The Proton Beam Therapy Facility at PSI

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Talk outline

Tradition of radiotherapy @ PSI

Some remarks on scanning techniques

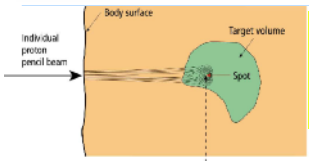
Motivation for, and brief description of, PROSCAN project

- description of the COMET cyclotron

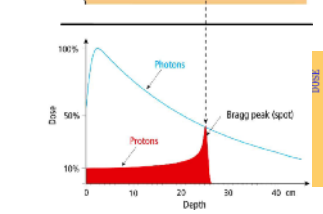
New treatment *gantry* and scanning improvements

Conclusions

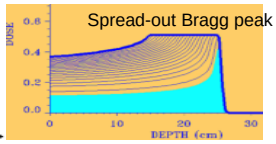
Why use protons for radiotherapy?



Radiation dose should be delivered to tumour while sparing the healthy cells that surround the tumour. The existence of the Bragg "peak" makes protons an attractive choice for therapy.



Spread-out Bragg peak



Generic proton therapy facility components

accelerator

energy selection

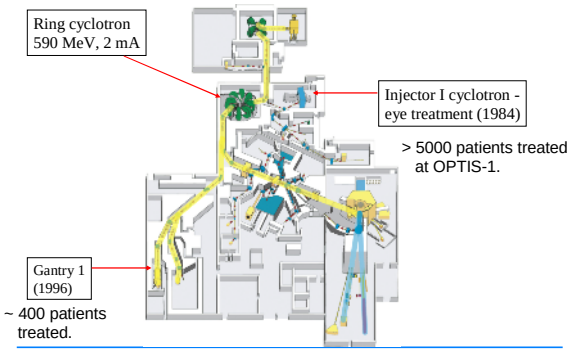
beam transport

gantry

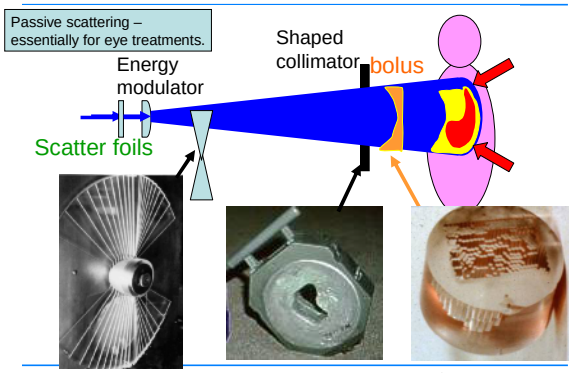
Control system:

- accelerator + beam transport
- treatment delivery + verification
- Interlocks + safety systems

Parasitic use of research facility for patient treatment.



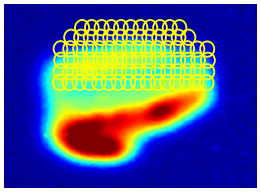
Classical "scattered" proton beam delivery technique



Spot scanning technique developed at PSI

Better for larger, deep seated tumours. Allows a "pencil" proton beam to deliver a high dose with high precision for a precisely specified period of time.

Spot scanning: **step** & **shoot**



Results in better dose distribution.

