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A Novel Scintillation Based Time Resolved Spot Size Diagnostic For Analyzing Various Flash Radiographic X-ray Sources

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OUTLINE

- Motivation for Diagnostic
- Description of Diagnostic
- Data Analysis
- Results for trials on two high brightness flash radiographic X-ray sources.
  - The Self Magnetic Pinched (SMP) diode on RITS-6
  - The Rod Pinch (RP) diode on Cygnus-1
- Results for trials on two high brightness Flash Radiographic x-ray sources.
- Summary

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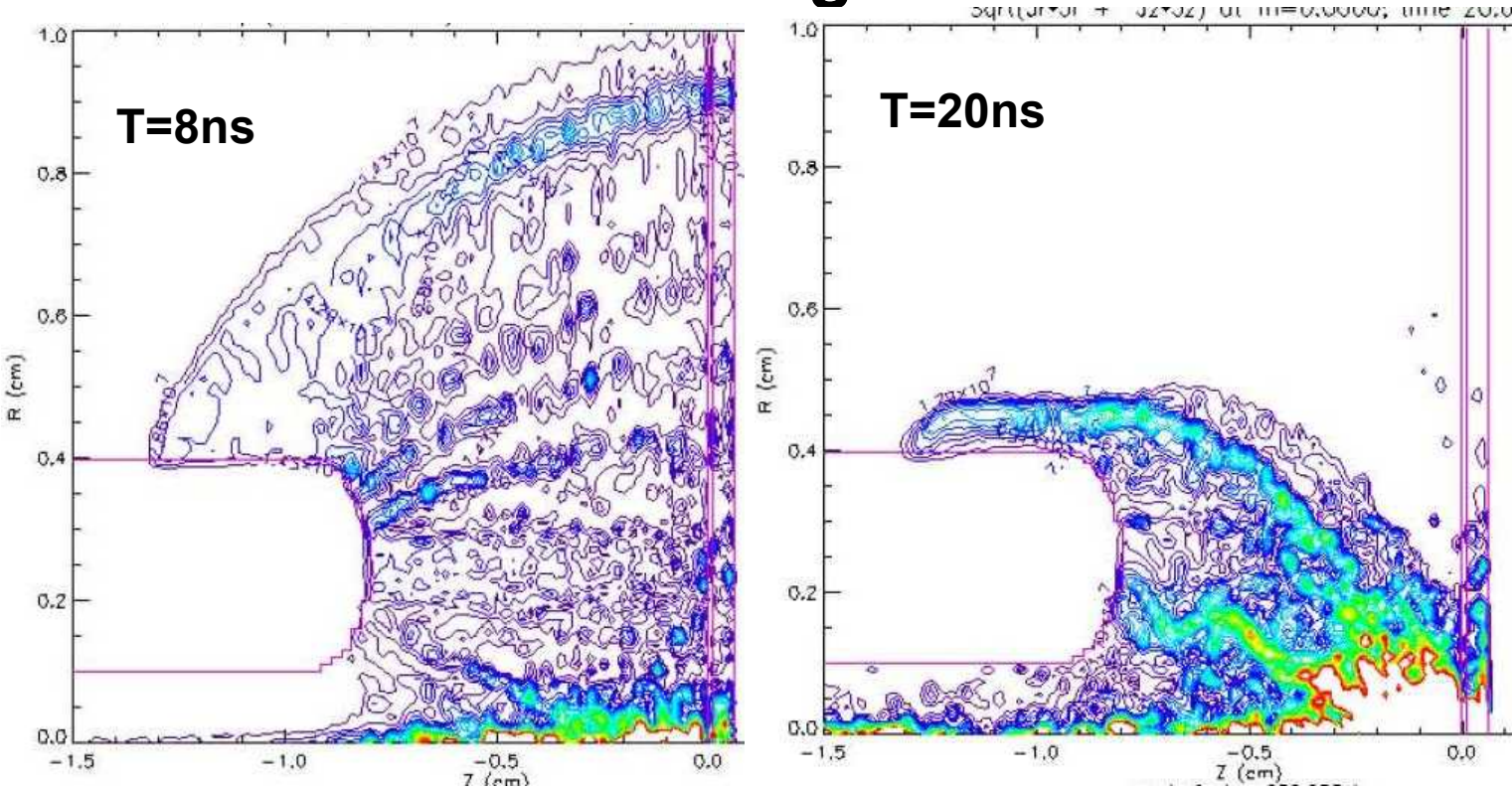
Motivation for Diagnostic

- Beam-plasma interactions can influence the beam spot on target-causing it to be time dependent.



Contours of current density from simulation with LSP courtesy of J.Threadgold and I. Crotch

We have developed a scintillation based Time Resolved Spot Size Diagnostic (TRSD) to measure this time dependence.

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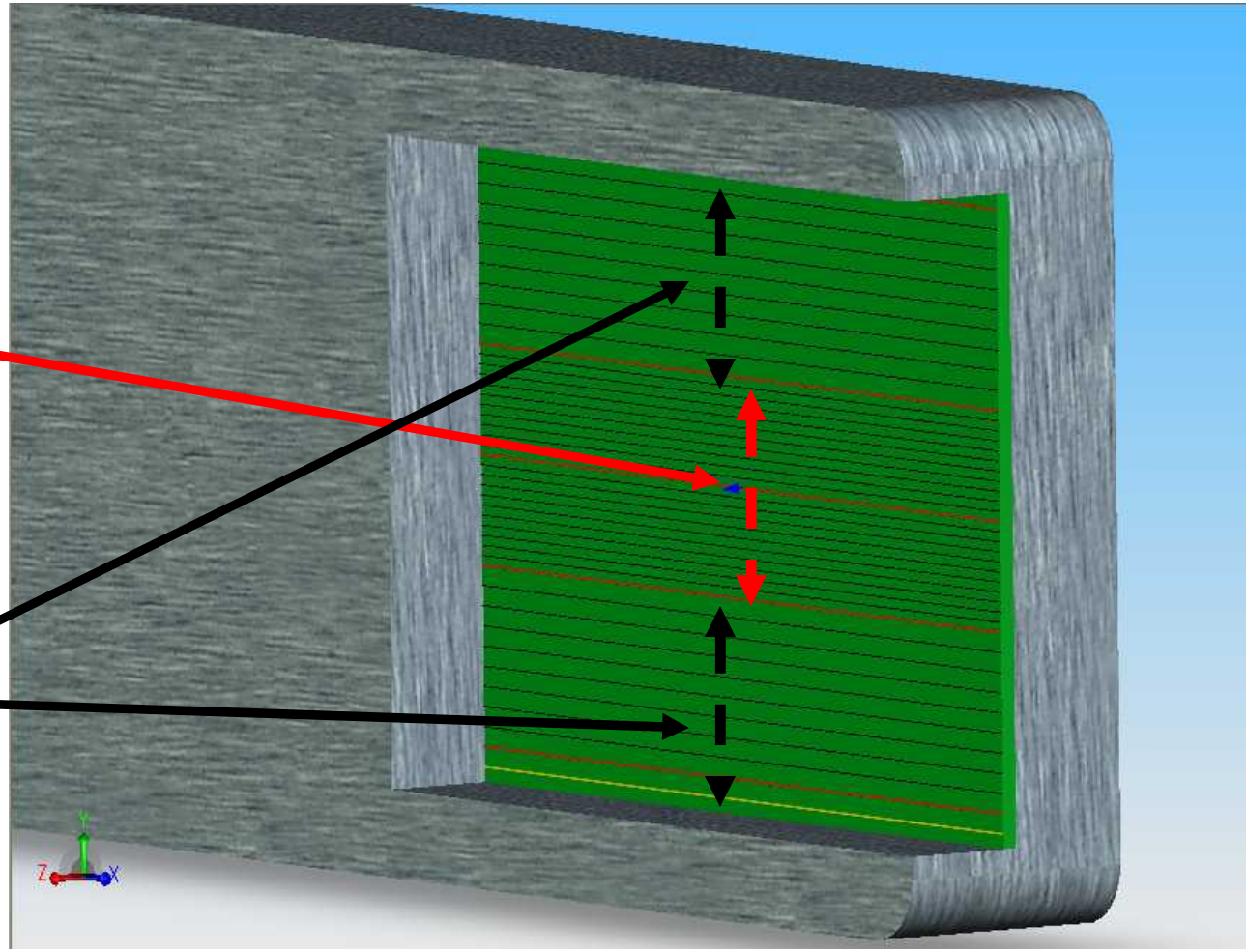
TRSD Description

- The TRSD consists of 84 scintillation fibers
- Bimodal sampling for higher resolution sampling in the center region,
- Lower sampled region for the least dynamic part of the measurement



