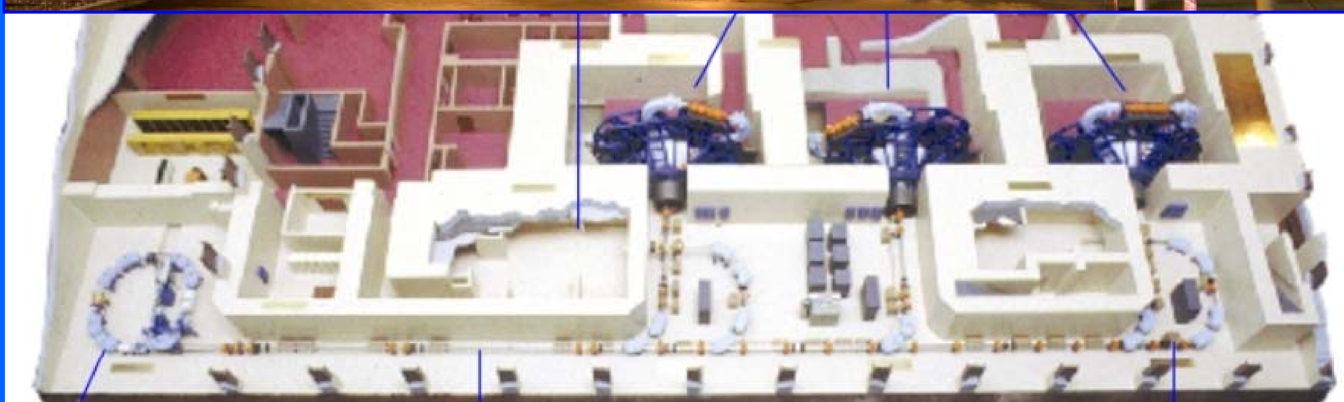
Outline

The Loma Linda University Medical Center

- **Founded in 1905 as the Loma Linda Sanitarium**
- **Now: 6000 employees, 550 physicians, 24000 inpatients/year, 650000 outpatients/year**
- **1993: Children's hospital (900 beds), world's leader for infant heart transplantation**

The proton-therapy facility



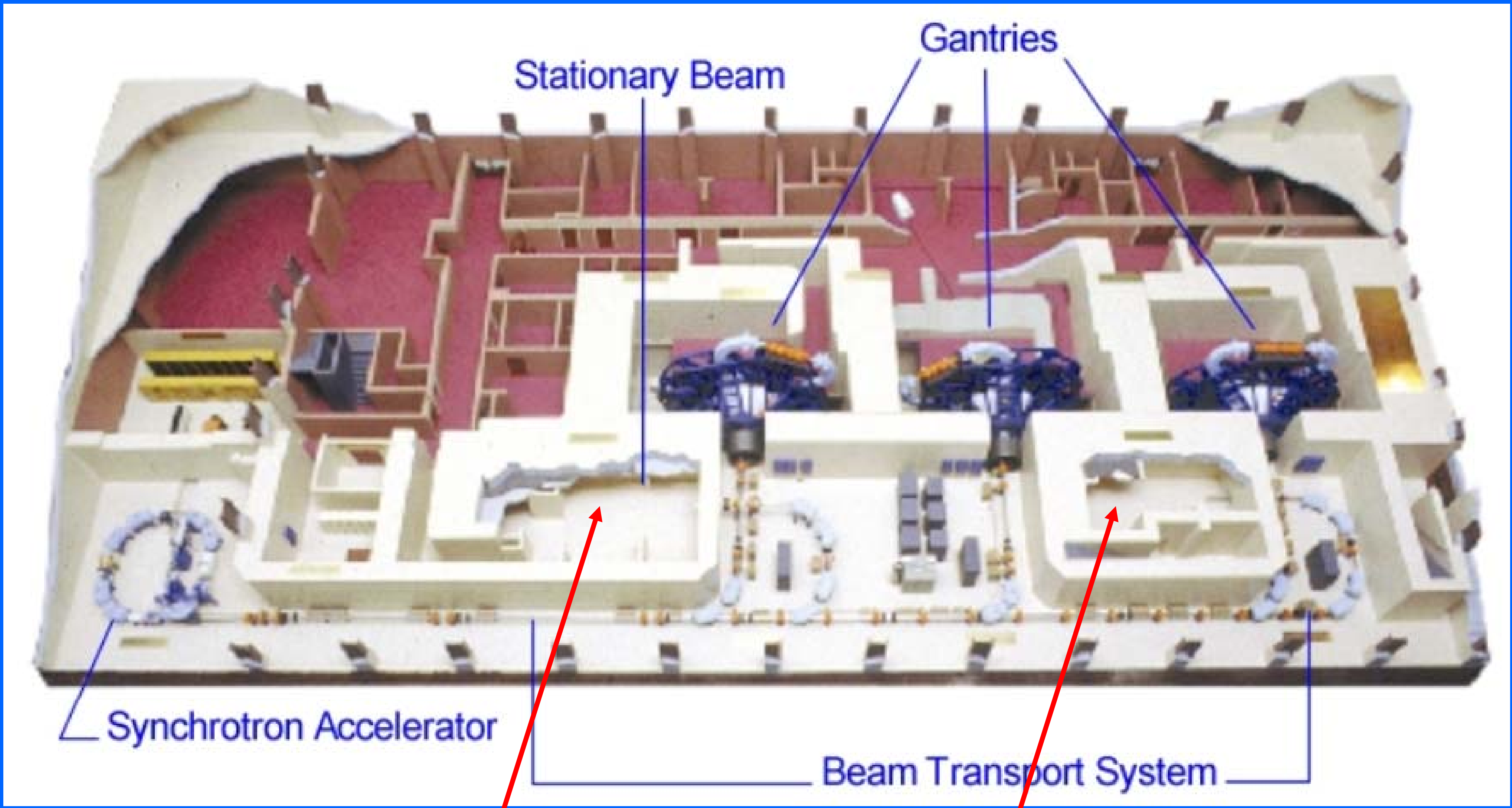
- Built in 1993 in the basement of the Children's Hospital
- About 80 M$, mostly from the US government
- 150 employees, 130/180 patients/day, 160 average patients/day
- 89% prostate cancer treatments
- Optivus: 60 employees, provides field service, maintenance and upgrading

What a patient sees

- Two floors, one for visits and one for treatments
- Two nice receptions, with games, internet, coffee, etc.

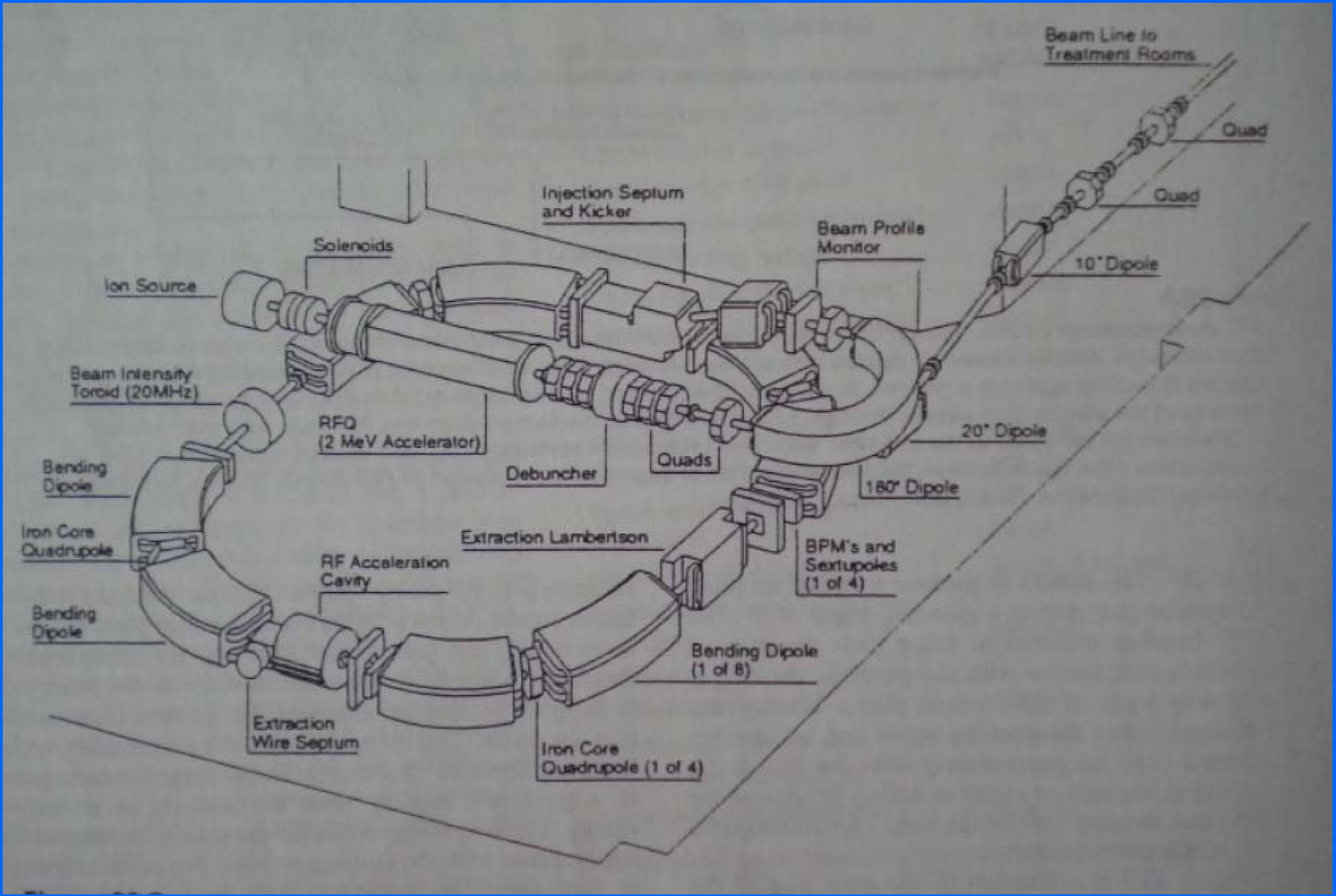
- A long corridor with patient preparation rooms on the right and four treatment rooms on the left

