NASA Space Radiation Laboratory

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Origins

- Motivation: Ground based ion source for simulating solar and cosmic ray radiation to study its affects on biology.
  - Assess the risks.
  - Study countermeasures.
- Funding: NASA ($33M)
- Know how: BNL (DOE)
- Project started 2000, commissioned 2003.
- On time, on budget.

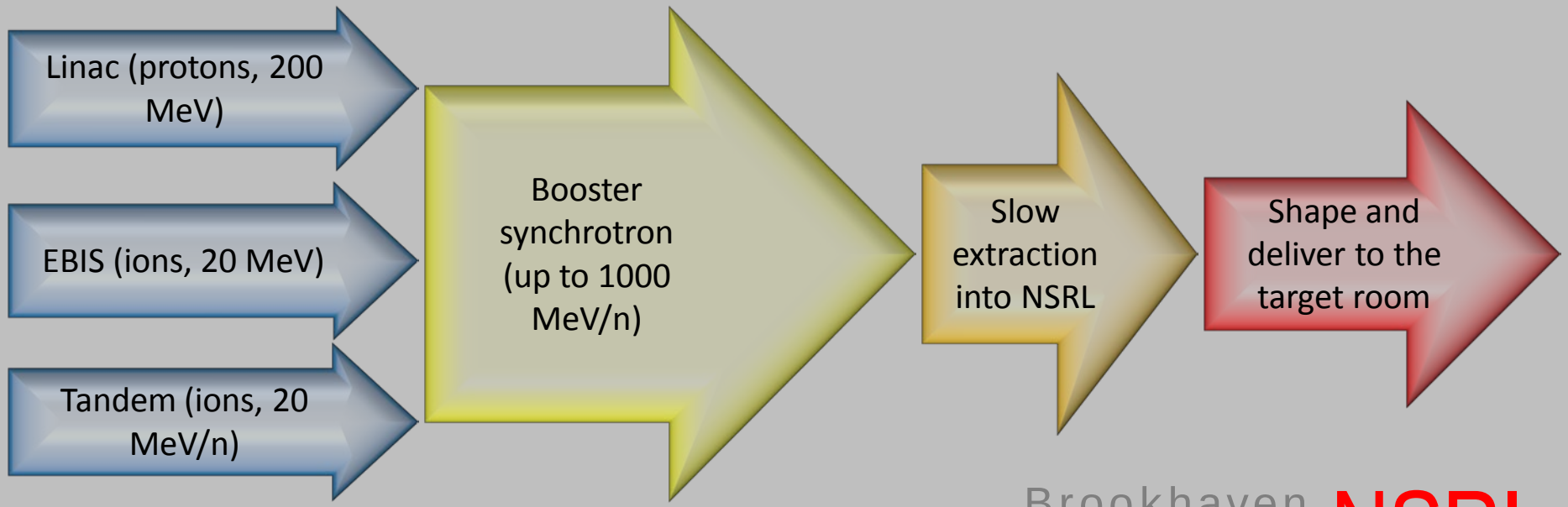
Beam Design

- Designed based on the experience gained through work at LBL and BNL (AGS)
  - Beam as uniform as possible (±10% was typical)
  - Usually round beam
  - Cutoff achieved by means of ion chambers/computer/extraction controls

- NSRL beam is geared towards (but not restricted to) biology work
  - Beam uniformity in the useful area is ±2.5%
  - Square beam (during biology work)
  - Cutoff achieved by means of ion chambers/computer/extraction controls

Beam

- Tandem/Linac/EBIS to Booster
- Booster to NSRL beam line by slow extraction
- Beam shaped in the 100 m beam line and
- Delivered to the NSRL target room (300ms spill every 4 sec)



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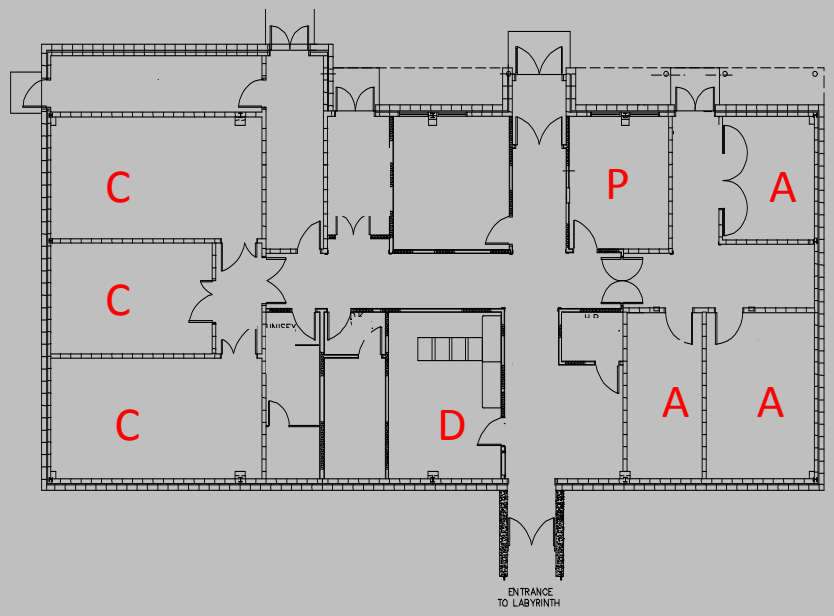
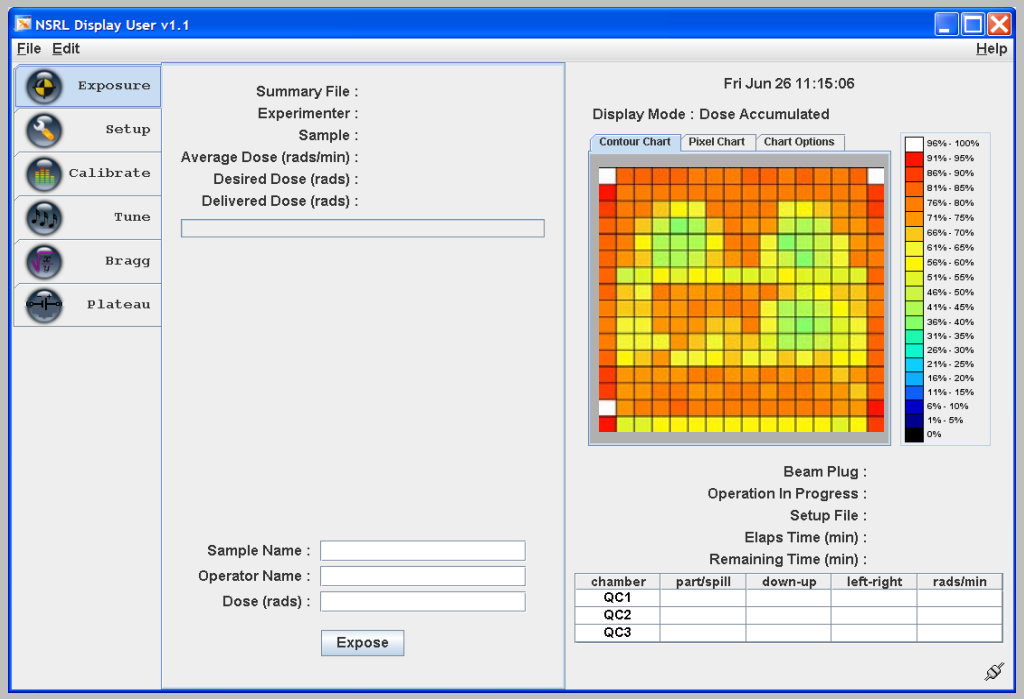
Support Building

- Beam and dosimetry control center
- Experiment staging area
- Cell labs (3) separated from animal labs (2)
- Physics support lab (1)



Operations

- Beam shaping, intensity done by dosimetry physicist (DP)
- Setup, dosimetry and QA done by DP
- Beam species/energy controlled by Main Control Room (MCR)
- Beam delivery done by users or DP
- Dosimetry, exposure data maintained and made available to users by DP



