



# XLI PhD cycle Kick-off presentation

University of Perugia  
Department of Physics and Geology

Supervisor:  
Dr. Mauro Piccini

Candidate:  
Arianna Codovini

05/12/25

## Bachelor thesis

(University of Perugia, 2023)

### **Study of the $\Sigma^+ \rightarrow p\mu^+ \mu^-$ decay at the LHCb experiment at CERN**

- Monte Carlo study of the statistical sample required for a competitive mass measurement



## INFN scholarship

(CERN-LHCb, 2024)

### **Muon mis-identification studies at LHCb**

- Reproduce templates for muon mis-identification backgrounds, including the momentum smearing from decays-in-flight



➔ Co-author of the internal note LHCb-INT-2025-003

## Master thesis

(University of Perugia, 2025)

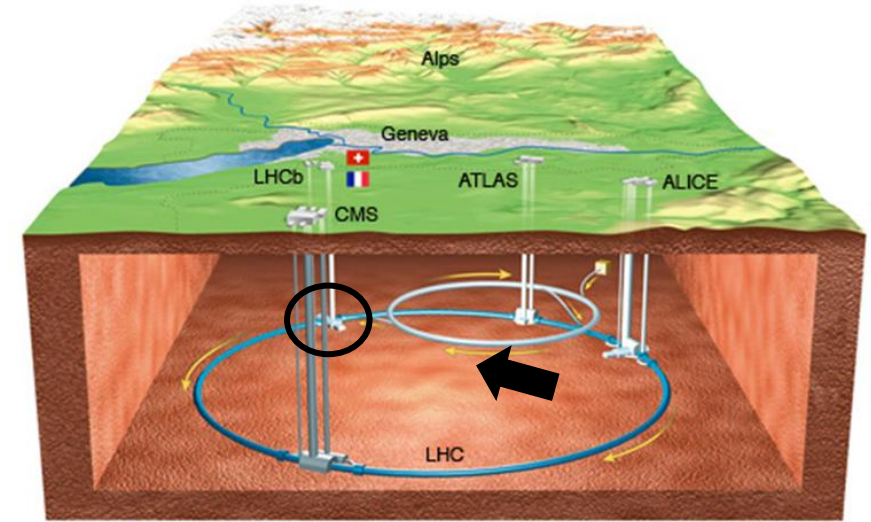
### **Forward-Backward asymmetry measurement of the $\Sigma^+ \rightarrow p\mu^+ \mu^-$ decay at the LHCb experiment at CERN**

- First measurement of the forward–backward asymmetry
- Laboratory analysis of Silicon Photomultipliers for the LHCb Upgrade II



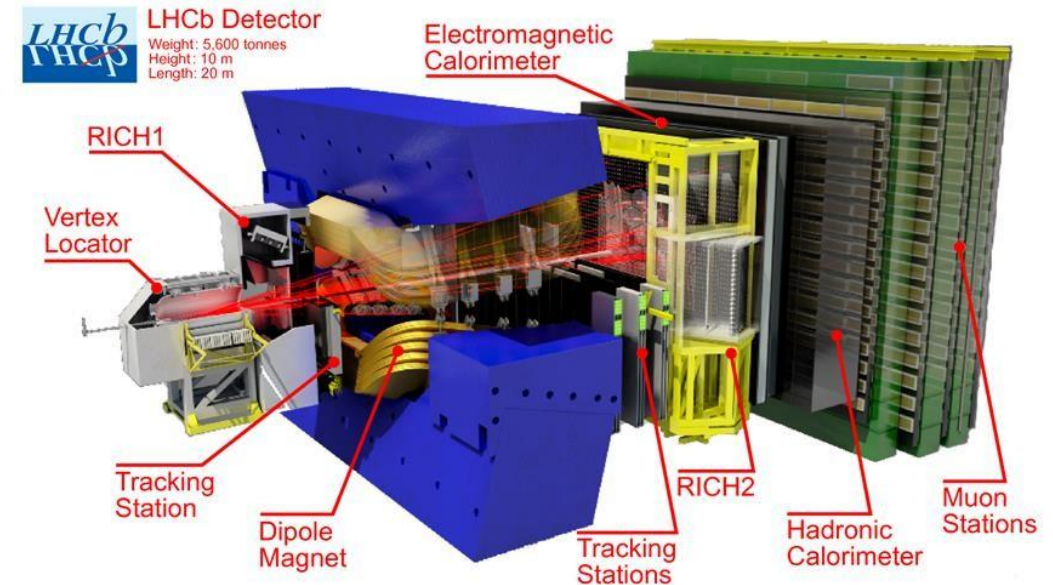
## Large Hadron Collider (LHC)

