BuSca: a *Buffer Scanner* at HLT1 to detect LLPs beyond the SM

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On behalf of the LHCb collaboration

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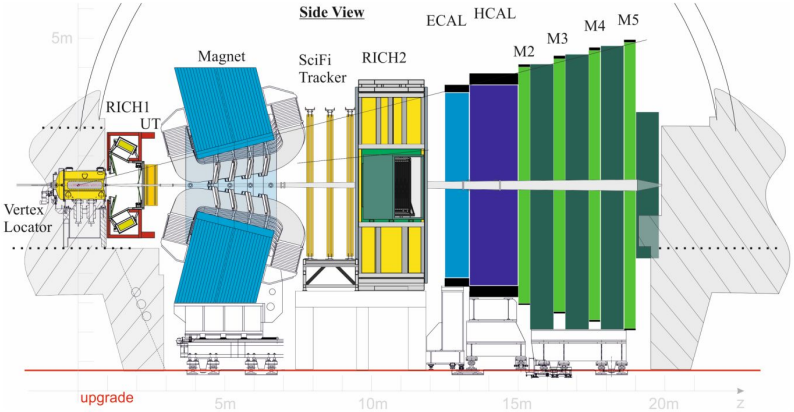
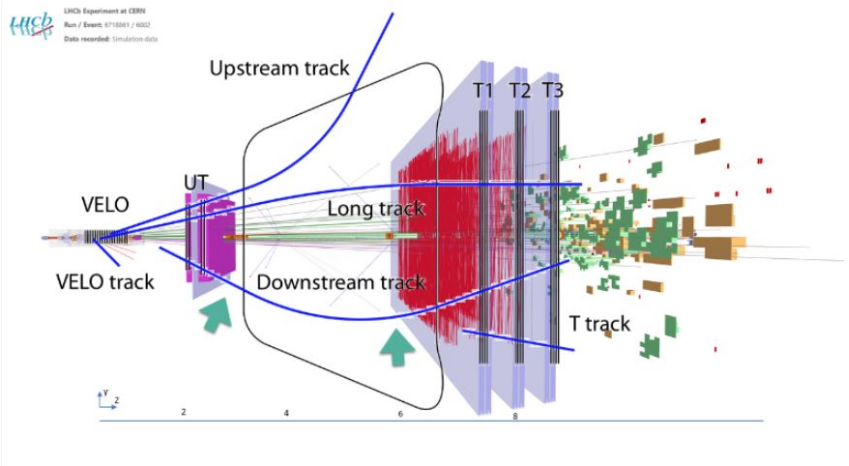
Outline

- LHCb detector and trigger system
  - Long Lived Particles (LLP) searches at LHCb
- BuSca algorithm
  - Technical implementation
  - Throughput impact
  - Trigger lines
- Test examples
- Background studies
- BuSca on data
- Summary

LHCb detector and trigger system





Forward spectrometer ($2 < \eta < 5$).
9.5 fb^{-1} from Run 3 (until Oct 13, 2024).

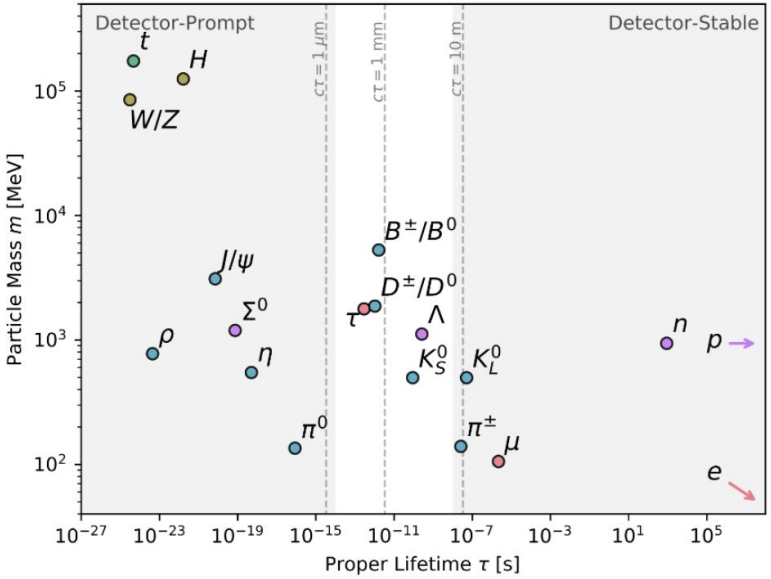
[CERN-LHCC-2014-001; LHCB-TDR-015]

