# T2K OTR Beam Profile Monitor

Status Report

David Morris - TRIUMF

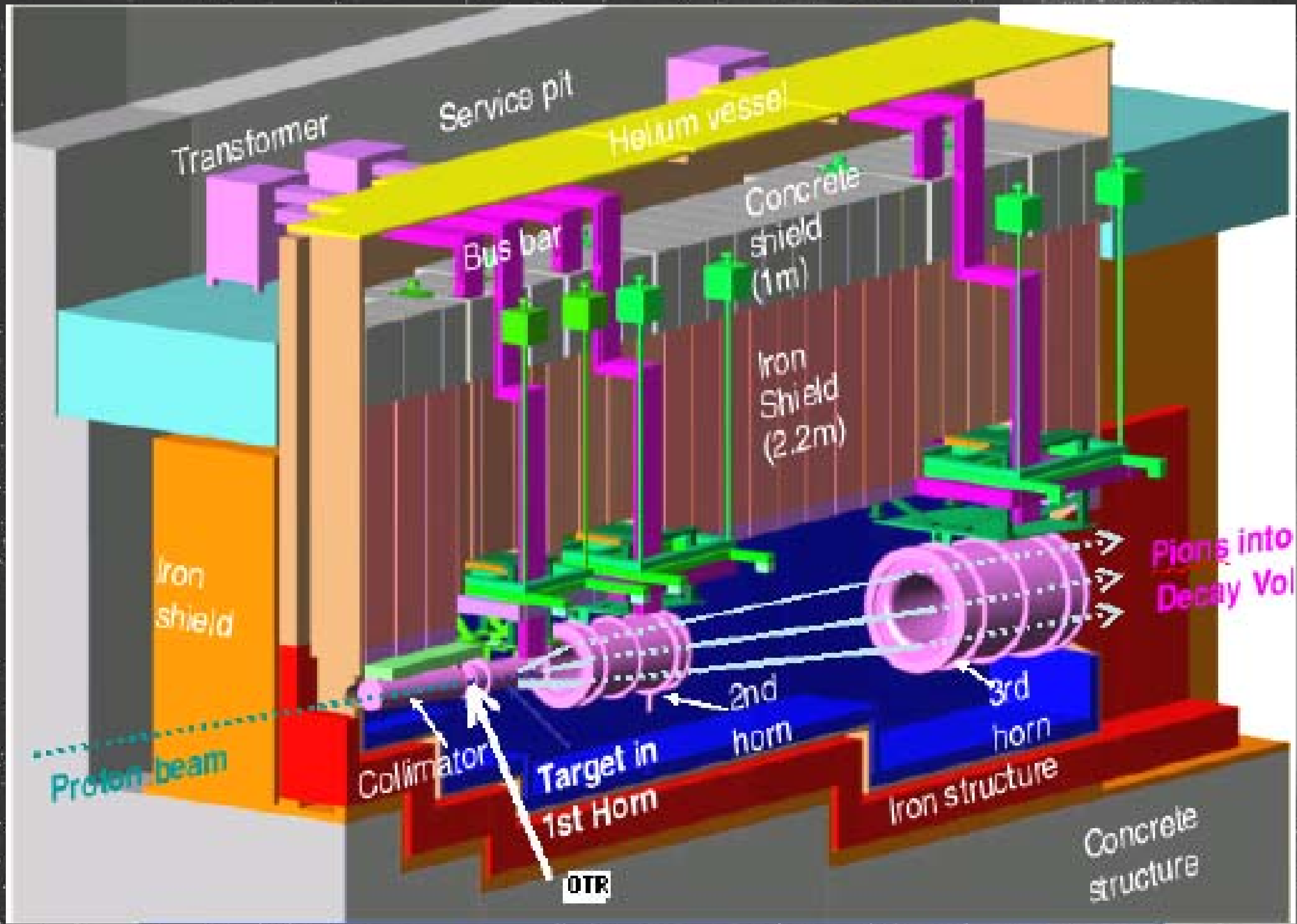
# Agenda

- OTR System Design
- Prototype Tests
- Materials Studies

# OTR Beam Profile Monitor Members

- York University - Sampa Bhadra, Brian Kirby, Slavic Galymov
- University of Toronto - John Martin, Mircea Cadabeschi, Alysia Marino
- TRIUMF – Akira Konaka, David Morris, Victor Verzilov, Clive Mark, Mike Gallop

# Target Box

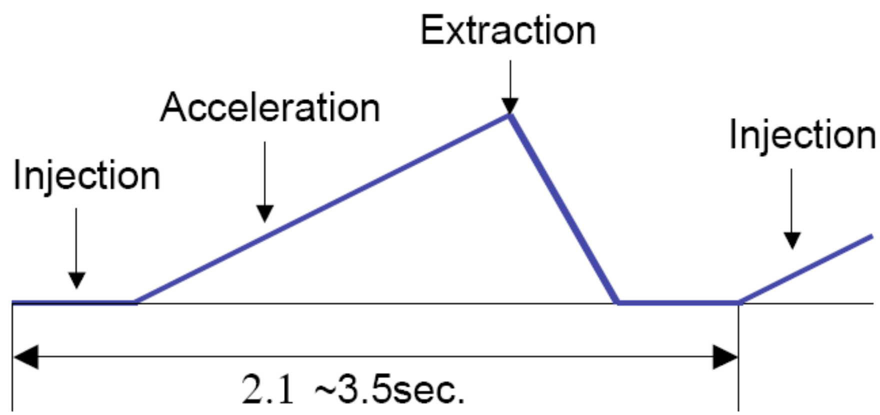

Transformer
Service pit
Helium vessel
Concrete shield (1m)
Bus bar
Iron Shield (2.2m)
Iron shield
Pions into Decay Vol
2nd horn
3rd horn
Proton beam
Collimator
Target in 1st Horn
OTR
Iron structure
Concrete structure

# Specifications

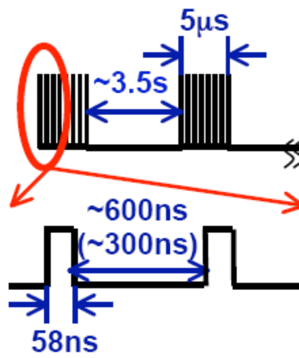
- Position of proton beam to 1mm
- Profile to ~ 10%
- Ladder with multiple OTR foils ~20 cm upstream of target face
- Helium environment ~9 m light path
- Four mirrors with dog-leg for radiation block
- 100 nsec camera shutter for micro-bunch imaging
- Radiation hard camera with remote readout electronics

# Beam Characteristics

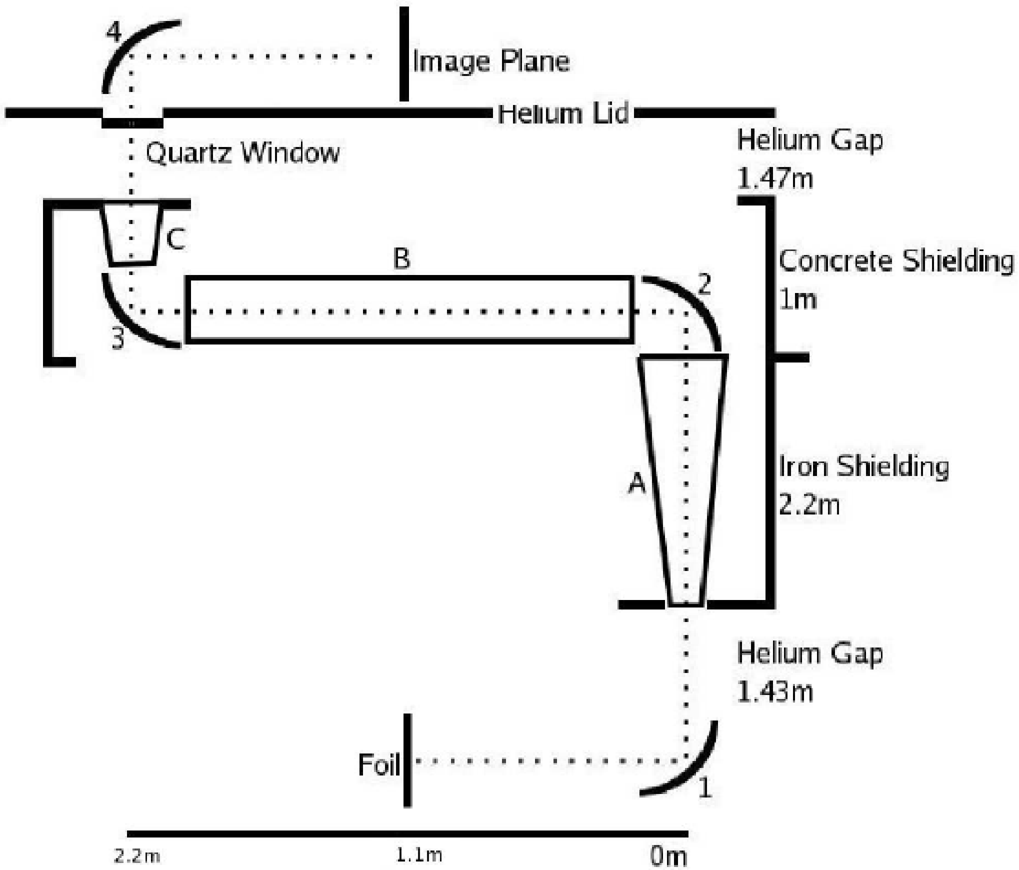
- T=0
  - # of bunches/ spill will be 8
  - 30GeV w/ 2.1 sec spill




| | |
|---|---|
| Repetition rate | ~0.3Hz |
| Spill width | ~5us |
| # of bunches/spill | 8 or 15 |
| width of bunch | ~60ns |
| gap between bunches | ~600ns (8-bunch case)<br>~300ns (15-bunch case) |



