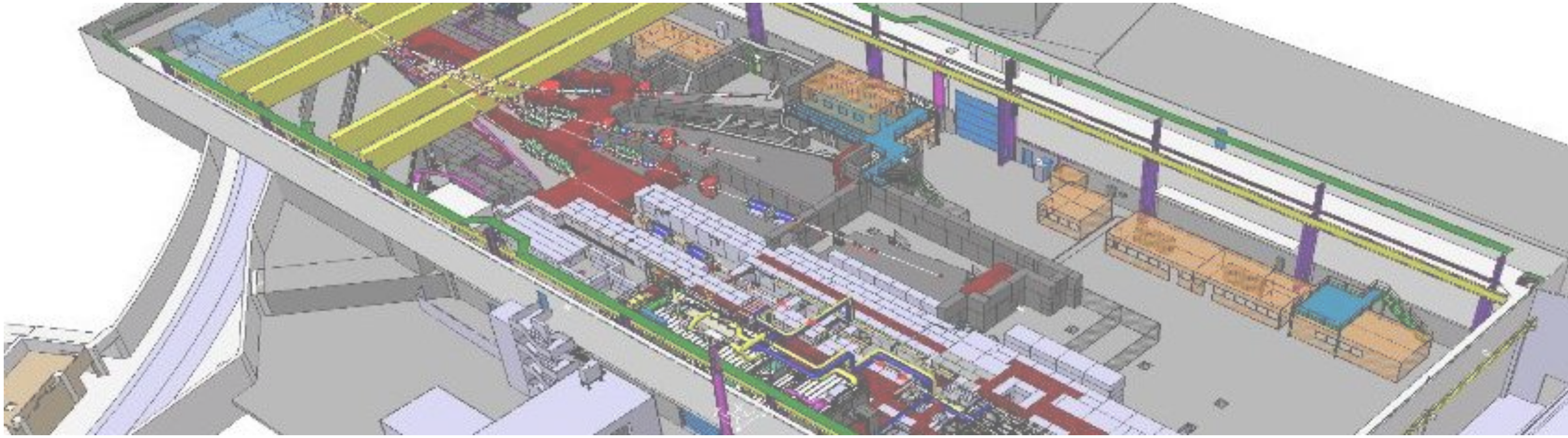

CHARM Dosimetry challenges and new opportunities

C. Cangialosi, Marie-Curie Fellow

R2E Annual Meeting 2018

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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RADECS 2017 Geneva, Switzerland, Oct. 2017.

C. Cangialosi et all. "Thermal Neutron SRAM Detector Characterization at the CERN Mixed-Field Facility, CHARM" **IEEE Trans. Nucl. Sci.**, vol. 65, issue 8, pp. 1887-1893. - 2018

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**

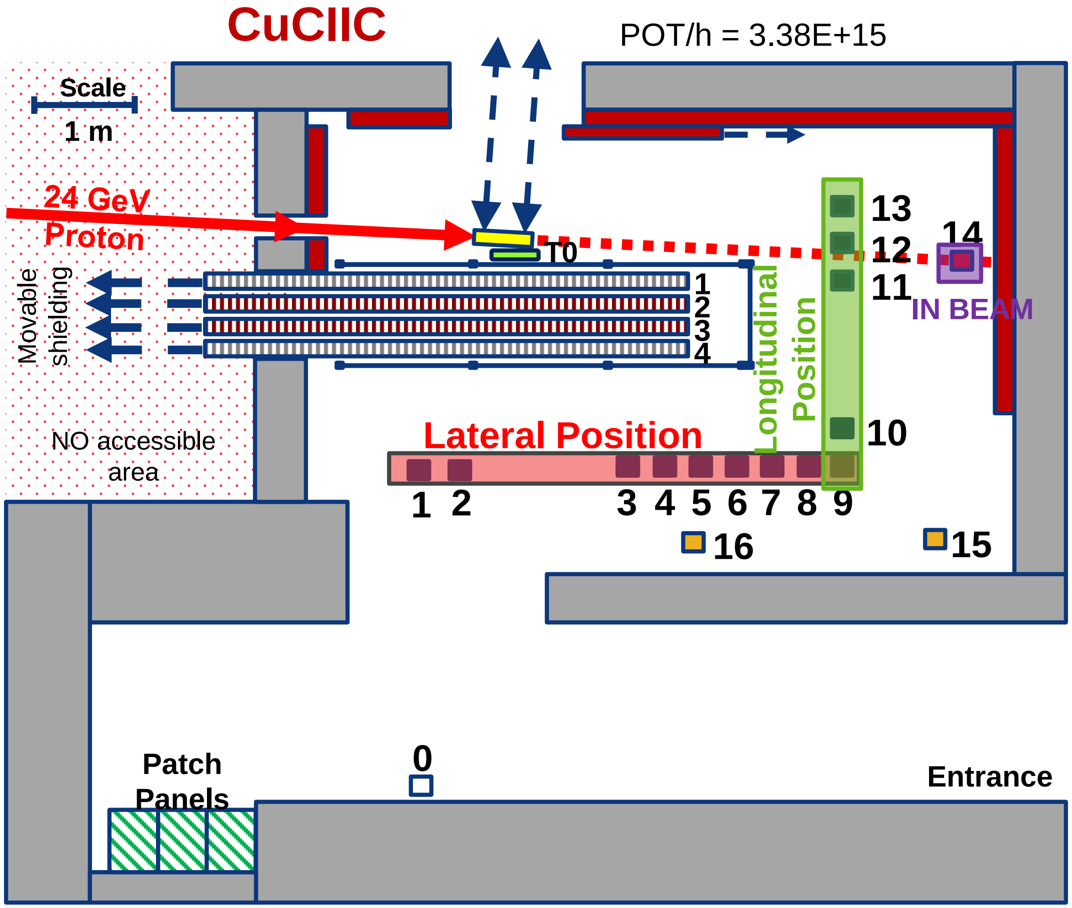
   C – Concrete (**1,4**)
   I – Iron (**2,3**)