Bimodal sampled scintillation fiber detector

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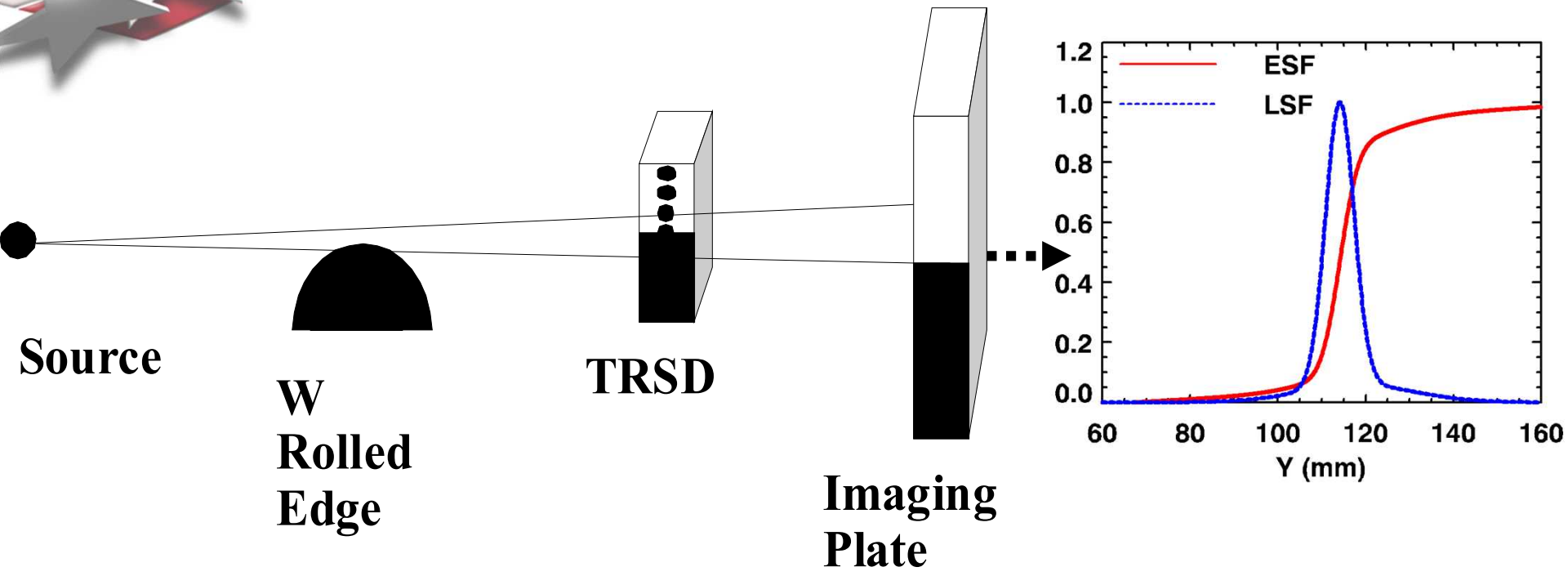
Typical Experimental Set Up



- A Rolled Edge is placed orthogonal to the source.
- Diagnostics are placed parallel to rolled edge
- The penumbra is measured

The resulting penumbral ESF-LSF measurement yield the spot size.

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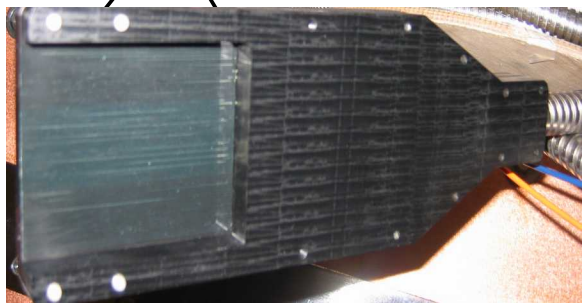
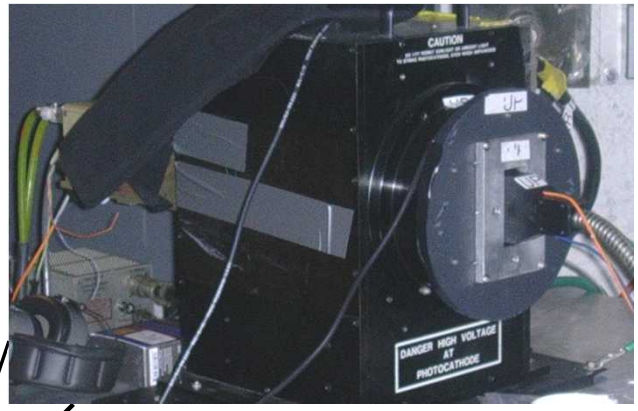
TRSD Layout

TRSD Array

Fiber Optic Cable

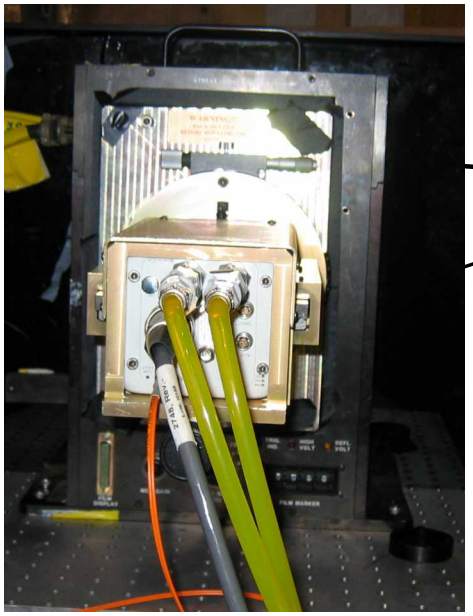


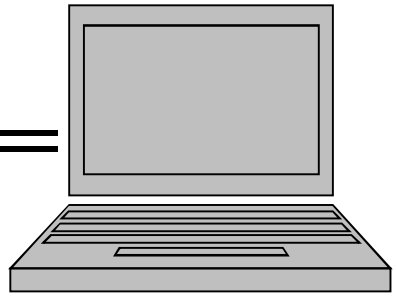


Streak Camera

Time

CCD Camera





Data Collection Computer

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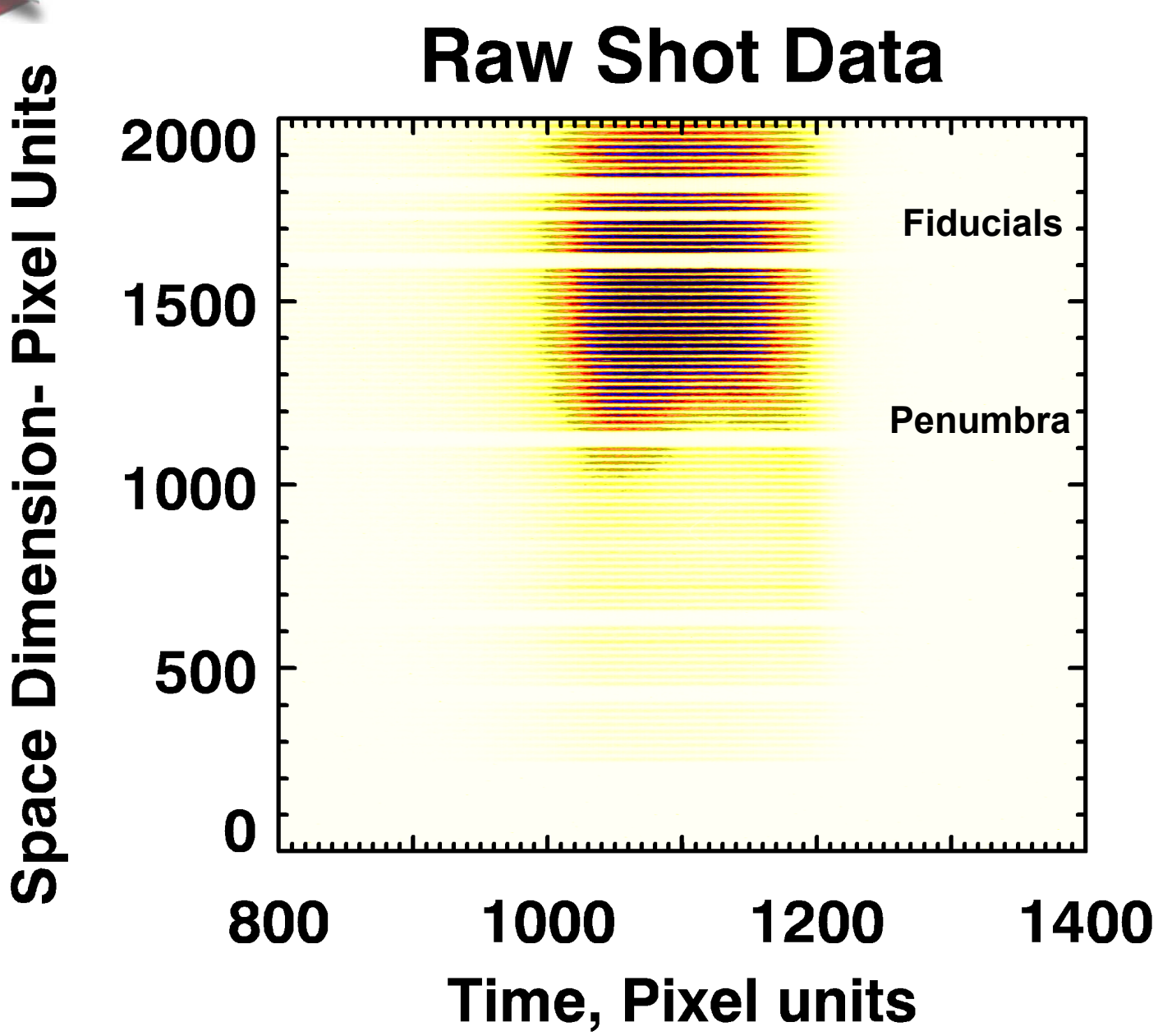
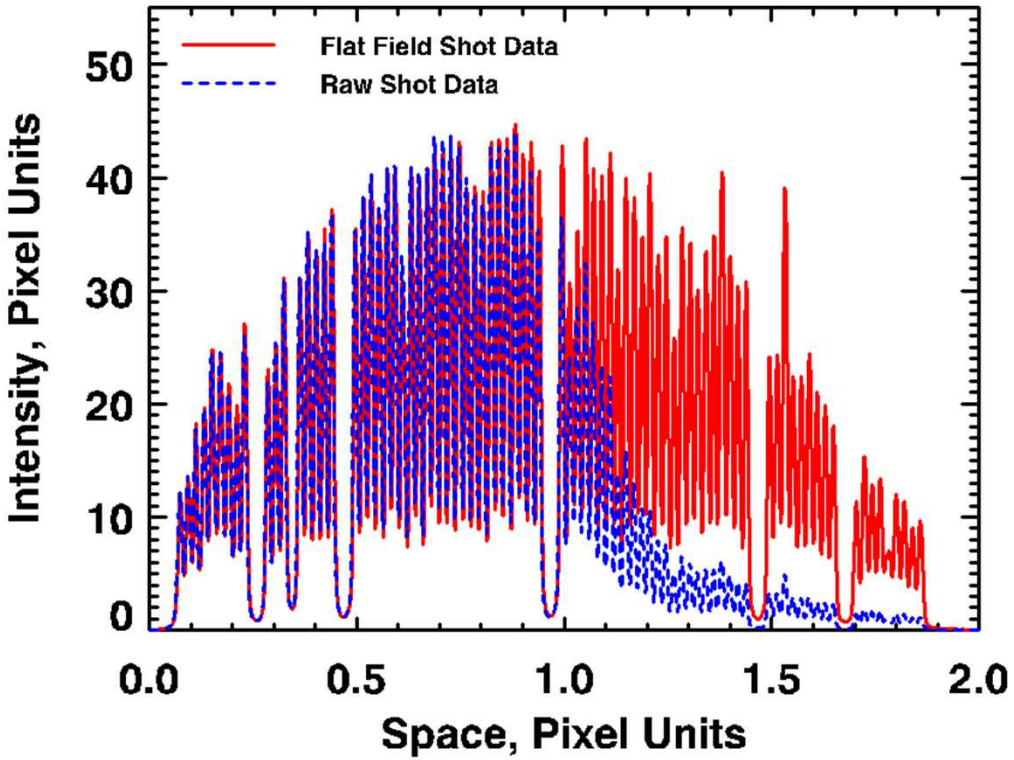
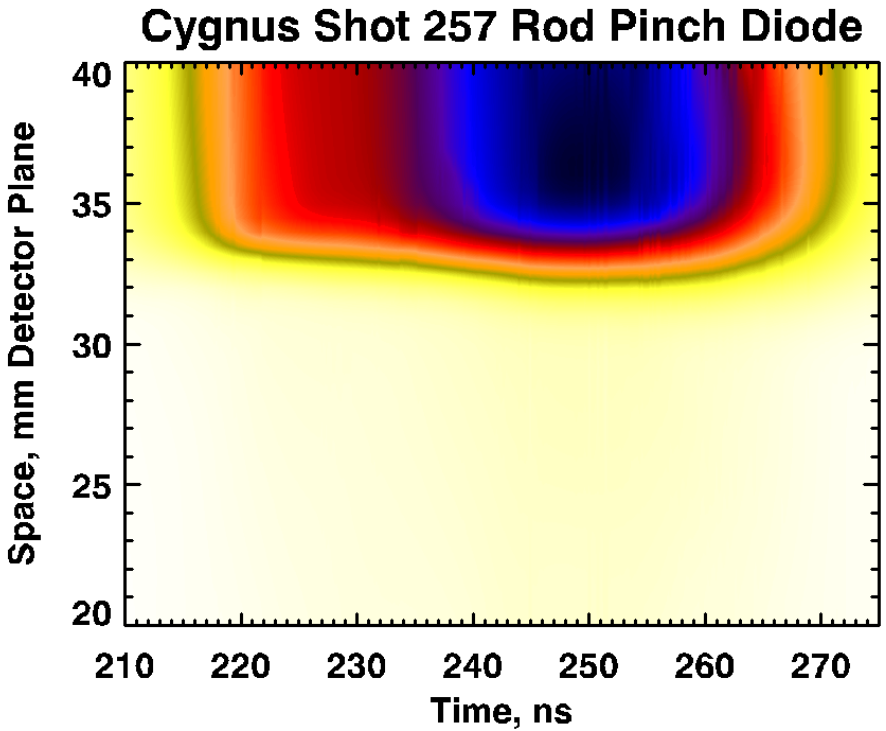
Data Analysis



