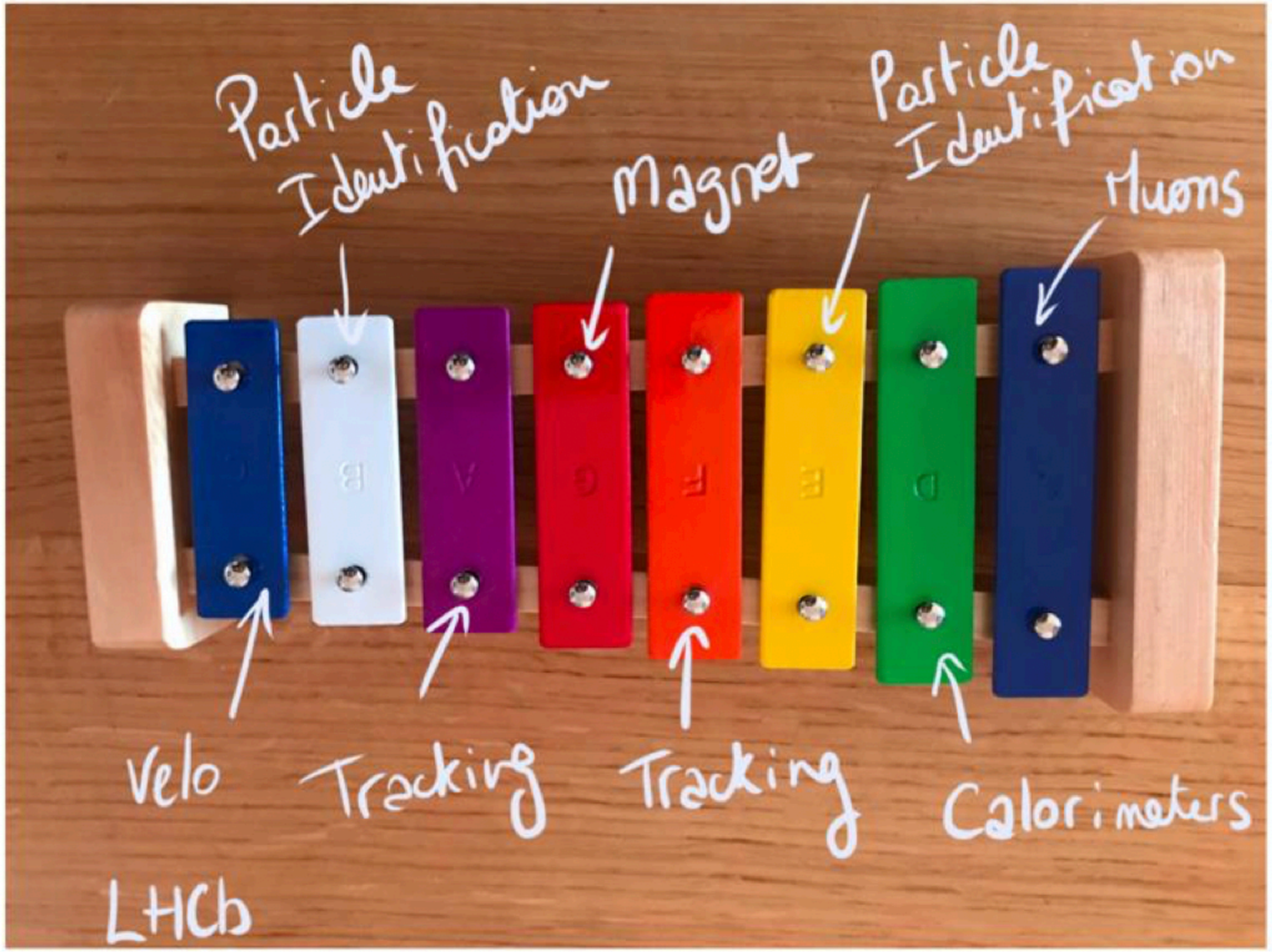
Welcome

13.02.2024

Yasmine Amhis

Welcome to LHCb !



My daughter's Xylophone or an artist view of LHCb up to you.

Who is the Physics Coordination?

Yasmine Amhis
(PC)
based at CERN

Picture taken @ LHCb week
in Dortmund 22

Picture taken @ LHCb
week in Marseille 23

Carla Göbel
(Deputy PC)
based in Rio

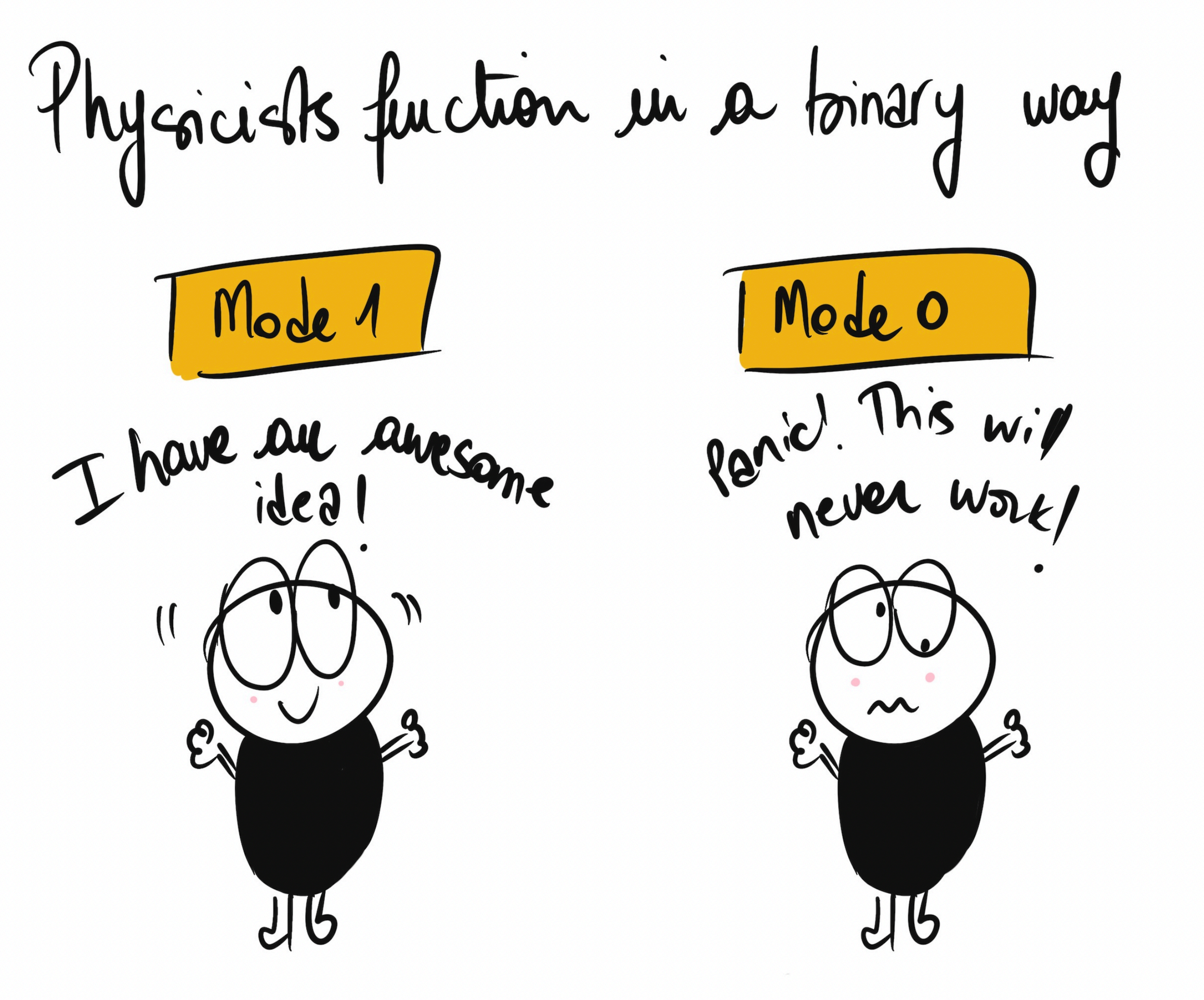
When you can hear/see us:

Talk at every Tuesday meeting.
We chair all the approvals.
We work very closely with the conveners.
We send a LOT of email

Given the time zone difference there
is almost always one of us who is awake:
lhcb-physics-coordination@cern.ch

PC office hours !
Next one this Friday at 12:00 CET.

Do I need to convince you why flavour physics is great ?



The strength of flavour physics and indirect searches

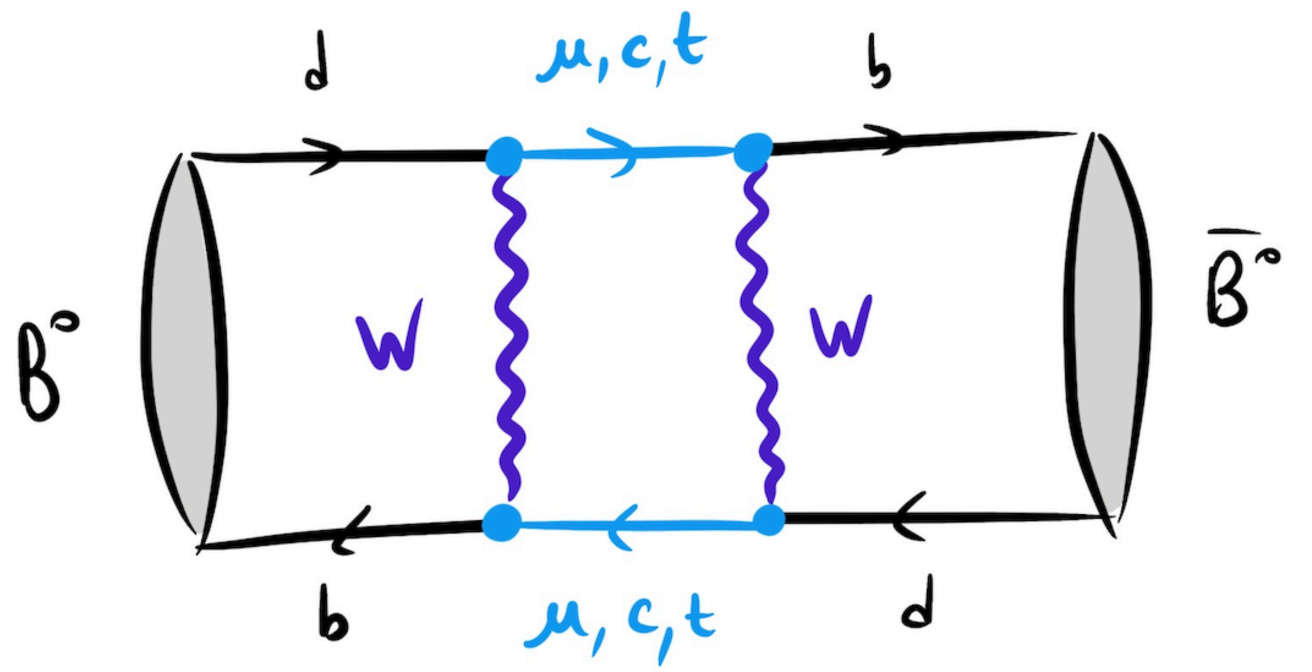
PLB 192 (1987)

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



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

One upon a time there was a roadmap

LHCb-PUB-2009-029
16 February 2010

Roadmap for selected key measurements of LHCb

The LHCb Collaboration[1]

Abstract

Six of the key physics measurements that will be made by the LHCb experiment, concerning CP asymmetries and rare B decays, are discussed in detail. The "road map" towards the precision measurements is presented, including the use of control channels and other techniques to understand the performance of the detector with the first data from the LHC.

[1]Authors are listed on the following pages.

This defined the "core" program of LHCb

One upon a time there was a roadmap

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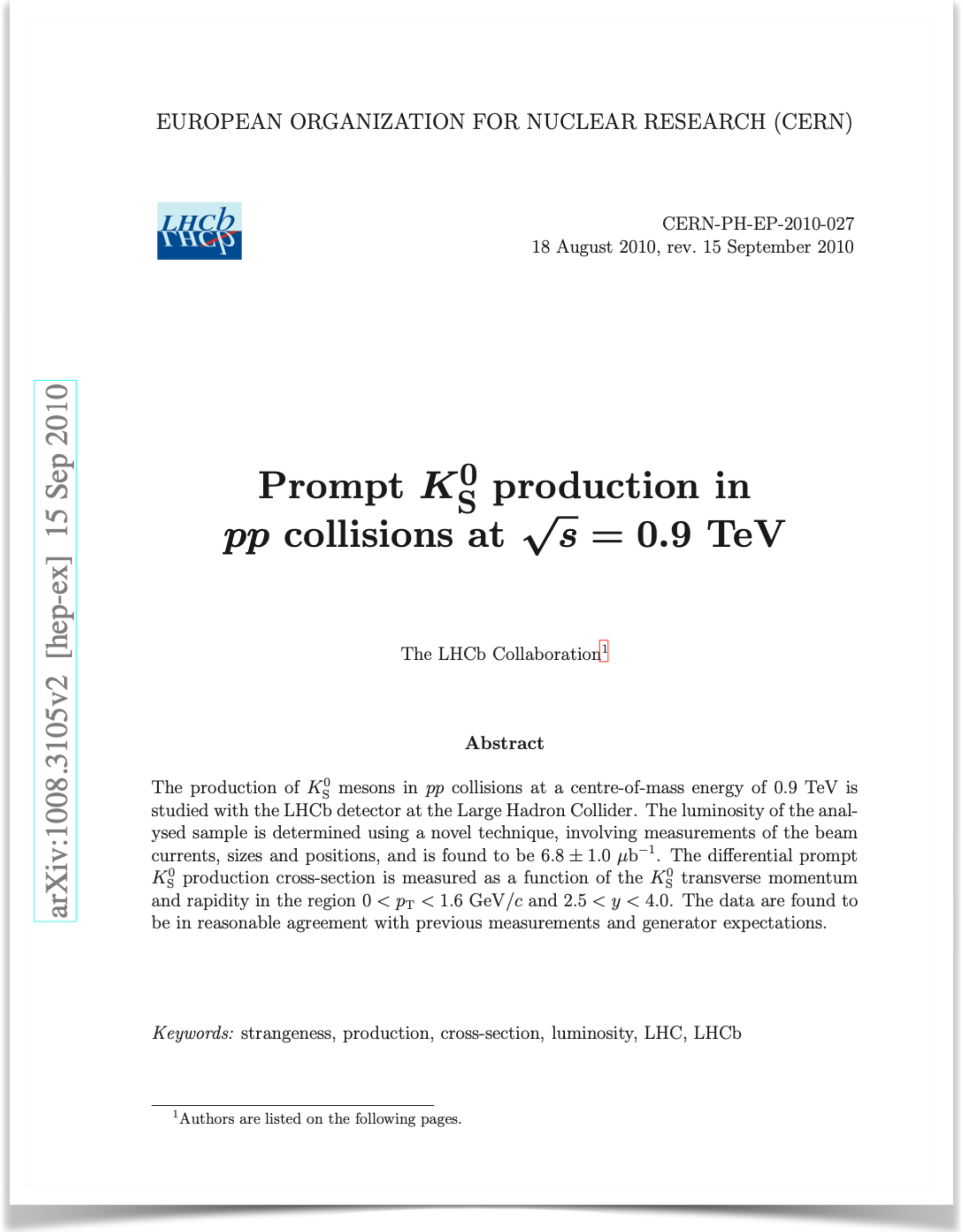
+ other things that I probably forgot

What did we first publish ?



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP-2010-027
18 August 2010, rev. 15 September 2010

arXiv:1008.3105v2 [hep-ex] 15 Sep 2010

Prompt K^0_S production in pp collisions at $\sqrt{s} = 0.9$ TeV

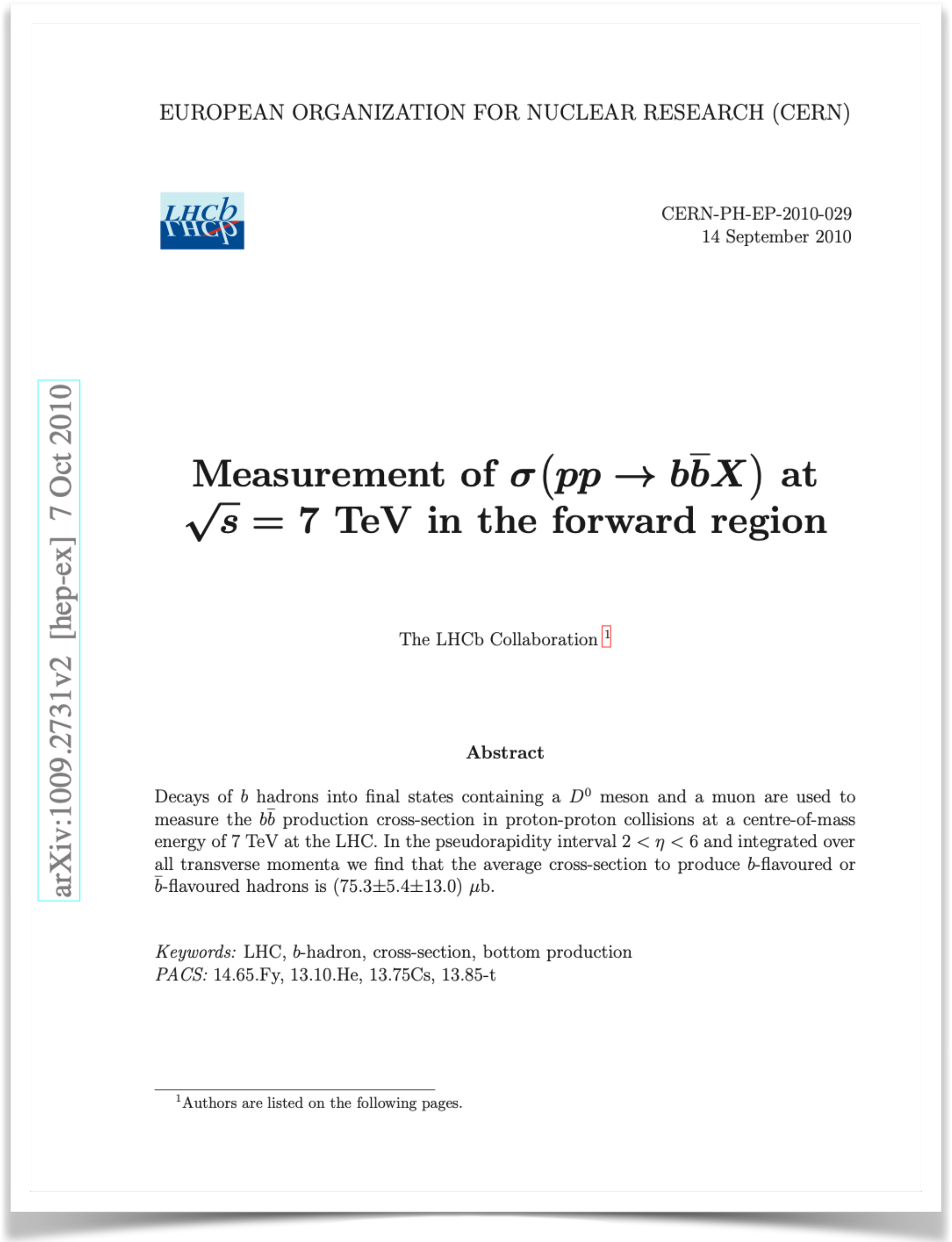
The LHCb Collaboration[1]

Abstract

The production of K^0_S mesons in pp collisions at a centre-of-mass energy of 0.9 TeV is studied with the LHCb detector at the Large Hadron Collider. The luminosity of the analysed sample is determined using a novel technique, involving measurements of the beam currents, sizes and positions, and is found to be $6.8 \pm 1.0\ \mu b^{-1}$. The differential prompt K^0_S production cross-section is measured as a function of the K^0_S transverse momentum and rapidity in the region $0 < p_T < 1.6$ GeV/c and $2.5 < y < 4.0$. The data are found to be in reasonable agreement with previous measurements and generator expectations.

Keywords: strangeness, production, cross-section, luminosity, LHC, LHCb

[1] Authors are listed on the following pages.



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP-2010-029
14 September 2010

arXiv:1009.2731v2 [hep-ex] 7 Oct 2010

Measurement of $\sigma(pp \to b\bar{b}X)$ at $\sqrt{s} = 7$ TeV in the forward region

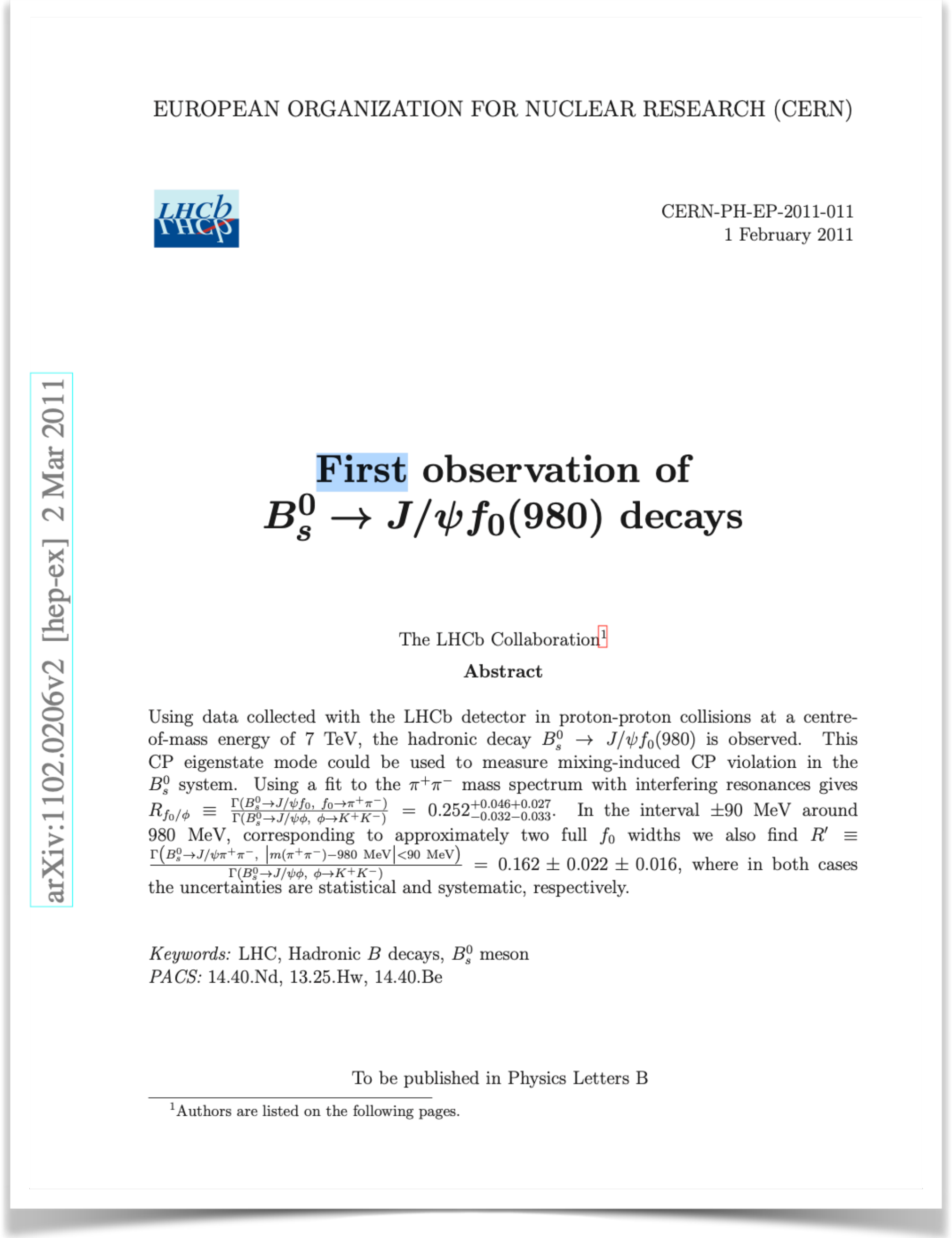
The LHCb Collaboration[1]

Abstract

Decays of b hadrons into final states containing a D^0 meson and a muon are used to measure the $b\bar{b}$ production cross-section in proton-proton collisions at a centre-of-mass energy of 7 TeV at the LHC. In the pseudorapidity interval $2 < \eta < 6$ and integrated over all transverse momenta we find that the average cross-section to produce b-flavoured or $\bar{b}$-flavoured hadrons is $(75.3 \pm 5.4 \pm 13.0)\ \mu$b.

Keywords: LHC, b-hadron, cross-section, bottom production
PACS: 14.65.Fy, 13.10.He, 13.75Cs, 13.85-t

[1] Authors are listed on the following pages.



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP-2011-011
1 February 2011

arXiv:1102.0206v2 [hep-ex] 2 Mar 2011

First observation of $B^0_s \to J/\psi f_0(980)$ decays

The LHCb Collaboration[1]

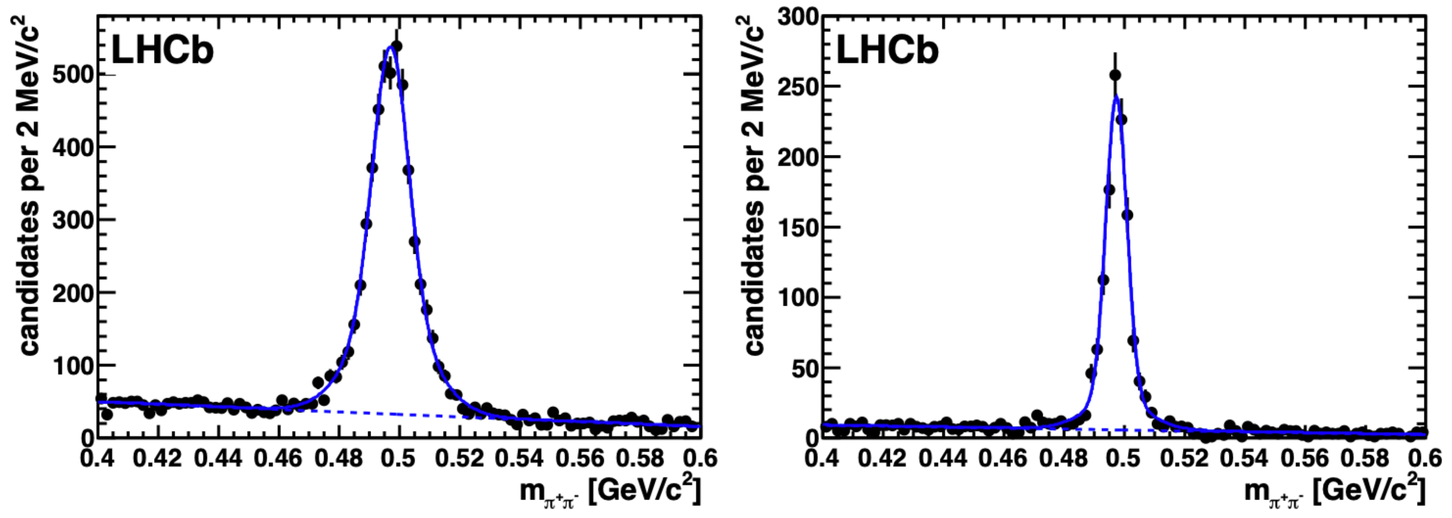
Abstract

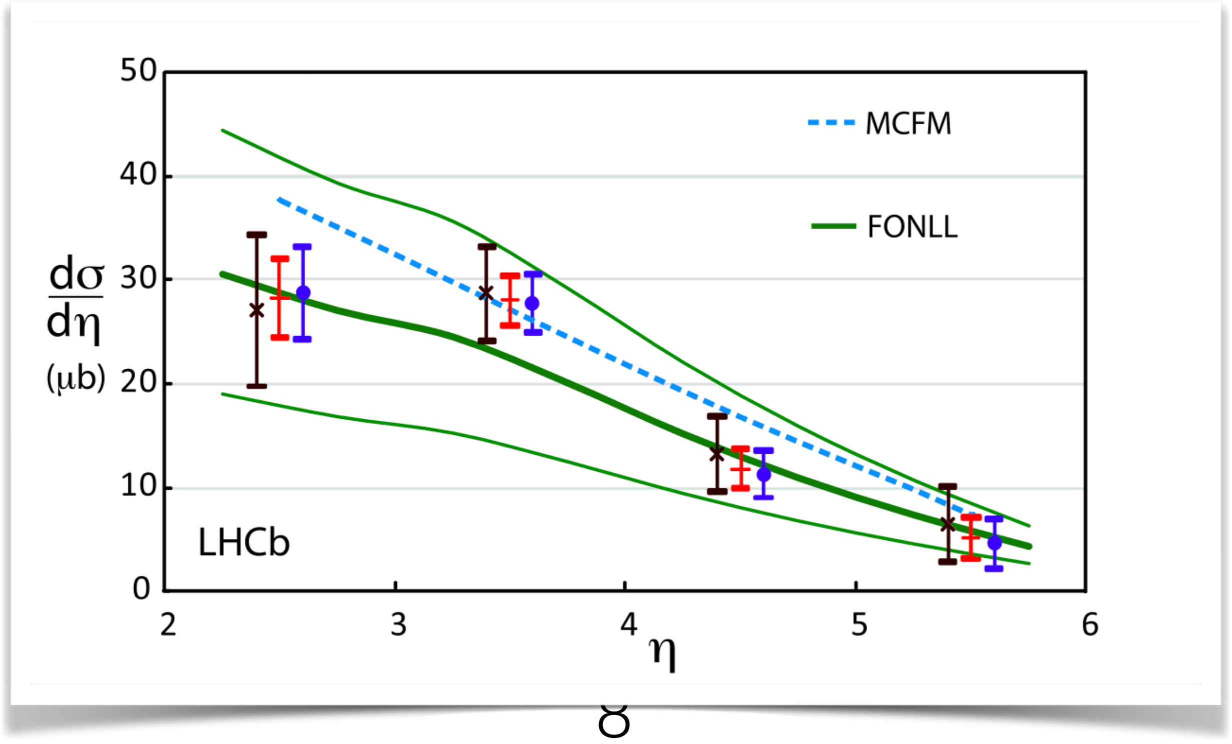
Using data collected with the LHCb detector in proton-proton collisions at a centre-of-mass energy of 7 TeV, the hadronic decay $B^0_s \to J/\psi f_0(980)$ is observed. This CP eigenstate mode could be used to measure mixing-induced CP violation in the B^0_s system. Using a fit to the $\pi^+\pi^-$ mass spectrum with interfering resonances gives $R_{f_0/\phi} \equiv \frac{\Gamma(B^0_s \to J/\psi f_0,\ f_0 \to \pi^+\pi^-)}{\Gamma(B^0_s \to J/\psi \phi,\ \phi \to K^+K^-)} = 0.252^{+0.046+0.027}_{-0.032-0.033}$. In the interval ± 90 MeV around 980 MeV, corresponding to approximately two full f_0 widths we also find $R' \equiv \frac{\Gamma(B^0_s \to J/\psi \pi^+\pi^-,\ |m(\pi^+\pi^-) - 980\ \text{MeV}| < 90\ \text{MeV})}{\Gamma(B^0_s \to J/\psi \phi,\ \phi \to K^+K^-)} = 0.162 \pm 0.022 \pm 0.016$, where in both cases the uncertainties are statistical and systematic, respectively.

