Advocacy for a dedicated 70 MeV Proton Therapy Facility

A. Denker, C. Rethfeldt, J. Röhrich,
Helmholtz-Zentrum Berlin, Protons for Therapy,

D. Cordini, J. Heufelder, R. Stark, A. Weber
Charité – Universitätsmedizin Berlin, BerlinProtonen

hmi + BESSY = HZB Helmholtz Zentrum Berlin

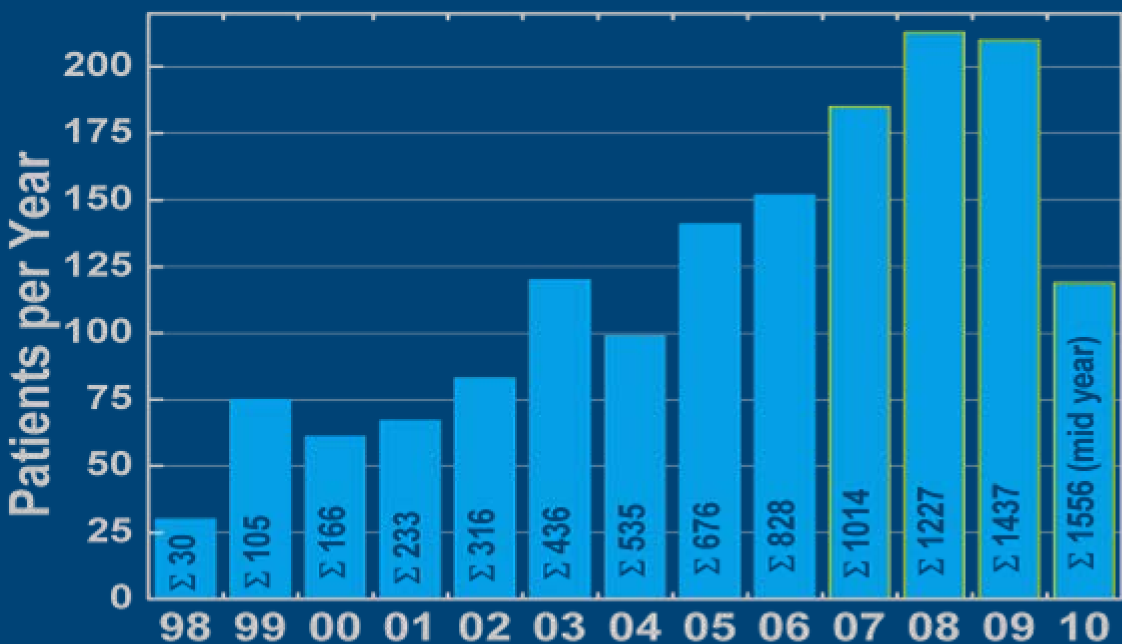
Hahn-Meitner-Institut
(reactor, cyclotron, solar energy)

BESSY
(synchrotron)

largest non-university research centre in Berlin

Introduction: Statistics

- eye tumour therapy with protons since 1998
- cooperation between the Charité and HZB (formerly HMI)
- 12 therapy weeks per year, 1 treatment room
- work flow allows the treatment of 200 - 300 patients per year
- tumour control rate after 3-years' follow-up ≥ 97 %
  - 85 % Melanoma 97 % control
  - 6 % Iris Melanoma 100% control
  - 5 % Hemangioma 100% control



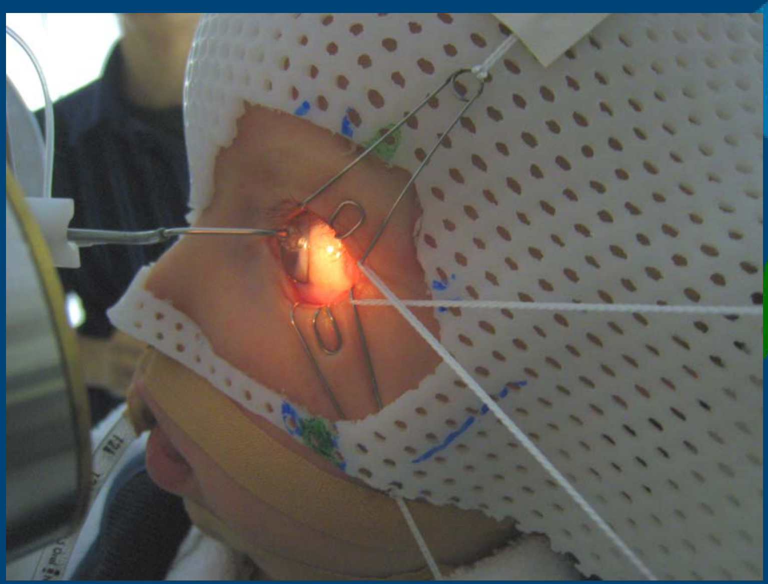
Introduction: Beam Conditions

- k = 132 isochronous cyclotron with 5 MV Van-de-Graaff injector, 5 GHz ECR source on HV terminal
- 68 ± 0.3 MeV proton beam with simple single scattering technique
- depth dose profile: distal fall-off 90 - 10% = 0.94 mm
  penumbra 80 - 20% = 2.1 mm
- all required therapeutic beam intensities delivered from cyclotron with dose rate of at least 15 Gy / min

Special Patients: Children

- proton therapy = powerful tool against ocular tumours (control rates higher than 95%)
- cooperation of the patient is indispensable during treatment
- small children are unable to cooperate
  $\Rightarrow$ treatment under general anaesthesia
- ➲ installation of mobile anaesthesia workstation with UPS
- ➲ modification of two conventional car seats for positioning



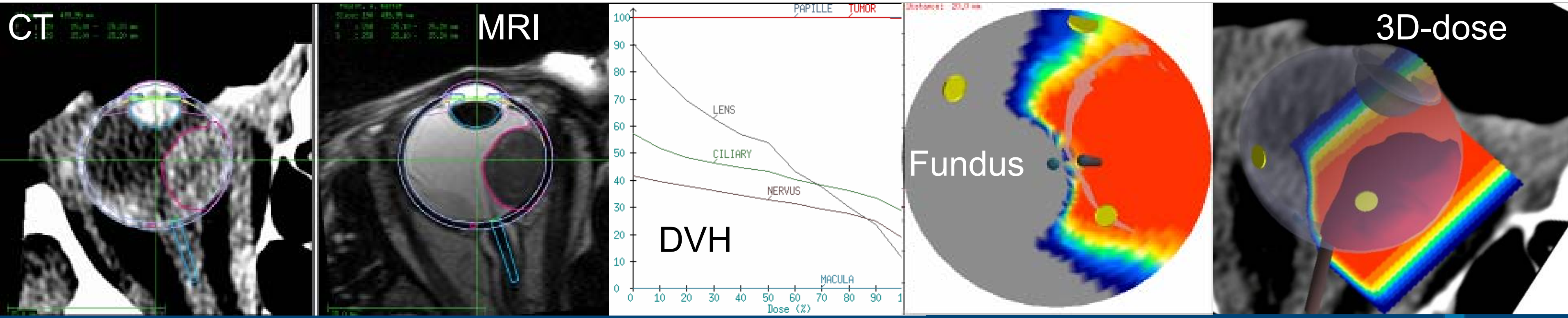


Special Patients: Children

- 2x retinoblastoma (7 and 10 months: 6x 5.27 CGE)
- 1x choroidal osteoma (5 years: 4x 5.0 CGE)
- daily treatment duration: ~ 2 h
  - anaesthesia and positioning: ~ 1 h
  - irradiation: ~ 1 min
  - dismounting: ~ 1 to 2 min
    (emergency dismounting: ~ 1 min)
  - recovering from anaesthesia: ~ 45 min

