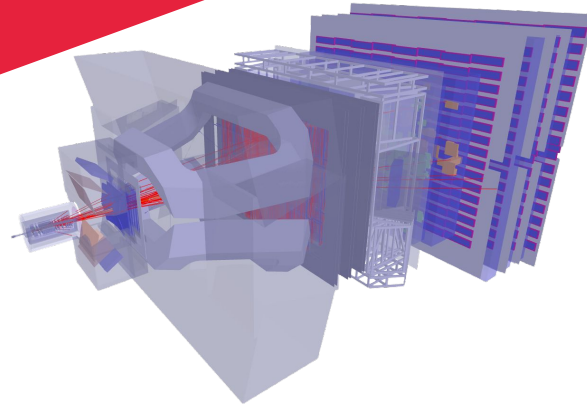


Nikhef



LHCb: health check to the Standard Model

Tim Evans and Zhihong Shen

Jamboree

May 12, 2026

Keeping elephants healthy at Amsterdam Zoo

- How do we weigh Mook Uhm and Yuki?



Photos from Mark Waterlaat

How to weigh an elephant?



Direct measurement



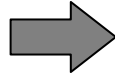
Indirect measurement: Cao Chong weighs an elephant



From weighing an elephant to particle physics

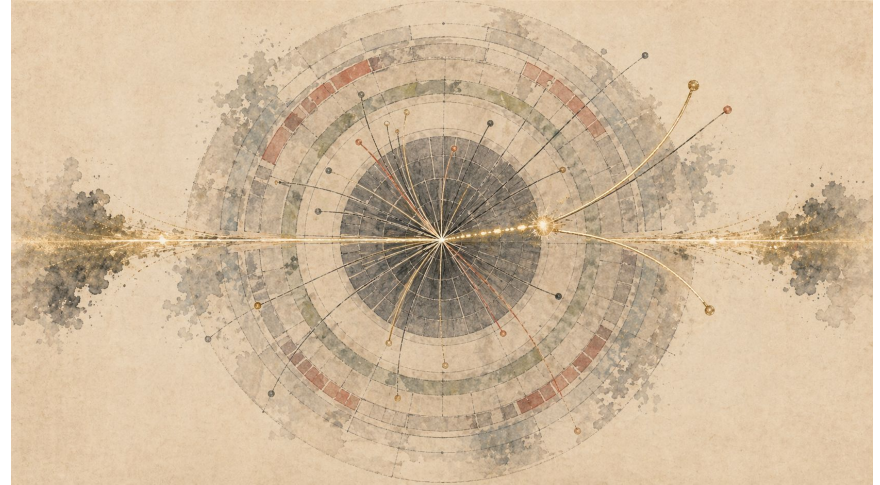
Weighing an elephant

health check to elephant



Search for potential new physics ?

health check to the Standard Model



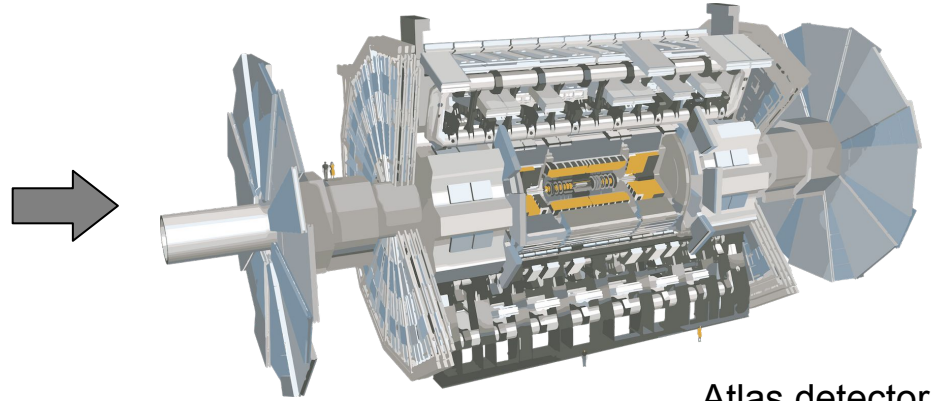
From weighing an elephant to particle physics

Directly weighing an elephant



Limited by the size of the scale

Direct searches for new physics



Atlas detector

Limited by collision energy

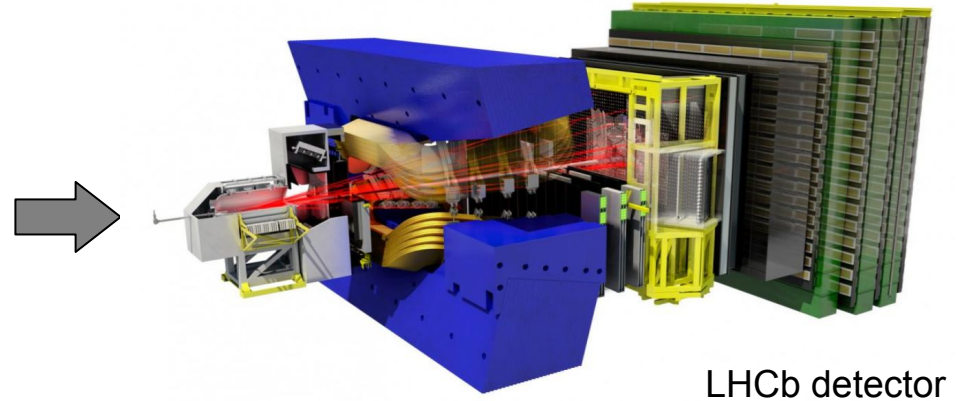
From weighing an elephant to particle physics

Indirectly weighing an elephant



**Measure the waterline
Infer the weight**

Indirect searches for new physics



LHCb detector

**Measure precision observables
Infer new physics**

The Nikhef LHCb group as Cao Chong



What is it made of?

LHCb @ Nikhef: staff

Nikhef:



Patrick



Kazu



Wouter



Niels

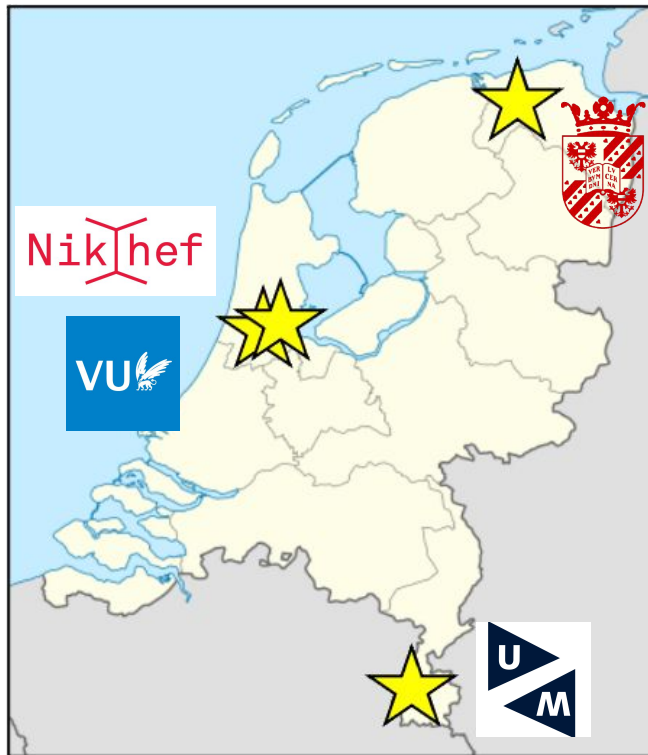
VU:



Mara



Gerhard



RUG:



Ann-Kathrin



Kristof

UM:



Jacco



Keri



Marcel



Chris



Maarten

NEW

LHCb @ Nikhef: postdocs and students



Joan



Andrii



Tim



Zhihong



Daniel



Xenofon



Rens



Davide



Andrej



Evridiki



Marta



Floris



Wouter



Daniel



George



Max

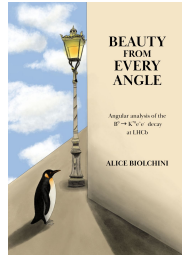


Mark

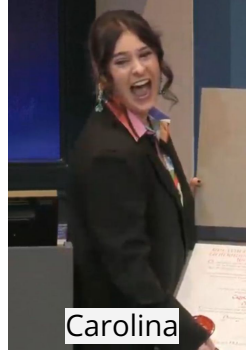


Lieke

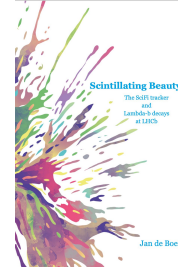
PhD defences



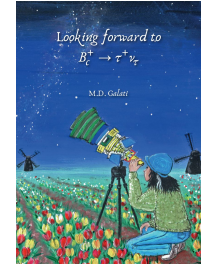
Beauty from every angle



The color of Flavour



Scintillating beauty

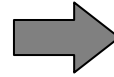


Looking forward to $B_c^+ \rightarrow \tau^+ \nu_\tau$

Departures

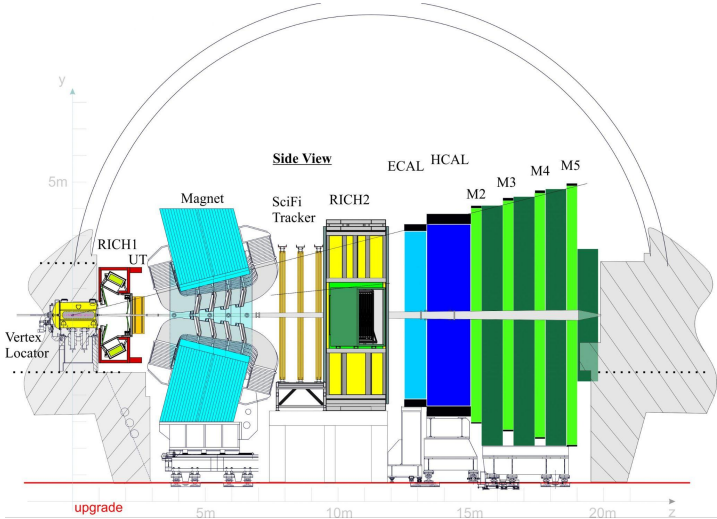
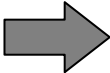
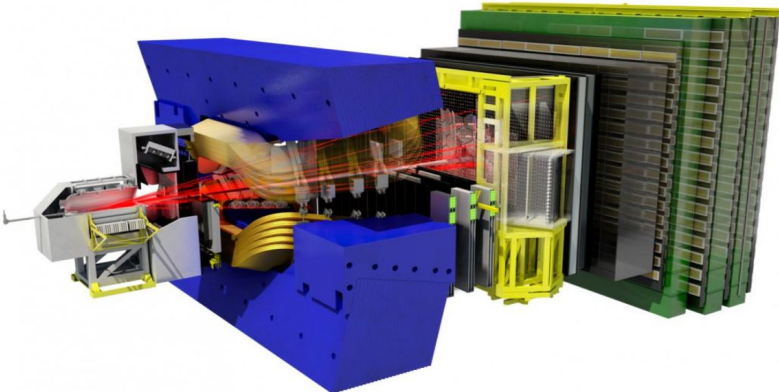


Mick
Postdoc at RUG

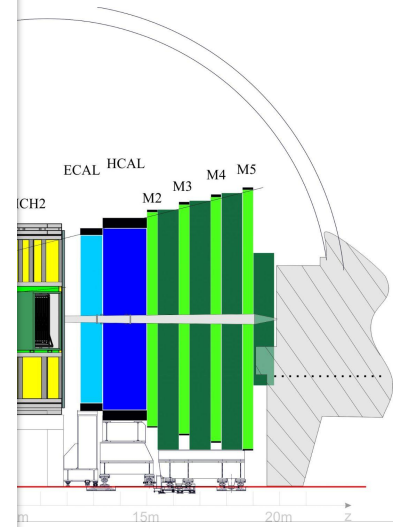
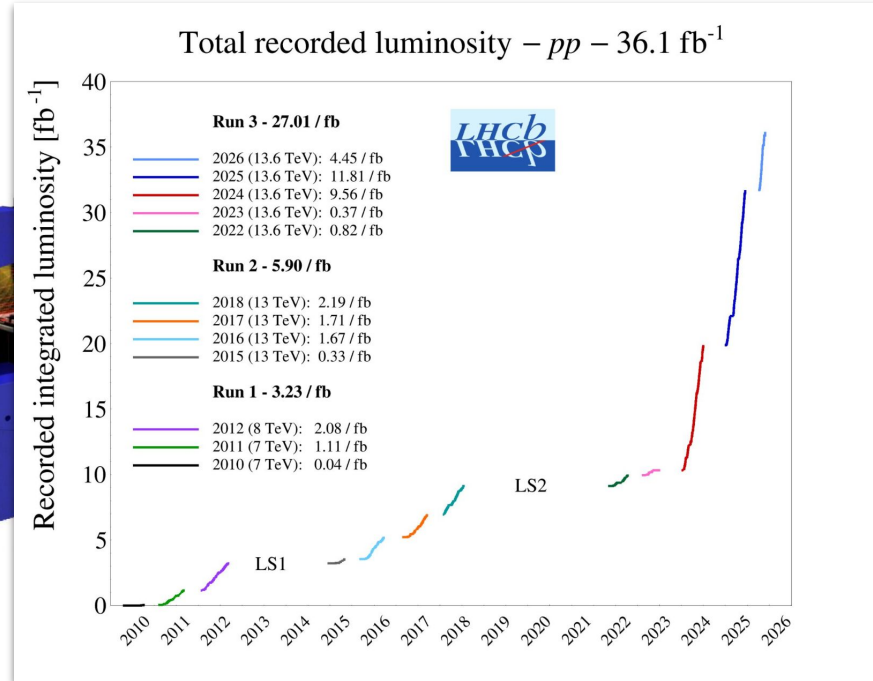
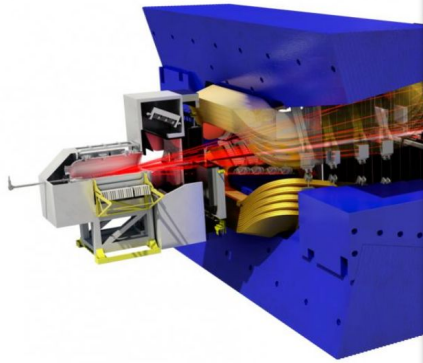


New Mick
**Junior faculty at
TU Dortmund**

Our boat (LHCb)

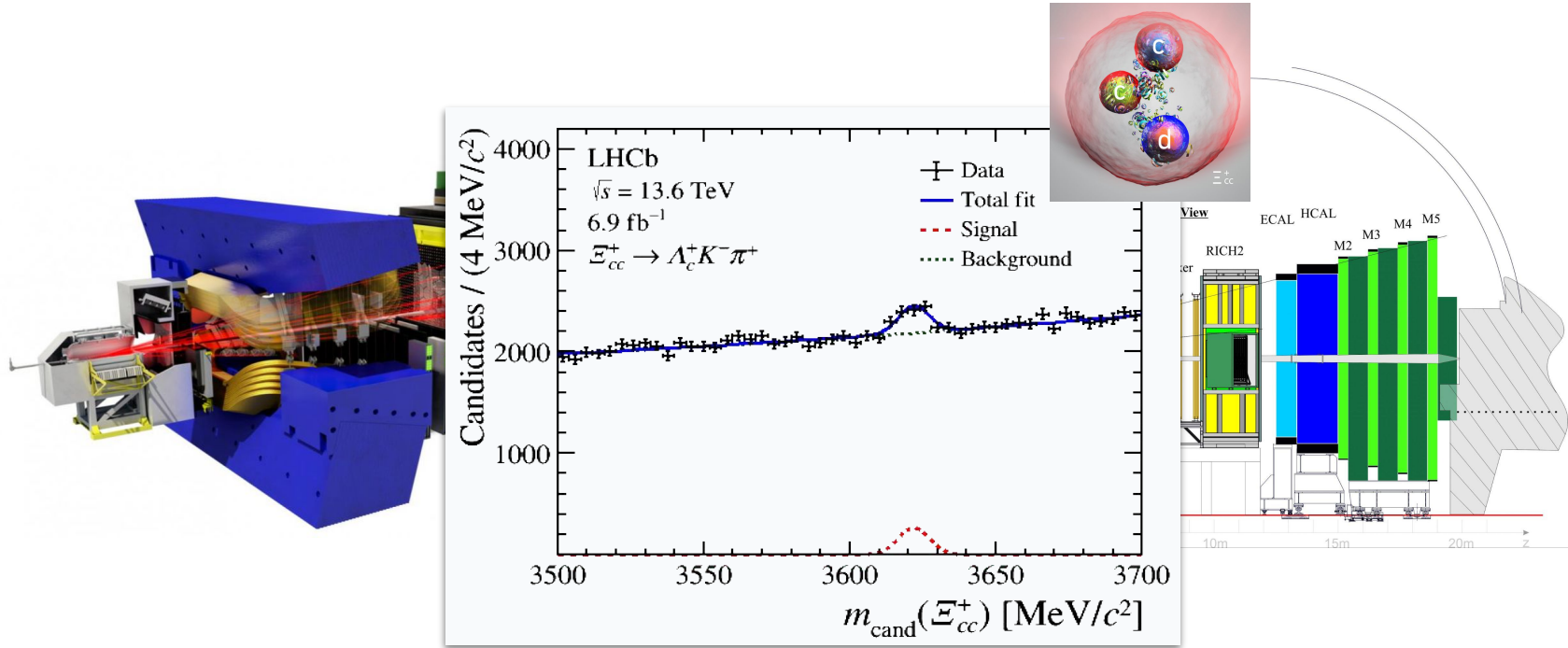


Our boat (LHCb)



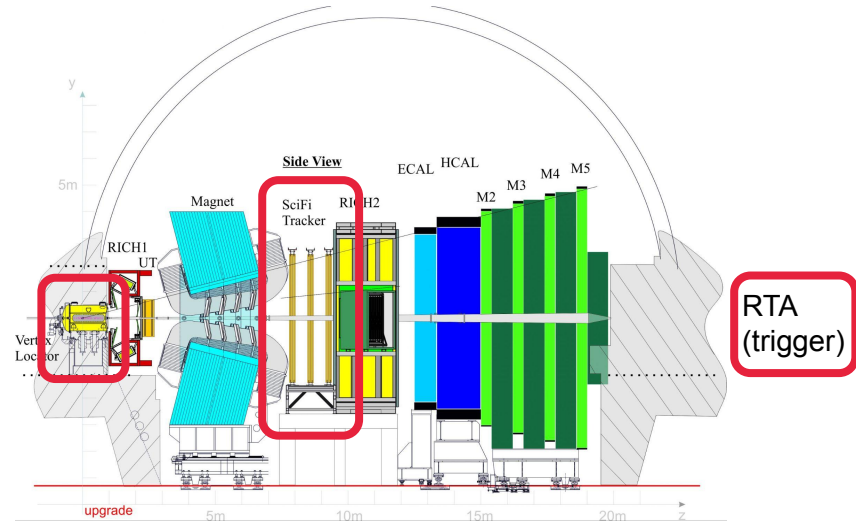
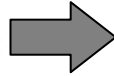
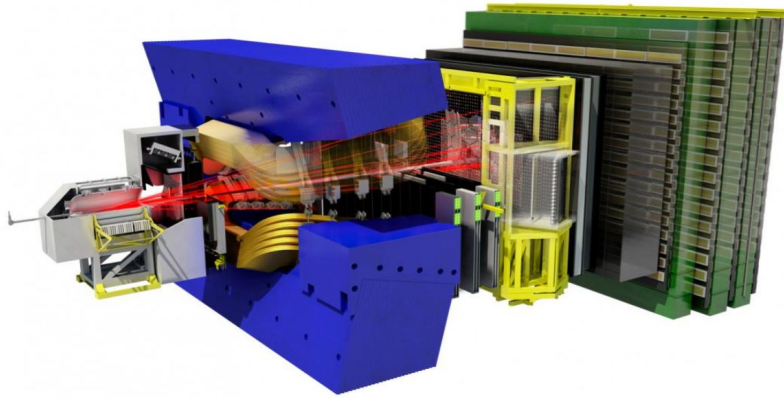
Enormous haul of data from the new detector

Our boat (LHCb)

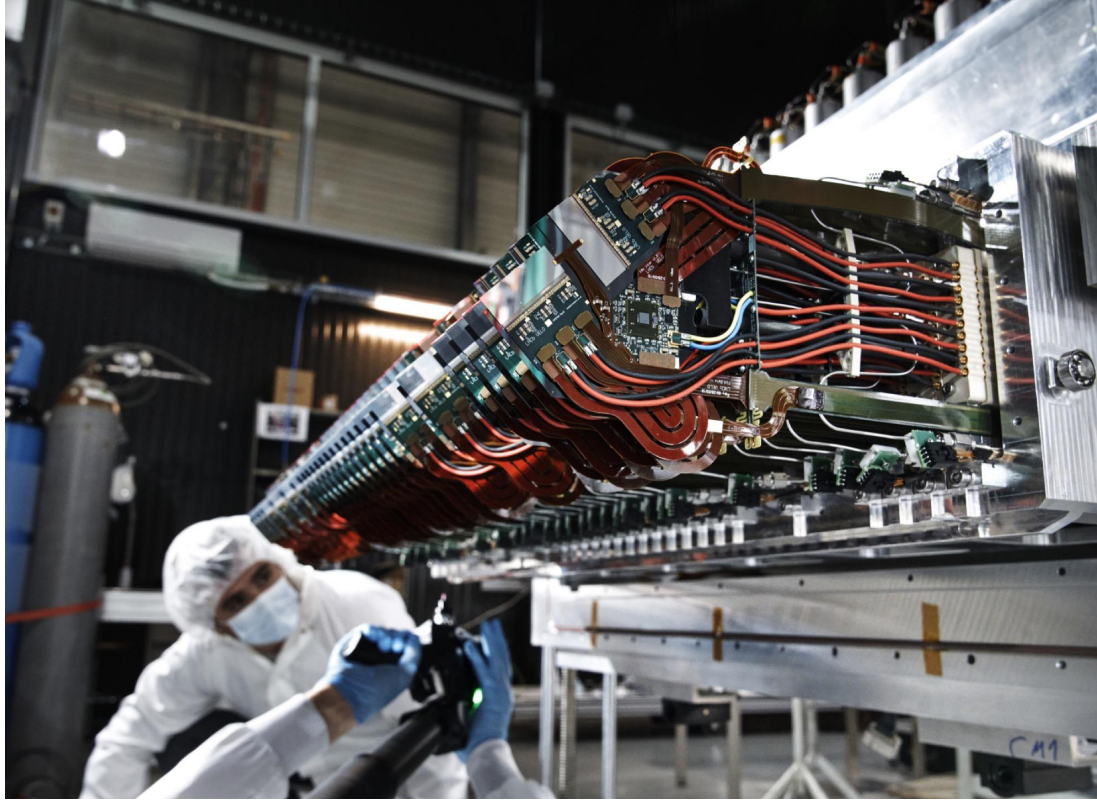
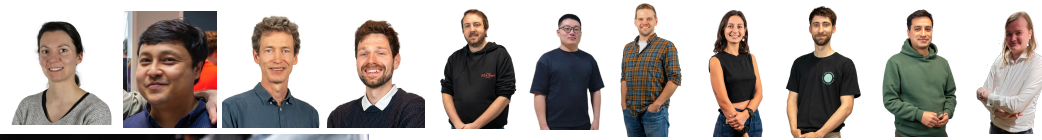


First discovery with new detector!

