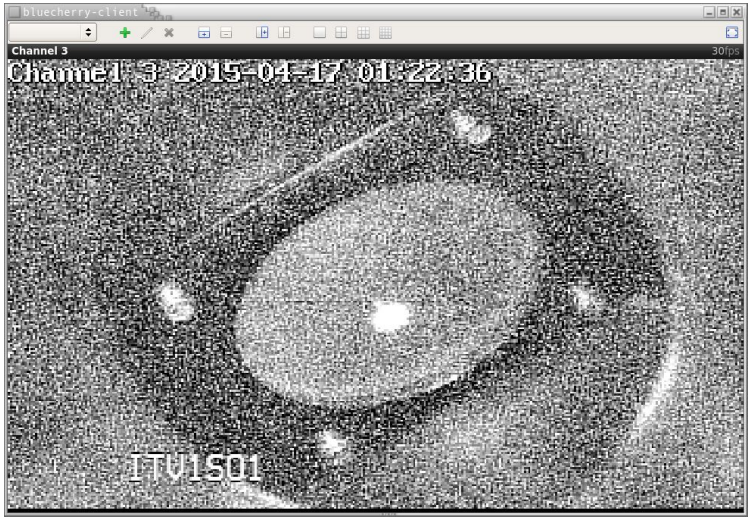
CEBAF Viewer Radiation Hardening

Operations StayTreat
June 2016

"The goal is not a status report, but to present on-going problems, issues and generate a discussion." -APF

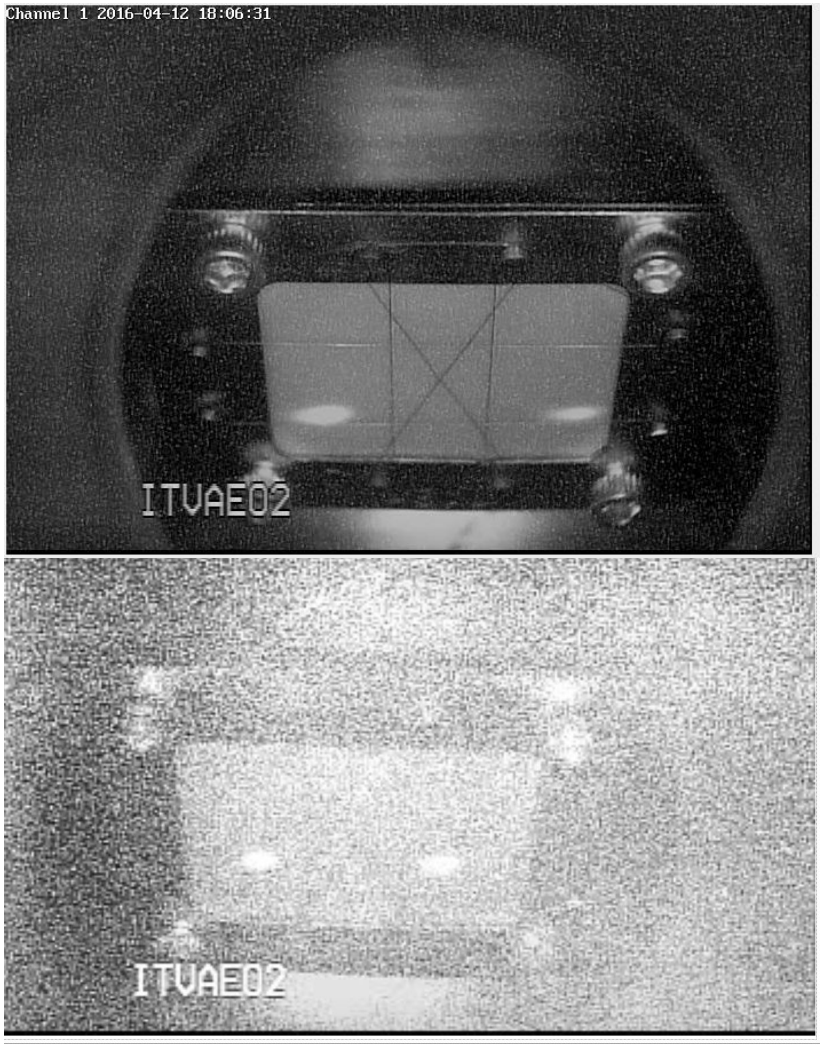
Problem

- Many of our diagnostic viewers are becoming damaged very quickly into a run.
- Some of the worst offenders are the extraction viewers, 1S01 and 2S01.