- frontal approach: possibility to spare bone structures nearly completely
- high precision in patient positioning (up to 0.2 mm)

Summary of our Experiences



- proton therapy - excellent tool for the treatment of eye tumors giving very high local control rates
- 70 MeV ± ≤ 0.5% proton beam - distal dose fall-off ≤ 1.0 mm:
  - often critical for preventing irradiation of sensitive structures
  - essential for sight (optic nerve, papilla, macula)
- dose rate over 15 Gy/min - permits the use of lid retractors
- patients require elaborate positioning
- CT/MRI based planning + digital image guided planning
  - essential for maximum plan conformity with tumour

Centres under Construction

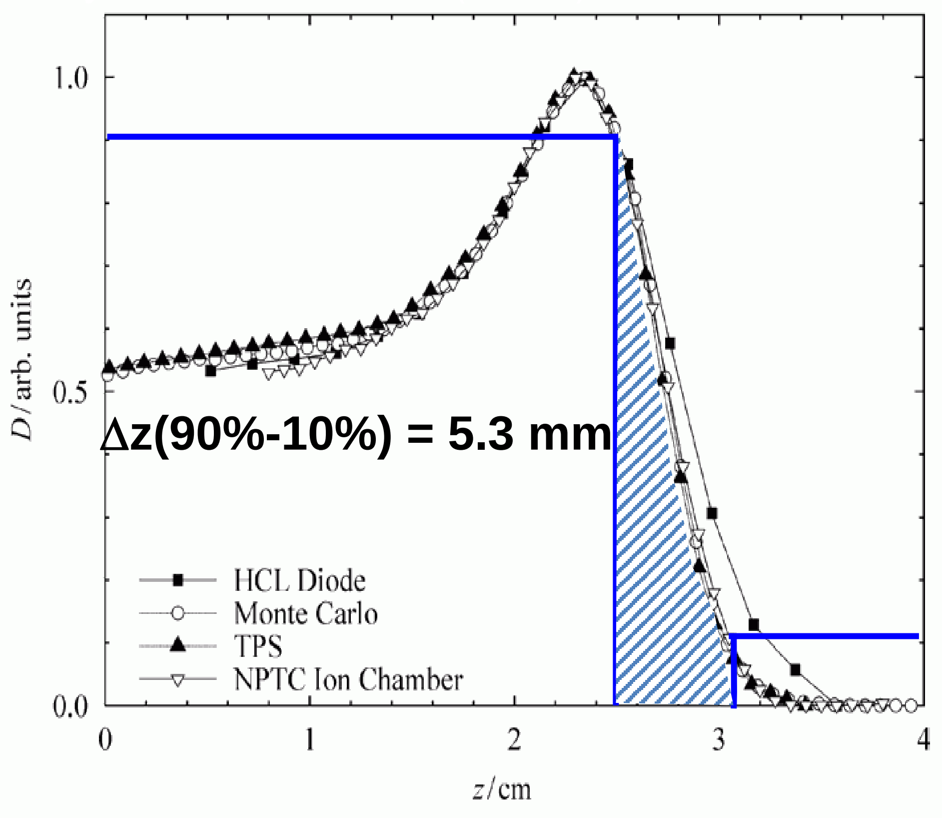
- 31. July 2010, http://ptcog.web.psi.ch/
- 11 centres with cyclotrons listed – all E_p > 200 MeV

Institution	Country	Energy	Start Treatment Planned
PSI Villingen	Switzerland	250 MeV	2010
WPE Essen	Germany	230 MeV	2010
CPO Orsay	France	230 MeV	2010
PTC Tohoku	Japan	230 MeV	2010
HUPBTC Hampton VA	USA	230 MeV	2010
CMHPTC Ruzomberok	Slovak. Rep.	250 MeV	2010
Chang Gung Mem. Taipei	Taiwan	235 MeV	2011
ProCure Chigaco	USA	230 MeV	2011
Northern Illinois…	USA	250 MeV	2012
PTC Praha	Czech. Rep.	230 MeV	2013
Trento	Italy	230 MeV	2013
Skandion Uppsala	Sweden	250 MeV	2013

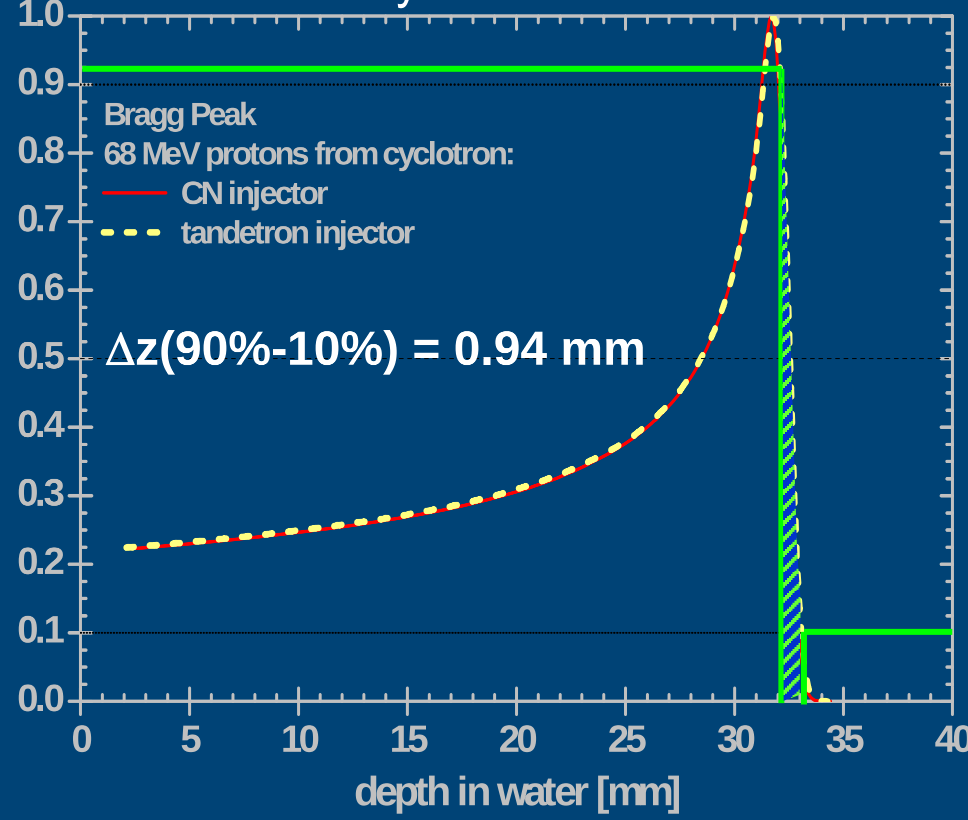
Status Quo

- degraded beam, 230(250) MeV → 70 MeV:
  - huge losses in beam intensity of more than 95%
  - large energy spread to allow reasonable treatment times

