Welcome to the LHCb Starterkit

Physics Coordination

Fred Blanc

LHCb Starterkit, CERN
26 November 2024

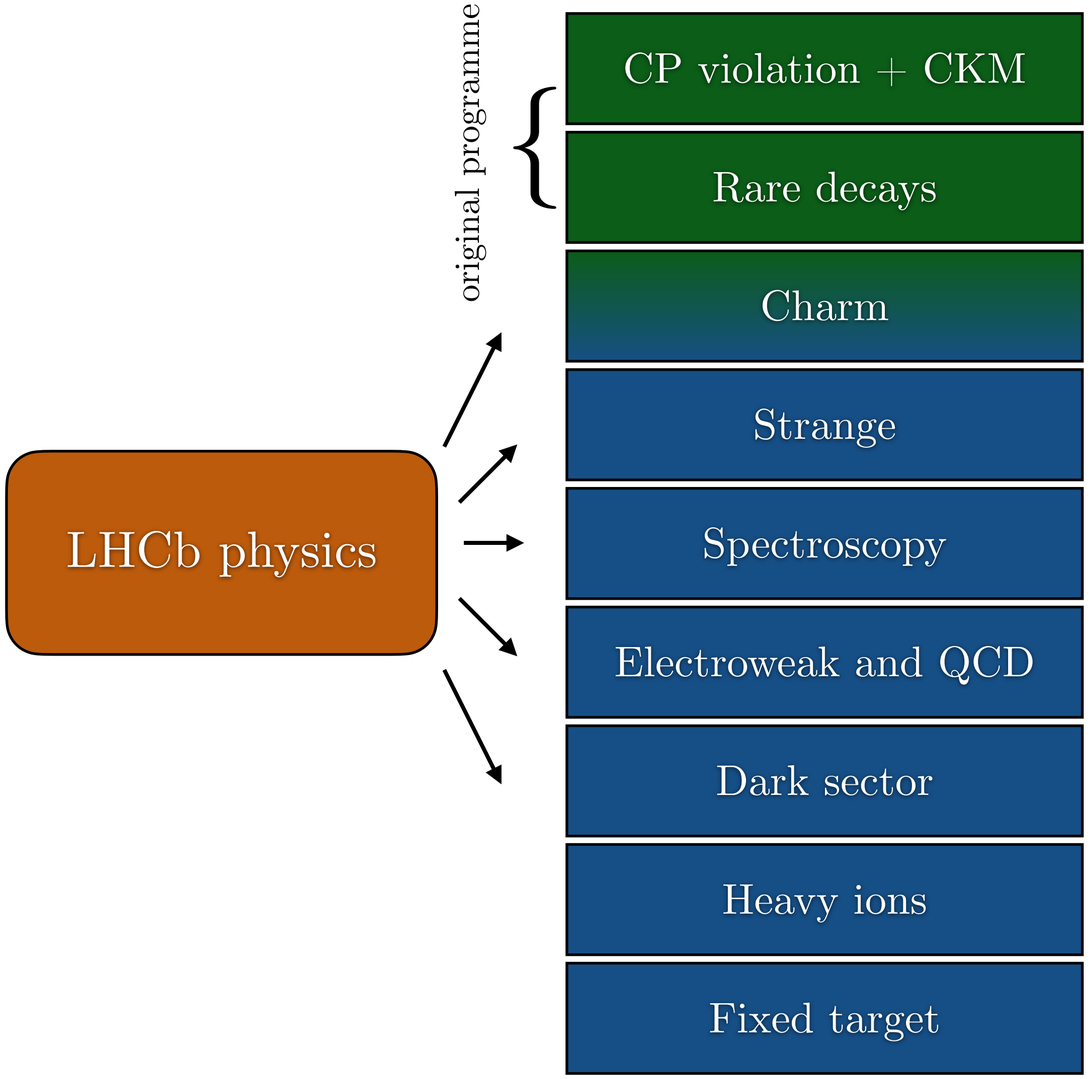
Physics coordination

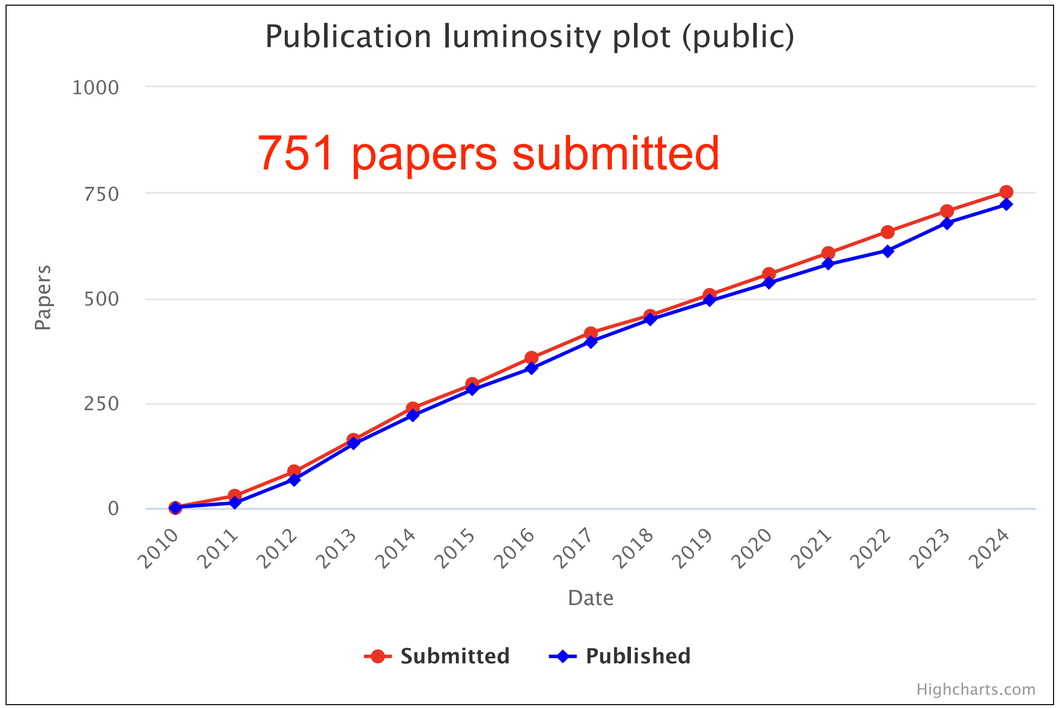
- Fred Blanc [fred.blanc@epfl.ch] (PC) → you can find me in office 2-1-043
- María Vieites Díaz [maria.vieites.diaz@cern.ch] (deputy PC)

- You can also reach us at lhcb-physics-coordination@cern.ch

- Some of our responsibilities:
  - we organise and chair the PPG meetings
  - we chair the approval presentations
  - we give weekly reports at the Tuesday Meeting
  - we give reports at the LHCb week
  - we approve the release of physics results (to conferences and to papers)
  - we coordinate the communication with the CERN courier and CERN seminars
  - we read and write lots and lots of emails...

