WP6 : Quantitative estimates of shielding effectiveness with GCR/SPE simulator

CERN, 20.01.2023

HEARTS Kick-off Meeting

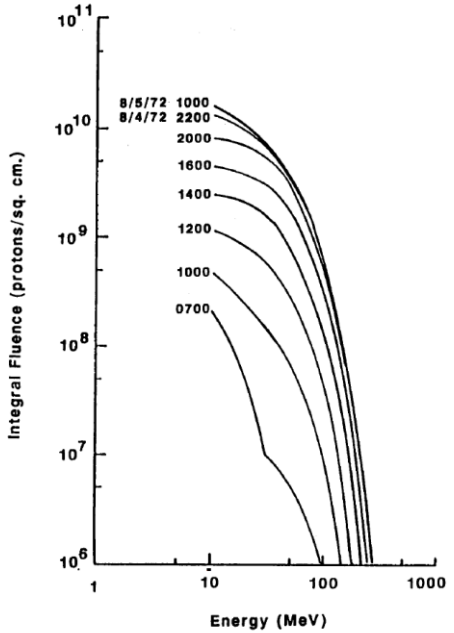
https://indico.cern.ch/event/1216205/

Christoph Schuy / GSI

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under GA No 101082402.

Space radiation

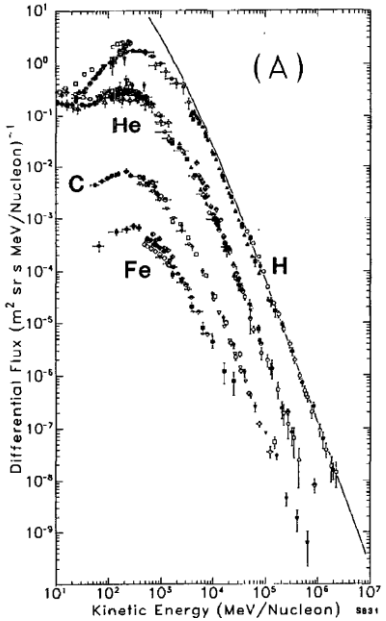
Solar particle event (SPE)



Townsend et al., Adv, Space Res. 1992

- sporadic
- mostly protons
- high flux
- max energy ≈ hundreds of MeV

Galactic cosmic rays (GCR)



Simpson et al., Ann. Rev. Nucl. Part. Sci. 1983

- chronic
- mostly heavy ions up to iron
  - negligible flux of heavier elements
- low flux
- up to extremely high energies ≈ tens of GeV/n

State-of-the-art

- High-energy heavy ion accelerator
  - (serialized) mono-energetic irradiations with a single ion species

➔ proxy used for extrapolation to space-like radiation

Complexity of proxy beams << Space radiation

Picture by David Carron at English Wikipedia

State-of-the-art

Space radiation simulation (GCR)

Implemented at NSRL
L. Simonsen et. al, PLoS, Biol 2020

	active
# of ion species	Multiple (e.g. P, ^{4}He, ^{16}O, ^{28}Si and ^{56}Fe)
Energies	Multiple each (e.g. 500, 900 and 1500 MeV/u)
Fragmentation targets	Simple (e.g. PE slab targets)

- high setup time
- high irradiation time
- field complexity per single irradiation low

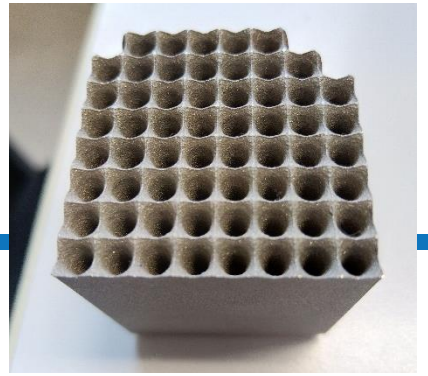
Proposed by Schuy et. al

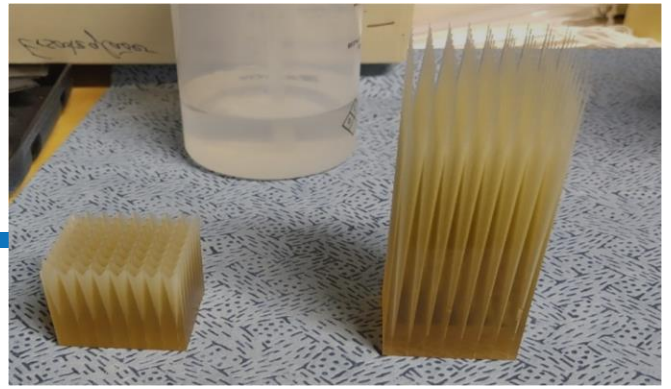
hybrid
One (^{56}Fe)
Multiple 350, 700,1000 MeV/u
Multiple (complex)

- reduced setup time
- fast irradiation speed
- high field complexity per single irradiation

