Upgrade Simulation: RICH + TORCH

LHCb Upgrade Simulation Kickoff Meeting

S. Easo, 5-12-2011
Outline

- Status of plans/ideas for RICH in the Hardware
- Simulation and Reconstruction of the base line option for RICH
- Status of RICH Software Integration
- Evolution of the plans for RICH
- TORCH: Status
- Answers to the remaining questions from Gloria
- Summary
Plans for RICH

• More Info: Recent LHCb week and PID workshop talks

➢ HPDs to be replaced to accommodate the 40 MHz readout
  Base line option: MAPMT
  Another Idea: Digital Silicon Photomultiplier (DSPM from Philips)

➢ No Aerogel. Low momentum PID: TORCH with Micro Channel Plate (MCP)
  Another option: TORCH with DSPM

➢ RICH optics: Base line option: Current Configuration
  Ideas for modification:
  • Avoid too many hits in a small number of photodetectors
  • Possible rotation of RICH1 by 90 degrees.

• RICH baseline options implemented in software.
MAPMTS for RICH

- The PMT considered: R11265
  - Area of pixels = 23 X 23 mm
  - Inter pixel gap = 0.1 mm
  - 23 = 8 x 2.7875 (pixels) + 0.1 x 7 (gaps)
  - Effective pixel size similar to that of HPDs

4 X 4 set of PMTs kept inside a Module
Layout Design: S. Eisenhardt (Edinburgh)

- Input window: £ Borosilicate < £ UV glass
- Photocathode: £ Common Bialkali < £ Super Bialkali < £ Ultra Bialkali
  - £ = Cost

- Current Default Option: CBA (common Bialkali) with Borosilicate

- Other options also being considered.
PMTs in Simulation

Module

Pictures from Panoramix

Single PMT
PMT Arrays installed in RICH1 and RICH2
SBA-UV, SBA-Borosilicate: Below 300 nm, only a ‘rough’ extrapolation from info available.

CBA: Info from Stephan Eisenhardt.
Simulation in GAUSS

- Simulation implemented in GAUSS.

- For running the program, the Gauss 'python configuration' slightly modified to access the MAPMT related parts of the simulation.

- Resolutions and yields obtained are compared with those from HPDs.

- This presentation:
  - Particle gun: 80 GeV pions, also used b-events.
  - All plots made in the good acceptance range: 0.09 < θ < 0.18 rad: RICH1
    0.04 < θ < 0.09 rad: RICH2
  - Results made using CBA, SBA (Super bialkali) options.
  - More explanations and options in previous talks in RICH meetings.

- For each QE option, a separate QE table (Tabulated Property) available in DB.

- Yield: Number of hits per saturated track.
RICH1: Yields with MAPMT

CBA: Borosilicate
Mean=21.

CBA: UV glass
Mean=25.7

SBA: Borosilicate
Mean=31

SBA: UV glass
Mean=34

Using P gun
RICH2 Yields with MAPMT

CBA: Borosilicate

Mean = 14.5

CBA: UV glass

Mean = 17.6

SBA: Borosilicate

Mean = 21.5

SBA: UV glass

Mean = 24.5

Using P gun
### RICH Yields

<table>
<thead>
<tr>
<th></th>
<th>RICH1</th>
<th>RICH2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMT: CBA Borosilicate</td>
<td>21</td>
<td>14.5</td>
</tr>
<tr>
<td>PMT: CBA UV glass</td>
<td>25.7</td>
<td>17.6</td>
</tr>
<tr>
<td>PMT: SBA Borosilicate</td>
<td>31</td>
<td>21.5</td>
</tr>
<tr>
<td>PMT: SBA UV glass</td>
<td>34 B-events : 33</td>
<td>24.5 B-events: 22</td>
</tr>
<tr>
<td>HPD layout HPD QE</td>
<td>34 B-events: 33</td>
<td>24 B-events: 22</td>
</tr>
<tr>
<td>PMT: layout HPD QE</td>
<td>31</td>
<td>21</td>
</tr>
<tr>
<td>PMT: UBA Borosilicate</td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>PMT: UBA UV glass</td>
<td>52</td>
<td>35</td>
</tr>
</tbody>
</table>
RICH1 resolutions: MAPMT - CBA Borosilicate

Overall
Width=1.09 mrad (rms)

Chromatic
Width=0.66 mrad (rms)

Emis Pt.
Width=0.62 mrad

Pixel
Width=0.60 mrad

Plots for other cathode options: talk at the RICH meeting last week.
## Resolutions

<table>
<thead>
<tr>
<th>RICH1</th>
<th>CBA: Borosilicate</th>
<th>CBA: UV glass</th>
<th>SBA: Borosilicate</th>
<th>SBA UV glass</th>
<th>HPD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromatic</td>
<td>0.66</td>
<td>0.78</td>
<td>0.66</td>
<td>0.74</td>
<td>0.84</td>
</tr>
<tr>
<td>Emis. Pt.</td>
<td>0.62</td>
<td>0.62</td>
<td>0.62</td>
<td>0.62</td>
<td>0.61, QW: 0.12</td>
</tr>
<tr>
<td>Pixel</td>
<td>0.60</td>
<td>0.60</td>
<td>0.60</td>
<td>0.60</td>
<td>0.59, PSF: 0.79</td>
</tr>
<tr>
<td>Overall</td>
<td>1.09</td>
<td>1.17</td>
<td>1.08</td>
<td>1.14</td>
<td>1.45 B ev: 1.49-&gt;1.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RICH2</th>
<th>CBA: Borosilicate</th>
<th>CBA: UV glass</th>
<th>SBA: Borosilicate</th>
<th>SBA UV glass</th>
<th>HPD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Chromatic</td>
<td>0.37</td>
<td>0.41</td>
<td>0.37</td>
<td>0.40</td>
<td>0.39</td>
</tr>
<tr>
<td>Emis. Pt.</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.38, QW: 0.07</td>
</tr>
<tr>
<td>Pixel</td>
<td>0.19</td>
<td>0.19</td>
<td>0.19</td>
<td>0.20</td>
<td>0.20, PSF:0.26</td>
</tr>
<tr>
<td>Overall</td>
<td>0.54</td>
<td>0.58</td>
<td>0.55</td>
<td>0.57</td>
<td>0.64 B ev: 0.65 -&gt;0.67</td>
</tr>
</tbody>
</table>