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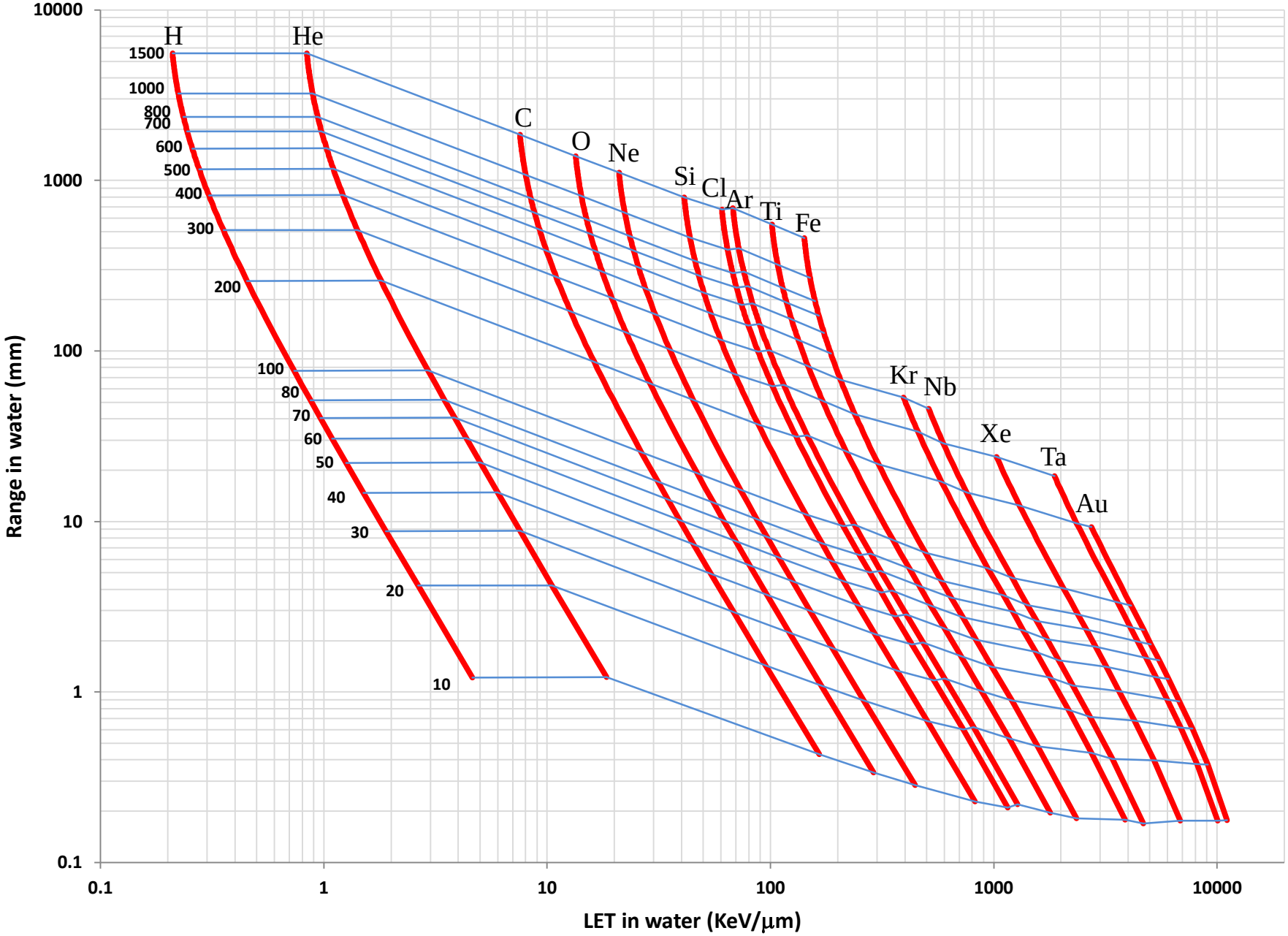
Schedule

- 3 runs, or campaigns a year: Spring, Summer and Fall
- 6-9 weeks each
  - Total of about 24 weeks per year, typically.
  - spring and summer have been run as one 16 week long run for the past 3 years
- Irradiations take place during 1-2 shifts daily, on week days only (almost true)
  - Leave a cushion for machine down time
  - Allow for lab time following irradiation


H
He
C
O
Ne
Si
Cl
Ar
Ti
Fe
Kr
Nb
Xe
Ta
Au
1500
1000
800
700
600
500
400
300
200
100
80
70
60
50
40
30
20
10
10000
1000
100
10
1
0.1
Range in water (mm)
0.1
1
10
100
1000
10000
LET in water (KeV/µm)

NSRL
NASA
Space
Radiation
Laboratory
LINAC
Linear
Accelerator
Proton Source
EBIS
Electron
Beam
Ion
Source
BOOSTER
Synchrotron
Medical
Department
Labs and User Support
RHIC
Relatevistic
Heavy
Ion
Collider
AGS
Alternating
Gradient
Synchrotron
TANDEM
Ion Source
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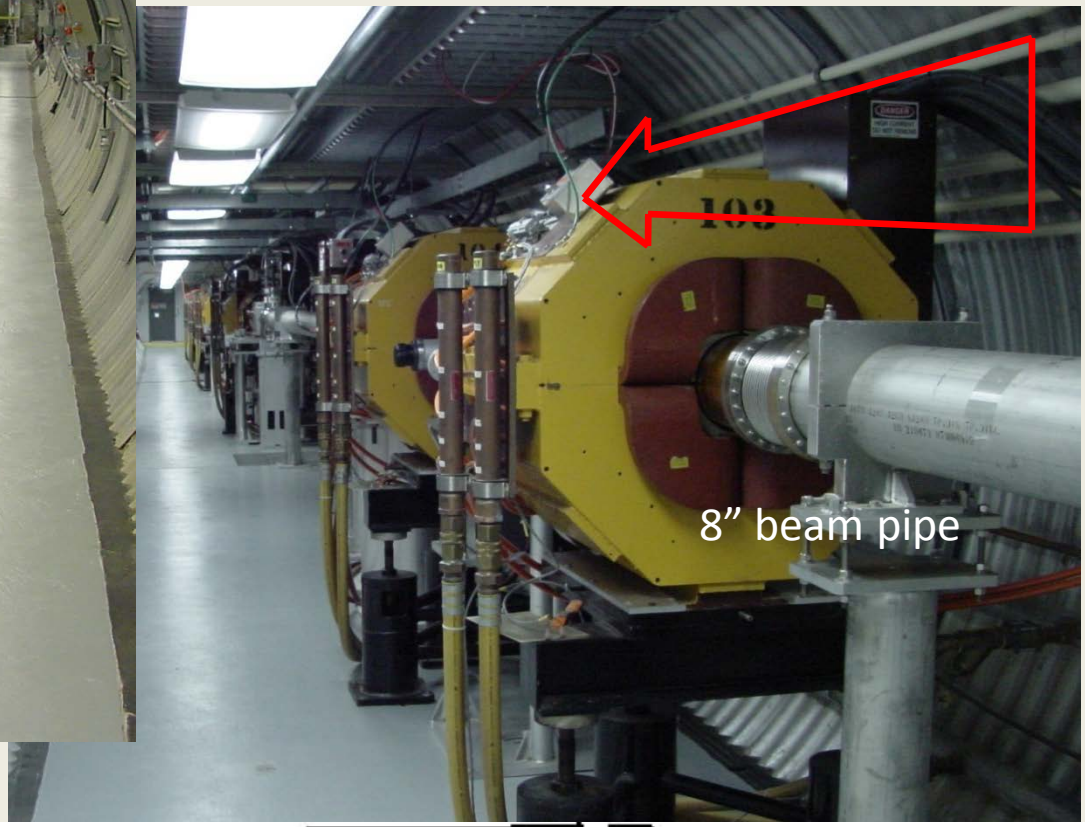
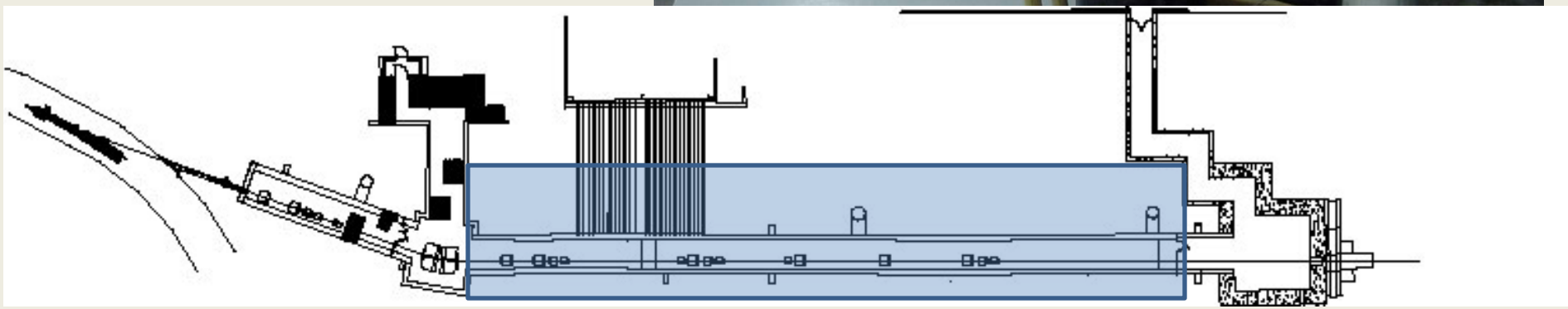
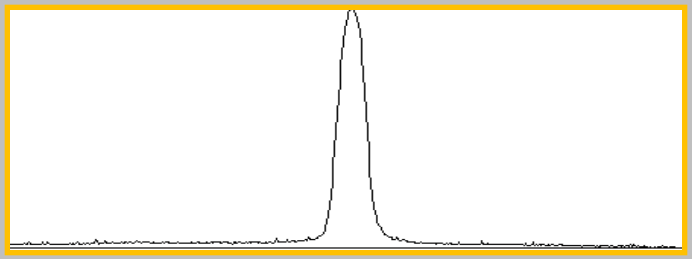
National Laboratory
NSRL