Our boat (LHCb): role of the Bfys group



VELO: current health

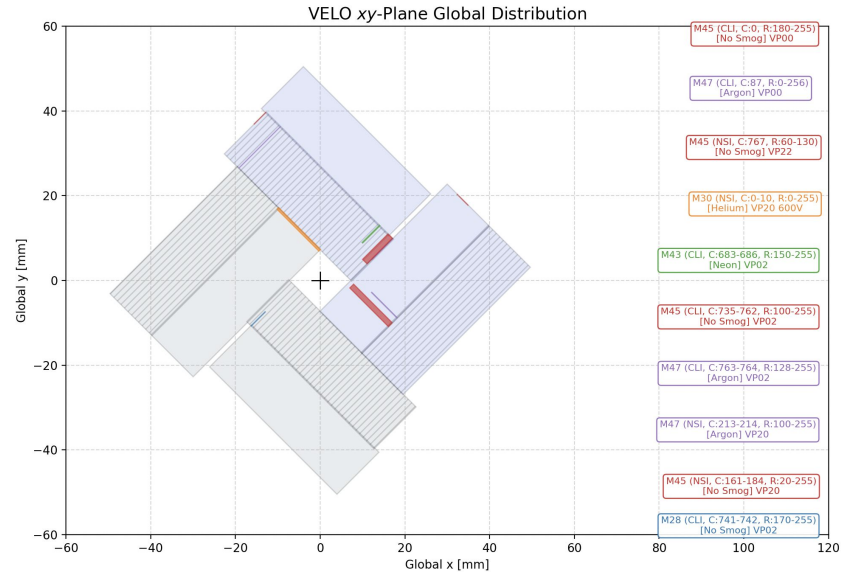


Bfys contributes to:

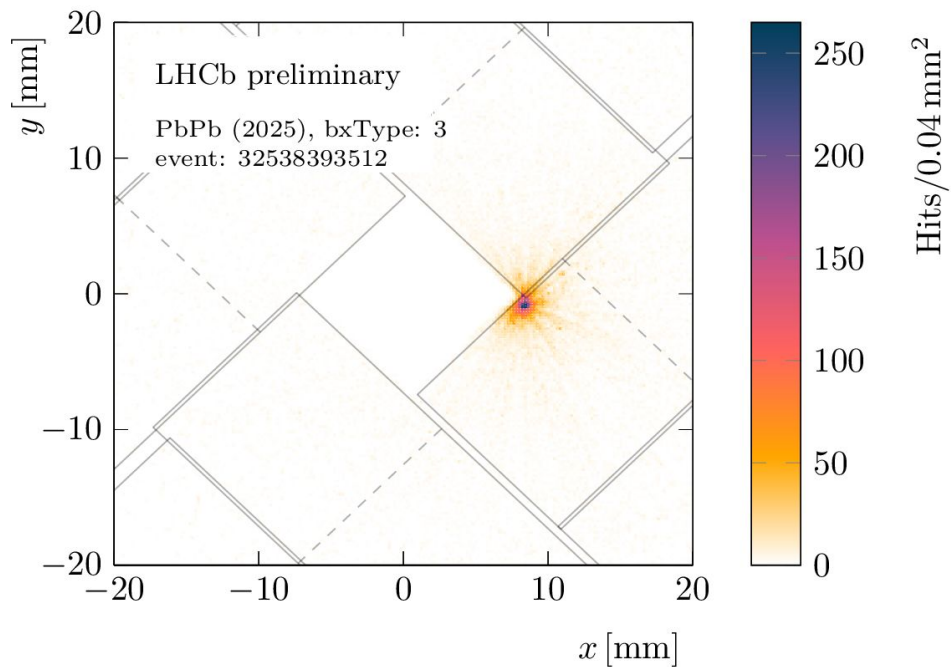
- Detector operations
- Studying radiation impact on efficiency and resolution
- Tomography and length scale calibration
-
- Future upgrades

VELO: on a less positive note

- Damage observed in some readout electronics (ASICs) starting in the heavy-ion run of 2025
- The good:
 - ◆ Still fully efficient over most of the angular coverage
 - ◆ For now still enough spares to repair in the next long shutdown (end 2026)
- The bad:
 - ◆ Loss in efficiency for $\eta > 4.3$
 - ◆ Exact cause of damage still unknown

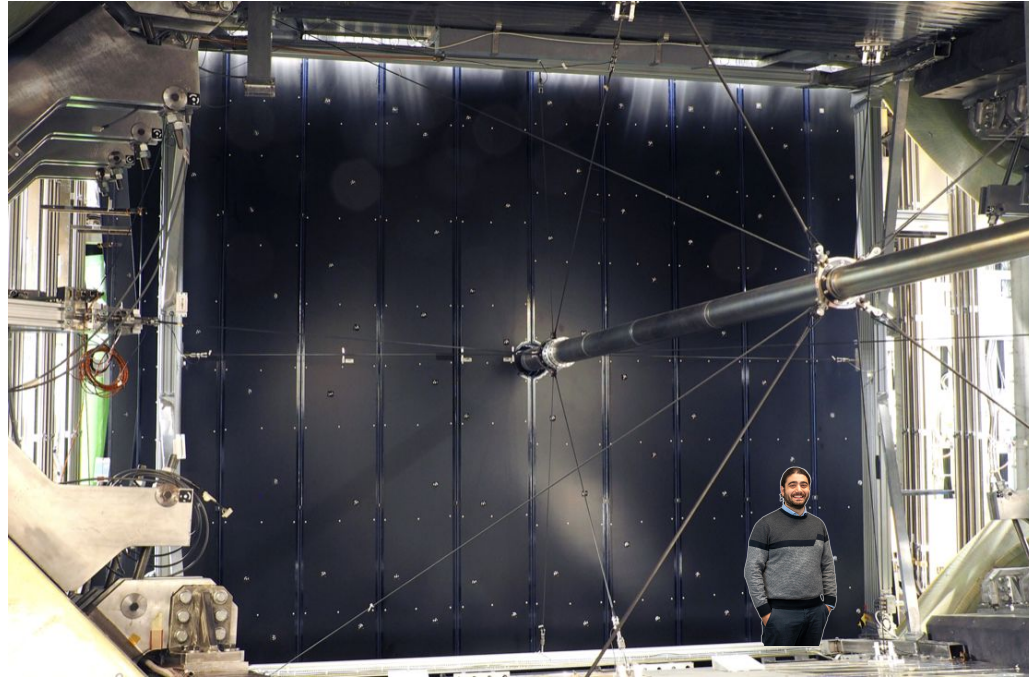


VELO: one possible suspect



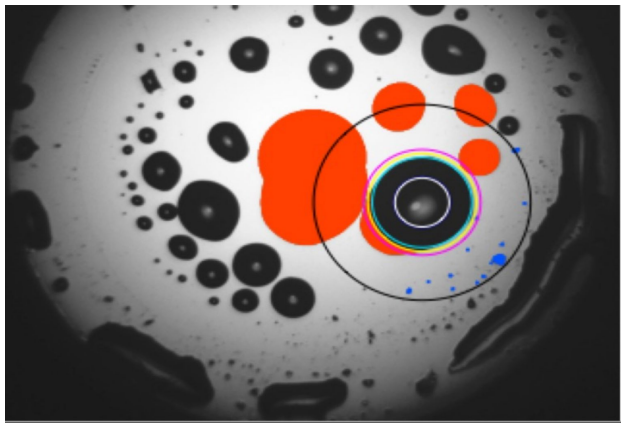
Fragment from lead nuclei interacting
with the detector

SciFi: current status

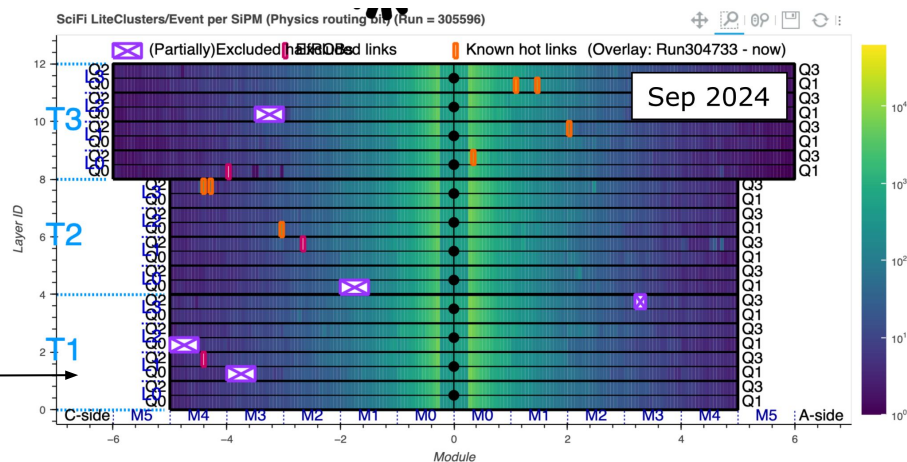


SciFi: fibre cleaning campaign

- Outgassing from glues used in optical links degrades signals over time
 - ◆ A campaign to clean the fibres!



Causes



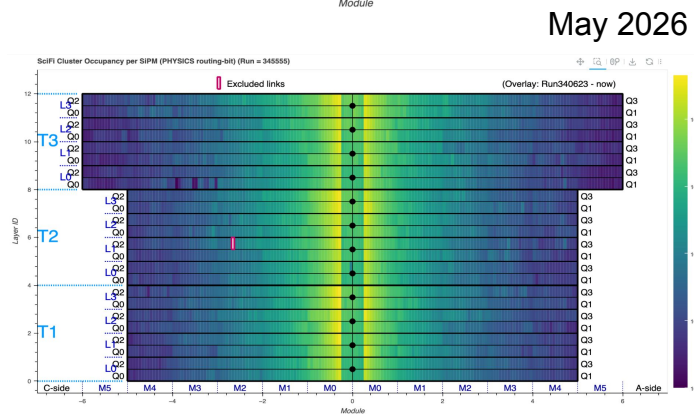
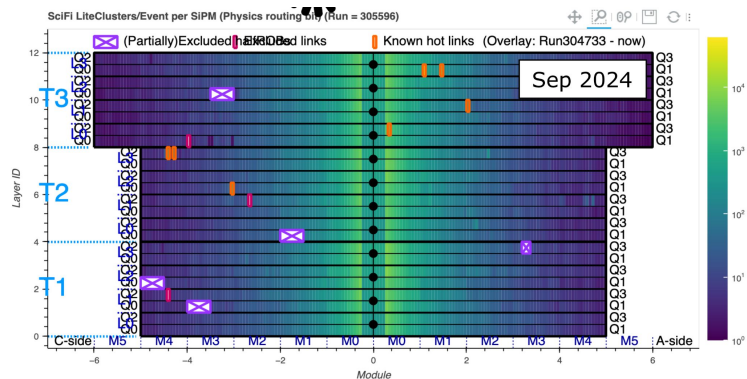
For details see

<https://indico.cern.ch/event/1099169/>

SciFi: fibre cleaning campaign

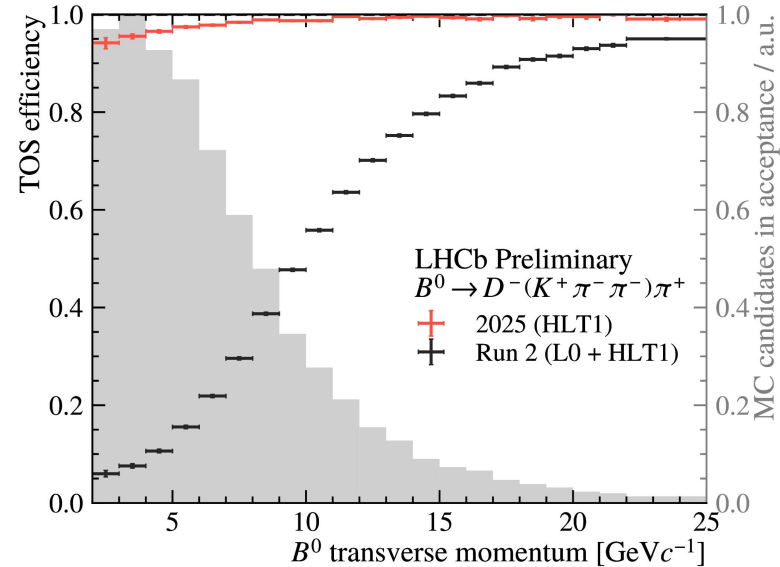
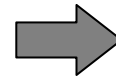
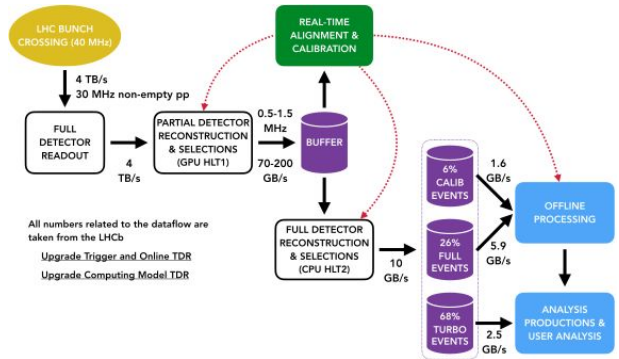


SciFi: fibre cleaning campaign

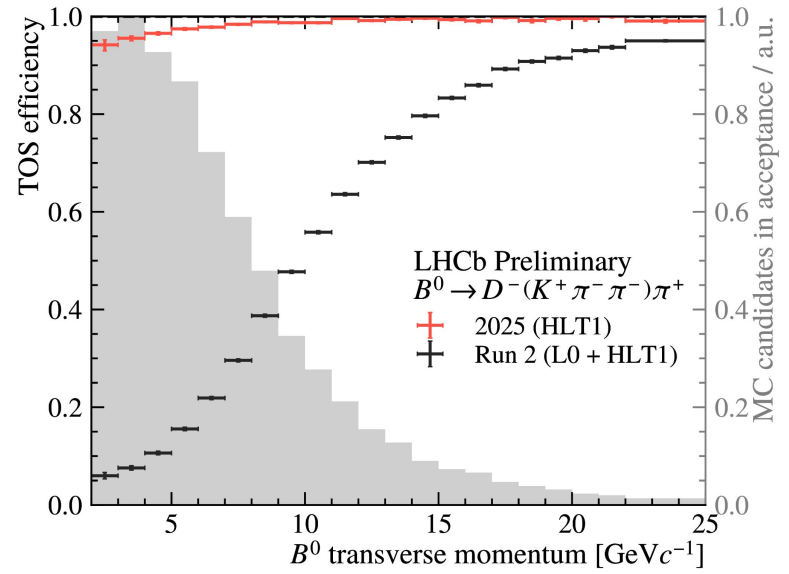
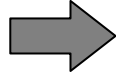
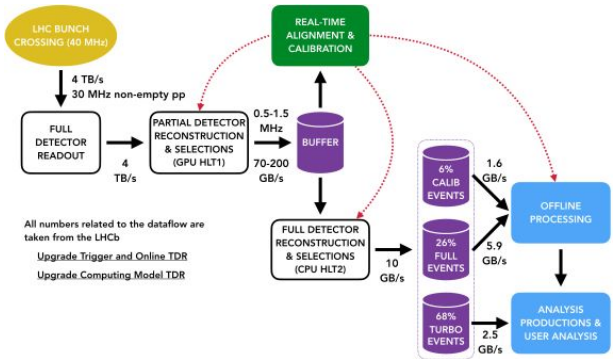


Success!

RTA: a triggerless trigger

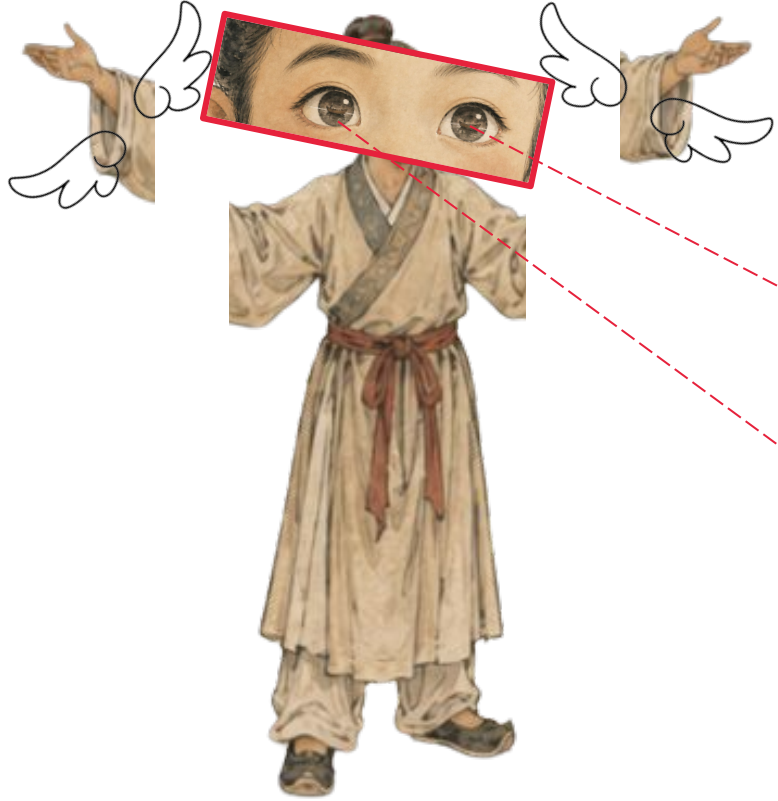


RTA: a triggerless trigger



- Reading out (and reconstructing) every BX of LHC one of the biggest challenges in HEP computing
- Now successfully demonstrated @ 40MHz, in many cases doubling efficiency w.r.t 'classic' LHCb
 - And then there is the future...

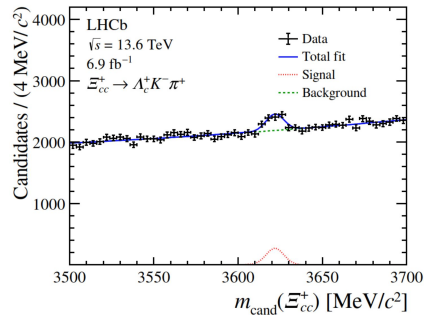
What waterlines do we read?



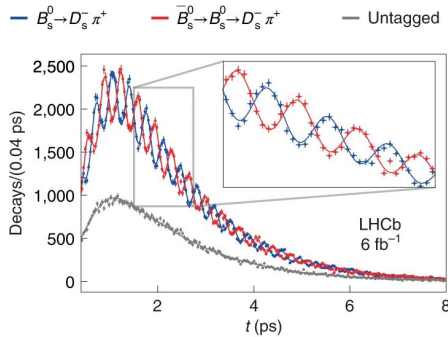
What waterlines do we read?

- LHCb extracts precision observables from reconstructed beauty and charm decays

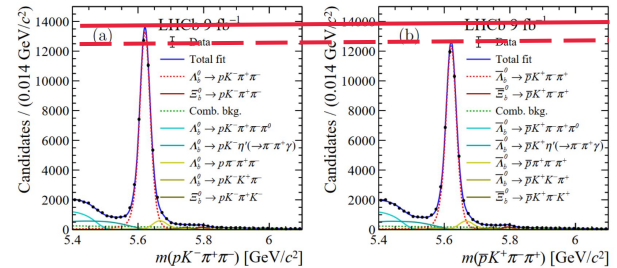
- Invariant mass



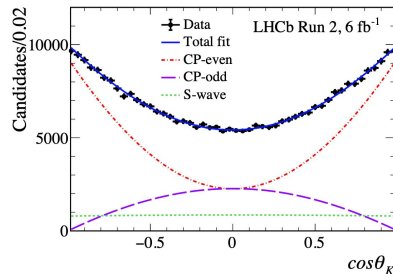
- Decay time



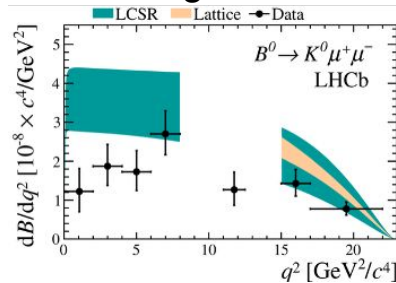
- Matter-antimatter asymmetry



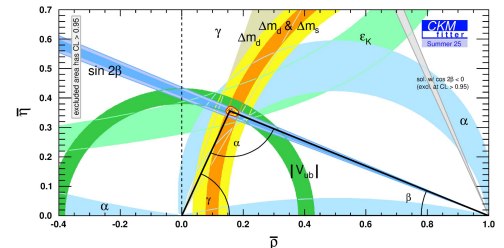
- Angular distribution



- Branching fraction



- CKM unitarity-triangle angles



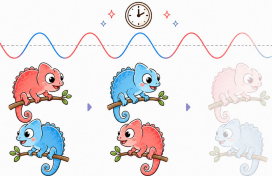
What physics do these observables measure?



Rare decays



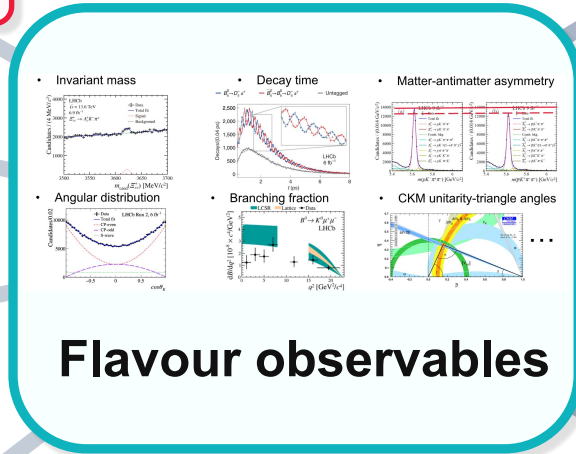
Exotic particles



Lifetimes & Mixing



CP violation



Lepton universality

Spectroscopy

...

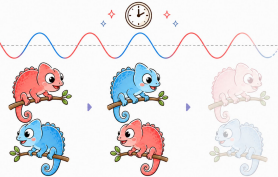
Nikhef LHCb physics contributions



Rare decays



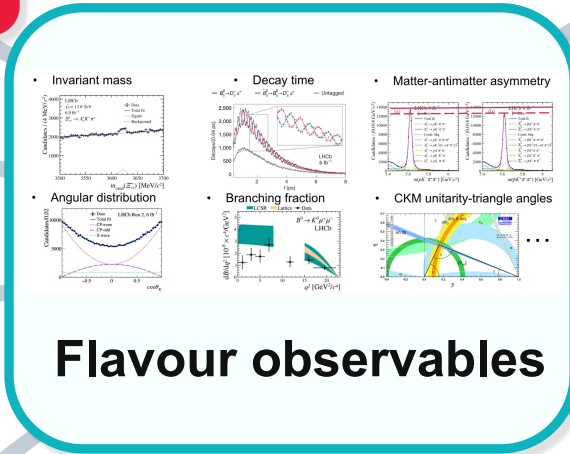
Exotic particles



Lifetimes & Mixing



CP violation



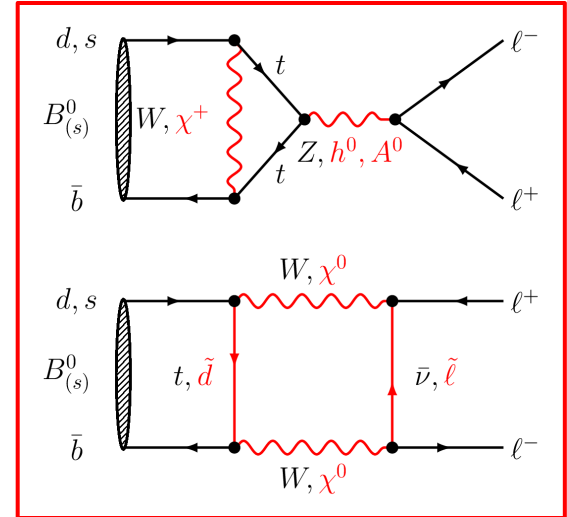
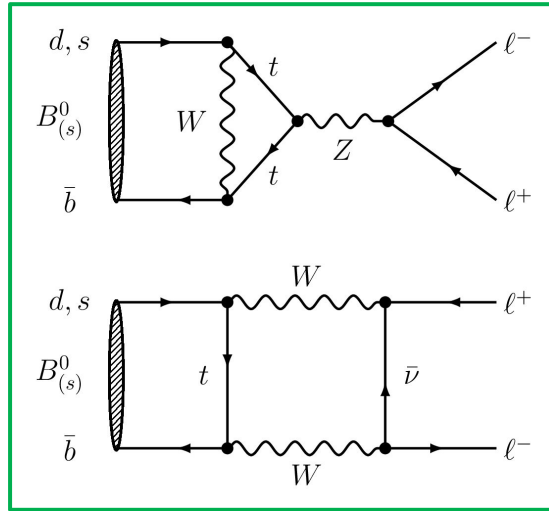
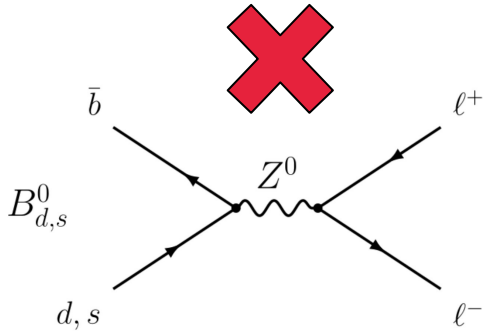
Lepton universality

Spectroscopy

...