W. Newhauser et al
Phys. Med. Biol. **50** (2005) 5229–5249

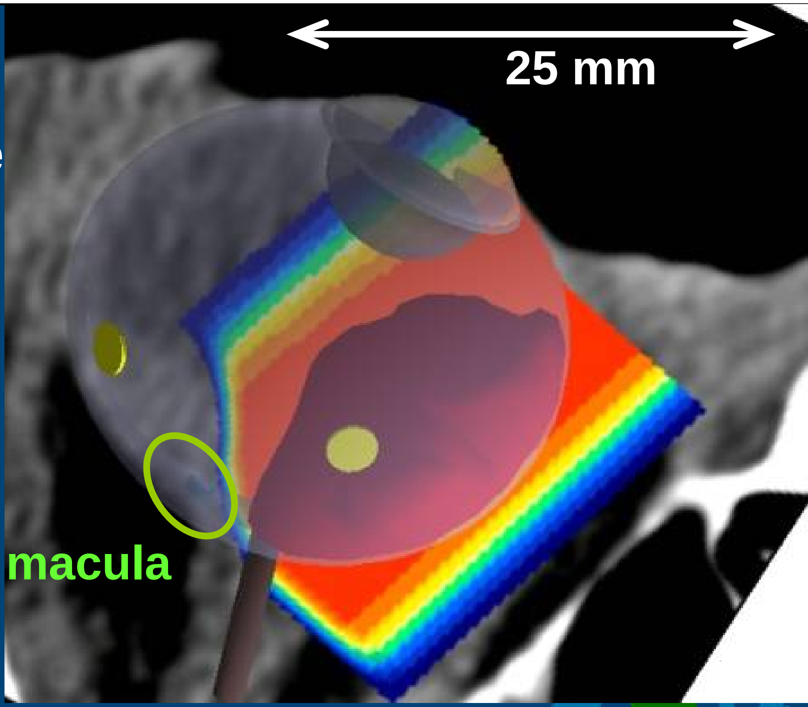


dedicated facility



Consequences of Degraded Beam

- 1. goal = tumour control
- 2. goal = spare healthy tissue from dose
  → quality of life, e.g. capacity to read



- ocular tumour therapy has to accept compromises regarding side effects or requires a sophisticated beam shaping technique as at OPTIS2 / PSI

➲ suggestion for a dedicated facility, optimized for the needs of ocular melanomas

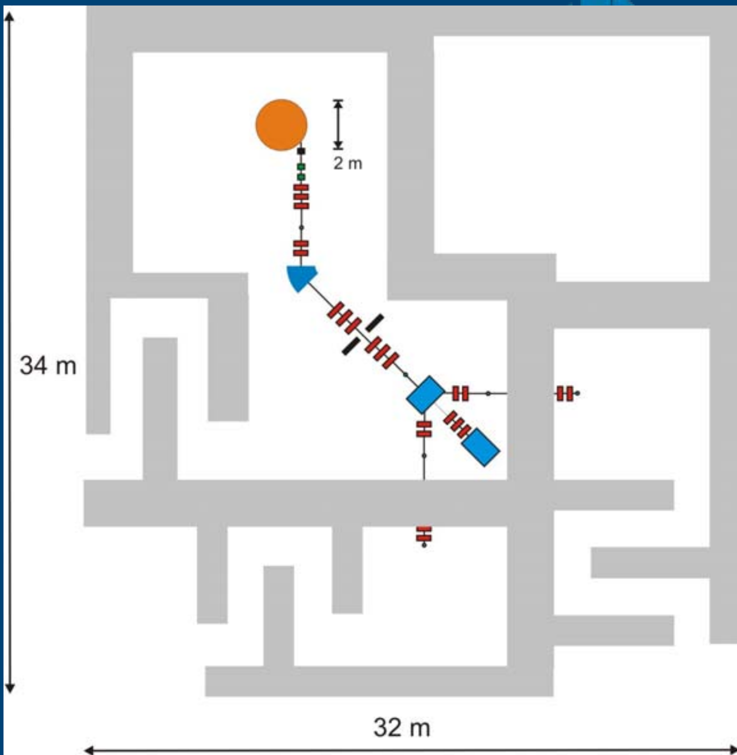
Wish List: Accelerator

- quasi-DC beam with the following properties:
- energy of extracted beam: 72 MeV
- intensity of extracted beam ~ 100 nA
- $dE/E \leq 0.4\%$
- half beam extent, $\sigma_{x,y}$: 2 mm • 4 mm
- half beam divergence x' • y': 4 mrad • 3 mrad

