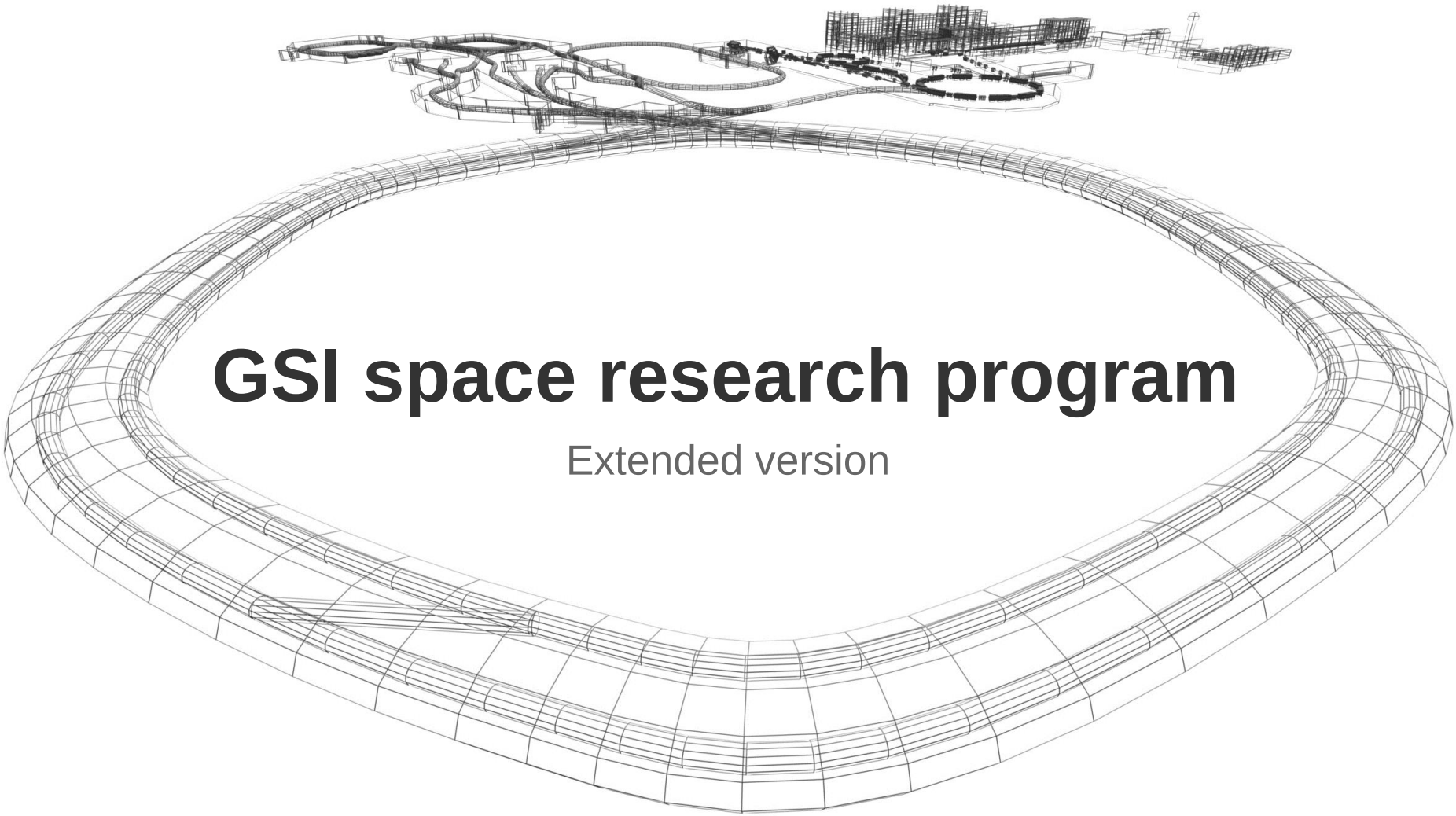


GSI space research program

Extended version

C.Schuy - GSI Biophysics - c.schuy@gsi.de

Introduction

Biophysics group 2017

G. Otto

Subgroups

- Molecular Radiobiology & Imaging
- Stem Cell Differentiation and Cytogenetics
- Immune system and tissue radiobiology
- Radiobiological Modelling
- Treatment Planning and Validation
- Medical Physics
- Space Radiation Physics

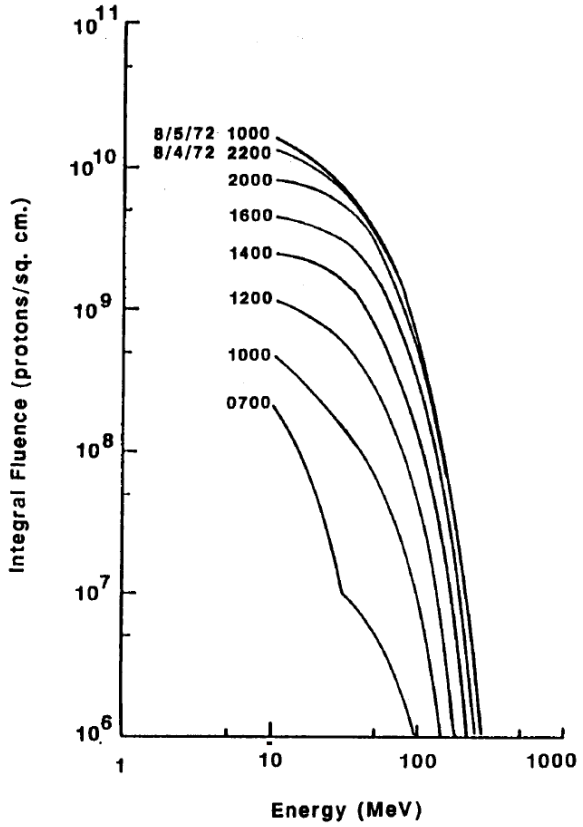
Outline

- Motivation
- Interaction of radiation with matter
- GSI irradiation facilities
- Experiments
- Summary / Outlook

