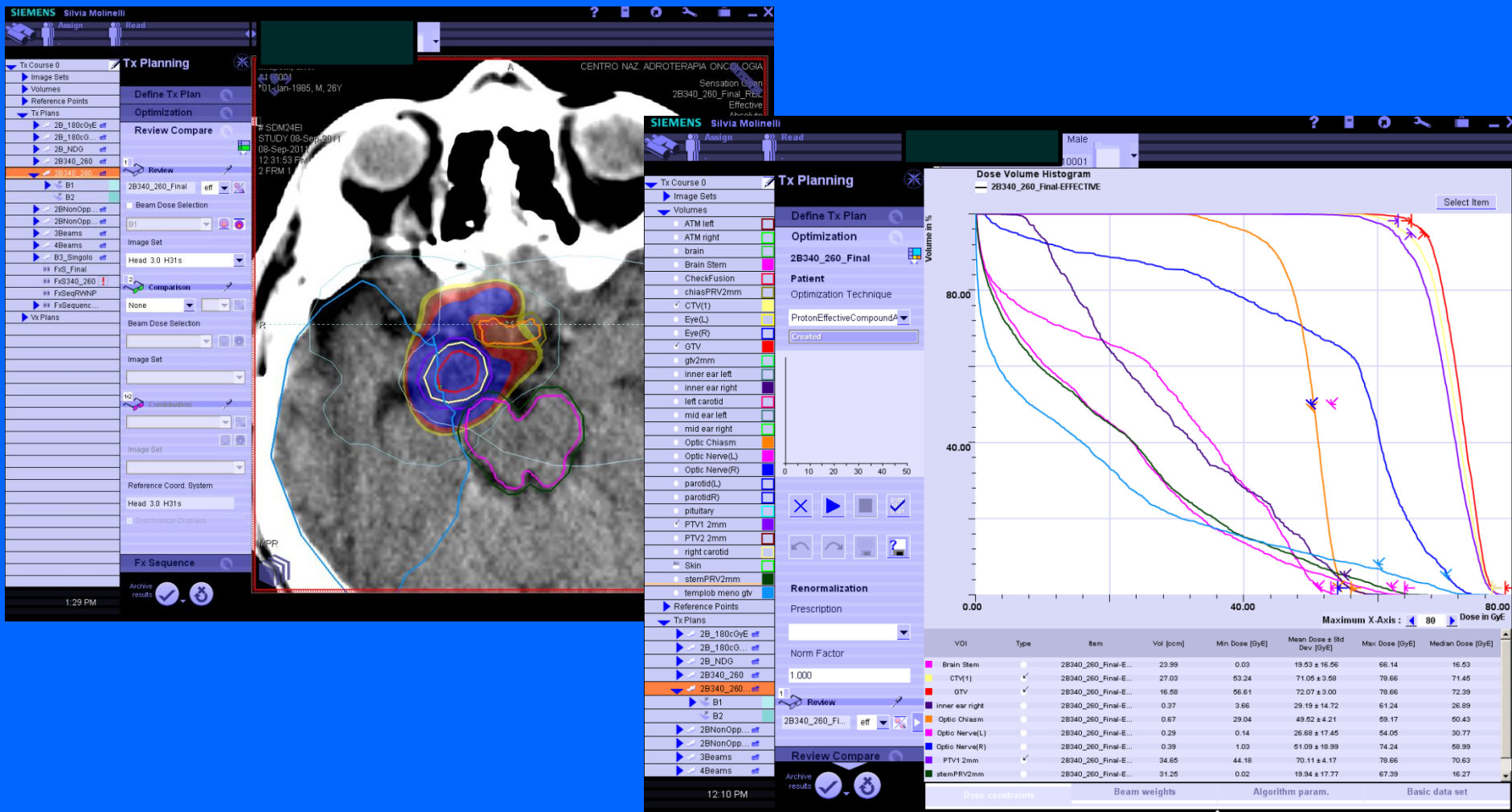


Medical Physics at CNAO



Treatment planning

Siemens syngo RT planning, CE-mark



Raystation V6.0 (Raysearch) installed and currently under commissioning (protons and LEM I-based carbon ions)

The screenshot displays the RayStation V6.0 software interface for patient ANNA BERTOLASI. The main window shows a CT scan of the chest with various contours (ROI) overlaid. A 'Welcome to RayLauncher' dialog box is open in the center, displaying the title 'Clinical version' and icons for RayStation, RayPhysics, and RayBiology. The interface includes a top menu bar with options like Patient Data Management, Plan Design, and Plan Optimization. On the left, there are panels for ROI List, POI List, Registration List, Scripting, Protocols, and Visualization Settings. The bottom of the interface shows an Image Set Library with thumbnails for 'supino', '4DCT 17-11-2014 SU...', 'CT 19', and 'CT 20'. The system tray at the bottom indicates the time as 08:58.

Beam commissioning and QA

Physics basic beam data acquired:

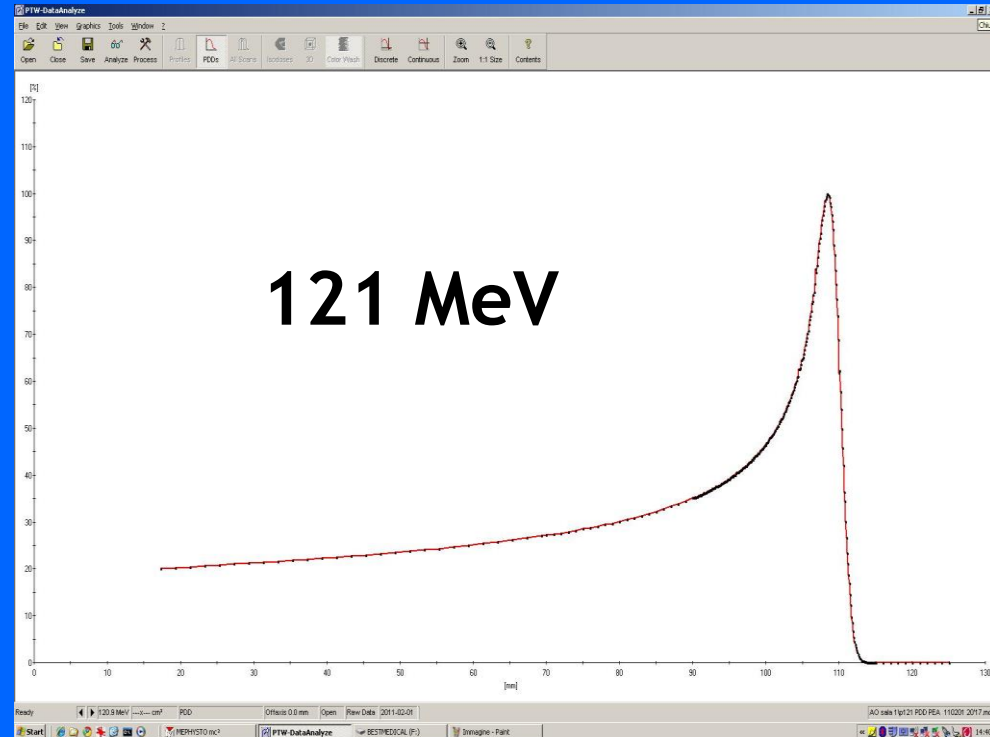
- experimentally
- Monte Carlo simulation (FLUKA code)

