QCD@Work 2014
Giovinazzo

# Latest LHCb Result

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on behalf the LHCb Collaboration

# The LHCb Experiment

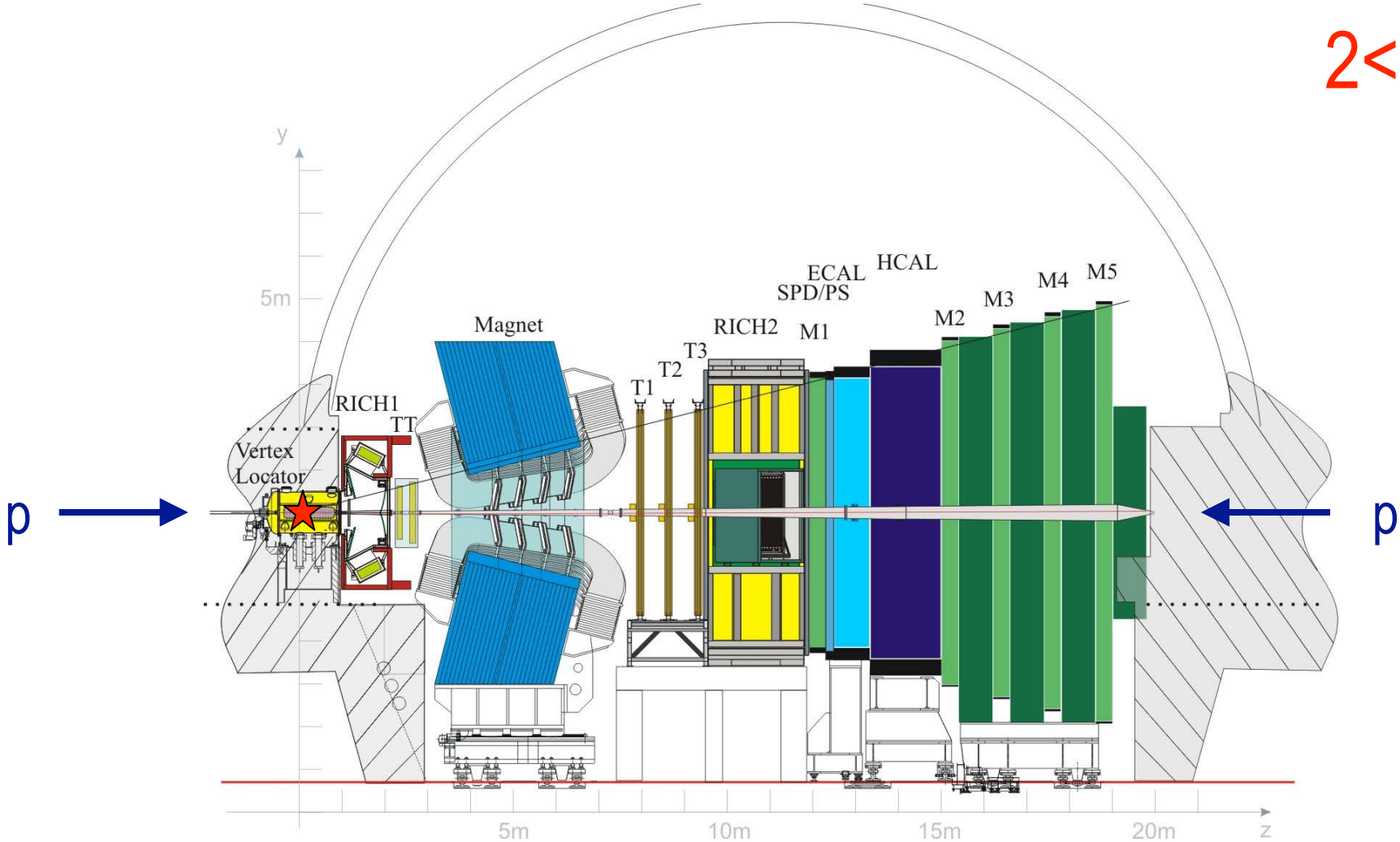
Rare B decays
CP violation
Charm Physics
Exotic Spectroscopy
QCD and Electroweak

~900 physicist from 64 universities/labs in 16 countries
Running since 2010, 191 papers published
O(100k) bb pairs produced per second