b- and *c*-meson decays can be reconstructed into long (VELO + UT + SciFi) tracks with high efficiency.

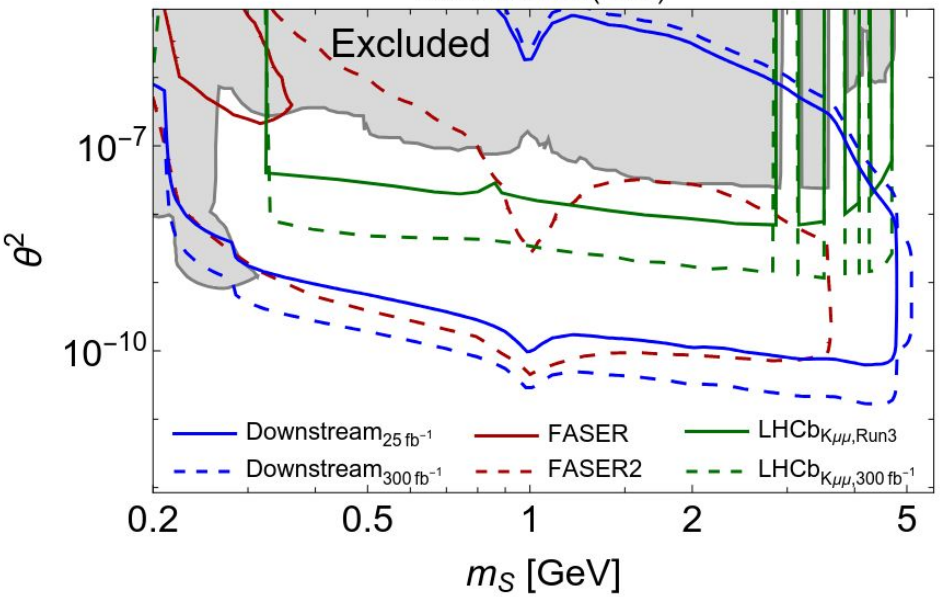
But for particles with $\tau > 100$ps many decays happen outside of the VELO detector. Long lived particle decays can be reconstructed with the *Downstream* algorithm.

Long Lived Particles search at LHCb

[Prog. in Part. and Nuc. Phys. 106 (19)210]



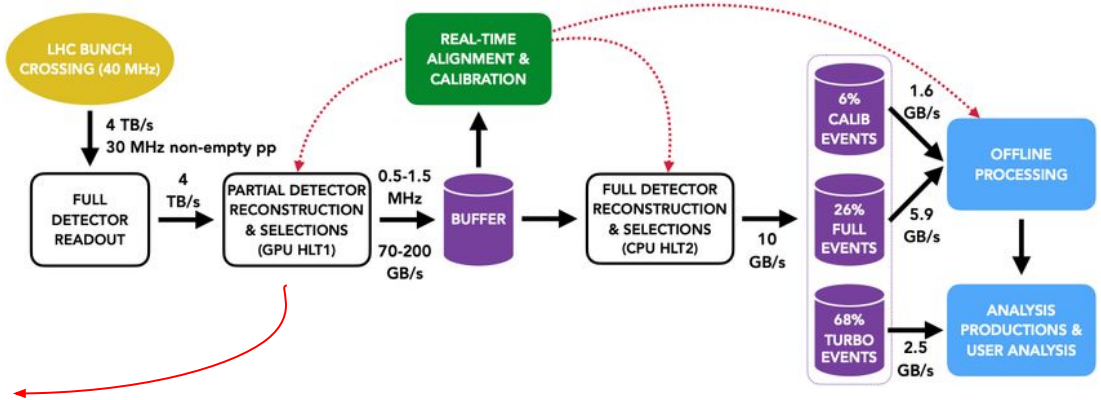
Dark scalars (BC4) [Eur.Phys.J.C 84 (2024)6, 608]



