

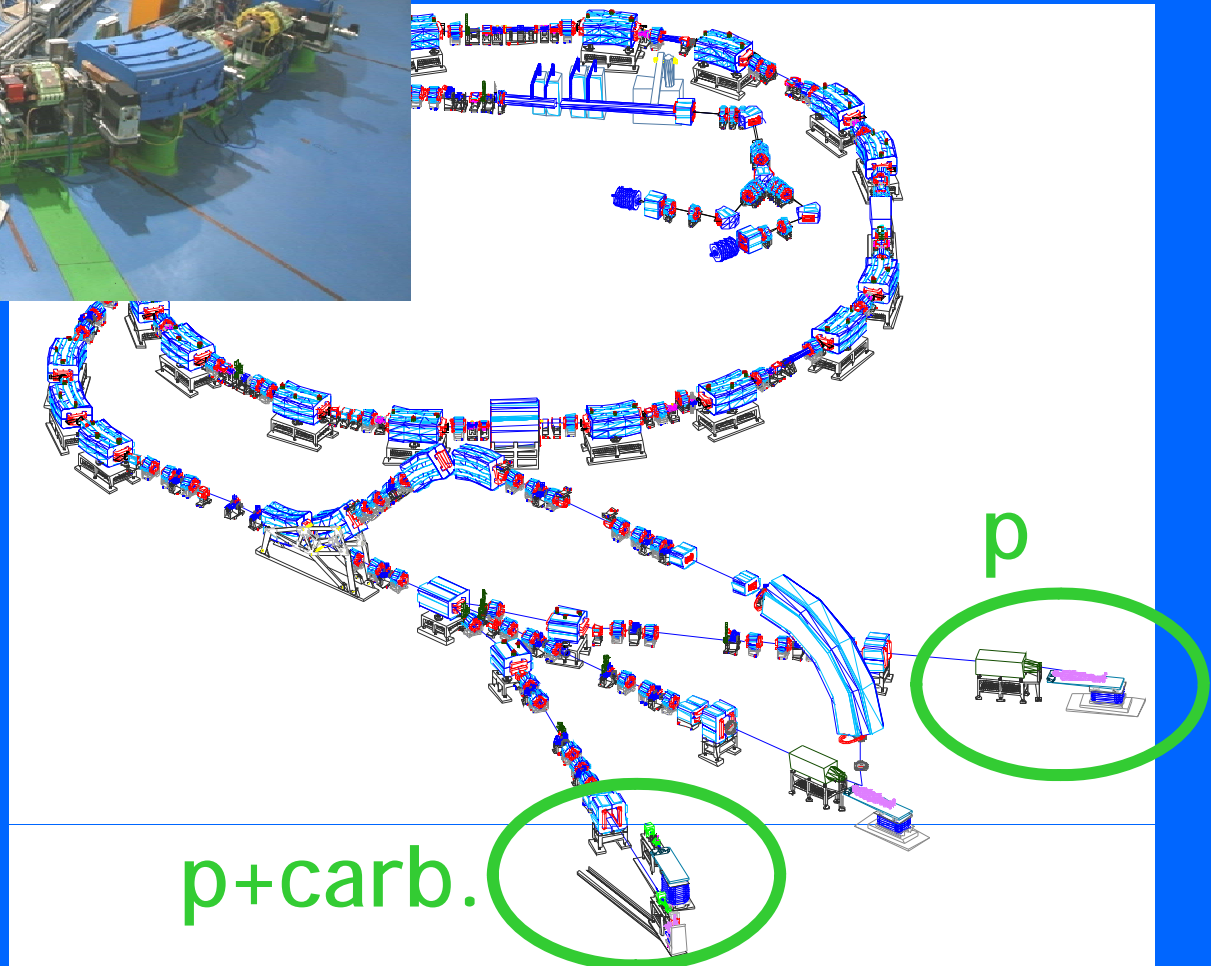
Commissioning and Quality Assurance of scanned beams for particle therapy

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Medical Physics Unit



CNAO



p+carb.

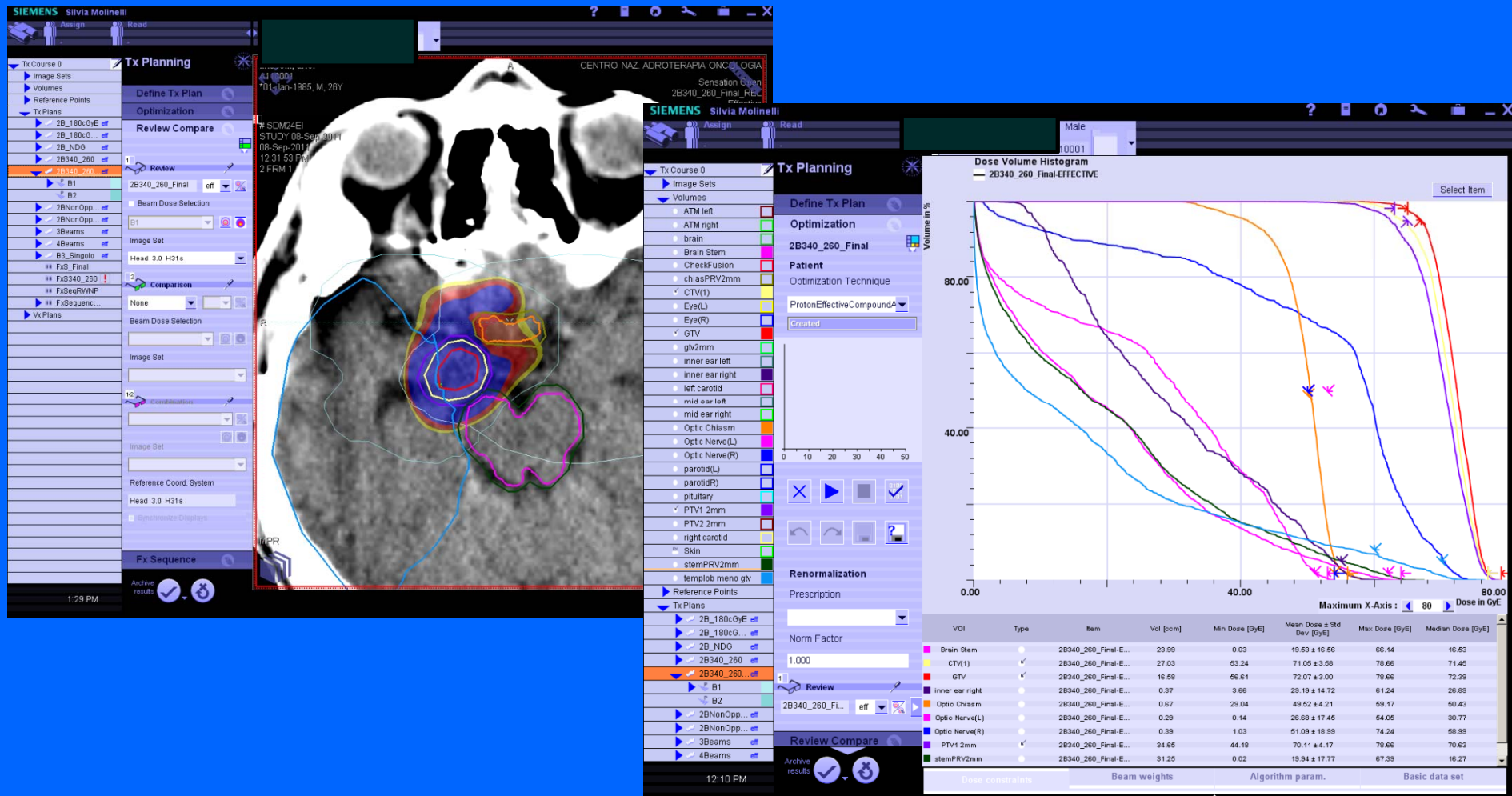
p

Physical characterization of CNAO particle beams

- Commissioning of the TPS (lat. integrated DDDs, transversal profiles, HU LUTs, simple/complex plan verification)
- Determination of absorbed dose to water under reference conditions and calibration of beam monitor chambers
- Determination of procedures and reference values for periodic QA checks
- Dosimetry for *in-vitro* (cell lines) and *in-vivo* (mice) RB experiments

Commissioning of the TPS

(Siemens syngo RT planning - VC10, CE-marked, used also at HIT)



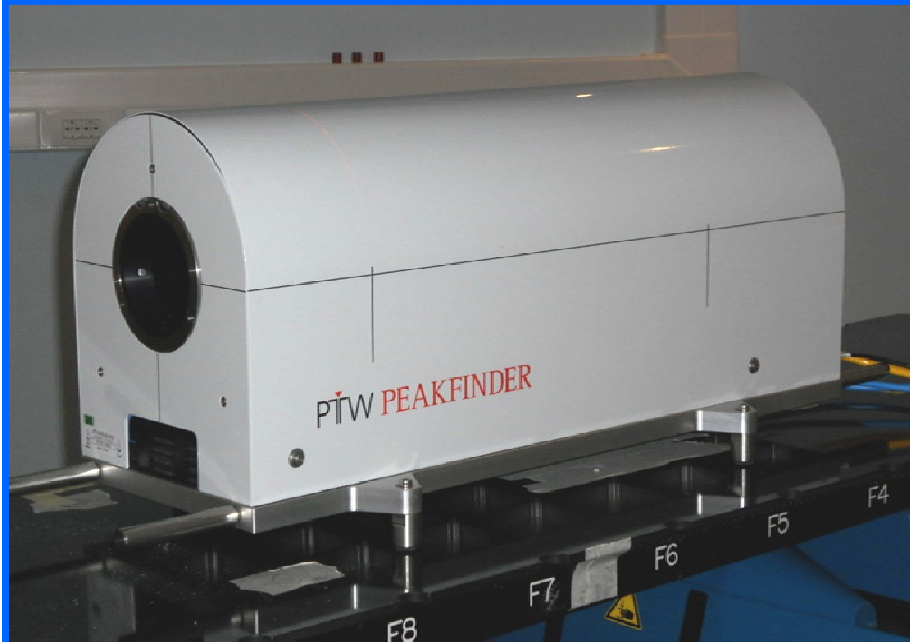
Commissioning of the TPS

Physics basic beam data acquired:

