aMUSE General Meeting - 17 September 2024

WP6 activities:

Irradiation Tests

Anna Ferrari

Helmholtz-Zentrum Dresden-Rossendorf

Partner von DRESDEN concept exzellenz-dresden.de

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

About the goal of the network

Goal: driving knowledge and technology developments in both different branches of research and several industrial applications

- A key point: study of radiation-hardened detector components

  The high level of irradiation dose and neutron flux foreseen at Mu2e-II required an extensive irradiation campaign at the HZDR facility to design analog and digital electronics, photo-sensors, optical fibres, crystals resistant to unprecedented radiation levels

Irradiation tests completed in March 2024

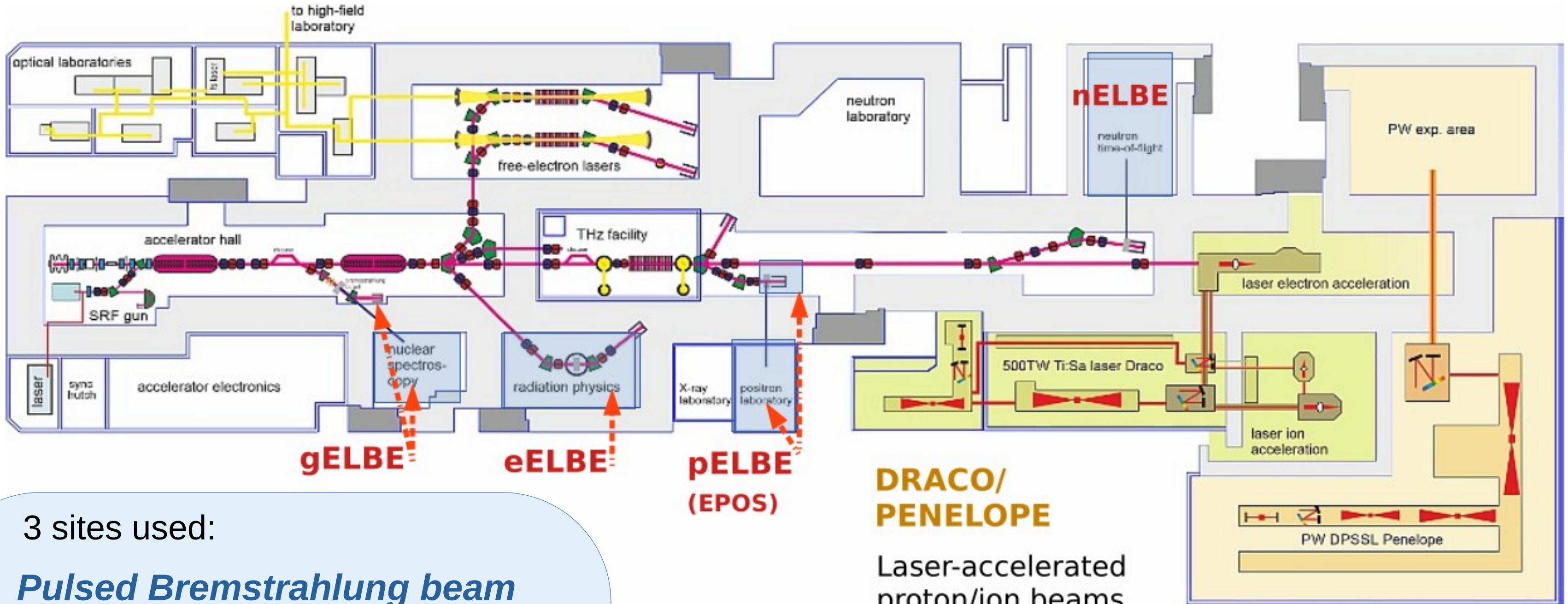
- A second aspect: study of full detector systems in harsh background condition

Irradiation tests completed in 2022

- Inter-multidisciplinary technology transfer: need of pushing frontier technology to fundamental research advancements (laser-plasma science, medical applications, safety research)

Activity of Task 6.3 starts in 2024!

