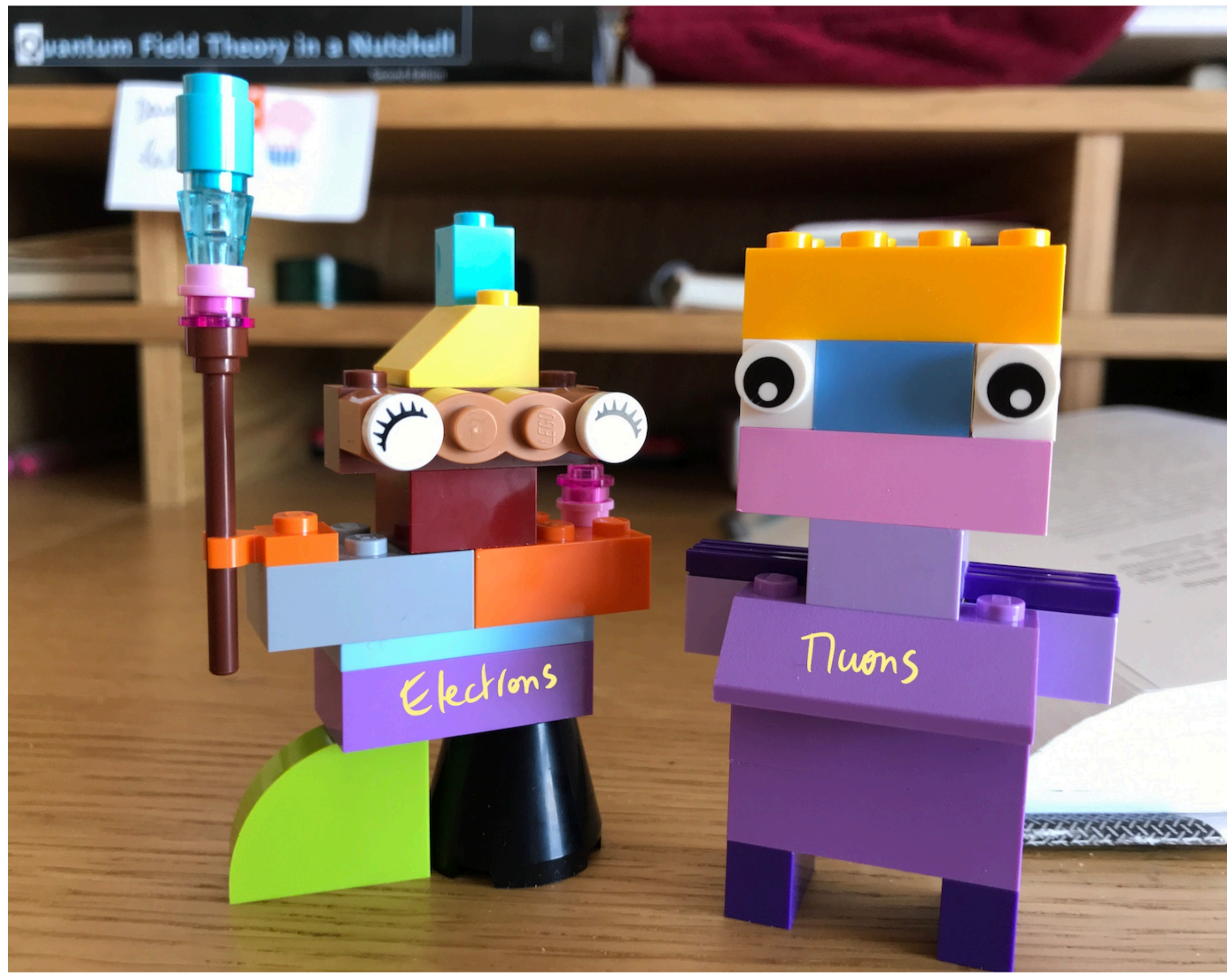
About the universality (or not) of loop induced beauty decays.

Yasmine Amhis (IJCLab)
May 2021
University of LIP



Are we the same?

IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

The strength of flavour physics and indirect searches

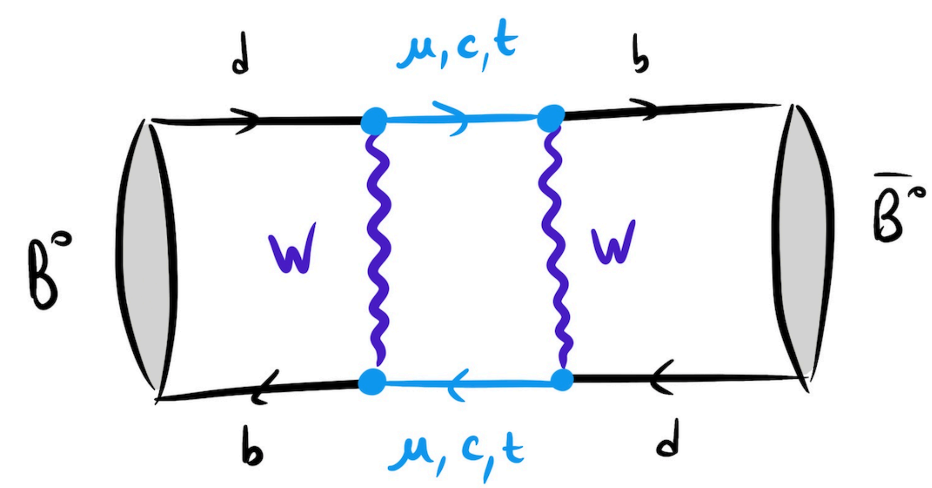
PLB 192 (1987)

OBSERVATION OF B^0–$\bar{B}^0$ MIXING

ARGUS Collaboration

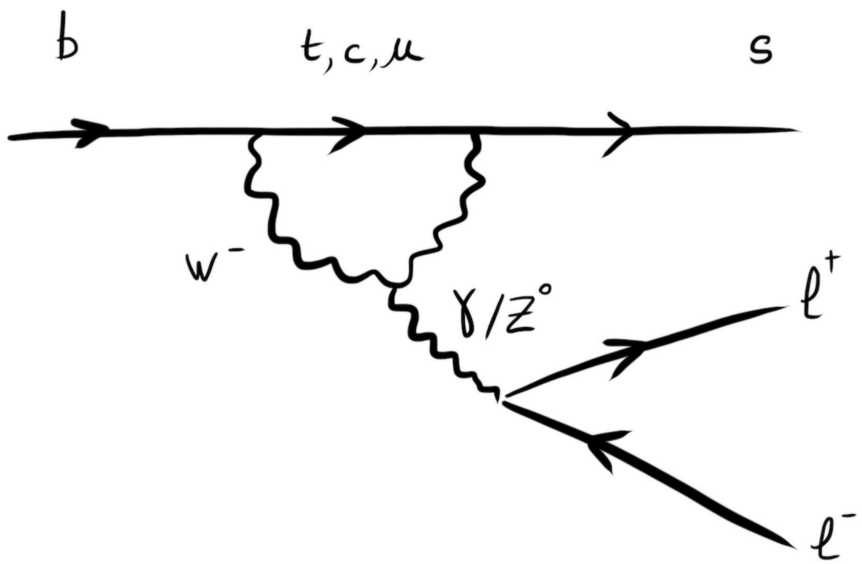
In summary, the combined evidence of the investigation of B^0 meson pairs, lepton pairs and B^0 meson–lepton events on the Υ (4S) leads to the conclusion that B^0–$\bar{B}^0$ mixing has been observed and is substantial.

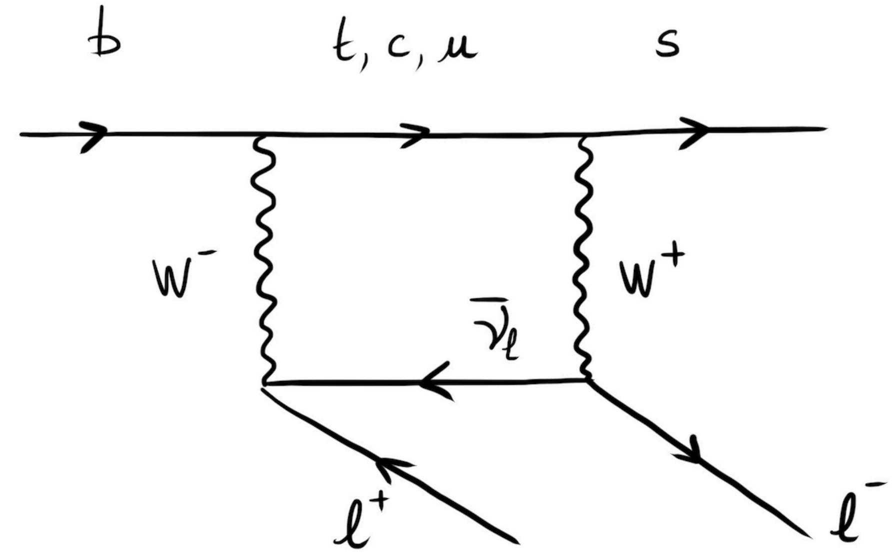
Parameters	Comments
$r > 0.09$ (90%CL)	this experiment
$x > 0.44$	this experiment
$B^{1/2} f_B \approx f_\pi < 160$ MeV	B meson ($\approx$ pion) decay constant
$m_b < 5$ GeV/c^2	b-quark mass
$\tau < 1.4 \times 10^{-12}$s	B meson lifetime
$\lvert V_{td} \rvert < 0.018$	Kobayashi–Maskawa matrix element
$\eta_{QCD} < 0.86$	QCD correction factor [a]
$m_t > 50$ GeV/c^2	t quark mass



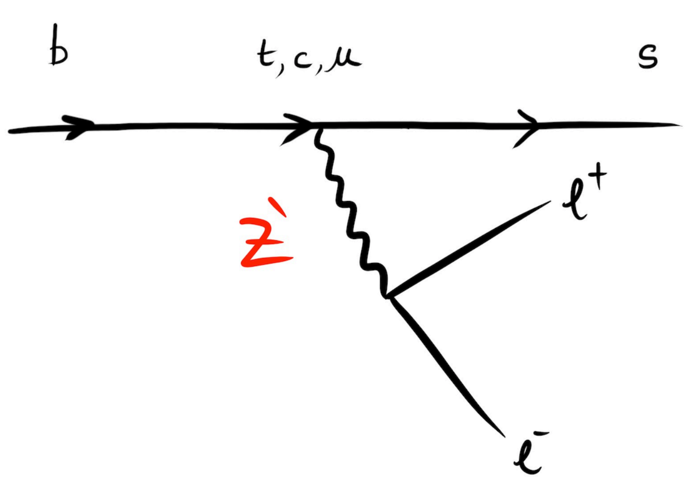
$$\mathcal{M}(B^0 - \bar{B}^0) \propto \sum_{ij} (V_{ib} V_{id}^*)(V_{jb} V_{jd}^*) F(m_{u_i}^2, m_{u_j}^2)$$

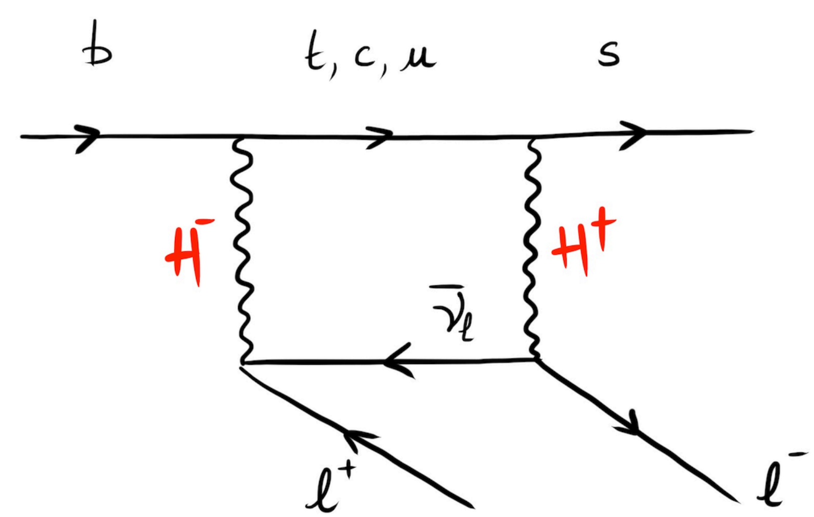
Standard Model



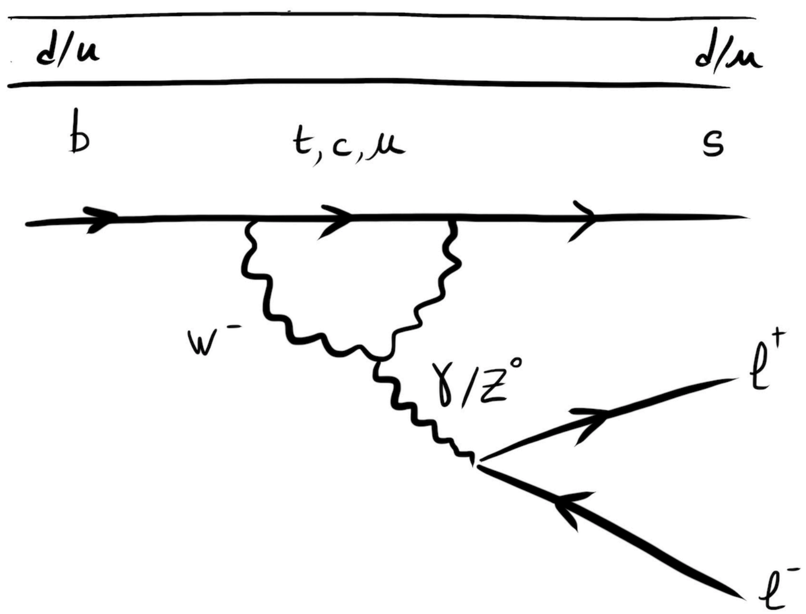


New Physics



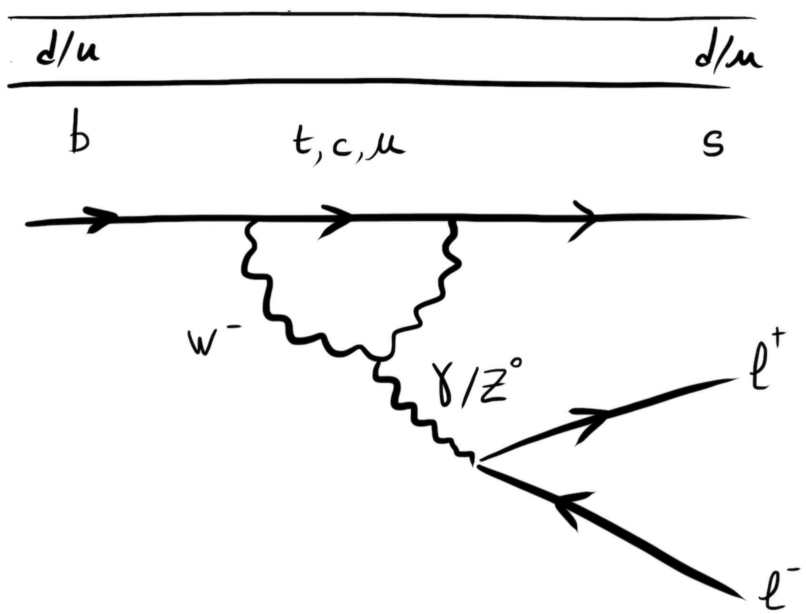


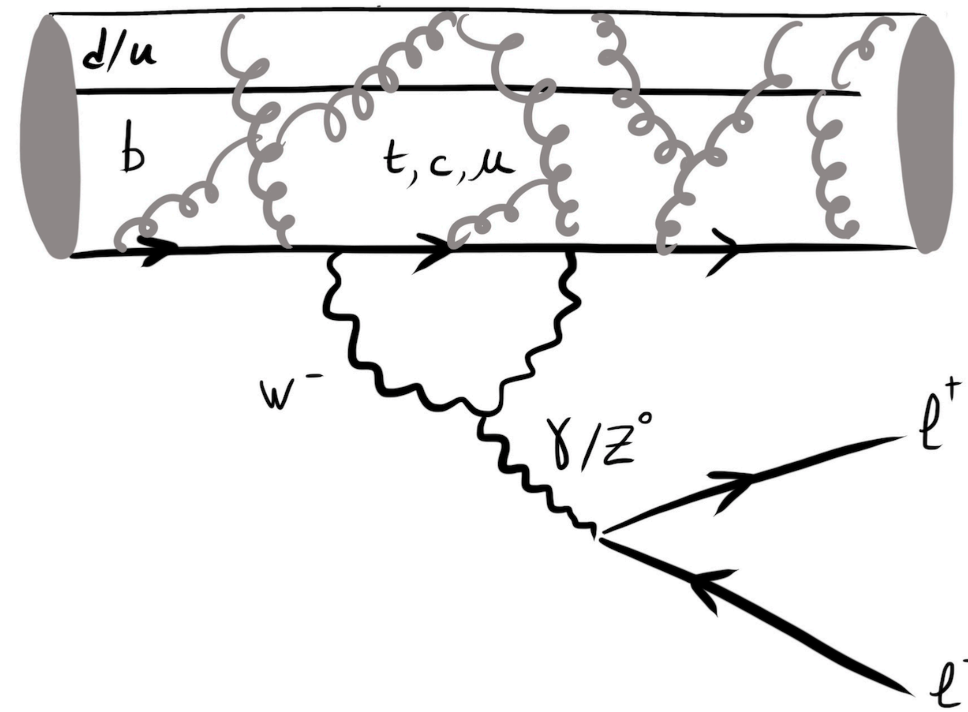
Effective Field Theory



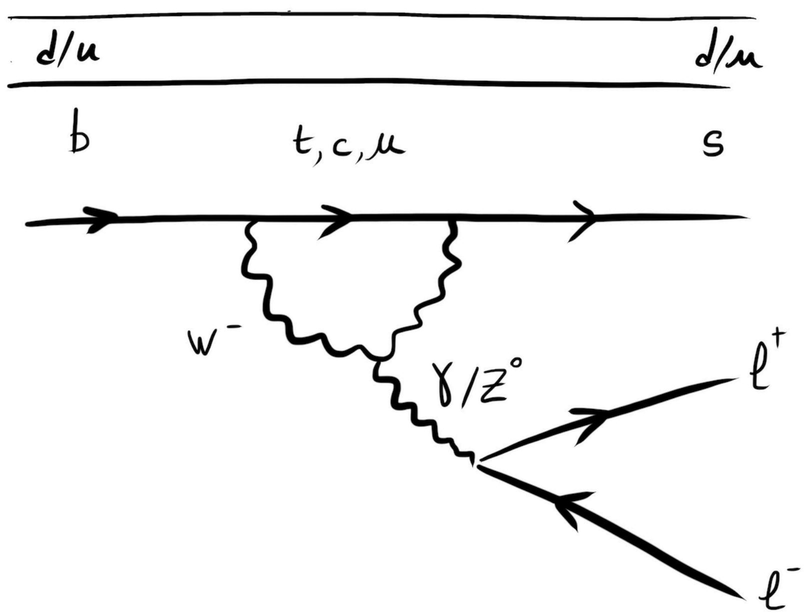
hep-ph/9806303

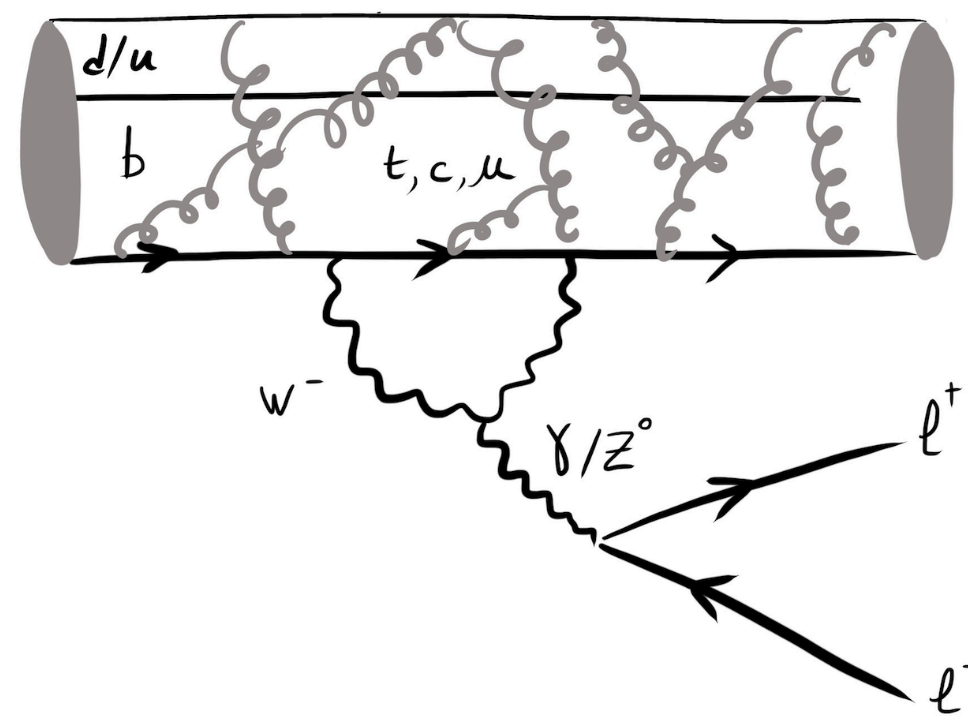
Effective Field Theory

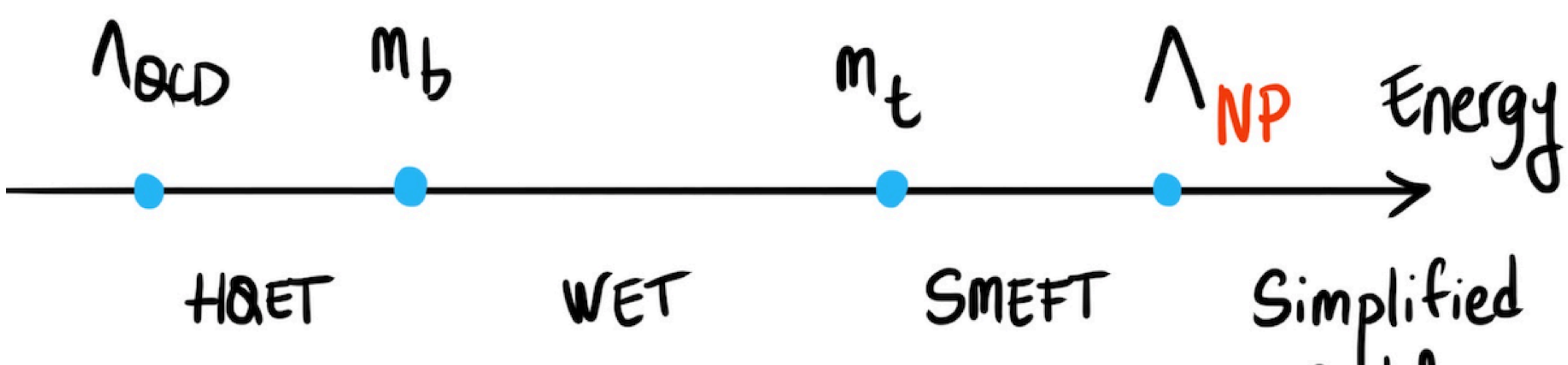




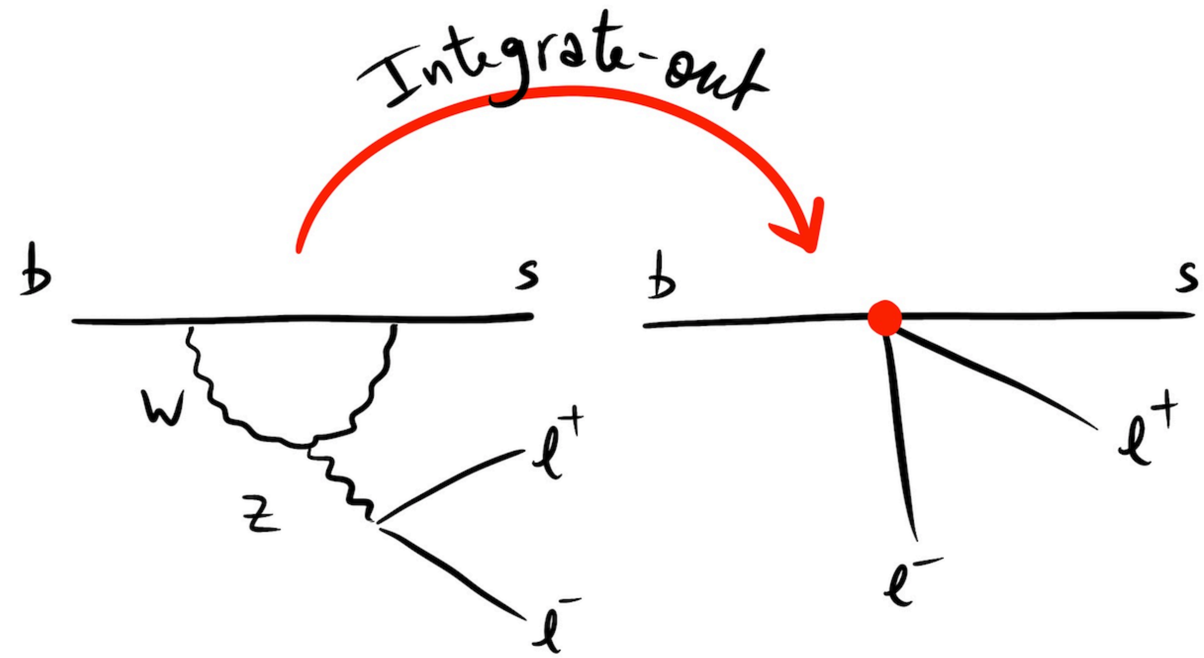
Effective Field Theory





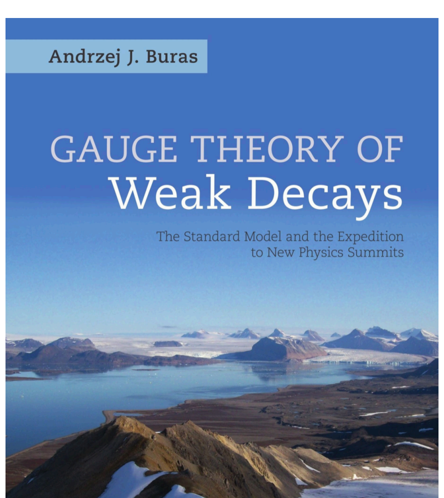


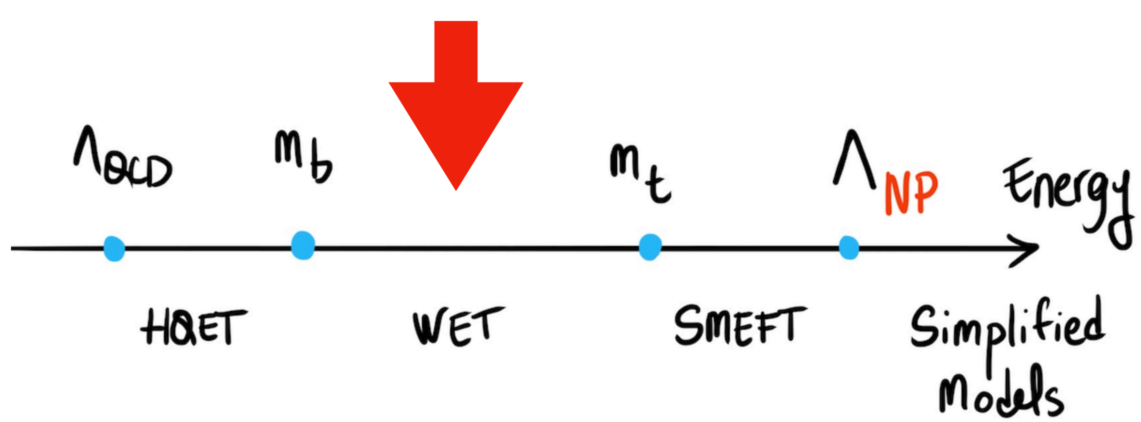
Effective Field Theory



$$\mathcal{H}_{\rm eff} = \frac{G_F}{\sqrt{2}} \lambda^{\rm CKM} \sum_i C_i \mathcal{O}_i + h.c,$$

hep-ph/9806303





Effective Field Theory

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} \lambda^{\text{CKM}} \sum_i C_i \mathcal{O}_i + h.c,$$

SD: Wilson coefficients + perturbative

LD: Local operators + non perturbative
(LCSR, Lattice, etc.)

Effective Field Theory

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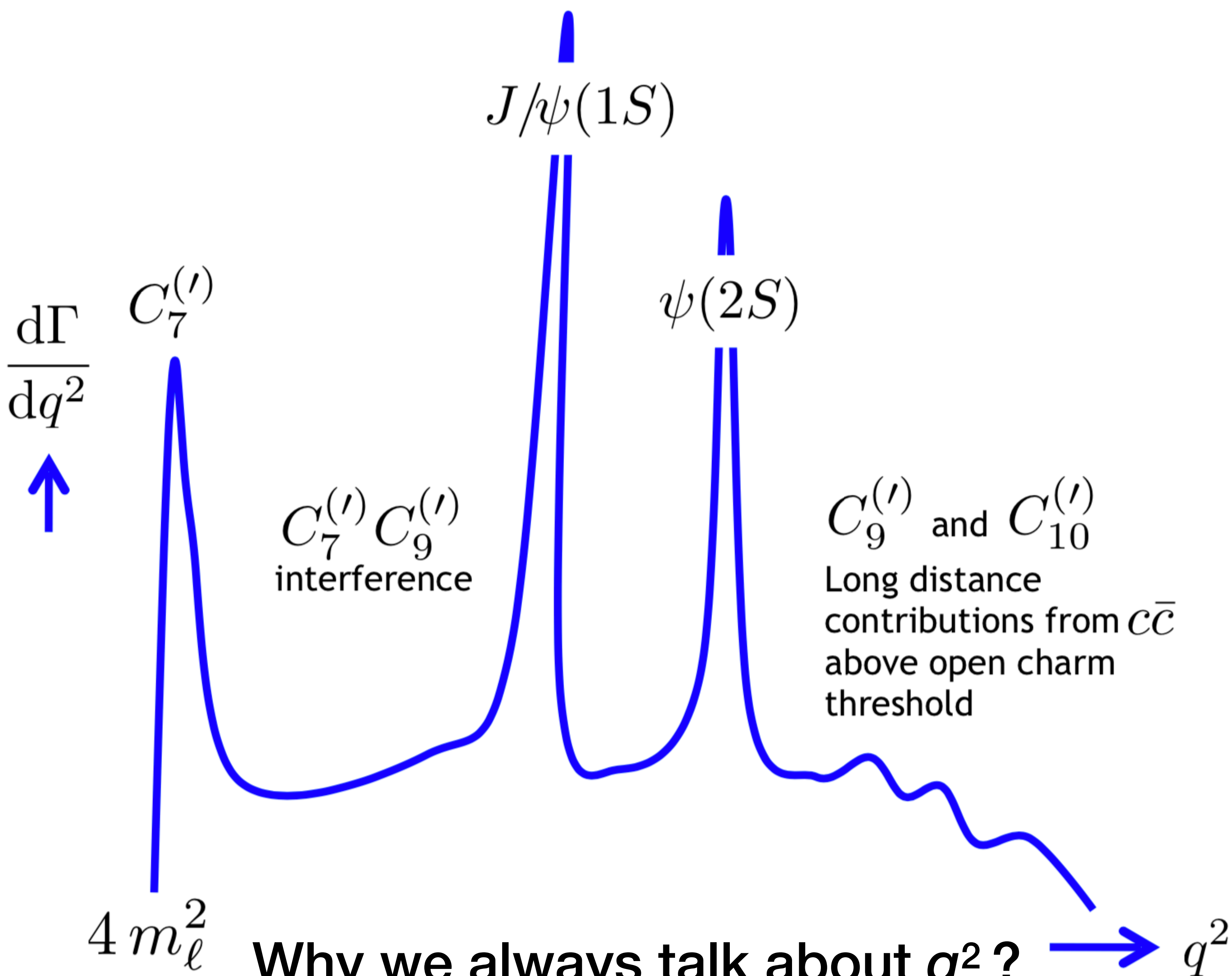
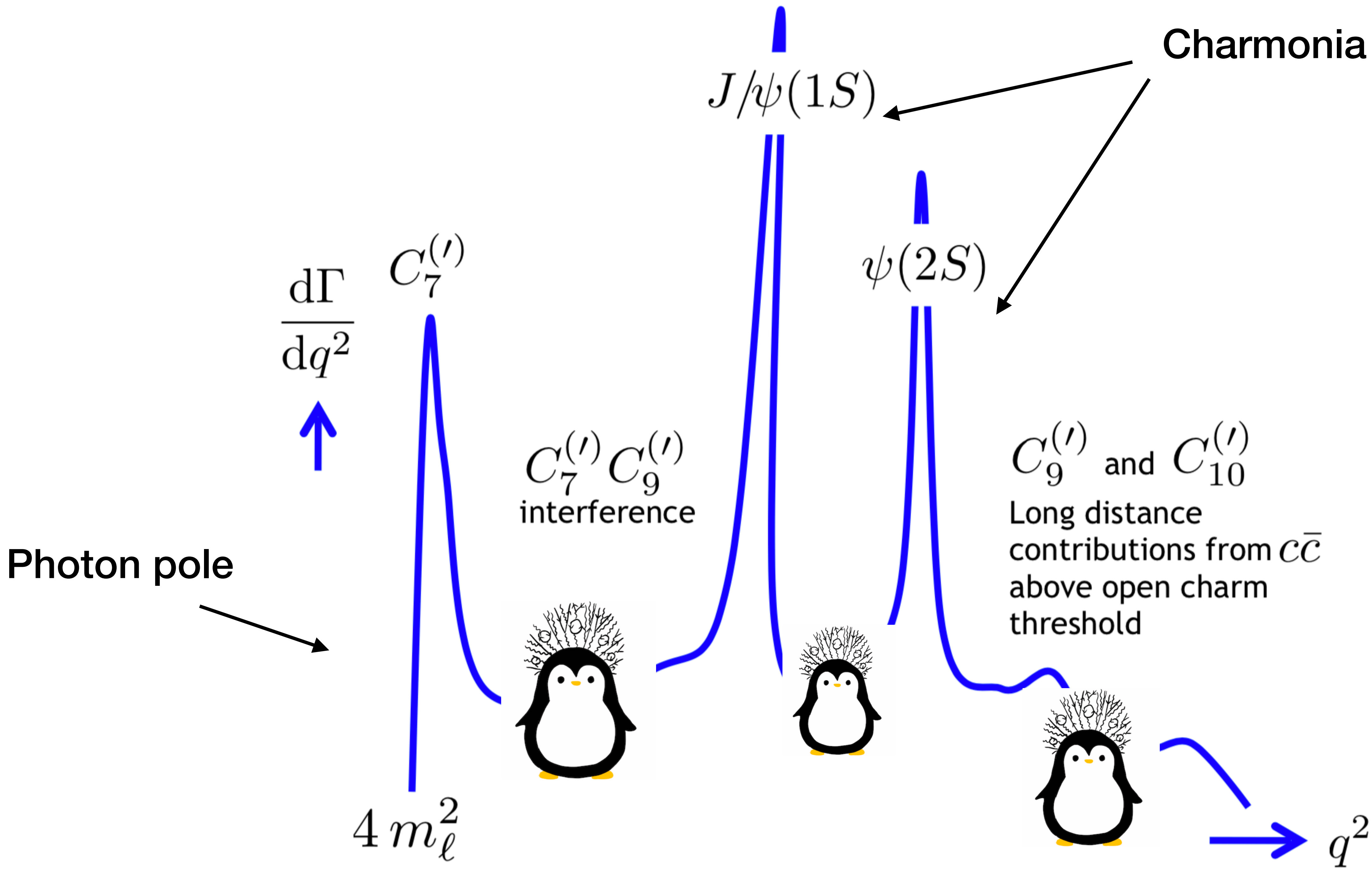
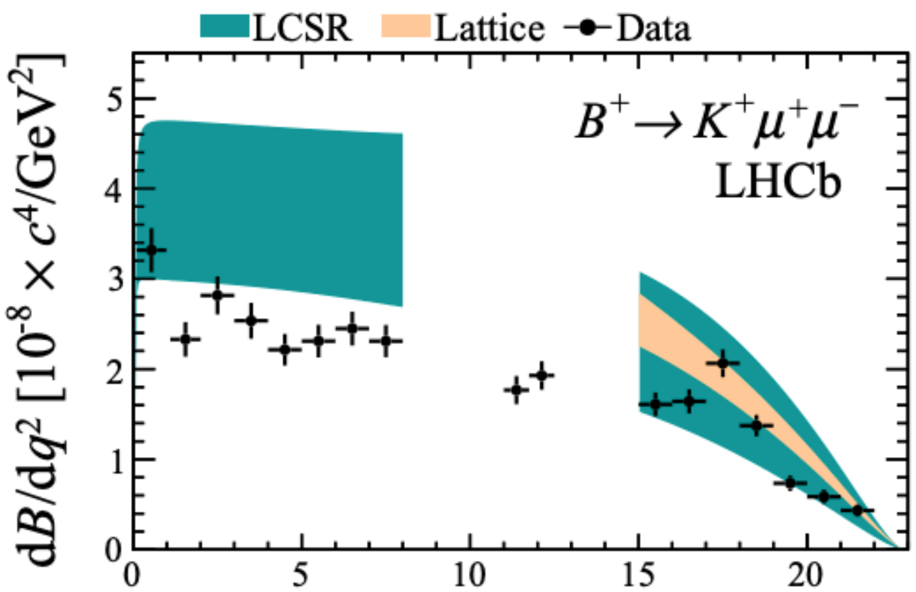


Why we always talk about q^2 ?

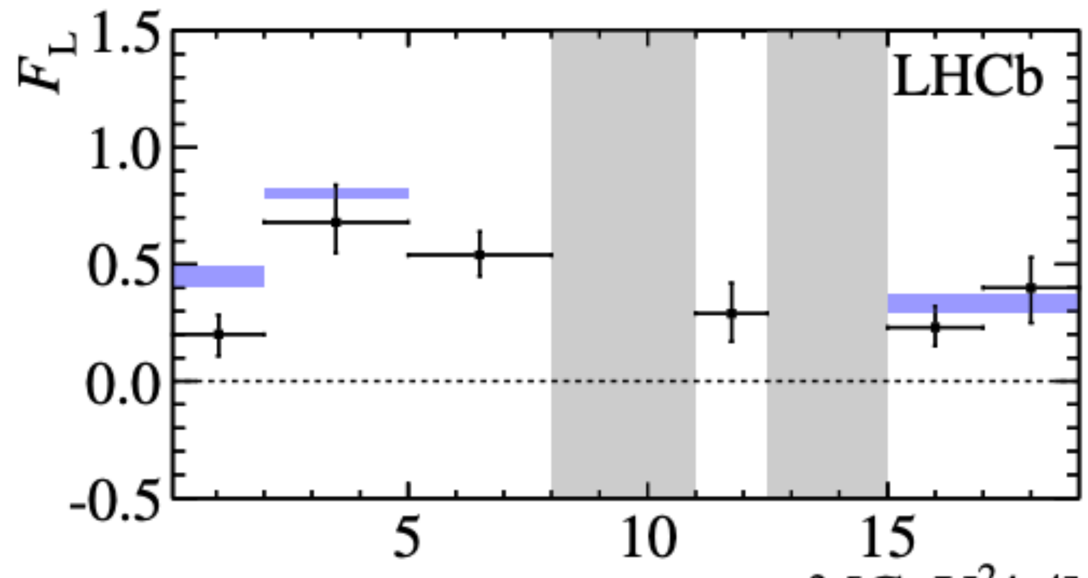
$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} \lambda^{\text{CKM}} \sum_i C_i \mathcal{O}_i + h.c,$$



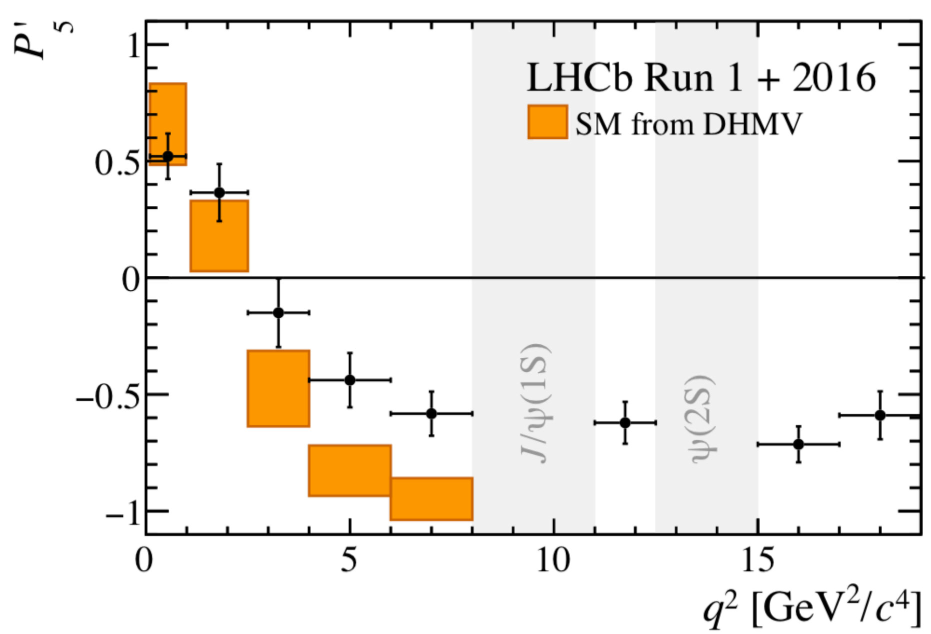
A collection of tensions



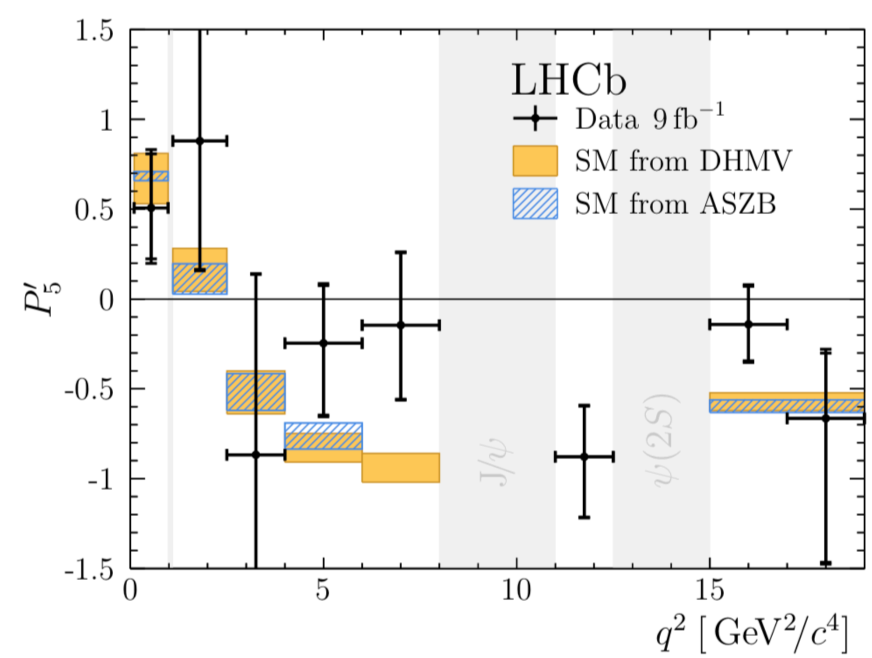
1403.8044



1506.08777



2003.04831



2012.13241

$d\Gamma/dq^2, F_L, P'_5, \ldots$

Large effort to develop optimised variables to cancel hadronic uncertainties from LD.

