Latest news from LHCb

(rare & semileptonic decays)

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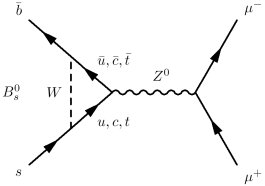
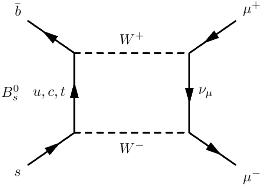
Rare decays

- Rare decays are generated by **transitions** or **annihilations** between down (up) type quarks (**Flavor Changing Neutral Current**)
- Forbidden at the tree level in Standard Model (SM) → **loop processes**





- Processes sensitive to New Physics (NP) effects: **indirect probes**
- Operator Product Expansion approach:

$$\mathcal{H}_{eff}|_{bs\ell\ell} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^{\star} \frac{e^2}{16\pi^2} [m_b \mathbf{C}_7^{(\prime)} (\bar{b}\sigma_{\mu\nu} P_{R(L)} s) F^{\mu\nu} + \mathbf{C}_9^{(\prime)} (\bar{b}\gamma^\mu P_{L(R)} s)(\bar{\ell}\gamma_\mu \ell) + \mathbf{C}_{10}^{(\prime)} (\bar{b}\gamma^\mu P_{L(R)} s)(\bar{\ell}\gamma_\mu \gamma^5 \ell) + \mathbf{C}_S^{(\prime)} (\bar{b}\ P_{L(R)} s)(\bar{\ell}\ell) + \mathbf{C}_P^{(\prime)} (\bar{b} P_{L(R)} s)(\bar{\ell}\gamma^5 \ell)]$$

- Observables related to those transitions (**$\mathcal{B}$, angular distributions**,...) depend on "Wilson coefficients" $\mathbf{C_i}^{(\prime)}$ and can shed light on the pattern of NP

Outline

- Search for NP in FCNC:
  - $B^0_{(s)} \to \mu^+\mu^-$ (constraints on $C_{10}^{(\prime)}$, $C_S^{(\prime)}$, $C_P^{(\prime)}$)
  - $b \to s(d)\ell\ell$ transitions (constraints on $C_7^{(\prime)}$, $C_9^{(\prime)}$, $C_{10}^{(\prime)}$): $B^0 \to K^{\star 0}\mu^+\mu^-$
- Search for Lepton Flavor Universality (LFU) violation:
  - in FCNC: $R(K)$ ratio
  - in tree processes: $R(D^\star)$
- Search for Lepton Flavor Violation (LFV): $B^0_{(s)} \to e^\pm\mu^\mp$

$B^0_{(s)} \to \ell^+\ell^-$: the golden channel

The expression for the Branching Ratio $\mathcal{B}$ reads:

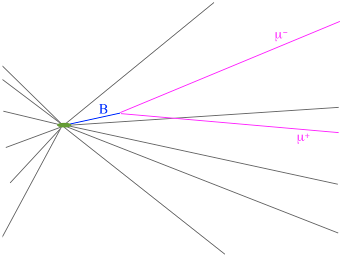
$$\mathcal{B}(B^0_q \to \ell^+\ell^-) = \mathcal{C} \cdot \beta_{m_\ell} \cdot \mathbf{f}^2_{B_q} \cdot \left\{ \left| 2\frac{\mathbf{m}_\ell}{M_{B_q}}(\mathbf{C}_{10} - \mathbf{C}'_{10}) + (\mathbf{C}_P - \mathbf{C}'_P) \right|^2 + \beta^2_{m_\ell} |\mathbf{C}_S - \mathbf{C}'_S|^2 \right\}$$

- **SM** case: $C^{(\prime)}_{S,P}, C'_{10} \simeq 0$
  - additional **helicity suppression**
  - only **one hadronic input**
- **BSM** scenarios:
  - $C^{(\prime)}_{S,P}, C'_{10} \neq 0,\ C^{SM}_{10} \to C^{SM}_{10} + \delta C^{NP}_{10}$
  - **NP not helicity suppressed !**

SM predictions ([PRL 112, 101801 (2014)])

$$\mathcal{B}(B^0_s \to \mu\mu) = (3.65 \pm 0.23) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu\mu) = (1.06 \pm 0.09) \times 10^{-10}$$

$B^0_{(s)} \to \mu^+\mu^-$ CMS-LHCb [Nature 522 (2015) 68]



Statistics: Full RunI datasets from both experiments

Reconstruction: 2 tracks with good μ-ID, coming from a good common vertex, well displaced wrt any PV in the event

- Kinematical and topological variables combined through a **BDT** to remove **combinatorial background**

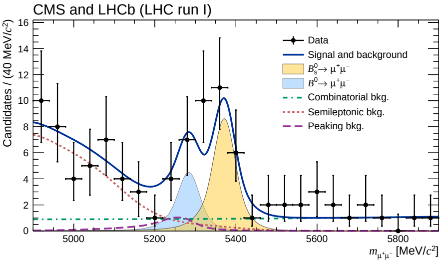
- Data classified in 20 categories
  - experiment: **LHCb** or **CMS**
  - **BDT** value
  - **period (2011/2012)**
  - **μ track detection region (barrel/endcap)**
- In total **8** $\oplus$ **12**

- **Normalization** through $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$

- **Extendend maximum likelihood fit in $\mathbf{m}_{\mu\mu} \in [4.9, 5.8]$ GeV/c^2** in all 20 categories simultaneously

- $\mathcal{B}(B^0_s \to \mu^+\mu^-)$ and $\mathcal{B}(B^0 \to \mu^+\mu^-)$ in common for the 20 categories

$B^0_{(s)} \to \mu^+\mu^-$ CMS-LHCb [Nature 522 (2015) 68]



$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (2.8^{+0.7}_{-0.6}) \cdot 10^{-9} \text{ @ } 6.2\sigma$$

First observation !

$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.9^{+1.6}_{-1.4}) \cdot 10^{-10} \text{ @ } 3.0\sigma^\star$$

* evaluated using simulated experiments

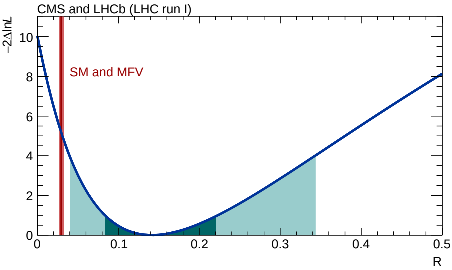
First evidence !

