First physics from LHCb and prospect for coming years on CP violation measurements

CPV from B factories to Tevatron and LHCb
1 Sept-2 Sept 2010, Sendai, Japan

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Swiss Federal Institute of Technology Lausanne (EPFL)
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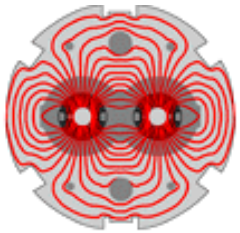
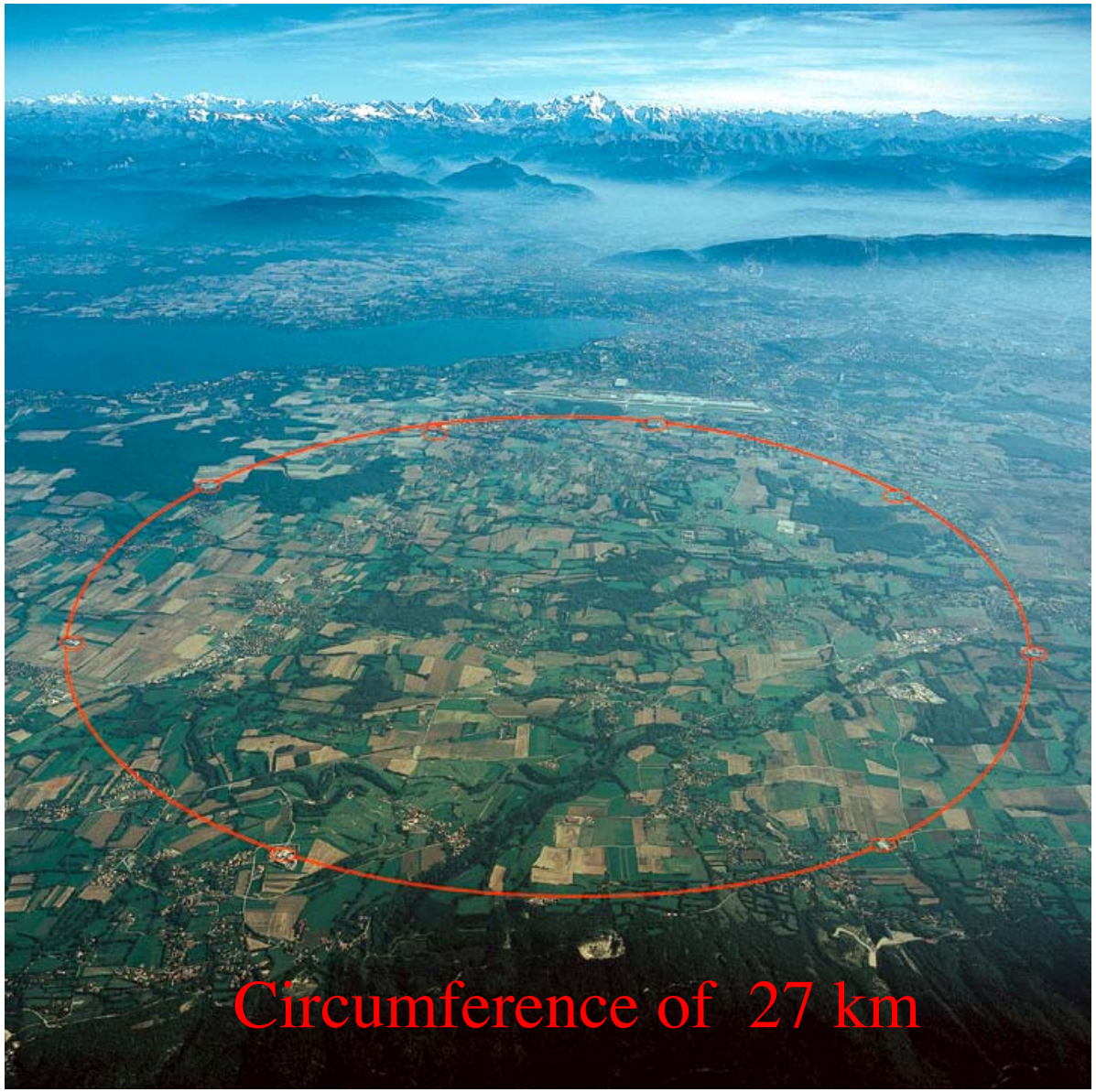
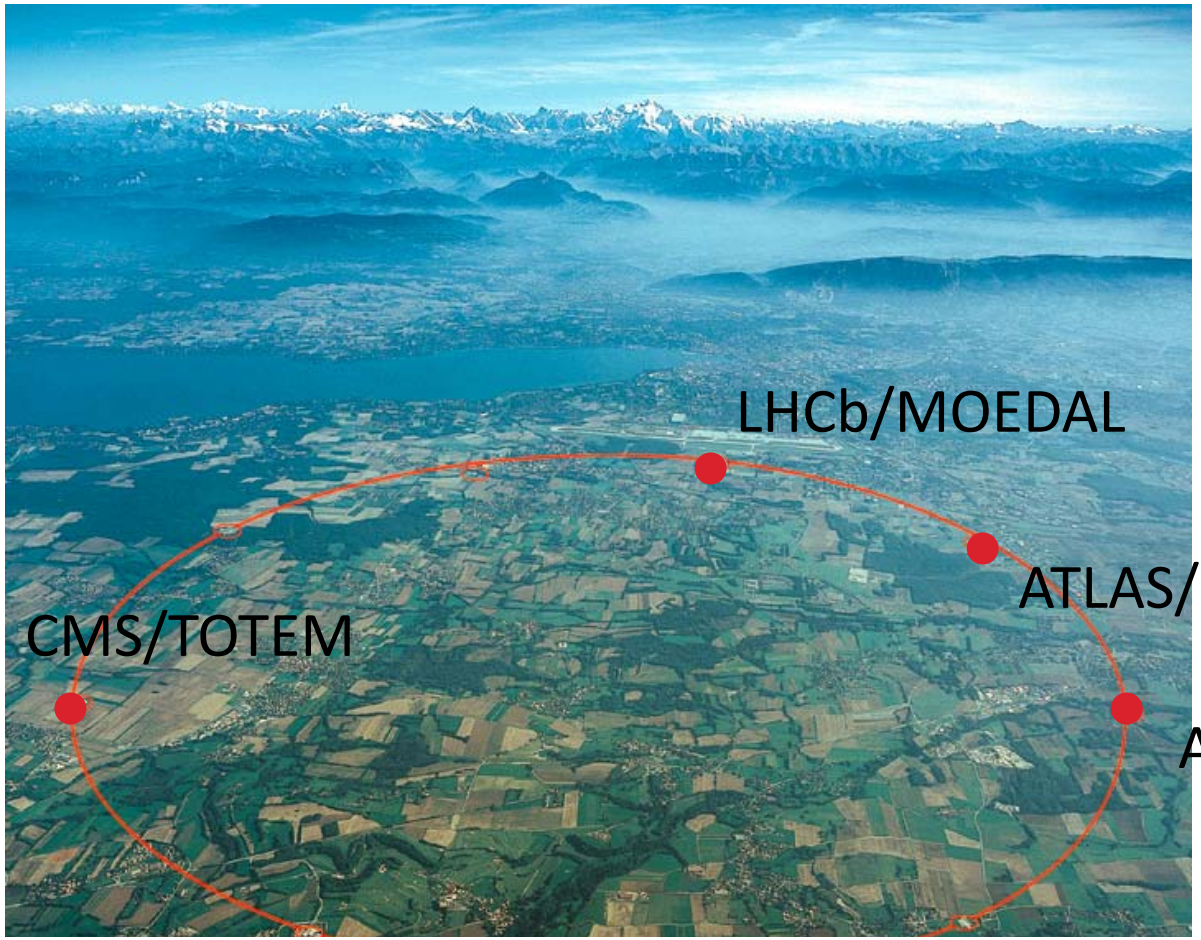
LHC at CERN





LHC at CERN



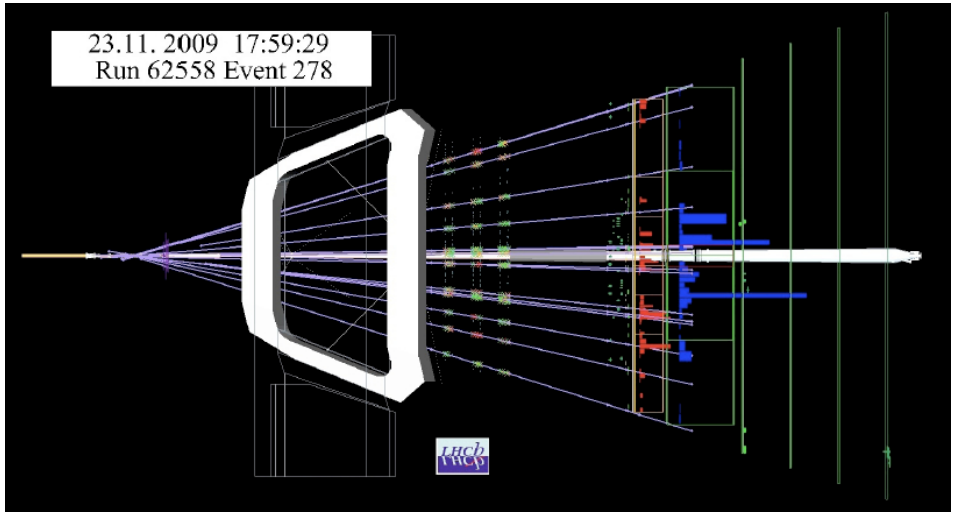
Two general purpose experiments (ATLAS and CMS), one dedicated b-experiment (LHCb), and one dedicated heavy ion experiment (ALICS) from the beginning.

LHC running, LHCb collecting data

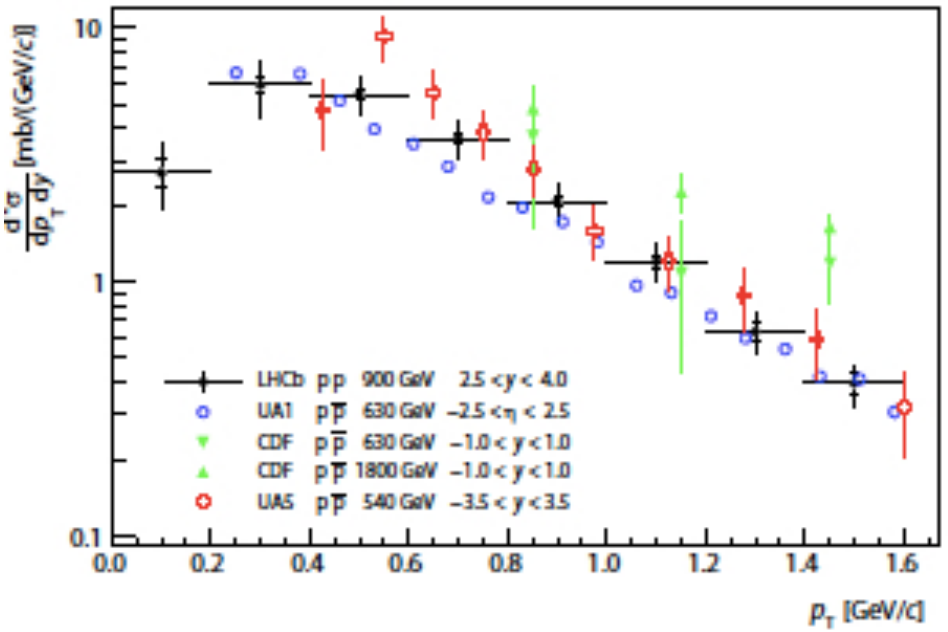
- November 2009, $\sqrt{s}$ = 900 GeV collisions took place

23rd November 2009

- First collisions took place at LHC
- 2009 run: $\int L\,dt \approx 7\ \mu b^{-1}$, at $\sqrt{s} = 900$ GeV



One of the first event



K_S^0 cross sections
to be published in PLB

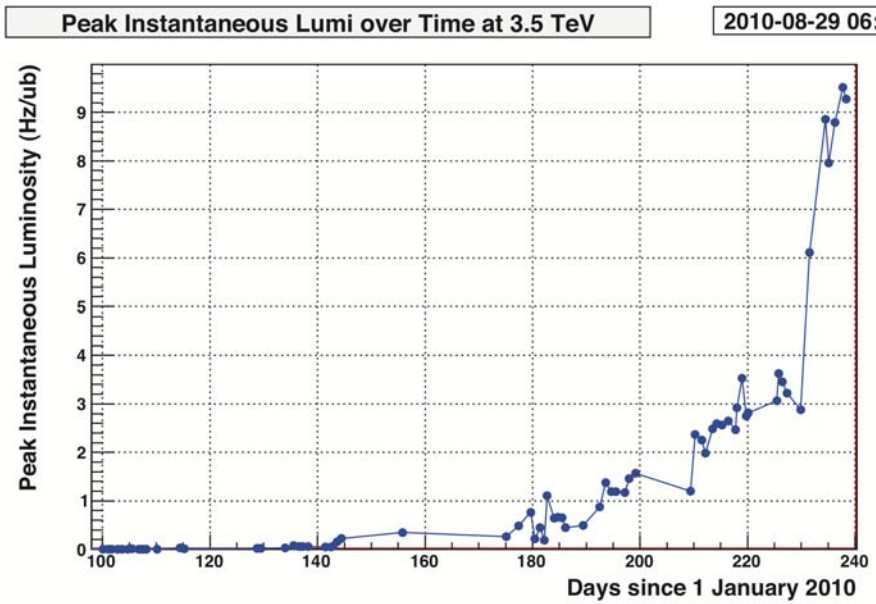
LHC running, LHCb collecting data

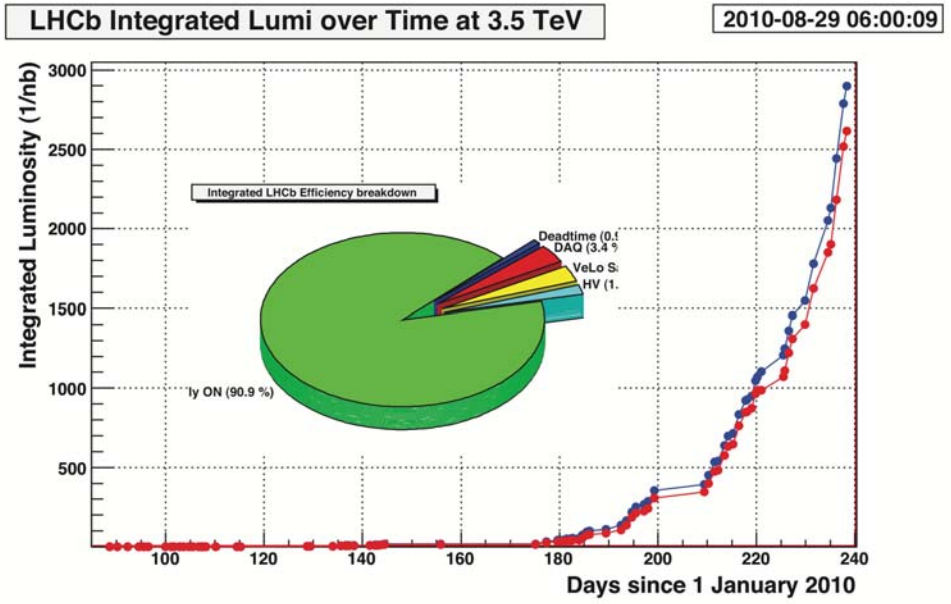
- November 2009, $\sqrt{s}$ = 900 GeV collisions took place
- Since March 2010, running at $\sqrt{s}$ = 7 TeV