- **World largest particle accelerator**
- $\sim 27$  km
- Proton (or heavy ions beams) collide in four interaction points
  - Run 2 (2015–2018) at 13 TeV
  - Run 3 started in 2022 at 13.6 TeV



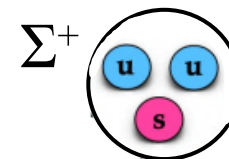
## Large Hadron Collider beauty (LHCb)

- **Single-arm forward spectrometer**
- Dedicated to study differences between matter and antimatter
- Precision measurements in heavy-flavour physics
  - ✓ Optimised for detection of **b** and **c** quarks  $\rightarrow$  produced forward in  $pp$  collisions
- Subdetectors:
  - ✓ **Tracking** system
  - ✓ **PID** system



## Forward-Backward asymmetry measurement of the $\Sigma^+ \rightarrow p\mu^+ \mu^-$ decay at the LHCb experiment at CERN

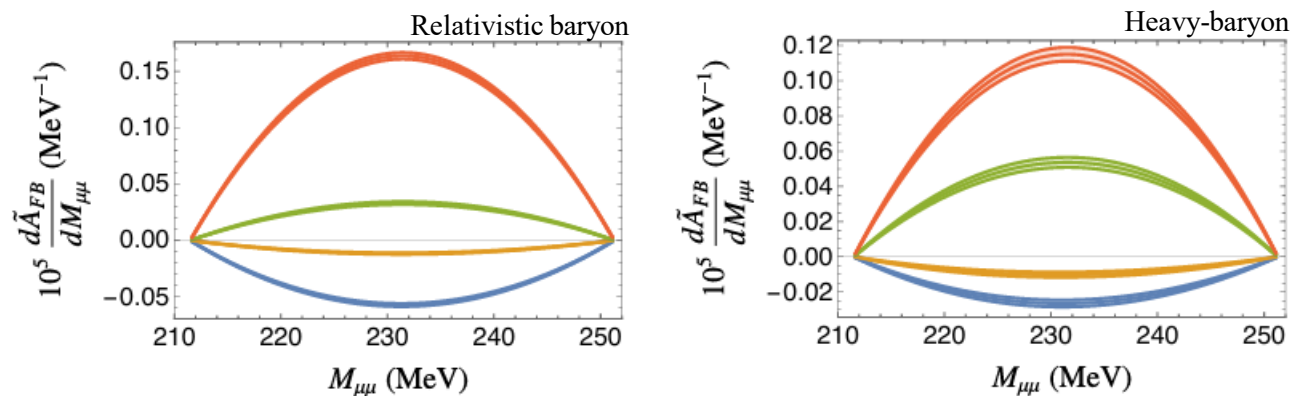
- **Flavour Changing Neutral Current (FCNC)**
  - **Forbidden** at tree level in the Standard Model (SM)
  - Only via **loops** (Z-penguin, box, photon-penguin)
- SM predictions
  - Short-Distance contributions estimated to be  $\sim 10^{-12}$
  - Dominated by Long-Distance contributions
- Chiral perturbation theory ( $\chi$ PT) :
  - Relativistic and heavy baryon approaches
  - **Fourfold ambiguity** in each prediction



	Re $a$ (MeV)	Re $b$ (MeV)	$10^8 \mathcal{B}_{\mu\mu}$	$10^8 \mathcal{B}_{\mu\mu}^{\text{Re}(c,d)=0}$	$10^5 \tilde{A}_{\text{FB}}$
Relativistic baryon	$-12.15 \pm 0.24$	$4.78 \pm 0.42$	$2.7 \pm 0.2$	$0.8 \pm 0.1$	$-1.59 \pm 0.04$
	$-4.78 \pm 0.42$	$12.15 \pm 0.24$	$7.8 \pm 0.3$	$5.8 \pm 0.2$	$-0.32 \pm 0.02$
	$4.78 \pm 0.42$	$-12.15 \pm 0.24$	$4.2 \pm 0.2$	$0.9 \pm 0.1$	$0.91 \pm 0.04$
	$12.15 \pm 0.24$	$-4.78 \pm 0.42$	$1.2 \pm 0.1$	$1.8 \pm 0.1$	$4.55 \pm 0.08$
Heavy-baryon	$-9.74 \pm 0.54$	$6.17 \pm 0.74$	$3.7 \pm 0.5$	$1.0 \pm 0.1$	$-0.73 \pm 0.06$
	$-6.17 \pm 0.74$	$9.74 \pm 0.54$	$6.1 \pm 0.5$	$4.4 \pm 0.4$	$-0.29 \pm 0.05$
	$6.17 \pm 0.74$	$-9.74 \pm 0.54$	$3.0 \pm 0.2$	$0.9 \pm 0.2$	$1.49 \pm 0.09$
	$9.74 \pm 0.54$	$-6.17 \pm 0.74$	$1.9 \pm 0.2$	$2.7 \pm 0.3$	$3.2 \pm 0.1$



