The T2K Optical Transition Monitor

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Outline

1) Motivation and introduction

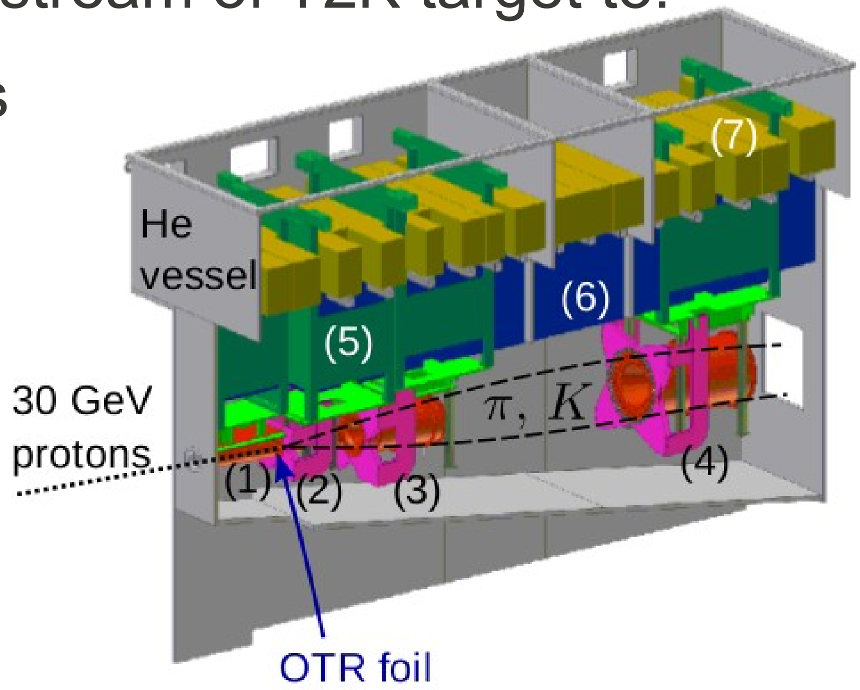
2) Monitor performance

3) Radiation effects and stability

4) Post earthquake alignment studies

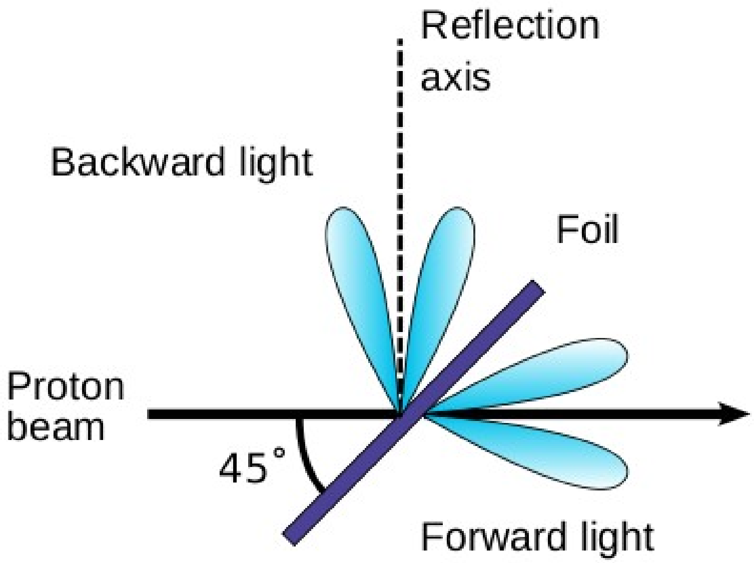
Motivation

- Install a profile monitor just 30 cm upstream of T2K target to:
  - Use in tuning beam orbit and optics
  - Measure profile for physics input
  - Monitor beam stability

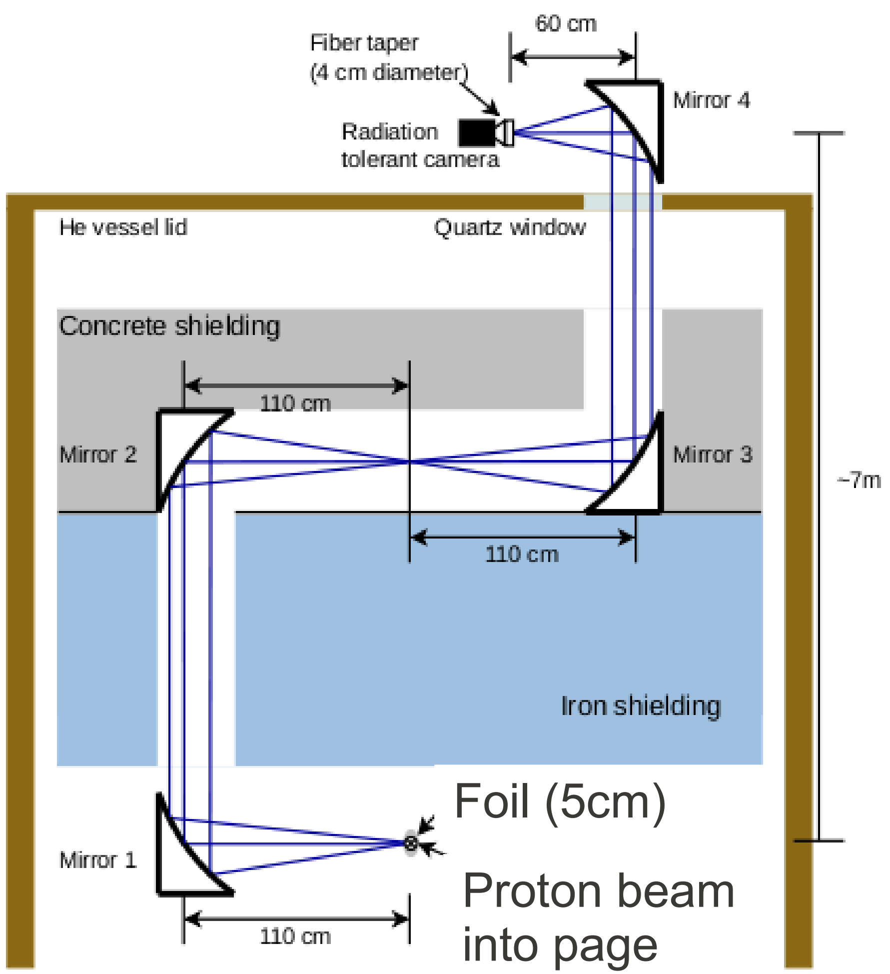


- Challenges:
  - High radiation environment: ~5 Sv/hr at design power
  - In helium target station vessel
  - Only accessible through remote manipulators if first horn is extracted
- Solution: an optical transition radiation monitor with a light path to a shielded camera and backup foil system

The OTR Monitor



- Transition radiation produced when the beam traverses a boundary with a change in dielectric constant
- Broad spectrum with light in the optical



- Transport light through shielding in the helium vessel with four parabolic mirrors
  - Minimize the radiation dose at the camera
- Readout by video camera (integrates all bunches in spill)

