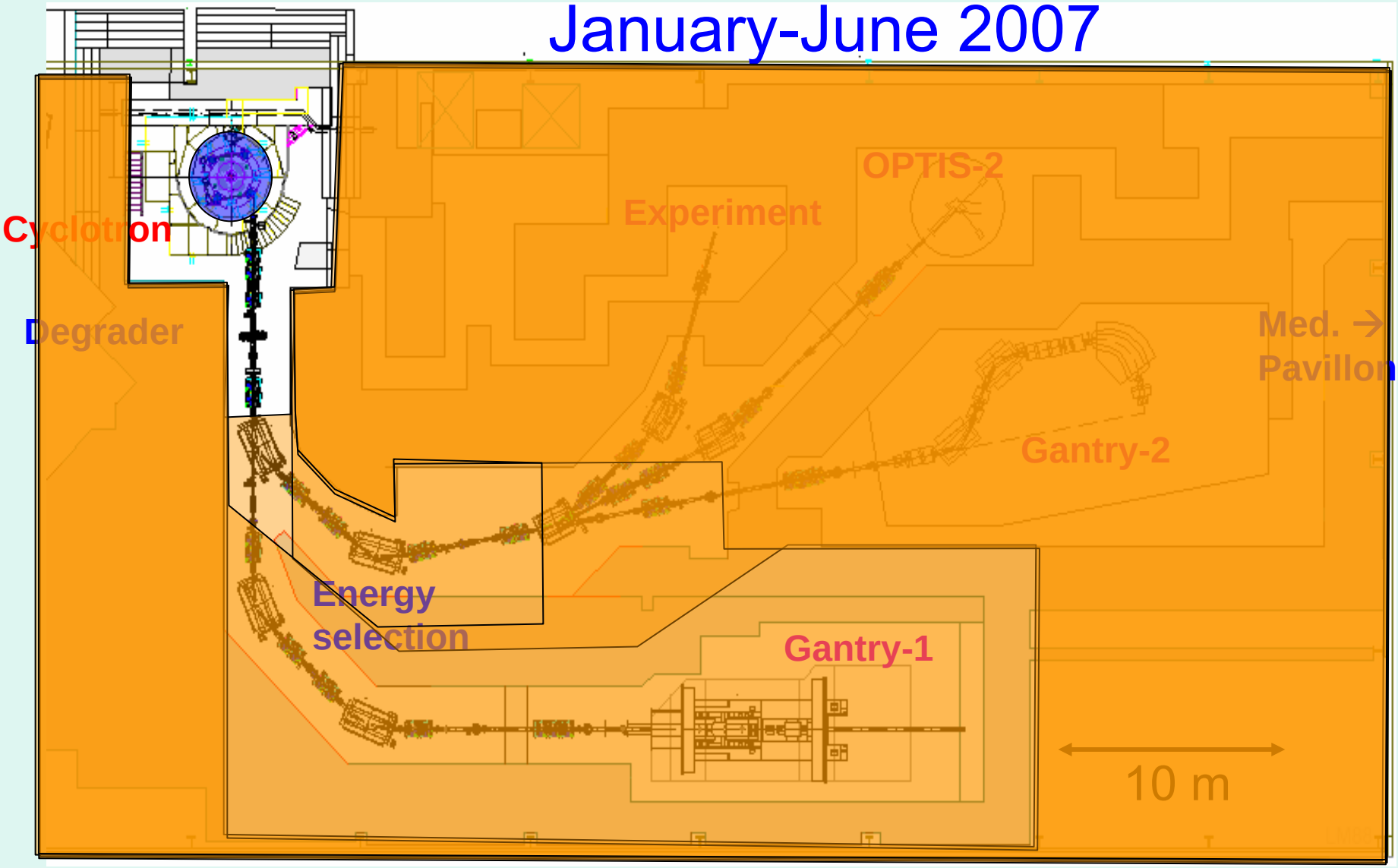
PAUL SCHERRER INSTITUT

The first year of operation of PSI's new SC cyclotron and beam lines for proton therapy.

Marco Schippers, Jürgen Duppich, Gudrun Goitein, Eugen Hug, Martin Jermann, Anton Mezger, Eros Pedroni,
for the PROSCAN team (>50 persons)

PROSCAN: Stand-alone facility at PSI



Contents

Acceptance tests of cyclotron

Commissioning of beam lines

Operation experience

Acceptance tests and commissioning of cyclotron

250 MeV SC-cyclotron

basic design: NSCL
(Henry Blosser)

Delivered by ACCEL/Varian

an intensive collaboration

Sign contract:	April 2001
Extracted beam:	April 2005
Beam on Gantry-1:	June 2006
First patient:	Febr 2007

Levels of Quality Assurance of cyclotron

- Measurements for information & reference, *not specified*
  e.g.: field maps

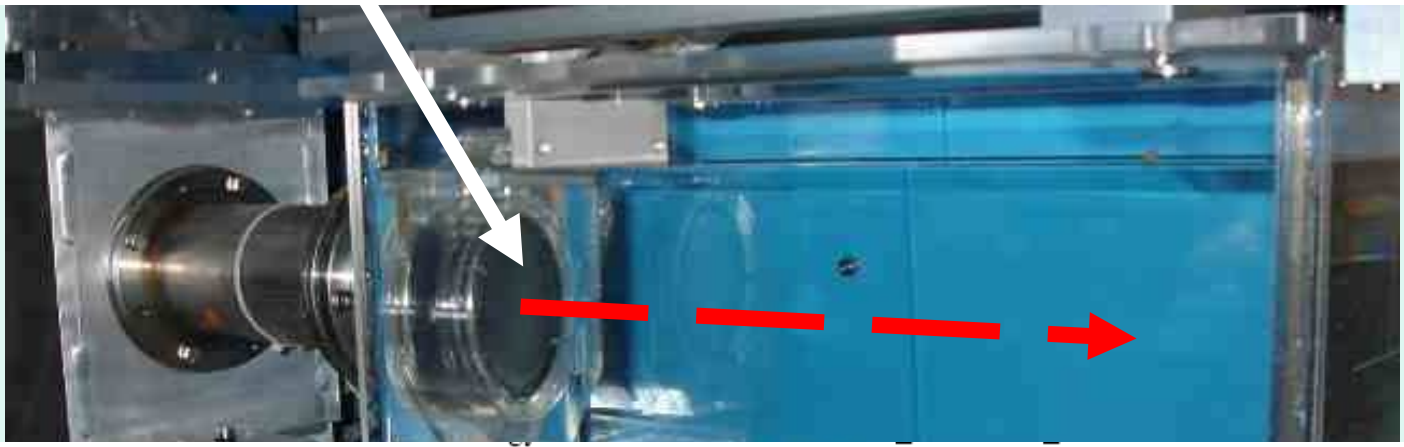
- Acceptance of subsystems (*factory acceptance* by ACCEL)
  e.g.: coil-winding
  vacuum

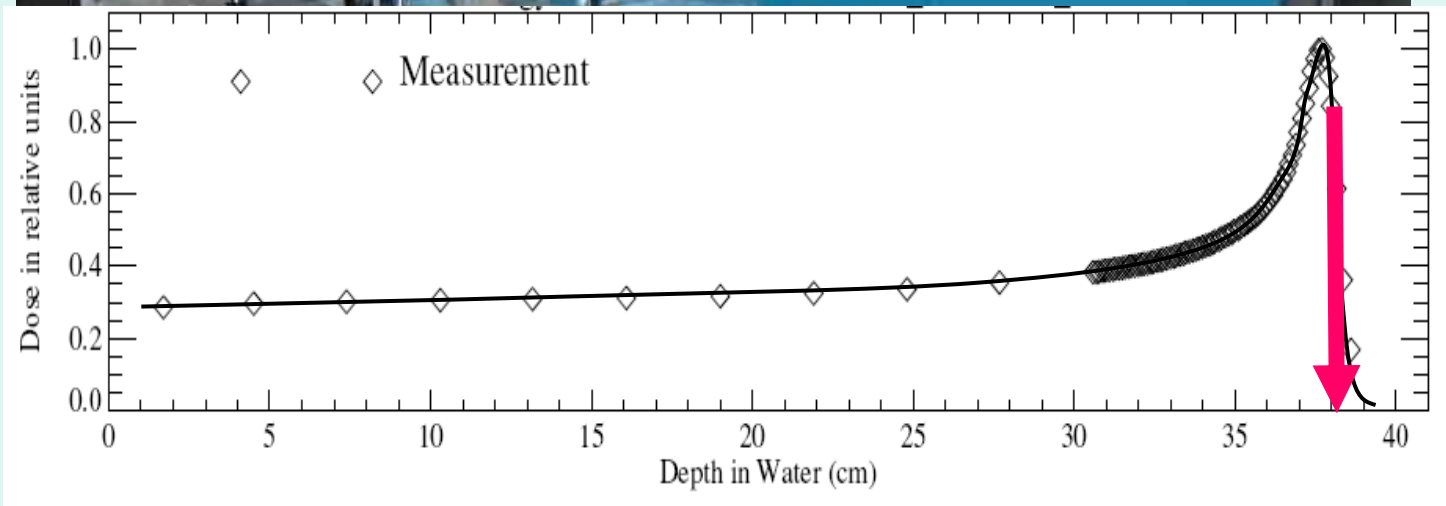
- Acceptance tests (**37**) *defined by PSI*
  acceptance measurements
  e.g.: beam quality
  nr. of beam interruptions
  access to components / exchange time
  acceptance checks
  e.g.: documentation