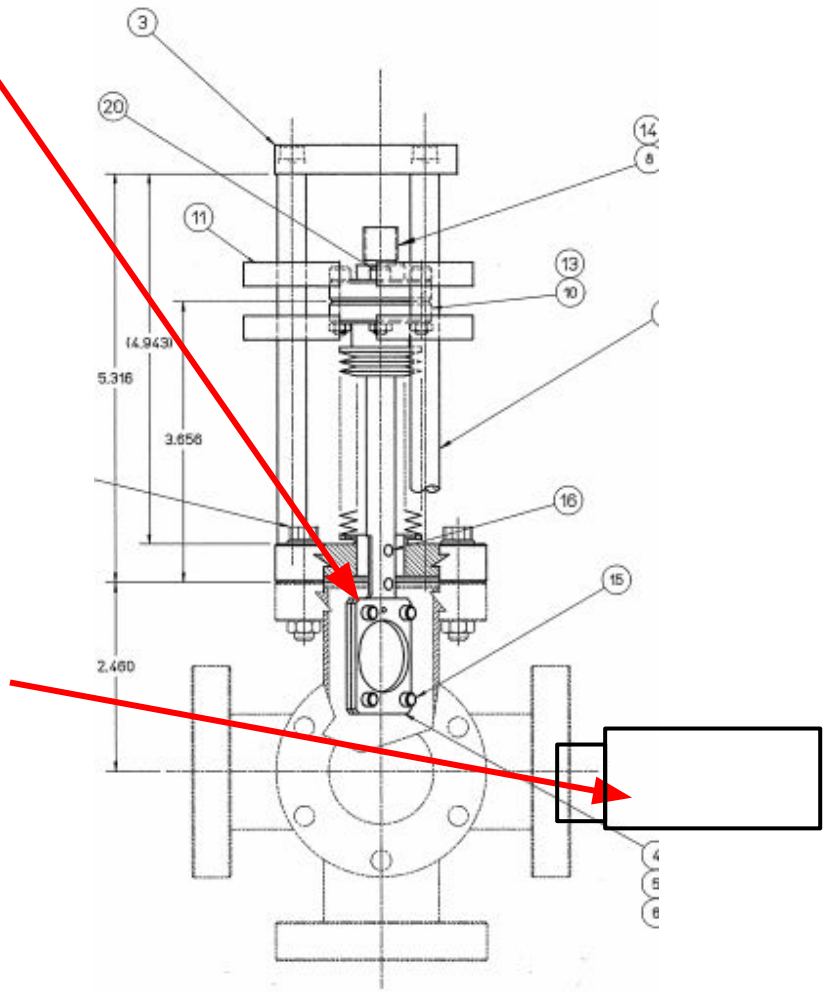
Problem Continued

- Viewers are rendered unusable through the run, sometimes when we need them the most.
- Could cause unnecessary downtime.
- Seen here is an example of 5th pass extraction viewer.
- When camera failed, could not be replaced due to a high rad area around AT YA Magnet.



What is a CEBAF Viewer?

- "Beam Viewer" consists of a target material installed on a plunger.
  - aluminum oxide doped w/ chromium [Chromox-6]
  - yttrium aluminum garnet doped w/ cerium [YAG:Ce]
- And camera usually installed so the "target" or "flag" is imaged.



What is Failing?

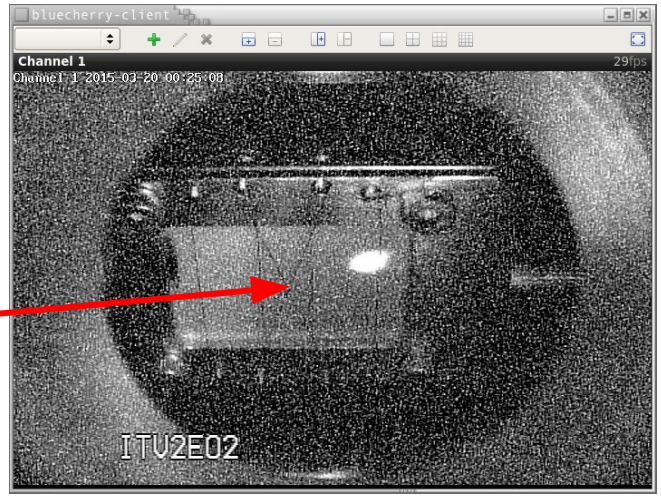
- Target is usually a ceramic material.
    - Fairly robust material
- Cameras seems to be the failing component.
- Two main questions:
    - Camera Component?
    - Source of Failures?