What a physicist can see…

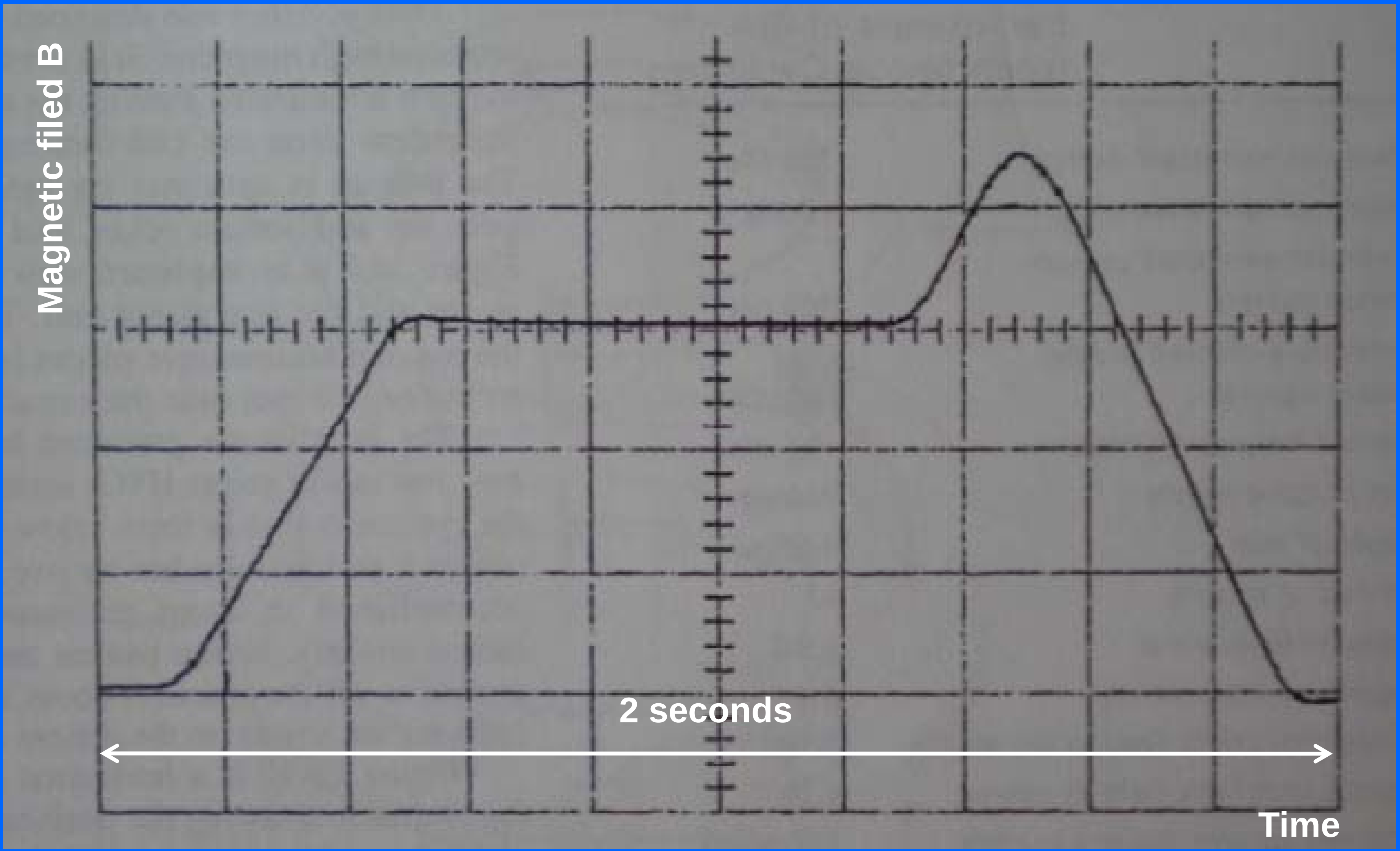


HBL – Eye treatment + horizontal beam

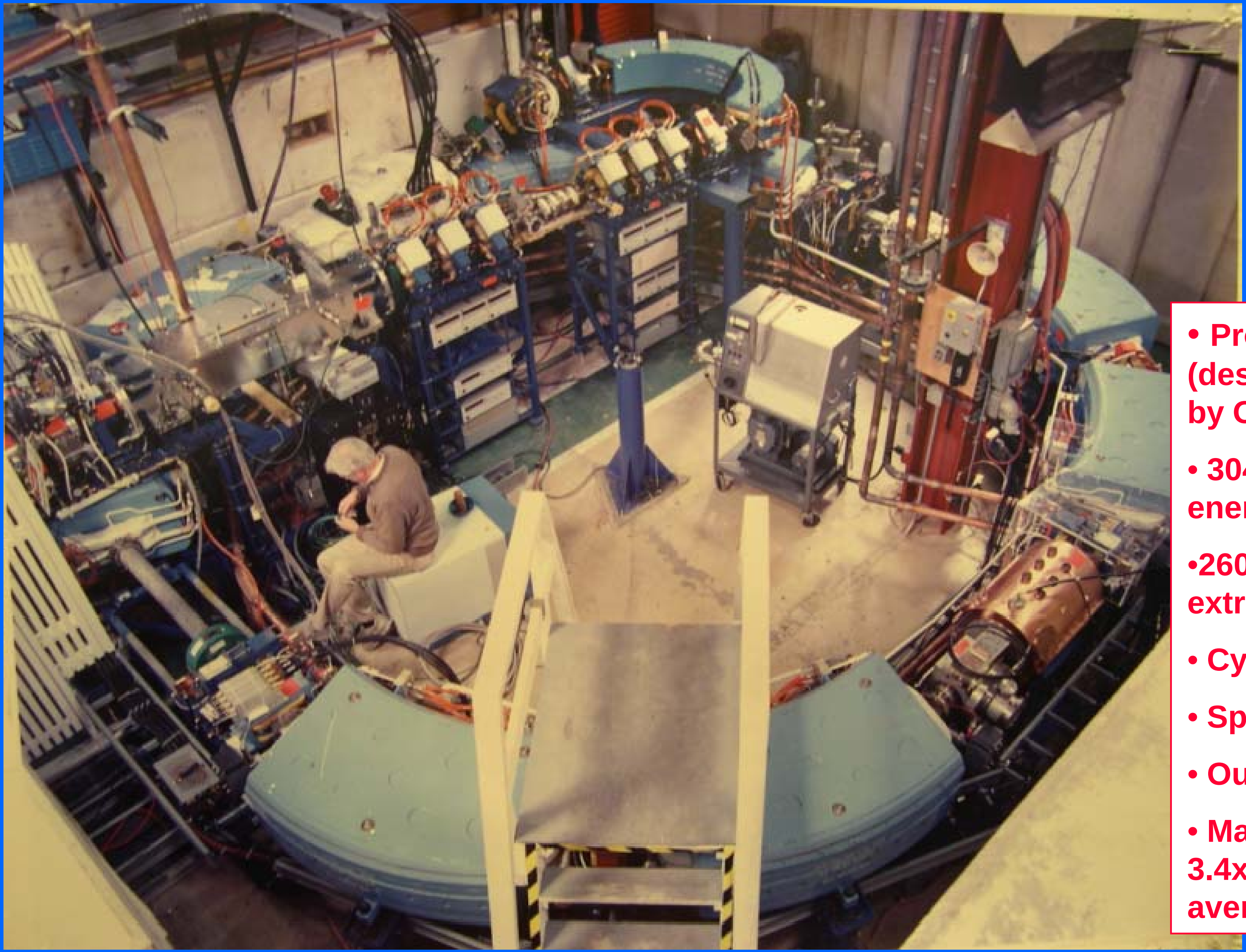
Experimental room – 3 horizontal beams


Beam Line to
Treatment Rooms
Quad
Quad
10° Dipole
Injection Septum
and Kicker
Beam Profile
Monitor
Solenoids
Ion Source
Beam Intensity
Toroid (20MHz)
RFQ
(2 MeV Accelerator)
20° Dipole
Debuncher
Quads
180° Dipole
Bending
Dipole
Iron Core
Quadrupole
Extraction Lambertson
BPM's and
Sextupoles
(1 of 4)
RF Acceleration
Cavity
Bending
Dipole
Bending Dipole
(1 of 8)
Extraction
Wire Septum
Iron Core
Quadrupole (1 of 4)

The "B train"



The accelerator

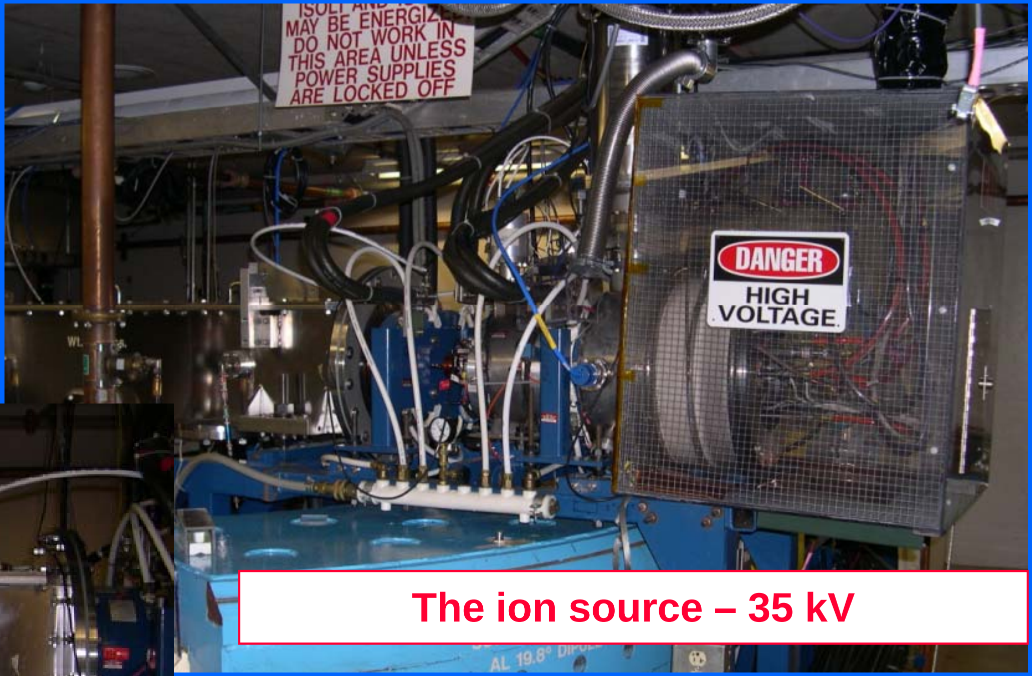


- Proton synchrotron (design Fermilab upgraded by Optivus)
- 304 MeV maximum energy
- 260 MeV maximum extracted energy
- Cycle 2.2 sec
- Spill duration 0.2-0.5 sec
- Outer diameter 6.71 m
- Maximum proton flux 3.4×10^{10} p/spill (2.5 nA average current)

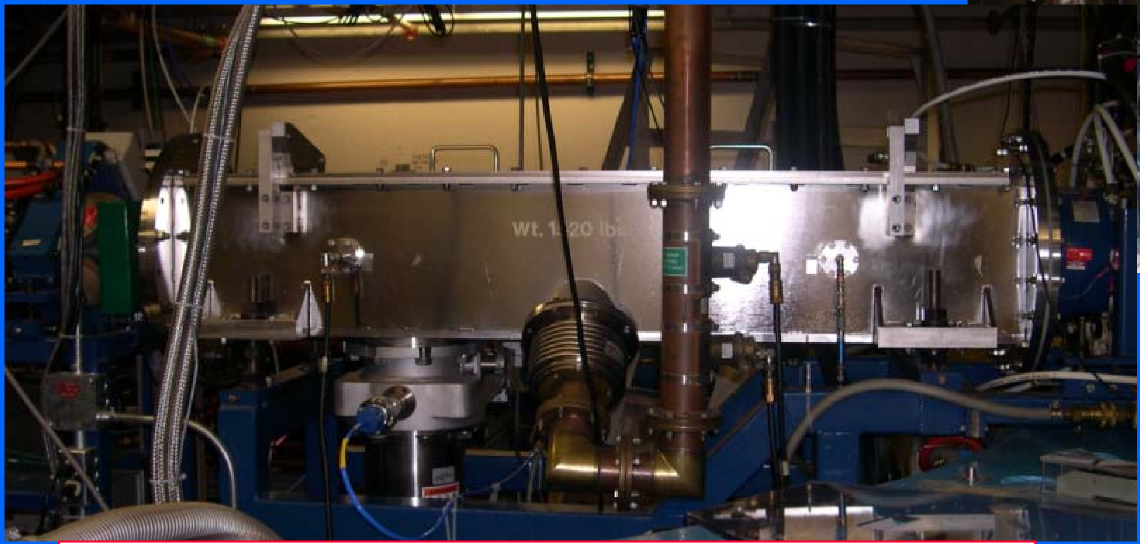
The “real” beginning

Hydrogen bottle + spare !!!

