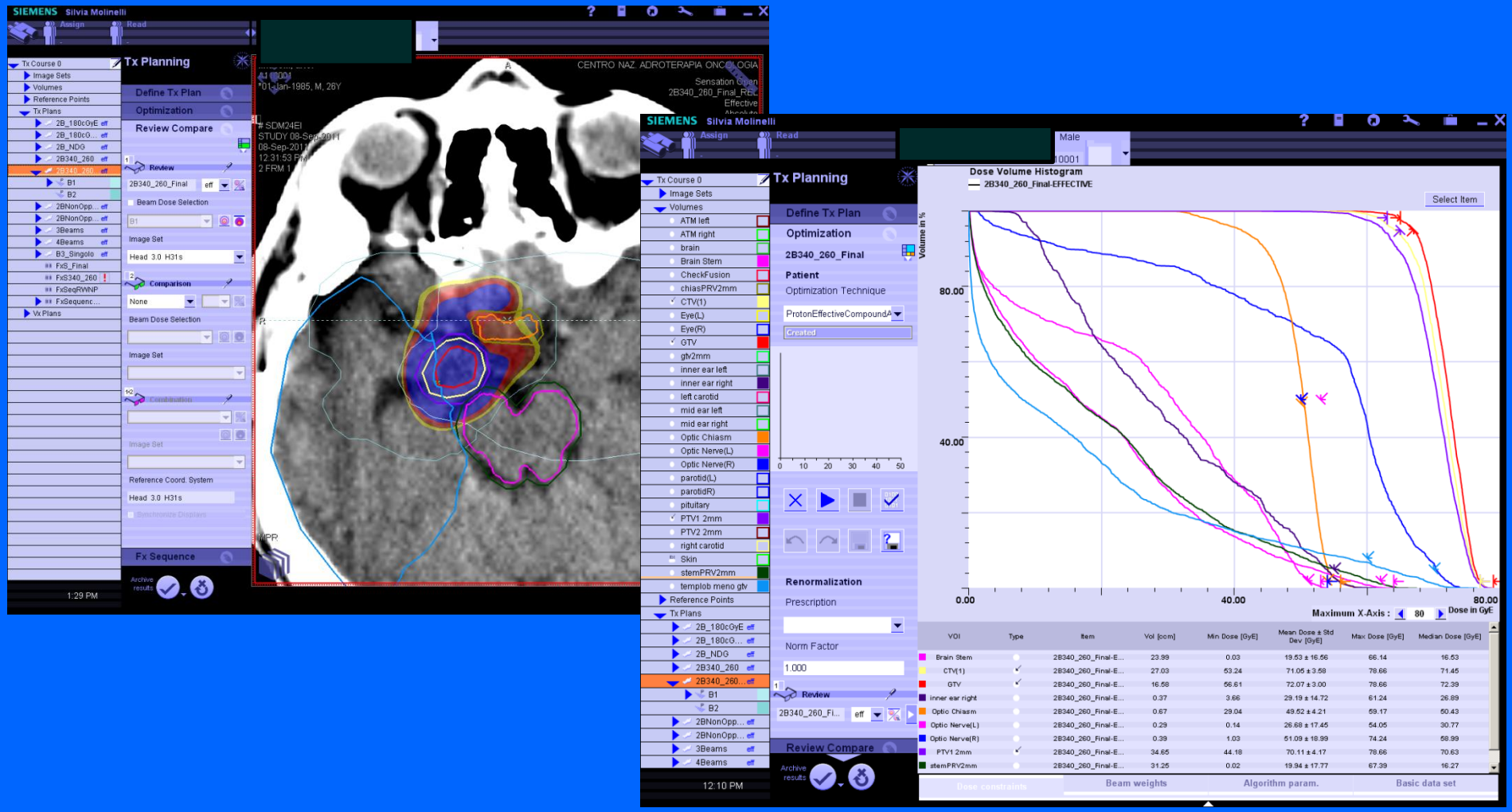
Medical Physics at CNAO

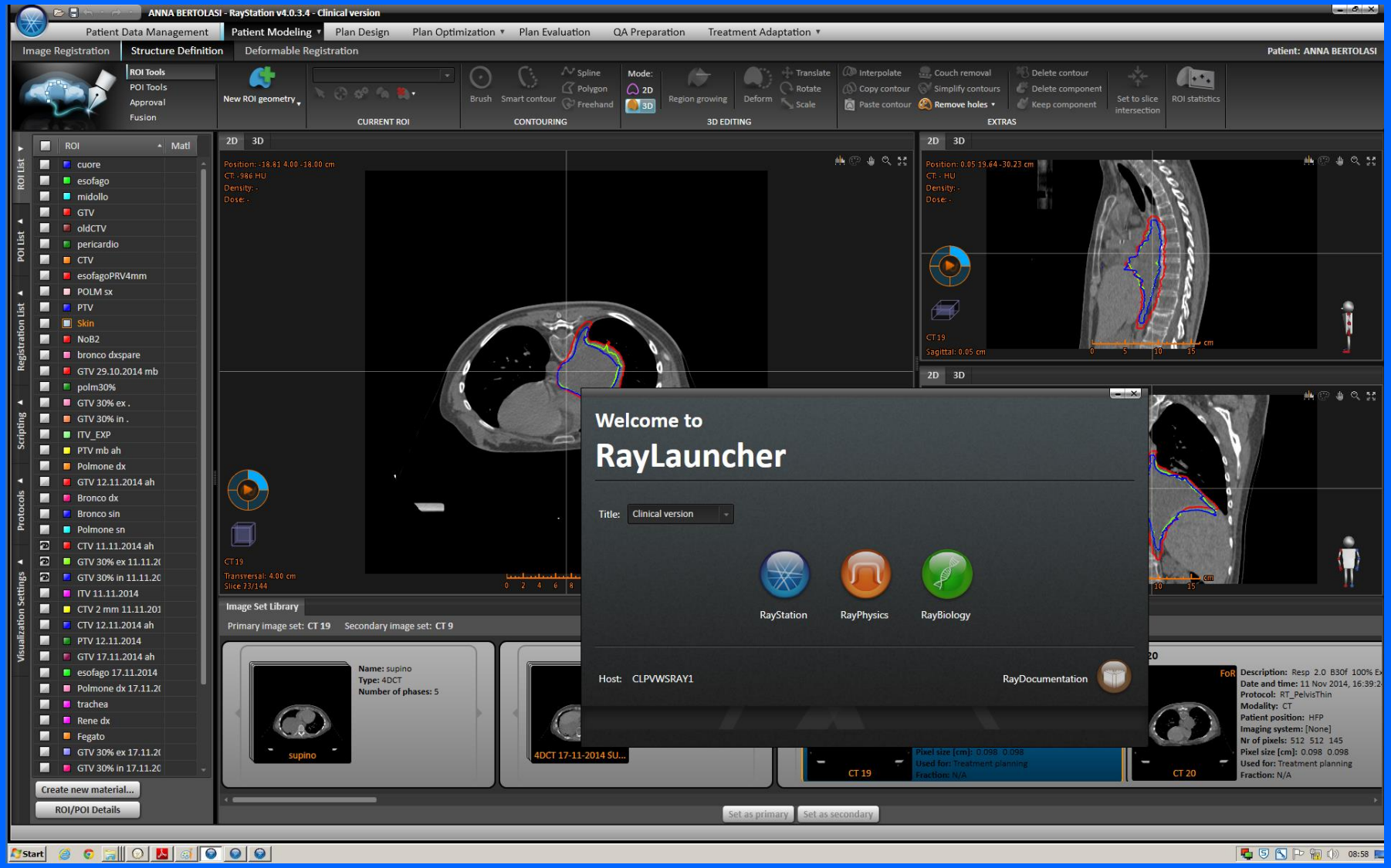
CNAO

Treatment planning

Siemens syngo RT planning, CE-mark



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



Beam commissioning and QA

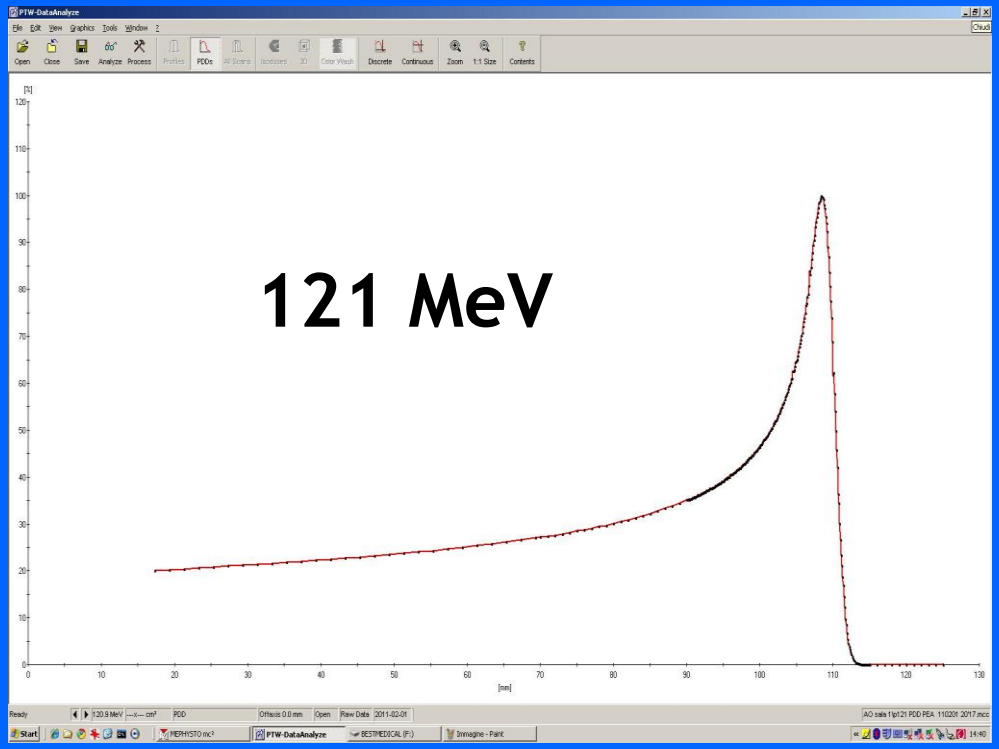
Physics basic beam data acquired:

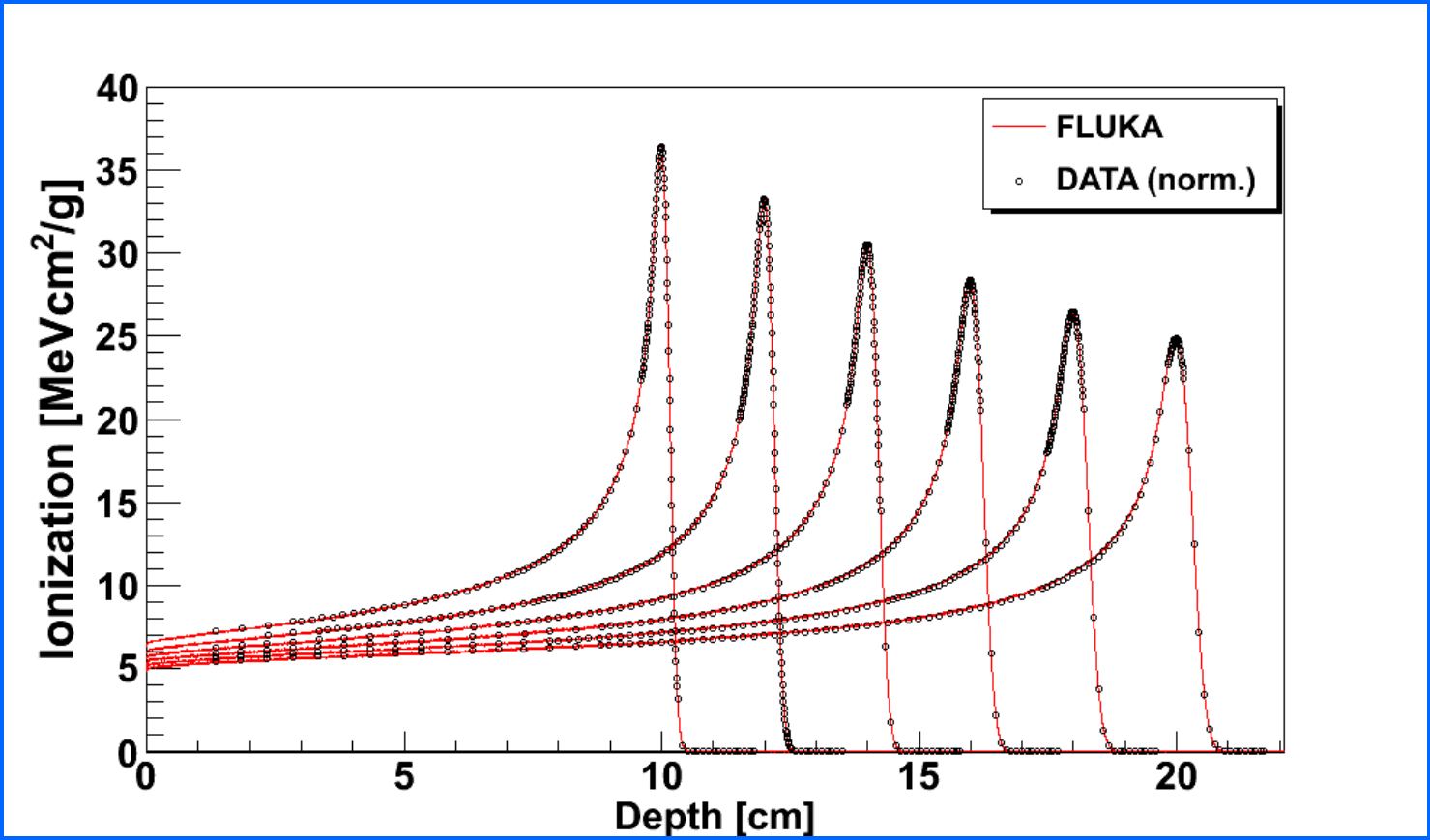
- experimentally
- Monte Carlo simulation (FLUKA code)

Experimental data

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

Peakfinder water column

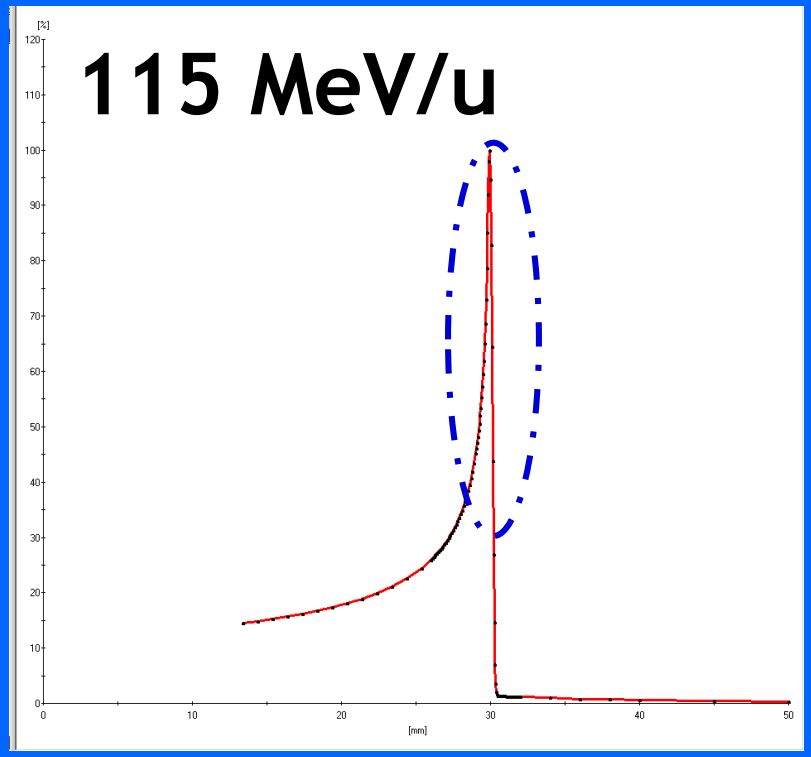


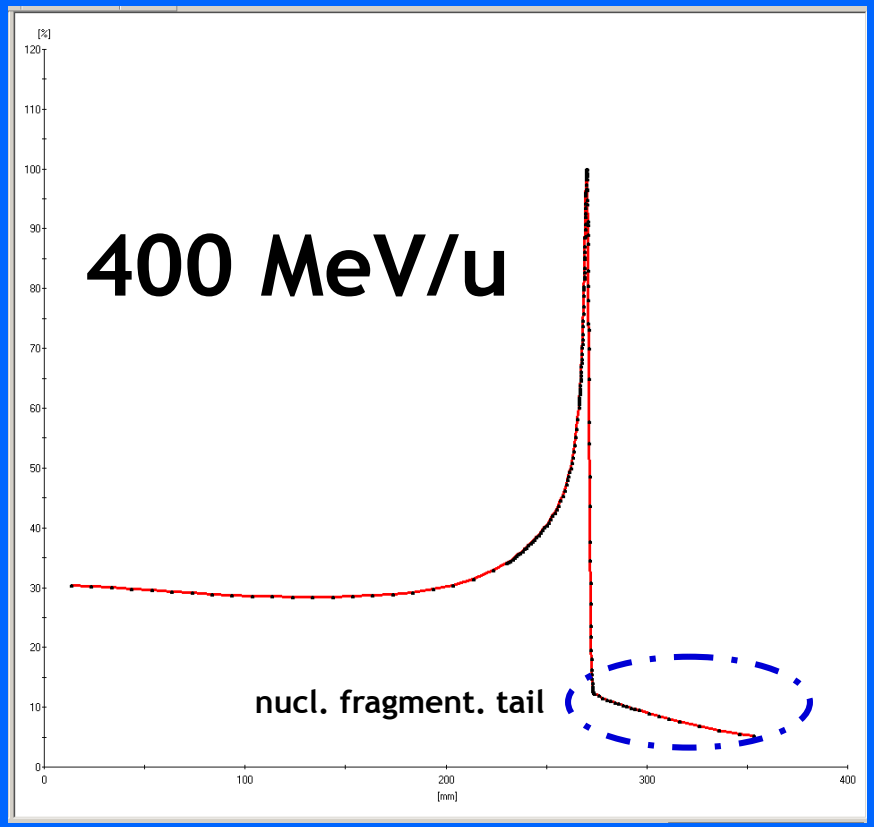


I_{pot} = 77 eV

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

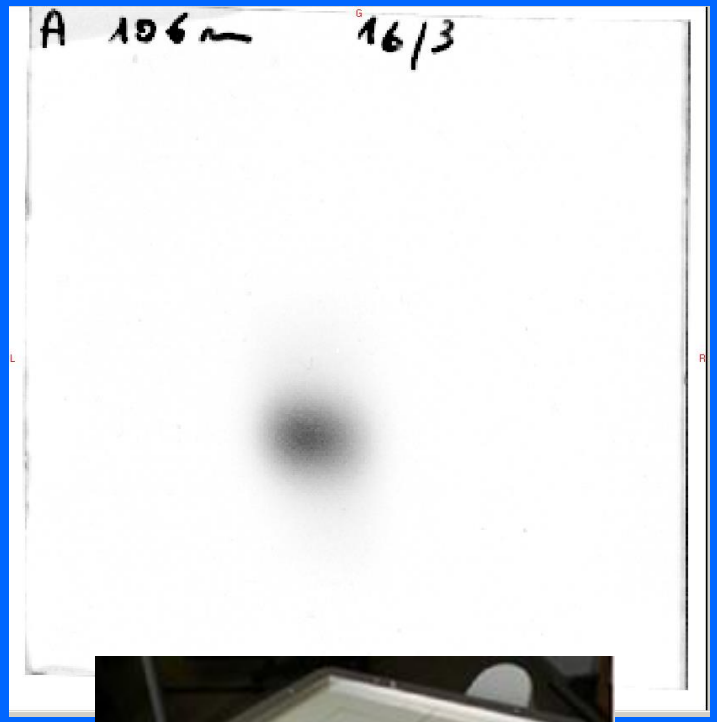
162 proton energies, 62.3-226.9 MeV/u (3-32 cm BP depth),
1-2 mm energy step

