EOS-BPM FY22 Progress and Plans for FY23

FACET-II PAC Meeting

Christopher Doss, Claire Hansel, Henrik Ekerfelt, Claudio Emma,
Spencer Gessner, Michael Litos, October 2022

U.S. DEPARTMENT OF ENERGY
Office of Science

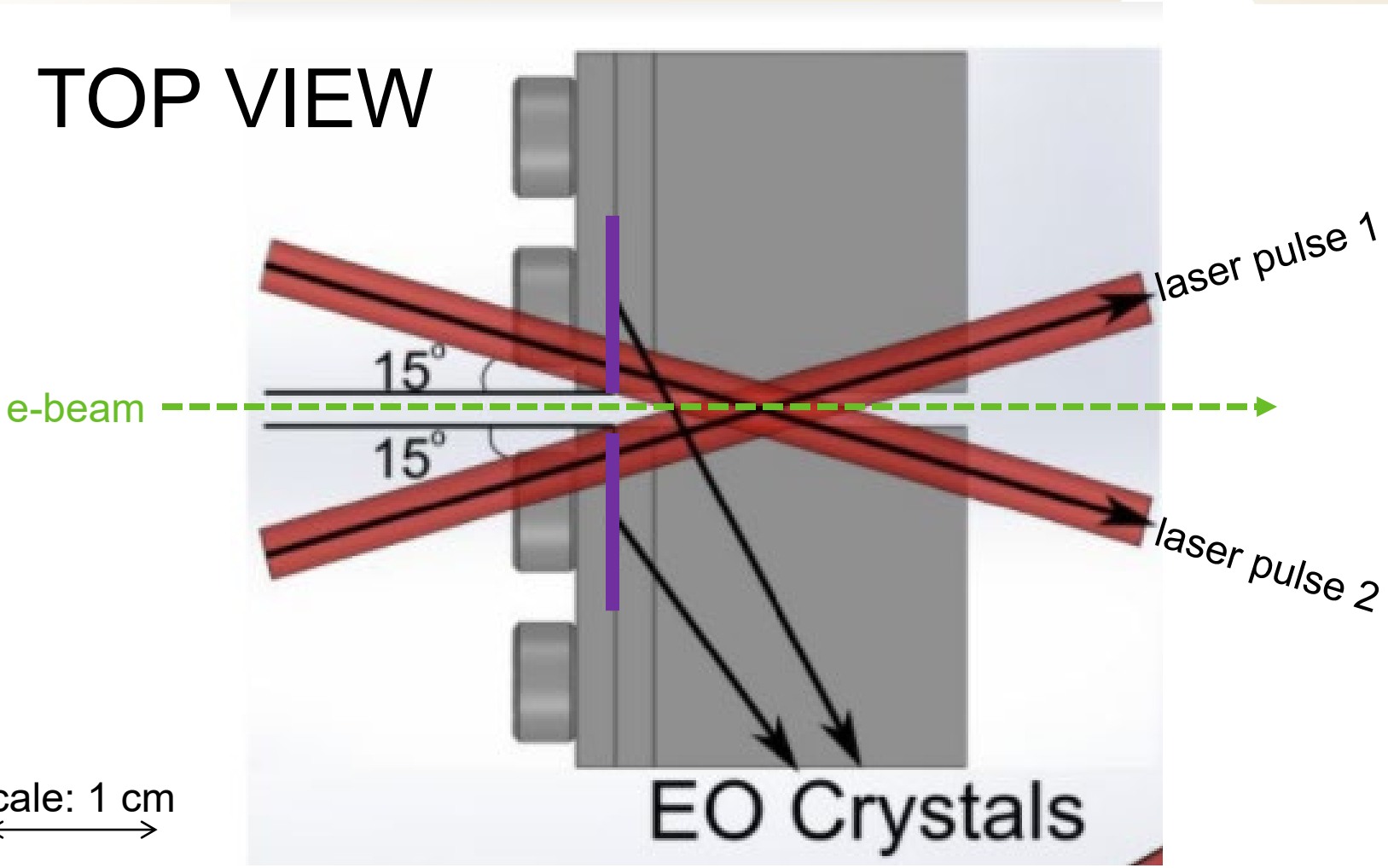
SLAC NATIONAL ACCELERATOR LABORATORY

EOS-BPM Overview

SLAC

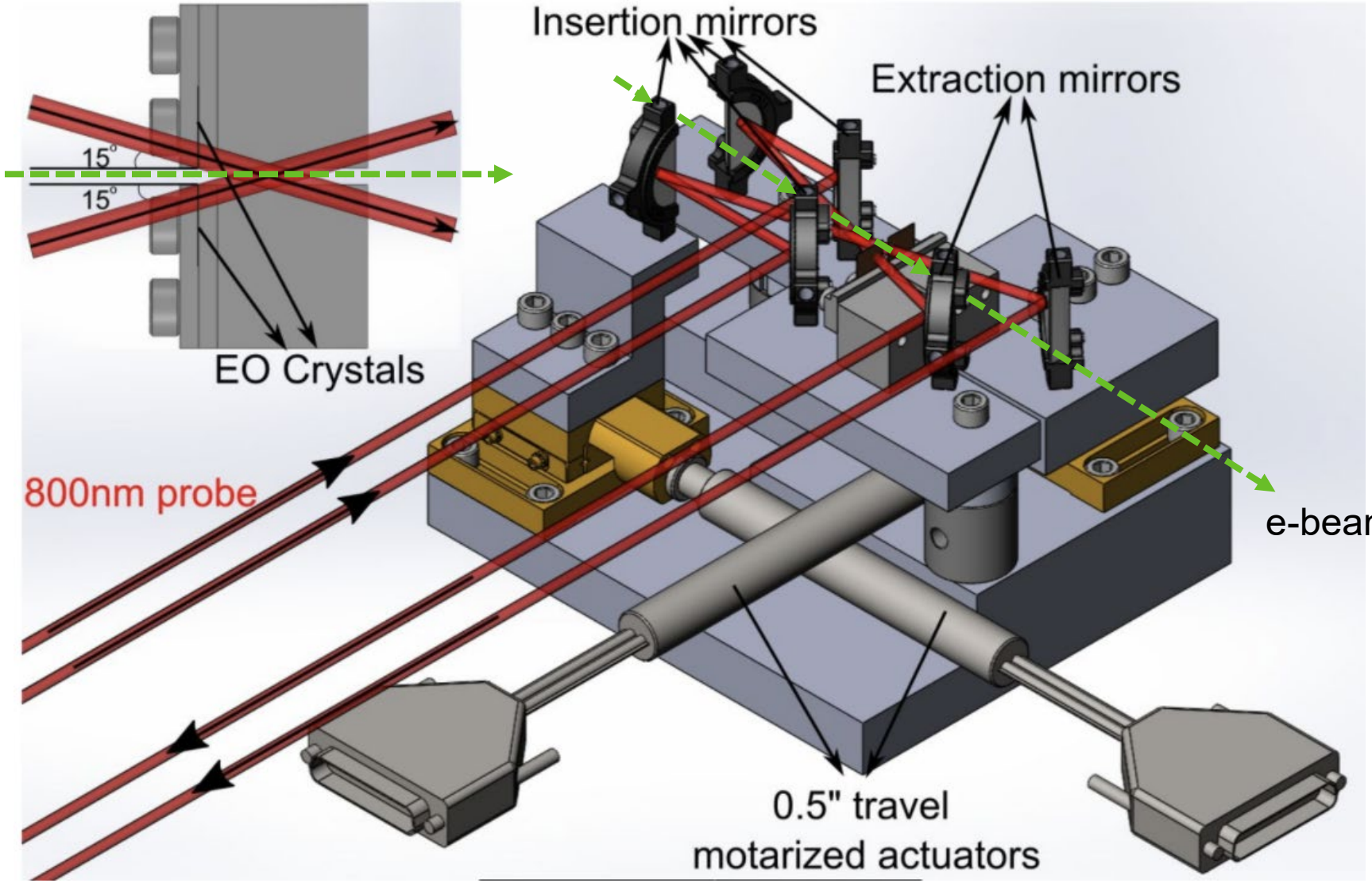
- Goal of EOS-BPM is to provide a non-destructive tool for measuring both transverse and longitudinal beam positions for each bunch on a shot-by-shot basis.
  - Theoretical Transverse Resolution of 1 μm
  - Theoretical Longitudinal/Temporal Resolution of 10 fs.
- A laser pulse within an EOS crystal will have its polarization rotated if the EOS crystal is also within the electric field of a passing electron bunch.
- One crystal can give info on bunch charge and timing
- Two crystals allows for the two signals to be compared, allowing for femtosecond time-resolved BPM capabilities.

