# Ocular treatments at CNAO

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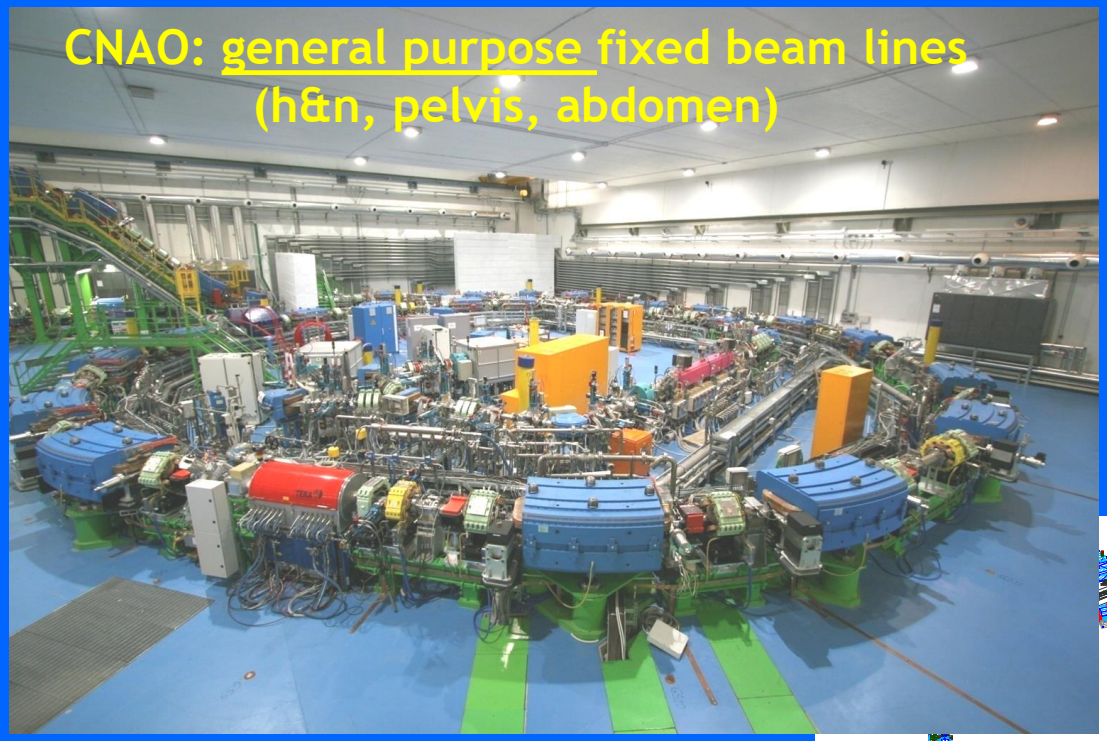
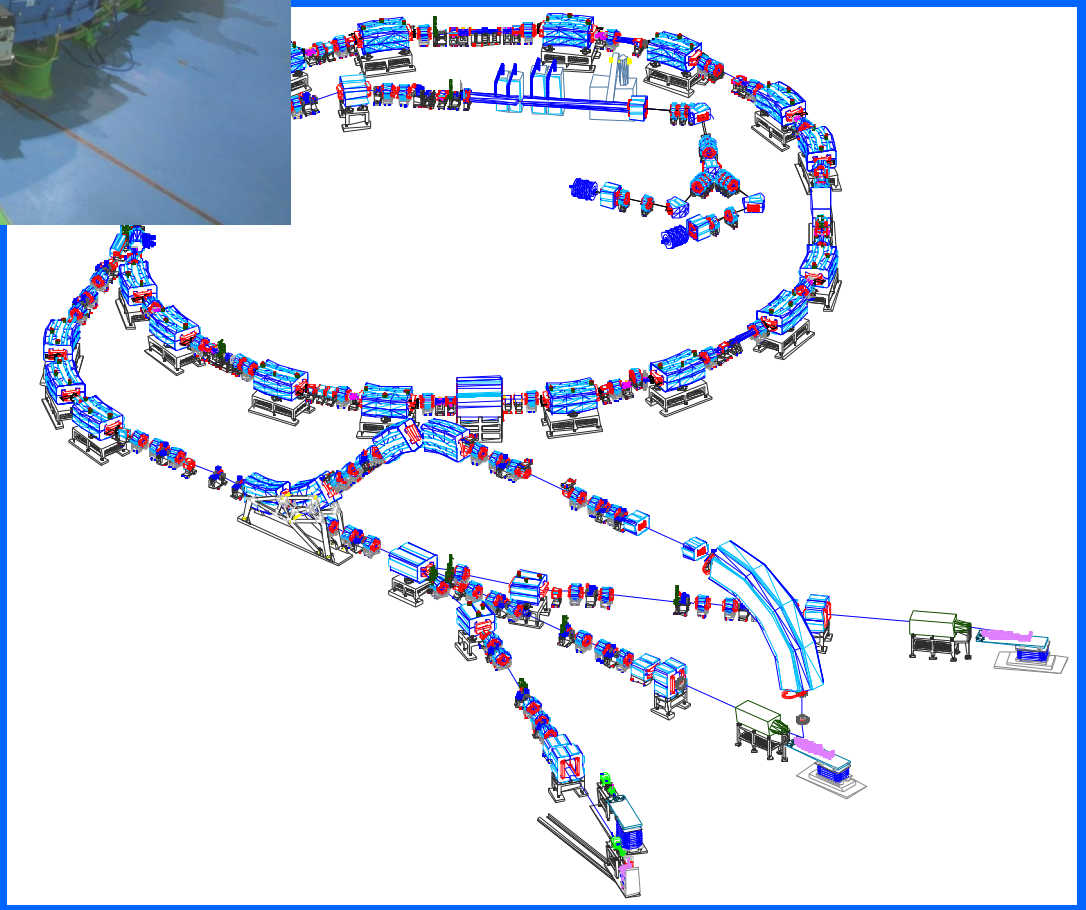
CNAO

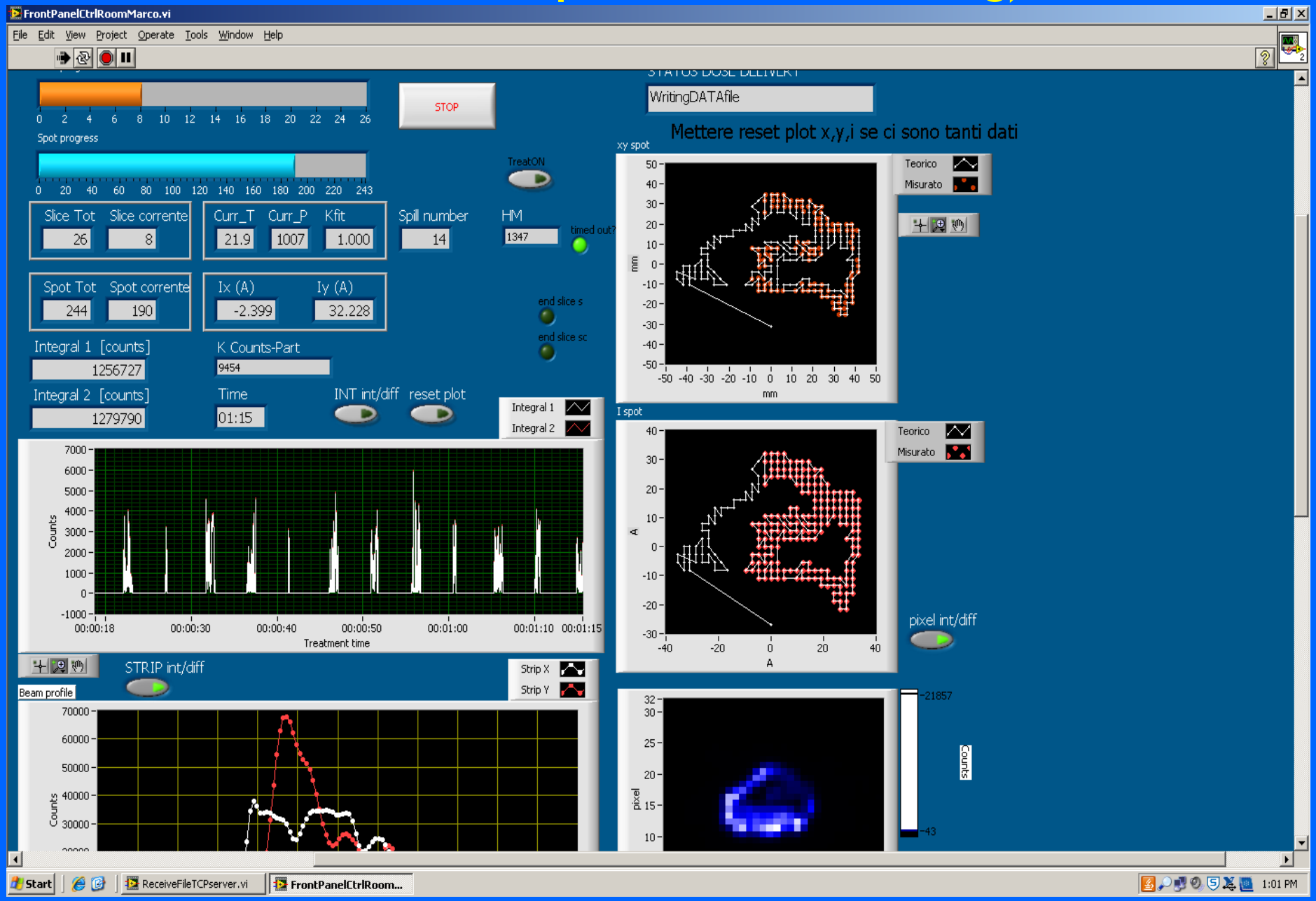
## CNAO: general purpose fixed beam lines (h&n, pelvis, abdomen)



