FACET-II | Facility for Advanced Accelerator Experimental Tests

Particle and Gamma Diagnostics at the Dump Table

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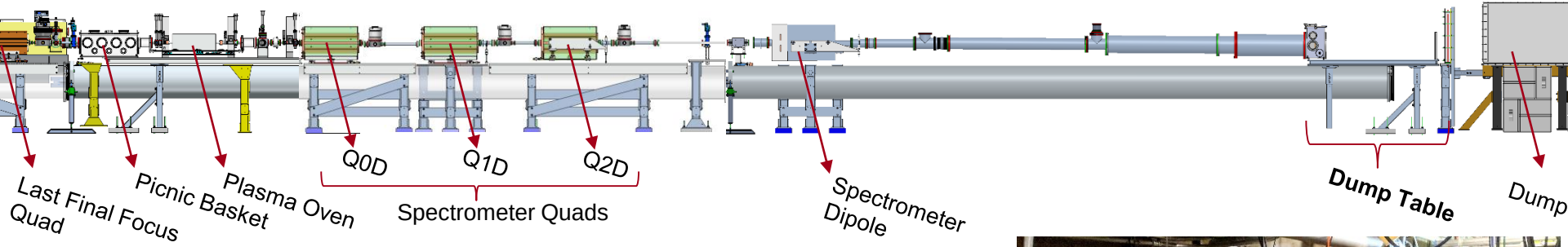
SLAC National Accelerator Laboratory

U.S. DEPARTMENT OF ENERGY | Stanford University

SLAC NATIONAL ACCELERATOR LABORATORY

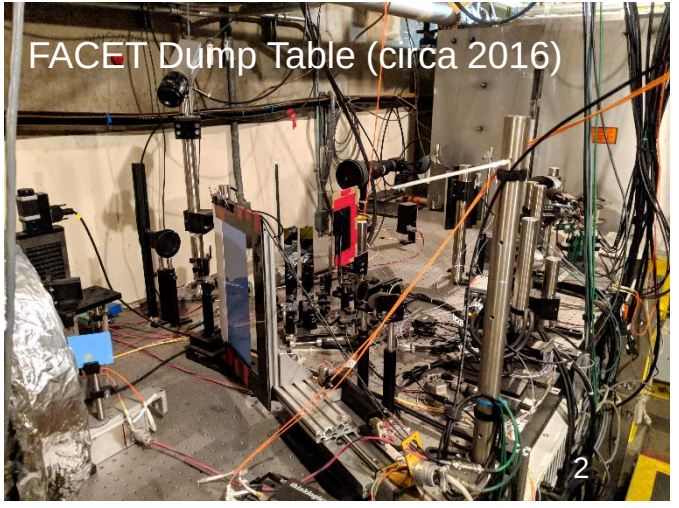
Dump Table Introduction

Sector 20: IP area to the main beam dump:



Particle and gamma diagnostics:

- After the reimaging quads and spectrometer dipole
- 4 x 8 foot^2 optical table immediately before dump
- 60 to 70 mm nominal electron dispersion
- In-air diagnostics after the 5mm Al exit window



Overview of particle and gamma diagnostics

Electron diagnostics

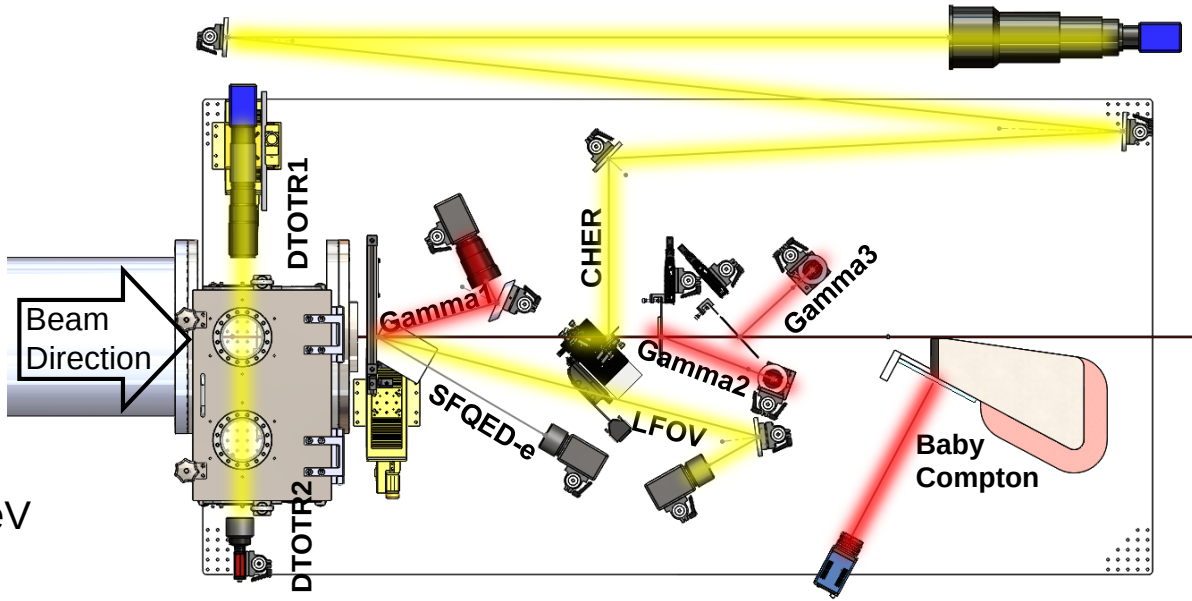
- DTOTR1/2 high resolution in-vacuum e- profile monitor
- LFOV – large field of view
- CHER – electron spectrometer