Motivation

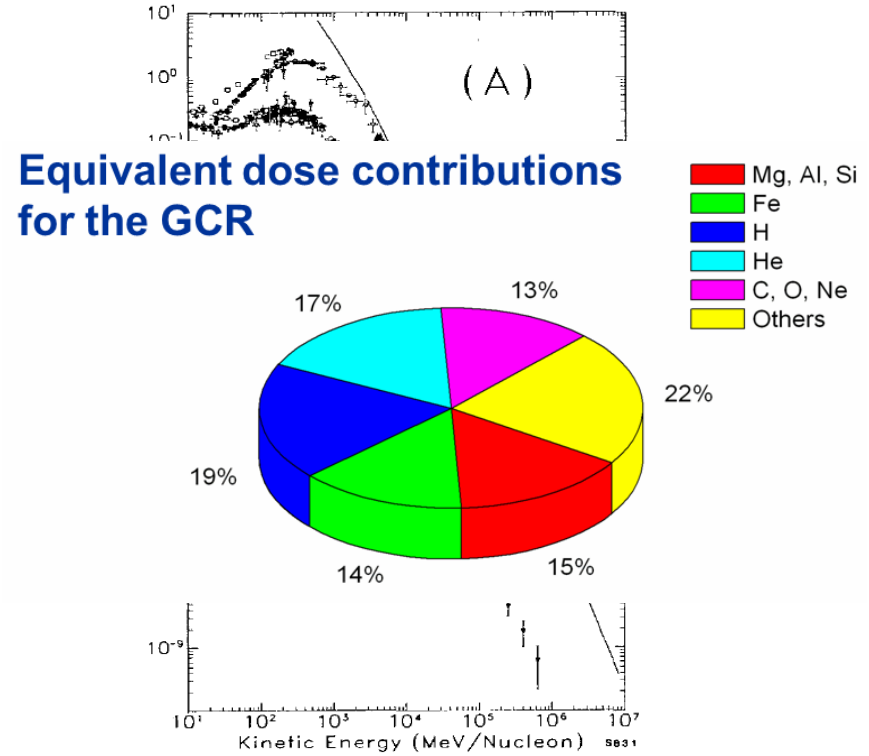
Deep space radiation environment

- Solar particle event (SPE)



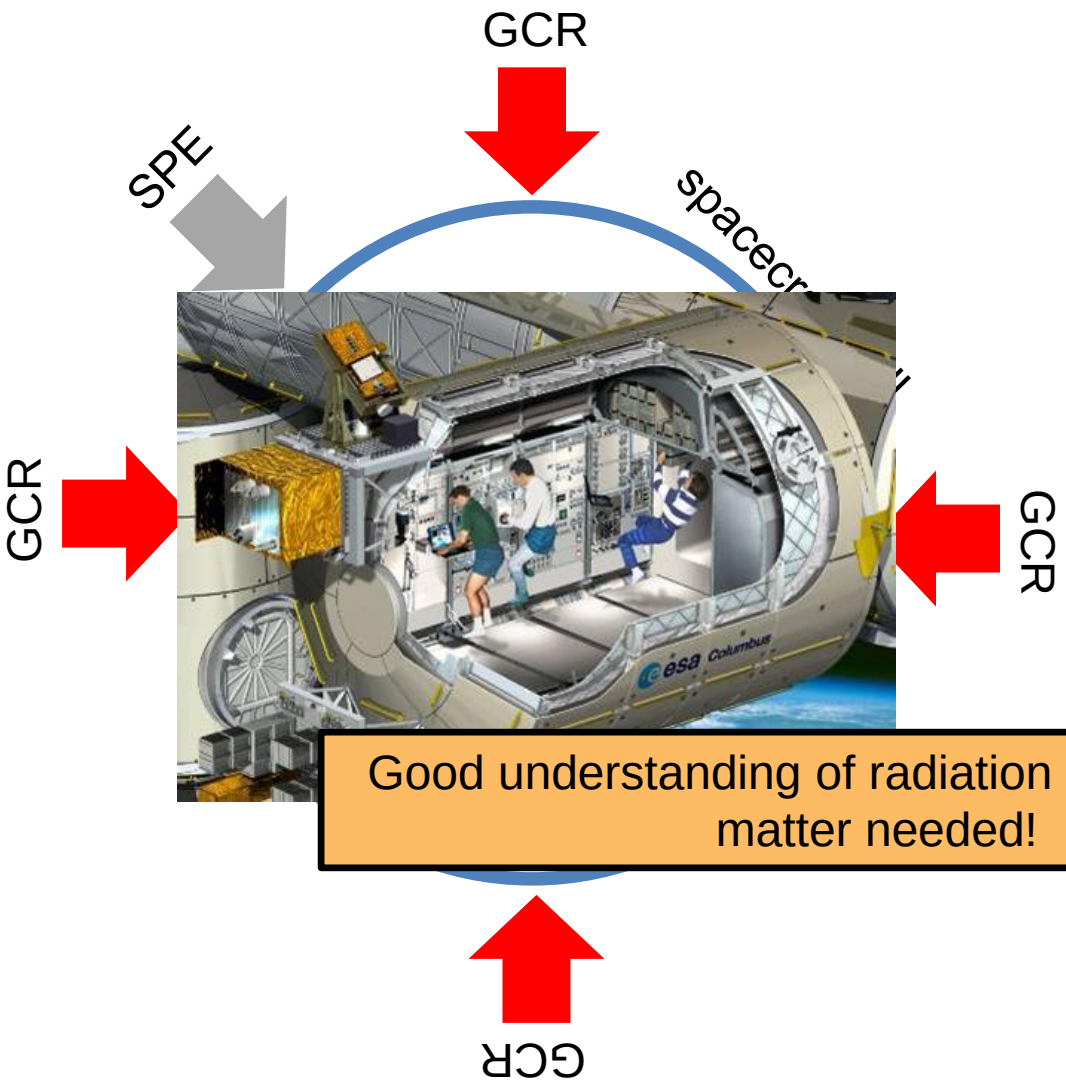
Townsend et al. 1992

- Galactic cosmic rays (GCR)



Simpson et al. 1983

Motivation



- Question: Risk?
- Problem: Charged particles interact with matter e.g.
  - Energyloss
  - Scattering
  - Fragmentation

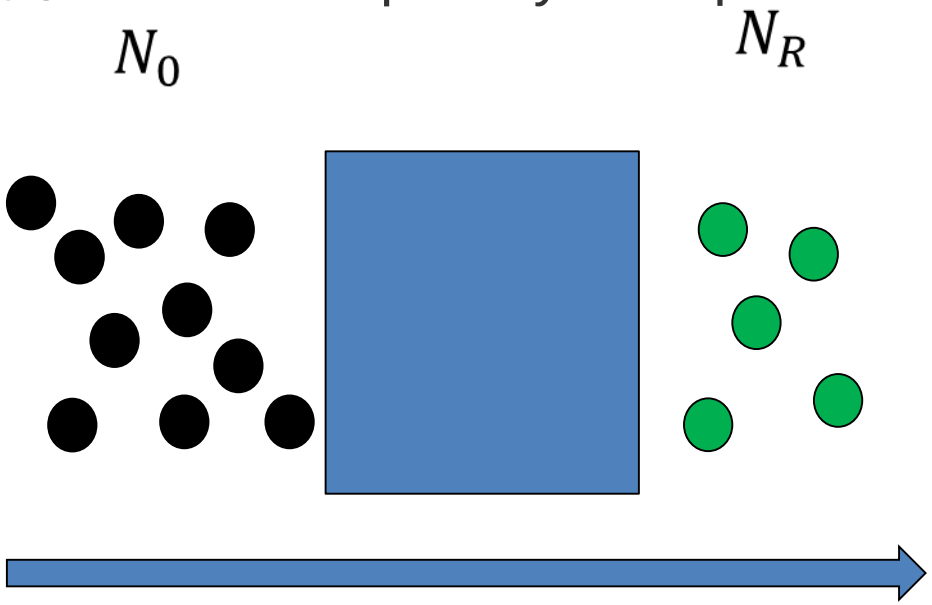
More complex radiation field

electronic
pends on the
quality of the radiation field

Good understanding of radiation interacting with matter needed!