Contribution of the ELBE Center for High Power Radiation Sources to Mu2e



3 sites used:

- ***Pulsed Bremstrahlung beam* in the gELBE experimental cave**
  ~ 2.5 × 10^{7} γ cm^{-2} s^{-1}
  @1 μA e- beam current, E_{e-}=15 MeV
- **High-dose site along the gELBE beamline for TID studies**
  1-2 order of magn. higher γ rate
- **Neutron irradiation site** outside the EPOS cage
  up to 10^{12} n$_{1MeV}$ /cm^{2} in one day

ELBE ("*Electron Linac for high Brilliance and low Emittance*") is based on a superconducting linear accelerator, which accelerates electrons to energies in the interval **[5, 40] MeV** at a beam current of up to **1 mA**

Guiding the electron beam on suitable targets allows the production of secondary radiation:

- in addition to **electrons**, intense **photon, positron and neutron beams** are available to the users in dedicated caves
- a unique feature: **pulsed beams**, with a pulse width between 10 ps and 1 μs, a repetition rate of 26 MHz/2^n (n=1,...,7) and a charge load up to ~77 pC/pulse.

Irradiation campaign at ELBE in 2023-2024

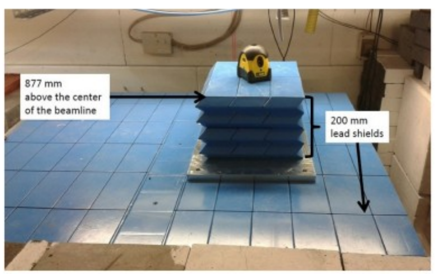
1) Irradiation of crystal and electronics components for Mu2e-II at gELBE
(October 2023)

- Crystals: LYSO, BaF2, LaBr3 and other components
- Request on integrated absorbed dose: 500 krad (1 Mrad as optimal goal) [in Si: 5 kGy / 10 kGy]

Irradiation of Sample 1 of $LaBr_3$ completed in March 2024 with 2 parasitic irradiation

RPL Glas dosimeters sent to CERN for integrated dose measurement

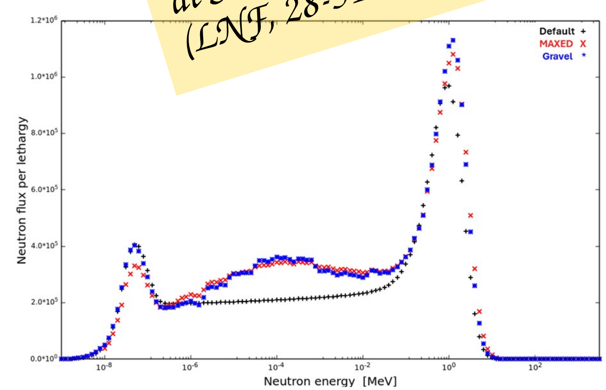
2) Spectral characterization with a Bonner Sphere Spectrometer of the Neutron Irradiation area for radiation hardness studies at the EPOS facility



- The EPOS neutron irradiation area has been well characterized only via Monte Carlo
  from 2016 simulation: ~1.5E^6 n/cm^2 per s @ 10 uA

