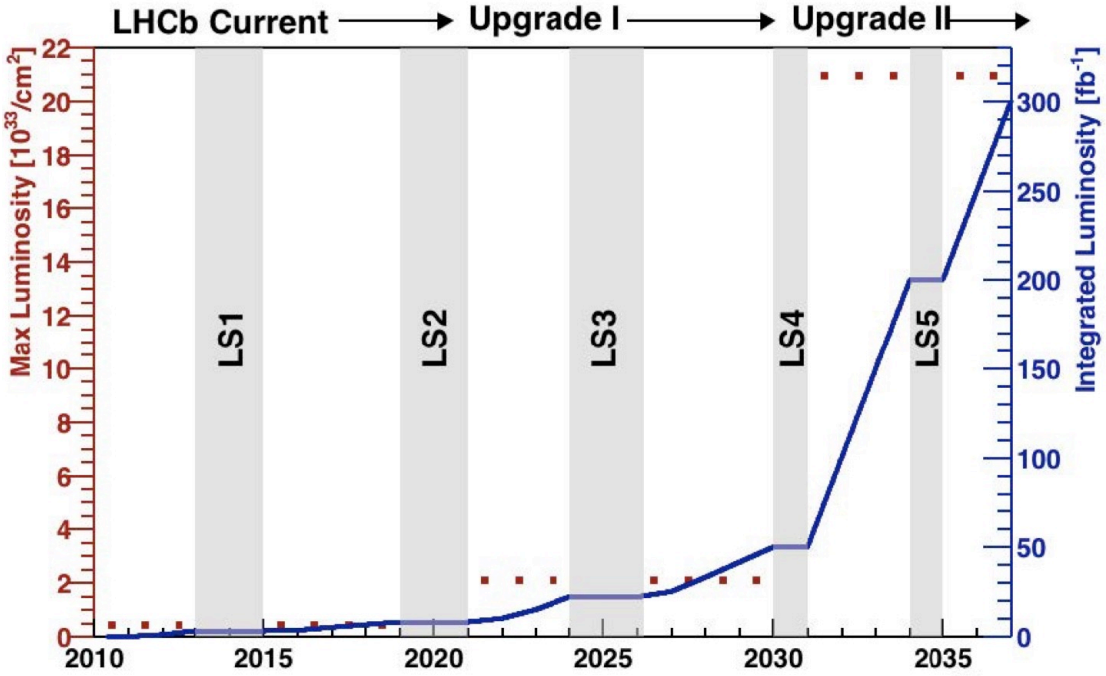
Flavour Physics at the High Luminosity LHC: LHCb Upgrade II

Chris Parkes

for LHCb Collaboration

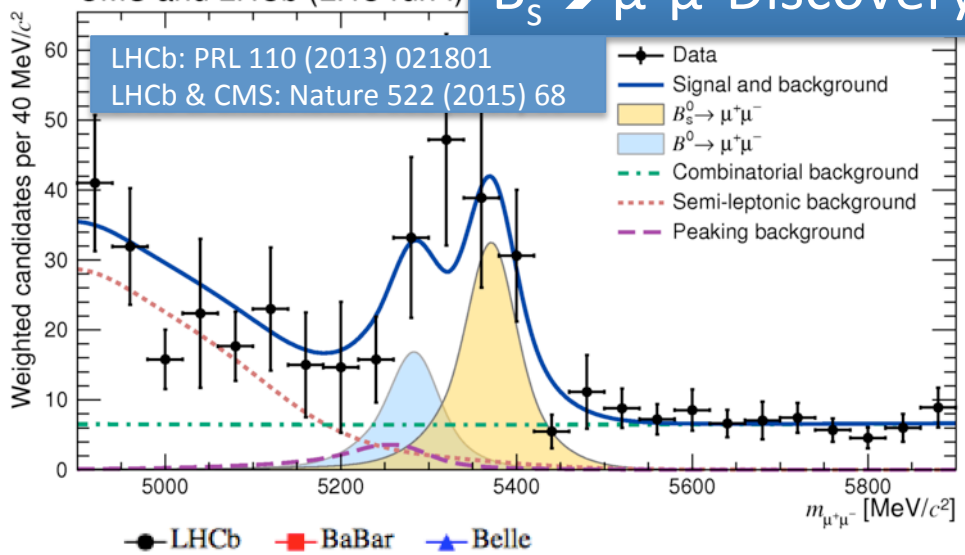
- Timeline
- Detector
- Physics Case
- HL- LHC machine



LHCb Highlights

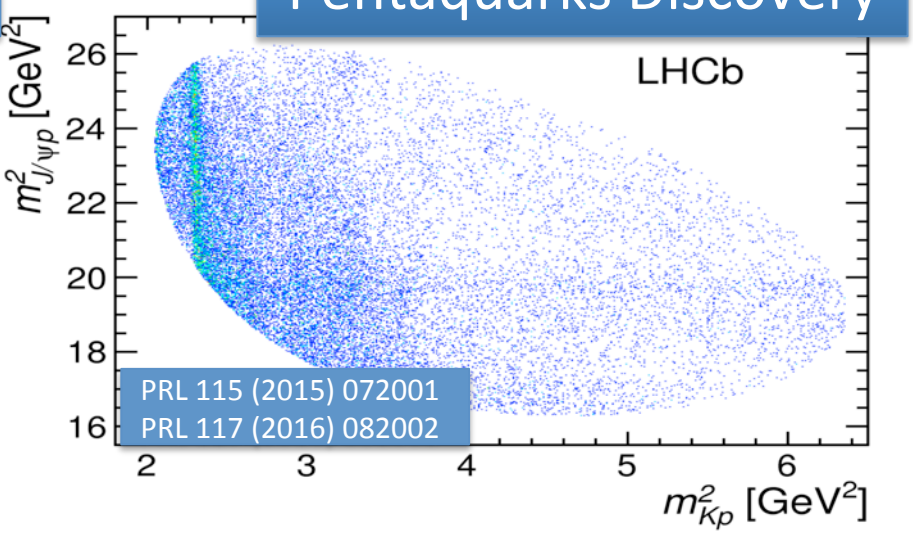
440 Physics Papers 842 Authors 79 Institutes

