FACET-II | Facility for Advanced Accelerator Experimental Tests

Experimental Area

2019 FACET-II Science Workshop

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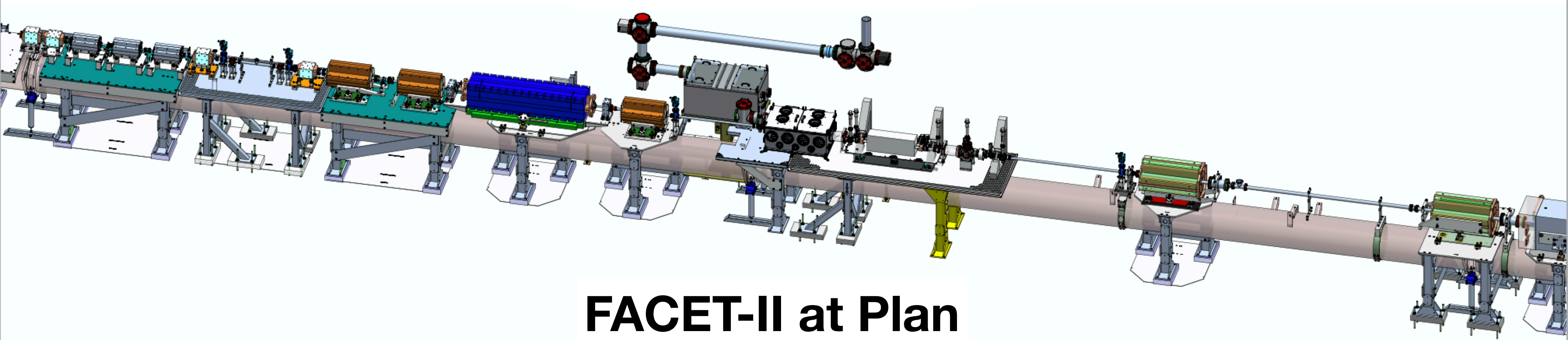
October 29, 2019

U.S. DEPARTMENT OF ENERGY | Office of Science

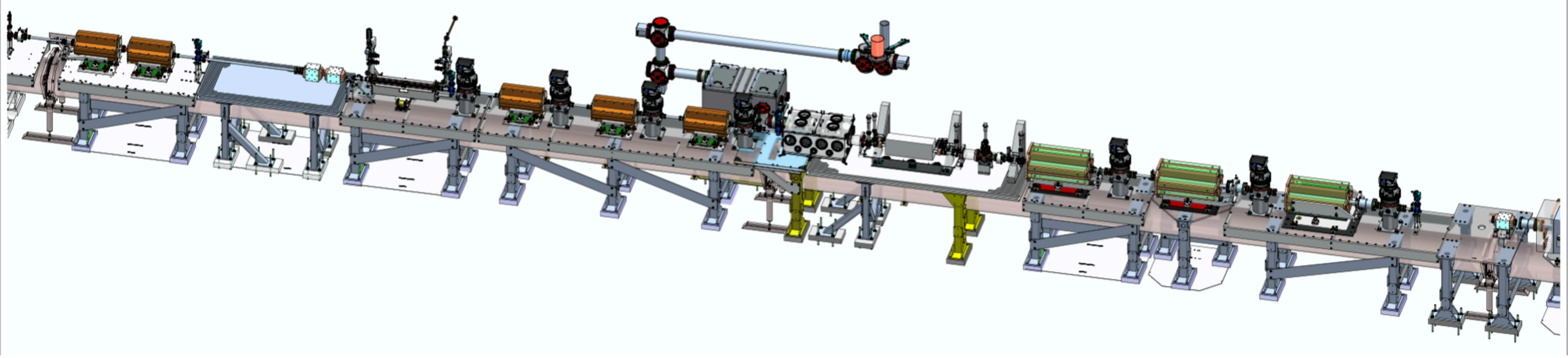
SLAC NATIONAL ACCELERATOR LABORATORY

S20 Beamline Evolution from FACET to FACET-II

FACET-II at Start

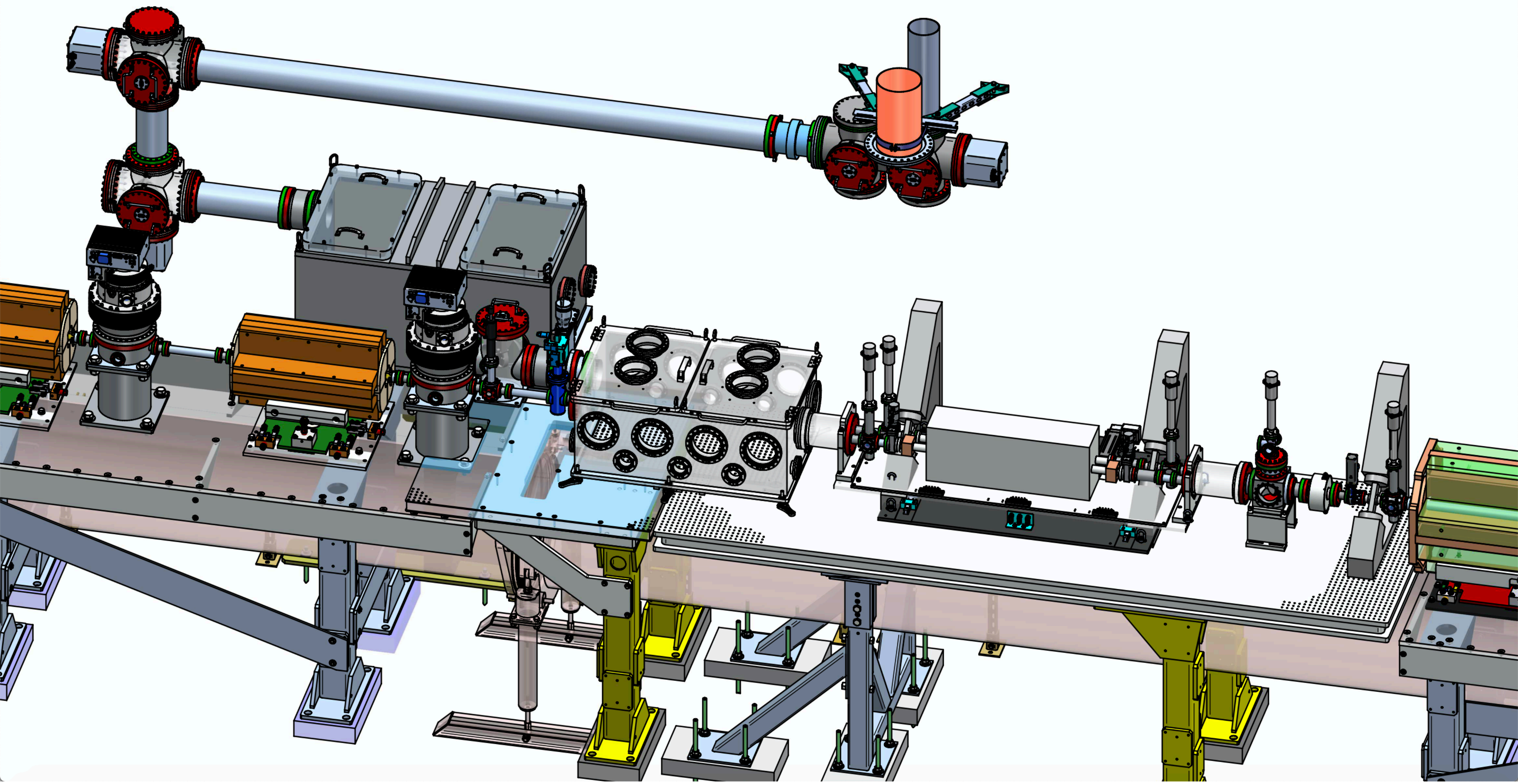


FACET-II at Plan



FACET-II Project and AIPs executed in parallel to commissioning will transition S20 beamline around experimental area (TCAV, FF, Spectrometer)

IP Experimental Area Modifications for FACET-II



Simplified laser transport, larger laser compressor chamber, rotated picnic basket, space for differential pumping

FACET Experiments use different Plasmas: Laser or Beam Field Ionization, "Heat pipe oven" or Gas

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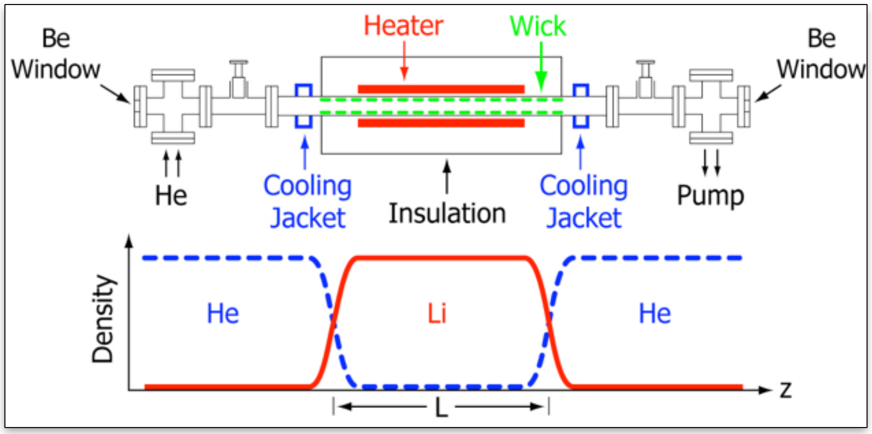
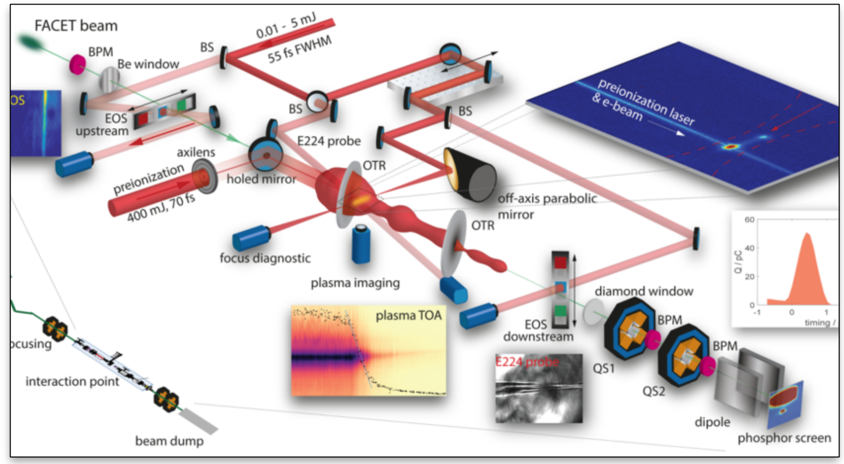
Heat Pipe Oven: Li/He or Rb/Ar Vapor/buffer gas (at same pressure):

