MASSACHUSETTS GENERAL HOSPITAL
CANCER CENTER℠

Proton Therapy Operations and Physics QA at MGH

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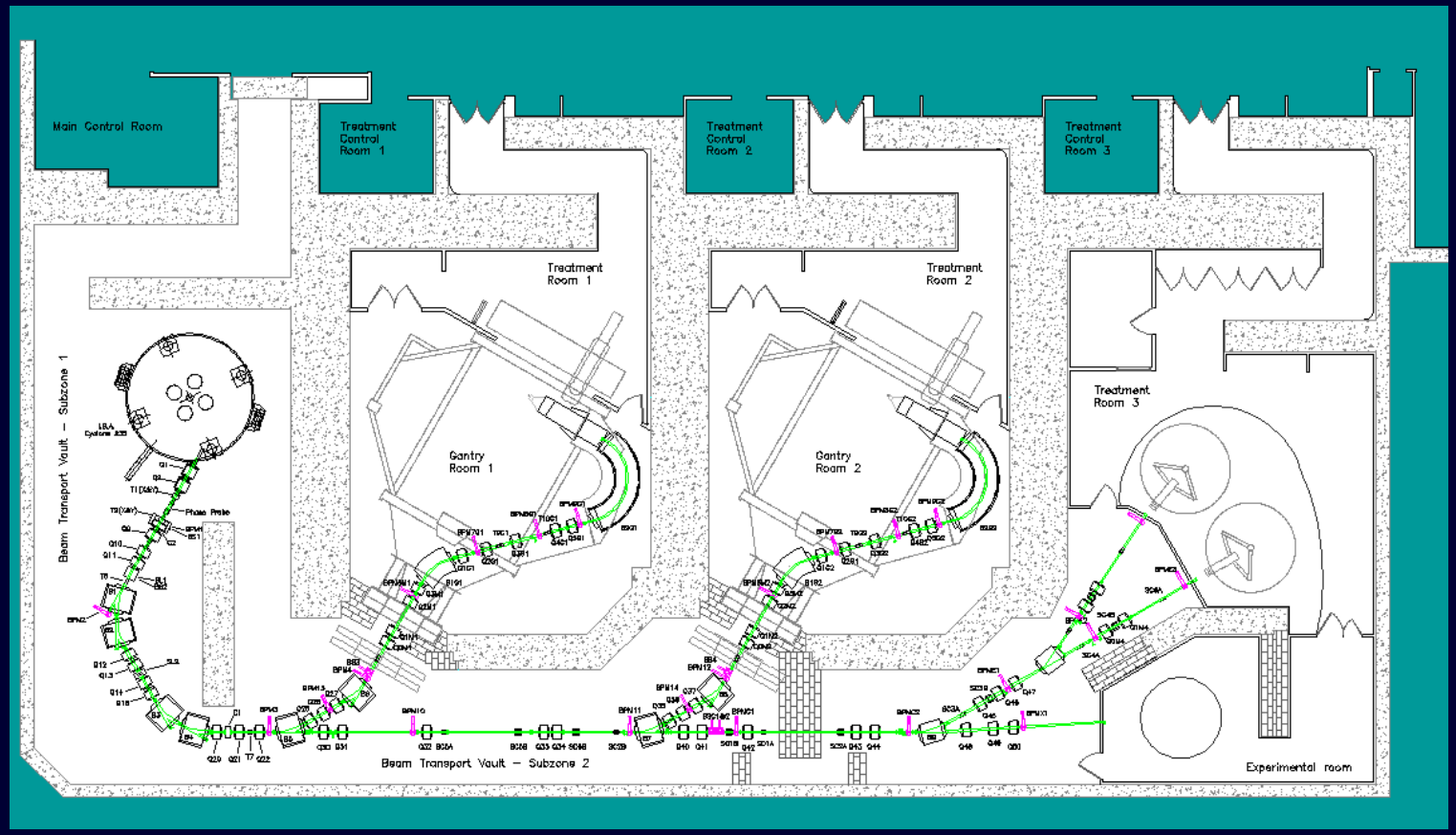
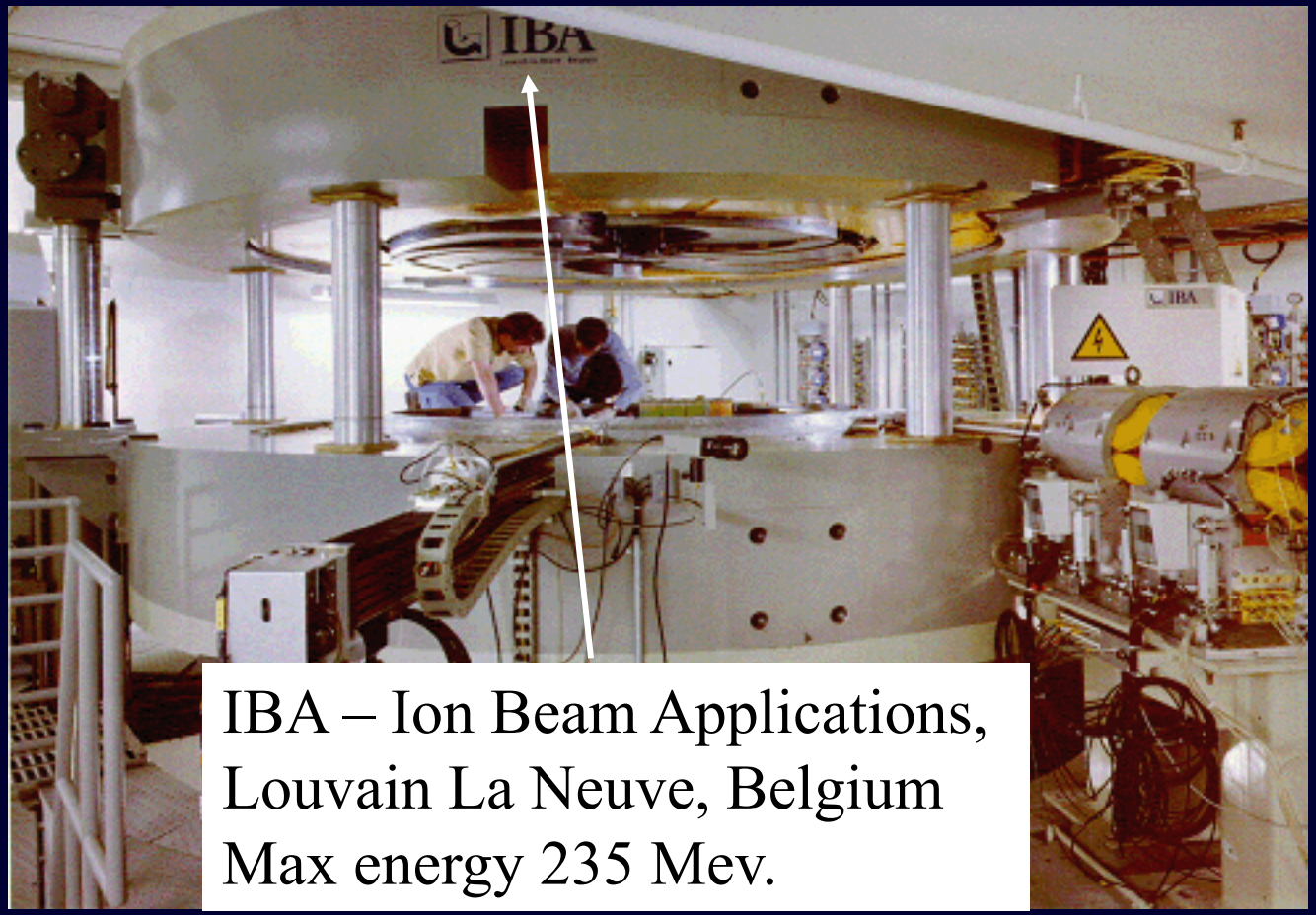
Francis H. Burr Proton Therapy Center, MGH

Treatment Room Layout



Accelerator



IBA – Ion Beam Applications,
Louvain La Neuve, Belgium
Max energy 235 Mev.

