Real-time search for Dark Photons at the Upgraded LHCb experiment

Carlos Cocha (Heidelberg University) &
Martino Borsato (University of Milano Bicocca)

SMARTHEP Edge Machine Learning School
Sep 23–27, 2024

Abstract

This poster presents a new search for light dark photons from charm decays, made possible by the novel real-time analysis (RTA) capabilities of the upgraded LHCb detector. The challenge consists in finding a peak on top of an irreducible non-resonant background of several kHz. In LHC Run 3, LHCb can read out the entire detector in real time (at 30 MHz) and filter interesting events through a two-stage software trigger using farms of GPUs (first stage) and CPUs (second stage). ML-based classification algorithms are employed at both stages to select charm decays, identify the extremely soft electrons that dark photons decay into, and reduce the overwhelming combinatorial background. The data throughput is further reduced by writing to disk only the interesting part of each event.

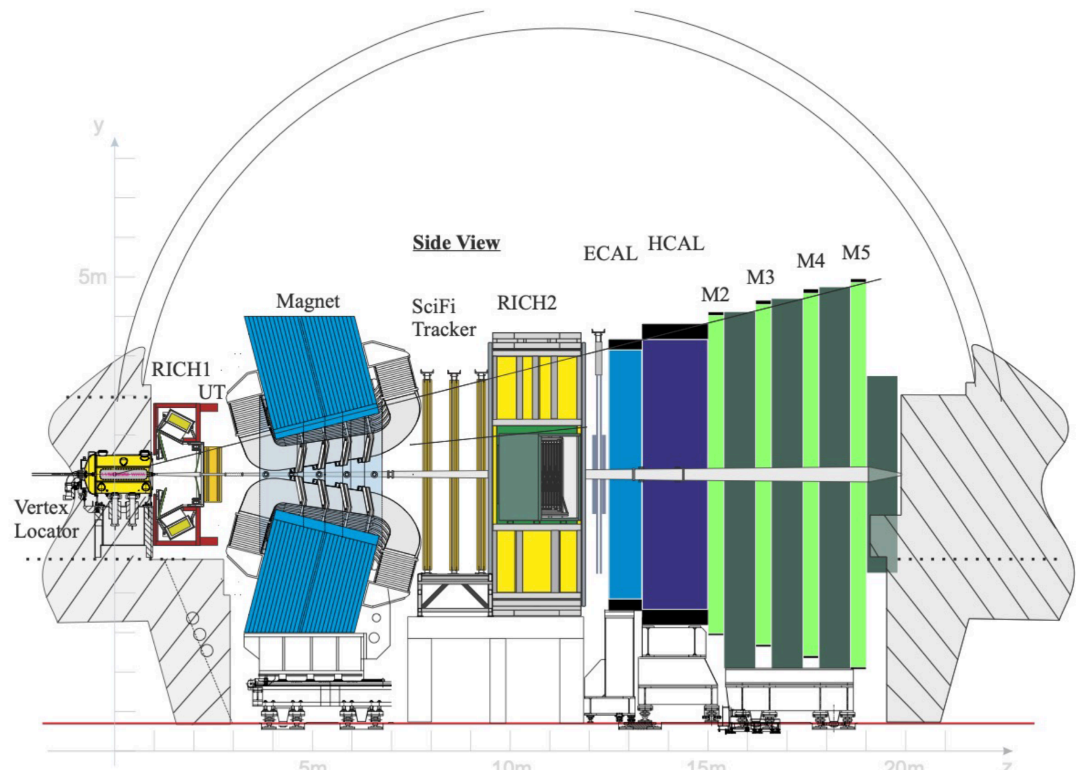
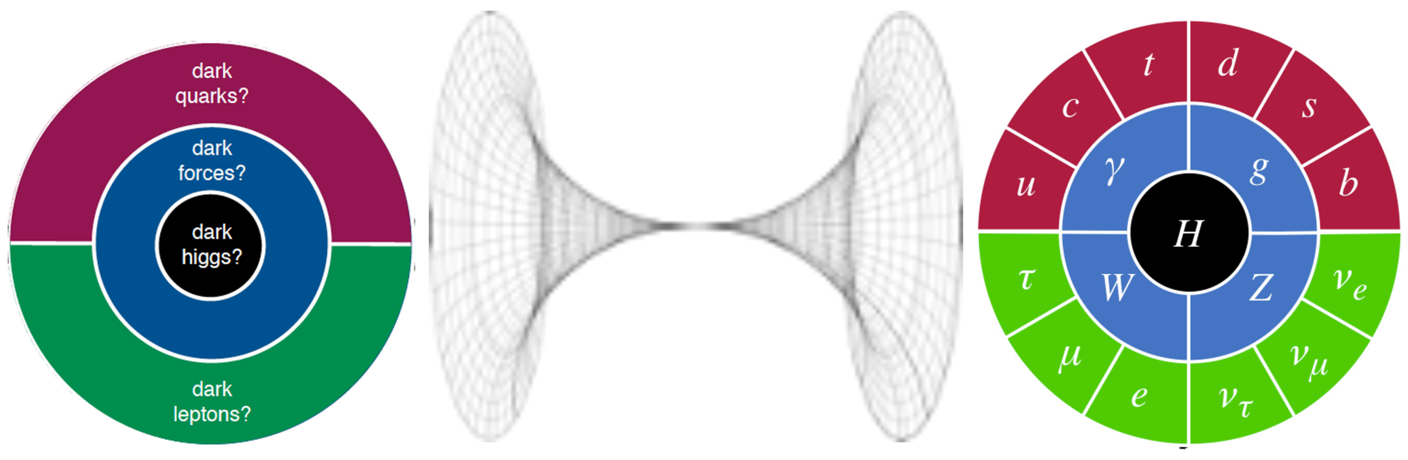