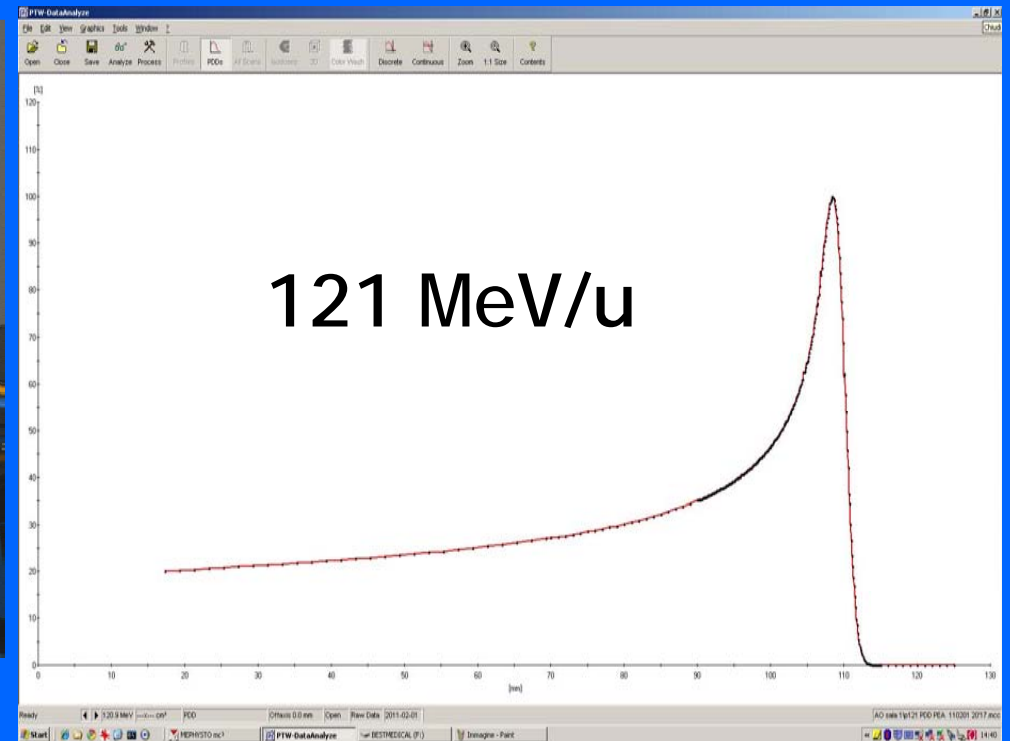
- experimentally
- Monte Carlo simulation (FLUKA code, CNAO-HIT agreement)

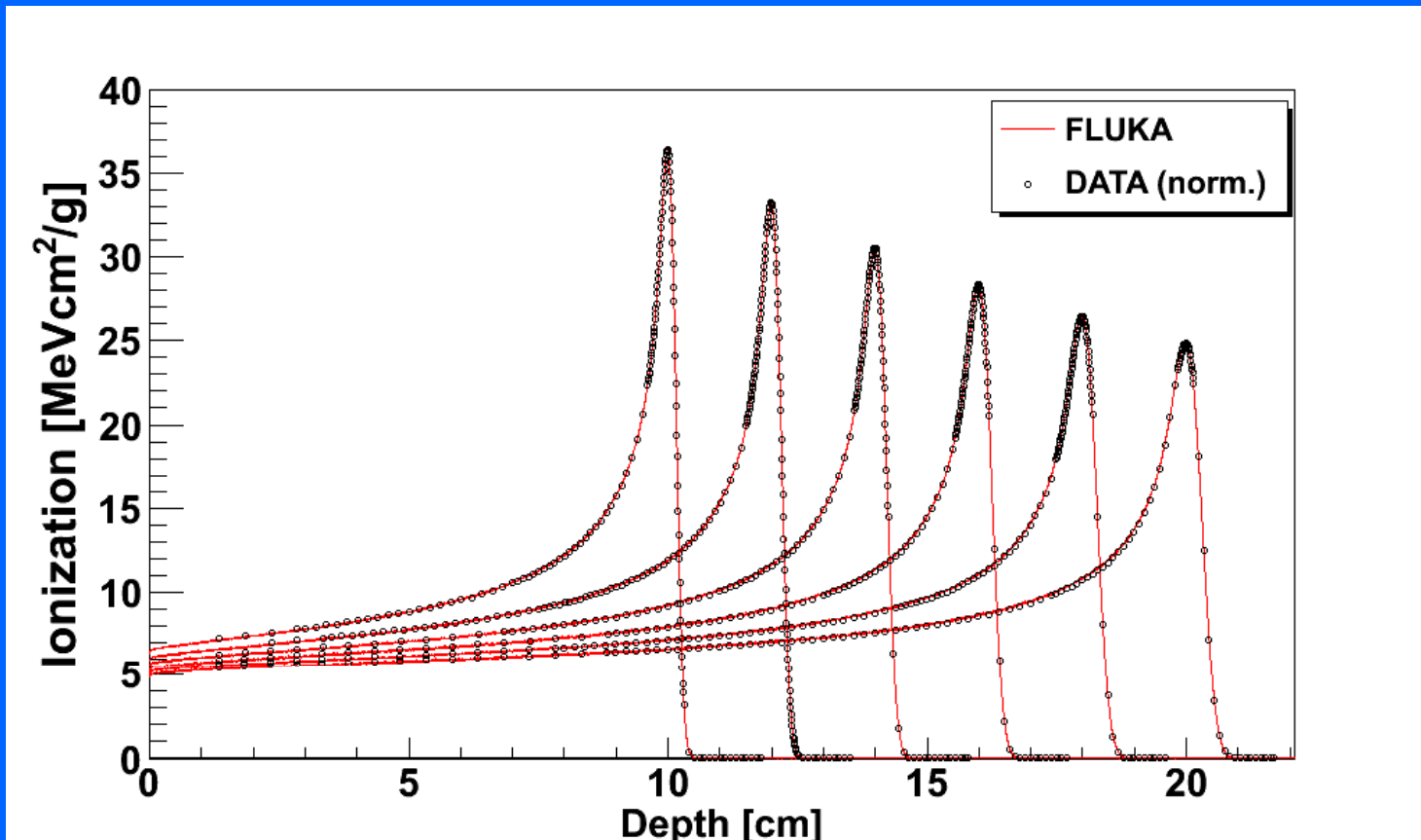
Experimental data

Integral Depth Dose Distributions (mono-en. pencil beams)



Peakfinder water column

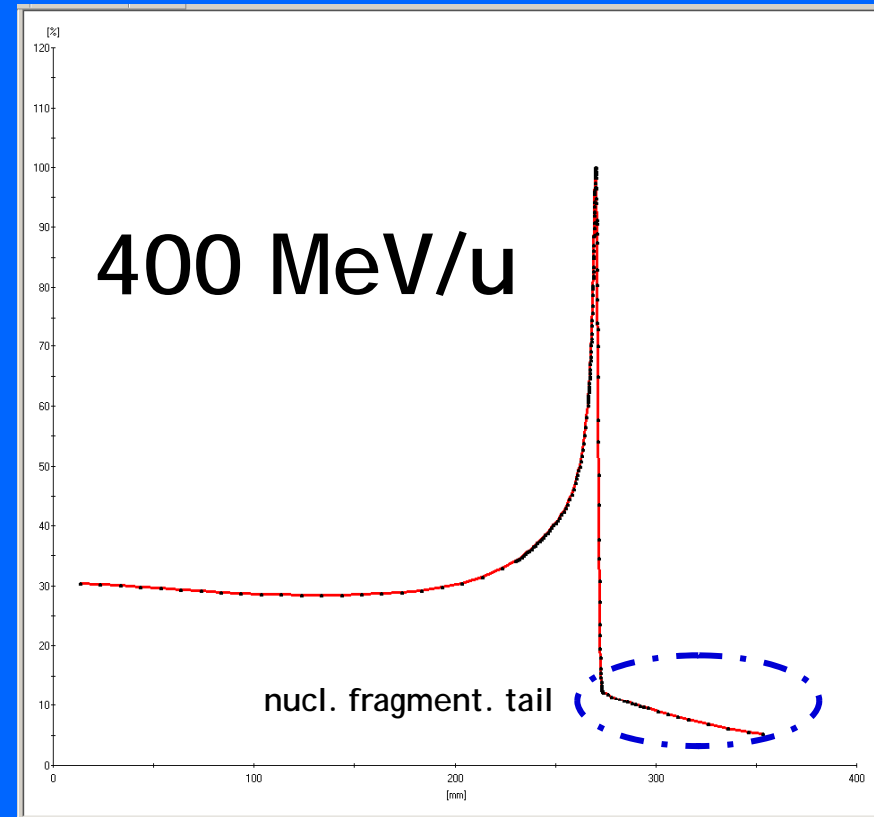
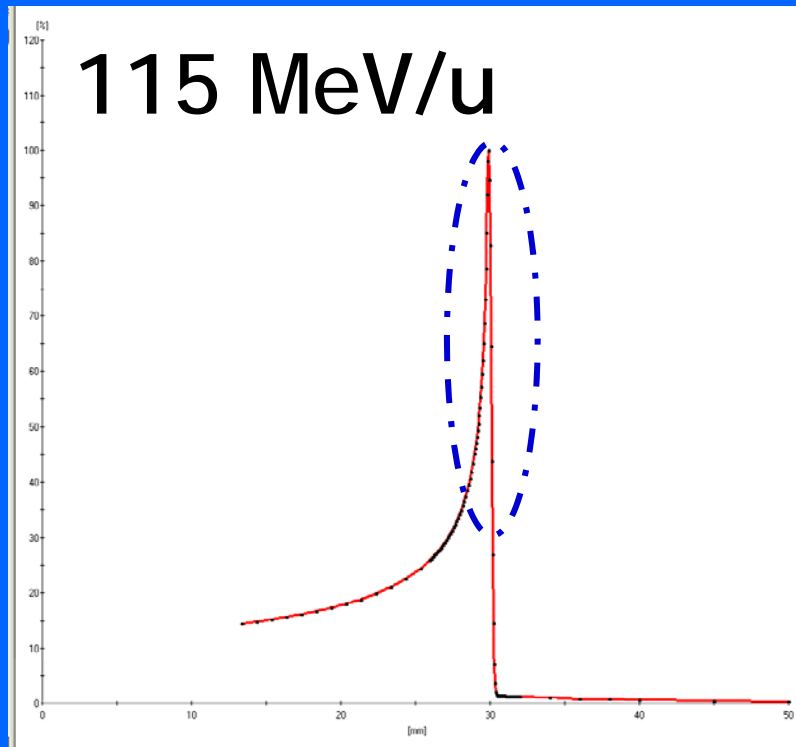