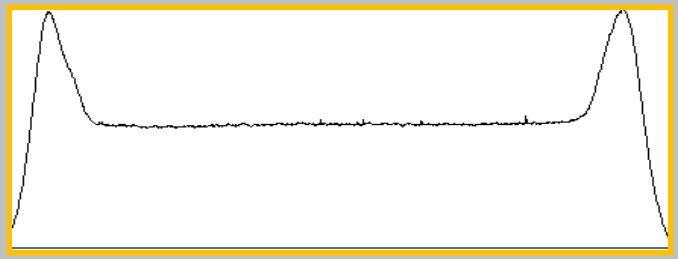
R-Line: From Booster to NSRL



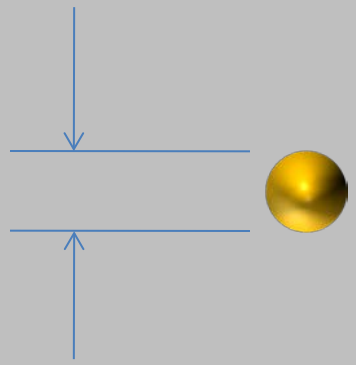


NSRL Beam Shapes and Sizes

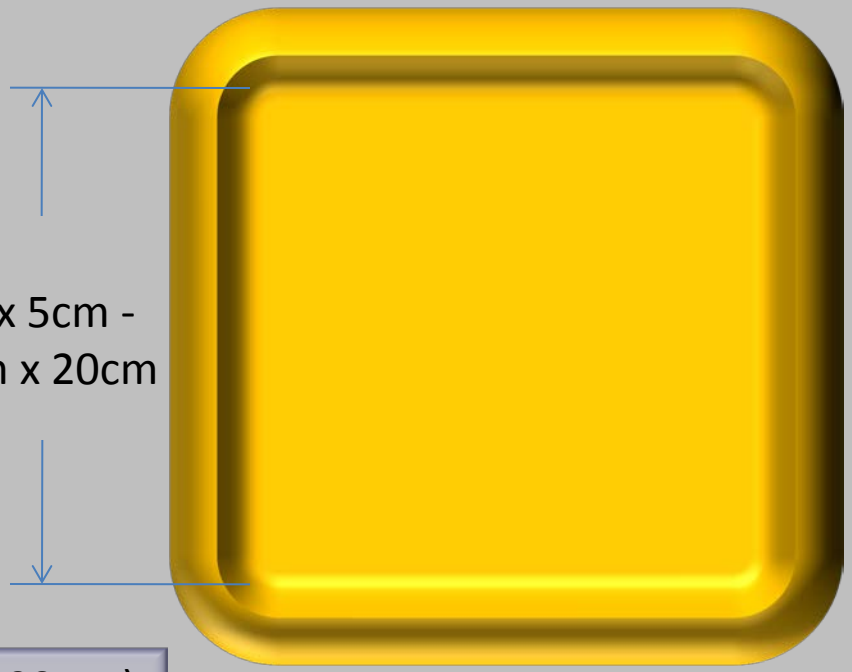




1.0 - 5.0 cm (fwhm)



5cm x 5cm -
20cm x 20cm



Beams can be both slow-extracted (300 – 500 ms)
Or fast-extracted (<1μs), once per 2-4 s cycle

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Target Room

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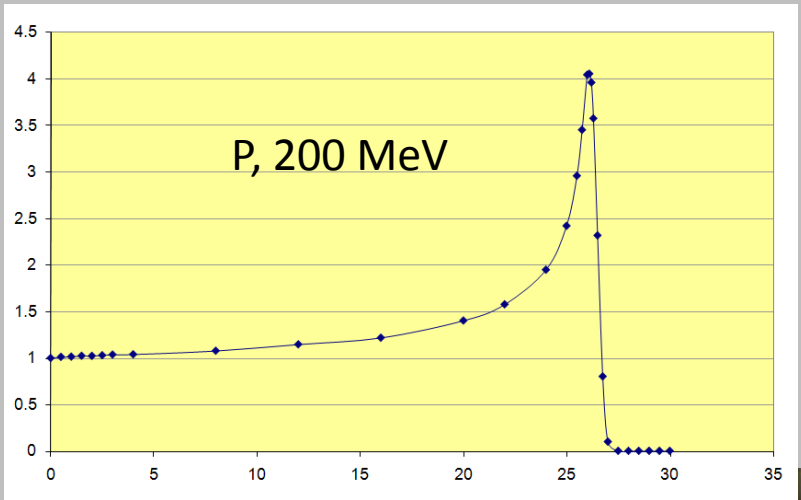