C. Schuy, U. Weber and M. Durante
Front. Phys., 2020

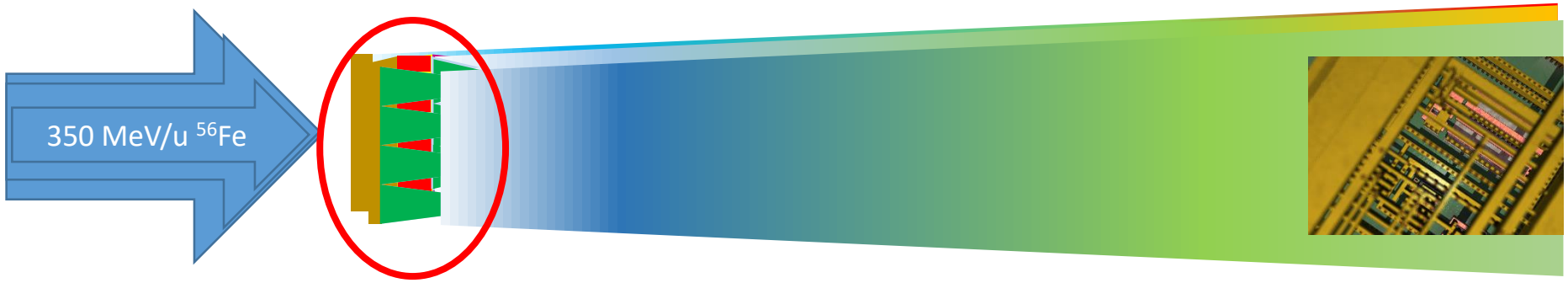
Basic hybrid GCR/SPE simulation





example for GCR

Irradiation 2:
Irradiation 3:



Benefits (GCR)

- three energies of a single ion species
- only three irradiations per target
- complex, fragmented field per irradiation

Benefits (SPE)

- single energy and single irradiation

Technical limitations

- stray radiation
- new modulator optimization and production if different field is required or energies are extended/changed

WP 6 timeline

Activities in WP6 span the full length of the project

M18
M19

WP6 \ Year	1	2	3	4
Task 6.1: Standardized setup for GR/SPE simulation experiments				
Task 6.2: Quantitative measurement of shielding effectiveness				
Task 6.3: Radiobiological characterization				

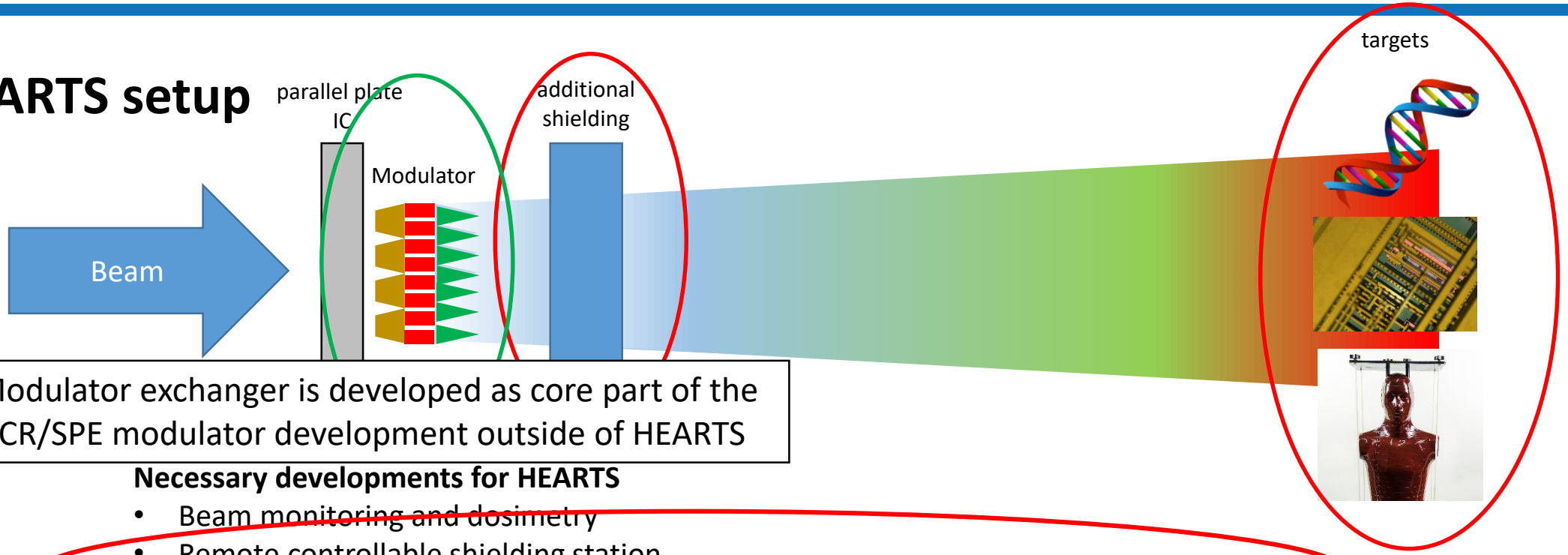
D6.1 D6.2 D6.3

- D6.1: GCR/SPE simulator setup
- D6.2: Dosimetry of the GCR/SPE simulator with shielding
- D6.3: Radiobiology of the GCR/SPE simulator with shielding

- M18: First experimental demonstration of dose increase behind thick shielding in Europe
- M19: Achievement of TRL6-7 for SIS18 GCR/SPE simulator