Foil Disk

Up to 8 foils on a rotating disk can be placed in the beam path

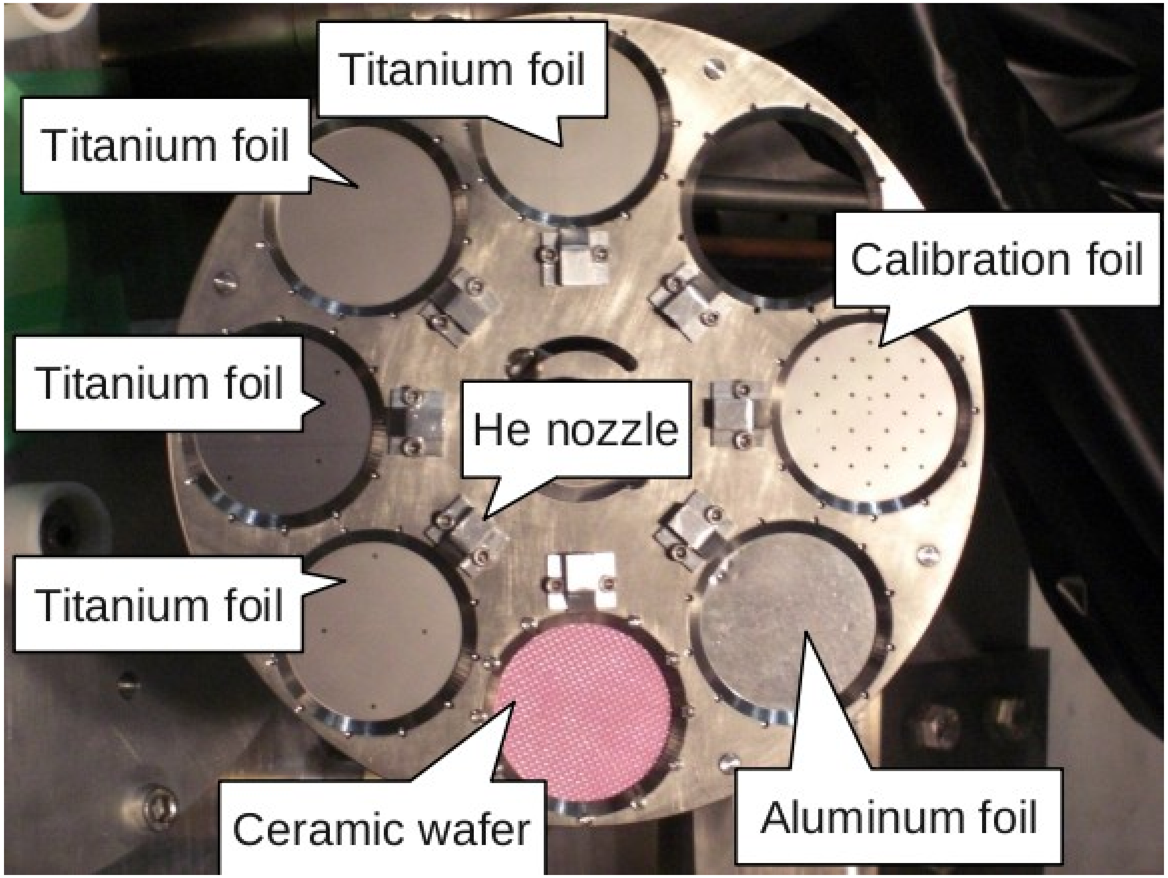
Current system has 7 foils and a blank

Ceramic – fluorescent light

4 Titanium – standard foils for OTR light

Aluminum – higher reflectivity than titanium foils

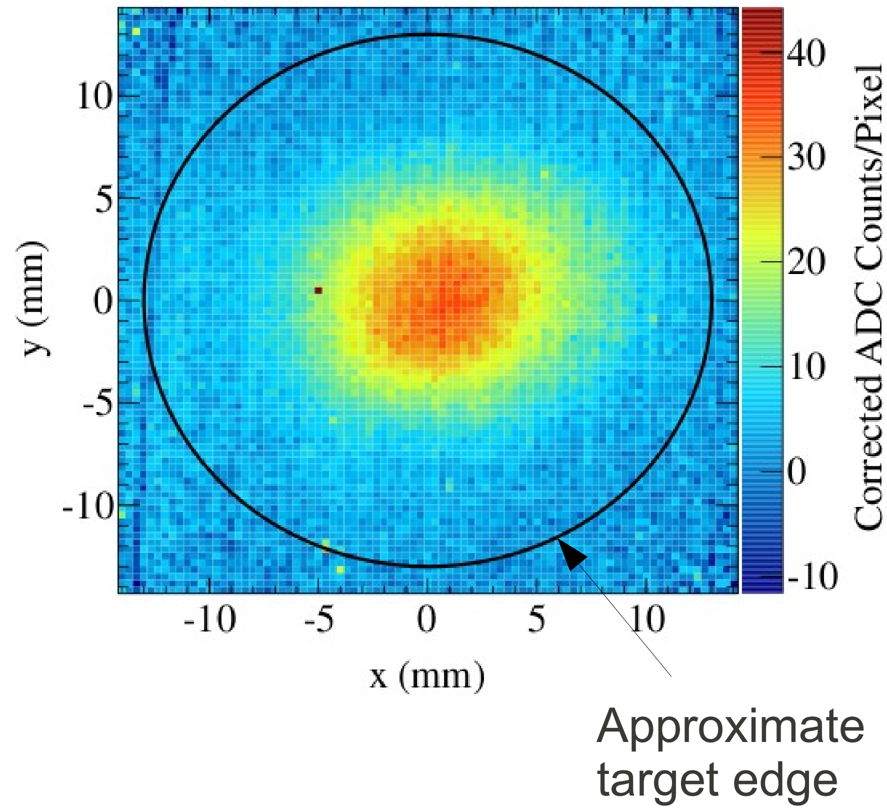
Calibration – machined hole pattern that is back-lit for calibration

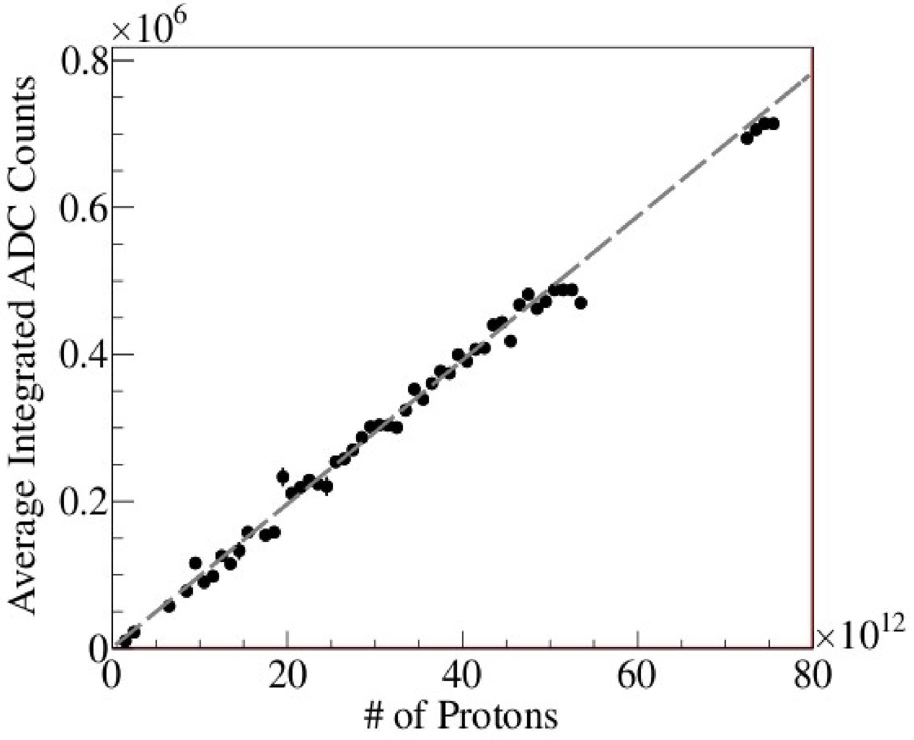


OTR Performance

- Image OTR light for >4x10^{12} protons/spill
- Fluorescent foil for low intensity studies
- Stable monitor operation during physics runs