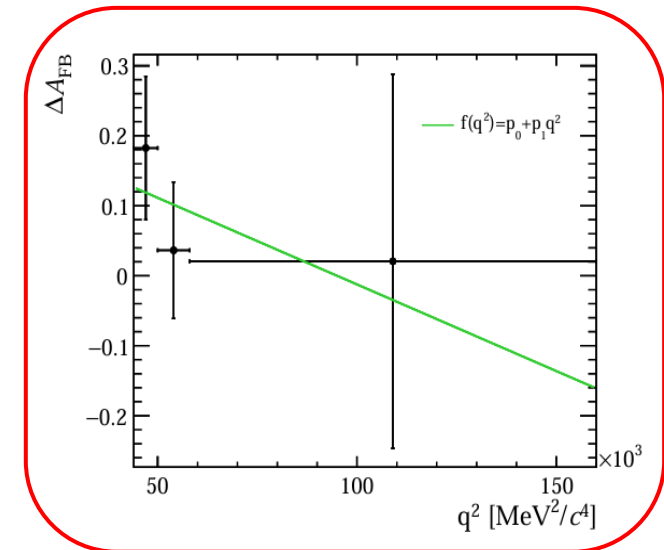
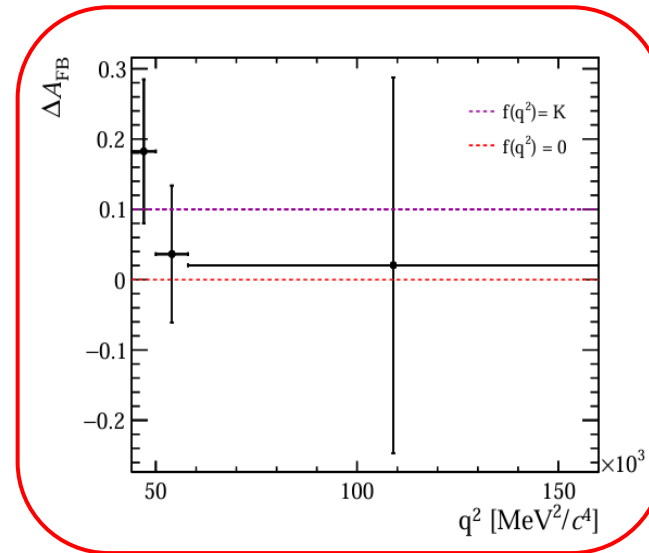
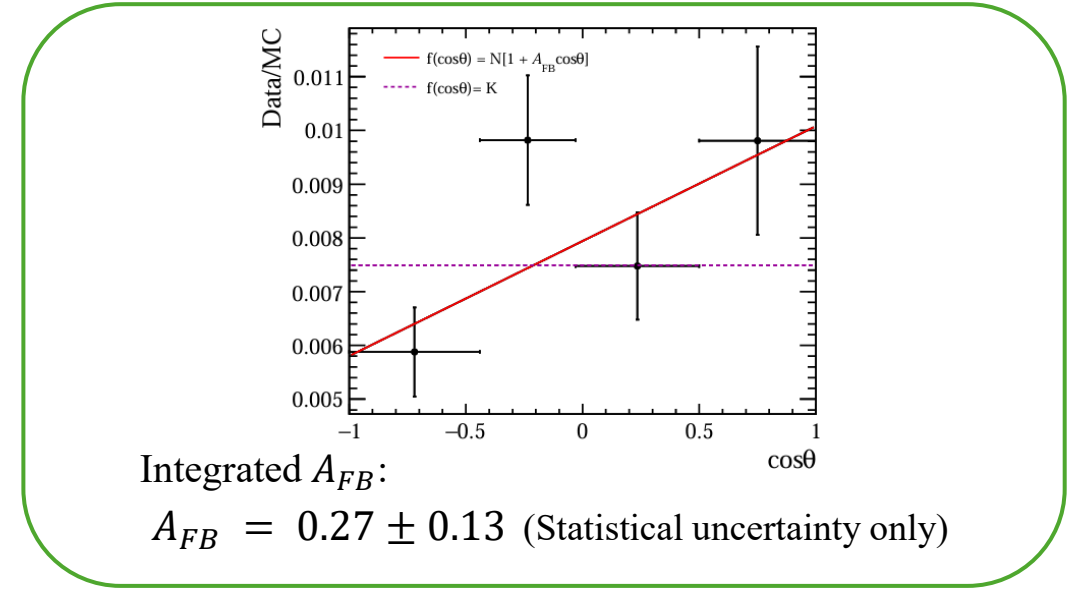
Precise measurements of observables needed