- $n_0 = 10^{14}$-10^{17} e^-/cm^3, L = 20-200 cm



Hydrogen, Argon or Mixed Gas Cells:

- $n_0 = 10^{16}$-10^{18} e^-/cm^3, L = 10-100 cm



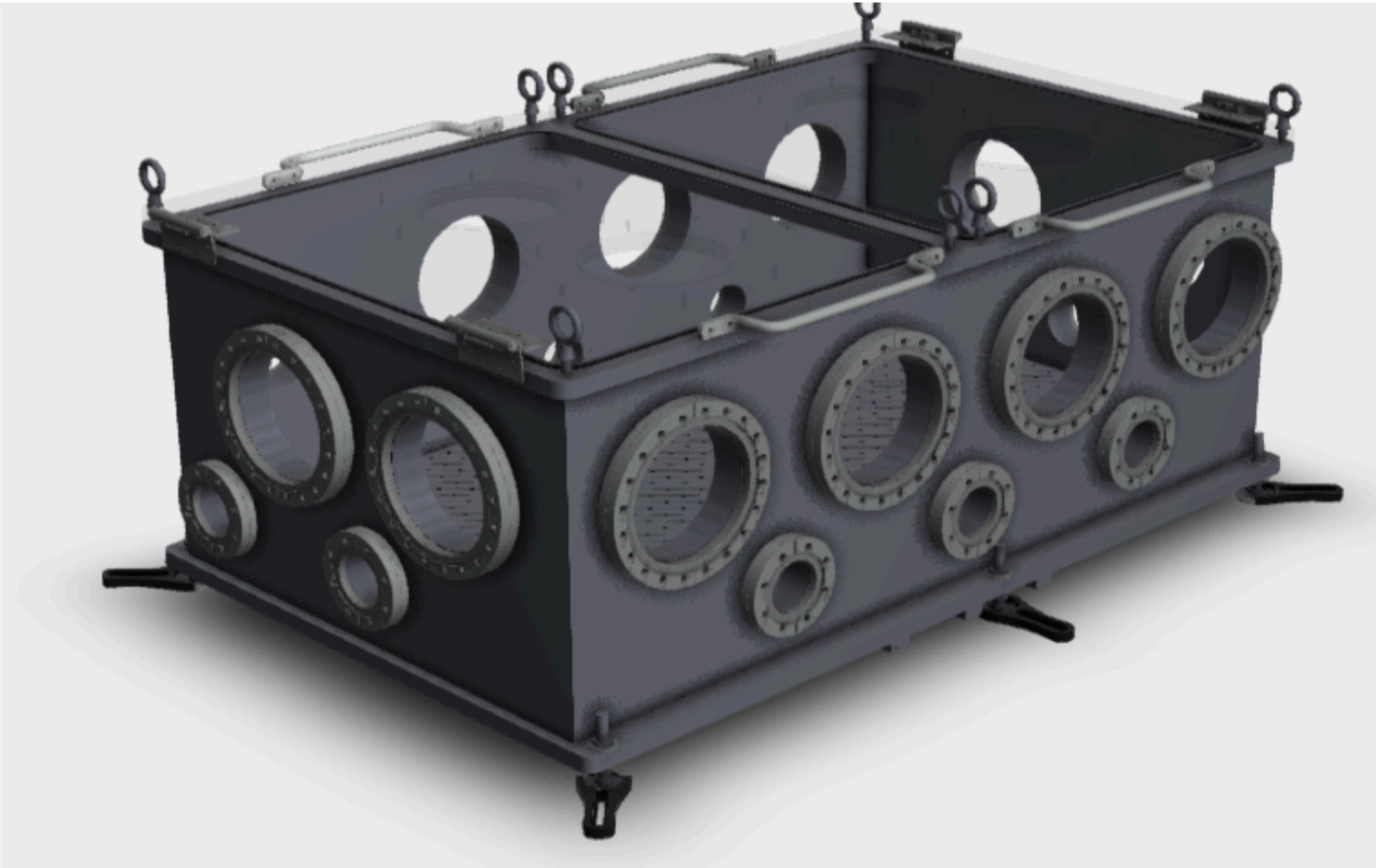
Enabled Many Advances in PWFA Physics:

- 42 GeV E-gain in one meter – ***Nature 2007*** ***(2.7E17, 35 Torr)***
- High efficiency acceleration – ***Nature 2014*** ***(5E16, 5.8 Torr)***
- Multi-GeV e^+ PWFA – ***Nature 2015*** ***(8E16, 9.6 Torr)***
- Hollow Channel e^+ PWFA – ***Nature Communications 2016*** ***(8E16, 9.6 Torr)***
- Wakefield Mapping – ***Nature Communications 2016*** ***(2.5E17, 32.5 Torr)***
- Ionization Injection – ***PRL 2014*** ***(2.7E17 Rb, 16 Torr)***
- High-field Acceleration – ***Nature Communications 2016*** ***(1E18 Ar, 32 Torr)***
- Trojan-horse Injection – ***Nature Physics 2019*** ***(1E17, 3.2 Torr H/He mix)***

FACET-II experiments will require new sources with additional flexibility and control

See presentation by Mike Litos Wed. 11:00AM

‘Picnic Basket’



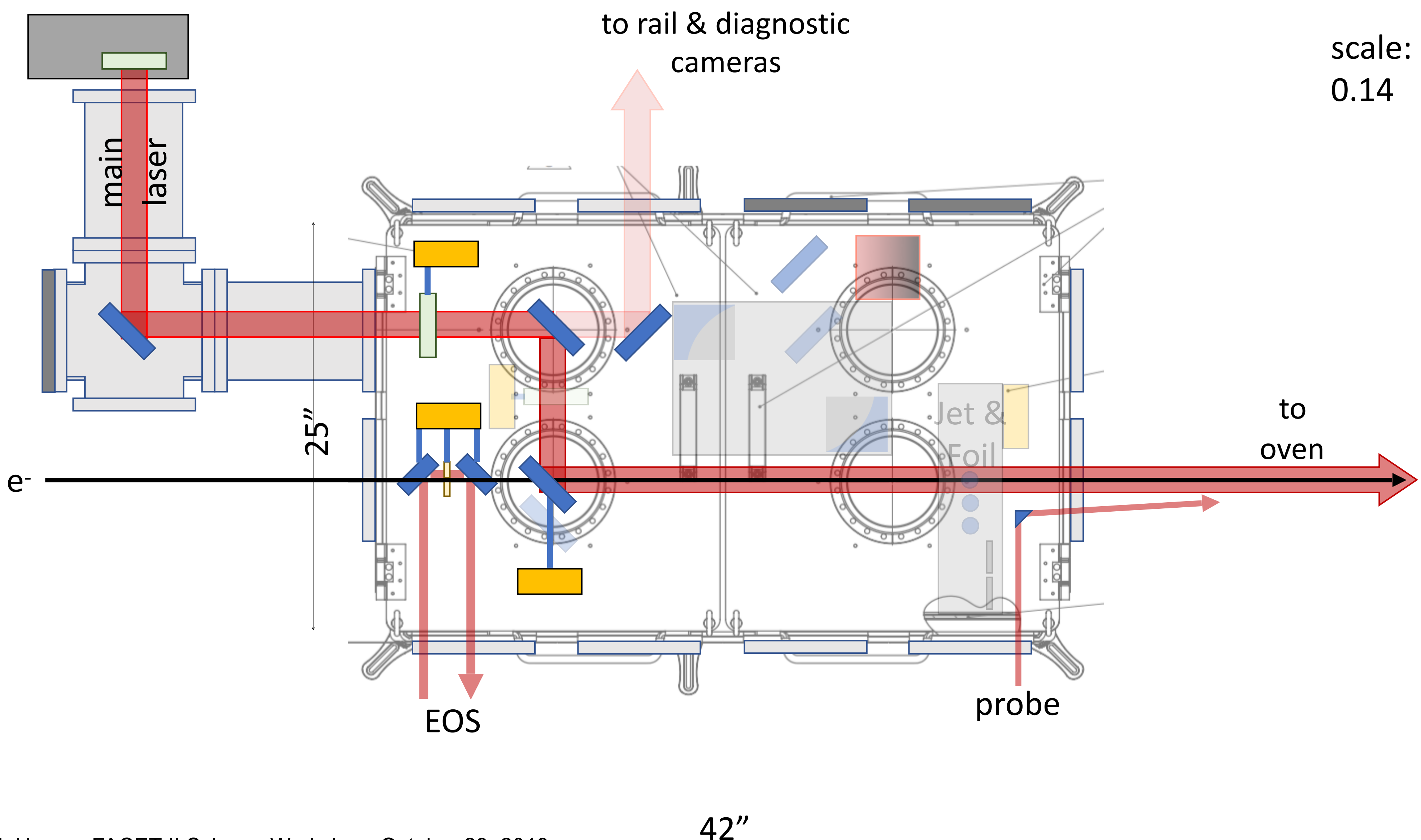
Seven ‘Excellent’ Experiments + 2:

1. E-300 E doubling, pump depletion, low dE/E, preserved emittance
2. E-301 (E300 in Hydrogen)
3. E-302 Transverse Wakefields in PWFA
4. E-303 Positron Generation & Acceleration
5. E-305 Filamentation & Gamma Bursts
6. E-308 Thin plasma lens
7. E-310 Trojan Horse II
8. E-320 SFQED
9. E-324 Plasma Imaging