EOS-BPM Hardware



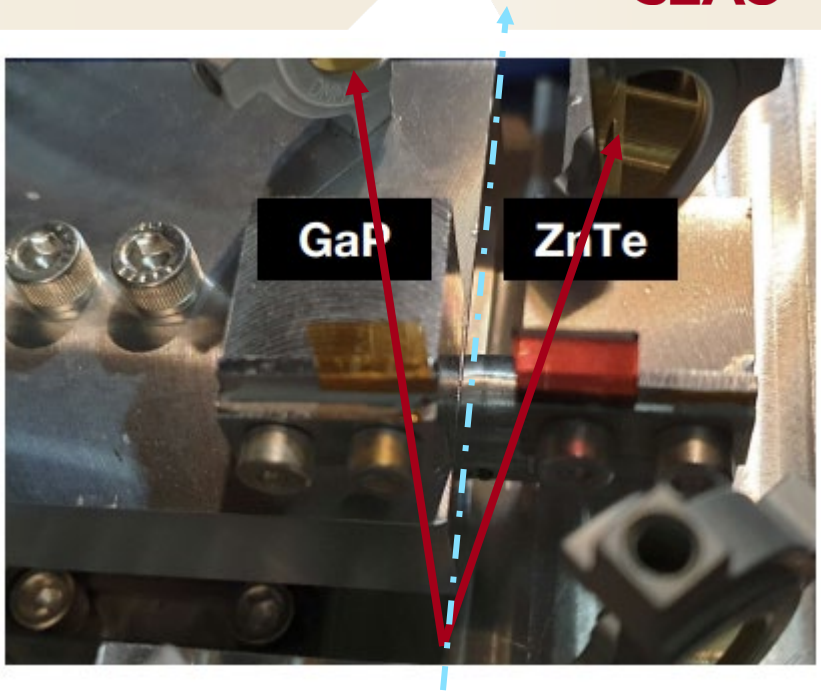
EO Crystals: 1cm x 1cm in transverse plane, 1-5 mm from e-beam axis

EOS-BPM Hardware



Installed for the Summer Run

- One 1mm thick ZnTe crystal
  - High-Signal, Low-Resolution
- One 100 um thick GaP crystal
  - Low-Signal, High-Resolution
- Right: laser paths in red and e-beam path in blue dashed.



- Cameras detect polarization rotation of the incoming probe laser due to the strength of the e-beam's electric fields.
  - Signal position on camera corresponds to the timing between the laser and e-beam.

Timeline

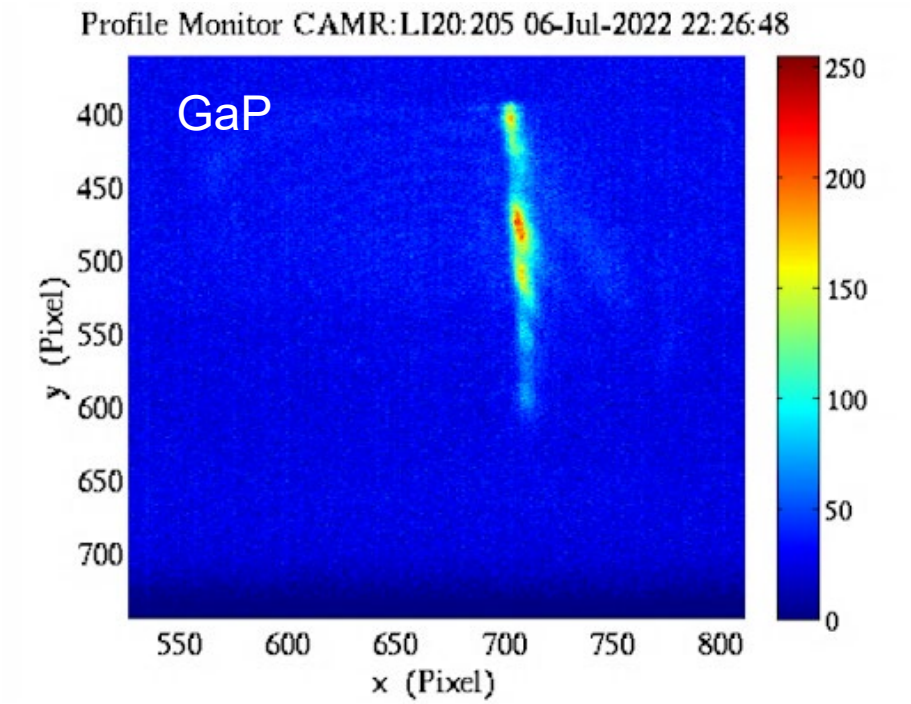
- ZnTe installed in “EOS1” – March 15th
- Failed t0 shift with only EOS’s ZnTe – May 11th
- Axilens plasma t0 shift – June 10th
- ZnTe t0 shift – June 16th
- GaP installed in “EOS2” – June 27th
- GaP t0 shift – July 6th
- TCAV jitter study with GaP EOS – July 12th

