

# **PRINCIPLES AND 10 YEAR EXPERIENCE OF THE BEAM MONITOR SYSTEM AT THE PSI SCANNED PROTON THERAPY FACILITY**

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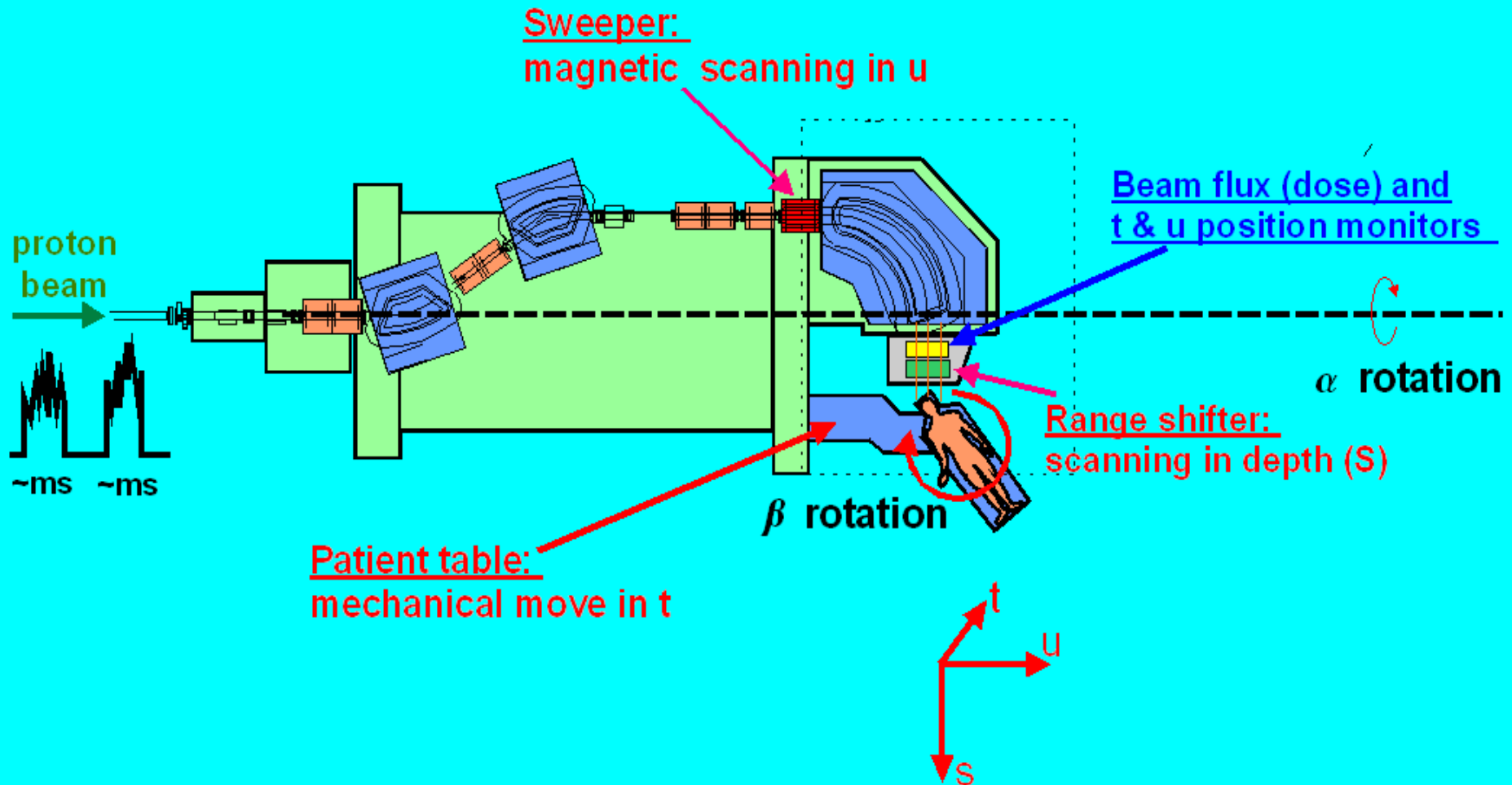