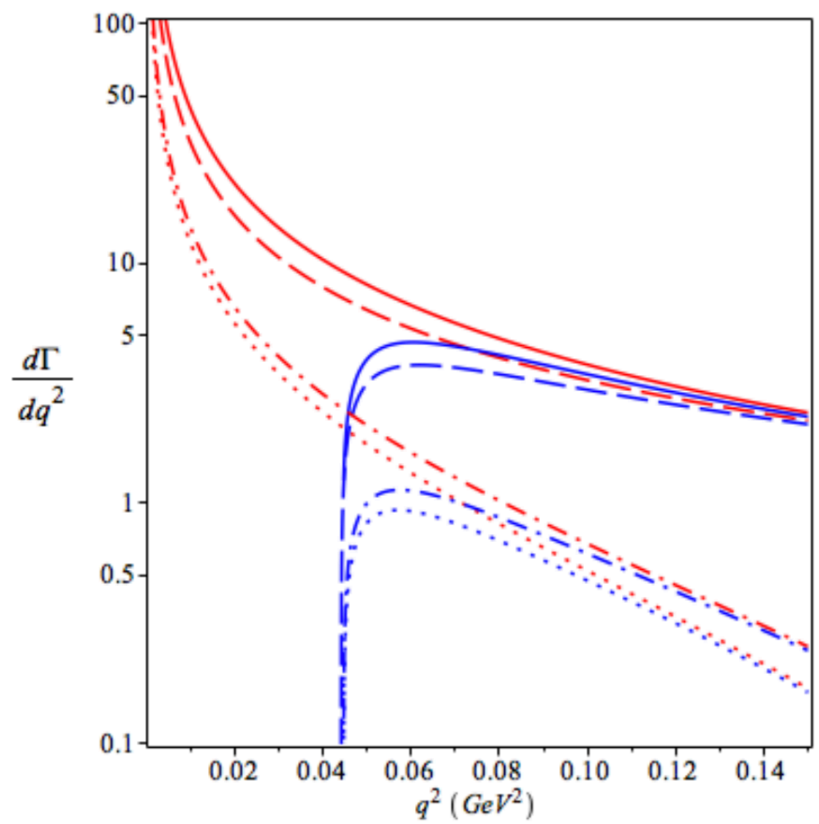
“The” observable

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

A powerful probe to look for NP in an indirect way.

Today, we discuss three papers: 1705.05802, 1903.09252, 2103.11769

What can we expect in the SM



1605.07633

$$R_{K^*}[1.1,\ 6.0]^{\rm SM} = 1.00 \pm 0.01_{\rm QED}$$

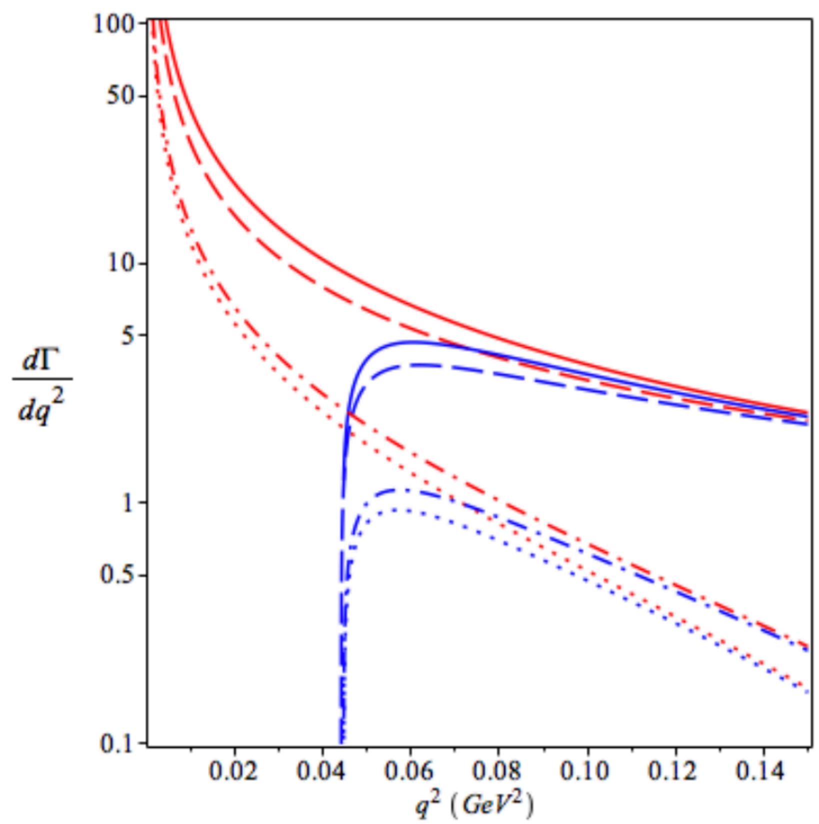
$$R_{K^+}[1.0,\ 6.0]^{\rm SM} = 1.00 \pm 0.01_{\rm QED}$$

Assuming V-A currents

$$R_\phi(B_s) \approx R_{\pi K}(B) \approx R(\Lambda_b)_\Lambda \approx R(\Lambda_b)_{pK} \approx \ldots \approx R_K$$

1909.02519

What can we expect in the SM



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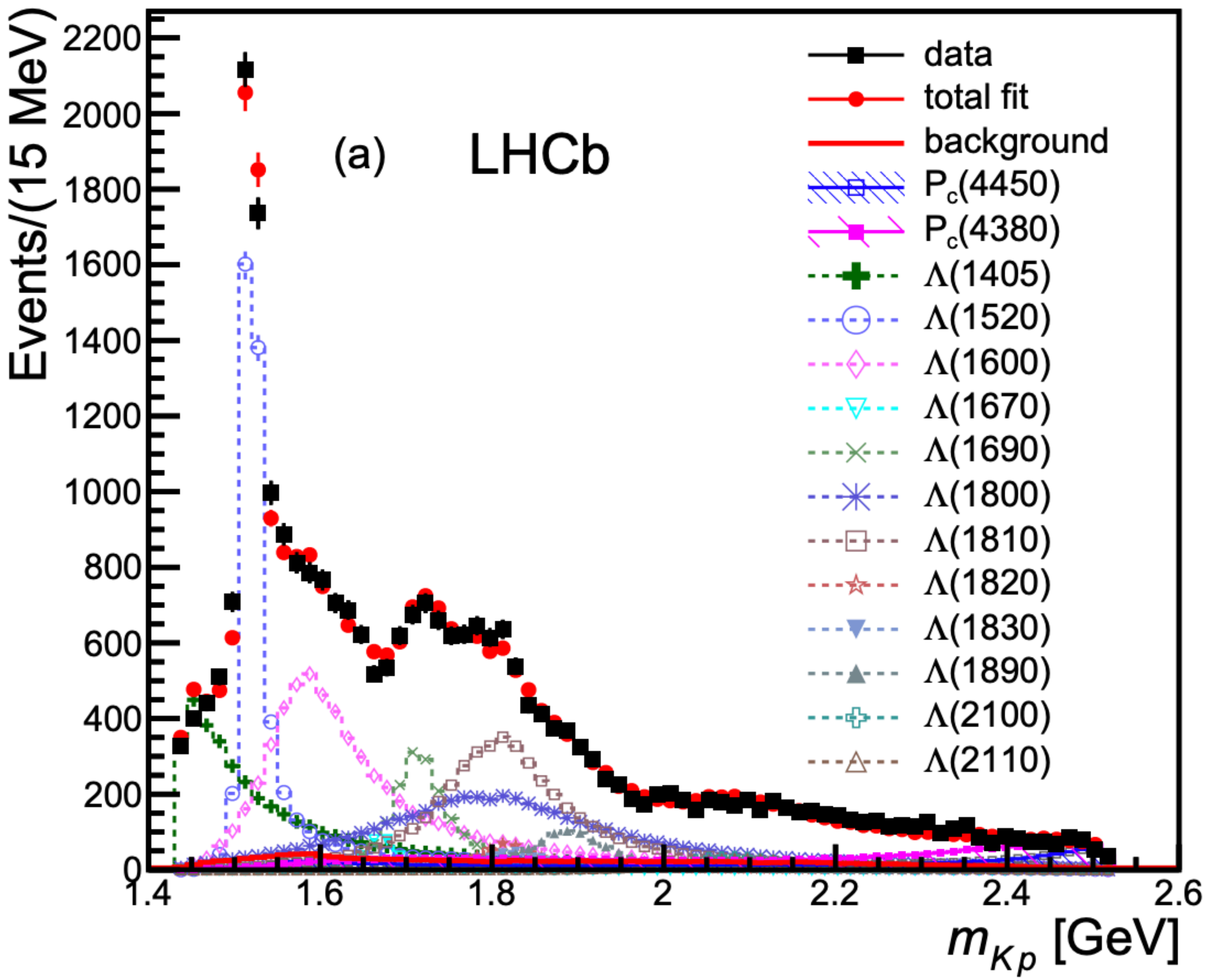
$$R_\phi(B_s) \approx R_{\pi K}(B) \approx R(\Lambda_b)_\Lambda \approx R(\Lambda_b)_{pK} \approx \ldots \approx R_K$$

1605.07633

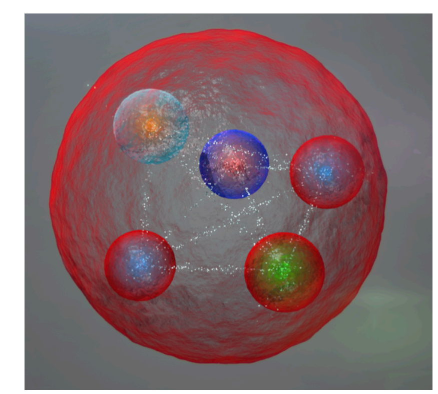
1909.02519

https://indico.in2p3.fr/event/18845/

A bit of complication



1507.03414



Why we call it R_{pK} → This will be true for all "complicated" final states.

A few particularities

$$R_{pK}^{-1} = \frac{\mathcal{B}(\Lambda_b^0 \to pK^- e^+ e^-)}{\mathcal{B}(\Lambda_b^0 \to pK^- J/\psi(\to e^+ e^-))} \Bigg/ \frac{\mathcal{B}(\Lambda_b^0 \to pK^- \mu^+ \mu^-)}{\mathcal{B}(\Lambda_b^0 \to pK^- J/\psi(\to \mu^+ \mu^-))}$$

→ $\Lambda_b \to pK\mu^+\mu^-$ **Was observed already & CPV : 1703.00256**

$\Lambda_b \to pKe^+e^-$ **First observation: 1912.08139**

What we measure

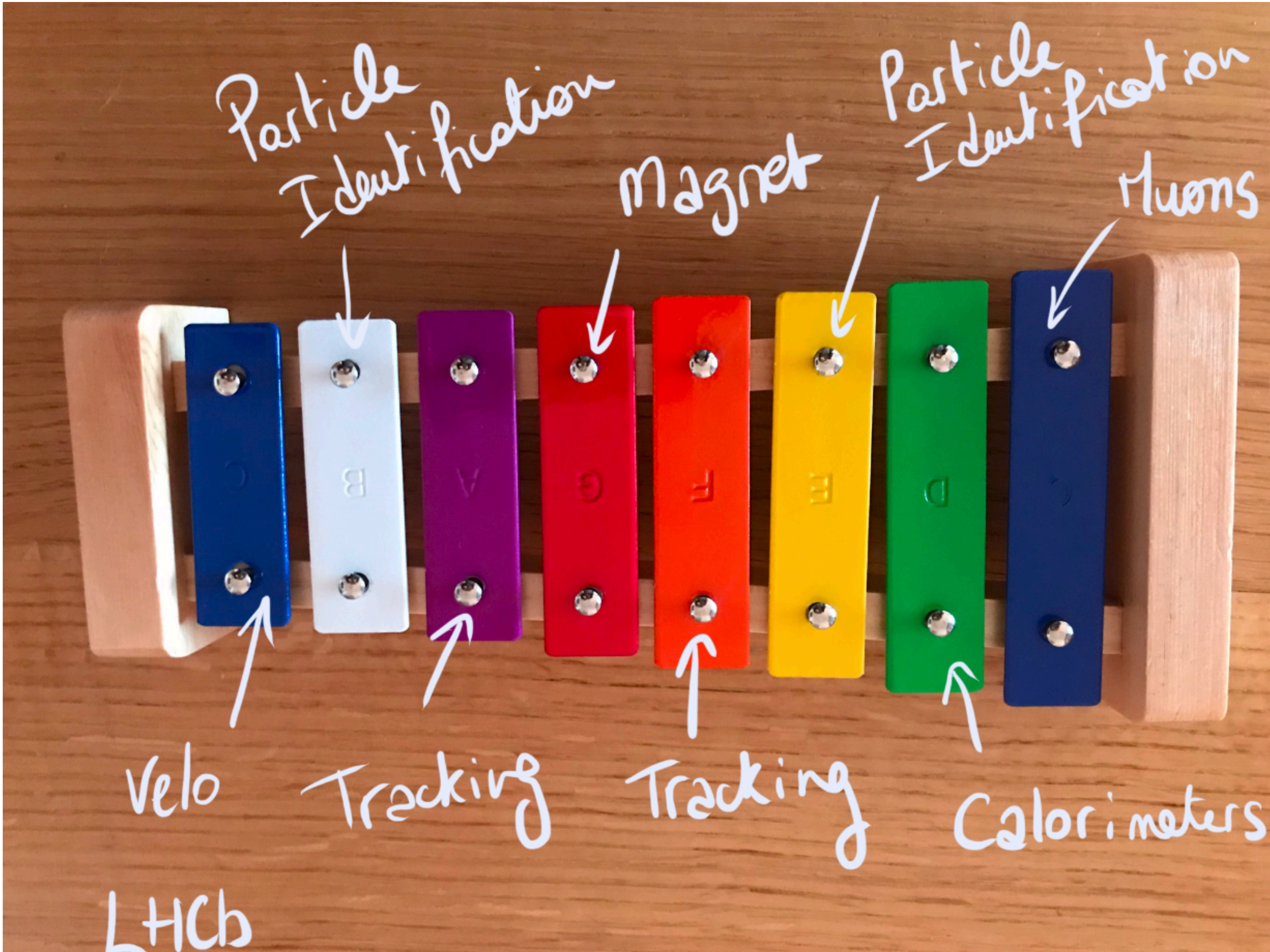
$$R_H \propto \frac{N(B \to H\mu^+\mu^-)}{N(B \to He^+e^-)} \times \frac{\epsilon(B \to He^+e^-)}{\epsilon(B \to H\mu^+\mu^-)}$$

Counting from mass fits

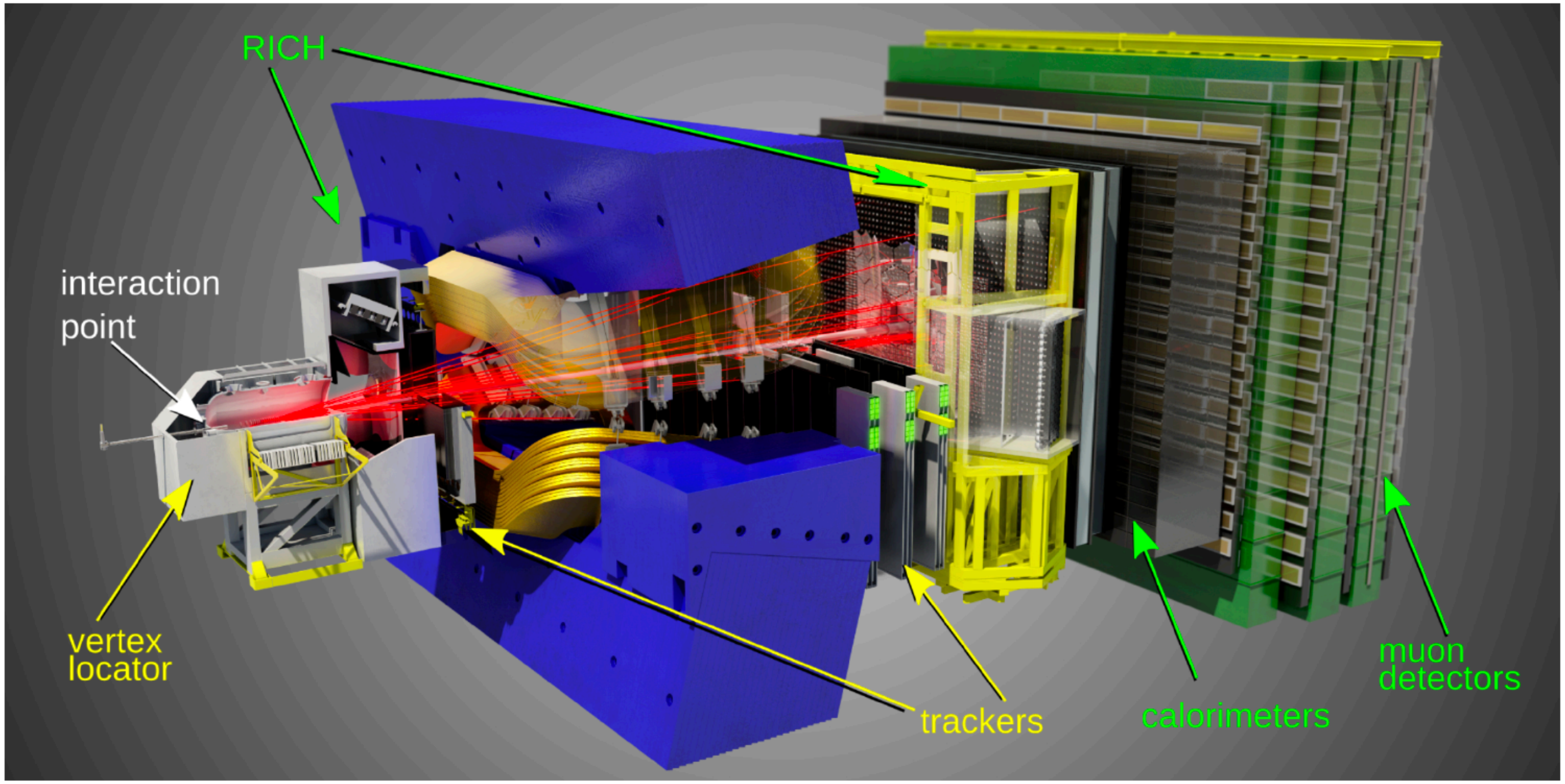
From simulation

$$r_{J/\psi} = \frac{BR(B \to HJ/\psi(\mu^+\mu^-))}{BR(B \to HJ/\psi(e^+e^-))} = 1$$

$$R_H = \frac{\frac{N(B \to H\mu^+\mu^-)}{N(B \to HJ/\psi(\mu^+\mu^-))}}{\frac{N(B \to He^+e^-)}{N(B \to HJ/\psi(e^+e^-))}} \times \frac{\frac{\epsilon(B \to He^+e^-)}{\epsilon(B \to HJ/\psi(e^+e^-))}}{\frac{\epsilon(B \to H\mu^+\mu^-)}{\epsilon(B \to HJ/\psi(\mu^+\mu^-))}}$$


Particle Identification
Magnet
Particle Identification
Muons
C
B
A
G
F
E
D
C
Velo
Tracking
Tracking
Calorimeters
LHCb

The LHCb detector



- Good vertex and impact parameter resolution σ (IP) = 15+29/p_T mm.
- Excellent momentum resolution ~ 25 MeV/c^2 two-body decays.
- Excellent particle ID (μ-ID 97% for (π → μ) misID of 1-3%).
- Versatile & efficient trigger.

JINST 3 (2008) S080005
Int. J. Mod. Phys. A 30 (2015) 1530022

What we reconstruct

$$B^+ \to K^+ \ell^+ \ell^-$$

$\ell^+\ell^- \to \mu^+\mu^-$

$\ell^+\ell^- \to e^+e^-$

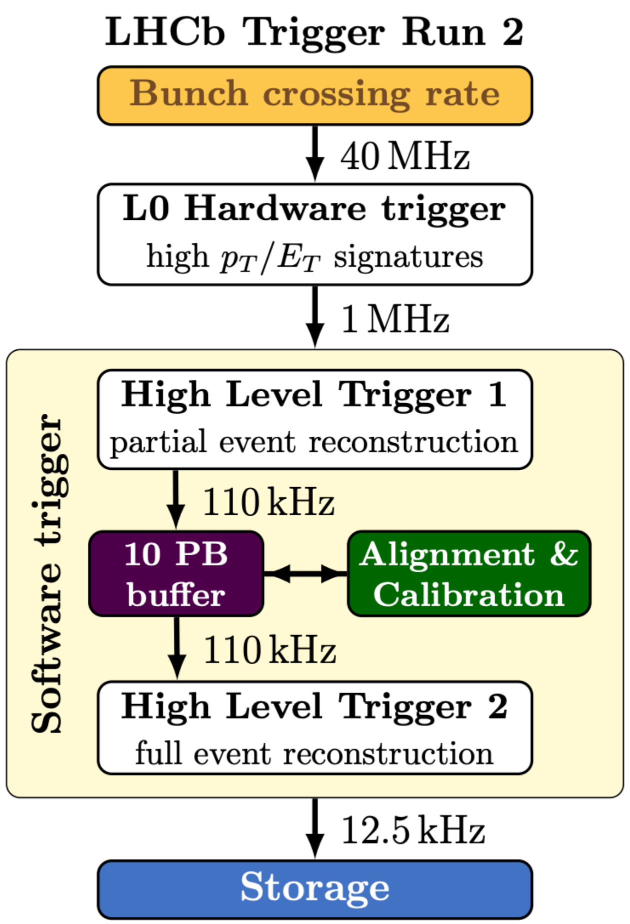
$$B^0 \to K^* \ell^+ \ell^-$$

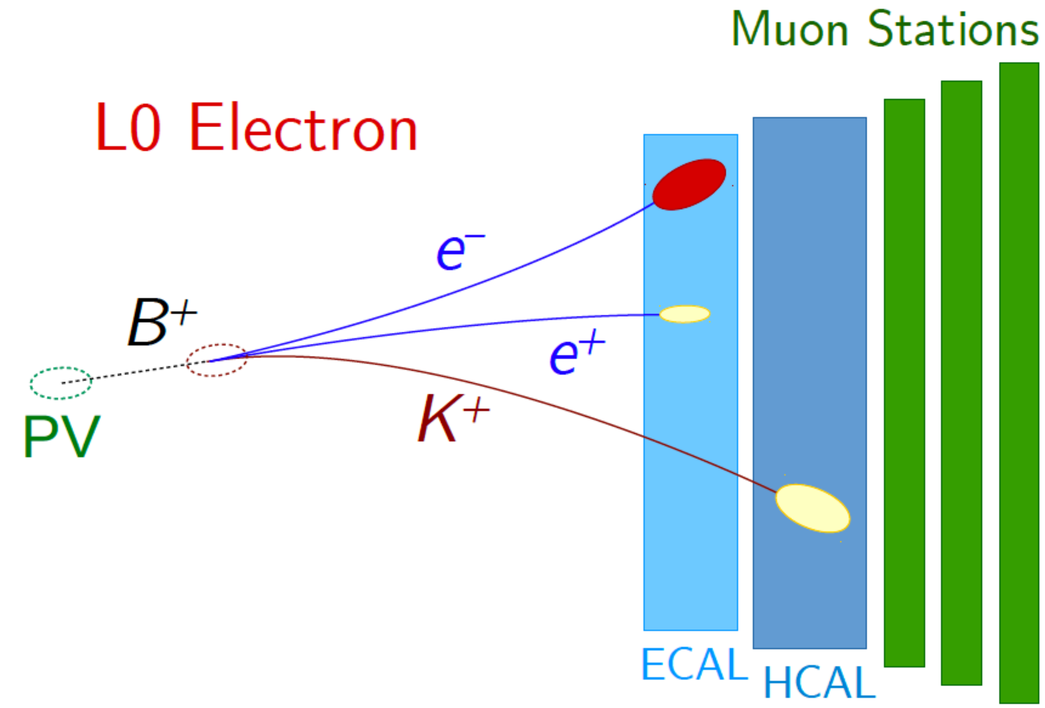
$\hookrightarrow K\pi$

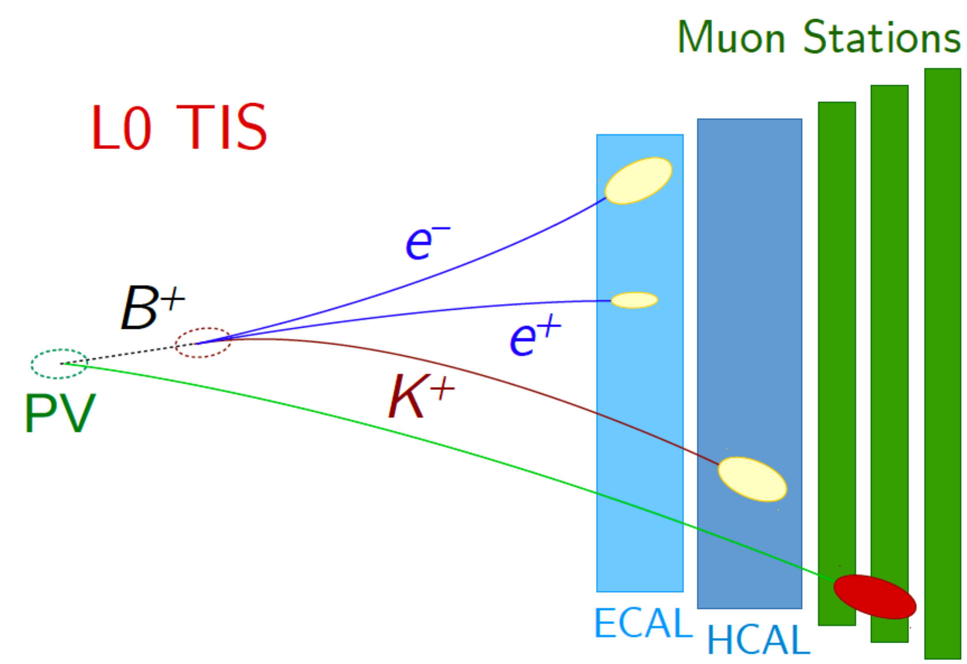
$$\Lambda_b \to \Lambda^* \ell^+ \ell^-$$

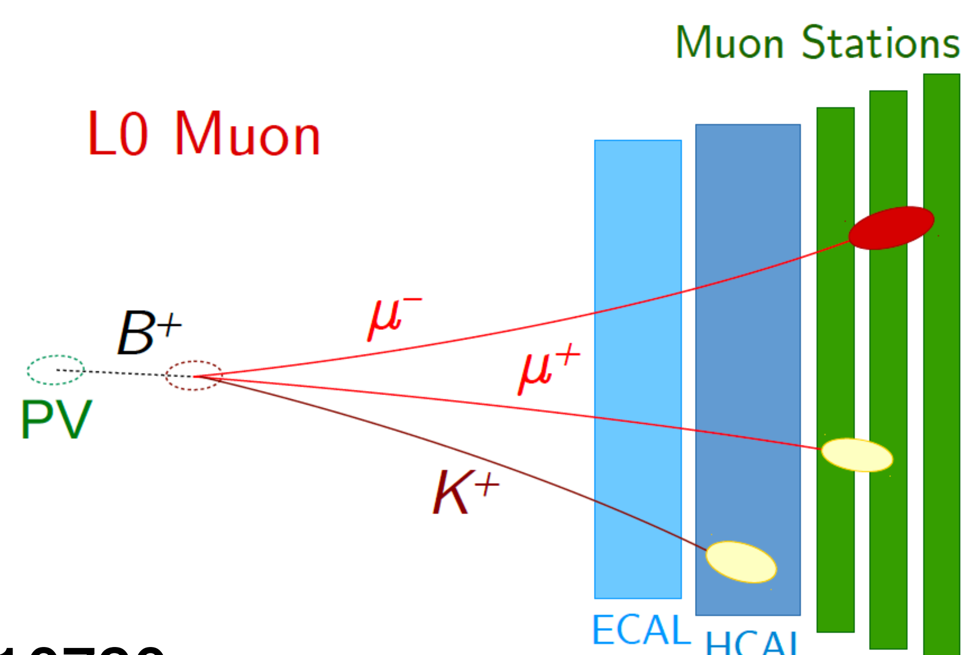
$\hookrightarrow pK$

Trigger





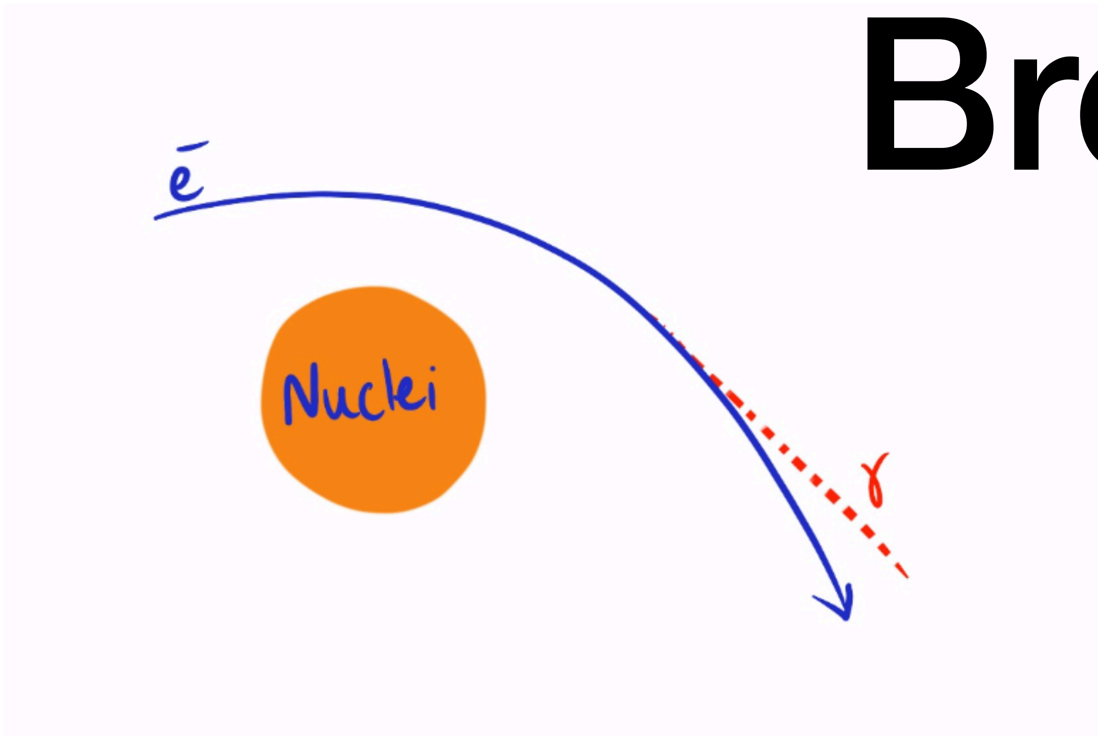




Electrons p_T > 2700/2400 MeV in 2012/2016
Muons p_T > 1700/1800 MeV in 2012/2016

1812.10790

Bremsstrahlung



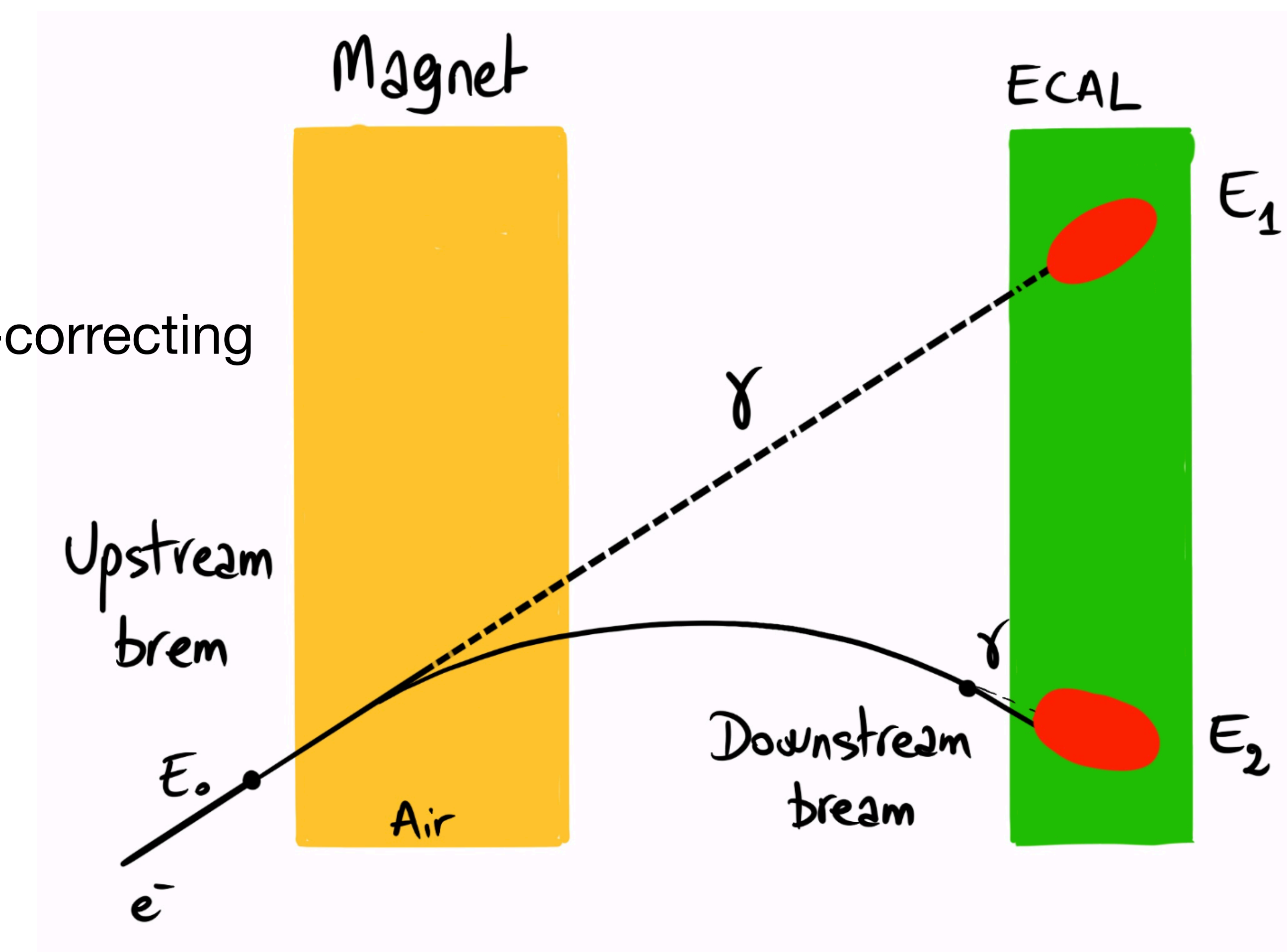
$\sigma \propto 1/m_l^2$

Energy loss $\propto E_e$

Energy loss $\propto$ material

Match electron tracks to photon clusters in the ECAL
Correct electron momenta by "attaching" photons.

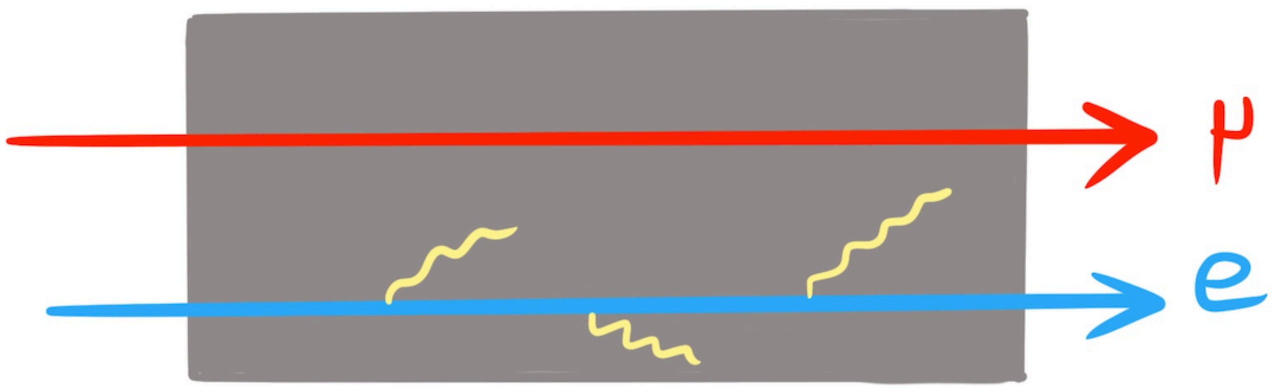
Three categories of events: 0, 1, > 1 photons
Different invariant mass shapes due to under- or over-correcting
ECAL resolution is worse than tracker.
Bin migration included in systematics.

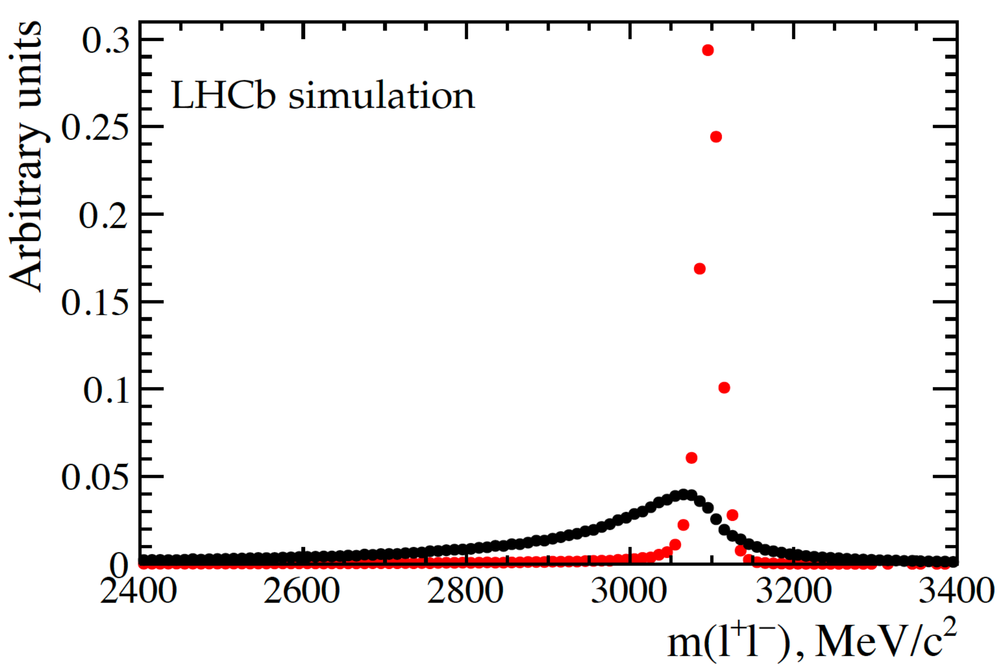


Electrons vs muons

Even after Bremsstrahlung recovery, electrons still have degraded momentum, mass, q^2 resolution.

Particle ID and track reconstruction efficiencies also larger for muons than for electrons.

