# Recent Developments On High Intensity Beam Diagnostics At SNS


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Spallation Neutron Source
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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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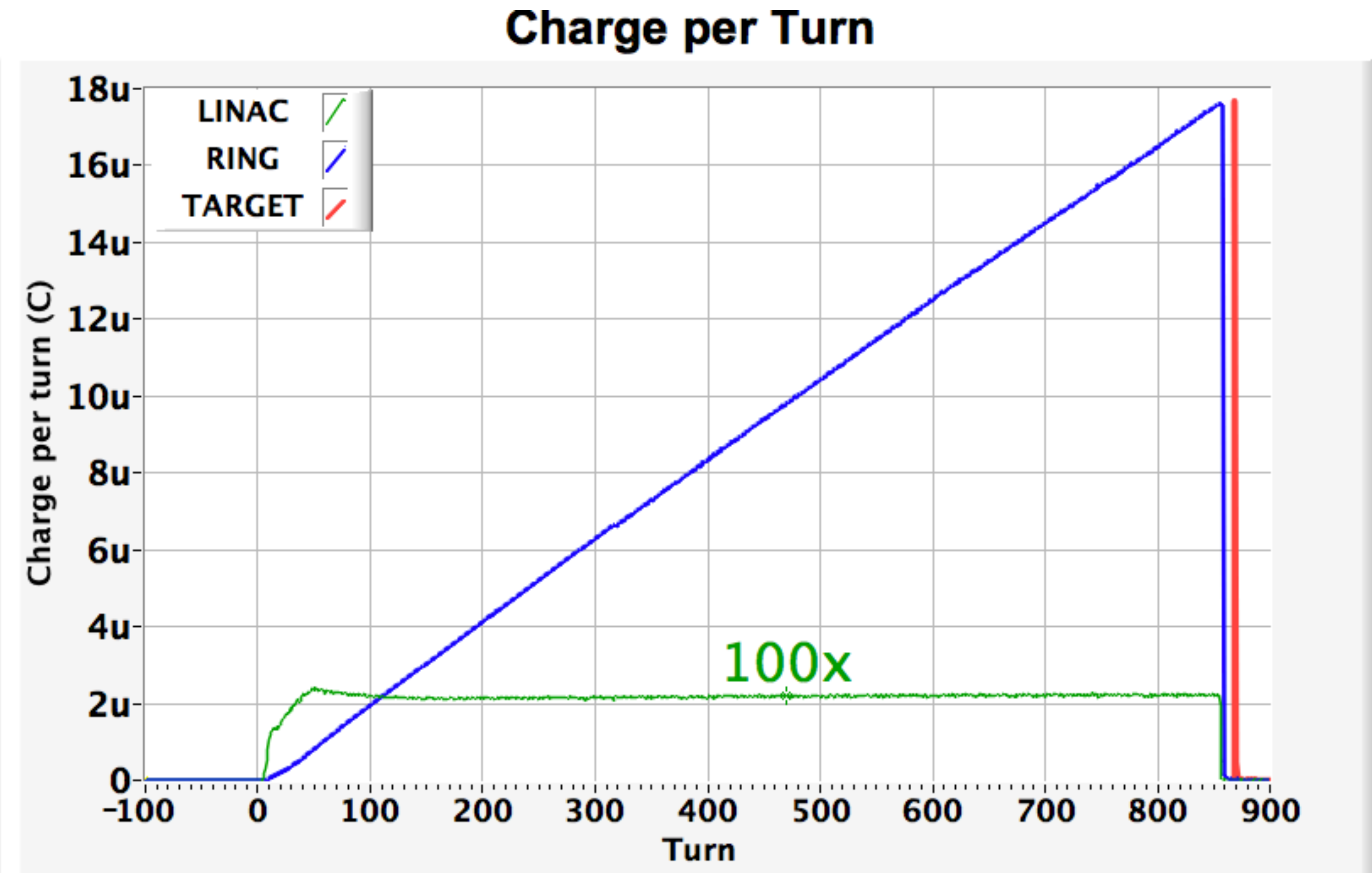
# Outline

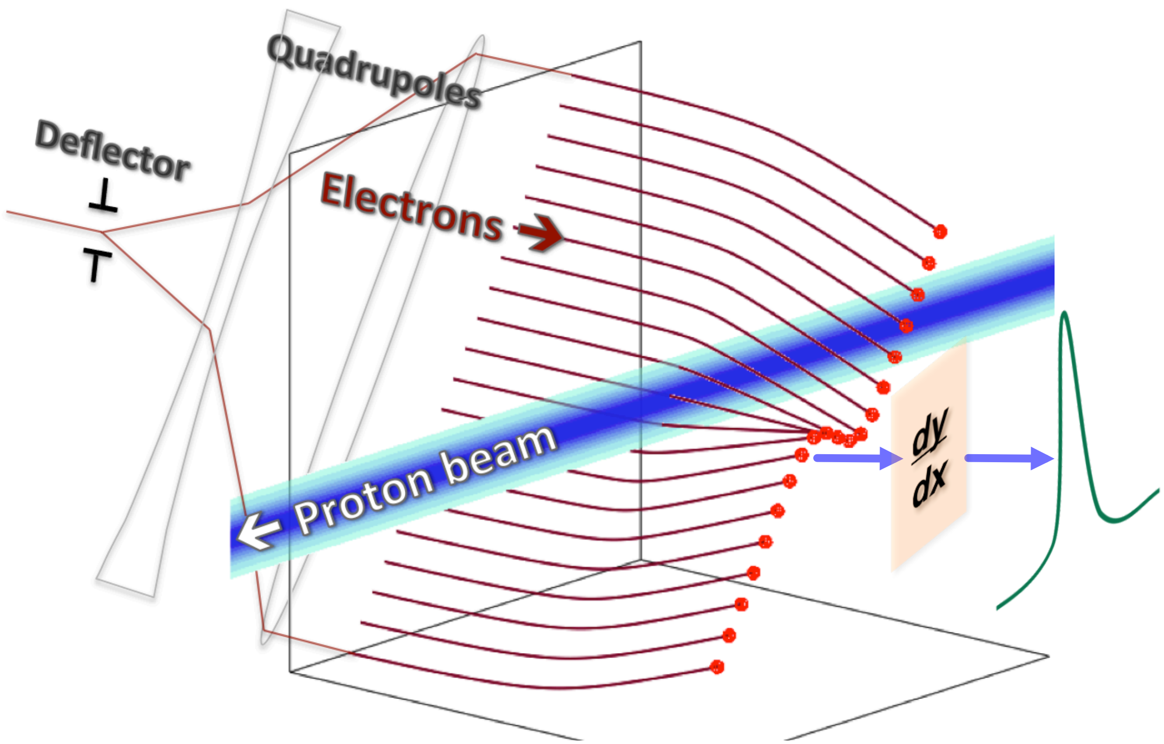
- Progress High Intensity Beam Diagnostics
  - Electron Beam Scanner
    - Simulation with short proton bunches
    - Image Analysis
    - Deflector angle adjustment
    - Cathode performance
    - Unwanted illumination
  - Target Imaging System
    - Lamp installation
  - Foil Imaging System
    - Remote system in non-radiation environment

