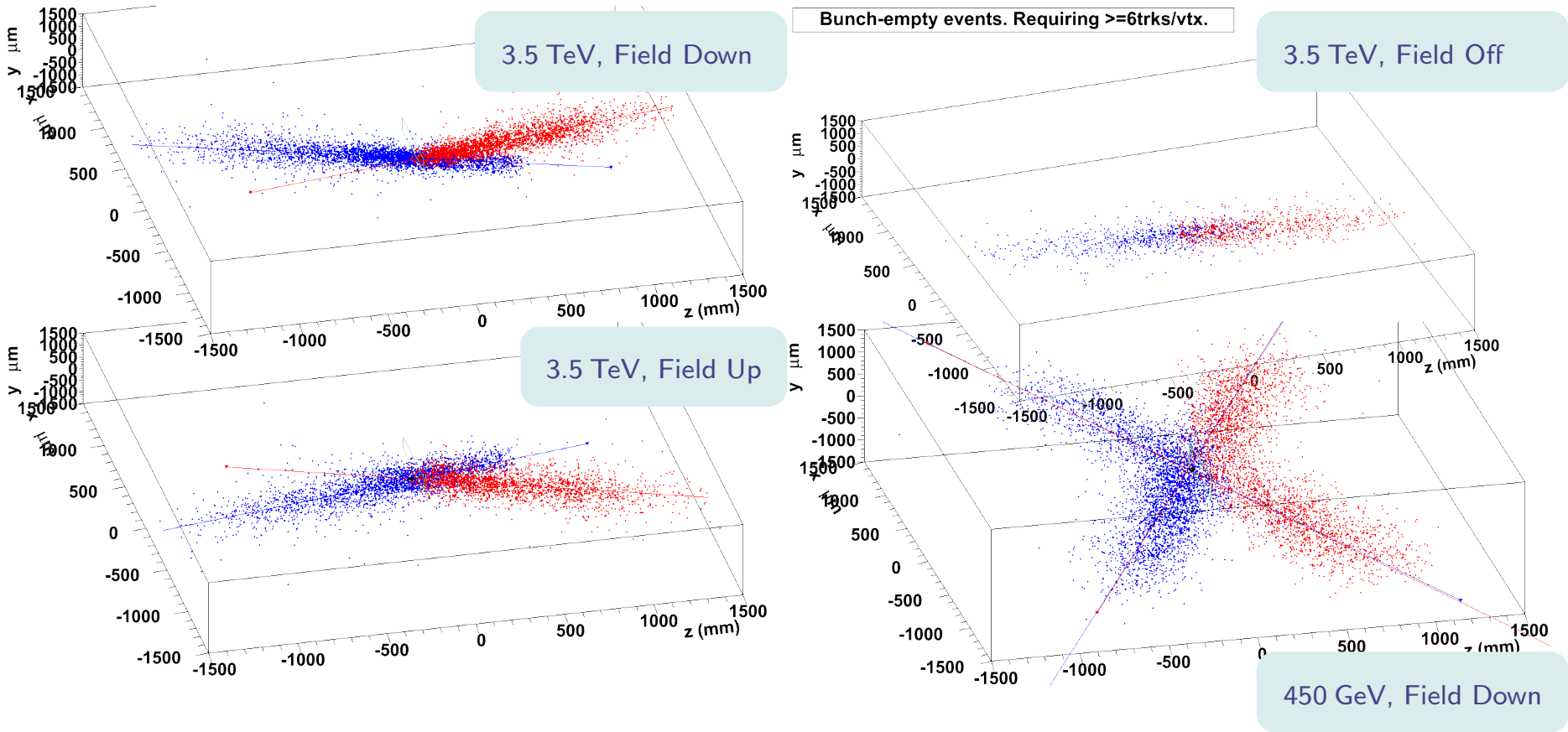
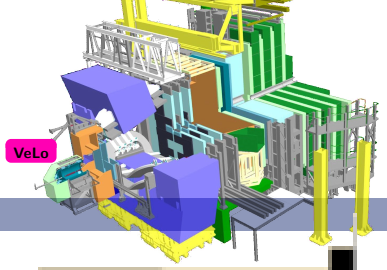
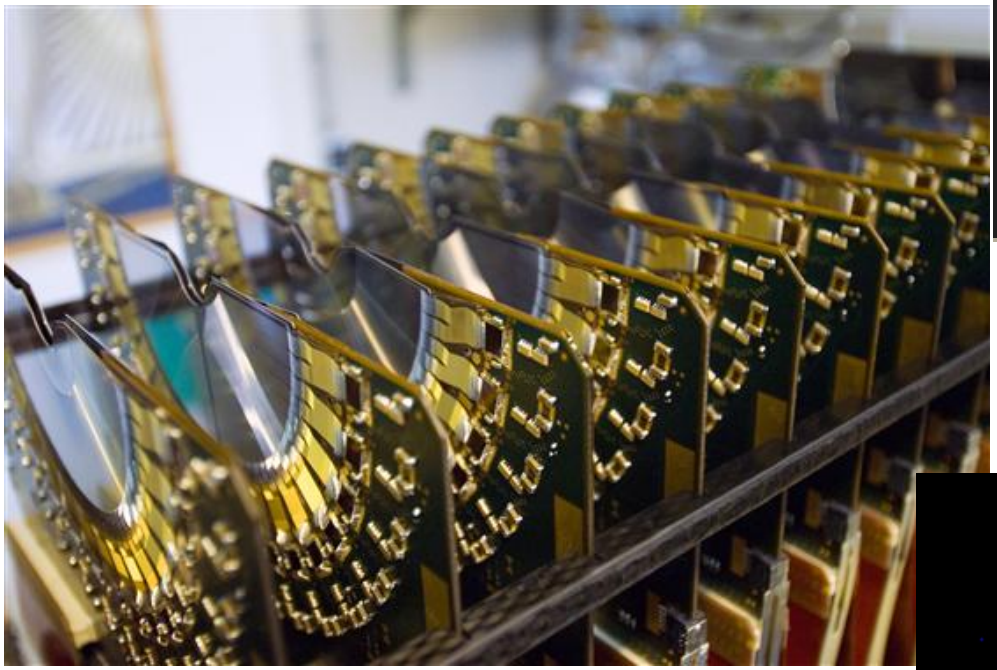
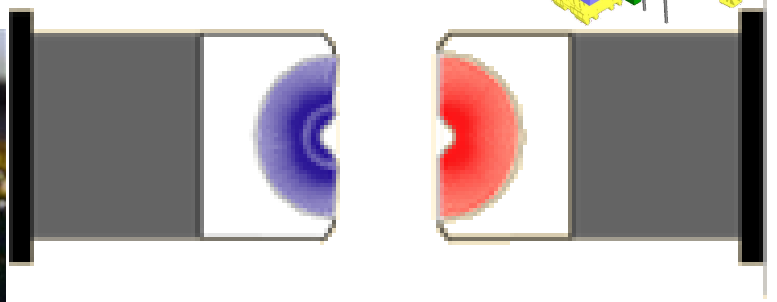
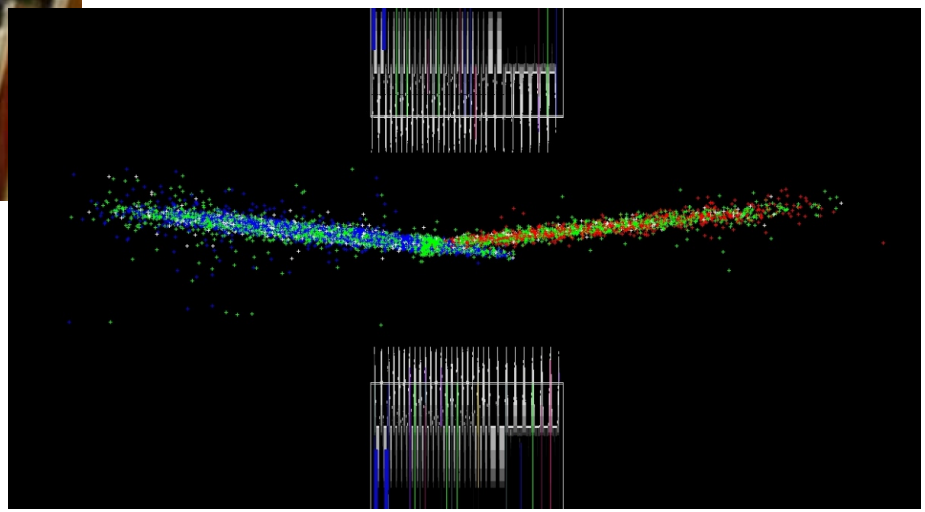


Velo



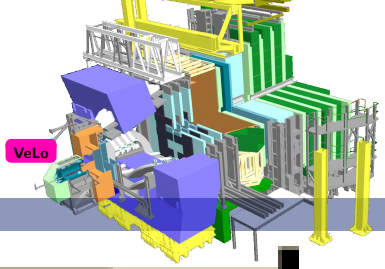


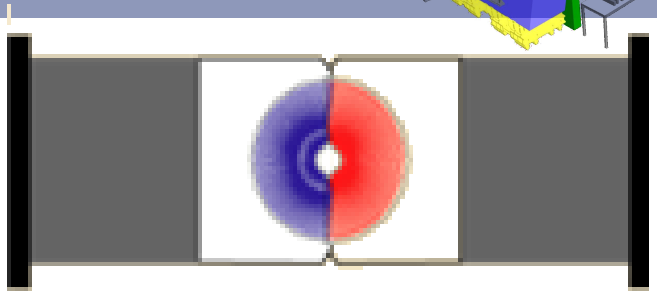


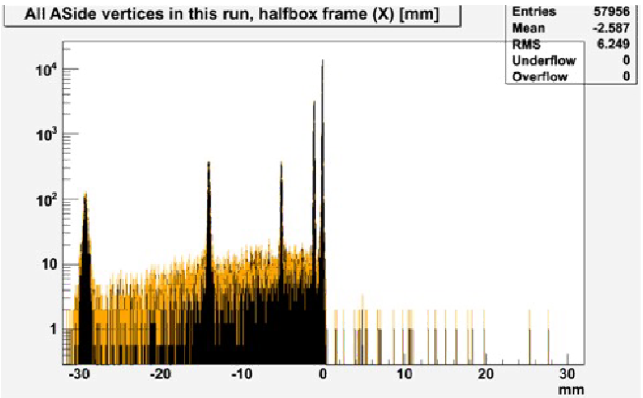


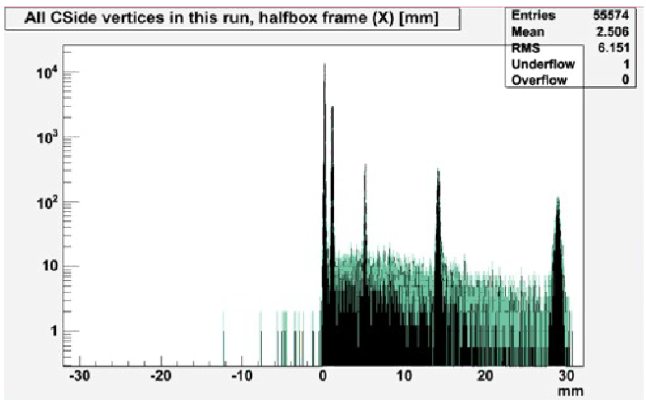
- Velo sensors all powered
- 99.3% are operational
- With 450 GeV beams we could not fully close the Velo
- . . . but we see where the beams are

Velo



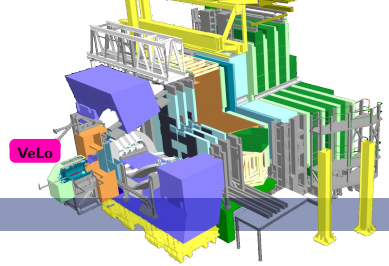




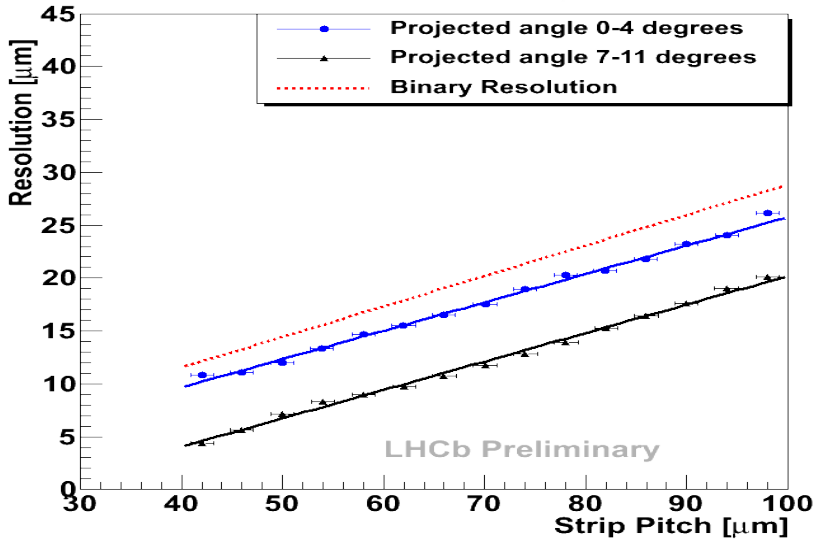


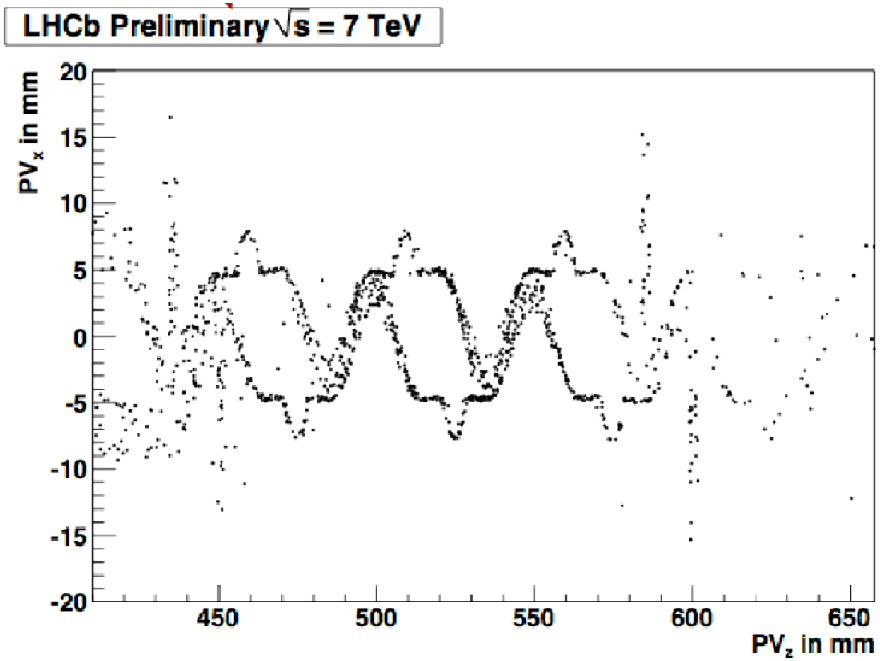
- Velo closed for the first time on 1. Apr
- Closing procedure now takes routinely < 6 minutes
- Stability in (X, Y, Z) : $(10, 5, 25)\ \mu\mathrm{m}$

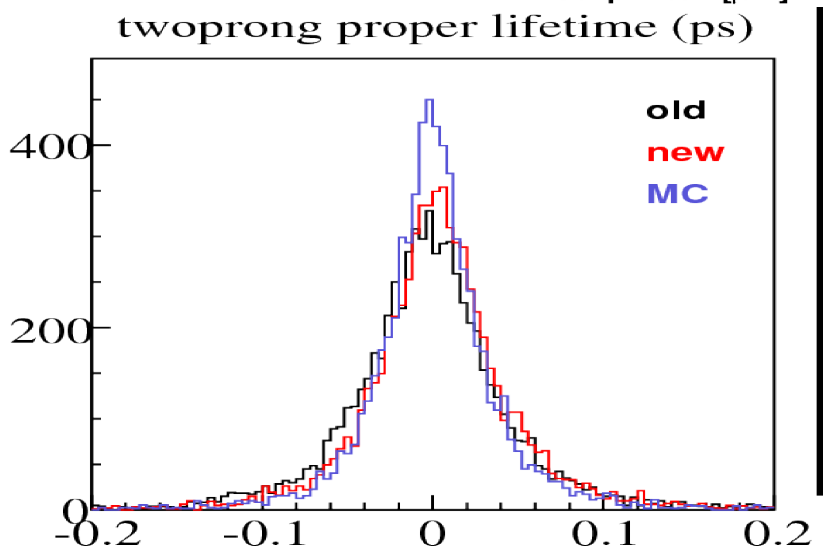
VELO



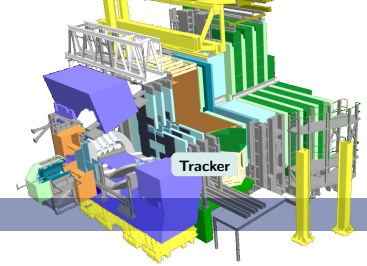
- Resolution is getting close to MC predictions
- One uncertainty was the thickness of the RF foil. But we start to see it.



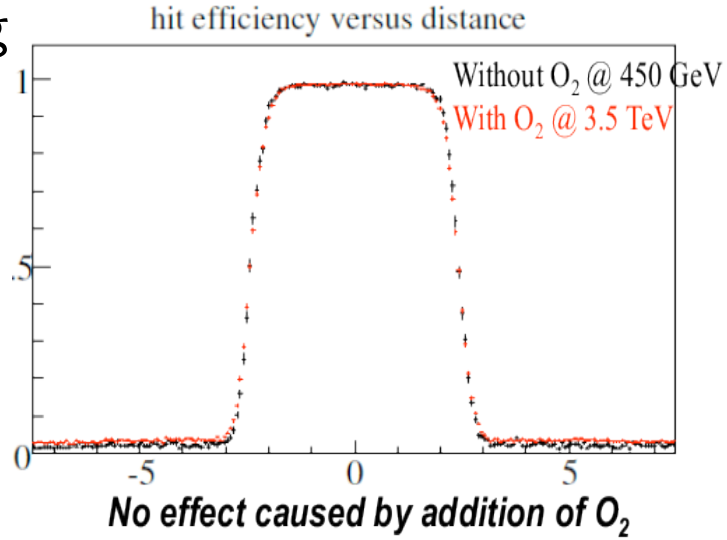


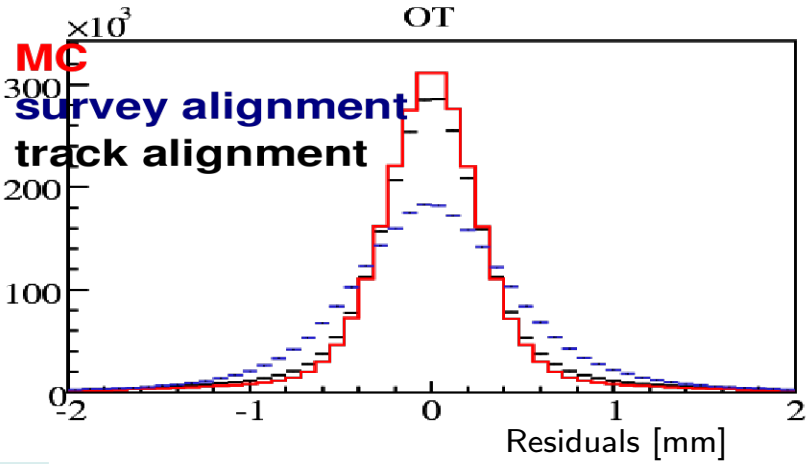


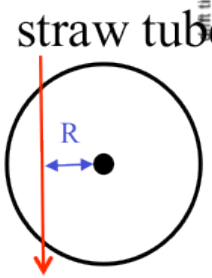
Outer Tracker

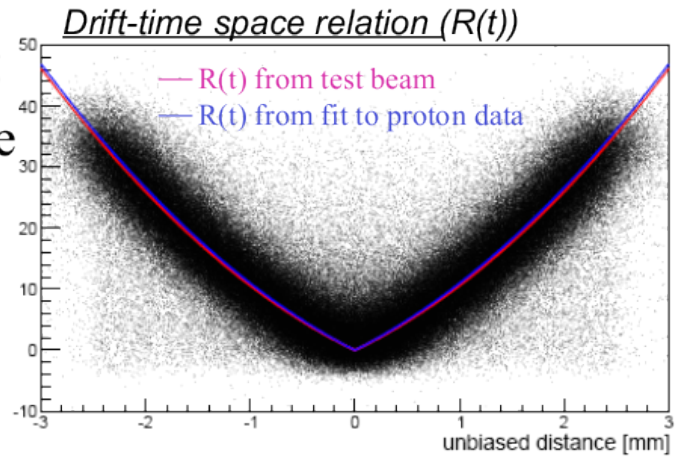


- Detector is 100% efficient and running at nominal threshold with low noise
- O_2 was added to the gas mixture in order to mitigate ageing effects. No effect on hit efficiency is observed.
- Space vs drift-time relation fits expectation from test beam
- Alignment is getting close to MC









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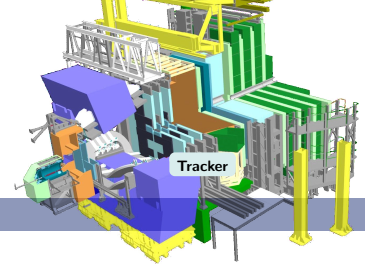
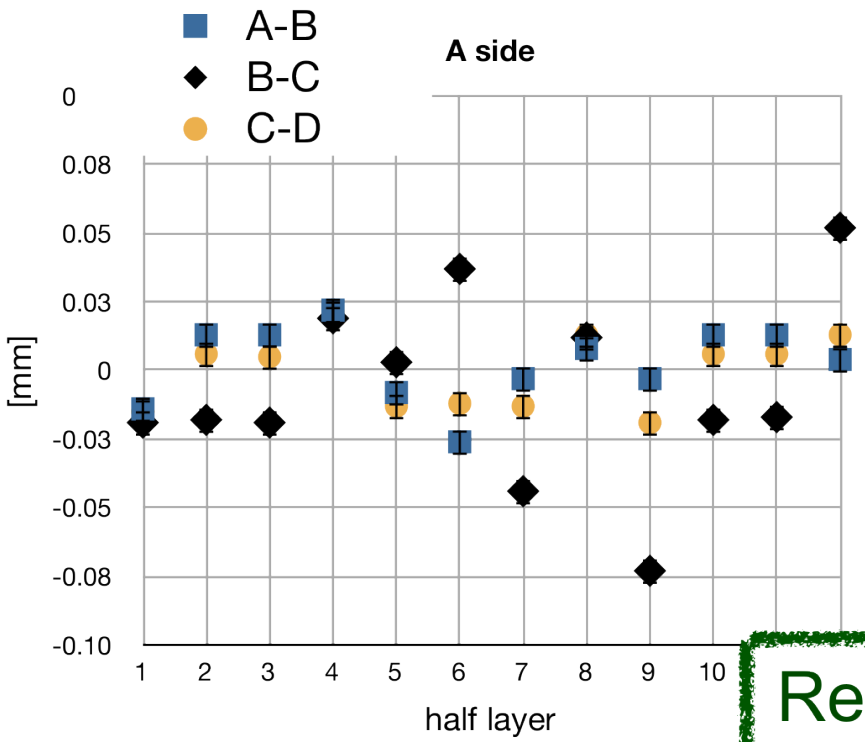
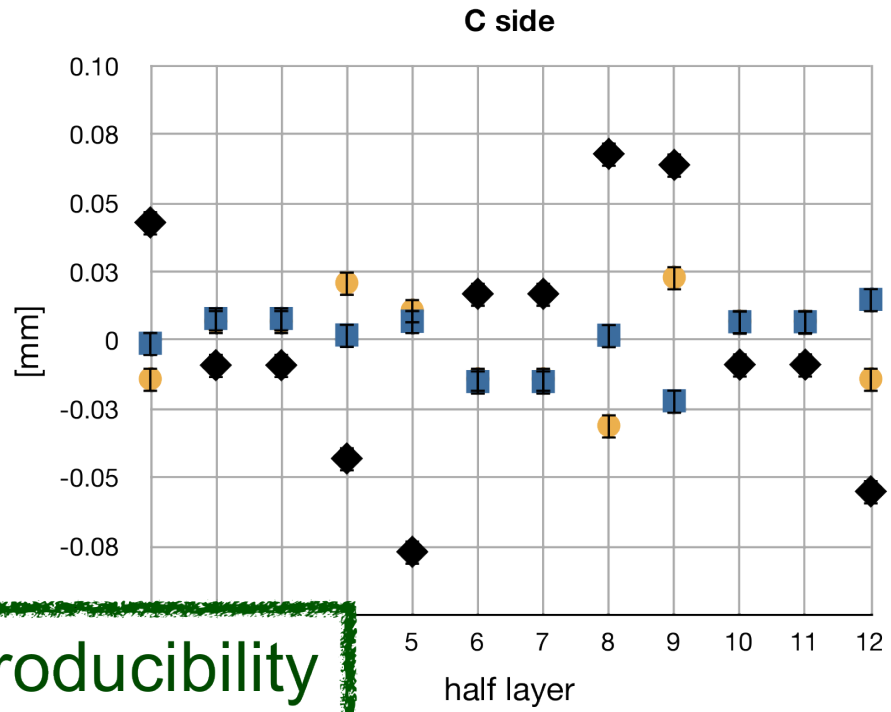


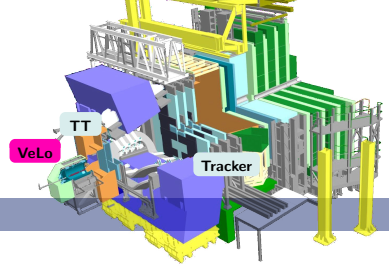
- OT openings for maintenance have little effect
- Stability within 80 μm (30 μm when nothing moves)