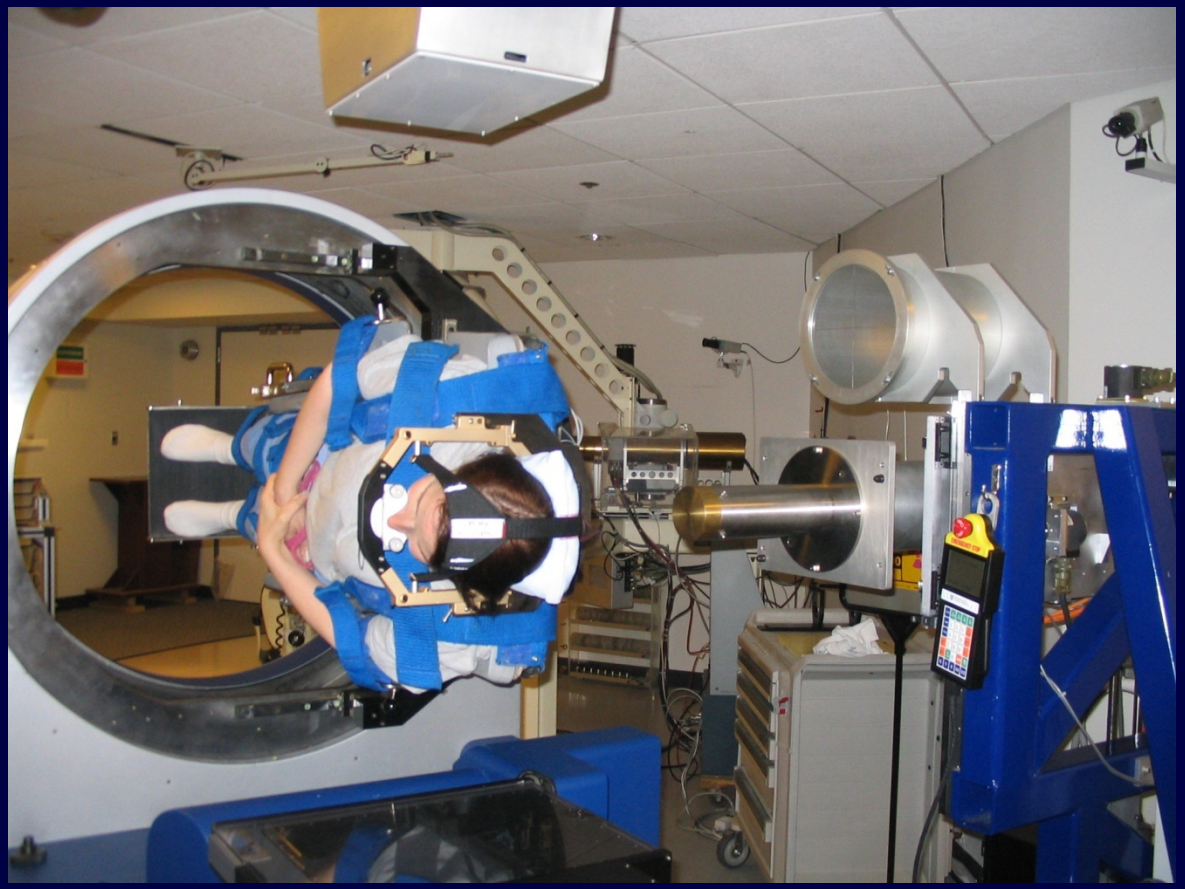
2 Gantry Rooms

1 Fixed Beam Room

Ocular Beamline: 164 MeV
Radiosurgery Beamline: 185 MeV

Fixed Beam CNS SRS/SRT

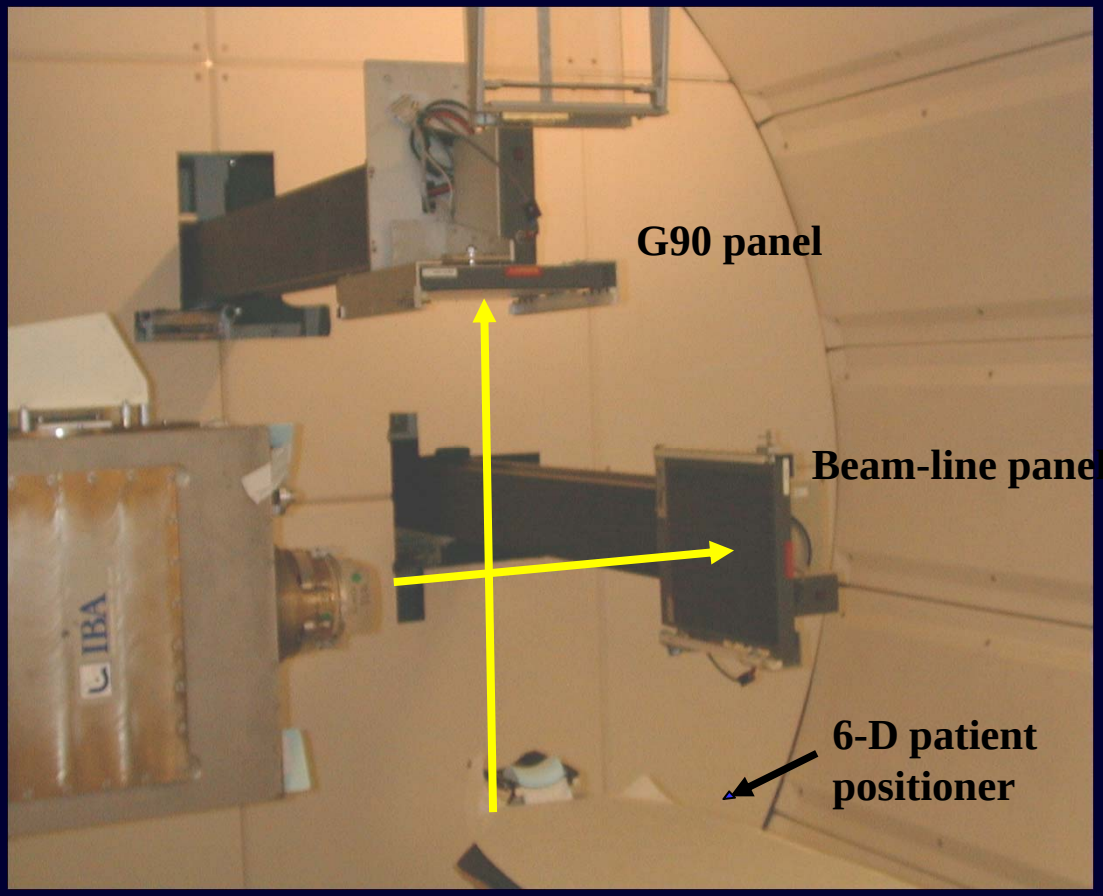
STAR (Stereotactic Alignment Radiosurgery)



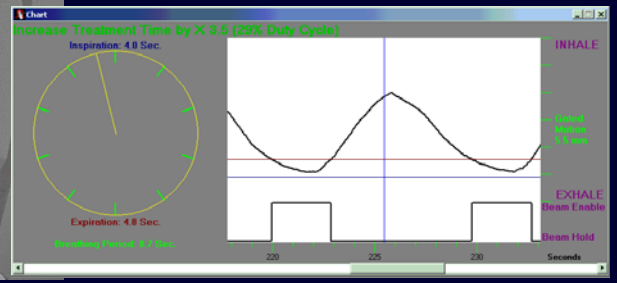
Digital Imaging Position System (DIPS)