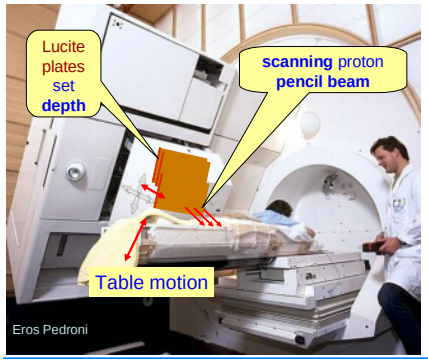
Beam size 7 mm FWHM
5 mm steps

10'000 spots/liter (21 x 21 x 21)
Dose painted only once

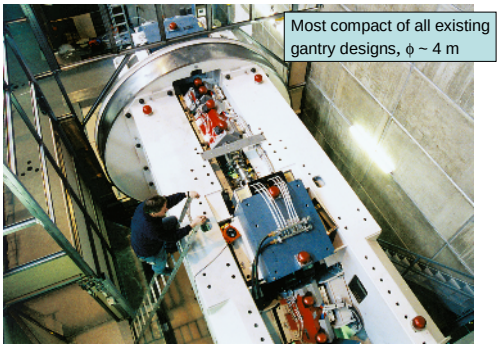
~1 Gy /litre/minute

Transverse motions via fast scanning magnet and patient table movement.
Depth variation by range shifter (lucite plates) in front of patient.

Compact "Gantry-1" at PSI (1996)



Gantry 1 – in use at PSI for treatment since 1996.



Limitations of spot-scanning technique with Gantry 1

- Beam spreading due to multiple scattering in the lucite plates.
  - less sharply demarcated dose distributions
- Relatively slow motion of table movement
- Dynamic treatment suffers from tumour or organ movement during scan
  - under/over dosage may occur

Motivation for the construction of the PROSCAN Facility

- Difficulties of parasitic use of Ring Cyclotron in a multi-user research environment
- Ring cyclotron and spallation neutron targets require long maintenance shutdowns ~ 4 months per year during which no treatment is available.
- Further development of PSI spot-scanning technology
  - Fast scanning techniques to deal with organ motion
- Transfer of technology to industry and radiation therapy centers

The PROSCAN facility consists of;

A 250 MeV proton cyclotron – COMET (COmpact MEdical Therapy cyclotron)

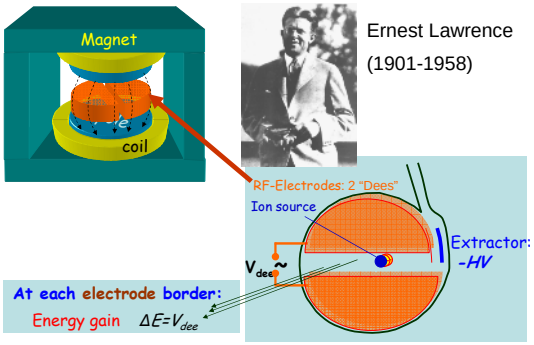
An energy "degrader"

Beam lines equipped with diagnostics

Therapy equipment

- previously existing gantry 1
- new gantry
- new eye treatment facility – OPTIS-2
- experimental beam line.

Cyclotron (1930)



Ernest Lawrence
(1901-1958)

Characteristics of the COMET cyclotron

COMET is a compact 4-sector AVF isochronous cyclotron employing a superconducting magnet.

RF System	
Frequency	72.8 MHz (h = 2)
RF power	100 kW
Dee voltage	80 – 130 kV

Beam properties	
Energy	250 MeV
Extracted current (max.)	800 nA
Extraction efficiency	80%*
Vert. emittance	< 3π mm-mrad
Horiz. emittance	< 5π mm-mrad
Momentum spread	± 0.2%
# of turns	650

* Important for activation issues.

The 250 MeV Cyclotron

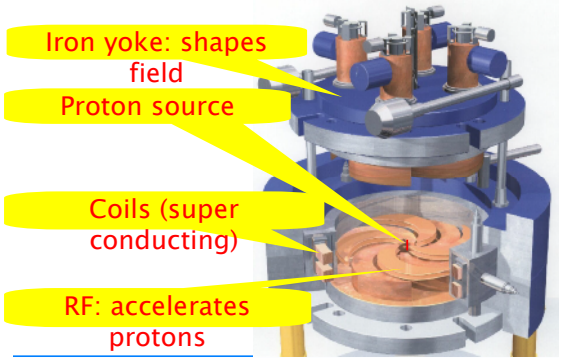
Based on a design from NSCL (H. Blosser).

Delivered by ACCEL/Varian.