# Optical Path




Mirror 1 - Parabolic, 50cm focal length,
10cm diameter,
1.1m away from foil

Mirror 2 - Parabolic, 50cm focal length,
12cm diameter,
3.73m above Mirror 1

Mirror 3 - Parabolic, 50cm focal length,
8cm diameter,
2.2m away from Mirror 2

Mirror 4 - Parabolic, 25cm focal length,
20cm diameter,
2.48m above Mirror 3

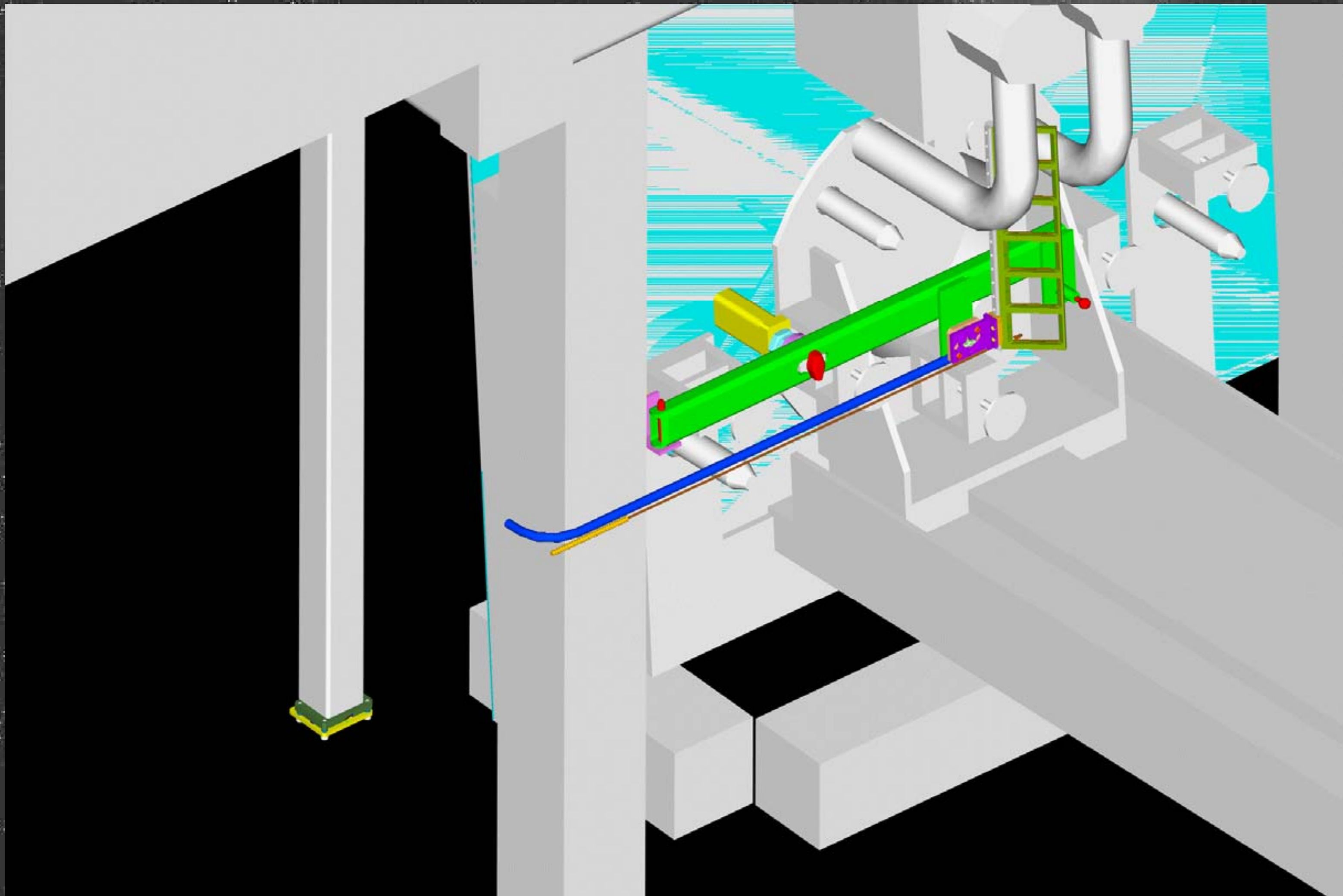
Light Pipe A - Conic, 2.2m high,
4cm wide at the bottom,
13.6cm wide at the top

Light Pipe B - Cylindrical, 1.8m long,
13.6 cm diameter,
axis is 4.63m above foil

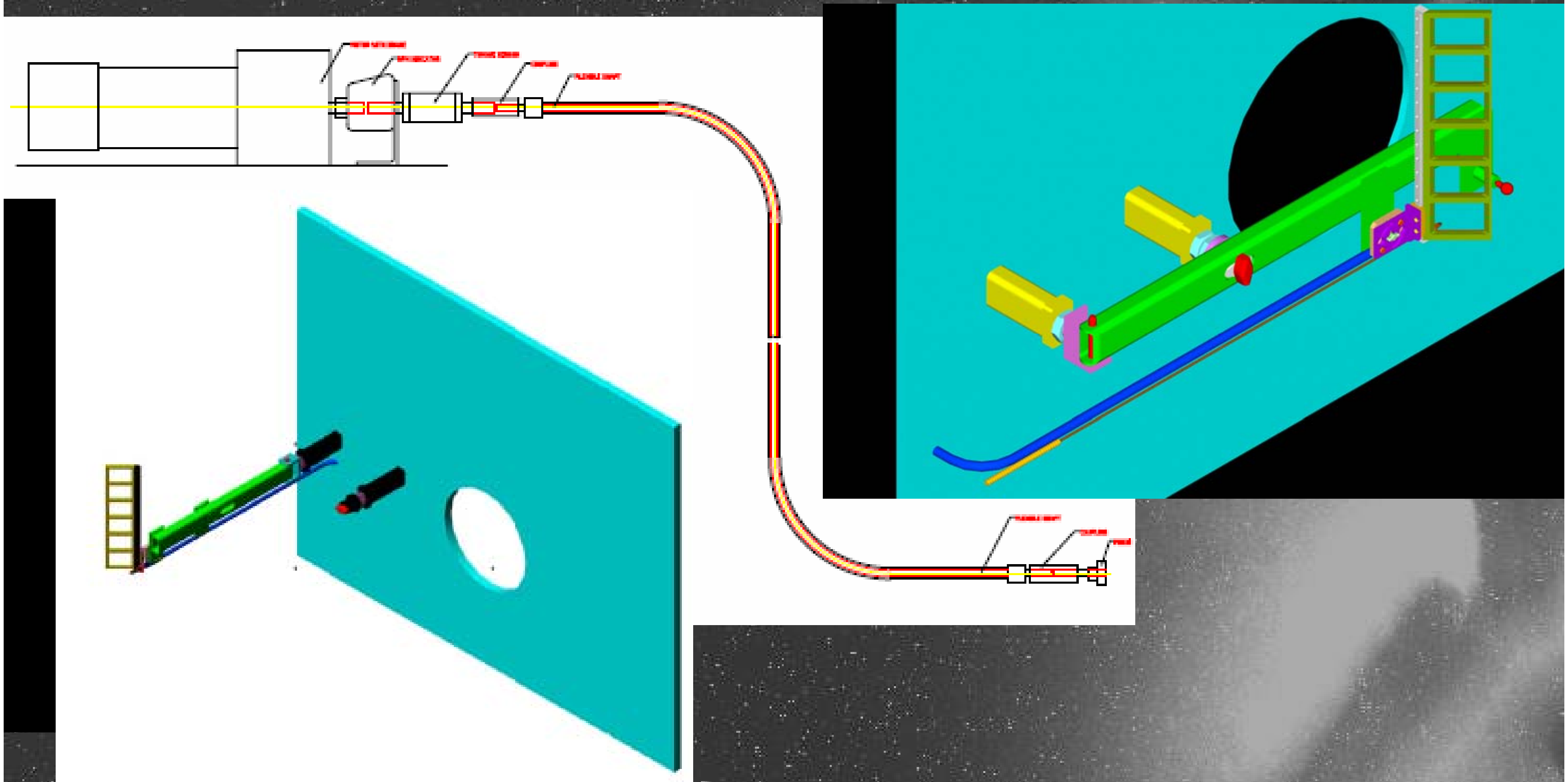
Light Pipe C - Conic, 0.9m high,
8.4cm wide at the bottom,
16.2cm wide at the top

