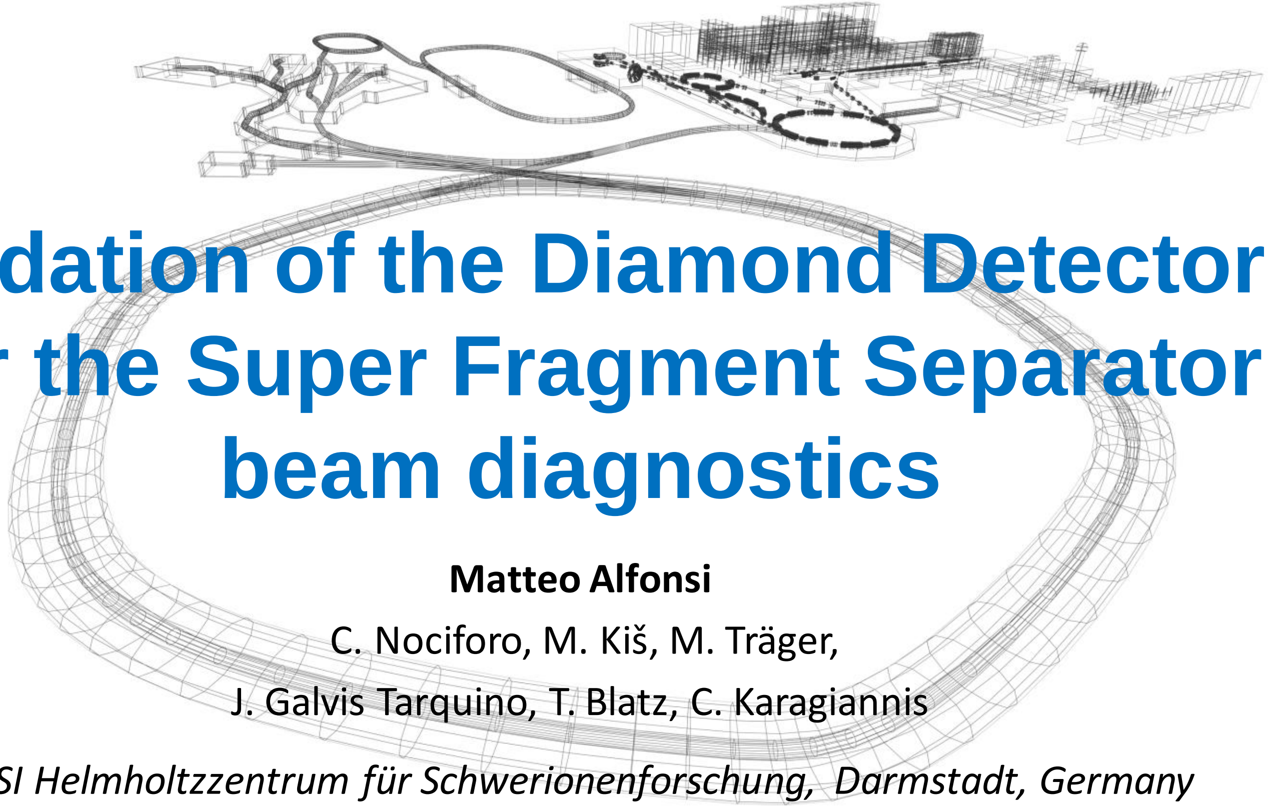

Validation of the Diamond Detectors for the Super Fragment Separator beam diagnostics

Matteo Alfonsi

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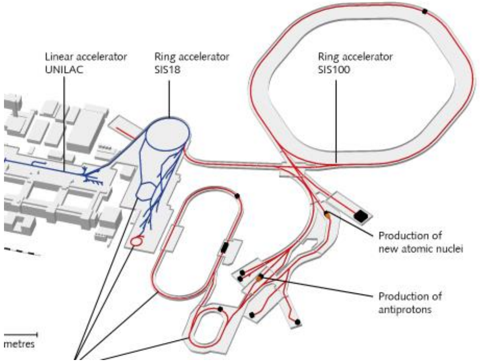
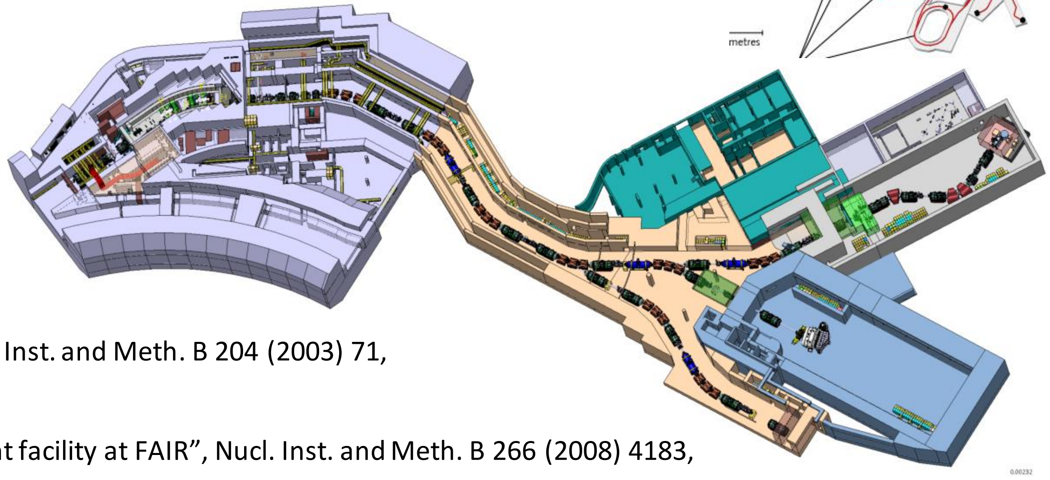
Super Fragment Separator

