# New Physics Searches via Rare Decays at LHCb

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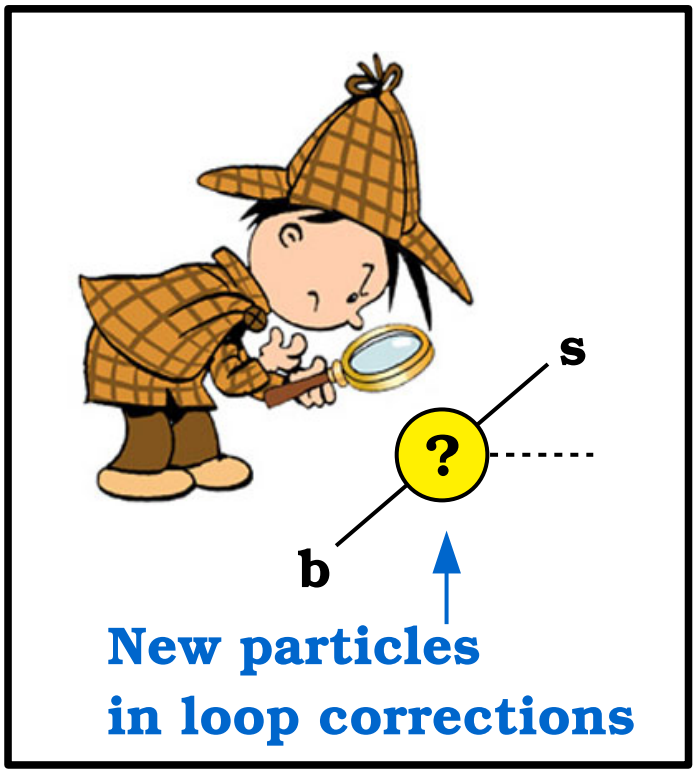
Traditio et Innovatio

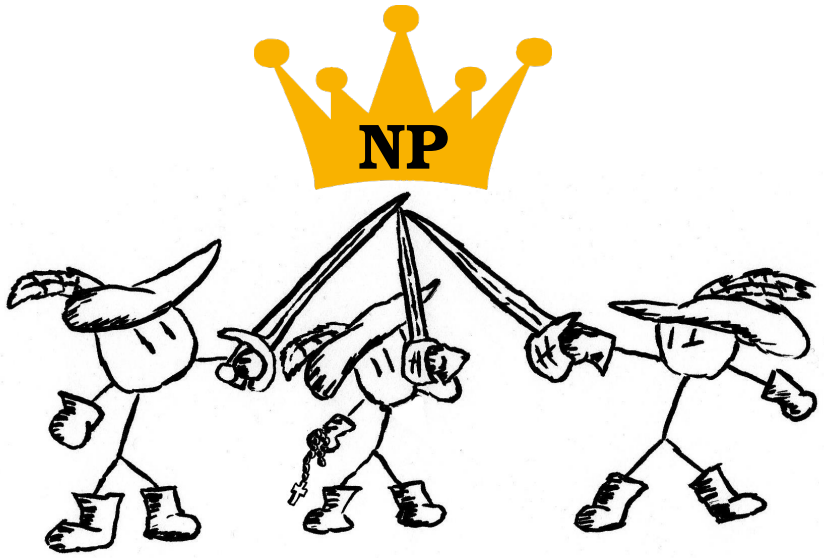
# Search for new physics (NP)

## Indirect searches




- Precision measurements in flavour physics
- Sensitivity on NP effects
  → $\mathcal{O}$(100TeV)

Tests of Standard Model (SM) predictions in flavour physics




| CP violation ↔ Phases | Decay rates ↔ Amplitudes | Angular distr. ↔ Lorentz struct. |
|---|---|---|

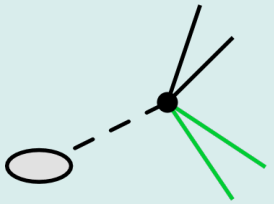
See also related LHCb talks:

- Rare decays *(F. Dettori)*
- Mixing & CP-violation measurments *(A. Bertolin)*
- Searches for LFU breaking *(V. Renaudin)*

# Rare decays outline

- Test of Lepton-flavour universality
  - $B^0 \to K^{*0} l^+l^-$ [arXiv:1705.05802] (submitted to JHEP) **New!**
- Search for rare decays with loops
  - $K_{(s)} \to \mu^+\mu^-$ [LHCb-PAPER-2017-009] **New!**
  - $B_{(s)} \to \mu^+\mu^-$ [PRL 118, 191801 (2017)]
  - $B_{(s)} \to \tau^+\tau^-$ [arXiv:1703:02508] (accepted by PRL)
  - $B_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ [JHEP 03 (2017) 001]
- Search for long-lived scalar particles
  - $B^+ \to K^+ \chi(\mu^+\mu^-)$ [PRD 95, 071101 (2017)]

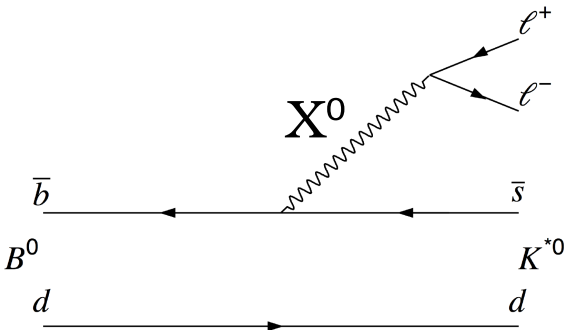
# Test of LFU with $B^0 \to K^{*0} l^+l^-$

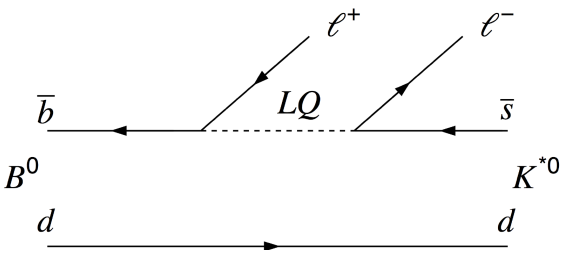


- $B^0 \to K^{*0} l^+l^-$ decay amplitude involves only loop diagrams
- Ratio of decay rates provide very sensitive probe for new particles in loops diagrams
  - hadronic uncertainties cancel in the SM ratio
- NP models include heavy gauge bosons ($X^0$) or leptoquarks (LQs)
- Hints of LFU violation:
  - Most precise measurement of $R_K$ by LHCb compatible with $R_K(SM) = 1$ [PRD69 (2004) 074020] within 2.6σ: $R_K = 0.745^{+0.090}_{-0.074}(\text{stat}) \pm 0.036(\text{syst})$ [PRL113 (2014) 151601]
  - Also seen in tree-level dominated decays $B \to D^{(*)}l\nu$ with high rates

$$R_H = \frac{\int \frac{d\Gamma(B\to H\mu^+\mu^-)}{dq^2}\, dq^2}{\int \frac{d\Gamma(B\to He^+e^-)}{dq^2}\, dq^2}$$

$q^2 = m^2(l^+l^-)$




[BABAR, PRD79 (2009) 012002]
[Belle, PRD92 (2015) 072014]
[LHCb, PRL115 (2015) 111803]

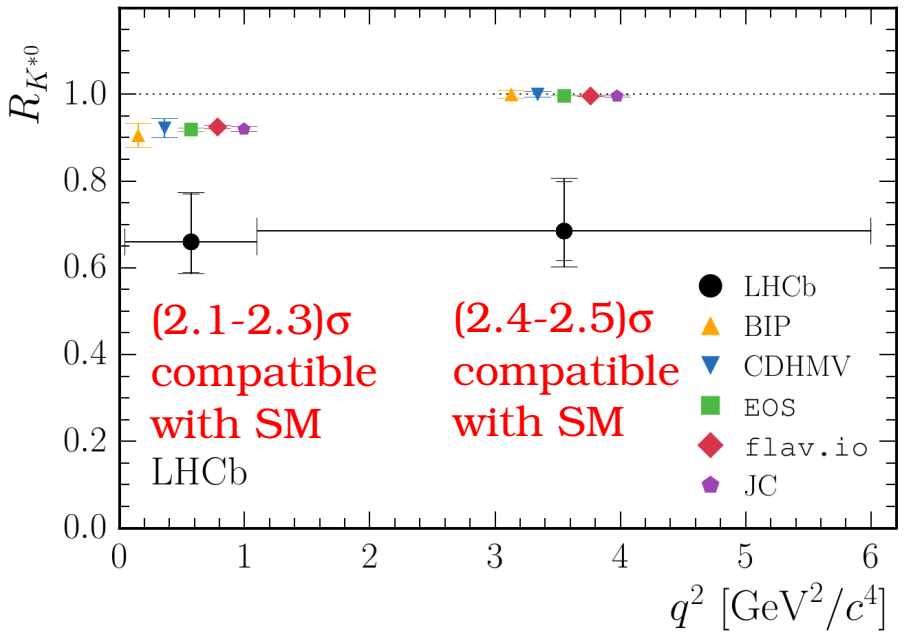
# Test of LFU with $B^0 \to K^{*0} l^+l^-$

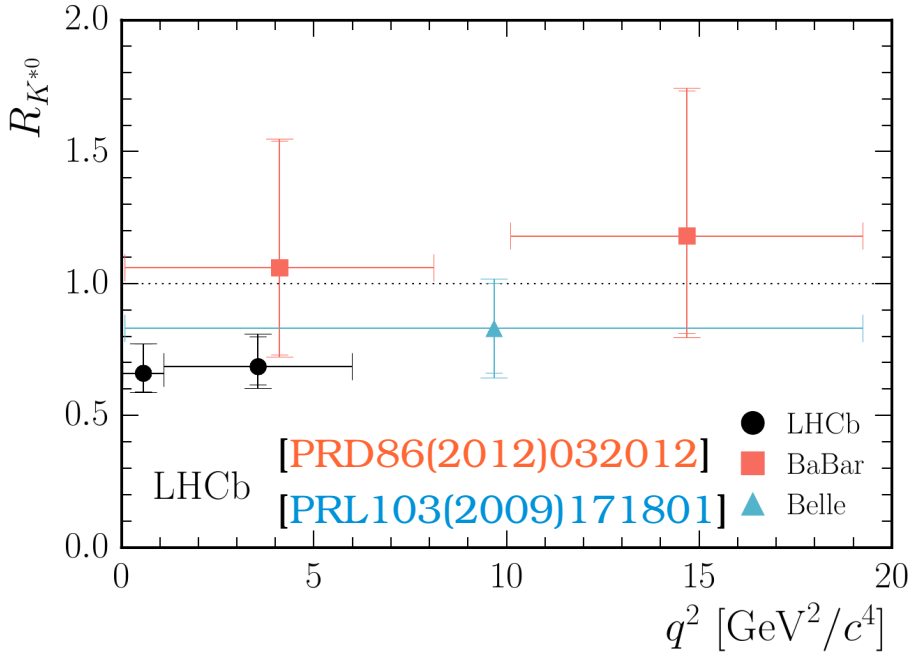
- Measurement of R(K*0) as double ratio comparing branching fractions of $B^0 \to K^{*0} l^+l^-$ over $B^0 \to K^{*0} J/\psi(\to l^+l^-)$ with l={e,μ}

$$R_{K^{*0}} = \frac{\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to \mu^+\mu^-))} \Big/ \frac{\mathcal{B}(B^0 \to K^{*0}e^+e^-)}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to e^+e^-))}$$

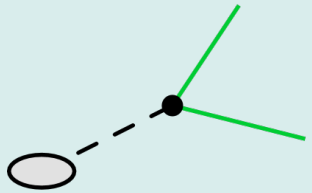
$$R_{K^{*0}} = \begin{cases} 0.66\ ^{+\ 0.11}_{-\ 0.07}\,(\text{stat}) \pm 0.03\,(\text{syst}) & \text{for } 0.045 < q^2 < 1.1\ \text{GeV}^2/c^4 \\ 0.69\ ^{+\ 0.11}_{-\ 0.07}\,(\text{stat}) \pm 0.05\,(\text{syst}) & \text{for } 1.1 \quad < q^2 < 6.0\ \text{GeV}^2/c^4 \end{cases}$$

[arXiv:1705.05802]



# Search for $K_s \to \mu^+\mu^-$

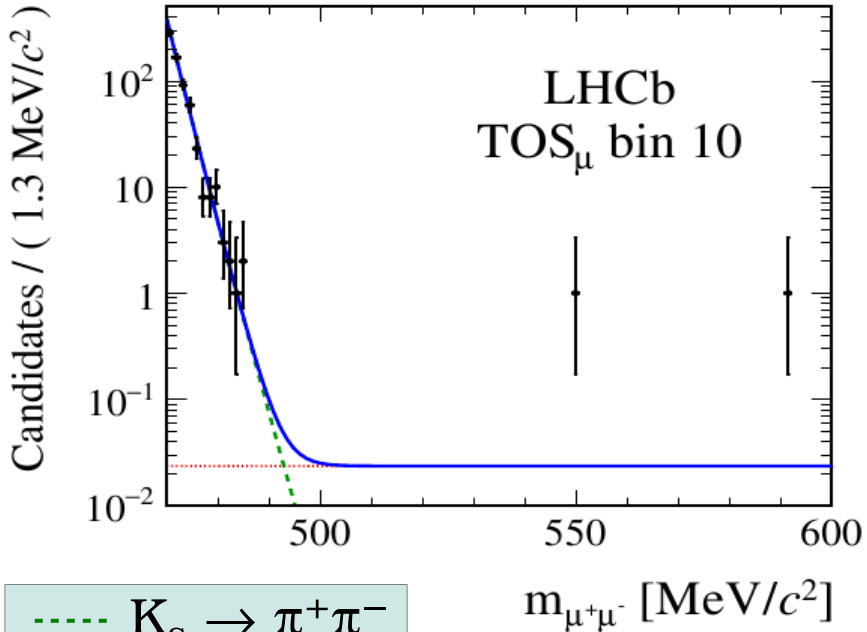


- Decay proceeds only via FCNC in the SM
- Dominated by long-distance contributions
- Rate suppressed by small CP violation in kaon system w.r.t. $\mathcal{B}(K_L \to \mu^+\mu^-)=6.84(11)\times10^{-9}$ [Rev.Part.Phys. 2016]
  - SM prediction: $\mathcal{B}(K_s \to \mu^+\mu^-)=5.0(1.5)\times10^{-12}$ [LHCb-PAPER-2017-009]
  - Current UL = $9\times10^{-9}$ @ CL=90% [JHEP01(2013)090]
- Search at LHCb
  - Around $10^{13}$ $K_s$ produced per $1fb^{-1}$ at LHCb
  - $K_s \to \pi^+\pi^-$ as control channel
  - Update of previous search with full $3fb^{-1}$ from Run1
  - Improved trigger efficiency and offline selections

