RICH Upgrade Status Report

Neville Harnew 27/11/12

On behalf of the RICH Upgrade Group
Outline

- Big issues for RICH upgrade geometry design: 3 options
  - Retain current RICH-1 & RICH- geometry
  - Re-design RICH-1 with new optical system
  - NEW : Single RICH - “TRID” concept
- Hardware and testbeam
  - MaPMT & Electronics development
  - Testbeam
RICH-1 occupancy problem (S.Easo)

- As reported in Davos, at $2 \times 10^{33}$ RICH-1 occupancies reach 30% in the hottest regions

- PID performance is not hitting a “cliff”, but is not so satisfactory
Try RICH1 upgrade optics with mirror radius of curvature R=3800 mm (from 2710 mm) – has the effect of spreading out the rings
RICH1: New optics occupancy

Lumi20-S: SBA Borosilicate

R : 2710 → 3800 mm  results in peak occupancy : 31% → ~20%
Performance in Lumi20
\(20 \times 10^{32}\) at 7 TeV

Current Optics: Lumi20-S

RICH1-Optics-Version3
Lumi20-S
\(20 \times 10^{32}\) at 7 TeV
PID performance comparison

RICH1: Optics-Version3 vs. Current Optics

No veto mode

With veto mode
Min \( P = 2 \text{ GeV/c} \),
Min \( P_T = 0.5 \text{ GeV/c} \)

The performance loss due to Lumi2 \( \rightarrow \) Lumi20 is mostly recovered using Optics-Version3

3.5 TeV at \( 2 \times 10^{32} \) \( \rightarrow \) 7 TeV at \( 20 \times 10^{32} \)
• Results indicate that we should re-build RICH-1.

• New RICH-1 comes with increased cost [the numbers below include 15% contingency]
  – The current RICH TDR design = 9.4 MCHF
  – With RICH-1 replaced = 12.6 MCHF
  – DIFFERENCE = 3.2 MCHF
  – The model assumes simply doubling the area of the photon detector plane. We know this is an overkill. We are now looking at the effect of removing photon detectors and introducing lenses (initial results promising – see Sajan’s talk yesterday).
A new concept for the RICH upgrade

Roger Forty (CERN) - presented in Davos

- RICH-1 has high occupancies – propose an alternative solution
- Remove RICH-1, replace RICH-2 with a full-acceptance device with twin gas radiators: “Twin Ring Imaging Detector” (TRID)
- Re-designed RICH-1 needs much more space, more photodetectors
  Have now found a solution that fits into available space, gives improved performance, and uses fewer photodetectors than the current baseline
- Written up in a note: LHCb-PUB-2012-012

RICH meeting (Davos), 3 September 2012
Initial performance of single tracks (after ray-tracing) - presented in Davos

- TRID performance parameters compared to current RICH-1 & 2 (measured using same procedure)

<table>
<thead>
<tr>
<th></th>
<th>RICH-1</th>
<th>RICH-2</th>
<th>TRID</th>
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<tbody>
<tr>
<td>$\langle N_{pe}\rangle$</td>
<td>$C_4F_{10}$</td>
<td>$CF_4$</td>
<td>$C_4F_{10}$</td>
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<td></td>
<td>30</td>
<td>22</td>
<td>27</td>
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<tr>
<td>$\sigma_{\text{emission}}$</td>
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<td>$\sigma_{\text{chromatic}}$</td>
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<td>$\sigma_{\text{pixel}}$</td>
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<td>$\sigma_{\text{track}}$</td>
<td>0.4</td>
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<td>$\sigma_{\text{total}}$</td>
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<tr>
<td>$p_{3\sigma}(K-\pi)$</td>
<td>51</td>
<td>92</td>
<td>69</td>
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</table>

A new concept for the RICH upgrade
Progress on 2-RICH and TRID(ENT)

- THE MAJOR QUESTION (decision by the end of the year unfortunately looking very tight)
- Need definitive performance indicator on current RICH-1 studies
- Monte Carlo TRID performance using stand-alone programme to proceed at full speed (Roger Forty)
- Full simulation including magnetic field and pattern recognition comes later (see Antonis talk)
- FEA study of gas separators to prove concept looks promising. Radiation hardness now a crucial issue.
- More robust cost comparison of TRID vs baseline (N. Harnew/ C. d'Ambrosio work has started)

Plan view (half)

RICH Upgrade Meeting CERN, 26 Nov 2012

N. Harnew
Mirrors and Detector boxes: XML description (Antonis Papanestis)
Window

- Difference in density of radiator gases → pressure difference across window ~ 1 mbar per m of height
- Assume gas pressures balanced at beam level → maximum pressure difference close to frame
- Some window distortion is acceptable at few-cm level
- Material: Mylar, Plexiglass, Glass? Transmission only needs to match that of borosilicate MaPMT window
Glass separator: Matthew Brock (Oxford)
6 mm thick glass Displacement

