Evaluation of a commercial scintillator screen detector for proton pencil beam QA

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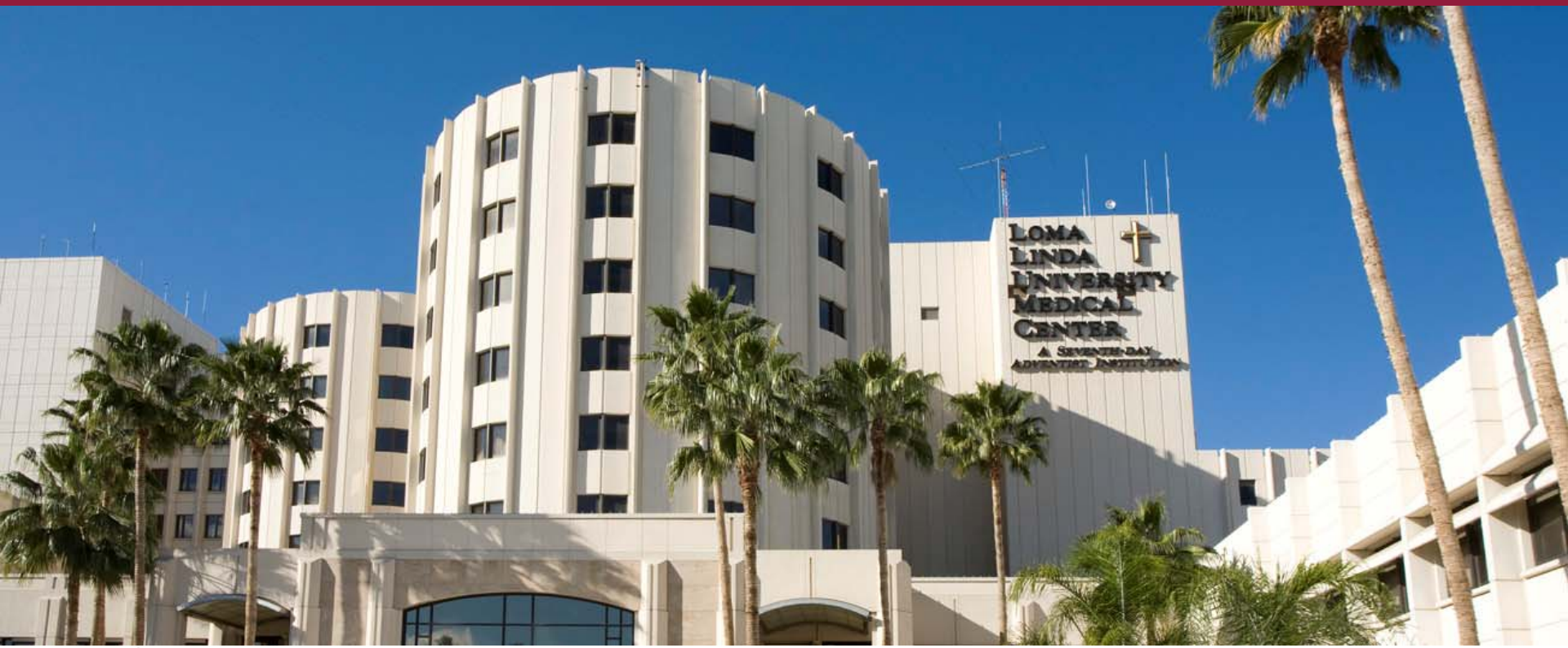

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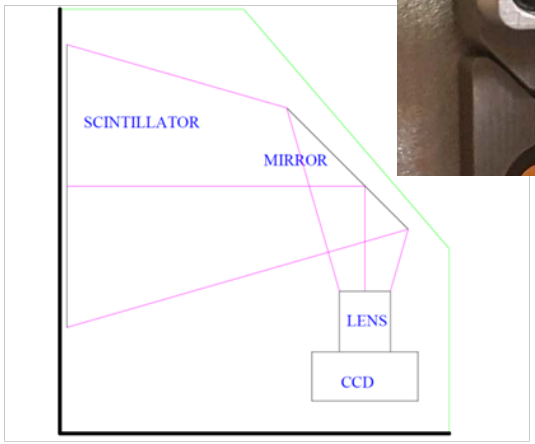
Background