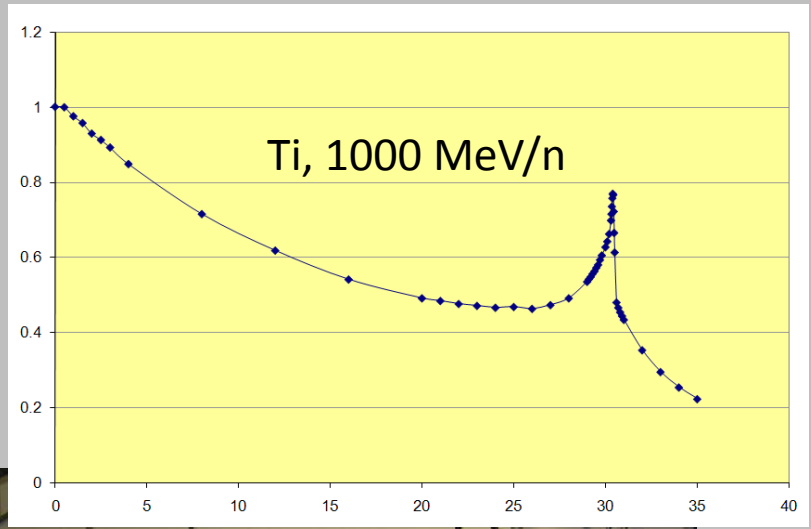

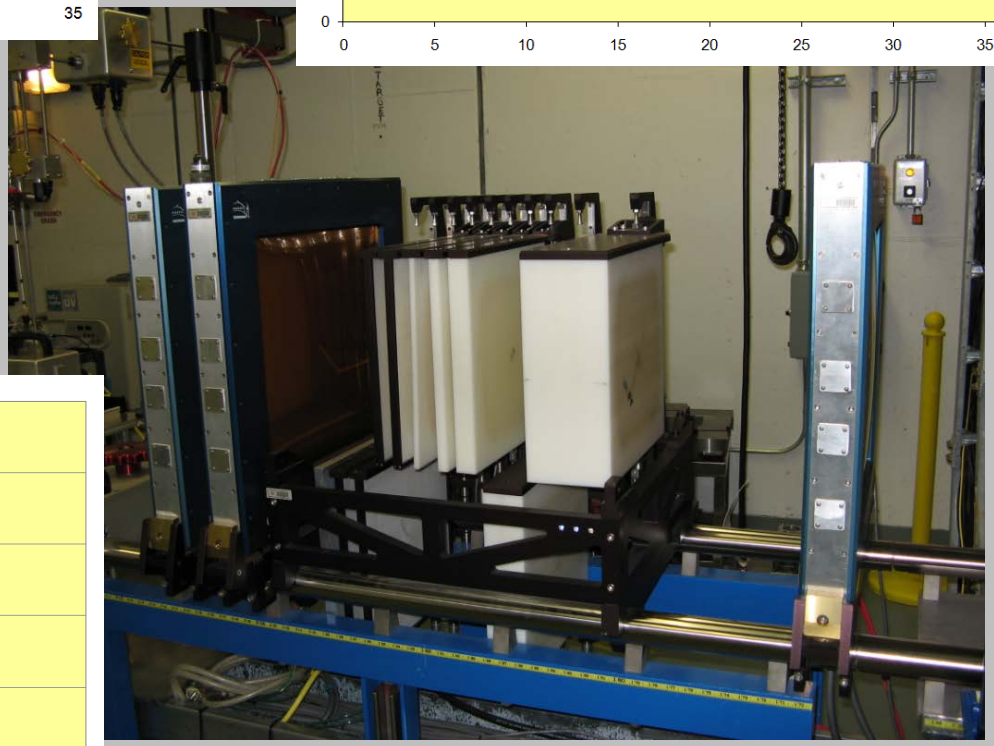

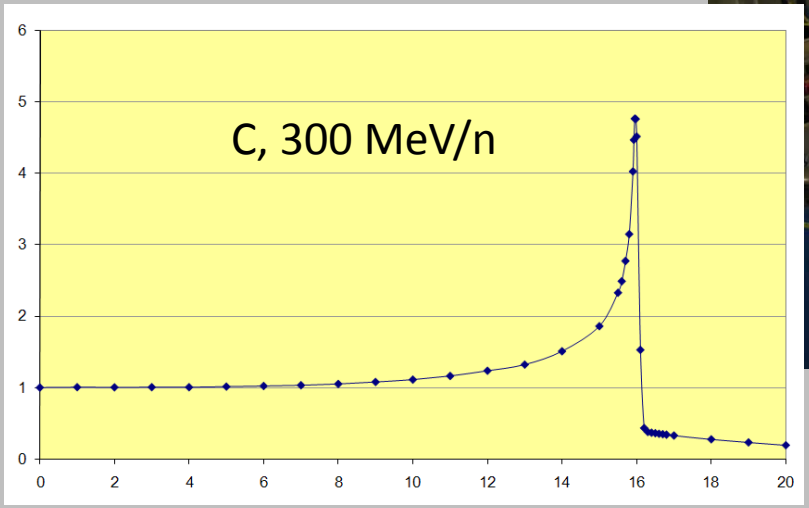

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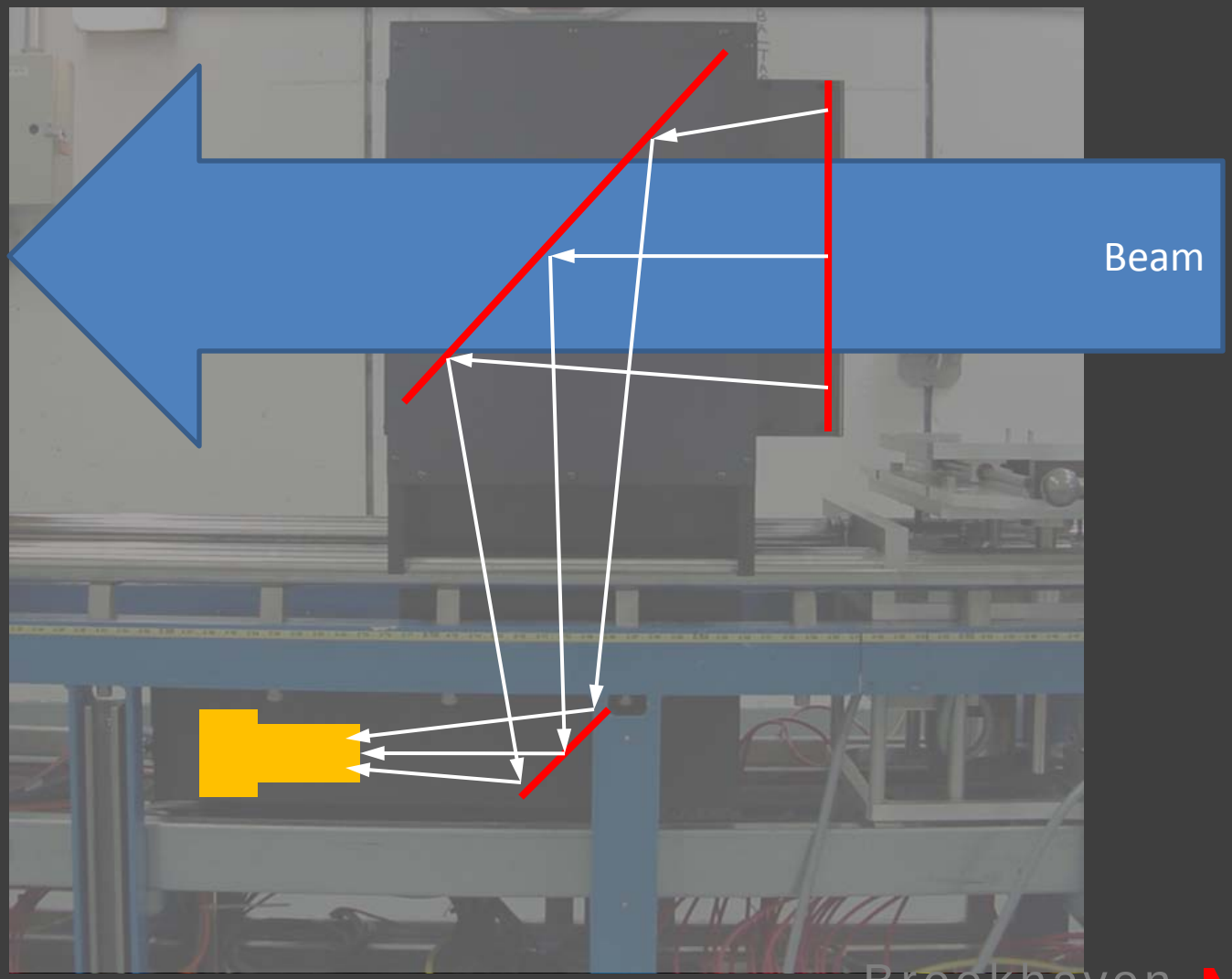

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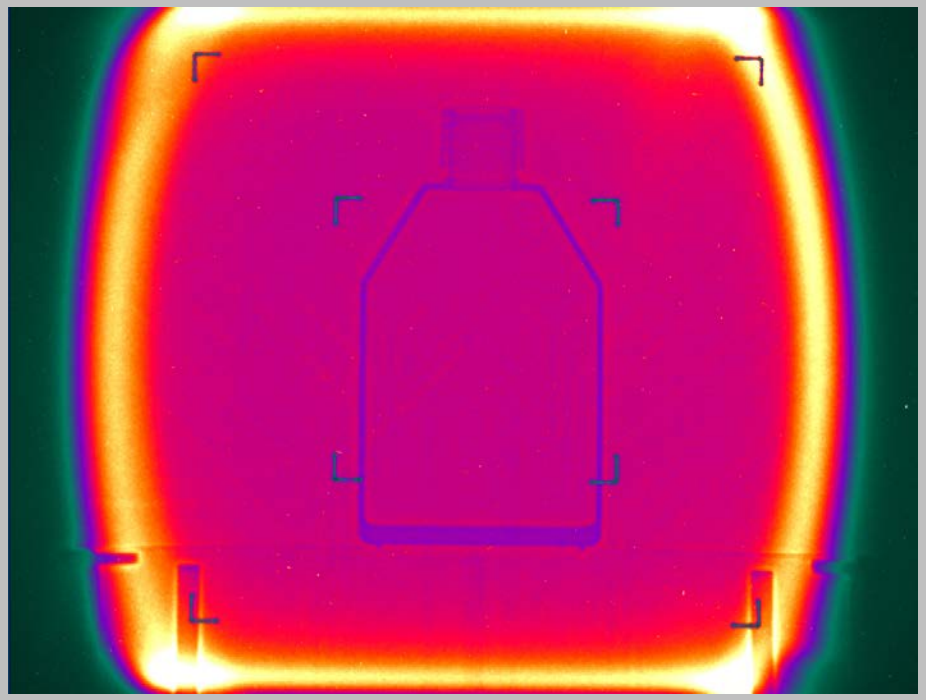