Quartz Window - 1cm thick

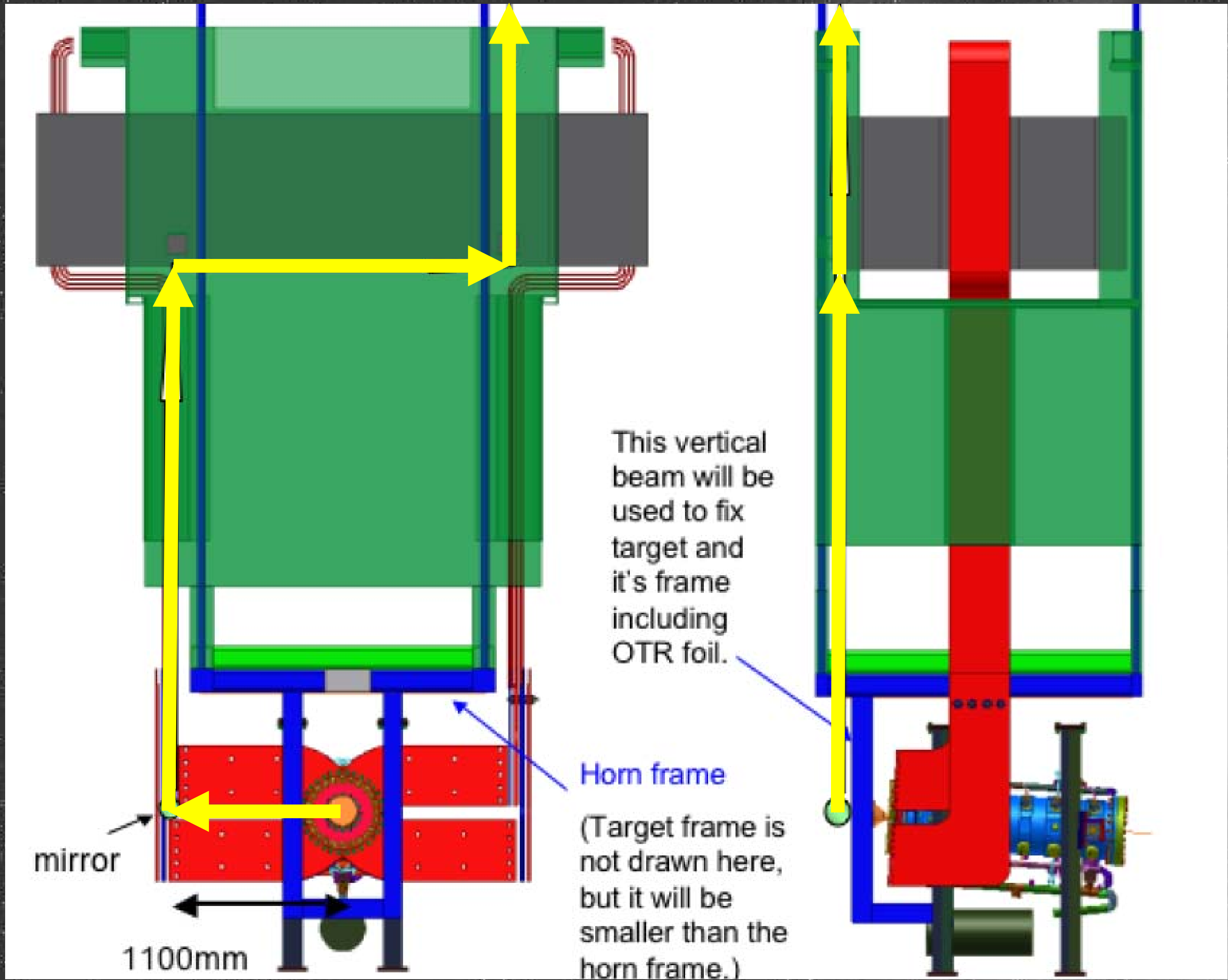
# Foil Ladder Mechanism



# Foil Ladder Mechanism

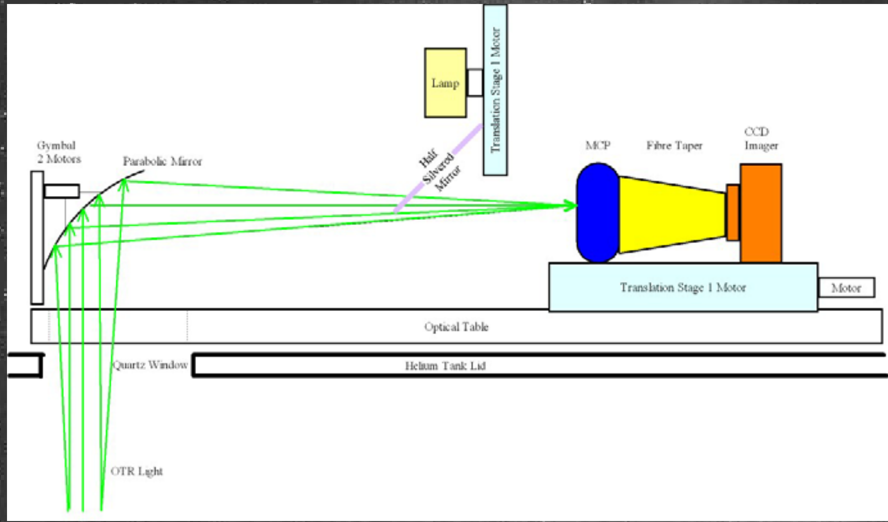


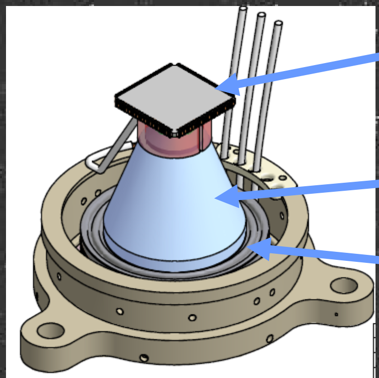
# OTR Light Path



# Camera System

Photek developed a MCP/taper/sensor package for UltraViolet Imaging Telescope on the ASTROSAT satellite which is identical to OTR requirements.



CMOS image sensor

Fibre Taper

Micro Channel Plate

Sira (now EWT Cameras Ltd) developed remote radiation hard camera using FillFactory Star250 CMOS sensor.
5 MRad tolerance.