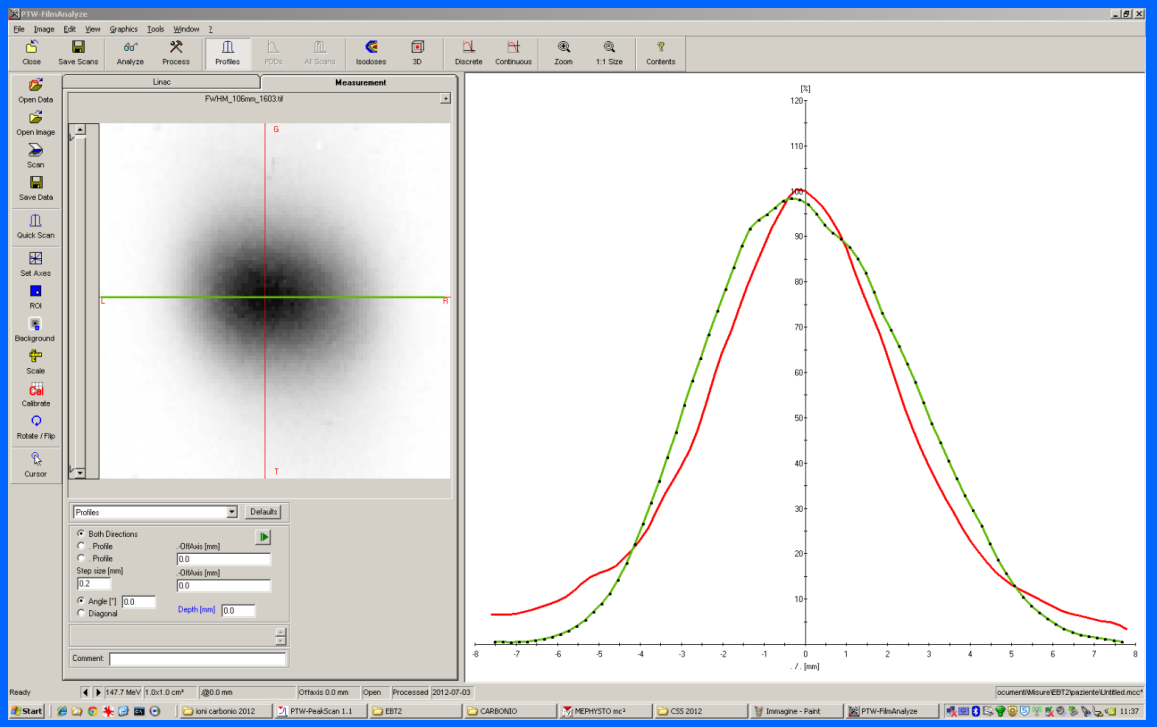




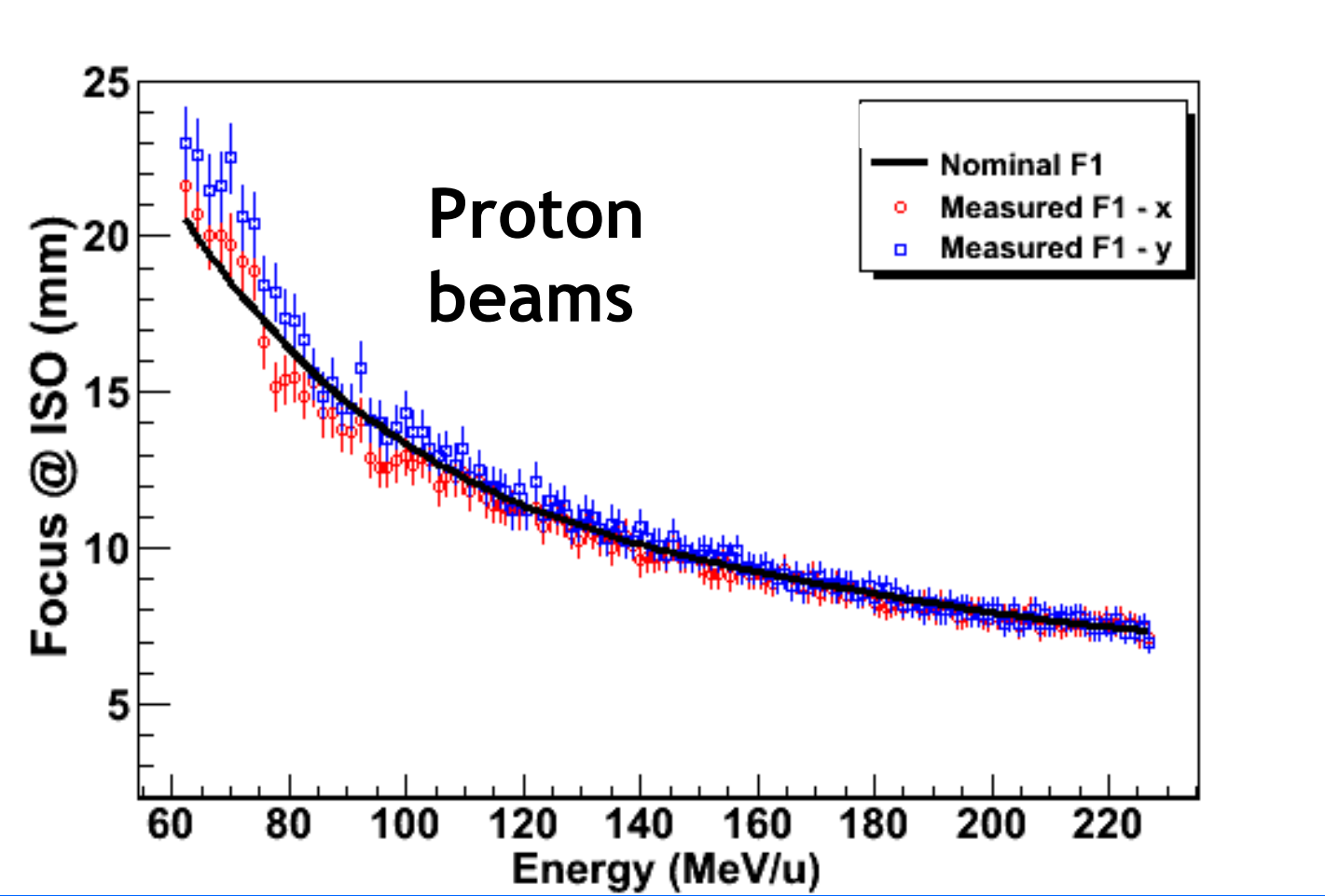
- 121 carbon ion energies, 115-400 MeV/u (3-27 cm), step 2 mm