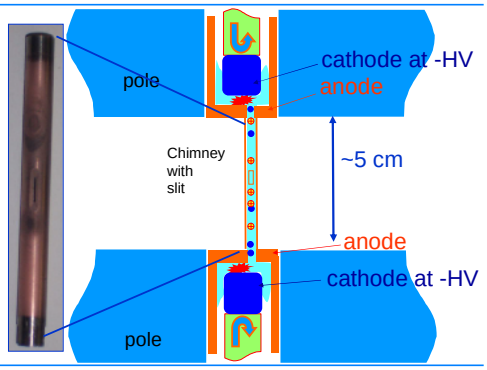
Strong ACCEL/PSI Collaboration.

Ordered – April 2001
First extracted beam – April 2005
Beam to gantry – June 2006
First patient – February 2007.

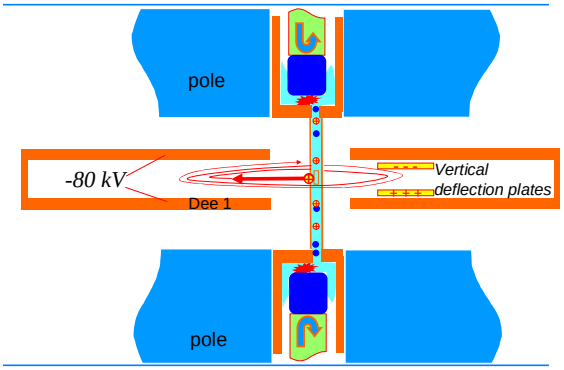
Main components of cyclotron



Internal proton source

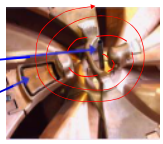


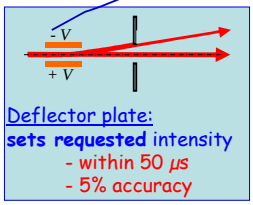
Internal proton source



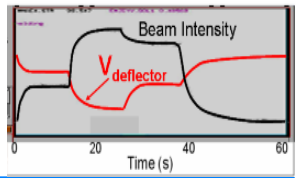
Intensity control

Max. intensity set by:
proton source





Deflector plate:
sets requested intensity
- within 50 μs
- 5% accuracy



Central region

Vertical deflection plate:
- Beam **on/off**
- **Intensity** modulation

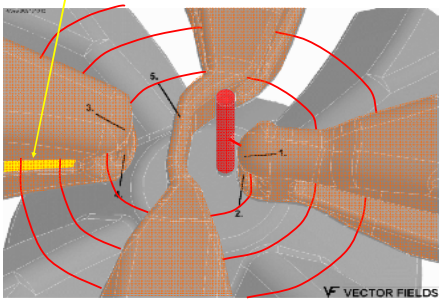
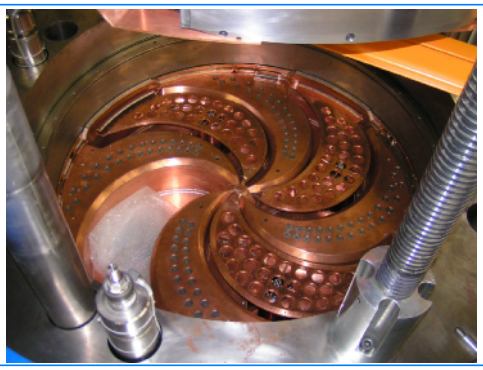
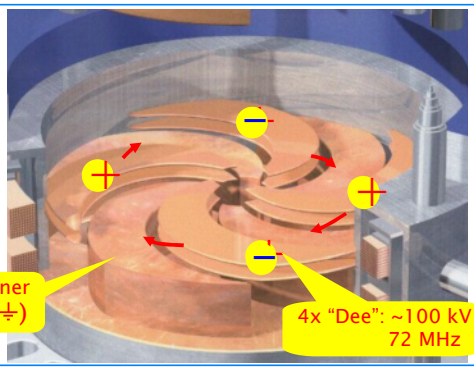


Image of lower “Dee’s”

