PET cyclotron based setup for proton radiobiology and radiophysiology

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1. Rationale

1. **Radiobiology & radiophysiology**

a) **Study tumor and normal tissue response to proton irradiation.**

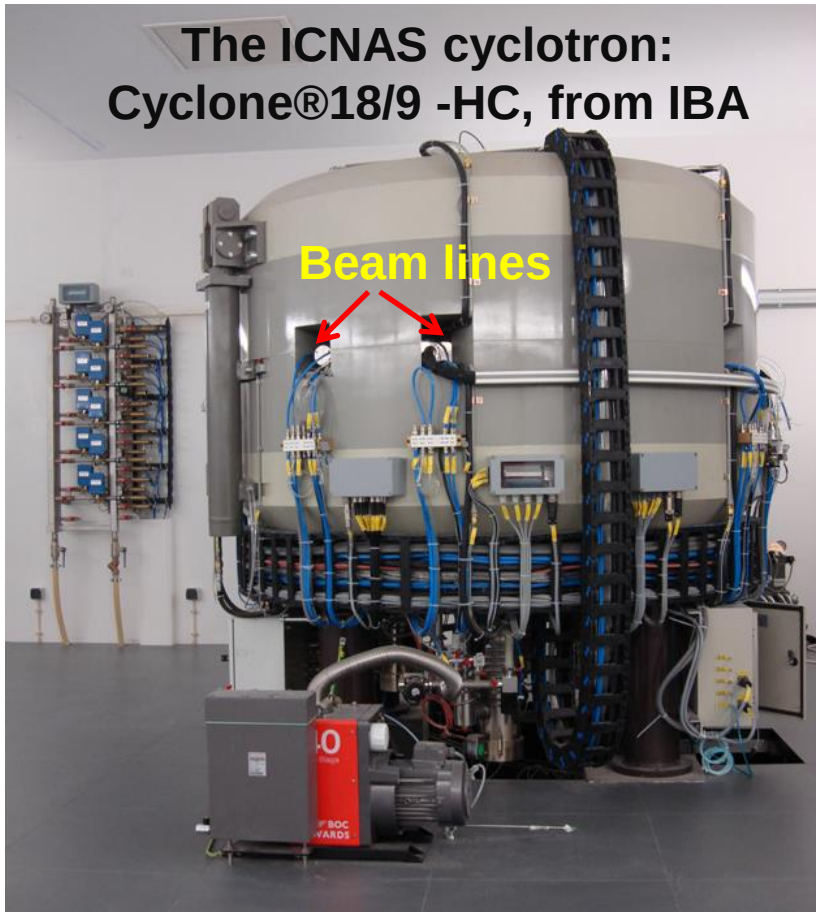
b) **Investigate efficacy of concomitant radiotherapy and chemical agents.**

c) **Research on very-low dose response of tissue and cell cultures: radiobiological models such as hormesis.**

S. Ghithan et al., IEEE NSS/MIC (2012)

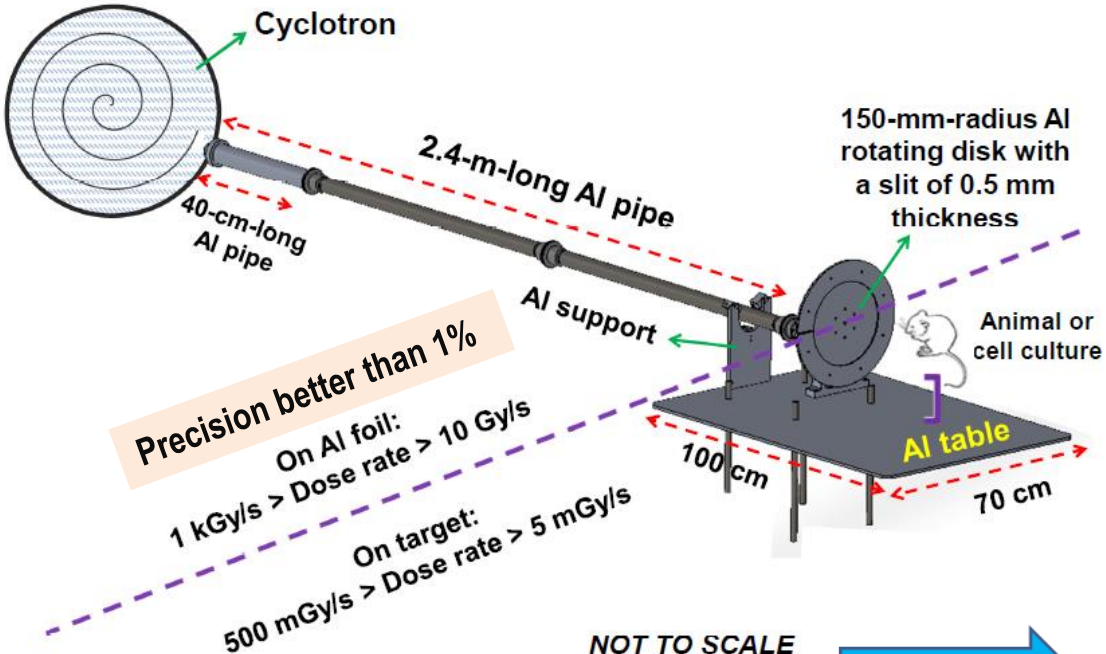
2. **Dosimetry**

3. **Others (e.g. space instrumentation)**



For production of short-lived radioisotopes for medical use such as ^{18}F widely applied in PET.

