The LHCb Experiment

Highlights of physics impact

&

upgrade plans

Joint Quark and Lepton Session
Snowmass-on-the-Mississippi
July 31, 2013

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Outline

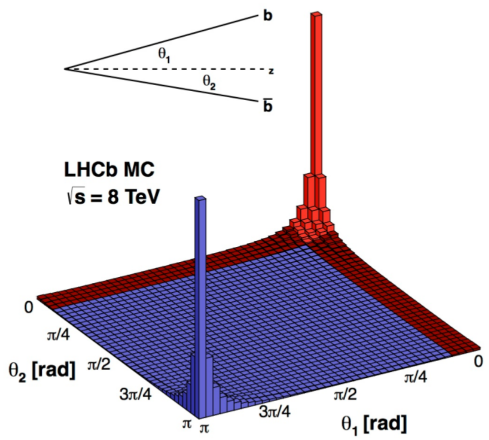
- LHCb detector
- Highlights of recent physics results & Their impact
- LHCb Upgrade

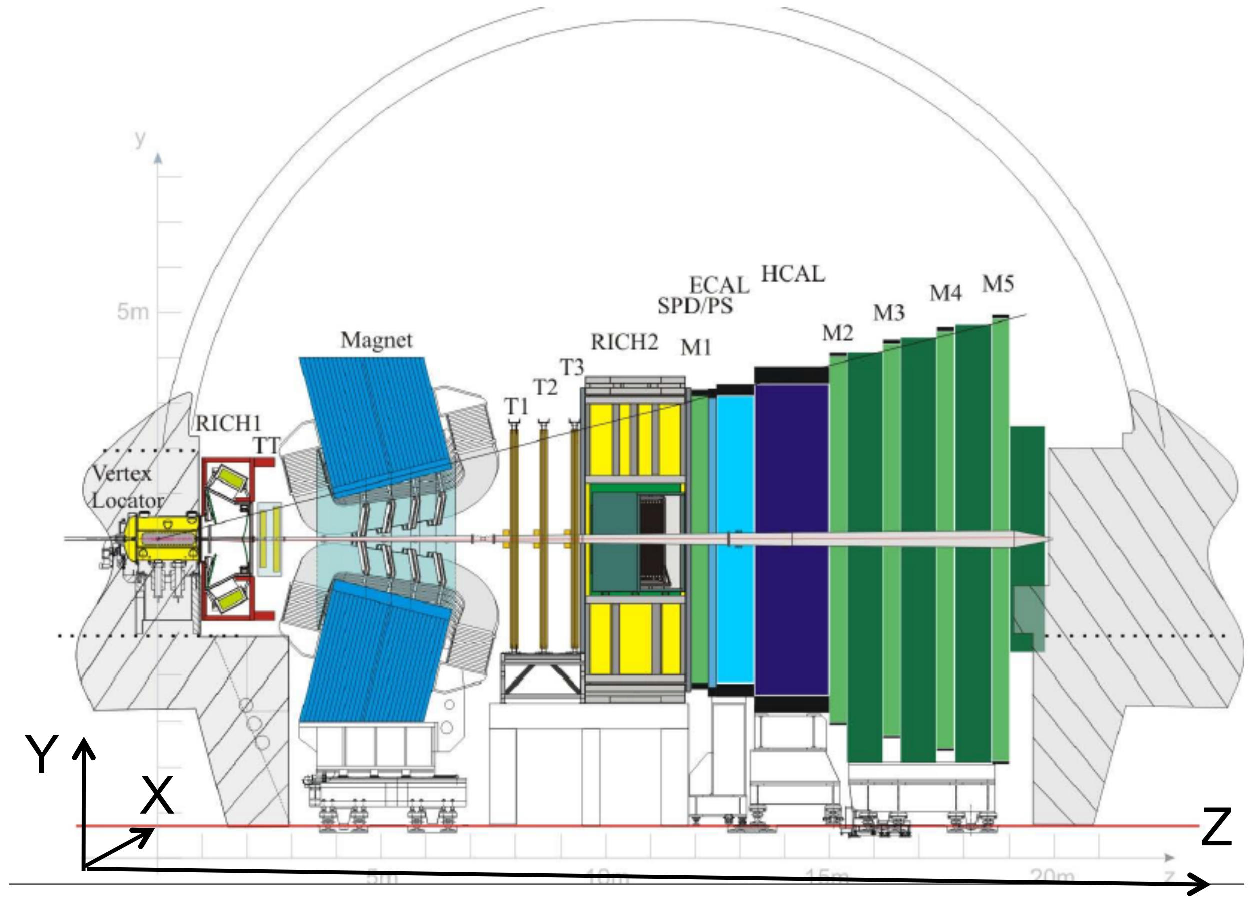
The LHCb Detector

A Single Arm Spectrometer at LHC
Acceptance: $2 < \eta < 5$

σ_{inel}~70-80 mb
σ_{cc}~6 mb (7 TeV)
σ_{τ}~80 μb (7 TeV)
σ_{bb}~280 μb (7 TeV)
σ_{bb}~500 μb (14 TeV)

$b\bar{b}$ peaked forward or backward with ~25% in detector acceptance





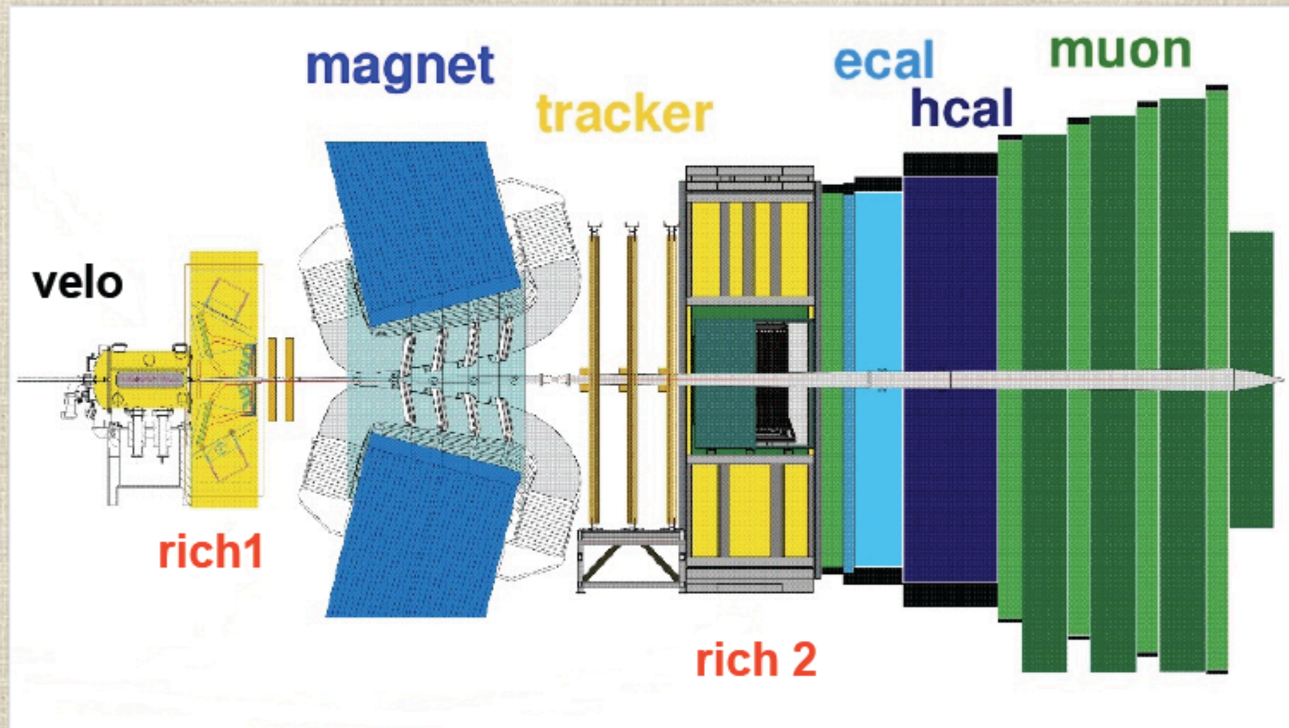
Access to all species of B hadrons

The LHCb detector

Brasil, China, France, Germany, Ireland, Italy, Netherlands, Pakistan, Poland, Romania, Russia, Spain, Switzerland, UK, Ukraine, US*, CERN

60 institutes, ~ 750 members

74 papers
>100 conf. contr.



VELO: 21 (R+φ) silicon stations
- Movable:7mm when stable beams

RICH1: C_4F_{10} + AEROGEL
- π/K separation for 2<p<60 GeV

Tracking: Si + straw tubes + 4Tm
- $\delta p/p$=0.45%

RICH2: CF_4
- π/K separation for 20<p<100 GeV

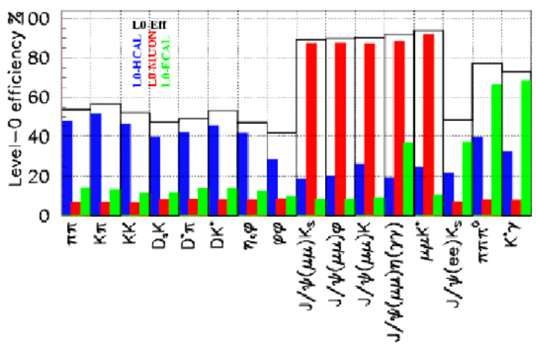
CALO:
- ECAL: lead+scintillating tiles
- HCAL: iron+scintillation tiles

MUON MWPC+GEM: π/μ separation

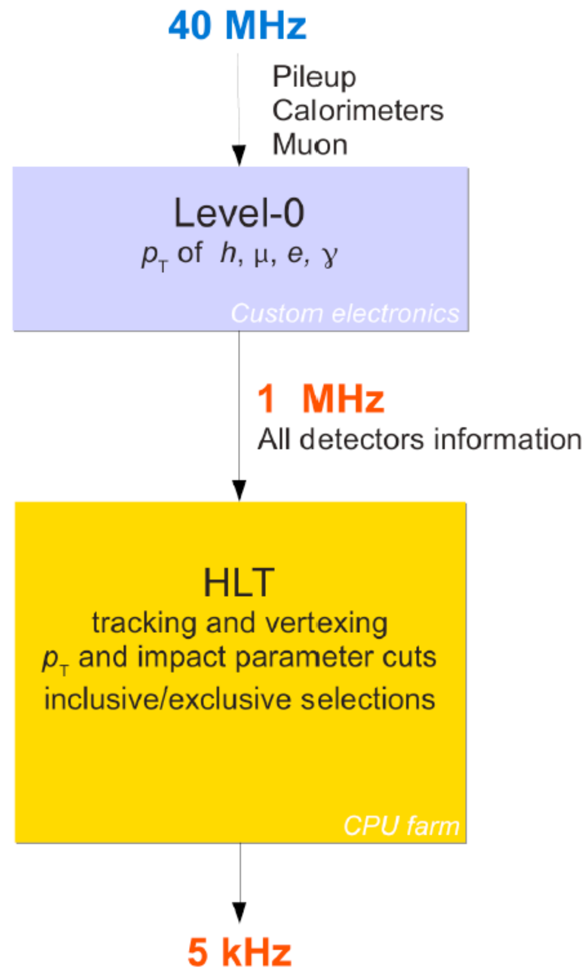
US Participation: Syracuse(since:2005); Cincinnati, Maryland & MIT (since 2012)

Trigger

- L0 Hardware trigger:
  - Require High Pt μ, e, γ or hadron candidates:
  - Maximum allowed rate is limited to ~1MHz



- High Level Trigger (HLT):
  - HLT1: topological trigger & cuts on impact parameter (50 kHz)
  - HLT2: Select inclusive or exclusive channels using full track reconstruction.



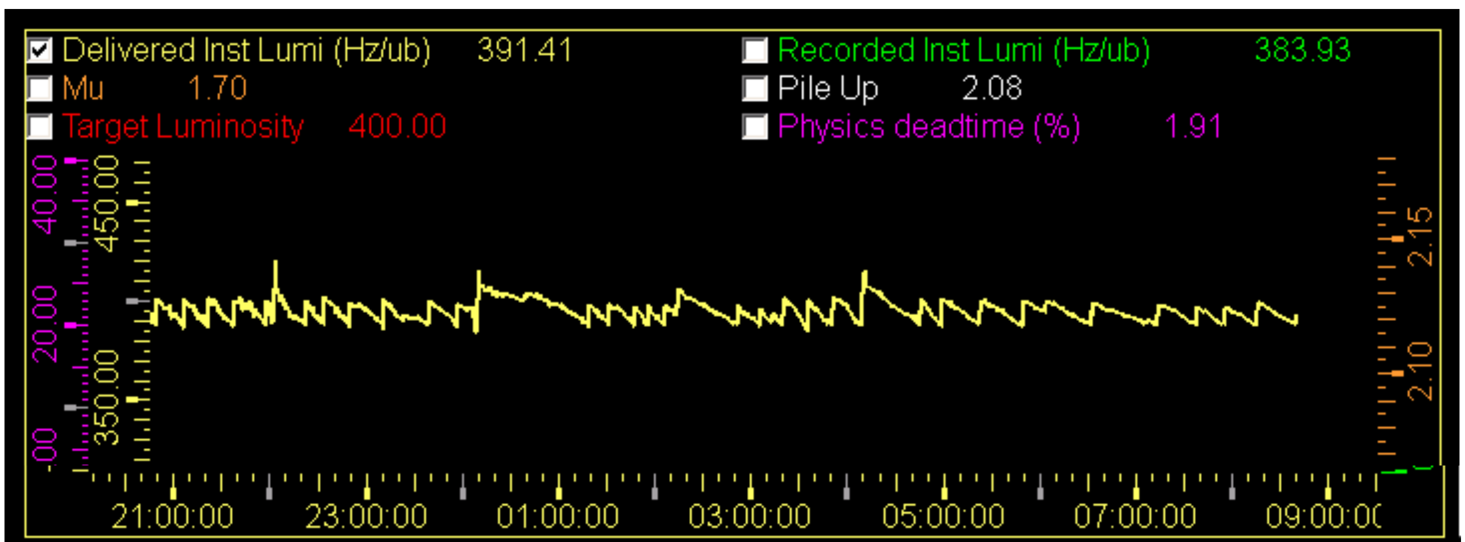
Operation

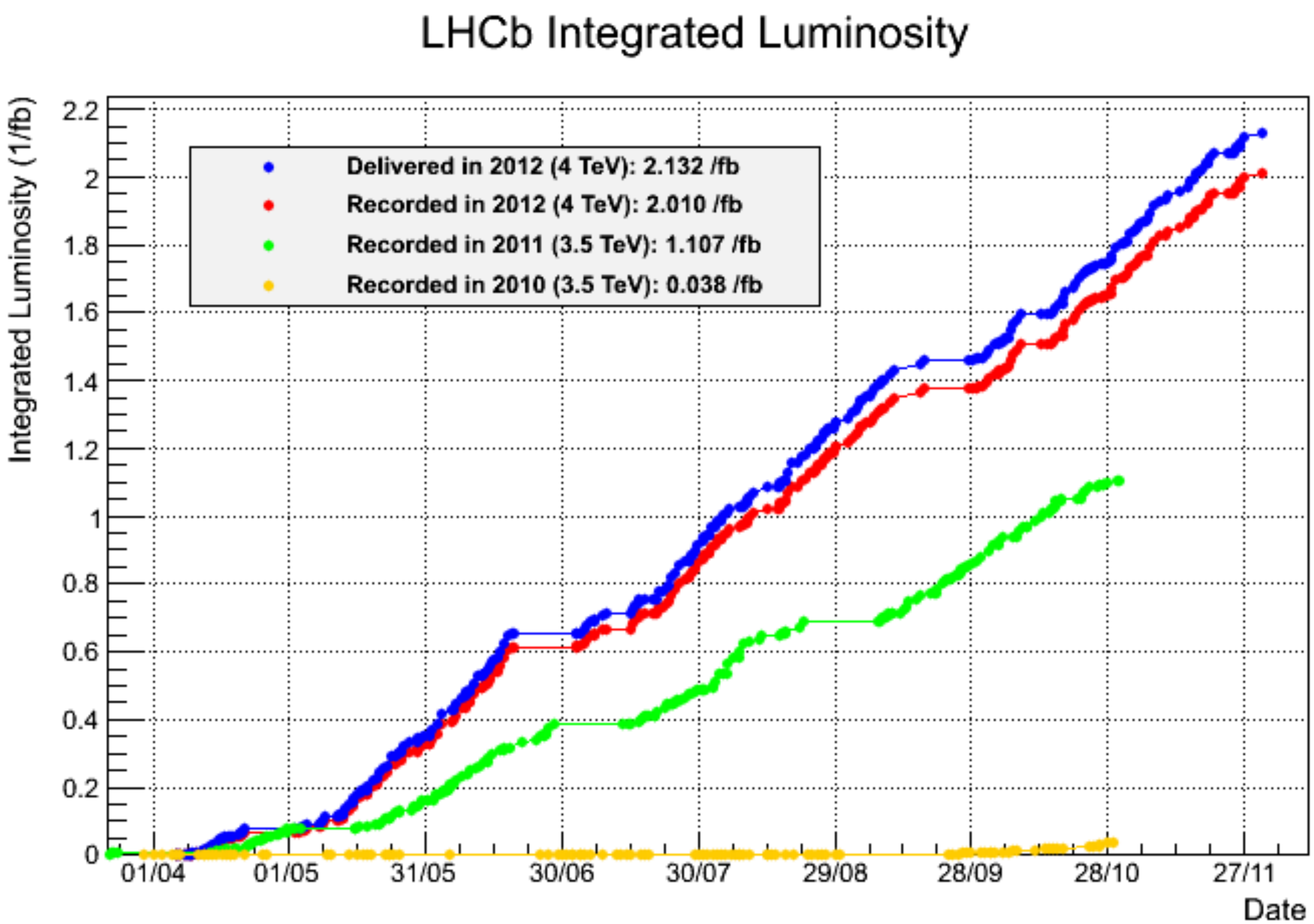
- In the latest run- has been running with **~4x10^{32} cm^{-2} s^{-1}** with 1262 colliding bunches with 50 ns bunch spacing (since end of 2011)
  - Was designed for peak luminosity 2x10 ^{32} cm^{-2} s^{-1} for ~2700 colliding bunches with 25 ns spacing.