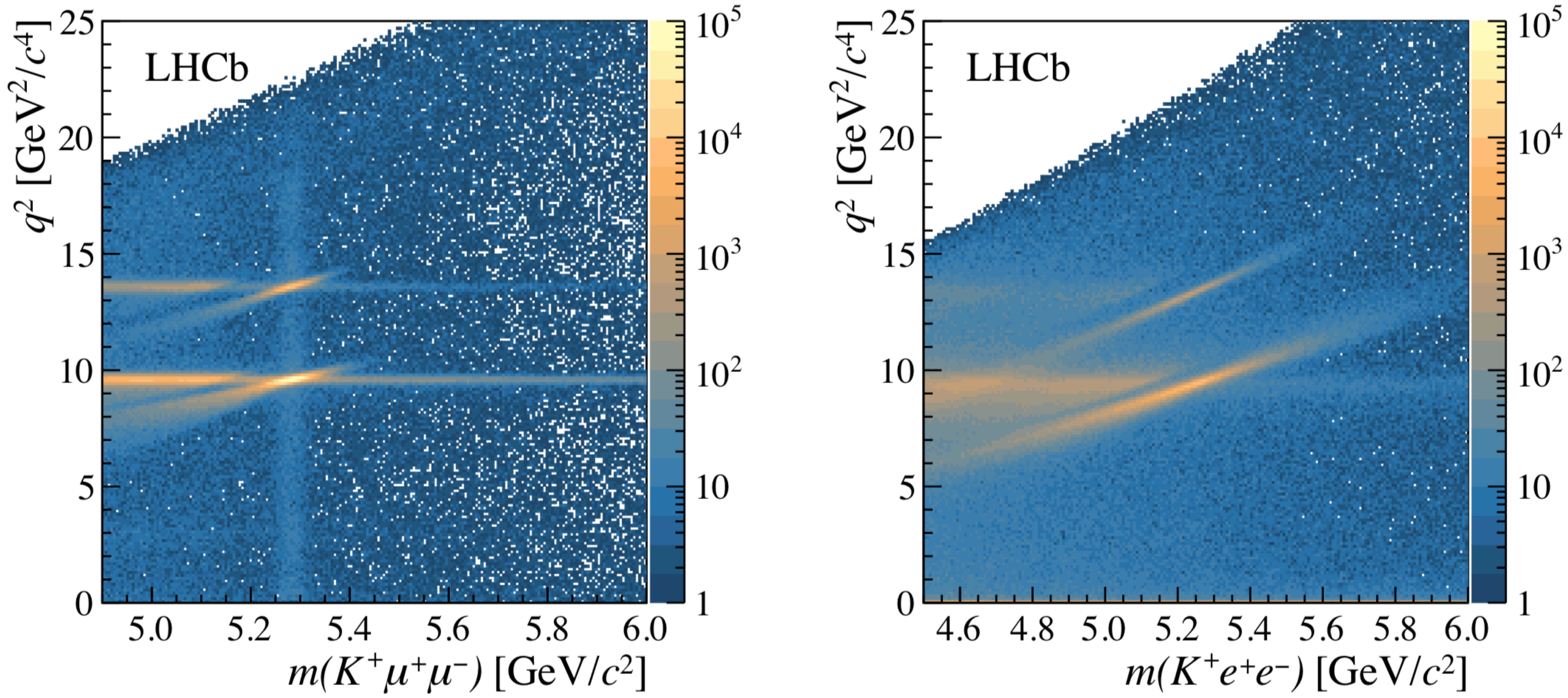




Get the differences between electron and muon efficiencies fully under control

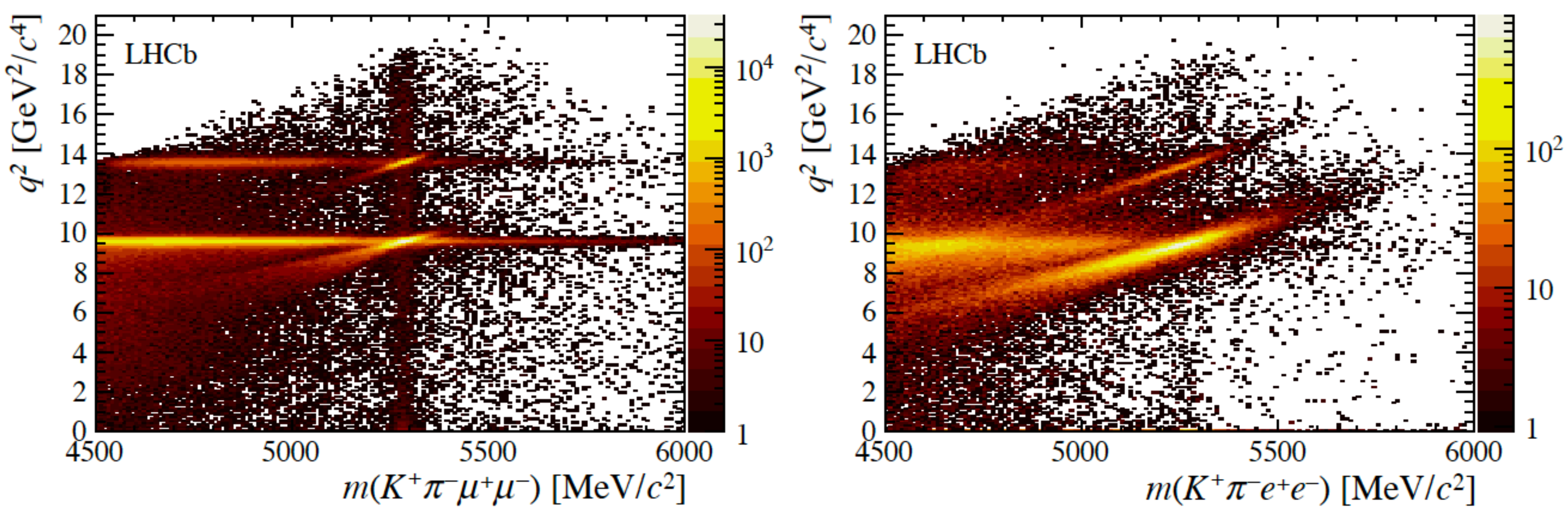
From V. Lisovskyi

B^+



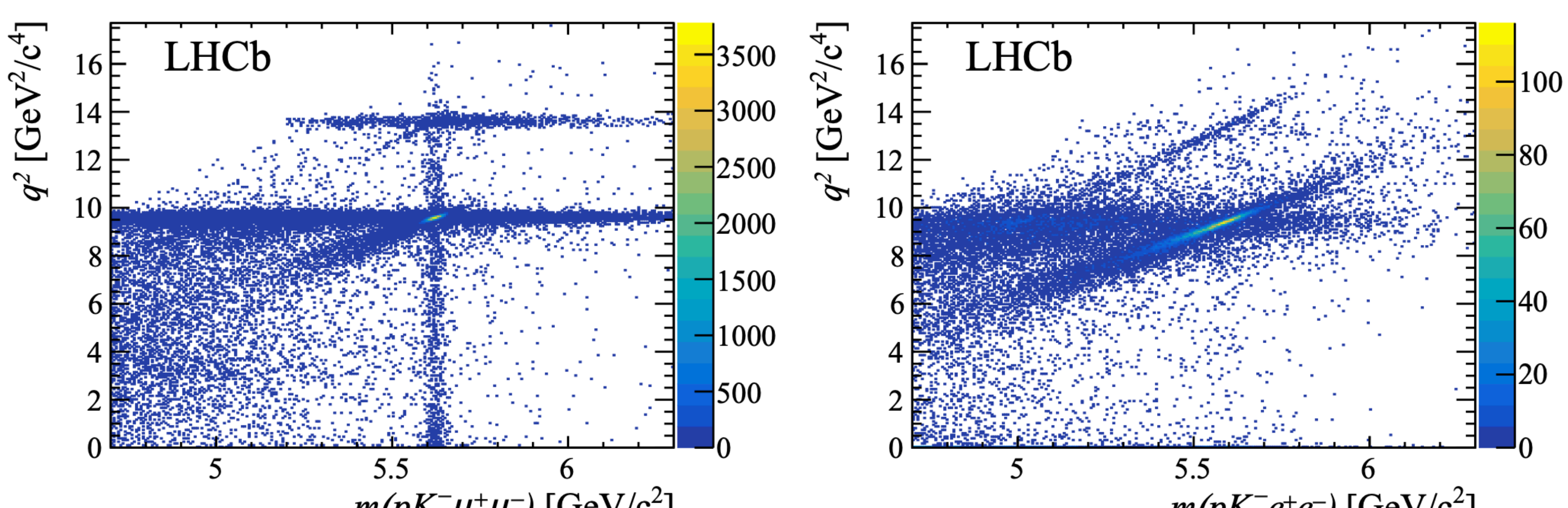
LHCb
q^2 [GeV^2/c^4]
$m(K^+\mu^+\mu^-)$ [GeV/c^2]
LHCb
q^2 [GeV^2/c^4]
$m(K^+e^+e^-)$ [GeV/c^2]

B^0



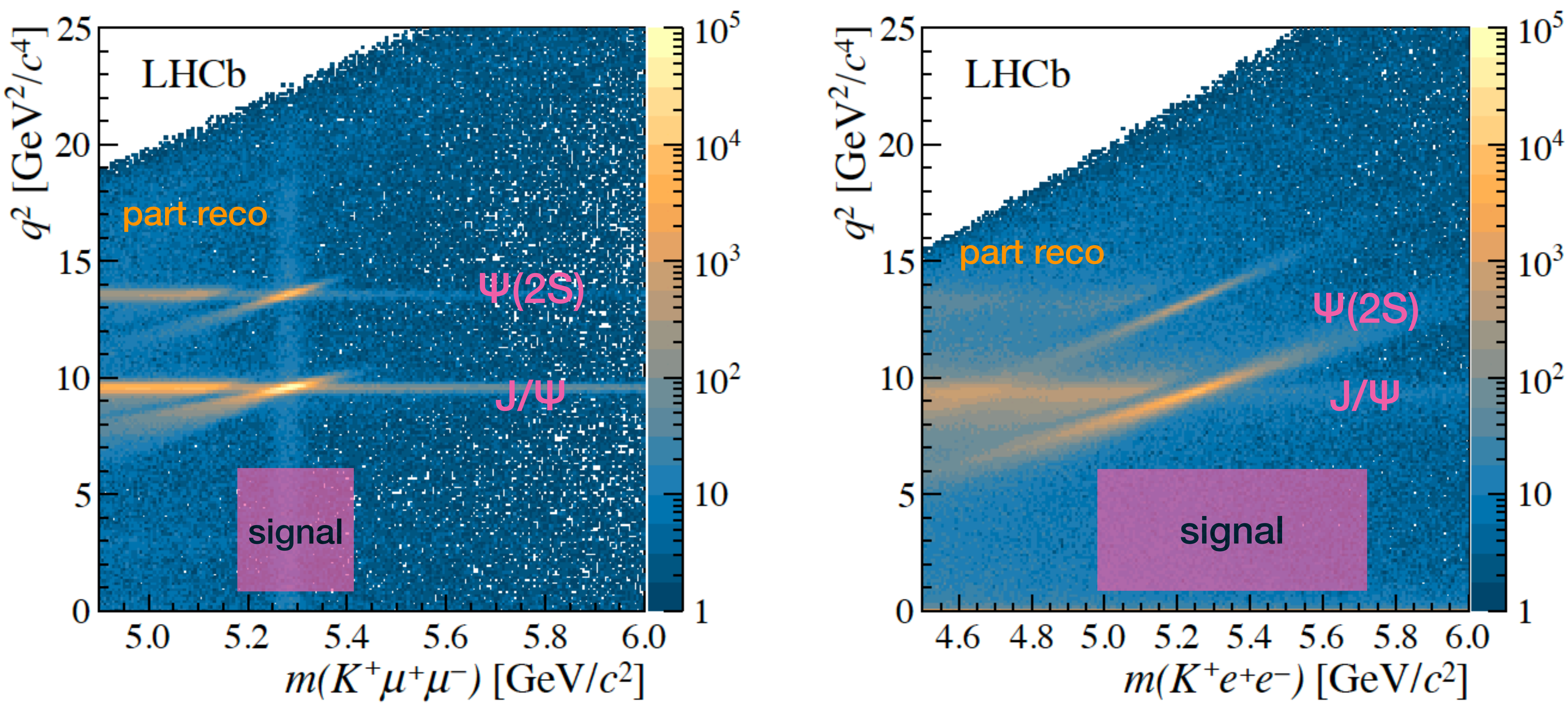
LHCb
q^2 [GeV^2/c^4]
$m(K^+\pi^-\mu^+\mu^-)$ [MeV/c^2]
LHCb
q^2 [GeV^2/c^4]
$m(K^+\pi^-e^+e^-)$ [MeV/c^2]

Λ_b

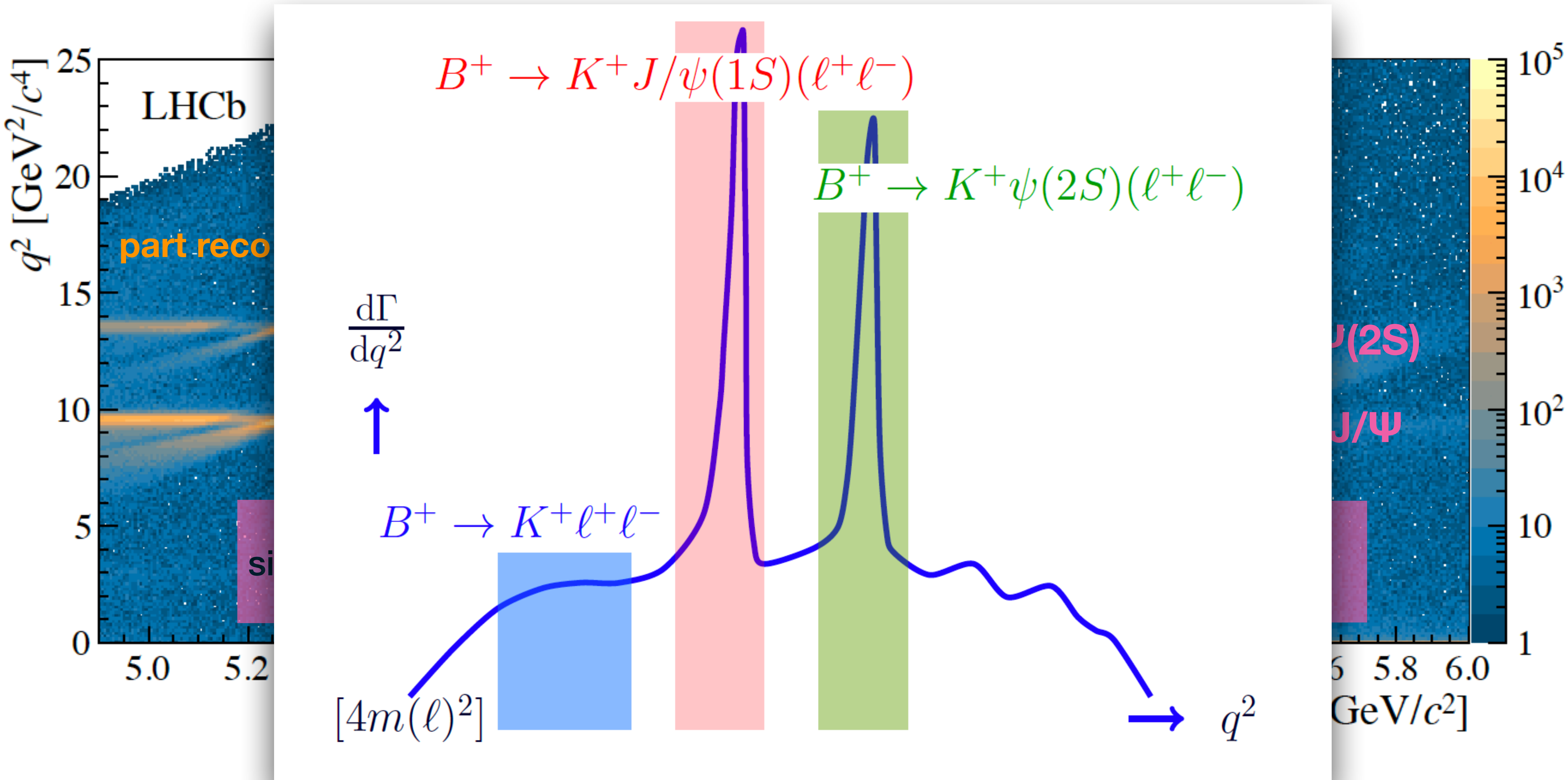


LHCb
q^2 [GeV^2/c^4]
$m(pK^-\mu^+\mu^-)$ [GeV/c^2]
LHCb
q^2 [GeV^2/c^4]
$m(pK^-e^+e^-)$ [GeV/c^2]

Looking closer

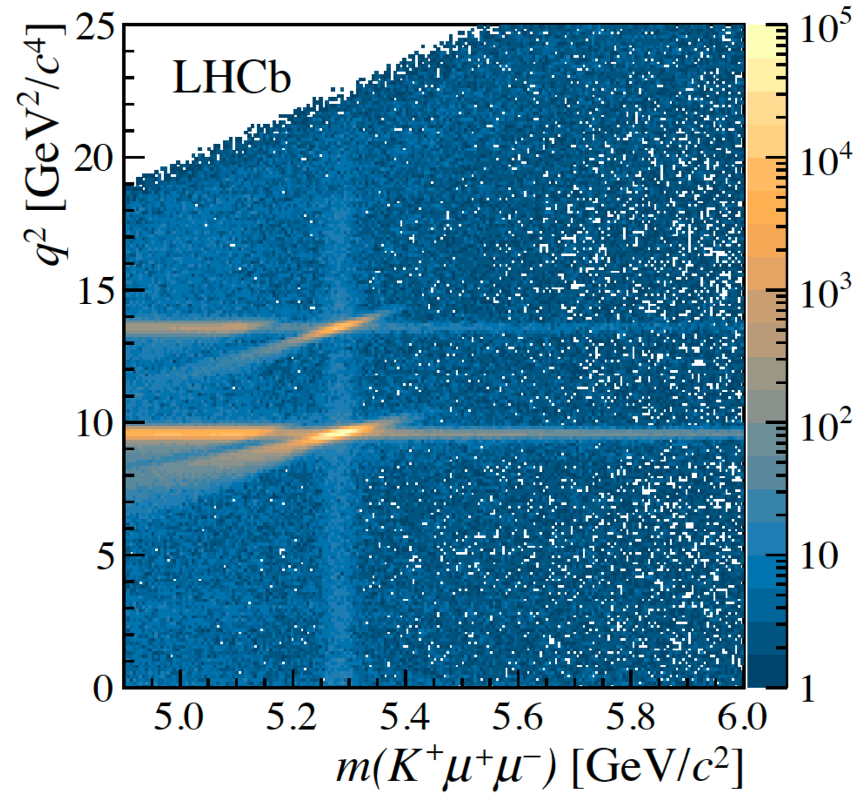


Looking closer



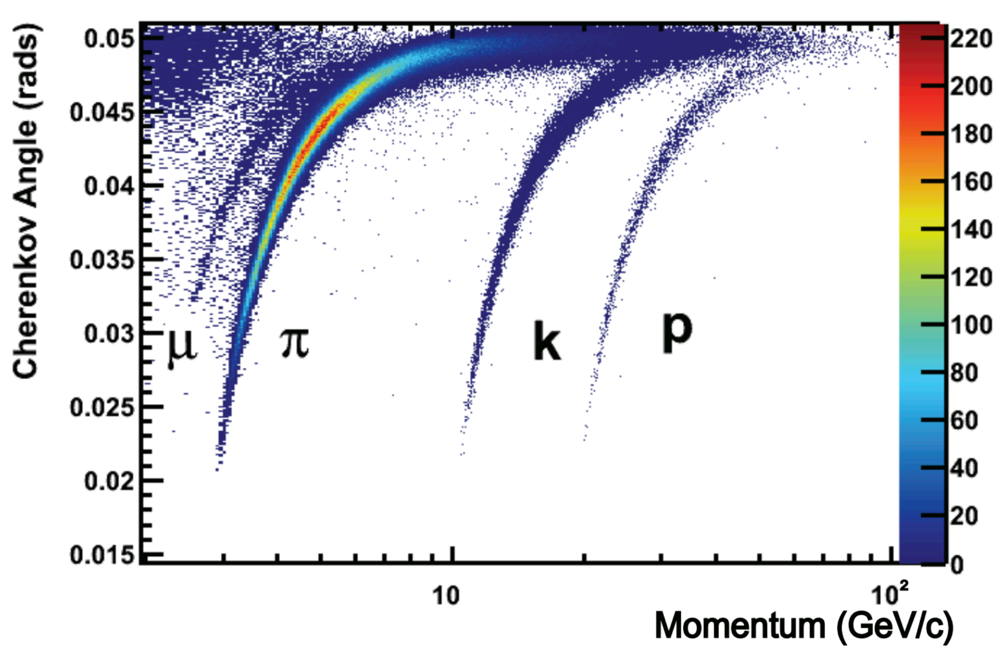
Suppressing backgrounds

Identical selection between rare and control mode.



Combinatorial background

Train an MVA (BDT, NN) against it.
Using simulation for signal and upper sidebands for background.

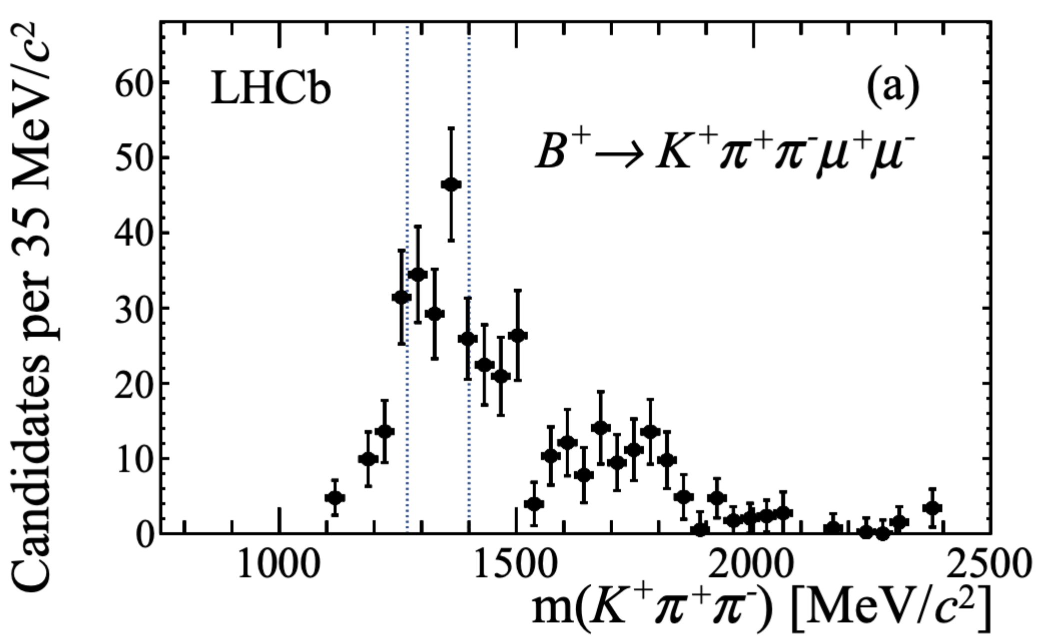


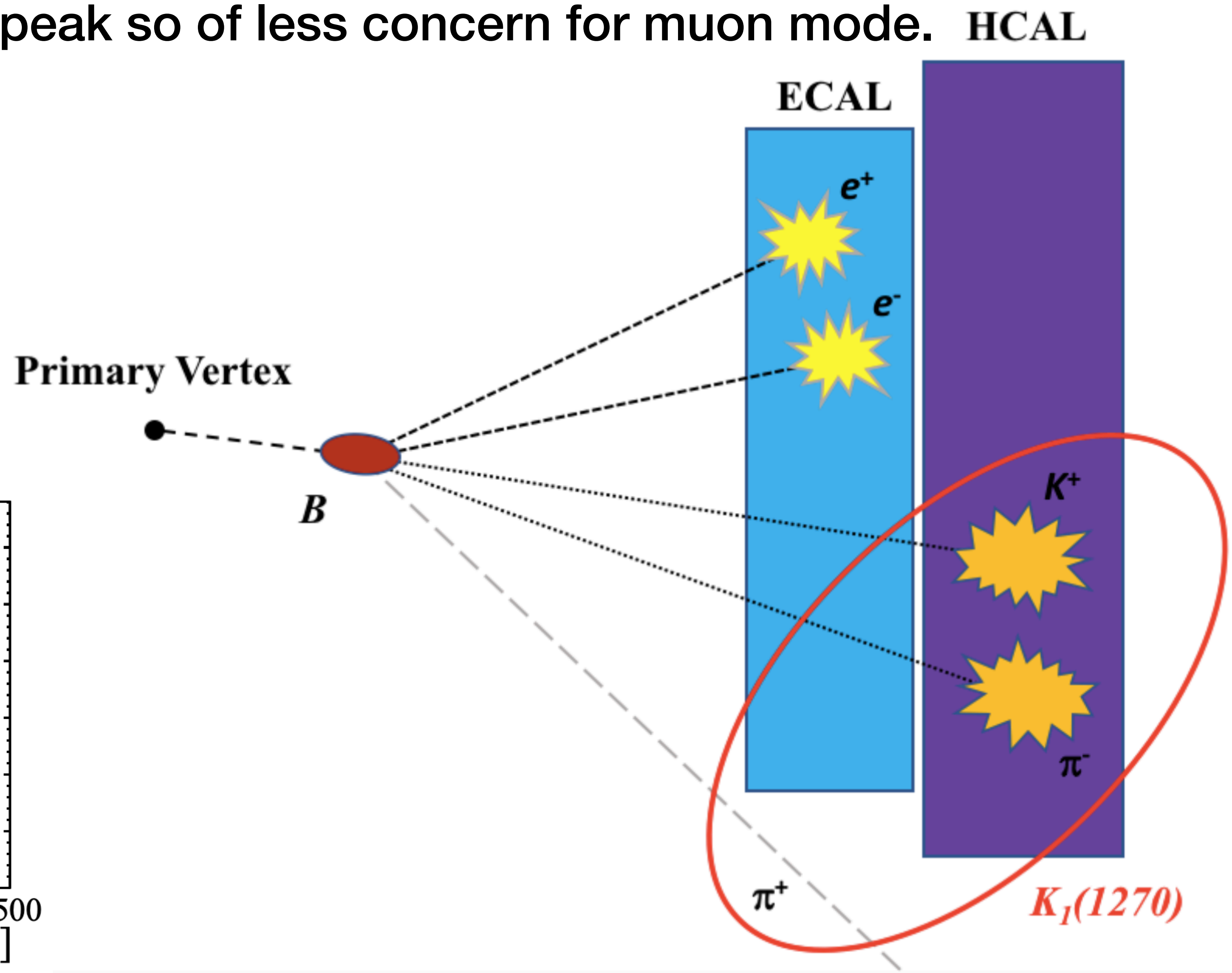
Particle misidentifications:

PID efficiencies measured using high-purity calibration samples.
Tag & probe technique.

Partially reconstructed background

Cascade b → c → s decays having same “visible” final state.
Or from excited states of final state hadrons.
Usually located below the signal peak so of less concern for muon mode.

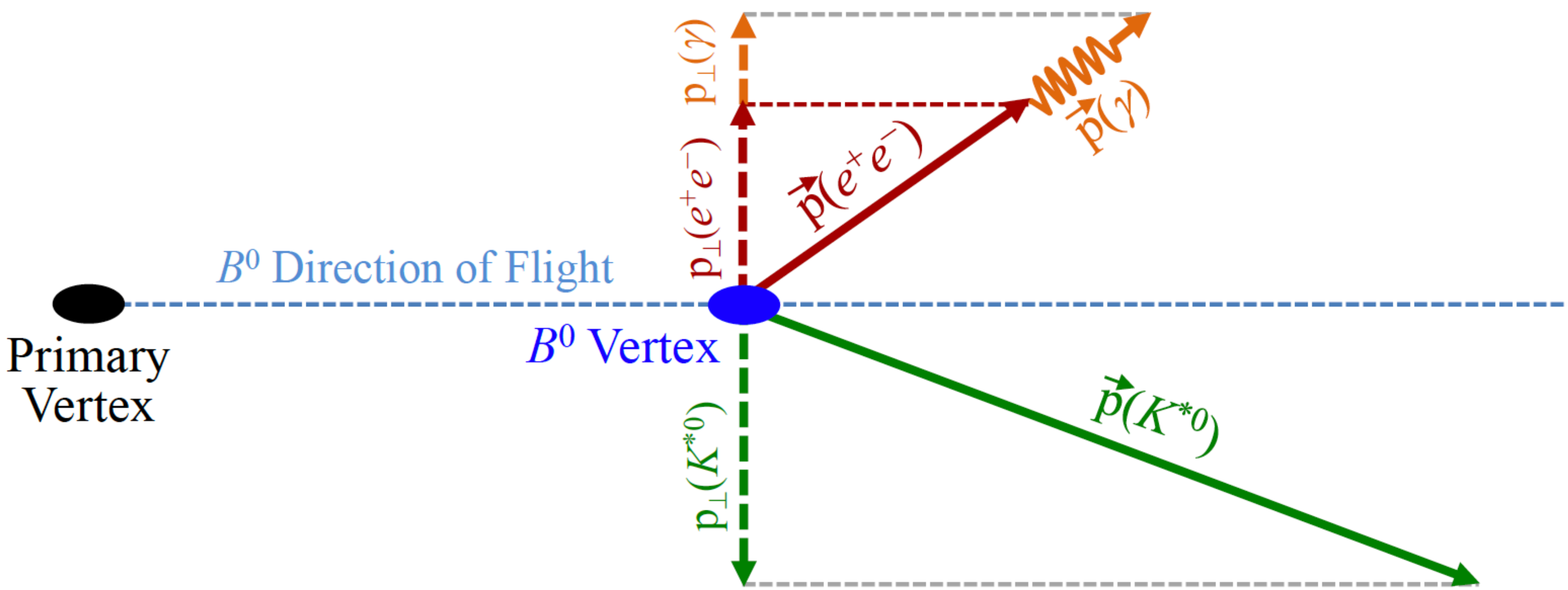




1408.1137

Suppressing backgrounds

Use the momentum balance for electron mode to reduce the background.

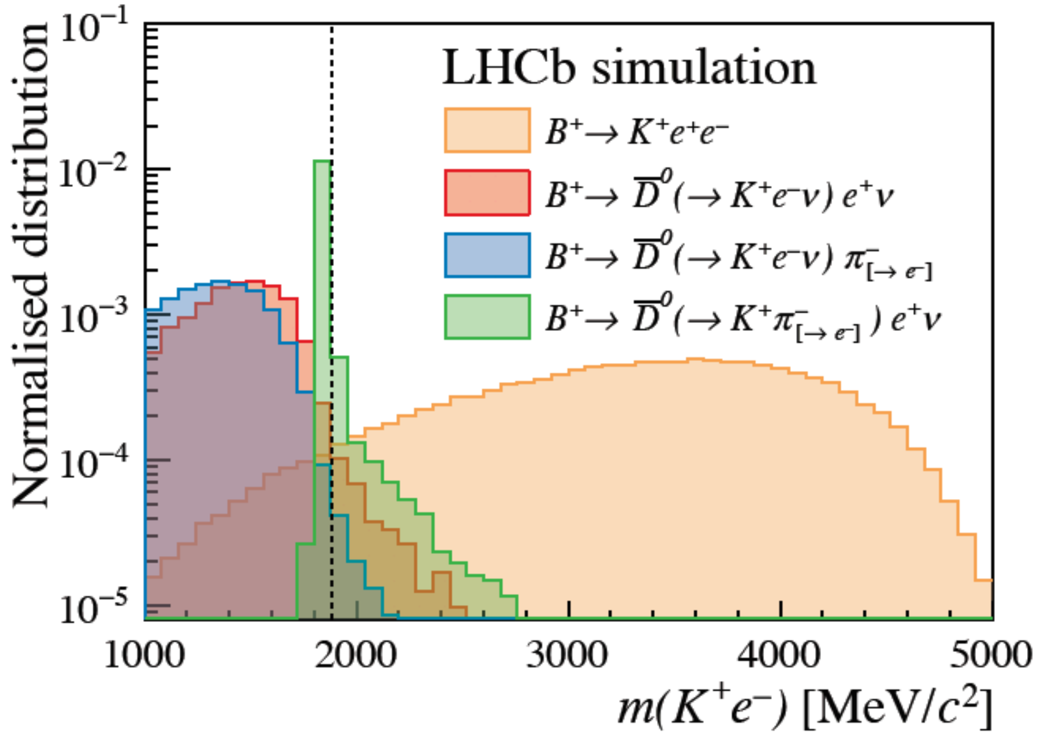


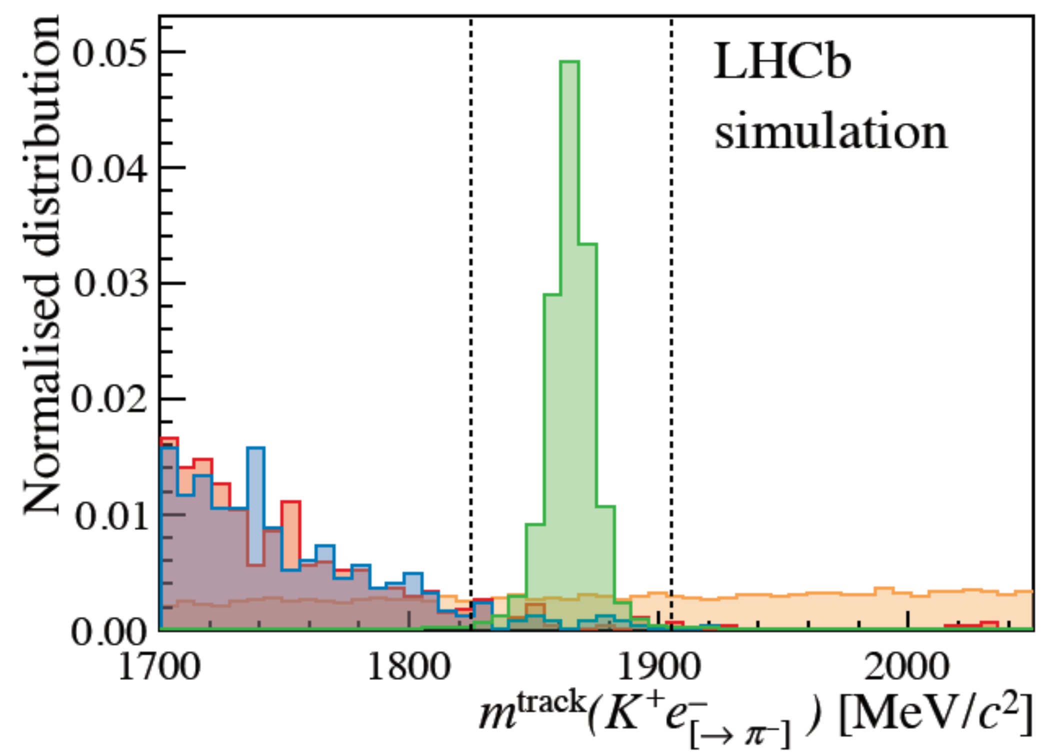
1705.05802

a.k.a HOP !