OTR profile on Ti foil, 9x10^{13} protons



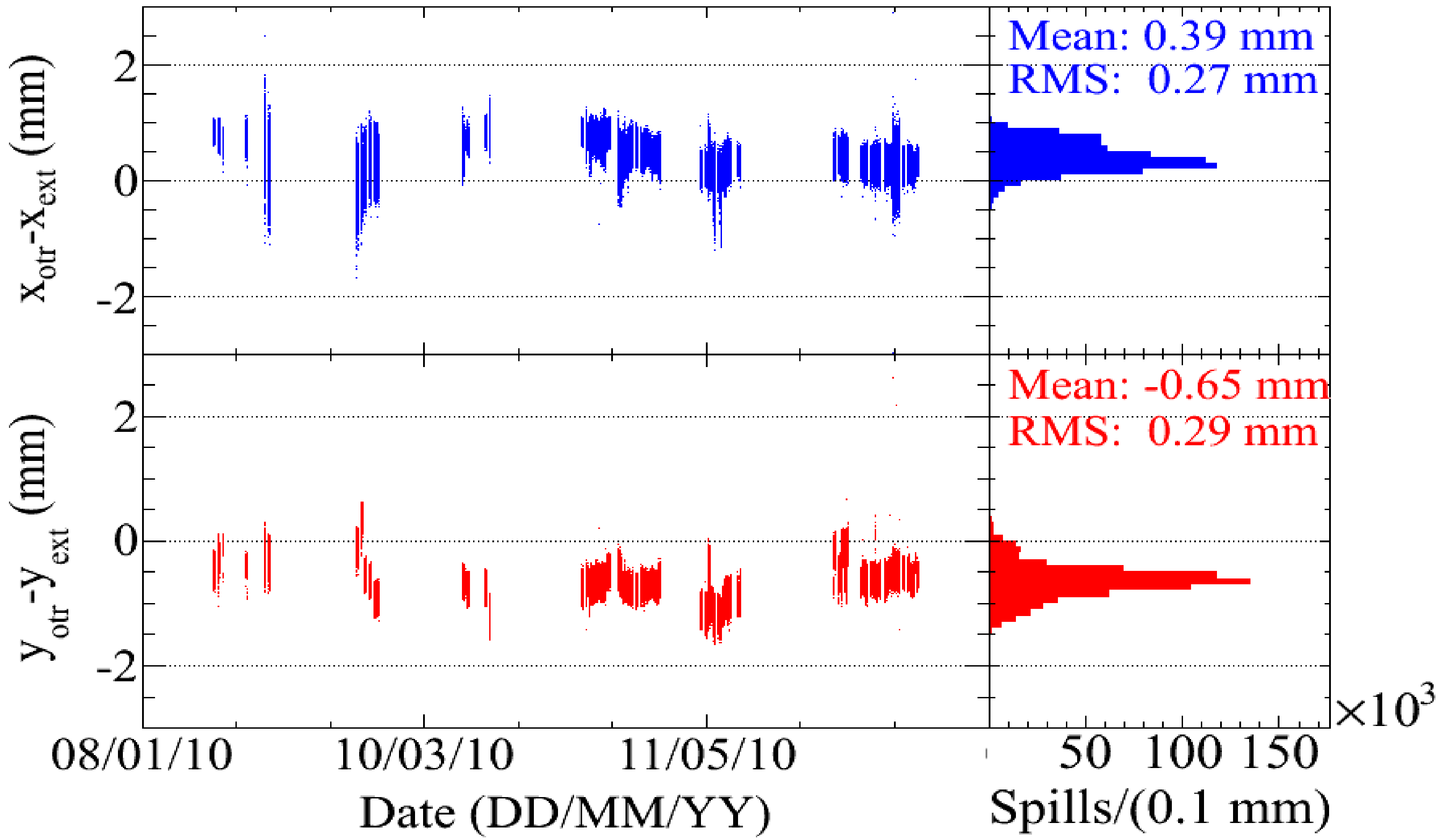


Linearity of the OTR signal is observed

Monitor Consistency

OTR measurements can be compared to extrapolations from the upstream SSEM/ESM pairs

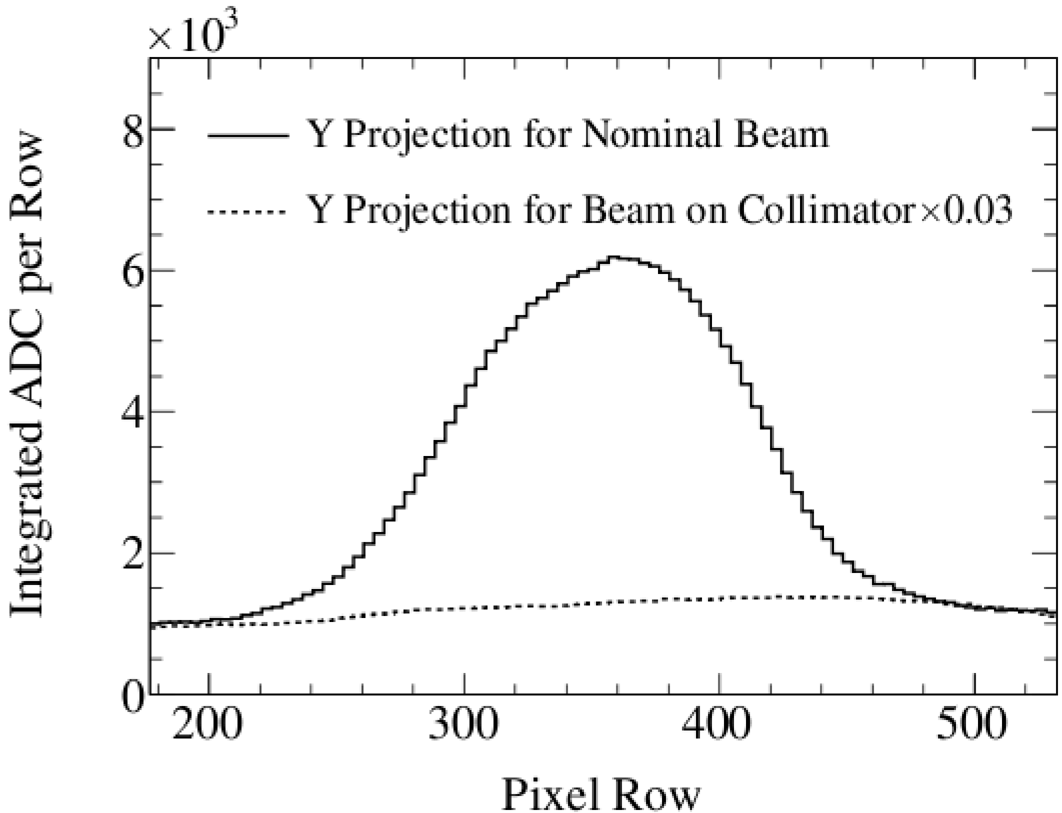
Consistency of position measurements within systematic uncertainties is observed



Background Light

- Broad (spatial) source of background light is observed
- Increases when more particles hit baffle upstream of OTR
  - Secondaries causing scintillation of helium or fluorescence of ceramics?