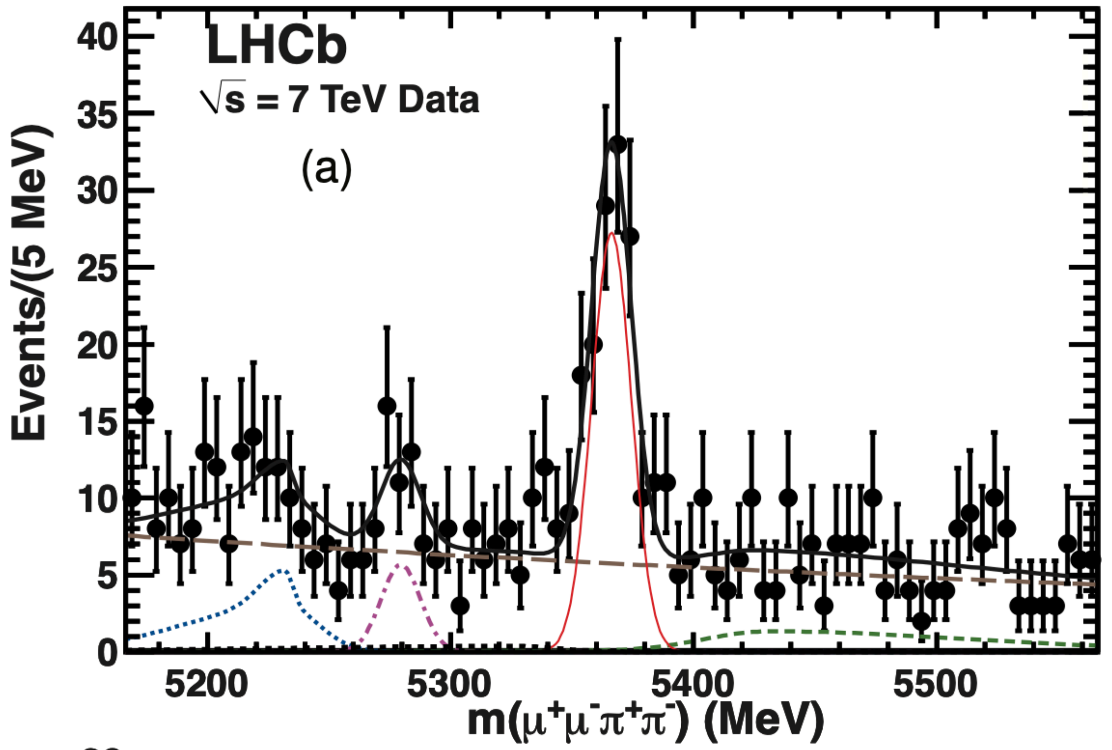
Keywords: LHC, Hadronic B decays, B^0_s meson
PACS: 14.40.Nd, 13.25.Hw, 14.40.Be

To be published in Physics Letters B

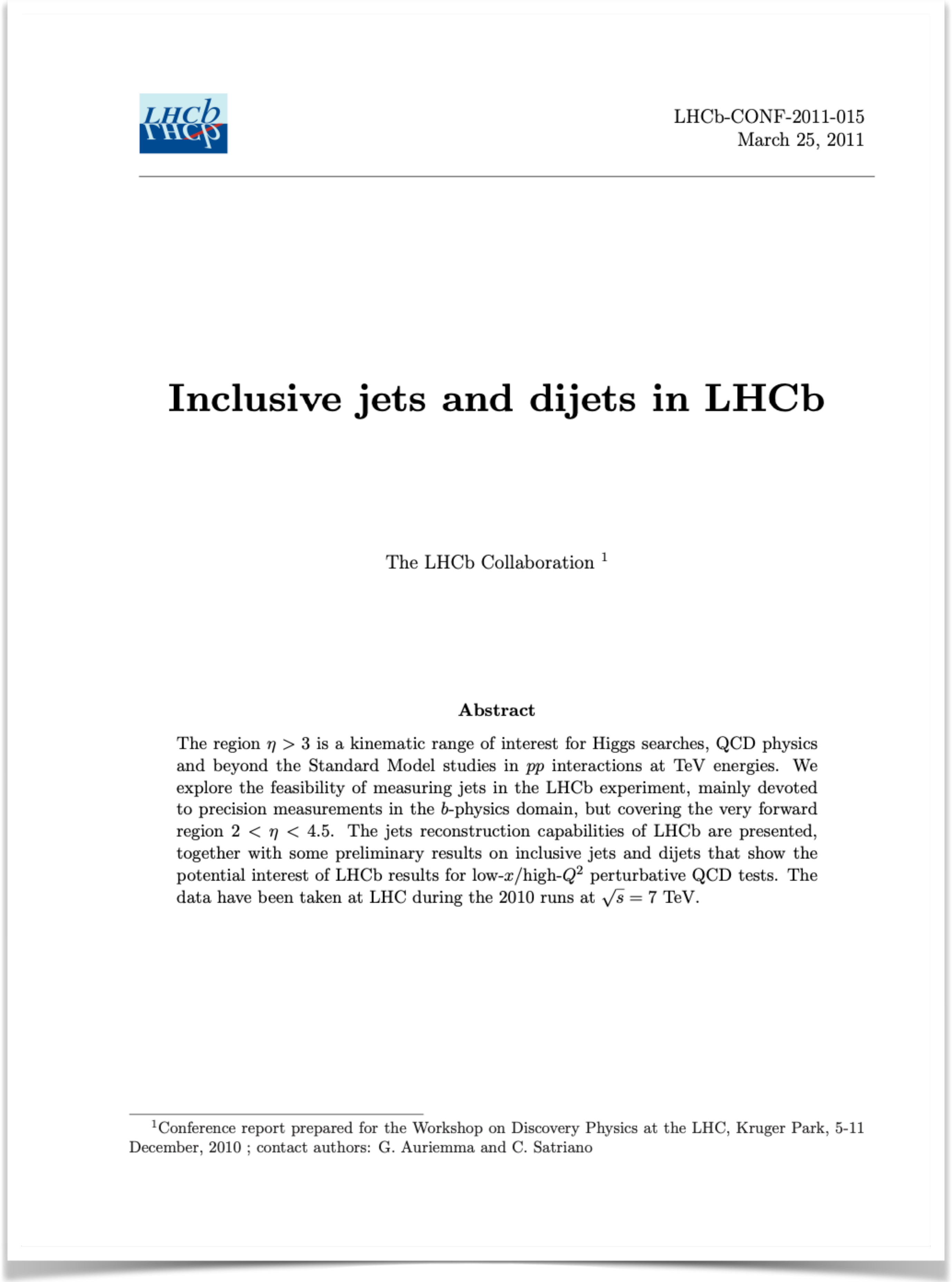
[1] Authors are listed on the following pages.







But not just the obvious



LHCb-CONF-2011-015
March 25, 2011

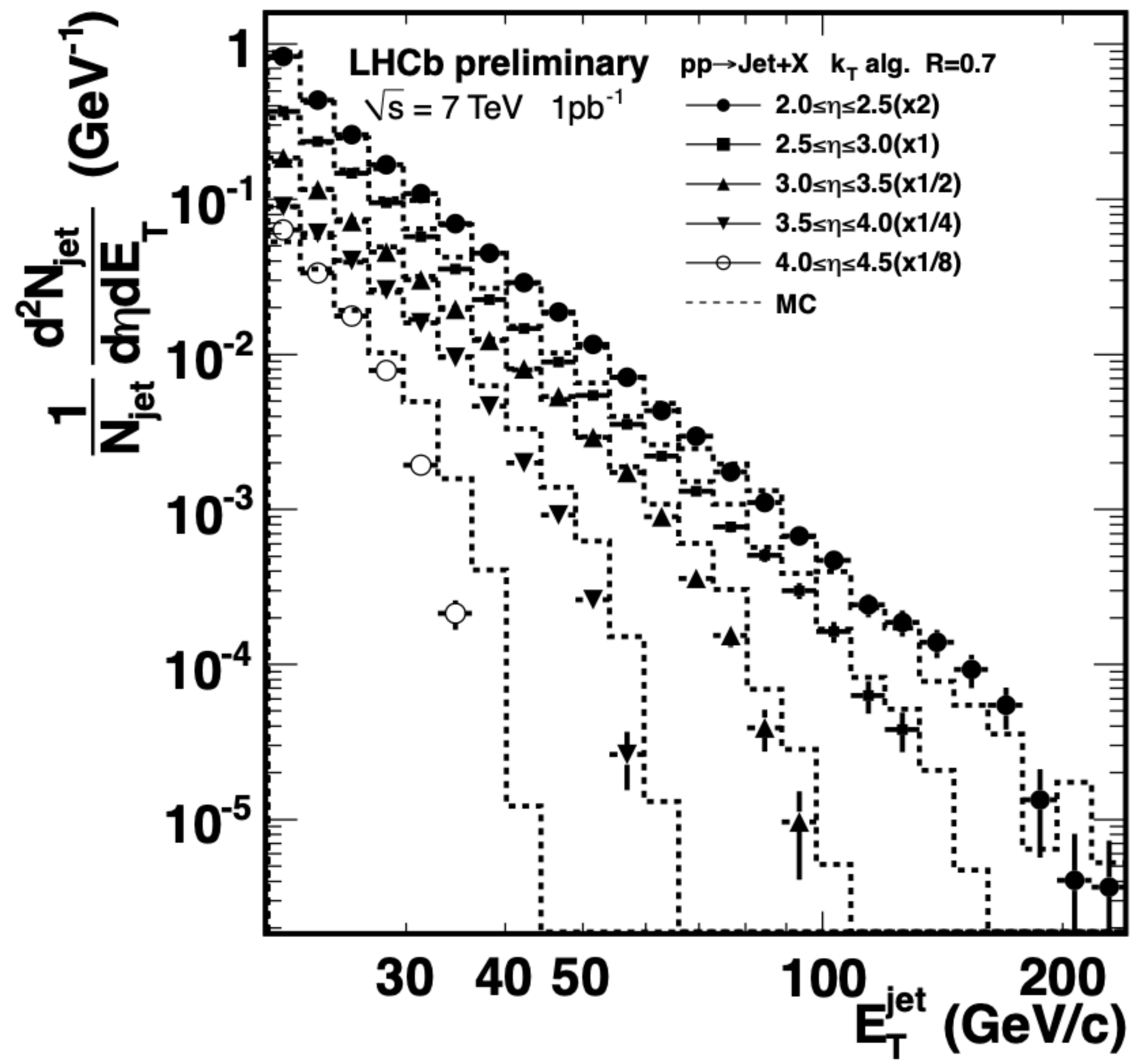
Inclusive jets and dijets in LHCb

The LHCb Collaboration [1]

Abstract

The region $\eta > 3$ is a kinematic range of interest for Higgs searches, QCD physics and beyond the Standard Model studies in *pp* interactions at TeV energies. We explore the feasibility of measuring jets in the LHCb experiment, mainly devoted to precision measurements in the *b*-physics domain, but covering the very forward region $2 < \eta < 4.5$. The jets reconstruction capabilities of LHCb are presented, together with some preliminary results on inclusive jets and dijets that show the potential interest of LHCb results for low-x/high-Q^2 perturbative QCD tests. The data have been taken at LHC during the 2010 runs at $\sqrt{s} = 7$ TeV.

[1] Conference report prepared for the Workshop on Discovery Physics at the LHC, Kruger Park, 5-11 December, 2010 ; contact authors: G. Auriemma and C. Satriano



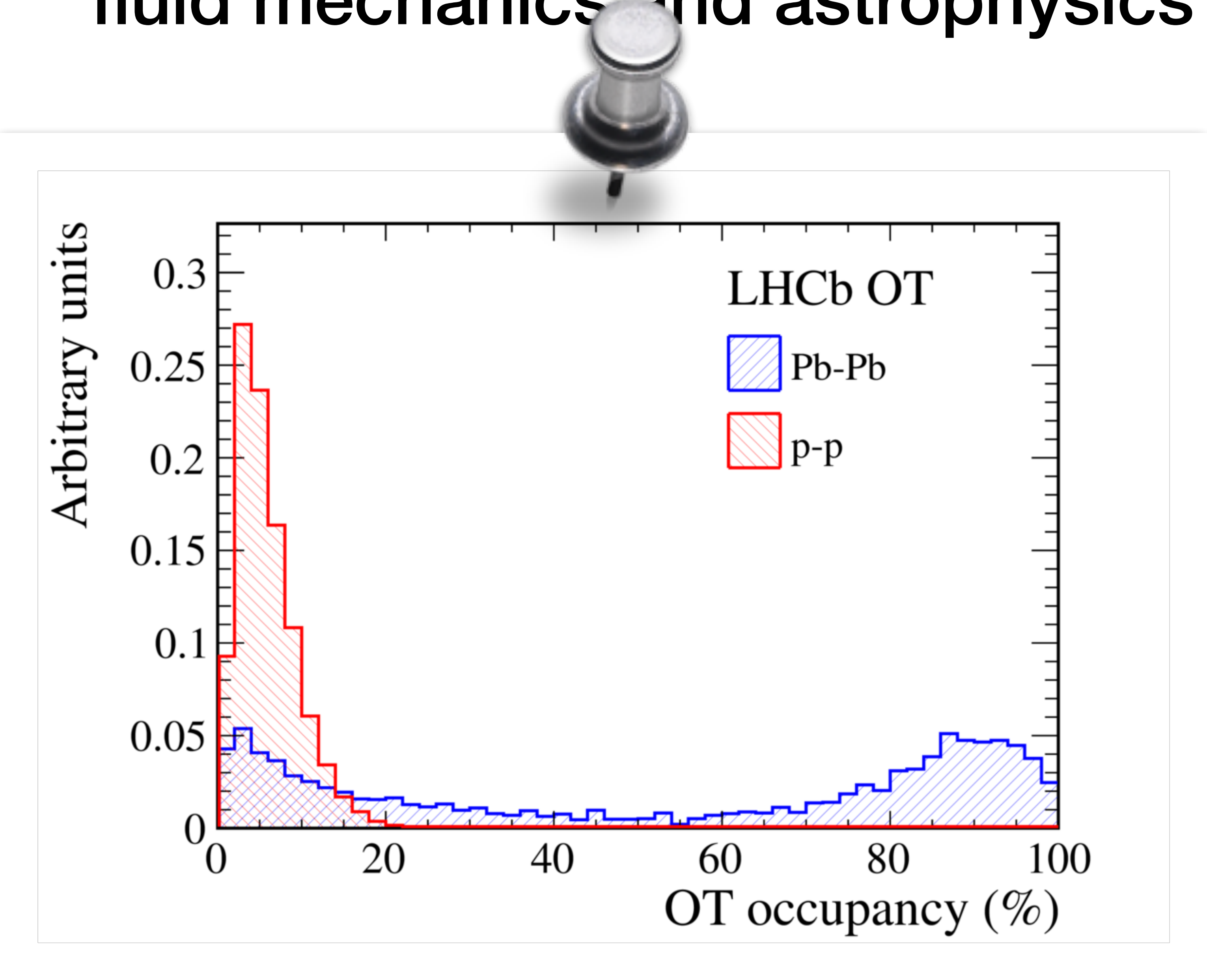
4 Conclusion

This preliminary analysis of $\sim$1 pb^{-1} of LHCb data shows that the inclusive jet distribution and dijet characteristics can be measured by the LHCb experiment in the range $2 \leq \eta \leq 4.5$. Interesting results on perturbative QCD at $x < 10^{-3}$ are expected from the ~ 36 pb^{-1} data obtained in the 2010 runs of LHC.

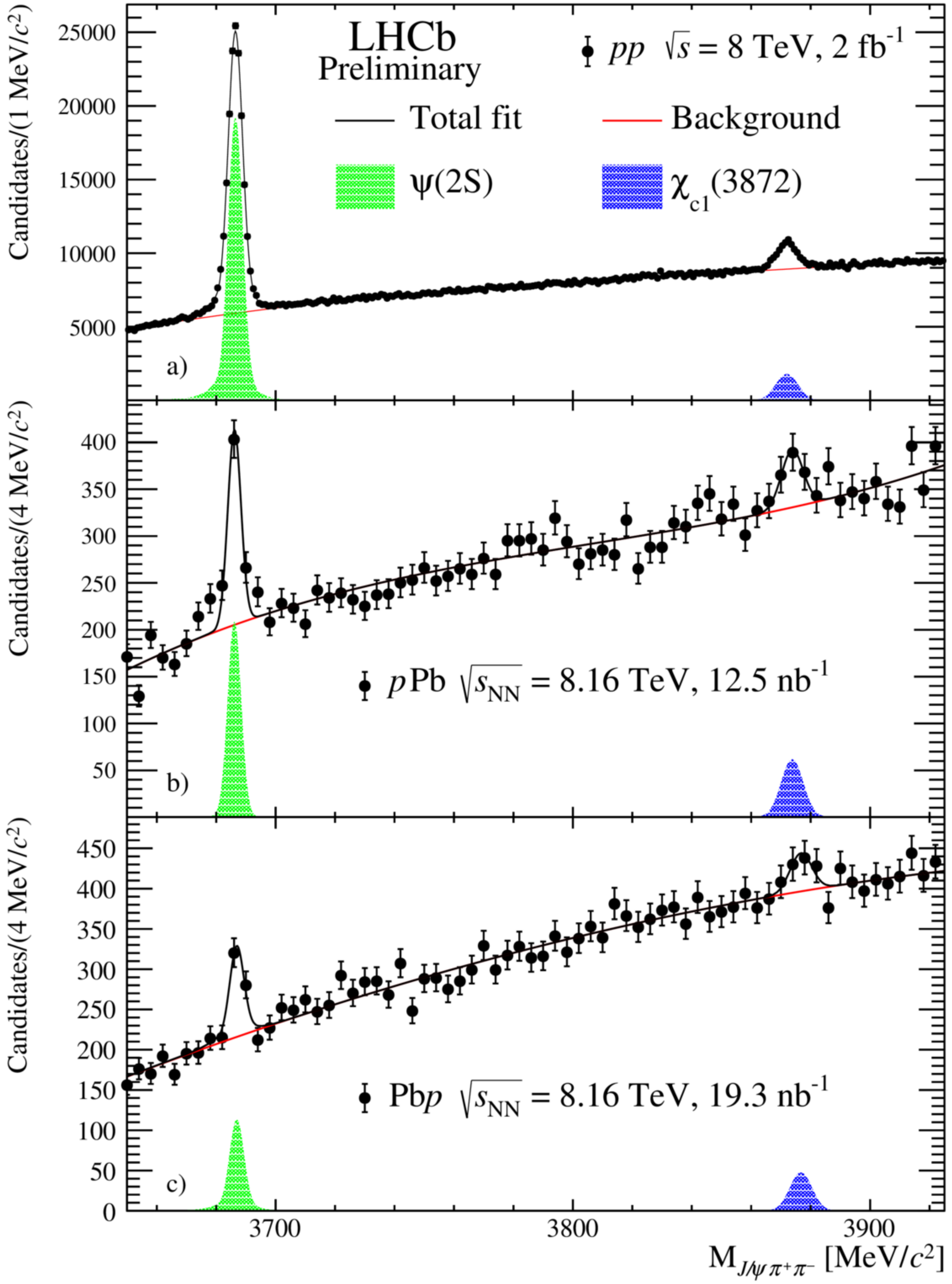
All the information is here : https://lhcbproject.web.cern.ch/Publications/LHCbProjectPublic/Summary_all.html

Fast forward to the future

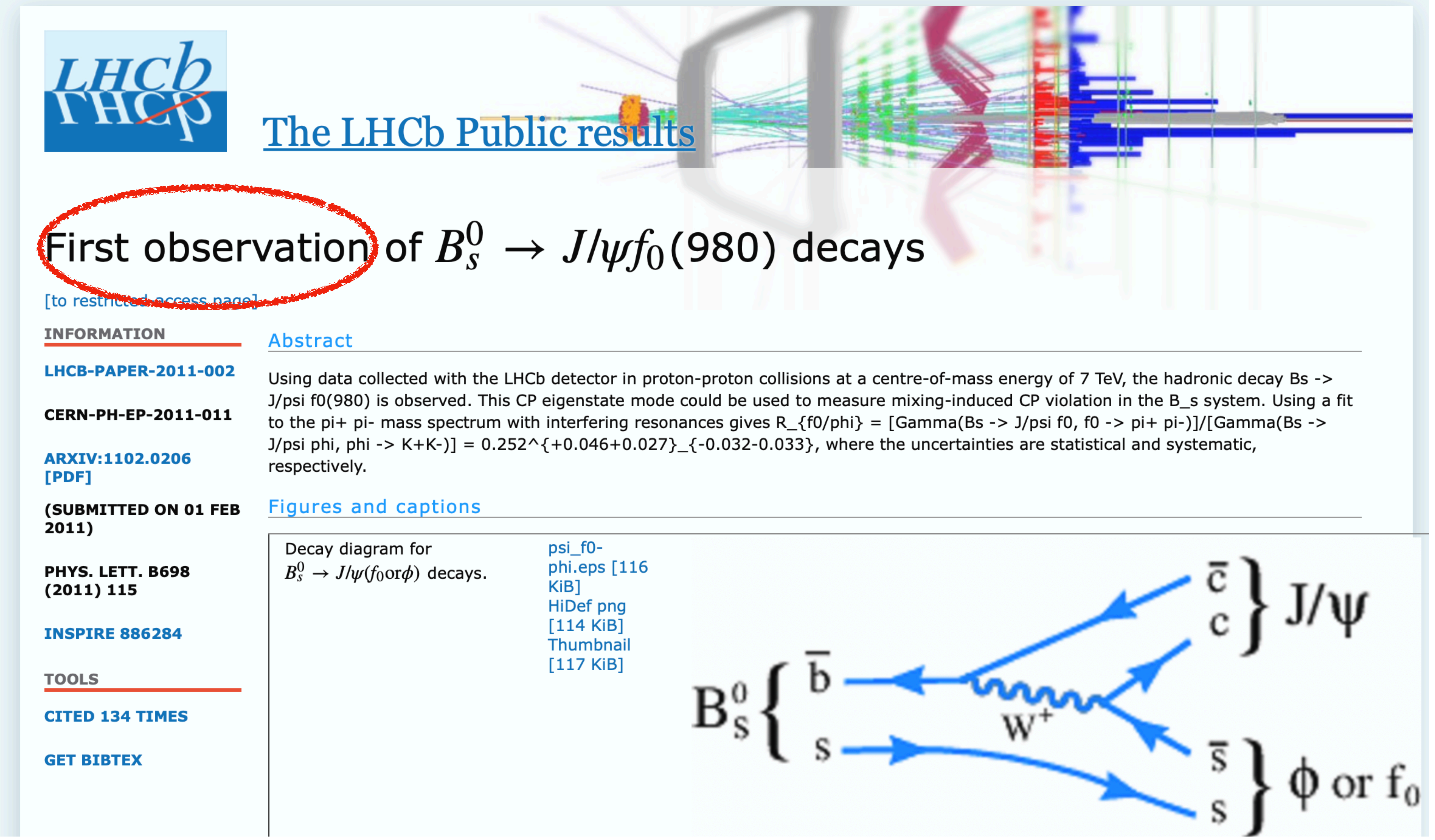
A whole new physics programme opened up !
A field which is close to nuclear physics, fluid mechanics and astrophysics



Big fan of the IFT group
except for the definition of centrality



Let's say you want to go one step deeper?



[The LHCb Public results]

First observation of $B_s^0 \to J/\psi f_0(980)$ decays

[to restricted-access page]

INFORMATION

LHCB-PAPER-2011-002

CERN-PH-EP-2011-011

ARXIV:1102.0206 [PDF]

(SUBMITTED ON 01 FEB 2011)

PHYS. LETT. B698 (2011) 115

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TOOLS

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Abstract

Using data collected with the LHCb detector in proton-proton collisions at a centre-of-mass energy of 7 TeV, the hadronic decay Bs -> J/psi f0(980) is observed. This CP eigenstate mode could be used to measure mixing-induced CP violation in the B_s system. Using a fit to the pi+ pi- mass spectrum with interfering resonances gives R_{f0/phi} = [Gamma(Bs -> J/psi f0, f0 -> pi+ pi-)]/[Gamma(Bs -> J/psi phi, phi -> K+K-)] = 0.252^{+0.046+0.027}_{-0.032-0.033}, where the uncertainties are statistical and systematic, respectively.