- Elements from p - U
- Energies up to 1500 MeV/nucleon
- Intensities up to 10^{12} /s (depending on element)
- DC or pulsed operation

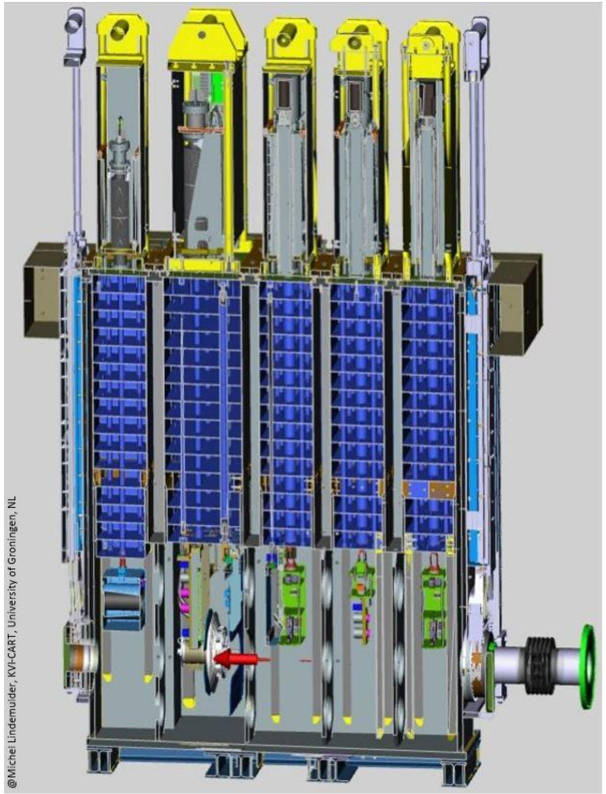




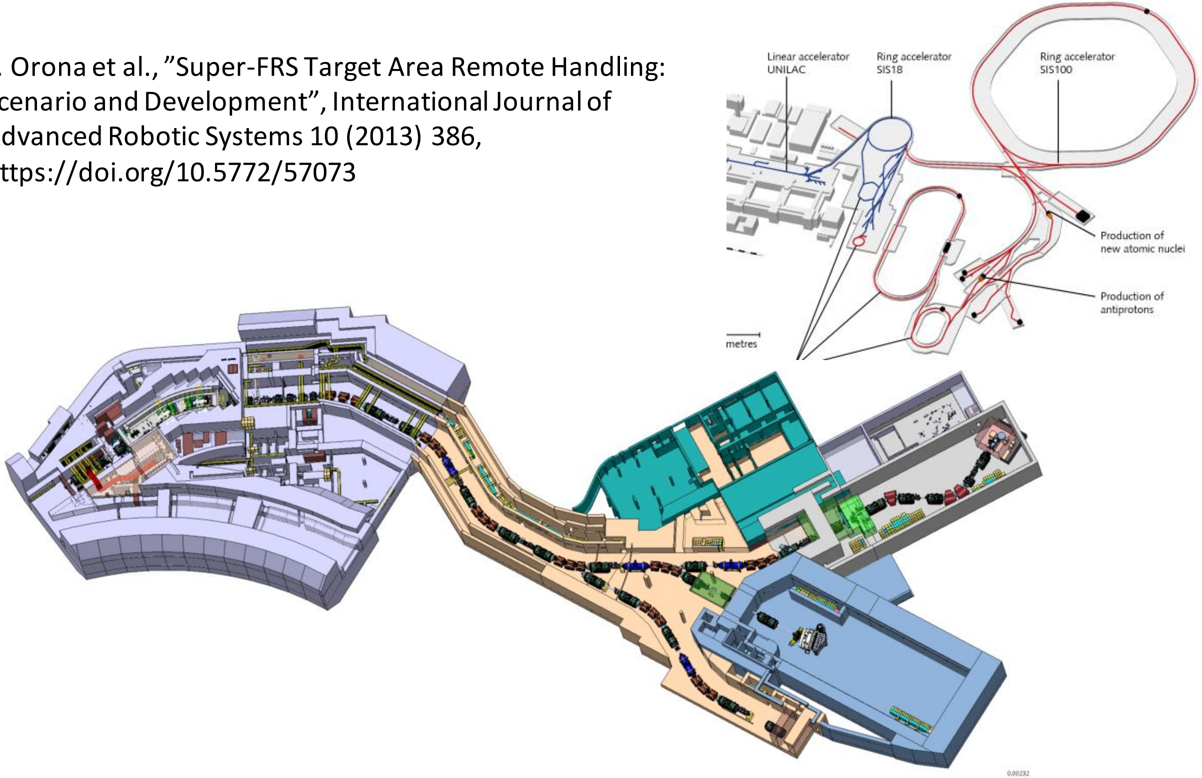
H. Geissel et al., “The Super-FRS project at GSI”, Nucl. Inst. and Meth. B 204 (2003) 71, https://doi.org/10.1016/S0168-583X(02)01893-1