$B_s \rightarrow \mu^+\mu^-$ Discovery



LHCb: PRL 110 (2013) 021801
LHCb & CMS: Nature 522 (2015) 68

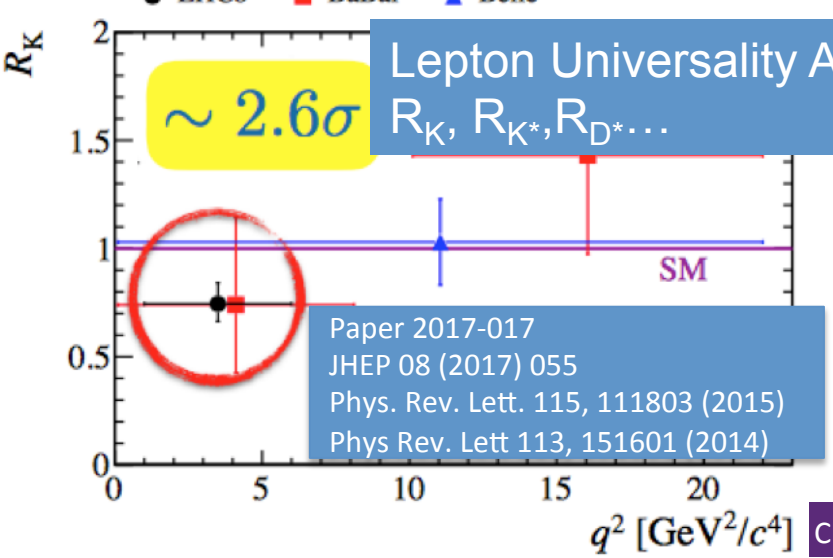
Pentaquarks Discovery



PRL 115 (2015) 072001
PRL 117 (2016) 082002

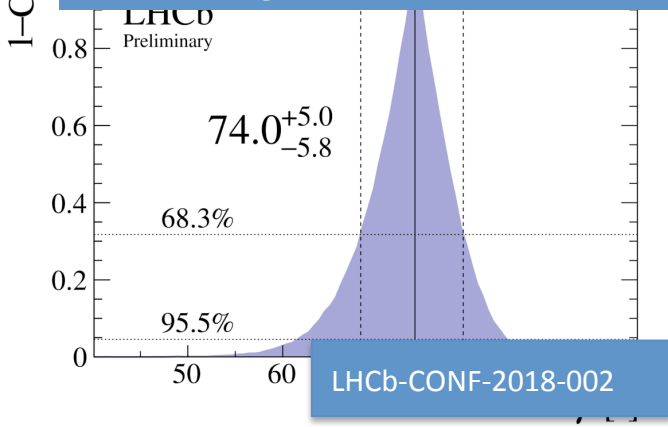
Lepton Universality Anomalies

R_K, R_{K^*}, R_{D^*}…



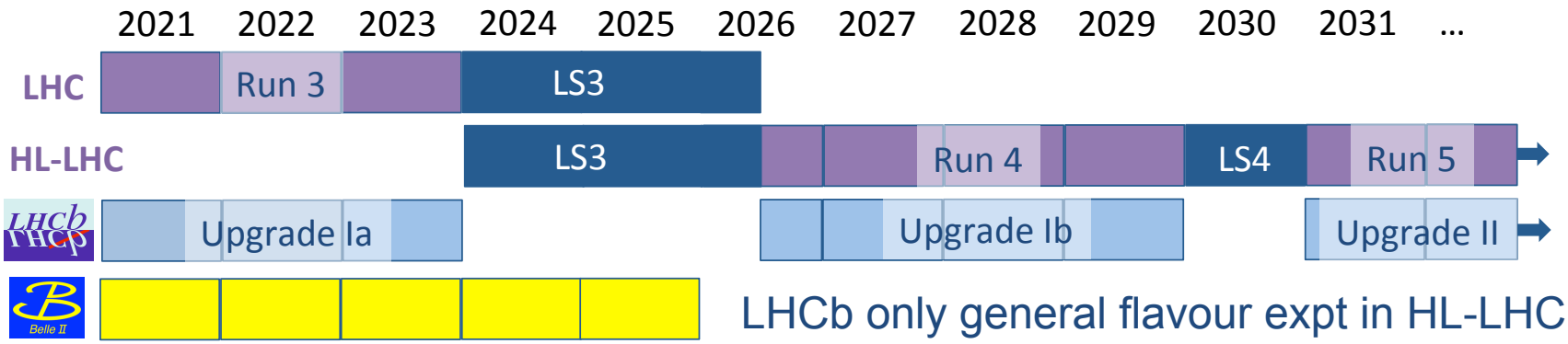
Paper 2017-017
JHEP 08 (2017) 055
Phys. Rev. Lett. 115, 111803 (2015)
Phys Rev. Lett 113, 151601 (2014)

CKM Angle γ Precision Era



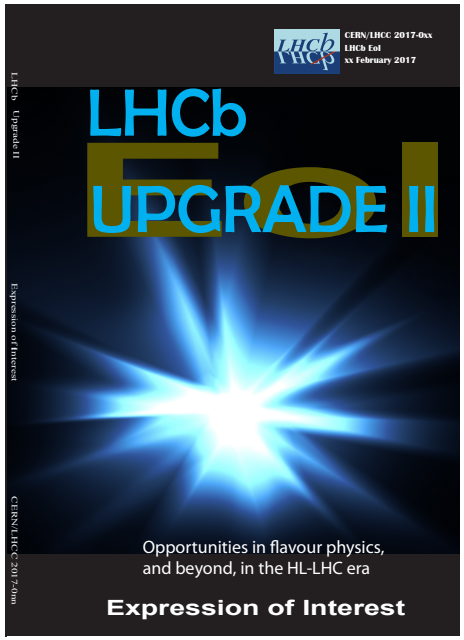
LHCb-CONF-2018-002

LHCb Timeline



LHCb only general flavour expt in HL-LHC era

- Upgrade I: **Installing from end of 2018**
- Upgrade Ib/II: **Expression of Interest 2017**



