Status of LHCb (the "beauty" experiment)

Outline:

- ➢ Introduction
- ➢ Detector Performance
- ➢ Physics Results and Prospects

Member countries of the LHCb Collaboration

Physics at LHC
Perugia,
6-11 June 2011

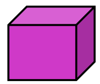
LHCb Collaboration:
730 members
15 countries
55 institutes

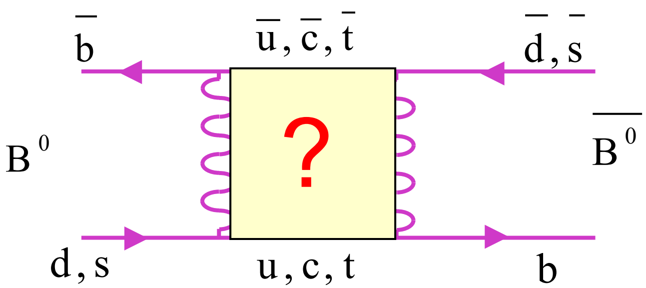
Andreas Schopper CERN **on behalf of the** LHCb **Collaboration**

LHC(b) physics goals

Search for deviations from Standard Model predictions due to
virtual contributions of new heavy particles in loop processes

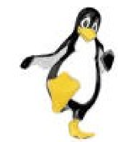
Box diagram

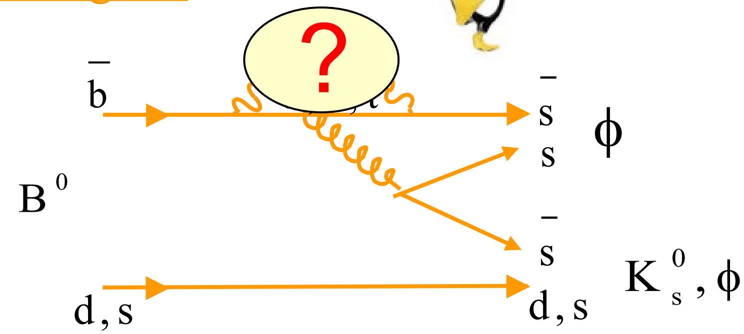




New Physics

Penguin diagram





measure:

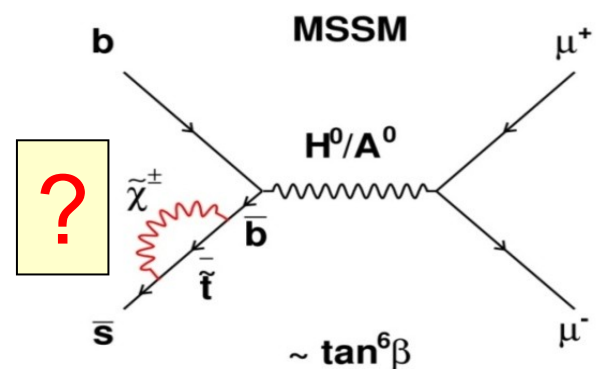
- ***CP violating phases*** in mixing and decay
- ***Rare Decays*** of heavy quarks

compare:

- to ***very precise predictions*** of the SM

→ discovery potential for ***New Physics*** extending to mass scales far in excess of the LHC centre-of-mass energy

$B_s \rightarrow \mu^+\mu^-$ "s-channel penguin"



Example of search for New Physics in $B_{d,s} \to \mu^+\mu^-$

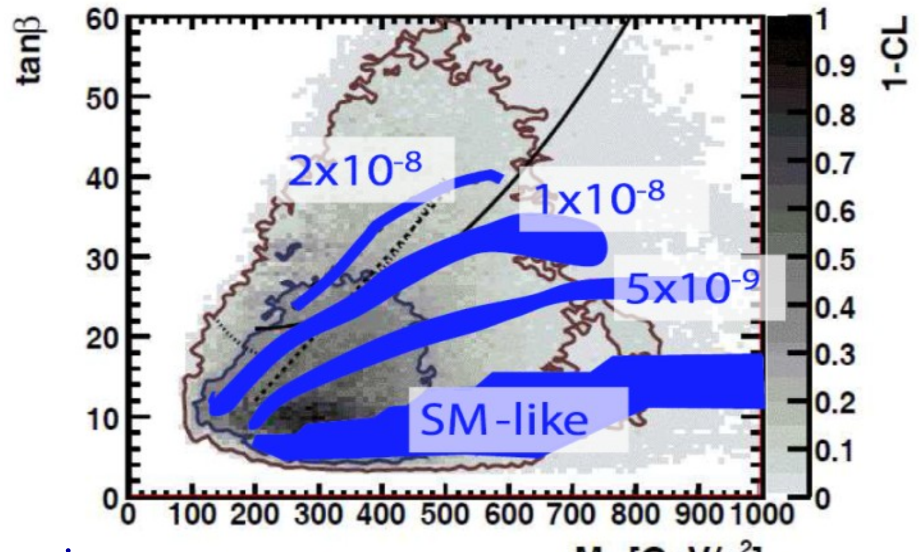
- ✓ in SM: $\mathcal{B}(B_S \to \mu^+\mu^-) = (3.2 \pm 0.2)\cdot 10^{-9}$
- ✓ sensitive to many NP models

MSSM: $BR\left(B_s \to \mu^+\mu^-\right) \propto \frac{\tan^6\beta}{m_A^4}$

NUHM1: (Non-Universal Higgs Mass)

- ➢ best fit contours in tanβ vs M_A plane
  [O. Buchmuller et al, arXiv:0907.5568]
- ➢ CMS ***direct search*** (5σ) contours 30 or 60 fb^{-1}
  $H,A \to \tau^+ \tau^-$ [arXiv:0704.0619]
- ➢ ***indirect limit*** from BR $B_s \to \mu^+\mu^-$ very discrim

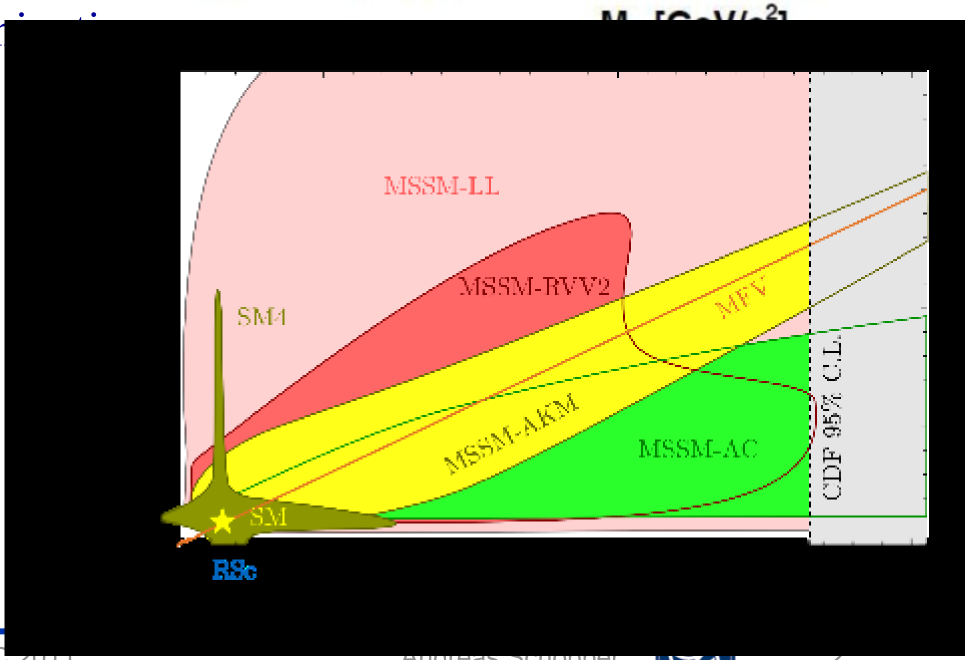
preferred values of tanβ vs M_A plane



- ➢ distinguish between different models by measuring ratio $\mathcal{B}(B_d \to \mu^+\mu^-)/\mathcal{B}(B_s \to \mu^+\mu^-)$

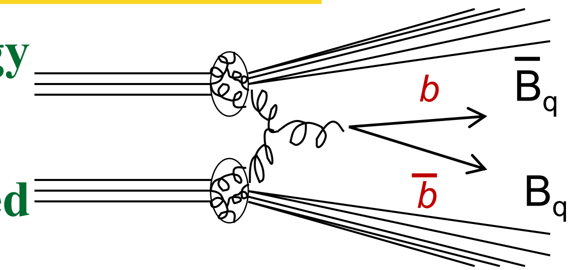
$$\frac{B\left(B_d \to \mu^+\mu^-\right)}{B\left(B_s \to \mu^+\mu^-\right)} = \left|\frac{V_{td}}{V_{ts}}\right|^2$$

- ➢ SM uncertainty ~5%

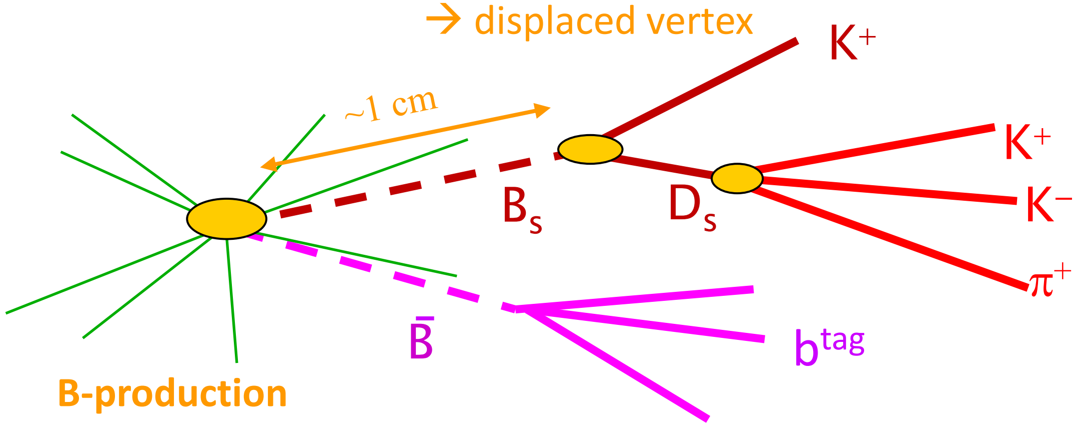


Why doing flavour physics at LHC? LHC is a *b*-factory!

- ✓ **$b\bar{b}$-pairs produced with high cross-section at LHC energy**
  (10^{12} $b\bar{b}$ produced in 2 years at $L=2\cdot10^{32}$ cm^{-2}s^{-1})



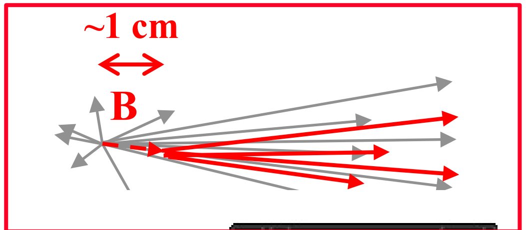
- ✓ **all species of particles containing a b-quark are produced**
  (B_u^+, B_u^-, B_d^0, $\overline{B}_d^0$, B_c^+, B_c^-, B_s^0, $\overline{B}_s^0$, Λ_b , etc.)
- ➢ **$b\bar{b}$-pair production is strongly correlated and sharply peaked forward-backward**
  → detector with forward geometry with unique $2 < \eta < 6$ coverage
- ➢ **B decays have long flight-distance ~1 cm** (allowing to distinguish B-decays from other background decays, and essential for ***time-dependent*** CP violation measurements)

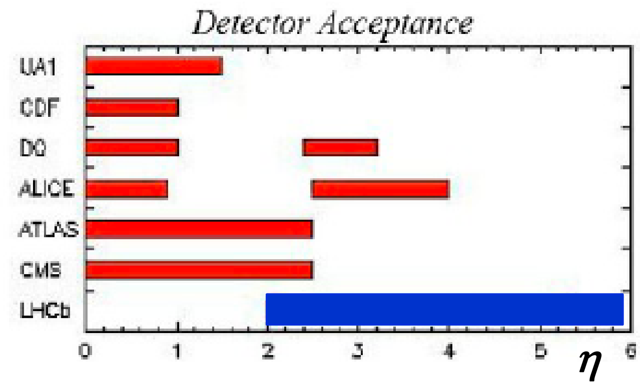


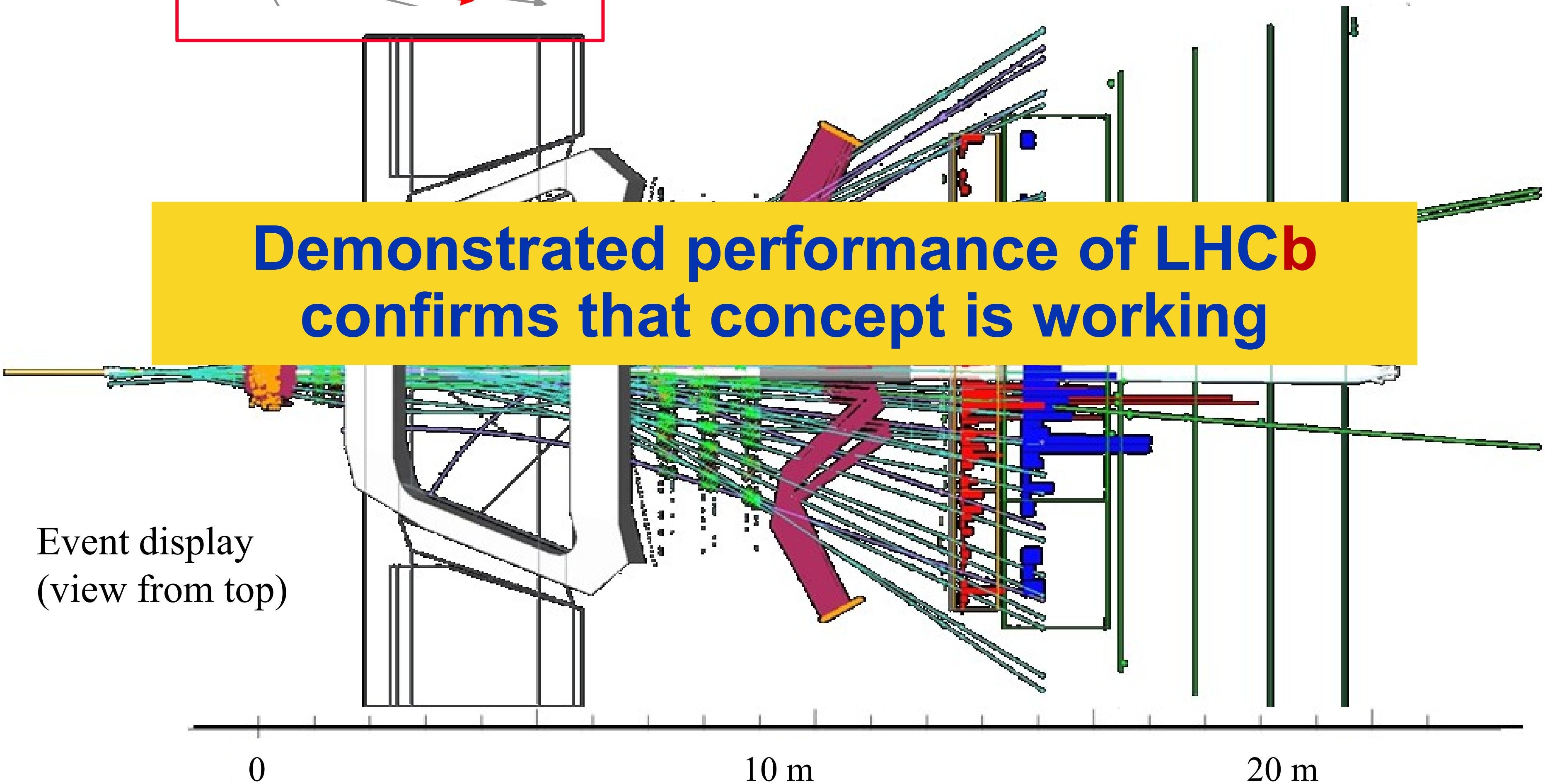
Big challenge to select events of interest:

- ✓ $\sigma_{b\bar{b}}$ is less than 1% of total inelastic cross section
- ✓ B decays of interest typically have BR < 10^{-5}
- ➢ **Need high statistics and high selectivity!**

The LHCb Detector optimized for hadronic environment







Demonstrated performance of LHCb confirms that concept is working

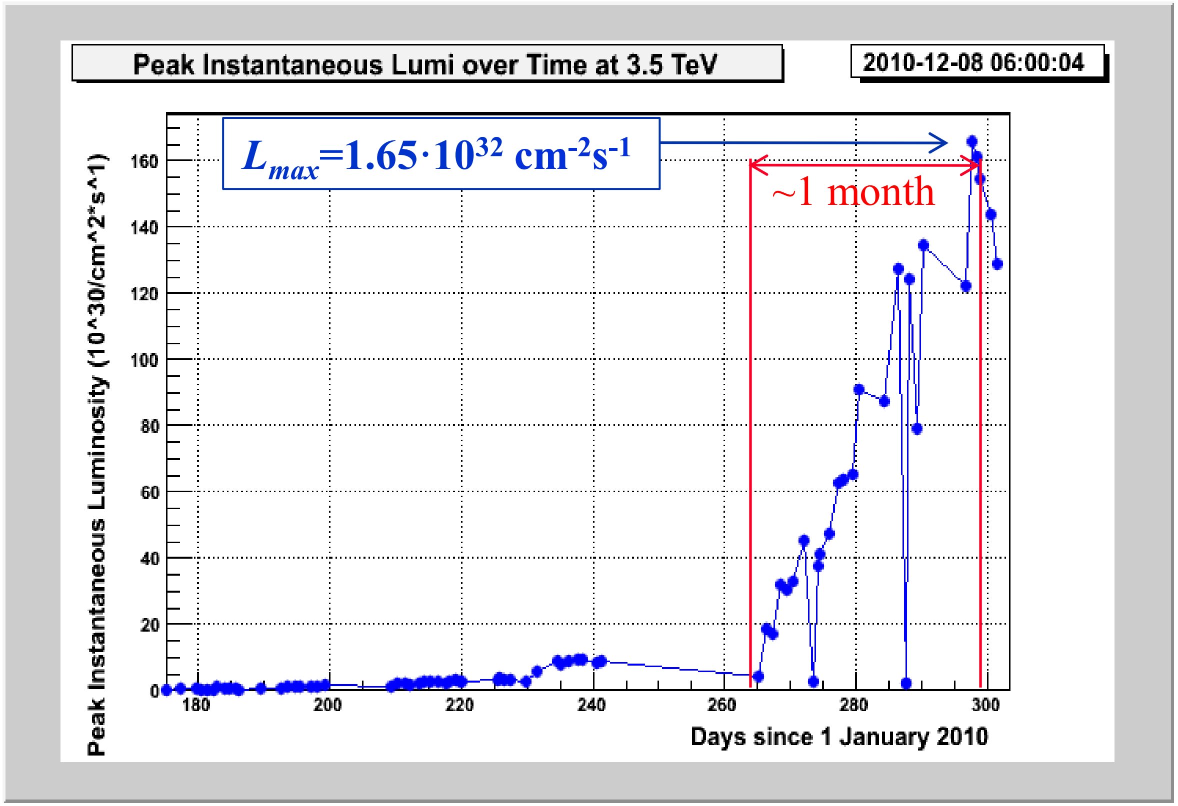
Event display (view from top)

LHC(b) operation in 2010

Outstanding machine performance thanks to our LHC colleagues!!!

Peak luminosity evolution with time:

- peak luminosity increased within ~1 month by factor 100!   (L~10^{30} to 10^{32} cm^{-2}s^{-1})
- for LHCb reached almost nominal L (L=1.6·10^{32} cm^{-2}s^{-1}, nominal 2·10^{32} cm^{-2}s^{-1}!)