The *Downstream* algorithm (see J. Zhuo talk in Track2) enhances the physics reach of LHCb.

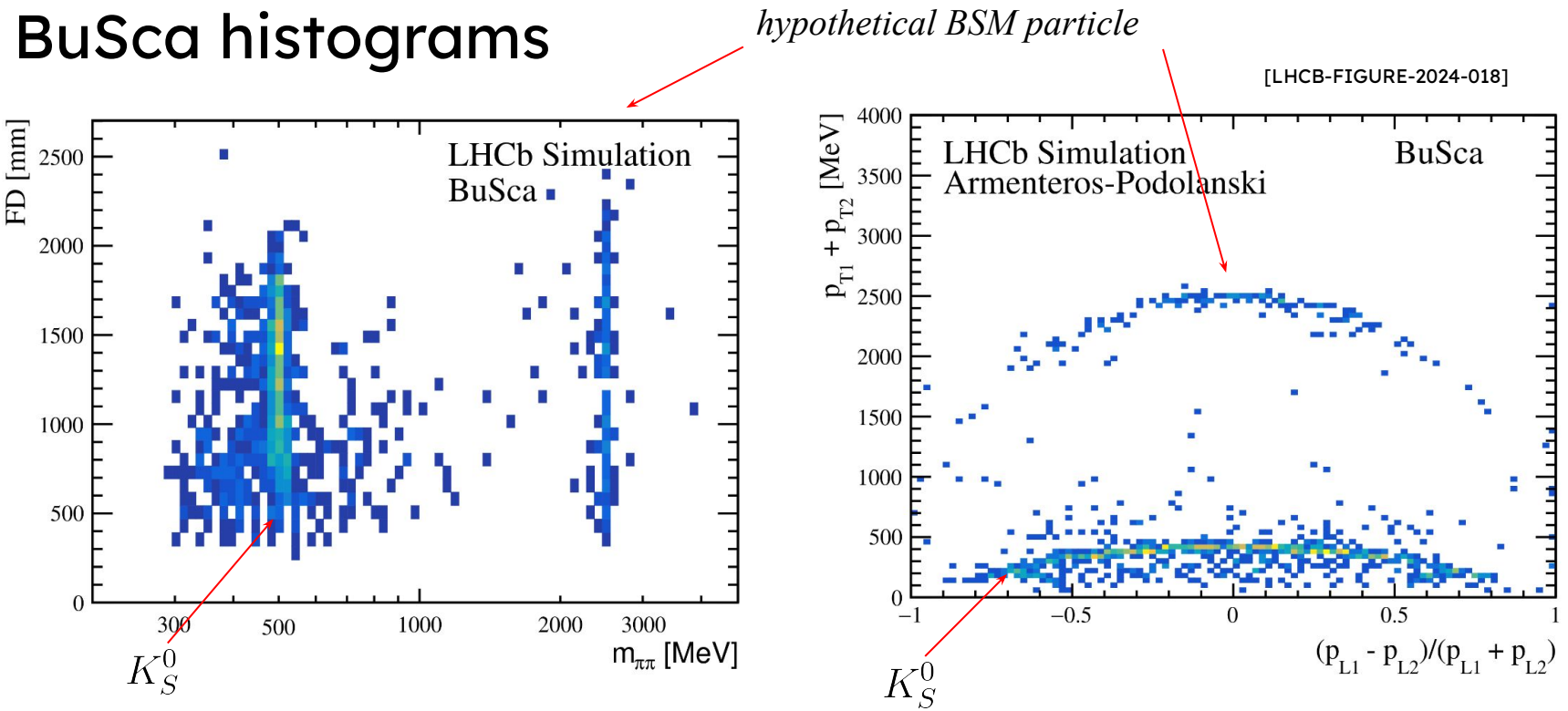
BuSca in LHCb dataflow

Buffer Scanner: write two values from selected events to histogram



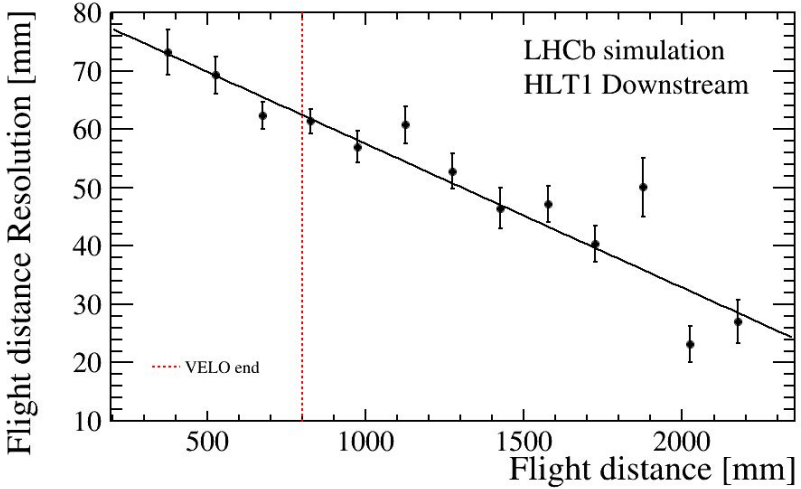
We introduce a model independent algorithm at HLT1 level. It fills 2D histograms