Landmark (bone edge or fiducials) based

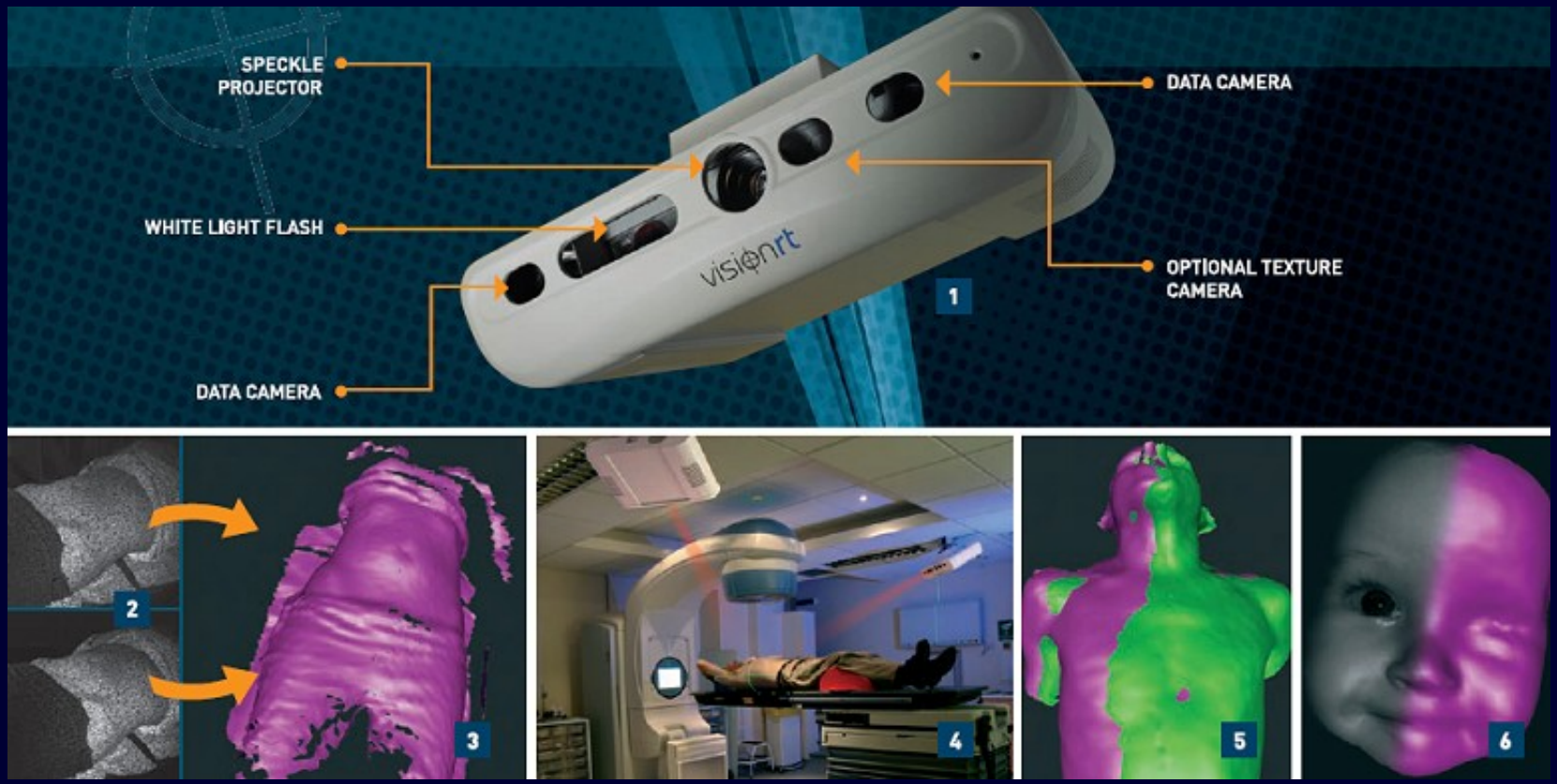
Home grown software



Respiratory Gating (G2)



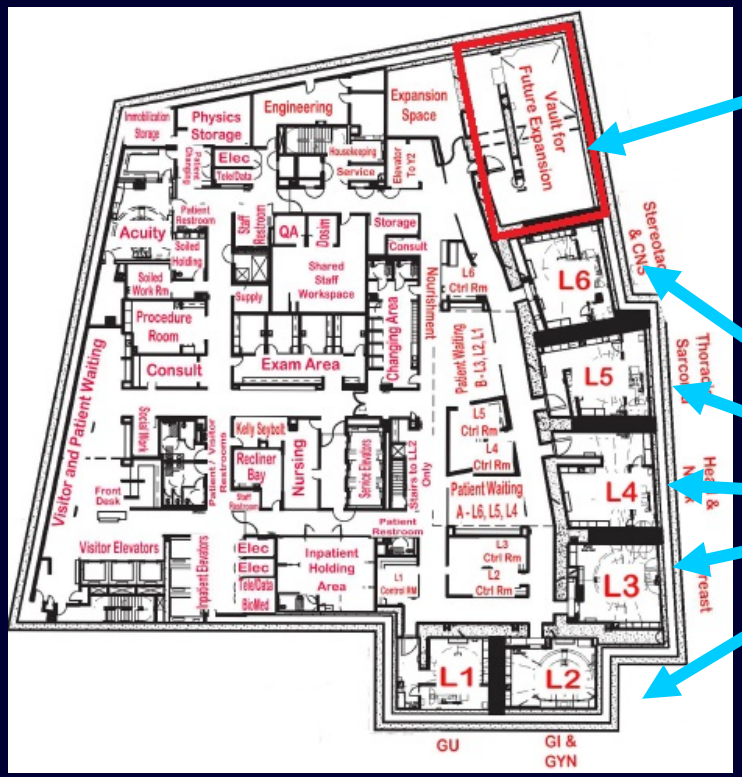
Align-RT (G2)



http://www.visionrt.com

Photon Resources

- Next Building (connected by a bridge)
- 6 LINACs (4 Elekta, 2 Varian), 180 daily treatments



Single room proton system in acquisition

LINACs

Clinical Staffing

8 Clinical Physicists

2 Physics Assistants

10 Proton system operators/engineers

12 Dosimetrists

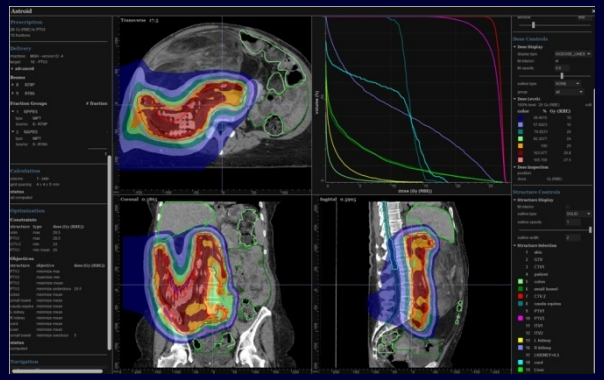
15 Therapists

~6 Radiation oncologists (equivalent)

Treatment Planning Systems

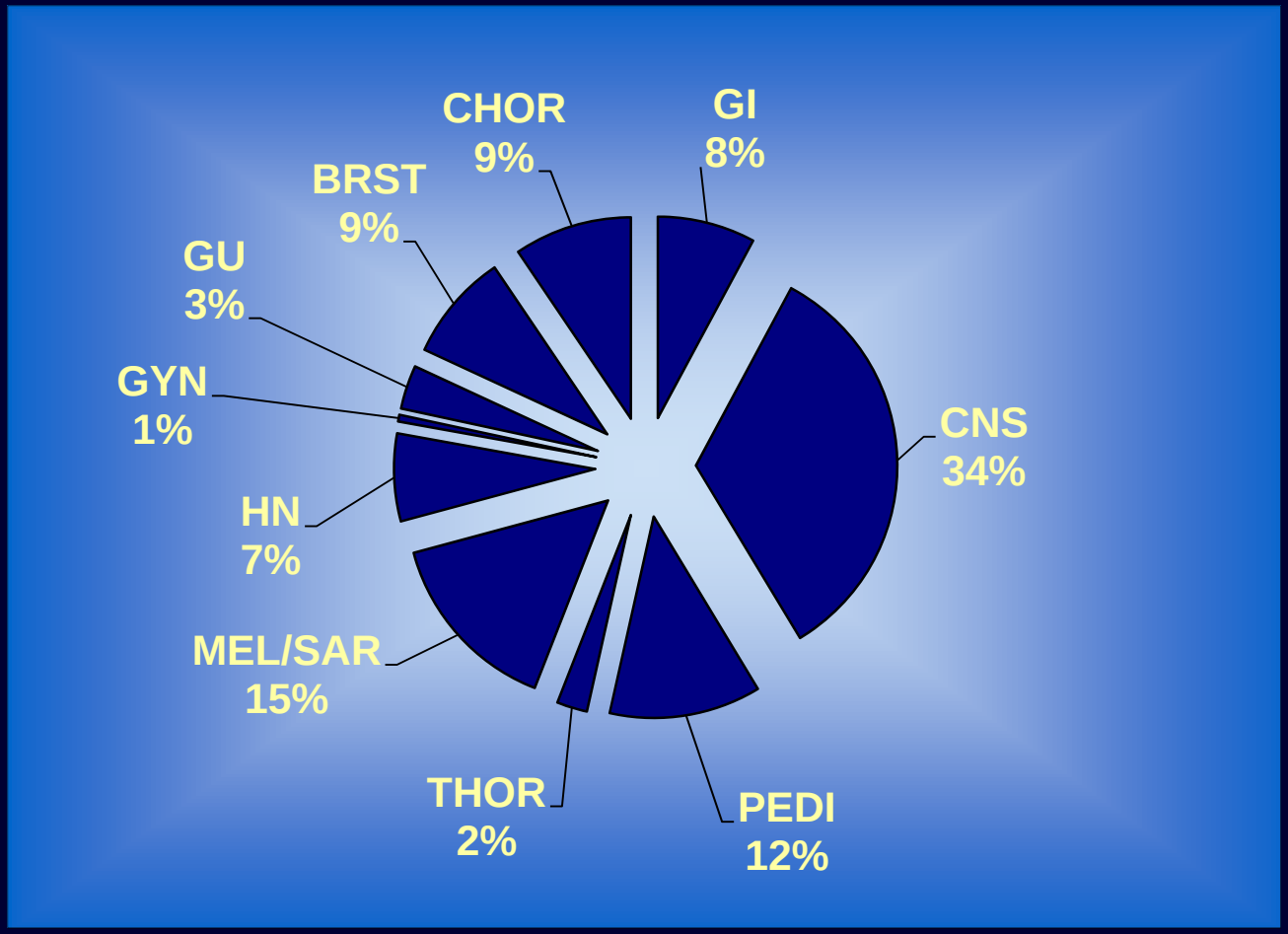
- PS (Gantry and STAR): pXio (Elekta)