CERN-LHCC-2017-003

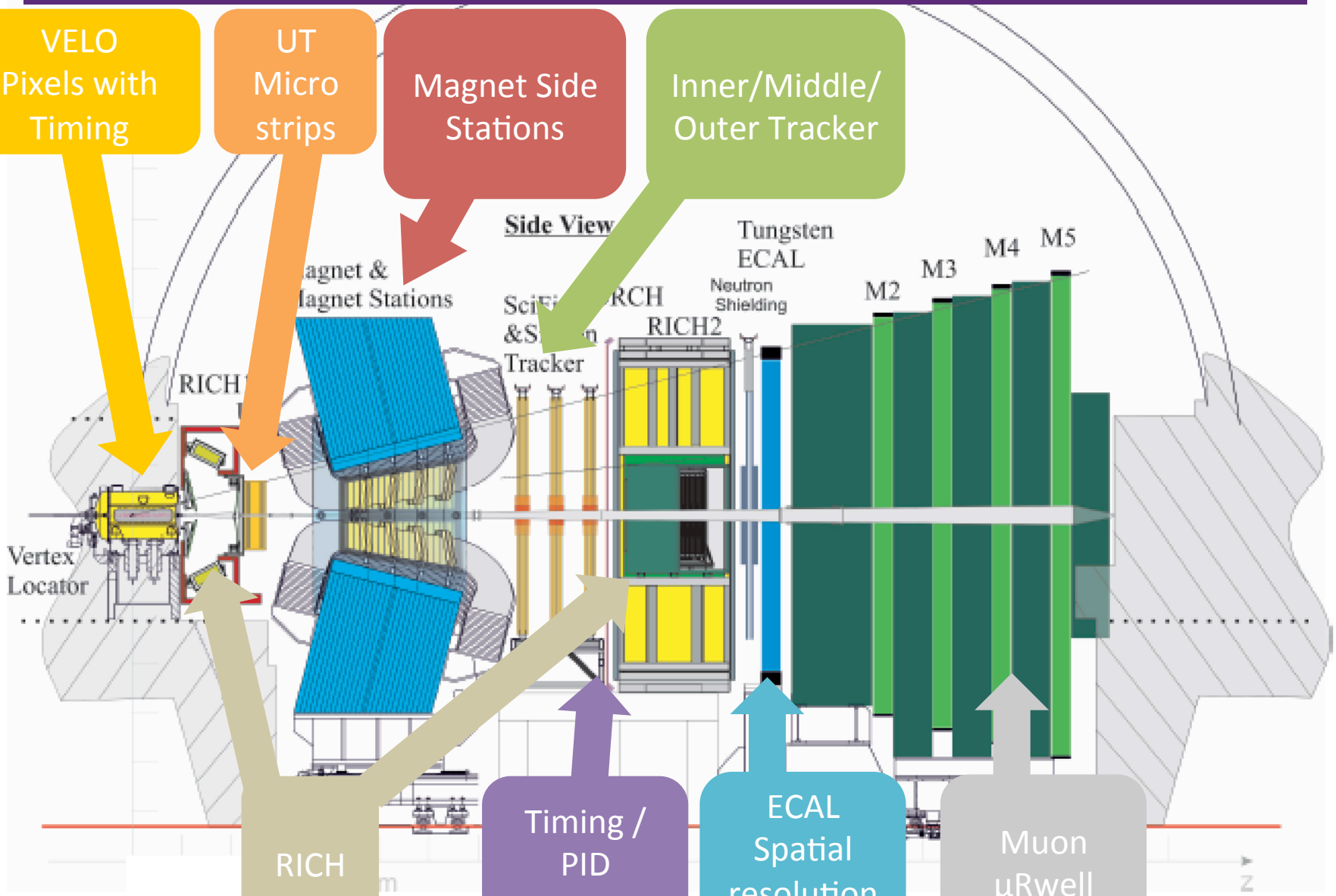
Physics case 2018

LHCb-PUB-2018-009, in preparation

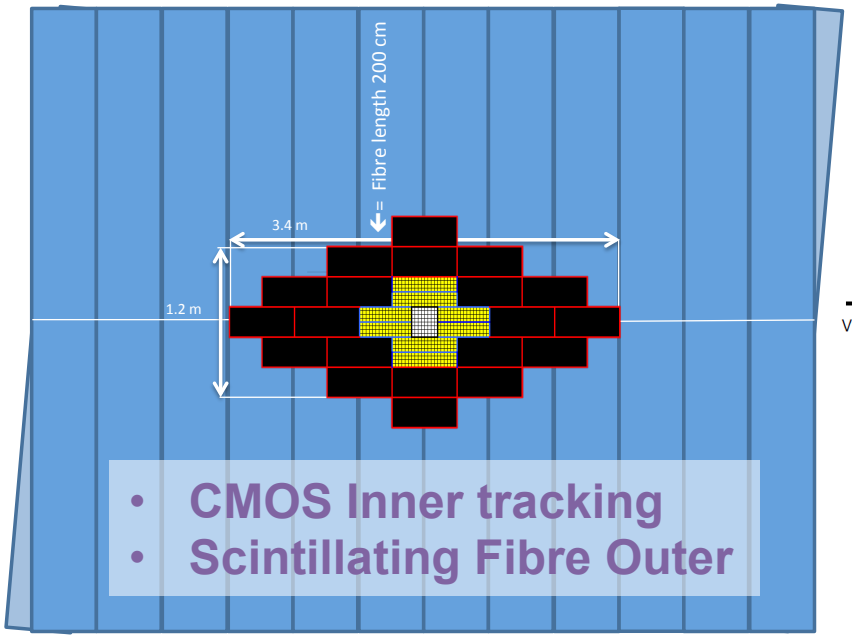
HL-LHC machine study 2018

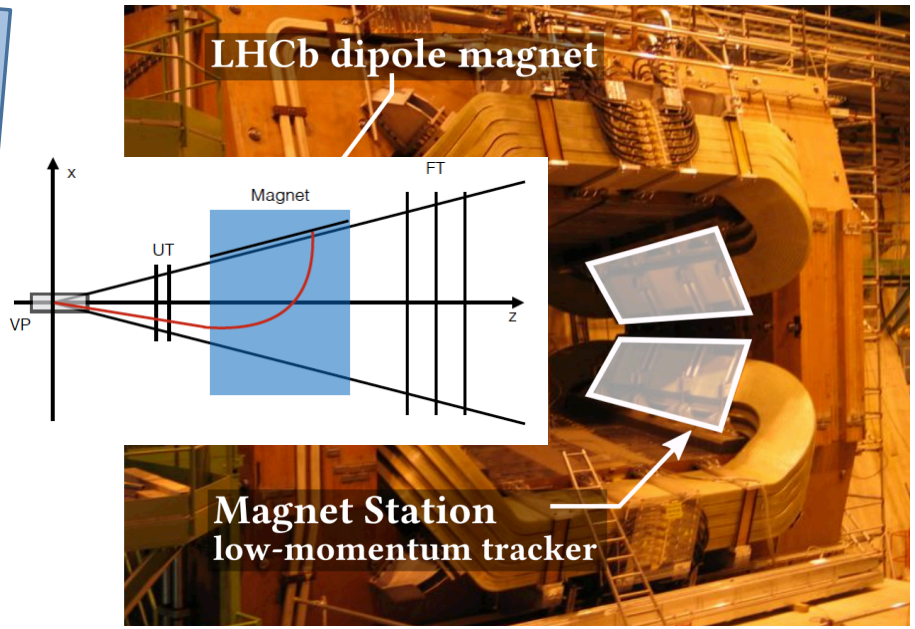
CERN-ACC-NOTE-2018-0038, in preparation

Upgrade II Detector



Detector - Tracking

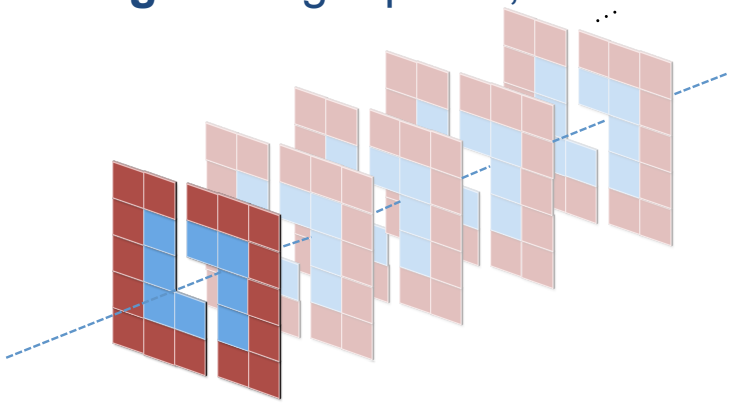


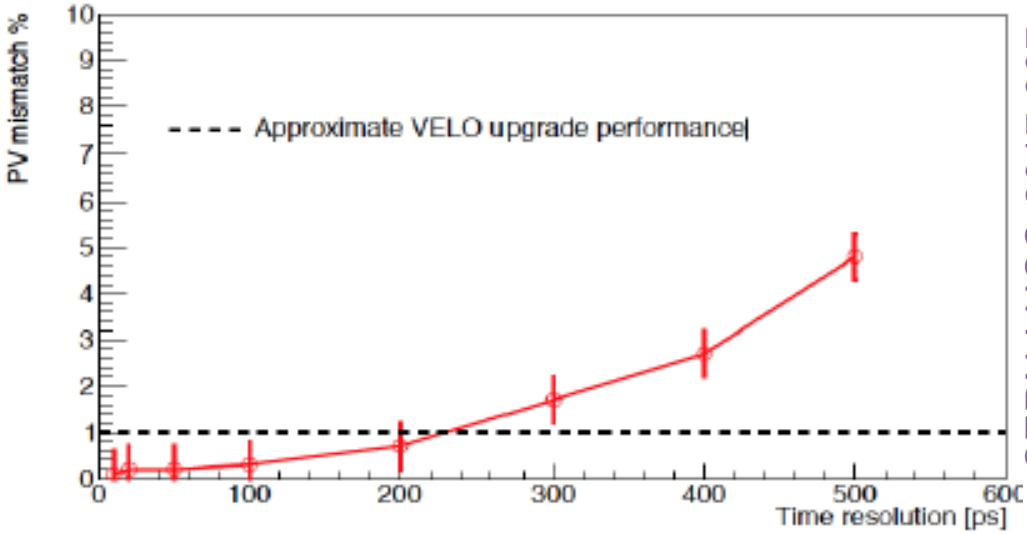


Vertex Detector

Small-r: small pixels, radiation hard