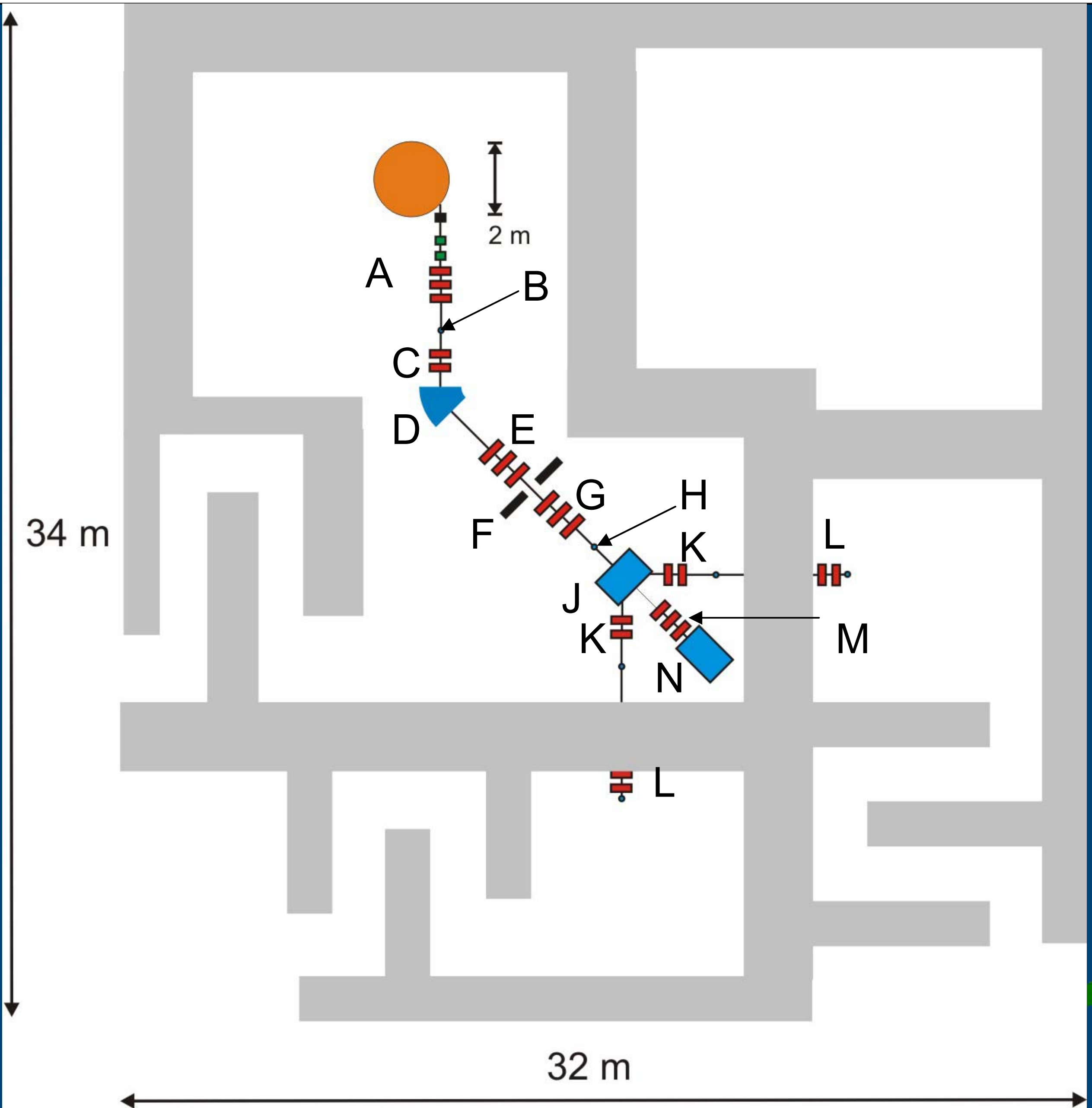
➲ small cyclotron

Wish List: Beam Lines

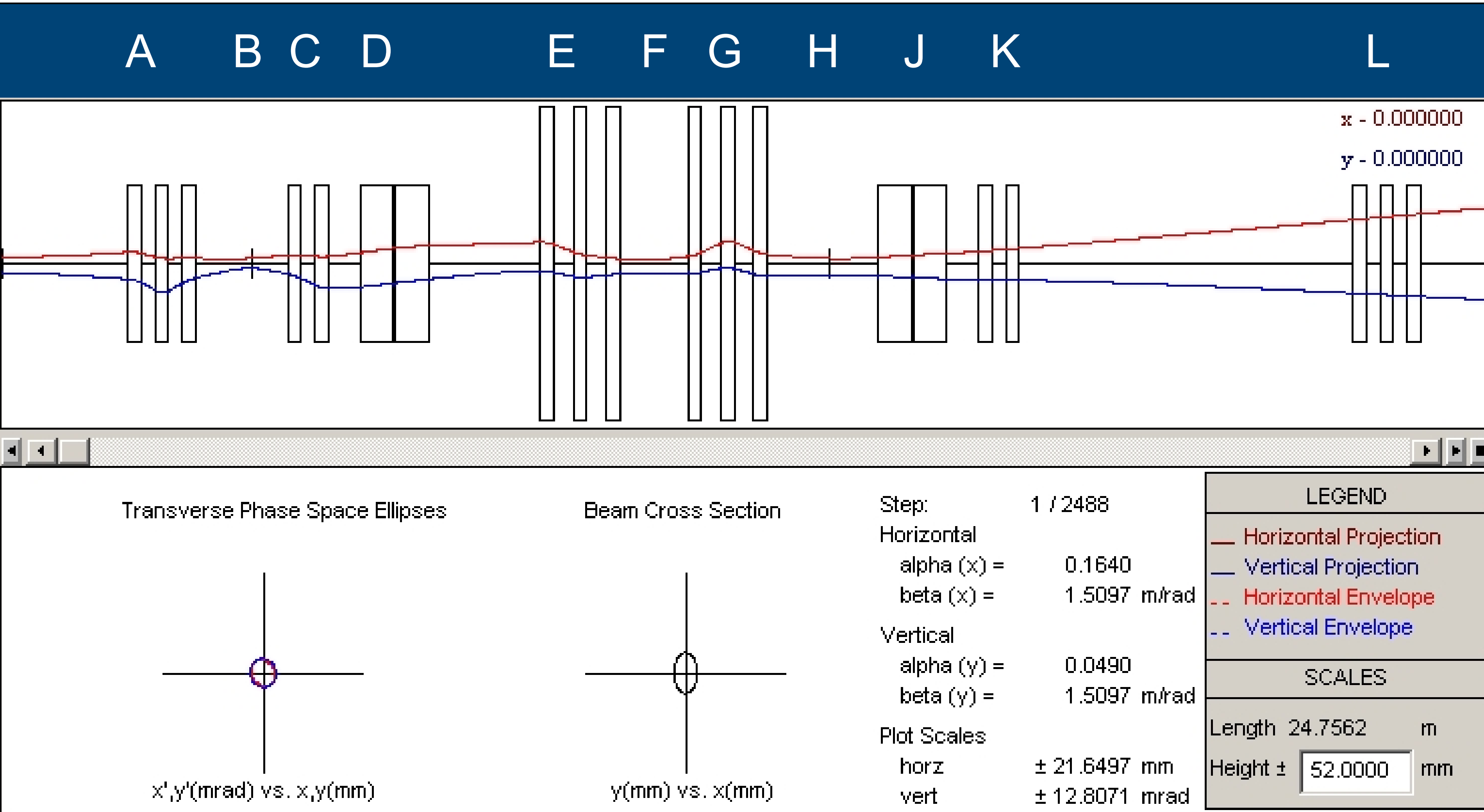
- two horizontal treatment rooms
- one vertical room: treatment of anesthetized children, physics
- broad <u>and</u> sharp beam in all rooms
- intensity broad beam in room: 4nA (short irradiation times)
- energy selection system: $\Delta E/E = 0.2\%$
  - close to physical limit
  - interest for the treatment of tumours lying close to sensitive structures, e.g. macula, papilla, and optic nerve