- ABS (Active Beam Scanning)
  - Spot size (sigma ~2.5 - 8 mm)
  - Spot position accuracy needed < 1 mm
  - Field sizes (40 cm x 40 cm)
  - Spot intensity a fraction of cGy
- ABS treatment planning requirement
  - Better than 2% in water
    - Sum of ~ 1000 spots
    - Dynamic range10^4 or better
- Current detectors are not suitable
  - To large for a single spot or hard to align (micro chamber)
  - Low resolution (2D array 5mm)
  - Dynamic range 10^2-10^3 (film)
  - Require higher dose

Lexitek Detector

- Thin Scintillator screen
  - ~ Speed
  - ~ Efficiency
  - ~ Energy dependence
- 16 bit scientific CCD, 1024x1024
- High quality 35mm camera lens
- Mechanical shutter
- 40 x 40 cm detector size
- LED illuminators for relative gain
- kinematic mounting (micron precision)
- Matlab and LabVIEW tools
- Commercially available

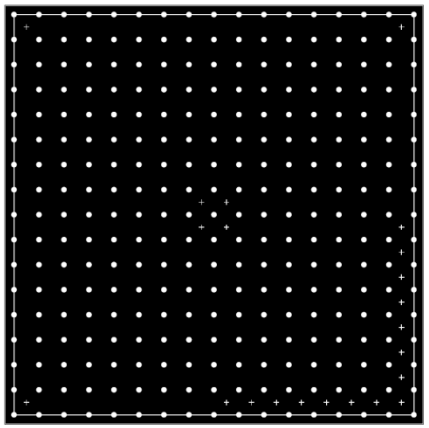


Detector Study

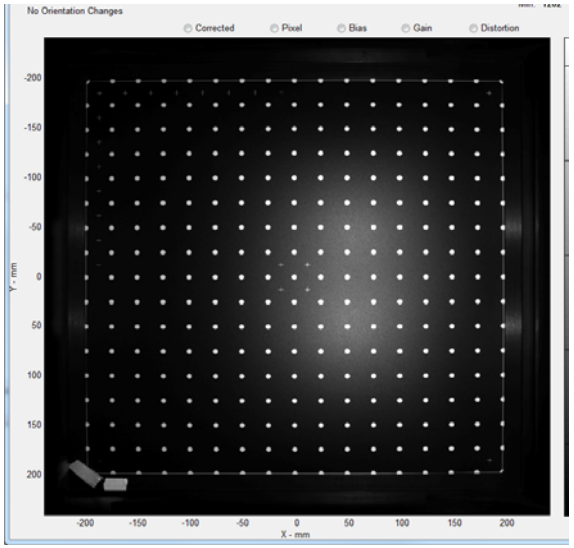
- Investigation were made
  - ~ Pixel resolution and image distortion
  - ~ Light tightness (work in room lights)
  - ~ Bias, dark current and time dependence
  - ~ Dynamic range
  - ~ Calibration Study
    - Gain variability
    - Non-uniformity of the scintillator
    - Vignetting due to the use a lens
  - ~ Shielding CCD
    - Radiation events
    - Pixel Correction
  - ~ Tools for single spot/ multiple spots evaluation

Resolution and Orientation

- Alignment grid consisting of any array 5 mm circles on 25 mm centers plus lines and crosses to measure the pixel scale and calibrate any distortion
- Pixel resolution was measured to be 0.45 mm/pixel
- No distortion was observed