3. **Positions**

   >16 test positions

> 150 official configurations

THE SPECTRA AND INTENSITY OF SECONDARY FIELD DEPEND ON THE POSITION



CHARM Facility

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:

$$Dose(p,c) = POT \cdot K_{dose}(p,c) \qquad Fluence_{HEH}(p,c) = POT \cdot K_{HEH}(p,c)$$

During the calibration session the Dose, the Fluence (RadMon) and the POT (SEC) are measured:

$$\frac{Dose(p,c)}{POT} = \boxed{K_{dose}(p,c)\ [\mathrm{Gy}/POT]} \qquad \frac{Fluence_{HEH}(p,c)}{POT} = \boxed{K_{HEH}(p,c)\ [cm^{-2}/POT]}$$

Each position ‘p’ and configuration ‘c’ can be calibrated with two factors K_{dose} and K_{HEH} .

During a standard irradiation session measuring the POT is possible to retrieve the Rad. Level on the DUT.

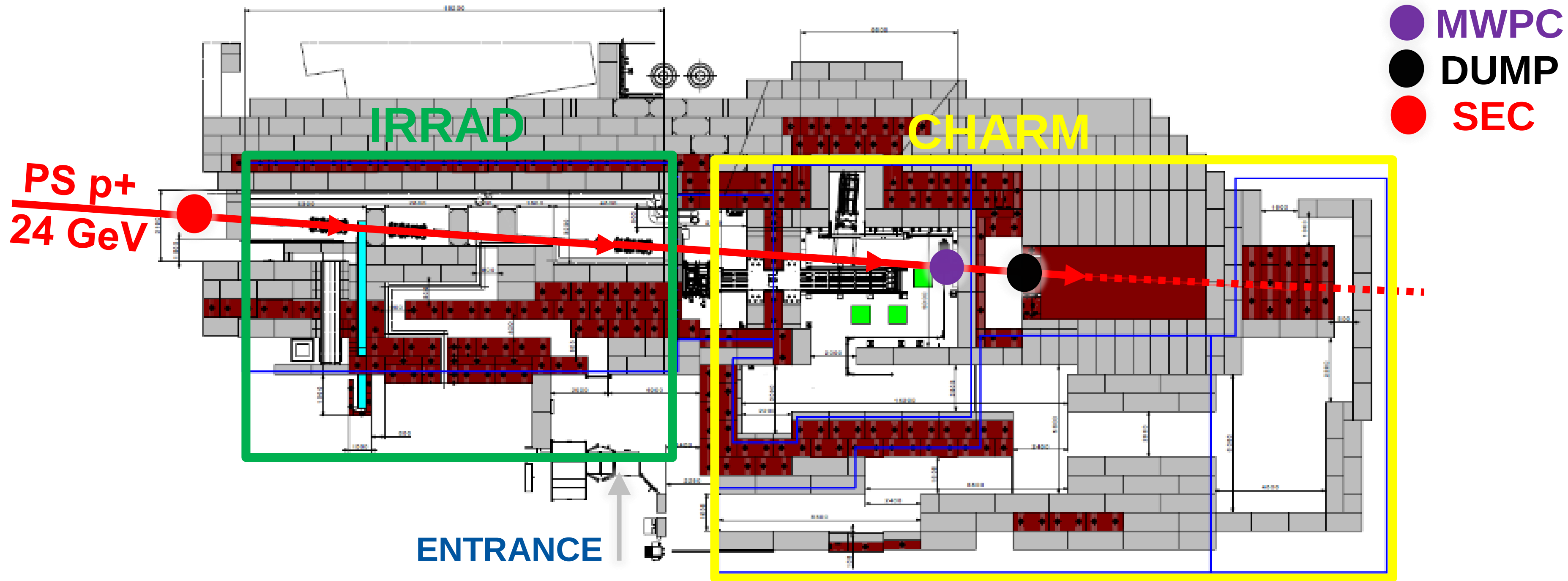
Studies of constraints encountered in the CHARM Dosimetry

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

S. Danzeca, C. Cangialosi et all. “Challenges in dosimetry and testing in the CERN CHARM mixed radiation field Facility”

Influence of IRRAD 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 that 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.