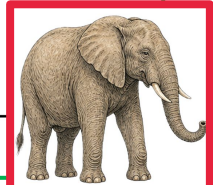
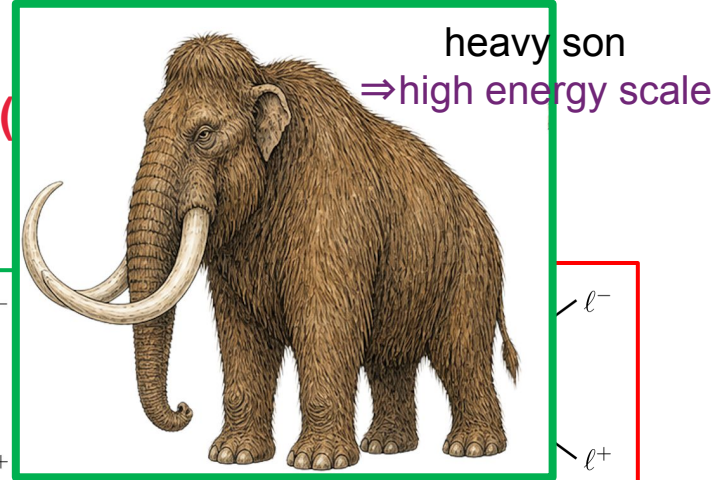
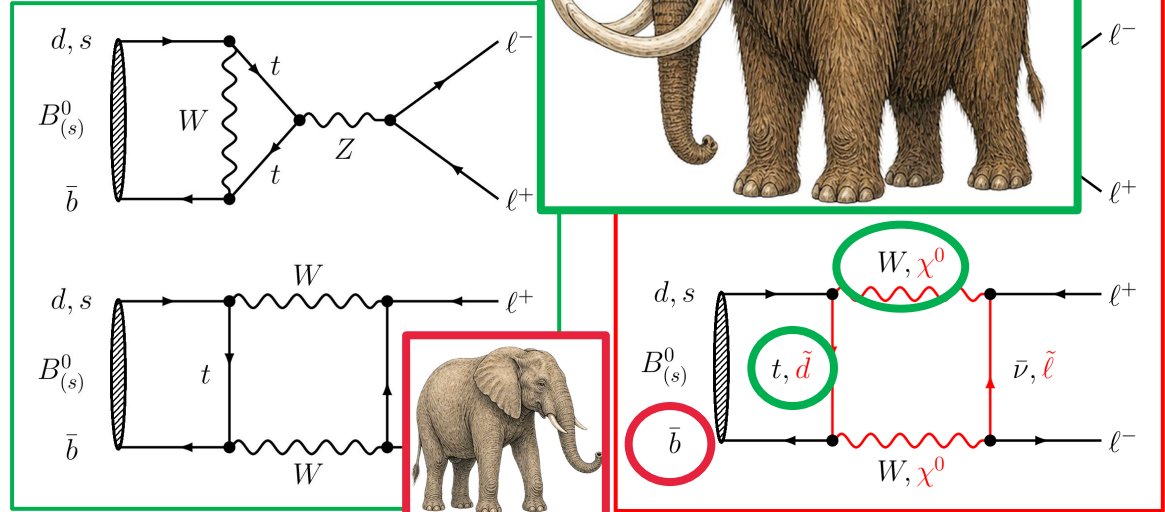
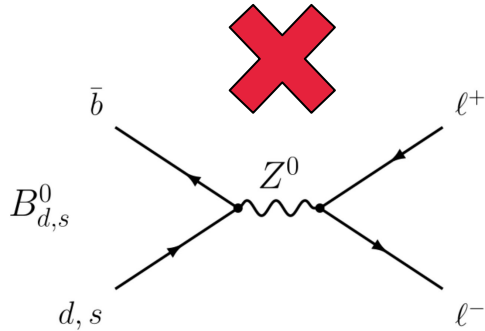
Why rare decays?

- Tree-level diagrams suppressed, **new physics (NP)** can arise at the same level as **standard model (SM)**



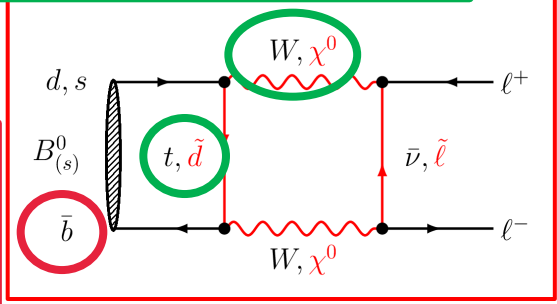
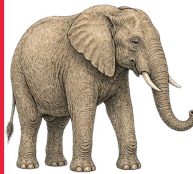
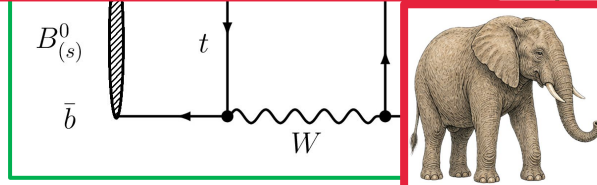
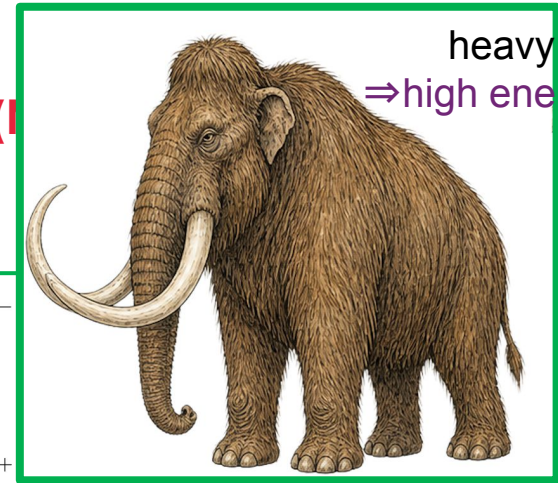
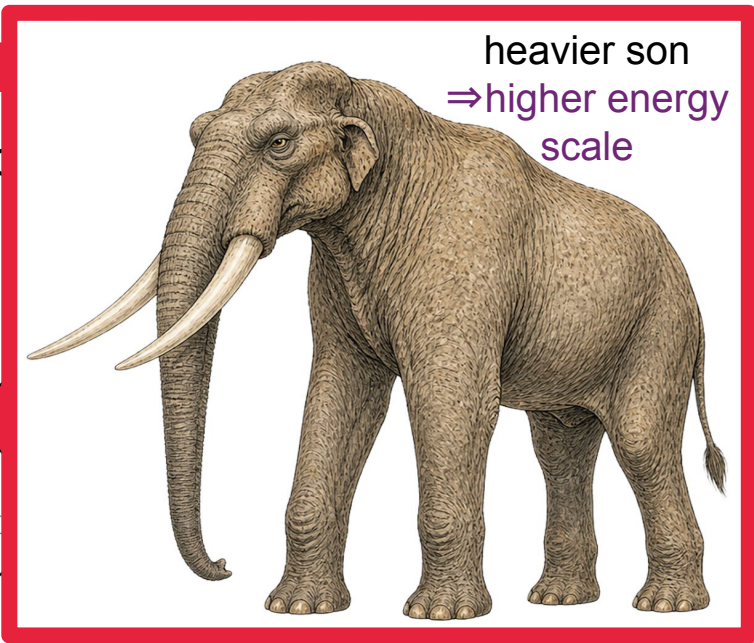
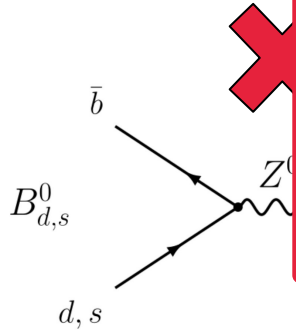
Why rare decays?

- Tree-level diagrams suppressed, **new physics** (same level as **standard model (SM)**)



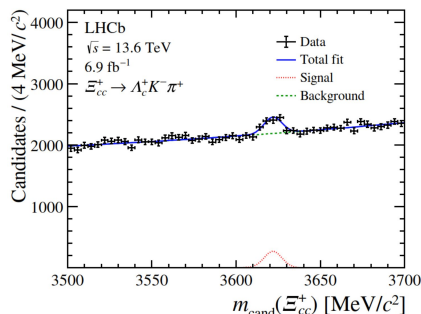
Why rare d

- Tree-level of same level

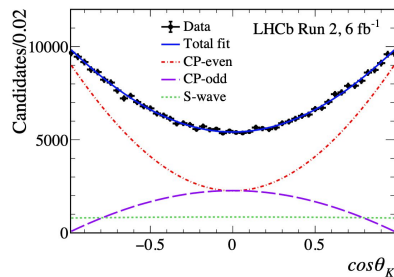


Observables that probe the “big elephant”

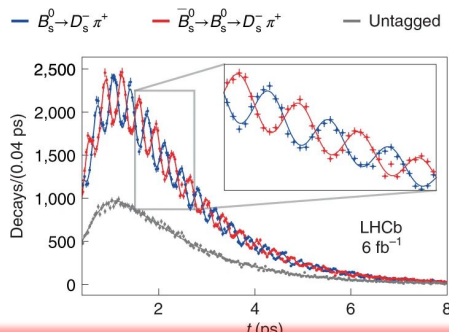
- Invariant mass



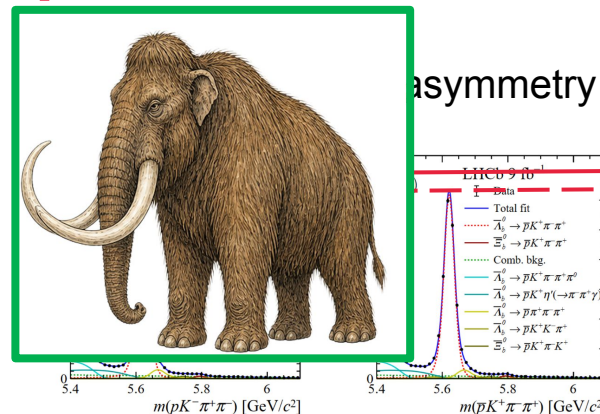
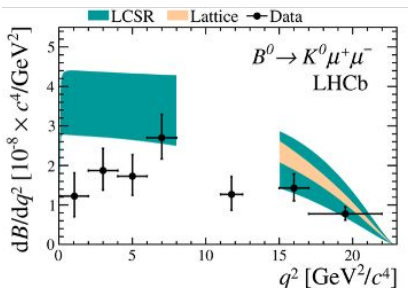
- Angular distribution



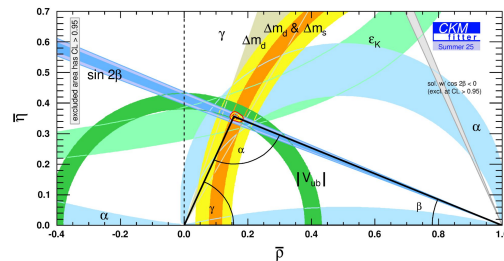
- Decay time



- Branching fraction



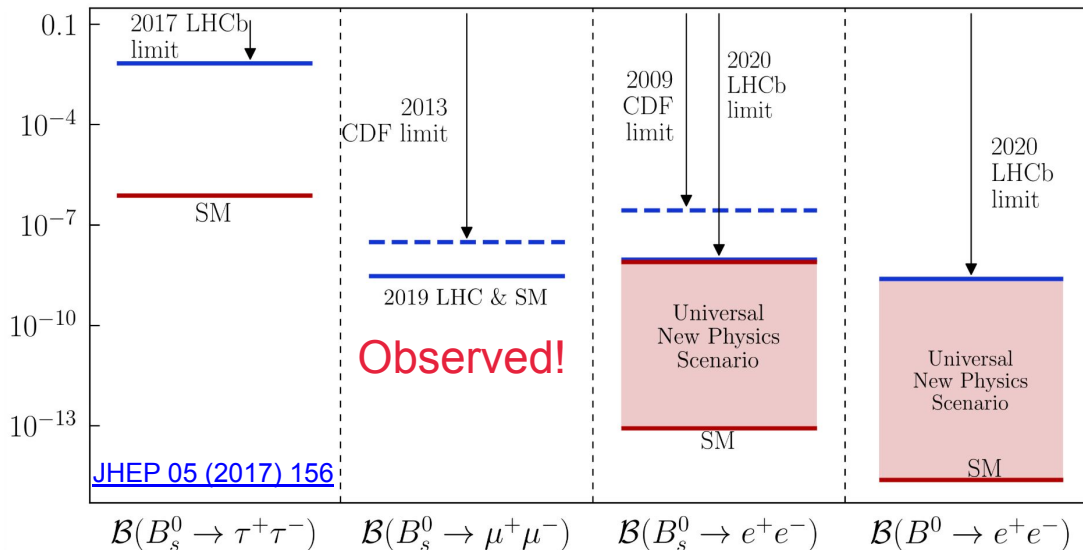
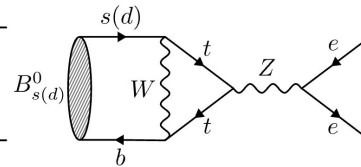
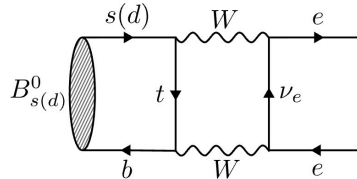
- CKM unitarity-triangle angles



Search for $B_{(s)}^0 \rightarrow e^+e^-$ decays with Run 1 + Run 2 data

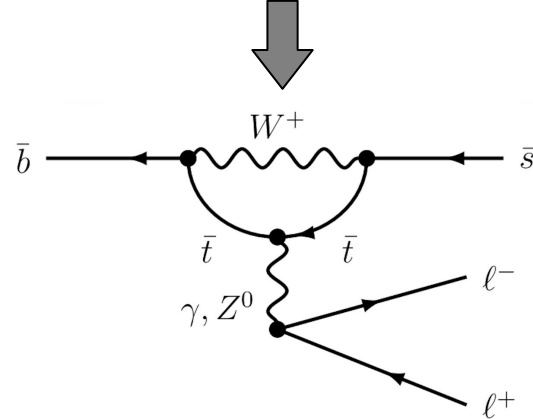
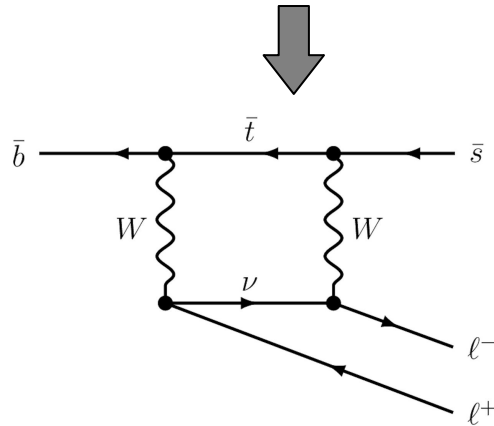
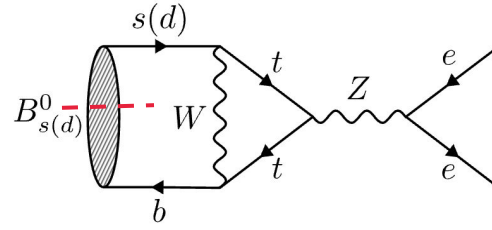
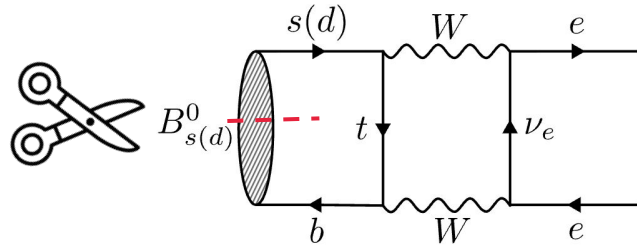
- Sensitive to new physics

- SM prediction: $\mathcal{O}(10^{-15})$
- Current limit set by LHCb: $\mathcal{O}(10^{-9})$



- We are updating this measurement using $\sim 2\times$ data with many improvements

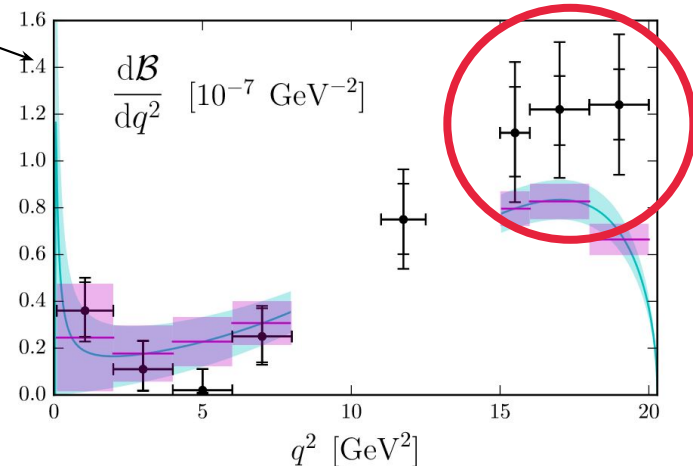
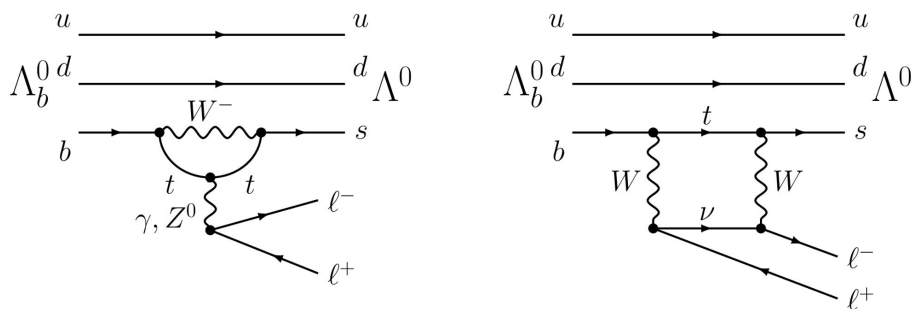
Connecting rare leptonic decays



Nikhef: add the $\Lambda_b^0 \rightarrow \Lambda^0 \ell \ell'$ system



- Current knowledge on $\Lambda_b^0 \rightarrow \Lambda^0 \mu^+ \mu^-$ is limited by the uncertainty in $\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0)$ ($\sim 20\%$)



[Phys.Rev.D 93 \(2016\) 7, 074501](https://arxiv.org/abs/1603.04817)

- Three goals of $\Lambda_b^0 \rightarrow \Lambda^0 \ell \ell'$ studies:



- Precisely measure $\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0)$

- First limit on $\Lambda_b^0 \rightarrow \Lambda^0 e^\pm \mu^\mp$

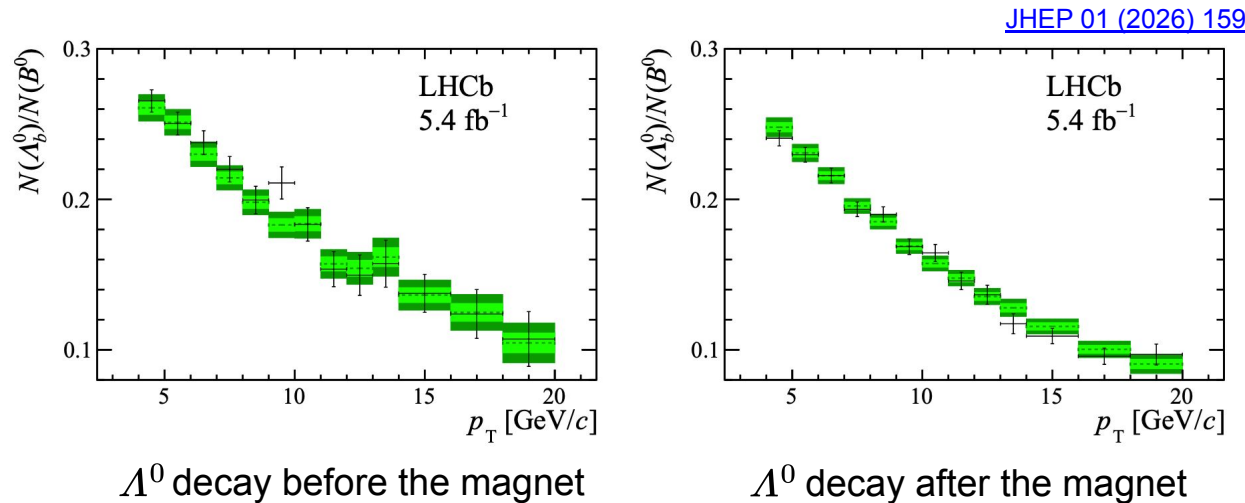
- First lepton universality test on $\Lambda_b^0 \rightarrow \Lambda^0 e^+ e^- / \Lambda_b^0 \rightarrow \Lambda^0 \mu^+ \mu^-$



Nikhef: add the $\Lambda_b^0 \rightarrow \Lambda^0 \ell \ell'$ system



- Precise measurement of branching fraction $\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0)$ using Run 2 data
 - Experimentally challenging, Λ^0 decays travel through detector

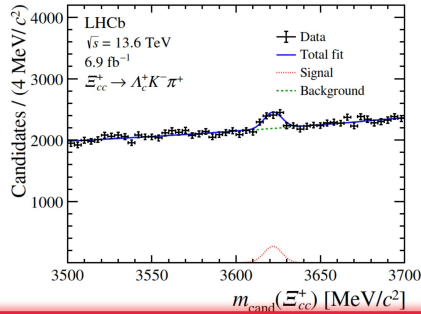


- Result:
$$\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0) = (3.34 \pm 0.31) \times 10^{-4}$$

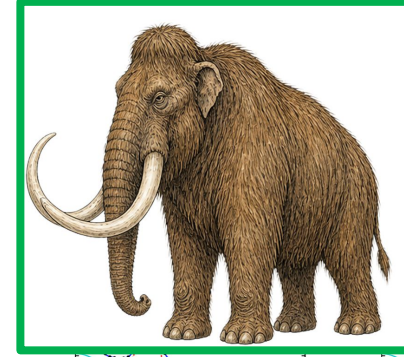
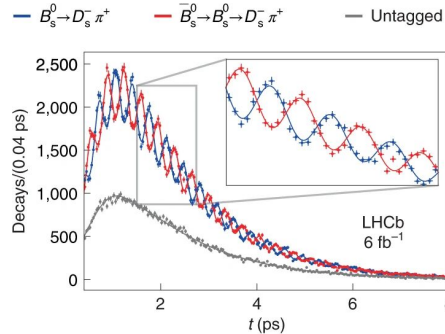
Reduce uncertainty by a factor of 3

Observables that probe the “big elephant”