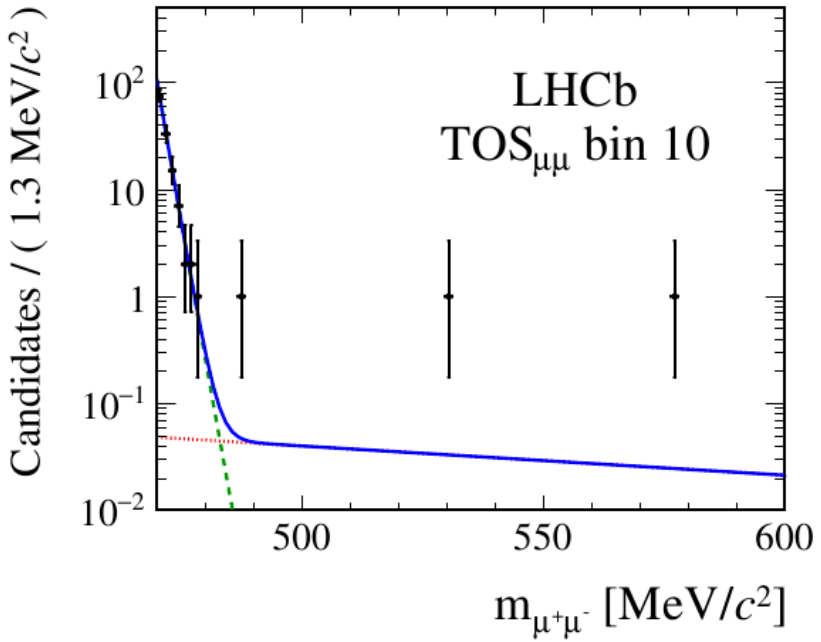
# Search for $K_s \to \mu^+\mu^-$

- Fit to the $m(\mu^+\mu^-)$ spectrum in two most sensitive selection bins

$TOS_\mu$: single-muon trigger




$TOS_{\mu\mu}$: double-muon trigger




$$\mathcal{B}(K_S^0 \to \mu^+\mu^-) < 0.8 \times 10^{-9} \quad @\ \mathrm{CL} = 90\,\%$$

$$\mathcal{B}(K_S^0 \to \mu^+\mu^-) < 1.0 \times 10^{-9} \quad @\ \mathrm{CL} = 95\,\%$$

[LHCb-PAPER-2017-009]

**Improvement by a factor >10 w.r.t. previous measurement**

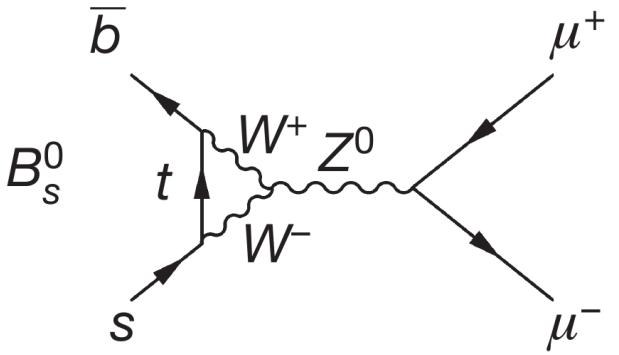
# Search for $B_{(s)} \to \mu^+\mu^-$

- suppressed decay in the SM (helicity, $V_{CKM}$)
- Precise SM prediction of the decay rate
  → $\mathcal{B}(B_s \to \mu^+\mu^-) = 3.65(23)\times10^{-9}$
  → $(\Delta\mathcal{B}/\mathcal{B} \approx 6\%)$
  [PRL 112 (2012) 101801 ]
- NP constributions may modify SM prediction
- New measurement: effective lifetime $\tau_{\mu^+\mu^-}$
  - Sensitive to NP and complimentary to $\mathcal{B}(B_s \to \mu^+\mu^-)$ [PRL 109 (2012) 041801 ]
  - Related to CP violation in the $B_s$ system

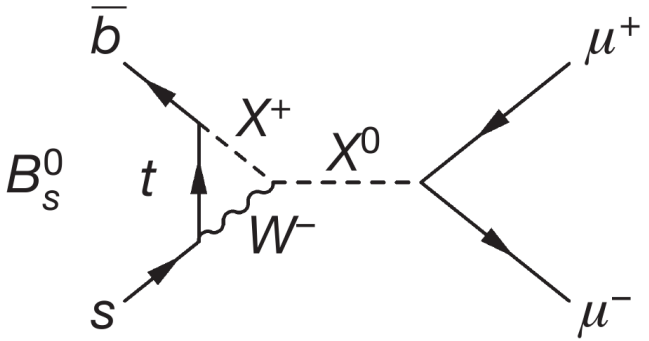
$$\tau_{\mu^+\mu^-} = \left[\frac{\tau_{B_s^0}}{1-y_s}\right]_{SM} \cdot \left[1 + \frac{(A-1)\,(y_s - y_s^2)}{(1+y_s)\,(1+A\,y_s)}\right]$$

$$y_s \equiv \tau_{B_s^0}\,\Delta\Gamma/2 \approx 0.062(6)$$

$$A = A_{\Delta\Gamma}^{\mu^+\mu^-} = \frac{-2\mathrm{Re}(\lambda)}{1+|\lambda|^2}\ ,\ \lambda = \frac{q}{p}\,\frac{A(B_s^0 \to \mu^+\mu^-)}{A(\overline{B}_s^0 \to \mu^+\mu^-)}$$



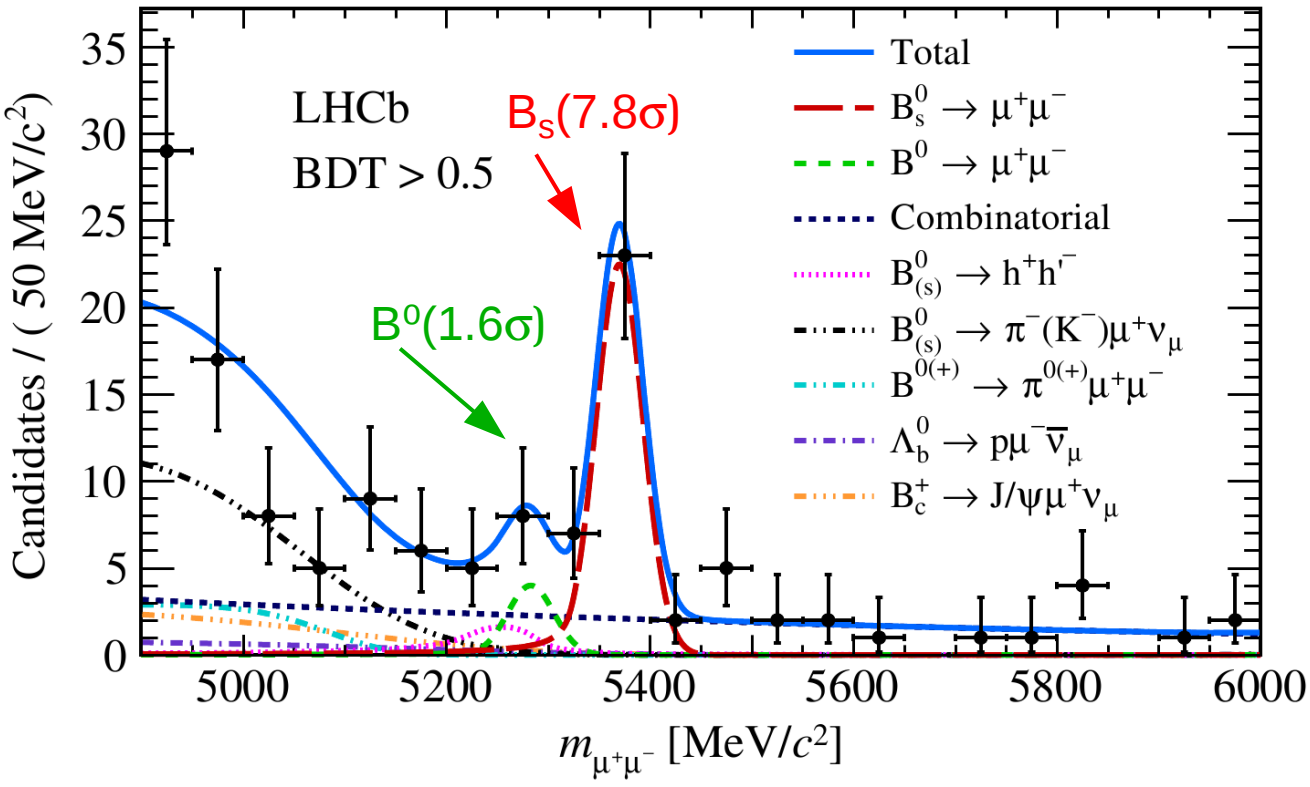

a SM diagram




a NP diagram

# Search for $B_{(s)} \to \mu^+\mu^-$

- LHCb measurement with (3+1.4)fb$^{-1}$ [PRL 118, 191801 (May 2017)]
- Changes w.r.t. CMS+LHCb combination [Nature 522, 68–72 (June 2015)]
  - Tighter muon identification (≈50% less $B_{(s)} \to h^+h'^-$ background)
  - Improved isolation variables (≈50% less comb. background)




Fit to mass distribution of selected B→μμ events

[PRL 118, 191801 (May 2017)]

# Search for $B_{(s)} \to \mu^+\mu^-$

**Results**

- First observation of $B_s \to \mu^+\mu^-$ in a single experiment

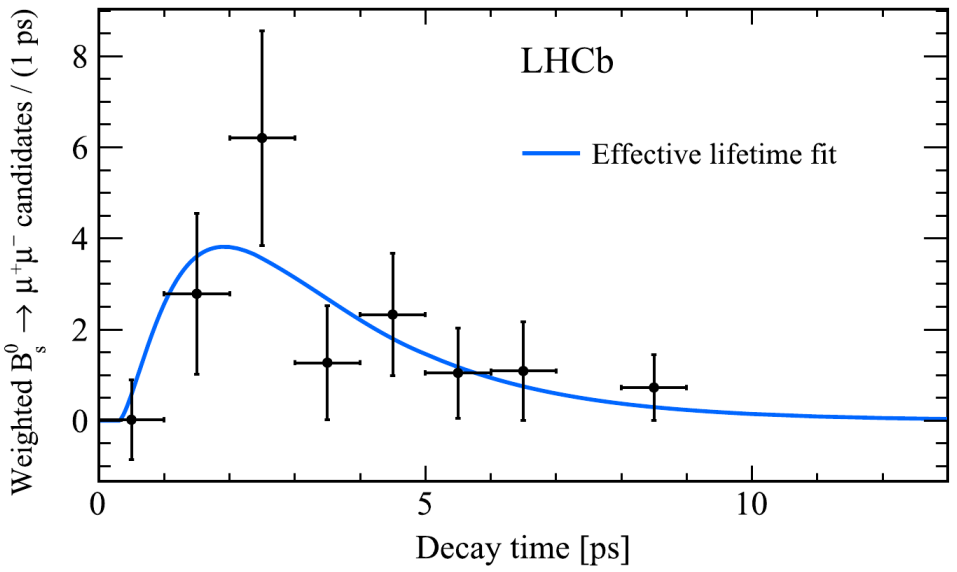
| $\mathcal{B}/10^{-10}$ | SM | Observed | Significance |
|---|---|---|---|
| $B_s \to \mu^+\mu^-$ | $36.5 \pm 2.3$ | $30 \pm 6_{(stat)} \, ^{+3}_{-2}{}_{(sys)}$ | $7.8\sigma$ |
| $B^0 \to \mu^+\mu^-$ | $1.06 \pm 0.09$ | $1.5 \, ^{+1.2}_{-1.0} \, ^{+0.2}_{-0.1}$ | $1.6\sigma$ |

[PRL 112 (2012) 101801]

- $\tau_{\mu^+\mu^-} = (2.04 \pm 0.44_{(stat)} \pm 0.05_{(sys)})$ps
- $\tau_{\mu^+\mu^-}(SM) = (1.61 \pm 0.16)$ps
- Compatible with SM within $1.0\sigma$
- More precision with full Run2 data

sWeighted decay time distribution of selected $B_s \to \mu\mu$ events

[PRL 118, 191801 (May 2017)]



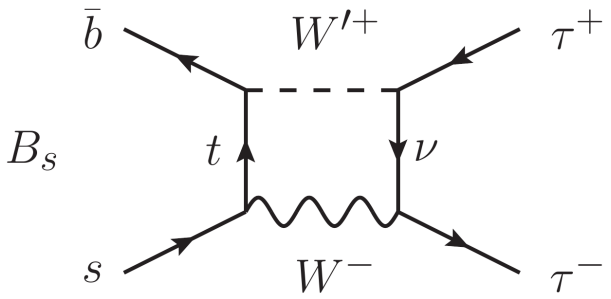
# Search for $B_{(s)} \to \tau^+\tau^-$

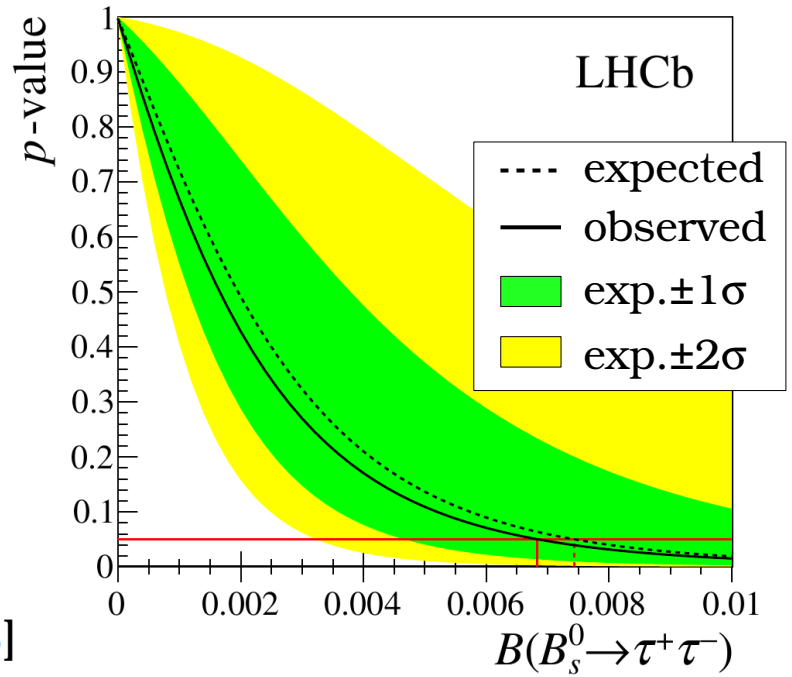
- SM prediction: $\mathcal{B}(B_s \to \tau^+\tau^-) = 7.73(49) \times 10^{-7}$ [PRL112(2014)101801]
- NP effects may enhance $\mathcal{B}(B_{(s)} \to \tau^+\tau^-)$ up to the percent level [PRD86(2012)054023]
  → e.g. by W' contributions
- Challenging analysis
  - At least two missing particles:
    $B_{(s)} \to \tau^+(\to \pi^+\pi^+\pi^-\nu)\ \tau^-(\to \pi^+\pi^-\pi^-\nu)$
- Upper limits at CL=95% excluding contribution from the other decay:

$$\mathcal{B}(B_s \to \tau^+\tau^-) < 6.8 \times 10^{-3}$$

$$\mathcal{B}(B^0 \to \tau^+\tau^-) < 2.1 \times 10^{-3}$$

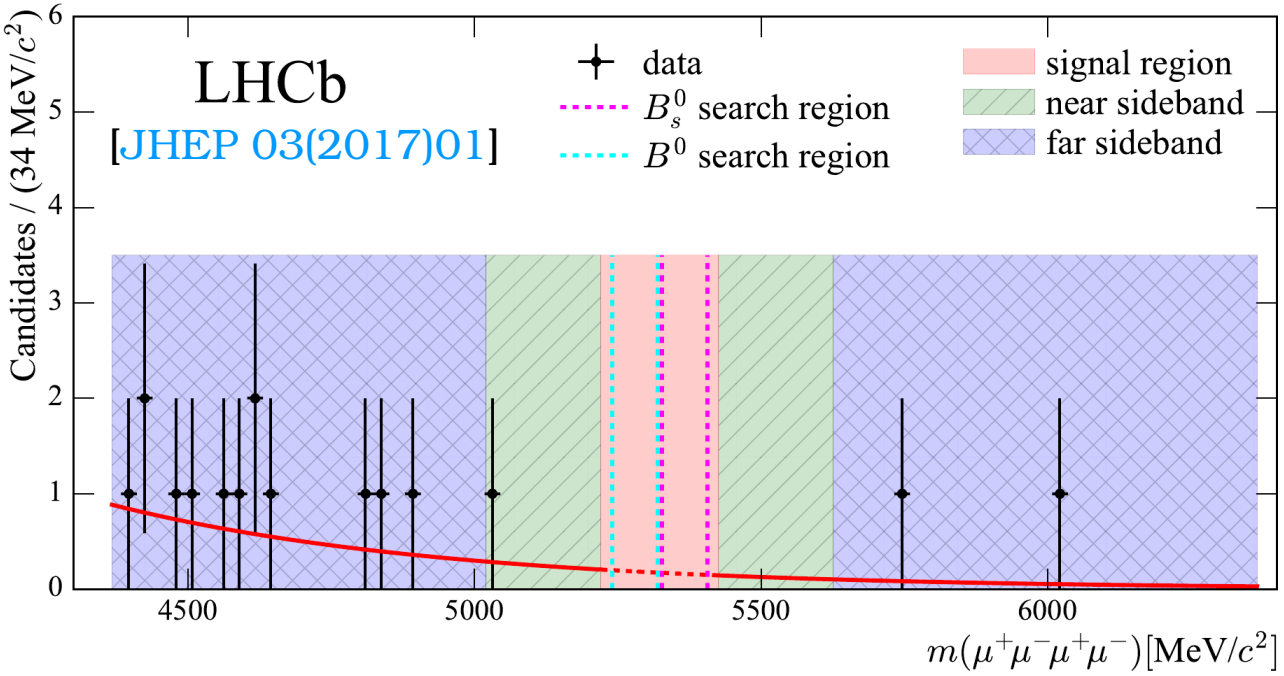
[arXiv:1703:02508]



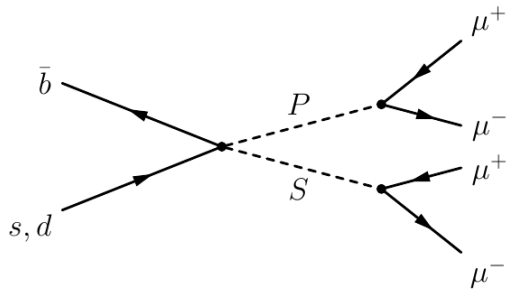




**First limit for $B_s \to \tau^+\tau^-$ and world's best for $B^0 \to \tau^+\tau^-$**

# Search for $B_{(s)} \to \mu^+\mu^-\mu^+\mu^-$




- Big enhancement by SUSY models possible



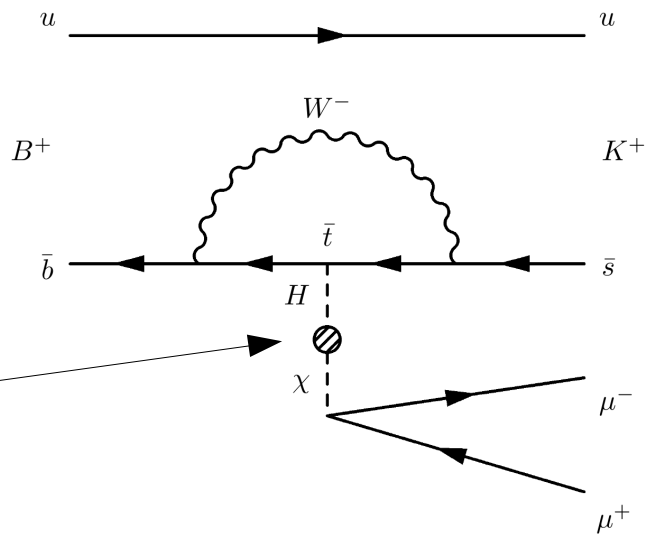

- **Results with full 3fb$^{-1}$**

| | UL on $\mathcal{B}$ at CL=95% | Efficiency |
|---|---|---|
| $B_s \to \mu^+\mu^-\mu^+\mu^-$ | $< 2.5\times10^{-9}$ | 0.580(3)% |
| $B^0 \to \mu^+\mu^-\mu^+\mu^-$ | $< 6.9\times10^{-10}$ | 0.568(3)% |
| $B_s \to S(\to\mu^+\mu^-)P(\to\mu^+\mu^-)$* | $< 2.2\times10^{-9}$ | 0.648(3)% |
| $B^0 \to S(\to\mu^+\mu^-)P(\to\mu^+\mu^-)$* | $< 6.0\times10^{-10}$ | 0.648(3)% |

*) assuming m(S) = 2.5GeV/c² and m(P) = 214.3GeV/c² [PRL94(2005)021801]

# Inflaton search in $B^+ \to K^+ \chi(\mu^+\mu^-)$

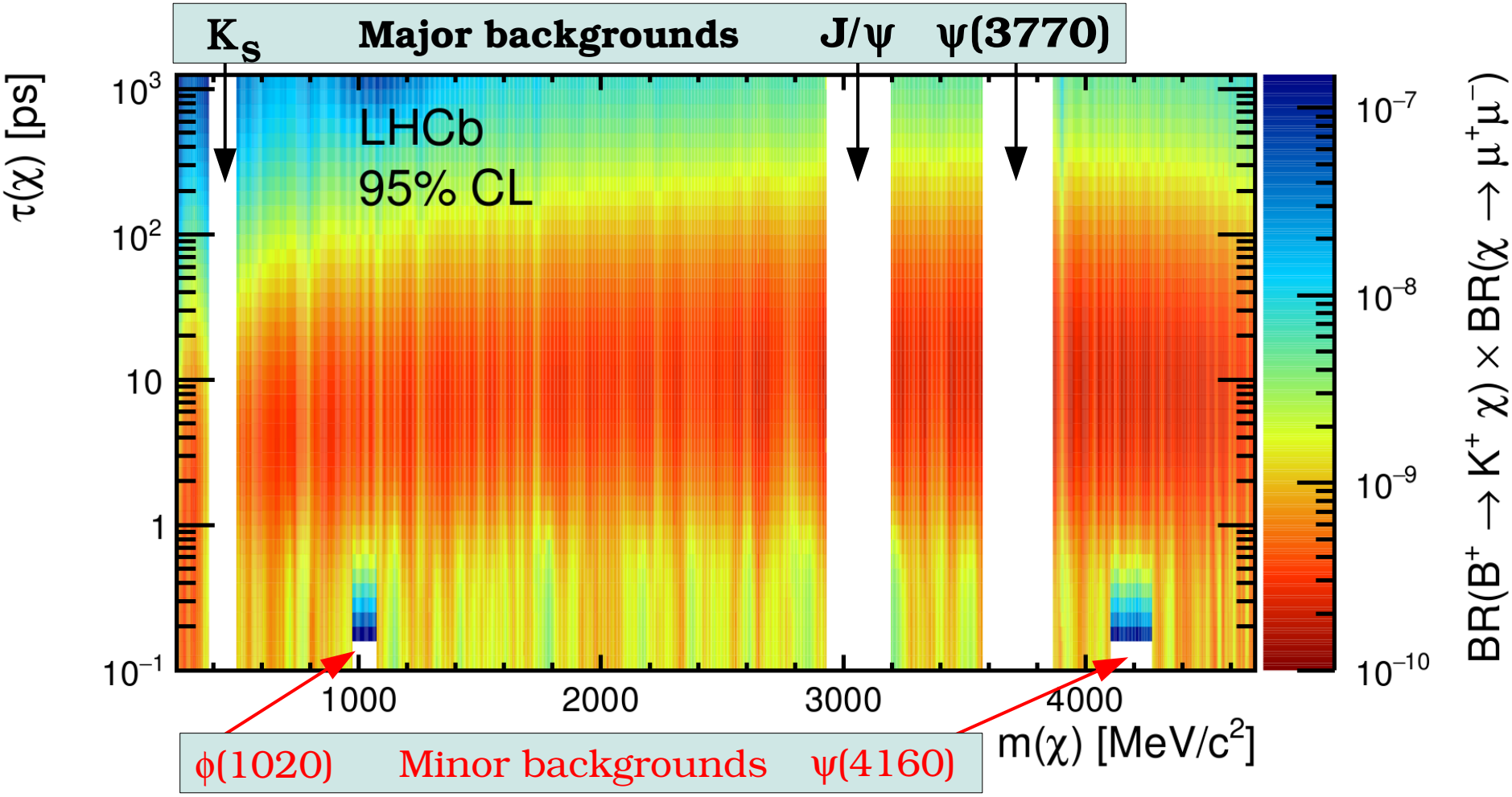
- Search for weakly interacting mediators that enable coupling b/w dark matter and SM fermions [arXiv:1311.0029], [PRD83(2011)054005]
- Here: Higgs portal scenario [JHEP05(2010)010], [JHEP07(2013)140]
  - New scalar particle ($\chi$) that mixes with SM Higgs boson
  - Motivated by inflaton theories to explain inflation of the early universe
- Search at LHCb: [PRD 95 071101(R) (April 2017)]
  - Dataset: full $3fb^{-1}$ from Run1
  - Measurement relative to $B^+ \to K^+ J/\psi(\to\mu^+\mu^-)$
  - vetos in $\tau(\mu\mu)$ and $m(\mu\mu)$ against $K_s$, $\phi(1020)$, and $\psi$ resonances



# Inflaton search in $B^+ \to K^+ \chi(\mu^+\mu^-)$

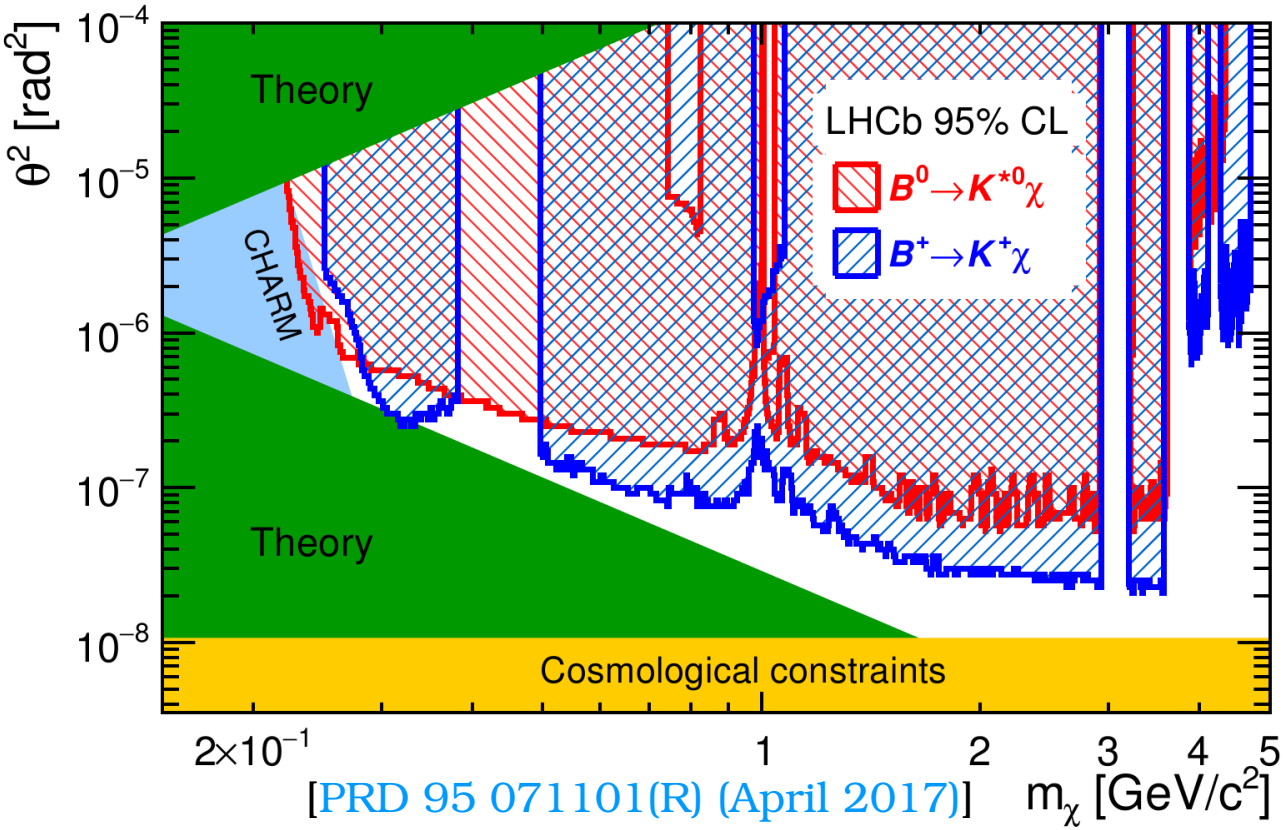
- Upper limits on $\mathcal{B}[B^+ \to K^+ \chi(\mu^+\mu^-)]$ in dependence of m(χ) and τ(χ)