Photographic Image

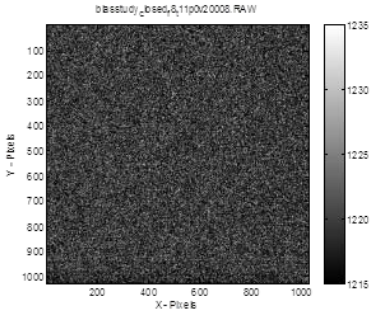


Lexitek LED Image

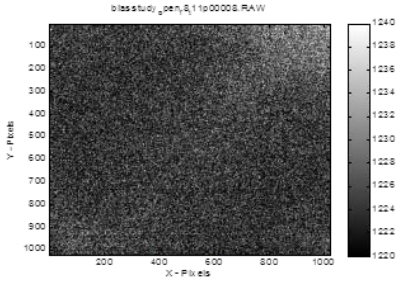
Light tightness and background

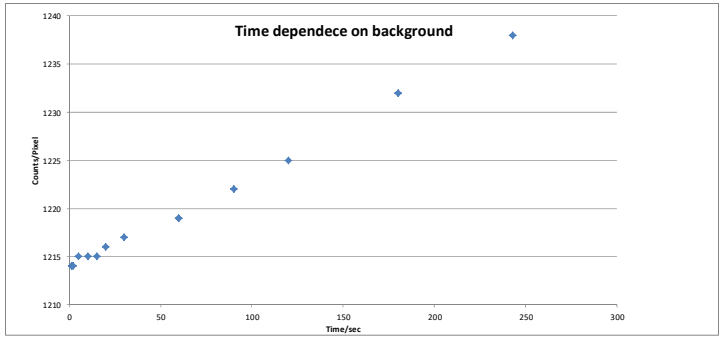
- Open and closed shutter images
- Closed shutter measurement
  - ~ Dark current 0.005 e^-/pixel/sec
  - ~ Biased above zero ~1250 (64K)
  - ~ Readout noise ~8DN
- Open shutter measurement
  - ~ Small light leak (lens sensor)
  - ~ Fixed with new firmware
  - ~ Enclosure is light tight
- Time dependence linear in time
- Background can be easily corrected
- Calibration time scale TBD
  - ~ For now, perform background before irradiation

Shutter closed



Shutter Open



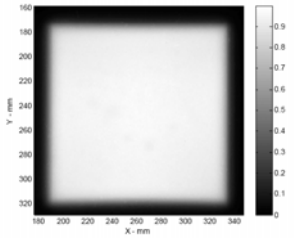


Calibration Study

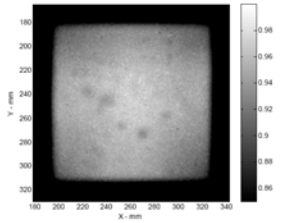
- Scintillator non-uniformity
- CCD pixel gain variability
  - 1.9 electron /count
  - pixel-to-pixel sensitivity ~90-110%
- Lens vignetting (edge softening)
- Unavailability of 40 x 40 uniform field
- Mosaic Illumination
  - HBL irradiation ~15 x 15
  - Measure ground truth (with film)
  - Reposition detector to record overlapped patterns (mosaic)
- Gain is corrected
  - GC(x,y)= Known Field/Measured

- Scintillator non-uniformity

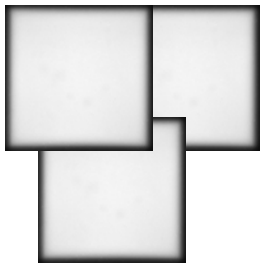
Normal view



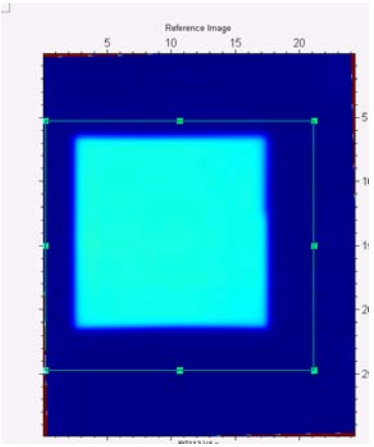
Contrast enhanced



Mosaic Irradiation

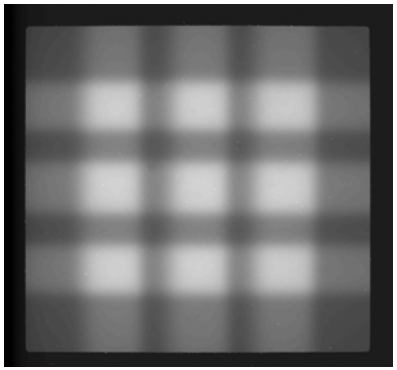


Film irradiation

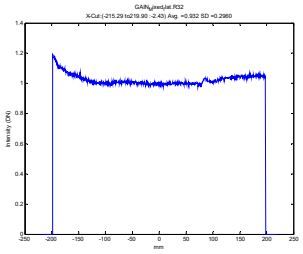


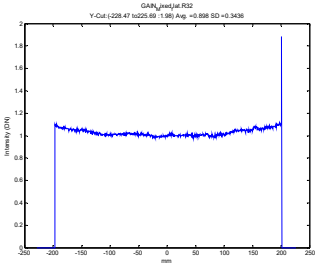
Calibration Study (& Vignetting)