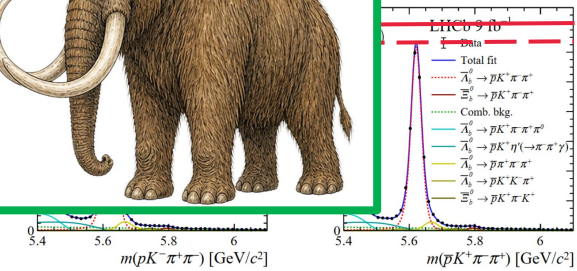
- Invariant mass



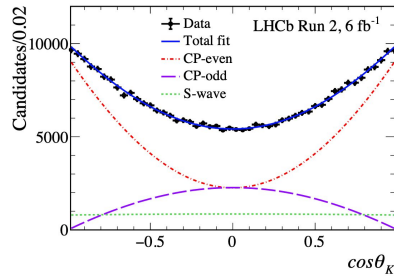
- Decay time



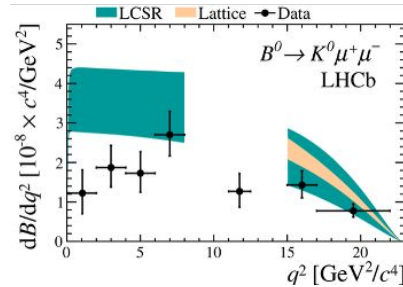
- Asymmetry



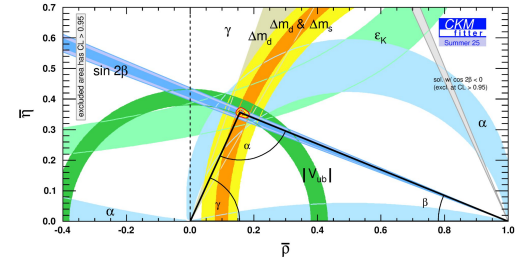
- Angular distribution



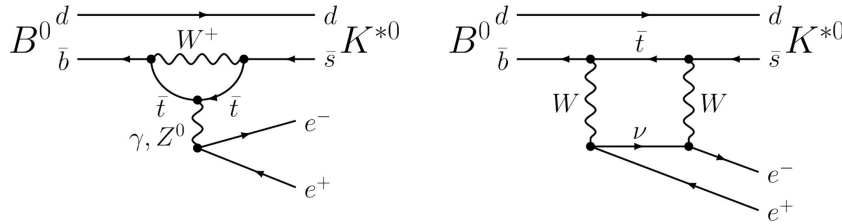
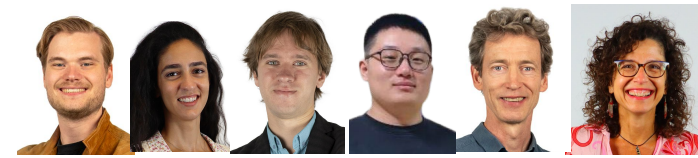
- Branching fraction



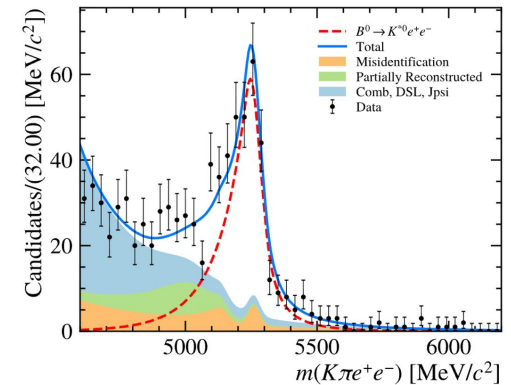
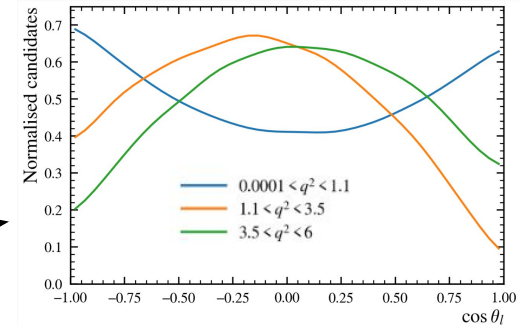
- CKM unitarity-triangle angles



Angular analysis of $B^0 \rightarrow K^{*0} e^+ e^-$



- Angular distributions are good probes for NP
- First LHCb measurement recently published [JHEP 06 \(2025\) 140](#)
- Ongoing effort to increase phase space and update with improvements
- Run3 analysis started, expected a 5-6 times increase in signal yields



Making $B_c^+ \rightarrow \tau^+ \nu_\tau$ visible with VELO hits



- Why so difficult?

$$B_c^+ \rightarrow \tau^+ \nu_\tau, \quad \tau^+ \rightarrow 3\pi + \bar{\nu}_\tau$$

two neutrinos \Rightarrow no full reconstruction

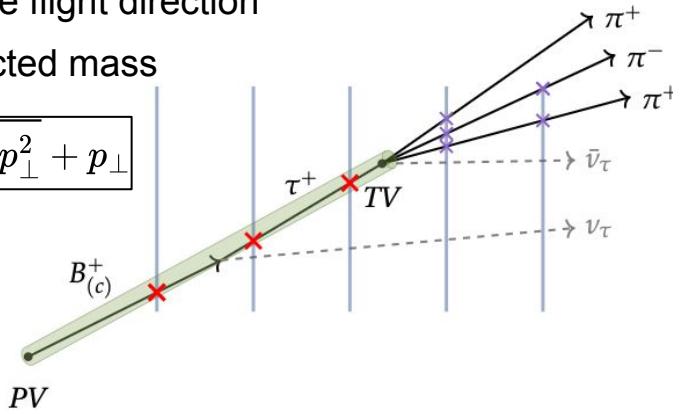
- Key idea

VELO hits between primary vertex (PV) and τ^+ vertex

\Rightarrow approximate flight direction

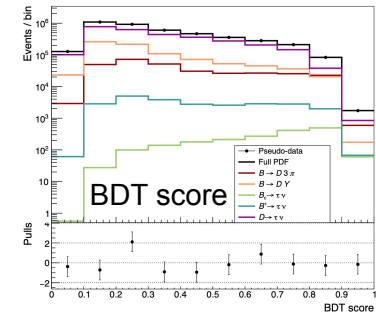
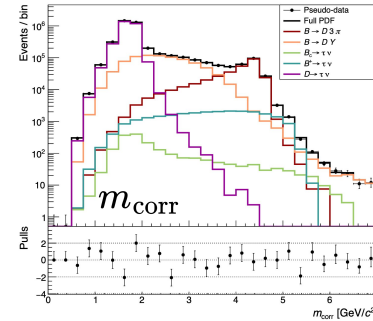
\Rightarrow build corrected mass

$$m_{\text{corr}} = \sqrt{m_{3\pi}^2 + p_\perp^2 + p_\parallel^2}$$



- Feasibility study

- Pseudo-experiments
- 2D template fit to extract yields



- Looking forward to Run 3

- Trigger line running since 2024
- Aim: first observation of $B_c^+ \rightarrow \tau^+ \nu_\tau$

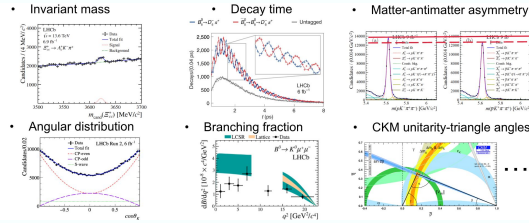
Nikhef LHCb physics contributions



Rare decays



Exotic particles



Lepton universality

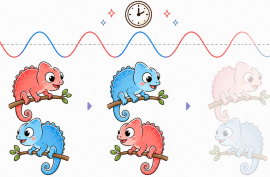
Spectroscopy

Lifetimes & Mixing

Flavour observables

...

CP violation

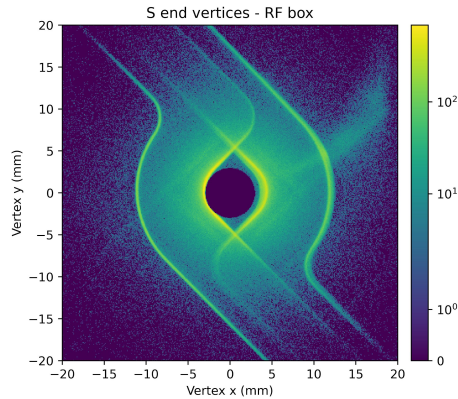
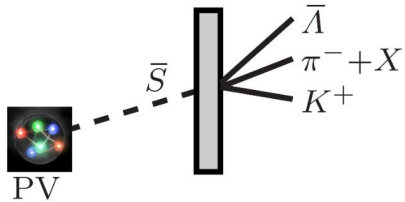


Exotic particles: unusual signatures, new opportunities

Sexaquark search



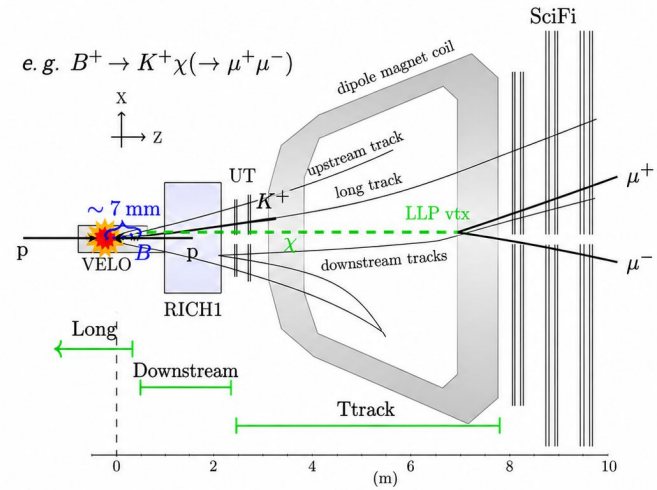
- Stable six-quark candidate \bar{S} ($\bar{u}\bar{u}\bar{d}\bar{d}\bar{s}\bar{s}$)
- Look for \bar{S} annihilation in detector material
- Using all 2024–2026 Run 3 data



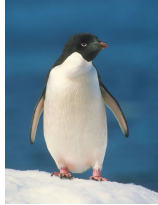
Long-lived particles in Run 3



- Increase long-lived particle acceptance using SciFi-only tracks (T track) [arXiv:2510.05257](https://arxiv.org/abs/2510.05257)
- Search for dark scalars in $b \rightarrow s(\chi \rightarrow \mu\mu)$
- Search for heavy neutral leptons in b -decay



Nikhef LHCb physics contributions

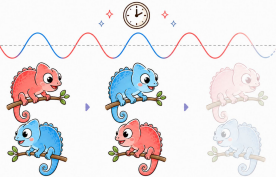


Rare decays

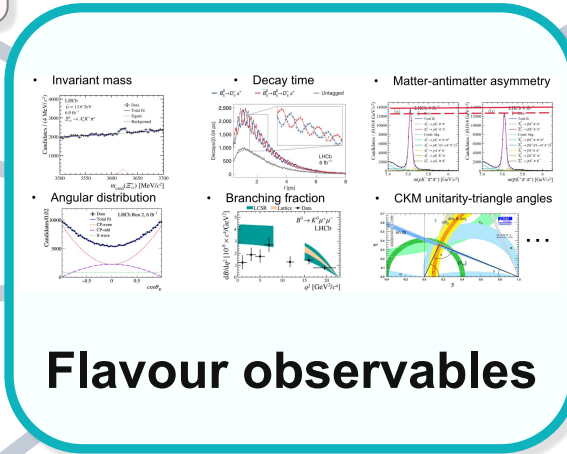


Exotic particles

Lifetimes & Mixing



CP violation



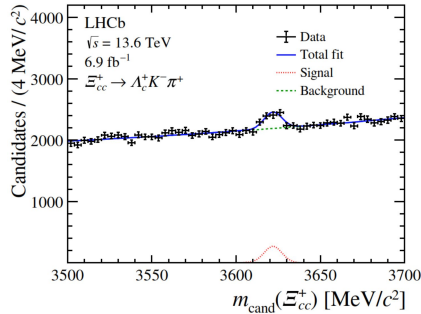
Lepton universality

Spectroscopy

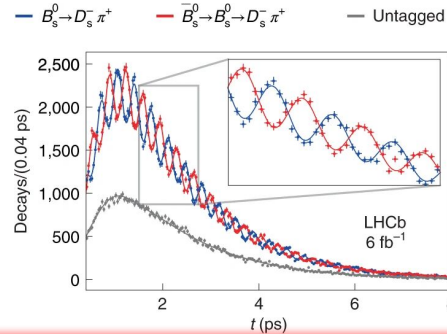
...

Observables that probe the lifetime and mixing

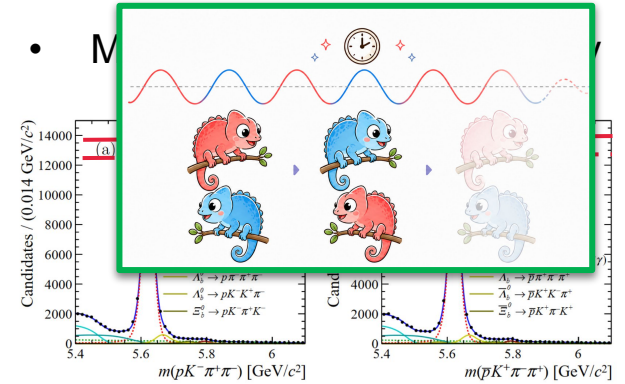
- Invariant mass



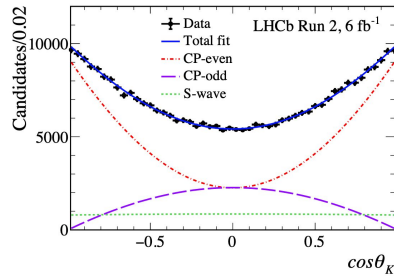
- Decay time



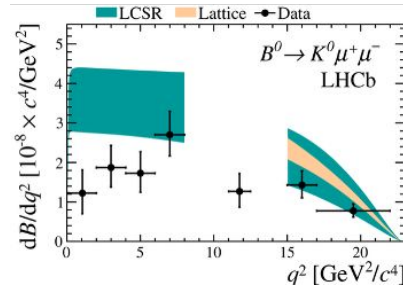
- Mixing



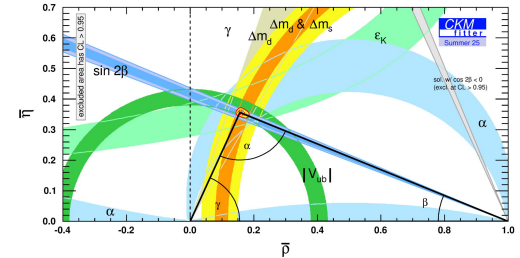
- Angular distribution



- Branching fraction



- CKM unitarity-triangle angles



Decay width difference in B^0 system using Run 2 data

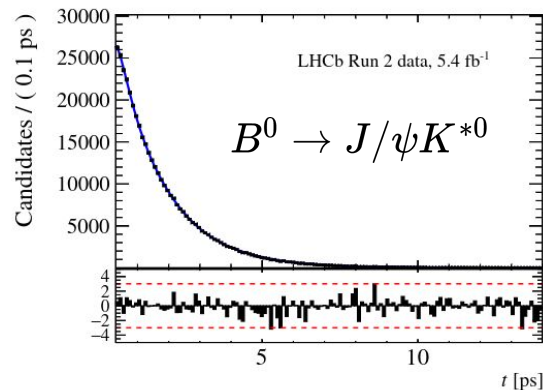
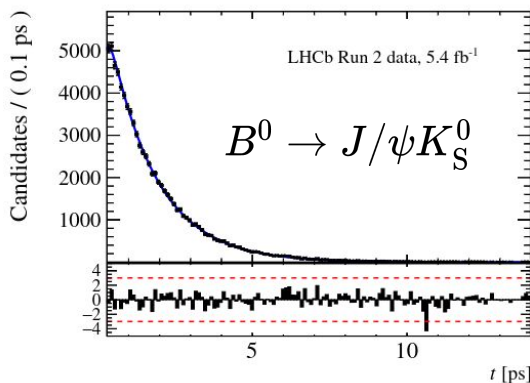
- Experimental precision is worse than theory prediction

$$\frac{\Delta\Gamma}{\Gamma}(\text{SM}) = (0.42 \pm 0.08) \times 10^{-2}$$

$$\frac{\Delta\Gamma}{\Gamma}(\text{exp. avg.}) = (0.1 \pm 1.0) \times 10^{-2}$$



- Simultaneous fit to $B^0 \rightarrow J/\psi K_S^0$ and $B^0 \rightarrow J/\psi K^{*0}$ decays
- Preliminary results: reduce uncertainty \sim by a factor of two



Nikhef LHCb physics contributions

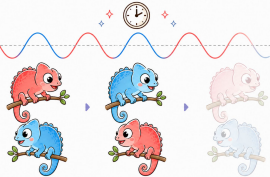


Rare decays



Exotic particles

Lifetimes & Mixing



CP violation

Flavour observables

- Invariant mass
- Decay time
- Matter-antimatter asymmetry
- Angular distribution
- Branching fraction
- CKM unitarity-triangle angles

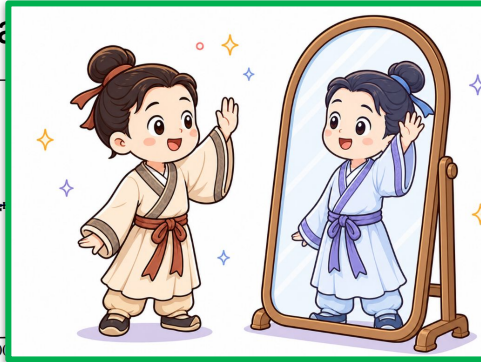
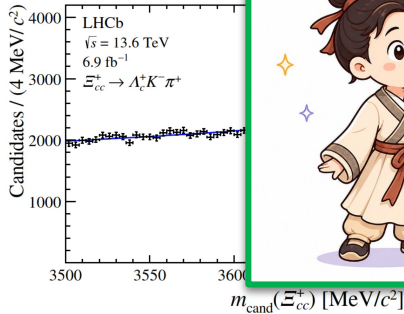
Lepton universality

Spectroscopy

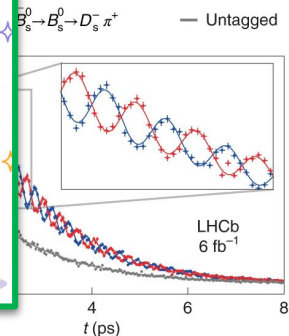
...

Observables that probe CP violation

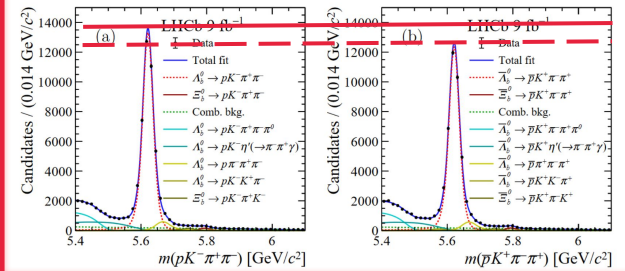
- Invariant mass



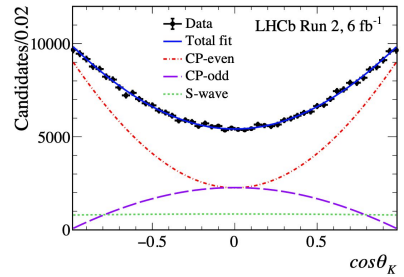
- Decay time



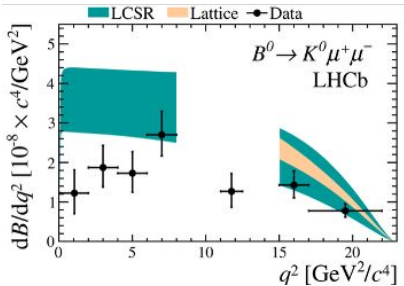
- Matter-antimatter asymmetry



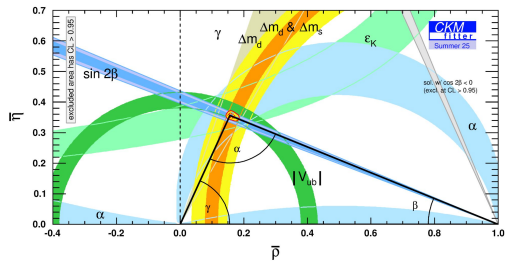
- Angular distribution



- Branching fraction



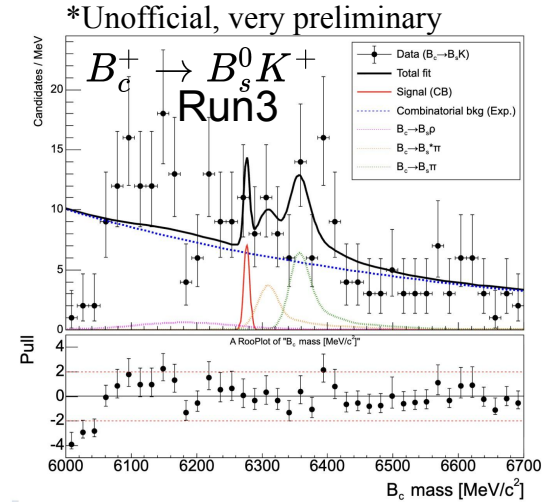
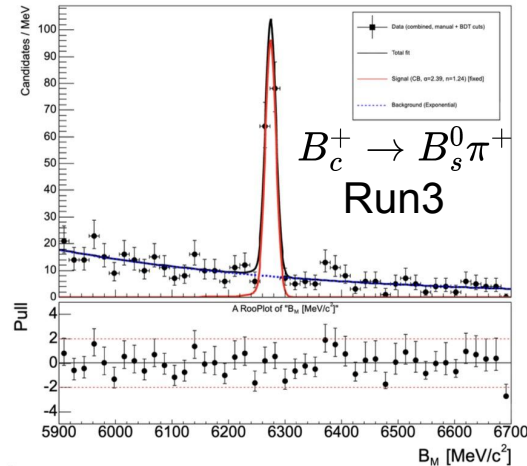
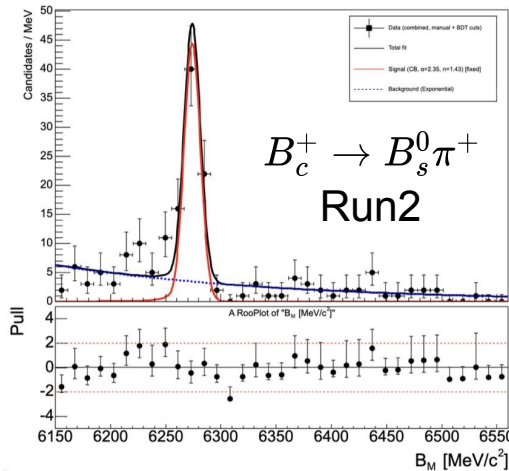
- CKM unitarity-triangle angles



Run 3 search for $B_c^+ \rightarrow B_s^0 K^+$ decays

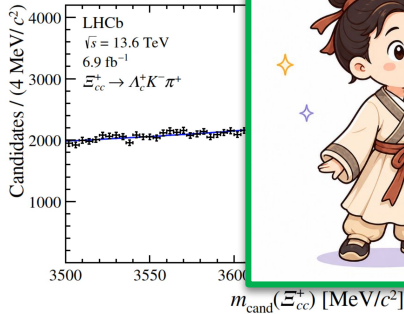


- ‘Charming beauty’: B_c^+ is a heavy ‘stable’ state produced at LHC
- ‘Beauty \Rightarrow Beauty’ transition: $B_c^+ \rightarrow B_s^0 \pi^+$ Cabbibo favoured, branching ratio $\sim 10\%$ (discovered @ Nikhef/LHCb)
- Now search for the suppressed mode $B_c^+ \rightarrow B_s^0 K^+$ [CP violation possible!]
 - No signal observed in first attempt