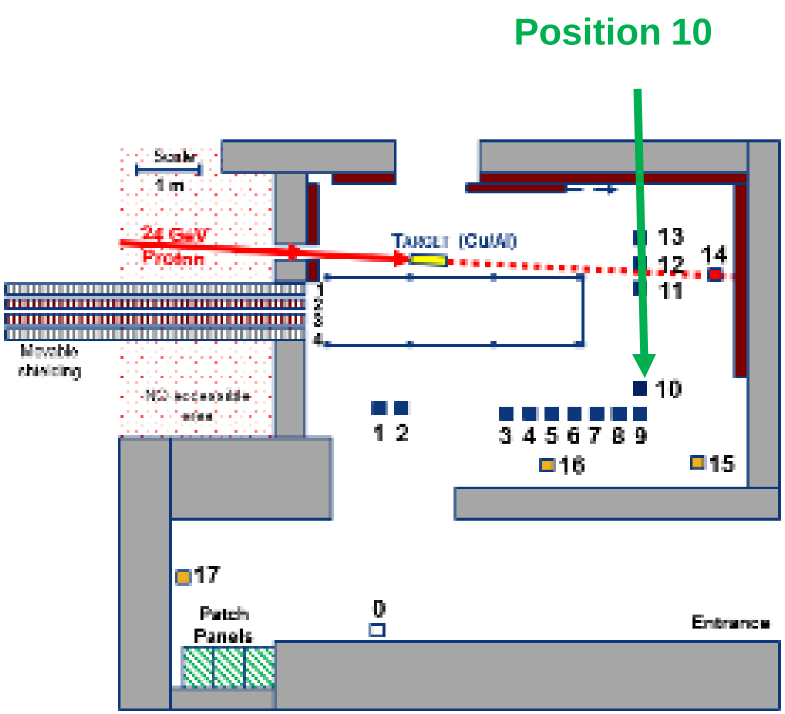
Influence of IRRAD Facility

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 CuOOOO CONFIGURATION

IRRAD Copper sample	k_{HEH} [$10^{-5}\cdot cm^{-2}$/POT]	Percentage difference with *Normal Run*
*Normal run**	7.44	0%
1.5 cm	6.88	-8%
3 cm	6.03	-19%
6 cm	4.68	-37%