- PBS: Astroid (in-house, MCO)



- Ocular: Eyeplan

Patient Population (~700 per year)



A Typical Day of Treatment and QA

	Gantry 1	Gantry 2	Fixed Beam
6:00AM	PS QA (POD)		
6:30AM		PBS QA (POD)	
7:00AM	Imaging QA (RT)	Imaging QA (RT)	Ocular QA (POD)
7:30AM	Pediatric Patients w/o anesthesia	PBS sarcomas chestwall …	Imaging QA (RT)
			Ocular treatment
~ 9:30AM			STAR QA (POD)
~10:30AM	Adult all indications	PS QA (POD)	CNS SRS/SRT
		Adult all indications	
5:30 PM	Prostate		

1) Proton engineers perform system QA before 6am

2) POD – Physicist Of the Day

QA Standards

Absolute Dosimetry

IAEA TRS-398	Absorbed Dose Determination in External Beam Radiotherapy
ICRU Report 59	Clinical Proton Dosimetry - Part I: Beam Production, Beam Delivery and Measurement of Absorbed Dose

Quality Assurance

AAPM TG-142	Quality Assurance of Medical Accelerators
AAPM TG-54	Stereotactic Radiosurgery

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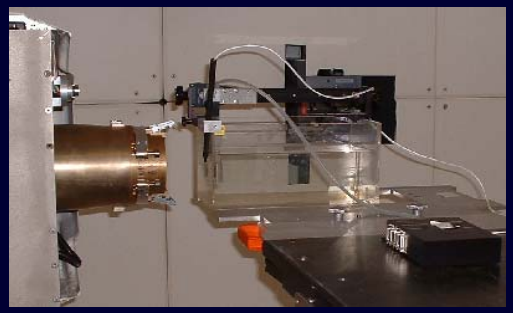
Passive Scattering - Daily QA

- Service Mode
  - Use a range verifier installed in the nozzle
    - Verifies integrity of scatters (first and second)
    - Verifies timing of range modulator wheels (3 wheels)
    - Verifies beam range (1.0 mm tolerance)
- Treatment Mode
  - Use ion chamber and Lucite phantom to measure output factor for a standard SOBP field
    - Verifies MU chamber system
    - Verifies beam current modulation system
    - Verifies the secondary MU tracker

Passive Scattering – Bi-Weekly

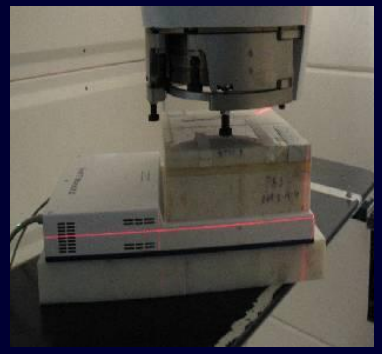
- Beam range and modulation
  - Measure SOBP depth-dose distributions for fixed set of fields spanning the entire treatment beam range (CRS 1D scanning tank)
  - Range tolerance (±1 mm)
  - Modulation tolerance (±3 mm)



- Output check
  - Measure output factor for these fields and compare with output factor calculation program
  - Tolerance (±3%)

Passive Scattering – Monthly

- Field flatness, symmetry, field radius (98-98%)
  - Measure 2D dose (Matrix with solid water slabs) for fixed set of fields spanning the clinical beam range



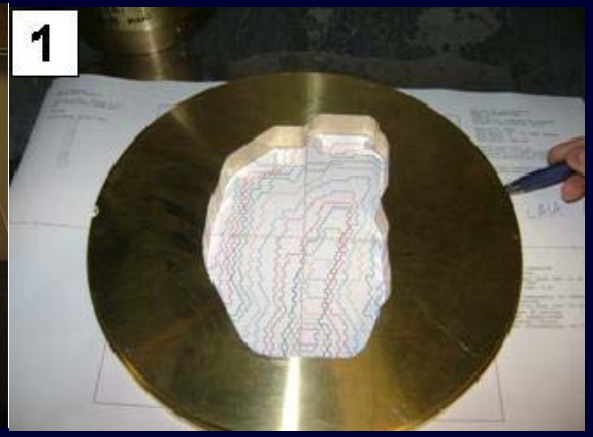
- Light/Proton field coincidence
  - Light field is used for field matching
  - Tolerance (±1 mm)
- Xray/Proton field coincidence
  - Tolerance (±0.5mm)

Passive Scattering – Annual

- Pristine peak depth dose distributions for all clinical beam ranges
- Field flatness, symmetry, field radius (98-98%) at other nominal gantry angles 90, 270, 180.
- MU chamber checks
  - Dose rate dependence
  - Gantry angle dependence
  - Voltage dependence
- X-ray/Proton/light field coincidence at all nominal gantry angles

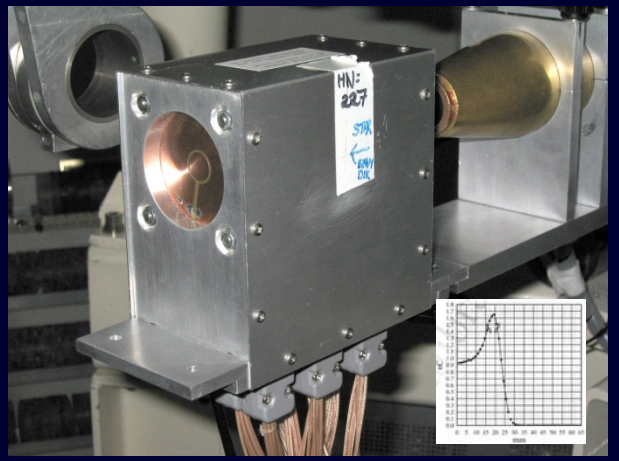
PS Patient Specific QA

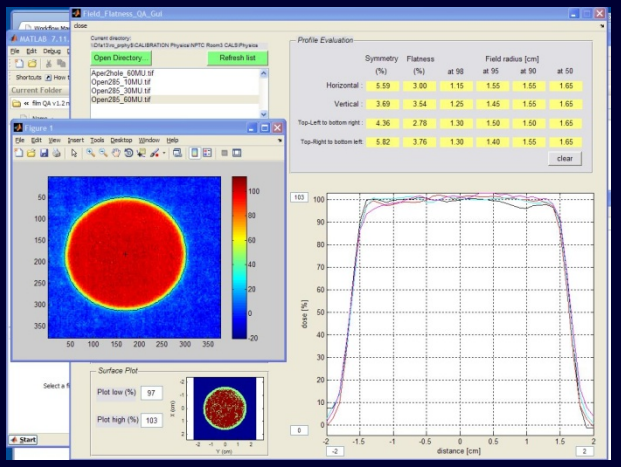
- Output factor calculation
  - Two separate programs
- Field hardware check
  - Aperture tolerance (±0.5mm)
  - Compensator tolerance (±0.5mm)