Task 6.1
Standardized setup for GCR/SPE simulation experiments

HEARTS setup



Modulator exchanger is developed as core part of the GCR/SPE modulator development outside of HEARTS

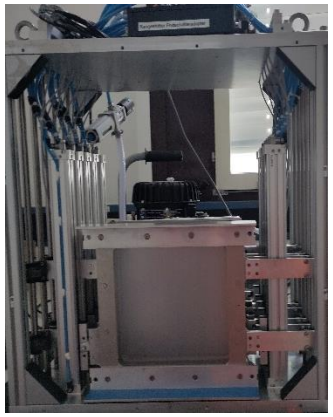
Necessary developments for HEARTS

- Beam monitoring and dosimetry
- Remote controllable shielding station
- Remote controllable (X/Y/Rotation) target station with standardized interfaces
  - biological samples
  - RANDO-like phantoms
  - electronic boards
- Implementation of output signals for external experimenters

Task 6.1
Standardized setup for GCR/SPE simulation experiments

Shielding and Target station

Flask exchanger

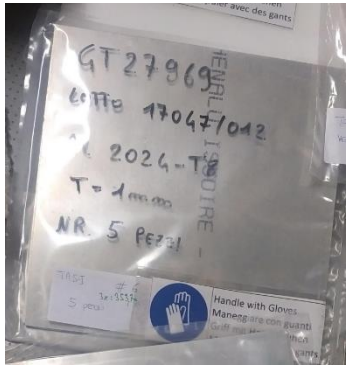


Range shifter

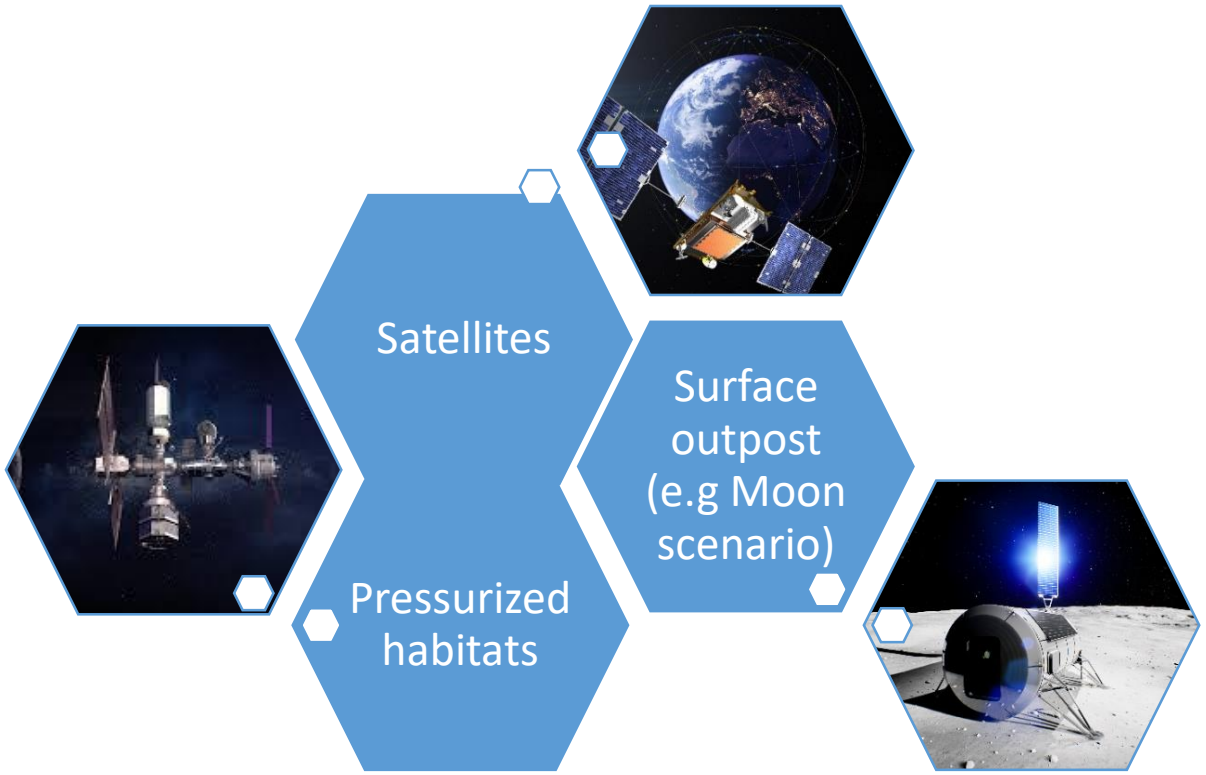
- In-house experience in producing automatic beam components
- Overall design and definition of suitable shielding materials, target station interfaces, etc. will be done in close collaboration with **TAS** and based on experience with previous projects like **RADNEXT** and **ROSSINI**

Task 6.1
Standardized setup for GCR/SPE simulation experiments

The setup will also allow the simulation of different space mission scenarios



Example of ROSSINI space materials (Al & moon concrete samples)