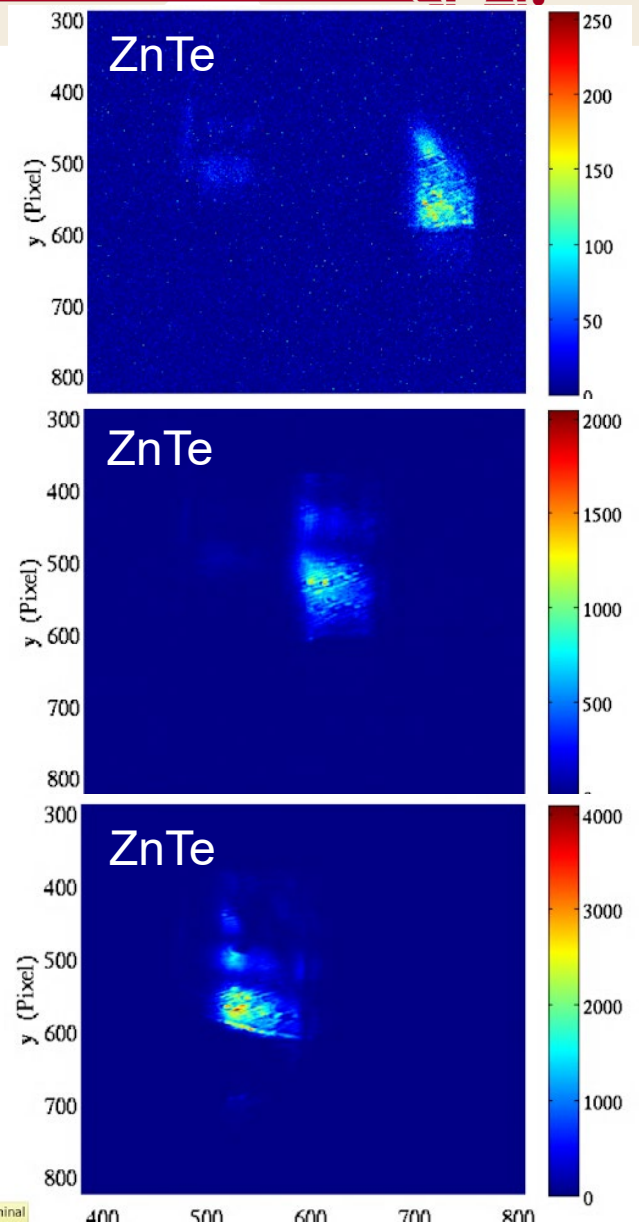
…

- Installation of two GaP crystals – By December
- Commissioning of ‘BPM’ capabilities – By December

ZnTe and GaP Raw Data

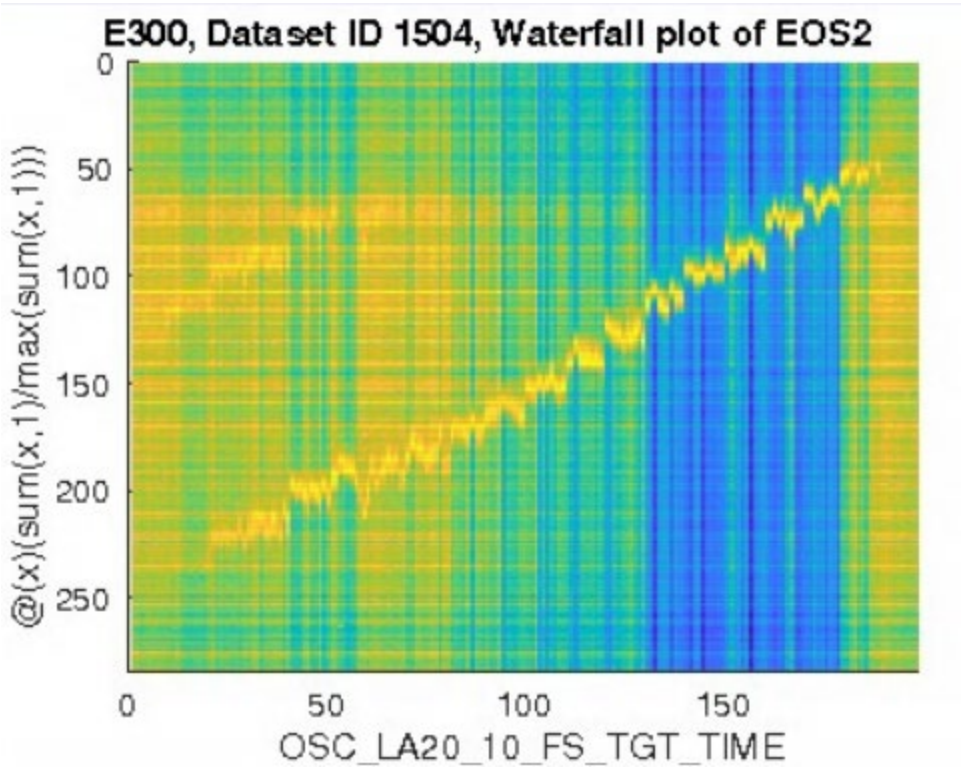
- EOS signal window is 4 ps wide on the ZnTe crystal.
  - Right: e-beam signal with laser arriving earlier (top) to later (bot).
- Signal on GaP is more narrow (below)