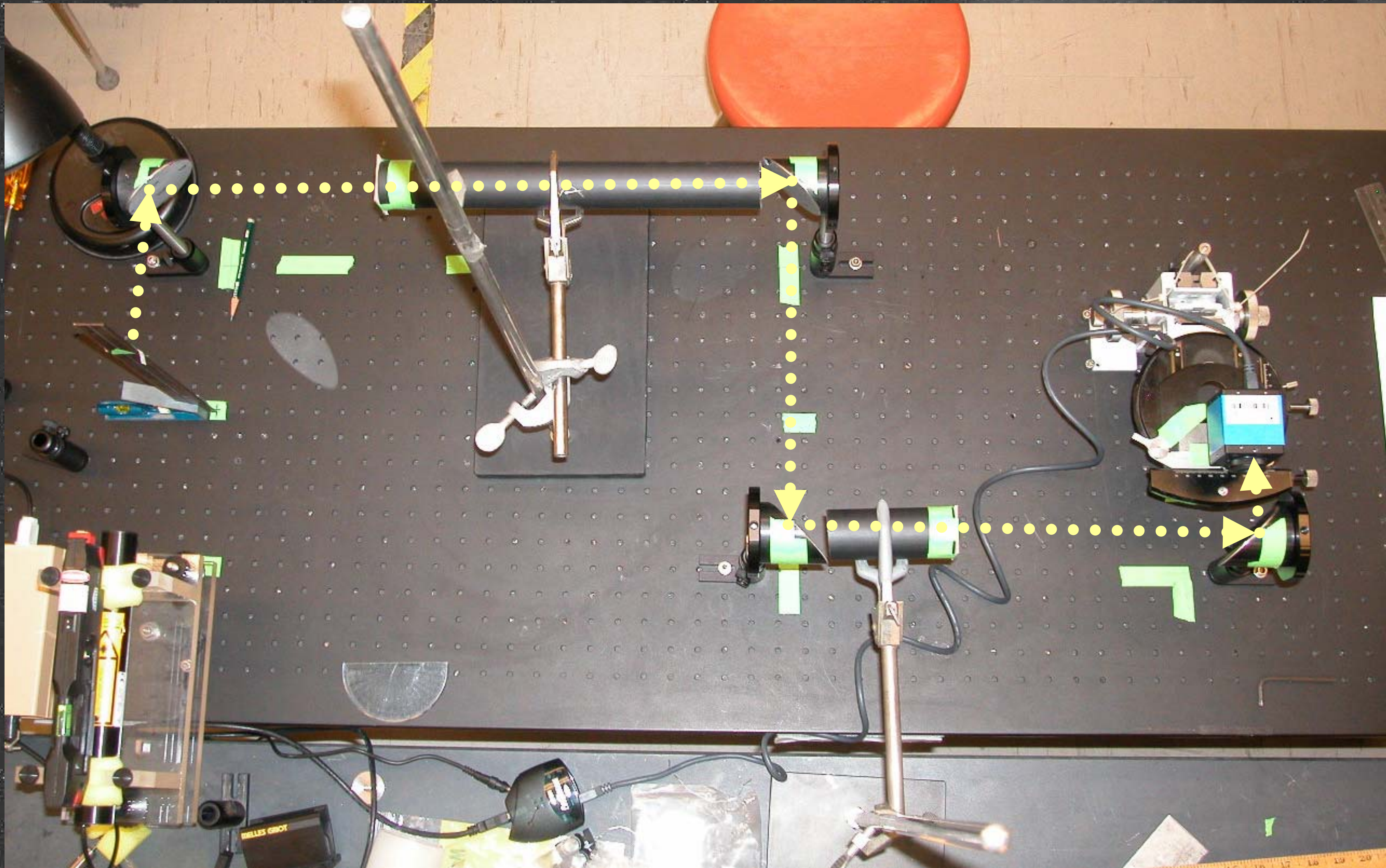
Camera Controller

Remote Sensor

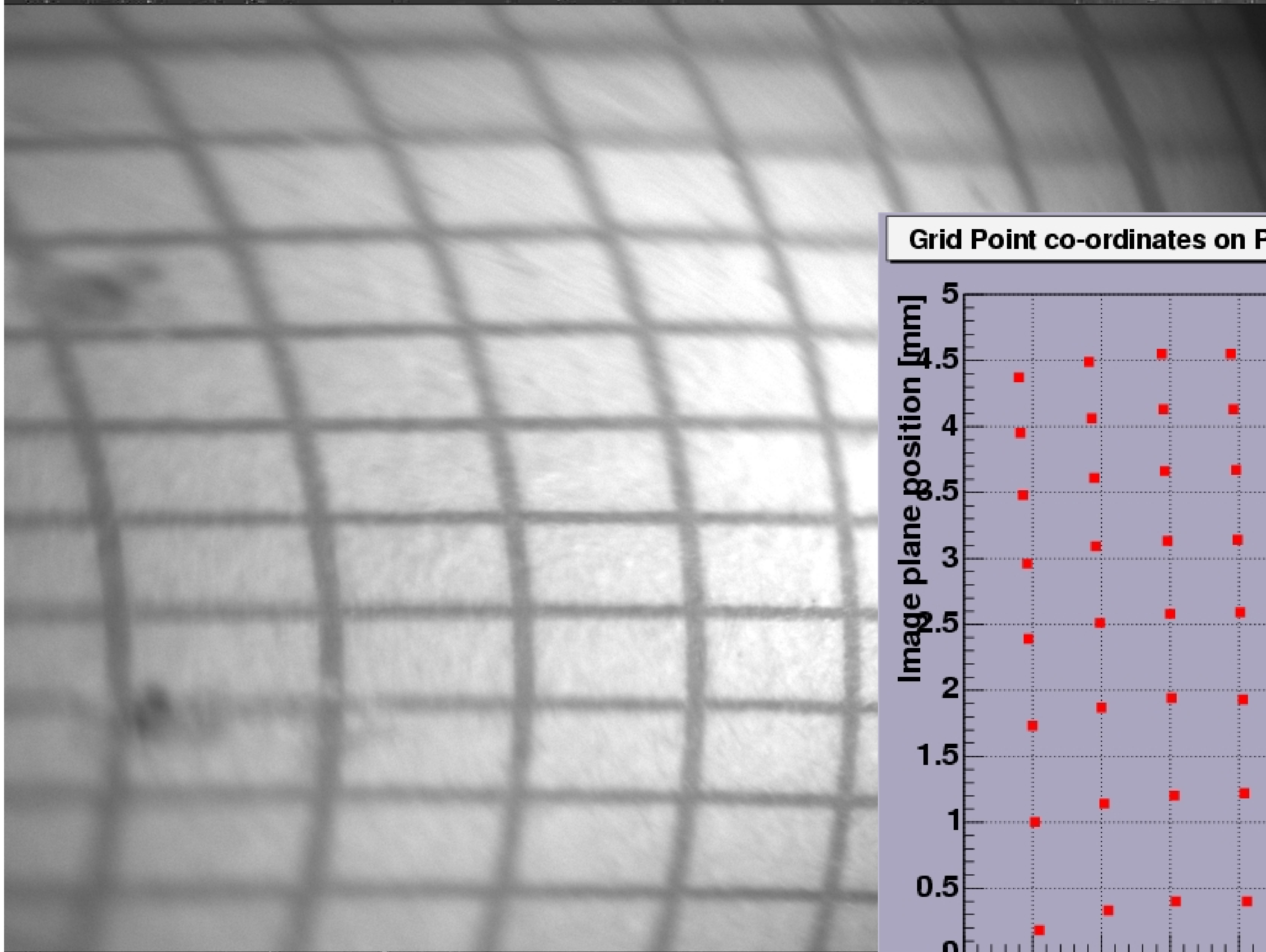
# Components for Study

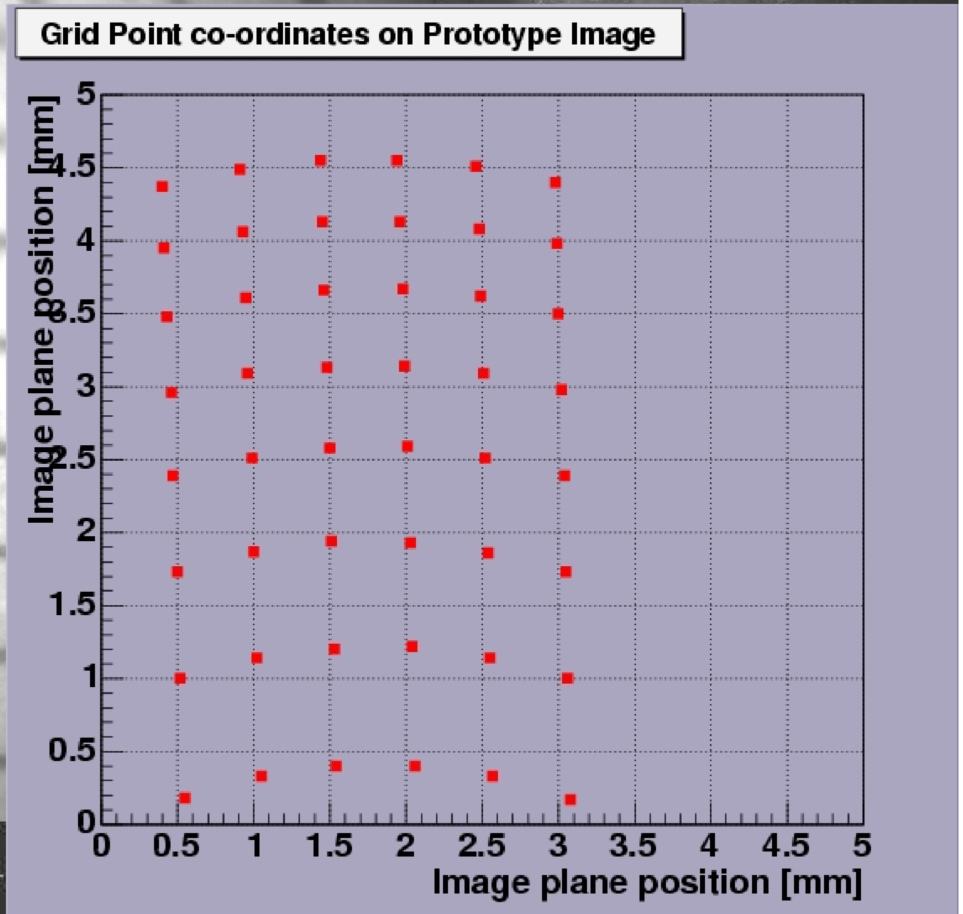
- OTR operation as beam profile monitor
- Front/Back lighting system
- OTR Foil Materials – light yield
- Foil and mirror materials – radiation effects

