Tracking performance for long living particles at LHCb

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on behalf of the LHCb collaboration

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Connecting the dots and Workshop on Intelligent Trackers
2 - 5 April, 2019

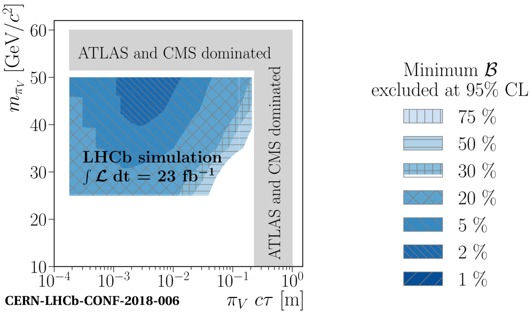
Outline

1. Motivation
    - Physics case: Long living particles
    - LHCb detector
2. Tracking efficiency
    - MC methods
    - Importance of Data-driven methods
3. Method description
    - Proof of principle
    - Result with Real Data
    - Result with Simulation Run III
4. Conclusions

Physics Case

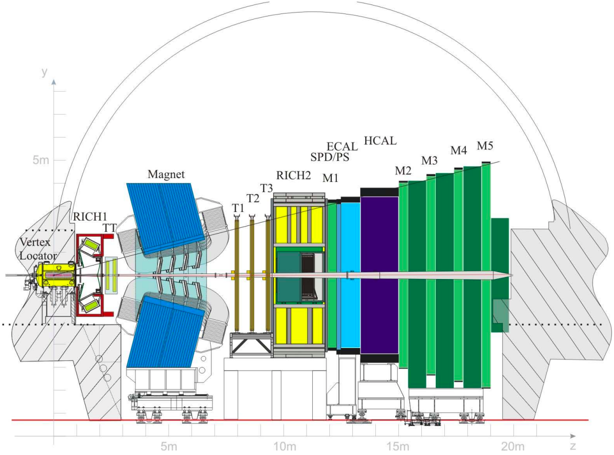
Long-lived particles (LLP) are important for many analyses:

- Λ frequenly appear in b-baryon analyses
  - Heavy baryon are produce only at pp collision (LHC)
- K_s are common in b-meson decays
  - Essential to e.g. any isospin-ratio measurement
- Many BSM physics extensions imply the existence of LLPs
- Expand life time range for LLP searches, e.g. Dark Matter candidates



Physics Case and LHCb detector

In the context of LHCb, long-lived (K_s, Λ):
$\tau(= 10^{-11} - 10^{-10}) \times c \times \gamma \rightarrow$ mean flight distance **3cm to 3m**.



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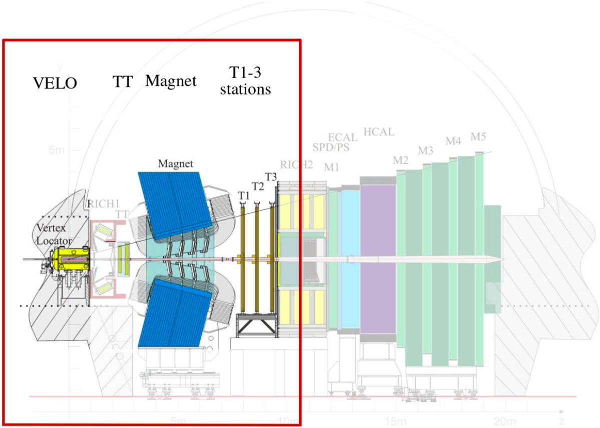

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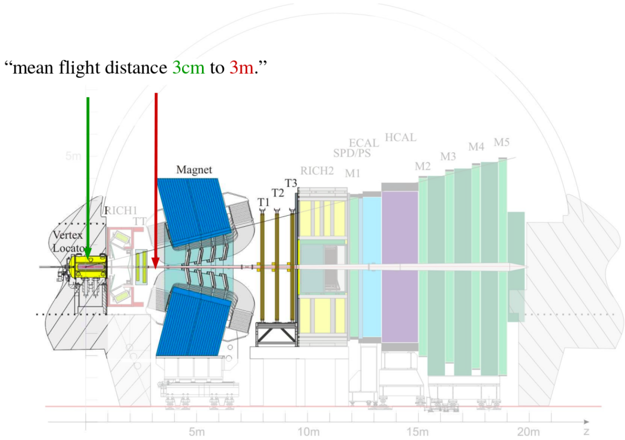