The LHCb physics programme





Broad variety of physics topics!
~50 publications every year

LHCb Datasets

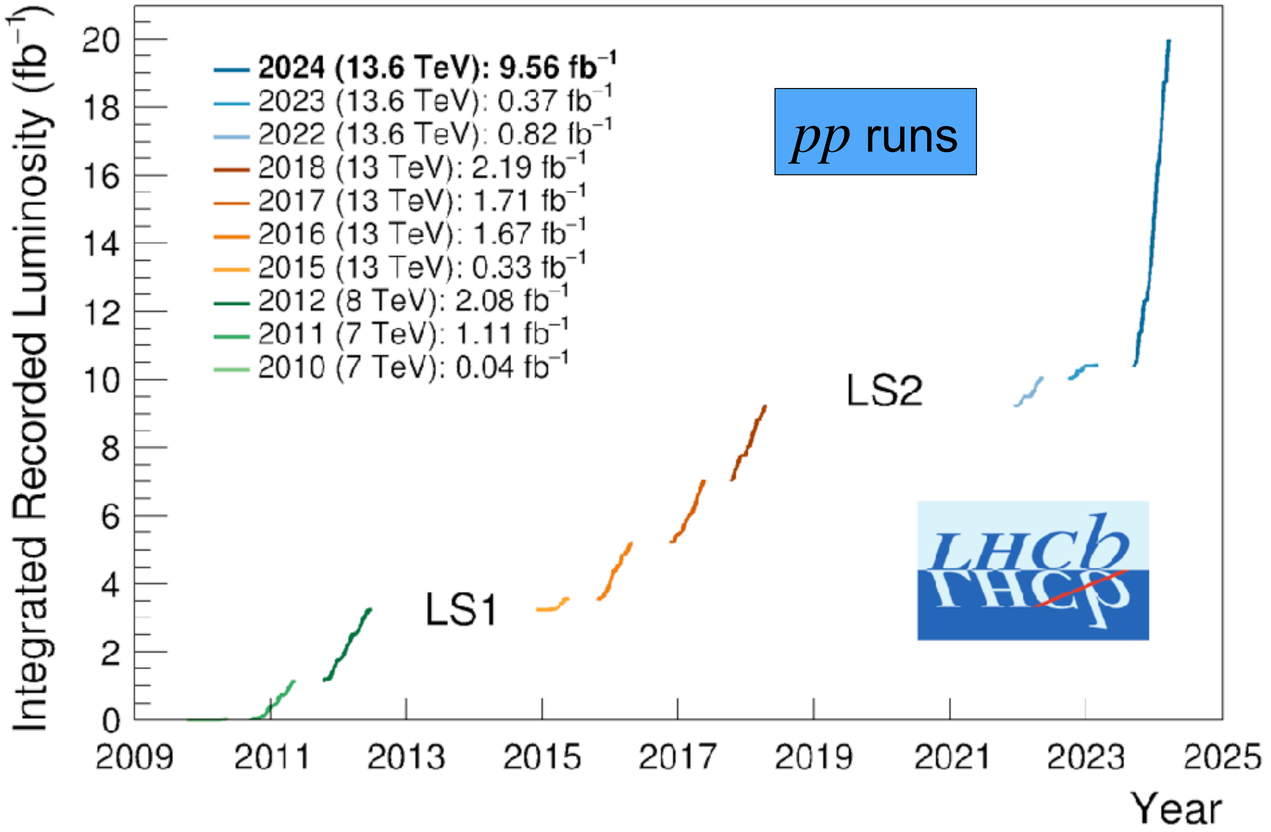
- Run 1 = 2011 + 2012 $\rightarrow 3\ \text{fb}^{-1}$
- Run 2 = 2015 + 2016 + 2017 + 2018 $\rightarrow 6\ \text{fb}^{-1}$
- Run 3 = 2022 + 2023 + 2024 (+ 2025 + 2026) $\rightarrow 10\ \text{fb}^{-1}$

Total $\approx 10^{12}$ B mesons

- 2011: $\sqrt{s} = 7$ TeV
- 2012: $\sqrt{s} = 8$ TeV
- Run 2: $\sqrt{s} = 13$ TeV
- Run 3: $\sqrt{s} = 13.6$ TeV

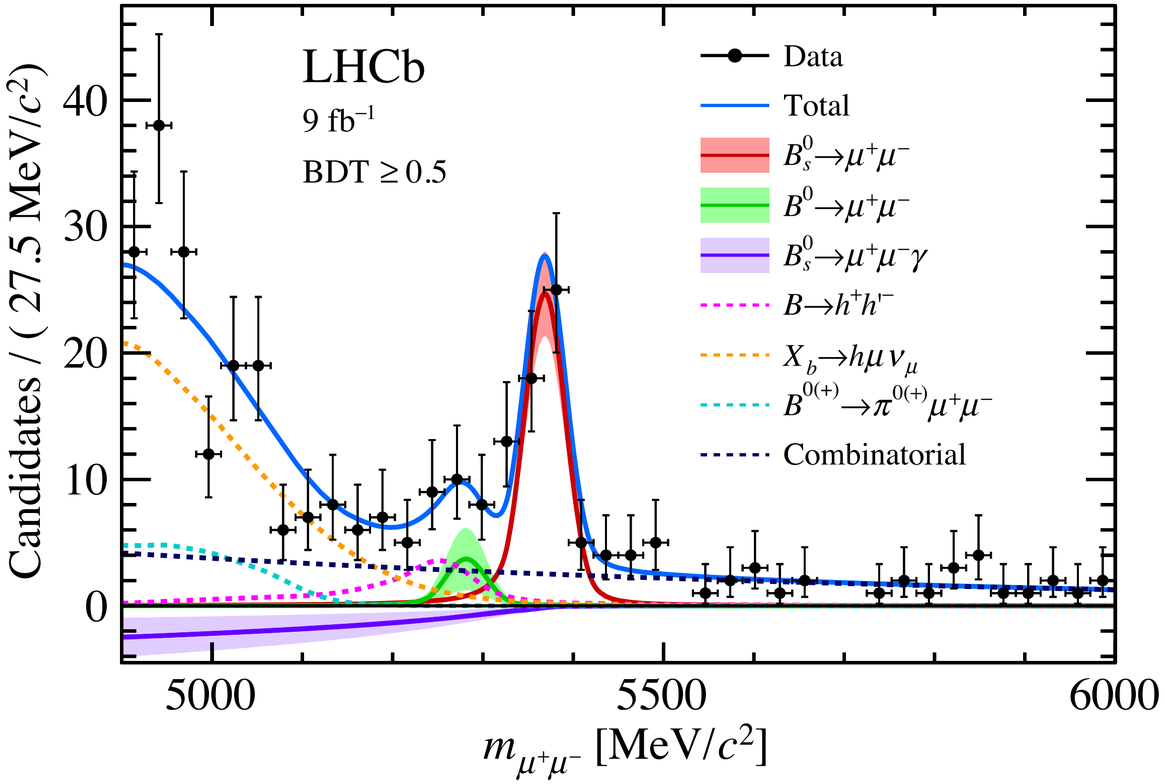
- $\sigma_{b\bar{b}} \sim \sqrt{s} \Rightarrow N_{b\bar{b}}$ scales with luminosity and with energy

