Multi-Leaf Faraday Cup for eye tumor therapy

C. Kunert, J. Bundesmann, T. Damerow, A. Denker, A. Weber

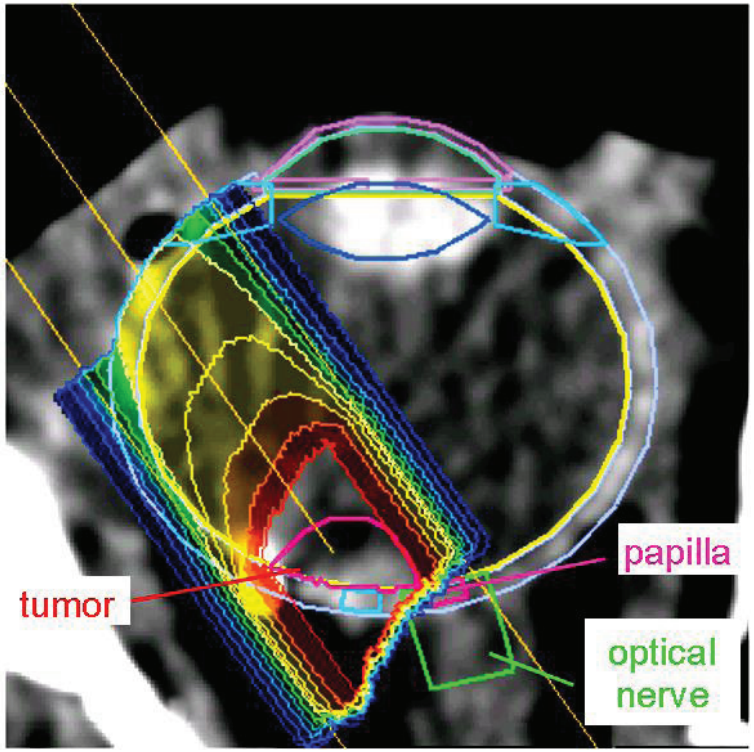
Helmholtz-Zentrum Berlin, protons for therapy