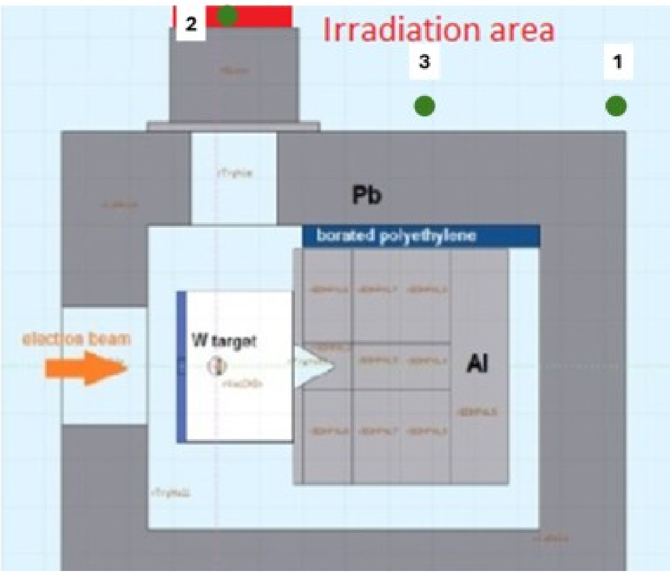
Measurements have been done in 3 dedicated shift system of Bonner spheres (INFN-LNF RP group)

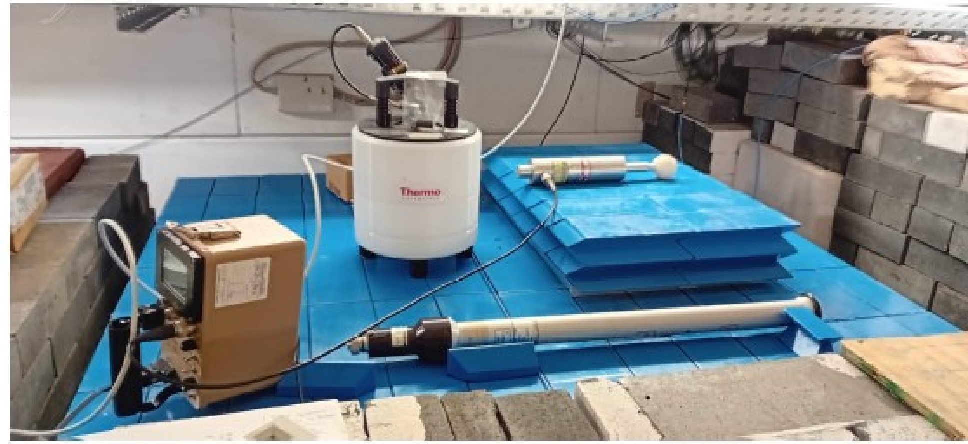
Results presented at SATIF-16 (LNF, 28-31 May 24)



Neutron characterization at the pELBE facility

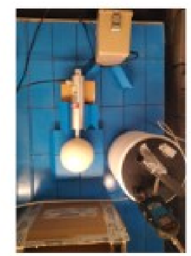
The complete characterization was performed for three different points placed on the pELBE lead roof under the same irradiation conditions, using the BSS of INFN Frascati National Laboratories.