M. Winkler et al., “The status of the Super-FRS in-flight facility at FAIR”, Nucl. Inst. and Meth. B 266 (2008) 4183, https://doi.org/10.1016/j.nimb.2008.05.073

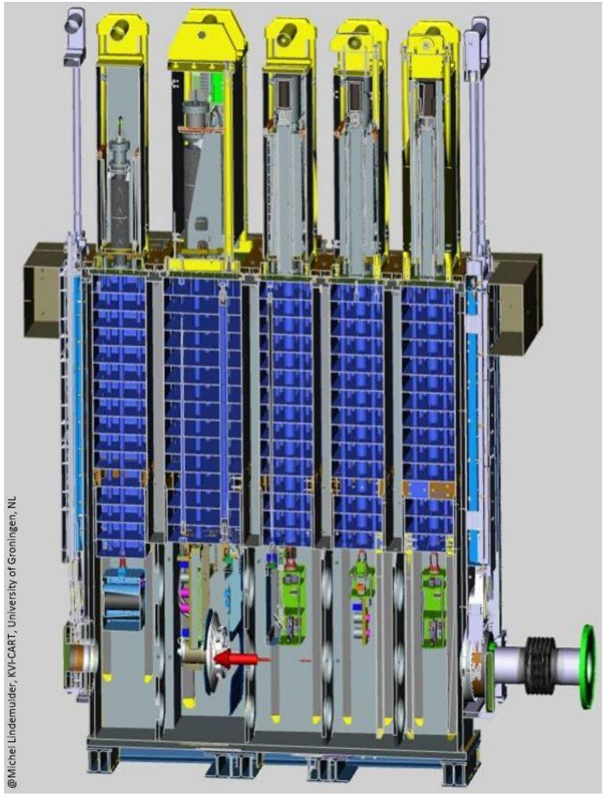
Target area



L. Orona et al., ”Super-FRS Target Area Remote Handling: Scenario and Development”, International Journal of Advanced Robotic Systems 10 (2013) 386, https://doi.org/10.5772/57073