  -Average number of visible collisions per crossing is ~1.8

- Luminosity levelling:
  - Beam separation is adjusted to maintain the luminosity constant.

Luminosity is frequently adjusted (±3% around target value



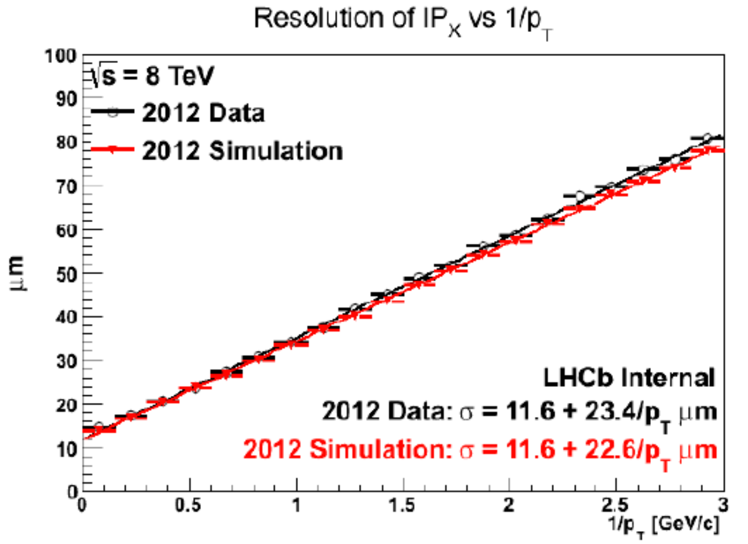


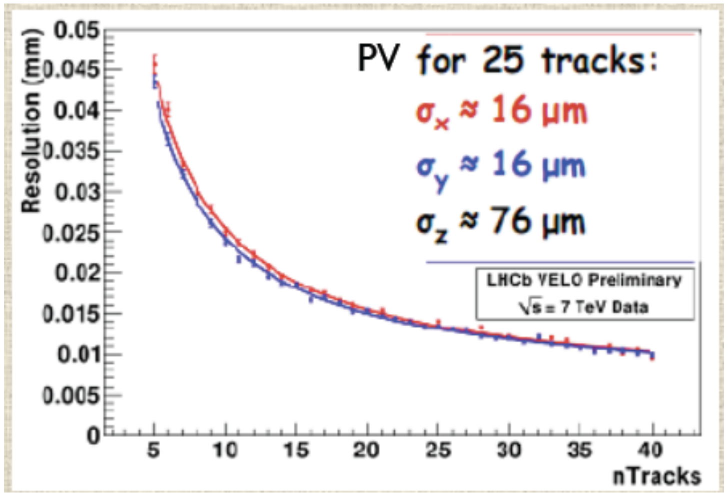
After the Long Shutdown 1 (LS1) will restart in 2015 at 13 TeV, with 25 ns bunch spacing (nominal)

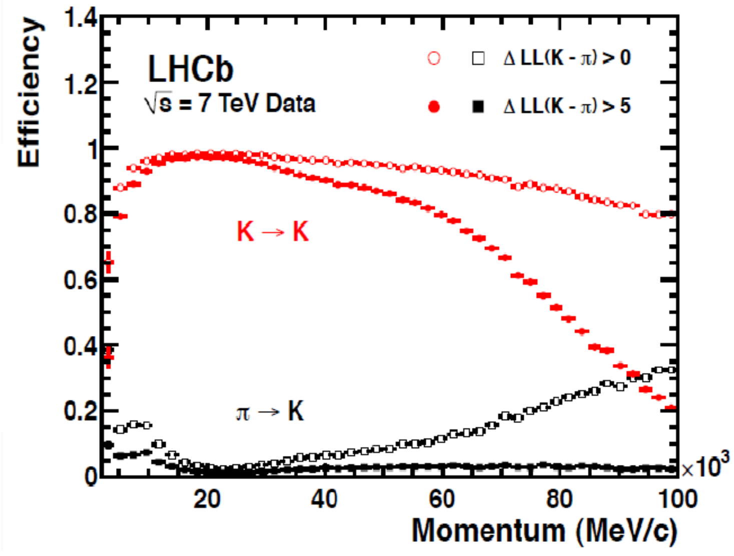
Expect to reach a total of ~7/fb by 2018

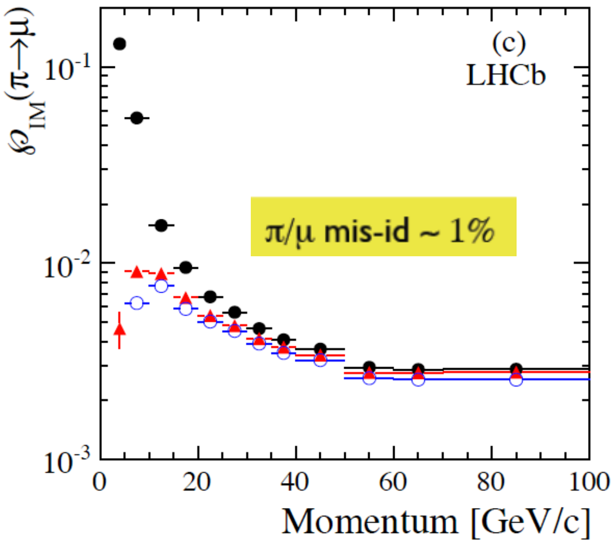
Detector & Reconstruction Performance (1)

- Detector & reconstruction Performance has been excellent- at about the design level in essentially all important aspects.



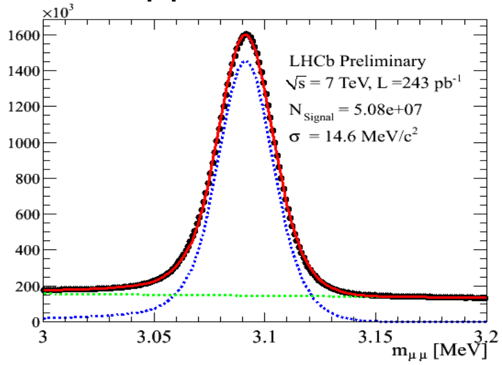




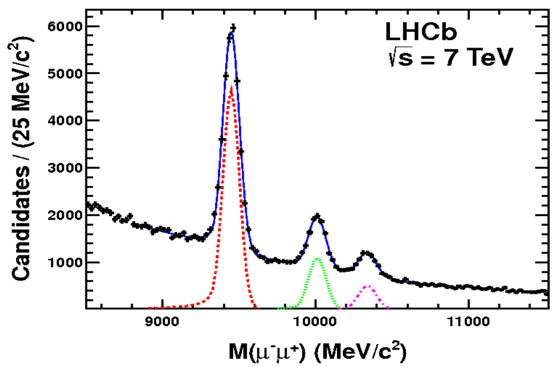


Detector & Reconstruction performance(2)

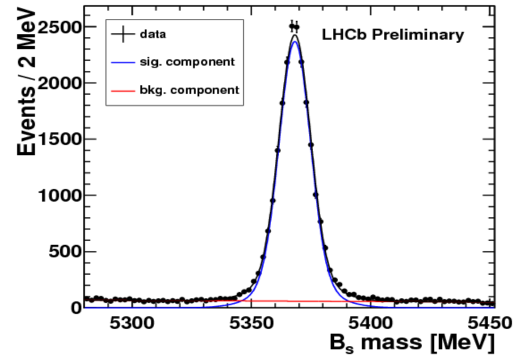
J/Ψ → μμ : σ ≈ 15 MeV/c²



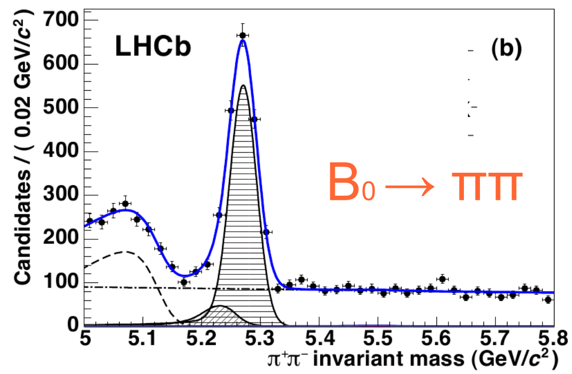
Υ(1S) → μμ : σ ≈ 54 MeV/c²

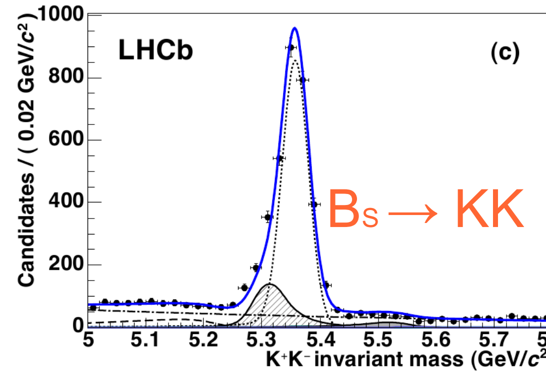


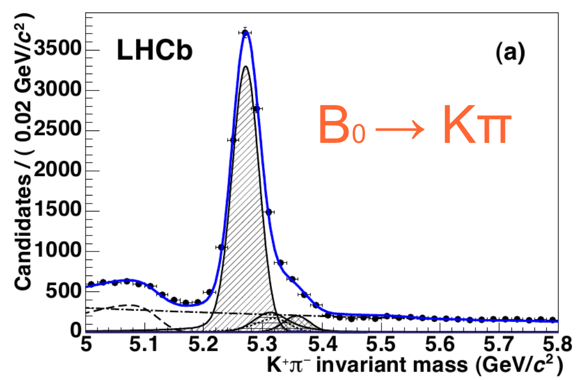
B_S→J/ΨΦ : σ ≈ 8 MeV/c²

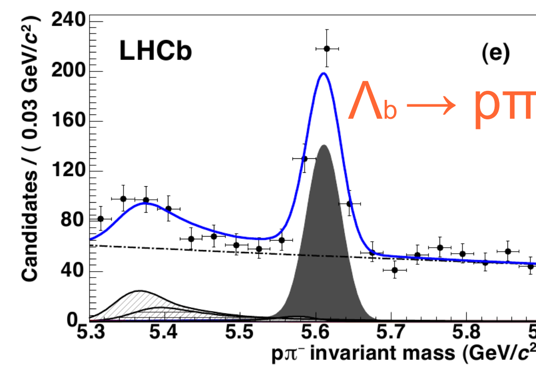


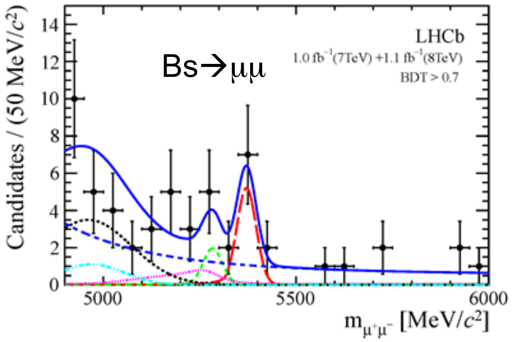
Excellent PID performance - as shown in separation of various 2-body charmless decays

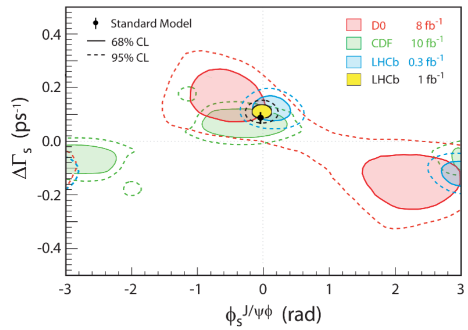


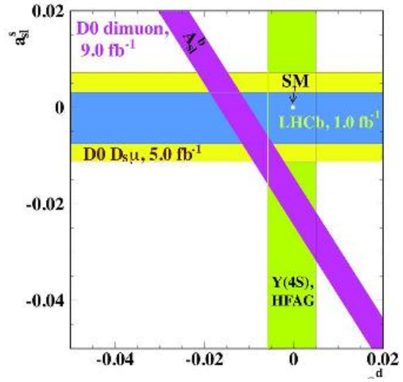


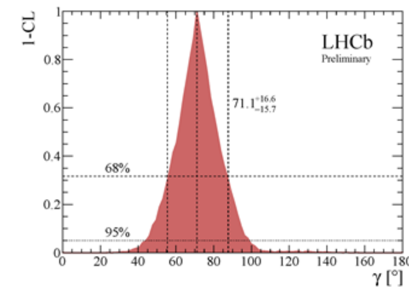


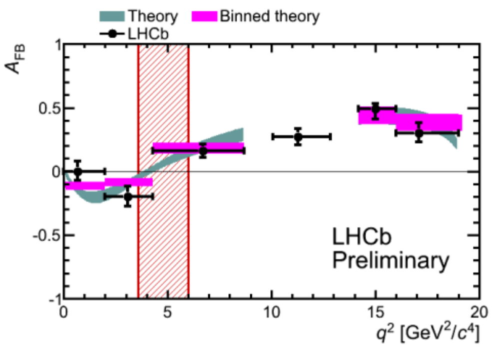


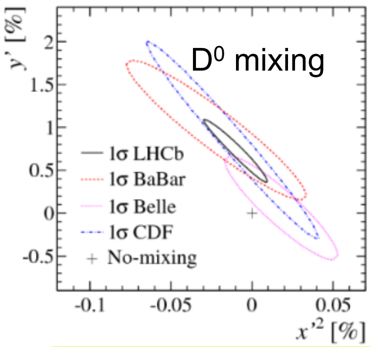


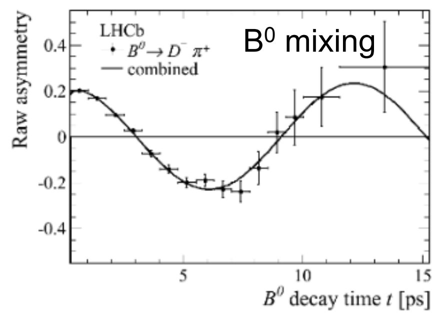


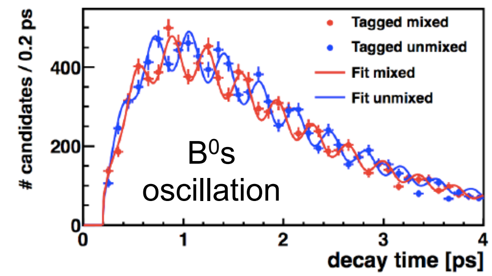


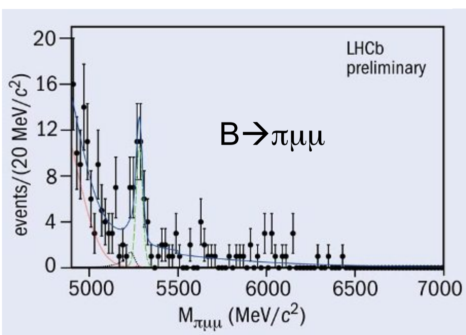




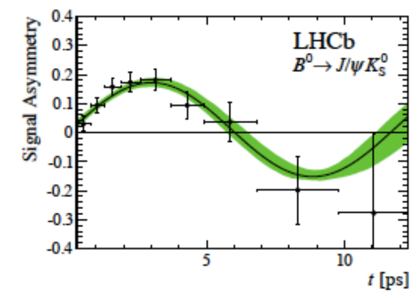


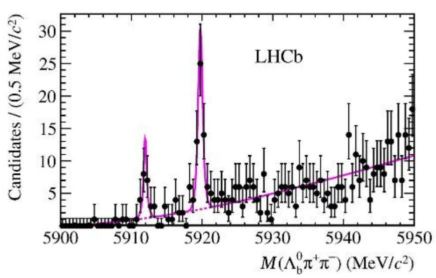


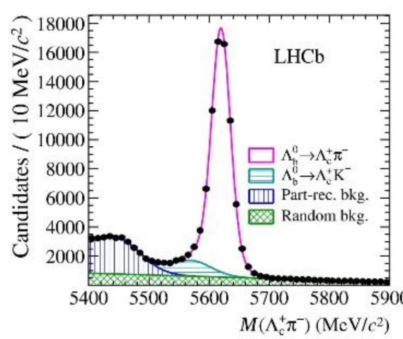


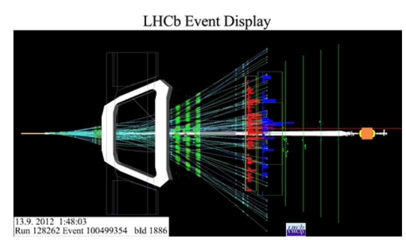


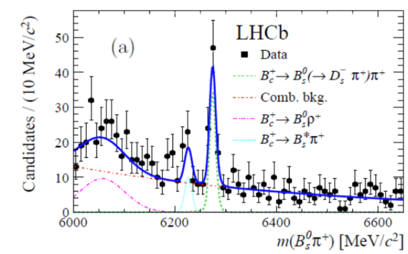
LHCb Physics Covers a very broad spectrum from Flavor to EW, QCD, pA…