Data Analysis

Fiber response for flat field and Diode shots





Reduced Image; Intensity vs. space and time

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TRSD Detector Response

- TRSD detector blur from contact shot = 1.28mm, which compares to the blur from Imaging Plate of ~2mm (@ 6,5MV, Blur=1.9mm
  - Blur Convolves with measurement
- If I want to measure a 2mm spot with ~4% error, I need a mag. of 3, given a detector blur of 1.28mm
- Minimum Dose on detector ~2 Rads (S/N)
- Maximum Dose On Array ~12 Rads.
- Temporal Resolution ~4ns, streak camera limited

Detector blur comparable to Imaging Plate blur

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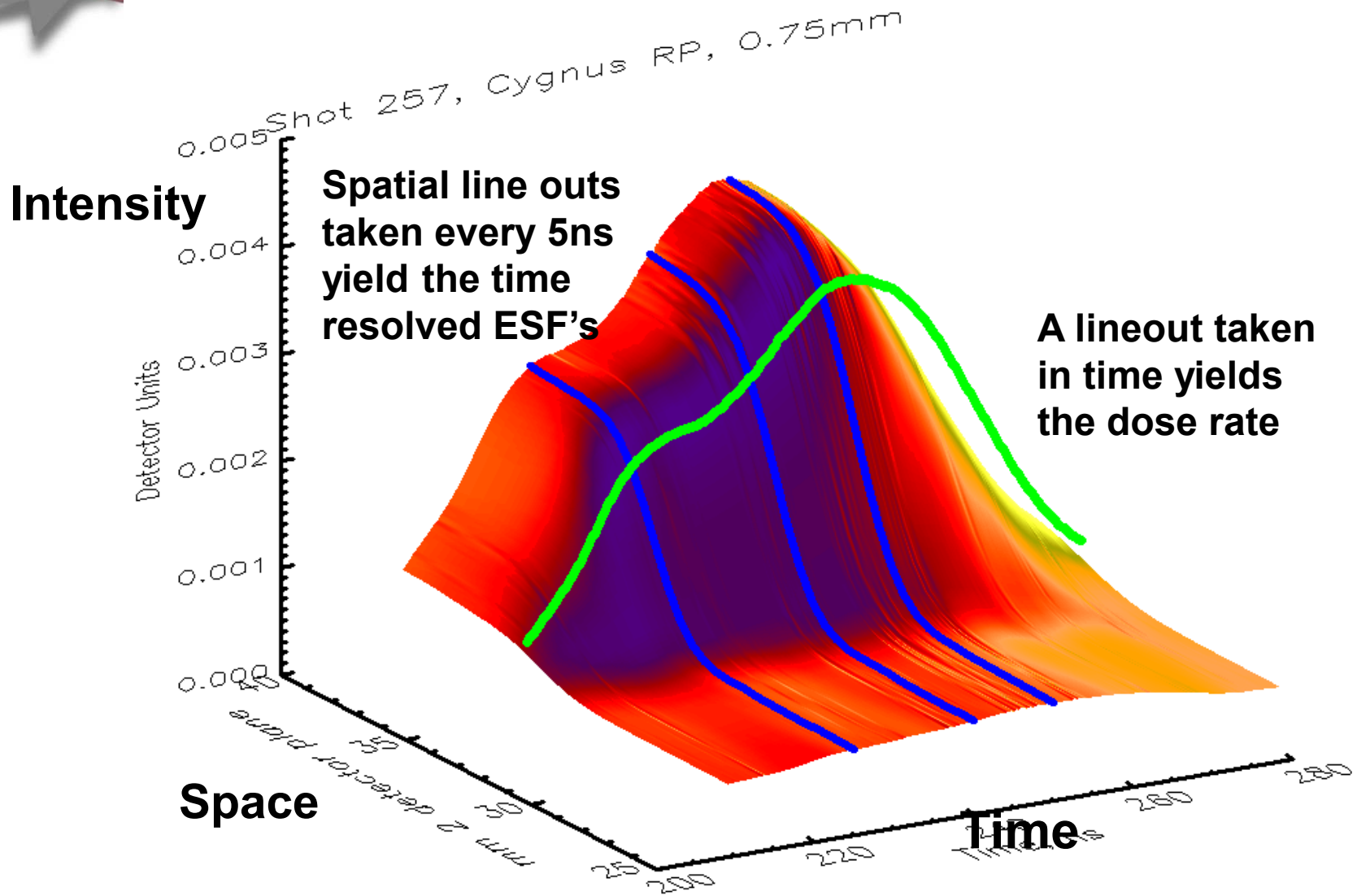
3D Contour image of reduced TRSD data



- Spatial line-outs yield time history of spot size
- Temporal line-out yields the dose rate