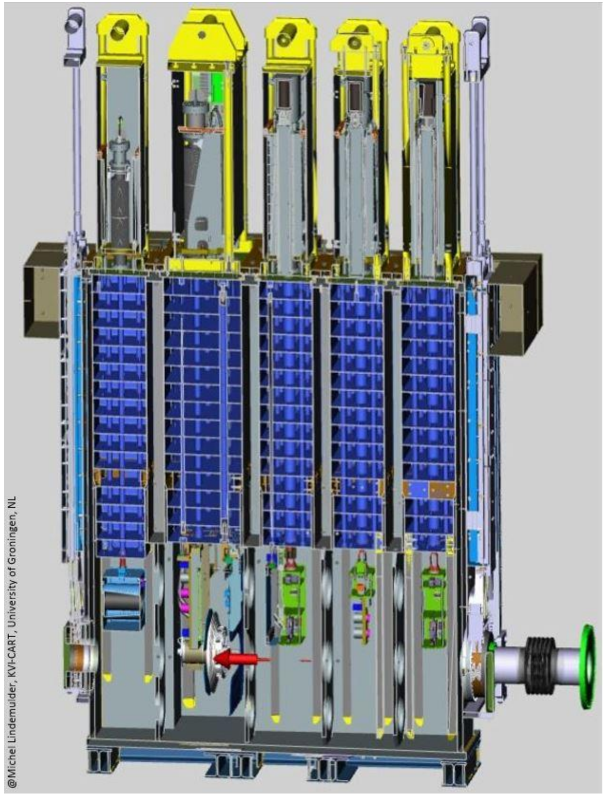


Target area

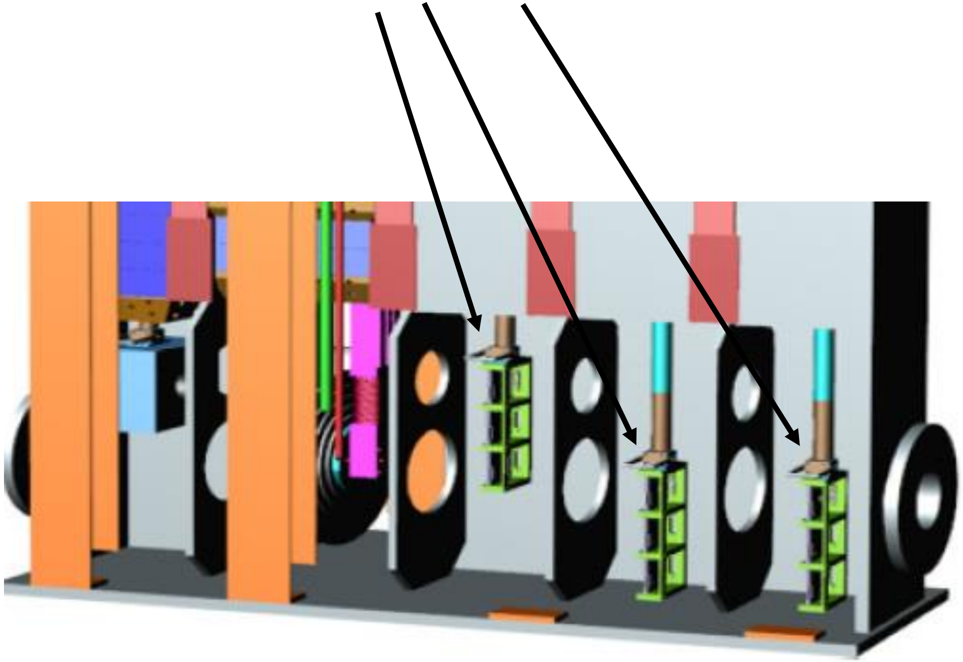


- Extremely high radiation requires thick shielding and special handling concepts
- Detectors must implement sturdy designs
- Amplifiers can be placed only outside, signals can be amplified only after ~15 m of transmission line.
- Detectors here must monitor **primary beam** intensity and profile in front of the target wheel.

Intensity monitor detectors

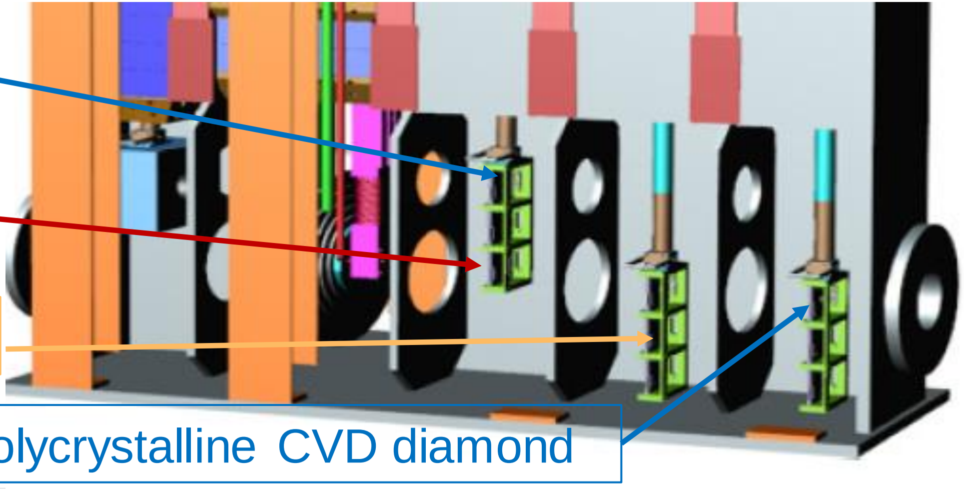


Slots for beam diagnostics devices



Intensity monitor concept

- Intercalibration between detectors:
  1. Small single crystal CVD diamond calibrates the larger area polycrystalline
  2. The polycrystalline CVD diamond calibrates the Ionization Chamber (for mid-high rate monitor) and the SEETRAM (for the highest intensity)



Diamond detectors R&D

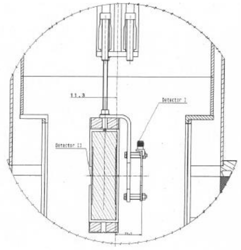
- The group already involved in the development of diamond detectors
- Polycrystalline diamonds are the only options for sizes > 20x20 mm^2
- Various characterization and irradiation campaigns already performed* **

- Here I report the irradiation and campaign with heavy ions (Pb & U)
- Performed at the GSI Fragment Separator in February and March 2021

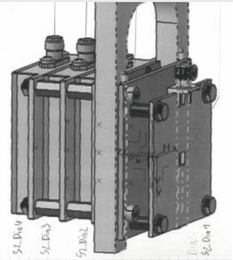
* S. Schlemme et al., “Long-term exposure of a polycrystalline diamond detector irradiated by 62 MeV/nucleon carbon beams”, Diamond and Related Materials 99 (2019) 107536, https://doi.org/10.1016/j.diamond.2019.107536

** F. Schirru et al., “Evaluation of the counting efficiency of a pcCVD diamond detector irradiated by 62MeV/nucl. carbon beams”, JINST 15 (2020) C04040 https://doi.org/10.1088/1748-0221/15/04/C04040

Irradiation Test Setup @ FRS

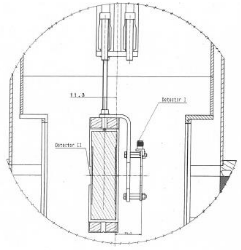


Ionization chamber (IC), Polycrystalline diamond (pcDIA) to be irradiated

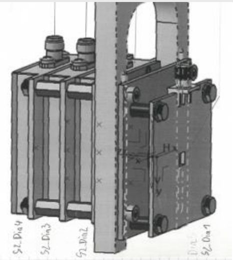


Stack of single-crystal diamond (scDIA) used as trigger

Irradiation Test Setup @ FRS



Ionization chamber (IC), Polycrystalline diamond (pcDIA)