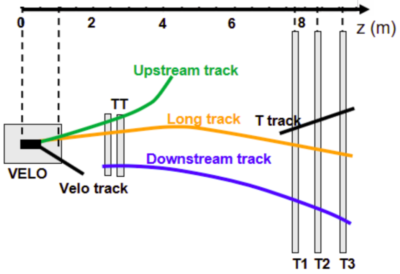
Long tracks

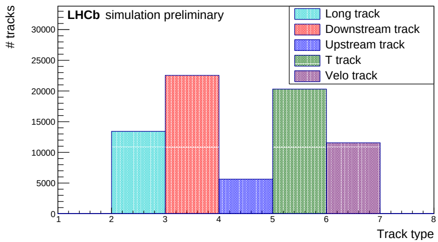
- Hits at least in VELO and T stations
- Used in majority of analyses

Downstream tracks

- Hits in TT and T stations (not in VELO)
- **Decay products of long-lived particles**

Proportion of each track type in the $\Lambda \to p\pi$ decay:





Large proportion of Downstream tracks ($\sim 1.5\times$Long tracks)

Track types

Long tracks

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Downstream tracks

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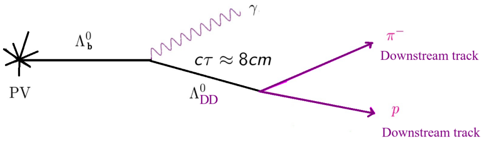
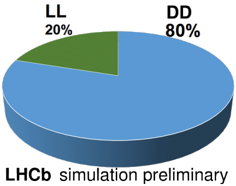
- **Decay products of long-lived particles**

Proportion of Λ from Long and Downstream tracks in $\Lambda_b \to \Lambda\gamma$ decay:





- Analyses mainly uses Long and Downstream tracks
- Λ coming from b-baryons have higher momentum $\implies$ higher proportion of downstream tracks

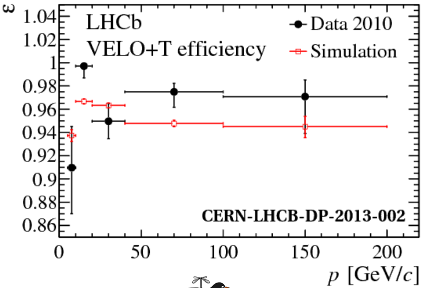
Tracking efficiency at LHCb

- **Why monitoring:** Need to check tracking performance, in particular the efficiency in order to optimize algorithms
- **How monitoring:** It is possible to extract tracking efficiency, ghost track rates using **simulated** decays

$$\epsilon = \frac{\#Reconstructed\ tracks_{L/D/T}}{\#Reconstructible\ tracks_{L/D/T}}$$

Tracking efficiency at LHCb

- **Why monitoring:** Need to check tracking performance, in particular the efficiency in order to optimize algorithms
- **How monitoring:** It is possible to extract tracking efficiency, ghost track rates using simulated decays
- **Importance of data-driven methods:** Simulation can not reproduce perfectly Real Data.
  Data-driven methods allow us to detect and correct these differences



Method description

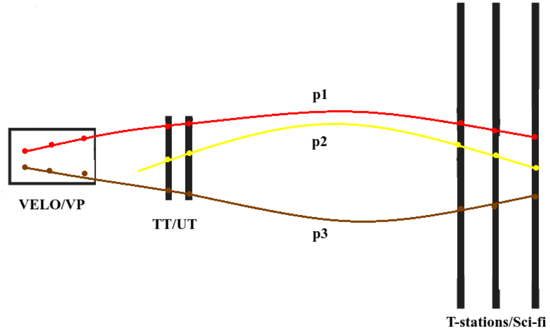
- **New method:** The performance of downstream tracking algorithm is extracted from Real Data using $\boldsymbol{\Lambda \to p\pi}$:

  1. Run Tracking algorithms keeping these track types:
     - L Long tracks
     - D Dowstream tracks
     - FD False Downstream tracks (Long tracks reconstructed as Downstream)
  2. Reconstruct prompt Λ from Long and False Downstream tracks
  3. Compute the efficiency using:

$$\epsilon = \frac{\#p_{\Lambda}^{FD}(\cancel{hits^{VeLo/VP}}, hits^{TT/UT}, hits^{Tstation/SciFi})}{\#p_{\Lambda}^{L}(hits^{VeLo/VP}, hits^{TT/UT}, hits^{Tstation/SciFi})}$$

Method description

- **New method:** The efficiency is computed as the number of downstream tracks reconstructed in a sample of Long tracks:



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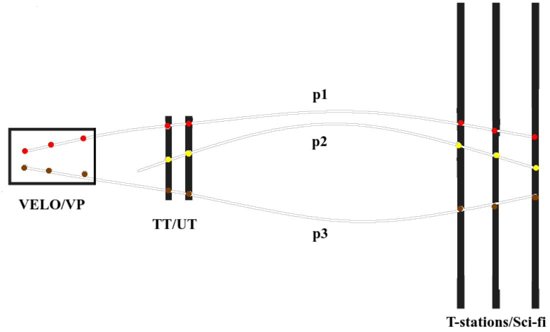

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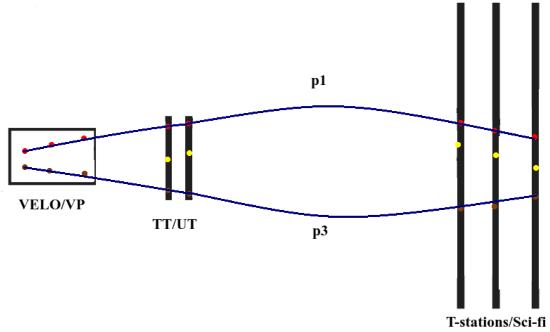

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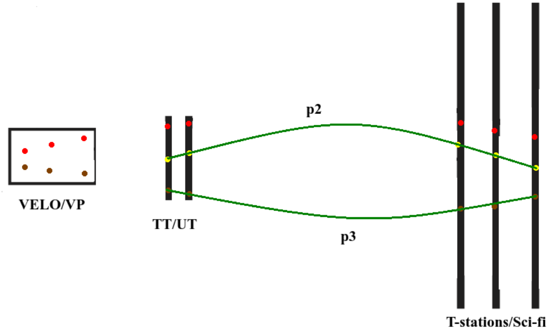

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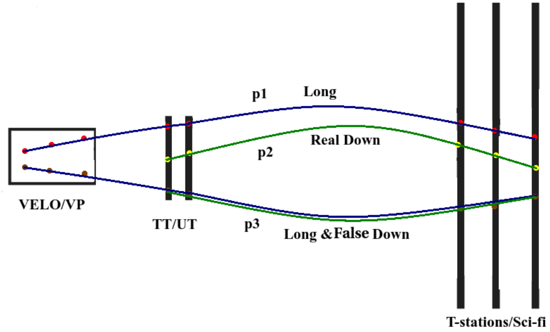

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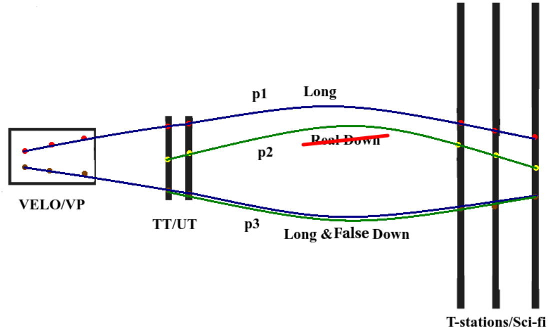
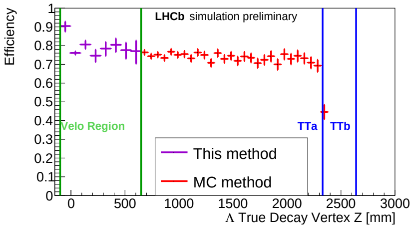


