Beam Monitoring System for Cyclotron Proton Beams at ICNAS

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Brainstorming meeting

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LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTICULAS
LIP

FCTUC DEPARTAMENTO DE FÍSICA

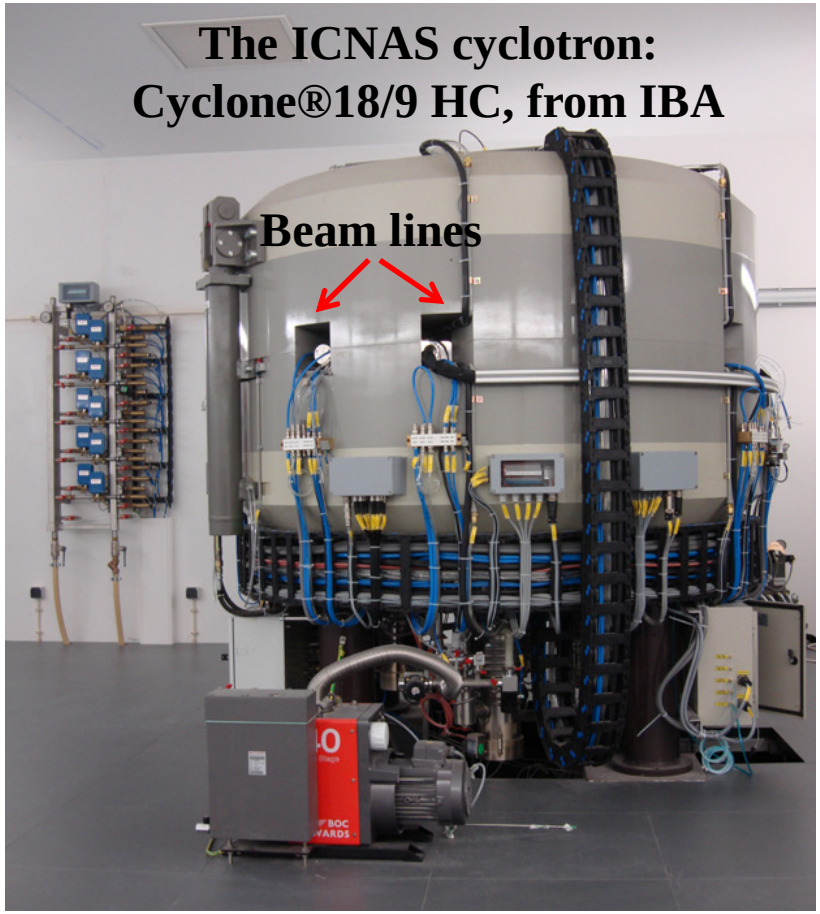
UNIVERSIDADE DE COIMBRA

1. ICNAS: Instituto de Ciências Nucleares Aplicadas à Saúde

Acceleration	H-	D-
Extracted beam	p	d
Energy (MeV)	18	9
Intensity (μA)	150	40

1×10^{15} particles/s

For production of short-lived radioisotopes for medical use such as ^{15}O and ^{18}F widely applied in PET



Radiobiological and dosimetric studies!

2. Main application fields of 18 MeV proton beam

1. Beam energy
2. Beam current
3. Beam profile
4. Fluence
5. Dose and dose rate

1. Radiobiological experiments
2. Radiation hardness test of devices for spacecraft
3. Detector development
4. For nuclear physics studies
5. Among others

2. Main application fields of 18 MeV proton beam

❖Biological and medical technology

- ➢Flux density : $1\times10^{9} \sim 1\times10^{11}$ protons/cm^2-sec
- ➢Irradiation uniformity : > 80%

❖Space technology

- ➢Flux density : $1\times10^{8} \sim 1\times10^{10}$ protons/cm^2-sec
- ➢Irradiation uniformity : > 90%

❖Material Science

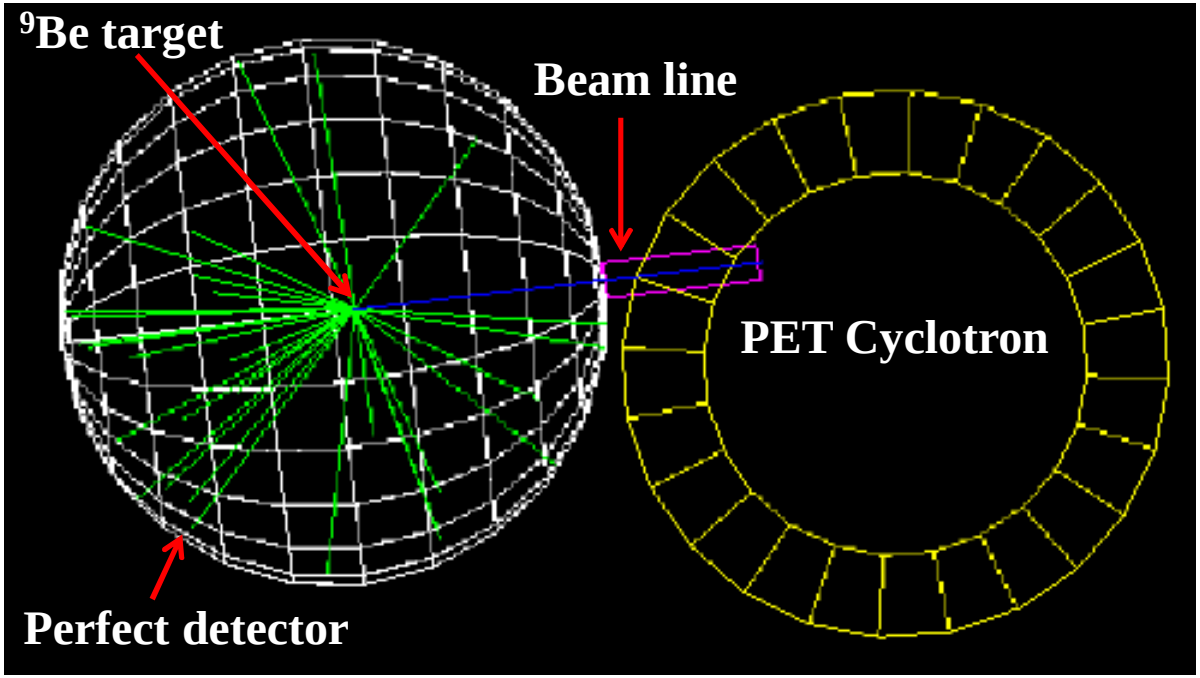
- ➢Flux density : $1\times10^{11} \sim 1\times10^{13}$ protons/cm^2-sec
- ➢Irradiation uniformity : > 95%