using all available data in real time (30 MHz). It is used to guide further BSM searches. Several trigger lines are developed in this framework.

BuSca histograms

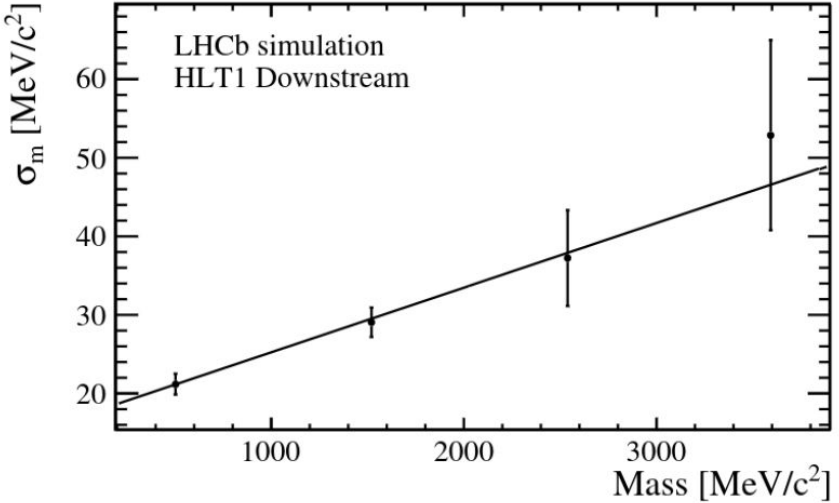


Data is stored in two 2D histograms: di-pion hypothesis mass vs flight-distance of the particle, and an Armenteros-Podolanski plot.

