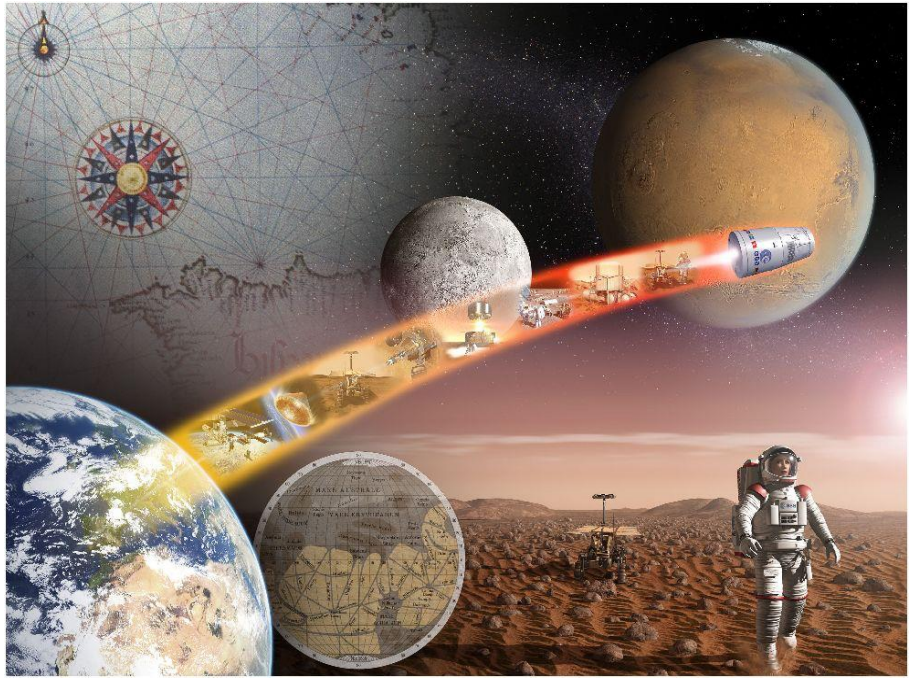
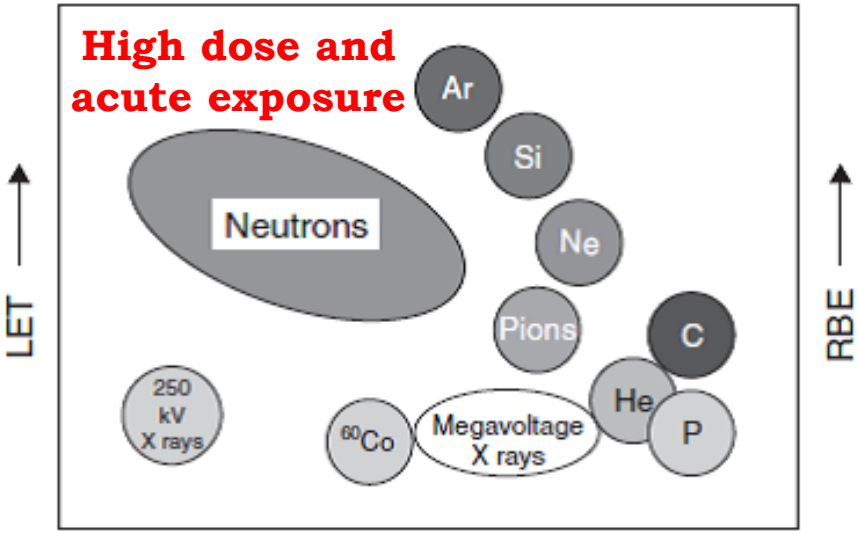
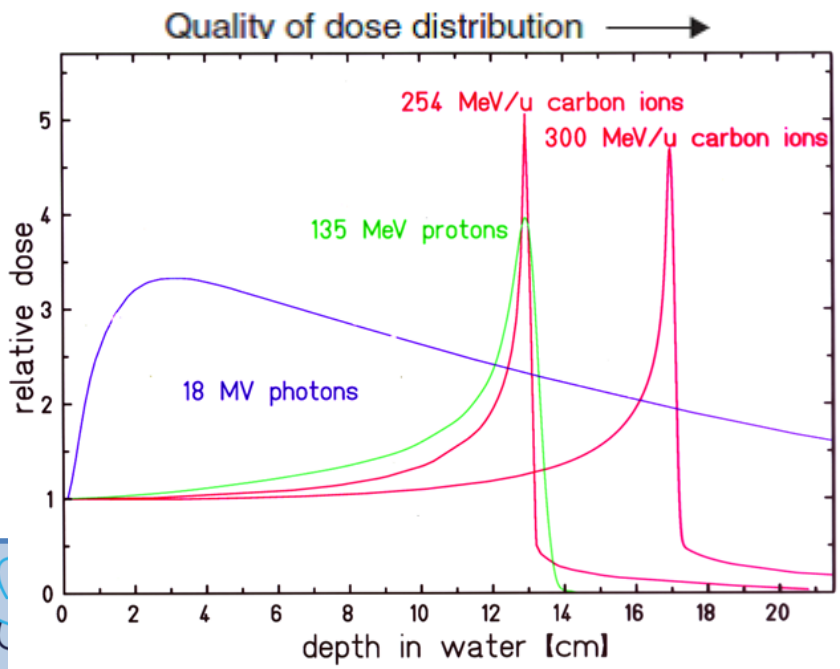
The role of detectors in nuclear physics measurements for radiotherapy and space applications