Let’s start the tour…

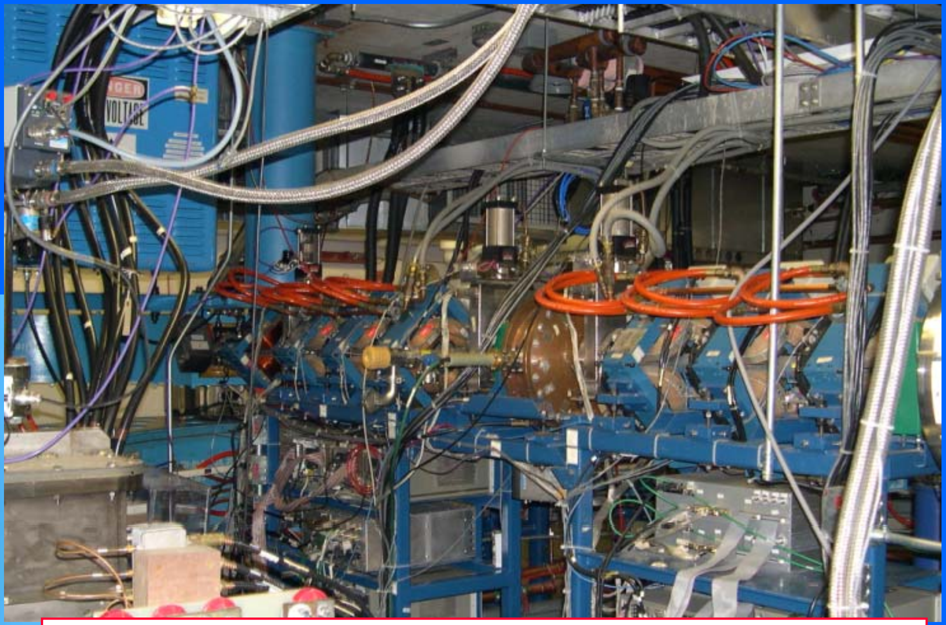


The ion source – 35 kV

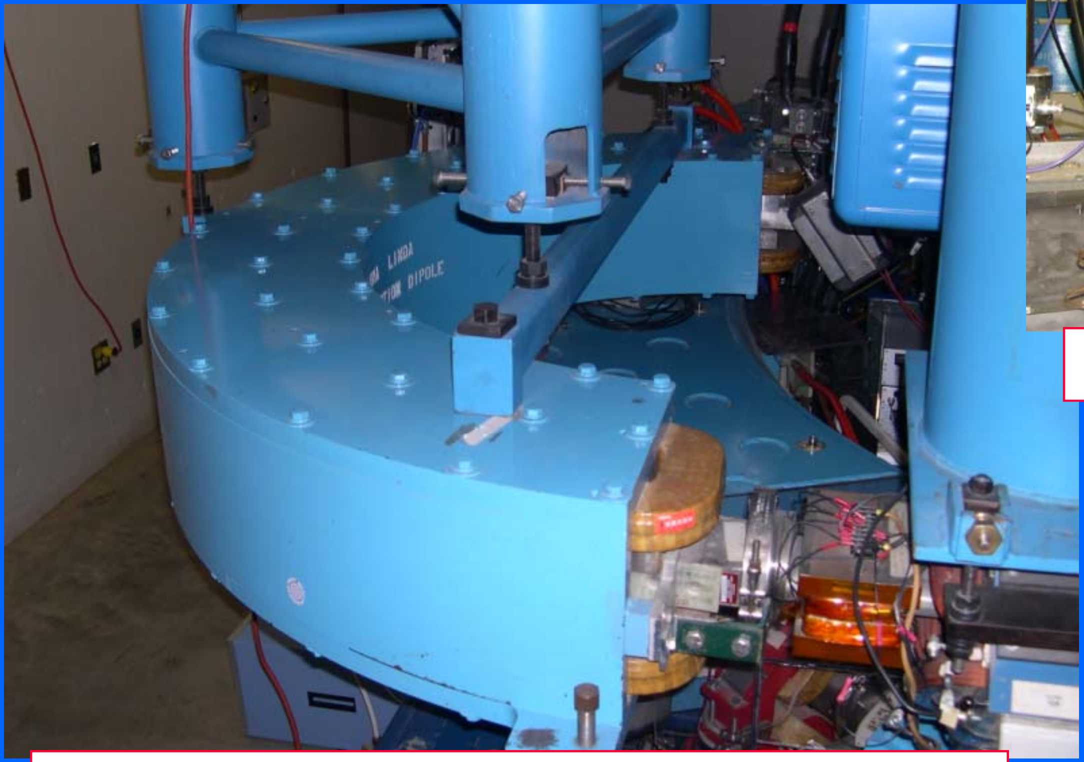


The RFQ – 425 MHz, 2 MeV output energy

Low energy beam lines

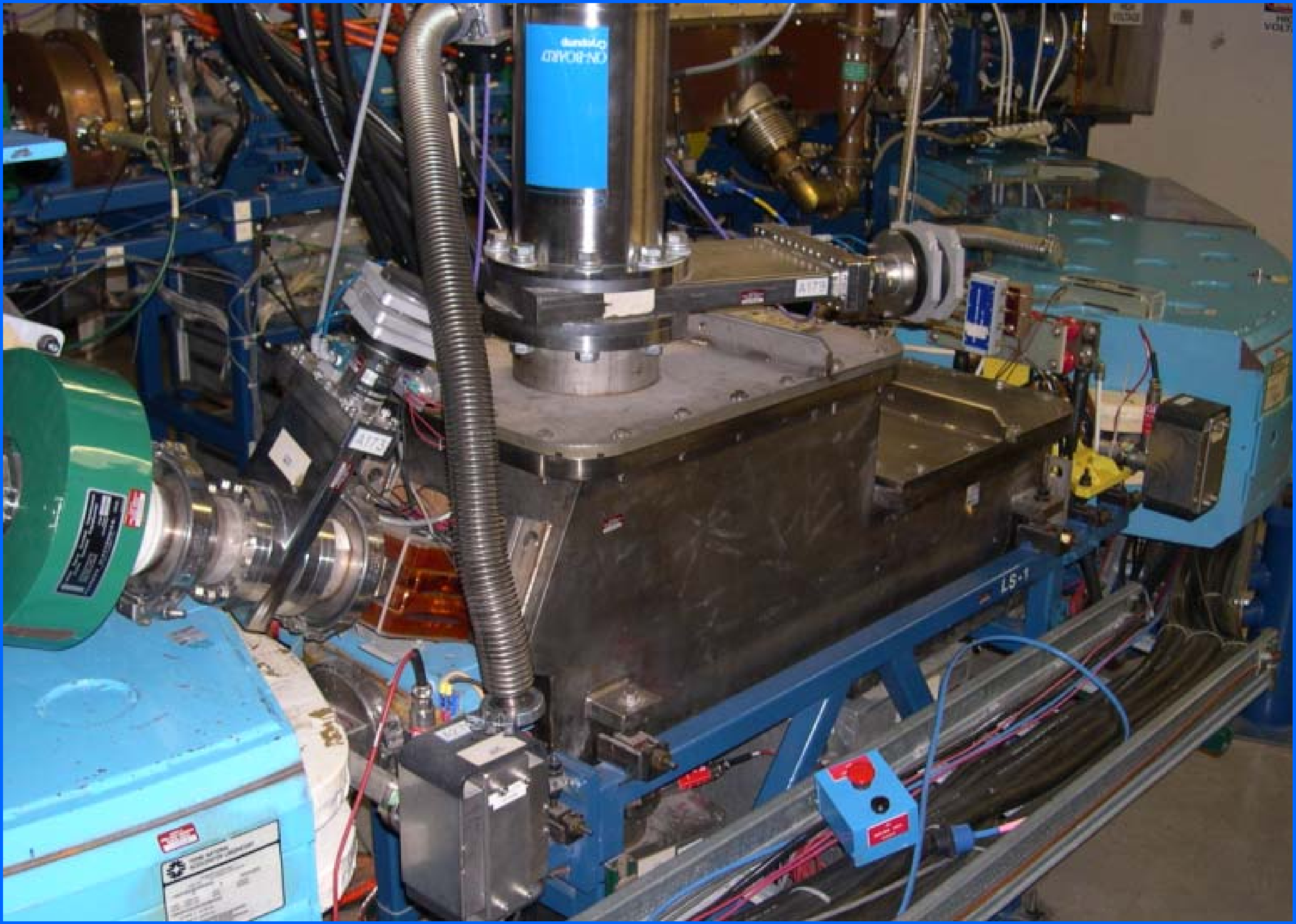


The debuncher + focussing quadrupoles



180º bending magnet

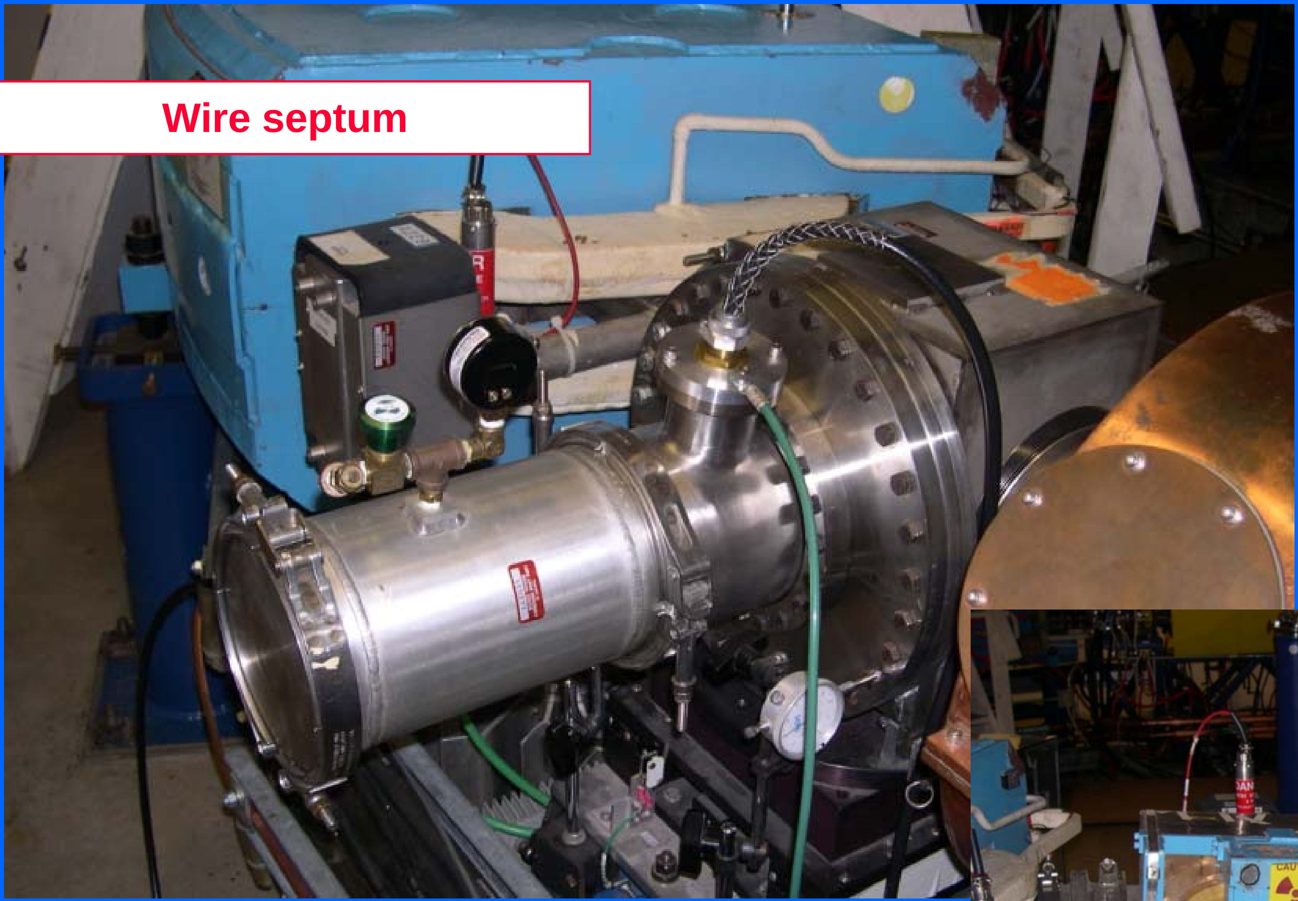
Injection septum and kicker



0.947 – 9.713 MHz

Extraction

Wire septum



Extraction efficiency 90%

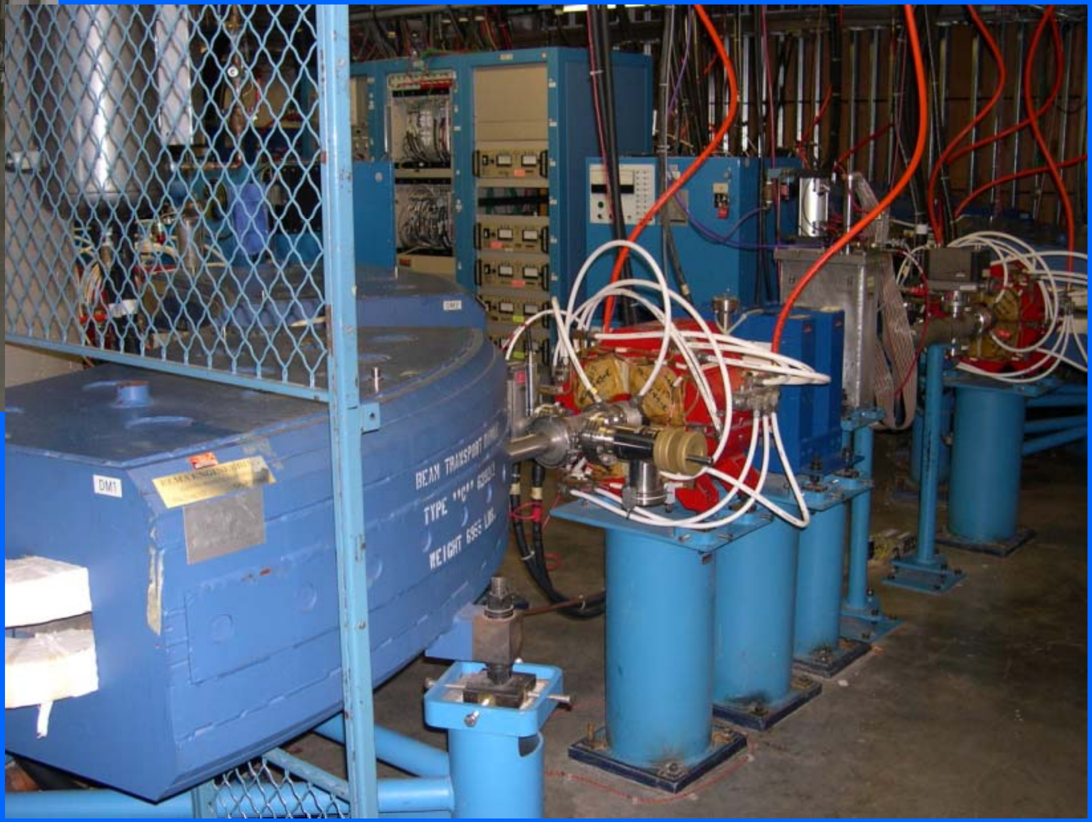
Extraction Lambertson magnet

Beam dump or beam line?