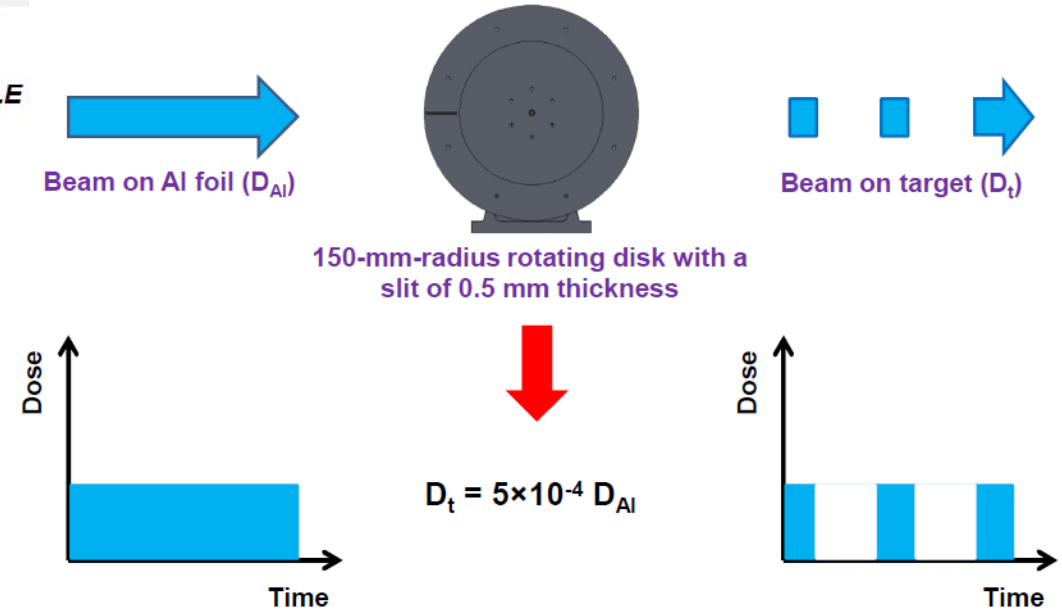
2. ICNAS dosimetry system



In-house developed vacuum pipes and rotating slit

LIP-Coimbra Workshop

S. Ghithan et al., 2013 JINST 8 P07010



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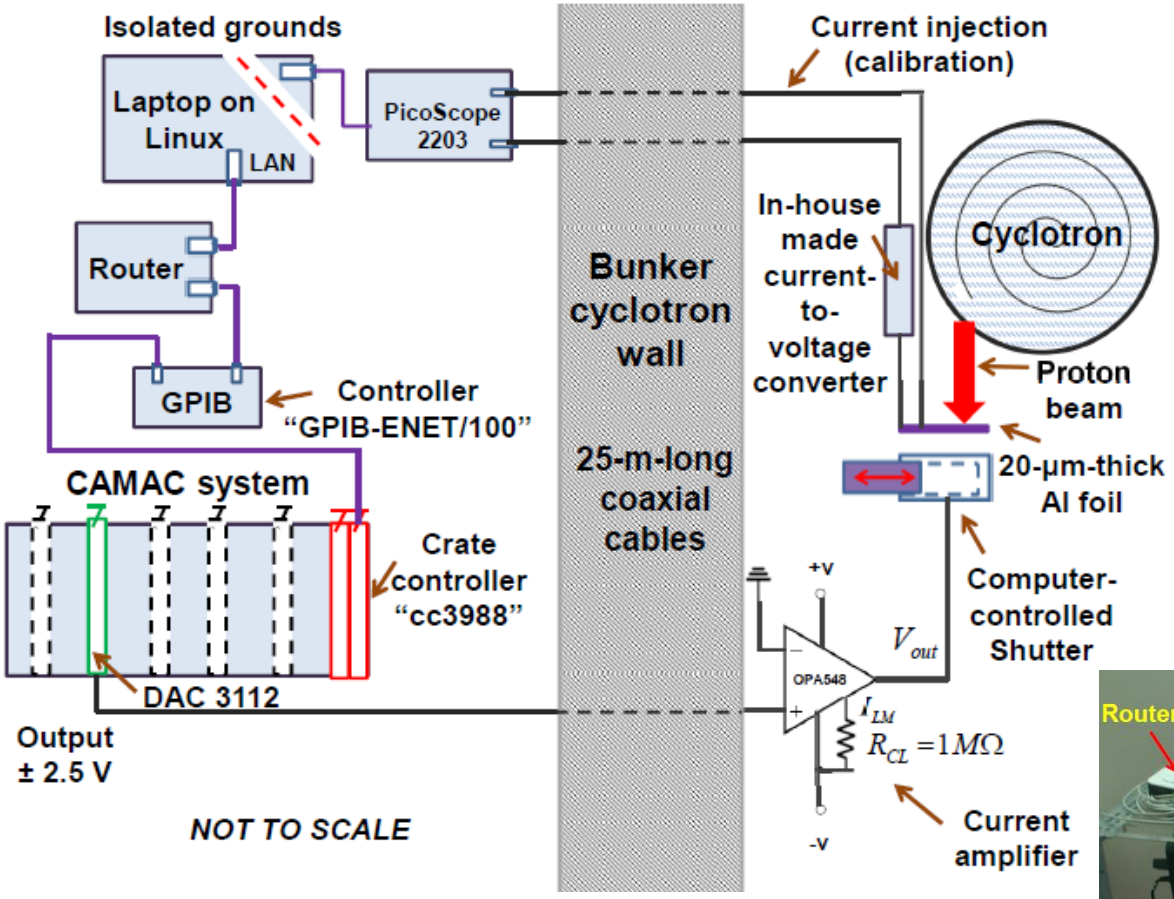
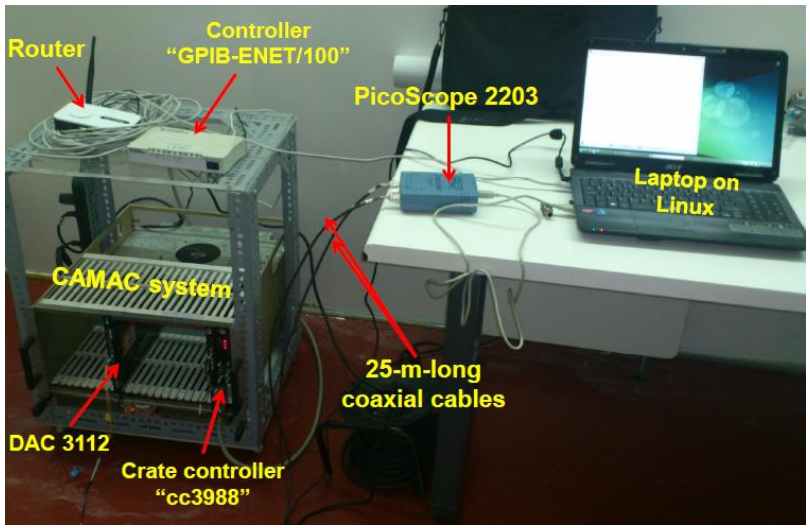


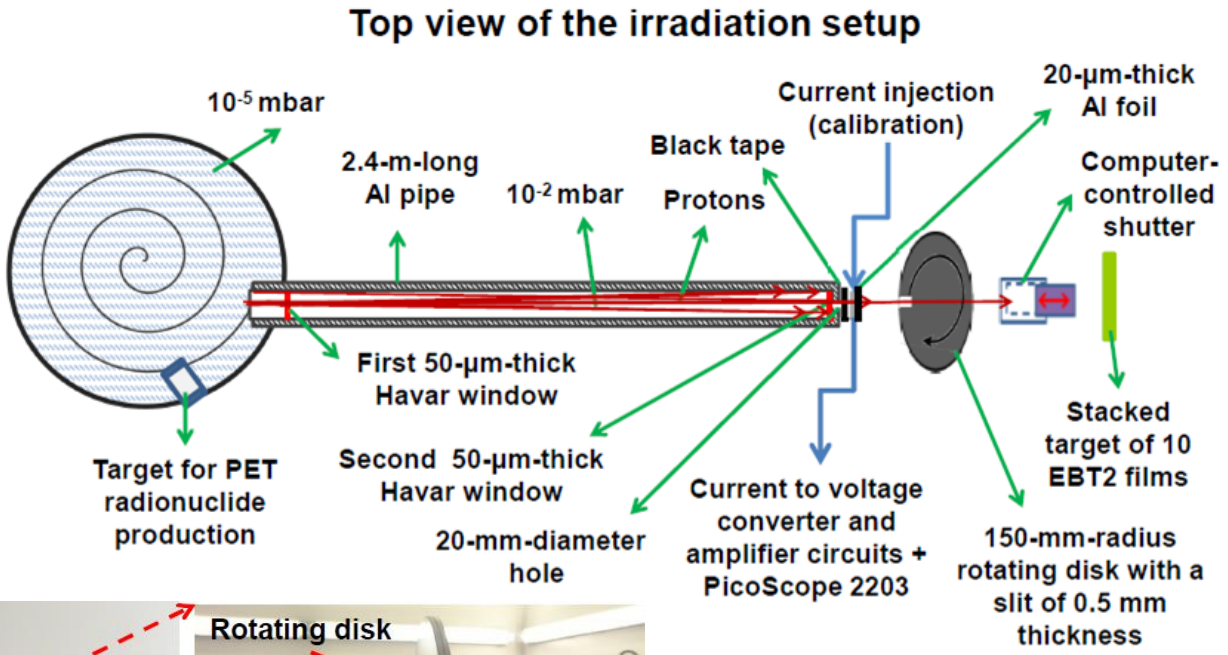
In-house developed electronics systems for beam readout and control of beam exposure