Compatibility with SM predictions:

$$\frac{\mathcal{B}^{B^0_s}_{meas}}{\mathcal{B}^{B^0_s}_{SM}} = \mathbf{0.76^{+0.20}_{-0.18}} \ (1.2\sigma \text{ from SM})$$

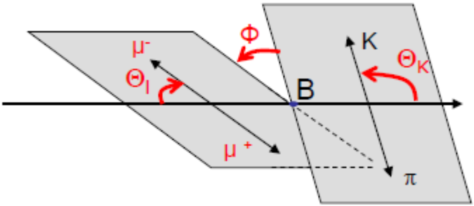
$$\frac{\mathcal{B}^{B^0}_{meas}}{\mathcal{B}^{B^0}_{SM}} = \mathbf{3.7^{+1.6}_{-1.4}} \ (2.2\sigma \text{ from SM})$$

$$\mathcal{R} = \frac{\mathcal{B}^{B^0}_{meas}}{\mathcal{B}^{B^0_s}_{meas}} = \mathbf{0.14^{+0.08}_{-0.06}} \ (2.3\sigma \text{ from SM})$$



$B^0 \to K^{\star 0}(K^+\pi^-)\mu^+\mu^-$ [JHEP 02 (2016) 104]

Differential decay width function of $q^2(\equiv m^2_{\mu\mu})$, $\vec{\Omega} = (\theta_\ell, \theta_K, \phi)$



- **Functions** of $K^\star$ polarization-dependent amplitudes depending on $C^{(\prime)}_{7,9,10}$ & $\langle K^\star | B^0 \rangle$ Form Factors (FF)
- some combinations, *e.g.* $\mathbf{P}'_{4,5} \equiv \mathbf{S}_{4,5}/\sqrt{\mathbf{F_L}(1-\mathbf{F_L})}$, have a reduced dependence on the hadronic FF [JHEP 05 (2013) 137]

S-wave pollution: $(K^+\pi^-)$ system can be in an S-wave state

- the differential rate must be corrected as (F_S fraction of S-wave contribution):

$$(1-\mathbf{F}_S)\frac{1}{d\Gamma_{CP}/dq^2}\frac{d^3\Gamma_{CP}}{d\vec{\Omega}} + \frac{3}{16\pi}\mathbf{F}_S \sin^2\theta_\ell + (S,P)_{interference}$$

- included as systematic in previous analysis, due to limited statistics

$B^0 \to K^{\star 0}(K^+\pi^-)\mu^+\mu^-$ [JHEP 02 (2016) 104]

Differential decay width function of $q^2 (\equiv m^2_{\mu\mu})$, $\vec{\Omega} = (\theta_\ell, \theta_K, \phi)$ $(\Gamma_{CP} \equiv \Gamma + \bar{\Gamma})$:

$$\frac{1}{d\Gamma_{CP}/dq^2}\frac{d^3\Gamma_{CP}}{d\vec{\Omega}} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-\mathbf{F}_L)\sin^2\theta_K + \mathbf{F}_L\cos^2\theta_K + \frac{1}{4}(1-\mathbf{F}_L)\sin^2\theta_K\cos 2\theta_\ell - \mathbf{F}_L\cos^2\theta_K\cos 2\theta_\ell + \mathbf{S}_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \mathbf{S}_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + \mathbf{S}_5\sin 2\theta_K\sin\theta_\ell\sin\phi + \frac{4}{3}\mathbf{A}_{FB}\sin^2\theta_K\cos\theta_\ell + \mathbf{S}_7\sin 2\theta_K\sin\theta_\ell\sin\phi + \mathbf{S}_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + \mathbf{S}_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big]$$

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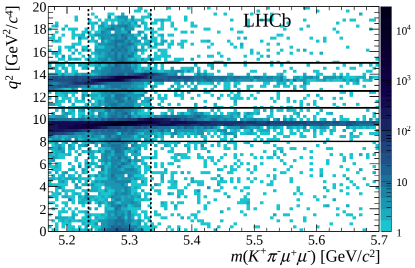
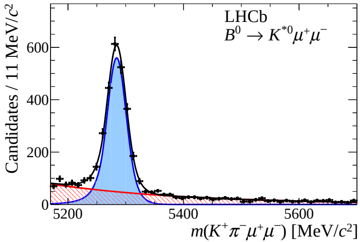
- included as systematic in previous analysis, due to limited statistics

$B^0 \to K^{\star 0}(K^+\pi^-)\mu^+\mu^-$ [JHEP 02 (2016) 104]

- Dataset: $3.1 fb^{-1}$ RunI dataset
- loose cut-based preselection $\oplus$ BDT
- kinematic, geometric, PID variables
- BDT trained on data:
  - signal: $B^0 \to K^\star J/\psi(\to \mu^+\mu^-)$ events
  - background: $5.35 < m(K^+\pi^-\mu^+\mu^-) < 7\ GeV/c^2$
- Veto on $J/\psi K^\star$, and $J/\psi(2S)K^\star$



Signal yield: 2398±57 events

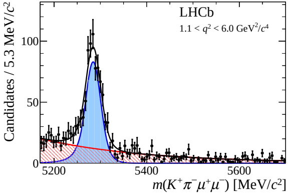


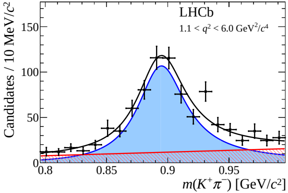
Angular analysis performed in 8 q^2 bins [0.1,0.98],[1.1,2.5],[2.5,4],[4,6],[6,8], [11,12.5],[15,17],[17,19] GeV^2/c^4

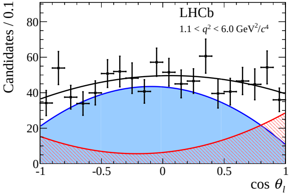
$B^0 \to K^{\star 0}(K^+\pi^-)\mu^+\mu^-$ [JHEP 02 (2016) 104]