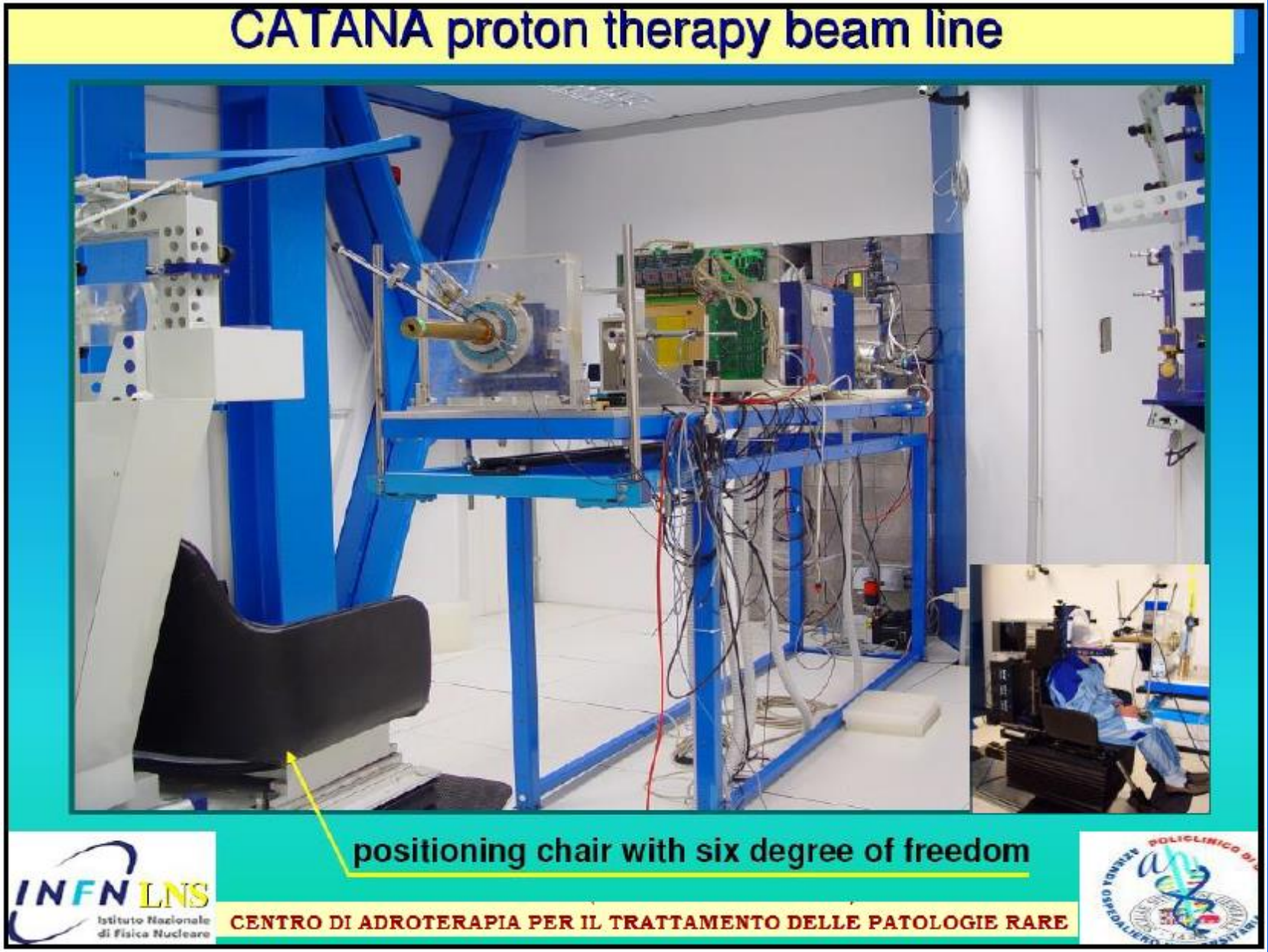
Treatment chair



# «*Only*» 3-D active system (synchrotron-based energy variation + pencil beam scanning)



# Ocular treatments: dedicated beam lines, cyclotron, passive scattering, pt-specific aperture (brass collimator)



Ocular melanoma in Italy: protontherapy at INFN- LNS CATANA, about 100 pts/yr sent abroad (Nice, …)

Collaboration started with Galliera H. in Genova (Dr. C. Mosci, oncol. opht.)

**Existing beam line adaptation to eye-specific requirements:**

- ✓ Monte Carlo simulations (FLUKA)
- ✓ Experimental dosimetry (EBT3 film)

TABLE III. Comparison of the proton energy, at accelerator exit and at room entry, and distal fall-off (90%–10%) and lateral penumbra (80%–20%) at several proton-therapy eye centers. Data reproduced by permission from Kacperek, *Ion Beam Therapy: Fundamentals, Technology, Clinical Applications*. Copyright 2011 Springer (Ref. 32) except for LLUMC (Ref. 17) and UFPTI data (this paper).

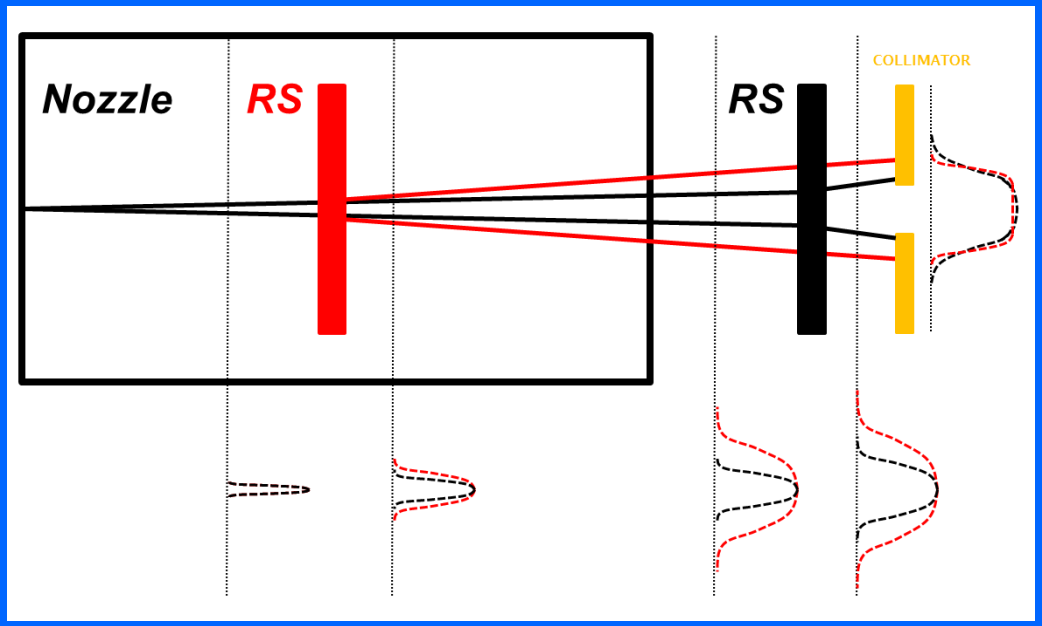
| Institution | Acc. energy (MeV) | Room energy (MeV) | Distal fall-off (mm) | Lateral penumbra (mm) |
|---|---|---|---|---|
| UFPTI, Jacksonville, FL | 230 | 105 | 3.2 | 1.1 |
| CAL, Nice, France | 65 | 65 | 1.0 | 1.4 |
| CCO, Wirral, UK | 62.5 | 62 | 0.9 | 1.1 |
| CPO, Orsay, France | 200 | 76 | 2.3 | 1.9 |
| FHBPTC, Boston, MA | 230 | 159 | 6.6 | 0.9 |
| HZB-Charité, Berlin, Germany | 72 | 68 | 1.0 | 1.9 |
| IFJ, Krakow, Poland | 60 | 60 | 0.7 | 2.2 |
| INFN-LNS, Catania, Italy | 62 | 62 | 0.9 | 1.2 |
| LLUMC, Loma Linda, CA | 100 | 100 | 2.0[a] | 1.1 |
| PSI (OPTIS2), Villingen, Switzerland | 250 | 75 | 1.5 | 1.8 |
| TRIUMF, Vancouver, Canada | 500 | 74 | 1.25 | 1.9 |

[a]This value was determined by a ruler measurements on the magnified printout of a SOBP depth dose distribution from the paper.