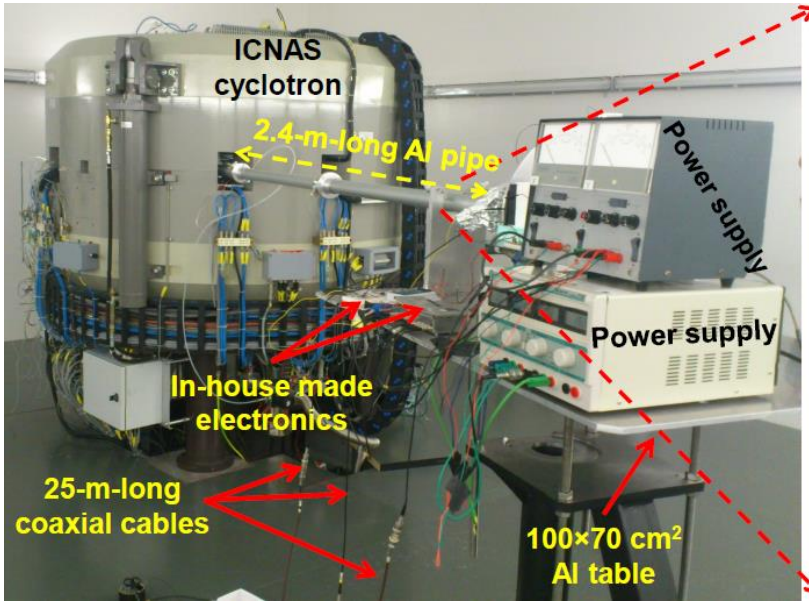


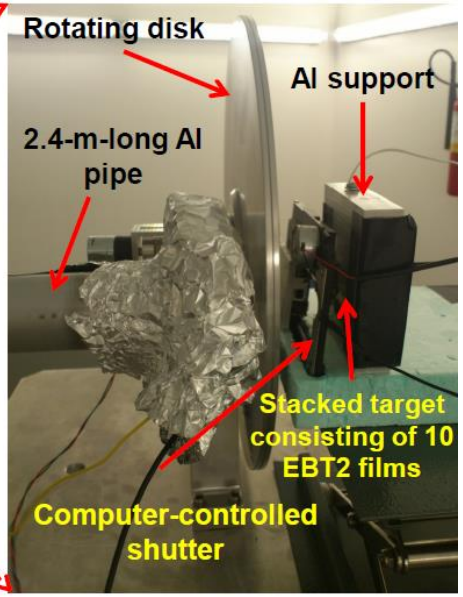
CAMAC modules kindly provided by Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany

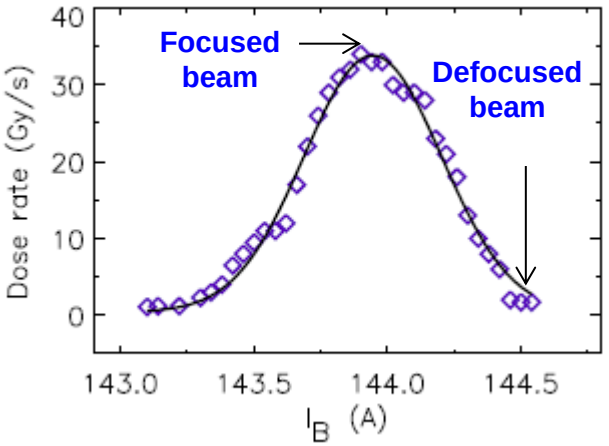
3. Dosimetric characterization of a PET cyclotron proton beam