$$I_{\text{pot}} = 77 \text{ eV}$$

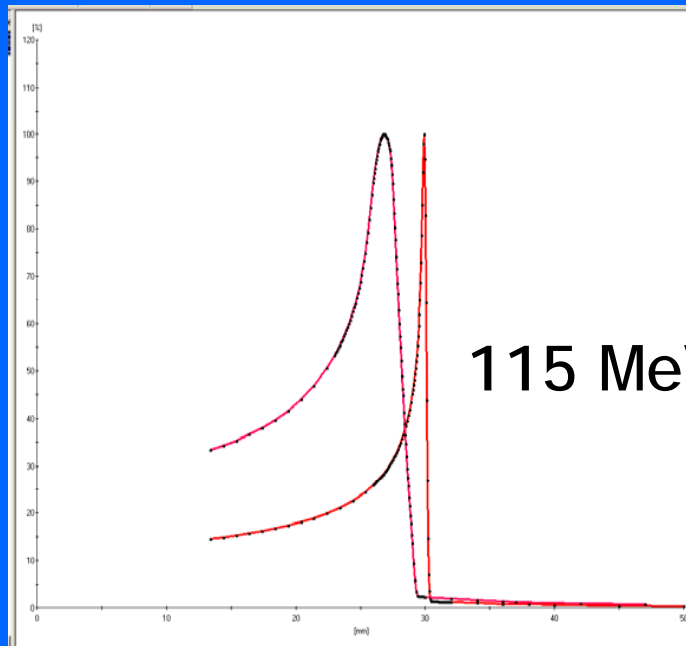
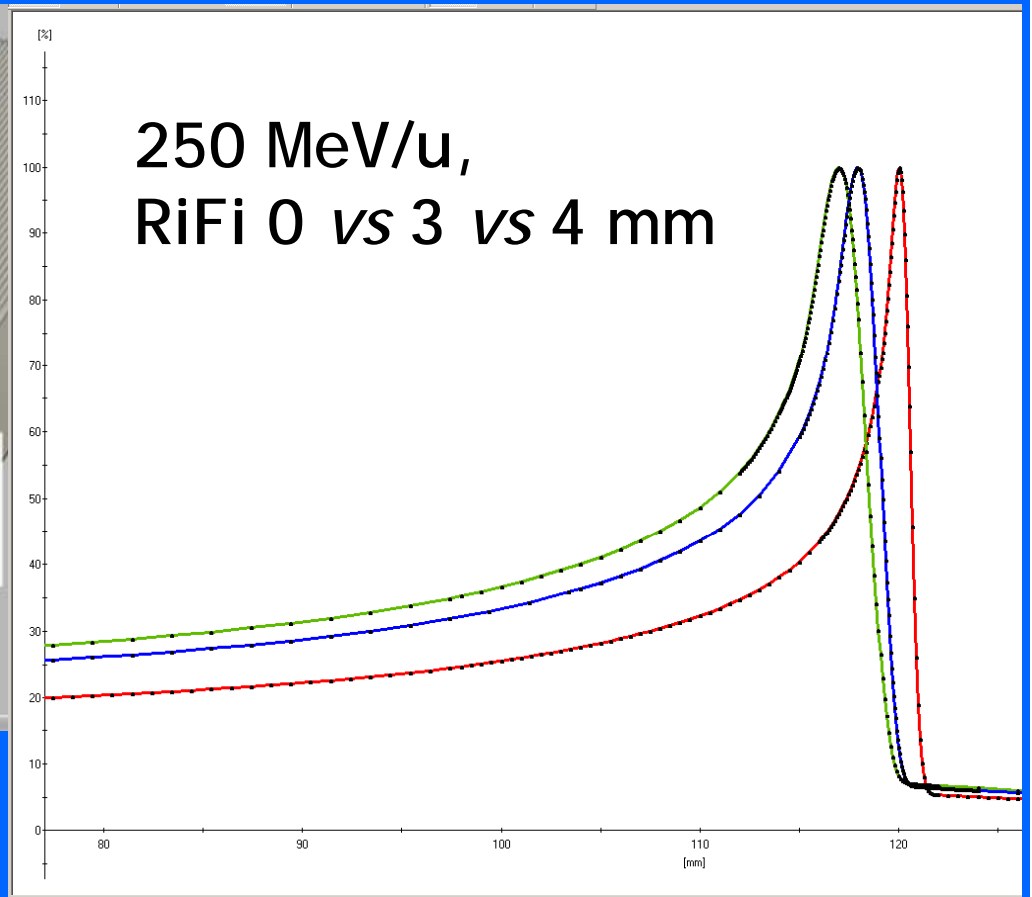
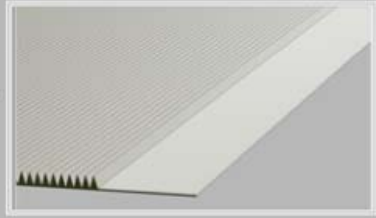
$$|BP_{\text{meas.}} - BP_{\text{FLUKA}}| \sim 0.1 \text{ mm}$$

147 **proton** energies, 62.3-226.9 MeV/u (3-32 cm BP depth),
2 mm energy step



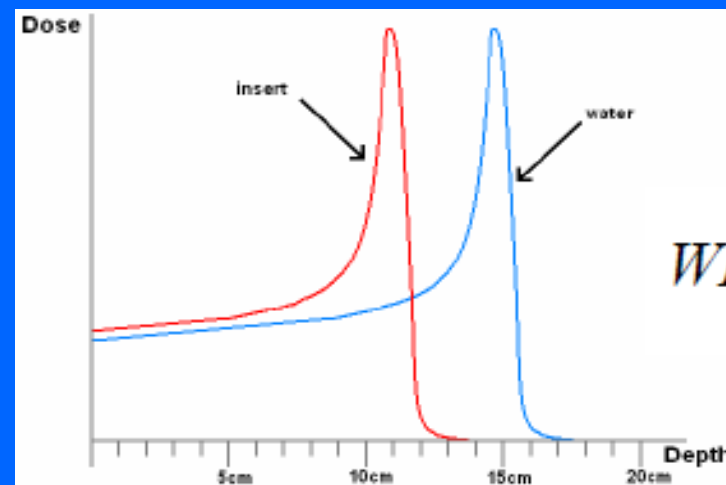
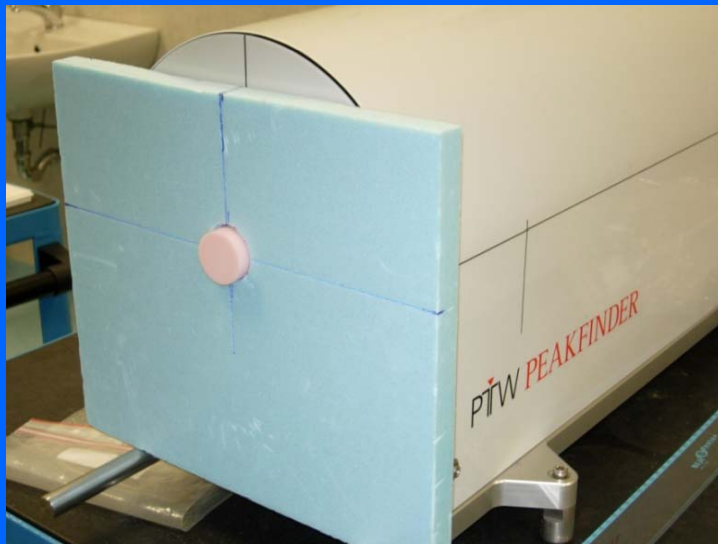
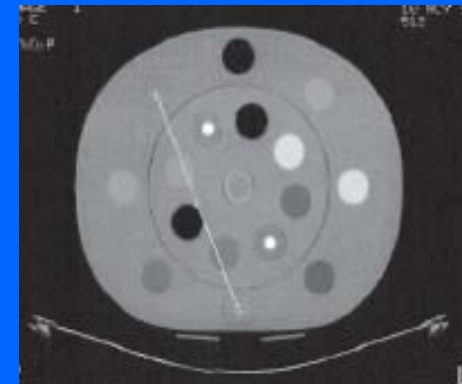
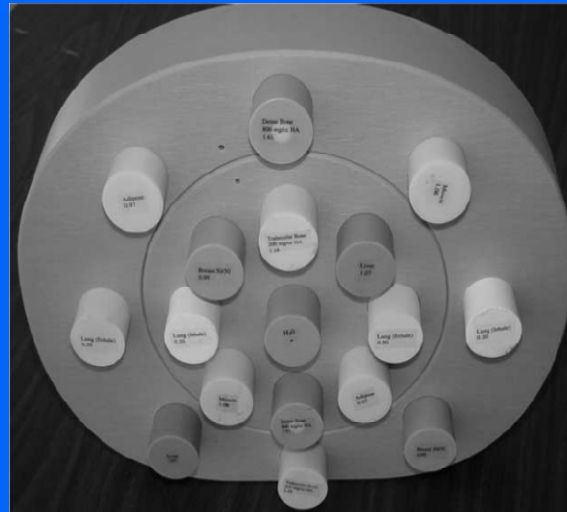
- 121 **carbon ion** energies, 115-400 MeV/u (3-27 cm), step 2 mm
- 4 intensities: $5 \cdot 10^6$ - $5 \cdot 10^7$ p/spill
- spill duration: 1 s
- 2 FWHM (at isocenter): 6-10 mm