Dec 05 - Febr 06
33 done & OK

Energy measurement

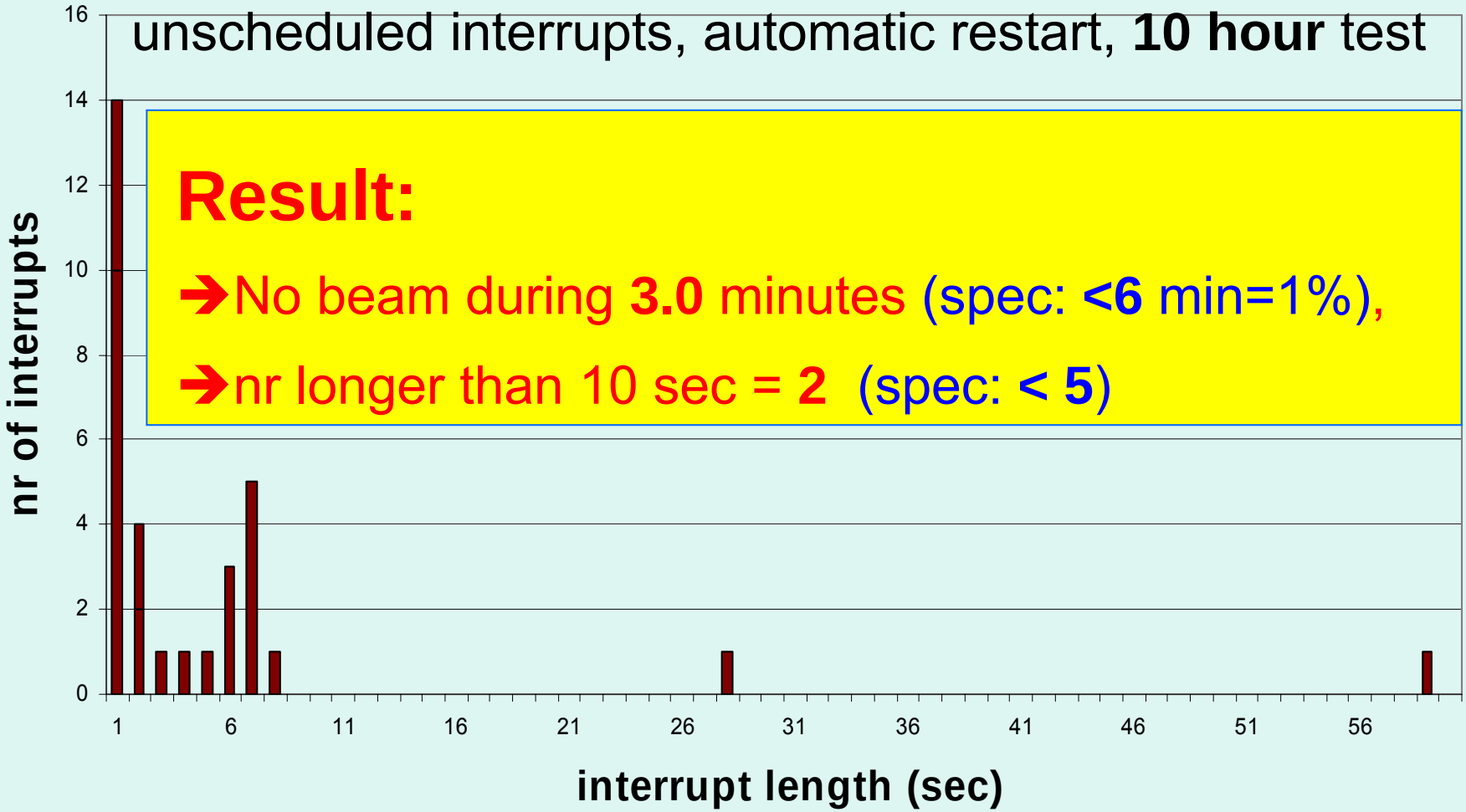
Ion chamber in water tank to measure proton range





Range in water => E=250.4(1) MeV

Reliability: beam interruptions



Beam on/off and stability

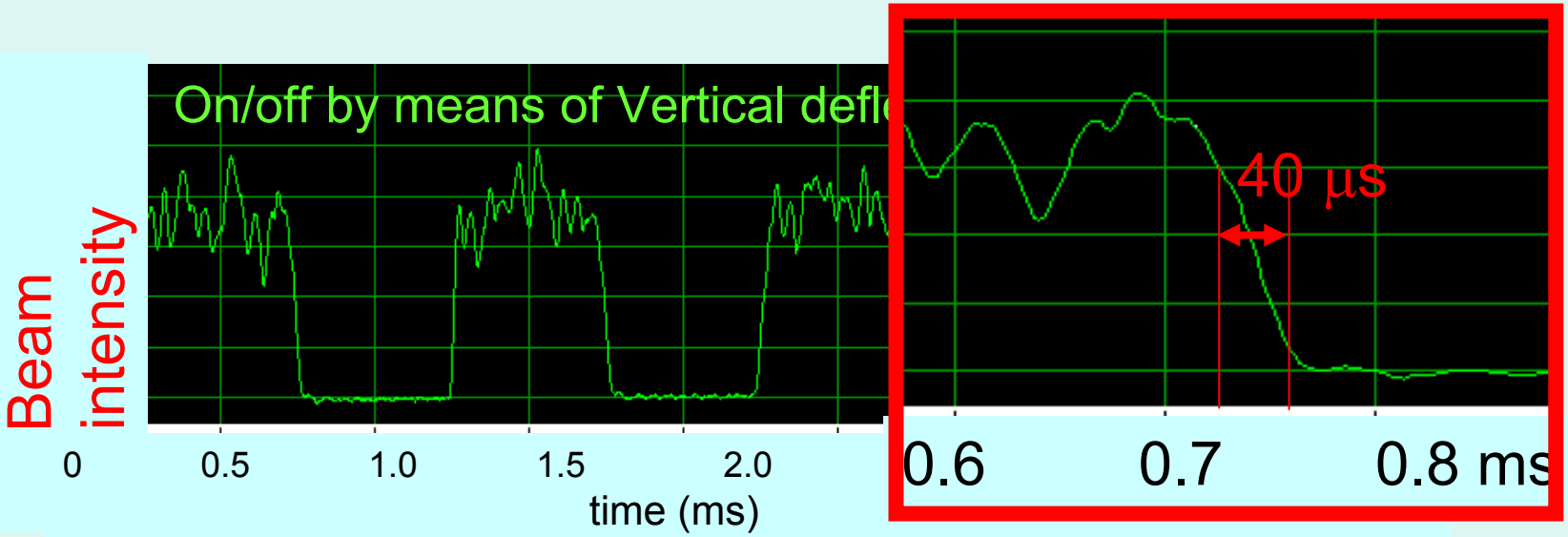
Necessary for fast dynamic scanning (Gantry-2)