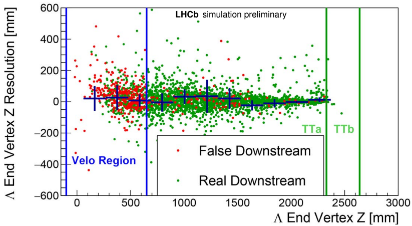
Proof of principle

This method works since the efficiency extracted:

- Does not depend on Z (track length)
- Coherent results outside the VELO detector
- Downstream algorithms should be able to reconstruct tracks from VELO region

Simulation Run II

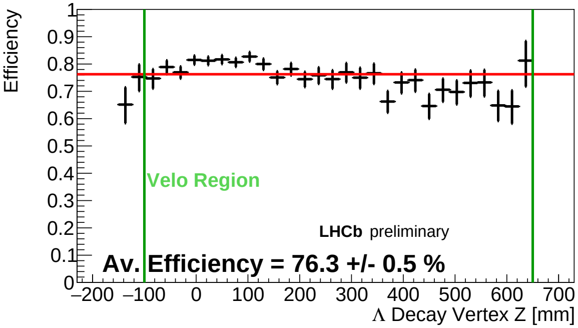




Compatible results with [LHCb-PUB-2017-001]

The independence with the *z* position can be checked in Real Data:

Real Data Run II

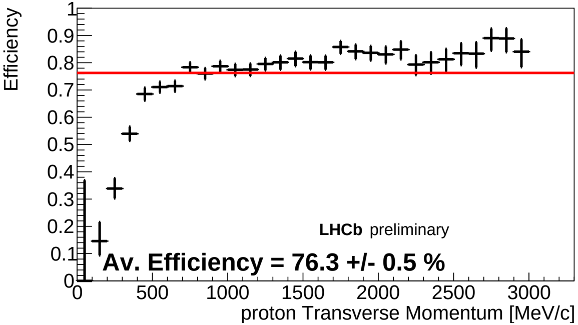


- Real Data results compatible with MC Run II

Results [Efficiency VS proton p_T]

To optimise the performance of the tracking algorithms, the efficiency can be expressed as function of other variables:

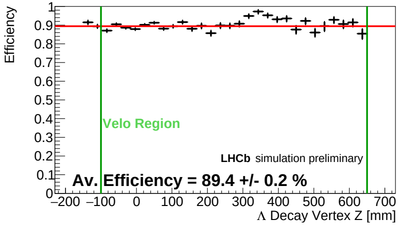
Real Data Run II

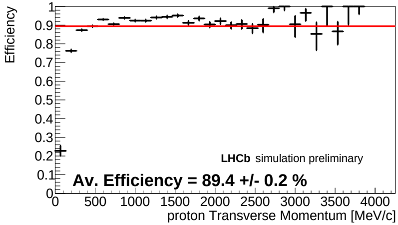


Large inefficiency for tracks with p_T lower than 0.5 GeV/c

The efficiency for the LHCb Upgrade detector with simulated data:

Simulation Upgrade (Run III)





New tracking detectors and algorithms provide an increase in the efficiency, even in the low p_T region

Downstream tracking peformance at LHCb

The efficiencies extracted using the method presented along with MC method are:

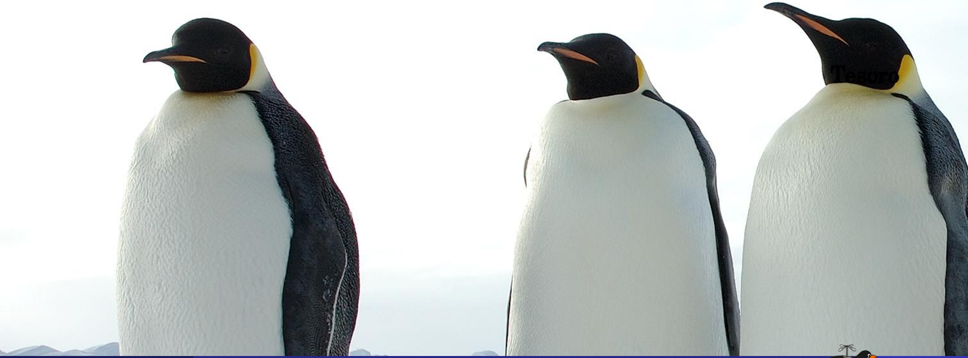
	Efficiency (%)	
	This method	MC Info
Simulation Run II	$\mathbf{77.4 \pm 0.7}$	74.5 ± 0.3
Real Data Run II	$\mathbf{76.3 \pm 0.5}$	–
Simulation Run III	$\mathbf{89.4 \pm 0.2}$	89.7 ± 0.1[1]