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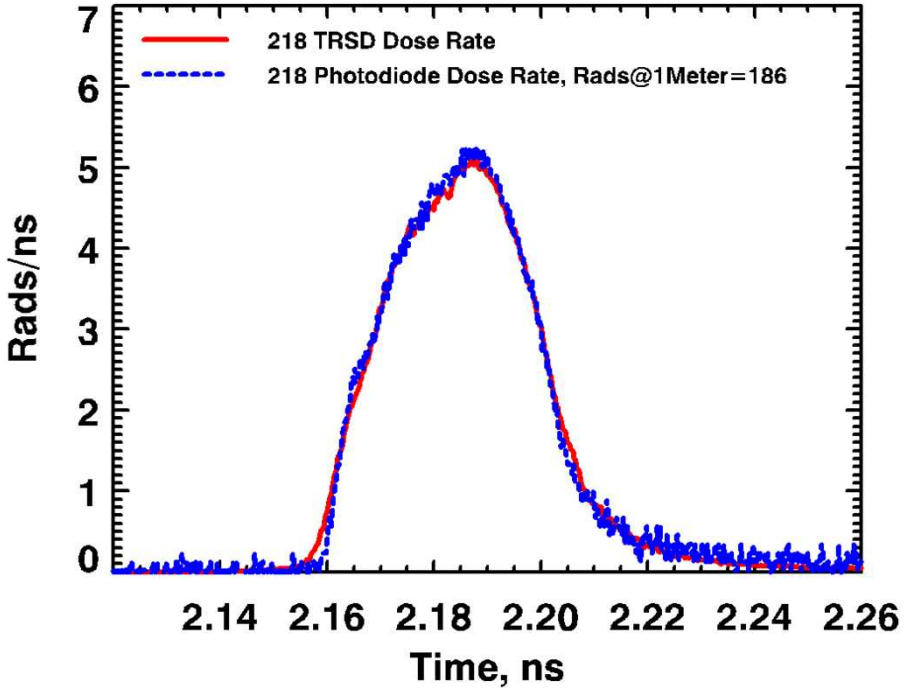
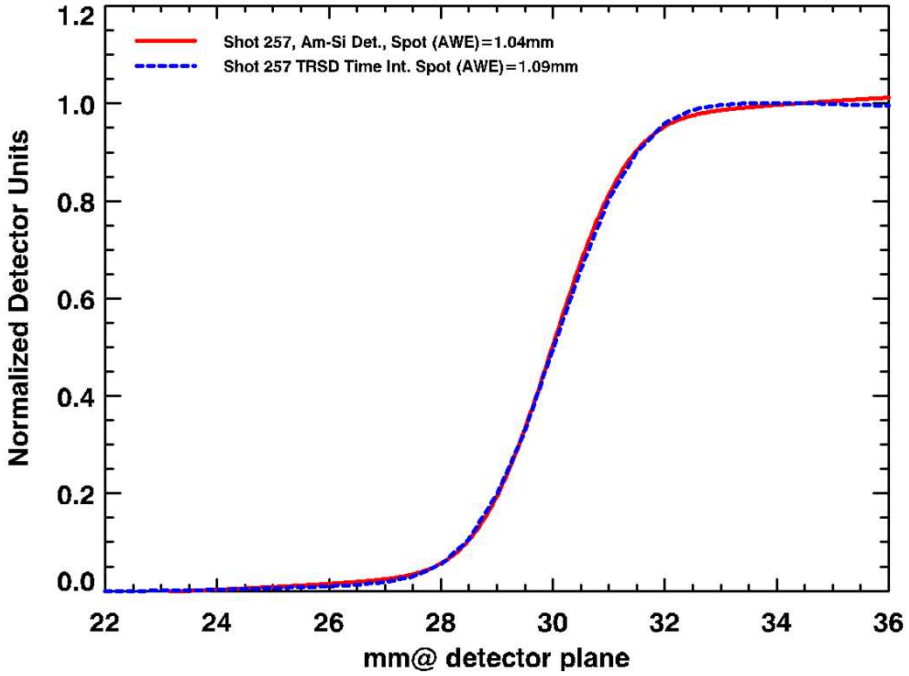
Comparison of Dose Rate from TRSD and Photodiode detector for RITS-6 SMP Shot



TRSD can replace the standard dose rate diagnostic

Comparison of ESFs from time integrated detector and the time integrated signal from the TRSD



Agreement is very good between TRSD ESF and standard time integrated diagnostic

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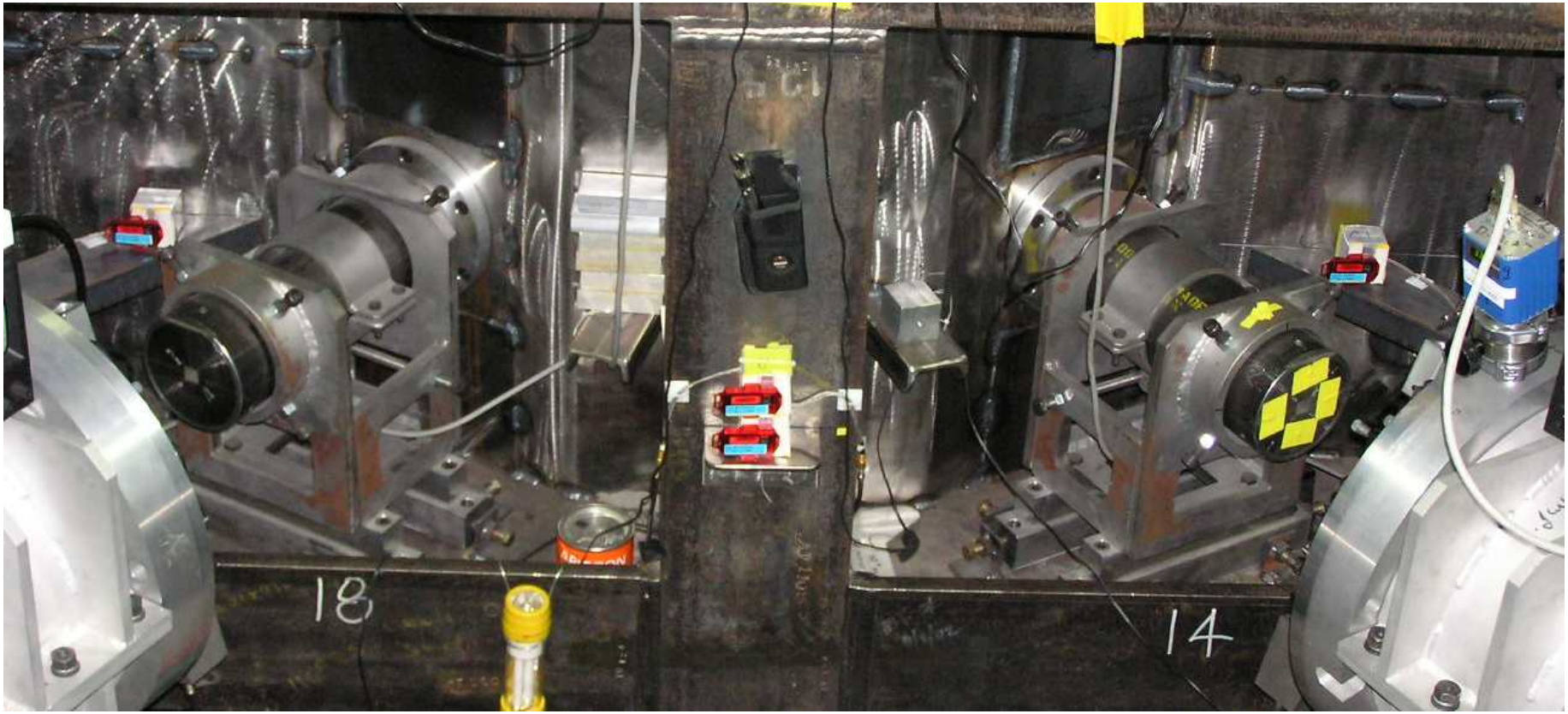
TRSD was fielded on Cygnus 1 accelerator at U1A



TRSD is a portable, compact diagnostic fielded at U1A

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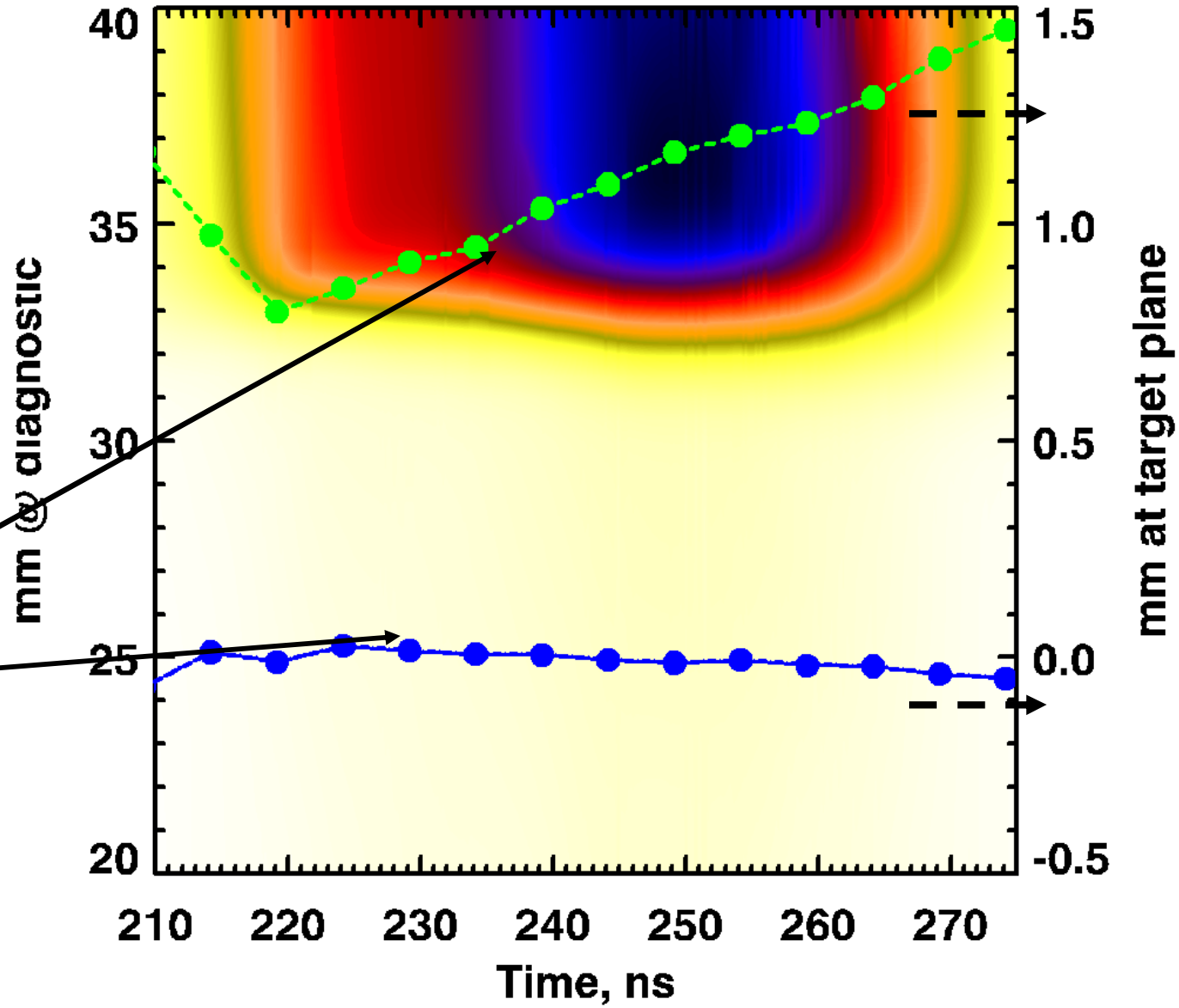
Cygnus Rod Pinch Shot, 0.75 mm W rod

- Cygnus Rod Pinch Shot, 0.75 W tapered rod- “Armando Configuration”.
- Dose@ 1 meter ~4 Magnification ~4
- Spot growth over time = 0.012mm/ns
- Stable Diode, micron sized movement from center.