Vertical deflector in cycl. Center

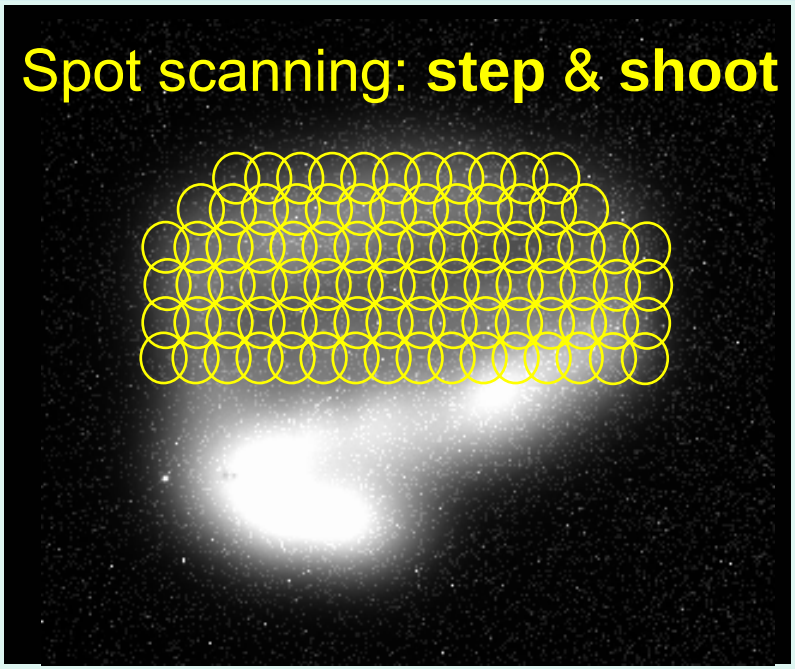
-beam on/off

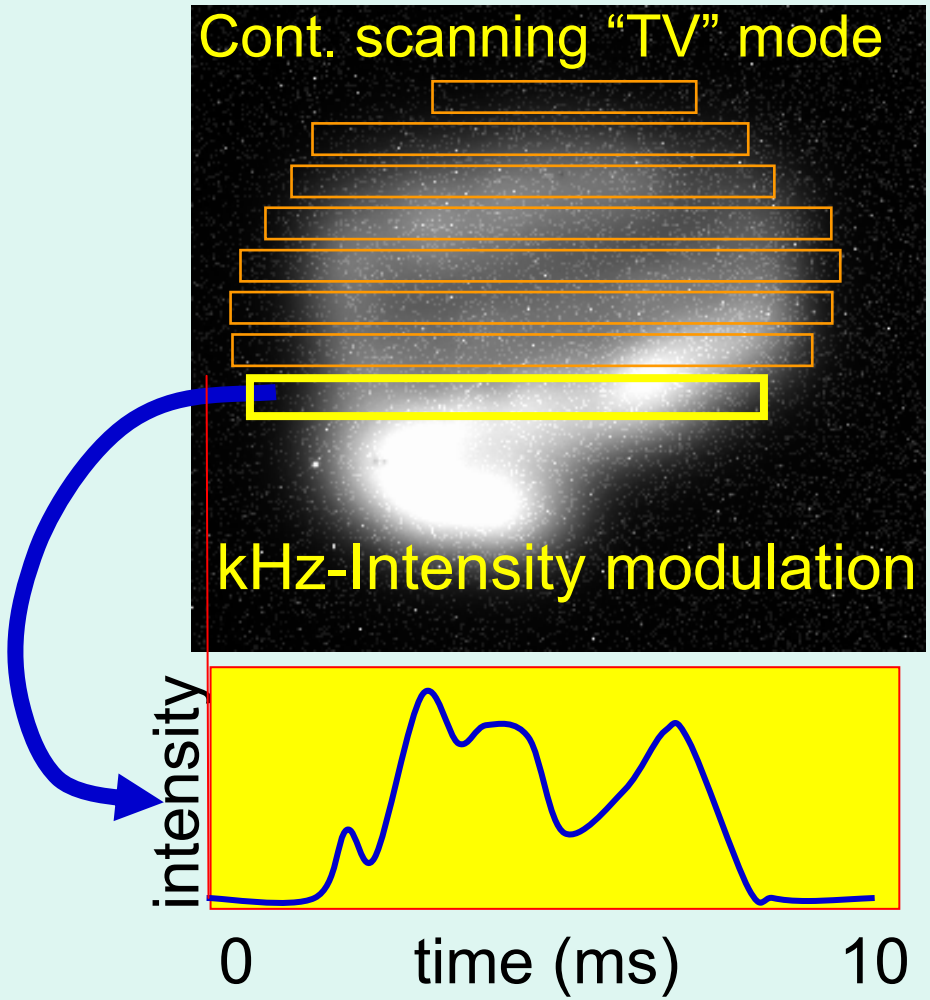
Acceptance tests:

- repetition rate 1 kHz √
- beam off < 50 μsec √
- intensity stability σ<5% —
  (for Gantry-1 and München: √)



Scan modes of new Gantry-2

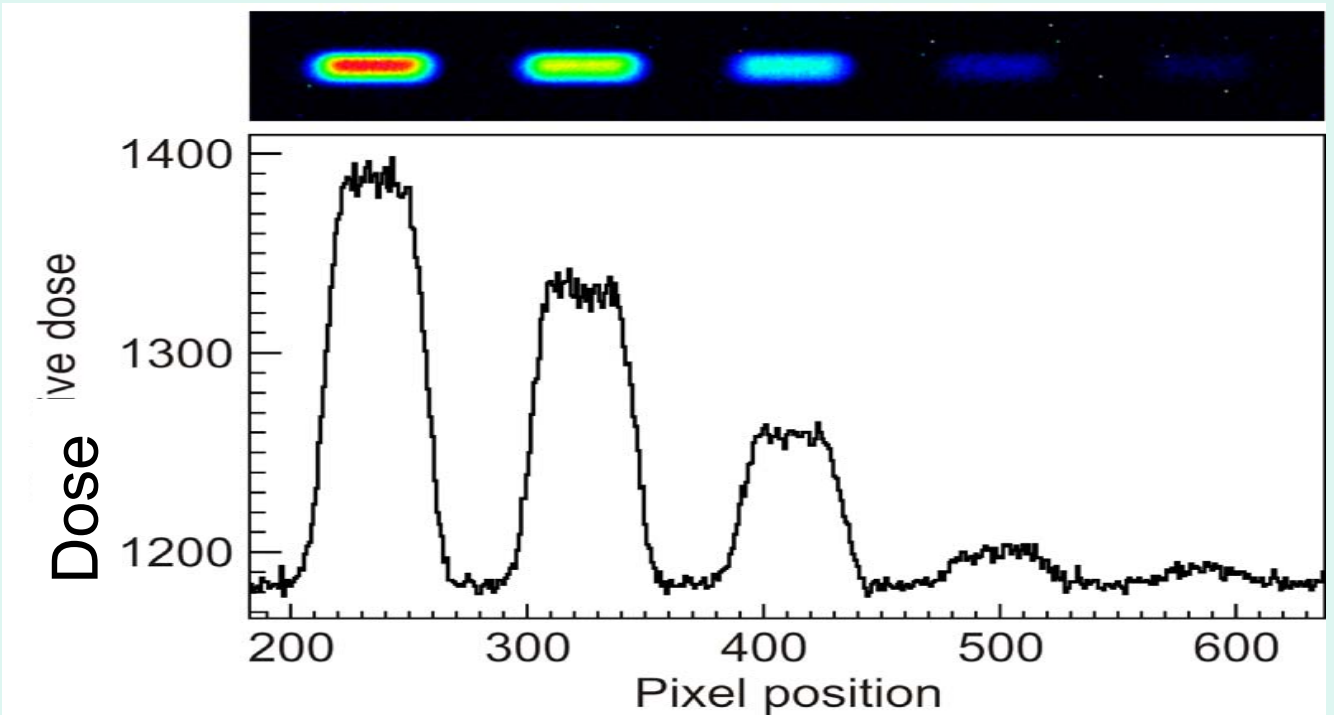




7 s for a 1 liter volume.
Target repainting: 17 scans / 2 min.