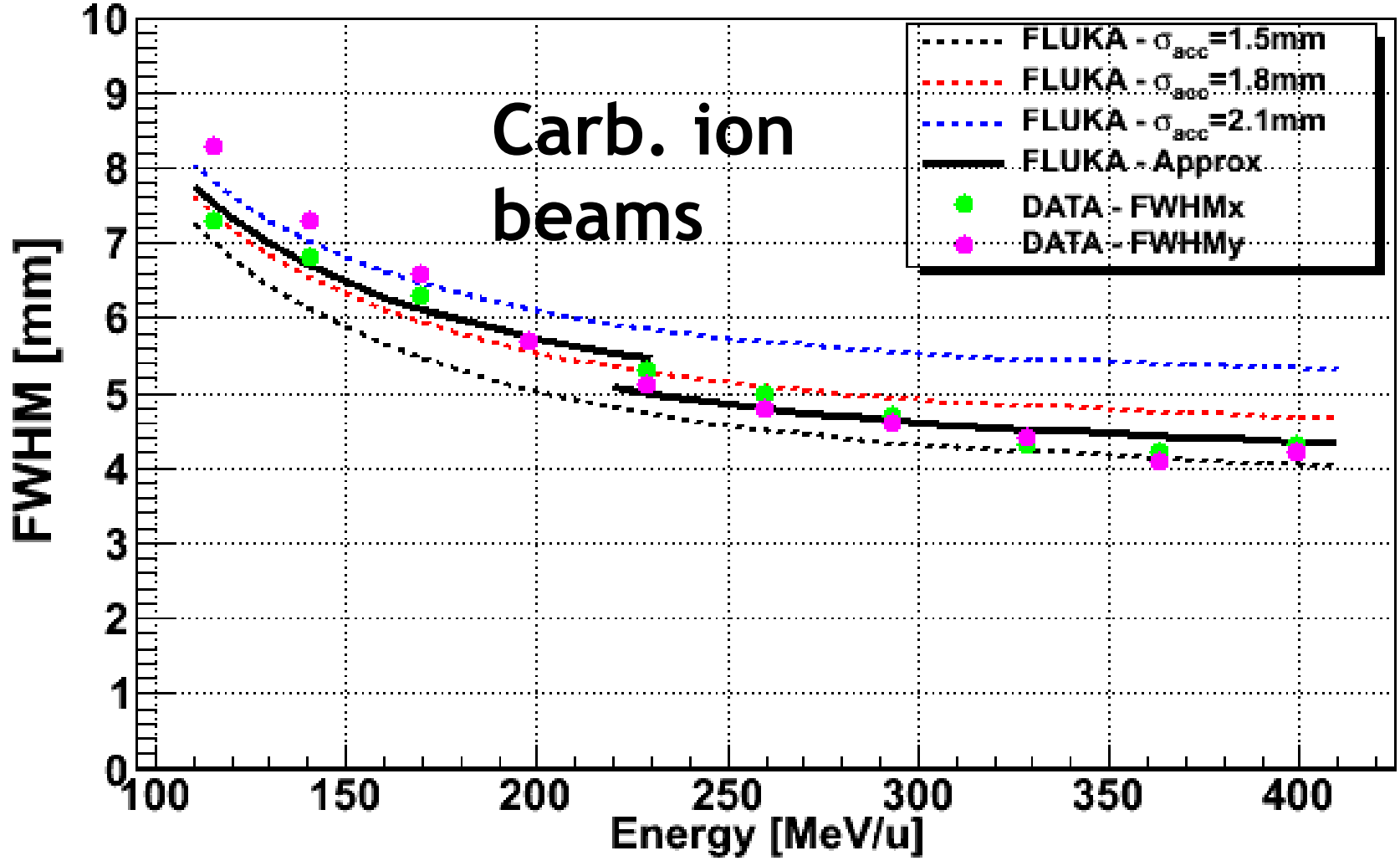
Transversal dose profiles in air





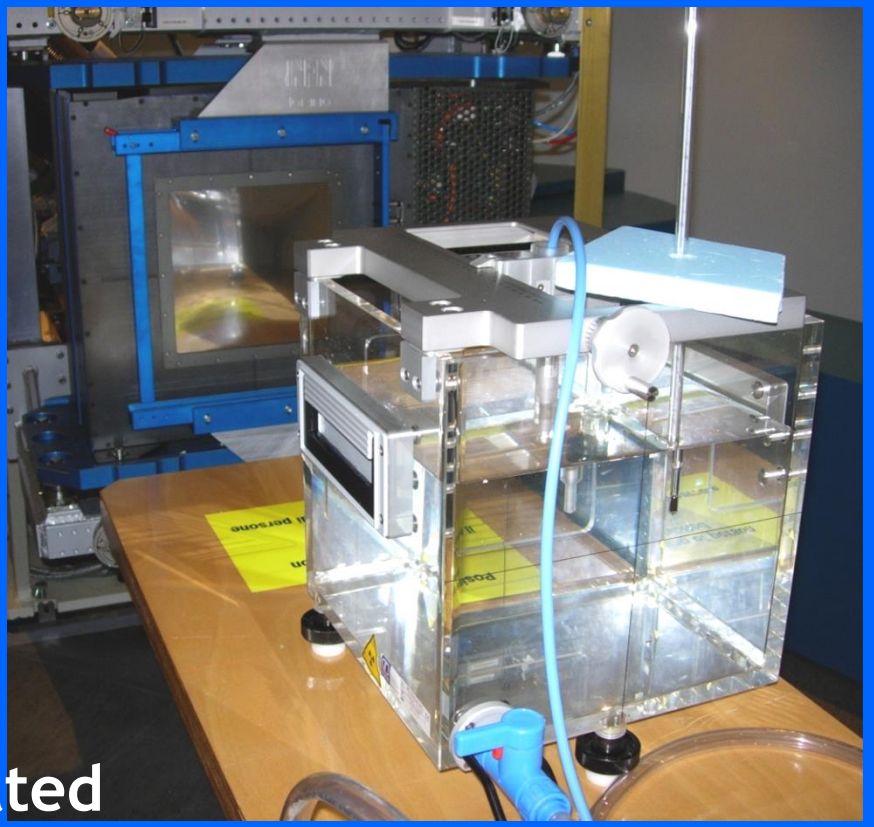
EBT3 radiochromic films




Carb. ion beams
FLUKA - σacc=1.5mm
FLUKA - σacc=1.8mm
FLUKA - σacc=2.1mm
FLUKA - Approx
DATA - FWHMx
DATA - FWHMy
FWHM [mm]
Energy [MeV/u]
0
1
2
3
4
5
6
7
8
9
10
100
150
200
250
300
350
400

Dose to water under ref. conditions

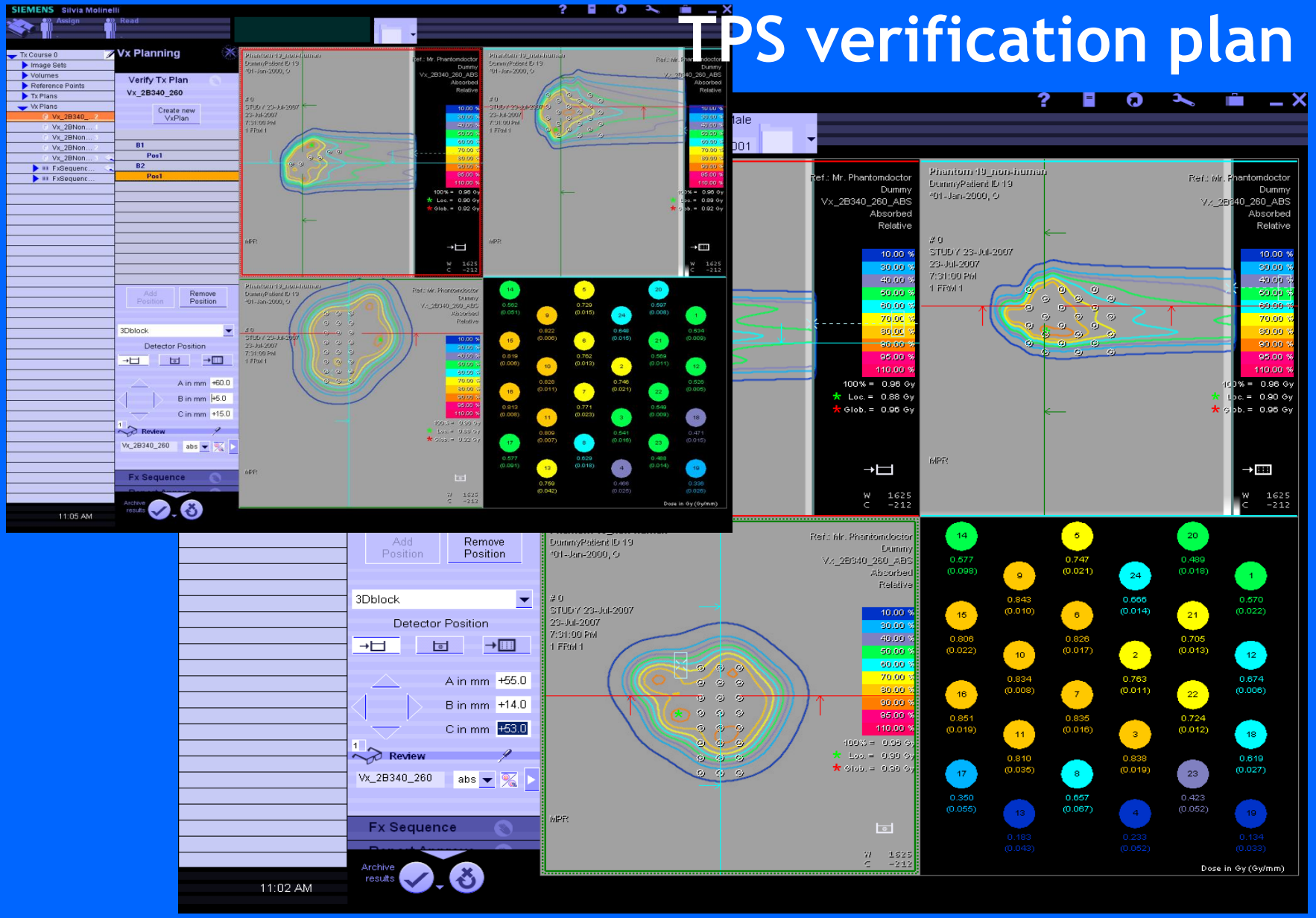
Based on IAEA TRS-398, 2000 + formalism Hartmann GH et al. (GSI, 1999)



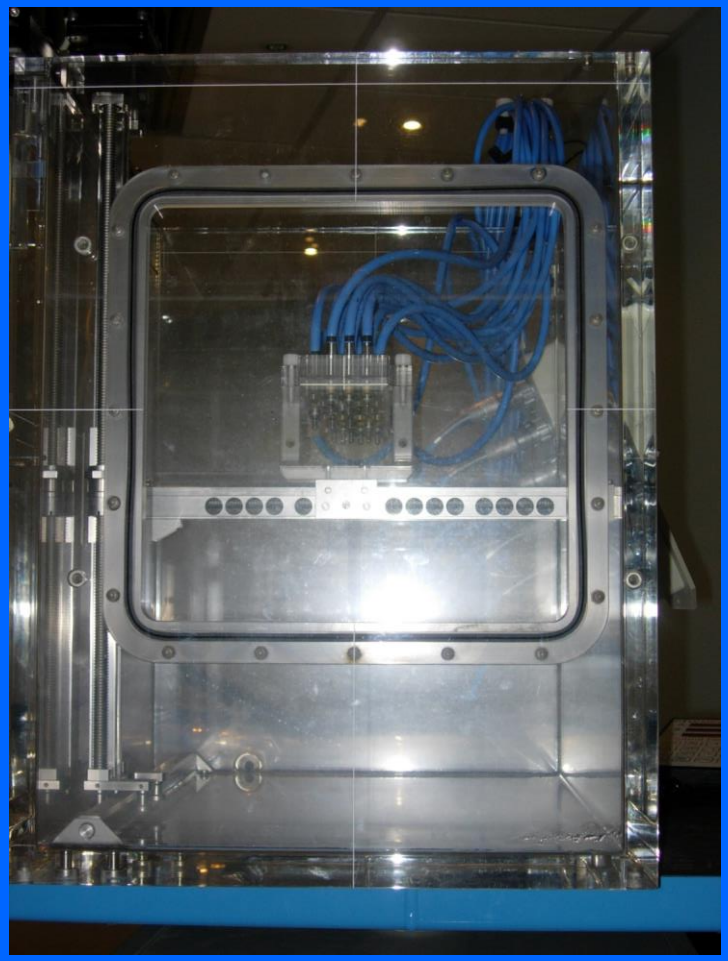
- Farmer-type IC, Co-60 calibrated
- At the isocentre, in the plateau region (2 cm), in water phantom
- Mono-energetic beams, different energies, 6x6 cm^2 homogeneous field
- Then, at middle SOBP (homogeneous cubic volumes) calculated by TPS