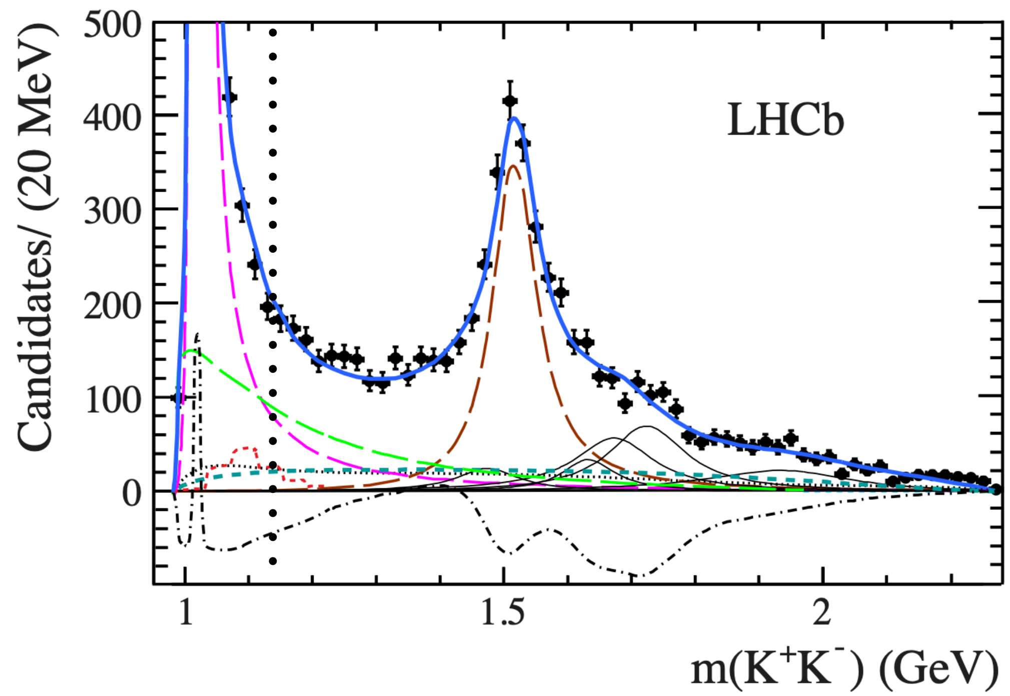
Example of vetos

B^+



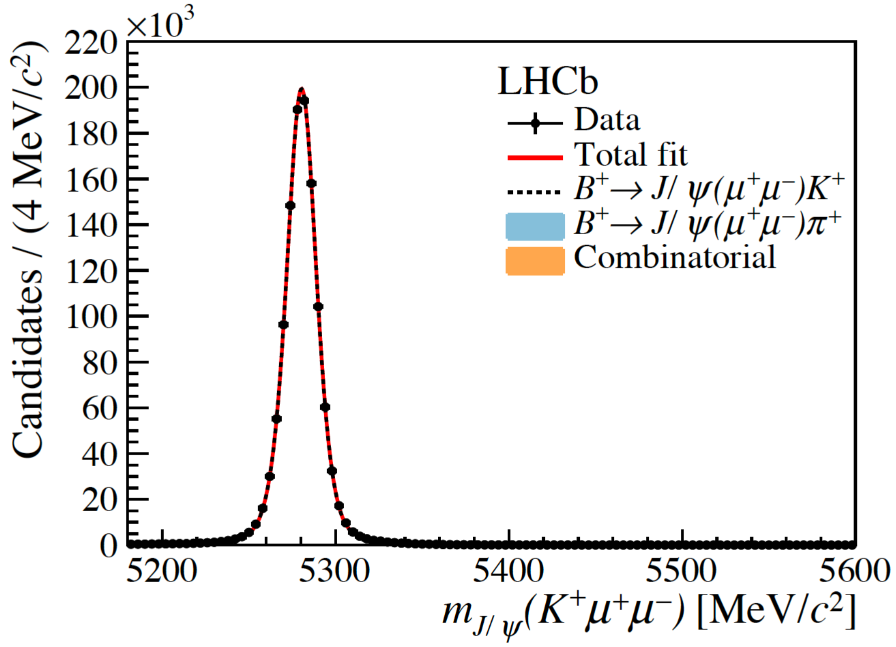


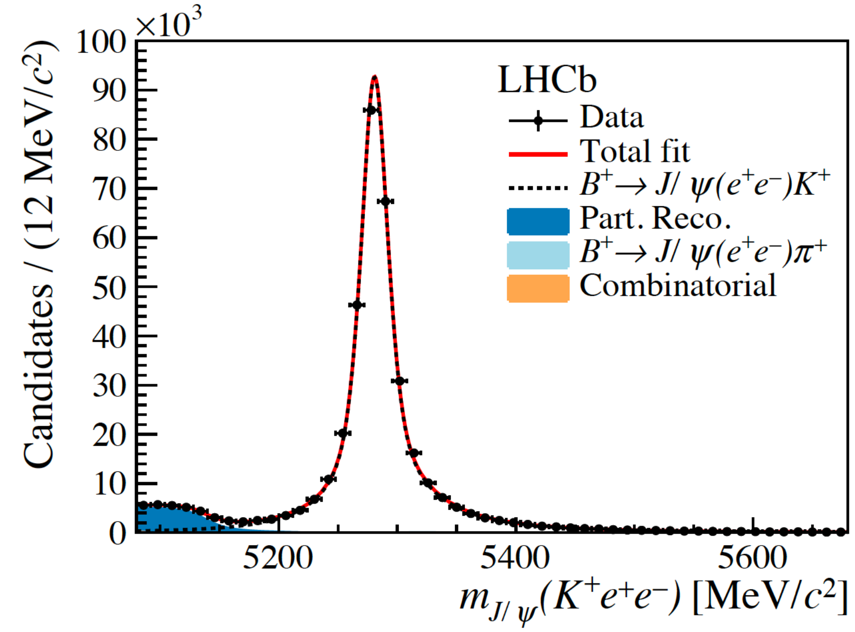
Λ_b



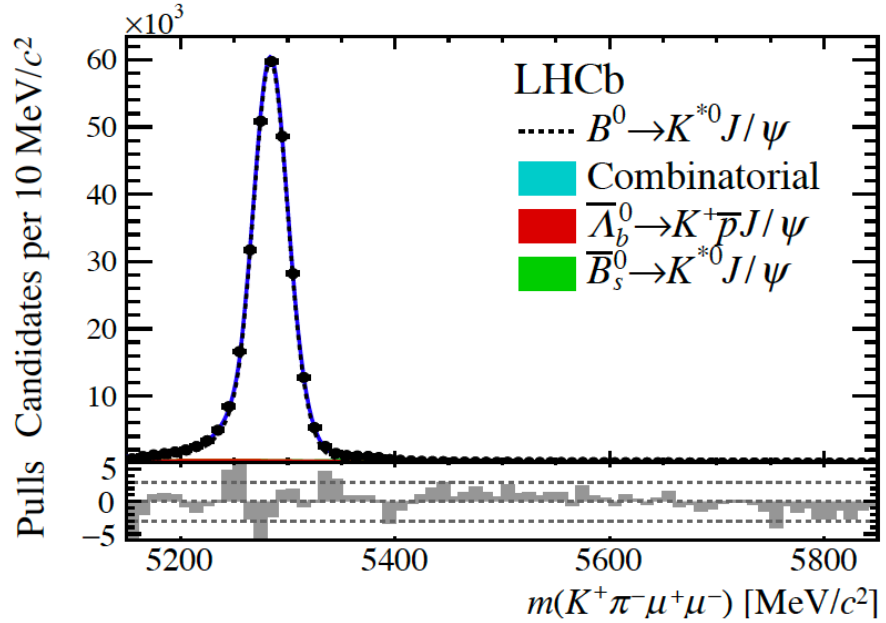
1302.1213

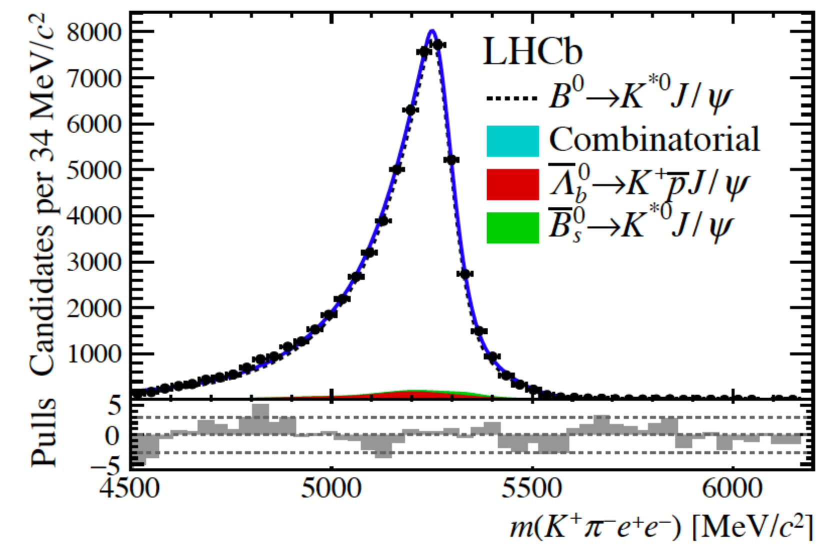
Control modes



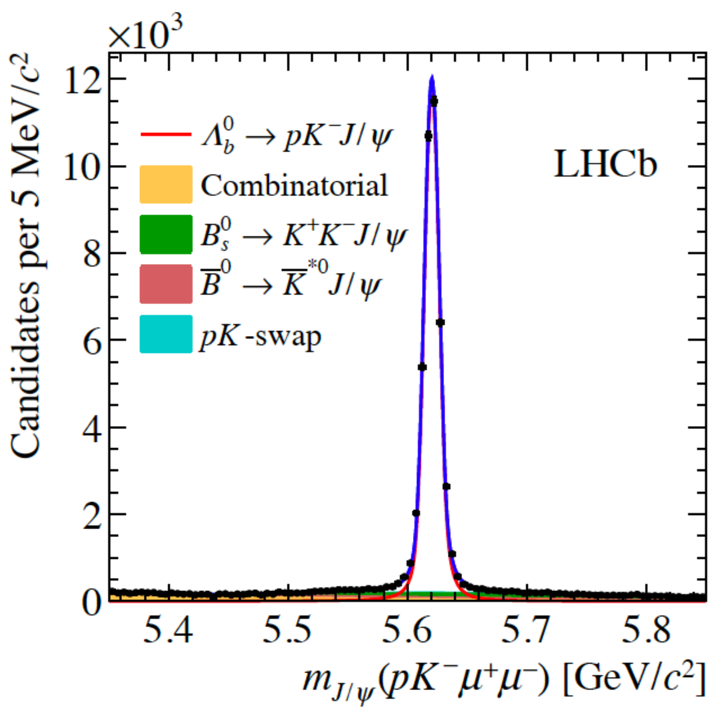


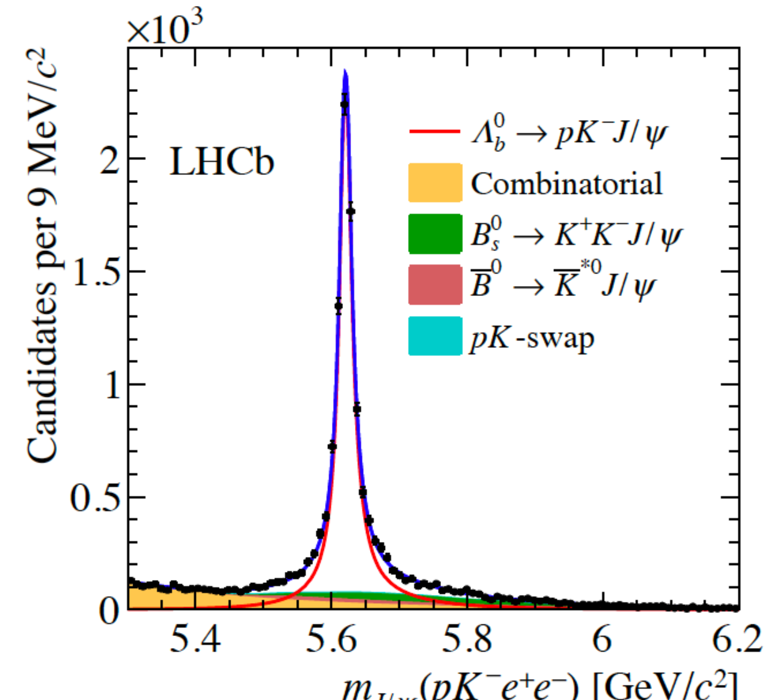
B^+





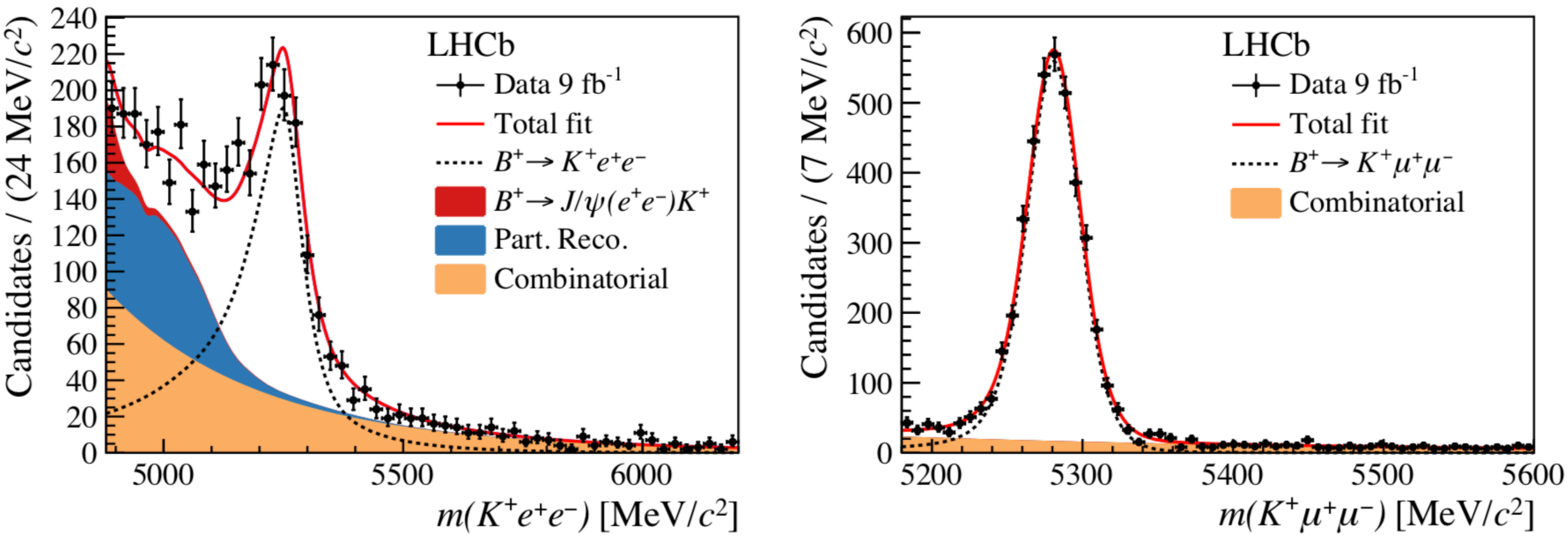
B^0





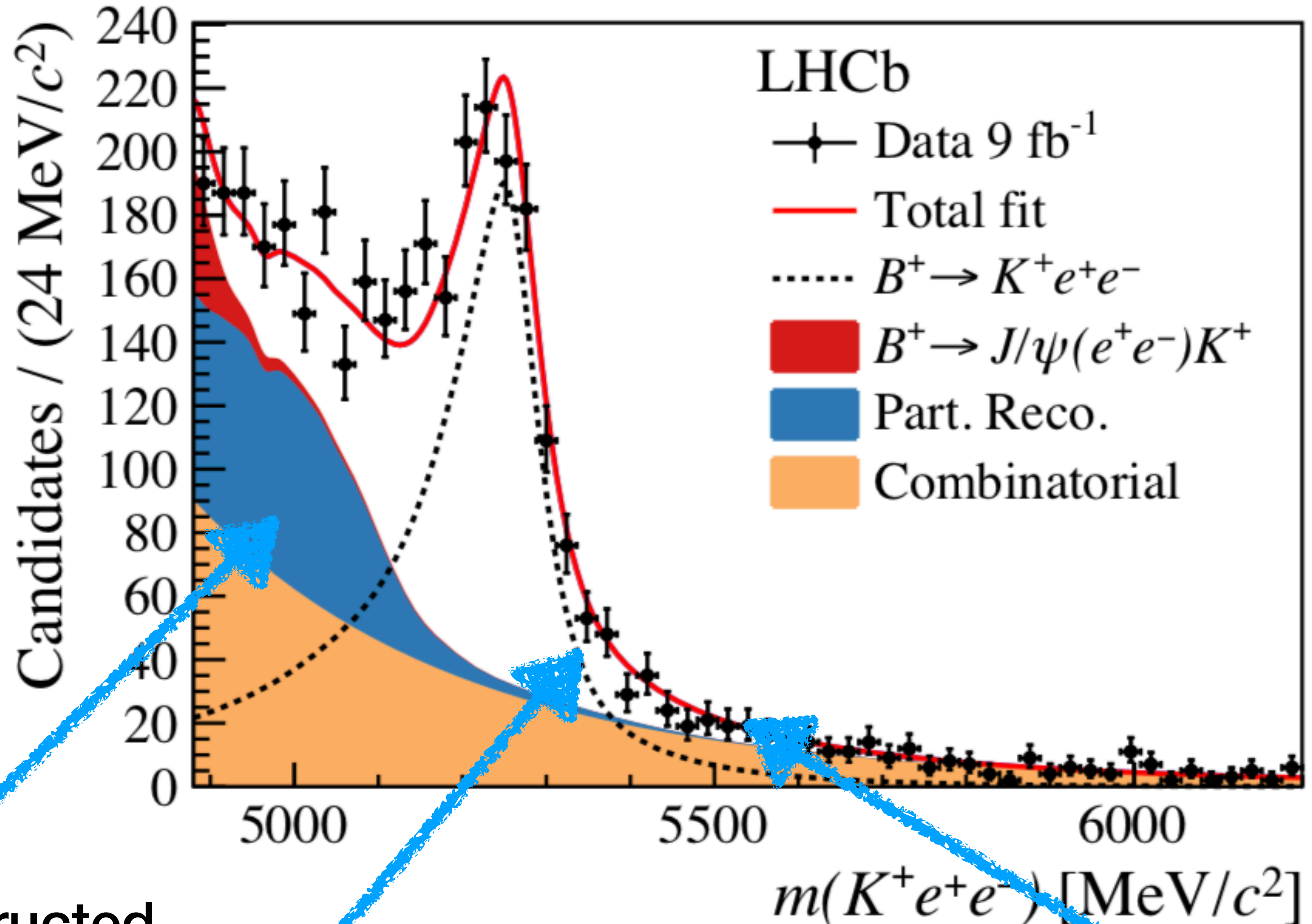
Λ_b

Invariant mass fits



Signal and background shapes determined from calibrated simulation.
J/Ψ leakage constraint from the fit to the resonant mode.

A closer look

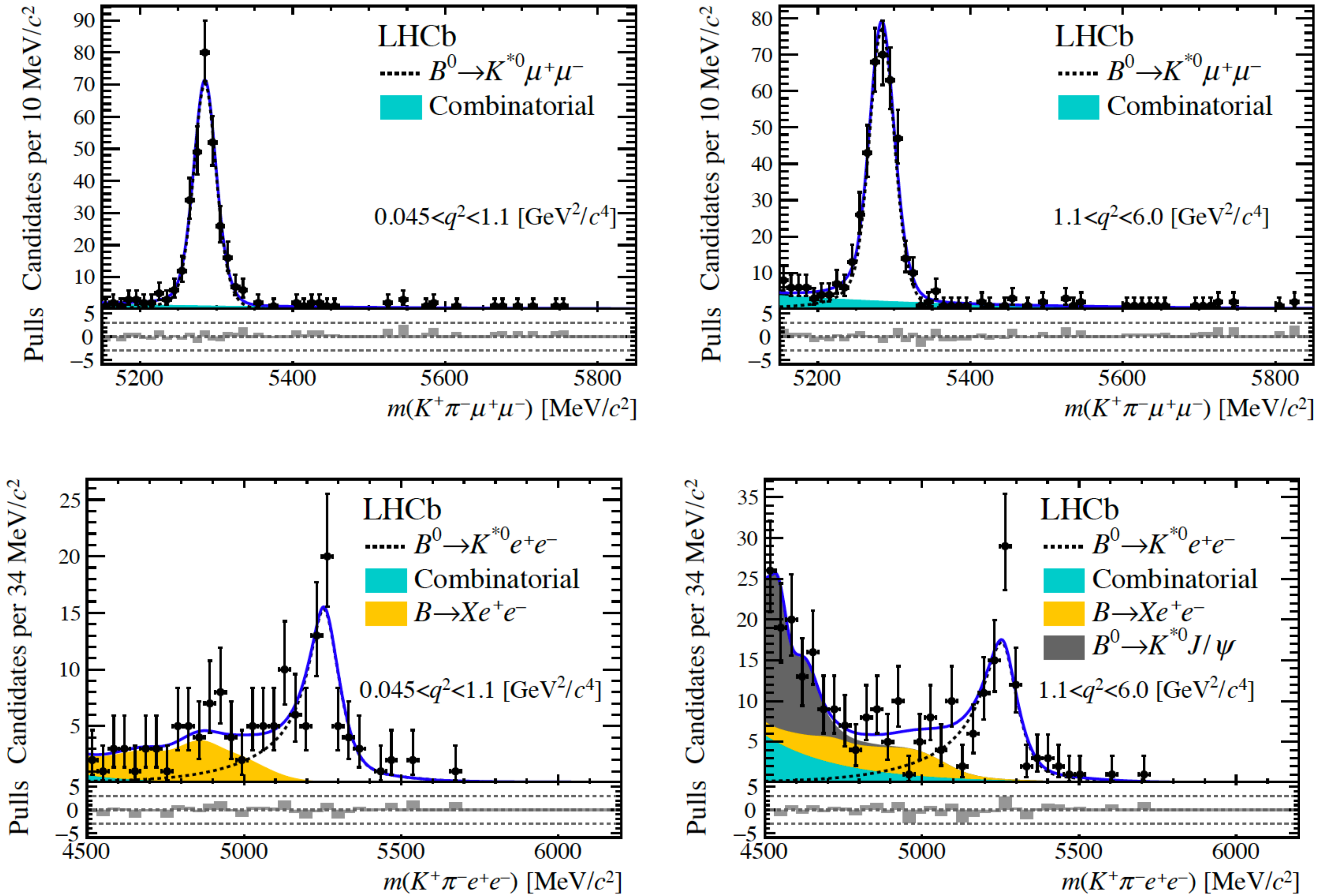


Partially reconstructed background

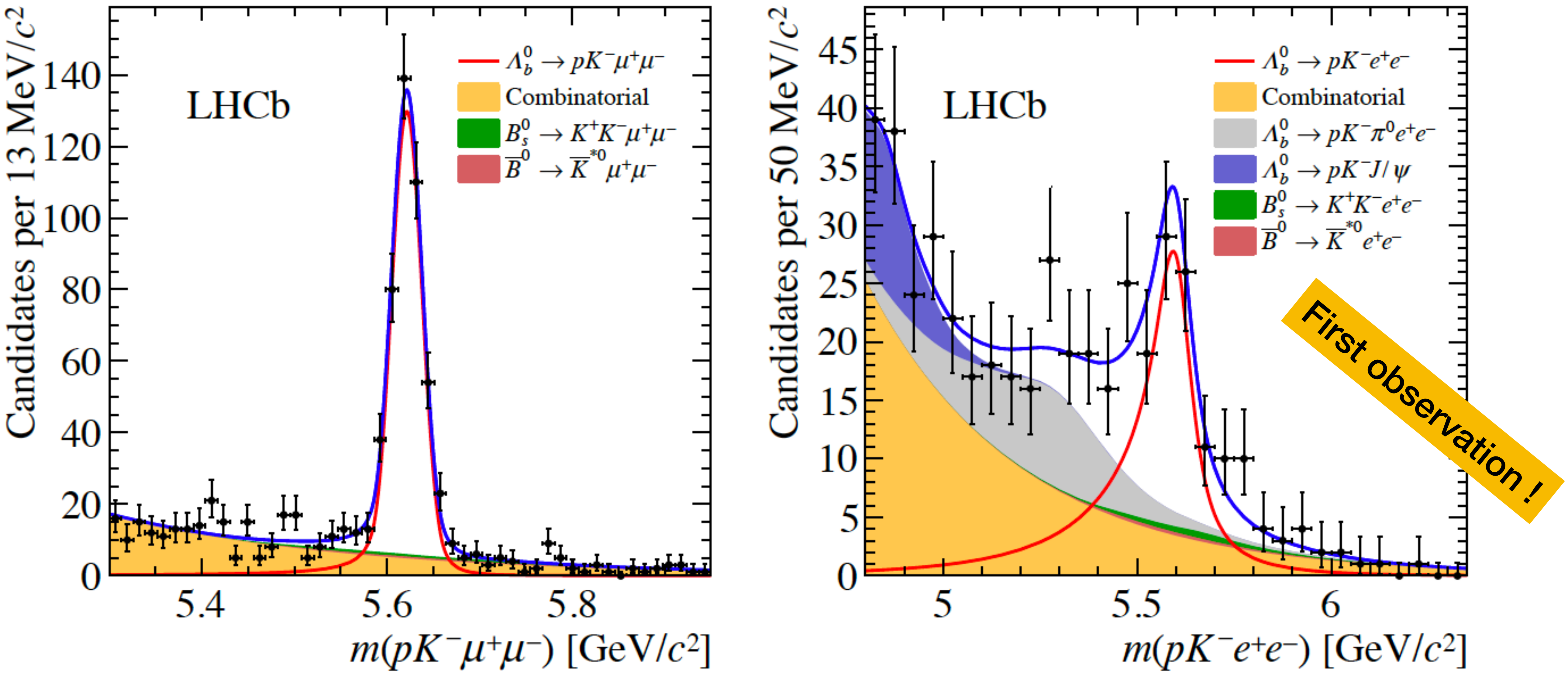
non trivial signal shape from simulation

When bremsstrahlung photons are added.

Invariant mass fits



Invariant mass fits



What we measure

$$R_H \propto \frac{N(B\to H\mu^+\mu^-)}{N(B\to He^+e^-)} \times \frac{\epsilon(B\to He^+e^-)}{\epsilon(B\to H\mu^+\mu^-)}$$

Counting from mass fits

From simulation

$$r_{J/\psi} = \frac{BR(B\to HJ/\psi(\mu^+\mu^-))}{BR(B\to HJ/\psi(e^+e^-))} = 1$$

$$R_H = \frac{\frac{N(B\to H\mu^+\mu^-)}{N(B\to HJ/\psi(\mu^+\mu^-))}}{\frac{N(B\to He^+e^-)}{N(B\to HJ/\psi(e^+e^-))}} \times \frac{\frac{\epsilon(B\to He^+e^-)}{\epsilon(B\to HJ/\psi(e^+e^-))}}{\frac{\epsilon(B\to H\mu^+\mu^-)}{\epsilon(B\to HJ/\psi(\mu^+\mu^-))}}$$

Calibration of simulation

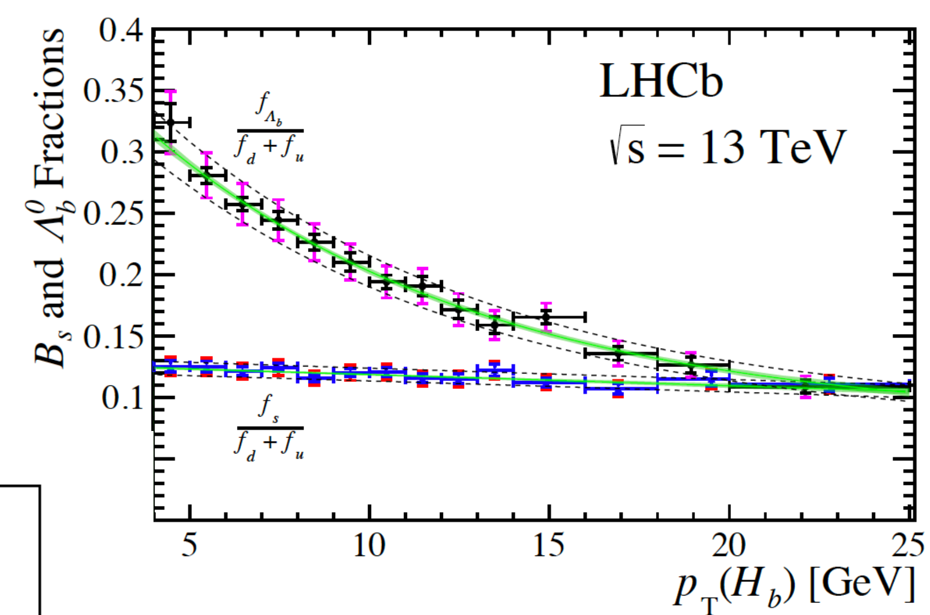
To get the reliable efficiencies, correct the simulation in a data-driven way.
Corrections are applied in terms of per-event or per-track weights.

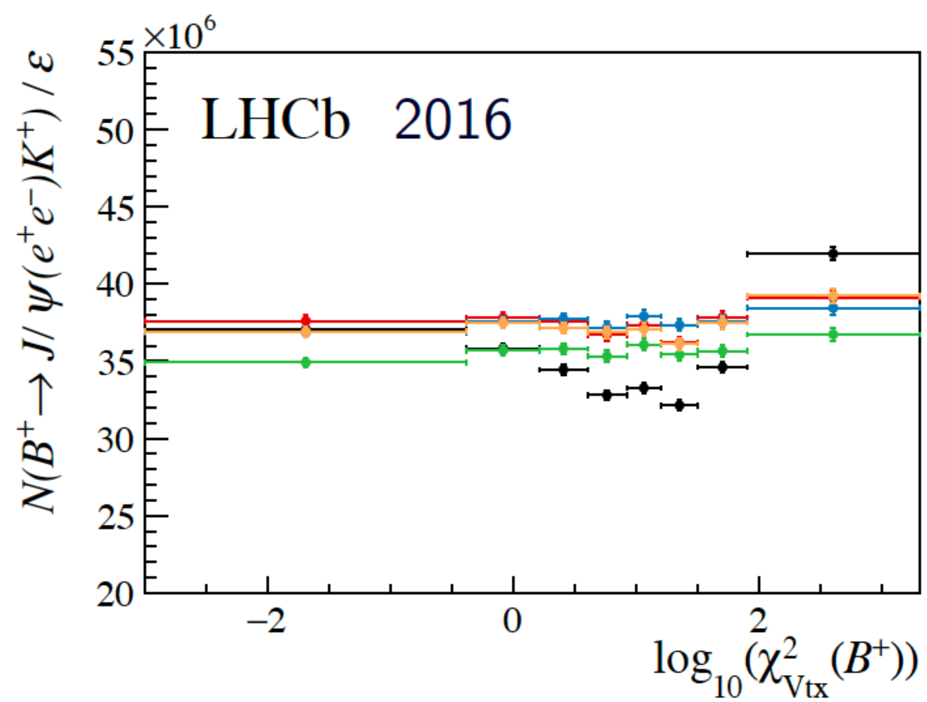
Examples:

Decay model *m(pK)* spectrum.

Correcting the generated quantities:

- Event multiplicity.
- Kinematics of the b-decay.
- Lifetime of the Λ_b.

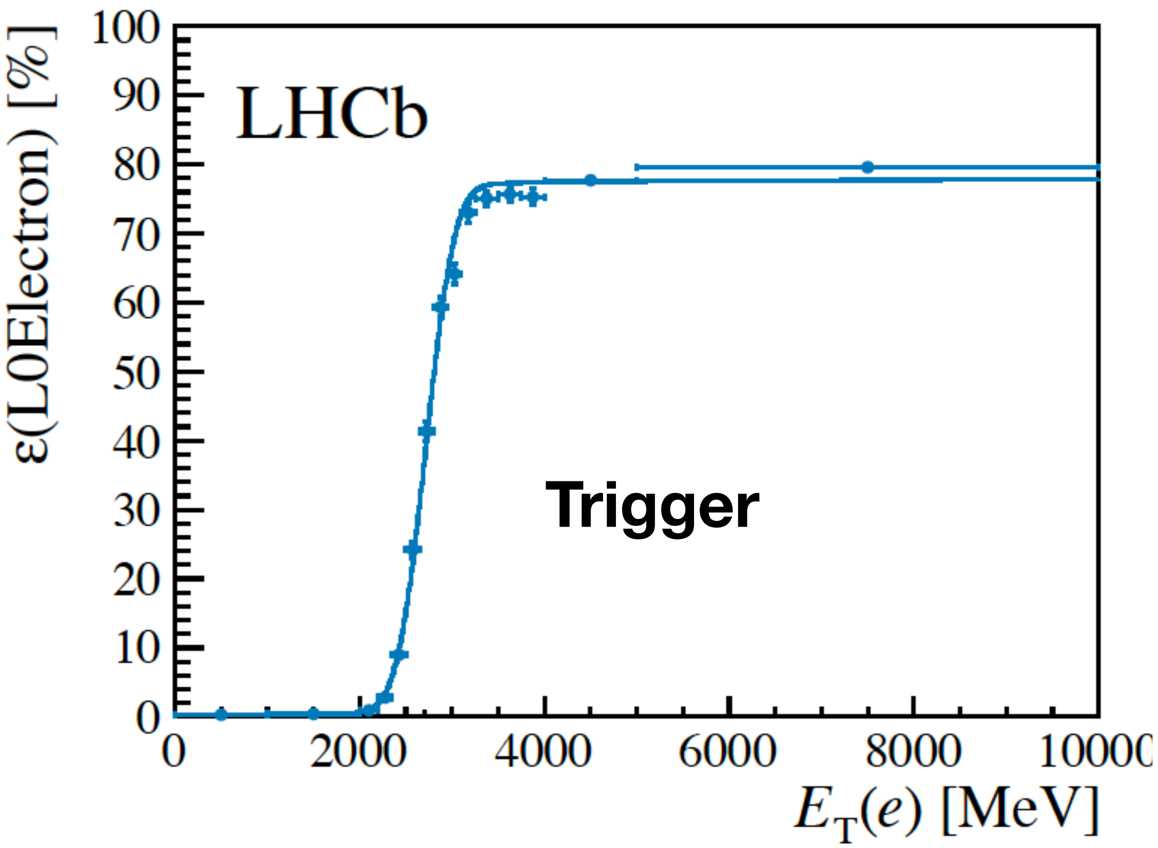


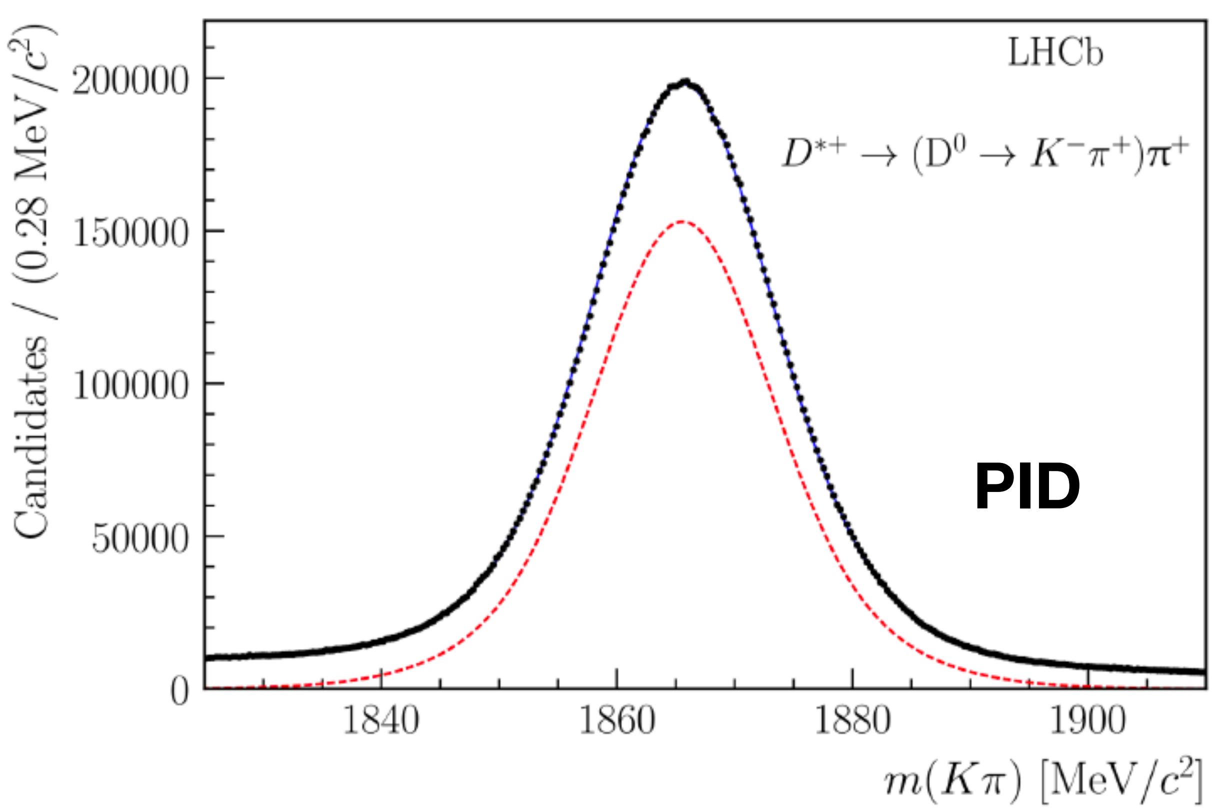


1902.06794

Calibration of simulation

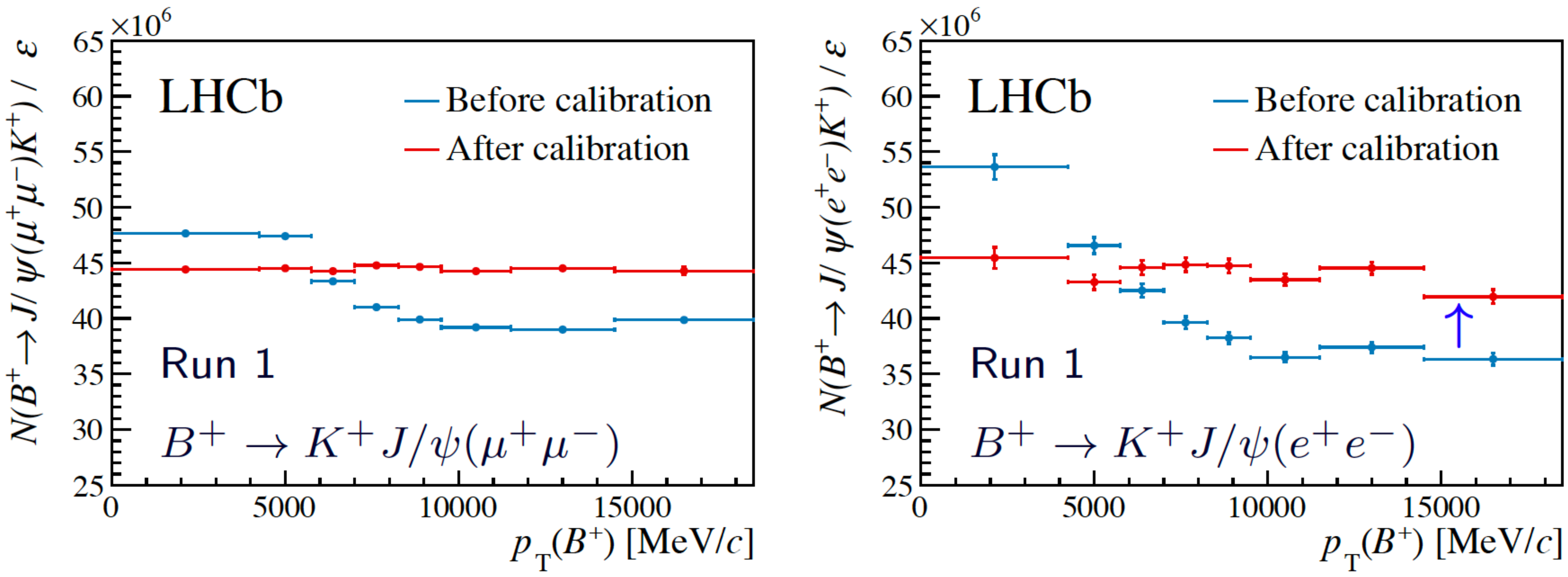
Most of corrections are computed by comparing the distributions of variables in *J/Ψ* mode of data and simulation samples.
Simulation is re-weighted to match the data.
10-folding technique to reduce correlations.





1902.06794

Efficiency calibration summary



After calibration, very good data/simulation agreement in all key observables.

Result of the cross-checks

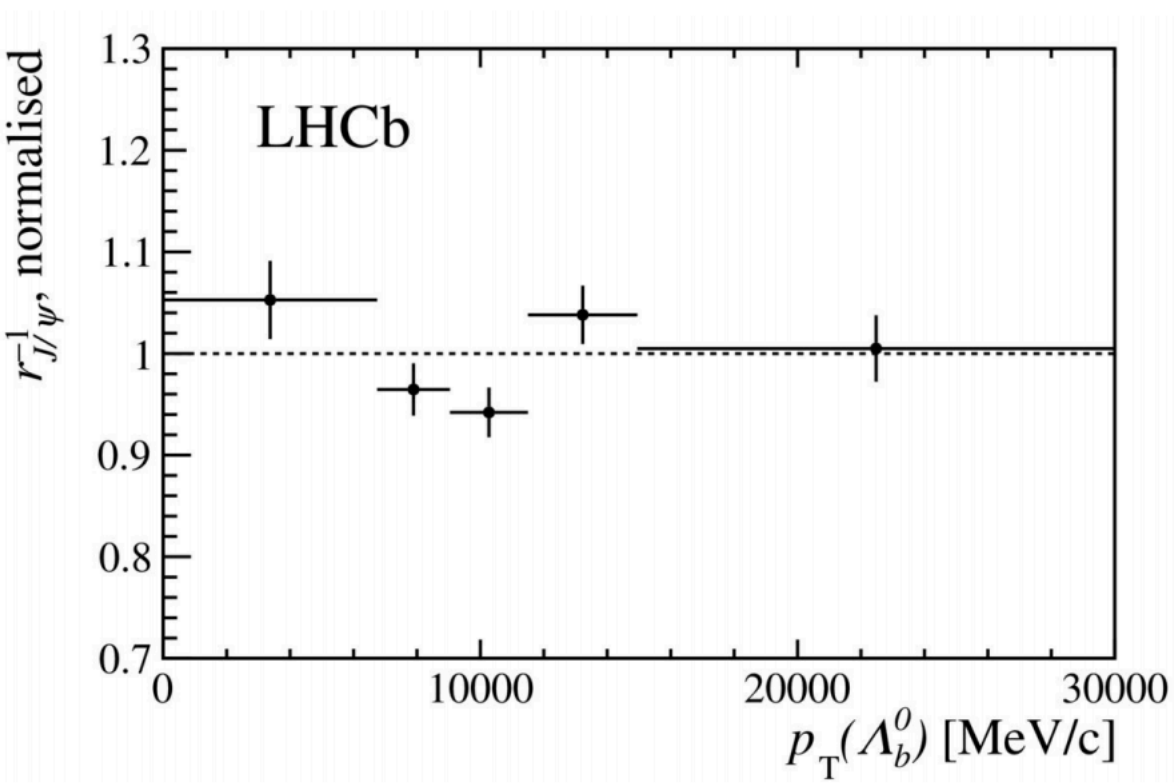
$$B^+ \quad r_{J/\psi} = 0.981 \pm 0.020$$

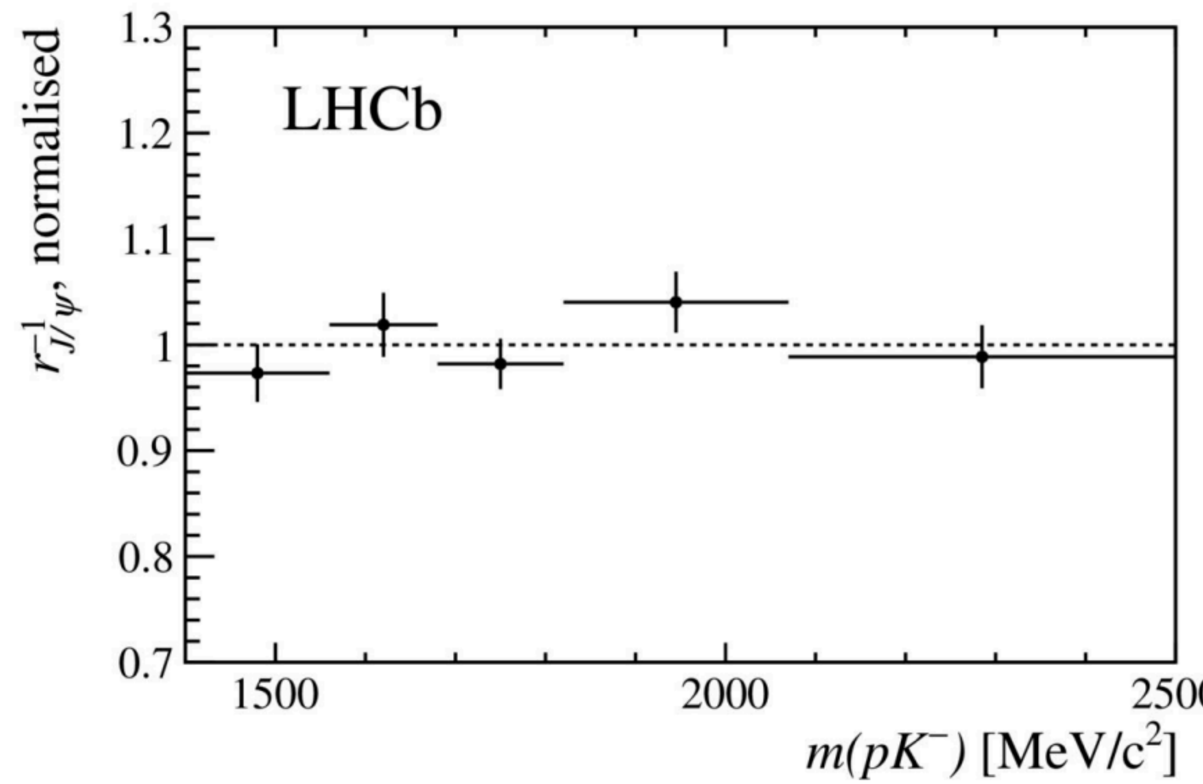
$$B^0 \quad r_{J/\psi} = 1.045 \pm 0.006 \pm 0.045$$

$$\Lambda_b \quad r_{J/\psi}^{-1} = 0.96 \pm 0.05$$

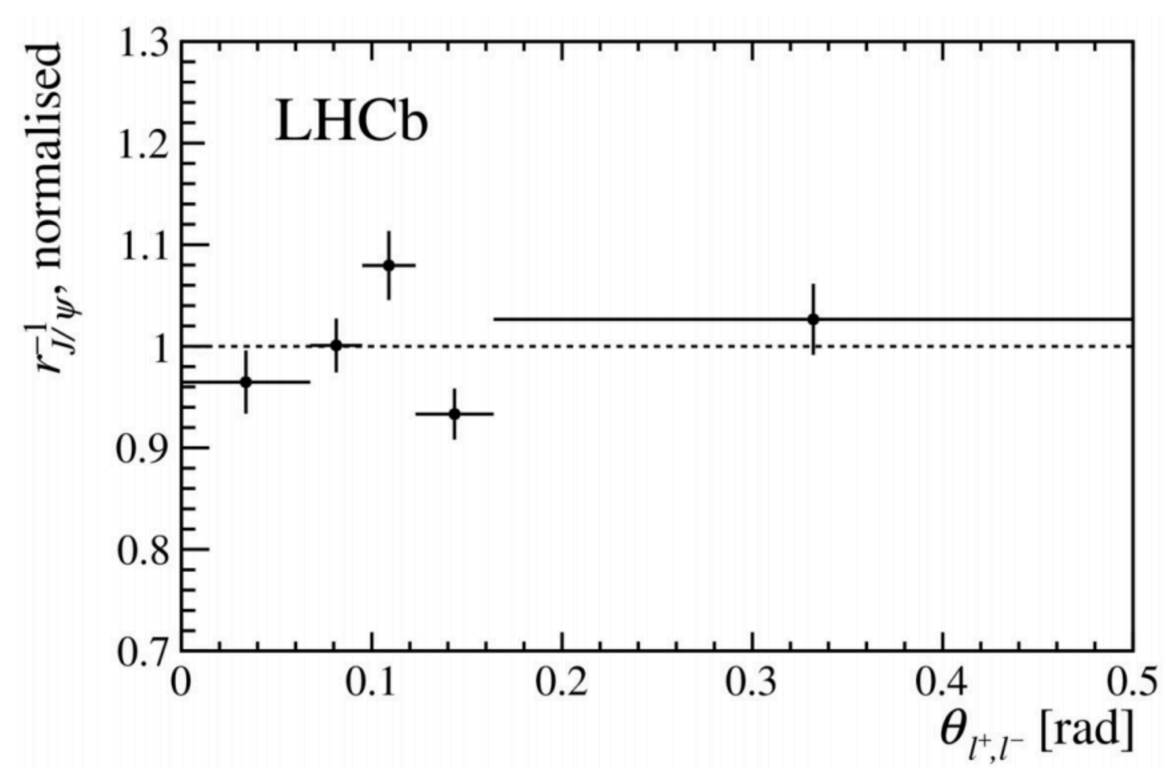
Compatibility with unity observed for all the modes !