Kim et al., 2006

3. Monte-Carlo validation

Geant4 version 9.3.p01, QGSP_BERT_HP physics package

Pinto, MSc U. Coimbra

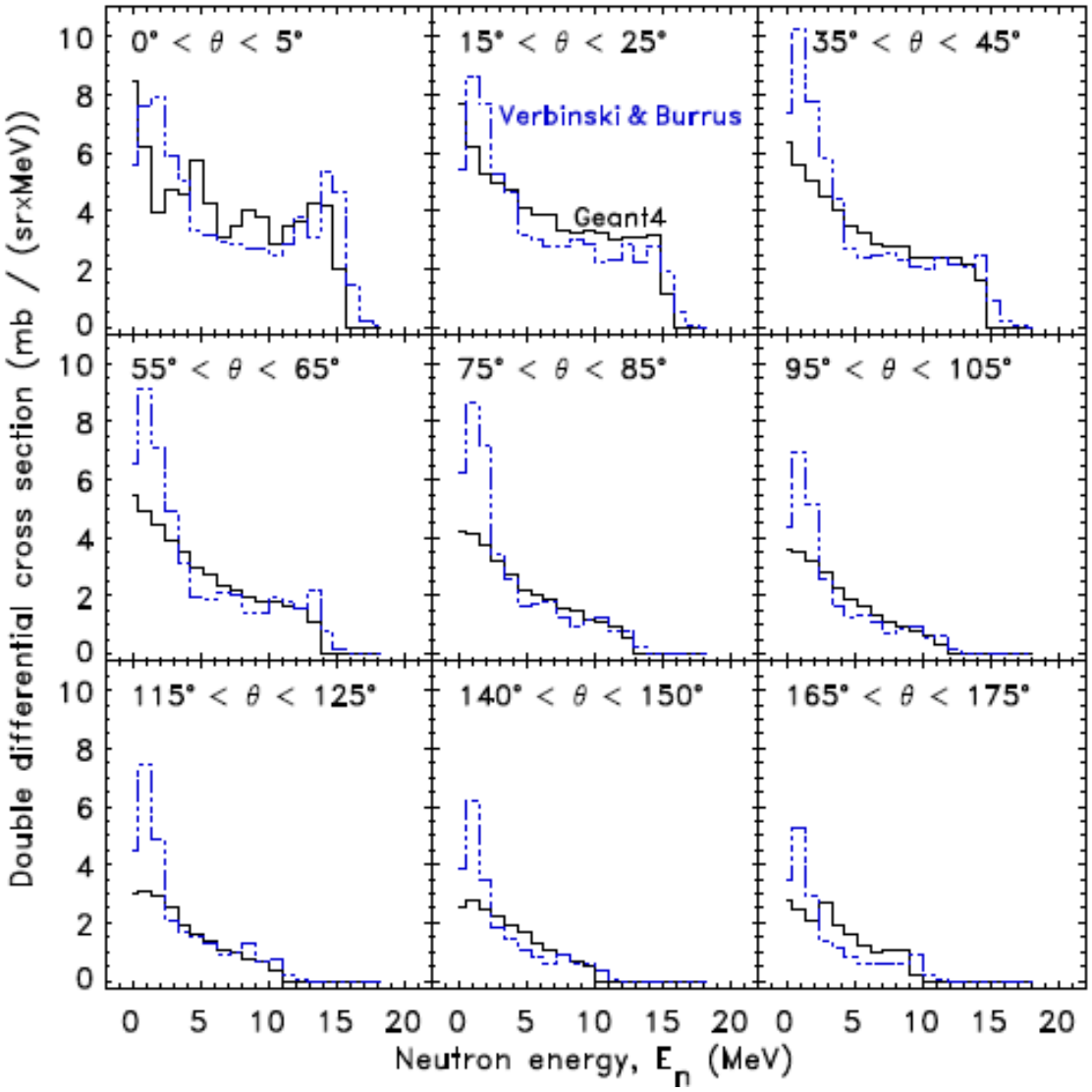


A proton beam with 18.5-MeV energy was shot in vacuum through a 25.2-µm-thick ^{9}Be target