# Overview

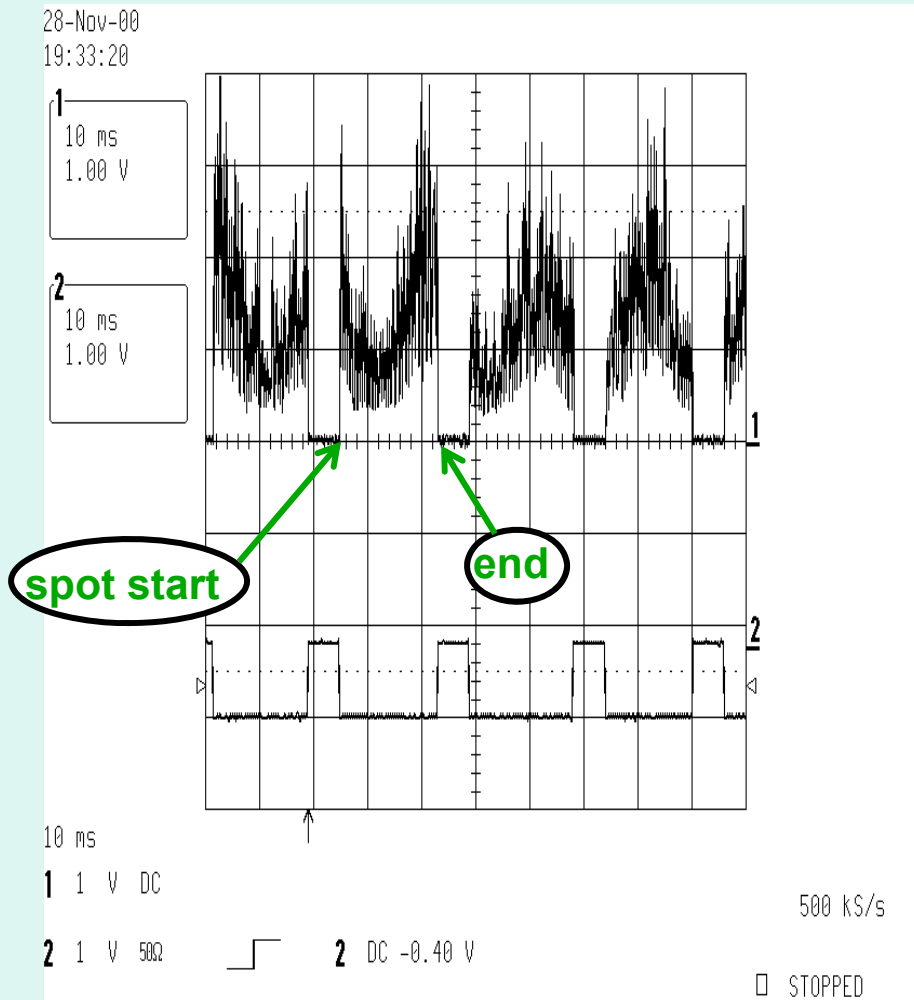
- **Spot scanning technique**
- **Beam flux (spot dose) monitoring**
- **Beam position monitoring**
- **Determination of absolute dose**
- **Dosimetry and QA results**
- **Conclusion**

- Dose delivery by dynamic beam scanning adopted at PSI in 1992
- Patient treatments since 1996

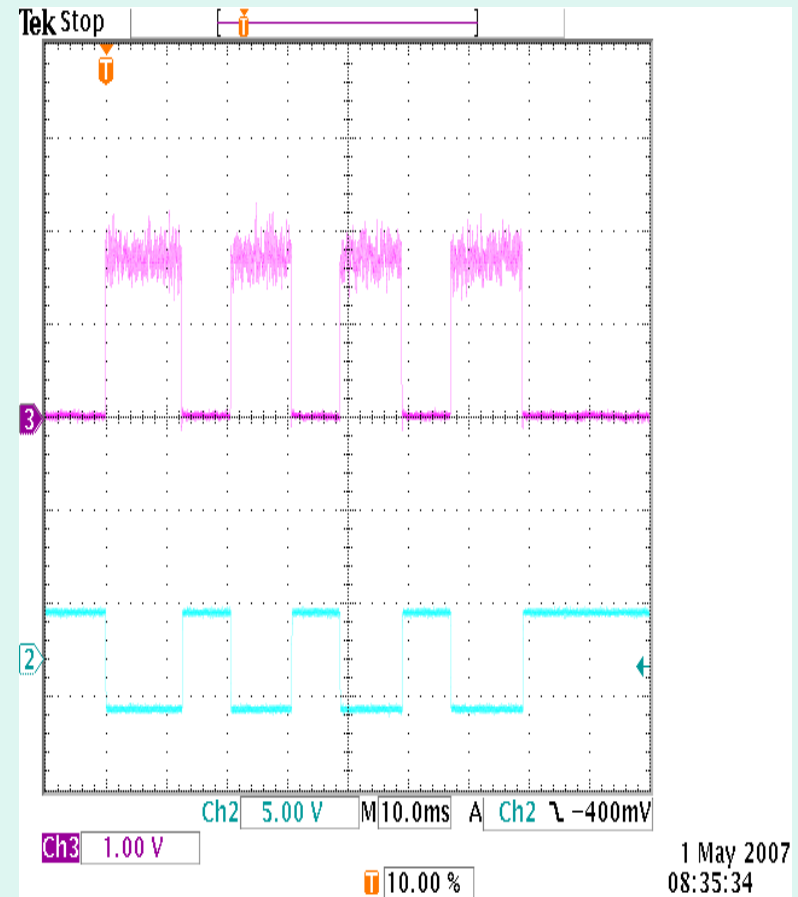
# The compact gantry dedicated to beam scanning