Layout of Facility: Beam Lines

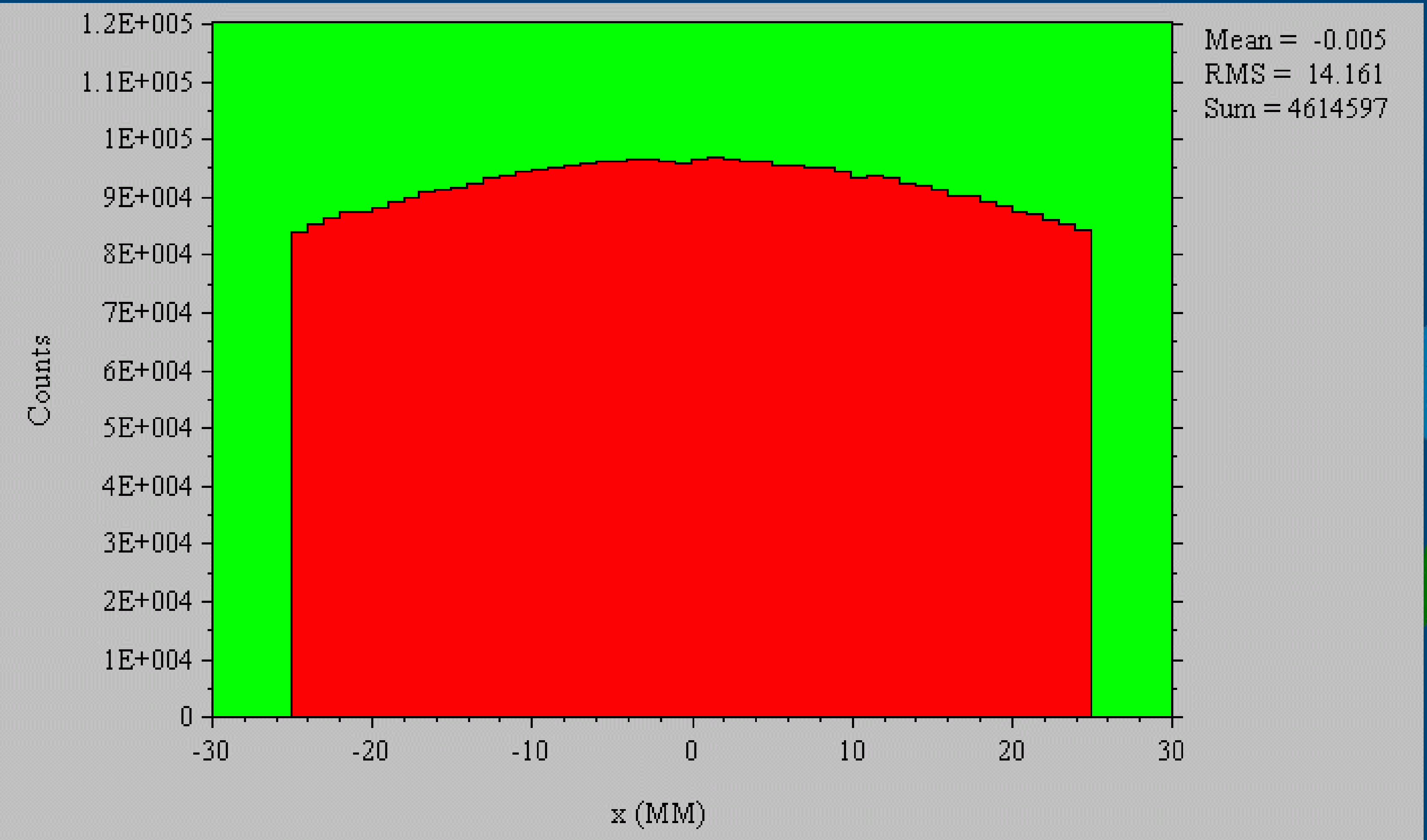


Horizontal Beam: Broad Beam



Horizontal Beam: Broad Beam

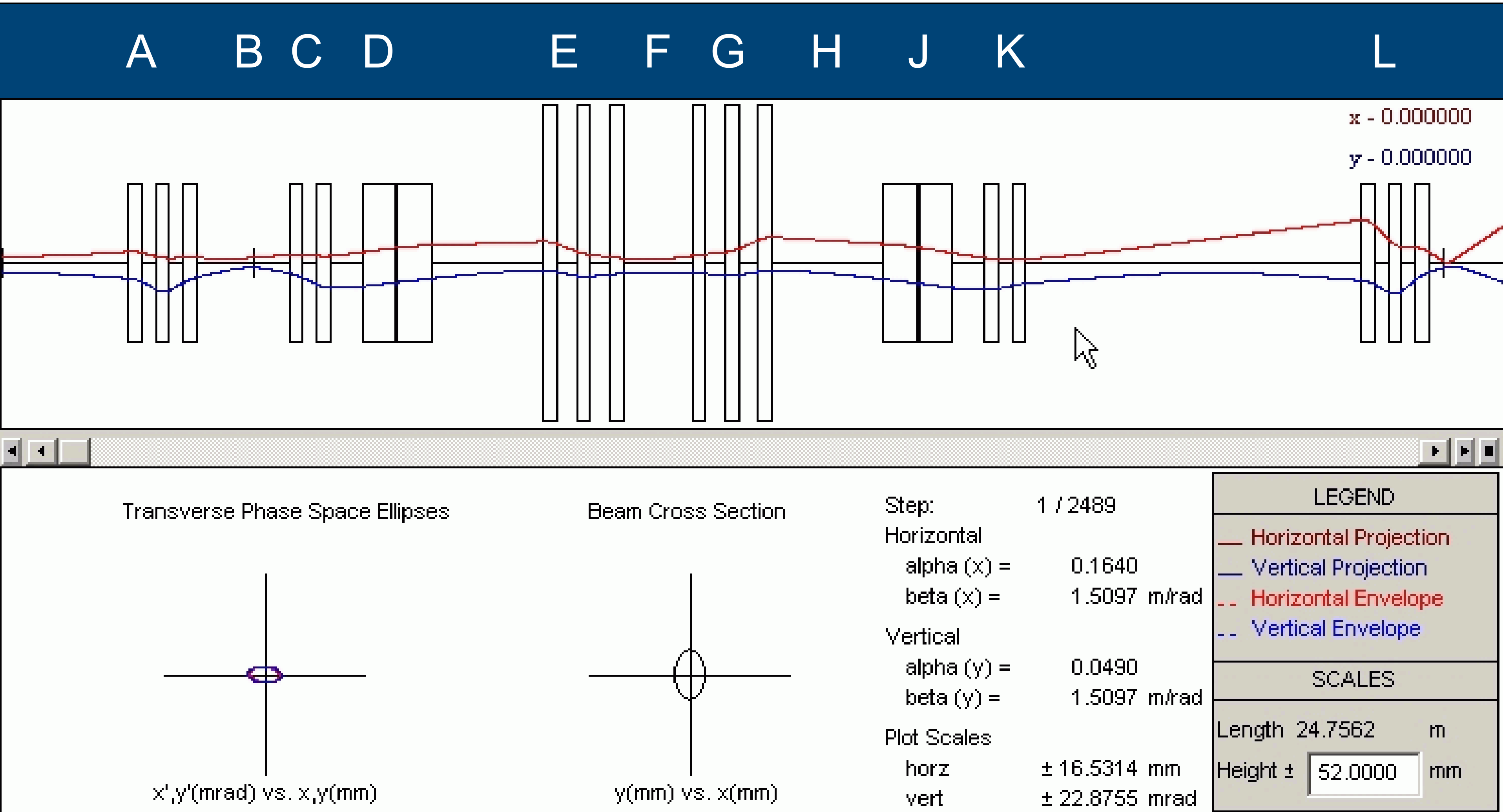
- turtle histogram of the horizontal broad beam behind the exit window: beam intensity sufficiently homogenous over more than 40 mm diameter