Chiara La Tessa

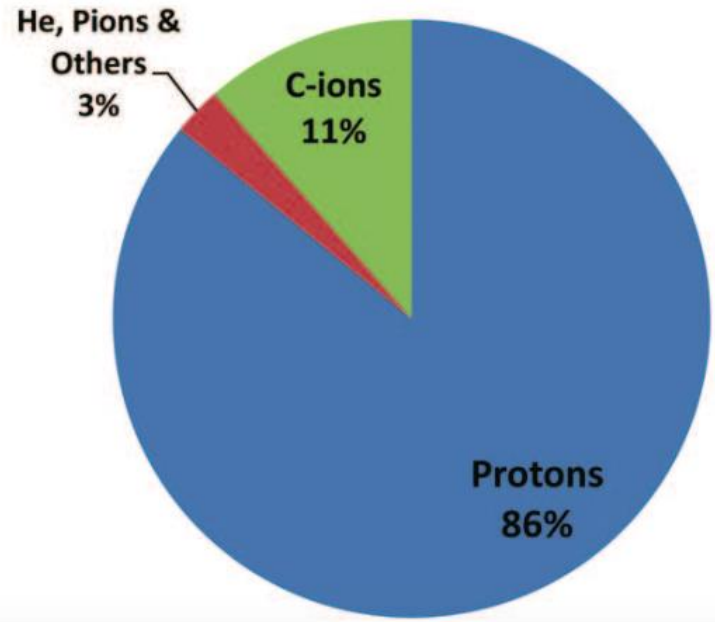


Cancer radiotherapy





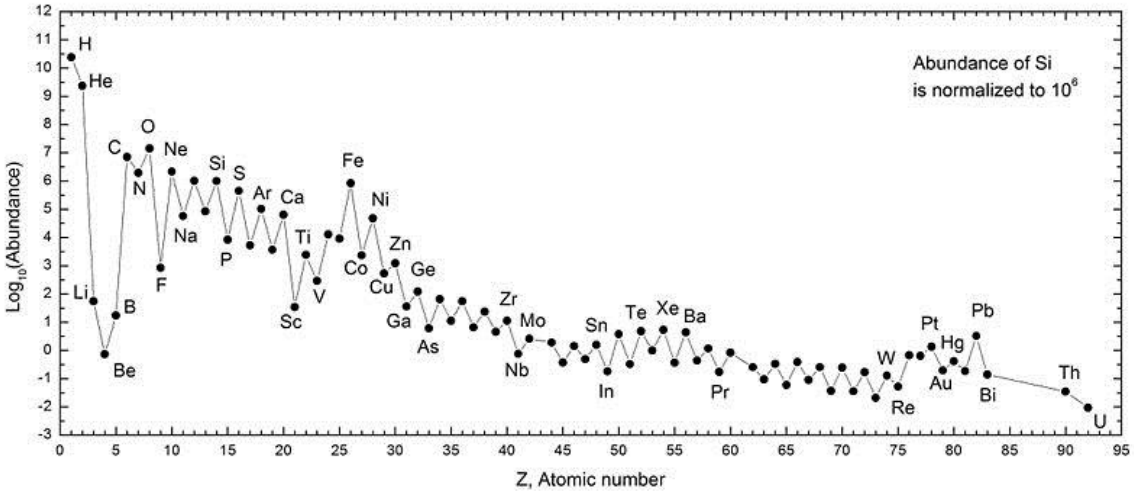
- 50% of all cancer patients undergo radiotherapy as part of the treatment
- X-rays are by far the most widely used beam but in the past decades the application of charged particles has gained popularity

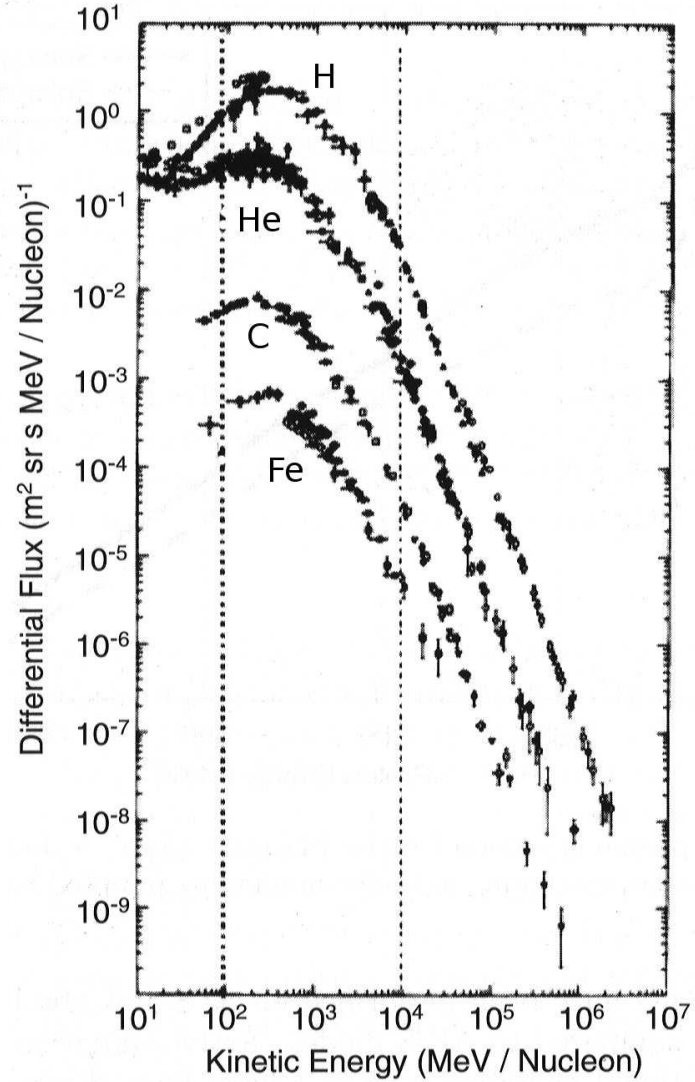


Space radiation environment

- GCR (Galactic Cosmic Rays)
- Solar particle events (mainly protons)
- Trapped particles (protons and electrons)

Low dose and chronic exposure





What ties them together?

Space

Combine the composition of the radiation field and dose to biological effects -> Health risk

Therapy

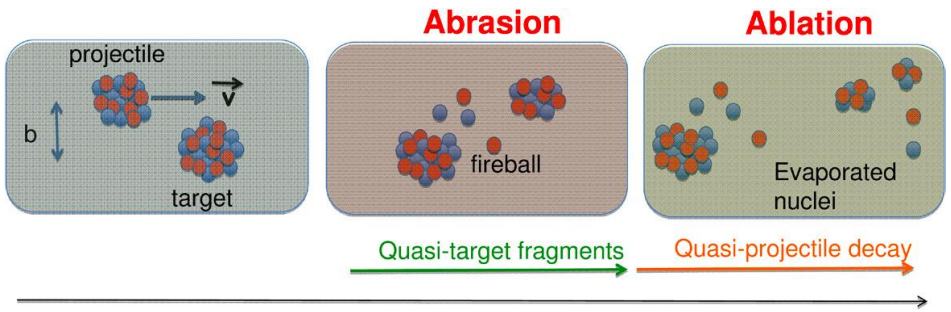
Treatment planning verification and optimization, online range verification, extension to other ions and diseases…

➡ **Physics and biology experiments to understand basic mechanisms and characterize specific systems**

➡ **Improve the predictive power and accuracy of deterministic code, Monte Carlo and treatment planning systems**