Figures and captions

Decay diagram for $B_s^0 \to J/\psi(f_0 \text{or} \phi)$ decays.

psi_f0-phi.eps [116 KiB]
HiDef png [114 KiB]
Thumbnail [117 KiB]

LHCb-ANA-2011-049
July 13, 2011
Version 8

Analysis of $\overline{B}_s^0 \to J/\psi\,(\pi^+\pi^-$ and $K^+K^-)$ and the first observation of $J/\psi f_2'(1525)$

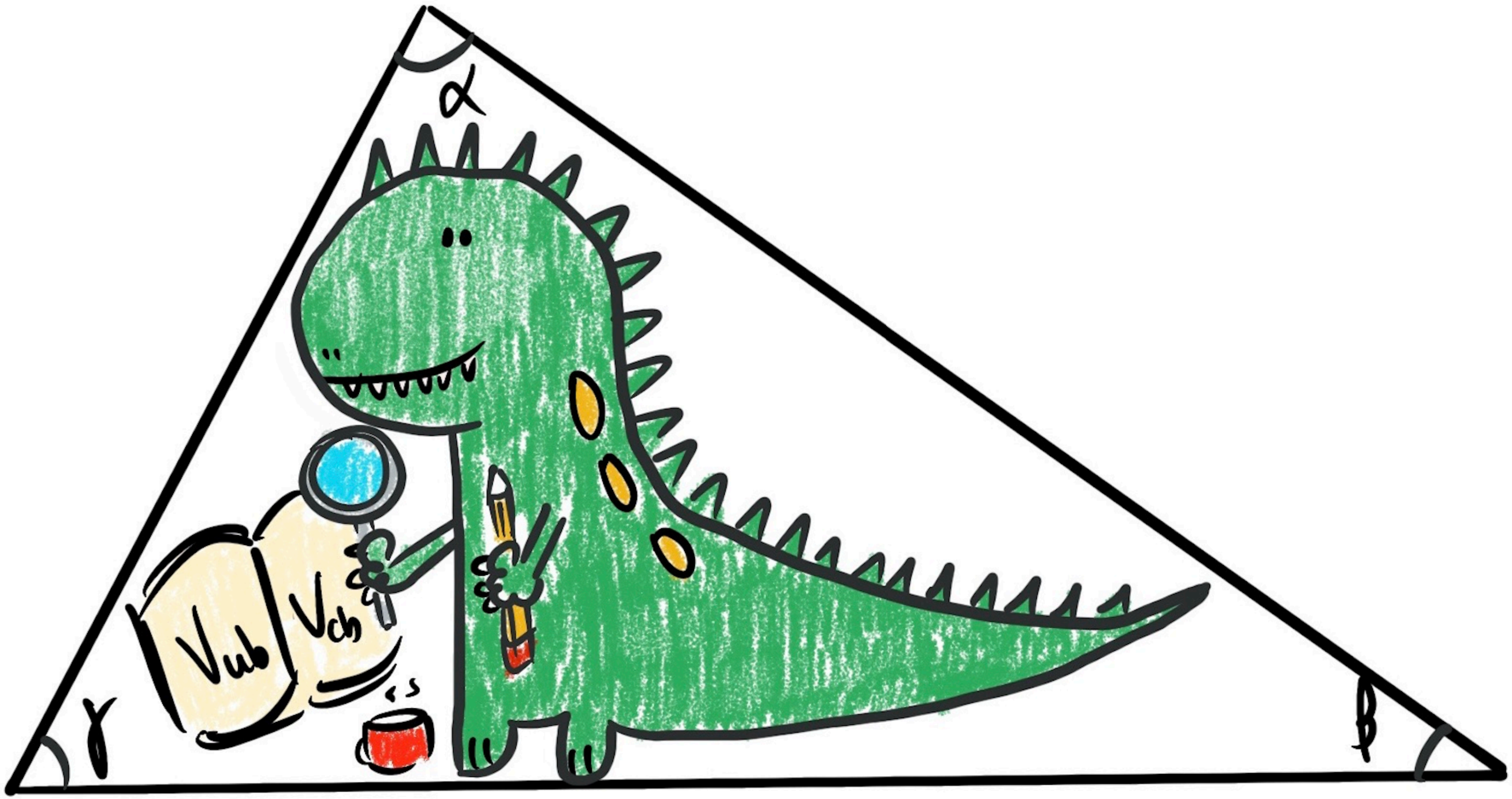
Sheldon Stone, CERN and Syracuse University
Bilas Pal and Liming Zhang, Syracuse University

Abstract

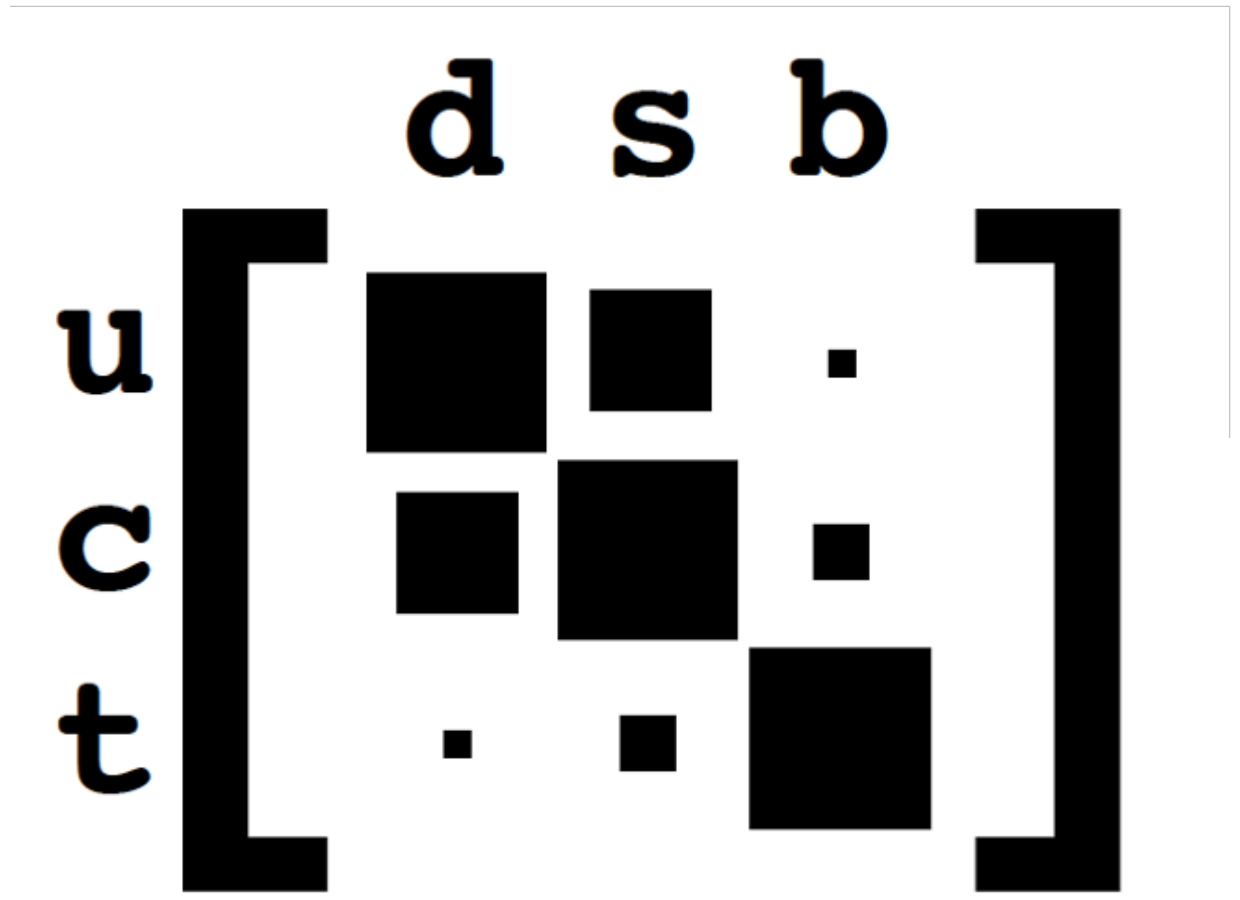
Measurement of mixing induced CP violation in $\overline{B}_s^0$ decays is of prime importance in probing new physics. So far only the channel $\overline{B}_s^0 \to J/\psi\phi$ has been used. Here we investigate possible $\overline{B}_s^0$ CP eigenstates and other modes in the $J/\psi\pi^+\pi^-$ and $J/\psi K^+K^-$ final states. The $\pi^+\pi^-$ mass spectrum has a relatively narrow structure peaking near 980 MeV first found by LHCb that we identify as the $f_0(980)$ and show that it is consistent with being pure S-wave. Thus, this is a CP-odd eigenstate. The ratio of rates for $J/\psi f_0(980)$ to $J/\psi\phi$, with $f_0(980) \to \pi^+\pi^-$ in a ± 90 MeV mass window around the $f_0(980)$ and $\phi \to K^+K^-$ is $R^{f_0}_{\text{effective}} = (21.7 \pm 1.1 \pm 1.0)\%$. Other structures at higher mass are shown to contain D-wave. The K^+K^- spectrum besides a large ϕ component has a shoulder at masses just above the ϕ, and significant $f_2'(1525)$. The mass and width are found to be $1532 \pm 5 \pm 2$ MeV and 90^{+16}_{-14} MeV, respectively. The ratio of rates for $J/\psi f_2'(1525)$ to $J/\psi\phi$, with $f_2'(1525) \to K^+K^-$ in a ± 125 MeV mass window around the $f_2'(1525)$ is $R^{f_2'}_{\text{effective}} = (19.4 \pm 1.8 \pm 1.1)\%$. These new channels may be useful for different aspects of CP violation measurements.

LHCb-ANA-2011-049 13/07/2011

32 pages !


α
γ
β
Vub
Vcb

CP violation

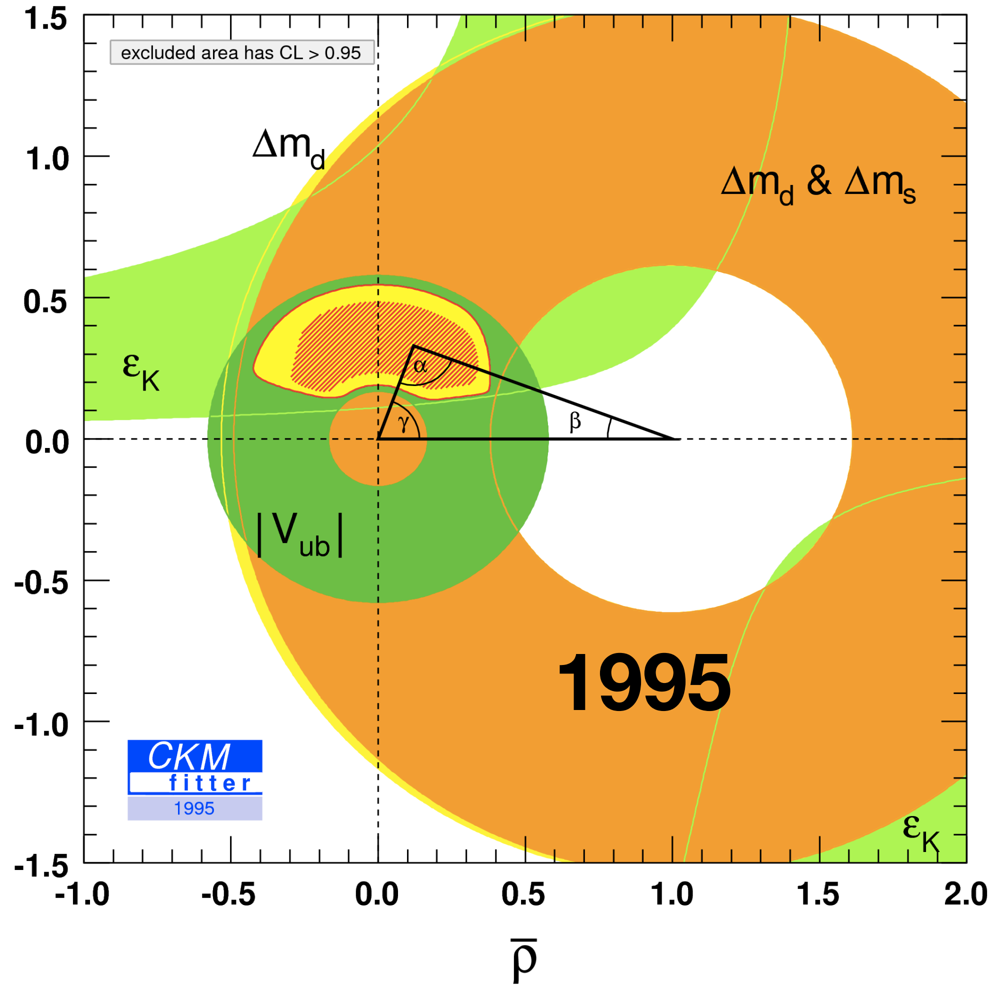


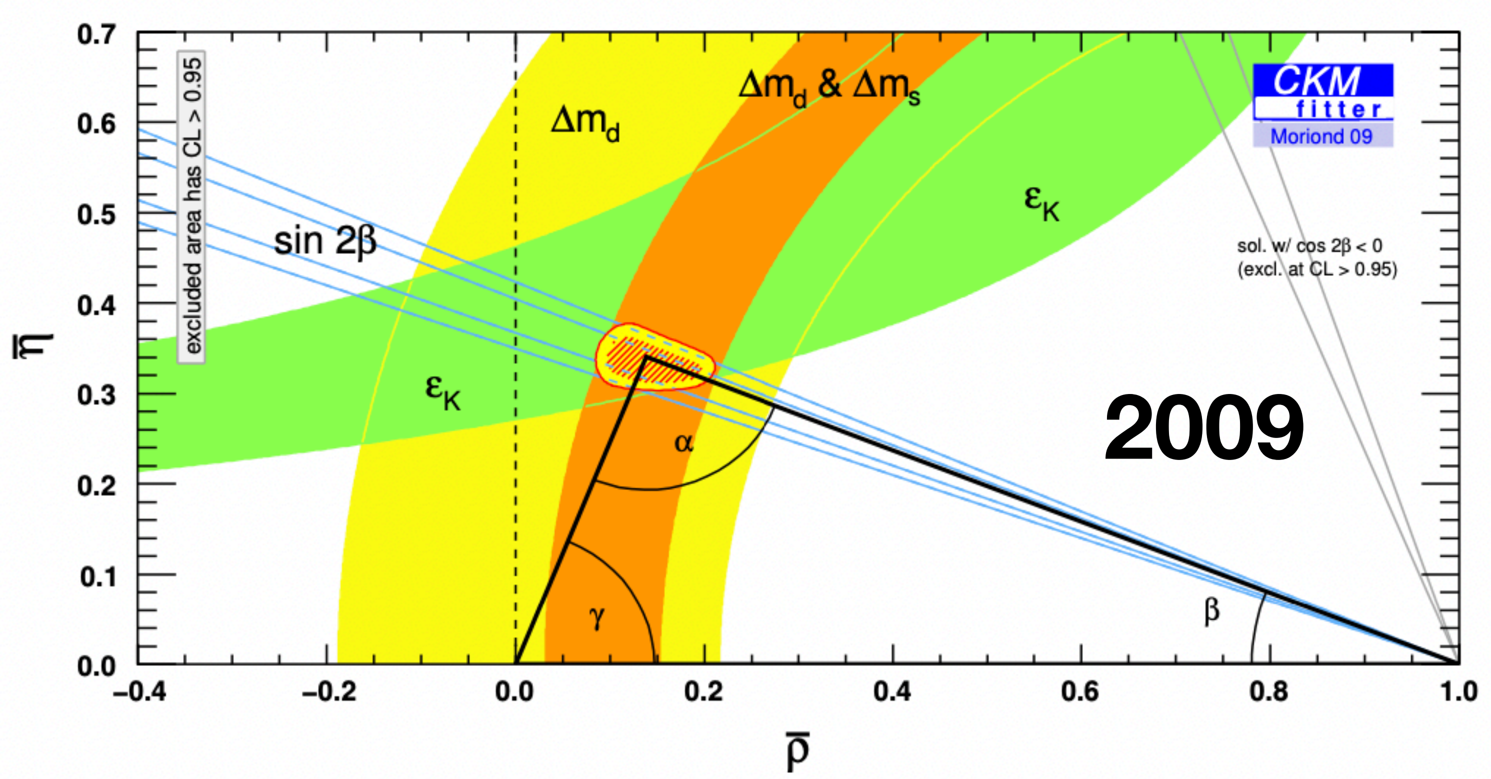
$$V_{\rm CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Origin of CP violation in the SM

Build Unitarity triangle

Parametrisation

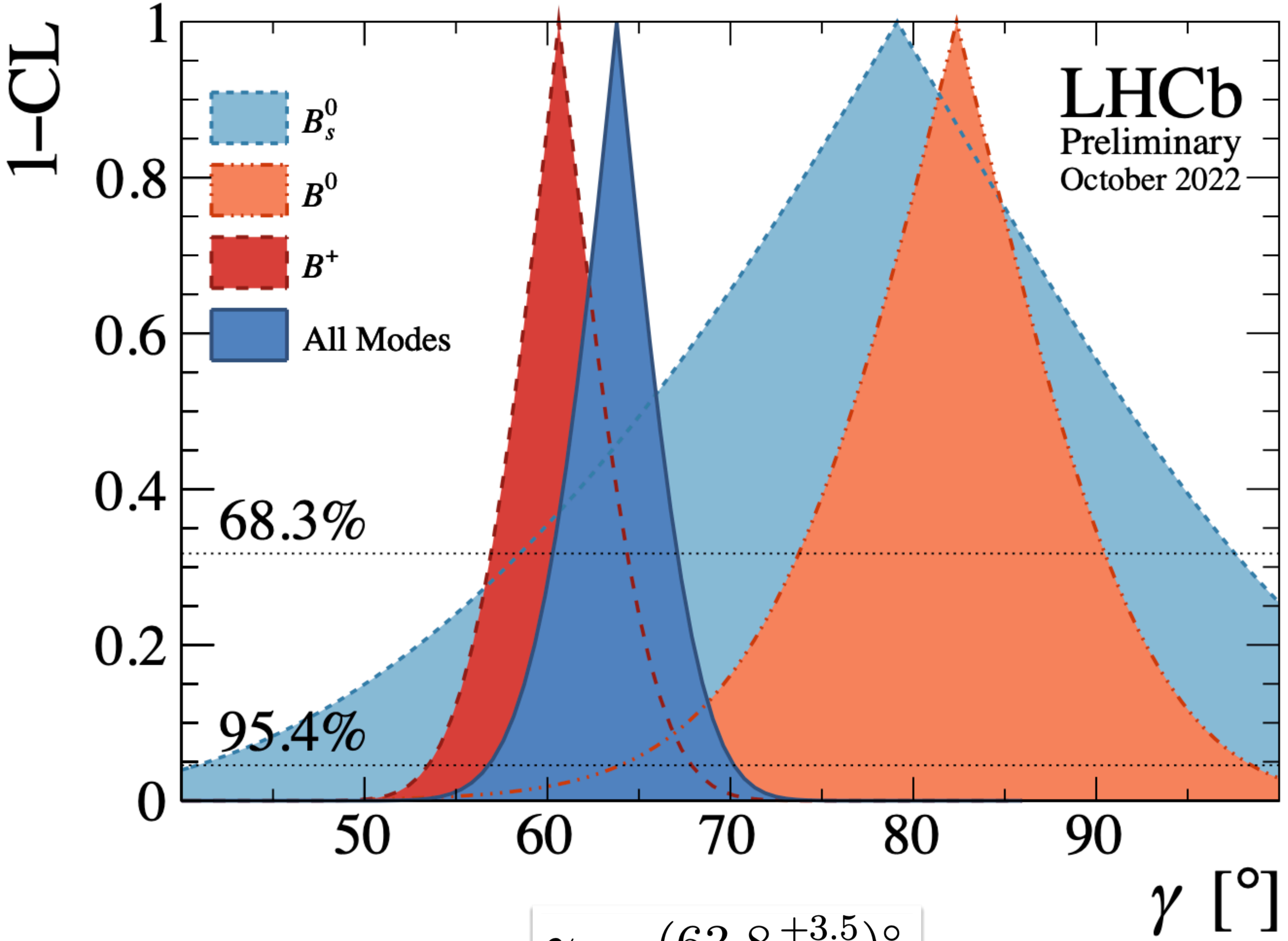




(b)

$$\begin{pmatrix} 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda+\frac{1}{2}A^2\lambda^5[1-2(\rho+i\eta)] & 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4(1+4A^2) & A\lambda^2 \\ A\lambda^3[1-(1-\frac{1}{2}\lambda^2)(\rho+i\eta)] & -A\lambda^2+\frac{1}{2}A\lambda^4[1-2(\rho+i\eta)] & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix}$$

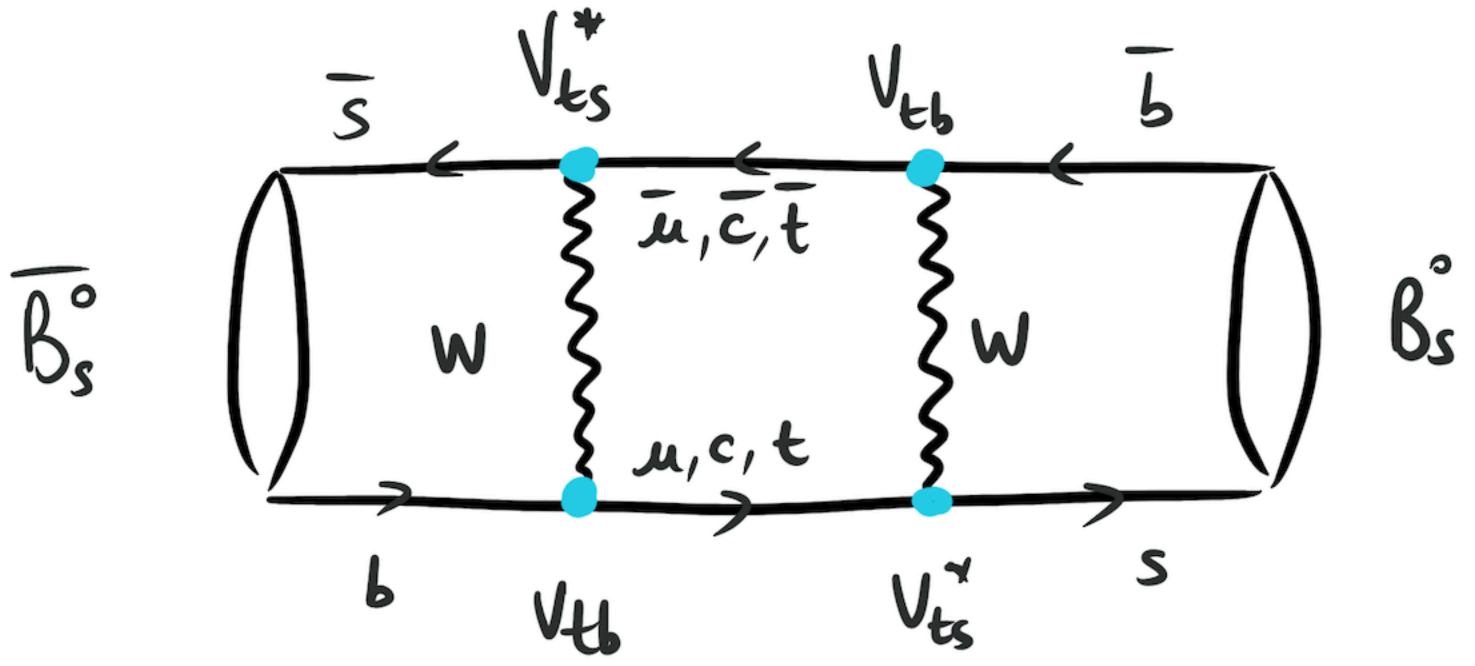
Goal: constrain sides and angles.

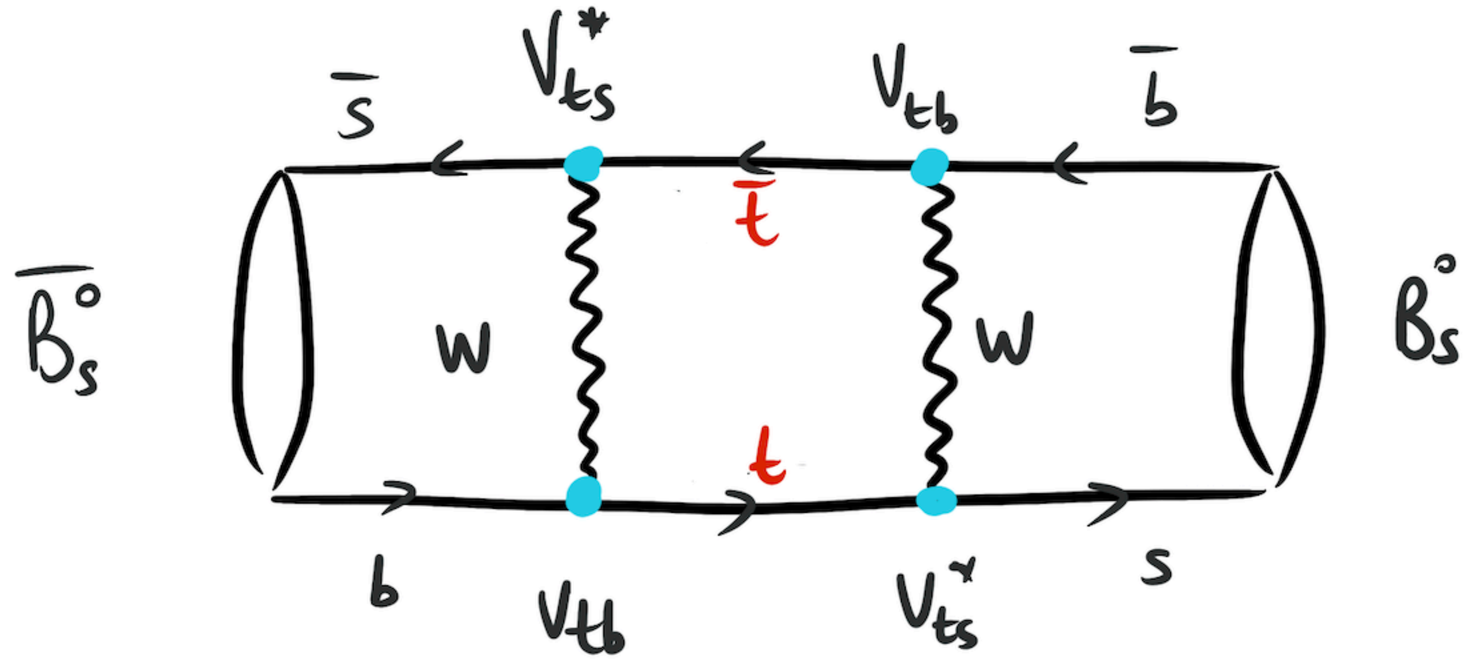


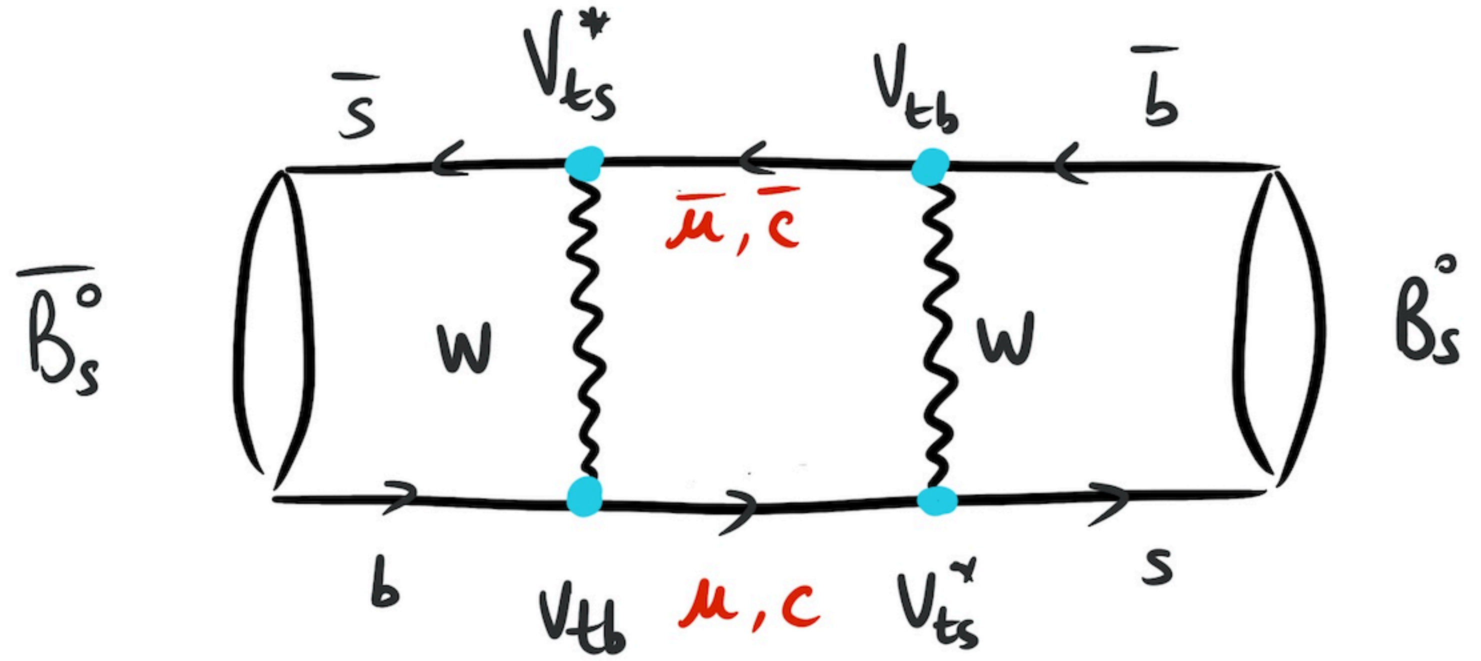
$$\gamma = (63.8\,^{+3.5}_{-3.7})^\circ$$