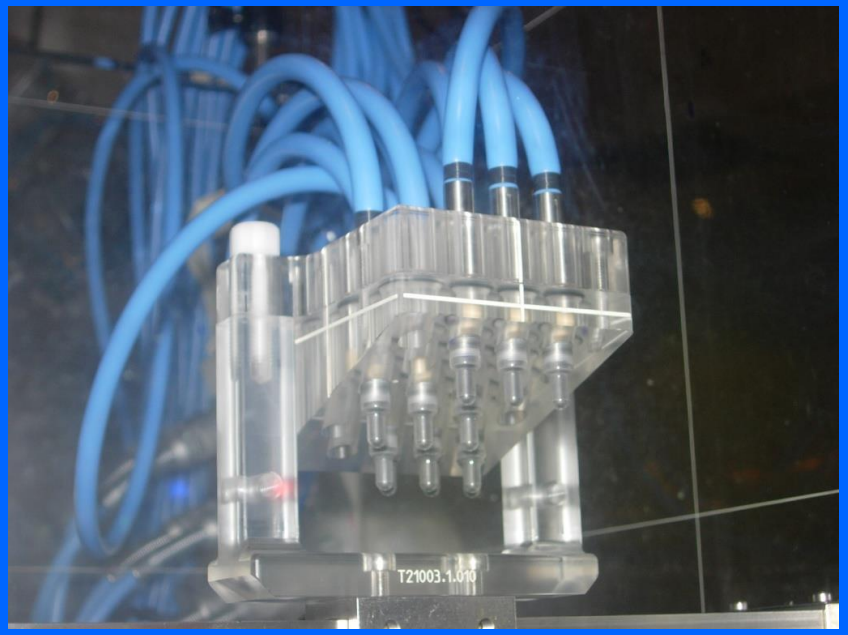
Pt-specific pre-treatment QA

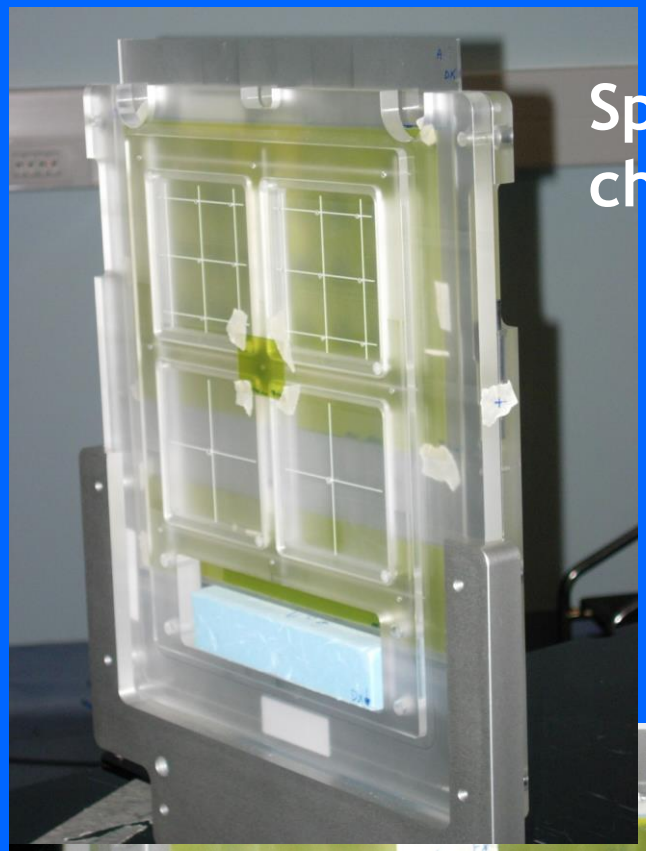
TPS verification plan



3-D block, multiple PinPoint chambers



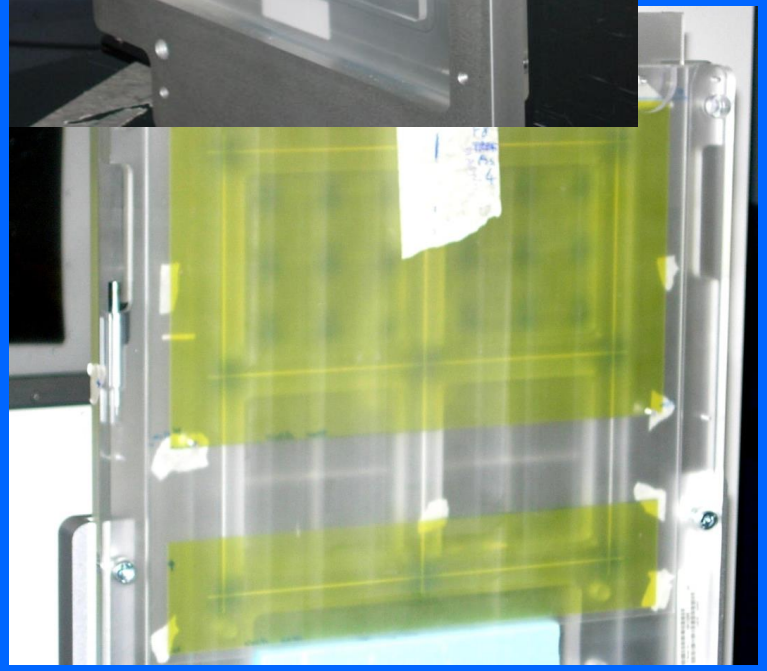




Spot position accuracy and size checks

Daily QA

EBT3 films

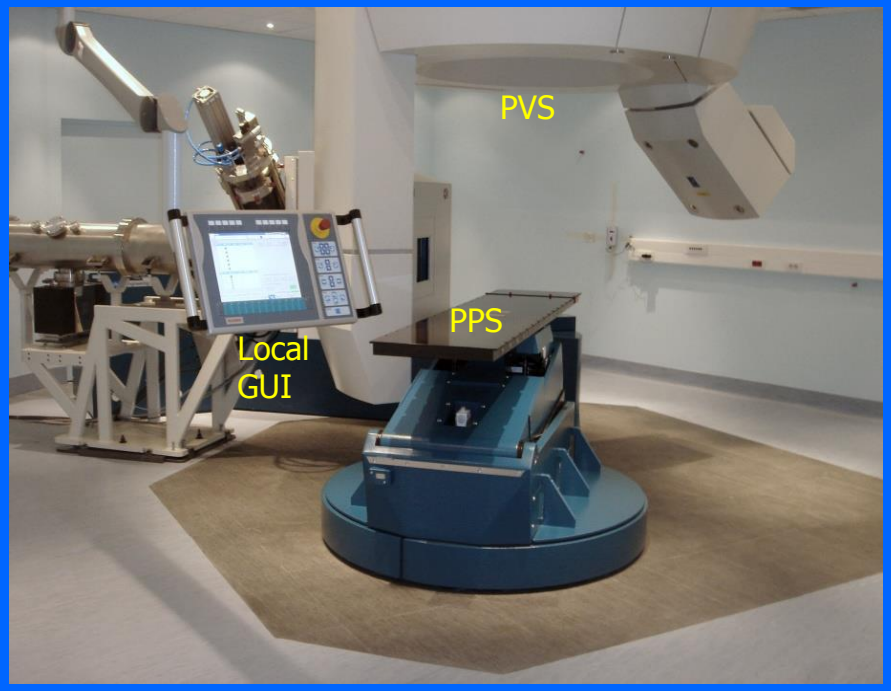


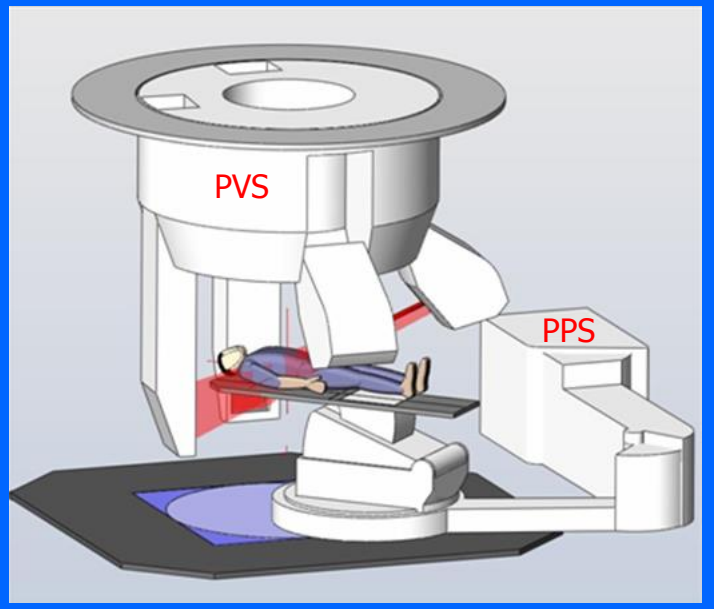
Beam energy constancy check

CNAO Integrated Systems for Patient Positioning and set-up Verification

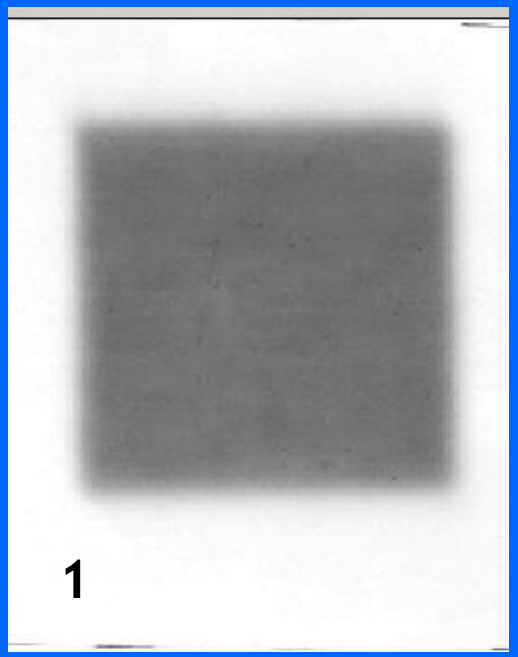
- ✓ **3 sub-systems:**
  - **6 DOF Patient Positioning System (PPS)**
  - **X-ray patient Verification System (PVS)**
  - **3D Real-time IR Optical Tracking (OTS)**