Impressive progress in L

Peak luminosity
already ~10^{31}cm^{-2}s^{-1}

Integrated luminosity
already ~3 pb^{-1}

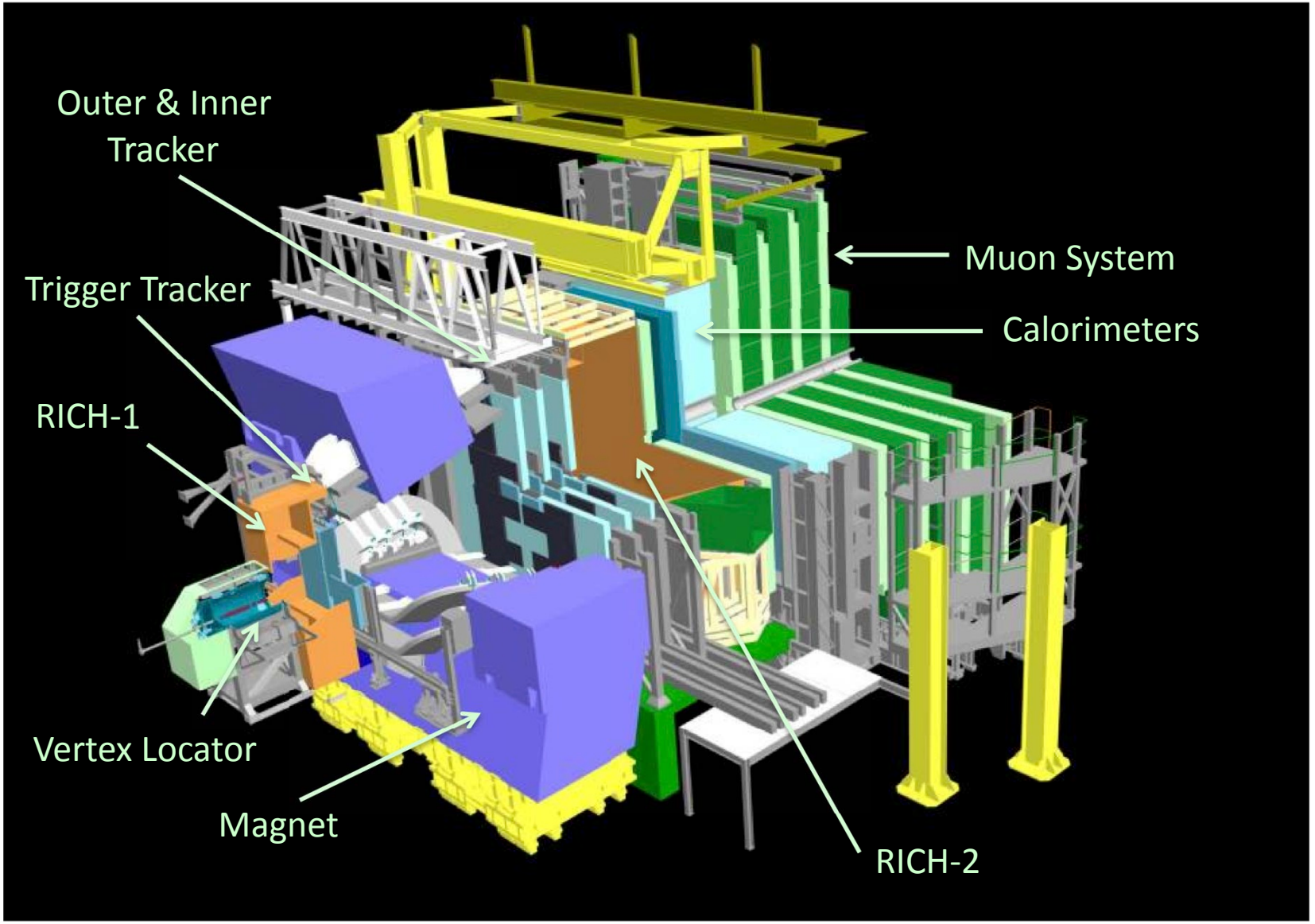




LHC running, LHCb collecting data

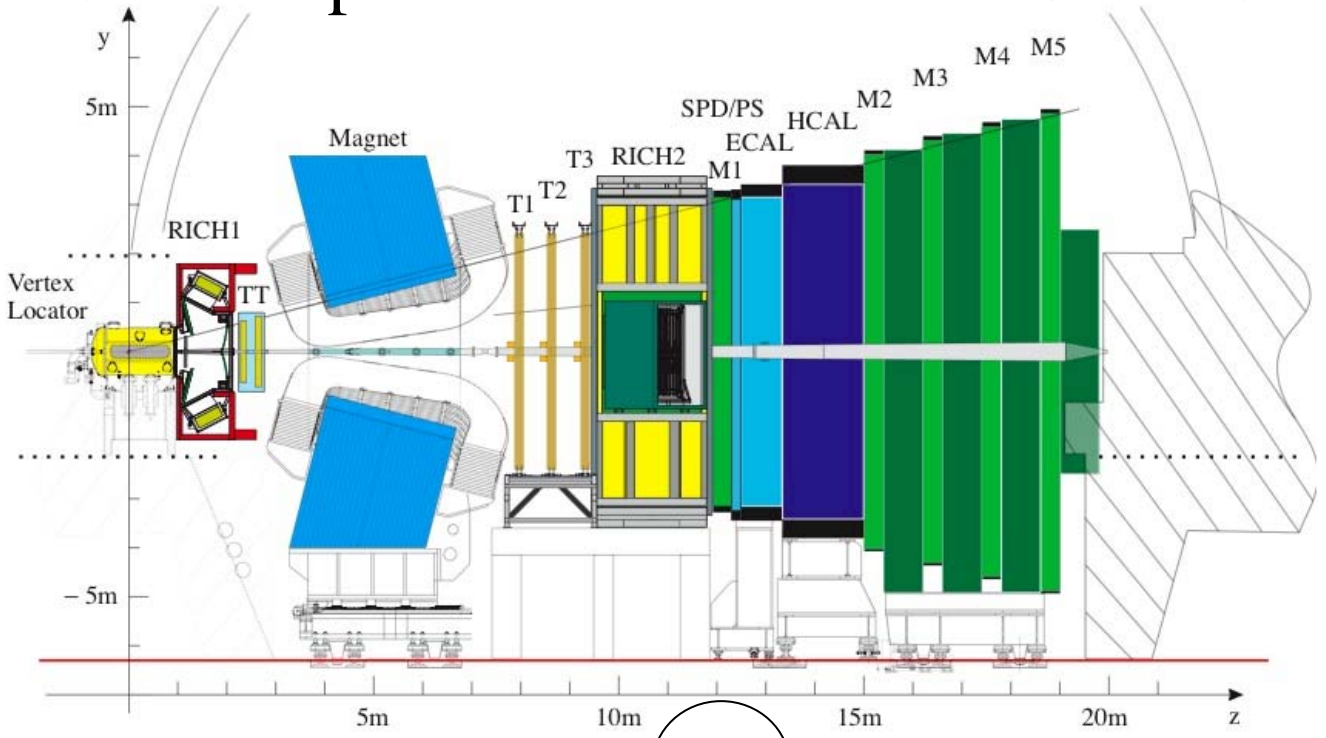
- November 2009, $\sqrt{s}$ = 900 GeV collisions took place
- Since March 2010, running at $\sqrt{s}$ = 7 TeV
  - $n_{\text{p-bunch}} \approx 10^{11}$ ⇔ already nominal value
  - $\beta^* = 3.5$ m ⇔ nominal 0.55 m for 10^{34} cm^{-2}s^{-1}
  - $n_{\text{bunch}} = 46$ ⇔ nominal = 2808
  - $L = 1 \times 10^{31}$ cm^{-2}s^{-1} ⇔ nominal = 10^{34} cm^{-2}s^{-1}
  - Experiments >90% DAQ efficiencies

LHCb Detector

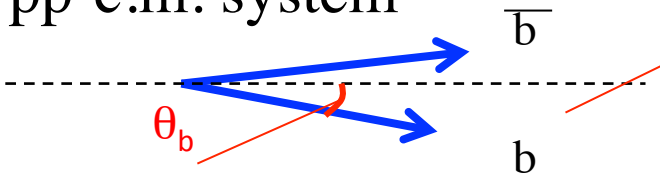


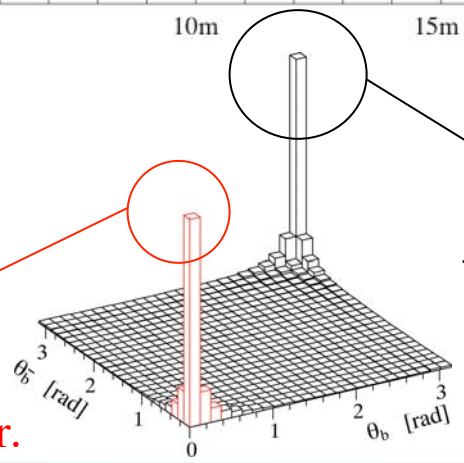
Quick reminder for LHCb

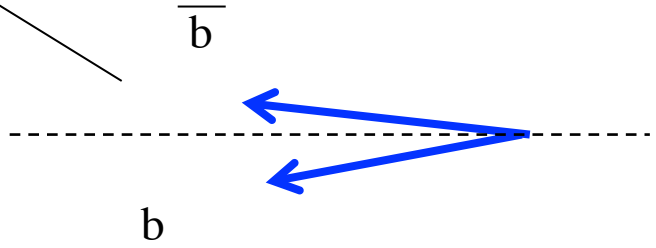
LHCb is a forward spectrometer dedicated for flavour physics



pp-c.m. system







Both b and $\overline{b}$ are in the spectrometer.

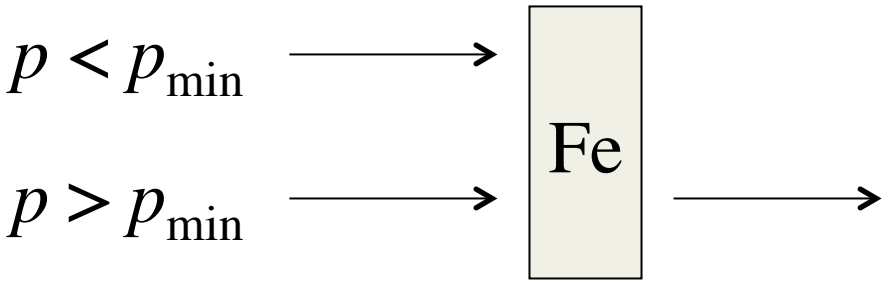
Quick reminder for LHCb

Forward: p_T threshold can be set low: → high b efficiency

For triggering…. $p > p_{min}$

muon: identification

hadron: energy resolution



$\sigma_E/E \approx \sqrt{70\%}/\sqrt{E}$

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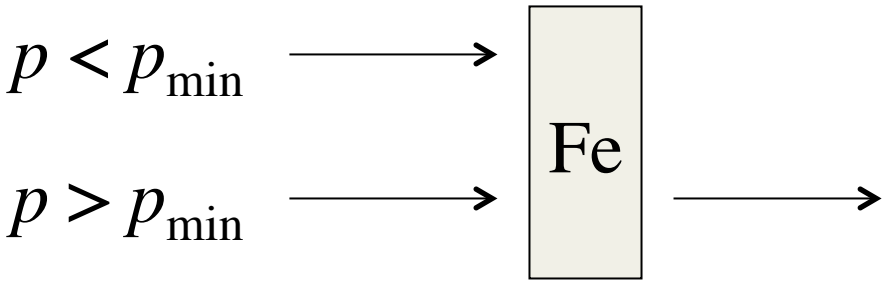
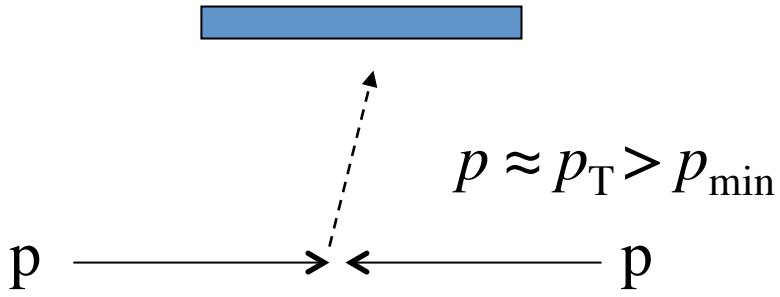


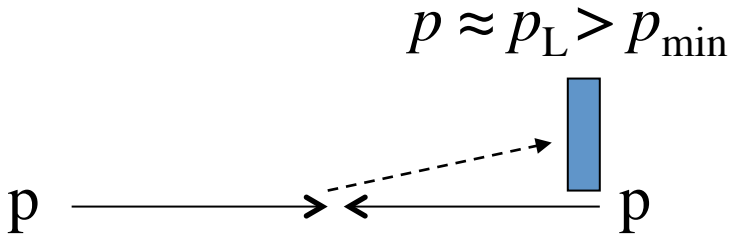
hadron: energy resolution

$\sigma_E/E \approx \sqrt{70\%}/\sqrt{E}$

central detector

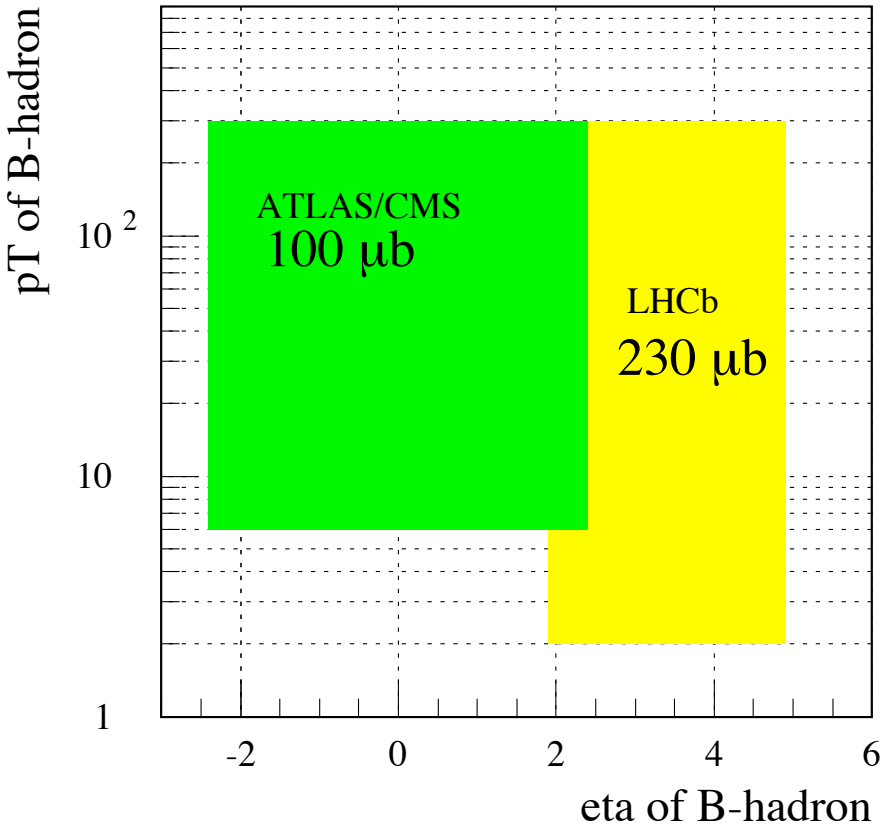


forward detector



Quick reminder for LHCb

Can exploit low p_T particles to trigger more b-hadron events



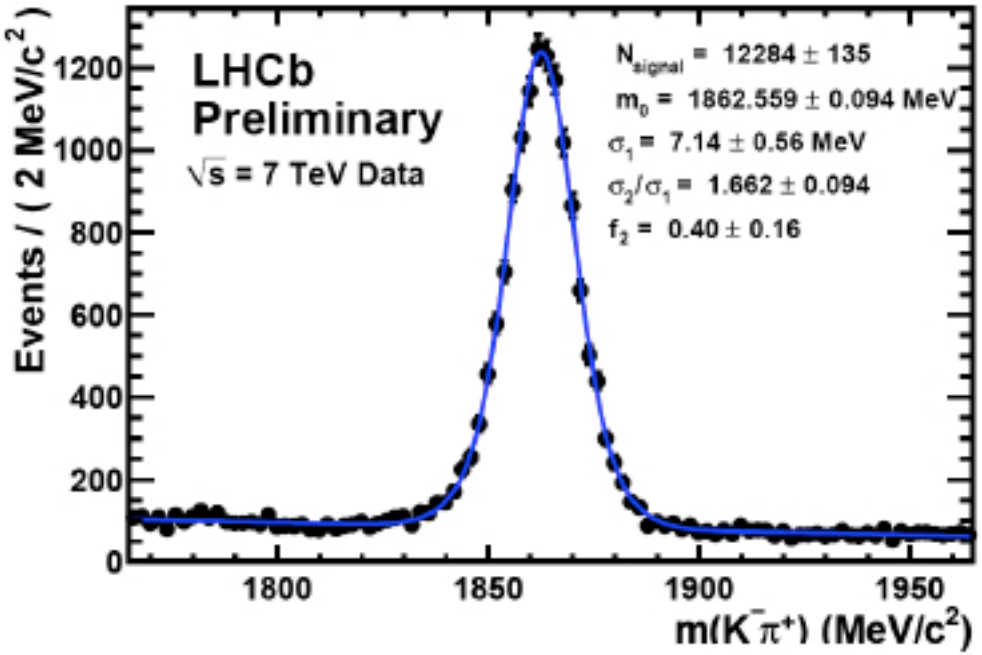
$\sigma_{b\bar{b}}$ expected in pp collisions at $\sqrt{s}$ = 14 TeV: 500μb