# Beam quality (beam flux monitor output)



before COMET

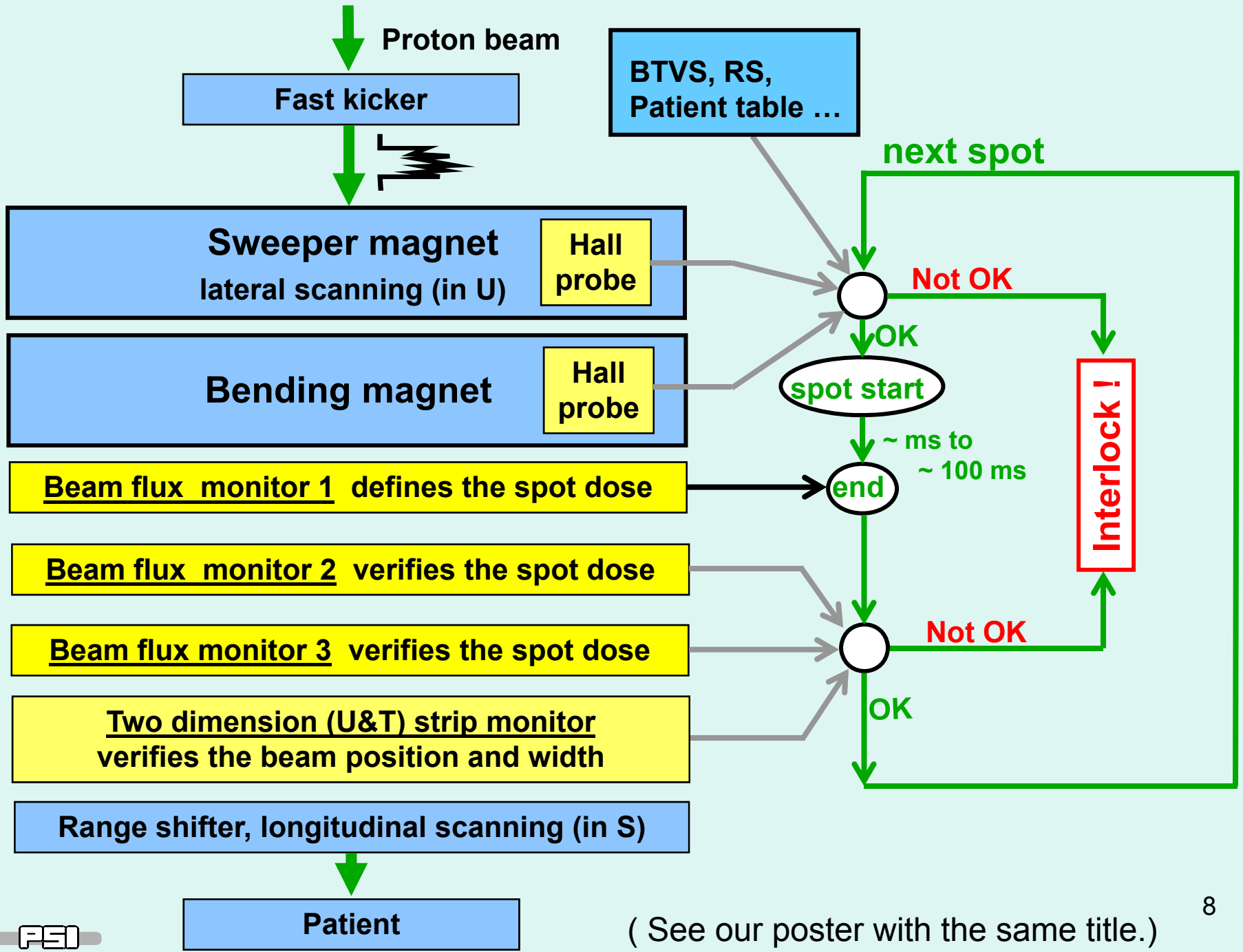


with COMET (since 2007)

(COMET: new cyclotron for medical application)

**Beam monitoring**  
**is the most crucial component**  
**of the scanning technique**

**How it works in the dynamic case**





Proton beam

~ 0.2 to 0.3 nA

(CFC : Current to frequency converter)

Therapy delivery  
VME Power PC1

dose steering

monitor 1

ionization  
current

CFC (2MHz/400nA)

NIM

dose check

monitor 2

CFC (2MHz/1000nA)

monitor 3

CFC (2MHz/652nA)

Therapy  
verification

VME  
Power PC2

beam  
position & width  
check

t position mon.

u position mon.

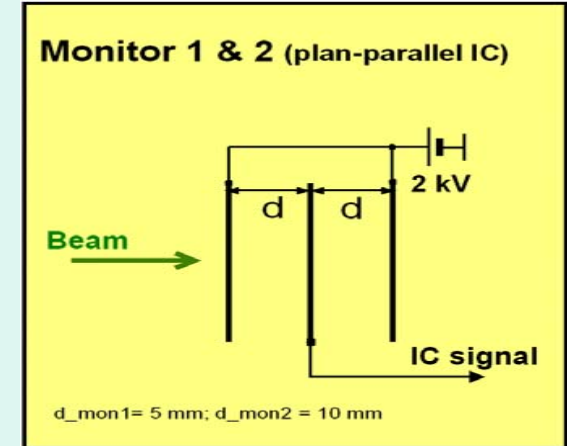
CFCs

(2MHz/150nA)

# Beam flux (dose to patient) monitors

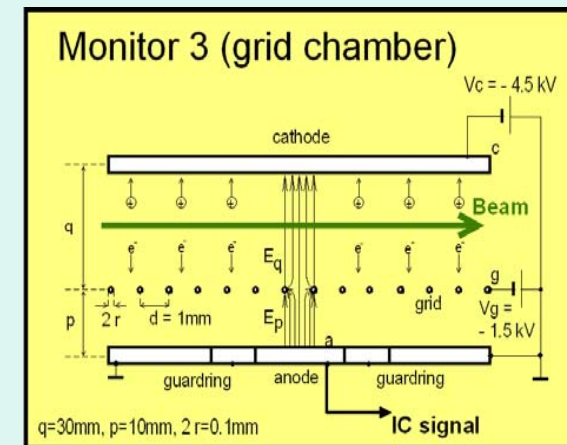
## (1) Two plane-parallel transmission ionization chambers:

- Ambient air
- HV plane: 20  $\mu\text{m}$  Mylar foils coated with Aluminum
- Signal plane: 20  $\mu\text{m}$  Aluminum foil as the signal plane
- Ion collection time ( $t$ ):
  - Monitor 1:  $\sim 90 \mu\text{s}$
  - Monitor 2:  $\sim 350 \mu\text{s}$
- Problem: Microphone effect.