LHC(b) operation in 2010

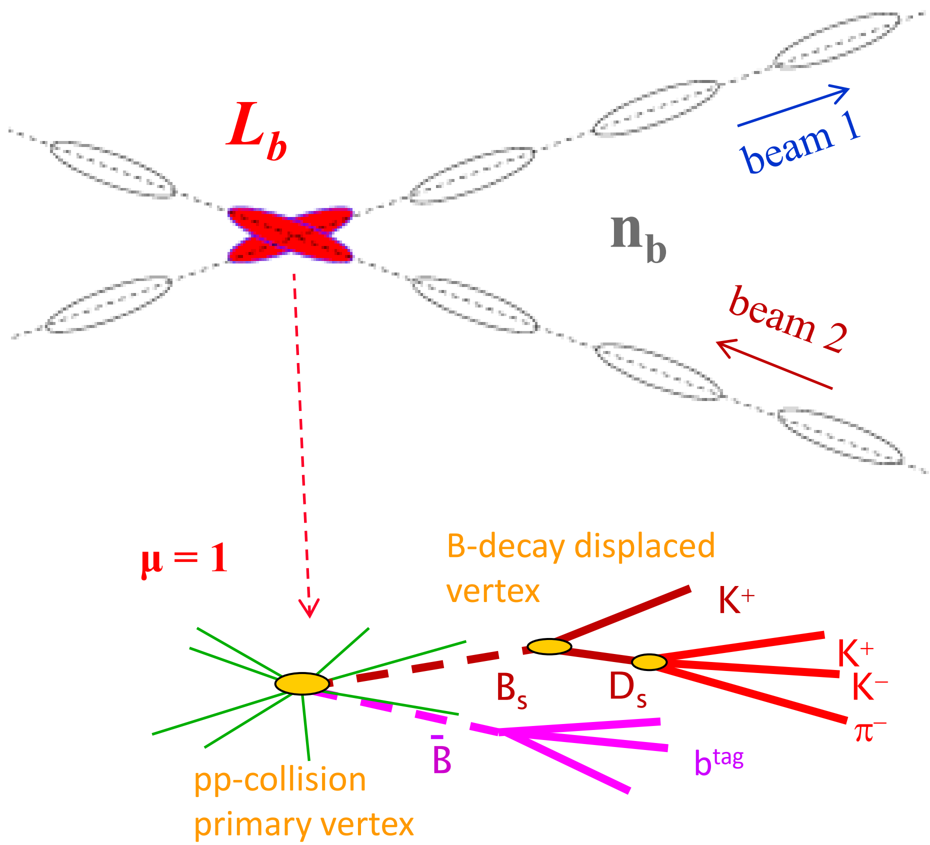
Evolution of average number of visible pp-collisions per bunch crossing:

$\boldsymbol{L} = n_b \cdot L_b \,\alpha\, n_b \cdot \mu$

LHCb design:

$L = 2 \cdot 10^{32}$; $n_b \sim 2600$ → $\langle\mu\rangle \sim 0.4$

- maximizes fraction of ***single interaction*** bunch crossings



LHC(b) operation in 2010

Evolution of average number of visible pp-collisions per bunch crossing:

$L = n_b \cdot L_b \propto n_b \cdot \mu$

LHCb design:

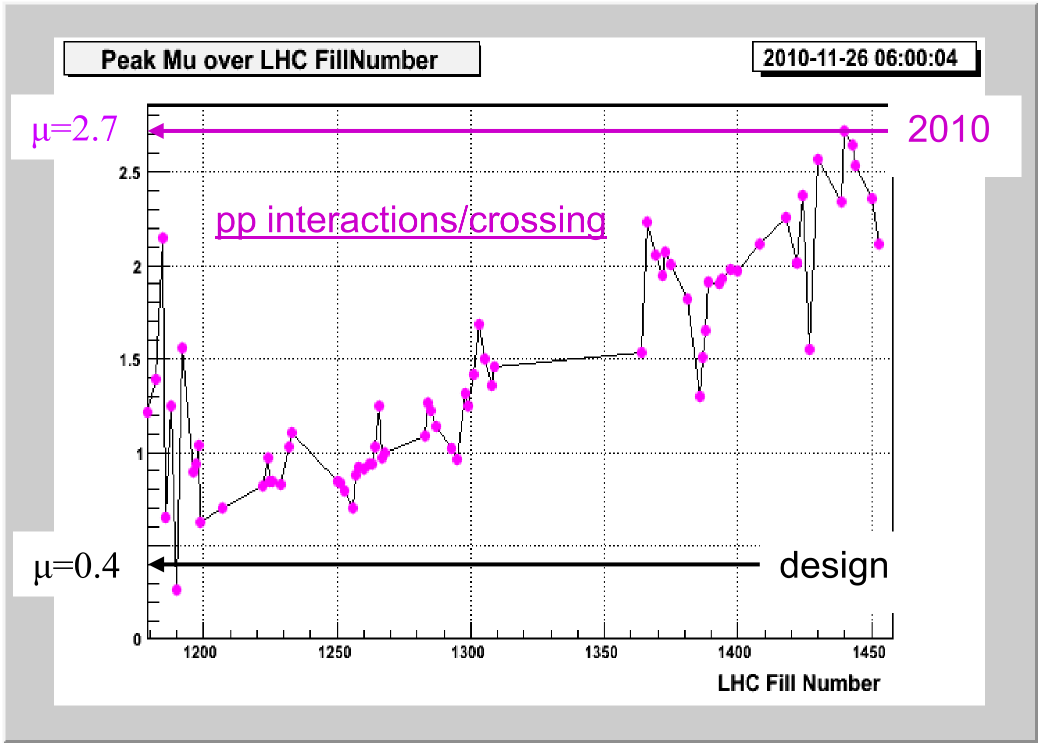
$L = 2 \cdot 10^{32}$; $n_b \sim 2600$ → $<\mu> \sim 0.4$

➢ maximizes fraction of ***single interaction*** bunch crossings

2010 run:

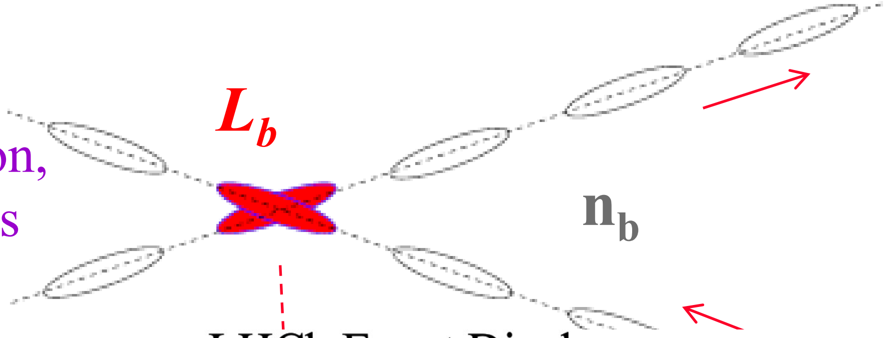
$L = 1.6 \cdot 10^{32}$; $n_b = 344$ → $\mu_{max} = 2.7$

➢ > 6 times nominal!

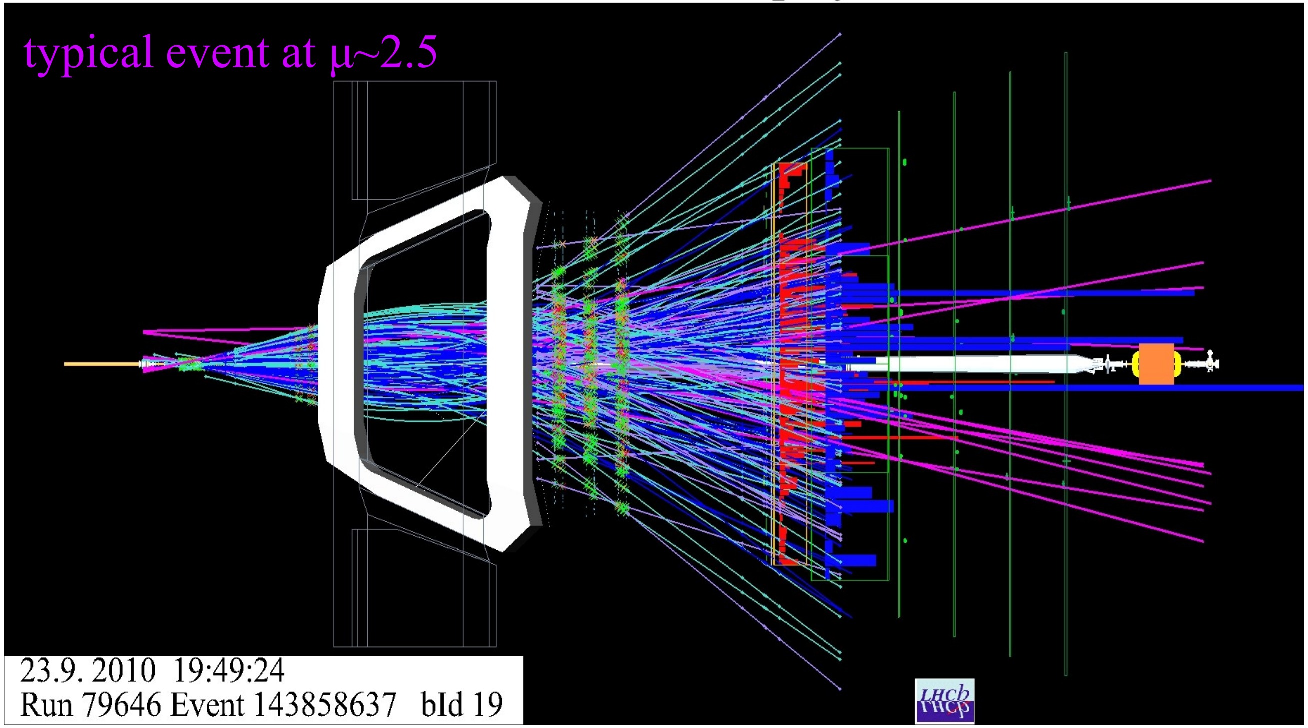


High multiplicity events

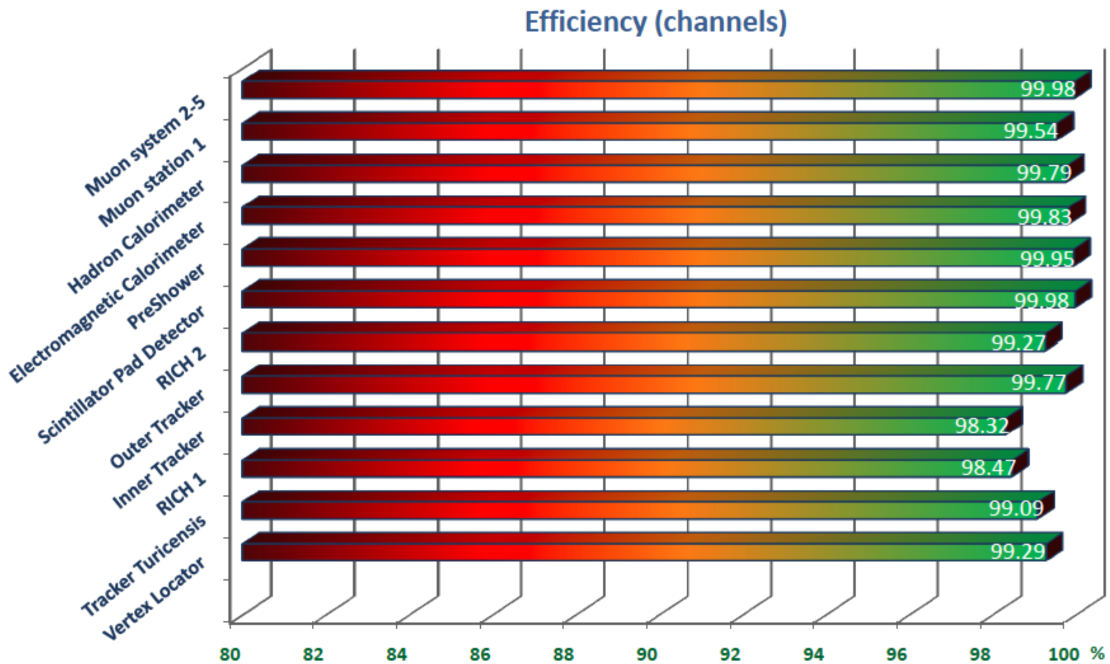
- ***high track multiplicity and many vertices*** in each collision event
- big challenge for detector operation, trigger, reconstruction and analysis



LHCb Event Display



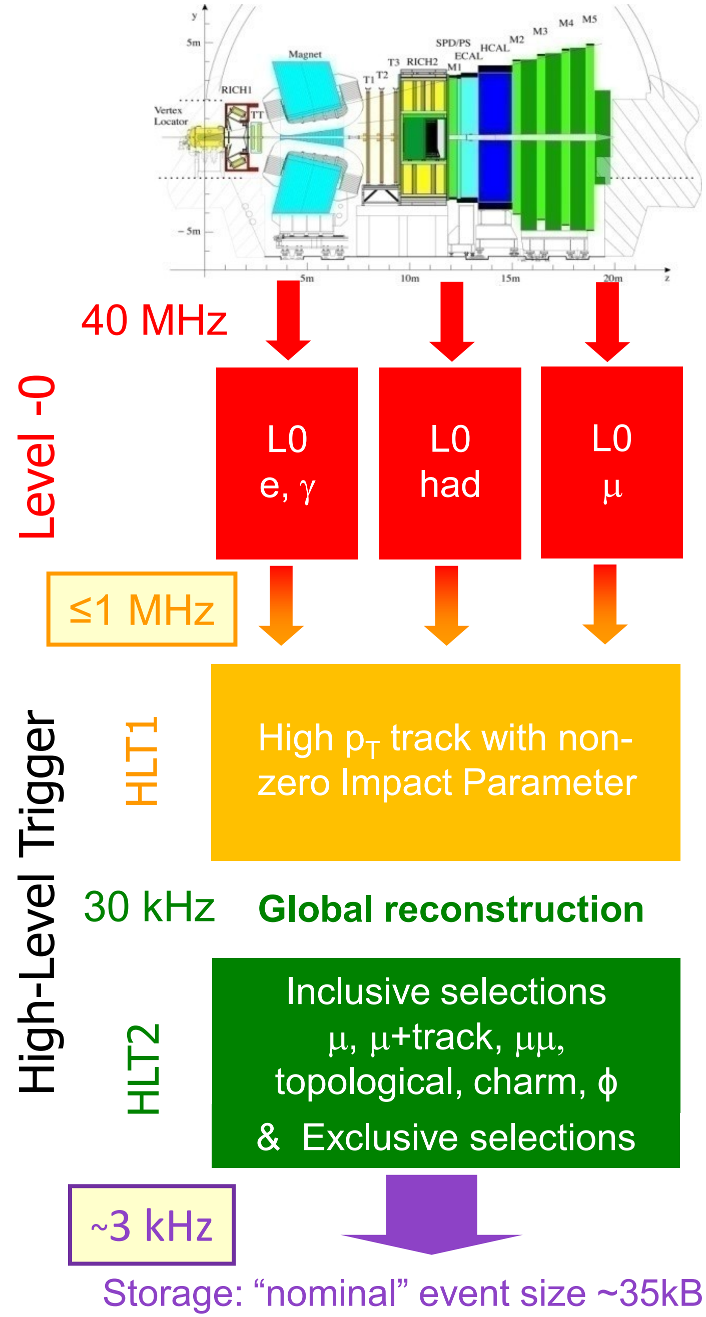
Detector & trigger efficiencies



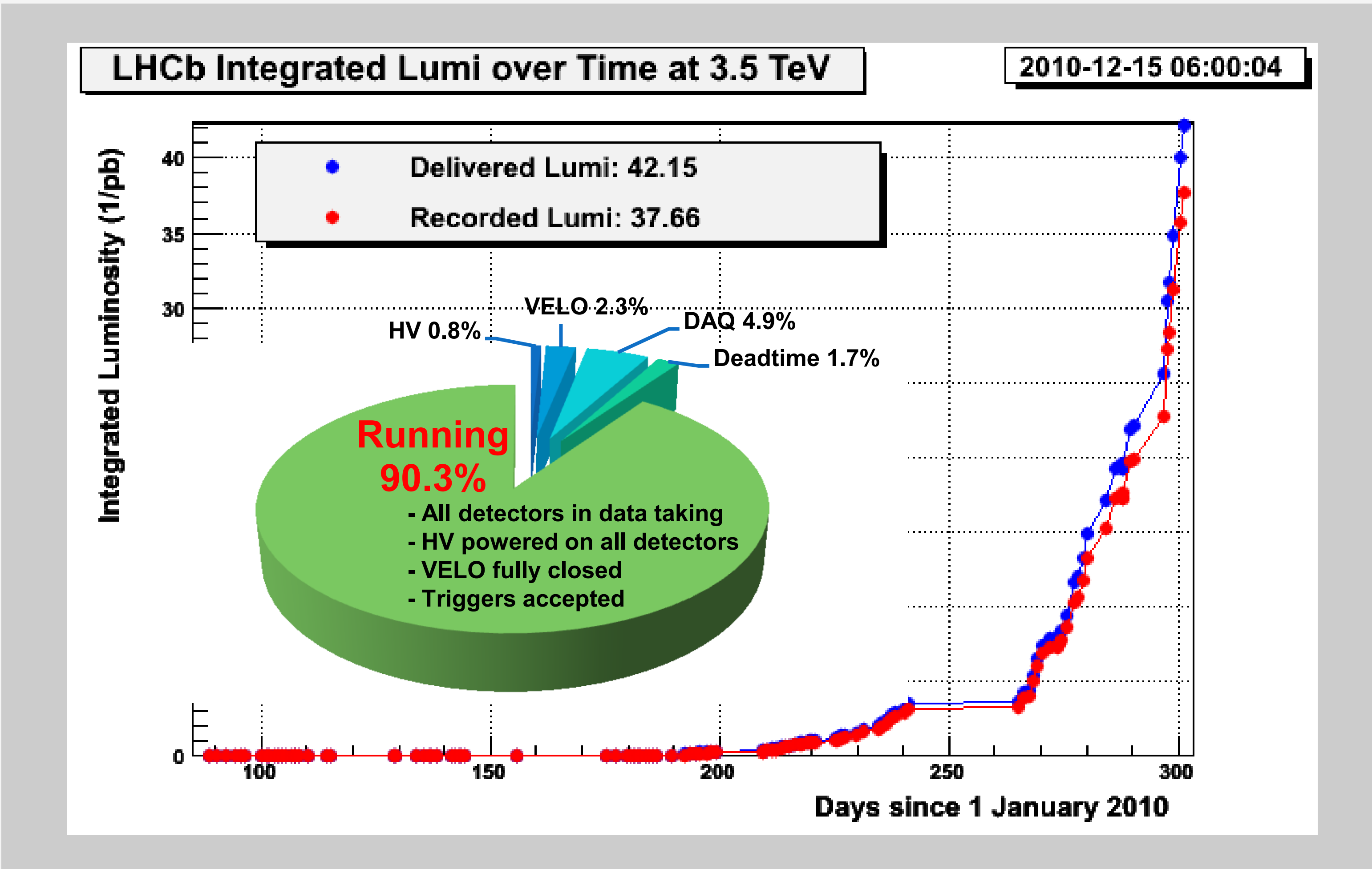
→ all detector components ~ 99 % efficient!

2010	Muon trigger (J/ψ)	Hadron trigger (D^0)
Data	94.9±0.2%	60±4%
MC	93.3±0.2%	66%

→ very high selection efficiencies!



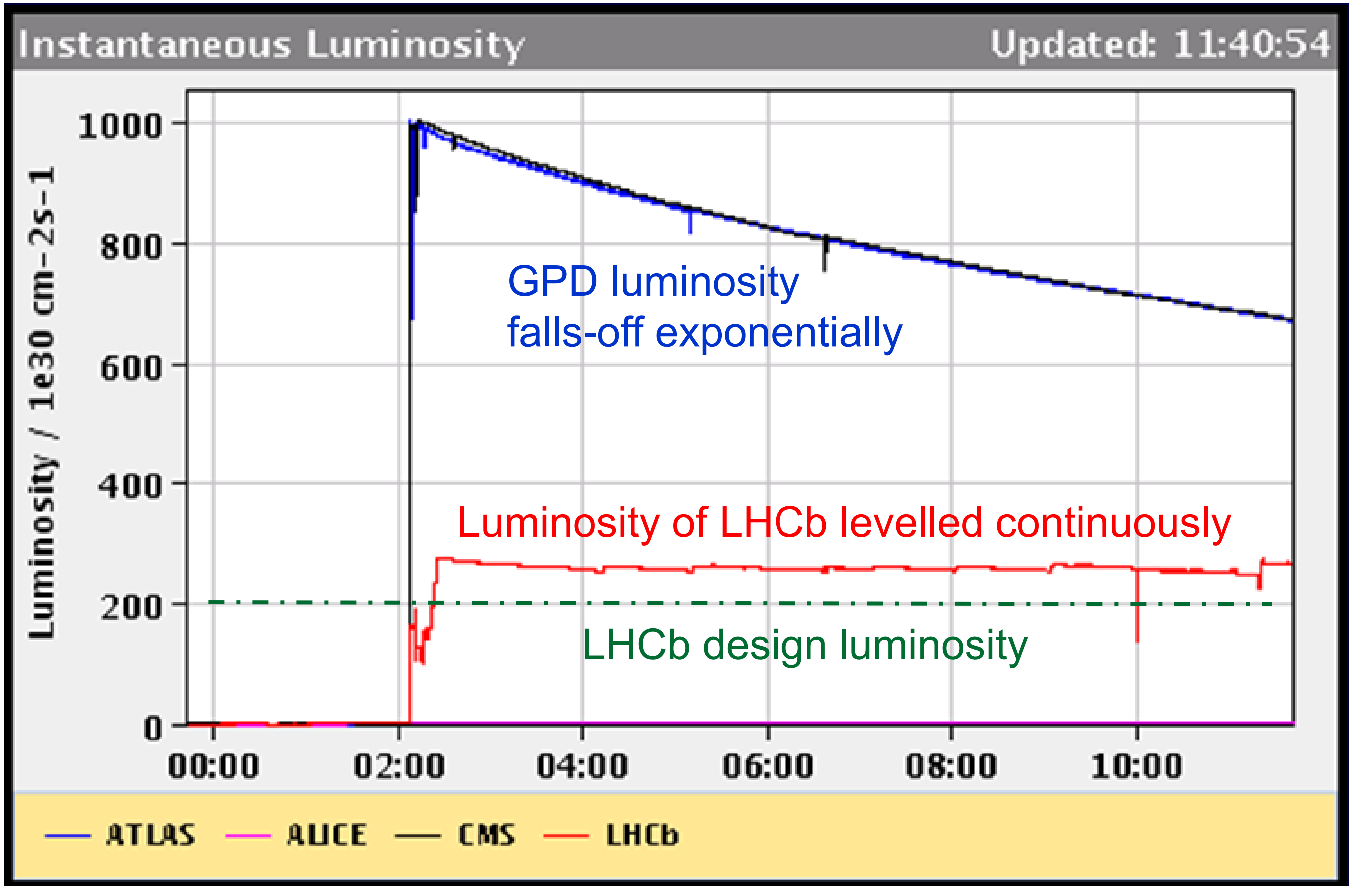
LHCb performance in 2010



- **~37 pb^{-1}** integrated luminosity
- with <u>all</u> sub-detectors fully operational
- overall data taking efficiency of **~90%**!