# The LHCb Detector

JINST(2008)3:S08005

$2<\eta<5$



# The LHCb Detector

Vertex

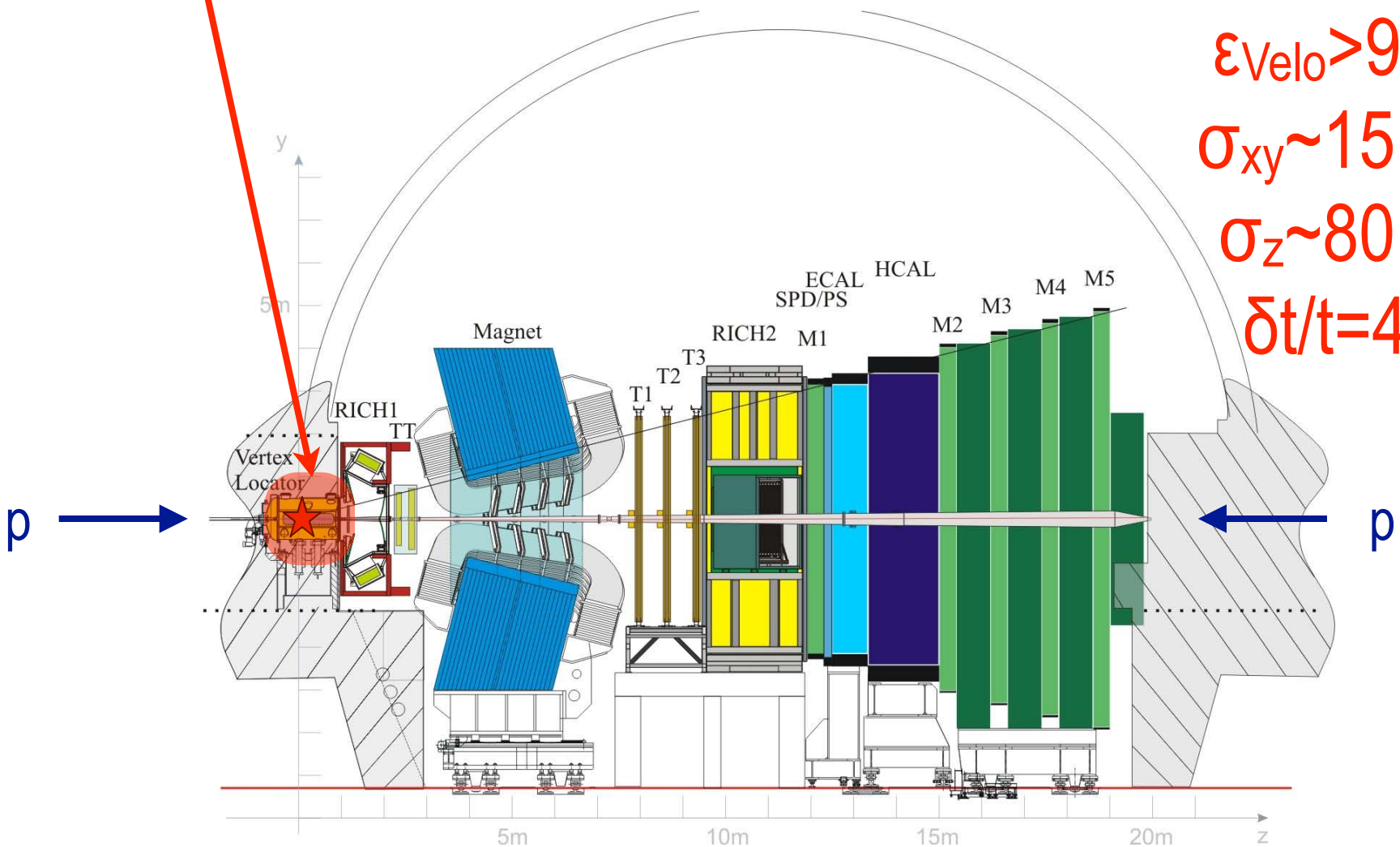
$\sigma(IP)\sim 20\mu m$

$\varepsilon_{Velo}>98\%$

$\sigma_{xy}\sim 15\mu m$

$\sigma_z\sim 80\mu m$

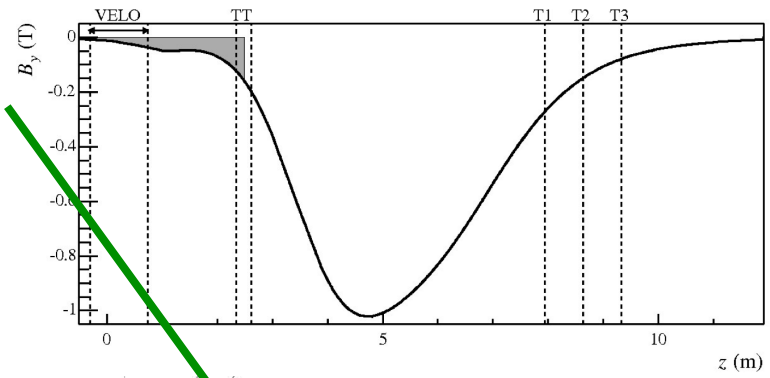
$\delta t/t=45fs$

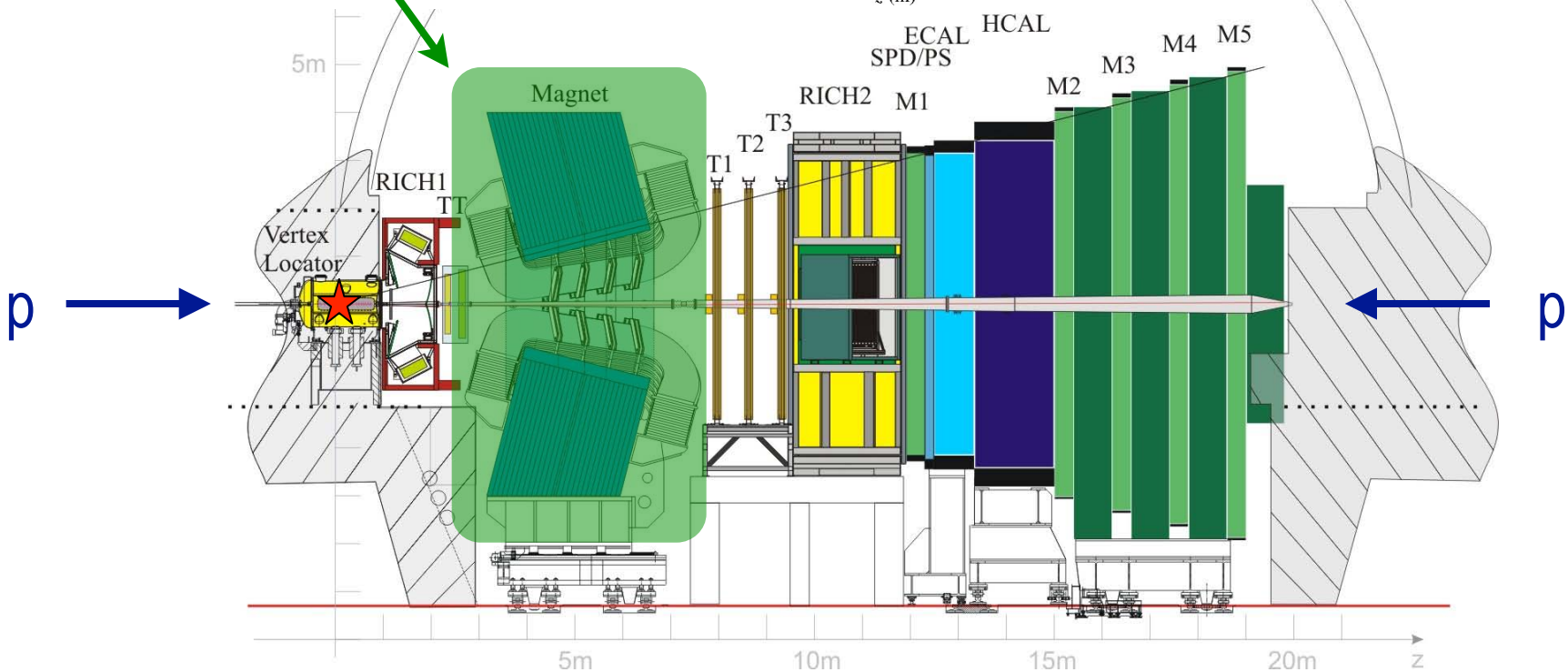


# The LHCb Detector

Vertex Magnet

$B_{max}$=1T



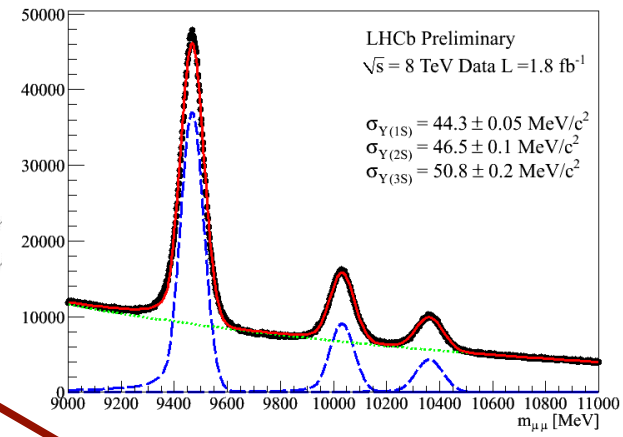



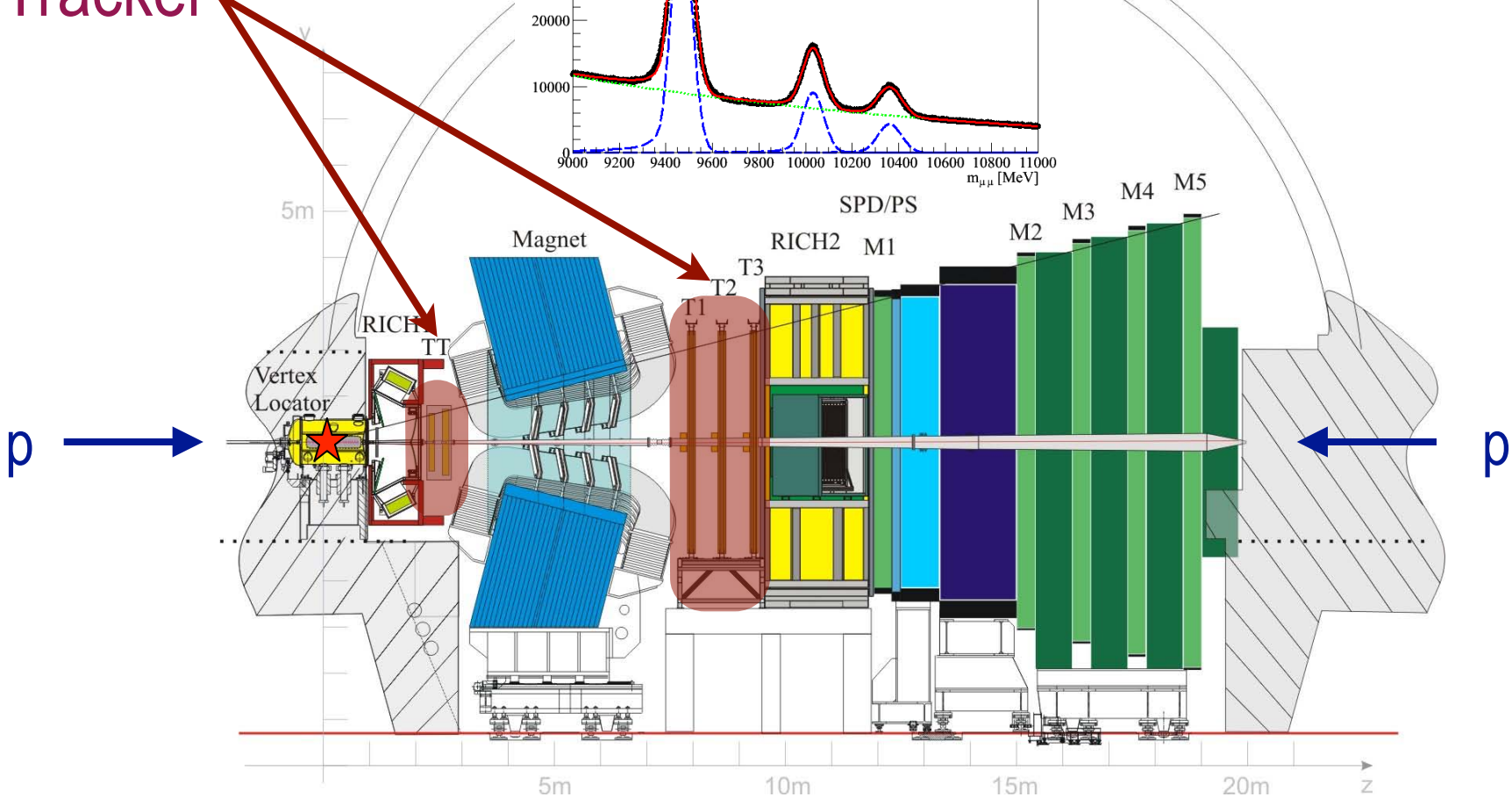
# The LHCb Detector

Vertex
Magnet
Tracker

$\delta p/p = 0.4\text{-}0.6\%$

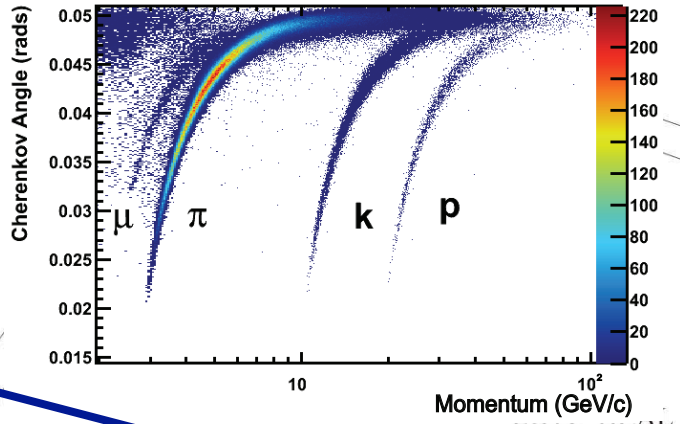
$\varepsilon_{track} > 95\%$



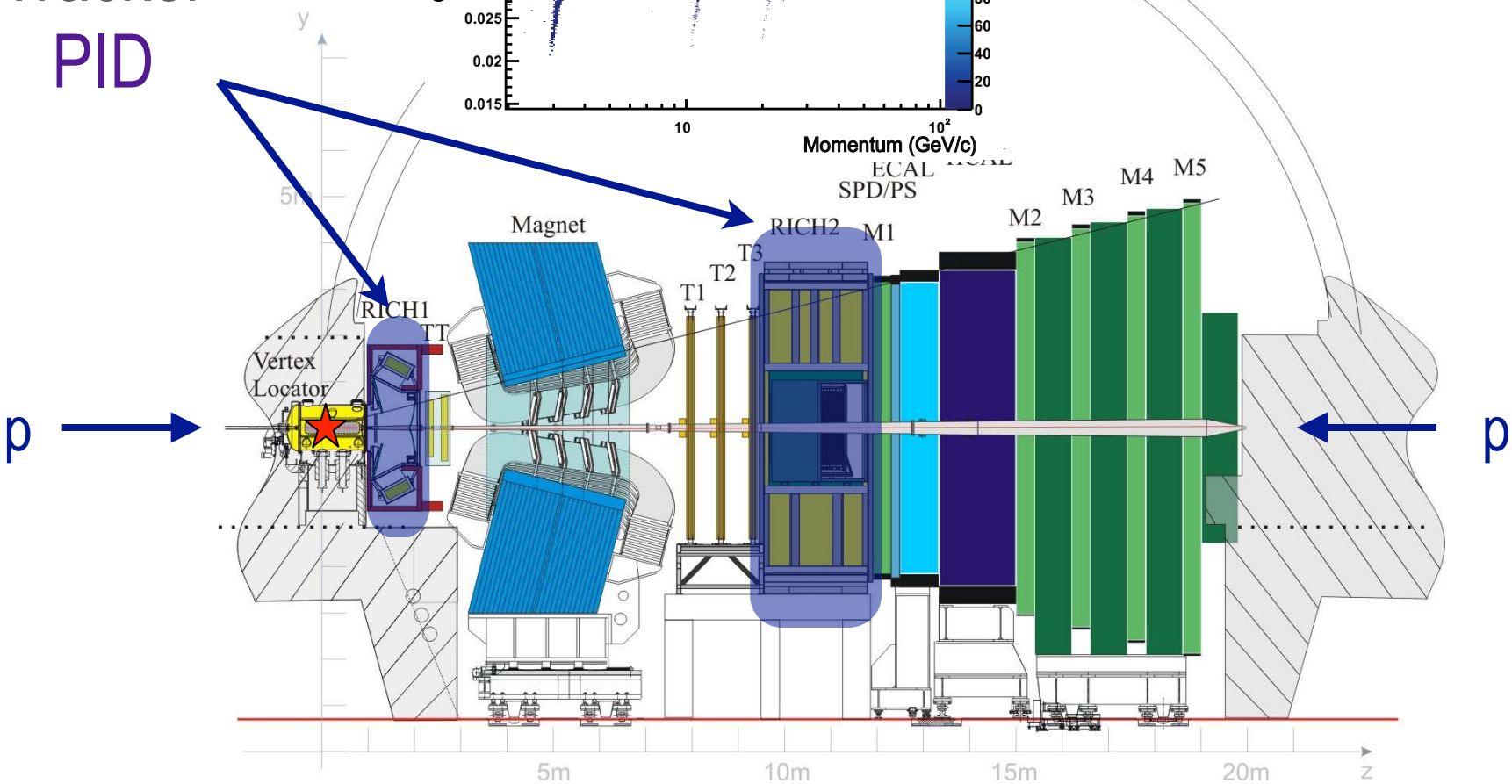
# The LHCb Detector

Vertex
Magnet
Tracker
PID




$\varepsilon_{PID}(K)\sim95\%$

$MisID(K\rightarrow\pi)\sim5\%$



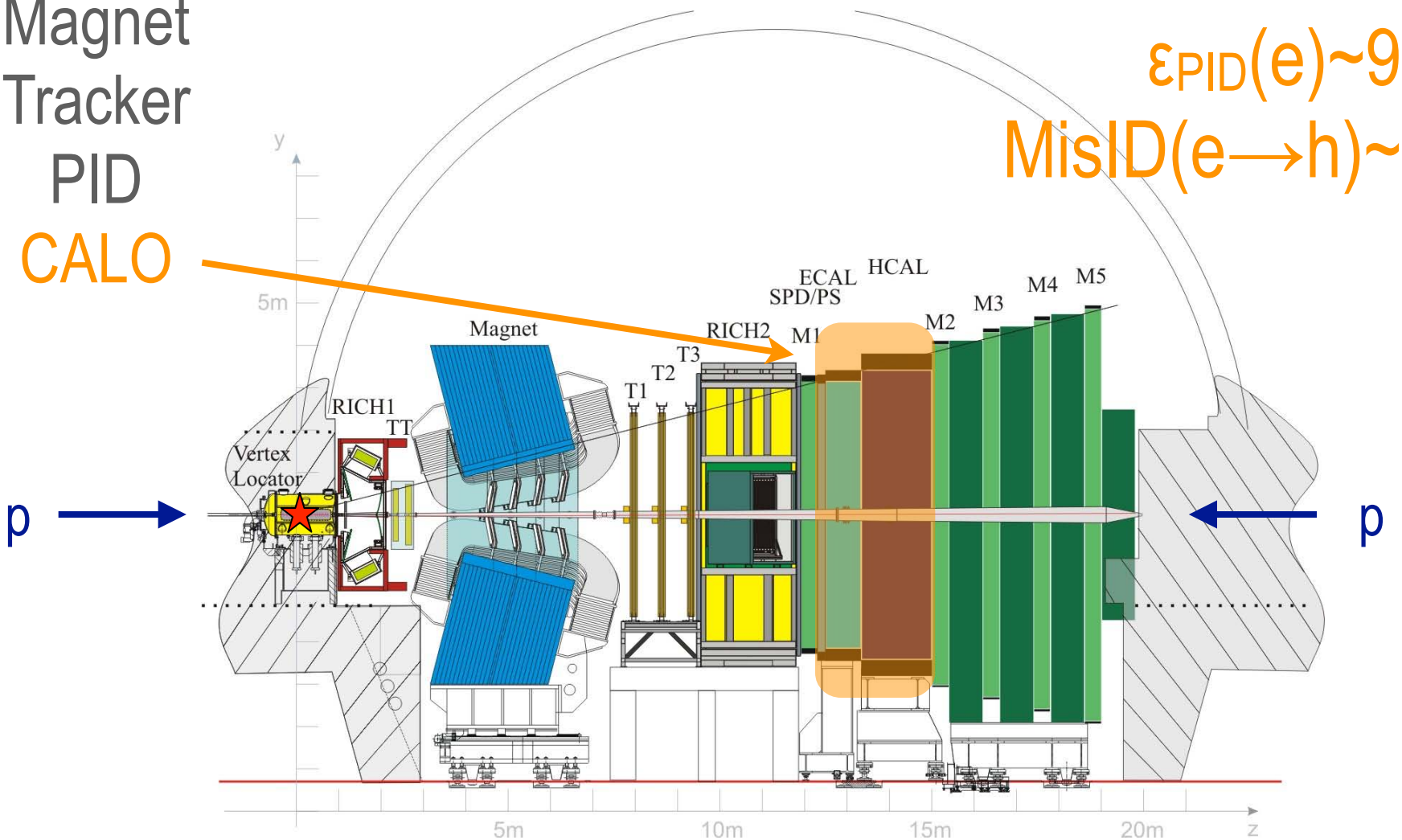
# The LHCb Detector

Vertex
Magnet
Tracker
PID
CALO

$\delta E/E = 1\% + 10\%/\sqrt{E}$

$\varepsilon_{PID}(e) \sim 90\%$

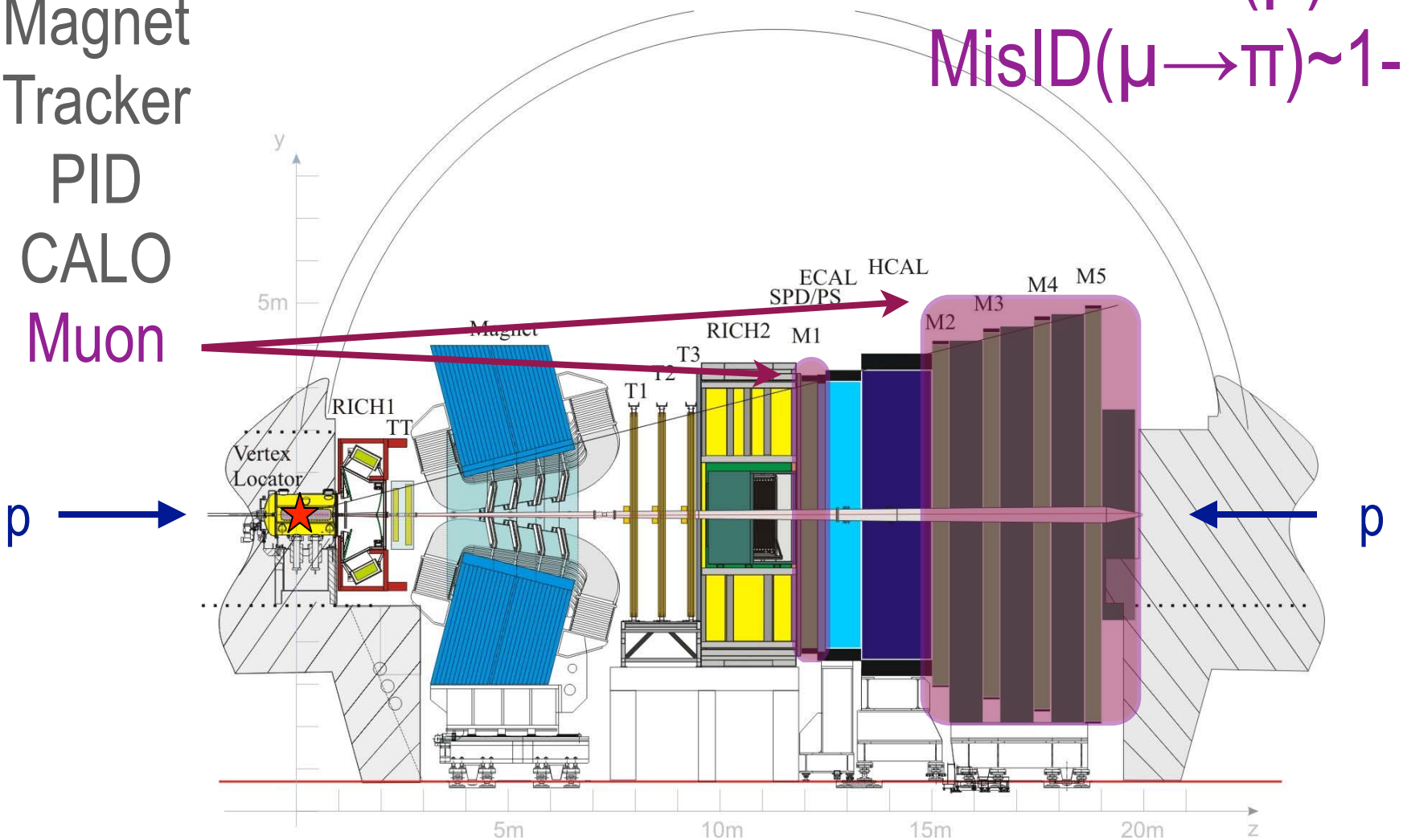
$MisID(e \rightarrow h) \sim 5\%$



# The LHCb Detector

Vertex
Magnet
Tracker
PID
CALO
Muon

$\varepsilon_{PID}(\mu)$~97%
MisID($\mu \rightarrow \pi$)~1-3%



# The LHCb Detector - Trigger

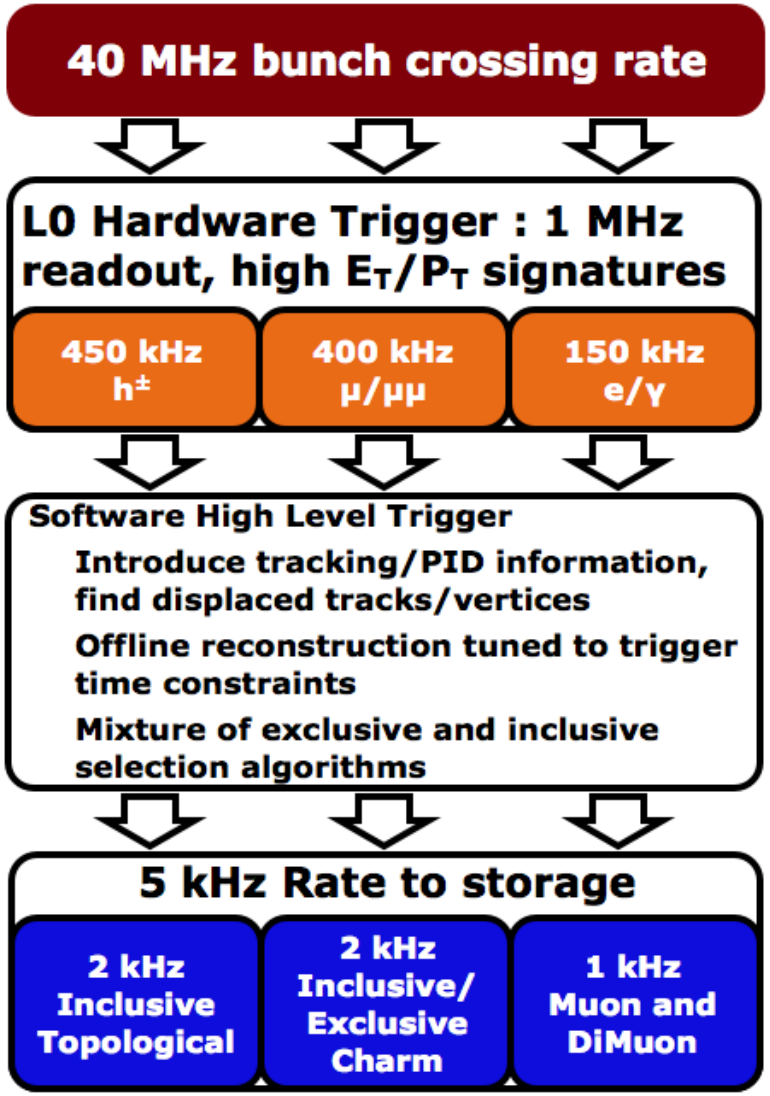
## Two stages trigger

- **Hardware**
  - $E_T(h)>3.5GeV/c^2$
  - $p_T(\mu)>1.5GeV/c$
  - $p_T(\mu_1)\cdot p_T(\mu_2)>(1.5GeV/c)^2$

  Reduce the rate from 40 MHz to 1MHz
  ~30(90)% efficient for h(μμ)

- **High-Level SoftwareTrigger**
  - **HLT1: track info, IP cuts**
  - **HLT2: tracking, selections**

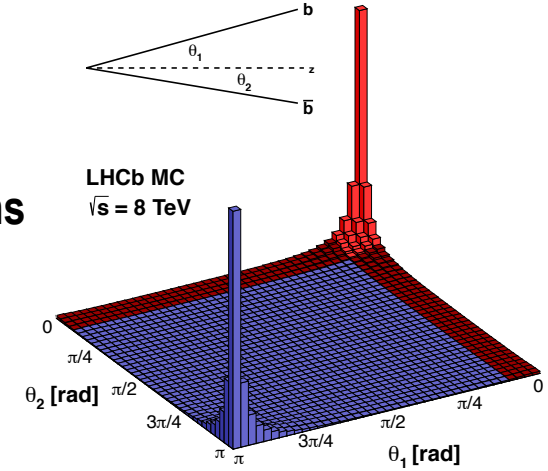
  From 1MHz to 5kHz to storage



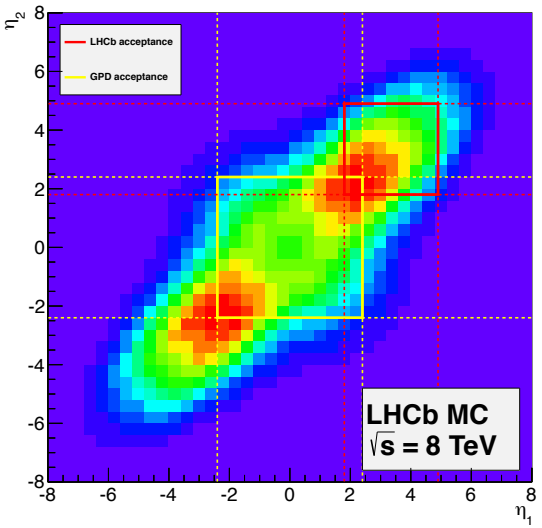
# LHCb Acceptance

## LHC is a flavor factory:

- Large $b\bar{b}$ and $c\bar{c}$ cross-sections from proton-proton collisions
- $b\bar{b}$ and $c\bar{c}$ pairs are produced mostly in the forward or backward regions

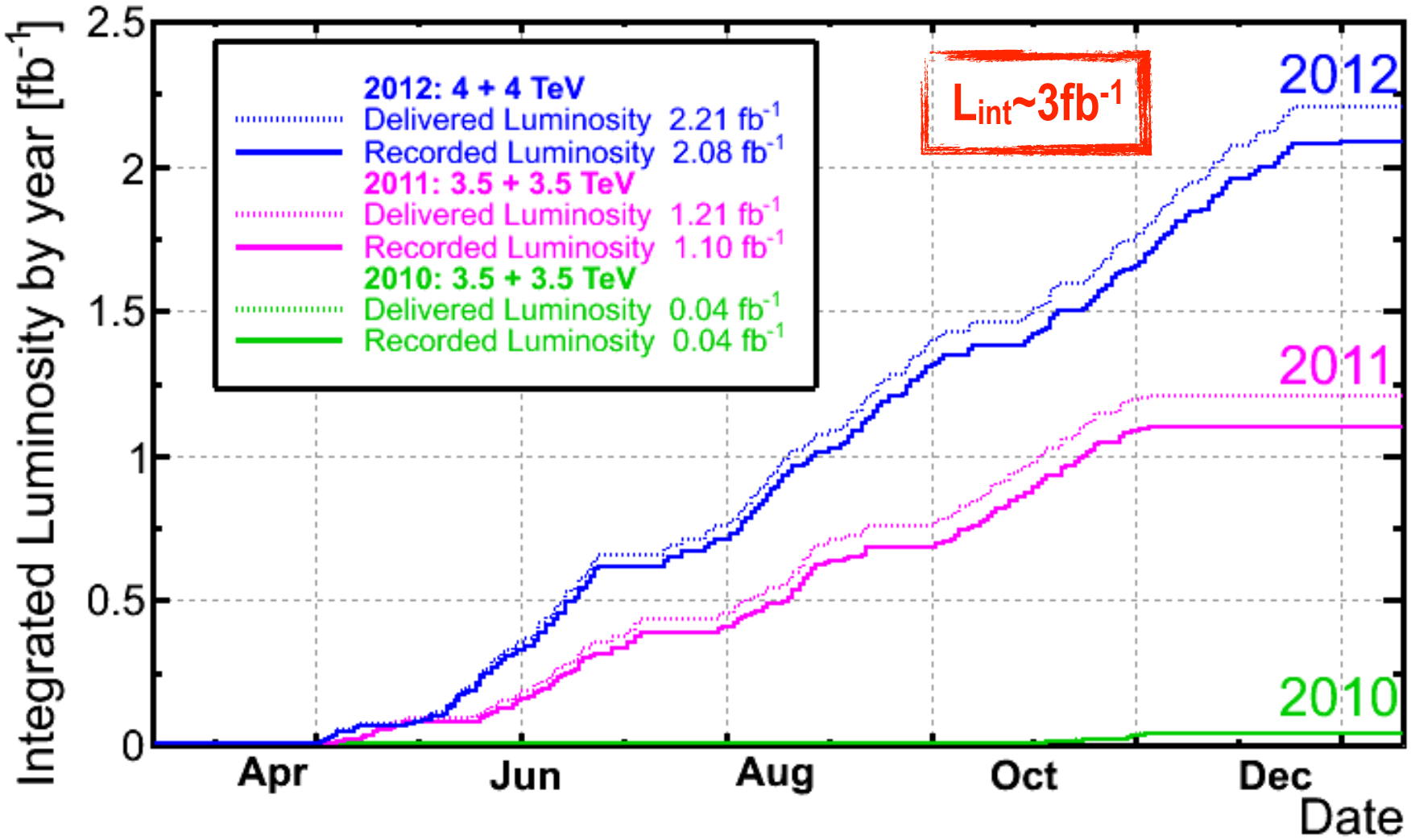