What Causes Camera Failure?

- Likely radiation? Where? Source?
  - Neutrons? Gammas? Spectrum?
  - Beam Scraping?
  - Synchrotron Radiation?
  - Transition Radiation?
  - Other?
- Dependent on target?
- Which viewers do we care about the most?
  - These are the ones we should analyze for the best redesign.

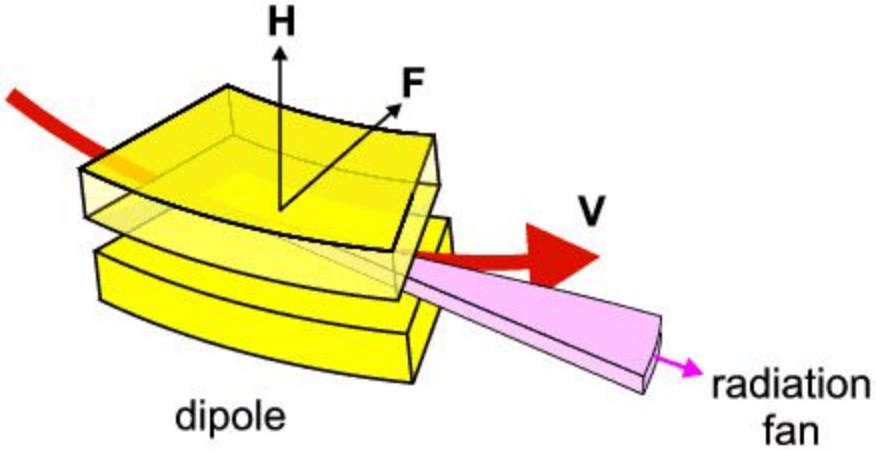
Beam Scraping in Extraction Region

- Viewers, when calibrated, provide a quick and efficient means at verifying the beam separation, as it enters the septa.
- Extraction viewers are susceptible to radiation from scraping in the YA septa magnets.
- Viewers also provide a lower powered beam to protect the septa, when setting up Extraction.
- Septa Nose



Synchrotron Radiation (SR)

- Electron bunches emit radiation as they are radially accelerated by the dipole magnets. This radiation is contained within a fan-like region.



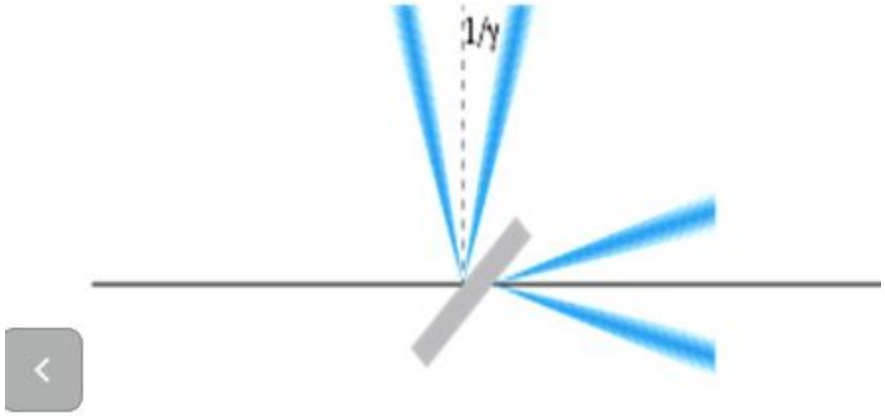
- Some viewer locations may be susceptible to damage from SR. Especially in the spreaders and recombiners, and Arcs.

Synchrotron Radiation (SR) Cont.

- Beam was purposefully turn off, viewer inserted, and then beam restored.
- No chance that the band observed here is persistence.
- Direct observation of SR fan.
- SR observed from dipole MXE8S06.
- According to calculations done in 2014 there are X-Rays above 50 keV in the upper Arcs.