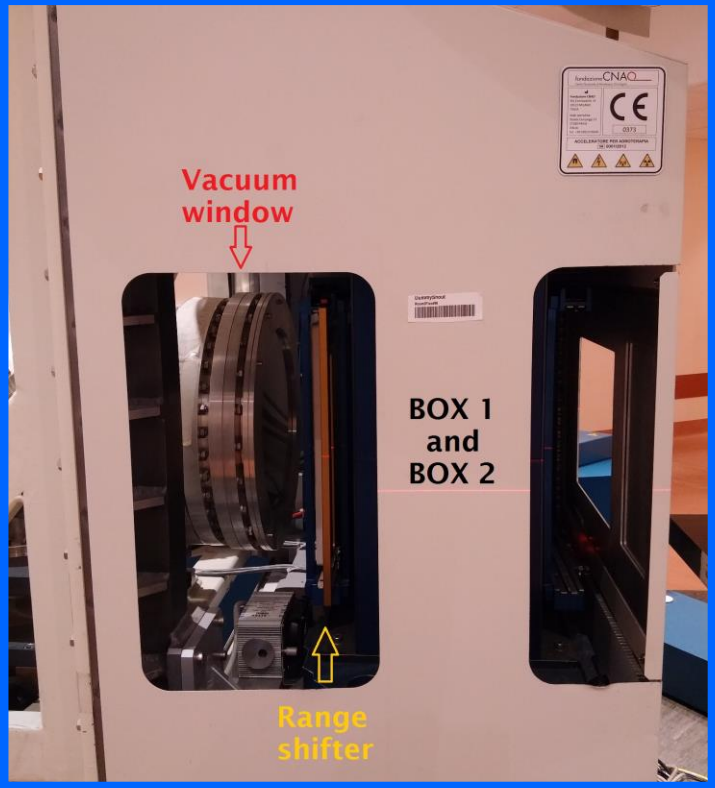
Slopsema RL et al. Med Phys 41, 2014

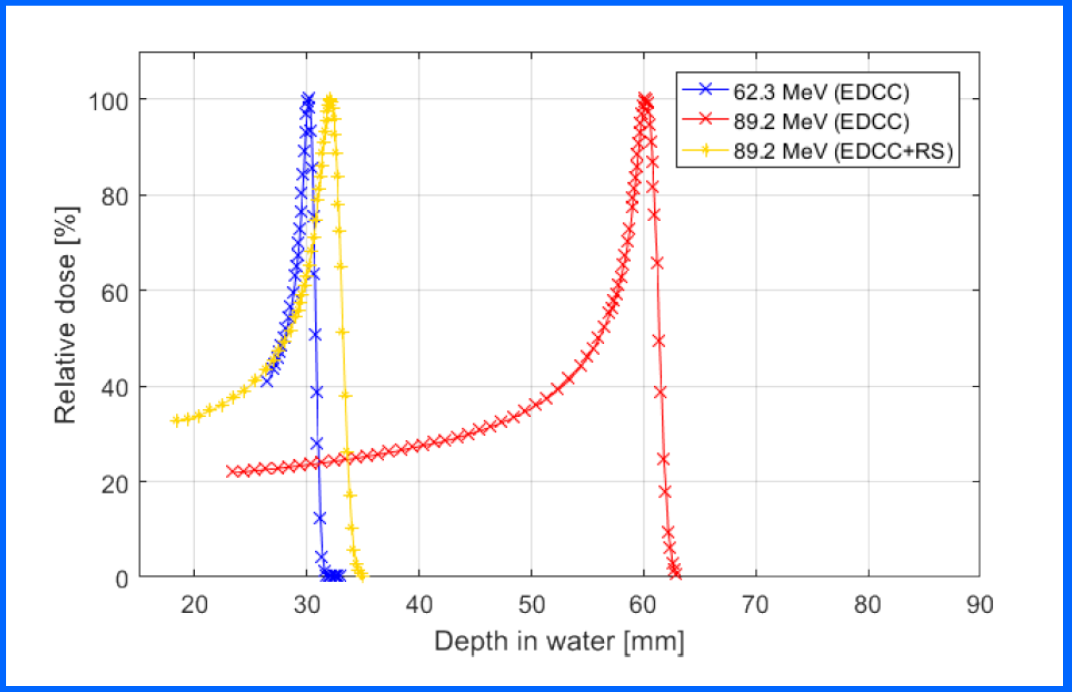
## Lateral penumbra optimization:

- ✓ 3x3 cm2 scanning field size
- ✓ Aperture at 5-6 cm from the skin
- ✓ Effect of RS-skin distance