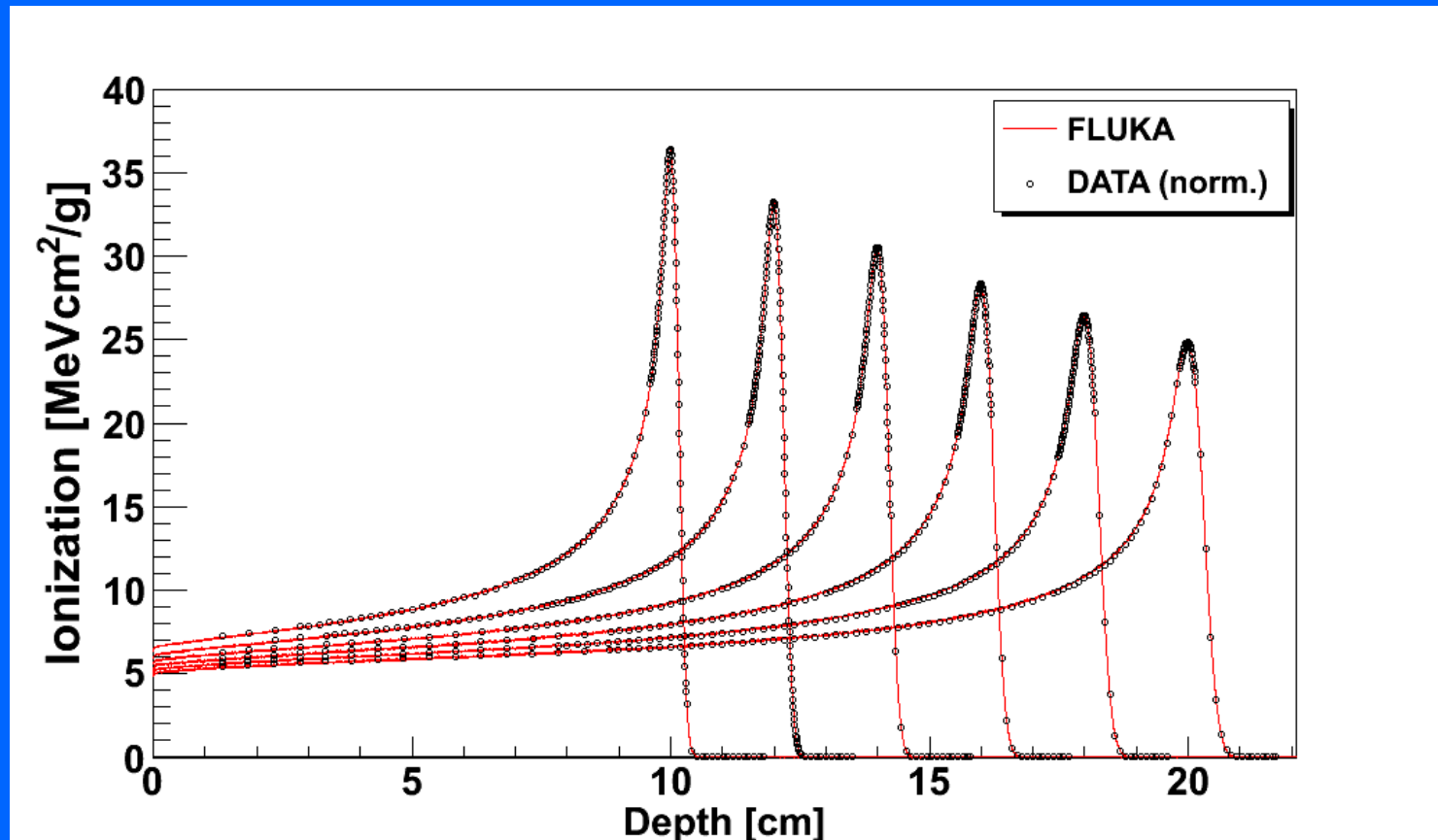
Experimental data

Lat-integrated Depth Dose Distributions (mono-en. pencil beams)



Peakfinder water column

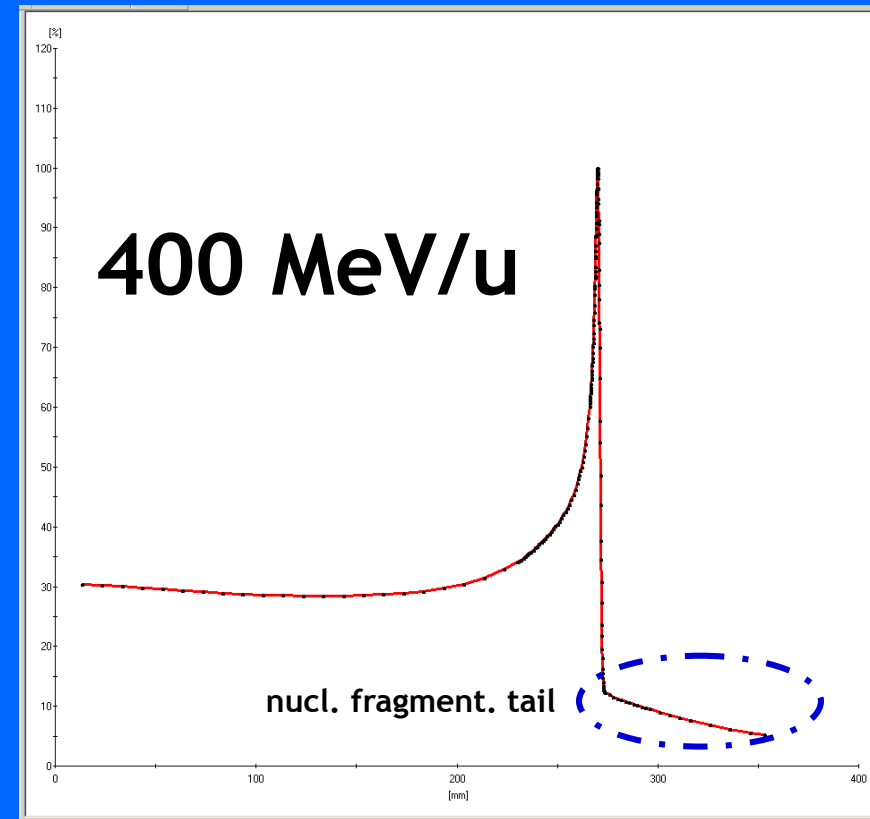
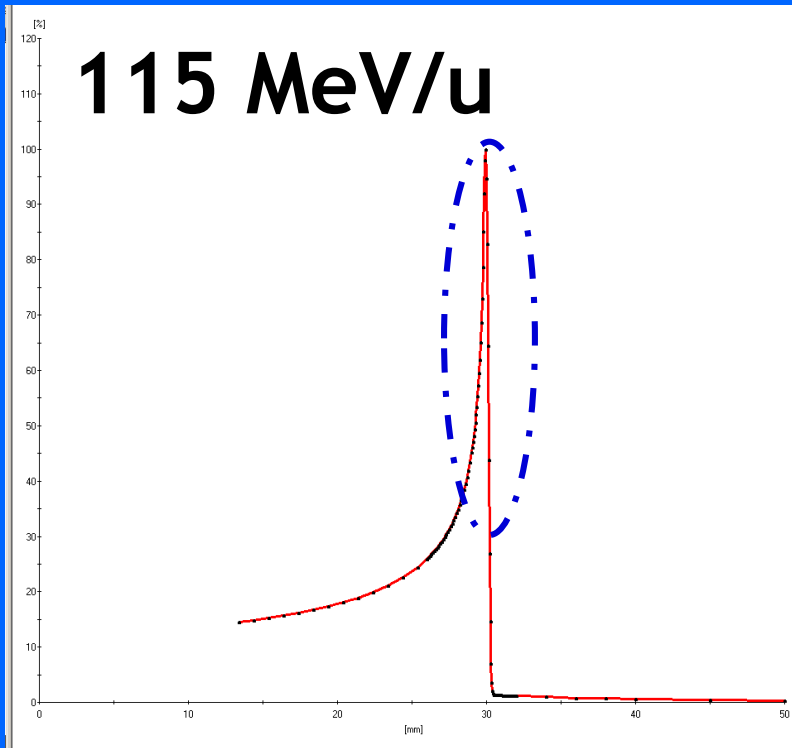




$$I_{\text{pot}} = 77 \text{ eV}$$

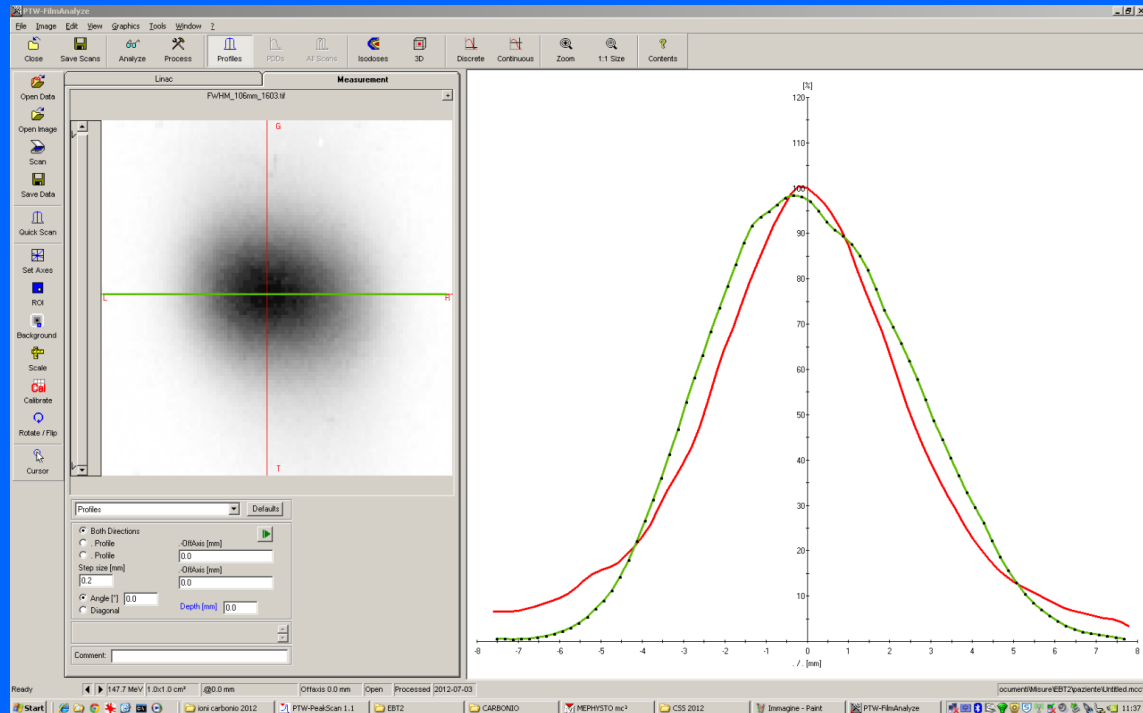
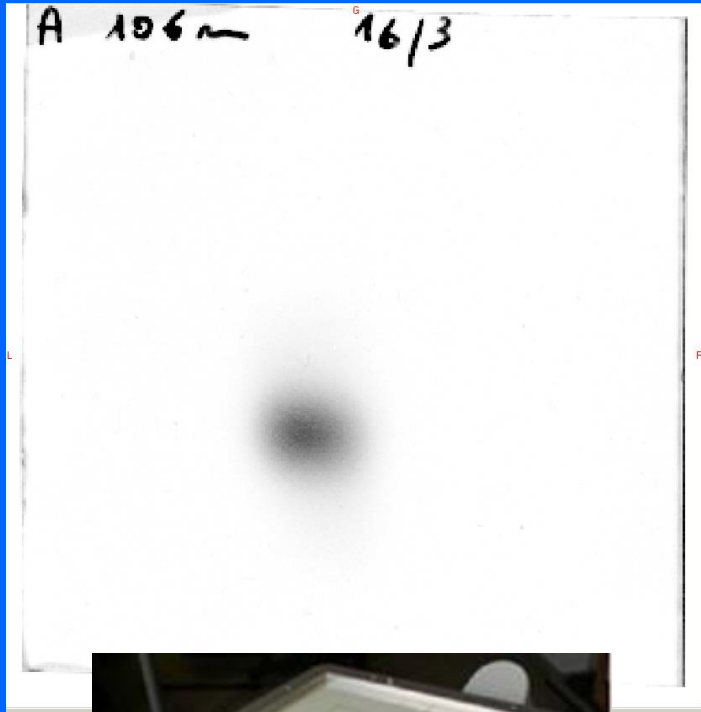
$$|BP_{\text{meas.}} - BP_{\text{FLUKA}}| \sim 0.1 \text{ mm}$$