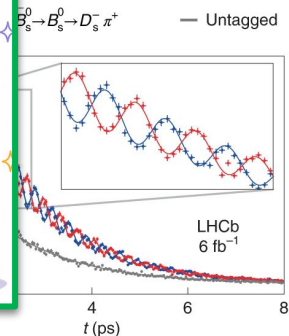


Observables that probe CP violation

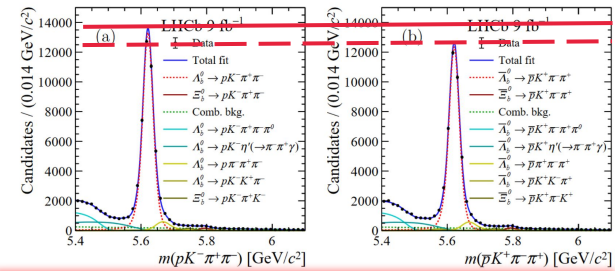
- Invariant mass



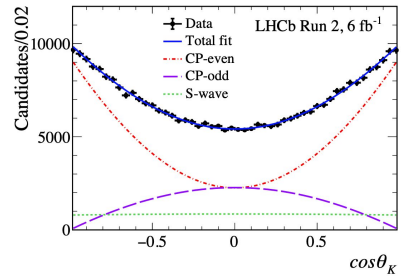
- Decay time



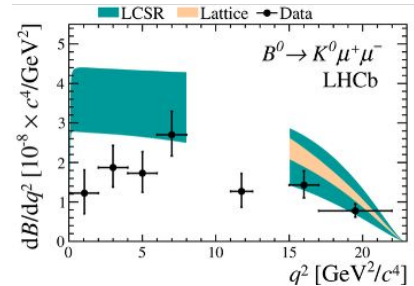
- Matter-antimatter asymmetry



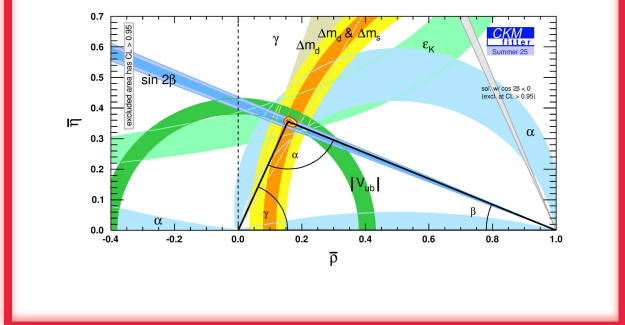
- Angular distribution



- Branching fraction



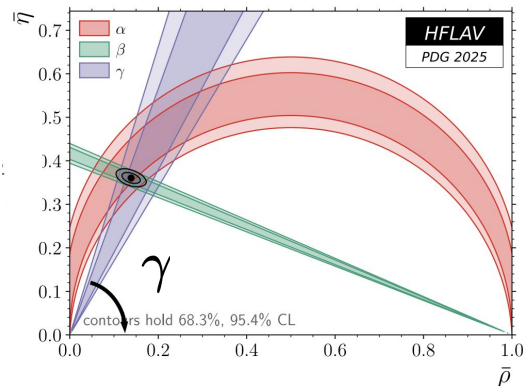
- CKM unitarity-triangle angles



Fitting CKM γ , charm mixing and CP violation together

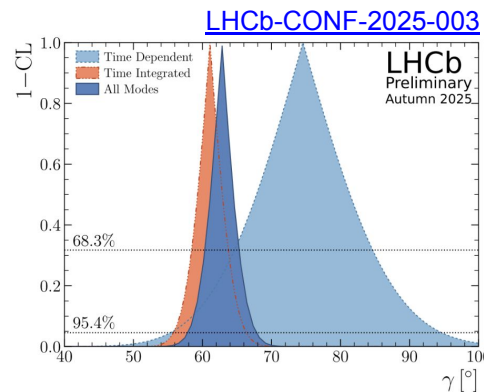
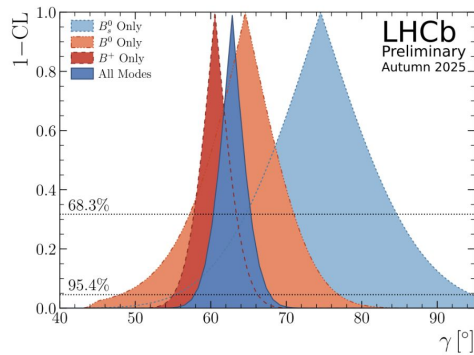
- CKM γ : CP-violating phase in CKM matrix
 - Good probe of CP violation in the SM
 - Direct measurements are less precise than indirect constraints
- Many existing direct measurements to be combined
- This update:
 - Add three new/updated inputs
 - Combination result:

$$\gamma = (62.8 \pm 2.6)^\circ$$
 - Consistent with indirect constraints



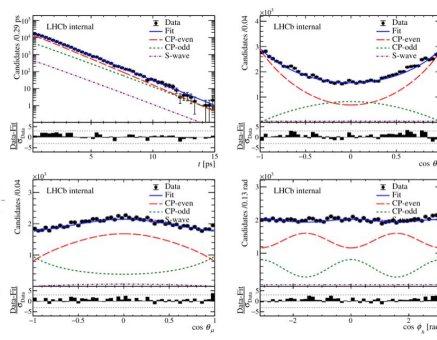
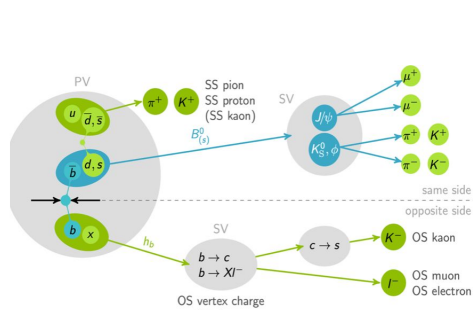
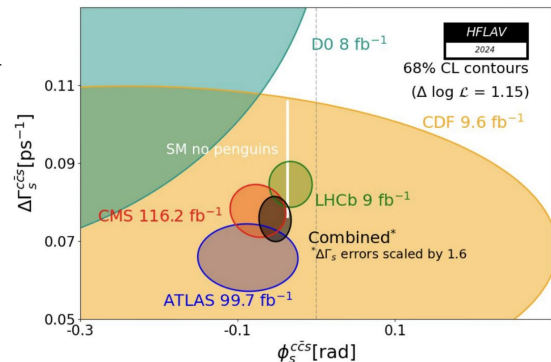
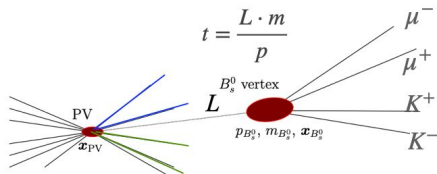
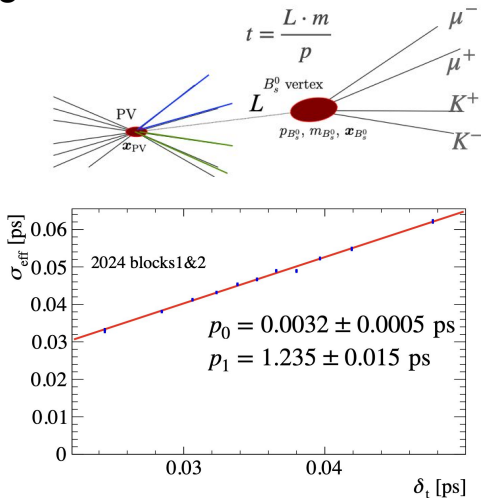
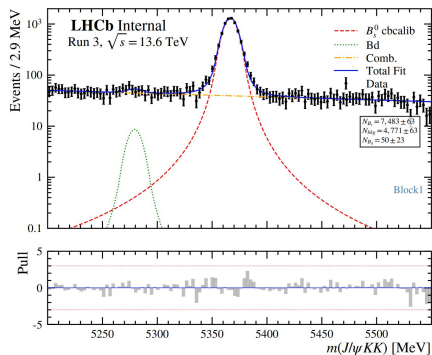
$$\begin{aligned} \gamma_{\text{indirect}} &= (66.3^{+0.7}_{-1.9})^\circ \\ &= (65.2 \pm 1.5)^\circ \end{aligned}$$

[CKM Fitter](#)
[UTfit](#)



Measurement of ϕ_s with $B_s^0 \rightarrow J/\psi \phi(KK)$ using Run 3 data

- Golden channel for B_s^0 mixing-induced CP violation
 - LHCb leads in precision
- Time-dependent angular analysis
 - Mass fit
 - Time resolution
 - Flavour tagging
 - Angular fit
 - ...

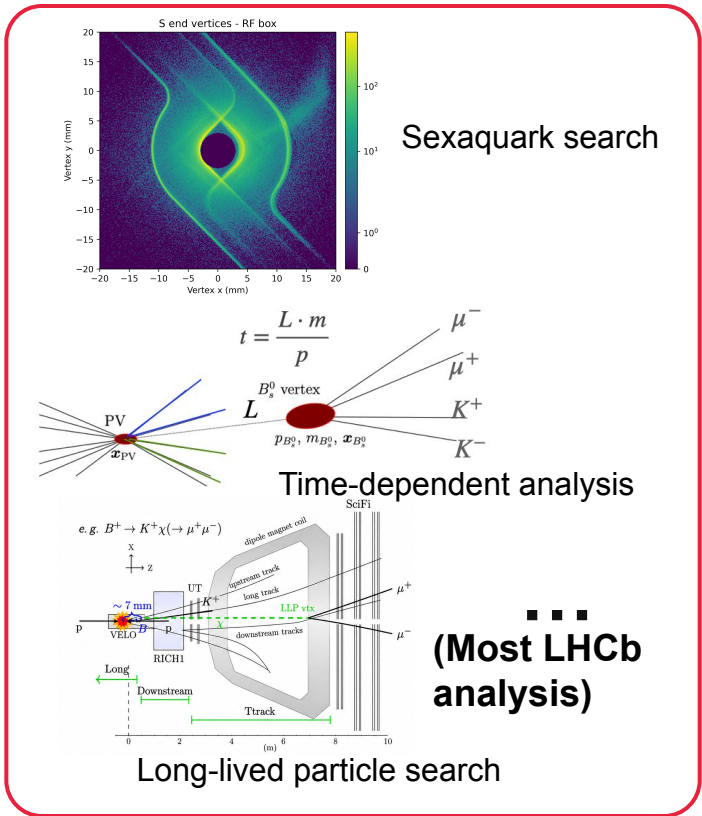
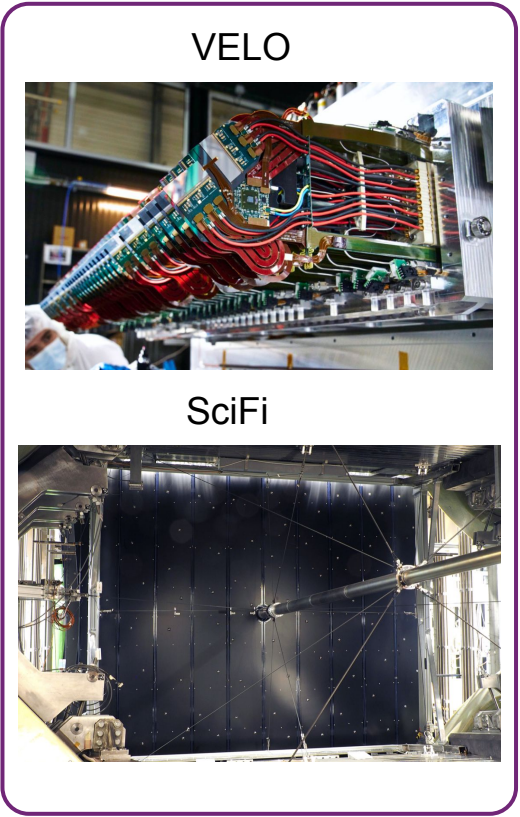


Synergy between physics analysis and detector work



Detector performance enables better physics

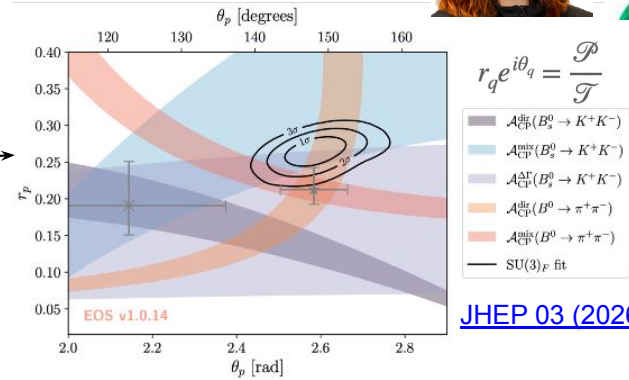
Physics drives detector performance



SU(3) flavour analysis of $B \rightarrow hh, h = \pi, K$



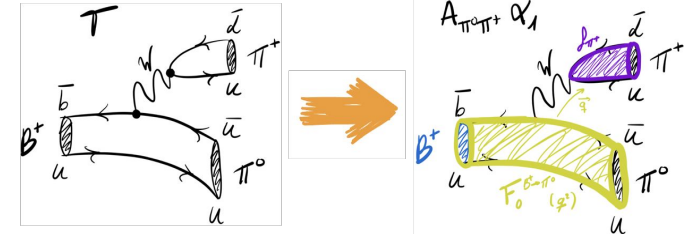
- Many experimental measurements exist, yet theoretical predictions remain challenging
- Exact SU(3) flavour symmetry cannot describe data →
- [NEW!]** Add factorizable SU(3) flavour breaking to
 - describe the existing data (branching fractions, CP asymmetries)
 - test QCD predictions



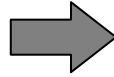
$$r_q e^{i\theta_q} = \frac{\mathcal{P}}{\mathcal{T}}$$

[JHEP 03 \(2026\) 227](#)

- Bridging theory and experiment
 - Improves theoretical predictions within frameworks such as **QCD factorization**
 - Identifying modes that could be experimentally improved (e.g. $B_s^0 \rightarrow \pi^+\pi^-$)

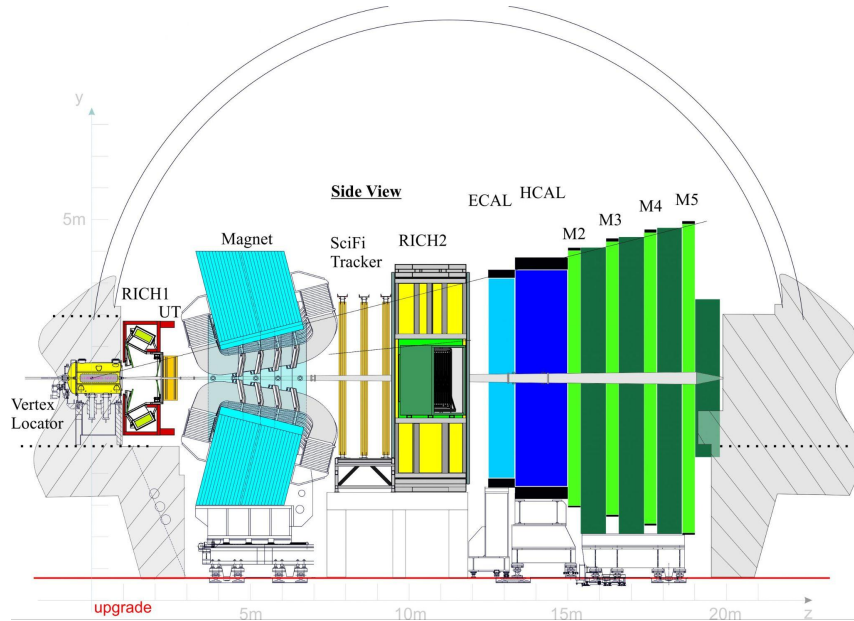


Building the next boat



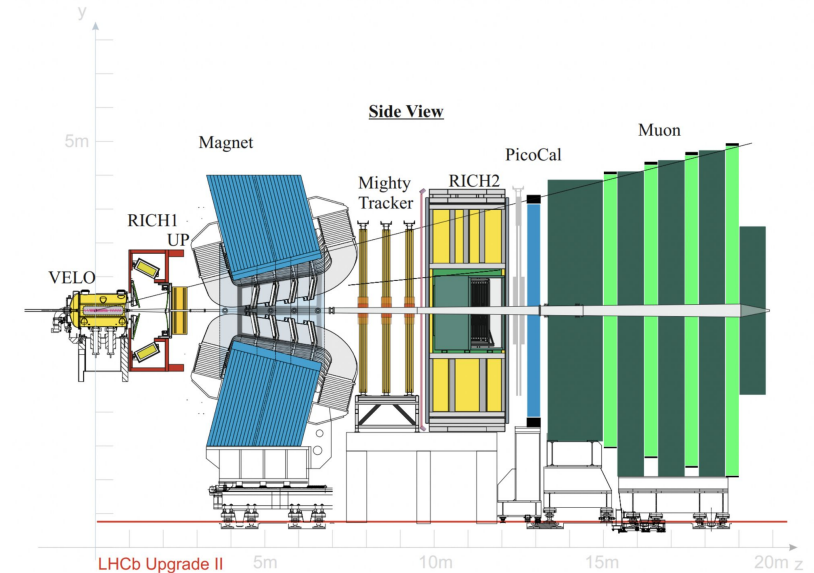
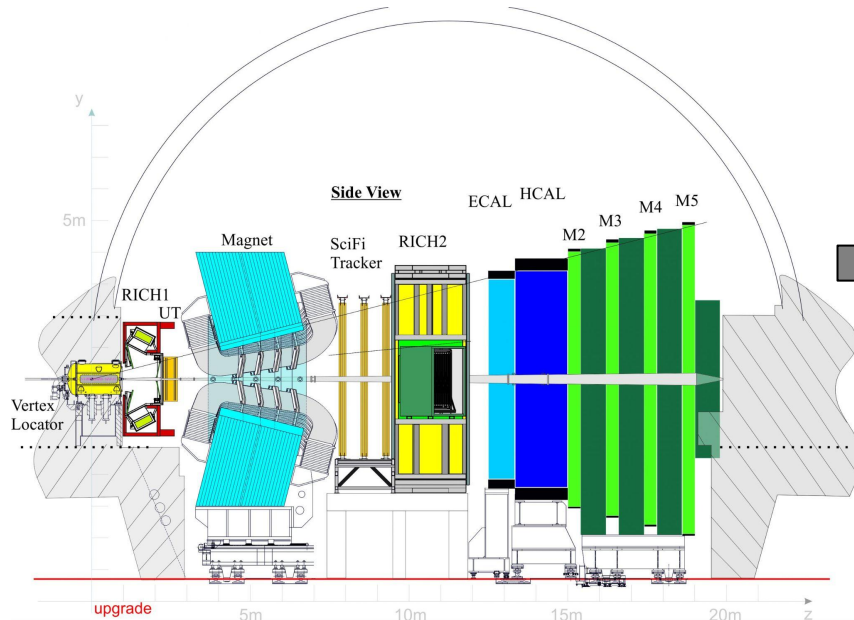
Building the next boat

Aim for a five-fold increase in collisions/time to exploit later HL-LHC runs



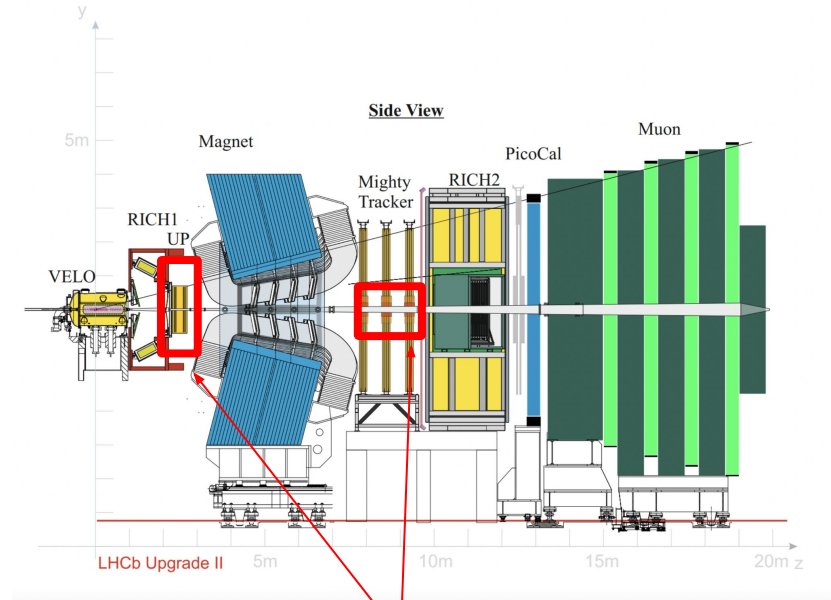
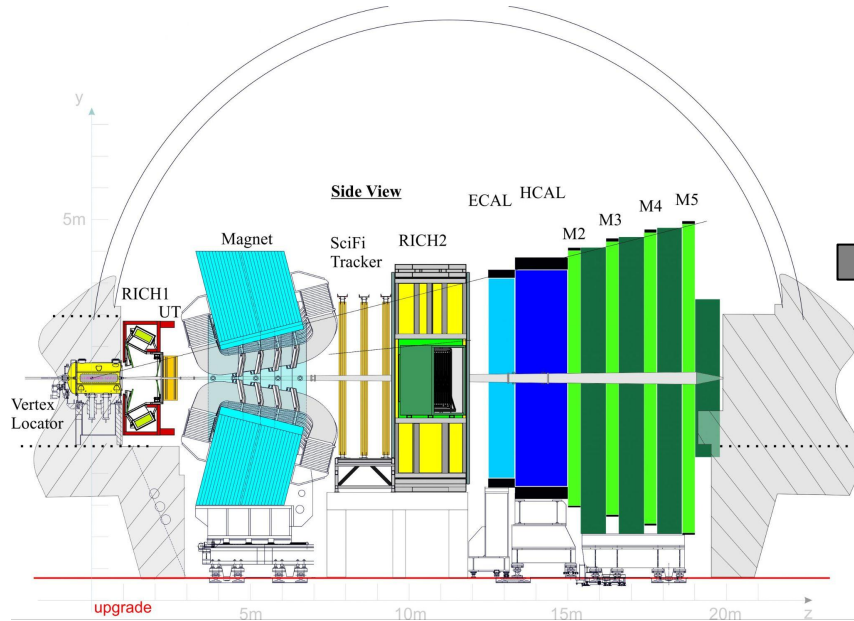
Building the next boat