Ripple filter



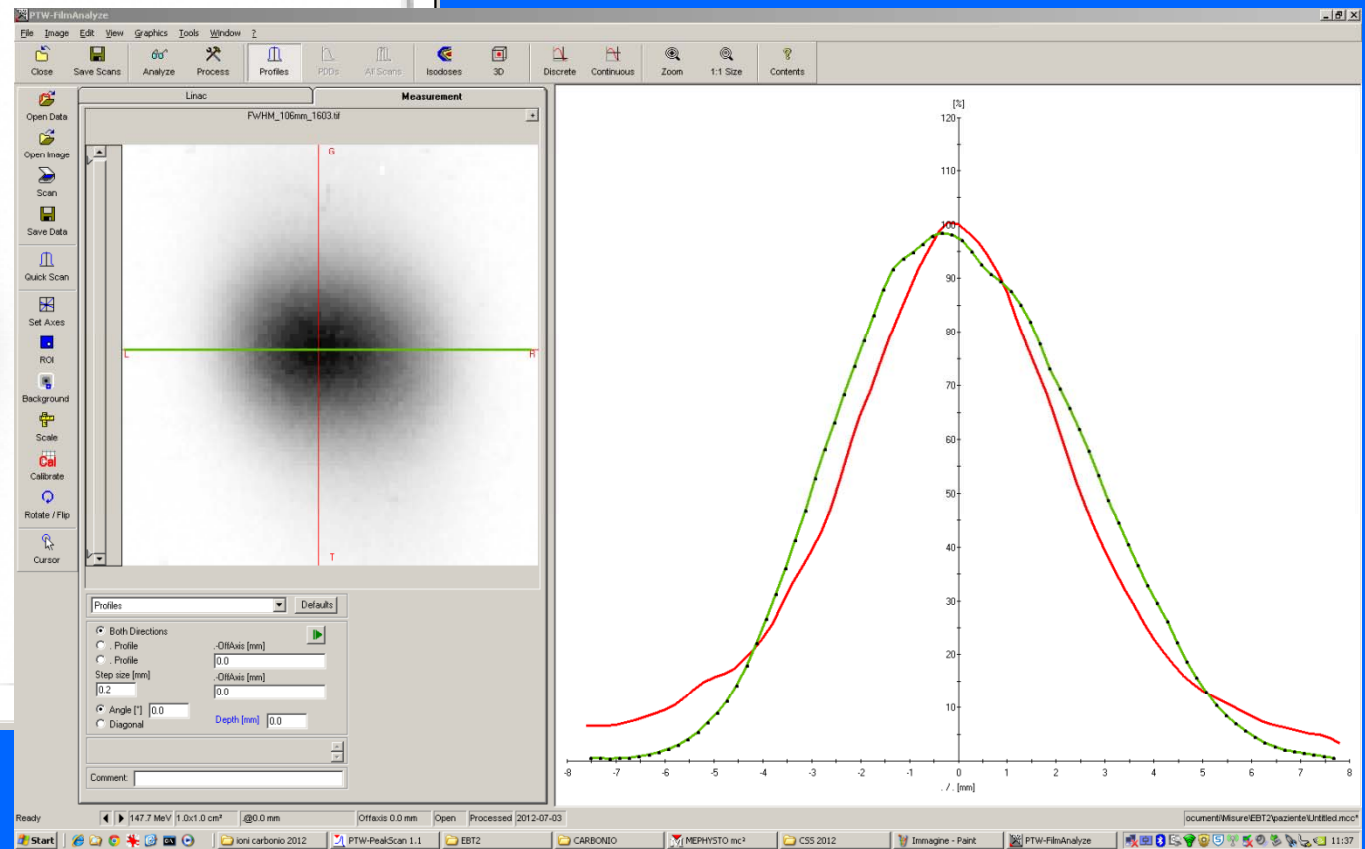
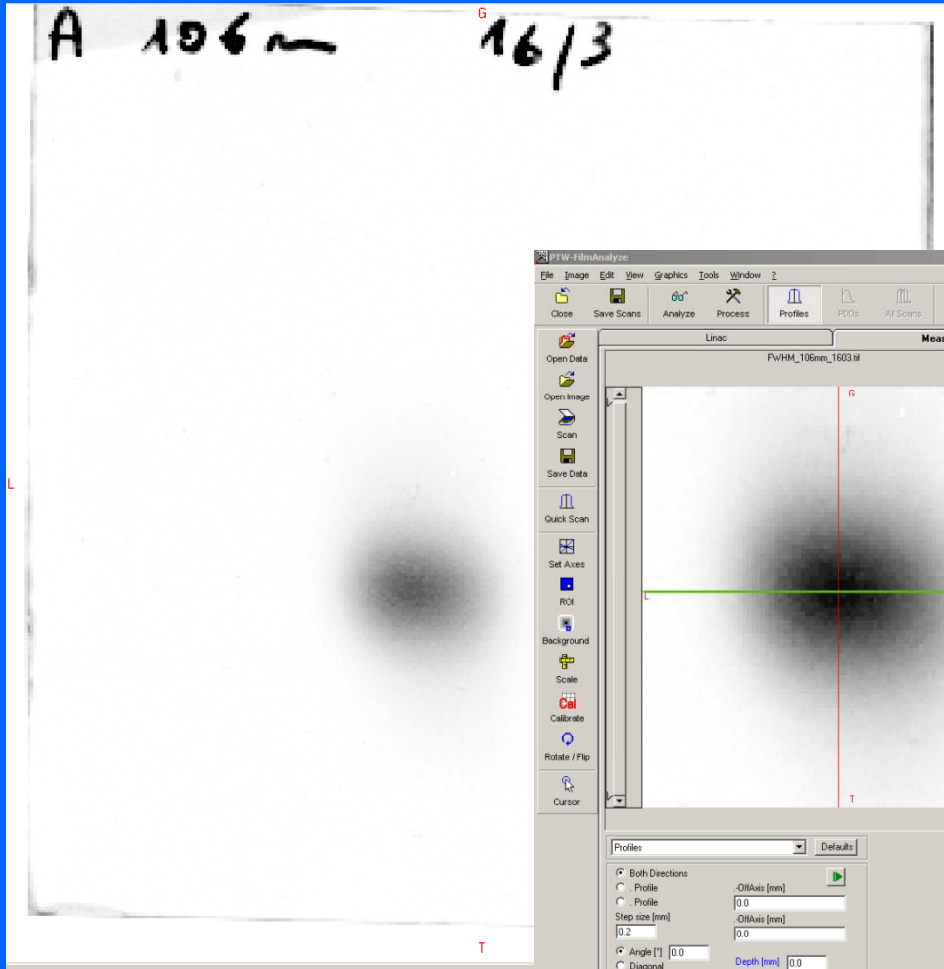
115 MeV/u, RiFi 0 vs 4 mm

HU calibration (CT scanner)