» Mosaic Illumination



» Horizontal and Vertical GC



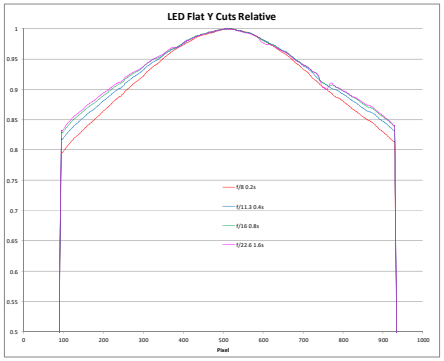


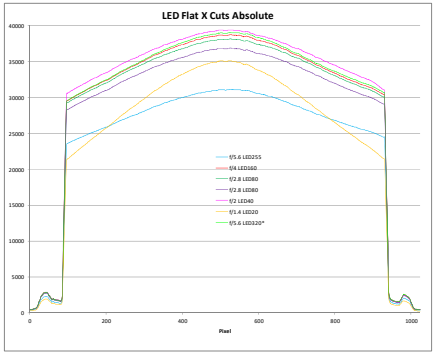
» Relative gain for additional F-stops

~ F-stop changed for varying dose

~ Measure each F-stop with internal LED

~ Calculate relative change (vignetting) for each F-stop

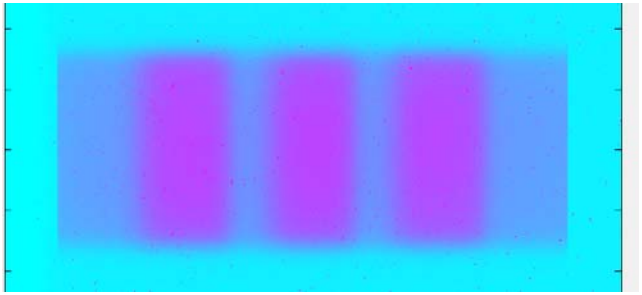




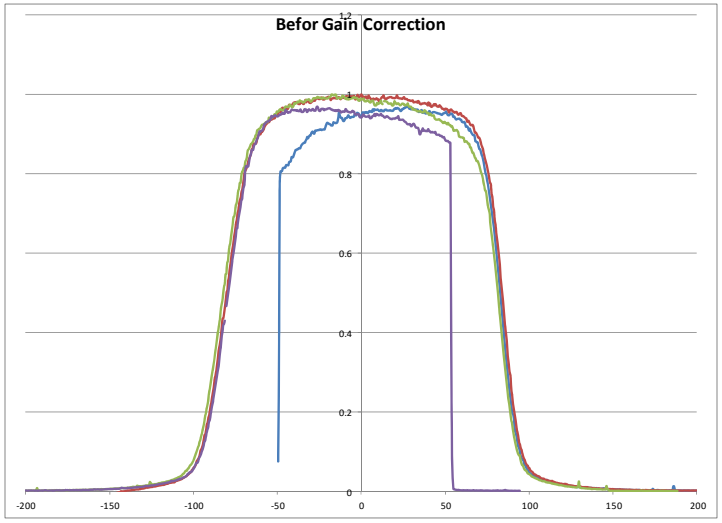
~ Non calibrated Gain

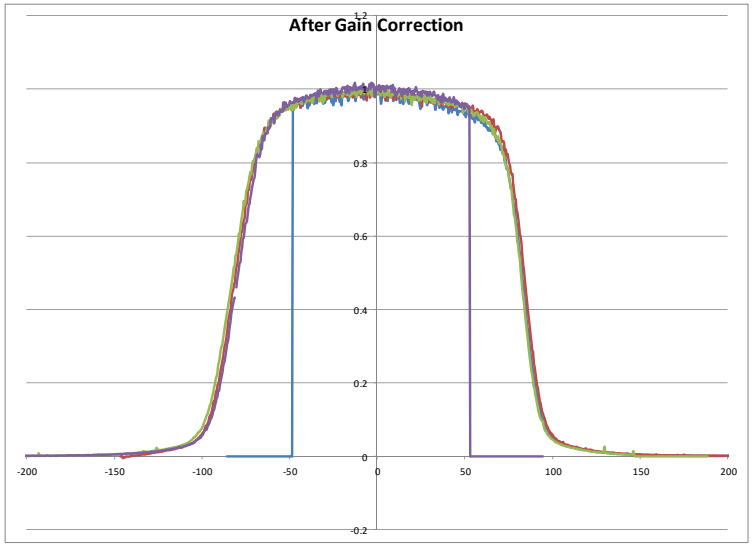
- $GC_{F\#}(x,y) = GC_{F8}(x,y)$ * relative vignetting
- Extends absolute gain calibration
- Not implemented yet

Result of gain correction



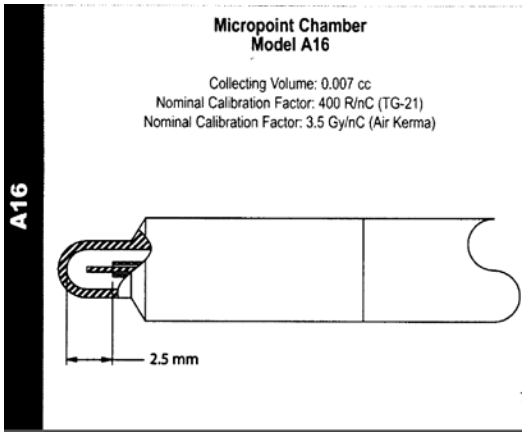
- Shift detector for the same irradiation field
- Align beam using edges for test purpose
- Result better than 1%