Figure 1. LHCb detector [1]

Introduction

Dark matter can interact with SM matter via "portals"



Dark photon can kinetically mix with the SM photon

$$\mathcal{L} \supset -\frac{1}{4}F'_{\mu\nu}F'^{\mu\nu} + \frac{1}{2}m_{A'}^2 A'_\mu A'^\mu + \epsilon e A'_\mu J^\mu_{EM}$$

$m_{A'}$: dark photon mass ϵ: kinetic-mixing parameter

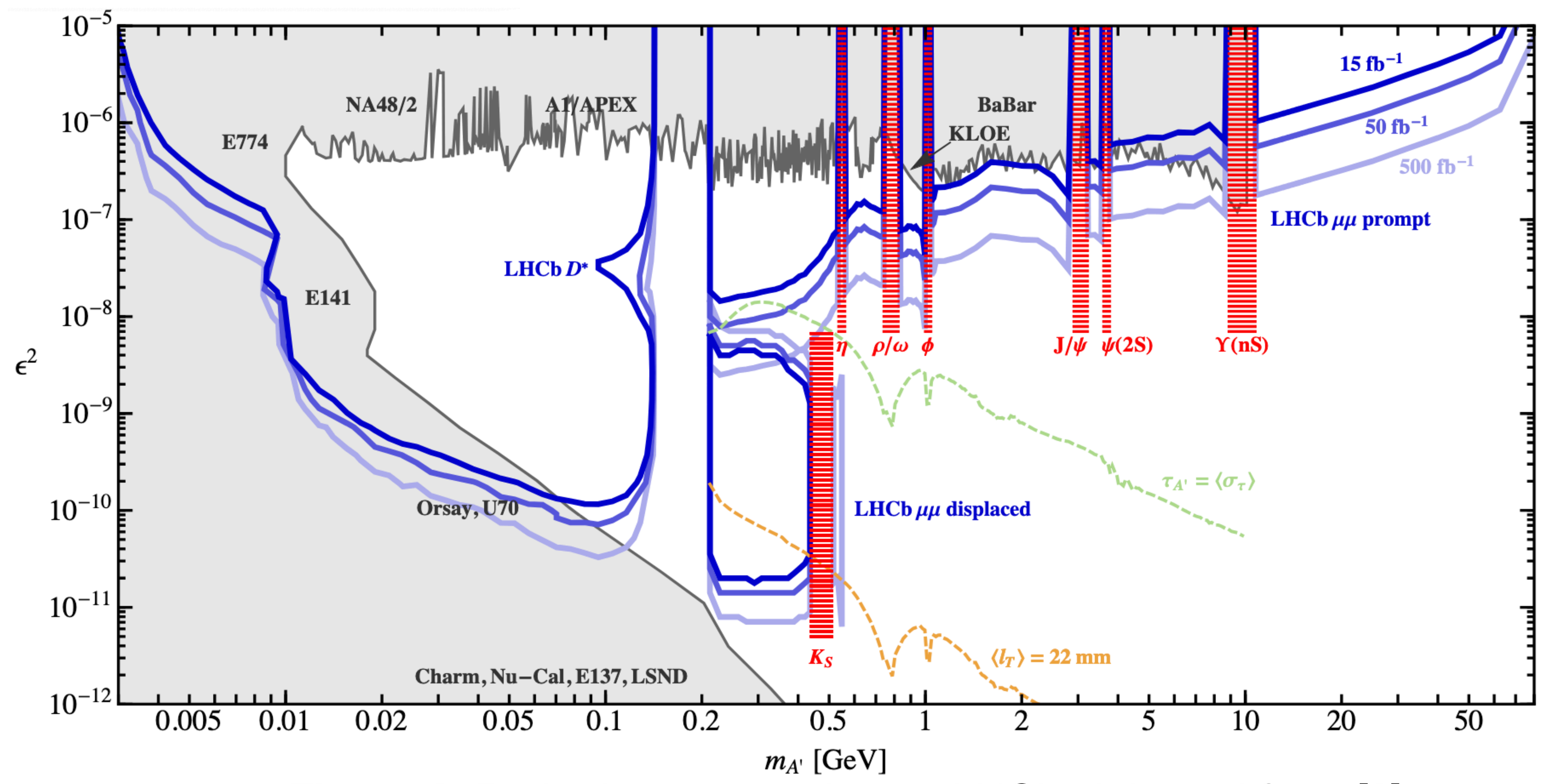


Figure 2. Dark photon searches at LHCb. Adapted from [2]

Strategy

- Special focus at low dark photon mass regions