162 **proton** energies, 62.3-226.9 MeV/u (3-32 cm BP depth),
1-2 mm energy step

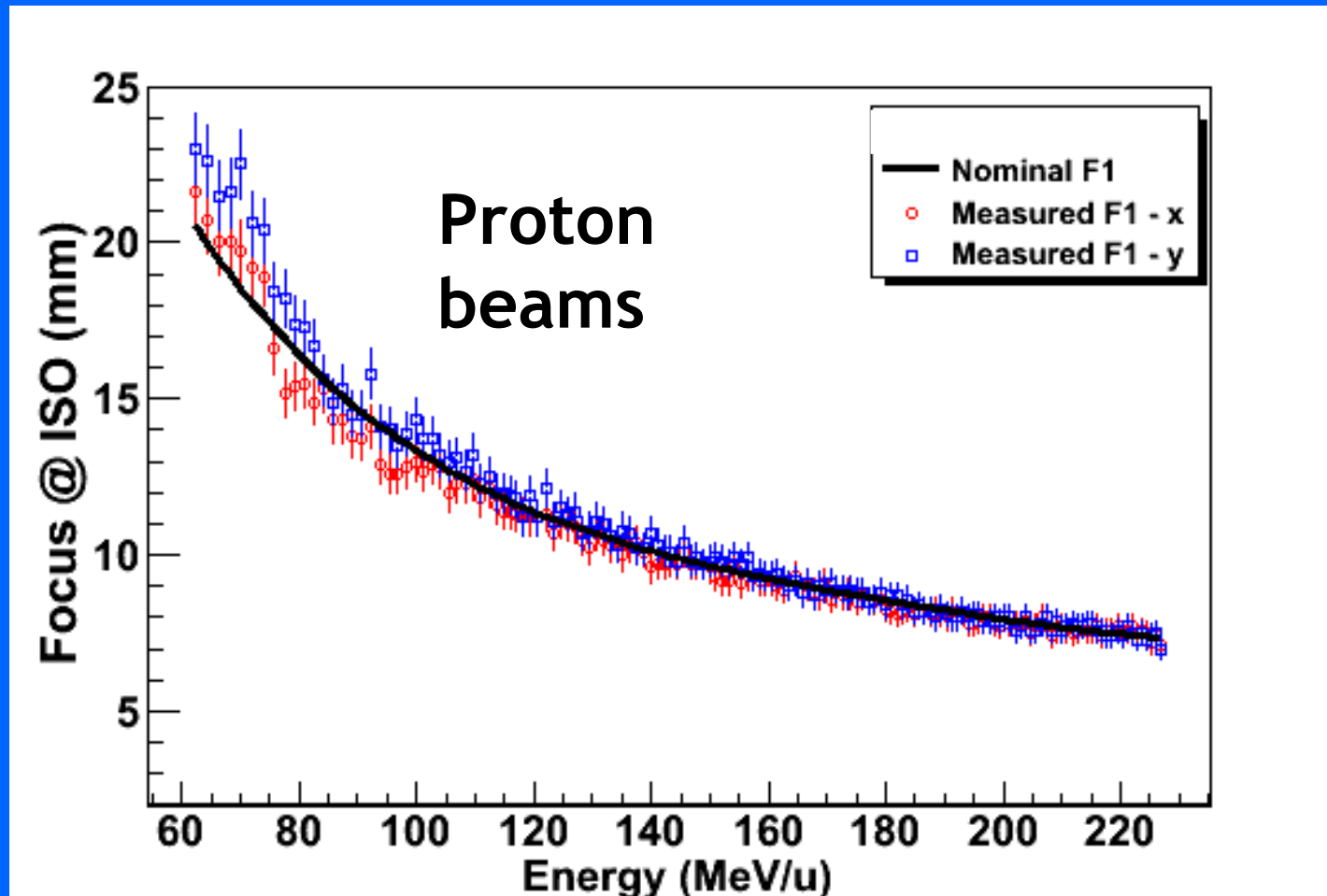


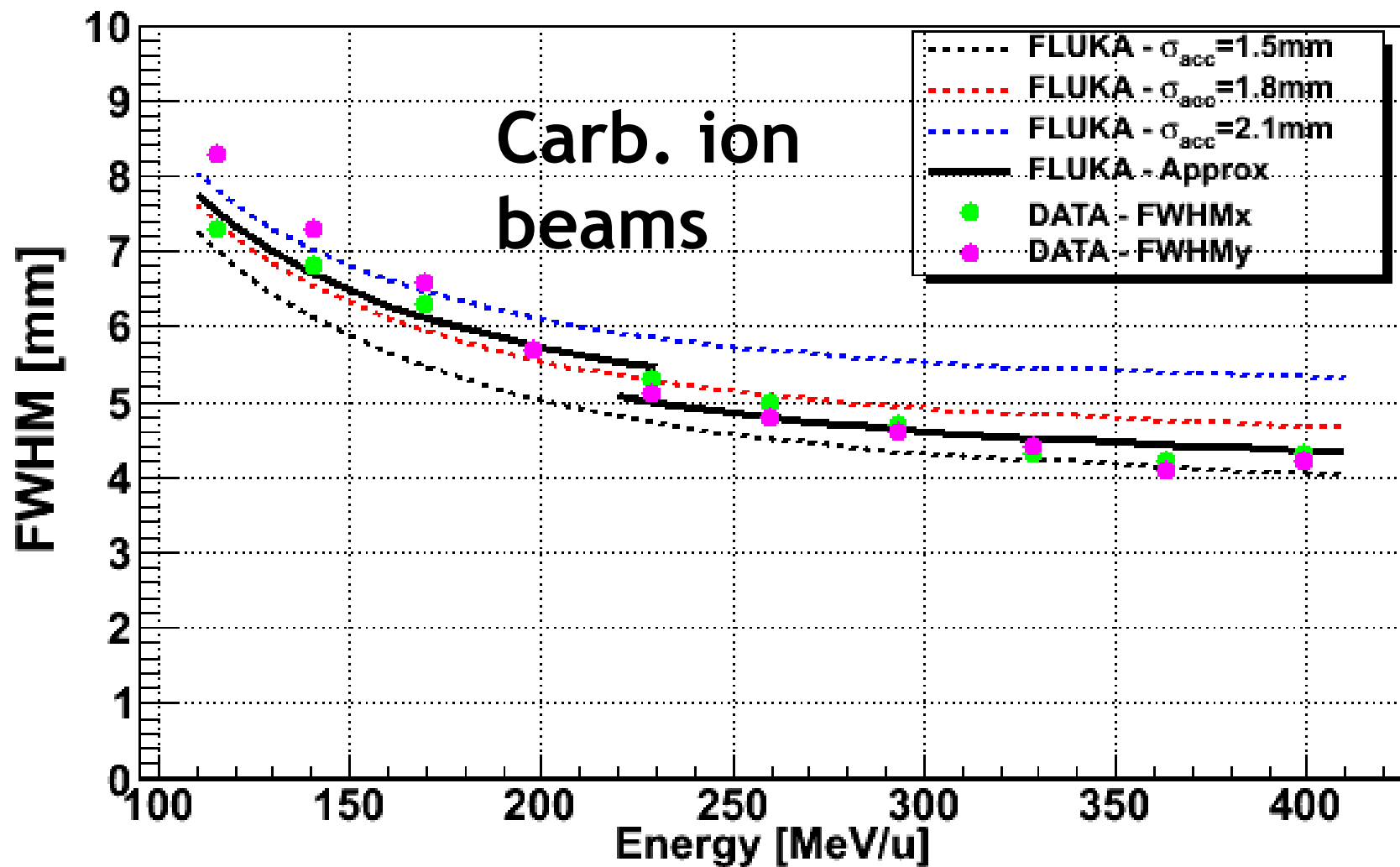
- 121 **carbon ion** energies, 115-400 MeV/u (3-27 cm), step 2 mm