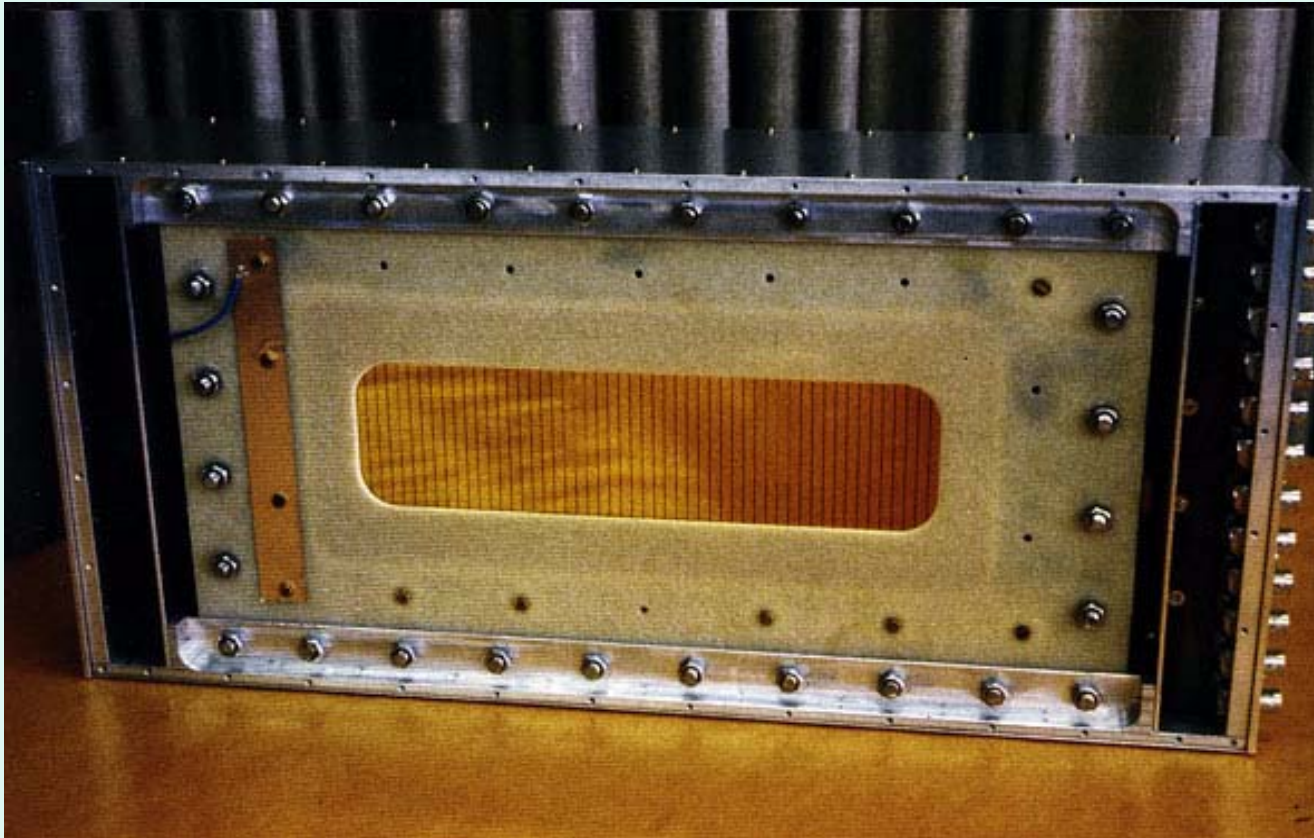
## (2) Monitor 3 (Grid monitor):

- Nitrogen gas  $\cdot t \sim 10 \mu\text{s}$
- No microphone effect
- Problem: Gain is less stable than parallel plane ICs.