Interaction of radiation with matter

- Cross section ≈ “Propability for a process to happen”

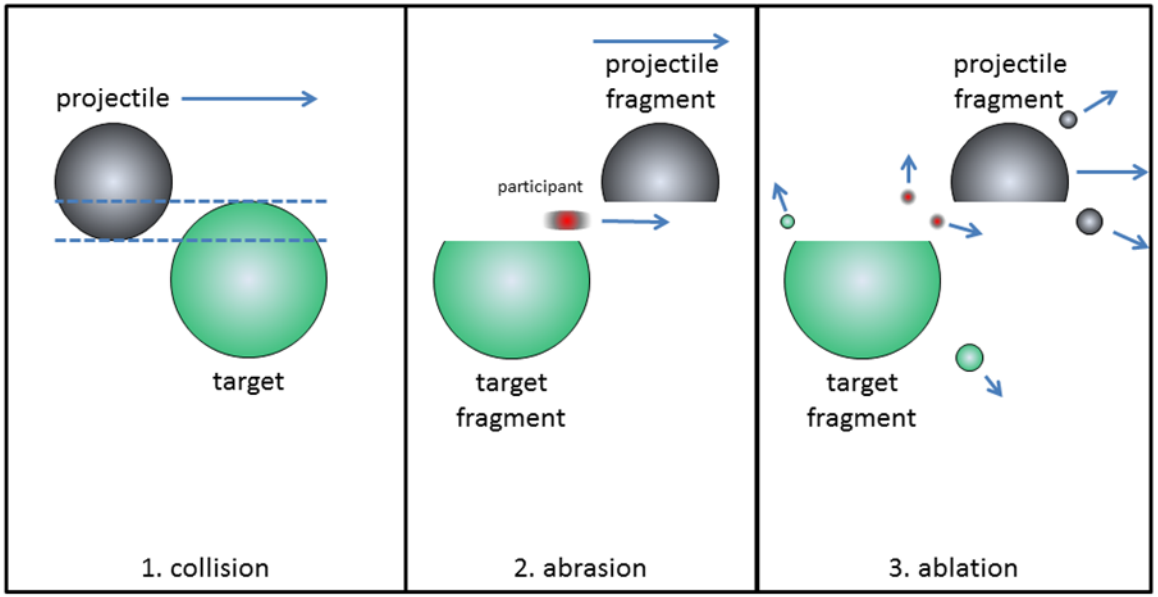


$$Yield \equiv \frac{N_R}{N_0}$$

$$Cross\ section \equiv Yield * \frac{A_{Target}}{\rho d N_A}$$

Interaction of radiation with matter

- Fragmentation

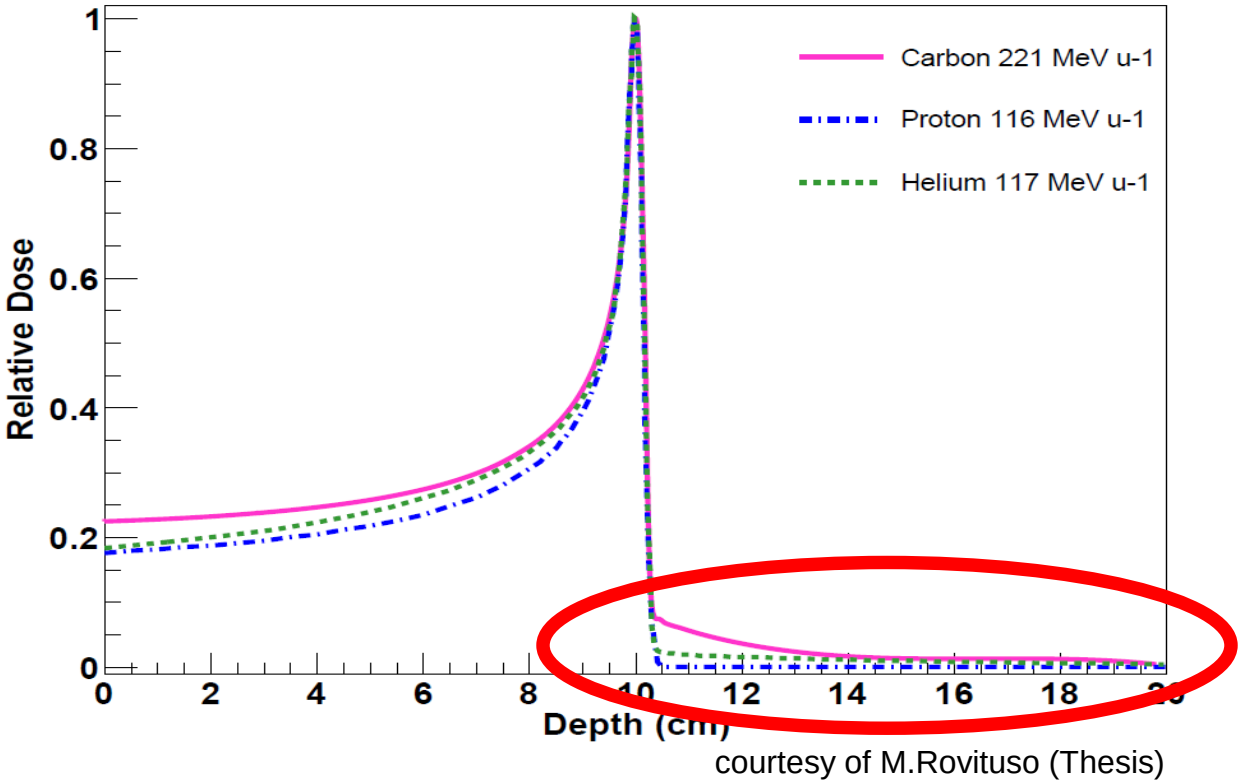


Fragmentation changes typically one or more of the following:

- kinetic energy
- direction
- multiplicity
- charge

Interaction of radiation with matter

- Energyloss



courtesy of M.Rovituso (Thesis)