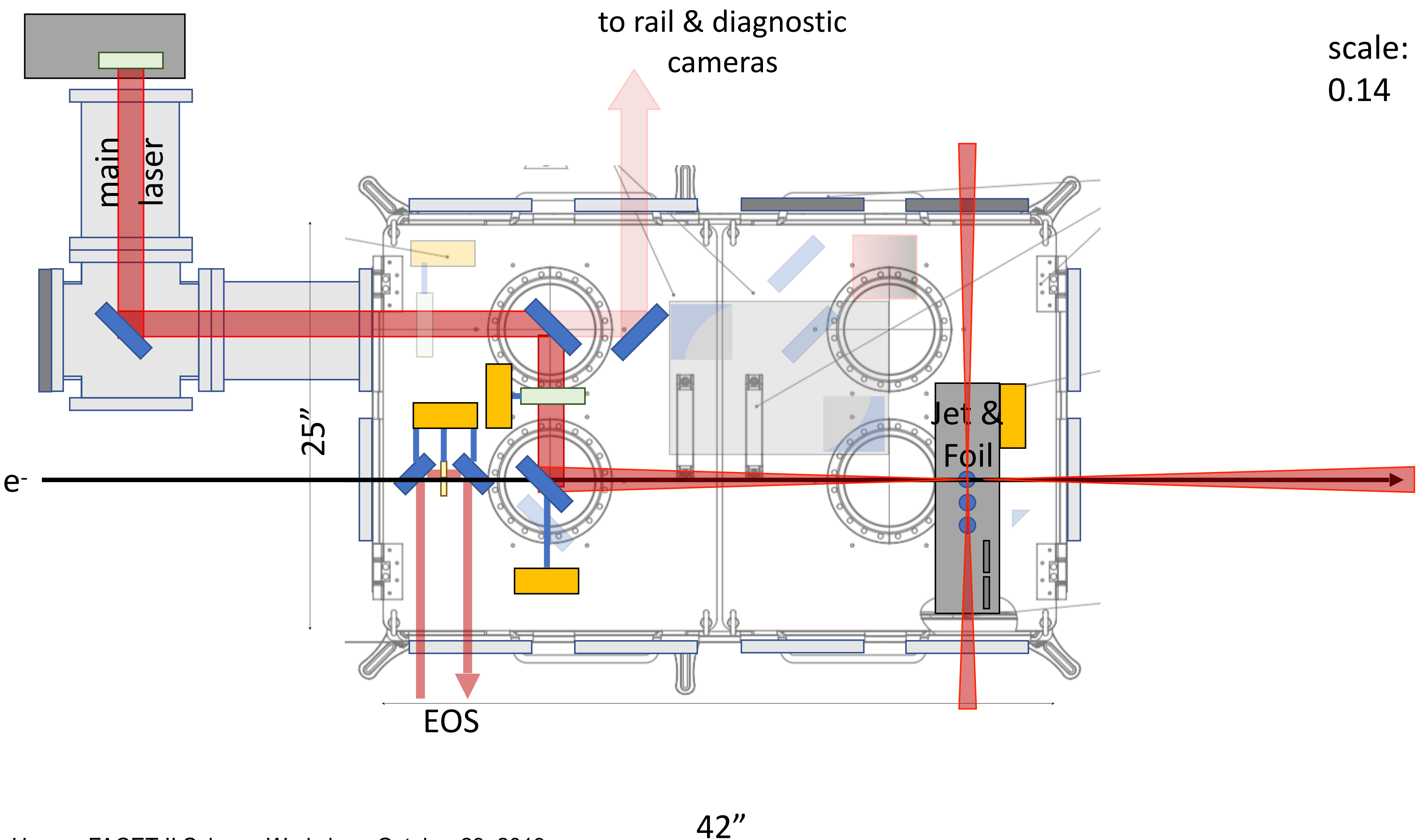
https://portal.slac.stanford.edu/sites/ard_public/facet/newnav/Pages/tf/facet/FACETCurrentResearch.aspx

Efficient utilization of space will be required to accommodate as many experiments as possible with minimal human intervention inside

E300, E301, E302 & E-324

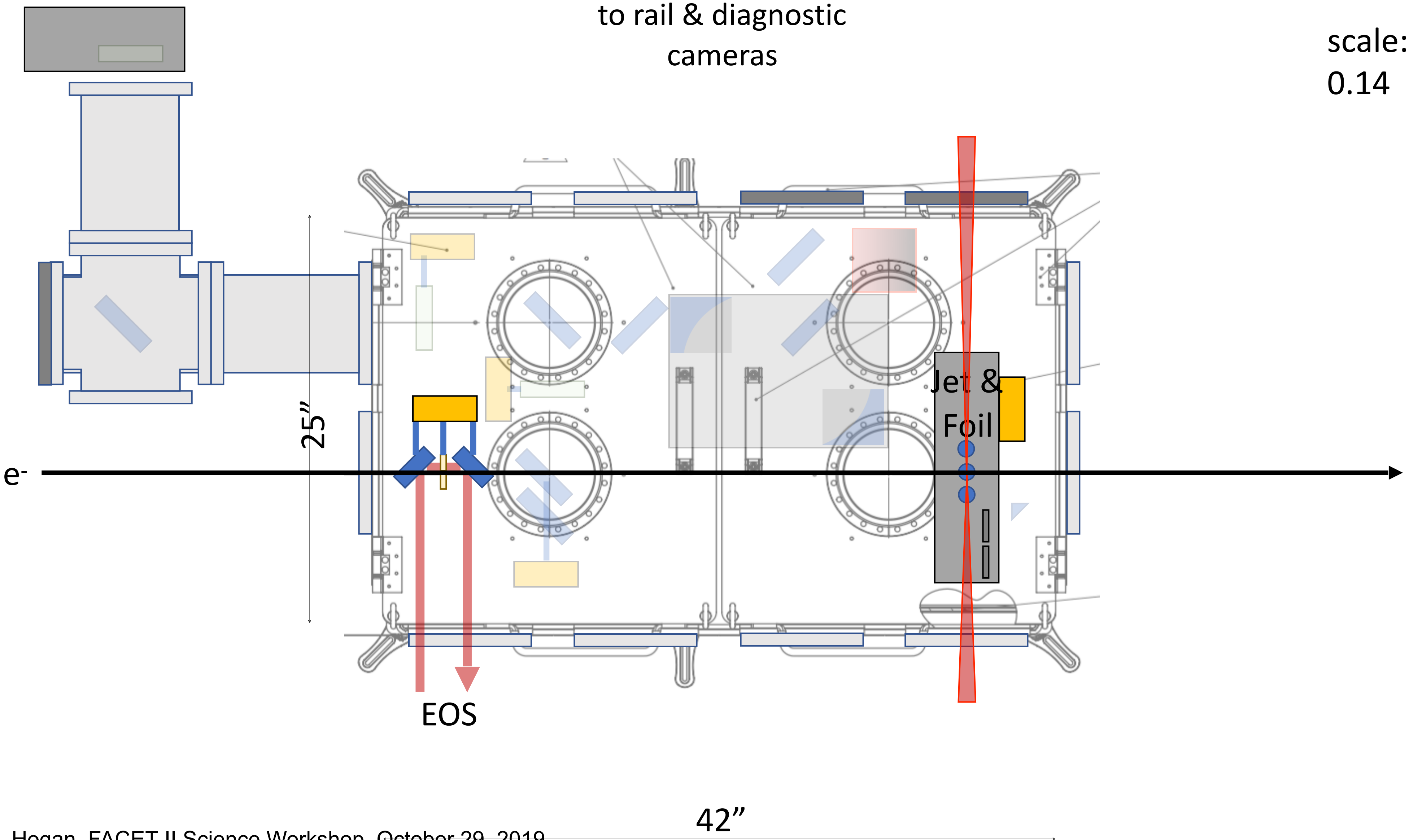


E308

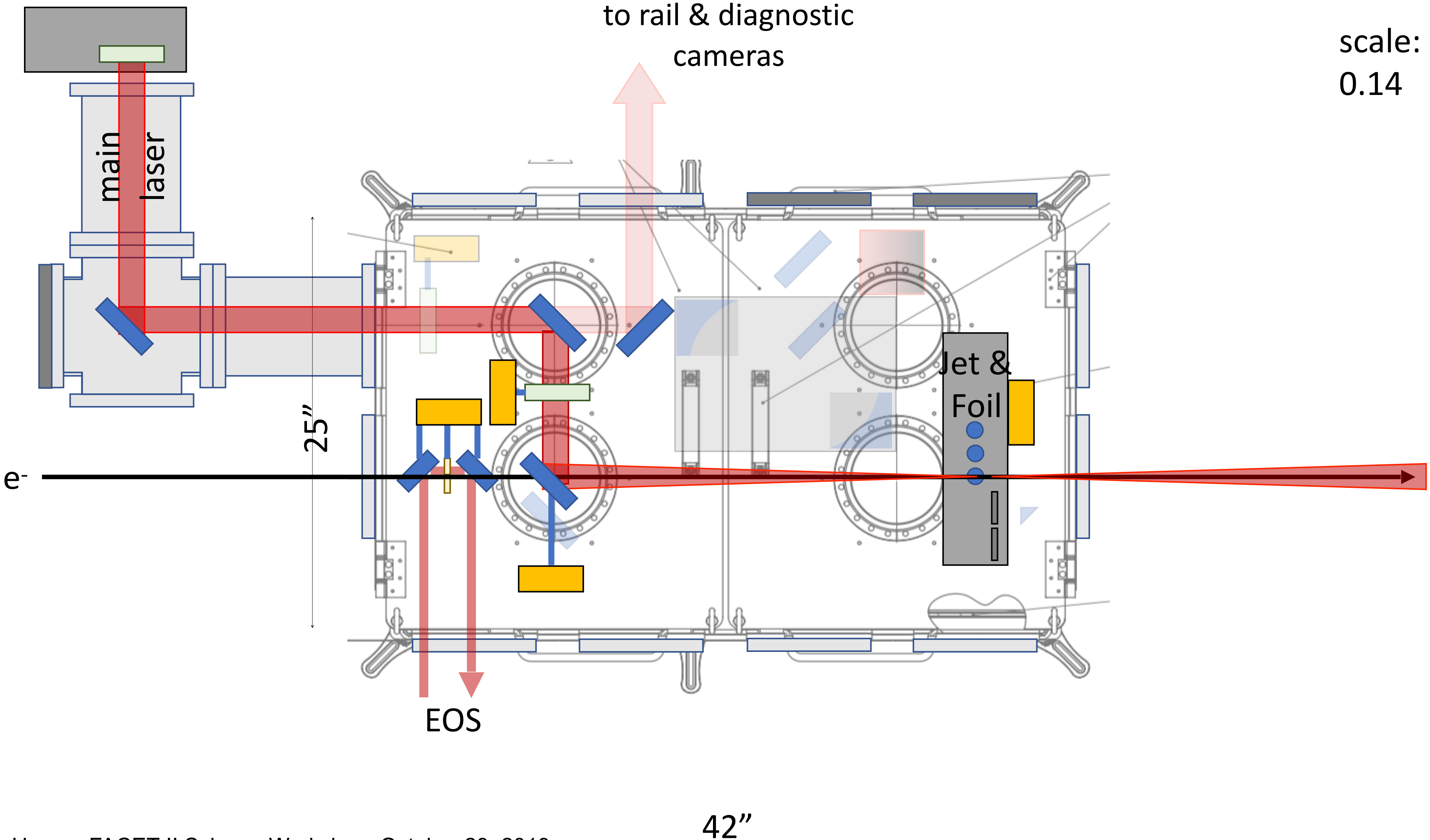


to rail & diagnostic cameras
scale: 0.14
main laser
25"
e-
Jet & Foil
EOS
42"