- LHCb covers ~4% of solid angle (2<η<5), corresponding to 40% the $b\bar{b}$ and $c\bar{c}$ cross-section
- Excellent tracking and particle identification performance provides high reconstruction efficiency




**LHCb is a forward detector to study flavour physics at LHC!**

# LHCb Data Sample



# The LHCb Experiment

## Target

- Search for New Physics in heavy flavour sector

## How?

- CP violation in B decays ($\gamma$, $\phi_s$)
- Rare decays of B and D mesons
- Exotics Spectroscopy
- Charm mixing and CP violation

# Overview

## Latest LHCb Results

- **Quarkonium**
  The $Z^+(4430)$ and light mesons
- **Rare Decays**
  $b \longrightarrow s$ transitions
- **Poorly Known Particles**
  $B_c^+$ and b baryons
- **Precision Physics**
  CP Violation in Charm

# Quarkonium - The Z(4430)$^-$

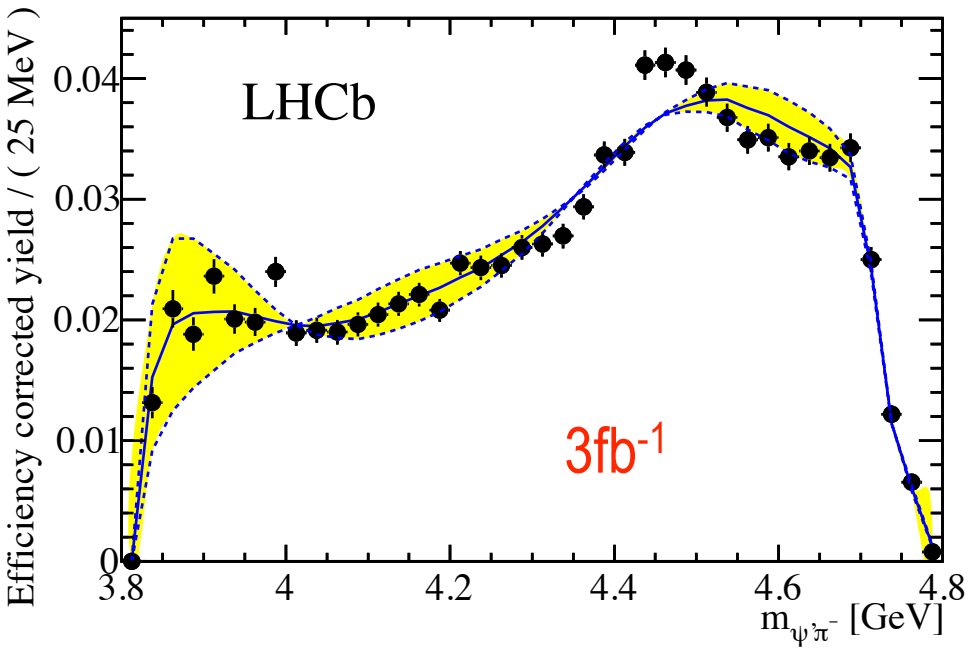
PRL112(2014)222002

## The story so far (2008-2014)

- **Belle observed evidence for Z(4430)$^-\to\psi'\pi^-$ in $B^0\to K^+\pi^-\psi'$ decays**
  PRL100(2008)142001
- **Minimal quark content $c\bar{c}d\bar{u} \Longrightarrow$ exotic state!**
- **BaBar never confirmed, the BaBar spectrum could be described with K* reflections in model independent analysis**
  PRD79(2009)112001

## 2014: LHCb in the game

- **A model independent approach like BaBar does not describe the data in Z$^-$ region**
  Any known $K^*\to K^+\pi^-$ resonance up to J<2 included to draw $\psi'\pi^-$ shape from simulations



# Quarkonium - The Z(4430)$^-$

## Model dependent fit

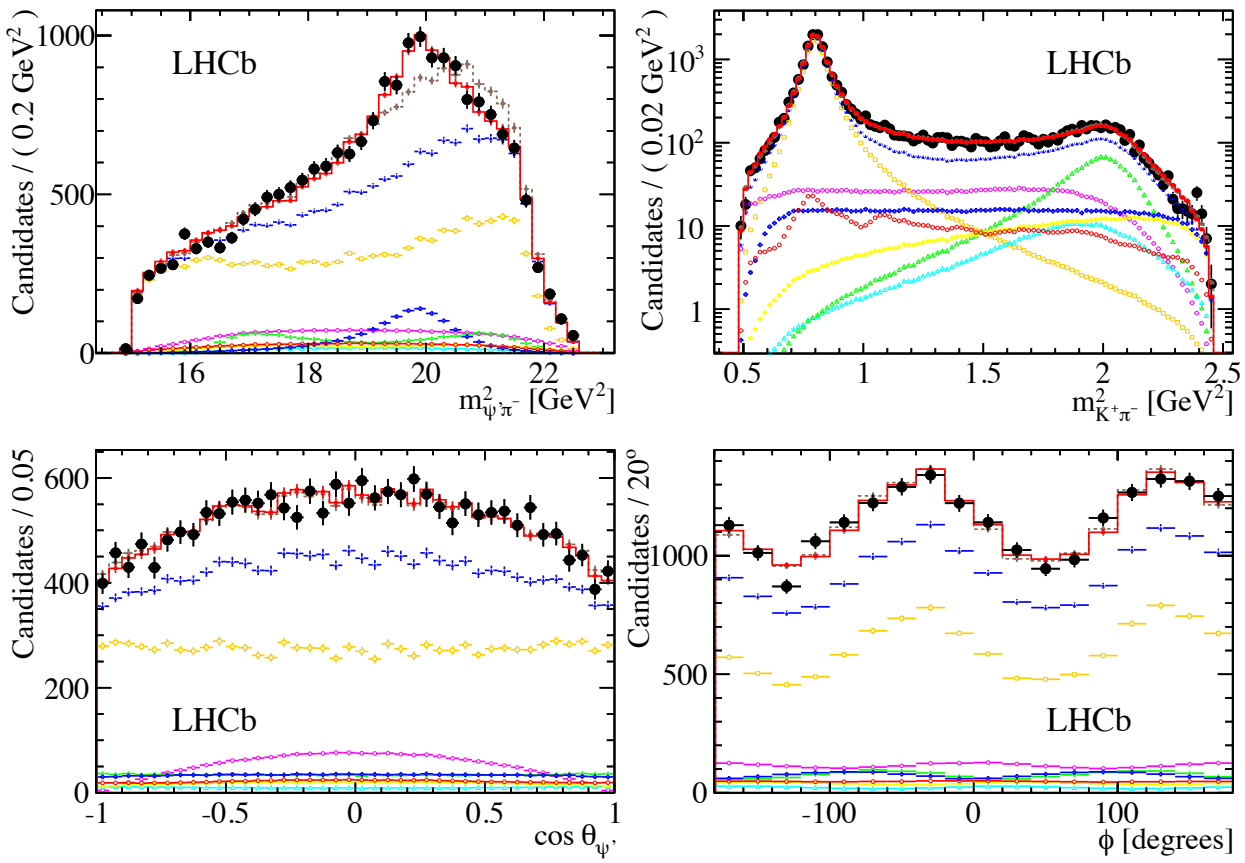
- **A 4D amplitude analysis is performed adding the Z(4430)$^-$ with $J^P=1^+$**
  $[m^2(\psi'\pi^-), m^2(K^+\pi^-), \cos\theta_{\psi'}, \phi]$

- **K* resonances up to K*(1680)**

- **Many models tested with different number of K*'s**
  $Z^-$ significance in [13.9,18.7]σ

- **Nominal fit results consistent to Belle**
  but more precise!