Large-r: larger pixels, **fast timing**

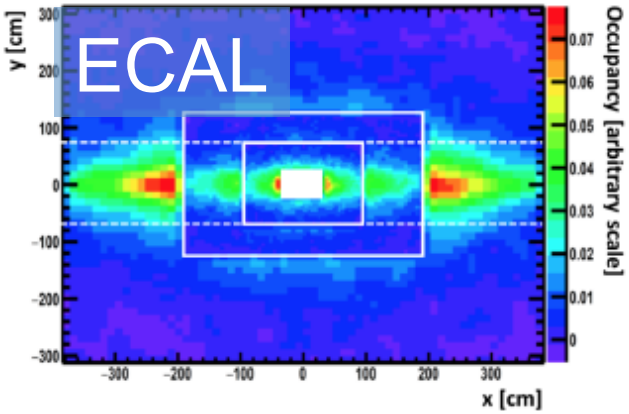


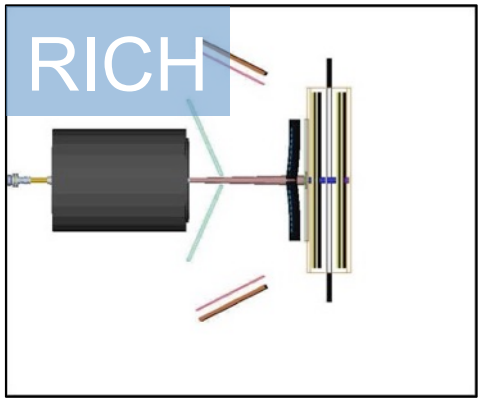


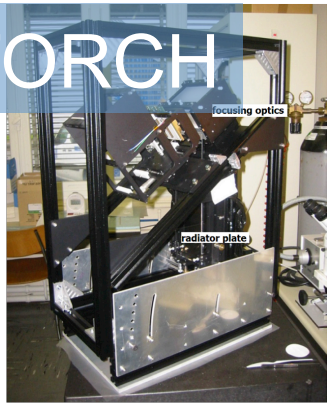
CERN-LHCC-2017-007

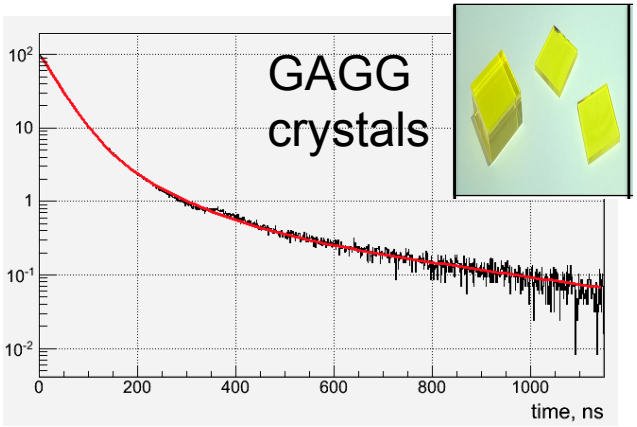
Detector – Particle ID

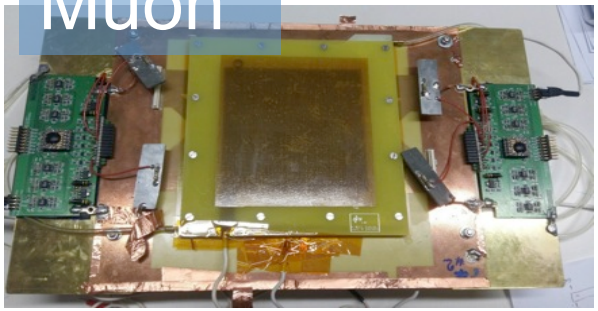
- "5D" ECAL: Energy, position, timing
- RICH: High granularity & time resolved
- TORCH: low-momentum particle ID from timing