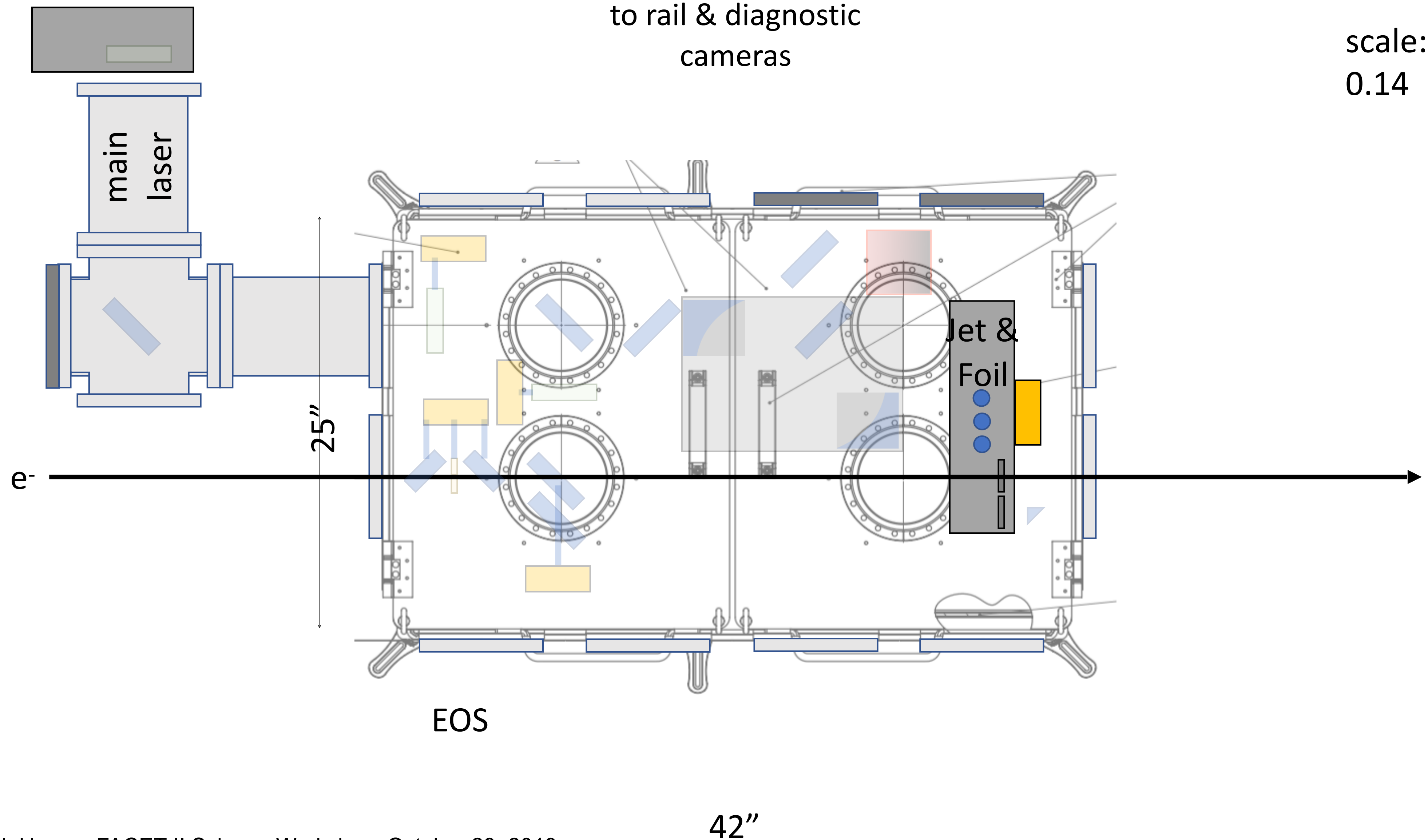
E310



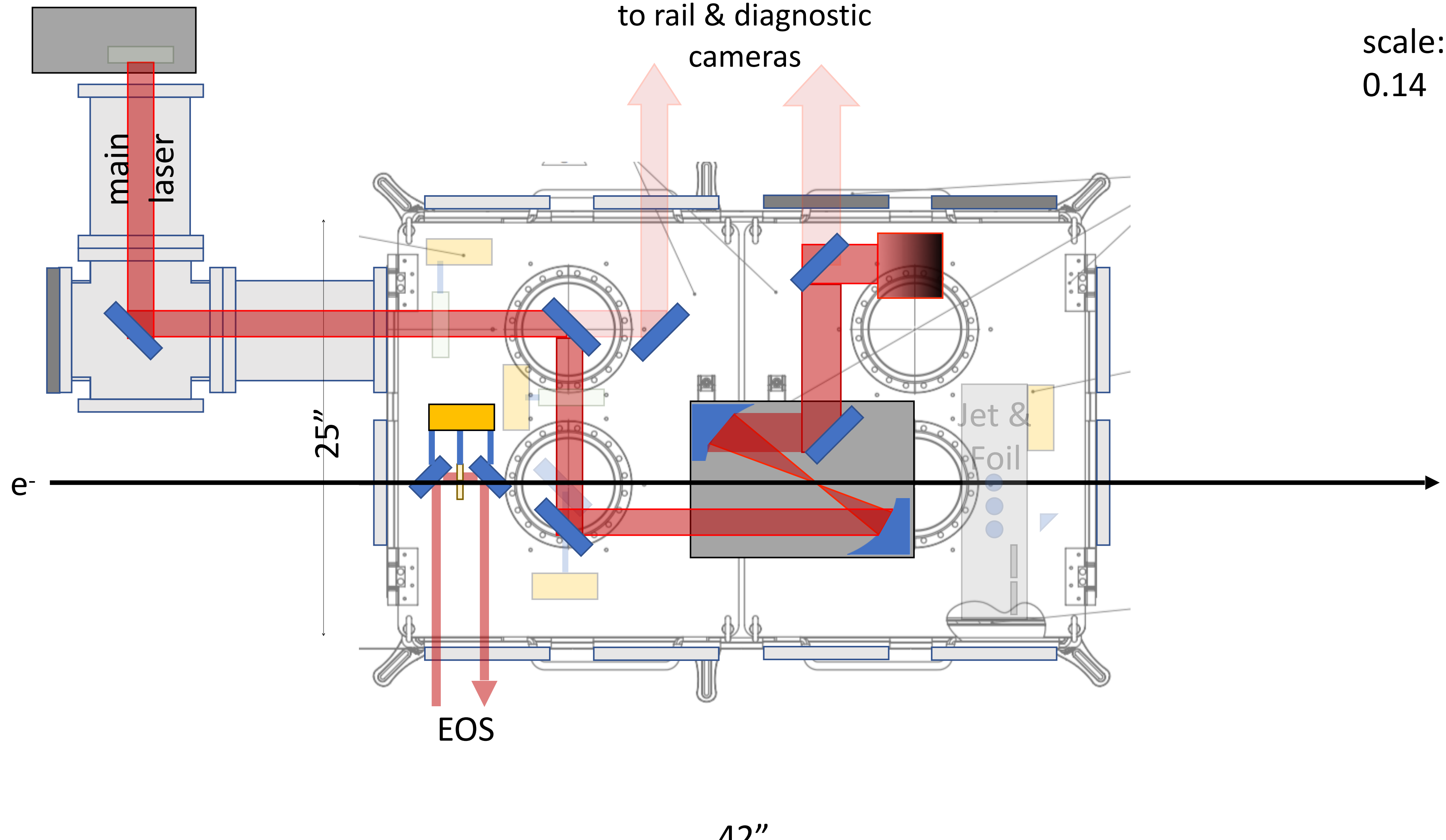
E305 (gas target)



E305 (solid target)

