CHARM Dosimetry challenges and new opportunities

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12/12/18 - CERN
Overview

1. Studies of constraints encountered in the CHARM Dosimetry. Indeed, a deep knowledge of these peculiarities become essential to characterize properly the mixed field of the facility during the test session.

2. Studies for the improvement of CHARM facility in term of new test opportunities, starting from 2021.
   - Boron Carbide shielding employment to protect electronic against ThNs.
   - Exploring the capabilities of CHARM facility to measure the ThNs cross section of SRAMs.
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CHARM Facility

PRIMARY PROTONS BEAM IMPINGES A METAL TARGET (POT): A SECONDARY RADIATION FIELD IS CREATED

3 KEY ELEMENTS:

1. Target
   - AlH - Aluminium Hole
   - Al - Aluminium
   - Cu - Copper

2. Movable Shielding
   - C – Concrete (1,4)
   - I – Iron (2,3)

3. Positions
   - >16 test positions
   - >150 official configurations

THE SPECTRA AND INTENSITY OF SECONDARY FIELD DEPEND ON THE POSITION

CERN, Dec. 12, 2018

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At CHARM the POT are proportional to the intensity of the radiation field, so the Radiation Level at CHARM are measured as a function of POT:

\[
Dose(p, c) = POT \cdot K_{dose}(p, c) \quad \ quad
Studies of constraints encountered in the CHARM Dosimetry

2018 Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC)
Sydney, Australia, from the 10th to 17th of November

S. Danzeca, C. Cangialosi et al. “Challenges in dosimetry and testing in the CERN CHARM mixed radiation field Facility”
CHARM beam line is placed downstream to IRRAD

If massive and bulky samples are tested in IRRAD, the effective proton impinging on the target might be less than the one measured by the SEC.

This leads to an overestimation of the POT and consequently, an overestimation of dose and fluence levels calculate for the test run.
Influence of IRRAD Facility

To assess the IRRAD impact on the CHARM dosimetry, the CHARM HEH k-factor where no samples are placed in IRRAD, are compared with the ones obtained when copper slabs of different thickness are placed in the IRRAD beam-line.

HEH CALIBRATION FACTOR RETRIEVED FOR POSITION 10
CuOOOOO CONFIGURATION

<table>
<thead>
<tr>
<th>IRRAD Copper sample</th>
<th>$k_{HEH}$ $[10^{-5} \text{cm}^2/\text{POT}]$</th>
<th>Percentage difference with Normal Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal run*</td>
<td>7.44</td>
<td>0%</td>
</tr>
<tr>
<td>1.5 cm</td>
<td>6.88</td>
<td>-8%</td>
</tr>
<tr>
<td>3 cm</td>
<td>6.03</td>
<td>-19%</td>
</tr>
<tr>
<td>6 cm</td>
<td>4.68</td>
<td>-37%</td>
</tr>
</tbody>
</table>

* NO Samples on the IRRAD beam line

The effects of a sample 6 cm thick lead to radiation levels up to 37% lower than the ones without any samples.

The dose and the fluences on the user’s equipment need to be monitored during the test runs.
Beam position Influence on the Dose

Position 1
Position 13
MWPC

Vertical profile

Normalized Amplitude
Center position (mm)

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Beam position Influence on the Dose

**POSITION 13 – Cu target**

<table>
<thead>
<tr>
<th>Beam position on the Horiz. axis (mm)</th>
<th>K\textsubscript{Dose} - Percentage difference with Centered Run (%)</th>
<th>Position A</th>
<th>Position B</th>
<th>Position C</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.7±0.2</td>
<td>59%</td>
<td>17%</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>23.0±0.6</td>
<td>27%</td>
<td>22%</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>1.3±0.4</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>-33.5±0.8</td>
<td>-43%</td>
<td>-57%</td>
<td>-59%</td>
<td></td>
</tr>
</tbody>
</table>

- The beam position influences the Rad. level measurement.
- The K decrease going away from the beam.
- This influence is also observed at test location 1 and 16.