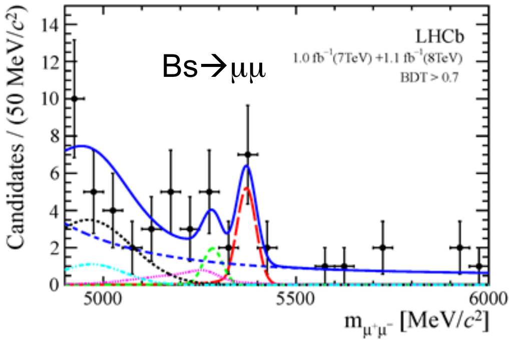


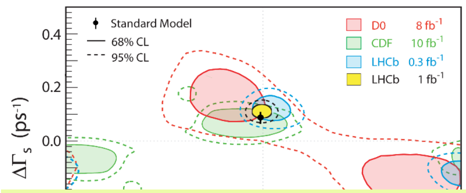


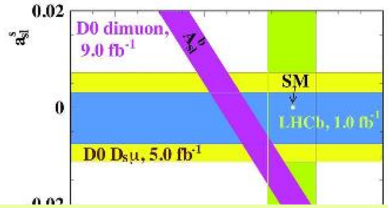


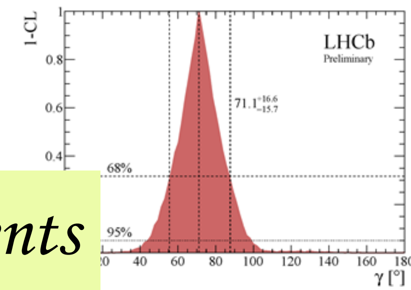












Comments on three key measurements

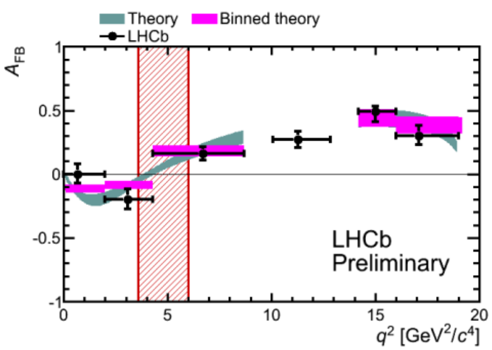
➢NP Search in B mixing

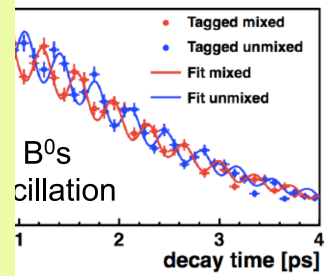
Φ_s & a^s_{sl}

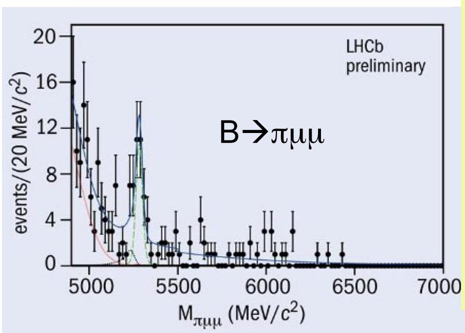
➢NP search in FCNC processes:

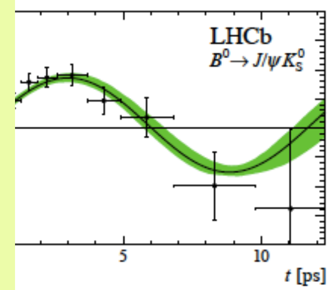
Observation of B→$\mu^+\mu^-$

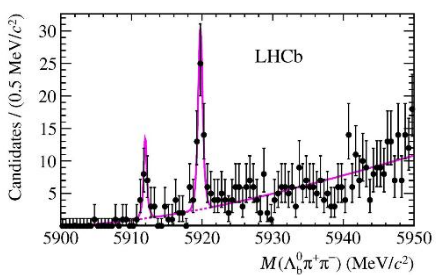
(Major milestones in Flavor Physics)

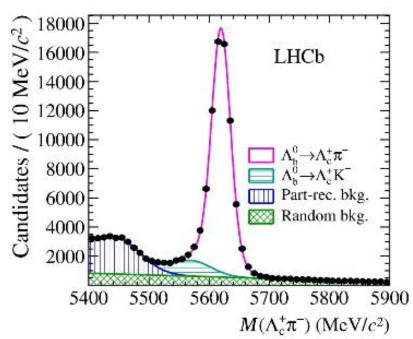


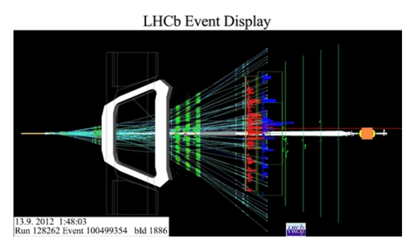


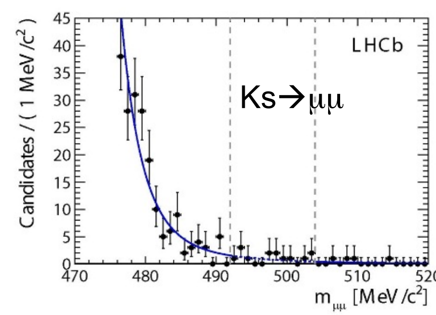




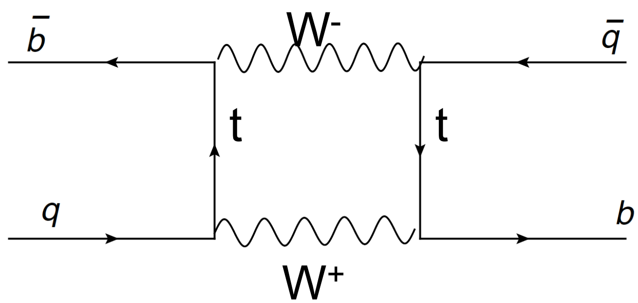




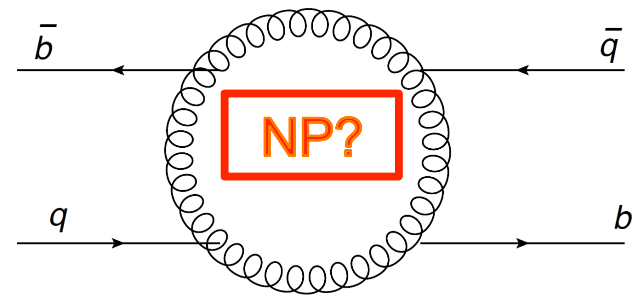




B^0 mixing as a probe of New Physics



$$\propto \frac{|V_{tq}|^2}{M_W^2}$$



$$\propto \frac{|C|^2}{\Lambda_{NP}^2}$$

Described by 2x2 mass matrix

$$i\frac{d}{dt}\begin{pmatrix} B \\ \bar{B} \end{pmatrix} = \begin{pmatrix} M_{11}-\Gamma_{11} & M_{12}-\Gamma_{12} \\ M_{21}-\Gamma_{21} & M_{22}-\Gamma_{22} \end{pmatrix}\begin{pmatrix} B \\ \bar{B} \end{pmatrix}$$

$$B_L = p|B^0> +q|\bar{B}^0>$$

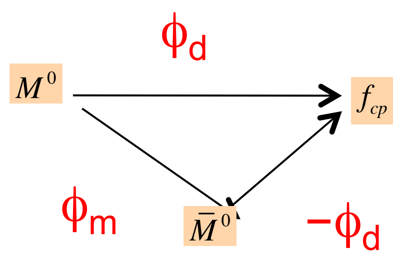
$$B_H = p|B^0> -q|\bar{B}^0>$$

➢Parameters: $\phi_{12}=\arg(-M_{12}/\Gamma_{12})$ $\Delta m=m_H-m_L=2|M_{12}|$ $\Delta\Gamma=\Gamma_H-\Gamma_\Lambda=2|\Gamma_{12}|\cos(\phi_M)$ are highly constrained within SM for the B_d and B_s systems.

➢New Physics contribution can manifest in sizeable CP violations effects & alter these parameters from SM values- in particular in the B_s system.

Key CPV observables in B^0_s system

ϕ_s: Relative phase of mixing and decay amplitude in CP eigenstates
Extract from Time-dependent CPV



$$\phi_s = \phi_m - 2\phi_d$$

$$A_{cp}(t) \simeq \eta_{cp} \sin\phi_s \sin\Delta mt$$

$$\varphi_s^{J/\psi\phi} = -2\arg\left(\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) \approx 0.04(SM)$$

A^s_{sl}: Semileptonic Asymmetry

$$a^s_{sl} = \frac{\Gamma(B^0_s \to l^+\nu_l X) - \Gamma(\bar{B}^0_s \to l^-\bar{\nu}_l X)}{\Gamma(B^0_s \to l^+\nu_l X) - \Gamma(\bar{B}^0_s \to l^-\bar{\nu}_l X)} = \frac{\Delta\Gamma_s}{\Delta M_s}\tan\phi_{12} = (2.06 \pm 0.57)\times 10^{-5}(SM)$$

Both parameters are small & with well defined SM predictions
Thus, highly sensitive probes of NP

ϕ_s results

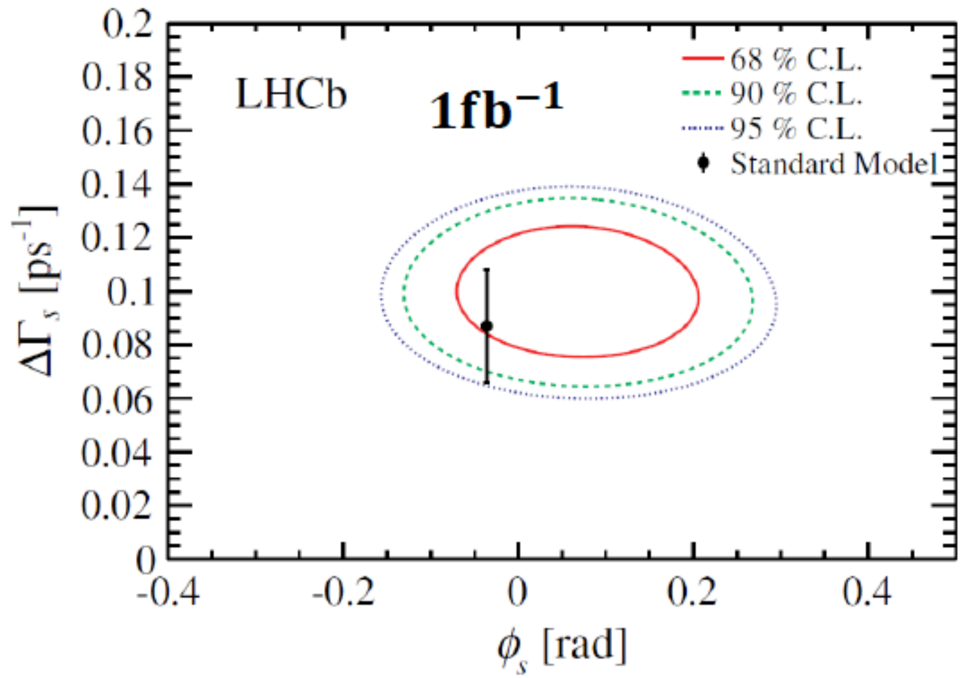
LHCb: From $J/\psi\phi$

$\phi_s = 0.07 \pm 0.09 \pm 0.01$ (rad)

$\Gamma = 0.663 \pm 0.005 \pm 0.006$ (ps^{-1})

$\Delta\Gamma = 0.100 \pm 0.016 \pm 0.003$ (ps^{-1})

Ambiguity removed using interference with K^+K^- S-wave



$\phi_s^{J/\psi\phi}$ (rad)

$$\phi_s(J/\psi\pi^+\pi^-) = -0.14^{+0.17}_{-0.16} \pm 0.01 \text{ rad}$$

Combining LHCb results:

$\Phi_s = 0.01 \pm 0.07 \pm 0.01$ rad

Future:
expected accuracy with 7/fb (2018): $\phi_s^{J/\Psi\phi} \sim \pm 0.025$ (rad)

ϕ_s results

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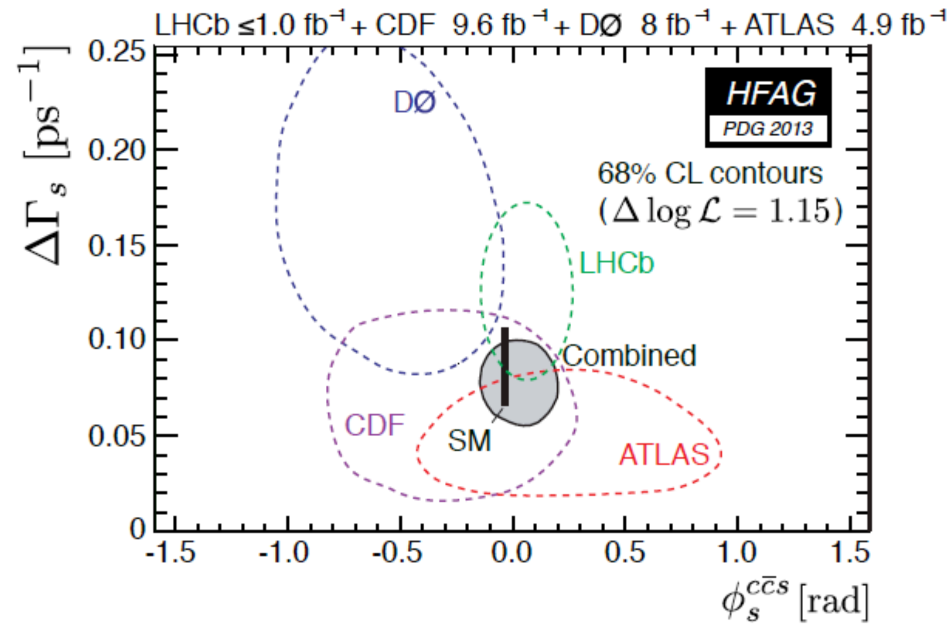