Physical processes of interest

- Energy loss
- Lateral scattering
- Nuclear fragmentation



Space

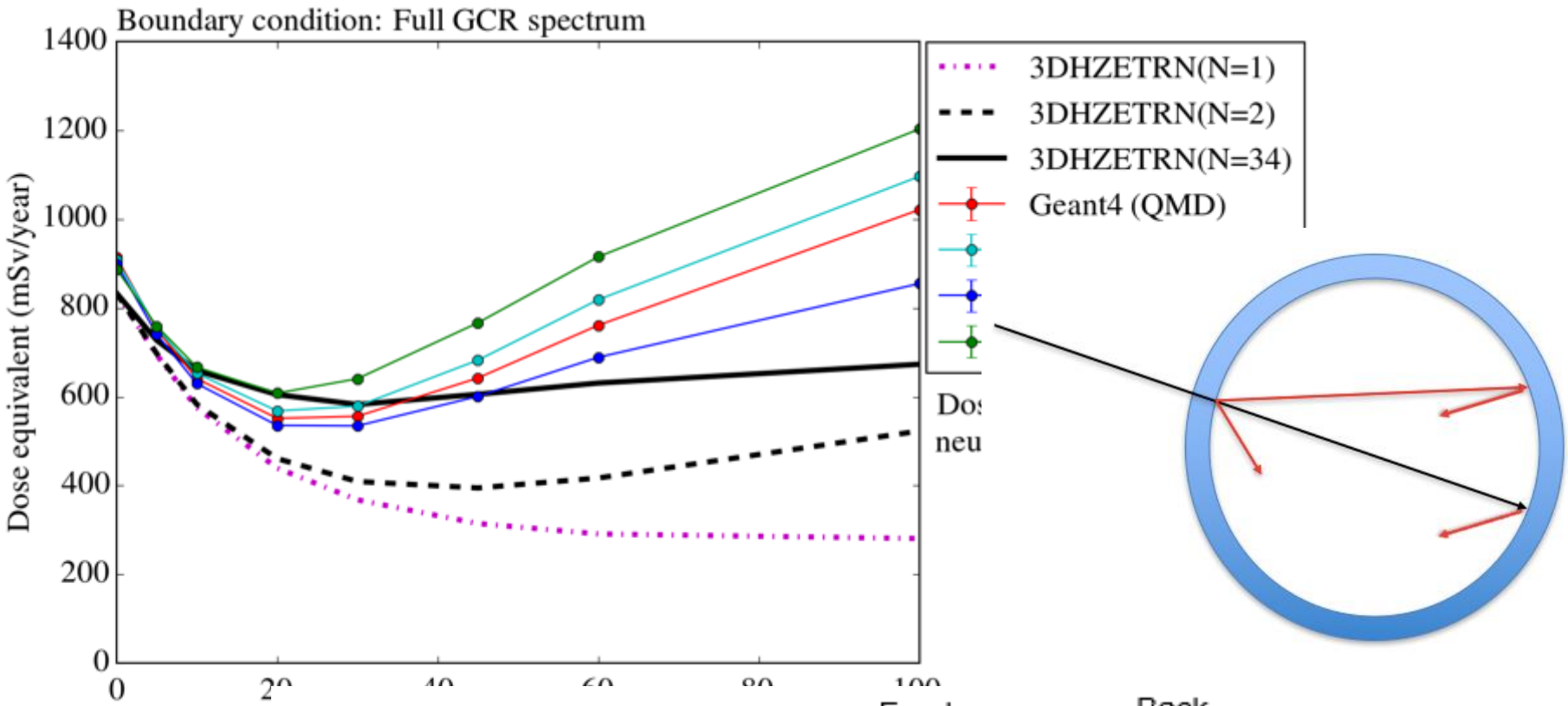
-Space craft hull and structure
-Shielding
-Astronaut's body