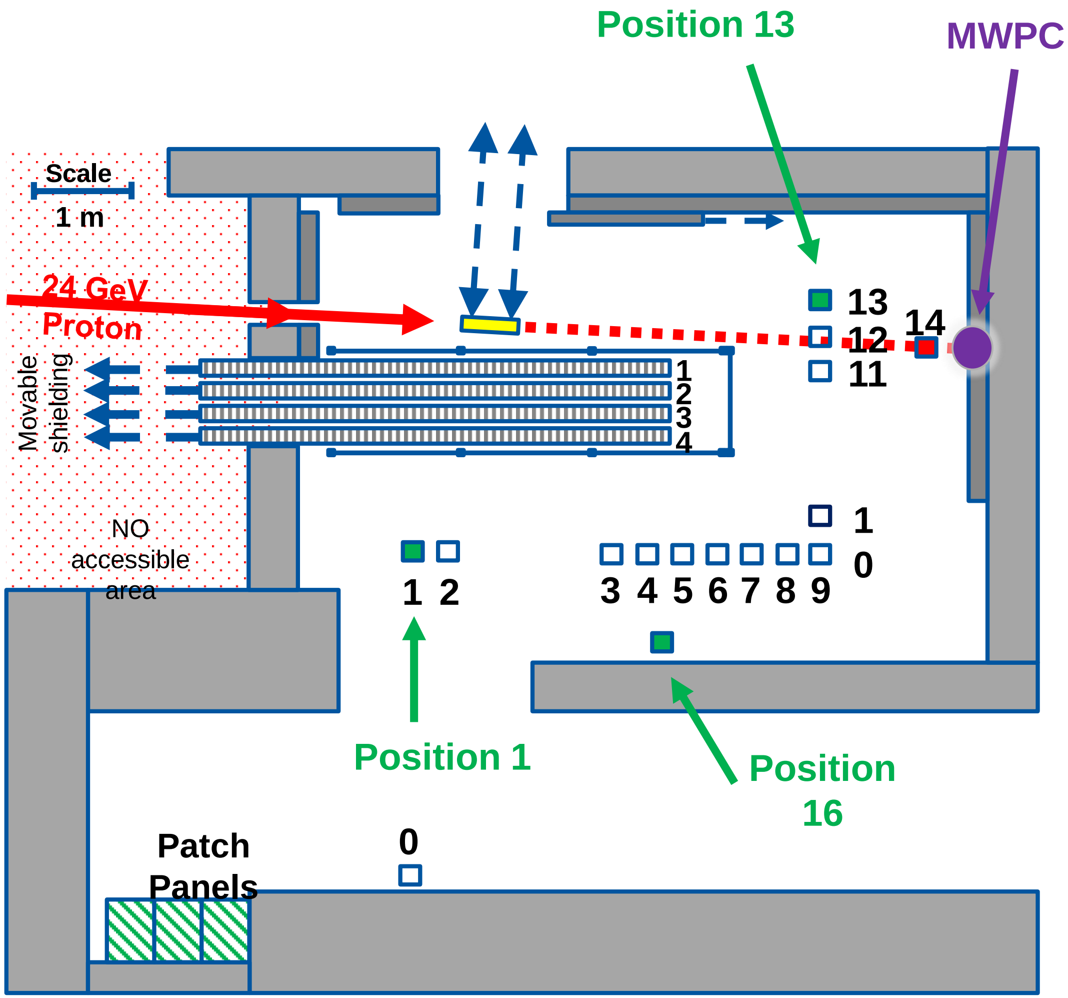
* NO Samples on the IRRAD beam line

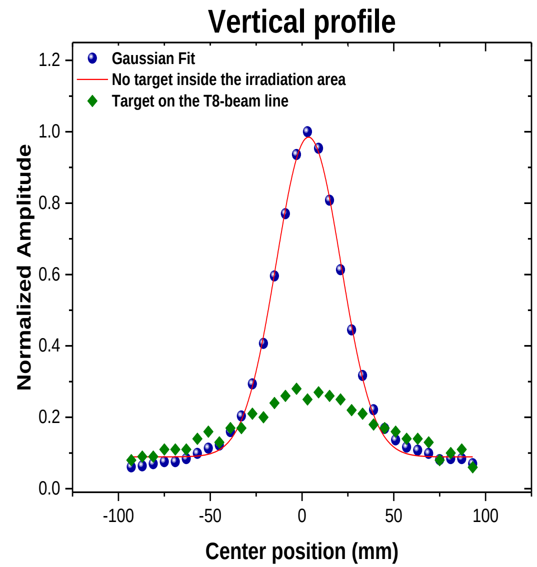


The effects of a sample 6 cm thick lead to radiation levels up to 37% lower than the ones without any samples.

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

Beam position Influence on the Dose



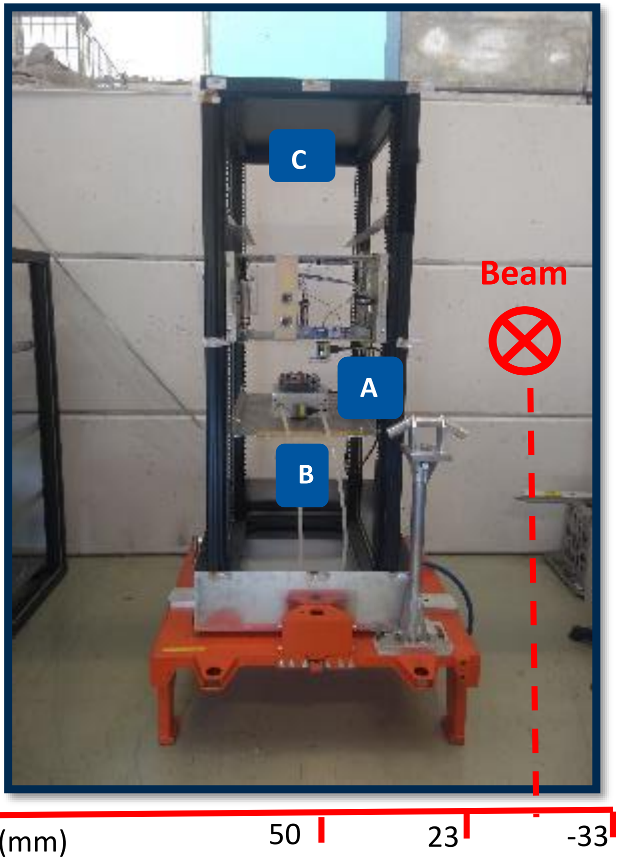


Beam position Influence on the Dose

Position 13 – Cu target

Beam position on the Horiz. axis (mm)	K_{Dose} - Percentage difference with *Centered Run* (%)		