To the treatment rooms

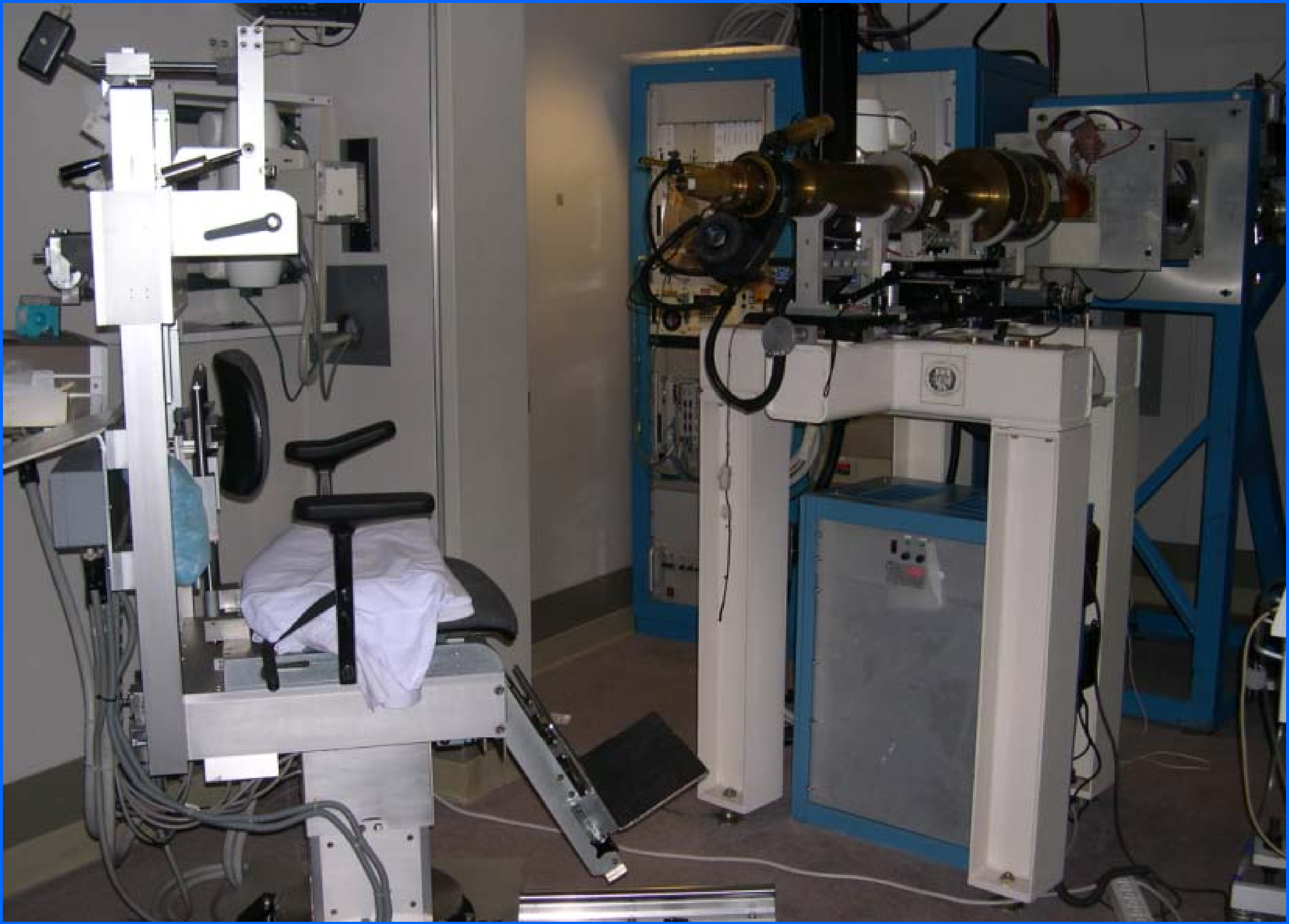
Beam dump down the floor

Beam transport lines

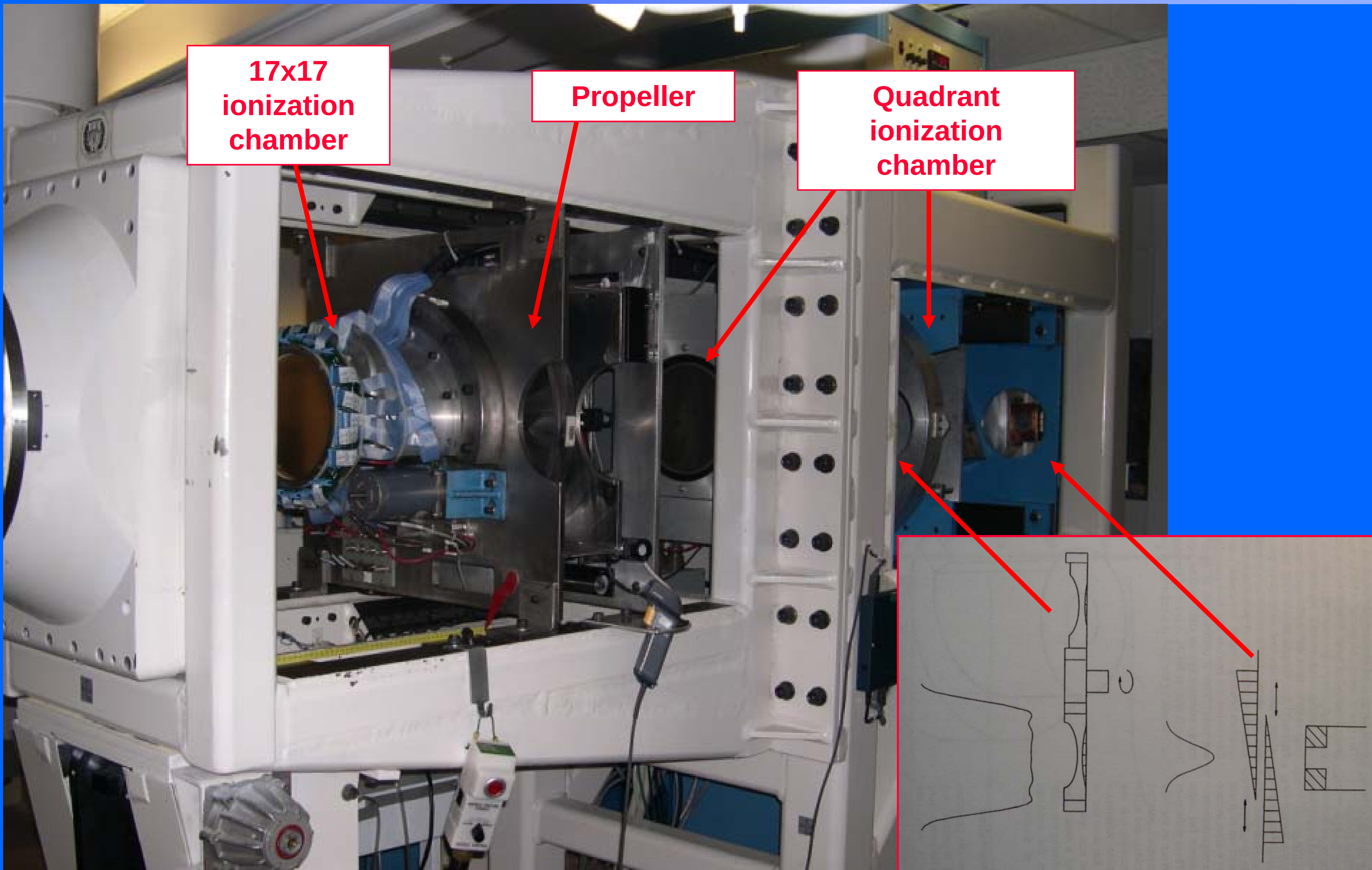


One of the three gantries

Eye treatment in HBL



The HBL horizontal beam line

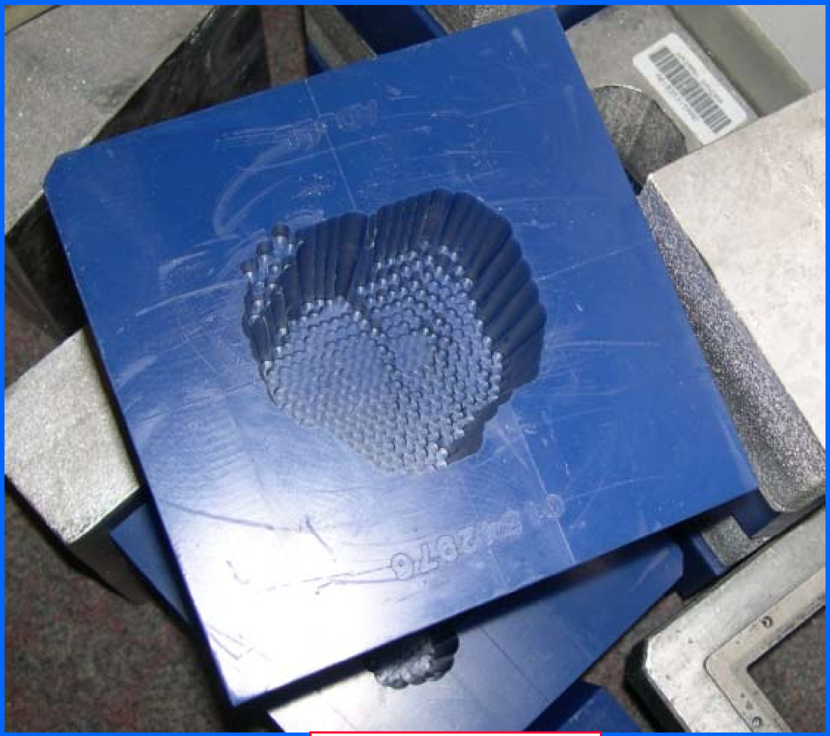

17x17 ionization chamber
Propeller
Quadrant ionization chamber

Propeller

One for each field

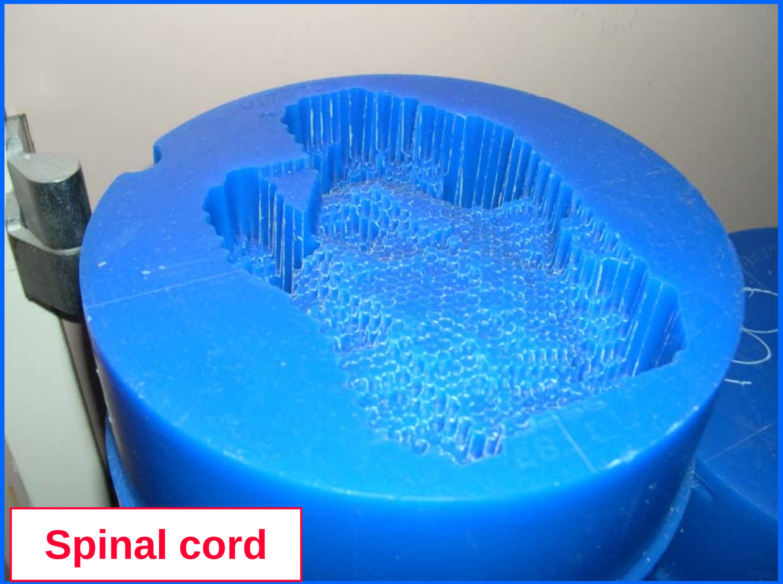
Collimator

One for each field



Prostate

One for
each field



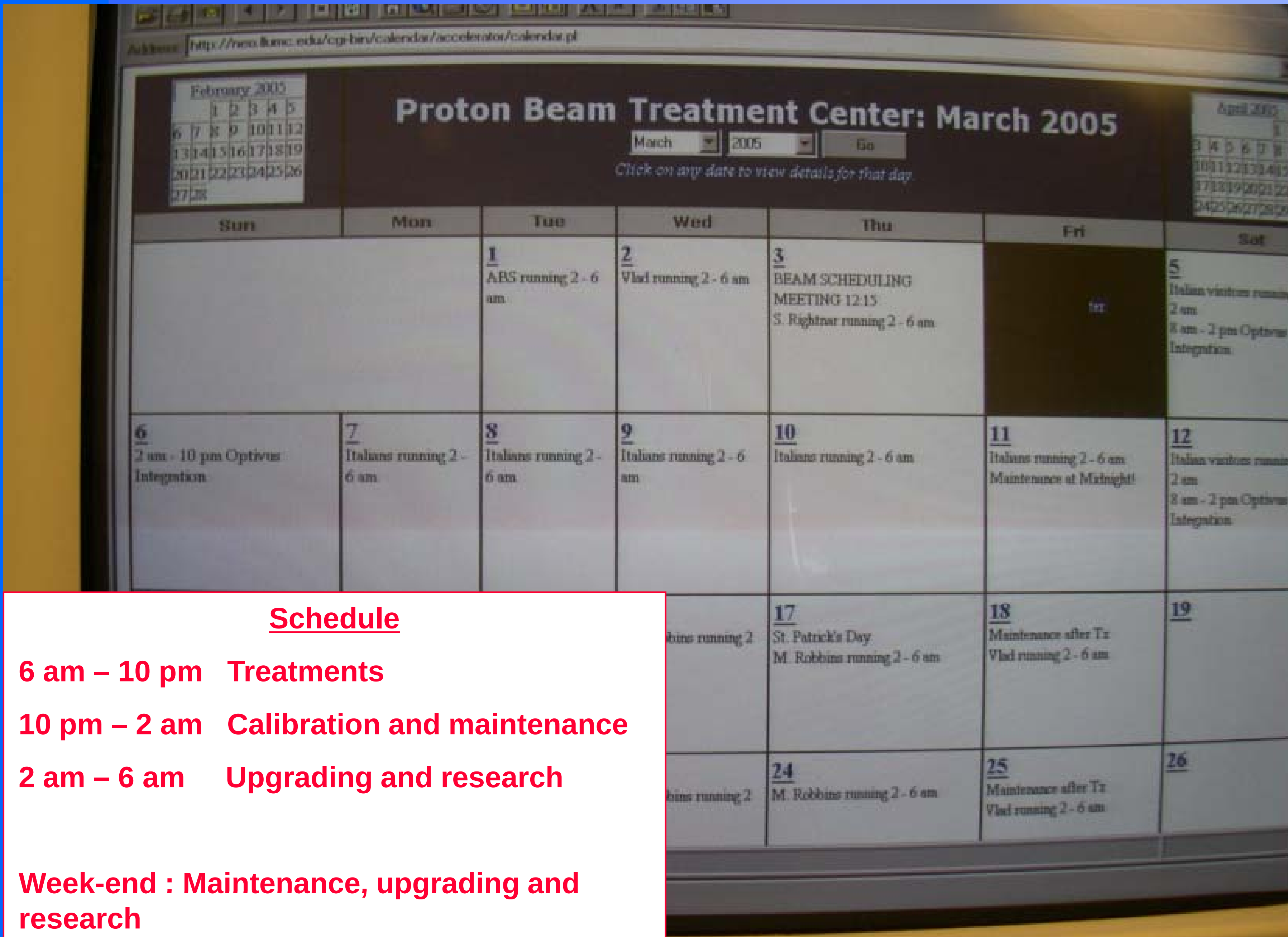
Spinal cord

Liver

Calibration