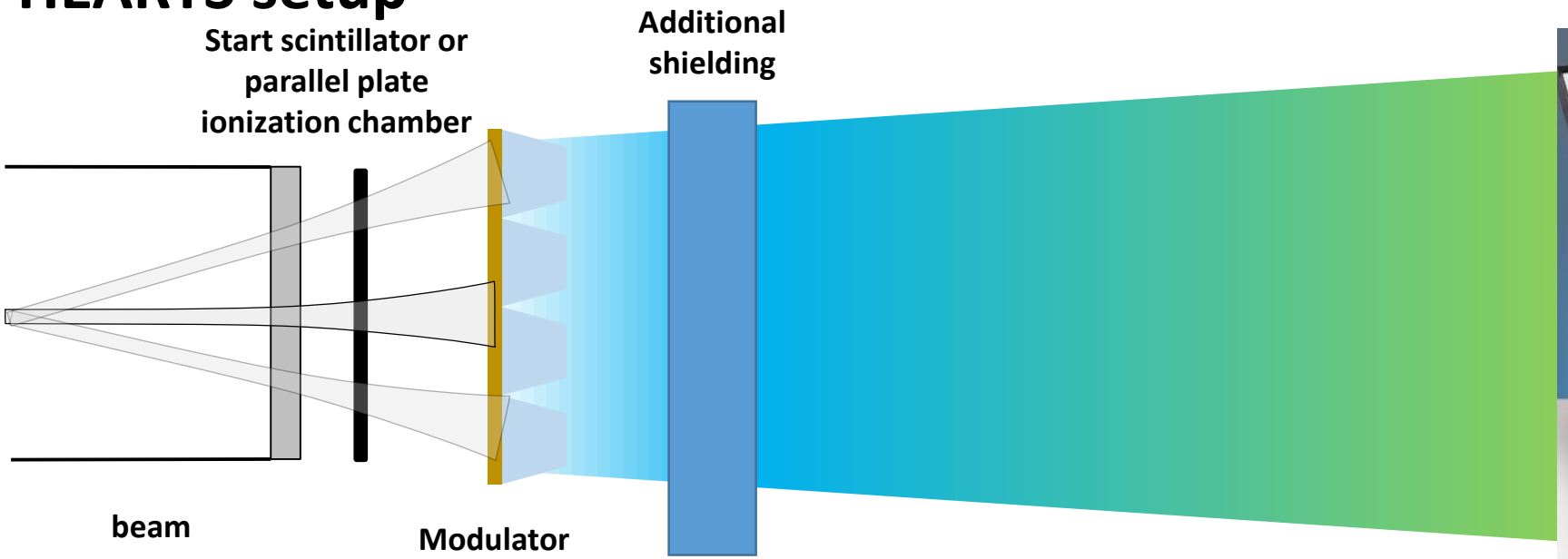
Anatomical phantom

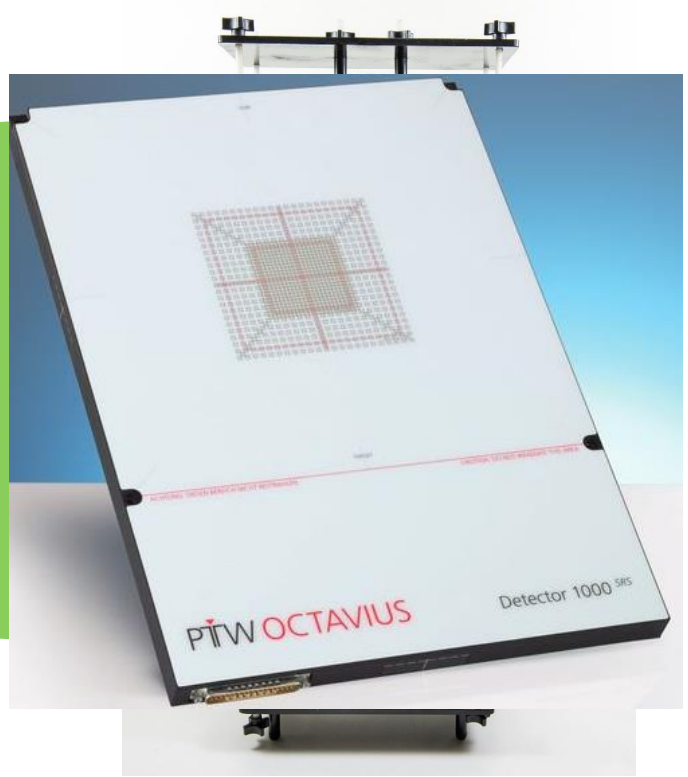
Personal/wearable shielding solutions testing