Ocular Beamline QA

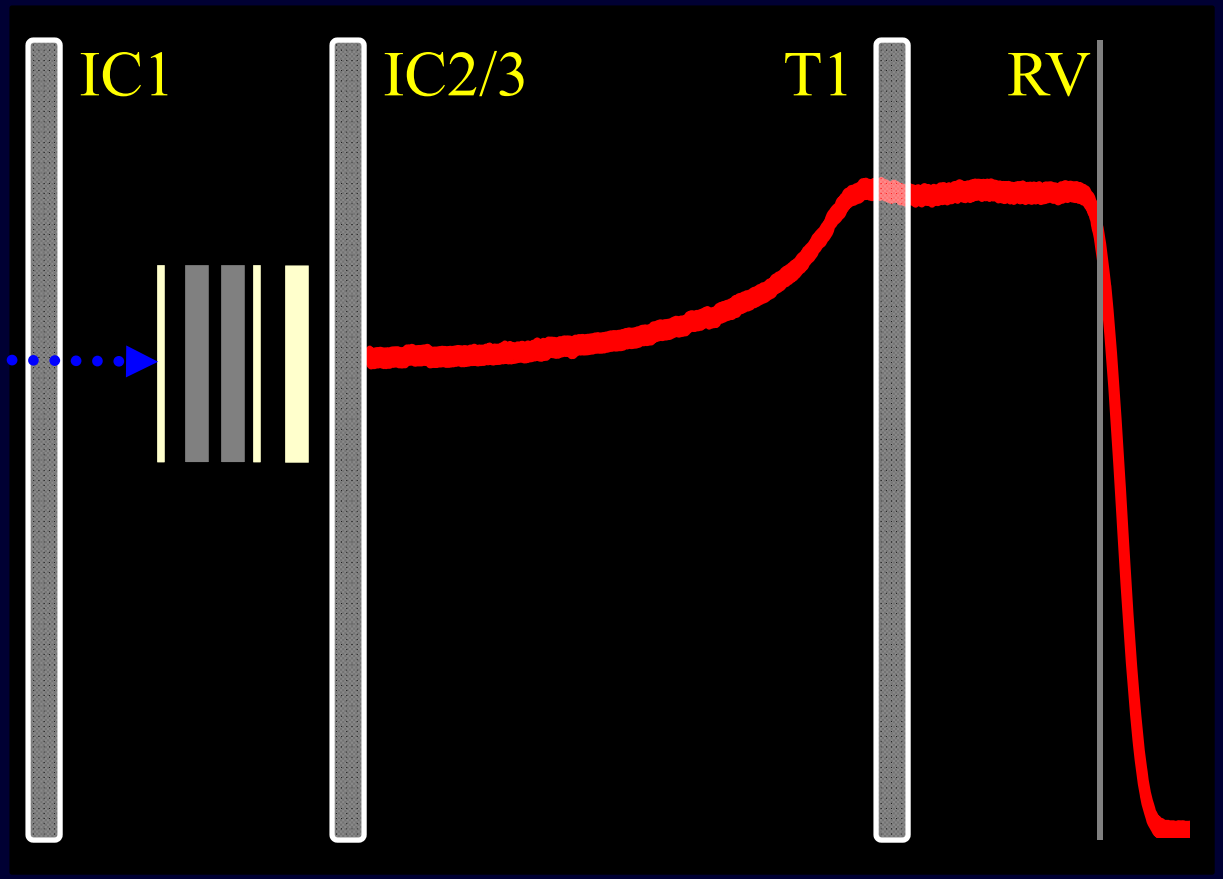
- Daily
  - Use Multi-Layer Ionization Chamber (MLIC)
  - Measure pristine peak range
  - Measure SOBP depth-dose and output
  - Check absorber setting
- Quarterly
  - Check MLIC calibration by a T1
  - Field flatness and symmetry (film)





STAR Beamline Daily QA

Range, Output, Beam Steering Constancy (5 R/M combinations)



IC1 to IC2/3 ratio
steering/hardware

T1 to IC2/3 ratio
output (cGy/MU)

RV
range

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STAR BeamlineWeekly QA

Range, Modulation, Output, Alignment

Multi-Layer Ion Chamber (MLIC) → R / M

Markus Chamber in water → output vs. R / M

$$\Psi = a_o \left(1 + a_1 \left[R/M - 1 \right]^{a_2} \right) \times \left(1 + a_3 R^2 + a_4 R + a_5 \right)$$

CT – CMS – DIPS/STAR/NOZZLE → alignment

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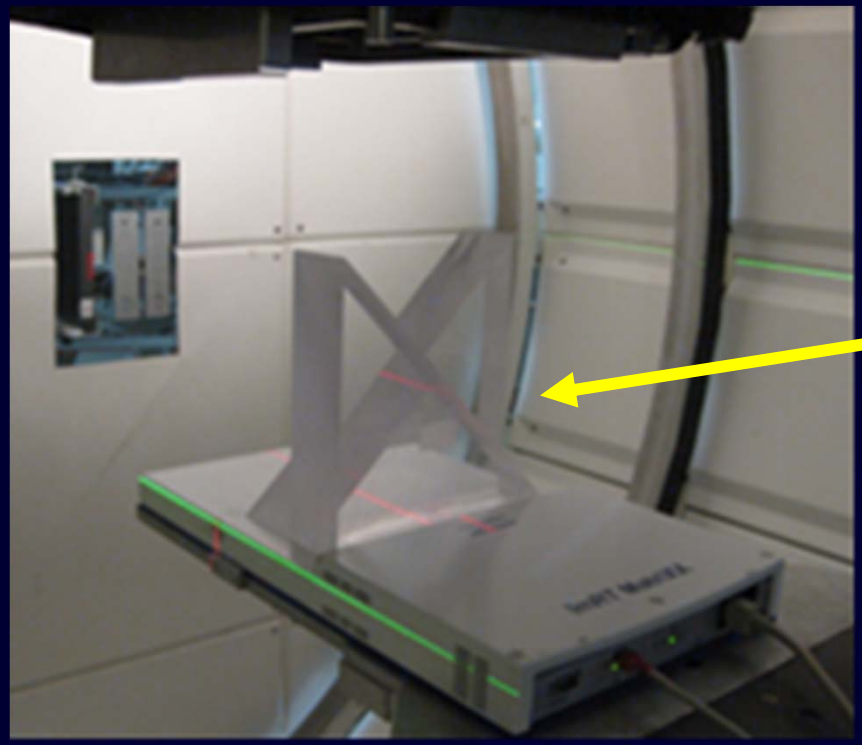
PBS Daily QA

1) MatriXX measurement for PBS QA field

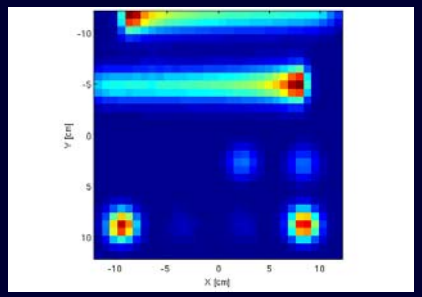


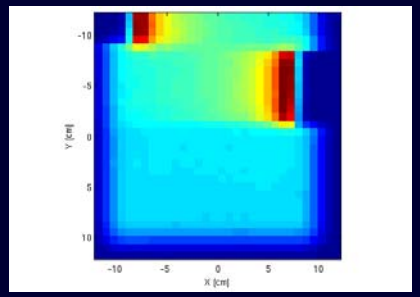
Opposing wedge phantom (Lucite) covers half of Matrixx

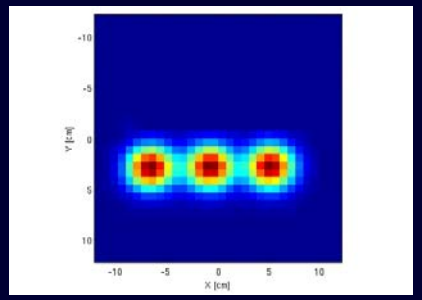
2) Run a typical patient treatment field with a more clinical spot map and check total MU variation

PBS Daily QA Field

Description	Checking
Layer 1 2 Bragg peaks 8 dots of various MU	Beam position Spot doses Spot sizes
Layer 2 Uniform layer (the wedge phantom causes the Bragg peak in the upper half of the field)	Proton range Dose uniformity Penumbra
Layer 3 Three spots with very tight MU tolerances	Interlocks