5×10^{11} bb pairs in 10^7 s with $L = 10^{32}$ cm^{-2}s^{-1}

LHCb $\sigma_{b\bar{b}}$ measurements

b detection from $b \rightarrow D^0(K^-\pi^+)\mu^- X$

Inclusive D:



Clean D signal with hadron PID

LHCb $\sigma_{b\bar{b}}$ measurements

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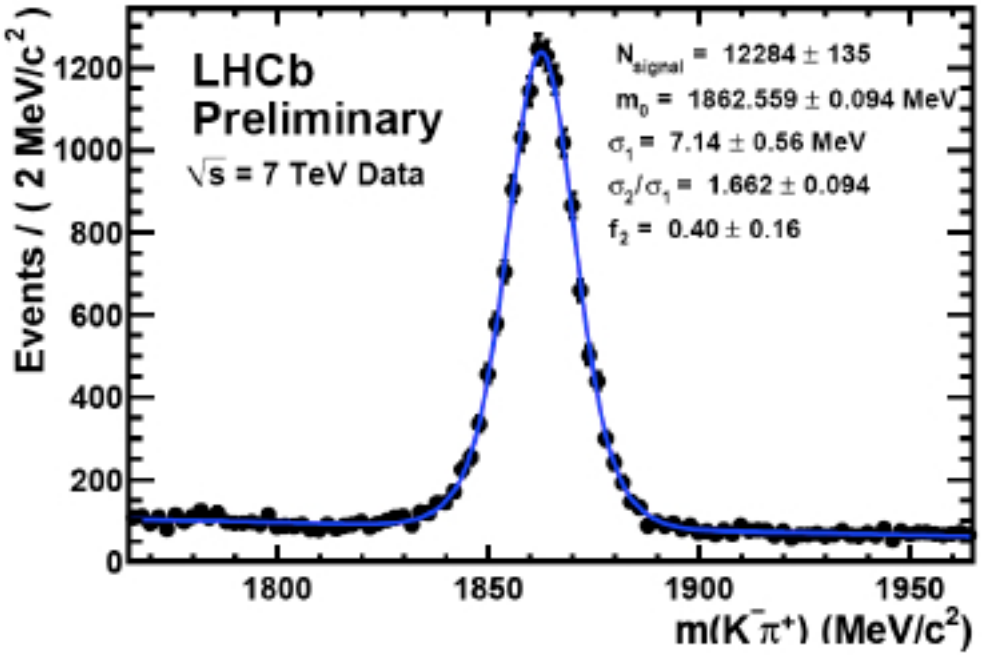
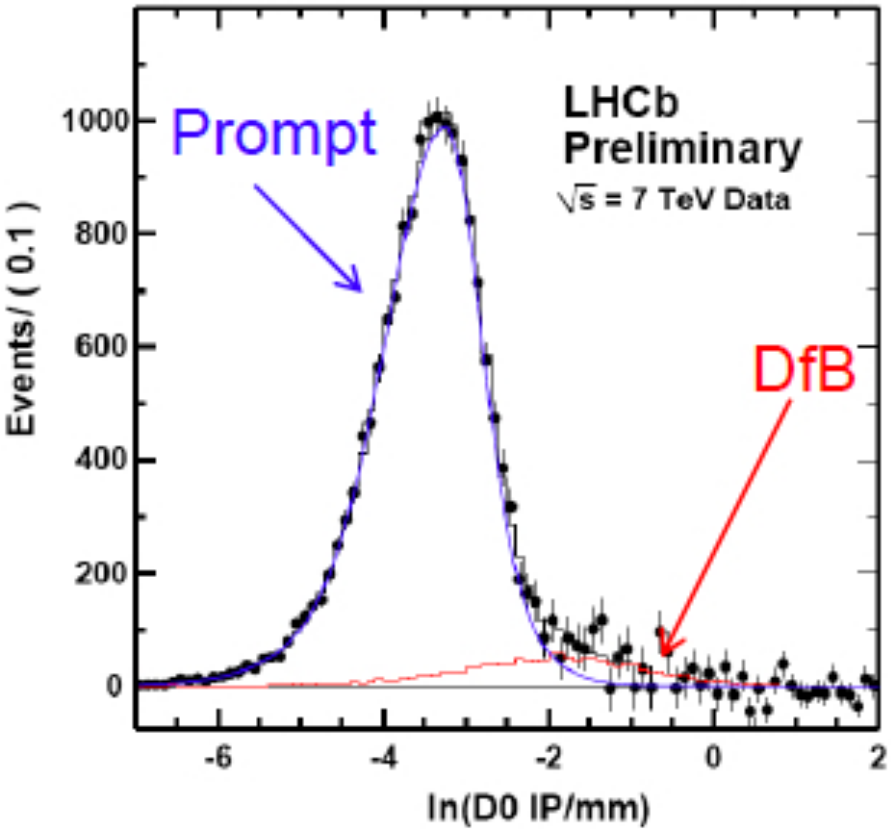
Inclusive D:
dominated by the prompt production





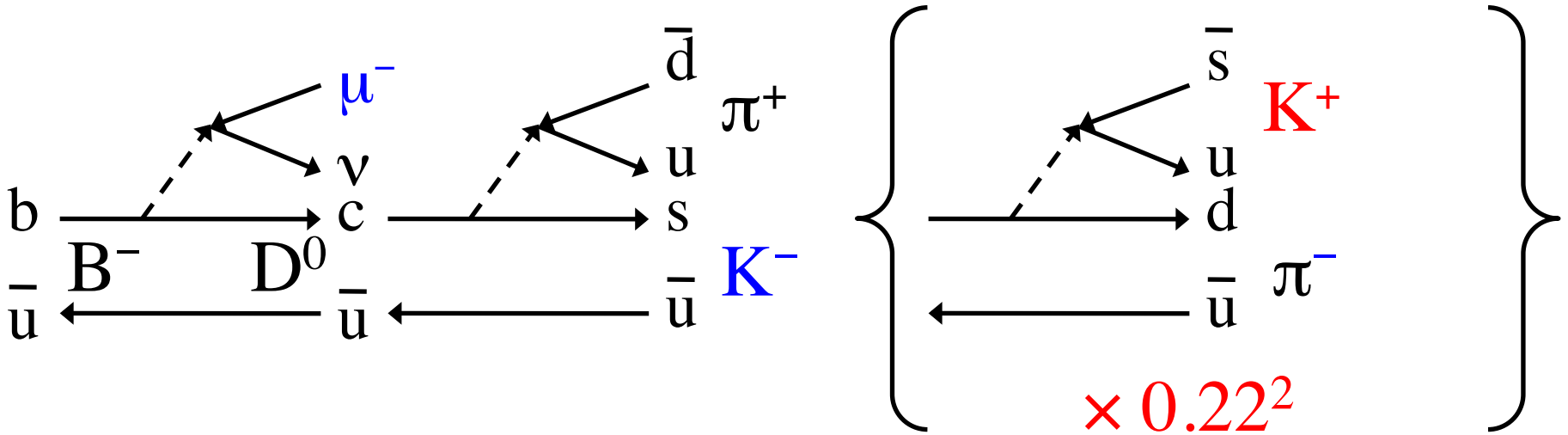
IP(D from $b \rightarrow D$) > IP (prompt D)

LHCb $\sigma_{b\bar{b}}$ measurements

b detection from $b \to D^0(K^-\pi^+)\mu^- X$

Adding μ with a right sign enhances D from b:

e.g. $B^- \to D^0(\to K^-\pi^+)\mu^- X$ [$B^- \to D^0(\to K^+\pi^-)\mu^- X$ only through DCSD]



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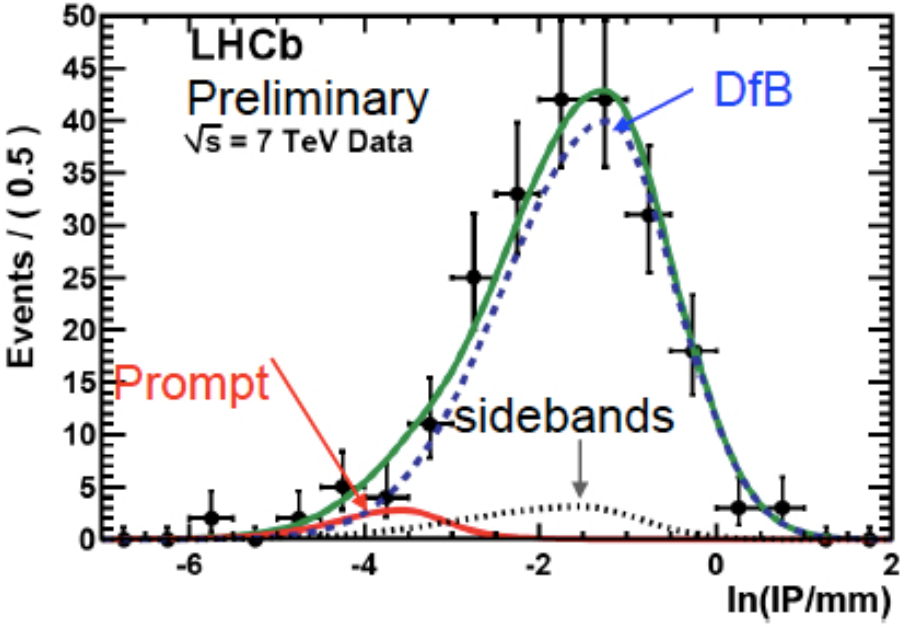
with right sign muons



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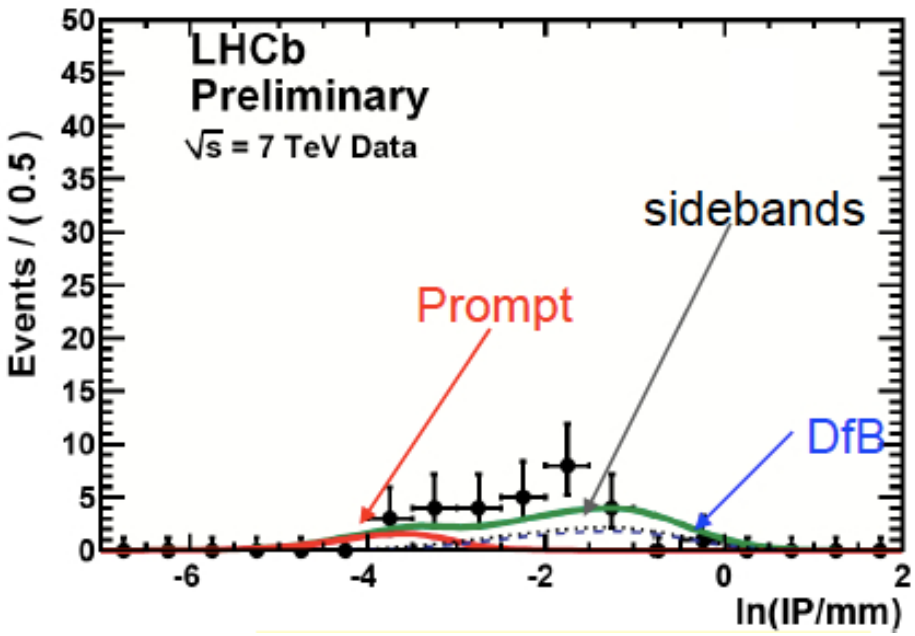
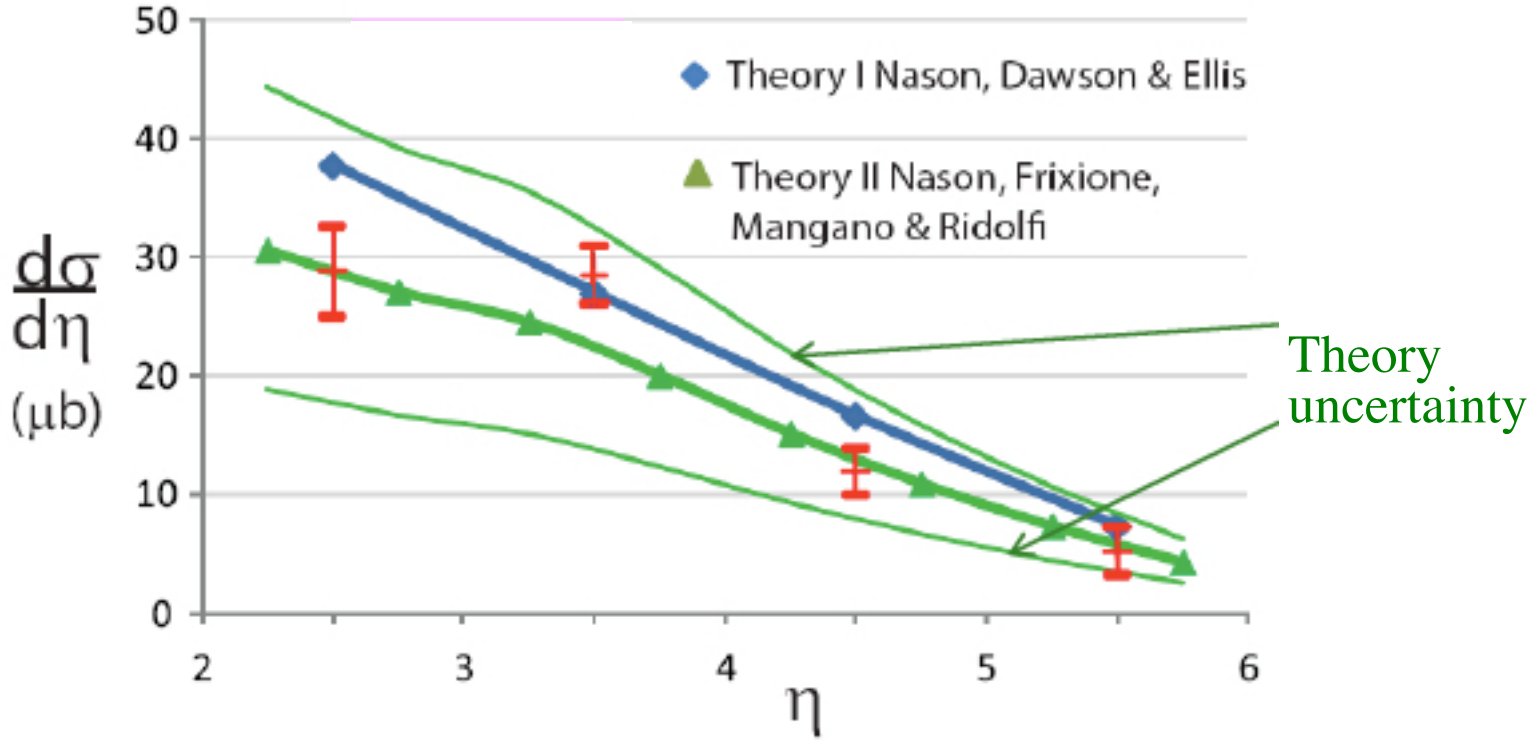