1

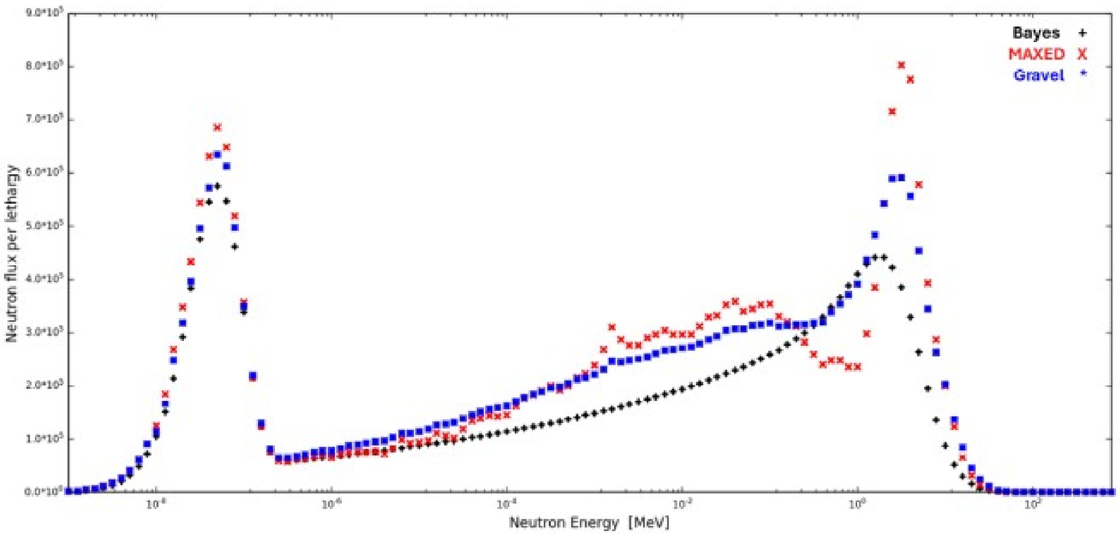

2

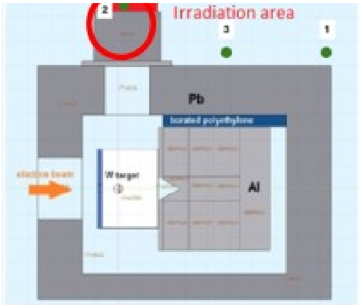

3

Irradiation conditions	
Energy [MeV]	34
Mean current [nA]	2
Neutron Flux [n/ cm²/s]	3 x 10^5
Irradiation time [s]	40-60

Unfolding methods adopted

Point 2

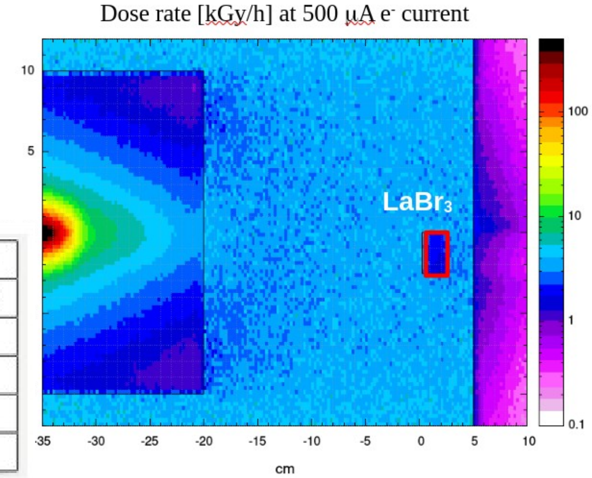




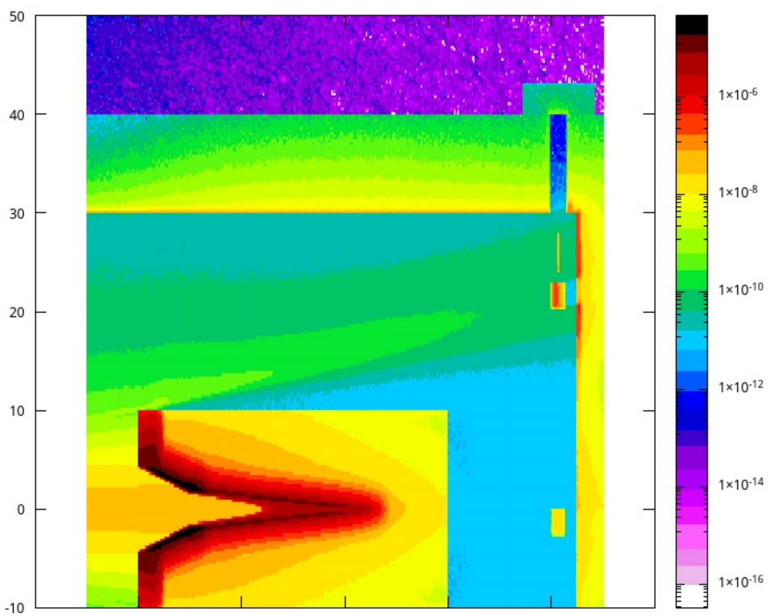
Sphere	Point 2 [cnt]
2''	$(2.222 \pm 0.004) \times 10^5$
2,5''	$(4.499 \pm 0.007) \times 10^5$
3''	$(5.291 \pm 0.008) \times 10^5$
3,5''	$(6.269 \pm 0.009) \times 10^5$
4''	$(6.746 \pm 0.008) \times 10^5$
4,5''	$(7.036 \pm 0.008) \times 10^5$
5''	$(6.849 \pm 0.008) \times 10^5$
7''	$(4.983 \pm 0.007) \times 10^5$
8''	$(4.171 \pm 0.006) \times 10^5$