Transition Radiation (TR)

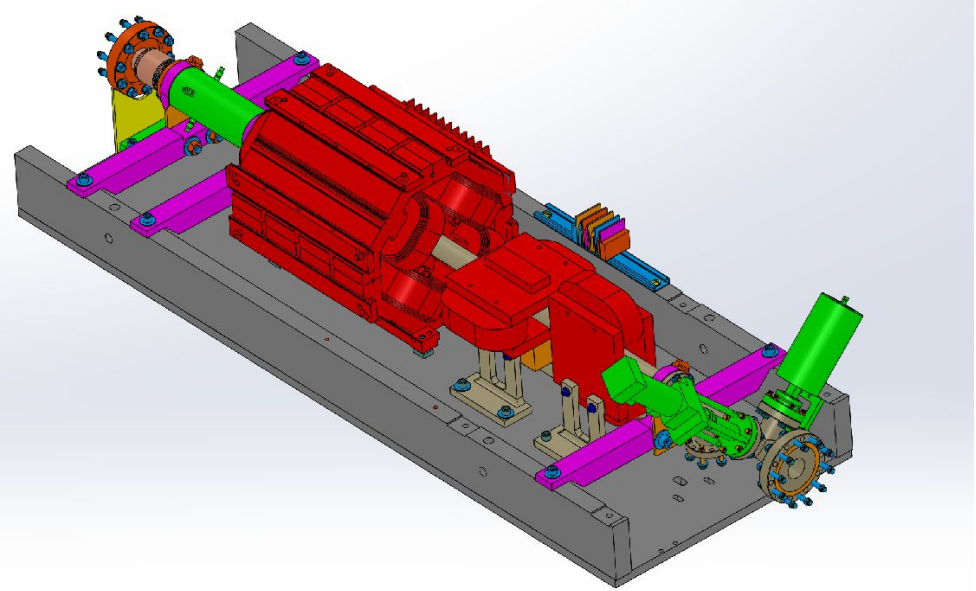
- Radiation emitted when a charged particle crosses a boundary of materials with different dielectric constants.

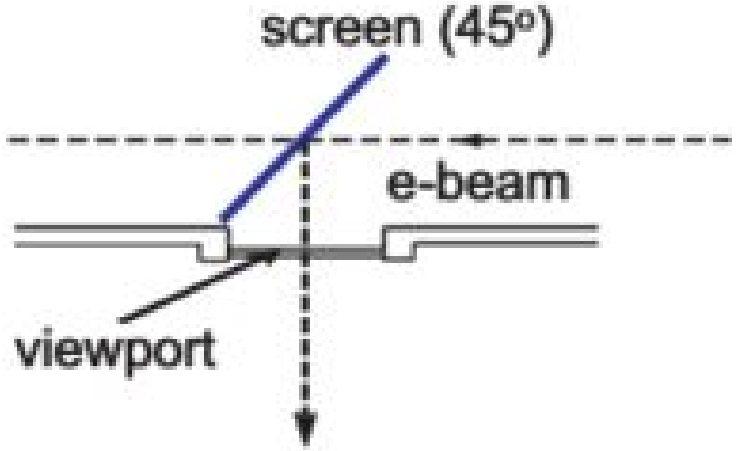


- Spectrum is mostly in the Visible? X-Rays? IR?
  - depends on material
- These things can be calculated, but to my knowledge has not been done for the CEBAF viewers?

CEBAF Viewer Design

- System lends itself to damage just from the design?

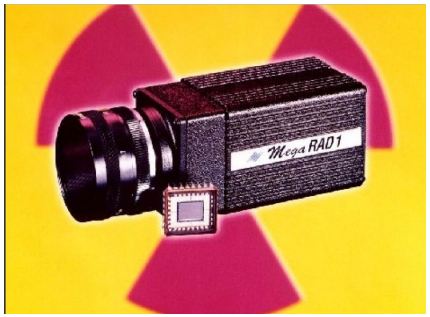




- All backward radiation and secondary electron scattering directed towards the camera, and image sensor.