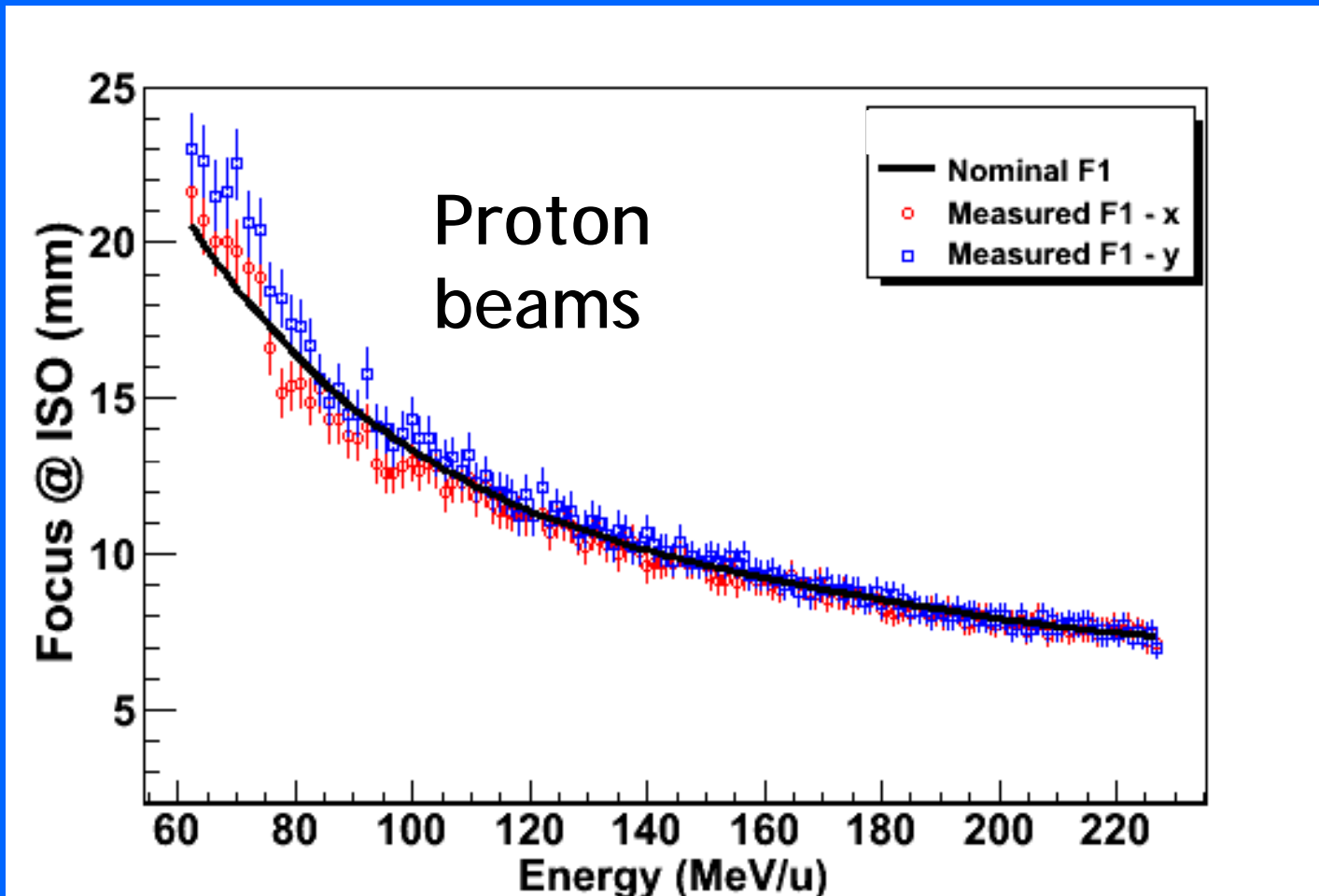
$$WEPL = \frac{\Delta x}{a}$$

Transversal dose profiles in air

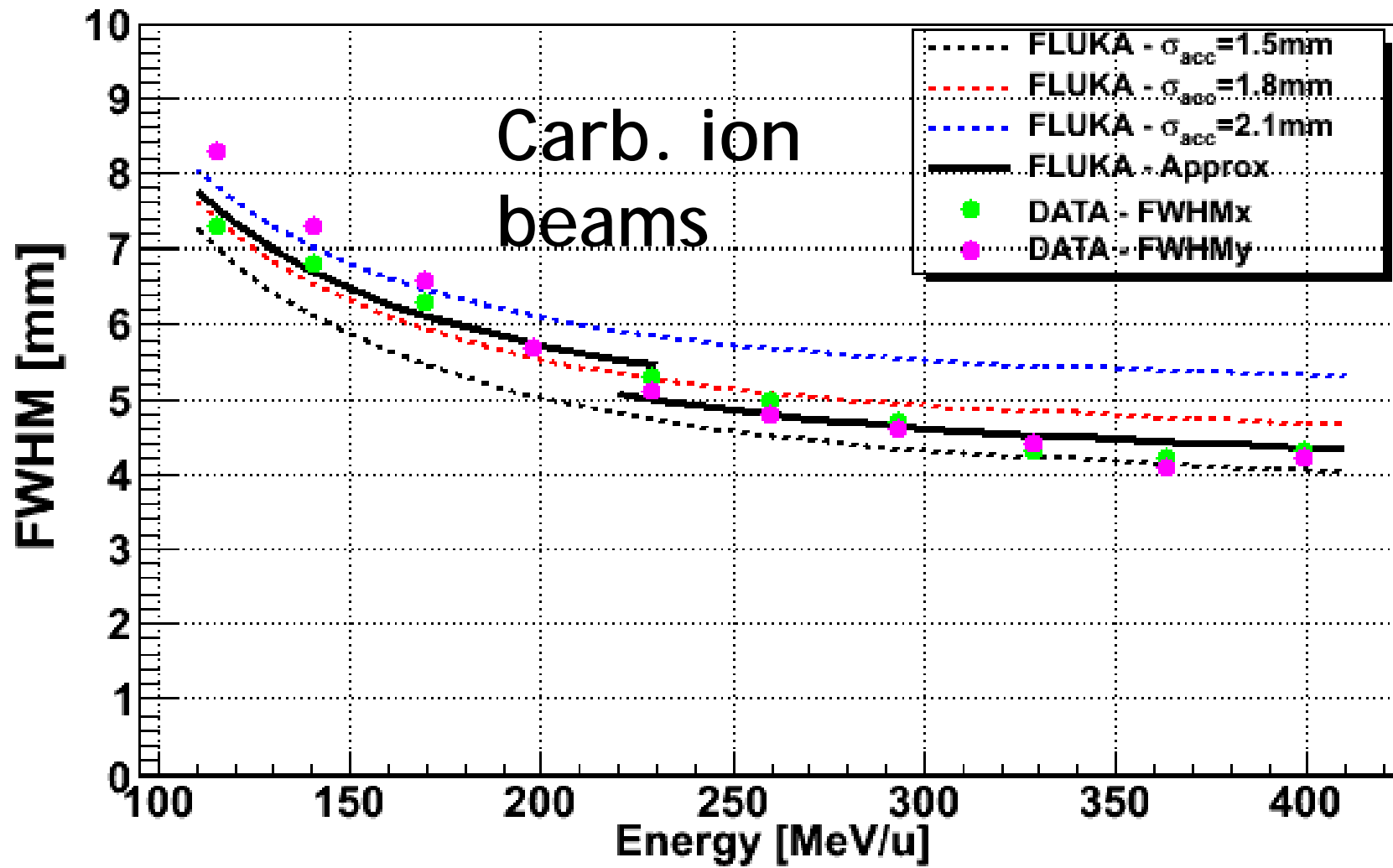


EBT3 radiochromic films

- self-developing and water resistant
- dose range : 0.01 - 10 Gy
- high spatial resolution (0.2 mm)
- no room light sensitivity



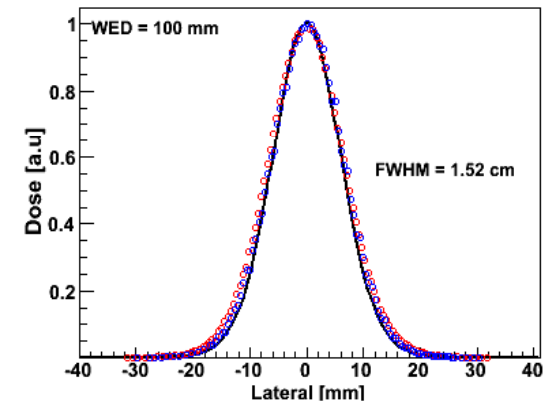
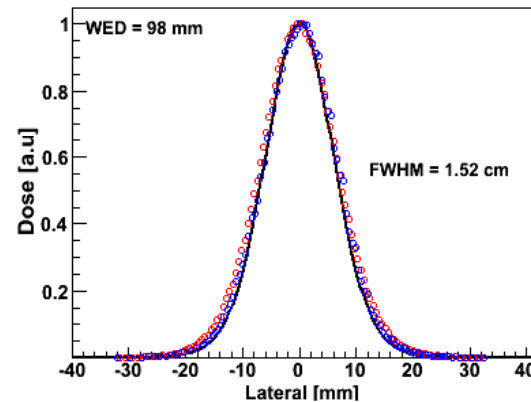
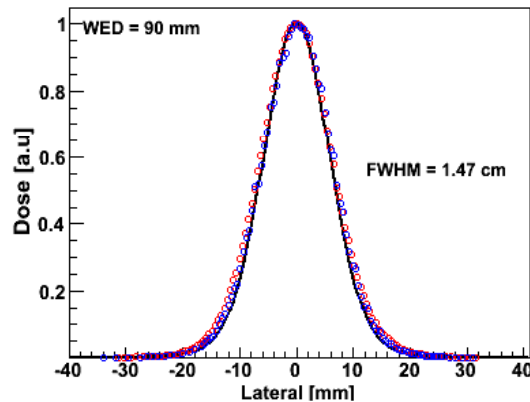
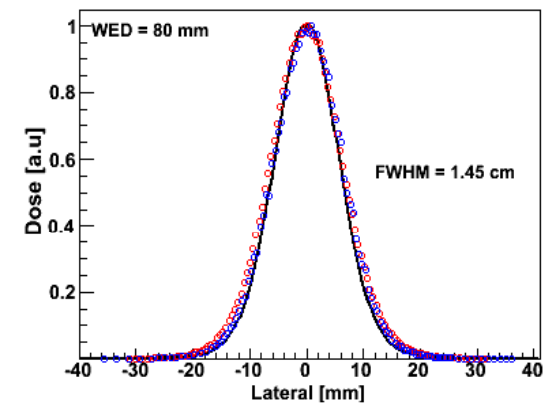
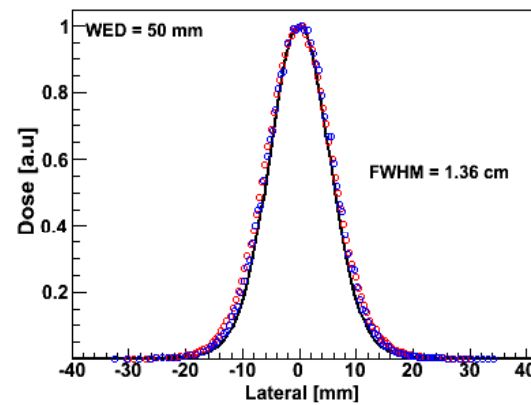
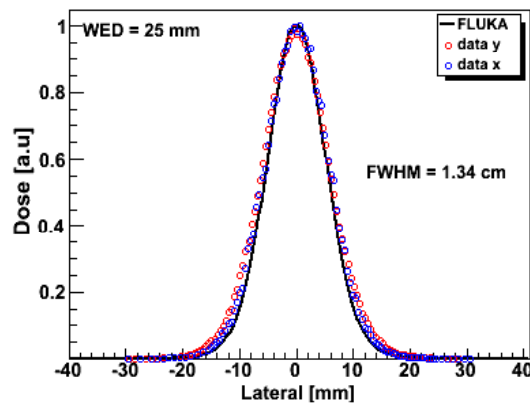
Carb. ion beams



Transversal dose profiles in the **water** phantom



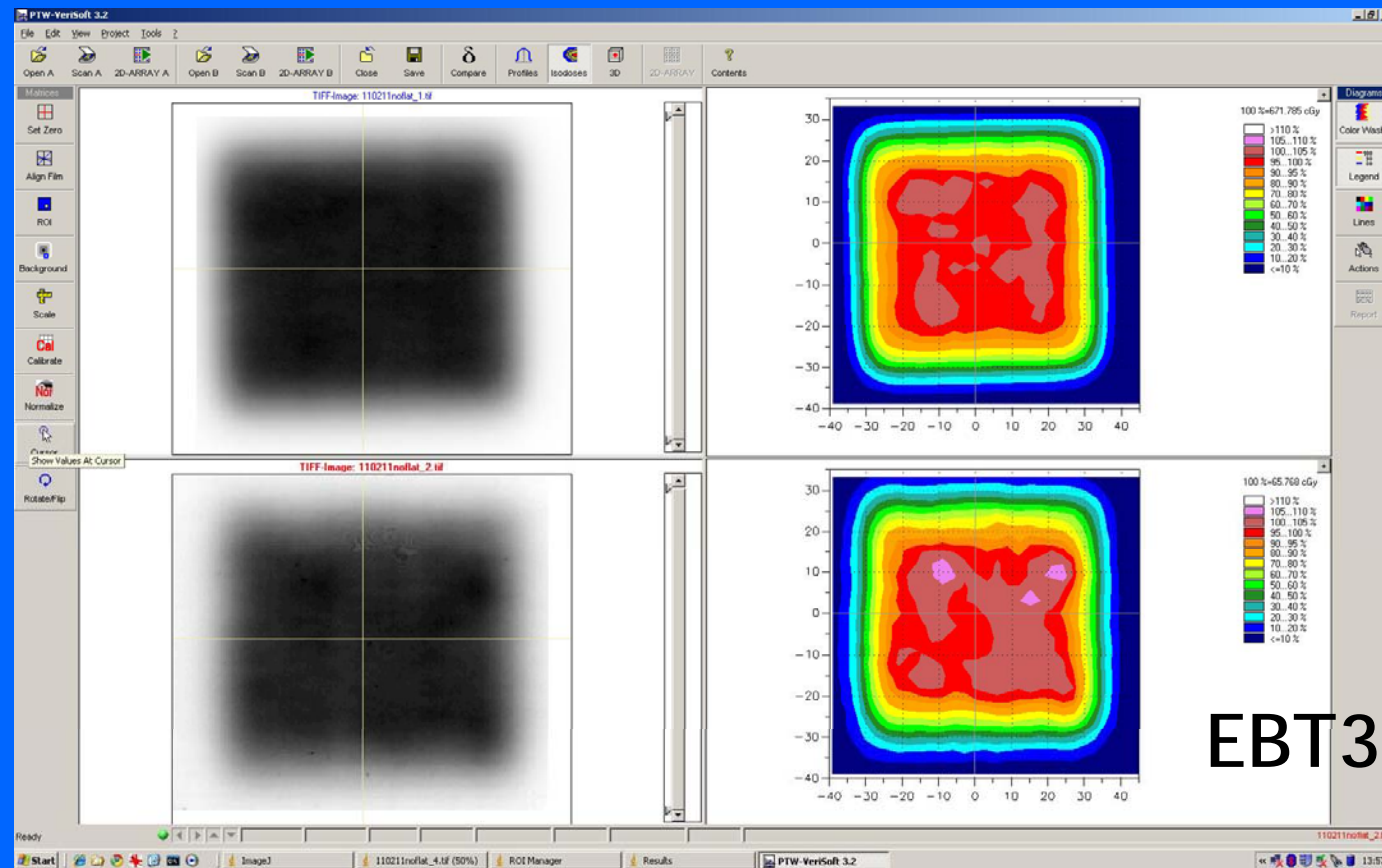
Pin-point IC (PTW 31014,
2-mm diameter)