At equal energies

↓

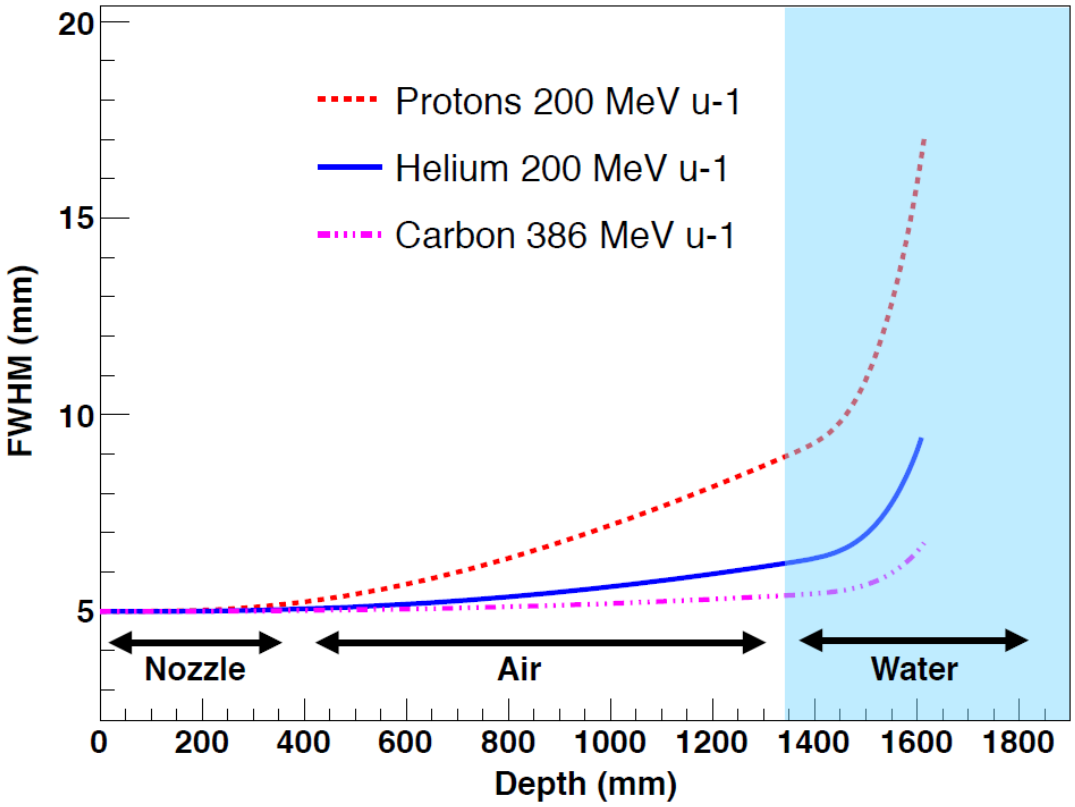
lower charge

↓

higher penetration depth

Interaction of radiation with matter

- Multiple scattering



courtesy of M.Rovituso (Thesis)

higher charge

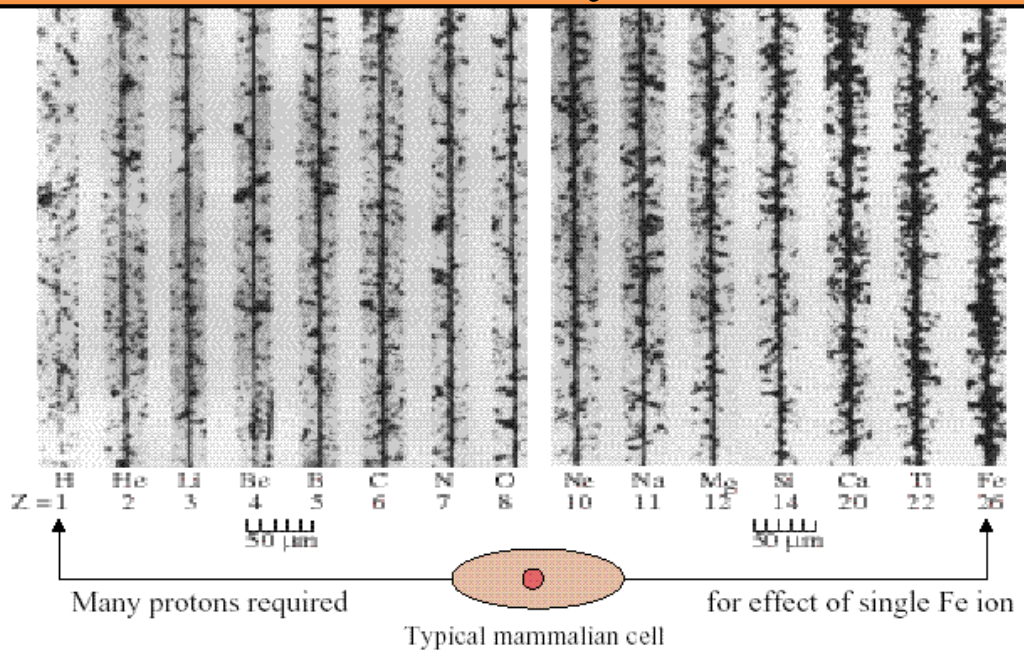
less scattering

Interaction of radiation with matter

- Biological effect

Higher charge → More complex damage

More complex damage → More difficult to repair



Cucinotta and Durante, *Lancet Oncol.* 2006

Interaction of radiation with matter

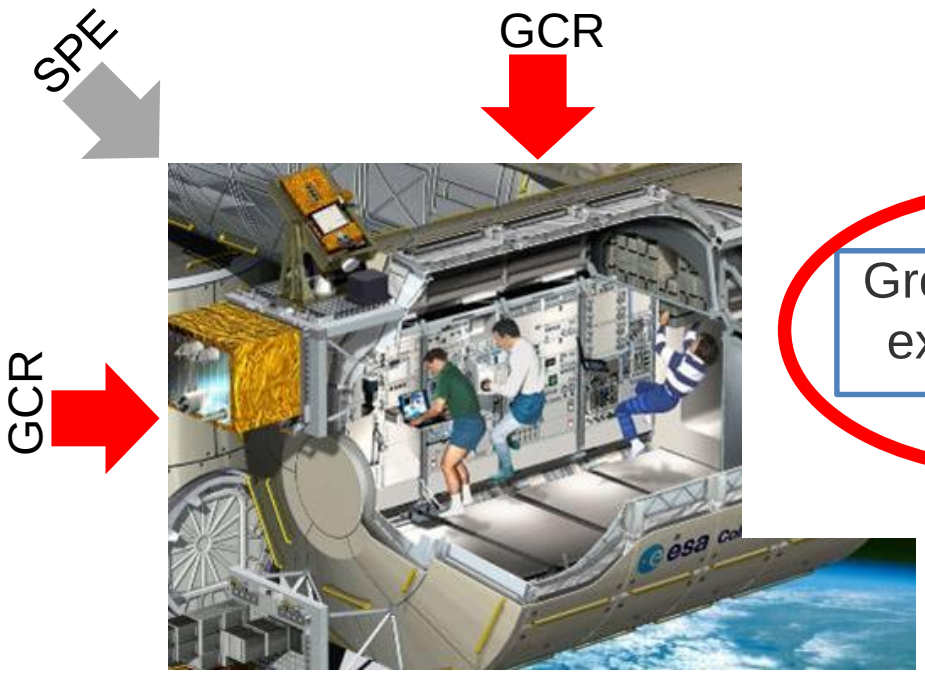
- Radiation protection ~~on earth~~ in space
  - ALARA - “As Low As Reasonably Achievable.”