CYCLOTRONS'13 - 19. September 2013

MOTIVATION

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)**

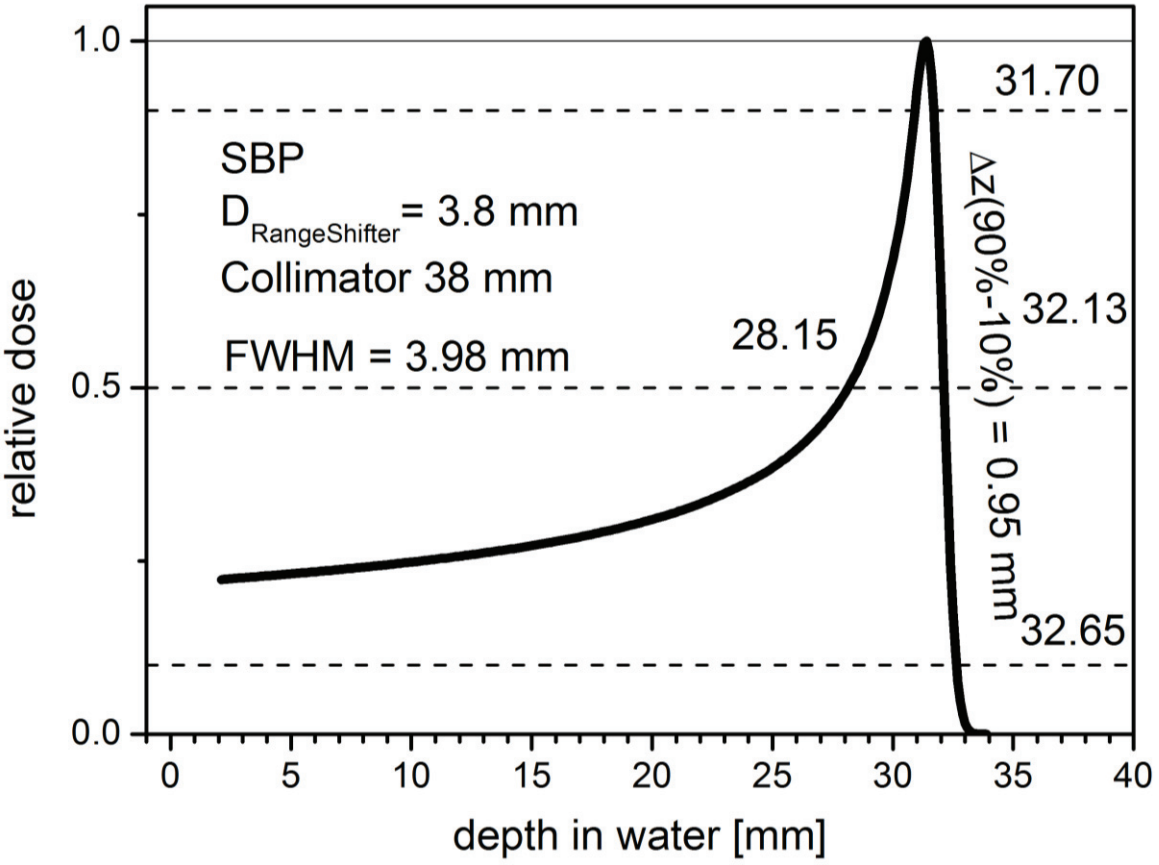


- **Small organ (6-7 cm³) with several critical structures**
- **Finite range → determined radiation fields → less dose to critical structures**

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_2O!**
- **Precise beam requires precise measurements of range (energy)**



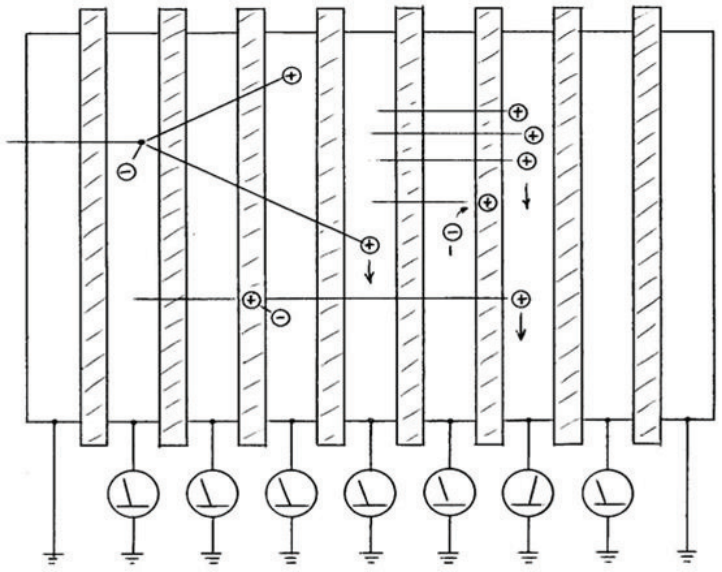
Radiation Hardness Tests

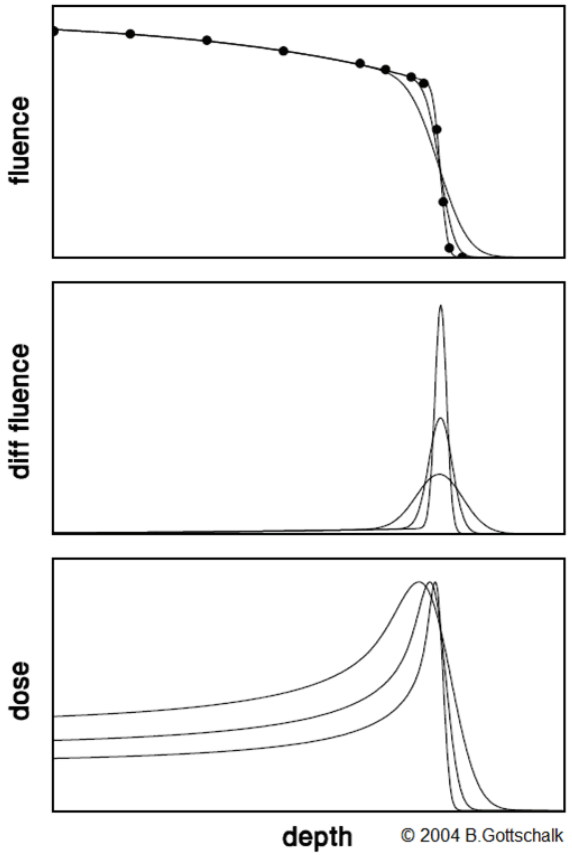
- **need different energies reached by degradation with absorbers**
- **Thickness and energy are calculated with SRIM using the known energy from the cyclotron**