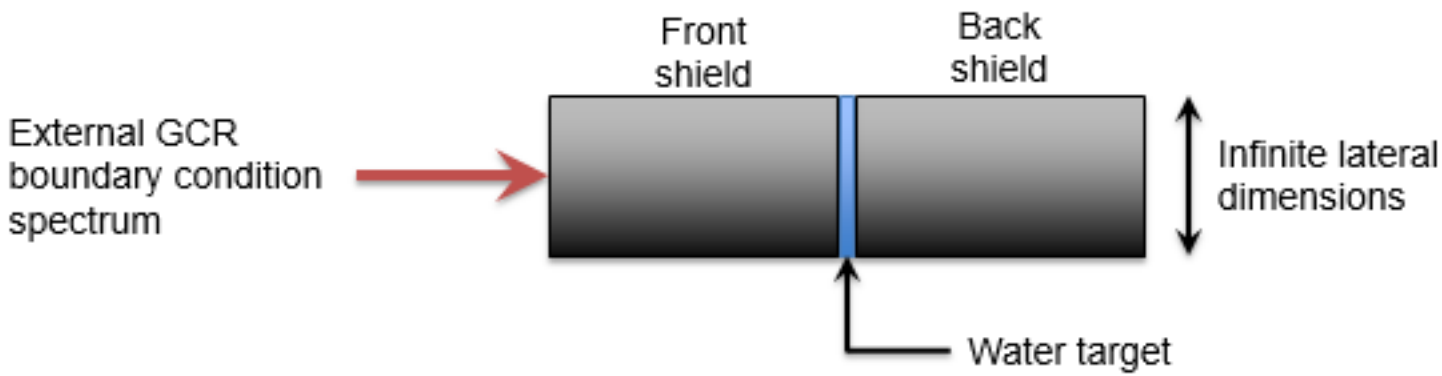
Radiotherapy

-Elements on the beam line (range shifter, collimator…)
-Patient's body

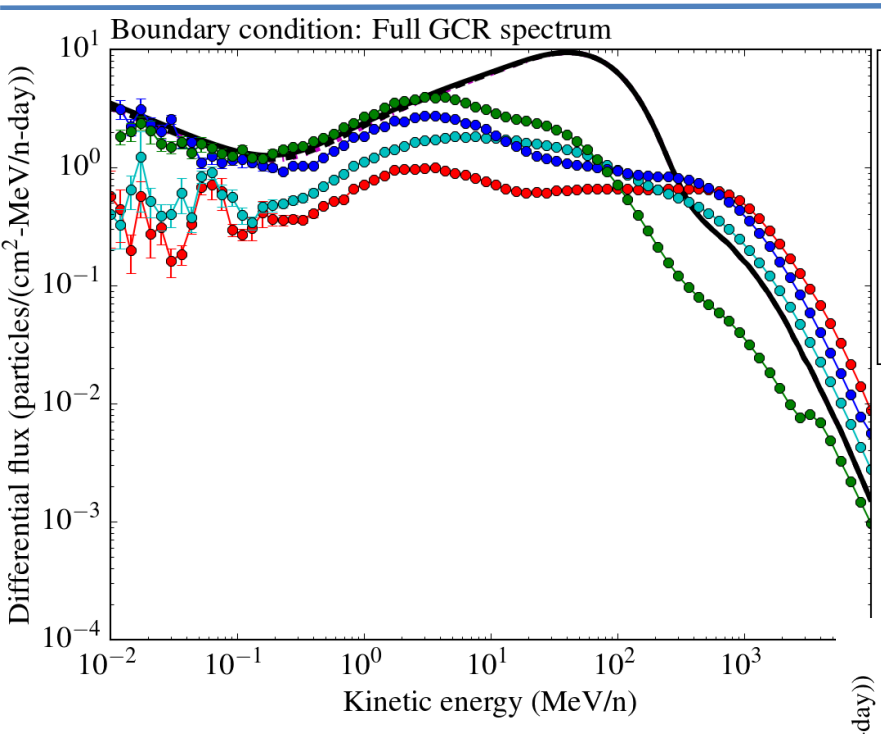
SPACE RADIOPROTECTION

Some missing pieces of the puzzle





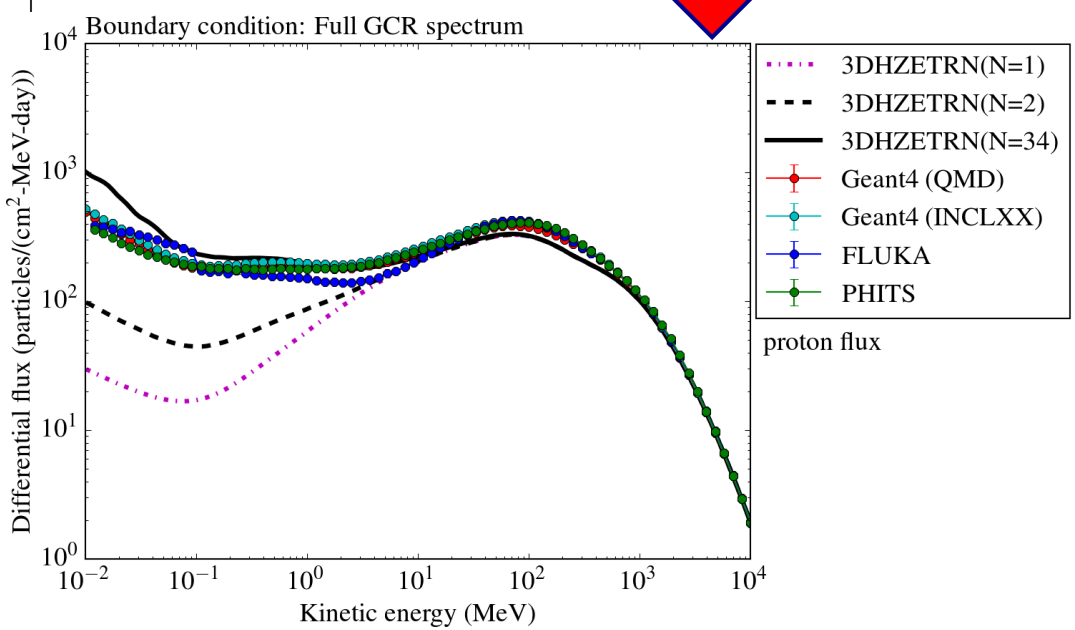
What codes predict for thick shielding



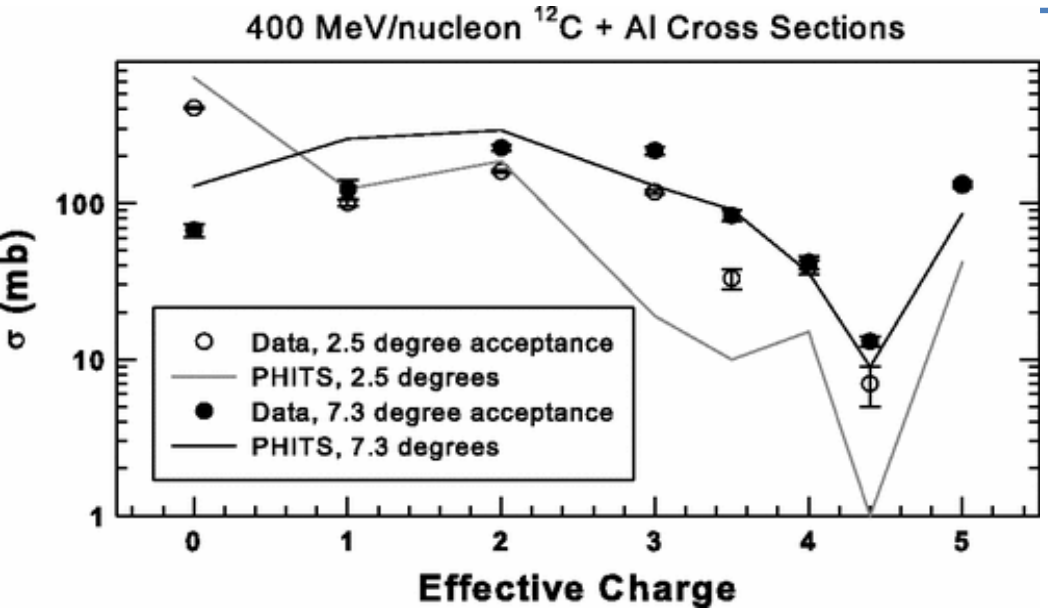
GCR spectrum interacting with 20 g cm^{-2} Al shielding

