G. Kourkafas, J. Bundesmann, A. Denker,
T. Fanselow, J. Röhrich

J. Heufelder, A. Weber

HZB Helmholtz Zentrum Berlin

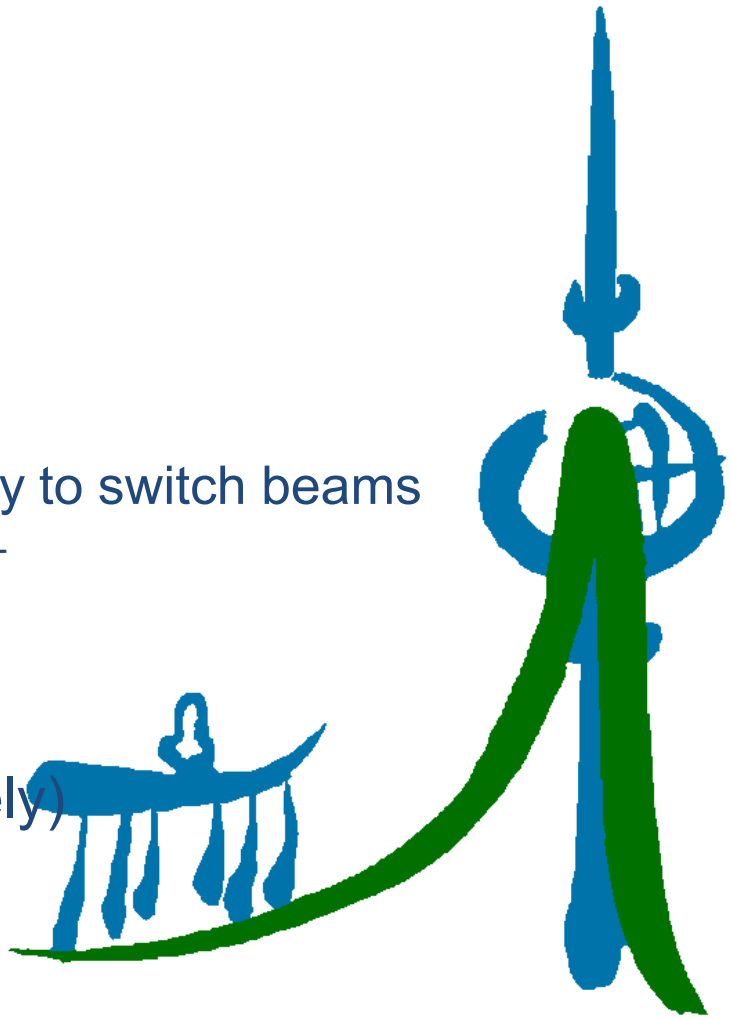
CHARITÉ

BEUTH HOCHSCHULE FÜR TECHNIK BERLIN
University of Applied Sciences

Acceleration and Measurement of α-Particles and Hydrogen Molecular Ions with the HZB Cyclotron

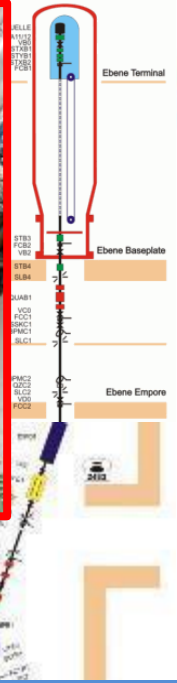
Motivation

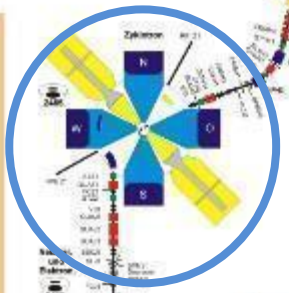
- more than 4000 patients treated with protons since 1998
- accompanying R & D:
  - beam delivery
  - dosimetry
  - investigations for FLASH irradiations
- “Cocktail beams”
  - same charge to mass ratio
  - same velocity
  - cyclotron operates as mass separator
  - only slight changes in cyclotron RF necessary to switch beams
- our cocktail: 45 MeV H_2^+ and 90 MeV He^{2+}
- charge to mass ratio 1:2
- nearly same velocity
  (22.34 MeV/u and 22.49 MeV/u respectively)
- fast switching of beams possible
  (less than 0.5 hours)