## (3) Use the sums of the strip (beam position) monitor as additional checks.

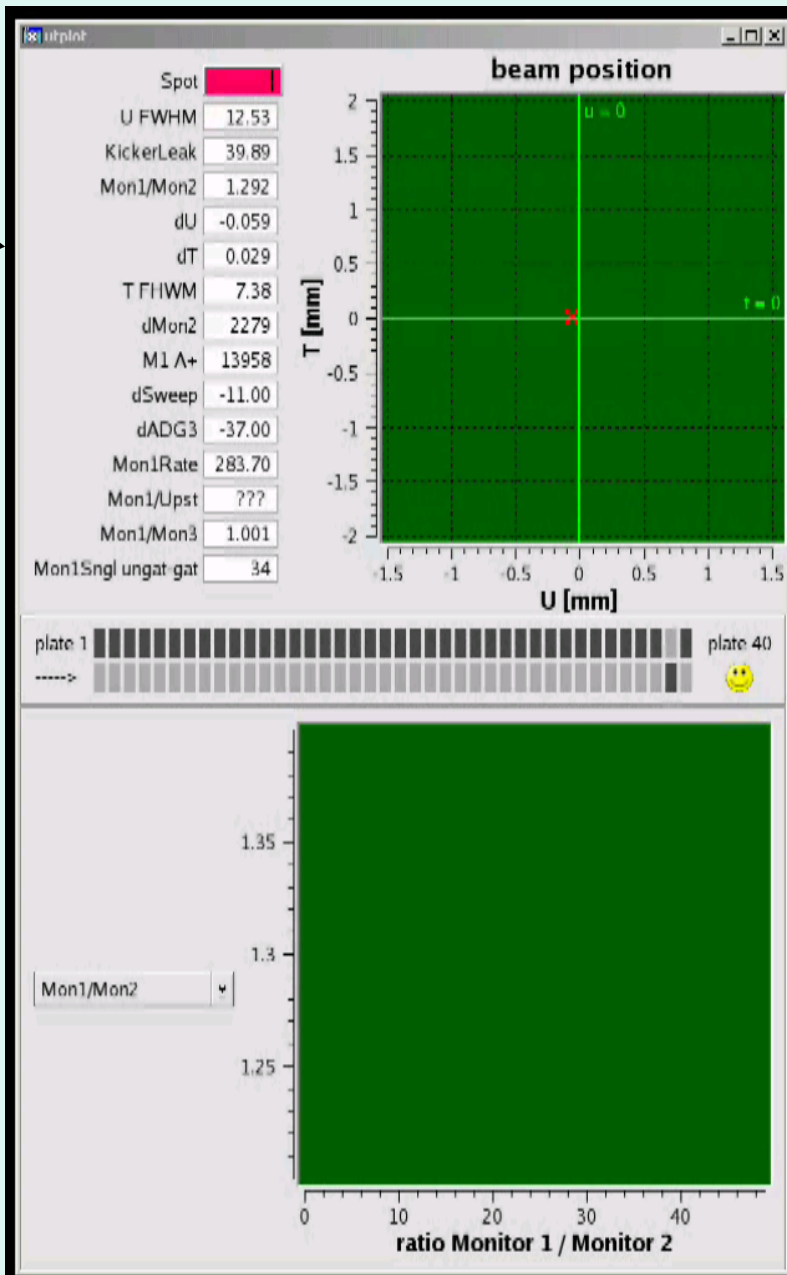
## Position sensitive Strip monitor



**Kapton foil (20  $\mu\text{m}$ ) coated with Aluminum**

**Strip width : 4.44 mm**

Verified  
data



## Online data show

UT\_plot :

- $U_{\text{measured}} - U_{\text{expected}}$
  - $T_{\text{measured}} - T_{\text{expected}}$
- ( spot: ~ ms to 100 ms)

Range shifter plates

# Determination & calibration of the absolute dose

**Faraday cup (FC)**  
(calibration of monitor 1)

**N of protons / MU**

### Treatment planning

predicts dose as a function of number of incident protons

- **Bethe-Bloch-formula**
- **Dose model:**
  - ◆ **Beam flux attenuation of total cross section on O, H**
  - ◆ **Effective total elastic proton-proton cross section**
  - ◆ **Nuclear interaction effects**

- \* Scheib S. "Spot-Scanning mit Protonen: Experimentelle Resultate und Therapieplanung" 1993, Diss. ETH Zürich Nr.10451
- \* Pedroni E. etc. "Experimental characterization and physical modelling of the dose distribution of scanned proton beams", Phys Med Biol. 2005 Feb 7;50:541-61