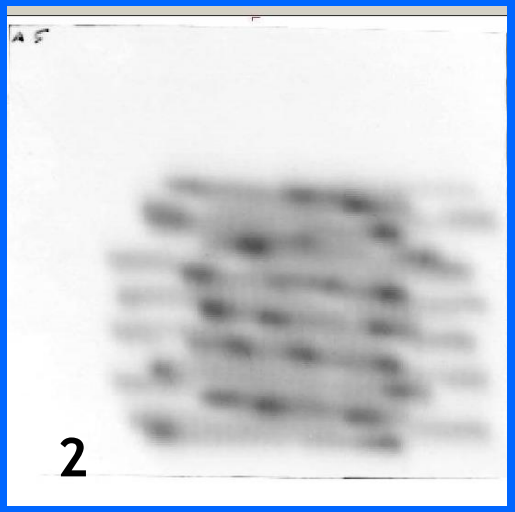
- **PPS and PVS systems designed and manufactured by Schaer Engineering AG (SEAG)**
- **OTS system custom designed and developed by CNAO**

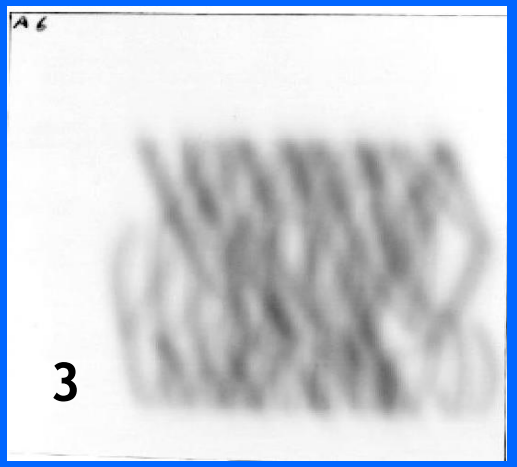


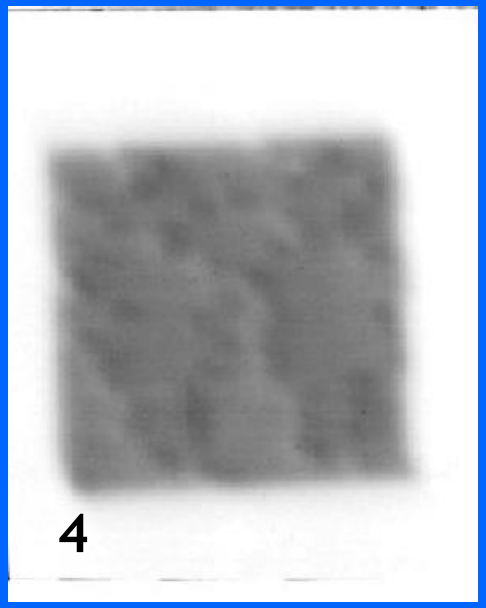


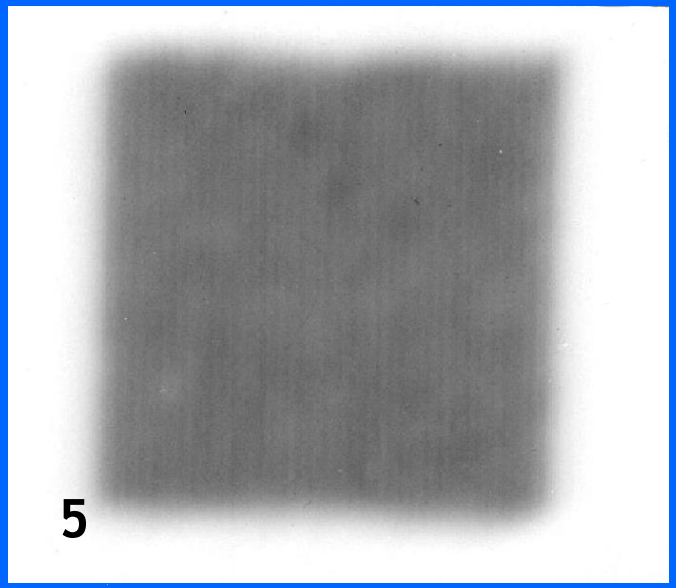
Organ motion management



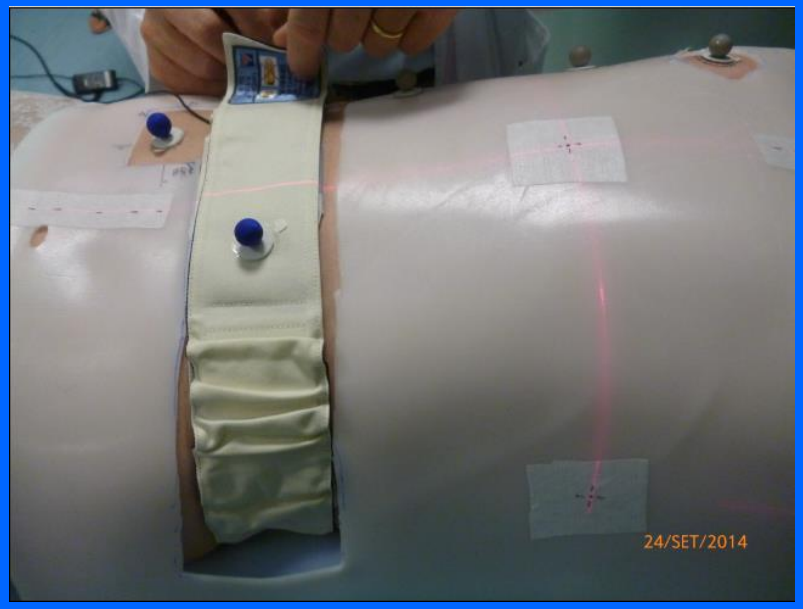






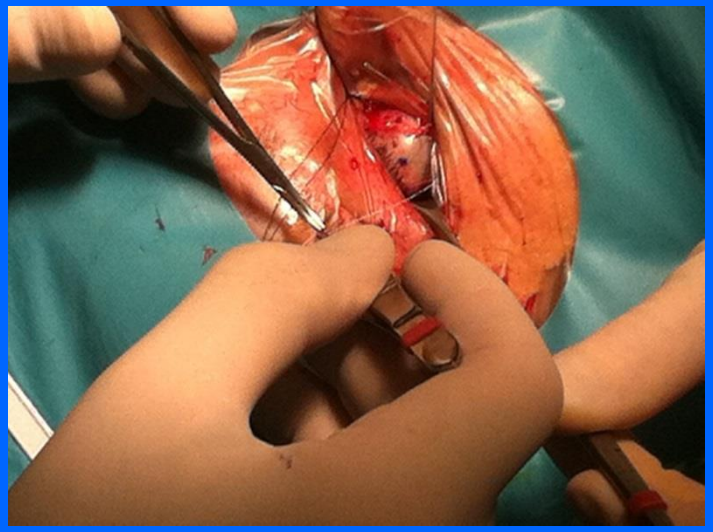


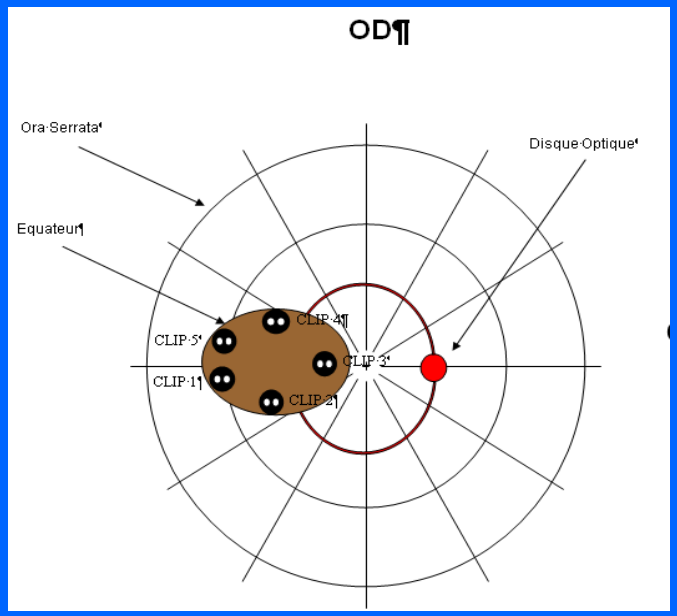
Moving organs: 4-D treatment strategies at CNAO