Aim for a five-fold increase in collisions/time to exploit later HL-LHC runs



Building the next boat

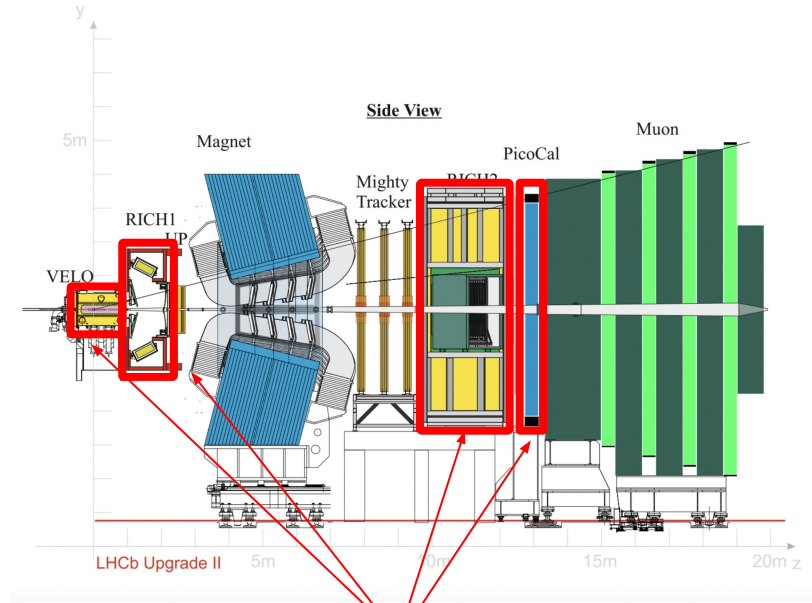
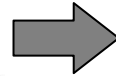
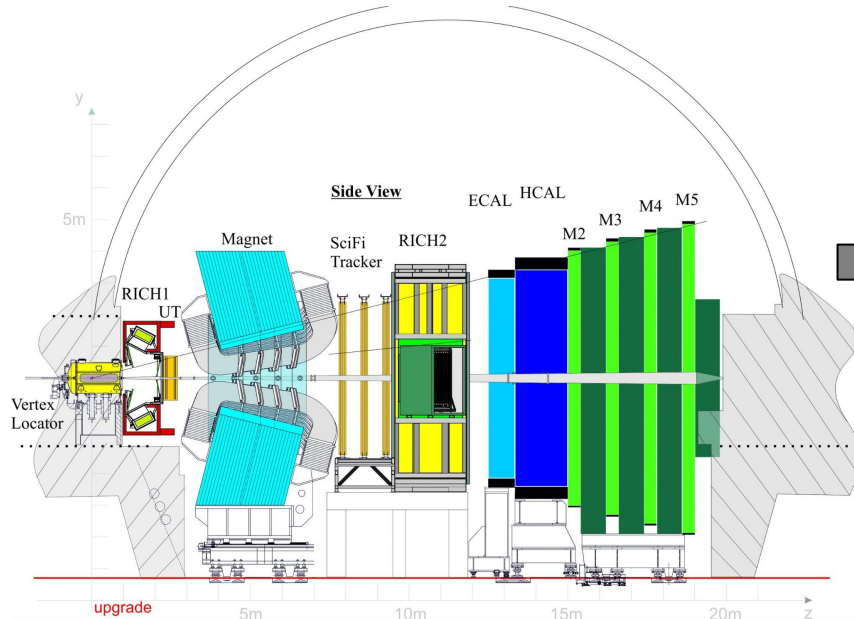
Aim for a five-fold increase in collisions/time to exploit later HL-LHC runs



Increased granularity from Si pixel detectors (MAPS)

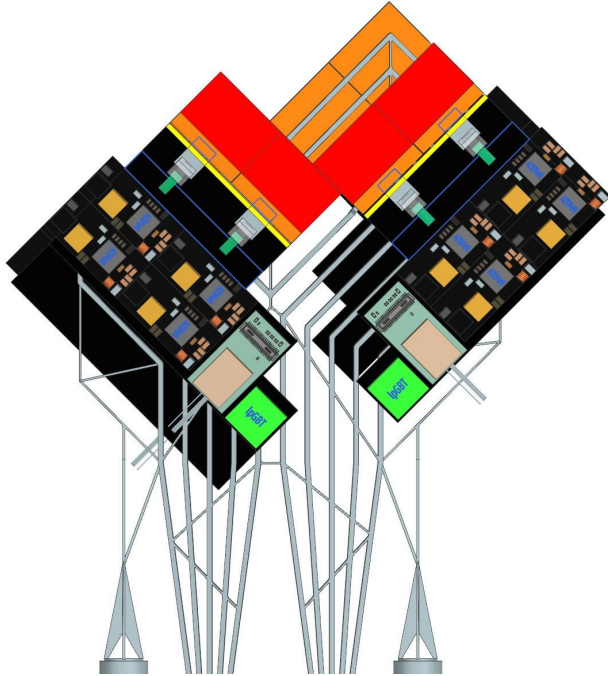
Building the next boat

Aim for a five-fold increase in collisions/time to exploit later HL-LHC runs



Detectors with timing (~ 20 ps resolution)

Building the next VELO

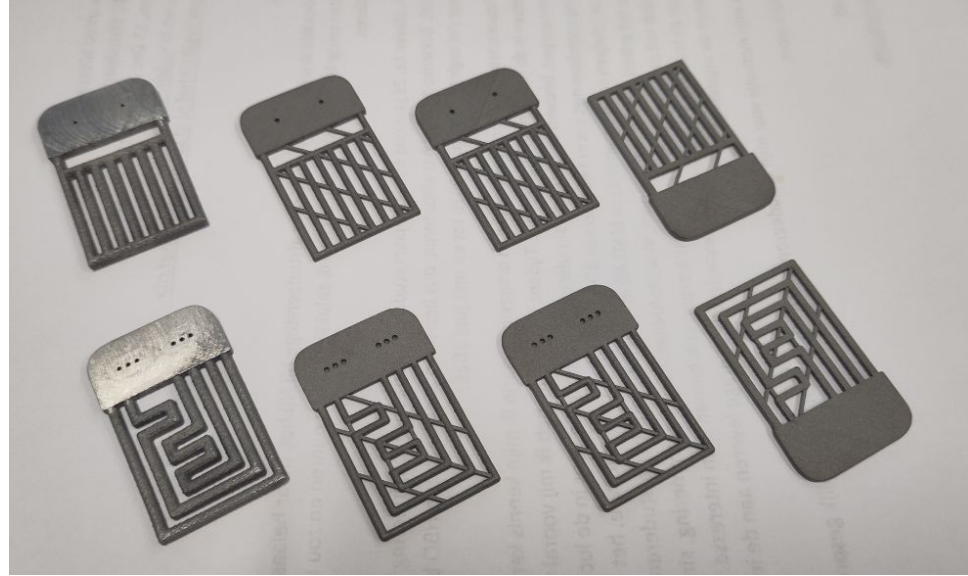
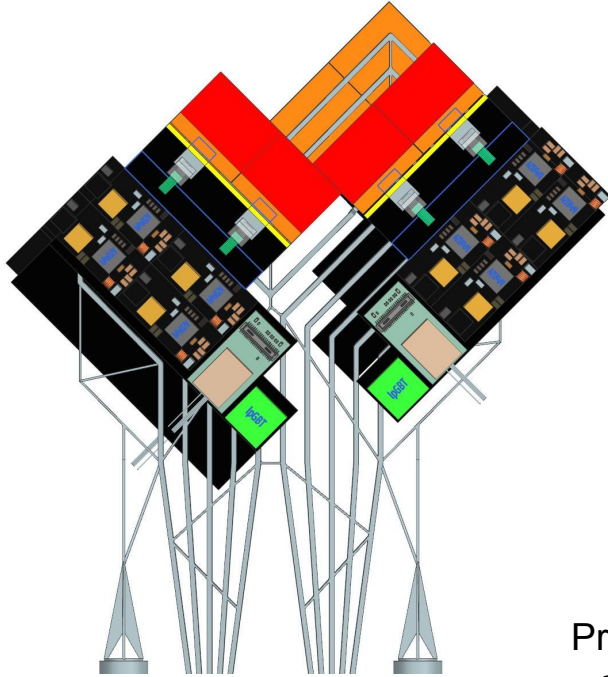


Collaborations between technical departments and Bfys lead many aspects of design

- Module mechanics & cooling
- Readout electronics (ASICs)
- Sensor development
- Global detector design
- Reconstruction

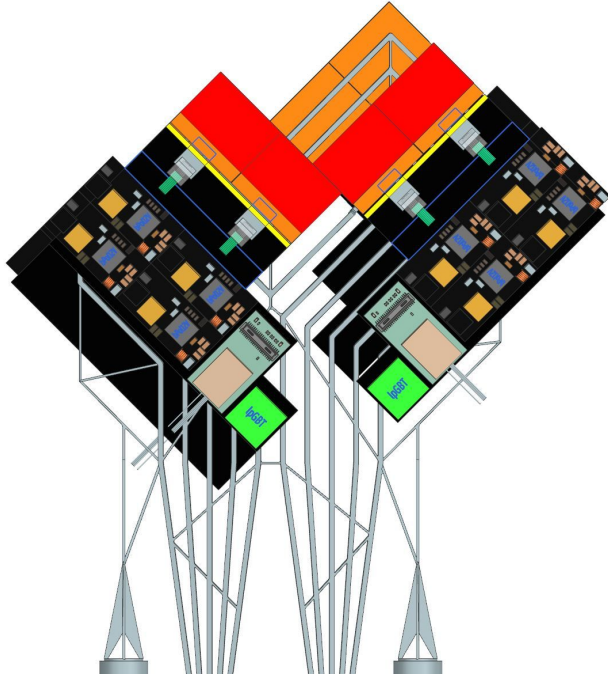
@Nikhef these activities will be under the FASTTRACK grant

Building the next VELO: 3D printed cooling substrates



- Prototypes of 3D printed cooling substrates, in various materials and patterns.
- Already tested for leak tightness and heat exchange.

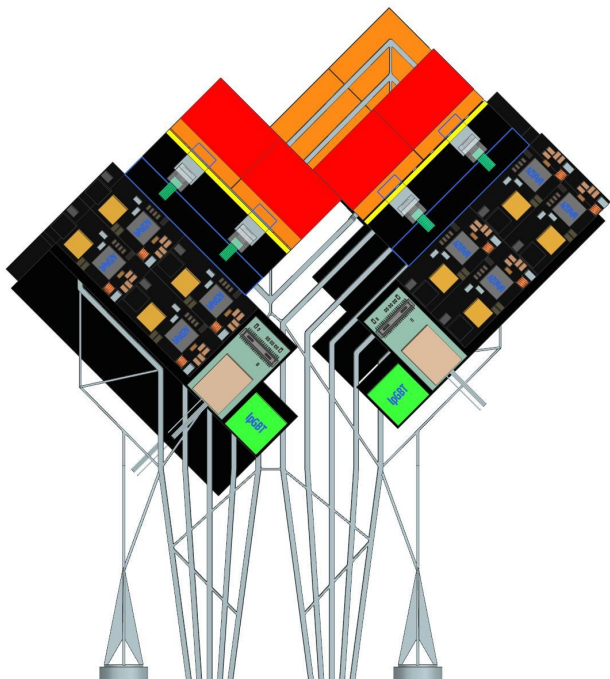
Building the next VELO: LAPicopix



Large area particle detector ASIC targeting many use cases, including the next VELO

- 384x256 $50\mu\text{m}^2$ pixels
- Targets $\sim 30\text{ps}$ time resolution

Building the next VELO: LAPicopix



Large area particle detector ASIC targeting many use cases, including the next VELO

- 384x256 50 μm^2 pixels
- Targets ~30ps time resolution

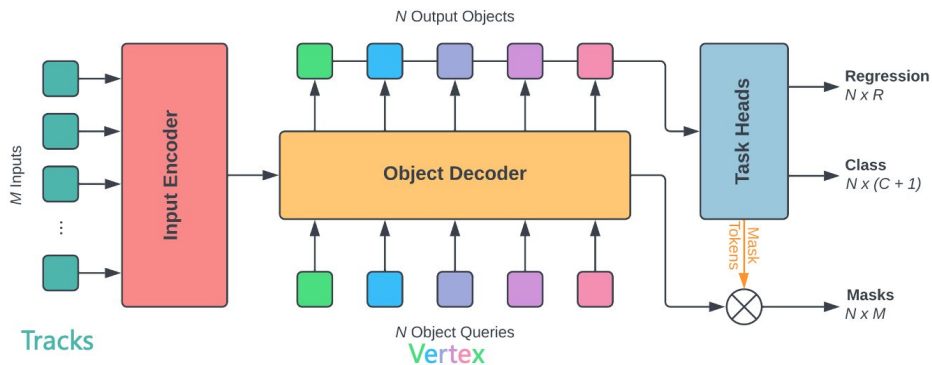
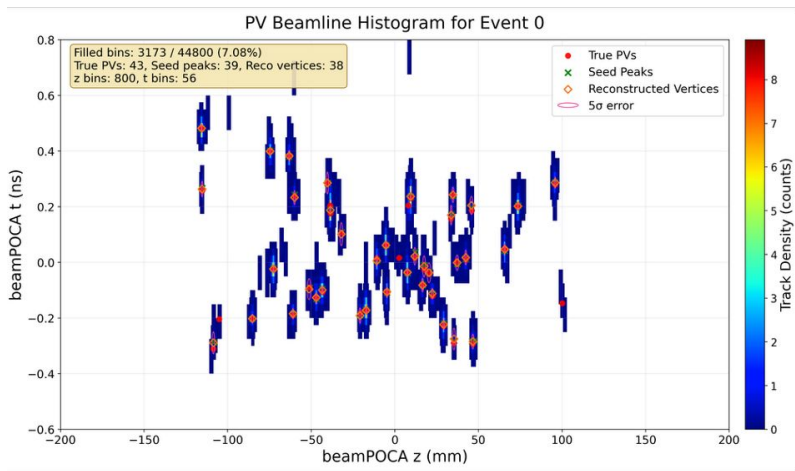
	RTL / Schematic	Physical design		COMPLETE	TO BE DONE
Analog Front-end	COMPLETE	IN PROGRESS	Data readout matrix	COMPLETE	TO BE DONE
Analog End-Of-Column	IN PROGRESS	IN PROGRESS	Digital End-Of-Column	COMPLETE	IN PROGRESS
ADC	IN PROGRESS	IN PROGRESS	Packet processor	COMPLETE	TO BE DONE
Front-end control	COMPLETE	COMPLETE	ESB packet-sorter	COMPLETE	IN PROGRESS
TDC block	COMPLETE	COMPLETE	Fast Command Control	COMPLETE	TO BE DONE
ADB (Vertical DLL)	COMPLETE	COMPLETE	Slow-control	COMPLETE	TO BE DONE
DLL control and calibration	COMPLETE	IN PROGRESS	High-Speed serializer	ADVANCED	ADVANCED
Horizontal DLL	COMPLETE	COMPLETE	ROSA (On-Chip CPU)	IN PROGRESS	TO BE DONE
Pixel Region	COMPLETE	FINALIZING	Pad-ring	COMPLETE	ADVANCED
Pixel Column	COMPLETE	FINALIZING	PICOPIX top	ADVANCED	TO BE DONE
Pixel Matrix	COMPLETE	FINALIZING			

Submission expected in the next few months!

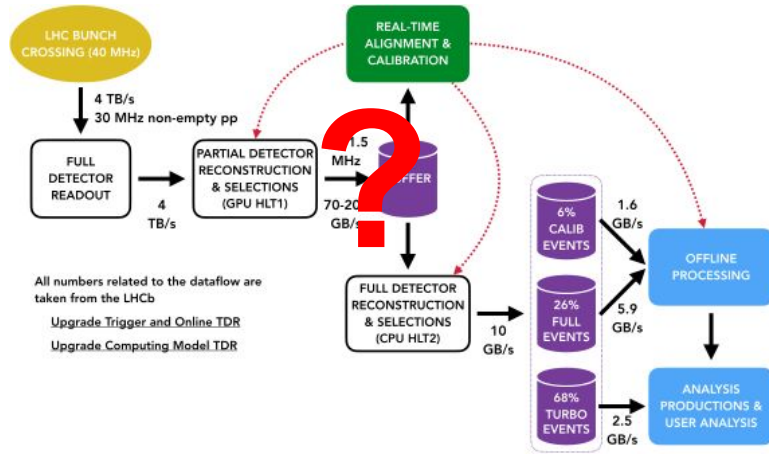
Building the next VELO: 4D vertexing



- First GPU vertex reconstruction algorithm for Upgrade II
- MaskFormer-based algorithm in collaboration with Sebastien from ATLAS



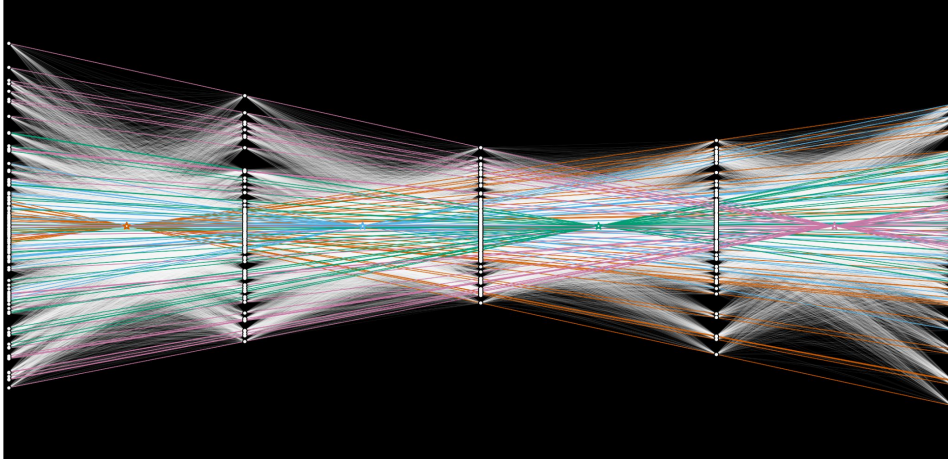
Building the next boat: RTA



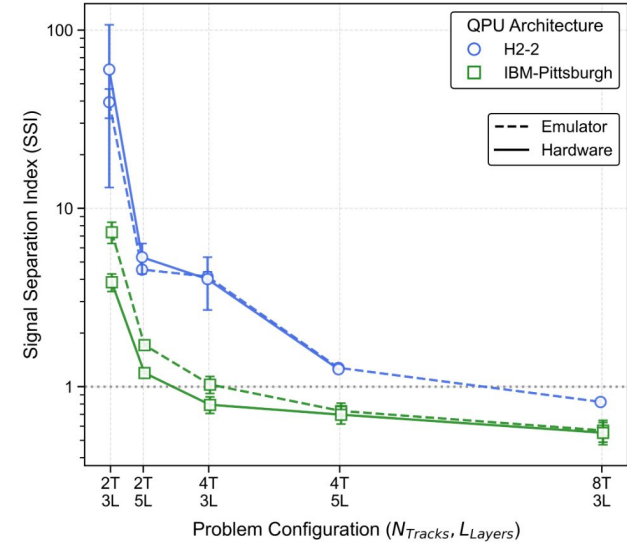
What might the architecture of LHCb's trigger look like in the 2030s?

- Build on the proven successes of triggerless readout
 - Likely use more GPUs, more ML
- First efforts towards 4D reconstruction algorithms on realistic hardware

To the further future: quantum tracking



SSI Performance Benchmark



- Simulated tracks reconstructed with a simplified VELO with real quantum computer
- For details see [Nature Comm. Physics](#)

Getting cleverer with our current boat: Flavour tagging



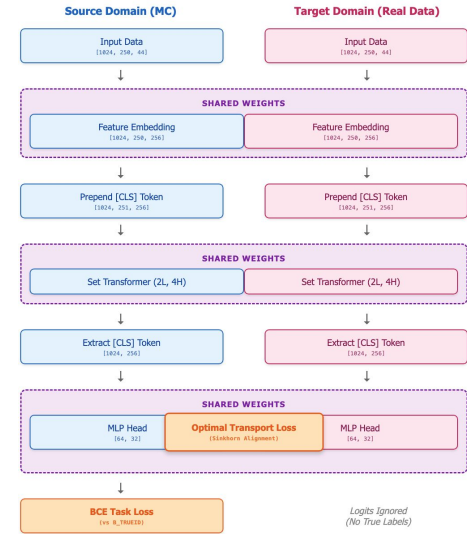
- ❖ Modern transformer-based inclusive flavour tagger performs excellently in simulation
 - Doubling tagging power \sim factor 4 in statistics



Getting cleverer with our current boat: Flavour tagging



- ❖ Modern transformer-based inclusive flavour tagger performs excellently in simulation
 - Doubling tagging power ~ factor 4 in statistics



Solvable with domain adaptation?

Getting cleverer with our current boat: AI agents

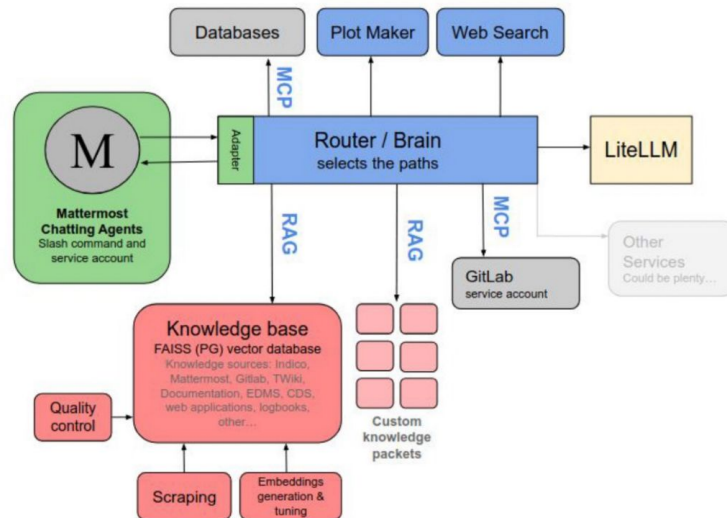


LHCb hackathon dedicated to:

- prototype LLM
- agent use cases

Team A: Code database
Team B: Knowledge base
Team C: Analysis Production
Team D: Simulation use cases
Team E: Analysis Assistance
Team F: Online shifter assistance

Hackathon on AI agents
2 Mar 2026, 09:00 → 6 Mar 2026, 20:00 Europe/Zurich
Daniel Magdalinski (Nikhef), Pawel Kopciwicz (CERN), Rosen Matev (CERN)
Sergio Arguedas Cuendis (Consejo Nacional de Rectores (CONARE) (CR))



Conclusions

LHCb is recording data more rapidly than ever before

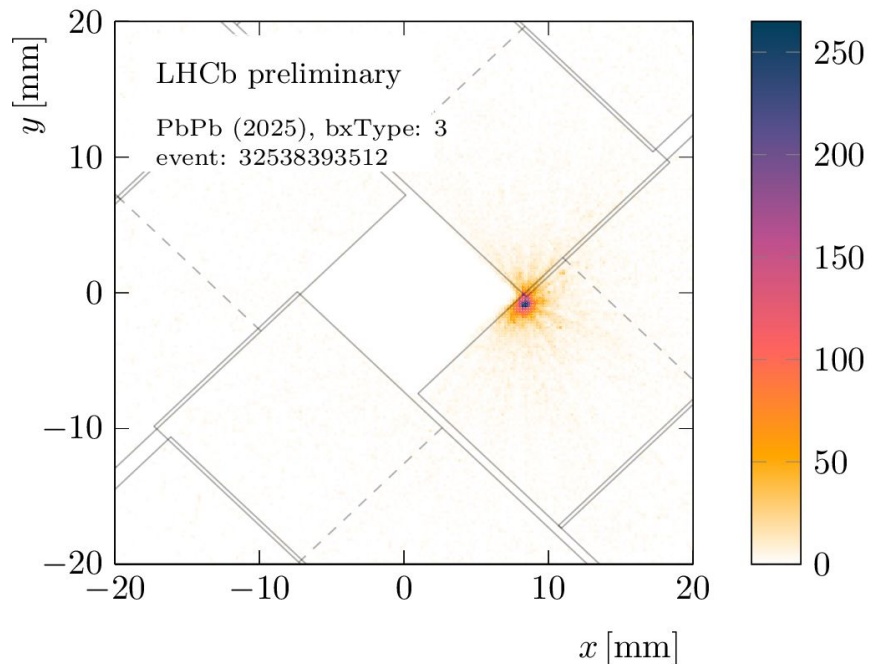
- Likely on track for $> 70\text{fb}^{-1}$ by the end of Run 4
- First publications (and discoveries!) with the new detector are out
- Detector is mostly in good health and has a promising future upgrade programme (FASTTRACK!)
- And we find new ways to improve measurements constantly



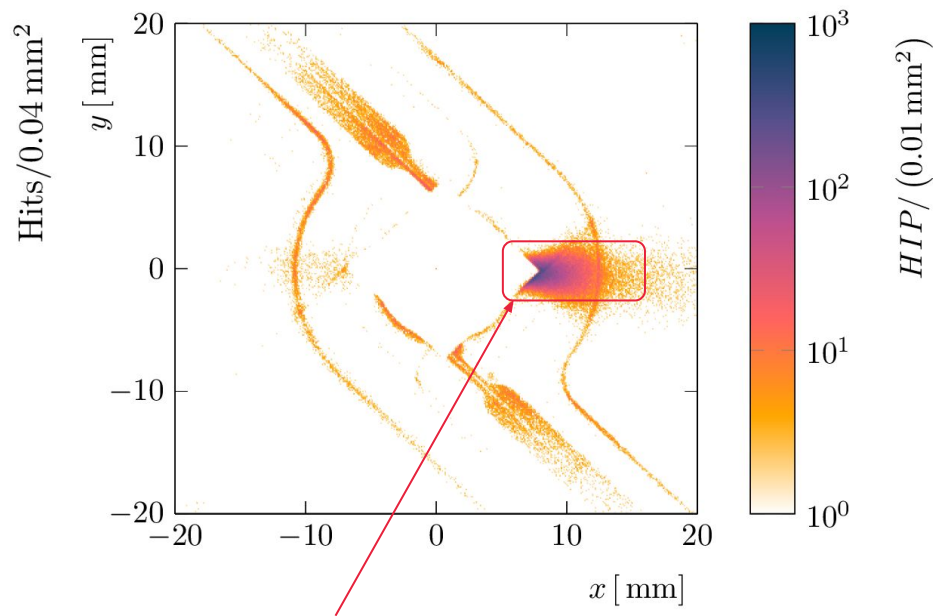
Thanks for your attention!