Accelerator Complex

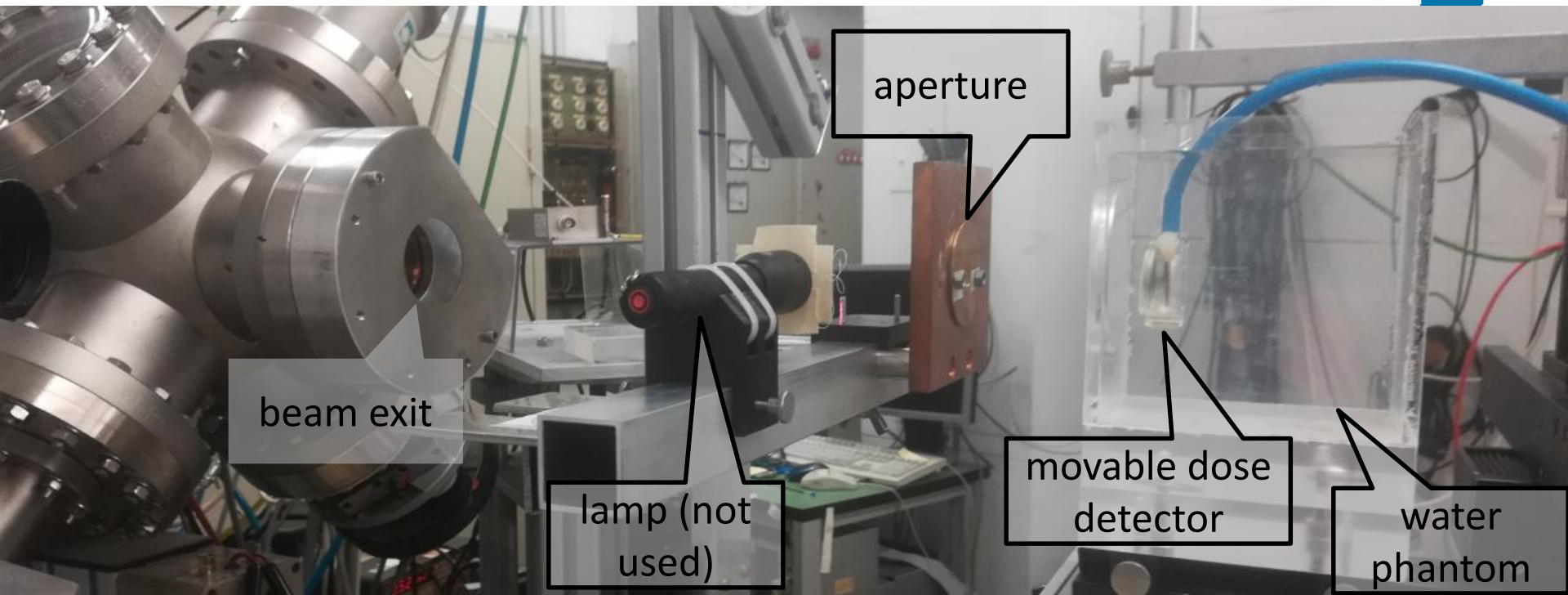
- k = 130 isochronous sector cyclotron
  10 – 20 MHz
- two injectors:
  - 2 MV Tandetron™
  - 6 MV Van-de-Graaff,
    with 5 GHz ECR Source
- three target stations:
  - treatment room
  - experimental station
    (I_{max}(DC) = 10 nA)
  - beam line end for tests in
    cyclotron vault





Experiments

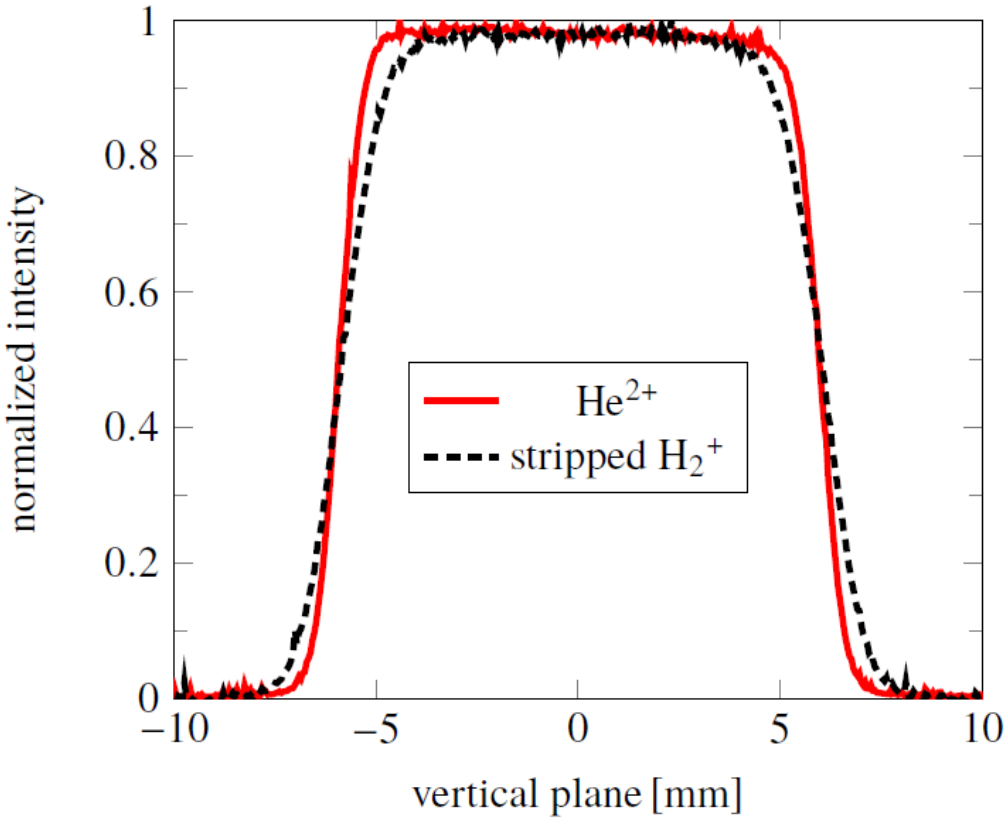
- verification that vacuum window (75 µm Kapton) completely strips H_2^+ beam using dipole magnet and stripper foil of 50 µm Kapton:
  - beam intensity doubles directly after the stripping foil
  - no beam intensity measured at dipole setting for 45 MeV H_2^+
- comparing the radiation fields of both fields created with 50 µm Kapton for 45 MeV H_2^+ and 130 µm Kapton for 90 MeV He^{2+}:
  foil induced angle of 2.45 mrad (calculated with lookup-code)