- **Run2 dataset** collected between 2016-2018
  - $L = 5.4 \text{ fb}^{-1}$  ,  $\sqrt{s} = 13 \text{ TeV}$
- **Selection**
  - Dedicated trigger lines
  - Preselection on kinematic variables
  - Final selection on PID variables and multivariate operator
  - Optimisation
- **Forward-backward asymmetry measurement**

$$A_{\text{FB}} = \frac{N_F - N_B}{N_F + N_B}$$

- **Integrated** asymmetry extracted from angular distribution
- **Differential** asymmetry as a function of the dimuon invariant mass squared



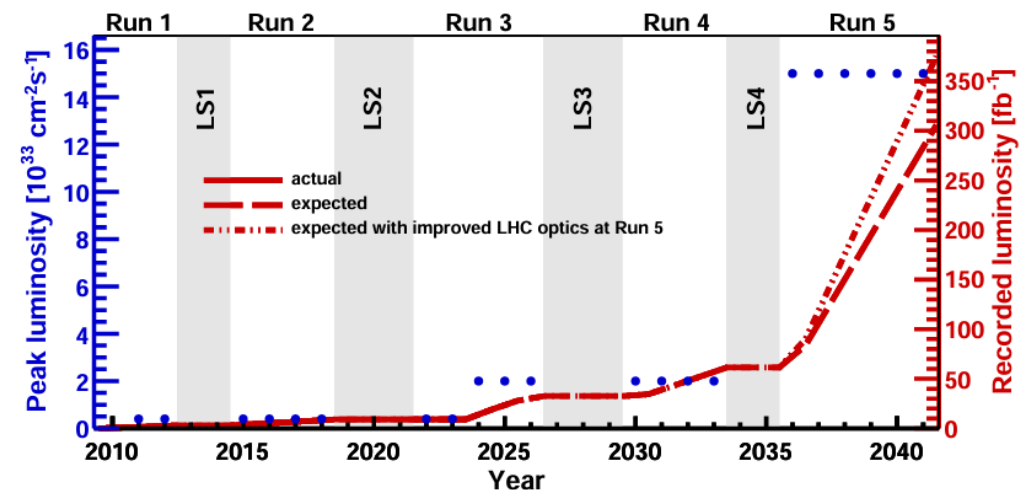
## Laboratory study (SiPMs for LHCb Upgrade II)

LHCb Upgrade II foreseen during LHC Long Shutdown 4 (LS4, in view of Run 5):

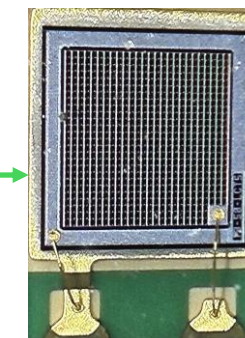
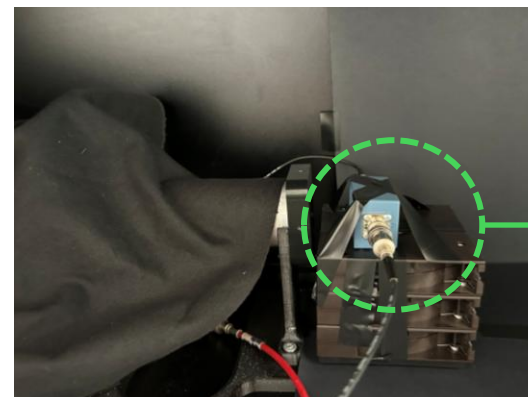
- HL-LHC (Run 5) → expected to record at least **300 fb<sup>-1</sup>**
- The RICH system must cope with **the high particle flux**
- Increased **occupancies**, harsher radiation environment
- **New photon detectors**