Fast intensity control with Vertical Deflector

Intensity + beam scanning:



15 cm / 30 ms

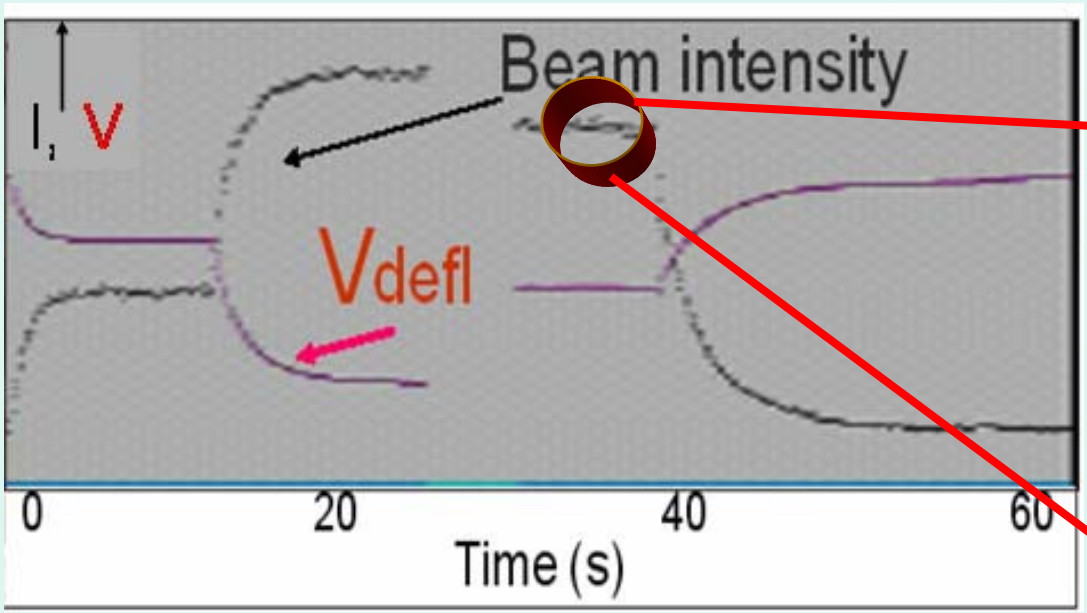
David Meer, Christian Hilbes, (Dec. 2006)

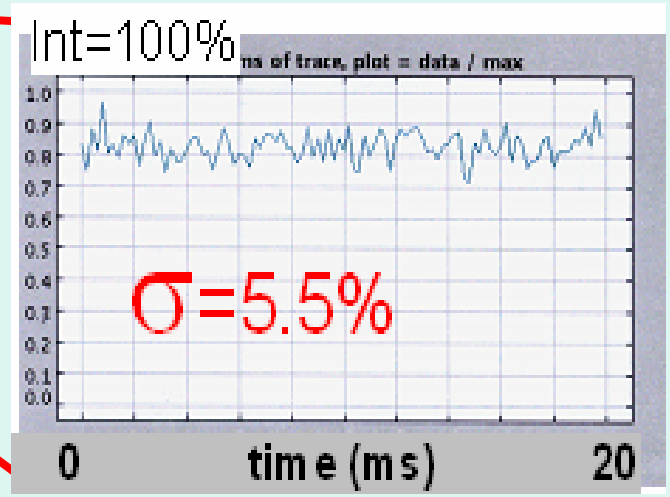
Intensity control

- **Max intensity** set by:
Ion source + phase slits

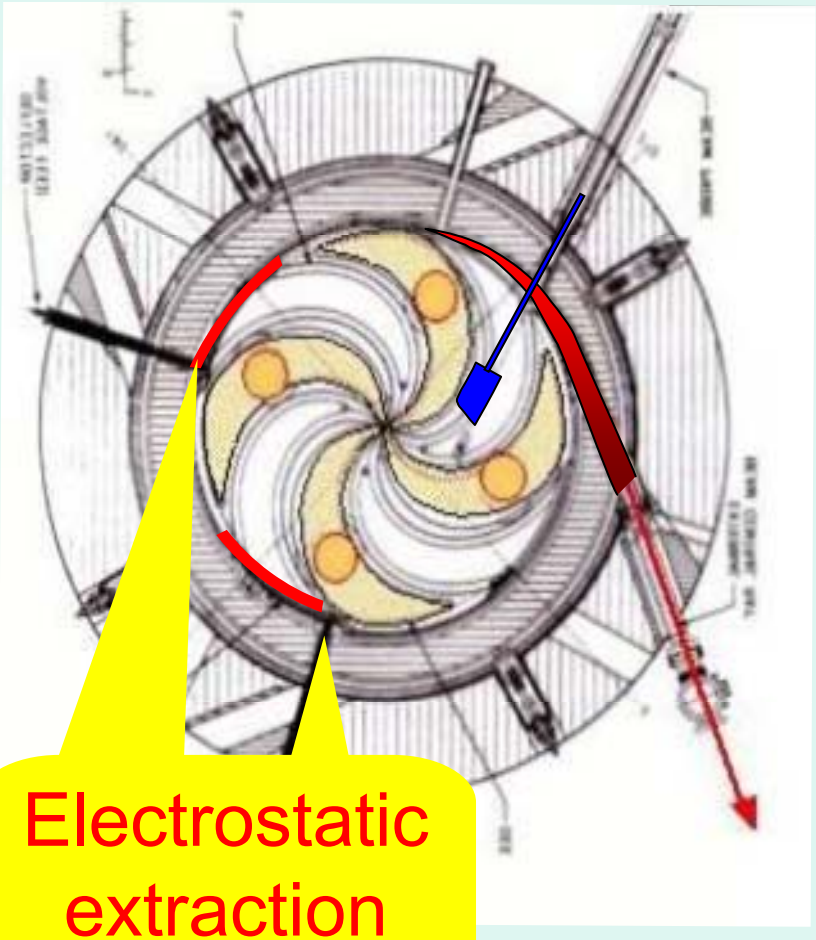
Roles of deflector plate:
- **decrease drift** of intensity
- **set requested** intensity within 5%

Febr. 2007: start program
to reach spec=> best:σ =3 %
(see poster)