LHCb $\sigma_{b\bar{b}}$ measurements

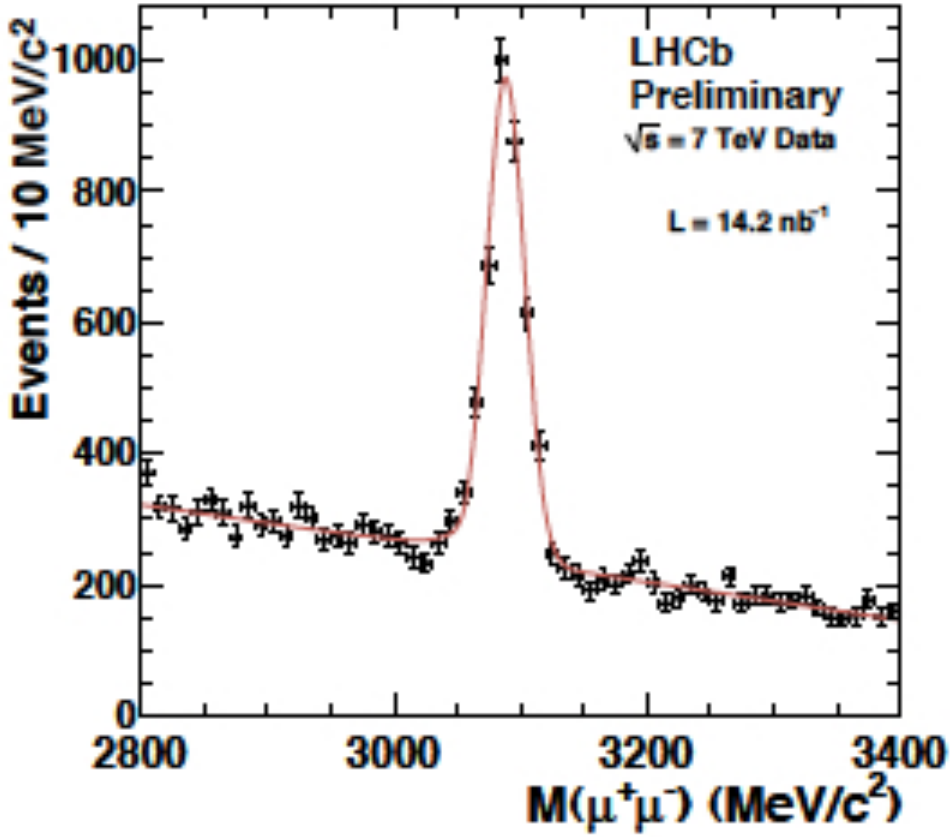
b detection from $b \rightarrow D^0(K^-\pi^+)\mu^- X$

$\int L\, dt = 25\ nb^{-1}$ data



LHCb $\sigma_{b\bar{b}}$ measurements

b detection from $b \rightarrow J/\psi X$

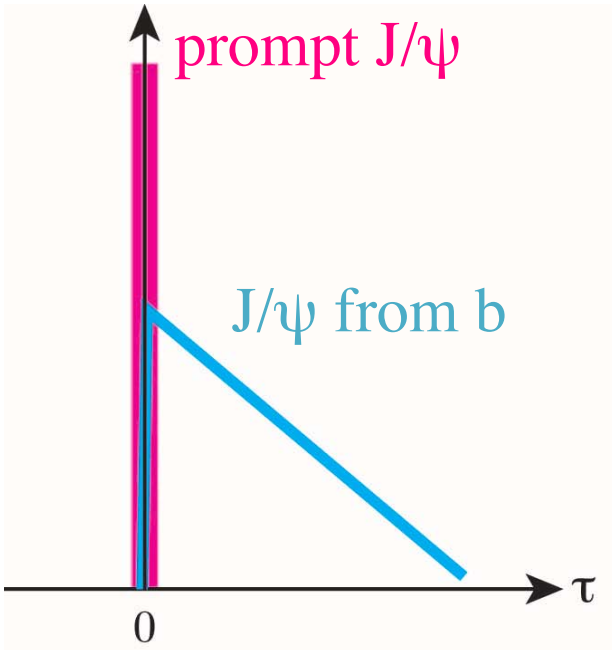


Clean $\mu^+\mu^-$ mass distribution
with $\int L\, dt = 14\ \text{nb}^{-1}$ data

LHCb $\sigma_{b\bar{b}}$ measurements

b detection from b→J/ψX

proper time distribution of J/ψ



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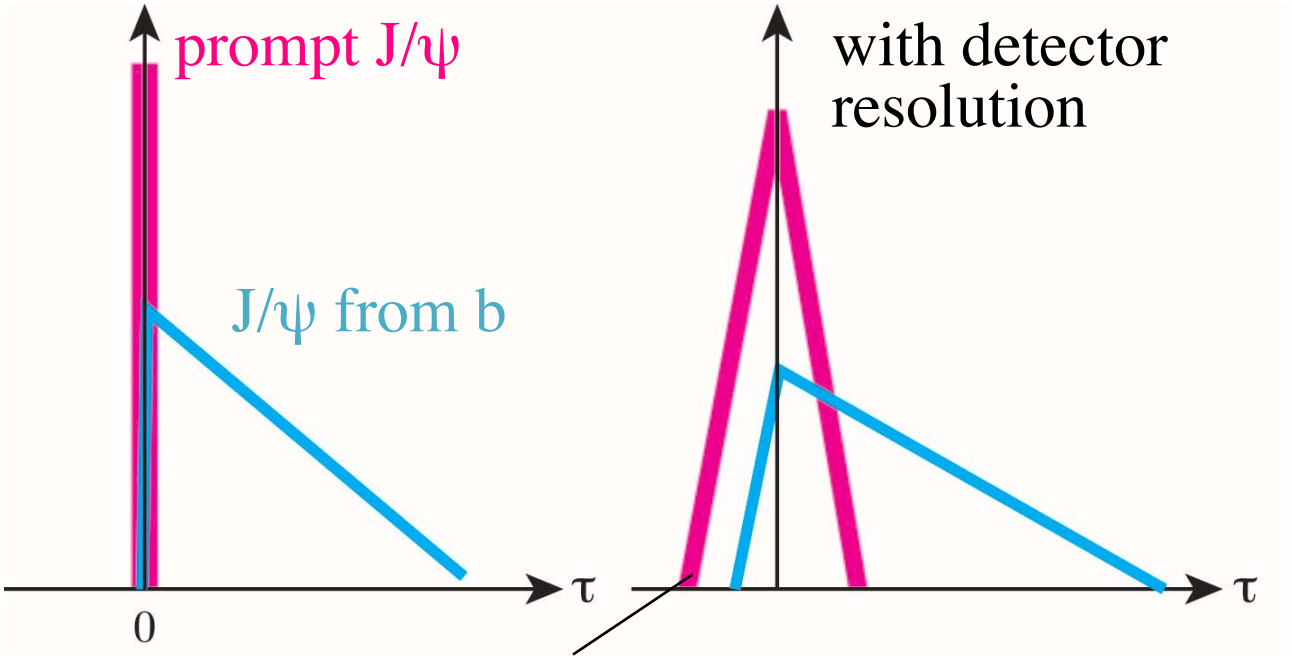

negative proper time important for studying resolution

LHCb $\sigma_{b\bar{b}}$ measurements

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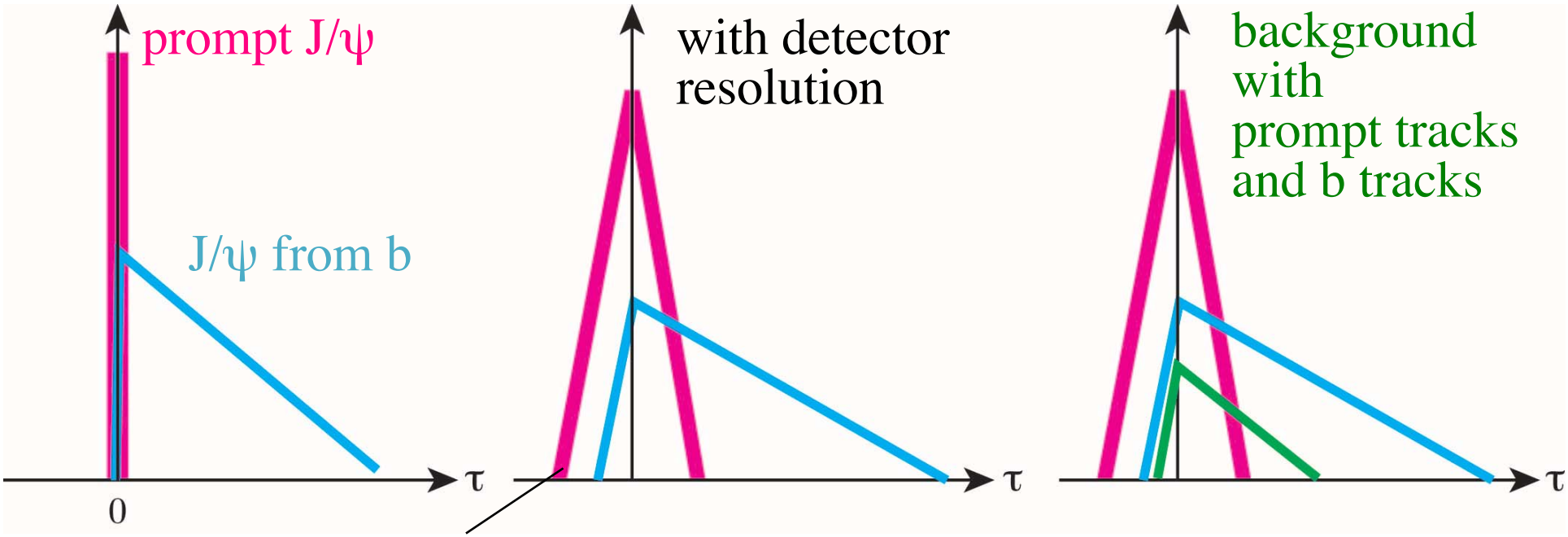


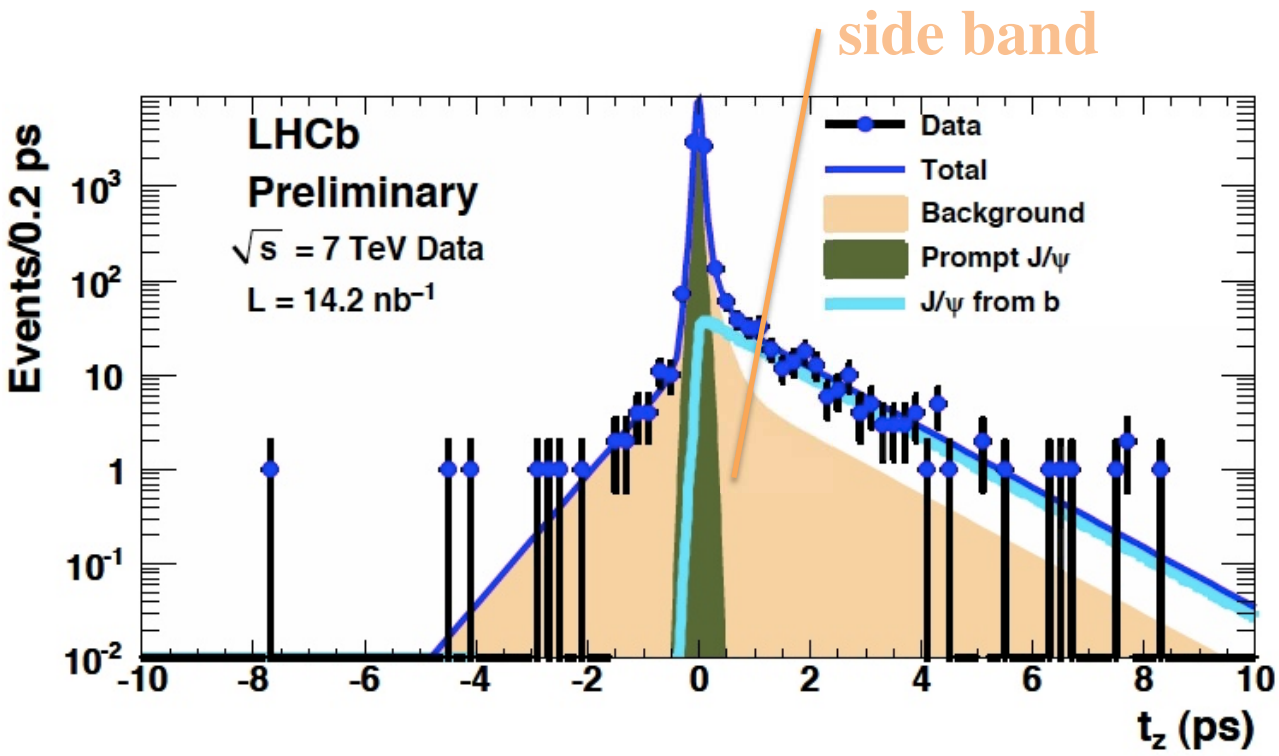
negative proper time important for studying resolution

LHCb $\sigma_{b\bar{b}}$ measurements

b detection from b→J/ψX

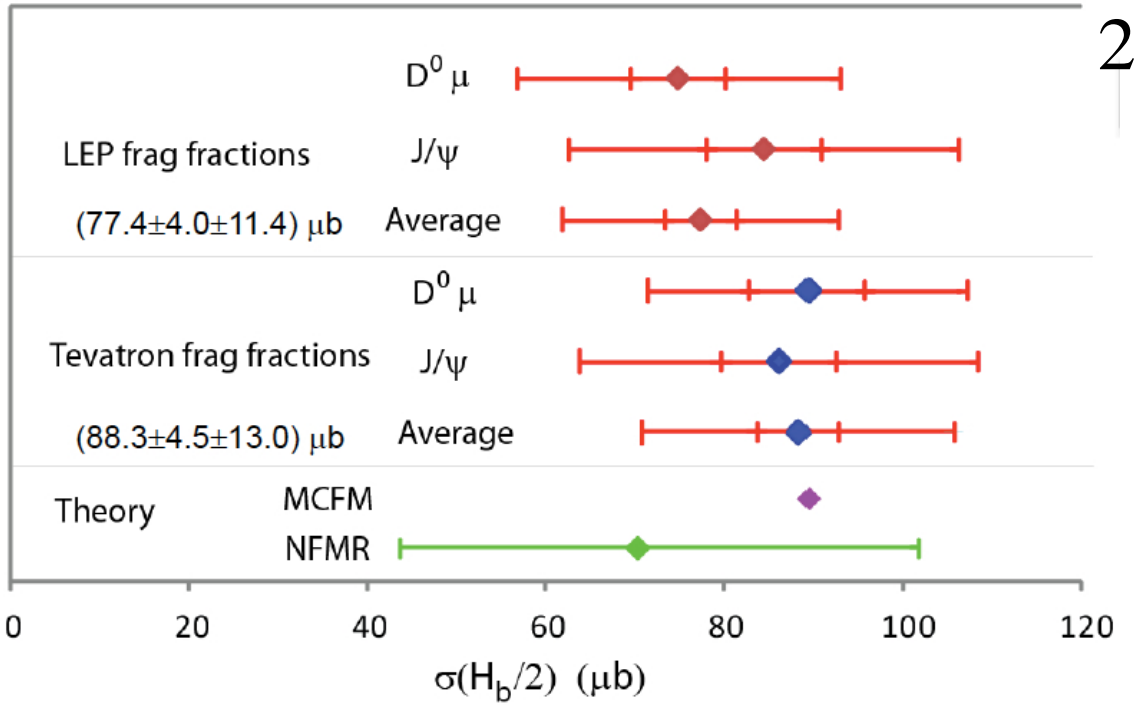
Proper time distribution with $\int L\,dt = 14\ \text{nb}^{-1}$ data

J/ψ with a long proper time due to b-hadron decays



LHCb $\sigma_{b\bar{b}}$ measurements

LHCb $\sigma_{b\bar{b}}$ from $b \rightarrow D^0 \mu X$ and $\rightarrow J/\psi X$