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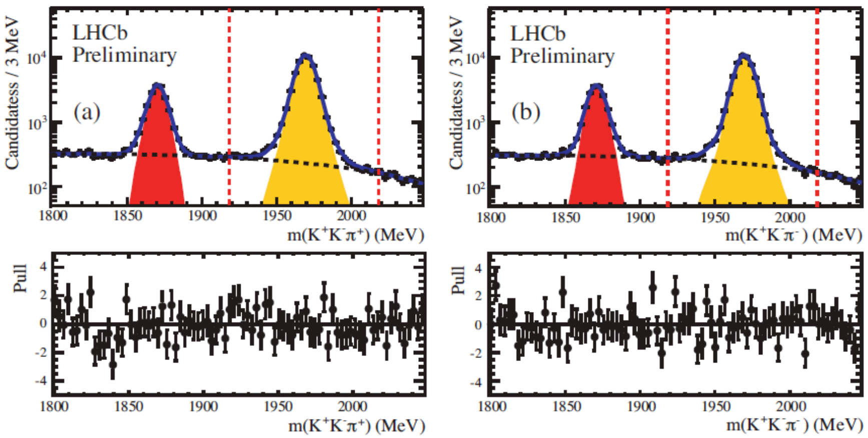
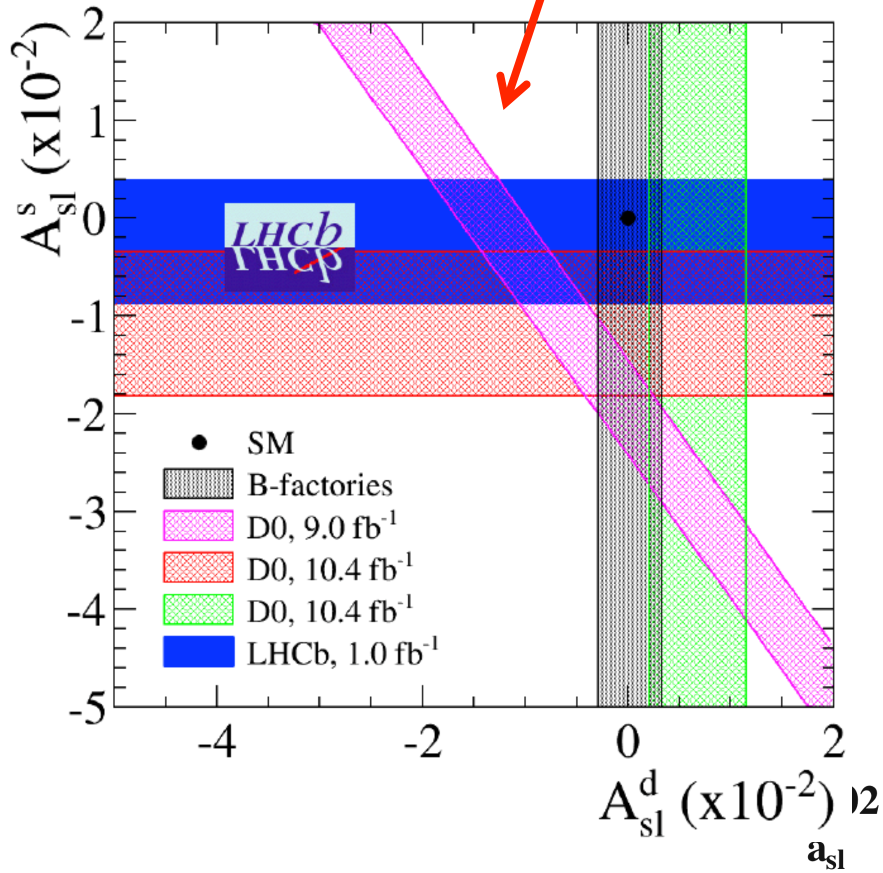
LHCb measurment of A^s_{sl}

$A^b_{sl}(D0) = C_d a^d_{sl} + C_s a^s_{sl}$

With $B_s \to D_s \mu \nu$ (with $1 fb^{-1}$)





LHCb finds

$$A^s_{sl} = \left(-0.06 \pm 0.50 \pm 0.36\right)\%$$

In good agreement with SM

A. Lenz

$$A^d_{fs} = (-4.1 \pm 0.6) \times 10^{-4}$$

$$A^s_{fs} = (1.9 \pm 0.3) \times 10^{-5}$$

B Factories: $a^d_{sl} = \left(-0.02 \pm 0.31\right)\%$

Combined D0: $a^d_{sl} = \left(0.10 \pm 0.30\right)\%$

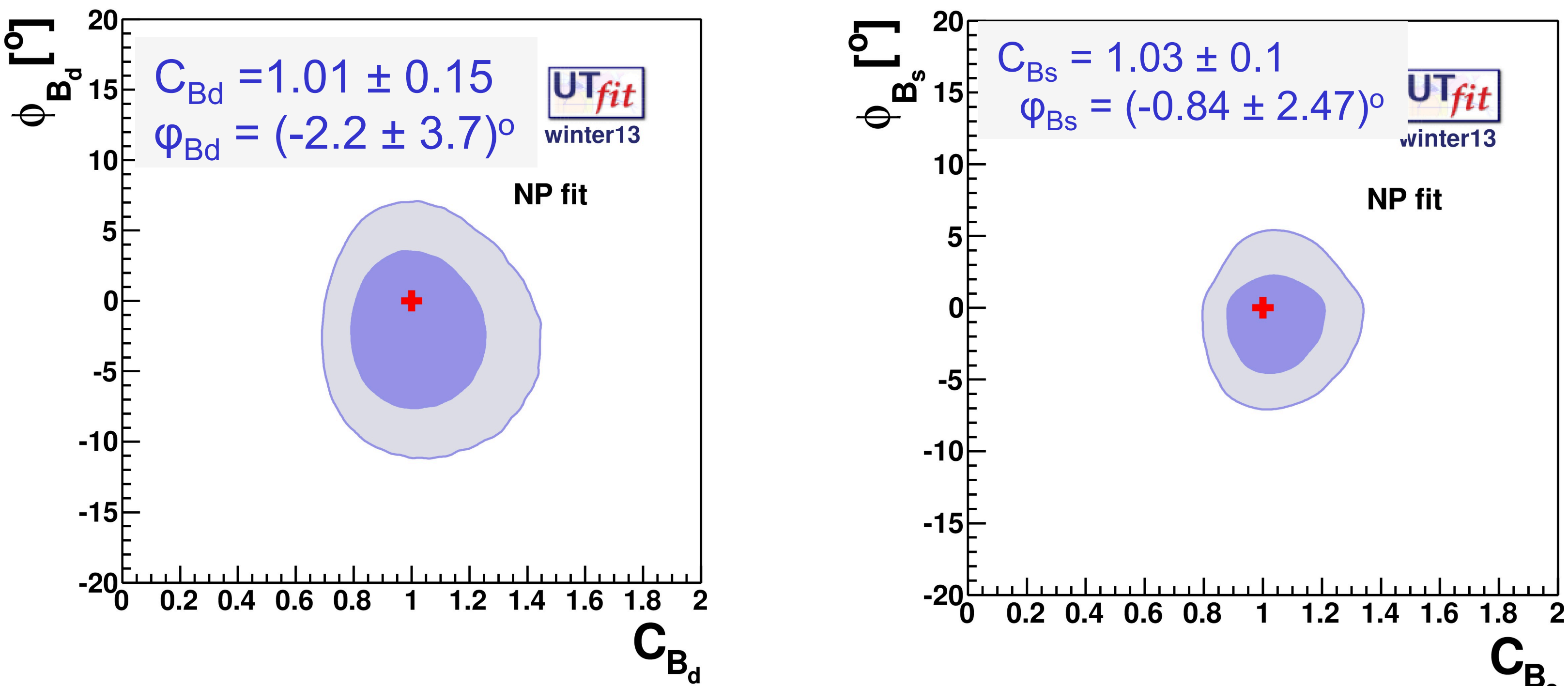
Implication for New Physics in Mixing (Utfit analysis)

Fitting the CKM parameters, allowing NP through mixing amplitude (Utfit group)- Model independent approach

$$C_{B_q} e^{2i\varphi_{B_q}} = \frac{< B_q \mid H_{eff}^{Full} \mid \bar{B}_q >}{< B_q \mid H_{eff}^{SM} \mid \bar{B}_q >}$$

$SM : C_{B_q} = 1 \qquad \varphi_{B_q} = 0$

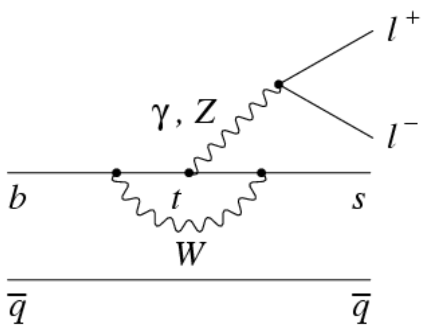
(Now includes LHCb results)

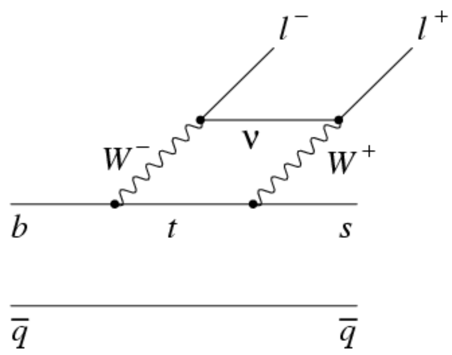


The NP test with B_s system is now as precise as that in B_d ;
Both consistent with SM, but still allow plenty of room for NP.

LHCb Measurements of FCNC Processes

$B \rightarrow K^{(*)} \ell^+ \ell^-$

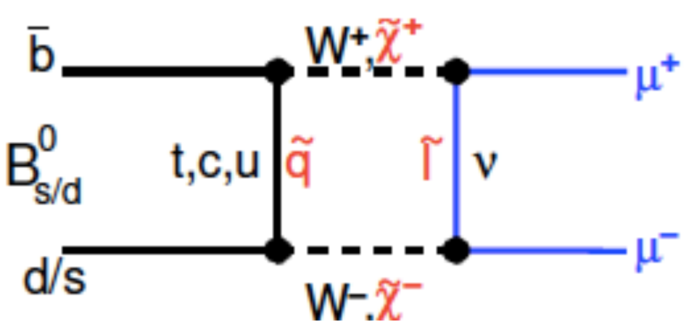


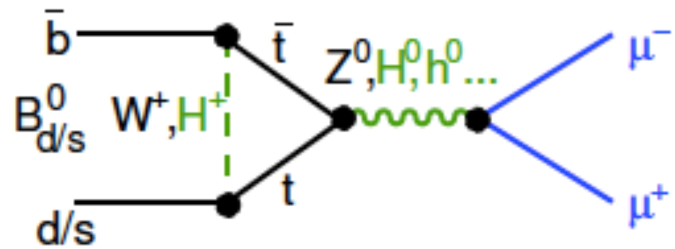


b→s processes are highly sensitive to parameters of most NP scenarios & are key to obtaining generic constraints on NP through wilson coefficients.

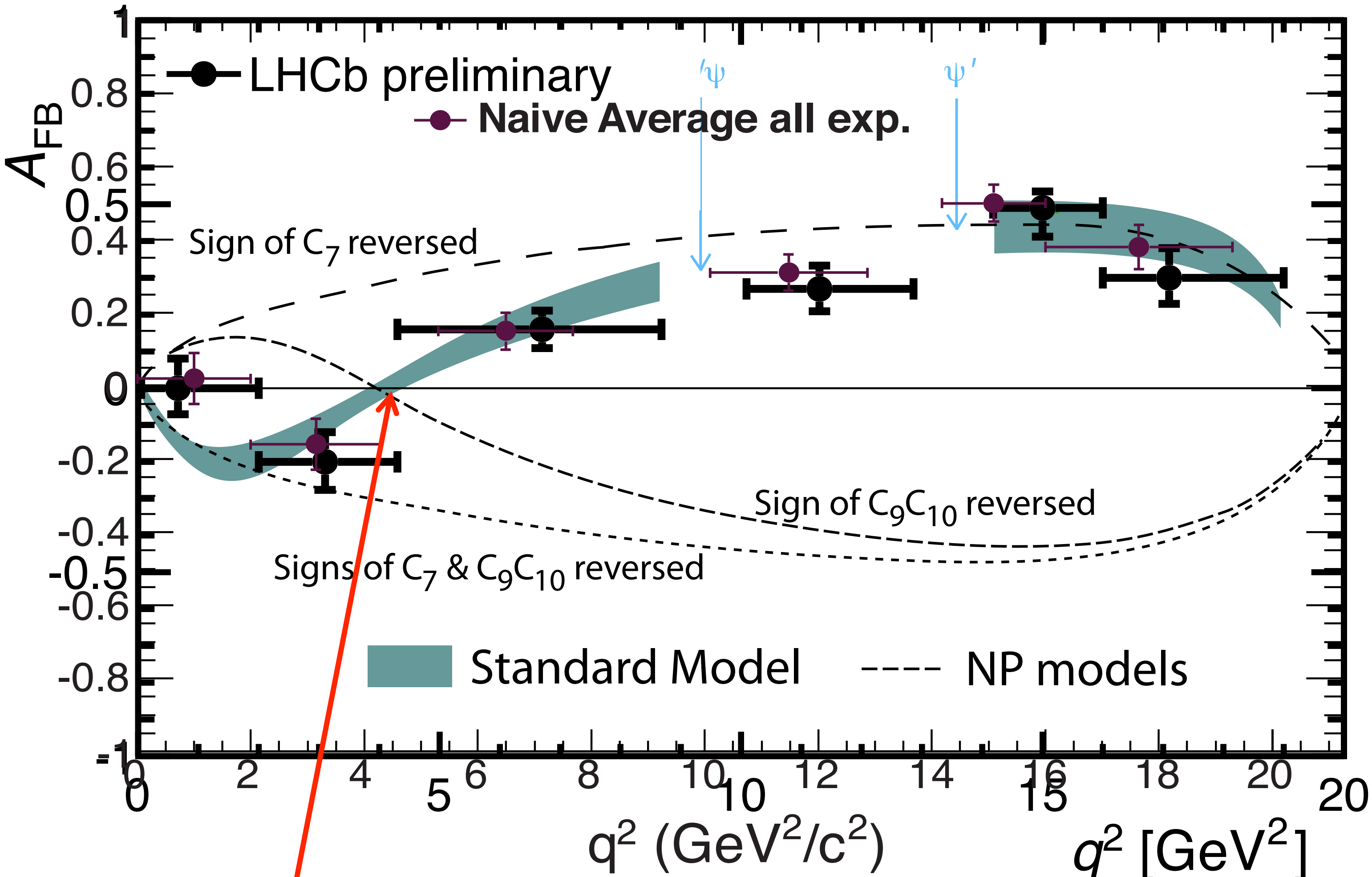
LHCb measurements of some exclusive channels have already significantly exceeded the sensitivities of previous measurements.

$B_{s/d} \rightarrow \mu^+ \mu^-$





$B^0 \to K^{*0}\mu^+\mu^-$: Forward-Backward asymmetry

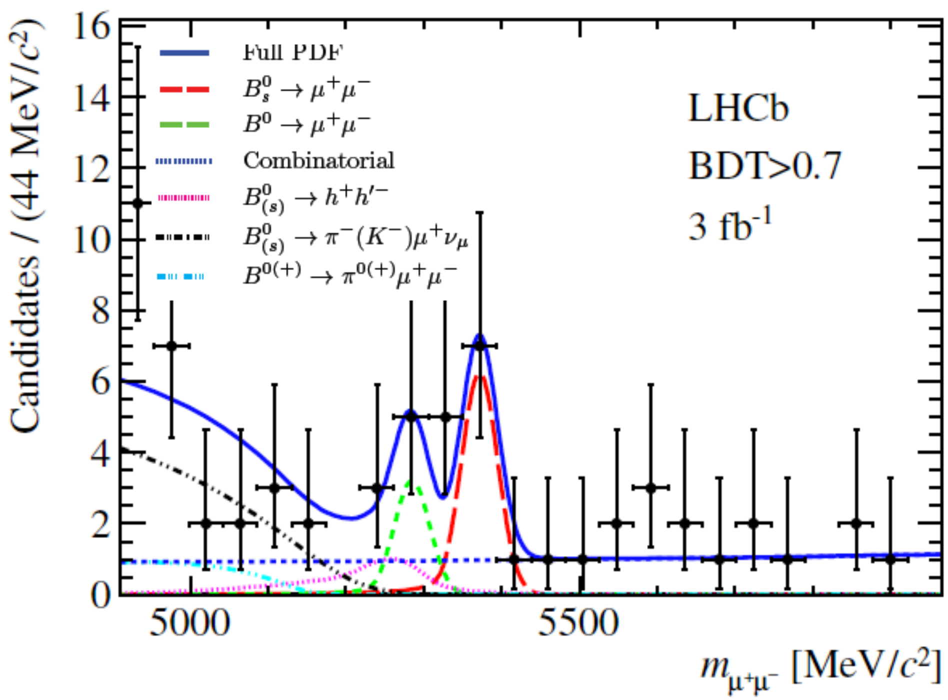


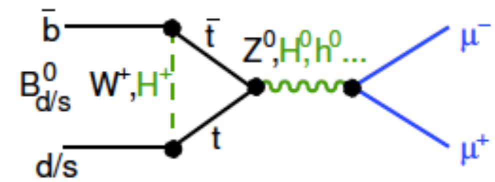
Zero crossing point
measured: $q_0^2 = 4.9 \pm 0.9 \quad GeV^2$
Consistent with SM

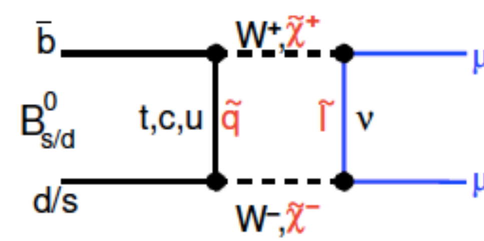
Consistent with SM

Evidence for $B_s \to \mu^+\mu^-$
A major milestone reached

- LHCb 3.0 fb^{-1}







Sensitive to new scalar sectors, extended Higgs.. in MSSM to high tanβ

4 σ excess ⇒

SM Br (time-integrated) for $B_s \to \mu^+\mu^-$ is $(3.56\pm0.3)\times10^{-9}$ arXiv 1207.1158]

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(2.9^{+1.1}_{-1.0}(stat)^{+0.3}_{-0.1}(syst)\right) x10^{-9}$$

$$\mathcal{B}(B_d^0 \to \mu^+\mu^-) = \left(3.7^{+2.4}_{-2.1}(stat)^{+0.6}_{-0.4}(syst)\right) x10^{-10}$$

$$CMS: \mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(3.0^{+1.1}_{-1.0}\right) x10^{-9}$$