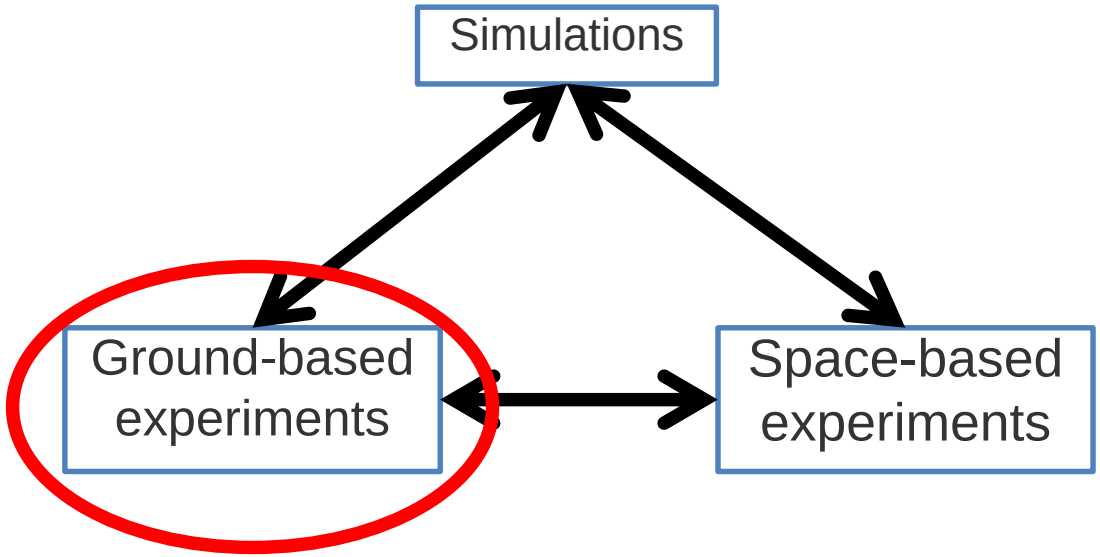
- ~~**Limit exposure time**~~
  longer missions
  faster travel?
- ~~**Increase distance**~~
  GCR has “no source”

- **Use “shielding”**
  weight and volume constraints
  GCR high energies
  SPE can be shielded “easily”

Can be shielded with in-situ materials for habitat

Back to the main question...

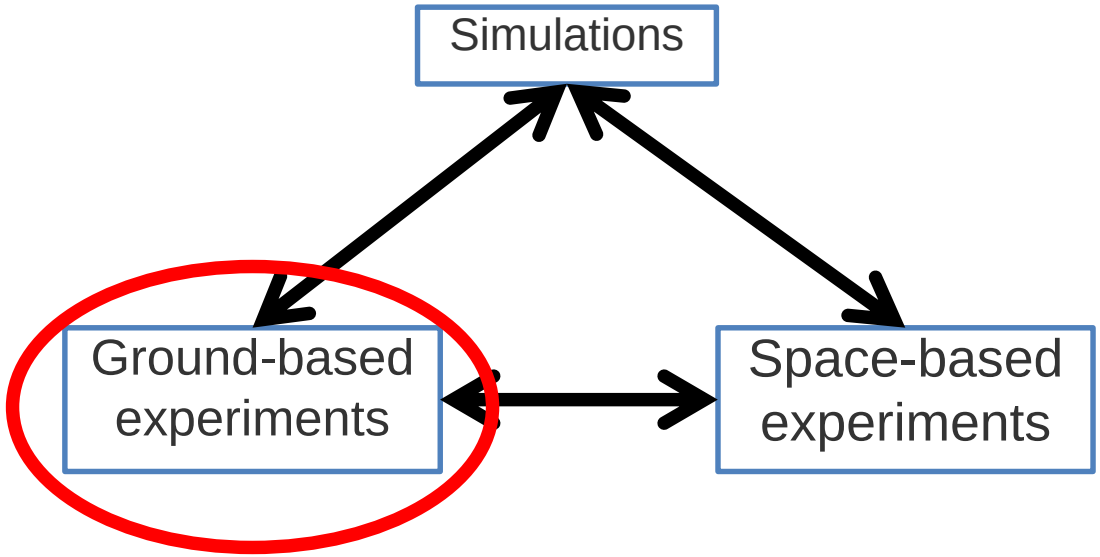




Question: Risk?

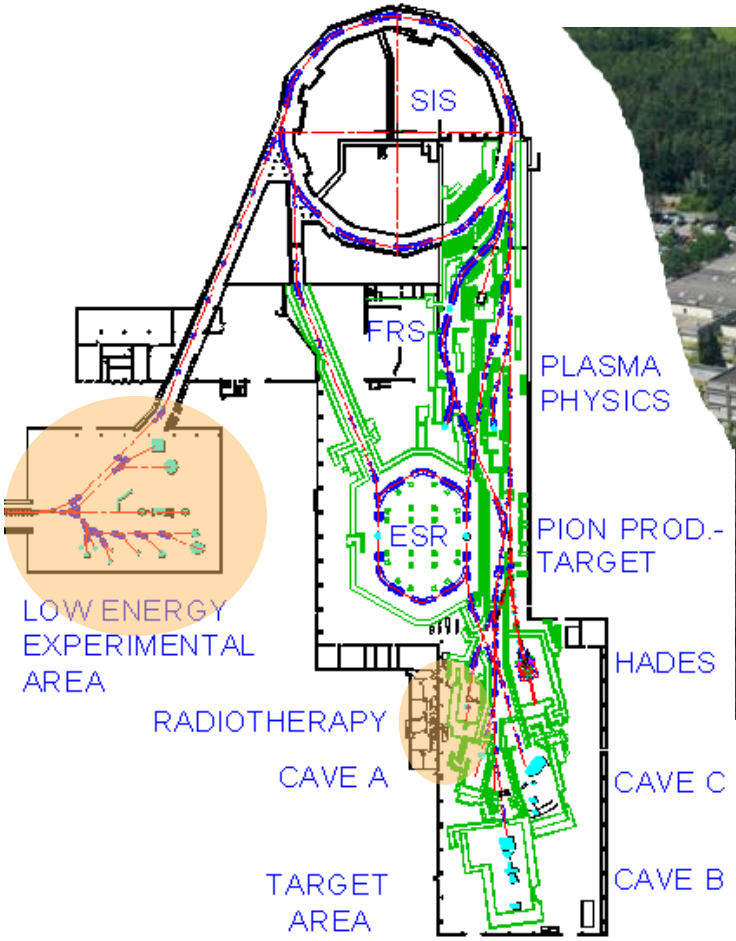
Back to the main question...