Verbinski and Burrus

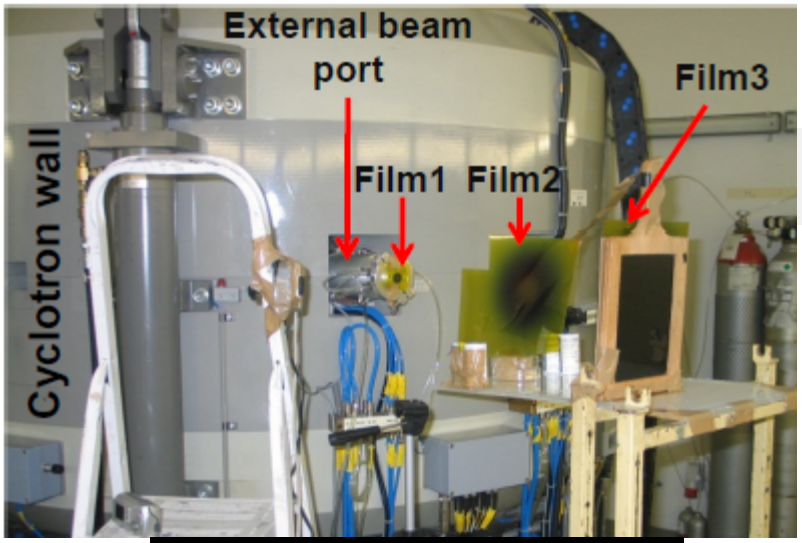
3. Monte-Carlo validation

Remarkable agreement between Simulation and experimental data



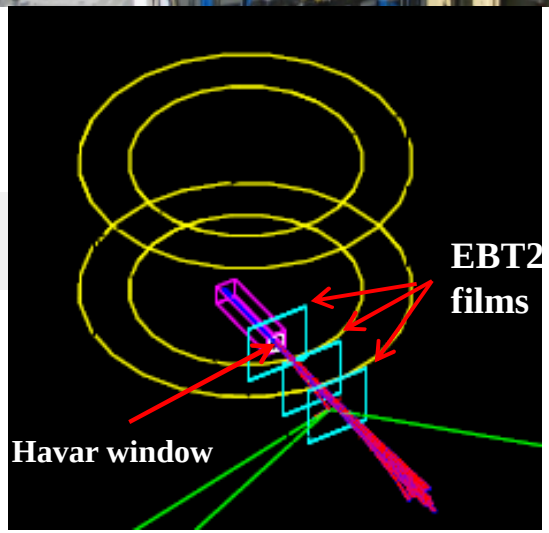
4. Characterization of in-air beam divergence

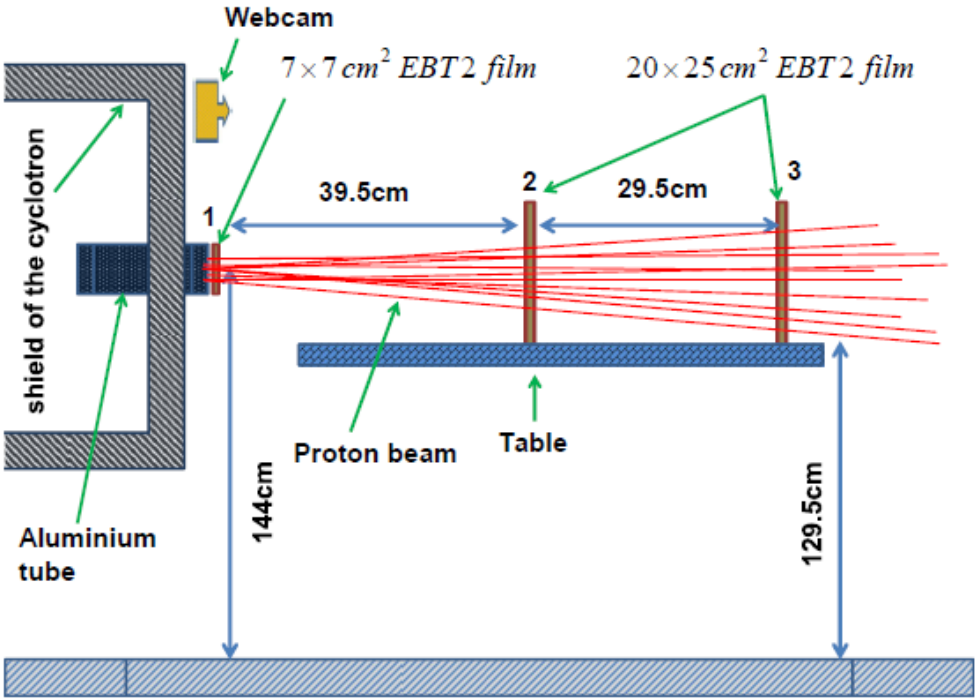
4.1 Experiment at the PET cyclotron at ICNAS