➔ D6.1: GCR/SPE simulator setup

Task 6.2
Quantitative measurement of shielding effectiveness

HEARTS setup



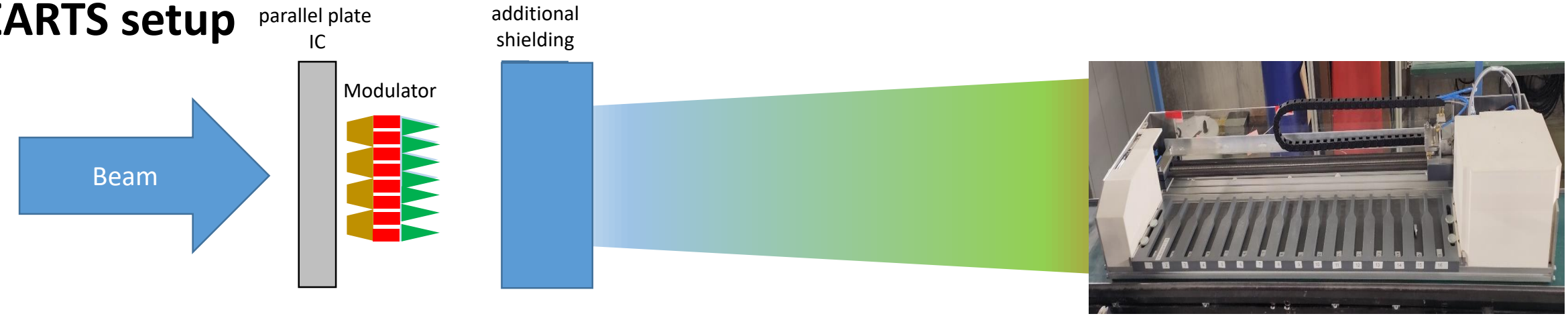


- Characterization of complex radiation fields
- Detailed characterization plan as well as Monte Carlo comparison will be designed in close collaboration with **TAS**

➔ D6.2: Dosimetry of the GCR/SPE simulator with shielding

Task 6.3
Radiobiological characterization

HEARTS setup



- Normal mammalian cell line model (typically CHO)
- Measurement of the RBE with and without additional shielding compared to standard X-rays
- RBE as a function of shielding thickness (can the equivalent dose even increase with thick shields?)
- In future the experiment can be reproduced in an animal model

➔ D6.3: Radiobiology of the GCR/SPE simulator with shielding

WP6 – personnel allocation

Christoph Schuy	6.1	20
	6.2	30
Tim Wagner	6.1	10
	6.2	10
HEARTS radiobiology post-doc	6.3	100
Marco Durante	6.1	20
Uli Weber	6.1	10
HEARTS engineer	6.1	30
Luca Bocchini	6.1 – 6.2	10
Claudio Cipriani	6.1 – 6.2	10

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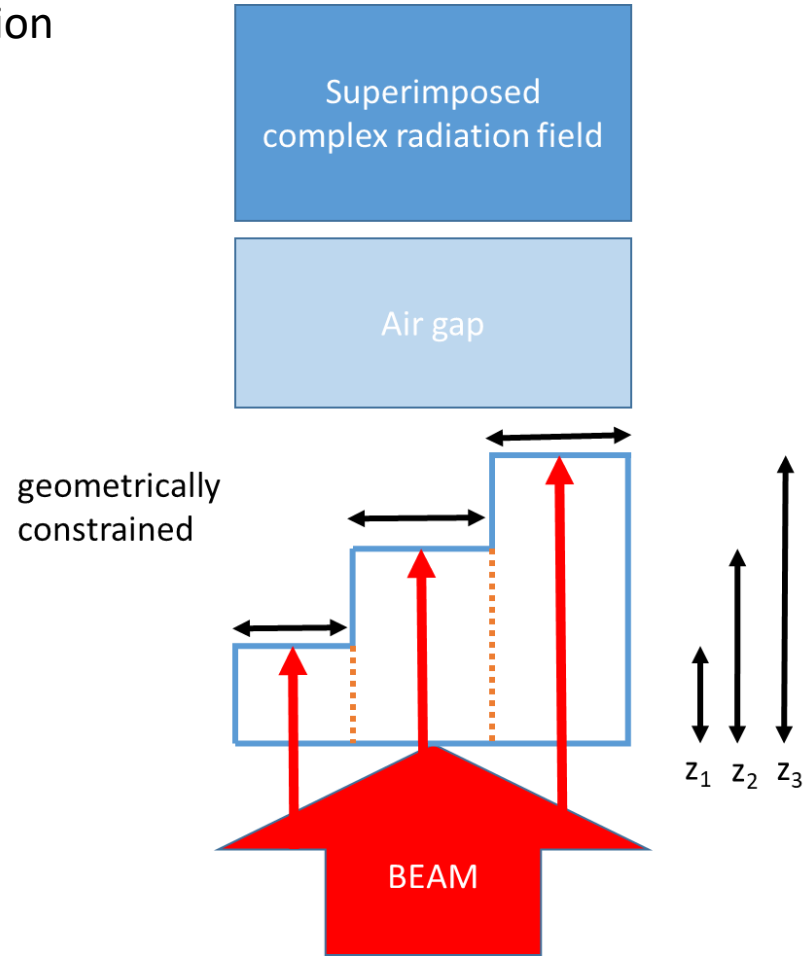
HEARTS

Backup

Passive modulation



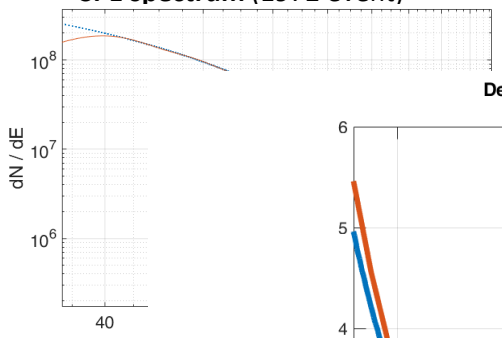
Different material thickness

Difference in:

- Energy-loss
- Scattering
- Fragmentation

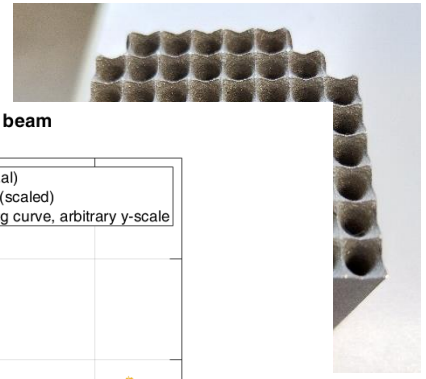
Backup

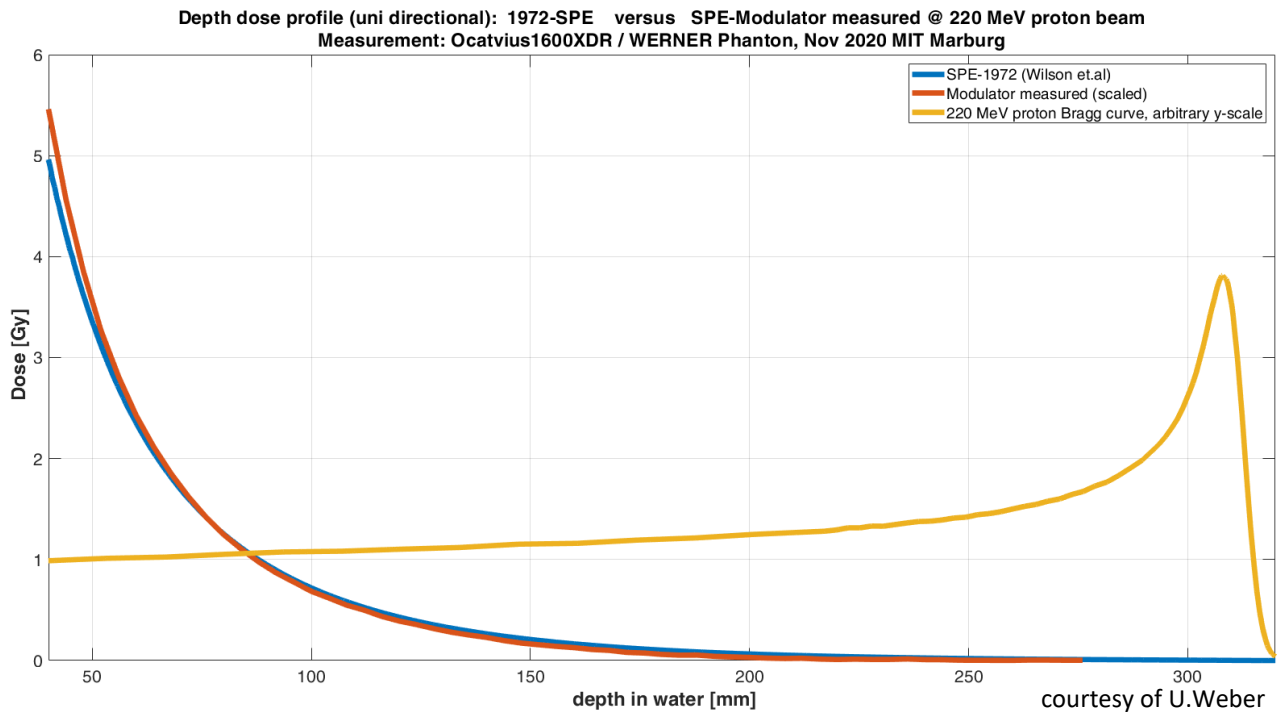
SPE spectrum (1972 event)