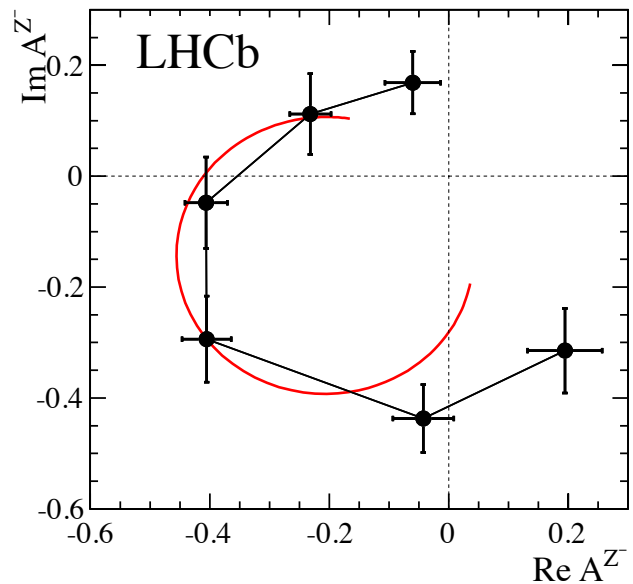
- **$0^-$ spin excluded in favour of $1^+$ at 25.7σ**



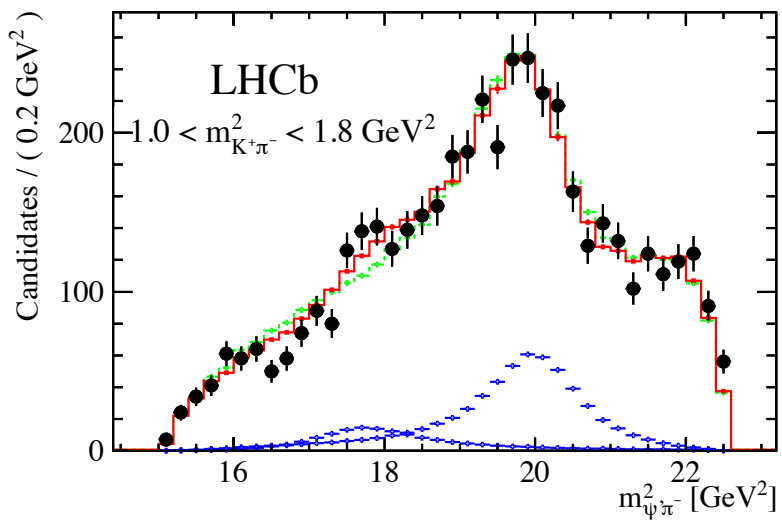
# Quarkonium - The Z(4430)$^-$

## Resonant Nature

- **The resonant nature of the structure is confirmed by the Argand diagram**
  It well matches the shape of a Breit-Wigner with m=4475,Γ=172 MeV
- **Indication of a structure at 4.1GeV ($Z_0^-$?)**
  Best fit with a Breit-Wigner with m=4239,Γ=220 MeV
- **Argand plot for $Z_0^-$ is not conclusive**
  Waiting for larger sample




$$M(Z_1^-)=4475\pm7^{+15}_{-25}\ \mathrm{MeV}/c^2$$
$$\Gamma(Z_1^-)=172\pm13^{+37}_{-34}\ \mathrm{MeV}/c^2$$

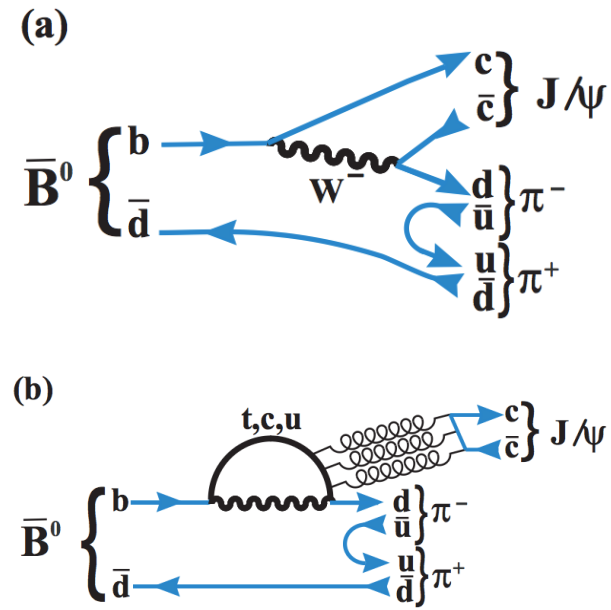


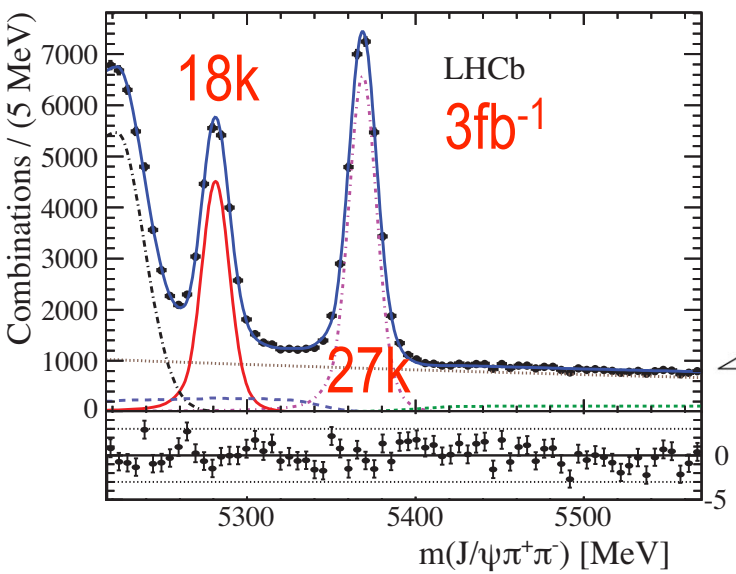
# $B^0 \to J/\psi \pi^+\pi^-$

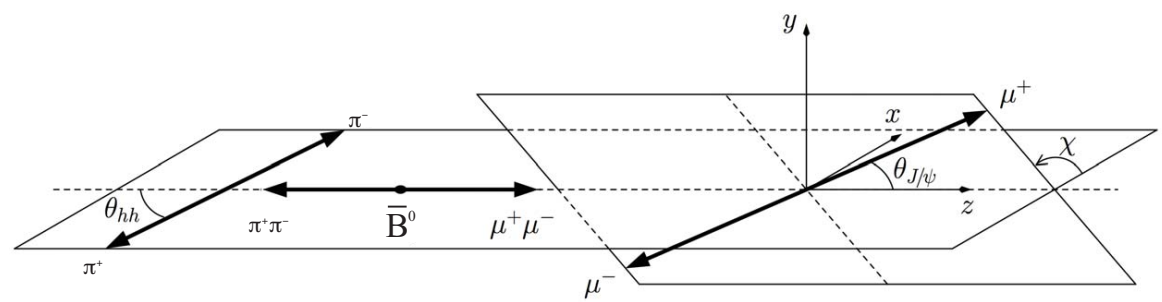
arXiv:1404.5673

## A multi-purpose channel

- **Study CP phases and compare to $B^0 \to J/\psi\rho$, $B^0 \to J/\psi K^0_S$**
  See Sevda talk on Wednesday
- **Extract information about substructure of light mesons decaying to $\pi^+\pi^-$**
  Amplitude analysis for extracting $m(\pi^+\pi^-)$ spectrum components and CP violating amplitudes
- **Angular analysis**
  $m(\pi^+\pi^-)$, $\cos\theta_{\pi\pi}$, $\cos\theta_{J/\psi}$, $\chi$



## $f_0(980)$ and $f_0(500)$: $q\bar{q}$ or tetraquarks?

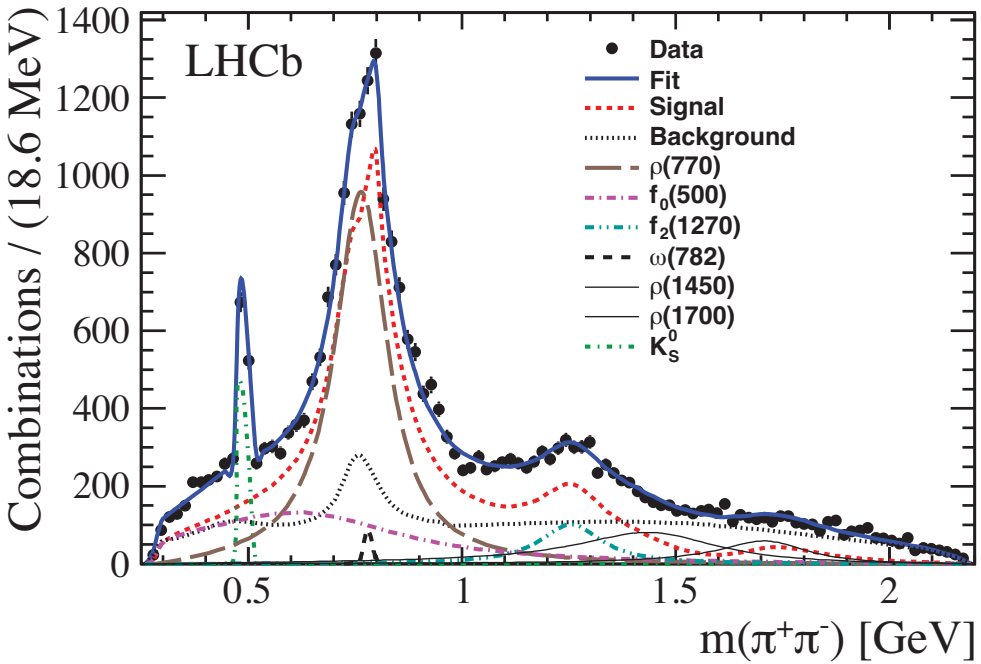
- **If tetraquarks $r_\sigma^f = 1/2$**
  Stone et al. PRL111(2013)062001

$$\tan^2\varphi_m \equiv r_\sigma^f = \frac{\mathcal{B}\left(\overline{B}^0 \to J/\psi\, f_0(980)\right)}{\mathcal{B}\left(\overline{B}^0 \to J/\psi\, f_0(500)\right)} \frac{\Phi(500)}{\Phi(980)}$$

## Results

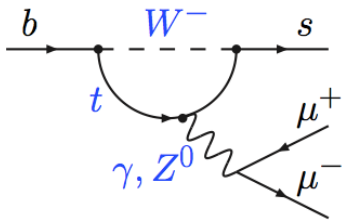
- **6 interfering states**
- **No $f_0(980)$ found**
  Limit on $|\varphi_m|<17^\circ$ @90% C.L.
  LHCb disfavours tetraquark interpretation at ~8σ

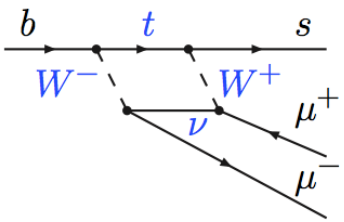
- **CP violation**
  The CP-even components sum up to (56.0±1.4)%



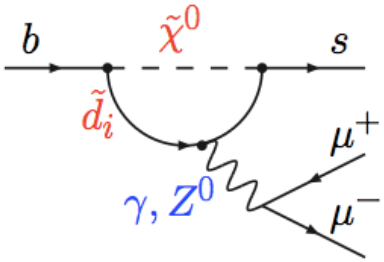
# Flavor Changing Neutral Currents in b→s transitions

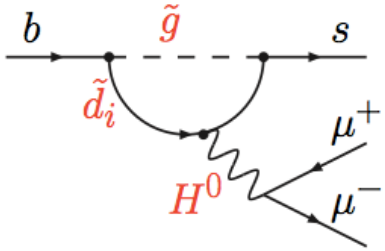
## Standard Model

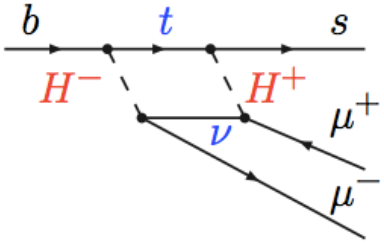


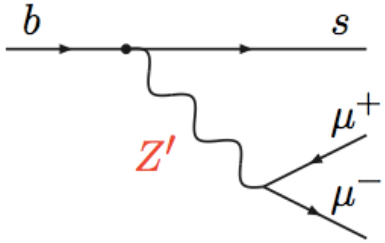




## New Physics (one loop+tree level)




**Sensitivity to the different SM and NP contributions through decay rates, angular observables and CP asymmetries**

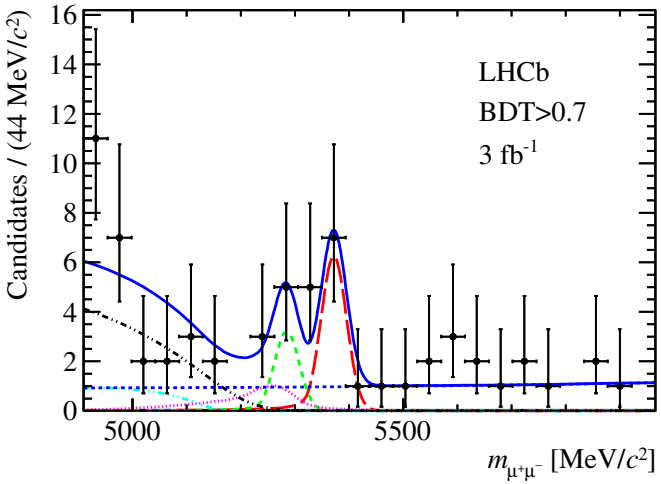
# $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$

LHCb: PRL111(2013)101805
CMS: PRL111(2013)101804

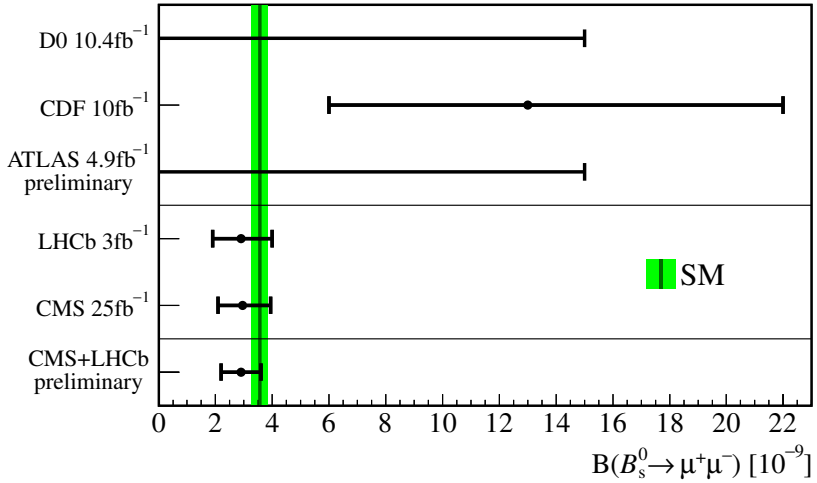
## Why are they so interesting?