https://cds.cern.ch/record/2838029/files/LHCb-CONF-2022-002.pdf

B_s mixing

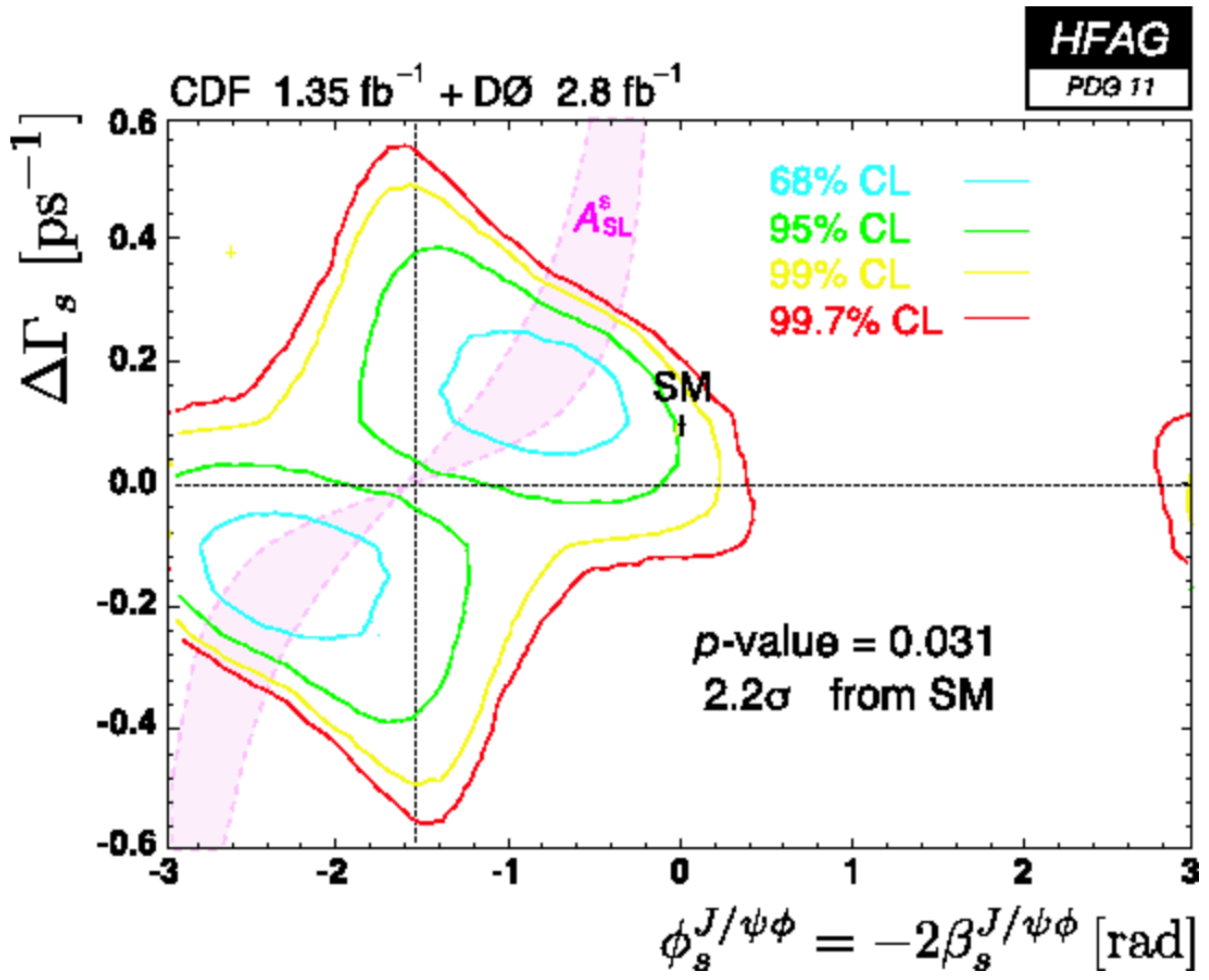




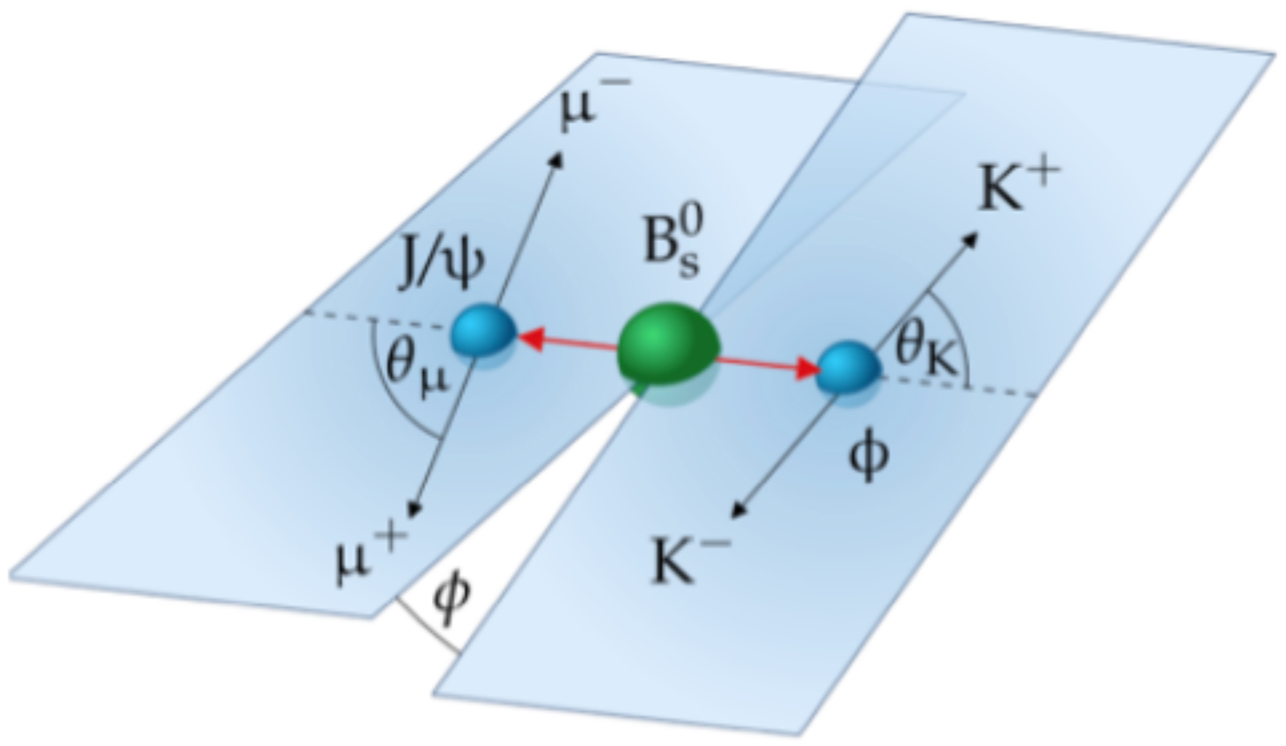


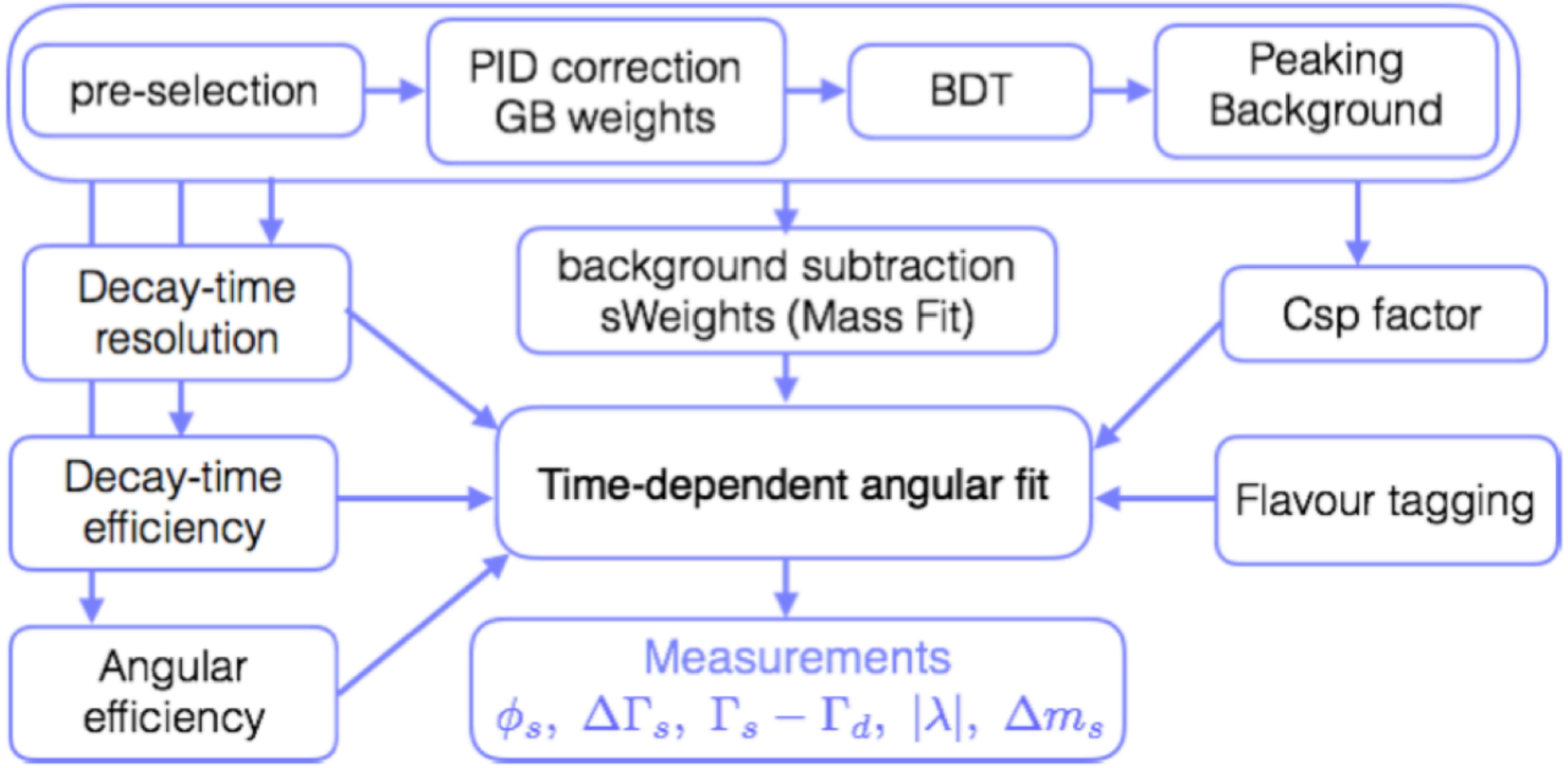
$$i\frac{d}{dt}\begin{pmatrix}|B_s(t)\rangle \\ |\bar{B}_s(t)\rangle\end{pmatrix} = \left(\begin{bmatrix}M_{11} & M_{12} \\ M_{12}^* & M_{22}\end{bmatrix} - \frac{i}{2}\begin{bmatrix}\Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22}\end{bmatrix}\right)\begin{pmatrix}|B_s(t)\rangle \\ |\bar{B}_s(t)\rangle\end{pmatrix}$$

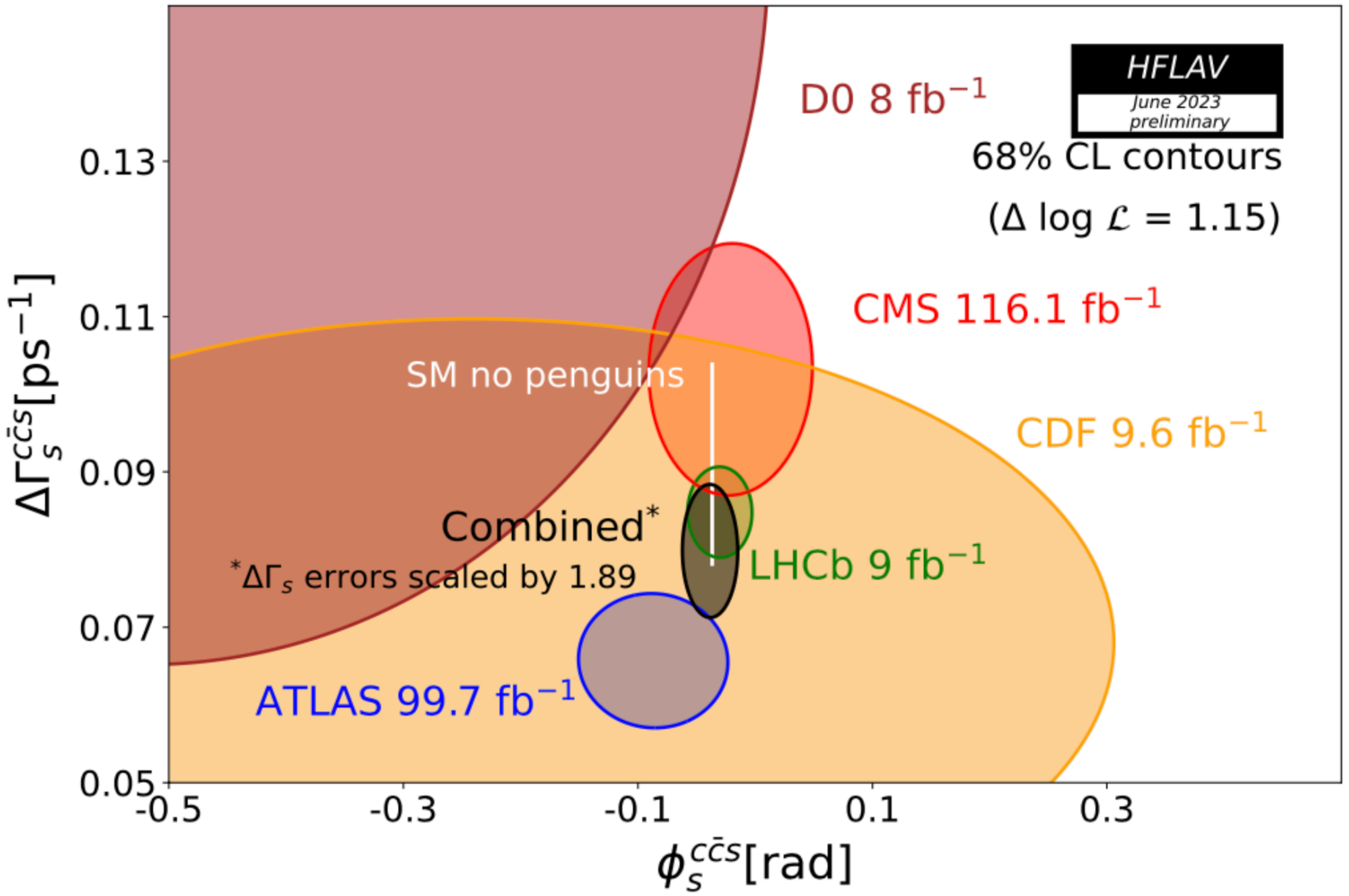
$\Delta m_s = M_H - M_L \qquad \Delta\Gamma_s = \Gamma_H - \Gamma_L \qquad \Gamma_s = (\Gamma_H + \Gamma_L)/2$



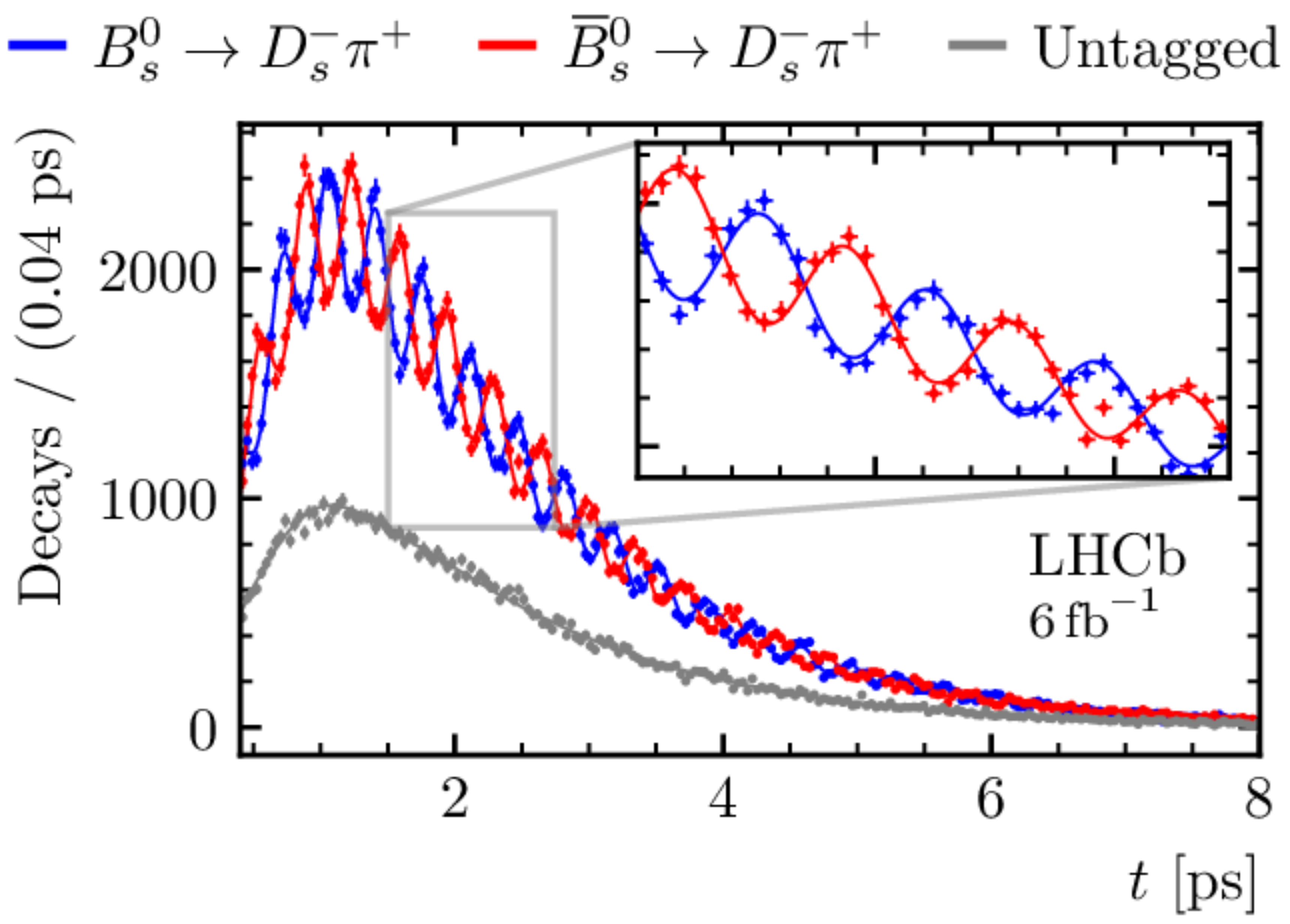
$$\frac{d^4\Gamma(t)}{dt\,d\cos\theta_K\,d\cos\theta_l\,d\phi} = \sum_{k=1}^{10} N_k h_k(t) f_k(\theta_K, \theta_l, \phi)$$





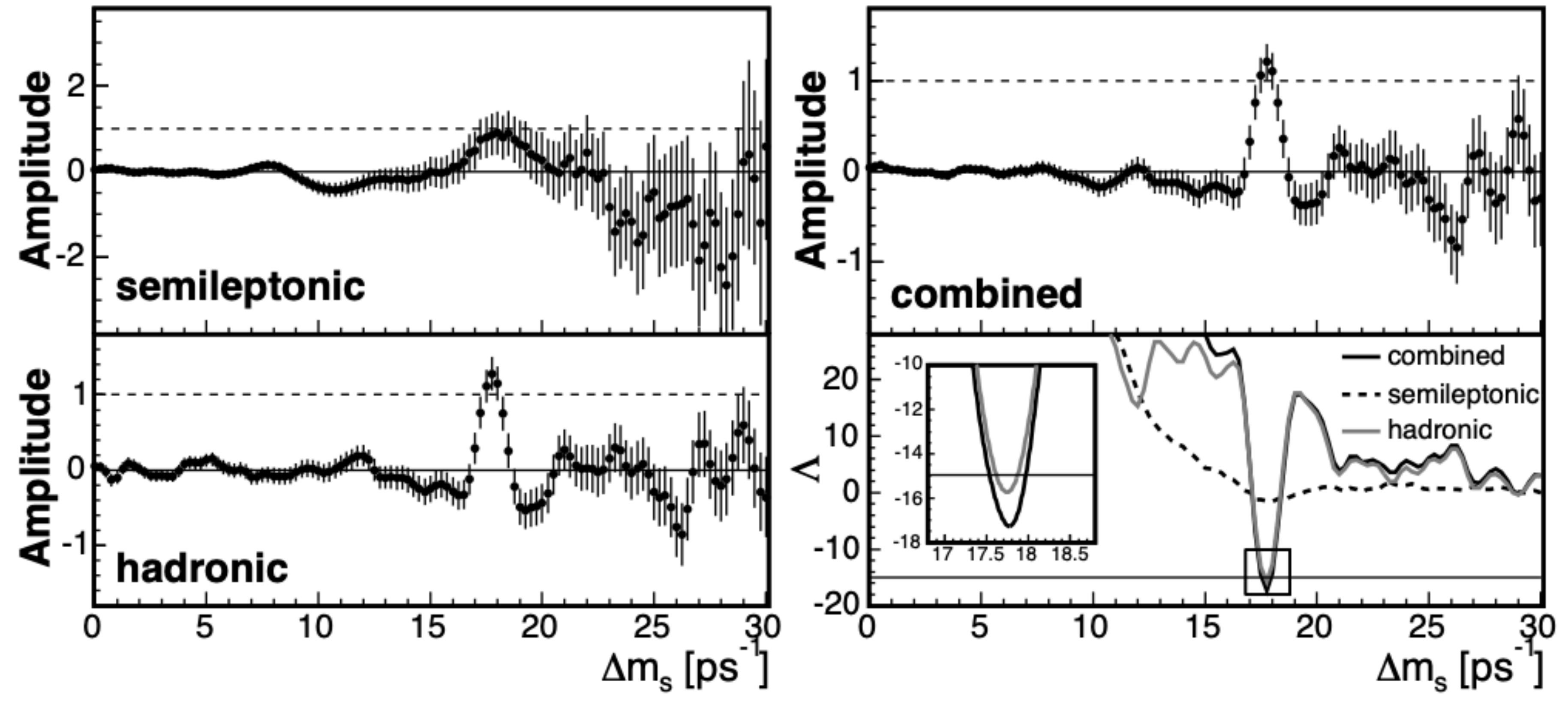


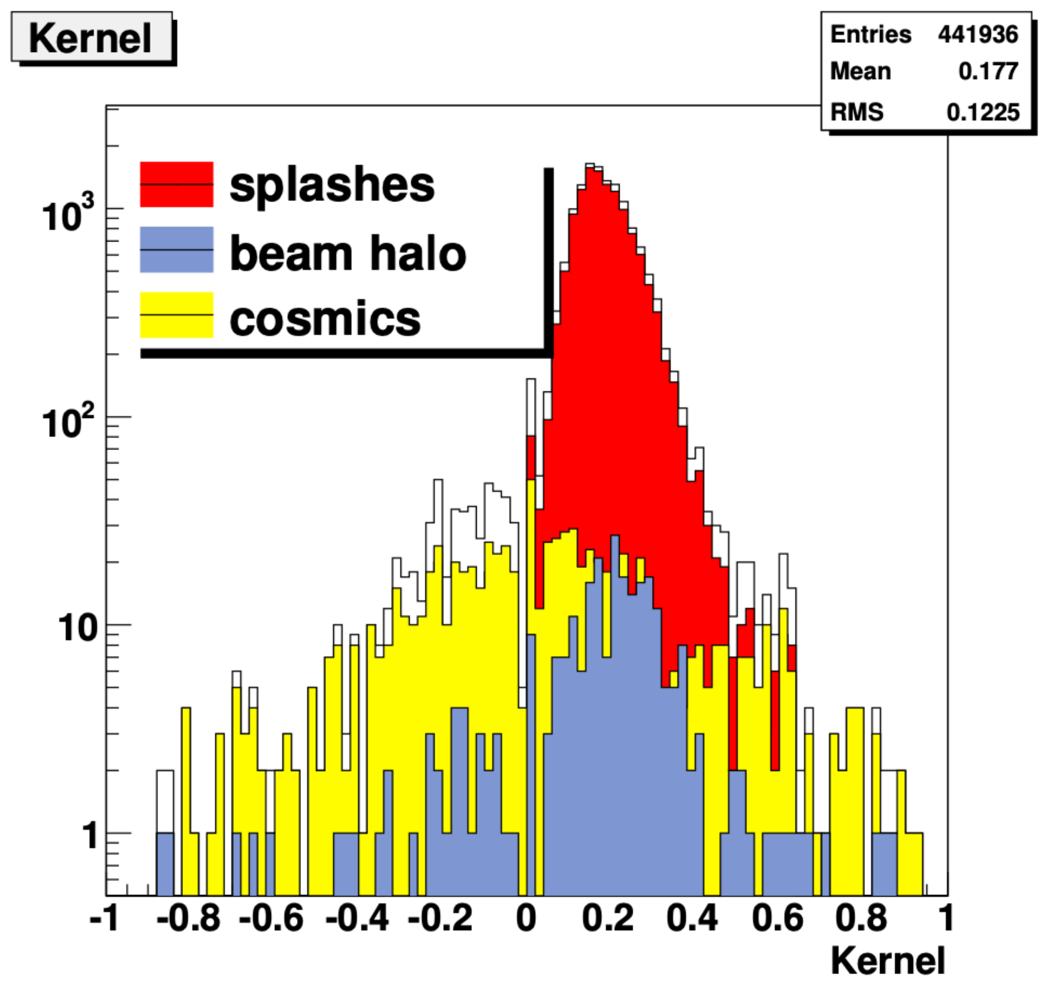
Things don't always go according to plan



What I thought the cool plot of my PhD would look like

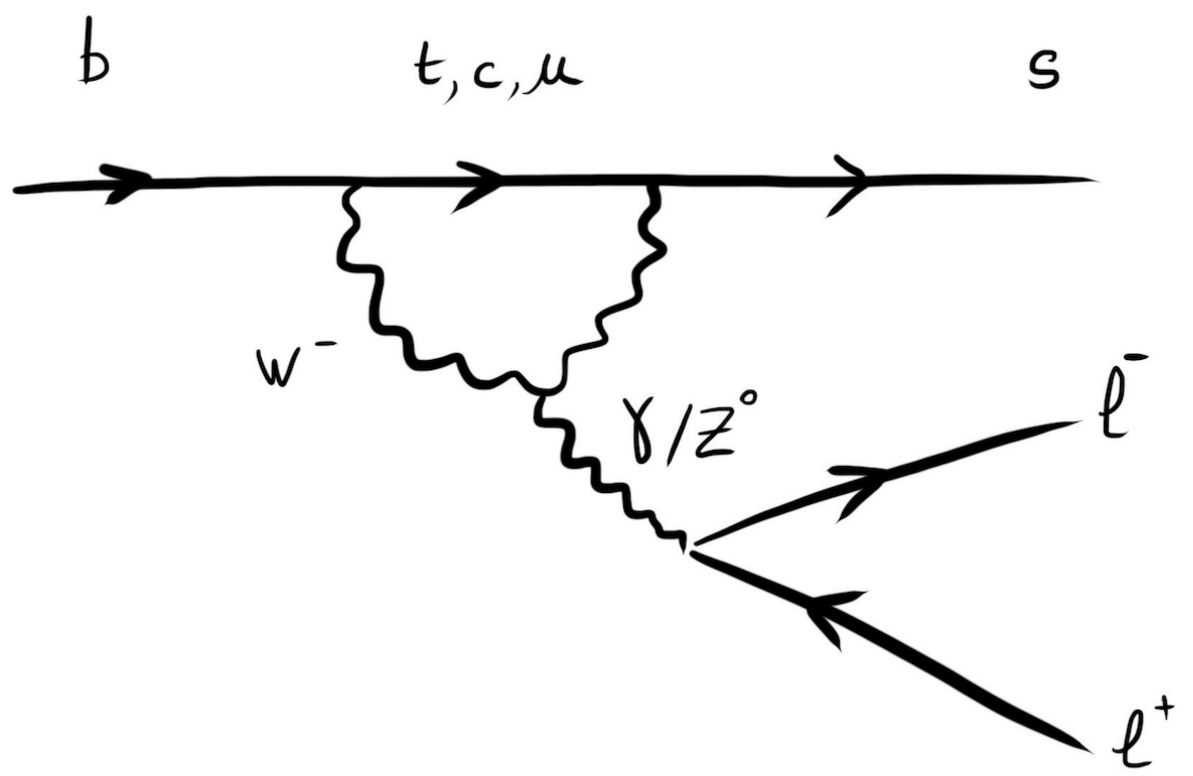
But there was competition in the world [CDF in this case] !