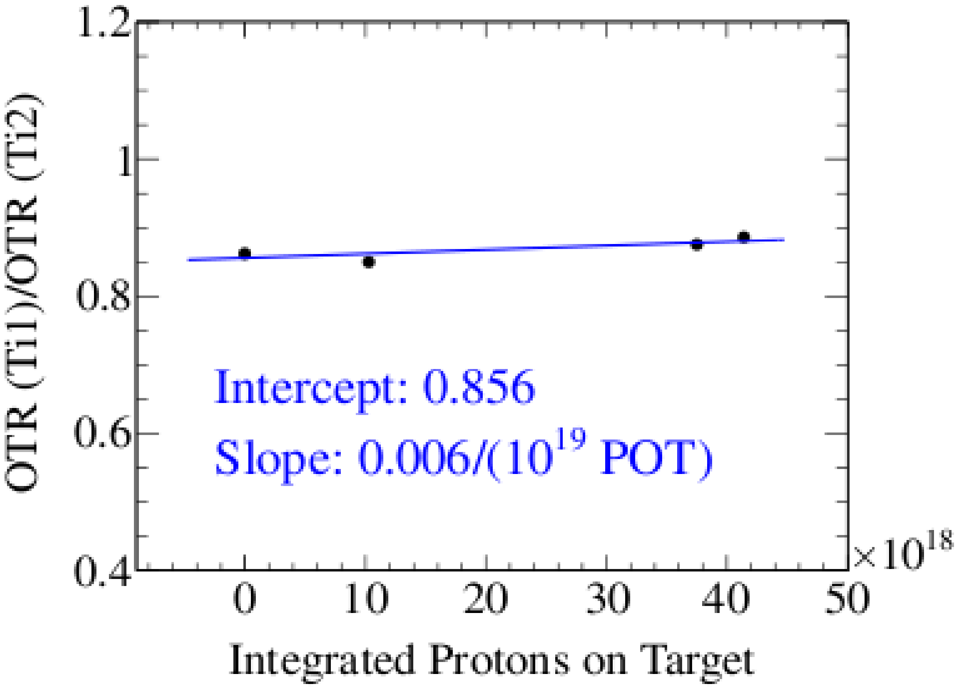
- Broad spectrum with most light in red or infrared (filter measurements)
- Measurement with liquid crystal shutter indicates lifetime <300 μs
- Significant source of uncertainty on beam width measurement



Radiation Dose and Stability

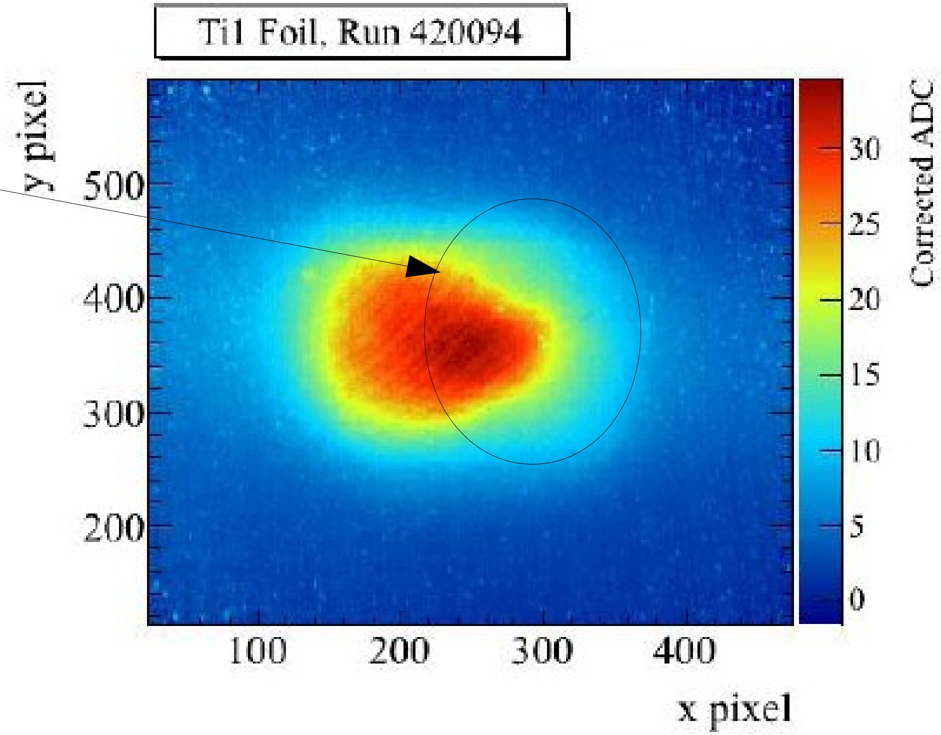
- Ionizing radiation dose at camera measured: 1.4 Sv/10^{19} protons
  - 1.09 kGy (Q=1) for full exposure – camera rated to 10 kGy
- Analysis of activation foils for neutron dose is ongoing
- Stability of foil in the beam was monitored in 2011 by regular comparisons of light yield from foil in the beam and spare:

No degradation observed over 4e19 integrated POT during the 2011 running



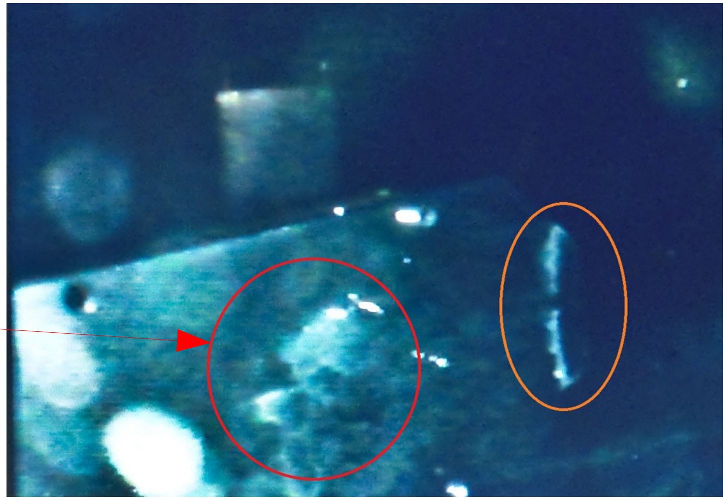
Foil Stability From March 2012

- In March/April of 2012, observed distortion of the OTR image from the Ti foil
- Not observed with the spare foils
- Amount of distortion fluctuated with time
- Have since switched to spare foil
- Cause is unknown



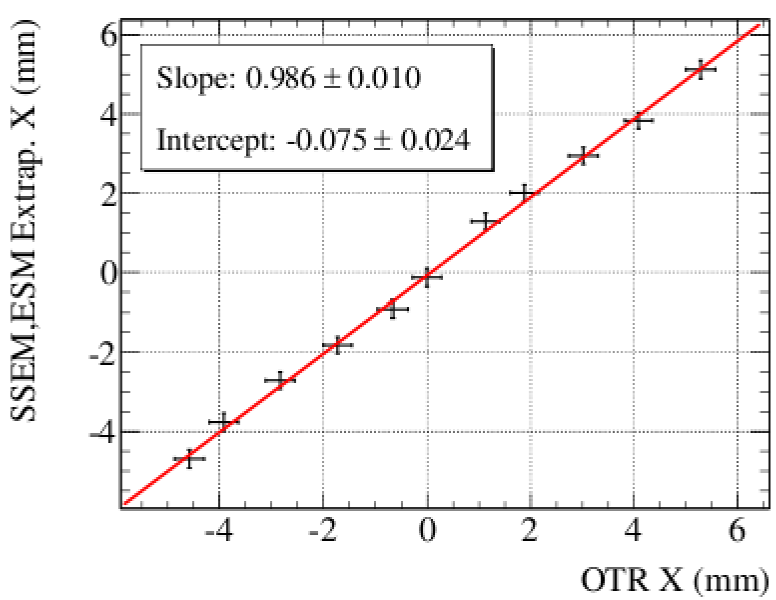
Images of back-lighting reflector using fiber-scope showed some type of deposit or corrosion.