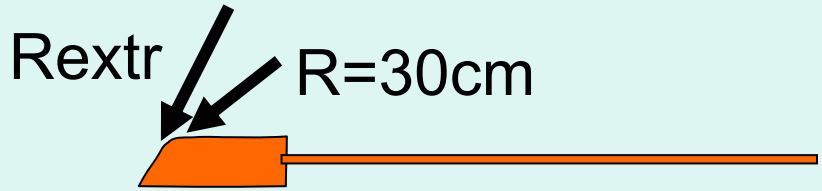


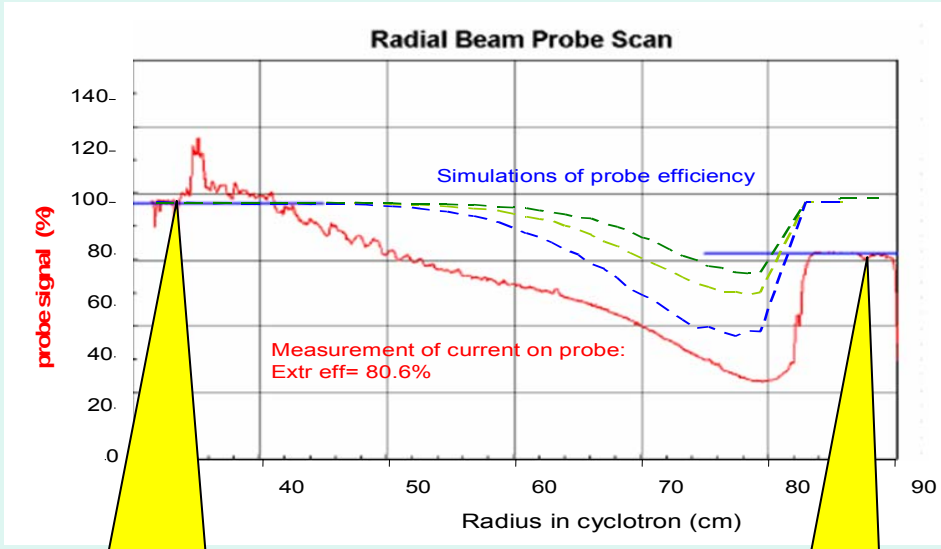


Extraction efficiency



Electrostatic extraction elements



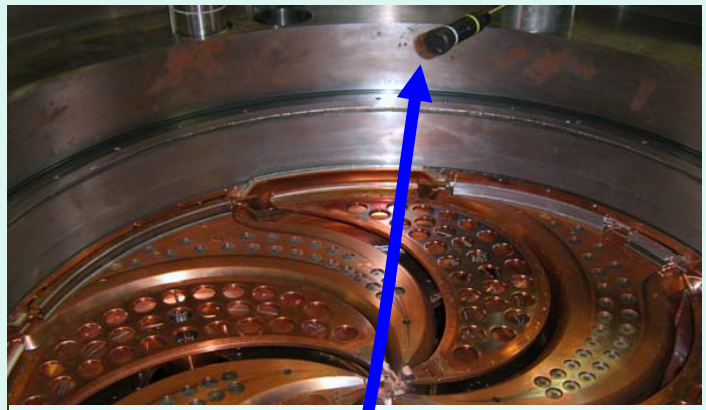


R=30 cm: 100%

Routinely: 80-83%

>80% extraction efficiency: Low dose to service staff

inside cyclotron



Mid plane, open cap

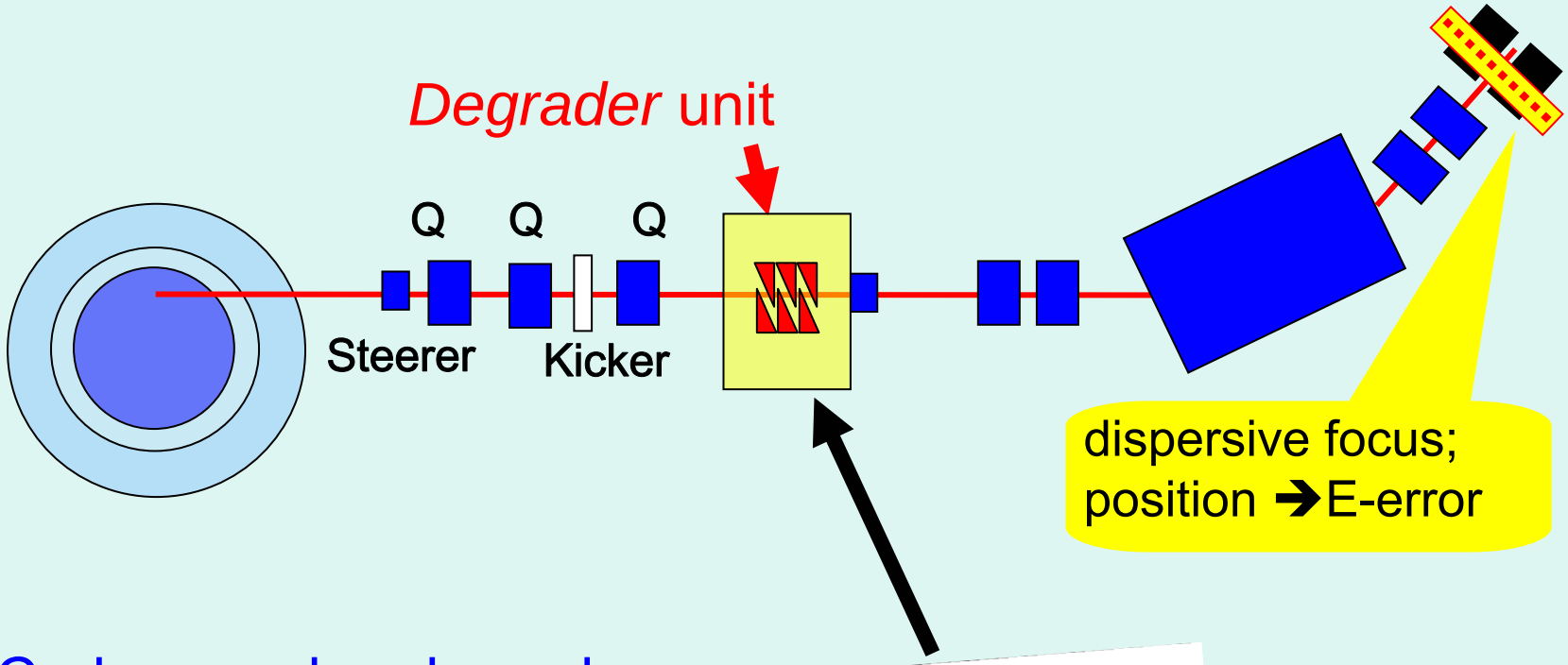
24 h after beam off, June 2007
(extracted beam integral 72 μA.h) :

on pole, closed cap: **400 μSv/h** (40 mrem/h)

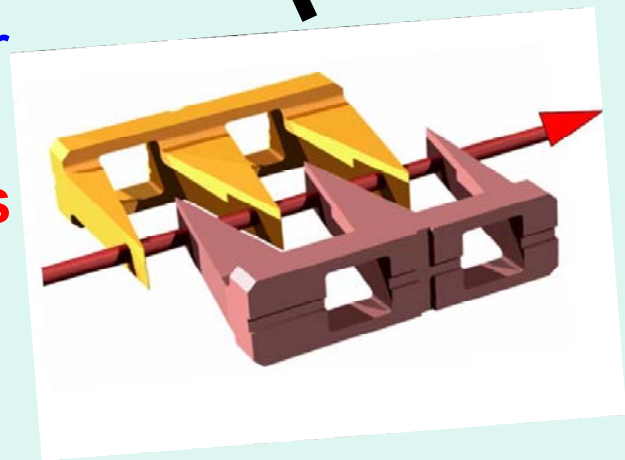
mid plane, open pole cap: **250 μSv/h** (25 mrem/h)