Transversal dose profiles in air



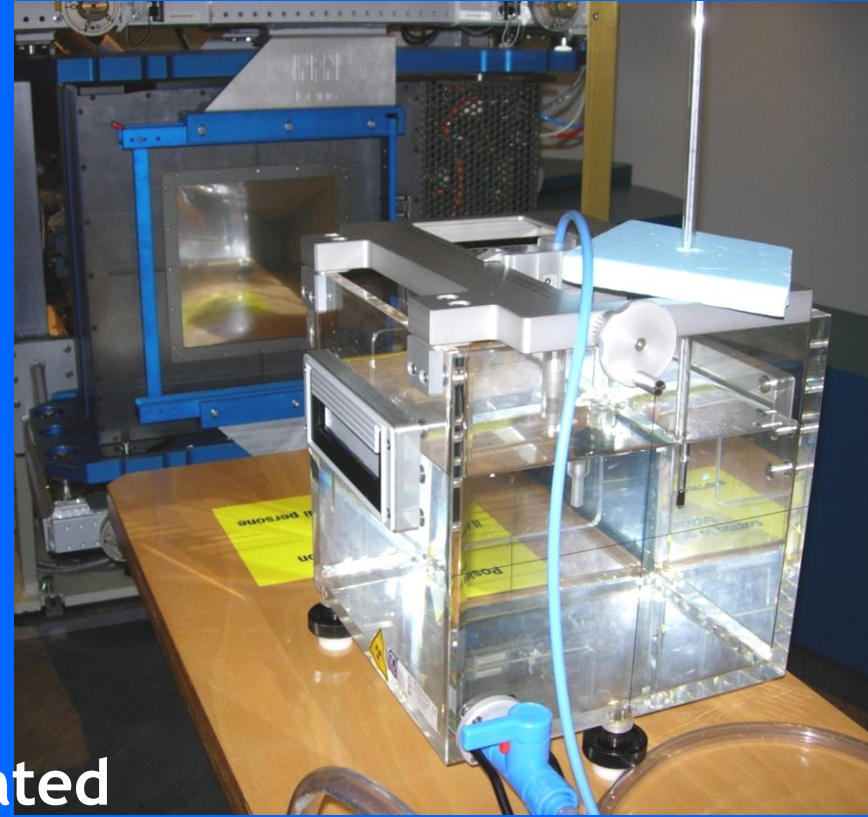
EBT3 radiochromic films





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

Pt-specific pre-treatment QA

TPS verification plan

The image displays three screenshots from the Siemens TPS software interface, illustrating the verification process for a treatment plan.

Top Left Screenshot: Verify Tx Plan

- Window:** Verify Tx Plan (Vx_2B340_260)
- Detector Position:** A in mm +60.0, B in mm +5.0, C in mm +15.0
- 3Dblock:** Selected
- Review:** Vx_2B340_260 abs
- Time:** 11:05 AM

Top Right Screenshot: Dose Distribution

- Reference:** Mr. Phantomdoctor, Dummy/Patient ID 19, 401-Jan-2000, 0
- Plan:** Vx_2B340_260_ABS
- Color Scale:** 10.00% (Blue) to 110.00% (Red)
- Summary:** 100% = 0.96 Gy, Loc. = 0.89 Gy, Glob. = 0.92 Gy
- Time:** 11:05 AM

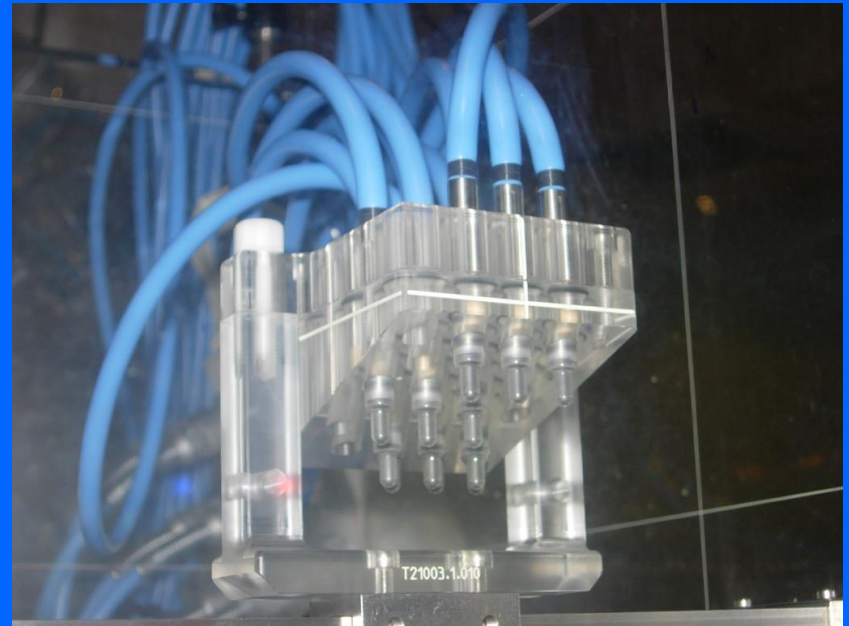
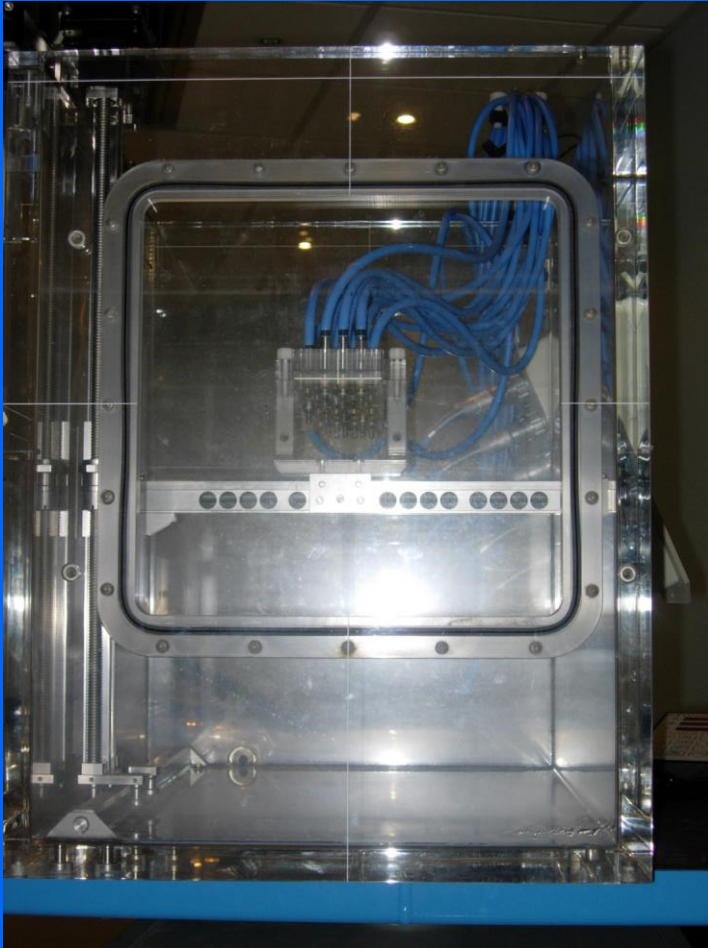
Bottom Screenshot: Detailed Verification

- Reference:** Mr. Phantomdoctor, Dummy/Patient ID 19, 401-Jan-2000, 0
- Plan:** Vx_2B340_260_ABS
- Detector Position:** A in mm +55.0, B in mm +14.0, C in mm +53.0
- Review:** Vx_2B340_260 abs
- Time:** 11:02 AM

Dose Distribution Data (Bottom Right):

Color	Value	Relative Error
Blue	10.00%	
Light Blue	20.00%	
Green	30.00%	
Yellow	40.00%	
Orange	50.00%	
Red	60.00%	
Dark Red	70.00%	
Dark Orange	80.00%	
Light Orange	90.00%	
Yellow-Orange	100.00%	
Orange	110.00%	