From S. Hansmann-Menzemer
(EPS Plenary talk on Flavor)

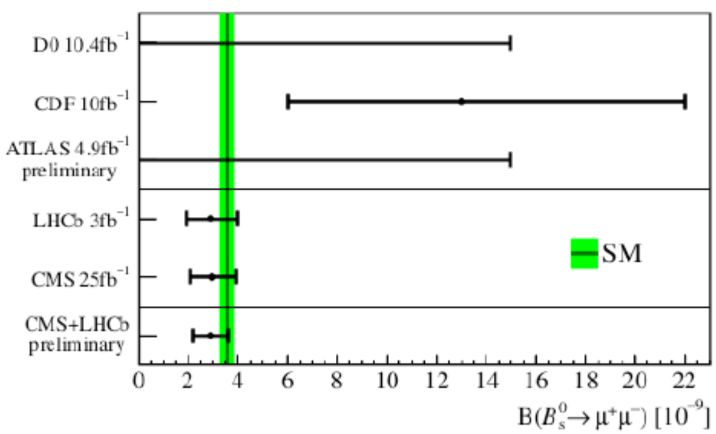
Combined LHCb + CMS Result

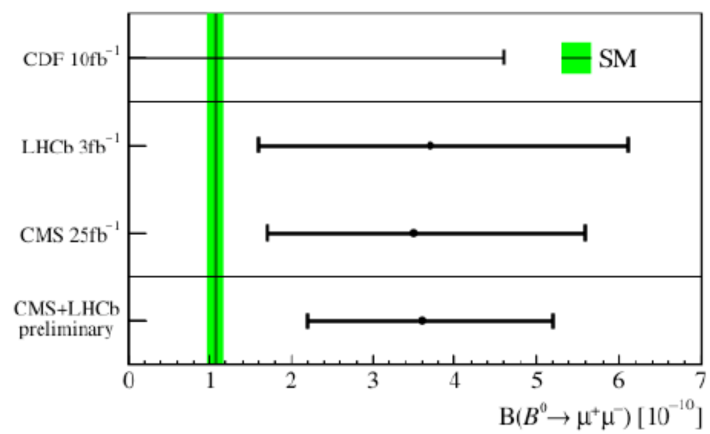
new @ EPS2013

Observation:

$$\mathrm{BR}(B_s \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$

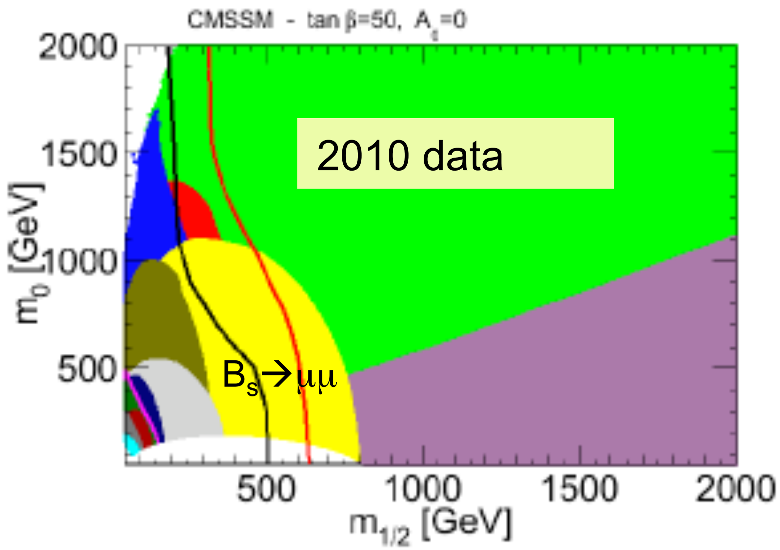
$$\mathrm{BR}(B^0 \to \mu^+\mu^-) = 3.6^{+1.6}_{-1.4} \times 10^{-10}$$

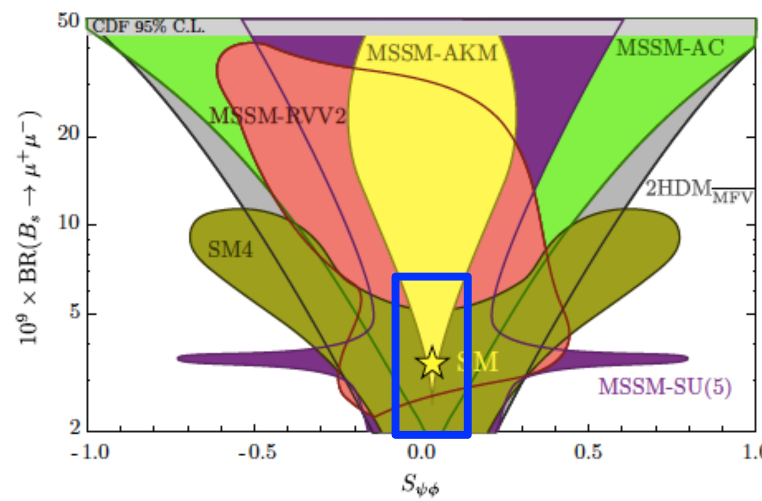


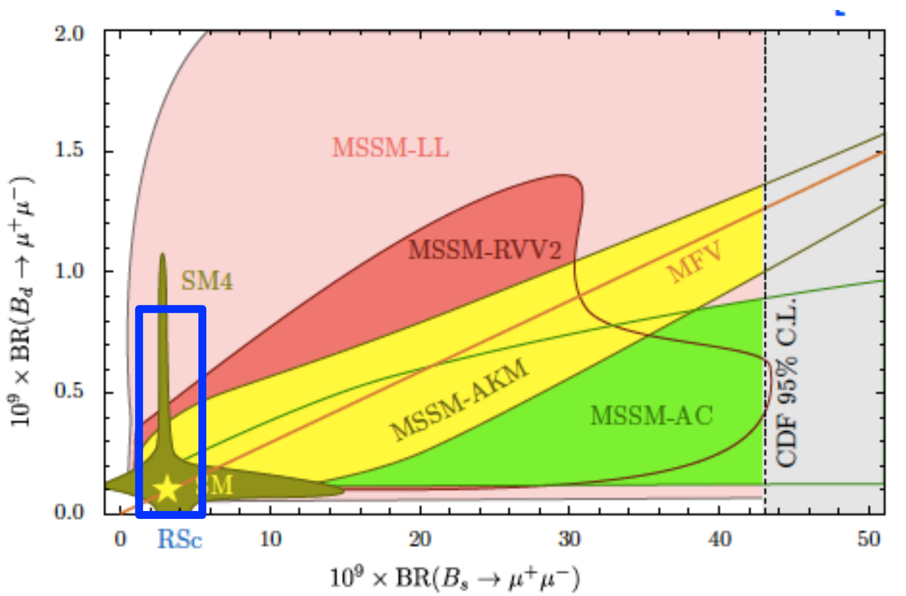


LHCb-CONF-2013-012, CMS-PAS-BPH-13-007

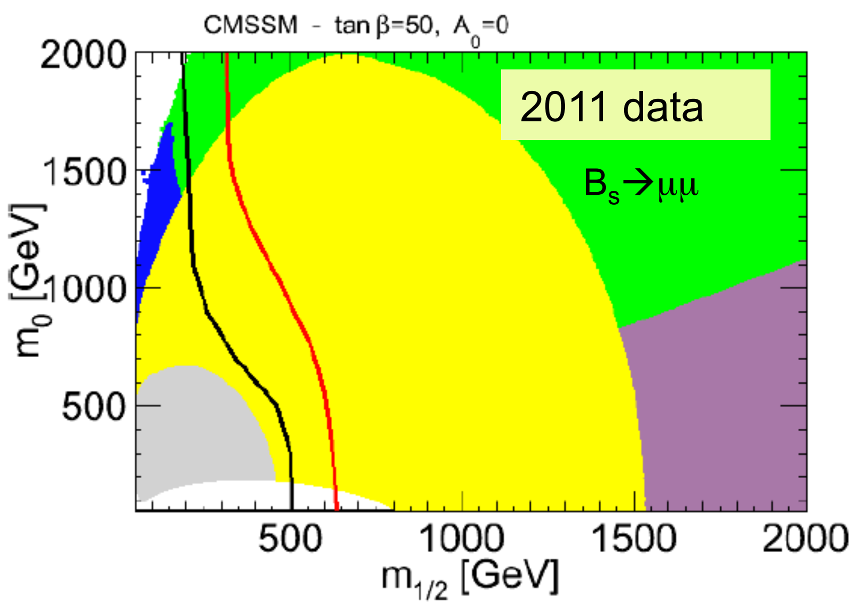
Example of impact on SUSY

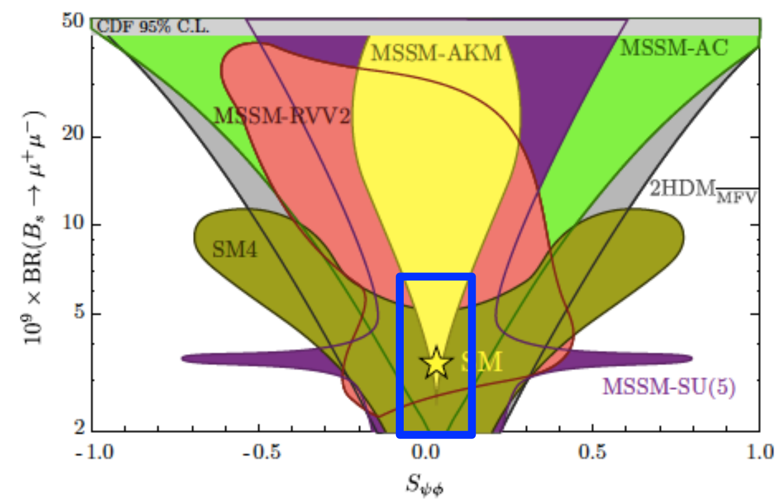


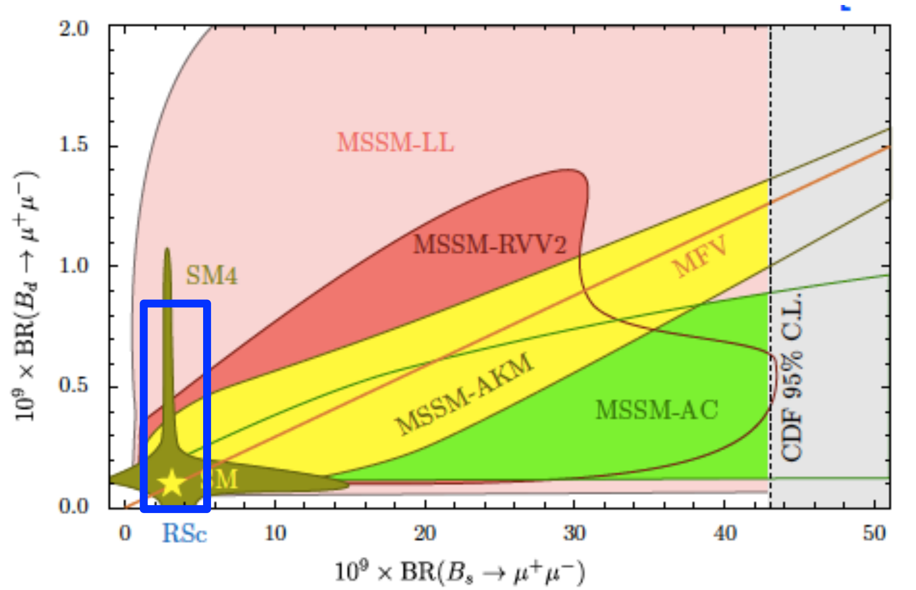




Example of impact on SUSY





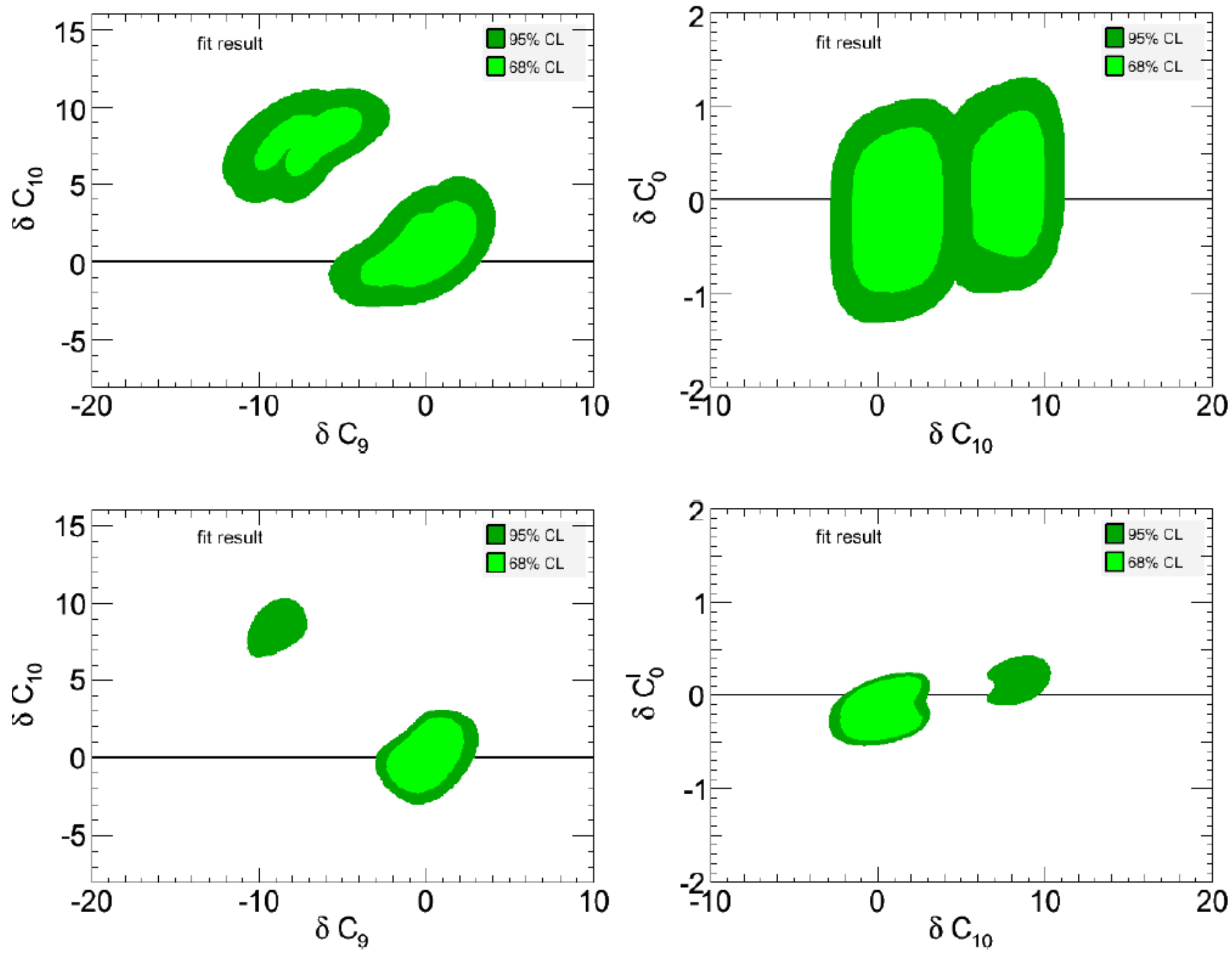


Impact on Wilson coefficients

Hurth & Mahmoudi
arXiv:1211.6453
Global Fit to MFV

Pre- LHCb

With LHCb data

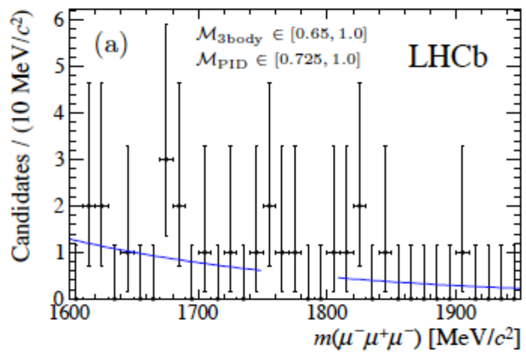


Search for LFV in τ decays with LHCb

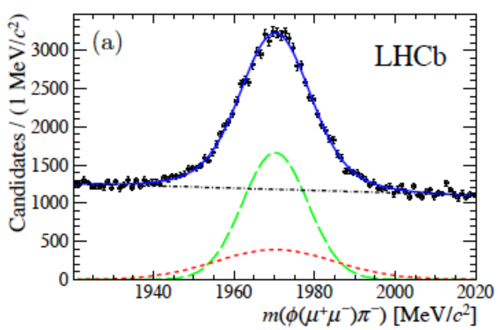
Sizeable τ cross-section (~80 μb) mostly from $D_s \rightarrow \tau\nu$.