METHODS AND MATERIAL

The MLFC principle

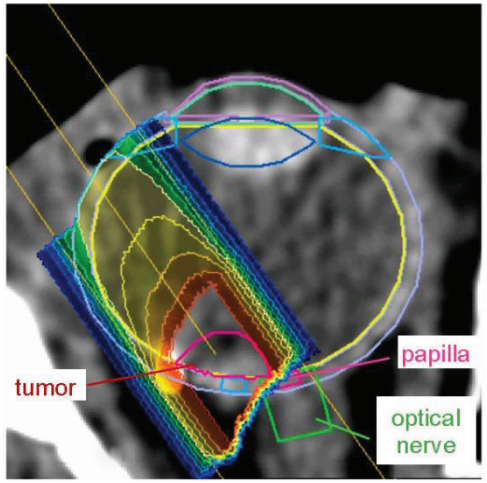
- **Stack of insulator and conductor foils**
- **Conductor foils connected to ground potential via ammeter**
- **Proton stops in conductor → additional positive charge pulls an electron from ground → current**
- **Proton stops in insulator foil → current via mirror charge**
- **MLFC counts only additional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





METHODS AND MATERIAL

Requirements of the eye tumor therapy

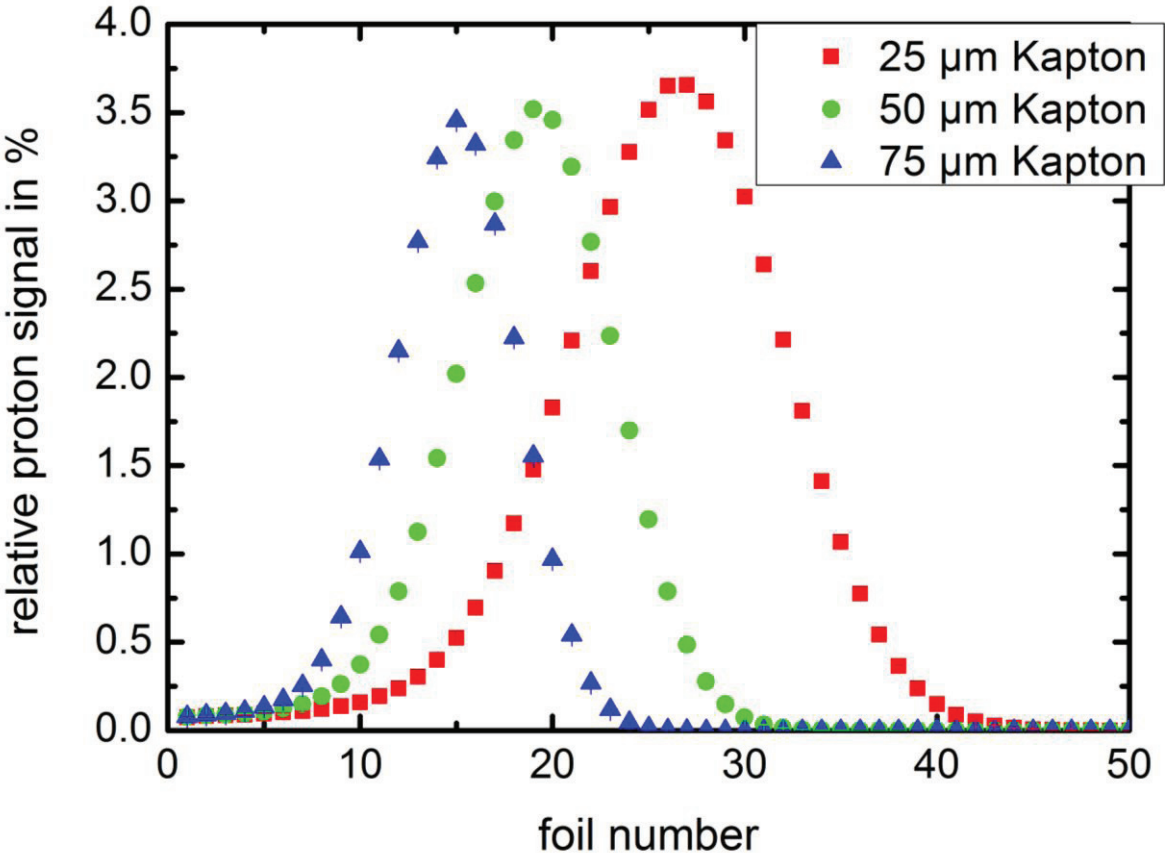


- **Required resolution in range measurements is 0.1 mm H_2O or better**
- **Conductor foils: 10 µm copper corresponds to approx. 50 µm H_2O**