- Characterisation of Silicon Photomultipliers (SiPMs) as photon sensors for future RICH detectors
- Measurements: I–V curves,  $R_q, V_{br}$ , gain, timing
- **Time resolution achieved:**
  - Threshold method:  $\Delta t = 204.1 \pm 10.0$  ps
  - CFD method:  $\Delta t = 198.3 \pm 18.9$  ps



[CERN-LHCC-2024-010]



Hamamatsu  
S13360-1350PE 145

## Training plan & research activities

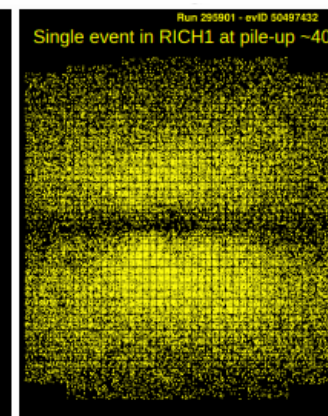
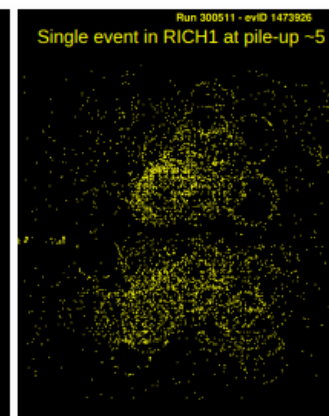
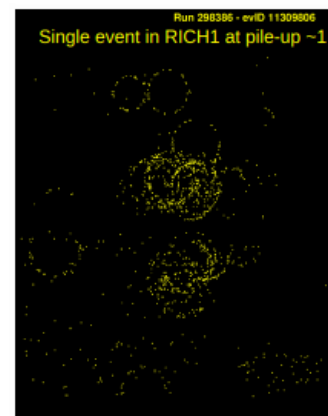
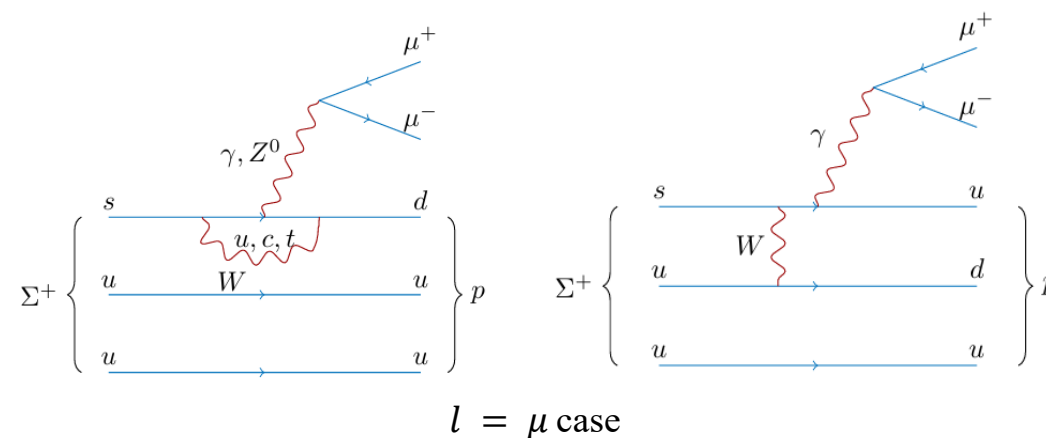
- International workshops, summer schools, conferences etc. related to the PhD project throughout the 3 years
- PhD courses in the 1<sup>st</sup> year  
→ (see Backup slide)

### 1 Physics analysis:

- Analysis towards rare hyperon observables as probes of **NP**
- Dedicated study of  $\Sigma^+ \rightarrow pl^+ l^-$  decay with Run 3
  - ✓ Large signal yield
  - ✓ Higher trigger efficiencies
  - ✓ Improved reconstruction performance
  - ✓ Better resolution on reconstructed observables

### 2 Detector R&D:

- Characterisation of next-generation photon sensors for the LHCb Upgrade II RICH system
  - ✓ Photon detectors with **high radiation tolerance** and good space & time resolution





**Thank you for your  
attention!**

# Backup slides