*All resolutions in mrad*
Occupancies
Occupancies
Digitization and Reconstruction

• Used 10K B-Events for the Gauss-Boole-Brunel Chain.

• Implemented the upgrades needed in various packages, including RichDet for processing the PMT data. ‘RichSmartID’ upgraded to use the PMT data (besides the HPD data). Reused existing software for data for HPDs, as much as possible.

• Boole: Simplified digitization for now.
  No charge sharing simulated. Software available for this, but need to know the amount of charge sharing to input. Placeholder for ‘readout boards’ configuration.

• Brunel: Performed reconstruction and PID with this data.
  Plots in the following slides using the CBA-Borosilicate option.
MAPMT Resolutions from Brunel

RICH1: MaPMT width=1.3 mrad
HPD: 1.53 mrad

RICH2: MAPMT width=0.59 mrad
HPD: 0.66 mrad
**PID Performance with MAPMTS**

\[
\pi \rightarrow e, \mu, \pi : 97.16 \pm 0.04 \%
\]
\[
K \rightarrow e, \mu, \pi : 2.60 \pm 0.12 \%
\]
PID Performance with MAPMTS

Heavy ID | Long Tracks | MC | Upgrade MAPMT

K → K, Pr : 97.40 ± 0.12 %
π → K, Pr : 2.84 ± 0.04 %
Software Integration

- All the C++ software for MAPMTs are in the recent versions of the various LHCb packages.

- The ‘DDDB’ configuration different than that for the ‘Current LHCb’. The DDDB_Ugrade.db, perhaps not compatible with recent versions of LHCb C++?

- In this situation, the DB modifications for ‘RICH -upgrade-with-MAPMT’ integrated as a ‘local tag’ in a special file in SQLDDDB. (Thanks to Illya and friends from the DB team for making this update). This enables one to use the ‘RICH upgrade’ with ‘Current rest -of-LHCb’.

- Eventually, we hope to integrate into something like DDDB_Ugrade.db.
Evolution of plans for RICH

- Modification of the RICH Optics (slide 3): Feasibility in hardware to be studied and discussed.

- Different photocathode options: Available in ‘options file’.

- So far, mostly used the ‘Current LHCb luminosity’ for running Gauss. Using spill over at 25 ns and high \( n (=3.4 \text{ for example}) \) takes too much CPU time in Gauss (especially on lxplus). Trying some ideas to get around this issue.

Use case: Plot the PMT occupancies to estimate the number of readout channels: Useful in the readout design.

- Charge sharing algorithm in Boole: To be tried, as we get more info.

- New Photodetectors (DSPMS): Do everything (optics, photodetectors) in software all over again.
• TOF detector, based on timing arrival of Cherenkov photons produced in quartz plate.

• Photons focussed onto an array of MCPs.
• aiming for a 15 ps resolution per track and 1 mrad angular resolution. Also aiming for 30 detected photons per track.
• So far used a standalone simulation with simplified geometry. It used the reconstructed tracks in DaVinci from full LHCb simulation, as input. The info from the standalone simulation then fed back directly into DaVinci. Results in LHCb-PUB-2009-030.
TORCH

• To use in the standard LHCb software chain, all the geometry and the Gauss simulation would need to be created from scratch.
• Current proposal from Roger: to keep it just upstream of RICH2. Requires shifting few detectors downstream to use up the space of M1. Requires corresponding changes in the DB.

• 4-year funding from ERC for TORCH R&D. Simulation is part of this R&D.
• Things to study: occupancy, pattern recognition performance as function of the quartz division plane. Performance in testbeam.
• People interested in contributing to these studies (besides Roger):
  a new CERN fellow in an year’s time, Mat Charles, Roberta Cardinale. Possible contribution from S.E. for setting up the geometry, Gauss part etc.
Questions from Gloria

- Detector configurations: Possibly, two types of photodetectors for RICH and TORCH, different RICH optics etc.

- Level of detail in simulation: Full details, as done for MAPMT.

- Would like to evaluate with other upgraded subdetectors if possible, in addition to testing with current LHCb configuration. Having an upgrade configuration for software and DB would be useful for this.

- Amount of data: About 20K for a configuration under study for RICH, to evaluate the PID performance. Possibly similar amount for TORCH.

- Test beam setup: It is planned for whenever the testbeam happens.

- Various specialized studies will happen as the detector development proceeds.
Summary

- Simulation of the baseline option for RICH upgrade using MAPMTs is implemented and integrated to LHCb software.

- The data produced from Gauss is reconstructed and the standard algorithm for Particle identification is used.

- This is likely to evolve with the various technology choices, which can potentially improve the PID performance.

- For integrating the low momentum PID upgrade, simulation of TORCH is the next major task.