Horizontal Beam: Sharp Beam

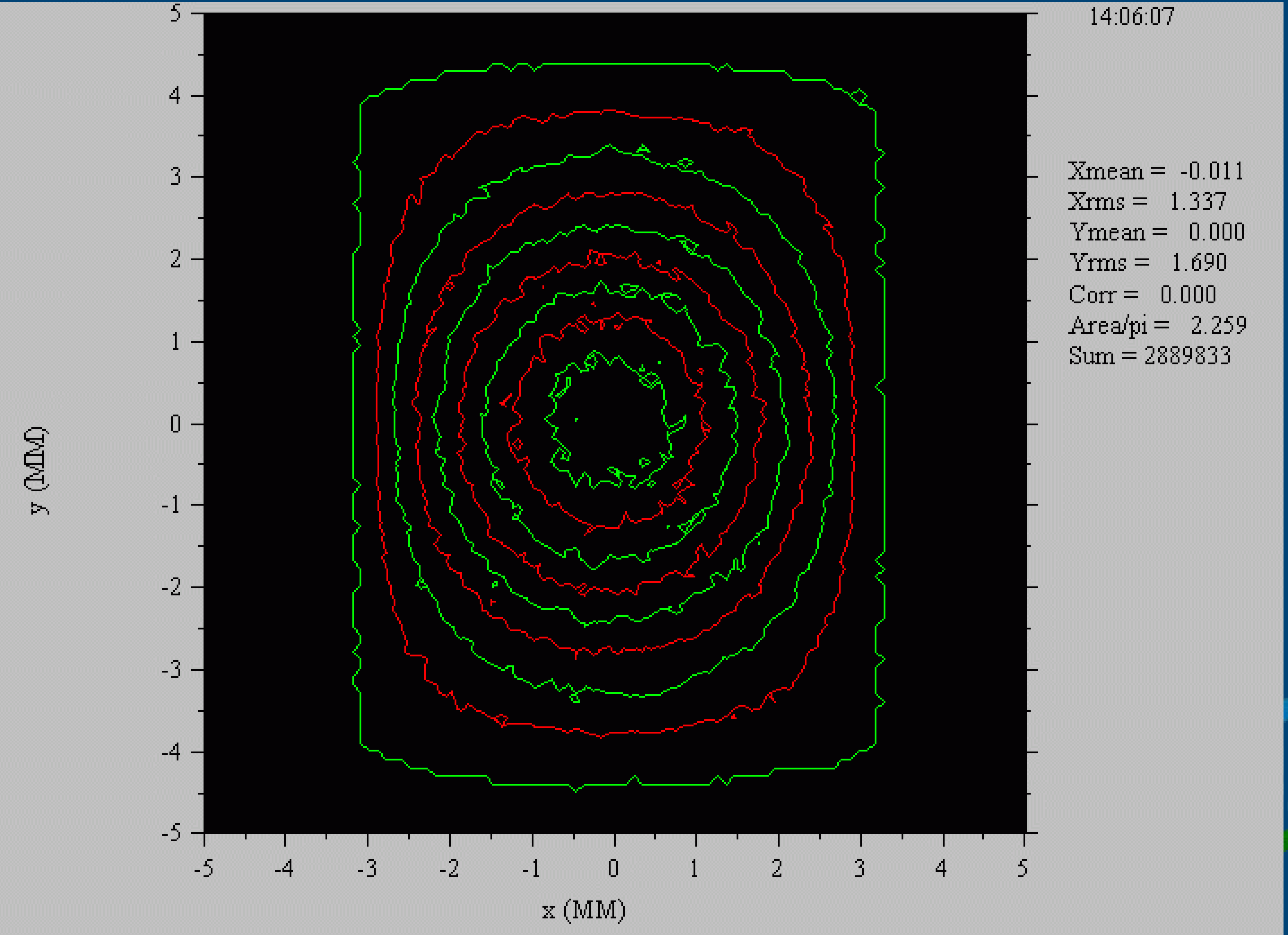
HZB Helmholtz Zentrum Berlin

CHARITÉ UNIVERSITÄTSMEDIZIN BERLIN



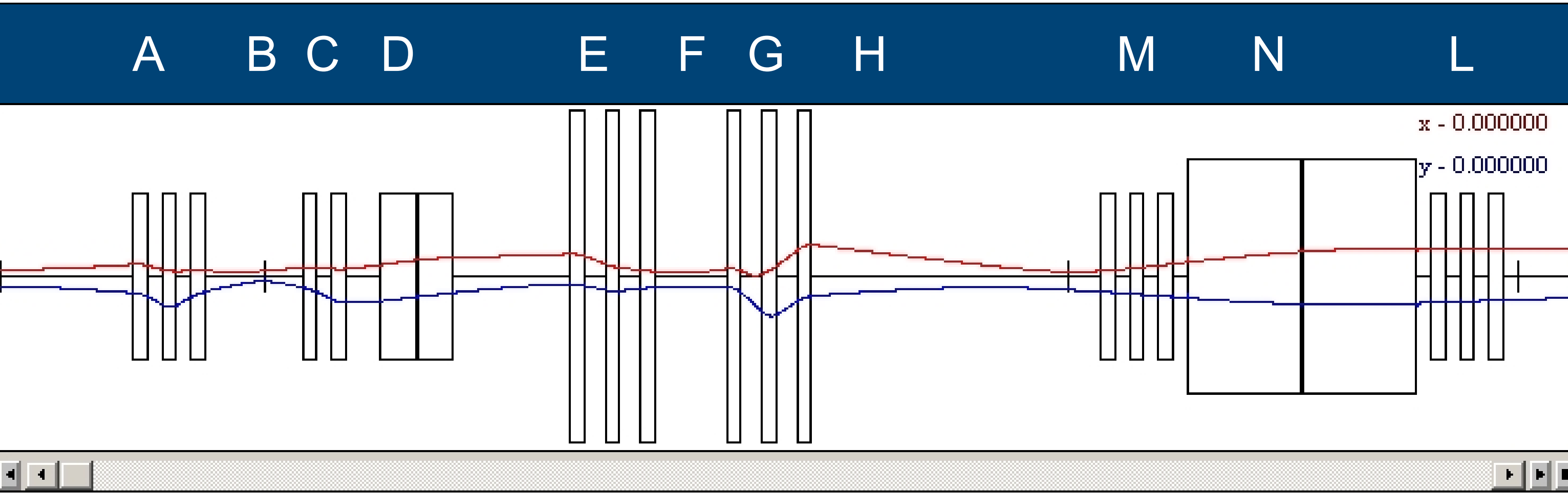
Horizontal Beam: Sharp Beam

- turtle histogram of the horizontal sharp beam in treatment room: well-defined beam spot

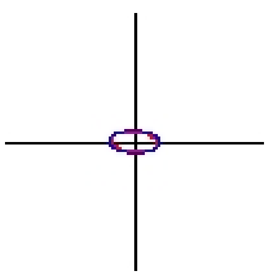


Vertical Beam: Broad Beam

HZB Helmholtz Zentrum Berlin
CHARITÉ UNIVERSITÄTSMEDIZIN BERLIN

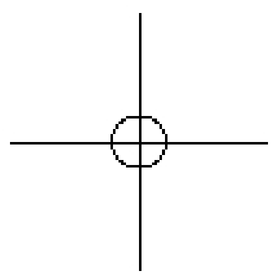


Transverse Phase Space Ellipses



x',y'(mrad) vs. x,y(mm)

Beam Cross Section



y(mm) vs. x(mm)