$r_{J/\psi}$



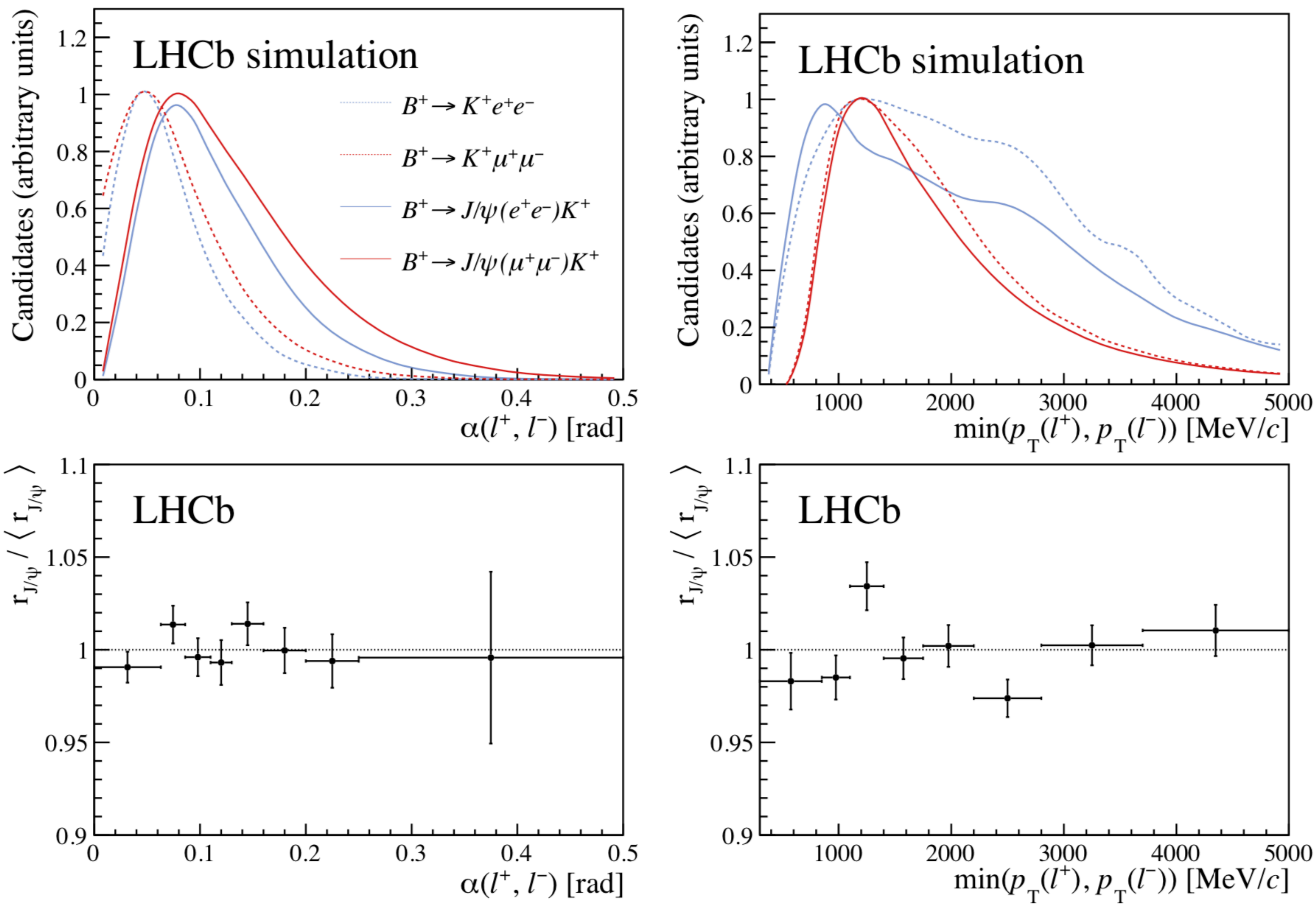


Compatible with unity and flat on kinematic and topological variables



Λ_b

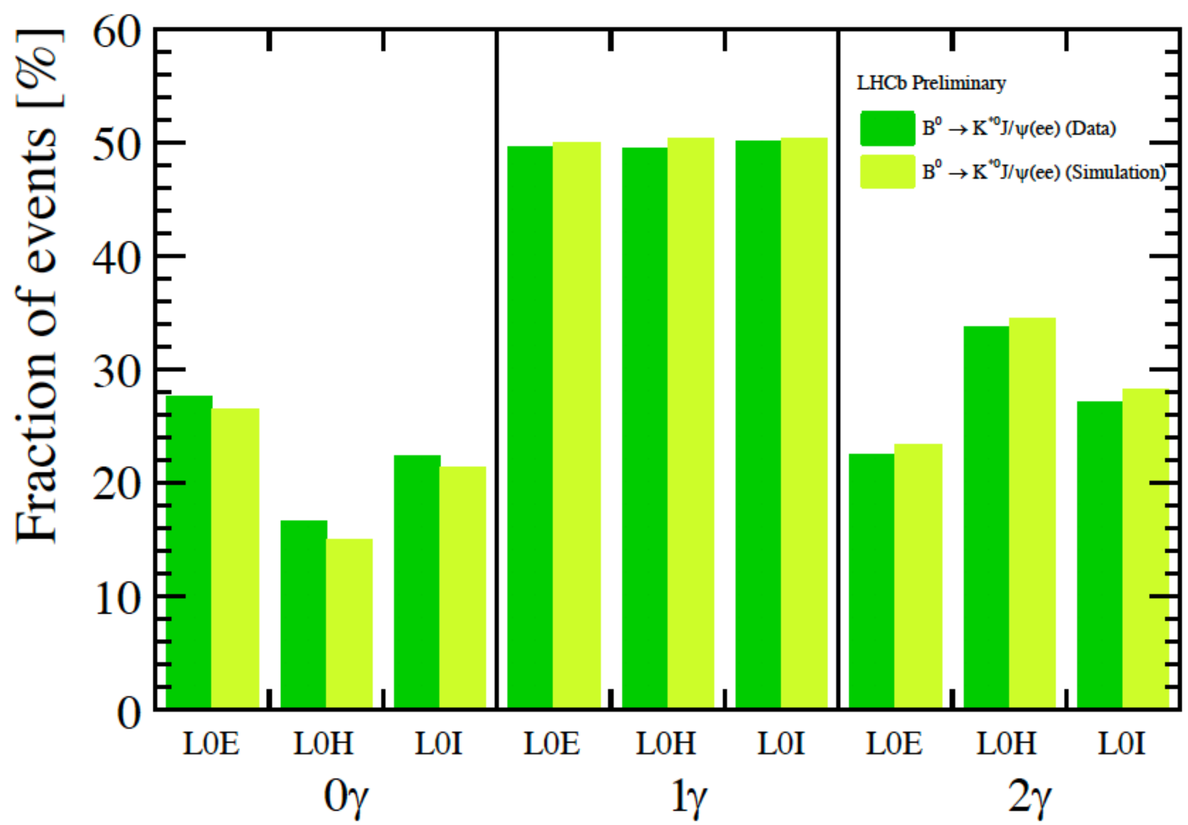
$r_{J/\psi}$

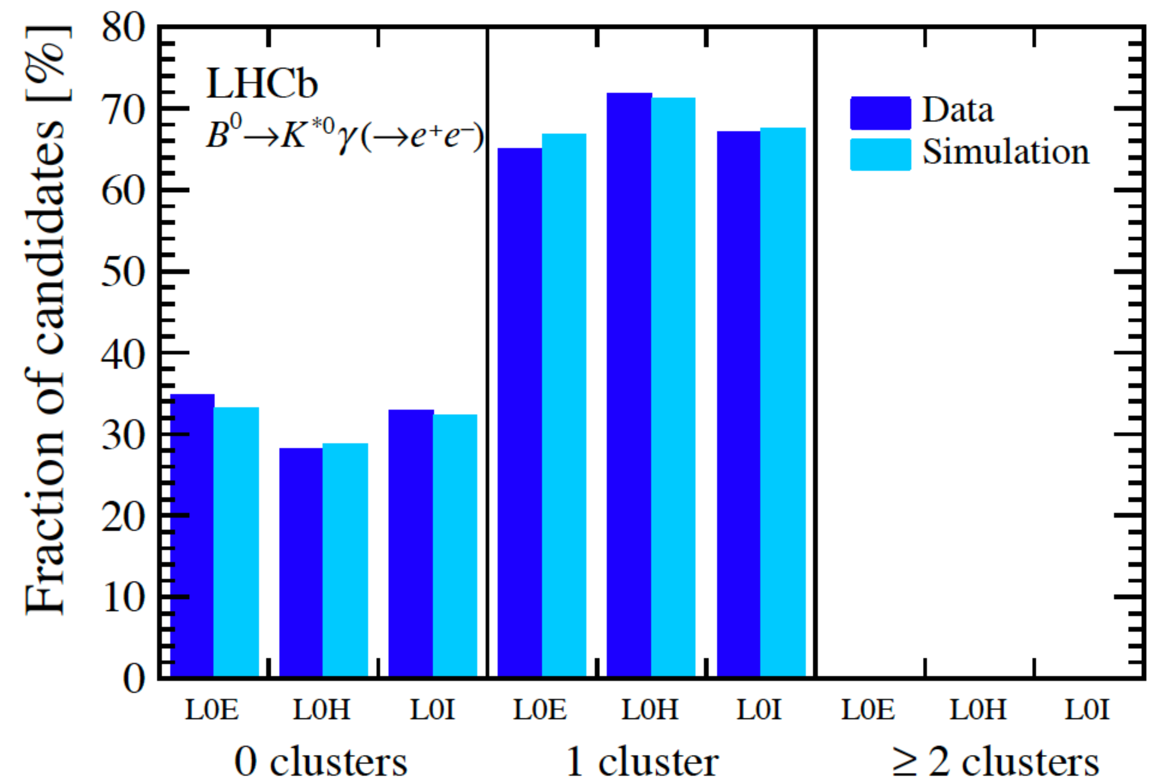


LHCb simulation
Candidates (arbitrary units)
$B^+ \to K^+ e^+ e^-$
$B^+ \to K^+ \mu^+ \mu^-$
$B^+ \to J/\psi(e^+e^-)K^+$
$B^+ \to J/\psi(\mu^+\mu^-)K^+$
$\alpha(l^+, l^-)$ [rad]
LHCb simulation
Candidates (arbitrary units)
$\min(p_T(l^+), p_T(l^-))$ [MeV/c]
LHCb
$r_{J/\psi} / \langle r_{J/\psi} \rangle$
$\alpha(l^+, l^-)$ [rad]
LHCb
$r_{J/\psi} / \langle r_{J/\psi} \rangle$
$\min(p_T(l^+), p_T(l^-))$ [MeV/c]

B^+

Cross-checks

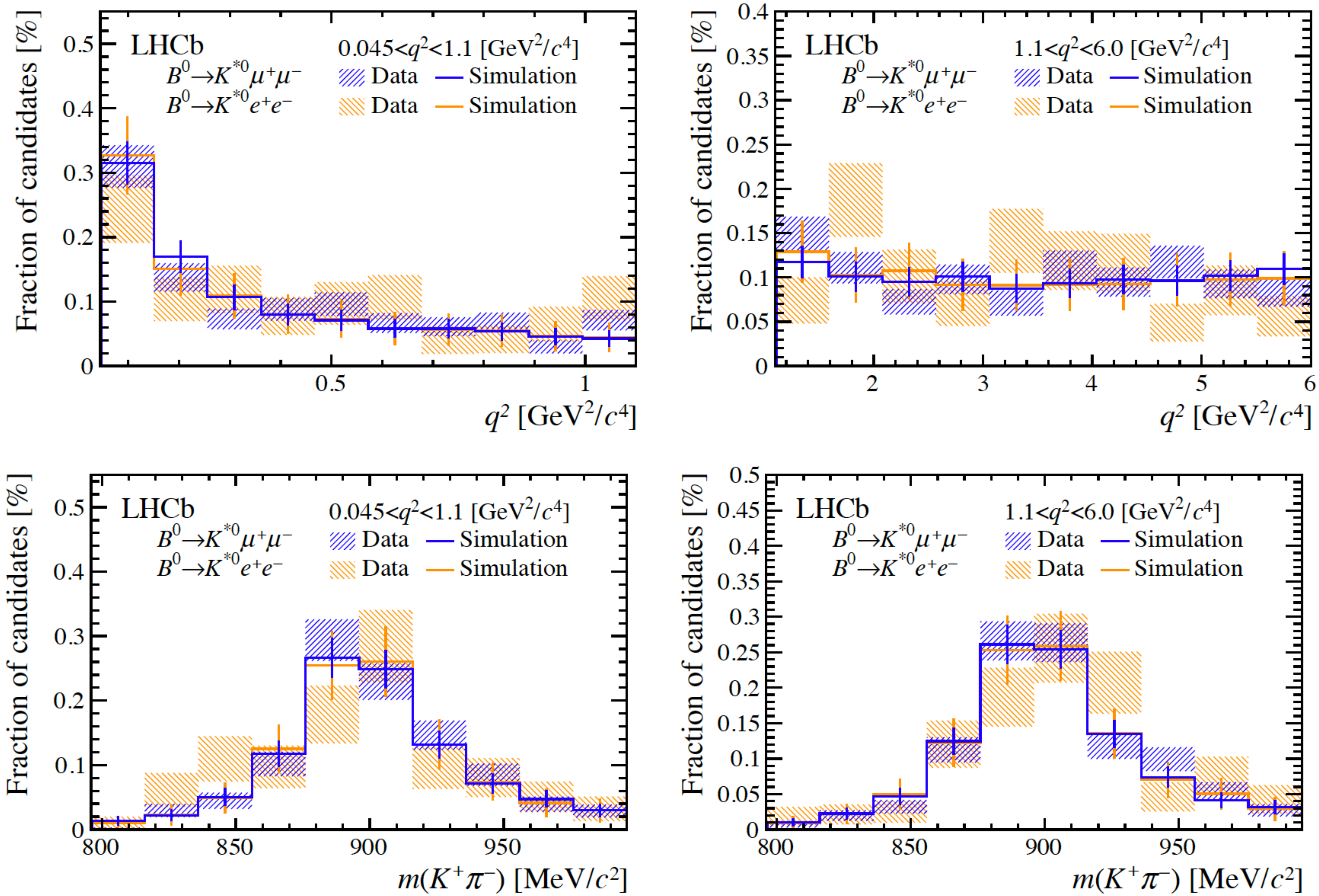




Relative population of bremsstrahlung categories compared between data and simulation.

B^0

Cross-checks



NIM A555, 356-369 (2005)

B^0

Fit construction

Fit construction

Simultaneous fit to electron and muon mode, in various data-taking and trigger categories.

$$N^i(\Lambda_b^0 \to pK^-\mu^+\mu^-) = r_{\mathcal{B}} \times \frac{N^i(\Lambda_b^0 \to pK^- J/\psi(\to \mu^+\mu^-))}{\mathcal{B}(J/\psi \to \ell^+\ell^-)} \times \frac{\epsilon^i(\Lambda_b^0 \to pK^-\mu^+\mu^-)}{\epsilon^i(\Lambda_b^0 \to pK^- J/\psi(\to \mu^+\mu^-))}$$

$$N^i(\Lambda_b^0 \to pK^-e^+e^-) = R_{pK}^{-1} \times r_{\mathcal{B}} \times \frac{N^i(\Lambda_b^0 \to pK^- J/\psi(\to e^+e^-))}{\mathcal{B}(J/\psi \to \ell^+\ell^-)} \times \frac{\epsilon^i(\Lambda_b^0 \to pK^-e^+e^-)}{\epsilon^i(\Lambda_b^0 \to pK^- J/\psi(\to e^+e^-))}$$

$$r_{\mathcal{B}} \equiv \mathcal{B}(\Lambda_b^0 \to pK^-\mu^+\mu^-)/\mathcal{B}(\Lambda_b^0 \to pK^- J/\psi)$$

Λ_b

Fit construction

$$N^i(\Lambda_b^0 \to pK^-\mu^+\mu^-) = r_{\mathcal{B}} \times \frac{N^i(\Lambda_b^0 \to pK^- J/\psi(\to \mu^+\mu^-))}{\mathcal{B}(J/\psi \to \ell^+\ell^-)} \times \frac{\epsilon^i(\Lambda_b^0 \to pK^-\mu^+\mu^-)}{\epsilon^i(\Lambda_b^0 \to pK^- J/\psi(\to \mu^+\mu^-))}$$

$$N^i(\Lambda_b^0 \to pK^-e^+e^-) = R_{pK}^{-1} \times r_{\mathcal{B}} \times \frac{N^i(\Lambda_b^0 \to pK^- J/\psi(\to e^+e^-))}{\mathcal{B}(J/\psi \to \ell^+\ell^-)} \times \frac{\epsilon^i(\Lambda_b^0 \to pK^-e^+e^-)}{\epsilon^i(\Lambda_b^0 \to pK^- J/\psi(\to e^+e^-))}$$

Observables

From resonant fit

From corrected simulation

From the PDG

Systematic treatment

Uncertainty treatment depending on whether there is correlation between data taking and trigger categories:

Uncorrelated:

Gaussian constraints included in the mass fit :
MC corrections, normalisation mode uncertainties.

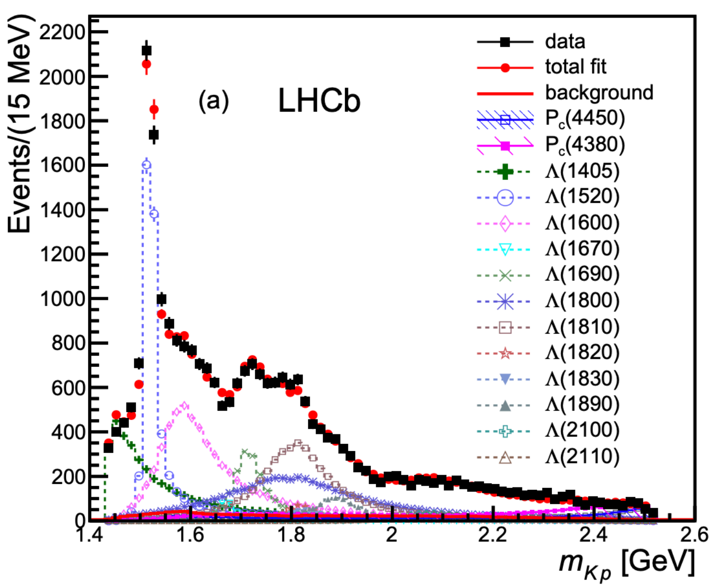
Correlated:

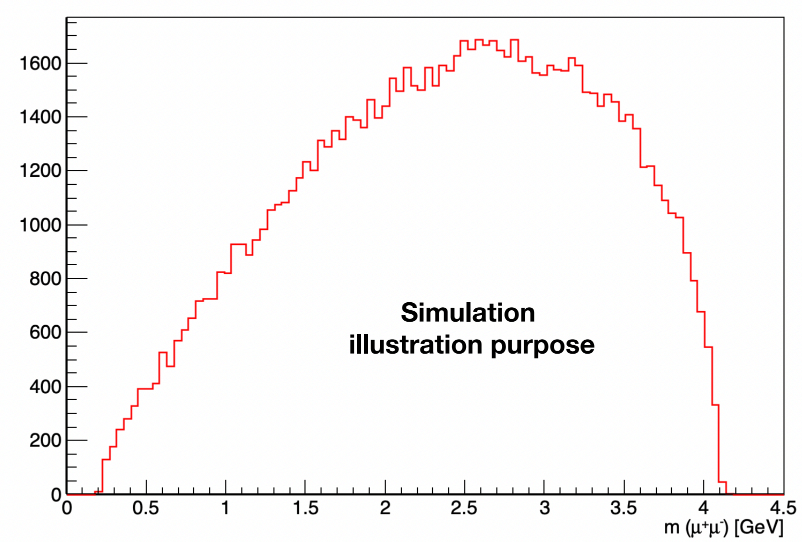
Gaussian smearing of likelihood profile :
Decay model corrections, fit model, m_{corr} cut efficiency, q^2 migration.

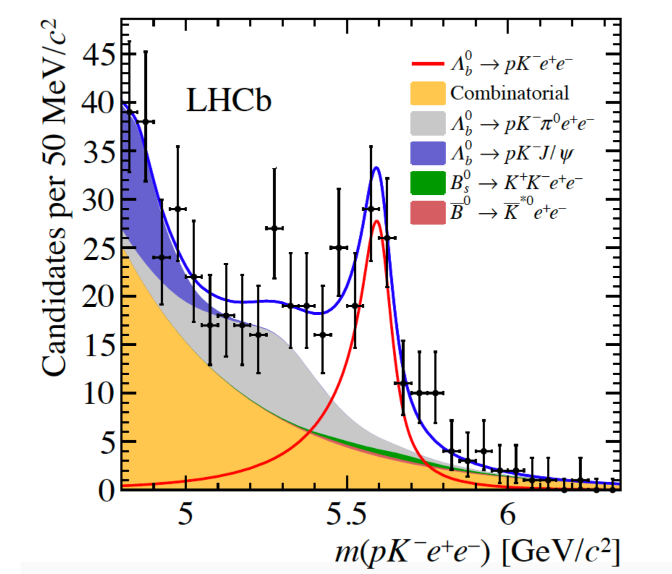
Systematic treatment

Decay model

Fit model
Variations of the signal & backgrounds.

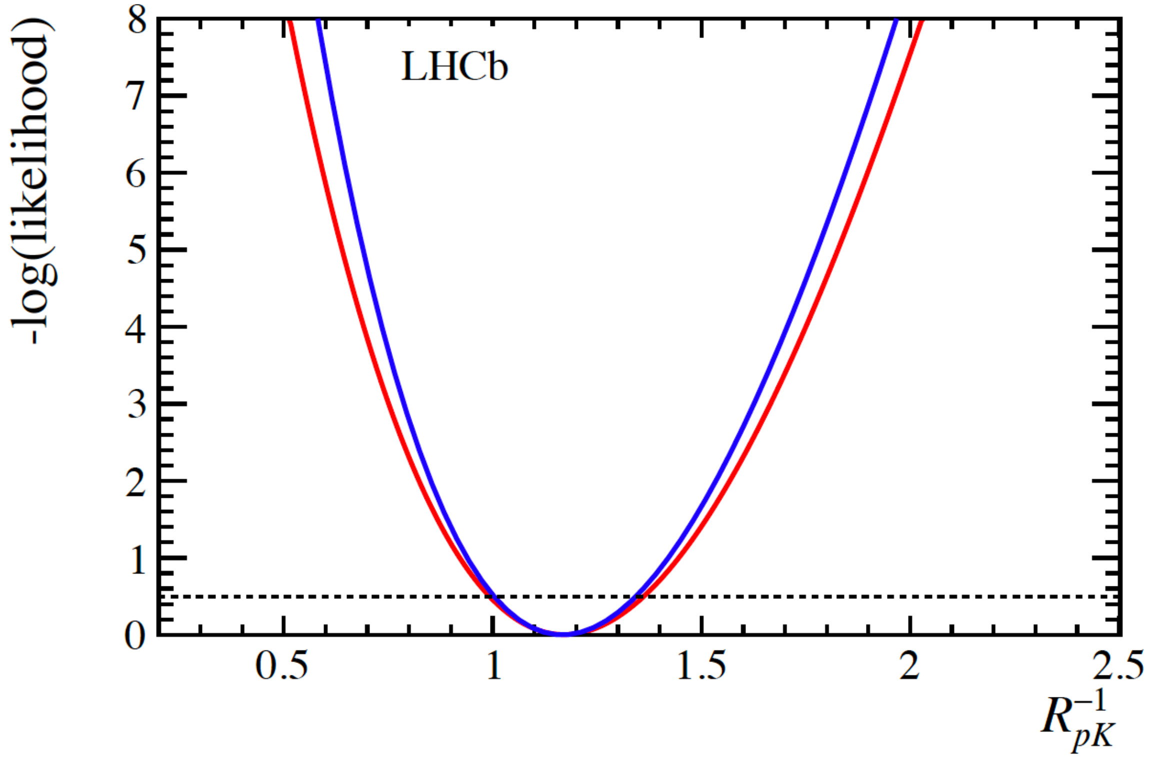






Source	Run 1 L0I	Run 1 L0E	Run 2 L0I	Run 2 L0E	Correlated
Decay model	–	–	–	–	1.9
Other corrections	3.4	3.6	3.6	3.2	–
m_{corr} cut efficiency	–	–	–	–	0.5
q^2 migration	–	–	–	–	2.0
Normalisation mode	3.7	3.7	3.5	2.7	–
Fit model	–	–	–	–	5.2
Total correlated	–	–	–	–	5.9
Total uncorrelated	5.0	5.2	5.0	4.2	–

Log likelihood profile



First test of LU in b-baryons

$$R_{pK}^{-1}\Big|_{0.1<q^2<6\,\mathrm{GeV}^2/c^4} = 1.17\,^{+\,0.18}_{-\,0.16} \pm 0.07$$

Inverting likelihood profile

$$R_{pK}\Big|_{0.1<q^2<6\,\mathrm{GeV}^2/c^4} = 0.86\,^{+\,0.14}_{-\,0.11} \pm 0.05$$

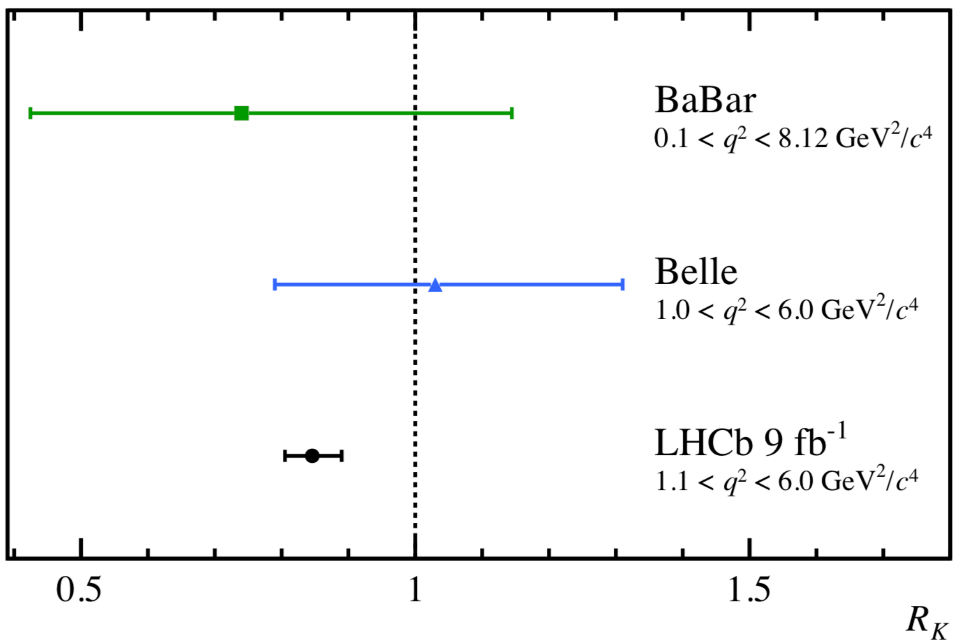
Statistical only

Statistical + systematics

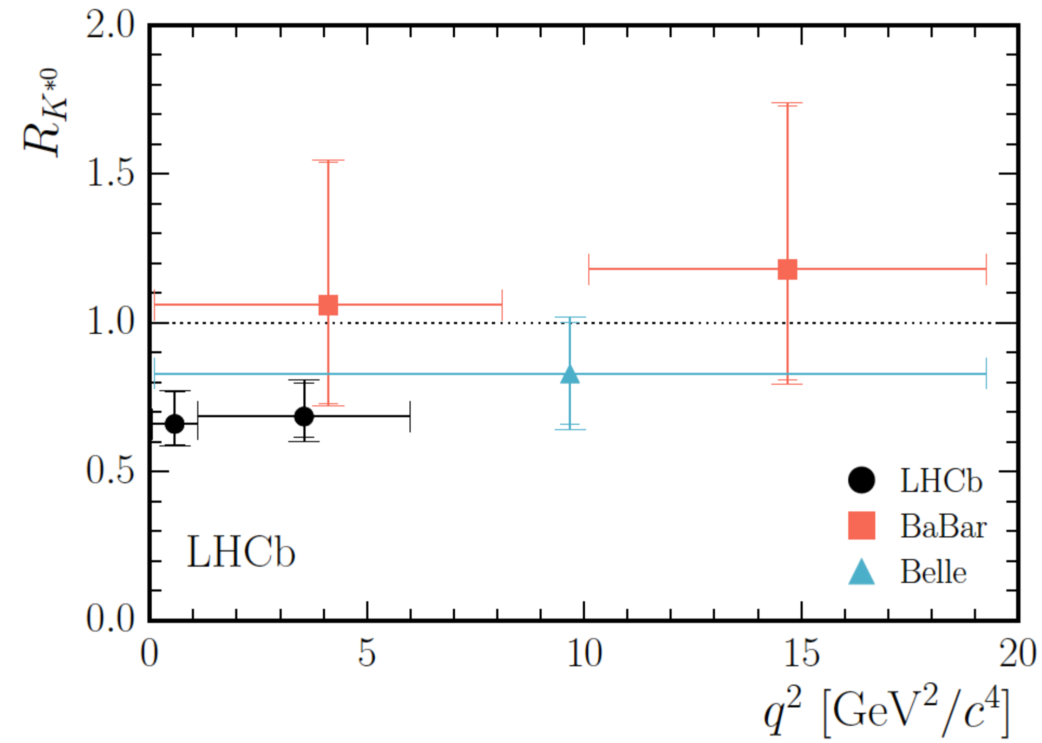
Λ_b

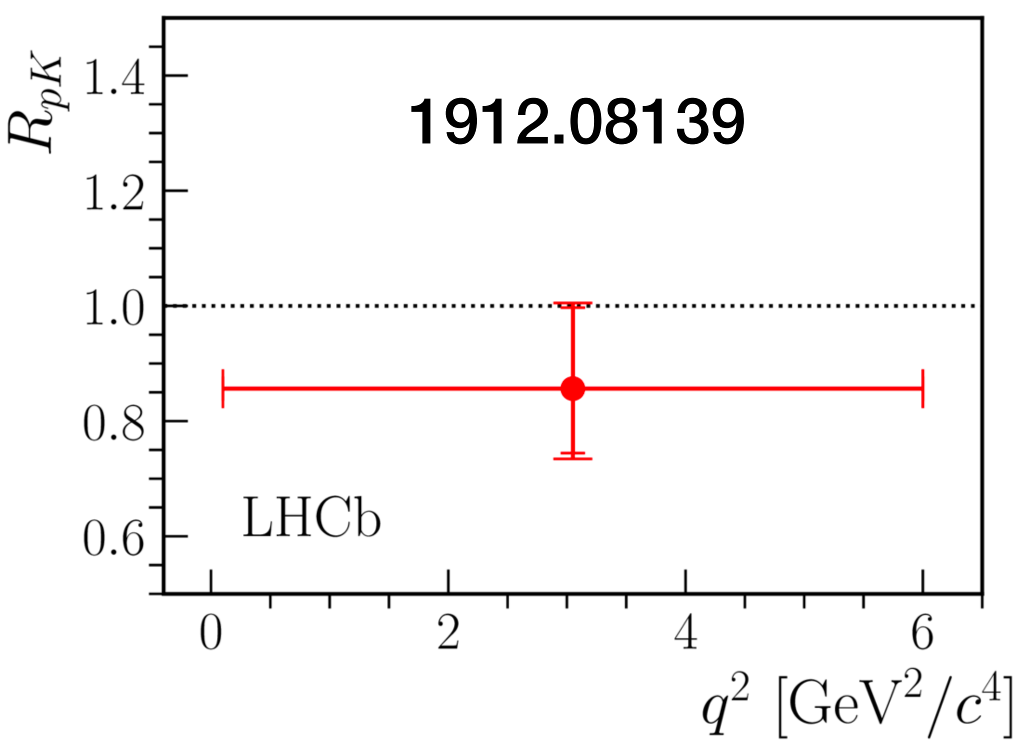
All the results

2103.11769



1705.05802



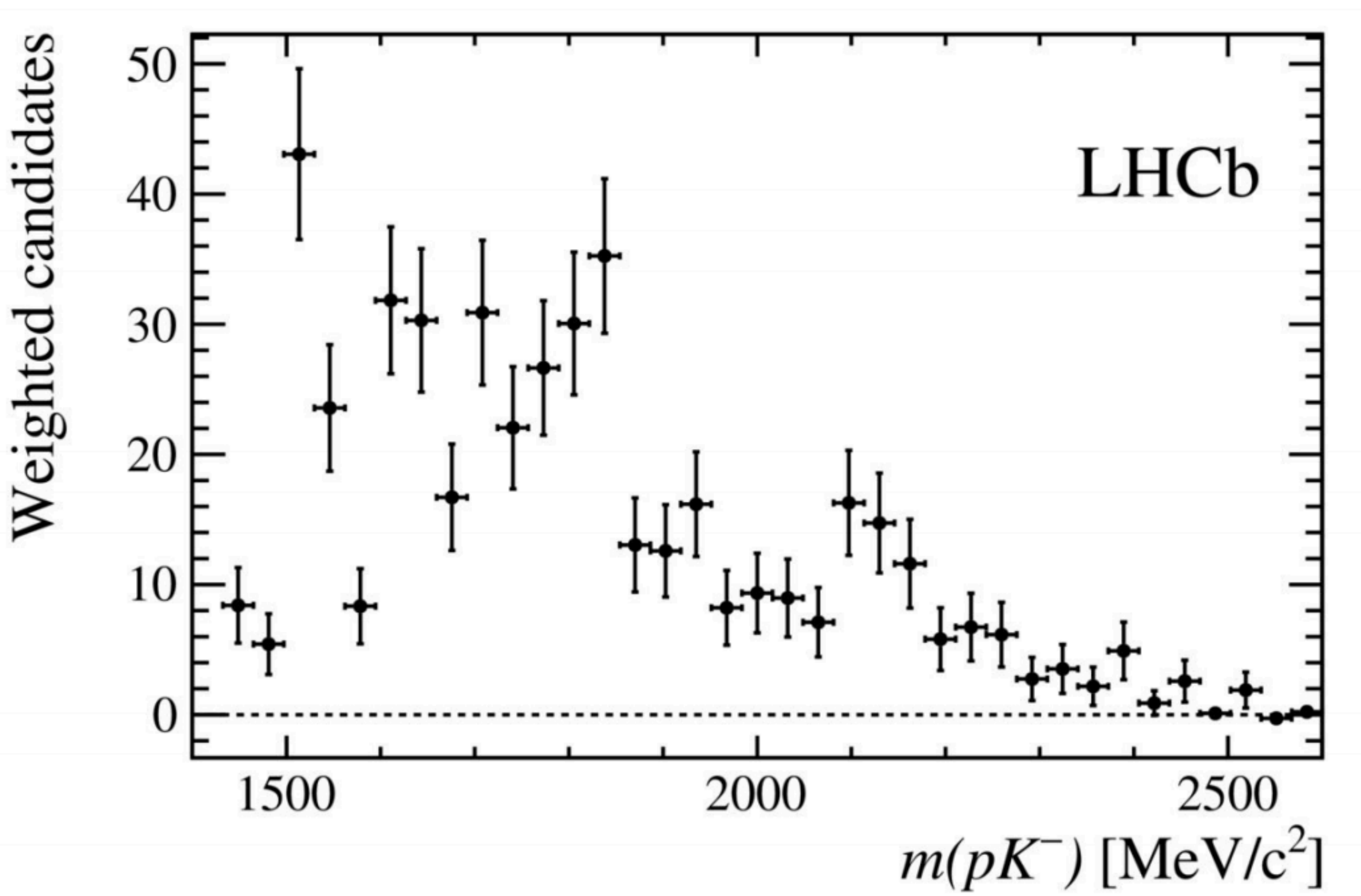


All results are statistically dominated.
Within these uncertainties,
the pattern is in the same direction ie :
a deficit of muons…

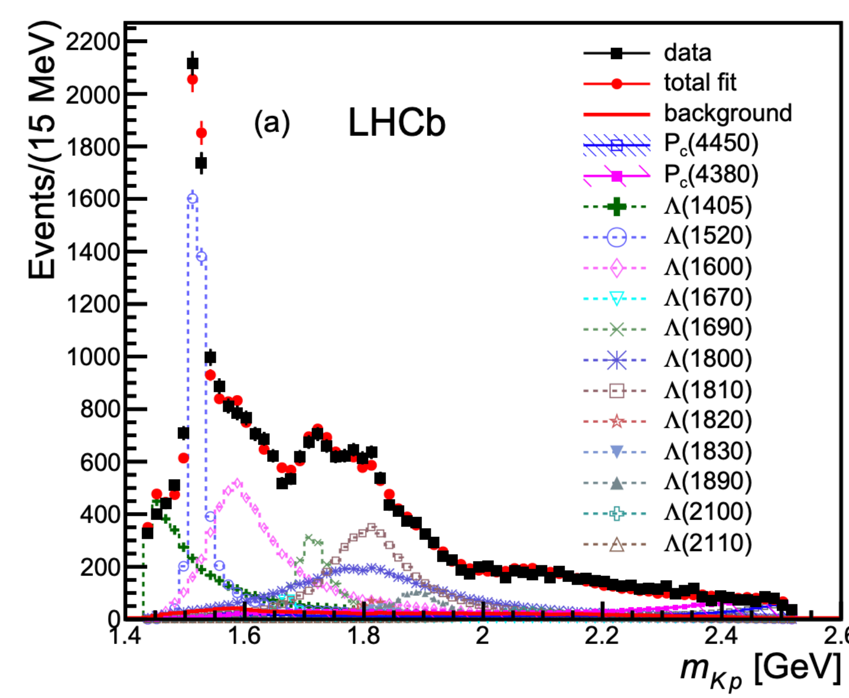
Interpretation

Interpretation of the result in terms of NP is tricky with current setup, with more data :

- Study rich structure in m(pK) spectrum.
- Split low and middle q^2 bins: [0.1, 1] and [1, 6] GeV/c^4 .