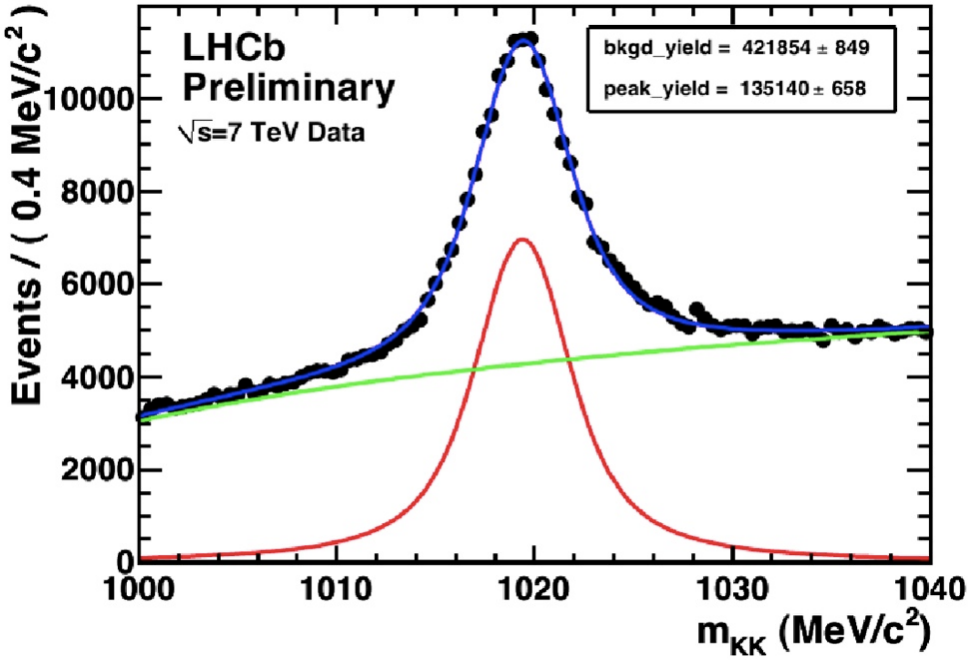
σ_{bb} in $4\pi = 292 \pm 15 \pm 43$ μb (with LEP $B_u/B_d/B_s/\Lambda_b$)

→agree with the Pythia used for the performance studies

LHC running, LHCb collecting data

- November 2009, $\sqrt{s}$ = 900 GeV collisions took place
- Since March 2010, running at $\sqrt{s}$ = 7 TeV
  - $n_{\text{p-bunch}} \approx 10^{11}$ ⇔ already nominal value
  - $\beta^* = 3.5$ m ⇔ nominal 0.55 m for 10^{34} cm^{-2}s^{-1}
  - $n_{\text{bunch}} = 46$ ⇔ nominal = 2808
  - $L = 1\times10^{31}$ cm^{-2}s^{-1} ⇔ nominal = 10^{34} cm^{-2}s^{-1}
  - Experiments >90% DAQ efficiencies
  - Current plan for this year
    $n_{\text{bunch}} = 46$ steadily increased to 384
    $L \approx 10^{31}$ cm^{-2}s^{-1} ⇒ 10^{32} cm^{-2}s^{-1} (~0.2 pb^{-1}/10h fill)
- 2011: $\int L\,dt = 1$ fb^{-1} goal to be achieved by running with a slight improvement (~2 in the luminosity) by further decreasing β^* and/or increasing the number of bunches.

LHCb how about $B_s \rightarrow J/\psi\phi$?



Nice ϕ with kaon identification

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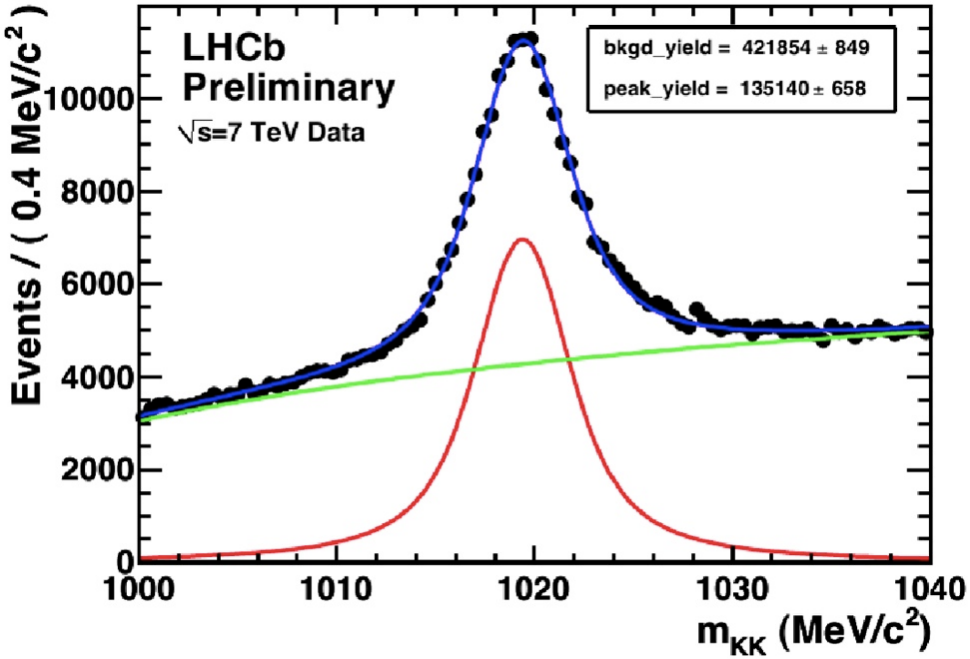
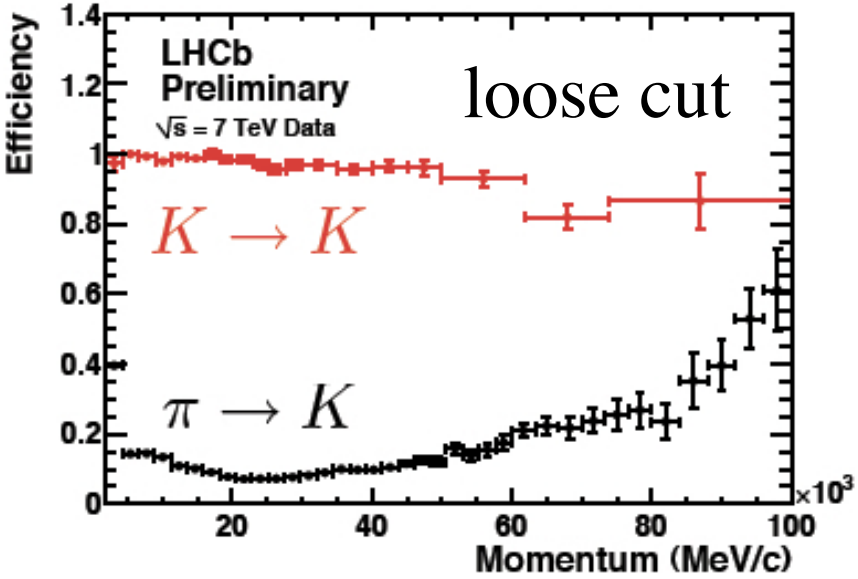
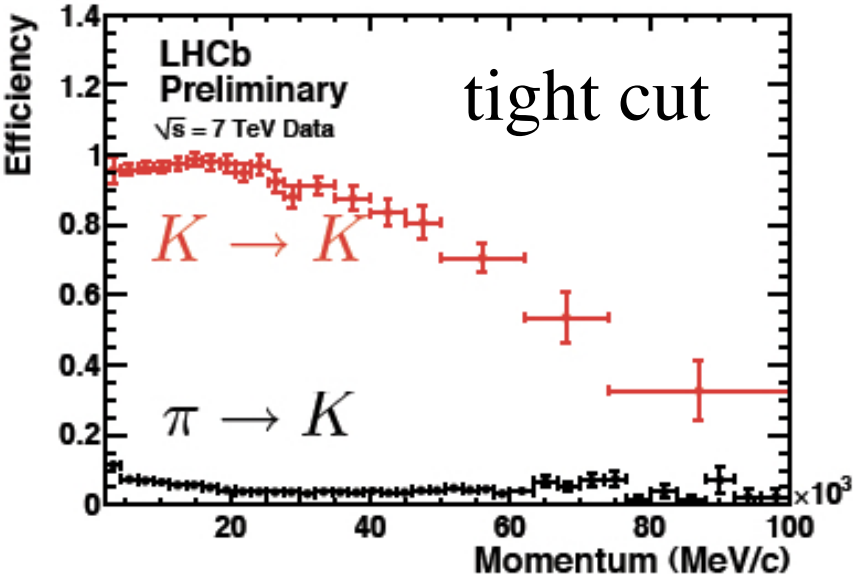


Nice ϕ with kaon identification

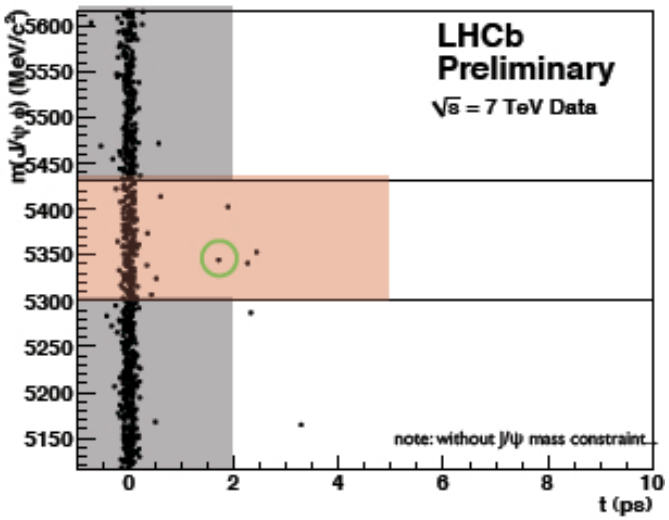
ϕ is also used to calibrate PID with one kaon identified
NB: flavour-tag with kaons





LHCb how about $B_s \rightarrow J/\psi\phi$?

$B_s \rightarrow J/\psi\phi$ candidates with $\int L\, dt = 140\ nb^{-1}$ data



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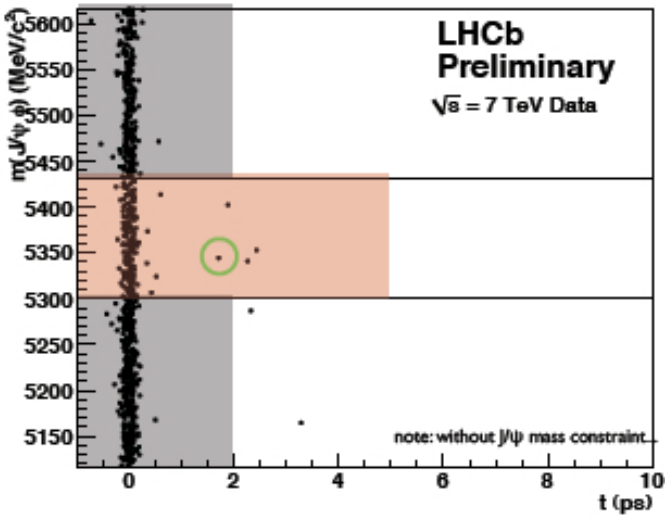
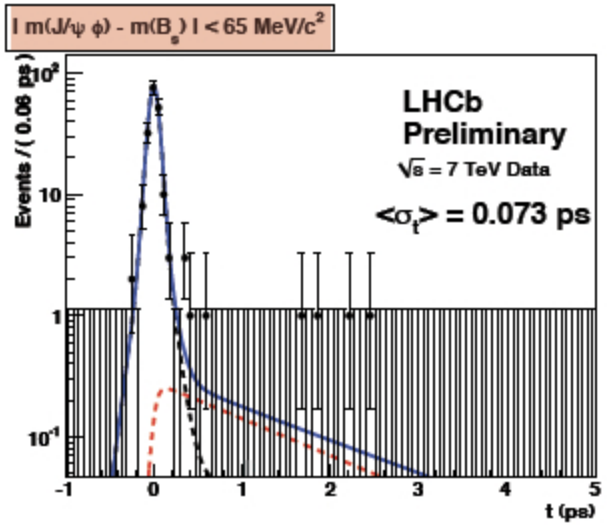
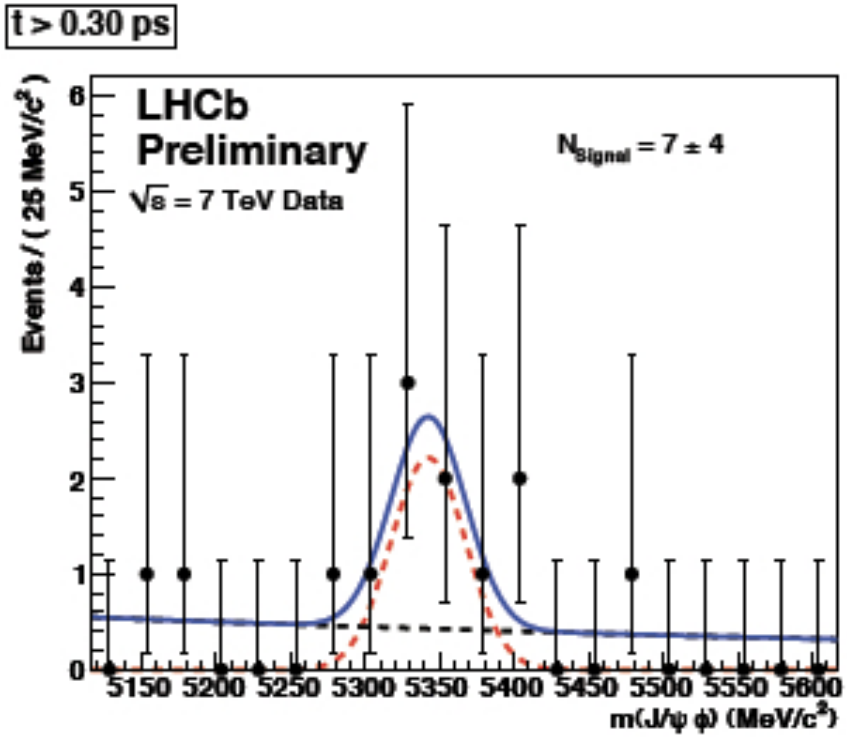


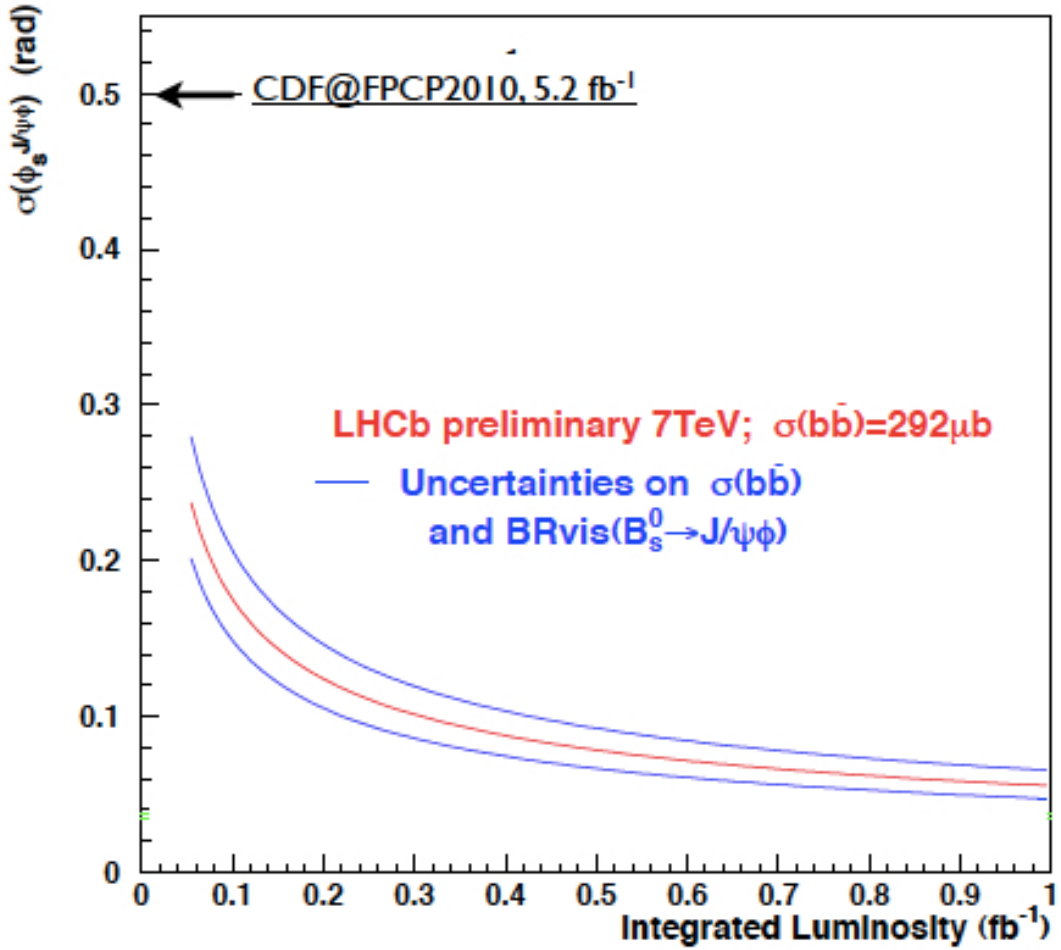




Yield agrees with the MC performance expectation of ~7

LHCb how about $B_s \to J/\psi\phi$?