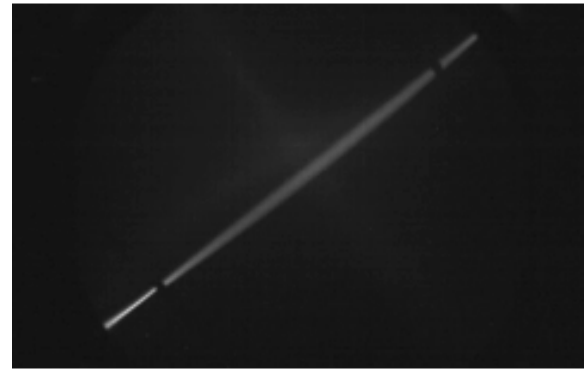
# Spallation Neutron Source Accelerator

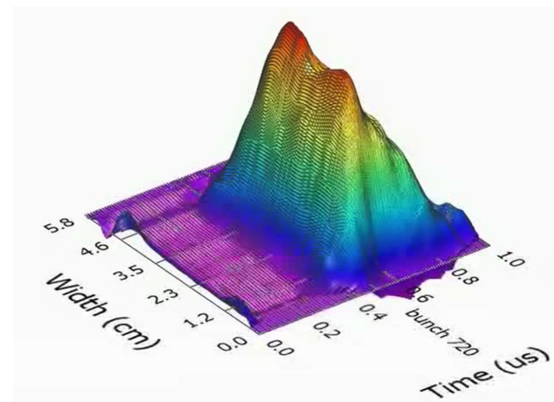



- **High Intensity Beam in the Ring: 1 ms ramp to 1.5E14 protons.**

# Electron Beam Scanner: Method



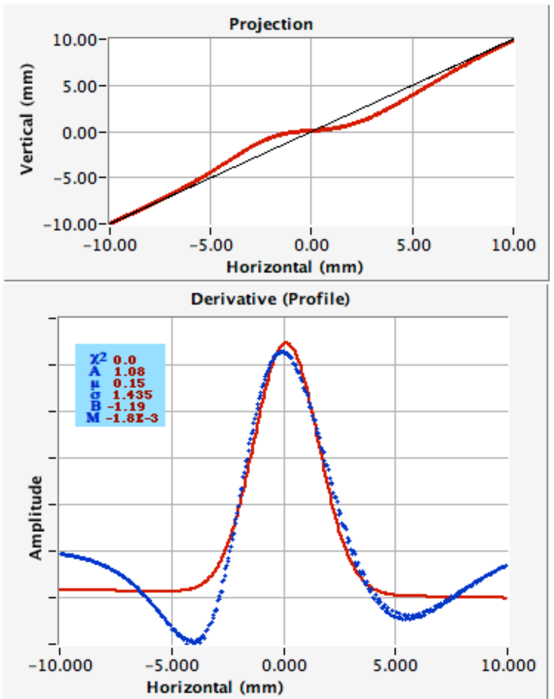





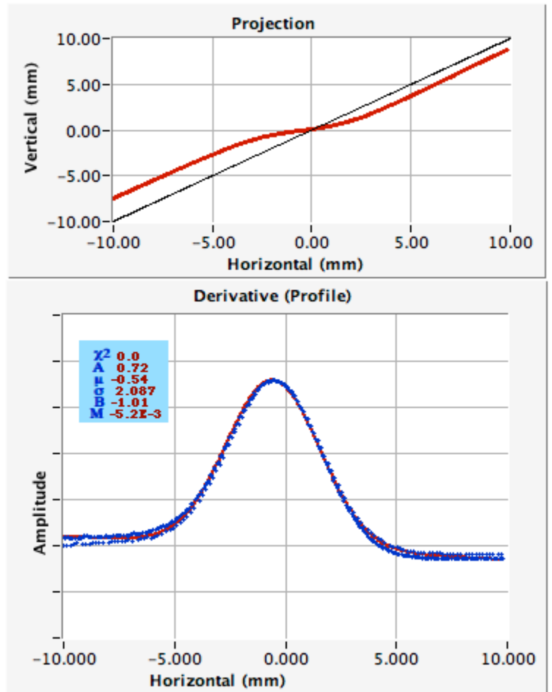

3D plot of Turn 720 at ~11uC

- **Non-intercepting transverse profile measurements at high intensity**
- **20 ns scan during ~640 ns long proton bunch (scan << bunch)**

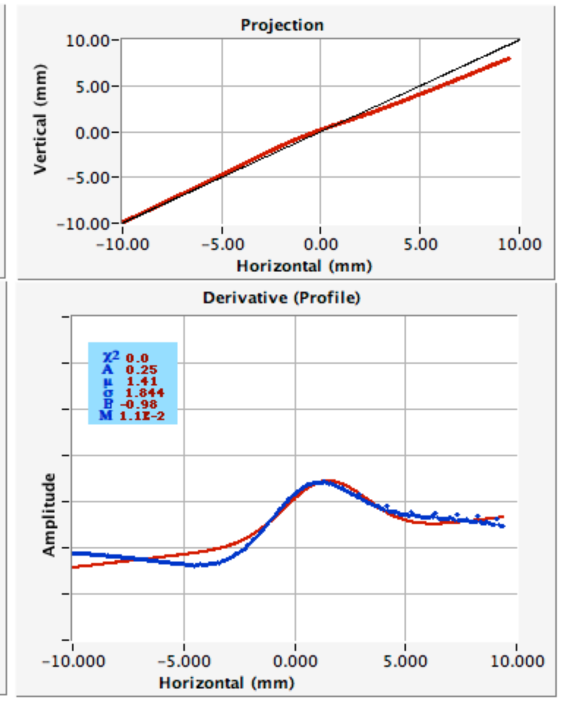
# Electron Beam Scanner: Scan Length




20 ns long scan



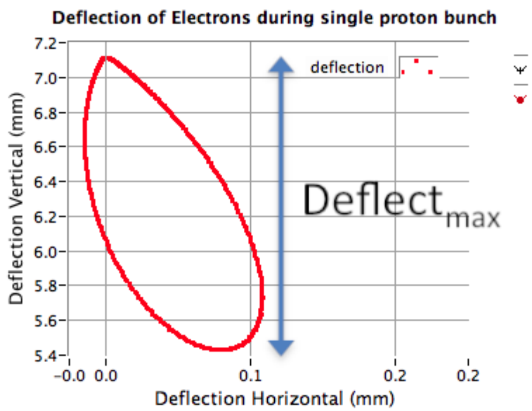

3 ns long scan

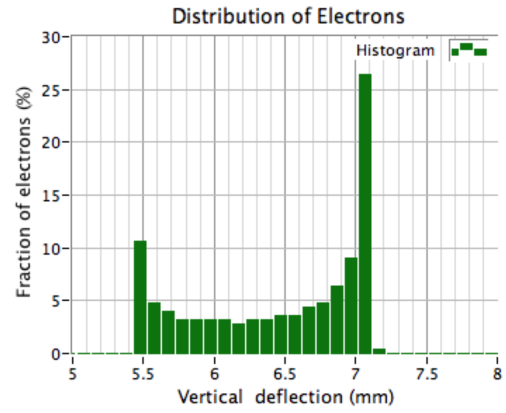


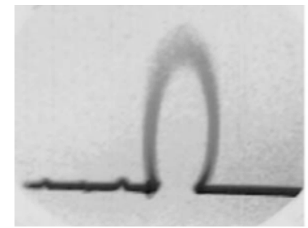

Off-center, 7ns long scan

- **Simulation to see what happens when the electron scan duration is longer than the proton bunch duration (ProjectX: Main Injector: 3 ns bunch)**