TRSD Fielded on Cygnus Rod Pinch Diode Saw hydrodynamic expansion effect

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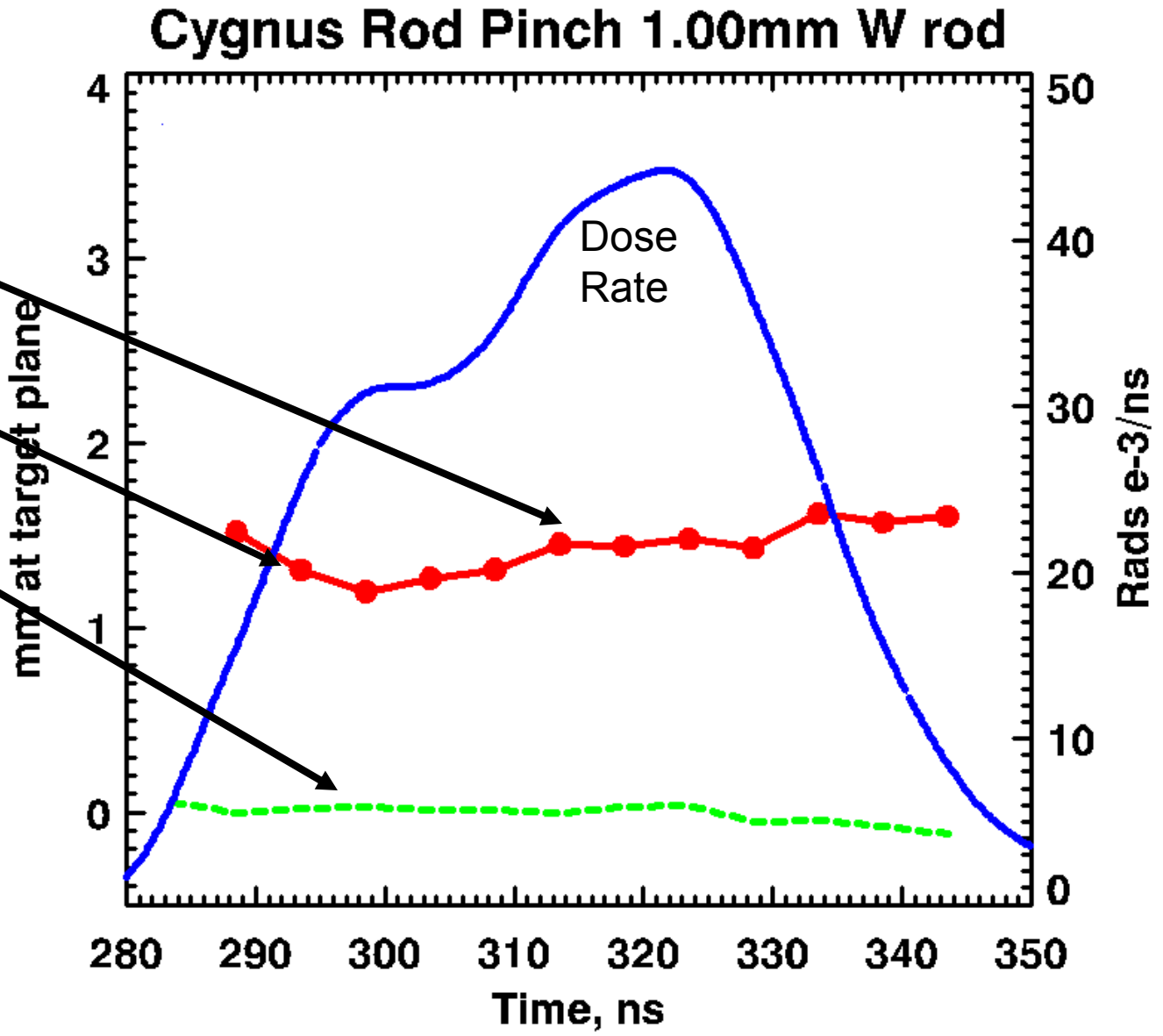
- Spot growth over time = 0.009mm/ns
- Pinch at.032 mm/ns
- Stable Diode, micron sized movement from center.



1.0mm blunt rod saw expansion in spot size at slower rate than 0.75mm W rod

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TRSD Diode Measurements

- First time hydrodynamic effect has been measured via spot size growth on Rod Pinch diode
- Self pinching effect has been measure on the SMP diode
- There is little movement from center
- Instrument has been validated with currently available time integrated measurement
- Temporal evolution of spot size has been measured

Temporal evolution of spot size has been measured

Summary

- A Time Resolved Spot Size Diagnostic (TRSD) has been described.
  - ~1.28mm detector blur
  - Minimum ~2 rads on instrument
  - 5ns temporal resolution
- Temporal evolution of the spot size for the Rod Pinch Diode and SMP Diode has been measured.
- Minimal Spot movement was evident on both the SMP and RP shots
- This is a compact, small and easy to transport diagnostic, which can be fielded easily at various accelerators.

Extra slides to talk to in case of questions

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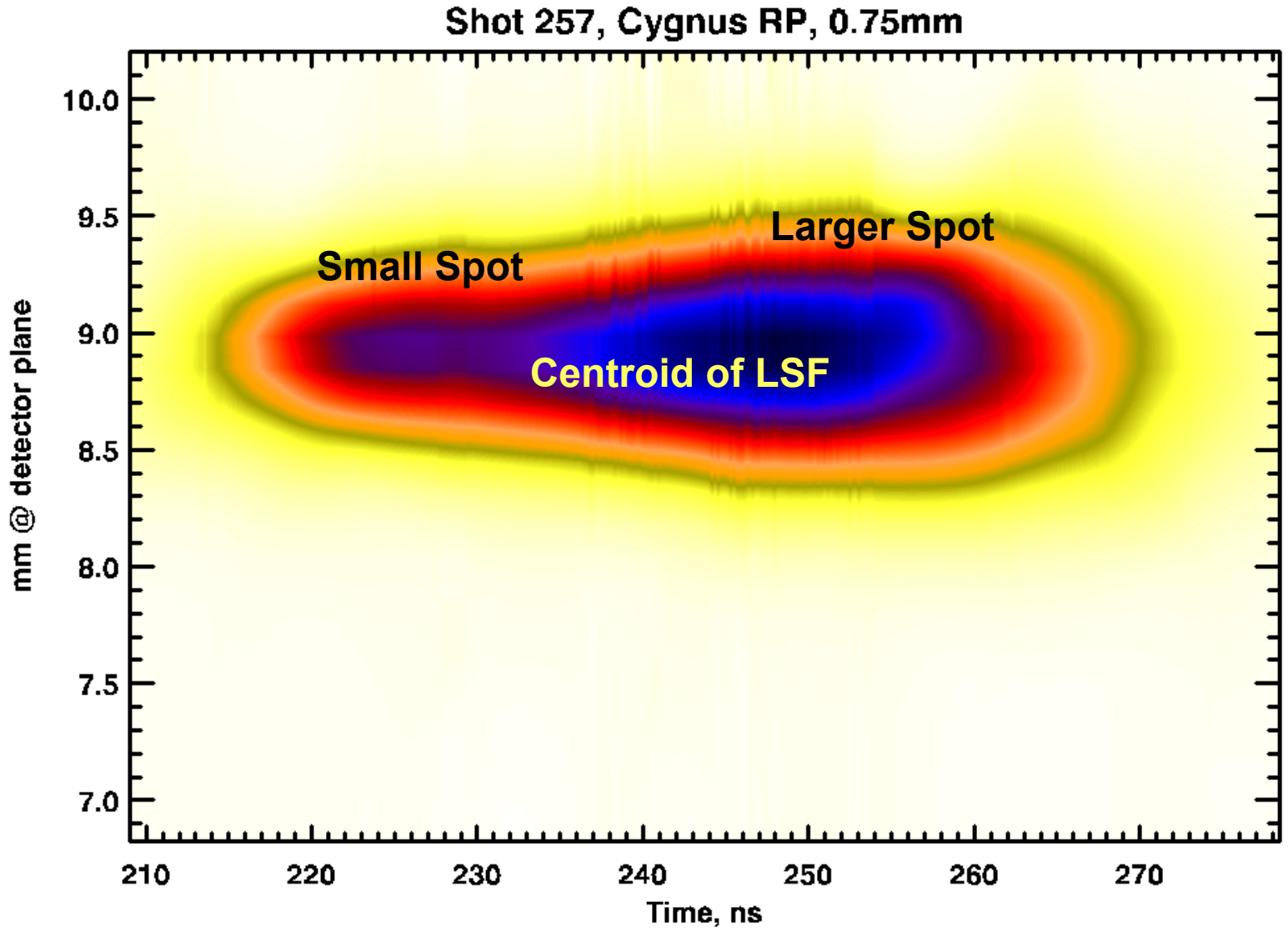
LSF Reduced Image reconstructed from individual LSF's