Step: 1 / 2493

Horizontal
- alpha (x) = 0.1640
- beta (x) = 1.5097 m/rad

Vertical
- alpha (y) = 0.0490
- beta (y) = 1.5097 m/rad

Plot Scales
- horz ± 13.7736 mm
- vert ± 20.9888 mrad

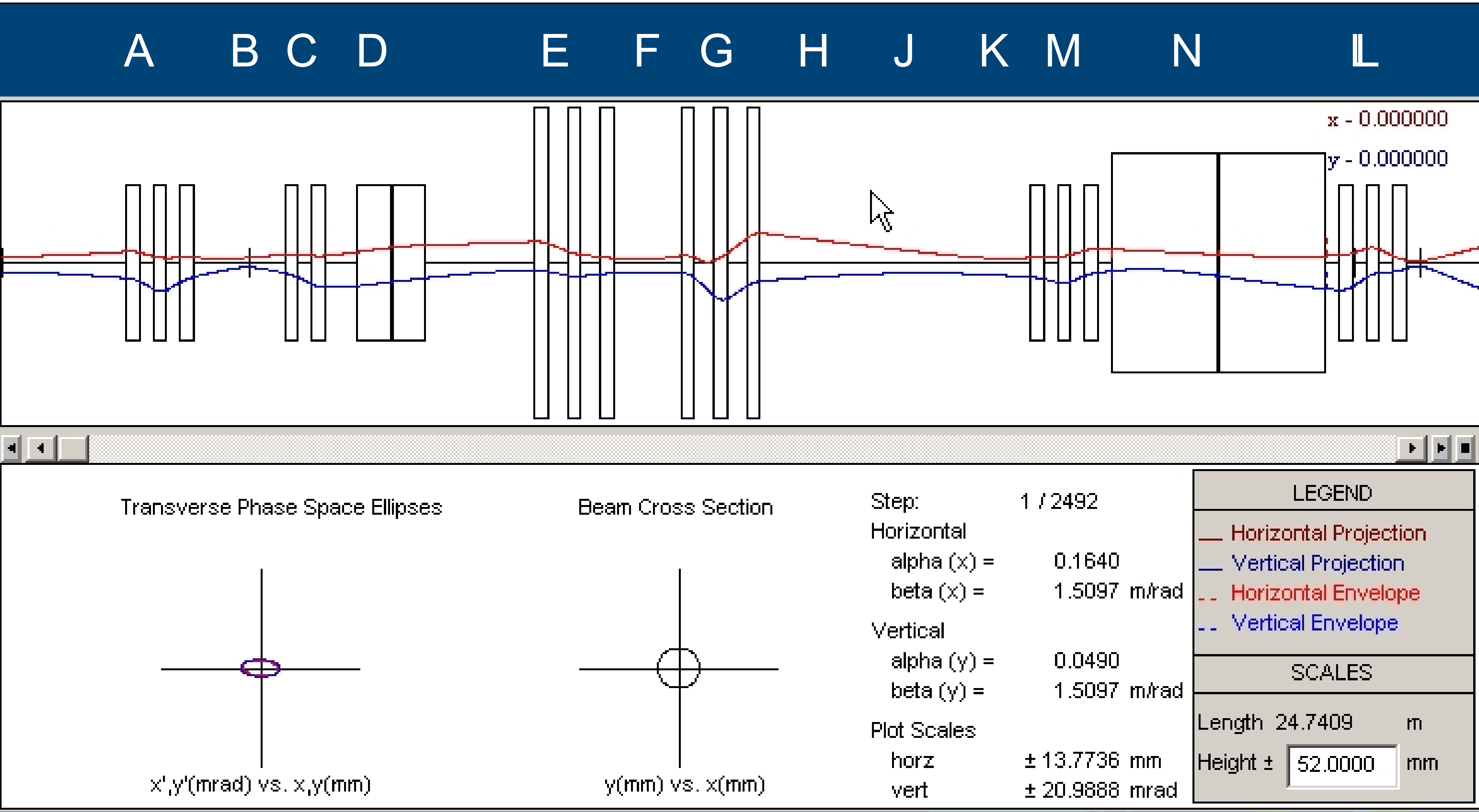
LEGEND
- Horizontal Projection
- Vertical Projection
- Horizontal Envelope
- Vertical Envelope

SCALES
- Length 24.7409 m
- Height ± 52.0000 mm

Vertical Beam: Sharp Beam

HZB Helmholtz Zentrum Berlin

CHARITÉ UNIVERSITÄTSMEDIZIN BERLIN



Transmissions

- **evaluated using Graphics TURTLE**
- **assumption: 80% extraction efficiency**

Place	**Broad Beam**	**Sharp Beam**
cyclotron exit	100 nA	100 nA
collimator 1 m behind exit	60 nA	60 nA
energy slits	30 nA	30 nA
collimator behind scattering foil	6.5 nA	
beam in treatment room	2.5 nA	30 nA

- these calculations are now the base for detailed FLUKA and MCNPX calculations for the radiation safety

Conclusion

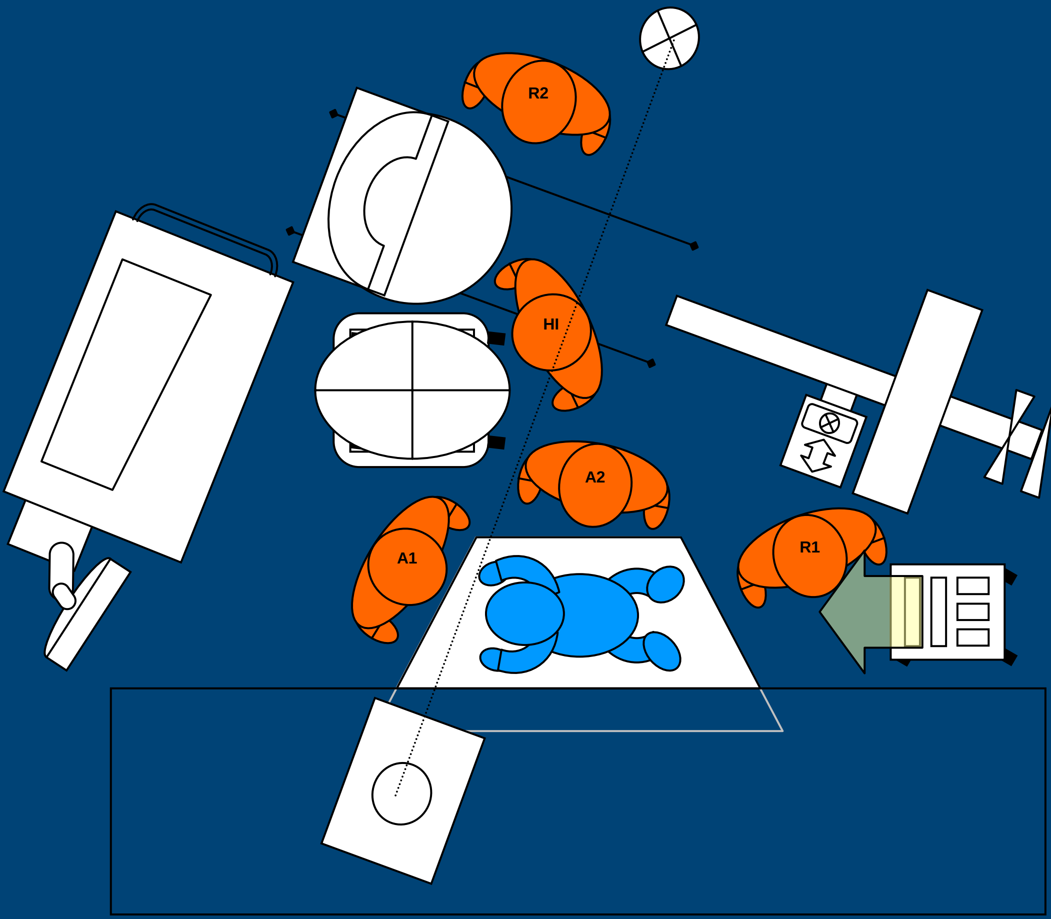
- dedicated facility:
- 72 MeV: all ocular tumours, even in the case of optic nerve infiltration
- best therapeutic options:
  - distal falloff close to physical limit, due to energy selection system
  - sharp penumbra
- vertical beam line for anesthetized patients
- ability to deal with the time consuming positioning process