BACKUP

VELO : suspects

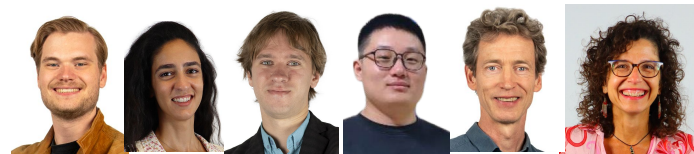


Fragment from lead nuclei interacting with the detector

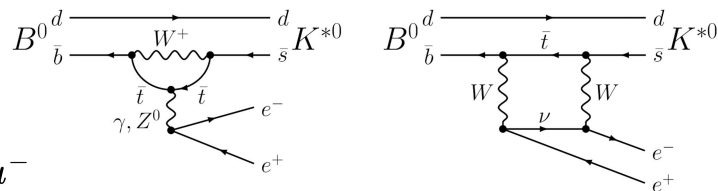


Highly charged beam fragments in this region now confirmed by LHC at \sim Hz rate

Angular analysis of $B^0 \rightarrow K^{*0} e^+ e^-$

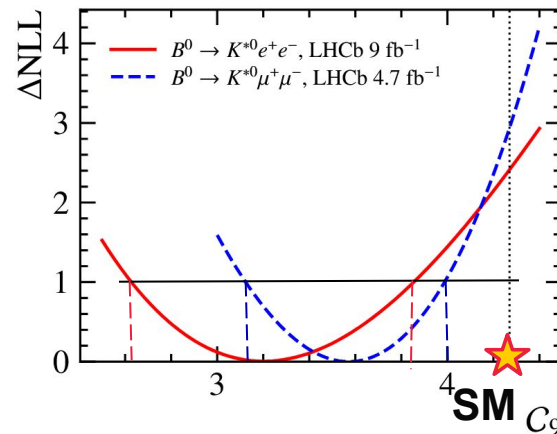
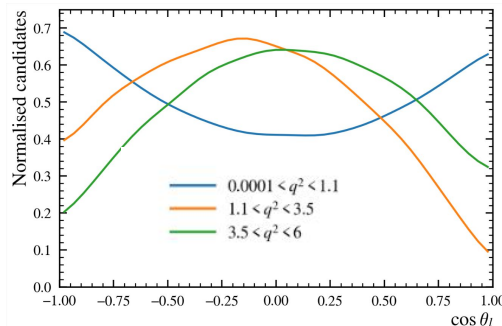
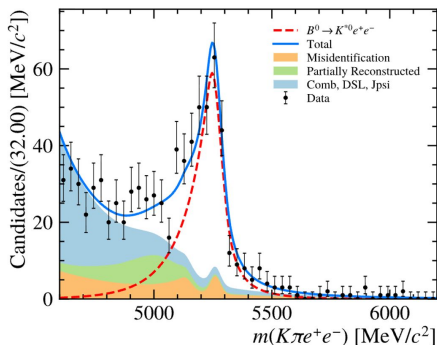


- Angular distributions are good probe for NP
- First LHCb measurement recently published
 - Angular distribution consistent with slightly deviate from SM
- Ongoing effort to increase phase space and updating with improvements



$$B^0 \rightarrow K^{*0} \mu^+ \mu^-$$

[JHEP 06 \(2025\) 140](#)



- Run3 analysis started, expected 5-6 times signal yields increase

From mesons to baryons: $\Lambda_b^0 \rightarrow \Lambda^0 \ell \ell'$ (cont.)

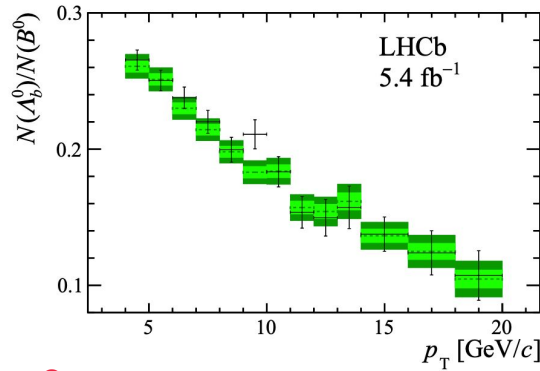


- Precise measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0) / \mathcal{B}(B^0 \rightarrow J/\psi K_S^0)$ using Run2 data
 - Experimentally challenging, Λ^0 decays traveling through detector

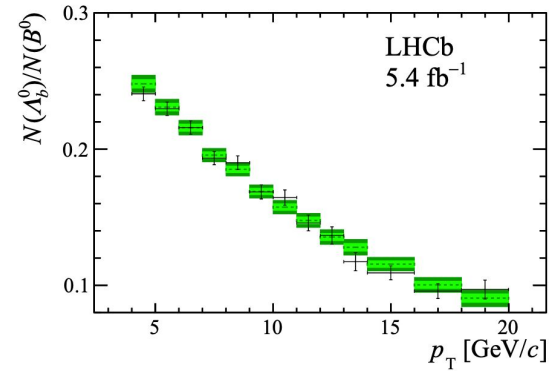
- Use improved detection of Λ_b^0 / B^0 production rate

- Results:

$$\begin{aligned} \mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0) \\ = (3.34 \pm 0.31) \times 10^{-4} \end{aligned}$$



Λ^0 decay before magnet

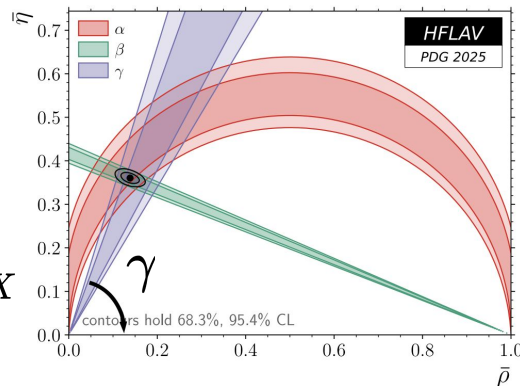


Λ^0 decay after magnet

Reduce uncertainty by factor 3

Fitting CKM γ , charm mixing and CP violation together

- What is γ ?
 - A CP-violating phase in CKM matrix
 - Good probe of CP violation in the SM
 - Direct measurements are less precise than indirect constraints
- Many existing measurements from $B \rightarrow D/D_s h X$
- Since 2021, simultaneous determination of γ with charm measurement
- This update:
 - Add three new/update inputs
 - Improvement on γ and charm mixing and CPV
$$\gamma = (62.8 \pm 2.6)^\circ$$
 - Consistent with indirect constraints



$$\gamma_{\text{indirect}} = (66.3^{+0.7}_{-1.9})^\circ$$

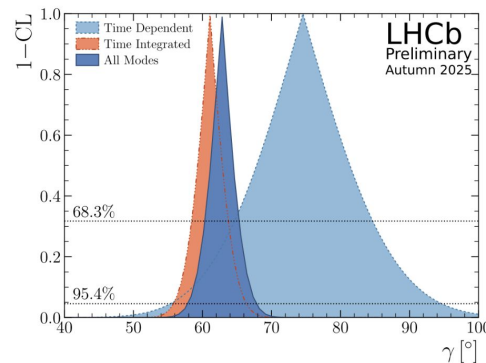
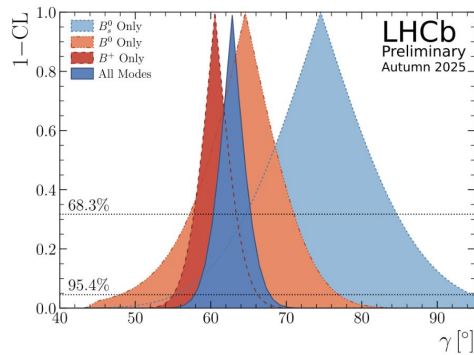
[CKM Fitter](#)

$$= (65.2 \pm 1.5)^\circ$$

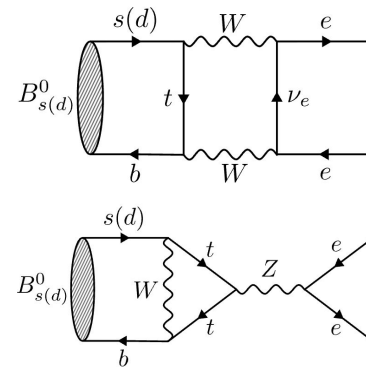
[UTfit](#)

$$\gamma = \arg \left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} \right)$$

[LHCb-CONF-2025-003](#)



Search for $B_{s(d)}^0 \rightarrow e^+ e^-$ decays in Run 1 + 2



- FCNC ($b \rightarrow s$ | I) \rightarrow Very suppressed

- Only loop diagrams in SM
- Helicity suppressed \rightarrow 40 000 more rare than $B_s \rightarrow \mu\mu$

$$\mathcal{B}(B_s^0 \rightarrow e^+e^-)_{\text{SM}} = (8.35 \pm 0.39) \times 10^{-14}$$

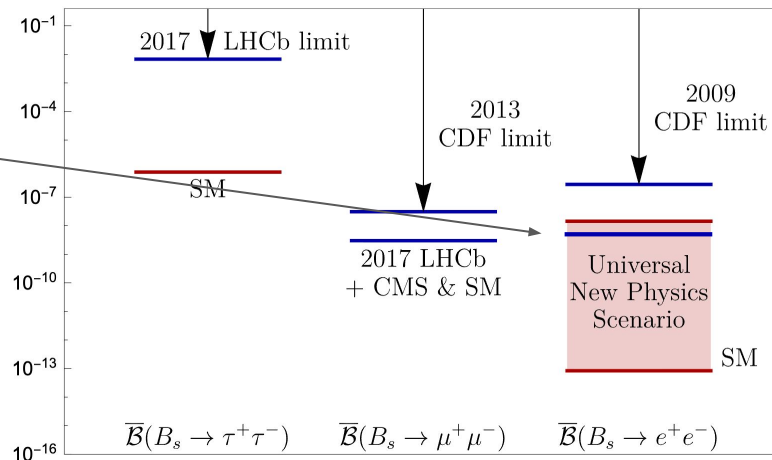
$$\mathcal{B}(B^0 \rightarrow e^+e^-)_{\text{SM}} = (2.39 \pm 0.14) \times 10^{-15}$$

- Current limits set by LHCb

$$\mathcal{B}(B_s^0 \rightarrow e^+e^-) < 9.4(11.2) \times 10^{-9}$$

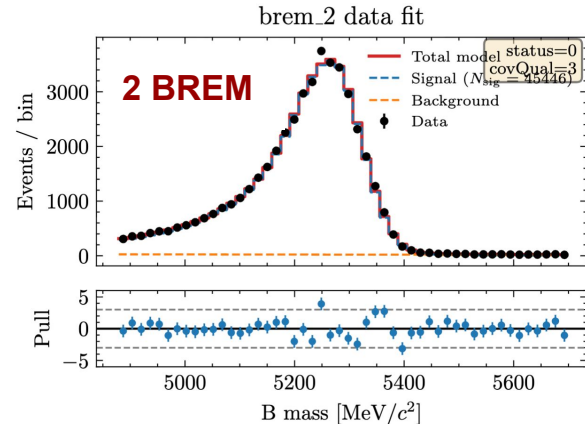
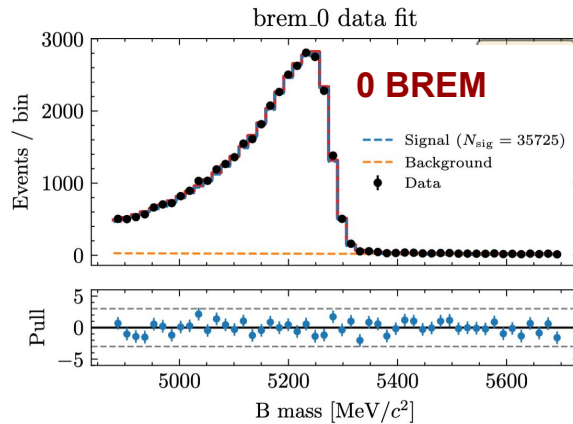
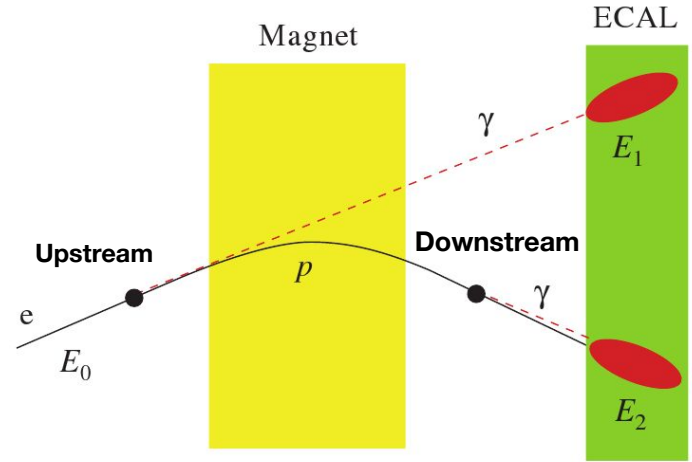
$$\mathcal{B}(B^0 \rightarrow e^+e^-) < 2.5(3.0) \times 10^{-9}$$

- We are updating it with \sim double the data



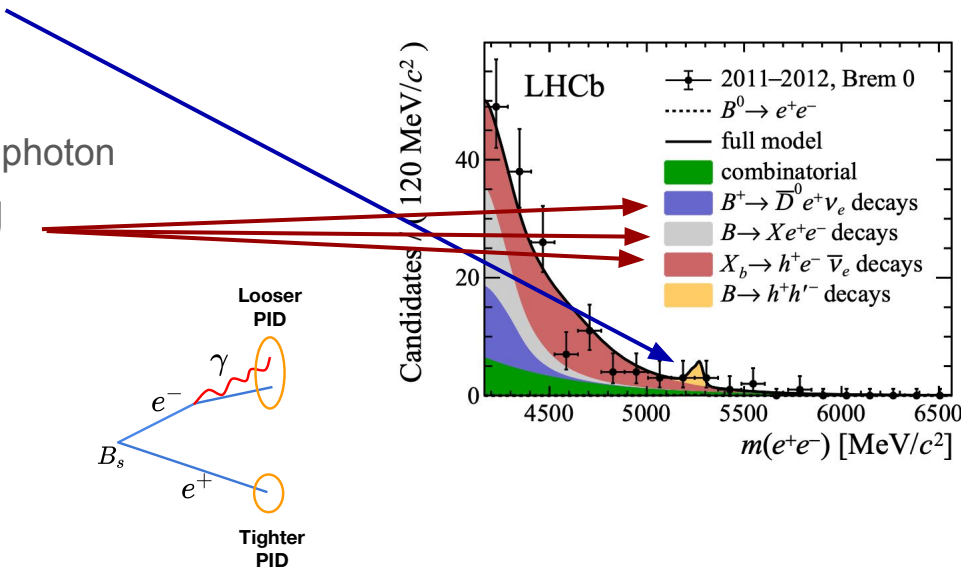
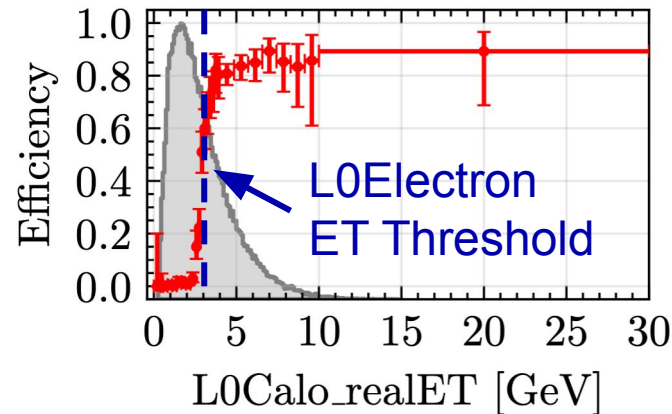
Electron reconstruction

- Electrons are harder to reconstruct
 - Multiple scattering → worse tracking
 - **Bremstrahlung**
 - Brem after the magnet → Photon in same ECAL Cell
 - Brem before the magnet → Brem recovery
- Brem-dependent signal shape, efficiencies, resolutions



Improvements from previous analysis

- **Data-driven trigger efficiencies**
 - Improved systematics
- **Brem-dependent PID working point**
 - Reject dangerous $B \rightarrow hh'$ background
Dominant in the signal region
 - Hadrons do not brem
 - Tight PID on electrons without a Brem photon
- **Improved Background modeling**
- **Improved BDT**
 - Better signal vs bkg separation



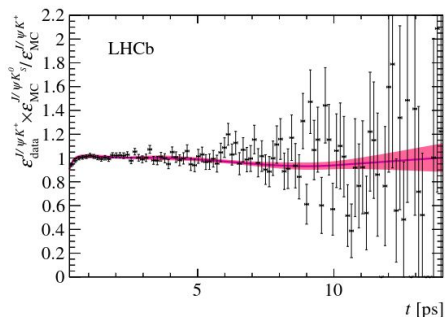
Fit results

- The measurement is currently blinded
- Statistical uncertainty reduced compare to current global average
- Systematics are currently being studied

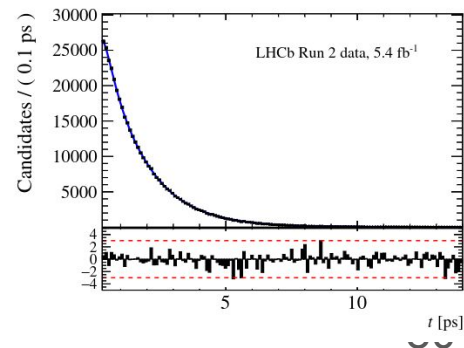
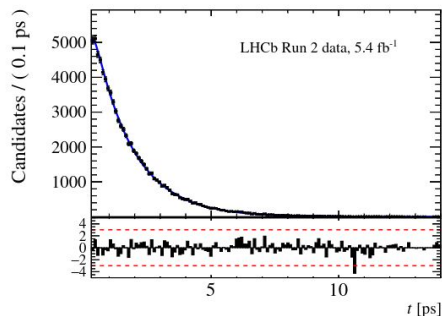
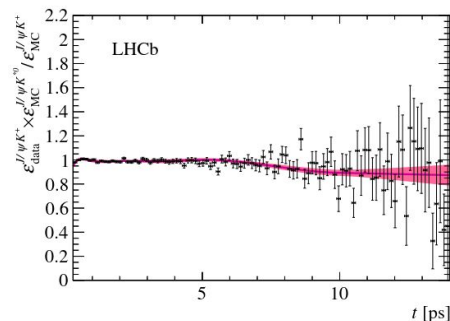
$$\frac{\Delta\Gamma}{\Gamma}(\text{SM}) = (0.42 \pm 0.08) \times 10^{-2}$$

$$\frac{\Delta\Gamma}{\Gamma}(\text{exp. avg.}) = (0.1 \pm 1.0) \times 10^{-2}$$

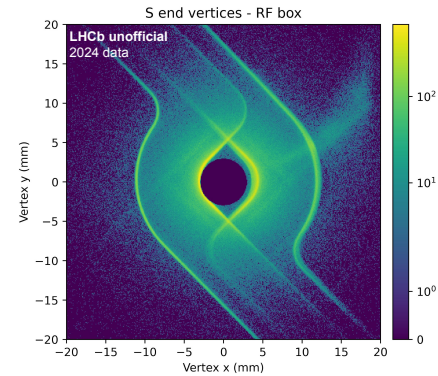
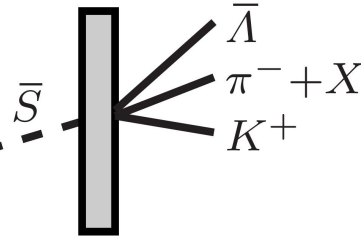
$B^0 \rightarrow J/\psi K_S^0$



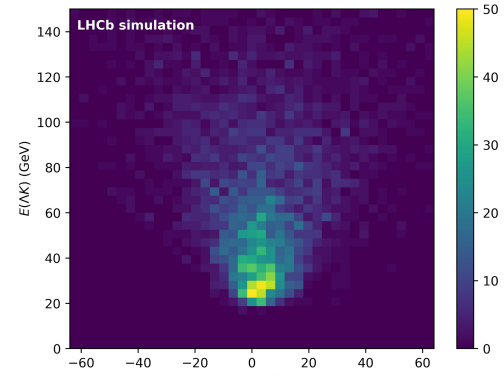
$B^0 \rightarrow J/\psi K^{*0}$



Sexaquark (uuddss)



- Stable six-quark doubly-strange singlet scalar \rightarrow DM?
- Look for inclusive \bar{S} annihilation with p, n in detector material
- Currently collecting all 2024-2026 data... (pp+PbPb)
- Made better and faster sim incl. Fermi momentum affecting m_S resolution
- Now simulated & triggering on all $S = 2$ combo's of $\bar{\Lambda}^0, K^+, K_S^0, \bar{\Xi}^+$
- To do:
 - Apply material cut and BDT
 - Obtain $\sigma(pp \rightarrow \bar{S}) \times \sigma(\bar{S}N \rightarrow X)$ & m_S
 - In case of observation, this hints whether $S \subseteq$ DM



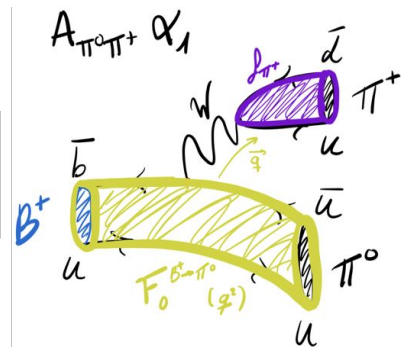
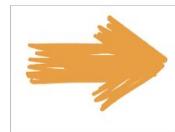
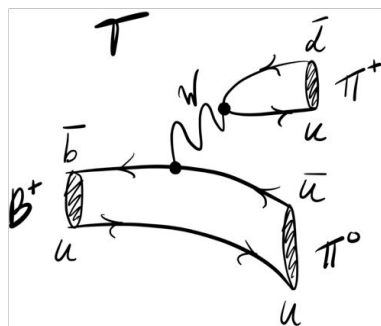
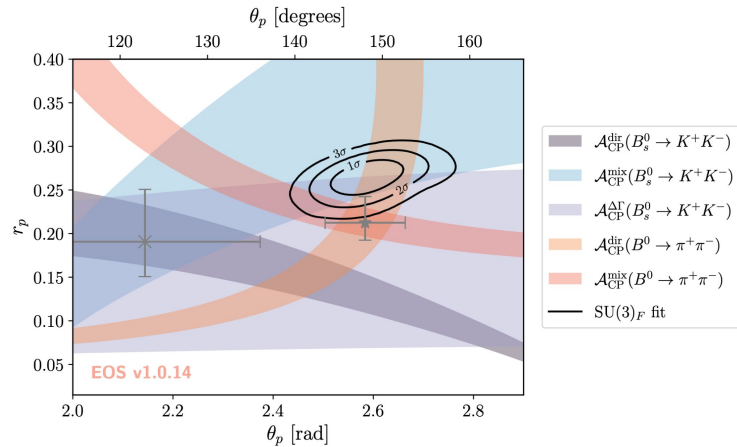
SU(3) Flavor analysis of B to HH, H = pi, K