Mass and Flight Distance binning schemes



[LHCB-FIGURE-2024-036]



Binning is adapted according to the expected mass and FD resolution:

$$\sigma_{FD} = 80 - FD \cdot 0.02 \quad [mm]$$

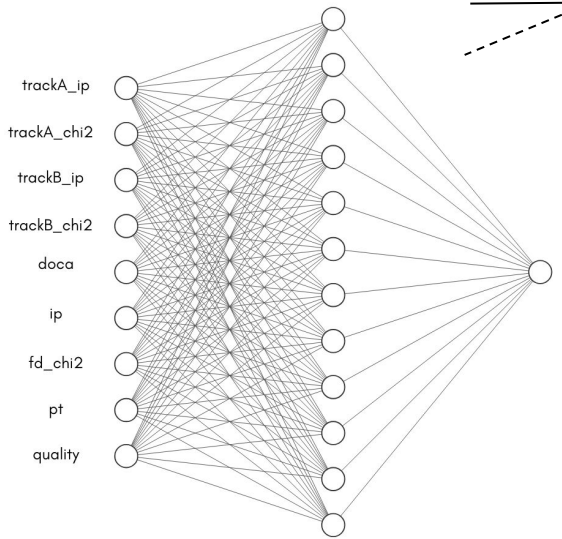
$$\sigma_m = m \cdot 0.02 \quad [MeV/c^2]$$

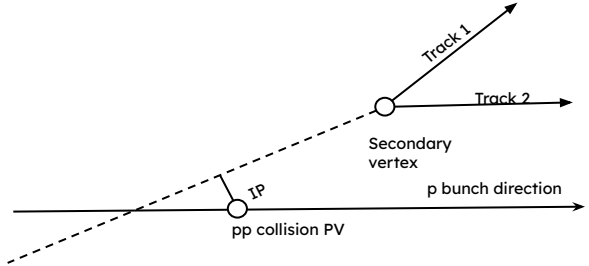
Selection algorithm

Neural network, trained to select true pairs based on their reconstruction quality

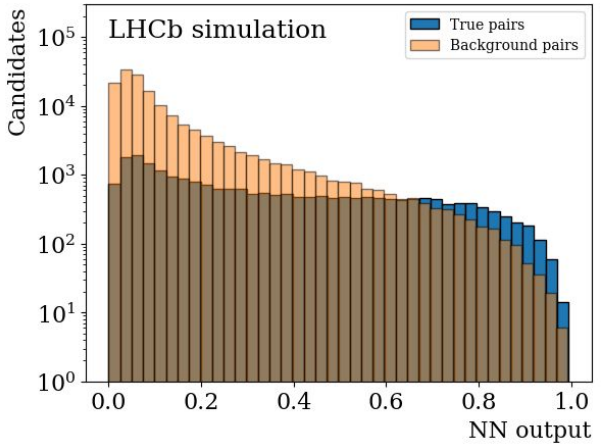
- 9 inputs
- 12 nodes
- [0, 1] output

Trained on MinBias using MC information.



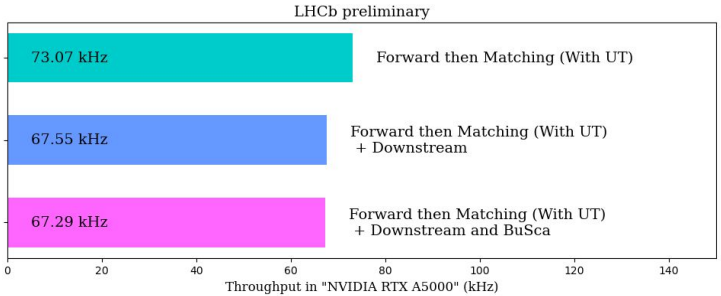


[LHCB-FIGURE-2024-036]



Performance impact

[LHCB-FIGURE-2024-036]



Global throughput impact:

0.38%

Three trigger lines are developed:

- diMuon line 0.11 kHz
- diElectron line 0.28 kHz
- diHadronline 0.16 kHz

HLT1 Bandwidth impact:

0.06%

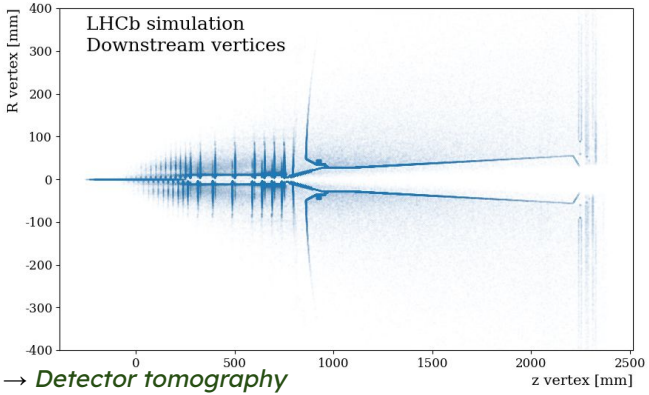
Background studies:

Hadronic resonances

► J/ψ, ψ, φ(1020), ψ(2S), ψ(3770), ψ(4160) decay in the VELO detector.

► Light resonance ($\varrho, f_2, \eta, \omega$…), can be created from material interaction.

[LHCB-FIGURE-2024-036]



→ *Detector tomography*

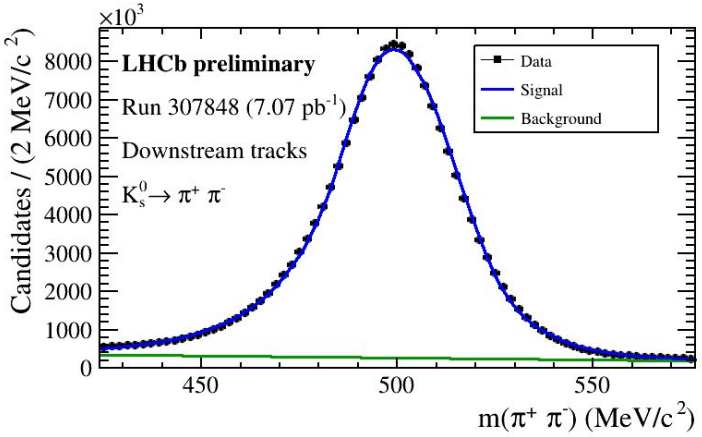
Strange candidates:

SM particles with large lifetimes:

K_s, Λ_0

→ *Have to be vetoed*

[LHCB-FIGURE-2024-035]

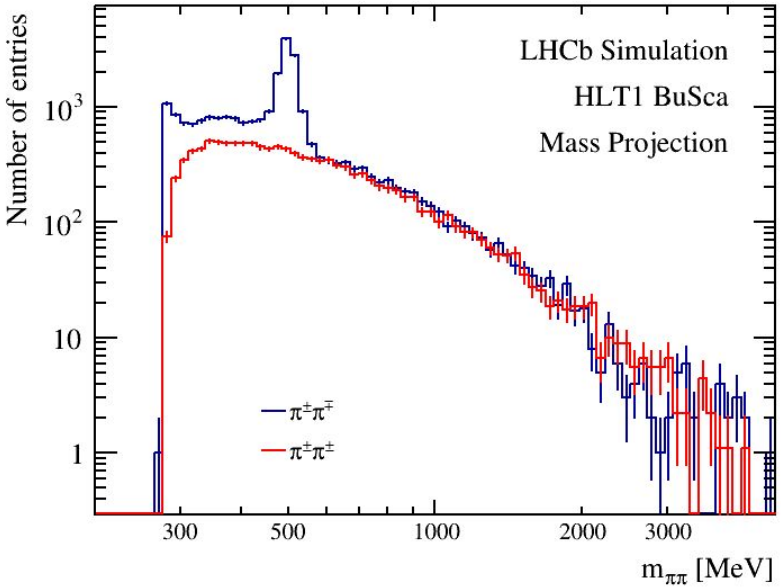


Background studies: combinatorial background

Random pair combination of muons or misidentified pions, coming from any hadron decays.