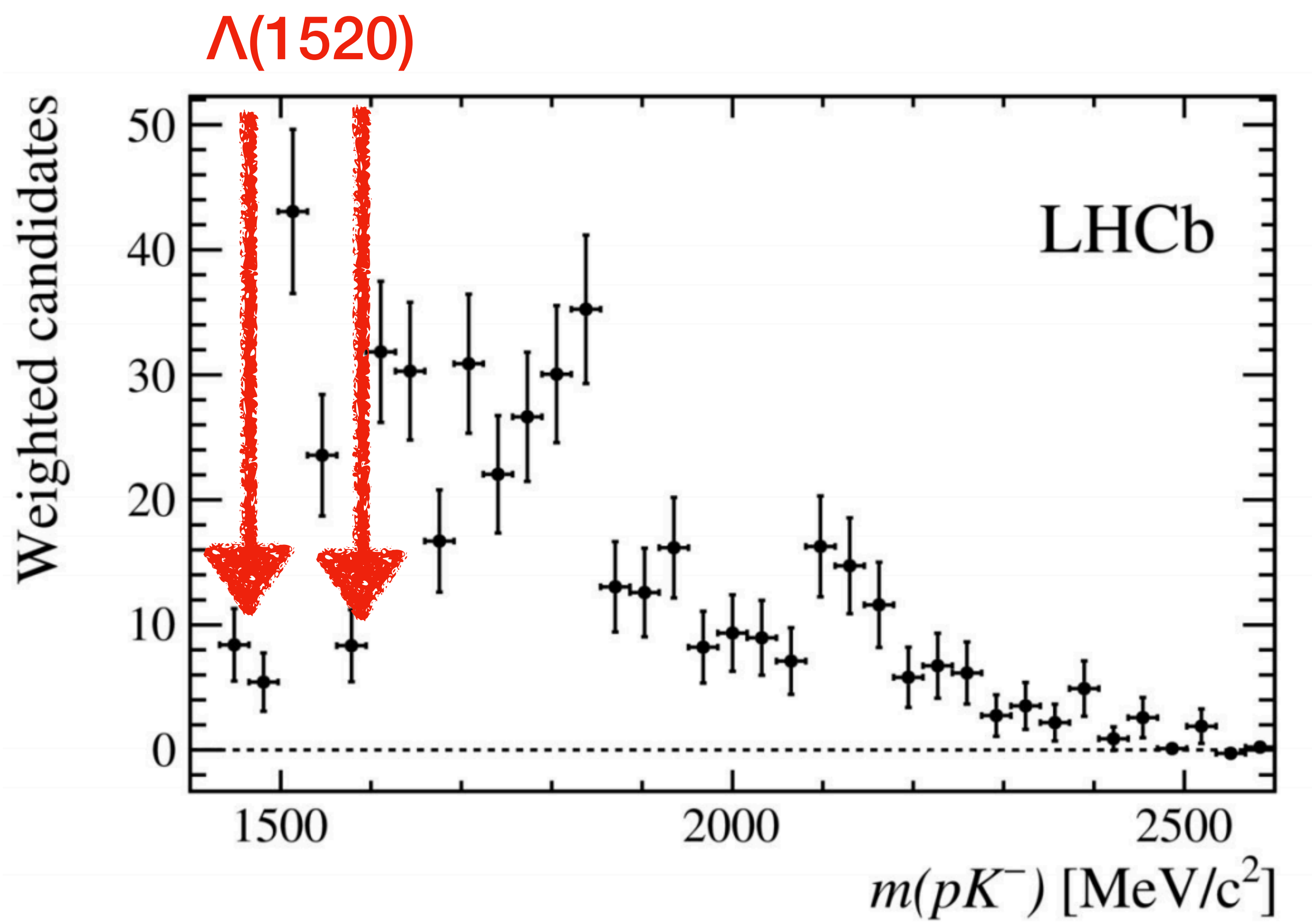
Remember we had:



A prospect

Interpretation of the result in terms of NP is tricky with current setup, with more data :

- Study rich structure in m(pK) spectrum.
- Split low and middle q^2 bins: [0.1, 1] and [1, 6] GeV/c^4 .



arXiv:2005.09602v1 [hep-ph] 19 May 2020

Prospects for New Physics searches with $\Lambda_b^0 \to \Lambda(1520)\ell^+\ell^-$ decays

Yasmine Amhis[1], Sébastien Descotes-Genon[1], Carla Marin Benito[1], Martín Novoa-Brunet[1], Marie-Hélène Schune[1]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France*

Email: yasmine.amhis@ijclab.in2p3.fr, sebastien.descotes-genon@ijclab.in2p3.fr, carla.marin@ijclab.in2p3.fr, martin.novoa@ijclab.in2p3.fr, marie-helene.schune@ijclab.in2p3.fr

Abstract

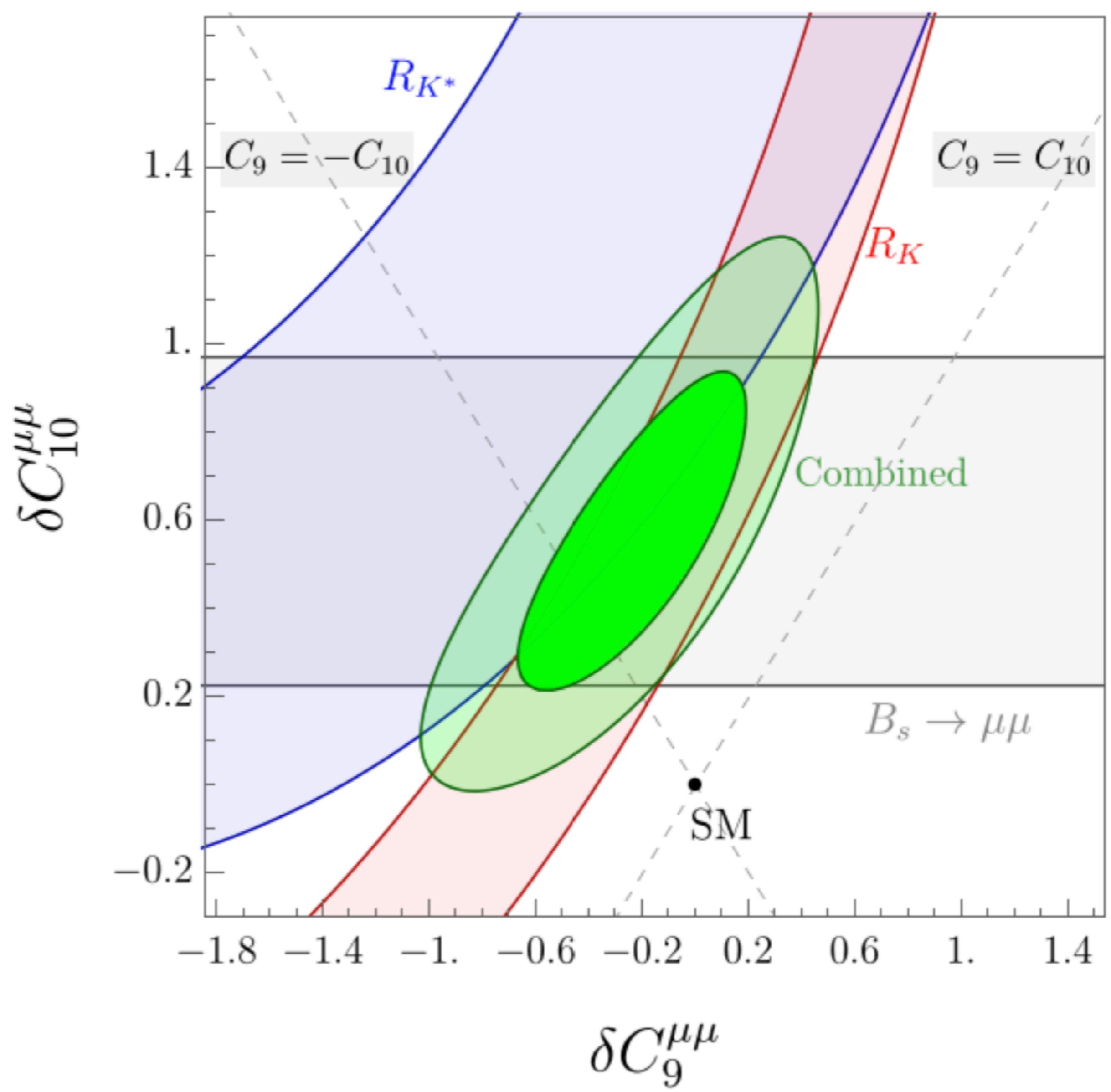
We present the prospects of an angular analysis of the $\Lambda_b^0 \to \Lambda(1520)\ell^+\ell^-$ decay. Using the expected yield in the current dataset collected at the LHCb experiment, as well as the foreseen ones after the LHCb upgrades, sensitivity studies are presented to determine the experimental precision on angular observables related to the lepton distribution and their potential to identify New Physics. The forward-backward lepton asymmetry at low dilepton invariant mass is particularly promising. NP scenarios favoured by the current anomalies in $b \to s\ell^+\ell^-$ decays can be distinguished from the SM case with the data collected between the Run 3 and the Upgrade 2 of the LHCb experiment.

1 Introduction

Over the last few years, the rare $b \to s\ell^+\ell^-$ decays have shown a growing set of deviations with respect to Standard Model (SM) expectations. On one hand, there have been deviations observed in the branching ratios for $B \to K\mu^+\mu^-$ [1], $B \to K^*\mu^+\mu^-$ [1–3], $B_s \to \phi\mu^+\mu^-$ [4] as well as for the optimised angular observables [5,6] in $B \to K^*\mu^+\mu^-$ [7–11], with deviations up to 2.6 σ. These deviations have been recently confirmed by the analysis of part of the Run 2 data set by the LHCb collaboration [12]. On the other hand, no such deviations have been observed in $b \to se^+e^-$ branching ratios and angular observables, as was summarised in measurements of the R_K [13] and R_{K^*} [14] ratios of branching ratios and $B \to K^*\ell^+\ell^-$ angular

1

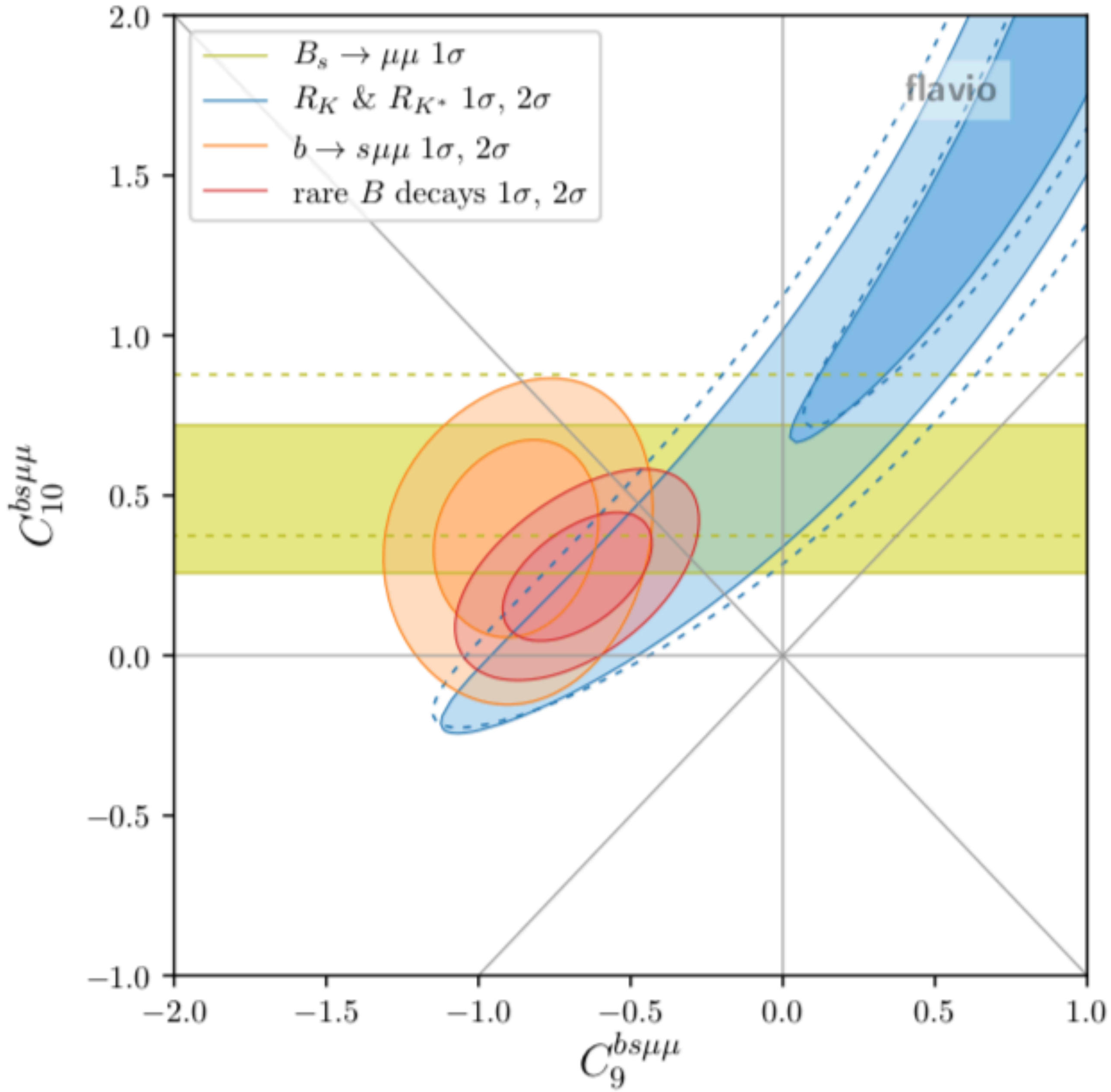
Example of global fits



Best fits using “clean” point to tensions with the SM.

2103.12504

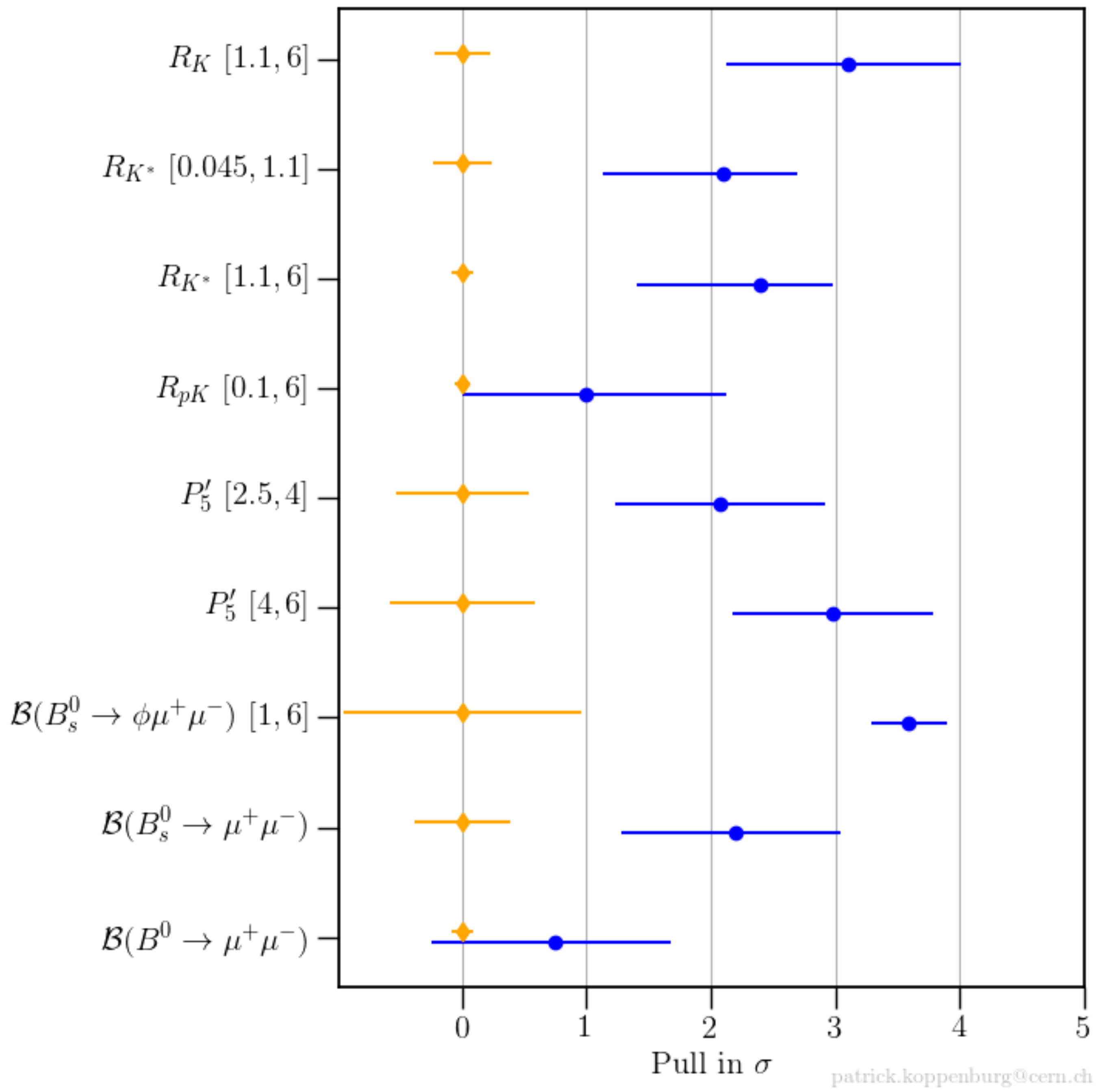
Another example



Similar picture including more observables.

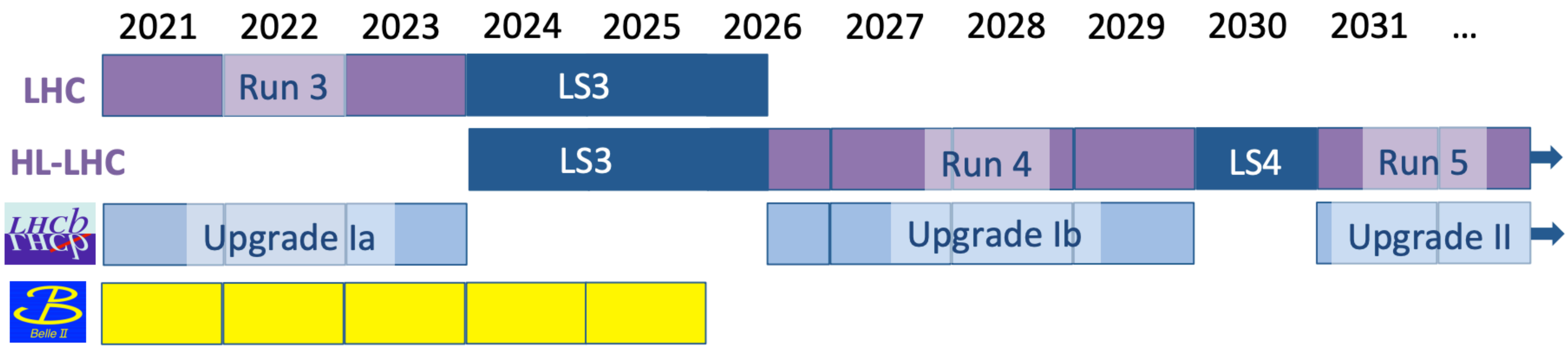
EFT WG @CERN

Is there something “funny” happening with the muons ?



Only more data analysed and improvements in the theory will tell us.

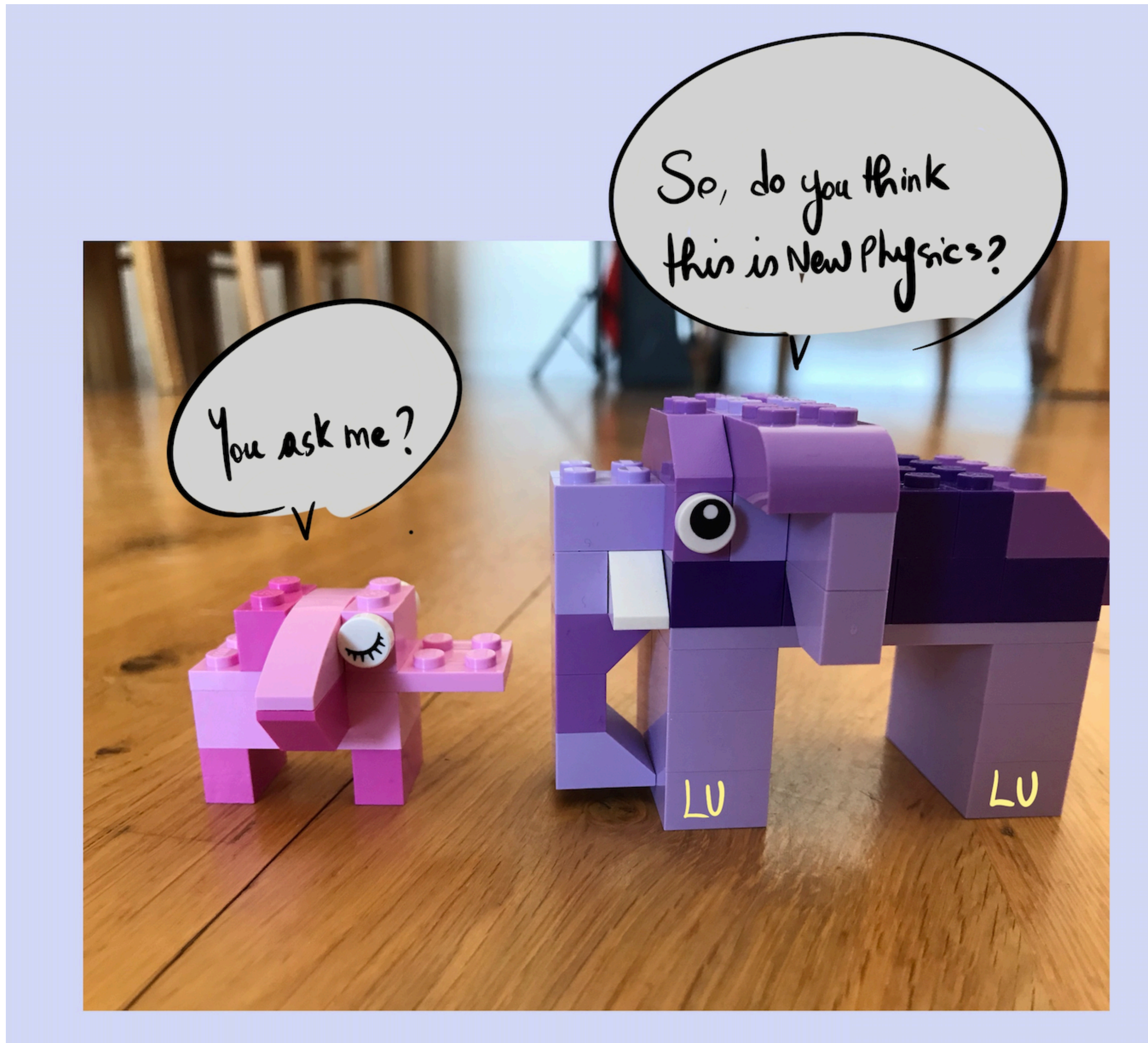
What to expect for LHCb?



Yield	Run 1 result	9 fb^{-1}	23 fb^{-1}	50 fb^{-1}	300 fb^{-1}
$B^+ \to K^+e^+e^-$	254 ± 29 [274]	1 120	3 300	7 500	46 000
$B^0 \to K^{*0}e^+e^-$	111 ± 14 [275]	490	1 400	3 300	20 000
$B^0_s \to \phi e^+e^-$	–	80	230	530	3 300
$\Lambda^0_b \to pKe^+e^-$	–	120	360	820	5 000
$B^+ \to \pi^+e^+e^-$	–	20	70	150	900
R_X precision	**Run 1 result**	**9 fb^{-1}**	**23 fb^{-1}**	**50 fb^{-1}**	**300 fb^{-1}**
R_K	$0.745 \pm 0.090 \pm 0.036$ [274]	0.043	0.025	0.017	0.007
$R_{K^{*0}}$	$0.69 \pm 0.11 \pm 0.05$ [275]	0.052	0.031	0.020	0.008
R_ϕ	–	0.130	0.076	0.050	0.020
R_{pK}	–	0.105	0.061	0.041	0.016
R_π	–	0.302	0.176	0.117	0.047

1812.07638
1808.08865

Conclusion



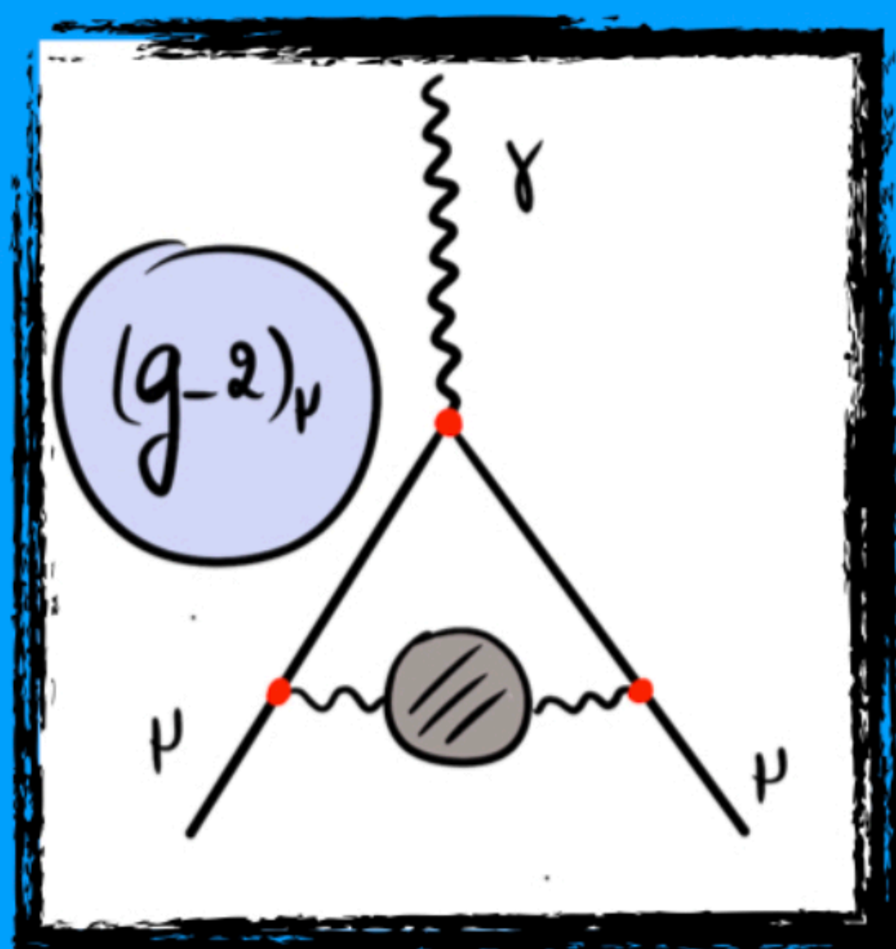
We are looking forward to new results and theory work
see what happens to these flavour anomalies.

GDR-Intensity Frontier & IJCLab Flavour GT :

"Virtual Breakfast with g-2"

Tackling $(g\text{-}2)_\mu$: theoretical efforts and latest results

May 19, 2021



Speakers :

Michel Davier (IJCLab, Orsay)
Laurent Lellouch (CPT, Marseille)
Harvey B. Meyer (Mainz)
Dominik Stöckinger (Dresden)

Organising committee :
Yasmine Amhis
Thibaut Louis
Olcyr Sumensari
Ana M. Teixeira

https://indico.ijclab.in2p3.fr/e/g-2

INTENSITY frontier

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

université PARIS-SACLAY

INTENSITY frontier GDR-InF

b-baryon Fest

14-15 mai 2020
Fuseau horaire Europe/Paris

- Accueil
- Programme scientifique
- Ordre du jour
- Inscription
- Liste des participants

In this workshop we will gather together experimentalists and theorists to discuss current research activities around rare decays of b-baryons.

Topics will be:

1) highlights of the most recent results

2) state of the art of theory and perspectives

Organising committee:

Yasmine Amhis

Carla Marin Benito

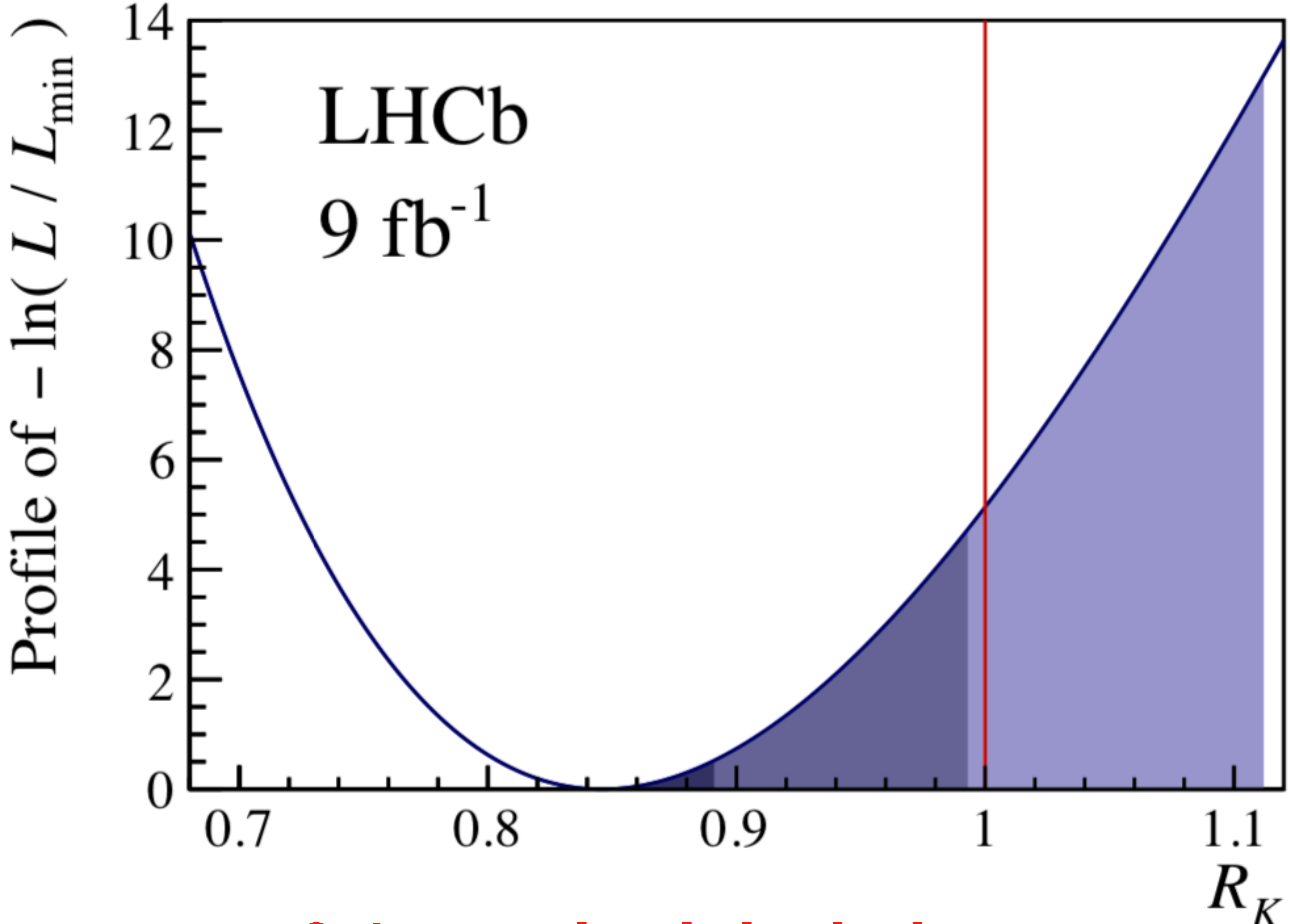
Sébastien Descotes-Genon

Danny van Dyk

- Lepton flavour universality (LU) violation
- QED effects in LU tests and predictions
- Form factors from Ligh-Cone Sum rules and Lattice QCD for Lambda(1520)
- Angular analyses
- Lambda decay asymmetry from BES III
- Radiative NLO computation of photon polarisation and measurement prospects
- Production fraction and lifetime
- Estimation of charm-loop contributions
- Prospects for the various modes at LHCb

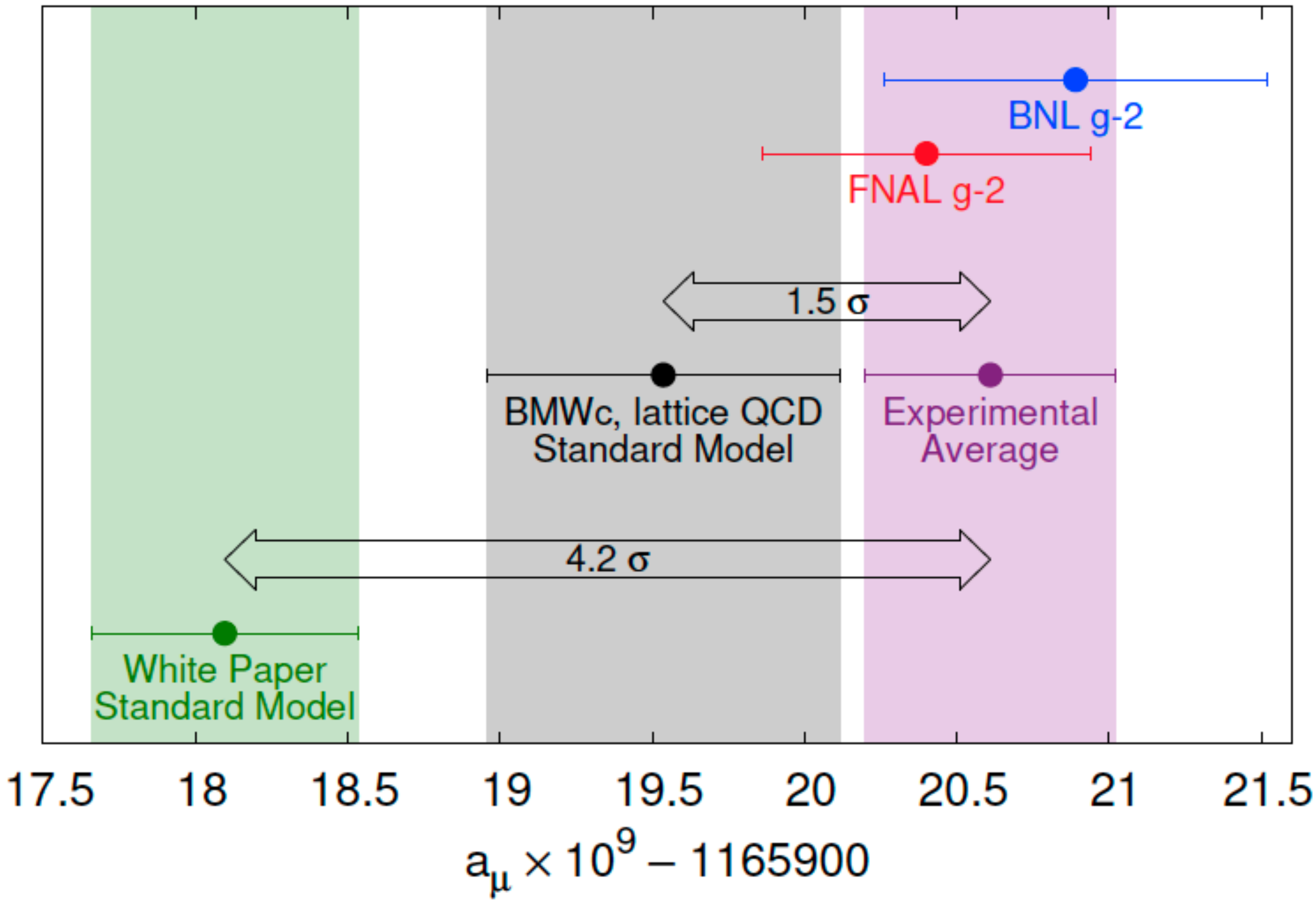
https://indico.in2p3.fr/event/20198/

About the significance



3.1 standard deviations

What about the muon g-2?



The effective Lagrangian for a generic exclusive decay based on $b \to s\ell_1^-\ell_2^+$, with $\ell_{1,2} \in \{e, \mu, \tau\}$ can be written as

$$\mathcal{L}_{\rm nc} \supset \frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_i C_i \, \mathcal{O}_i + \text{h.c.}\,, \tag{9}$$

where the effective couplings (Wilson coefficients) $C_i \equiv C_i(\mu)$ and the operators $\mathcal{O}_i \equiv \mathcal{O}_i(\mu)$ are defined at the scale μ. The operators relevant to this study are

$$\begin{aligned}
\mathcal{O}_9^{\ell_1\ell_2} &= \frac{e^2}{(4\pi)^2}(\bar{s}\gamma_\mu P_L b)(\bar{\ell}_1\gamma^\mu \ell_2)\,, \\
\mathcal{O}_{10}^{\ell_1\ell_2} &= \frac{e^2}{(4\pi)^2}(\bar{s}\gamma_\mu P_L b)(\bar{\ell}_1\gamma^\mu\gamma^5 \ell_2)\,, \\
\mathcal{O}_S^{\ell_1\ell_2} &= \frac{e^2}{(4\pi)^2}(\bar{s} P_R b)(\bar{\ell}_1 \ell_2)\,, \\
\mathcal{O}_P^{\ell_1\ell_2} &= \frac{e^2}{(4\pi)^2}(\bar{s} P_R b)(\bar{\ell}_1\gamma^5 \ell_2)\,,
\end{aligned} \tag{10}$$

in addition to the chirality flipped ones, $\mathcal{O}_i'$, obtained from $\mathcal{O}_i$ by replacing $P_L \leftrightarrow P_R$. The effect of opera-

2103.12504

Who's your favorite LQ?

Model	$R_{K^{(*)}}$	$R_{D^{(*)}}$	$R_{K^{(*)}}$ & $R_{D^{(*)}}$
$S_1 = (3,1)_{-1/3}$	✖	✔	✖
$R_2 = (3,2)_{\ 7/6}$	✖	✔	✖
$\widetilde{R}_2 = (3,2)_{\ 1/6}$	✖	✖	✖
$S_3 = (3,3)_{-1/3}$	✔	✖	✖
$U_1 = (3,1)_{\ 2/3}$	✔	✔	✔
$U_3 = (3,3)_{\ 2/3}$	✔	✖	✖

Requires UV completion

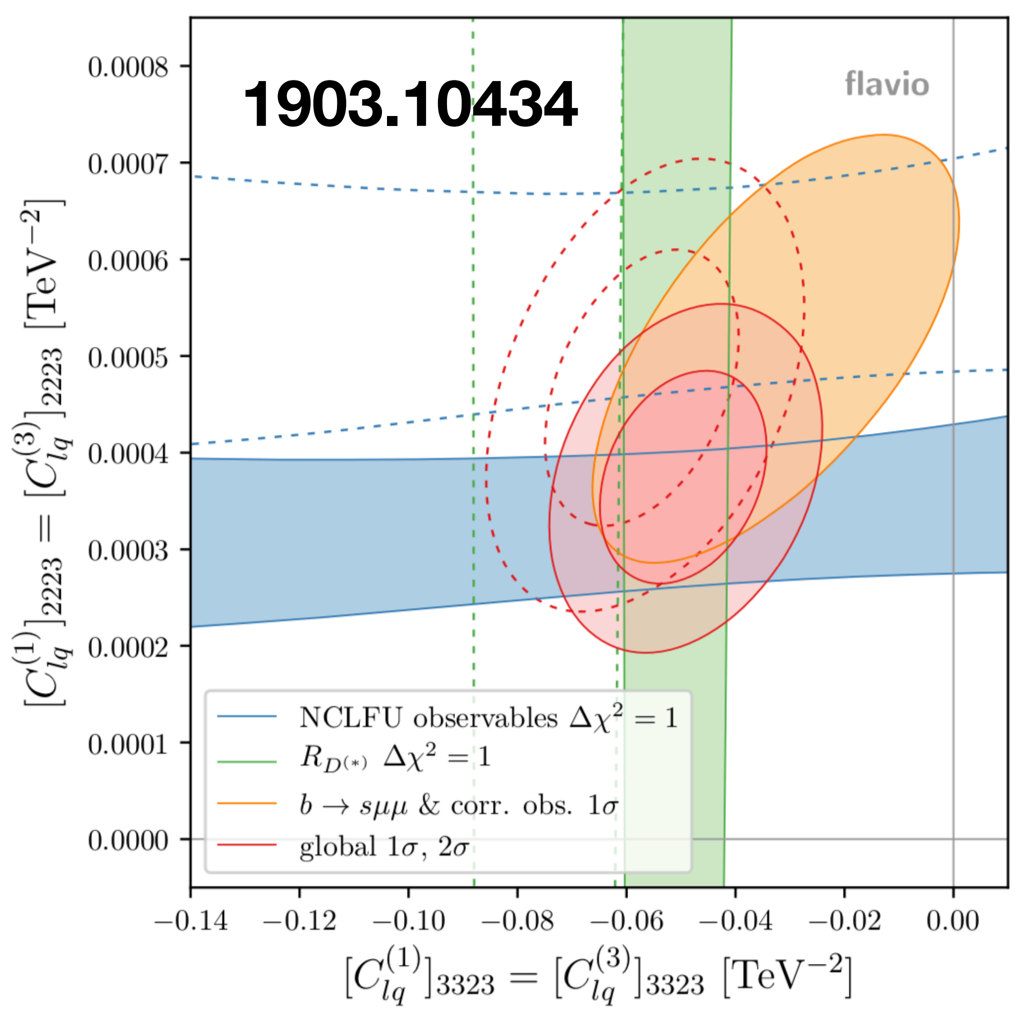
There appears to be a few scenarios which can accommodate the anomalies including those seen in semi-leptonic tree level decays.