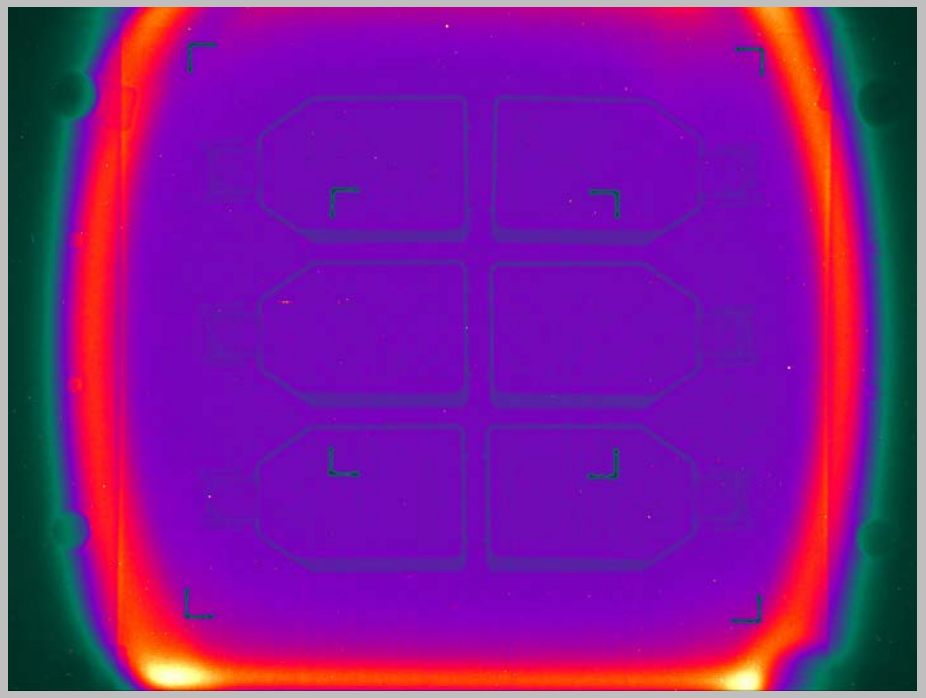

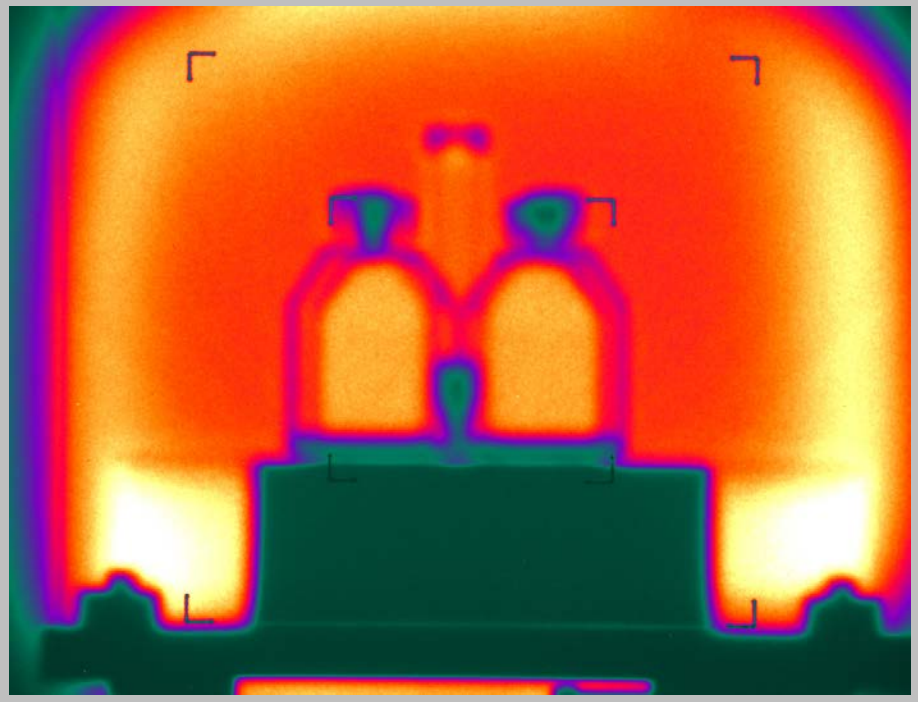

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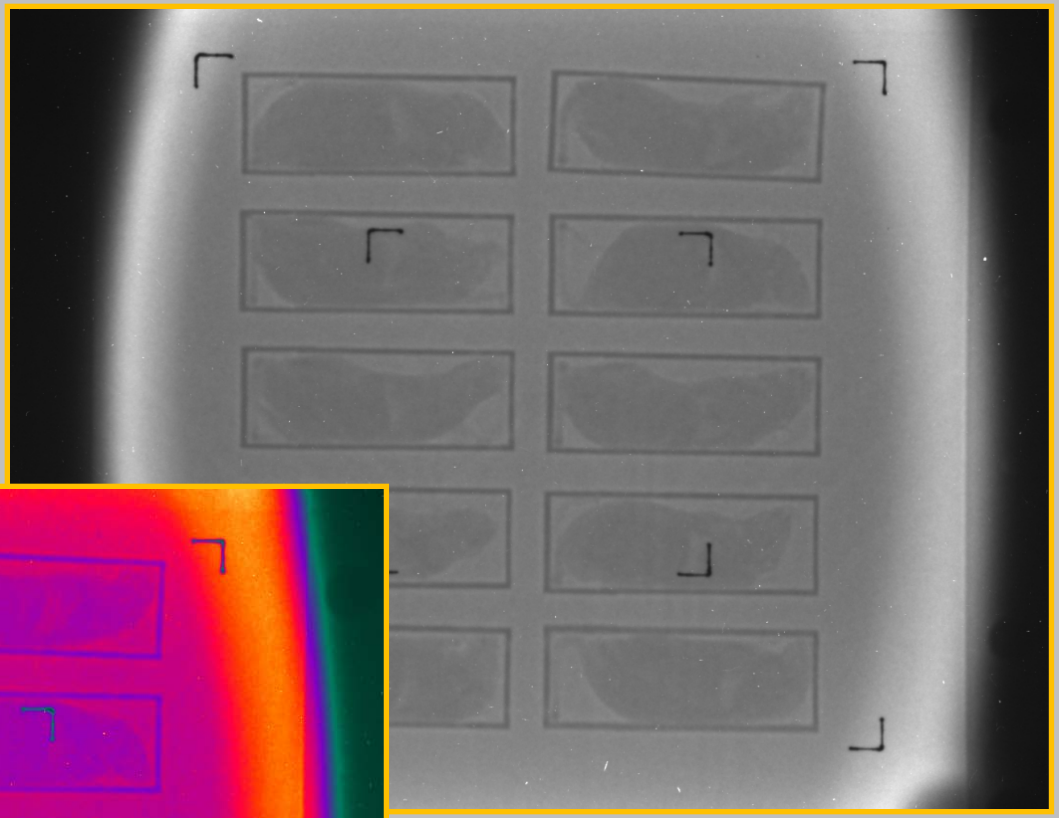

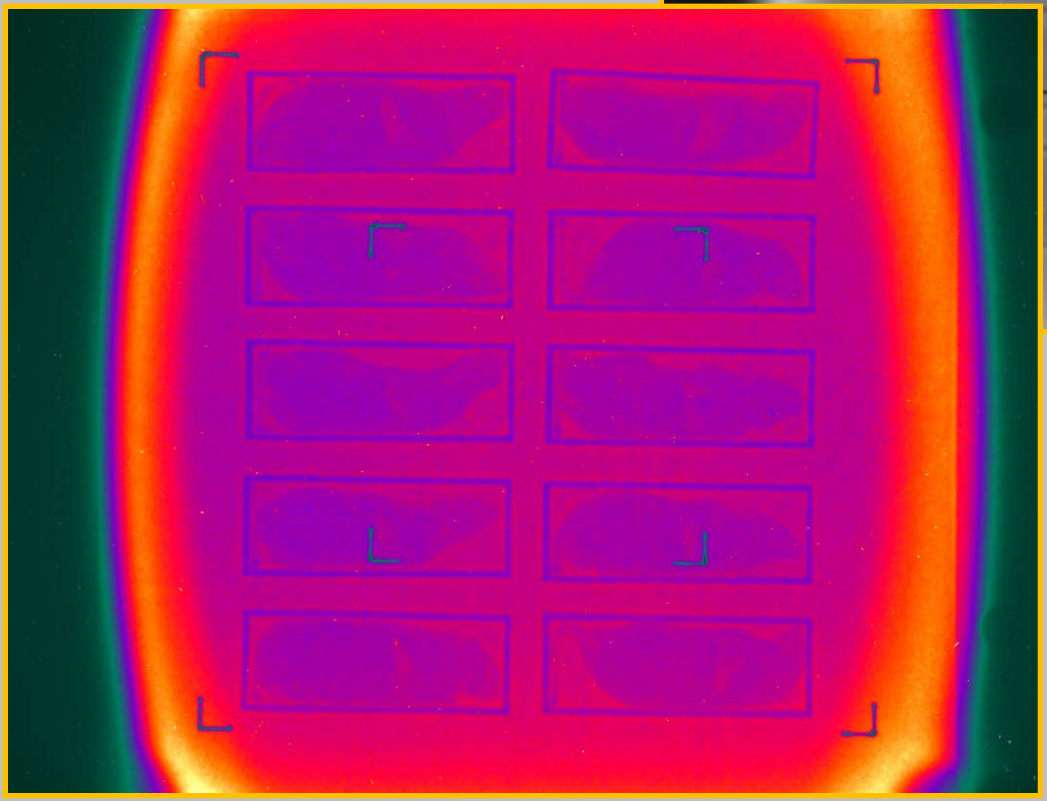

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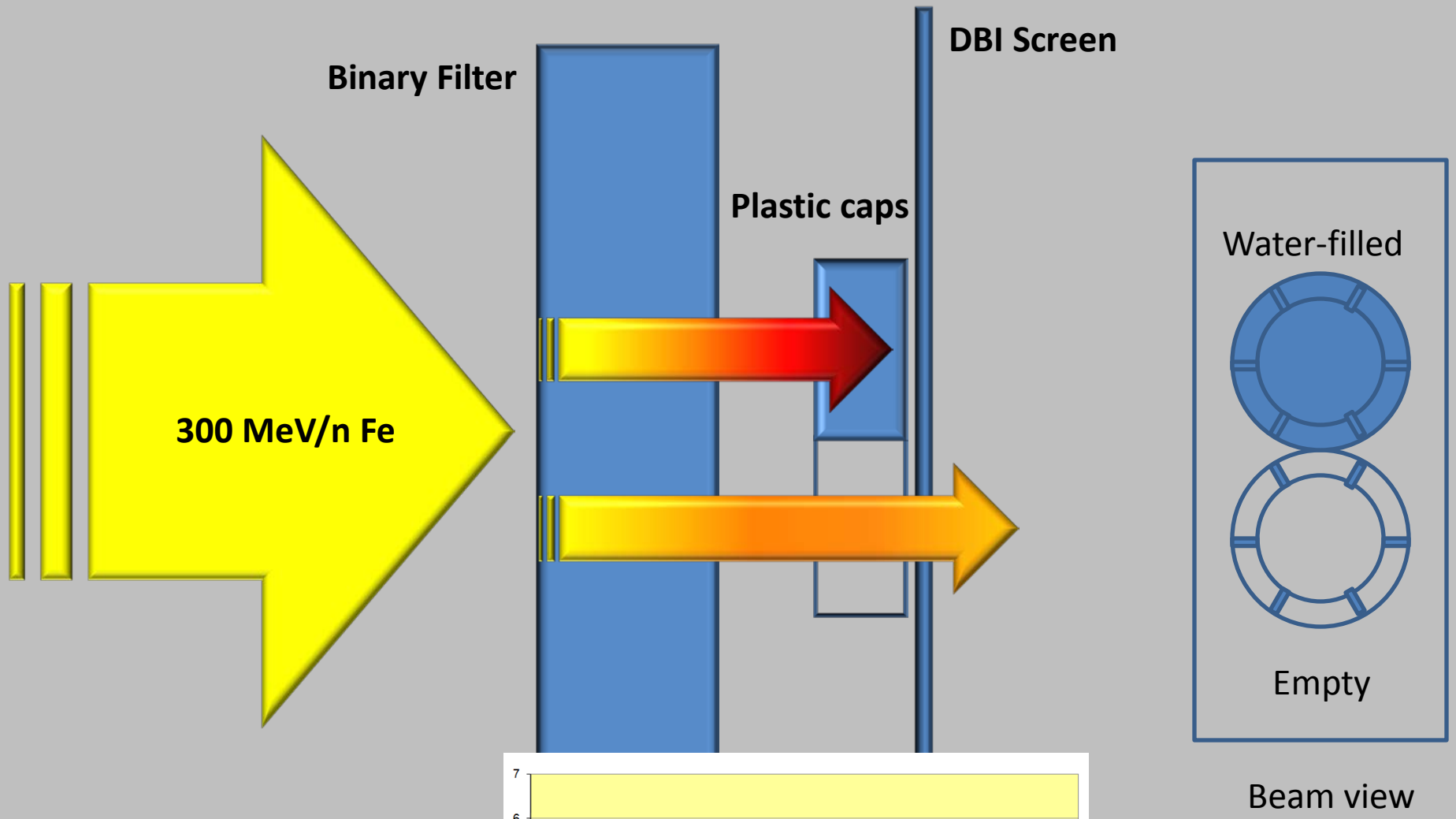
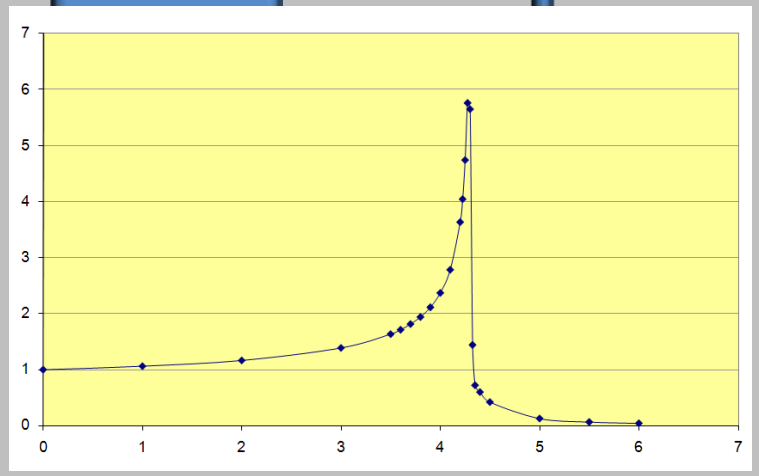