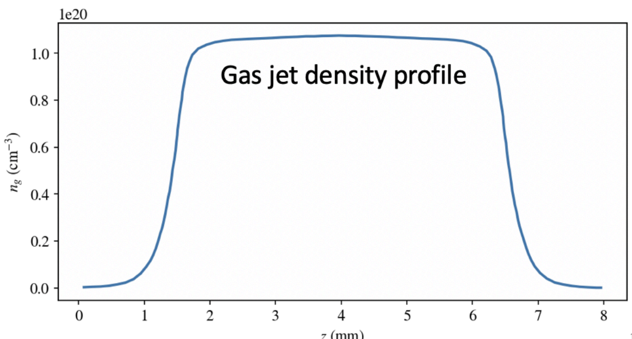


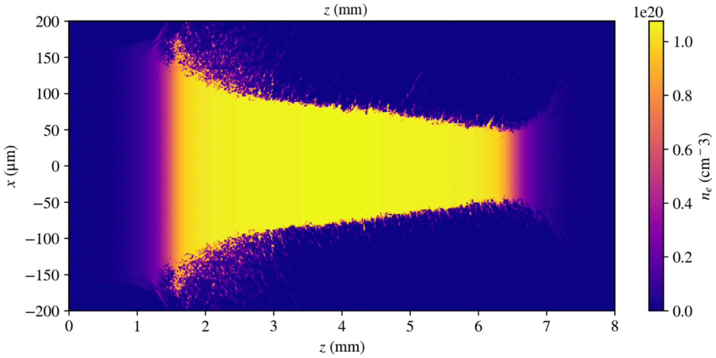
E320

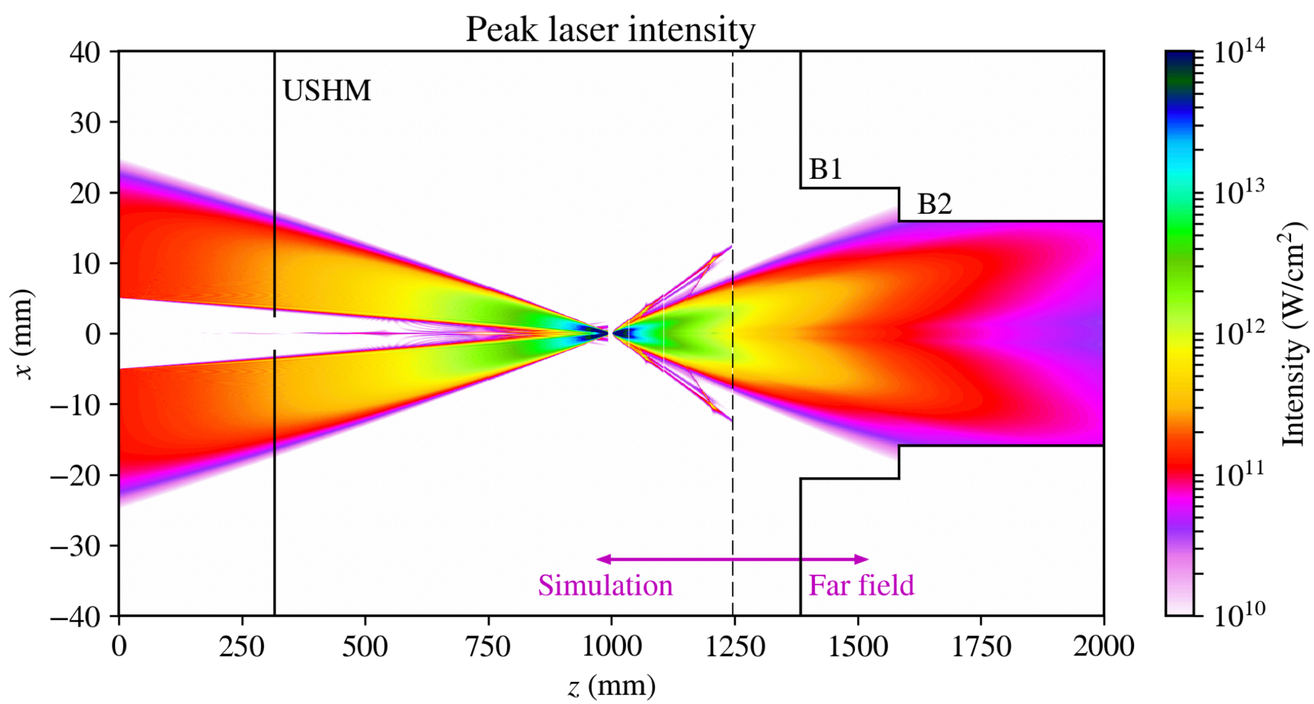

to rail & diagnostic cameras
scale: 0.14
main laser
25”
e-
Jet & Foil
EOS
42”

Safely Dumping the Ionization Laser

- Important to understand where the spent laser goes after ionization for multiple configurations in picnic basket
- Avoids unanticipated ablation and damage to beamline and/or experimental equipment







Building on lessons learned at FACET and utilizing better modeling tools to include important effects like apertures, refraction…

Probe Line Design Will Be Flushed Out in Plasma Sources WG

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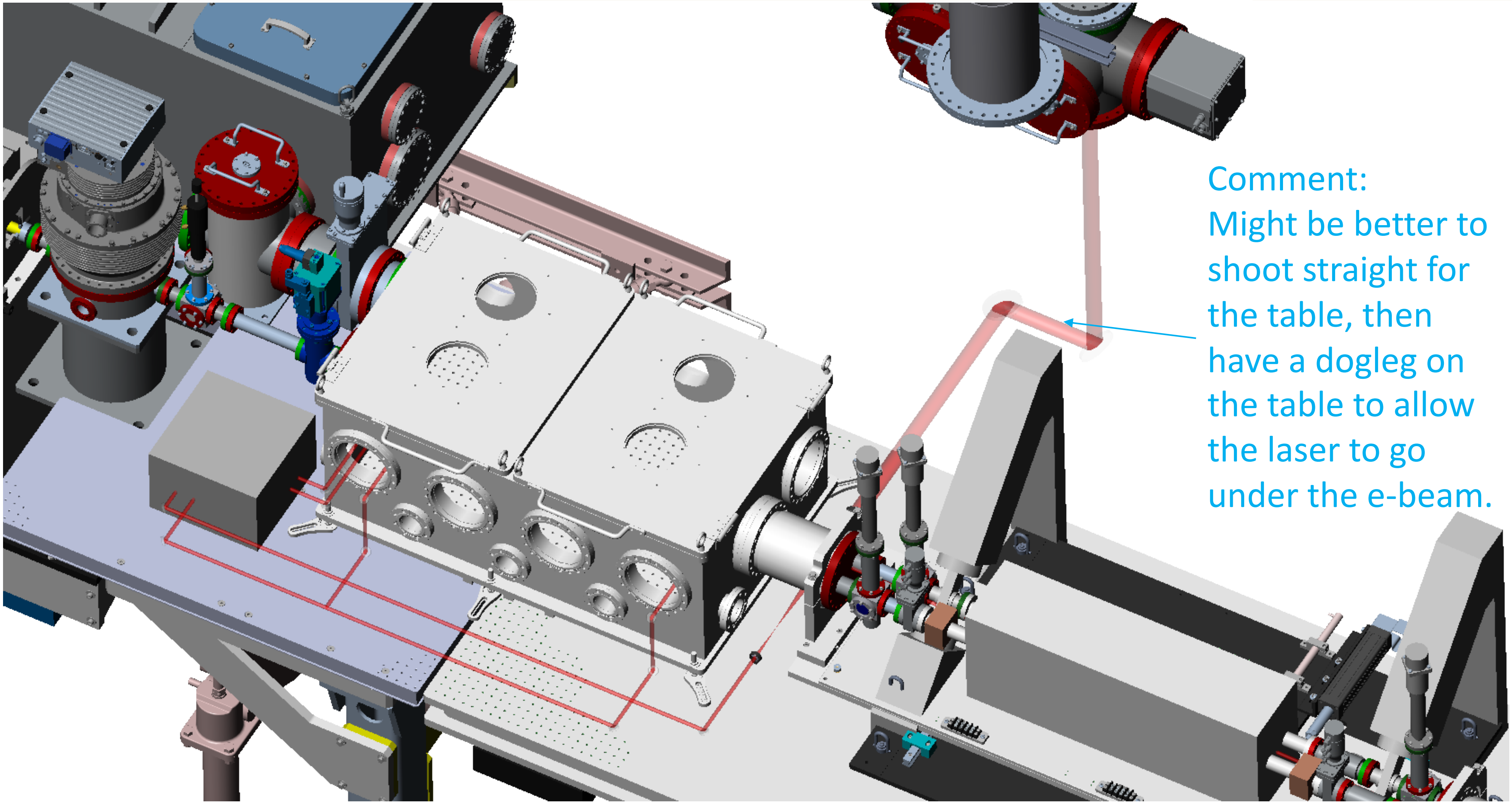
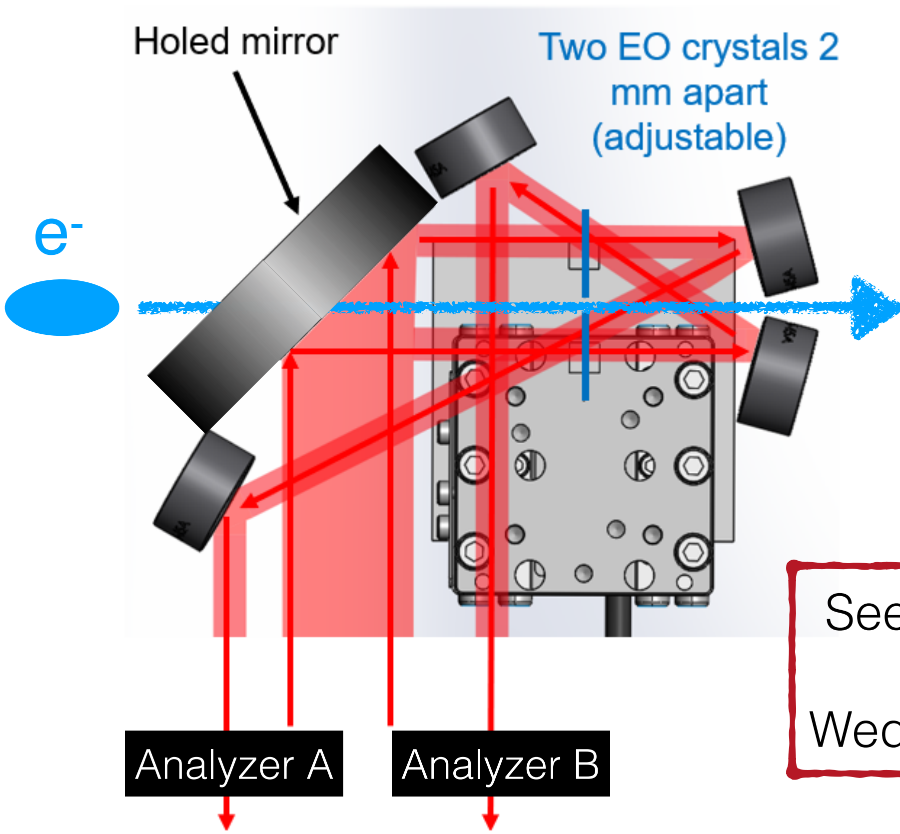


Comment:
Might be better to shoot straight for the table, then have a dogleg on the table to allow the laser to go under the e-beam.