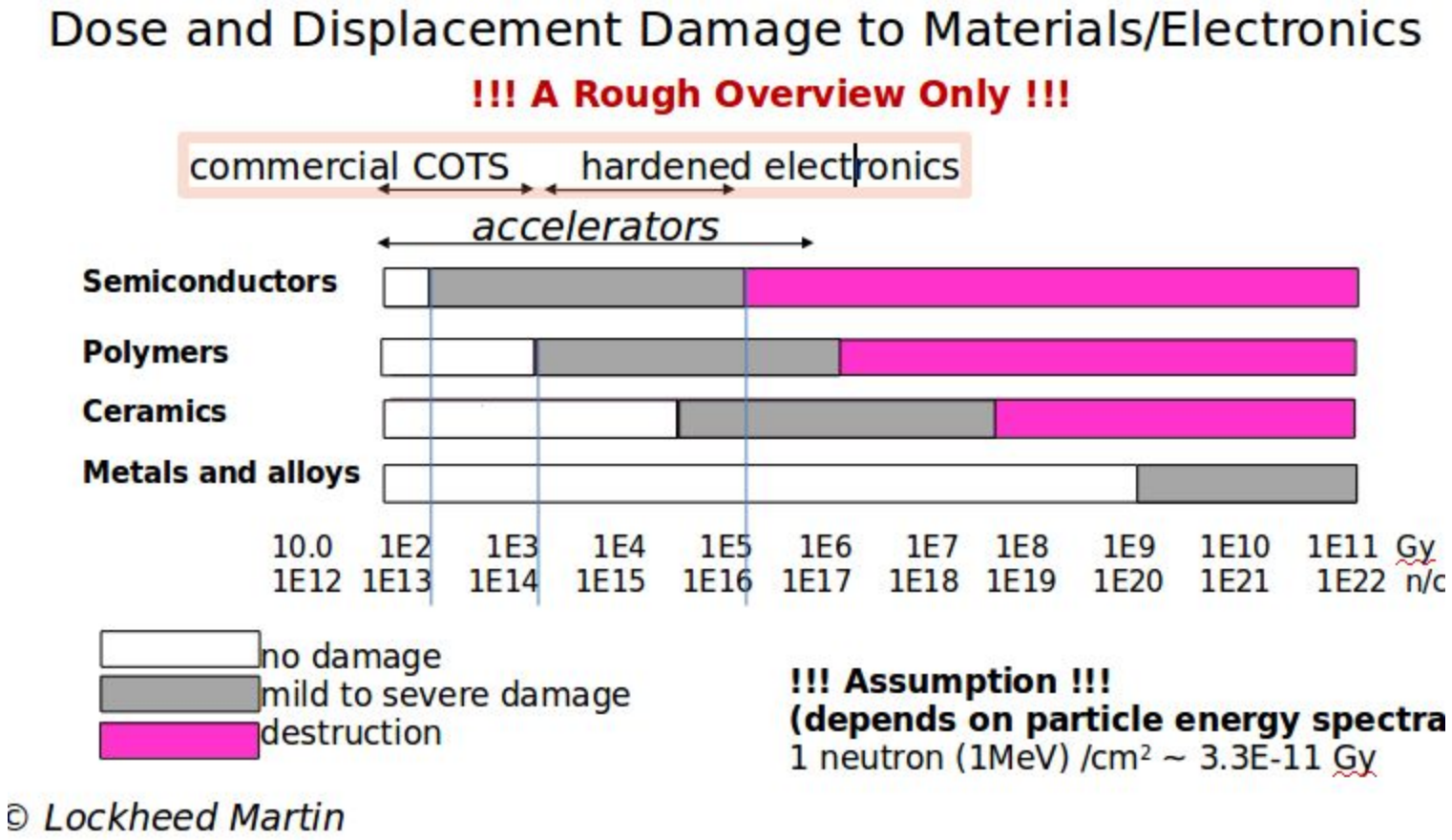
What Camera Sensors Do We Use

- Charge Coupled Devices (CCD) for beam viewers.
- A CCD is a semiconductor made of Si
- There are manufactures that produce CCD sensors that are more radiation resistant.
  - By way of special manufacturing methods they are able to increase Si purity and decrease oxygen content.
- Could buy cameras with different sensor technology.
  - Many cameras marketed as radiation hardened tend to use CID (Charge Injection Devices) sensor technology
    - Thermo Scientific [CID8712D]
    - Advertised 1 Mega Rad Limit
    - Cost???



From Yesterday …

- G. KHARASHVILI Slides :
  - https://www.jlab.org/indico/event/154/session/3/contribution/4/material/slides/3.pptx