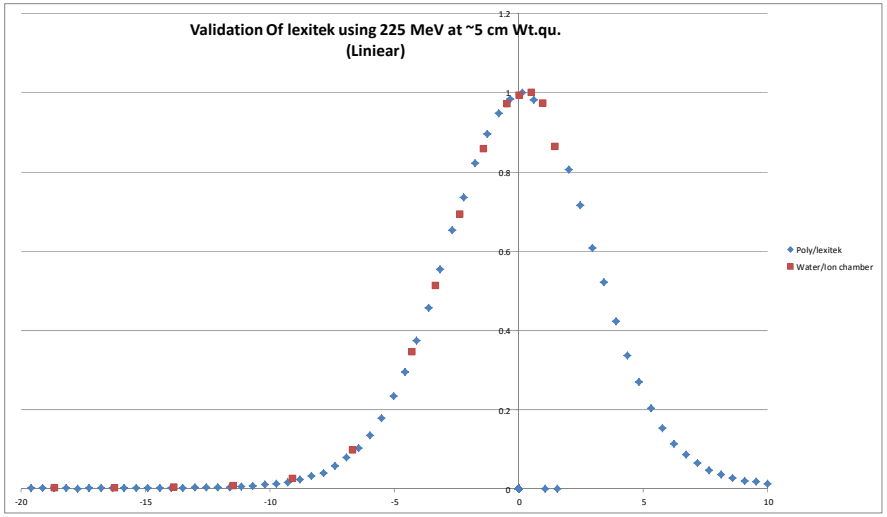


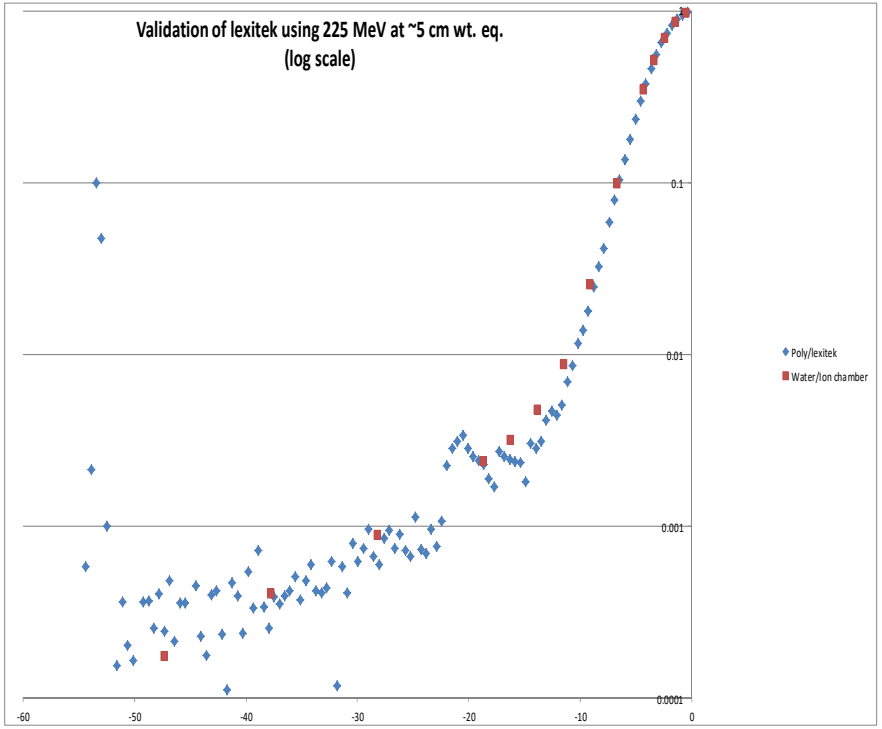


Dynamic and Linearity

- Compared with Micro ion chamber
  - ~ Exradin A16 0.007 cc

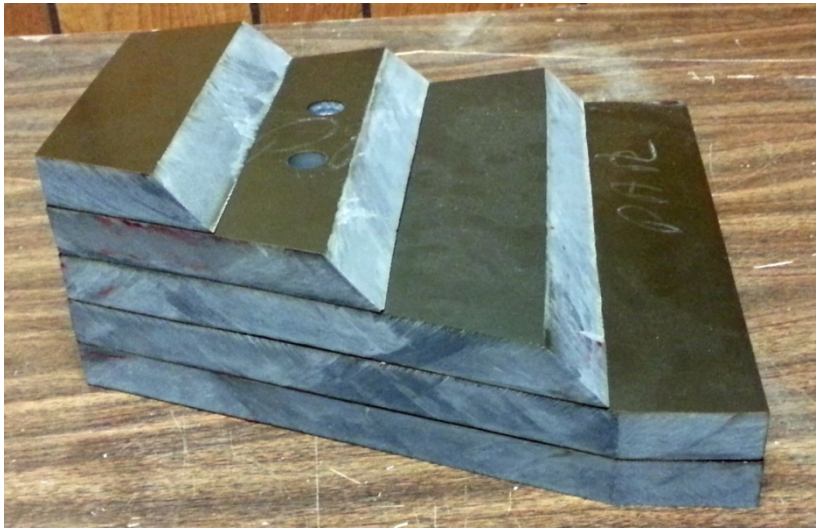




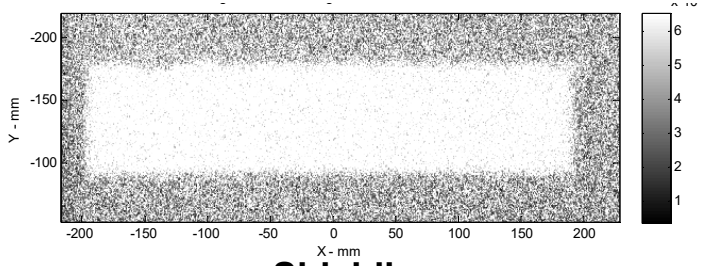


Shielding and Pixel Correction

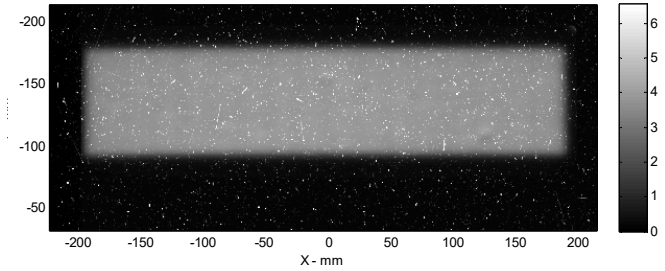
- Borated shielding was made to stop some secondary particles from directly hitting the CCD
- Additional pixel correction tools procedures were implemented
  - ~ More work in progress