[PRD 95 071101(R) (April 2017)]



# Inflaton search in $B^+ \to K^+ \chi(\mu^+\mu^-)$

- Additional constraints on mixing angle $\theta^2$ of H and $\chi$ in cominbation with $B^0 \to K^{*0} \chi(\mu^+\mu^-)$ search [PRL 115, 161802 (2015)]



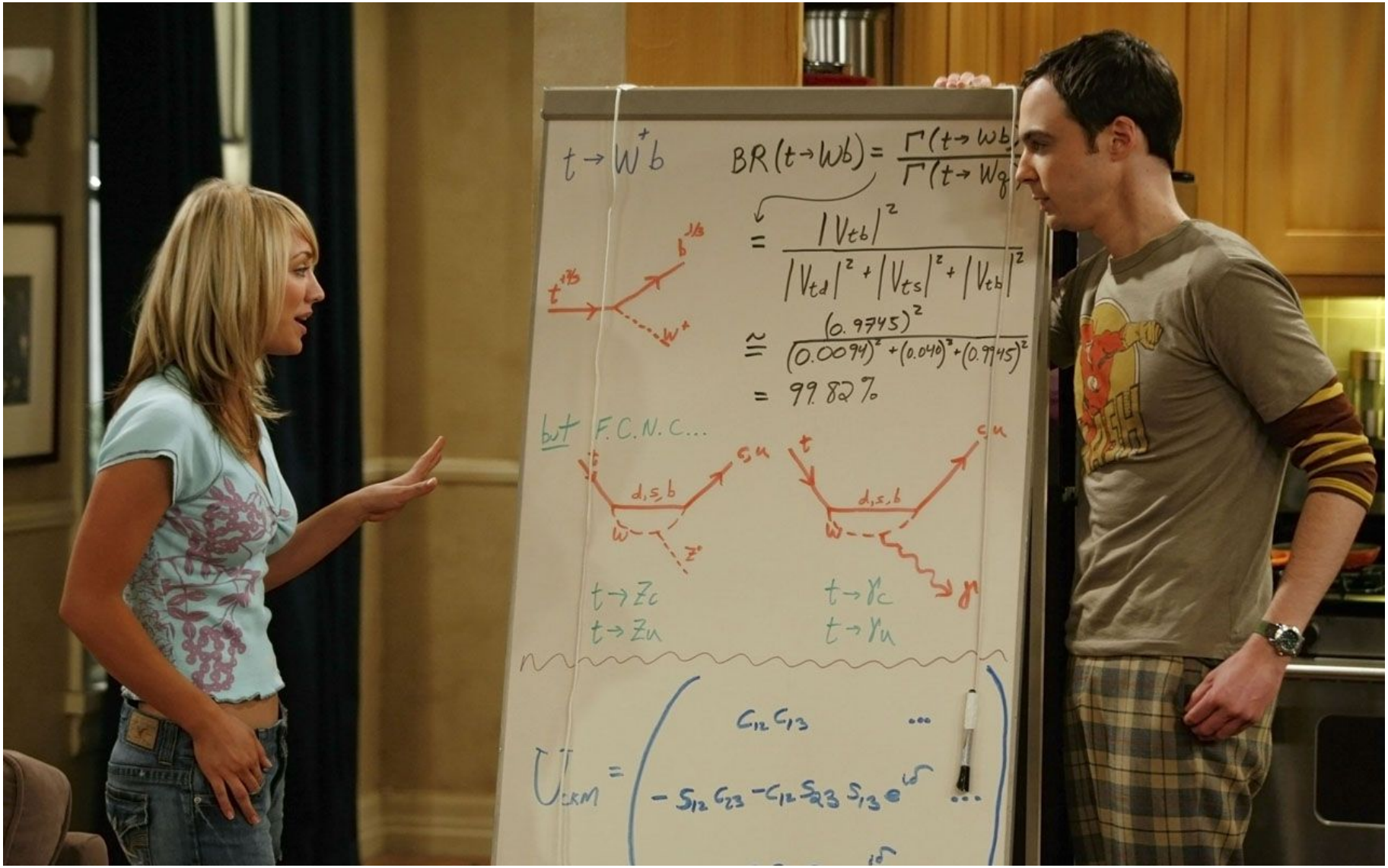

[PRD 95 071101(R) (April 2017)]

**Inflaton with m<4 GeV/c² mostly excluded by combination of CHARM, LHCb results and Theory constraints**

# Summary and conclusions

- LHCb offers a unique data set with high statistics to search for rare decays
- LHCb has proven to be able to conduct both high-precision and complicated analyses, e.g. $B_{(s)} \to \mu^+\mu^-$ and $B_{(s)} \to \tau^+\tau^-$
- Many other searches ongoing
  - Lepton-flavour violation
  - Baryon and Lepton number violation
  - Majorana neutrinos
- Additional Run2 data will increase signal yield of b-decays by a factor of about four

# Thanks for your attention!



# Other recent searches by LHCb

- **„Observation of the decay $\Lambda_b \to p K^- \mu^+\mu^-$ and a search for CP violation“**,
  [arXiv:1703.00256] (submitted to PRL)

  → 600±44 events in 3fb$^{-1}$ and no CP violation found

- **„Observation of the suppressed decay $\Lambda_b \to p \pi^- \mu^+\mu^-$“**,
  [JHEP 1704 (2017) 029]

  → 22±6 events (5.7σ) in 3fb$^{-1}$

- **„Search for CP-violating strong decays $\eta^{(\prime)} \to \pi^+\pi^-$“**
  [Phys.Lett.B 764 (2017) 233-240]

  → $\mathcal{B}(\eta \to \pi^+\pi^-)<1.6\times10^{-5}$ ; comparable to existing UL

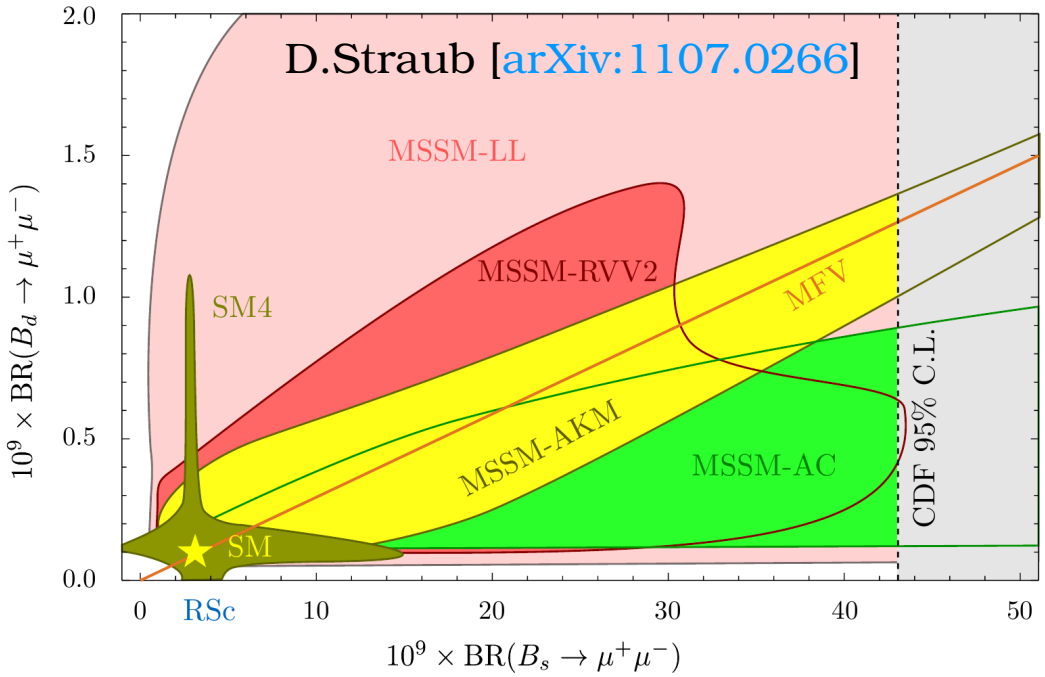
  → $\mathcal{B}(\eta' \to \pi^+\pi^-)<1.8\times10^{-5}$ ; improvement by a factor of three

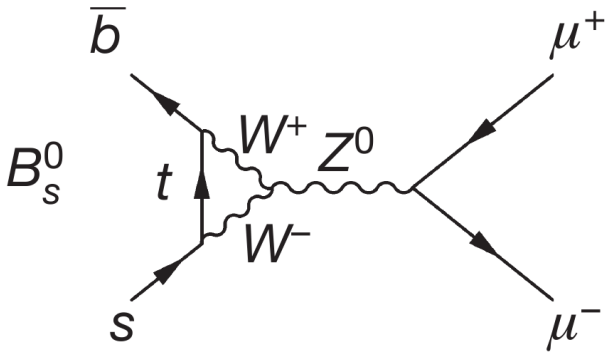
# Backup

# Search for $B_{(s)} \to \mu^+\mu^-$

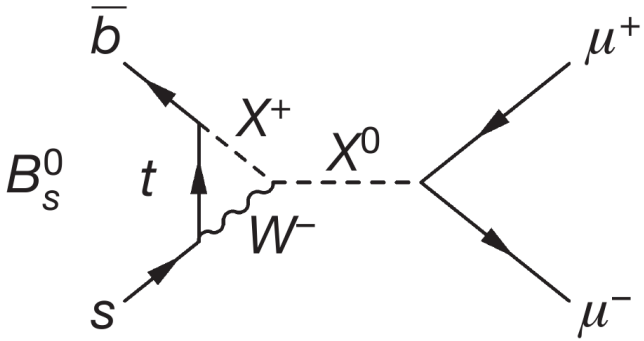
- Suppressed in the SM (helicity, $V_{CKM}$)
- Precise prediction of $\mathcal{B}$ in the SM ($\Delta\mathcal{B}/\mathcal{B}\approx 6\%$)
- NP constributions may modify SM prediction
- Sensitive to NP also from ratio of rates

$$\frac{\mathcal{B}(B^0 \to \mu^+\mu^-)}{\mathcal{B}(B_s^0 \to \mu^+\mu^-)} = \frac{\tau_{B^0}}{\tau_{B_s^0}} \cdot \frac{m_{B^0}}{m_{B_s^0}} \cdot \frac{f_{B^0}^2}{f_{B_s^0}^2} \cdot \left|\frac{V_{td}}{V_{ts}}\right|^2$$



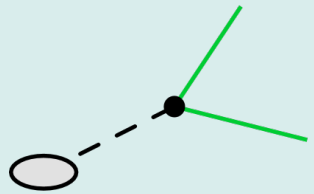




A SM diagram




NP contributions may lead to different rate

# Search for $B_{(s)} \to \mu^+\mu^-$



- Only the heavy $B_s$ mass eigenstate (CP=-1) can decay to $\mu^+\mu^-$

$$\tau_{\mu^+\mu^-} = \left[\frac{\tau_{B_s^0}}{1-y_s}\right]_{SM} \cdot (1+\varepsilon_{\mathrm{NP}})$$

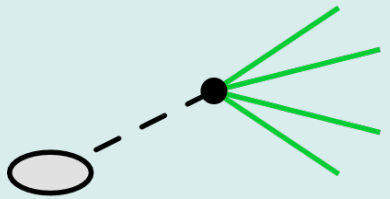
$$y_s \equiv \tau_{B_s^0}\,\Delta\Gamma/2 \approx 0.062(6)$$

$$\varepsilon_{\mathrm{NP}} = \frac{(A-1)\,(y_s - y_s^2)}{(1+y_s)\,(1+A\,y_s)}$$

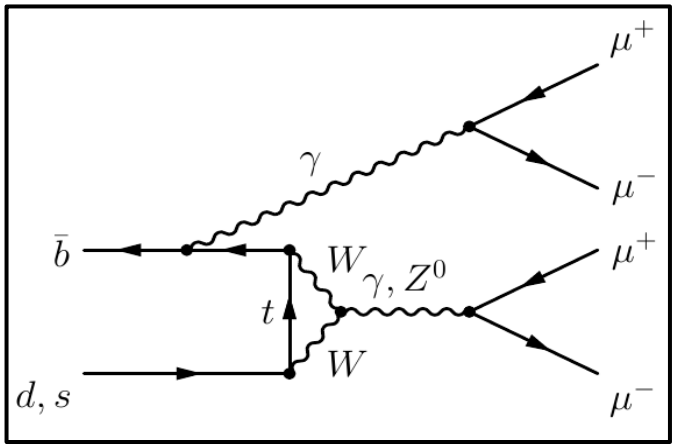
$$A = A_{\Delta\Gamma}^{\mu^+\mu^-} = \frac{-2\mathrm{Re}(\lambda)}{1+|\lambda|^2}\ ,\ \lambda = \frac{q}{p}\,\frac{A(B_s^0 \to \mu^+\mu^-)}{A(\overline{B}_s^0 \to \mu^+\mu^-)}$$

$$\left[\frac{\tau_{B_s^0}}{1-y_s}\right]_{SM} = (1.61 \pm 0.16)\,\mathrm{ps}$$

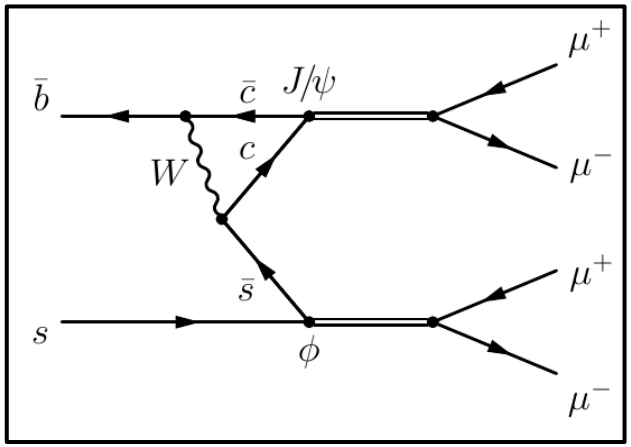
# Search for $B_{(s)} \to \mu^+\mu^-\mu^+\mu^-$