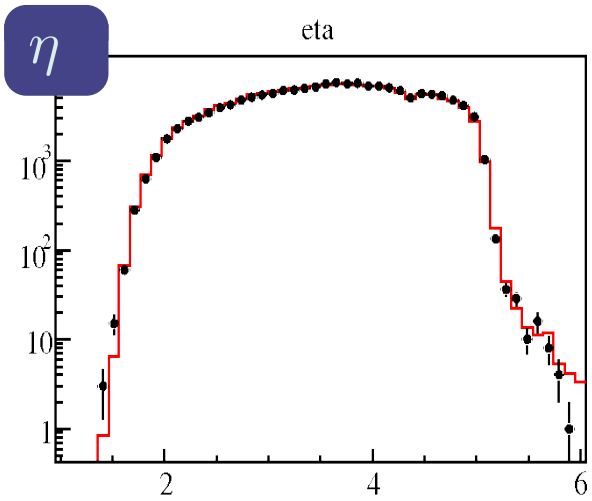


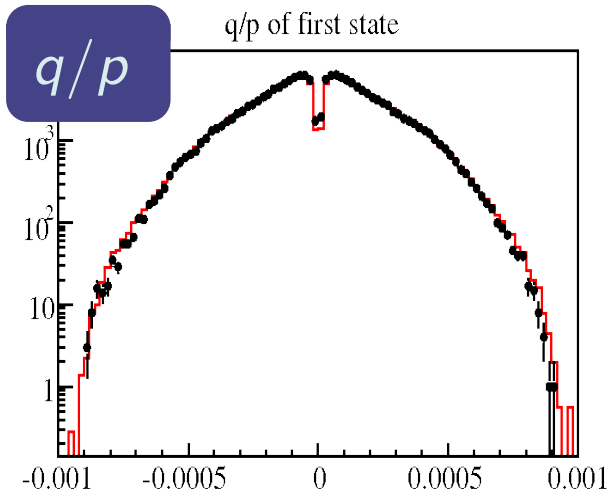


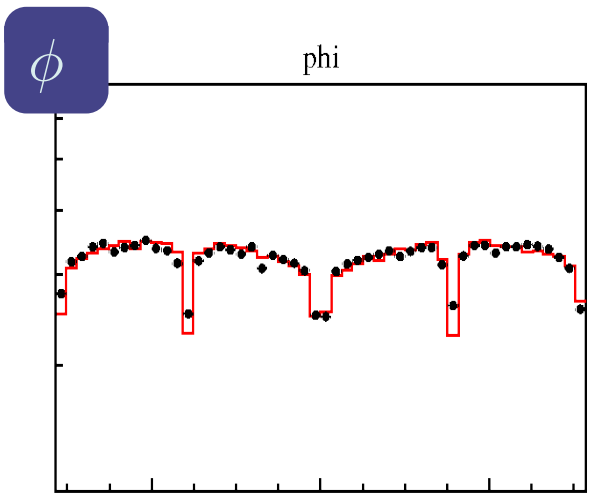
Reproducibility within 80 µm

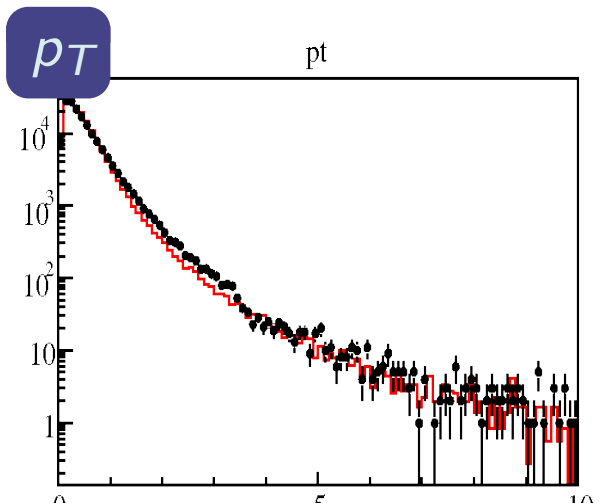
Long Tracks (Velo & T stations)





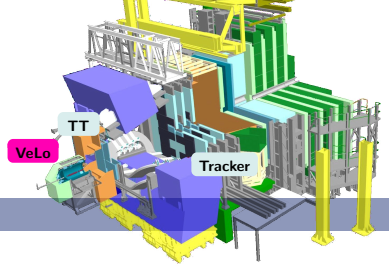




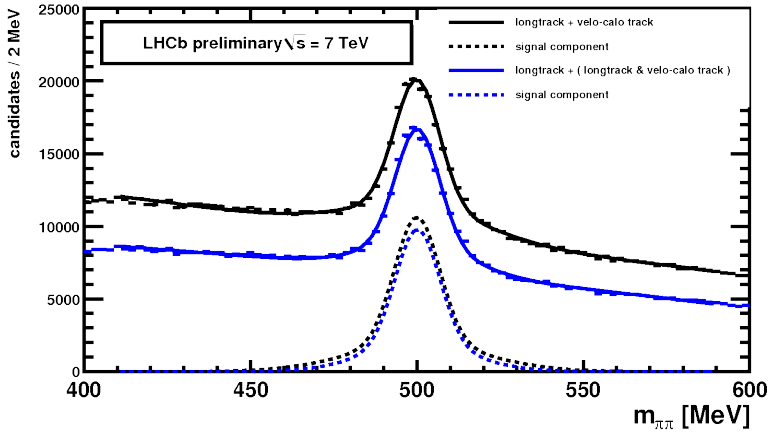


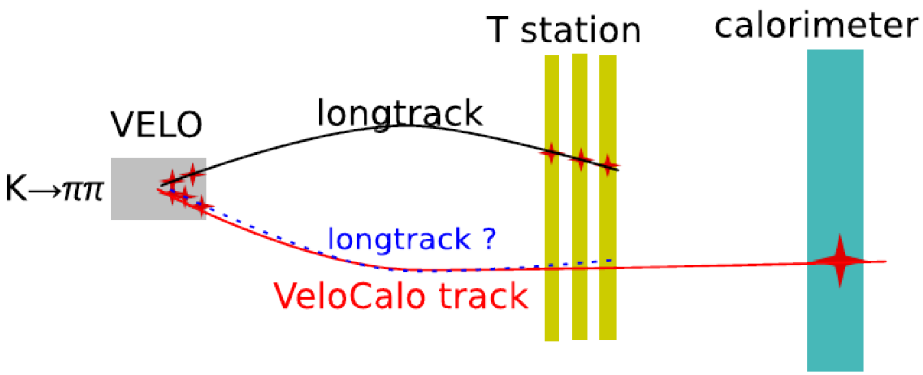
- Good agreement between data and MC

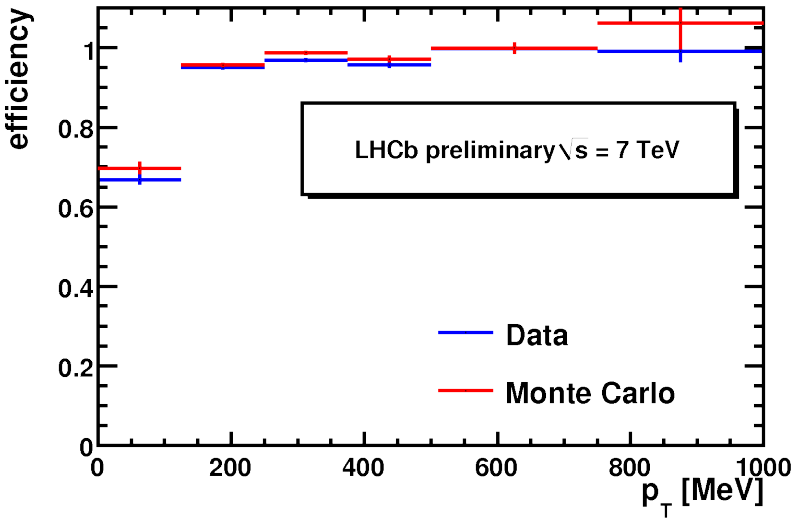
Tracking Efficiency



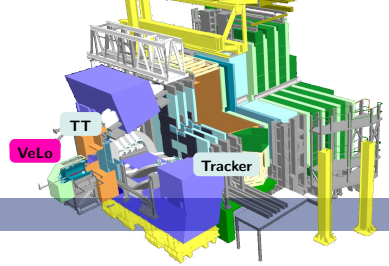
- Tracking Efficiency from Tag and Probe method using K^0_S with Calo : $\pm 4\%$



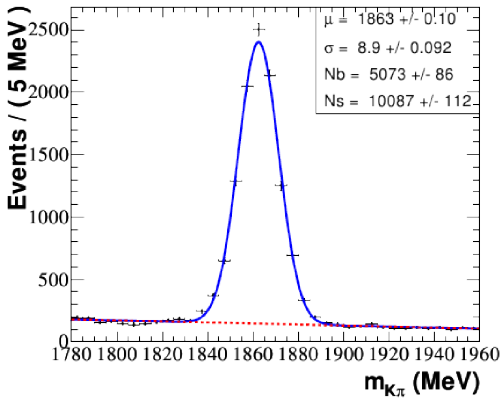


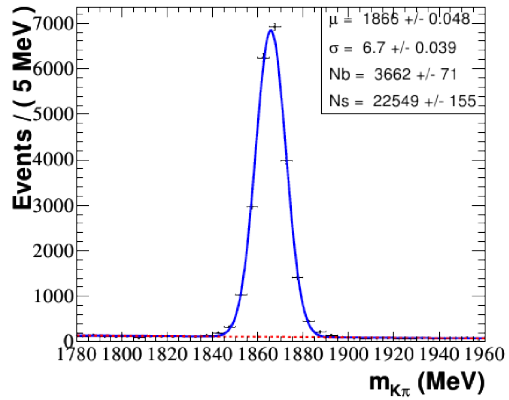


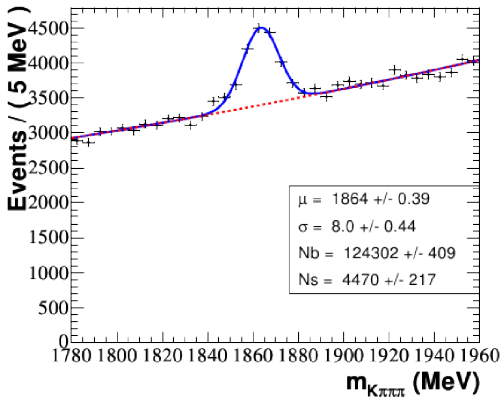
Tracking Efficiency

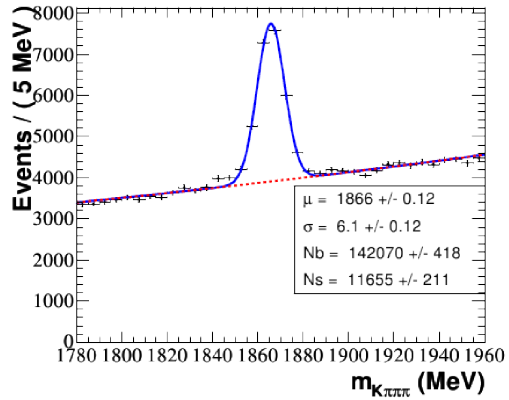


- Tracking Efficiency from Tag and Probe method using K^0_S with Calo : $\pm 4\%$
- From $D \to K\pi$ and $D \to K\pi\pi\pi$: $\pm 3\%$

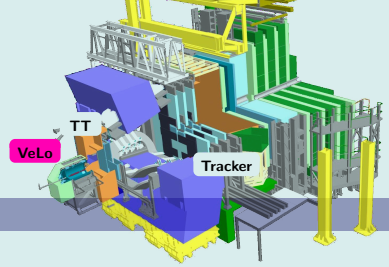




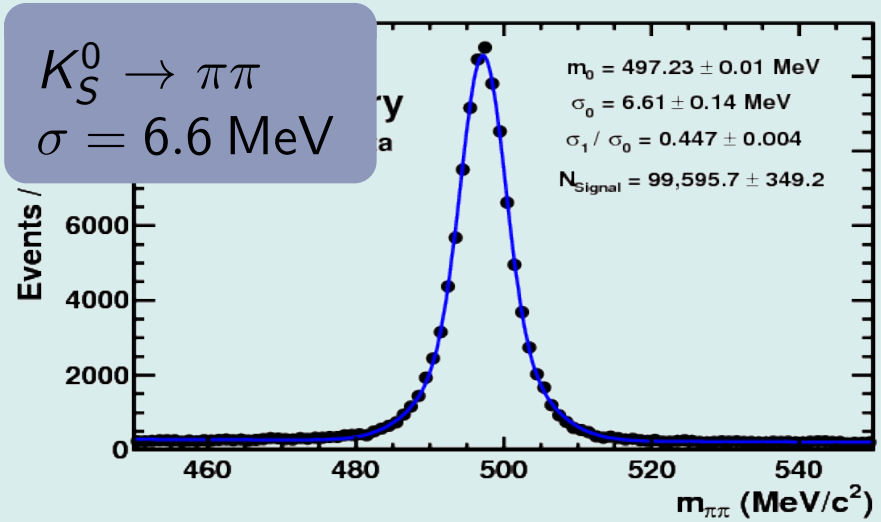




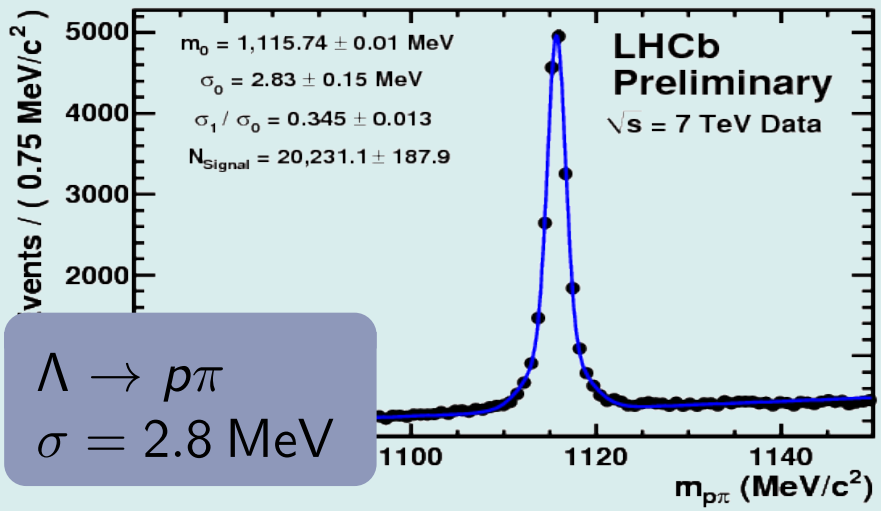
Zoology 1 — K^0_S, Λ, Ξ, Ω



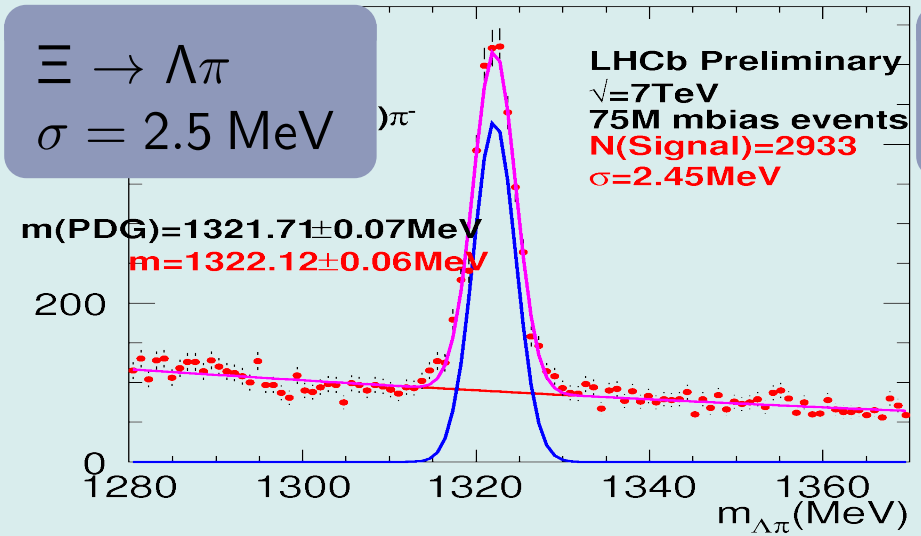
$K^0_S \to \pi\pi$
$\sigma = 6.6$ MeV



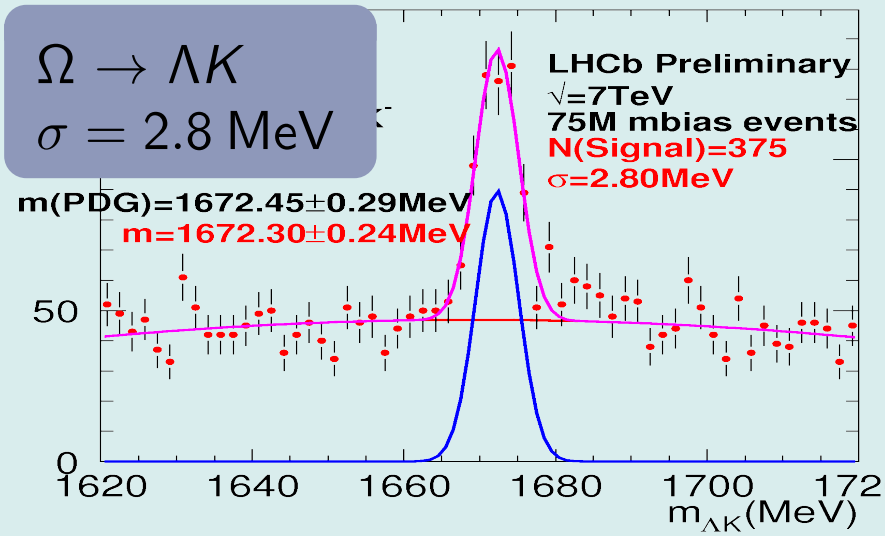
$\Lambda \to p\pi$
$\sigma = 2.8$ MeV



$\Xi \to \Lambda\pi$
$\sigma = 2.5$ MeV

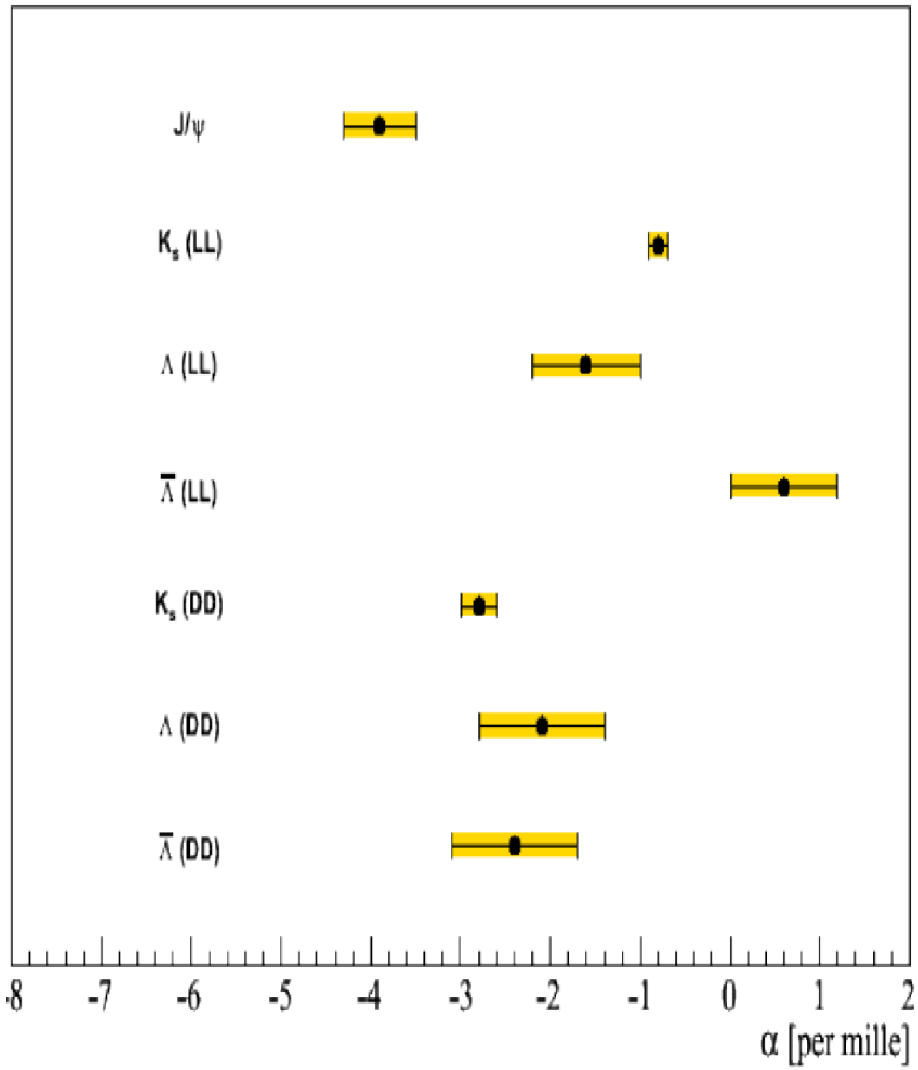


$\Omega \to \Lambda K$
$\sigma = 2.8$ MeV

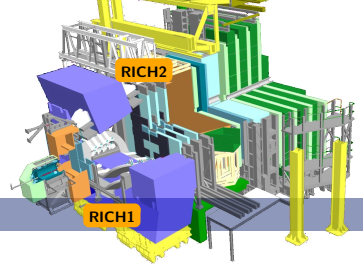


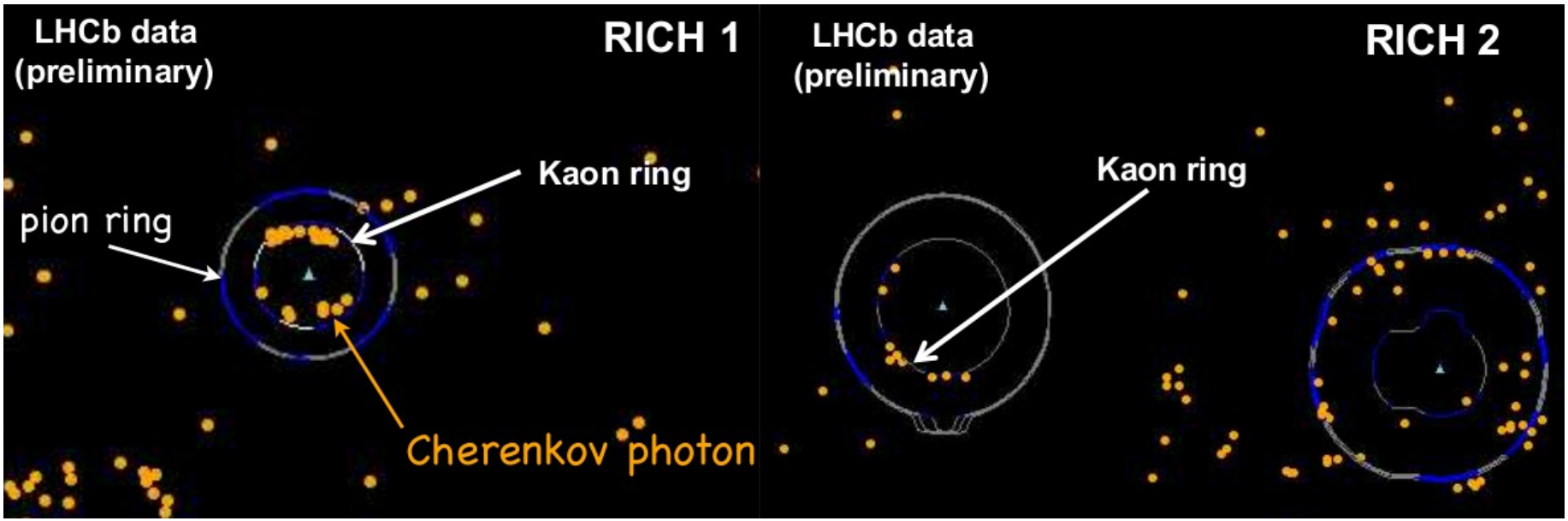
Mass Scale

- Residuals: We are getting there. But alignment is not perfect yet.
- Mass scale: B field or alignment or both? Need more statistics.