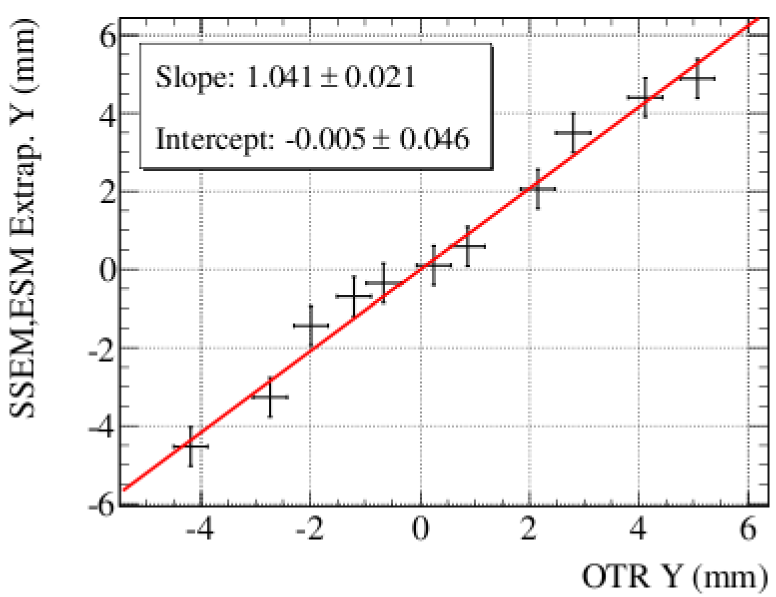
Could be related?



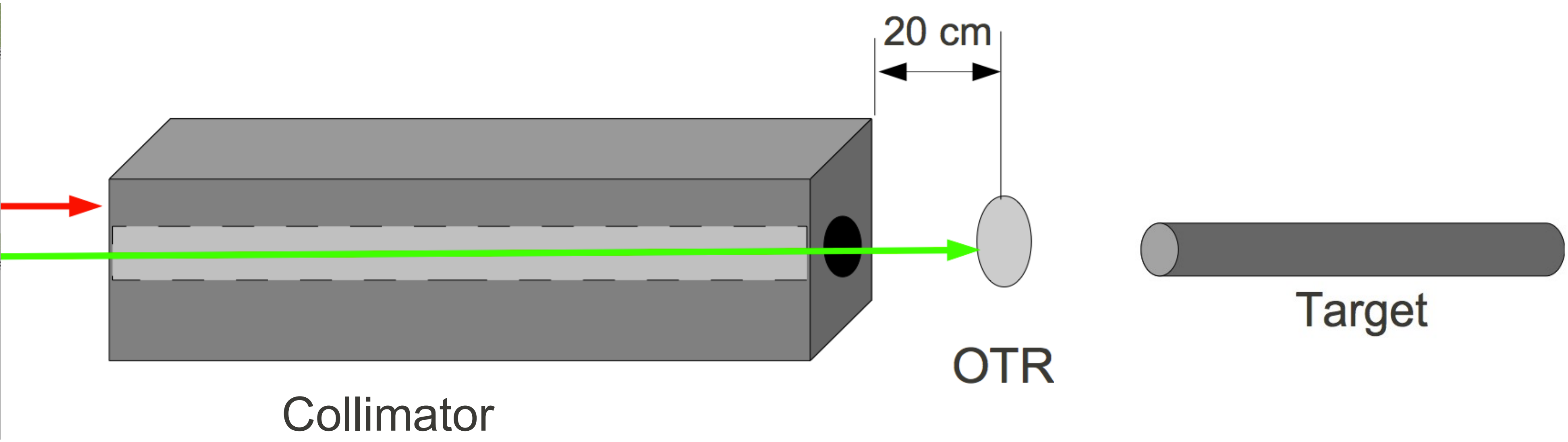
Post Earthquake Alignment Studies

- OTR foil disk (including calibration foil) is rigidly attached to front plate of first horn
- Ideal for beam based check of relative alignment between secondary and primary beamline after earthquake
- Scan beam and compare OTR measurement with extrapolation from primary beamline SSEM/ESM pairs
- Measurements are consistent within alignment uncertainties





Collimator Alignment



OTR foils are downstream of the collimator

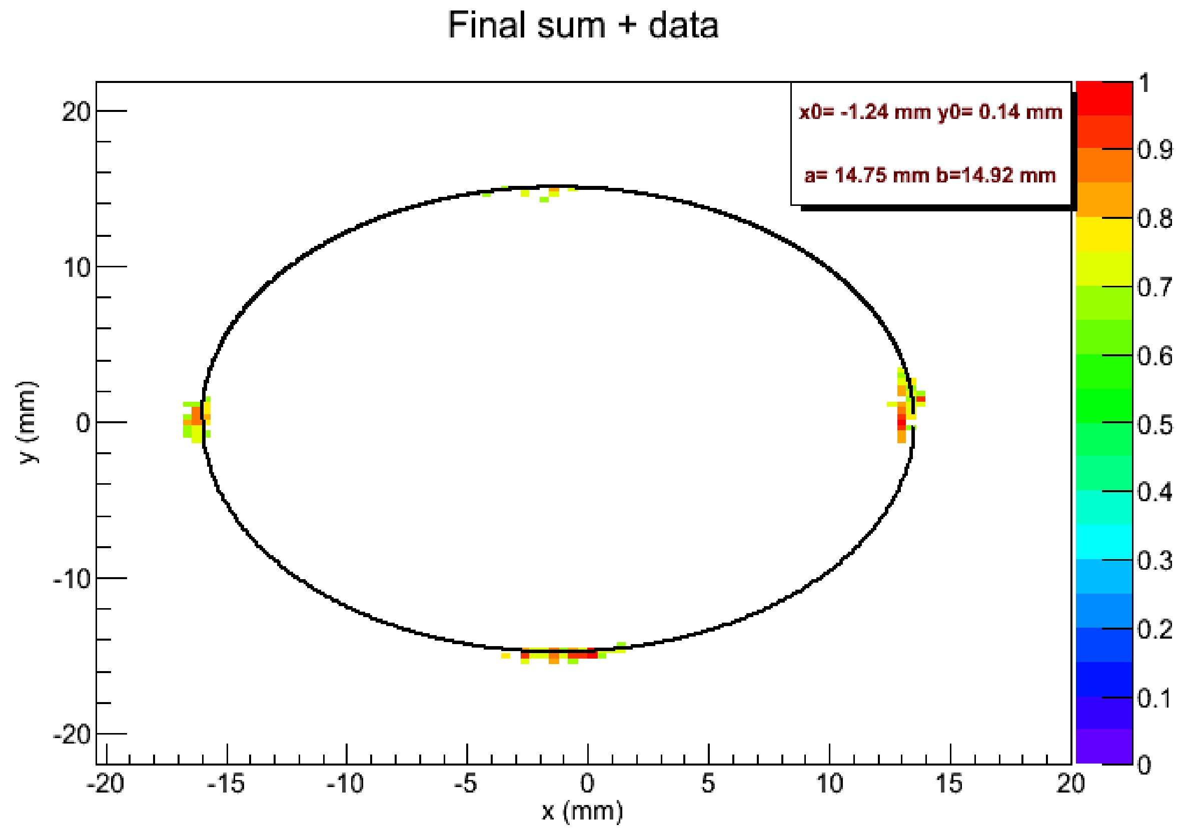
Can measure relative alignment of collimator by scanning beam to the baffle edge and looking for the collimator shadow

Study done at low intensity with ceramic wafer (fluorescent light)

Collimator Alignment Study

Analysis looks for large derivatives in the light distribution where the beam is scanned near the collimator edge