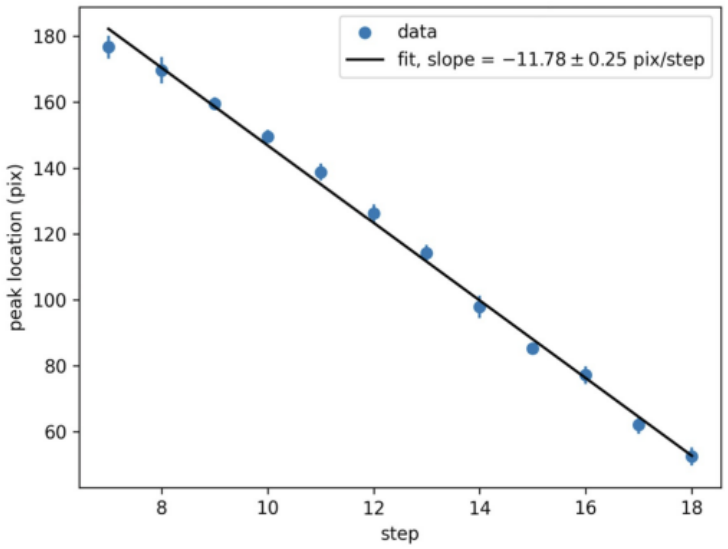


Timing Calibration Study

Left image shows the stripe position on the GaP when we vary the laser timing using a digital. Right image fits this to a timing calibration. Across longer timescales, e-beam laser timing jitters by 48 fs rms.



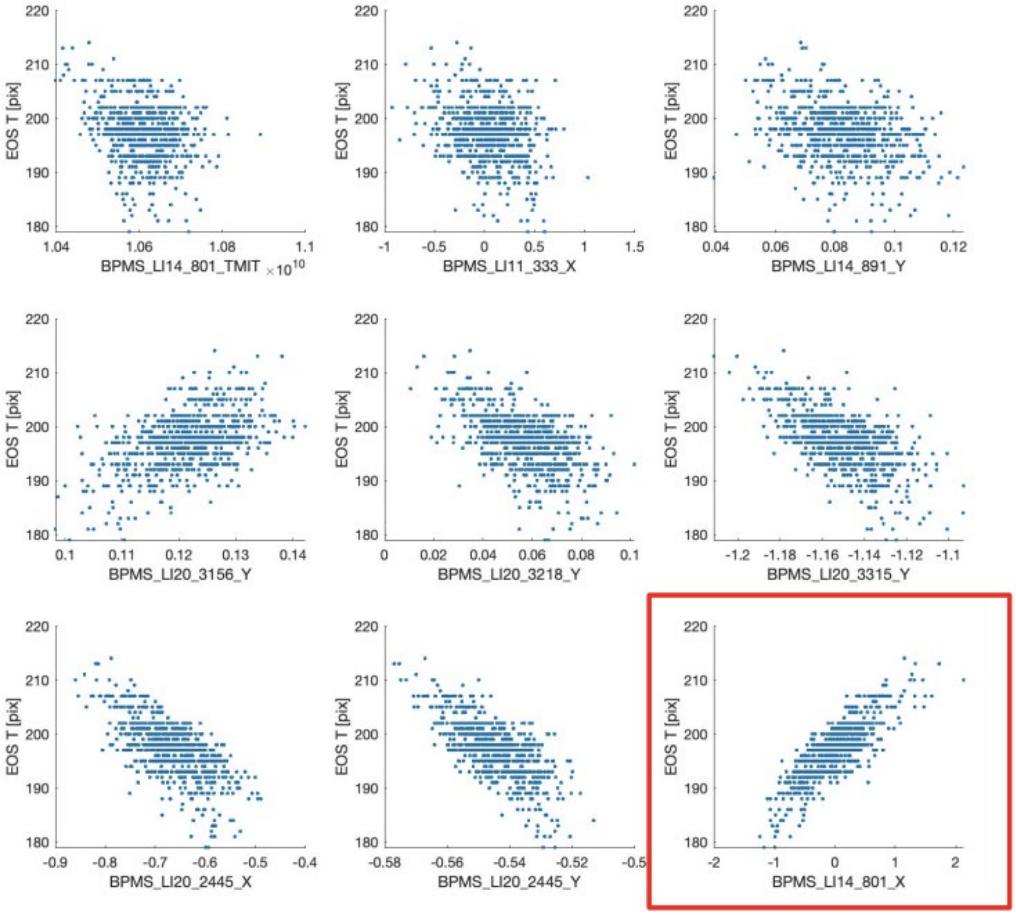
- Femtosecond-to-Pixel Conversion Factor
  - 18.26 ± 0.38 fs/pix



Correlation between EOS and upstream PVs (C. Emma)

SLAC

- EOS timing has been used to investigate sources of ToA jitter.
- Right: correlation plots between EOS (y axis) and various PVs.
- Strong correlation with energy BPMs but also horizontal and vertical BPMs in LI14/LI20
  - Dispersion leaking out of compressors?



EOS Goals Going Forward

- Continue supporting FACET-II user experiments with the ‘EOS’ aspect by measuring the shot-by-shot relative timing between the laser and the electron beam.
- Commission the ‘BPM’ aspect after installing two GaP crystals by being able to measure transverse offset of an electron beam and comparing to existing BPM’s.
- Improve analysis tools and make such software available to users.
- Demonstrate capabilities of resolving the longitudinal separation between drive and witness bunches in two-bunch operation.

Thanks!

SLAC

Any Questions?

Publications, Collaborators, Funding

Publication on the EOS-BPM Design:

Hunt-Stone, K., Ariniello, R., Doss, C.E., Lee, V., and Litos, M.D., *Electro-optic sampling beam position monitor for relativistic electron beams*, Nuclear Instruments and Methods in Physics Research Section A, Vol. **999**, 165210 (2021)
https://doi.org/10.1016/j.nima.2021.165210

Collaborators:

Funding Acknowledgements:

U.S. Department of Energy grant number DE-SC0017906

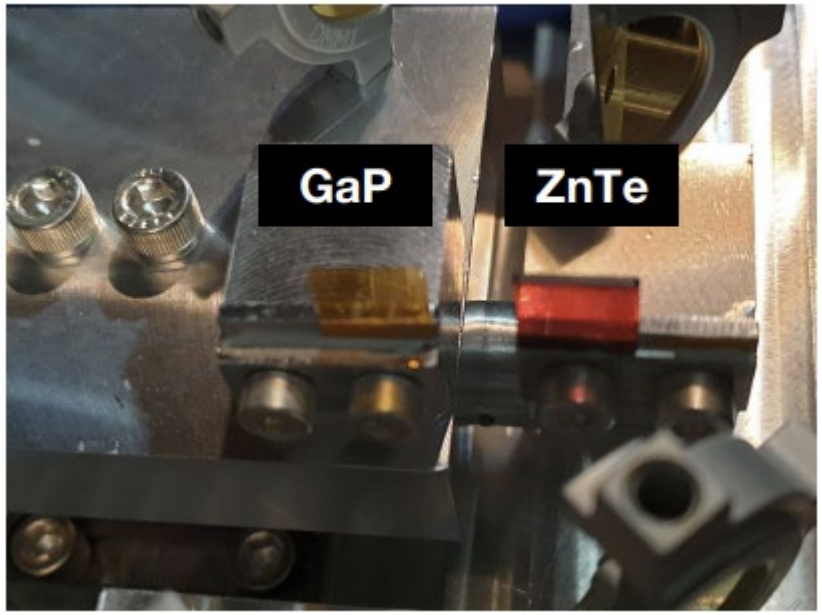
Picture of EOS-BPM Mounts and Crystals

Photo of the current mounts of the EOS-BPM (right).

Looking at how we can change the mounting of the crystals to better protect them from nearby work.

Since this picture was taken, the GaP crystal has passed away from a collision with a ball driver…

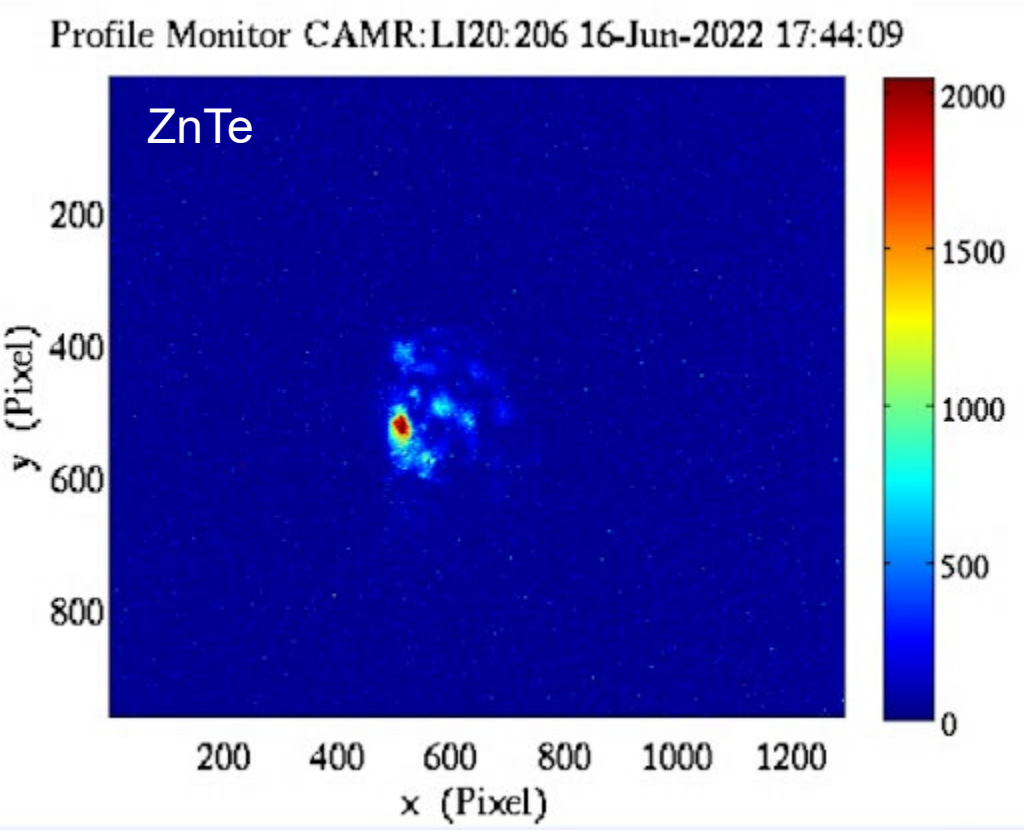
EOS

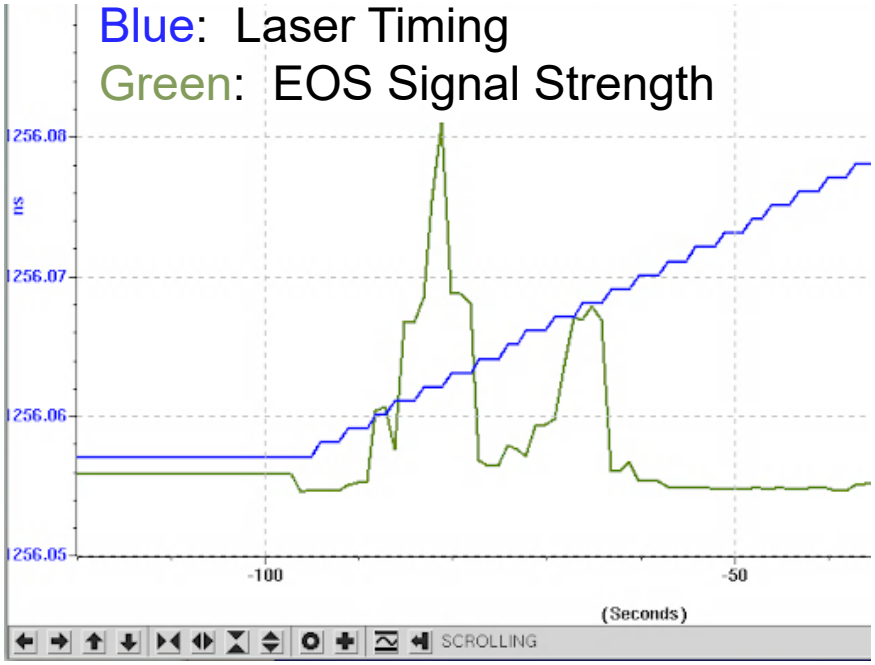


First ZnTe Signals

Left: First EOS signal due to e-beam. This image was with the laser about 0.5 ns after the e-beam.

Right: Timing in the laser using the electronic timing delay.