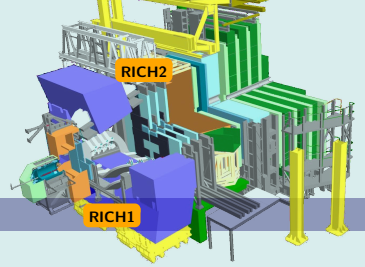
RICH



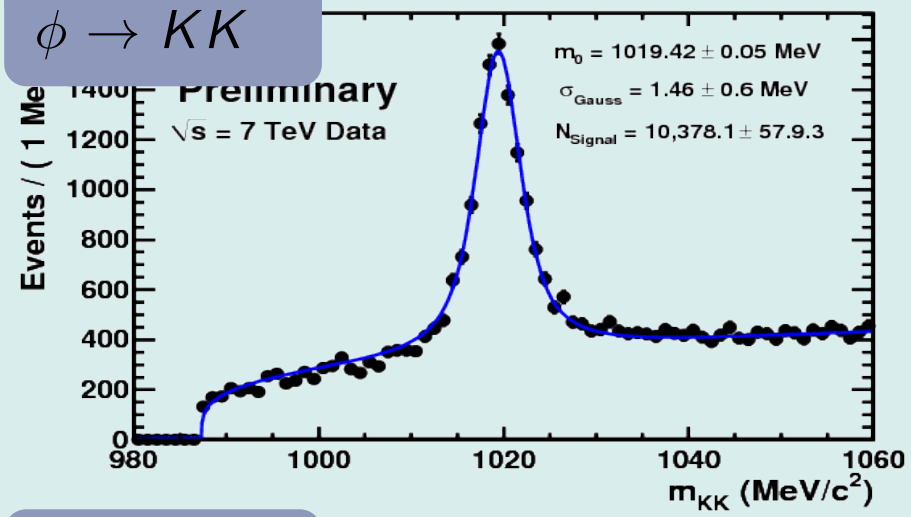


- RICH1 and RICH2 being aligned wrt tracking system
- Nice kaon and pion rings seen in both systems

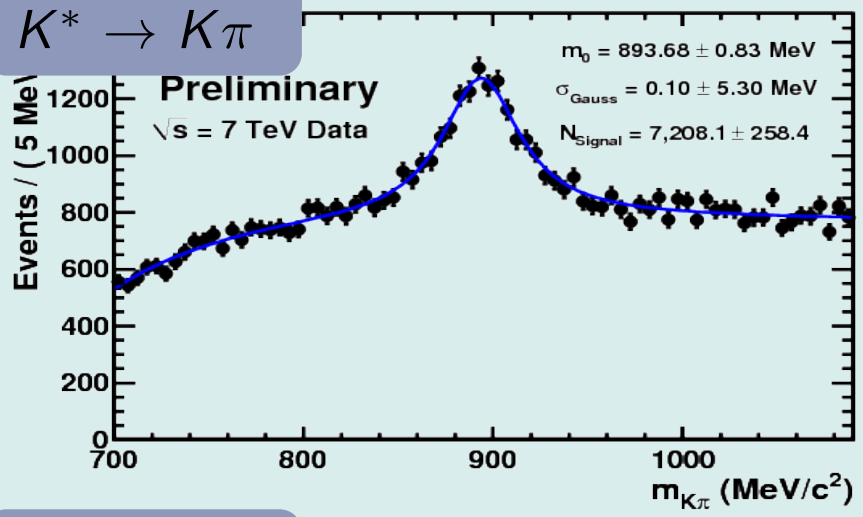
Zoology 2: Particles with Kaons



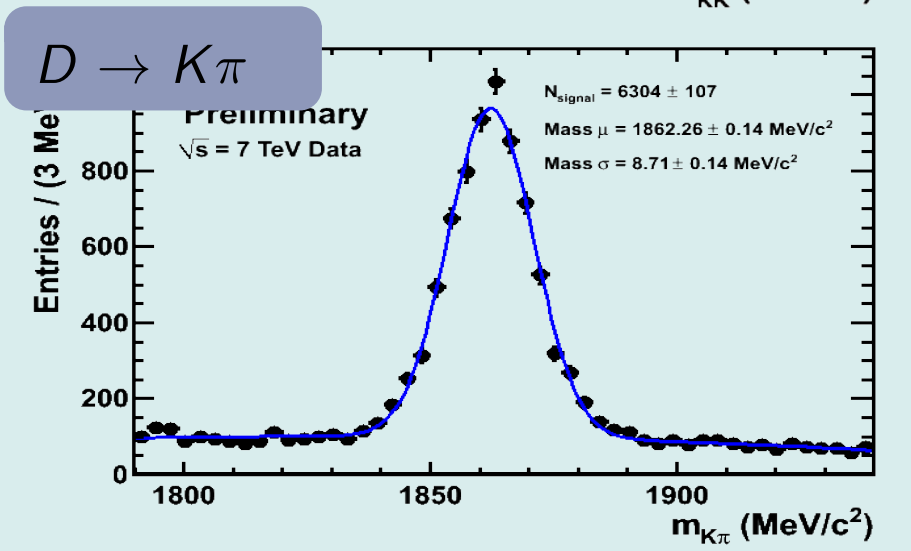
$\phi \to KK$



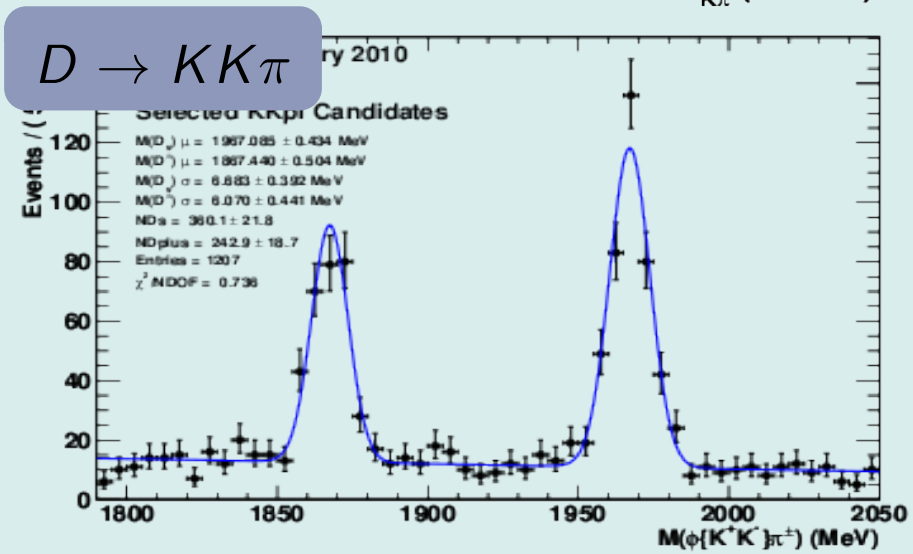
$K^* \to K\pi$



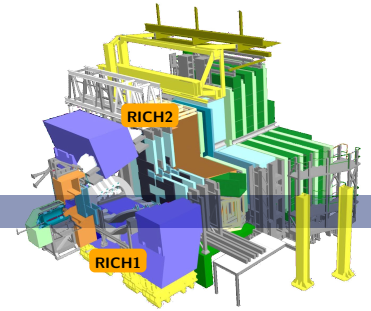
$D \to K\pi$



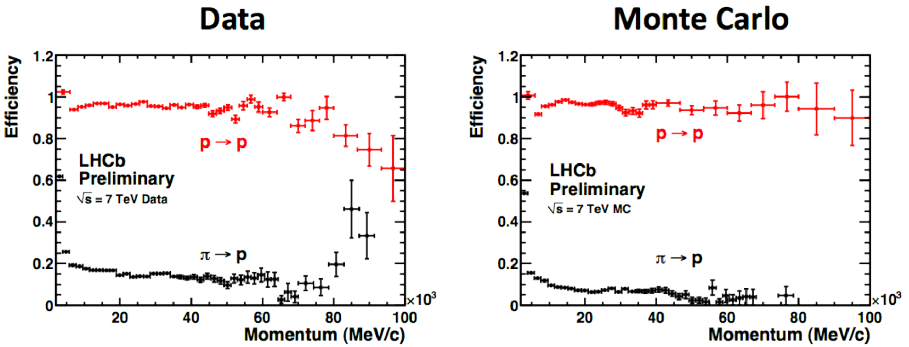
$D \to KK\pi$



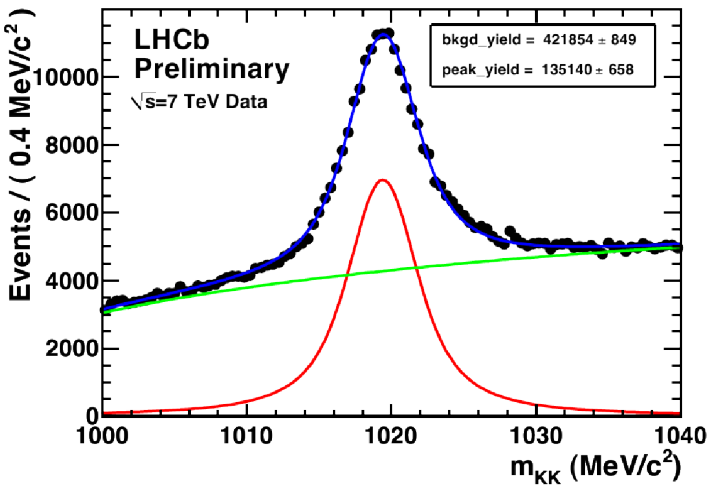
RICH-ID

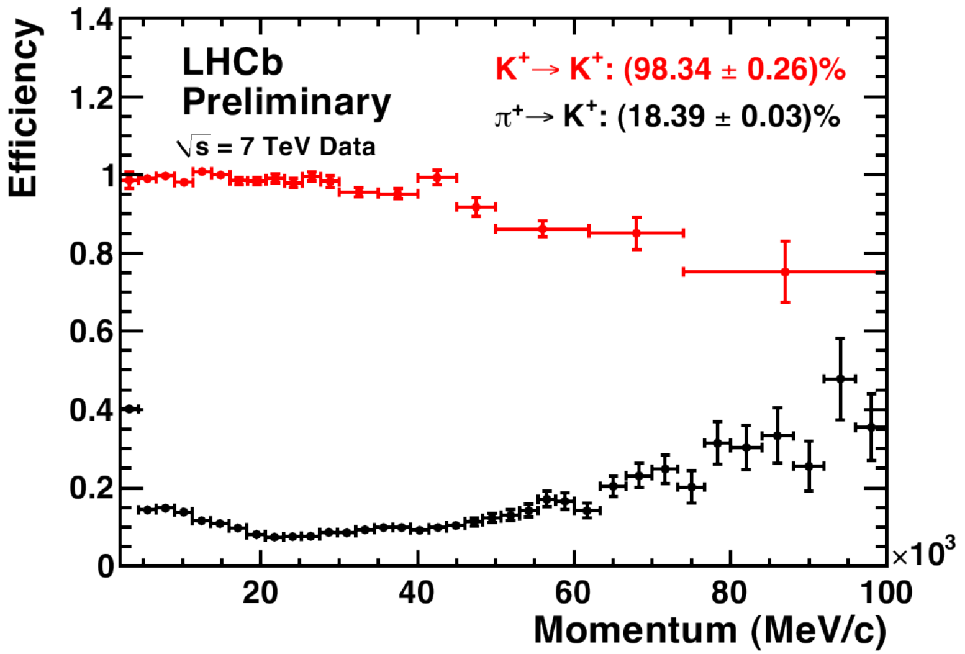


- Proton-ID efficiency and mis-ID using pions and protons from Λ and K^0_S
- Kaon-ID from ϕ tag-and-probe (one K RICH-IDed)

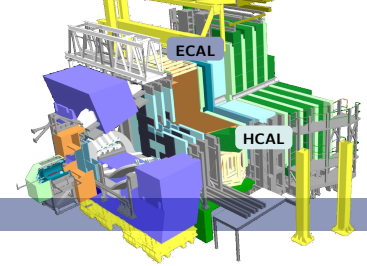


$\Delta\log\mathcal{L}(\mathrm{p}-\pi) > 0$

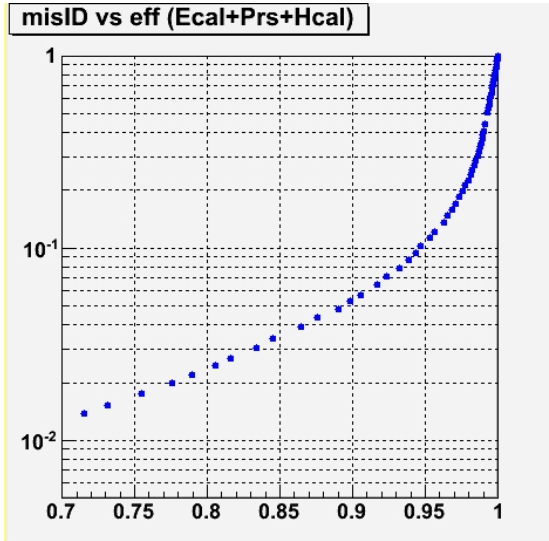




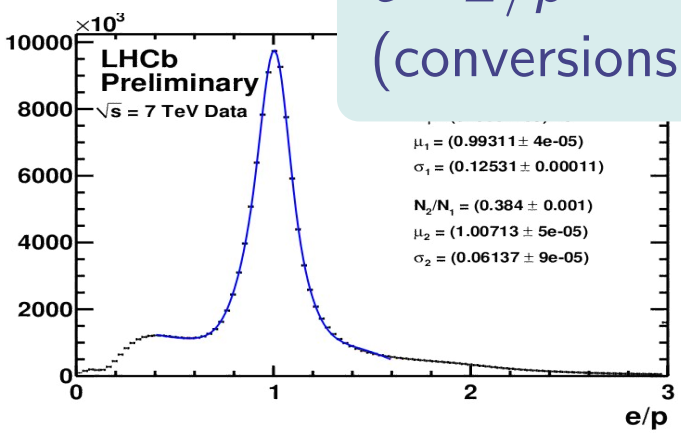
Calorimetry



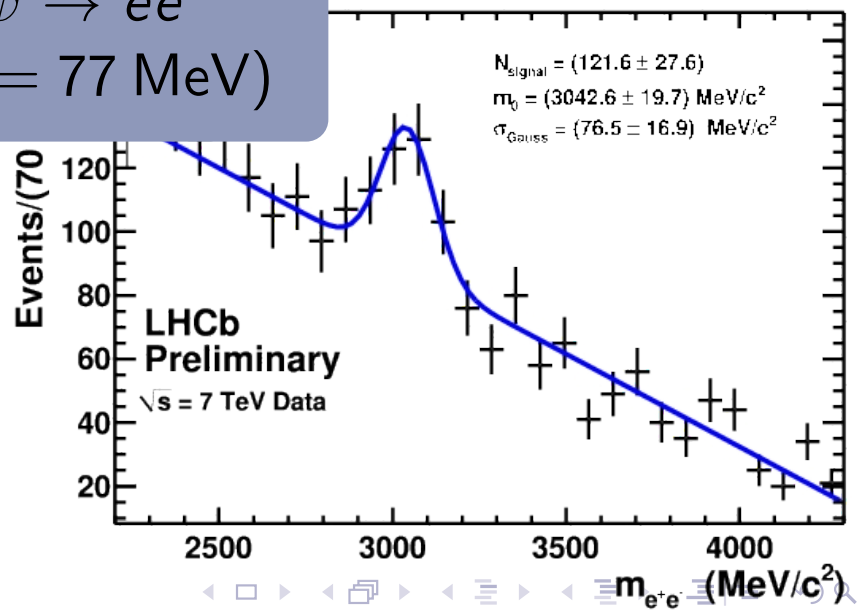
- The calorimeters systems work very effectively, providing the principal L0 trigger at LHCb
- Time alignment now 1 ns
- PS/SPD calibration using MIPs
- ECAL Energy calibration better than MC



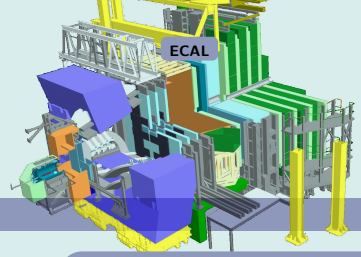
$e^{\pm}$ E/p (conversions)



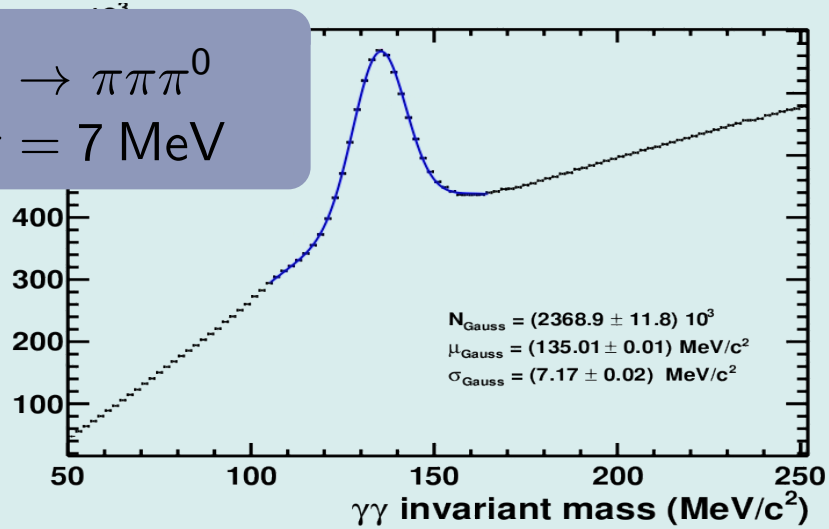
$J/\psi \to ee$ ($\sigma = 77$ MeV)



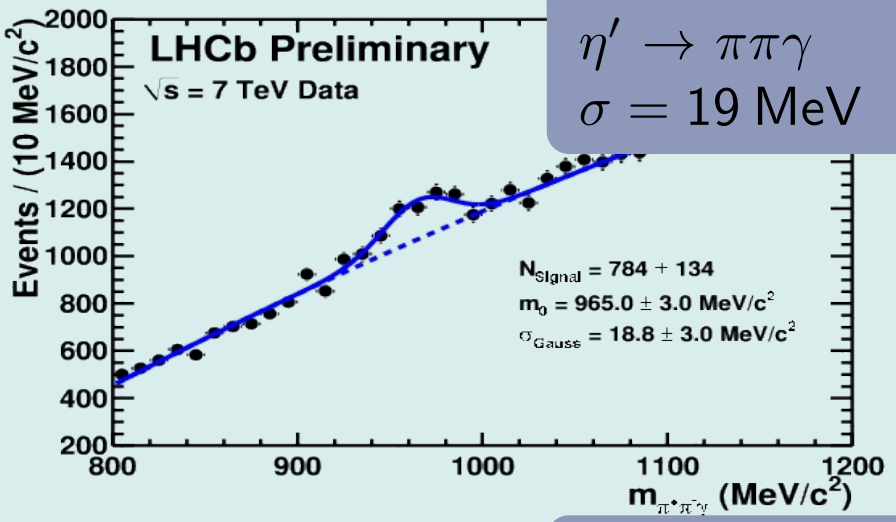
Zoology 3: π^0



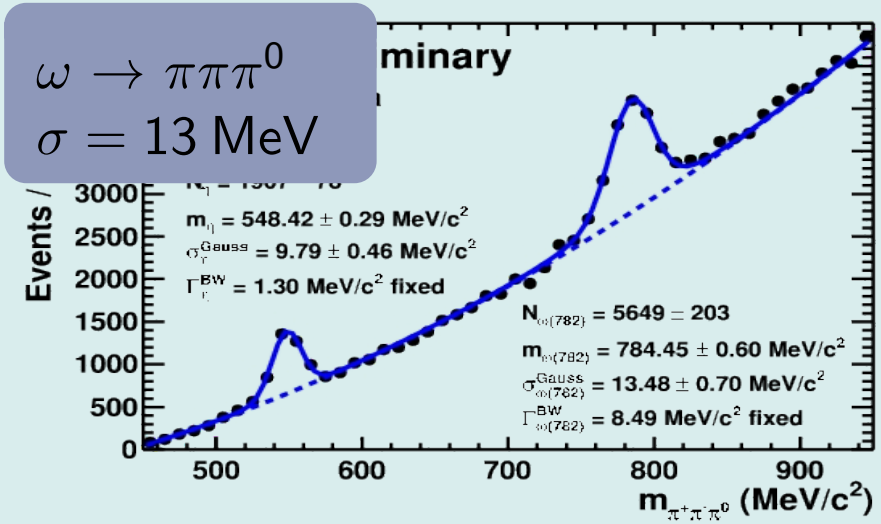
$\eta \to \pi\pi\pi^0$
$\sigma = 7$ MeV



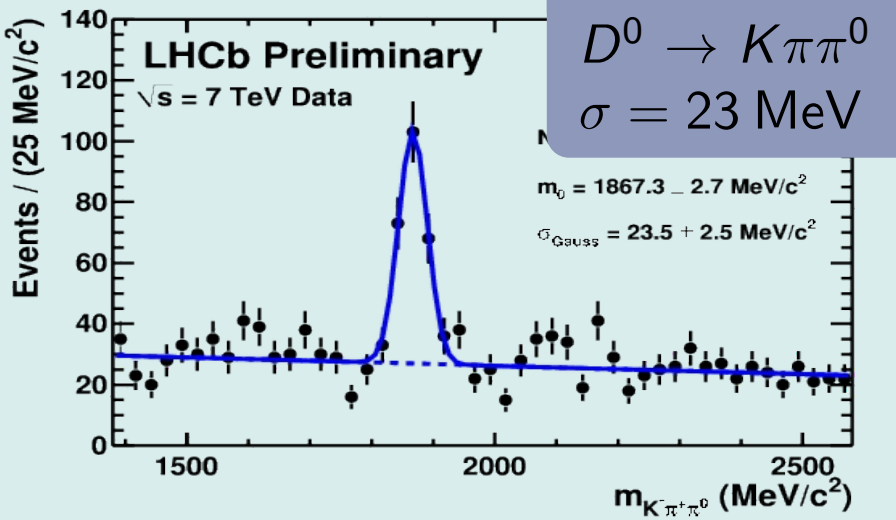
$\eta' \to \pi\pi\gamma$
$\sigma = 19$ MeV



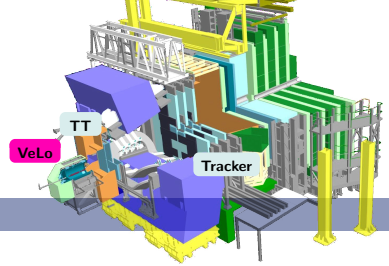
$\omega \to \pi\pi\pi^0$
$\sigma = 13$ MeV



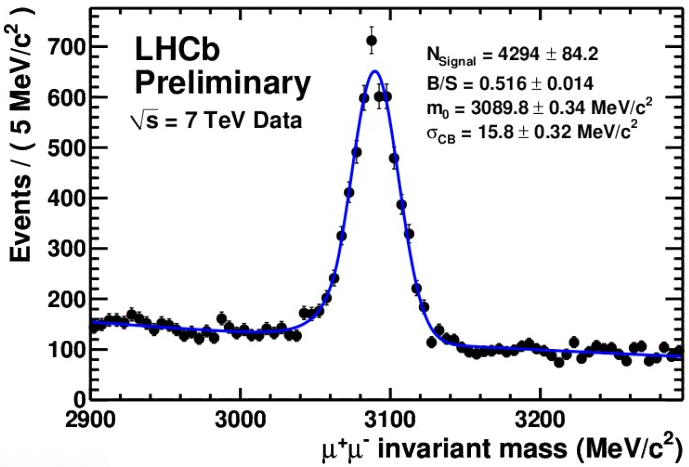
$D^0 \to K\pi\pi^0$
$\sigma = 23$ MeV



Muon-ID

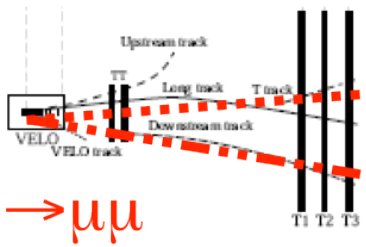


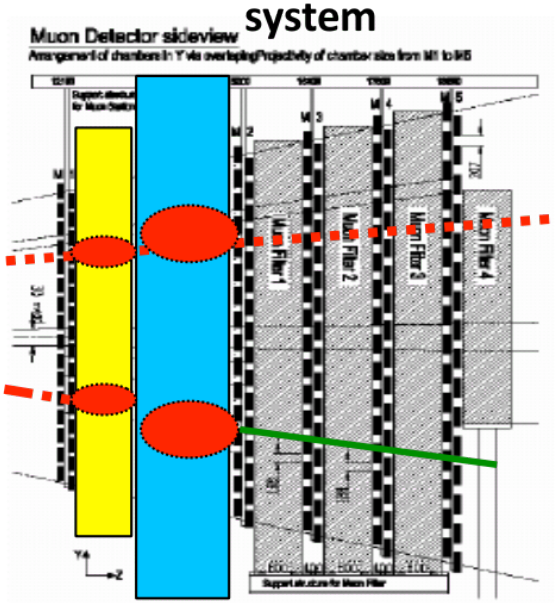
- Muon-ID from Tag and Probe method using J/ψ with Calo



Muon system

Tracking system



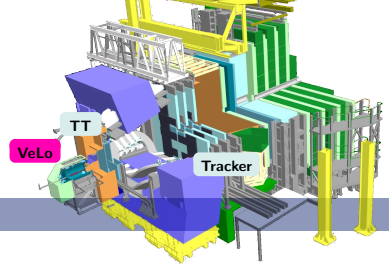


J/ψ→μμ

μ tag

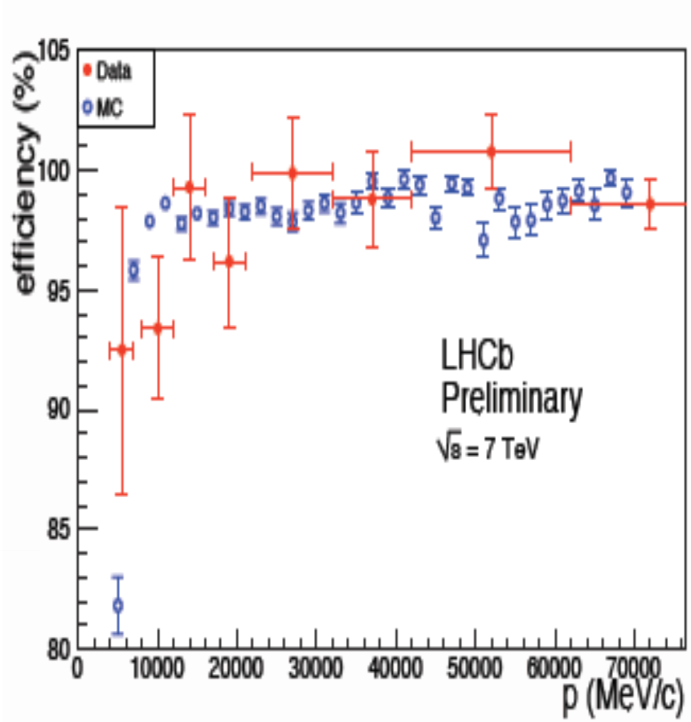
μ probe

Muon-ID

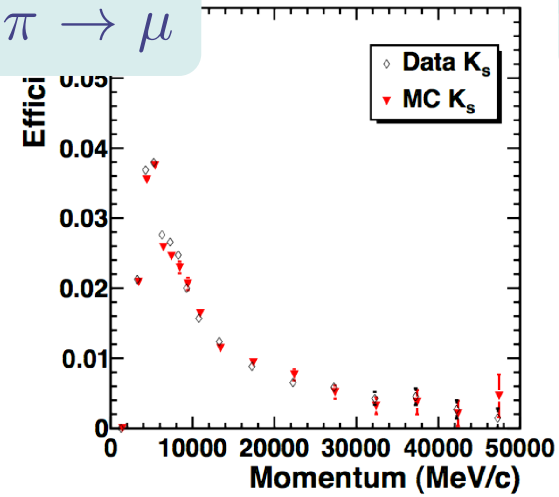


- Muon-ID from Tag and Probe method using J/ψ with Calo
- Efficiency : $(97.3 \pm 1.2)\%$
- Mis-ID from K^0_S and Λ
- Pion Mis-ID: $(2.35 \pm 0.04)\%$