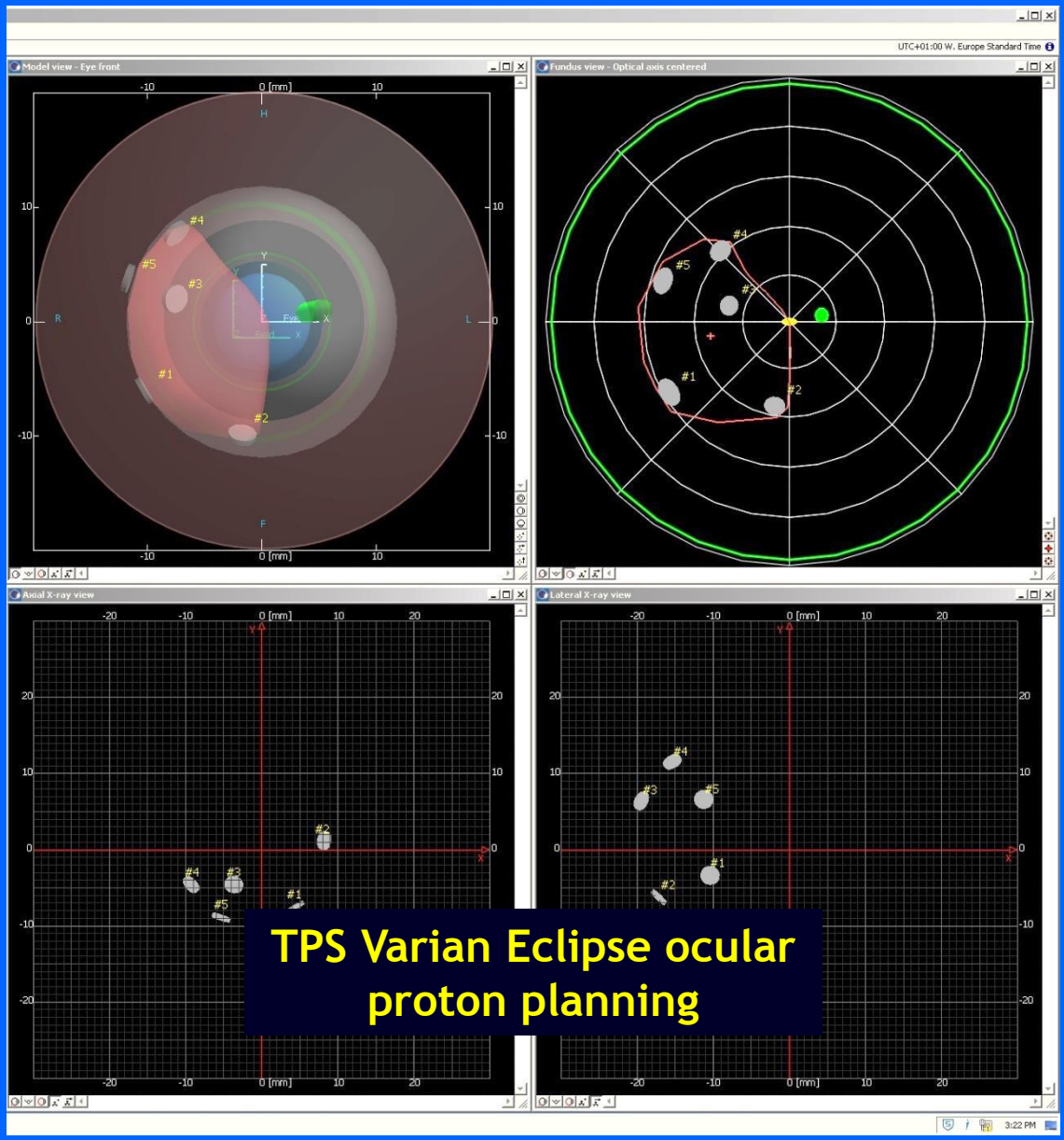


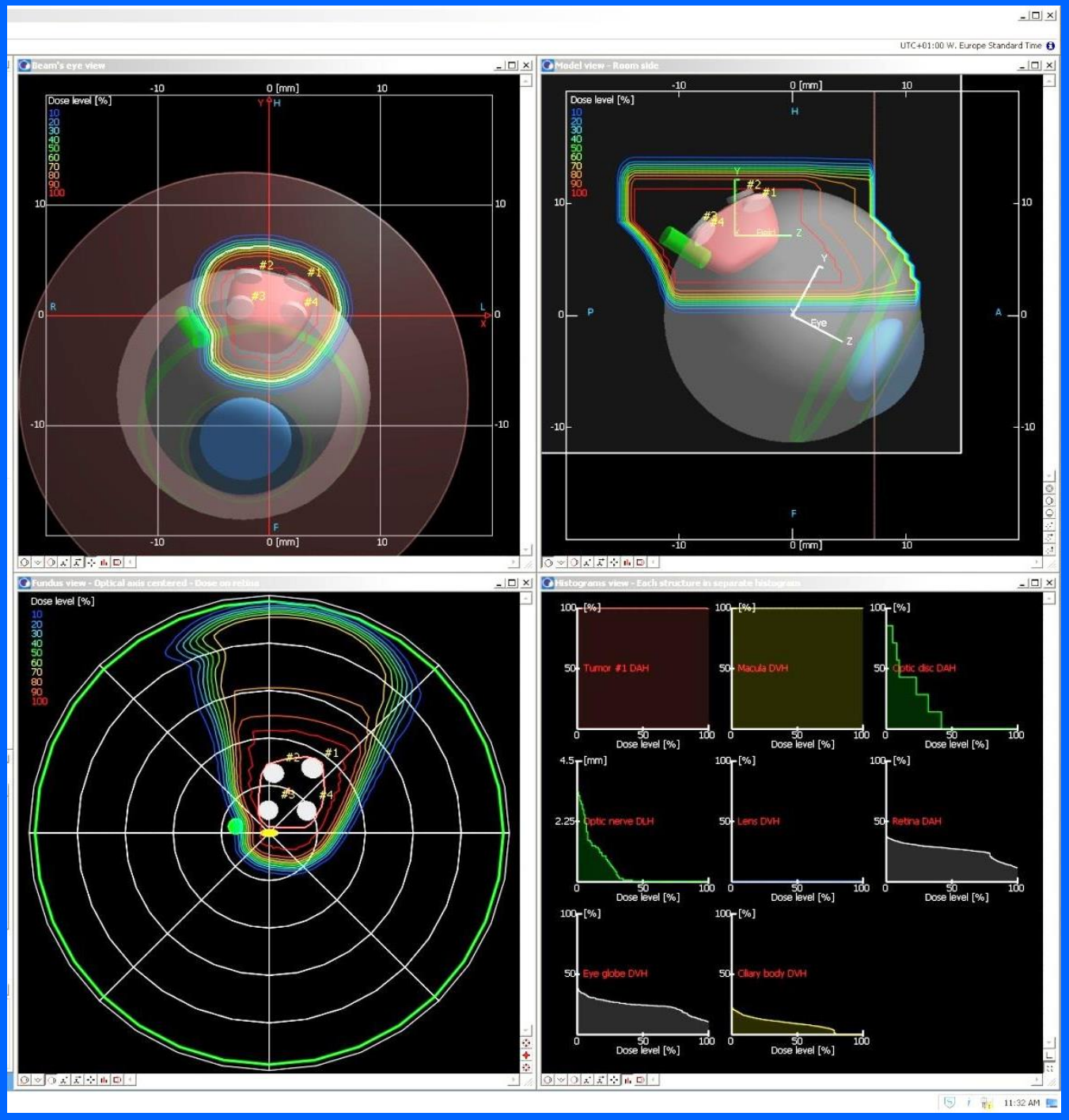
- Resp. motion reduction (down to 5 mm) using thermo-plastic mask or pneumatic compression belt
- Multiple beams (2-3) and multi-fractionation
- Gating (ref. phase: end-exhale; ANZAI system or OTS) plus rescanning (N=5)

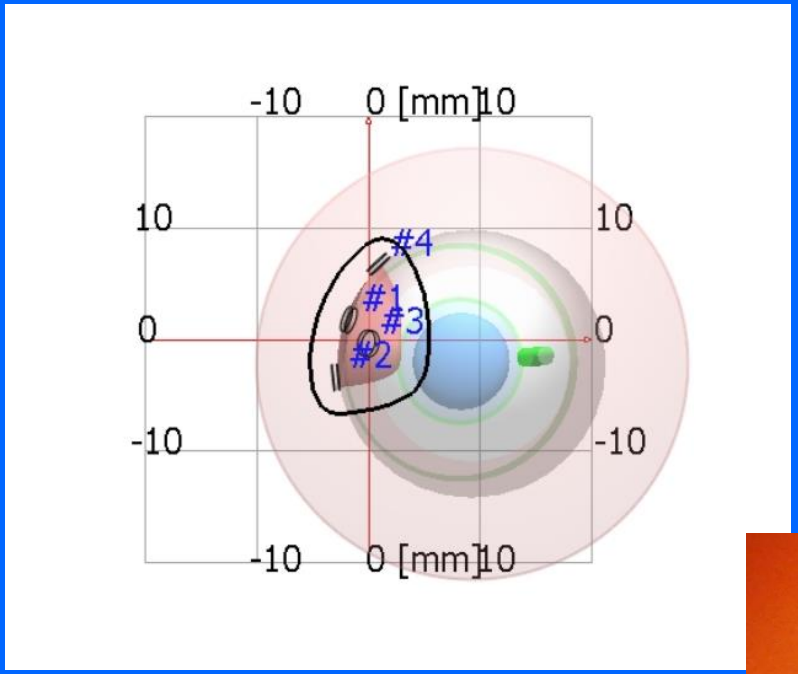
Ocular treatments (proton beams)