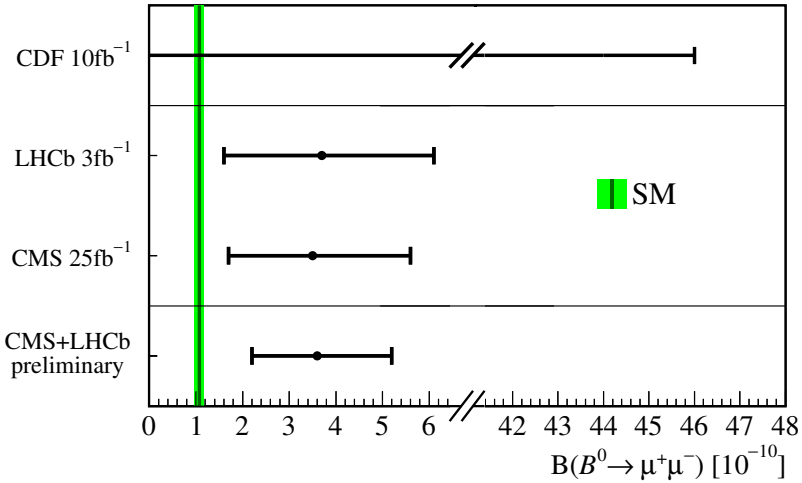
- **GIM (loop) and helicity suppressed in the SM**
- **Sensitive to contributions from (pseudo)scalar sector**
  Interesting probe for NP models with extended Higgs sector (e.g. MSSM, 2HDM, …)
- **Predicted precisely in SM** Bobeth et al. PRL112(2014)101801
  $B^0$ suppressed by $|V_{td} / V_{ts}|^2$

$$\mathcal{B}(B_s \to \mu^+\mu^-) = (3.65 \pm 0.23) \times 10^{-9}$$




- **LHCb and CMS saw evidence of $B_s^0$ decay placing strong constraints to BSM**
- **Small tension wrt SM for $B^0$**



# FCNC in b→s transitions: $B^0 \to K^{*0}\mu^+\mu^-$

PRL111(2013)191801

## Sensitive to indirect searches for NP

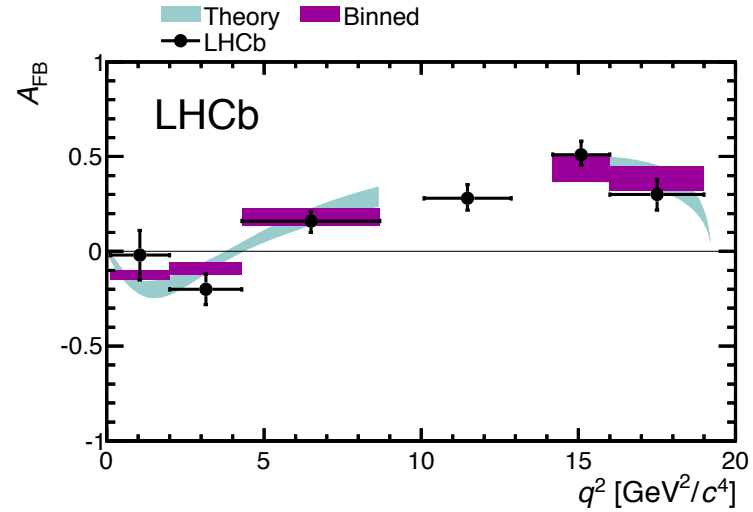
- **Large set of observables, mostly compatible with SM, but local tension observed in $P_5'$**

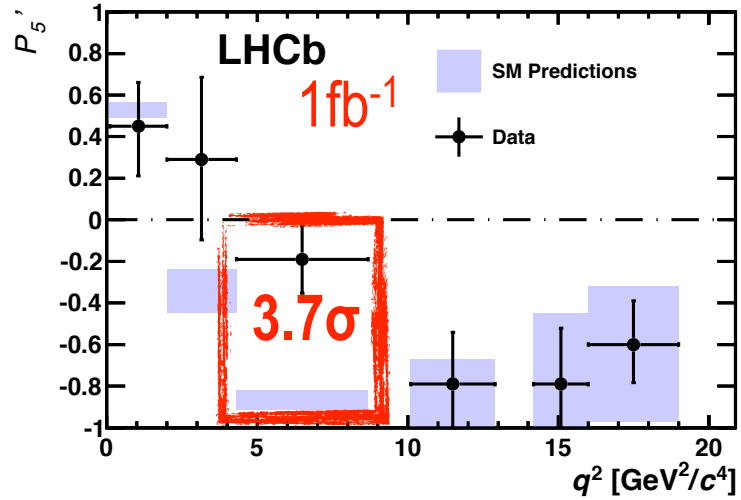
## Experiment

- **More data is needed**
  $3fb^{-1}$ analysis on its way
- **Need to study more b→sμμ decays and look for more observables**

## Theoretical Interpretations

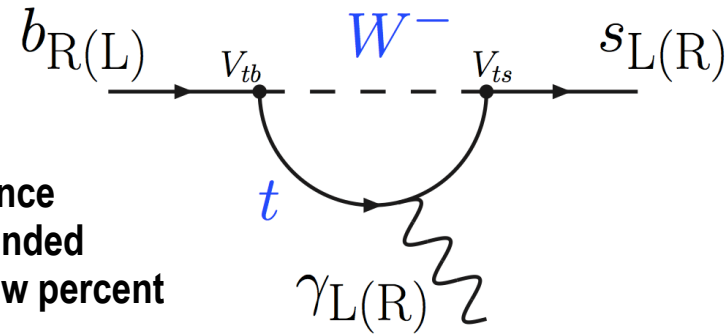
- **Underestimation of theoretical uncertainties**
  Beaujean et al. arXiv:1310.2478
  Jäger et al. arXiv:1212.2263
- **Difficult to explain with SUSY scenarios**
  Almannshofer et al. arXiv:1308.1501
- **Consistent to Z' at 7TeV mass**
  Straub JHEP1308(2013)108



# Photon Polarisation in $B^+ \to K^+\pi^+\pi^-\gamma$

PRL112(2014)161801

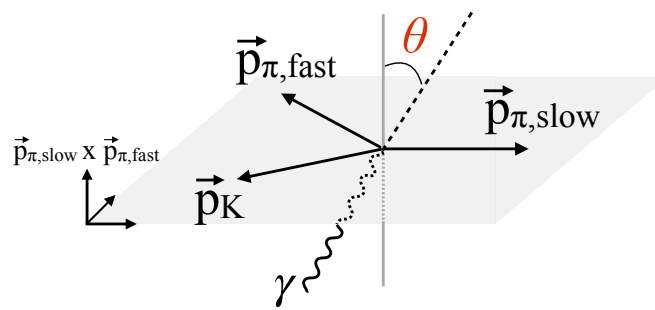



## Yet another b→s (loop) transition

- **SM: photon polarization is predominantly left-handed, since the recoiling s quark that couples to a W boson is left-handed**
- **Maximal parity violation holds in the SM up to within a few percent**
  up to corrections ~$m_s/m_b$
- **BSM: photon acquires appreciable right-handed component due to chirality flip in along a heavy fermion line in the electroweak loop process**
  e.g.: LR, $W_L$-$W_R$ mixing; MSSM, left-right squark mixing

## Inspired by classic

- **Measurement conceptually similar to Wu measurement of parity violation**
  In this case the polarisation angle of the photon is measured with respect to the normal to the plane of the K* daughters
- **Unpolarised photons would show no asymmetry**

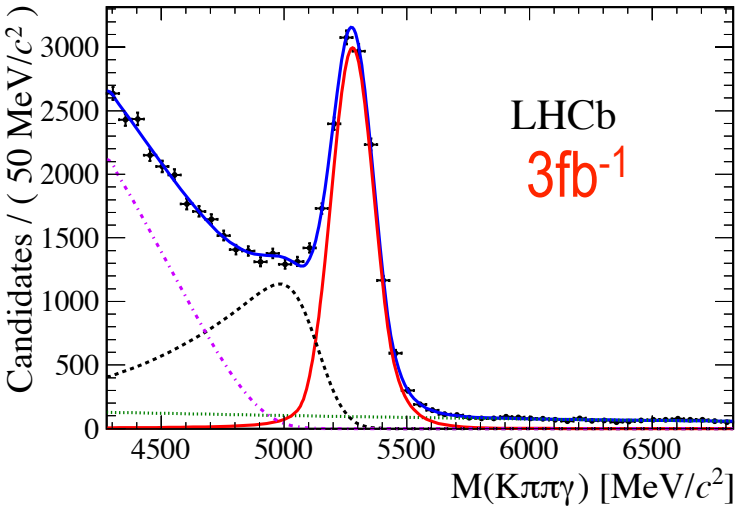


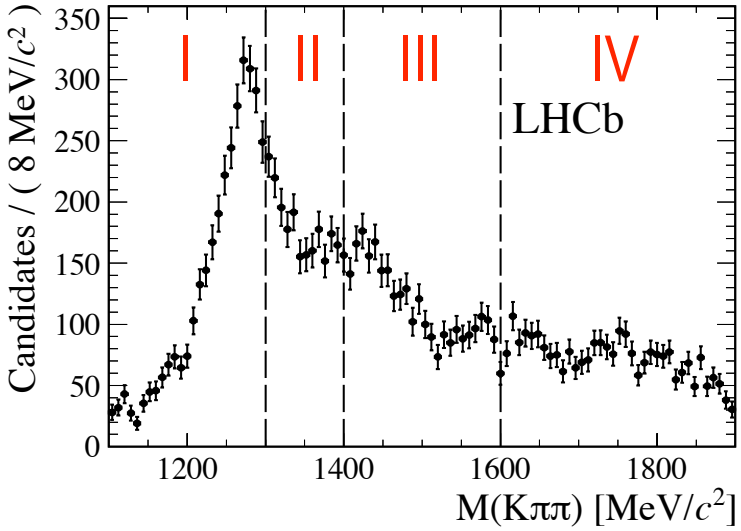
# Photon Polarisation in $B^+ \to K^+\pi^+\pi^-\gamma$

## Experimental challenges

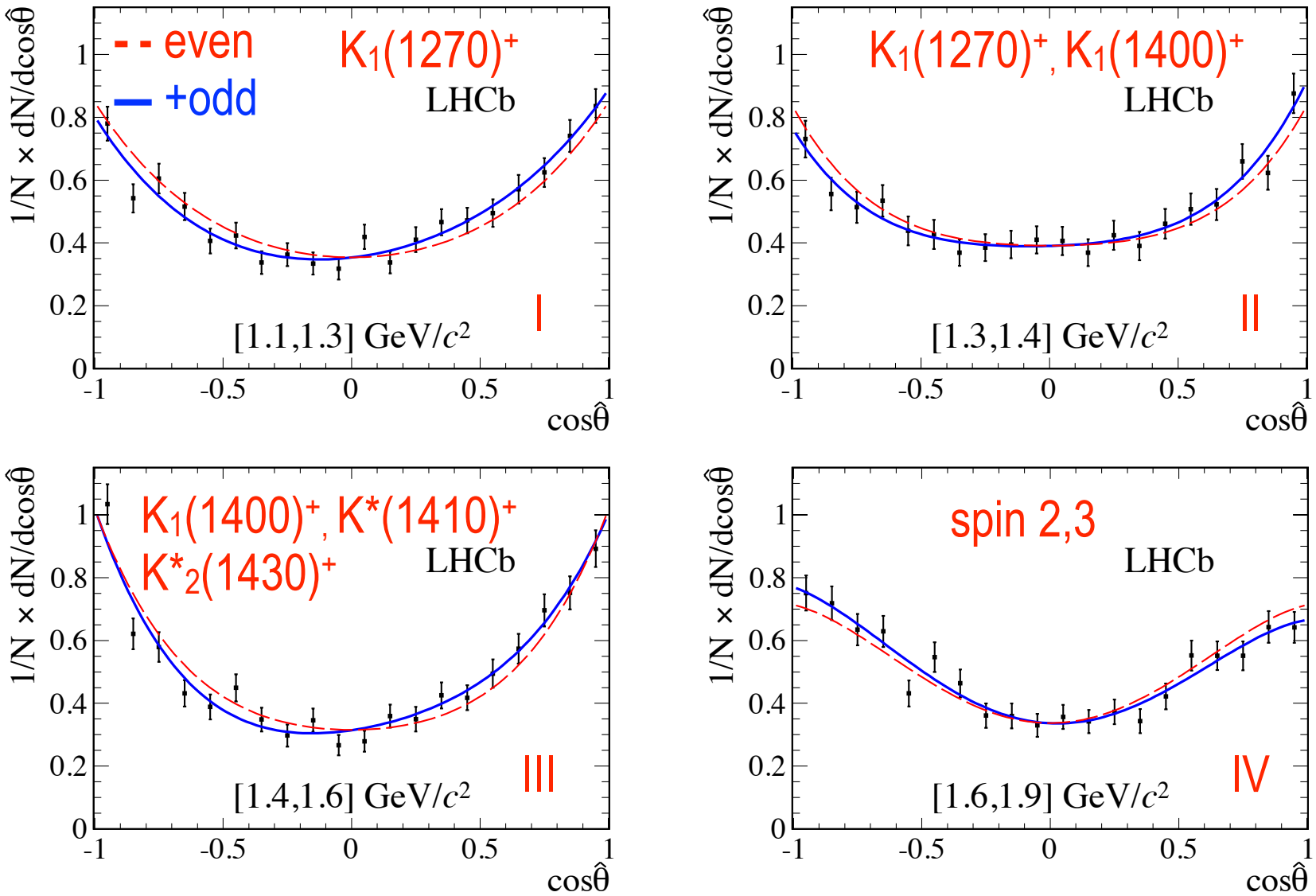
- **14k decays reconstructed at LHCb in 3fb$^{-1}$ data using calorimeter photons**
- **The $K^+\pi^+\pi^-$ mass spectrum is rich of resonances**
  $K_1(1270)^+$, $K_1(1400)^+$, $K_2^*(1430)^+$, $K^*(1410)^+$
- **Mass spectrum divided in four regions associated to the various resonance contributions**
- **Photon polarisation asymmetry measured in each bin of $K^+\pi^+\pi^-$ mass**
- **Background subtracted $\cos\hat{\theta}$ distribution described as**

$$f(\cos\hat{\theta}; c_0 = 0.5, c_1, c_2, c_3, c_4) = \sum_{i=0}^{4} c_i L_i(\cos\hat{\theta})$$