Centroid of LSFs show little movement from center

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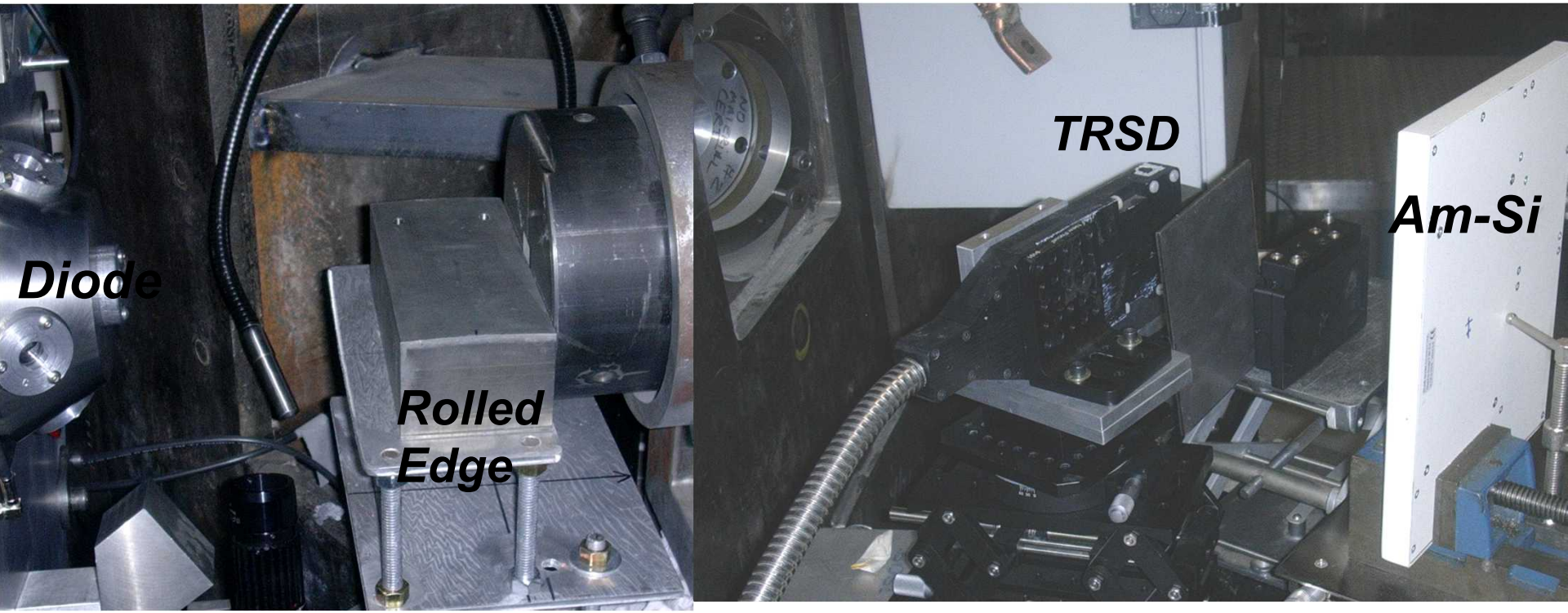
Standard Cygnus RP TRSD Configuration



~1.1 Meter, Mag.=~4

TRSD Fielded on RP diode on Cygnus-1.

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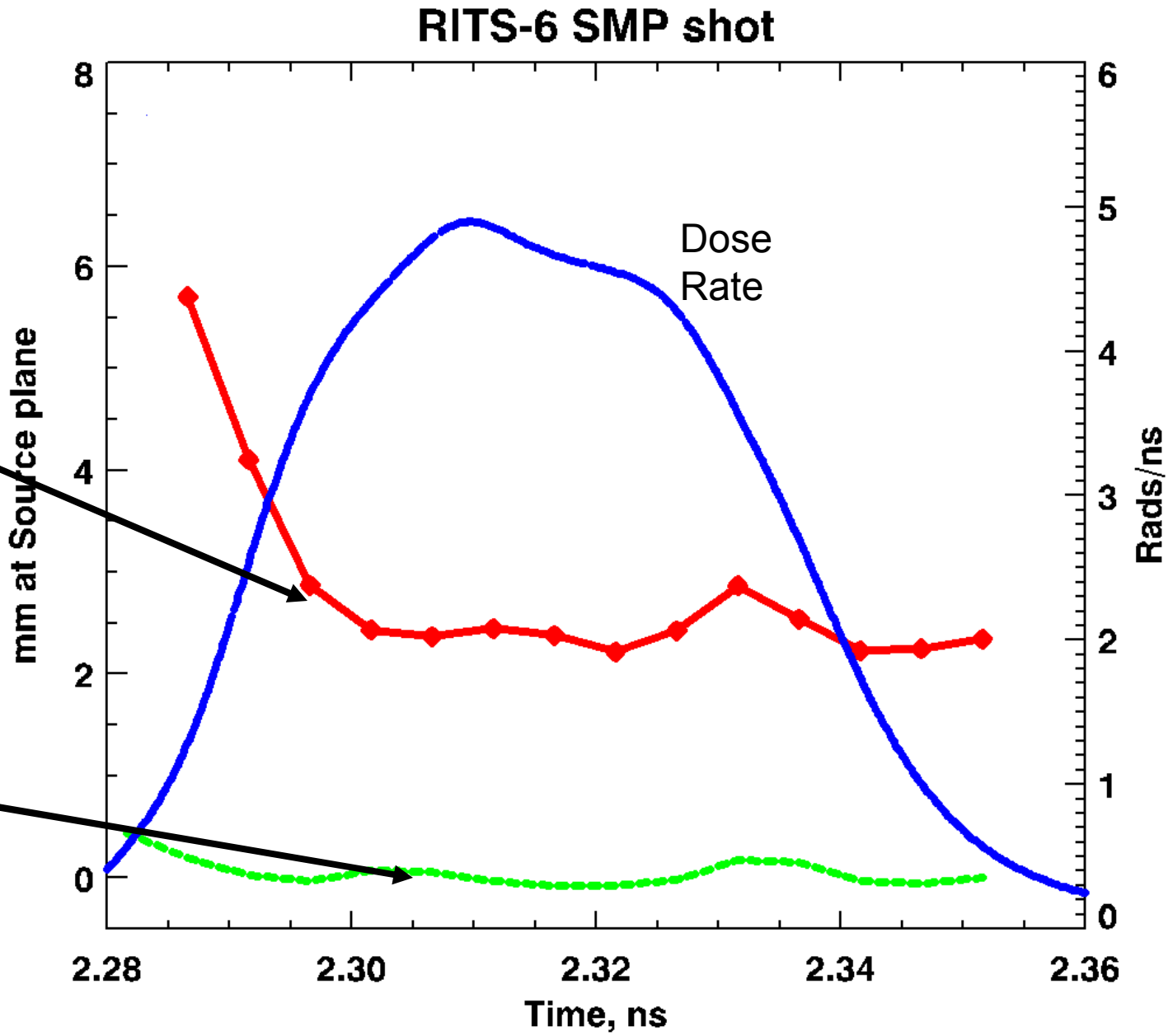
Time Resolved Spot is :

Pinching in the first 15ns

- **The pinch is maintained throughout the radiation pulse**
- **Little movement from Center, sub mm.**
- **Dose >200 rads**