Expected integrated luminosity for LHCb in 2011

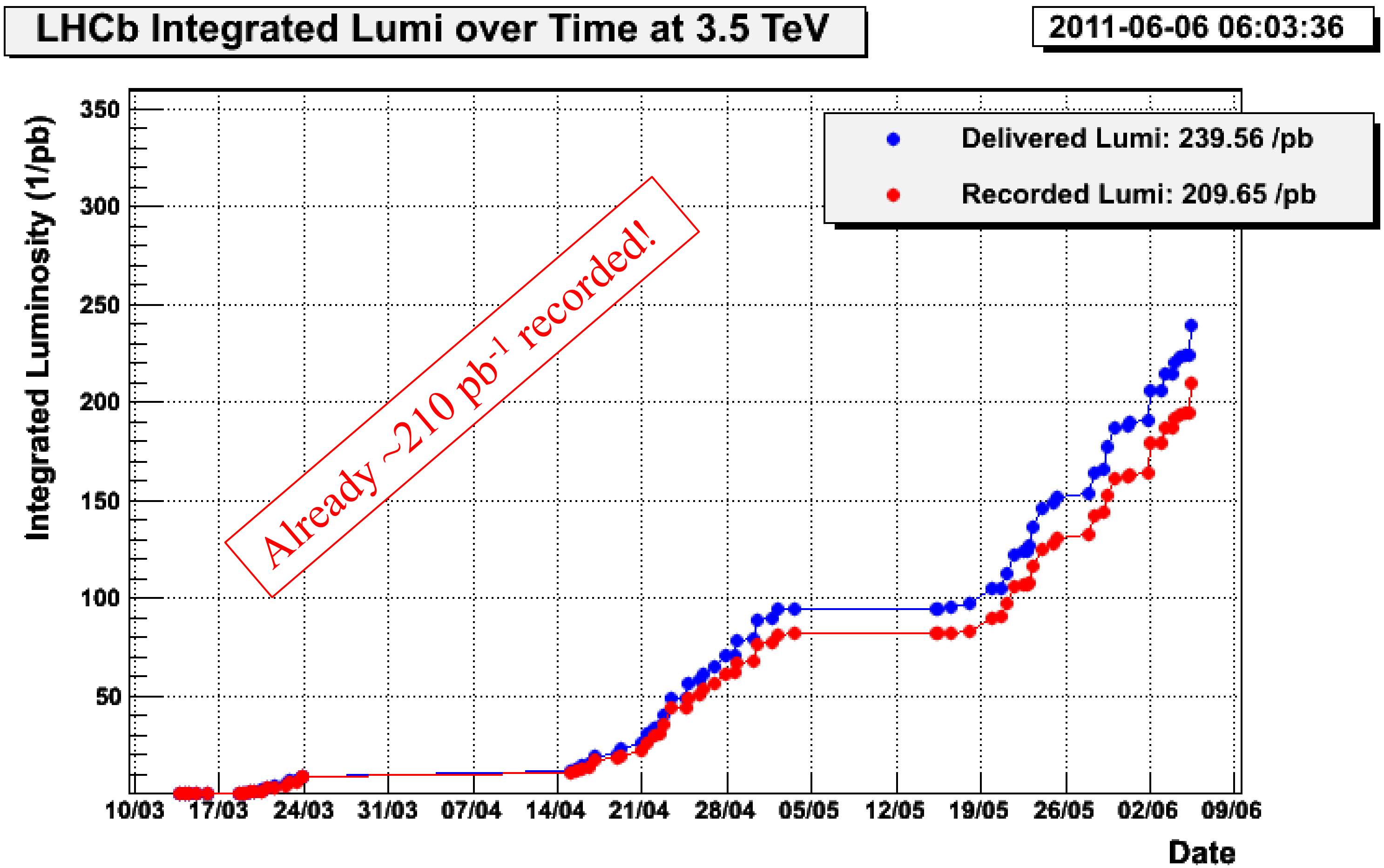
Introduced luminosity leveling for LHCb → can run at optimal μ and L_{max}



→ Since end of May running at constant $L \sim 3 \cdot 10^{32}$ cm^{-2}s^{-1} with μ ~ 1.5

Expected integrated luminosity for LHCb in 2011

Introduced luminosity leveling for LHCb → can run at optimal μ and L_{max}

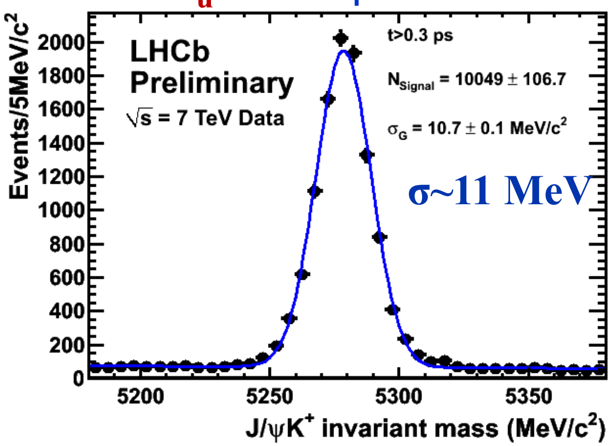


→ LHCb expects to collect ~1000 pb^{-1} in 2011 (and ≥ same in 2012)

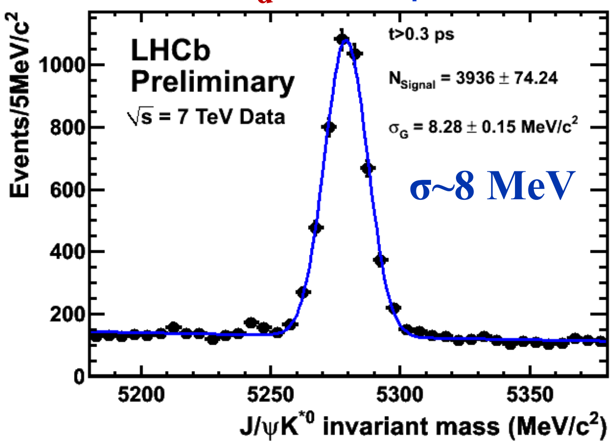
Detector performance: mass resolution

Detection of different B species: for B → J/ψ X with 34 pb^{-1} ~ full statistics of 2010

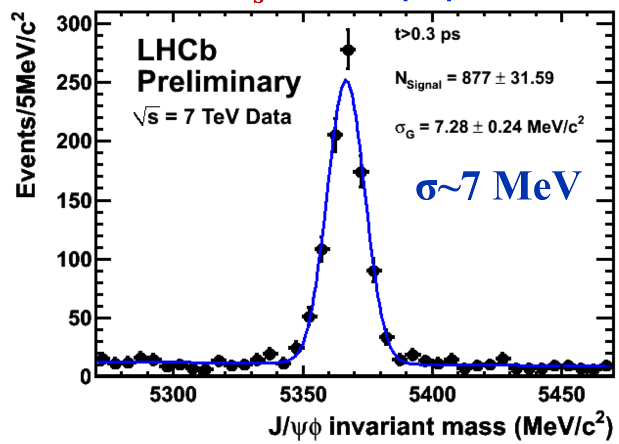
$B_u^+ \to J/\psi K^+$



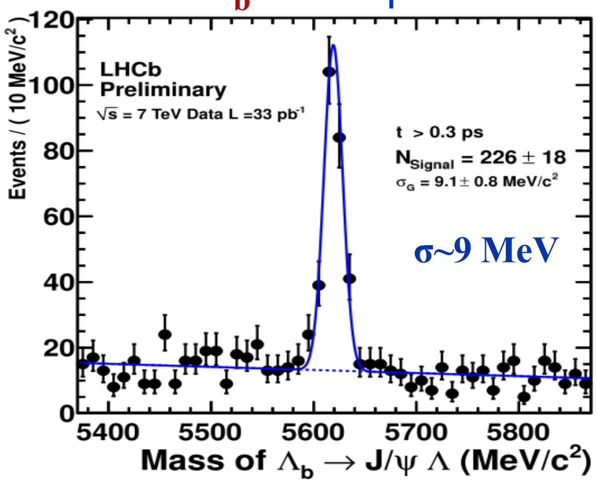
$B_d^0 \to J/\psi K^*$



$B_s^0 \to J/\psi \varphi$



$\Lambda_b^0 \to J/\psi \Lambda$



- very good mass resolution
- very low background (comparable to e^+e^- machines)
- ***worlds best*** mass measurements

Comparison GPDs:

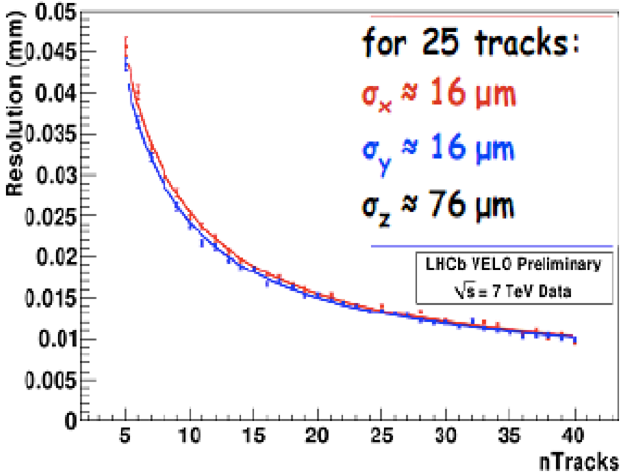
- CMS: σ~16 MeV
- ATLAS: σ~26 MeV

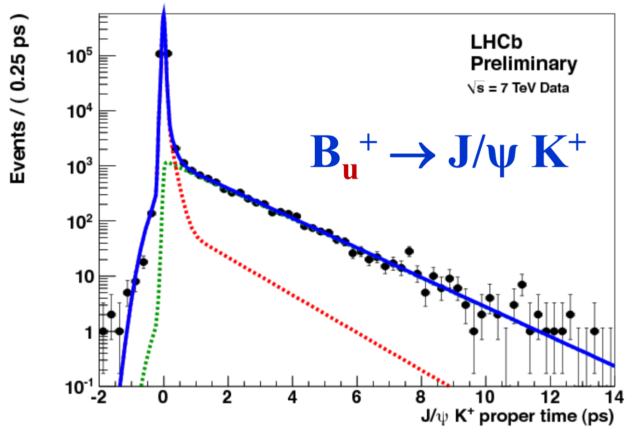
[LHCb-CONF-2011-027]

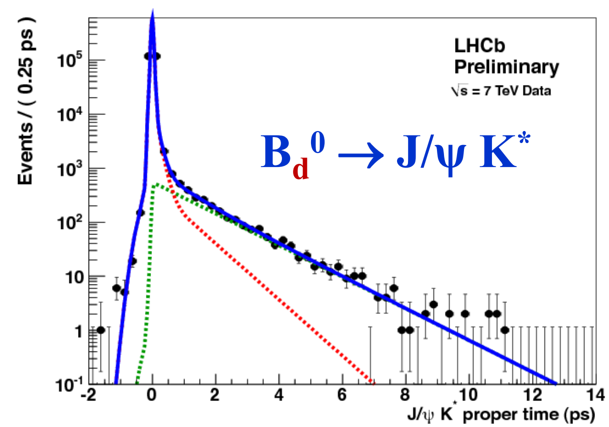
Channel		LHCb mass [MeV/c^2]	PDG [MeV/c^2]
$M(B^+ \to J/\psi K^+)$	=	$5279.27 \pm 0.11\,(\text{stat}) \pm 0.20\,(\text{syst})$	5279.17 ± 0.29
$M(B^0 \to J/\psi K^{*0})$	=	$5279.54 \pm 0.15\,(\text{stat}) \pm 0.16\,(\text{syst})$	5279.50 ± 0.30
$M(B^0 \to J/\psi K^0_S)$	=	$5279.61 \pm 0.29\,(\text{stat}) \pm 0.20\,(\text{syst})$	5279.50 ± 0.30
$M(B^0_s \to J/\psi \phi)$	=	$5366.60 \pm 0.28\,(\text{stat}) \pm 0.21\,(\text{syst})$	5366.30 ± 0.60
$M(\Lambda_b \to J/\psi \Lambda)$	=	$5619.49 \pm 0.70\,(\text{stat}) \pm 0.19\,(\text{syst})$	5620.2 ± 1.6
$M(B^+_c \to J/\psi \pi^+)$	=	$6268.0 \pm 4.0\,(\text{stat}) \pm 0.6\,(\text{syst})$	6277 ± 6

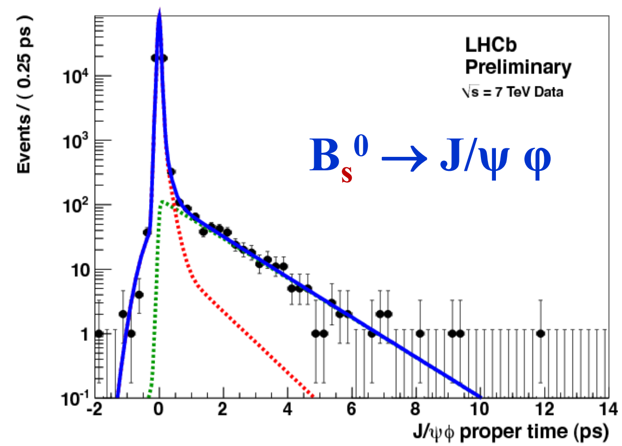
Detector performance: proper-time resolution

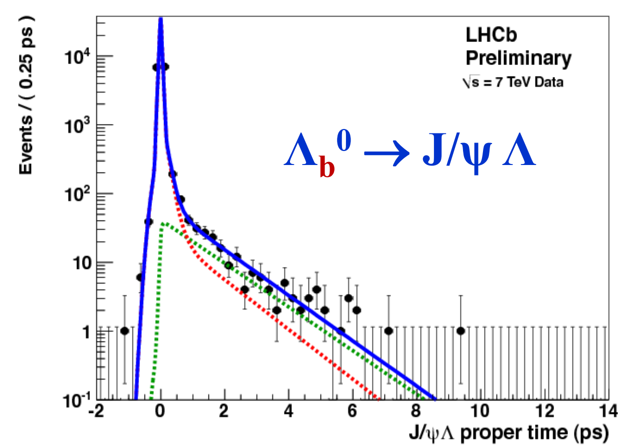
Vertex resolution on primary vertex











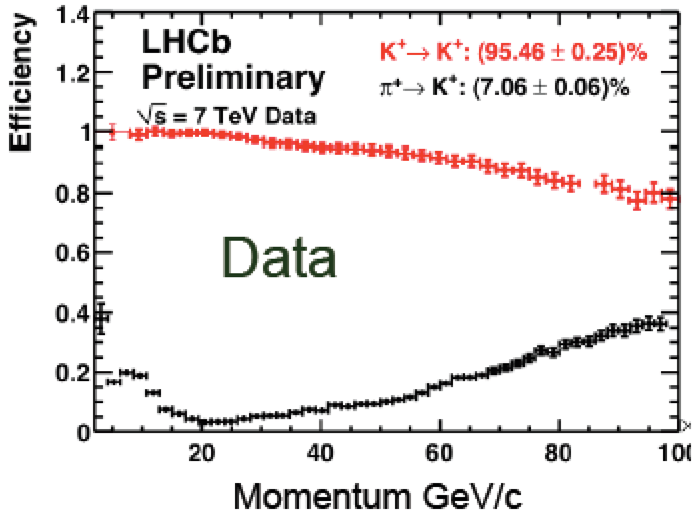
- excellent proper time resolution of ~50 ps

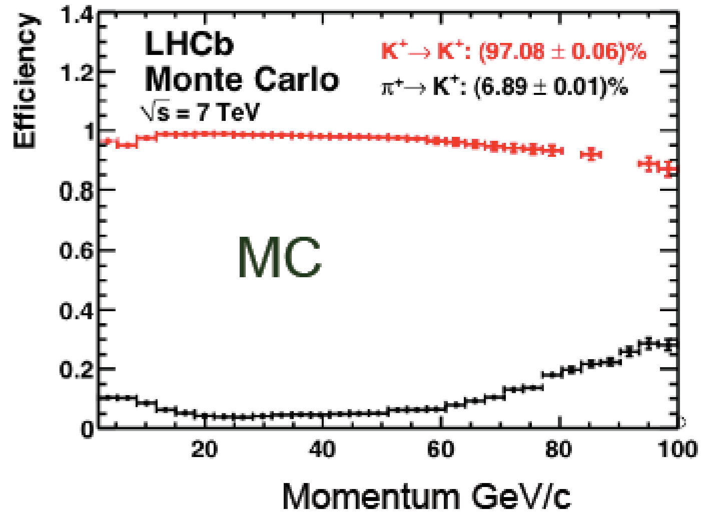
Channel		LHCb lifetime [ps]	PDG [ps]
$\tau(B^+ \to J/\psi K^+)$	=	1.689 ± 0.022 (stat.) ± 0.047 (syst.)	1.638 ± 0.011
$\tau(B^0 \to J/\psi K^{*0})$	=	1.512 ± 0.032 (stat.) ± 0.042 (syst.)	1.525 ± 0.009
$\tau(B^0 \to J/\psi K^0_S)$	=	1.558 ± 0.056 (stat.) ± 0.022 (syst.)	1.525 ± 0.009
$\tau^{\text{single}}(B^0_s \to J/\psi \phi)$	=	1.447 ± 0.064 (stat.) ± 0.056 (syst.)	1.477 ± 0.046
$\tau(\Lambda_b \to J/\psi \Lambda)$	=	1.353 ± 0.108 (stat.) ± 0.035 (syst.)	1.391 ± 0.038

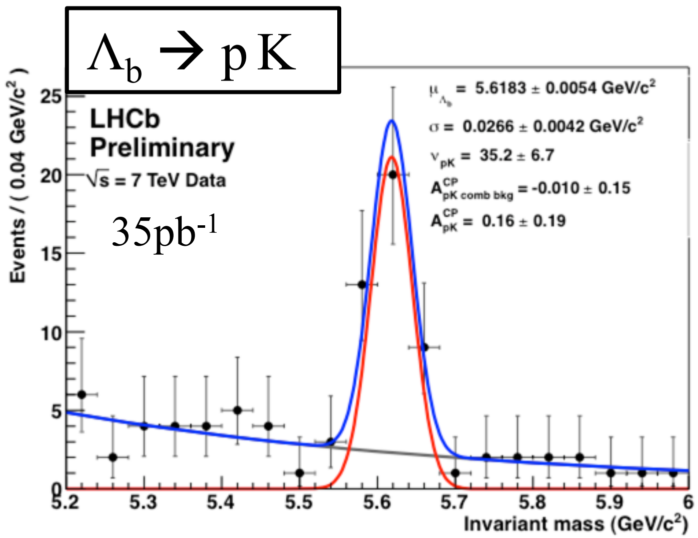
[LHCb-CONF-2011-001]

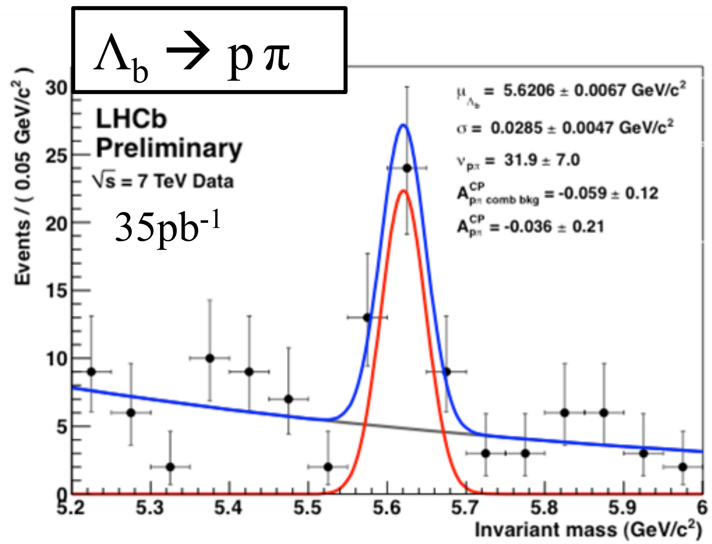
Detector performance: hadron PID performance

Kaon identification efficiency and miss-identification as function of momentum





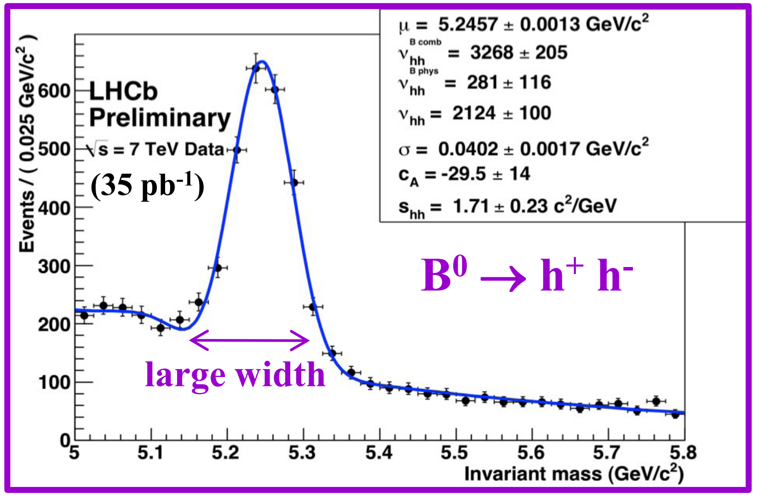




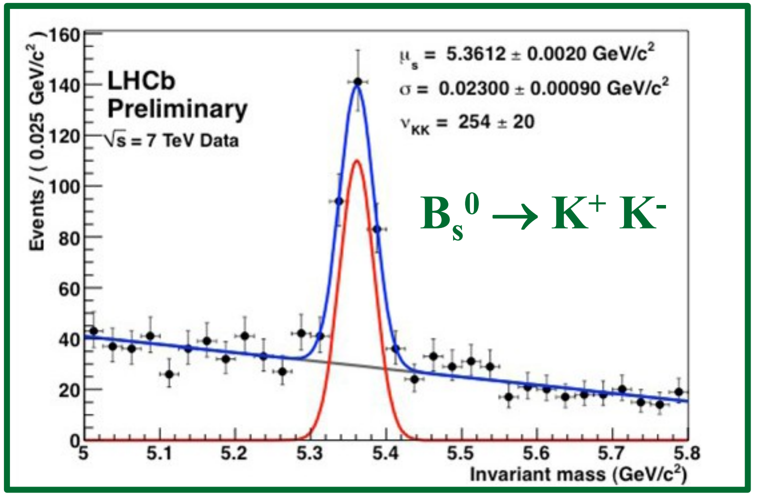
- excellent prospects for observation of CP violation with $L \sim 1\ \mathrm{fb}^{-1}$

Detector performance: Particle Identification on B→hh

No particle identification → any 2 hadrons!