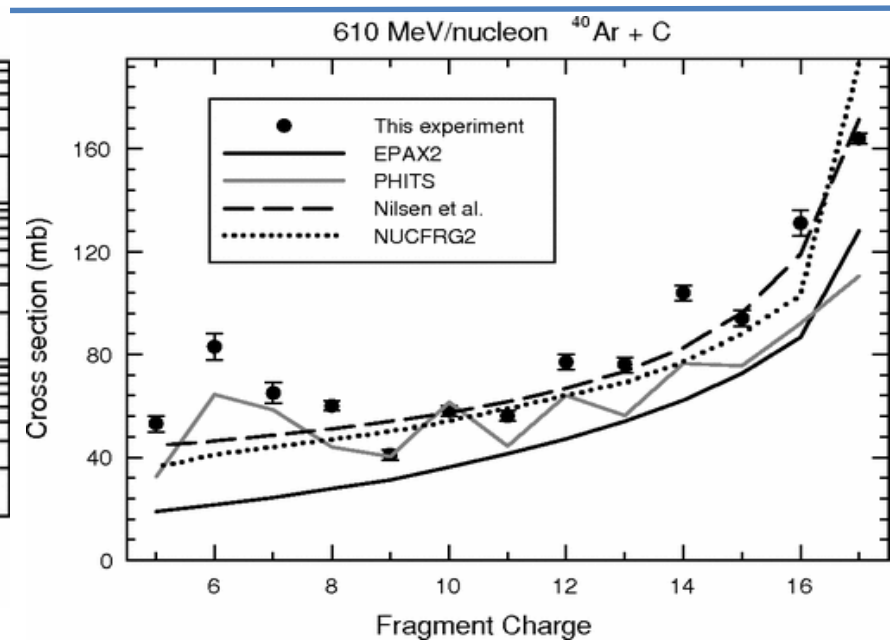
d, t, ^{3}He, ^{4}He

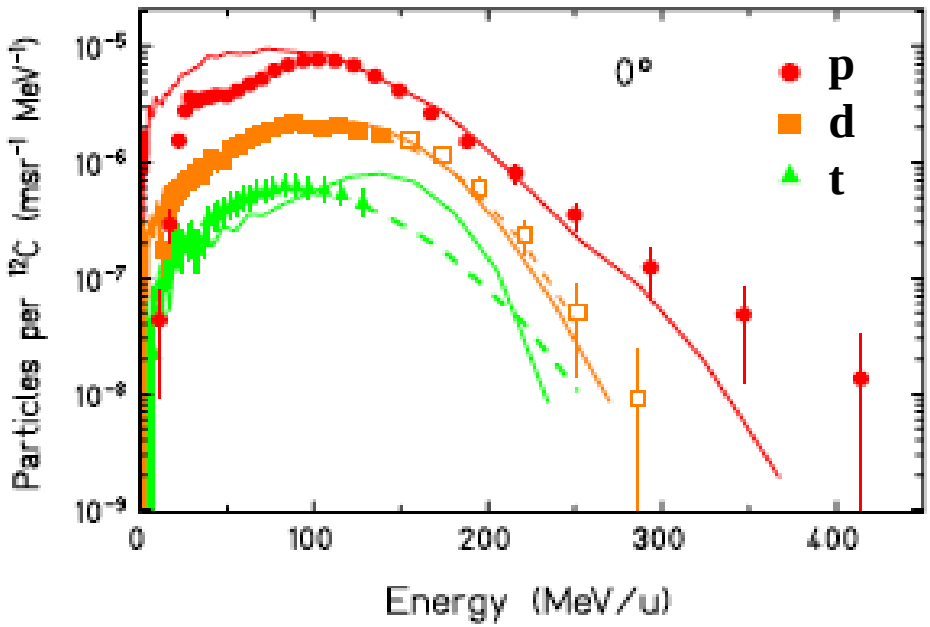
Protons

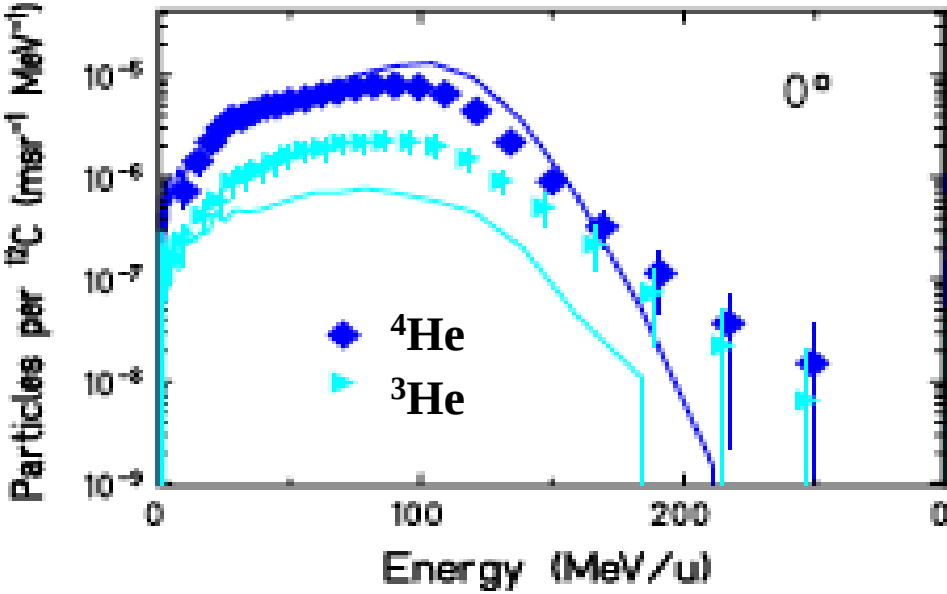


What codes predict for thin shielding

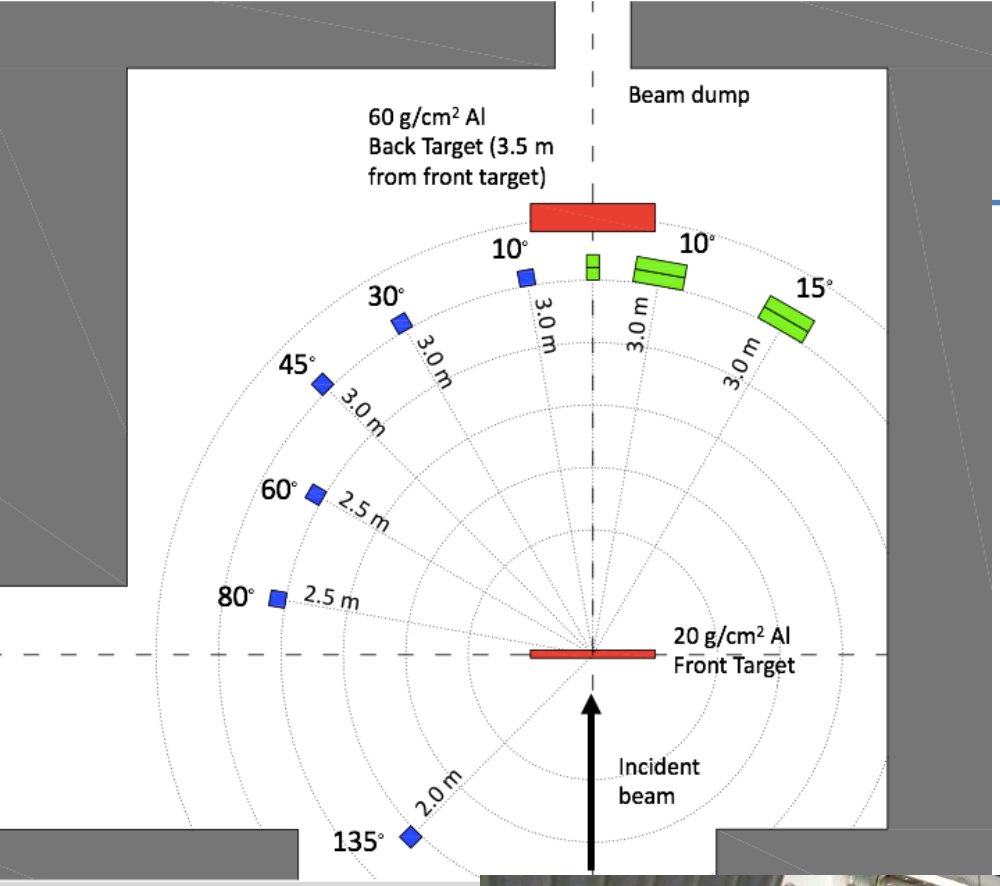








The experiment
(performed at NSRL, US)



- **Beams:** H to Fe
- **Energies:** up to 1500 MeV/u
- **Targets:** elemental (C, Al) and composite (PE, H_2O)