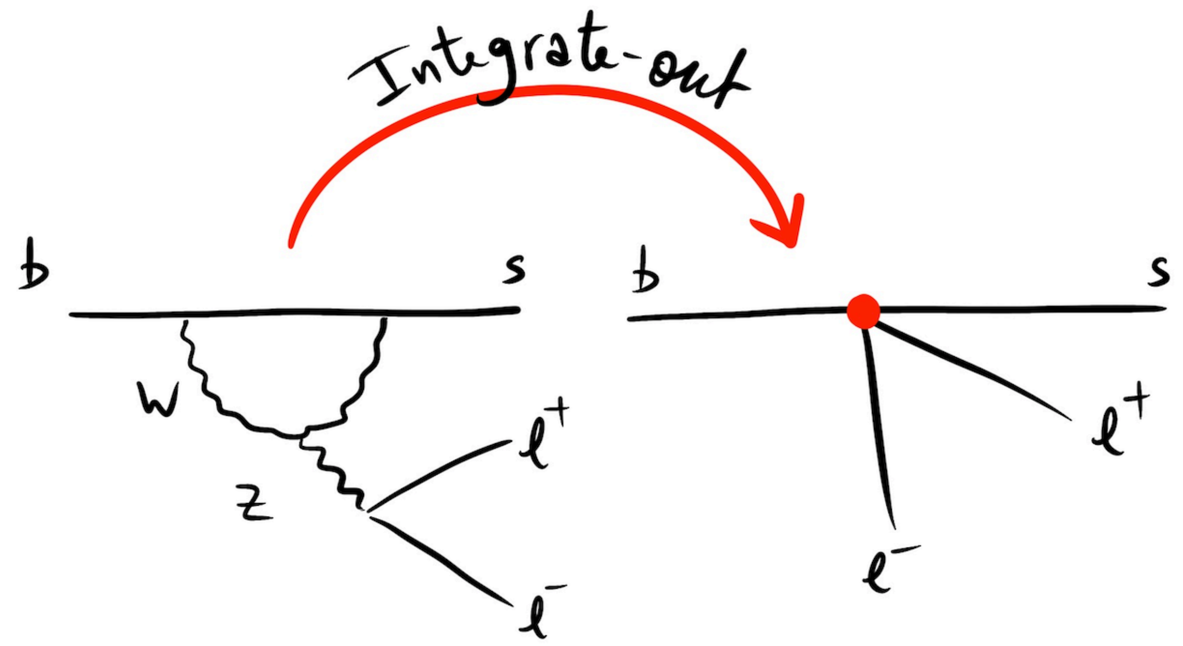


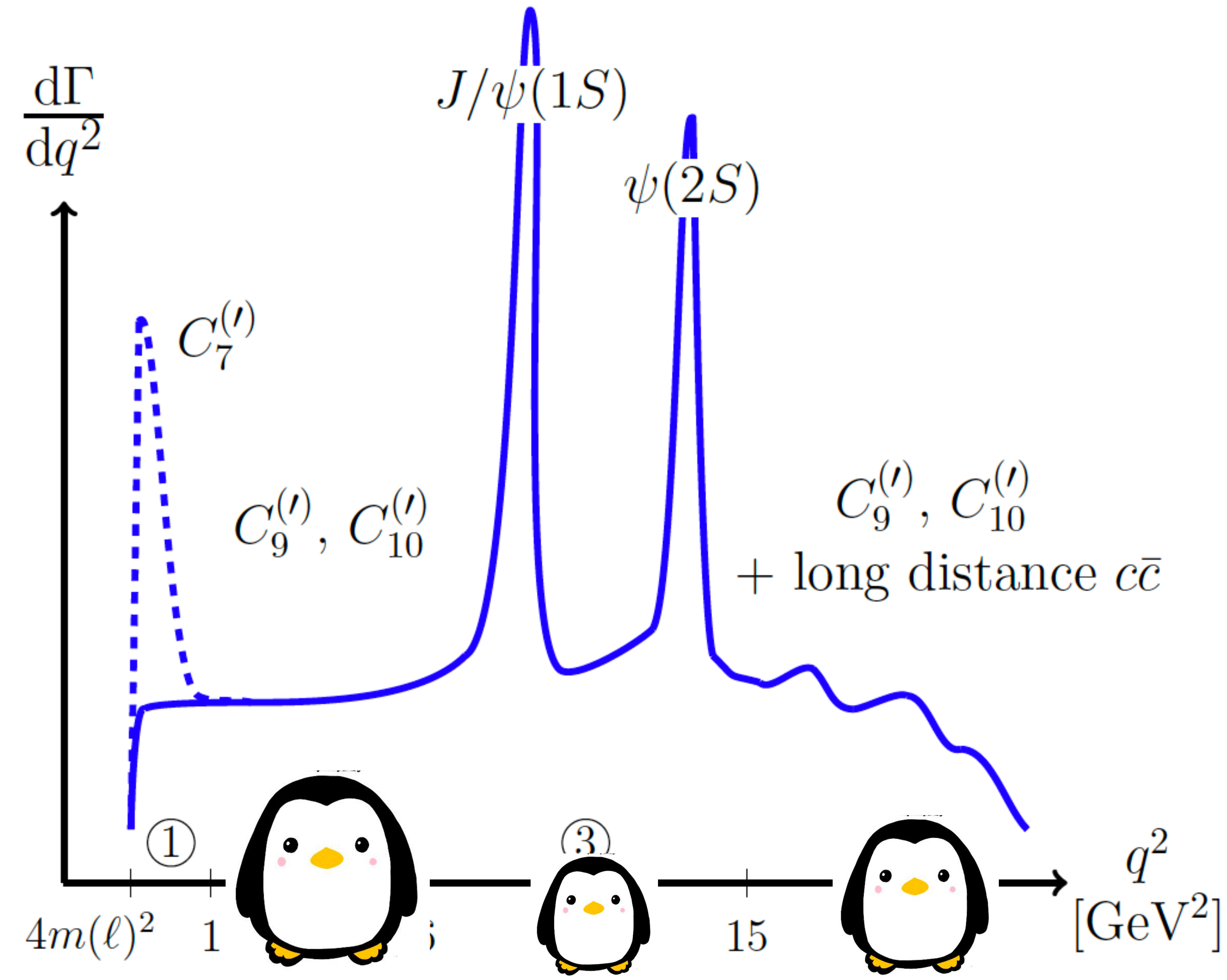
What I ended up being a plot I was proud of

Multiscale problem



EFT





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

$B \to K^*\mu\mu$

Really great summary !

General overview

- Each of these analyses have to tackle the same challenges

	Binned fit	Amplitude ansatz	Z- expansion	Dispersion relation
q^2 **range** $(\mathrm{GeV}^2/\mathrm{c}^4)$	$0.1 - 19.0$	$1.25 - 8.0$ $11.0 - 12.5$	$1.1 - 8.0$ $11.0 - 12.5$	$0.1 - 18.0$
$B \to K^*$ **form factors**	N/A	N/A	External inputs + constrained	External inputs + constrained
$m(K\pi)$ **line shape**	Parameterized	Integrated over	Parameterized	Integrated over
Exotic contributions e.g. $B^0 \to Z(4430)K$	N/A	N/A	Ignored (systematic)	Ignored (systematic)
Outputs	A_i, S_i $\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-)$ $A_{CP}(B^0 \to K^{*0}\mu^+\mu^-)$	**Polynomial coefficients**	$C_{9,10}^{(\prime)}$ **+ Polynomial coefficients**	$C_{9,10}^{(\prime)}$ C_9^τ **+ Non-local phases & magnitudes**

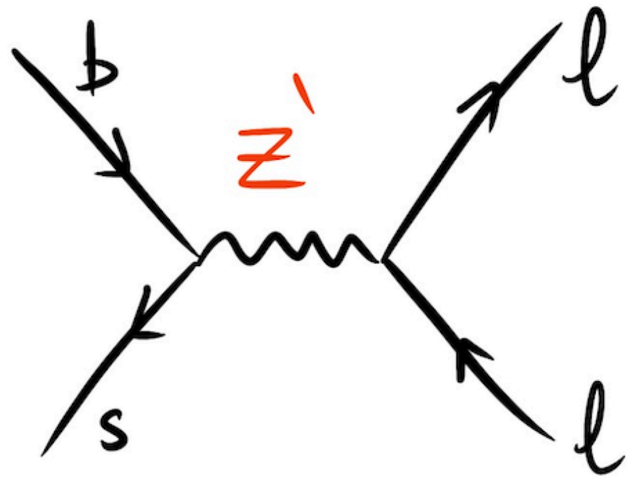
$B_q^0 \to \ell^+ \ell^-$

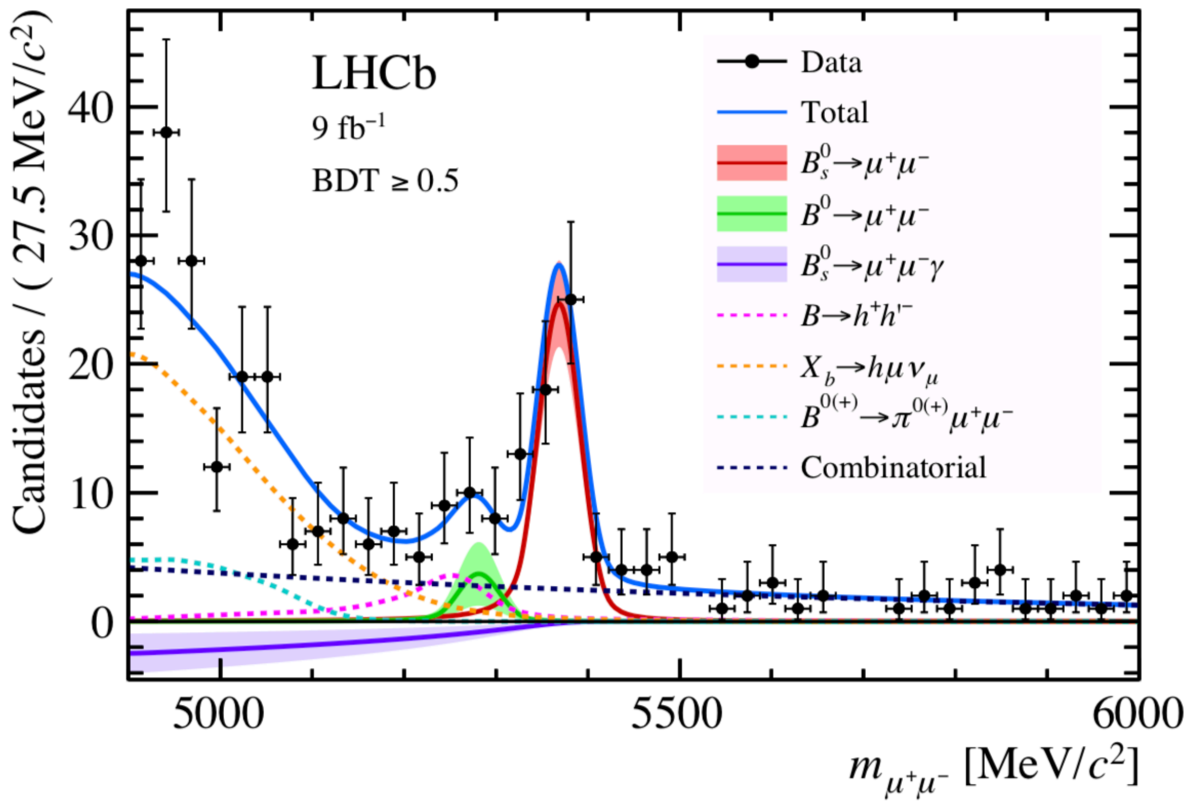
Branching fraction prediction in the SM:

$$\bar{\mathcal{B}}_{q\ell} = \frac{|N|^2 M_{B_q}^3 f_{B_q}^2}{8\pi \Gamma_H^q} \beta_{q\ell}\, r_{q\ell}^2 \,|C_A(\mu_b)|^2 + \mathcal{O}(\alpha_{em})$$

$$r_{q\ell} = \frac{2 m_\ell}{M_{B_q}} \qquad \beta_{q\ell} = \sqrt{1 - r_{q\ell}^2}$$

Theoretically clean observable

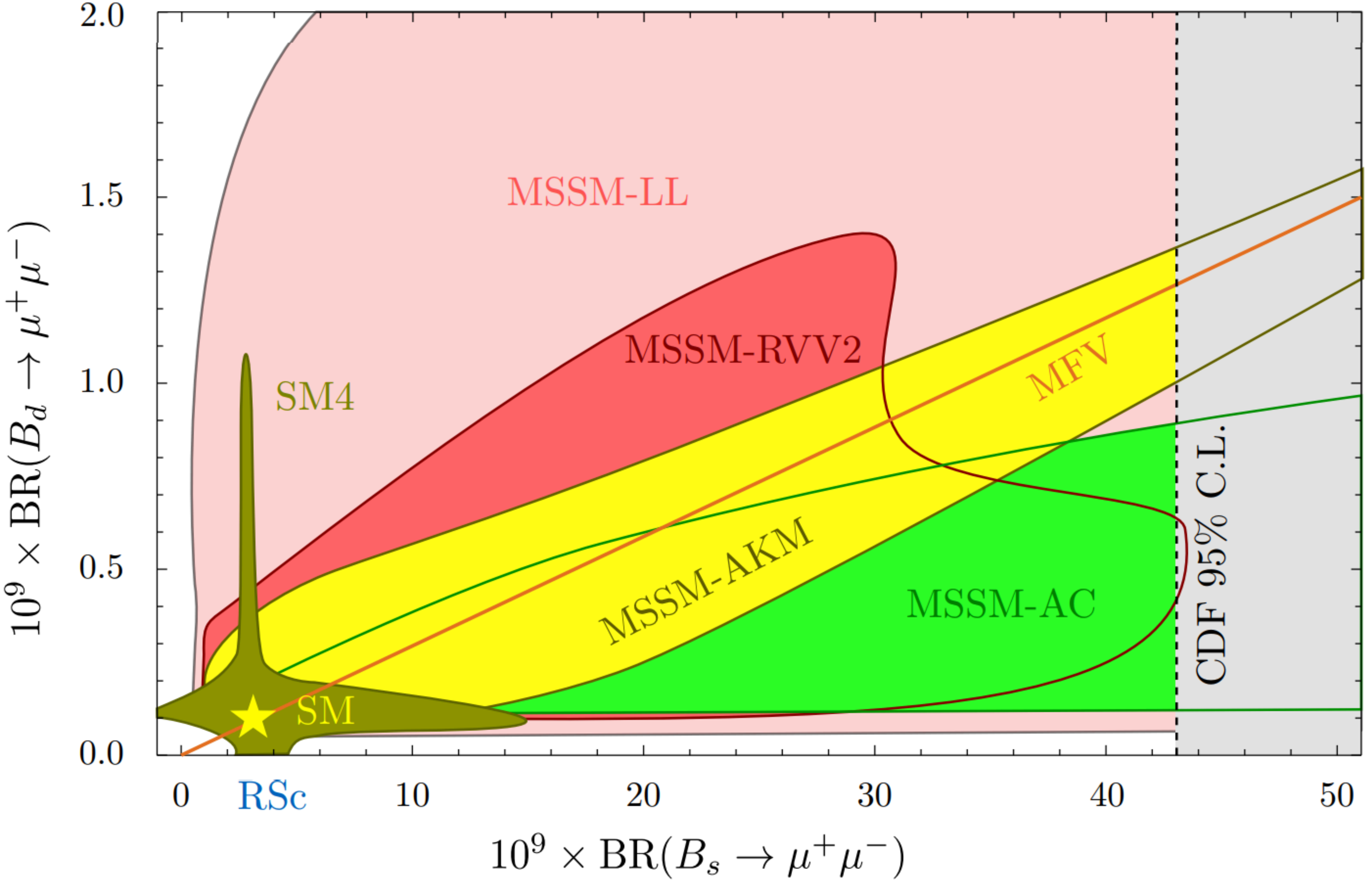




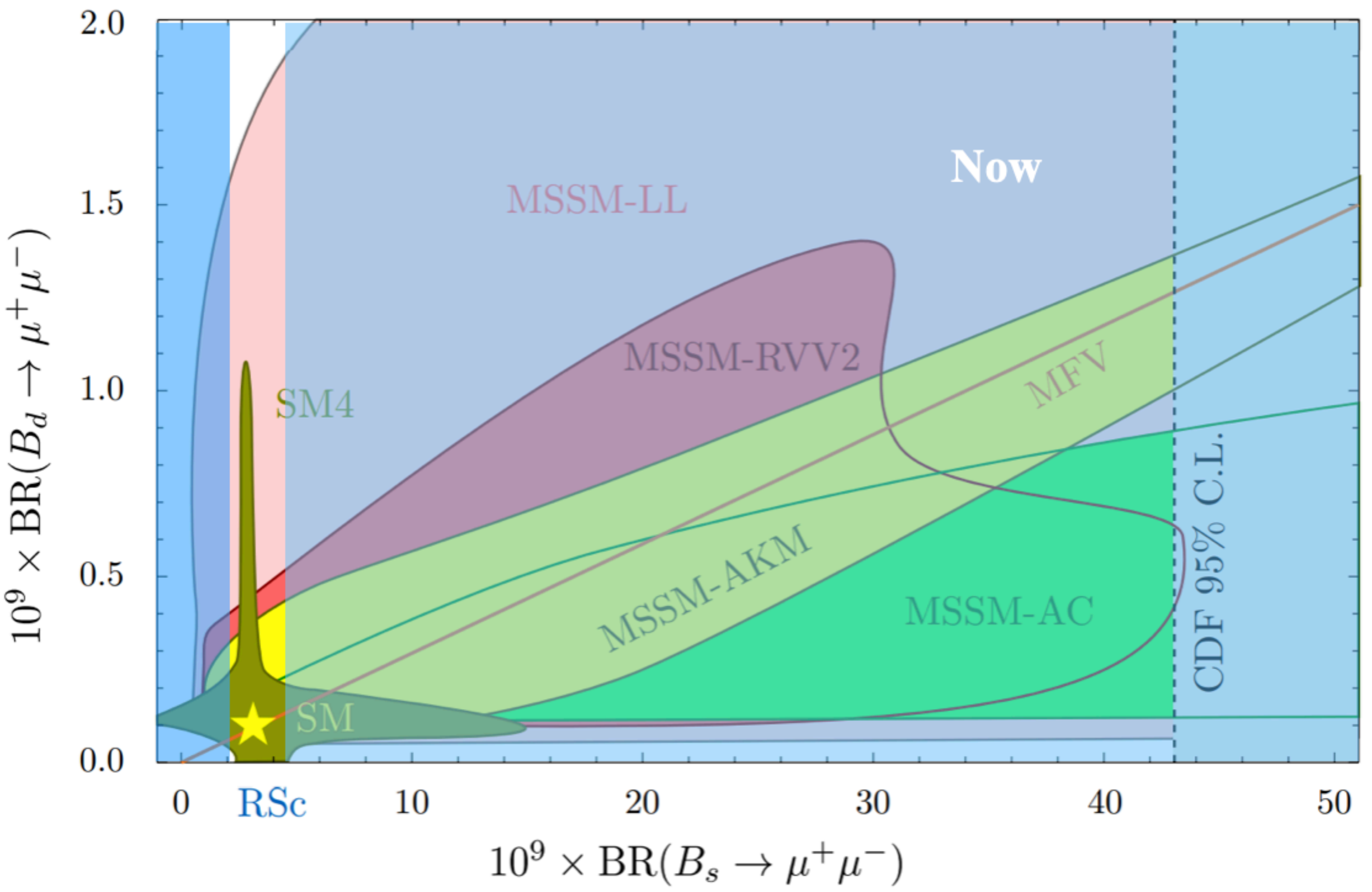
Bobeth et al. PRL 112 101801

Beneke et al. JHEP10(2019)232

This was in 2010 roughly

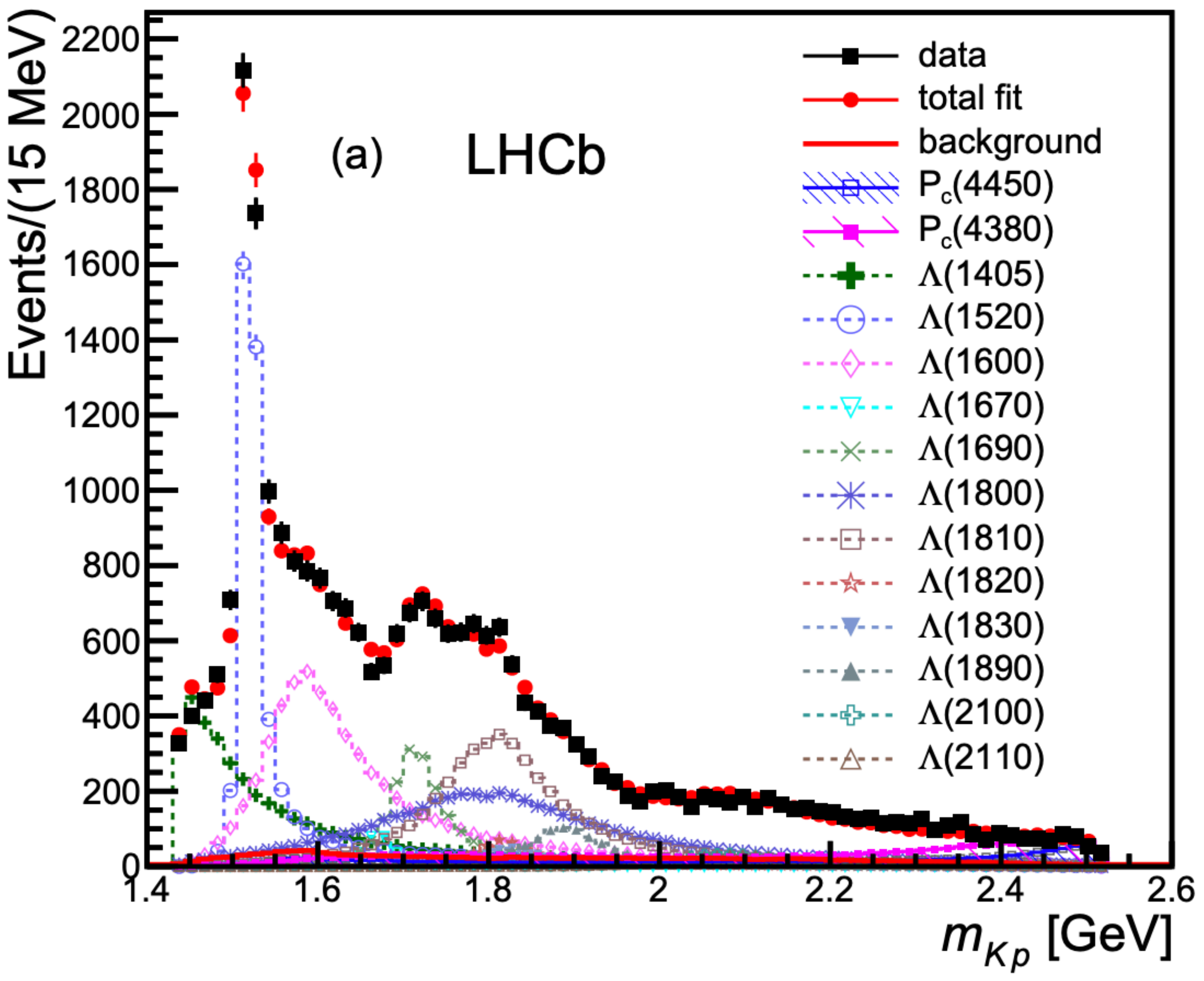


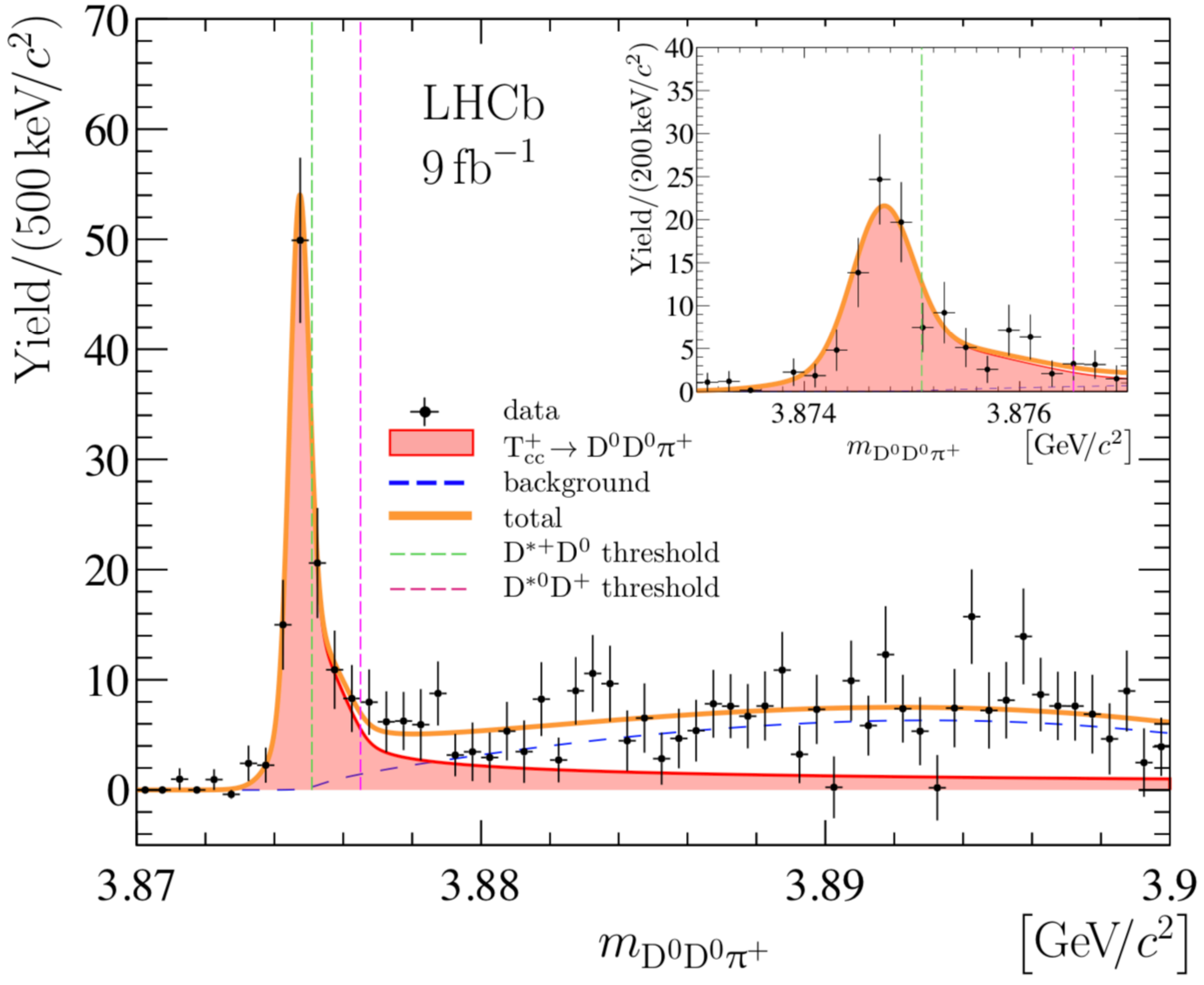
The “Now” is actually from a few years ago but the point remain