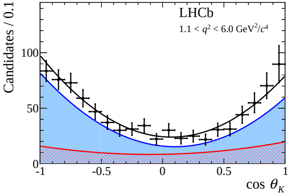
- **Simultaneous Unbinned Maximum Likelihood fit** to $\mathbf{m}(K^+\pi^-\mu^+\mu^-)$, $\mathbf{m}(K^+\pi^-)$, $\vec{\boldsymbol{\Omega}}$: **sig-bkg separation**, **S-wave fraction (F_S) constraint** (BW for P-wave, LASS model for S-wave), $\mathbf{P}_{bkg}(\vec{\boldsymbol{\Omega}})$: 2^{nd} order Chebychev polynomial

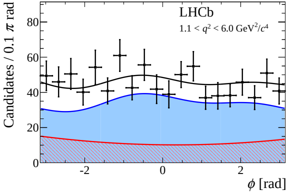
Likelihood projections in $[1.1, 6.0]\,GeV^2/c^4$











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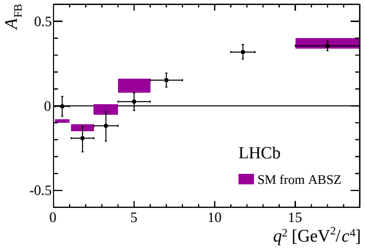
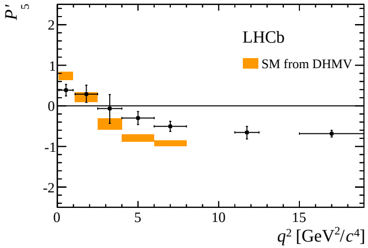




- **SM predictions** (from [arXiv:1503.05534], [arXiv:1411.3161])
- Data slightly below SM at low q^2 for $\mathbf{A}_{FB}$
- Confirmed tension in $\mathbf{P}'_5$ (**SM predictions** from [JHEP 1412 (2014) 125], [arXiv:1407.8526]) (seen in [PRL 111, 191801 (2013)]): 2.9σ per bin $\Rightarrow$ 3.4σ combined
- Differences could be explained by
  - contributions from physics beyond the SM: modified vector coupling $C_9^{NP} \neq 0$
  - an unexpectedly large hadronic effect not accounted for in theory predictions

LFU in FCNC: $R(K)$ [PRL 113 (2014) 151601]

- The observable $R(K) \equiv \frac{\mathcal{BR}(B^+ \to K^+ \mu^+ \mu^-)}{\mathcal{BR}(B^+ \to K^+ e^+ e^-)}$ is predicted to be $1 \pm \mathcal{O}(10^{-3})$ in SM [PRL112,149902(2014)]

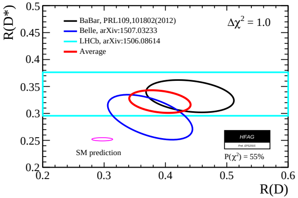
- In the ratio hadronic form-factors cancel out $\Rightarrow$ very precise theory prediction

- Experimental challenge due Bremsstralhung of e wrt μ

  - LHCb measured $R(K)$ in $1 < q^2 < 6\ Gev^2/c^4$
  - $R(K) = 0.745^{+0.090}_{-0.074} \pm 0.036$
  - Consistent with SM at $\sim 2.6\sigma$

LFU in tree processes: $R(D^\star)$ [PRL 115 111803 (2015)]

- $R(D^\star) \equiv \frac{\mathcal{BR}(B^+ \to D^+ \tau^+ \nu_\tau)}{\mathcal{BR}(B^+ \to D^+ \mu^+ \nu_\mu)}$ is predicted to be 0.252±0.003 in SM [PRD **85**, 094025 (2012)]
- Deviation from unity arise because of phase-space factors due to μ-τ mass differences
- Sensitive to charged Higgs sector & NP coupling with third generation fermions
  - Reconstruction and preselection of $\bar{B}^0 \to D^{\star +}(\to D^0(\to K^- \pi^+)\pi^+)\tau^-(\to \mu^- \nu_\mu \nu_\tau)\nu_\tau$
  - Characterization of backgrounds using simulations and data-driven methods
  - Signal-background separation variables: Muon energy, $m^2_{miss} = (p_B - p_D - p_\mu)^2$, $q^2 = (p_B - p_D)^2$, computed in an approximated B rest-frame
  - $R(D^\star) = 0.336 \pm 0.027(\mathrm{stat}) \pm 0.030(\mathrm{syst})$



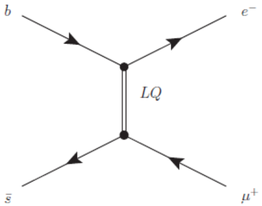
Combined tension wrt SM $\sim 3.9\sigma$

First measurement of any decay of b hadron into a final state with τ at a hadron collider

Dileptonic decays: $B^0_{(s)} \to \ell^\pm \ell'^\mp$

- In **SM** only flavour conserving currents in the leptonic sector $\Rightarrow$ Lepton Flavour Violation (LFV) modes $B^0_{s,d} \to \ell^\pm \ell'^\mp$ are forbidden.

- **NP models** (*e.g.* Pati-Salam model [Phys. Rev. D 10 275]):
  - gauge symmetry between quarks and leptons requires the existence of a spin-1 gauge boson Leptoquark (LQ)
  - quark-lepton interaction allowed at tree level



Status before LHCb measurements: CDF ($2fb^{-1}$) [CDF, Phys. Rev. Lett. 102 201901]

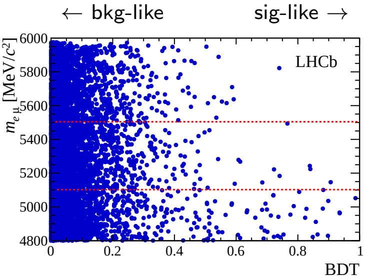
$$BR(B^0_s \to e\mu) < 20.0(20.6) \cdot 10^{-8} \text{ @ } 90(95)\%\ CL$$

$$BR(B^0 \to e\mu) < 64.0(79.0) \cdot 10^{-9} \text{ @ } 90(95)\%\ CL$$

$B^0_{(s)} \to e^{\pm}\mu^{\mp}$ [PRL 111 (2013) 141801]