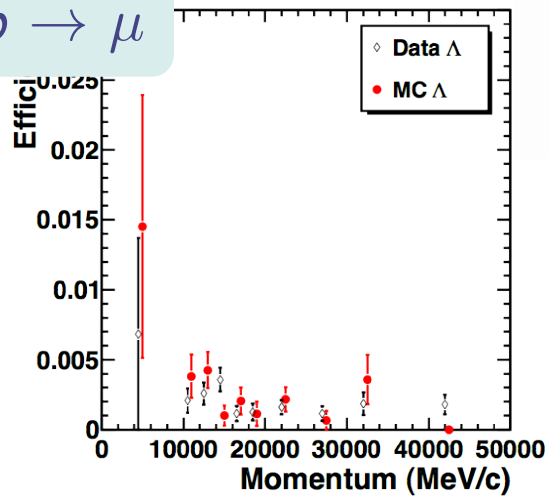
✔ All agrees with MC



$\pi \rightarrow \mu$

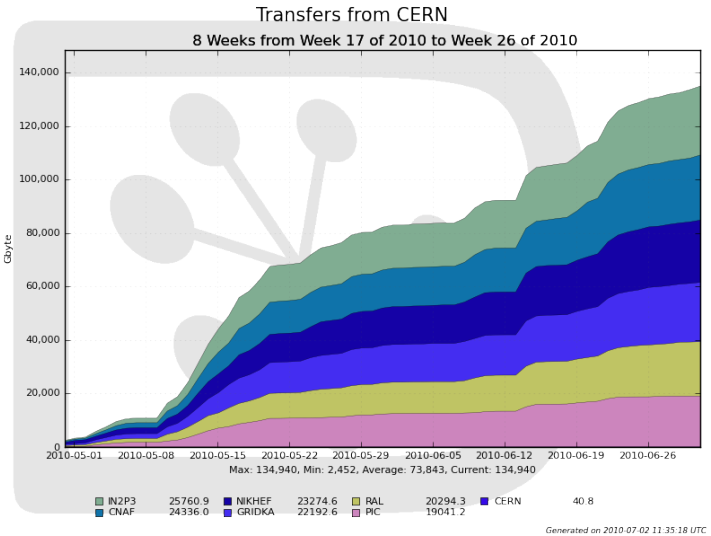


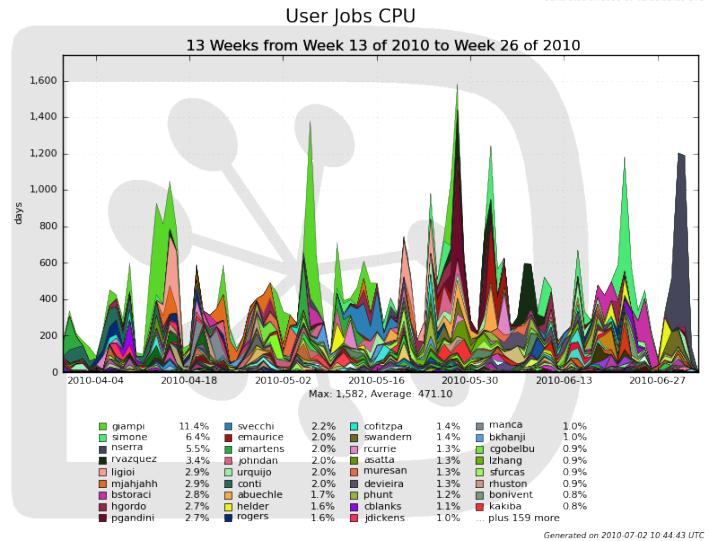
$p \rightarrow \mu$



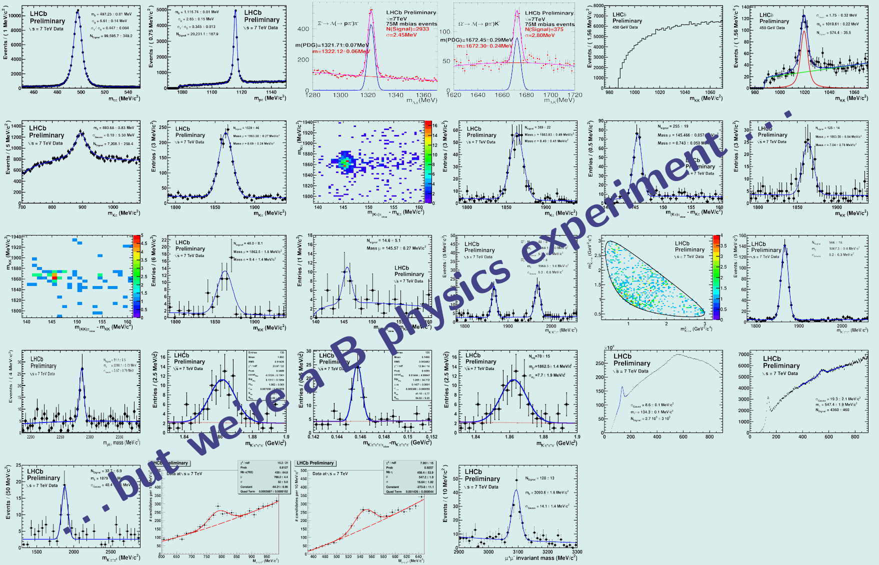
Offline Computing

- Data processing chain works well. Several reprocessings already done.
- New data is distributed to the Tier1s
- Some issues with Tier1 stability regarding storage
  - So far CERN had highest share of CPU
  - ➜ Getting better
- 200 Grid users (1/4 of the collaboration)
- 2010 Simulation campaign started



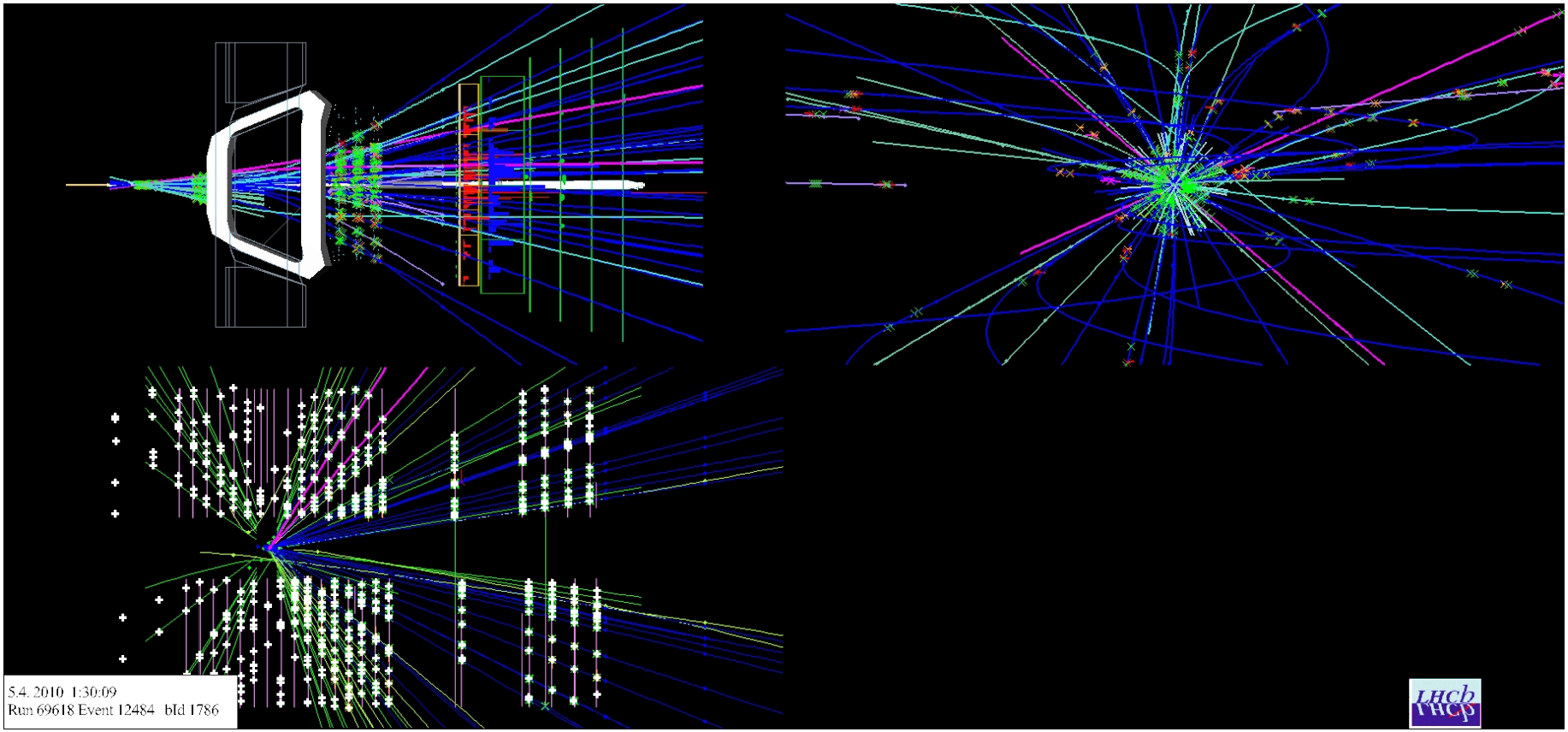


Very Nice Peaks!

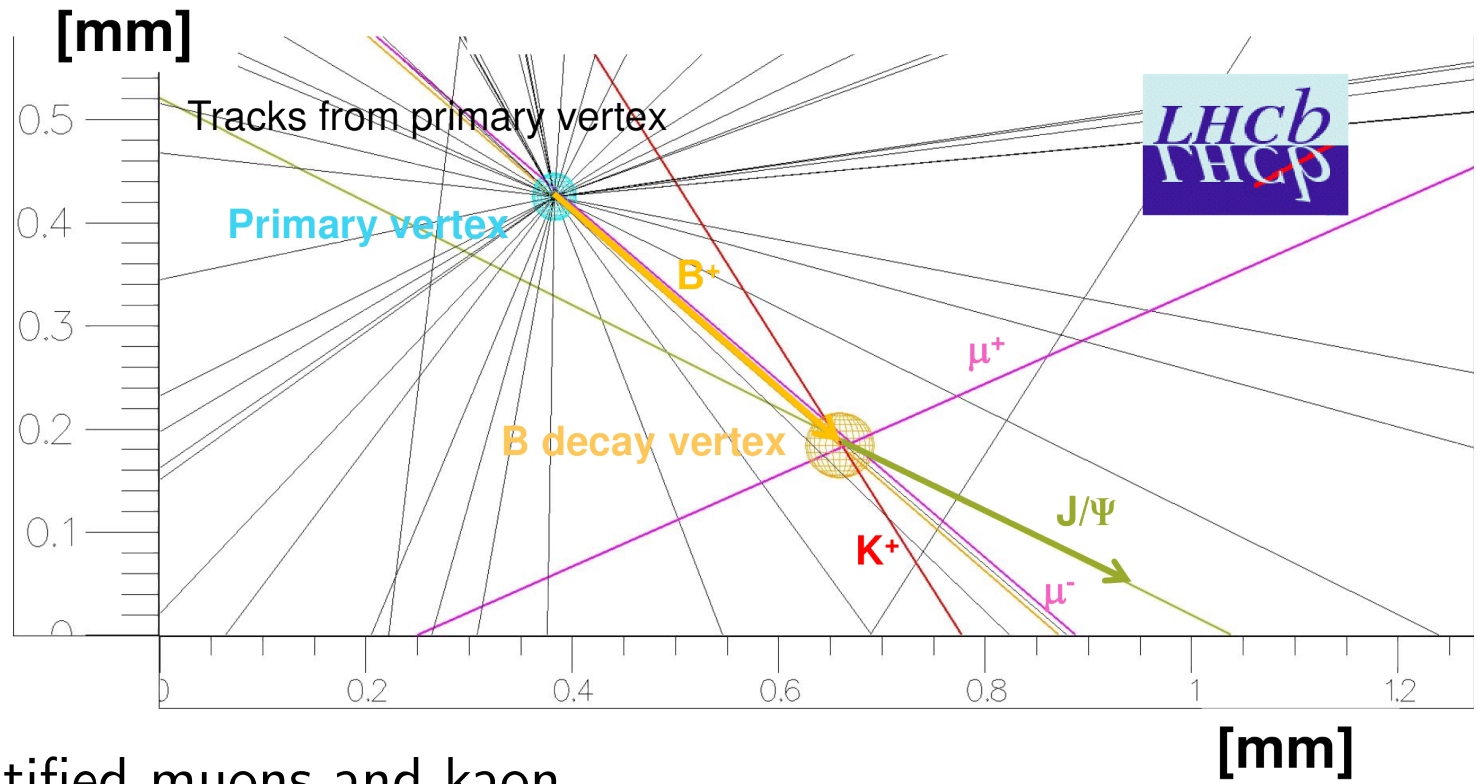


. . . but we're a B physics experiment . . .

First B^+ Candidate



B^+ Candidate

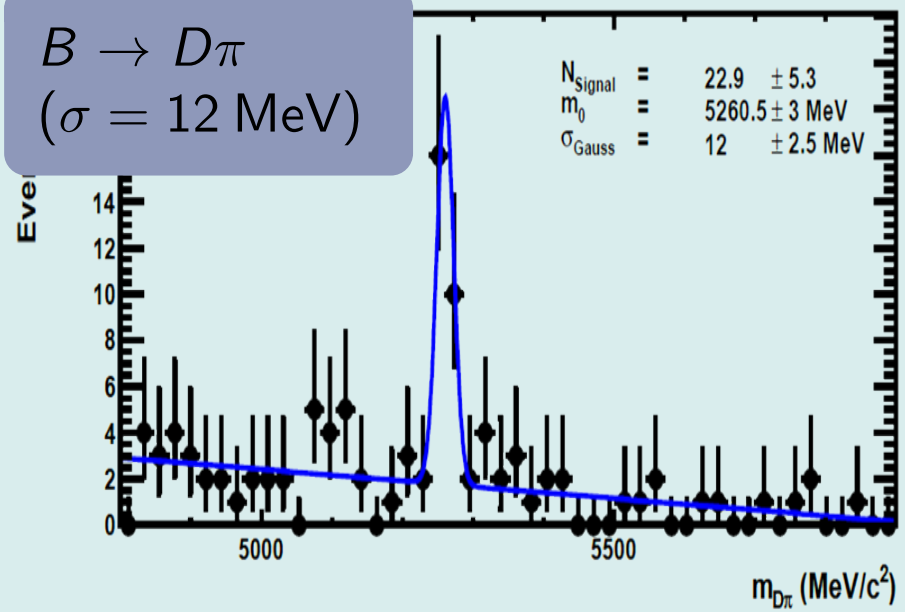


- Well identified muons and kaon.
- $m_{J/\psi} = 3097.90$ MeV, $m_{B^+} = 5319.90$ MeV
- Proper time $= 0.6\,\mathrm{ps}$ ($26\,\sigma$ from PV)
- Angle of flight and momentum of $B^+ = 0.7°$

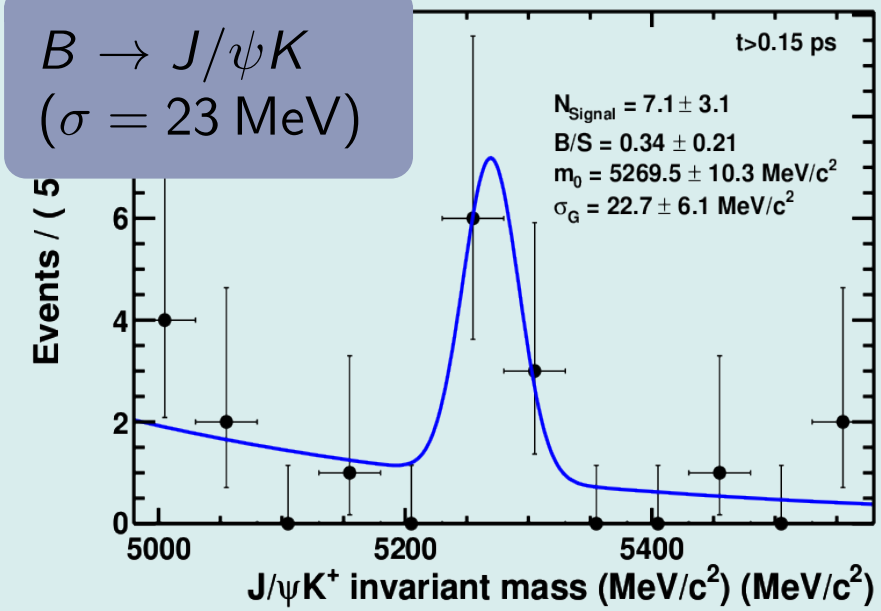
More B

- We are starting to see B peaks in $\mathcal{O}(10)\,\mathrm{nb}^{-1}$
- Don't know yet how many there are in the full sample ...

$B \to D\pi$
($\sigma = 12$ MeV)



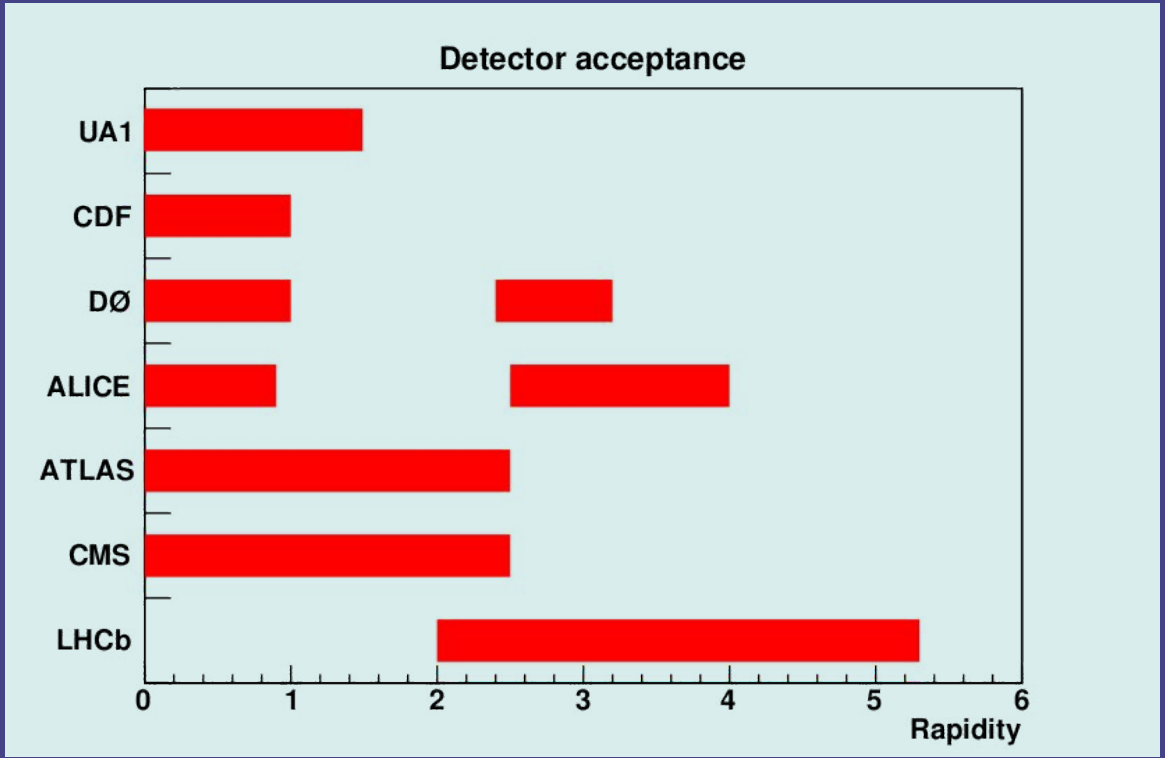
$B \to J/\psi K$
($\sigma = 23$ MeV)



2010 Physics

Physics

- At low luminosities we can do cross-section measurements
  - ✔ Unbiased trigger
  - ✔ Unique rapidity coverage
- K^0_S cross-section
- $\Lambda/\overline{\Lambda}$ and $p/\overline{p}$
- Open charm
- J/ψ
- B

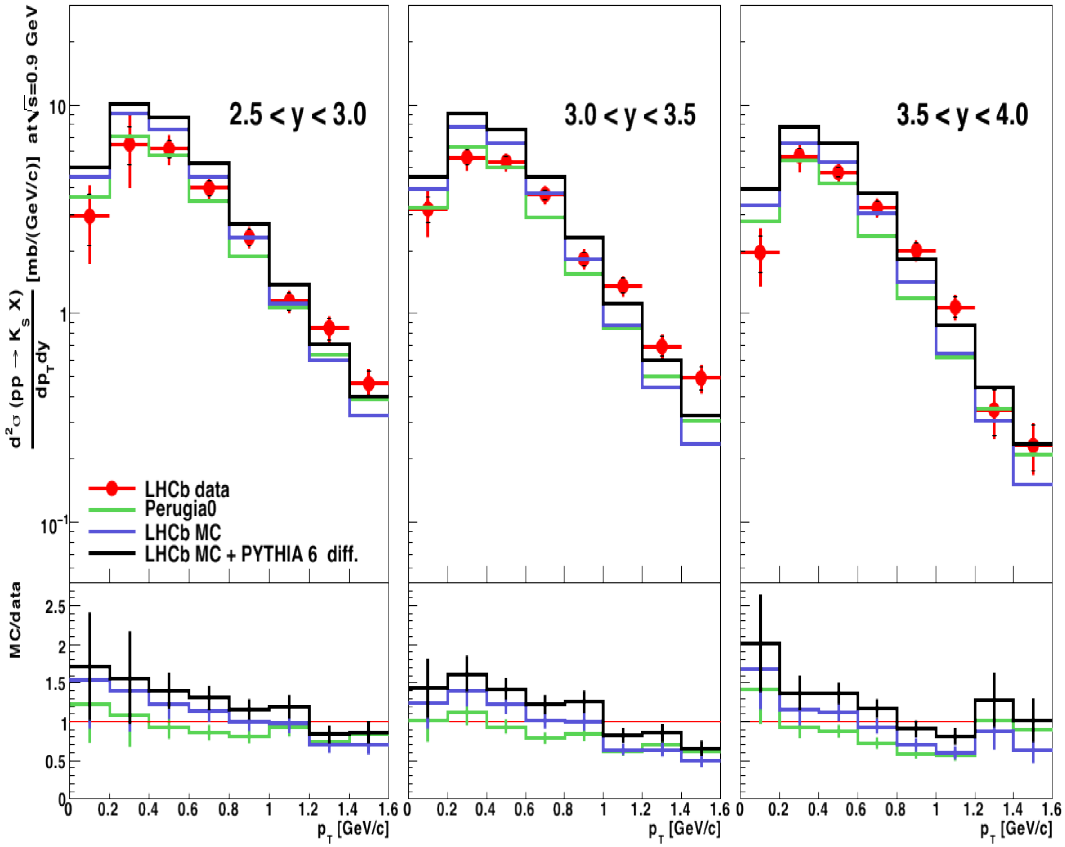


This is the tracking acceptance.
For composites we get a bit higher.

K^0_S 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

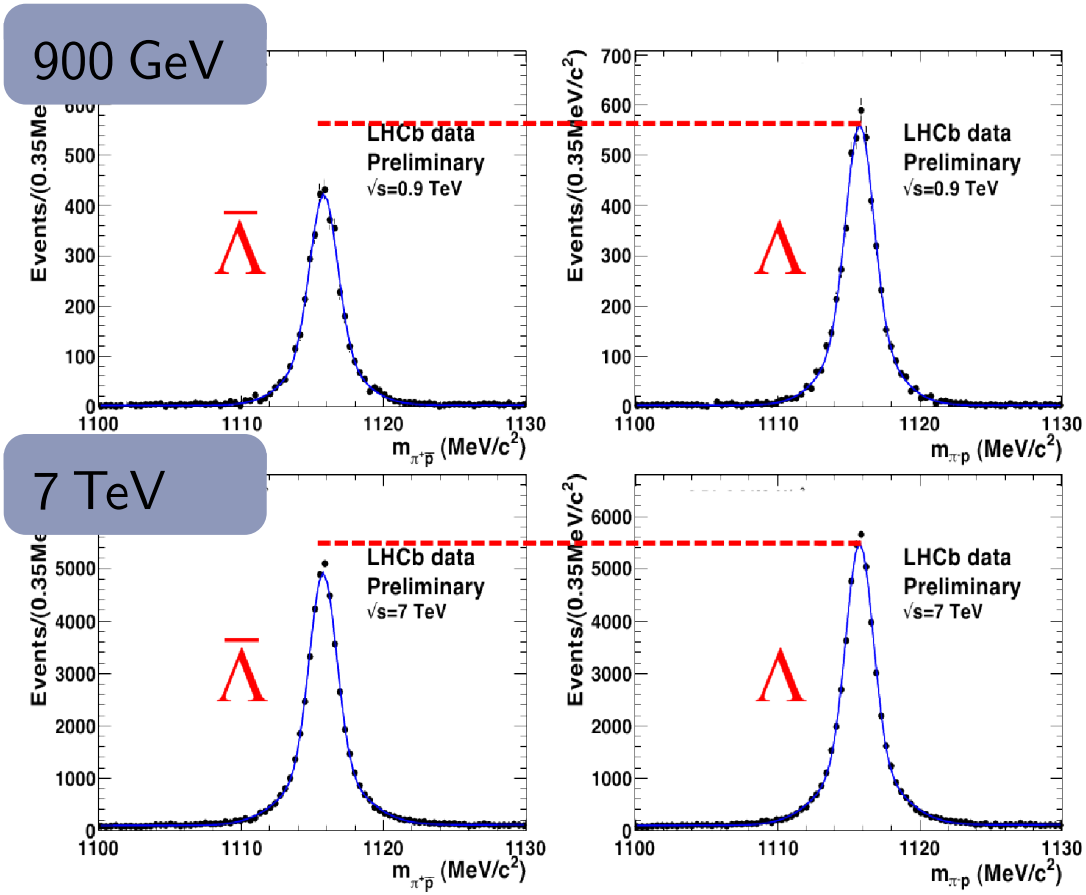
➜ First LHCb paper



p_T spectrum in bins of y.