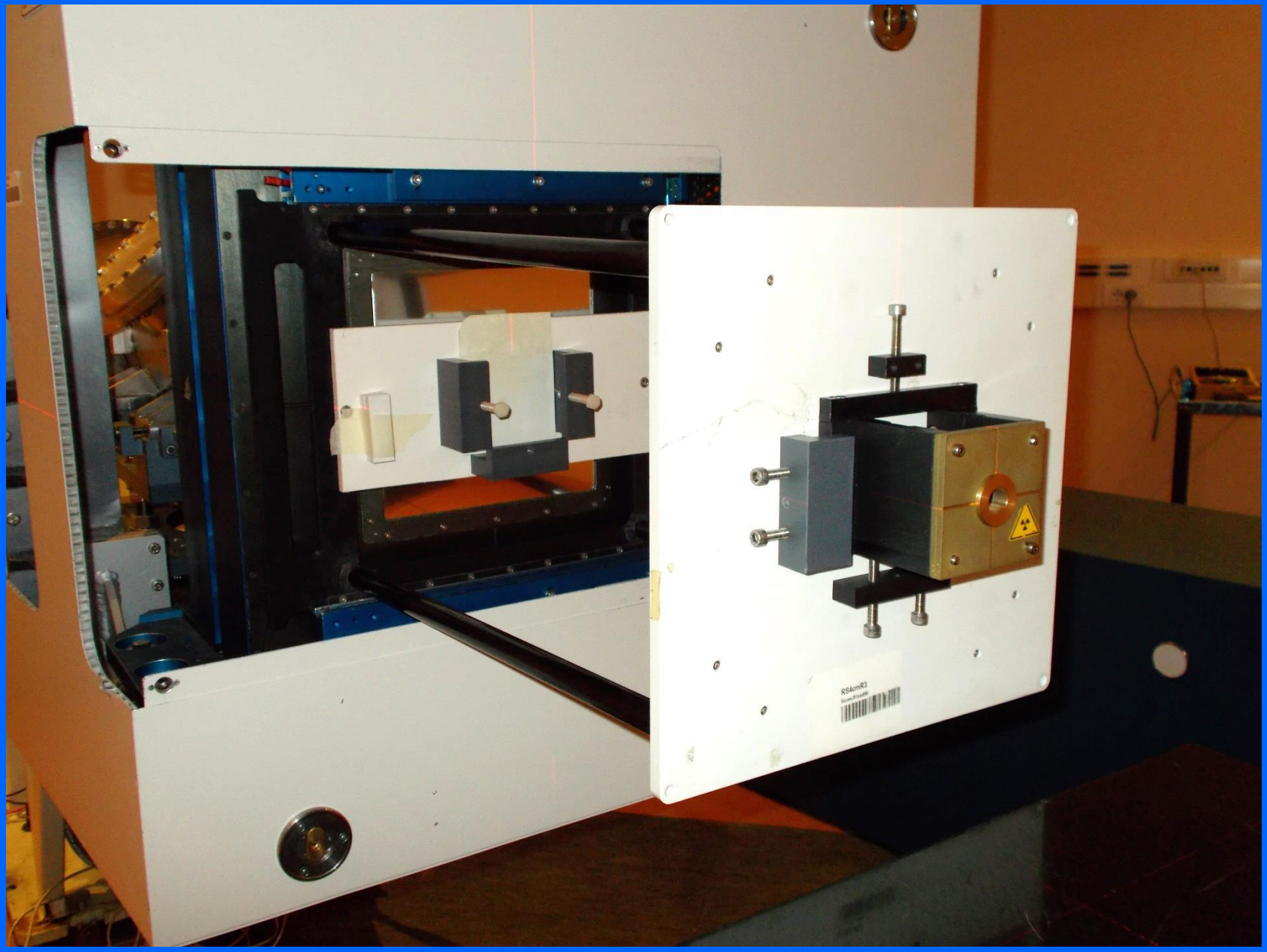


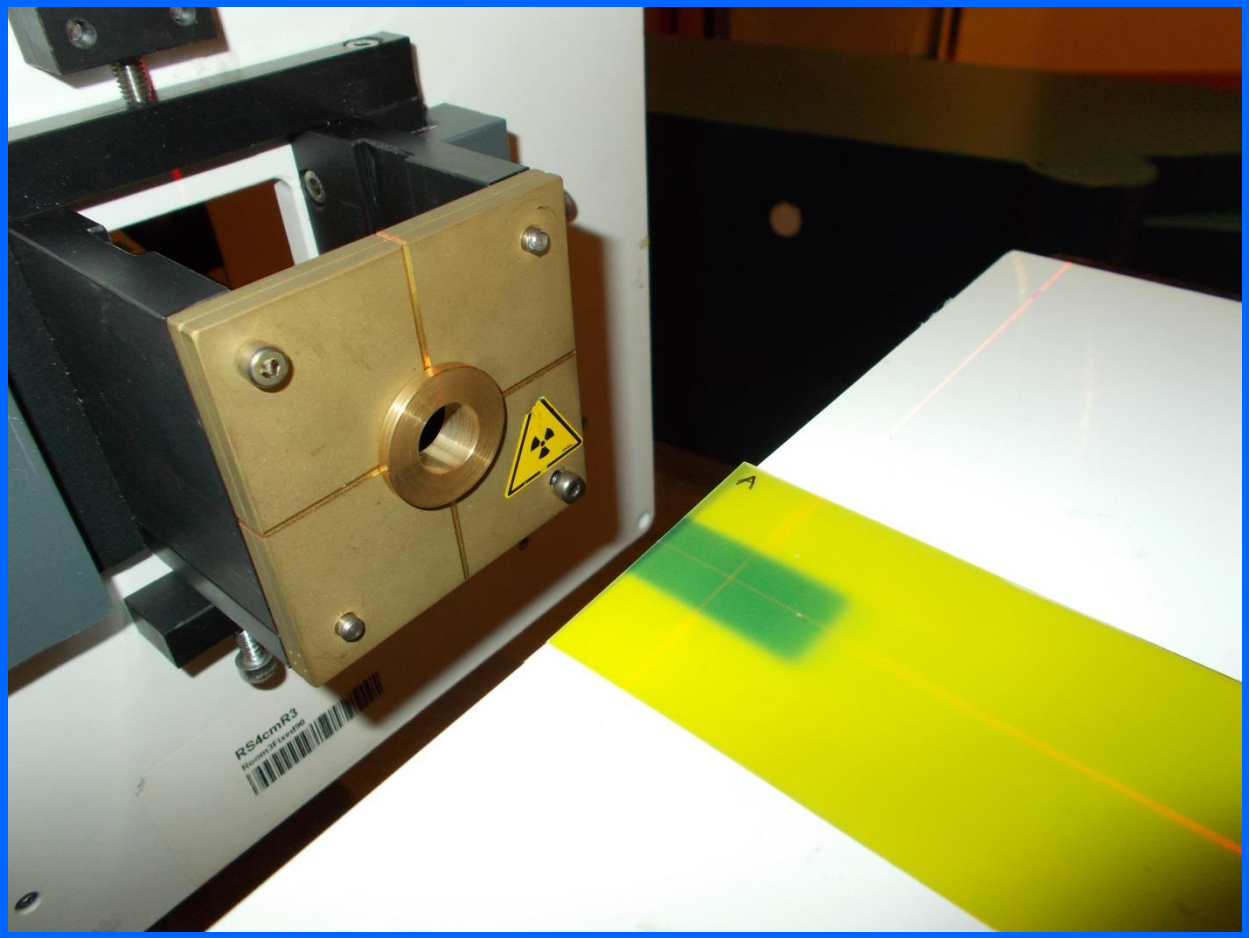

**Dedicated DDS calibration curve is needed** (fixed 28 mm water-eq. RS behind DDS)**!**





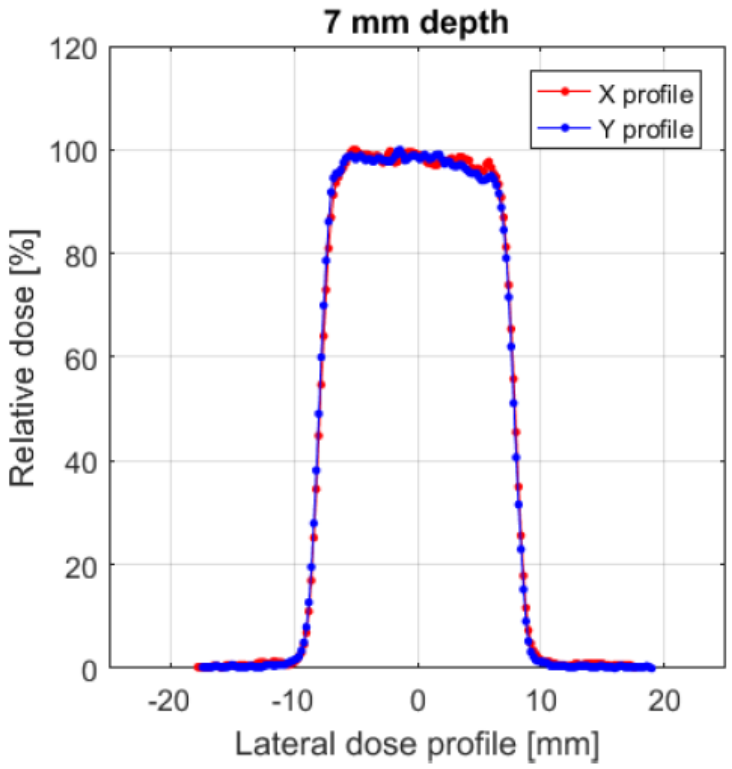

| | **62.73 MeV** | | **89.91 MeV** | | |
|---|---|---|---|---|---|
| Measure | SC | EDCC | SC | EDCC | EDCC + RS |
| $BP_w$ $[mm]$ | 30.12 | 30.14 | 60.15 | 60.19 | 32.06 |
| $R_{50}$ $[mm]$ | 30.79 | 30.82 | 61.32 | 61.39 | 33.21 |
| $R_p$ $[mm]$ | 31.19 | 31.21 | 62.28 | 62.37 | 34.16 |
| $DF_{90-10}$ $[mm]$ | 0.79 | 0.79 | 1.67 | 1.72 | 1.65 |
| $DF_{80-20}$ $[mm]$ | 0.50 | 0.50 | 1.12 | 1.15 | 1.10 |

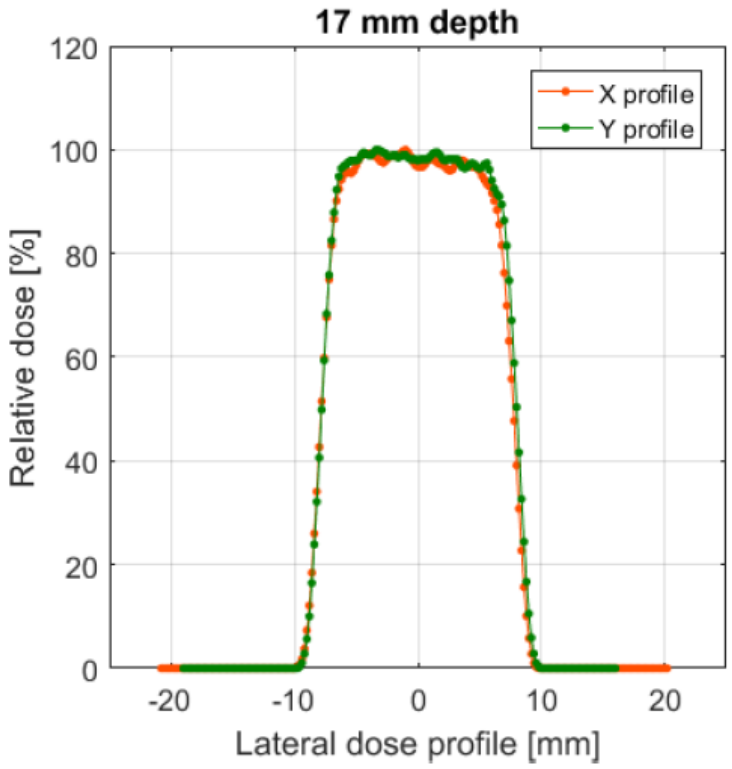

RS4cmR3


RS4cmR3

| Lateral penumbra 90-50 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth (mm) | Measures (mm) | | | | | | | | Mean ± std |
| 0 | 0.8 | 0.9 | 0.9 | 0.9 | 0.8 | 0.9 | 1.0 | 0.9 | $0.9 \pm 0.1$ |
| 7 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.2 | 1.1 | 1.0 | $1.0 \pm 0.1$ |
| 12 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.2 | 1.0 | 0.9 | $1.0 \pm 0.1$ |
| 17 | 1.0 | 1.2 | 1.1 | 1.3 | 1.1 | 1.2 | 1.2 | 1.1 | $1.2 \pm 0.1$ |
| **Lateral penumbra 80-20** | | | | | | | | | |
| Depth (mm) | Measures (mm) | | | | | | | | Mean ± std |
| 0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 1.1 | $1.1 \pm 0.1$ |
| 7 | 1.2 | 1.3 | 1.3 | 1.3 | 1.2 | 1.3 | 1.3 | 1.2 | $1.3 \pm 0.1$ |
| 12 | 1.2 | 1.3 | 1.2 | 1.3 | 1.2 | 1.3 | 1.2 | 1.2 | $1.2 \pm 0.1$ |
| 17 | 1.4 | 1.4 | 1.5 | 1.5 | 1.3 | 1.4 | 1.4 | 1.3 | $1.4 \pm 0.1$ |

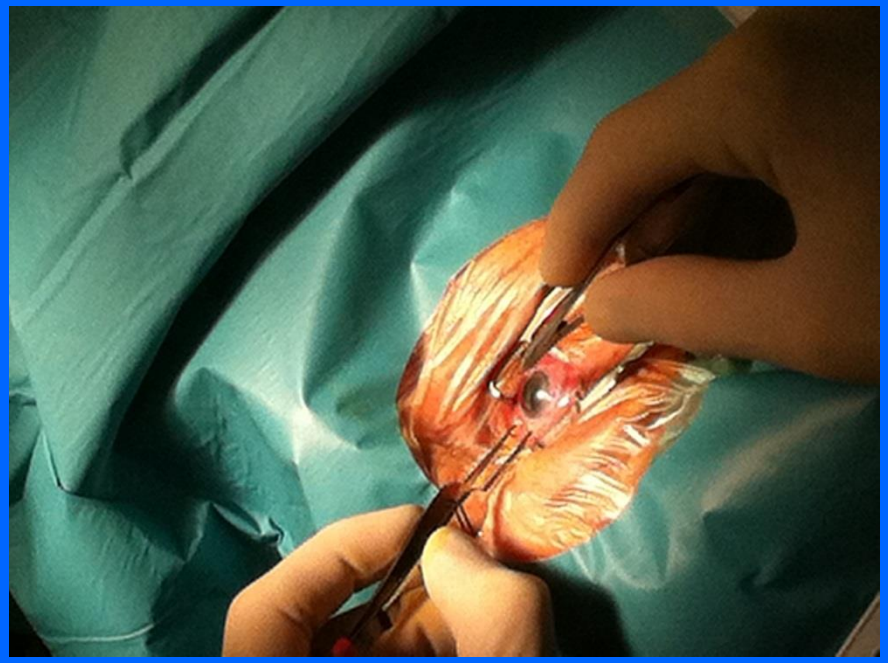
**Table 3.3:** Lateral penumbra data acquired using a 15 $mm$ collimation and a SOBP with penetration depth and modulation in water of 20 $mm$ and 15 $mm$ respectively.