- GCR
  - ions up to iron
  - low flux
  - kinetic energy up to some GeV/u
- SPE
  - typically protons
  - high flux
  - some hundred MeV



Accelerator requirements

GSI overview



Accelerator

- Ions: p - U
- UNILAC ≈ 11 MeV/u
- SIS18 ≈ 1 GeV/u

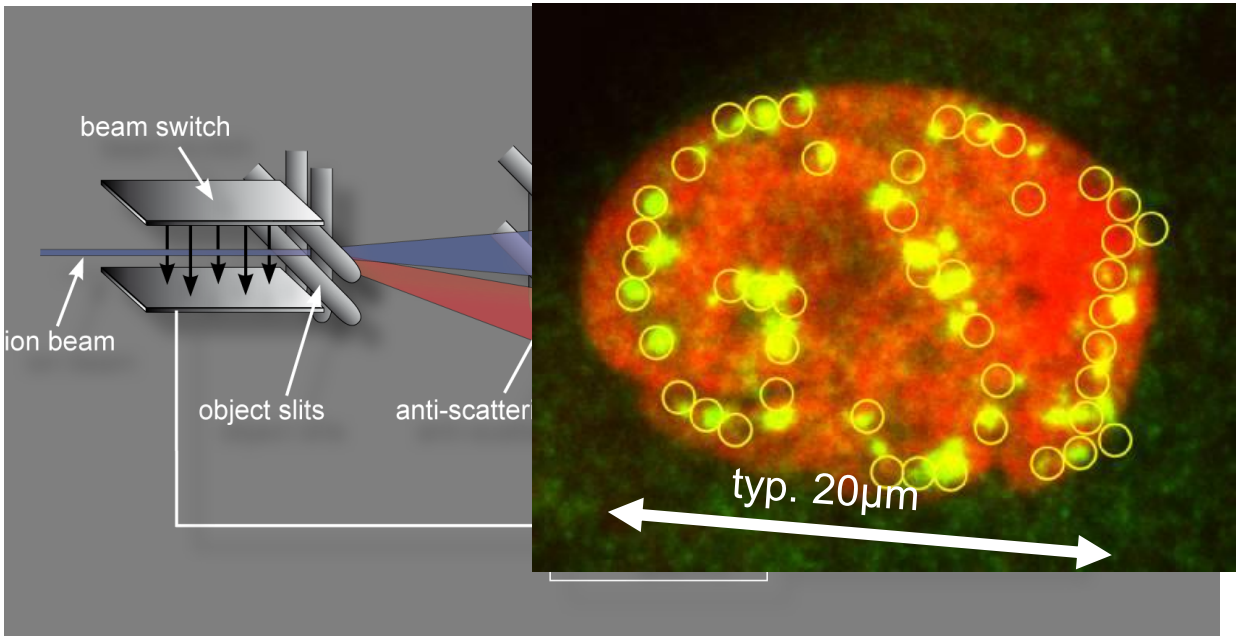
Experimental sites

- X0 - microprobe
- X6 - cell biology
- Cave A

/.gsi.de

https://web-docs.gsi.de/~wolle/EB_at_GSI/GSI/ACCELERATOR/IMAGES/accel_overview.gif

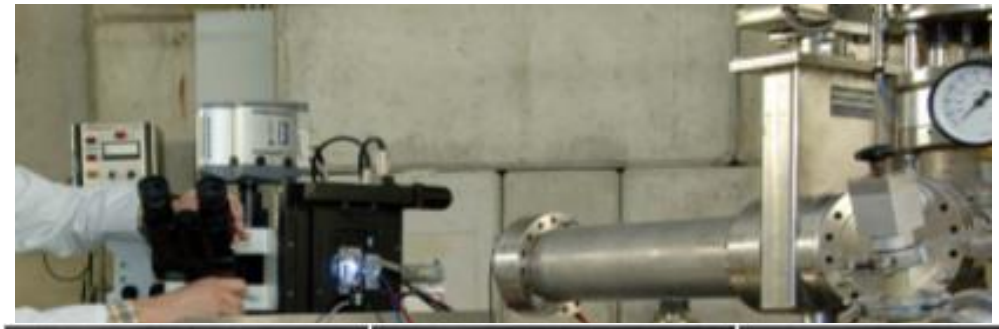
X0 - Microprobe



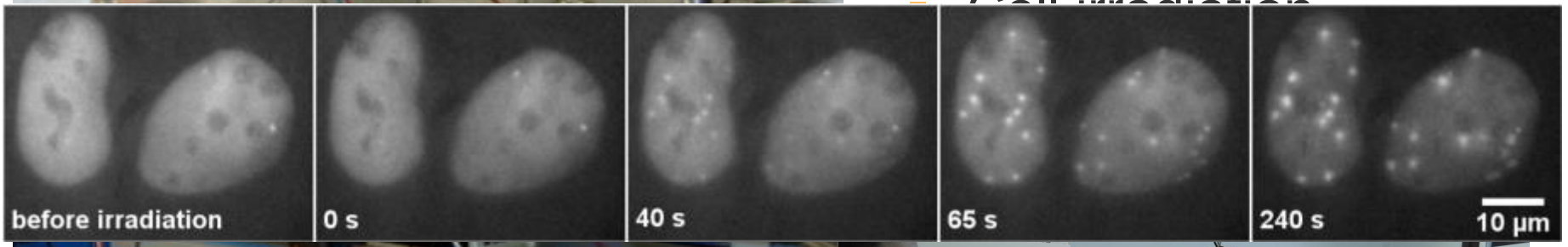
- E_{MAX}:11.4 MeV/u
- Ions: p – U
- Accuracy < 1µm
- Targeting rate 1000 *ions/s*

B.E. Fischer, K.O. Voss, B. Merk, (Material Research)
in-house collaboration with Biophysics Dept.