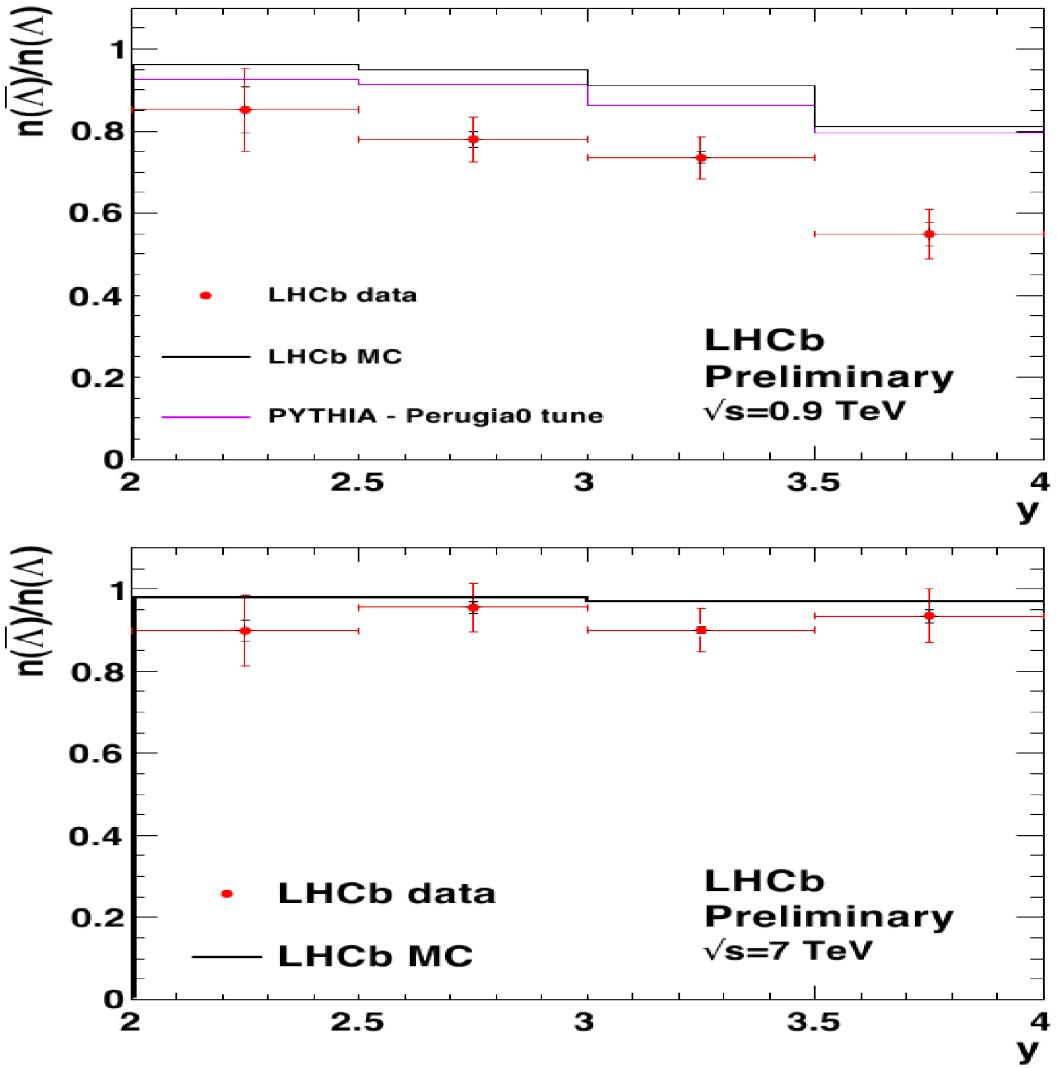
Λ AND $\overline{\Lambda}$ AT $\sqrt{s} = 900$ GeV AND $\sqrt{s} = 7$ TeV

- Measure Λ and $\overline{\Lambda}$ ratios versus rapidity
- Clear asymmetry in the mass peaks



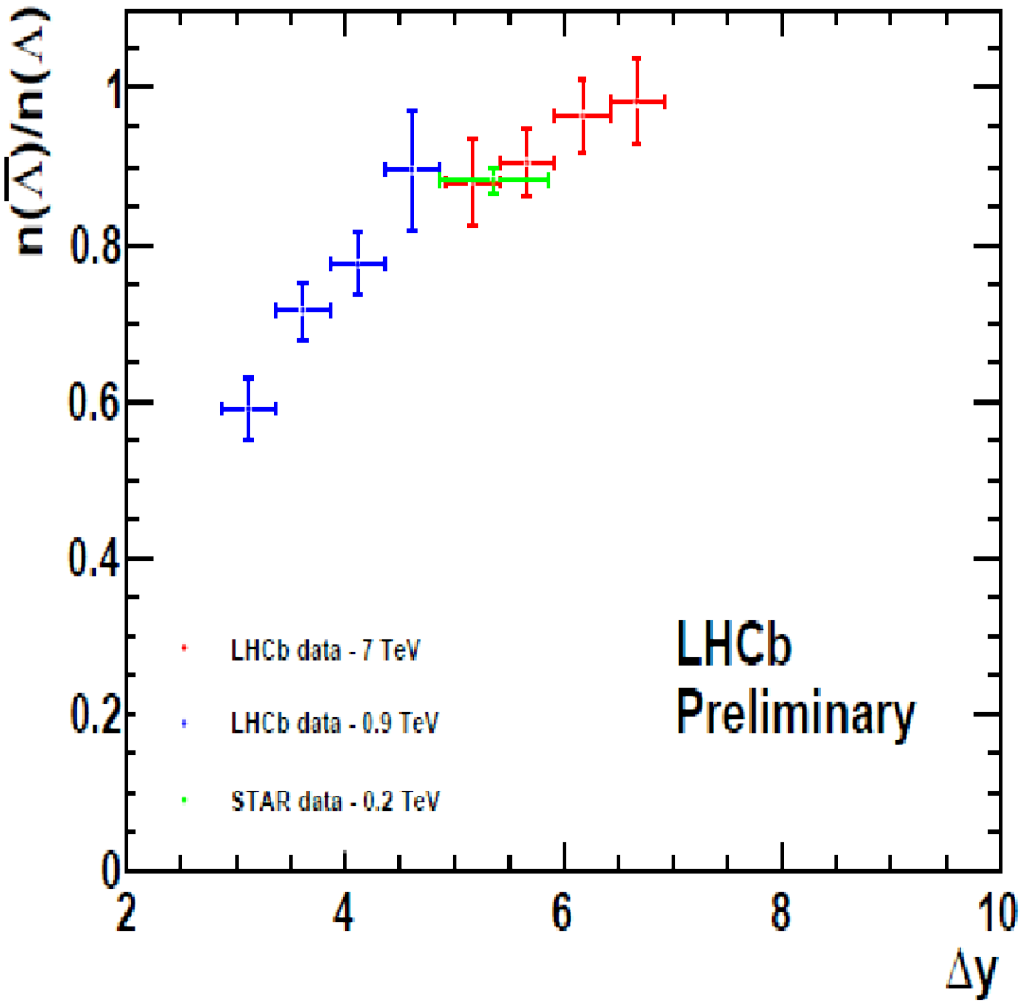
Λ AND $\overline{\Lambda}$ AT $\sqrt{s} = 900$ GeV AND $\sqrt{s} = 7$ TeV

- Measure Λ and $\overline{\Lambda}$ ratios versus rapidity
- Clear asymmetry in the mass peaks
- Asymmetry at 900 GeV larger than predicted in MC
- Not the case at 7 TeV



Λ AND $\overline{\Lambda}$ AT $\sqrt{s} = 900$ GEV AND $\sqrt{s} = 7$ TEV

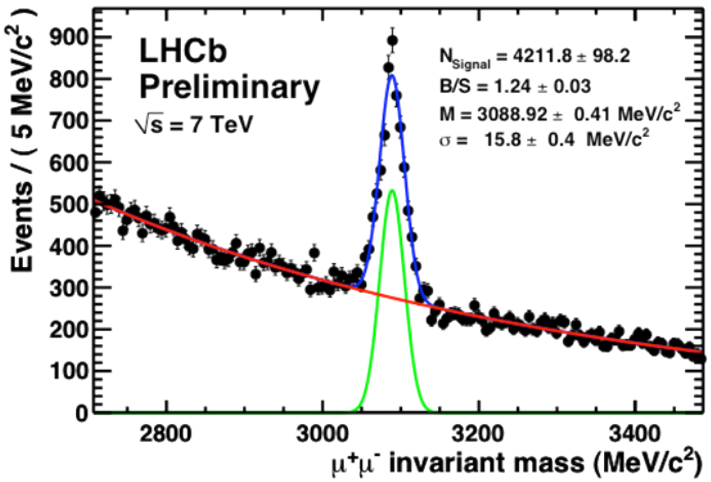
- Measure Λ and $\overline{\Lambda}$ ratios versus rapidity
- Clear asymmetry in the mass peaks
- Asymmetry at 900 GeV larger than predicted in MC
- Not the case at 7 TeV
- In $\Delta y(\Lambda - \text{Beam})$ all data agrees well

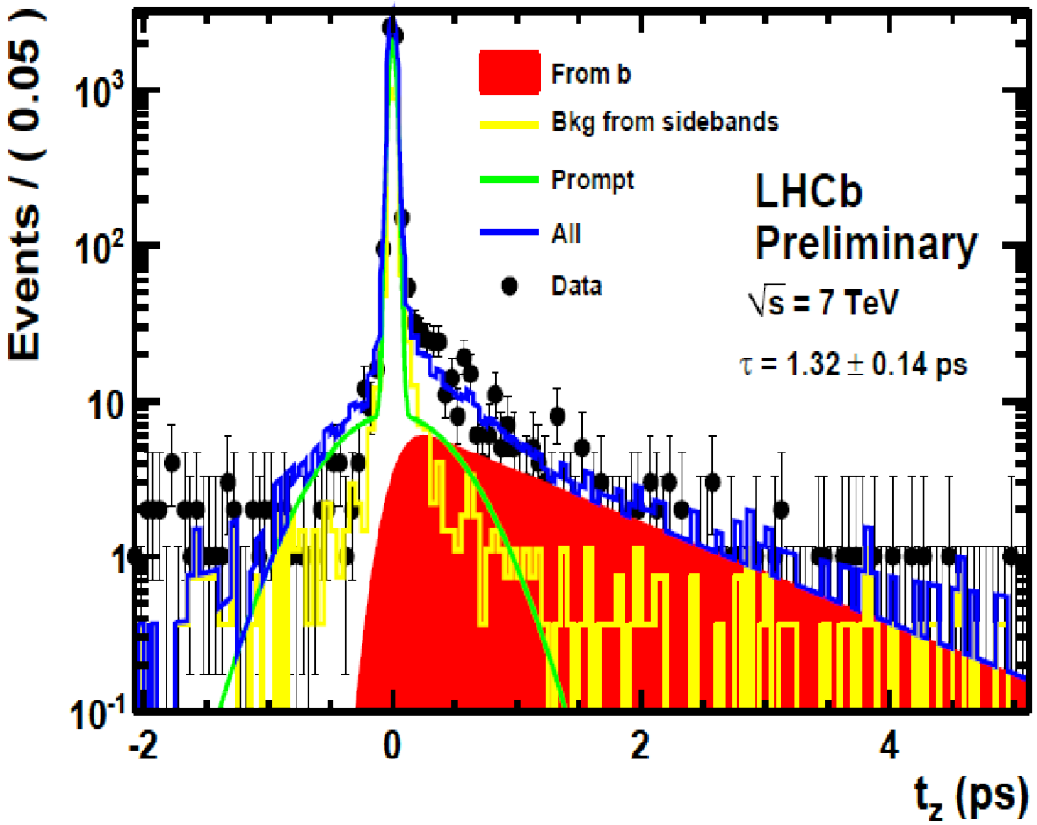


J/ψ AT $\sqrt{s} = 7$ TEV

We can measure

- $\frac{\mathrm{d}\sigma}{\mathrm{d}p_T}$ for all J/ψ
- σ for prompt J/ψ
- σ for non-prompt J/ψ
  ➜ B cross-section
- No numbers yet...

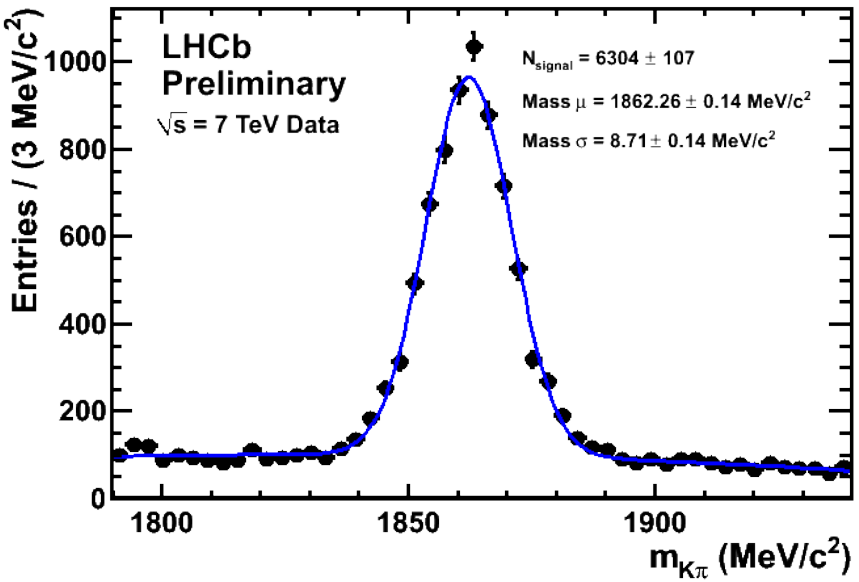


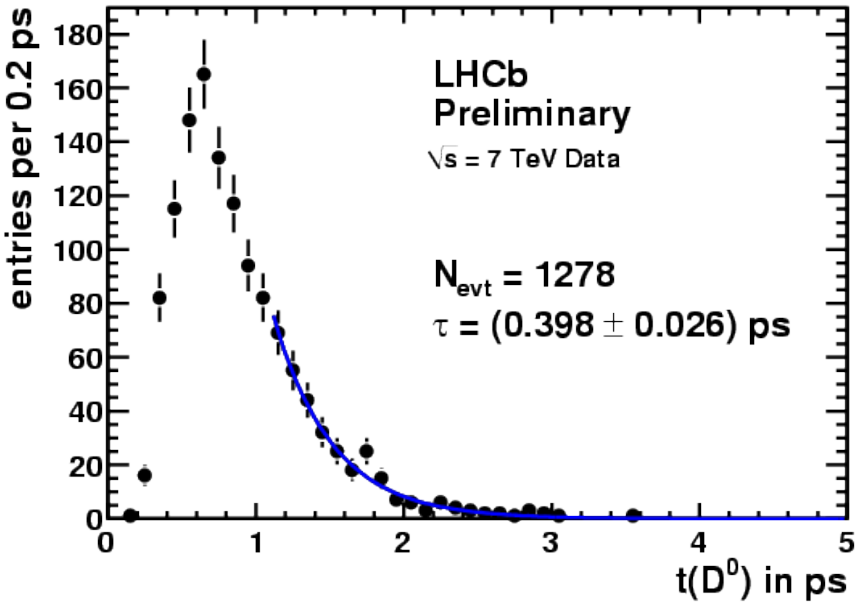


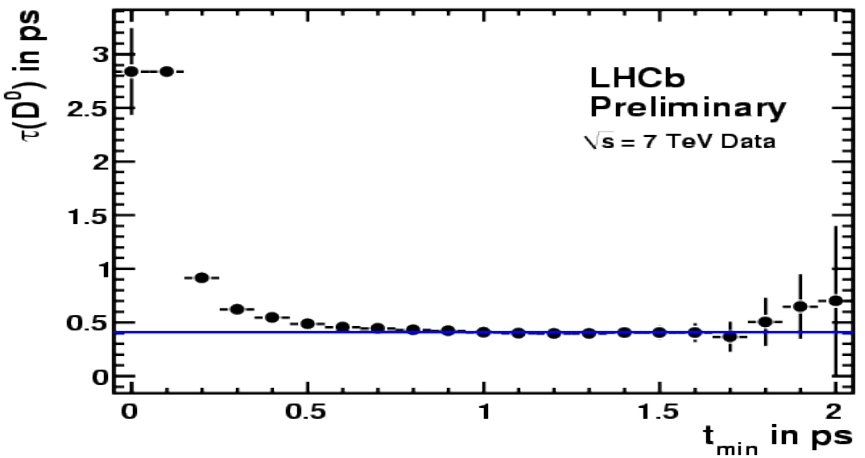
Warning : This is a pseudo-lifetime.

Here's a Real Lifetime

- $D \to K\pi$ lifetime is measured as (0.398 ± 0.026) ps (only statistical)
- PDG says $(0.410.1 \pm 0.0015)$ ps. Still some way to go ...



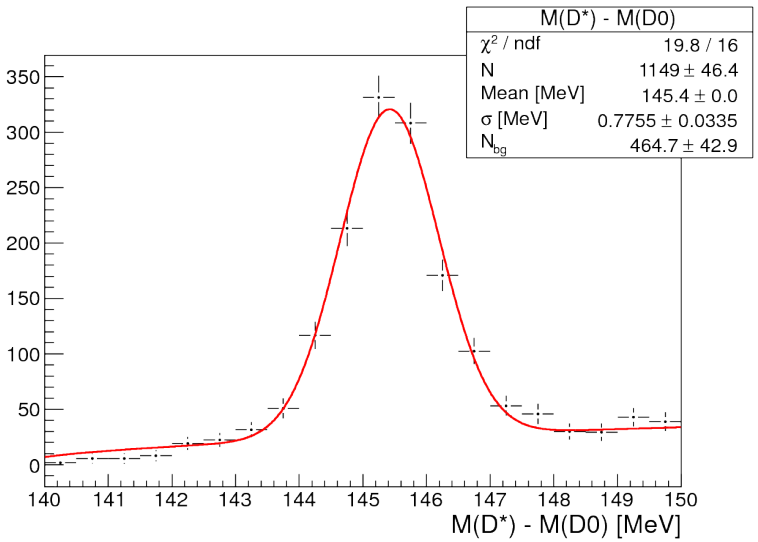


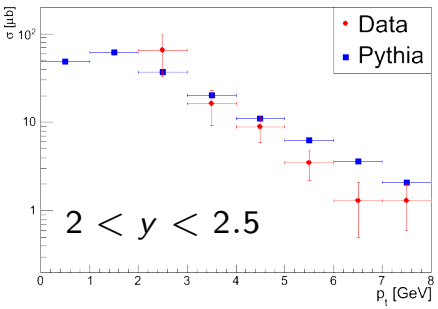


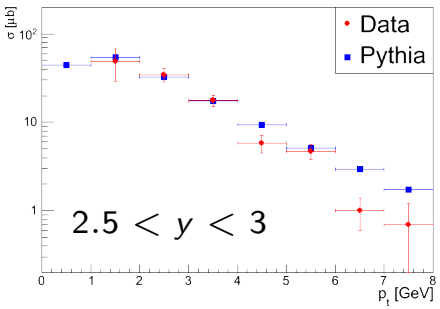
D^* CROSS-SECTION

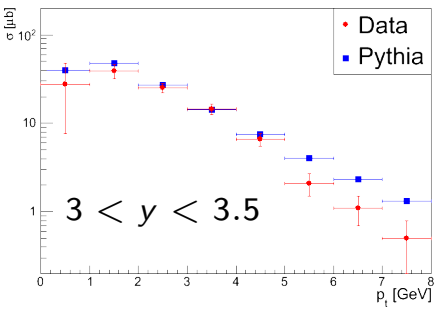
Work done by Alexandr Kozlinskiy with Ivan Belyaev and Thomas Bauer

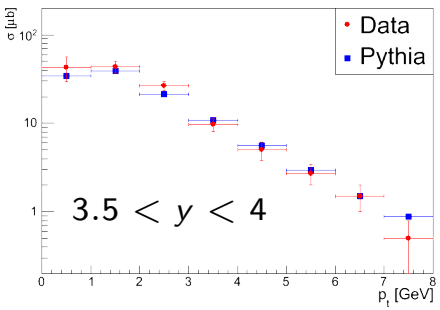
- Very clean sample of D^*
- Pointing requirement removes all non-prompt

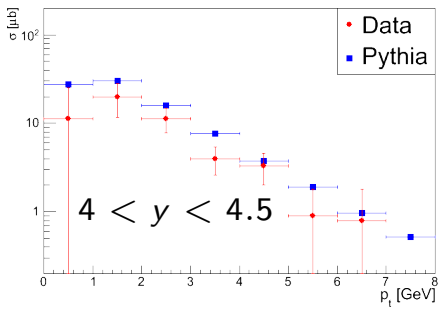








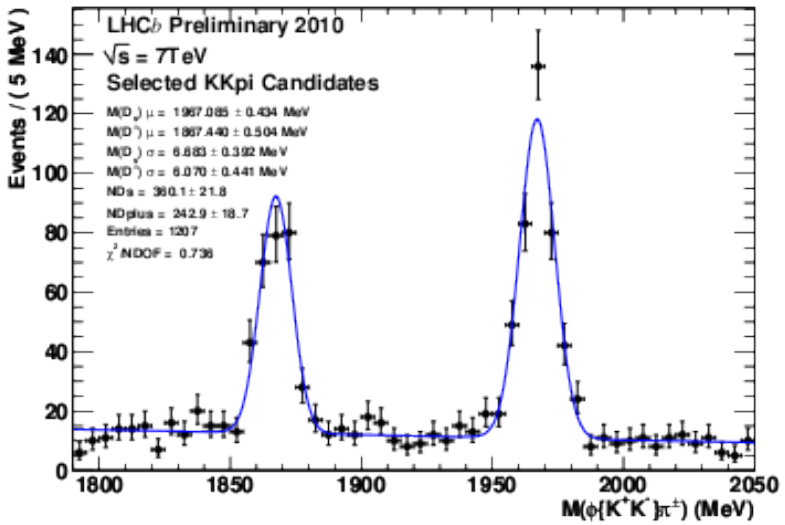


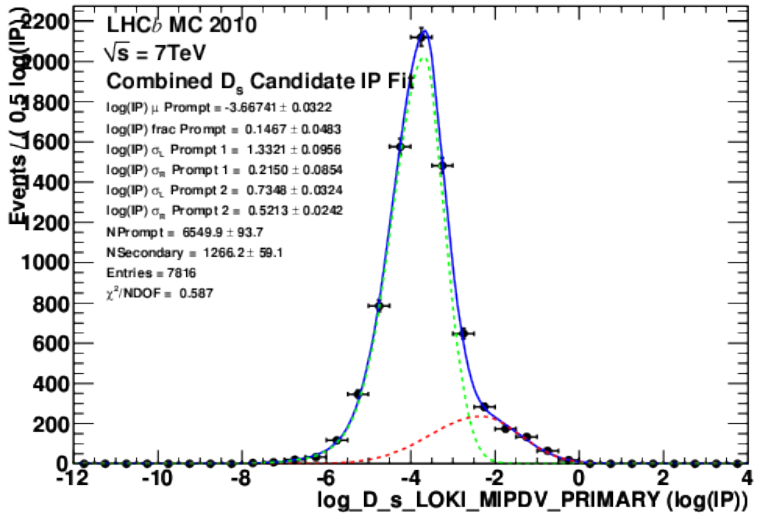


D_s CROSS-SECTION

Measure D_s cross section in bins of p_T and rapidity

- Select $\phi\pi$ candidates:
  - See favoured D_s
  - and Cabibbo-suppressed D^+
- Look at log(IP) ➜ separate prompt and B component

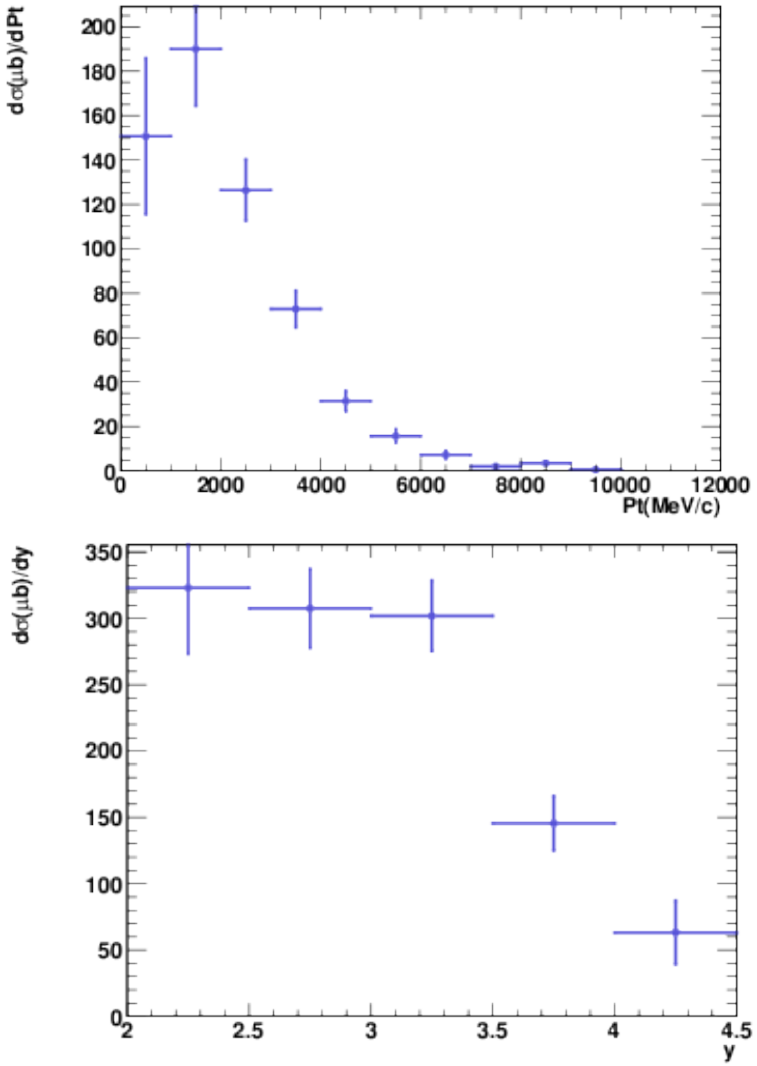




D_s CROSS-SECTION

Measure D_s cross section in bins of p_T and rapidity

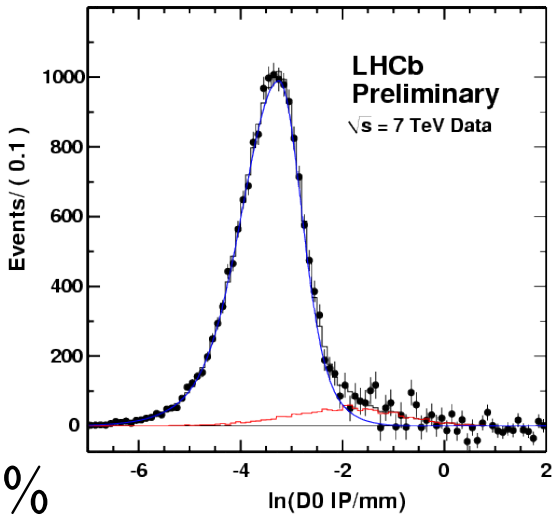
- Select $\phi\pi$ candidates:
  - See favoured D_s
  - and Cabibbo-suppressed D^+
- Look at log(IP) ➜ separate prompt and B component
- Get distributions in p_T and y.