Optim

min. hole diameter 50 microns

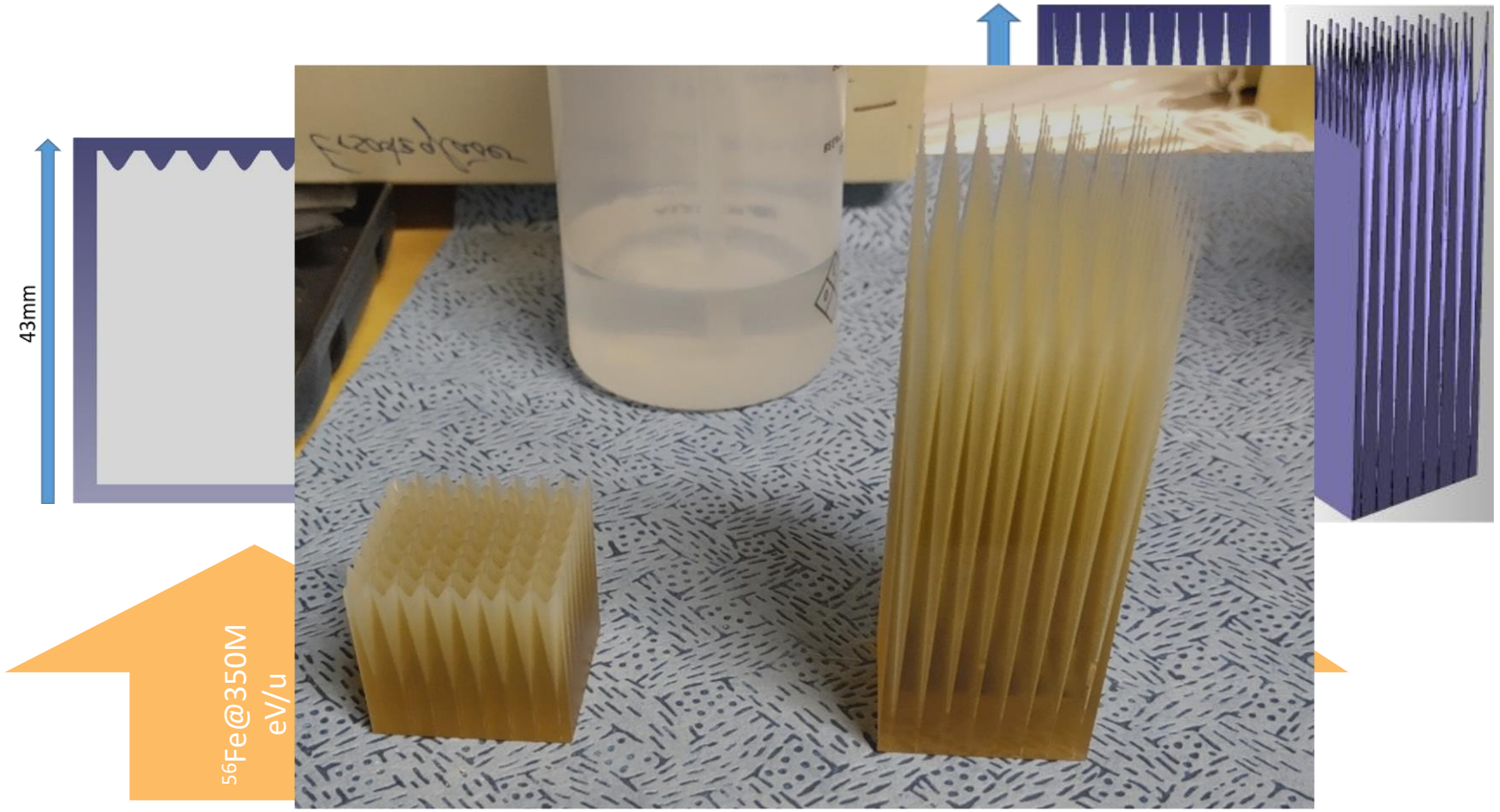




courtesy of U.Weber

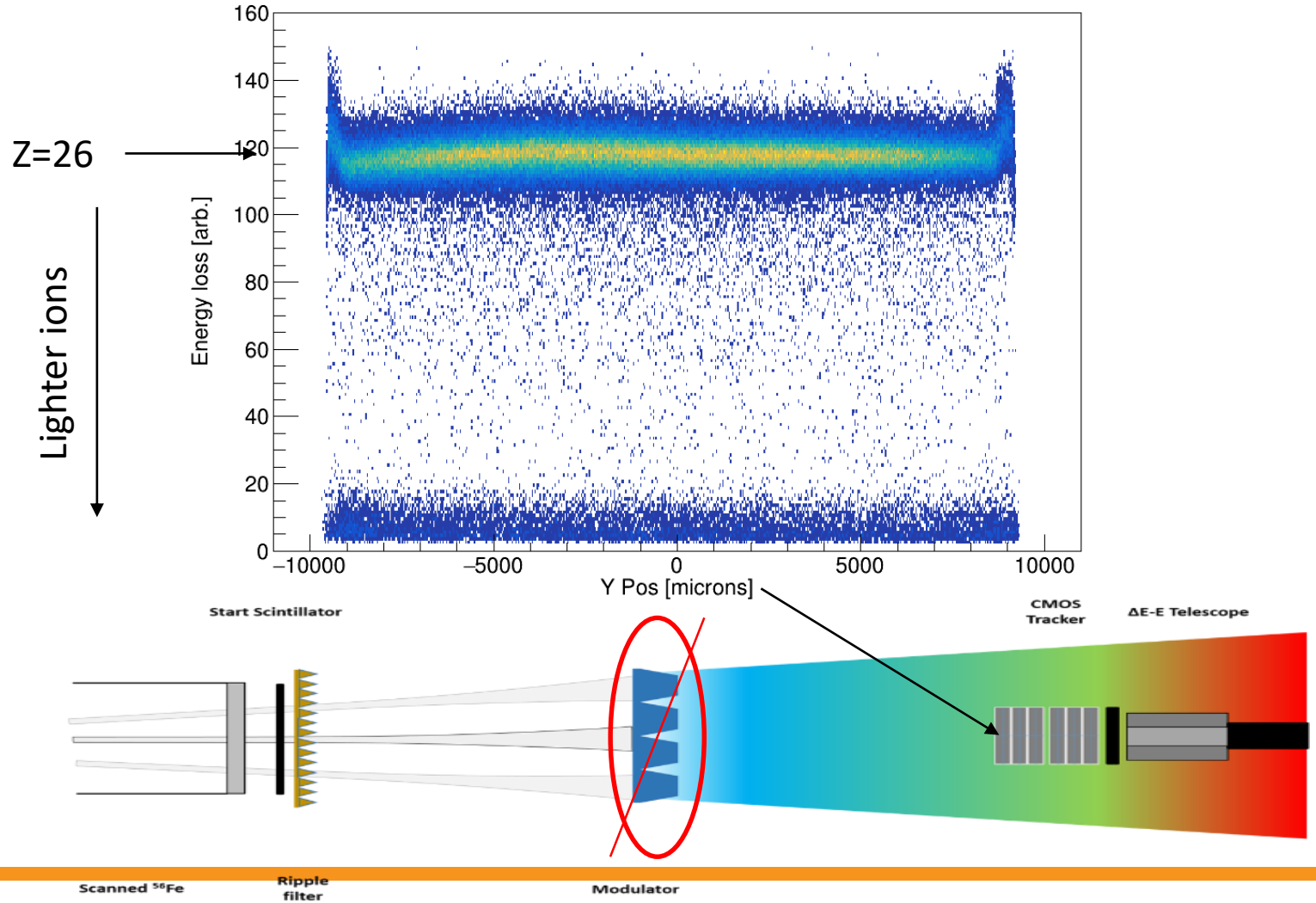
Verification measurement

Backup



Backup