Assessing beam uniformity and range





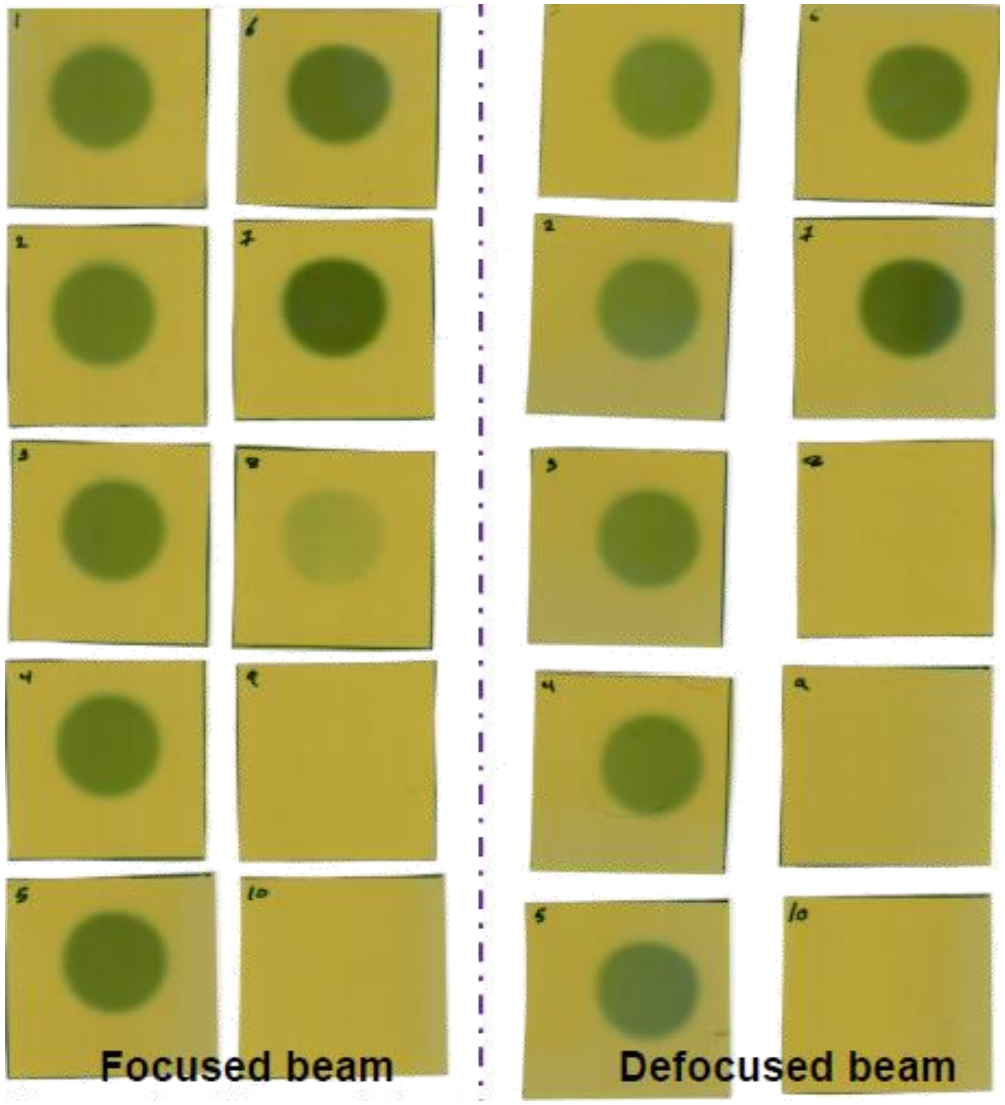




3. Dosimetric characterization of a PET cyclotron proton beam

Assessing beam uniformity and range

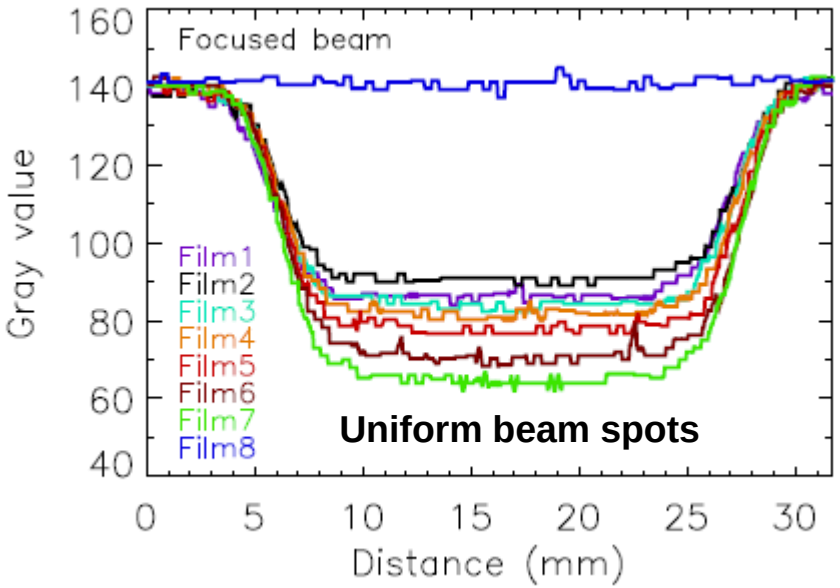
3.1 Gy
I_B = 144.06 A

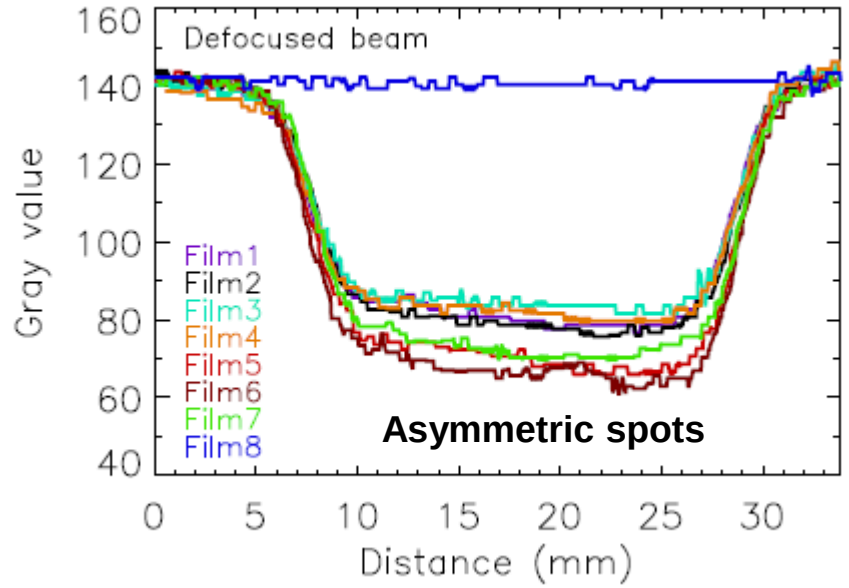


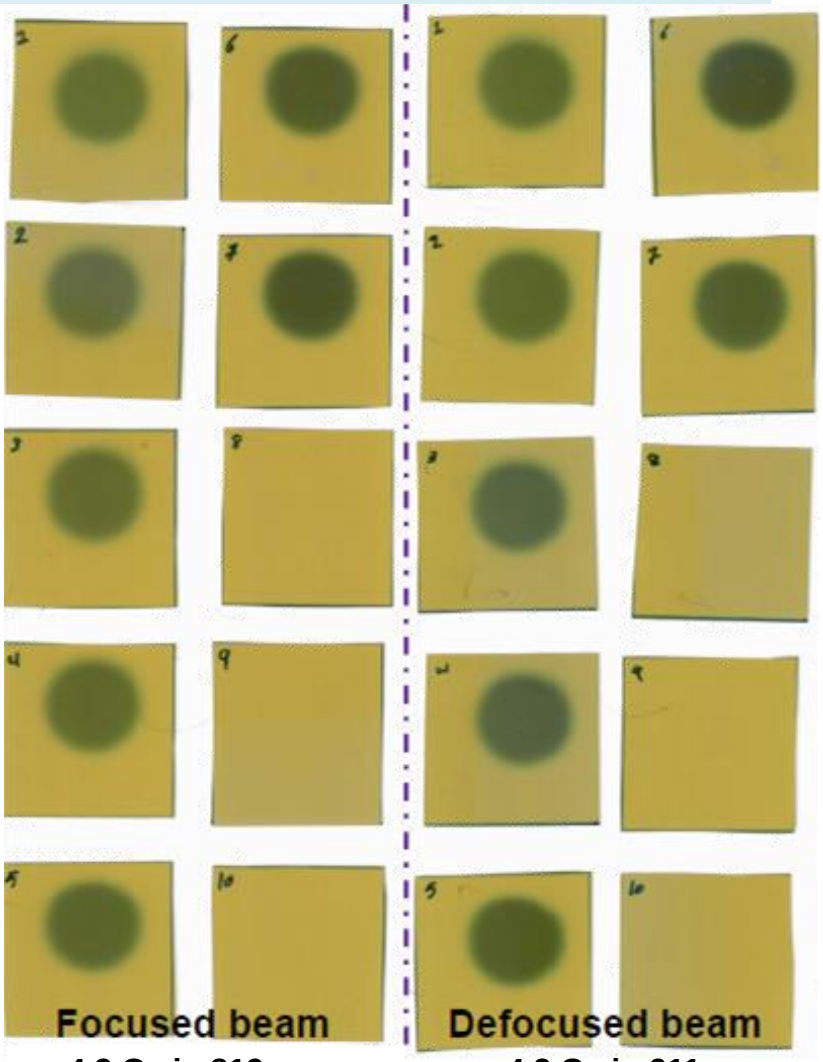
3.1 Gy
I_B = 143.6 A

3. Dosimetric characterization of a PET cyclotron proton beam

Assessing beam uniformity and range







Focused beam
4.2 Gy in 819 s
DR_{Al} = ~9.8 Gy/s
I_B = 144.10 A
I_{source} = 1 mA

Defocused beam
4.2 Gy in 911 s
DR_{Al} = ~9.5 Gy/s
I_B = 144.54 A
I_{source} = 50 mA

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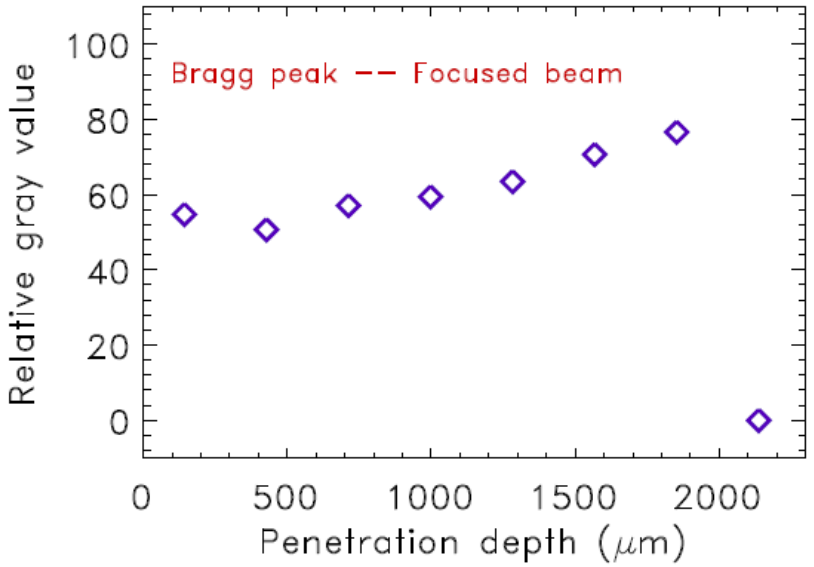
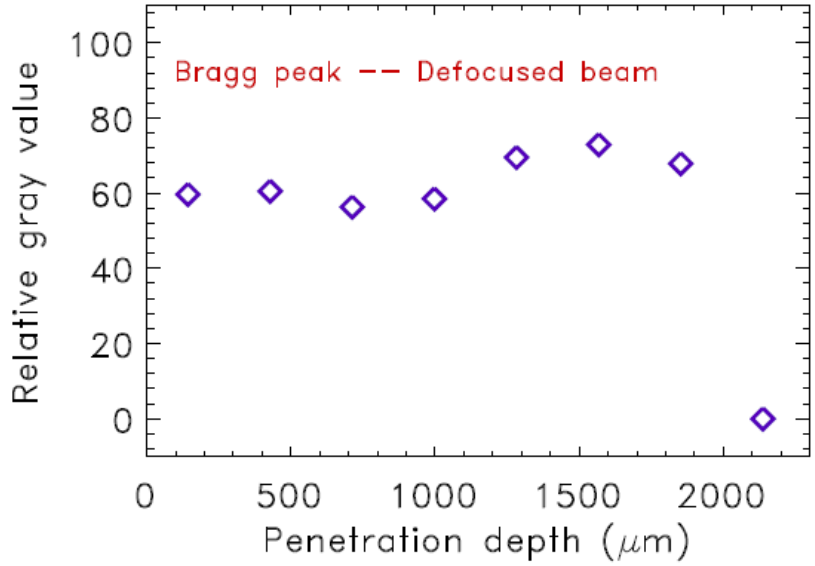
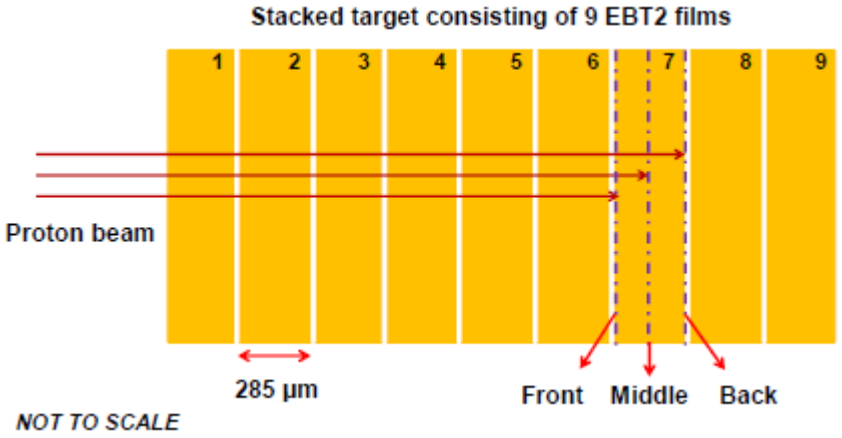