**Scanning applied to a Perspex phantom**  
**10x10x10 cm<sup>3</sup> uniform field (1Gy)**

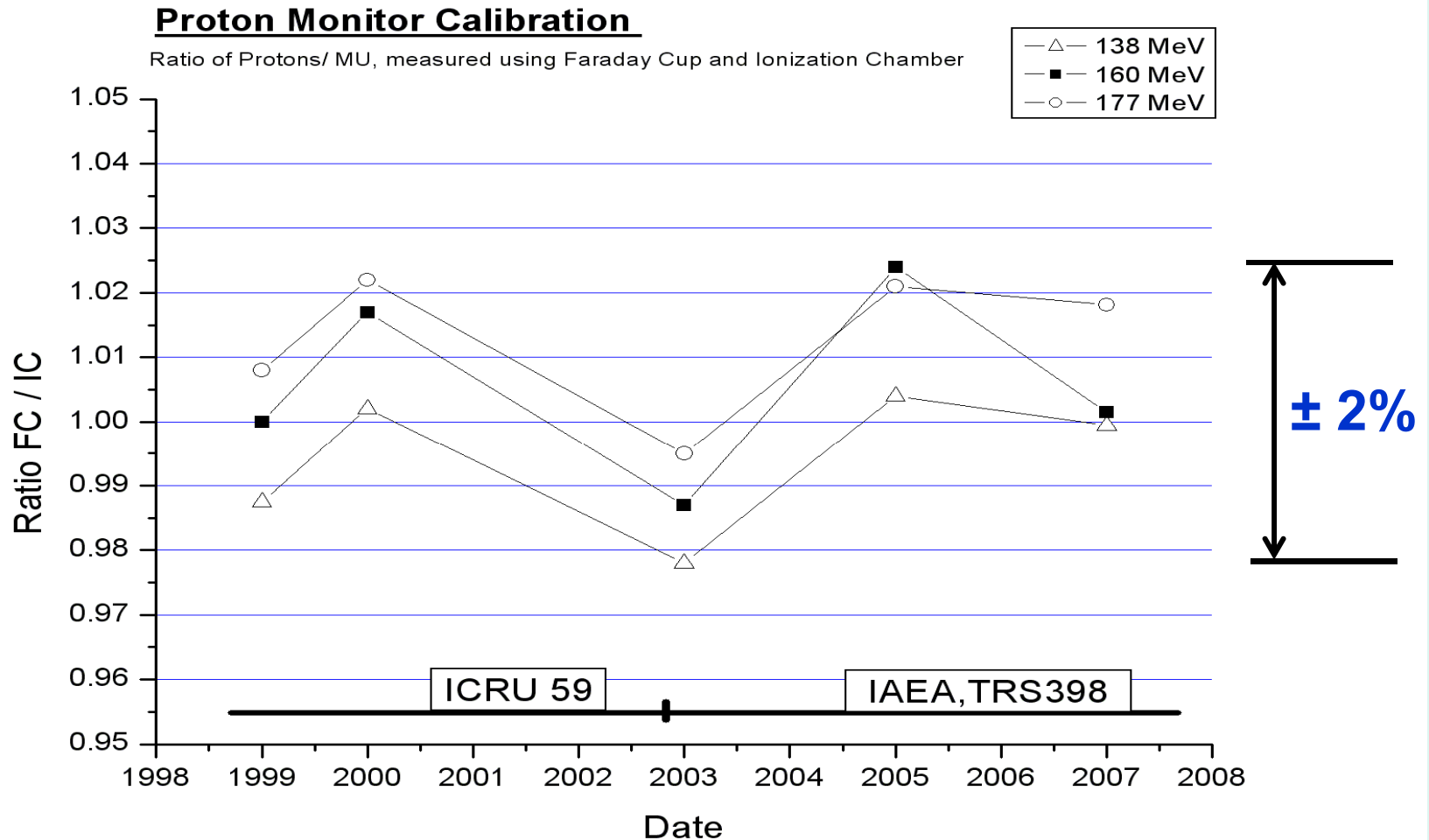
**Thimble ionization chambers (IC)**

(Calibrated with a Cobalt source  
at Swiss Federal Office of Metrology)

**comparison**

**Calculated dose agrees with calibrated IC result.**

# Comparison of FC & Thimble IC results (1999 to 2007)



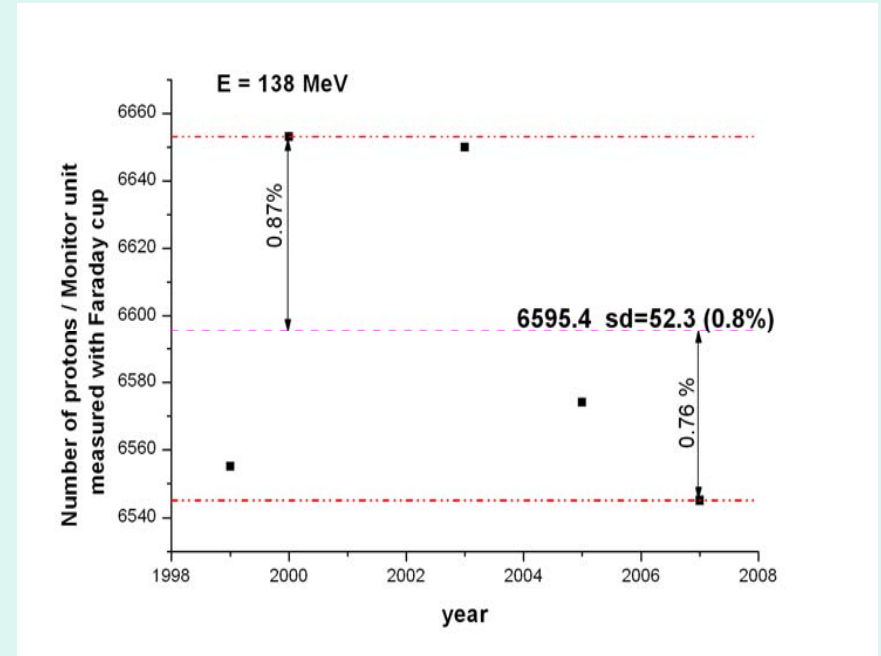
FC\_IC\_Monitor\_Calib.opj/CA21/29.9.2005

Thimble ionisation chambers: Exradin, T2 Shonka, 0.5 cm, Farmer NE2571A, 0.6 cm<sup>3</sup>

# Stability of Faraday cup results:

Number of protons / Monitor unit  
measured with Faraday cup (1999 to 2007)