Commissioning of beam lines

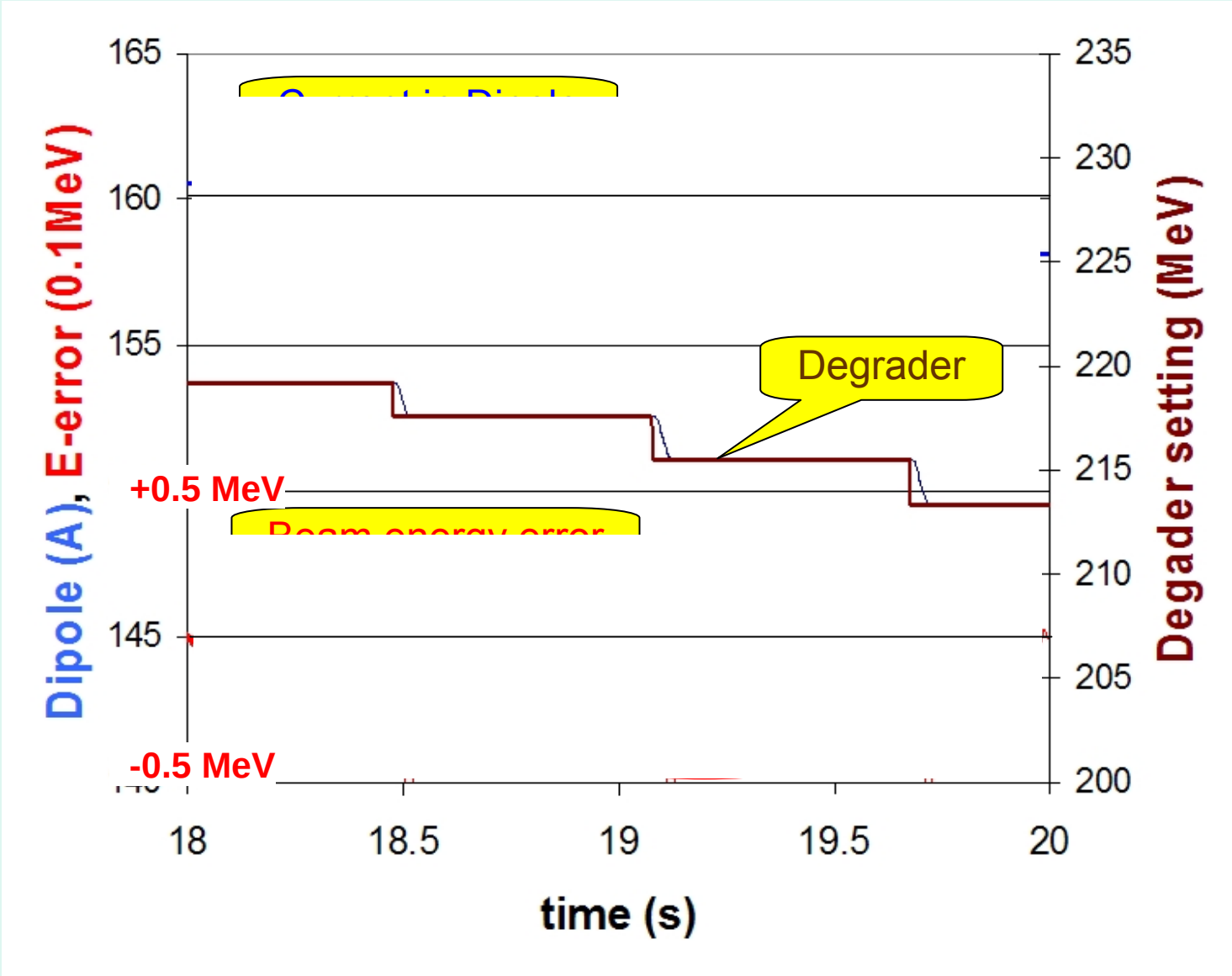
Beam-energy adjustment



Carbon wedge degrader
238-70 MeV
5 mm ΔRange in 50 ms

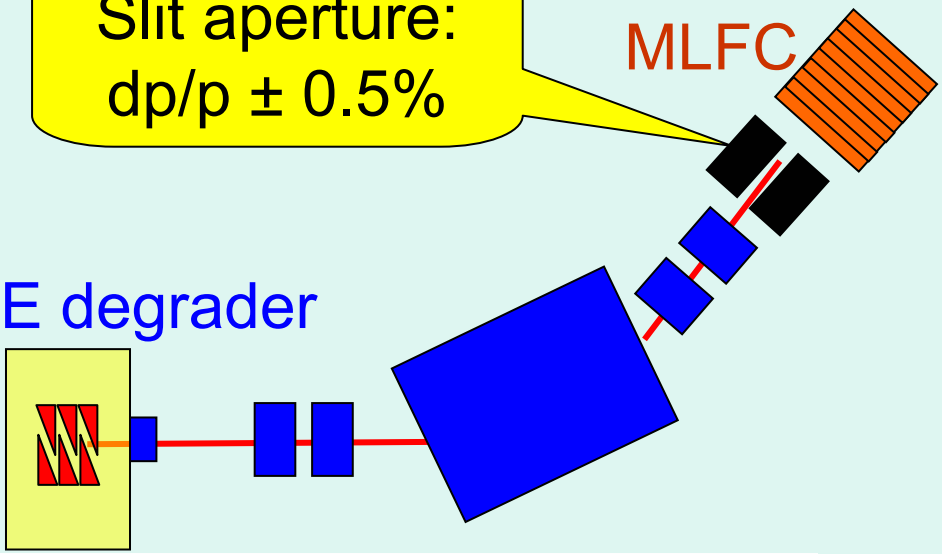


Energy scanning, Estep ~5 mm range in water.



Energy: Degrader error sensitivity

Slit aperture:
dp/p ± 0.5%

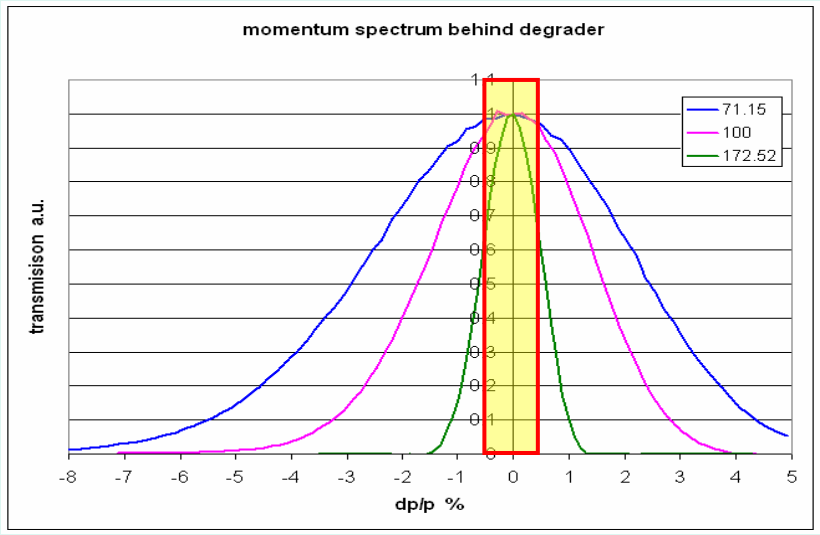


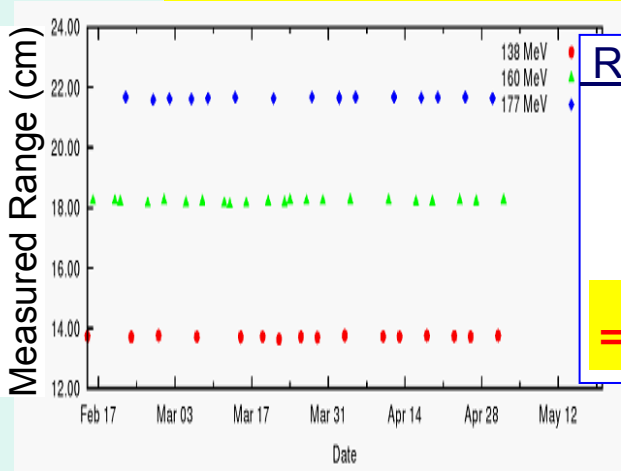
If degrader-error ±5 MeV:

	E-shift (MeV)
200 MeV:	± 1.5
90 MeV:	± 0.2

- highest sensitivity at high energy

- if degrader error <1 MeV:
  mainly transmission loss.





Range Variations:

σ = 0.4 mm

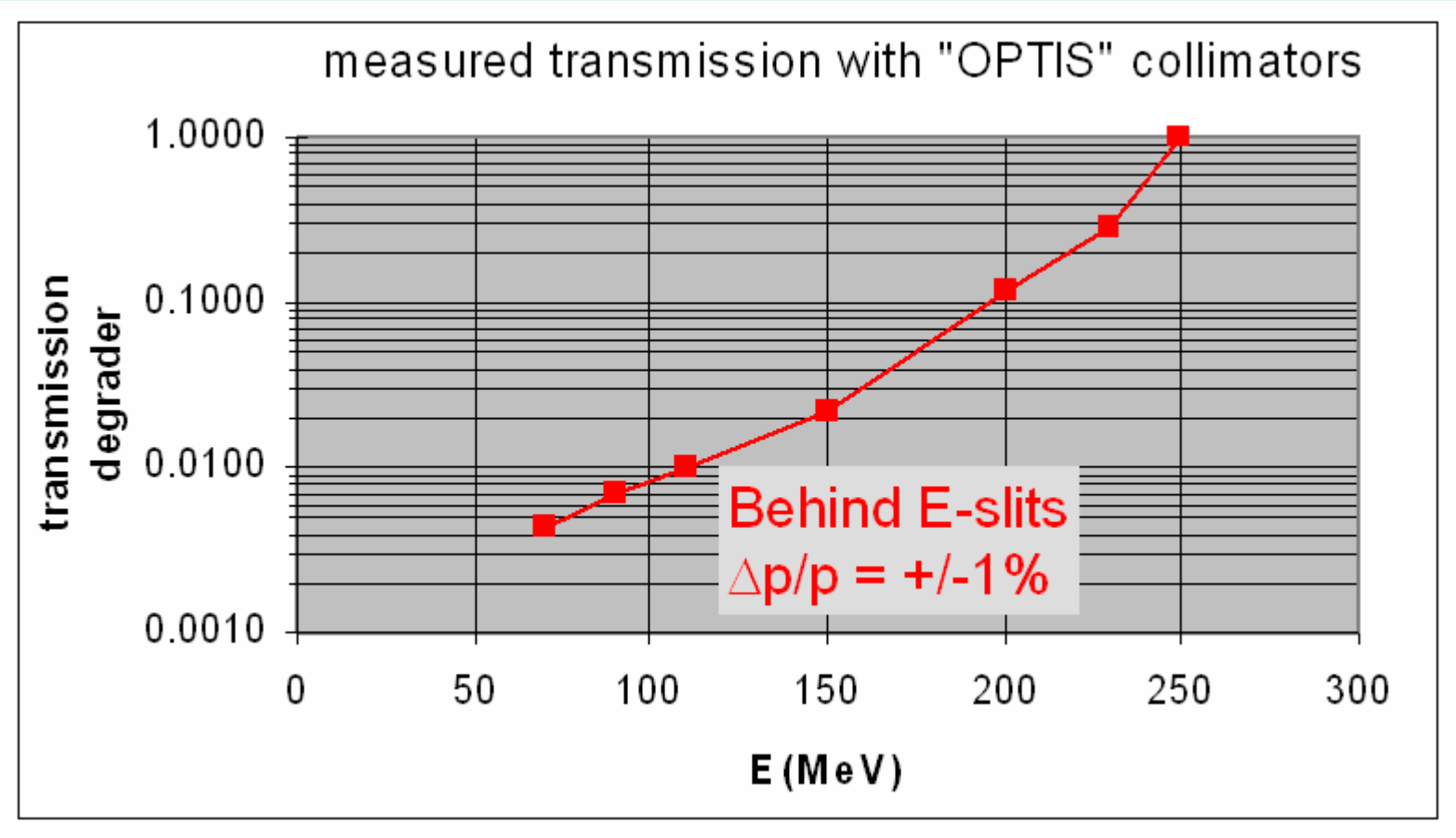
σ = 0.4 mm

σ = 0.3 mm

=> σ_E < 0.05%

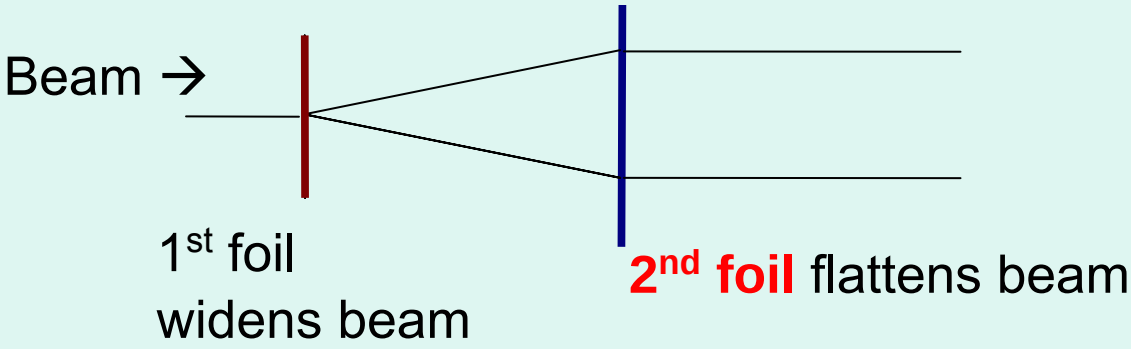
Cycl+beamline

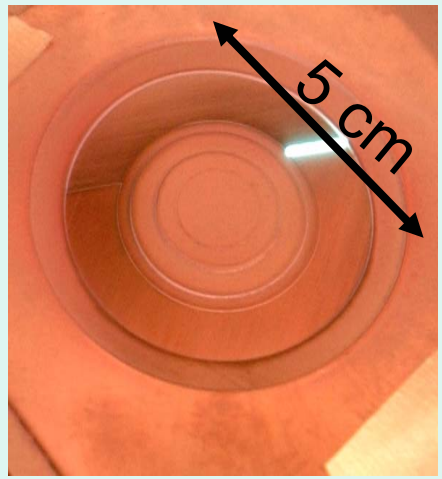
Transmission



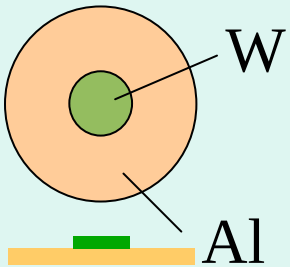
Dual scattering system for OPTIS-2

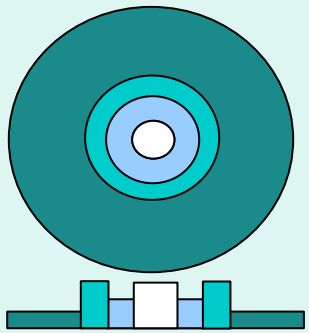
Transmission = 0.5% at 70 MeV, dp/p=+/- 1% => Optimize scattering system





Test foil made by laser ablation
(Fachhochschule Windisch)





Dual Ring: eff. = 36%

Multiple Ring: eff. = 57%

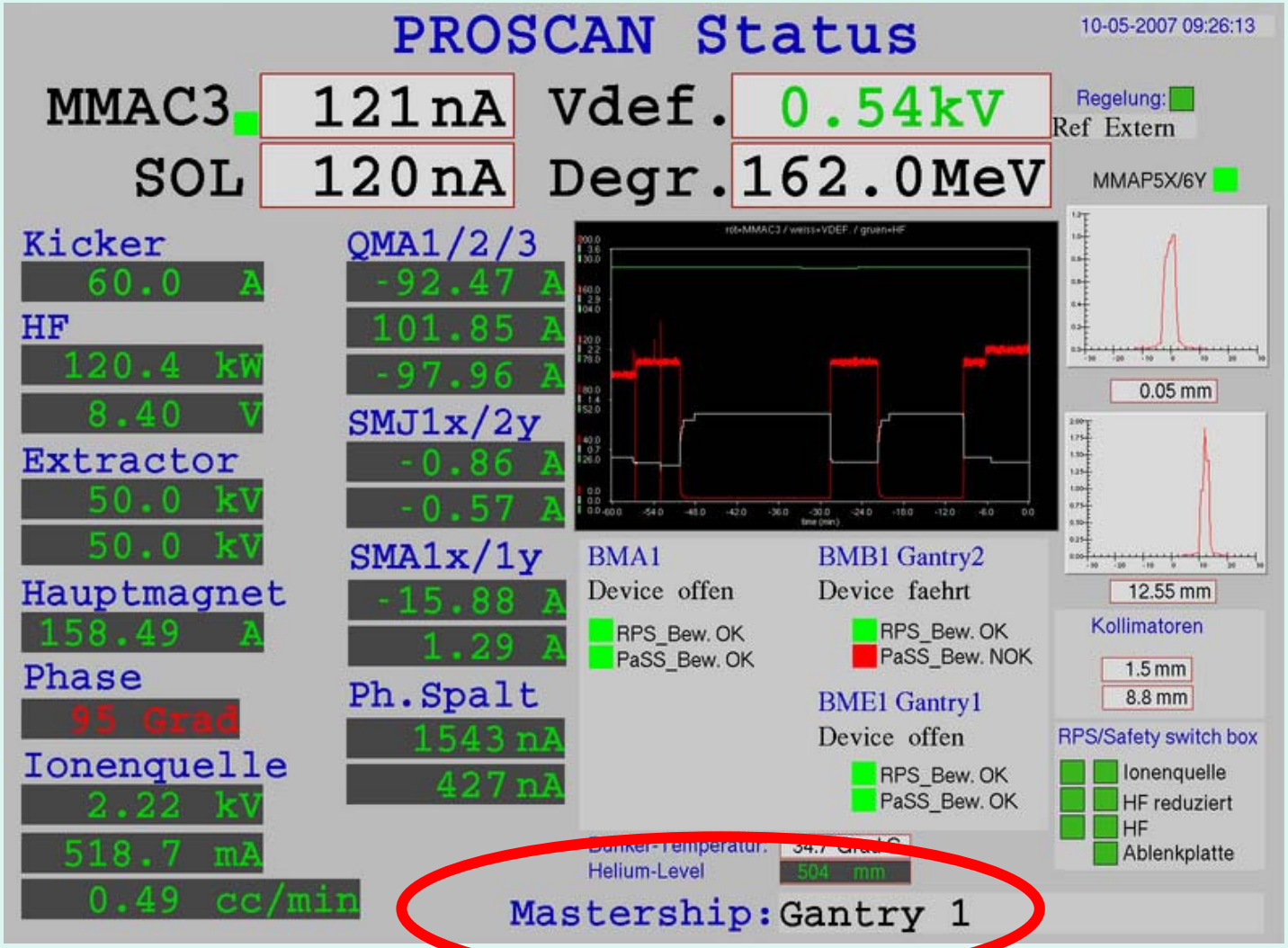
Design model tested and confirmed at HMI