Beam range = 1.85 ± 0.14 mm

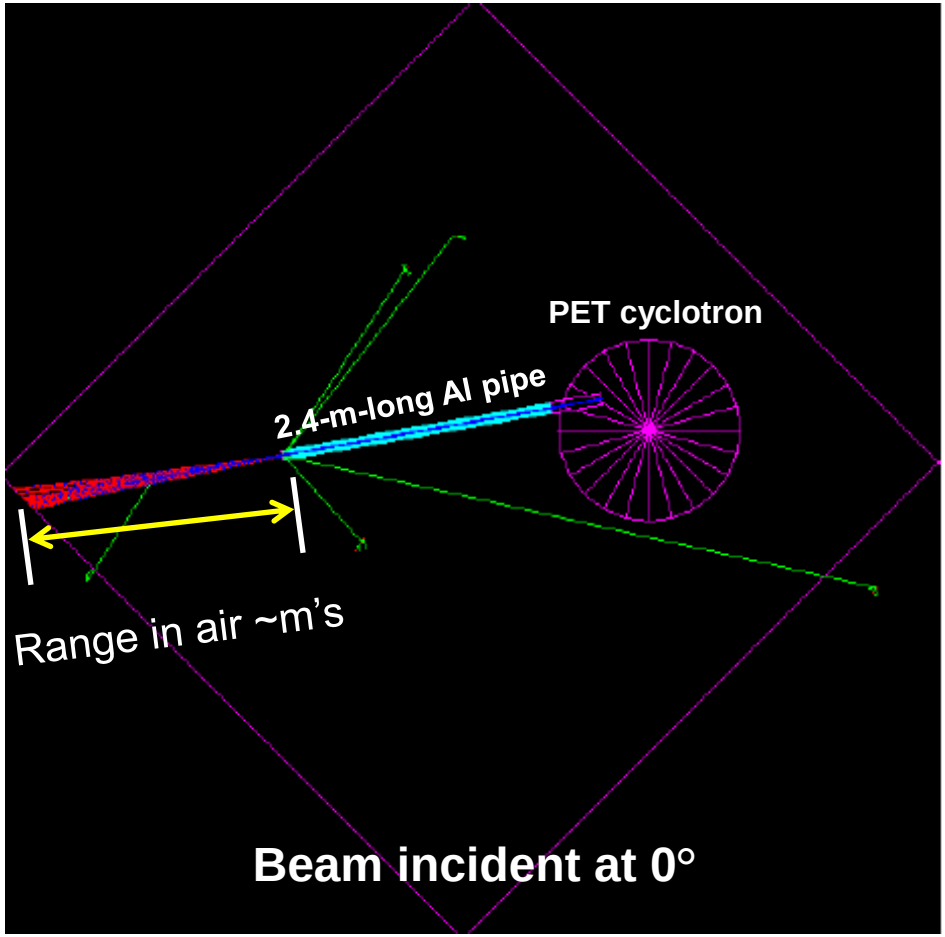
SRIM/TRIM simulation

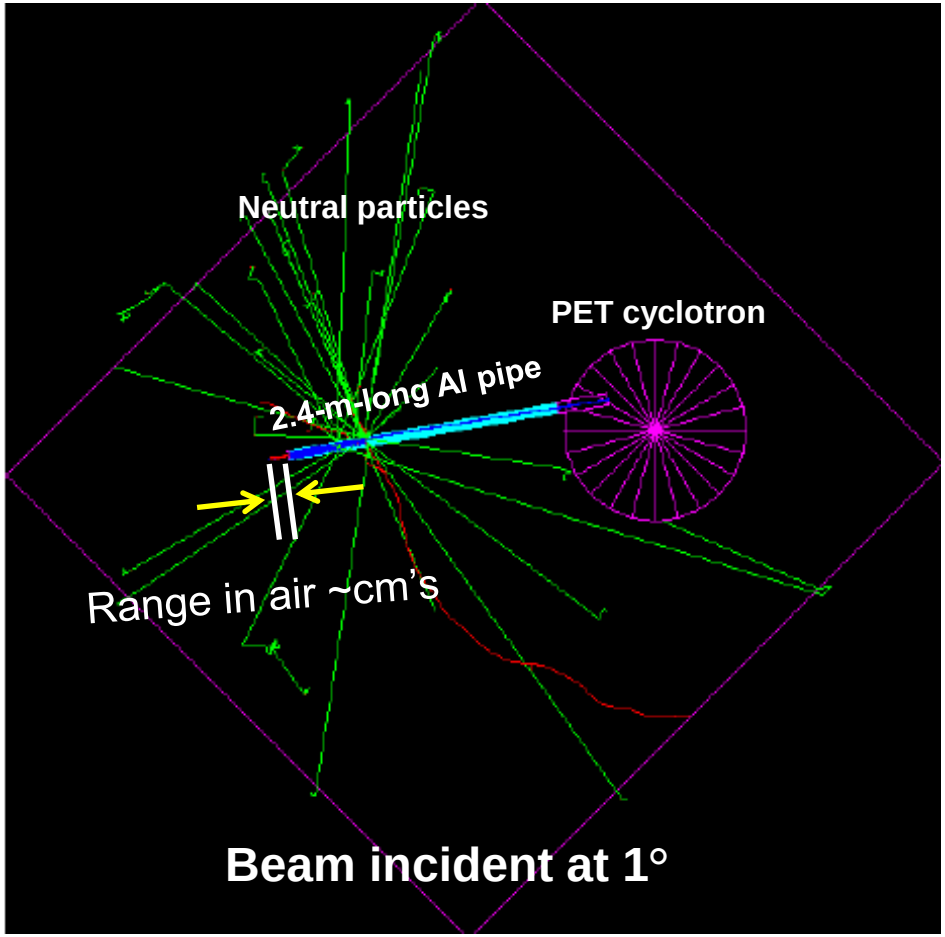
Beam energy = 13.75 ± 0.55 MeV



3. Dosimetric characterization of a PET cyclotron proton beam

Assessing beam uniformity and range – Geant4 simulation

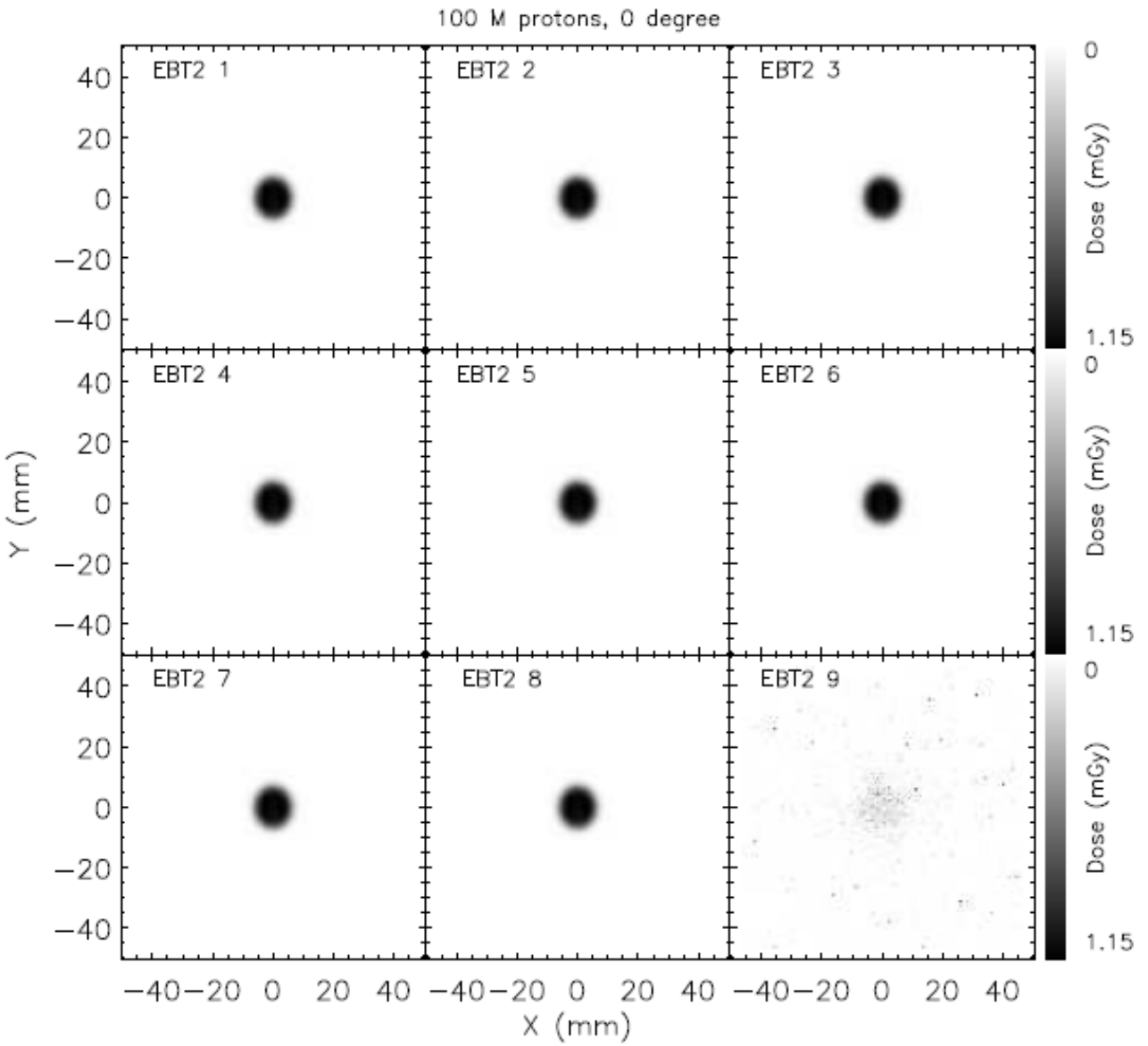