# Prototype Optics

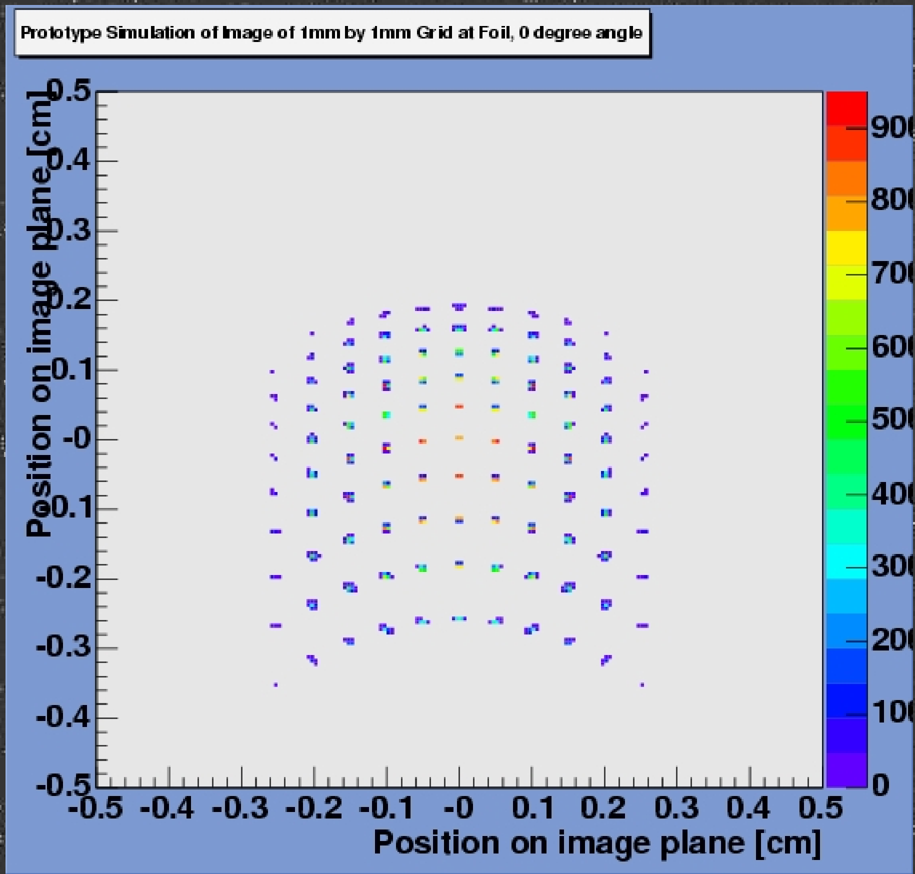


# Image Analysis

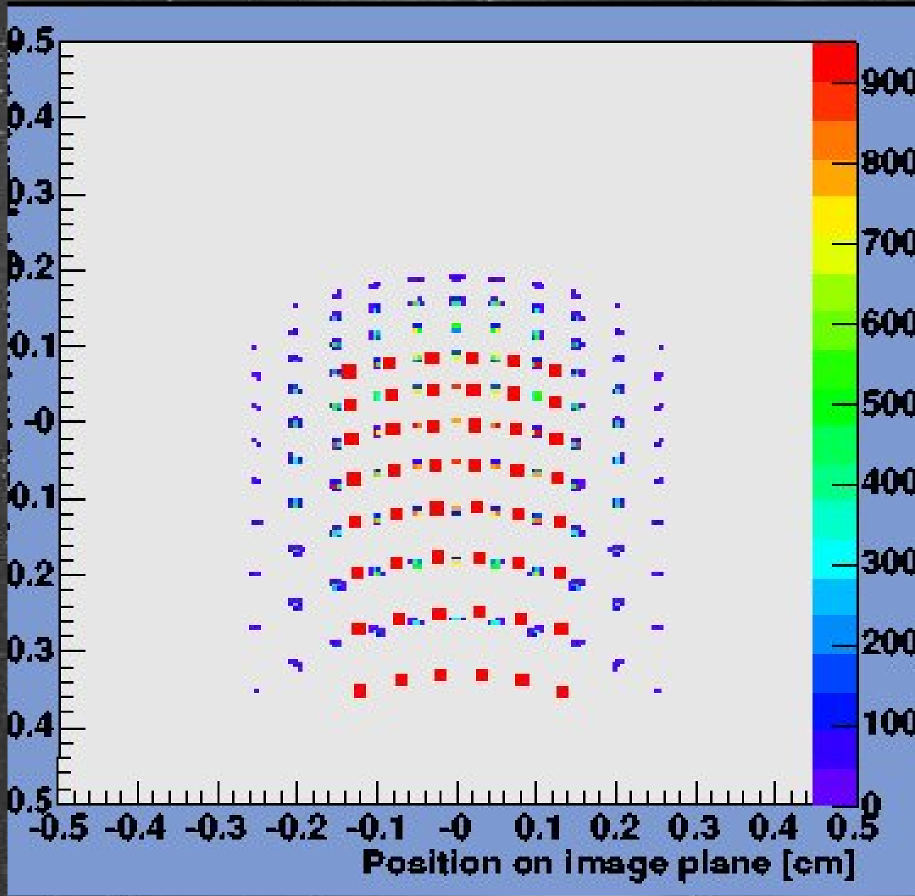




# Distortion Analysis




Simulation Grid Points



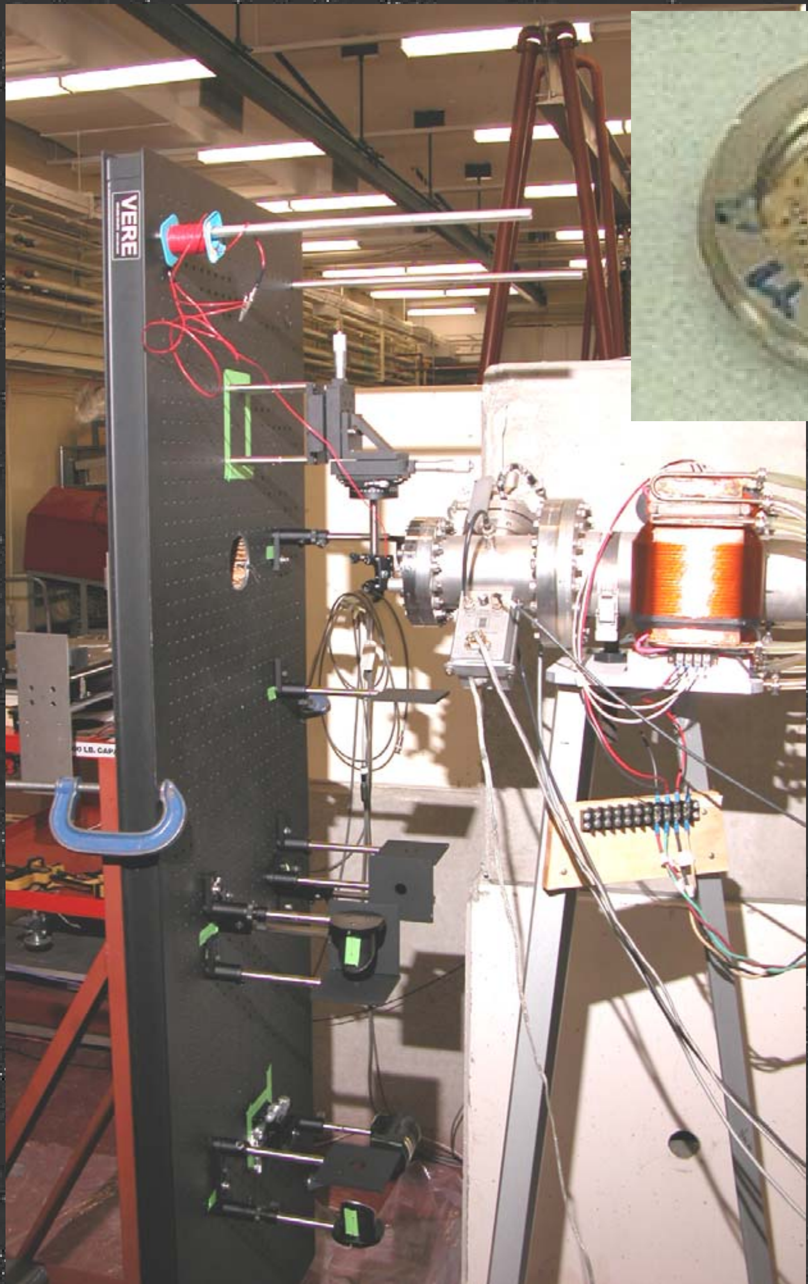

Superimposed Measured Positions

# Prototype tests at NRC

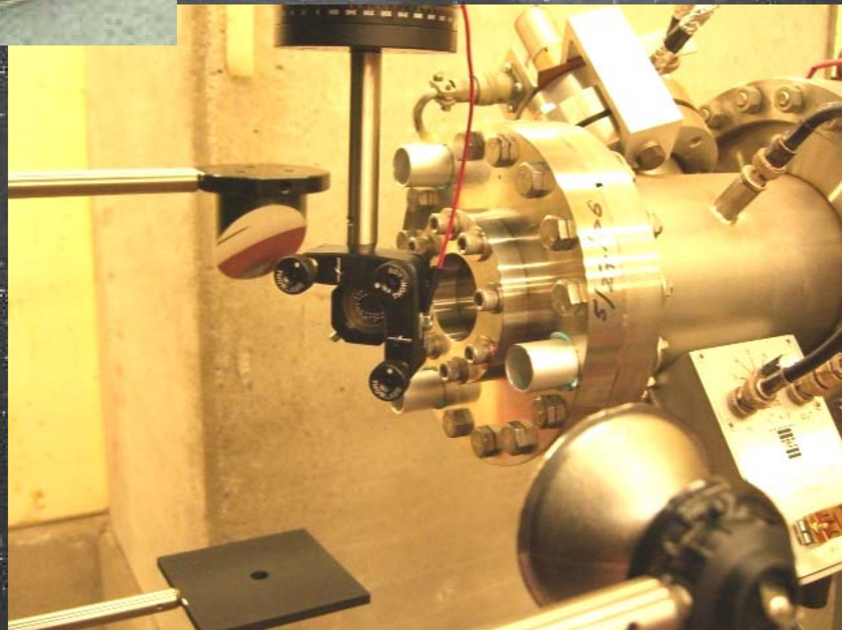
- Elekta Linear Accelerator
- 20 MeV Electron beam at 400 nA DC
- Ti90/Al6/V4 exit window 43µm thick
- Distance to foil 25mm
- 15% scale model of optics
- Peltier cooled CCD camera

# 20Mev $e^-$ versus 30 Gev p

- J-PARC beam is $3x10^{14}$ protons per spill (8 micro- bunches)
- 200nA beam at NRC corresponds to $1.25x10^{12}$/sec
- OTR light yield goes with the velocity ($gamma^2$) of the particles. Velocity of 20MeV electron is the same as 40GeV proton beam
- 1sec exposure at NRC corresponds to 0.4% of the full intensity (750MW) J-PARC spill or 3% of full J-PARC micro-bunch.