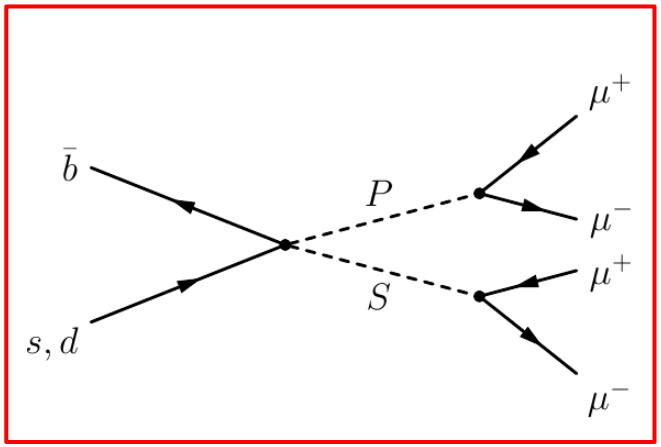
- SM prediction $\mathcal{B}(B_s \to \mu^+\mu^-\mu^+\mu^-) = 3.5 \times 10^{-11}$ [Phys.Lett. B 556 (2003) 169]
- Significant enhancement possible due to minimal SUSY model with S and P sgoldstino particles: $\mathcal{B}(B_s \to SP) \leq 10^{-4}$ , $\mathcal{B}(B^0 \to SP) \leq 10^{-7}$ [PRD 85 (2012) 077701]
- SUSY model motivated by excess of three events consistent with $\Sigma^+ \to P(\to \mu^+\mu^-)p$ with $m(P) = 214.3(5)\,\mathrm{MeV}/c^2$ seen by HyperCP collab. [PRL 94 (2005) 021801]




Non-resonant decay

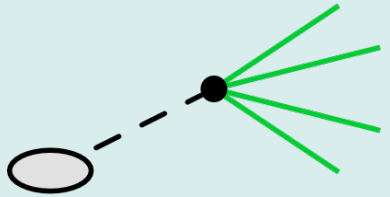



Resonant decay → background




Supersymmetric decay

# Search for $B_{(s)} \to \mu^+\mu^-\mu^+\mu^-$



- Update of previous measurement using $1fb^{-1}$ from 2011

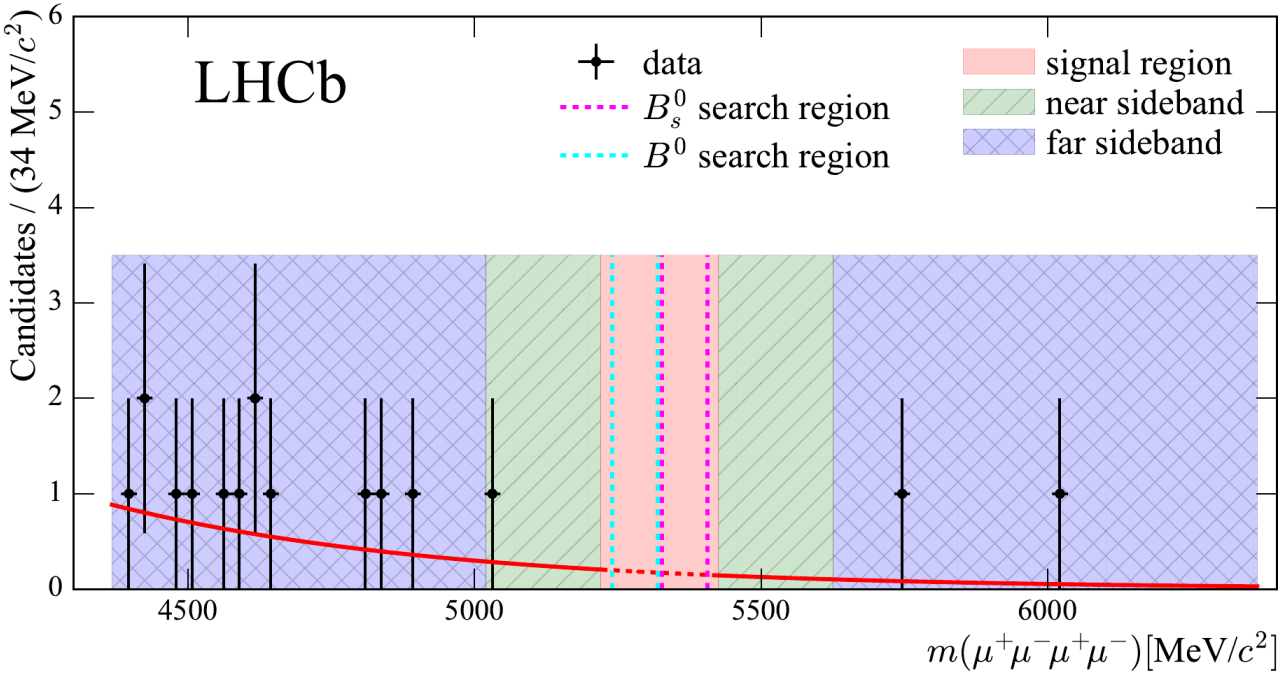
  ☺ More data: $+2fb^{-1}$ from 2012 at $\sqrt{s}(pp) = 8$ TeV

  ☺ Less systematic uncertainties:

  - New normalisation channel $B^+ \to J/\psi(\mu^+\mu^-)K^+$ ( well known $\mathcal{B}$ )
  - Bigger signal MC samples (incl. MC with dedicated MSSM model)

- General analysis strategy
  - Blind analysis with multivariate selection (BDT)
  - Data driven correction of simulated event samples
  - Selection optimisation in BDT variable and muon PID
  - Optimisation of Punzi-FoM for an evidence ($\sigma$=3)
  - Independent cross check of analysis strategy using $B^+ \to J/\psi(\mu^+\mu^-)\phi(\mu^+\mu^-)$ events

# Search for $B_{(s)} \to \mu^+\mu^-\mu^+\mu^-$




- Fit to complete data after MVA selections
- Exponential function to model background
- No signal events

- **Results**

| | UL on $\mathcal{B}$ at CL=95% | Efficiency |
|---|---|---|
| $B_s \to \mu^+\mu^-\mu^+\mu^-$ | $< 2.5\times10^{-9}$ | 0.580(3)% |
| $B^0 \to \mu^+\mu^-\mu^+\mu^-$ | $< 6.9\times10^{-10}$ | 0.568(3)% |
| $B_s \to S(\to\mu^+\mu^-)P(\to\mu^+\mu^-)$ | $< 2.2\times10^{-9}$ | 0.648(3)% |
| $B^0 \to S(\to\mu^+\mu^-)P(\to\mu^+\mu^-)$ | $< 6.0\times10^{-10}$ | 0.648(3)% |

# Search for $B_{(s)} \to \tau^+\tau^-$

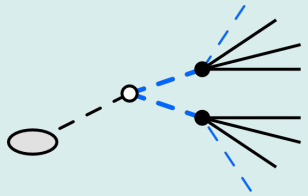
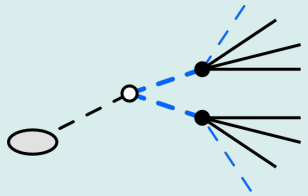


TABLE I. Summary of experimental and predicted values for $R(D)$ and $R(D^*)$.

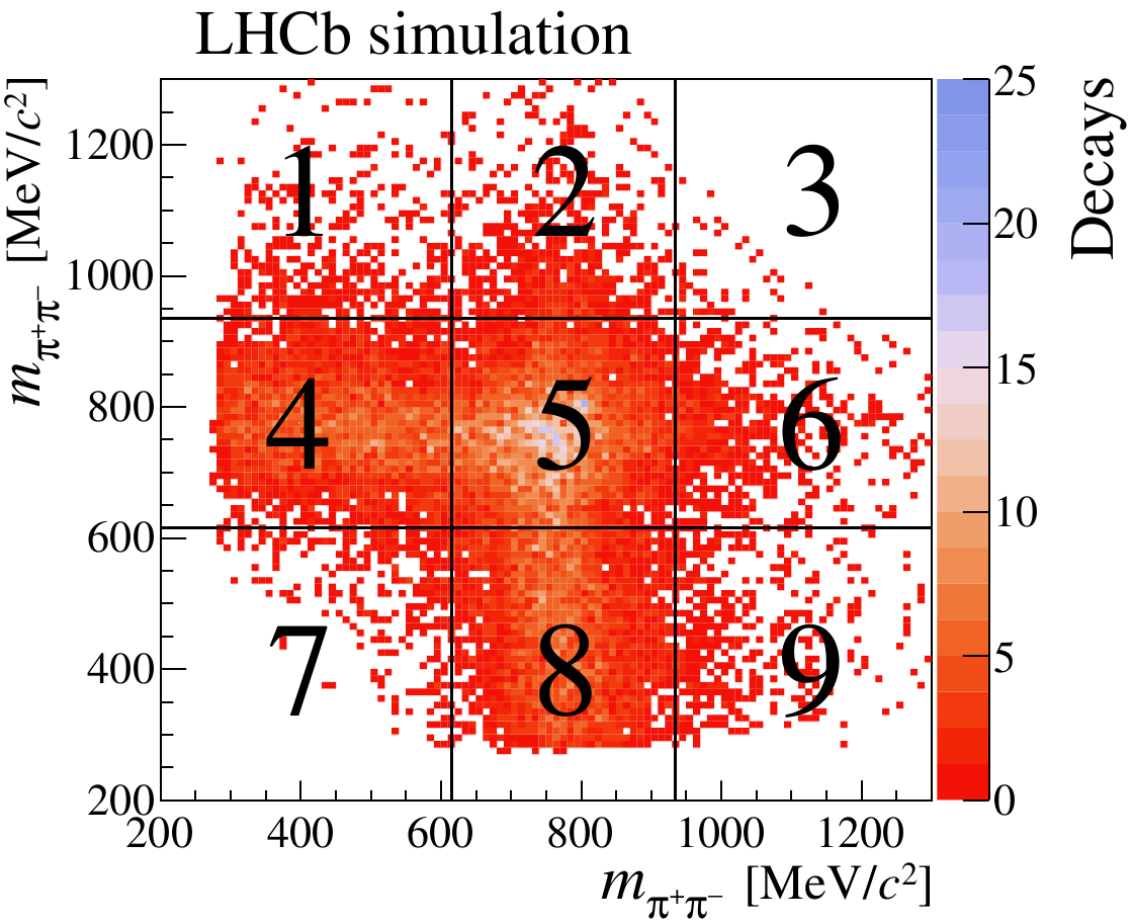
| ... | $R(D)$ | $R(D^*)$ |
|---|---|---|
| SM | $0.297 \pm 0.017$ | $0.252 \pm 0.005$ |
| Belle [6] | $0.375 \pm 0.064 \pm 0.026$ | $0.293 \pm 0.038 \pm 0.015$ |
| *BABAR* [5] | $0.440 \pm 0.058 \pm 0.042$ | $0.332 \pm 0.024 \pm 0.018$ |
| LHCb [7] | | $0.336 \pm 0.027 \pm 0.030$ |
| Experimental average | $0.408 \pm 0.050$ | $0.321 \pm 0.021$ |

[PRD 93, 075017 (2016)]

# Search for $B_{(s)} \to \tau^+\tau^-$



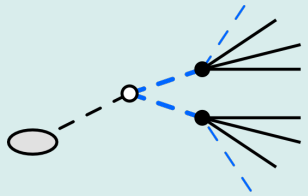
- Definition of signal and control regions



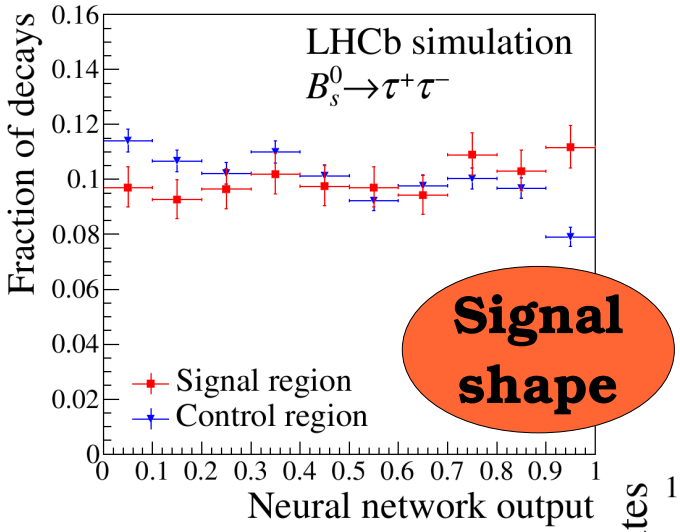

- Signal region:
  {5}x{5} — **1**
- Signal-depleted:
  {1,3,7,9}⊗{all} ⊕ {all}⊗{1,3,7,9} — 2*4*9 -4*4 =**56**
- Control region:
  {4,5,8}⊗{4,8} ⊕ {4,8}⊗{4,5,8} — 2*3*2 -2*2 =**8**
- Not considered:
  {2,6}⊗{2,4,5,6,8} ⊕ {2,4,5,6,8}⊗{2,6} — 2*2*5 -2*2 =**16**

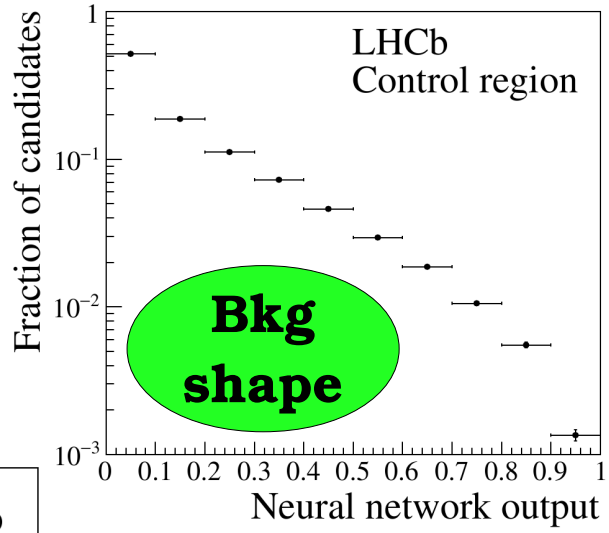
**81**

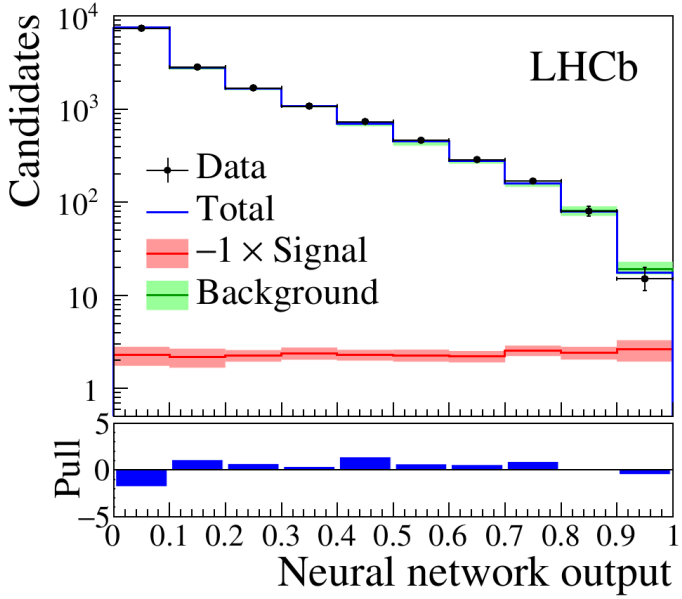
# Search for $B_{(s)} \to \tau^+\tau^-$



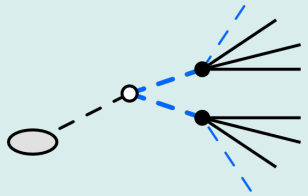
- Binned likelihood fit to Neural network output variable