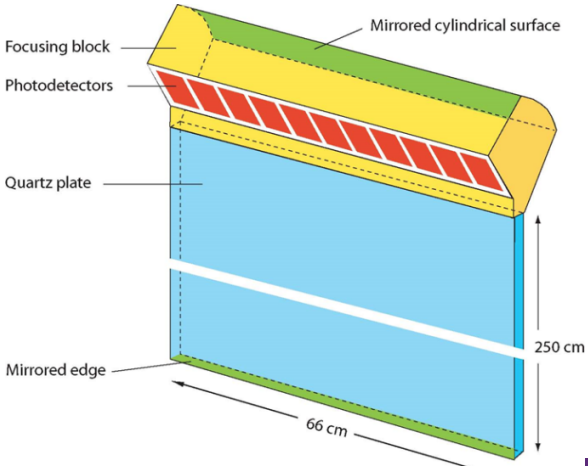






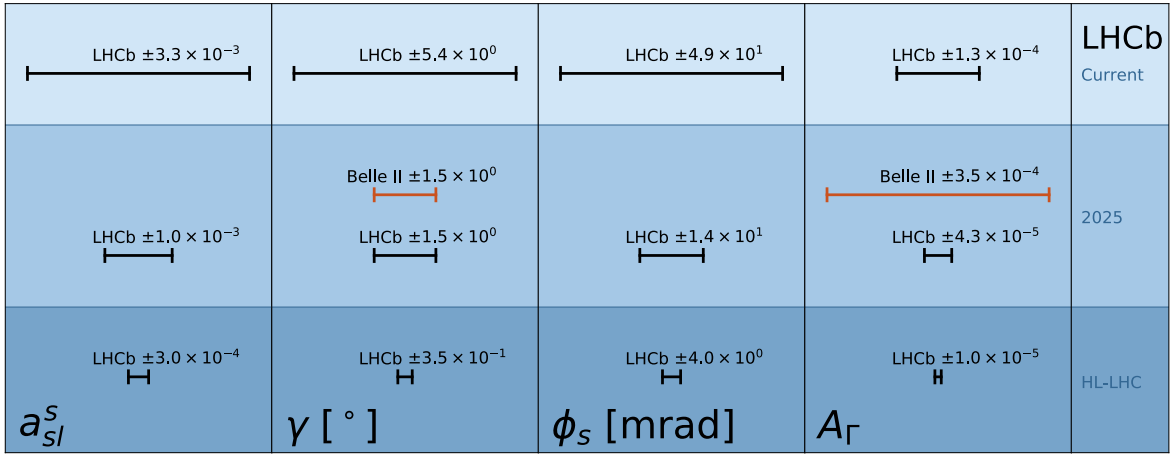


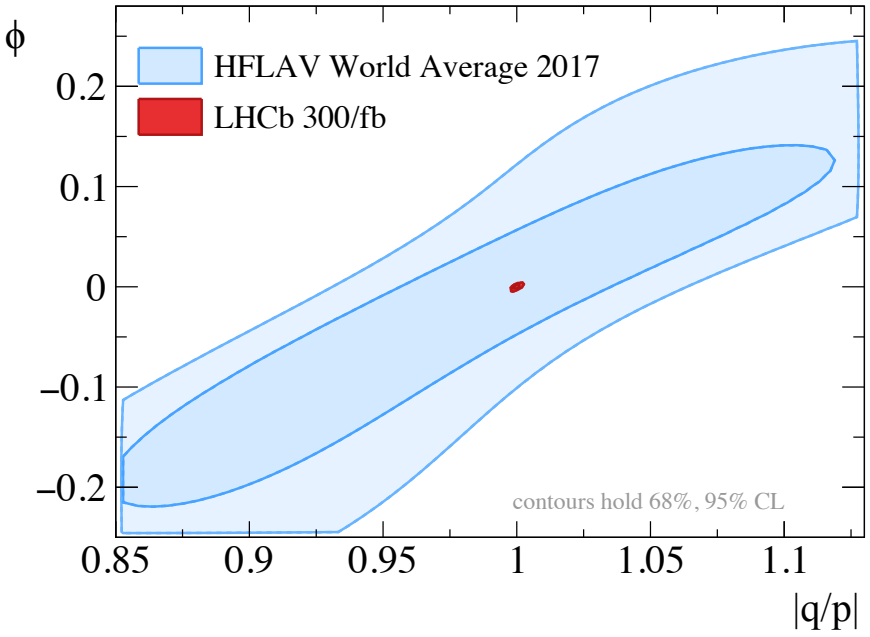


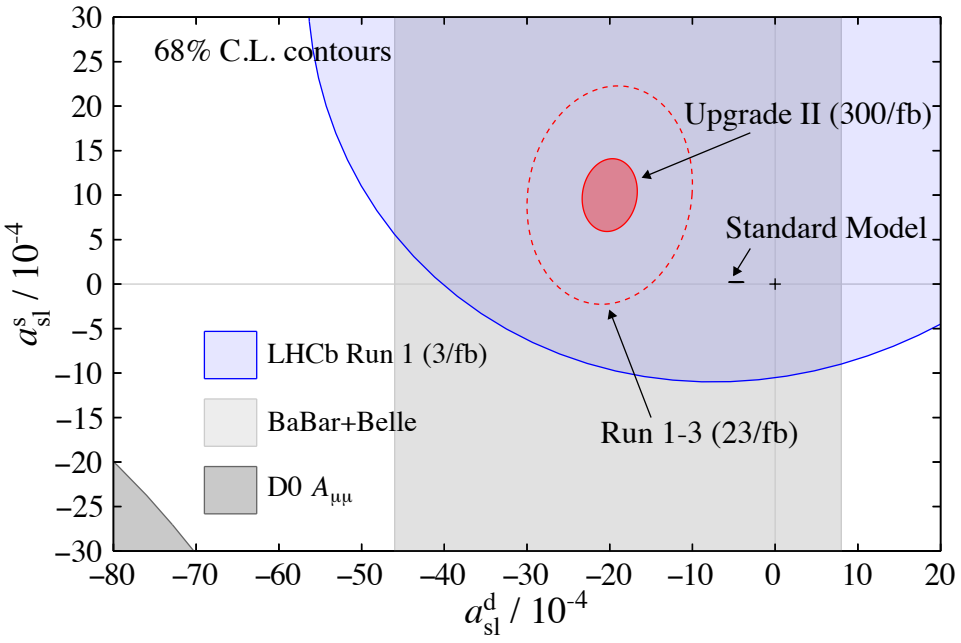


Physics Case – CPV

- γ: 0.4°
- ϕ_s: 3 mrad
- Charm CPV: $O(10^{-5})$



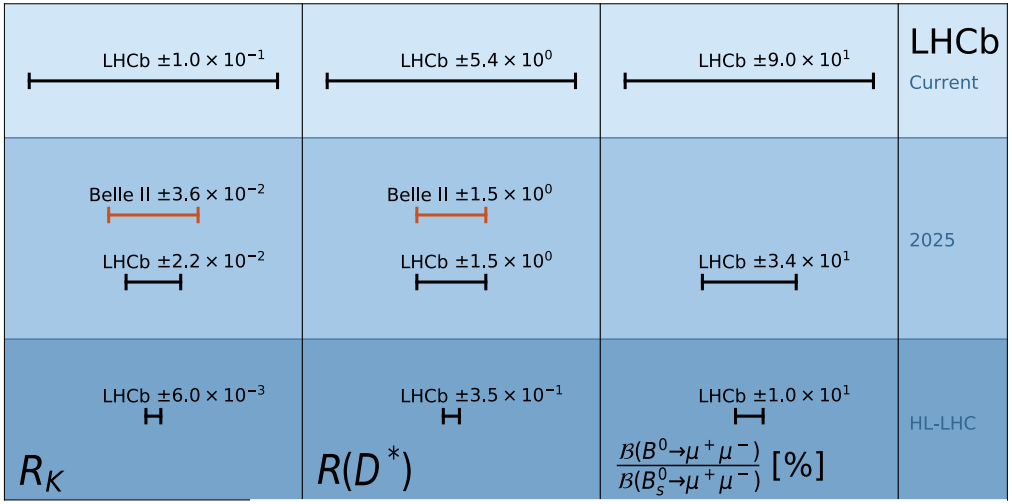