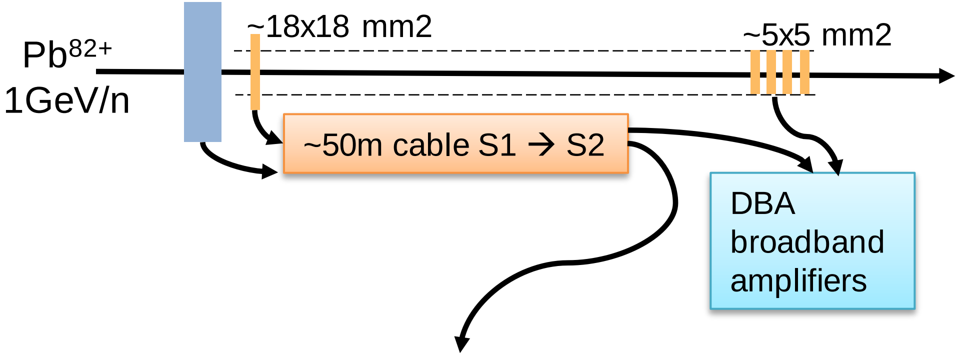


Stack of single-crystal diamond (scDIA), plastic scintillator, used as trigger

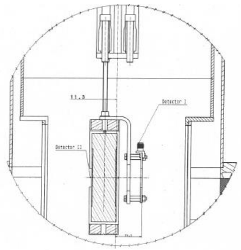
- Electronics at S2, amplifier only after long cable

S1 focal plane

S2 focal plane

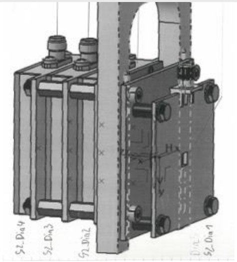


Irradiation Test Setup @ FRS



Ionization chamber (IC), Polycrystalline diamond (pcDIA)

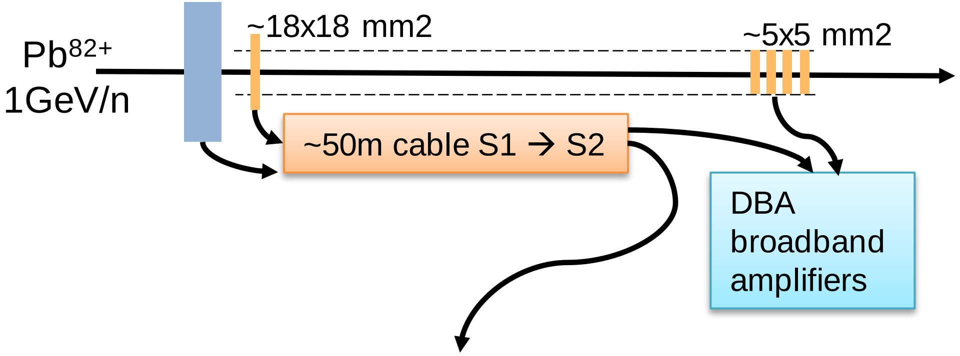
S1 focal plane



Stack of single-crystal diamond (scDIA), plastic scintillator, used as trigger

S2 focal plane

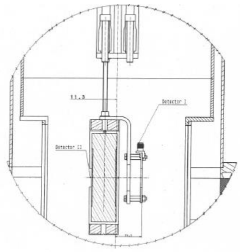
- Electronics at S2, amplifier only after long cable



To ensure no damage to the trigger and reference detectors during high irradiation periods, two steps:

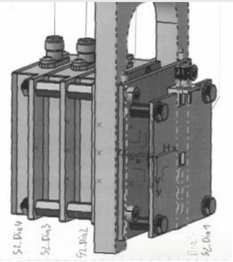
1. Move out of beam the diamond stack drive
2. Dump the beam before it reaches the S2 focal plane

Irradiation Test Setup @ FRS



Ionization chamber (IC), Polycrystalline diamond (pcDIA)