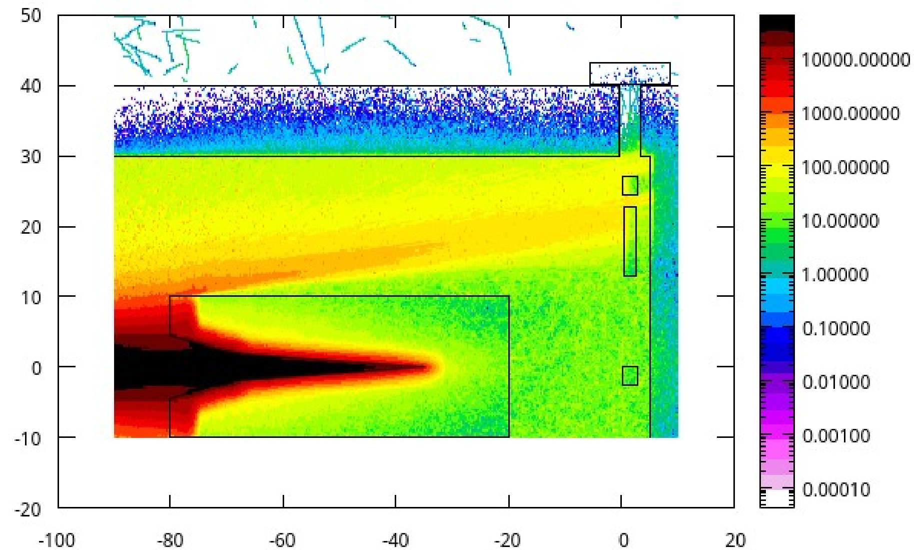
Beamtime results of the last campaigns in a glance

Testing radiation damage to new crystals for Mu2e-II at gELBE



	CsI	LYSO	BaF_2	PbF_2	CRY18	GAGG	LaBr
Light Yield (γ /MeV)	1700	33200	13000, 1700	~20	30000	Up to 50000	63000
Wavelength [nm]	310	420	300,220	-	425	520	380
Decay time [ns]	26	40	600,0.9	-	45	90	16
Density [g/cm^3]	4.51	7.4	4.89	7.77	4.5	6.63	5.08
Radiation length [cm]	1.86	1.14	2.03	0.93	2.74	TBA	1.88



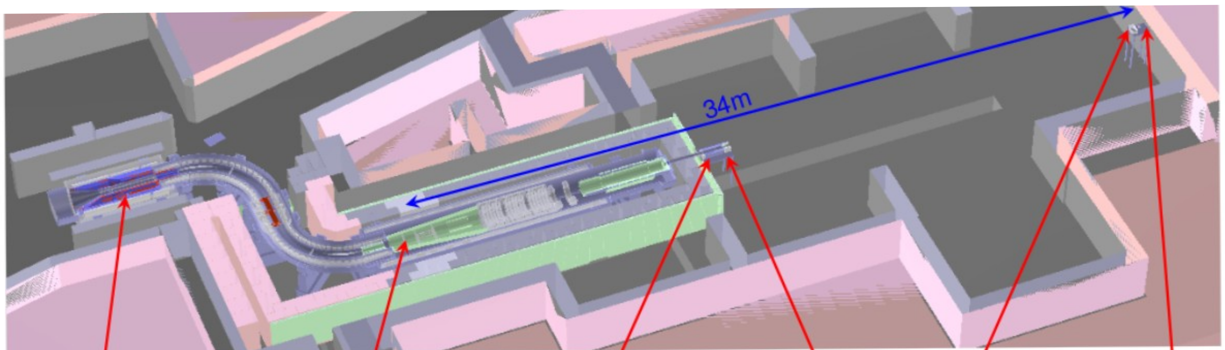


Anna Ferrari I Institute of Radiation Physics / Helmholtz-Zentrum Dresden-Rossendorf I www.hzdr.de