  [+ PbPb (+pPb +Pbp) datasets]



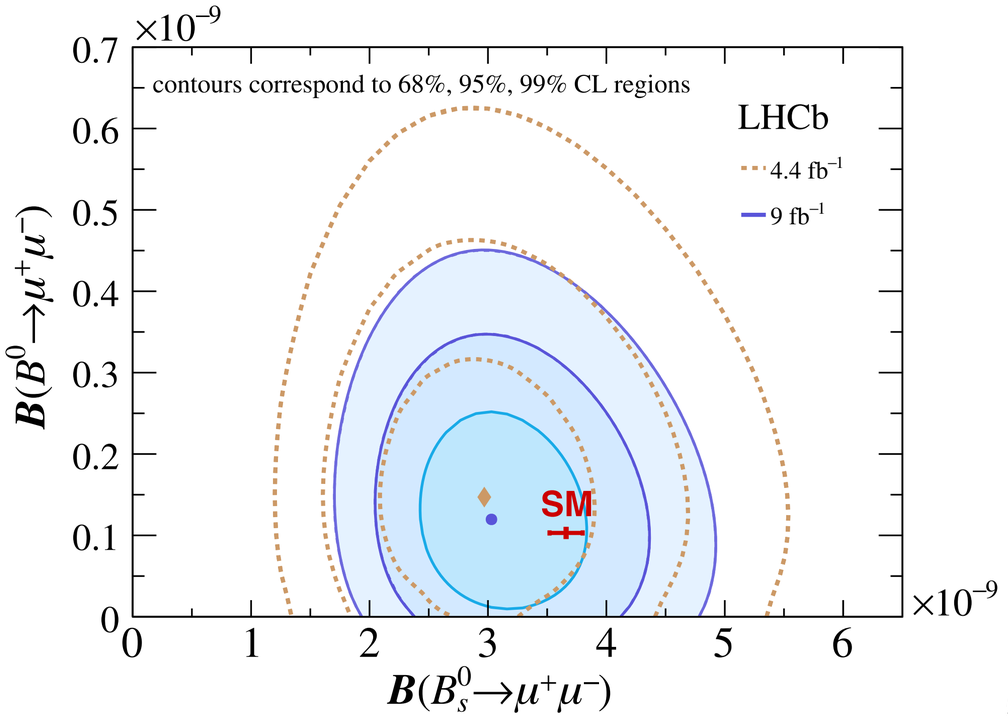
Rare decays: $B_s \to \mu^+\mu^-$

LHCb-PAPER-2021-007
Phys. Rev. Lett. 128 (2022) 041801



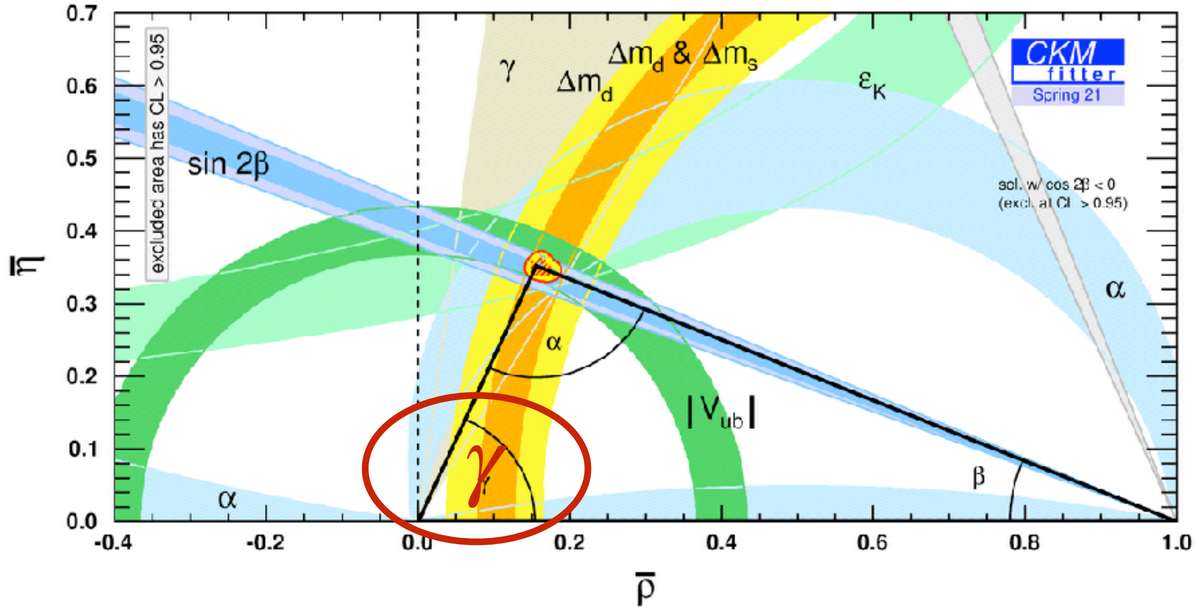
$$\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-) = \frac{\mathcal{B}_{\rm norm}\epsilon_{\rm norm} f_{\rm norm}}{N_{\rm norm}\epsilon_{\rm sig} f_{d(s)}} N_{B^0_{(s)}\to\mu^+\mu^-}$$

$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (3.09^{+0.46+0.15}_{-0.43-0.11}) \times 10^{-9},$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.2^{+0.8}_{-0.7} \pm 0.1) \times 10^{-10}, < 2.6 \times 10^{-10}$$



Take advantage of cancellation of systematic effects in ratios
Huge data sample allows to reach sensitivity down to 10^{-9}