- Performed overnight for each field by a physicist
- Only one point is tested (chosen by a medical physicist)
- All the components are bar-coded
- Precision within 2%

The beam time schedule



Schedule

6 am – 10 pm Treatments

10 pm – 2 am Calibration and maintenance

2 am – 6 am Upgrading and research

Week-end : Maintenance, upgrading and research

- **Pixel ionization chamber**
- **On-line monitoring during hadron-therapy treatments**

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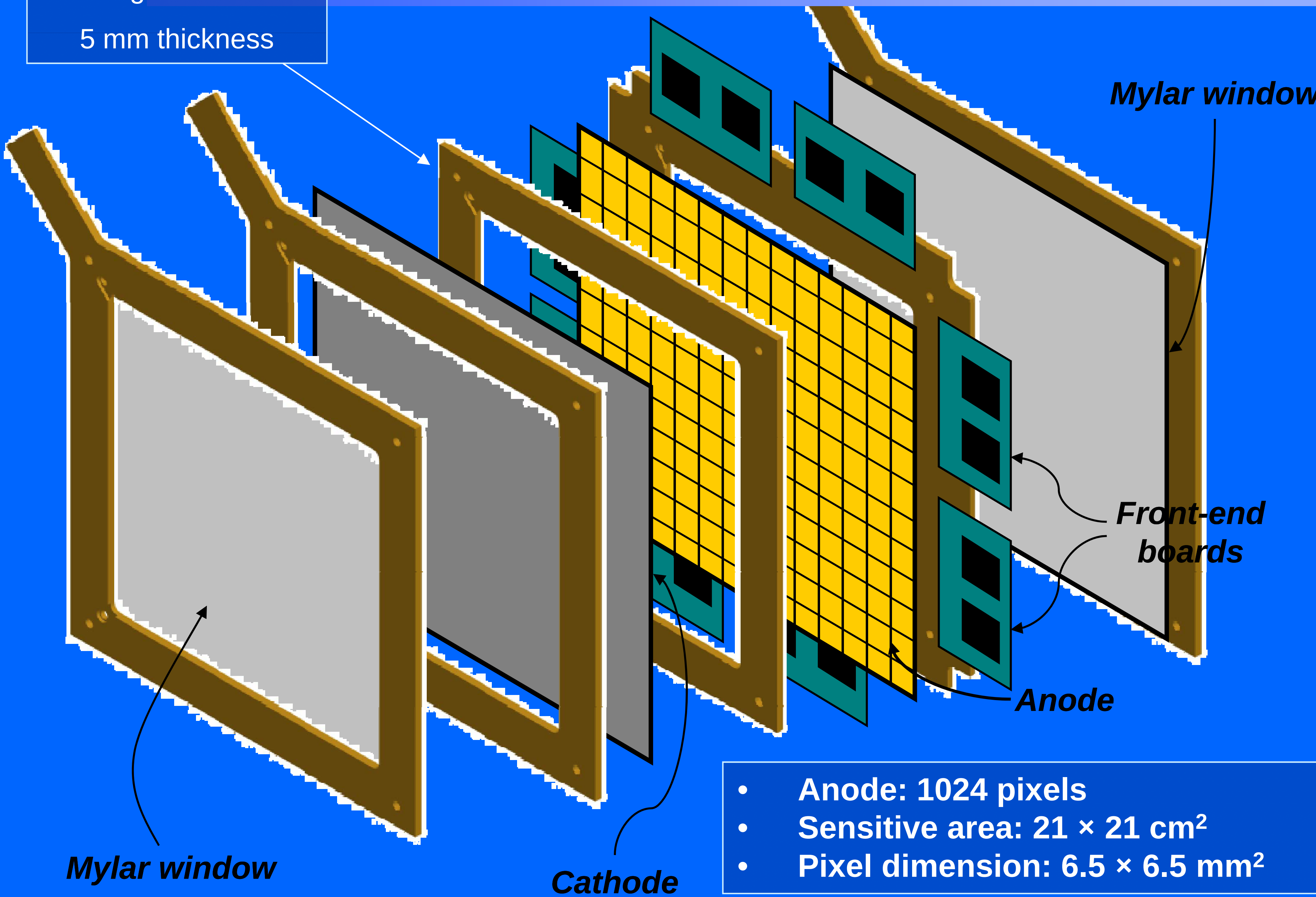
2D information:

Dose

Beam position

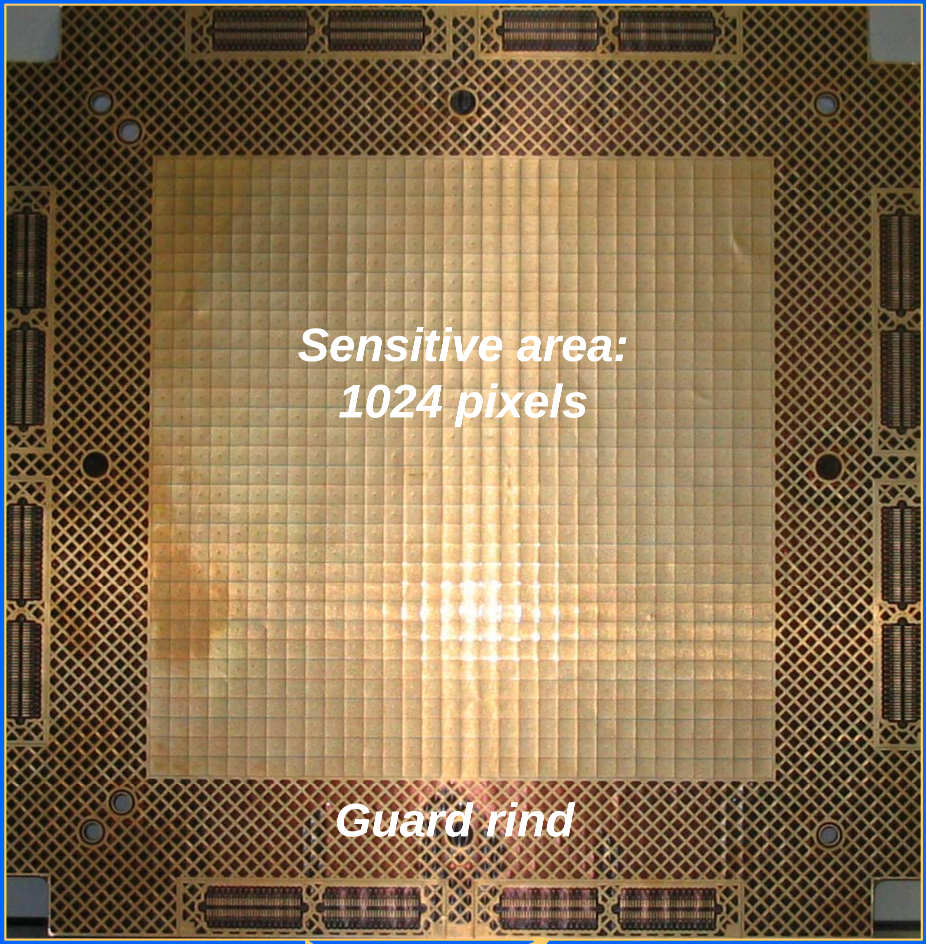
- **Collaboration TERA – University and INFN Torino**

Structure of the detector



- **Anode: 1024 pixels**
- **Sensitive area: 21 × 21 cm^2**
- **Pixel dimension: 6.5 × 6.5 mm^2**