3. Dosimetric characterization of a PET cyclotron proton beam

Assessing beam uniformity and range - Geant4 simulation

Uniform beam spots



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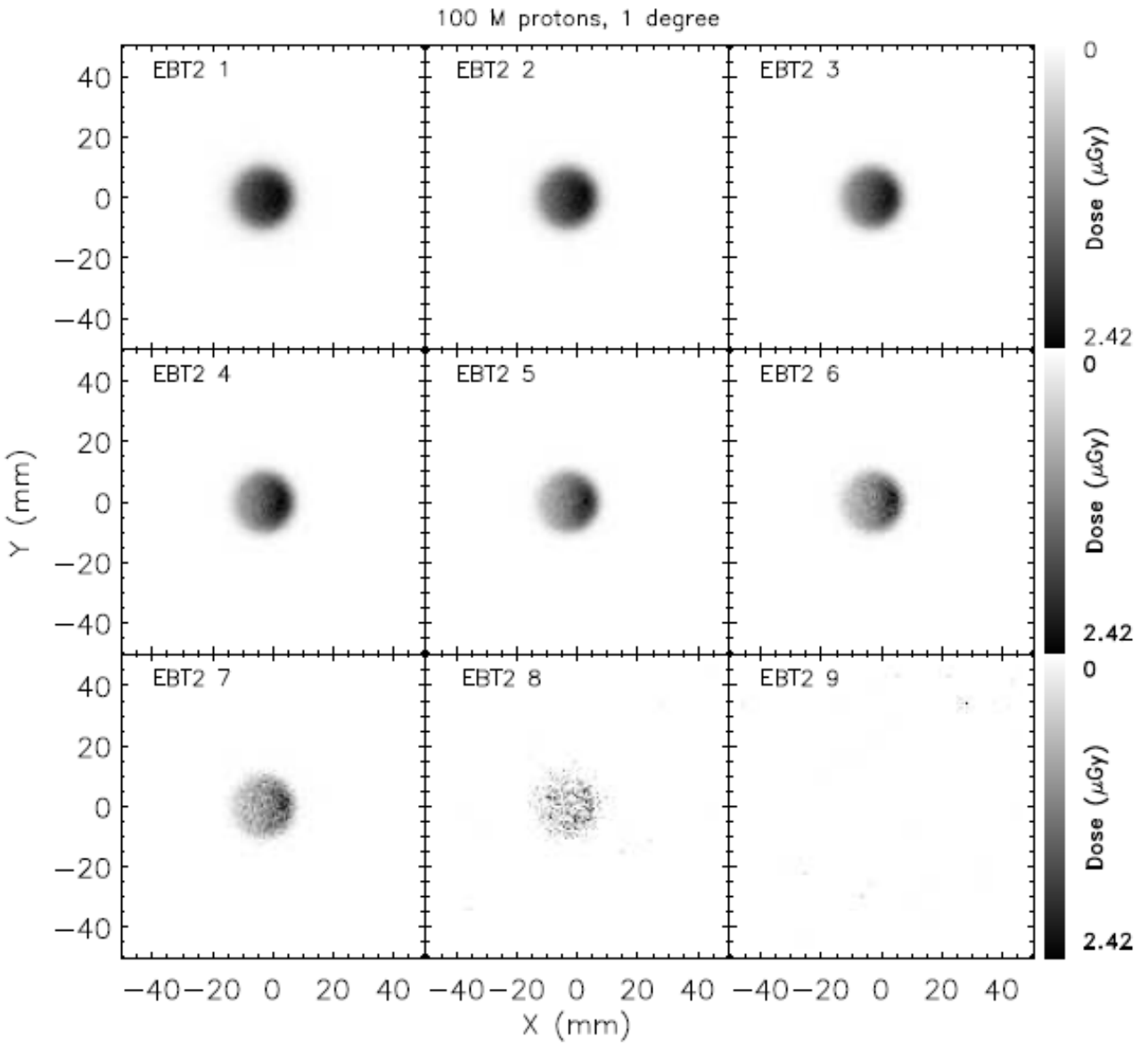
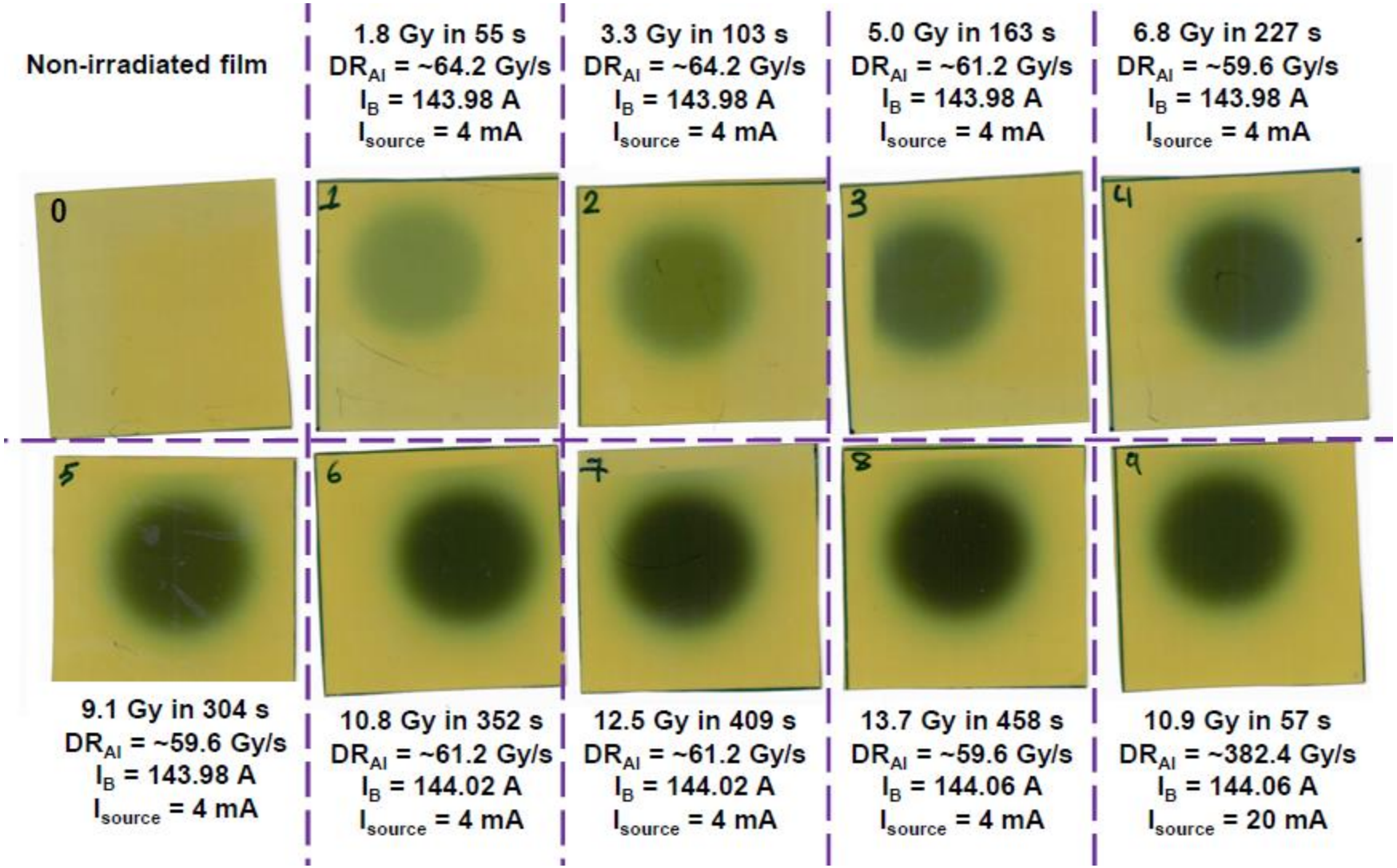
Assessing beam uniformity and range - Geant4 simulation