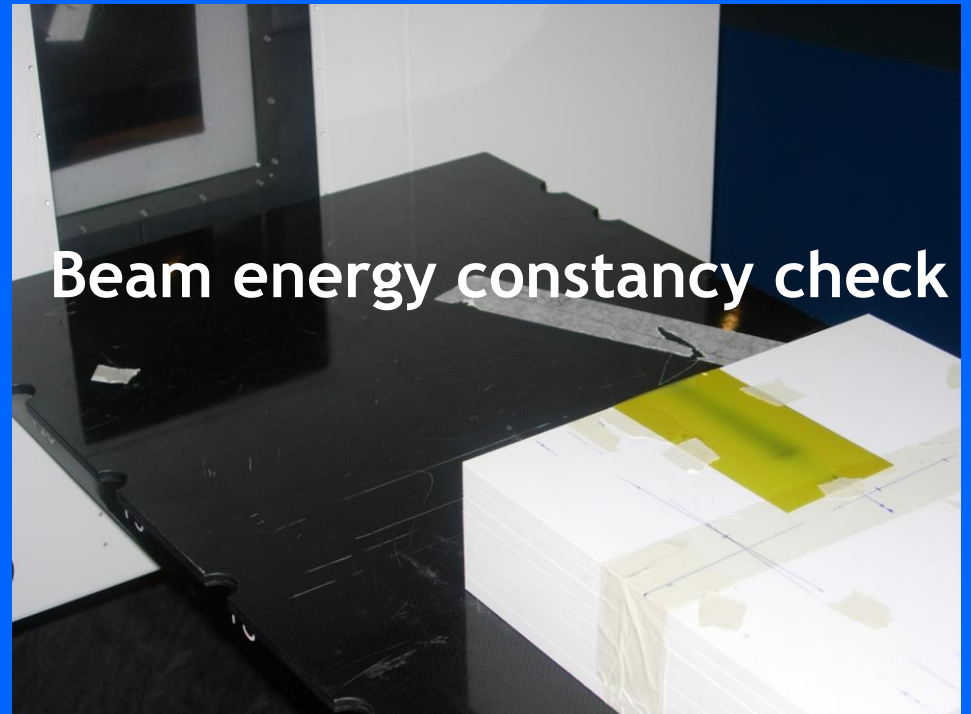
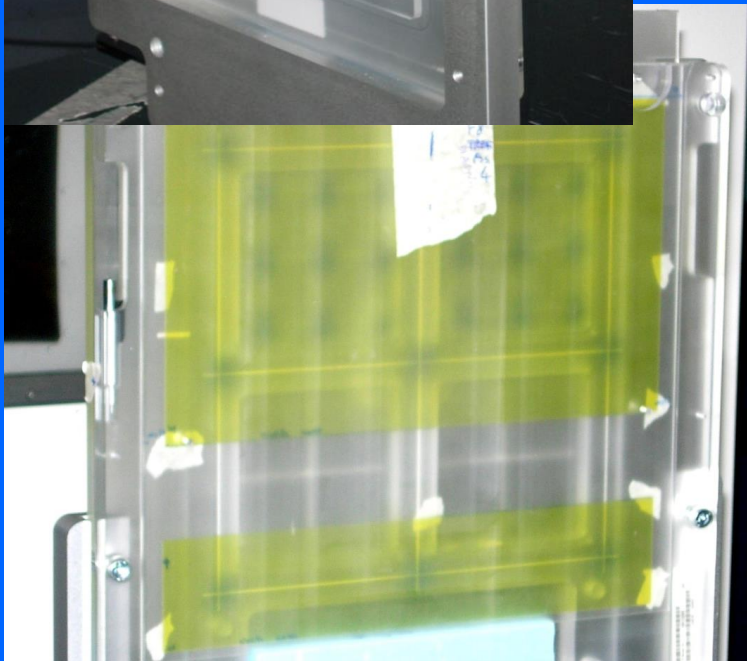
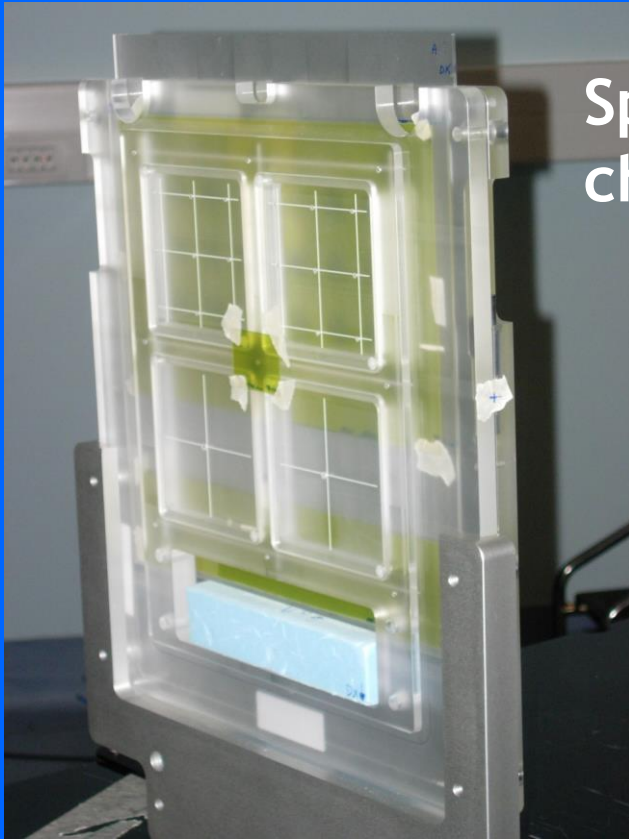
3-D block, multiple PinPoint chambers



Spot position accuracy and size checks

Daily QA

EBT3 films

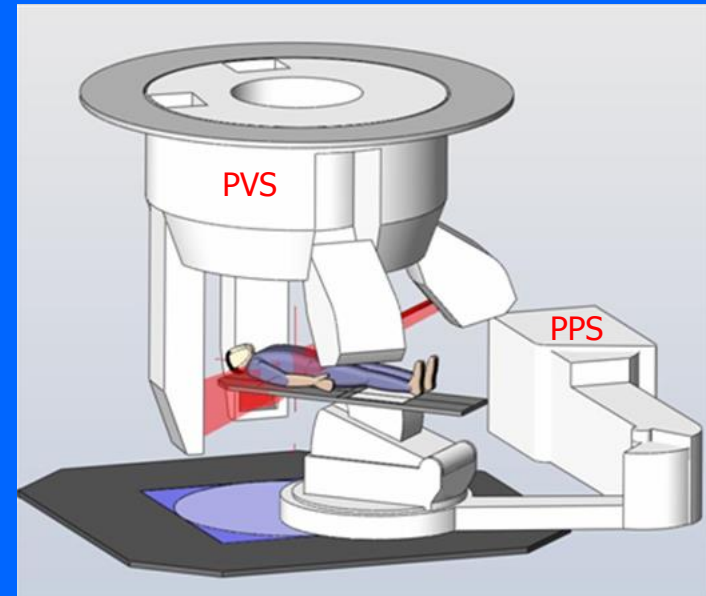
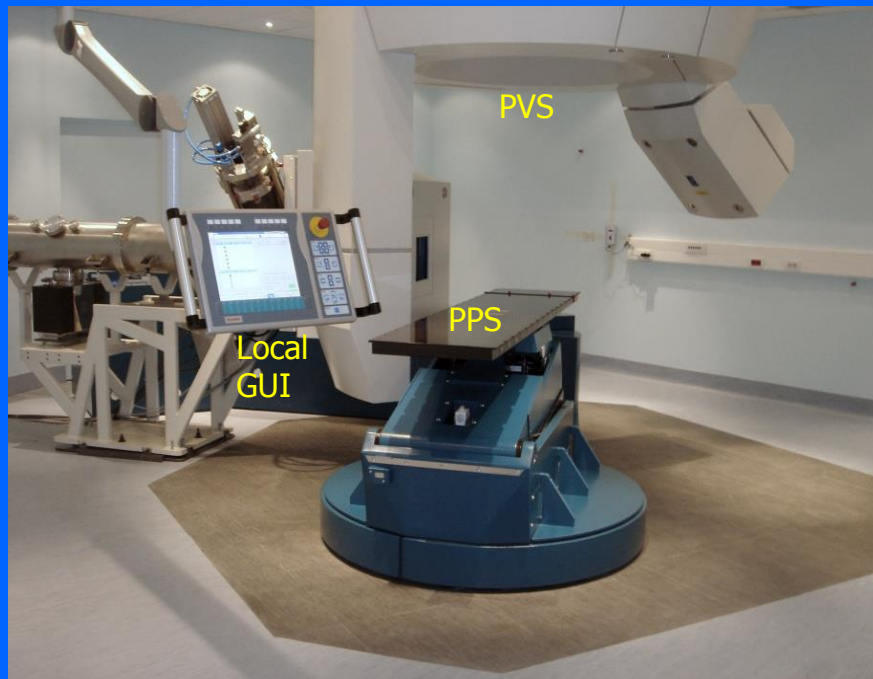