Time history of SMP spot and movement measured

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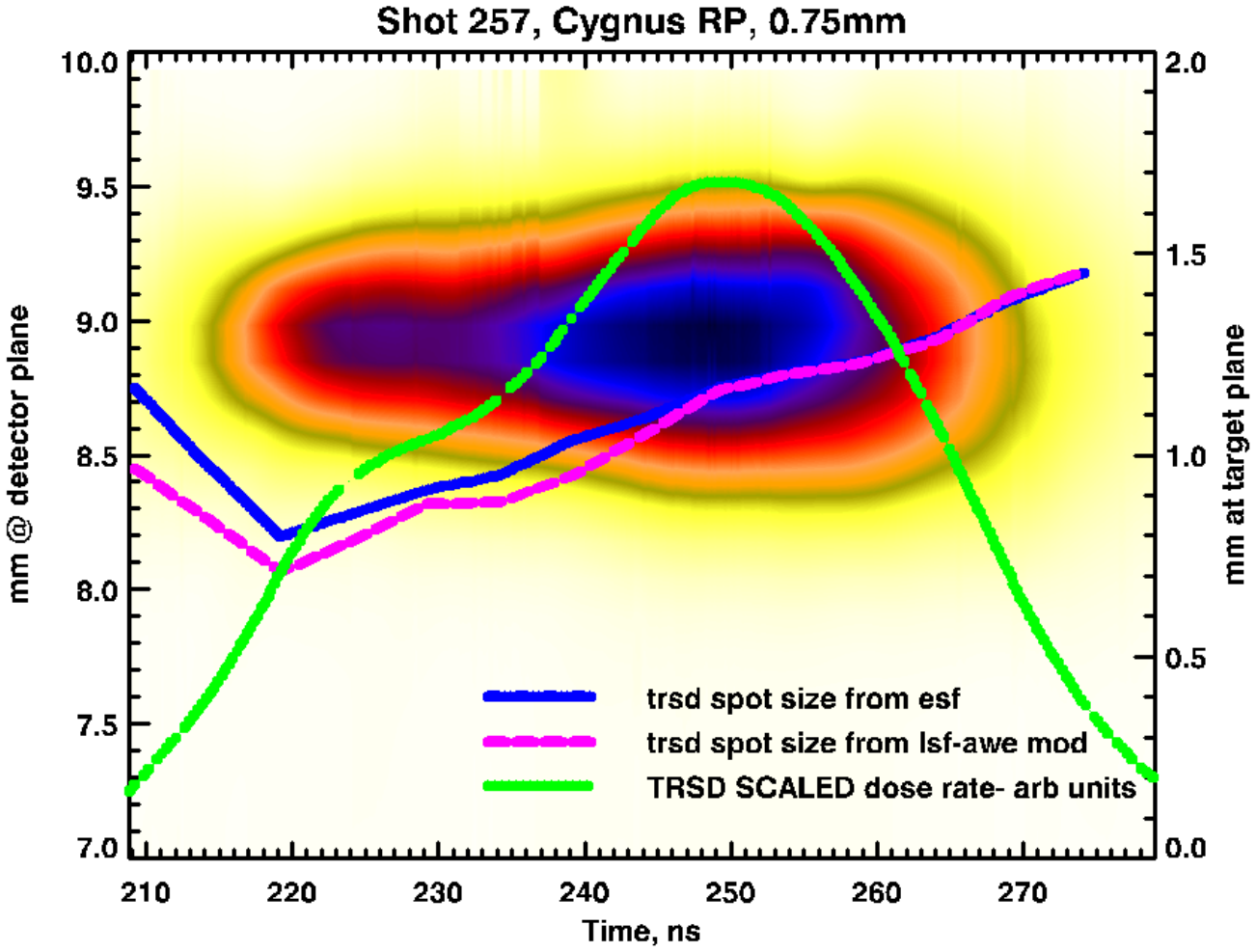
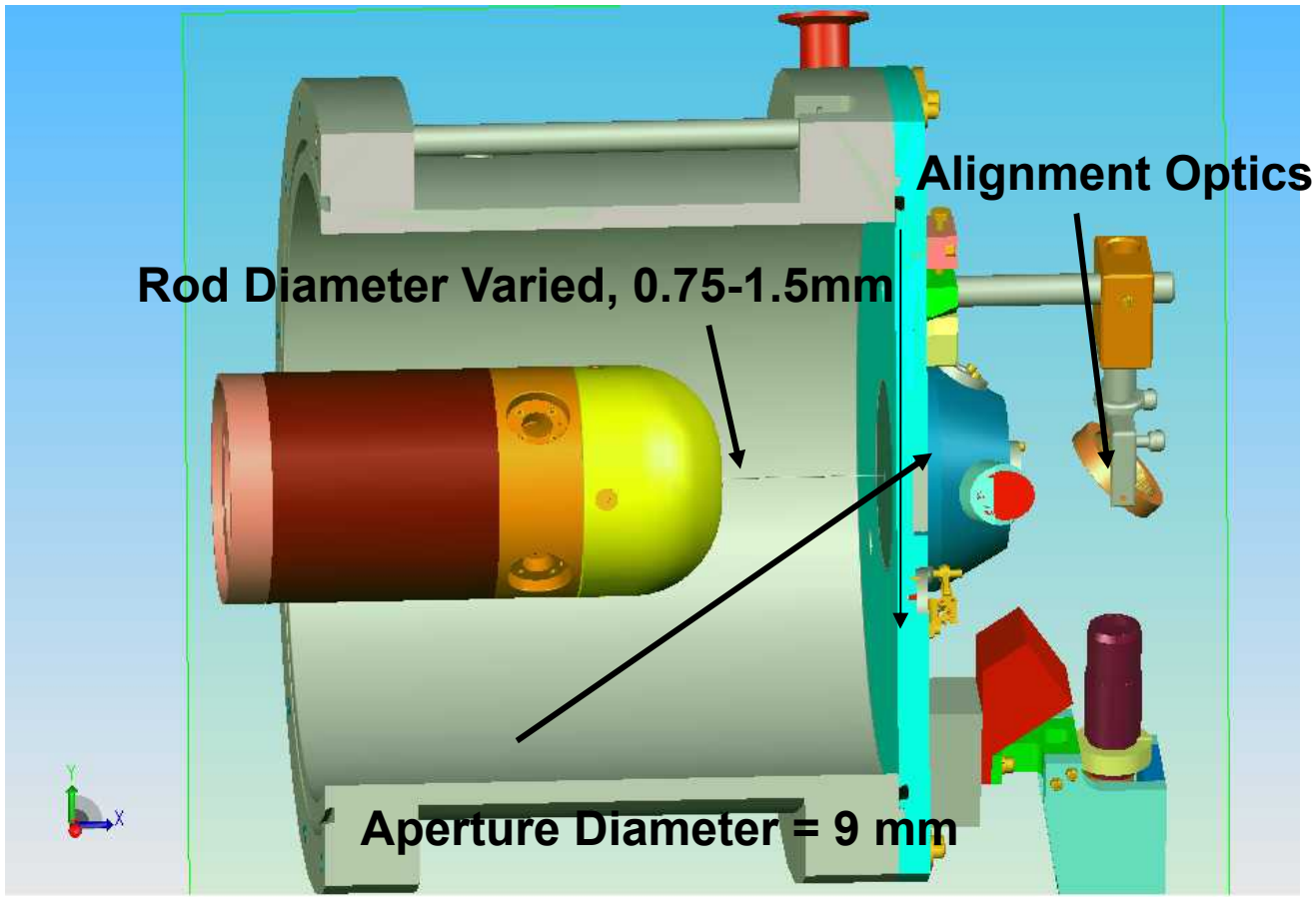
Temporal evolution of spot size from ESFs (Blue) and LSFs (Purple) superimposed over the LSF of the TRSD data. Green waveform is the scaled dose rate

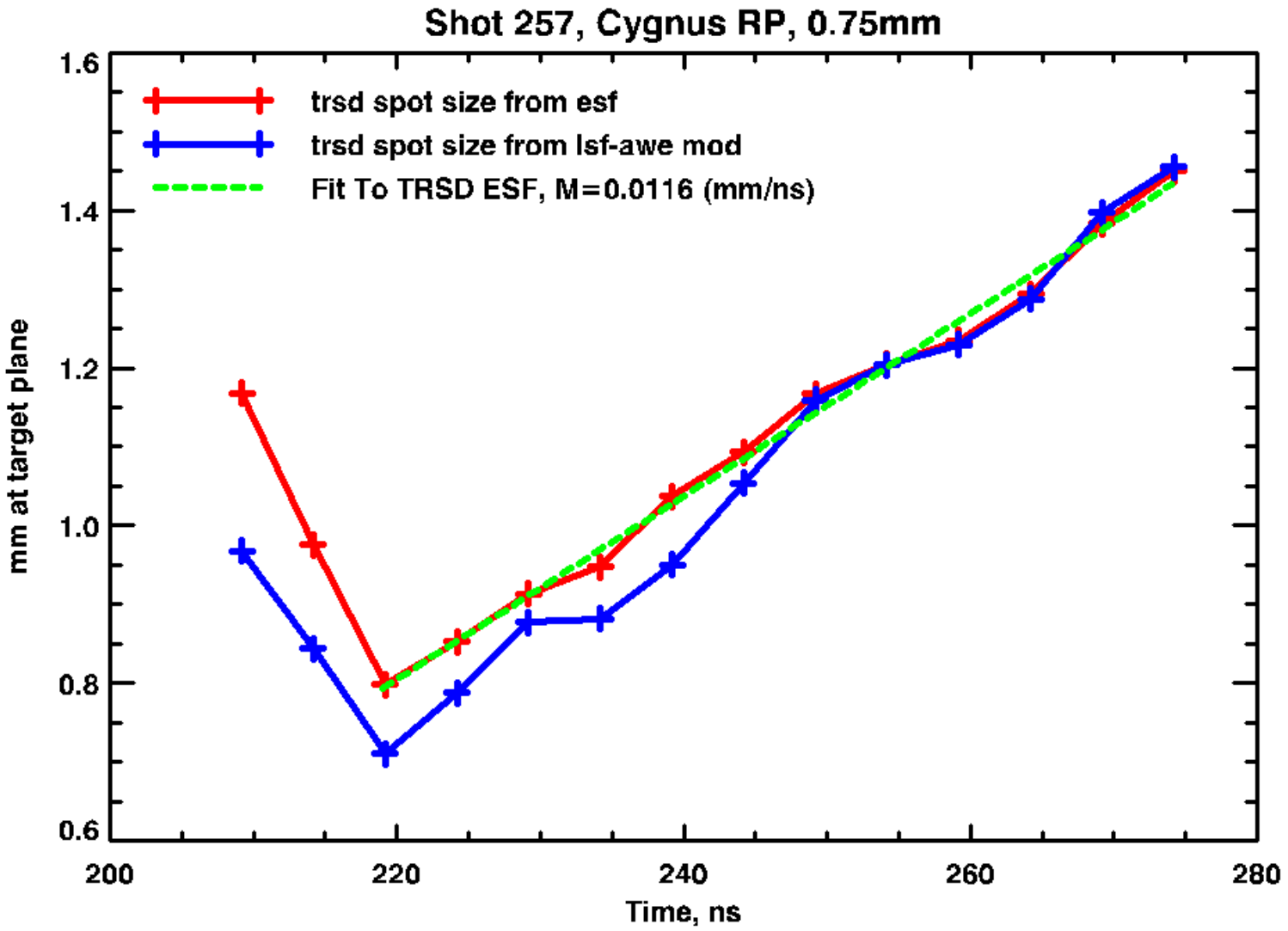


Standard Cygnus Rod Pinch Configuration

- TRSD was fielded on the Rod Pinch of the Cygnus 2 Accelerator, Fall/2006.
- Principal goal was to measure:
- The time history of the spot size,
- Movement from center
- And to characterize diagnostic with a 'well behaved' diode
- Several configurations where needle size varied were shot



Linear fit (Green) to the Temporal evolution of spot size from ESFs (Red) and LSFs (blue). Smaller spot from LSF indicates larger 'Wings' on ESF