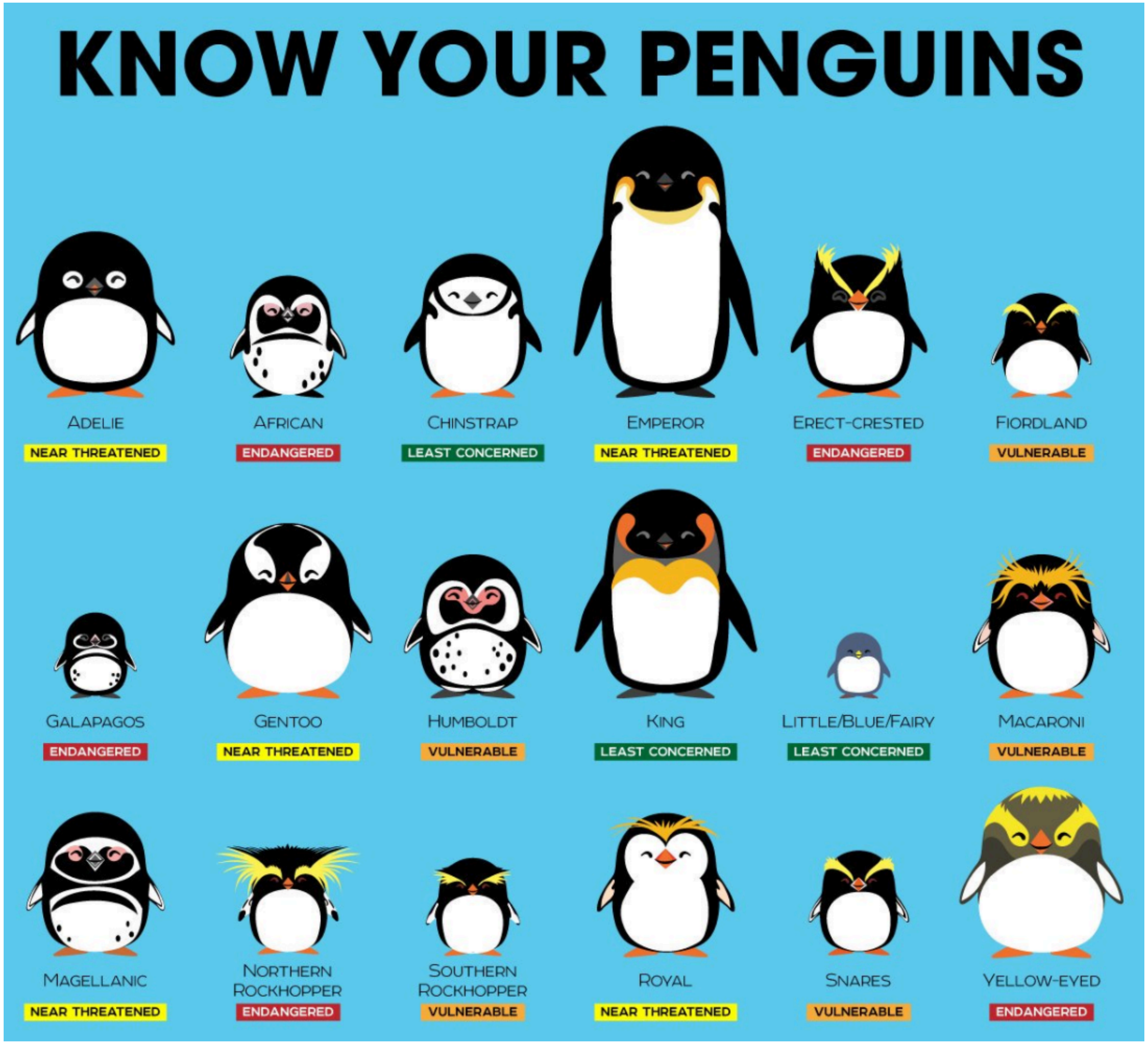
WET

$$\mathcal{H}_{\text{WET}}^{b\to s} \supset -\frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10,S,P} \mathcal{C}_i^\ell \mathcal{O}_i^\ell$$

SMEFT

$$O_{2223}^{LQ^{(1)}} = (\bar{L}_2\gamma_\mu L_2)(\bar{Q}_2\gamma^\mu Q_3)\,,$$
$$O_{2223}^{LQ^{(3)}} = (\bar{L}_2\gamma_\mu \tau^A L_2)(\bar{Q}_2\gamma^\mu \tau^A Q_3)\,,$$
$$O_{2322}^{Qe} = (\bar{Q}_2\gamma_\mu Q_3)(\bar{e}_2\gamma^\mu e_2)\,,$$
$$O_{2223}^{Ld} = (\bar{L}_2\gamma_\mu L_2)(\bar{d}_2\gamma^\mu d_3)\,,$$
$$O_{2223}^{ed} = (\bar{e}_2\gamma_\mu e_2)(\bar{d}_2\gamma^\mu d_3)\,,$$



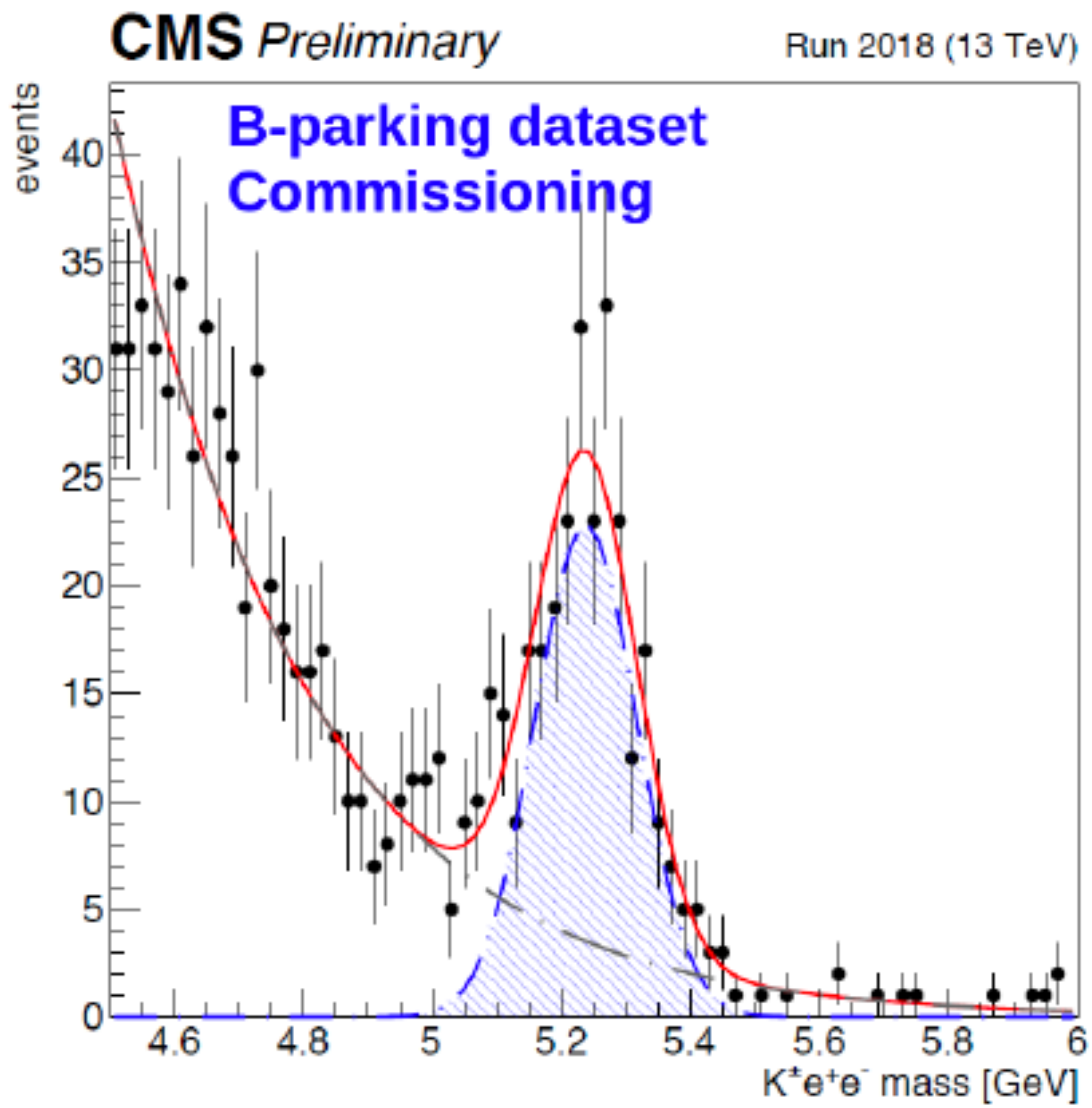

KNOW YOUR PENGUINS
ADELIE
NEAR THREATENED
AFRICAN
ENDANGERED
CHINSTRAP
LEAST CONCERNED
EMPEROR
NEAR THREATENED
ERECT-CRESTED
ENDANGERED
FIORDLAND
VULNERABLE
GALAPAGOS
ENDANGERED
GENTOO
NEAR THREATENED
HUMBOLDT
VULNERABLE
KING
LEAST CONCERNED
LITTLE/BLUE/FAIRY
LEAST CONCERNED
MACARONI
VULNERABLE
MAGELLANIC
NEAR THREATENED
NORTHERN ROCKHOPPER
ENDANGERED
SOUTHERN ROCKHOPPER
VULNERABLE
ROYAL
NEAR THREATENED
SNARES
VULNERABLE
YELLOW-EYED
ENDANGERED

CMS status report

Laurent Thomas,
on behalf of the CMS collaboraton

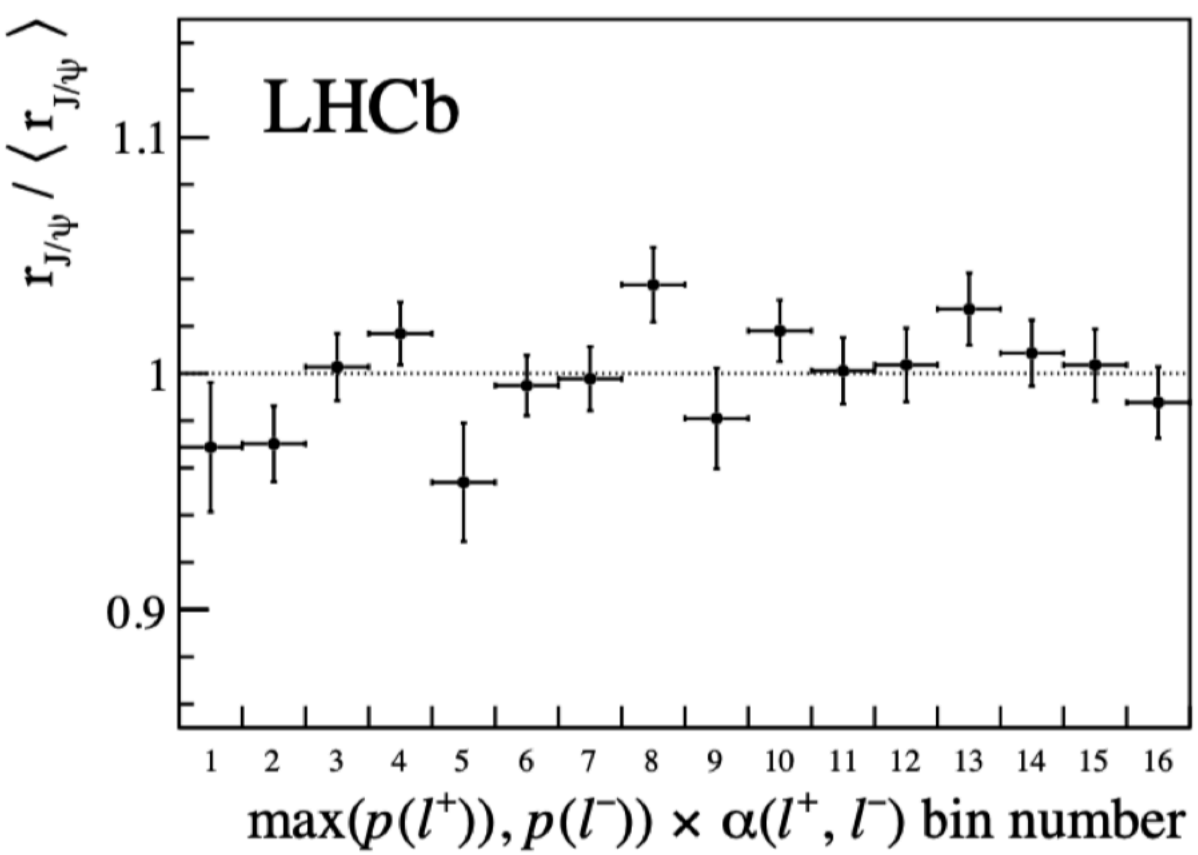
LHCC Open Session,
November 20th, 2019

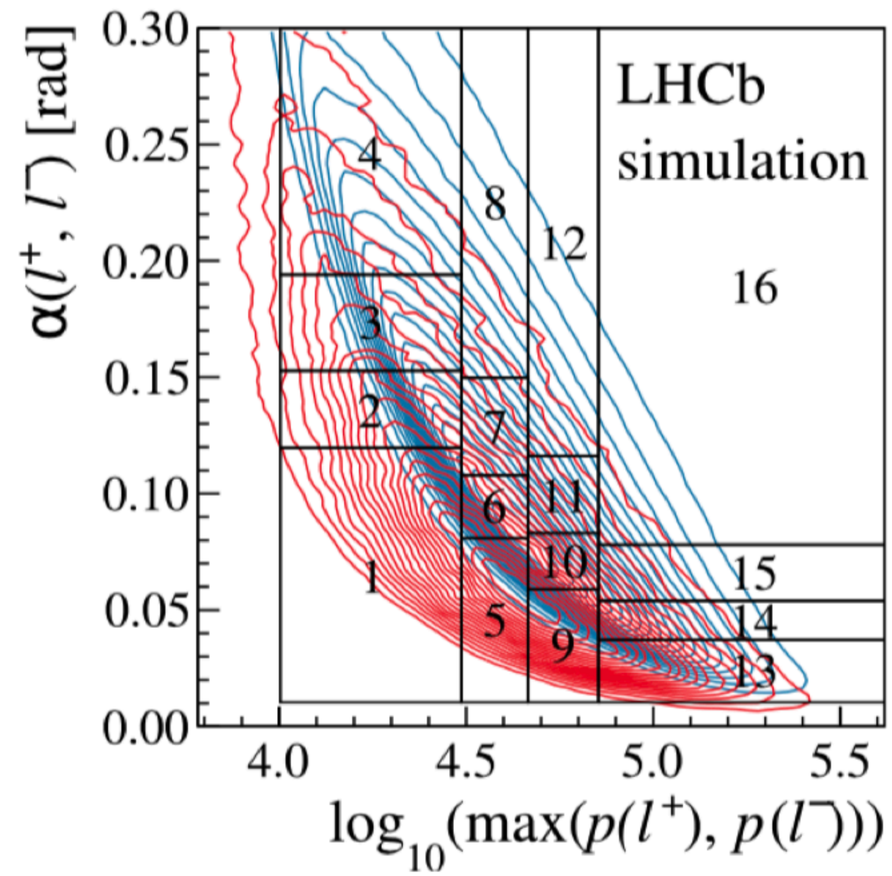
CMS



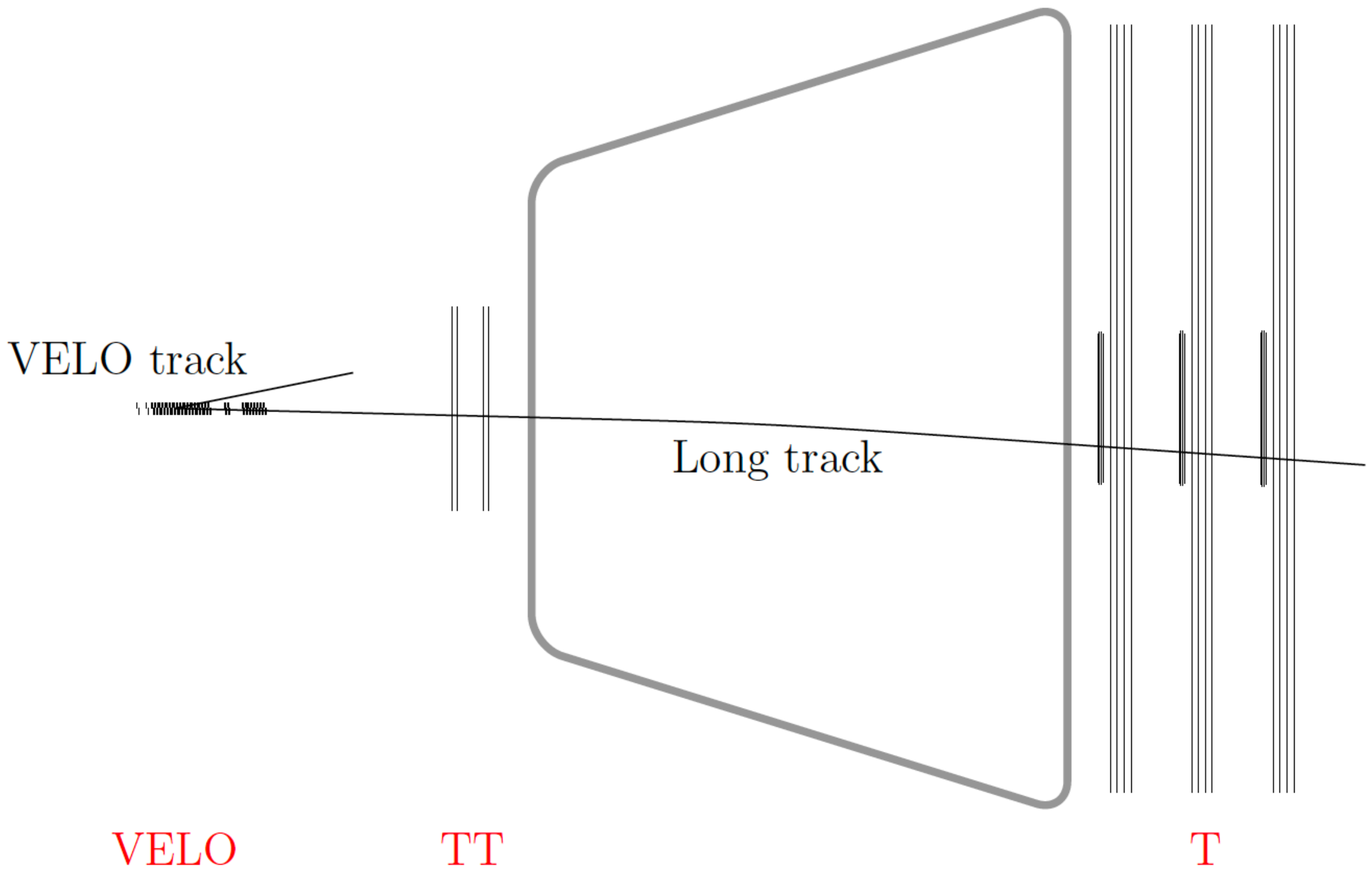
Efficiency

RK- cross-checks





Electron tracking



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Electron tracking

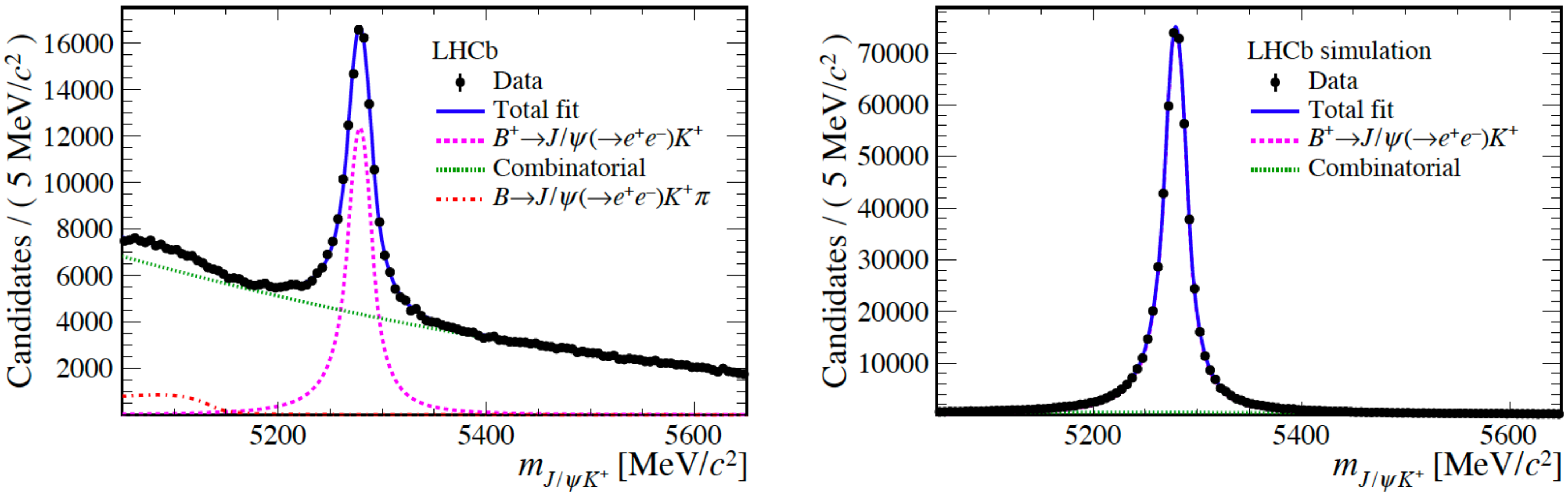

Figure 3: Distribution of the constrained invariant mass for (left) data and (right) simulated events, together with an example of a fit to this distribution. The simulated events contain at least one signal decay, resulting in a higher signal purity than is observed in data.

$$p_{\text{probe}} = \frac{1}{2}\frac{m_{J/\psi}^2 - 2m_{\text{e}}^2}{E_{\text{e,tag}} - p_{\text{e,tag}}\cos\theta},$$

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Electron tracking

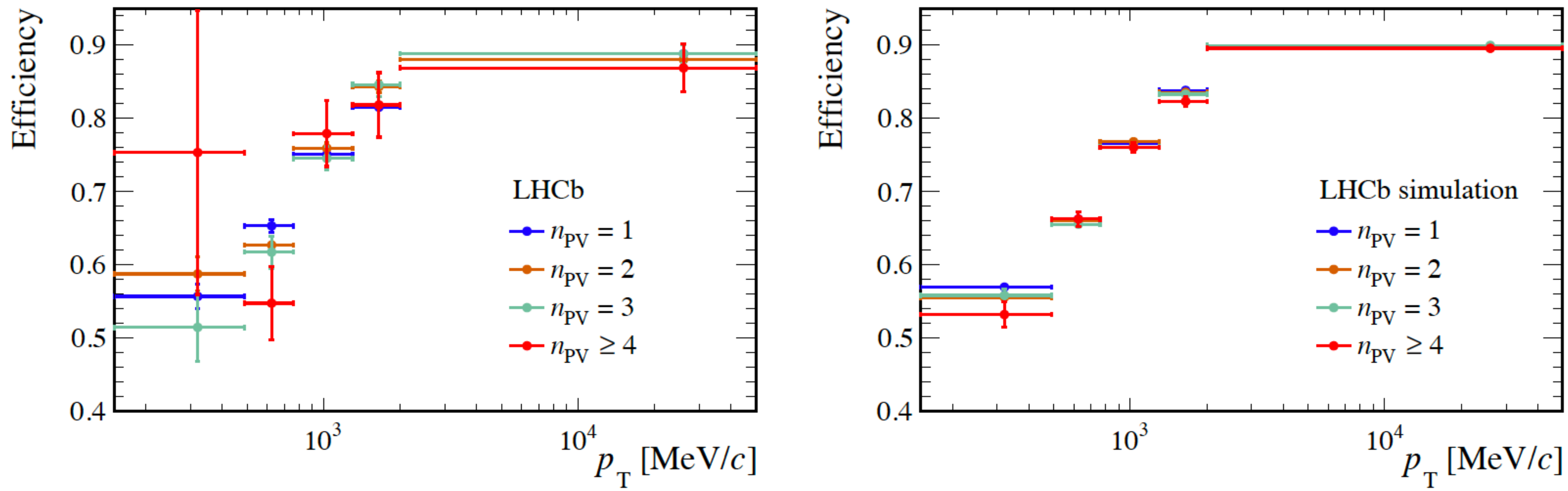

Figure 6: Efficiency in bins of number of primary vertices and the transverse momentum of the probe electron for (left) data and (right) simulation. The uncertainties shown are statistical only.

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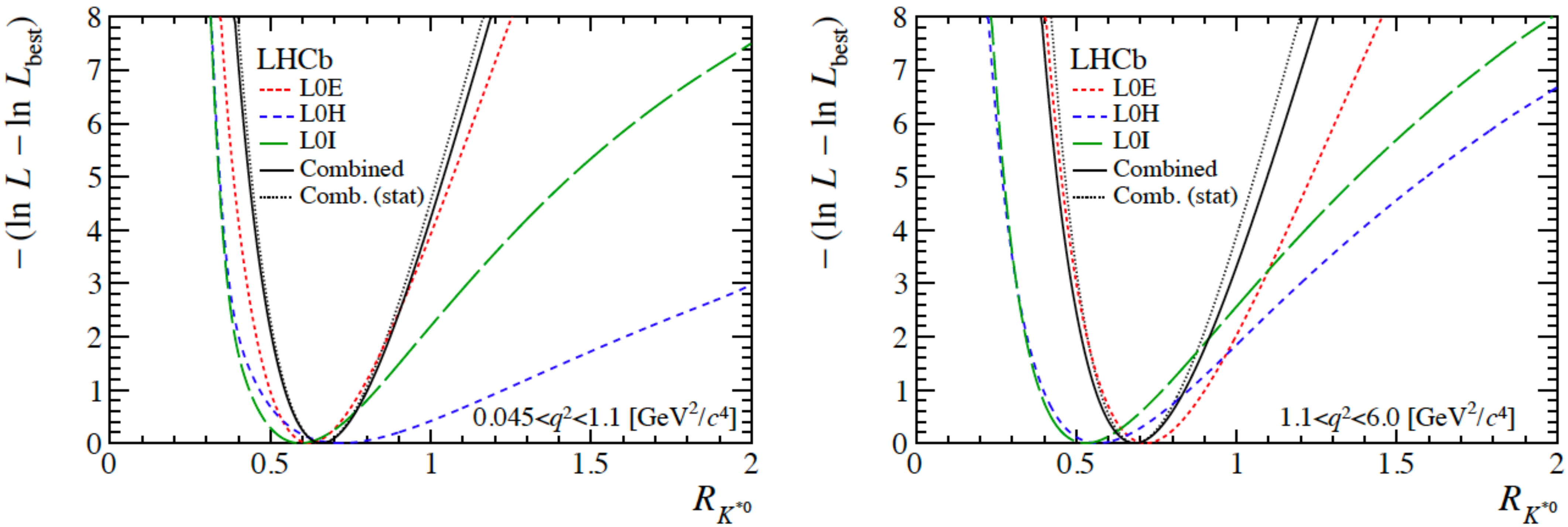
Profiles from R_{K^*}



R_{pK}

q^2 windows

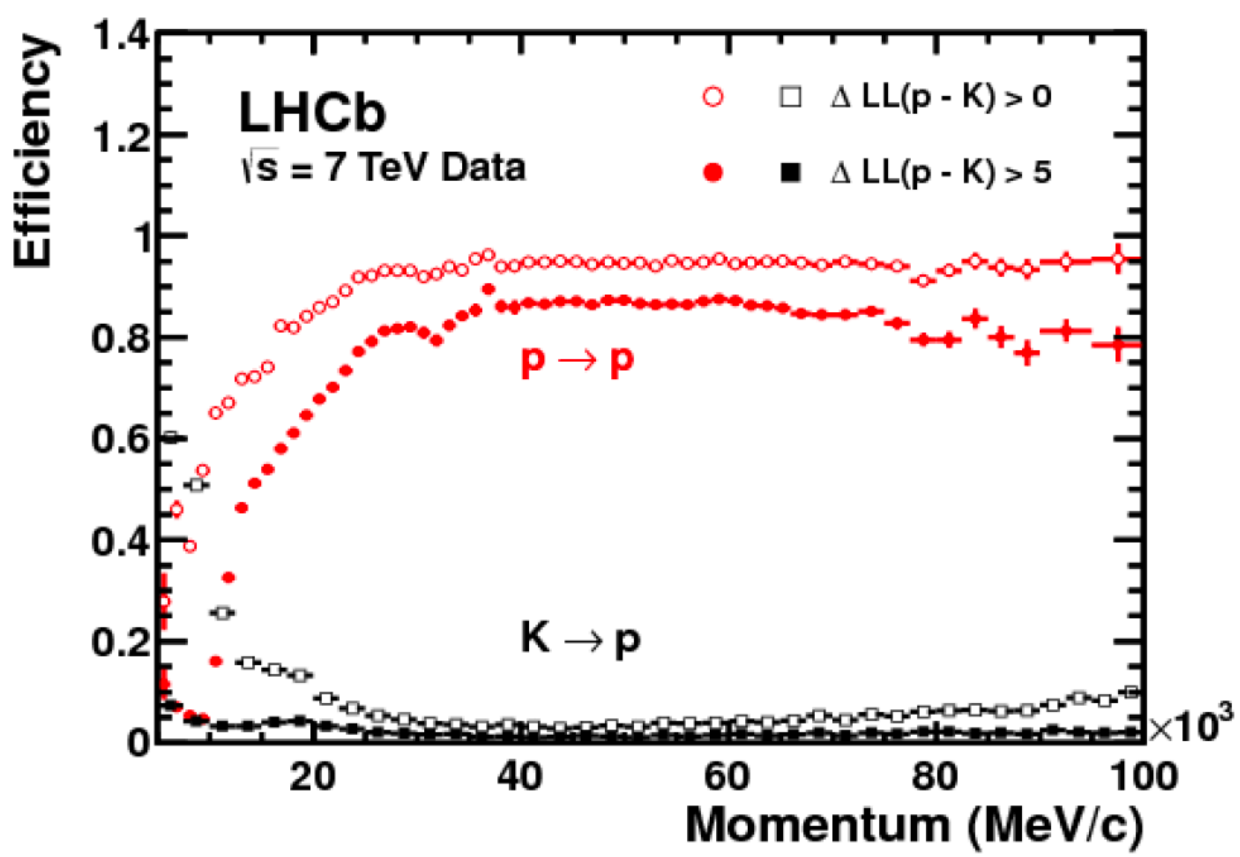
Decay mode	q^2 [GeV^2/c^4]	$m_{(J/\psi)}(pK^-\ell^+\ell^-)$ [GeV/c^2]
nonresonant e^+e^-	0.1 – 6.0	4.80 – 6.32
resonant e^+e^-	6.0 – 11.0	5.30 – 6.20
nonresonant $\mu^+\mu^-$	0.1 – 6.0	5.10 – 6.10
resonant $\mu^+\mu^-$	8.41 – 10.24	5.30 – 5.95

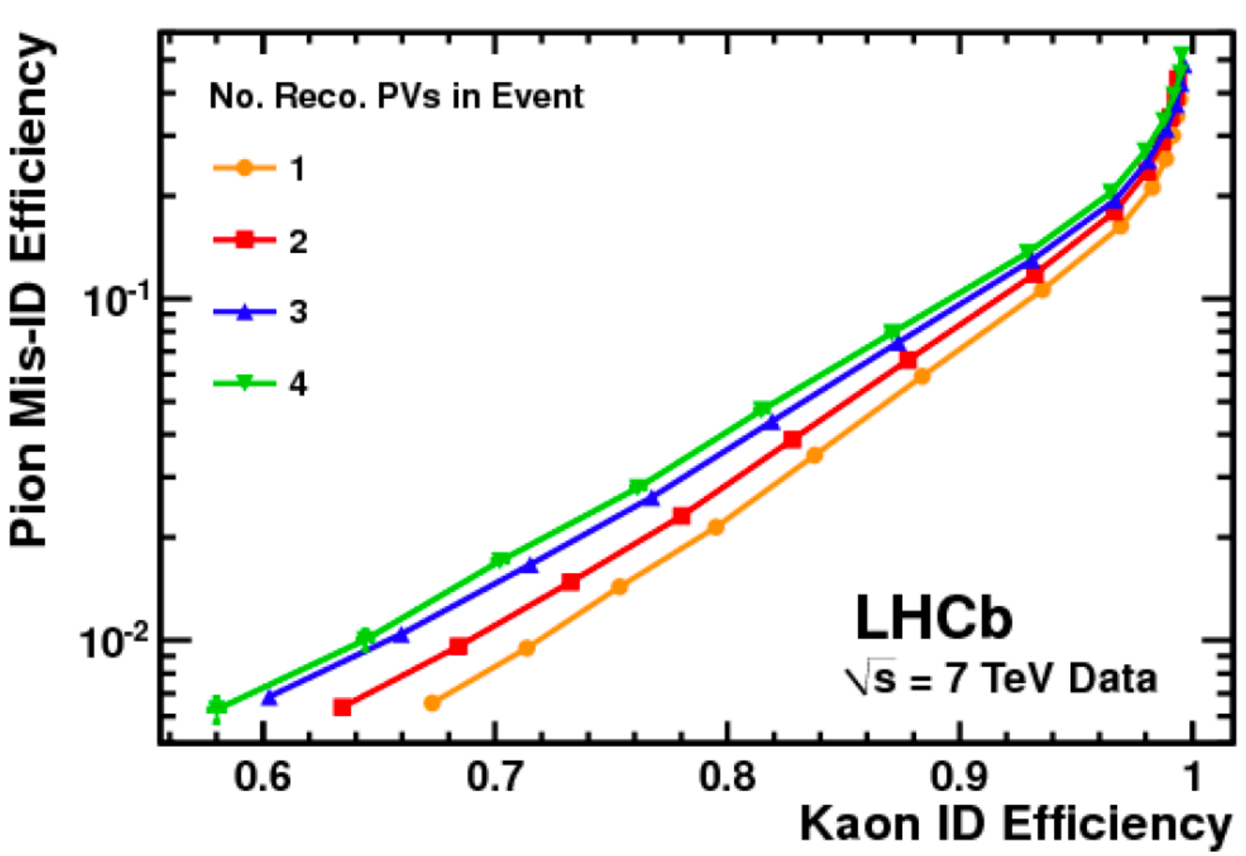
Systematic uncertainties

	low-q^2			central-q^2		
Trigger category	L0E	L0H	L0I	L0E	L0H	L0I
Corrections to simulation	2.5	4.8	3.9	2.2	4.2	3.4
Trigger	0.1	1.2	0.1	0.2	0.8	0.2
PID	0.2	0.4	0.3	0.2	1.0	0.5
Kinematic selection	2.1	2.1	2.1	2.1	2.1	2.1
Residual background	–	–	–	5.0	5.0	5.0
Mass fits	1.4	2.1	2.5	2.0	0.9	1.0
Bin migration	1.0	1.0	1.0	1.6	1.6	1.6
$r_{J/\psi}$ **flatness**	1.6	1.4	1.7	0.7	2.1	0.7
Total	4.0	6.1	5.5	6.4	7.5	6.7

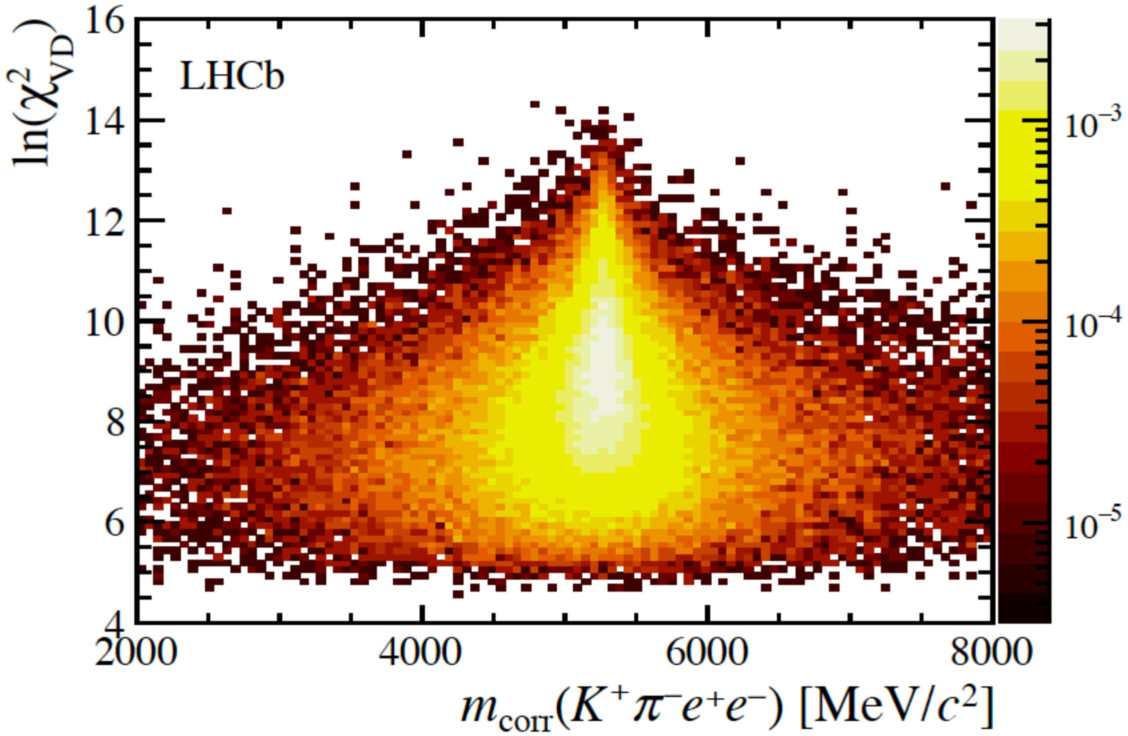
R_{K^*}

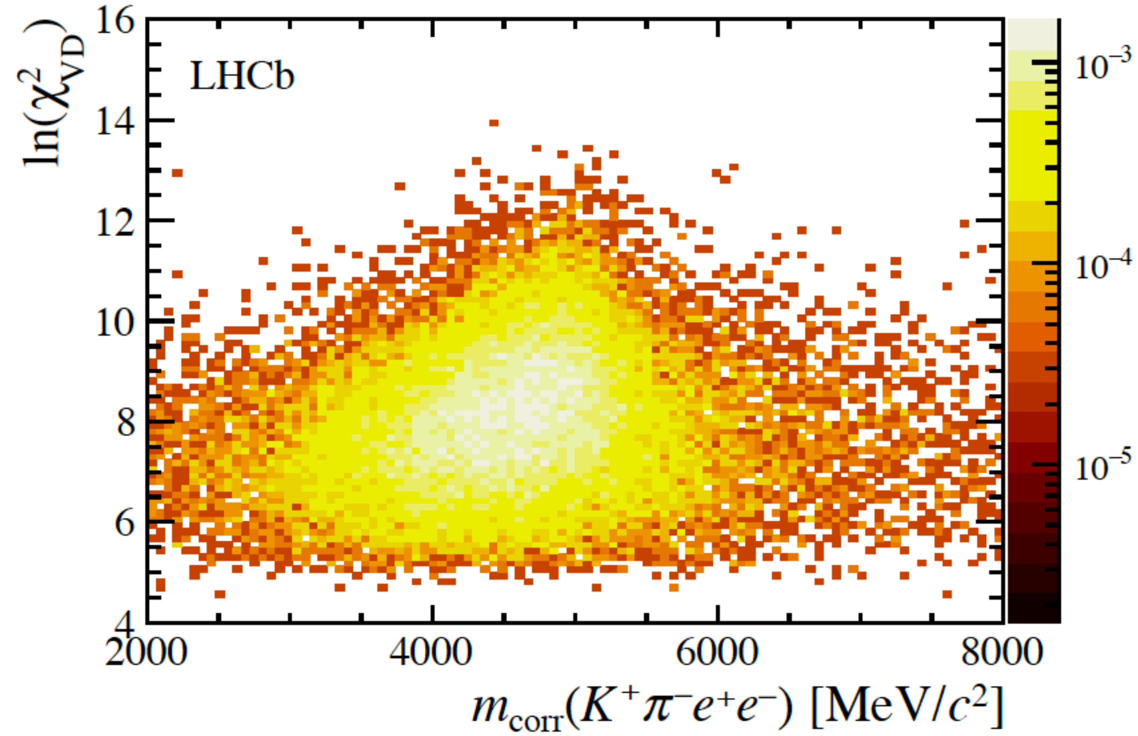
PID performances @ LHCb





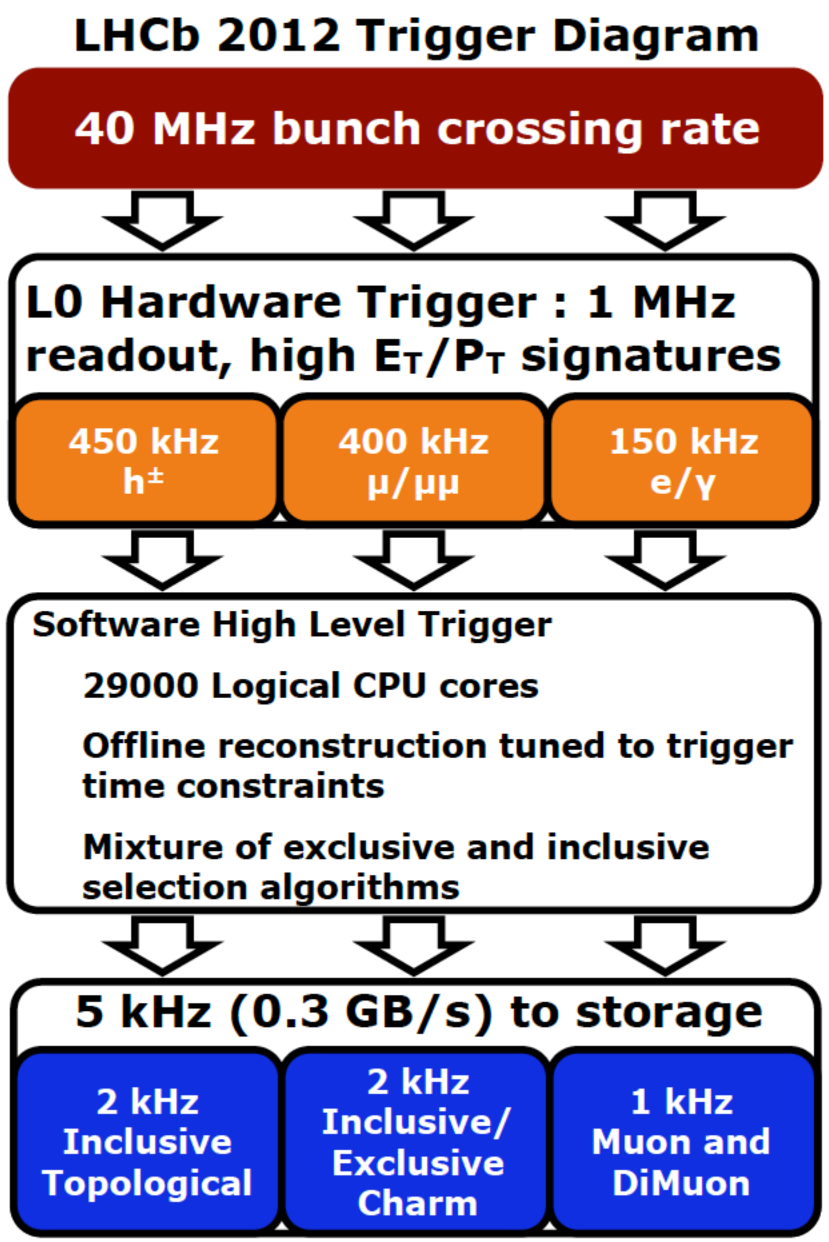
R_{K^*}- HOP

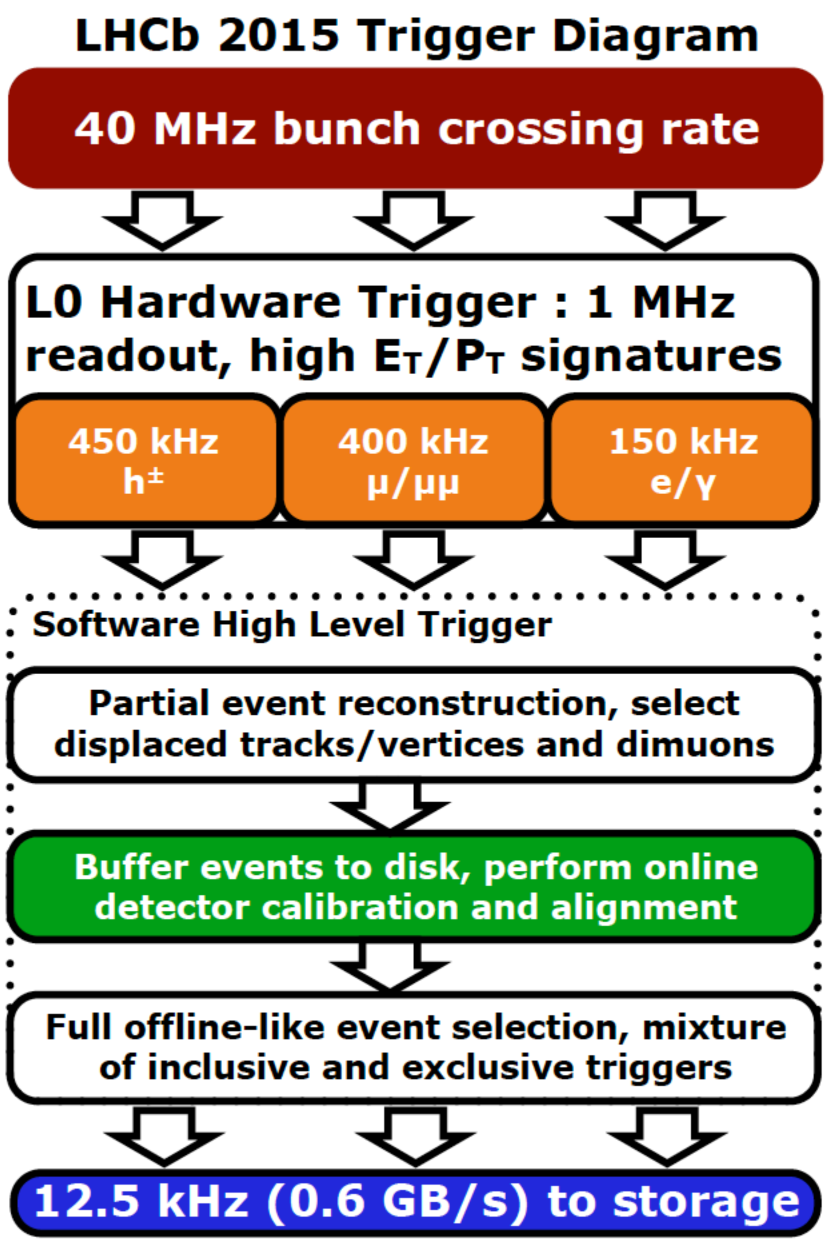

LHCb
$\ln(\chi^2_{VD})$
$m_{corr}(K^+\pi^-e^+e^-)$ [MeV/c^2]
10^{-3}
10^{-4}
10^{-5}


LHCb
$\ln(\chi^2_{VD})$
$m_{corr}(K^+\pi^-e^+e^-)$ [MeV/c^2]
10^{-3}
10^{-4}
10^{-5}

R_{K^*}

Trigger schemes





Partially reconstructed backgrounds

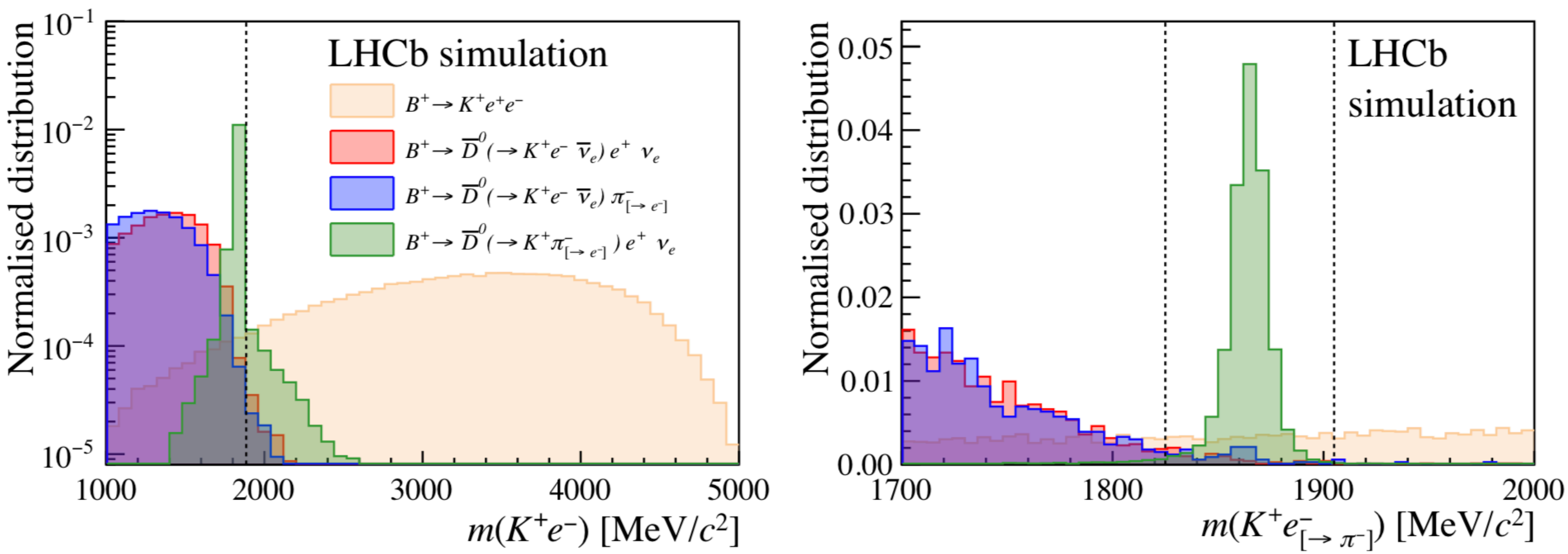


Figure 5: Simulated K^+e^- mass distributions for signal and various cascade background samples. The distributions are all normalised to unity. (Left, with log y-scale) the bremsstrahlung correction to the momentum of the electron is applied, resulting in a tail to the right. The region to the left of the vertical dashed line is rejected. (Right, with linear y-scale) the mass is computed only from the track information. The notation $\pi^-_{[\to e^-]}$ ($e^-_{[\to \pi^-]}$) is used to denote an electron (pion) that is misidentified as a pion (electron). The region between the dashed vertical lines is rejected.