- **Insulator foils: 25 µm Kapton corresponds to approx. 32 µm H_2O**
- **Measurement of the full beam field**
- **In air measurement, due to time efficiency**
- **For 68 MeV protons 6.75 mm copper is necessary to dump the beam**
- **6.75 mm / 10 µm = 675 foils**

METHODS AND MATERIAL

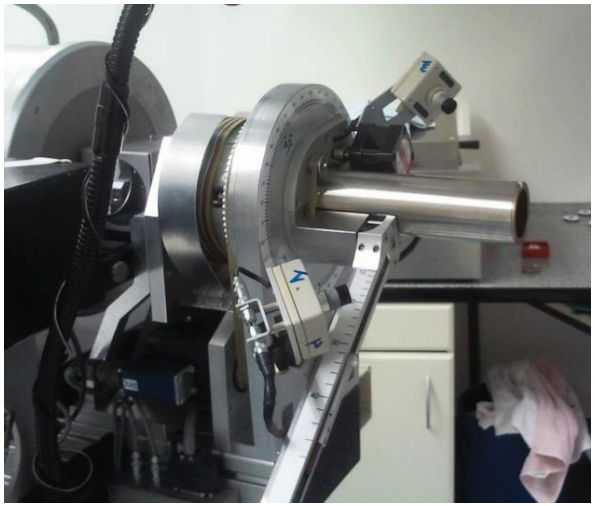
Simulation

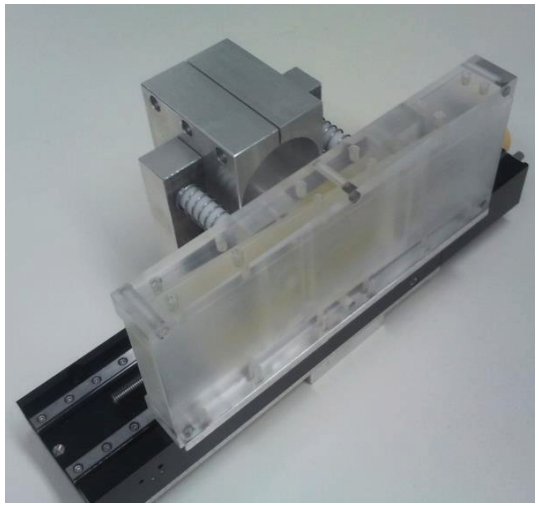
- **Simulating the principle stack with the nozzle in a MC calculation (MCNPX 2.6)**
- **Charge deposition in 50 copper foils (10 µm) is simulated for different Kapton foils**
- **68 MeV proton beam with a Gaussian shape comparable to our real beam**
- **Simulated preabsorber of 31.5 mm of acrylic glass**
- **Less than 50 foils are enough to cover the whole range peak**