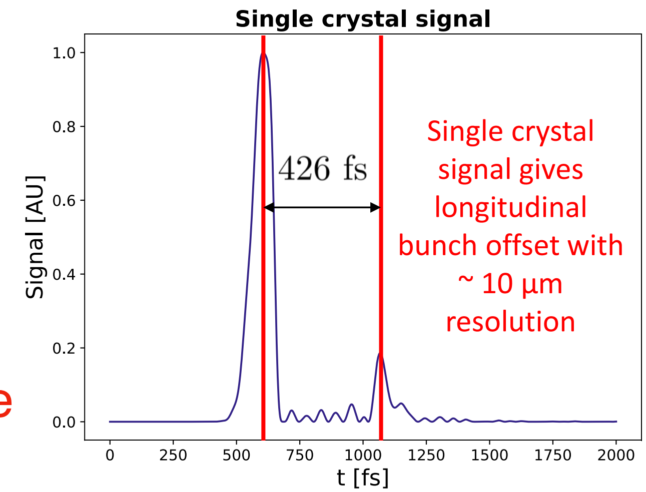
Low energy probe pulses provide valuable diagnostic information e.g. timing & alignment: EOS, Afterglow and plasma evolution (E-224)

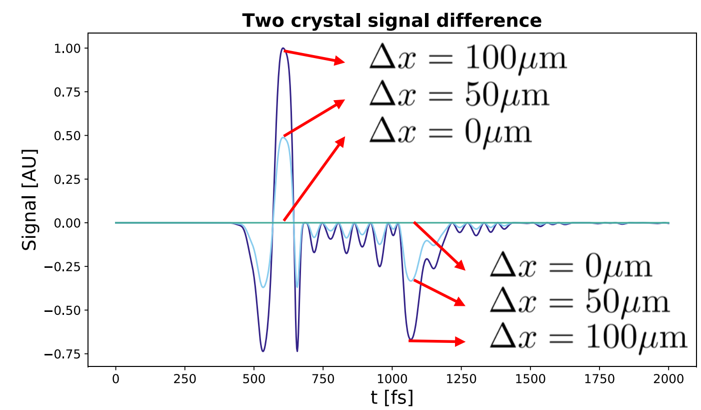
Developing an EOS BPM for Transverse Wakefield Studies

- Single crystals provide standard measurement of longitudinal spacing
- Difference signal provides horizontal offset
- First generation will measure one transverse direction
- Calibrated with stage translation



Signal difference of two EO crystals measures transverse offset with ~ 5μm resolution





See presentation by Mike Litos Wednesday 11:00AM

Use single shot information to correlate emittance growth vs witness beam offset

Discussing Modified Lithium Oven Bypass Line for Improved Alignment and Greater Flexibility

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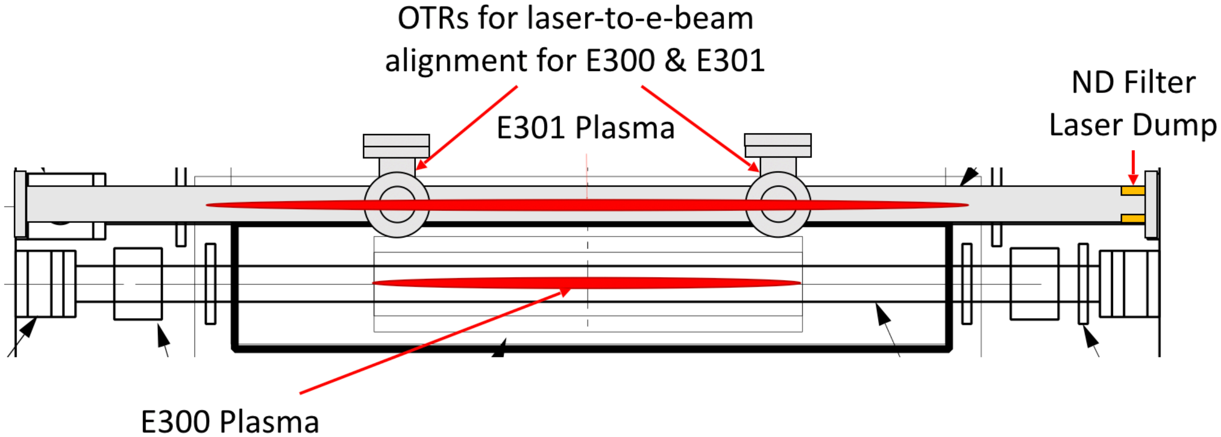
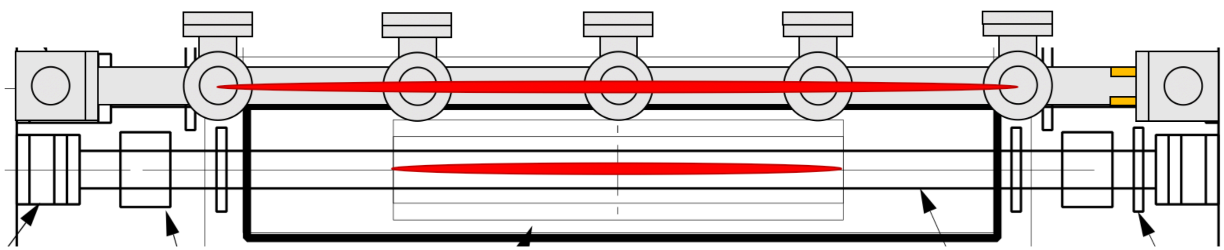
- Baseline design: two alignment OTRs and ND filter plug for E-300



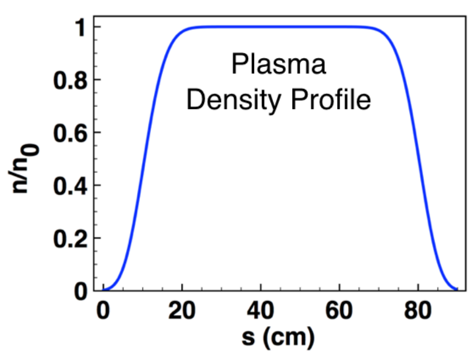
- Upgraded design: 5 OTRs along full length of E301 plasma + end cubes for dumping/observing E-305 laser
  - Understand the role of refraction: compare predictions to simulations
  - Investigating combination of holed mirrors and filter discs to dump E-305 filamentation laser and not interfere with E-301 ionization laser

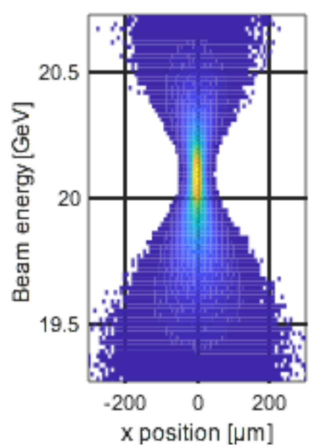


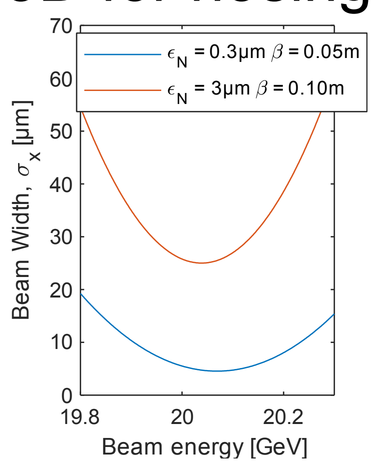
Key Upgrades for Two-bunch Experiments

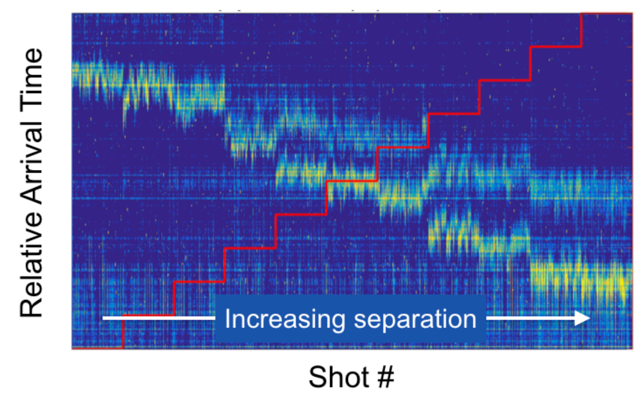
For **emittance preservation** under high beam-loading, **hosing suppression** and **in-situ positron generation** and trapping

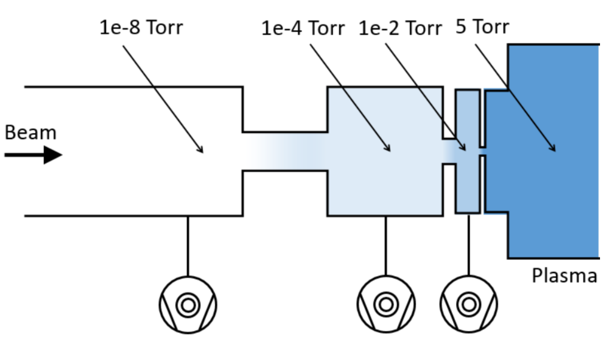
- Plasma source with ramps, in-situ target (UCLA/CU Boulder)
- Photoinjector and differential pumping to deliver mm-mrad emittance
- Upgraded spectrometer to measure energy spectrum and emittance
- EOS system extended from 1D to 3D for hosing studies









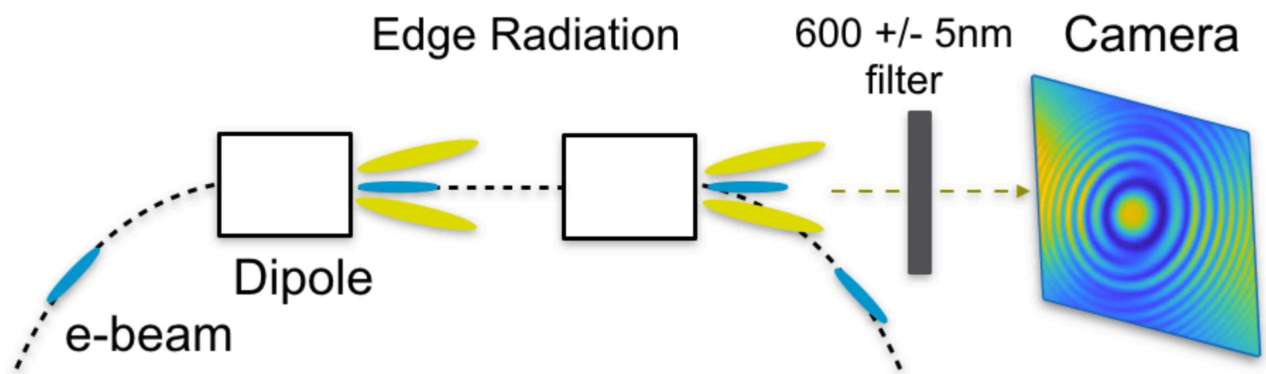


Designing, building and commissioning experimental apparatus and specialized diagnostics employs research-funded scientific personnel from both SLAC and universities and is coordinated by SLAC AARD