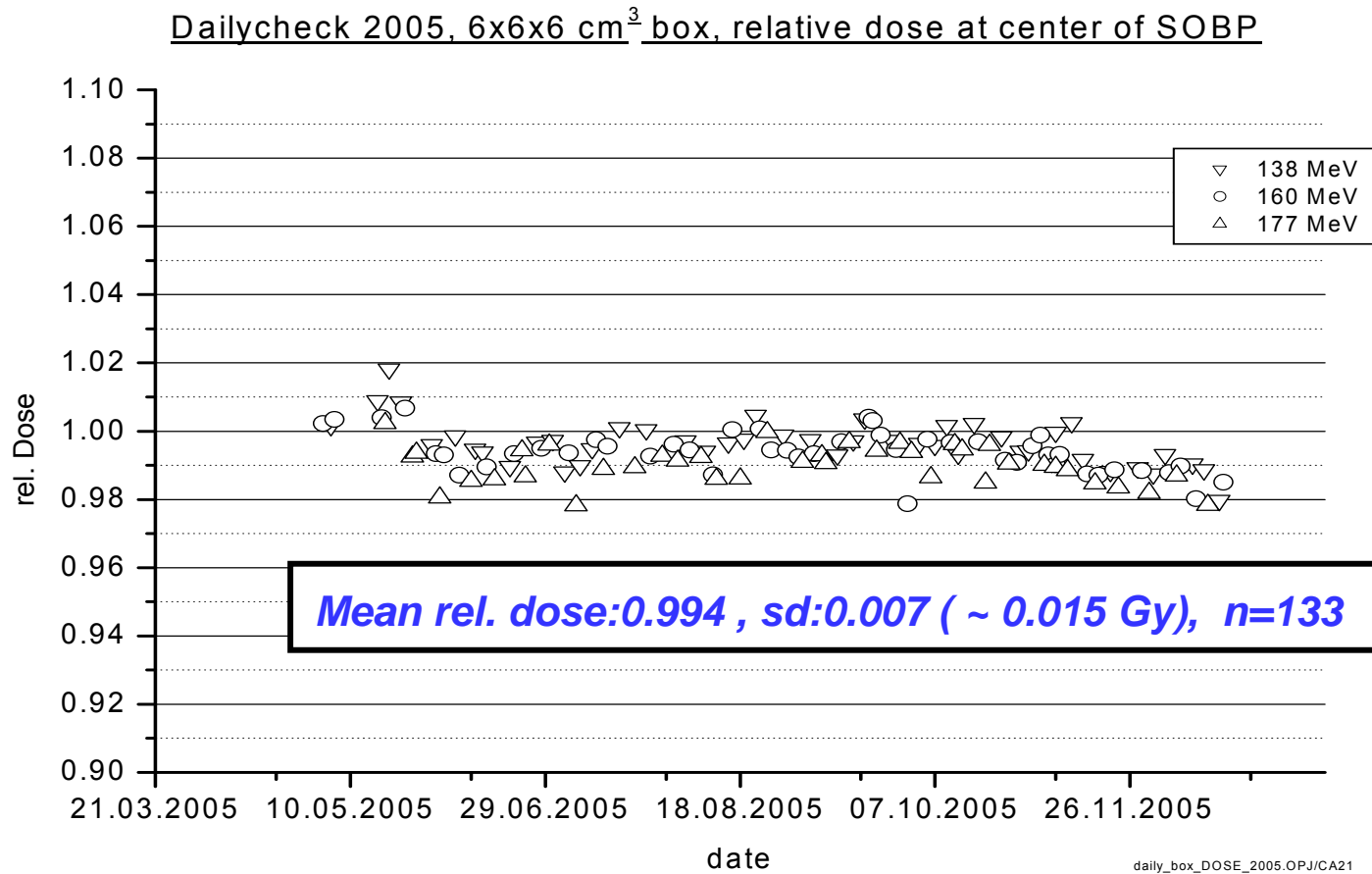
Year	138 MeV	160 MeV	177 MeV
1999	6555	7333	7921
2000	6653	7457	8032
2003	6650	7449	8042
2005	6574	7354	7915
2007	6545	7336.6	7891
Average	6595	7386	7960
sd	52.2 (0.8%)	61.8 (0.8%)	70.9 (0.9%)



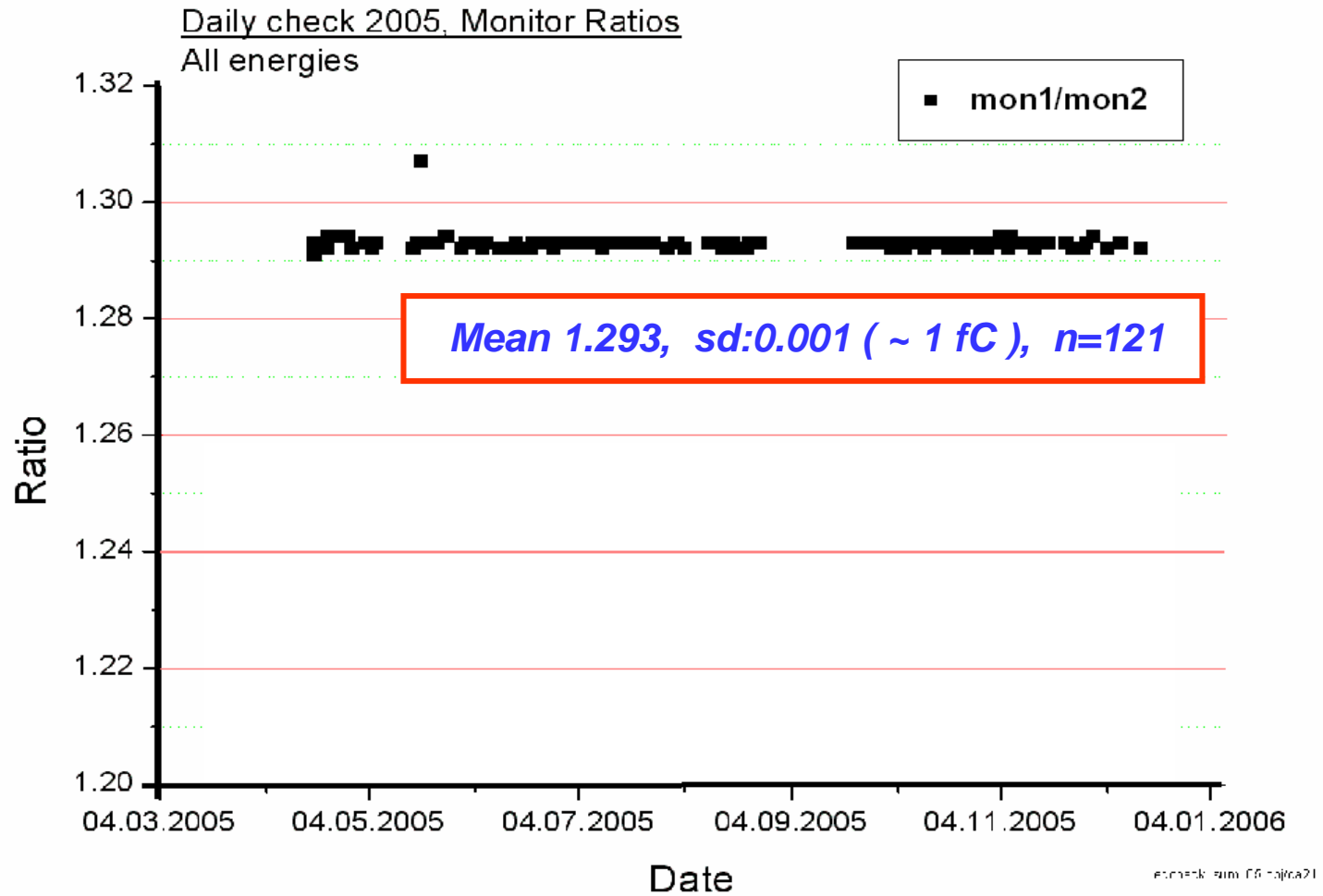
sd & max. variation:  $\sim 10^{-2}$  fC



