Tracking performance for long living particles at LHCb

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Connecting the dots and Workshop on Intelligent Trackers
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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:

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

$$\tau(= 10^{-11} - 10^{-10}) \times c \times \gamma \rightarrow \text{mean flight distance 3cm to 3m.}$$
Physics Case and LHCb detector

In the context of LHCb, long-lived ($K_s, \Lambda$):

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Track types

**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

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

- Analyses mainly uses Long and Downstream tracks
- $\Lambda$ coming from $b$-baryons have higher momentum $\Rightarrow$ 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

\[ \epsilon = \frac{\# \text{Reconstructed tracks}_{L/D/T}}{\# \text{Reconstructible tracks}_{L/D/T}} \]
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
New method: The performance of downstream tracking algorithm is extracted from Real Data using $\Lambda \rightarrow p\pi$:

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

$$\epsilon = \frac{\# p^F_D(\text{hits}^{\text{VeLo}/\text{VP}}, \text{hits}^{\text{TT}/\text{UT}}, \text{hits}^{\text{Tstation}/\text{SciFi}})}{\# p^L(\text{hits}^{\text{VeLo}/\text{VP}}, \text{hits}^{\text{TT}/\text{UT}}, \text{hits}^{\text{Tstation}/\text{SciFi}})}$$
**New method**: The efficiency is computed as the number of downstream tracks reconstructed in a sample of Long tracks:
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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]
Proof of principle

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

Real Data Run II

Av. Efficiency = 76.3 +/- 0.5 %

Real Data results compatible with MC Run II
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)**

Av. Efficiency = 89.4 +/- 0.2 %

New tracking detectors and algorithms provide an increase in the efficiency, even in the low $p_T$ region
The efficiencies extracted using the method presented along with MC method are:

<table>
<thead>
<tr>
<th>Efficiency (%)</th>
<th>This method</th>
<th>MC Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Run II</td>
<td>77.4 ± 0.7</td>
<td>74.5 ± 0.3</td>
</tr>
<tr>
<td>Real Data Run II</td>
<td>76.3 ± 0.5</td>
<td></td>
</tr>
<tr>
<td>Simulation Run III</td>
<td>89.4 ± 0.2</td>
<td>89.7 ± 0.1[1]</td>
</tr>
</tbody>
</table>

Conclusions

- A new method has been developed 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 used in any other experiment with similar track type topology

- It will be used for monitoring algorithms with Run III Real Data

Stay Tuned for something awesome!
Thanks for your attention
Backup slides
Efficiency VS \( \Lambda \) End Vertex Z

**Simulation Run II**

Av. Efficiency = 77.4 +/- 0.7 %

LHCb simulation preliminary
Tracking sequence

Downstream and Long tracks are independents
It is possible to extract the track momentum resolution:

**Simulation Run II**

\[ \sigma = (0.63 \pm 0.02) \% \]

**Simulation Run III**

\[ \sigma = (0.46 \pm 0.02) \% \]

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