Channels: $\tau^+ \rightarrow \mu^+\mu^-\mu^+$, $p\mu^+\mu^-$ are searched for via similar strategies- trigger and selection criteria as $B \rightarrow \mu\mu$:

LFV decay t$\rightarrow \mu^-\mu^+\mu^-$ (1 fb^{-1})

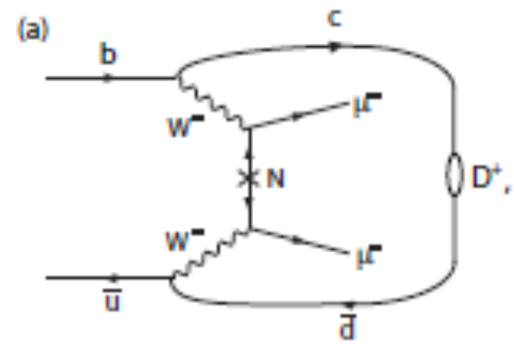


Normalization channel: $D_s \rightarrow \phi(\mu^-\mu^+)\pi^-$



$$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 8.0\ (9.8) \times 10^{-8},$$
$$\mathcal{B}(\tau^- \to \bar{p}\mu^+\mu^-) < 3.3\ (4.3) \times 10^{-7},$$
$$\mathcal{B}(\tau^- \to p\mu^-\mu^-) < 4.4\ (5.7) \times 10^{-7}.$$

Search for majorana n in B decays



Mode	$\mathcal{B}$ upper limit	Approx. limits as function of M_N
$D^+\mu^-\mu^-$	6.9×10^{-7}	
$D^{*+}\mu^-\mu^-$	2.4×10^{-6}	
$\pi^+\mu^-\mu^-$	1.3×10^{-8}	$(0.4 - 1.0) \times 10^{-8}$
$D_s^+\mu^-\mu^-$	5.8×10^{-7}	$(1.5 - 8.0) \times 10^{-7}$
$D^0\pi^+\mu^-\mu^-$	1.5×10^{-6}	$(0.3 - 1.5) \times 10^{-6}$

$B(\tau^- \to \mu^-\mu^+\mu^-) < 2.1 \times 10^{-8}$ *Belle*

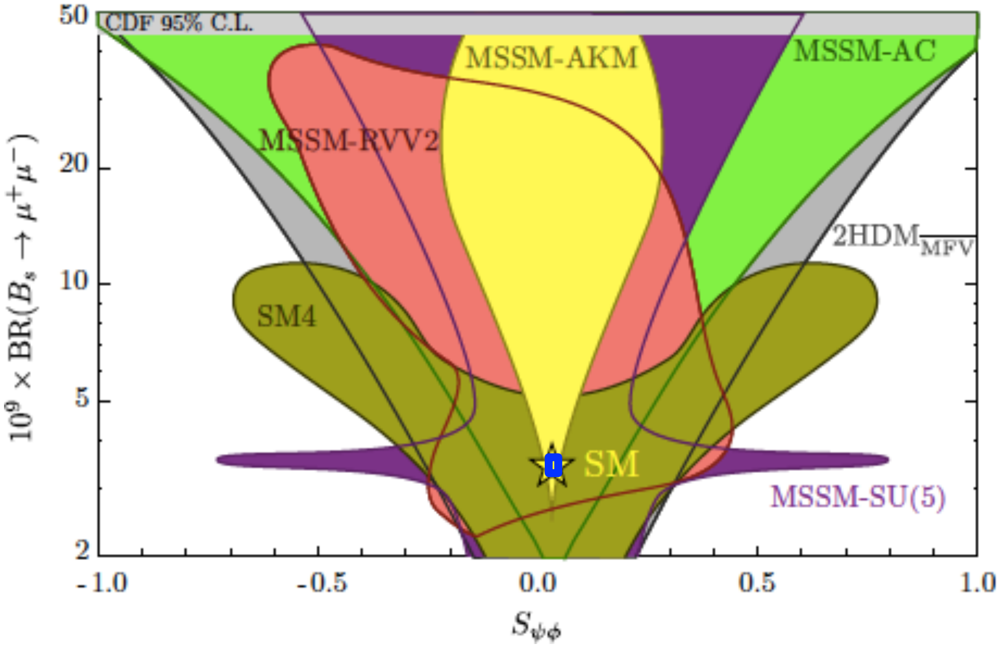
$< 3.3 \times 10^{-8}$ *BABAR*

Future of LHCb program

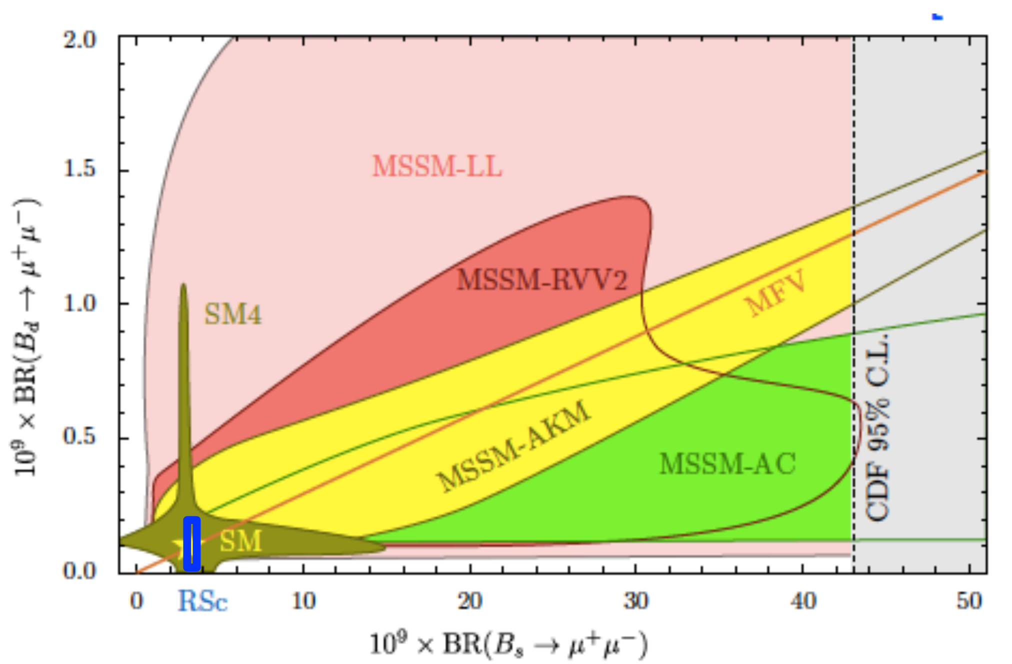
LHCb sensitivity to key flavour channels

Type	Observable	Current precision	LHCb 2018	Upgrade (50 fb^{-1})	Theory uncertainty
B_s^0 mixing	$2\beta_s$ ($B_s^0 \to J\psi\,\phi$)	0.10	0.025	0.008	~ 0.003
	$2\beta_s$ ($B_s^0 \to J\psi\,f_0$)	0.17	0.045	0.014	~ 0.01
	$A_{\rm fs}(B_s^0)$	6.4×10^{-3}	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{\rm eff}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$		0.30	0.05	0.02
R-handed currents	$2\beta_s^{\rm eff}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
EW penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-)$ $(1 < q^2 < 6{\rm GeV}^2/c^4)$	0.08	0.025	0.008	0.02
	$s_0(B^0 \to K^{*0}\mu^+\mu^-)$	25 %	6 %	2 %	7 %
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9}	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	γ ($B \to D^{(*)}K^{(*)}$)	~ 10–$12°$	4°	0.9°	negligible
	γ ($B_s^0 \to D_sK$)	–	11°	2.0°	negligible
	β ($B^0 \to J/\psi\,K_S^0$)	0.8°	0.6°	0.2°	negligible
Charm CPV	A_Γ	2.3×10^{-3}	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3}	0.65×10^{-3}	0.12×10^{-3}	–

- Unique potential B_s / b baryon sector [LHCb-PUB-2012-009]
- Charged particle final states far in excess of other facilities



CDF 95% C.L.
MSSM-AKM
MSSM-AC
MSSM-RVV2
2HDM$_{\overline{\rm MFV}}$
SM4
SM
MSSM-SU(5)
$10^9 \times \mathrm{BR}(B_s \to \mu^+\mu^-)$
$S_{\psi\phi}$



MSSM-LL
MSSM-RVV2
SM4
MFV
MSSM-AKM
MSSM-AC
CDF 95% C.L.
SM
RSc
$10^9 \times \mathrm{BR}(B_d \to \mu^+\mu^-)$
$10^9 \times \mathrm{BR}(B_s \to \mu^+\mu^-)$

The LHCb upgrade

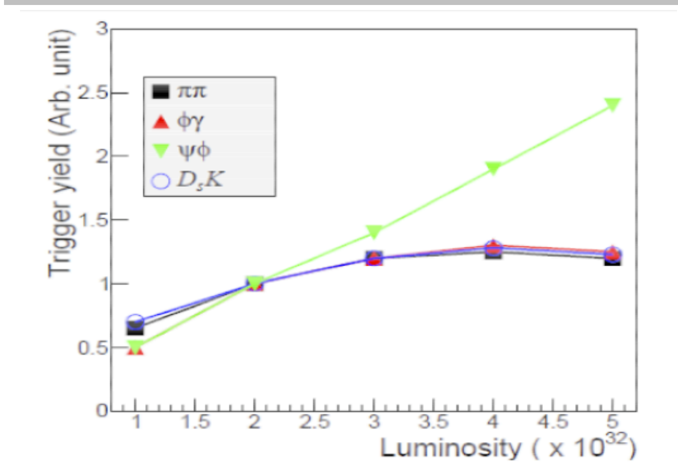
- The upgrade is aimed at a data set of 50 fb^{-1}, with the sensitivity to set strong constraints on NP & potential to reveal evidence for it.
  - The LHCb program has unique capability in the B^0_s sector, as well as the Bc & B-baryons, and extremely high statistical power in key exclusive B decays, and the charm system.

- The upgrade is designed to run at luminosity of (1-2)x10^{33} $cm^{-2}s^{-1}$.
  - $\mathcal{L}$x$t_{LHC\text{-}running}$ ~5fb^{-1}/year
  - All sub-detectors must be compatible with 2x10^{33} $cm^{-2}s^{-1}$.
  - 25 ns LHC bunch spacing needed to limit pile-up (#interactions/ crossing)

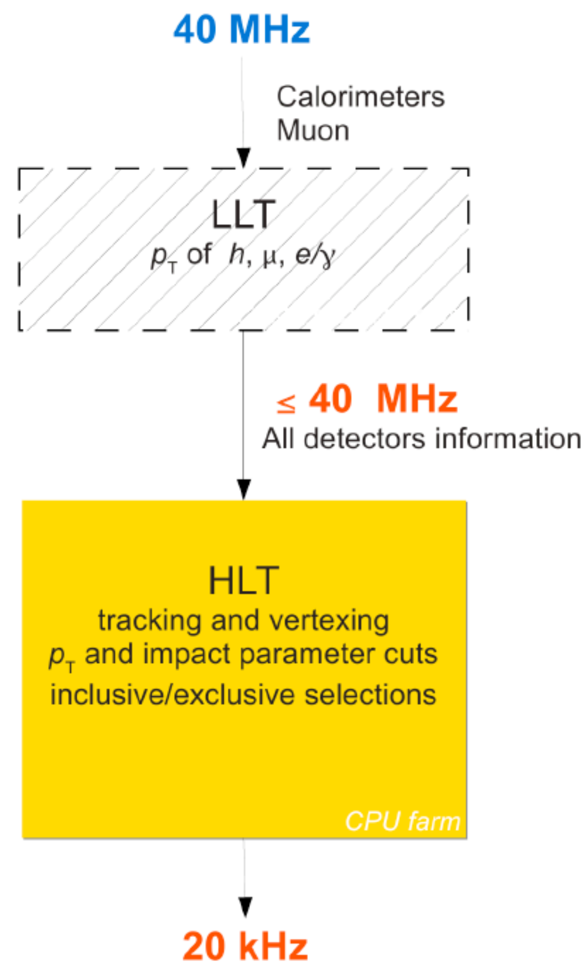
The LHCb upgrade: Trigger

High Luminosity running requires major change to the LHCb trigger scheme

Saturation of yields with 1MHz L0 limit
Must raise P_T cut to stay below 1 MHz



Upgrade Trigger

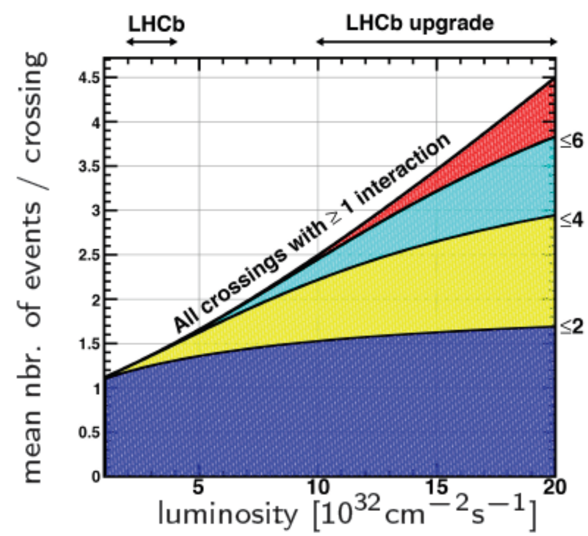


➔ New Apporach:

- Remove L0 (hardware) trigger
- Readout the detector at the 40 MHz LHC clock rate
- Move to a fully flexible software trigger

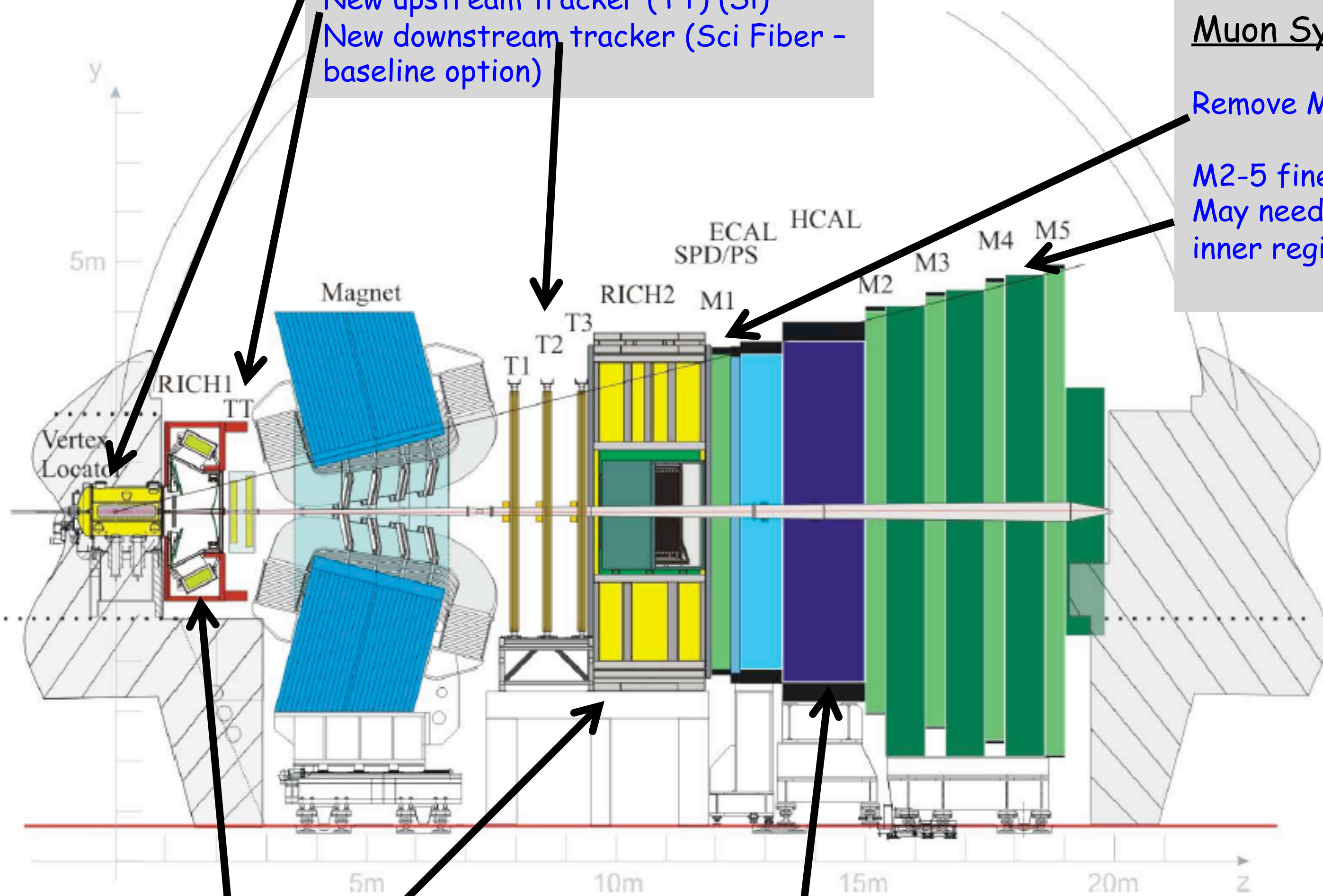
Other major challenges

- High data rate
- Increased detector occupancy
- Radiation damage
- Material budget
- Event reconstruction Performance with increased pile up



- Replace all FE electronics & DAQ system for 40 MHz readout
- Replace all Tracking sub-detectors: VELO, TT, IT & OT
- Upgrade of RICH photo-detectors and optics
- Calorimeters and Muon system OK at the beginning, but may require upgrade in regions near beam as luminosity rises.