<table>
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<th>Thickness (mm)</th>
<th>Stress (N/mm²)</th>
<th>Displacement (mm)</th>
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<tr>
<td>4</td>
<td>21.25</td>
<td>32.24</td>
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<tr>
<td>5</td>
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<td>10</td>
<td>3.274</td>
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Figures with a * are approximate. Error occurred at peak stress node.
Displacement – 8 segments aluminium frame

An engineering design was made with a full bolted construction and O ring grooves. The frame is 30 mm wide and the stress and deflection are well within acceptable limits.
Future work

• Radiation tolerance of borosilicate glass? May need to change to quartz or some other radiation resistant glass
• Use of a thin polymer film can be used if sandwiched between two thick meshes to provide support?
• Further information is required on the transparency and radiation hardness of polymers.
• Following this a mesh and film design can also be modelled.
To do list

• Pursue current RICH-1 studies – firm decision on new optics for RICH-1 by end of year
• Fill Monte Carlo TRID performance including magnetic field -> ready by next April
• In parallel – continue ray-tracing techniques to prove TRID concept for occupancy (R.Forty)
• Continue FEA studies of gas separators – radiation tolerance of borosilicate glass
• More robust cost comparison of TRID vs baseline.
• Preliminary decision on RICH configuration by the beginning of next year [slippage]
R&D on photodetectors and electronics

- Baseline photodetector: MAMPT Hamamatsu R11265
  - Tests underway at Milano - no new news since last report
- Baseline FE electronics: CLARO chips, backup MAROC or Si-strip chips
  - CLARO 8-channel chips currently under test in Milano
  - MAROC board for MAPMT in RICH-2 under test in Cambridge
MAPMT Baseplate scheme (Genoa)
Typical Signal Spectrum of R11265

- Signal spectrum of pixel 11 (medium gain) at 800V
- Fitted average phe at photocathode $\mu = 0.26$
- The valley between one phe signal and pedestal is achieved 200V below nominal HV

MaPMT histogram

- **global fit**
- **pedestal**
- **one phe**
- **2 and 3 phe**
- **one phe at 1st dynode**
- **2 phe at 1st dynode**
Test-beam news (S.Wotton/M.Maino/C.Gotti)

(October/November beam periods)

1. Behaviour of a matrix 2x2 of MaPMT R11265
   read with FEBrick (Front End Brick): this system provides all the chain of acquisition
   (available from IASF Palermo group, eventually other 3 packages 2x2 of R7600)

2. New front end chip CLARO
   Unfortunately not yet ready for testbeam

3. Maroc3 chip applied to R11265
Comparison of the two matrix 2x2 of MaPMTs using only one configuration:
AEROGEL (n=1.03) radiator 10x10x1cm³
Radius of ring 12cm
Every matrix 2x2 cover about 7% of the ring
Testbeam set-up
The Time Resolution is in agreement with the internal clock (10ns)

Number of photons per triggered event

M.Maino – RICH Upgrade Meeting 26/11/2012
2×MaPMT MAROC3 module

- 2×MaPMT base
- SAMTEC High-density connector
- MAROC (underneath)
- LV, HV, trigger & DAQ feedthroughs
Beam’s eye view

- Cerenkov ring (Very approximate)
- Light-tight plate
- Square opening in RICH box
- Pixels not read out
- R11265 MaPMTs

Event display

... on Wednesday night with first beam run!
We received the PCBs about 10 days ago and sent them to an external company for mounting.

We did not make it in time for the test beam, but we plan to have the system ready to readout one R11265 soon.

It will then be tested with LED light, Cherenkov photons from large n crystals illuminated with radioactive sources, etc.
Signal at the discriminator output in response to 1 Me- PMT-like signals (threshold set at 300 ke-):

In conclusion:
- The response of the CLARO has a small temperature dependence (as expected), which is of the order of 1000 ppm/°C.
- Irradiation up to $10^{12}$ neutrons/cm$^2$ produces small variations in the signal characteristics, none of which seems troubling.
- Probably we will need to irradiate the chip up to a higher dose (maybe another factor of 10, for a safe margin)
Conclusions

● RICH geometry
  - This is the critical issue.
  - Baseline vs redesigned RICH vs new “TRID”
  - Programme of work mapped out
  - Preliminary decisions by early next year (slightly delayed since Davos)

● RICH photon detector and electronics
  - Tests underway of all components
  - Testbeam for MAPMTs and MAROC.
  - CLARO tests will follow (Frascati)
**TRID**

- Performance seems to surpass that of current baseline, for fewer photodetectors: 2368 MaPMTs required (150k channels) instead of 3712 = 64%

- Current baseline cost estimate = 9.4 MCHF [Framework TDR] → MAPMT costs reduced by 1/3rd, will be more than enough for construction costs of TRID – seems to have a substantial cost saving

- RICH-2 technology can essentially be re-used (maybe even some parts?) Cost for RICH-2 mechanics + optics was estimated at 1.2 MCHF [MoU]
The Time Resolution is in agreement with the internal clock (10ns)

Number of photons per triggered event