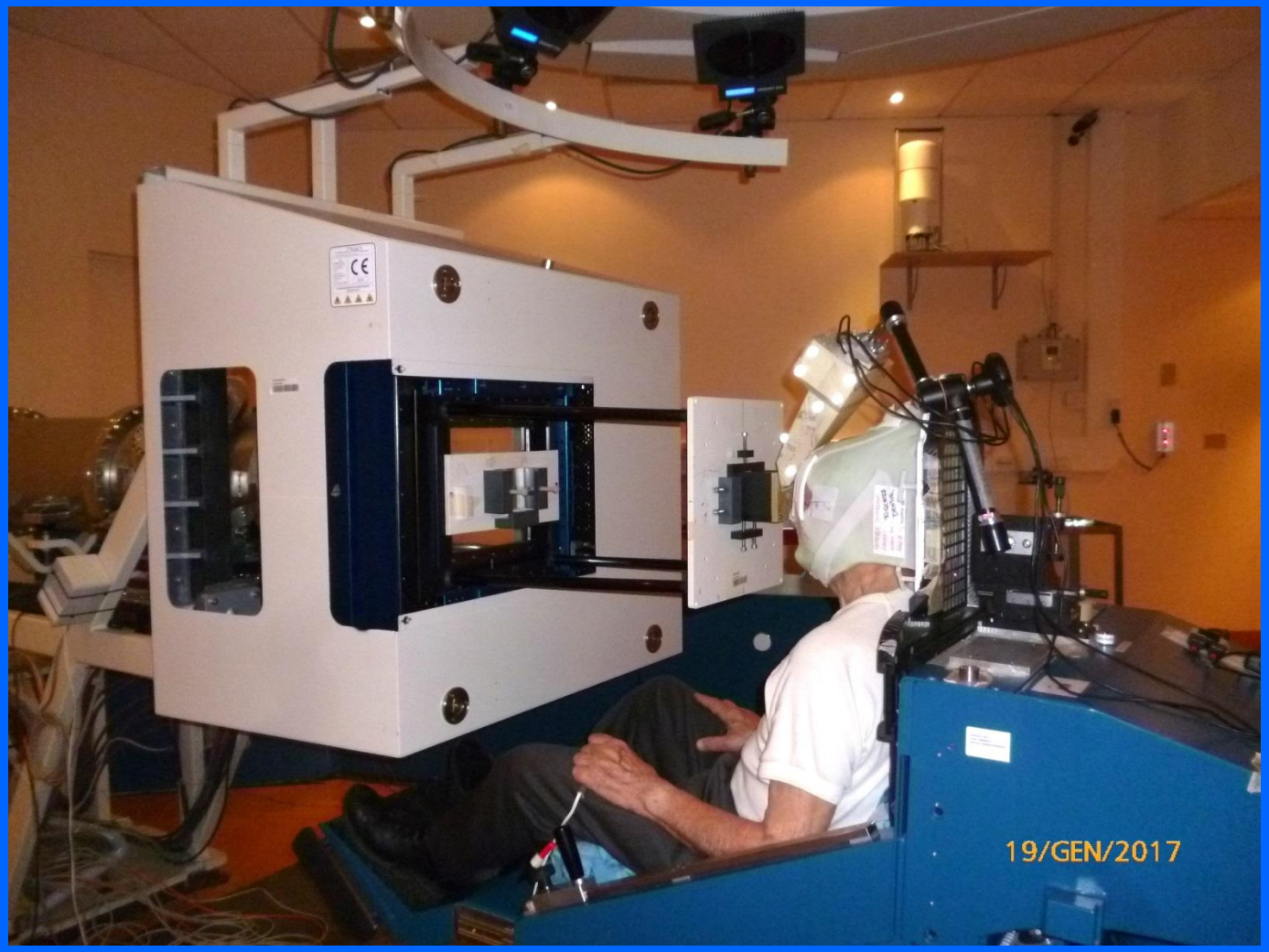

UTC+01:00 W. Europe Standard Time
Beam's eye view
Dose level [%]
10
20
30
40
50
60
70
80
90
100
-10
0 [mm]
10
H
F
R
L
#1
#2
#3
#4
Model view - Room side
P
A
Eye
Fundus view - Optical axis centered - Dose on retina
Histograms view - Each structure in separate histograms
Tumor #1 DAH
Macula DVH
Optic disc DAH
Optic nerve DLH
Lens DVH
Retina DAH
Eye globe DVH
Ciliary body DVH
[%]
[mm]
Dose level [%]
11:32 AM



Individualized brass collimator (aperture)

INFN-Pavia workshop

Treatment delivery

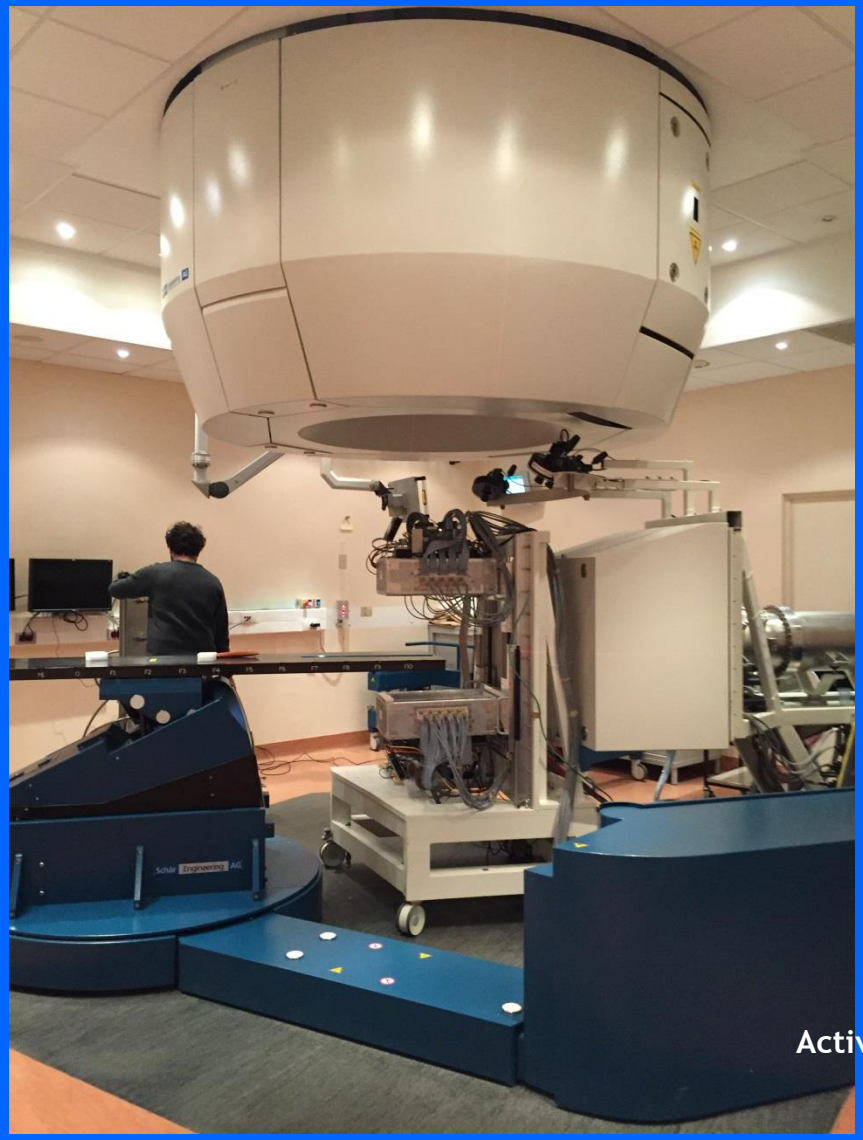


- ✓ 20 pts treated so far (since Aug 2016)
- ✓ about 3’ delivery time
- ✓ 52 Gy (RBE) prescribed in 4 daily fractions

Medical Physics at CNAO: main research activities

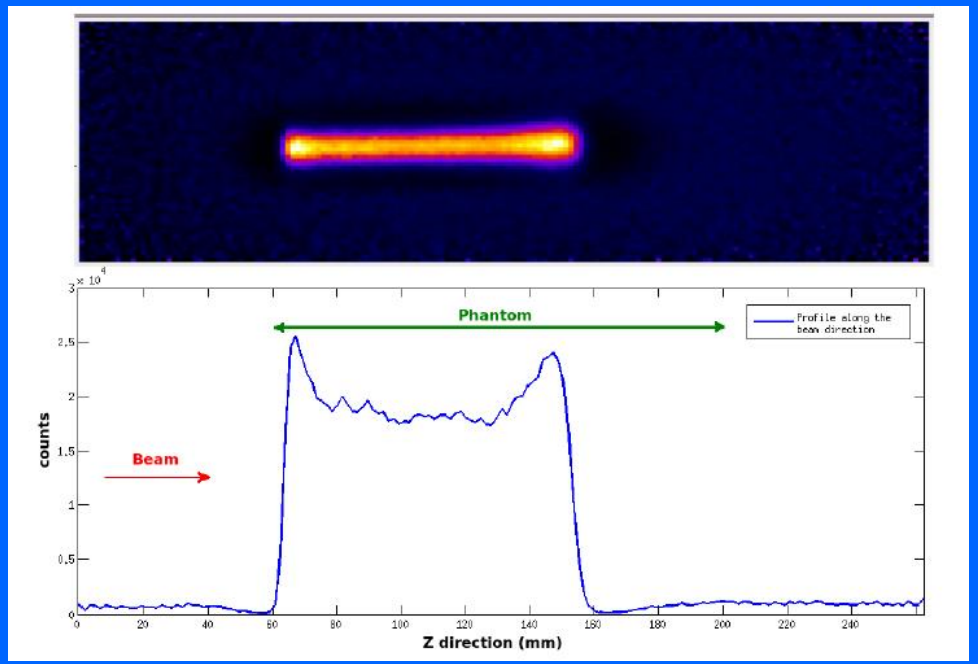
- ✓ In-vivo range verification (INFN INSIDE project)
- ✓ GEMPix detector characterization for particle beam dosimetry and QA (CERN, INFN PV)
- ✓ Microdosimetry using mini-TEPC detectors (INFN Legnaro)
- ✓ FLUKA Monte Carlo simulations of real pt treatment plans from NIRS to allow RBE-weighted dose conversions 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 Epothilone 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 mm^3 PMMA phantom