CKM angle γ

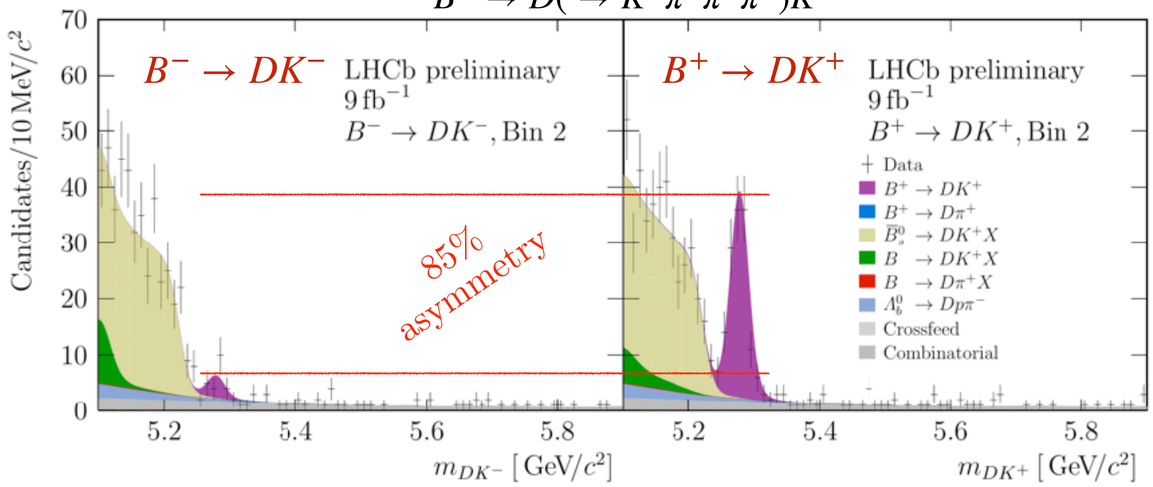


Combination of several results

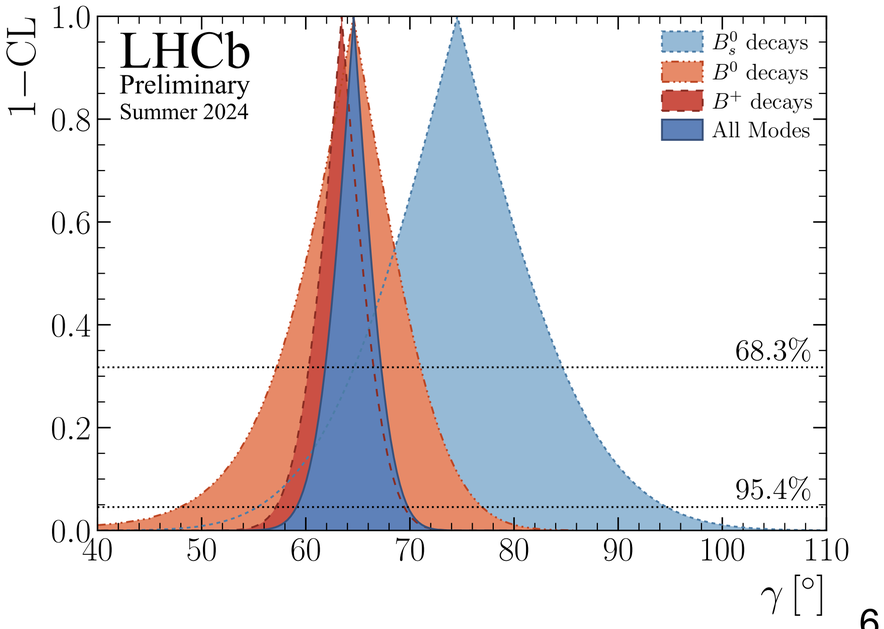
$$\gamma = (64.6 \pm 2.8)^\circ$$

B decay	D decay	Ref.	Dataset	Status since Ref. [14]
$B^\pm \to Dh^\pm$	$D \to h^+h^{(\prime)-}$	[35]	Run 1&2	*As before*
$B^\pm \to Dh^\pm$	$D \to h^+h^-\pi^+\pi^-$	[19]	Run 1&2	**New**
$B^\pm \to Dh^\pm$	$D \to K^\pm\pi^\mp\pi^+\pi^-$	[36]	Run 1&2	*As before*
$B^\pm \to Dh^\pm$	$D \to h^\pm h'^\mp\pi^0$	[37]	Run 1&2	*As before*
$B^\pm \to Dh^\pm$	$D \to K^0_S h^+h^-$	[38]	Run 1&2	*As before*
$B^\pm \to Dh^\pm$	$D \to K^0_S K^\pm\pi^\mp$	[39]	Run 1&2	*As before*
$B^\pm \to D^*h^\pm$	$D \to h^\pm h'^\mp$ (PR)	[35]	Run 1&2	*As before*
$B^\pm \to D^*h^\pm$	$D \to K^0_S h^+h^-$ (PR)	[20]	Run 1&2	**New**
$B^\pm \to D^*h^\pm$	$D \to K^0_S h^+h^-$ (FR)	[21]	Run 1&2	**New**
$B^\pm \to DK^{*\pm}$	$D \to h^\pm h'^\mp$	[22]†	Run 1&2	**Updated**
$B^\pm \to DK^{*\pm}$	$D \to h^\pm\pi^\mp\pi^+\pi^-$	[22]†	Run 1&2	**Updated**
$B^\pm \to DK^{*\pm}$	$D \to K^0_S h^+h^-$	[22]†	Run 1&2	**New**
$B^\pm \to Dh^\pm\pi^+\pi^-$	$D \to h^\pm h'^\mp$	[40]	Run 1	*As before*
$B^0 \to DK^{*0}$	$D \to h^\pm h'^\mp$	[23]	Run 1&2	**Updated**
$B^0 \to DK^{*0}$	$D \to h^\pm\pi^\mp\pi^+\pi^-$	[23]	Run 1&2	**Updated**
$B^0 \to DK^{*0}$	$D \to K^0_S h^+h^-$	[24]	Run 1&2	**Updated**
$B^0 \to D^\mp\pi^\pm$	$D^+ \to K^-\pi^+\pi^+$	[41]	Run 1	*As before*
$B^0_s \to D^\mp_s K^\pm$	$D^+_s \to h^+h^-\pi^+$	[25, 42]†	Run 1&2	**Updated**
$B^0_s \to D^\mp_s K^\pm\pi^+\pi^-$	$D^+_s \to h^+h^-\pi^+$	[43]	Run 1&2	*As before*
D decay	Observable(s)	Ref.	Dataset	Status since Ref. [14]
$D^0 \to h^+h^-$	ΔA_{CP}	[44–46]	Run 1&2	*As before*
$D^0 \to K^+K^-$	$A_{CP}(K^+K^-)$	[46–48]	Run 2	*As before*
$D^0 \to h^+h^-$	$y_{CP} - y^{K^-\pi^+}_{CP}$	[49,50]	Run 1&2	*As before*
$D^0 \to h^+h^-$	ΔY	[51–54]	Run 1&2	*As before*
$D^0 \to K^+\pi^-$ (double tag)	$R^\pm$, $(x'^\pm)^2$, $y'^\pm$	[55]	Run 1	*As before*
$D^0 \to K^+\pi^-$ (single tag)	$R_{K\pi}$, $A_{K\pi}$, $c^{(\prime)}_{K\pi}$, $\Delta c^{(\prime)}_{K\pi}$	[27,56]	Run 1&2	**Updated**
$D^0 \to K^\pm\pi^\mp\pi^+\pi^-$	$(x^2+y^2)/4$	[57]	Run 1	*As before*
$D^0 \to K^0_S\pi^+\pi^-$	x, y	[58]	Run 1	*As before*
$D^0 \to K^0_S\pi^+\pi^-$	x_{CP}, y_{CP}, Δx, Δy	[59]	Run 1	*As before*
$D^0 \to K^0_S\pi^+\pi^-$	x_{CP}, y_{CP}, Δx, Δy	[60,61]	Run 2	*As before*
$D^0 \to \pi^+\pi^-\pi^0$	$\Delta Y^{\rm eff}$	[26]	Run 2	**New**