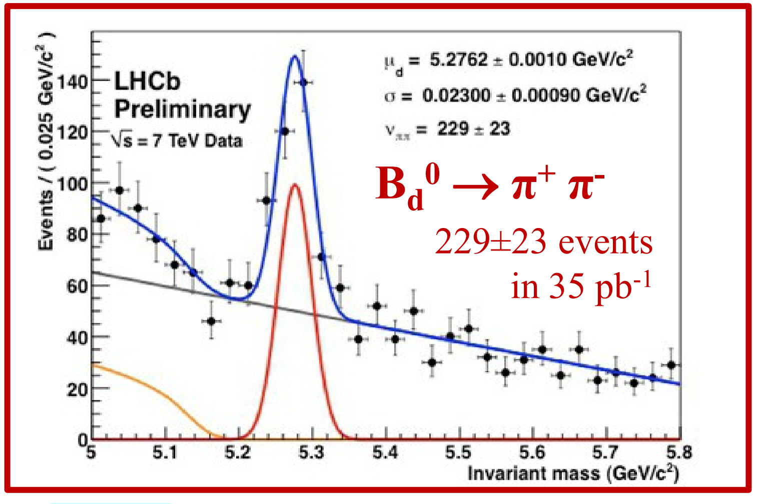


particle identification of 2 Kaons



particle identification of 2 π

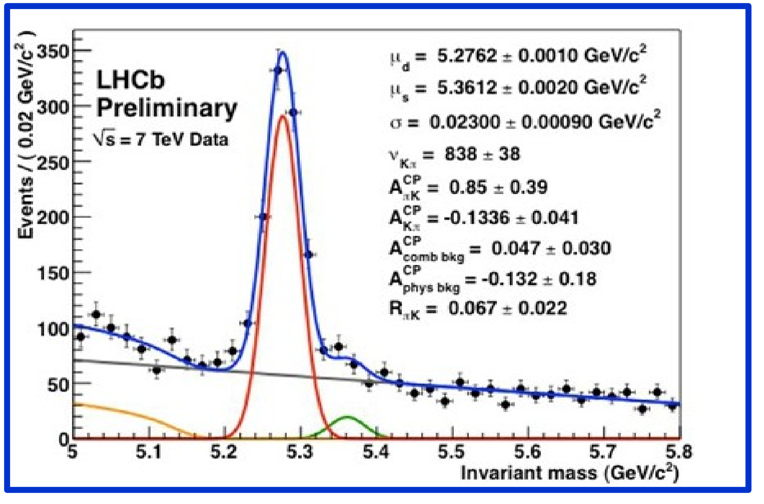
$BR(B \to \pi^+\pi^-) = 5 \times 10^{-6}$!



particle identification of 1 π and 1 K

$B_d^0 \to K\pi$ & $B_s^0 \to K\pi$

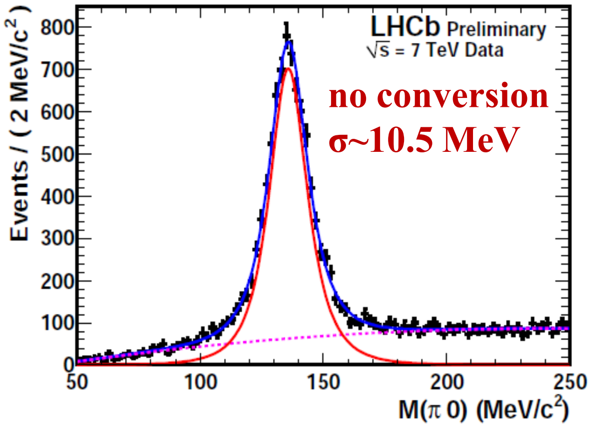
(will get as many Kπ in <1 fb⁻¹ as Belle in 1000 fb⁻¹)

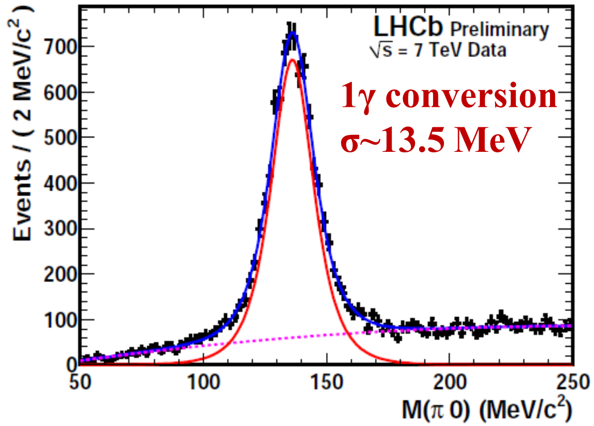


Expectations 2011:
LHCb: 6500 ev./fb⁻¹
(CDF: 1100 ev./fb⁻¹)

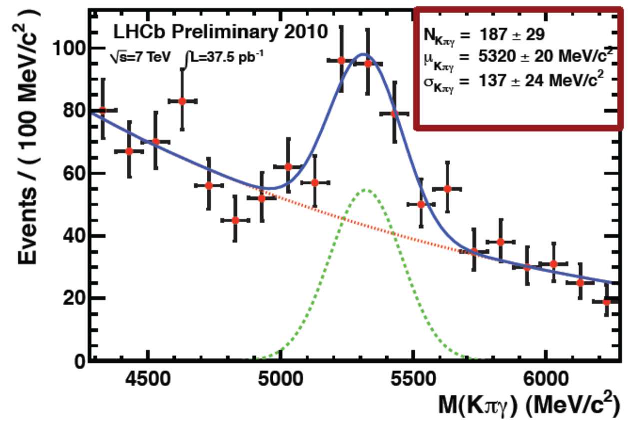
Detector performance: photon PID

π^0 reconstruction performance

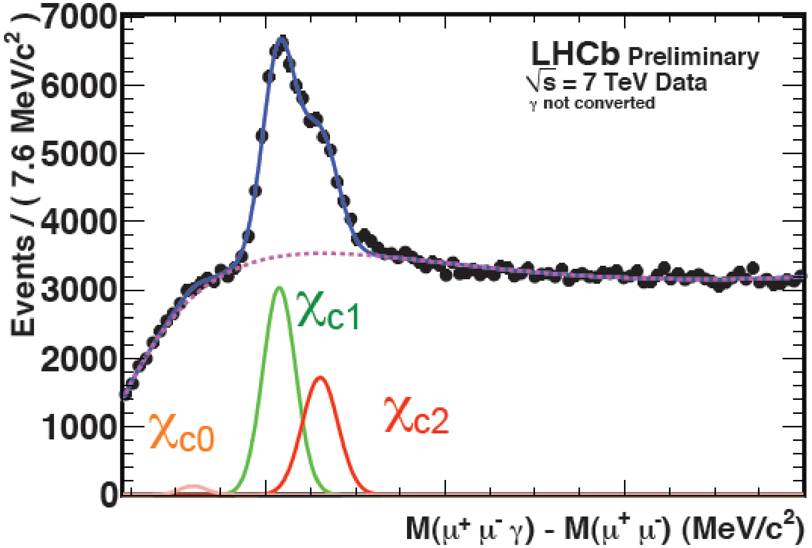




$B_d^0 \rightarrow K^*\gamma$

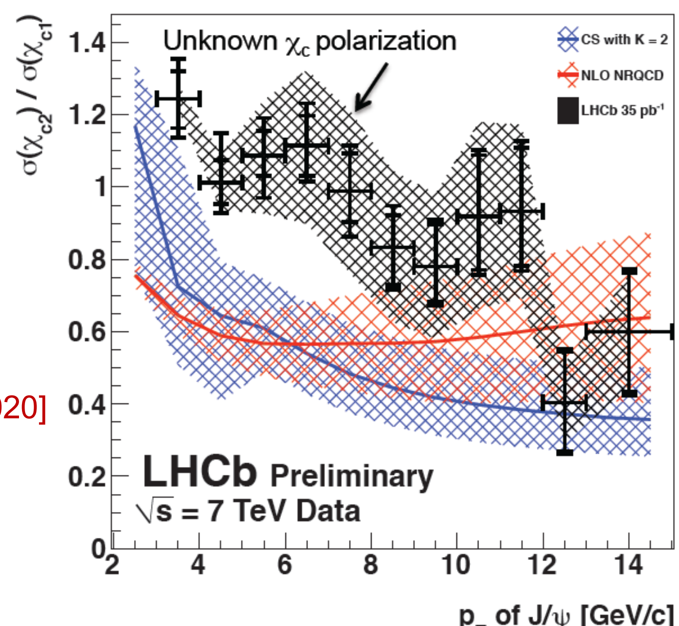


$\chi_c \rightarrow J/\psi\ \gamma$

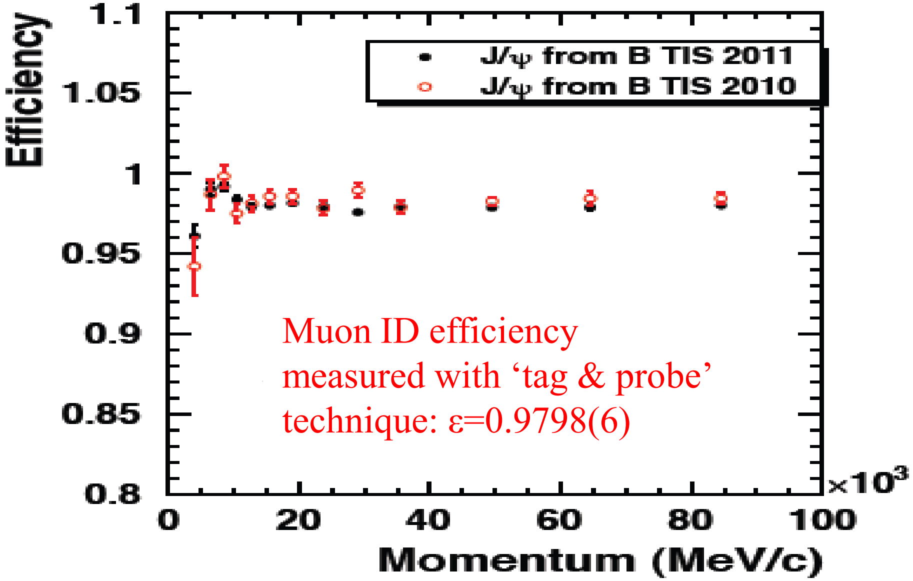


cross section ratio χ_{c2} / χ_{c1} for prompt χ_c production at $\sqrt{s} = 7$ TeV

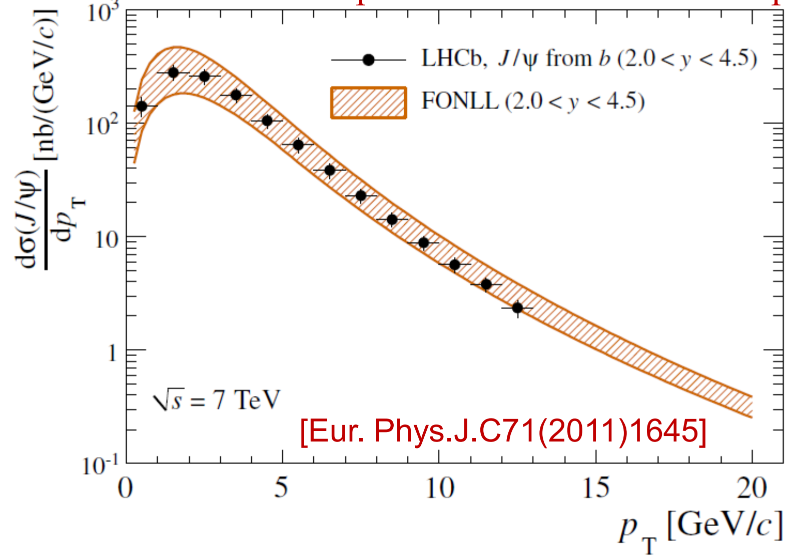
[LHCb-CONF-2011-020]

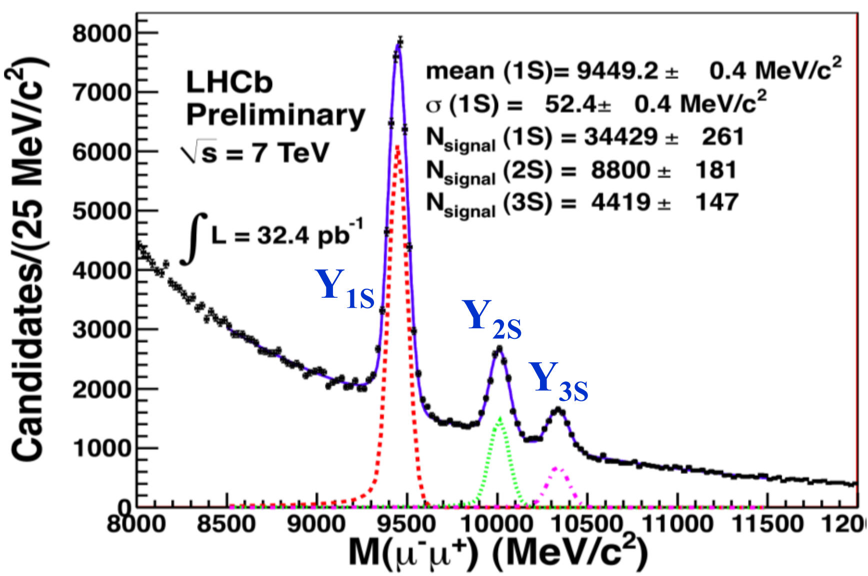


Detector performance: muon PID

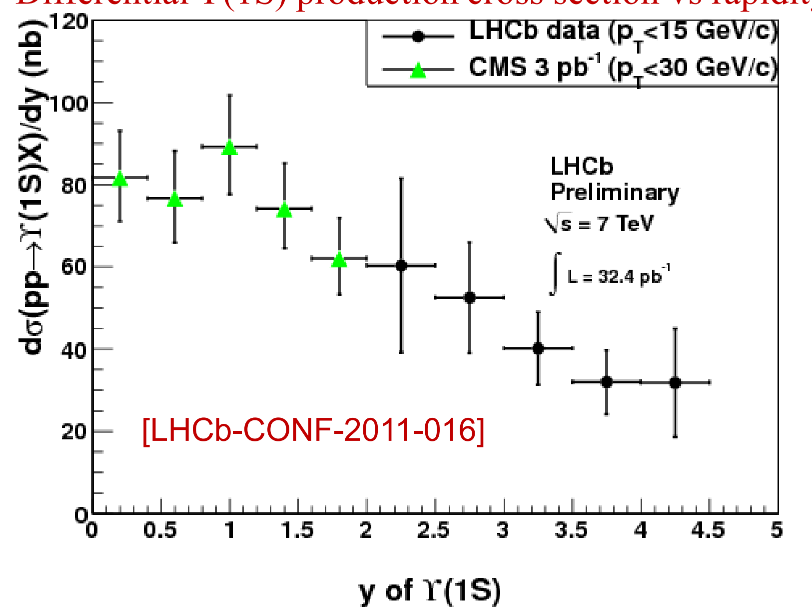


Differential J/Ψ production cross section vs p_T



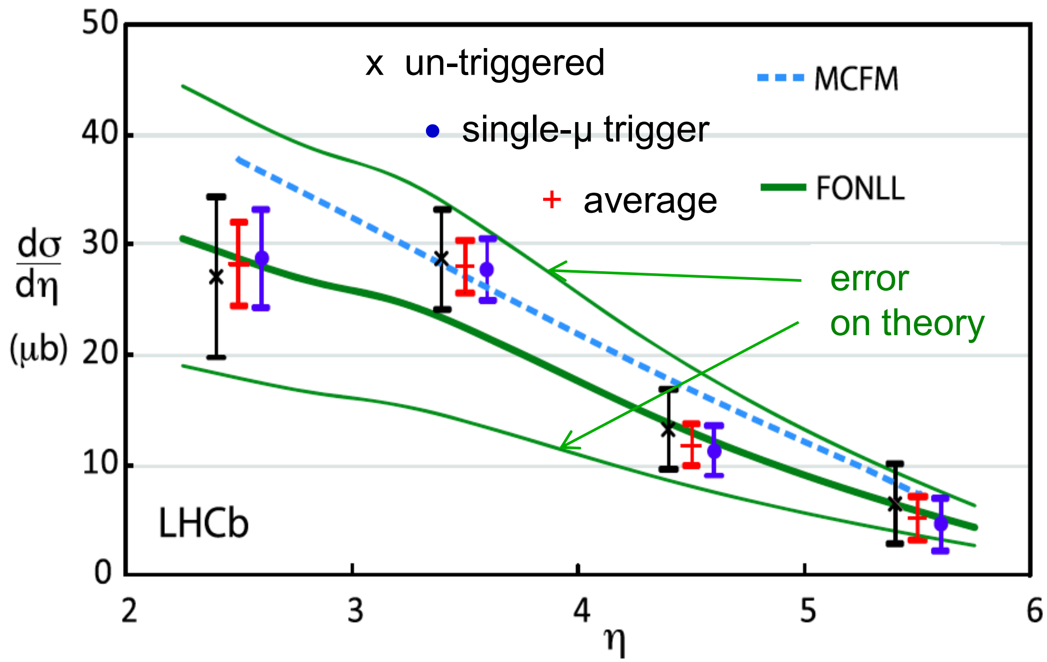


Differential Y(1S) production cross section vs rapidity



High $b\bar{b}$-cross section confirmed

$b\bar{b}$-cross section at $\sqrt{s}$ = 7 TeV from semileptonic B decays



From $B^0 \to D^0 X^+ \mu^- \nu$ with $D^o \to K^- \pi^+$
total $b\bar{b}$ cross-section in 4π:

$$\sigma(pp \to b\bar{b}X) = 284 \pm 20 \pm 49\ \mu b$$

[Physics Letters B 694 (2010) 209]

In perfect agreement with result from $B \to J/\psi X$:

$$\sigma(pp \to b\bar{b}X) = 288 \pm 4 \pm 48\ \mu b$$

[Eur. Phys. J. C 71 (2011) 1645]

Thanks to its excellent detector performance, with ~37 pb^{-1} LHCb is already competitive with Tevatron results based on 6000 pb^{-1}, even though $b\bar{b}$ cross-section only 3 times higher

Towards LHCb Core Physics with 2010 data

CP violation

- prospects for measuring angle γ
  - ✓ trees
  - ✓ loops
- direct CP violation ($B \rightarrow K\pi$)
- mixing induced CP violation (Φ_s)

Rare decays

- $B_s \rightarrow K^*\mu\mu$
- $B_s \rightarrow \mu\mu$

LHCb as General purpose detector

- electroweak physics

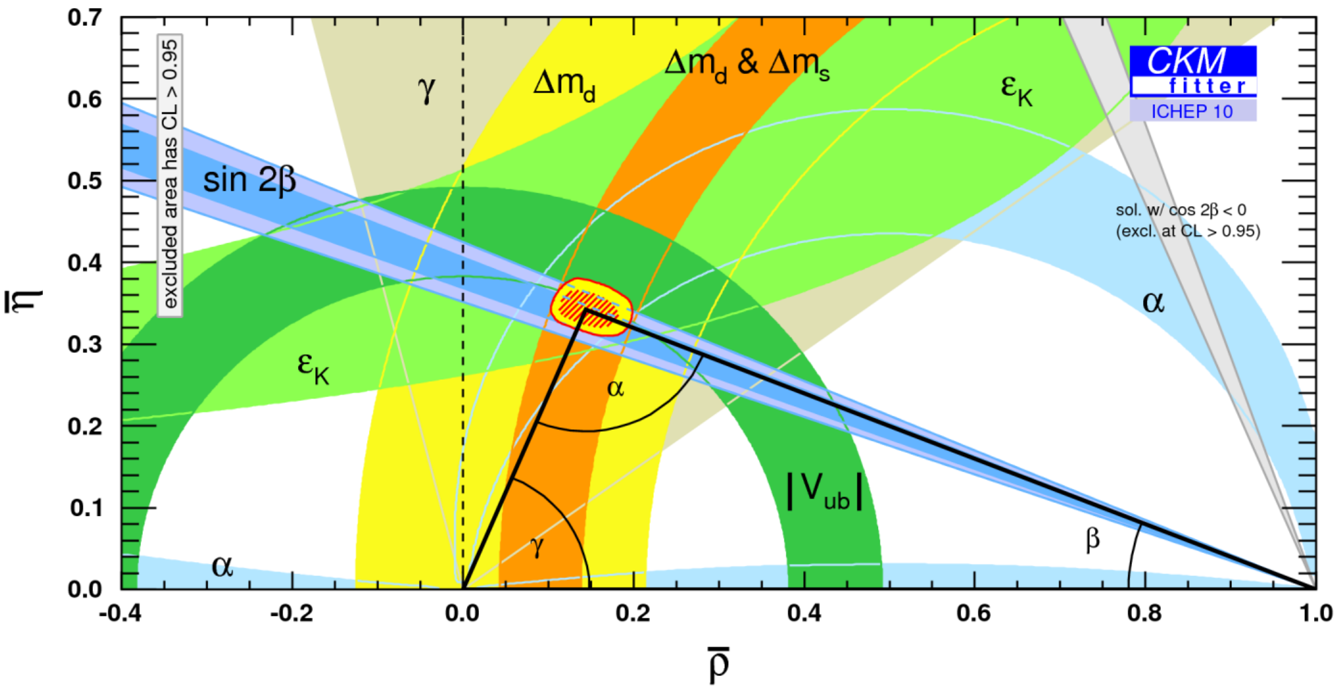
And many more! → see plenary talks by Marta Calvi & Giulia Manca

- Charm, Spectroscopy, Onia ….

And many parallel sessions for details….