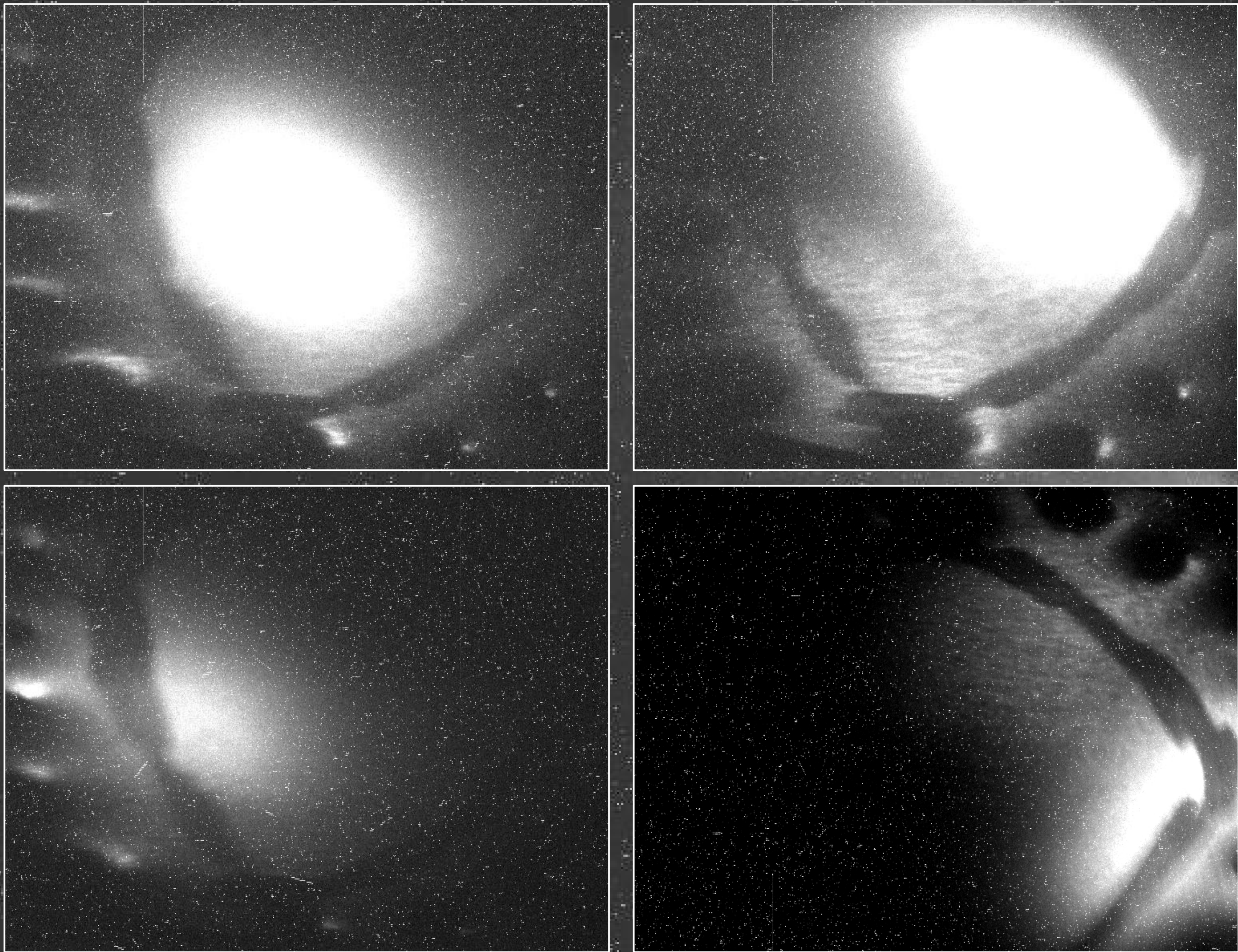



Titanium alloy foil with backlight holes and front markings

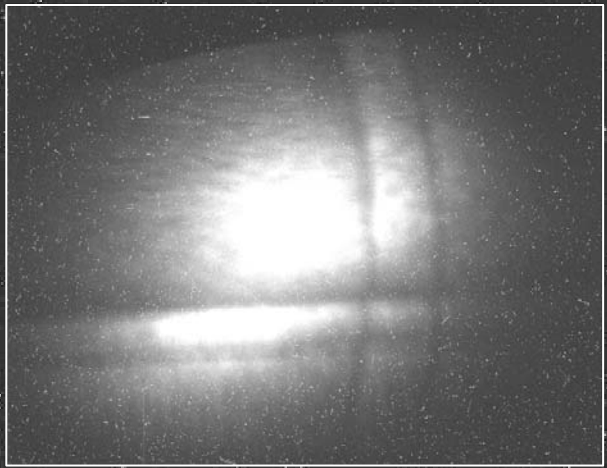


Foil mounted close to exit window to reduce multiple scattering

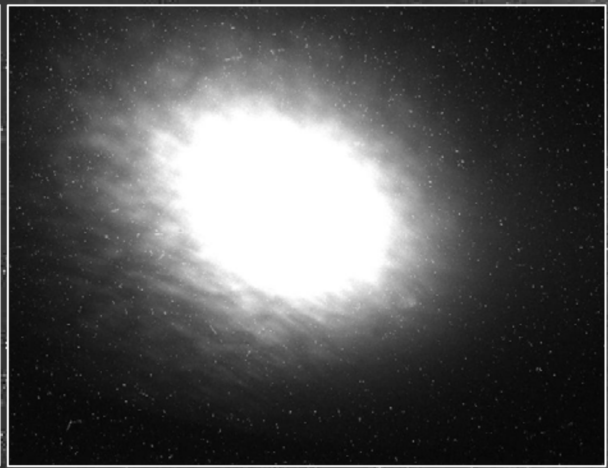
# OTR Images - Steering



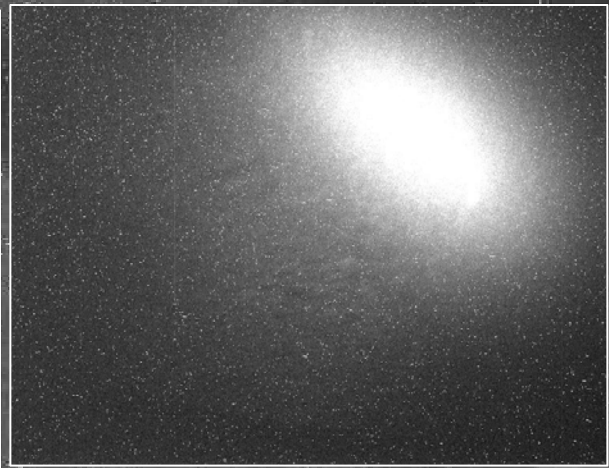
# OTR Images – Foil Reflectivity



Titanium foil



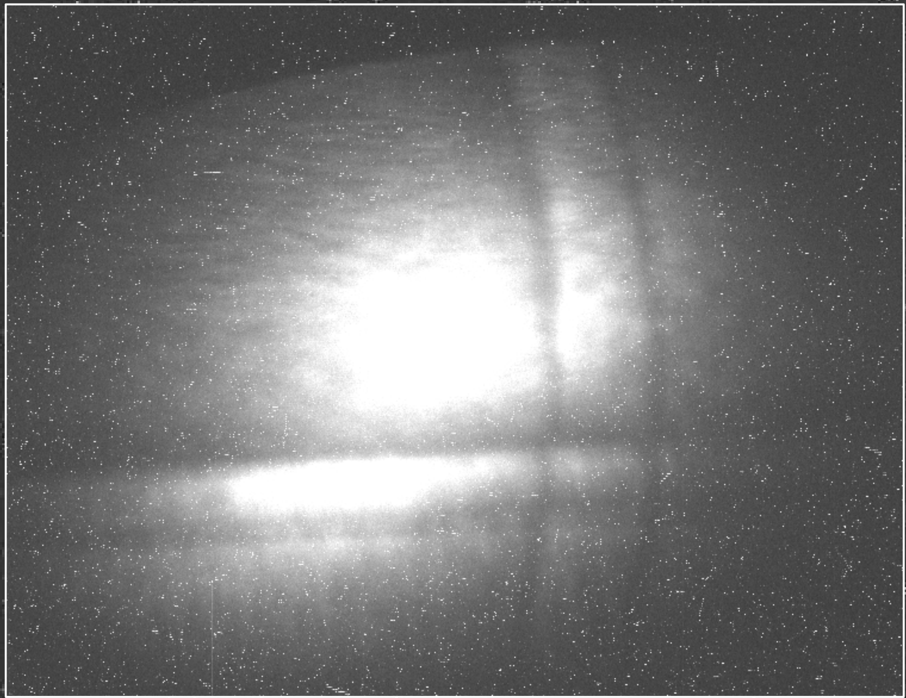