# Electron Beam Scanner: Static Scan



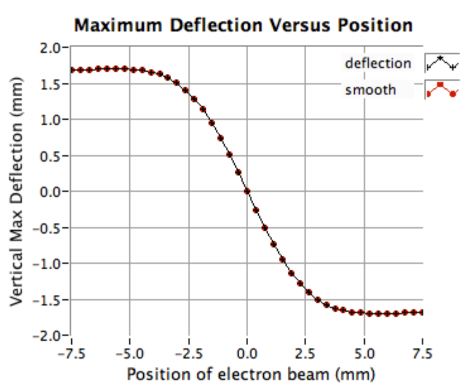



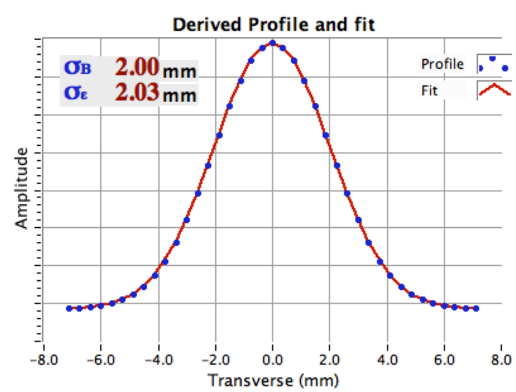



Experimental result

[5] P. V. Logachev, D. A. Malyutin, and A. A. Starostenko

- Non-moving pencil electron beam while proton bunch passes by




- Step the electron beam slowly through the repeating proton bunches
- Determine the profile from the maximum deflection at each step

# Electron Beam Scanner: Direct Fit

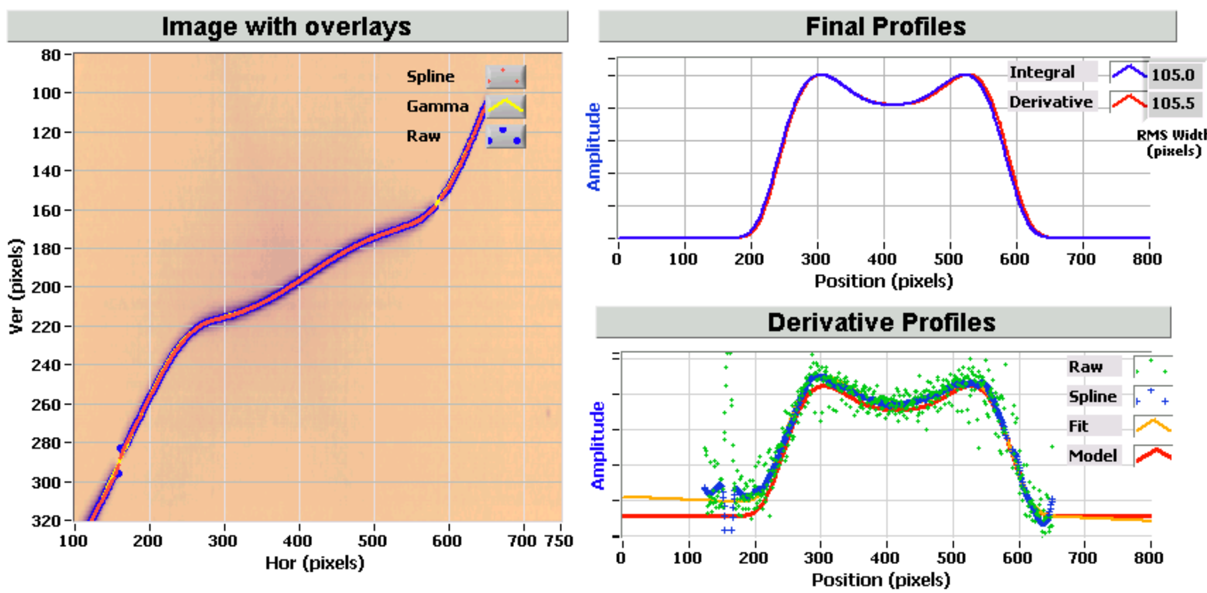
$$\int \left( a \cdot e^{-0.5\left(\frac{x-\mu}{\sigma}\right)^n} + sl \cdot x + o \right) dx =$$

$$a \cdot \frac{2^{\frac{1}{n}}}{n} \cdot sign\,(x-\mu) \cdot \mathrm{Gamma}\left[\frac{1}{n}, 0.5\left(\frac{x-\mu}{\sigma}\right)^n\right] +$$

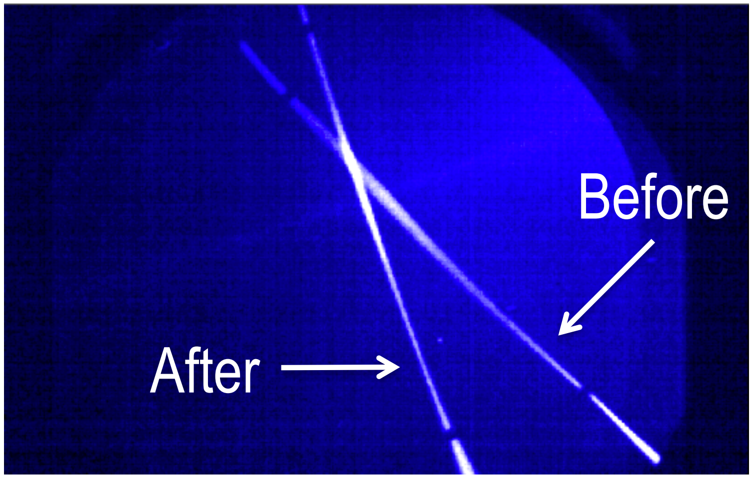
$$o \cdot x + \frac{sl}{2} \cdot x^2 - sl \cdot \mu \cdot x + c$$

- Fit a model (e.g. super-gaussians) directly to projected curve to increase stability and fitting speed (no intermediate derivative)

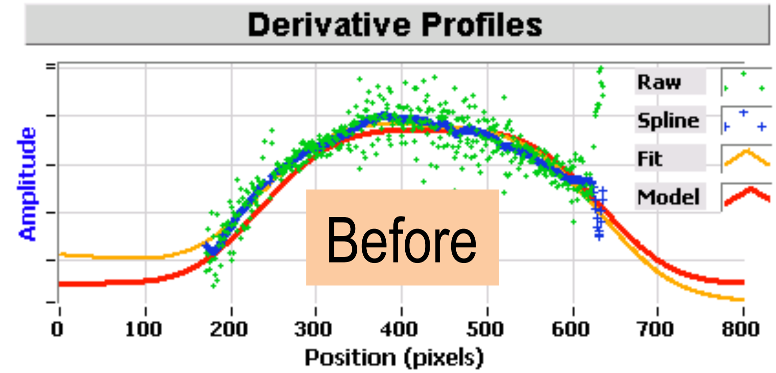
- Same stability as derivative method
- Too slow (up to 1-20 s versus 1-3 s)