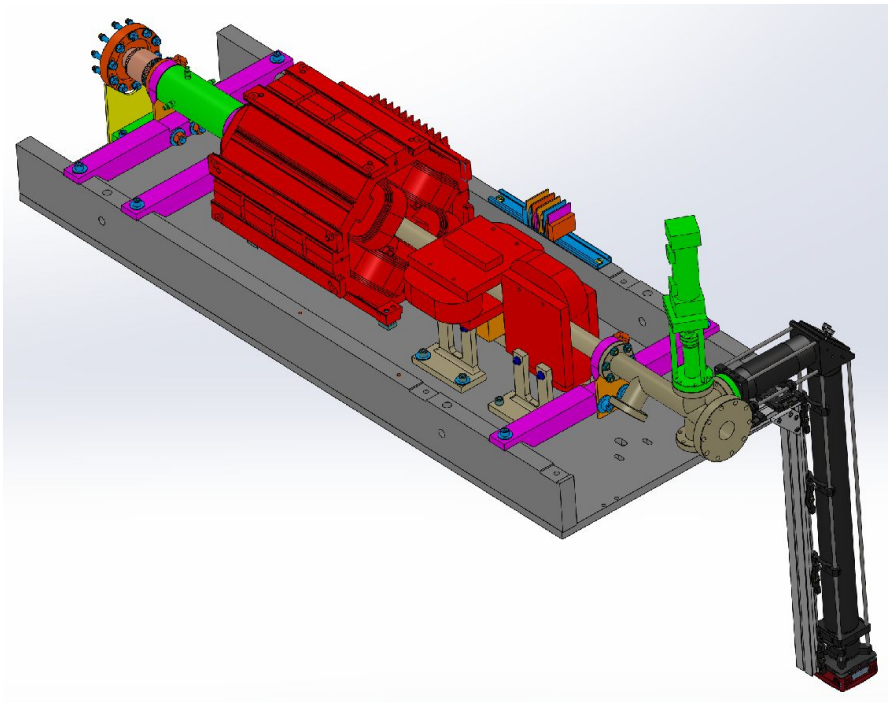


So What Do We Need To Do?

1. Come up with a list of the most important locations:
   a. **Extraction Viewers**: Checking Separation
   b. **1S01 and 2S01** : Used for phasing the Linacs
   c. **Lambertson**: Used for setup out of the Transport recombiner.
   d. Others?
2. Simulate and Analyze sources of radiation in these locations.
3. Design a new set camera optics that gets the camera out of the radiation, and/or uses different cameras.

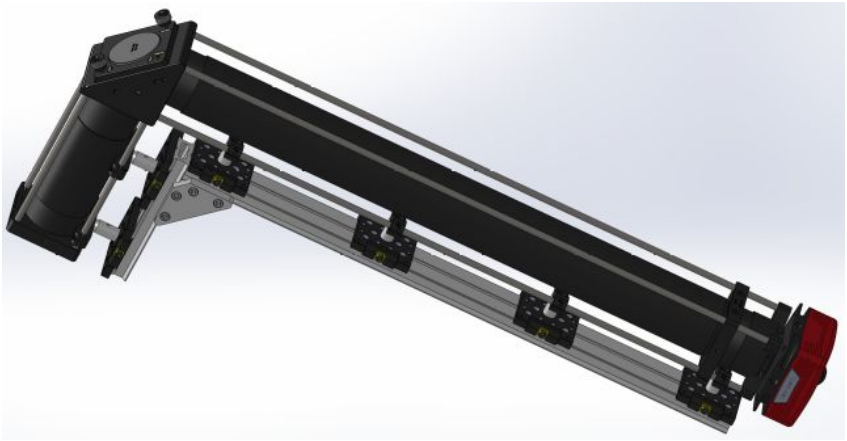
New Layout (Courtesy J. Gubeli)

- Camera shielded from secondary electrons off the viewer flag
- Camera can be positioned to be shielded or in lower radiation areas
- It can be easily configurable to not interfere with existing equipment



New Layout (Courtesy J. Gubeli)

- Highly configurable, rigid and lightweight (~16 lbs)
- Can accommodate any camera
- Magnification can be easily changed
- Nearly no machining required
- Easily field focused and aligned
- Entirely light tight
- ~$2K + camera per device



Issues and Open Questions

- What is damaging cameras, radiation sources?
- Is there a more robust camera?
  - Rad Hard Camera in certain locations?
  - Overkill?
  - Cost analysis vs. camera optics change
- Would bandpass filters help?
- Outfit certain cameras with dosimetry first?
- Other sensor technology?
  - Another CCD?
  - CID?
  - CMOS?
  - Other?

Acknowledgements

- Synchrotron Radiation viewer analysis done by Freyberger and Wang:
  - https://logbooks.jlab.org/entry/3321463
  - https://logbooks.jlab.org/entry/3321480
- Good Information on Radiation effects on CCD sensors:
  - http://acfahep.kek.jp/acfareport/node220.html
- Spec sheet for CID camera:
  - https://tools.thermofisher.com/content/sfs/brochures/D10423~.pdf
- New Layout Slides provided by J. Gubeli.
- StayTreat Slides G. KHARASHVILI:
  - https://www.jlab.org/indico/event/154/session/3/contribution/4/material/slides/3.pptx