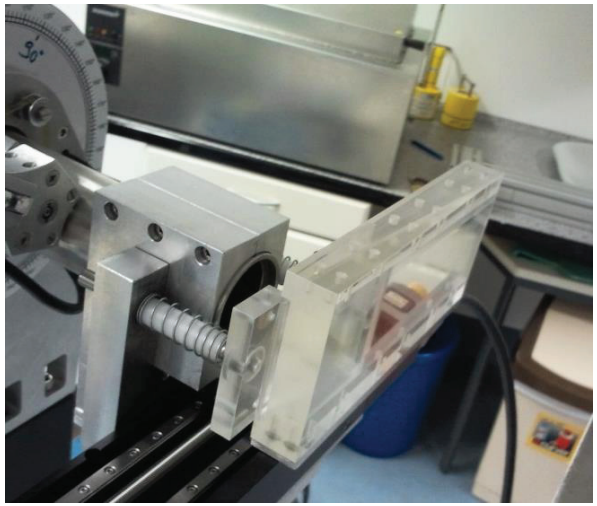


METHODS AND MATERIAL

Range Shifter and Double Wedge







- 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

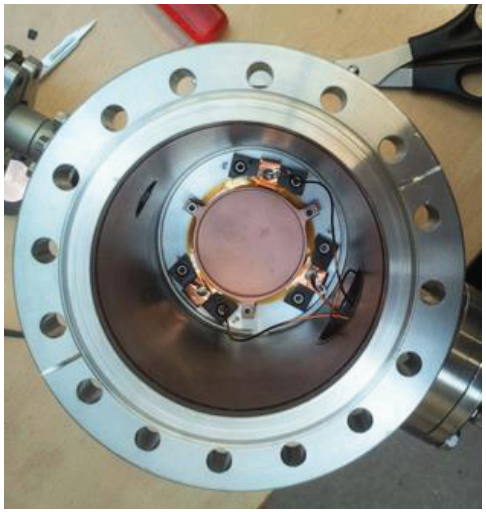
- **3 electrometers from Keithley Model 617**
- **Only one channel, but precise measurements**

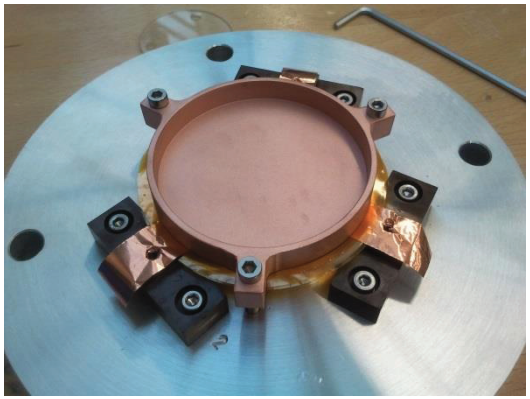
- **Rabbit Box from iThemba Labs**
- **48 channels for simultaneous measurements**
- **Higher noise than electrometers in the lower pA region**

