Future upgrade of LHCb RICH

On behalf of LHCb RICH collaboration

Goal: Search for New Physics:
- Indirect search by measuring parameters related to CP-violation in B-decays and D-decays with unprecedented precision
- Search for signals of BSM and dark sector particles through rare decays
- Examples of expected precisions from LHCb

Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current</th>
<th>2025</th>
<th>HL-LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_{B^{0}}</td>
<td>0.75</td>
<td>0.41</td>
<td>0.38</td>
</tr>
<tr>
<td>R_{B^{+}}</td>
<td>0.82</td>
<td>0.49</td>
<td>0.38</td>
</tr>
<tr>
<td>R_{B^{0}K^{0}}</td>
<td>0.63</td>
<td>0.48</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Upgrade coverage in the momentum ranges below 10 GeV/c and above 80 GeV/c

Future Upgrade:
- Upgrade Phase1a: Use
  - MaPMT (Silicon Photomultiplier) with 1 mm pixel size
  - Simultaneous readout of new silicon detectors
  - Use Hits from RICH1 to further enhance the PID performance.

Results from GEANT4 based simulations listed below for RICH1. Similar results obtained from RICH2 also. Simulations use beam conditions of Phase1a upgrade.

RICH1:
- Phase1a:
  - MaPMT (R13742) with 2.78 mm pixel size for RICH1 and central part of RICH2.
  - 35% efficiency.
- Upgrade:
  - Use SiPM (Silicon Photomultiplier) with 1 mm pixel size and use both RICH1 and RICH2.

RICH2 Hit Time
- For track start position: Track start time = Track start position + 5 mm
- For 5 mm < Track start position < 5 mm

RICH reconstruction: Using a fast modelling of RICH Hit Time for PID
- Avoid backgrounds from out-of-time hits

RICH hit time from LHCb simulations using PYTHIA+EVTGEN+ GEANT4
- Primary Vertex generator model the beam bunches as 4D-Gaussians (X,Y,Z, time)
- PDF calculated when the bunches travel towards the collision point at beam crossing
- A Markov chain sampler used to sample from the 4D PDF

Using B events

PV Time vs Z

LHCb detector until 2024

LHCb Timeline

1.5
0.022
(R13742) with 2.78 mm pixel size for RICH1 and central part of RICH2

Photonic crystal create an effective refractive index different than those of silicon photomultiplier.

Avoid backgrounds from out-of-time hits

Simulations using PYTHIA+EVTGEN+ GEANT4

RICH collaboration

Photonic crystals are made from transparent dielectric materials.

Possibility of using them as radiators, is under investigation.

Photonic crystal create an effective refractive index different than those of the component materials they are made of.

Three aspects of improving RICH performance with increased luminosity

(1) Resolutions, yield and occupancy

Upgrade Phase1a: MaPMT (R13742) with 2.78 mm pixel size for RICH1 and central part of RICH2. λ>280 nm. Future Upgrade: Use SiPM (Silicon Photomultiplier) with 1 mm pixel size and use λ>400 nm. Also considering improvements in RICH optics geometry.

Results from GEANT4 based simulations listed below for RICH1. Similar results obtained from RICH2 also. Simulations use beam conditions of Phase1a upgrade.

RICH1:
- Phase 1:
  - MaPMT 0.78 0.57 0.36 0.45 41.2
  - SiPM 0.40 0.11 0.36 0.15 47
  - SiPM+a new geometry version 0.22 0.11 0.12 0.15 34

Emission point

Yield

Chromatic

Pixel

Point emission chromatic

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

mrad

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