Beam energy constancy check

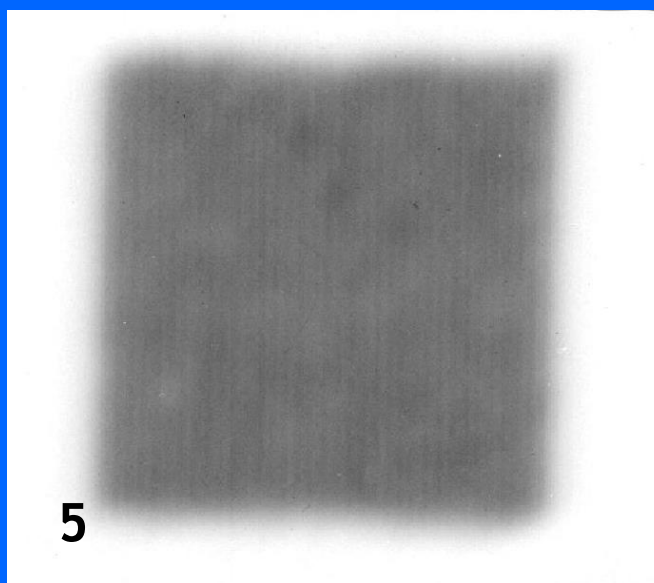
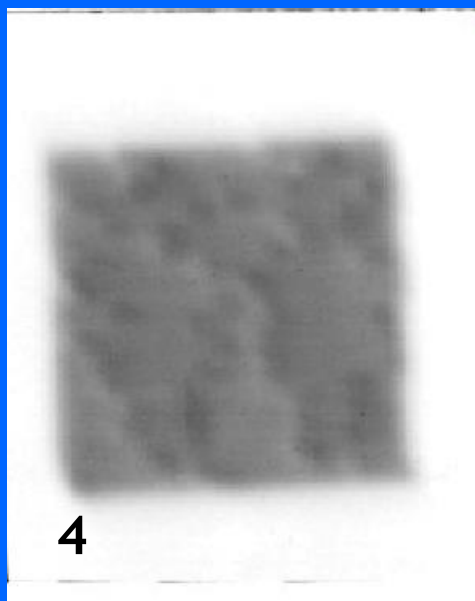
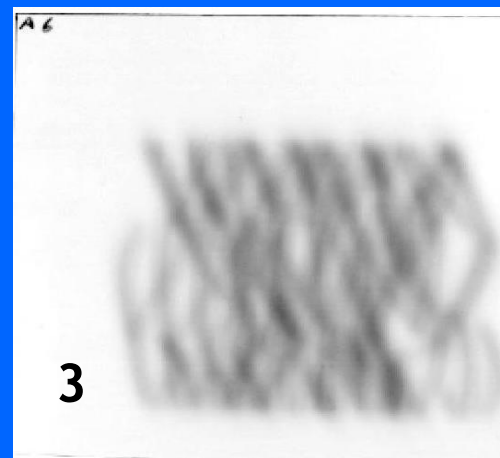
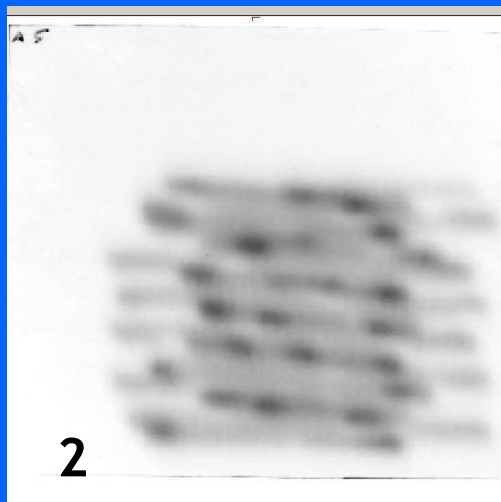
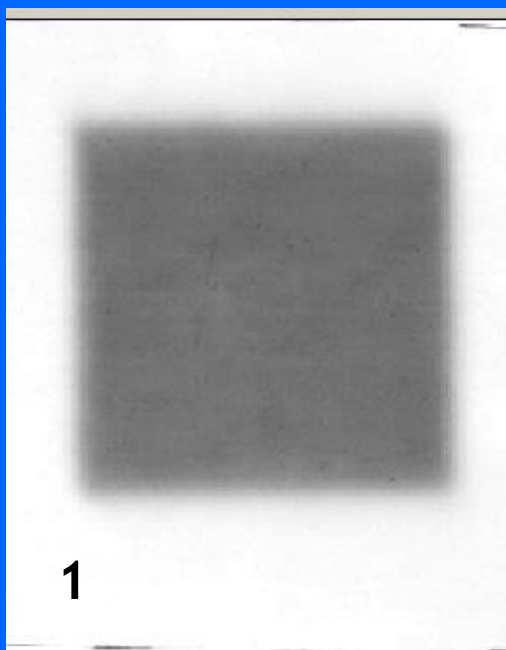
CNAO Integrated Systems for Patient Positioning and set-up Verification

✓ 3 sub-systems:

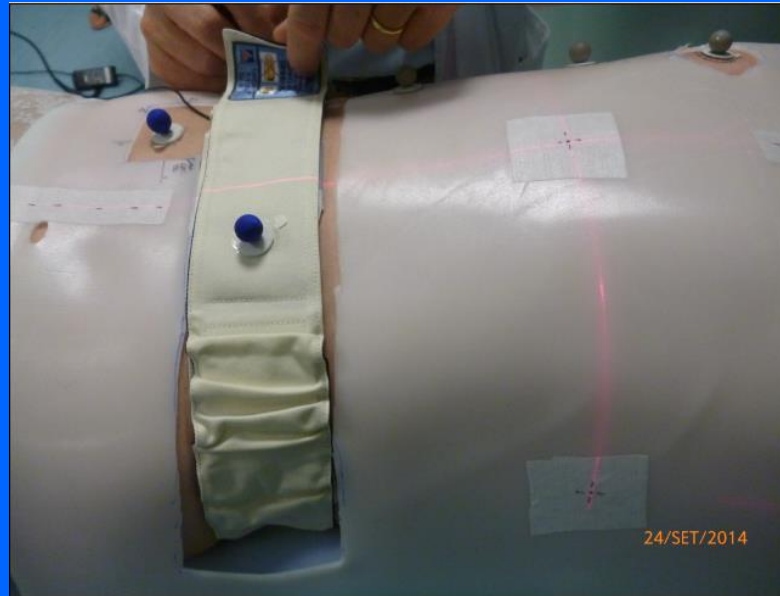
- 6 DOF Patient Positioning System (PPS)
 - X-ray patient Verification System (PVS)
 - 3D Real-time IR Optical Tracking (OTS)
-
- PPS and PVS systems designed and manufactured by Schaer Engineering AG (SEAG)
 - OTS system custom designed and developed by CNAO