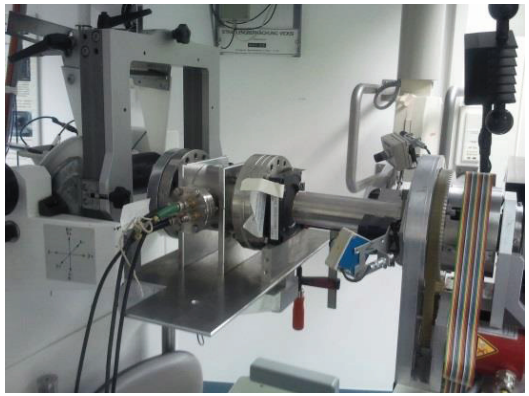
METHODS AND MATERIAL

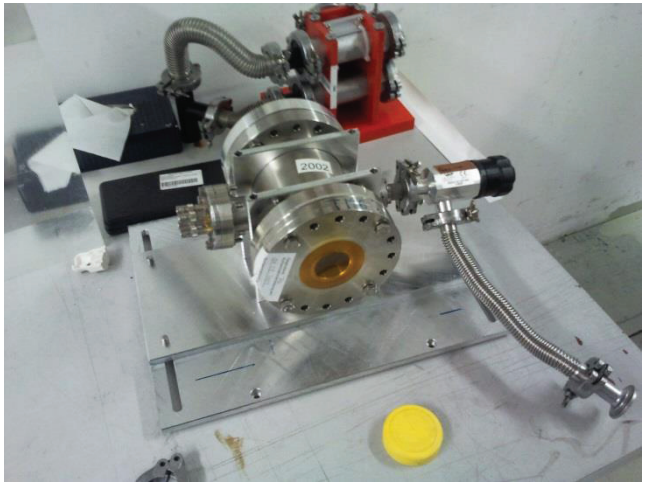
Three foil setup

- **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**





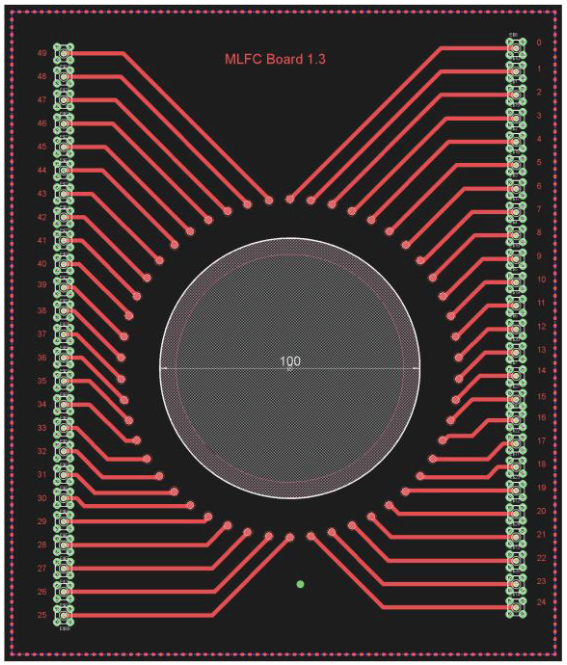


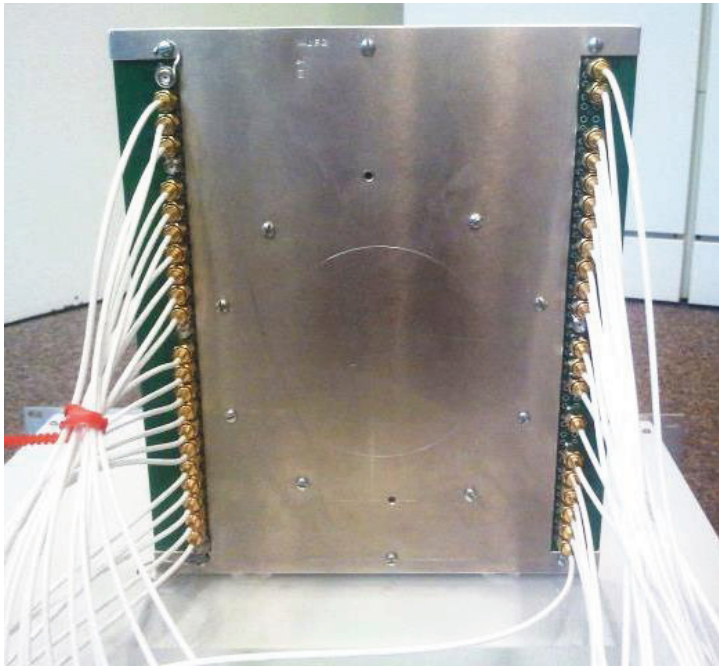


METHODS AND MATERIAL

More foils…

- **Copper foils with a diameter of 10 cm**
- **Connections planned for 50 conductor foils**
- **Each foils has a 50 Ω 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**