Aluminum foil

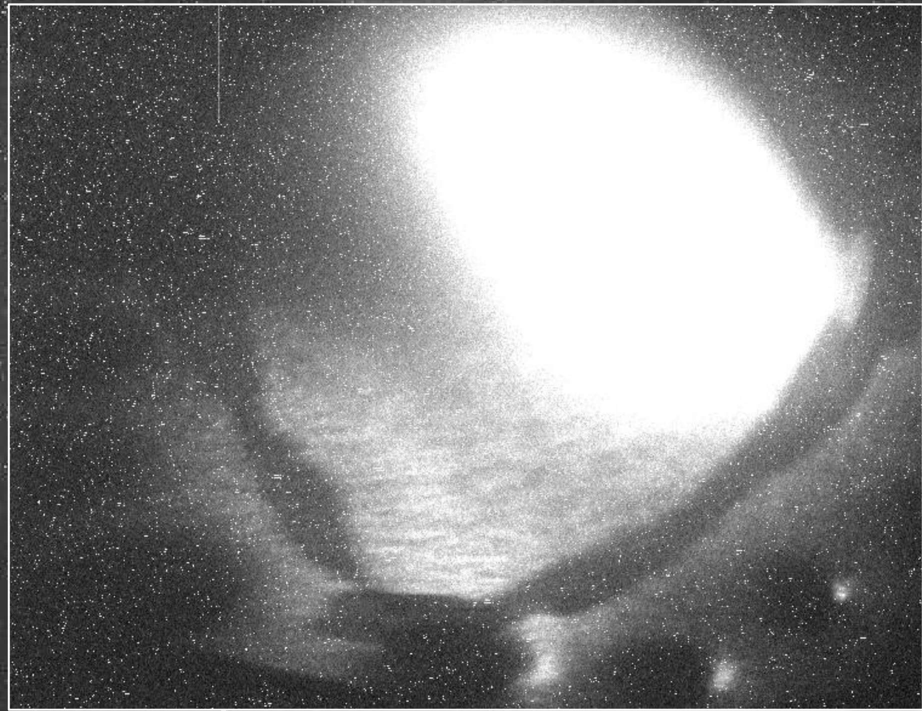


Polycrystalline graphite foil

| Foil Material | Amplitude | Reflectivity |
|---|---|---|
| Ti-alloy | 300 | 0.4-0.5 |
| Aluminum | 1422 | 0.9 |
| Graphite | 37.9 | 0.1-0.2 |

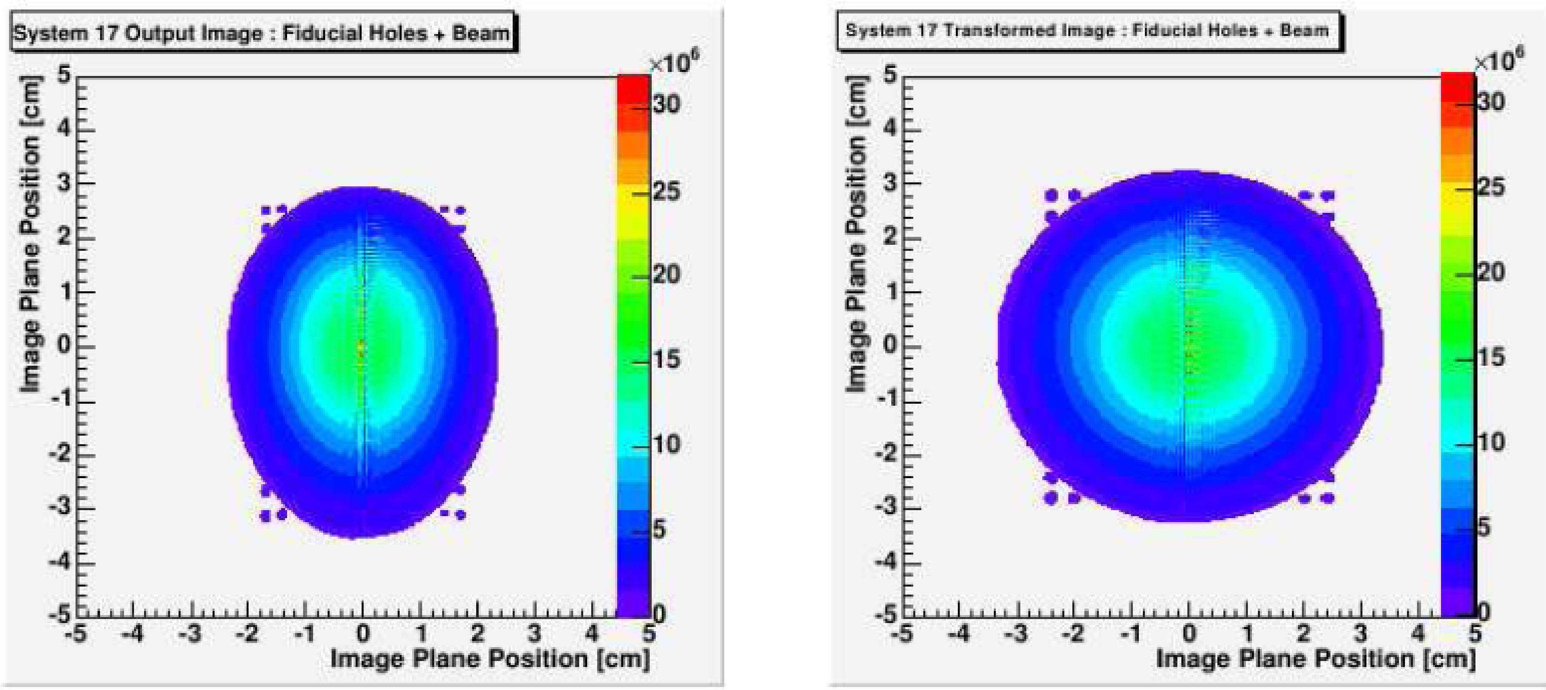
# Foil Surface Effects





- Ink marks and scratches on the foil are observable.
- Perimeter holes on foil for backlight and registration.