# Photon Polarisation in $B^+ \to K^+\pi^+\pi^-\gamma$ - Fit Results



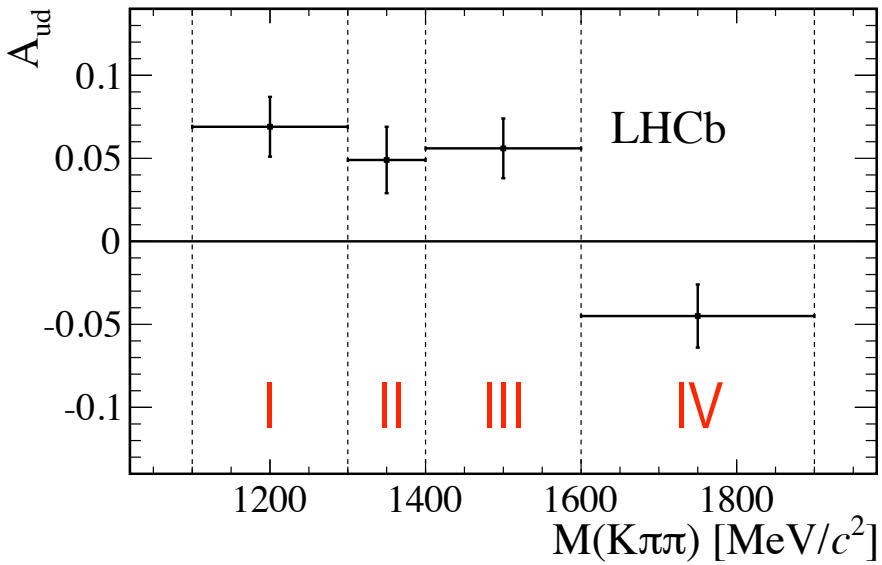
# Photon Polarisation in $B^+ \to K^+\pi^+\pi^-\gamma$ - Fit Results

## Asymmetry

- Asymmetry calculated as

$$A_{ud} = c_1 - \frac{c_3}{4}$$

First observation of photon polarisation with 5.2σ combined significance



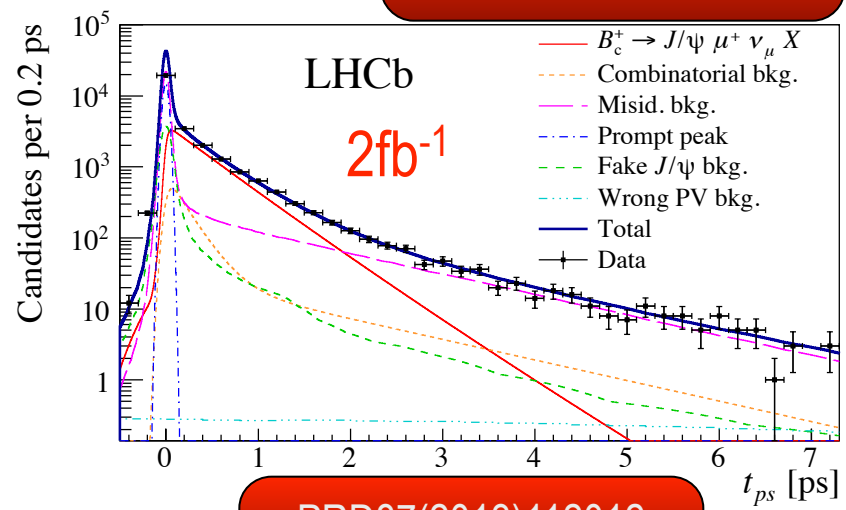

| | [1.1, 1.3] | [1.3, 1.4] | [1.4, 1.6] | [1.6, 1.9] |
|---|---|---|---|---|
| $c_1$ | 6.3±1.7 | 5.4±2.0 | 4.3±1.9 | −4.6±1.8 |
| $c_2$ | 31.6±2.2 | 27.0±2.6 | 43.1±2.3 | 28.0±2.3 |
| $c_3$ | −2.1±2.6 | 2.0±3.1 | −5.2±2.8 | −0.6±2.7 |
| $c_4$ | 3.0±3.0 | 6.8±3.6 | 8.1±3.1 | −6.2±3.2 |
| $\mathcal{A}_{ud}$ | 6.9±1.7 | 4.9±2.0 | 5.6±1.8 | −4.5±1.9 |

# $B_c^+$ Mesons

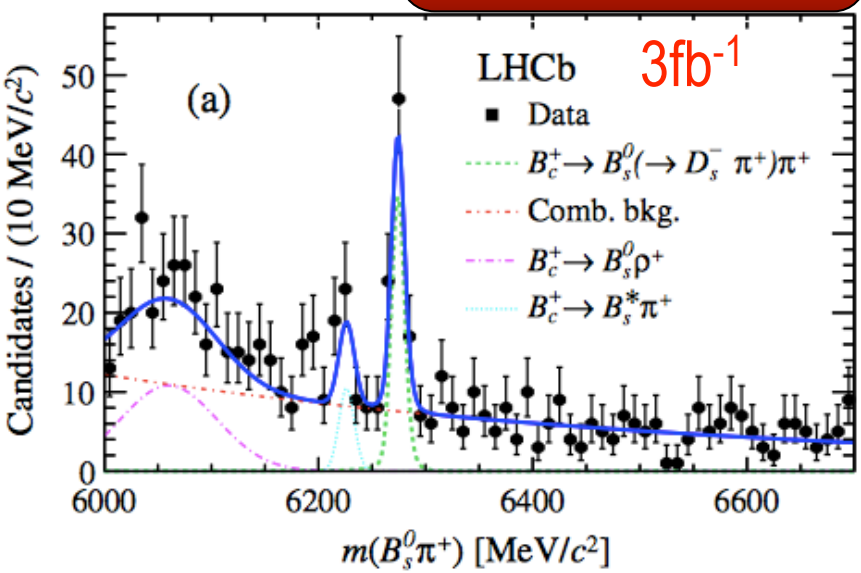
EPJC74(2014)2839

## LHCb is adding knowledge

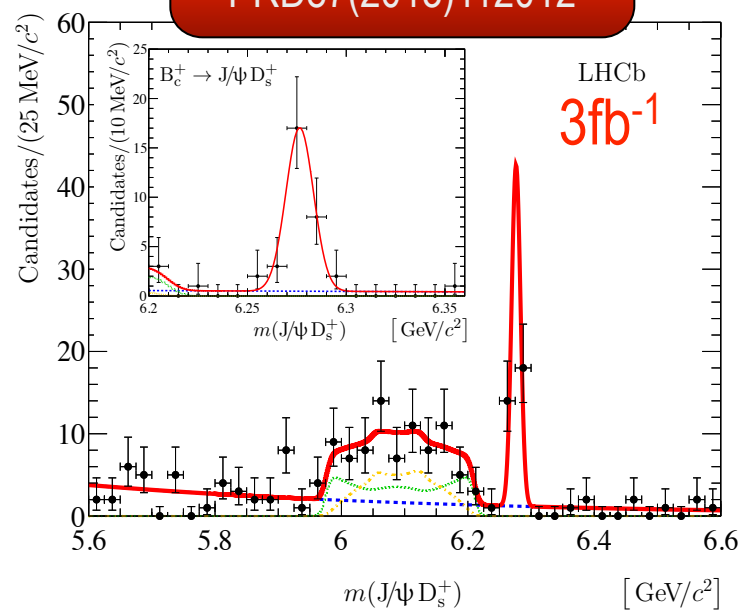
- **Many decay modes observed**
  Among which first weak B→B decay ($B_c^+ \to B_s^0 \pi^+$)
- **Most precise measurement of proper time to date**
  Using $B_c^+ \to J/\psi \mu^+ n_\mu X$
- **More to come…**




PRL111(2013)181801




PRD87(2013)112012

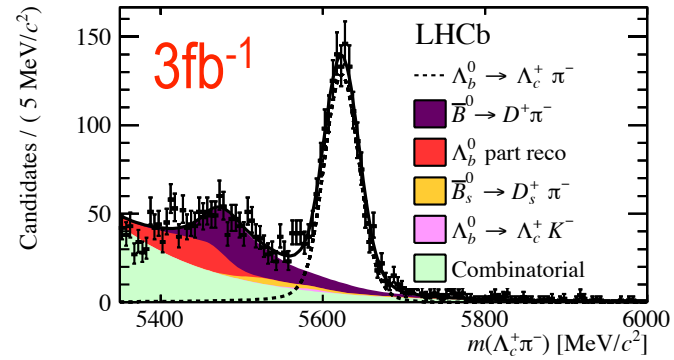


# $\Lambda_b^0 \to \Lambda_c^+ \pi^-$: $f_{\Lambda_b}/f_d$

arXiv:1405.6842

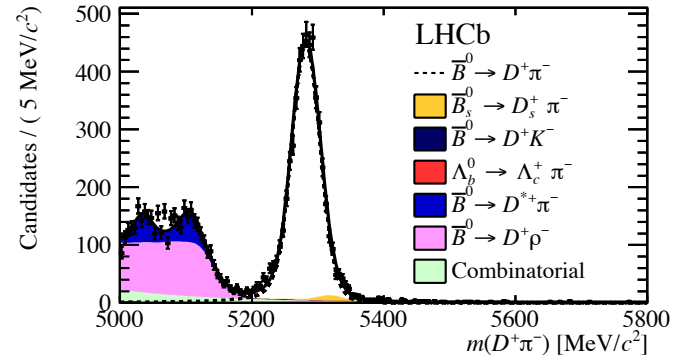
## Beauty Baryons

- Limited knowledge of production and decay properties
- Abundant production at LHC
- $f_{\Lambda_b}/f_d$ fundamental for improving $\Lambda_b$ BR measurements

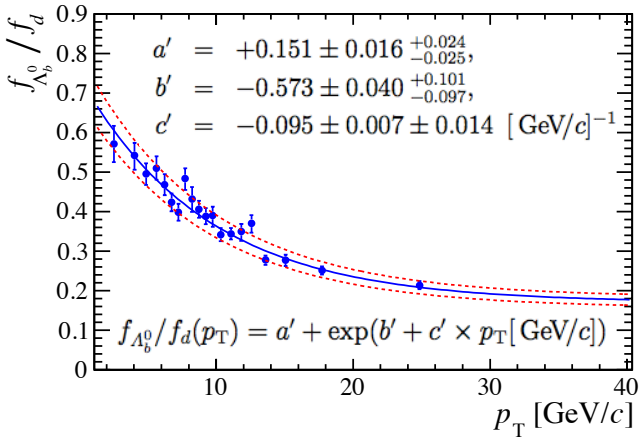


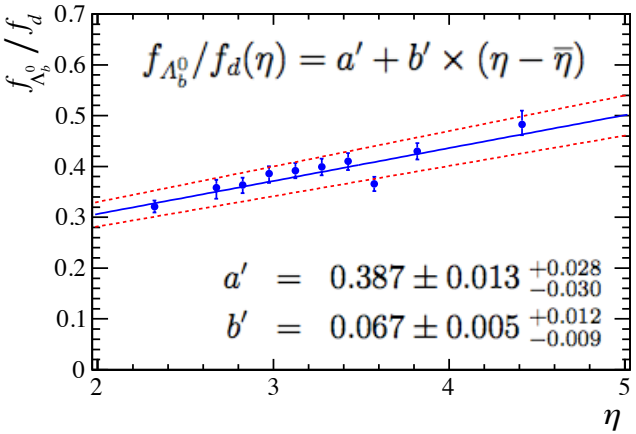

## LHCb

- Previous LHCb analysis with semileptonic decays showed clear dependence vs $p_T$
- Hadronic measurement improves on $p_T$ dependence
  Absolute $f_{\Lambda_b}/f_d$ measurement not competitive due to poor BR($\Lambda_b^0 \to \Lambda_c^+\pi^-$)
- External input allowed to make most precise BR($\Lambda_b^0 \to \Lambda_c^+\pi^-$) measurement to date




$$\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-) = \left(4.30 \pm 0.03\ ^{+0.12}_{-0.11} \pm 0.26 \pm 0.21\right) \times 10^{-3}$$



# $\Xi_b^-$ and $\Omega_b^-$ Baryons lifetime

arXiv:1405.1543

## Useful input to QCD models

- i.e. HQE allows calculations in powers of $\Lambda_{QCD}/m_b$
- Predictions for b-hadron lifetimes differ ~$O(\Lambda_{QCD}^2/m_b^2)$