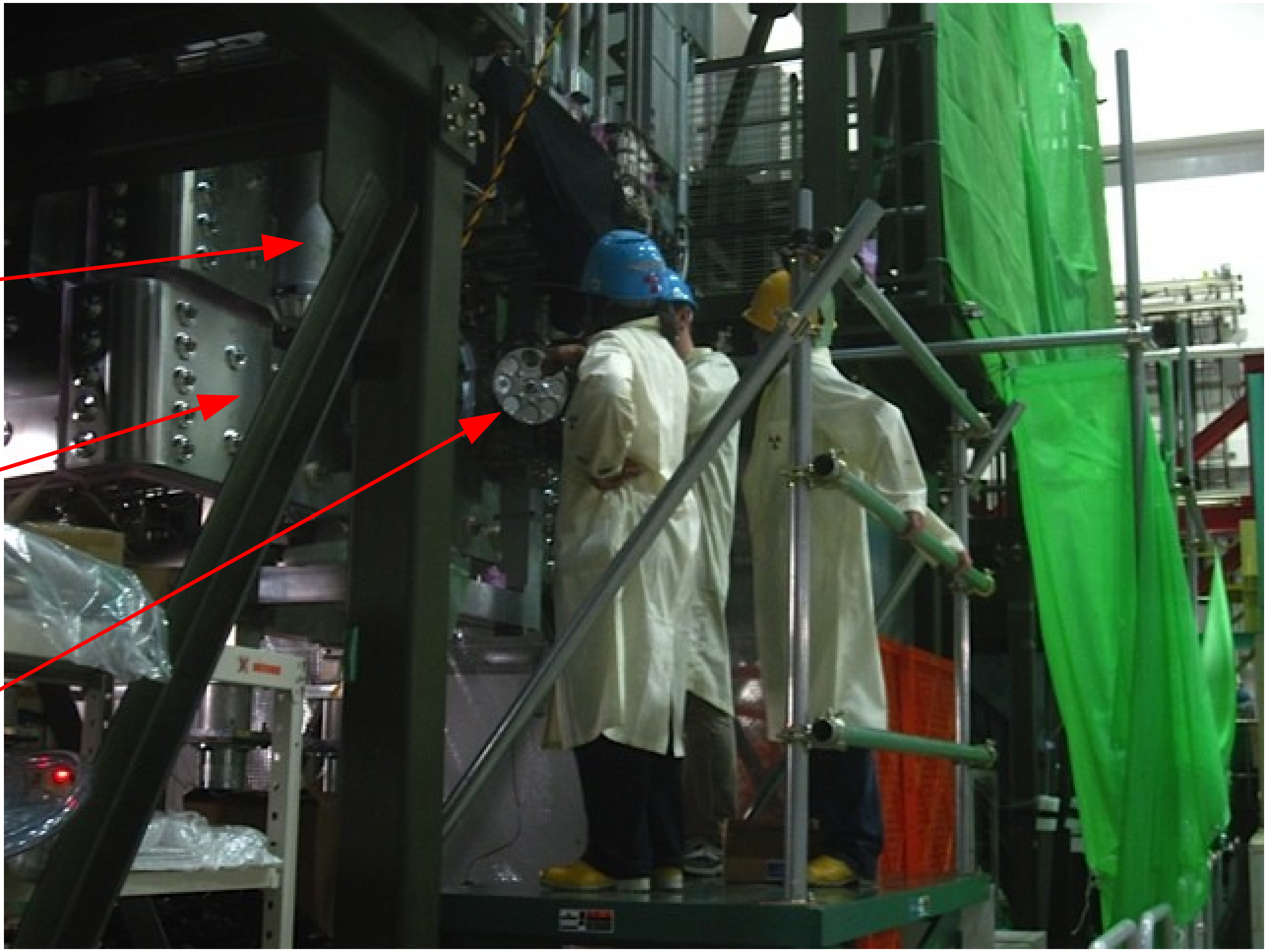
Measurements before and after earthquake differ by <0.7 mm



	X center (mm)	Y center (mm)	X width (mm)	Y width (mm)
Pre-earthquake	-0.55	0.17	15.0	14.8
Post-earthquake	-1.24	0.14	14.8	14.9

Spare OTR System

- OTR optical system mounted to first horn support module, OTR foil disk mounted to front plate of first horn
- Spare OTR system assembled on spare first horn and support module