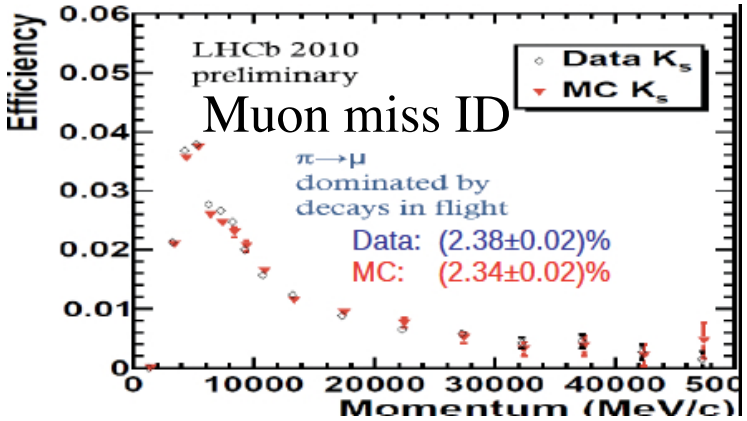
1σ error for CPV in $B_s \to J/\psi\phi$

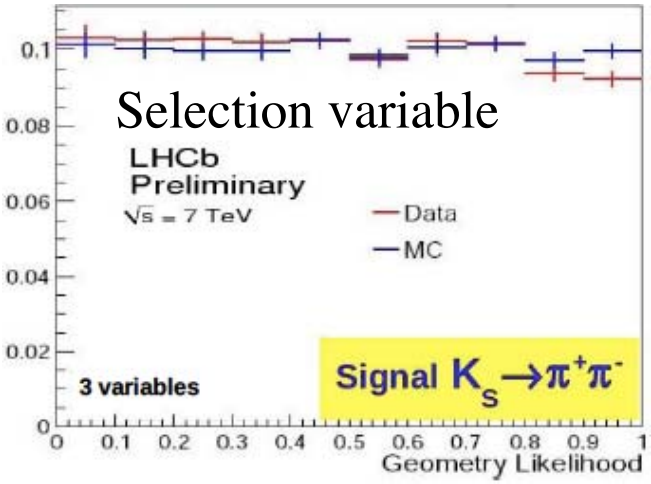


1 fb^{-1} of data expected by the end of 2011

LHCb how about $B_s \to \mu^+\mu^-$?

Of course we see currently no serious background, but can validate analysis method with data by comparing with MC; → They agree well!





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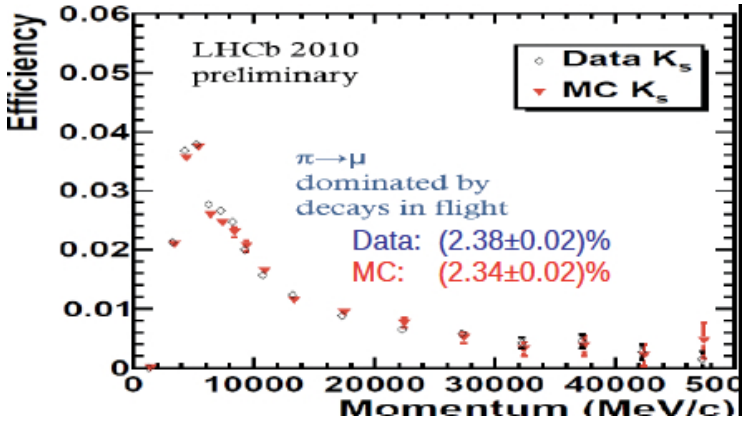
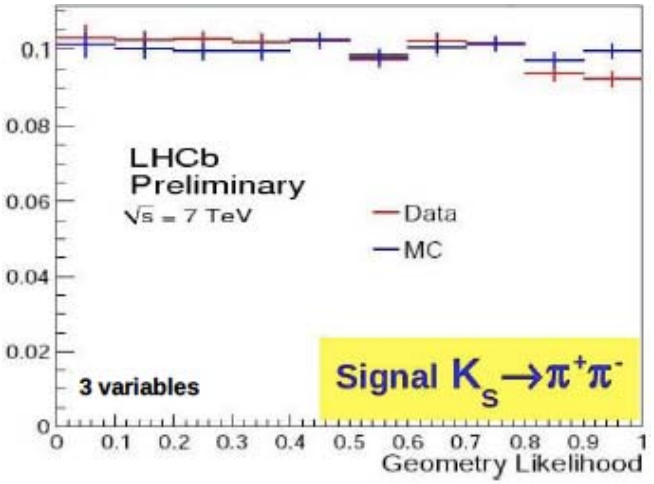
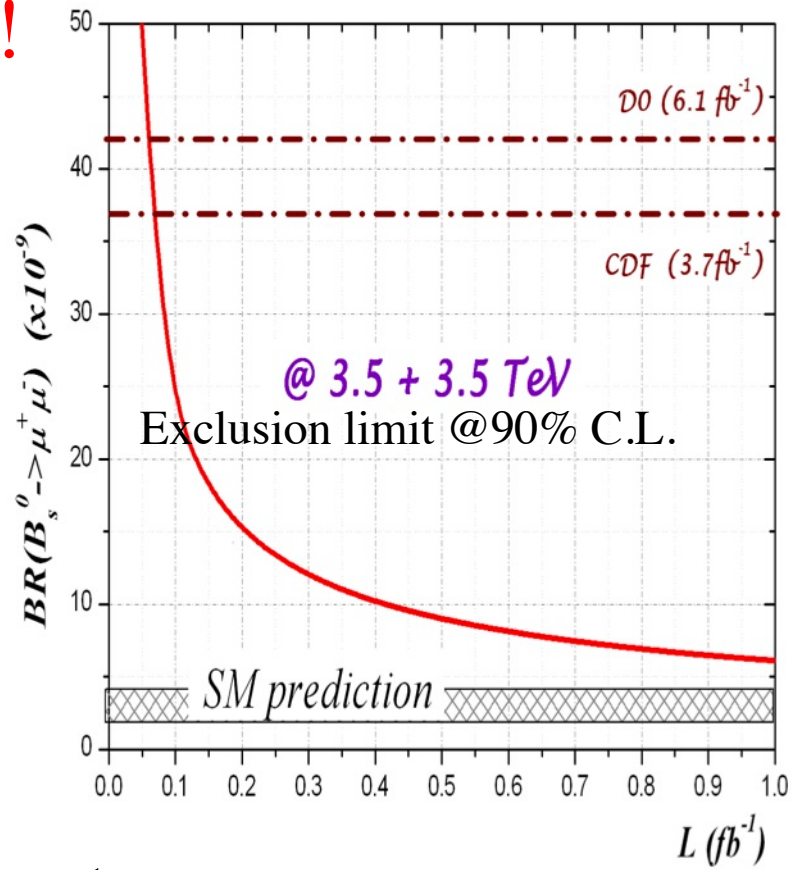


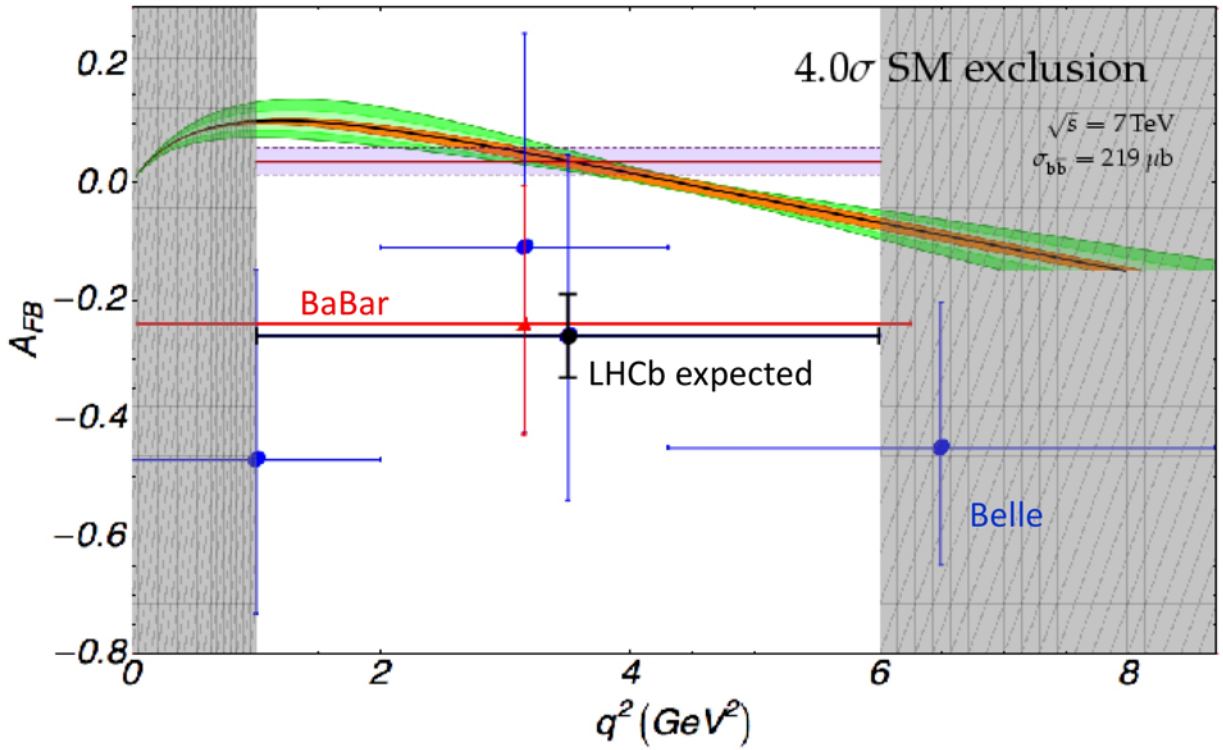




1 fb^{-1} of data expected by the end of 2011

LHCb how about $B_d \to K^{*0}\mu^+\mu^-$?

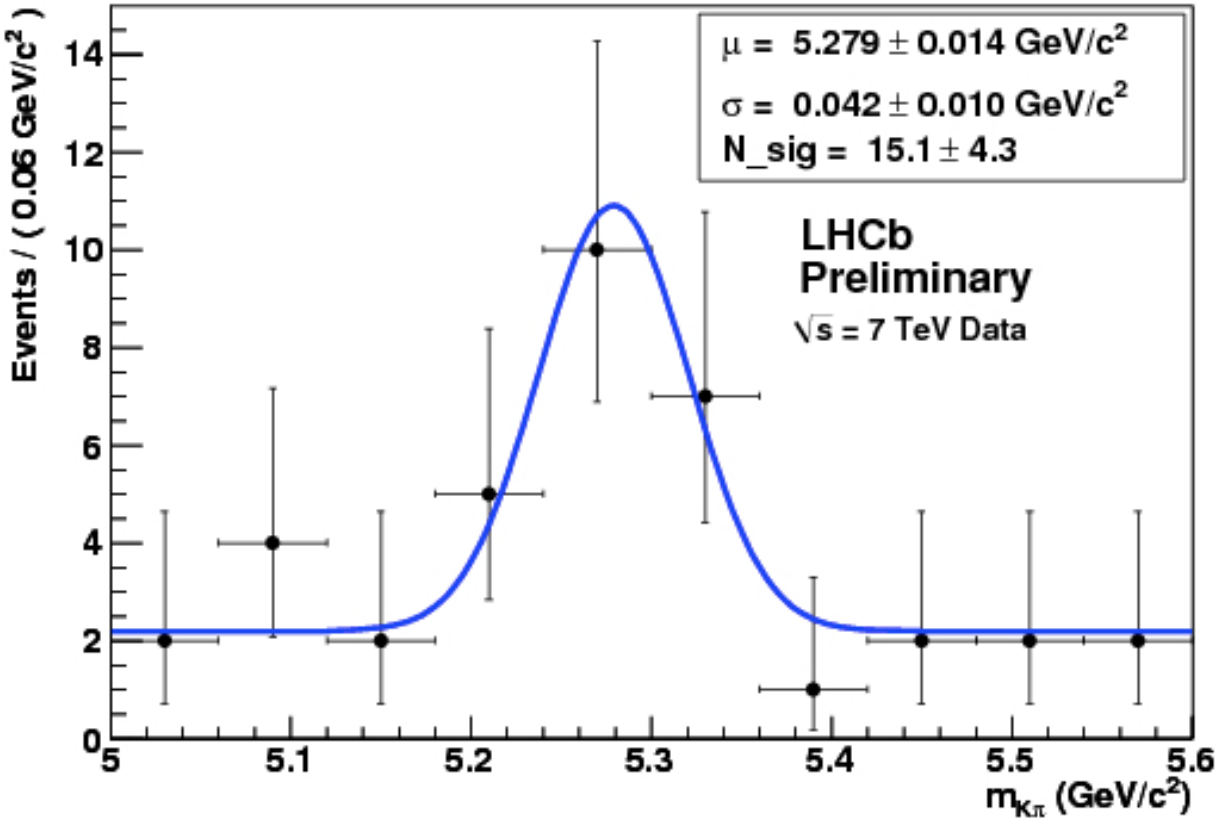
With 1 fb^{-1} LHCb expects 1200 events



If the current BABAR and Belle results are correct, LHCb could exclude SM prediction with 4σ significance

LHCb how about B→hh?

$B_d \to K^{\pm}\pi^{\mp}$ candidates with $\int L\, dt = 122\ nb^{-1}$ data



PID, IP, vertex, p_T cuts

Agrees with the MC performance expectation of ~16

With 1 fb-1 data, >100k events!