The dose and the fluences on the user’s equipment need to be monitored during the test runs.
Self shielding effect – R10

Possibility to test large volumes electronic equipment

1 x Tester Rack = 1 x 2kA Sub-converter at CHARM:
- 1 x Illimit + 1 x Earthing Protection modules
- 1 x Common Control Electronics module
- 2 x Output modules
- 1 x Input module
- 1 x Auxiliary PSU module
- 1 x Free-Wheeling Diode module
The dose and the fluences on the user’s equipment need to be monitored during the test runs.
Boron Carbide shielding employment to protect electronic against ThNs

14th Specialists' workshop on Shielding aspects of Accelerators, Targets, and Irradiation Facilities.
Gyeongju, Korea, Oct. 30 2018

C. Cangialosi et al. “Evaluation of future employment of Boron Carbide shielding at CERN High energy AcceleRator Mixed field (CHARM) Facility”.
High appreciation in SATIF-14!
Evaluation of a new type of shielding (B₄C)

To assess the effectiveness of this type of shielding in accelerator-like environment.

- Comparison of different B₄C shielding:
  1. 80% B content
  2. 25% B content

- Evaluation of the shielding as a function of Boron sheet thickness (from 2mm to 7mm)

The B₄C shielding employment at CHARM can improve the facility test capability?
For a particular configuration the B\textsubscript{4}C shielding has no effect on the $\phi\text{_{HEH}}$. This is observed during all tests presented in this work.

The B\textsubscript{4}C sheet reduces the $\phi\text{_{ThN}}$ a factor:
- $\sim 3$ for CuOOOO
- $\sim 4$ for CuCIOO
- $\sim 13$ for CuCIIC

A similar behavior is observed with the Al target at the same position.
### B₄C shielding effect at CHARM

<table>
<thead>
<tr>
<th>FACILITY CONFIGURATION</th>
<th>POSITION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boron free</td>
</tr>
<tr>
<td></td>
<td>$R^{B-free}$</td>
</tr>
<tr>
<td>CuOOOOO</td>
<td>0.81</td>
</tr>
<tr>
<td>CuCIOOO</td>
<td>1.12</td>
</tr>
<tr>
<td>CuCIIC</td>
<td>8.41</td>
</tr>
</tbody>
</table>

- The B₄C sheet (both 80% and 25% B content) modifies the particle spectra in favour of HEH with respect to ThN, also for facility configuration with high R factor value.
- The thickness of the B₄C sheet plays a key role at higher R-factor value.
- In configuration CuOOOOO the sheet thickness is negligible for 80% B-sheets, but significant for the 25% one.

\[ R = \frac{\Phi_{th}}{\Phi_{HEH}} \]
Conclusion and Outlook

✓ The Irrad-influence, the beam position influence and the self-shielding effect of massive equipment, make the Dosimetry at CHARM is a real challenge. For this reasons the Radiation Level monitoring during user’s test is necessary.

✓ The tests a CHARM shows the B\textsubscript{4}C sheet an efficient solution to protect the electronics operating in the LHC and in the accelerator-like environment.

✓ The B\textsubscript{4}C sheets with 80% of Boron seems the best solution for environment defined by spectra dominated by ThN.

✓ 2018:
  • More than 150 configurations.

✓ 2021:
  • The use of a rack covered of B\textsubscript{4}C sheet will increase the number of configurations exploitable at CHARM. It will enhance the facility test capability covering new radiation environments suitable for new applications.

Thank you all the CHARM Team!!!
Thank you for your attention!
**NA62 Experiment**

Aim to study rare kaon decays

2017:
several failures in the readout of electronic equipment.

\[ \Phi_{HEH} \text{ and } \Phi_{THN} \sim 7 \cdot 10^7 \text{ pp cm}^{-2} \text{ week} \]

can induce failures to electronic components (FPGAs or SRAM).

2018:
- Concrete shielding
- B$_4$C shielding
- BatMon System
Application

The Co-shielding reduces the $\Phi_{HEH}$ by a factor $\sim 10$

$B_4C$-shielding reduces the $\Phi_{ThN}$ by a factor 12

The two shielding are very effective to capture ThN, indeed the $\Phi_{ThN}$ is reduced by a factor 28.
Application Vs CHARM

NA62 $\rightarrow$ Position A $\rightarrow$ $7.1 \cdot 10^7 \frac{pp \cdot cm^{-2}}{week}$

CHARM conf. $\rightarrow$ AlHOOOO at Position 0 $\rightarrow$ $8.5 \cdot 10^7 \frac{pp \cdot cm^{-2}}{week}$