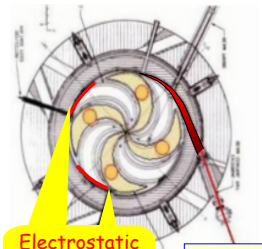


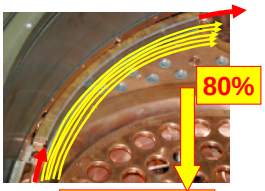
RF-System



Cryogenics: closed He-system 4x1.5 W

Extraction from COMET





Low activation

24 h after beam off (extracted beam integral: 200 μA.h)
on pole: 400 - 500 μSv/h
mid plane: 250 - 400 μSv/h
10 cm **un**shielded degr. 500-1000 μSv/h
next to shielded degrader 10-20 μSv/h

Degrader for fast beam energy change.

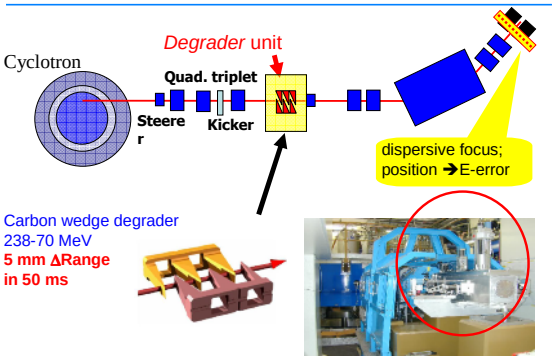
Main disadvantage of cyclotron is its “fixed” energy.

“Degrader” is used to alter energy of beam delivered to patient.

Variable thickness of material is inserted in front of beam to vary energy from 70 to 238 MeV.

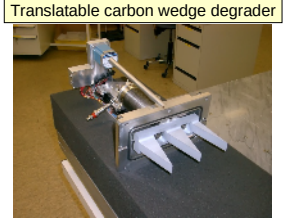
5 mm range variation produced in 50 ms.

Beam-energy adjustment

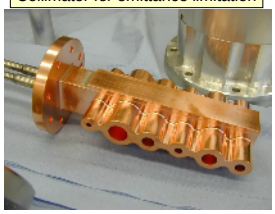


Collimating apertures define acceptance of beam transport system and limit emittance of degraded and “scattered” beam.

Translatable carbon wedge degrader

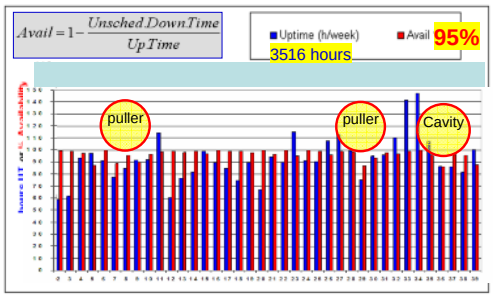


Collimator for emittance limitation



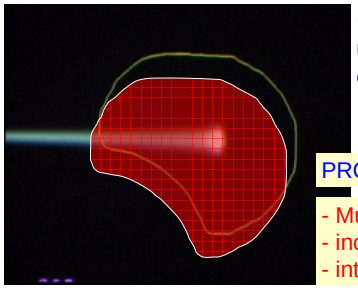
Dipole magnet and energy selection slits limit ΔE/E to ± 0.7%

Availability 2008 (first 9 months)



The problem in dynamical treatments:

Organ movement

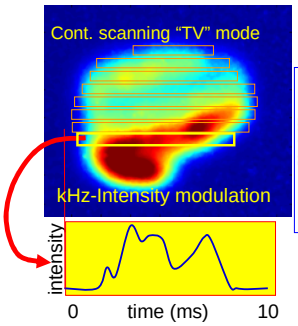


➔Danger of underdose and/or overdose

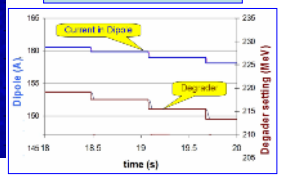
PROSCAN approach:

- Multiple scans of tumor
- increase scan speed
- intensity modulation

Fast pencil beam scanning & IMRT

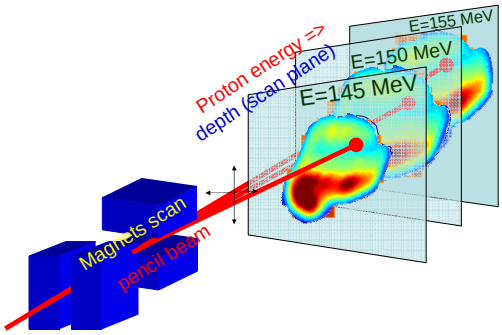


After each layer:
Energy change in 80 ms

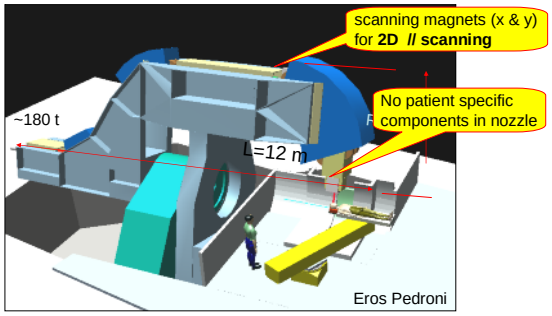


7 s for a 1 liter volume.
Target repainting:
15-30 scans / 2 min.

3D Pencil beam scanning



New Gantry 2 at PSI (2009)

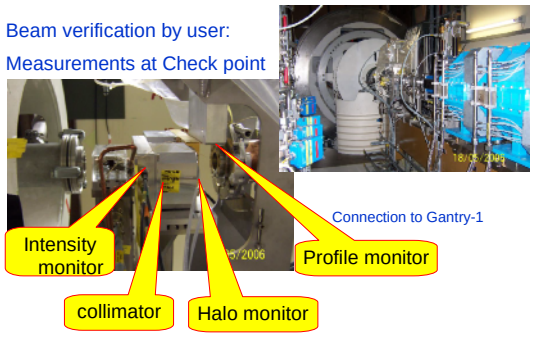


Gantry - 2

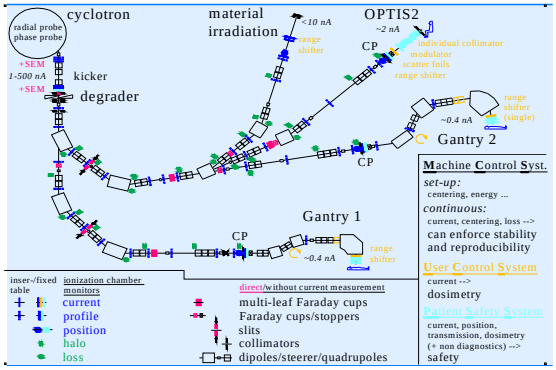
Gantry-1 connection: check point

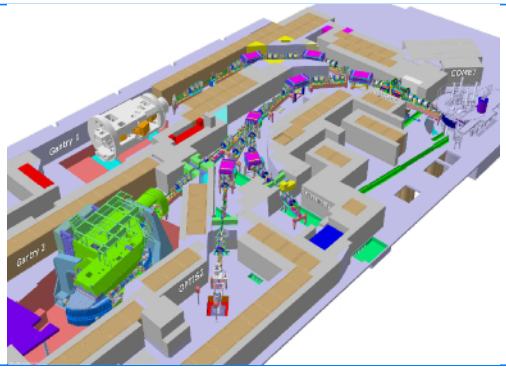
Beam verification by user:

Measurements at Check point



DIAGNOSTICS





Conclusions

- The long tradition of radiotherapy at PSI is strengthened by the PROSCAN project.
- The choice of a superconducting cyclotron as a dedicated accelerator has proven to be judicious.
- COMET is performing in a satisfactory and reliable fashion
- The installation of such a facility in a hospital environment could be envisaged.

Acknowledgement: I should like to thank the PSI communications department, and my colleagues, H. Fitze, R. Dölling, J. Düppich, S. Forss and R. Köferli for providing Images. The PROSCAN project is the result of the work of many people at PSI.

Thank you for your attention!