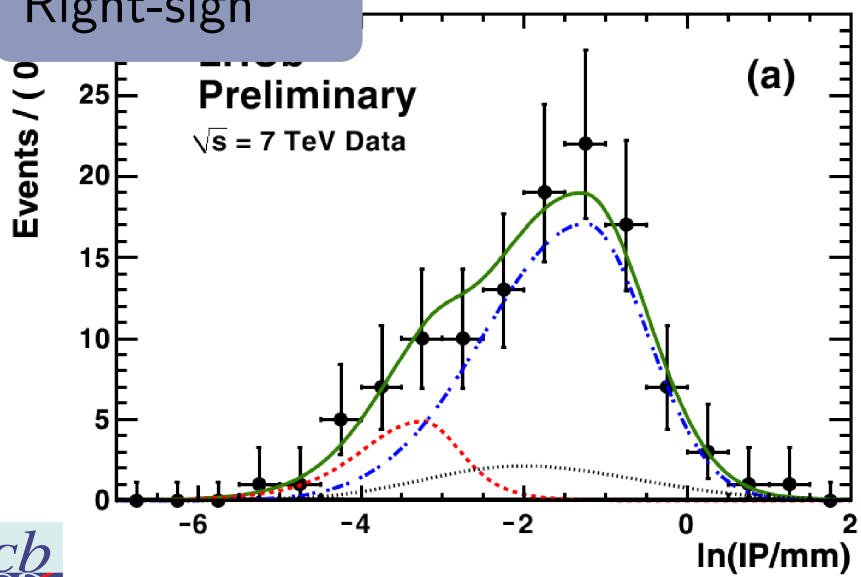
B Cross-Section

This time keep only the non-prompt part

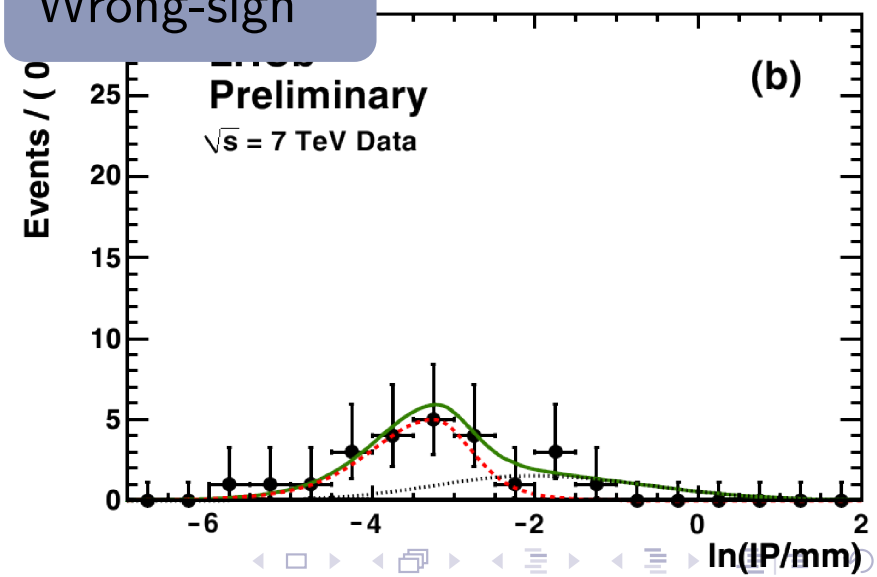
- Start from log(IP) of $D^0 \to K^-\pi^+$
  - Clear non-prompt contribution
- Add a non-prompt muon : $B^- \to D^0\mu^-\nu$
  - Wrong sign distribution dominated by prompt D
- Get $b\bar{b}$ cross section from $\mathcal{B} = (6.82 \pm 0.35)\%$



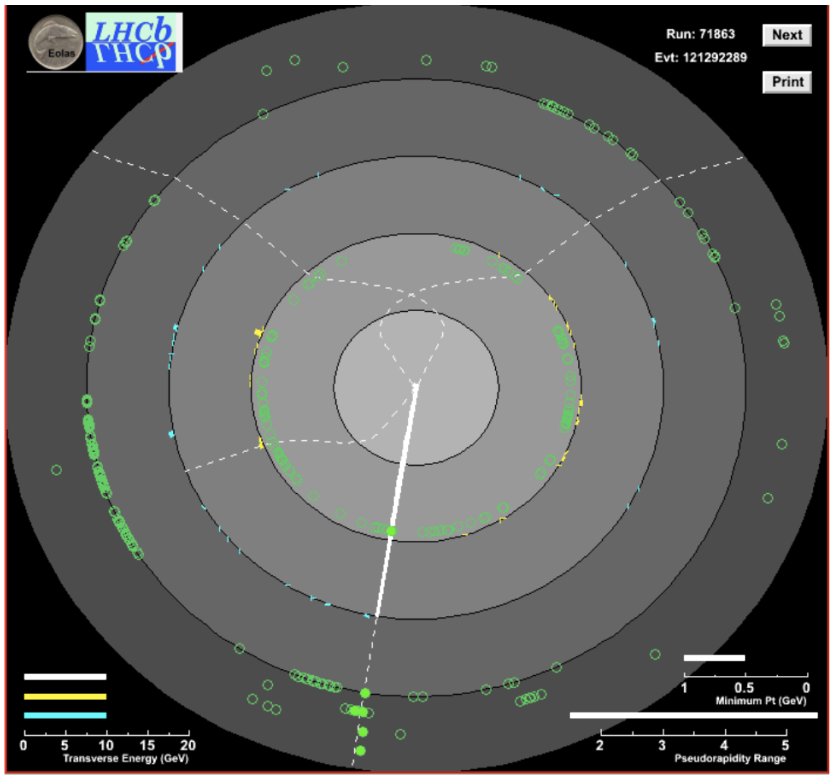
Right-sign



Wrong-sign

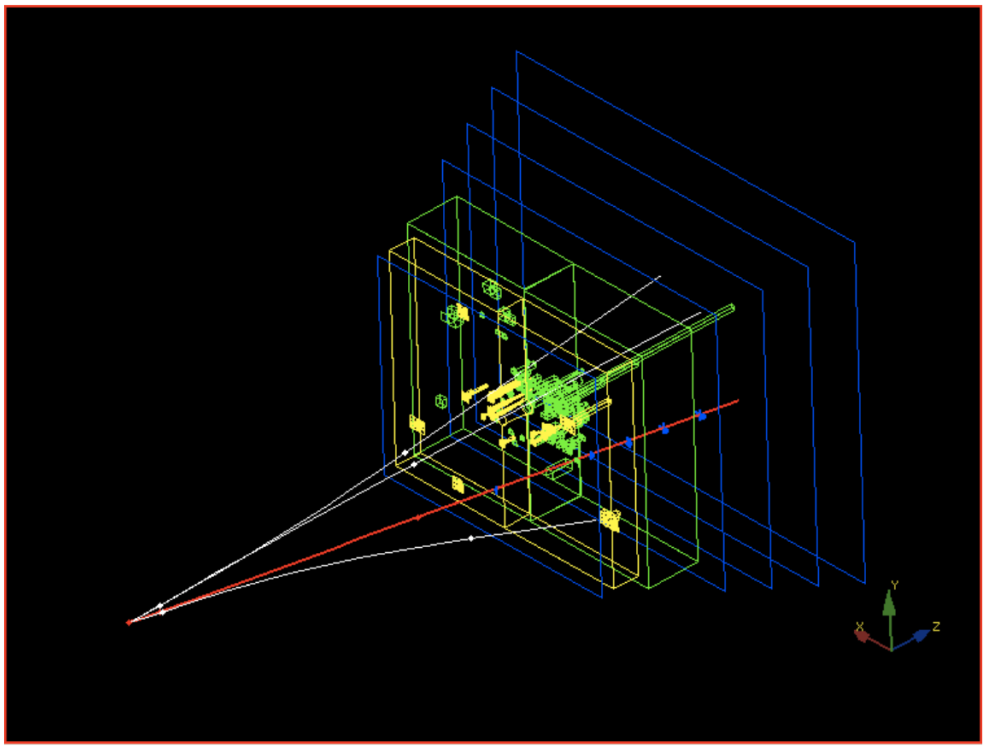


One more thing...



Charge = +1

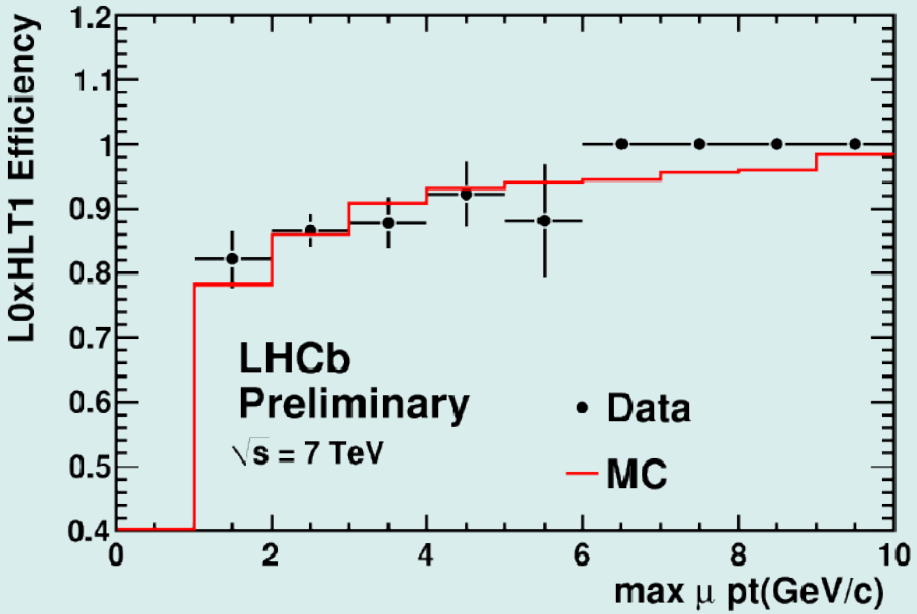
$\eta = 2.65$



$p_T = 39.2$ GeV/c

$A_{pT} = 0.93$

Outlook



- We now have $\sim 100\,\mathrm{nb}^{-1}$
- With a few $100\,\mathrm{pb}^{-1}$ we are in business for
  - $B_s \to \mu\mu$
  - $B_d \to \mu\mu K^*$
  - D mixing
- For more B physics wait for $1\,\mathrm{fb}^{-1}$

- We are starting to look at trigger efficiencies
- Backgrounds, PID, lifetimes...

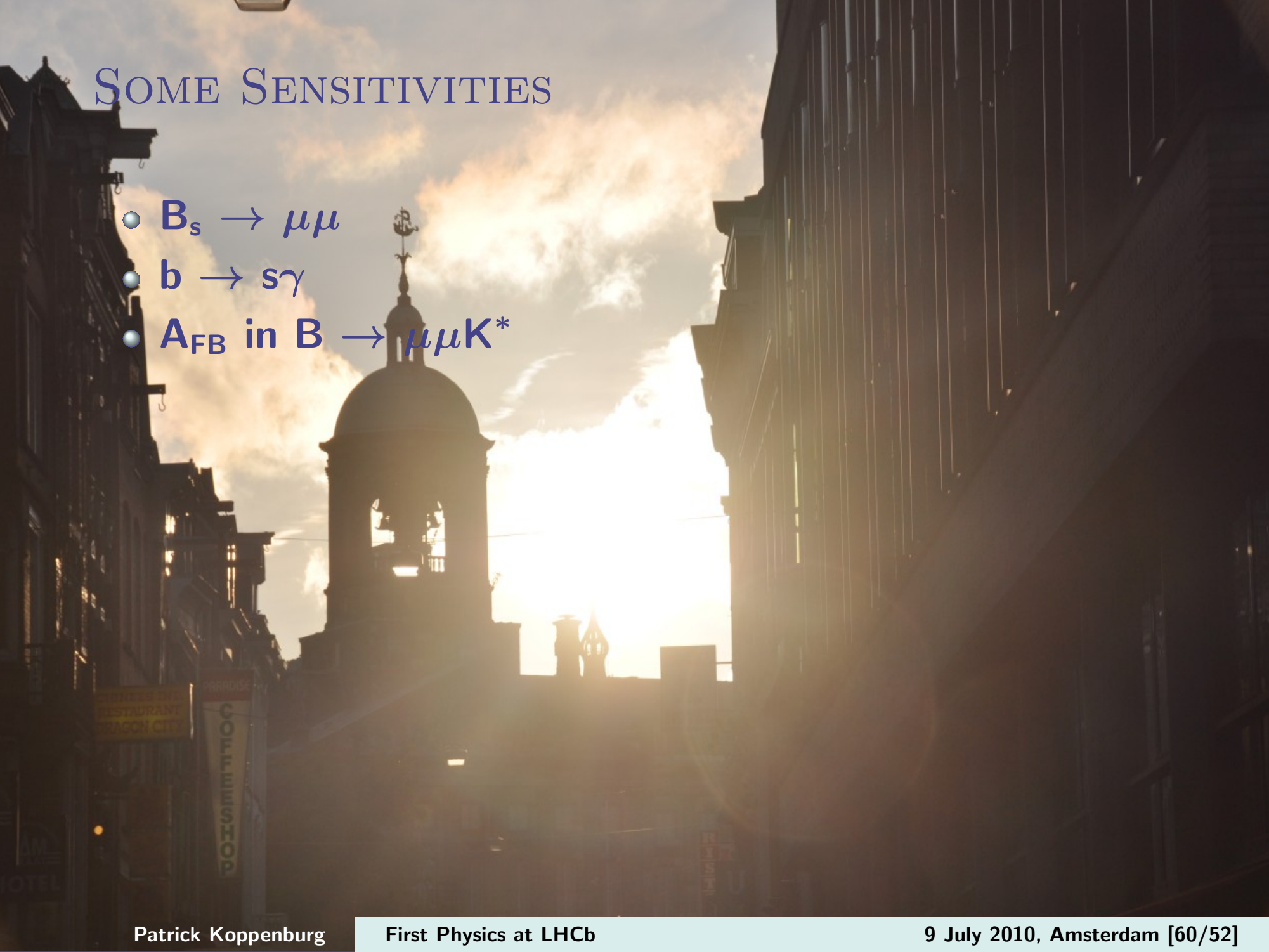
➜ We will be ready for B physics

Conclusion

- Very good start in 2010
- First measurements are coming out ➜ more at ICHEP
- We should be able to get new results in $B_s \to \mu\mu$ and $B \to \mu\mu K^*$ in 2011

A new era in flavour physics is starting

Questions?

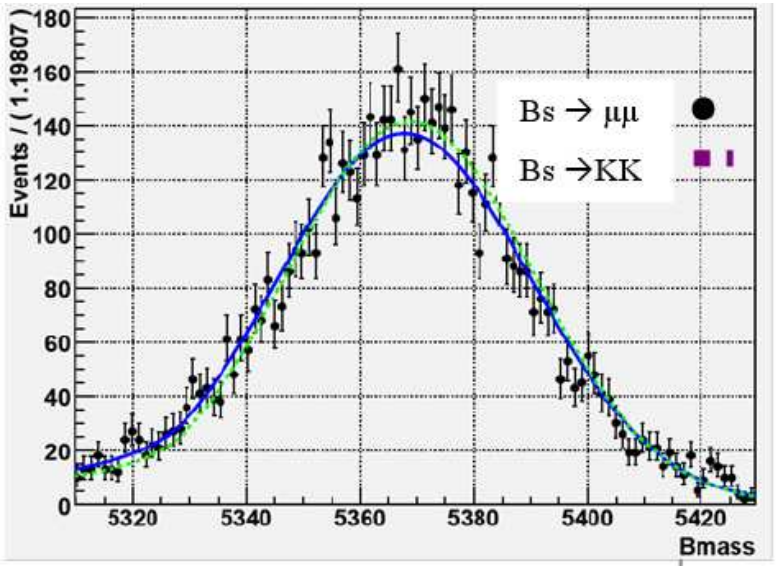


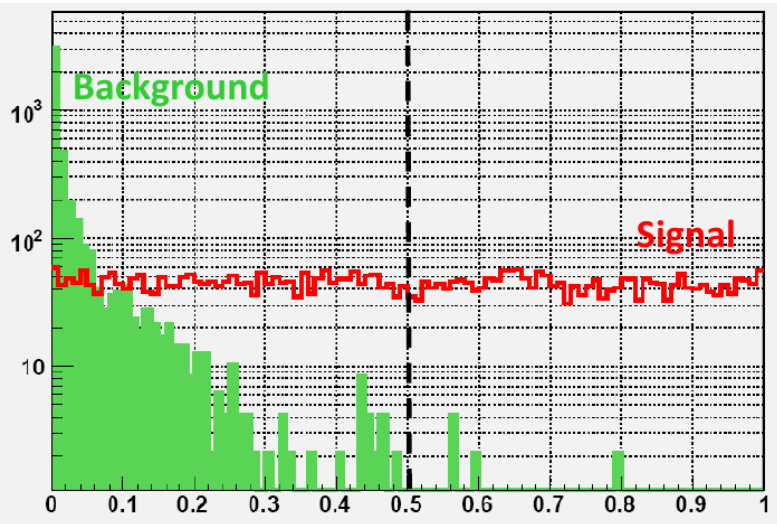
Some Sensitivities

- $B_s \to \mu\mu$
- $b \to s\gamma$
- A_{FB} in $B \to \mu\mu K^*$

$B_s \to \mu\mu$

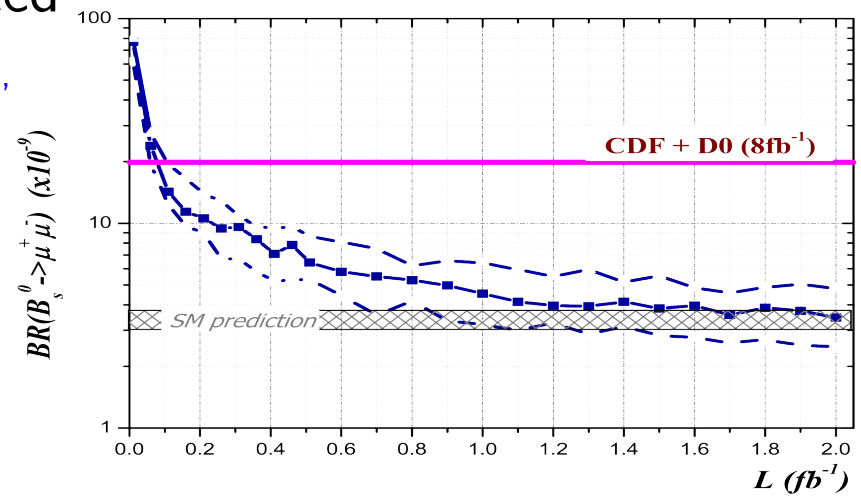
- Very rare but SM BF well predicted $\mathcal{B} = (3.35 \pm 0.32) \cdot 10^{-9}$ [Blanke et al., JHEP0610:003,2006]
- Sensitive to (pseudo)scalar operators
  - MSSM: $\mathcal{B} \propto \frac{\tan^6 \beta}{M_A^4}$
- Present limit from CDF $\mathcal{B} < 4.3 \cdot 10^{-8}$ (95% CL)
- Select signal in a 3D-box of mass, geometrical likelihood, PID likelihood
  - Uncorrelated variables with different control samples
  - B mass resolution ~ 20 MeV

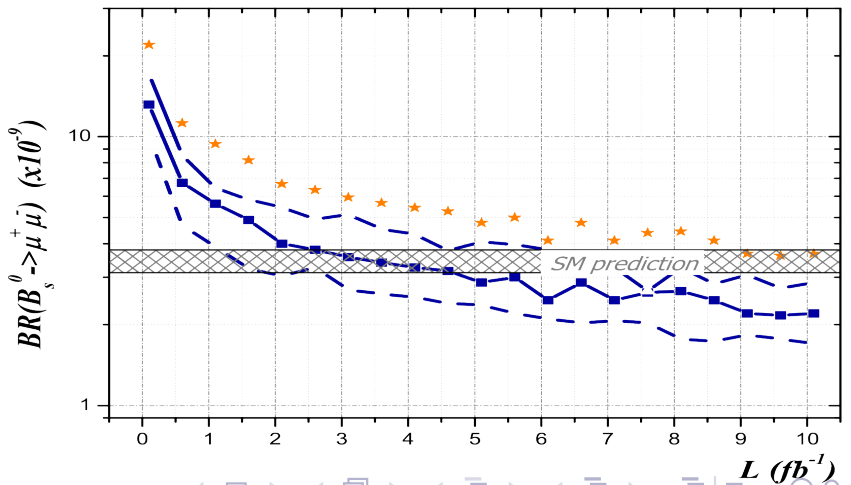




$B_s \to \mu\mu$

- Very rare but SM BF well predicted $\mathcal{B} = (3.35 \pm 0.32) \cdot 10^{-9}$ [Blanke et al., JHEP0610:003,2006]
- Sensitive to (pseudo)scalar operators
  - MSSM: $\mathcal{B} \propto \frac{\tan^6 \beta}{M_A^4}$
- Present limit from CDF $\mathcal{B} < 4.3 \cdot 10^{-8}$ (95% CL)
- With SM BF, expect 8 signal and 12 background events in most sensitive bin in $2\,\text{fb}^{-1}$
  - ➜ 3σ evidence with $2\,\text{fb}^{-1}$
  - ➜ 5σ observation with 6–10 fb^{-1}

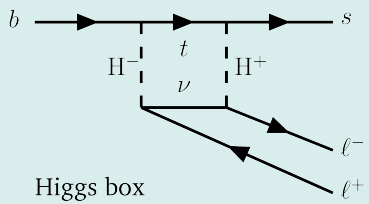




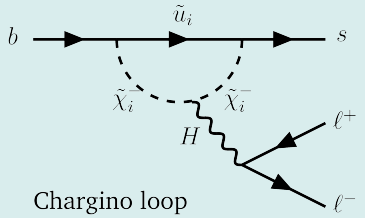
$B \to \mu\mu K^*$

- $B \to \mu\mu K^*$ very rare in the SM
  $\mathcal{B}(B \to \ell\ell K^*) = (1.2 \pm 1.0) \cdot 10^{-6}$
- Sensitive to
  - Supersymmetry,
  - Graviton exchanges,
  - Extra dimensions

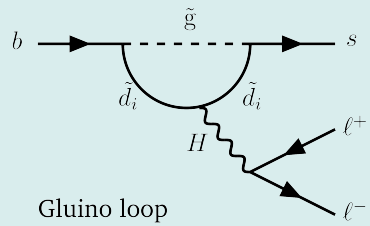
➜ Ideal place to look for new physics



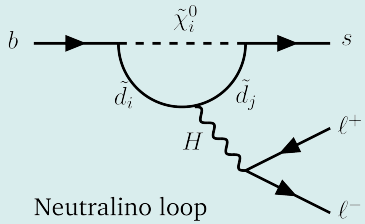
Higgs box



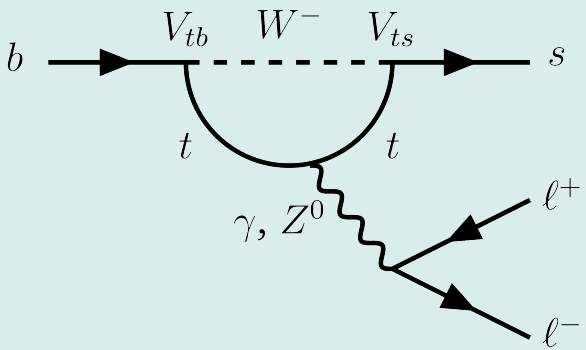
Chargino loop

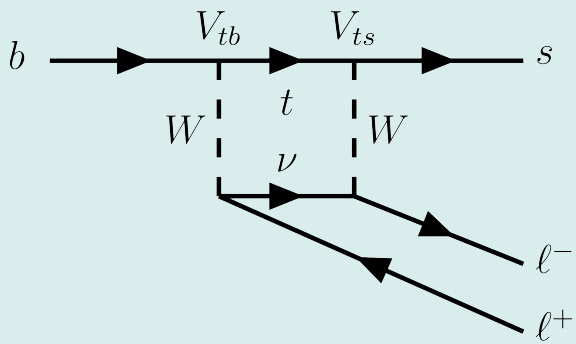


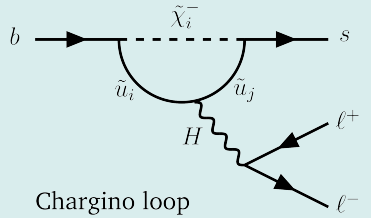
Gluino loop



Neutralino loop







Chargino loop

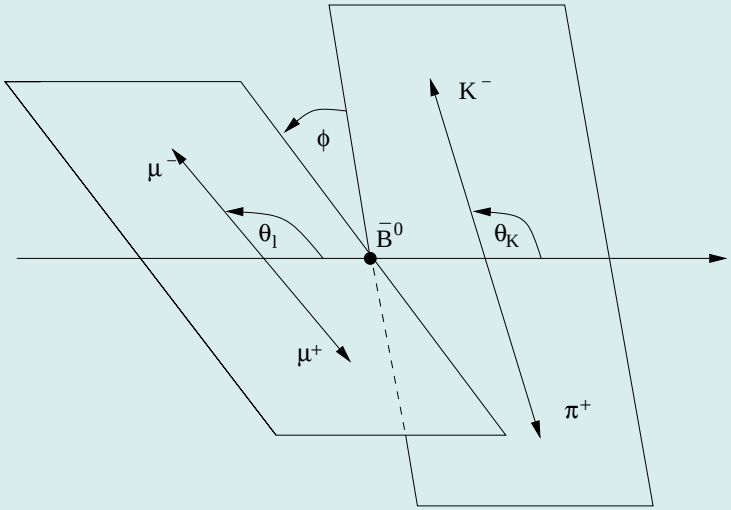
Angular Distributions

A lot of information in the full θ_ℓ, θ_K and ϕ distributions

$$\frac{d\Gamma'}{d\theta_l} = \Gamma' \left(\frac{3}{4} F_L \sin^2\theta_l + A_{FB} \cos\theta_l + \frac{3}{8}(1-F_L)(1+\cos^2\theta_l) \right)$$

$$\frac{d\Gamma'}{d\phi} = \frac{\Gamma'}{2\pi} \left(\frac{1}{2}(1-F_L) A_T^{(2)} \cos 2\phi + A_{Im} \sin 2\phi + 1 \right)$$

$$\frac{d\Gamma'}{d\theta_K} = \frac{3\Gamma'}{4} \sin\theta_K \left(2F_L \cos^2\theta_K + (1-F_L)\sin^2\theta_K \right)$$



➜ **Many observables**

[Krüger & Matias]
[Egede, et. al.]