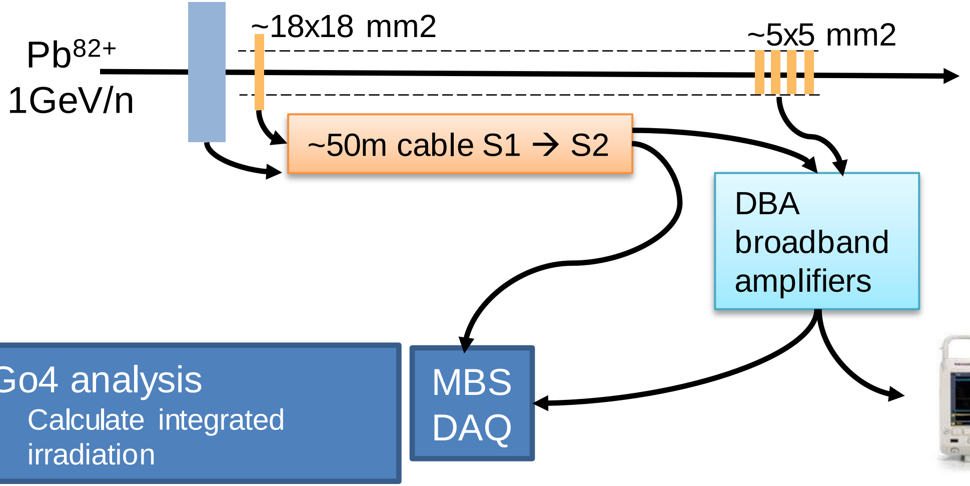
S1 focal plane

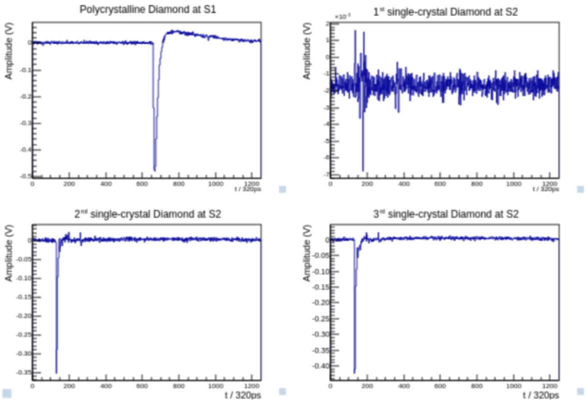


Stack of single-crystal diamond (scDIA), plastic scintillator, used as trigger

S2 focal plane

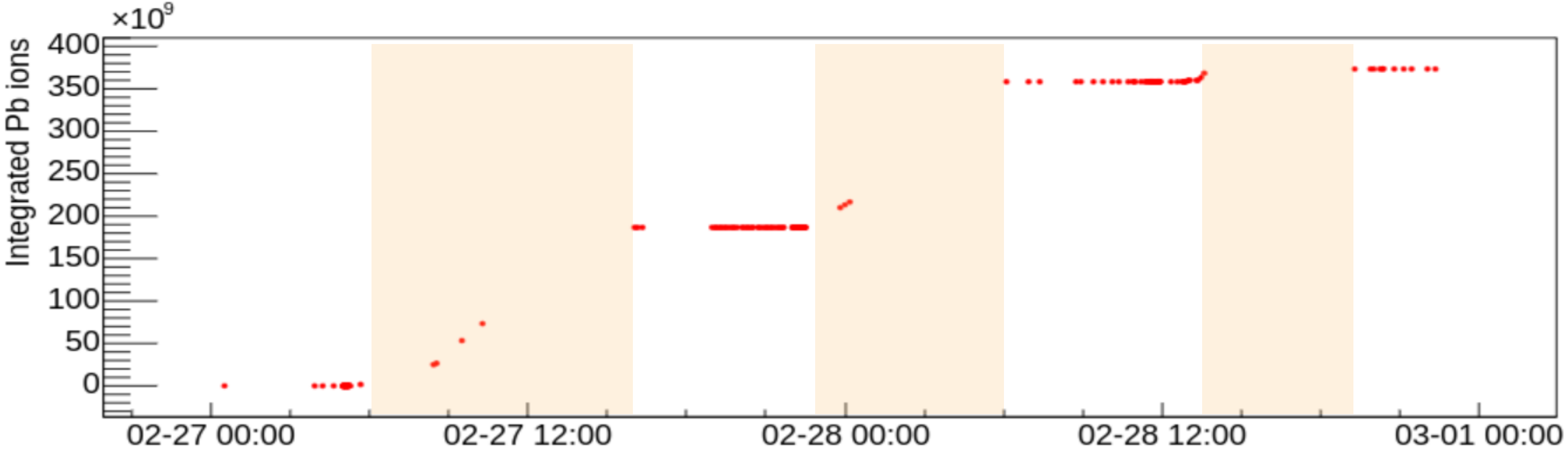
- Electronics at S2, amplifier only after long cable
- Both MBS DAQ & waveform saving





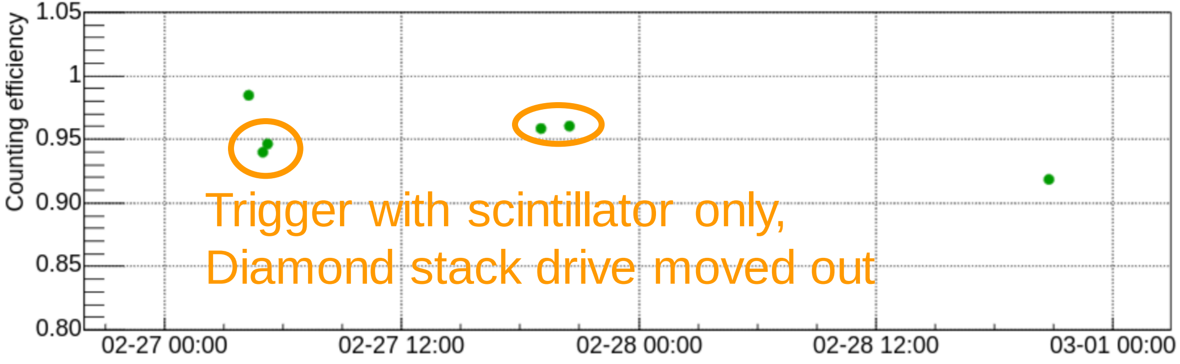
Irradiation accounting

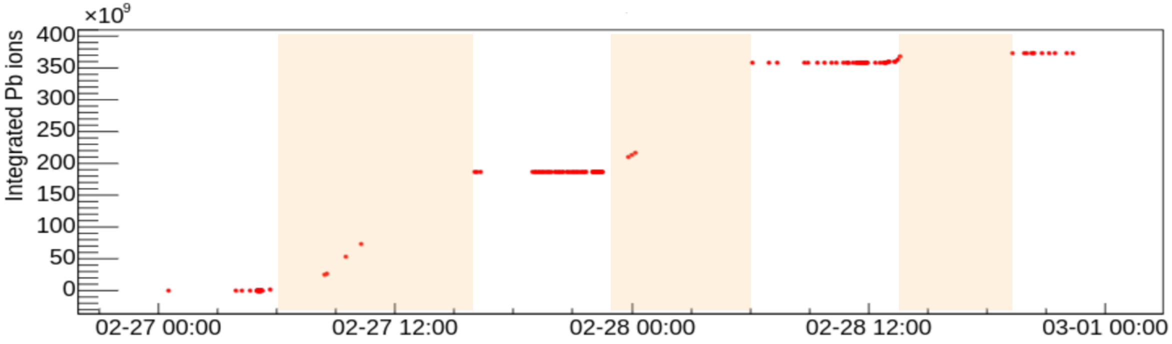
- Crossing particle counted with the plastic scintillator in S2 when possible, then the (inter-calibrated) ionization chamber and another FRS SEETRAM at S1