X6 – Cell irradiation



- Multi-purpose
- E_{MAX}:11.4 MeV/u
- Ions: p – U
- Cell irradiation



Live cell imaging, B. Jakob,
GBS/DNA-Repair , Sept 2012

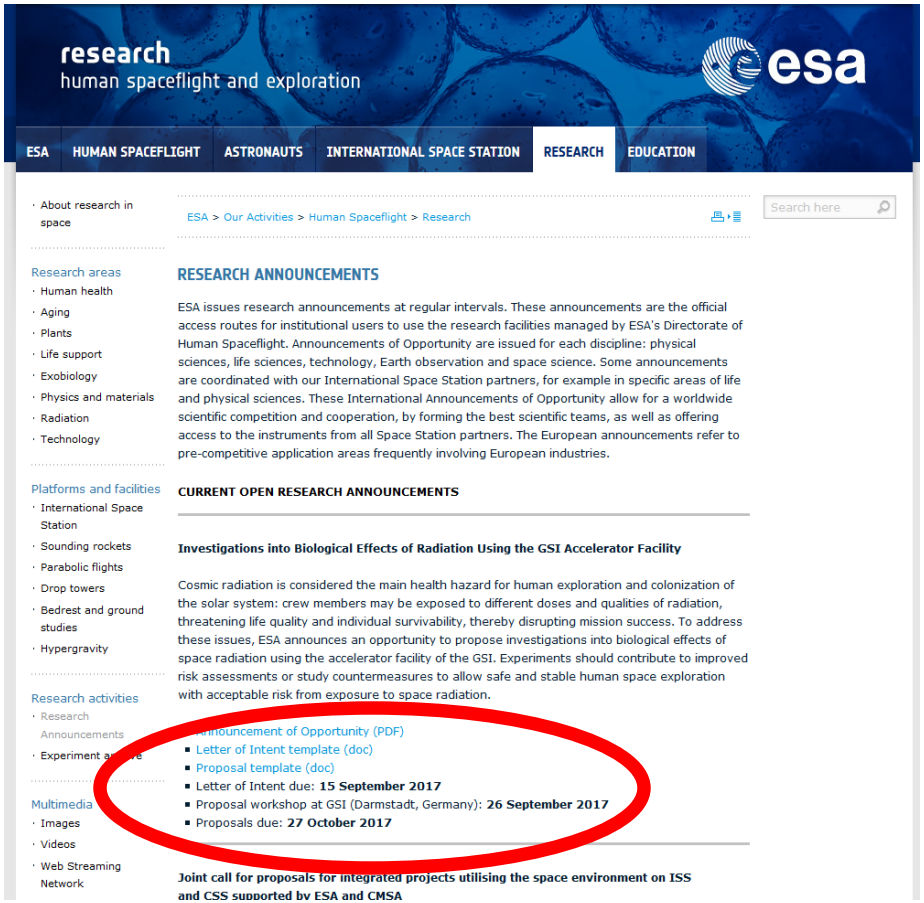
Cave A

C. La Tessa, source: G.Otto

- Multi-purpose
- Ions: p – U
- $E_{MAX} \approx 1$ GeV/u
- Intensity: 10 – 10^9 pps

- Active scanning
  - $Size_{MAX}$: 20 * 20 cm^2

Side note...



- ESA research announcement
- Topics
  - Risk assessment
  - Countermeasures
- More infos:

http://www.esa.int/Our_Activities/Human_Spaceflight/Research/Research_Announcements

Experiments

- ROSSINI 1 & 2
  - RadiationOn Shielding by ISRU and/or INovative MaterIals for EVA, Vehicle and Habitat
  - supported by

Goals:
Recommendations on shielding materials
Monte Carlo benchmarking

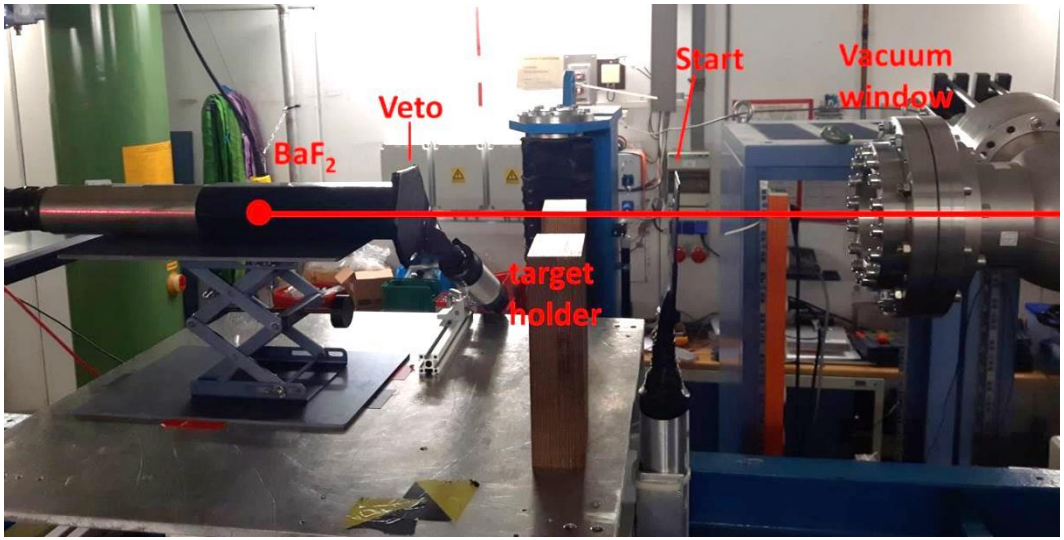
- Experiments
  - Dose attenuation
  - Attenuation of the primary beam
  - Neutron production
  - Microdosimetry

- Labs
  - GSI, Germany
  - BNL, USA
  - PTC Trento / TIFPA, Italy

Experiments

- Passive shielding → CGR energy to high to stop for deep space missions
  - Simplified idea → Use fragmentation to decrease received dose

➔ Measure loss of primary ions per unit mass



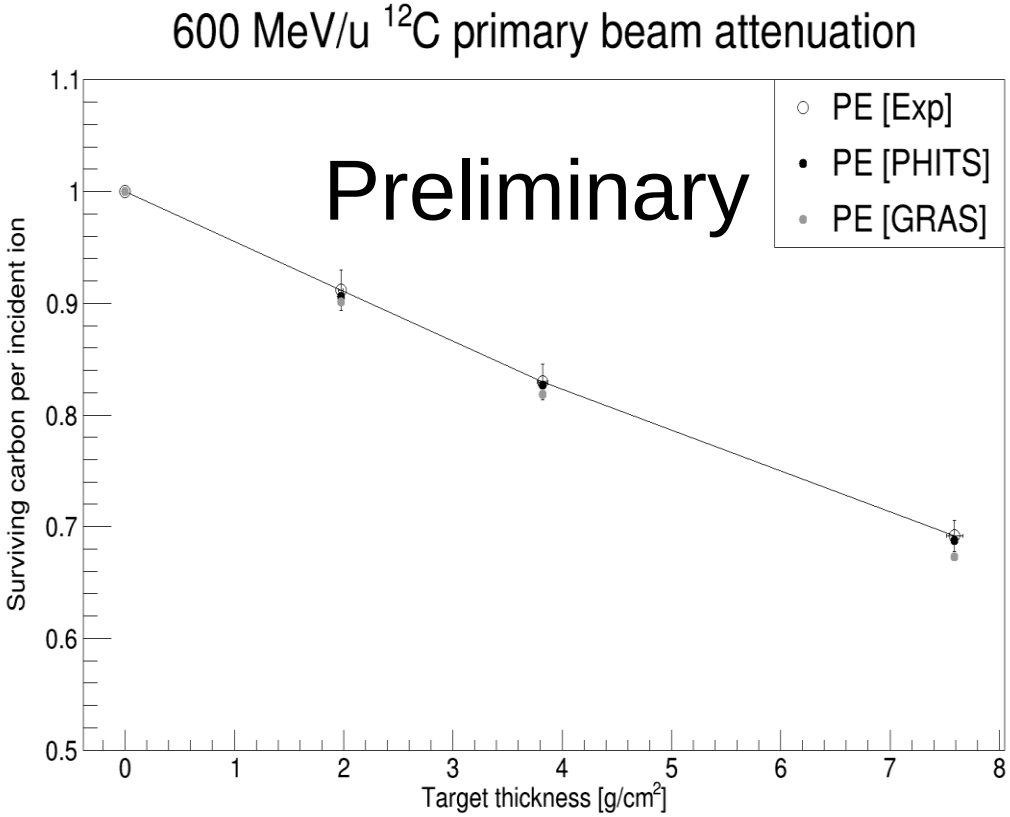
Start: Count number of primaries
Veto: Energyloss
BaF2: Total energy