Upgrade plan



Tracking system:
New VELO (Si strip → Pixel)
New upstream tracker (TT) (Si)
New downstream tracker (Sci Fiber – baseline option)

Muon System:

Remove M1

M2-5 fine for $1x10^{33}$
May need upgrade of inner region at $2x10^{33}$

RICH 1 & RICH 2
HPD→ MaPMT
New 40 MHz R/O
RICH1: new optics
remove aerogel

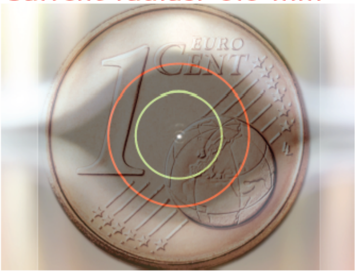
Calorimeter:
New 40 MHz R/O
Lower PMT gain to reduce anode current
Remove SPD & PS

Vertex Locator (VELO) Upgrade

- Recent decision on technology: Pixel detector with microchannel evaporative Co^2 cooling

Move closer to the beam
Reuse the existing VELO vacuum system

Current radius: 5.5 mm



Upgrade radius: 3.5 mm

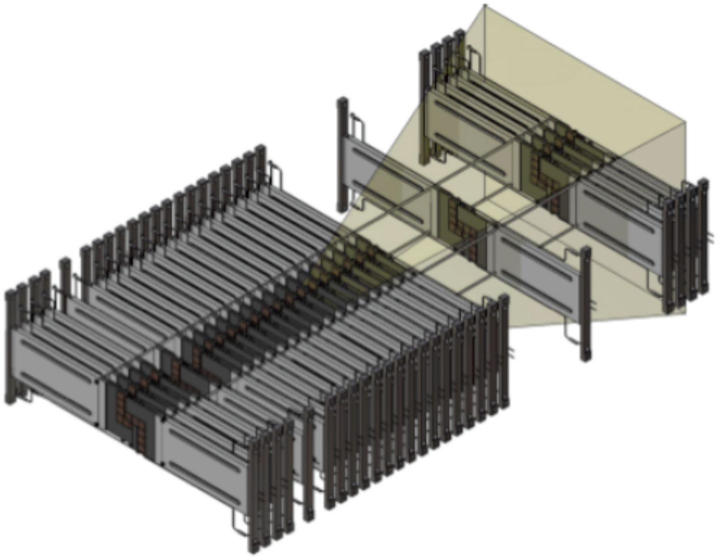
Working on thinner RF foil- Currently accounts for ~40% of VELO material

<u>Major challenges</u>:

- Improve IP resolution- move closer to beam & reduce material- reduce occupancy
  - Improved pattern recognition with pixel helps reduce ghost (fake) track rate.

- Must cope with Large differences in track density and radiation level vs distance from beam (370 Mrad near beam)

- High data rate:
  Total rate ~ 2-2.5 TBits/s
  - Single chip: >13 Gbits/s



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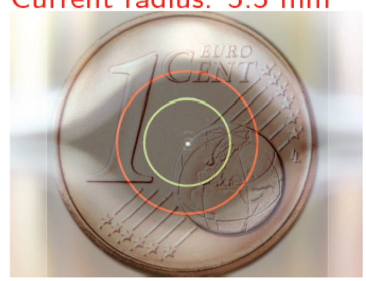

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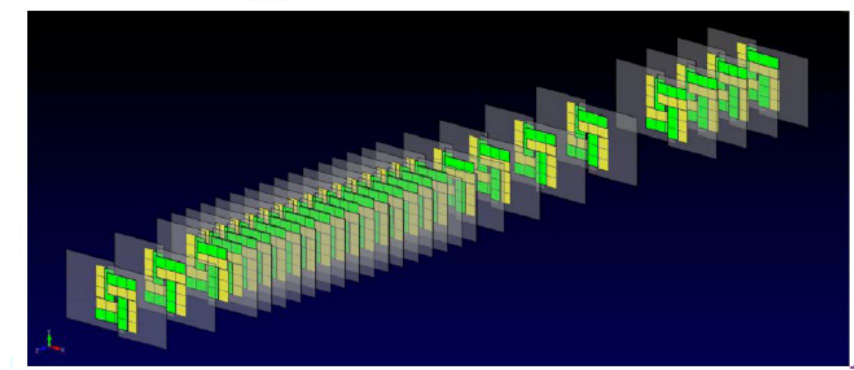

Pixels: 55x55 μm^2
41×10^6 channels

Vertex Locator (VELO) Upgrade

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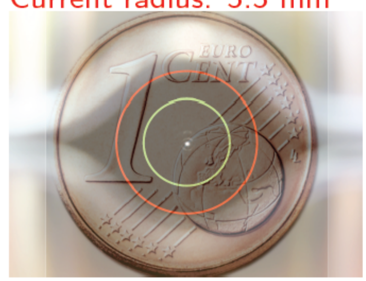
Move closer to the beam
Reuse the existing VELO vacuum system

Current radius: 5.5 mm



Upgrade radius: 3.5 mm

Working on thinner RF foil- Currently accounts for ~40% of VELO material

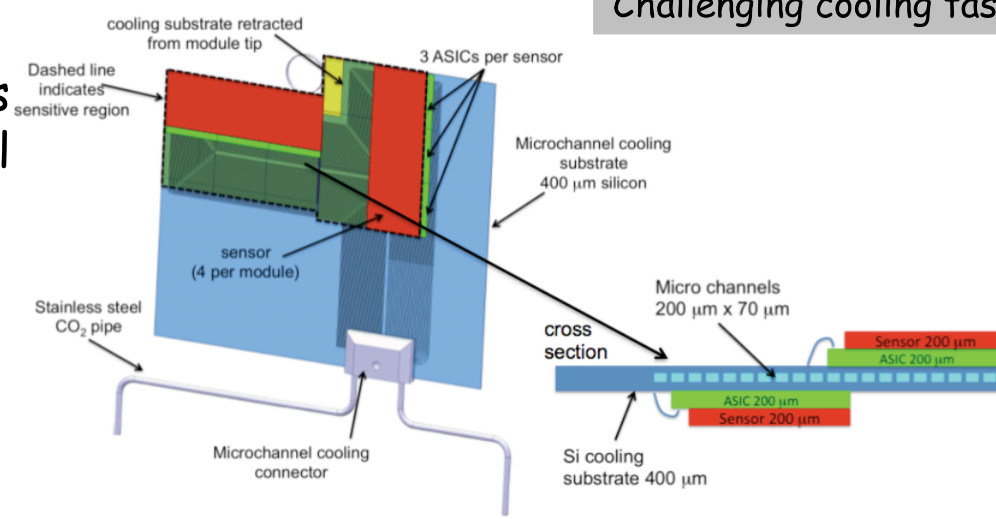
<u>Major challenges</u>:

- Improve IP resolution- move closer to beam & reduce material- reduce occupancy.
  - Improved pattern recognition with pixel helps reduce ghost (fake) track rate.

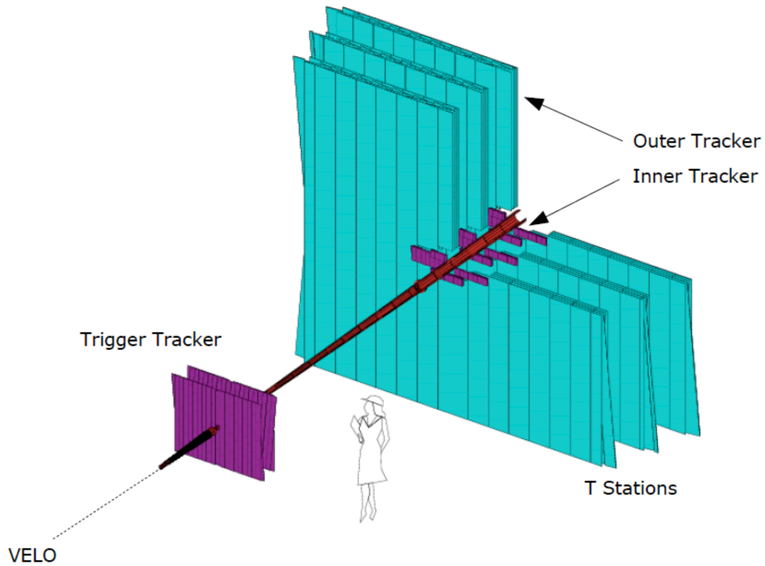
- Must cope with Large differences in track density and radiation level vs radial distance from beam

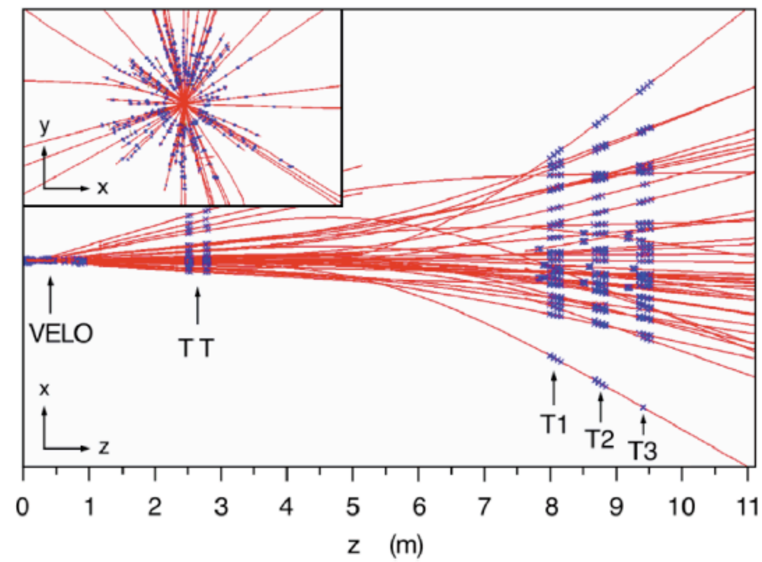
- High data rate:
  Total rate ~ 2-2.5 TBits/s
  - Hottest chip: >13 Gbits/s

Challenging cooling task



Tracking upgrade





➢Must preserve/improve the current performance in upgrade conditions: increased occupancy & higher pile up rate.

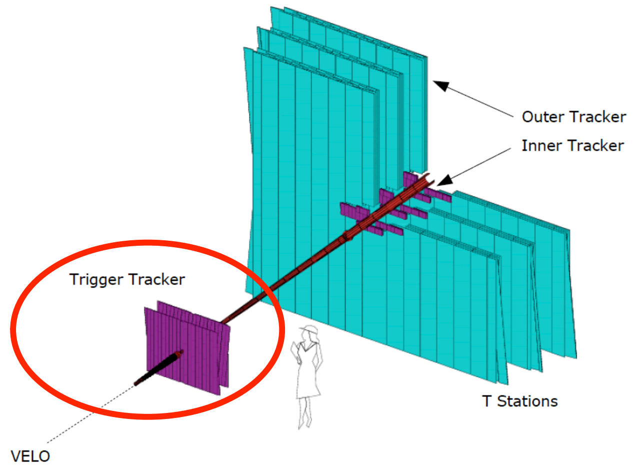
➢Reconstruction speed, efficiency and ghost rate is critical to HLT & flavor tagging

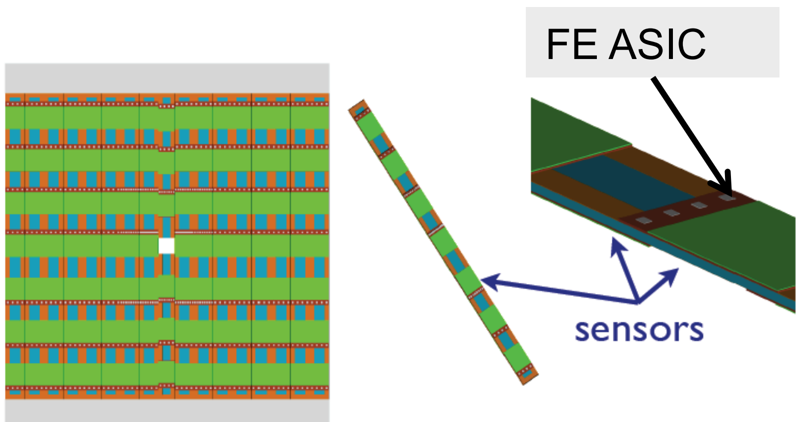
~35 tracks/primary vertex

Current performance

- High momentum resolution [$\sigma(p)/p$ = 4×10^{-3} at 5 GeV/c
- High IP resolution [20 μm at hight p_T]
- High Track efficiency [96% for long tracks]
- Low Ghost rate [~10%]
- Fast pattern recognition

Tracking upgrade





Upstream Tracker (TT→UT): (US led effort)

•New system:

4 planes (x,u & v,x) of single sided (9.8x9.8 cm^2) silicon sensors (thickness: 250 μm vs 500 μm current TT sensors)

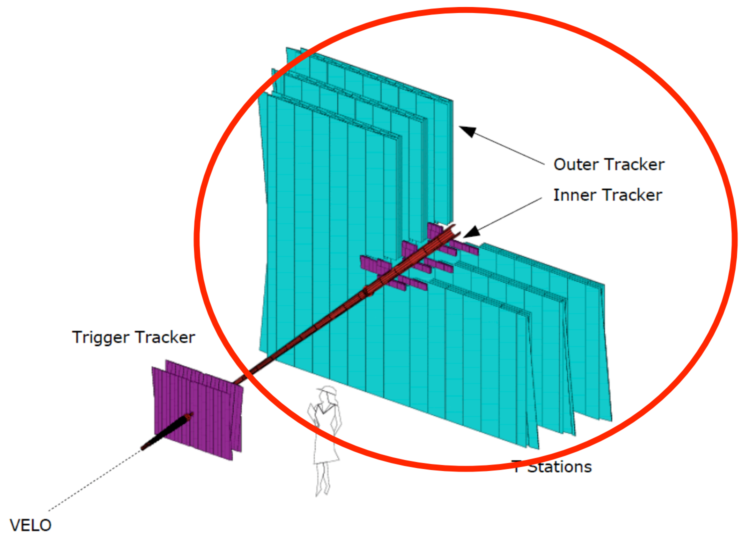
•Finer segmentation vs TT, optimized to the expected occupancy increase with distance from the beam, improved coverage & reduced material budget

•FE ASIC directly on Si sensor; digital data processing including zero suppression on the FE ASIC to cope with high data rate.