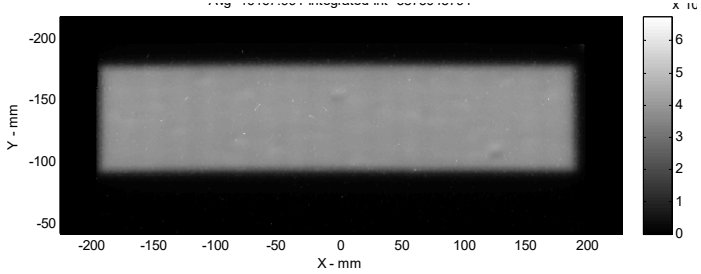
No shielding



Shielding



Shielding with Pixel correction

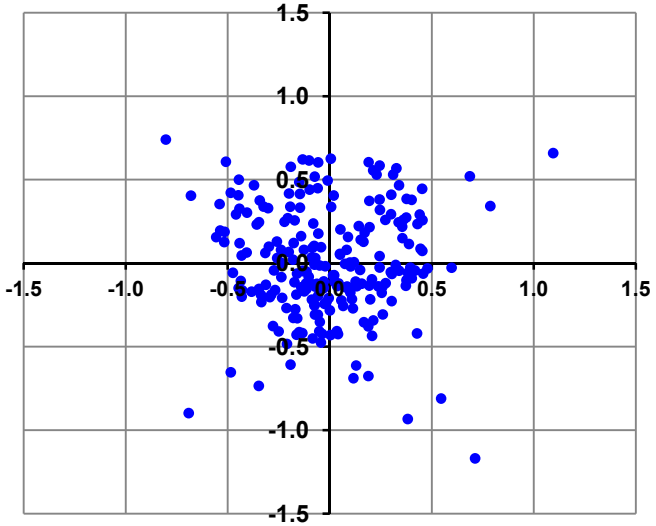


Features

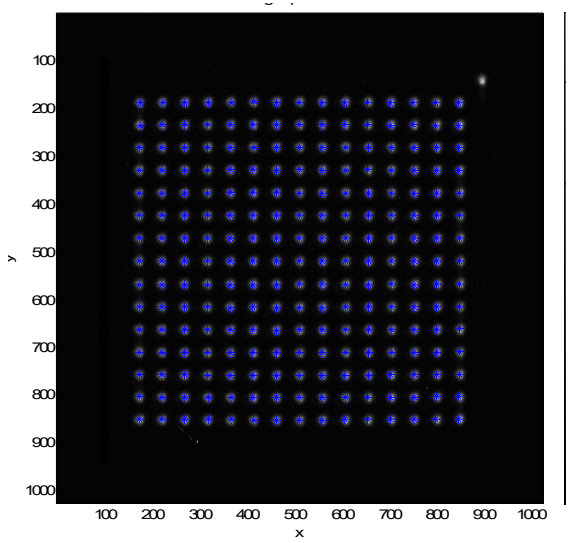
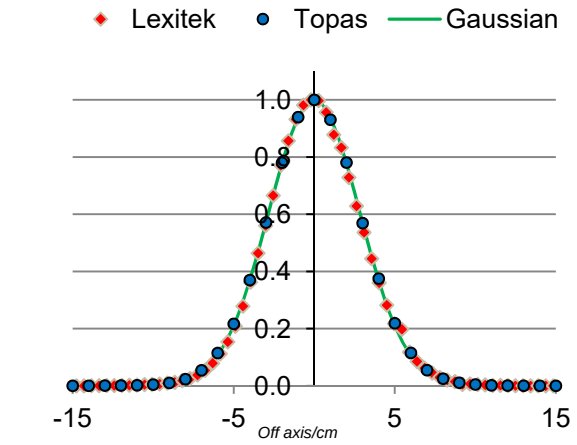
» Single spot fitting for dose modeling

» Multiple Spot fitting for reproducibility and and beam QA

Difference between the planned position and the measured position (in mm)



Lexitek Analysis



Profile Comparison