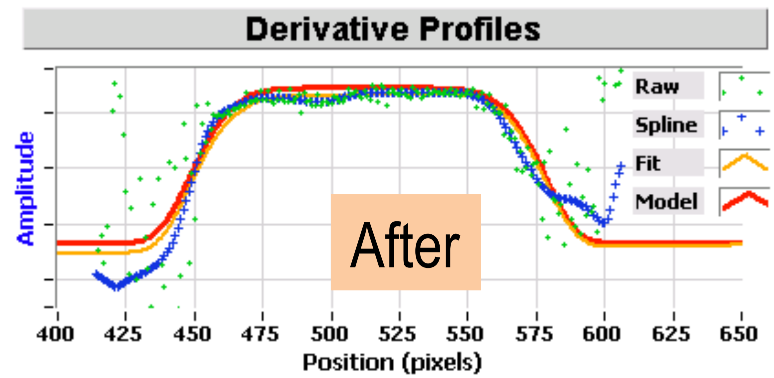


# Electron Beam Scanner: Deflector



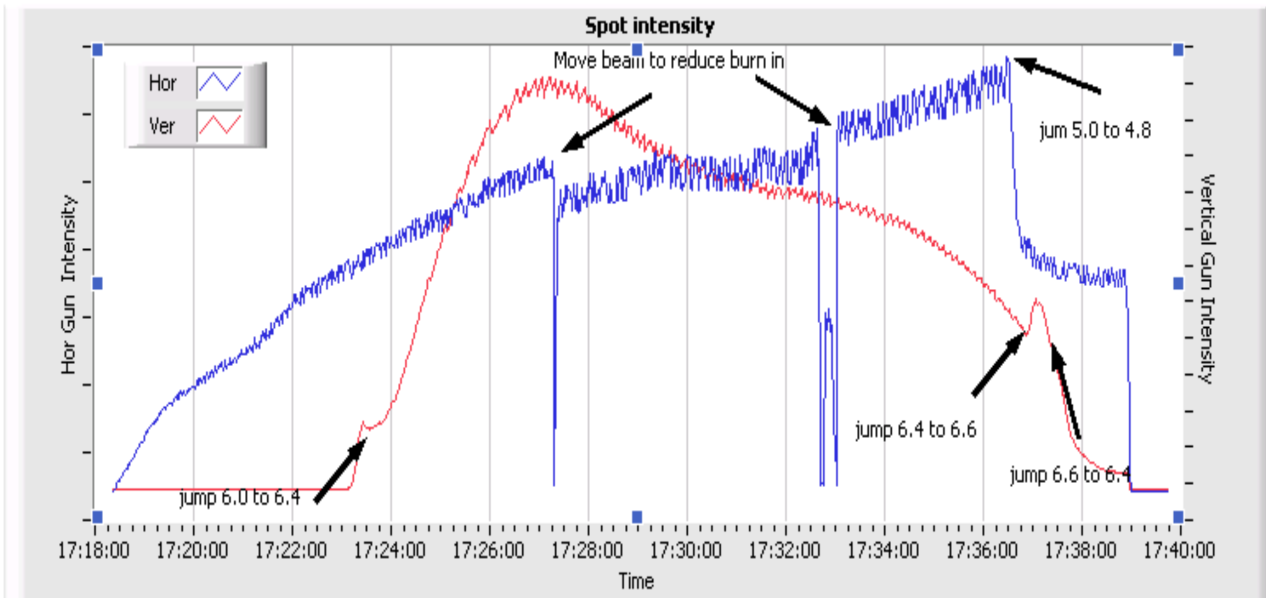

Projection without beam before and after the rotation




- **Range of vertical profile scanner is not wide enough -> rotating the deflector from 45 degrees to almost 70 degrees adds almost 30% to range (but we loose resolution)**
- **Camera does not see top and bottom of screen -> improve**

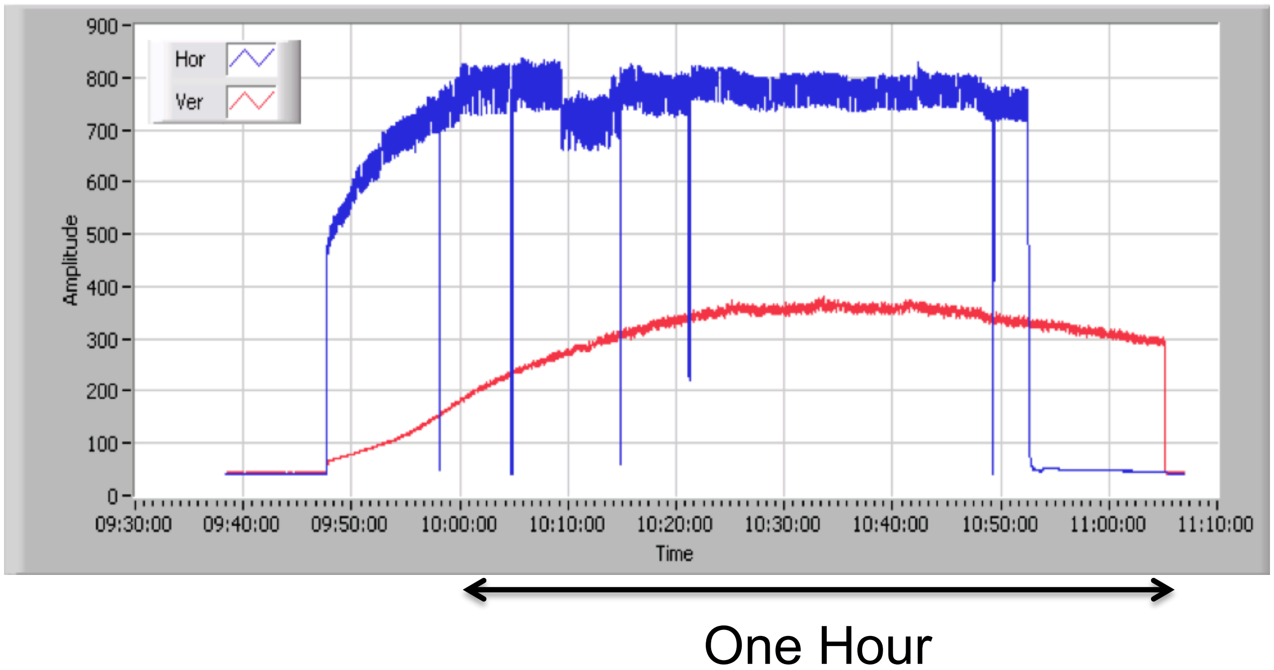
# Electron Beam Scanner: Cathode




Only 14 minutes!!!