Organ motion management

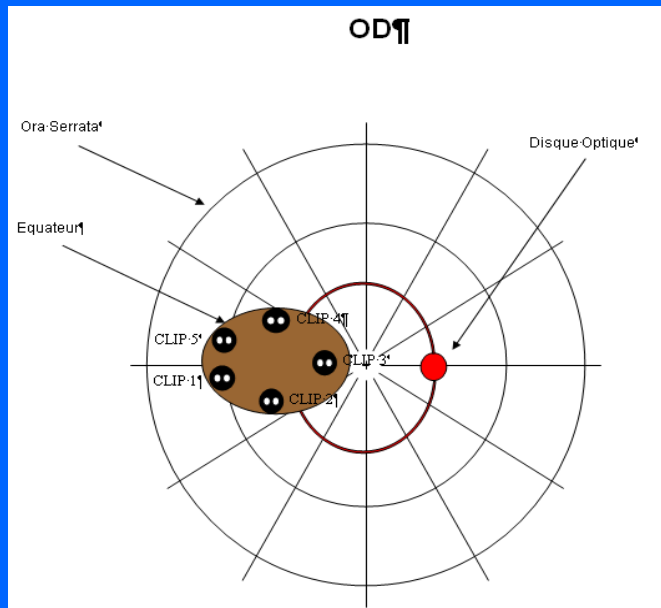
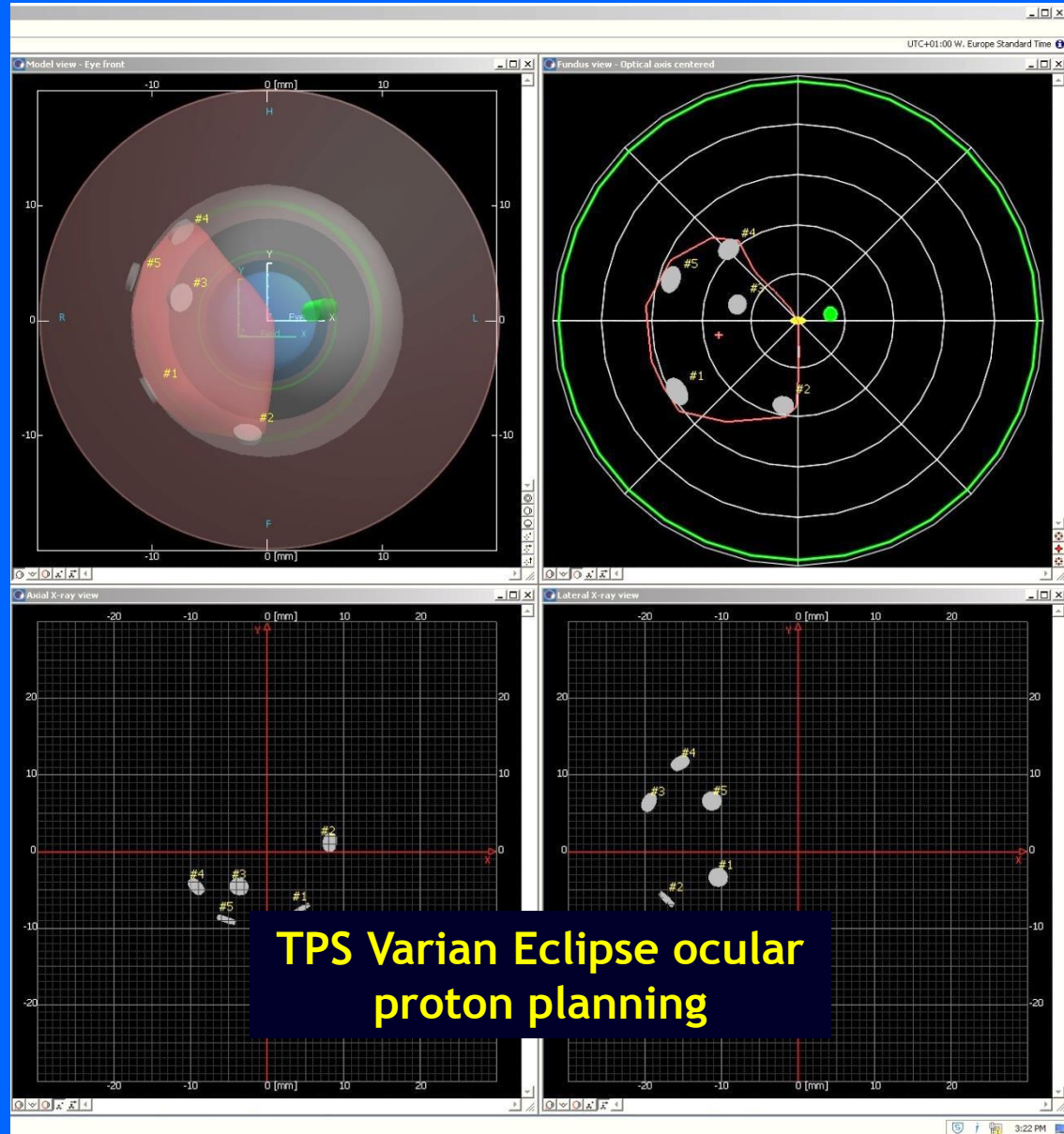
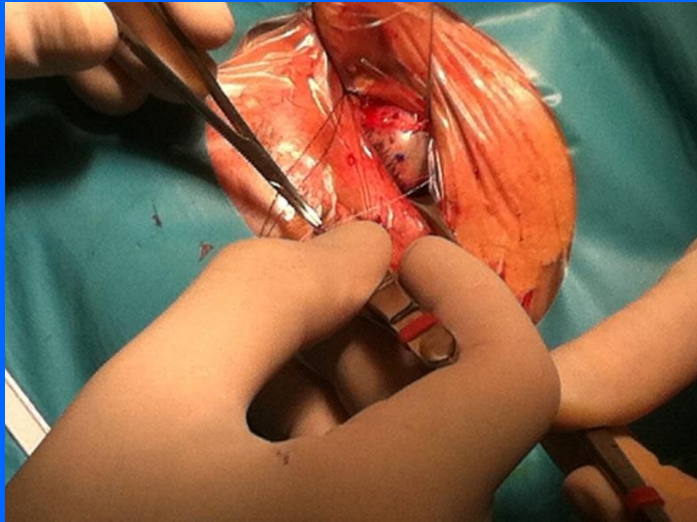


Moving organs: 4-D treatment strategies at CNAO

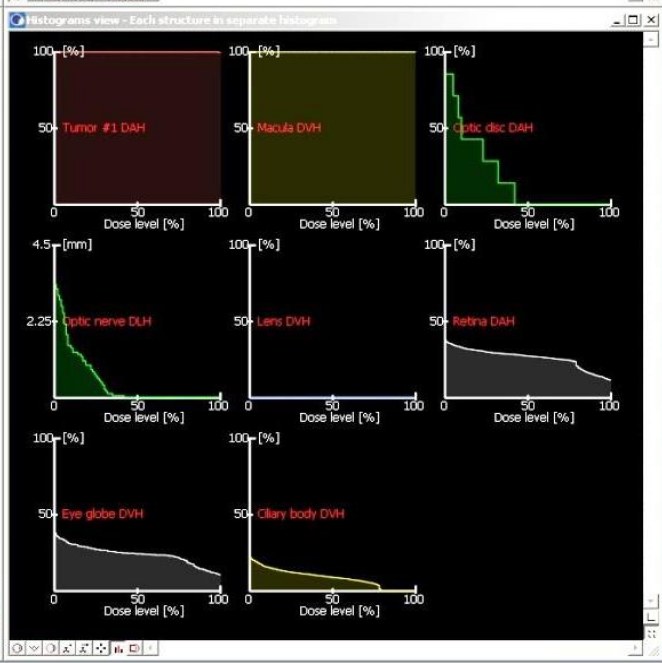
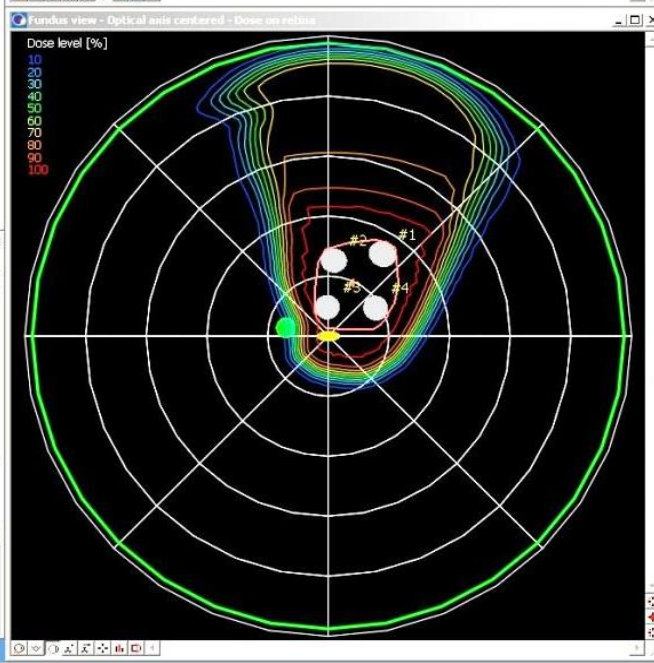
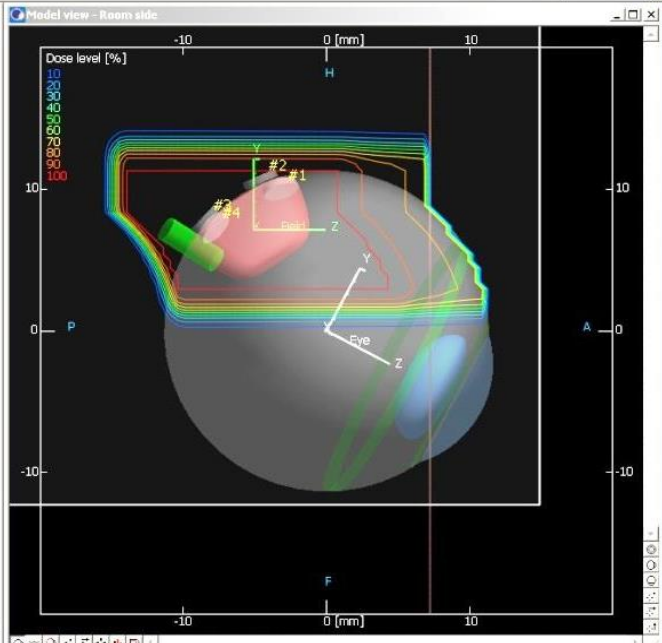
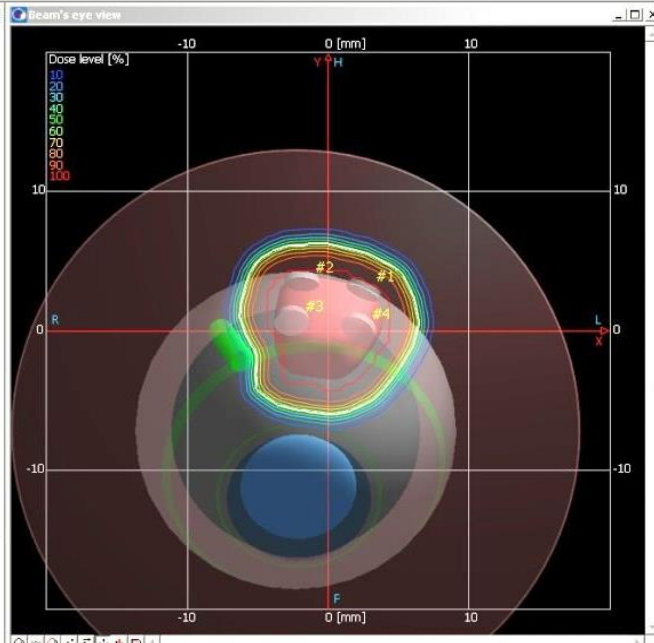