$B^\pm \to D(\to K^\mp\pi^\pm\pi^\pm\pi^\mp)K^\pm$



CKM angle γ determined from tree processes

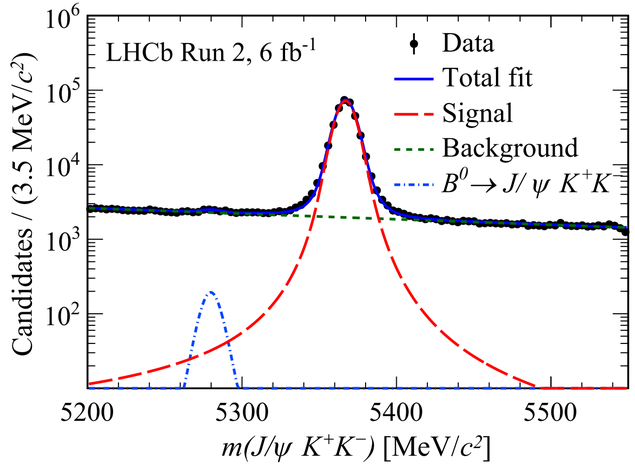


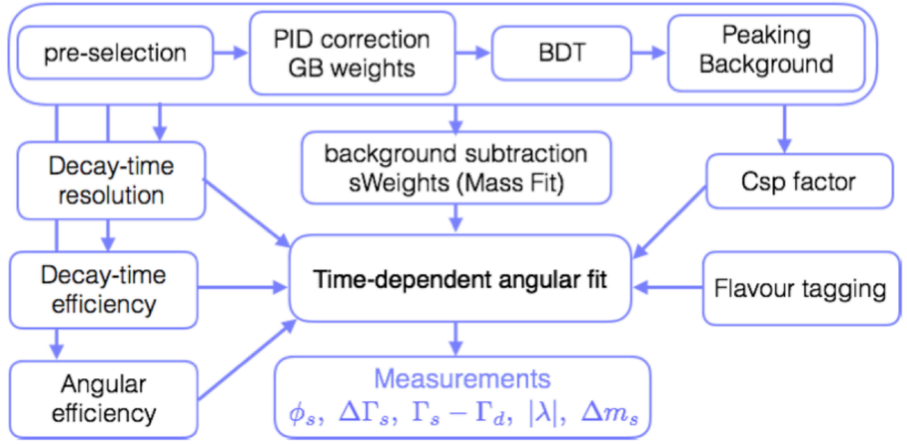
LHCb-PAPER-2022-017
JHEP 07 (2023) 138

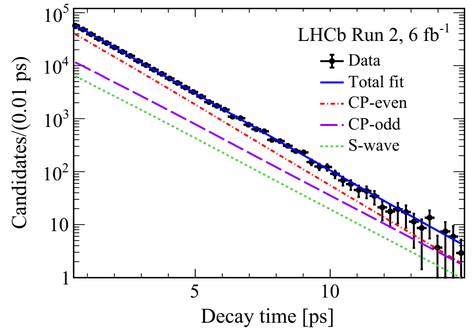
ϕ_s in $B_s \to J/\psi K^+K^-$ decays

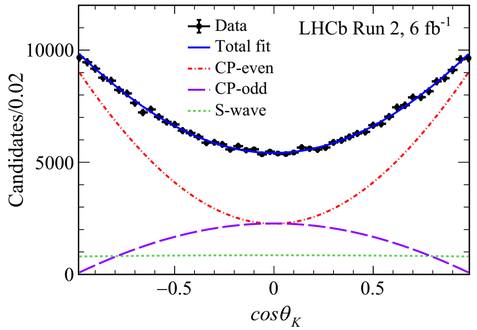
LHCb-PAPER-2023-016
Phys. Rev. Lett. 132 (2024) 051802

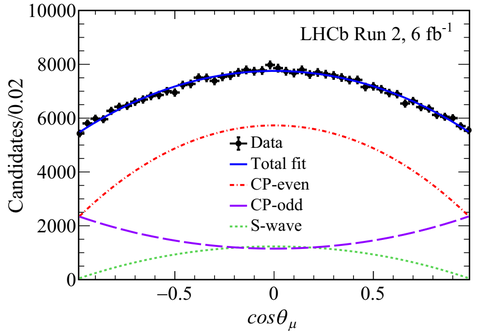
- CP violation in the interference between decay and mixing
- Sensitive to physics beyond the Standard Model

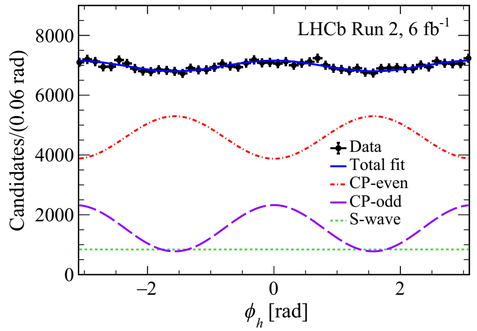












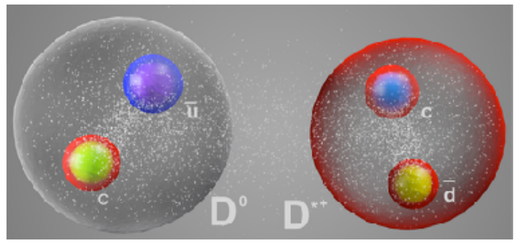
Measurement relying on the full capabilities of the detector:
- decay time
- flavour tagging (identify the flavour of the produced B meson)
- angular analysis