7 mm depth
X profile
Y profile
Relative dose [%]
Lateral dose profile [mm]
120
100
80
60
40
20
0
-20
-10
0
10
20

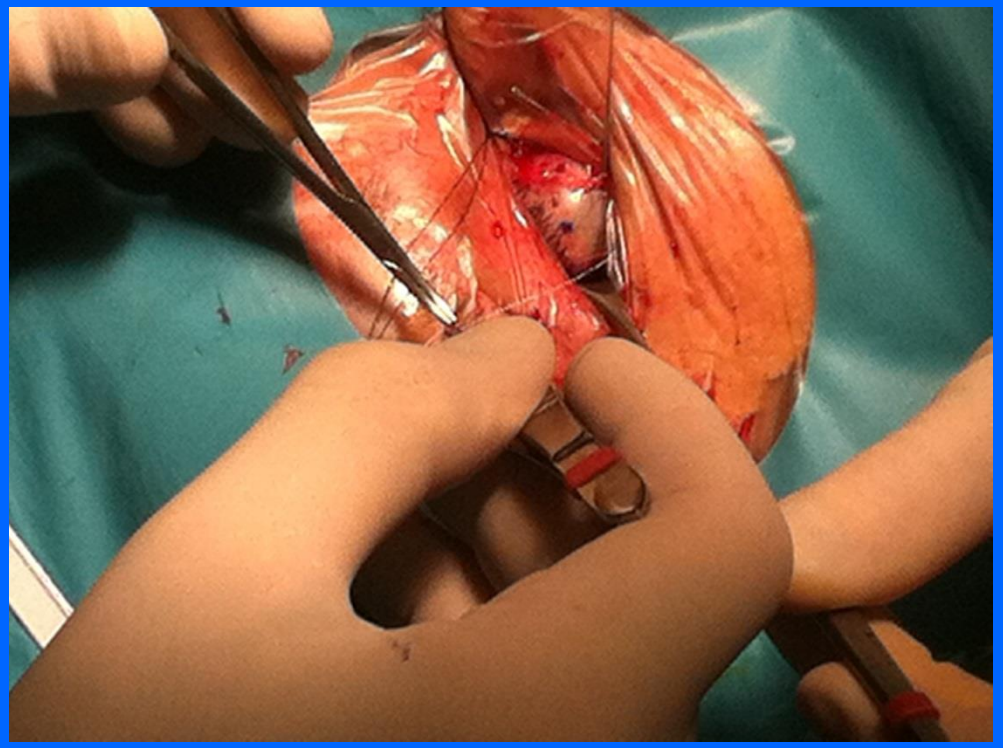

17 mm depth
X profile
Y profile
Relative dose [%]
Lateral dose profile [mm]
120
100
80
60
40
20
0
-20
-10
0
10
20

**Neutron dose to the contralateral eye: 3 mSv**

# Clinical workflow

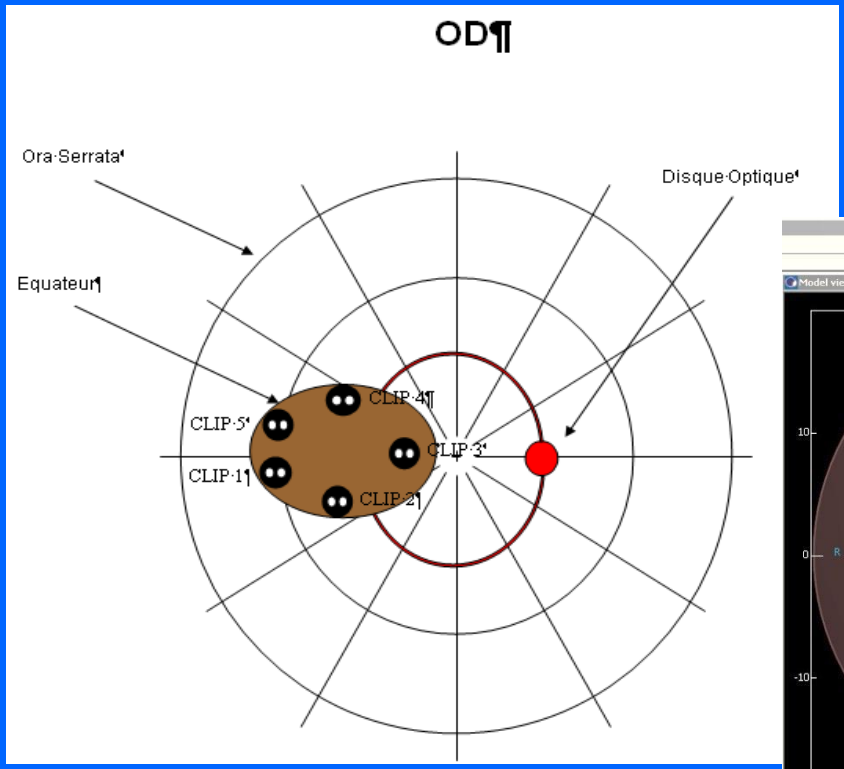


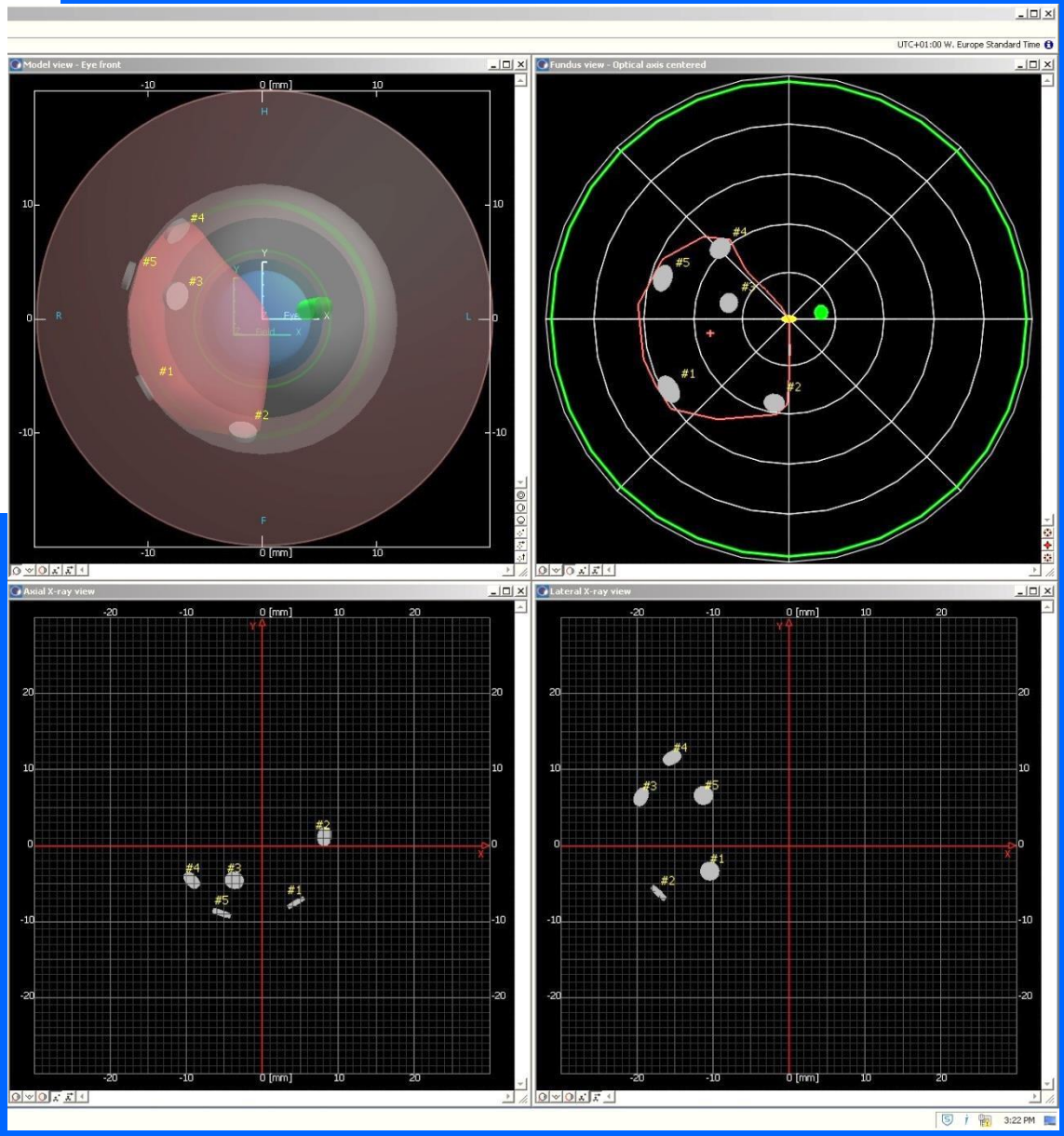
**Pre-treatment surgical phase (ophtalmologist): clip implantation for target localization**