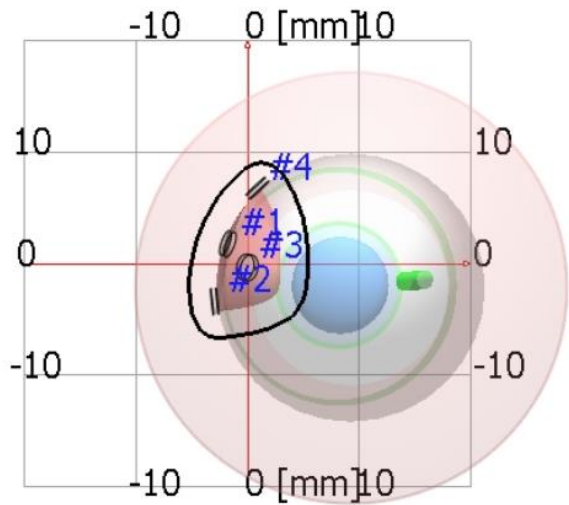
- Resp. motion reduction (down to 5 mm) using thermo-plastic mask or pneumatic compression belt
- Multiple beams (2-3) and multi-fractionation
- Gating (ref. phase: end-exhale; ANZAI system or OTS) plus rescanning (N=5)

Ocular treatments (proton beams)



TPS Varian Eclipse ocular proton planning





Individualized brass collimator (aperture)



INFN-Pavia workshop

23/FEB/2017

Treatment delivery



- ✓ 20 pts treated so far (since Aug 2016)
- ✓ about 3' delivery time
- ✓ 52 Gy (RBE) prescribed in 4 daily fractions

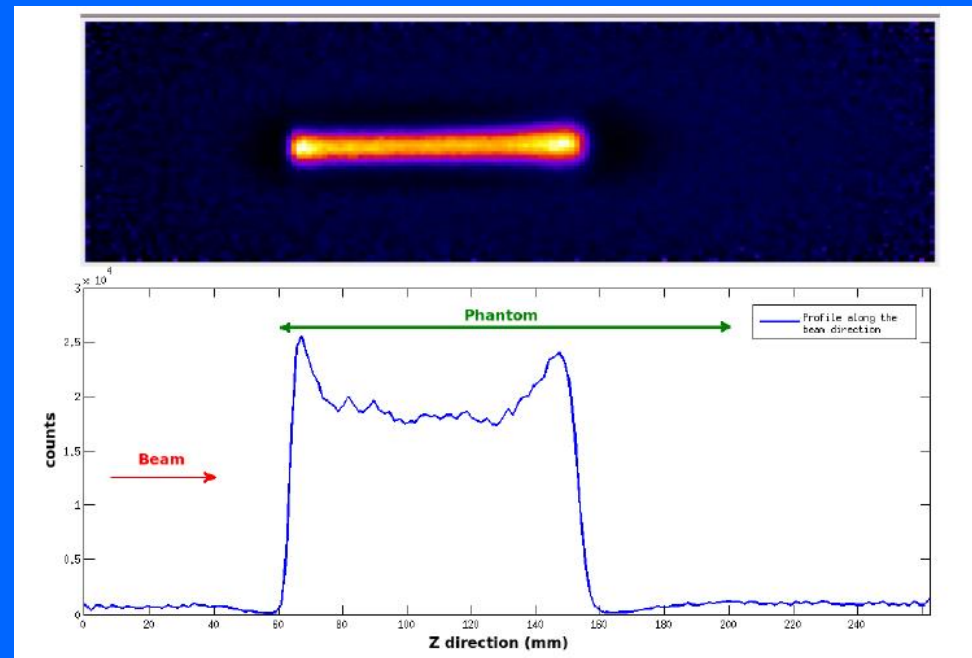
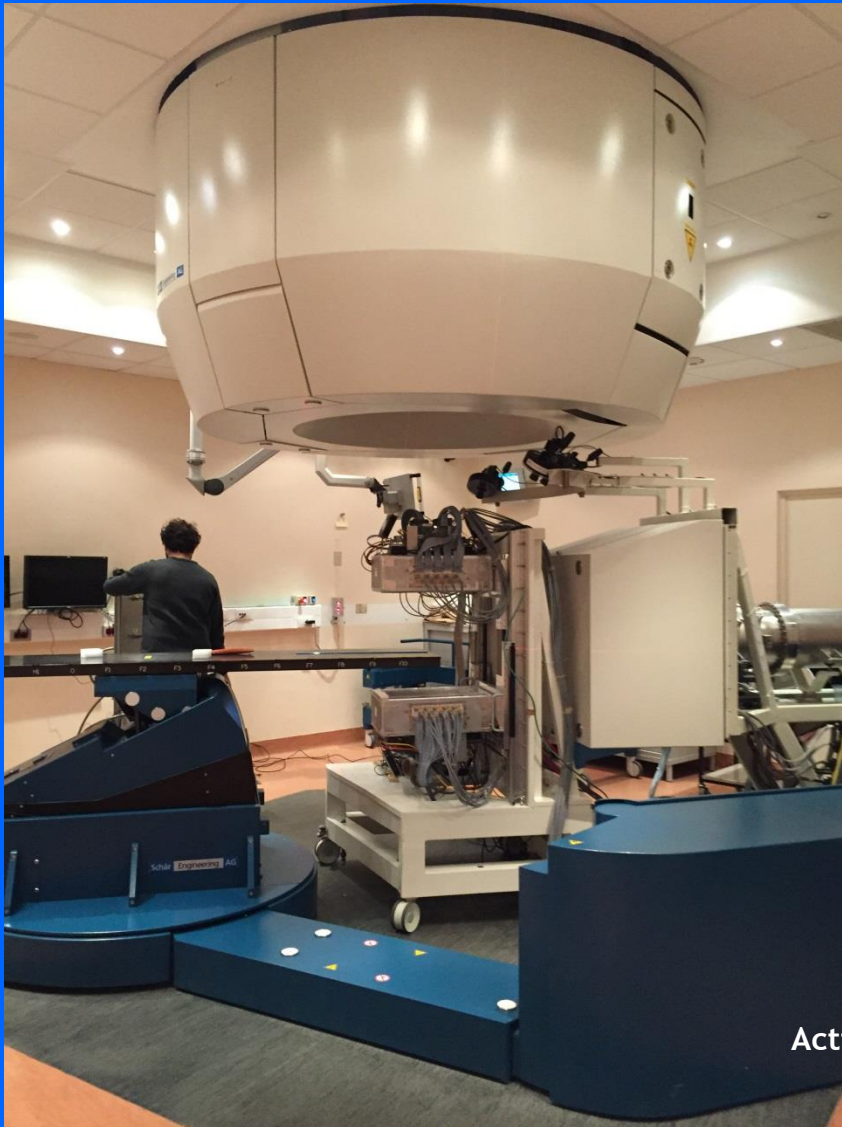
Medical Physics at CNAO: main research activities

- ✓ In-vivo range verification (INFN INSIDE project)
- ✓ GEMPix detector characterization for particle beam dosimetry and QA (CERN, INFN PV)
- ✓ Microdosimetry using mini-TEPC detectors (INFN Legnaro)
- ✓ FLUKA Monte Carlo simulations of real pt treatment plans from NIRS to allow RBE-weighted dose conversions for organs at risk (NIRS vs LEM I approach conversion study, phase 2, CNAO-NIRS-University of Bergen collaboration)
- ✓ DWI and DCE-MRI data acquisition in ACC pts for early treatment response evaluation (Univ. of Bergen, Norway)
- ✓ In-vitro radiobiology experiments: role of Etoposide B as a radiosensitizing agent to particle irradiation (INFN Milano)

Real-time in-vivo particle range verification

The INSIDE INFN project, in collaboration with CNAO

- ✓ In-beam PET (β^+)
- ✓ Dose profiler (prompt secondary particles detection)



Activation map (top) and z-profile (bottom) of a 124 MeV proton beam in a 49x49x140 mm³ PMMA phantom