- •Considering microchannel evaporative Co^2 cooling

• UT is an important element of HLT due to its role in reducing ghost rate & fast momentum measurement for trigger using the small B field in UT region ; ➔ clean up & speed up event reconstruction

Tracking upgrade



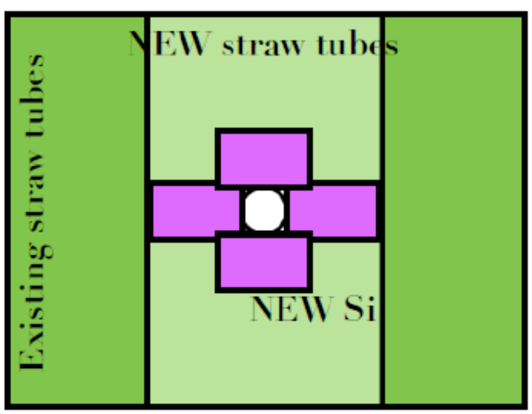
Downstream tracker:
Current system: IT (si) + OT(Straw tube)

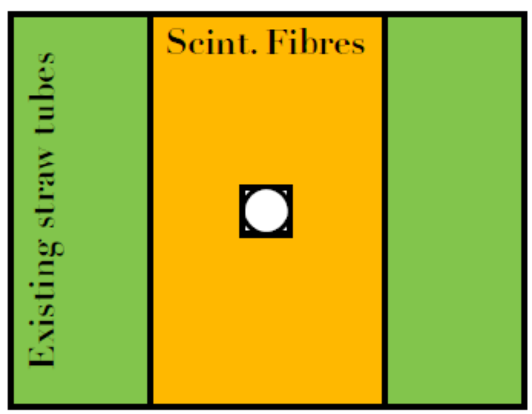
Straw tubes occupancy too high in the inner region (>40%) at upgrade luminosity

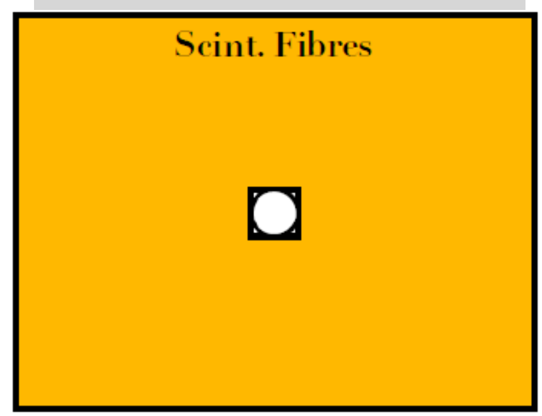
Three possible upgrade options considered

Technology Options:

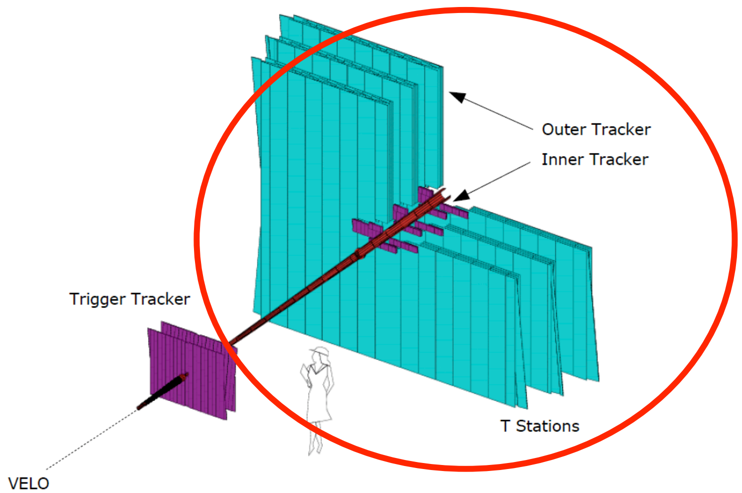
Chosen as the baseline option







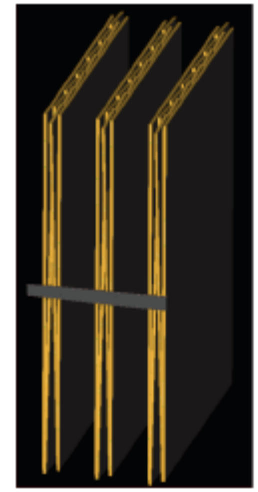
Tracking upgrade



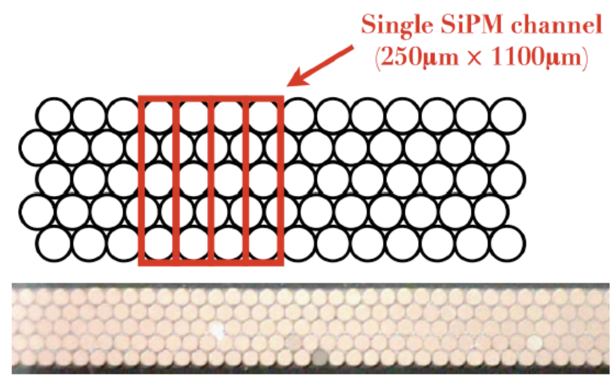
Down stream tracker:

Baseline option:
Replace current Si (IT) + Straw tube (OT) system with Scintillating fibers

The viability of SciFiber tracker – from radiation damage- demonstrated

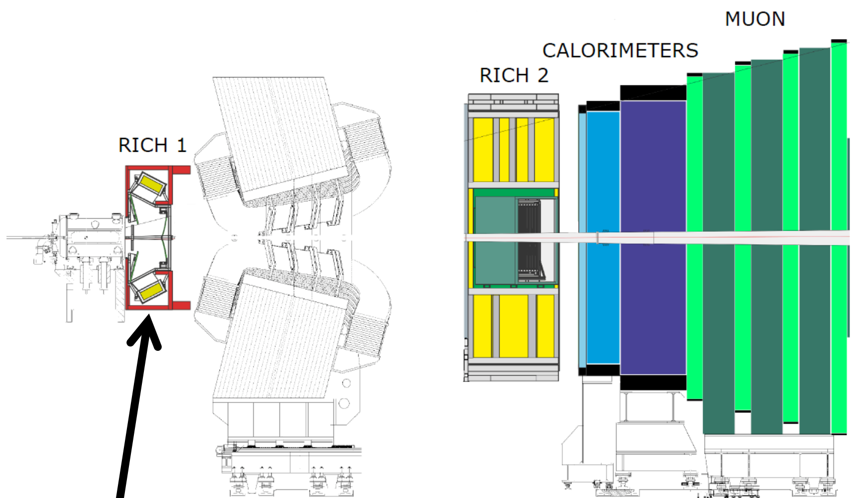


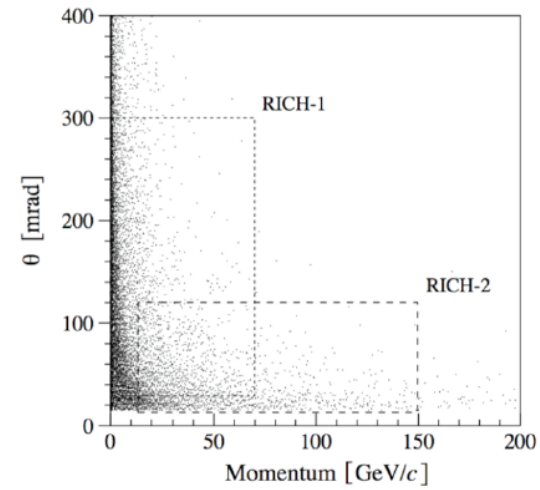
- Fibers: 2.5 m long, 250 μm sci Fibers; mirror on one side
- Modules: 5 rows deep
- 12 layers: x & u, v & x
- Read out with SiPM outside the detector acceptance
- Challenges: radiation hardness, noise, mechanical precision

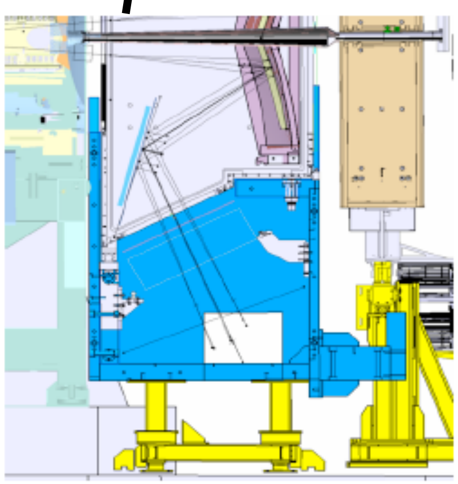


SiPM dark currrent is senstive to neutron fluence (expected ~ 6×10^{11} neq/cm2): Neutron shielding and cold (~ -50° C) operation required to extend lifetime.

RICH upgrade







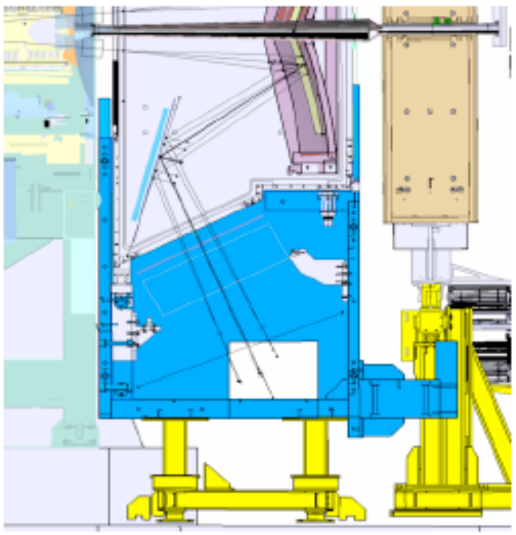
Current system:
- RICH1: Aerogel & C_4F_{10} gas radiator with HPD
- RICH 2: CF_4 gas radiator with HPD

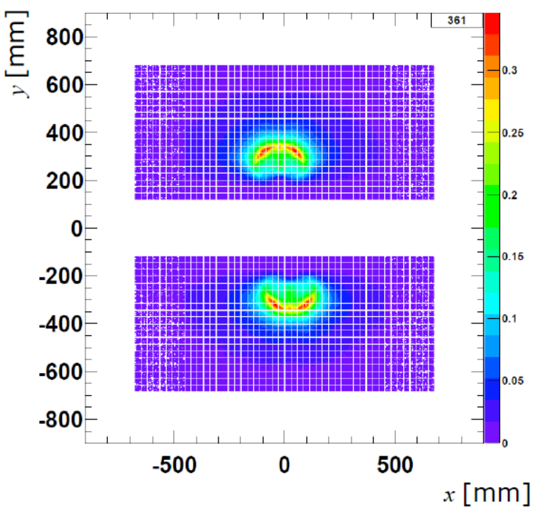
- Upgrade
- Remove Aerogel (too low p.e yield for upgrade conditions)
- Replace HPD(FE chip in HPD vacuum) with MaPMT
- Replace FE electronics for 40 MHz readout.

- Must reduce occupancy in inner region of RICH1: (expected >30%) New optics (increase radius of curvature of spherical mirror 2.7 →3.8 m) to spread the Cerenkov rings

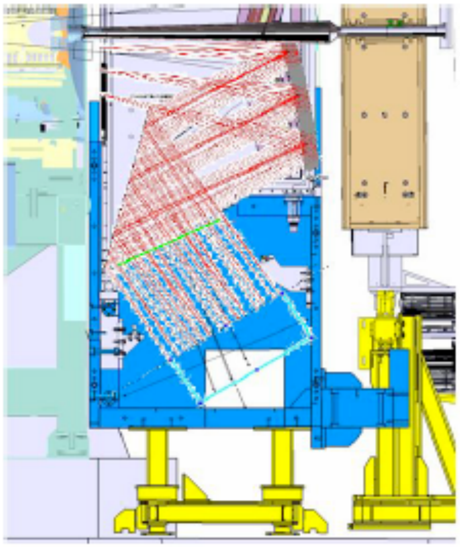
RICH upgrade (2)

Current RICH1 (ROC 2.7 m)

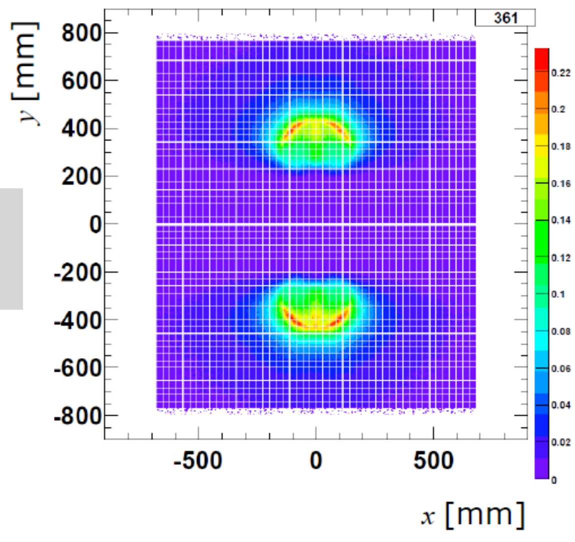




Upgrade RICH1 (ROC 3.8 m)



Occupancy in hot region
30% → 20%

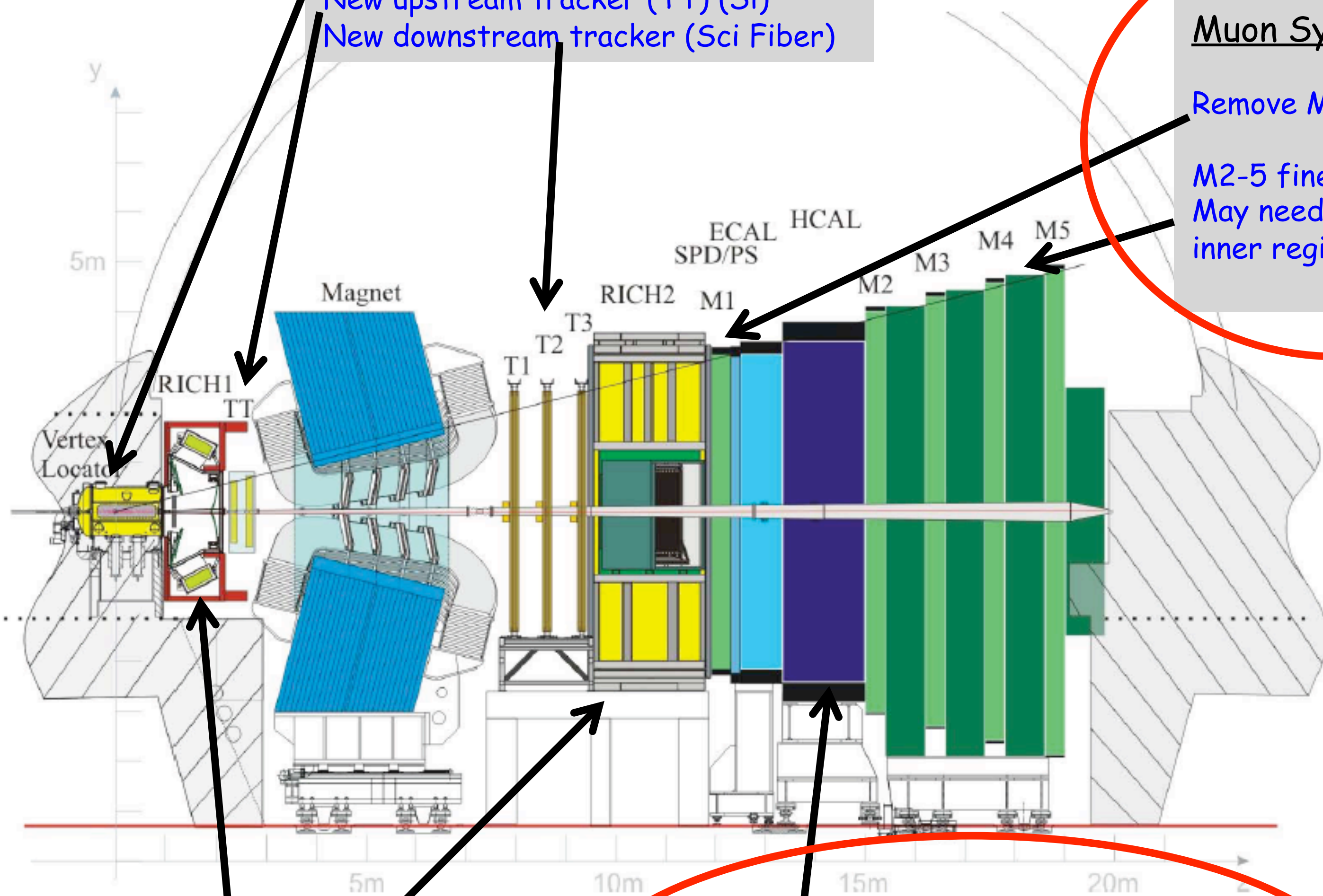


Tracking system:
New VELO (Si strip → Pixel)
New upstream tracker (TT) (Si)
New downstream tracker (Sci Fiber)

Muon System:

Remove M1

M2-5 fine for 1×10^{33}
May need upgrade of inner region at 2×10^{33}



RICH 1 & RICH 2
HPD→ MaPMT
New 40 MHz R/O
RICH1: new optics
remove aerogel

Calorimeter:
New 40 MHz R/O
Lower PMT gain to reduce anode current
Remove SPD & PS

The schedule of the LHCb upgrade

P.Campana

2013-14 Long Shutd. 1 / LHCb maintenance, first infrastructures for upgrade
2015-17 LHCb data taking (13-14 TeV) / 40 MHz protos in test
2018-19 Long Shutd. 2 / LHCb upgrade [Atlas/CMS upgrades phase 1]
≥ 2019 Upgraded LHCb in data taking (14 TeV)

- LHCb Upgrade preparation

2013 R&D, technological choices, preparation of subsystems TDRs
2014 Funding/Procurements
2015-19 Construction & installation

"Framework TDR for the Upgrade" submitted to LHCC and F. Agencies in June 2012
→ European Strategy doc. : Flavor Physics (LHCb) is part of future exploitation of LHC
→ The Upgrade has been endorsed (for approval) by the LHCC in September 2012
→ CERN Research Board has approved the LHCb upgrade at the end of 2012
→ Upgrade TDRs ready by December 2013 - March 2014

Two documents prepared for the European Strategy Group for Particle Physics:

- LHCb collab. – The LHCb Upgrade – LHCb-PUB-2012-008
- LHCb collab. & 40 theorists – Implications of LHCb measurements and future prospects - LHCb-PUB-2012-009 (to be updated by the end of 2013)

Summary

- LHCb detector & its trigger concept as a powerful flavor experiment has now been successfully demonstrated and operated at LHC:
  - It operated at 4xdesign luminosity and higher interaction/crossing, with excellent detector performance- at about the design level.

- The current physics output has already left a major mark on the search for New Physics through rare flavor processes:
  - Precision tests of NP in B^0_s mixing: ϕ_s & A^s_{sl} & First evidence for $B^0_s \rightarrow \mu^+\mu^-$
  - Has significantly constrained the parameter space of many NP scenarios.

- The LHCb- including the upgrade program- will remain a central element of the overall LHC program for NP search. (A message that has emerged from many studies, including last year's intensity frontier workshop).
  - Planning for LHCb upgrade is progressing well- now in R&D and design stage & funding planning.

- The US effort has had major impact on the program thus far. The recently strengthened group (4 institutions) also has a major role in upgrade of the tracking system.