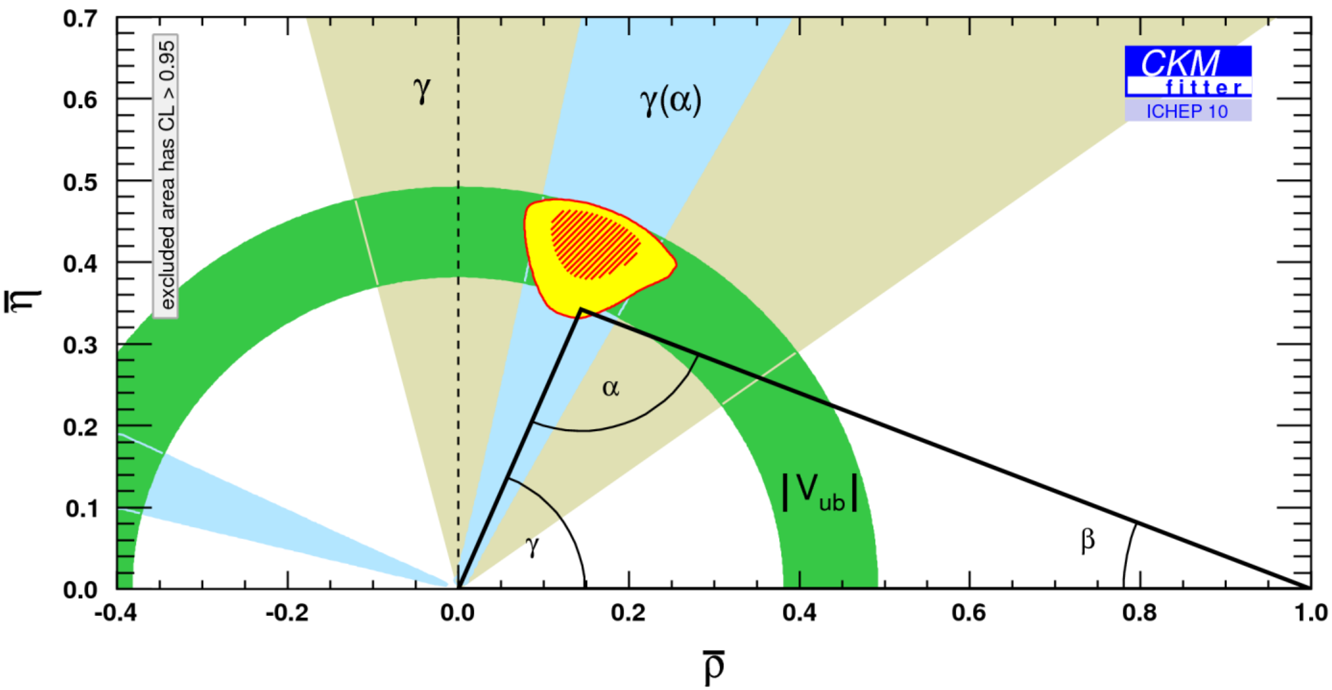
Determination of CKM angle γ

- All measurements together (trees & loops) determine "indirectly" the CKM angle $\gamma = (67 \pm 4)^o$



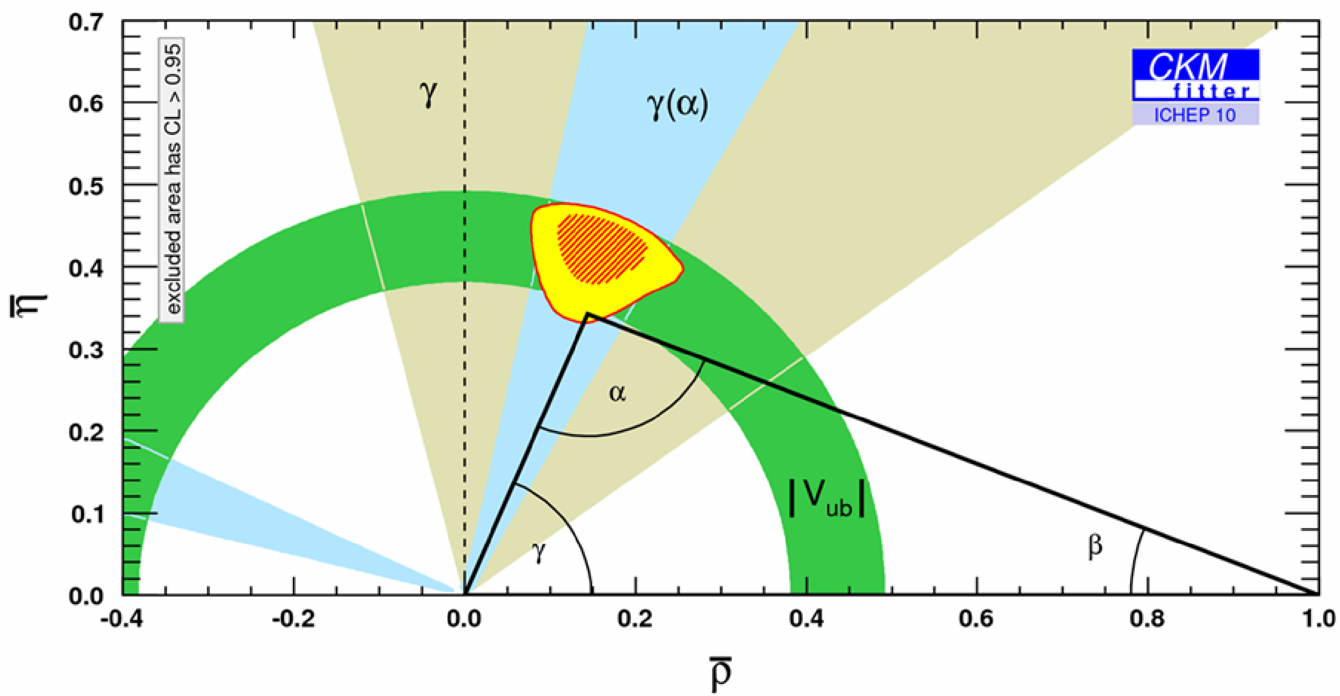
Determination of CKM angle γ

- However, processes involving loops may be affected by New Physics → should compare measurements from loop processes with tree processes only!
- But γ from trees only poorly constrained: $\gamma = (73\ ^{+22}_{-25})^{o}$ (direct measurement)



Determination of CKM angle γ

- However, processes involving loops may be affected by New Physics → should compare measurements from loop processes with tree processes only!
- But γ from trees only poorly constrained: $\gamma = (73\ ^{+22}_{-25})^{o}$ (direct measurement)
- Compare with loops only → room for New Physics →
  - ✓ measure γ precisely from tree decays only and compare to loop decays
  - ✓ access interference effects involving the phase between V_{ub} and V_{cb}



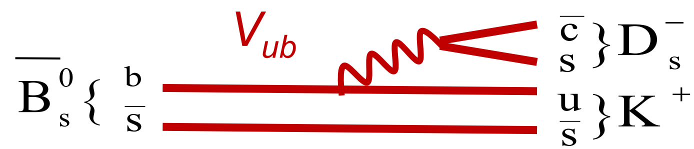
Prospects for γ in trees from $B_s \to D_sK$

✓ 2 time dependent asymmetries from 4 decay rates:
B_s ($\overline{B}_s$) $\to D_s^- K^+$, $D_s^+ K^-$

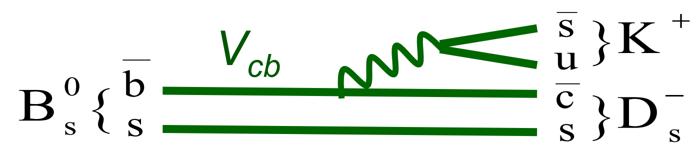
✓ 2 tree decays *(b→c)* and *(b→u)* of same magnitude interfere via B_s mixing:

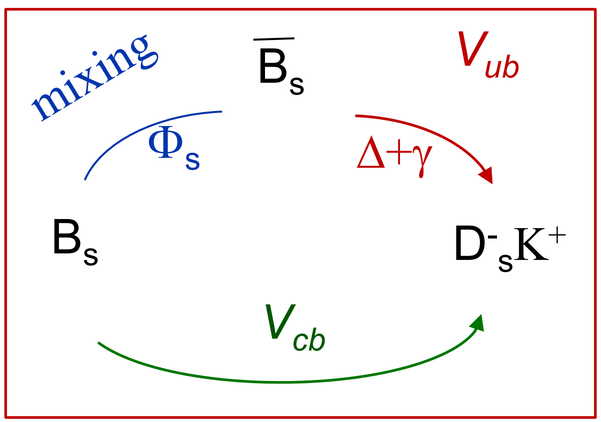
→ large interference effects expected

→ insensitive to new physics



***b→u* transition, phase Δ+γ**
***b→c* transition, phase 0**





Fit the 4 tagged, time-dependent rates:

✓ phase of $D^-_s K^+ = \Delta + (\gamma + \phi_s)$

✓ phase of $D^+_s K^- = \Delta - (\gamma + \phi_s)$

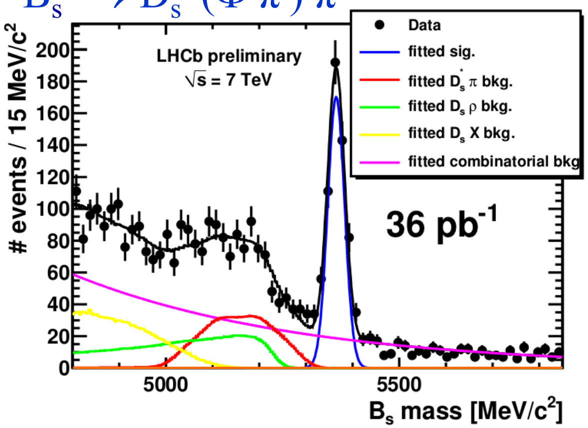
→ extract both Δ and $(\gamma + \phi_s)$
with ϕ_s being determined using $B_s \to J/\psi\ \phi$

- $B_s \to D_sK$ final state under study
- expect world's first time-dependent analysis with 2011 data
- first step: measurement of Δm_s with $B_s \to D_s\ \pi$

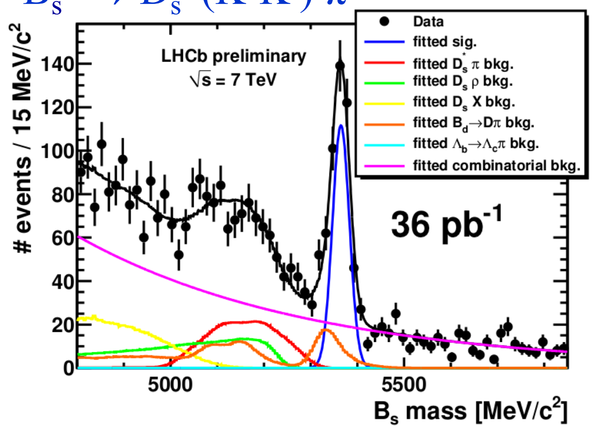
Measurement of Δm_s from $B_s \to D_s \pi$

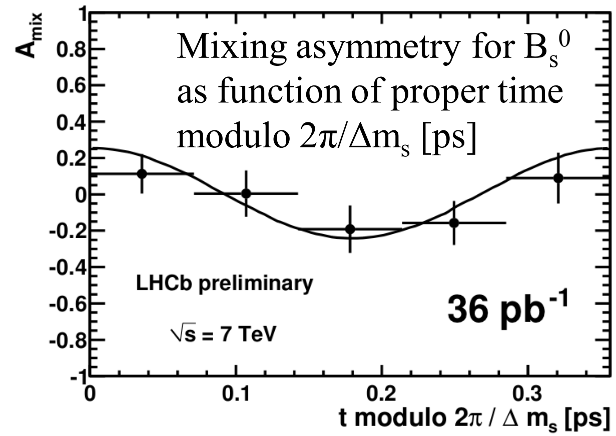
With 2010 data large signals for $B_s \to D_s \pi$ useful for Δm_s measurement

$B_s^0 \to D_s^- (\Phi \pi^-) \pi^+$

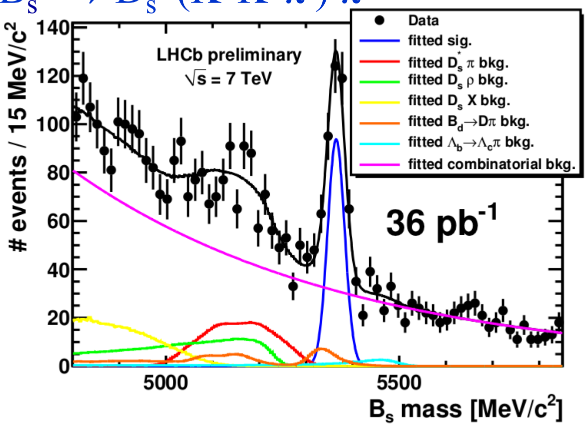


$B_s^0 \to D_s^- (K^* K^-) \pi^+$

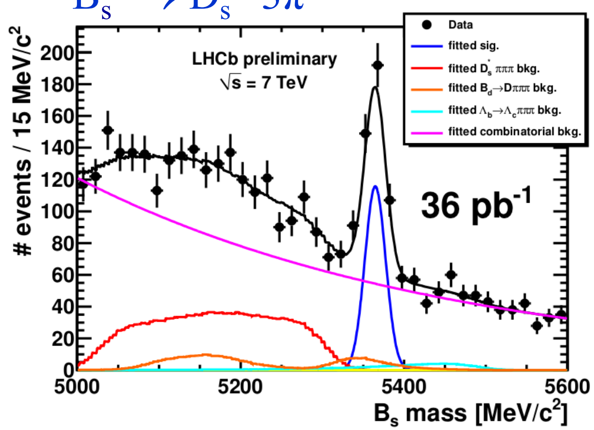


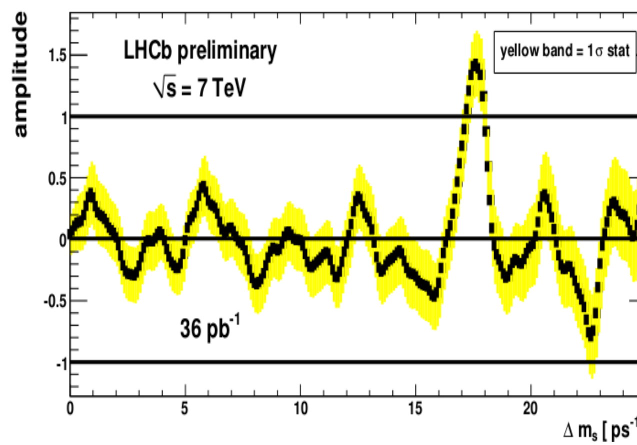


$B_s^0 \to D_s^- (K^+ K^- \pi^-) \pi^+$



$B_s^0 \to D_s^- \ 3\pi$





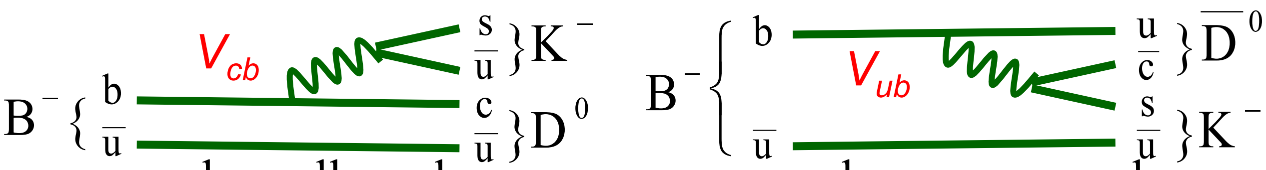
World average $\Delta m_s = (17.77 \pm 0.10 \pm 0.07)\ ps^{-1}$

$\Delta m_s = (17.63 \pm 0.11 \pm 0.04)\ ps^{-1}$

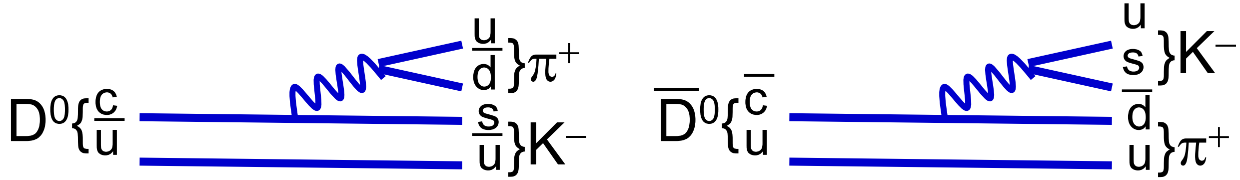
[LHCb-CONF-2011-020]

Prospects for γ in trees from $B^{\pm} \rightarrow DK^{\pm}$

- based on Gronau-London-Wyler & Atwood-Dunietz-Soni method
  [Phys. Lett. B270, 75 (1991) ; Phys. Rev. Lett. 78, 3257 (1997)]
- measure relative rates of $B^- \rightarrow D(K\pi)\, K^-$ and $B^+ \rightarrow D(K\pi)\, K^+$
  - ✓ two interfering tree B-diagrams, one colour-suppressed
  - ✓ two interfering tree D-diagrams, one Double Cabibbo-suppressed



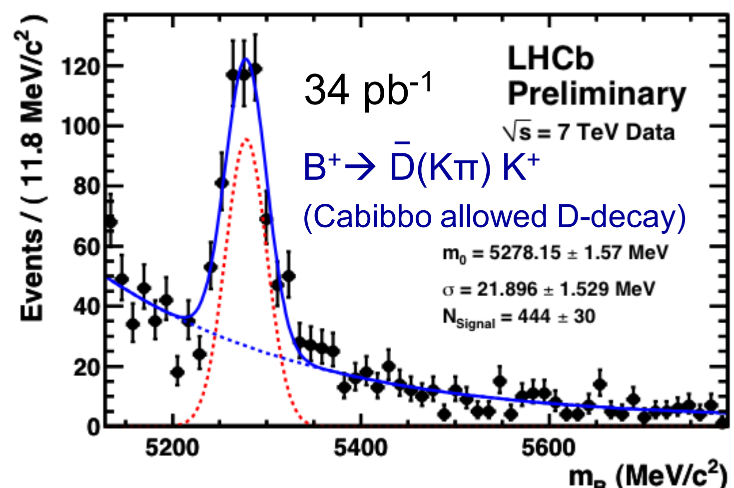
Weak phase diff.: γ
Magnitude ratio: r_B
Strong phase diff.: δ_B



Magnitude ratio: $r_D^{K\pi}$
Strong phase diff.: $\delta_D^{K\pi}$

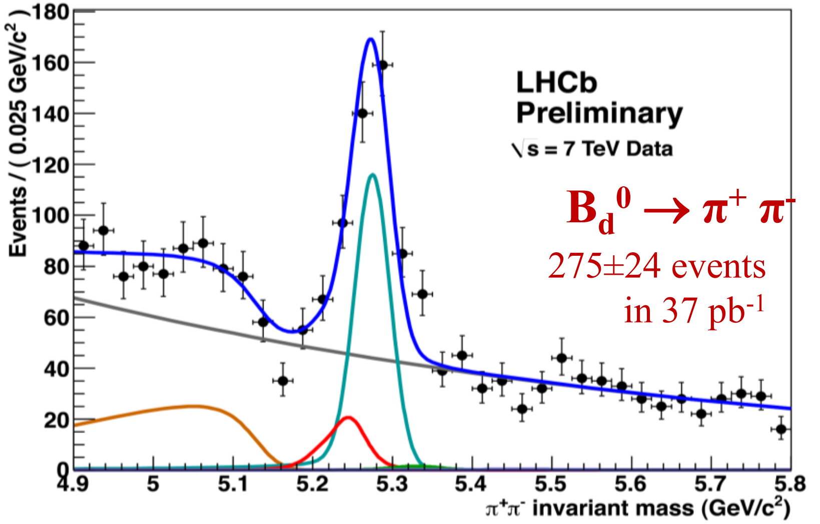
Add further D-decays:

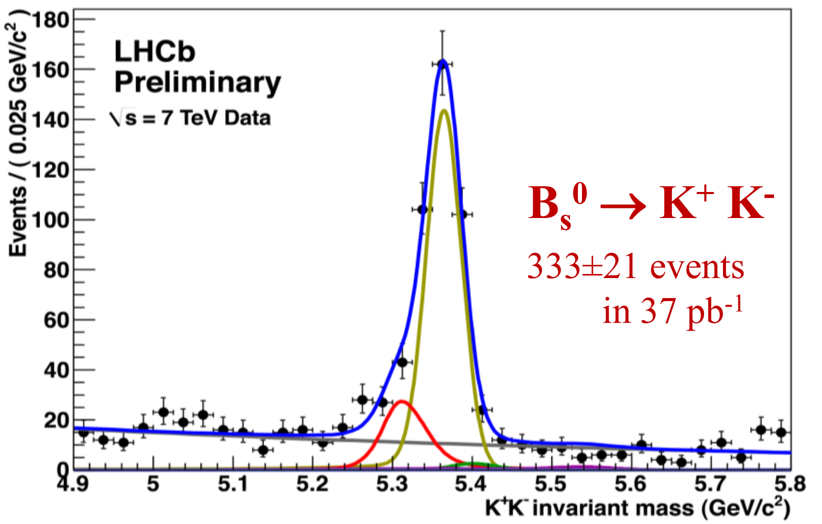
- $D \rightarrow K\pi\pi\pi$ (Cabibbo favoured + DCS decay)
- $D \rightarrow KK$ (CP eigenstate)



combine $B^+ \rightarrow DK^+$, $B^0 \rightarrow DK^{*0}$, $B_s \rightarrow D_s^{\pm} K^{\pm}$
→ σ(γ) ~ 5° with 2 fb^{-1} from 2011/2012 data

Prospects for γ in loops from $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$



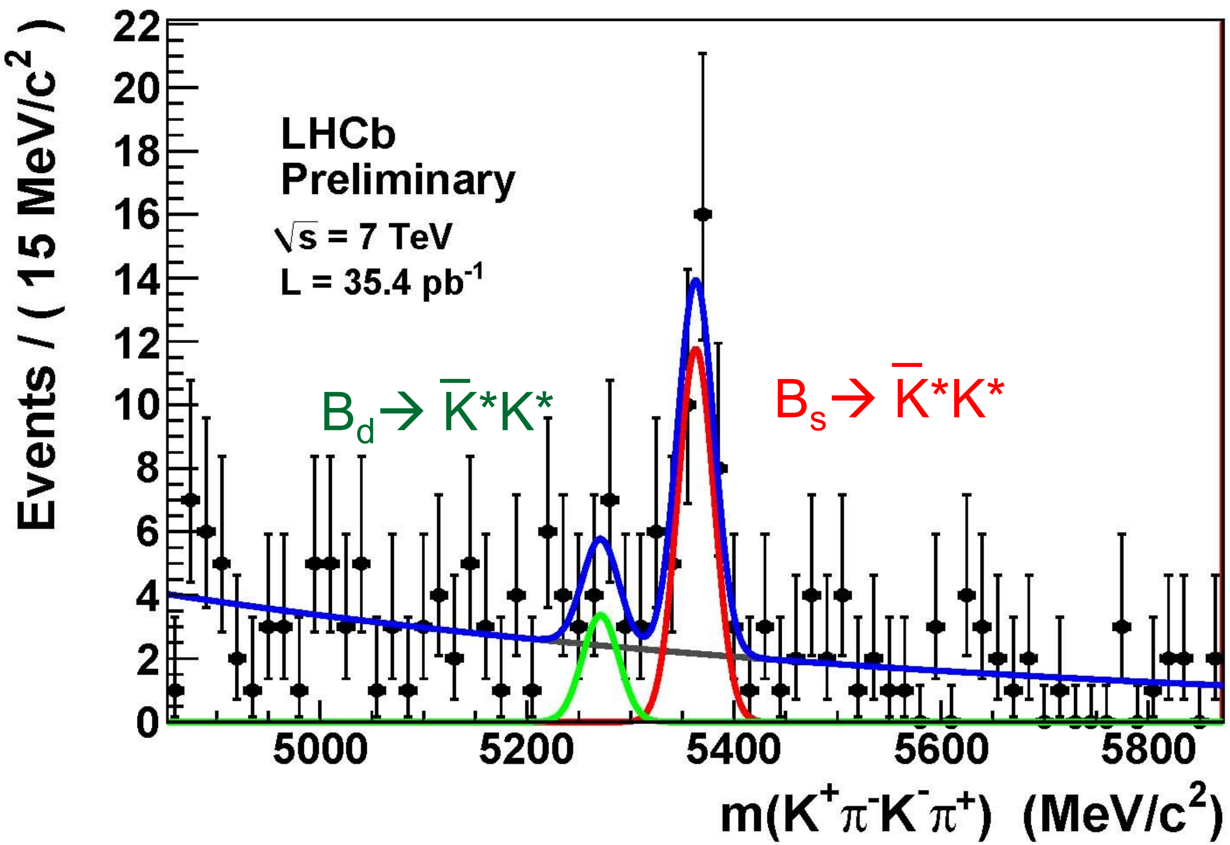


- measure time-dependent CP asymmetry for $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$
  - ✓ $A_{CP}(t) = A_{dir} \cos(\Delta mt) + A_{mix} \sin(\Delta mt)$
  - ✓ A_{dir} and A_{mix} depend on γ, mixing phases, and ratio of penguin to tree = $d\, e^{i\theta}$
- exploit "U-spin" symmetry (d↔s) [R.Fleischer, Phys.Lett. B459, 306 (1999)]
  - ✓ $d_{\pi\pi} = d_{KK}$ and $\theta_{\pi\pi} = \theta_{KK}$
  - ✓ 4 measurements and 3 unknowns, if mixing phases taken from $B^0 \to J/\psi K_S$ and $B_s \to J/\psi\phi$