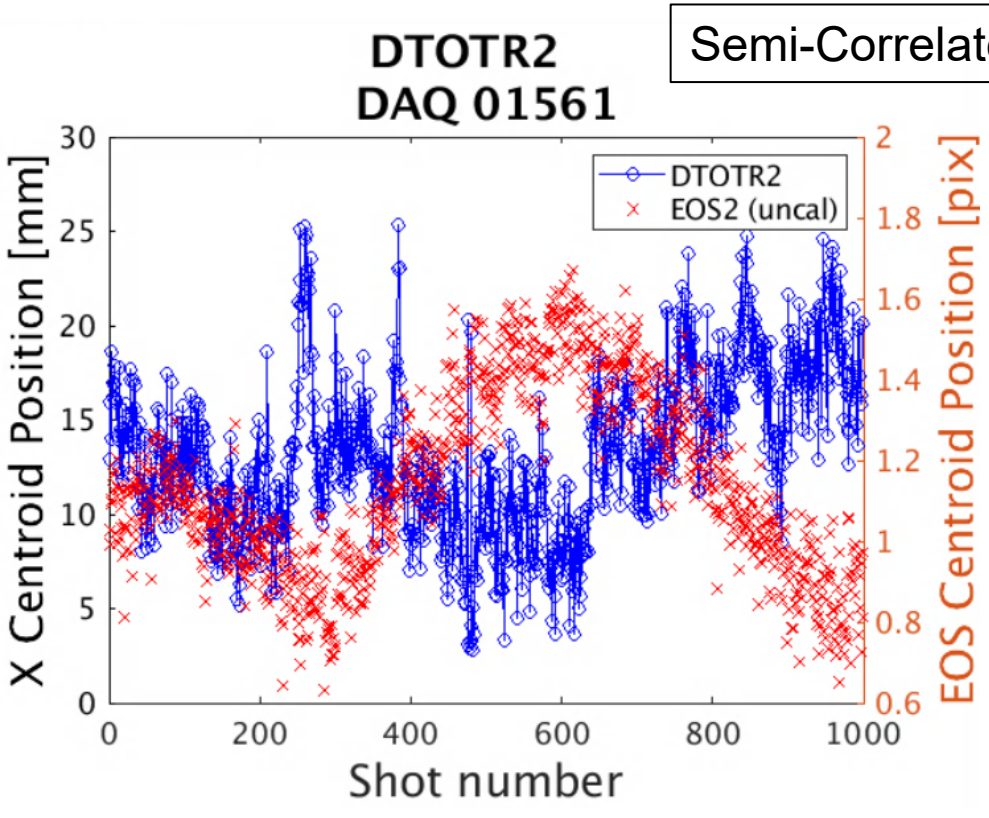


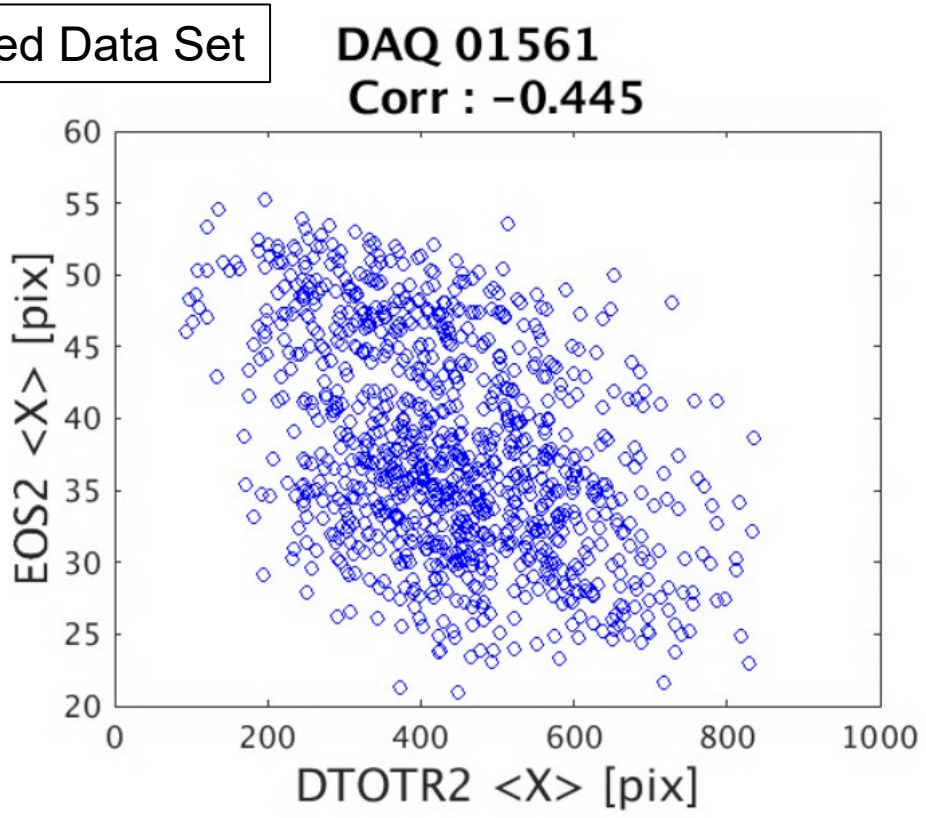


TCAV Phase Jitter Study (1/2)

With the TCAV running and deflecting the beam onto DTOTR2, we attempted to see if there was a correlation between TCAV deflection and TOA at the EOS