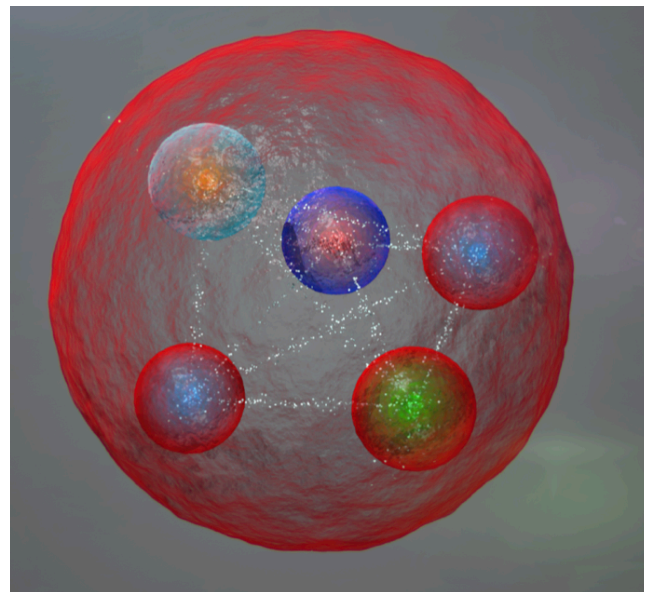


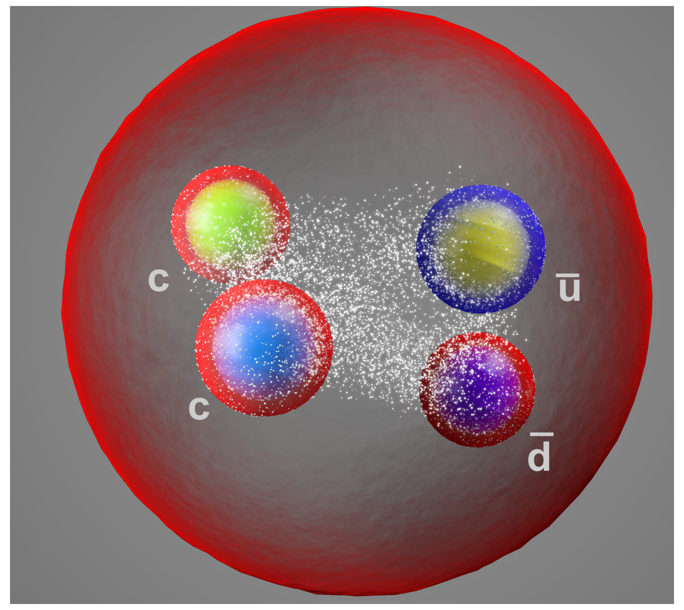
Beyond mesons and baryons

About 50 years after the predictions from Gell-Mann and Zweig

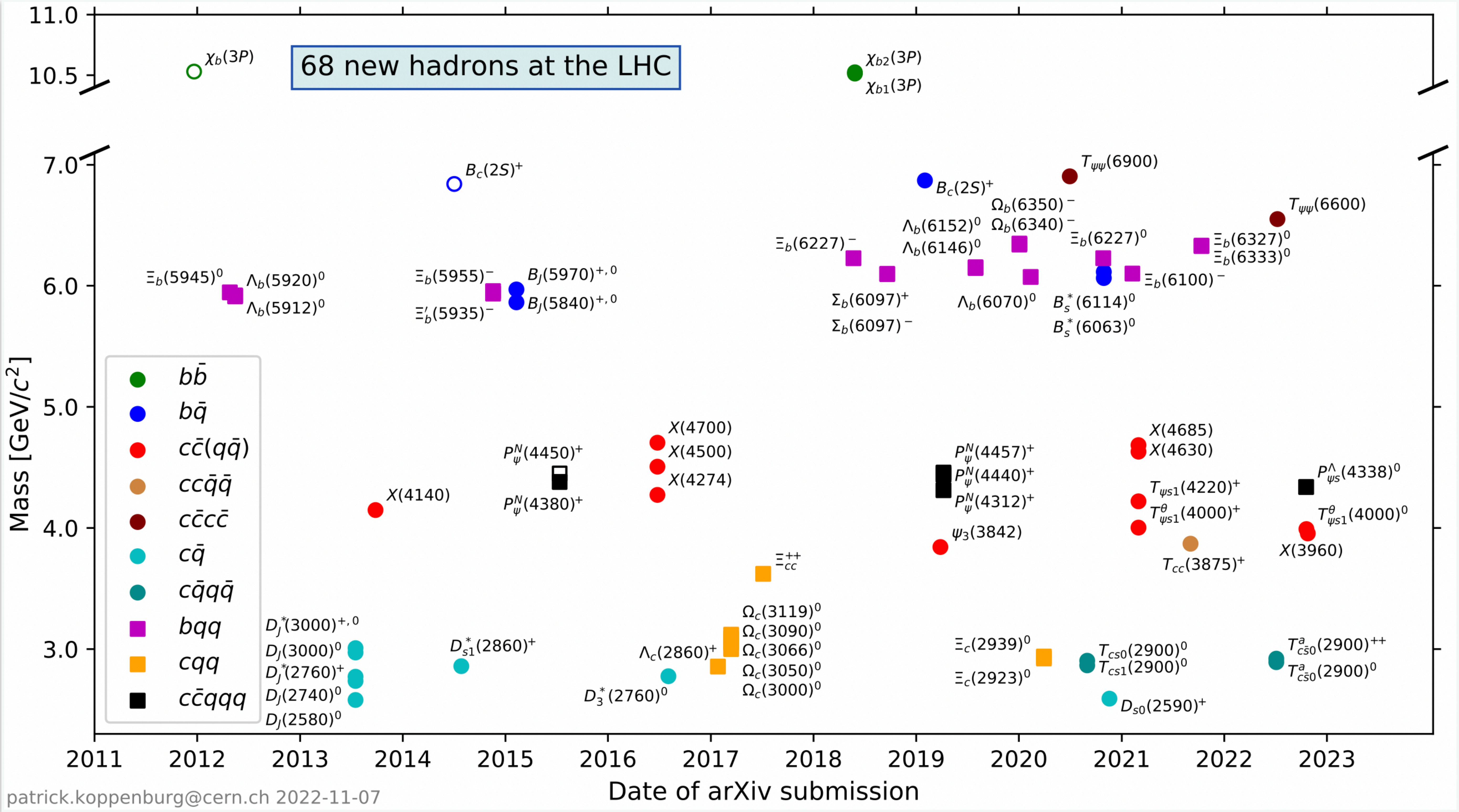




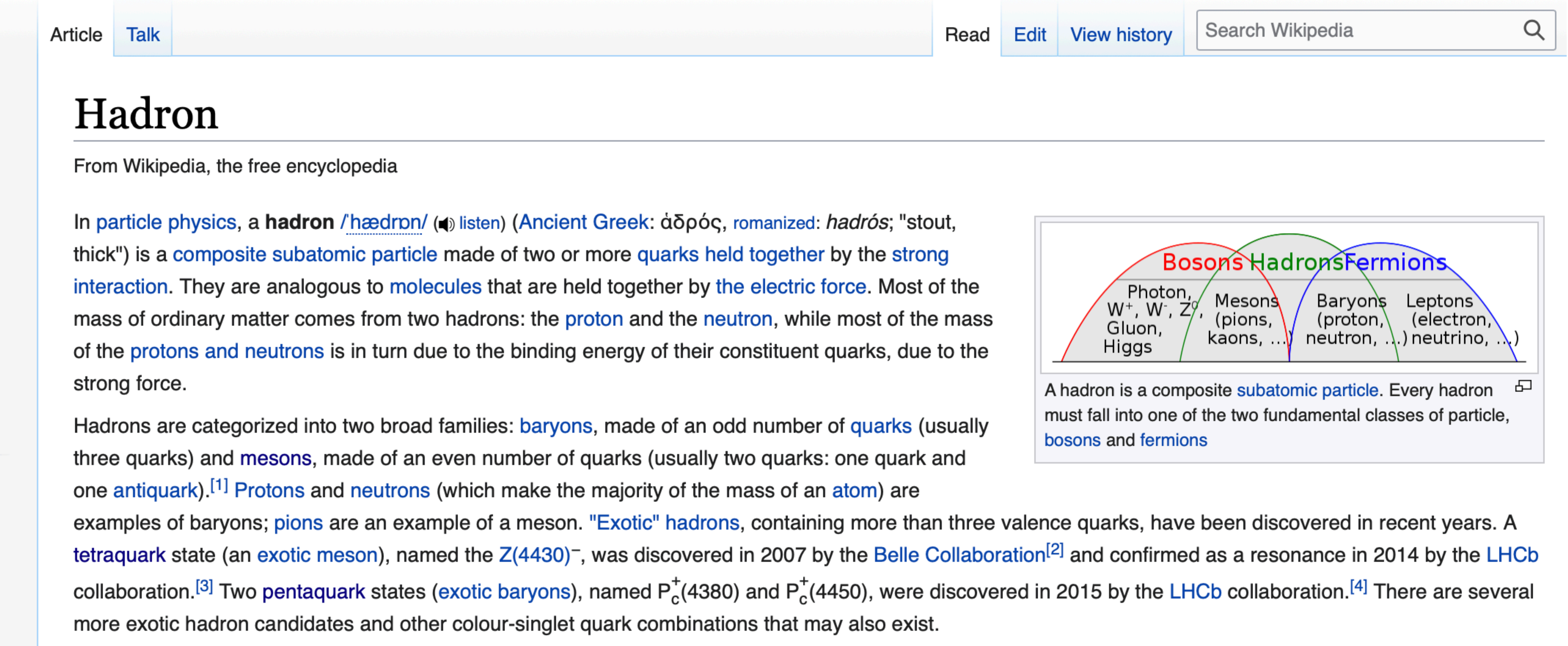




Many discoveries



Good old Wikipedia !


Article Talk Read Edit View history Search Wikipedia

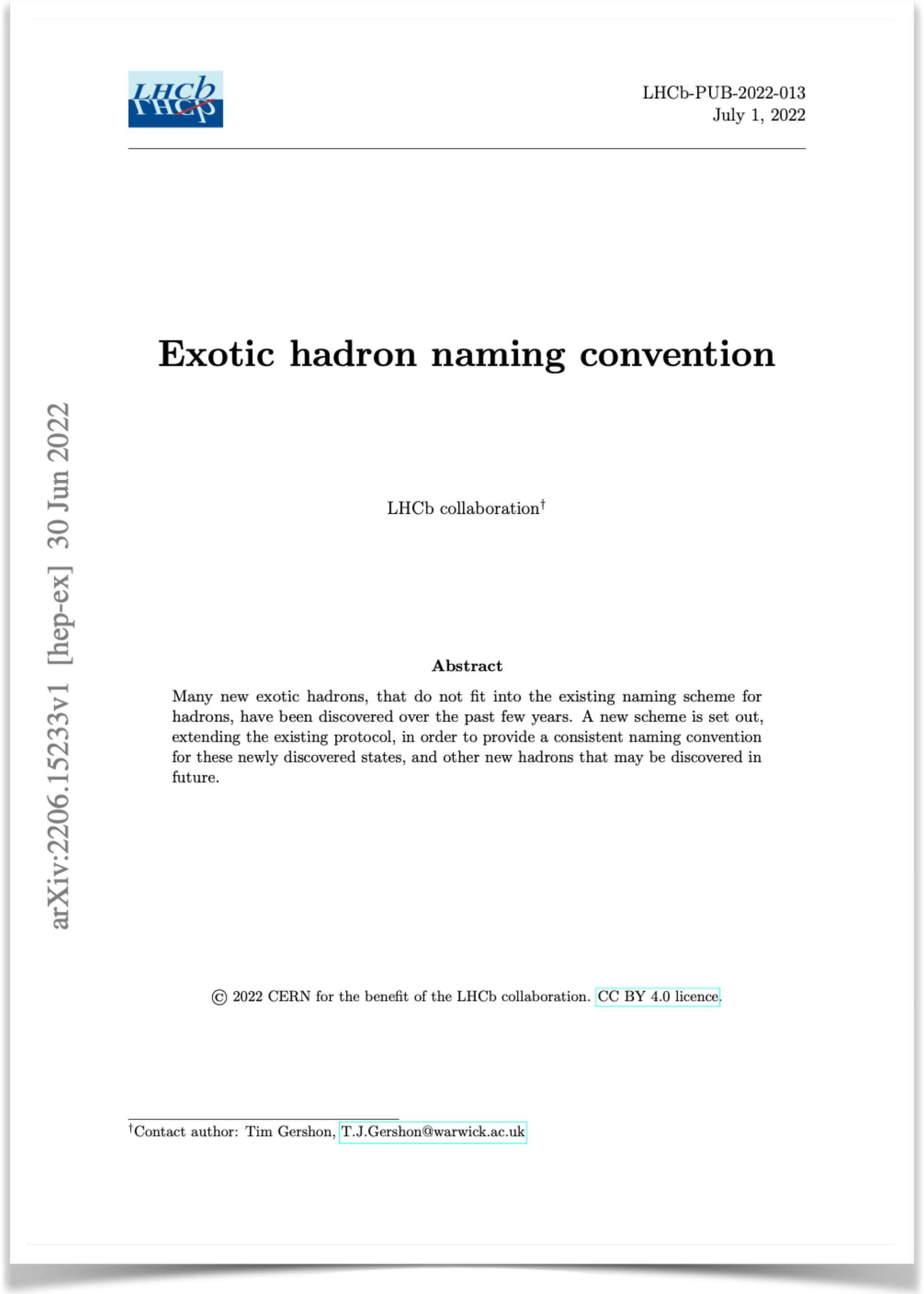
Hadron

From Wikipedia, the free encyclopedia

In particle physics, a **hadron** /ˈhædrɒn/ (listen) (Ancient Greek: ἁδρός, romanized: *hadrós*; "stout, thick") is a composite subatomic particle made of two or more quarks held together by the strong interaction. They are analogous to molecules that are held together by the electric force. Most of the mass of ordinary matter comes from two hadrons: the proton and the neutron, while most of the mass of the protons and neutrons is in turn due to the binding energy of their constituent quarks, due to the strong force.

Hadrons are categorized into two broad families: baryons, made of an odd number of quarks (usually three quarks) and mesons, made of an even number of quarks (usually two quarks: one quark and one antiquark).[1] Protons and neutrons (which make the majority of the mass of an atom) are examples of baryons; pions are an example of a meson. "Exotic" hadrons, containing more than three valence quarks, have been discovered in recent years. A tetraquark state (an exotic meson), named the Z(4430)−, was discovered in 2007 by the Belle Collaboration[2] and confirmed as a resonance in 2014 by the LHCb collaboration.[3] Two pentaquark states (exotic baryons), named $P_c^+(4380)$ and $P_c^+(4450)$, were discovered in 2015 by the LHCb collaboration.[4] There are several more exotic hadron candidates and other colour-singlet quark combinations that may also exist.

A hadron is a composite subatomic particle. Every hadron must fall into one of the two fundamental classes of particle, bosons and fermions


LHCb-PUB-2022-013
July 1, 2022

arXiv:2206.15233v1 [hep-ex] 30 Jun 2022

Exotic hadron naming convention

LHCb collaboration†

Abstract

Many new exotic hadrons, that do not fit into the existing naming scheme for hadrons, have been discovered over the past few years. A new scheme is set out, extending the existing protocol, in order to provide a consistent naming convention for these newly discovered states, and other new hadrons that may be discovered in the future.

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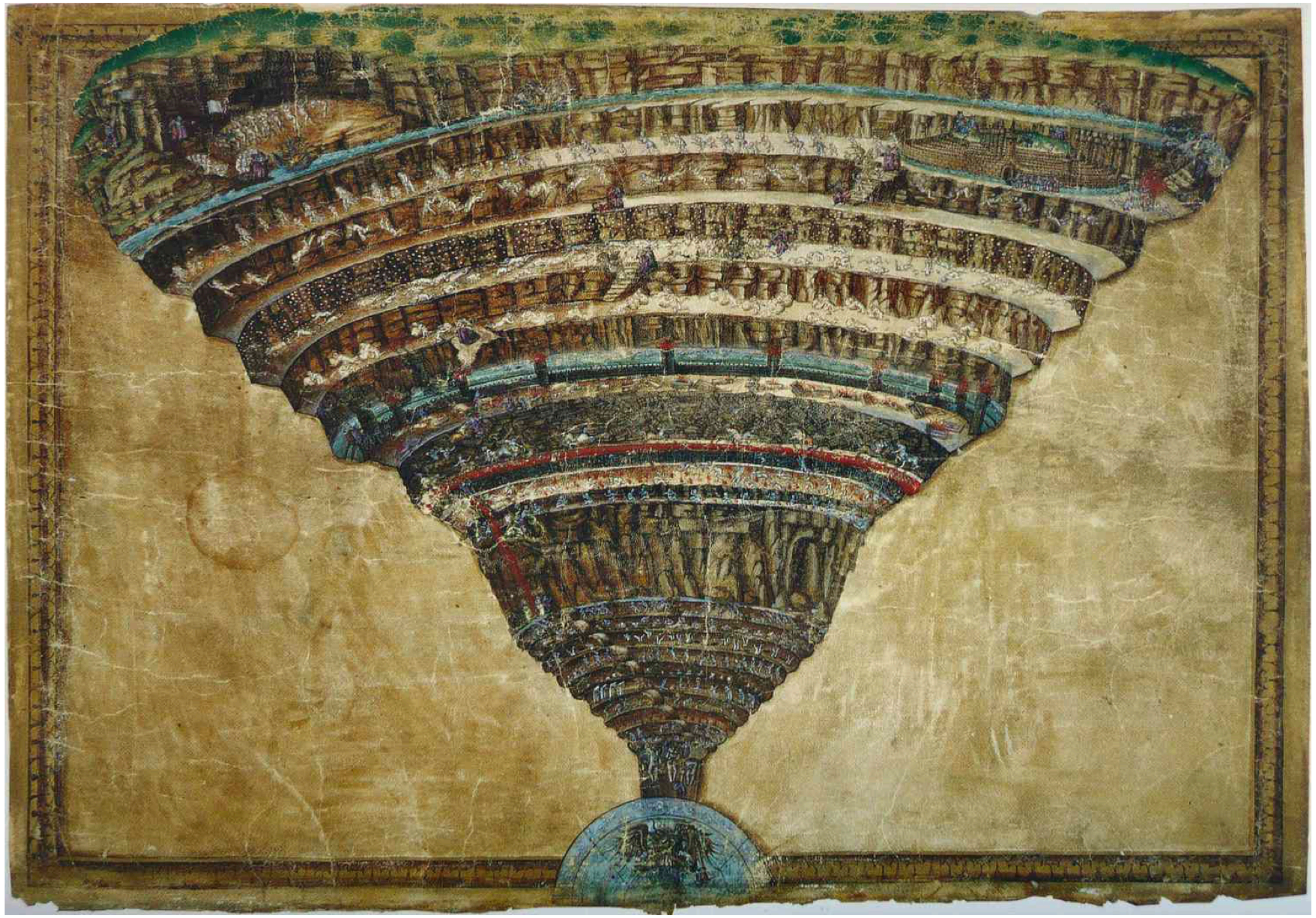
†Contact author: Tim Gershon, T.J.Gershon@warwick.ac.uk

https://cds.cern.ch/record/2814506/files/2206.15233.pdf

Systematics



- Systematics are hard because there is no a standard way of computing them.
- It's something we learn by doing.
- Really recommend many analyses notes.

https://indico.cern.ch/event/1219682/

https://indico.cern.ch/event/1219695/

Questionnaire de Proust

What is the observable? A branching fraction? An angle?

What is the process? Tree level? Penguin?

What are we testing? SM? QCD? NP?

What is the statistics? Rare decay? Normalisation?

What is the topology of the decay?

Are we going to ever see it?

What about systematics?

Do we actually care about it?

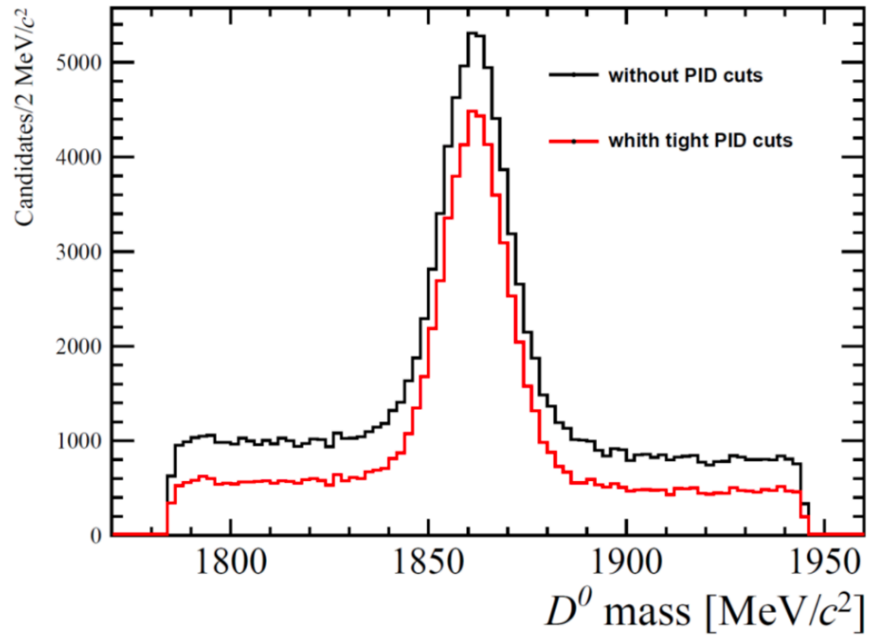
It will take a bit of time and effort

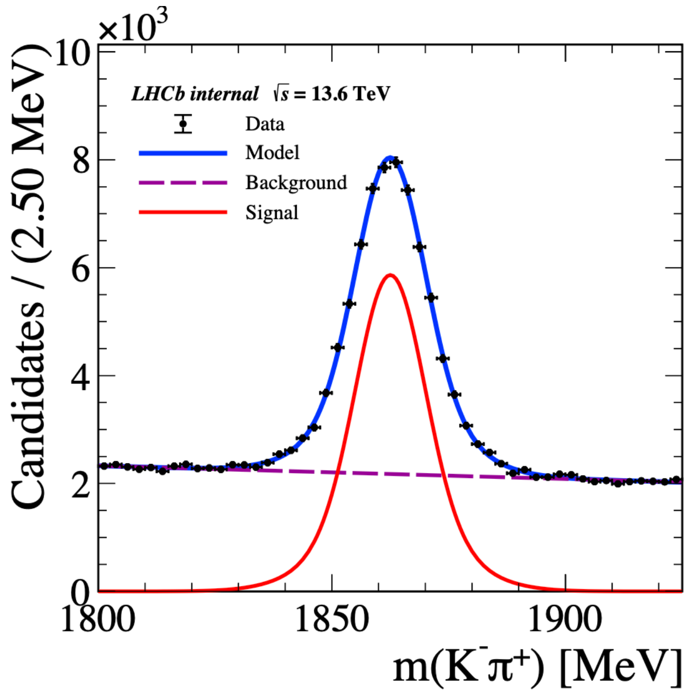
Run 1/2 “final” analyses

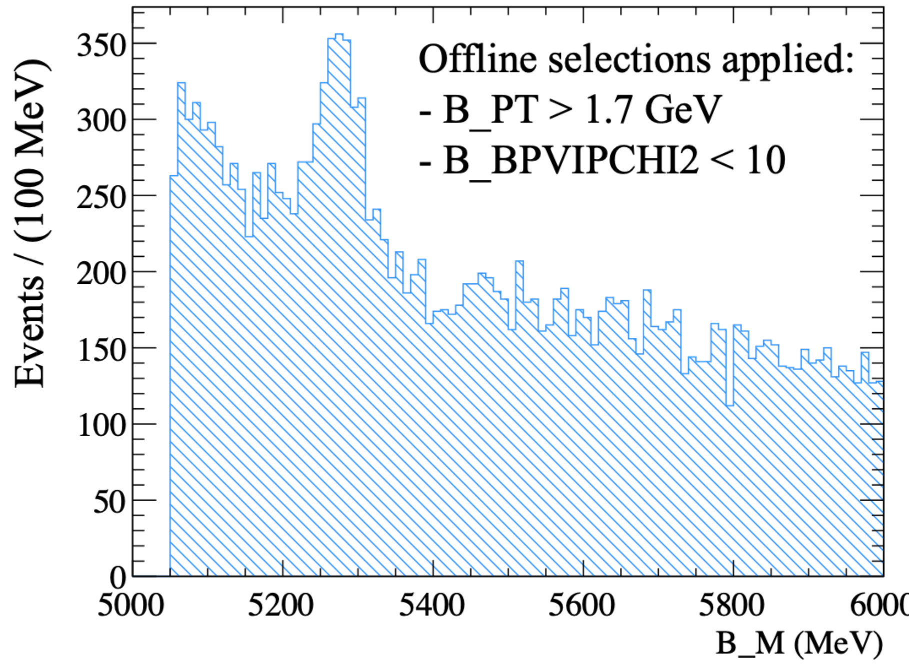
Run 3 “first” analyses

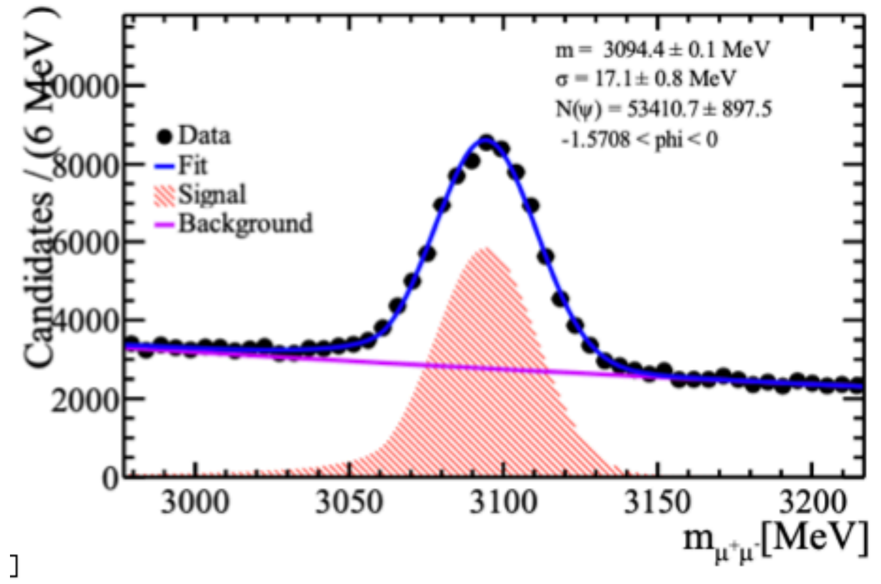
But we will get there !