700 MeV/u ^{56}Fe



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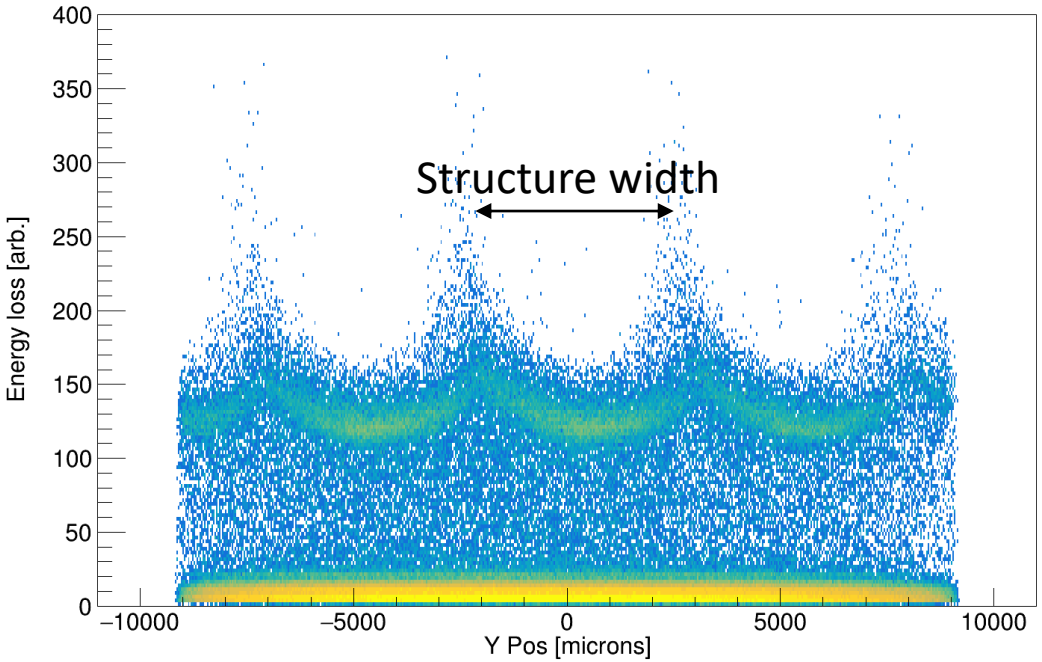

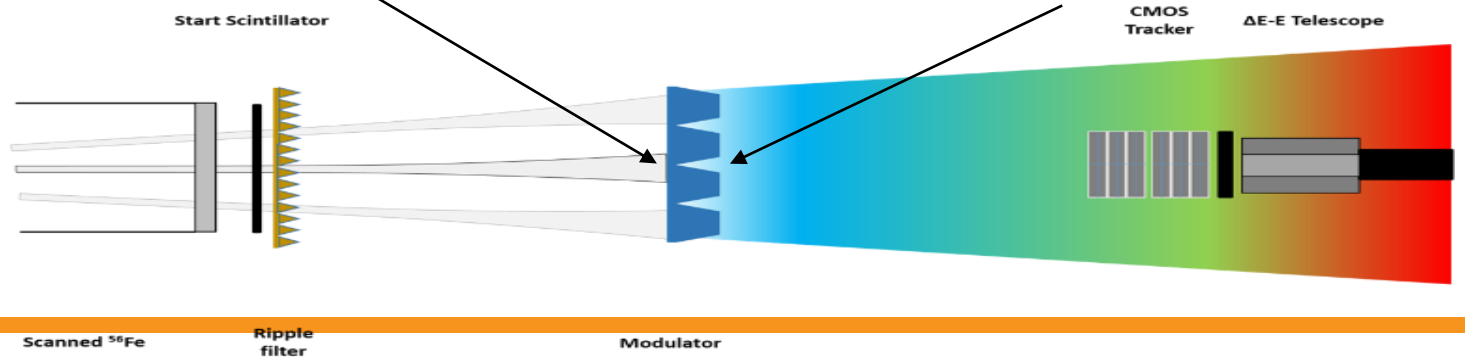

Backup

700 MeV/u ^{56}Fe