	Position A	Position B	Position C
48.7±0.2	59%	17%	42%
23.0±0.6	27%	22%	43%
1.3±0.4	0%	0%	0%
-33.5±0.8	-43%	-57%	-59%

Position 13

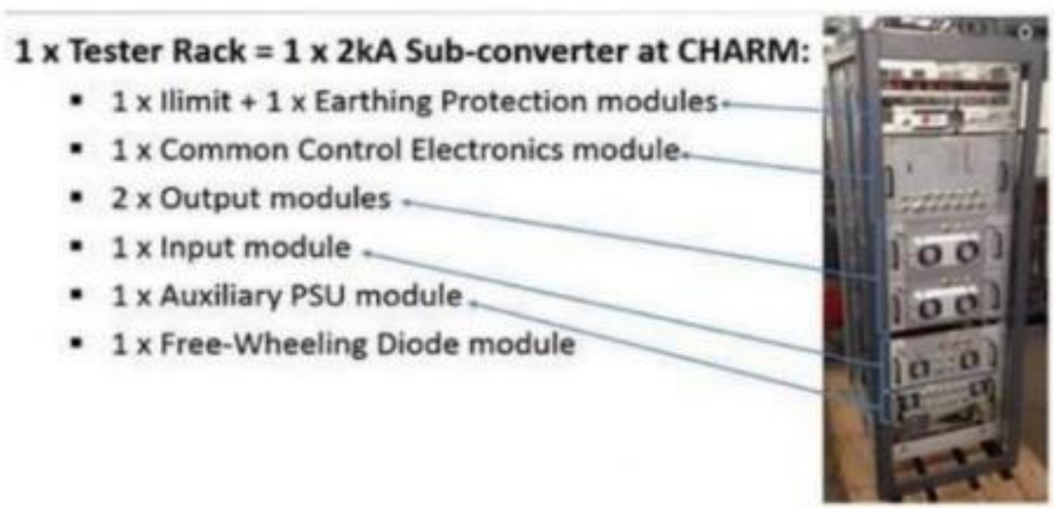


- **The beam position influences the Rad. level measurement.**
- **The K decrease going away from the beam.**
- **This influence is also observed at test location 1 and 16.**

The dose and the fluences on the user's equipment need to be monitored during the test runs.