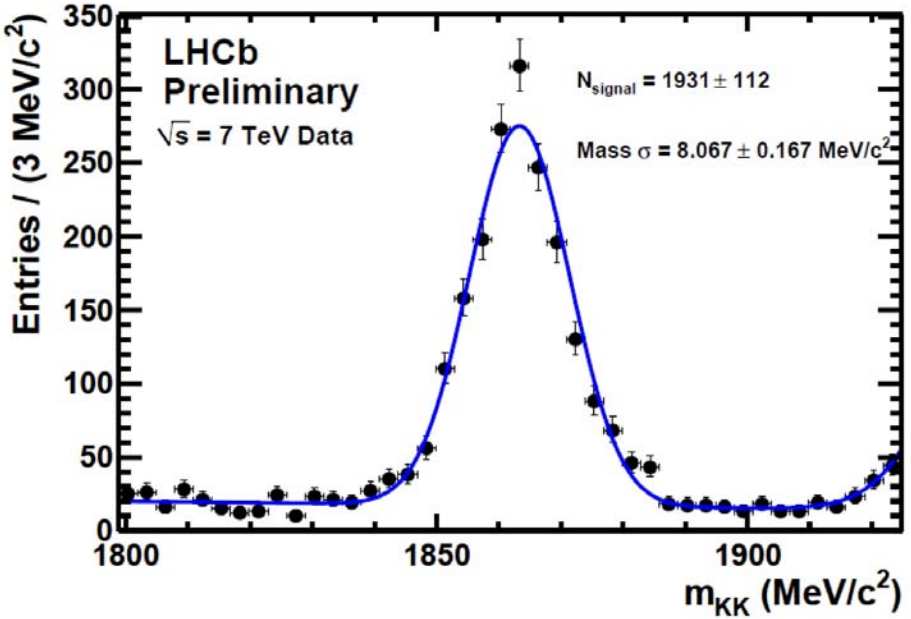
similar improvements for all the other B→hh modes

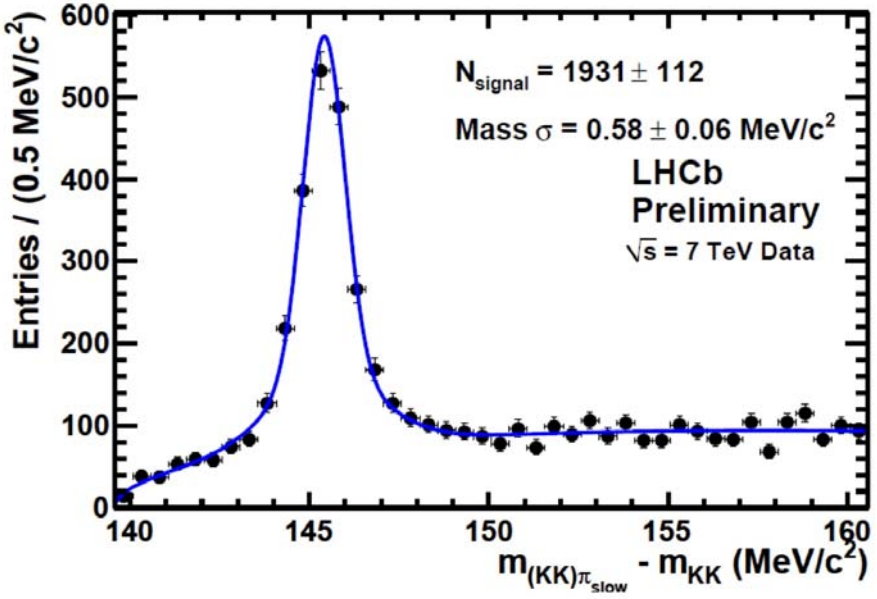
LHCb how about charm physics?

Huge number of charms can be detected with LHCb

Initial flavour tagged D^0 decays:

$D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^+K^-$ with 124 nb^{-1} data





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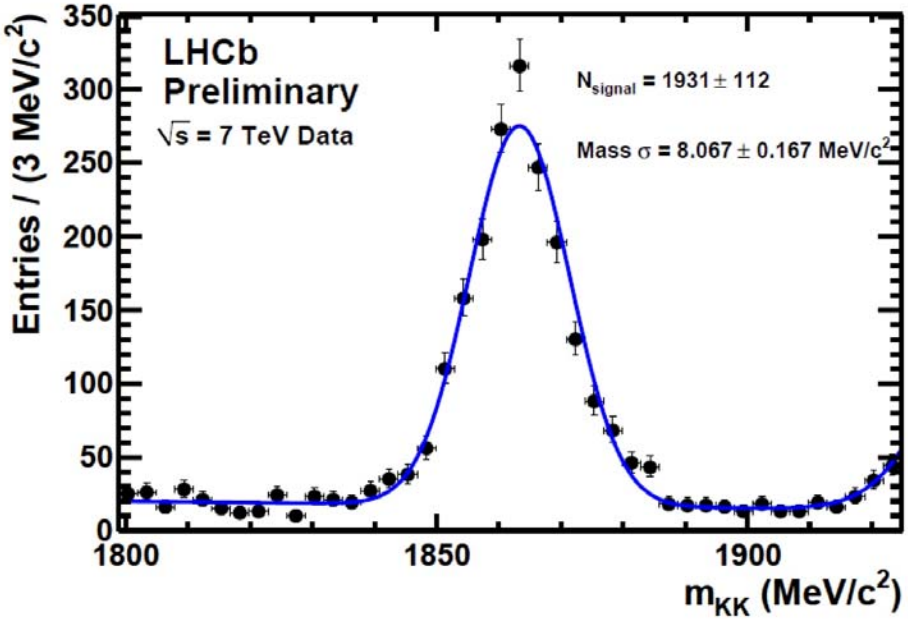

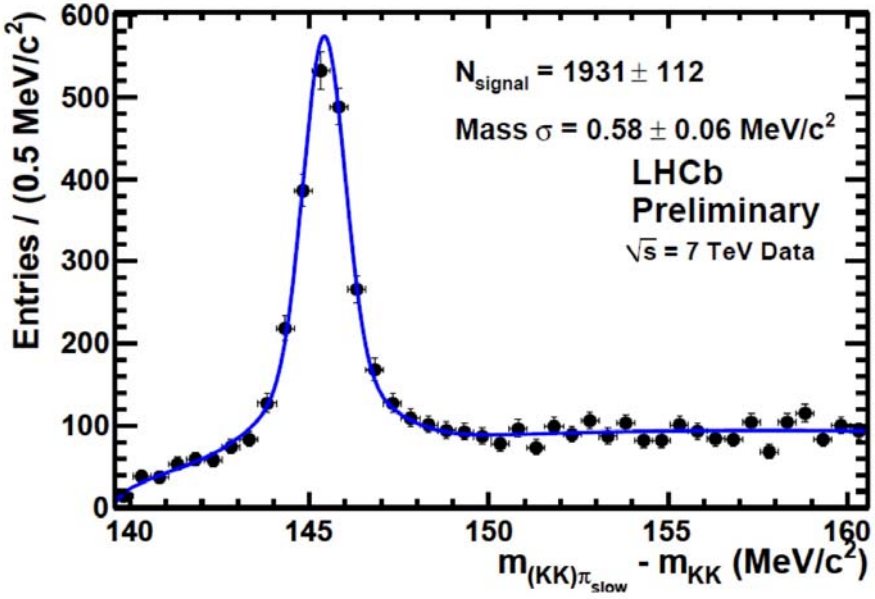

Huge statistics to study CPV from the decay time distribution between D^0 and $\overline{D}^0 \rightarrow K^+K^-$, well before reaching 1 fb^{-1} (~15×10^6 events)

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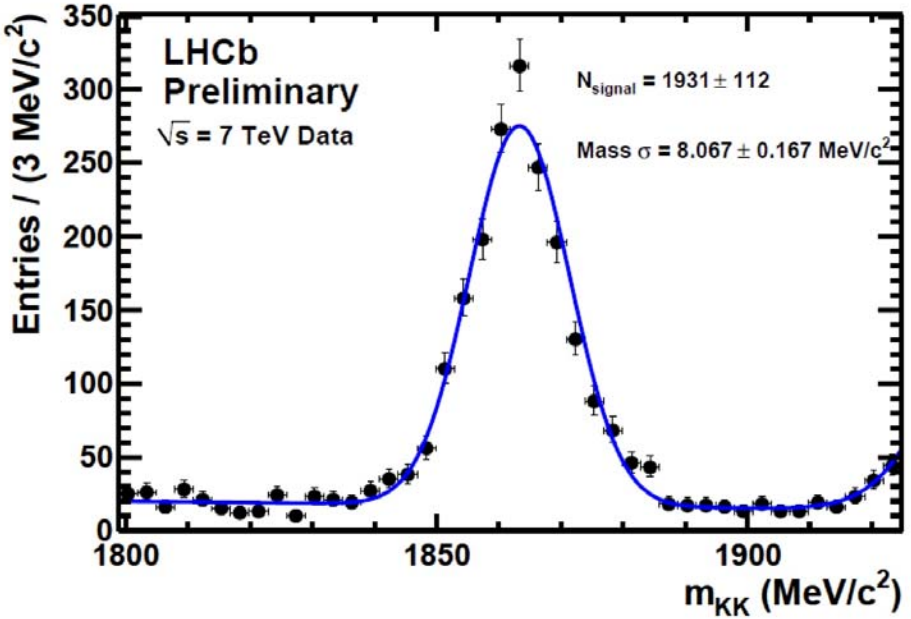

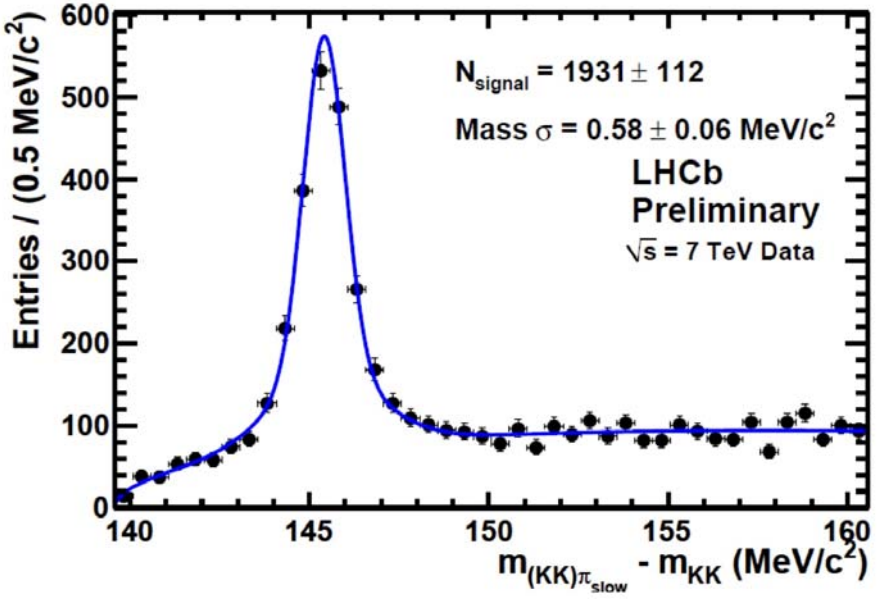

Huge statistics to study CPV: comparing the decay time distribution between $D^0 \to \pi^+K^-$ and $D^0 \to K^+K^-$, comparing the D^0 and $D^0 \to K^+K^-$,
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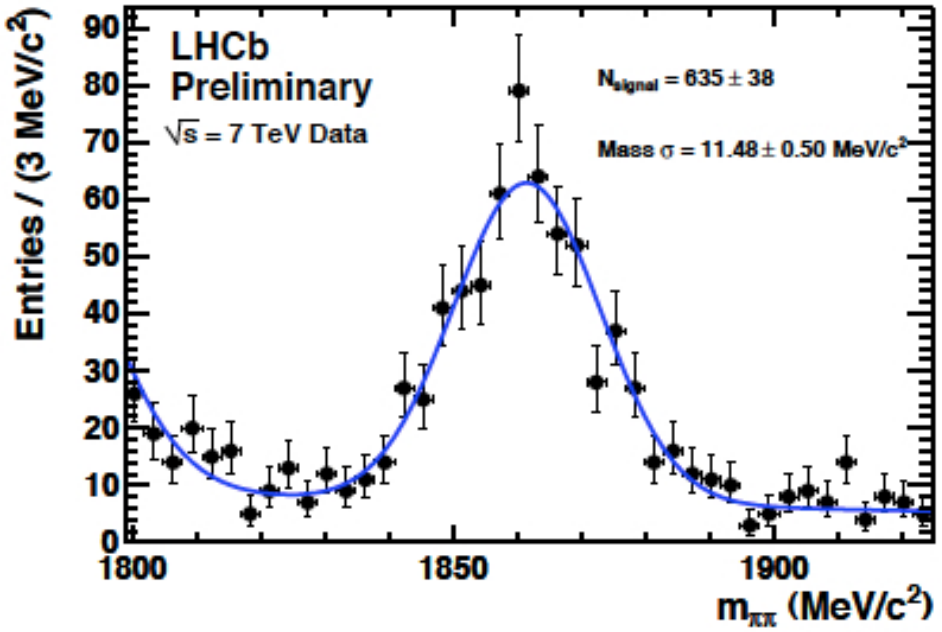
Other interesting D^0 decays: with 124 nb^{-1} data



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$D \rightarrow \pi^+\pi^-$

CPV study with
~5×10^6 events (1 fb^{-1})

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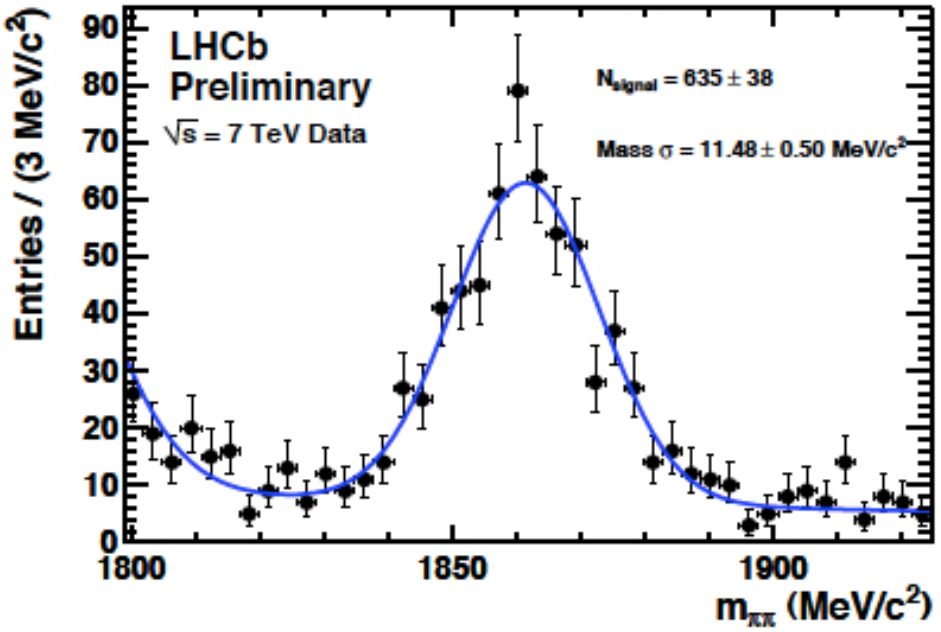