Asymmetric spots



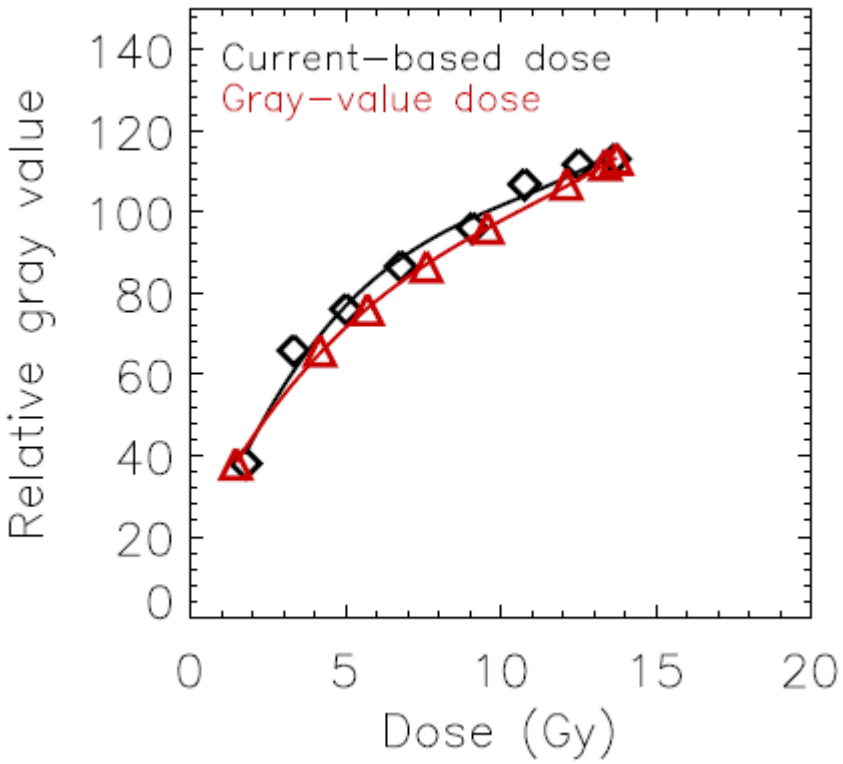
3. Dosimetric characterization of a PET cyclotron proton beam

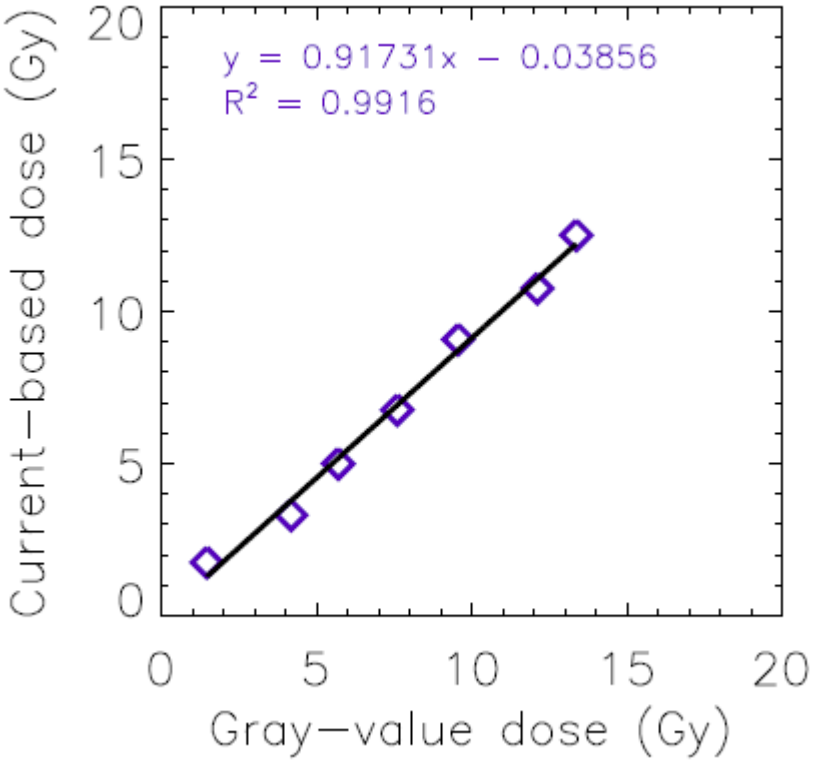
Online current-based dose measurement



4. Validation of the measured current-based dose

Published experimental data (EBT2 films)
Wang et al., Phys. Med. Biol. (2012)