Plenty of experimental data, theoretically still governed by uncertainties

Under full SU(3) Flavor symmetry ($u=d=s$) we can not describe experimental data

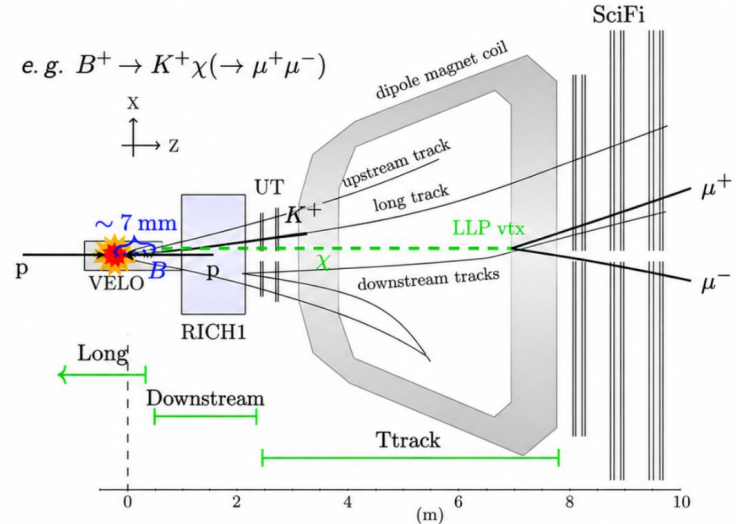
By taking into account **factorizable effects**, we are able to:

- Describe data
- Make branching ratio and CP asymmetry predictions
- Test whether QCD factorization works as expected

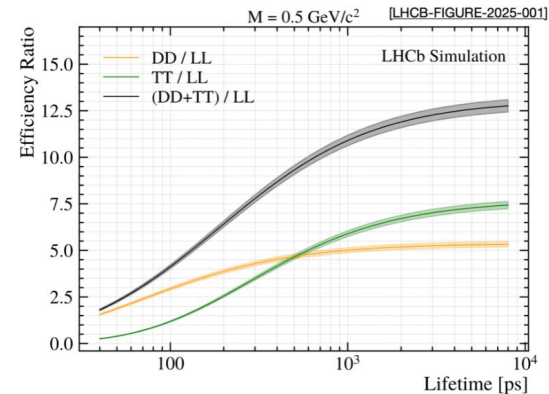


Long-lived particles in Run 3

- **Lifetime frontier**: increase the lifetime acceptance at HLT2 **using SciFi-only tracks (T tracks)**
- Access to Long-Lived Particles decaying in the middle of the magnet

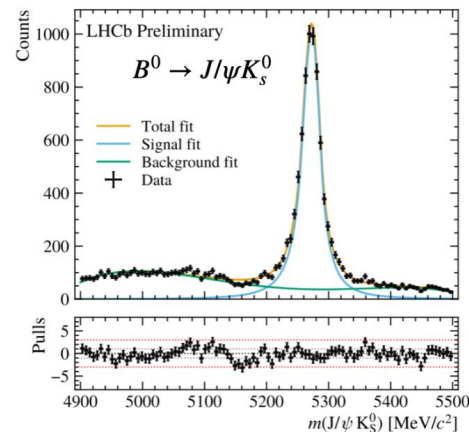


- \sim order of magnitude better signal efficiency for lifetimes of $O(\text{ns})$
- but limited momentum resolution
- see proceedings FIPs @ LHCb workshop 2025 [arXiv:2510.05257](https://arxiv.org/abs/2510.05257)

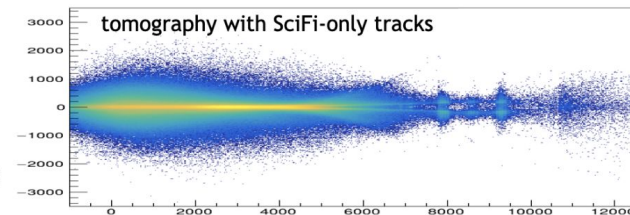


Long-lived particles in Run 3

- First targets with di-muon signature
 - Dark Scalars in b-decays
 $b \rightarrow s(\phi \rightarrow \mu\mu)$
 - to be continued with HNLs in b-decays
- Control channel - well known $B^0 \rightarrow J/\psi K_s^0$ with K_s^0 decaying in the magnet region
- Backgrounds from combinatorial and material interactions
- [ABCDiSCoTEC](#) from CMS method to
 - a) suppress bkg
 - b) de-correlate the classifier from invariant mass
 - c) minimise non-closure of the ABCD method



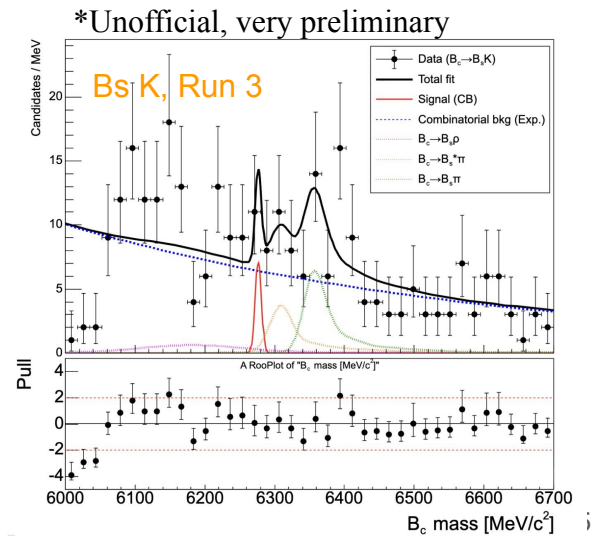
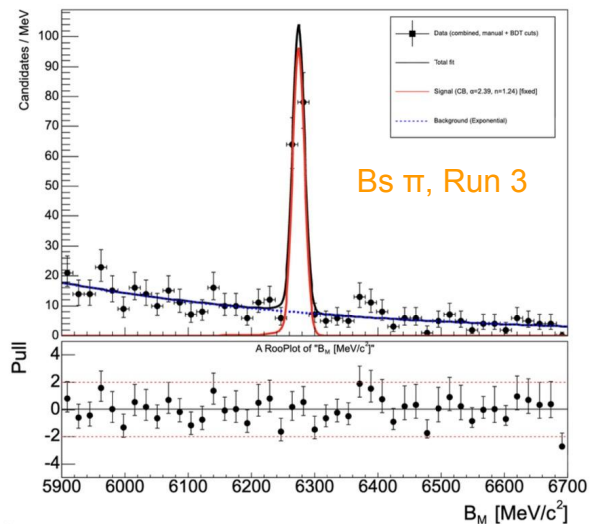
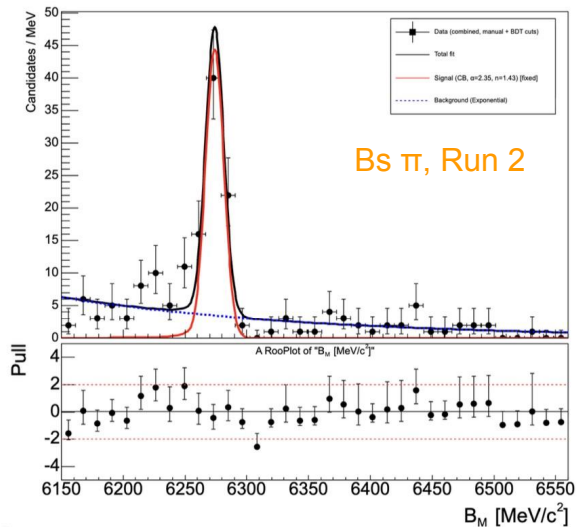
X vs Z



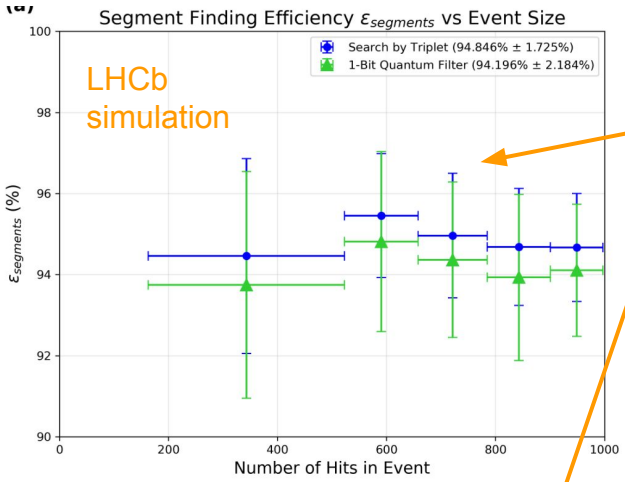
Searching for $B_c \rightarrow B_s K$ in LHCb run 3

Bachelor Thesis of Clotilde Papot (UM)

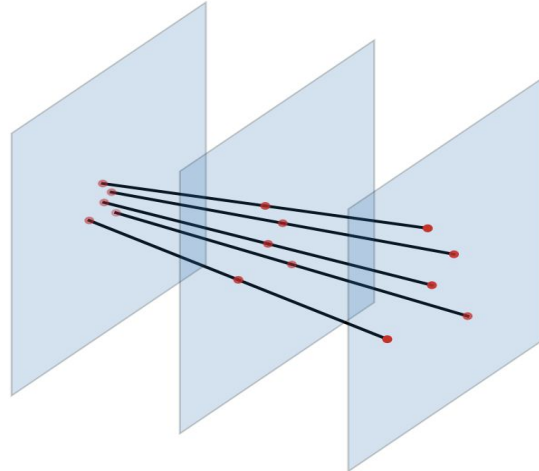
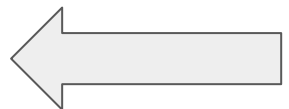
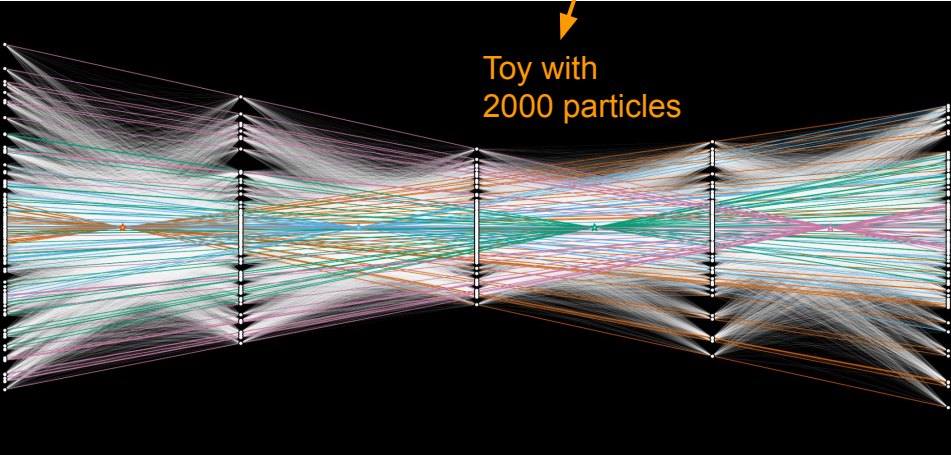
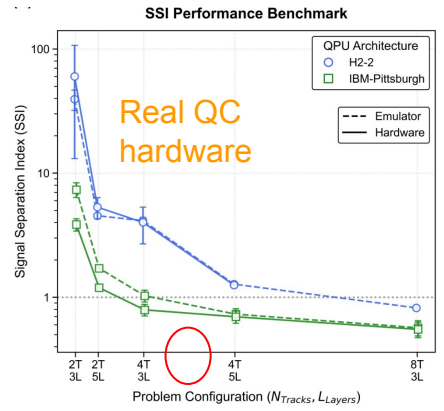
- 'Charming Beauty': heavy 'stable' state produced at LHC
- 'Beauty \rightarrow Beauty' transition: large, Cabibbo favoured ($c \rightarrow s$): $\sim 10\%$ (discovered @ Nikhef/LHCb)
- Now search for the suppressed kaon mode \rightarrow CP-violation possible, 'Mesogenesis' candidate \rightarrow first attempt still elusive, $BR < 3 \times 10^{-3} *$



Particle Tracking Using Quantum Computers



- New method using global matrix inversion (HHL) and spectral filtering
- Can reconstruct realistic LHCb MC (using noiseless simulators)
- Can reconstruct Toy events up to 2000 particles, based on LHCb Velo geometry
- Test on quantum hardware:
 - IBM QPUs (SC qubits) via CERN QTI,
 - access to **Quantinuum** QPUs (trapped-ions) via GWFP/UM
- Submission to [Nature Comm. Physics](#)



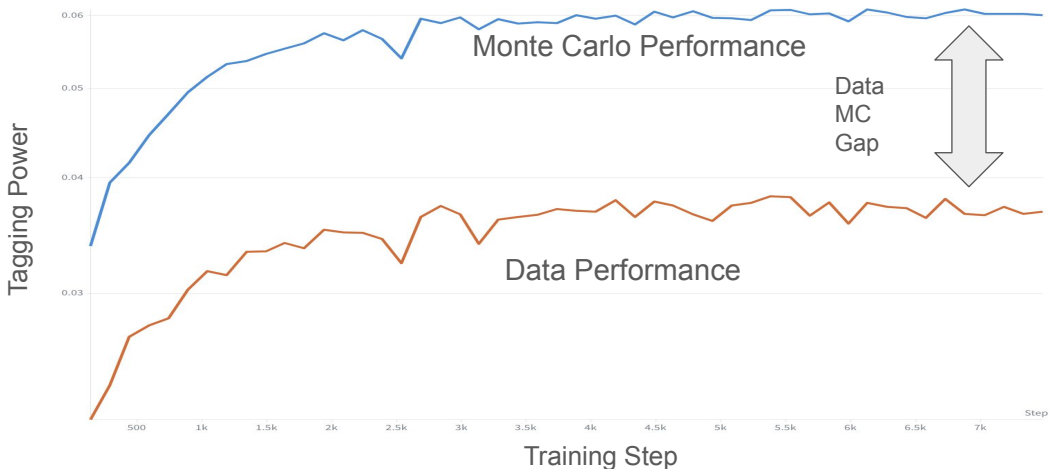
Set Transformer for Flavour Tagging: Closing the Gap with Domain Adaptation



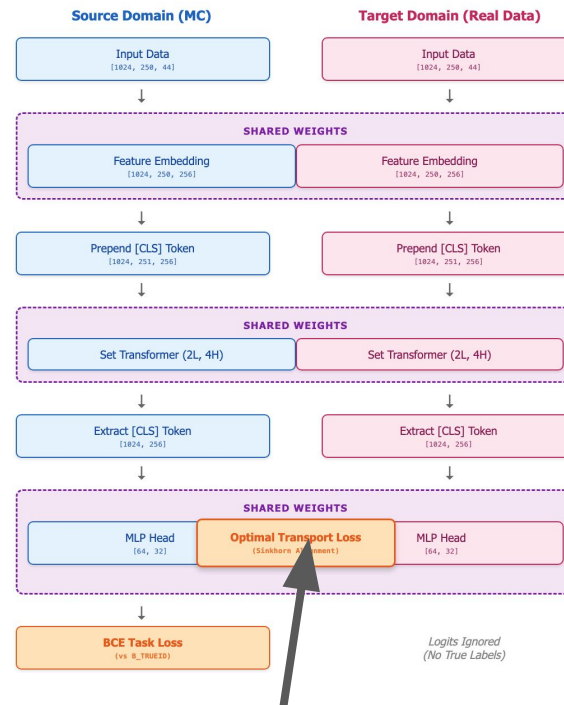
- Data and MC see large differences in tagging performance with inclusive taggers
- We benchmark using self tagging modes:



- Ideally will standardize tagger response across domains



(Trained on Limited data as a benchmark)



Tagging Loss + Adaptation Loss

LHCb and AI: hackathon on AI agents *(our Daniel Magdalinski :-)*



LHCb hackathon dedicated to:

- prototype LLM
- agent use cases

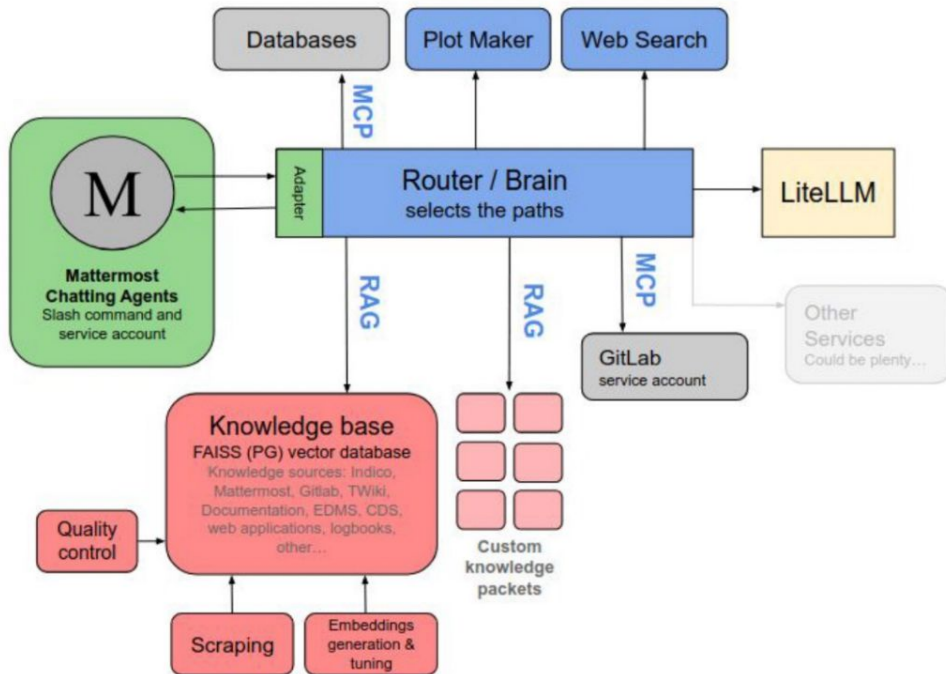
Team A: Code database
Team B: Knowledge base
Team C: Analysis Production
Team D: Simulation use cases
Team E: Analysis Assistance
Team F: Online shifter assistance



Hackathon on AI agents

📅 2 Mar 2026, 09:00 → 6 Mar 2026, 20:00 Europe/Zurich

👤 Daniel Magdalinski (Nikhef), Pawel Kopciewicz (CERN), Rosen Matev (CERN)
Sergio Arguedas Cuendis (Consejo Nacional de Rectores (CONARE) (CR))

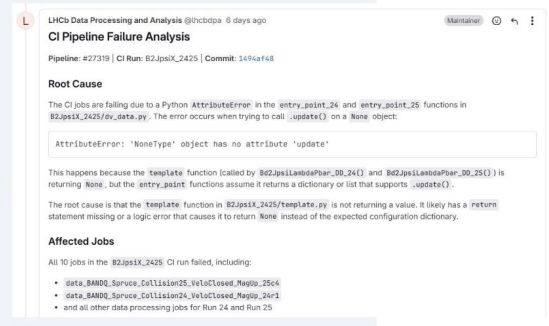
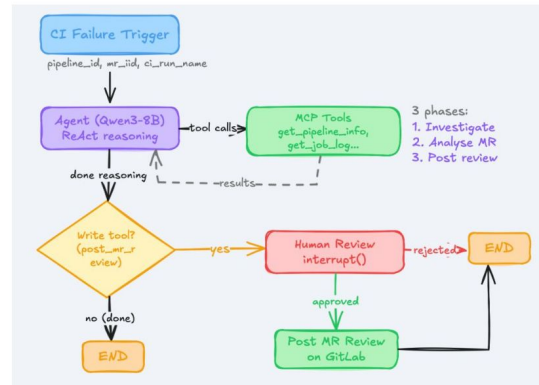


LHCb hackathon on AI agents

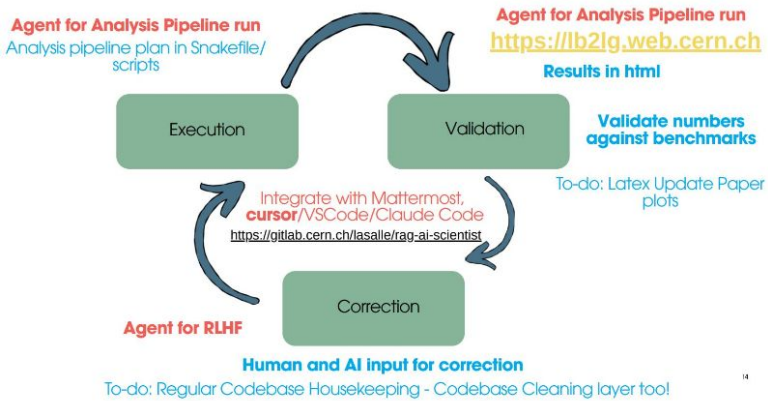


- LHCb hackathon dedicated to prototype LLM and agent use cases

Automatic CI pipeline analysis



Analysis code assistance



Indico event chatbot

Pawel Kopciwicz 2:28 PM
Please give me a summary of Feb 18 Charm meeting!

Team B: Indico + Docs knowledge agent BOT 2:28 PM
The Charm Working Group (WG) meeting on February 18, 2026, covered several updates on charm physics analyses. Here's a summary of the key points discussed:

- Update on Search for CPV in $D^0 \rightarrow K_S^0 K^{\pm} \pi^{\mp}$:** Francesco Paciolla presented an update on the measurement of CP asymmetry in $D^0 \rightarrow K_S^0 K^{\pm} \pi^{\mp}$ decays, focusing on systematic uncertainties. The dominant source of uncertainty was identified as the efficiency model. The analysis is currently in the Working Group review, in its third round of questions.
- Update on Search for CPV in $D^+ \rightarrow \pi^+ \pi^+ \pi^+$:** Beatriz Moraes Vivacqua presented an update on the search for CP violation in $D^+ \rightarrow \pi^+ \pi^+ \pi^+$ decays. The presentation covered the selection, mass fits per Dalitz Plot bin, background parametrization, and control channel fits. Suggestions were made for additional cross-checks, such as splitting by H11 lines and checking PID variables.
- Update on Charm Cross-Sections with 2024 Data:** Lucas George Girardey presented an update on charm cross-sections using 2024 data. Discussions included the efficiency corrections, comparisons between data and Monte Carlo simulations, and the impact of disabled detector modules. Suggestions were made to improve the analysis, including checking the effect of multiplicity distributions and using different H11 lines for less-correlated TIS samples.
- News:** The meeting also included a news section presented by Giulia Tuci, Serena Maccolini, and Tommaso Pajero, highlighting upcoming presentations at the LHCb Week and changes to the arXiv summary, which will now advertise interesting theory papers instead of providing a weekly summary.

These updates reflect the ongoing efforts within the Charm WG to refine analyses and prepare for future measurements, showcasing the collaborative and detailed work being done in the field.



LHCb hackathon on AI agents

- LHCb hackathon dedicated to prototype LLM and agent use cases