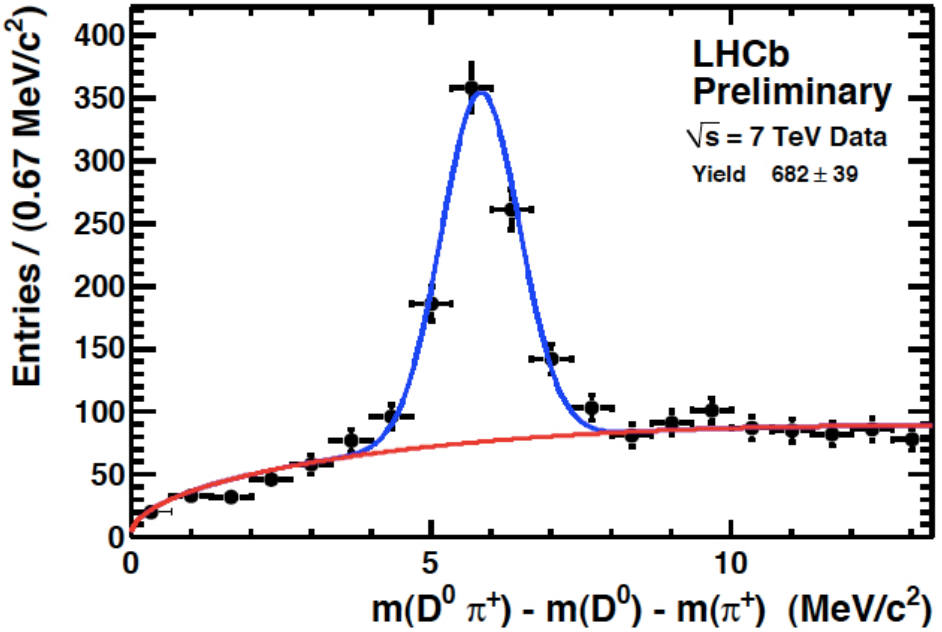

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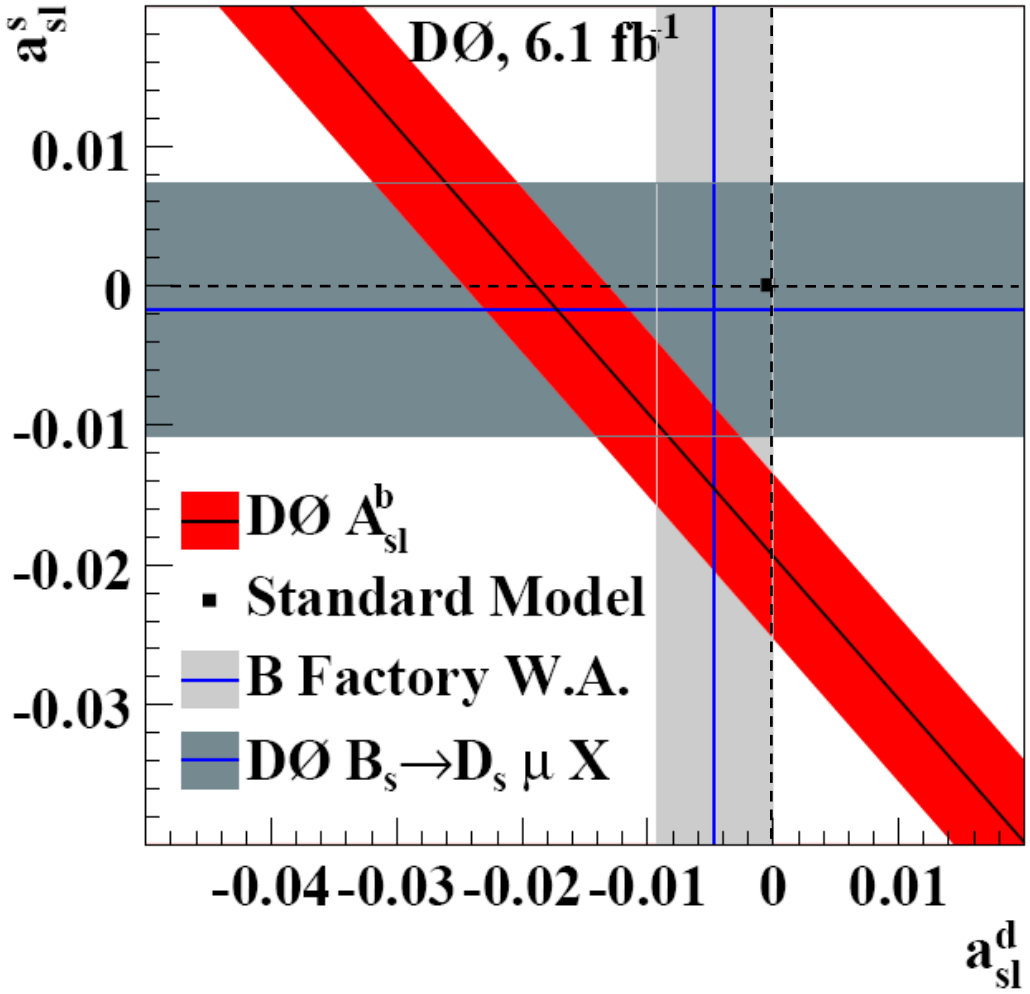
$D \to \pi^+\pi^-$

Initial flavour tagged
$D \to K_S\pi^+\pi^-$

CPV study with
$\sim 5\times10^6$ events (1 fb^{-1})

Bench mark for γ_{CKM} with
$B \to DK$ Dalitz method

Current situation with a^s_{SL}?



LHCb how about a^{s}_{SL}?

How to deal with
-possible $B_s^0 / \overline{B}_s^0$ production asymmetry in pp $2<\eta<6$
-controlling detection and background asymmetries to $< 10^{-3}$

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$D_s^+(K^+K^-\pi^+)\pi^-$ vs $D_s^-(K^+K^-\pi^+)\pi^+$
production or detection asymmetry from data

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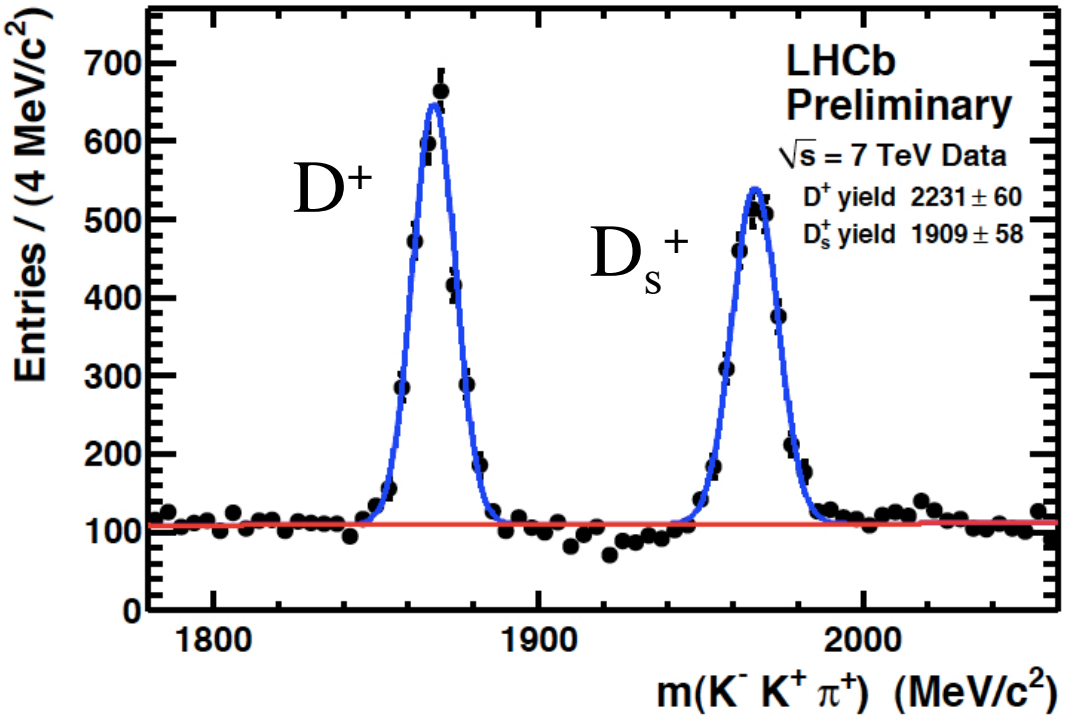
$D_s^+(K^+K^-\pi^+)\pi^-$ vs $D_s^-(K^+K^-\pi^+)\pi^+$
production or detection asymmetry from data

B_d and B_s time depended CP asymmetries from the same final ftates: i.e.
$B_d \to D^+(K^+K^-\pi^+)\mu^- X$ - c.c. and $B_s \to D_s^+(K^+K^-\pi^+)\mu^- X$ - c.c.
difference depends only on $a^s_{SL} - a^d_{SL}$

LHCb how about a^{s}_{SL}?

$D^+ \rightarrow K^+K^-\pi^+$ and $D_s^+ \rightarrow K^+K^-\pi^+$
with 124 nb^{-1} data



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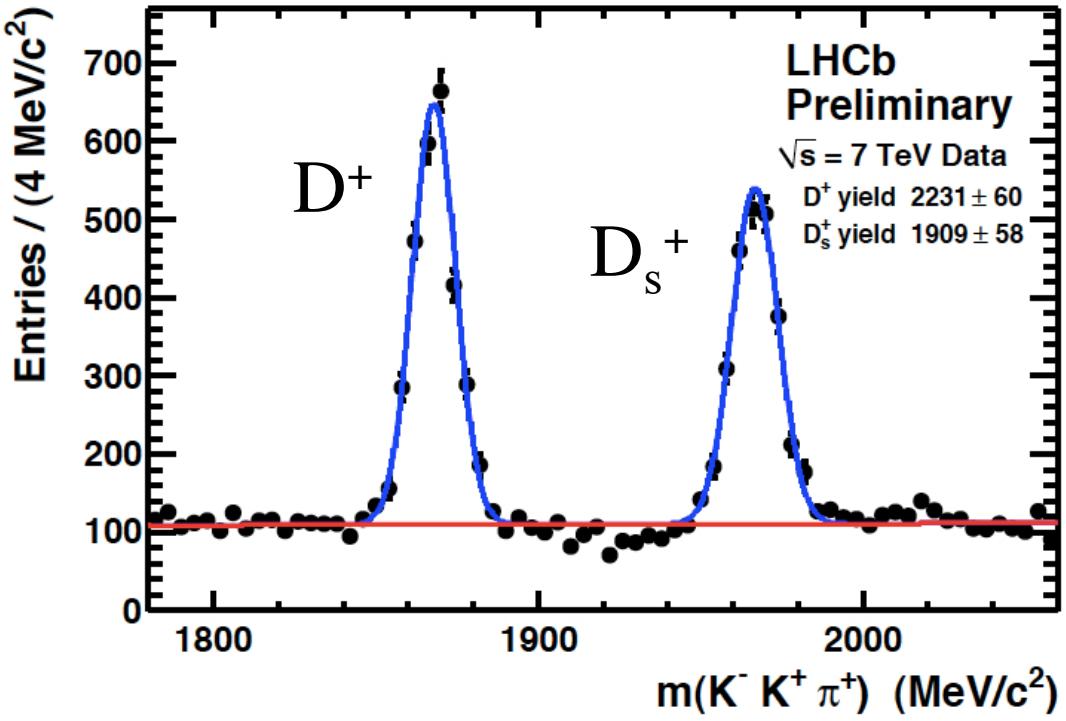


Expected statistical errors on

$\Delta_{SL} \equiv a^{s}_{SL} - a^{d}_{SL}$

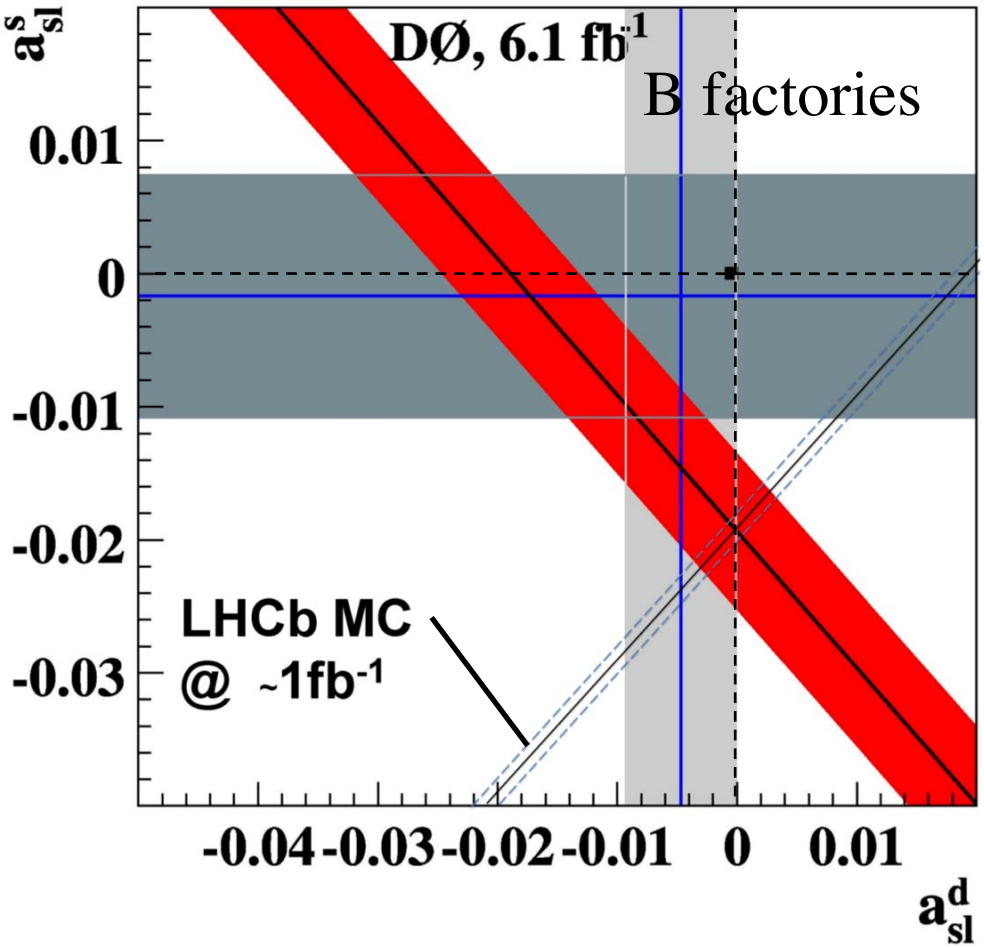
6.3×10^{-4}

with 1 fb^{-1} of data

Systematic errors still to be investigated

LHCb how about a^{s}_{SL}?

LHCb expected performance with 1 fb^{-1} data
assuming Δ_{SL}(LHCb measured) = A^{b}_{SL}(D0 now)



Conclusions

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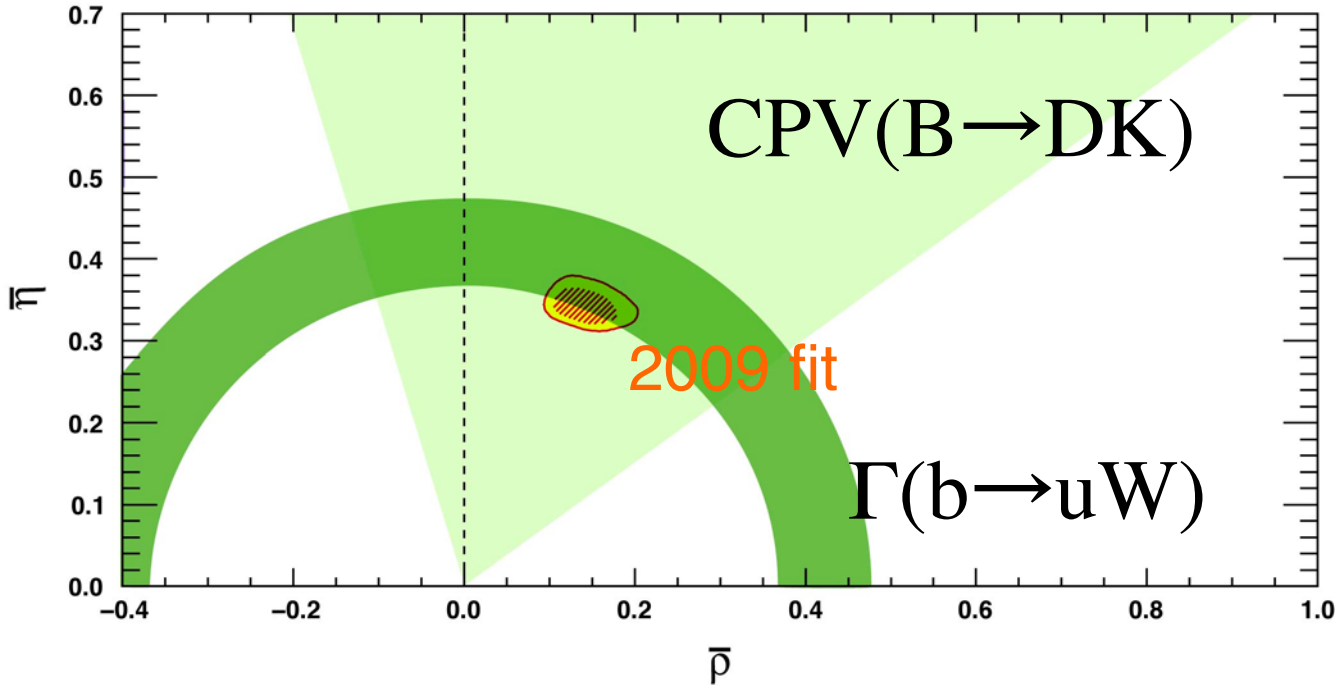
Conclusions

- LHC has made a successful start at $\sqrt{s} = 7$ TeV
- LHCb is taking data with >90% efficiency
- LHCb starts to reconstruct b-hadrons and measured σ_{bb} in pp interactions at $\sqrt{s} = 7$ TeV
- LHCb data shows that they agree well with the MC expectations of the detector performance
- LHC luminosity is expected to reach ~10^{32}, i.e. the designed luminosity for LHCb, and collect 1 fb^{-1} of data by the end of 2011: significant results can be expected from LHCb for $B_s \to J/\psi\phi$, $\to \mu^+\mu^-$, $B_s \to J/\psi K^{*0}$, CPV in charm, and others
- In 2013, LHC will start at $\sqrt{s} = 14$ TeV; LHCb, γ_{CKM}, photon polarization in $b \to s\gamma$, and others.

Now


CPV(B→DK)
2009 fit
Γ(b→uW)
$\bar{\eta}$
$\bar{\rho}$
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0

May be a surprise!

LHCb with 10 fb^{-1}