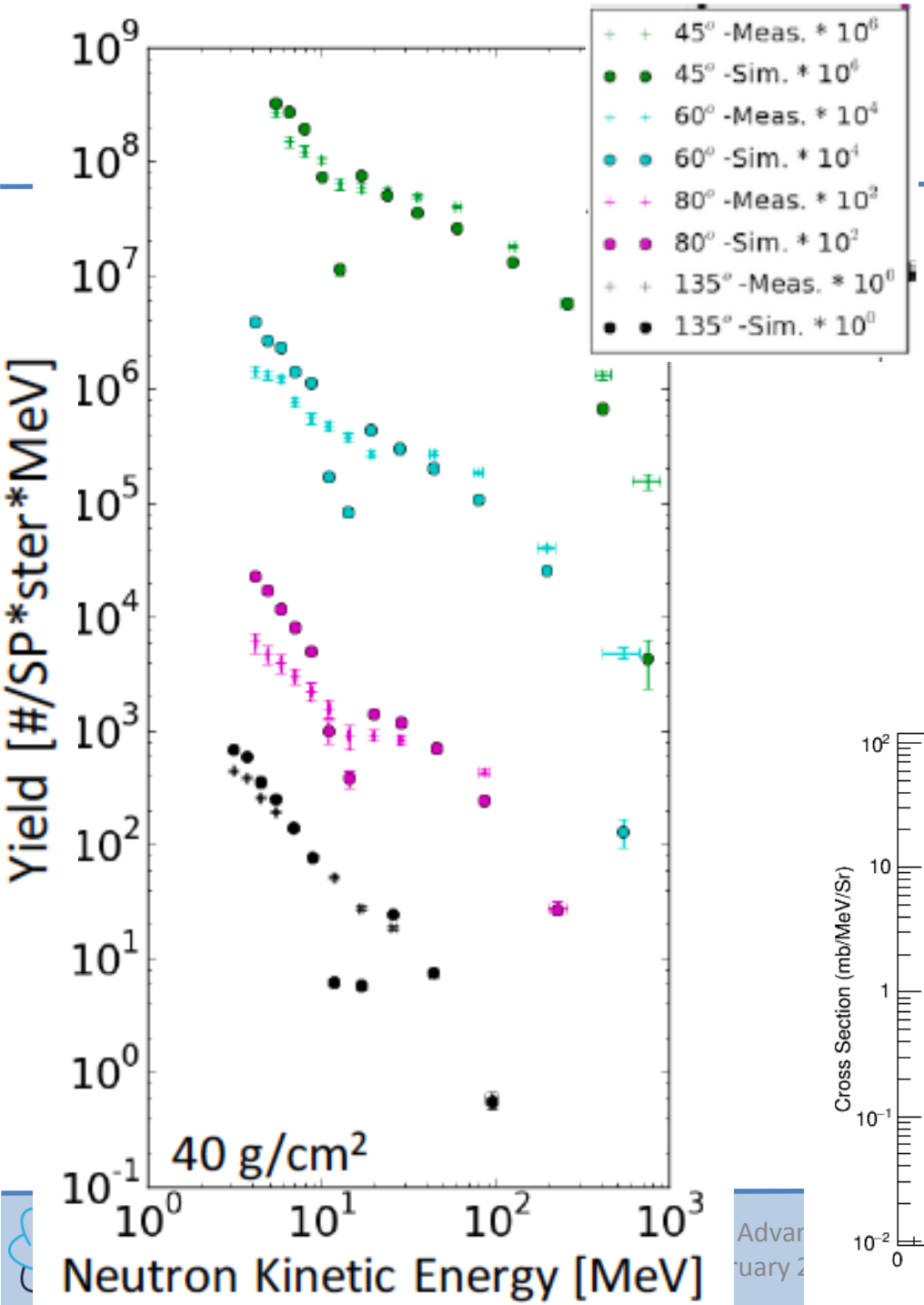
Detectors

- Pixel chamber
- Plastic scintillators
- Liquid scintillators
- NaI crystals
- BaF_2 crystals

Methodologies

- Energy deposition (ΔE and E)
- Time-of-flight (TOF)

Results

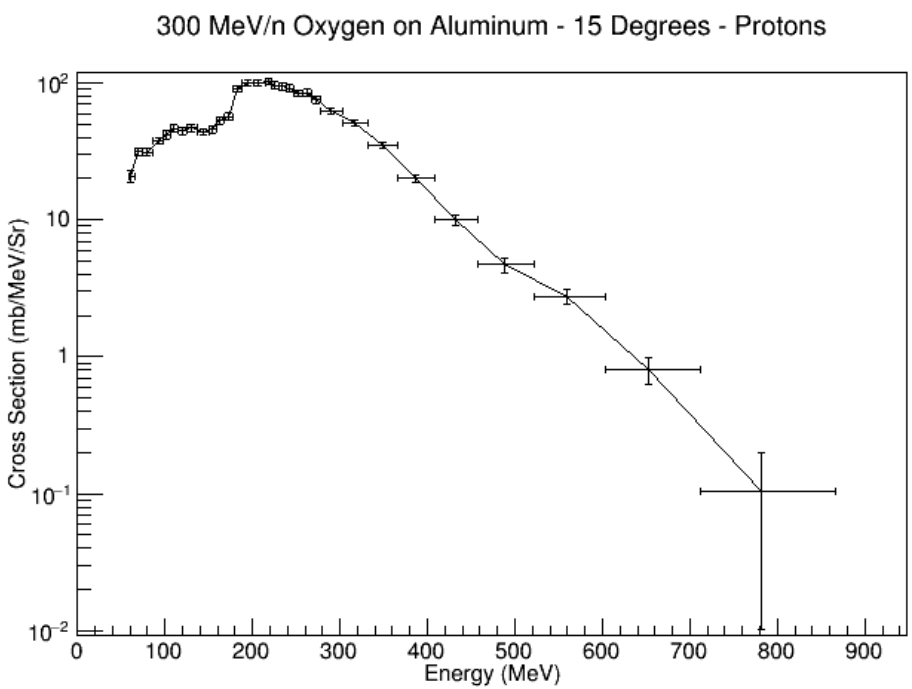


Outputs:

- yield
- kinetic energy

of all fragments types (including isotope discrimination) at several angles

Double-differential cross sections



RADIOTHERAPY WITH IONS

Real-time verification of the PTV position during a treatment

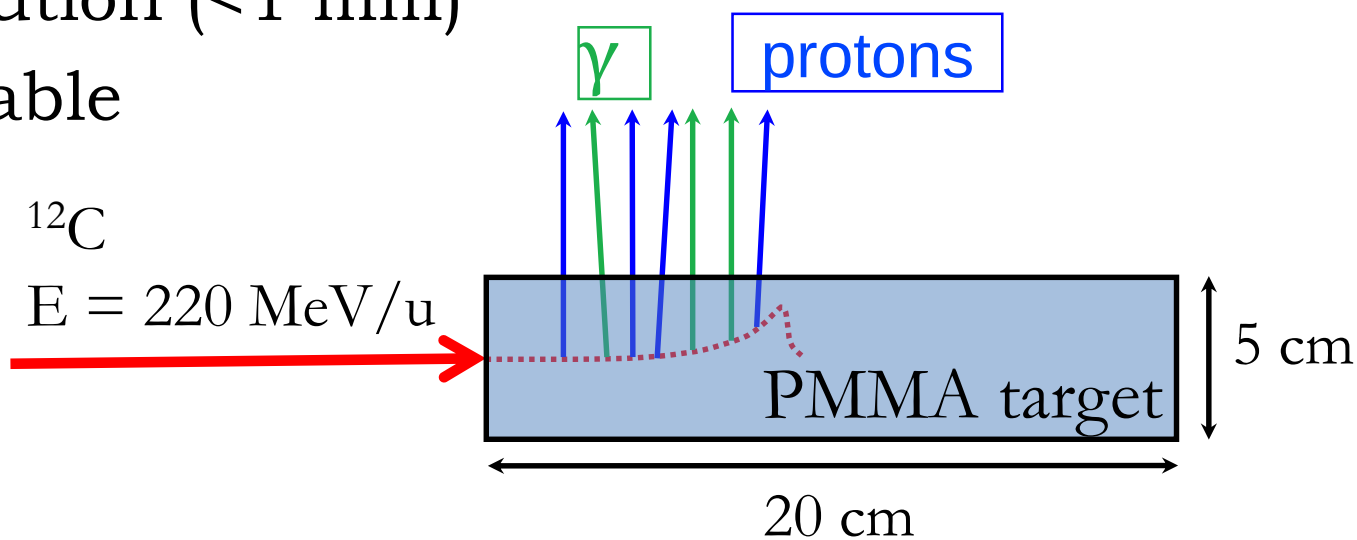
Idea: Exploit fragmentation of the primary beam at large angles (>60 deg) to monitor the position of the PTV – Planned Target Volume

