Tracking performance of the LHCb spectrometer

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On behalf of the LHCb collaboration
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Tracking Components

- VERTex LOcator: For Primary/Secondary Vertex separation
- Primary Vertex (25 tracks): $\sigma(x \text{ and } y) \approx 13\,\mu m$ and in $z \approx 69\,\mu m$
**Tracking Components**

- **VELO**
  - Vertex Locator: For Primary/Secondary Vertex separation
  - Primary Vertex (25 tracks): $\sigma(x \text{ and } y) \approx 13\,\mu m$ and in $z \approx 69\,\mu m$
  - **TT**: Reconstruction of long lived particles (Ks,..)
    
    and better momentum resolution after scattering in RICH1
• **Vertex Locator**: For Primary/Secondary Vertex separation

• Primary Vertex (25 tracks): $\sigma(x \text{ and } y) \approx 13\mu m$ and in $z \approx 69\mu m$

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• From **Tracking Stations**: $\Delta p/p \approx 0.4\% \Rightarrow J/\psi$ mass resolution $\sigma \approx 12\ MeV/c^2$

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**Tracking Components**

- Magnet
- Vertex Locator
- VELO
- TT
- T Stations
- LHCb

**Graph**

- LHCb
- $2.5 < y < 3.0$
- $3 < p_T < 4\ GeV/c$
- $M_{\mu\mu}$ [MeV/c$^2$]
- $J/\psi$ candidates per 5 MeV/c$^2$
Track Finding

VELO

Magnet

T stations

TT

T1T2T3

B
Track Finding

- Pattern Recognition finds individual hits that compose a track
- Most valuable for physics analysis are “long tracks”, they pass the full tracking system (from VELO to T station)
Pattern Recognition finds individual hits that compose a track

Most valuable for physics analysis are “long tracks”, they pass the full tracking system (from VELO to T station)

Figure of merit:

- Efficiency
- Ghosts (fake combinations)
  - Random combination of hits that form a track
  - Wrong combination of subdetector tracks (matching)
Efficiency $\varepsilon$

Tracking efficiency is crucial ingredient for many analyses:

- e.g. branching ratio, production cross section

Efficiencies are taken from MC: requires confirmation of MC results from data

LHCb Strategy:

- Measure ratio of efficiencies data/MC and their uncertainties
- data/MC ratio applicable for each track selection
- Idea: Tag and probe technique using resonances $J/\psi, Z, K_S$
Reconstruct a $J/\psi$ using tag and probe leg

- **Tag:** long track (fully reconstructed)
- **Probe:** matched TT to T station track (no VELO hits)

Look for long track that matches the probe

Remove background using sideband subtraction
Efficiency Measurement

Use tag and probe for $J/\psi \rightarrow \mu^+ \mu^-$

Coverage of interesting momentum region for B physics analysis

Three different approaches:

1a) VELO efficiency (probe leg:TT+T station)

1b) T station efficiency (probe leg:VELO+Muon)

2) Long(VELO+T station) efficiency (probe leg:TT+Muon)
Results

- Different mass resolutions, background fractions, therefore errors are different for each method
  - Important crosscheck for systematics
- Errors not only binomial: take also background into account
- Good agreement within 1% between data and MC
Efficiencies vs Multiplicities

- Efficiencies in data and MC have the same dependencies
- Relatively stable efficiency up to higher multiplicities
Applying the results

- Particular phase space covered by samples used for measurement
- Bin relative efficiencies in $\eta$ and $p$
- Provide 2D efficiency correction table
- Very good agreement between data and MC

- Absolute efficiency depends on the (eta, p) spectrum of each decay/track selection
- Apply the results on $J/\psi \rightarrow \mu^+ \mu^-$ decay spectrum:
  - For 2011 data /MC

$$\varepsilon(\text{data2011})/\varepsilon(\text{MC}) = 1.000 \pm 0.001$$
Systematics

Systematic uncertainties on tracking efficiency:

- Difference between two methods (Long vs. VELO & T station)
- Sideband subtraction (comparison with full mass fit)
- MC re-weighting to describe data
  - Final systematic uncertainty is 0.7%

Additional tracking uncertainty due to material effects

- Tag and Probe method relies on J/Psi legs reconstructed in muon system
- For hadrons: need to add about 1.5% uncertainty from hadronic interactions due to uncertainty on material budget
LHCb Tracking Performance
- Very good performance, high precision experiment
- Efficiencies: 96% for long tracks
- Measurement of tracking efficiencies
  - Tag and probe with $J/\psi$, $Z$, $K_S$ (VELO,T Stations & Long)
  - Example: application on $J/\psi \rightarrow \mu^+\mu^-$
    - $\epsilon(\text{data2011})/\epsilon(\text{MC}) = 1.000 \pm 0.001$
    - Systematic uncertainty of the method: 0.7%
    - For hadrons additional uncertainty: 1.5%
- Dedicated B-Physics experiment
- For studying rare phenomena in B-decays with high precision
- Boost of B-Bbar pairs: significant amount of data in high eta region
Several methods for the measurement

- Measure very theoretically well known ratios: $BR\left(\frac{D^0 \rightarrow K\pi\pi\pi}{D^0 \rightarrow K\pi}\right)$
  - Uncertainty 3-4%
- More Precise: Tag and probe technique for resonances $J/\psi, Z, K_S$

What we do:

Use tag and probe for $J/\psi \rightarrow \mu^+\mu^-$

Coverage of interesting momenta region for B physics analysis

Three different approaches:

- VELO Method
- T Station Method
- Long method

<table>
<thead>
<tr>
<th></th>
<th>VELO method</th>
<th>T station method</th>
<th>Long method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data2010</td>
<td>25 pb$^{-1}$</td>
<td>25 pb$^{-1}$</td>
<td>29 pb$^{-1}$</td>
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<tr>
<td>Data2011</td>
<td>202 pb$^{-1}$</td>
<td>340 pb$^{-1}$</td>
<td>more than 281 pb$^{-1}$</td>
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<tr>
<td>MC2010,</td>
<td>10 M</td>
<td>20 M</td>
<td>20 M</td>
</tr>
</tbody>
</table>
Test VELO efficiency

- Tag: long track (With Muon IDs)
- Probe: matched TT to TStations track (with Muon IDs)
- Very good agreement for data and MC
Test T station efficiency

- Tag: long track
- Probe: matched VELO to MUON track
- MC describes data very well
Long Method

- Tag: long track
- Probe: matched TT to MUON track
- Good agreement for data and MC
Motivation

Tracking finding Efficiency is used by many physics Analysis

- Production cross section
- Branching ration
- ...

Example:

\[
\sigma_i = \frac{N_{obs}^i}{\epsilon_{trig}^i \epsilon_{sel}^i \epsilon_{reco}^i L_{int}}
\]

- Direct impact on the systematic error

Aim is to

- measure data track finding efficiency relative to MC
- correct for discrepancies and determine systematic uncertainties
LHCb Event Display

mu-mu mass=(3103.8+/−9.4)MeV/c²
momentum: p=39.98 GeV/c pt=0.72 GeV/c