# Search for $B_{(s)} \to \tau^+\tau^-$



- Fit model:

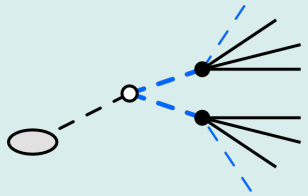
Signal yield in signal region

Scaling of background yield

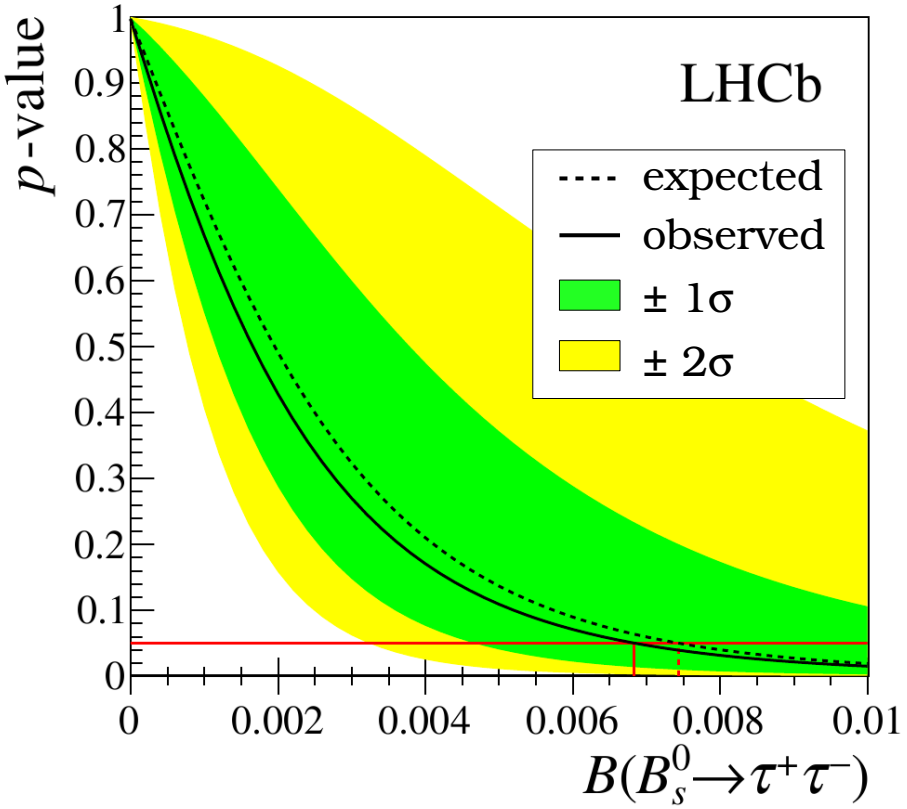
$$\mathcal{N}^{\mathrm{SR}}_{\mathrm{data}} = s \times \widehat{\mathcal{N}}^{\mathrm{SR}}_{\mathrm{sim}} + f_b \times \left( \mathcal{N}^{\mathrm{CR}}_{\mathrm{data}} - s \times \frac{\varepsilon^{\mathrm{CR}}}{\varepsilon^{\mathrm{SR}}} \times \widehat{\mathcal{N}}^{\mathrm{CR}}_{\mathrm{sim}} \right)$$

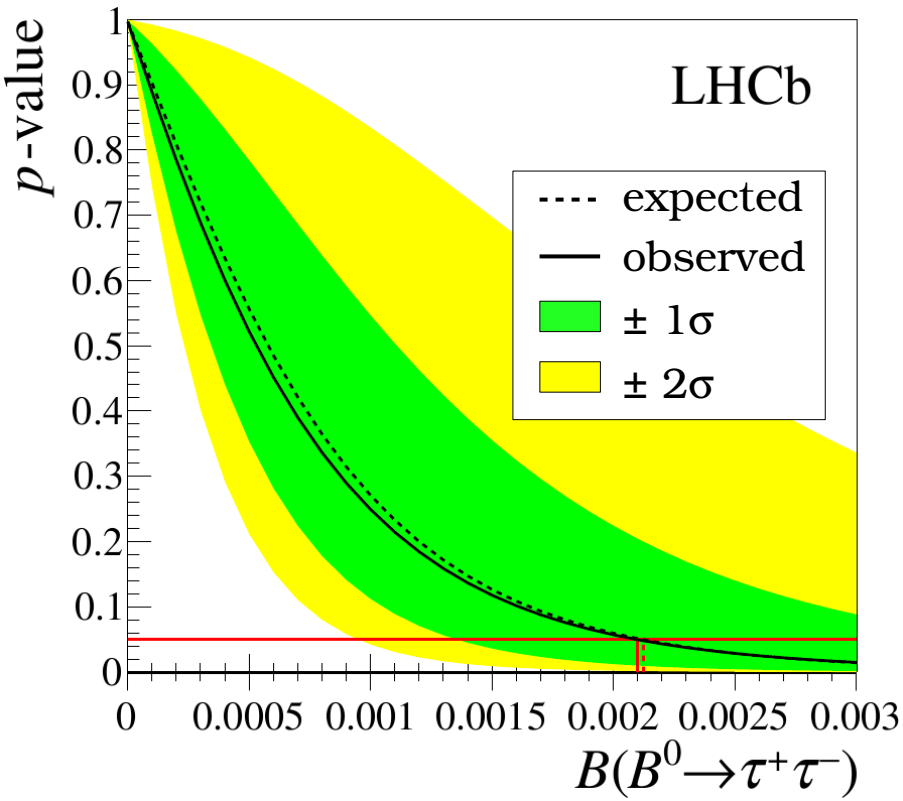
Signal PDF in signal region

# Search for $B_{(s)} \to \tau^+\tau^-$



- Fit yields are negative




$\mathcal{B} < 5.2\times10^{-3}$ @ CL=90%

$\mathcal{B} < 6.8\times10^{-3}$ @ CL=95%

# Search for $\eta \to \pi^+\pi^-$ and $\eta' \to \pi^+\pi^-$

**„Search for CP-violating strong decays $\eta \to \pi^+\pi^-$ and $\eta' \to \pi^+\pi^-$“**

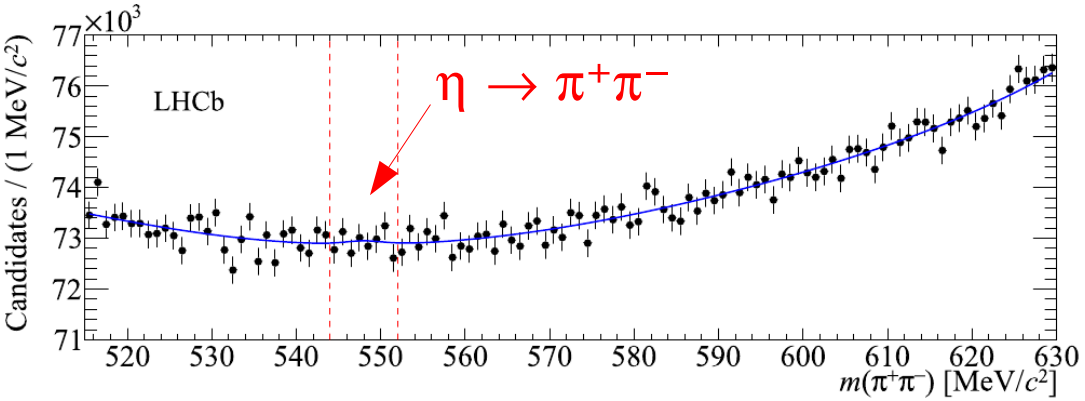
- Motivation:
  - Search for CP violation in QCD , SM: $\mathcal{B}(\eta^{(\prime)} \to \pi^+\pi^-)<10^{-27}$ [PRD 52 (1995) 248-253]
- Analysis strategy
  - Search in exclusive sample of $D^+_{(s)} \to \pi^+\pi^-\pi^+$ decays
  - $\mathcal{B}(D^+ \to \eta^{(\prime)}\pi^+) \approx 0.35(0.47)\%$ , $\mathcal{B}(D^+_s \to \eta^{(\prime)}\pi^+) \approx 1.7(3.9)\%$
- No events found in $2.4\times10^7$ $D^+_{(s)} \to \pi^+\pi^-\pi^+$ decays
- Upper limits at CL=90%

(1) $\mathcal{B}(\eta \to \pi^+\pi^-)<1.6\times10^{-5}$

(2) $\mathcal{B}(\eta' \to \pi^+\pi^-)<1.8\times10^{-5}$

(1) **comparable to existing UL**

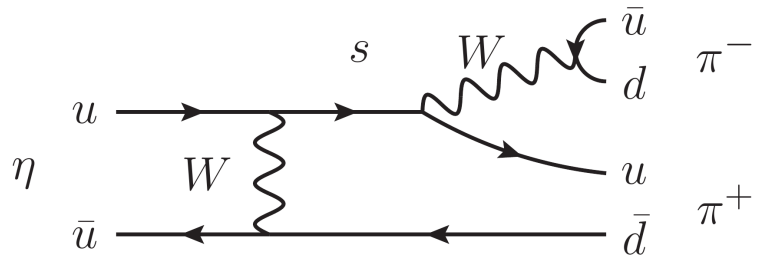
(2) **improvement by factor 3**




[Phys.Lett.B 764 (2017) 233-240]

# Search for $\eta \to \pi^+\pi^-$ and $\eta' \to \pi^+\pi^-$

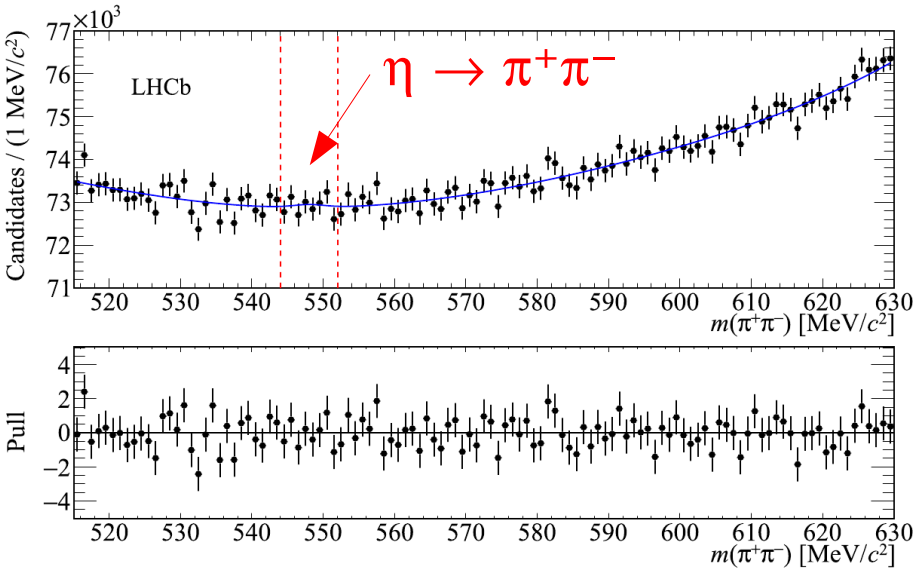
- Decays allowed in SM via virtual $K_s$ meson

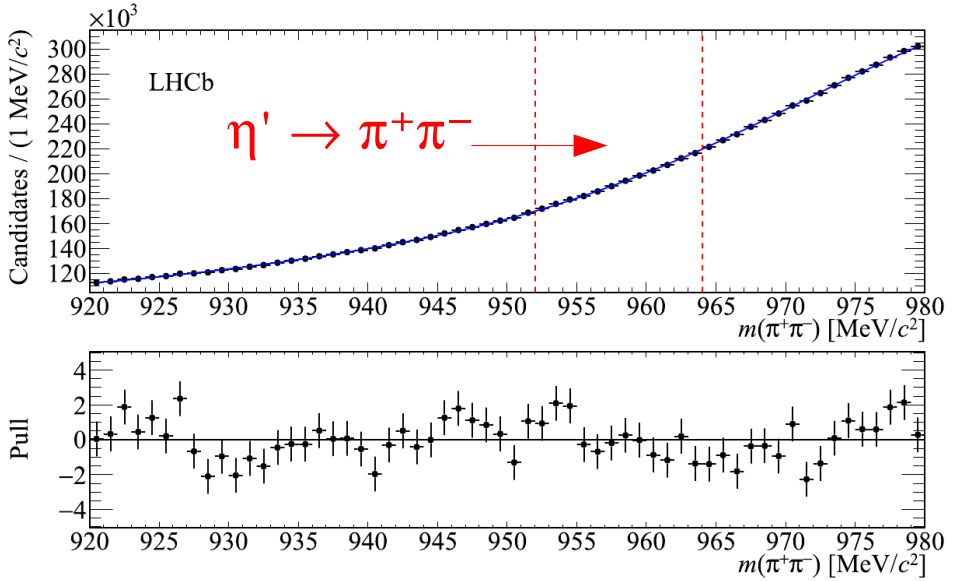



$\mathcal{B}(\eta \to \pi^+\pi^-) < 10^{-27}$

[PRD 52 (1995) 248-253]