Predictions

q^2 range $[\,\mathrm{GeV}^2/c^4\,]$	$R_{K^{*0}}^{\mathrm{SM}}$	References
[0.045, 1.1]	0.906 ± 0.028	BIP [26]
	0.922 ± 0.022	CDHMV [27–29]
	$0.919\ ^{+\,0.004}_{-\,0.003}$	EOS [30, 31]
	0.925 ± 0.004	flav.io [32–34]
	$0.920\ ^{+\,0.007}_{-\,0.006}$	JC [35]
[1.1, 6.0]	1.000 ± 0.010	BIP [26]
	1.000 ± 0.006	CDHMV [27–29]
	$0.9968\ ^{+\,0.0005}_{-\,0.0004}$	EOS [30, 31]
	0.9964 ± 0.005	flav.io [32–34]
	0.996 ± 0.002	JC [35]

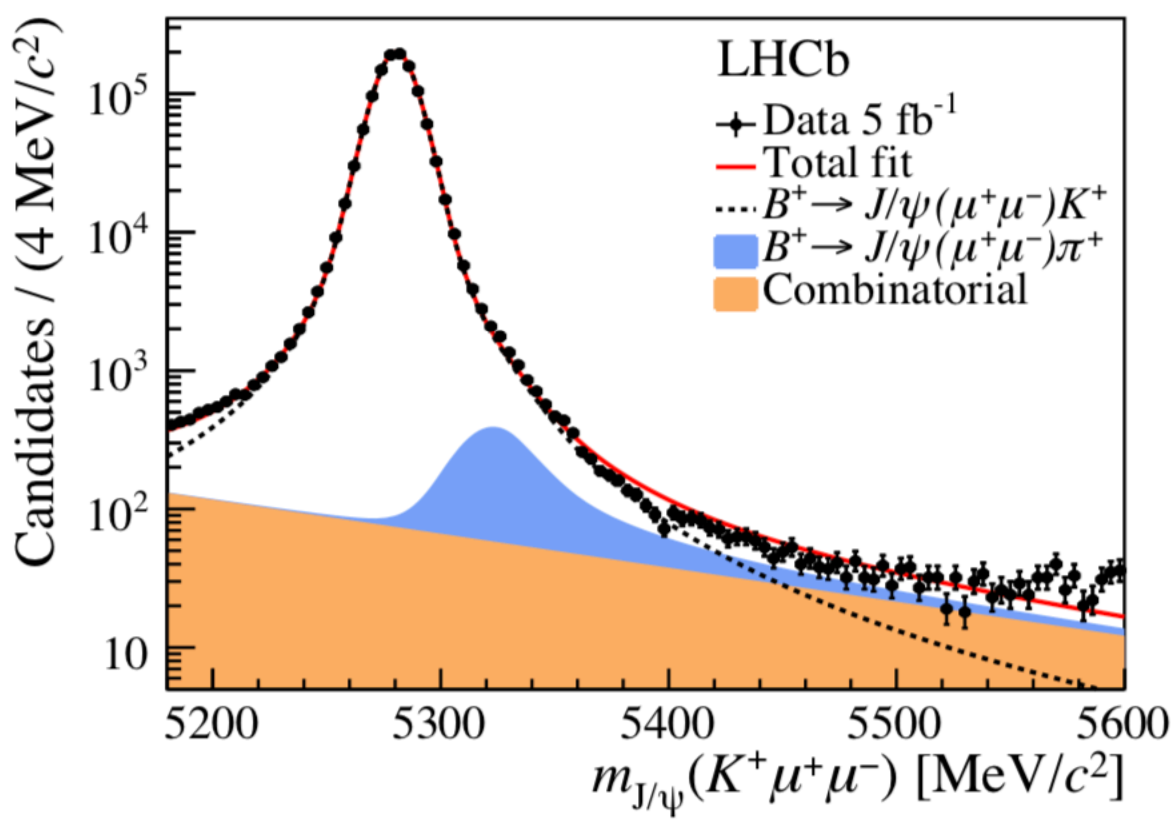
R_{K^*}

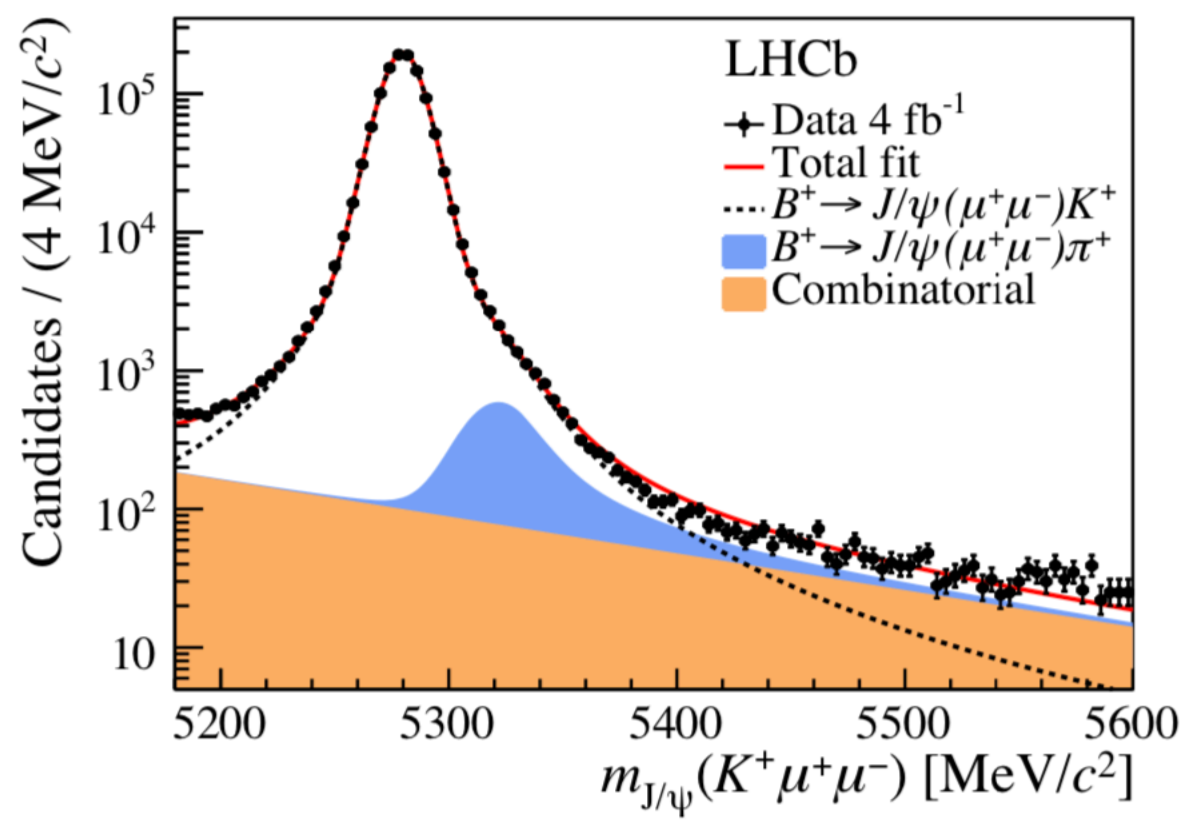
Yields

Decay Mode	Event Yield
$B^+ \to K^+ e^+ e^-$	766 ± 48
$B^+ \to K^+ \mu^+ \mu^-$	$1\,943 \pm 49$
$B^+ \to J/\psi\,(\to e^+ e^-) K^+$	$344\,100 \pm 610$
$B^+ \to J/\psi\,(\to \mu^+ \mu^-) K^+$	$1\,161\,800 \pm 1\,100$

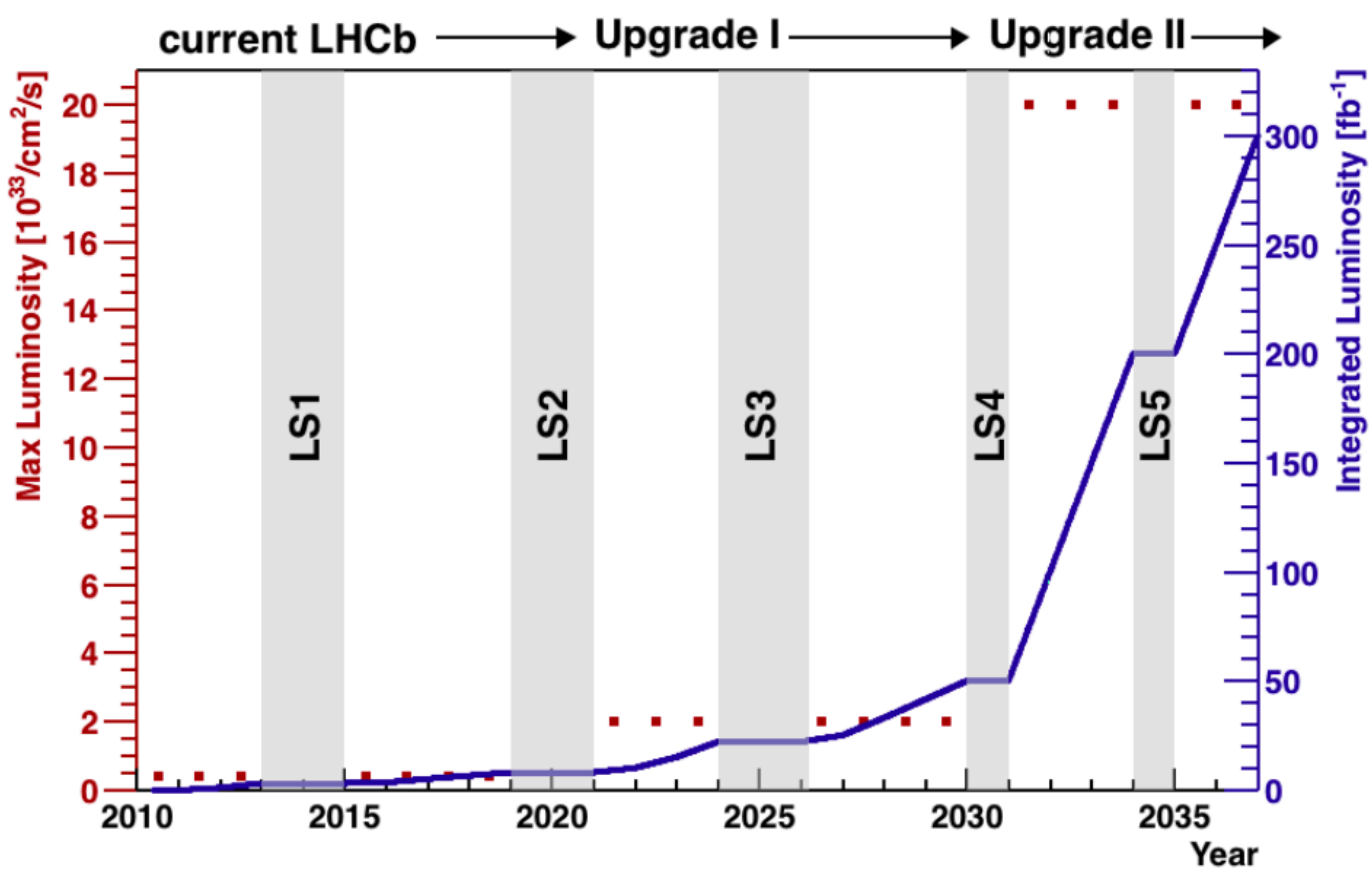
	$B^0 \to K^{*0} \ell^+ \ell^-$		$B^0 \to K^{*0} J/\psi\,(\to \ell^+ \ell^-)$
	low-q^2	central-q^2	
$\mu^+\mu^-$	$285\,^{+\,18}_{-\,18}$	$353\,^{+\,21}_{-\,21}$	$274416\,^{+\,602}_{-\,654}$
e^+e^- (L0E)	$55\,^{+\,9}_{-\,8}$	$67\,^{+\,10}_{-\,10}$	$43468\,^{+\,222}_{-\,221}$
e^+e^- (L0H)	$13\,^{+\,5}_{-\,5}$	$19\,^{+\,6}_{-\,5}$	$3388\,^{+\,62}_{-\,61}$
e^+e^- (L0I)	$21\,^{+\,5}_{-\,4}$	$25\,^{+\,7}_{-\,6}$	$11505\,^{+\,115}_{-\,114}$

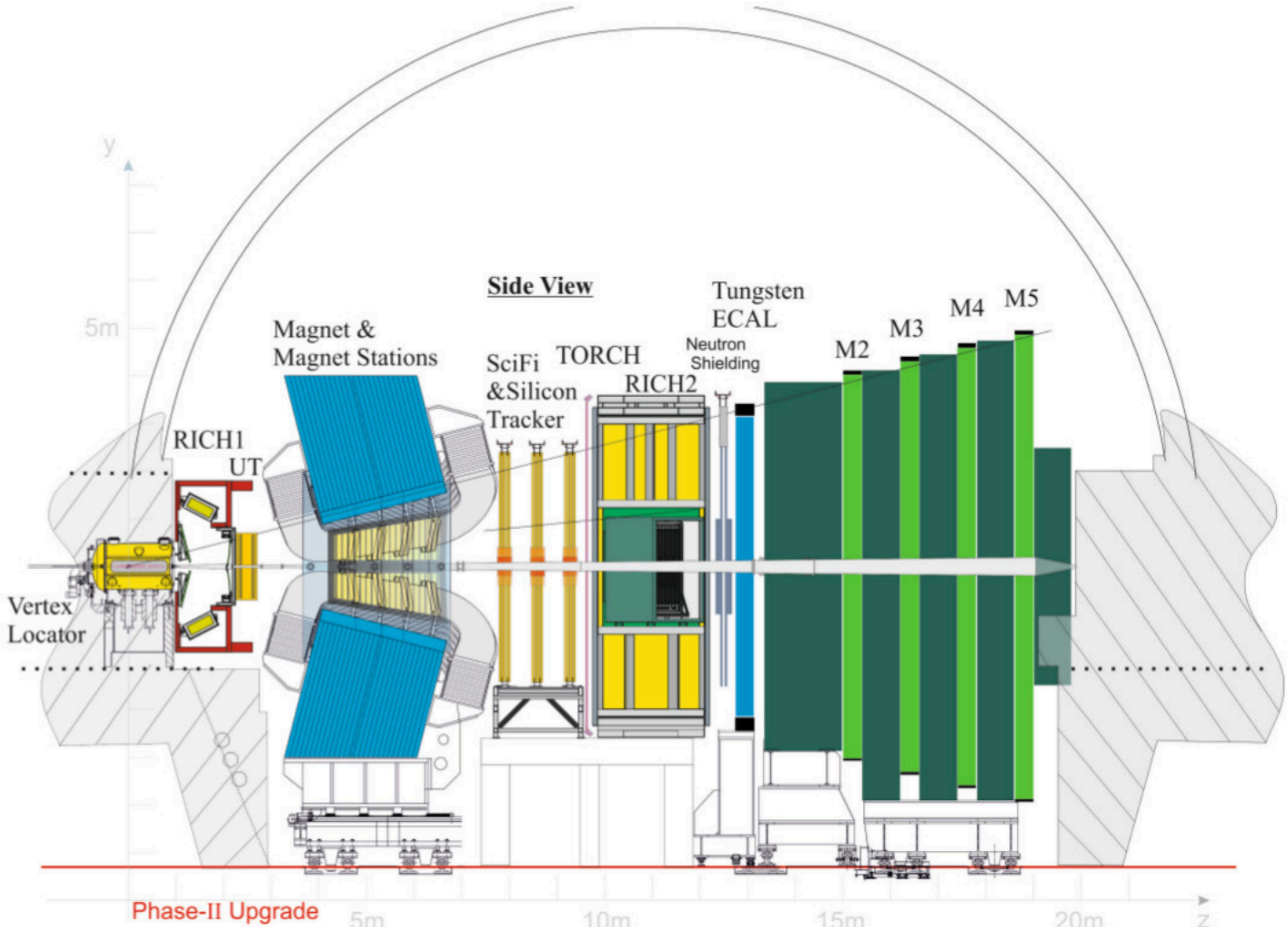
Log plots - control modes





Luminosities @ LHCb





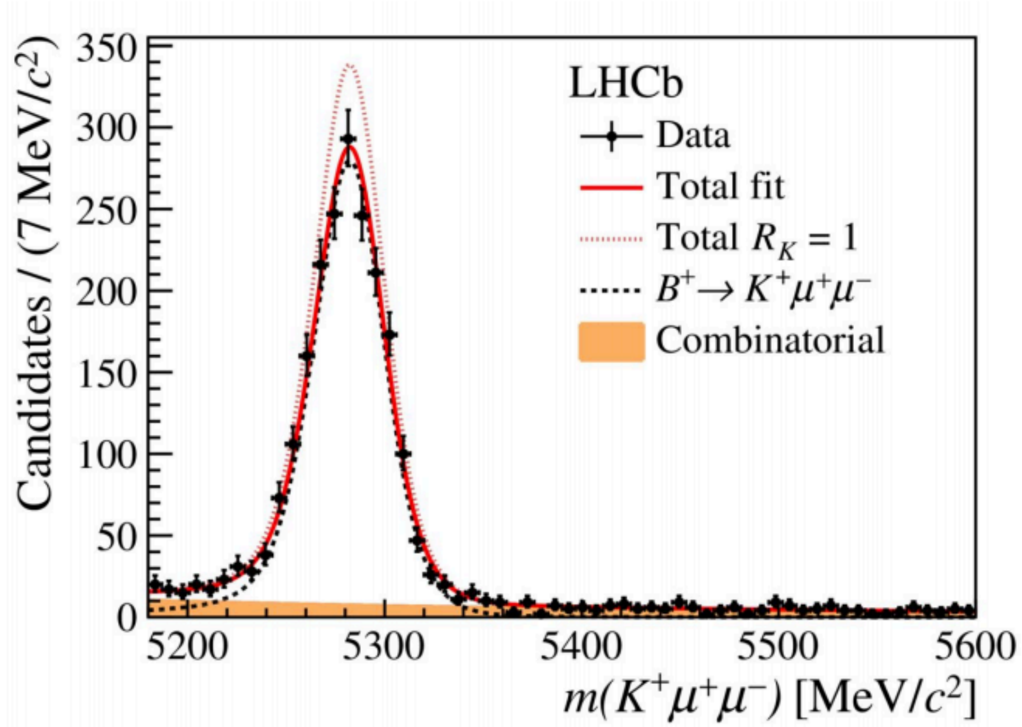
y
5m
Side View
Magnet &
Magnet Stations
SciFi
&Silicon
Tracker
TORCH
RICH2
Tungsten
ECAL
Neutron
Shielding
M2
M3
M4
M5
RICH1
UT
Vertex
Locator
Phase-II Upgrade
5m
10m
15m
20m
z

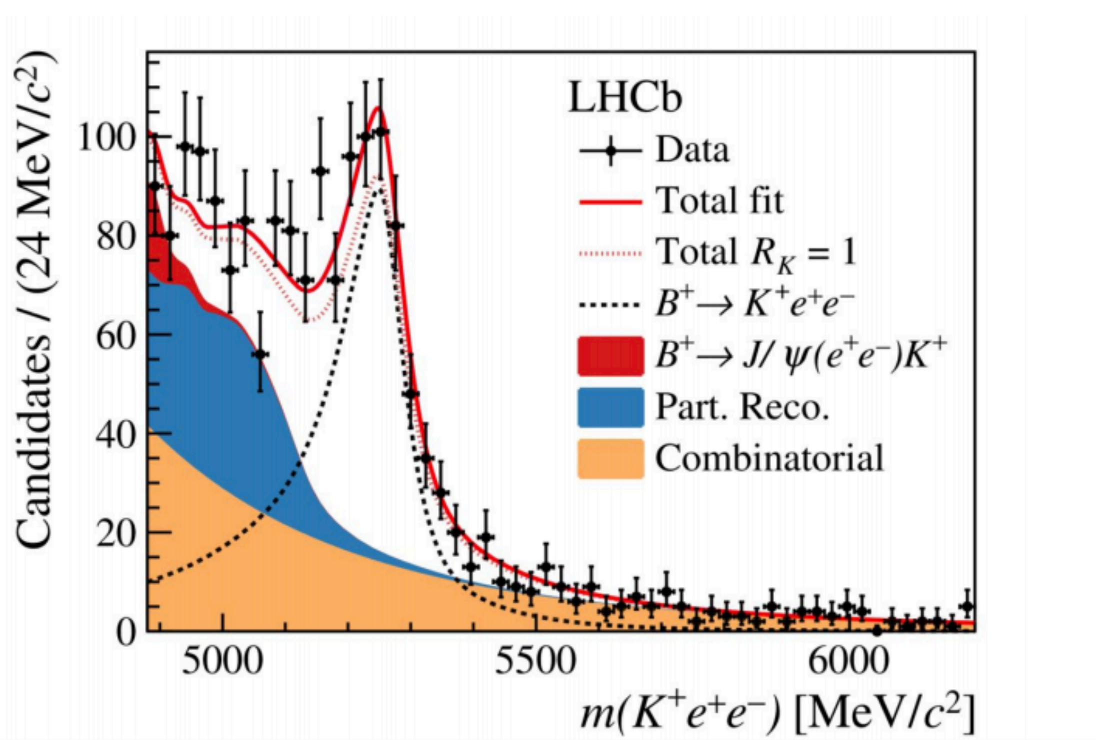
Background vetos

B^+	$m(K\ell^+\ell^-) < 5200\ \text{MeV}/c^2$, $m(p\ell^+\ell^-)_{p\leftarrow K} < 5200\ \text{MeV}/c^2$	all
ϕ	$abs(m(pK)_{p\leftarrow K} - 1020) > 12$	all
Λ_c^+	$m(pK\ell^+) > 2320\ \text{MeV}/c^2$, $m(pK\ell^-)_{p\leftrightarrow K} > 2320\ \text{MeV}/c^2$	all
D^0	$abs(m(K^-\ell^+)_{\ell\leftarrow\pi} - 1865) > 20$	all rare
swaps	$abs(m(K^-\mu^+)_{K\leftarrow\mu} - 3097) > 35$	rare $\mu\mu$
	$m(K^-e^+)_{K\leftarrow e} < 2900$ or > 3150	rare ee
conversions	$m(K^-e^+)_{K\leftarrow e} > 10$, $m(pe^-)_{p\leftarrow e} > 10$	all ee
clones	$\theta(K,\ell) > 0.5$ mrad, $\theta(p,\ell) > 0.5$ mrad	all

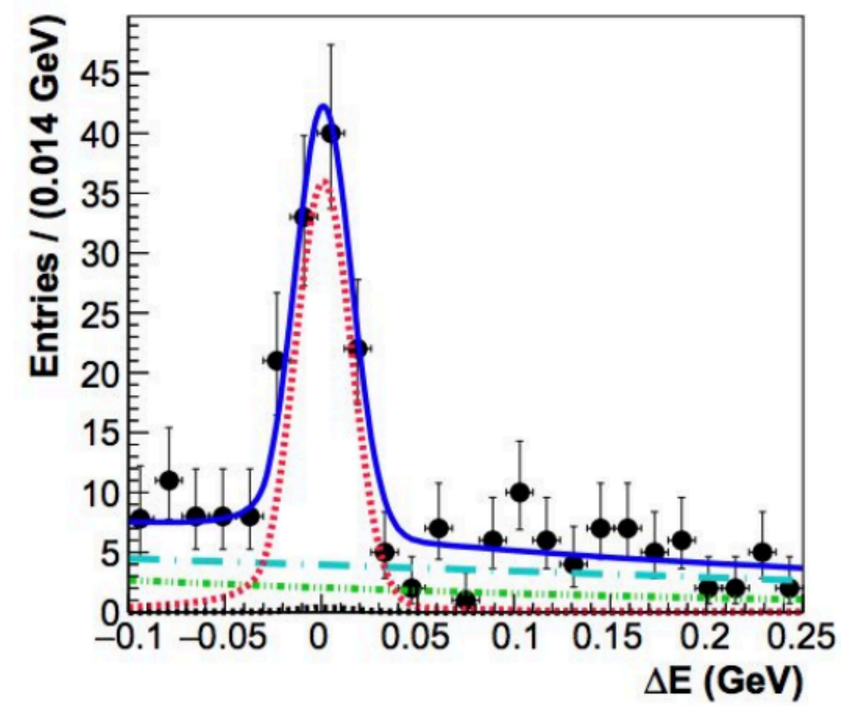
Λ_b

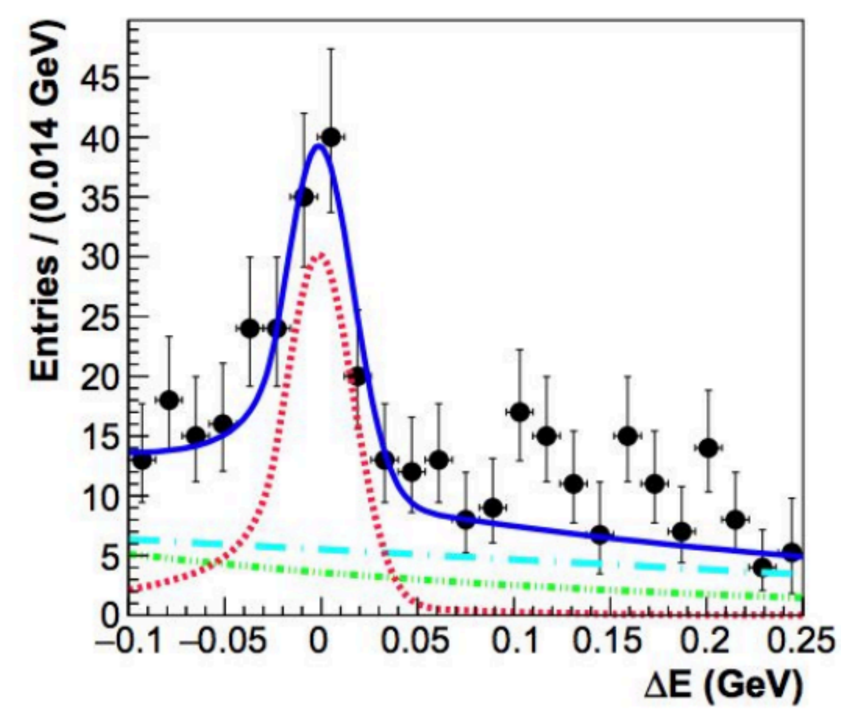
Electrons are a challenge at LHCb





much more similar to muons at Belle.





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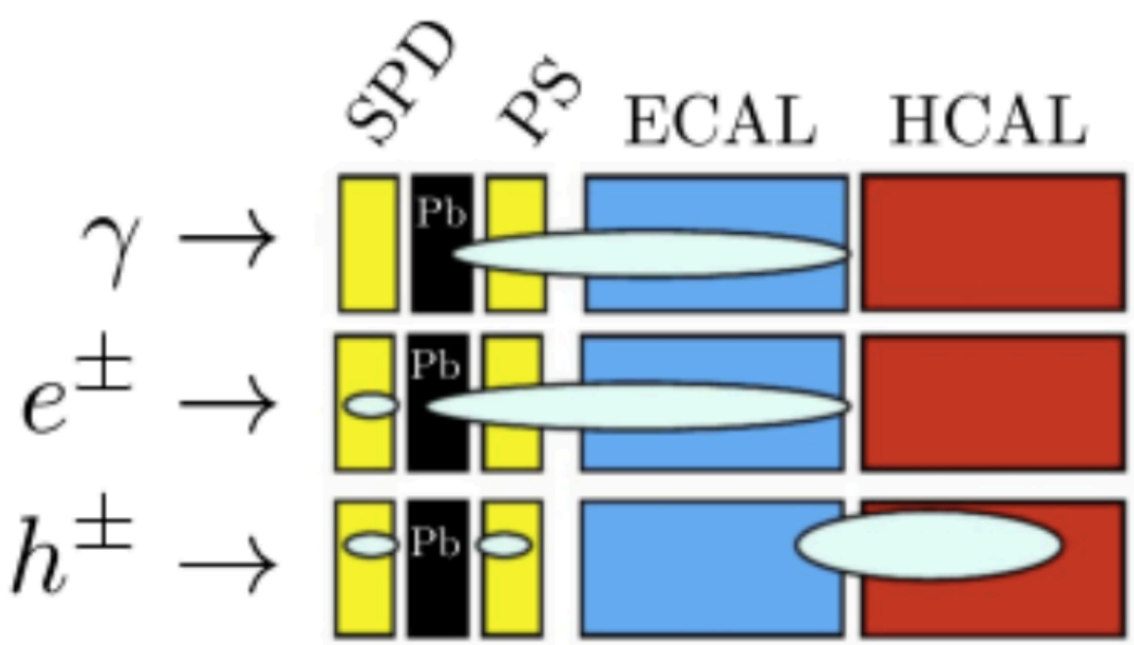
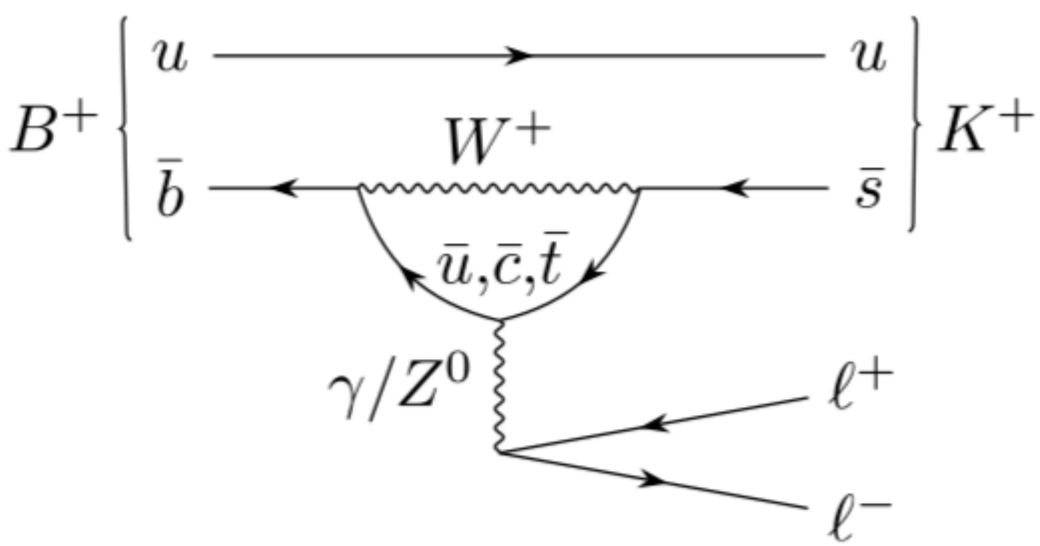
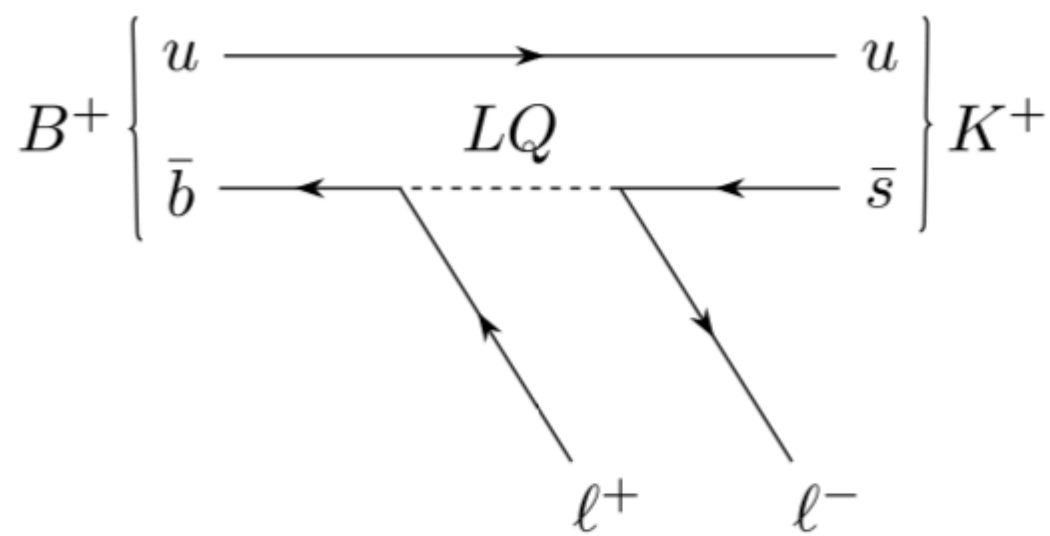
Calorimeter

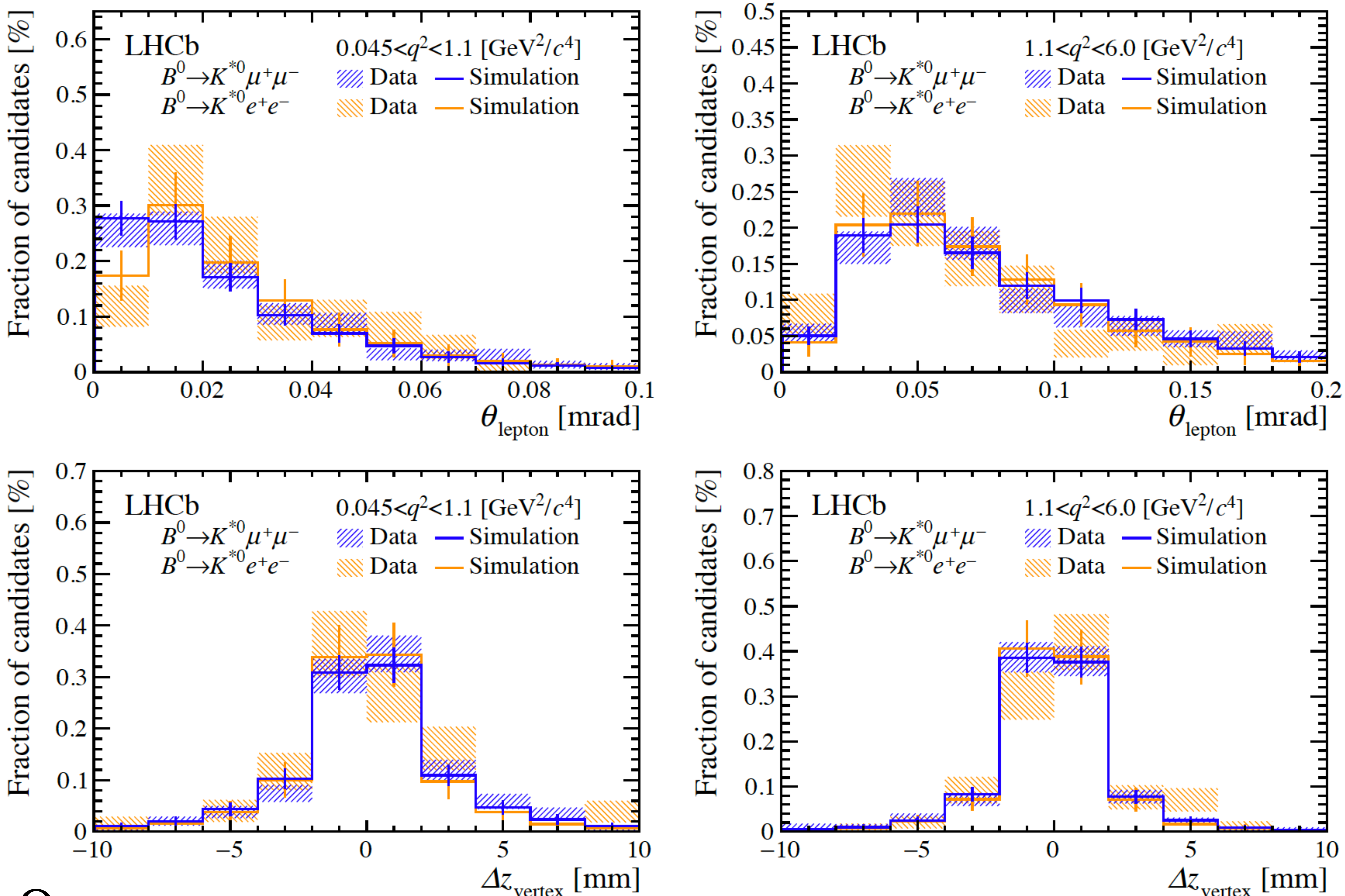
- The **SPD** and the **PS** consist of a plane of scintillator tiles (2.5 radiation lengths, but to only ~6% hadronic interaction lengths)
- The **ECAL** has shashlik-type construction, i.e. a stack of alternating slices of lead absorber and scintillator (25 radiation lengths)
- The **HCAL** is a sampling device made from iron and scintillator tiles being orientated parallel to the beam axis (5.6 interaction lengths)




B+
u
u
K+
W+
b̄
s̄
ū,c̄,t̄
γ/Z0
ℓ+
ℓ−


B+
u
u
K+
LQ
b̄
s̄
ℓ+
ℓ−

Cross-checks



B^0

What we measure

$$R_H \propto \frac{N(B\to H\mu^+\mu^-)}{N(B\to He^+e^-)} \times \frac{\epsilon(B\to He^+e^-)}{\epsilon(B\to H\mu^+\mu^-)}$$

Counting from mass fits

From simulation

$$r_{J/\psi} = \frac{BR(B\to HJ/\psi(\mu^+\mu^-))}{BR(B\to HJ/\psi(e^+e^-))} = 1$$

$$R_H = \frac{\frac{N(B\to H\mu^+\mu^-)}{N(B\to HJ/\psi(\mu^+\mu^-))}}{\frac{N(B\to He^+e^-)}{N(B\to HJ/\psi(e^+e^-))}} \times \frac{\frac{\epsilon(B\to He^+e^-)}{\epsilon(B\to HJ/\psi(e^+e^-))}}{\frac{\epsilon(B\to H\mu^+\mu^-)}{\epsilon(B\to HJ/\psi(\mu^+\mu^-))}}$$