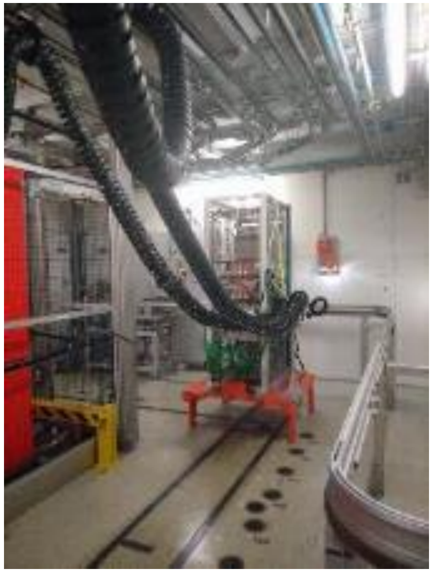
Self shielding effect – R10

Possibility to test large volumes electronic equipment



Self shielding effect – R10

Side A



Side B

TE/EPC Test

POSITION 10 – CUOOOO

Radiation Level	Percentage difference between side A and side B (%) 119 cm
Dose	-34%
HEH	-32%

The dose and the fluences on the user's equipment need to be monitored during the test runs.

CHARM

Boron Carbide shielding employment to protect electronic against ThNs

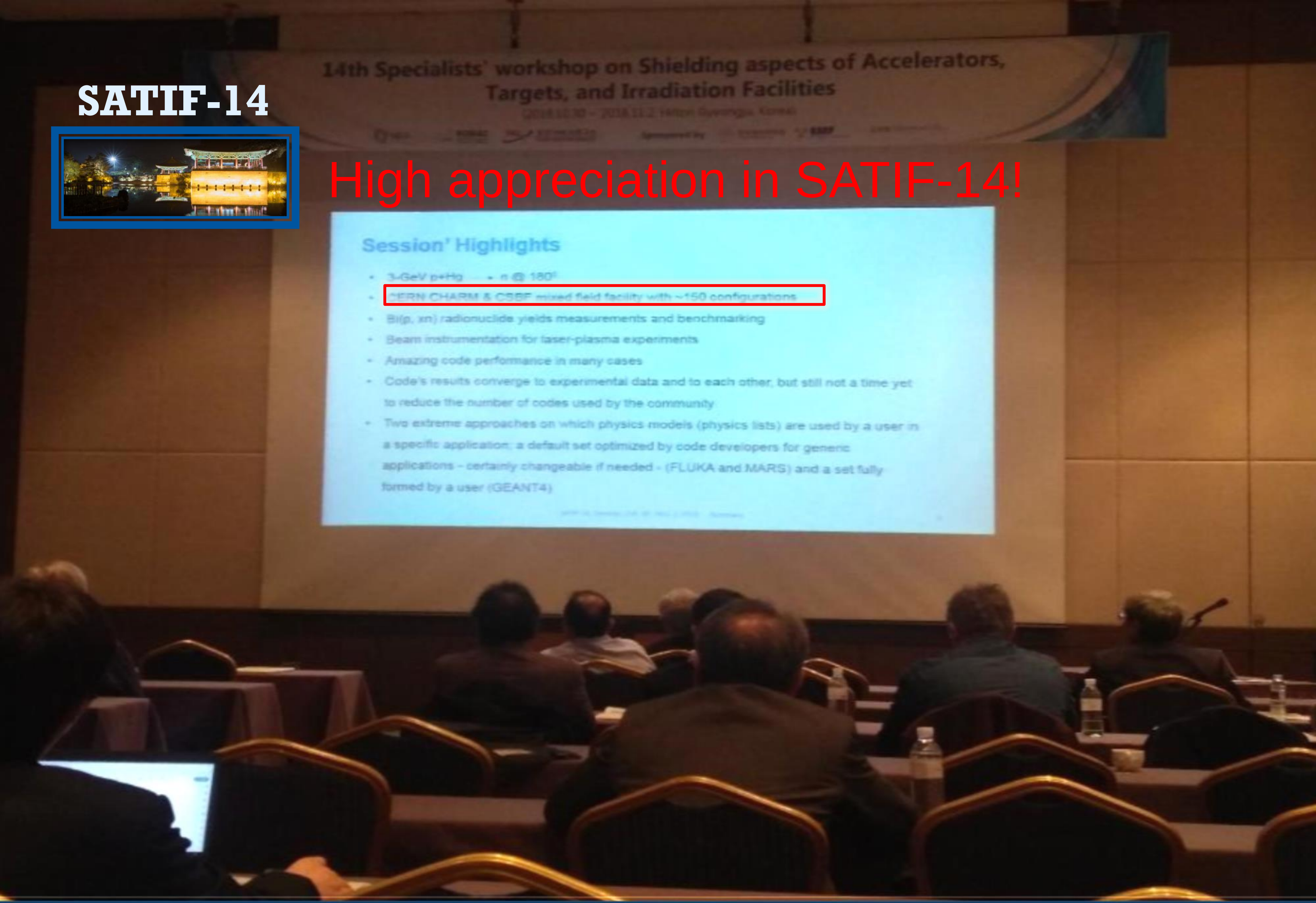
SATIF-14

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

C. Cangialosi et all. “Evaluation of future employment of Boron Carbide shielding at CERN High energy AcceleRator Mixed field (CHARM) Facility”.

SATIF-14

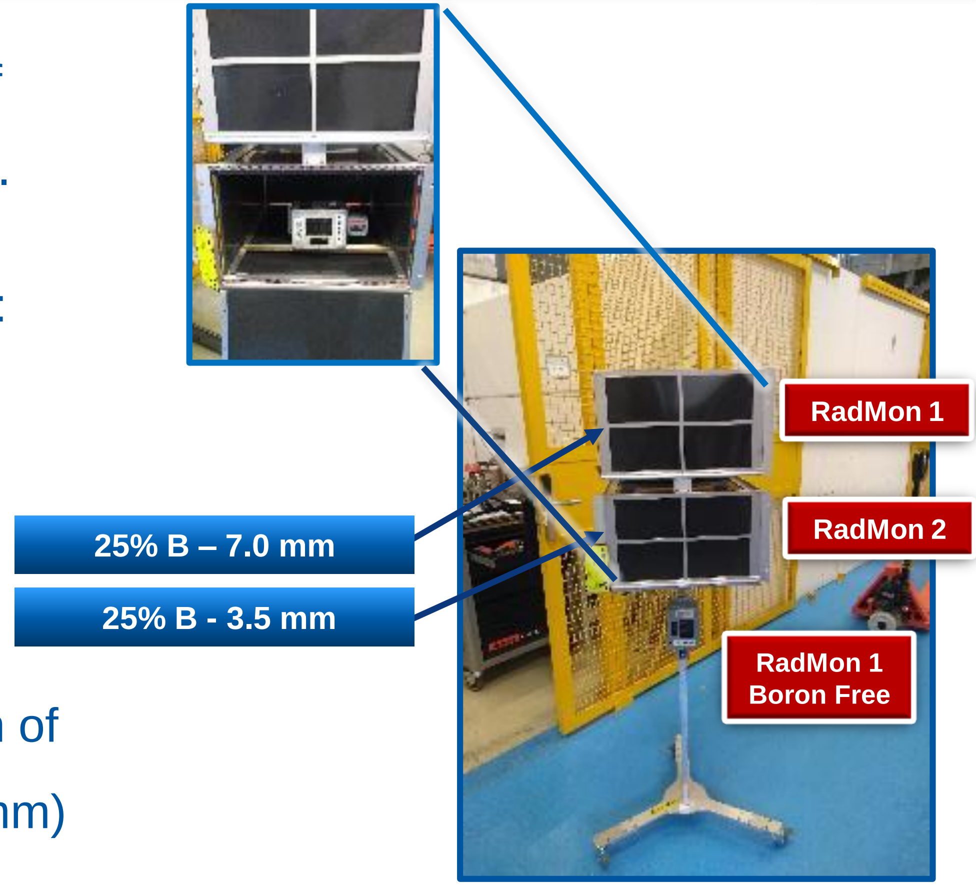
High appreciation in SATIF-14!



Evaluation of a new type of shielding (B_4C)

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

- Comparison of different B_4C 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 B_4C shielding employment at CHARM can improve the facility test capability?