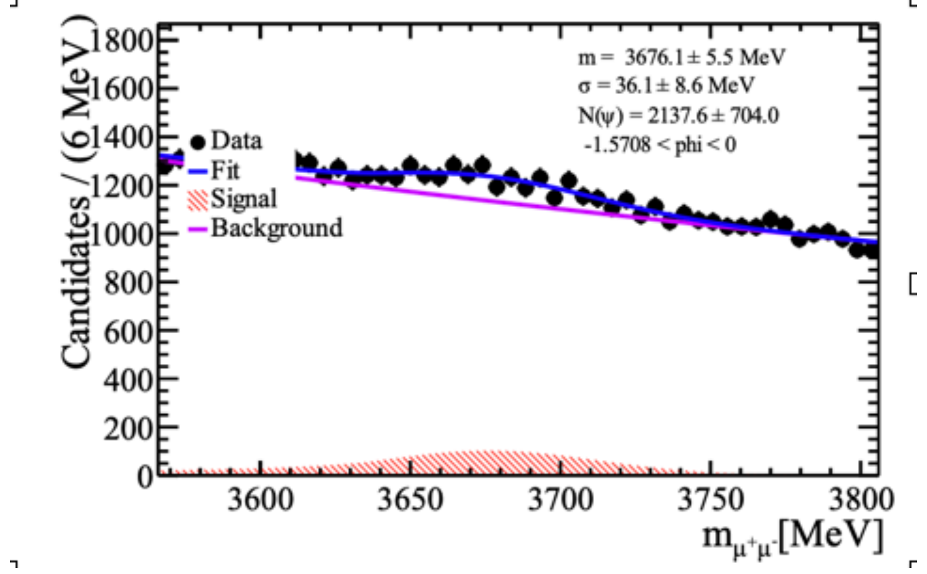
23’Data Summer Camp

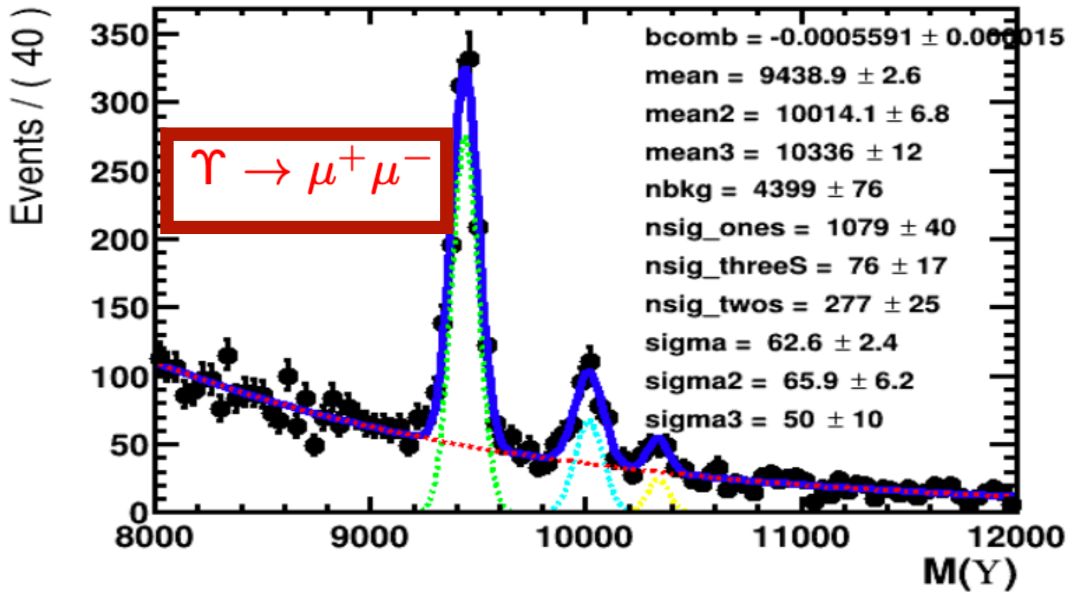


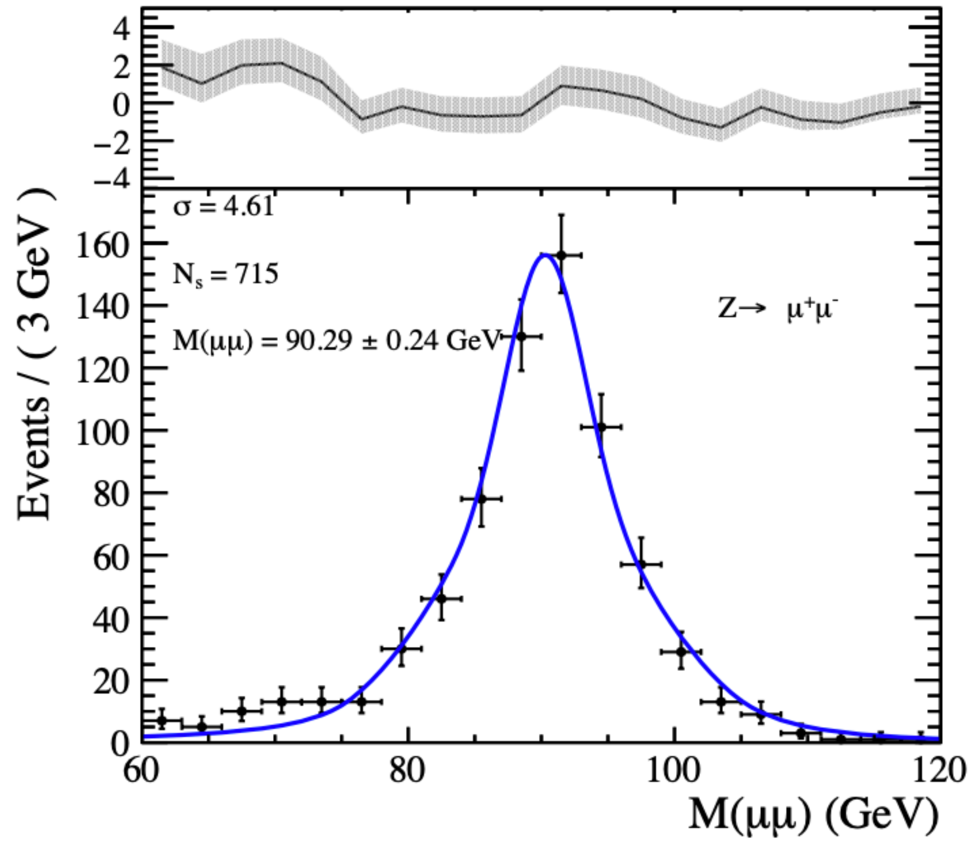


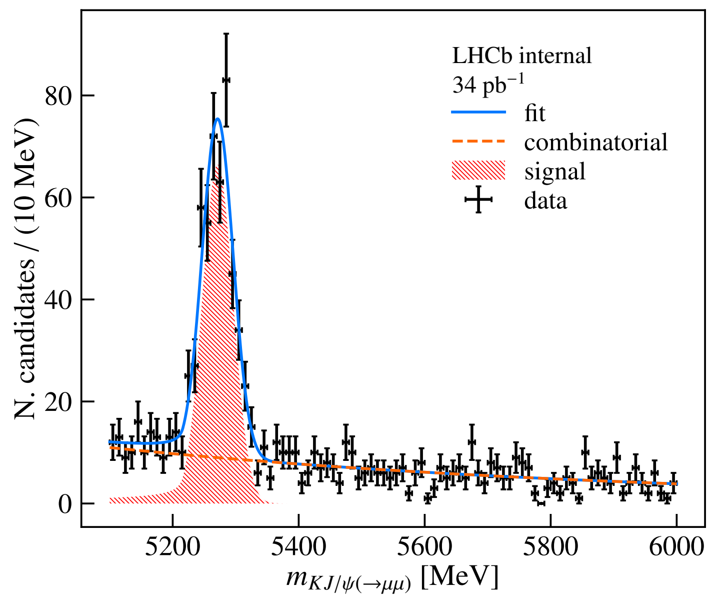


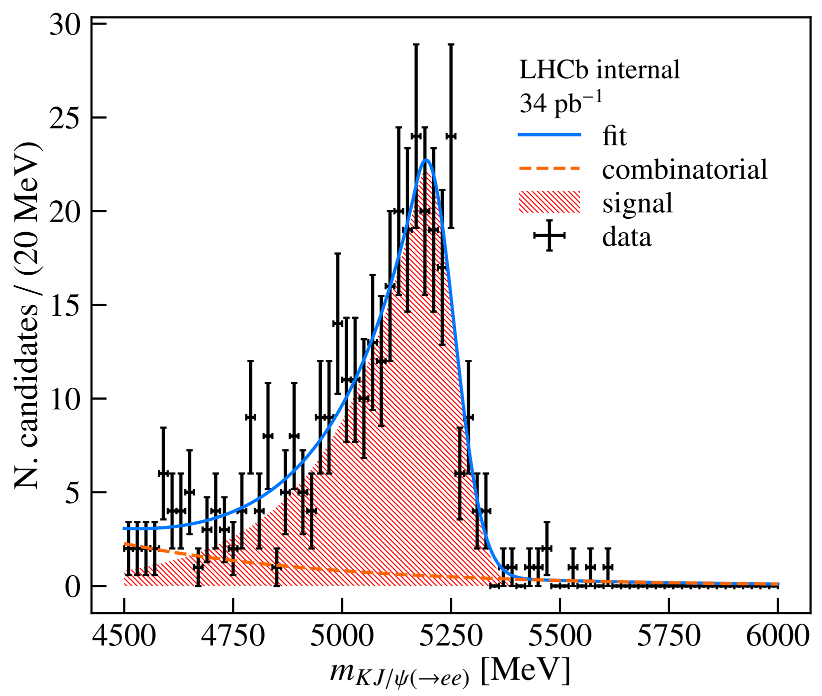


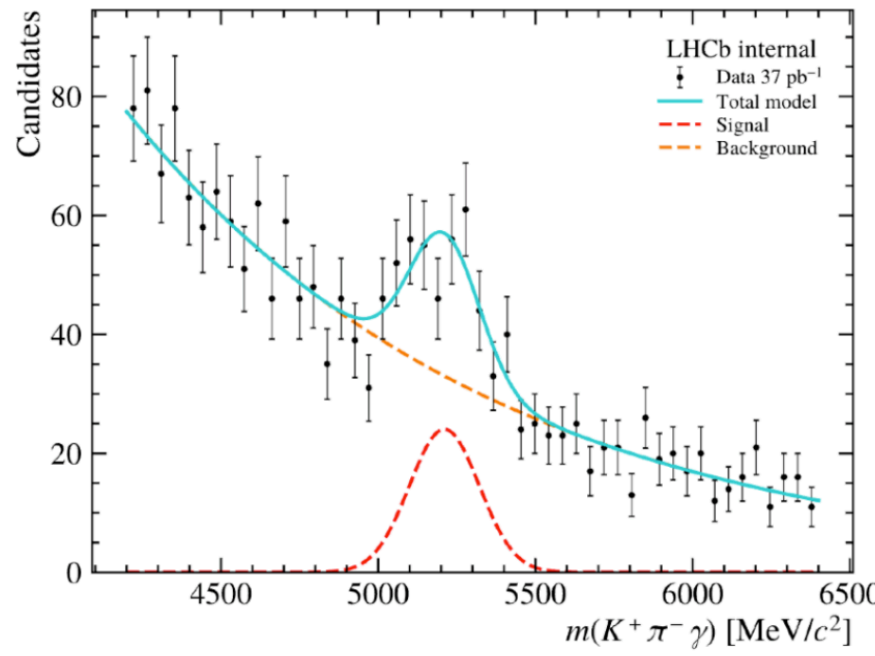


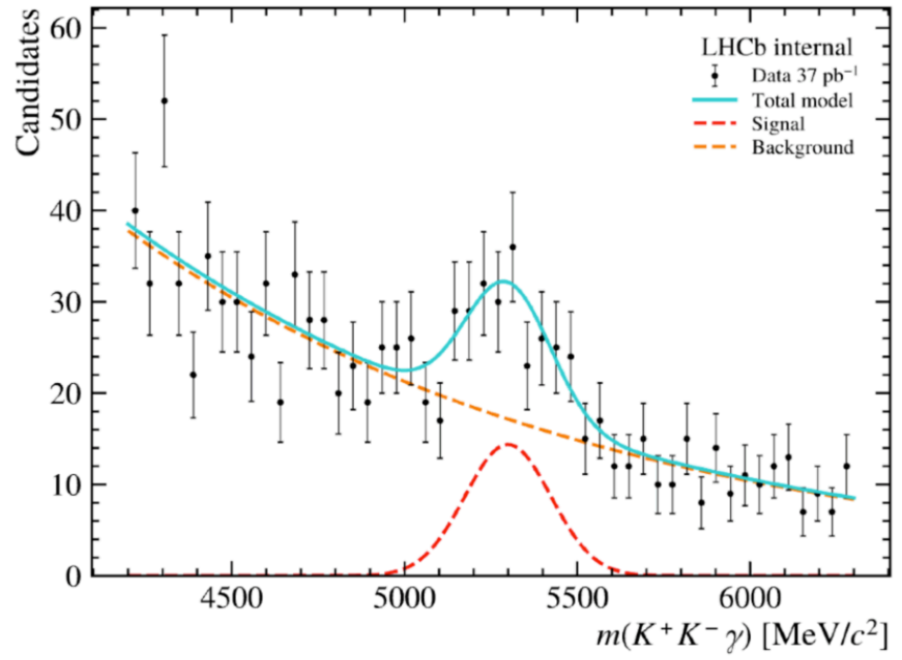


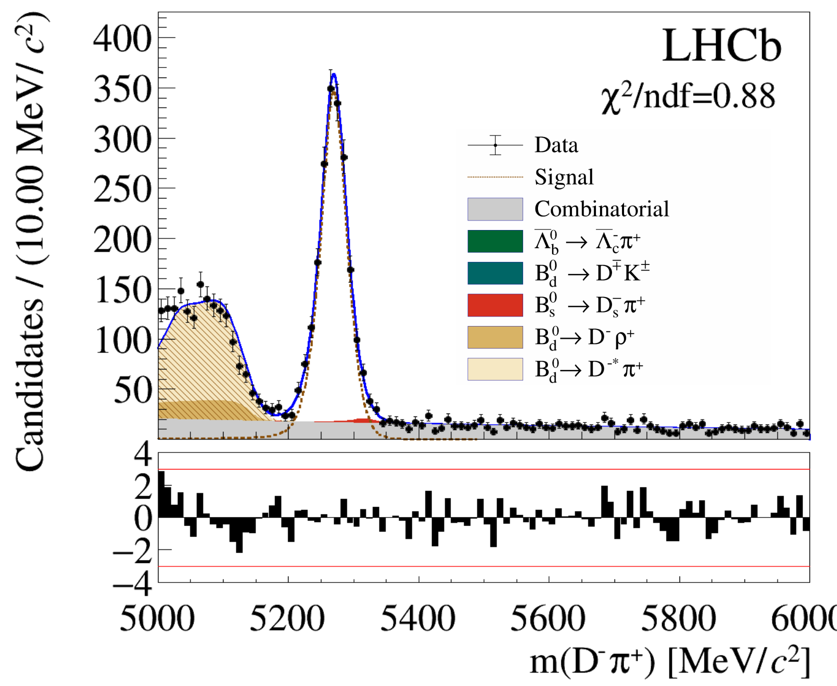


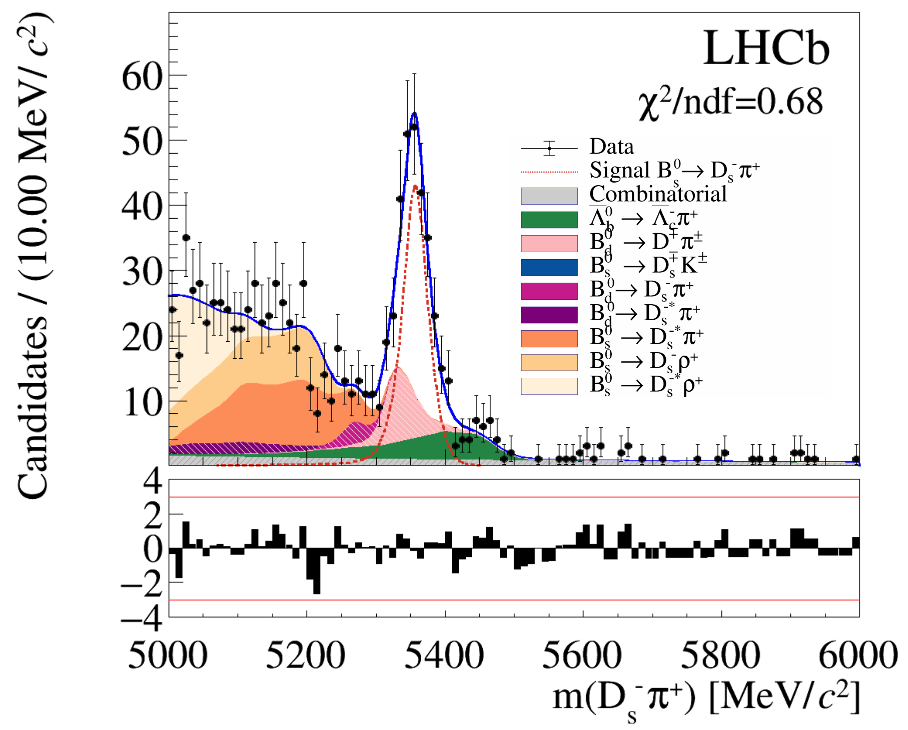


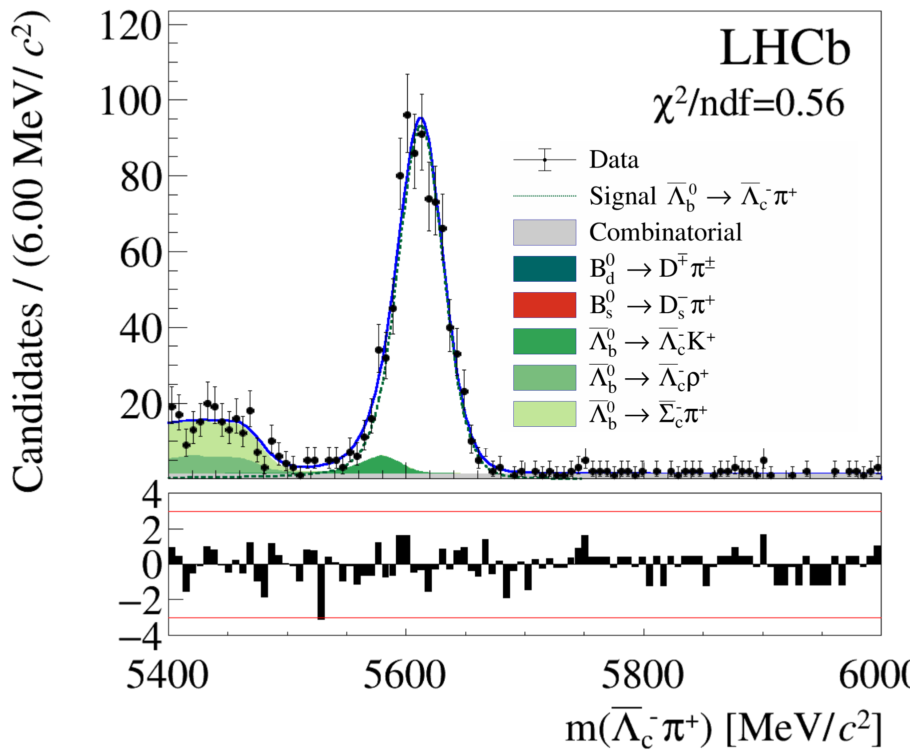


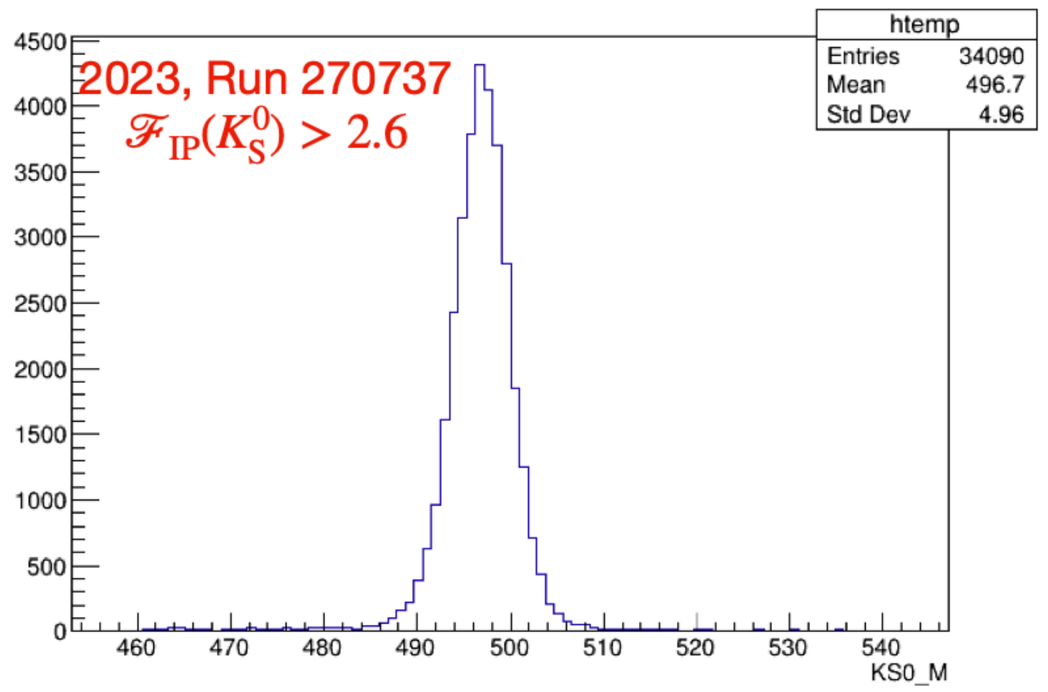


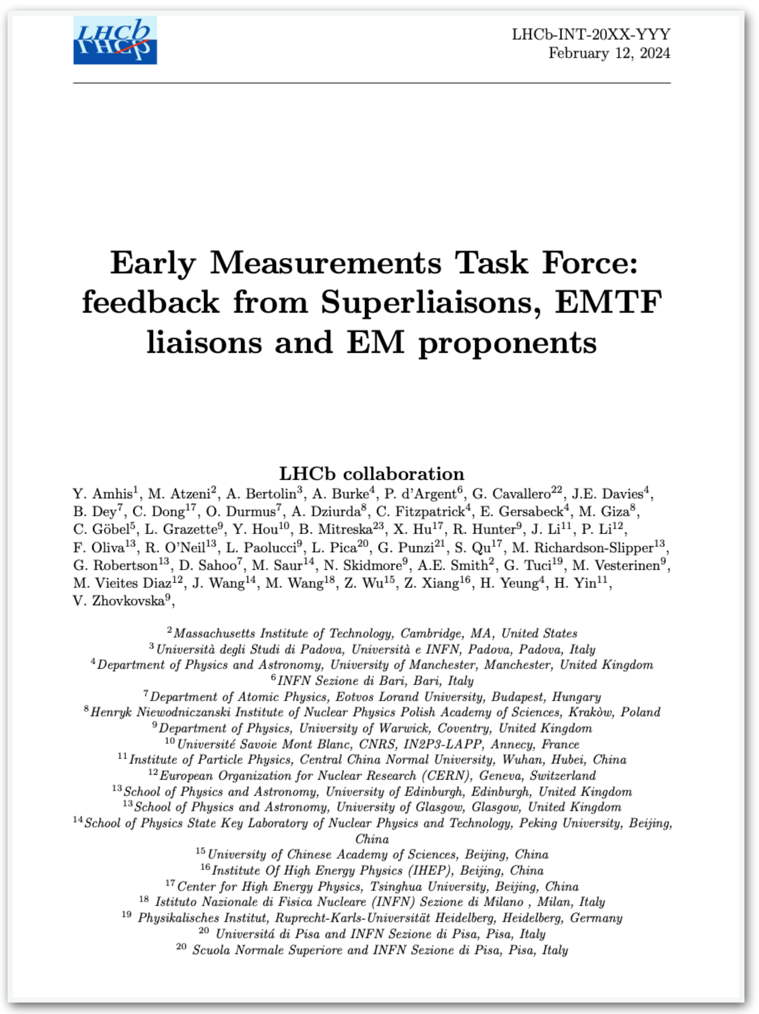











LHCb-INT-20XX-YYY
February 12, 2024

Early Measurements Task Force: feedback from Superliaisons, EMTF liaisons and EM proponents

LHCb collaboration

Sources of headaches or joy ?

These are “classic” things that you will encounter during your PhD and beyond.

Depending on your topic
some of the steps will take you a week or a year

None of it is linear and what is difficult is that it’s hard to predict sometimes how long something will take

“If we had all the answers in advance it would not be research”

You might also a hardware/software project in parallel !

How we are organised ?

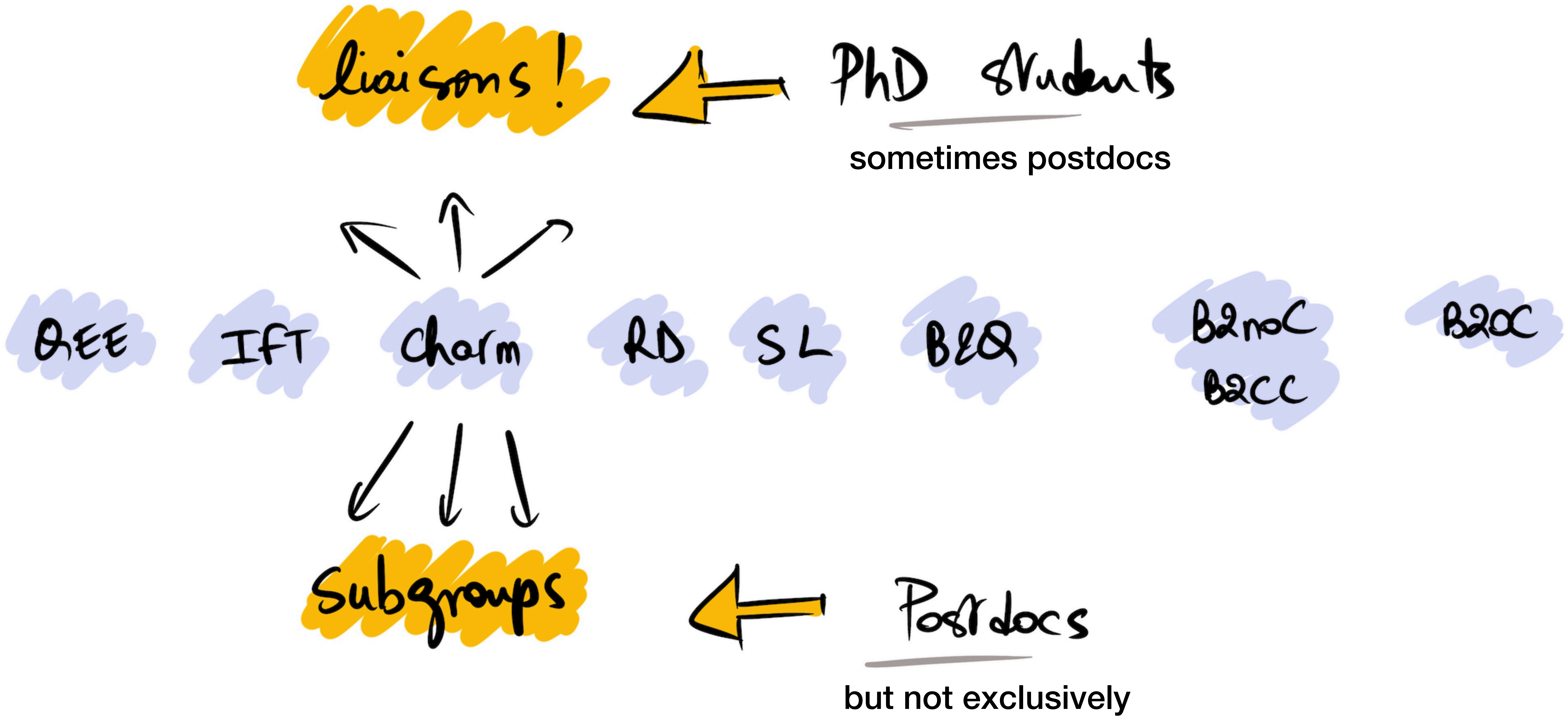
PWG ⇒ QEE IFT Charm RD SL B&Q B2noC B2CC B2OC

PPWG & Task forces ⇒ Amplitude Analyses, Statistics, Flavour tagging, Luminosity, EMTF (Until 2023), Outreach

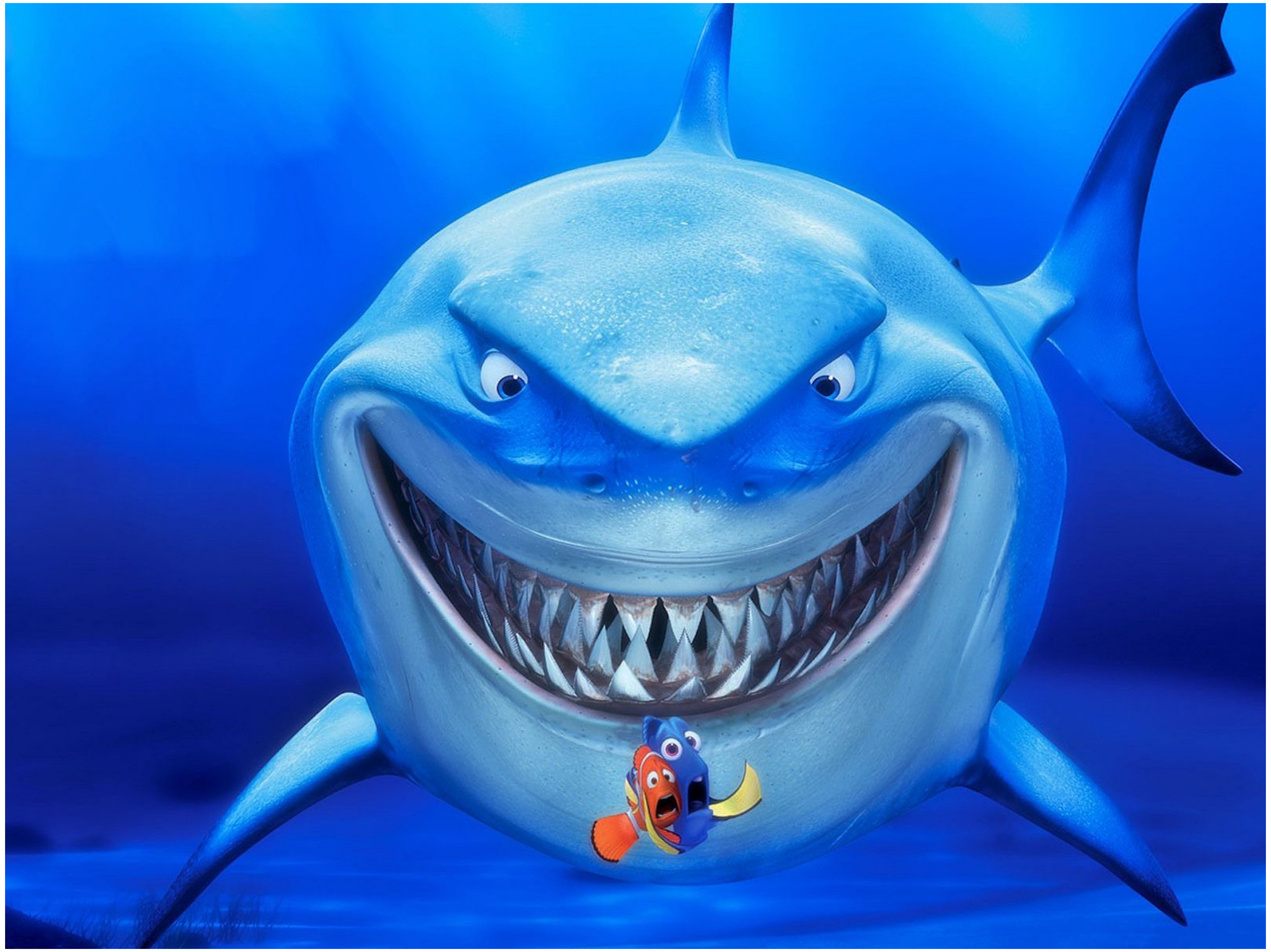
Projects ⇒ Simulation RTA DPA Computing

Statistically who will you interact with first ?