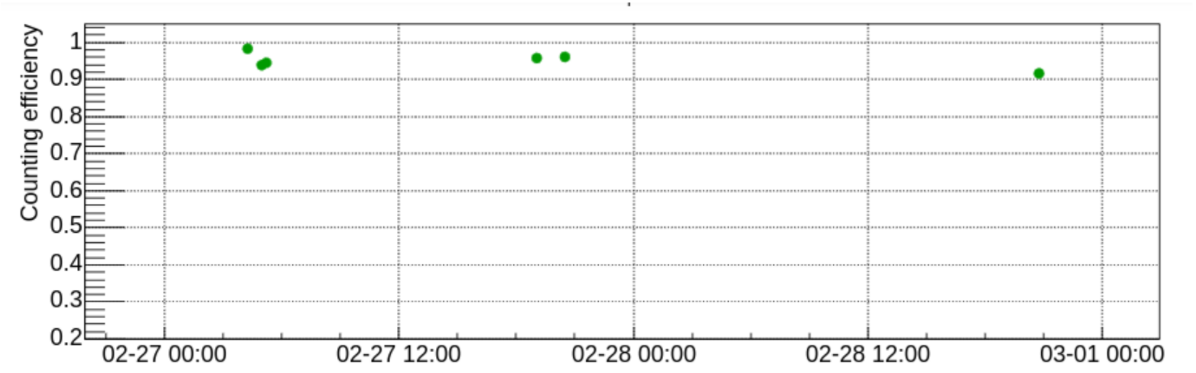
- At the end of March another irradiation of about 3×10^{10} U ions

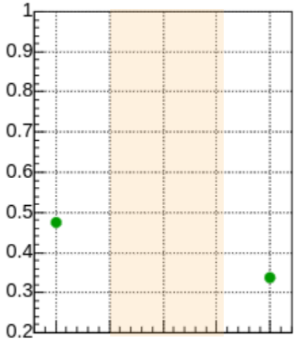
Counting efficiency @ ~1V/µm





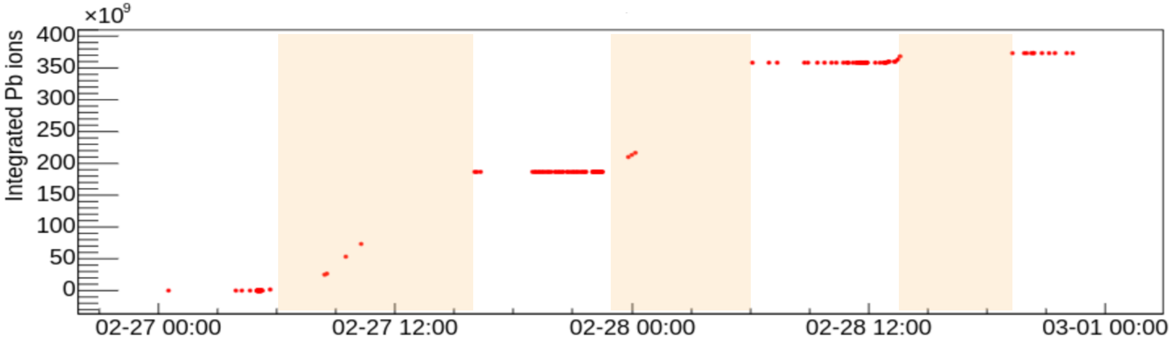
Counting efficiency @ ~1V/µm



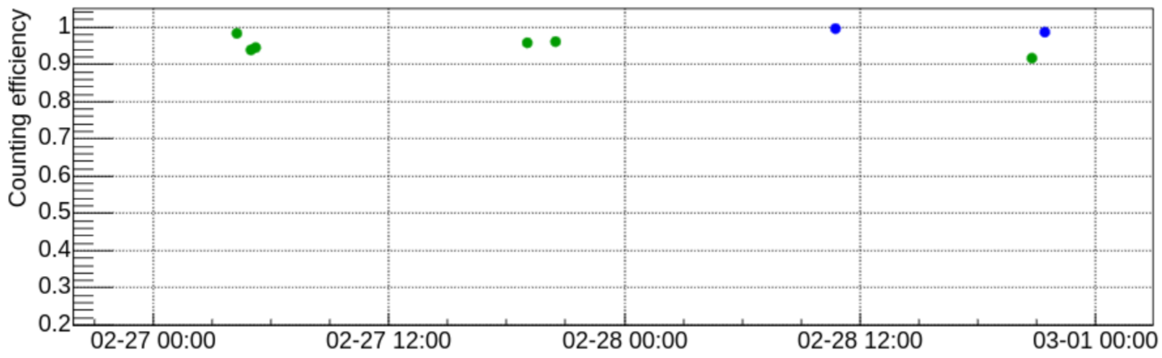


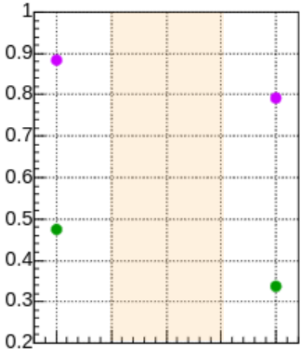
March

N.B. reduced amplifier gain by a factor 2.67 !!!