B_4C shielding effect at CHARM

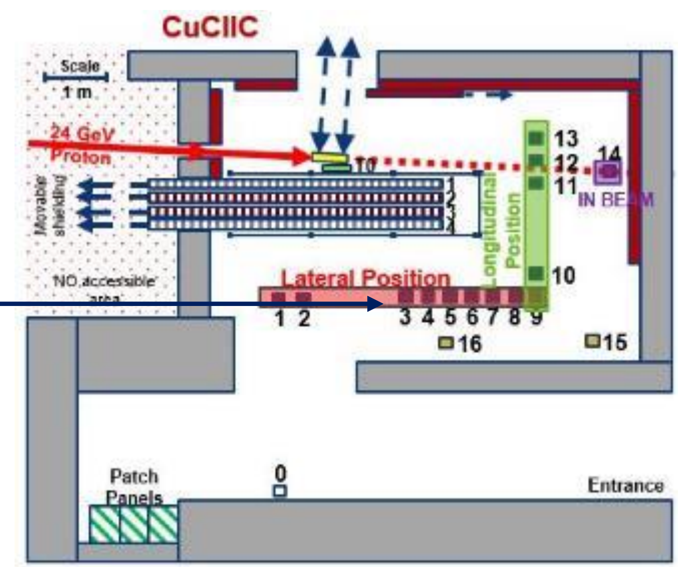
CHARM

$\phi_{HEH}^{Cu} \sim (4 \div 8) \cdot 10^{11}\ cm^{-2}/week$	Position 3				
Facility Configuration	K_{HEH}^{B-free} $[cm^{-2}/POT]$	K_{ThN}^{B-free} $[cm^{-2}/POT]$	R^{B-free}	$\frac{K_{HEH}^{B-free}}{K_{HEH}^{80\%-B}}$	$\frac{K_{ThN}^{B-free}}{K_{ThN}^{80\%-B}}$
CuOOOO	5.15E-05	4.16E-05	0.81	1.06	2.65
CuCIOO	1.15E-05	2.21E-05	1.12	1.08	4.28
CuCIIC	3.15E-06	2.65E-05	8.41	1.03	12.99

POT=Protons impinging on the target

- For a particular configuration the B_4C shielding has no effect on the ϕ_{HEH}. This is observed during all tests presented in this work.
- The B_4C sheet reduces the ϕ_{ThN} a factor:
  - ~3 for CuOOOO
  - ~ 4 for CuCIOO
  - ~13 for CuCIIC
- A similar behavior is observed with the Al target at the same position.

Pos. 3



B_4C shielding effect at CHARM

Position 3							
Facility Configuration	Boron free	80% - B content			25% - B content		
	R^{B-free}	$R^{80\%-B}_{5mm}$	$R^{80\%-B}_{2mm}$	$\frac{R^{80\%-B}_{2mm}}{R^{80\%-B}_{5mm}}$	$R^{25\%-B}_{7mm}$	$R^{25\%-B}_{3.5mm}$	$\frac{R^{25\%-B}_{3.5mm}}{R^{25\%-B}_{7mm}}$
CuOOOO	0.81	0.32	0.31	1.0	0.20	0.24	1.4
CuCIOO	1.12	0.43	0.51	1.2	--	--	--
CuCIIC	8.41	0.66	0.86	1.3	--	--	--

- The B_4C 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 B_4C sheet plays a key role at higher R-factor value.
- In configuration CuOOOO 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_4C sheet an efficient solution to protect the electronics operating in the LHC and in the accelerator-like environment.
- ✓ The B_4C 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_4C 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!