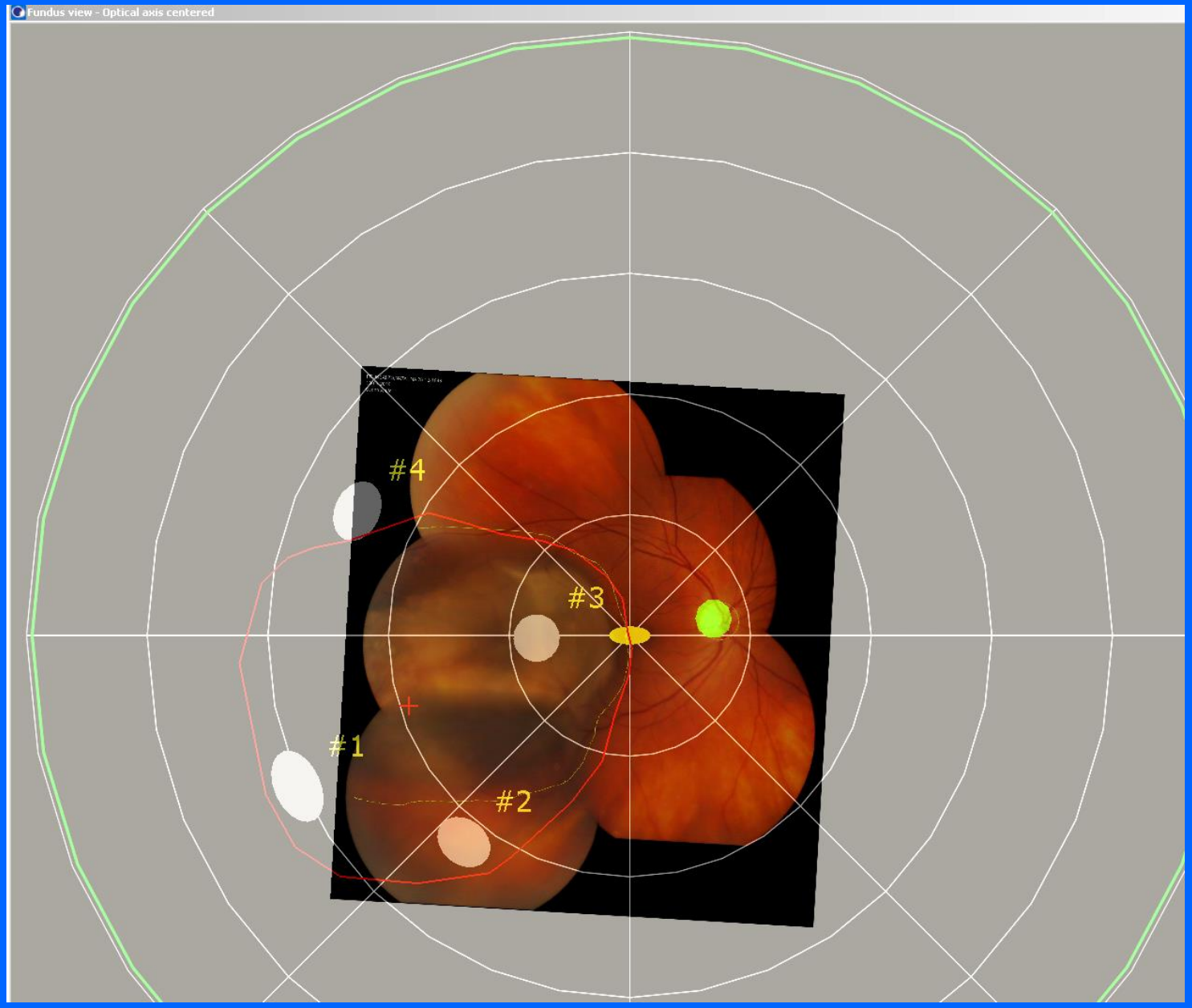
# Treatment simulation
# (pt immobilization and CT scan)