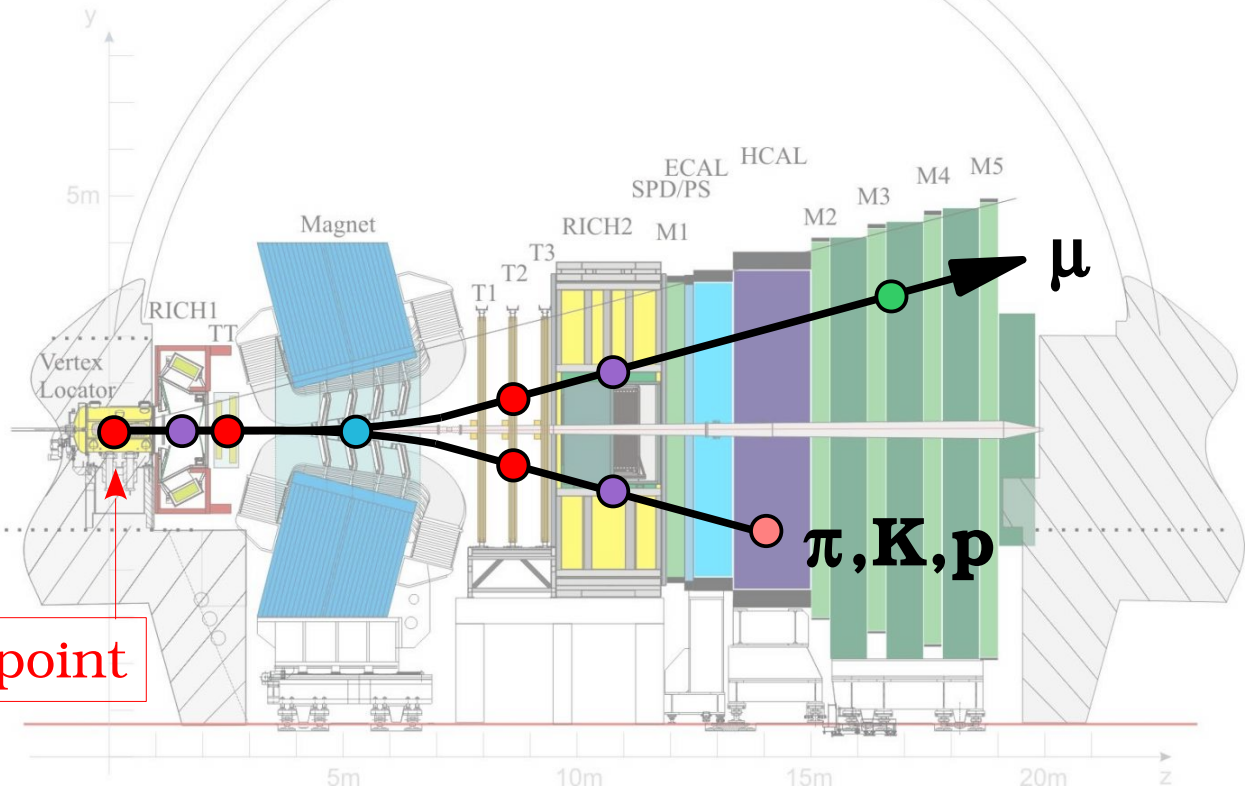
- $m(\pi^+\pi^-)$ spectra of selected $D^+_{(s)} \to \pi^+\pi^+\pi^-$ events [Phys.Lett.B 764 (2017) 233-240]



# The LHCb Detector

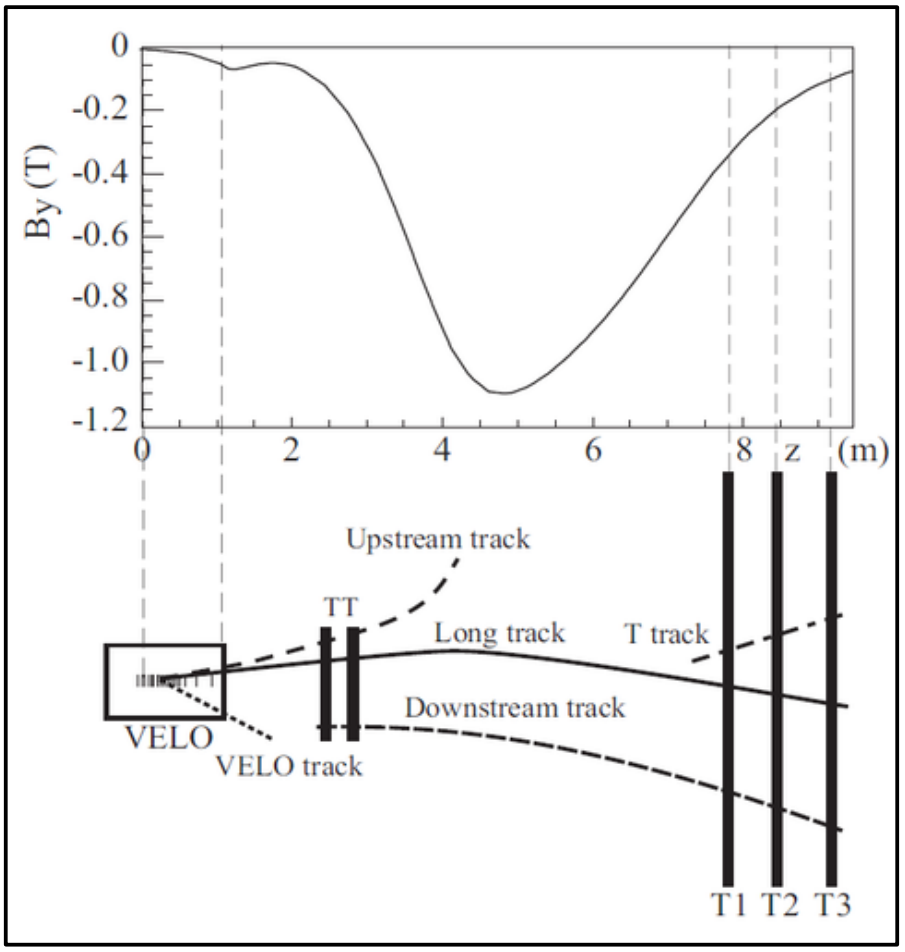
- Single-arm spectrometer for charged particles and photons
- Momentum range of p = 1 ... 200 GeV/c and $\Delta p/p \approx 0.5\%$
- High b-hadron production of about $10^{11}$ per year
- Good K/π separation: $\varepsilon(K \to K)/\varepsilon(\pi \to K) \approx 95\%/5\%$

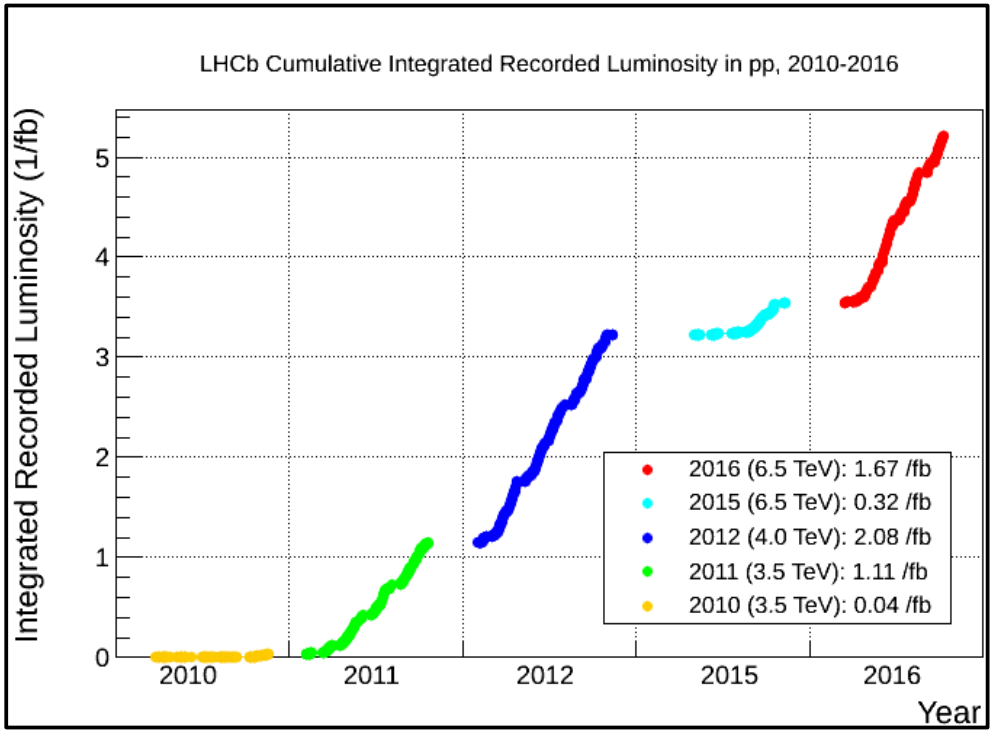



pp collision point

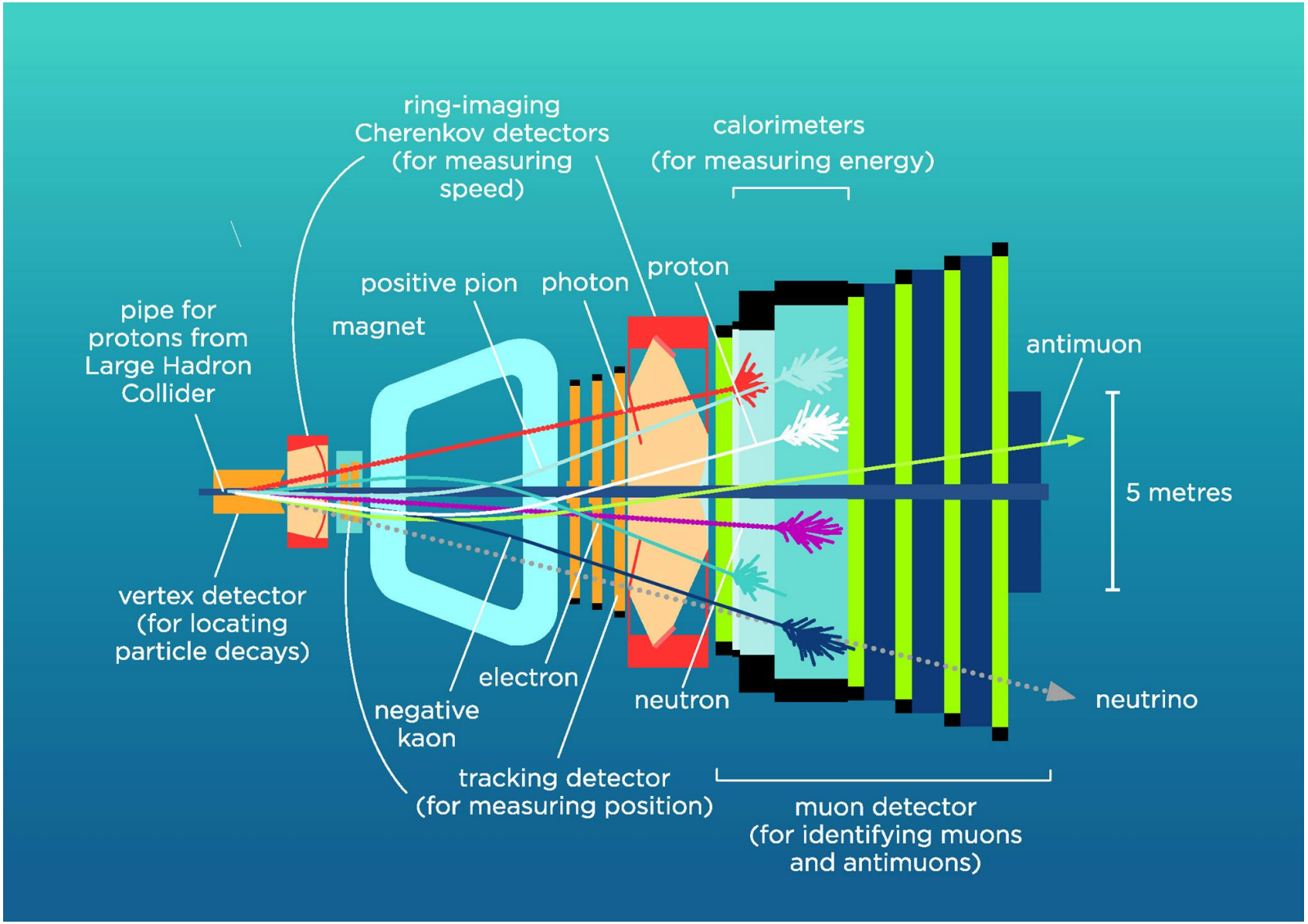
- Tracking
- PID
- Momentum
- Calorimeter
- Muon-ID

# The LHCb Detector

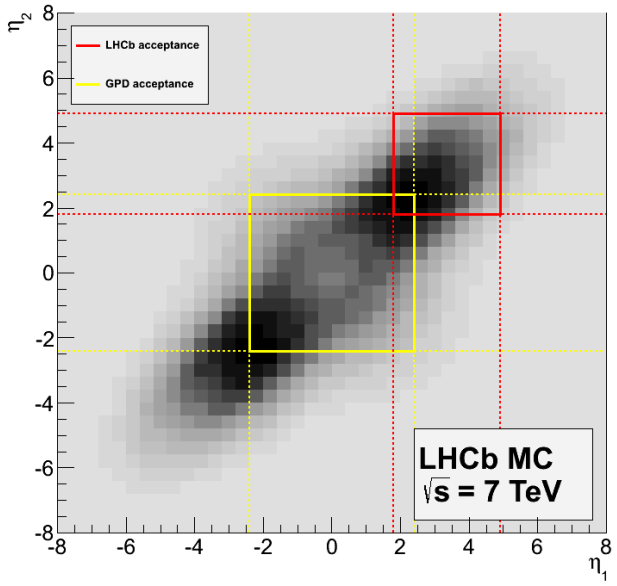


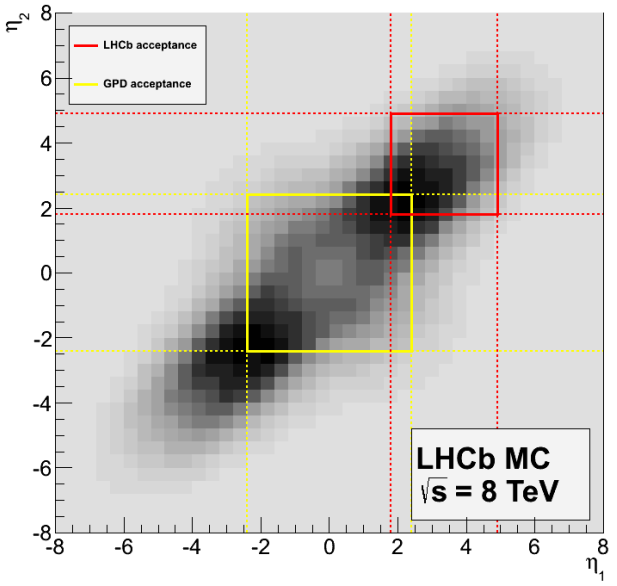



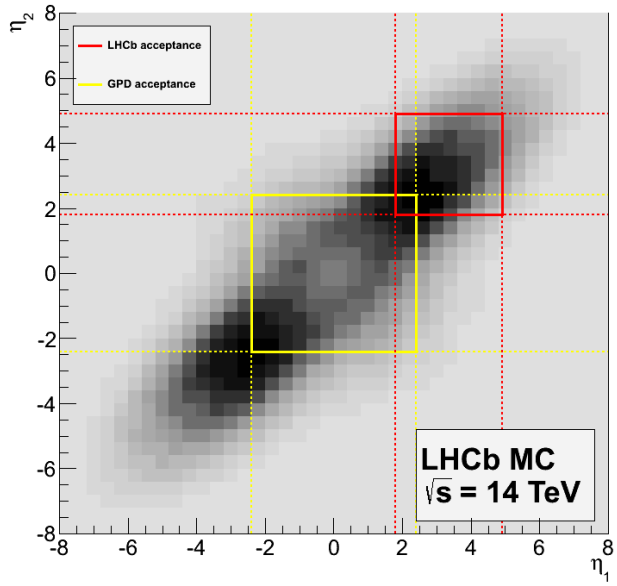
# The LHCb Detector



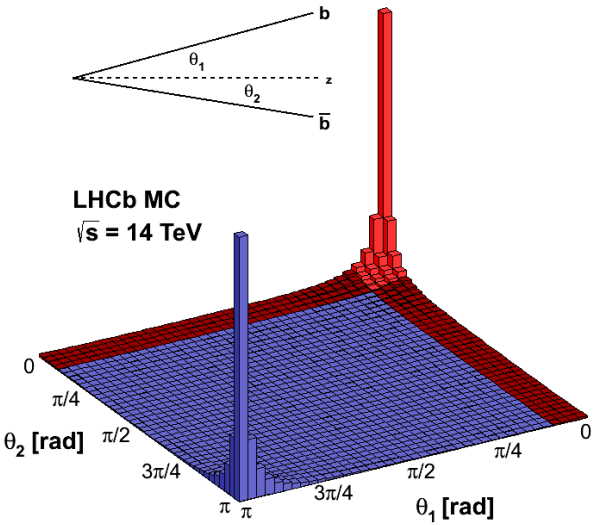
# Angular acceptance of $b\bar{b}$-production



