Multi-Leaf Faraday Cup for eye tumor therapy

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Helmholtz-Zentrum Berlin, protons for therapy

CYCLOTRONS’13 - 19. September 2013
Proton therapy for ocular cancer

- Corporation of HZB and Charité Berlin University Hospital
- Treatment for uveal melanomas
- Since 15 years in Berlin with over 2200 patients
- 96% tumor control after 5 years
- For more details see the poster: “Status of the HZB-Cyclotron” (MOPPT002)

- Small organ (6-7 cm³) with several critical structures
- Finite range → determined radiation fields → less dose to critical structures
**MOTIVATION**

Protons for therapy

- Main dose delivery at the end of the proton range (Bragg curve)
- In medicine the reference material is water
- Our Beam: 68 MeV, distal fall off (90/10) below 1 mm H$_2$O!
- Precise beam requires precise measurements of range (energy)

Radiation Hardness Tests

- need different energies reached by degradation with absorbers
- Thickness and energy are calculated with SRIM using the known energy from the cyclotron
The MLFC principle

- Stack of insulator and conductor foils
- Conductor foils connected to ground potential via ammeter
- Proton stops in conductor → additional positive charge pulls an electron from ground → current
- Proton stops in insulator foil → current via mirror charge
- MLFC counts only additional (!) charge
- Gaussian shaped range peak is created at the end of the MLFC (depending on the energy/range)
Requirements of the eye tumor therapy

- Required resolution in range measurements is 0.1 mm H₂O or better
- Conductor foils: 10 μm copper corresponds to approx. 50 μm H₂O
- Insulator foils: 25 μm Kapton corresponds to approx. 32 μm H₂O
- Measurement of the full beam field
- In air measurement, due to time efficiency
- For 68 MeV protons 6.75 mm copper is necessary to dump the beam
- 6.75 mm / 10 μm = 675 foils
Simulation

- Simulating the principle stack with the nozzle in a MC calculation (MCNPX 2.6)
- Charge deposition in 50 copper foils (10 μm) is simulated for different Kapton foils
- 68 MeV proton beam with a Gaussian shape comparable to our real beam
- Simulated preabsorber of 31.5 mm of acrylic glass
- Less than 50 foils are enough to cover the whole range peak
• To dump the whole energy over 600 foils would be necessary, but if using 50 foils the beam has to be degraded
• The range shifter is followed by a distance of air → high scattering losses
• The double wedge is at the end of the beam line → low losses through scattering

• Range shifter: used for therapy to adapt the maximum range for each patient
• Double wedge: one thin and fixed, one thick and movable; used for experiments with MLFC or for cell irradiation
METHODS AND MATERIAL

Electronics

- 3 electrometers from Keithley Model 617
- Only one channel, but precise measurements

- Rabbit Box from iThemba Labs
- 48 channels for simultaneous measurements
- Higher noise than electrometers in the lower pA region
METHODS AND MATERIAL

Three foil setup

- First setup with three foils due to the available electrometers
- Evacuated and in-air measurements are possible
- Permanently improved
- Foil diameter approx. 5 cm but still too small
METHODS AND MATERIAL

More foils…

- Copper foils with a diameter of 10 cm
- Connections planned for 50 conductor foils
- Each foils has a 50 \( \Omega \) impedance connection to a SMA connector
- Due to difficulties with soldering and dark currents (up to 1 nA), only 42 channels are used
- Connection to the Rabbit Box with special double shielded low noise cables
RESULTS

3 foils – foil 1 is first to the beam

- foil 1 shows the highest signal at the thickest range shifter position, that means at the lowest beam energy
- Error bars correspond to the standard deviation and represent the noise coming from the long (10 m) BNC cable
- In air measurements have a higher noise
RESULTS

42 foils background

- MLFC connected to the Rabbit Box without beam
- Measurement over seven hours
- ±60 pA dark current, 30 of 42 channels between ±20 pA
- Most dark currents are constant over time
- Differential measurements are possible and necessary
42 foils measurement

- First measurement of the 68 MeV cyclotron beam (700 pA)
- A preabsorber of acrylic glass with a thickness of 27.23 mm was used
- Center of the Gaussian curve lies at channel 21 and corresponds to 67.6 MeV
- 5% current of the incident beam in foil 21, slightly higher than in the simulation
- As expected, at the left side of the curve the signals are above zero

<table>
<thead>
<tr>
<th>Results of Gaussian fit</th>
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<tbody>
<tr>
<td>Center</td>
<td>20.67 ± 0.05</td>
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<tr>
<td>Sigma</td>
<td>5.55 ± 0.08</td>
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</table>
Energy check for radiation hardness tests (RHT) of the DLR (German center for aeronautics and space research)

- For RHT different energies are needed
- Energies are reached through degradation with a certain stack of Aluminum plates in front of the nozzle
- To know the needed thickness, calculations with SRIM were conducted
- With the MLFC an independent experimental energy measurement is possible

<table>
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<tr>
<th>Requested energy</th>
<th>Measured energy</th>
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<tr>
<td>30 MeV</td>
<td>30.8 MeV</td>
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<tr>
<td>50 MeV</td>
<td>49.2 MeV</td>
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<tr>
<td>68 MeV</td>
<td>67.6 MeV</td>
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CONCLUSION AND OUTLOOK

Summary

• Measurements with the three foil setup showed the importance of shielding and short cables
• In air measurements produce good results with the 42 channel MLFC
• First measurements with the 42 channel MLFC show expected Gaussian shaped curves
• The measurements agree well with the simulations, approx. 5% of the incident beam current in the center of the measured peak compared to 4% in the simulation.
CONCLUSION AND OUTLOOK

Work in progress, the next steps:

- Further measurements are necessary to characterize the MLFC, e.g. measurements with different energy spectra
- Test with especially designed amplifiers are planned
- Development of a special preabsorber and a software tool for automated measurements
- Implementation of a Bragg curve calculation directly from the measured energy

Thanks to iThemba Labs!
Thanks to the CYC13 organizers for invitation and support!
Thank you for your attention!

Any questions?