Semi-Correlated Data Set

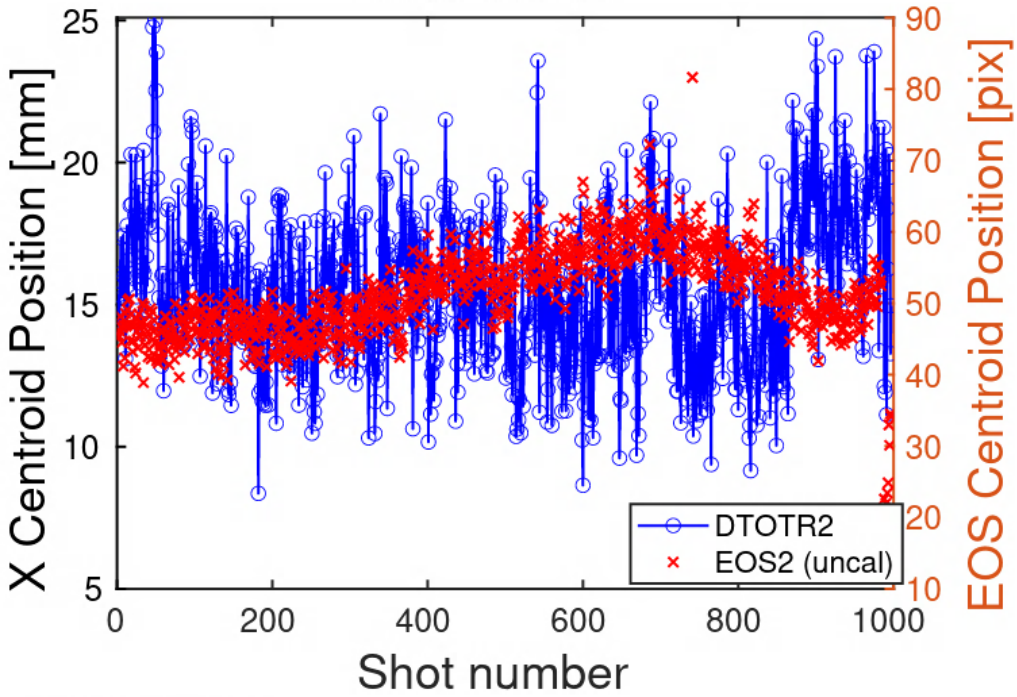


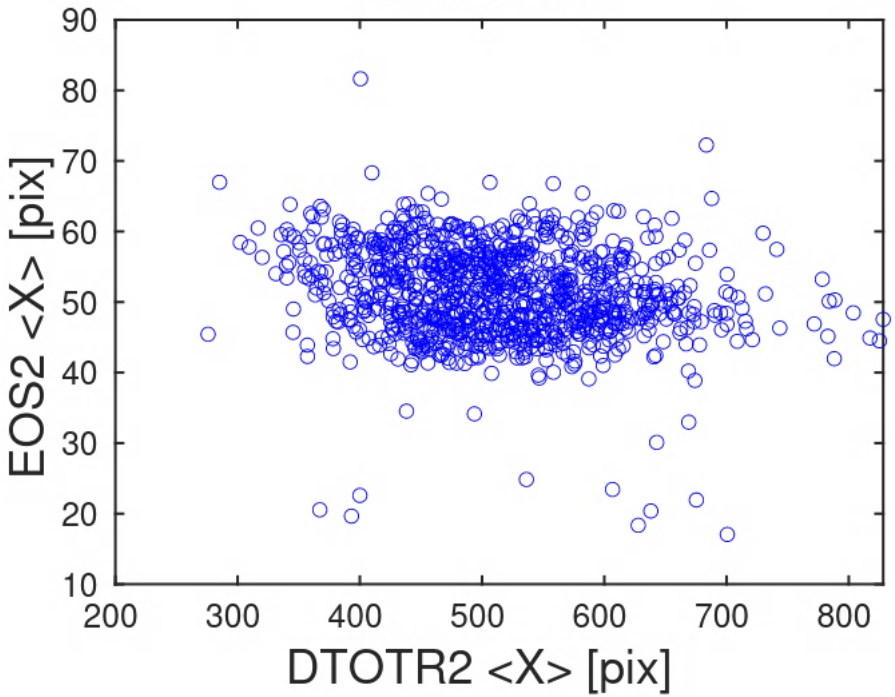


TCAV Phase Jitter Study (2/2)

With the TCAV running and deflecting the beam onto DTOTR2, we attempted to see if there was a correlation between TCAV deflection and TOA at the EOS