- Very promising channel: *D*→D**A'**(→ee)*
- *D*→Dee* production rate: ~4 kHz
- **Challenge:** Save these events within trigger capabilities
- **Solutions:**
  - HLT1 trigger on displaced D decay (on GPU)
  - HLT2 trigger based on BDT (on CPU)
  - Identify online very soft electrons from PV
  - Save signal objects plus extra photons to remove $\pi^0 \to ee\gamma$

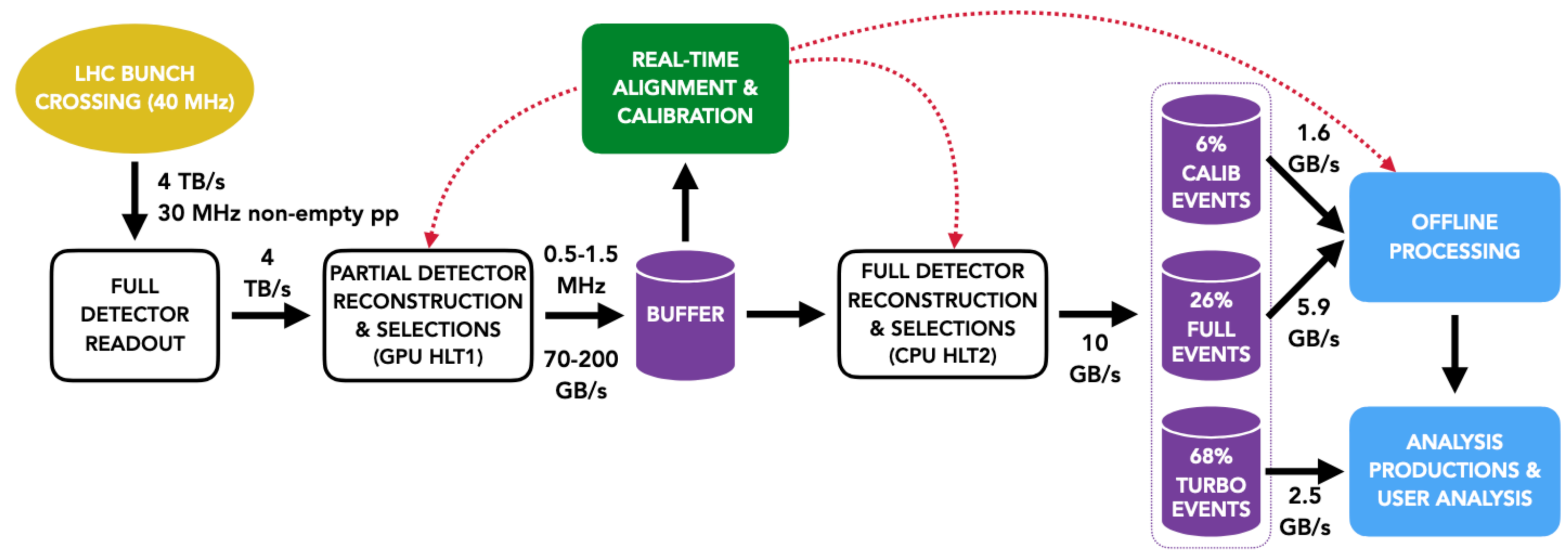


Figure 3: LHCb upgrade dataflow focusing on the real-time aspects [3]