$$\phi_s = -0.044 \pm 0.020 \text{ rad}$$

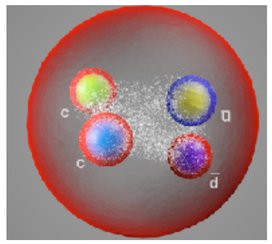
Discovery of new (exotic) hadrons

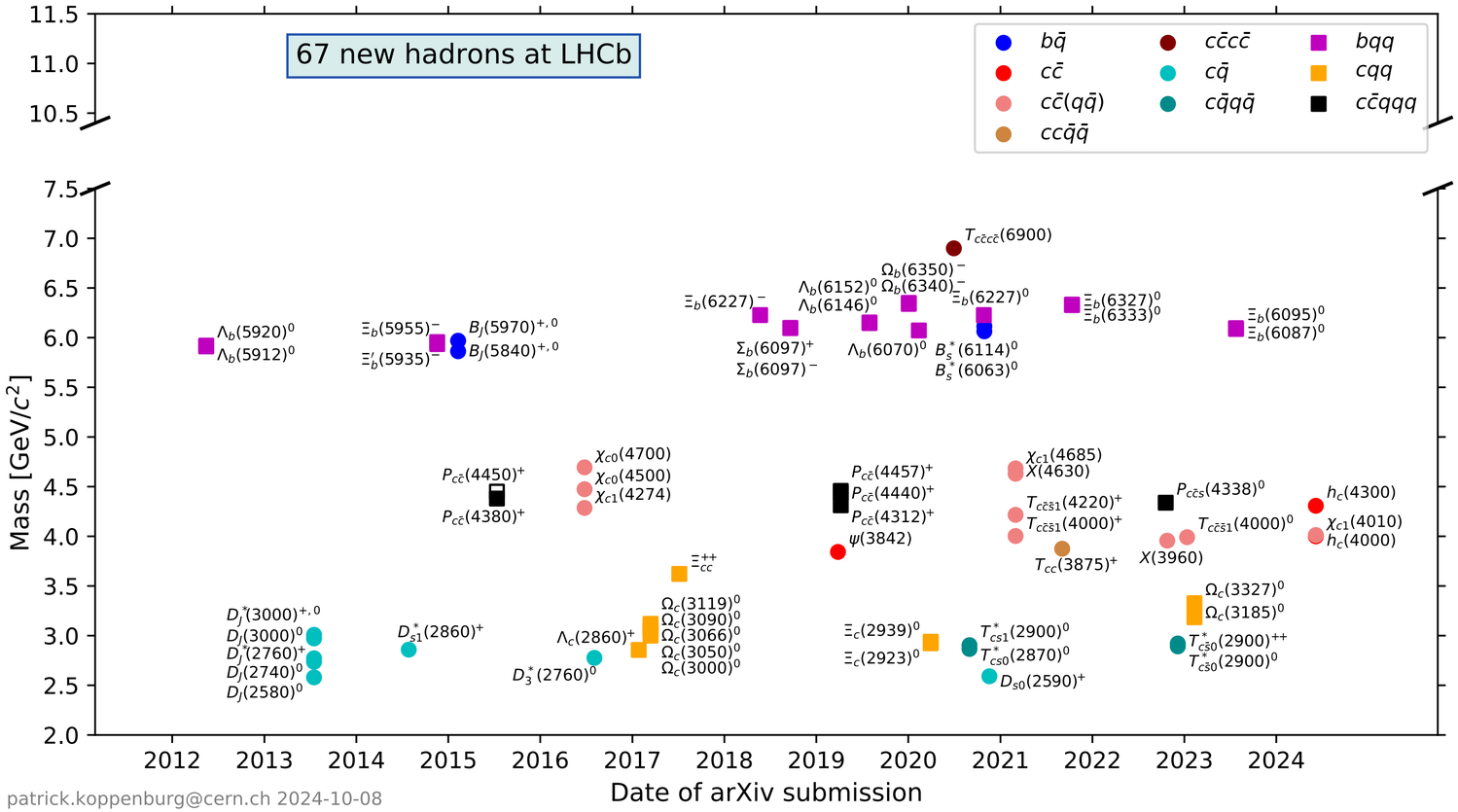
- Several new hadrons discovered at LHCb
- Study the nature of these hadrons
  - isospin structure
  - spin-parity
  - ...

- For example, are these loosely bound "molecular" states?



..or tightly bound states?





credit: Patrick Koppenburg

You and your analysis (or any other work!)

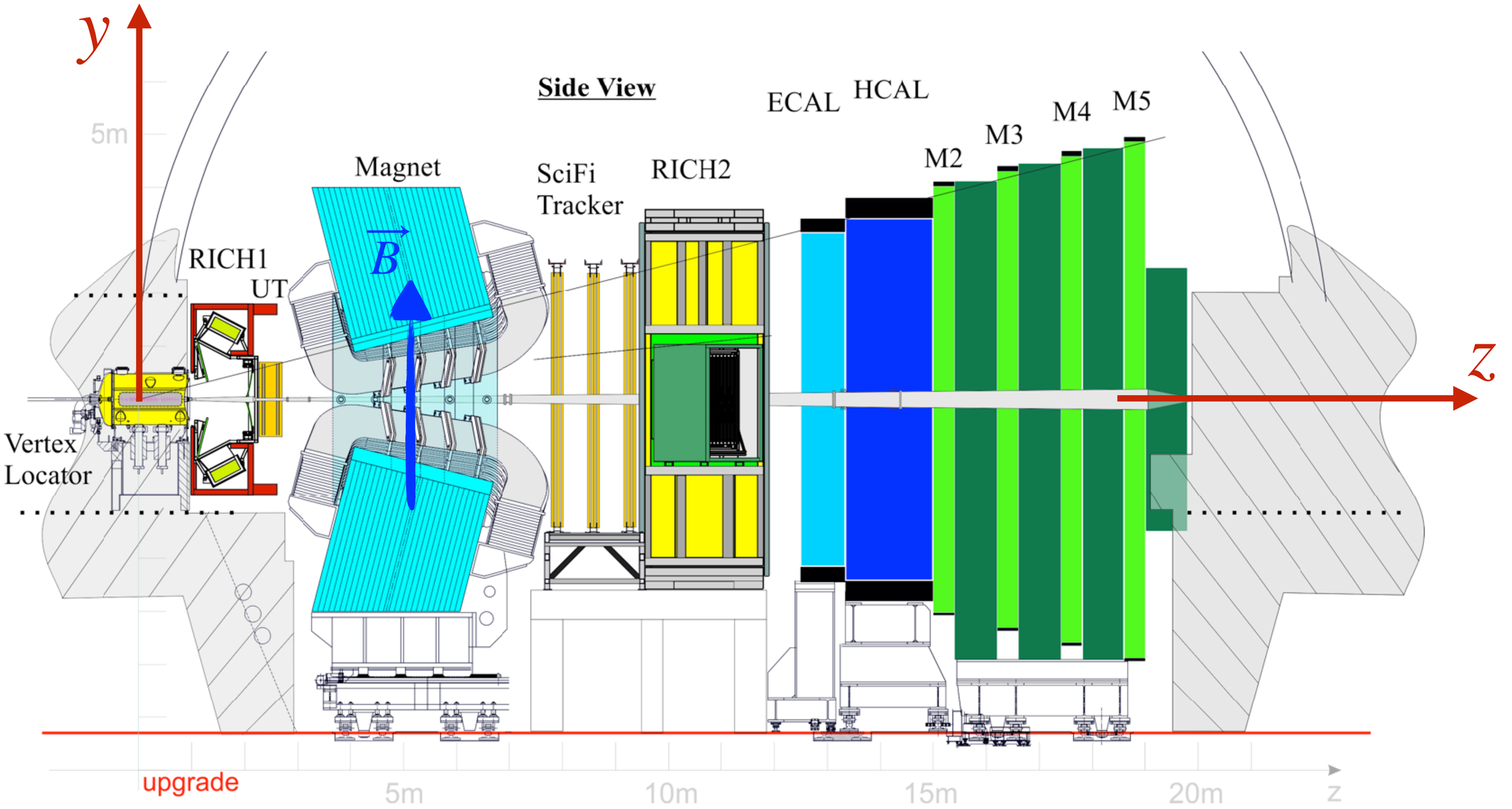
- All analyses have a great value!
  - some get more visibility, but this is be no means a judgement of the value of any analysis
  - any contribution is important for the project you work on (LHCb in our case)

- What you will learn from performing an analysis → experience!
  - experience with tools: tools specific to LHCb; statistics; fitting techniques; etc...
  - experience with failures: failures are useful to understanding what works and what doesn't
  - experience with collaborative work and communication
    - present your work as frequently as possible at working group meetings

- Enjoy what you are doing
  - we are lucky to work with exceptional data collected with a very unique detector
  - the time of a PhD allows you to explore uncharted territory

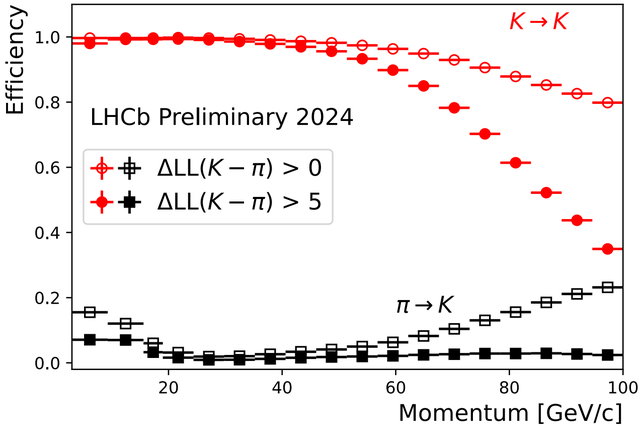
Let's look into LHCb-specific aspects of your analysis:
→ **EVERYTHING STARTS WITH KNOWING YOUR DETECTOR**

Know your detector!