Expected sensitivity for γ in loops → σ(γ) ~ 5° with 2 fb^{-1} from 2011/2012 data

First observation of $B_s \to \overline{K}^* K^*$

With increased statistics (also upgrade) measure time dependent CP asymmetries in penguin decays of $B_s \to \overline{K}^* K^*$ and $B_s \to \Phi\Phi$

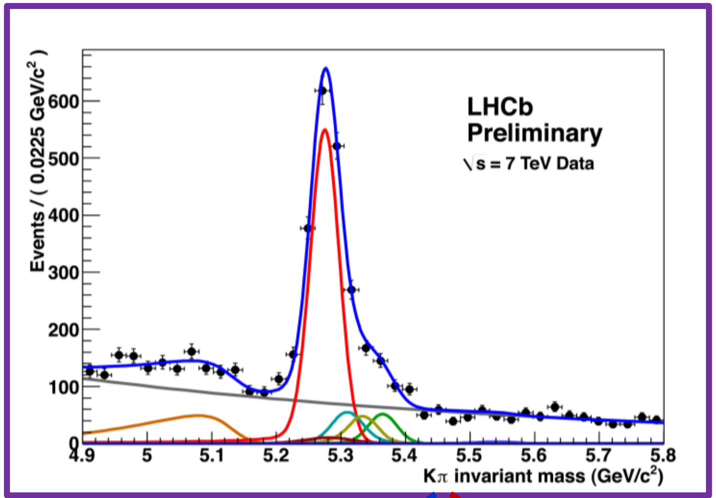


$$\mathcal{B}(B_s^0 \to K^{*0}\overline{K}^{*0}) = (1.95 \pm 0.47(\text{stat.}) \pm 0.51(\text{syst.}) \pm 0.29\,(f_d/f_s)) \times 10^{-5}$$

[LHCb-CONF-2011-019]

Direct CP violation in $B^0_{d,s} \rightarrow K\pi$

$B_d^0 \rightarrow K\pi$ &
$B_s^0 \rightarrow K\pi$



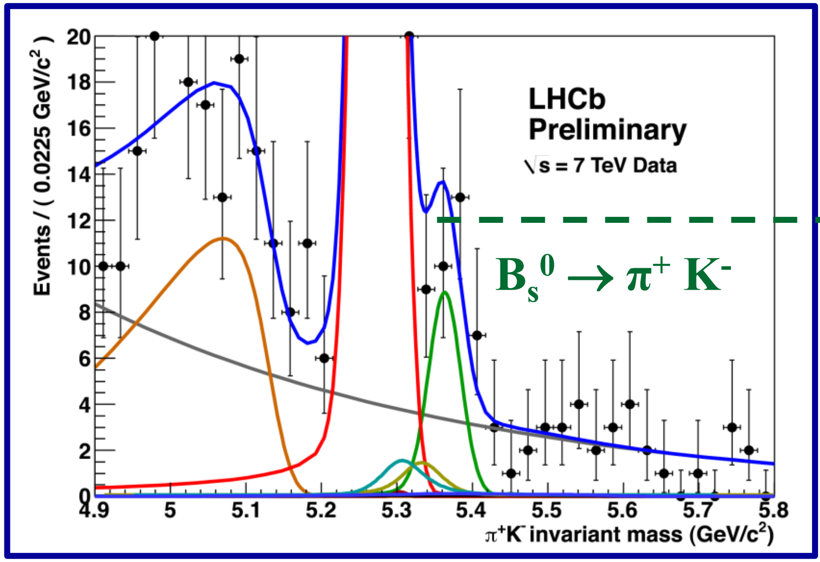
B_s^0/B_d^0 yield = (10.7±2.0)%,

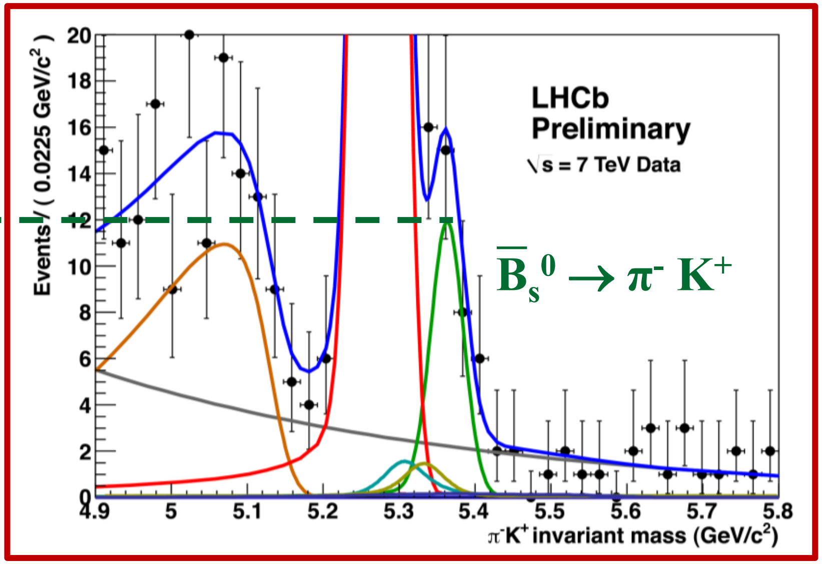
$A_{CP}(B_d^0) = (-7.4 \pm 3.3 \pm 0.8)\%$
[HFAG: (-9.8 ± 1.2)%]

$A_{CP}(B_s^0) = (15 \pm 19 \pm 2)\%$
[CDF: (39 ± 15 ± 8)% in 1 fb^{-1}]

[LHCb-CONF-2011-011]

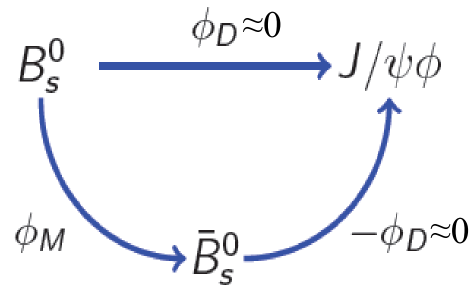
B^0 $\bar{B}^0$

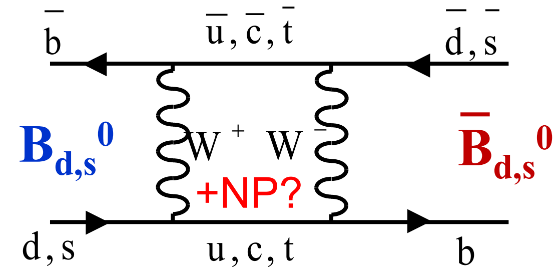




Mixing induced CP violation in $B_s \rightarrow J/\Psi\ \Phi$

- ✓ mixing phase very precisely known in Standard Model: $\phi_s = -2\beta_s = -0.0363 \pm 0.0017$
- ✓ sensitive to New Physics effects
- ➢ $\phi_s = \phi_s(SM) + \phi_s(NP)$



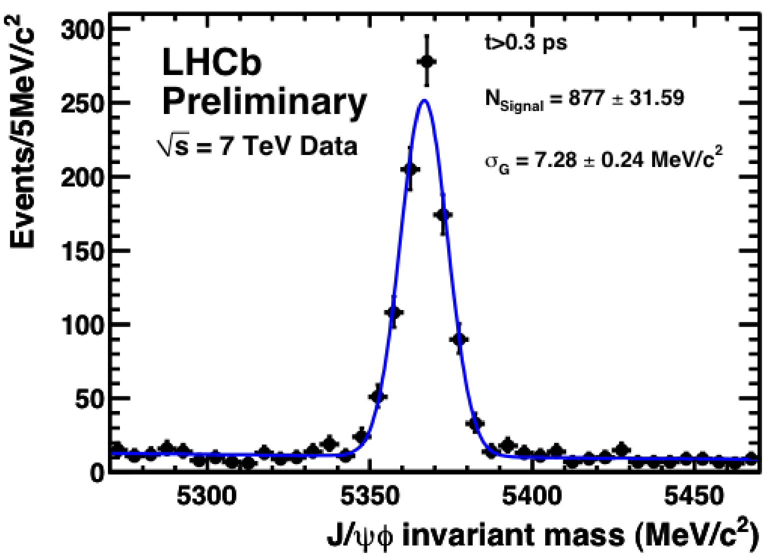


$$A_{CP}(t) = \frac{\Gamma[\overline{B}_s(t) \rightarrow f] - \Gamma[B_s(t) \rightarrow f]}{\Gamma[\overline{B}_s(t) \rightarrow f] + \Gamma[B_s(t) \rightarrow f]}$$

$$A_{CP}(t) = \frac{\eta_f sin\phi_s sin(\Delta m_s)t}{cosh(\Delta\Gamma_s t/2) - \eta_f cos\phi_s sinh(\Delta\Gamma_s t/2)}$$

$\eta_f = +, -1$ **CP eigenstates**

$B_s \rightarrow J/\psi\ \phi$: [LHCb-CONF-2011-002]

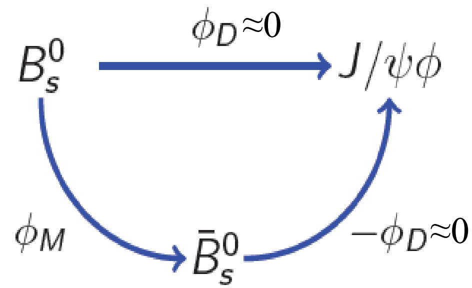


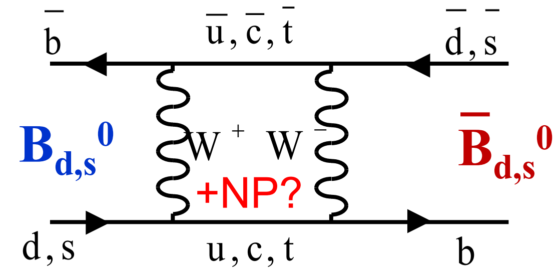
<u>$J/\psi\phi$ is not a pure CP eigenstate:</u>

- ✓ 2 CP even, 1 CP odd amplitudes contributing
- ✓ need to fit angular distributions of decay final states as function of proper time (external Δm_s)
- ✓ requires very good proper time resolution

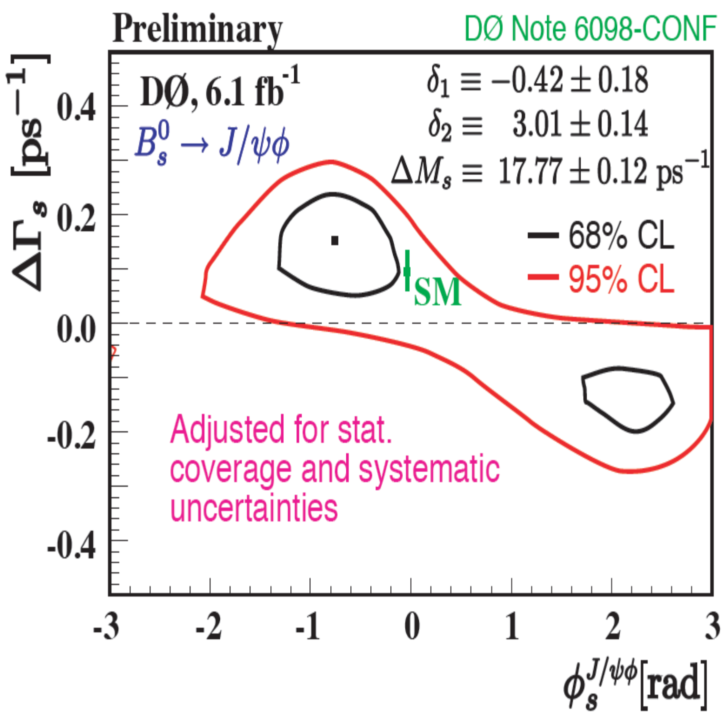
Mixing induced CP violation in $B_s \rightarrow J/\Psi\ \Phi$

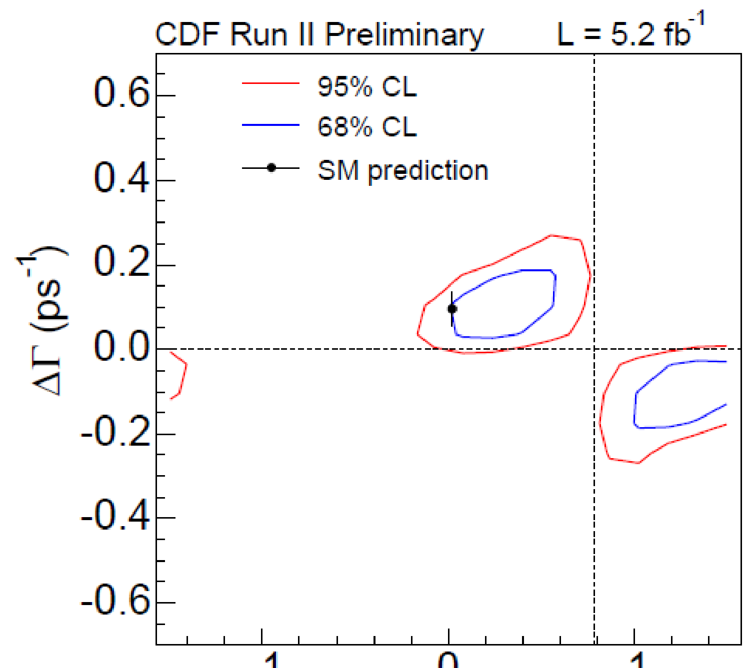
- ✓ mixing phase very precisely known in Standard Model: $\phi_s = -2\beta_s = -0.0363 \pm 0.0017$
- ✓ sensitive to New Physics effects
- ➢ $\phi_s = \phi_s(SM) + \phi_s(NP)$





Intriguing results by Tevatron



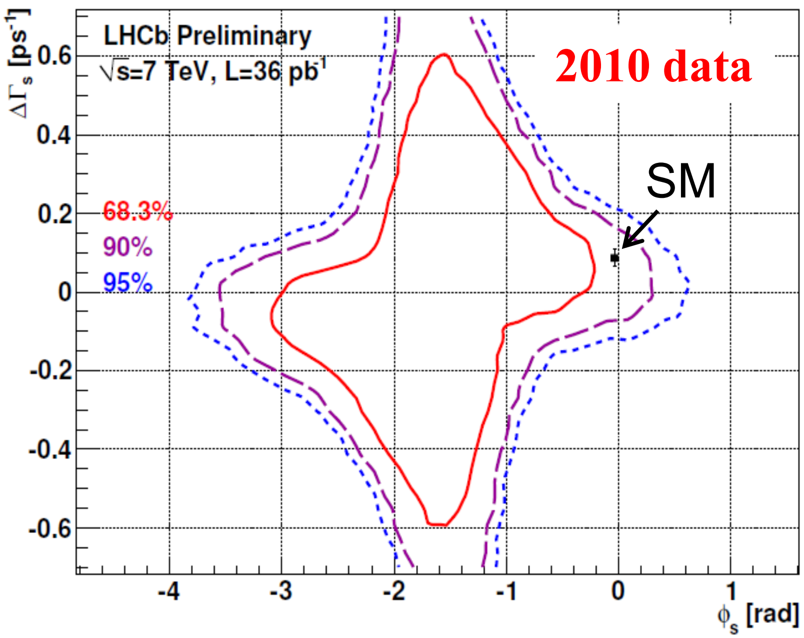


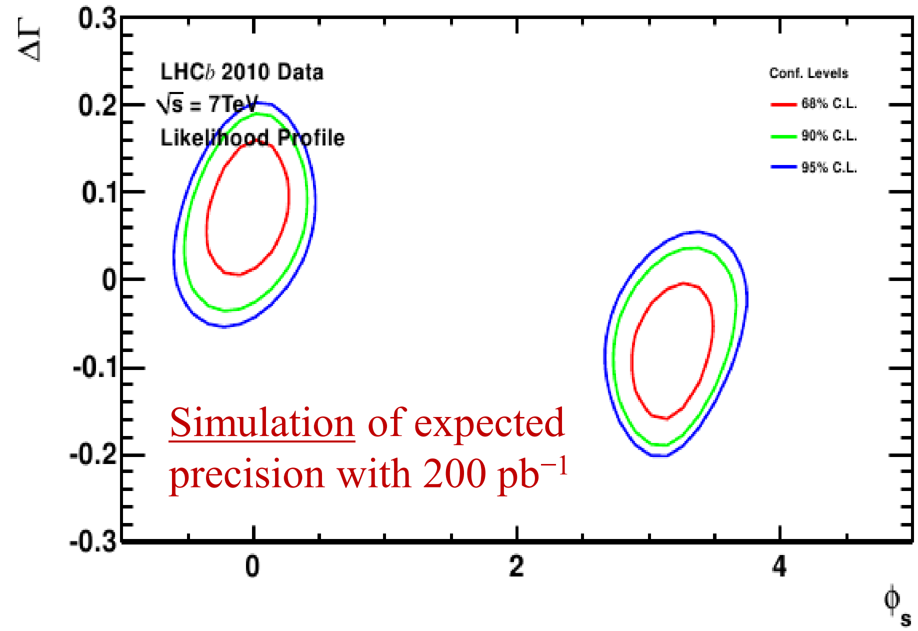
(note: $\phi_s = -2\beta_s$)

Mixing induced CP violation in $B_s \rightarrow J/\Psi\ \Phi$

[LHCb-CONF-2011-006]

$\phi_s \in [-2.7, -0.5]$ rad at 68% CL
$\phi_s \in [-3.5, 0.2]$ rad at 95% CL





- expect $\sigma(\Phi_s) \sim 0.2\text{-}0.3$ rad with 200 pb^{-1}

Further improvements expected with full 2011 data set:

- ✓ ~30 times larger sample than 2010
- ✓ improved 'opposite side tagging' (present $\varepsilon D^2 = 2.2 \pm 0.5\%$)
- ✓ including 'same-sign' kaon tagger

Mixing induced CP violation using other B_s decays

With more statistics (also in view of upgrade):

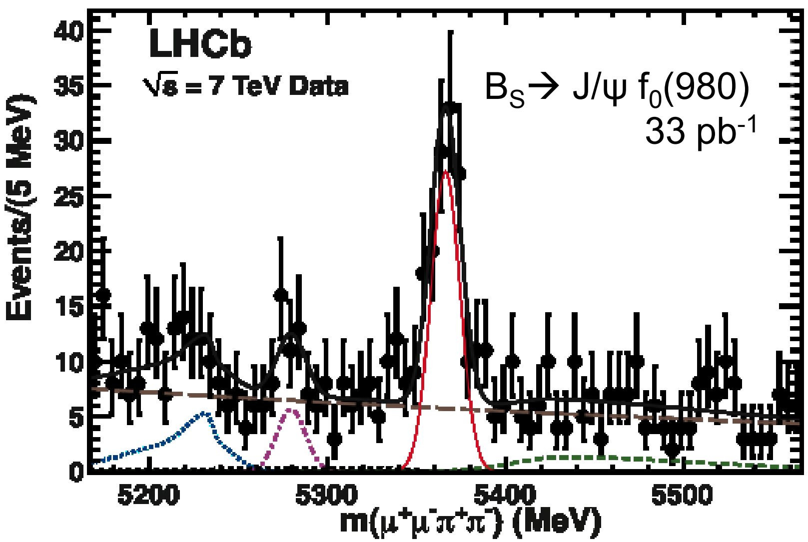
- add pure CP states: $B_s \to J/\psi\, f_0$ and $B_s \to D_s^+ D_s^-$ → no need for angular analysis
- reduce SM uncertainties due to (suppressed) penguin contribution by using $B_s \to J/\psi\, K^*$ and penguin-free $B_s \to D^0\, \Phi$ decays

  [S. Faller et al, Phys. Rev. D 709 (2009) 014005; K. De Bruyn et al, arXiv:1012.0840]

  [R. Fleischer, Nucl. Phys. B 659 (2003) 321]

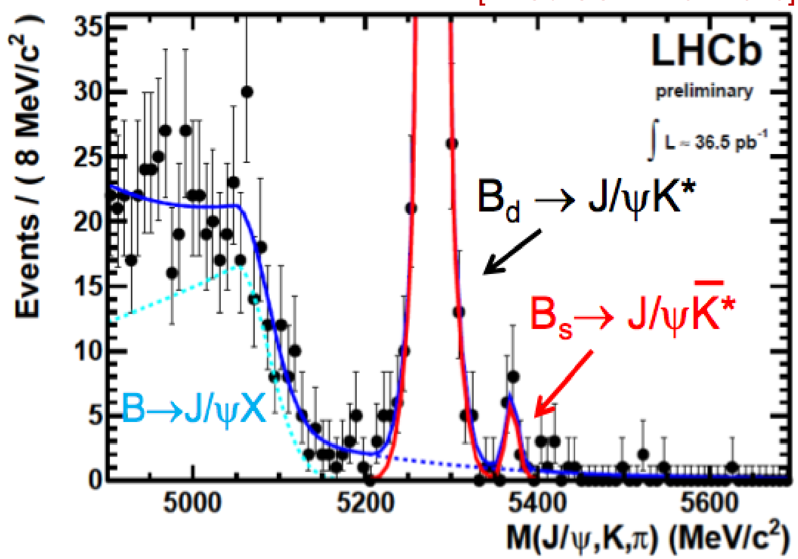
First observation of $B_s \to J/\psi\, f_0$

f_0 resonance: $|M(\pi^+\pi^-) - 980 \text{ MeV}| < 90$ MeV



First observation of $B_s \to J/\psi\, K^*$

[LHCb-CONF-2011-025]