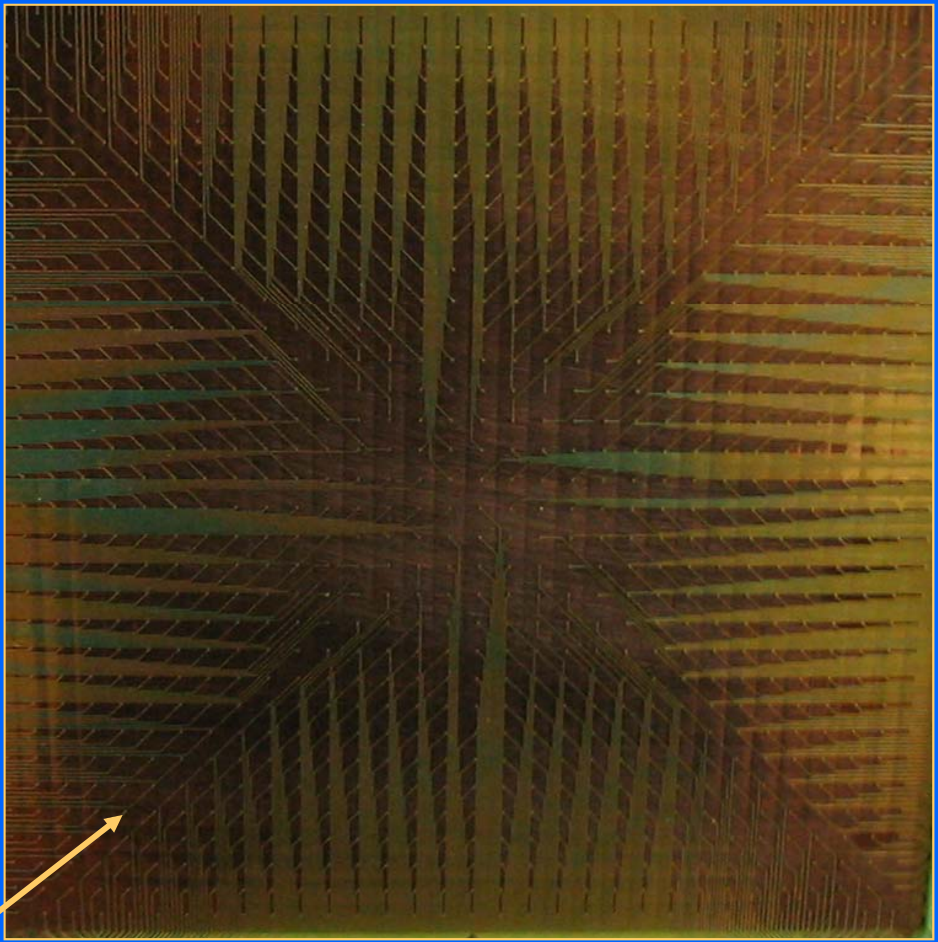
Anode



Connection with front-end boards – pads for connectors

Kapton: 50 μm

Copper: 17 μm



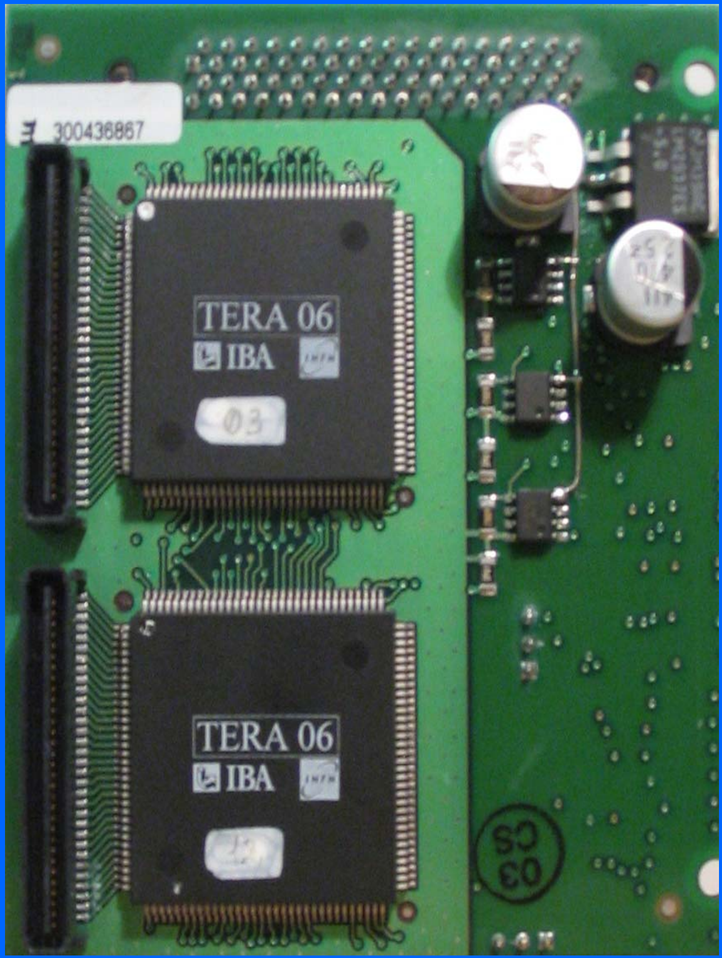
pixels – pads for connectors

Aluminized mylar

Applied voltage: - 400 V

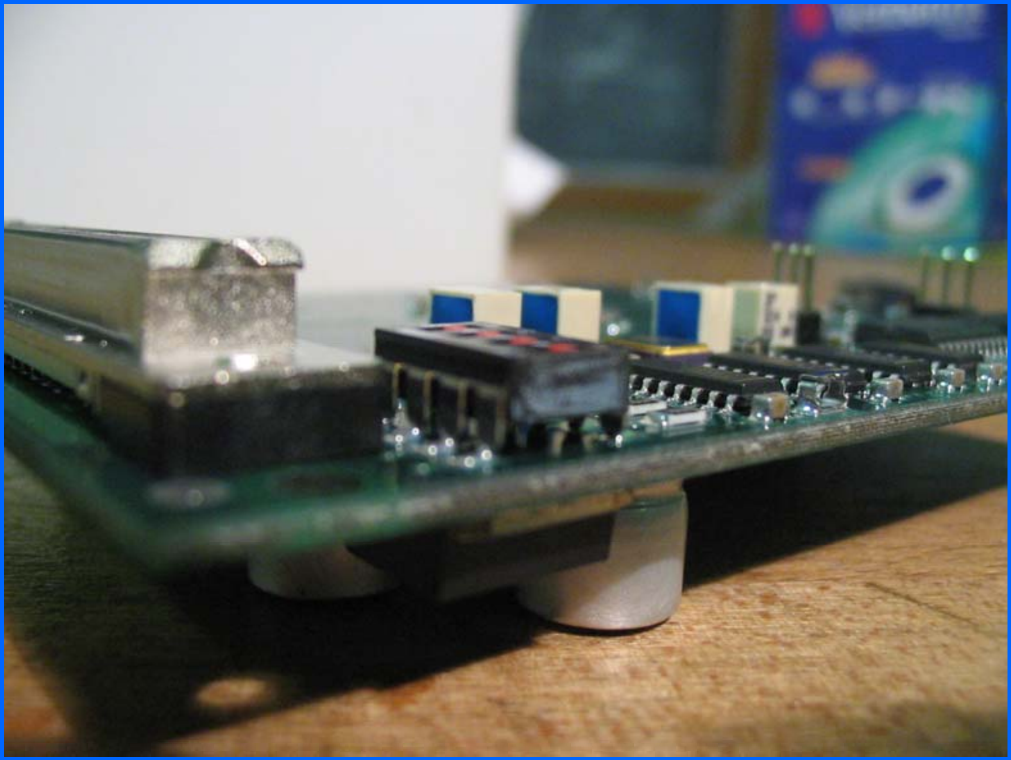
Fiberglass frame

Front-end board



Chip TERA 06
Recycling integrator
2 x 64 channels

1024 pixels : 8 boards, 16 chips



Charge quantum: 100 – 800 fC

Q = 100 fC → I_{max}= 0.5 μA

Q = 800 fC → I_{max}= 4.0 μA

The lower the charge quantum

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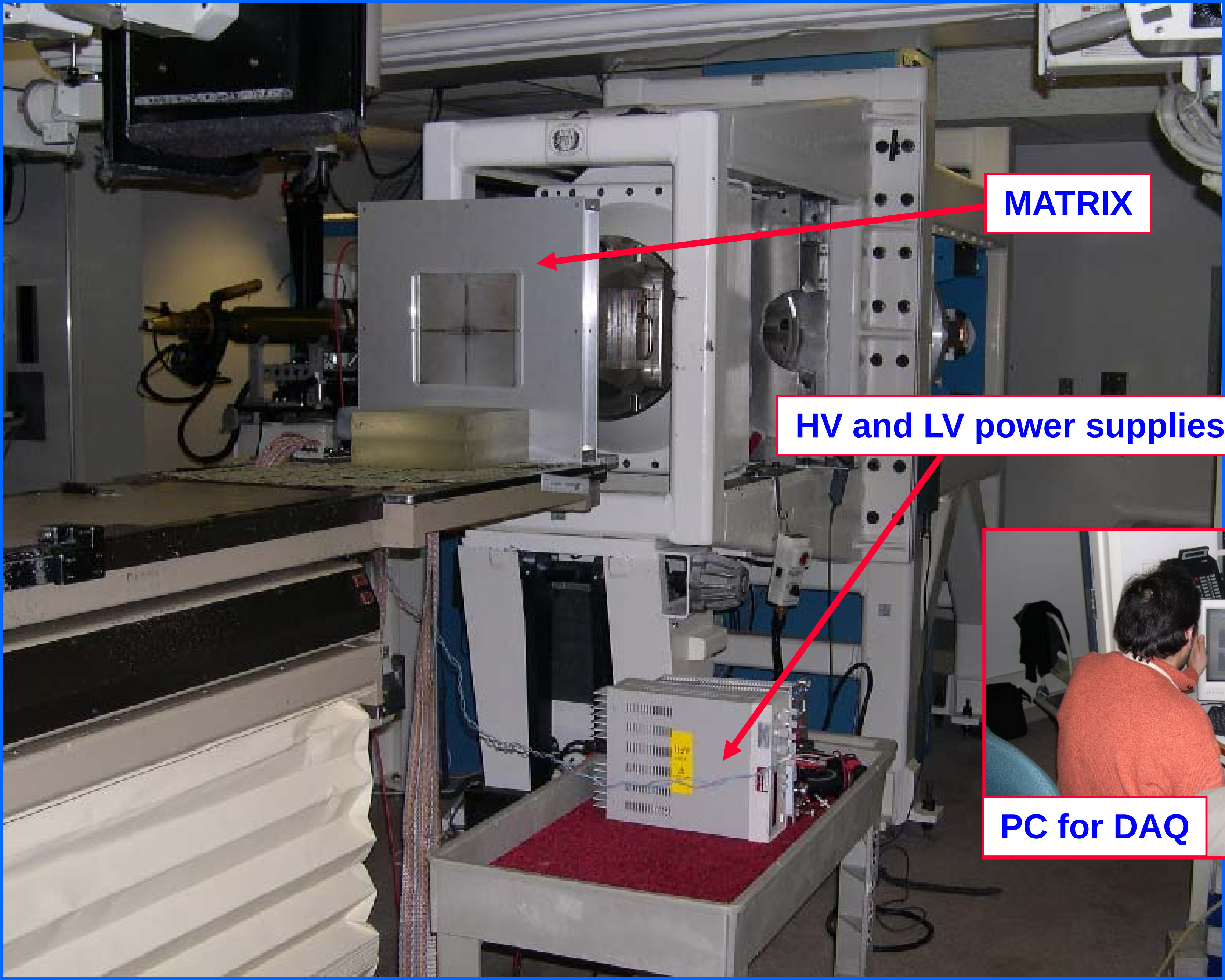
The better the measurement

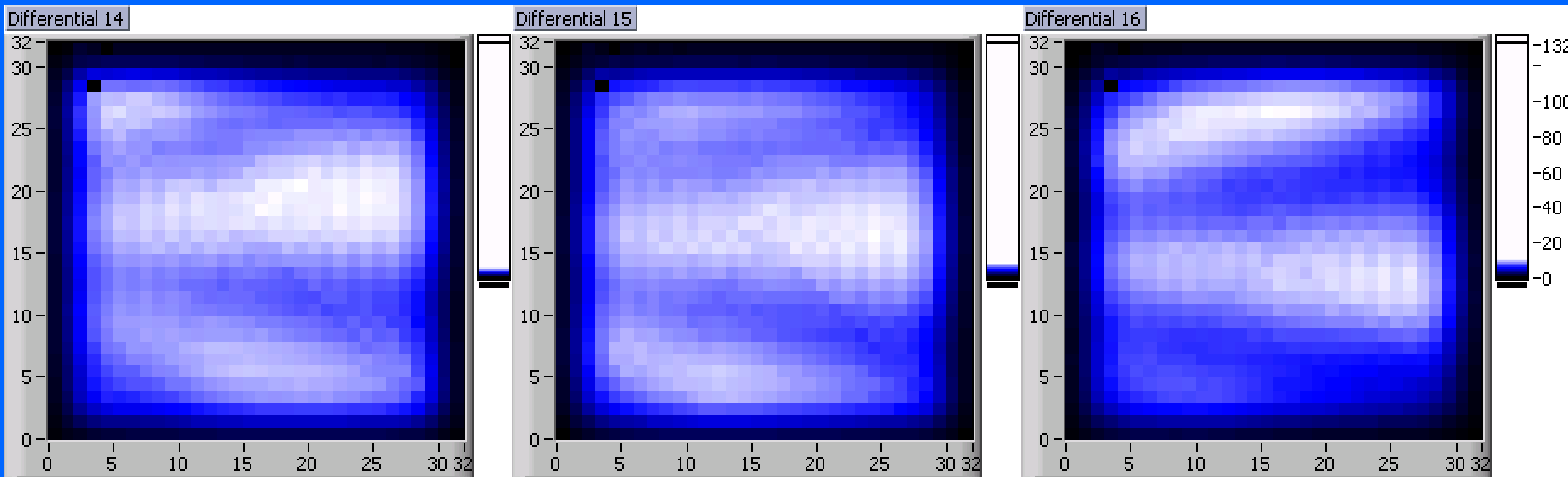
The charge quantum can be adjusted according to the beam current:
100 fC for LLUMC

MATRIX at LLUMC



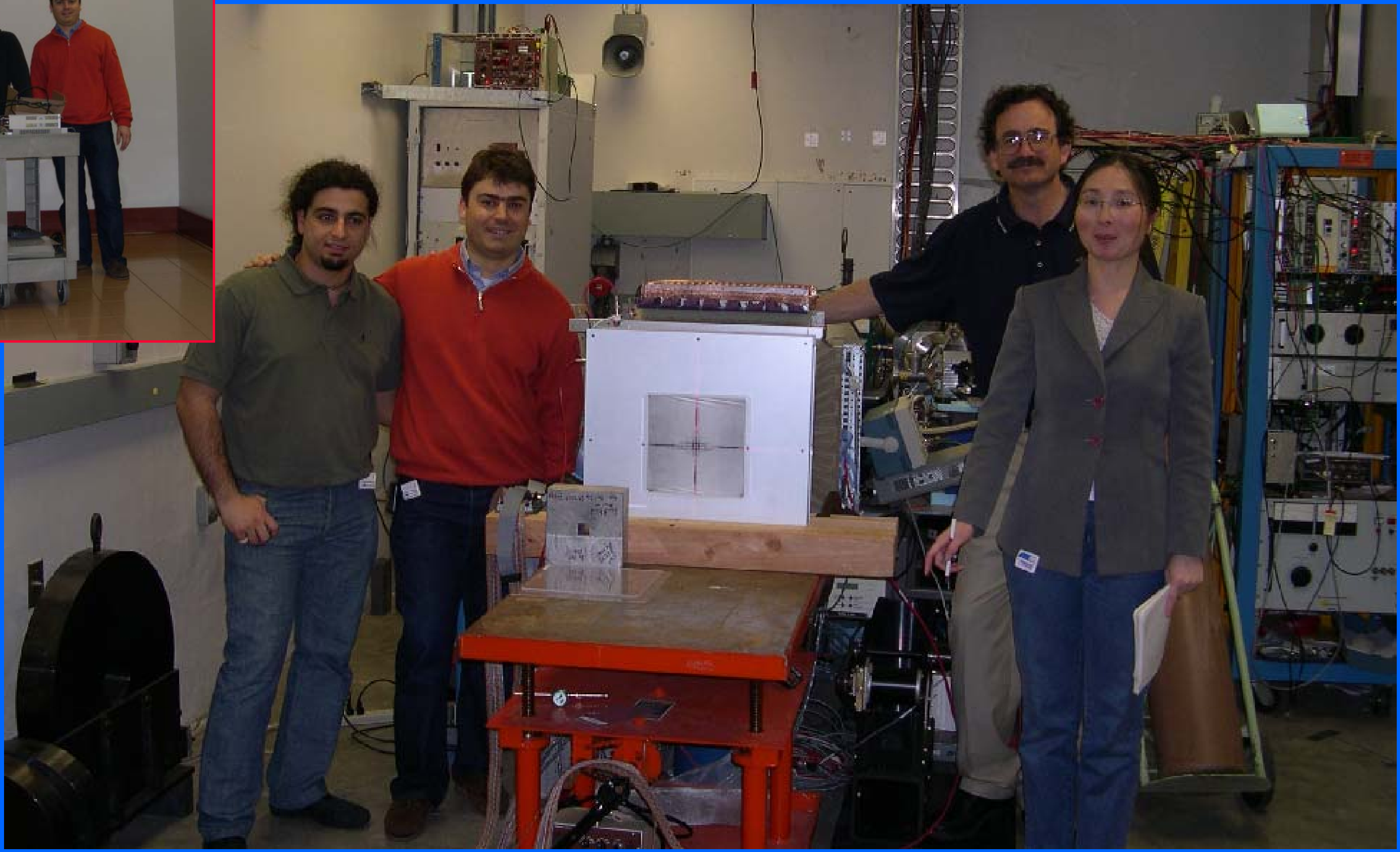
A nice effect…

Detection of the movement of the propeller by means of ionization!