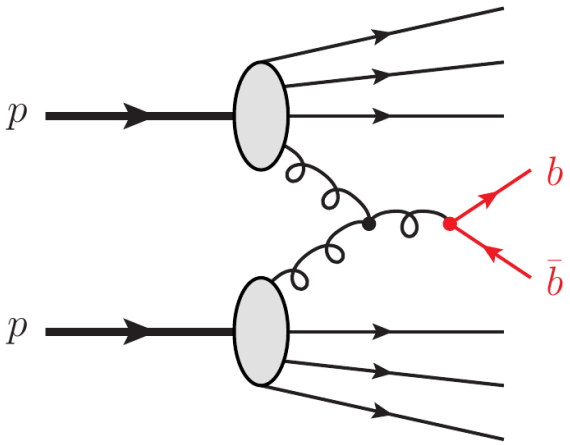




≈25% of $b\bar{b}$ produced inside LHCb acceptance



# LHCb - full of *beauty*

- High $b\bar{b}$ production at LHCb

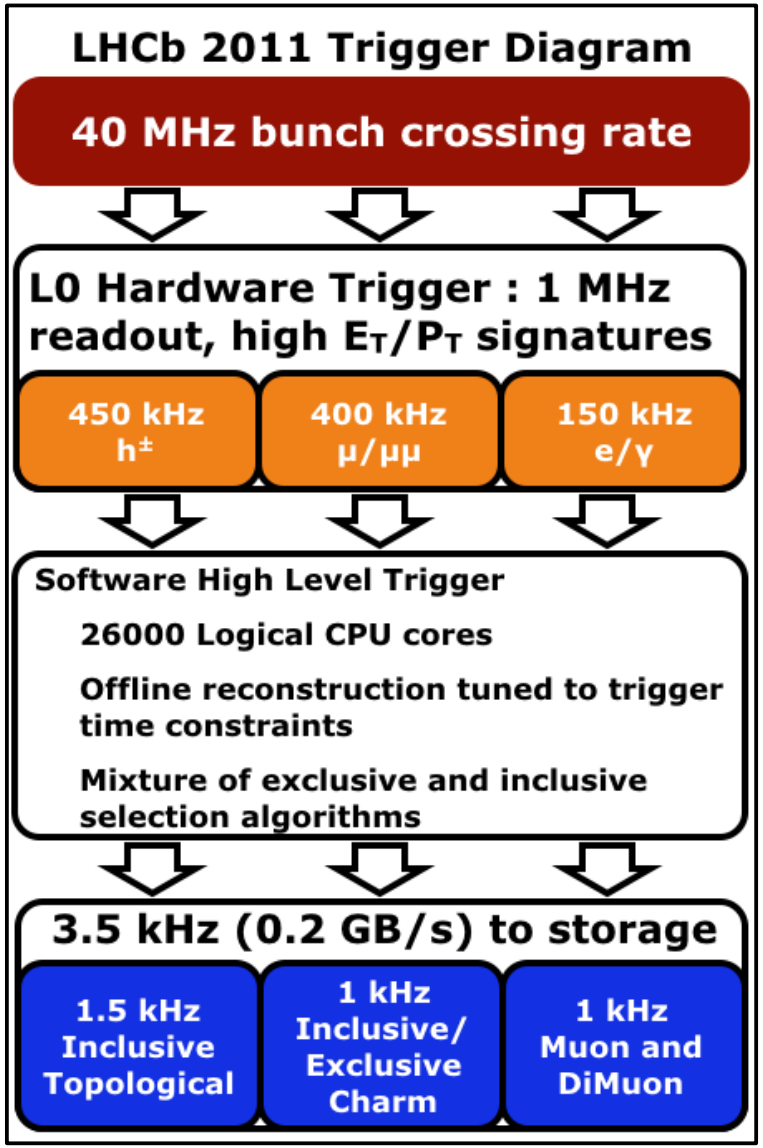


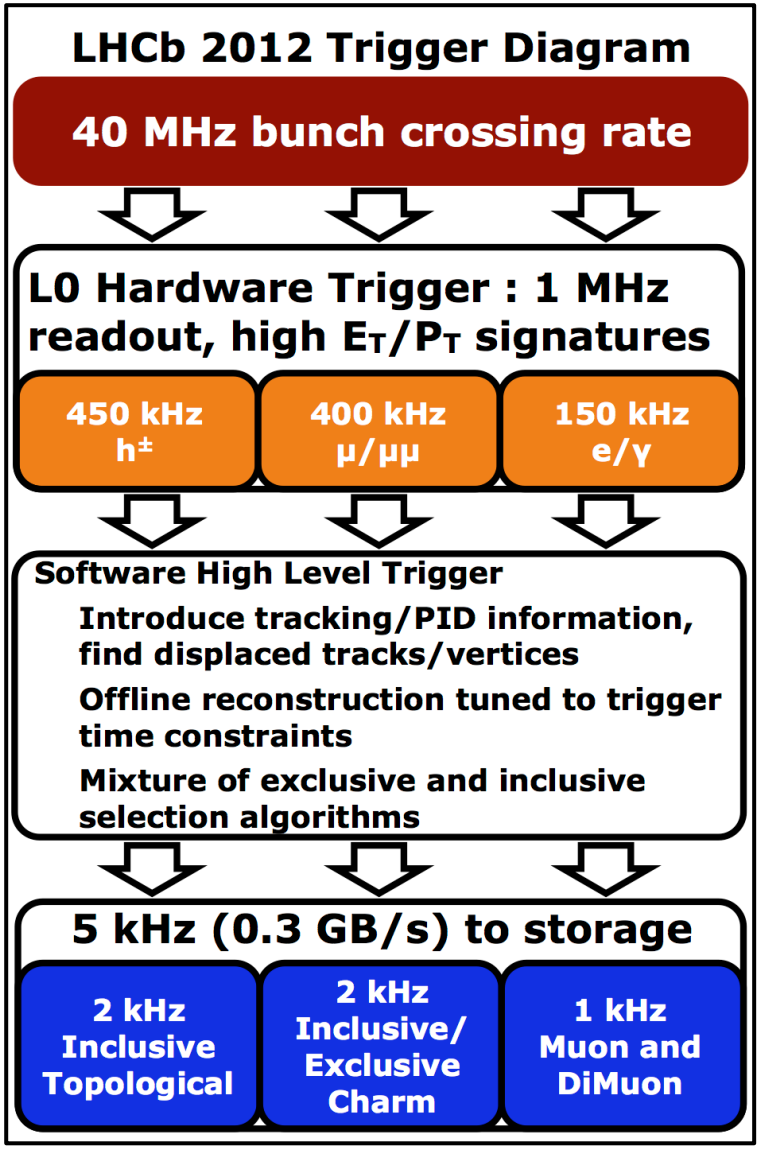

- $b\bar{b}$ production within LHCb
  - Run 1 (2011-2012): $2.6\times10^{11}$ $b\bar{b}$
  - Run 2 (2015-2016): $3.1\times10^{11}$ $b\bar{b}$
- Relative fragmentation rates:
  - $B^0 : B^+ : \Lambda_b : B_s \approx 1 : 1 : 40\% : 25\%$

- High trigger efficiencies
  - 90% for dimuon channels
  - 30% for multi-body hadronic channels

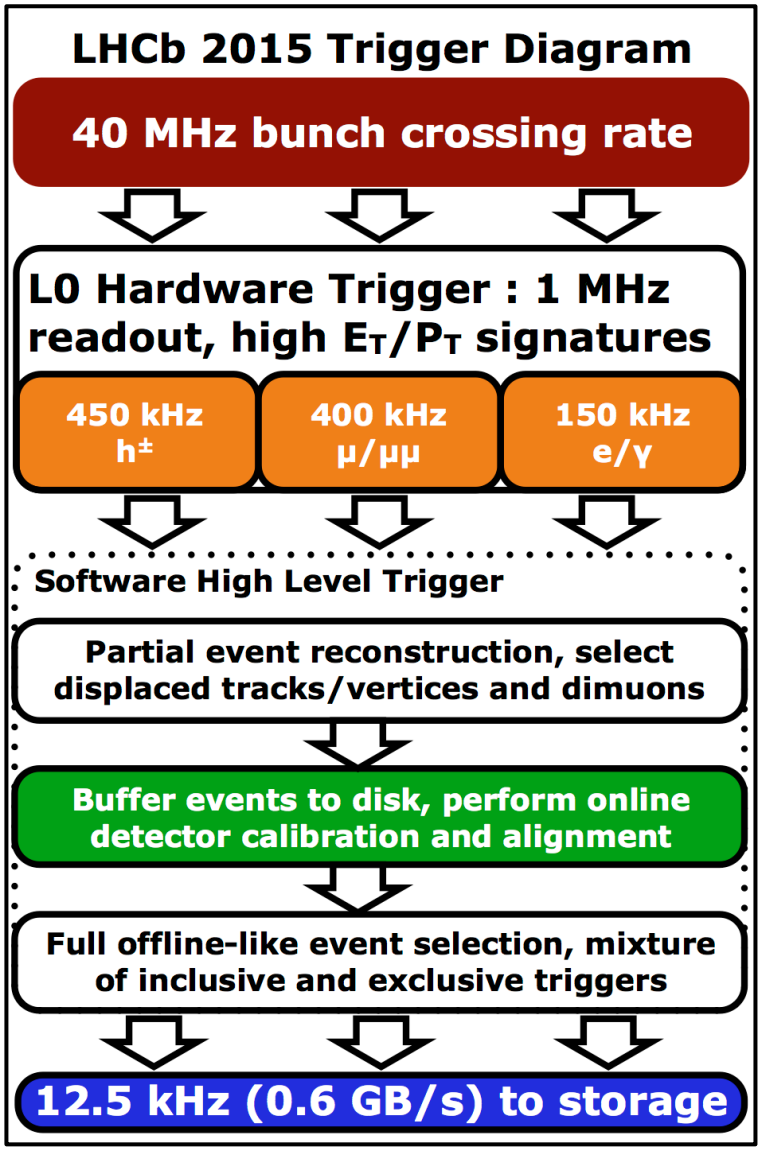
⇨ **Sensitivity for b-decays down to $\mathcal{B} = 10^{-11}$**

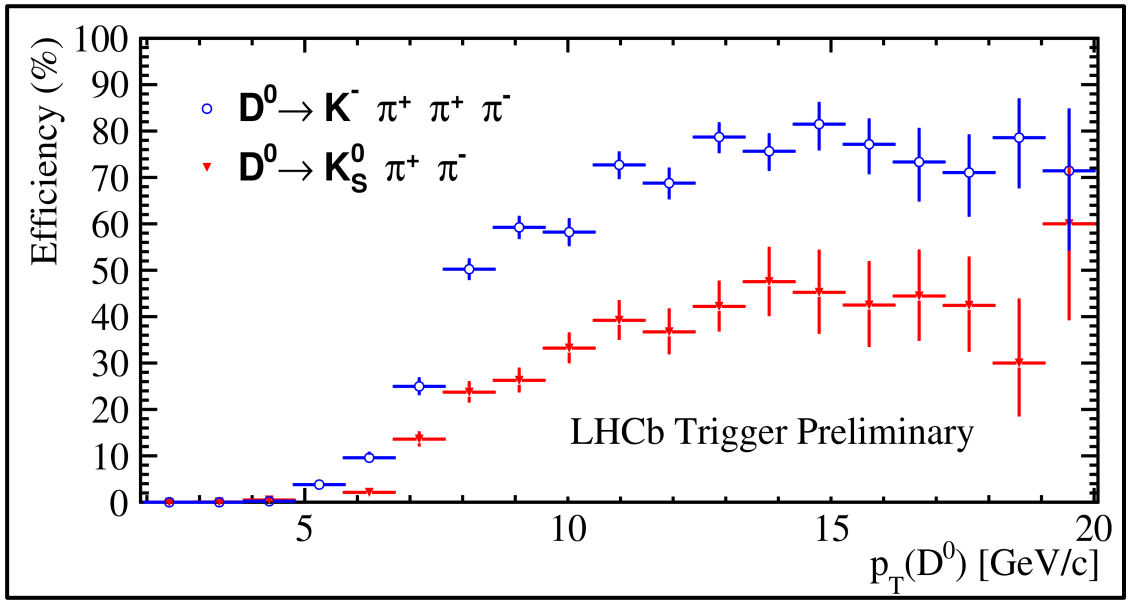
# LHCb trigger schemes: Run1



# LHCb Run2 trigger and performance




TISTOS efficiency of the inclusive D* trigger in dependence of $p_T(D^0)$