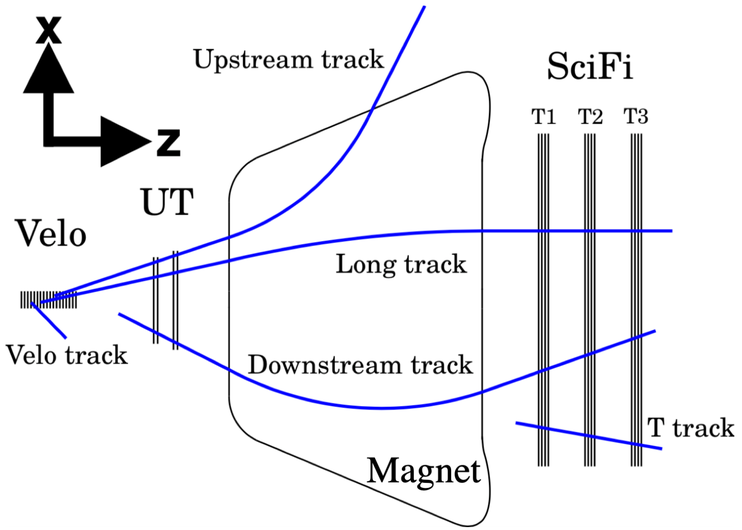


Detector performance and corrections

- Each analysis will ultimately be applied to the data
  - develop the analysis on real data (control channel, signal sidebands) and/or on simulation
  - corrections need to be applied to the simulation to match the data



- Types of corrections
  - PID response → applied to simulation
  - Tracking efficiency corrections
  - Trigger efficiency corrections (mostly Level-0 in Run1+2)

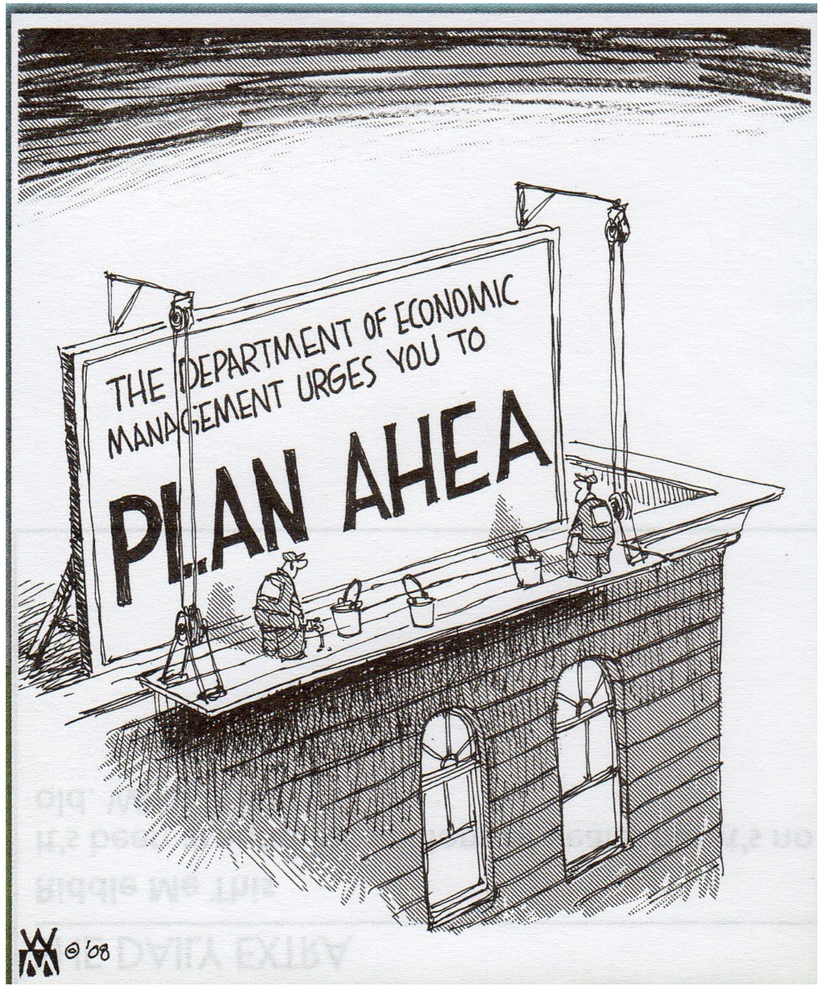


- Don't forget the systematic uncertainty associated with each correction

Analysis development and review process

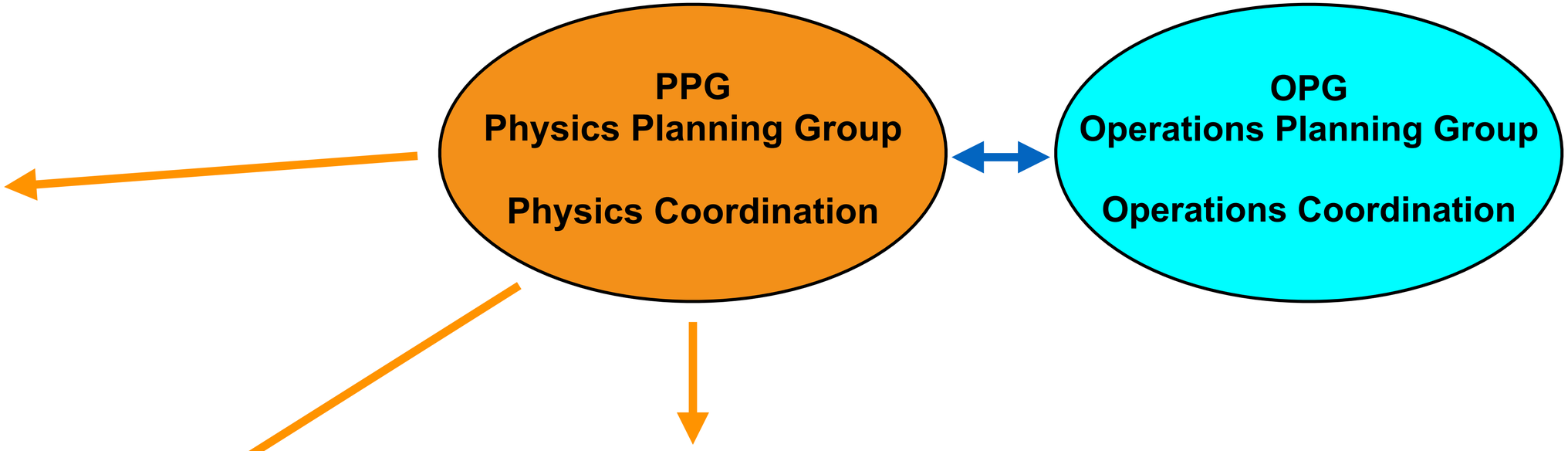
- Develop your analysis within a Working Group (WG)
  - present regularly at WG meetings ⇒ receive comments and suggestions
- Once the analysis is ready, it is reviewed within the WG
  → WG approval
- Review committee (RC) stage:
  - two LHCb members are assigned to each analysis
  - RC checks and validates the scientific value of the analysis
- When RC has finalised its review:
  → "Approval to go to paper", organised by PC
  - obtain approval to publish your results
  - first paper draft is available for "circulation" within 2 weeks
- First and second collaboration wide circulations (CWR)
  - under the responsibility of the Editorial Board (EB)
- Submit your paper! (LHCb-PAPER-20YY-NNN)