Outlook

- exhaustive calculations of the neutron doses are in progress
- detailed design for treatment nozzles is planned
- next step: design of the accelerator

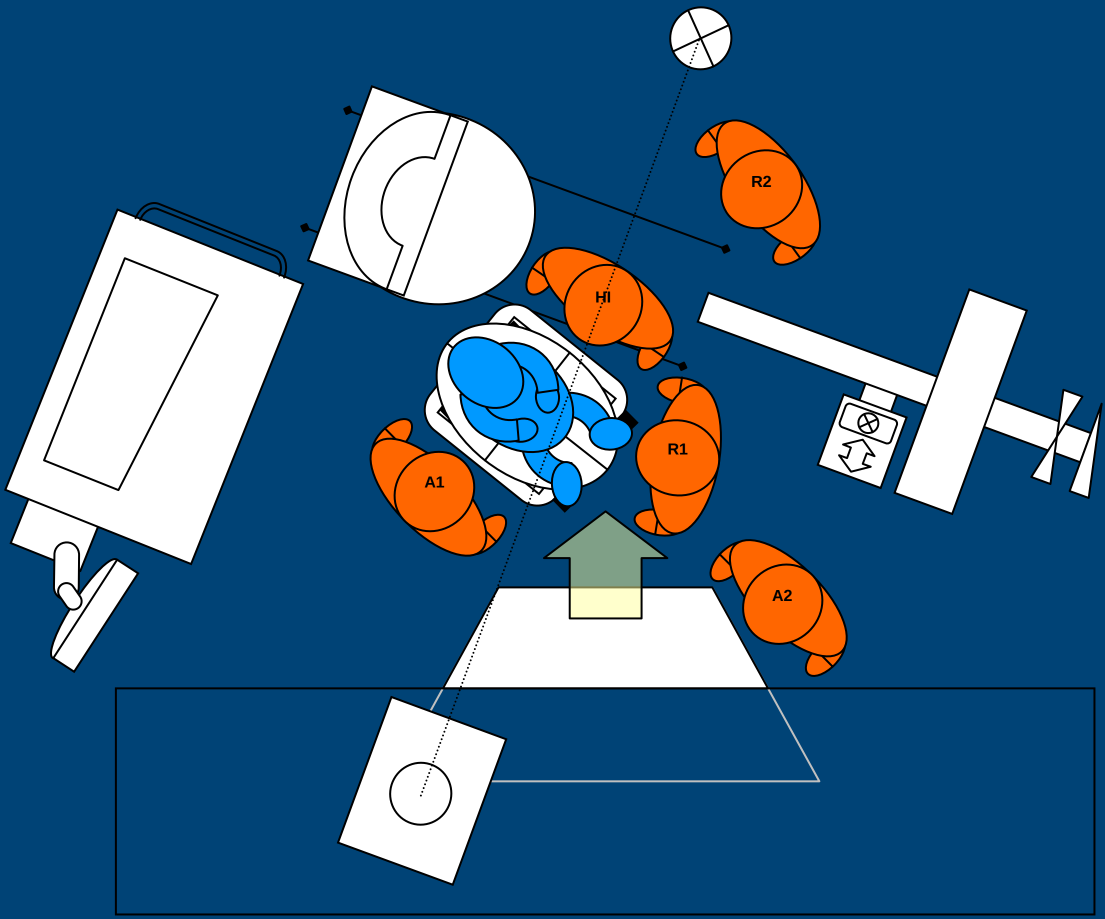
Children: Preparation

- step 1: anaesthesia on separate table



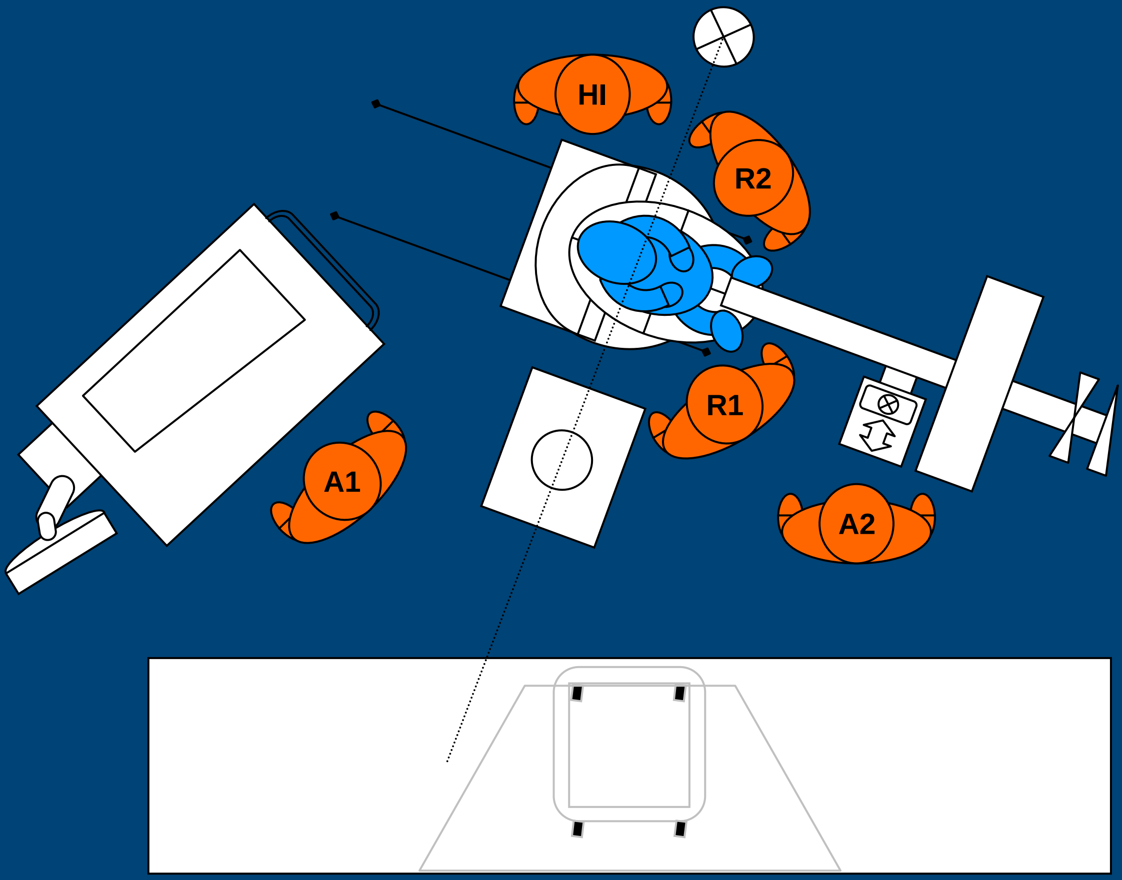
Children: Preparation

- step 2: transfer into car seat



Children: Preparation

- step 3: treatment position



Children: Positioning