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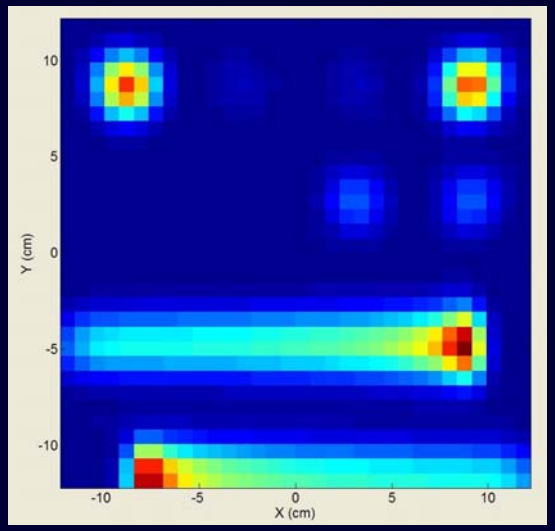
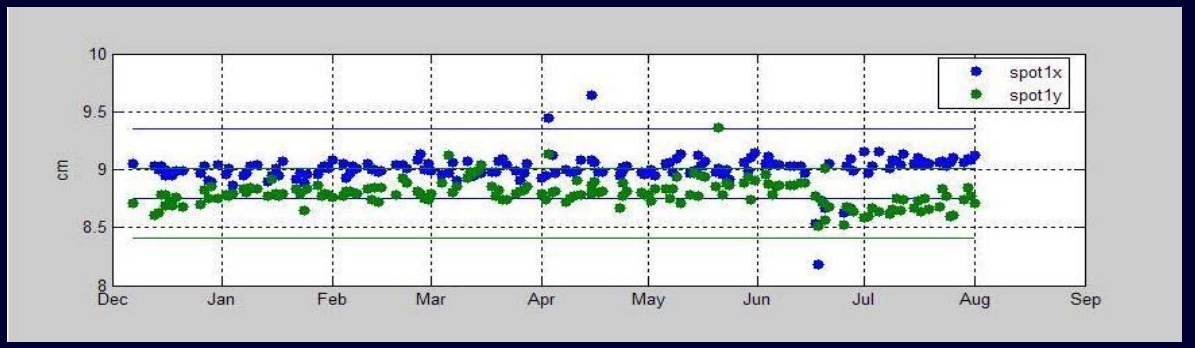
Layer 1

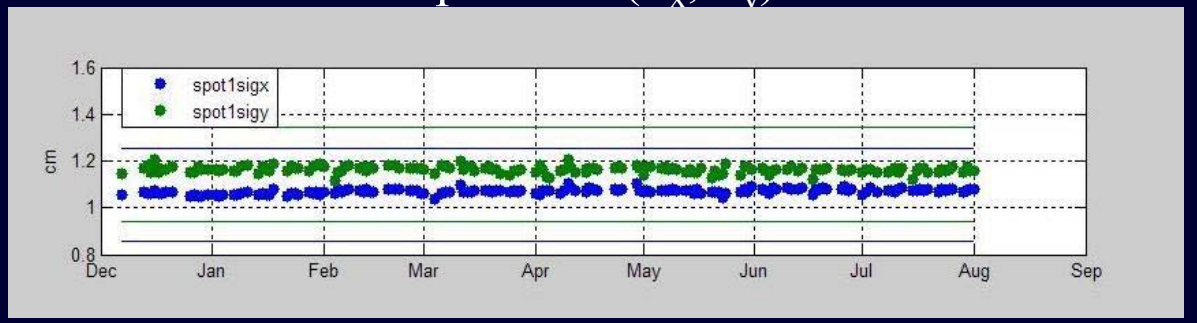
8 spots



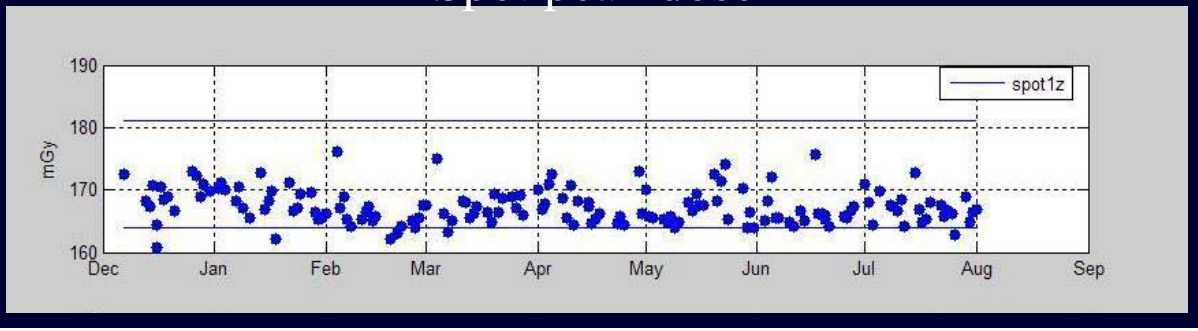
Spot Positions (x, y)



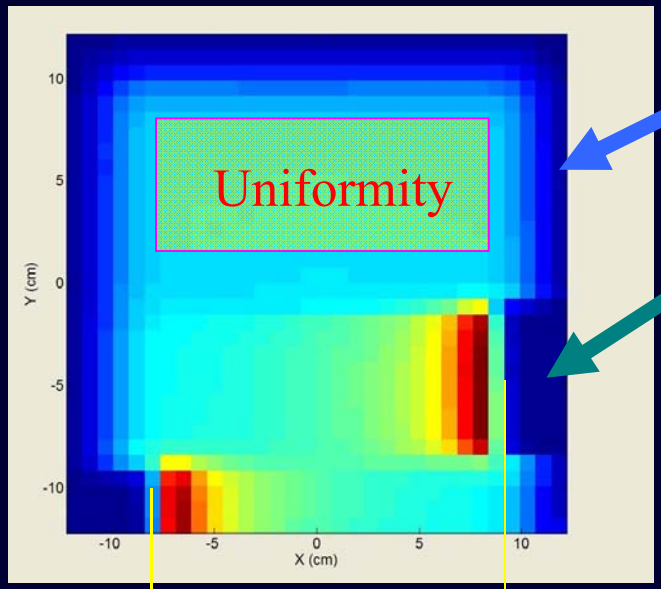
Spot Size (σ_x, σ_y)