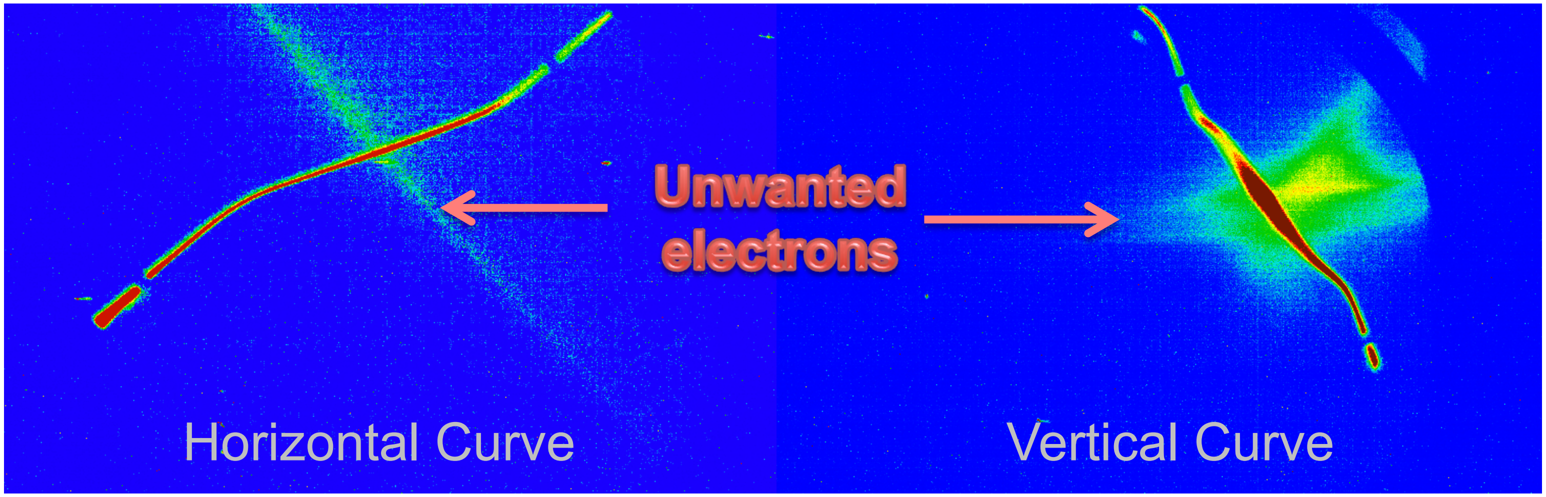
- **After rotation, the vertical cathode (focused beam, deflector off) delivered very short lived and low intensity current -> cathode poisoned?!**

# Electron Beam Scanner: Cathode

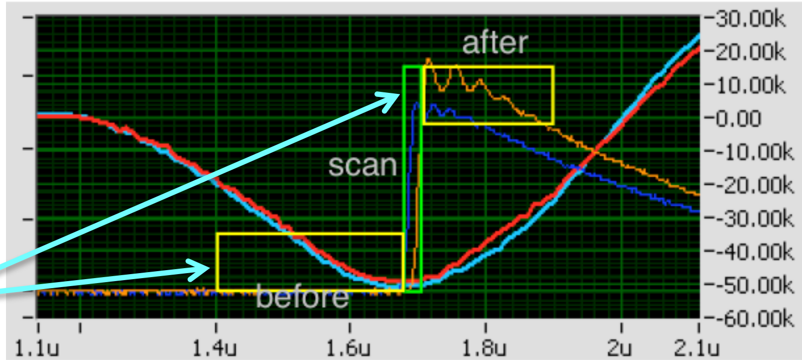



- **Cure cathode (Lanthanum Hexaboride: LaB6) poisoning by overheating**
- **Must also turn HV Off**
- **Repeated several times to recover and even improve performance**

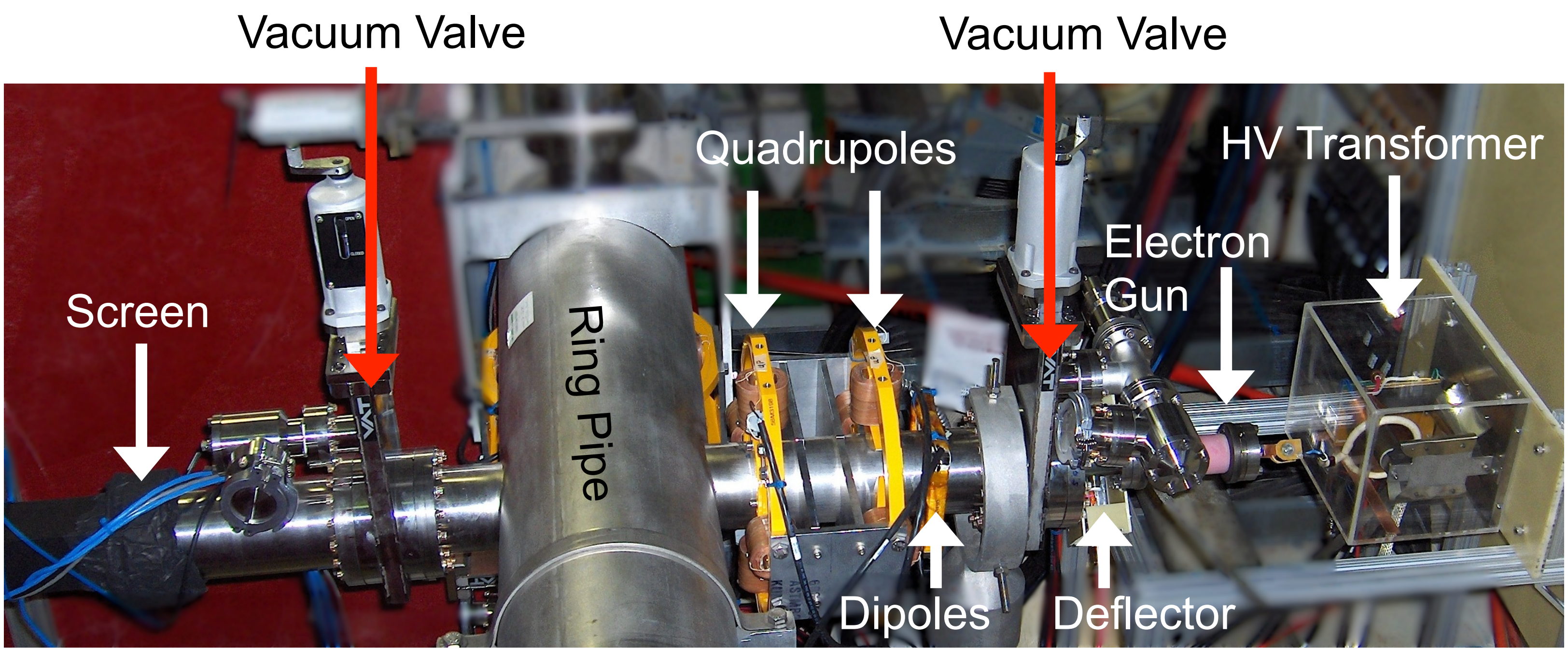
# Electron Beam Scanner: illumination




- Unwanted electrons illuminate the screen and impede the analysis
- These electrons are thought to originate from before and after the deflector scan