Upstream tracking

- Upstream (U) and long (L) electron track combinations: LL, UL, UU
- Very low momentum electron reconstruction (*p*>500 MeV)

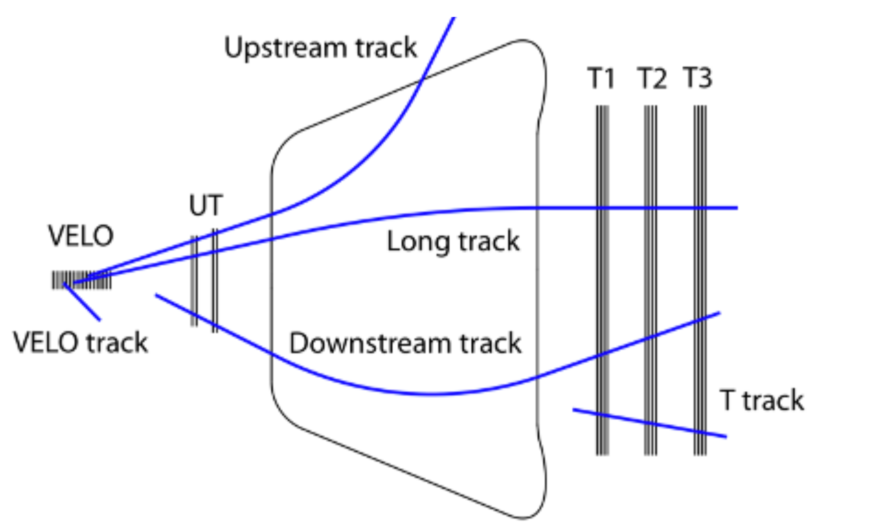


Figure 4: Track types defined in LHCb [4]

Trigger MVA Implementation

- Real-time analysis using BDT → increase efficiency for same rate and bandwidth
- BDT based on PID, kinematic, vertex and track features
- Trained on MC with 2024 conditions
- Implemented in the HLT2 trigger
- 12 HLT2 trigger lines (6 BDT-based)

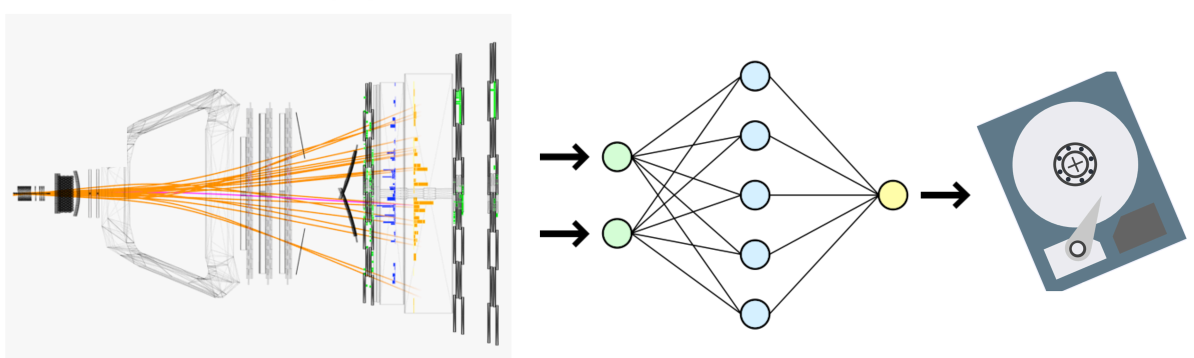


Figure 5: Data workflow

Preliminary results

Optimization	Efficiency gain
Upstream tracking	~ 5
MVA classifier	~ 2

Next steps

- 2024 data validation:
  - Test the MVA-based lines performance in the trigger
  - Validate low momentum electron reconstruction
- Dark photon search

We acknowledge funding from the European Union Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086

MARIE CURIE ACTIONS

References
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