ICNAS

Geant4

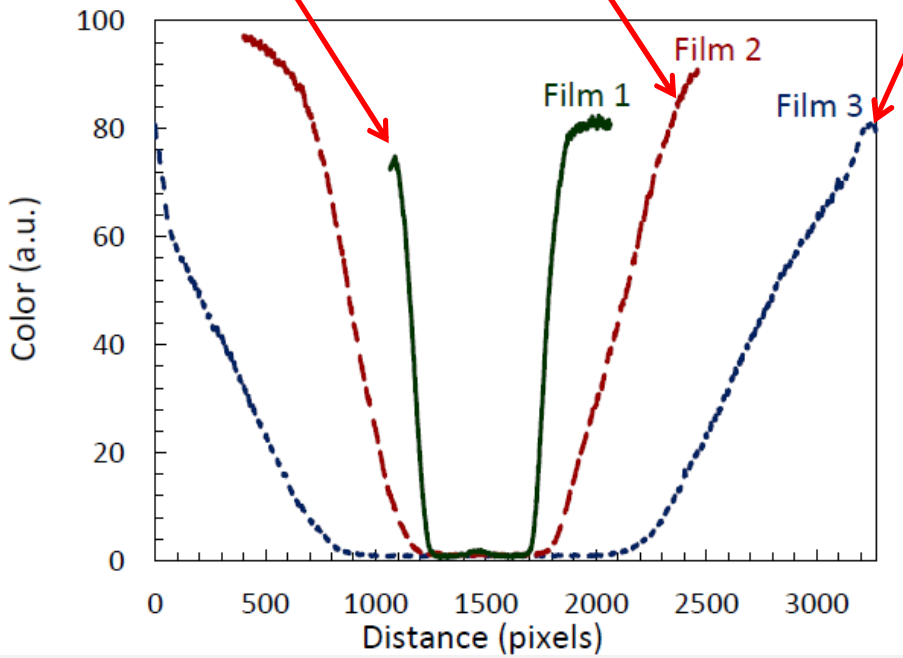


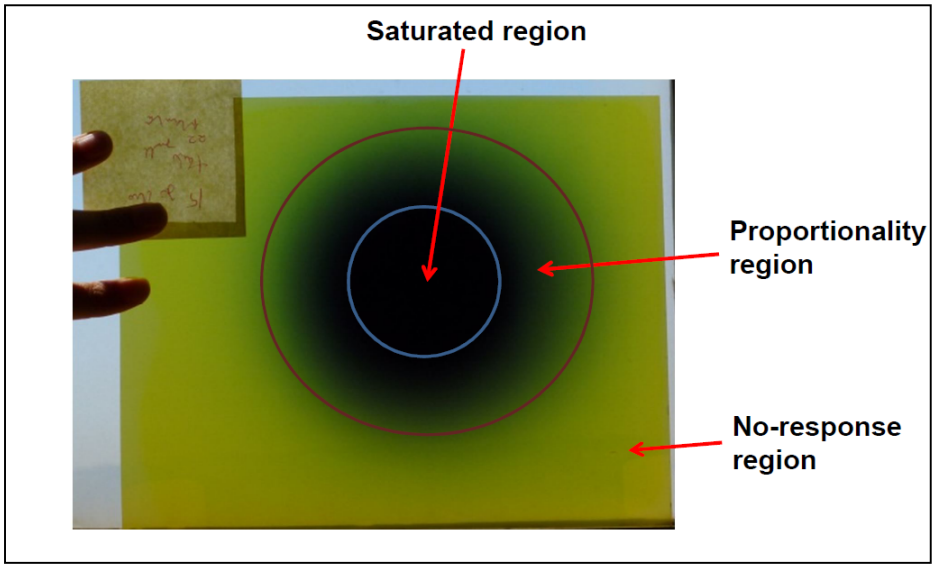


4. Characterization of in-air beam divergence

4.1 Experiment at the PET cyclotron at ICNAS

The beam profile becomes broader with increasing distance in-air

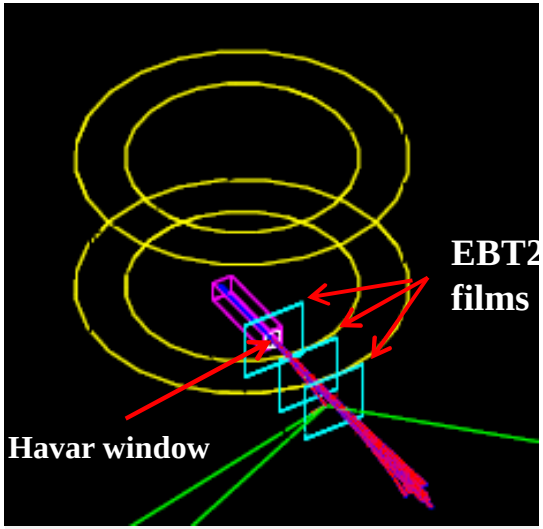




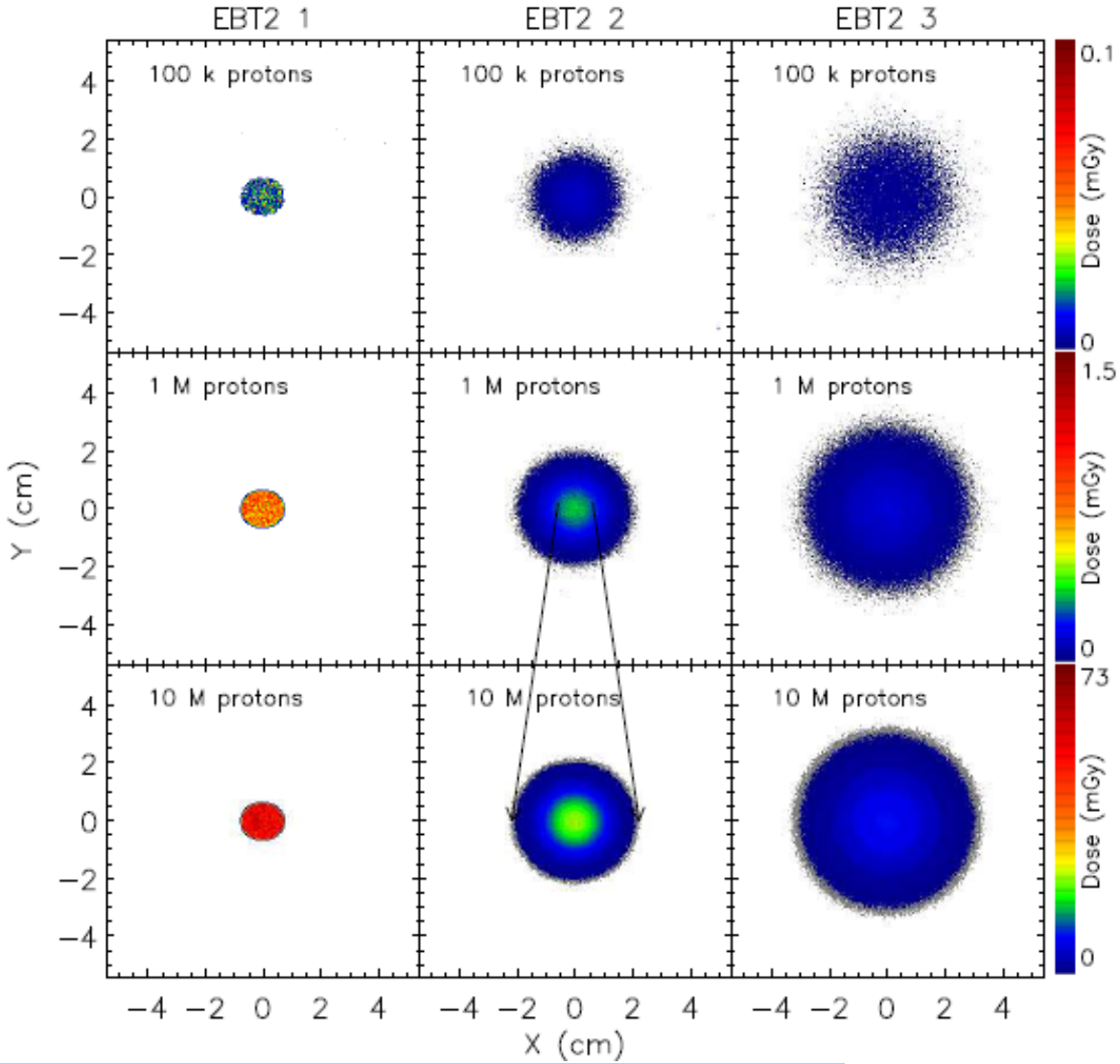
The normalized beam profiles of the three films