Application

NA62 Experiment

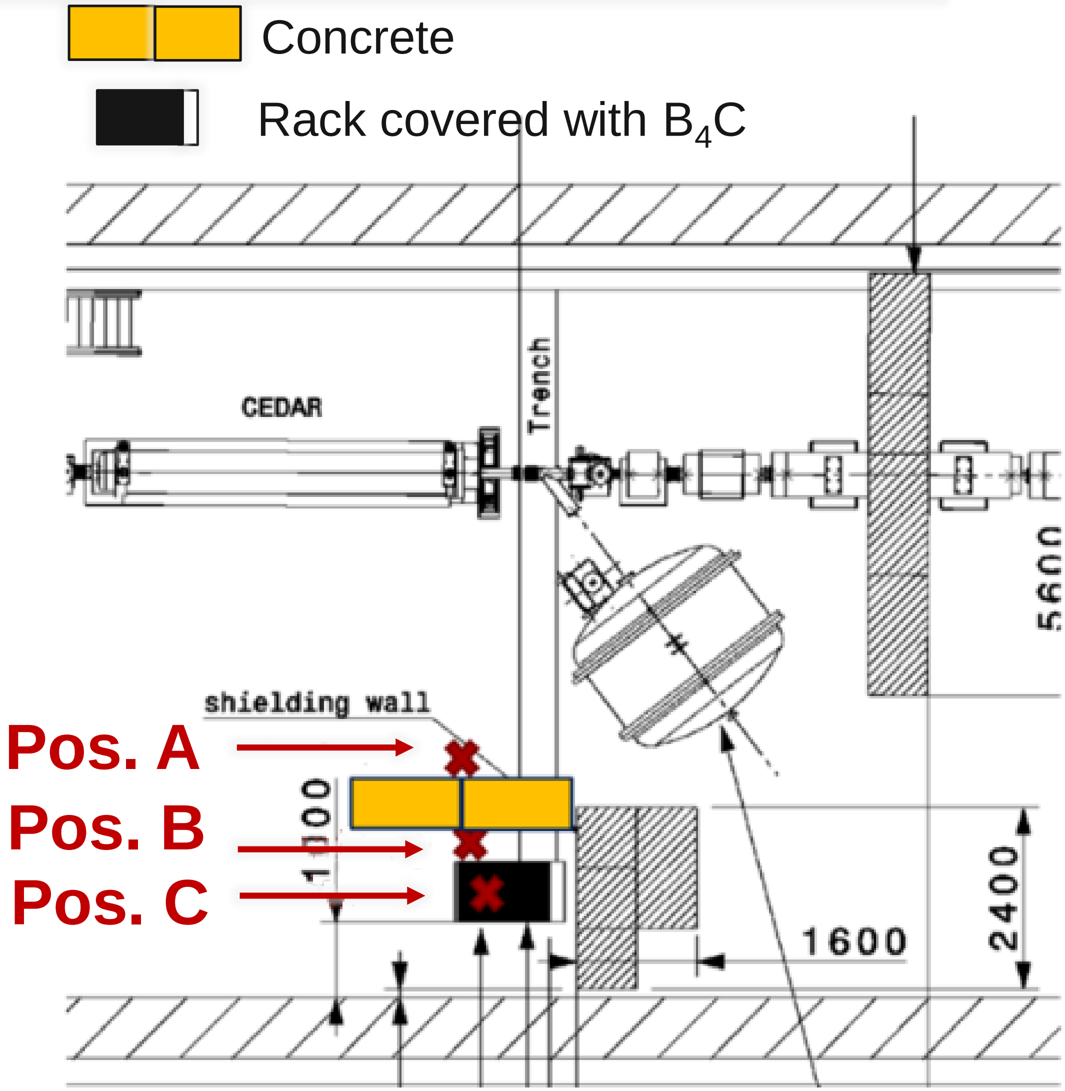
Aim to study rare kaon decays

2017:
several failures in the readout of electronic equipment.

$\Phi_{HEH}\ and\ \Phi_{ThN} \sim 7 \cdot 10^{7}\ pp \cdot cm^{-2}/week$

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

2018:
- Concrete shielding
- B_4C shielding
- BatMon System



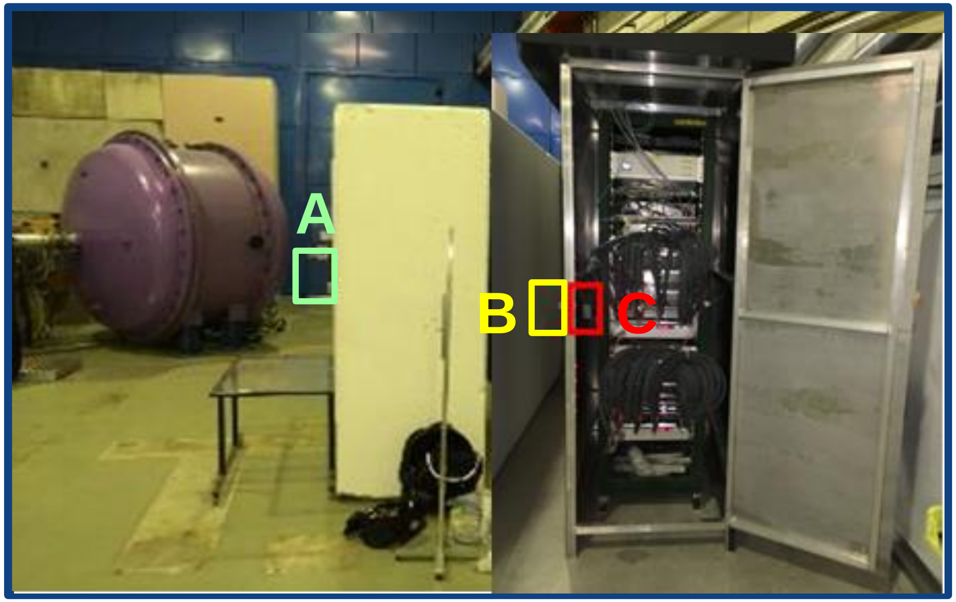
Application

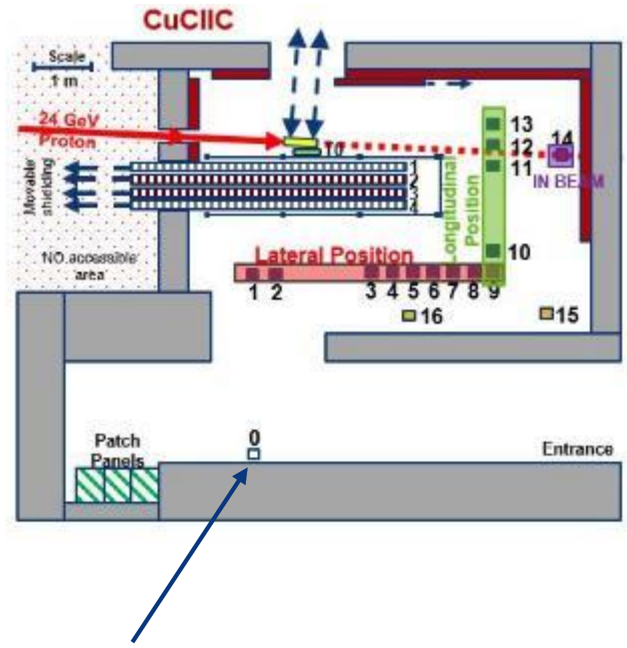
SHIELDING EFFECT EVALUATION		
FLUENCE RATIO	Φ_{HEH} *ratio*	Φ_{ThN} *ratio*
$\frac{\Phi_A}{\Phi_C}$	14.2	28.0
$\frac{\Phi_A}{\Phi_B}$	9.2	2.8
$\frac{\Phi_B}{\Phi_C}$	1.4	12.4

- The **C**o-shielding reduces the Φ_{HEH} by a factor ~10
- B_4C-shielding reduces the Φ_{ThN} by a factor 12

The two shielding are very effective to capture ThN, indeed the Φ_{ThN} is reduced by a factor 28.

Application Vs CHARM





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

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