Angular Distributions

A lot of information in the full θ_ℓ, θ_K and ϕ distributions

$$\frac{d\Gamma'}{d\theta_l} = \Gamma' \left(\frac{3}{4} F_L \sin^2\theta_l + A_{FB} \cos\theta_l + \frac{3}{8}(1-F_L)(1+\cos^2\theta_l) \right)$$

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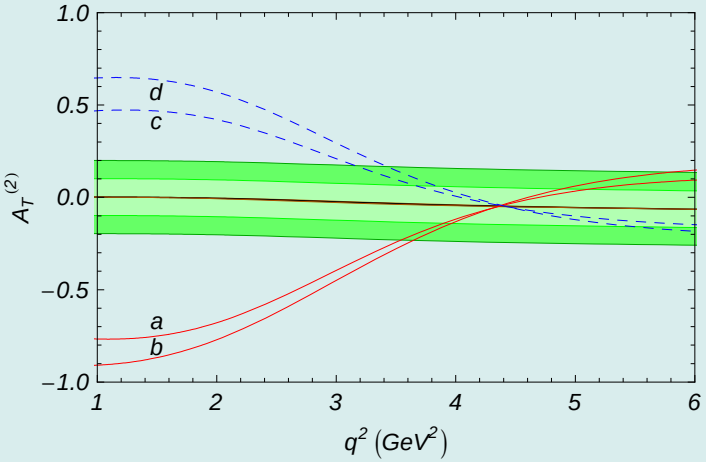
$$\frac{d\Gamma'}{d\theta_K} = \frac{3\Gamma'}{4} \sin\theta_K \left(2F_L \cos^2\theta_K + (1-F_L)\sin^2\theta_K \right)$$



➜ **Transverse asymmetry $A_T^{(2)}$ (RH)**

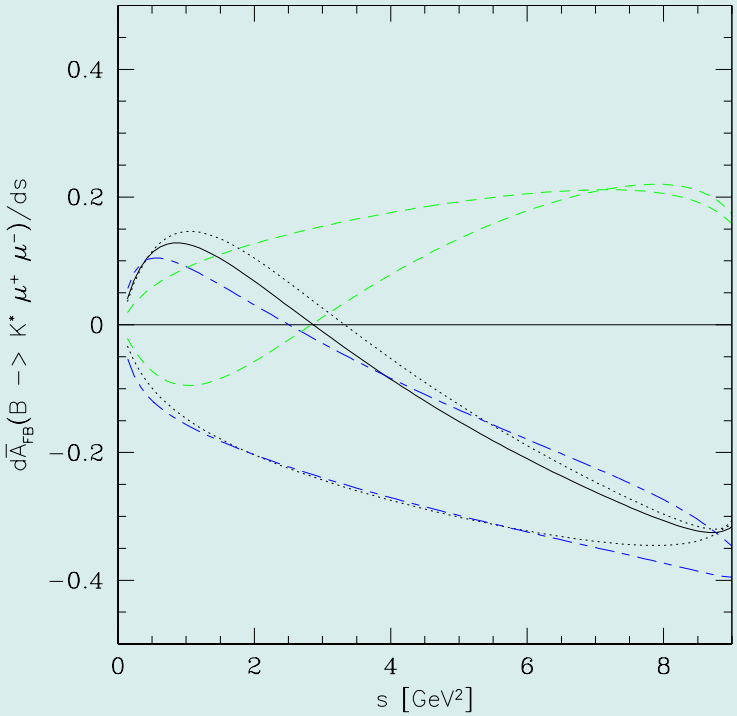
[Krüger & Matias]
[Egede, et. al.]

Angular Distributions

A lot of information in the full θ_ℓ, θ_K and ϕ distributions

$$\frac{\mathrm{d}\Gamma'}{\mathrm{d}\theta_l} = \Gamma' \left(\frac{3}{4} F_L \sin^2\theta_l + A_{\mathrm{FB}} \cos\theta_l + \frac{3}{8}(1 - F_L)(1 + \cos^2\theta_l) \right)$$

$$A_{\mathrm{FB}} = \frac{\left(\int_0^1 - \int_{-1}^0 \right) \mathrm{d}\cos\theta_l \frac{\mathrm{d}^2\Gamma}{\mathrm{d}q^2 \mathrm{d}\cos\theta_l}}{\int_{-1}^1 \mathrm{d}\cos\theta_l \frac{\mathrm{d}^2\Gamma}{\mathrm{d}q^2 \mathrm{d}\cos\theta_l}}$$



➜ Zero point measures ratio of Wilson coeffs C_9/C_7.

➜ **Forward-backward asymmetry A_{FB}**

[Krüger & Matias]
[Egede, et. al.]

Messages from Other Experiments

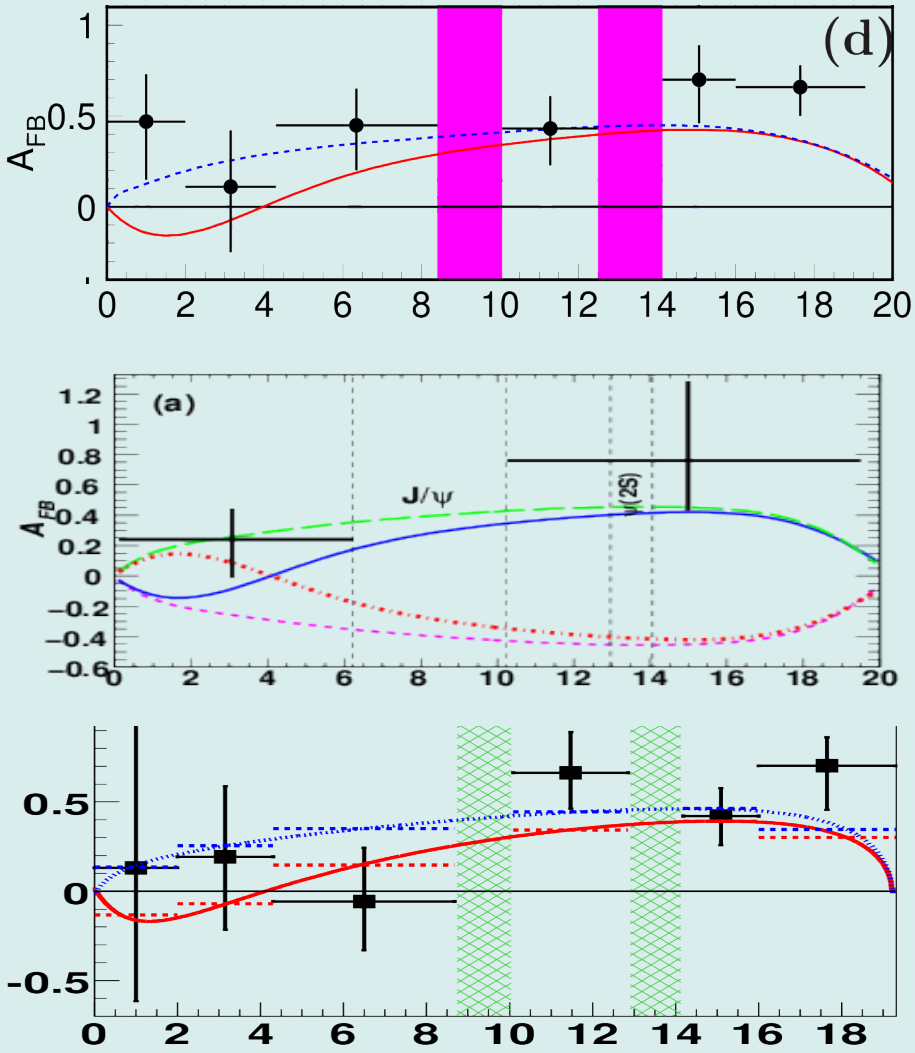
Belle: 230 $B \to \ell\ell K^*$ events in $657 \cdot 10^6$ $B\overline{B}$ [PRL103:171801,2009]

BABAR: 60 $B \to \ell\ell K^*$ events in $384 \cdot 10^6$ $B\overline{B}$ [PRD79:031102,2009]

CDF: 100 $B \to \ell\ell K^*$ events in $4.4\ \text{fb}^{-1}$ [CDF public note]

FB asymmetry: All seem to favour $C_7 = -C_7^{SM}$ case. Not conclusive yet...

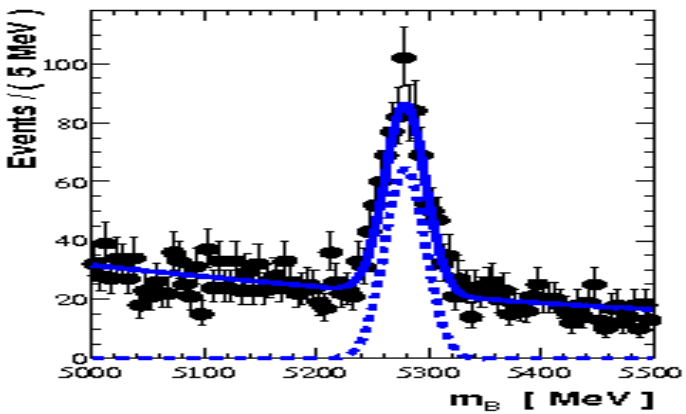
➜ Need much more statistics

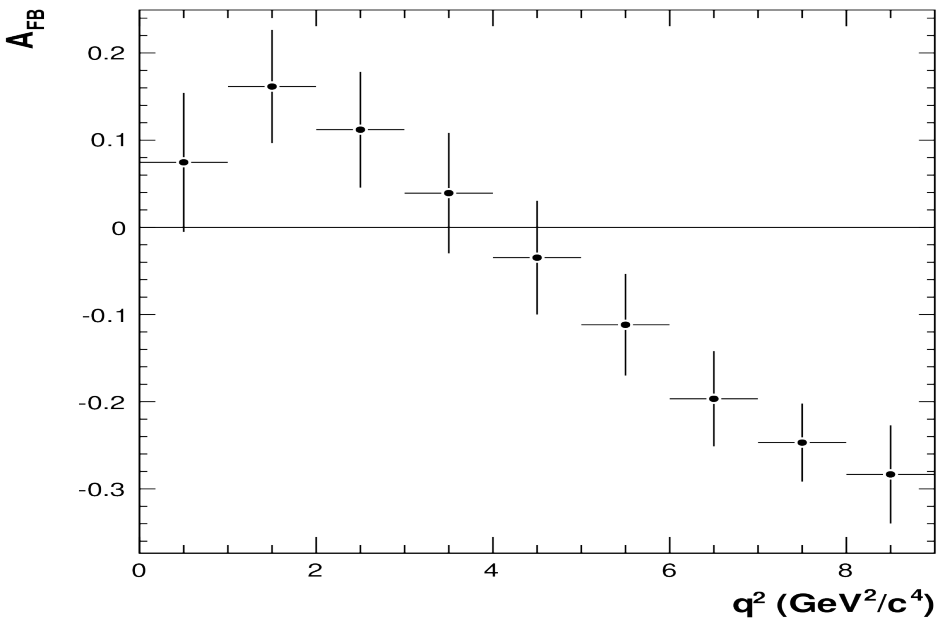


$B_d \to \mu\mu K^*$ YIELDS WITH $2\,\mathrm{FB}^{-1}$

Expected signal and background yields in $2\,\mathrm{fb}^{-1}$ of data (Assuming the SM BR of $\mathbf{12 \cdot 10^{-7}}$):

Sample	Yield
$\mathbf{B_d \to \mu\mu K^*}$	$\mathbf{7200 \pm 2100}$
$b \to \mu\mu s$	2000 ± 100
$2(b \to \mu)$	1050 ± 250
$b \to \mu c(\mu q)$	600 ± 200
Background	3700 ± 300
B/S	$\mathbf{0.5 \pm 0.2}$

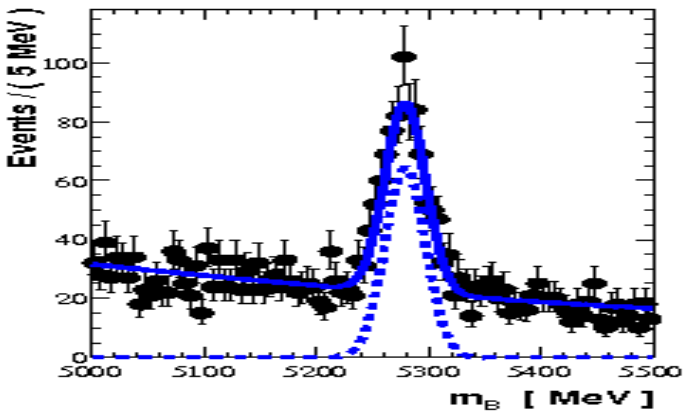


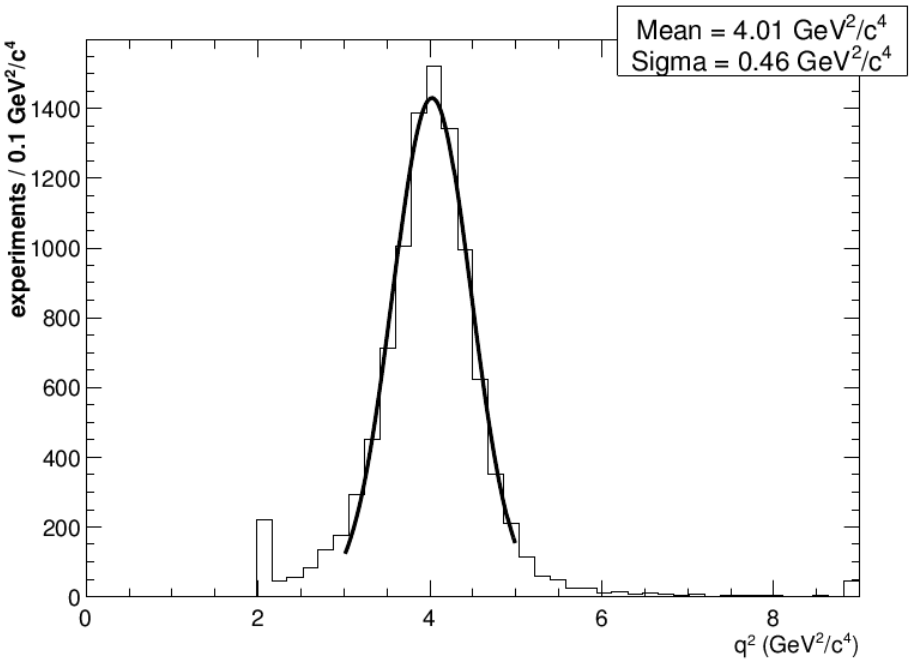


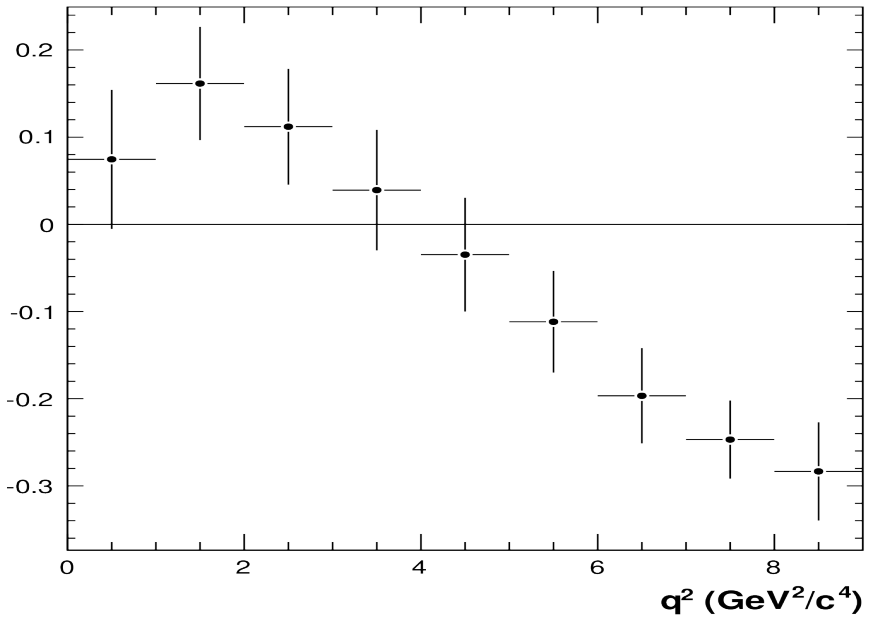
$B_d \to \mu\mu K^*$ YIELDS WITH $2\,\mathrm{FB}^{-1}$

Expected signal and background yields in $2\,\mathrm{fb}^{-1}$ of data (Assuming the SM BR of $\mathbf{12 \cdot 10^{-7}}$):

➜ Resolution on A_{FB} zero : $\pm 0.46\,\mathrm{GeV}^2$ (12%) in $2\,\mathrm{fb}^{-1}$





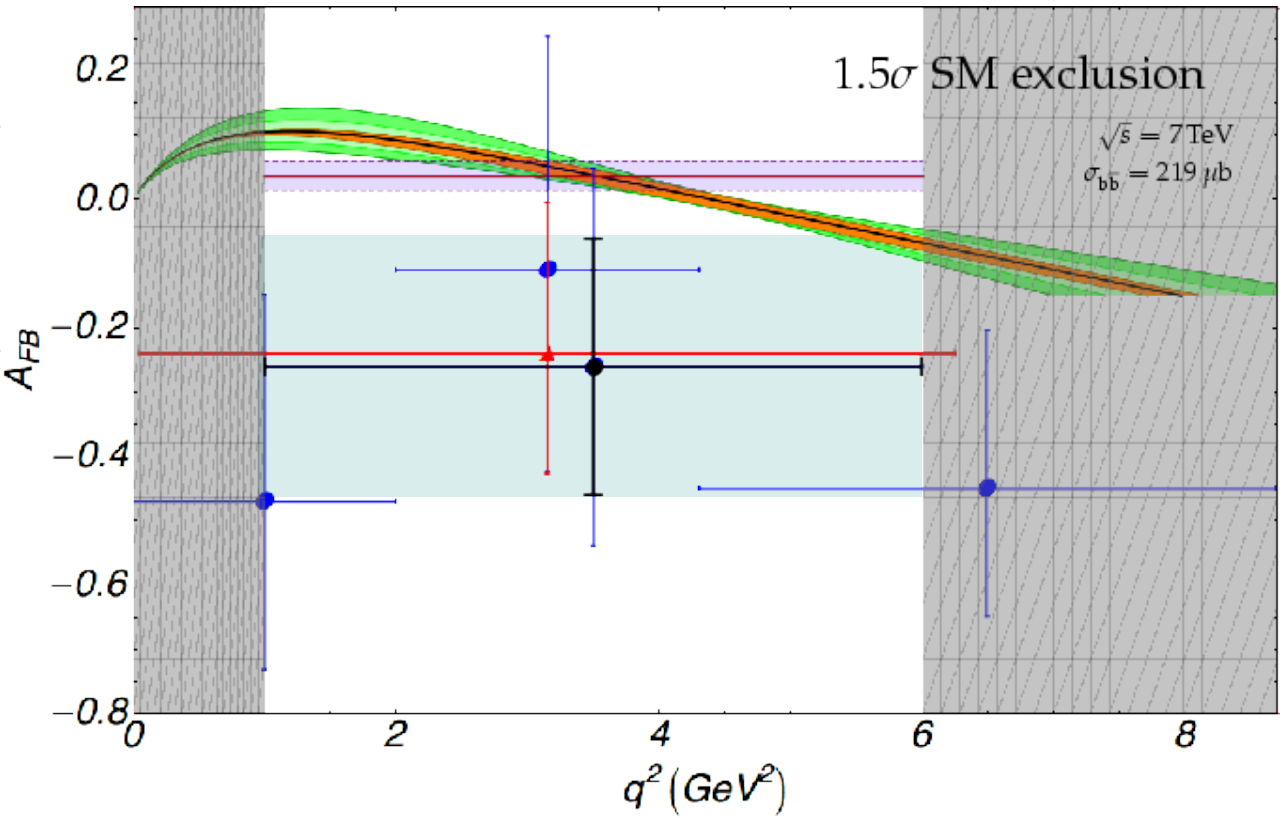


Scaling to Lower Luminosities

Assume Belle is right.

If we measure the mean A_{FB} in a bin 1–6 GeV^2. How well can we exclude the SM?

100 pb^{-1}: 1.5σ



SM prediction — Babar — Belle

LHCb at 100 pb^{-1}

Scaling to Lower Luminosities

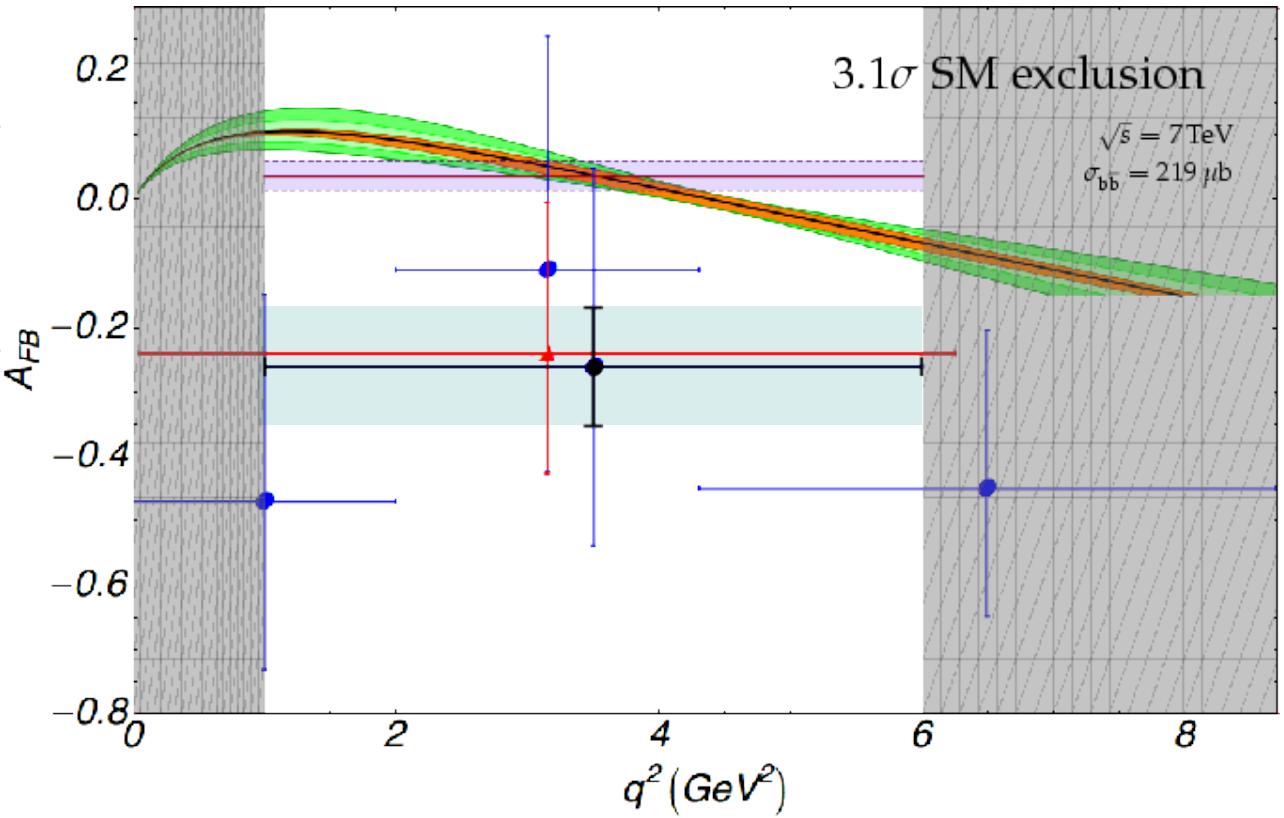
Assume Belle is right.

If we measure the mean A_{FB} in a bin 1–6 GeV^2. How well can we exclude the SM?

100 pb^{-1}: 1.5σ

300 pb^{-1}: 2.4σ

500 pb^{-1}: 3.1σ



SM prediction — Babar — Belle

LHCb at 500 pb^{-1}

Scaling to Lower Luminosities

Assume Belle is right.

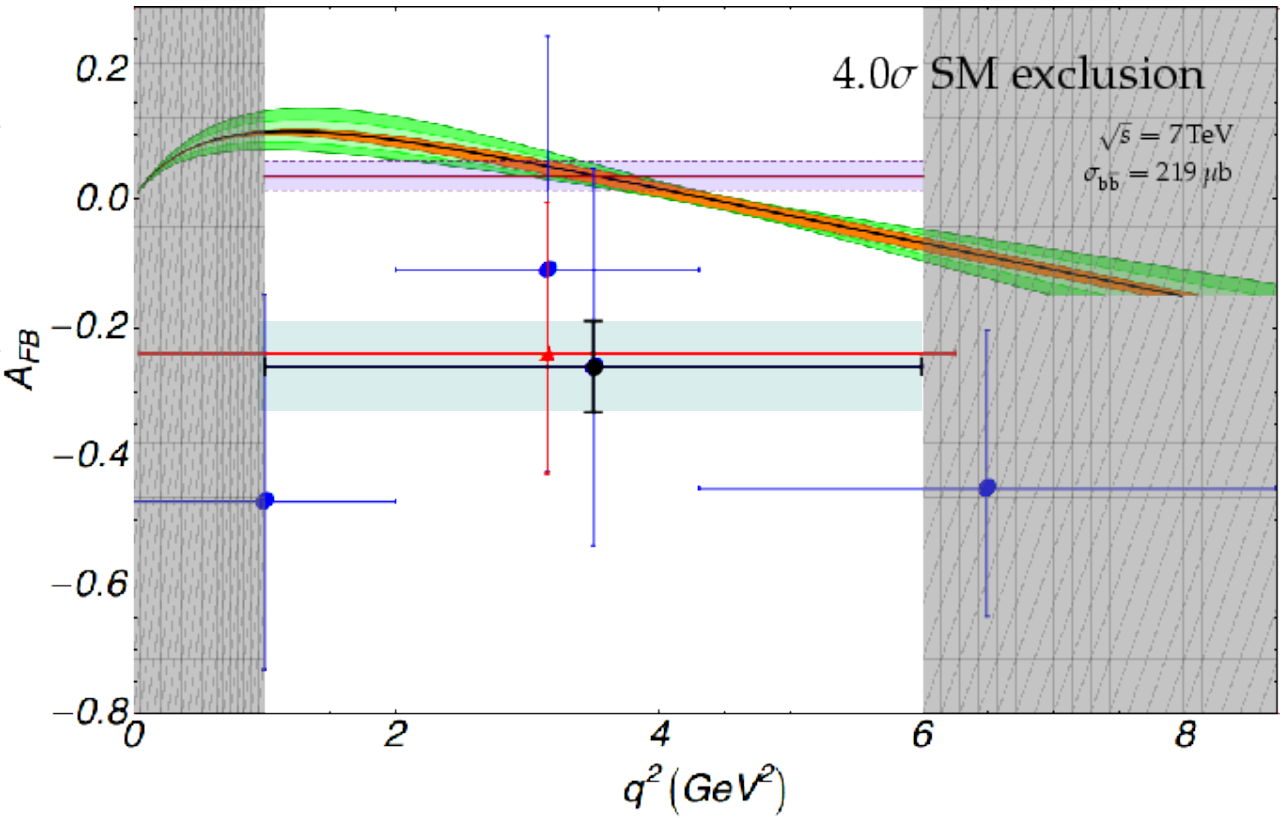
If we measure the mean A_{FB} in a bin 1–6 GeV^2. How well can we exclude the SM?