# Plan generation

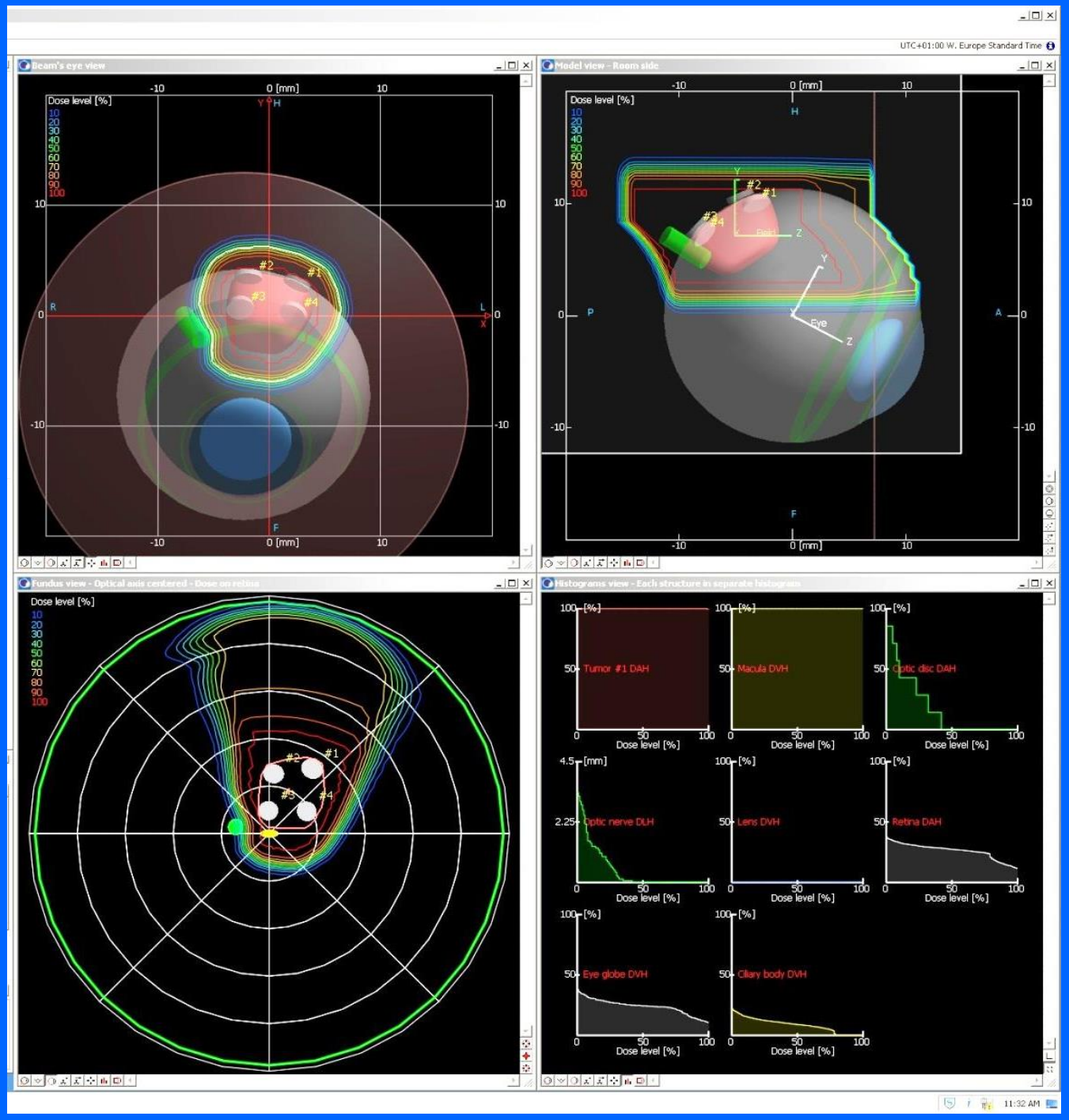



Varian Eclipse ocular proton planning

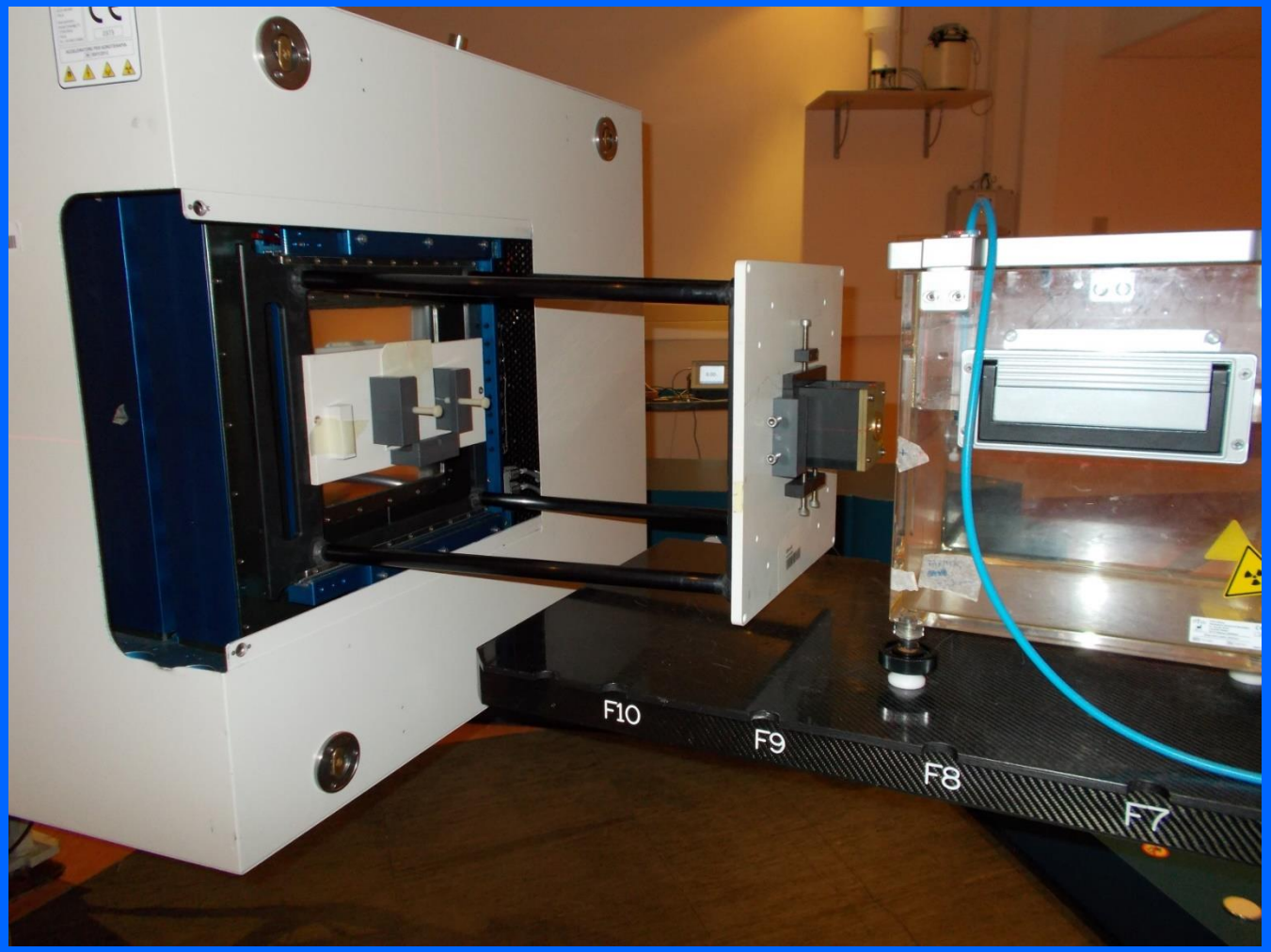


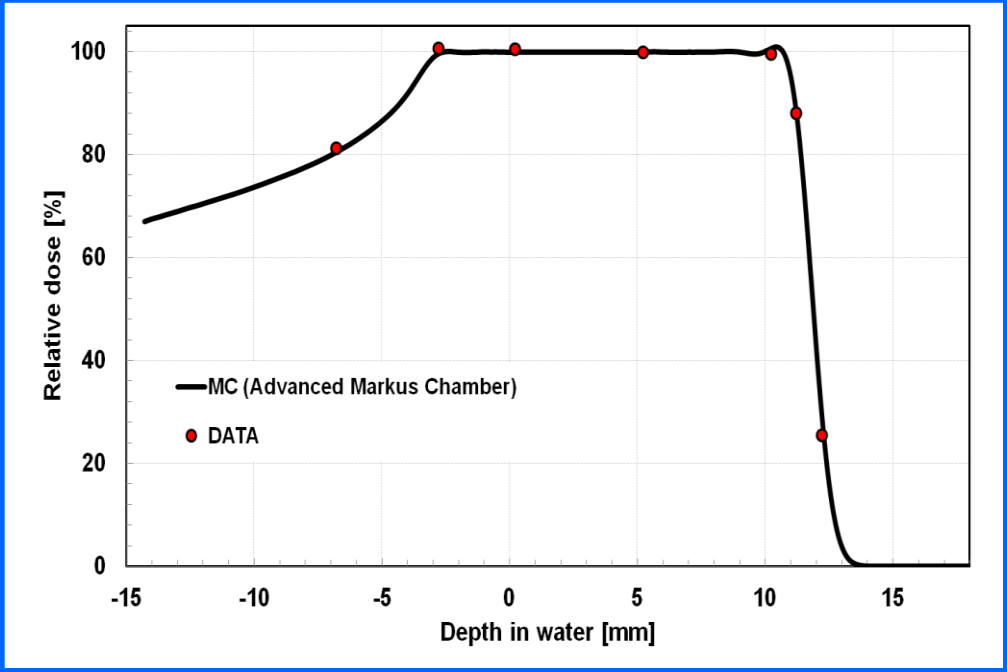

Fundus viewer SW, IFJ PAN Cyclotron Center, Krakow, Poland


UTC+01:00 W. Europe Standard Time
Beam's eye view
Model view - Room side
Fundus view - Optical axis centered - Dose on retina
Histograms view - Each structure in separate histograms
Dose level [%]
10
20
30
40
50
60
70
80
90
100
-10
0 [mm]
10
H
F
R
L
P
A
Eye
#1
#2
#3
#4
Tumor #1 DAH
Macula DVH
Optic disc DAH
Optic nerve DLH
Lens DVH
Retina DAH
Eye globe DVH
Ciliary body DVH
[%]
[mm]
4.5
2.25
50
100
11:32 AM