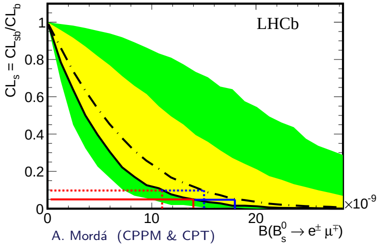
Strategy *á la* $B^0_{(s)} \to \mu\mu$

- Dataset: 1 fb^{-1} collected in 2011 at $\sqrt(s)$= 7 TeV
- $B^0 \to K\pi$ as normalization channel
- events classification in $m_{e\mu}$ - BDT plane



No excess over background is seen ⇒ upper limit on $BR(B^0_{(s)} \to e\mu)$ is obtained using the CL_s method

$B^0_s \to e\mu$, background-only expectation



Results

$BR(B^0_s \to e\mu) < 1.1(1.4) \cdot 10^{-8}$ @ 90(95)% CL

$BR(B^0 \to e\mu) < 2.8(3.7) \cdot 10^{-9}$ @ 90(95)% CL

$\sim$ 20 times more stringent than previous limits

Conclusions

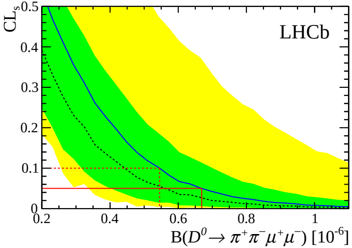
- Rare decays are excellent tools to have a sight inside NP
- They offer a wide range of observables ($\mathcal{B}$, angular distributions) to test the NP realization pattern
- An overall agreement with SM prediction is observed but...
- ...tensions are there (*e.g.* P_5')
- LHCb can deal also with τ final states
- Other variables & modes not yet studied due to statistics limitation are planned for LHC RunII

Thanks for your attention !

Backup

$D^0 \to \pi^+\pi^-\mu^+\mu^-$ - [PLB 728 (2014) 234]

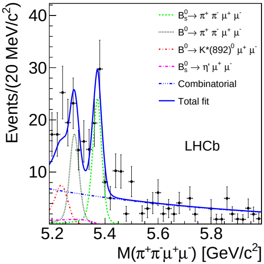
- $\mathcal{B}_{SM}(D^0) \simeq 10^{-9}$
- $1fb^{-1}$ data @ 7 TeV
- D^0 from $D^{\star +} \to D^0 \pi^+_{soft}$
- Signal search in $m(\pi^+\pi^-\mu^+\mu^-) \otimes (m_{D^\star} - m_{D^0})$
- no evidence for signal $\Rightarrow$ upper limit with CL_s method



$\mathcal{B}(D^0) < 6.7 \cdot 10^{-7}$ **@ 95% CL**

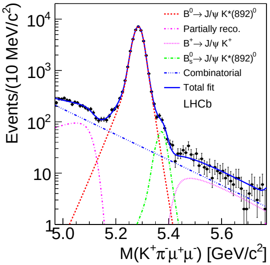
$B^0_{(s)} \to \pi^+\pi^-\mu^+\mu^-$ - [PLB 743 (2015) 46]

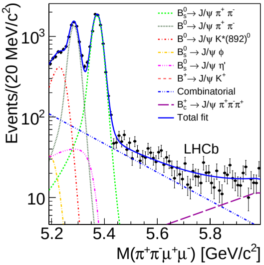
- $\mathcal{B}_{SM}(B^0) = (5-9)\cdot 10^{-8}$ ([PRD 79 014013], [PRD 81 074001], [PRD 80 016009])
- $\mathcal{B}_{SM}(B^0_s) = 0.6\cdot 10^{-9} - 5.2\cdot 10^{-7}$ ([PRD 56 5452-5465], [Eur.Phys.J.C 41 173-188])
- 1+2 fb^{-1} data set @ 7 & 8 TeV
- Signal search in $m(\pi^+\pi^-\mu^+\mu^-)$



$$\mathcal{B}(B^0_s) = 8.6 \pm 1.5_{stat} \pm 0.7_{syst} \pm 0.7_{norm} \cdot 10^{-8} \text{ @ } 7.6\sigma$$
$$\mathcal{B}(B^0) = 2.11 \pm 0.51_{stat} \pm 0.15_{syst} \pm 0.16_{norm} \cdot 10^{-8} \text{ @ } 4.8\sigma$$