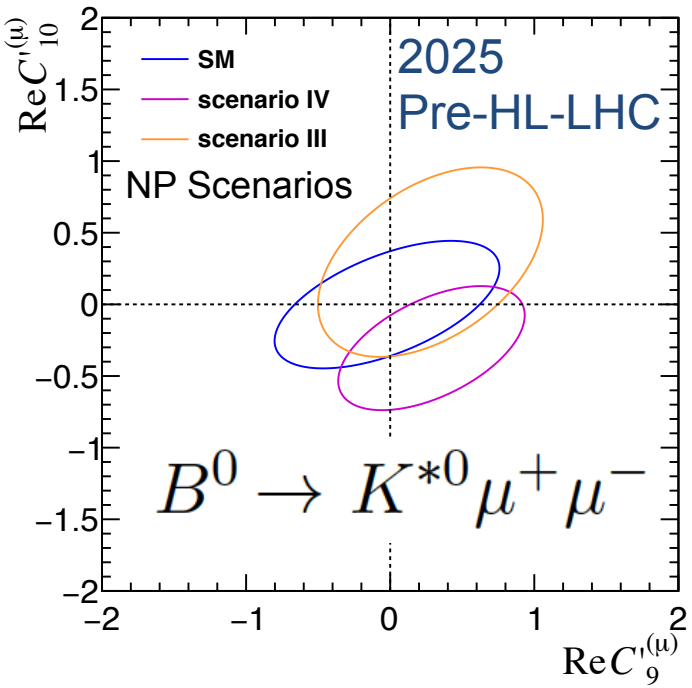


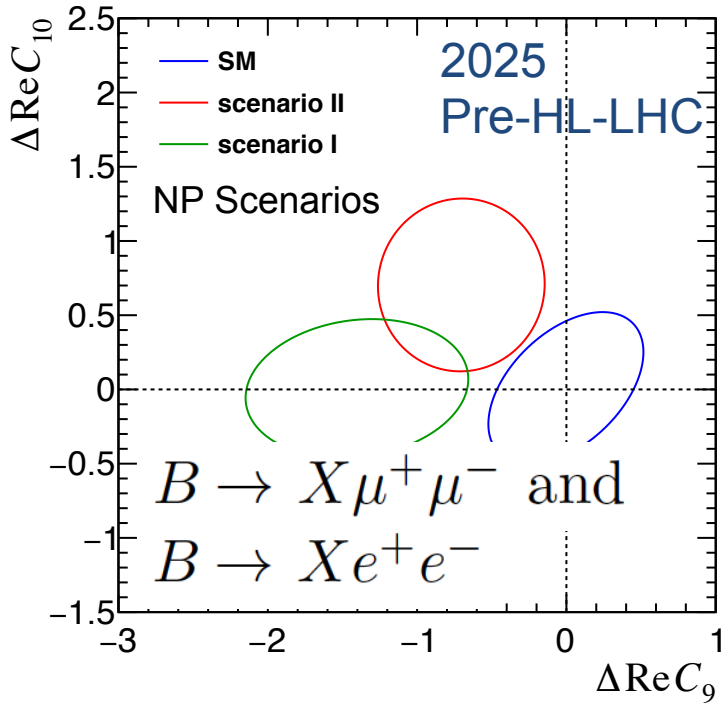
Physics Case – Rare Decays

- Wide range of b➔sl$^+$l$^-$/dl$^+$l$^-$ observables
- 10 % precision on

$$R \equiv \mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$$