4. Characterization of in-air beam divergence

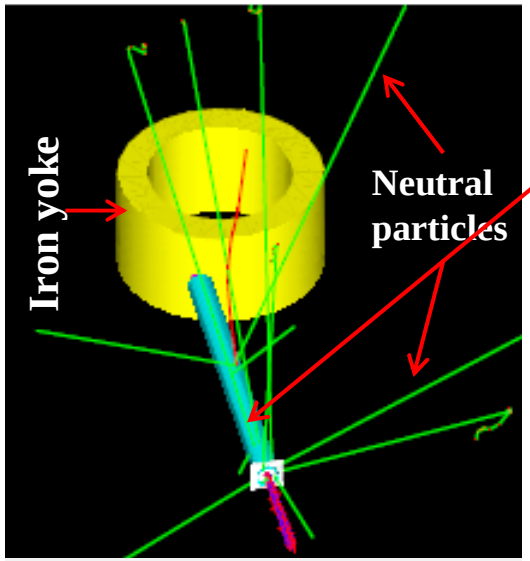
4.2 Geant4 simulations



View of the setup simulated with Geant4

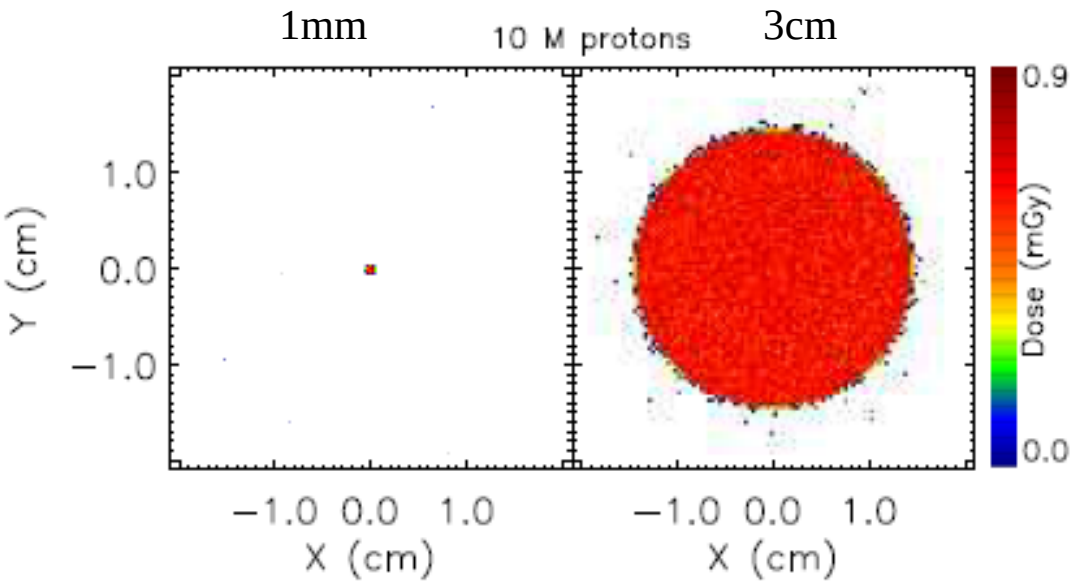


5. Neutron and γ-ray dose contribution



View of the irradiation setup simulated with Geant4

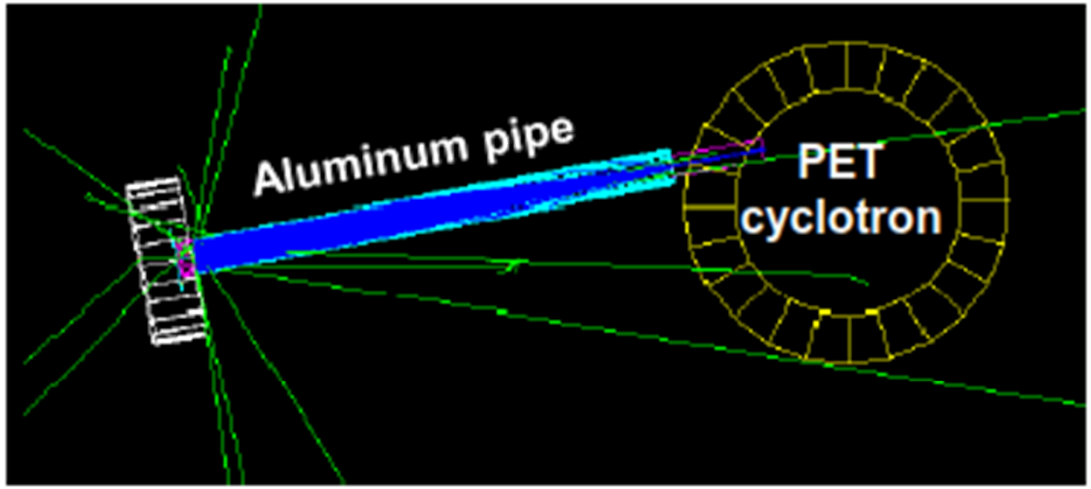
Pipe length : 3 m

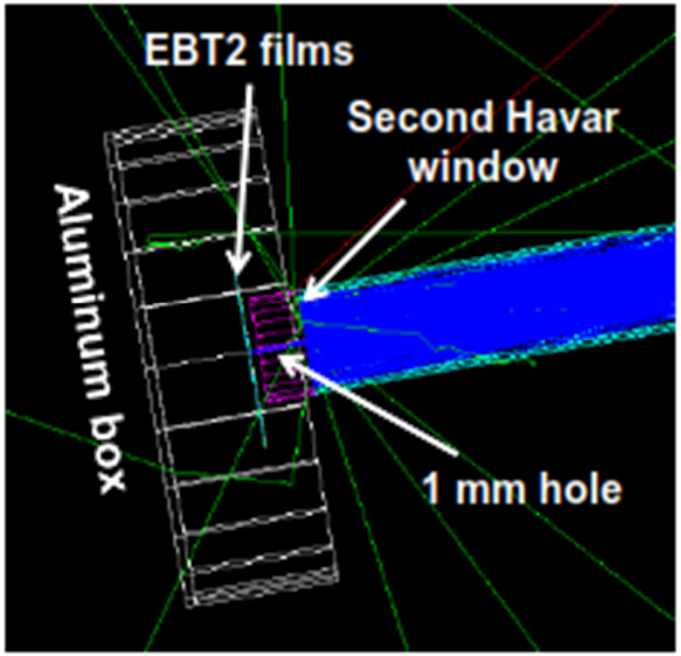


The dose contribution from neutrons and γ-rays is negligible down to at most the 1% level

Ten million protons were simulated. A beam current of 1.5 μA corresponds to a film dose rate of 1 kGy/s (plateau) and 3 kGy/s (Bragg peak)