Pros compared to PET

+ Online

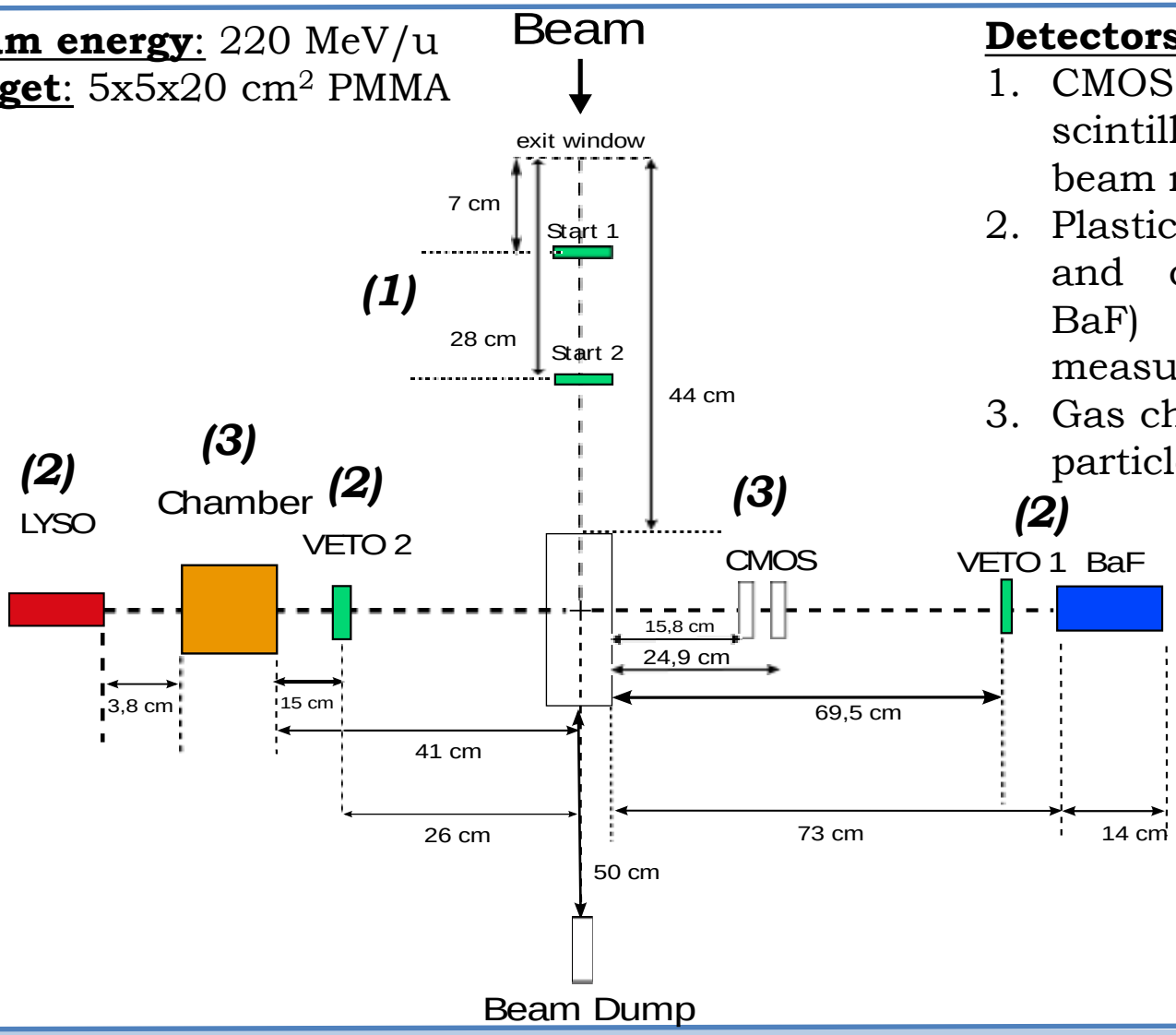
+ Better resolution (<1 mm)

+ More affordable



Experimental setup

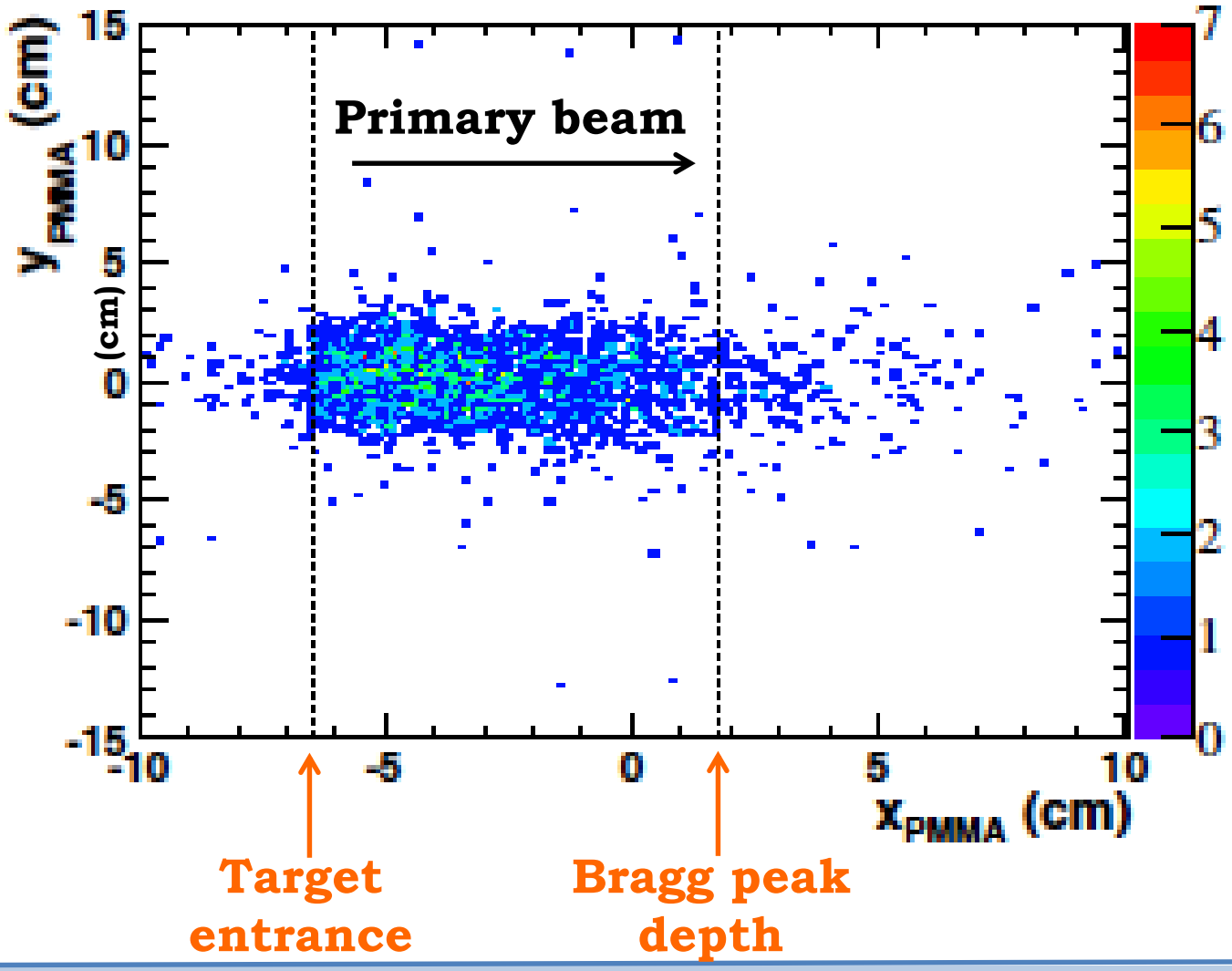
- **Beam energy**: 220 MeV/u
- **Target**: 5x5x20 cm^2 PMMA



Detectors:

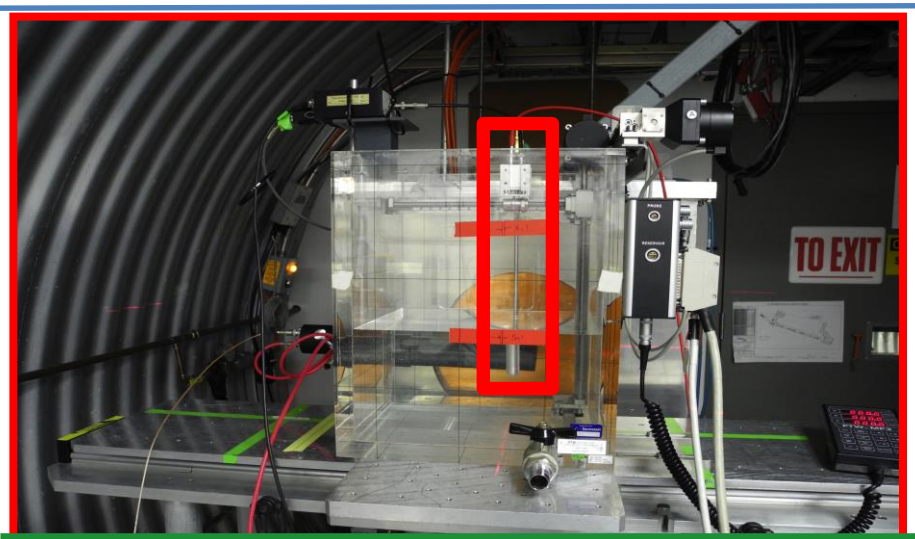
1. CMOS and plastic scintillator (START) for beam monitoring
2. Plastic scintillator (VETO) and crystals (LYSO and BaF) for ΔE-E and TOF measurements
3. Gas chamber and CMOS for particle tracking

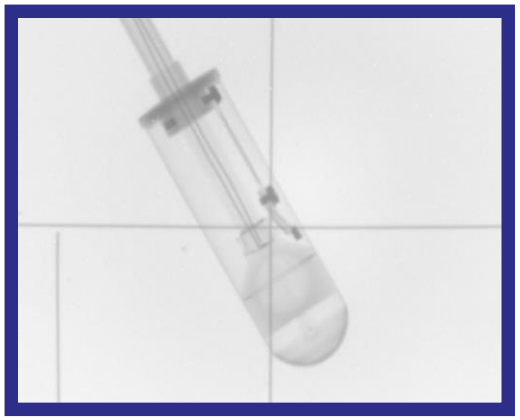
2D spatial distribution of secondary protons



RADIOTHERAPY WITH IONS AND SPACE RADIOPROTECTION

TEPC
Tissue Equivalent Proportional Counter



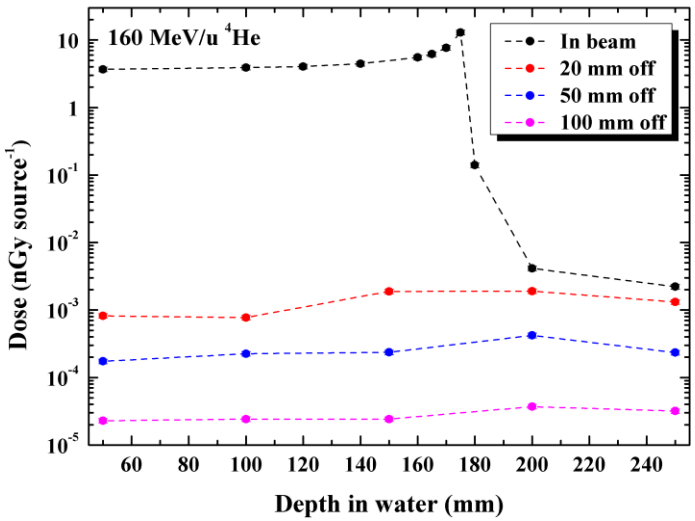


TEPC (Tissue Equivalent Proportional Chamber LET-1/2 Far West Technology) is equivalent to a tissue sphere of 2 μm diameter

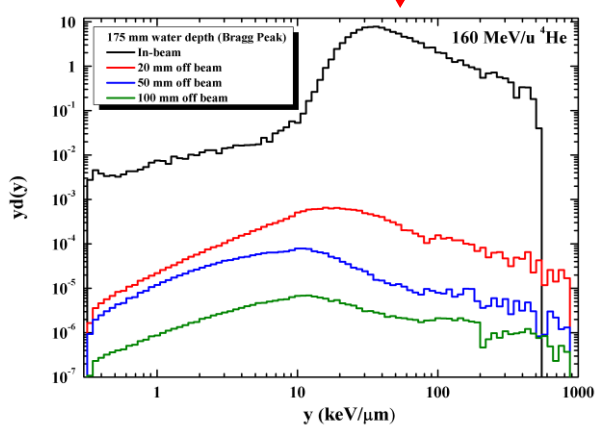
- **Lineal energy spectra**
- **Dose profile**
- **Radiation quality factor (y_D)**
- **RBE estimate**

Microdosimetry spectra

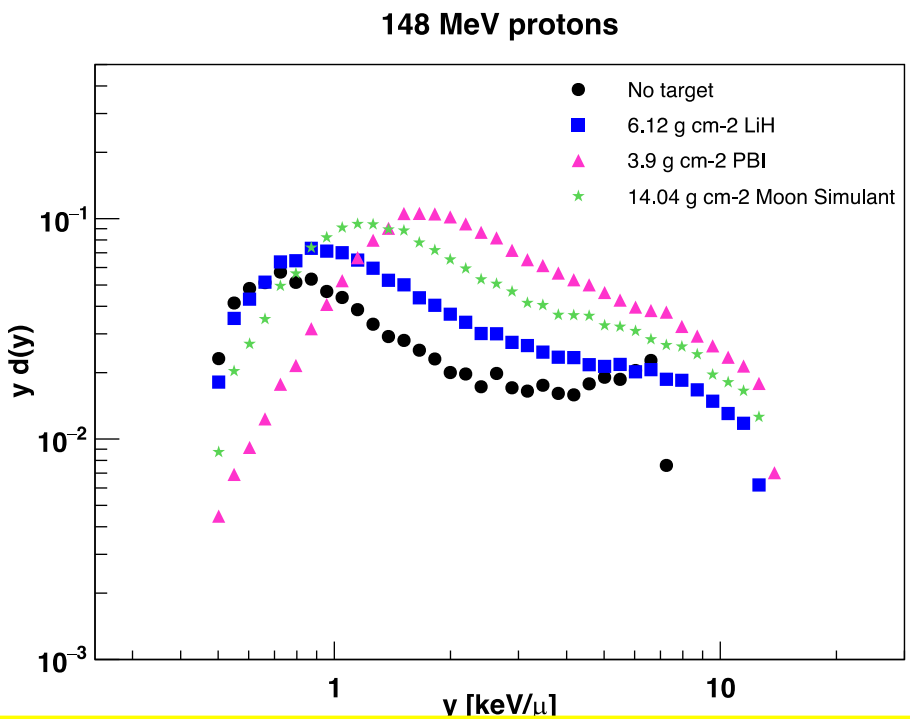
Radiotherapy



Bragg Peak (17.5 cm)



Radioprotection in space



It would be very interesting to add a charge-identification detector in front of the TEPC to disentangle the contribution of all particle types to the total spectrum

Thank you for your attention