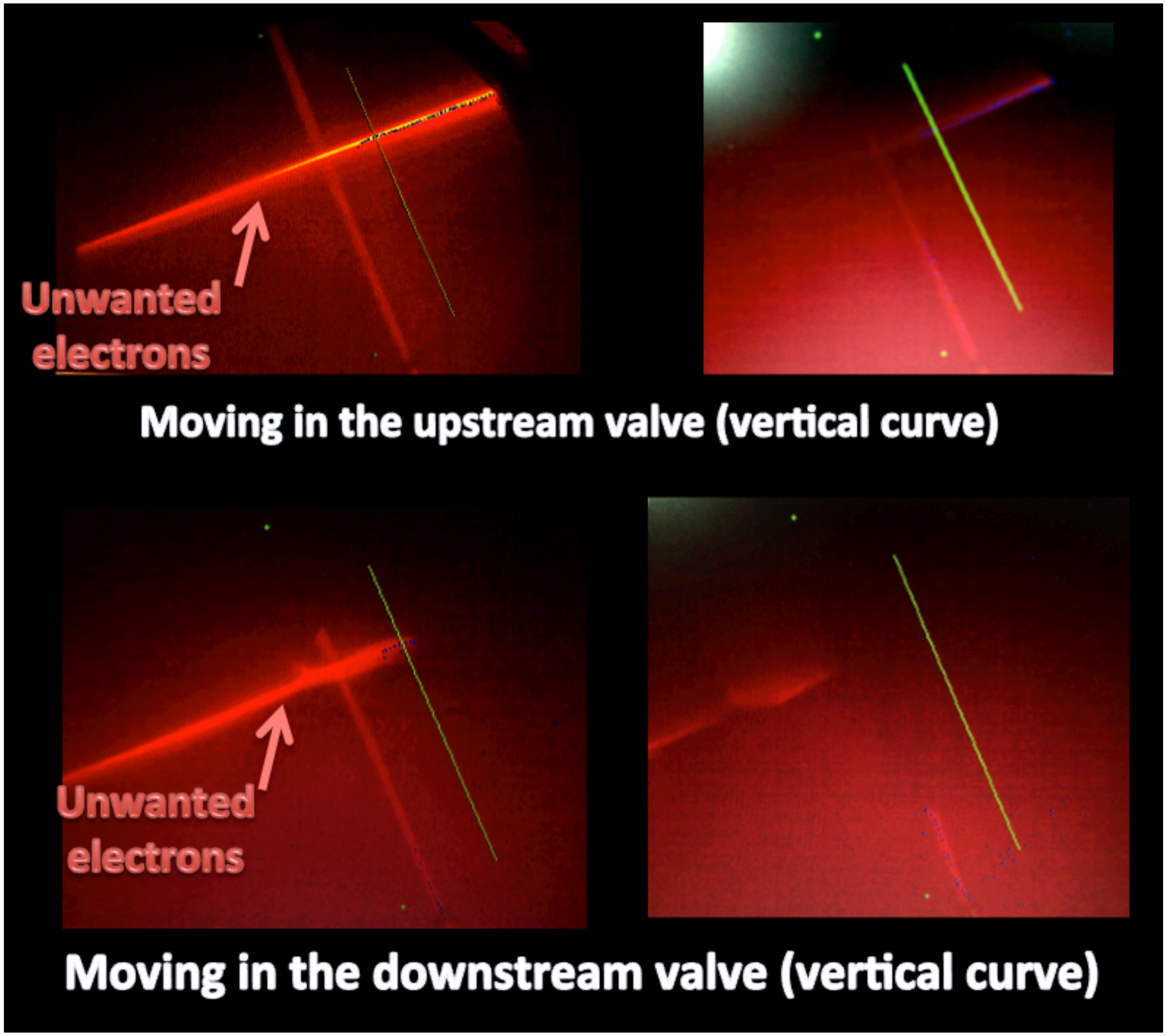


# Electron Beam Scanner: illumination




- **Note the manual vacuum valves**

# Electron Beam Scanner: illumination

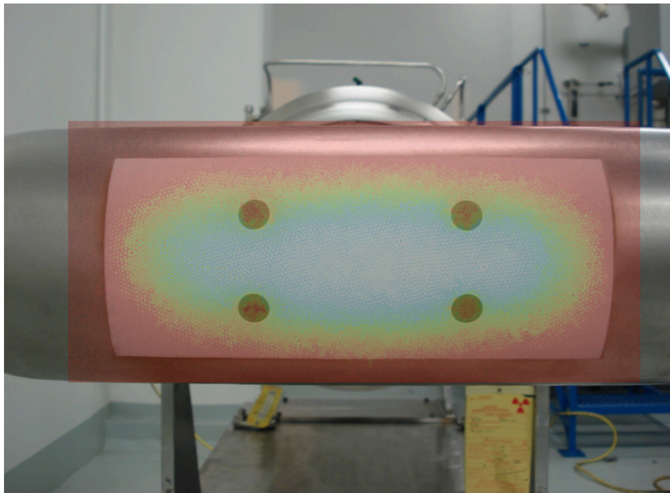



- No proton beam
- Setup ES to show unwanted electrons
- Manually adjust valves

→ able to scrape some of the unwanted electrons away

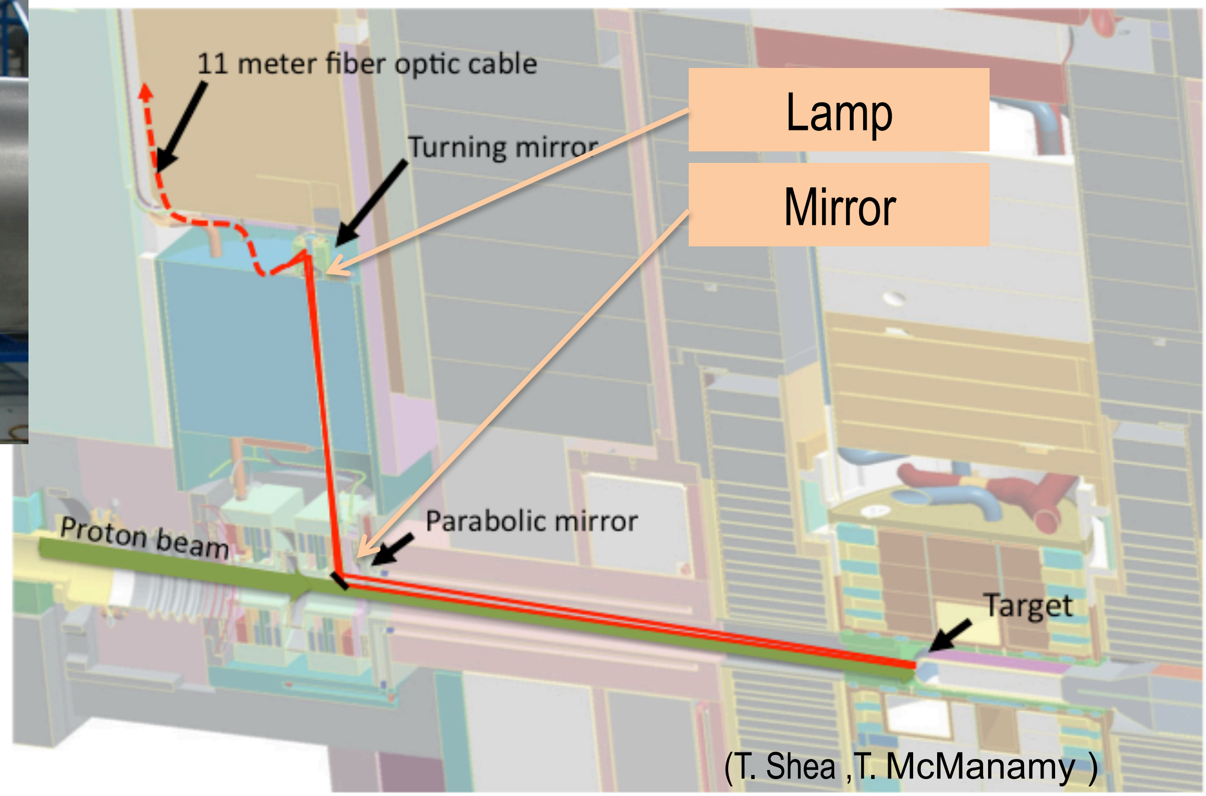
→ Install aperture restriction in the future (upstream of proton beam)