$E = 117.54 \text{ MeV/u}$ (100 mm BP)

Scanned beam uniformity tests

3-4 mm step used in the clinical practice

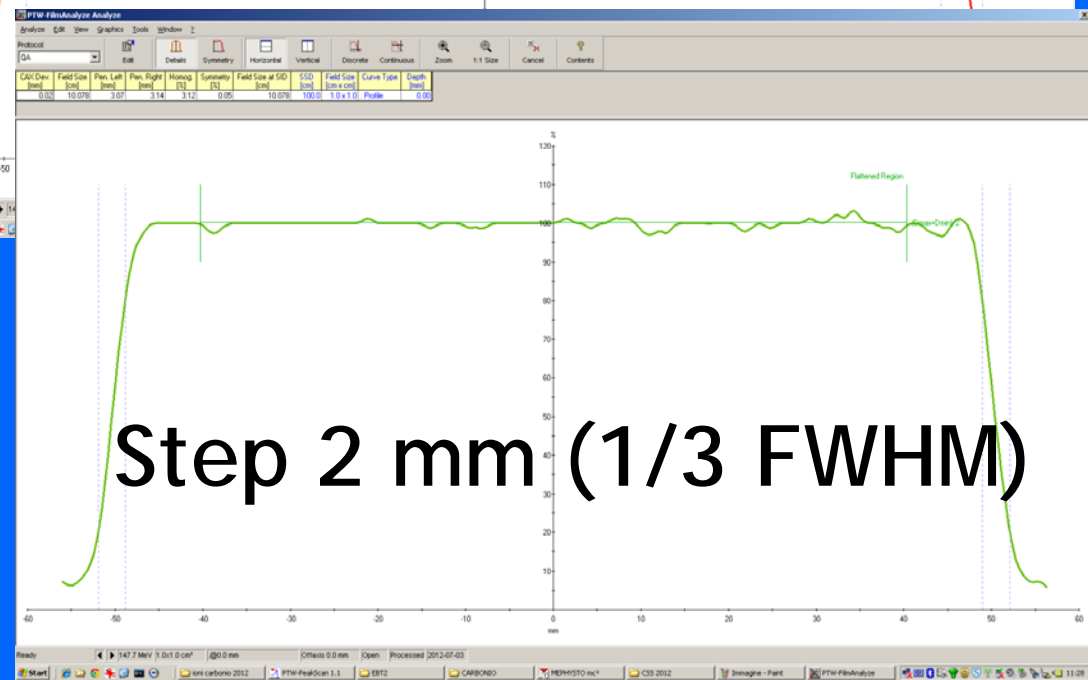
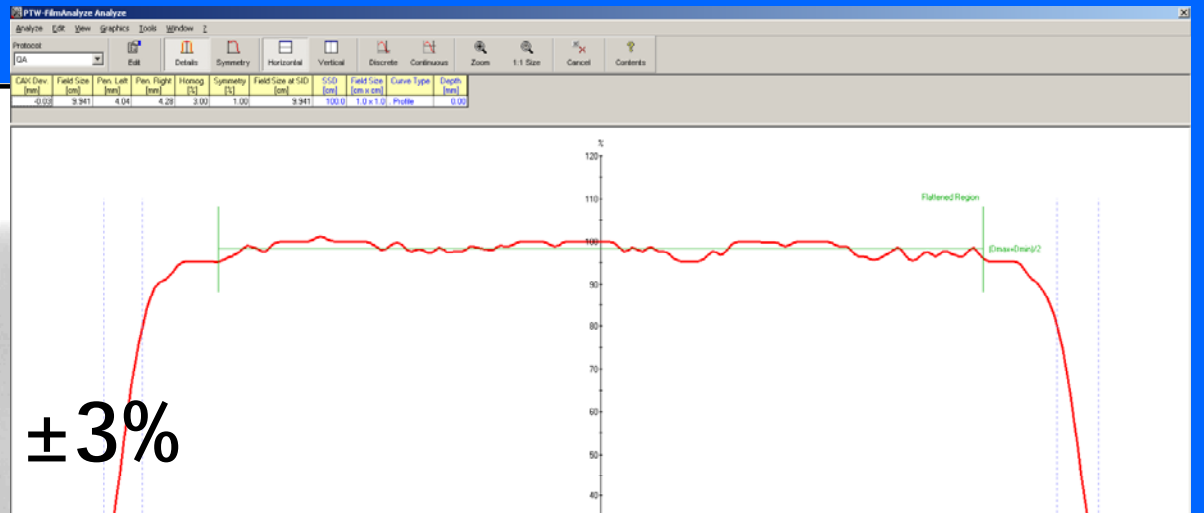


Scanned beams (carb.)

Uniformity: $\pm 3\%$

Field size 10 x 10 cm²

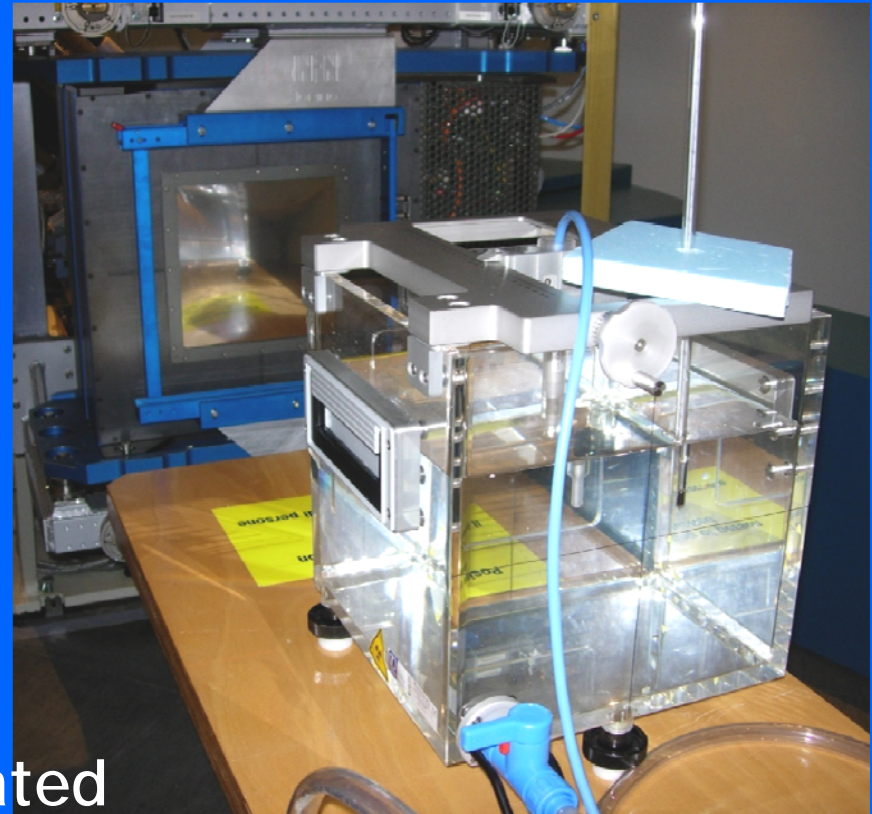
180 mm



Step 2 mm (1/3 FWHM)

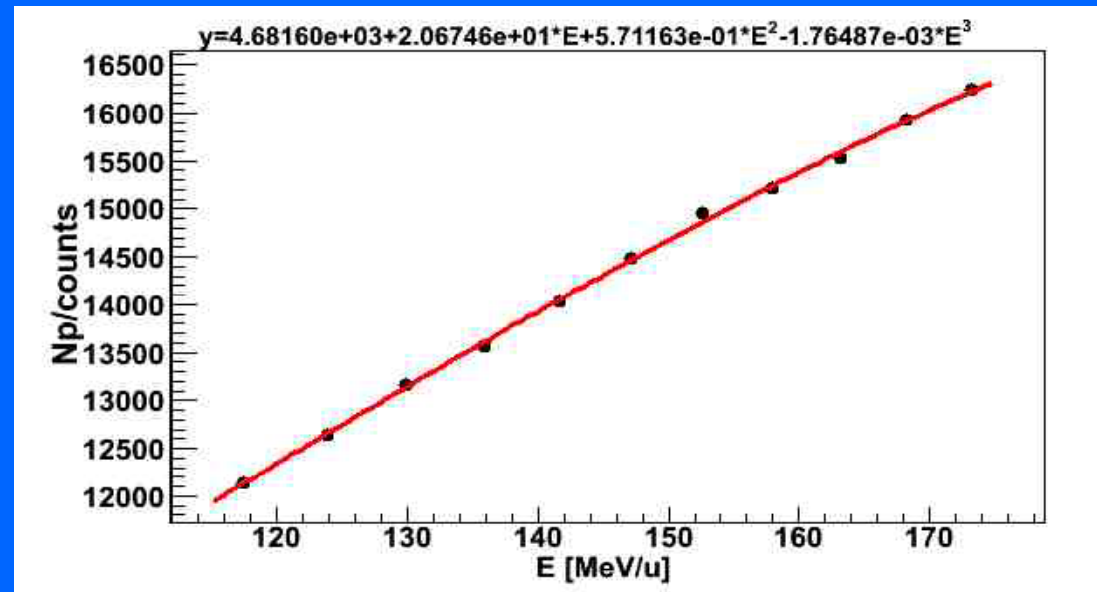
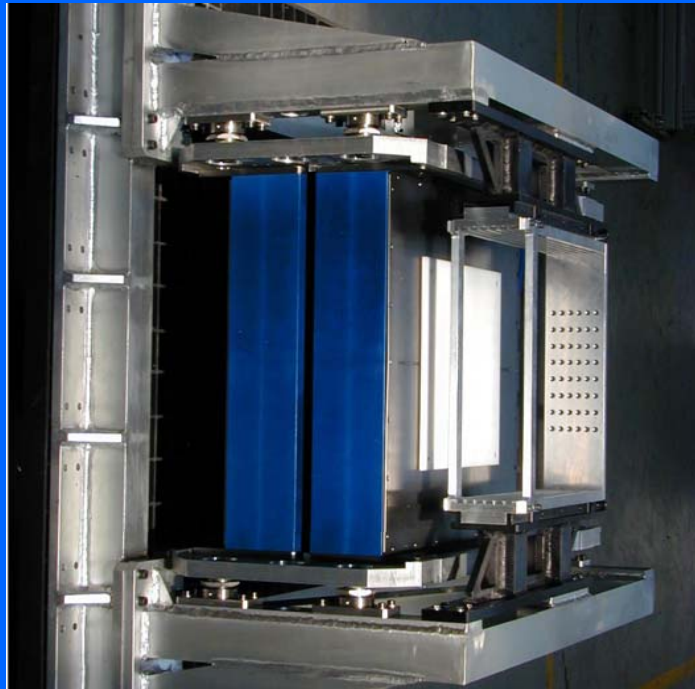
Dose to water under ref. conditions