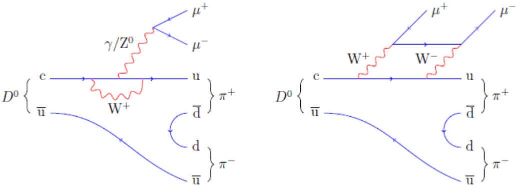
$B^0_{(s)} \to \pi^+\pi^-\mu^+\mu^-$

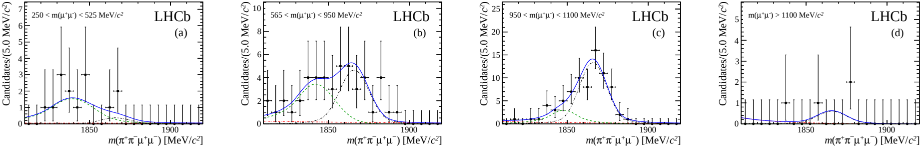




- Normalization channel: $B^0 \to K^\star(K^+\pi^-)J/\psi(\mu\mu)$

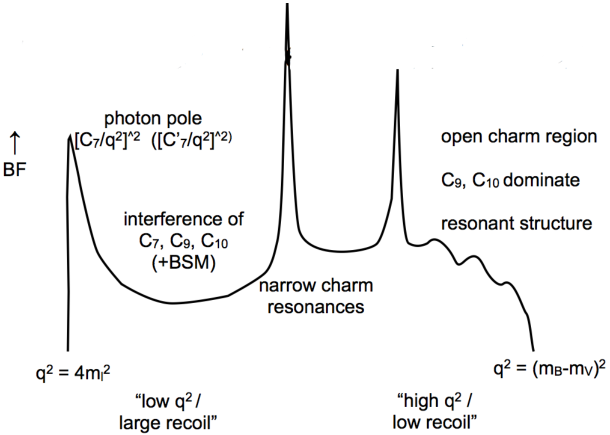
$D^0 \to \pi^+\pi^-\mu^+\mu^-$





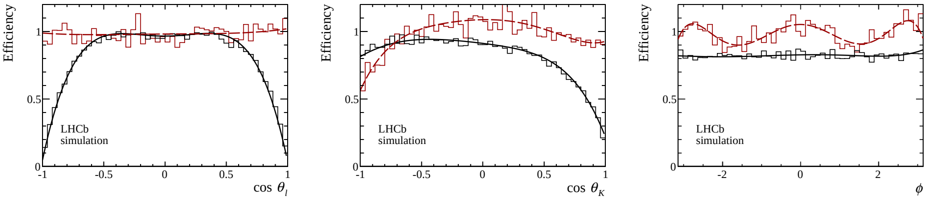
- Signal regions away from η, ϕ, ρ $(250 < m_{\mu\mu} < 525 MeV/c^2)$
- Peaking backround: $D^0 \to \pi^+\pi^-\pi^+\pi^-$
- MVA Analysis using θ_D, χ^2 of D^0 decay vertex and flight distance, p & p_T of all tracks, μ PID variables

$B^0 \to K^{\star 0}(\to K^+\pi^-)\ell^+\ell^-$



$B^0 \to K^{\star 0}(\to K^+\pi^-)\mu^+\mu^-$

Acceptance effects



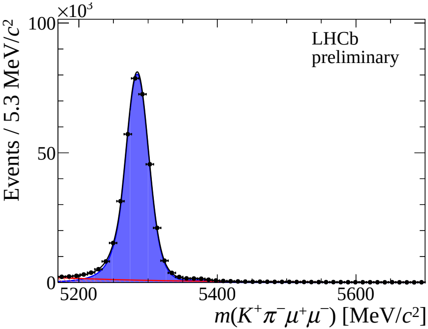
- Decay angles and q^2 distributions are distorted by
  - trigger
  - reconstruction
  - selection
- 4D $(q^2, \vec{\Omega})$ efficiency parametrized using Legendre polynomials:

$$\epsilon = \sum c_{klmn} P_k(\cos\theta_\ell) P_l(\cos\theta_K) P_m(\phi) P_n(q^2)$$

- $\cos\theta_\ell$: 5^{th}, $\cos\theta_K$: 6^{th}, $\cos\phi$: 6^{th}, q^2: 7^{th} order
- coefficients c_{klmn} from momentum analysis of $B^0 \to K^{\star 0}\mu^+\mu^-$ MC
- crosscheck on $B^0 \to K^{\star 0} J/\psi(\mu^+\mu^-)$ control channel

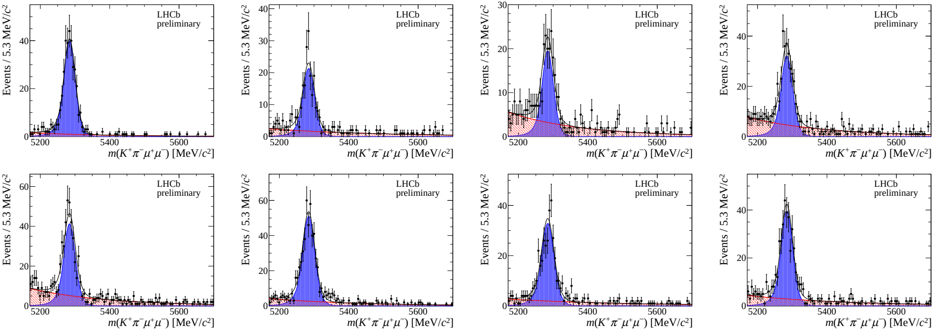
$B^0 \to K^{\star 0}(\to K^+\pi^-)\mu^+\mu^-$

Mass model from high statistics $B^0 \to K^{\star 0} J/\psi(\mu^+\mu^-)$ (distribution in the plot)



- sum of two gaussians with common means and with power-law tails in the low-mass side
- parameters determined from a fit to $B^0 \to K^{\star 0} J/\psi(\mu^+\mu^-)$ in data and fixed when fitting the $B^0 \to K^{\star 0}\mu^+\mu^-$
- corrections eveluated on MC to account q^2-dependent resolution

$B^0 \to K^{\star 0}(\to K^+\pi^-)\mu^+\mu^-$



Significant signal yield in all q^2 bins

$B^0 \to K^{\star 0}(\to K^+\pi^-)\mu^+\mu^-$

Peaking backgrounds

- due to **partially reconstructed** physical decays & **misidentification**: veto on kinematic and PID variables
- mass vetoes and PID algorithm exploited
- most relevant modes: $\Lambda_b \to pK^-\mu^+\mu^-$, $B^0 \to K^+\pi^-_{rndm}\mu^+\mu^-$, $B^0_s \to \phi(K^+K^-)\mu^+\mu^-$

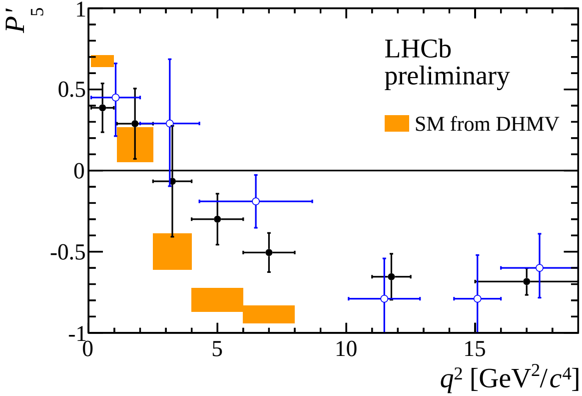
Mode	% of sig yield
$\Lambda_b \to pK^-\mu^+\mu^-$	1.0 ± 0.4
$B^0 \to K^\star_{swap}\mu^+\mu^-$	0.64 ± 0.06
$B^0_s \to \phi(K^+K^-)\mu^+\mu^-$	0.33 ± 0.12