Spot peak dose

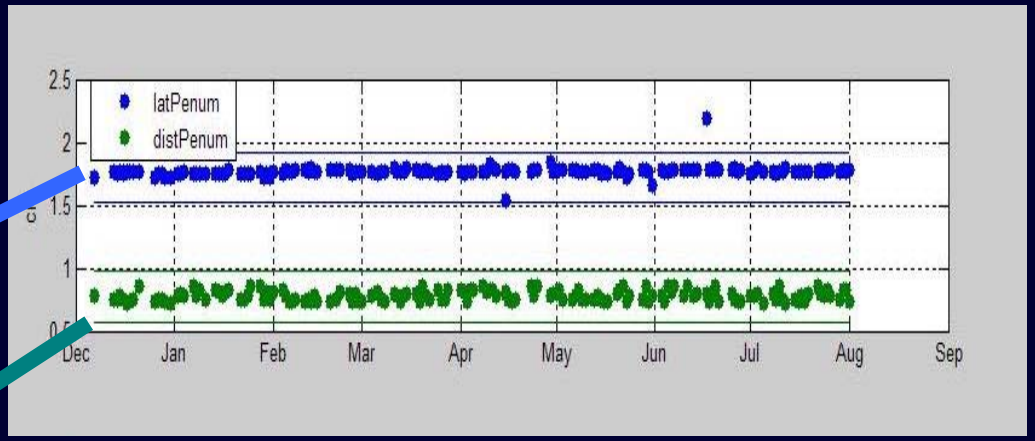


Layer 2

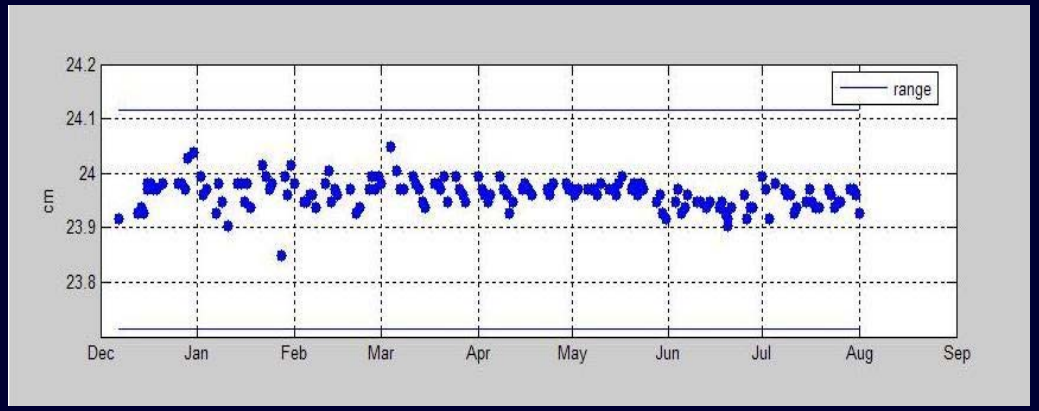


Range difference

Penumbra check

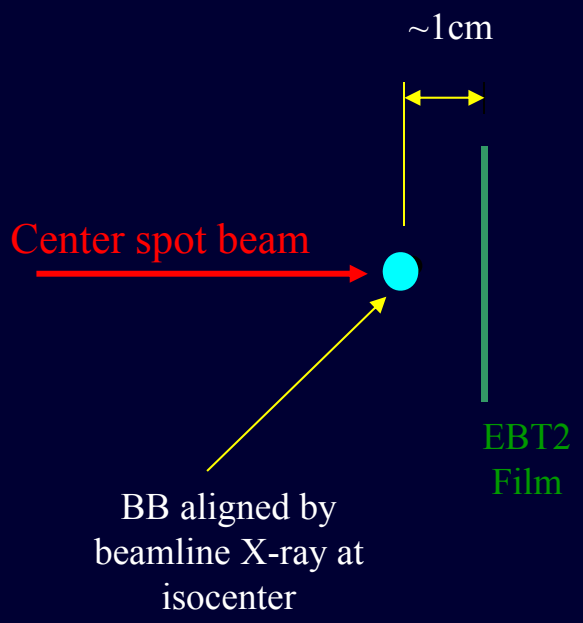


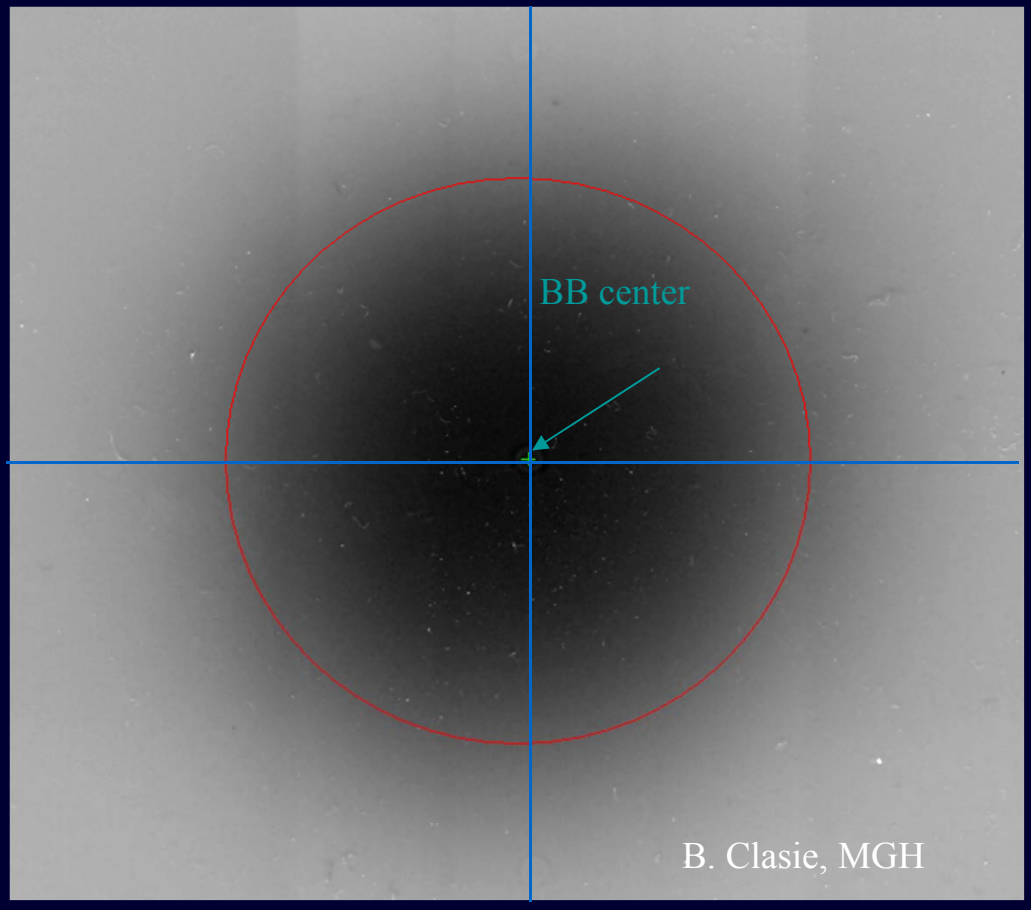
Beam range check



Xray/PBS beam Alignment

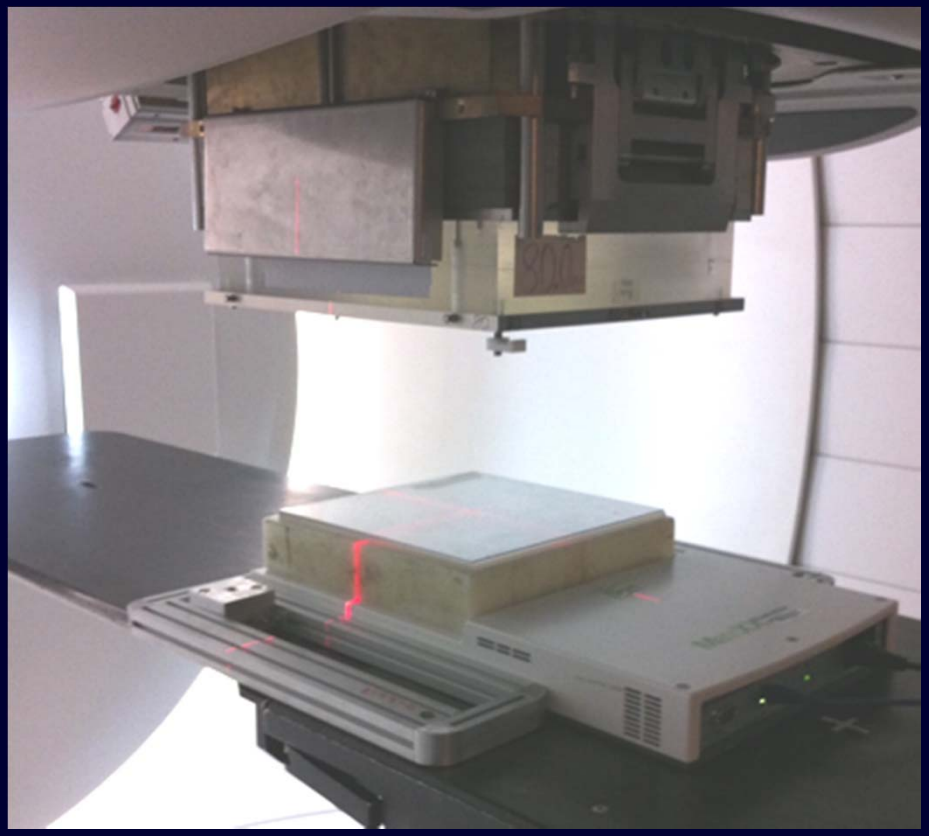
- The BB perturbs the proton beam a little and is visible on the EBT2 film together with the beam profile