5. Neutron and γ-ray dose contribution





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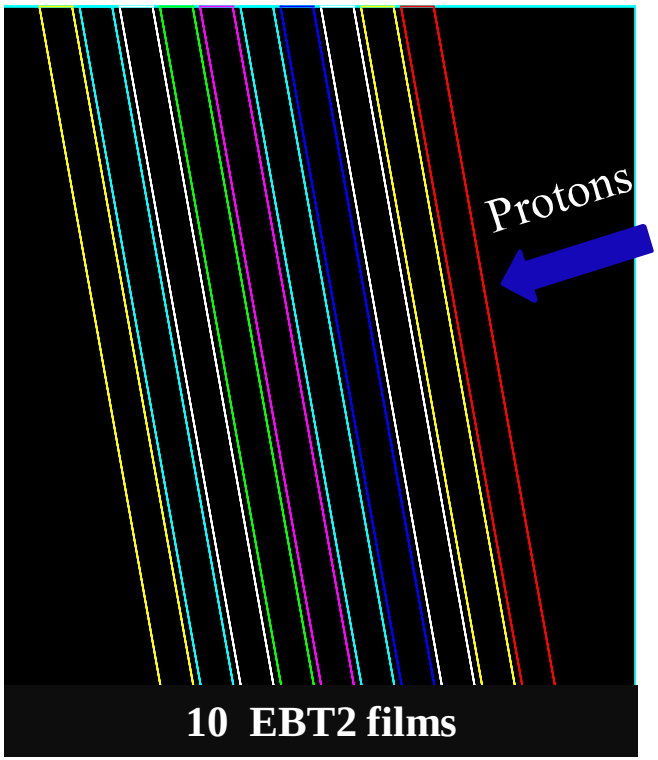