[1] CERN-THESIS-2017-254

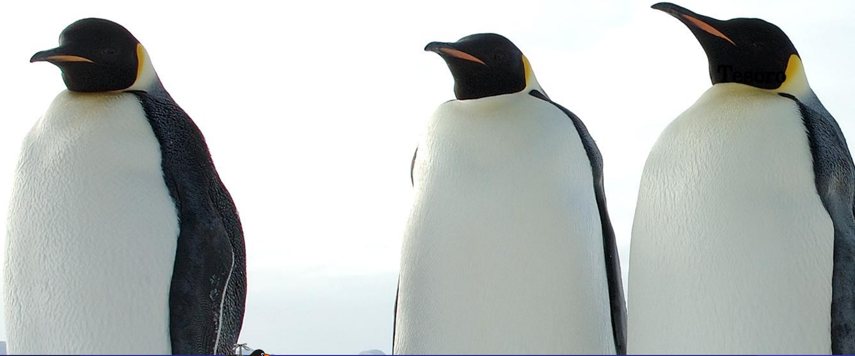
Conclusions

- A new method has been developpped to check the performance of downstream tracking at LHCb.
  It allows to calibrate the algorithms with real data
- Results are compatible between simulation and real data
- Coherent with other monitoring methods
- Can be use in any other experiment with similar track type topology
- It will be used for monitoring algorithms with Run III Real Data

Thanks for your attention

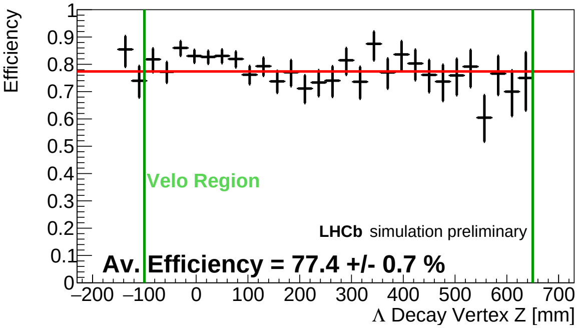


Backup slides

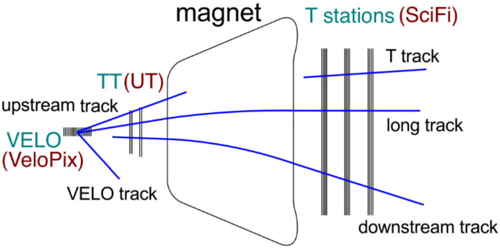


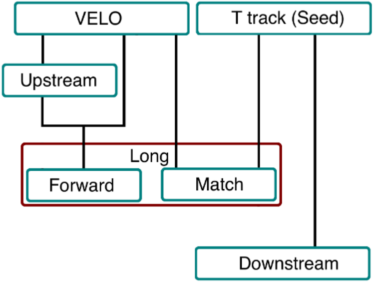
Efficiency VS Λ End Vertex Z

Simulation Run II



Tracking sequence



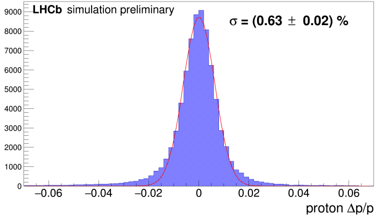


Downstream and Long tracks are independents

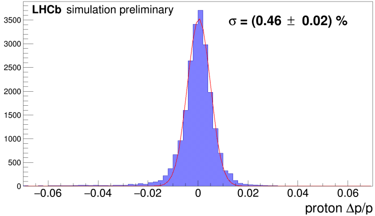
Results [Proton momentum resolution]

It is possible to extract the track momentum resolution:

Simulation Run II



Simulation Run III



The new algorithms for the downstream tracking Run III has improved the momentum resolution [CERN-THESIS-2017-254]