Based on IAEA TRS-398,
2000 + formalism
Hartmann GH et al. (GSI,
1999)



- Farmer-type IC, Co-60 calibrated
- At the isocentre, in the plateau region (2 cm), in water phantom
- Mono-energetic beams, different energies, 6x6 cm² homogeneous field
- Then, at middle SOBP (homogeneous cubic volumes) calculated by TPS

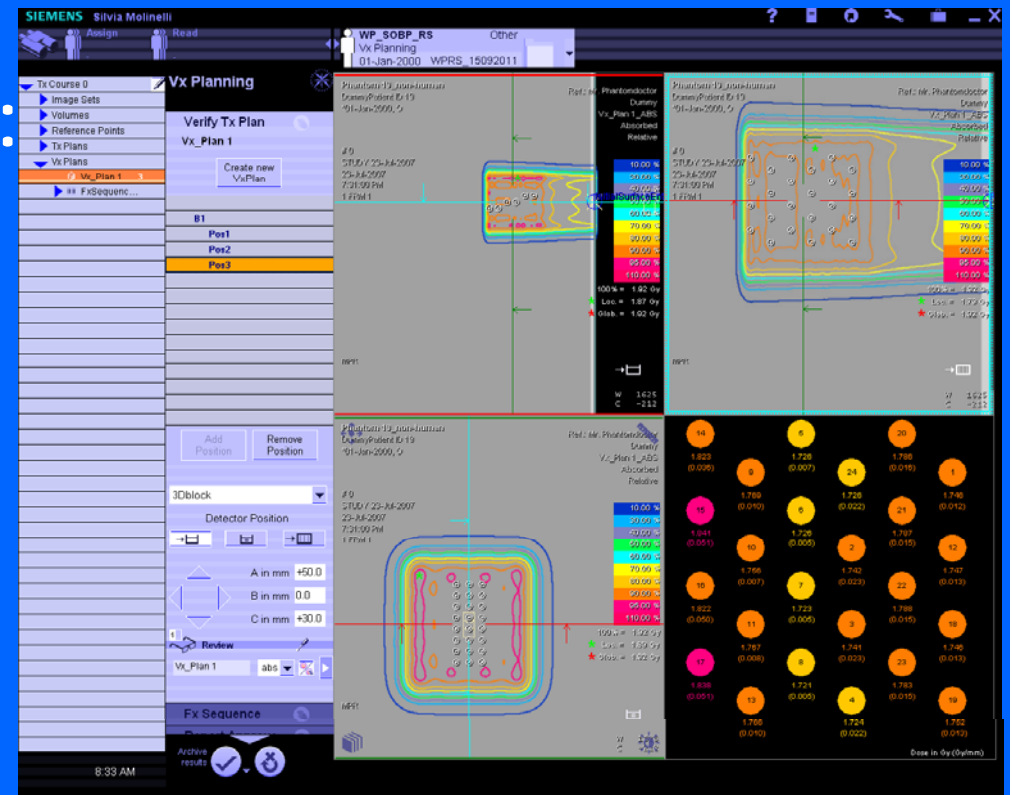
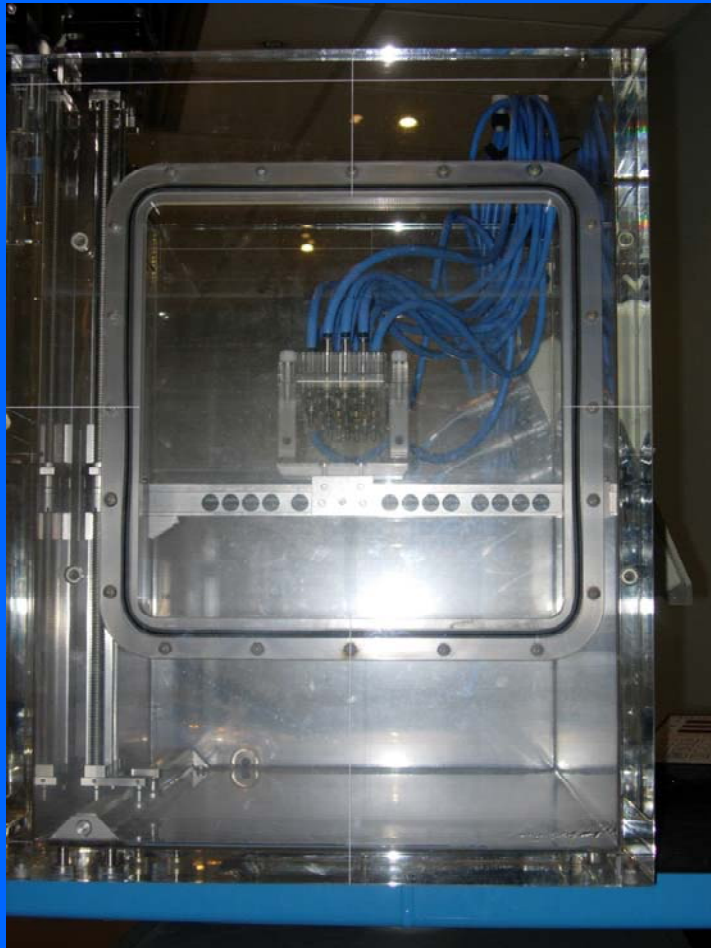
Calibration of beam monitor chambers

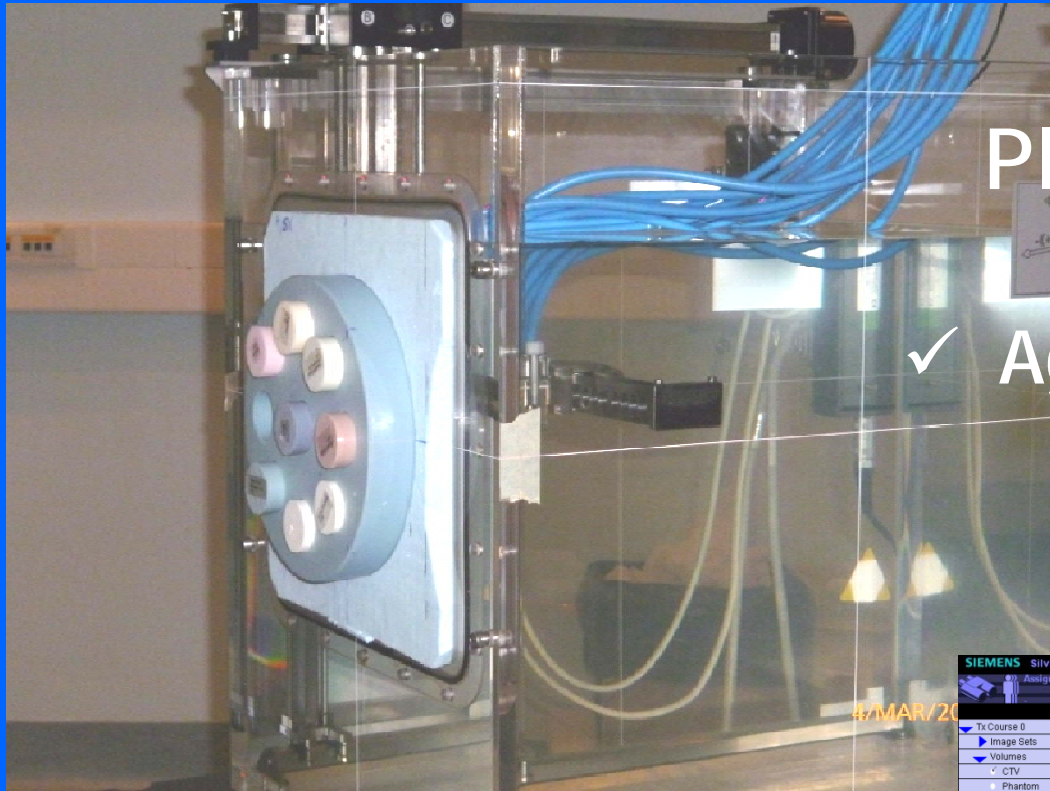


- ✓ Short-term reproducibility: $\pm 0.5\%$
- ✓ Long-term stability (9 months): $\pm 1\%$
- ✓ Proportionality: $\pm 1\%$
- ✓ Beam intensity dependence: $< 1\%$

Plan verification (1): simple cases

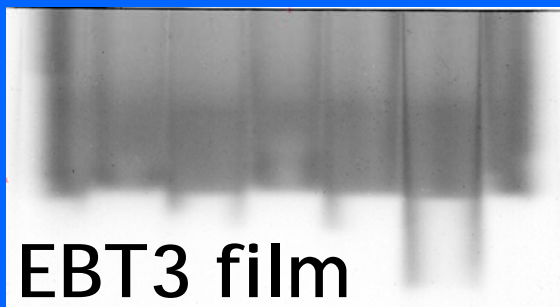
- ✓ Excellent agreement found ($\pm 2\%$)