Transverse Profiles

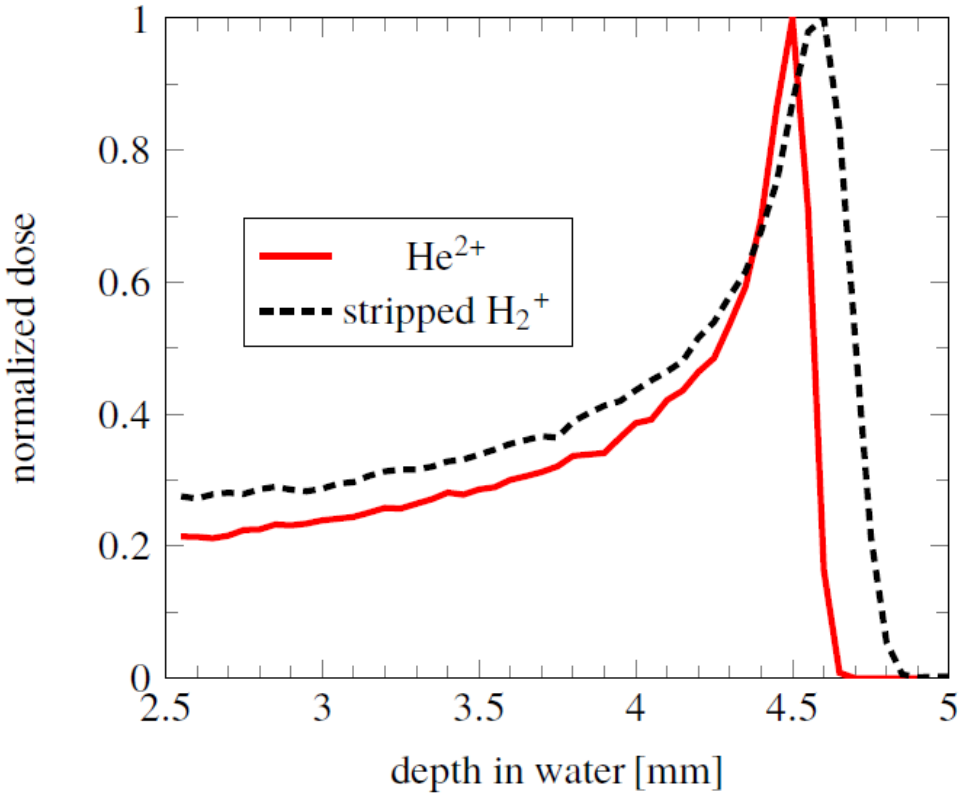
- measured using a CCD camera, data evaluation with image pro plus

Ion	Uniformity = average level in flat-top region	Penumbra = lateral fall-off from 90% to 10%	Symmetry = difference between lateral edges
Stripped H_2^+	15%	2.1 mm	2%
He^{2+}	7%	1.2 mm	2%



Depth-Dose Profiles

- Bragg-Peak measured in water
  - Measurement starts at 2.6 mm due to thickness of tank and detector cover
  - Range of He^{2+} beam 0.1 mm smaller due to thicker scattering foil
  - Distal fall-off (90% to 10% of dose):
    0.16 mm for H_2^+ and 0.1 mm for He^{2+} beam
  - He^{2+} beam: better peak-to-plateau ratio



Conclusion and Outlook

- HZB cyclotron provides similar radiation fields using the same nozzle (scattering foil for He^{2+} beam thicker)
- rapid changes between ion species
- He^{2+} beam: sharper penumbra, better peak-to-plateau ratio
- Outlook:
  - biological experiments using both ion species
  - evaluate FLASH effect for both ion species
- dedicated clinical cyclotron can provide both ion species

Thank you for your attention!

apertures of the individual patients used at HZB over the past years