Conveners of groups and subgroups, liaisons are a very good first point of contact



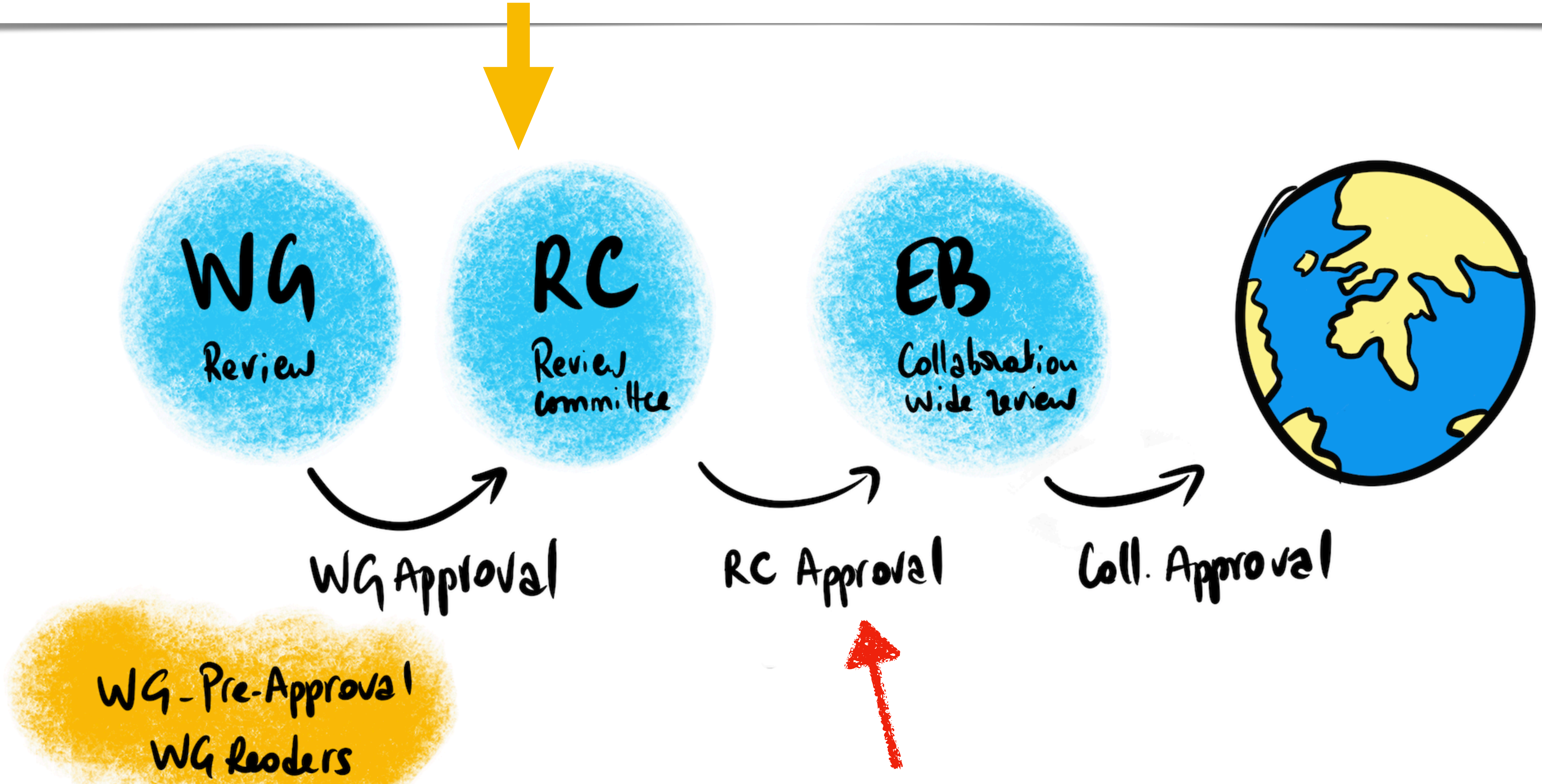
Presenting at Physics Working Groups



Yes it can be very scary !
But it's a great exercise and the more you do it the better you will become at it.

Review organisation

A kick-off meeting between RC and proponents is expected within 1 month from the date on which the ANA note is handed over to the RC. Preliminary questions, time constraints, conference target, etc should be discussed. Minutes of the meeting should be posted to the review egroup below.



Here we become fairly active

You may hear about us also if there are “problems” with the analysis

Review organisation

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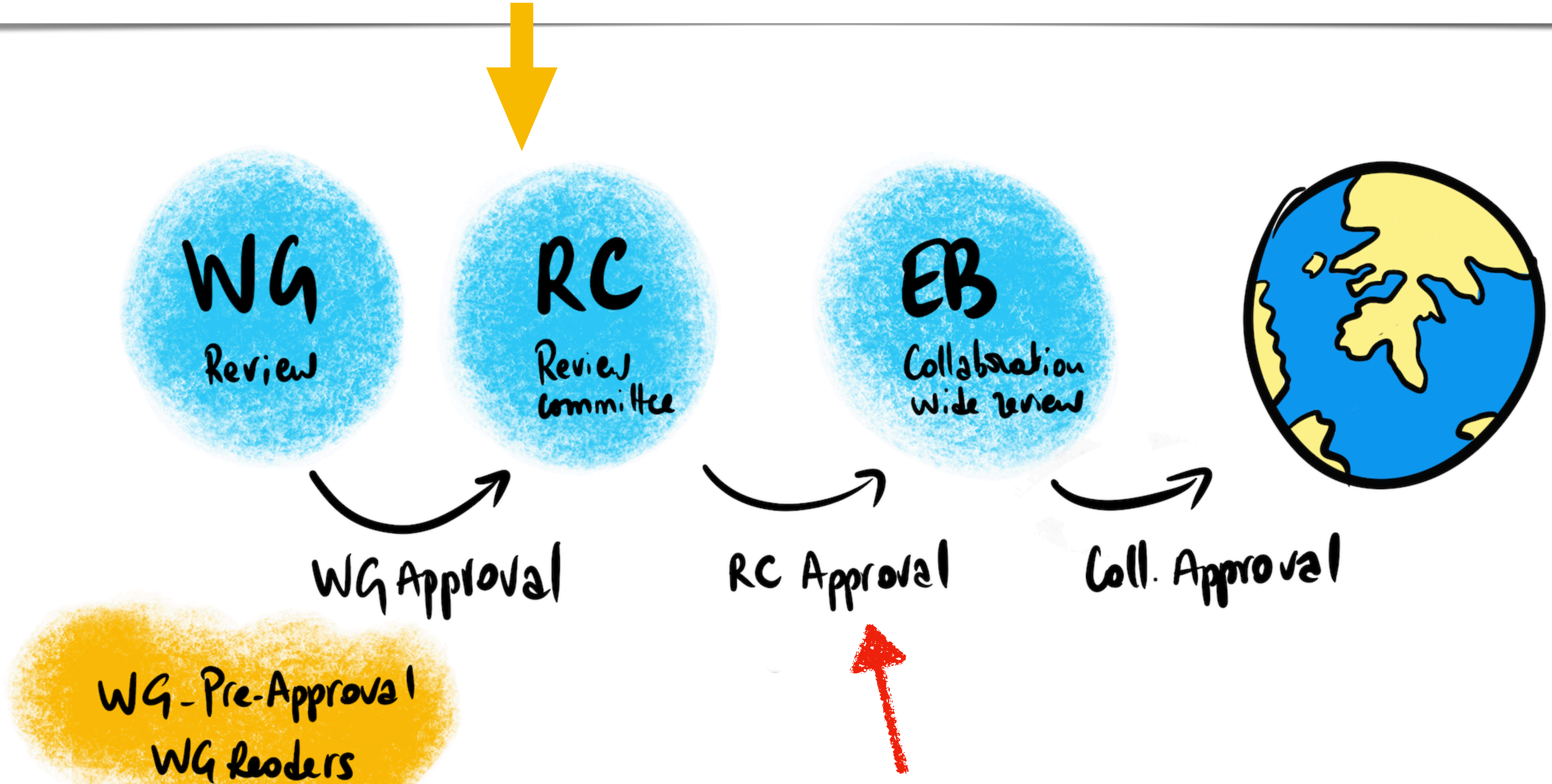

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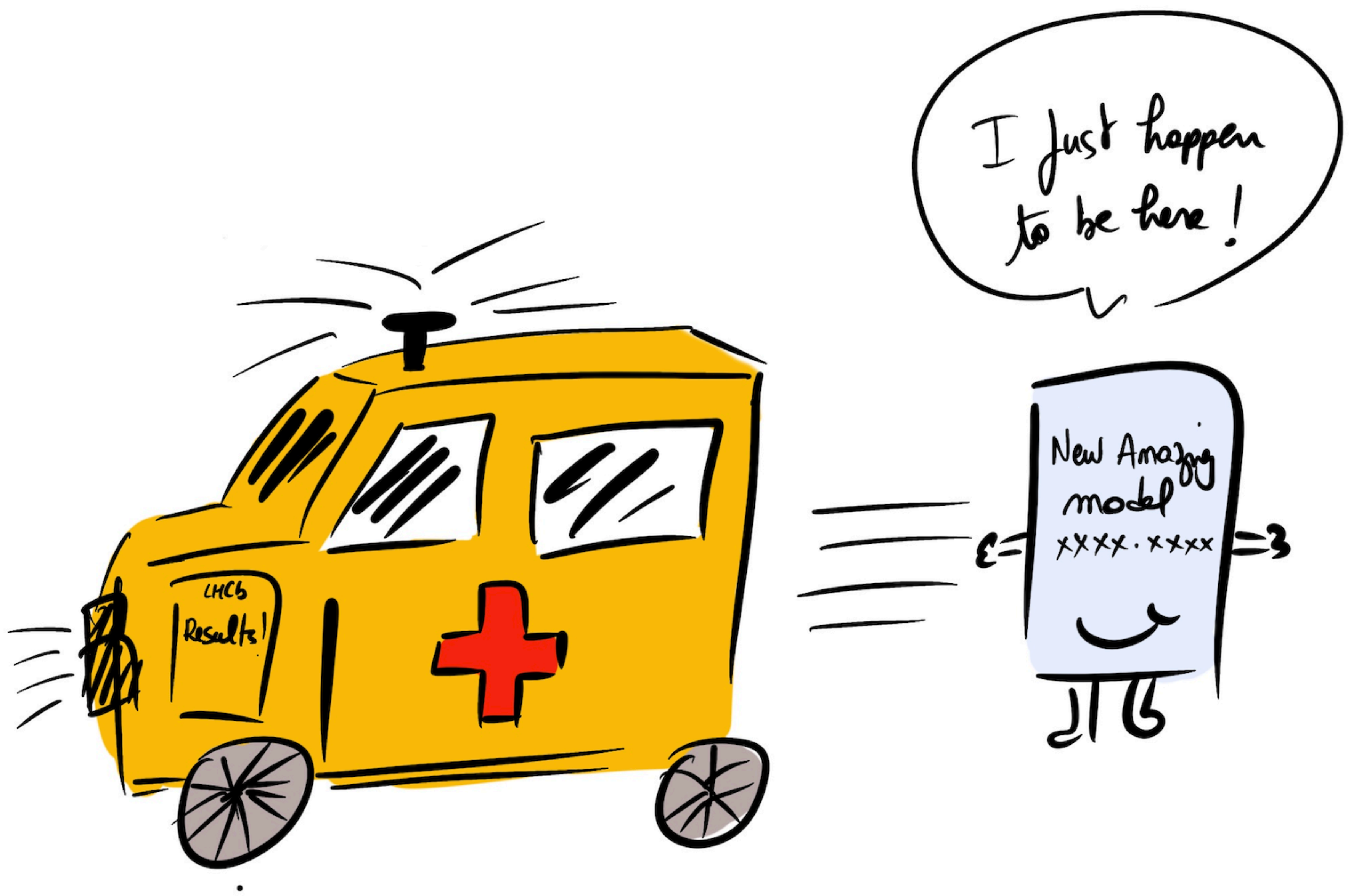
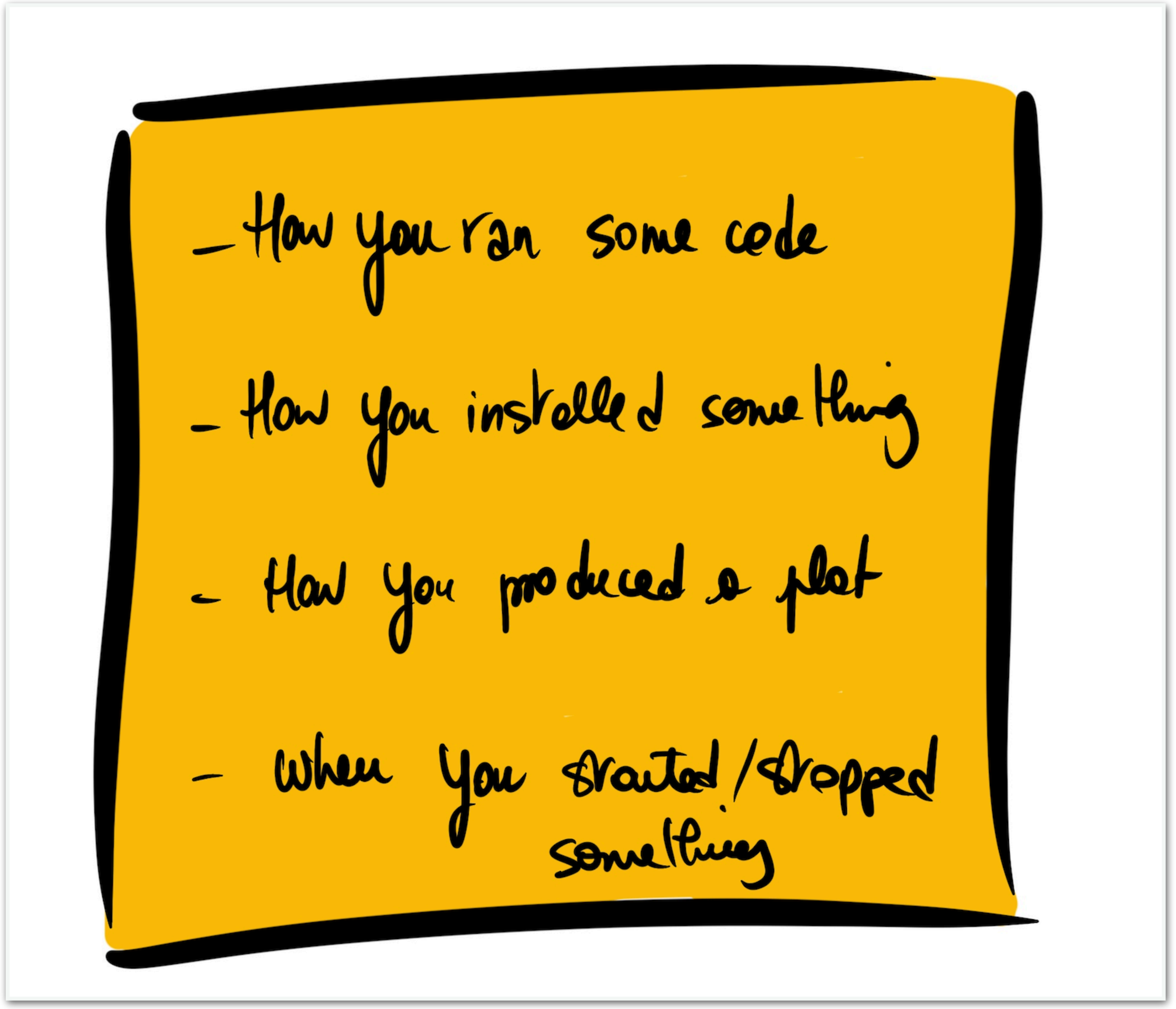
Good practices



- Browsing randomly indicos of other WGs.
- Check the WG selected topics at the TM.
- Keep an eye on arXiv.
- Check the TH and EXP summery talks at conferences and workshops
- Check the review articles.
- Check other submitted PhDs manuscripts.

And please please please

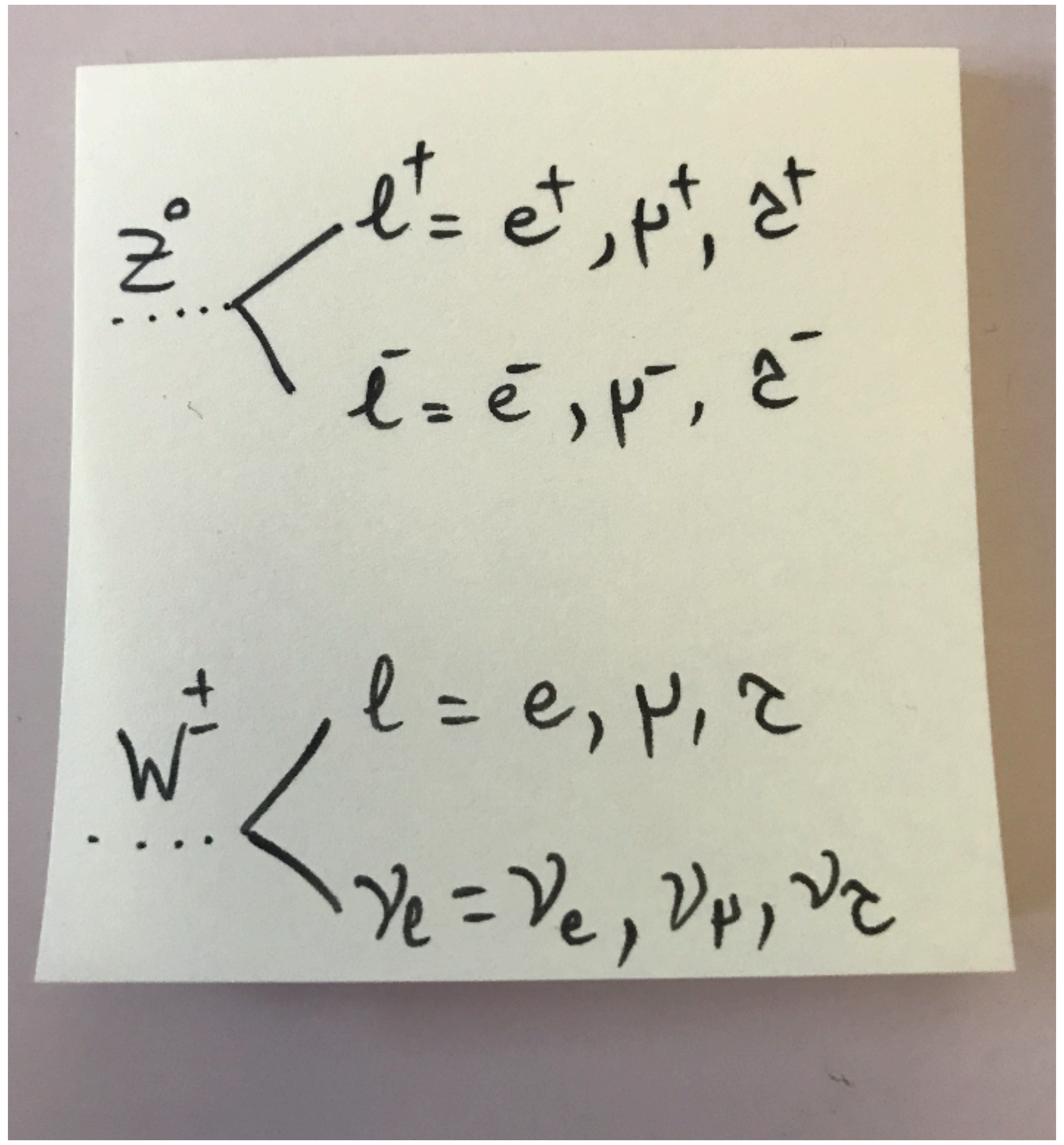
- Log your work, it does not matter if you use notebooks, software, whatever.
- Keep track of everything you do, we forget details, we forget obvious things. We always think that we will remember.
- The amount of information to store only increases, so help your future you and write down things.



That's it !

- I wish you all the best !
- I will not lie, it's not easy to do a PhD at LHCb
- But ! You are in a very special place and this is a unique moment in the History of LHCb
- Three years will fly at the speed of light
- Make the most of it

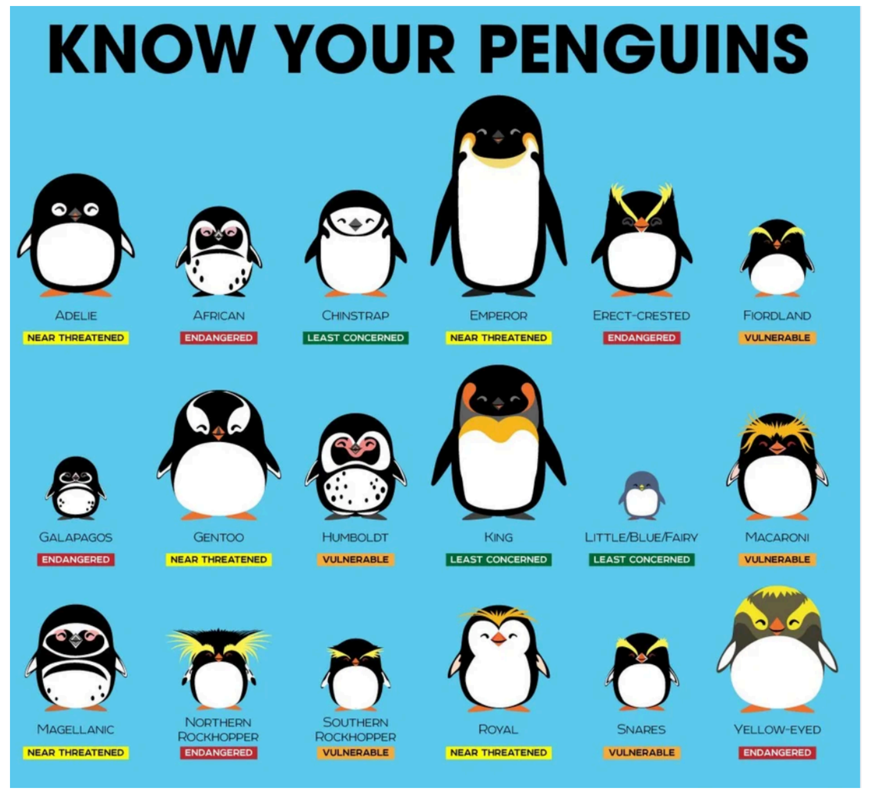
Lepton Flavour Universality

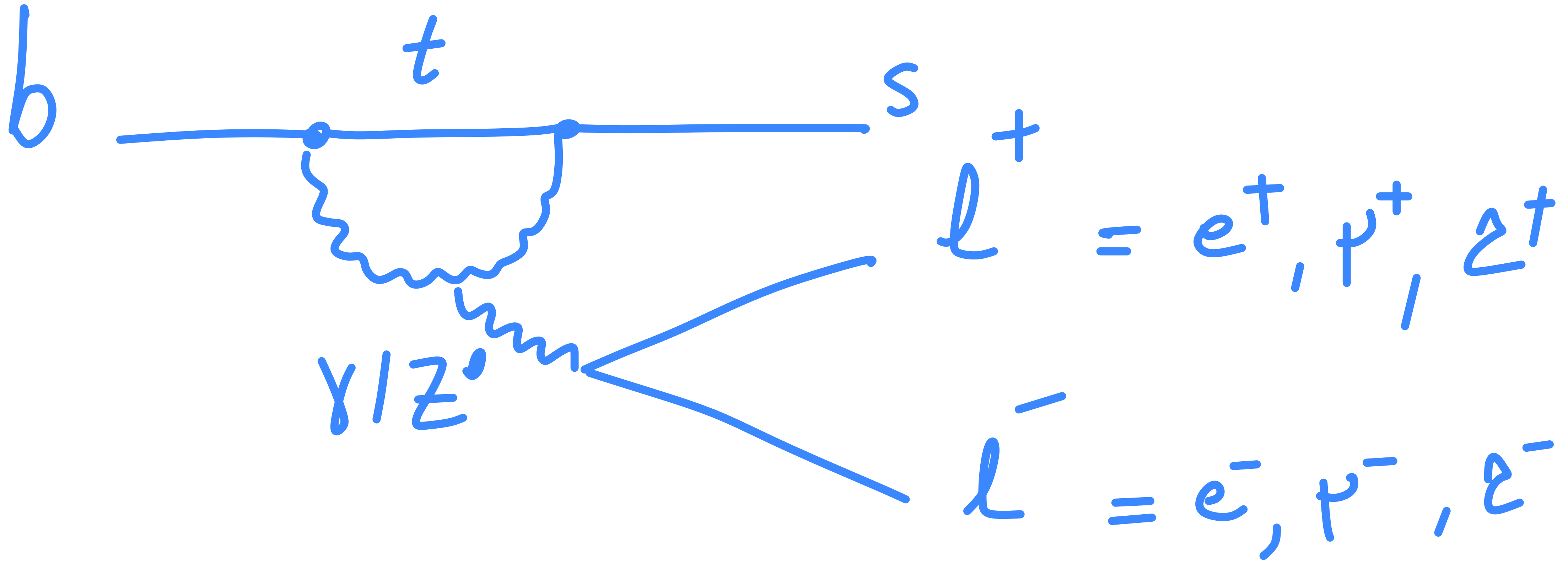


From the PDG or equivalent :

$$\frac{\Gamma_{Z \to \mu^+\mu^-}}{\Gamma_{Z \to e^+e^-}} = 1.0009 \pm 0.0028\,,$$

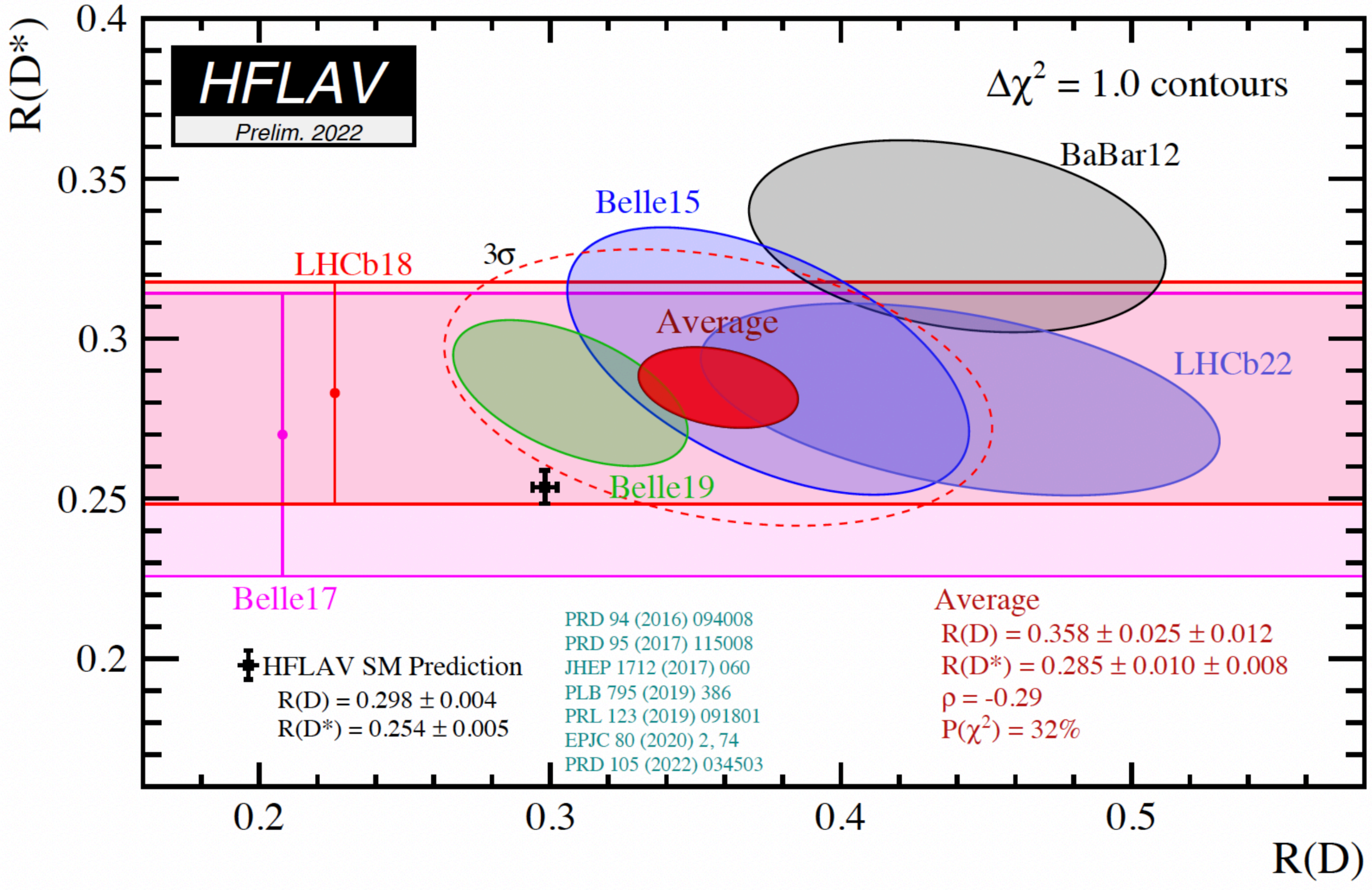
$$\frac{\Gamma_{Z \to \tau^+\tau^-}}{\Gamma_{Z \to e^+e^-}} = 1.0019 \pm 0.0032\,.$$





$$R = \frac{\#\,\text{muons}}{\#\,\text{electrons}}$$

This was one was not a piece of cake !



Very large branching fraction with respect to b →sll,
but neutrinos in the final states and a bazillion hadronic backgrounds to model.