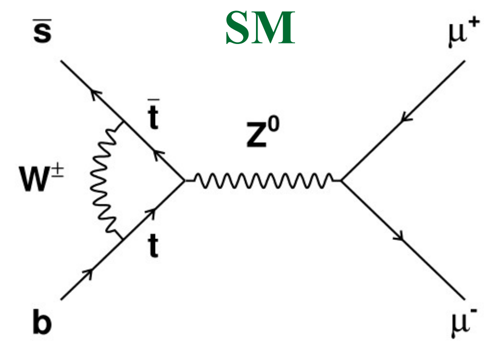


$$R_{f_0/\phi} \equiv \frac{\Gamma(B_s^0 \to J/\psi f_0,\ f_0 \to \pi^+\pi^-)}{\Gamma(B_s^0 \to J/\psi\phi,\ \phi \to K^+K^-)} = 0.252^{+0.046+0.027}_{-0.032-0.033}$$

[Phys.Lett.B 698 (2011) 115]

Very rare decays: search for $B_{d,s} \to \mu\,\mu$

$B_{d,s} \to \mu\mu$ the **super** rare loop decay



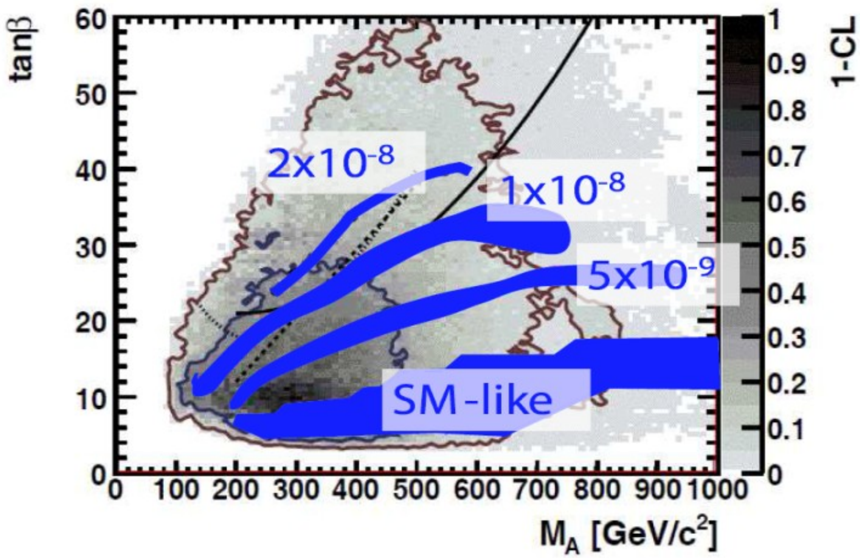
In Standard Model:

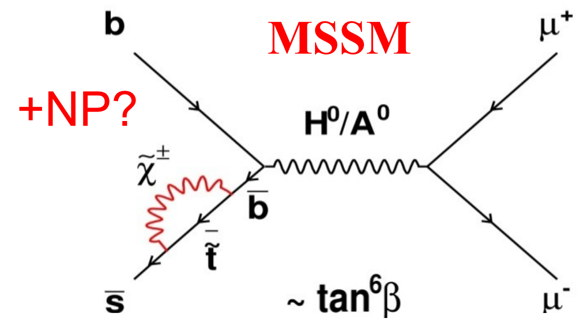
$B(B_d \to \mu\,\mu) = (0.10 \pm 0.01)\times 10^{-9}$

$B(B_s \to \mu\,\mu) = (3.2 \pm 0.2)\times 10^{-9}$

[A.J.Buras: arXiv:1012.1447]

- ✓ sensitive to New Physics, can be strongly enhanced in SUSY with scalar Higgs exchange
- ✓ sensitive probe for MSSM with large tanβ: $B(B_S \to \mu^+\mu^-) \sim \tan\beta^{\,6} / M_A^{\,4}$





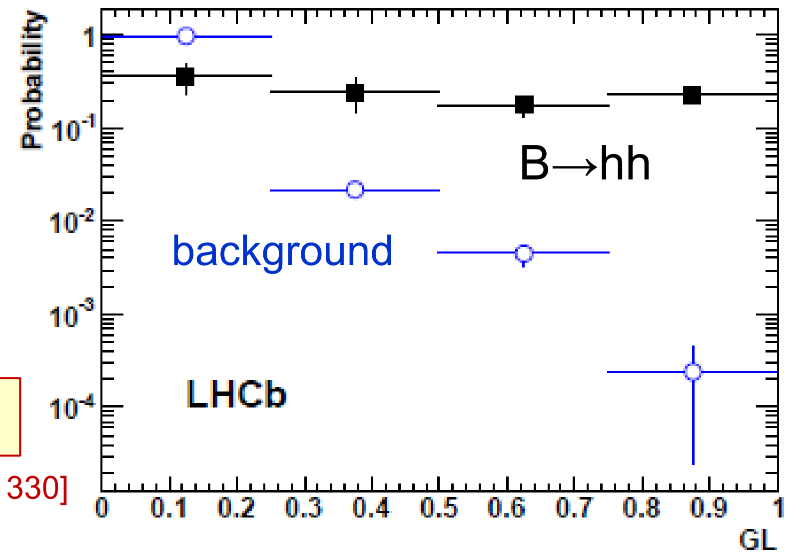
➢ entering interesting regime with limits of $B(B_s \to \mu\,\mu) < 10^{-8}$

Very rare decays: search for $B_{d,s} \to \mu\mu$

LHCb:

- ✓ form geometrical likelihood (GL) out of discriminant variables
- ✓ look for enhancement in GL vs $m_{\mu\mu}$ space
  - ➢ data driven analysis
  - ➢ $B \to hh$ sample particularly valuable given its identical topology to signal mode

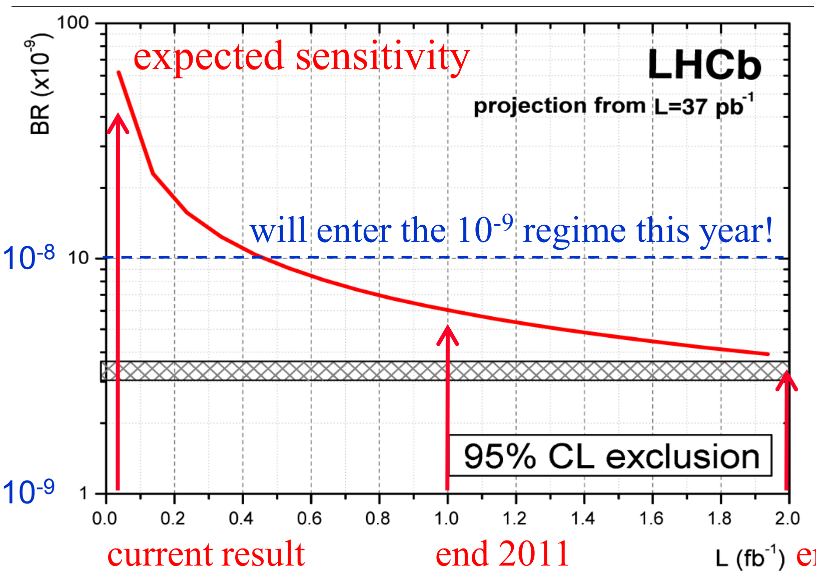
$\mathcal{B}(B_s\to\mu\mu) < 5.6\times10^{-8}$; $\mathcal{B}(B_d\to\mu\mu)<1.5\times10^{-8}$ (95% CL)

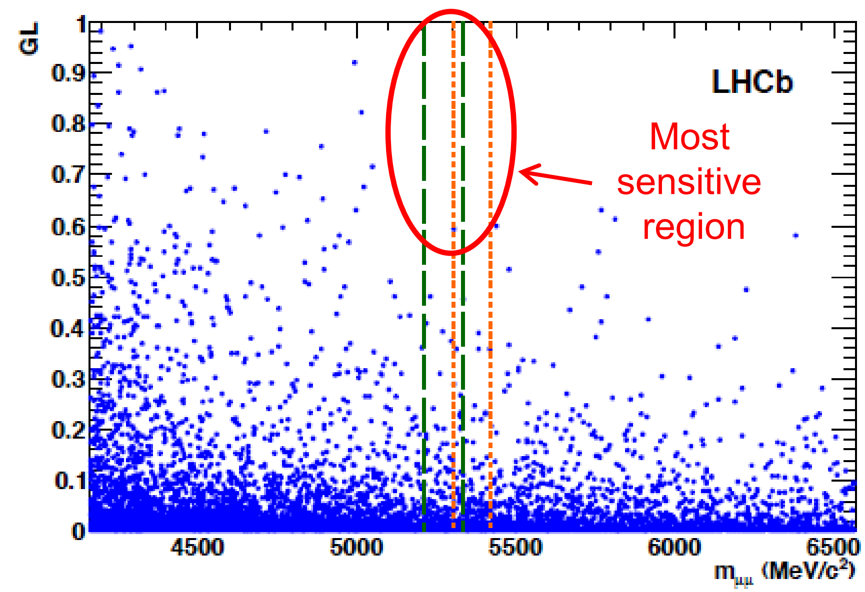


[Phys.Lett.B 699 (2011) 330]

CDF BR($B_s\to\mu\mu$) < 4.3×10^{-8} at 95% CL, with 3.7 fb^{-1}

D0 BR($B_s\to\mu\mu$) < 5.1×10^{-8} at 95% CL, with 6.1 fb^{-1}



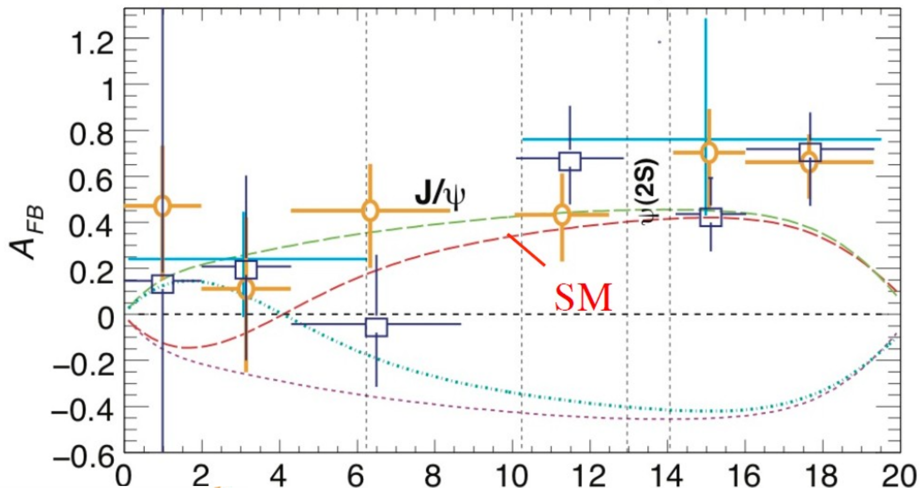


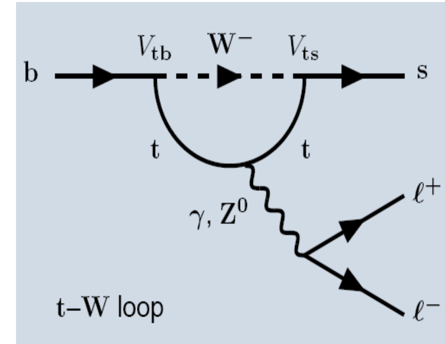
Rare decays: prospects for $B^0 \to K^{*0}\mu^+\mu^-$

$250\ K^*l^+l^-$
80% of data

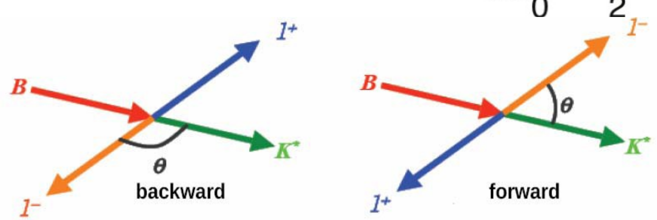
$100\ K^*l^+l^-$
75% of data

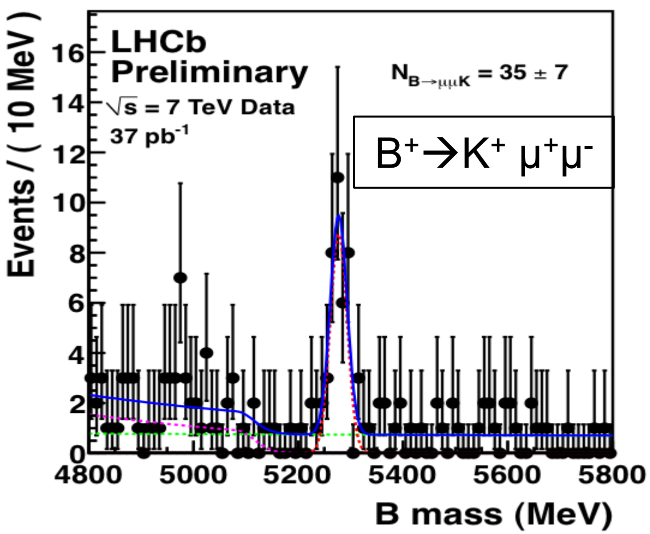
$100\ K^*\mu^+\mu^-$
$4.4\ fb^{-1}$





$$A_{FB}\left(s = m^2_{\mu^+\mu^-}\right) = \frac{N_F - N_B}{N_F + N_B}$$



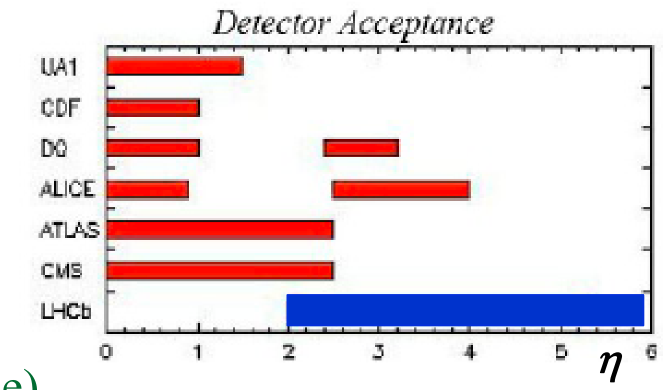


- suppressed decays (ΔB=1 FCNC), SM BR ~ 10^{-6}
- forward-backward asymmetry $A_{FB}(s)$ in the μμ rest-frame is a sensitive probe of New Physics
  [A.Ali et al., Phys. Lett. B273,505 (1991)]
- zero point can be predicted at LO with no hadronic uncertainties, known at 5% level in SM, sensitive to NP via non-standard values of Wilson coefficients

with 1 fb^{-1} LHCb expects ~1000 events

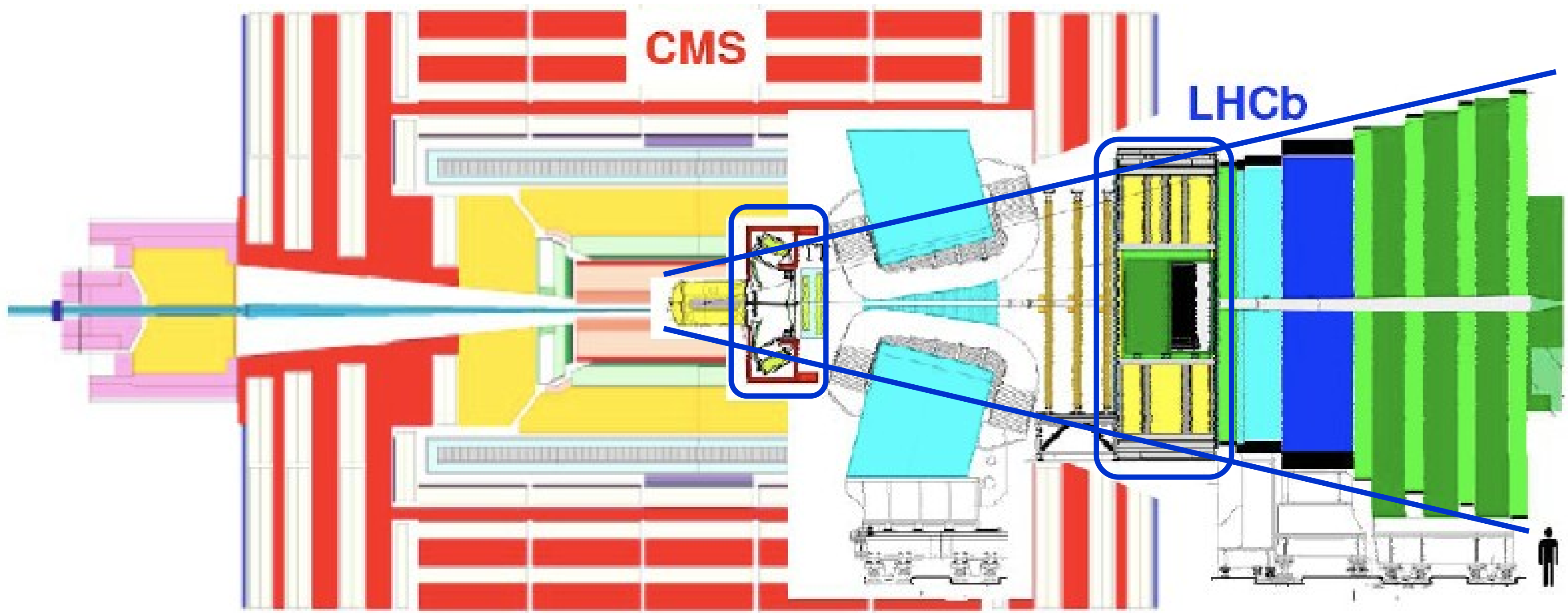
- zero crossing point in SM: $s_0 = (4.36{+}0.36{-}0.33)\ GeV^2$
- measure s_0 to 0.4 GeV^2 in 2-3 years

LHCb as a "General Purpose Detector"

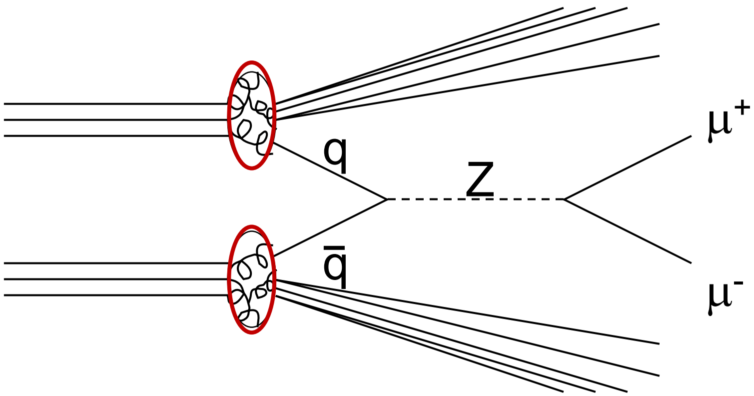


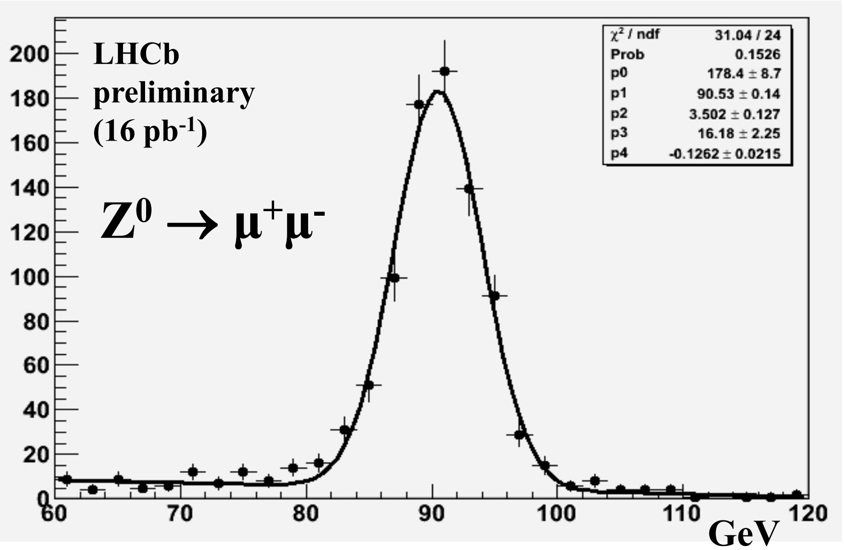
Specific feature of LHCb:

- ✓ particle detection in the forward region (down to beam-pipe)
- ✓ particle identification capability in particular for hadrons due to RICH detector
- ✓ precise vertexing

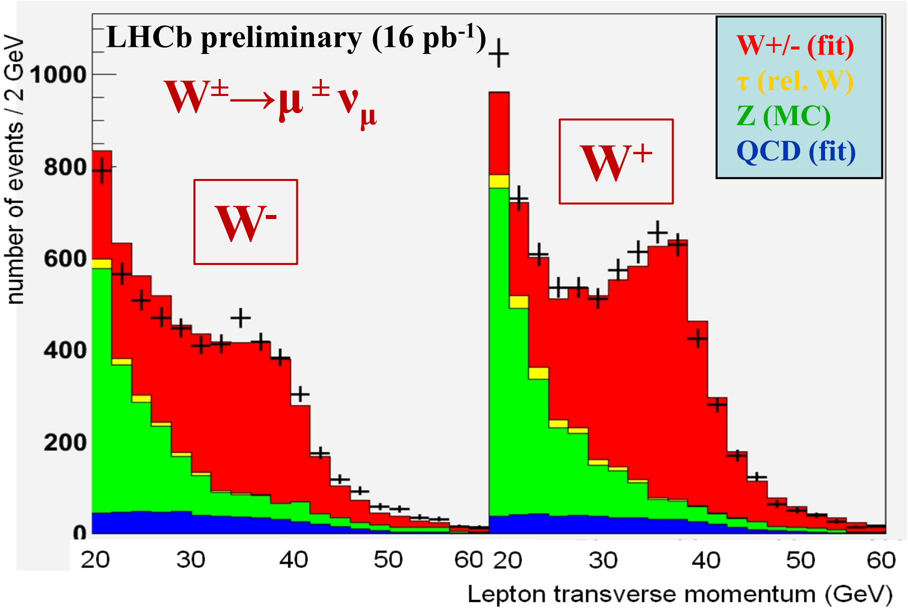


Production of Z and W in forward direction





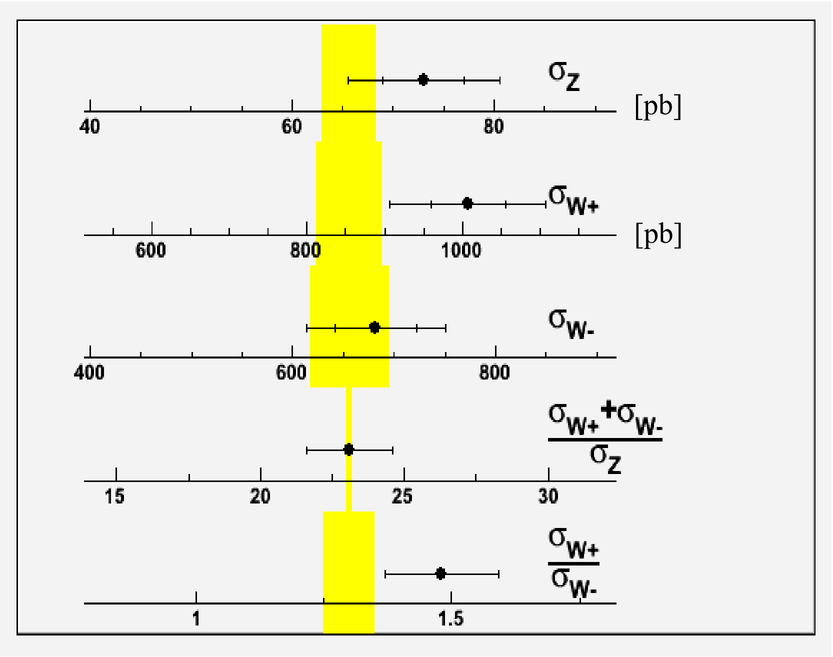
➢ provides information on the Parton Distribution Functions