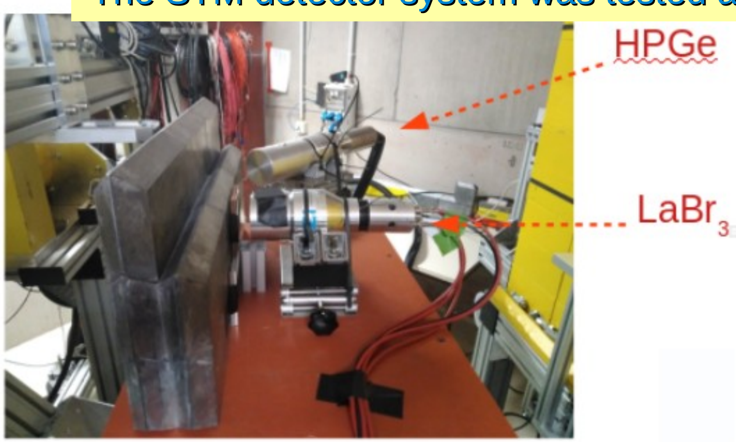
Normalization of signal events: the Stopping Target Monitor

Goal: monitoring the muon capture rate in Aluminum at the 10% level

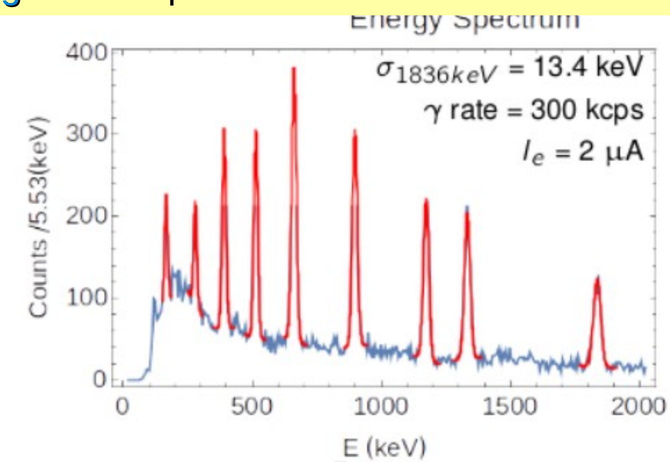
Detector system: High Purity Germanium detector + $LaBr_3$ detector
LaB_3 has worse energy resolution, but can sustain higher rates



The STM detector system was tested at gELBE in pulsed beam conditions similar to Mu2e



HPGe test of energy resolution, radiation damage and sustained rate
Energy resolution between
3 keV and **6 keV**



LaBr3 response to a set of radioactive sources that mimic the X- and γ-ray signals in Mu2e

$LaBr_3$ can handle data taking at twice the expected photon rate
Pulse frequency: **813 kHz**

DRESDEN concept HZDR

Conclusion

- In 2023/2024 we concluded a bunch of Irradiation Campaign at ELBE
- The ELBE High Power radiation sources at HZDR contributed to the Mu2e effort with several beamtime campaigns:

  - to *optimize the detector design of the Stopping Target Monitor* (STM), which will provide the normalization of the final measurement by measuring the total number of muon captures
  - to *study radiation hardness of crystals end electronics* for the Calorimeter system

- We are ready to write the **Deliverable due for October 2024**, with the aim to write a Summary Paper with all the Irradiation Tests performed at ELBE for Mu2e