Binary Filter
DBI Screen
Plastic caps
300 MeV/n Fe
Water-filled
Empty
Beam view


0
1
2
3
4
5
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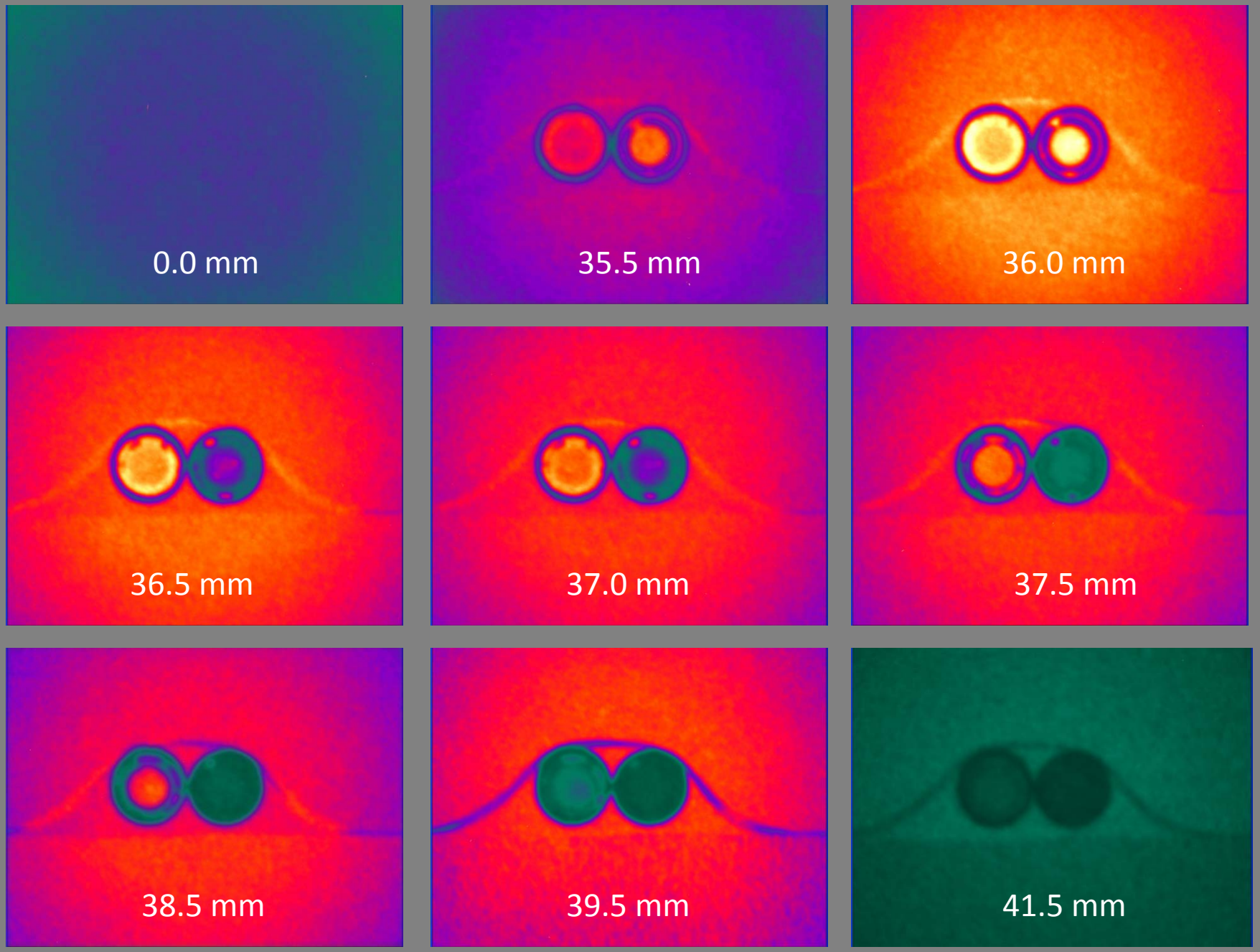
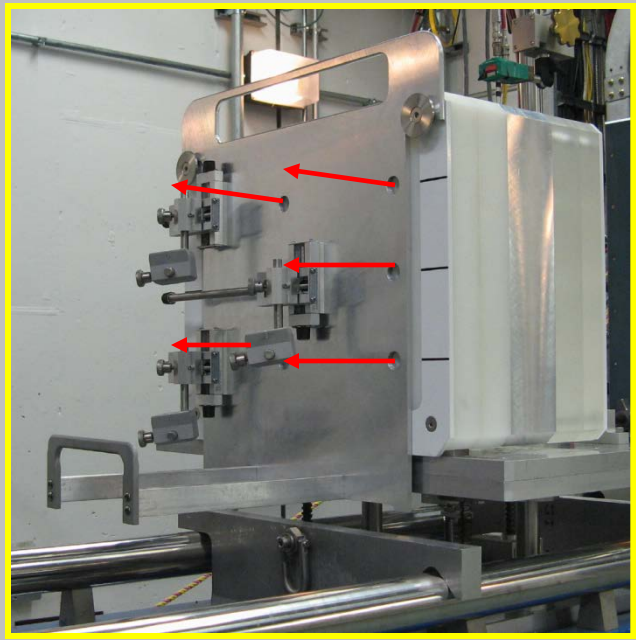
7

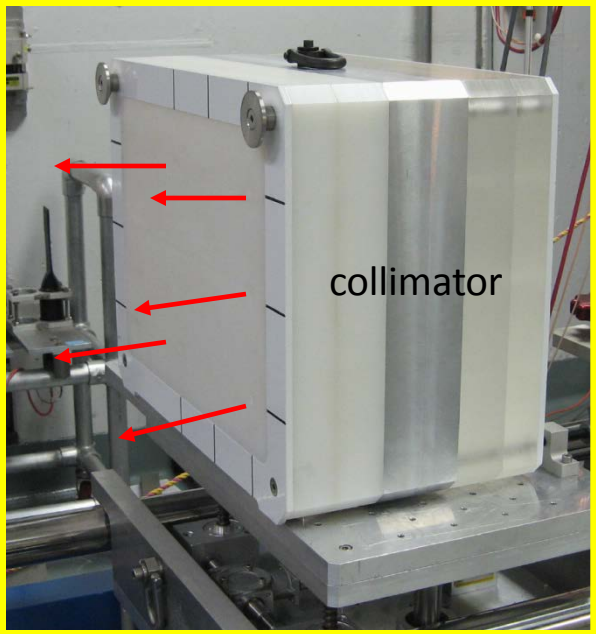
Fe 300

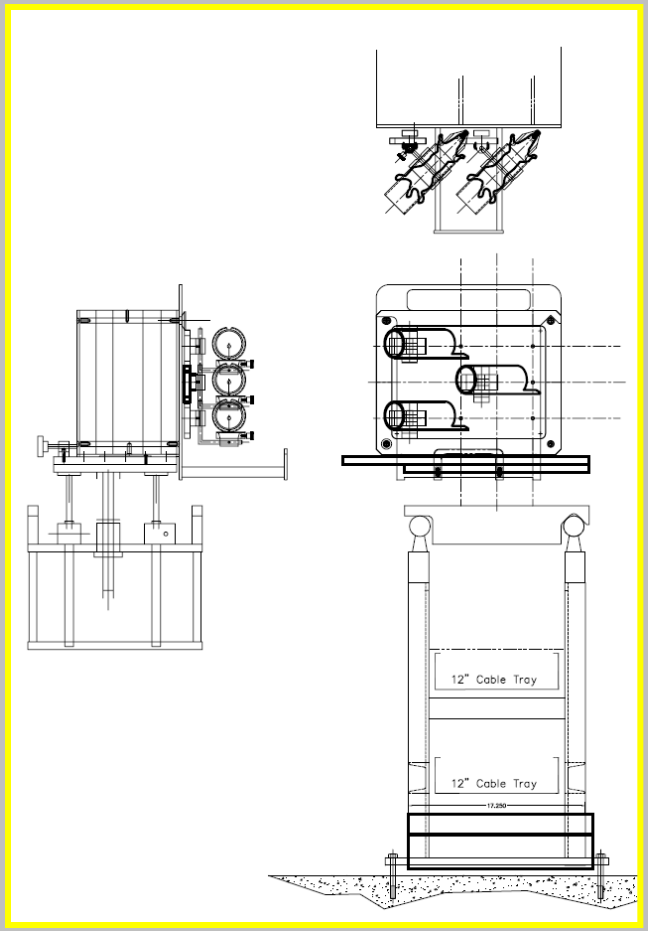


Single Eye Exposure

- Right eyes of three rats at a time.