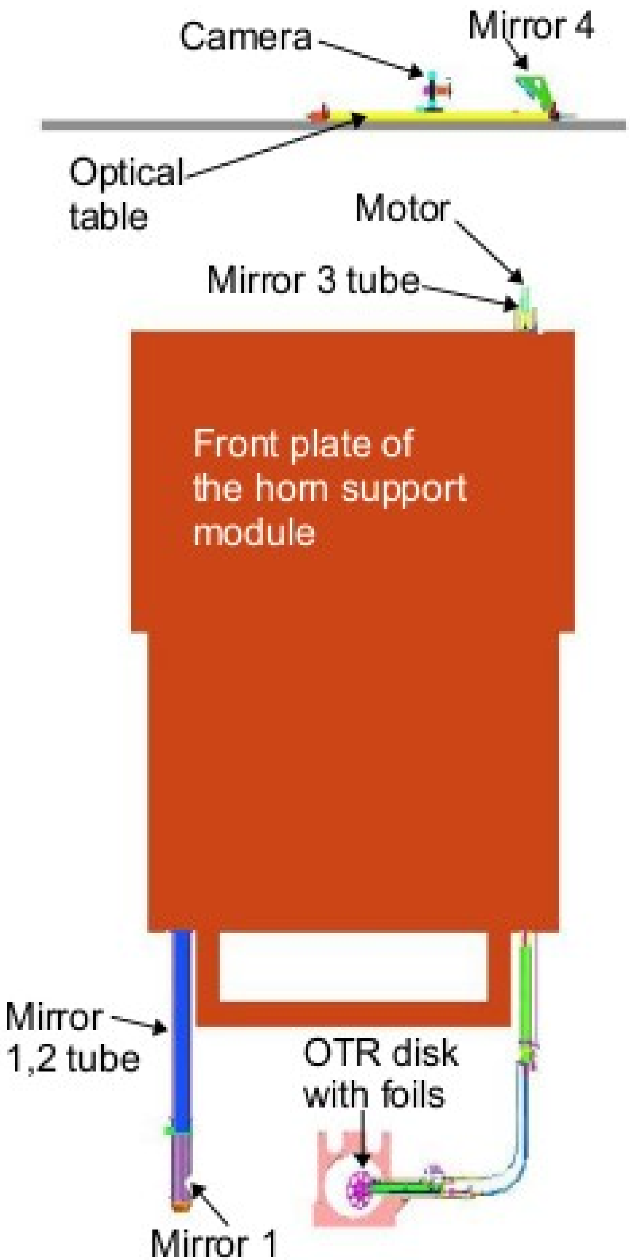


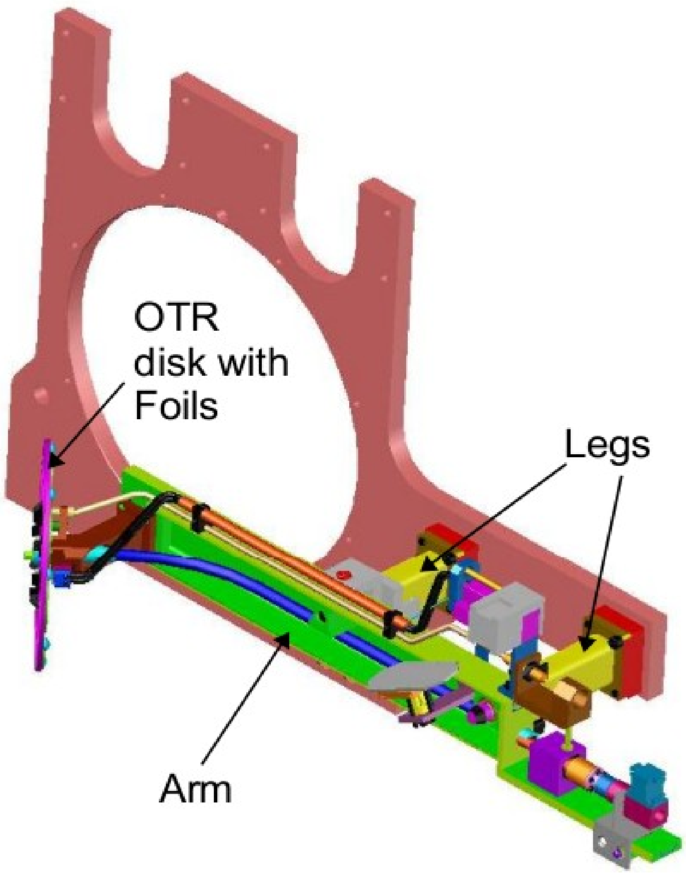
Conclusions

- The T2K OTR monitor measures the proton beam profile 30 cm upstream of the T2K target
- Stable operation so far, valuable input for physics
  - In-beam foil stable through 2011 running
  - In 2012 run, possible damage to first foil was observed
- OTR monitor has been used for beam based studies of post earthquake primary and secondary beamline alignment
- Spare OTR monitor assembled on spare first horn/support module
- Paper has been submitted to NIM: arXiv:1201.1922