Production of Z and W in forward direction

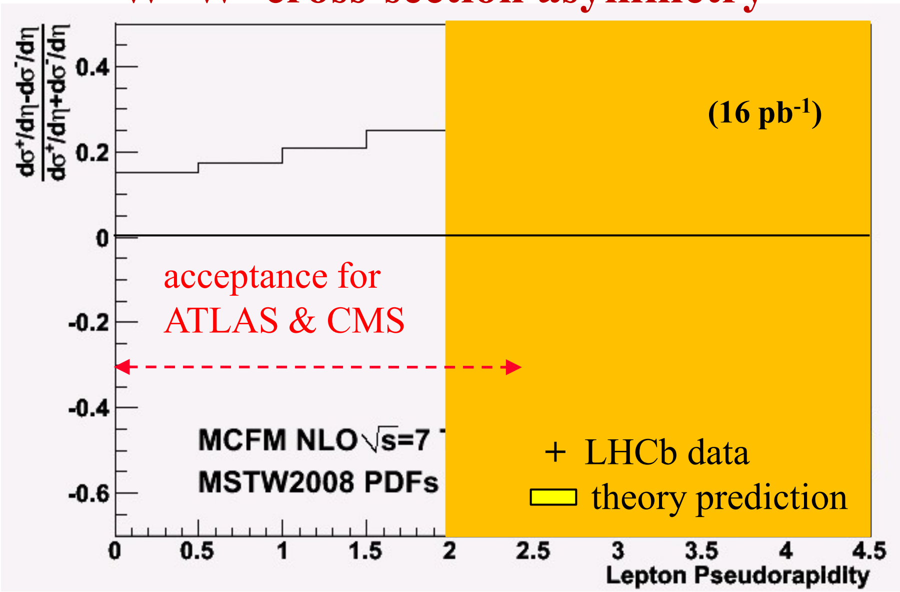
[LHCb-CONF-2011-012]

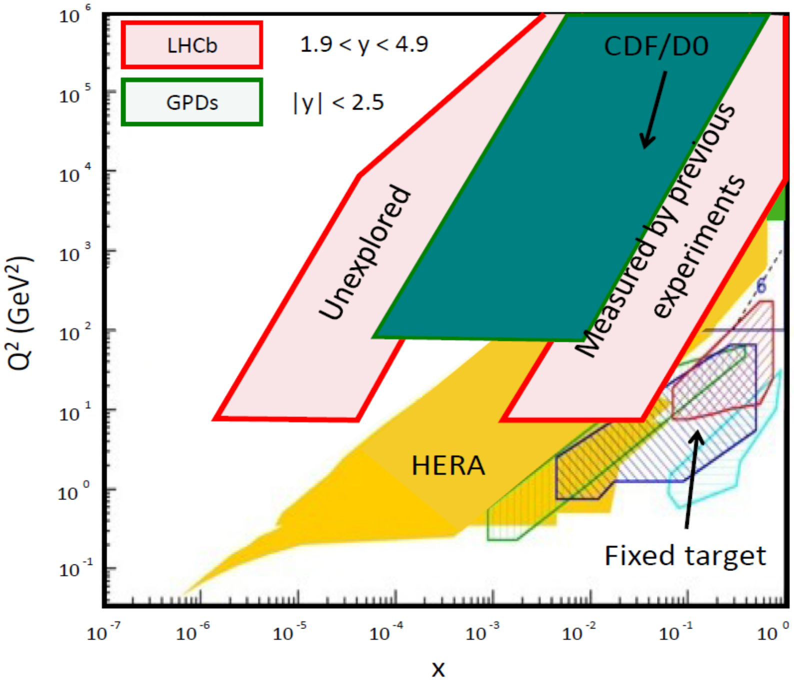
production cross-section σ



W/Z ratios test SM at 6%

W^+W^- cross-section asymmetry

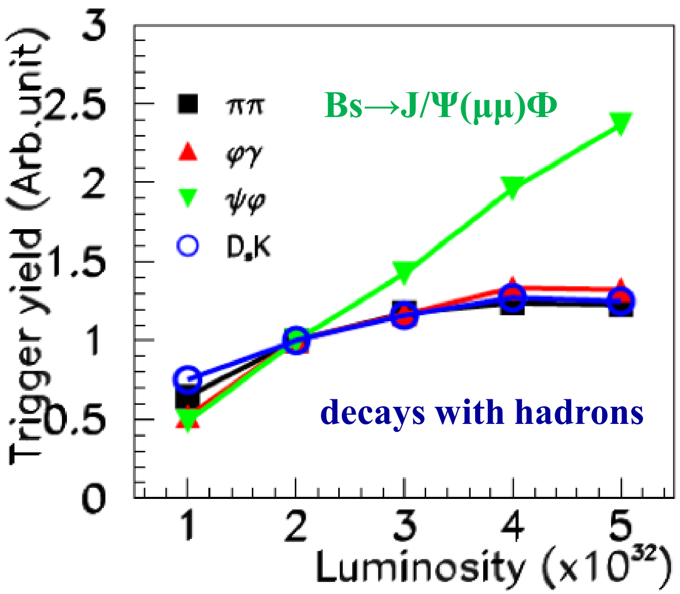




Outlook: Upgrade LHCb to 40MHz readout

Limitations of current detector:

yields for hadron decays saturate at luminosities above ~$3\cdot10^{32}$ since p_T cuts at L0 trigger must be raised to stay within 1 MHz R/O limit



Baseline for LHCb upgrade:

- ✓ increase luminosity to $\mathcal{L} \geq 10^{33}$ cm^{-2} s^{-1}
- ✓ upgrade readout electronics and DAQ architecture to 40 MHz to full software trigger
- ✓ increase signal yields by factor ~5 for muonic and ~7 for hadronic channels

→ collect 5 fb^{-1} per year with much increased efficiency for hadronic final states

Submitted upgrade LOI to LHCC beginning of March: [CERN-LHCC-2011-001]

- ➔ physics case well received!
- ➔ 40 MHz architecture under review at present
- ➔ aim: produce TDRs in time for installing the detectors & electronics in 2018 (LS2)

LHCb sensitivities to key channels

[CERN-LHCC-2011-001]

Type	Observable	Current precision	LHCb (5 fb^{-1})	upgrade (50 fb^{-1})	Theory uncertainty
Gluonic penguin	$S(B_s \to \phi\phi)$	-	0.08	0.02	0.02
	$S(B_s \to K^{*0}\bar{K}^{*0})$	-	0.07	0.02	< 0.02
	$S(B^0 \to \phi K^0_S)$	0.17	0.15	0.03	0.02
B_s mixing	$2\beta_s\ (B_s \to J/\psi\phi)$	0.35	0.019	0.006	~ 0.003
Right-handed currents	$S(B_s \to \phi\gamma)$	-	0.07	0.02	< 0.01
	$\mathcal{A}^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	-	0.14	0.03	0.02
E/W penguin	$A_T^{(2)}(B^0 \to K^{*0}\mu^+\mu^-)$	-	0.14	0.04	0.05
	$s_0\ A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	-	4%	1%	7%
Higgs penguin	$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	30%	8%	$< 10\%$
	$\frac{\mathcal{B}(B^0\to\mu^+\mu^-)}{\mathcal{B}(B_s\to\mu^+\mu^-)}$	-	-	$\sim 35\%$	$\sim 5\%$
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim 20^\circ$	$\sim 4^\circ$	0.9°	negligible
	$\gamma\ (B_s \to D_s K)$	-	$\sim 7^\circ$	1.5°	negligible
	$\beta\ (B^0 \to J/\psi\, K^0)$	1°	0.5°	0.2°	negligible
Charm CPV	A_Γ	2.5×10^{-3}	2×10^{-4}	4×10^{-5}	-
	$A_{CP}^{dir}(KK) - A_{CP}^{dir}(\pi\pi)$	4.3×10^{-3}	4×10^{-4}	8×10^{-5}	-

Summary & Conclusion

- LHCb has demonstrated with its 2010 data
  - ✓ excellent detector performance
  - ✓ ability to work in a hadronic environment very efficiently
  - ✓ competitive physics results with B-factories and Tevatron
- LHCb perspectives for 2011
  - ✓ collect 1 fb^{-1} by end of the year
  - ✓ produce world-class measurements in CP violation (e.g. Φ_s) and rare decays (e.g. $B_s \to \mu\mu$) already by summer this year
  - ✓ search for New Physics with unprecedented precision, in particular in the B_s system
- LHCb outlook
  - ✓ collect ~5 fb^{-1} by 2018
  - ✓ upgrade detector to accumulate 5 fb^{-1}/year with flexible software trigger

➔ exciting times ahead of us!

LHCb related talks at this conference

Plenary

- B decays, CKM, spectroscopy B and Charm at LHCb - Marta Calvi
- Onia results from LHC - Giulia Manca

Parallel session on B, Charm and Onia

- Search for New Physics with rare decays of B and B_s mesons at LHCb - Johannes Albrecht
- Mixing and CP violation in the B_s system at LHCb - Greig Cowan
- CP-violation measurements and prospects with hadronic B decays at LHCb - Lars Eklund
- CP-violation studies with charm decays at LHCb - Vladimir Gligorov

Parallel session on EW and QCD

- Studies of electroweak boson production in the forward region with LHCb - Stephen Farry

Parallel session on hard QCD and diffraction

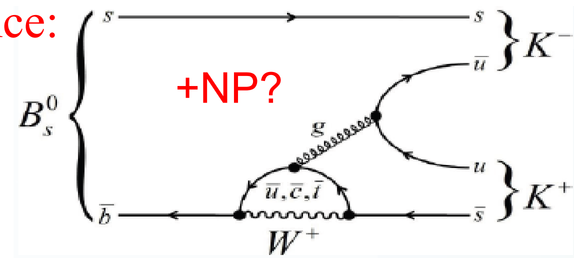
- Exclusive dimuon measurements with LHCb - Valentin Niess

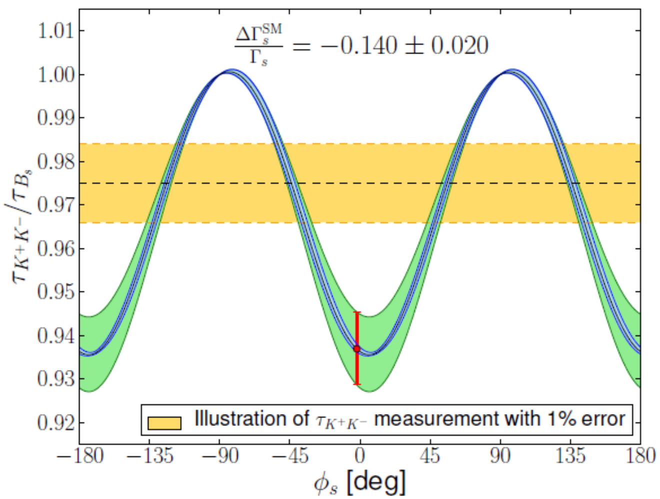
And: many LHCb posters !!!

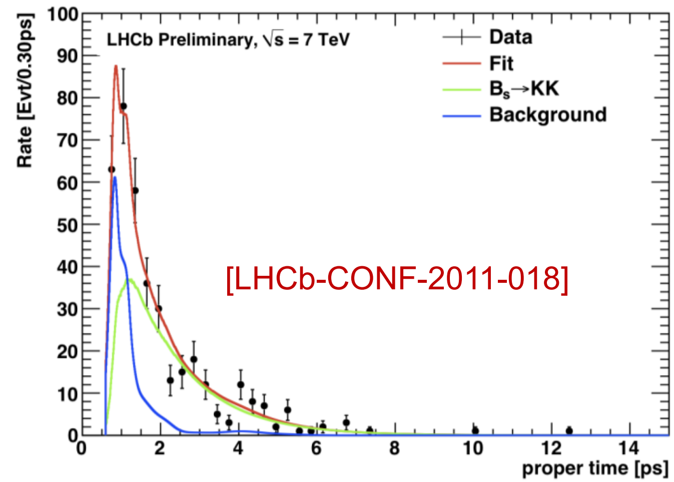
Back-up slides

Lifetime measurement of $B_s \to K^+K^-$

- effective lifetime of $B_s^0 \to K^+ K^-$ decay dominated by penguin diagram
- can receive important NP contributions affecting lifetime difference:
  $\Delta\Gamma s = \Gamma_L - \Gamma_H \cong \Delta\Gamma_s^{SM} \cdot \cos(\Phi^{NP})$
- in the SM: $\tau_{K+K-}(SM) = 1.390 \pm 0.032$ ps
  [R. Fleischer, R. Knegjens, arXiv:hep-ph/1011.1096]







Fitting the decay rate with a single exponential an effective lifetime is measured:

$$\tau_{KK}^{-1} = \frac{R_L/\Gamma_L + R_H/\Gamma_H}{R_L/\Gamma_L^2 + R_H/\Gamma_H^2}$$

with R_L, R_H: fraction of L, H states in the $B_s^0 \to K^+ K^-$ decay, mainly light

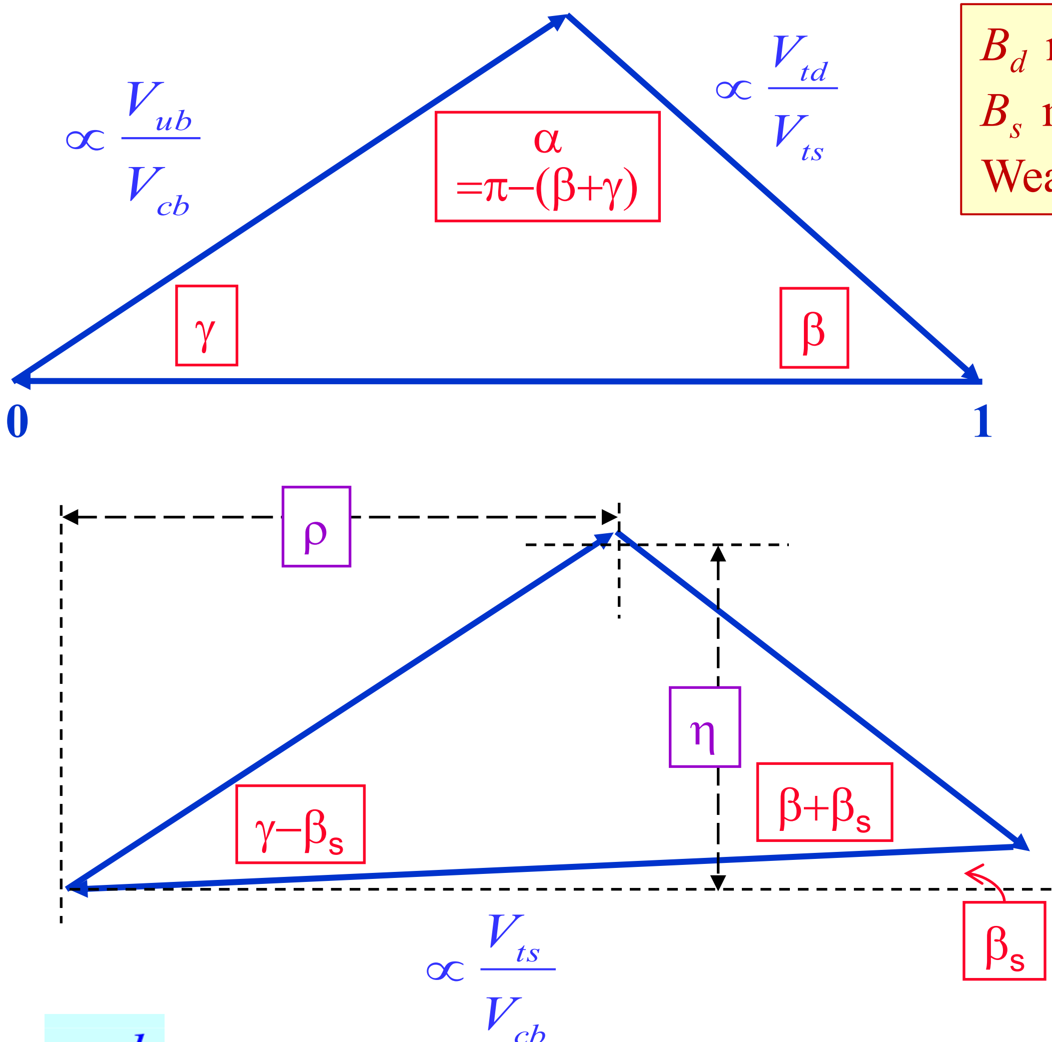
CDF:
$\tau_{K+K-} = 1.53 \pm 0.18 \pm 0.02$ ps

Most precise measurement by LHCb with 37 pb^{-1}:
$\tau(B_s^0 \to K^+K^-) = 1.440 \pm 0.096(stat) \pm 0.010(syst)$ ps

- interesting NP constraints will come with 2011 data!

CKM Unitarity Triangles

Two non-degenerated (normalized) CKM Unitarity Triangles



B_d mixing phase: $\phi_d = 2\beta = -\arg(V_{td}^2)$

B_s mixing phase: $\phi_s = -2\beta_s = -\arg(V_{ts}^2)$

Weak decay phase: $\gamma = -\arg(V_{ub})$

Extract angles from decay channels:

β	$B_d \to J/\psi\, K_S$
β_s	$B_s \to J/\psi\, \Phi$
γ (loop)	$B_d \to \pi\pi$, $B_s \to KK$
γ (tree)	$B_{u,d} \to D\, K$
γ (tree)-$2\beta_s$	$B_s \to D_s K$
$\gamma+2\beta$	$B_d \to D^* \pi$
α	$B_d \to \pi\pi, \rho\pi, \rho\rho$

β_s is very small in Standard Model

Mixing induced CP violation using other B_s decays

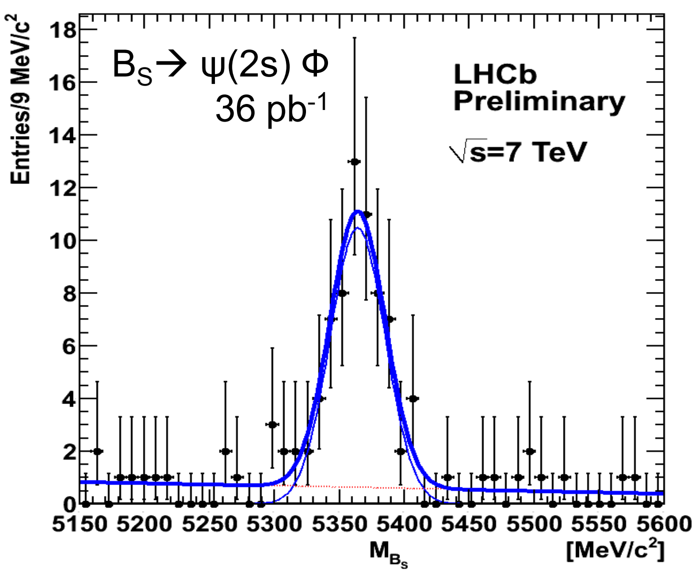
With more statistics (also in view of upgrade):

- add pure CP states: $B_s \to J/\psi\, f_0$ and $B_s \to D_s^+ D_s^-$ → no need for angular analysis
- reduce SM uncertainties due to (suppressed) penguin contribution by using $B_s \to J/\psi\, K^*$ and penguin-free $B_s \to D^0\, \Phi$ decays

  [S. Faller et al, Phys. Rev. D 709 (2009) 014005; K. De Bruyn et al, arXiv:1012.0840]

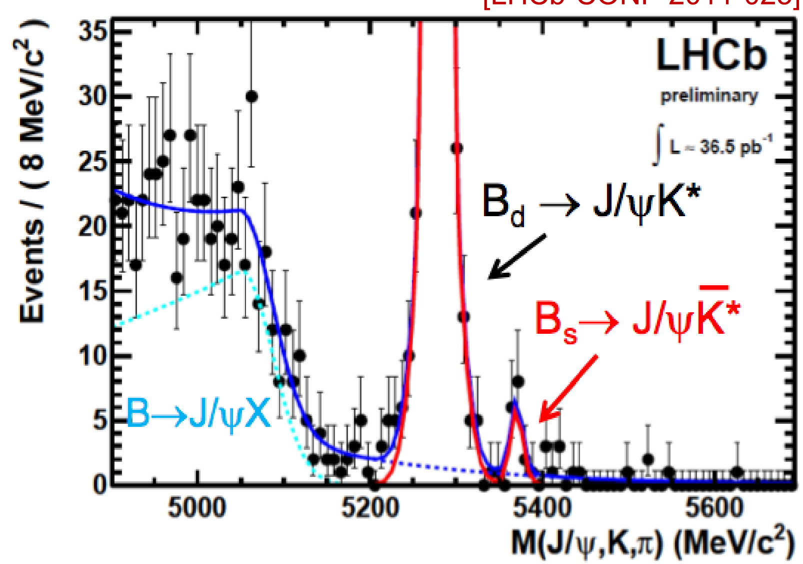
  [R. Fleischer, Nucl. Phys. B 659 (2003) 321]

First observation of $B_s \to \psi(2s)\, \Phi$



First observation of $B_s \to J/\psi\, K^*$

[LHCb-CONF-2011-025]



$$\frac{\mathcal{B}(B_s^0 \to \psi(2S)\phi)}{\mathcal{B}(B_s^0 \to J/\psi\,\phi)} = 0.68 \pm 0.10(\mathrm{stat}) \pm 0.09(\mathrm{syst}) \pm 0.07(\mathcal{B})$$

[LHCb-CONF-2011-014]