Physics Case – Rare Decays

- Wide range of b➔sl⁺l⁻/dl⁺l⁻ observables
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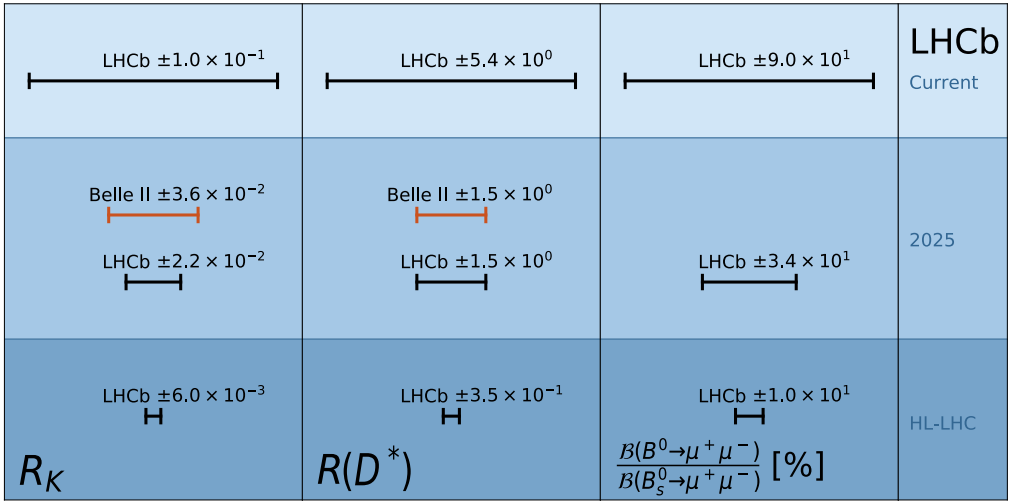
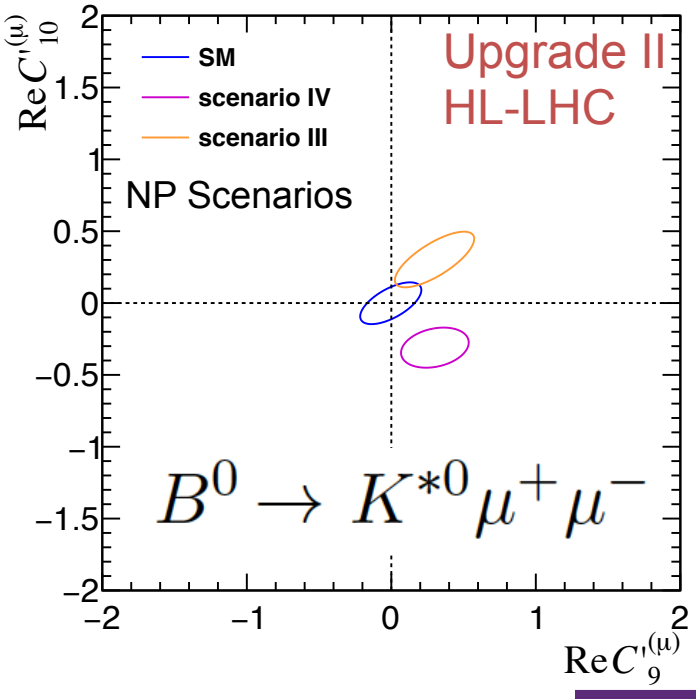
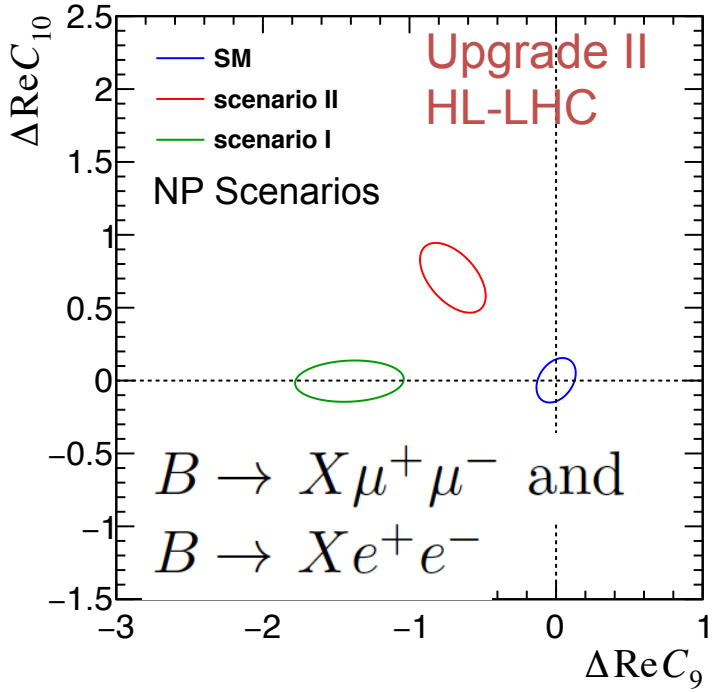
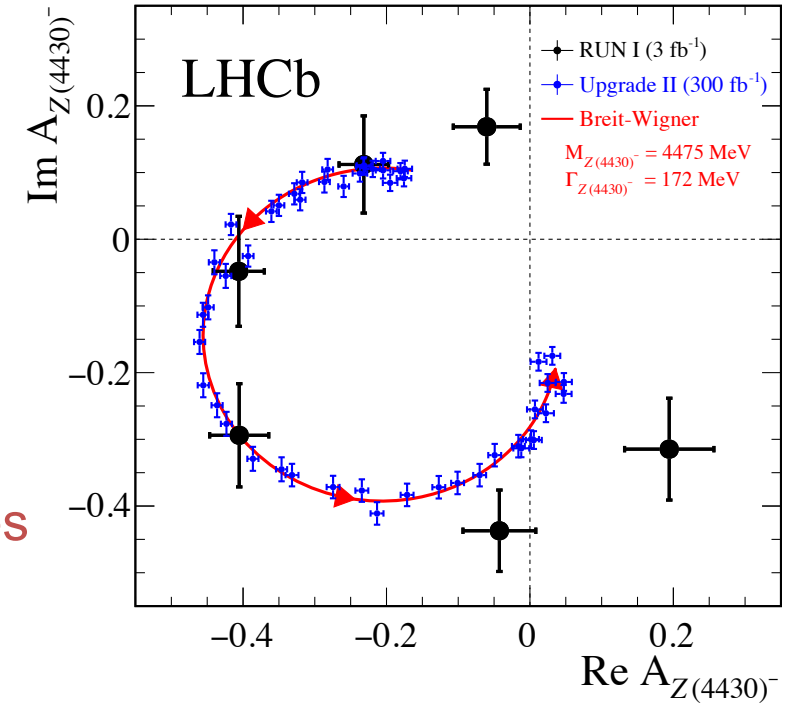