# Target Imaging System



Target with superimposed proton beam image

TIS Layout

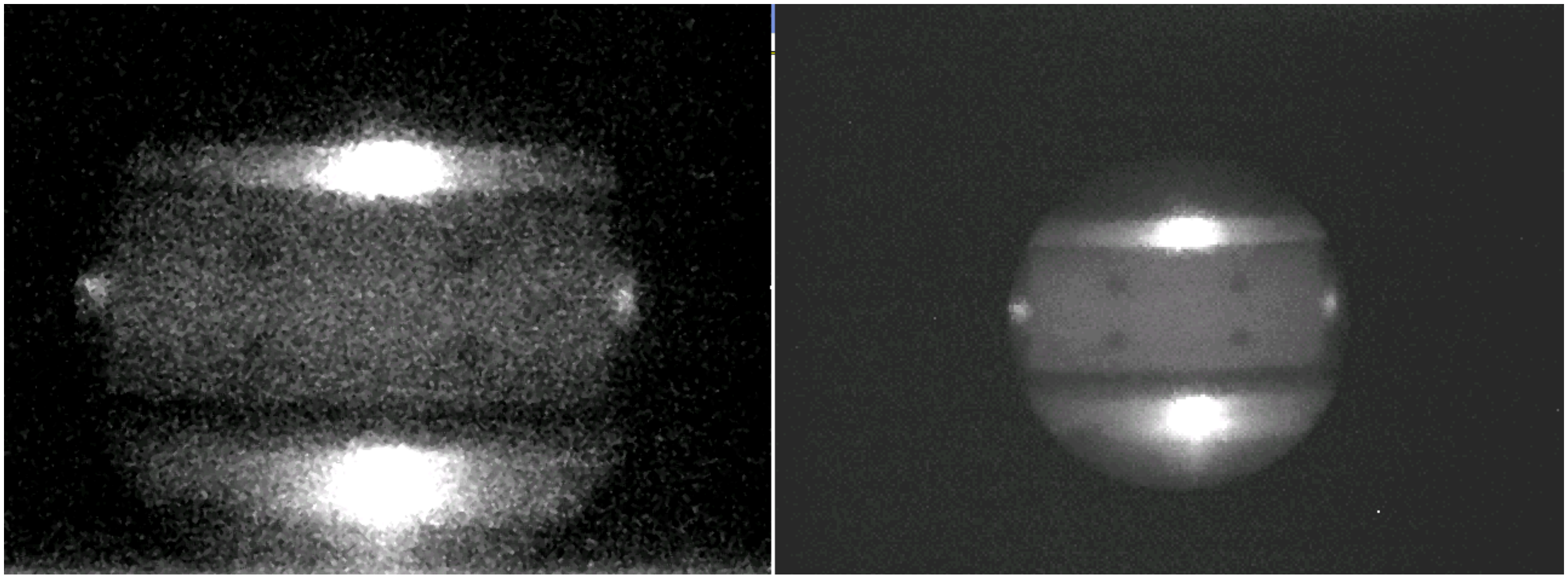



(T. Shea ,T. McManamy )

- **Last diagnostics to provide transverse profiles (at full power)**
- **New Target and new Proton beam window**

**→ Calibration and opportunity to install additional mirror and lamp**

# Target Imaging System



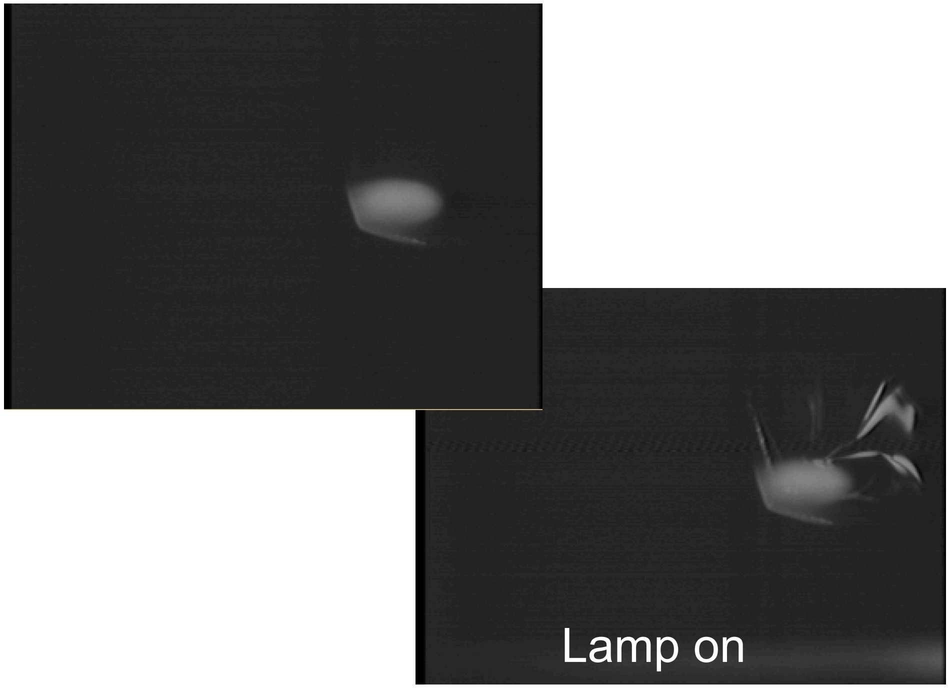
GC-1290 ATV G-145-B

- **Lamp installed to shine on target to allow for calibration before beam on target**