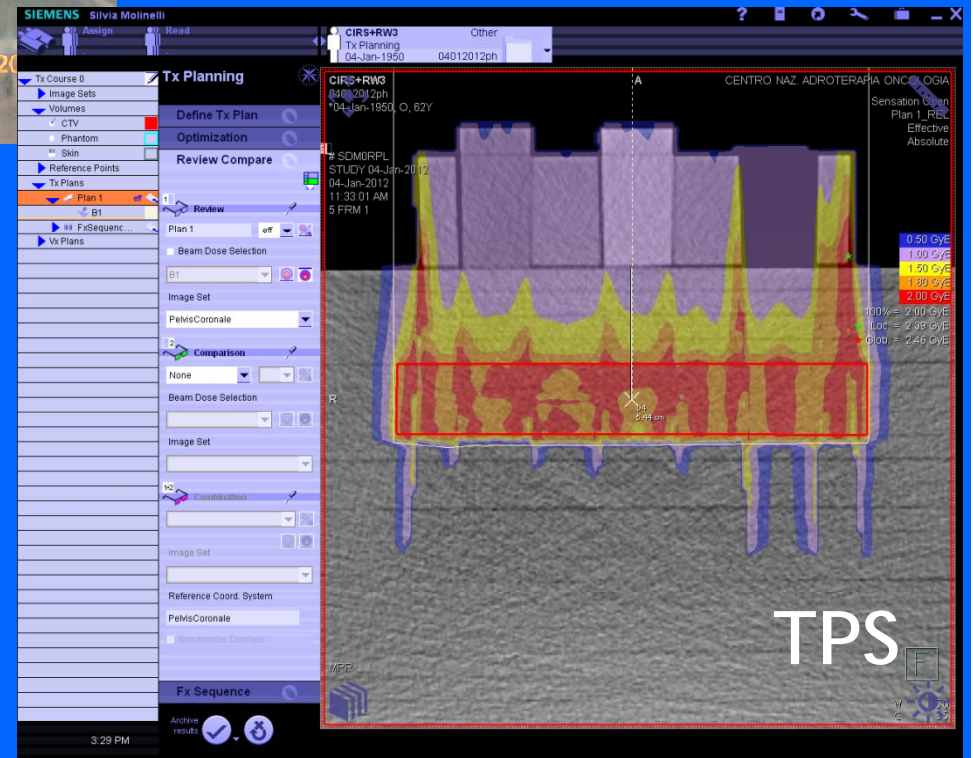


Plan verification (2): complex case

✓ Agreement within $\pm 5\%$



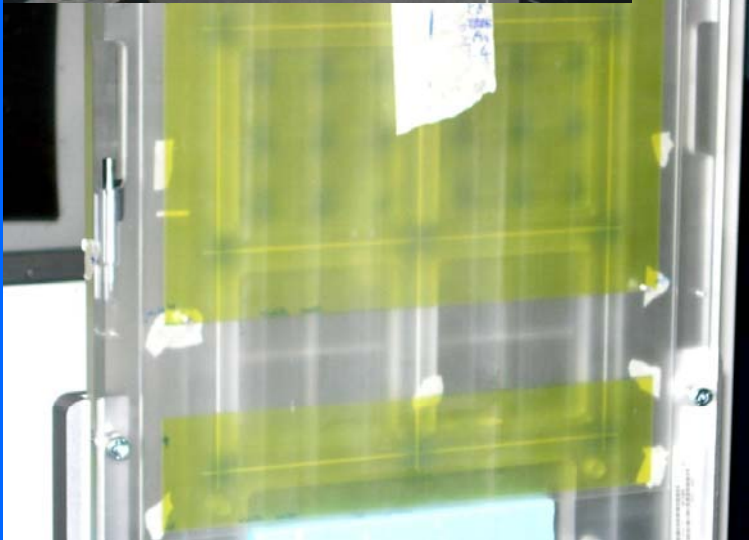
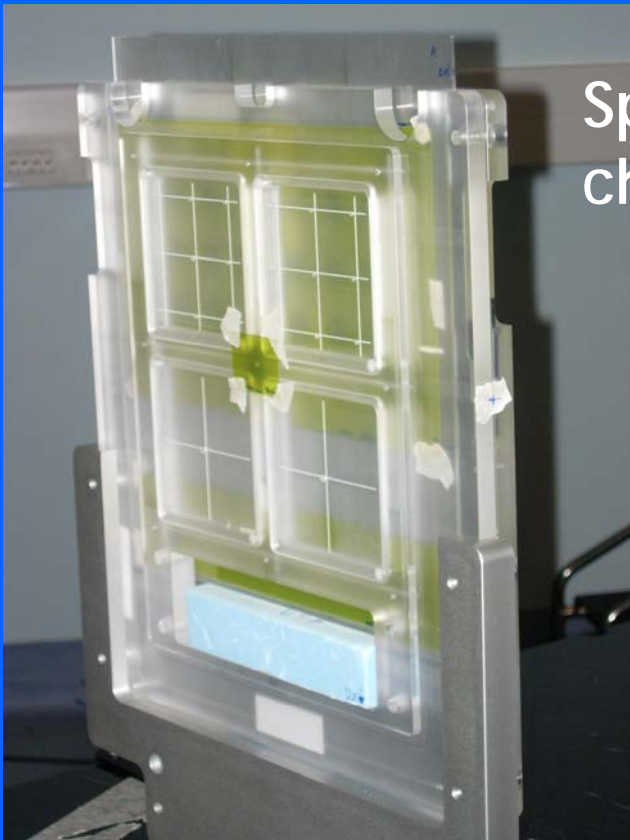
EBT3 film



Spot position accuracy and size checks

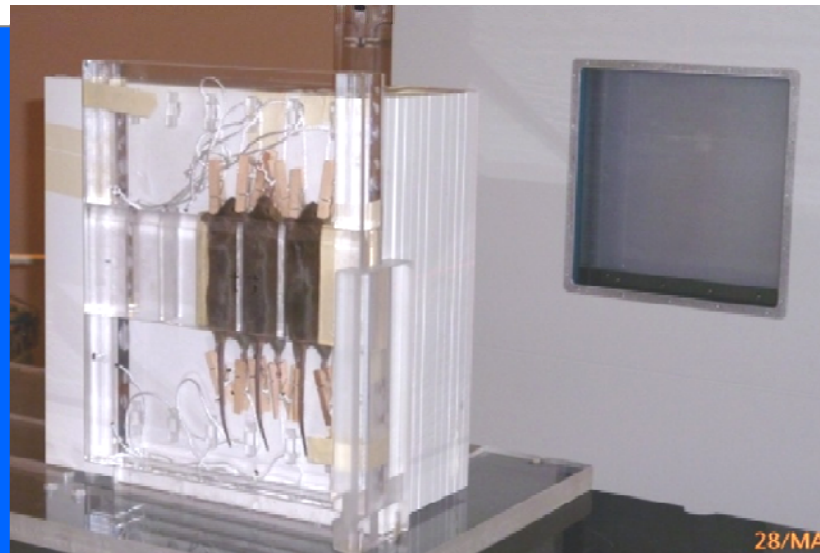
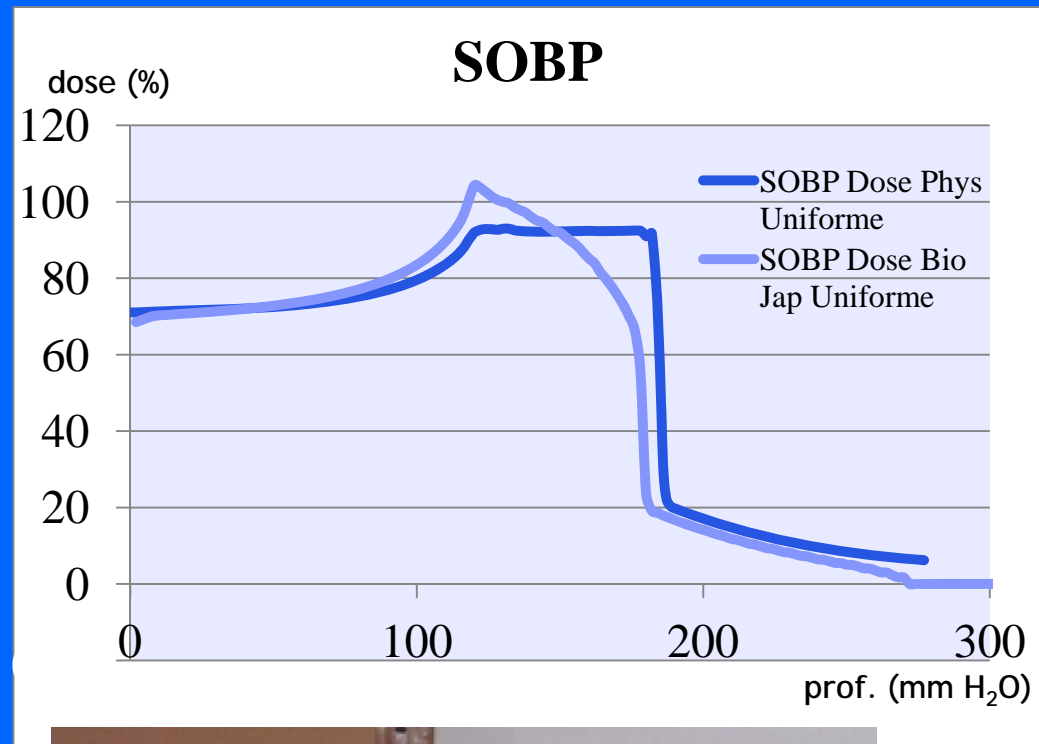
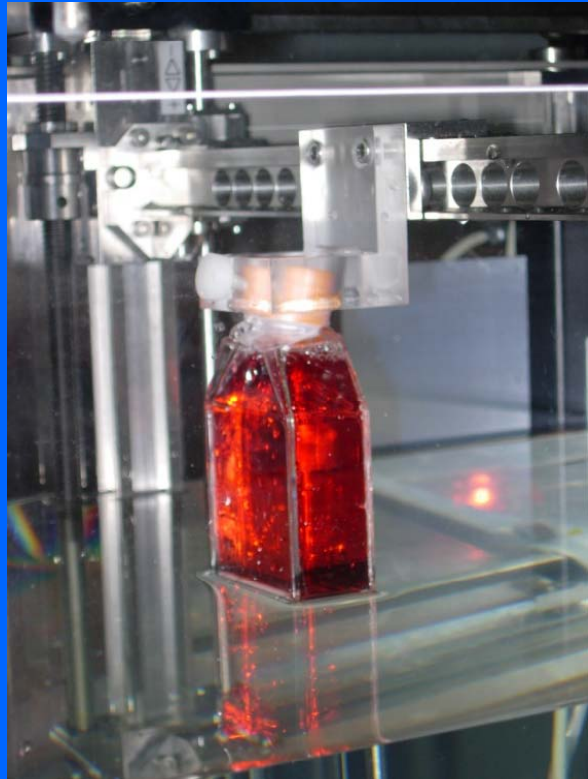
Daily QA

EBT3 films



Beam energy constancy check

Dosimetry for RB experiments



Actual status of CNAO (Clinical Area) and ongoing work

- ✓ Pt treatment start: Sept. 2011 (protons)
- ✓ N. of pts treated: 40 (2 treat. rooms)
- Carbon ion beam commissioning (1 horizontal beam line): just completed
- 1st pt expected in November 2012
- 2013: ocular treatments, organ motion, vertical beam line commissioning