An Ultra-Fast Transparent Scintillator Beam Monitor for FLASH-RT

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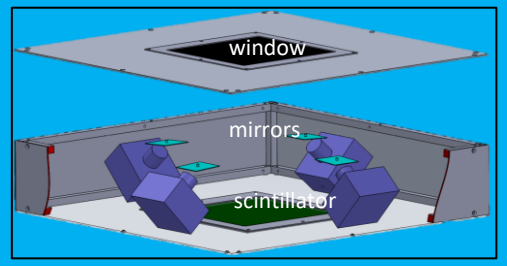
FLASH Scintillator Beam Monitor Features

- **U**ltra-**F**ast **T**ransparent **M**onitor (**UFTM**):
- Four (4) ultra-fast machine-vision cameras
- One camera/quadrant
- Folded optics - reduces depth profile
- Thin geometry: ~ 14 cm
- Positioned between nozzle & patient
- Two novel low-mass (< 1 mm WE) transmissive scintillators:
  - **PM**: *Polymer* Material microcrystalline films
  - **HM**: *Hybrid* Material inorganic crystal + polymer
- FPGA-based data readout and analysis
- Internal calibration: UV + photodiodes

Fast, Real-Time DAQ

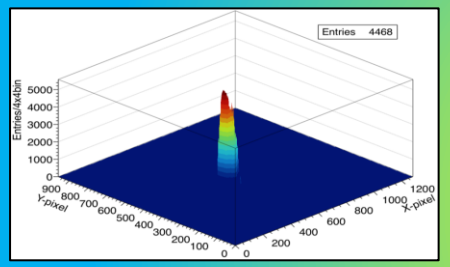
- Continuous real-time analysis during treatment
- Images analyzed every 50-100 µs
- Generates: beam position, profile, and dosimetry.
- Generates fast beam interrupt signal

Design of Four-Camera UFTM



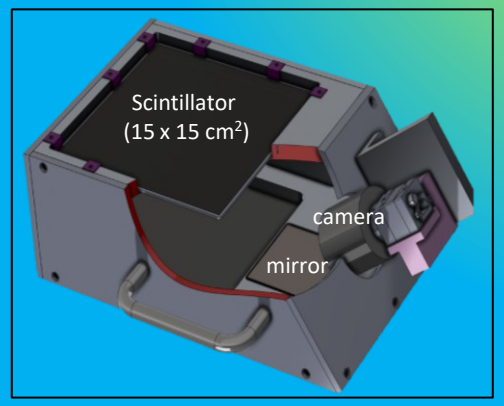
Design Concept Tested

- *5 MeV protons (Michigan Ion Beam Lab)*
- *8 MeV electrons (Notre Dame Radiation Lab)*
- *3 MeV/u $^{86}Kr^{+26}$ beam at DOE-FRIB*
- *6-16 MeV electrons at UM Hospital*

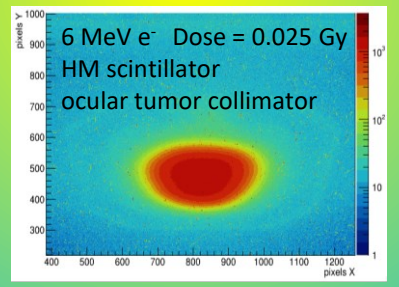


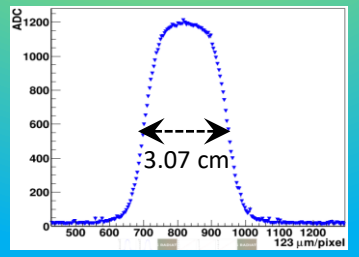
10 µs exposure of 2x2 cm^2 **PM**-scintillator & machine vision camera. 10 nA, ***5.4 MeV proton beam*** 2.5 mm diameter, sweeping at 2 kHz x 200 Hz *Dose rate* ***~ 200 Gy/s***.

1st Prototype UFTM – single camera



1st Prototype UFTM

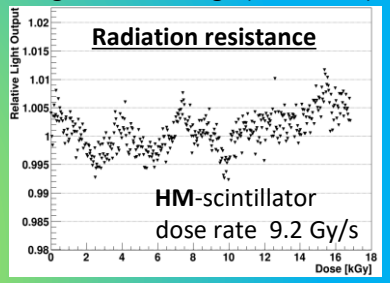


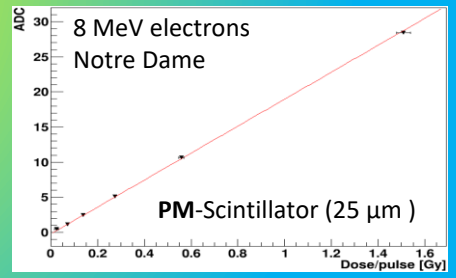


X-projection of radiometric image

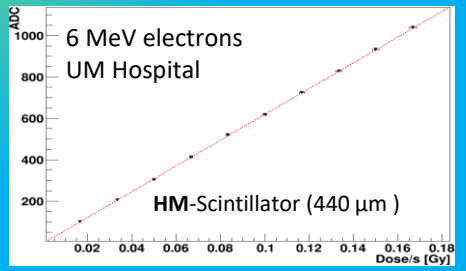
Scintillators

- Microcrystalline scintillator films, novel to this application
- Almost transparent to beam
- Excellent radiation hardness
- large-area coverage (30x30 cm^2)





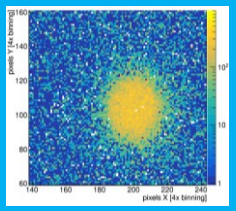
Linearity: FLASH dose/ pulse

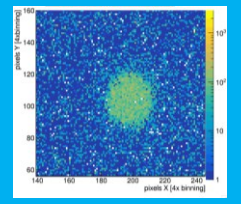


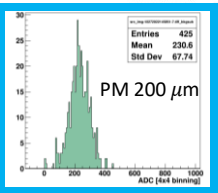
Linearity: conventional dose

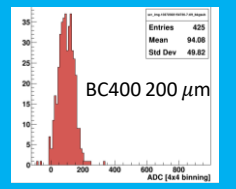
Scintillator Comparisons

- PM vs BC-400
- 3mm beam of ^{90}Sr β^-
- 24 db gain, 4x4 binning



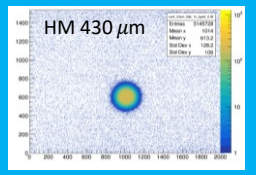


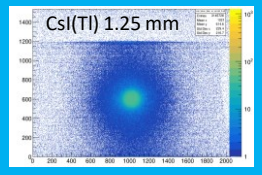




➔PM gives 2.5 x BC-400 signal

- 0.4mm HM vs 1.2mm CsI(Tl) single crystal
- 3mm beam of ^{90}Sr β^-





Relevant Results for Electron & Proton FLASH

8 MeV electron beam
Single **2 ns pulse** (1.9 Gy)
Peak dose rate 950 MGy/s
1 A peak pulse current
HM scintillator (440 µm)

*Thinner **HM** & **PM** also suitable for proton FLASH*