Key Upgrades for Single-bunch High Peak Current Experiments

See presentation by Claudio Emma Tuesday 11:30AM

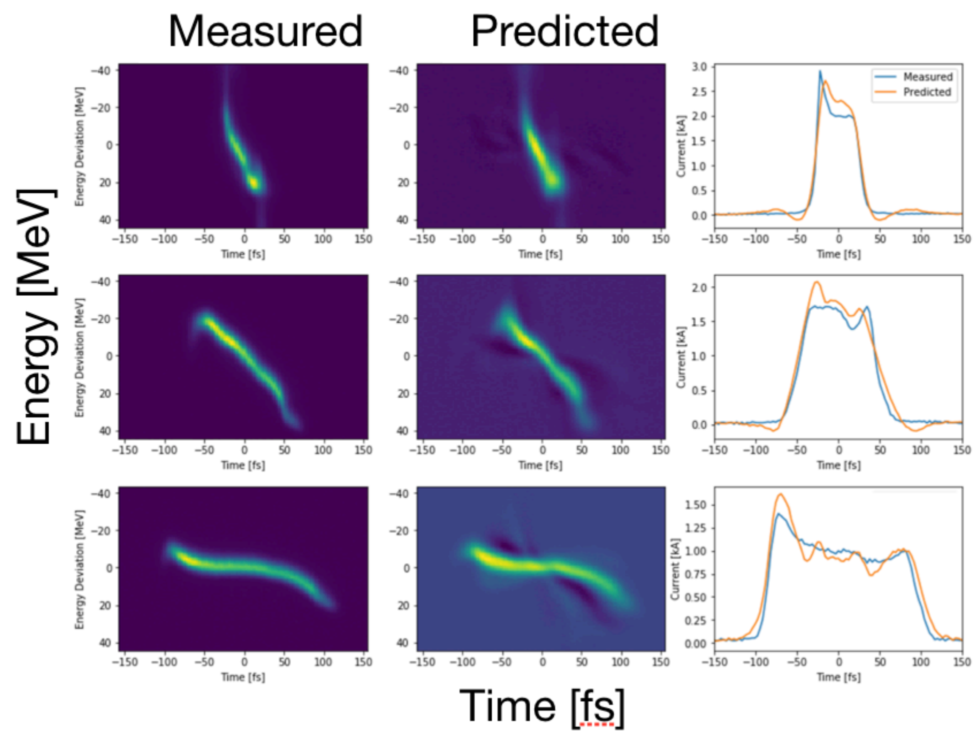
Edge radiation for online emittance & energy spread measurement benefits nearly every experiment



For **filamentation, injection** and **wake imaging:**

Virtual diagnostic for longitudinal phase space & peak current up to 300kA

FACET-II has unique challenges related to high intensity beams that require new approaches



C. Emma – Phys. Rev. Accel. Beams ***21****, 112802 (2018)*

Updated Electron and Betatron Radiation Diagnostics for Measuring Beams after PWFA

See presentation by Doug Storey Tuesday 1:50PM

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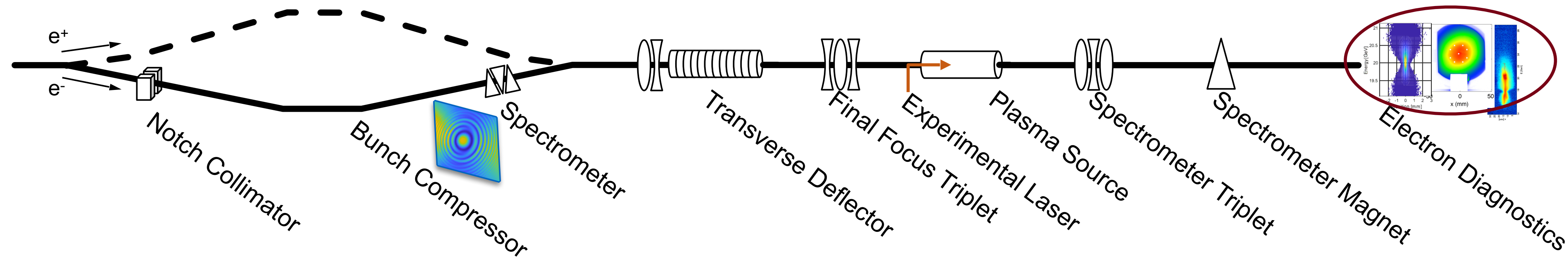
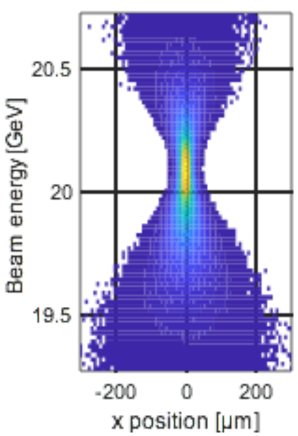
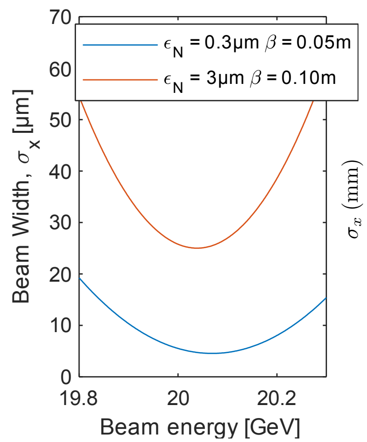


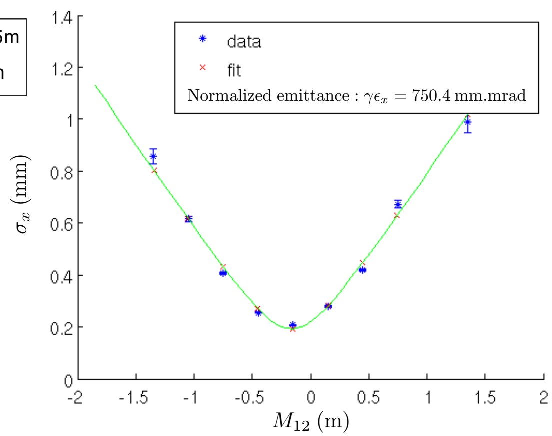
Electron Beam

Emittance:

- Edge radiation in bunch compressors
- High resolution in vacuum OTR in spectrometer for single shot butterfly or multi-shot dispersive quad scan

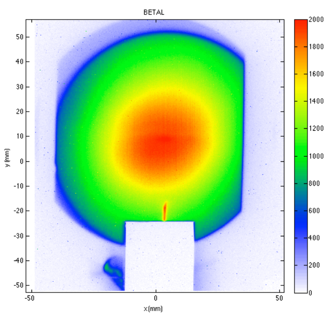




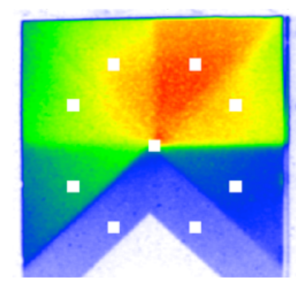


Gamma-rays

Angular distribution: convertor + scintillator, and pixelized CsI array for higher sensitivity



Spectrum: transverse array of filters/convertors
Ross filters (<100keV)
Step filters (up to 250keV)



Particle and Gamma-ray Working Group provides input to design diagnostics that simultaneously benefit multiple experiments