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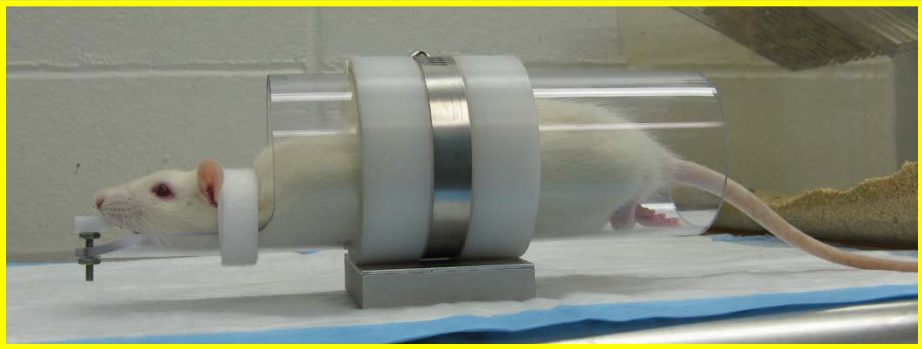
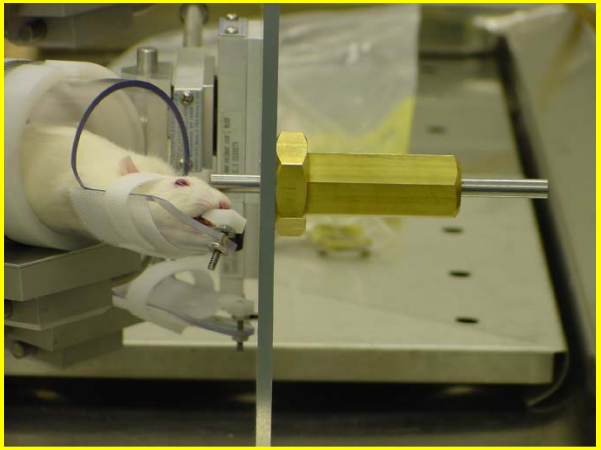
Single Eye Exposure

- Right eyes of three rats at a time.
- Two plates, 9 tubes, for streamlined operation.
- Lots of flexibility, easy alignment.





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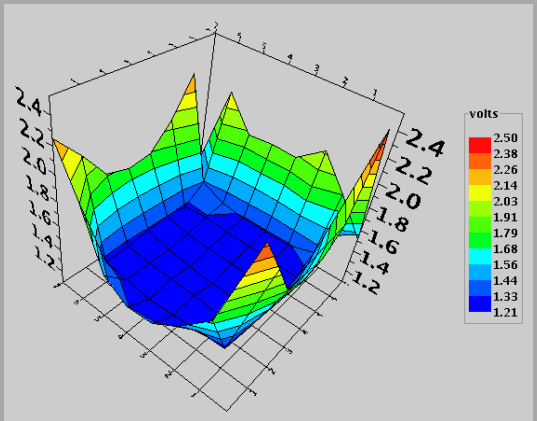
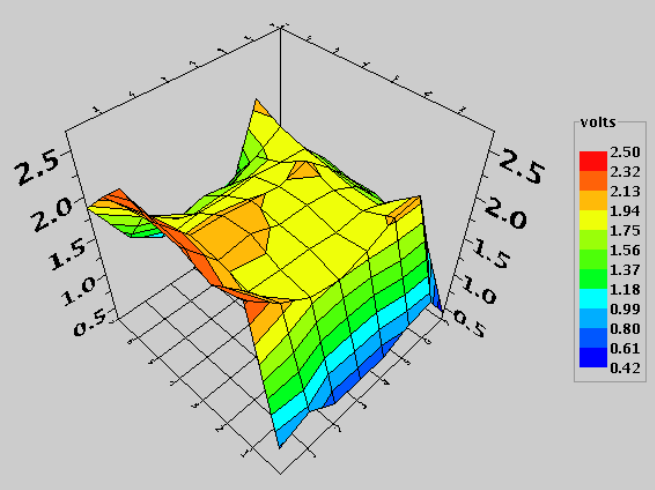
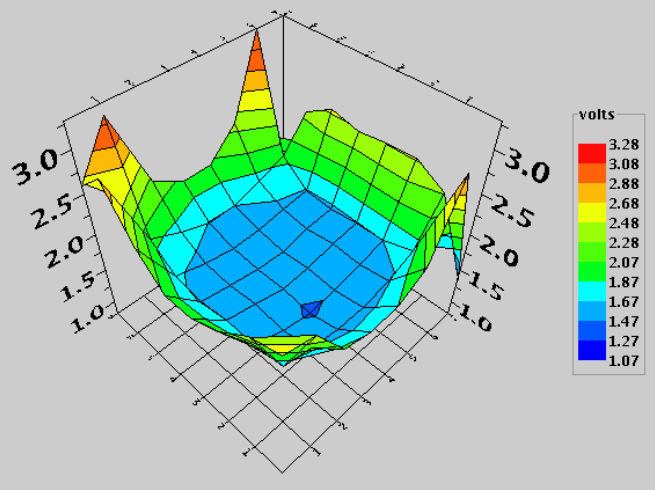
Pixel Ion Chamber with Gain

- Can image the beam at very low fluence
  - 2 Fe/cm^2
  - 1,000 p/cm^2





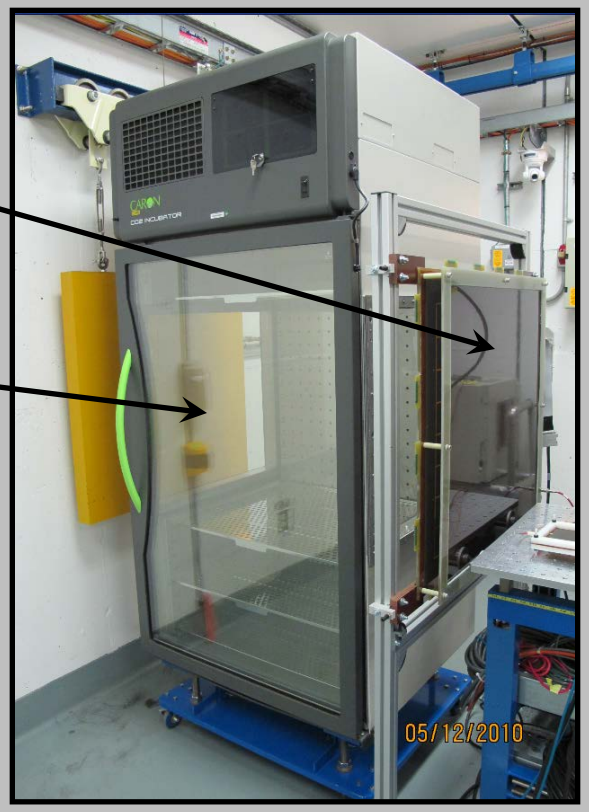
30,000 p/cm^2



22,500 Fe/cm^2

Large Beam

- 60x60 cm^2 (50x50 cm^2 useful area).
- Large pixel chamber (8x8) to monitor beam uniformity.
- Exposure incubator for long exposures.



SPE Simulation

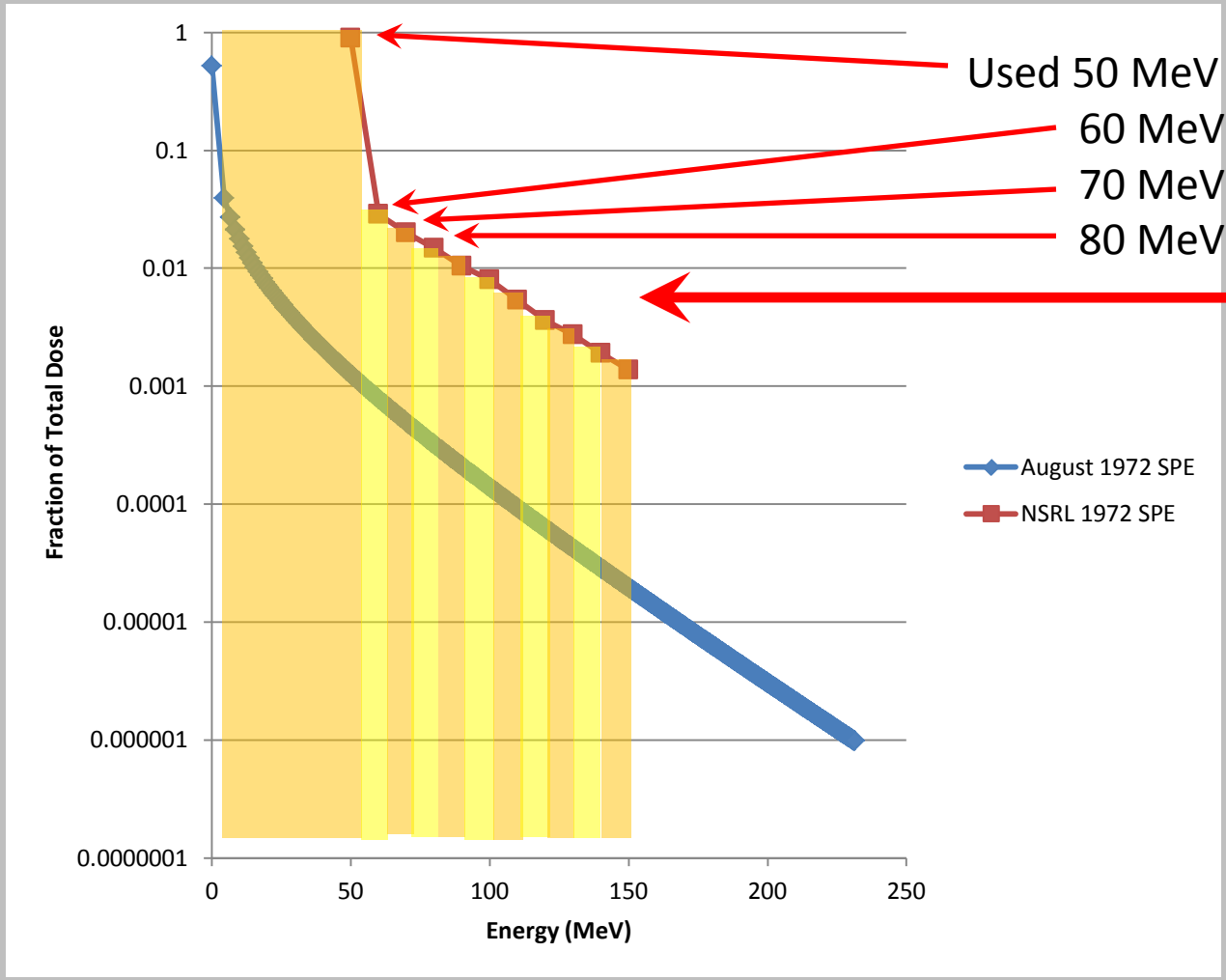
Requires

- Fast energy changing
  - Directly from the booster
  - By binary filter
- Large beam
  - For long, low dose-rate exposures