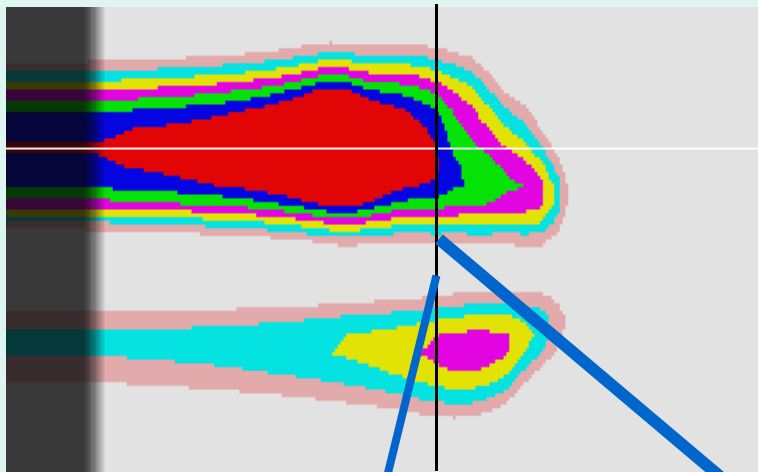
# Daily check (QA) results: dose check (May – Nov. 2005)



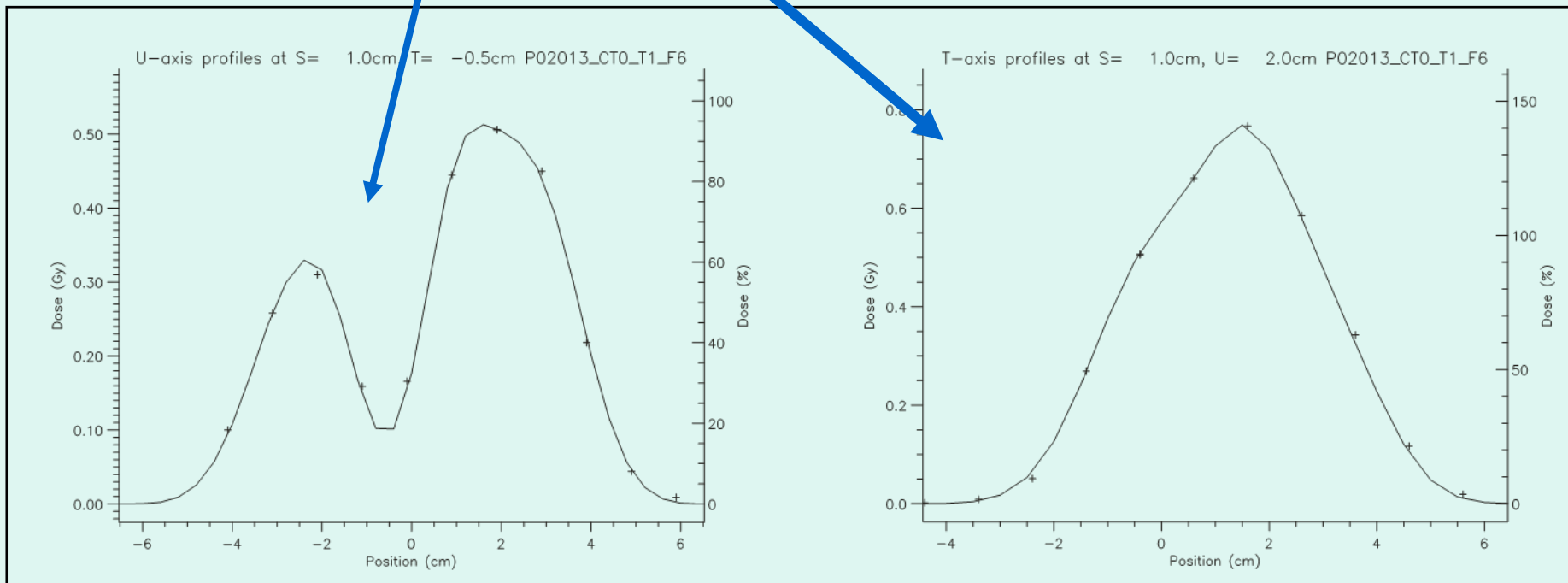
# Daily check (QA) results: monitor ratios (May – Nov. 2005)



# Example of dose verification of individual patient treatment plans



Water phantom: Orthogonal IC array  
2 x 13 cylindrical chambers ( 0.08cm<sup>3</sup> )



## Conclusion:

*Our 10 year experience has proved that  
the beam monitor system for the scanned proton therapy is  
very precise, stable and reliable.*

***Thank you***

**谢谢！！**

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**质子理疗中心  
瑞士**