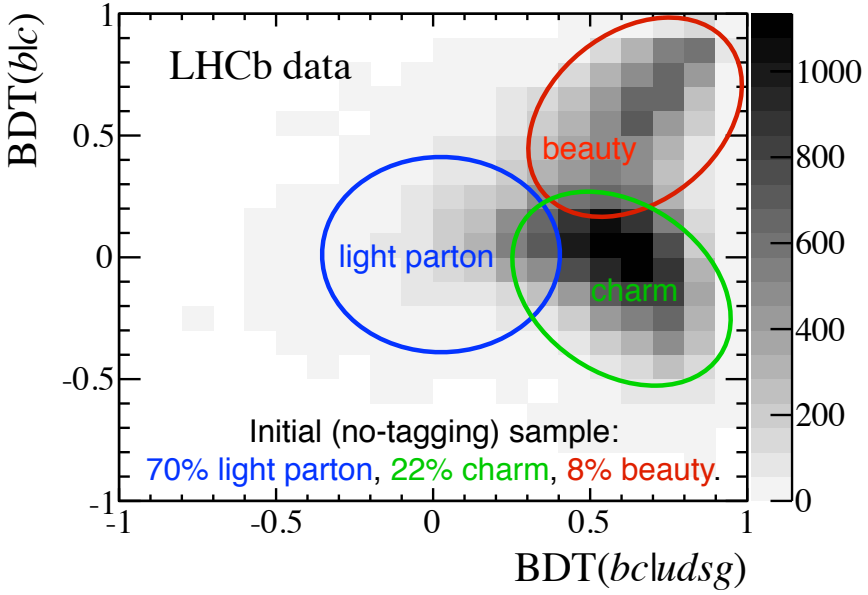




Physics Case – Other Opportunities

- General purpose facility
  - unique forward acceptance
- LHCb has had transformative effect on spectroscopy
  - Many more discovery opportunities





- Potential for best Higgs to charm limits at LHC
- Unique sensitivity for BSM long-lived and dark sector particles

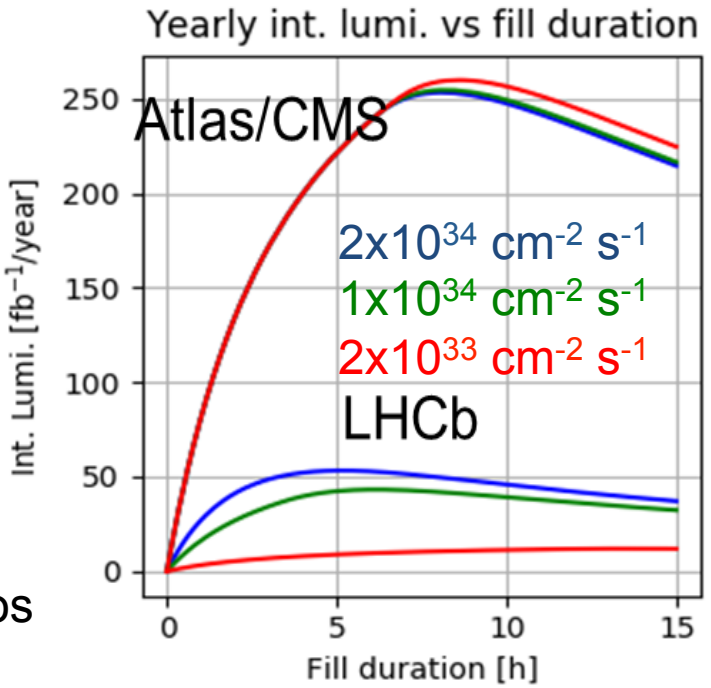
HL-LHC Machine Considerations

CERN-ACC-NOTE -2018-0038

- "LHCb Upgrades and operation at 10^{34} cm^{-2} s^{-1} luminosity –A first study":

"identified a range of potential **solutions**…permitting the collection of **300 fb^{-1}** or more"

Accelerator elements for modification:
Absorbers, Collimators, Cryogenics, Shielding…

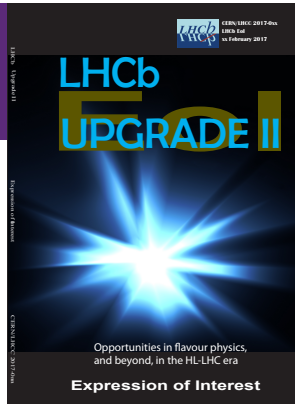


Examples of HL-LHC LHCb operational scenarios

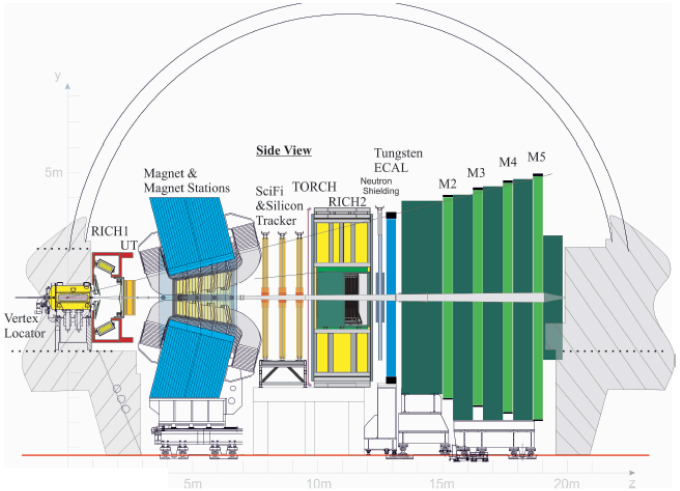
L /yr LHCb	62	46	51	[fb^{-1}]
L /yr ATLAS/CMS	255	257	256	
Beta*	1.5	1.5	1.5	[m]
Crossing Plane	H	H	V	Horizontal/Vertical
Magnet Polarity	-	+	±	

- **2-3% effect on *L* at ATLAS-CMS**
- **Field reversal used for CPV systematics**

Summary - Take Home Message



- 2021: LHCb Upgrade I, construction on track
- 2025: **Upgrade I(b)**: consolidate & enhance
  - Same luminosity as upgrade I(a)
- 2030: **Upgrade II**
  - Challenging project
  - Physics – leaps in performance in key channels
  - Detector – timing information may be key to coping with pile-up
  - Factor five-ten increase in luminosity
    - LHC can provide



Backup