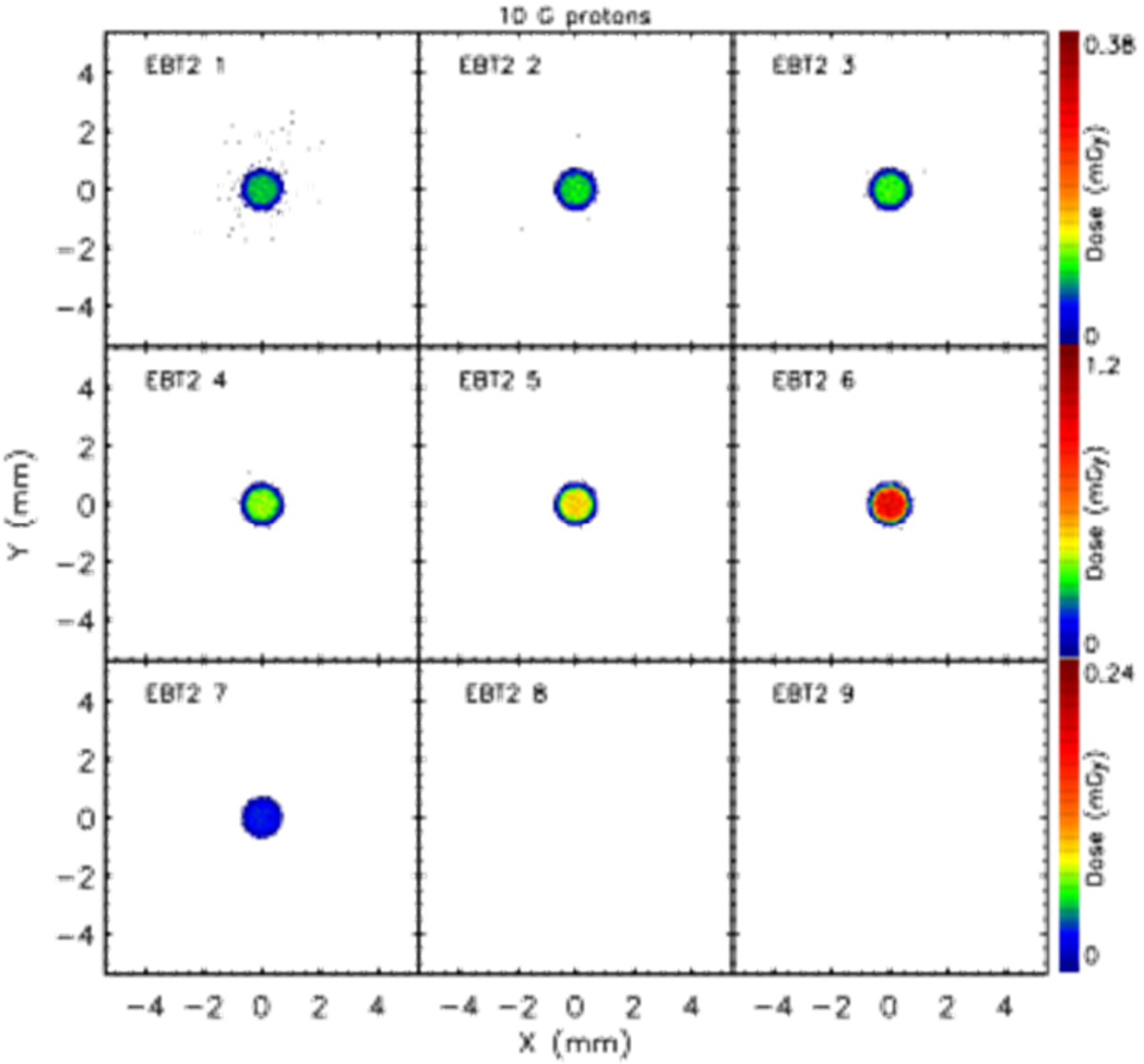
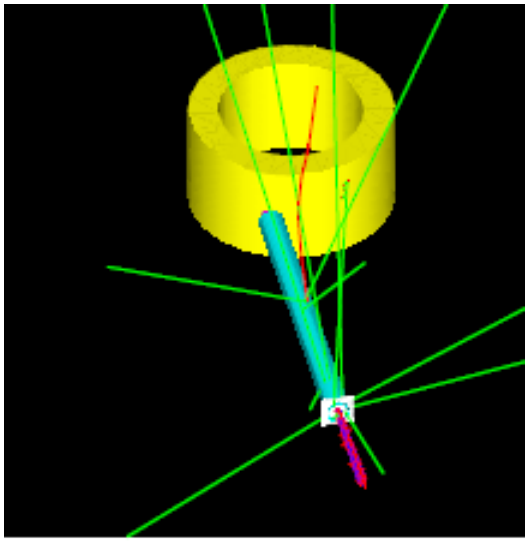
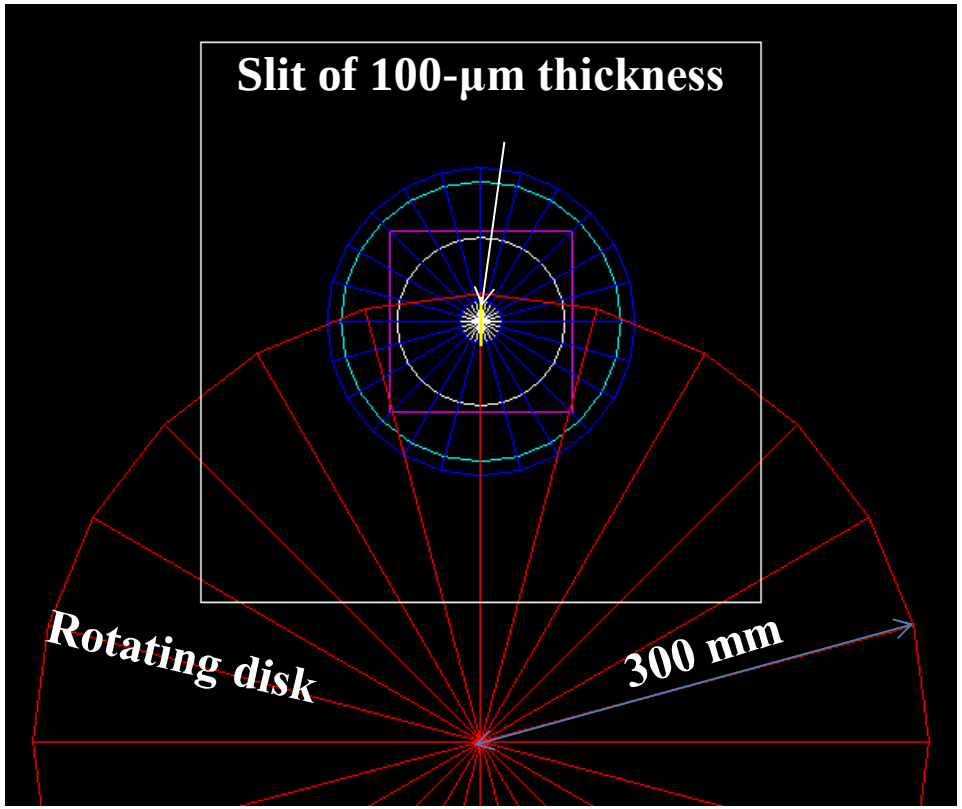