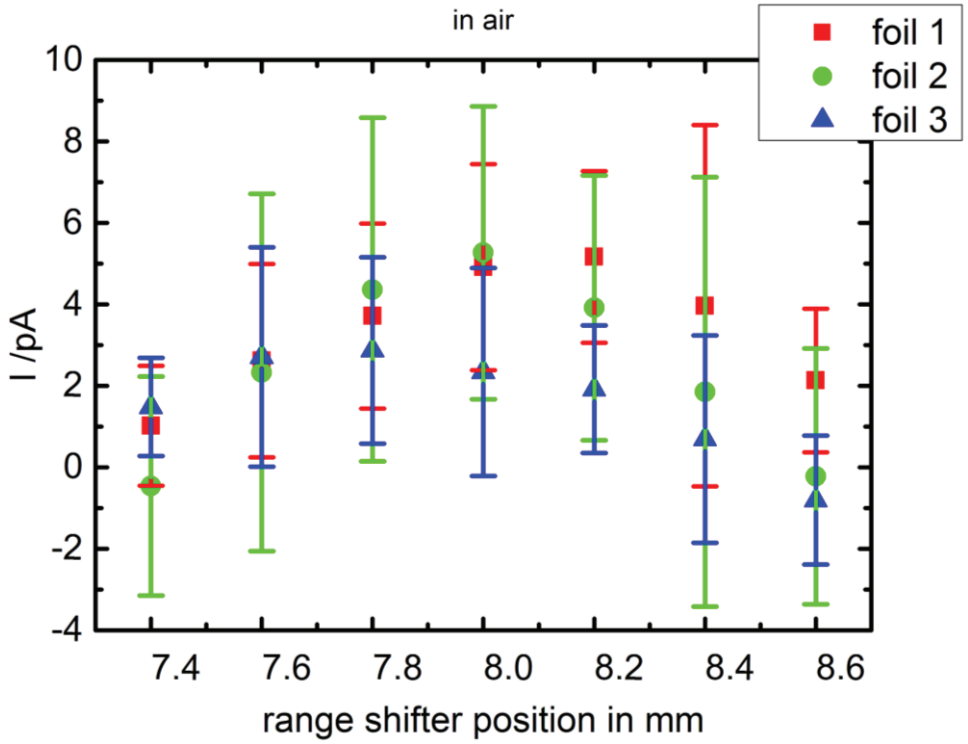


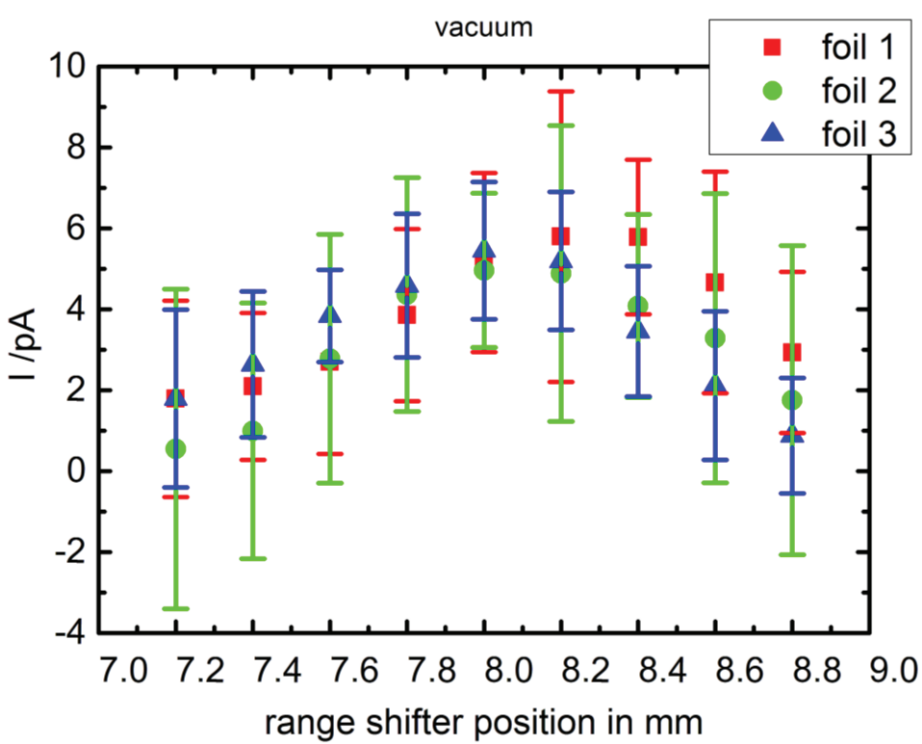


RESULTS

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**

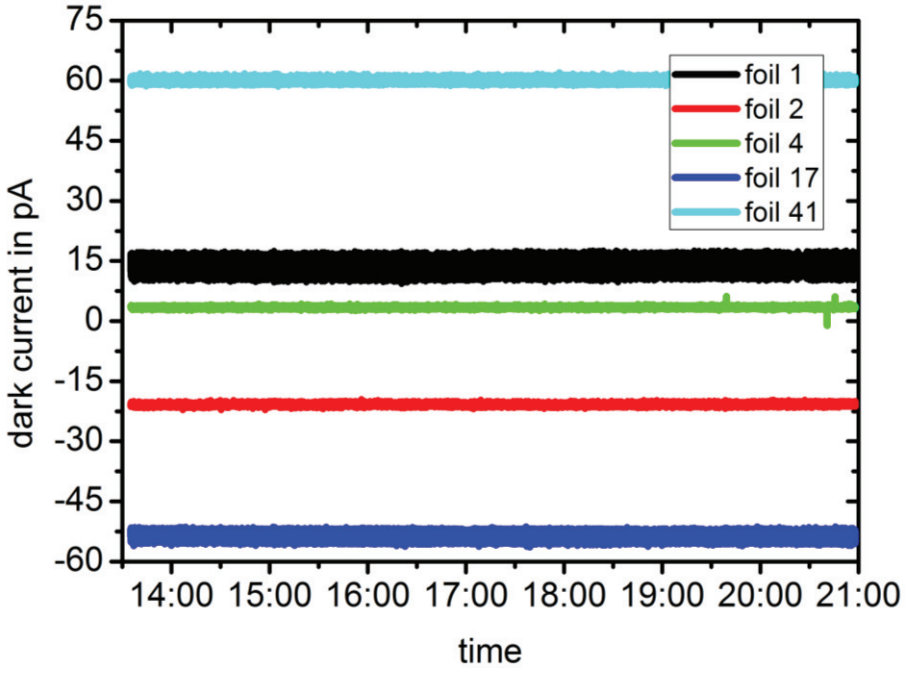




RESULTS

42 foils background

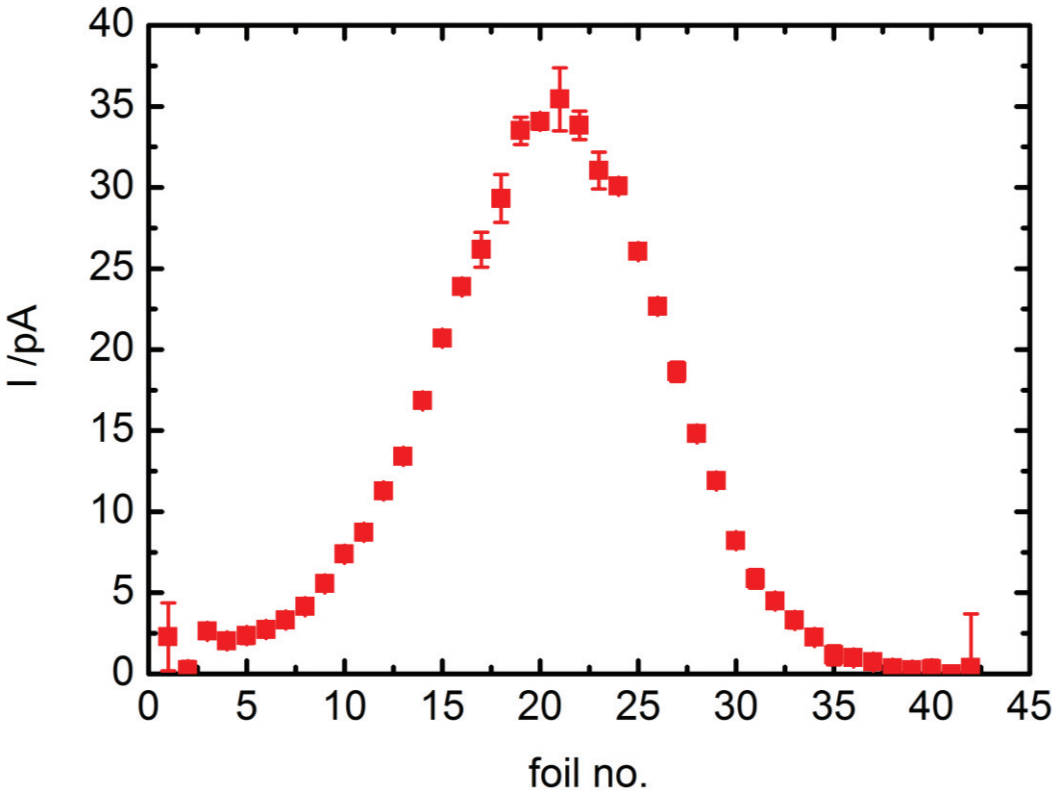
- **MLFC connected to the Rabbit Box without beam**
- **Measurement over seven hours**
- **±60 pA dark current, 30 of 42 channels between ±20 pA**
- **Most dark currents are constant over time**
- **Differential measurements are possible and necessary**



RESULTS

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**



Results of Gaussian fit	
Center	20.67 ± 0.05
Sigma	5.55 ± 0.08

RESULTS

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**

Requested energy	Measured energy
30 MeV	30.8 MeV
50 MeV	49.2 MeV
68 MeV	67.6 MeV

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?