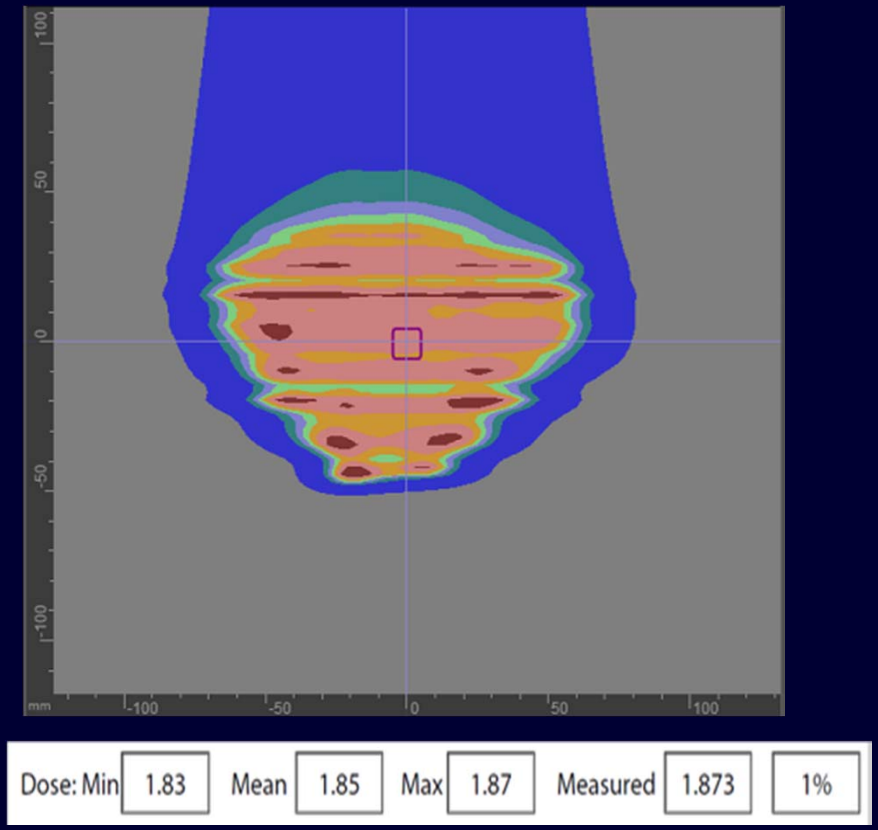




Patient-Specific QA I: Absolute Dose

- Range shifter and air gap are the same as used for the patient
- Wellhofer MatriXX detector
- Measured dose at center point is compared to the prescribed dose





Dose: Min	1.83	Mean	1.85	Max	1.87	Measured	1.873	1%

B. Clasie, MGH

Patient-Specific QA II: Dose Distribution

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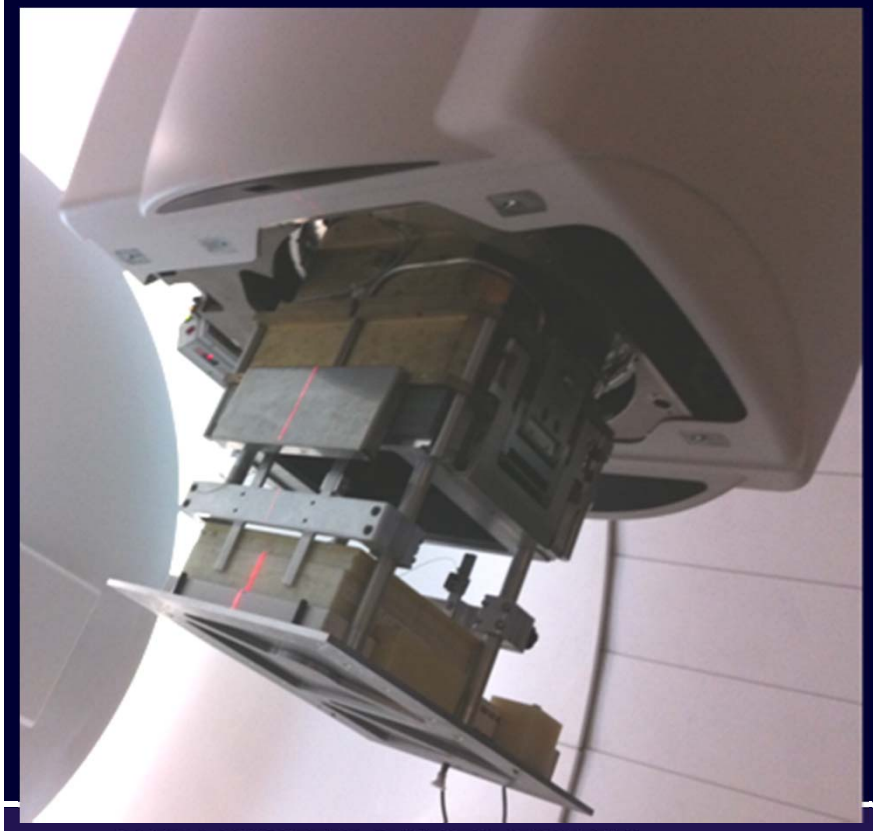
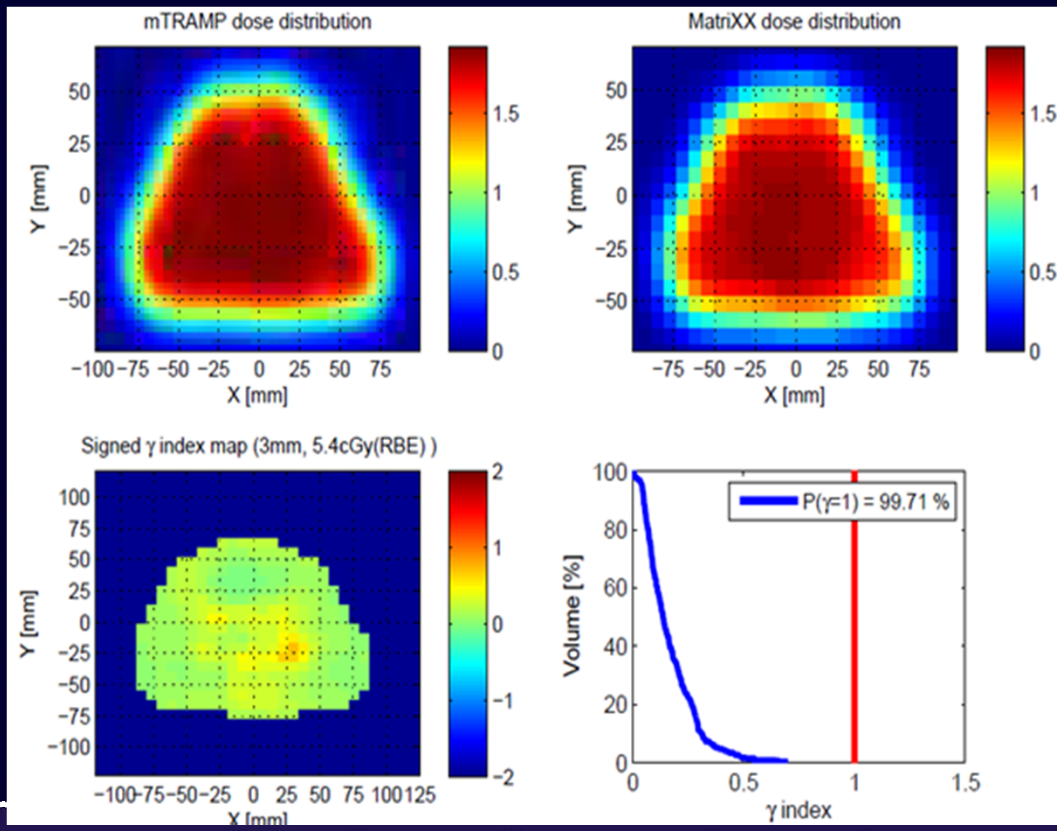
- Wellhofer MatriXX detector and solid water phantom
- At treatment gantry angle
- Measured dose distributions at 3 depths and compare with calculated dose distribution using γ(3mm, 3%)





PBS Monthly QA

- Monthly measurements are done weekly on a rotating schedule
  - Absolute dose using T1 reference chamber
  - Cross calibrate MatriXX used for daily QA
  - Field flatness and symmetry (±2%)
  - SOBP longitudinal dose uniformity (±2%)
  - Range uniformity vs. (X,Y) (±0.5mm)
  - Dose distribution constancy with a standard patient-like field
- We are gaining experience with the system and some of the daily tasks may move from daily to monthly, etc. as we learn more about the necessary frequency of tests

B. Clasie, MGH

Three Wishes

- Better patient setup
  - Integrate X-ray, CBCT, Vision RT, RPM
  - Fast and accurate
- Better treatment control software
  - A physics/QA to unnecessary steps that slow you down, for example, a “repeat” button to do the field again
- Better tool to measure 3D dose for PBS
  - Run the field only once and get full 3D dose

“Impossible!!!”

Thank You!