The Multiple Ring solution follows the ideas presented by Yoshihisa Takada (poster PTCOG43)

Operation experience

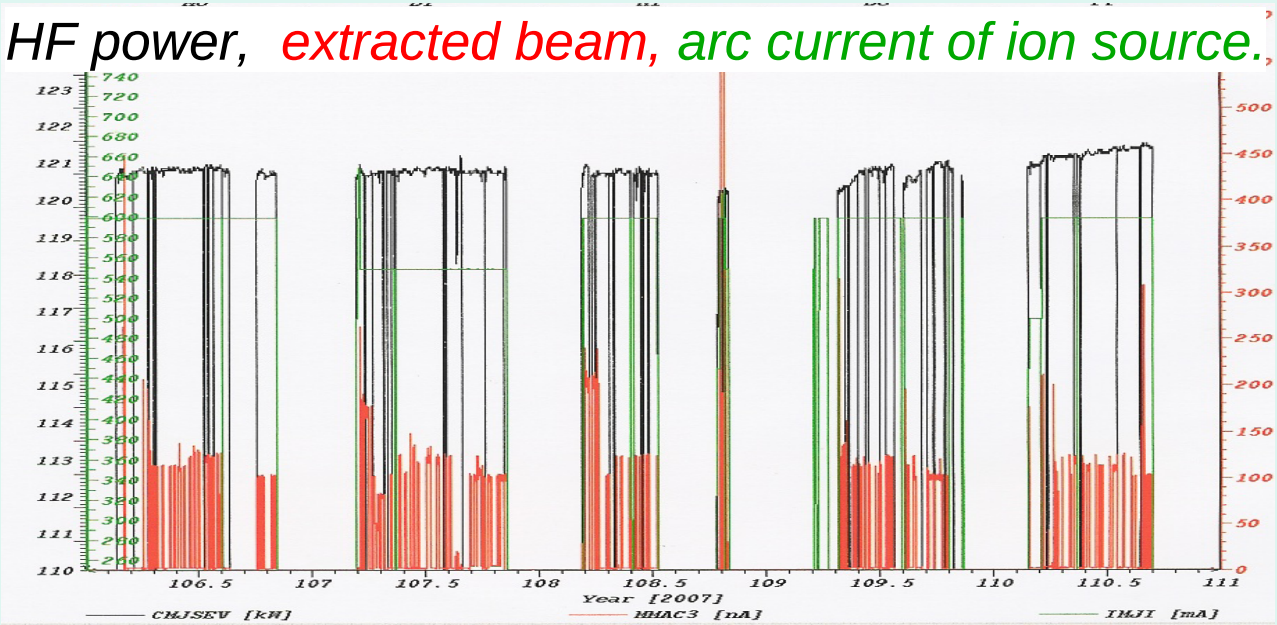
Operation during patient treatment

Febr-May 2007: 18 patients treated at Gantry-1



Operation statistics
first 15 weeks of patient treatment

HF power, extracted beam, arc current of ion source.

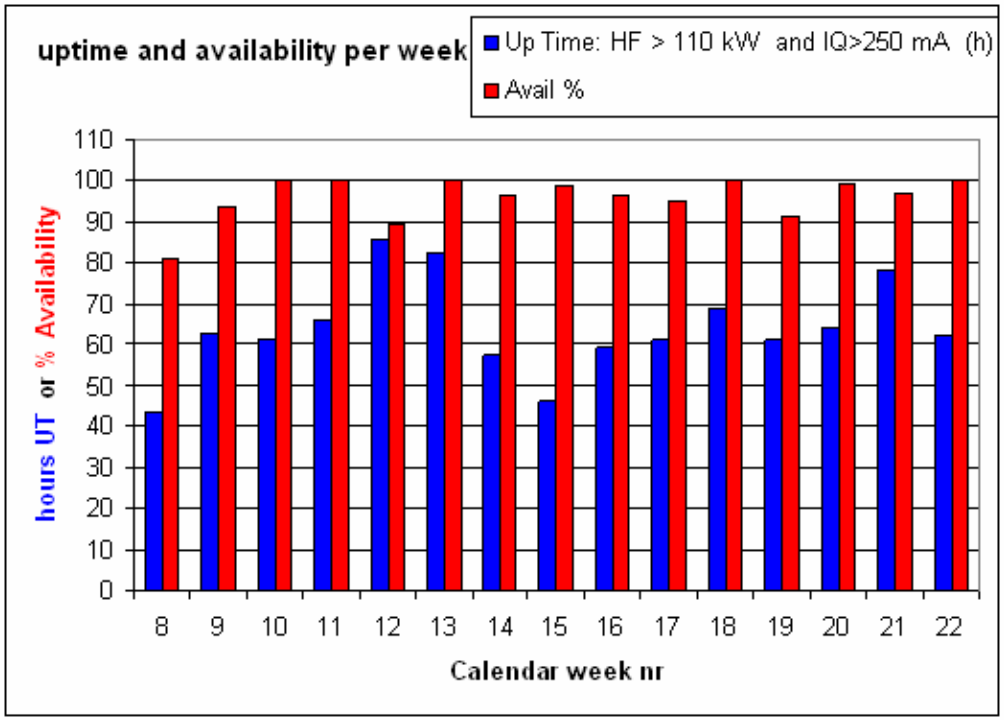


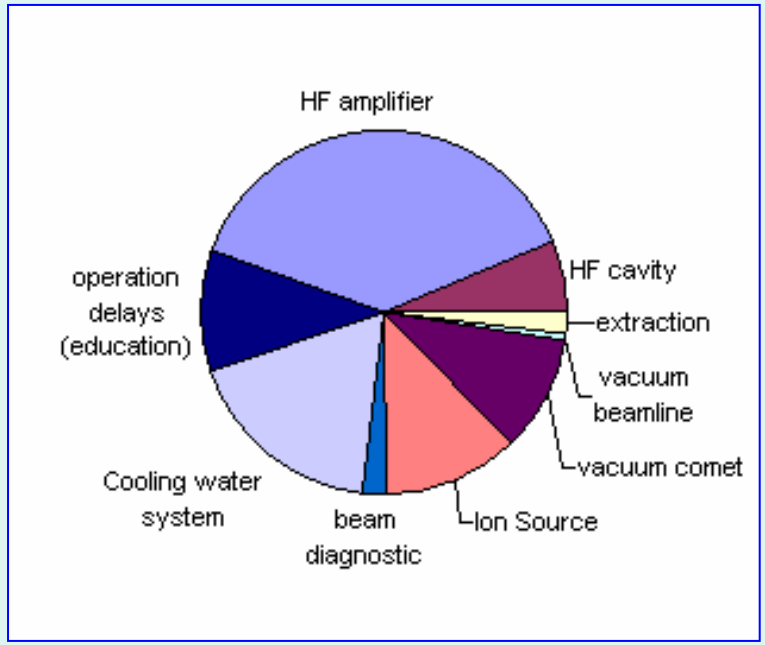
Machine "Up" when:
HF "on"
AND
Ion source "high"

961 hours Up Time
18 patients Gantry-1

$$Avail = 1 - \frac{Unsched\,Down.Time}{Up.Time}$$

Analysis of Unsched. Down Time





UDT per week: occurs as single events

⇒ MTBF (UDT>0.5 h) ≈ 1.5-2 weeks (typically at start up)

Conclusions and Outlook:

- We are happy with performances of cyclotron and beam lines
- Last problems are being solved
- Patient treatment has started at Gantry-1 and runs successfully

Currently in progress: (see poster)

⇒ acquire experience and optimize operation

⇒ commissioning OPTIS-2

⇒ installation Gantry-2


The End