- The whole review process takes time...



Organisation of physics at LHCb

- Physics Analysis Working Groups (PAWG):
  - **BandQ**
  - **B2CC/BnoC**
  - **B2OC**
  - **Charm**
  - **IFT**
  - **QEE**
  - **RD**
  - **SL**



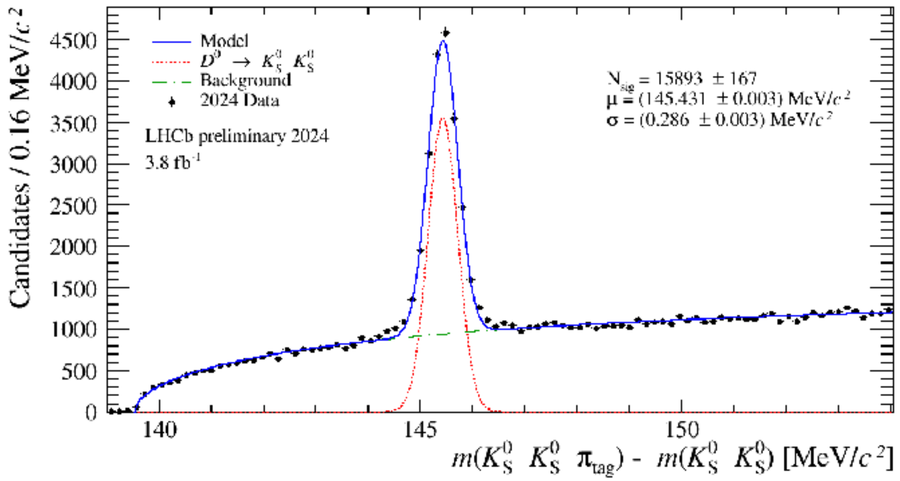
- Projects:
  - **RTA**
  - **DPA**
  - **Simulation**
  - **Computing**

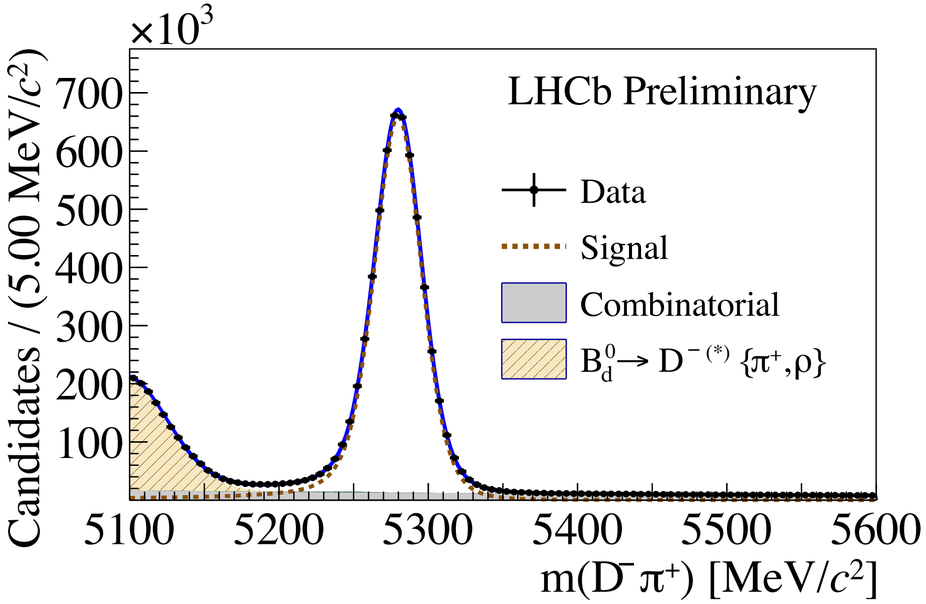
- Physics Performance Working Groups (PPWG) and Task forces:
  - **ML & Statistics (MLStat)**
  - **Amplitude Analysis (AmAn)**
  - **Flavour Tagging (FT)**
  - **Luminosity**

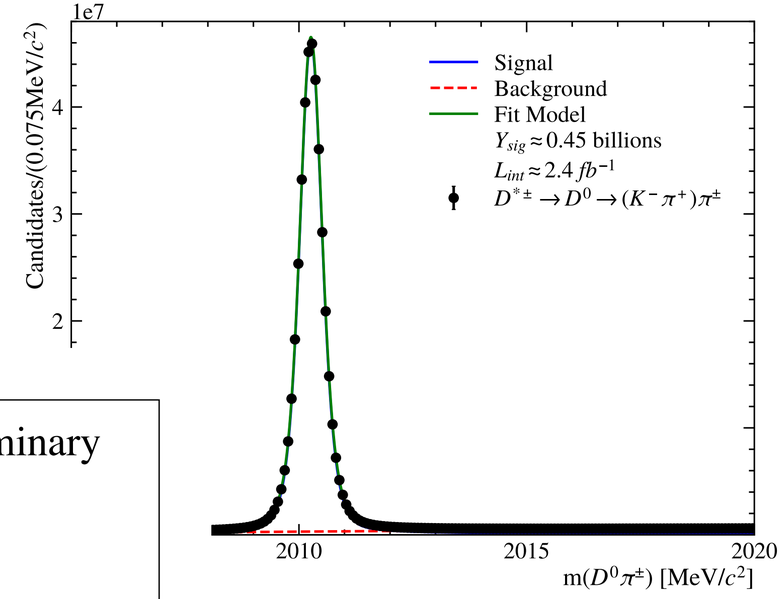
Final words

- It is now your turn to produce (physics) results!
- I wish you to enjoy this opportunity
- A PhD is not always easy, but never ever doubt about your ability to succeed!
- Seek help and advice when you need it
- This Starterkit is a fantastic tool,
  which will be a precious source of information

⇒ Thank you to the organisers!







Some Run 3
preliminary results!