Counting efficiency





March

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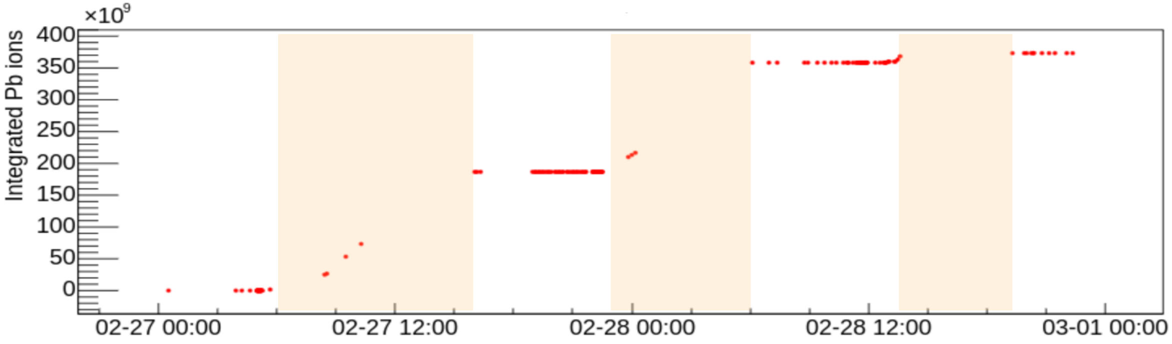
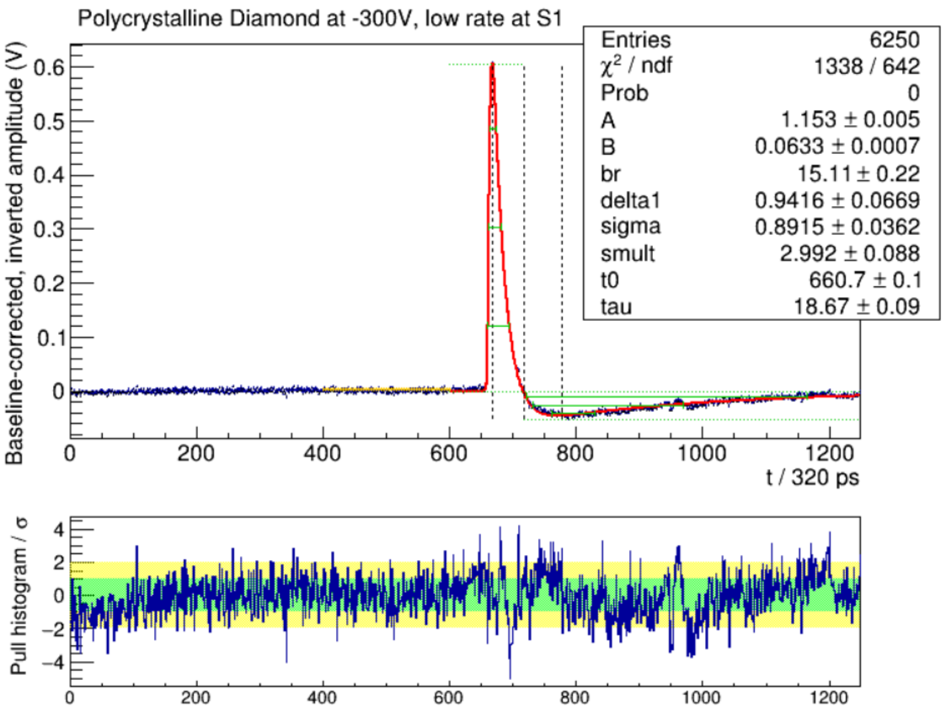


HV -2.0V/µm

HV -1.5V/µm

HV -1V/µm

Waveform analysis



$$f(t|A,B,b_r,\delta_1,\sigma,s_m,t_0,\tau) = \frac{A\left(e^{-\frac{t-t_0}{\tau}} - Be^{-\frac{t-t_0}{\tau \cdot b_r}}\right)}{\left(1+e^{-\frac{t-t_0}{\sigma}}\right)\left(1+e^{-\frac{t-t_0-\delta_1}{\sigma \cdot s_m}}\right)}$$

- A decrease on the amplitude is observed also from the waveform analysis

Conclusion and outlook

- Polycrystalline diamond counting efficiency decreases after high irradiation of heavy ions.
- A possible approach can be to use higher voltages to postpone the replacement of the detector
- The possibility to inter-calibrate with a single-crystal diamond allows to monitor the degradation of the performance

- We are investigating also alternative technologies, e.g. in the same beam period a Diamond on Iridium sample was measured together with the trigger diamond stack