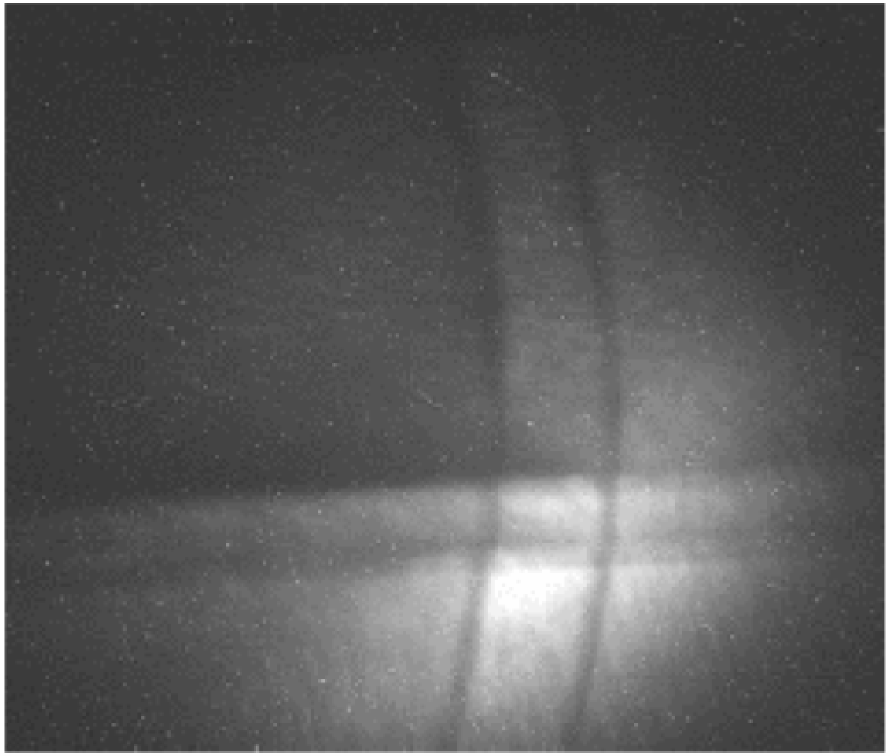
# Image Processing



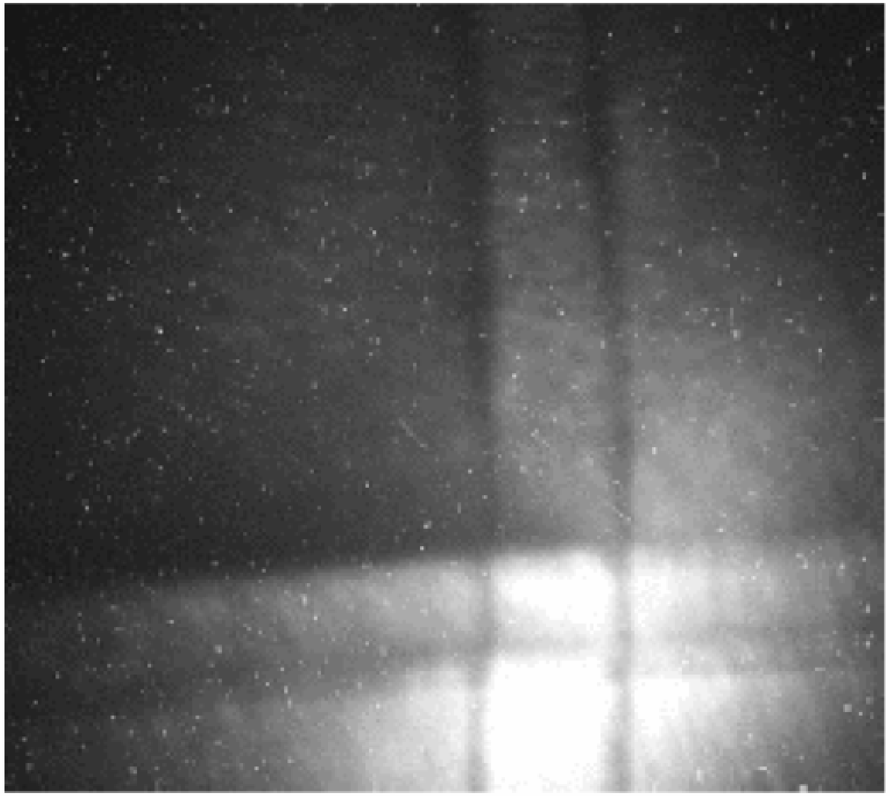

(a) Distorted Image.

(b) Transformed image.

# Image Processing



Original Image



Corrected Image

# Current Work

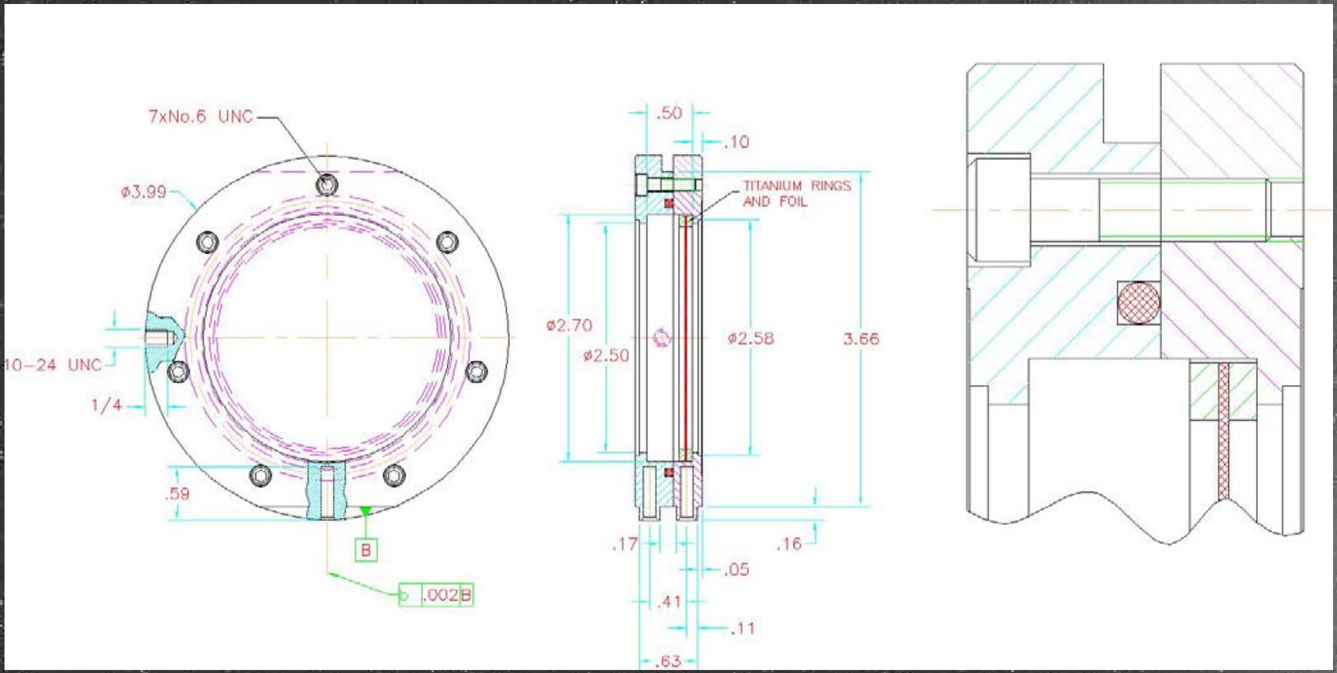
- Front/Back lighting components
- Radiation damage studies in proton beam
- Mechanical design of target ladder

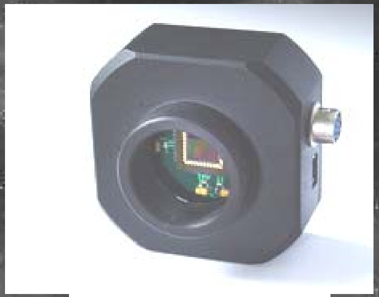
# Front/Back Lighting

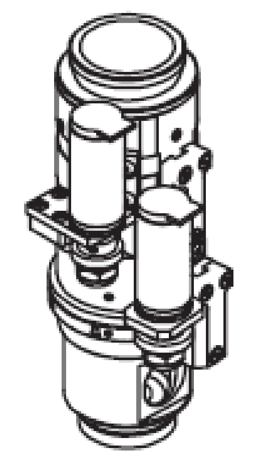
- Front and back lighting of the foil for alignment and focusing of image
- Nichrome wire filament to survive operation in air or helium
- Multiple filaments for redundancy

# Radiation Damage Studies

- TRIUMF 500 MeV Proton Beam at 50 to 100 μA
- J-PARC equivalent beam intensity is 15 uA
- Beam size similar, accelerated beam exposure
- Two part cassette, helium filled 1 atm
- Multiple samples in one cassette is possible





Motorized microscope with digital camera on X-Y table in hotcell

# Conclusions

- Optics agree with simulations using model
- OTR provides effective tool for beam profile monitoring
- Radiation damage analysis to determine beam effects.