$B^0 \to K^{\star 0}(\to K^+\pi^-)\mu^+\mu^-$

$$
\begin{aligned}
log\mathcal{L} = \sum_{bins} \log[\epsilon(\vec{\Omega}, q^2) f_{sig}\mathcal{P}_{sig}(\vec{\Omega})\mathcal{P}_{sig}(m_{K\pi\mu\mu}) \\
+ (1 - f_{sig})\mathcal{P}_{bkg}(\vec{\Omega})\mathcal{P}_{bkg}(m_{K\pi\mu\mu})] \\
+ \sum_{bins}[f_{sig}\mathcal{P}_{sig}(m_{K\pi}) + (1 - f_{sig})\mathcal{P}_{bkg}(m_{K\pi})]
\end{aligned}
$$

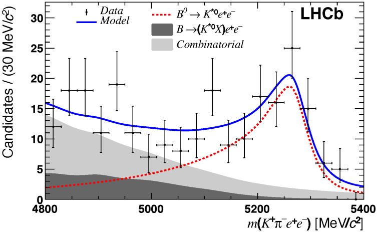
- Systematics from:
  - Kinematic differences between data and MC simulations
  - q^2 dependence of acceptance
  - Acceptance model (order of parametrization)
  - statistical uncerainties

$B^0 \to K^{\star 0}(\to K^+\pi^-)\mu^+\mu^-$



$B^0 \to K^{\star 0}(K^+\pi^-)e^+e^-$ [JHEP 1504 (2015) 064]

- Allows to explore the low-q^2 region, near the photon pole ($[0.0004\text{-}1.0]\mathrm{GeV}^2/\mathrm{c}^4$) $\Rightarrow$ **sensitivity to $C_7^{(\prime)}$!**
- Experimental challenges due to **trigger** and **bremsstrahlung** (worsen invariant mass resolution)



- Dataset: $3.1 fb^{-1}$ RunI dataset
- Measure angular observables (with 124 events) F_L , $A_T^{(2)}$, A_T^{Re}, A_T^{Im}

Observable	Obs	SM [JHEP 05 (2013) 043]
F_L	$+0.16\pm0.06\pm0.03$	$+0.10^{+0.11}_{-0.05}$
$A_T^{(2)}$	$-0.23\pm0.23\pm0.05$	$+0.03^{+0.05}_{-0.04}$
A_T^{Re}	$+0.10\pm0.18\pm0.05$	$-0.15^{+0.04}_{-0.03}$
A_T^{Im}	$+0.14\pm0.22\pm0.05$	$(-0.2^{+1.2}_{-1.2}) \times 10^{-4}$

- Overall good agreement with SM
- constraints on $\mathbf{C}_7^{(\prime)}$ competitive with radiative decays

$B^0 \to K^{\star 0}(\to K^+\pi^-)e^+e^-$

$$\frac{1}{d\Gamma_{CP}/dq^2}\frac{d^3\Gamma_{CP}}{d\vec{\Omega}} = \frac{9}{16\pi}\Big[\frac{3}{4}(1-\mathbf{F}_L)\sin^2\theta_K + \mathbf{F}_L\cos^2\theta_K + \frac{1}{4}(1-\mathbf{F}_L)\sin^2\theta_K\cos 2\theta_\ell$$
$$- \mathbf{F}_L\cos^2\theta_K\cos 2\theta_\ell + \frac{1}{2}(1-\mathbf{F}_L)\mathbf{A}_T^{(2)}\sin^2\theta_K\sin^2\theta_\ell\cos 2\tilde{\phi}$$
$$+ (1-\mathbf{F}_L)\mathbf{A}_T^{Re}\sin^2\theta_K\cos\theta_\ell$$
$$+ \frac{1}{2}(1-\mathbf{F}_L)\mathbf{A}_T^{Im}\sin^2\theta_K\sin^2\theta_\ell\sin 2\tilde{\phi}\Big]$$

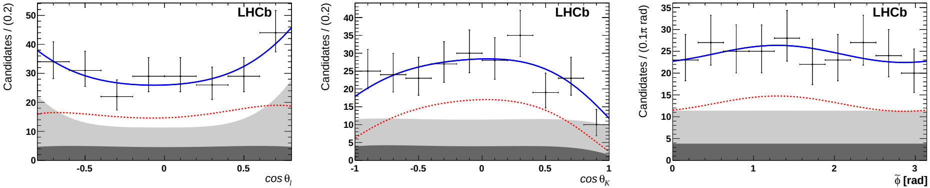
- $\tilde{\phi} = \phi + \pi$ for $\phi < 0$, $m_e = 0$
  - F_L: longitudinal polarization of photon (small being the photon almost real, and thus with the only transverse polarization)
  - A_T^{Re}: linked to forward-backward asymmetry A_{FB}: $A_T^{Re} = \frac{4}{3}A_{FB}/(1-F_L)$
  - $A_T^{(2)}$ and A_T^{Im} functions of $C^{(\prime)}$ for $q^2 \to 0$:

$$A^{(2)}(q^2 \to 0) = \frac{2\Re(C_7 C_7'^{\star})}{|C_7|^2 + |C_7'|^2}$$

$$A^{(2)}(q^2 \to 0) = \frac{2\Im(C_7 C_7'^{\star})}{|C_7|^2 + |C_7'|^2}$$

$B^0 \to K^{\star 0}(\to K^+\pi^-)e^+e^-$

Fit projection of angular distributions

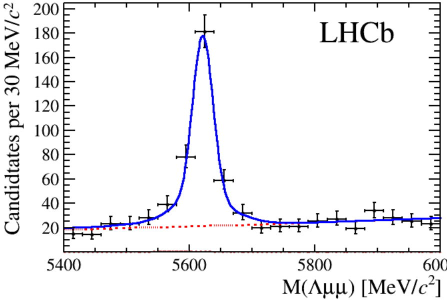


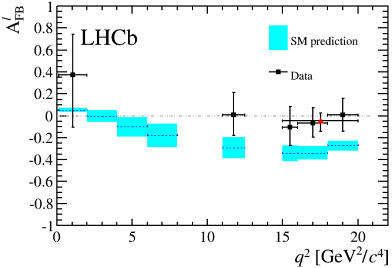
$\Lambda_b \to \Lambda(p\pi^-)\mu^+\mu^-$ - [LHCb-PAPER-2015-009]

- $b \to s\ell\ell$ transition in a spin-$\frac{1}{2}$ system
- Dataset: $3.1 fb^{-1}$ RunI dataset