Non-Correlated Data Set

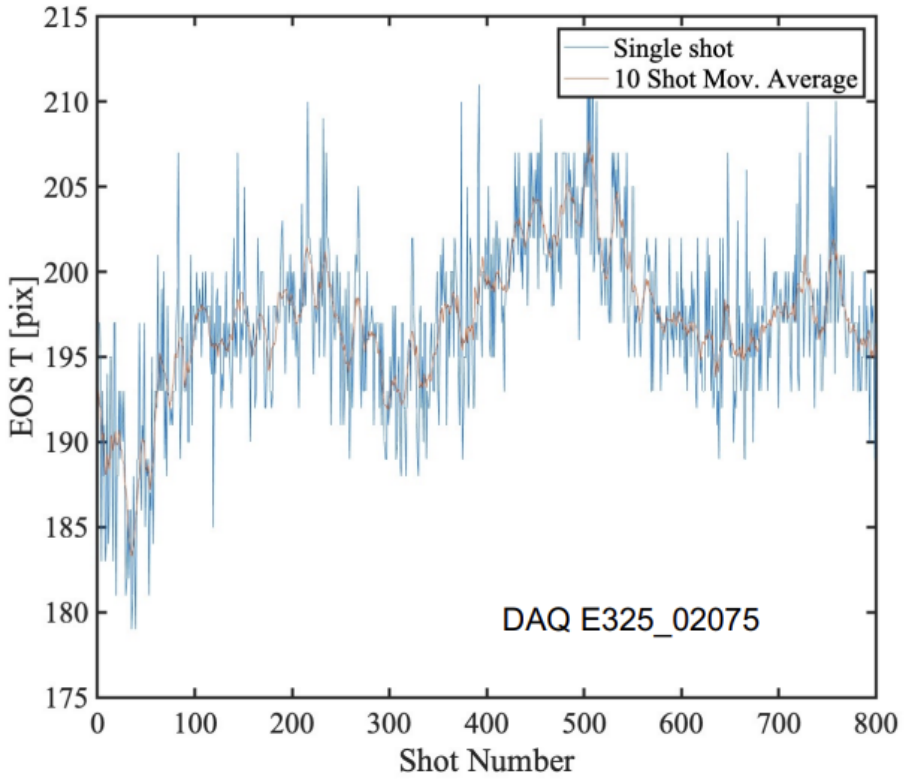


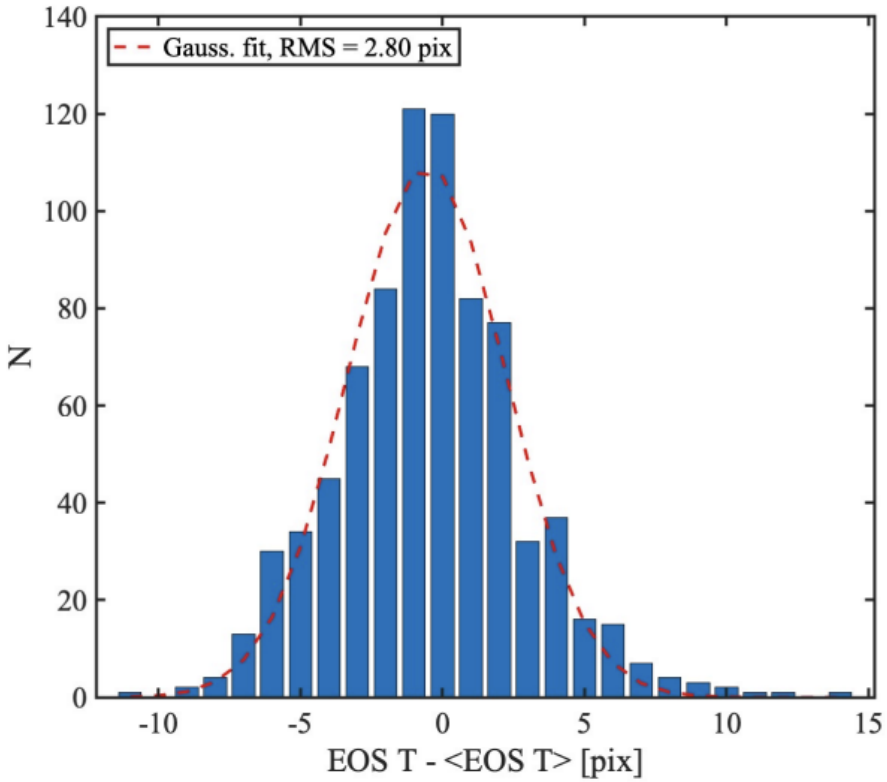


ToA Jitter Study Comparing TCAV to EOS (1/2)

SLAC

Measurement of EOS ToA jitter (C. Emma)

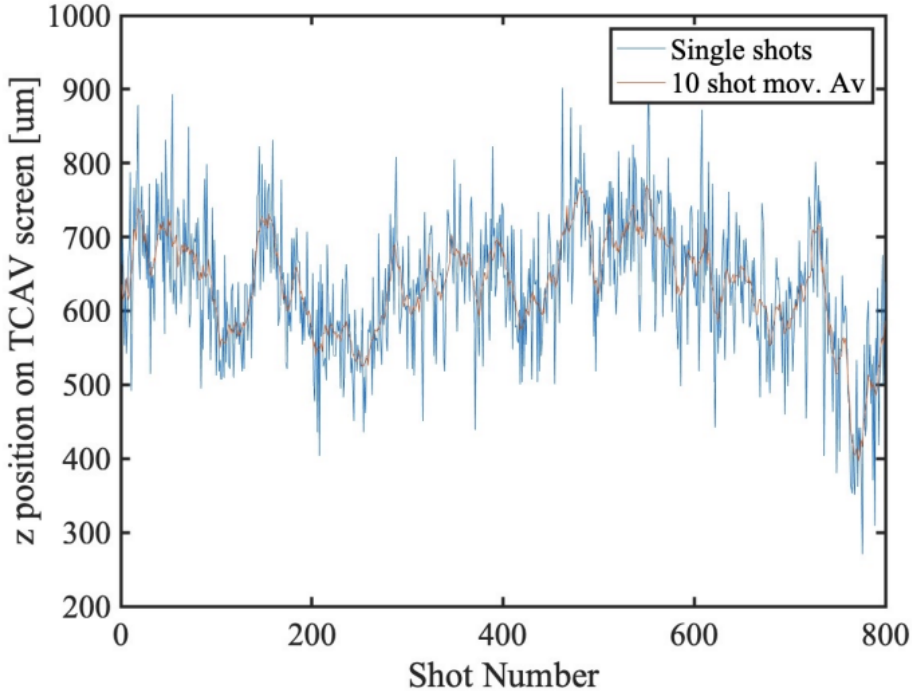


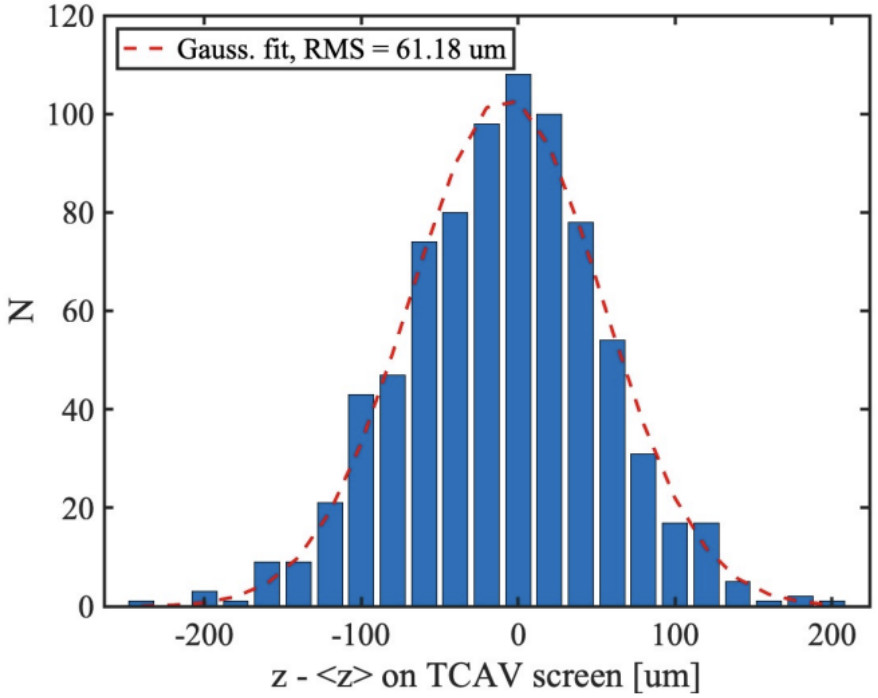


RMS jitter between electron beam and laser = 2.8 pix * 17 fs/pix = 48 fs

ToA Jitter Study Comparing TCAV to EOS (2/2)

SLAC





RMS timing jitter between e-beam and TCAV = 61 um = 200 fs.

That's 4x larger than the laser to e-beam jitter on the same data set

Single GaP Crystal Beamline Separation Study

SLAC

Additionally, we were able to make a collection of datasets with varying GaP – beamline spacing.

Top is ~1 mm to beamline and is much brighter than bottom, ~4.5 mm to beamline.

Had to vary both EOS stage position and electronic laser delay, so data is spread out over multiple shots.