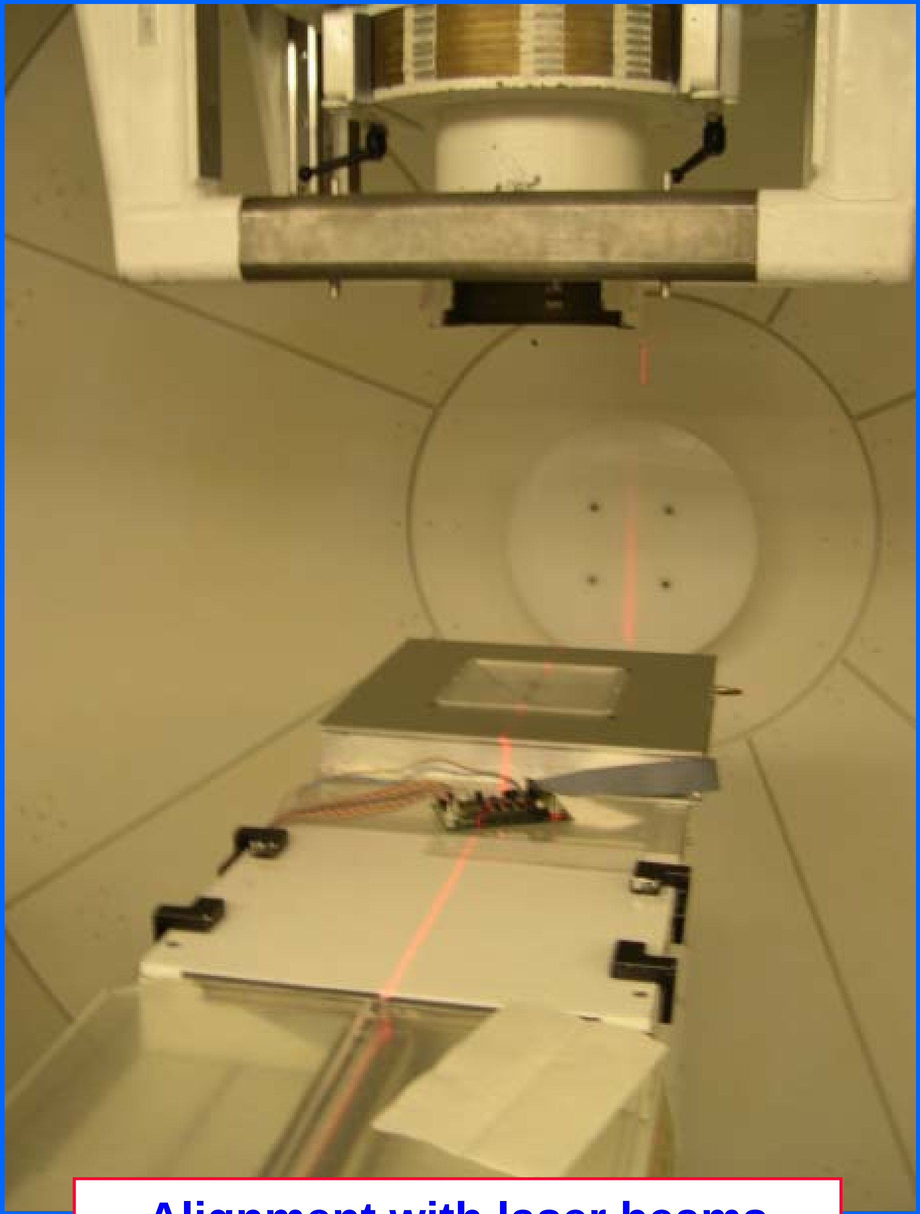
Time

…in the experimental beam room

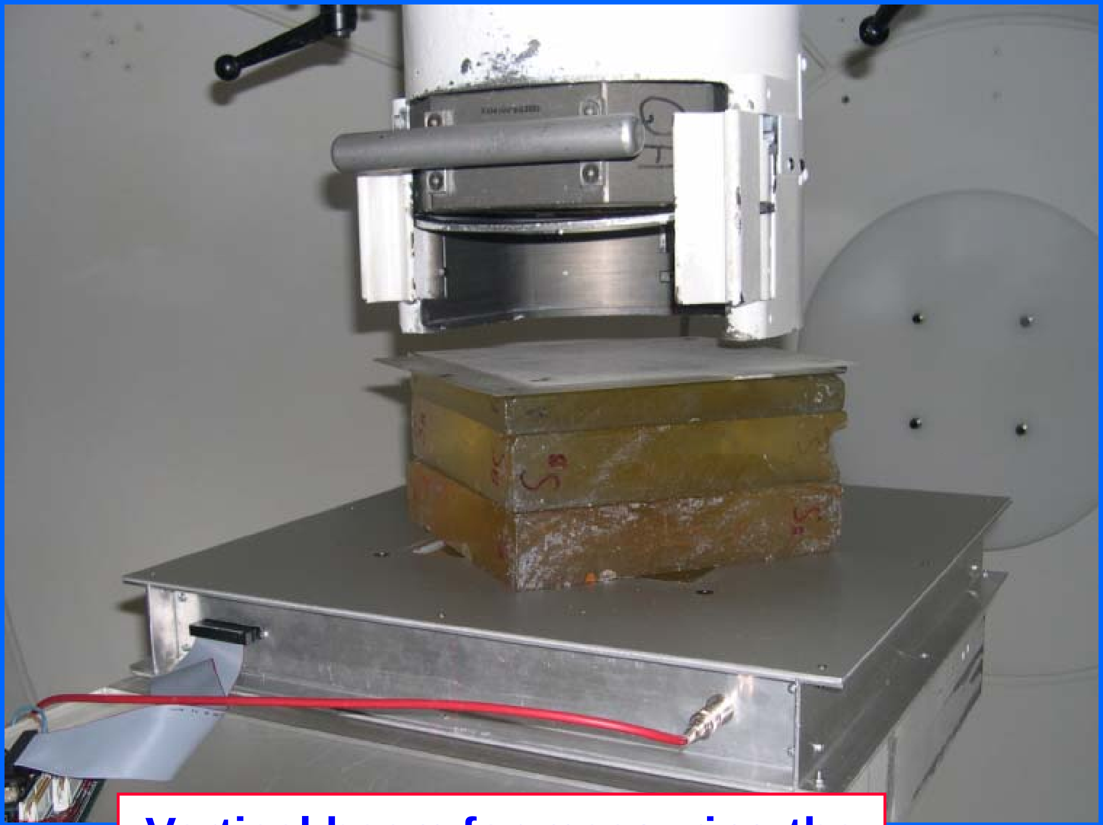


Measurements in Gantry 2

Measurements in Gantry 2



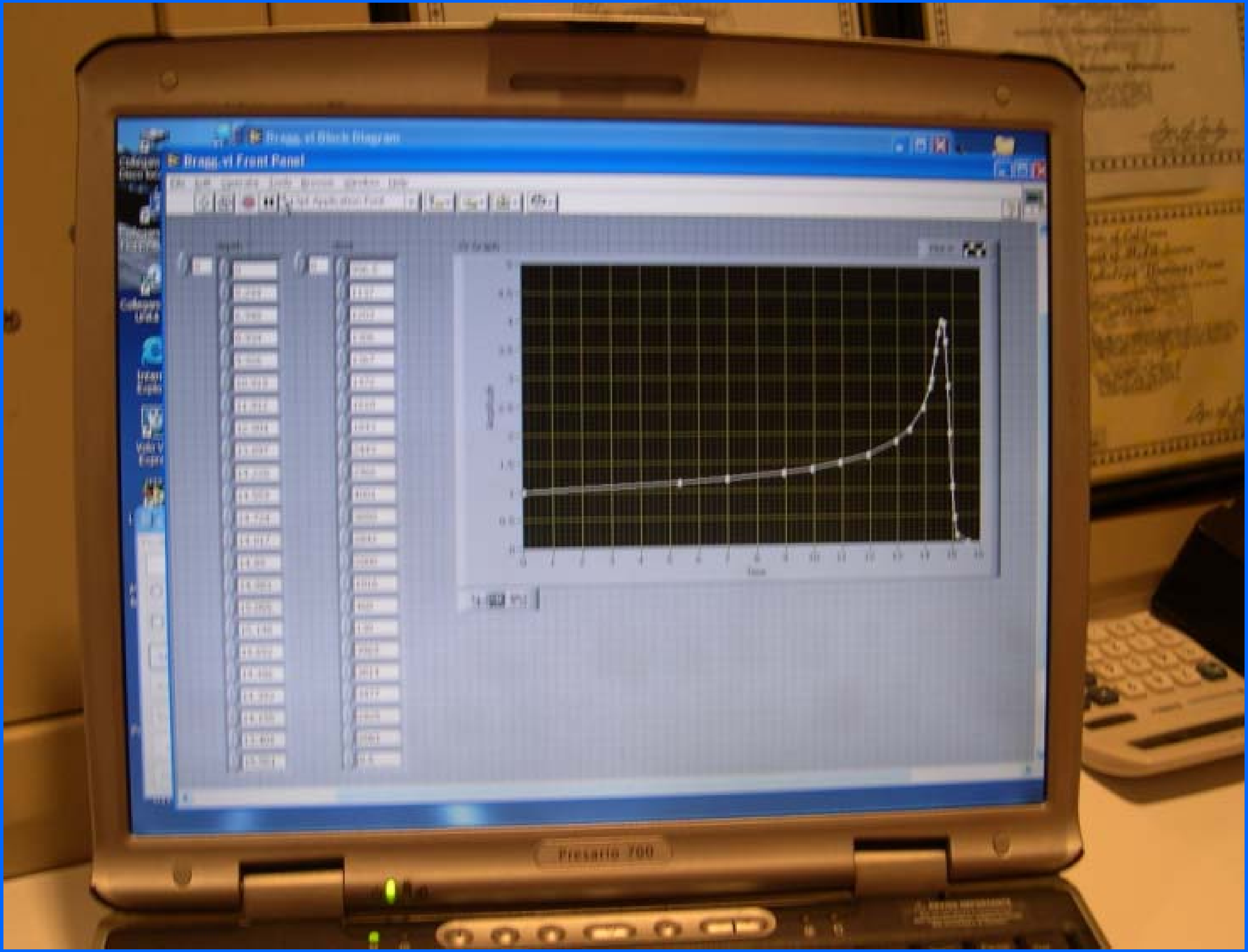
Alignment with laser beams



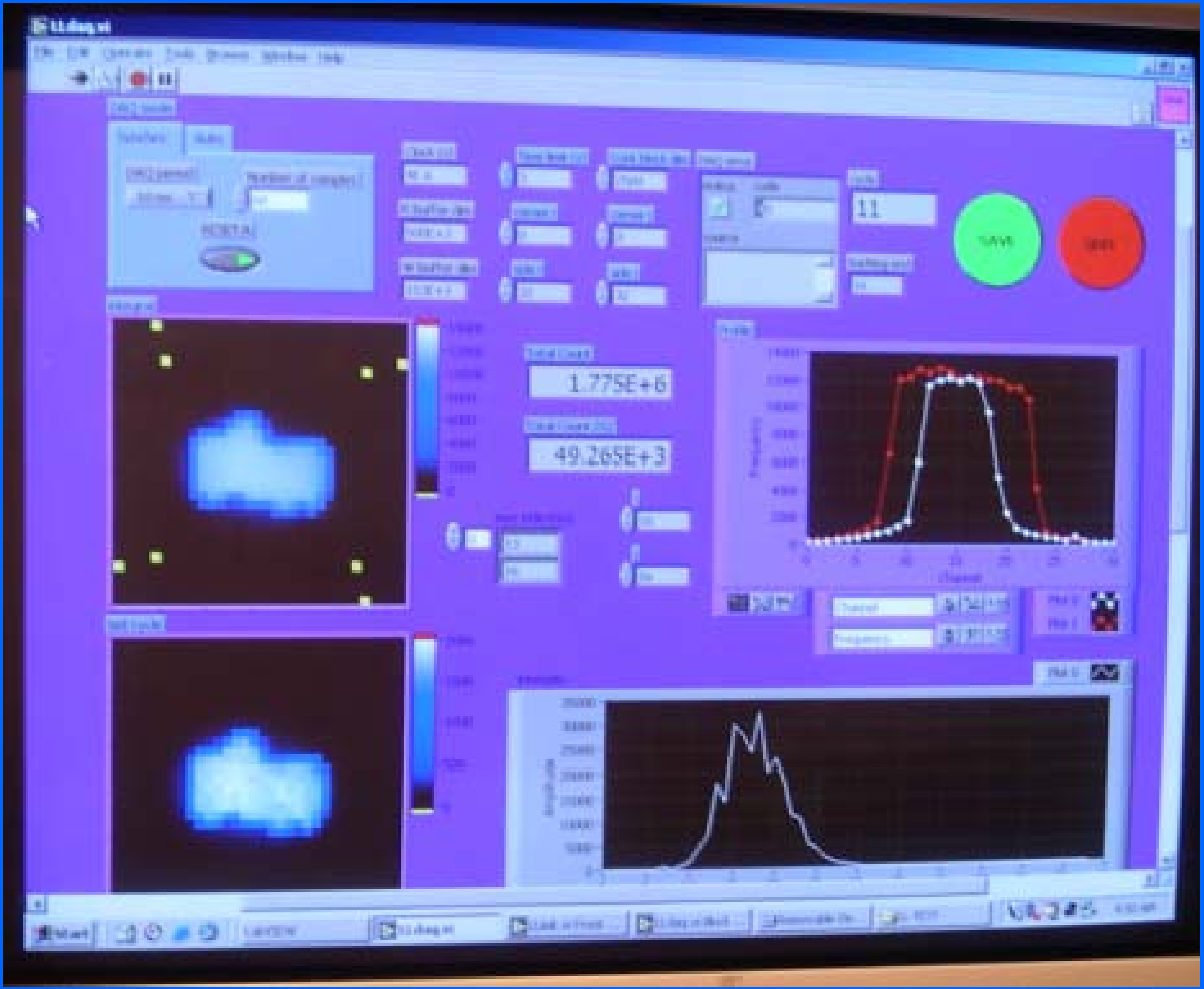
Vertical beam for measuring the Bragg peak

E_{beam} = 149 MeV

The Bragg Peak



Beam shape for a prostate cancer treatment



End of part VII