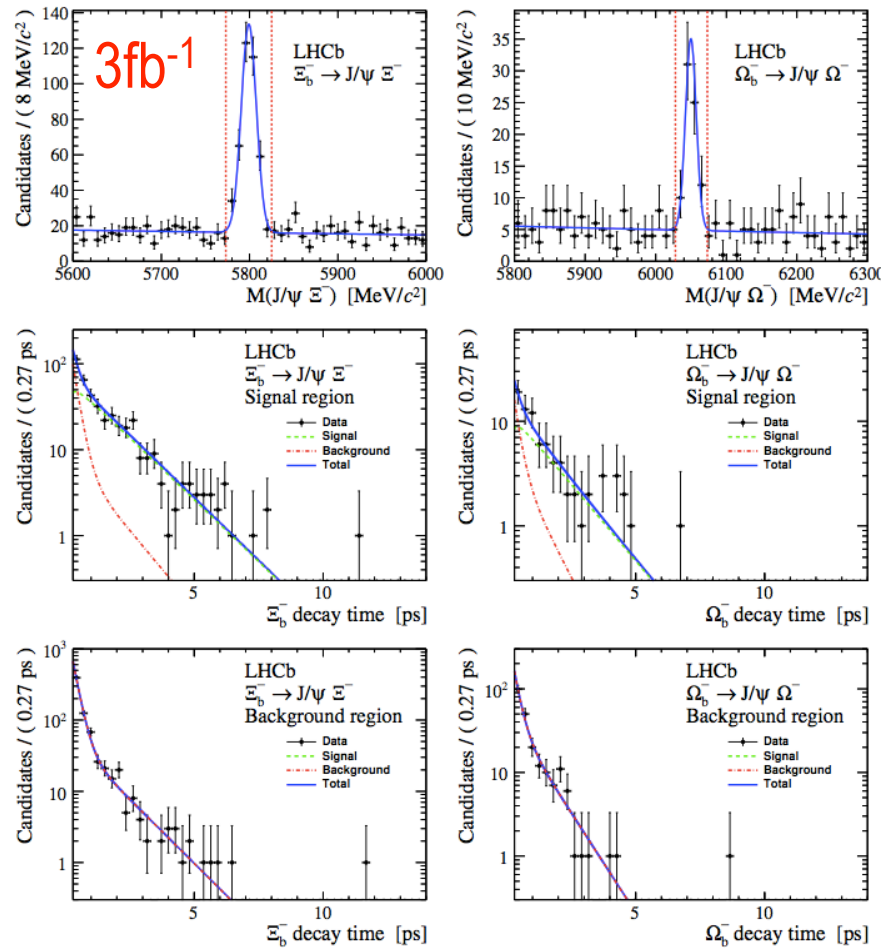
## Experimental Status

- Lots of data on $\Lambda_b$(udb)
- Poor knowledge of strange b baryons
  especially $\Xi_b^-$(dsb) and $\Omega_b^-$(ssb)
- Theoretical expectations $\tau$=1-1.7ps

## LHCb

- 3fb$^{-1}$ LHCb data

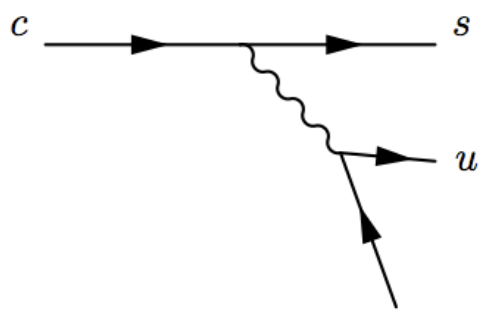
$$\tau(\Xi_b^-) = 1.55\,^{+0.10}_{-0.09}\,(\text{stat}) \pm 0.03\,(\text{syst})\,\text{ps}$$
$$\tau(\Omega_b^-) = 1.54\,^{+0.26}_{-0.21}\,(\text{stat}) \pm 0.05\,(\text{syst})\,\text{ps}$$



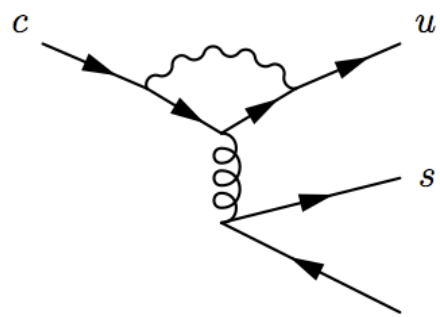
# CP Violation in Charm Decays

## CP Violation in Charm Mesons

- **Suppressed to the order O($10^{-3}$) or less**
  The CKM matrix elements relevant for these processes are related to the first two generation of quarks, and are almost real




(a) *Tree diagram.*




(b) *Penguin diagram.*

- **Sensitive no NP effects that may enhance CPV to >0.1%**
  - **Tree-level: extra quarks, supersymmetry without R-parity, multiple Higgs doublet**
  - **Loop: QCD penguin and dipole operators, FCNC in supersymmetric flavor models**

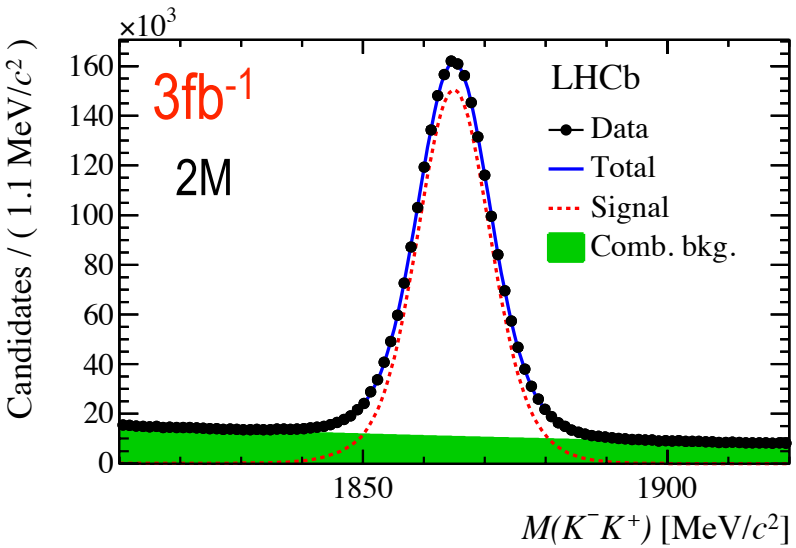
- **Experimental sensitivity now approaching <0.1%**

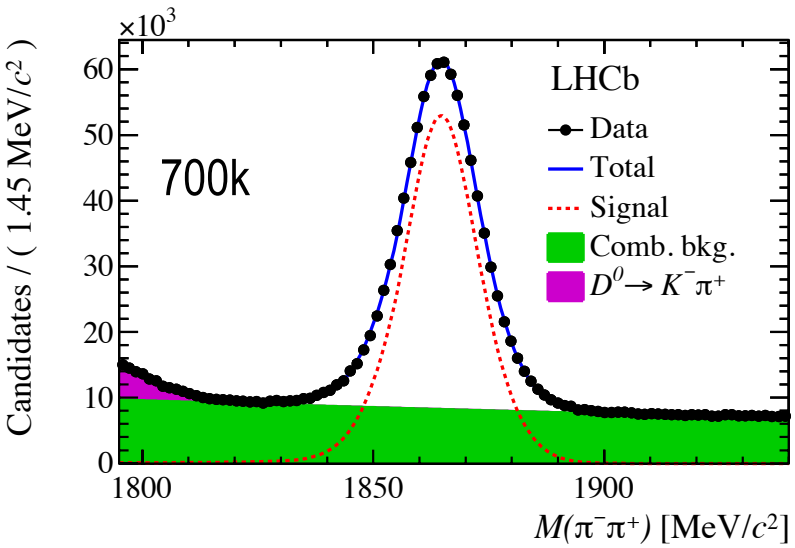
# CP Violation in Charm Decays - $D^0 \to h^+h^-$

arXiv:1405.2797

## Highly Sensitive Measurement

- **Huge sample of $D^0 \to h^+h^-$ decays at LHCb, $O(10^6) \Longrightarrow \sigma \sim 10^{-3}$**
- **LHCb provided results with prompt ($D^{*+} \to D^0\pi^+$), and semileptonic B ($B^- \to D^0\mu^-\nu_\mu X$) decays**
  Prompt analysis based on $0.6 fb^{-1}$, Semileptonic on $1 fb^{-1}$
- **B Semileptonic analysis now released with full data sample ($3 fb^{-1}$) analysis**



# CP Violation in Charm Decays - $D^0 \to h^+h^-$

## Why $\Delta A_{CP}$?

- **Easy way to average out detector and production asymmetries**

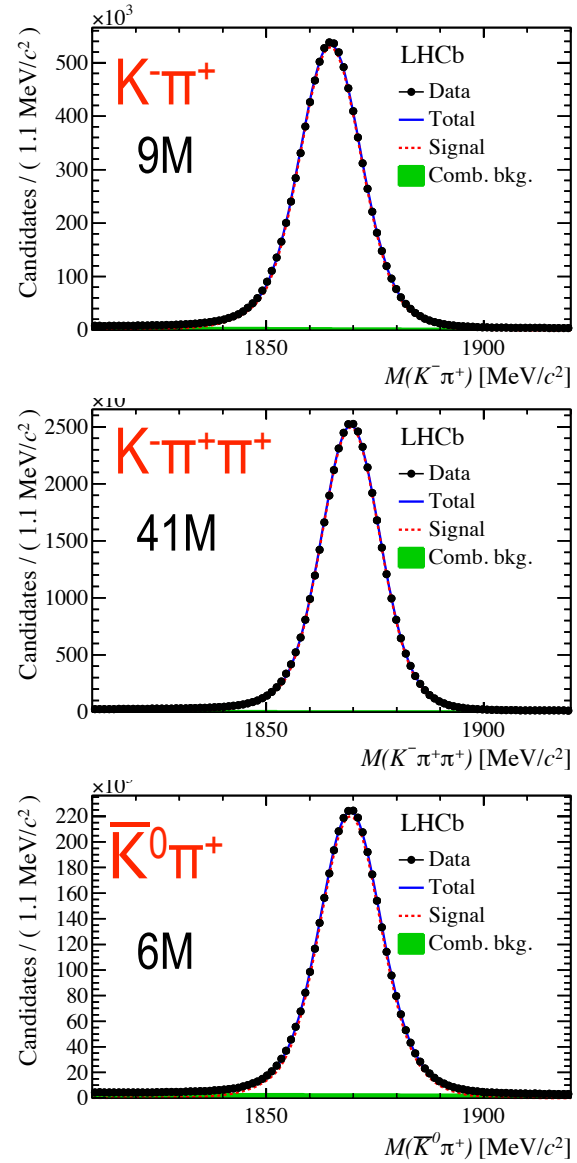
$$A_{raw} \equiv \frac{N(D \to f) - N(\bar{D} \to \bar{f})}{N(D \to f) + N(\bar{D} \to \bar{f})} = A_{CP} + A_D(\mu^-) + A_P(\bar{B})$$

$$\Delta A_{CP} \equiv A_{raw}(K^+K^-) - A_{raw}(\pi^+\pi^-)$$
$$= A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$$

## What about direct CPV?

- **Use control samples**

$$A_{raw}(K^-\pi^+) = A_D(\mu^-) + A_P(\bar{B}) + A_D(K^-\pi^+)$$
$$A_{raw}(K^-\pi^+\pi^+) = A_P(D^+) + A_D(K^-\pi^+) + A_D(\pi^+)$$
$$A_{raw}(\overline{K}^0\pi^+) = A_P(D^+) + A_D(\pi^+) - A_D(K^0)$$
$$A_D(K^-\pi^+) = A_{raw}(K^-\pi^+\pi^+) - A_{raw}(\overline{K}^0\pi^+) - A_D(K^0)$$
$$A_{CP}(K^+K^-) = A_{raw}(K^+K^-) - A_{raw}(K^-\pi^+) + A_D(K^-\pi^+)$$



# CP Violation in Charm Decays - $D^0 \to h^+h^-$

No CPV up to 0.2%

## Results:

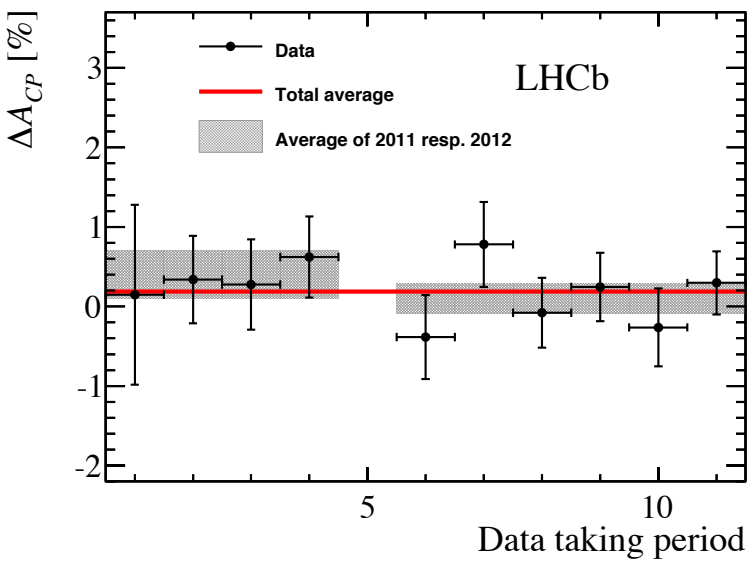
- **CP asymmetries directly measured:**

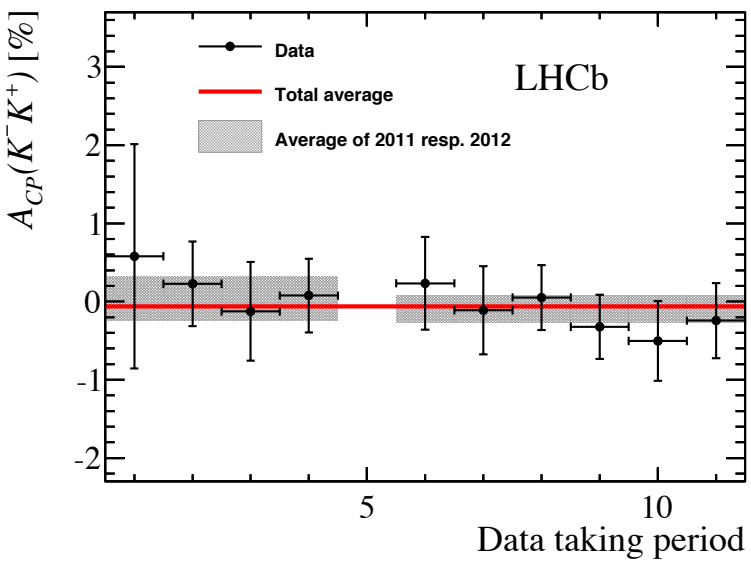
$$\Delta A_{CP} = (+0.14 \pm 0.16(\text{stat}) \pm 0.08(\text{syst}))\%$$

$$A_{CP}(K^+K^-) = (-0.06 \pm 0.15(\text{stat}) \pm 0.10(\text{syst}))\%$$

- **Allow to extract**

$$A_{CP}(\pi^+\pi^-) = (-0.20 \pm 0.19(\text{stat}) \pm 0.10(\text{syst}))\%$$



# CP Violation in Charm Decays - $D^+ \to K^0_S K^+$ and $D_s^+ \to K^0_S \pi^+$

arXiv:1406.2624

## CP Asymmetries

- **From the general formula**

$$A_{raw}(D^{\pm}_{(s)} \to K^0_S h^{\pm}) = A_{CP}(D^{\pm}_{(s)} \to K^0_S h^{\pm}) + A_P(D^{+}_{(s)}) + A_D(h^{\pm}) + A_{K^0/\overline{K}^0}$$