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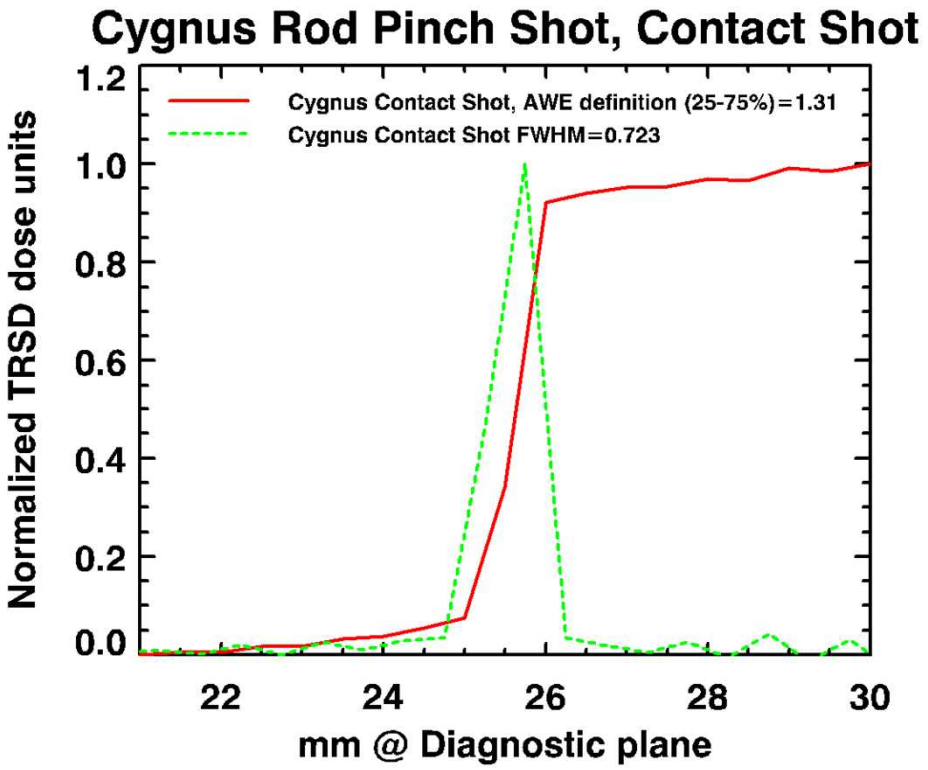
- TRSD detector Blur from contact shot = 1.28mm
- LANL Spot = 1.24, Fc = 0.57
- Mag. to account for detector blur, with 2mm spot, is = 3 (4% error)
- Minimum Dose ~3 Rads
- Maximum Dose On Array = 12 Rads
- Temporal Resolution ~4 ns, streak camera limited



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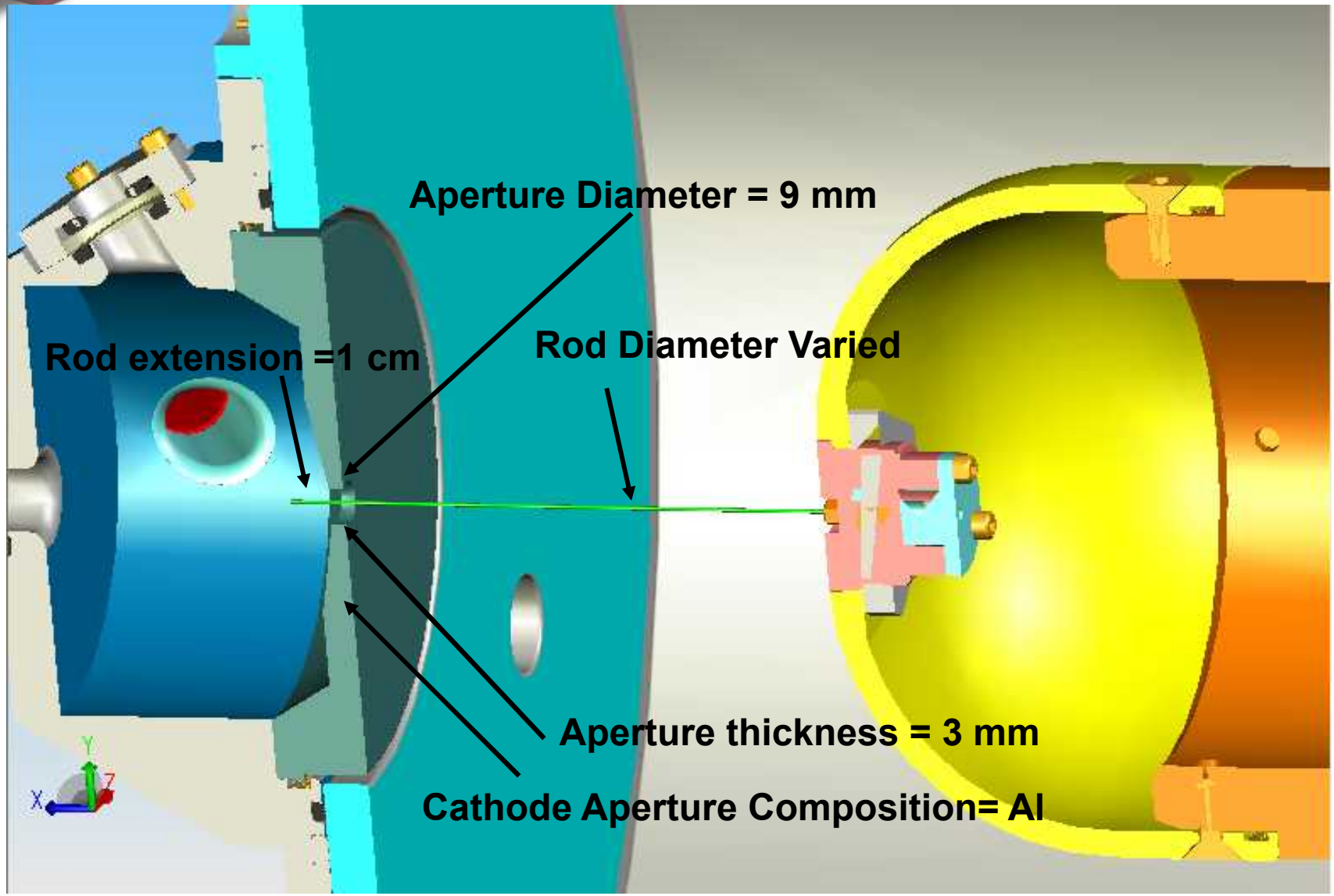
Standard Rod Pinch Diode Configuration

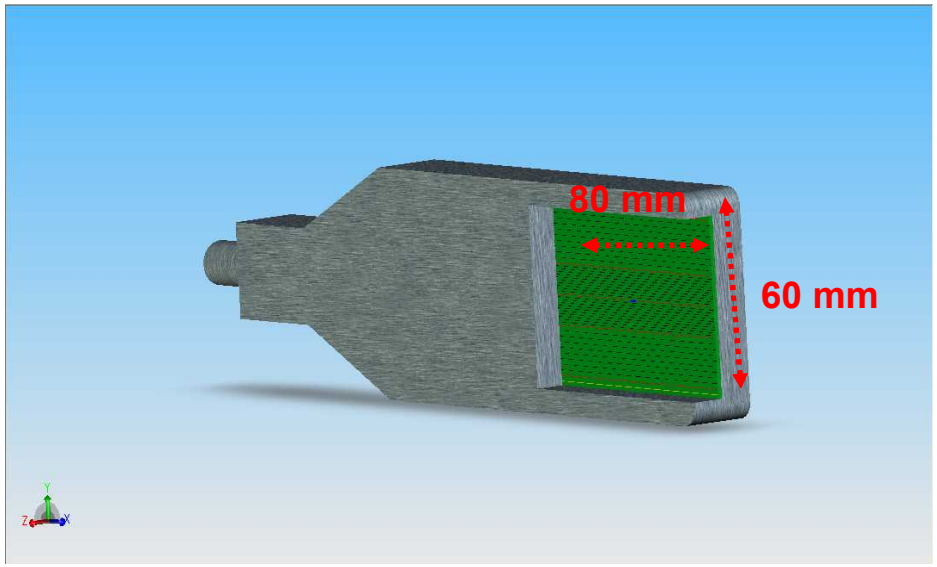


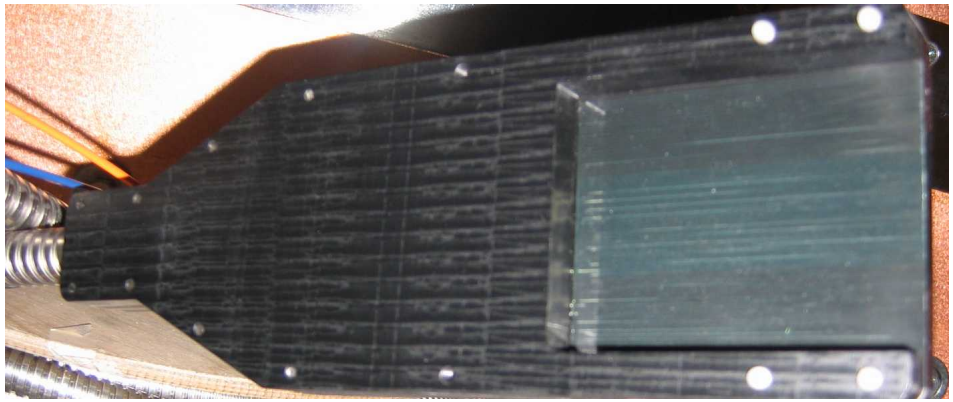
Cygnus Shot Matrix, TRSD Shots

Shot #	Rod Diameter (mm)	Rod Material	Tip Shape	Comments
254		W		LAD for timing on Cygnus 1
255	0.75	W	tapered	first Rp shot on Cyg 2., bad timing. Missed shot
256	0.75	W	tapered	Flat field
257	0.75	W	tapered	first 0.75 mm shot
258	0.75	W	tapered	repeat of 256
259	1.00	W	blunt	first 1 mm needle
260	1.00	W	blunt	repeat of 259
261	1.50	W	blunt	Largest needle used
262	1.50	W	blunt	repeat of 261
263	1.50	W	blunt	Flat field. Larger rods needed new FF
264	1.00	W	blunt	Contact shot
265	0.50	W	blunt	Cyg 1 small diam. Rod
266	0.50	W	blunt	Repeat of 255, small diameter rod

Description of The Time Resolved Spot Size Diagnostic (TRSD)

- The TRSD consists of 90 scintillation fibers (BC-20, 3ns response), 80mm in length with a 250u diameter, bimodally spaced across 60mm
- The fibers are then coherently coupled to a streak camera by a fiber optic bundle.
- Cost, including Streak Camera and CCD ~350k





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Standard Cygnus RP TRSD Configuration

TRSD Welded on RP diode on Cygnus-1.

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