Dump Table Diagnostic Installation is Progressing

See presentation by Doug Storey Tuesday 1:50PM

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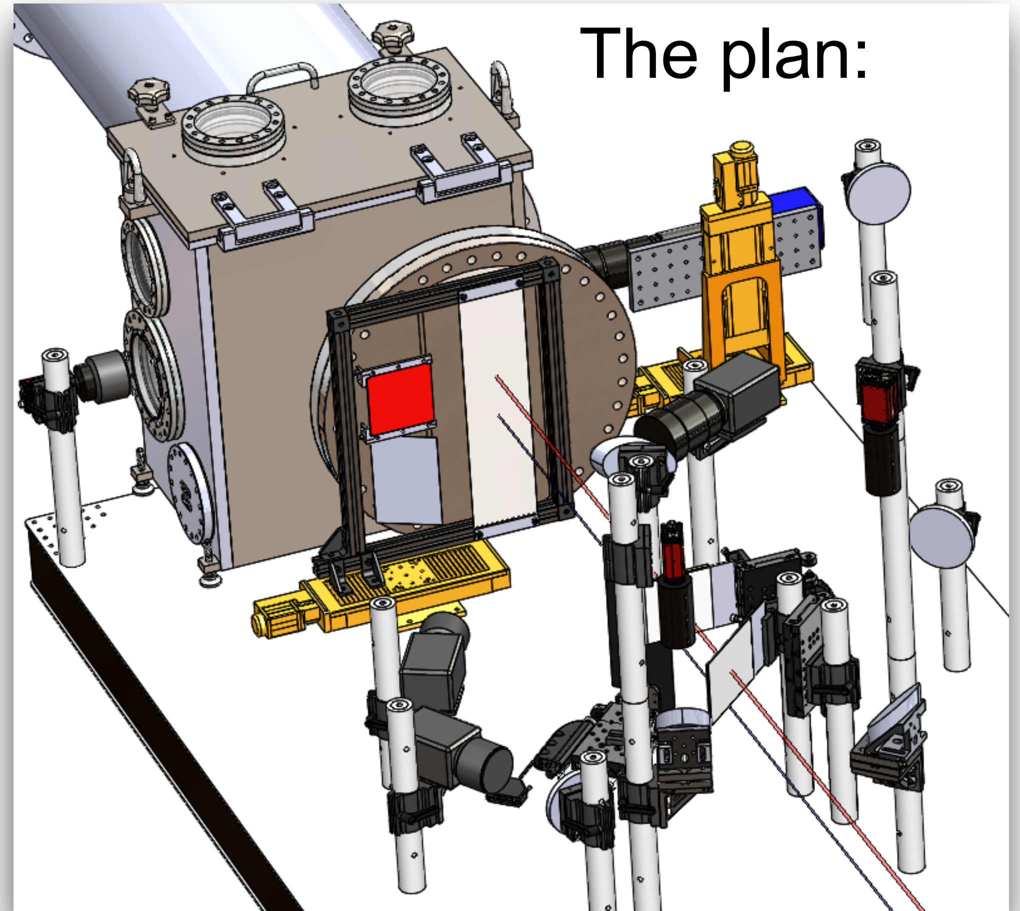
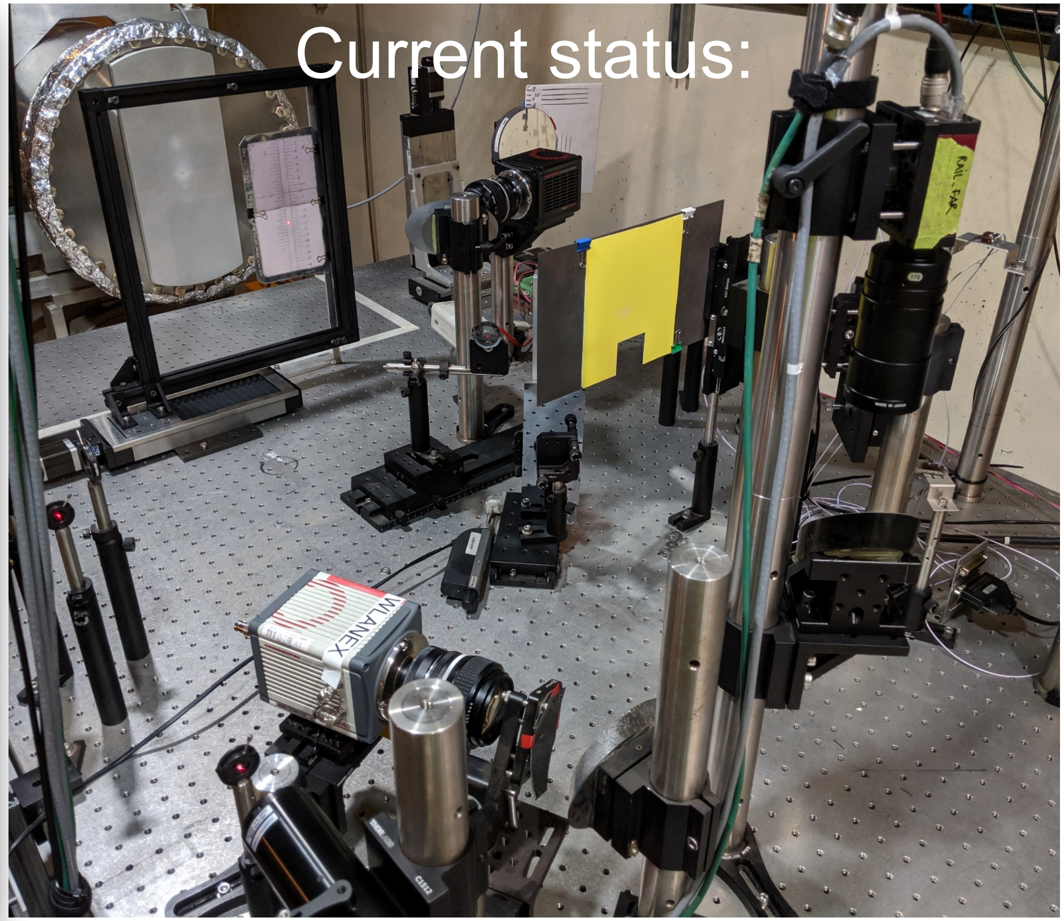


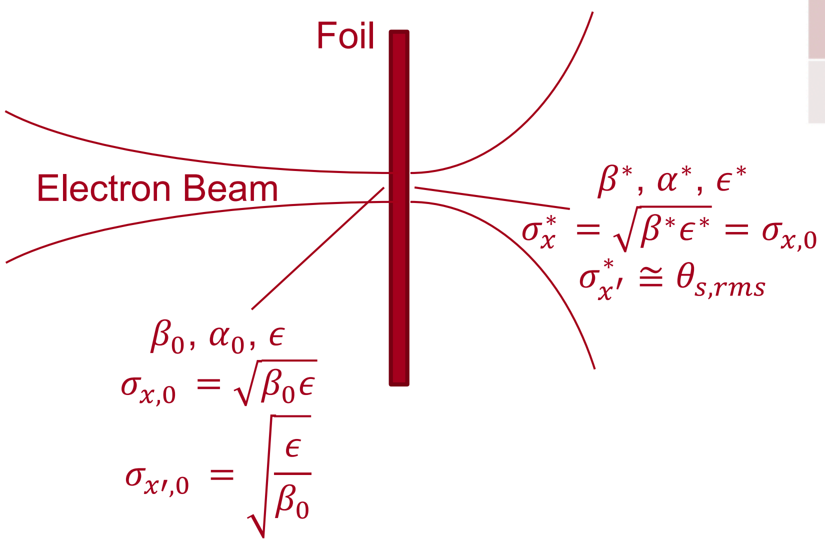


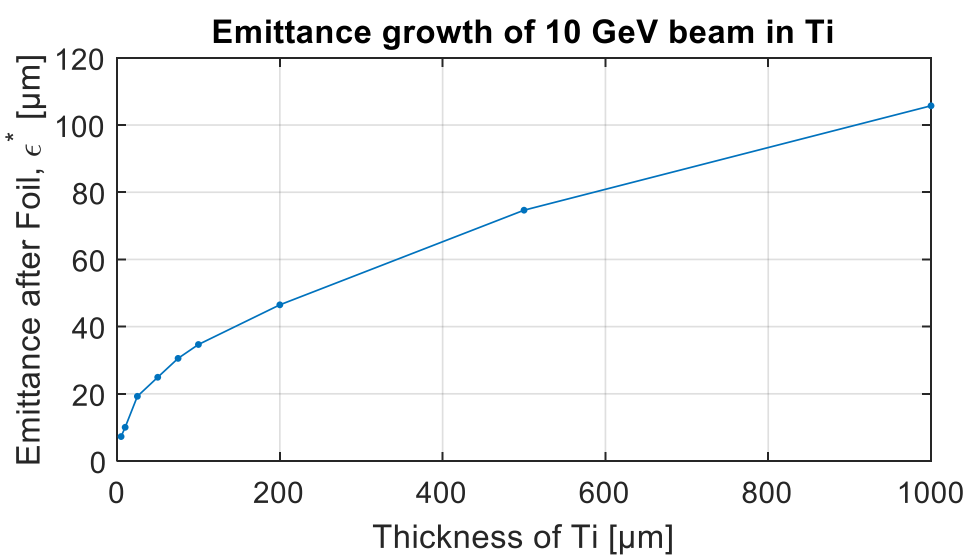
Particle and Gamma-ray Working Group provides input to design diagnostics that simultaneously benefit multiple experiments

Designing Spoiler Foils for Emittance Control

- Experiments desire ability to systematically scan emittance, preferably without lengthy retuning between values
- Independent control of drive & witness beam emittance preferred
- Investigating use of spoiler foils in S20 upstream of notch collimator or BC14

β_0 , ϵ_0	ϵ^*	$\Delta\theta_{s,rms}$	Thickness of Ti	β^*
3 m, 3 µm	30 µm	71 µrad	75 µm	0.3 m
3 m, 3 µm	100 µm	240 µrad	0.9 mm	0.09 m





- Issues under study:
  - Peak intensity & foil damage
  - Equal emittance growth in both transverse planes

Coarse High Level Schedule

Job	October 2019	November 2019	December 2019
Laser Room	Restore Laser Timing; Restore full laser energy; Laser Monitoring Cameras		
Laser Room To Transport	Design Laser Transport	Install Room -> Transport	Certify Tunnel LSS
Laser Transport		Install Compressor Optics; Install Tunnel Transport (Vacuum)	
DM Install		DM Arrives	Test DM in Laser Room
Accelerator			PPS/BCS complete
IP Area		Lift; Legs for IP Table; IP Table in place; spoiler properties	New compressor legs; spoiler conceptual mechanical design
Dump Table	Clean out; GAMMA2,3, CHER installed, GAMMA1 LFOV coarse install.	Butterfly chamber installed, finalise coarse alignment	Camera motors commissioning
Final Focus			
Dumpline			

Coarse High Level Schedule

Job	January 2020	February 2020	March 2020
Laser Room			
Laser Room To Transport	Commission compressor		
Laser Transport	Measure Wavefront in Tunnel		
DM Install		Install/Characterize E300 Optics	
Accelerator	ARR	Hardware checkouts S10-20, high charge 335MeV to S11	S14/20 deflector cavities, 10GeV to S20 dump, KPP, Users: background/alignment
IP Area	Compressor install; Picnic basket install; spoiler review & installation		
Dump Table			
Final Focus			
Dumpline			

Coarse High Level Schedule

Job	April 2020	May 2020	June 2020
Laser Room			
Laser Room To Transport			
Laser Transport			
DM Install			
Accelerator	Beam quality, test various beam configurations, CD-4	Regular operations (6 days/week, 24 hours/day)	
IP Area			
Dump Table			
Final Focus			
Dumpline			

Experimental Area Timeline

For first set of experiments:

- Dump table diagnostics & butterfly chamber (November)
- Laser transport in tunnel except last piece to compressor (November)
- Legs for optical table (1st week November)
- IP Optical table empty and in place (Nov/Dec)
- Compressor box legs (DS check arrival date) (Dec)
- Compressor box (Jan)
- Picnic basket breadboard support (Jan)
- Picnic basket (Jan)
- Li oven beam line (windows on valves for SFQED) (Jan)
- Pumps, gauges, valves, cameras, probe lines, cables…

Later (AIPs):

- New SFQED chambers for dumpline
- Spoiler foils
- Differential pumping
- Final focus
- TCAV relocation and rotation
- Spectrometer (triplet)