- search performed in 8 q^2 bins: **[0.1,2.0]**,[2,4],[4,6,][6,8],**[11,12.5]**, **[15,16]**,**[16,18][18,20]** GeV^2/c^4

- Evidence for signal in **5 q^2 bins** $\Rightarrow$ measurement of forward-backward asymmetries A^{ℓ}_{FB}, A^{h}_{FB}



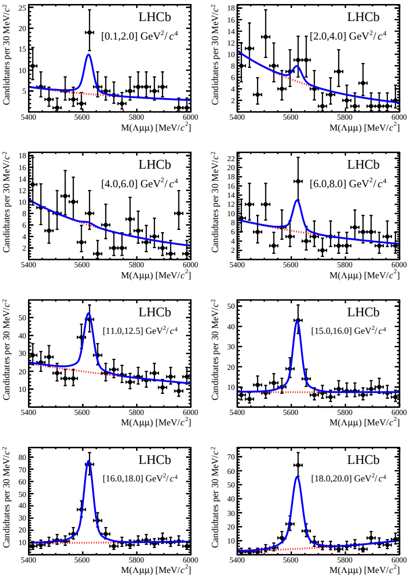


Results for $15 < q^2 < 20\ GeV^2/c^4$

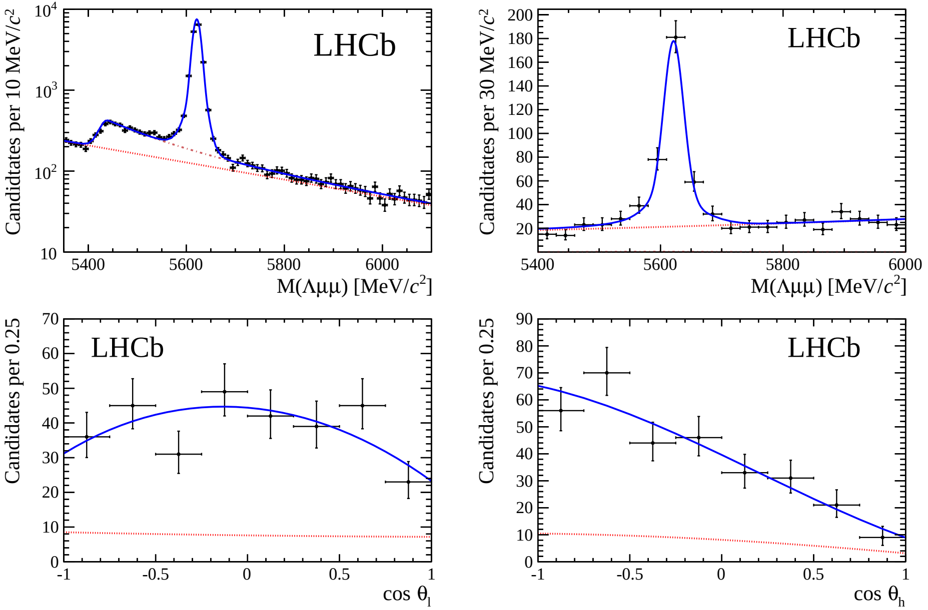
$$d\mathcal{B}(\Lambda_b \to \Lambda\mu^+\mu^-)/dq^2 =$$
$$(1.18^{+0.09}_{-0.08} \pm 0.03_{syst} \pm 0.27_{norm}) \cdot 10^{-7}(GeV^2/c^4)^{-1}$$
$$A^{\ell}_{FB} = -0.05 \pm 0.09_{stat} \pm 0.03_{syst}$$
$$A^{h}_{FB} = -0.29 \pm 0.07_{stat} \pm 0.03_{syst}$$

Measured values of A^{ℓ}_{FB} sligthly above **SM prediction** [arxiv:1401.2685]

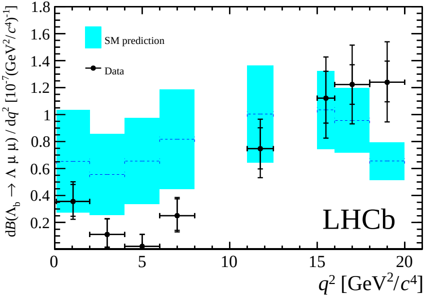
$\Lambda_b \to \Lambda\mu^+\mu^-$

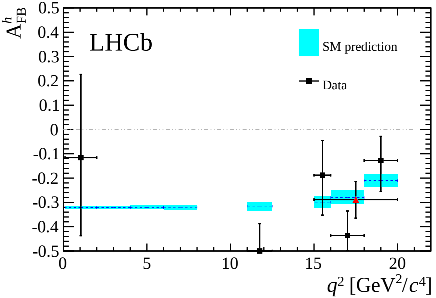


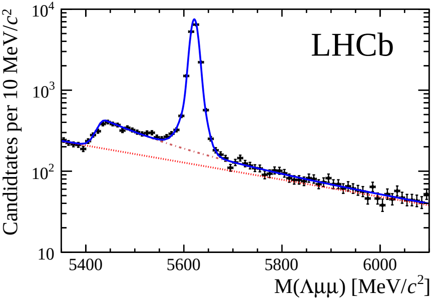
$\Lambda_b \to \Lambda\mu^+\mu^-$



$\Lambda_b \to \Lambda\mu^+\mu^-$







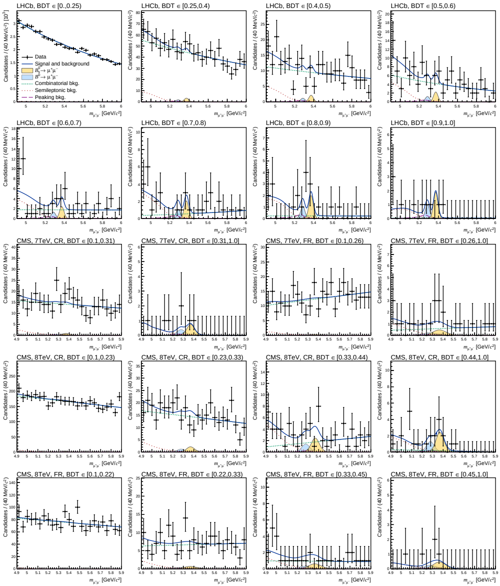
- normalization channel: $\Lambda_b \to \Lambda J/\psi(\to \mu^+\mu^-)$