100 pb^{-1}: 1.5σ

300 pb^{-1}: 2.4σ

500 pb^{-1}: 3.1σ

1 fb^{-1}: 4.0σ

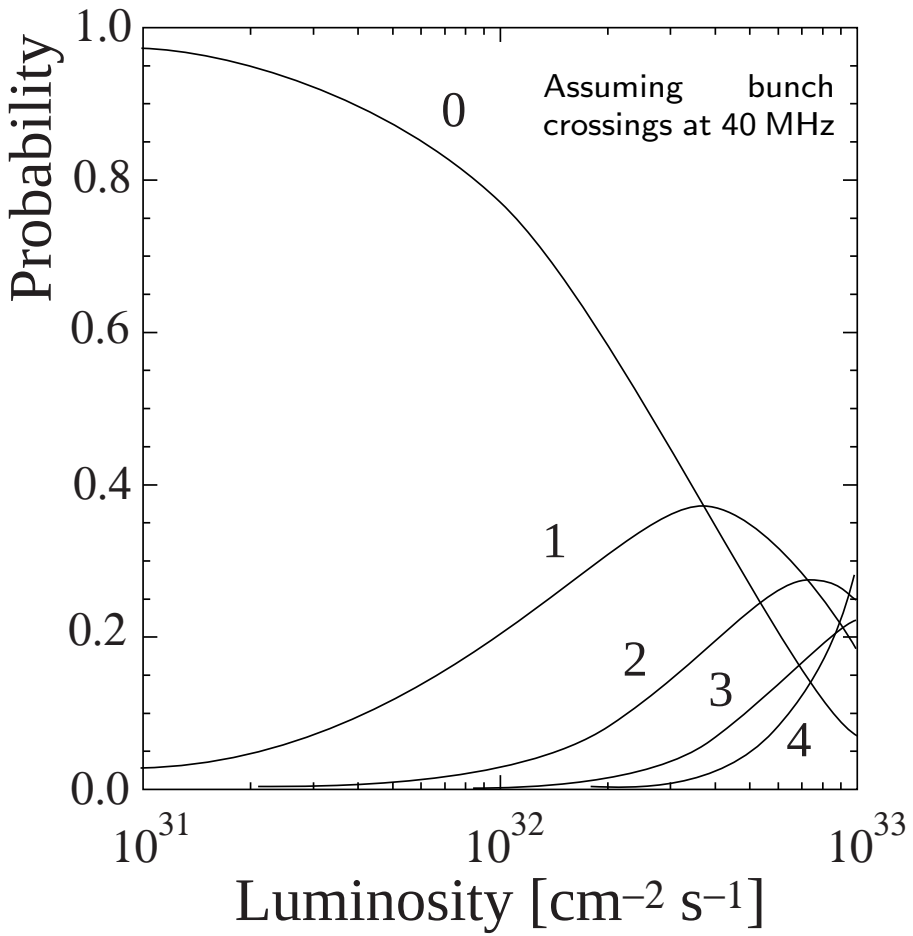


SM prediction — Babar — Belle

LHCb at 1 fb^{-1}

b Physics at Hadron Colliders

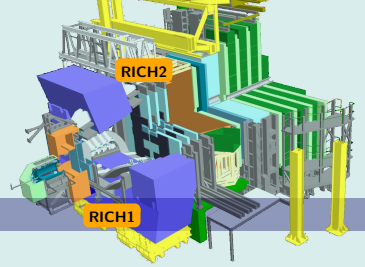
- B mesons have a long lifetime $c\tau = 0.5\,\mathrm{mm}$ with $\gamma = \mathcal{O}(10\text{–}100)$
  - You want to make lifetime-dependent measurements
    - ✔ Good vertex resolution
- ✗ Not too many pp interactions per bunch crossing
  ➜ Control luminosity to avoid multiple pp collision events
  - We will reach baseline luminosity very early



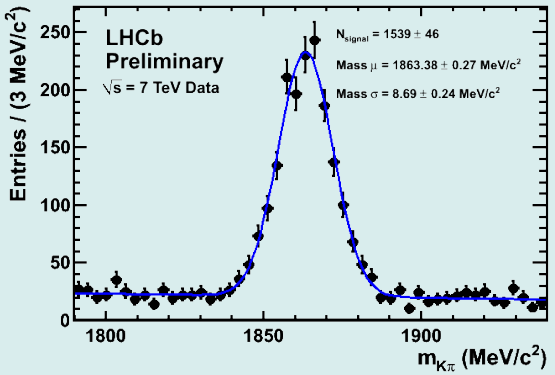
b Physics at Hadron Colliders

- B mesons have a long lifetime $c\tau = 0.5\,\mathrm{mm}$ with $\gamma = \mathcal{O}(10\text{–}100)$
  - You want to make lifetime-dependent measurements
    - ✔ Good vertex resolution
- They have a large mass $\sim 5\,\mathrm{GeV}$, but not very large.
  - Look for particles with a transverse momentum $p_T = \mathcal{O}(1)\,\mathrm{GeV}$
- $b \to c$ and $c \to s$. 20% B decay to leptons.
  - ✔ Use Kaon, muon and electron-ID
- ✔ Good particle ID to fight large background
- There will still be a lot of background
  - ✔ Good mass, i.e. momentum resolution

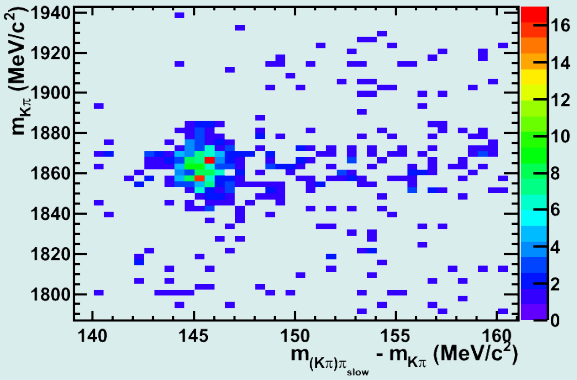
Zoology 3: $D \to K\pi$ and D^*



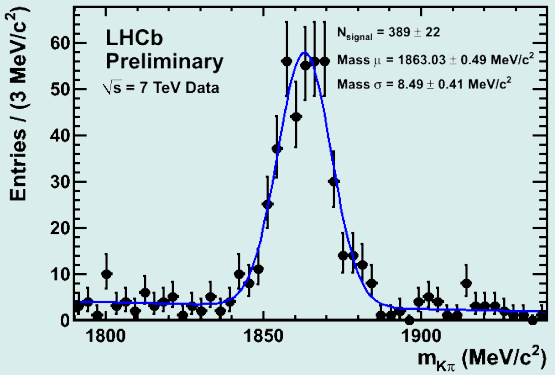
Untagged $K\pi$ mass



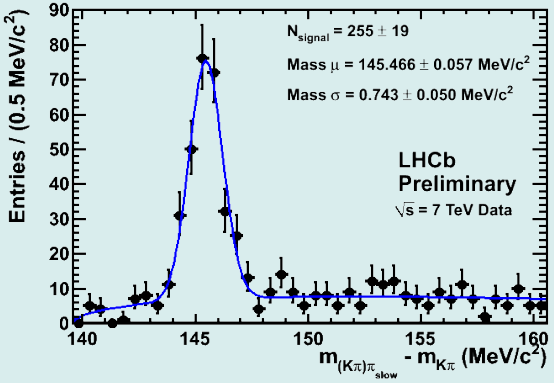
$m_{K\pi}$ vs Δm



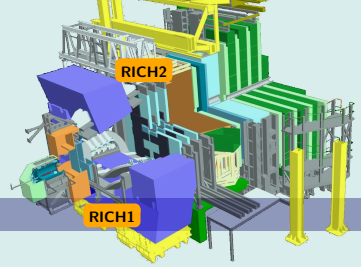
Tagged $K\pi$ mass



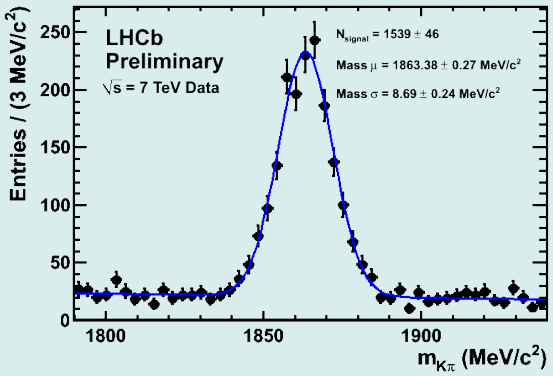
Δm



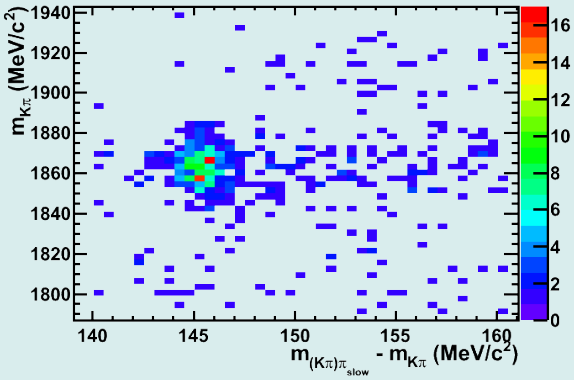
Zoology 3: $D \to K\pi$ and D^*



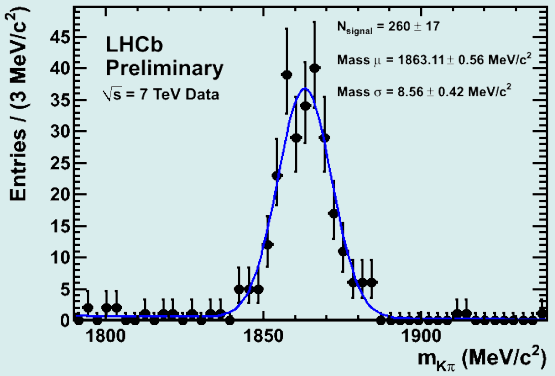
Untagged $K\pi$ mass



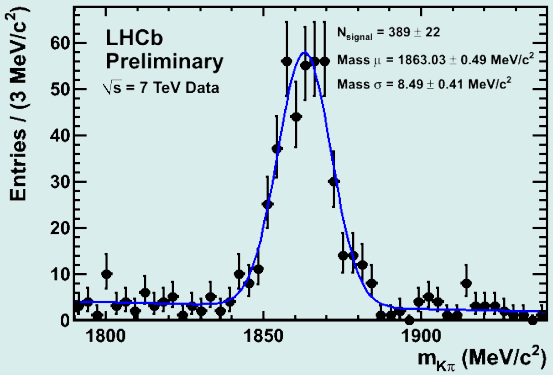
$m_{K\pi}$ vs Δm



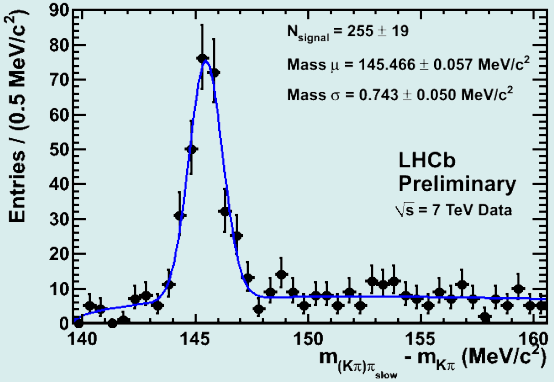
$m_{K\pi}$ with Δm cut



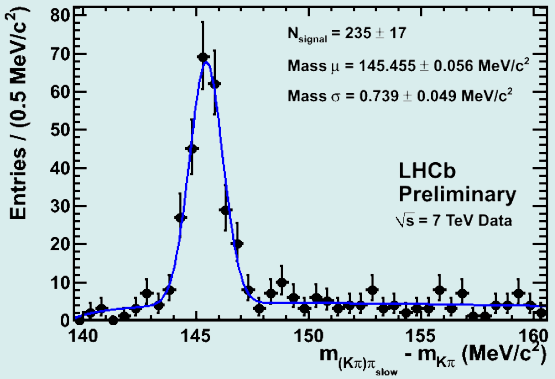
Tagged $K\pi$ mass



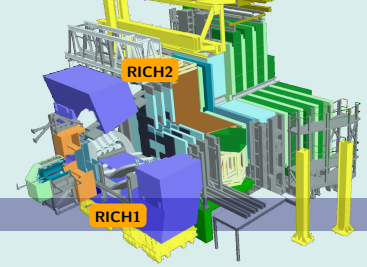
Δm



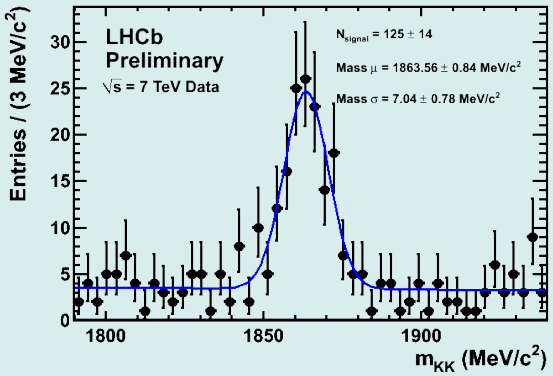
Δm with $m_{K\pi}$ cut



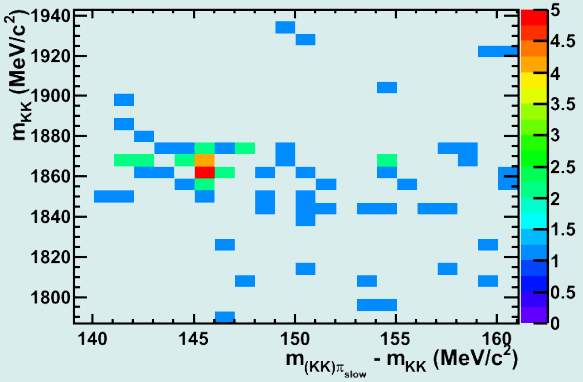
Zoology 3: $D \to KK$ and D^*



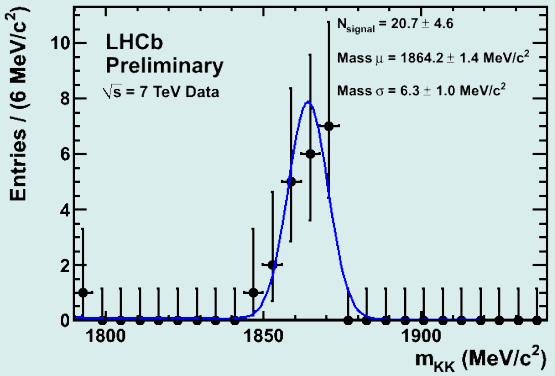
Untagged KK mass



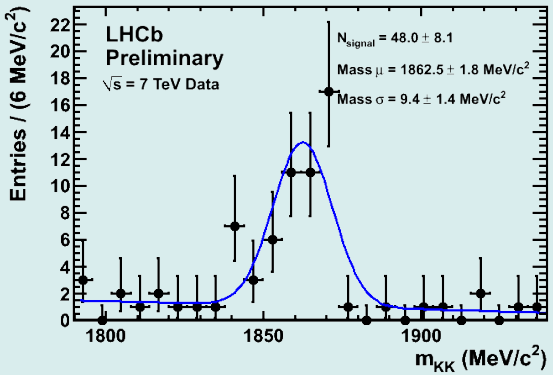
m_{KK} vs Δm



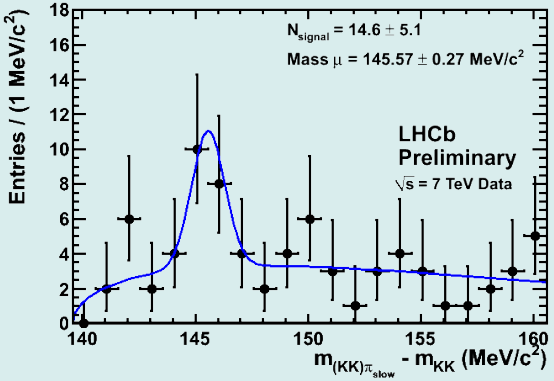
m_{KK} with Δm cut



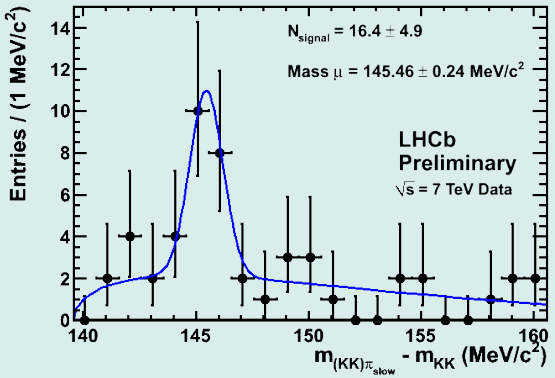
Tagged KK mass



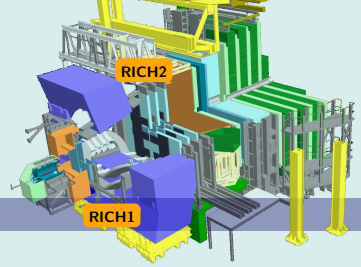
Δm



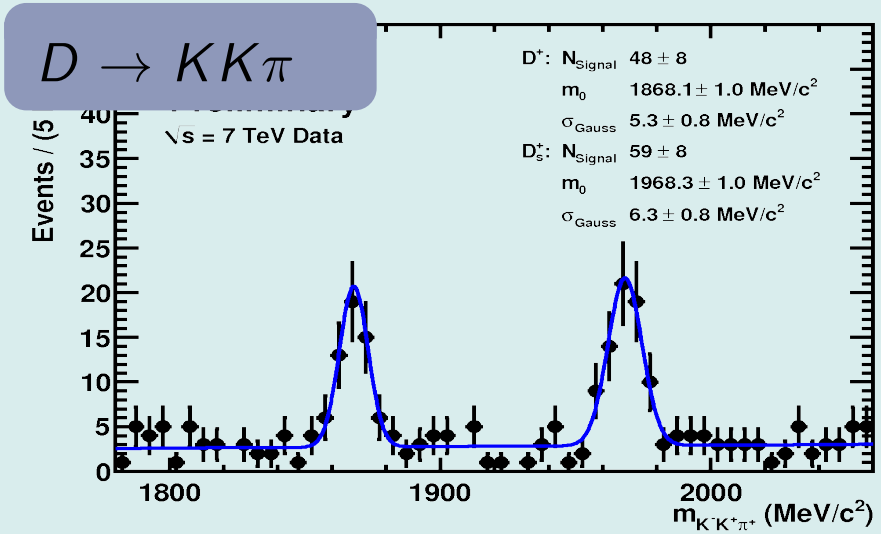
Δm with m_{KK} cut



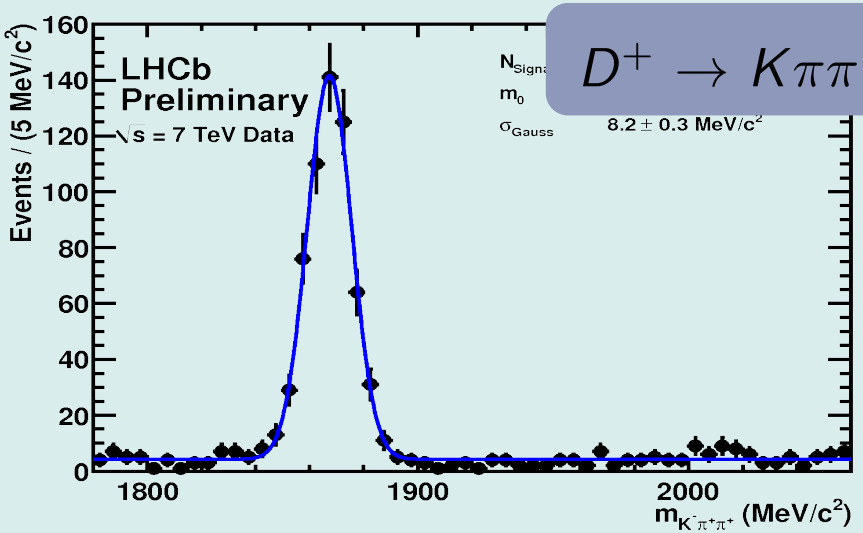
Zoology 4: D^+, D_s^+, Λ_c



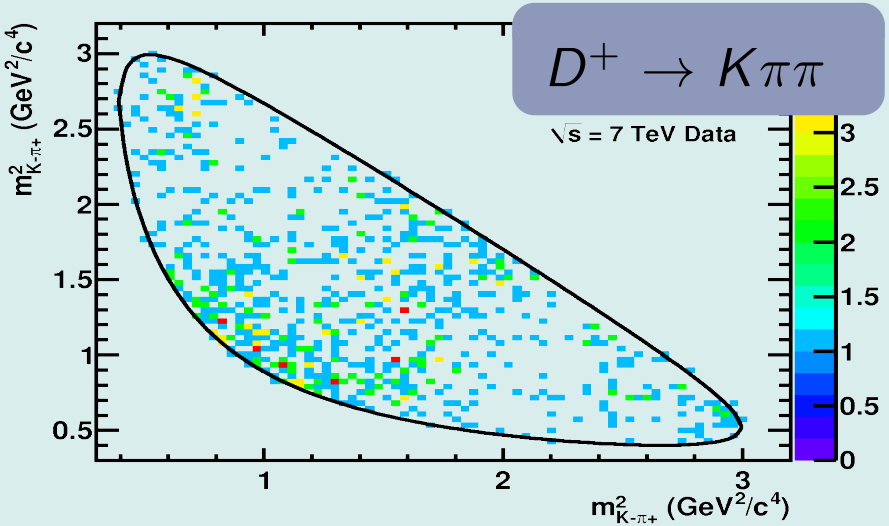
$D \to KK\pi$



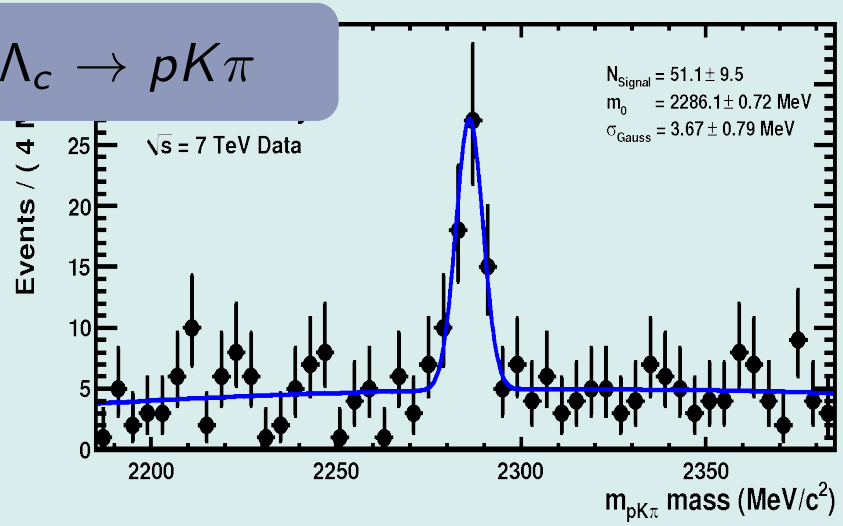
$D^+ \to K\pi\pi$



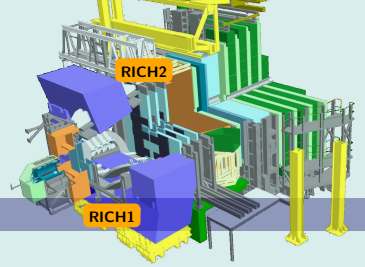
$D^+ \to K\pi\pi$



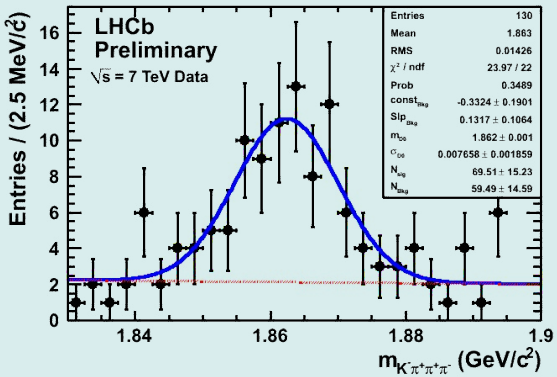
$\Lambda_c \to pK\pi$



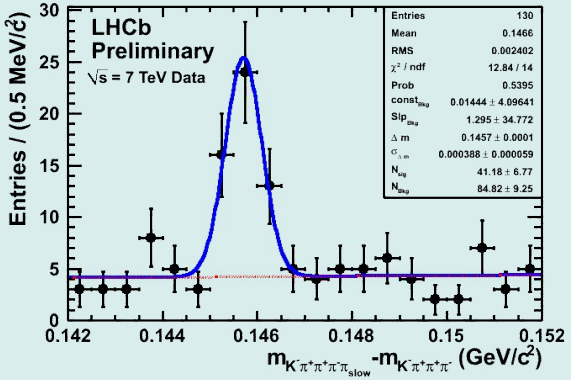
Zoology 5: $D^0 \to K\pi\pi\pi$



Untagged $K\pi\pi\pi$



Δm



$m_{K\pi\pi\pi}$ with Δm cut