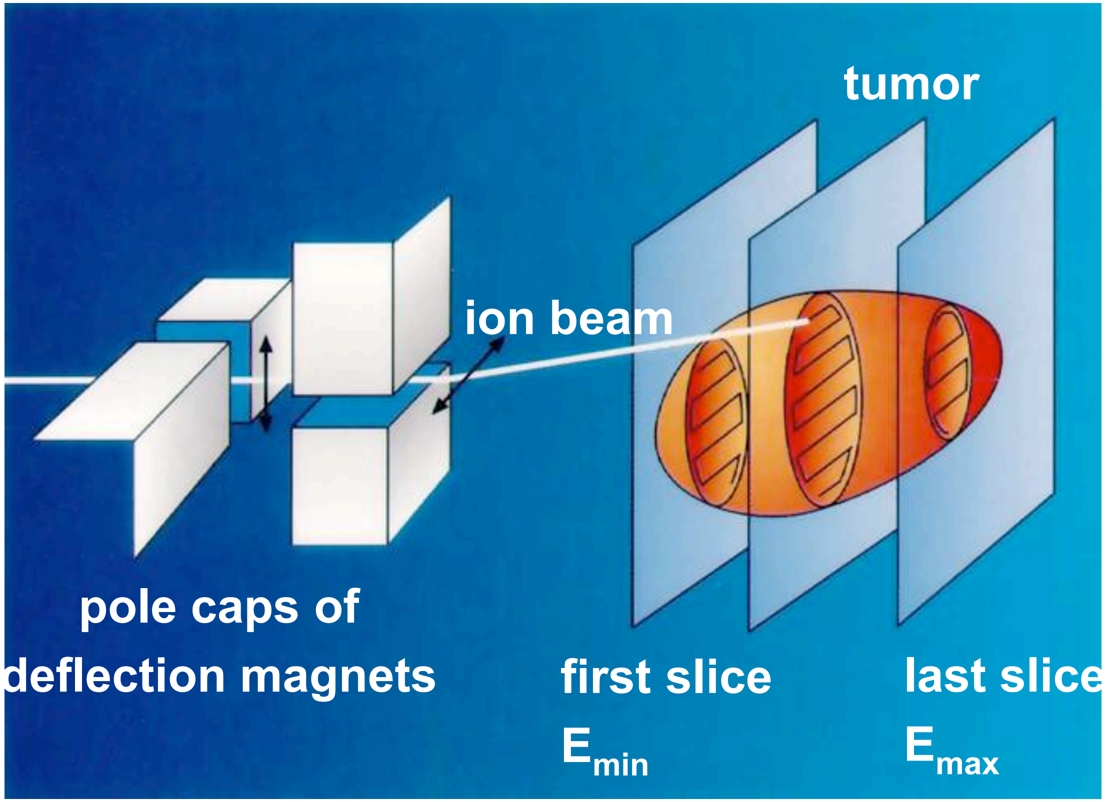
Neutrons in carbon ion therapy

Thilo Elsässer

GSI Biophysics

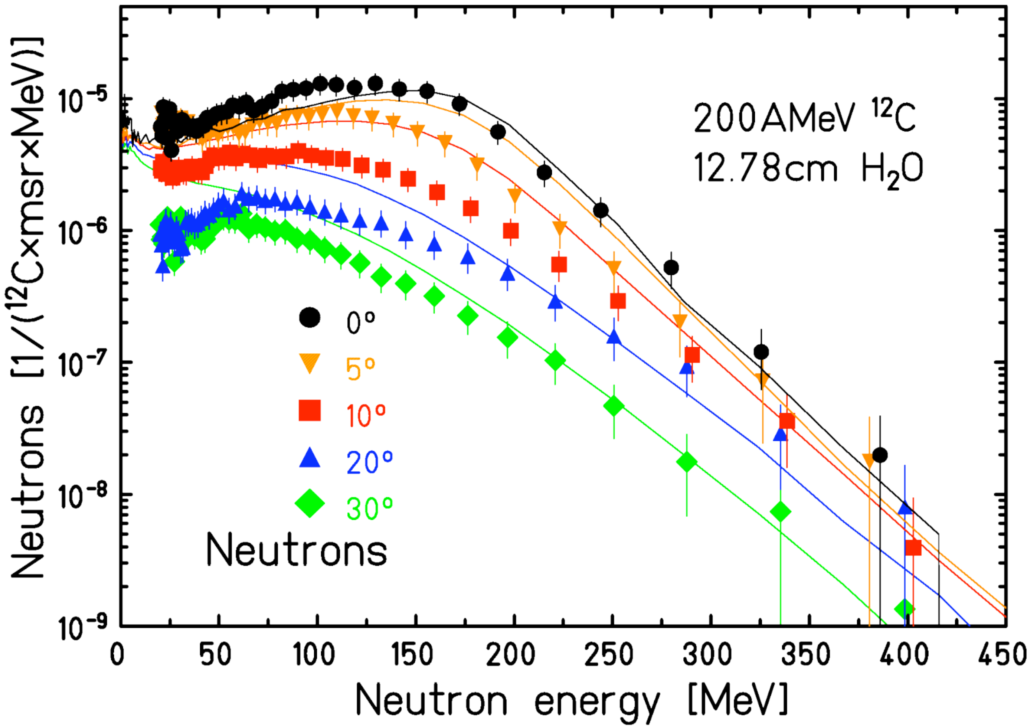
Active scanning at GSI

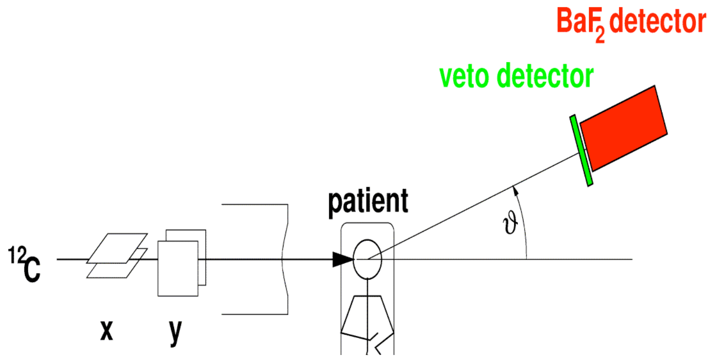


Additional: active energy variation with 250 different energies

Minimum absorber material

Measurement of secondary neutrons in a water phantom





maximum neutron yield at 100 MeV

peaked in forward direction

K. Gunzert-Marx, New Journal of Physics 2008

Neutron yields per primary ion

	Beam [MeV/u]	Target [g/cm^2]	Neutrons per primary ion	Beam application	Dose equivalent [mSv/Gye]
GSI	^{12}C (200)	H_2O (12.78)	0.54 ± 20%	scanning	5.4 ± 20%
Schneider*	p (177)	H_2O (30.1)	(0.025)	scanning	2.3 ± 30%

*Schneider et al.: Int. J. Radiat. Oncol. 53 (2002) 244-251

K. Gunzert-Marx, New Journal of Physics 2008

More Neutrons per primary carbon ion than per proton

However: More primary protons than carbon ions
for same level of absorbed dose (LET effect)

Measurements independently confirmed by PHITS and GEANT4 (Pshenishnov, PMB05)

Conclusion

- **Previous talk: Active scanning is the optimal method to reduce the effective neutron dose**

- **Scanned carbon beams exhibit similar absorbed and effective neutron dose as scanned protons**

- **Secondary neutrons are of no particular concern in carbon ion therapy**