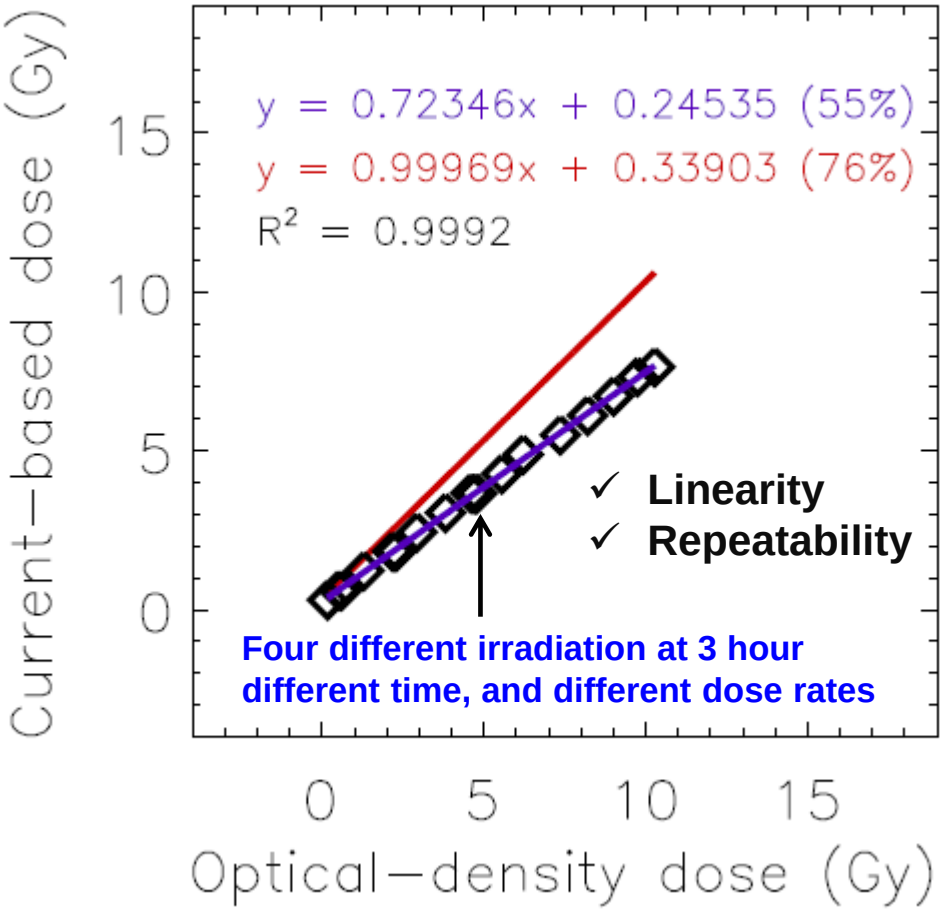


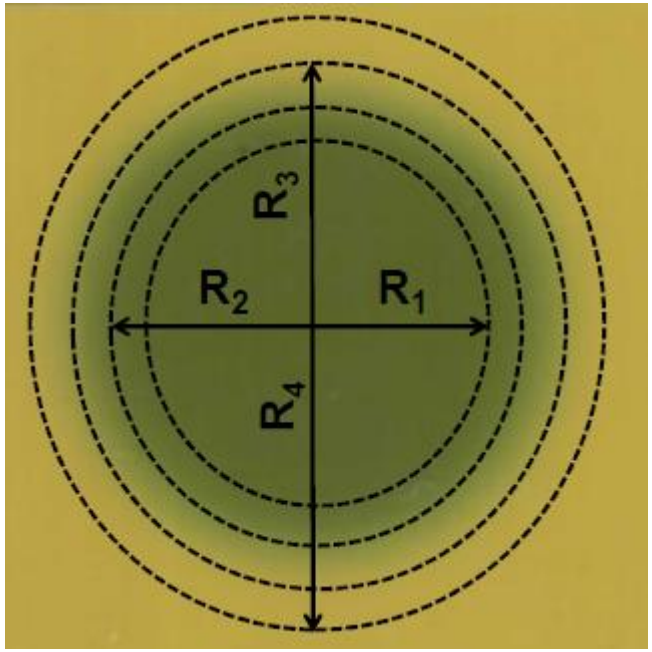


Both values are in agreement with about 8% accuracy.

4. Validation of the measured current-based dose

Experimental data using EBT2 films – CHUC, E.P.E. (megavoltage X rays)
Preliminary results (ongoing work)



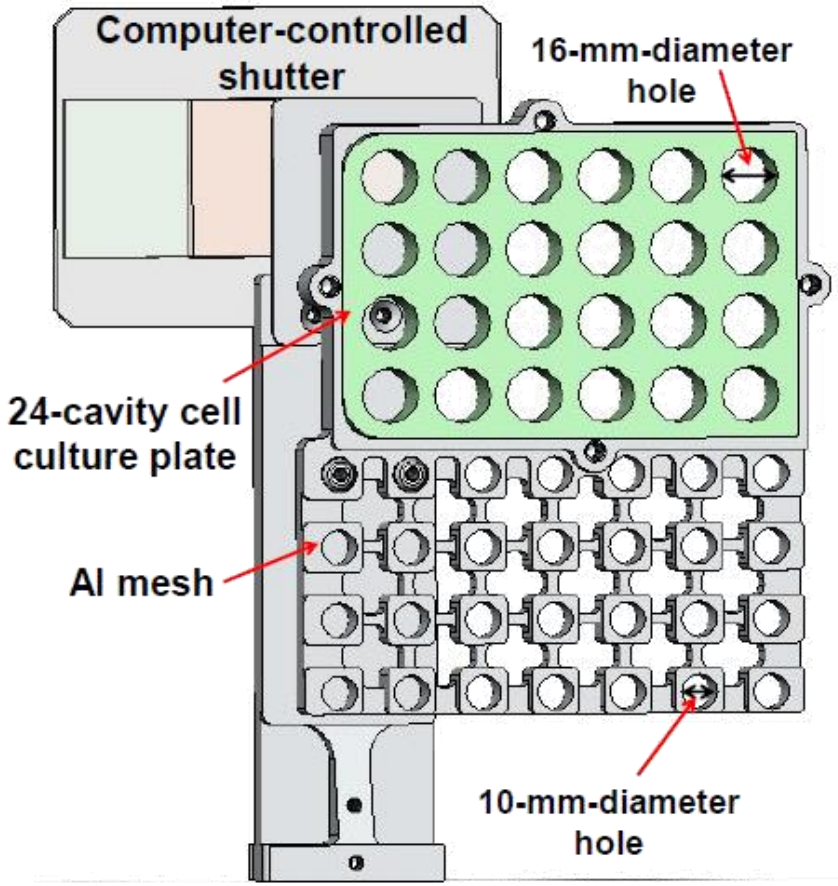


$$Current\ ratio\ [R_1] = \frac{\pi(R_1^2 - R_0^2)D_1}{\sum_{i=1}^{N} \pi(R_i^2 - R_{i-1}^2)Di}$$

5. Conclusions and future work

- An out-of-yoke dosimetry system with accelerated proton beams from a PET cyclotron is being developed, characterized, calibrated, and validated.
- The measured dose rate on target is being characterized. Range achievable so far: from 500 mGy/s down to 10 mGy/s.
- It is planned that, in the future, in the position of the EBT2 films, it will be possible to locate a small animal, cell cultures, or other materials or samples.

24-cavity cell culture plate



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