**→ Current camera (GC1290) not light sensitive enough**

**→ Future camera (ATV G-145B) good but we need to replace final optics before using the camera**

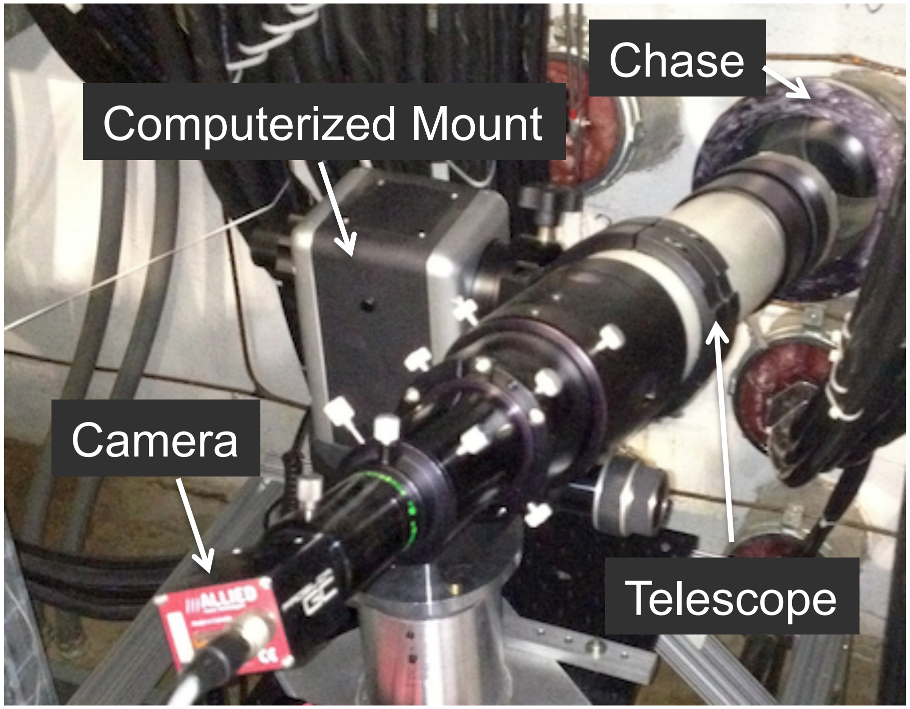
# Foil Imaging System: Analog

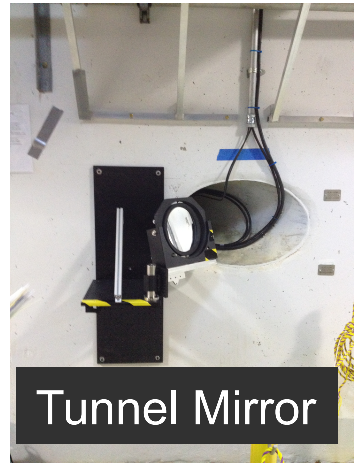



Rad-hard Analog system

- **Analog Video System is rad-hard and receives 1-20 kRad/month**
  - **Nearby to give stable image (5m)**
  - **Can not adjust exposure**
  - **Is not light sensitive enough**
  - **Needs regular replacement (2-3 years)**

# Foil Imaging System: Digital



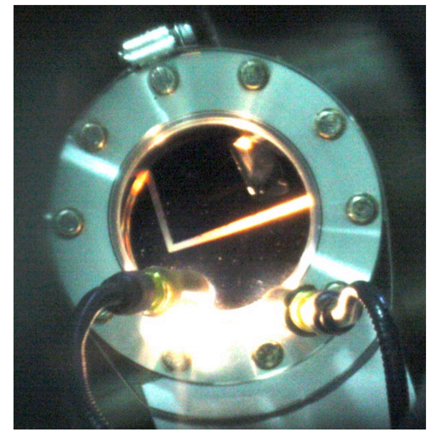



Photo through chase by R. Dickson with Canon camera

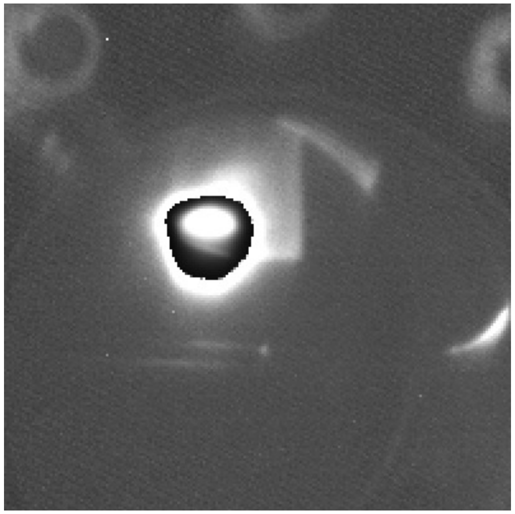
- **Setup in non-radiation area: look through cable chase (45m)**

→ **Use digital and more sensitive cameras**

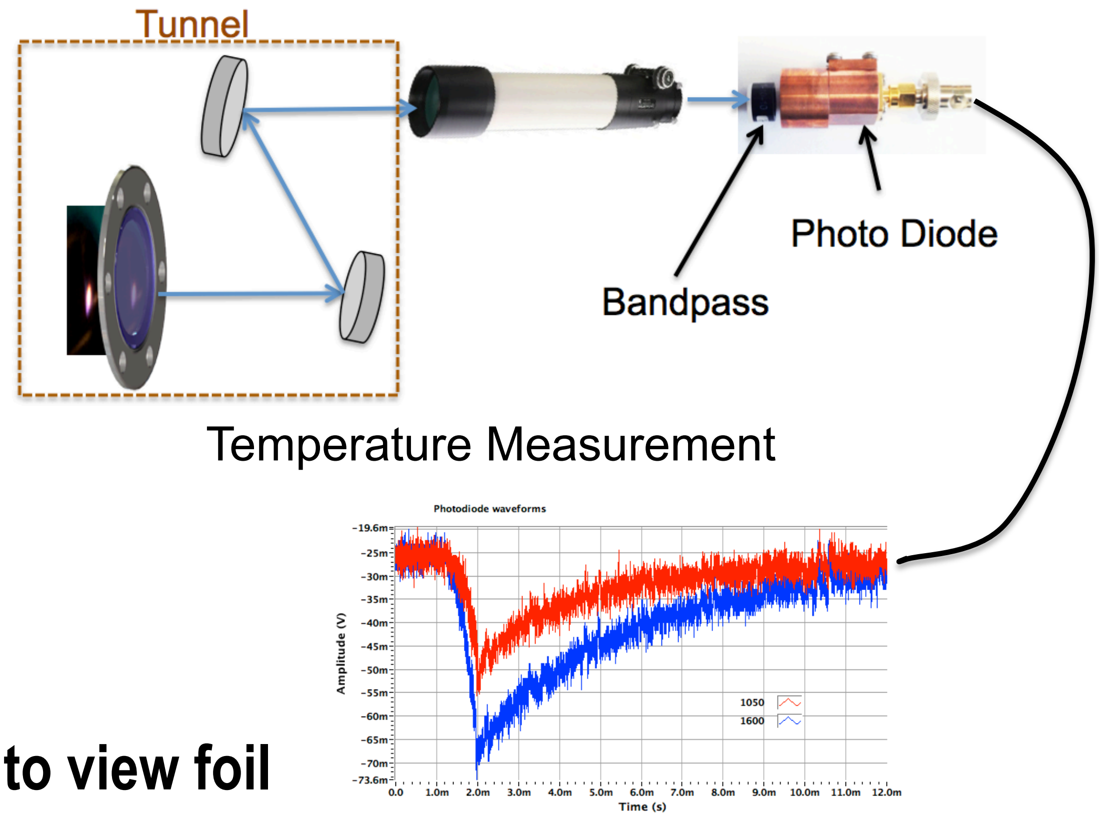
→ **Can test (and return) many cameras**

→ **Develop temperature measurement of foil**

# Foil Imaging System: Temperature



Control Room Display




- **Display in Control Room to view foil**
  - **Does have some air turbulence and vibrations**
- **Temperature measurements**
  - **Photo Diode and Bandpass Filters in shielded eye-piece**
  - **Program created to input optical path characteristics to calculate temperature**
  - **Must limit light to spot on foil and scan foil area and counter turbulence**

# Summary

- Electron Scanner progress:
  - Method for short bunches
  - Improved scan range and cathode current
  - Future aperture restriction to remove unwanted illumination
- Target Imaging System to be calibrated without requiring beam time
- We now have a development platform for stripper foil measurements

# ACKNOWLEDGEMENTS

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