→ *Can be studied in data using track pairs with same sign.*

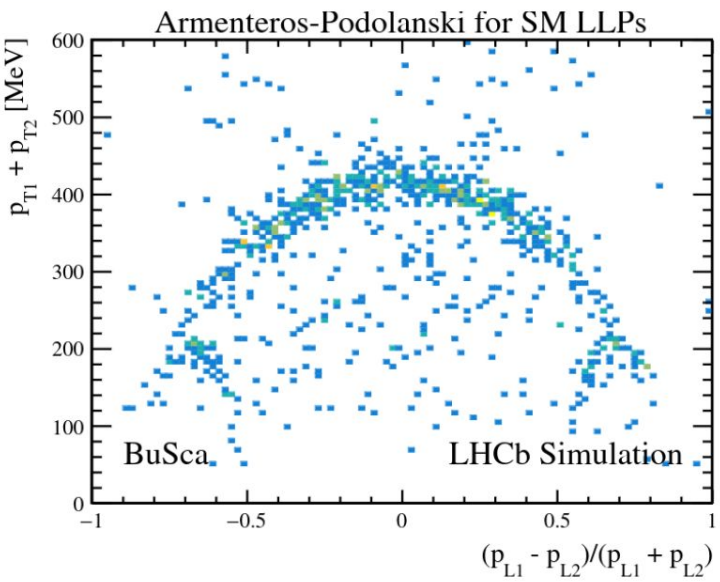
[LHCB-FIGURE-2024-036]



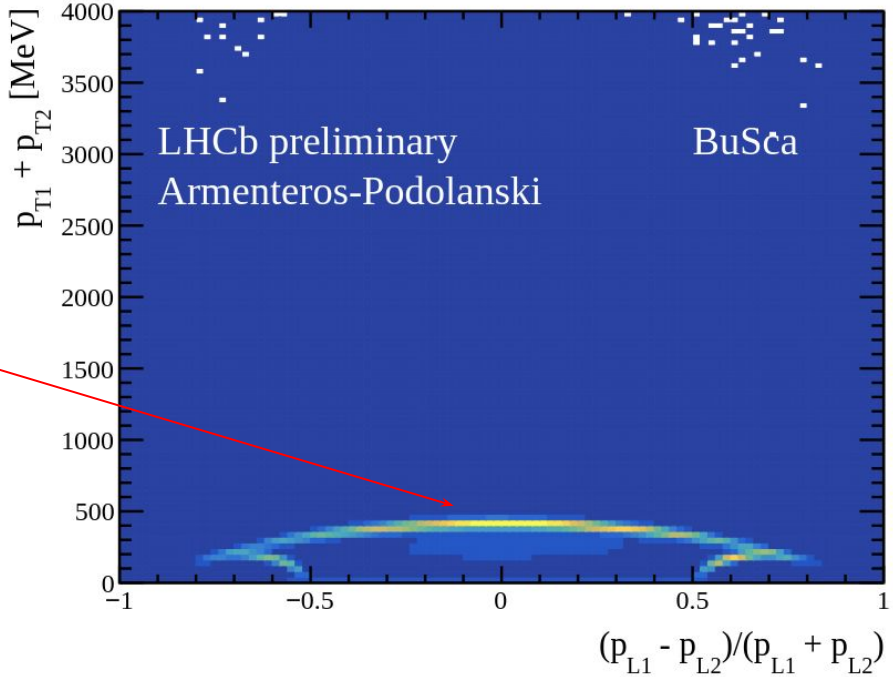
→ *Detector tomography*

BuSca on data: Armenteros-Podolanski plot

[LHCB-FIGURE-2024-018]



[LHCB-FIGURE-2024-036]



Summary

- The new trigger scheme has amazing possibilities to increase the LHCb capabilities for LLPs searchs.
- BuSca is a model independent LLPs search algorithm at HLT1 level in real time over 30 MHz of data.
- Already used with $1fb^{-1}$ data-taking!
- Ongoing further developments: optimize BSM reconstruction, better match with muons, 3+ tracks vertices reconstruction.