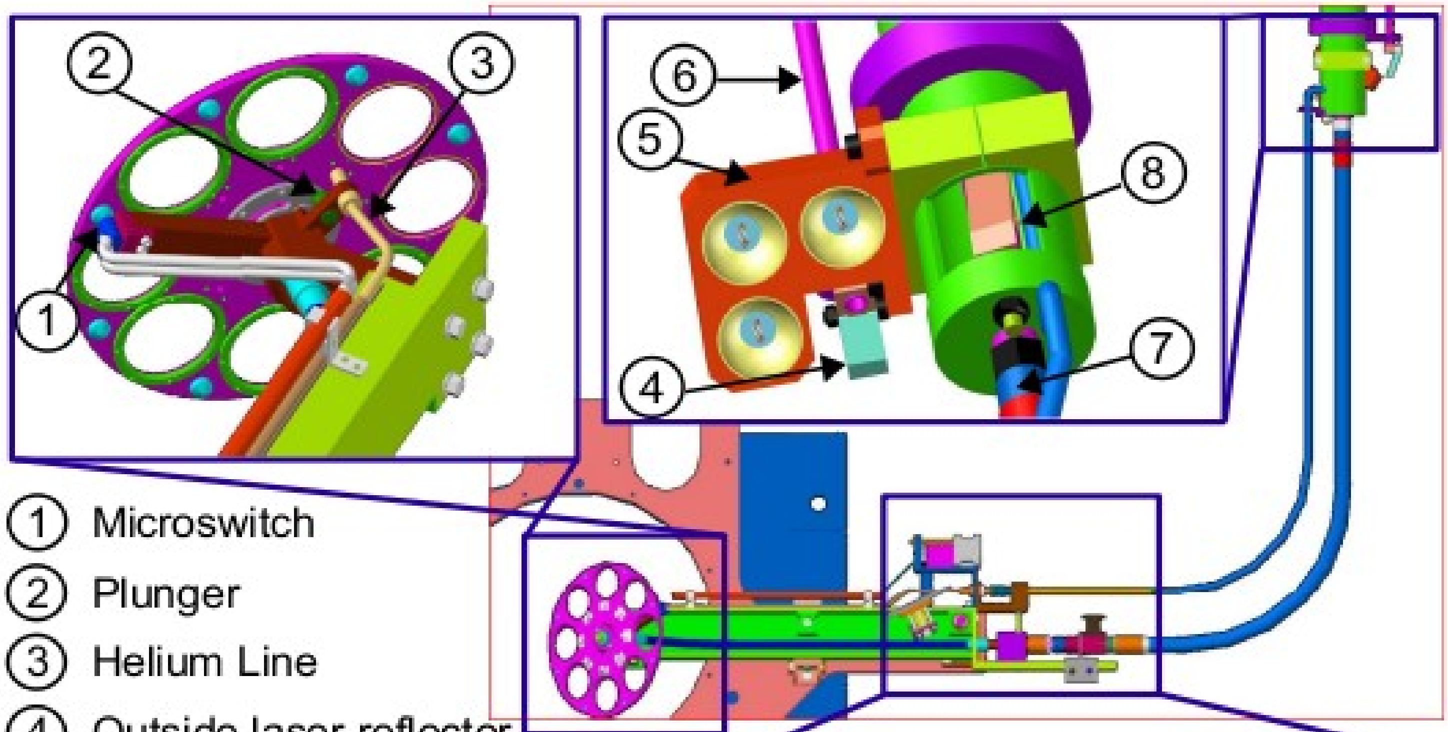
Extra Slides

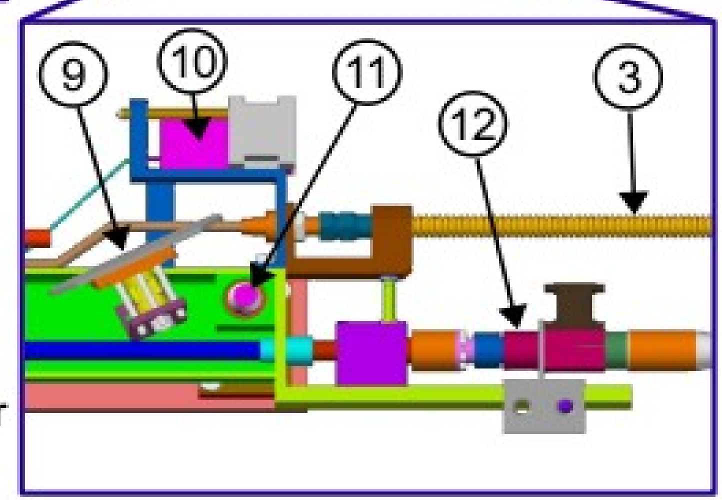
OTR Schematics





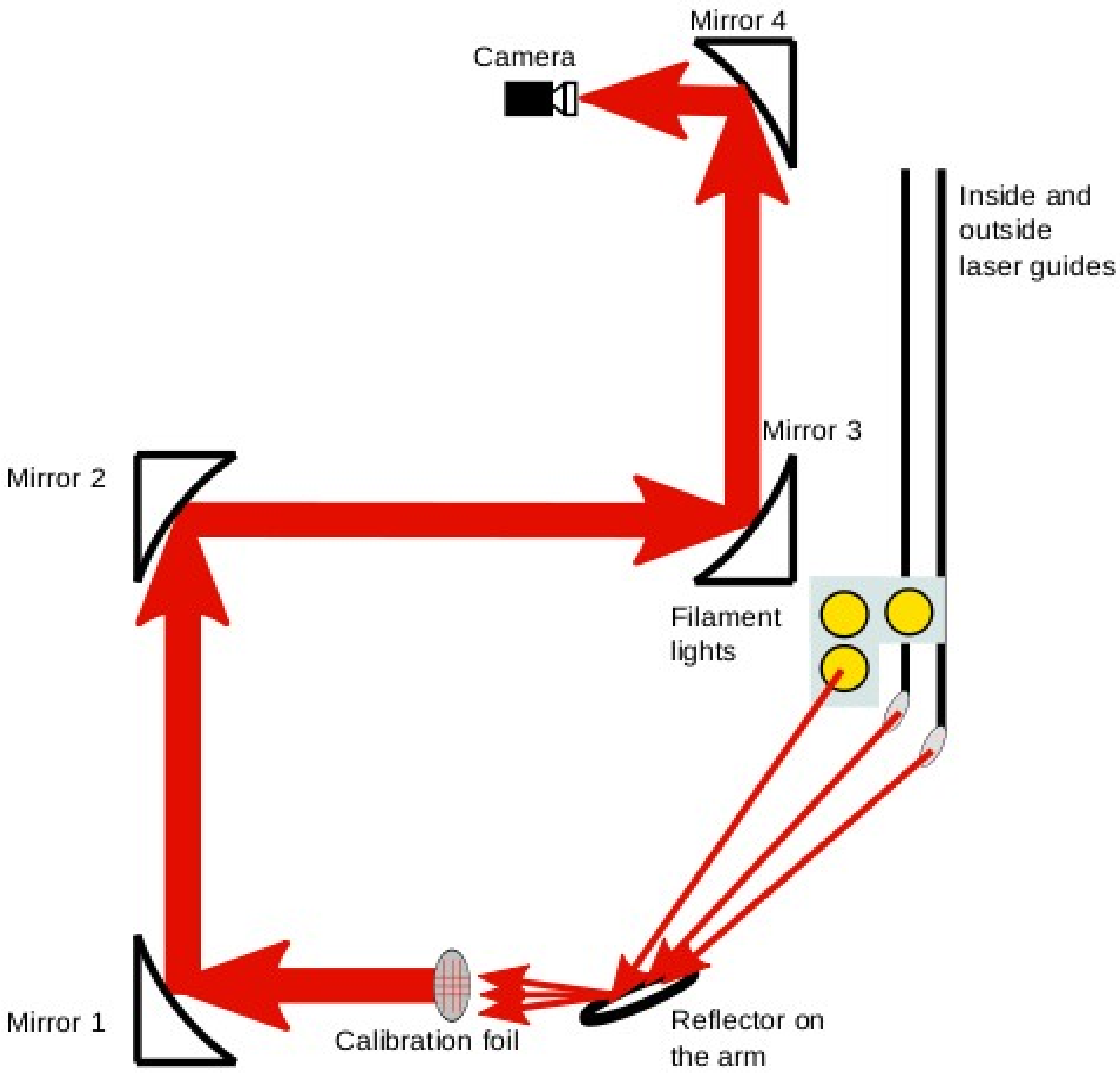
OTR Schematics

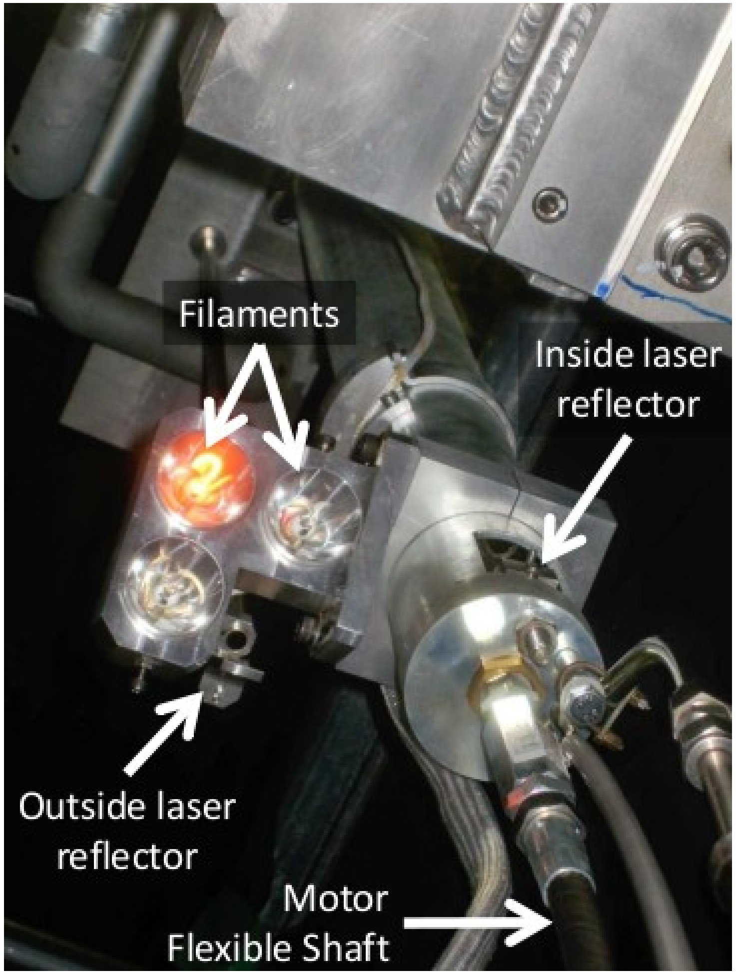




1. Microswitch
2. Plunger
3. Helium Line
4. Outside laser reflector
5. Filament housing
6. Outside laser tube
7. Flexible shaft
8. Inside laser reflector
9. Arm reflector
10. Ceramic thermocouple connector
11. Arm pivot point
12. Motor shaft connector

Calibration Back-lighting

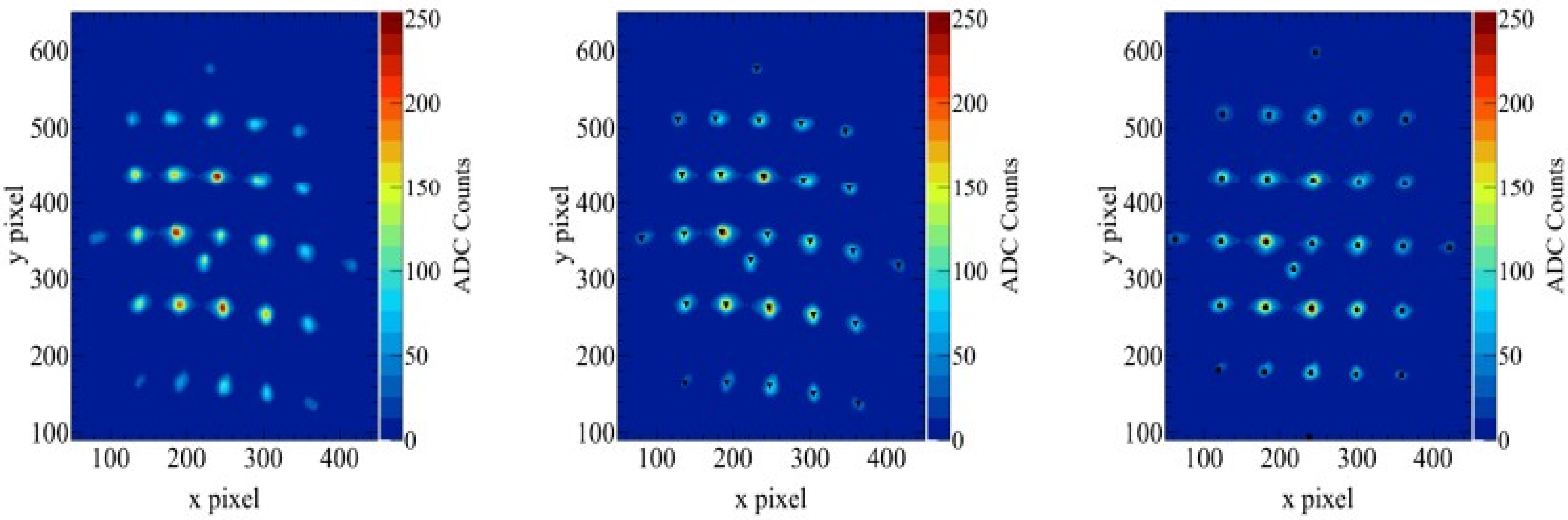




OTR Calibration

• The calibration foil is surveyed and aligned to the axis through the center of the first horn

• Images of the back-lit calibration foil give the hole positions after distortion by the optical system



• The images is corrected based on the mapping between the hole positions on the distorted image, and the surveyed true positions of the holes