“spin-off”

- Fast energy changes
  - Easier operations
  - Easier scheduling

A Recent SPE Simulation



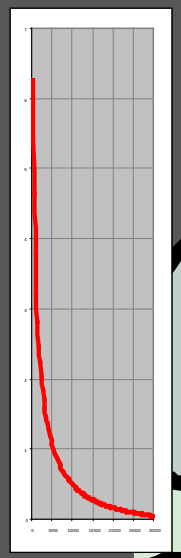
Used 50 MeV to represent 0 – 50 MeV

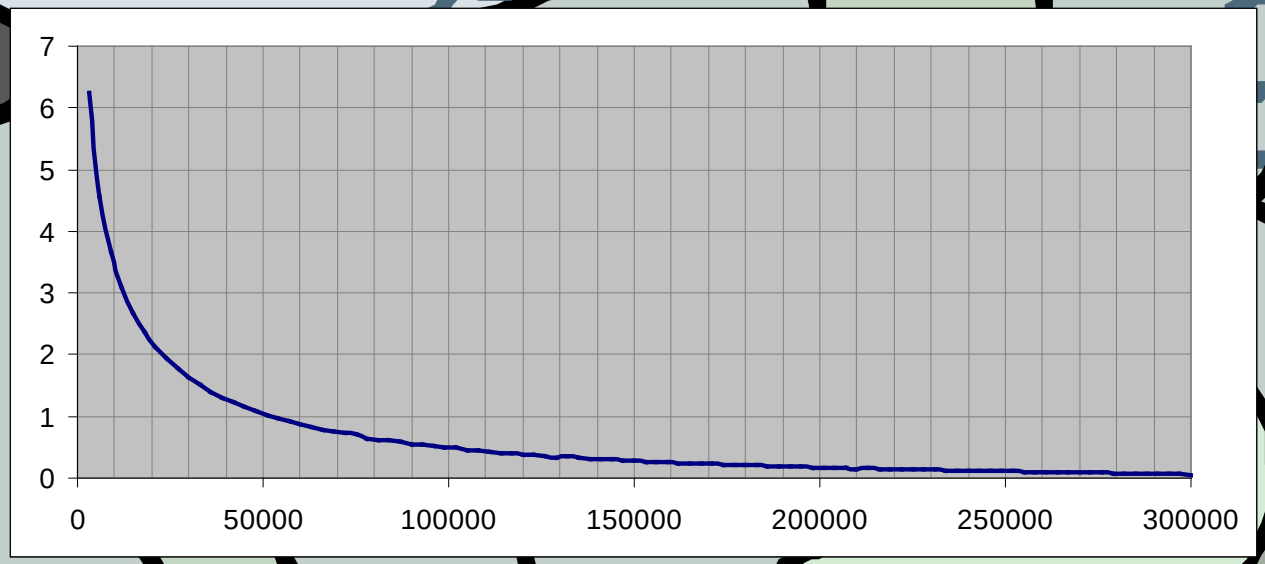
60 MeV to represent 50 – 60 MeV

70 MeV to represent 60 – 70 MeV

80 MeV to represent 70 – 80 MeV

And so on….





Dose (arbitrary)

Depth (µm)

GCR Simulation

Requires

- Fast ion changes
- Availability of many ions
- Upper energy of at least 1.5 GeV/n
- Large beam
  - For long, low dose-rate exposures

“spin-off”

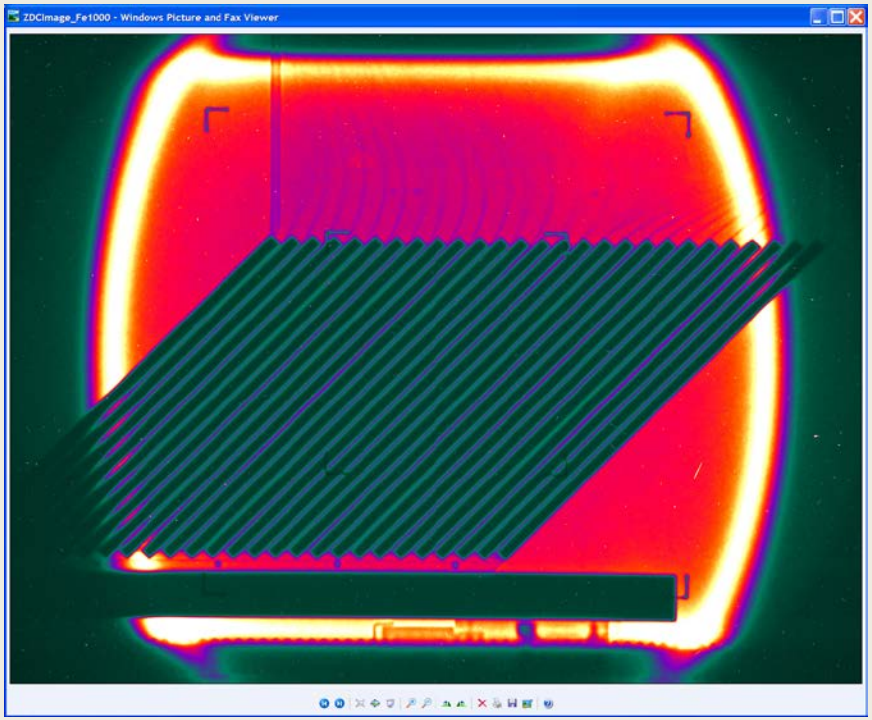
- Ultimately we should be able to change ions from NSRL dosimetry room(!)

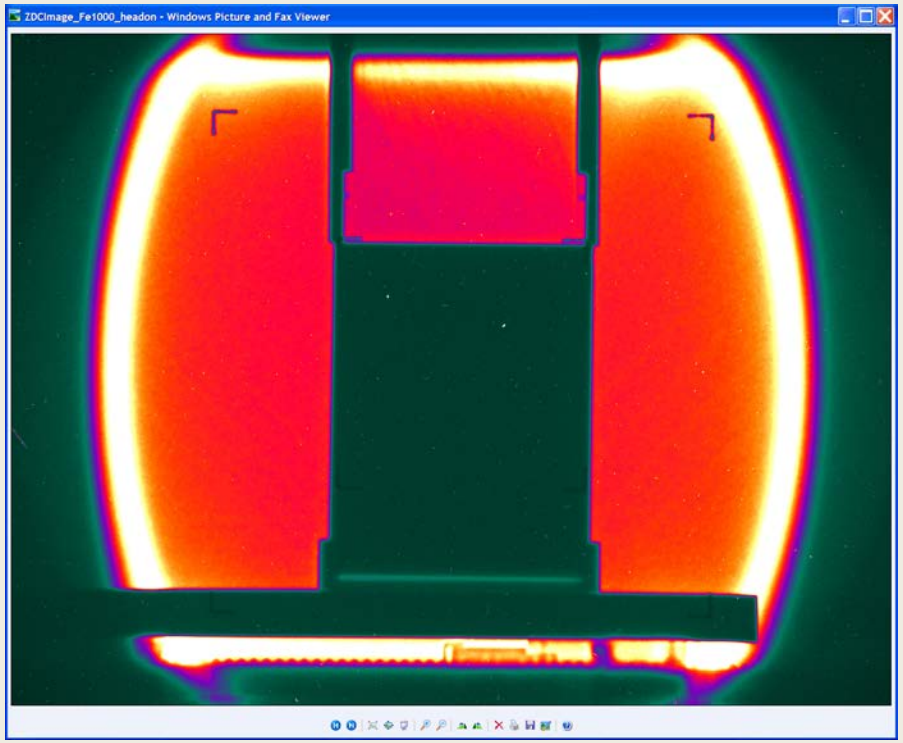
Type of Studies and Investigations

- Biology >90%
  - Tending more and more to the lower doses now
  - Ion, LET, Energy studies
  - Cancer, CNS, Cardio-Vascular, BPO, Acute effects…..
- Shielding
- Materials (radiation hardness etc.)
- Electronics (radiation hardness etc.)
  - NASA, NRO, others
- Instrument testing and calibration
  - NASA, others.
- Therapy research
  - Limited to physics and biology

On the side

- Fragmentation Cross sections.
  - 4He, 3He, C, O, on elemental targets and water
- Detector and readout developments.
  - Specialty ion-chambers, adaptation of commercial readout for medical imaging to multi-channel ion chamber.
- Calibration and testing.
  - Example: ZDC's, water-based liquid scintillator (BNL development)


ZDCImage_Fe1000 - Windows Picture and Fax Viewer


ZDCImage_Fe1000_headon - Windows Picture and Fax Viewer

Existing Capabilities

Beam

- Variety of shapes and sizes
  - Square beam from 5 to 50 cm
  - Round beam from 0.5 to 10 cm
- Good uniformity (>95%)
- Many ions available
- Wide energy range available
- Slow-extracted beam
- Fast-extracted beam

Dosimetry

- Good dynamic range
  - 1 – 2000 rads/min (ion chambers)
  - < 1 rad/min (scintillator)
- Self calibration capabilities
- Cutoff within >1% of total dose
- Good imaging methods
  - DBI
  - Ion chambers with gain

Thanks for your attention!