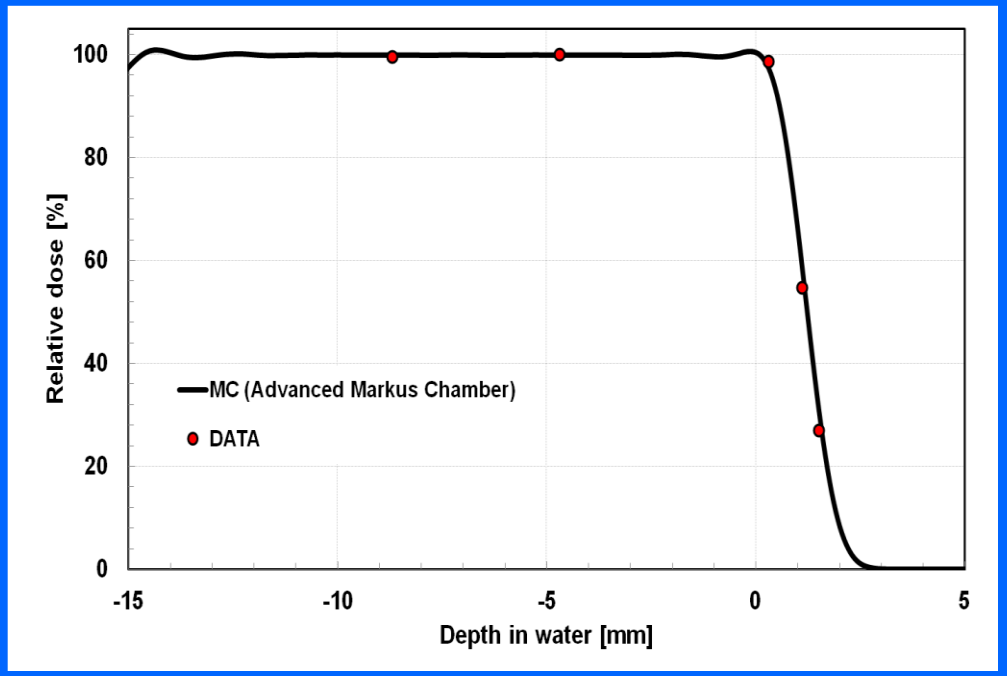

# INFN-Pavia workshop

# Pre-treatment plan verification:
# Markus ion chamber or silicon diode detector






# Calculated *vs* measured SOBP



## Optical eye tracking system for real-time noninvasive tumor localization in external beam radiotherapy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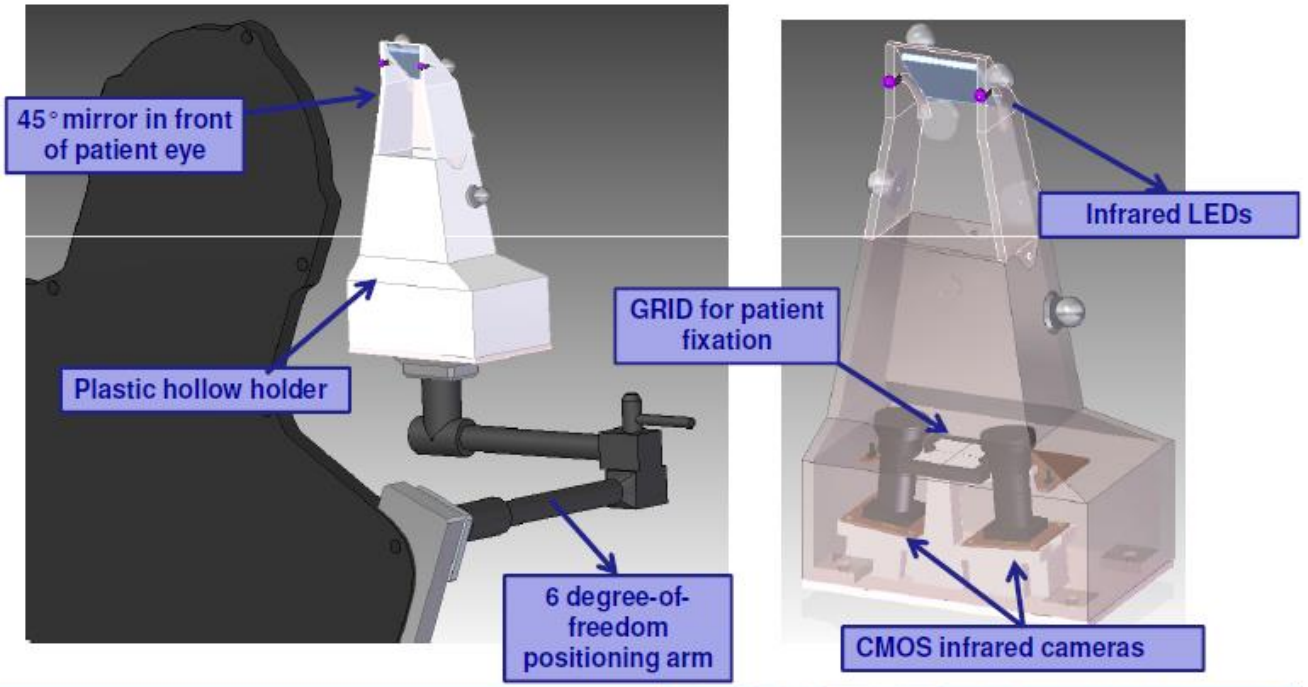
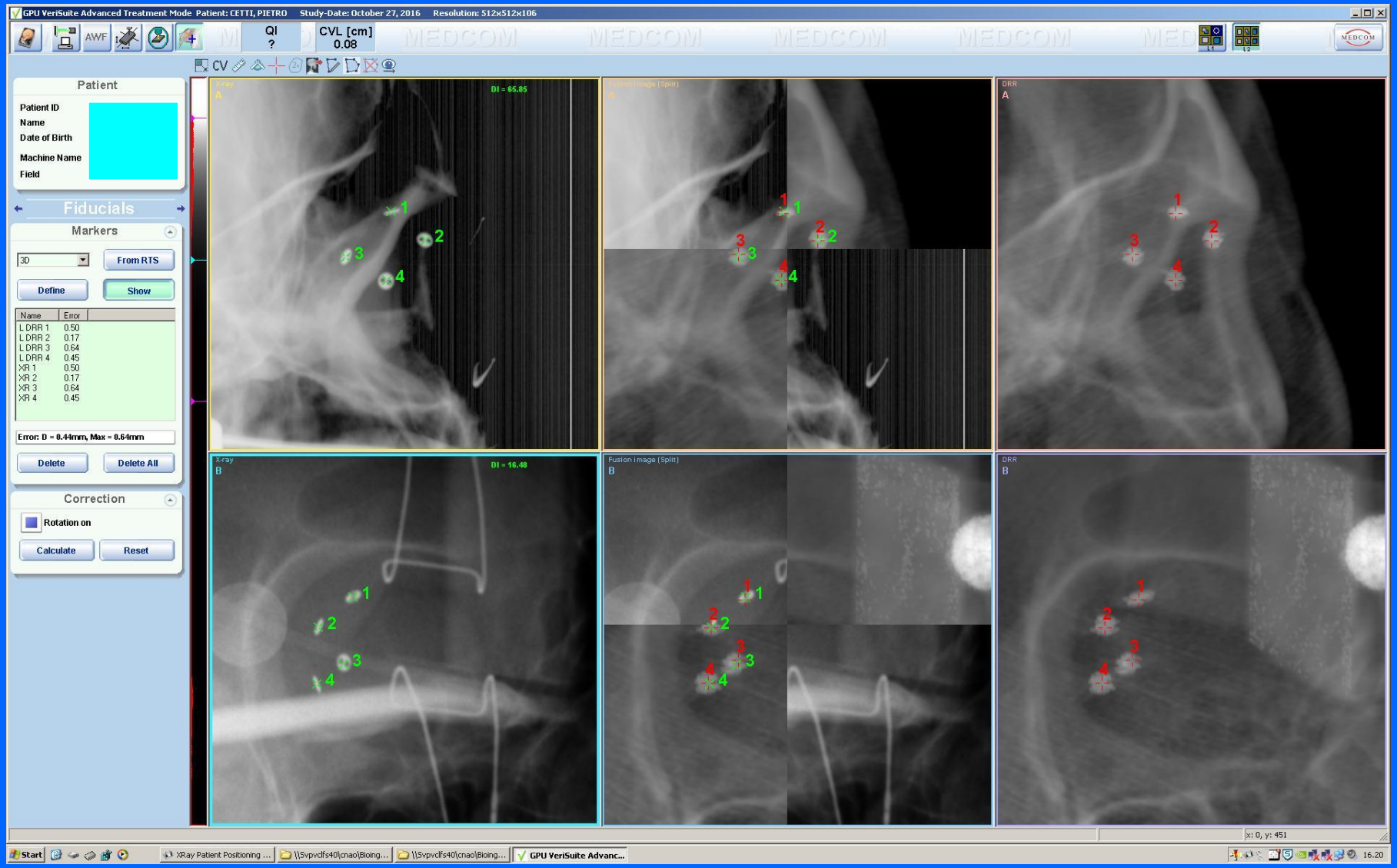
# Gaze fixation monitoring

**DESIGN:** - reduced size in the region near the treated eye
- removal of electronic components (cameras, leds) from the imaging FOV

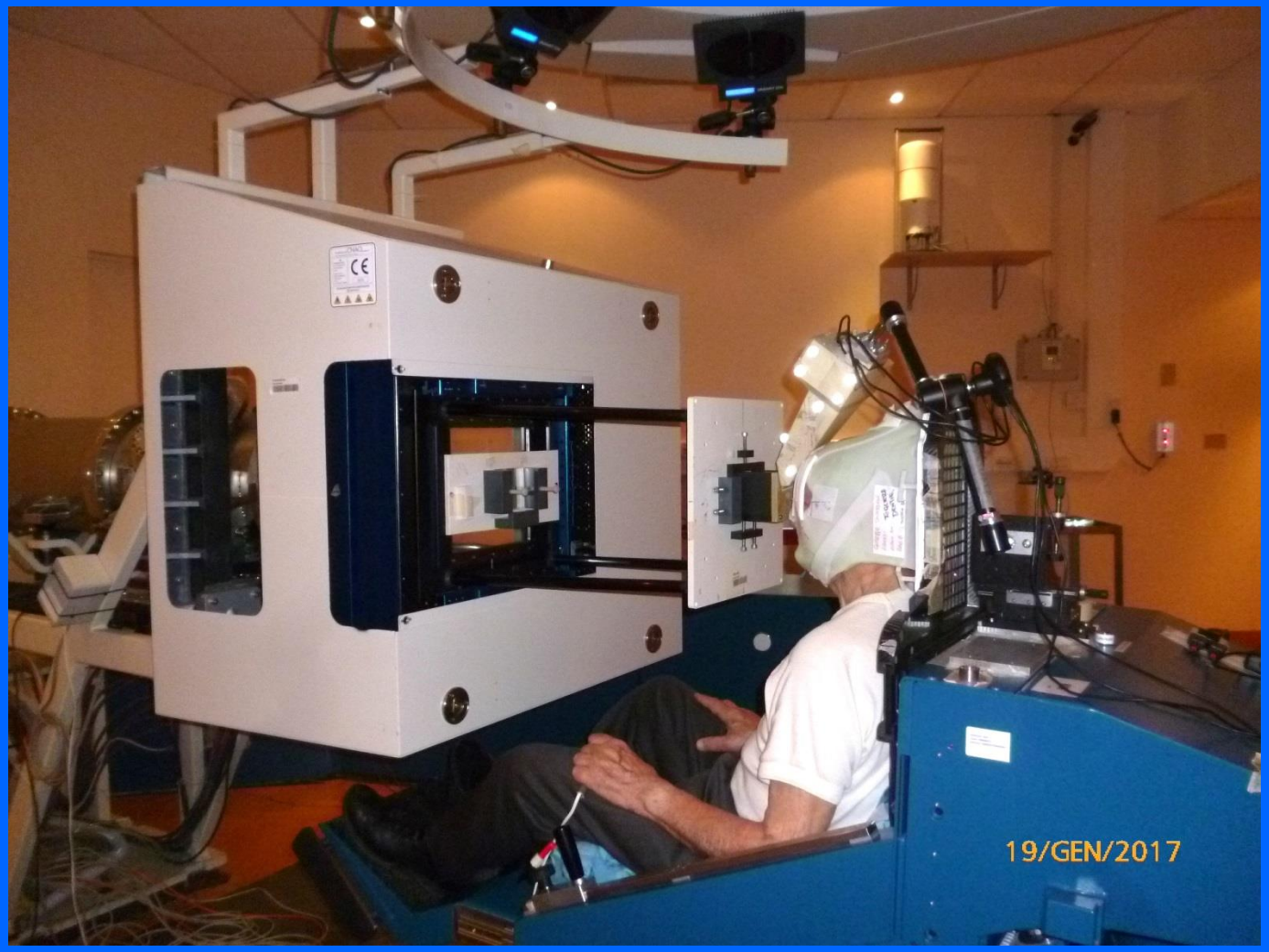


# Treatment verification

## (2 orthogonal x-ray images, image registration based on fiducial markers)



# Treatment delivery




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