$B^0_{(s)} \to \mu^+\mu^-$ - CMS-LHCb combination

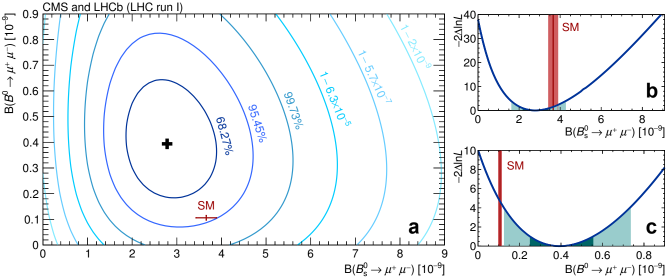
- Mass resolutions:
  - $M_{B^0_s} - M_{B^0} \simeq 87\ MeV/c^2$
  - CMS: $\delta_M \simeq 32 - 75\ MeV/c^2$ depending on the μ angle wrt the beam axis
  - LHCb: uniform $\delta_M \simeq 25\ MeV/c^2$

- LHCb and CMS dataset combined by fitting a common value for each $\mathcal{B}$ for B^0 and B^0_s modes

$B^0_{(s)} \to \mu^+\mu^-$ - CMS-LHCb combination



$B^0_{(s)} \to \mu^+\mu^-$ - CMS-LHCb combination



- Test statistics $-2\Delta lnL$ difference in log-likelihood between fits with fixed values of POIs and the nominal one

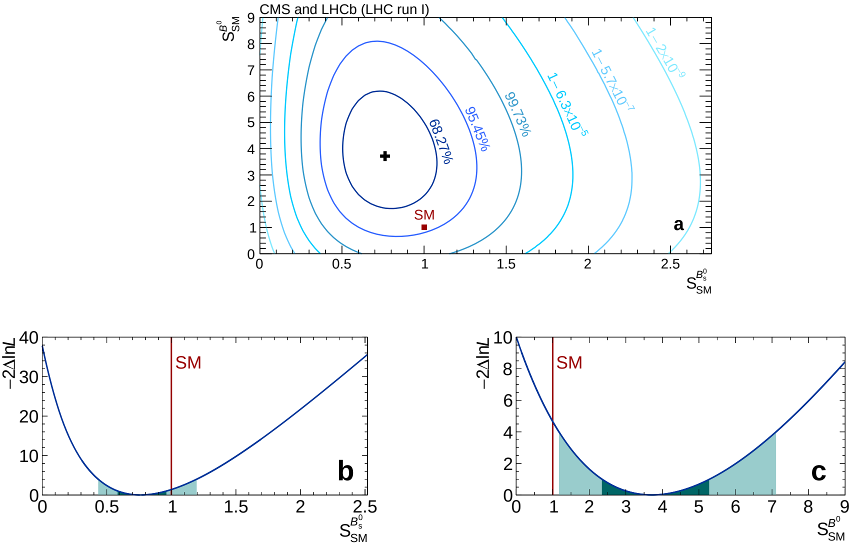
- Profiles by fixing only one POI and allowing the other to vary during the fit

- $B^0 \to \mu^+\mu^-$ confidence intervals using Feldman-Cousins method:

$$\mathcal{B}(B^0 \to \mu^+\mu^-) \in [2.5, 5.6] \times 10^{-10} \text{ @ } 1\sigma$$

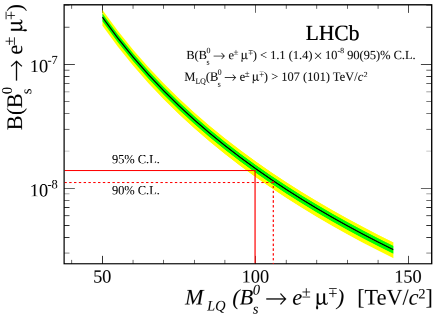
$$\mathcal{B}(B^0 \to \mu^+\mu^-) \in [1.4, 7.4] \times 10^{-10} \text{ @ } 2\sigma$$

$B^0_{(s)} \to \mu^+\mu^-$ - CMS-LHCb combination



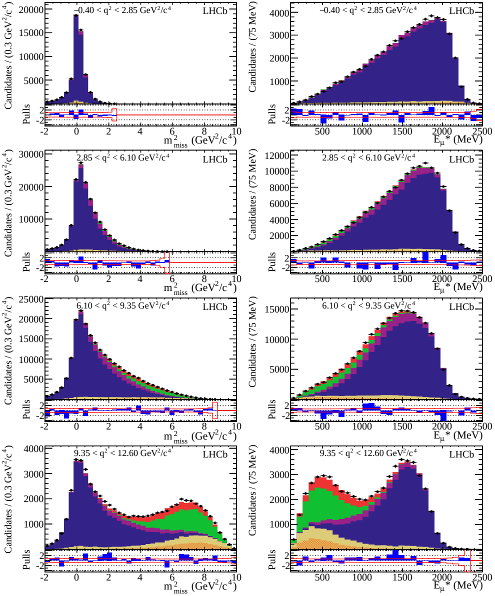
$B \to e\mu$ - Implications of measurements

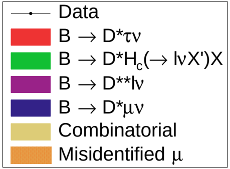
From limits on $BR(B^0_{(s)} \to e\mu)$ lower bounds on Pati-Salam LeptoQuark masses are inferred (formula from [Phys. Rev. D 50 6843])



$$m_{LQ_s}(B^0_s \to e\mu) > 107(101)\, TeV/c^2 \text{ @ } 90(95)\%\ CL$$
$$m_{LQ_d}(B^0 \to e\mu) > 135(126)\, TeV/c^2 \text{ @ } 90(95)\%\ CL$$

$R(D^\star)$





- E_μ: μ energy
- $m^2_{miss} = (p_B - p_D - p_\mu)^2$
- $q^2 = (p_B - p_D)^2$

$$(p_B)_z = \frac{m_B}{m_{reco}}(p_{reco})_z$$