6. Discussion and Conclusions

Target dose rates between 1 Gy/s and 100 Gy/s





Allows for decreasing target dose rates by a factor 10^{-4}, from kGy/s down to Gy/s

Installing a simple mechanical shutter capable of 10 ms exposure timings allows to further bring down the dose on target to units of cGy

6. Discussion and Conclusions

Measured beam profiles show good qualitative agreement with simulations performed with Geant4

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The dose achievable with the proposed setup may span 4-orders-of-magnitude, ranging from 10 mGy to 100 Gy

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The dose contribution from neutron and γ-ray on a target is negligible down to at most the 1% level when compared to the proton dose

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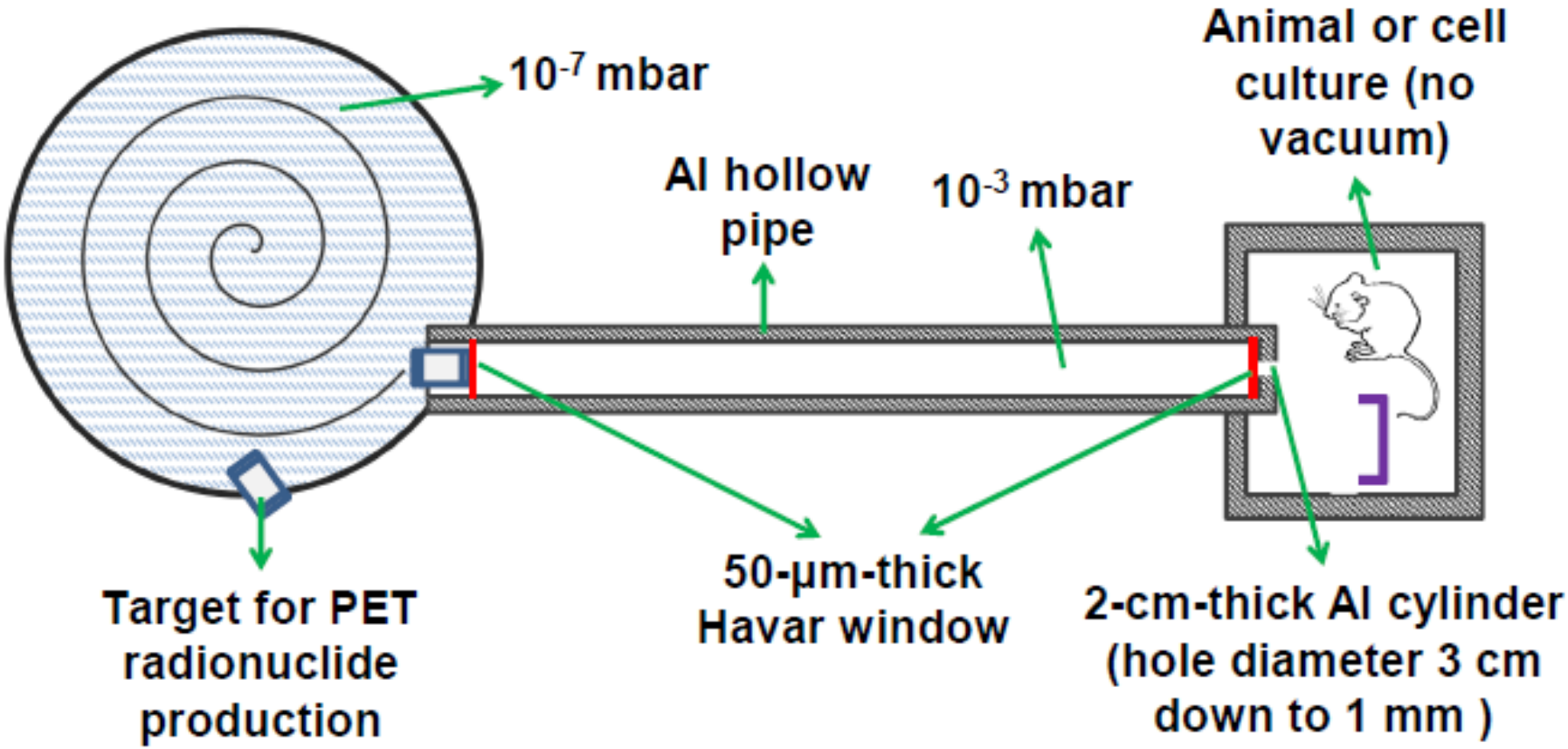
It is possible and feasible to use the cyclotron proton beam to perform radiobiological and dosimetric studies among others

7. On-going



THANK YOU FOR YOUR ATTENTION!