- **One can combine asymmetry measurements to extract the parameters of interest**

$$\begin{aligned} A_{CP}^{DD} &= \left(A_{raw}^{D_s^{\pm}\to K_S^0\pi^{\pm}} - A_{raw}^{D_s^{\pm}\to K_S^0 K^{\pm}}\right) - \left(A_{raw}^{D^{\pm}\to K_S^0\pi^{\pm}} - A_{CP}^{D^{\pm}\to K_S^0 K^{\pm}})\right) - 2A_{K^0} \\ &= A_{CP}^{D^{\pm}\to K_S^0 K^{\pm}} + A_{CP}^{D_s^{\pm}\to K_S^0\pi^{\pm}} \\ A_{CP}^{D^{\pm}\to K_S^0 K^{\pm}} &= \left(A_{raw}^{D^{\pm}\to K_S^0 K^{\pm}} - A_{raw}^{D_s^{\pm}\to K_S^0 K^{\pm}}\right) - \left(A_{raw}^{D^{\pm}\to K_S^0\pi^{\pm}} - A_{raw}^{D_s^{\pm}\to \phi\pi^{\pm}})\right) - A_{K^0} \\ A_{CP}^{D_s^{\pm}\to K_S^0\pi^{\pm}} &= A_{raw}^{D_s^{\pm}\to K_S^0 pi^{\pm}} - A_{raw}^{D_s^{\pm}\to \phi\pi^{\pm}} - A_{K^0} \end{aligned}$$

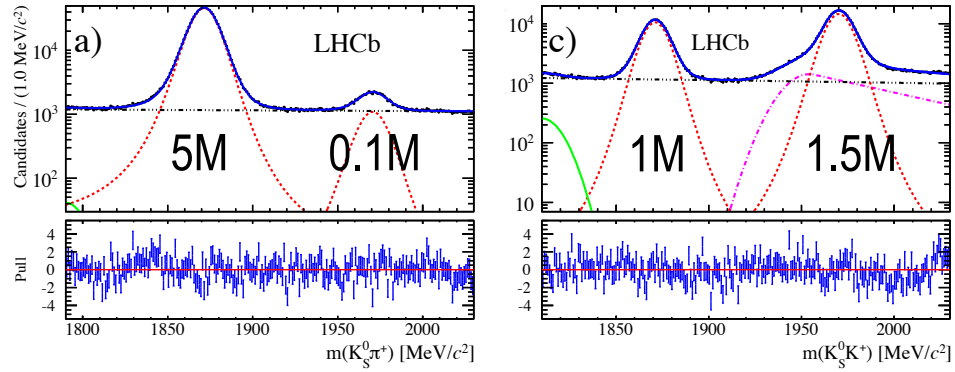
n.b.: $A_D(h^{\pm})$ cancels only if the kinematic distribution of the bachelor particle is matching between the two decay modes
$\Longrightarrow$kinematic re-weighting is applied

- **$K^0$ regeneration and material interaction asymmetry from analytical expression**

# CP Violation in Charm Decays - $D^+ \to K^0_S K^+$ and $D_s^+ \to K^0_S \pi^+$

## Backgrounds

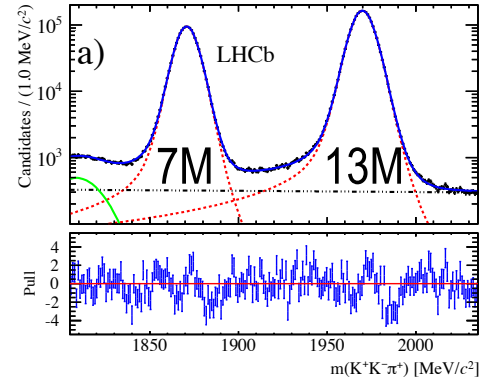
- **$D^\pm \to K^0_S \pi^\pm \pi^0$, $D_s^\pm \to K^\pm K^\mp \pi^\pm \pi^0$**
  green line in the plot
- **$D_{(s)}^\pm \to K^0_S h'^\pm$ cross-feed**
  $\pi$(K) misidentified as K($\pi$) - magenta line




## Systematics

- **Mainly from fit procedure, choice of kinematic region and trigger**
  All of them evaluated from control samples, likely to scale down with statistics

3fb$^{-1}$




## Results

**No CPV up to 0.2%**

$$A_{CP}^{D^\pm \to K^0_S K^\pm} = (+0.03 \pm 0.17 \pm 0.14)\%$$

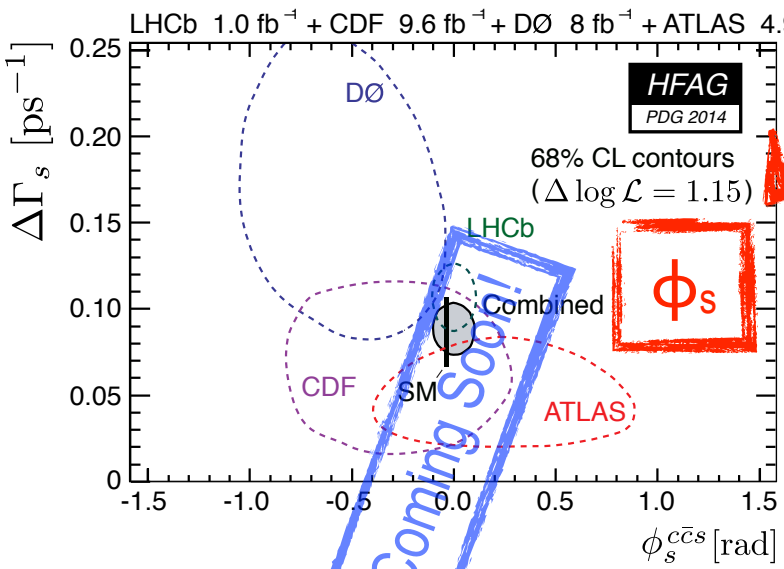
$$A_{CP}^{D_s^\pm \to K^0_S \pi^\pm} = (+0.38 \pm 0.46 \pm 0.17)\%$$

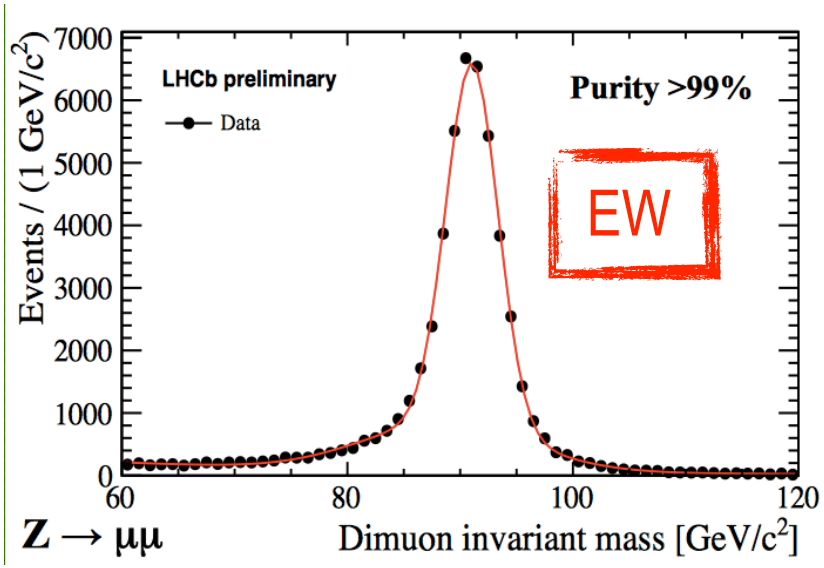
$$A_{CP}^{DD} = (+0.41 \pm 0.49 \pm 0.26)\%$$

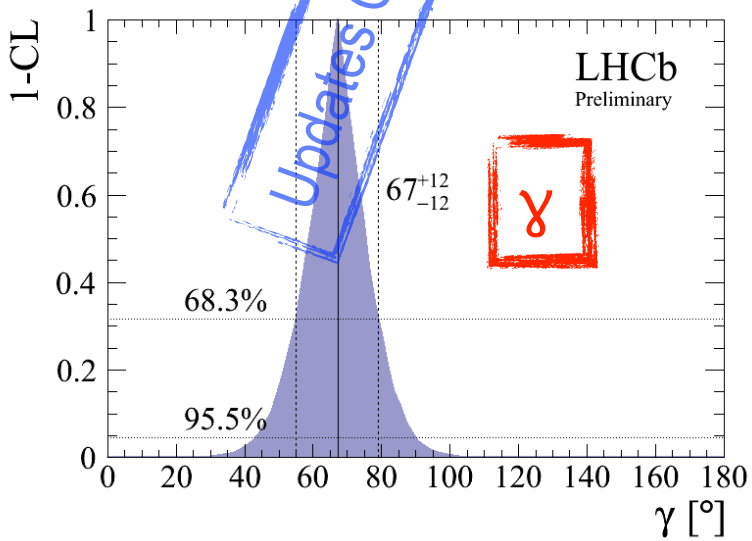
| | $\sqrt{s} = 7$ TeV | | | $\sqrt{s} = 8$ TeV | | |
|---|---|---|---|---|---|---|
| Source | $\mathcal{A}_{CP}^{DD}$ | $\mathcal{A}_{CP}^{D^\pm \to K^0_S K^\pm}$ | $\mathcal{A}_{CP}^{D_s^\pm \to K^0_S \pi^\pm}$ | $\mathcal{A}_{CP}^{DD}$ | $\mathcal{A}_{CP}^{D^\pm \to K^0_S K^\pm}$ | $\mathcal{A}_{CP}^{D_s^\pm \to K^0_S \pi^\pm}$ |
| Fit procedure | 0.14 | 0.09 | 0.11 | 0.07 | 0.05 | 0.01 |
| Cross-feed bkgd. | 0.03 | 0.01 | 0.02 | 0.01 | – | 0.01 |
| Non-prompt charm | 0.01 | – | – | 0.01 | – | – |
| Kinematic weighting | 0.08 | 0.06 | 0.13 | 0.05 | 0.07 | 0.12 |
| Kinematic region | 0.10 | 0.06 | 0.04 | 0.19 | 0.02 | 0.17 |
| Trigger | 0.13 | 0.13 | 0.07 | 0.17 | 0.17 | 0.09 |
| $K^0$ asymmetry | 0.03 | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 |
| Total | 0.23 | 0.18 | 0.19 | 0.27 | 0.19 | 0.22 |

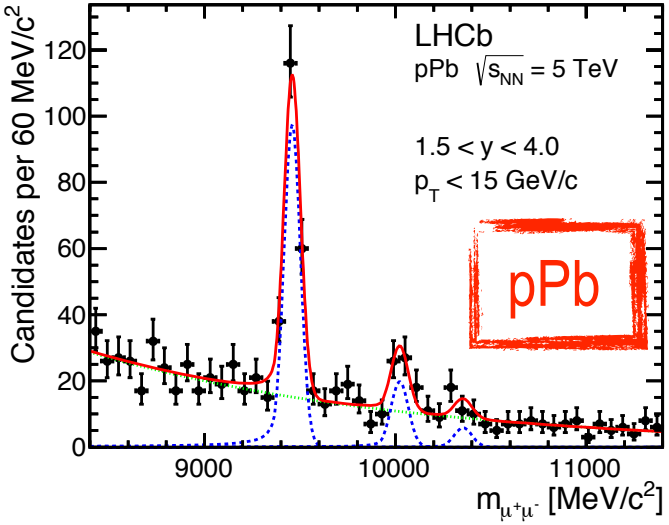
# And Much More...

See talk by Sevda on Wednesday



# Future Prospects

Letter Of Intent
Framework TDR

## 2015-2018

- In 2015 LHC will be back in business, ready to deliver 13TeV collisions!
- LHCb is preparing to record ~2fb$^{-1}$/year for a legacy 10fb$^{-1}$ dataset before 2018

## 2018-2019

- 2nd Long Shutdown of LHC
- LHCb Upgrade installation
  Pixel Velo, UT, New Scintillating Fiber Tracker, 40MHz detectors readout, New Trigger

## 2020-…

- LHCb upgrade will record 50fb$^{-1}$
- Many measurement will reach sensitivity ~ theoretical error

*Framework TDR for the LHCb upgrade: Technical Design Report*

| Type | Observable | LHC Run 1 (~3/fb) | LHCb 2018 (~8/fb) | LHCb upgrade (~50/fb) | Theory |
|---|---|---|---|---|---|
| $B_s^0$ mixing | $\phi_s(B_s^0 \to J/\psi\,\phi)$ (rad) | 0.05 | 0.025 | **0.009** | $\sim 0.003$ |
| | $\phi_s(B_s^0 \to J/\psi\, f_0(980))$ (rad) | 0.09 | 0.05 | **0.016** | $\sim 0.01$ |
| | $A_{\rm sl}(B_s^0)$ $(10^{-3})$ | 2.8 | 1.4 | **0.5** | 0.03 |
| Gluonic penguin | $\phi_s^{\rm eff}(B_s^0 \to \phi\phi)$ (rad) | 0.18 | 0.12 | **0.026** | 0.02 |
| | $\phi_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$ (rad) | 0.19 | 0.13 | **0.029** | $< 0.02$ |
| | $2\beta^{\rm eff}(B^0 \to \phi K_S^0)$ (rad) | 0.30 | 0.20 | **0.04** | 0.02 |
| Right-handed currents | $\phi_s^{\rm eff}(B_s^0 \to \phi\gamma)$ | 0.20 | 0.13 | **0.030** | $< 0.01$ |
| | $\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$ | 5% | 3.2% | **0.8%** | 0.2% |
| Electroweak penguin | $S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$ | 0.04 | 0.020 | **0.007** | 0.02 |
| | $q_0^2\, A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$ | 10% | 5% | **1.9%** | $\sim 7\%$ |
| | $A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$ | 0.14 | 0.07 | **0.024** | $\sim 0.02$ |
| | $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$ | 14% | 7% | **2.4%** | $\sim 10\%$ |
| Higgs penguin | $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ $(10^{-9})$ | 1.0 | 0.5 | **0.19** | 0.3 |
| | $\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ | 220% | 110% | **40%** | $\sim 5\%$ |
| Unitarity triangle angles | $\gamma(B \to D^{(*)}K^{(*)})$ | 7° | 4° | **1.1°** | negligible |
| | $\gamma(B_s^0 \to D_s^{\mp}K^{\pm})$ | 17° | 11° | **2.4°** | negligible |
| | $\beta(B^0 \to J/\psi\, K_S^0)$ | 1.7° | 0.8° | **0.31°** | negligible |
| Charm $CP$violation | $A_\Gamma(D^0 \to K^+K^-)$ $(10^{-4})$ | 3.4 | 2.2 | **0.5** | – |
| | $\Delta A_{CP}$ $(10^{-3})$ | 0.8 | 0.5 | **0.12** | – |

# Conclusions

## Performance

- **LHCb detector has been performing very well during 2011 and 2012 and allowed us to produce many interesting physics results**
  Many of them with best sensitivity so far
- **We are preparing for another successful run in 2015-2018**
  Trying to squeeze out observed hints for NP and constrain even better the SM

## Analysis

- **The analysis of the RunI data is not over**
  Many interesting new results and updates with $3fb^{-1}$ on their way
- **Basically, all the LHCb results are limited by statistics, therefore improvements are foreseen for the future**
  Your favourite BSM effect may just be hiding behind the corner!
- **Some tension observed in b→s transitions**
  More data to come!
  $3fb^{-1}$ update on $B^0 \to K^{*0}\mu^+\mu^-$ coming soon!