PID

Number of surviving primaries

Compare with Monte carlo

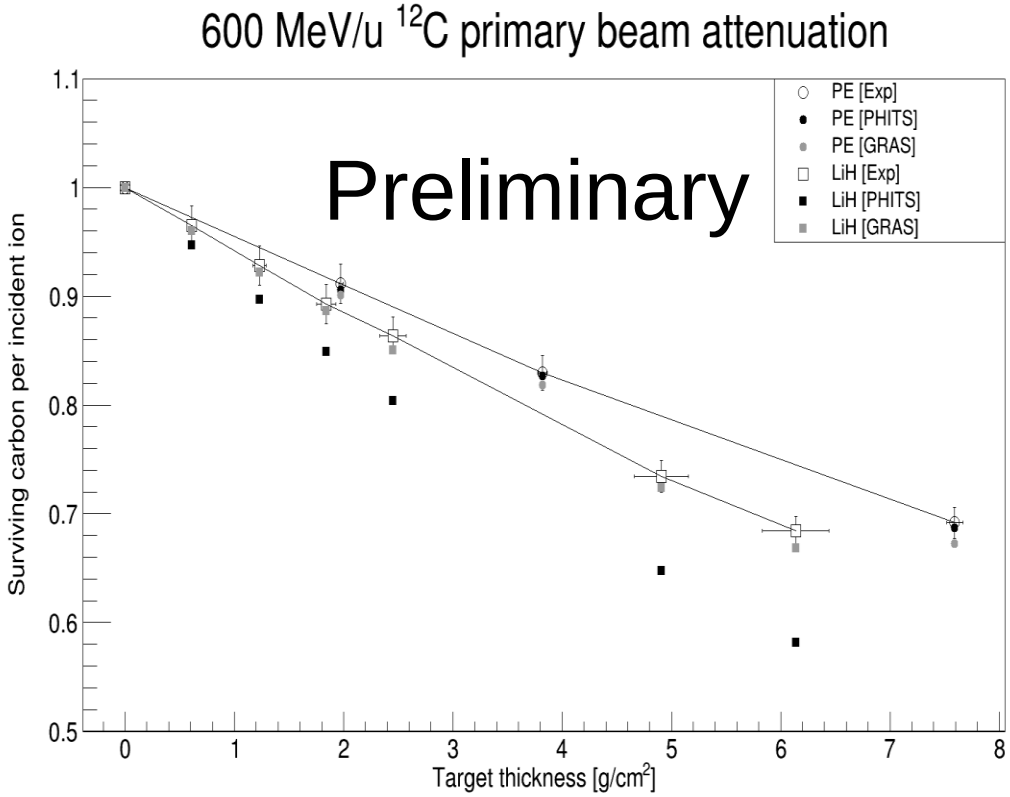
Experiments



data not published yet

- PE “gold standard” for shielding
- used in therapy as well
- MC can reproduce results

Experiments



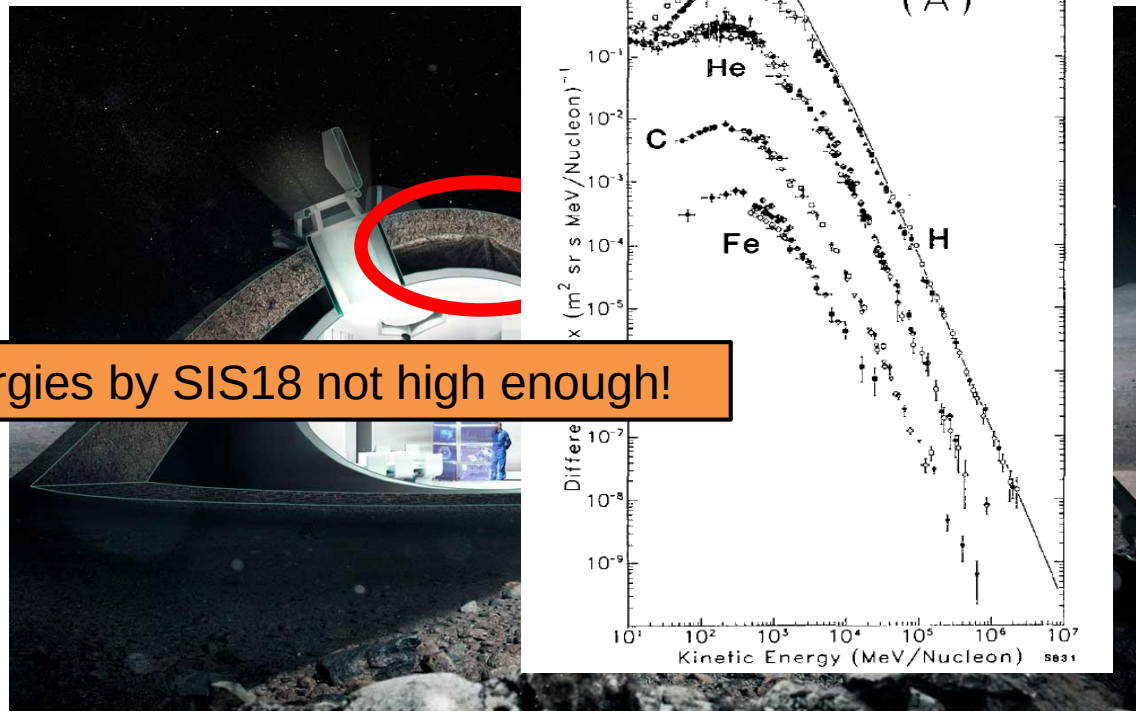
data not published yet

- LiH shows higher fragmentation
- PHITS can not reproduce results

Experiments

- Passive shielding for habitats
  - no weight constraints if using in-situ materials

➔ Fully stop CGR



Provided energies by SIS18 not high enough!

Simpson et al. 1983

Summary

- 3 pillars of space radiation risk assessment
  - Monte Carlo
  - Space-based experiments
  - Accelerator-based experiments

- GSIs UNILAC + SIS18 well suited for space research
  - but higher energies are needed to cover full GCR -> **FAIR**

Thanks for your attention