Gamma diagnostics

- Gamma1 – intensity and angular distribution
- Gamma2/3 – rough spectral measurement: 10keV to ~MeV
- Baby Compton – 200keV – 20MeV

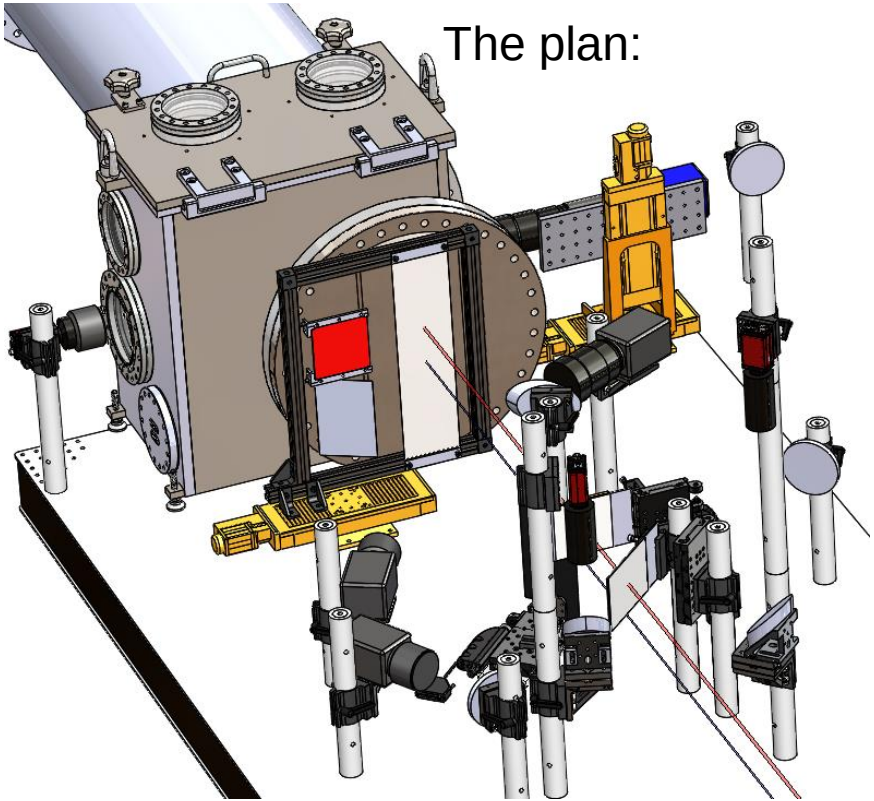
Future planned diagnostics:

- Full Compton spectrometer
- SFQED-e

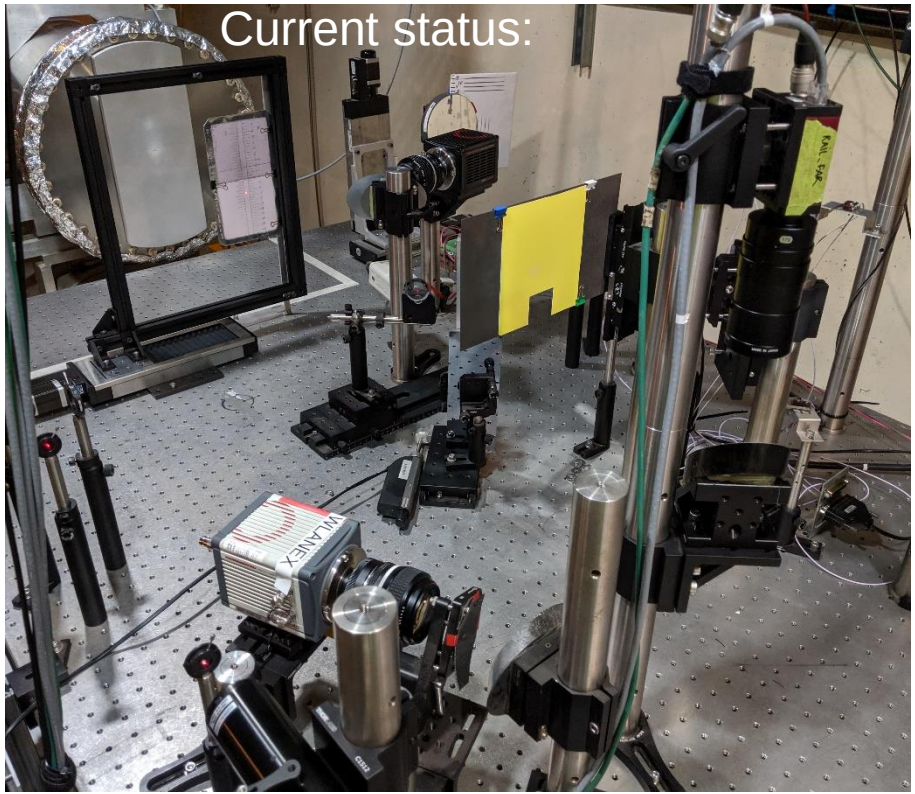


Dump table installation

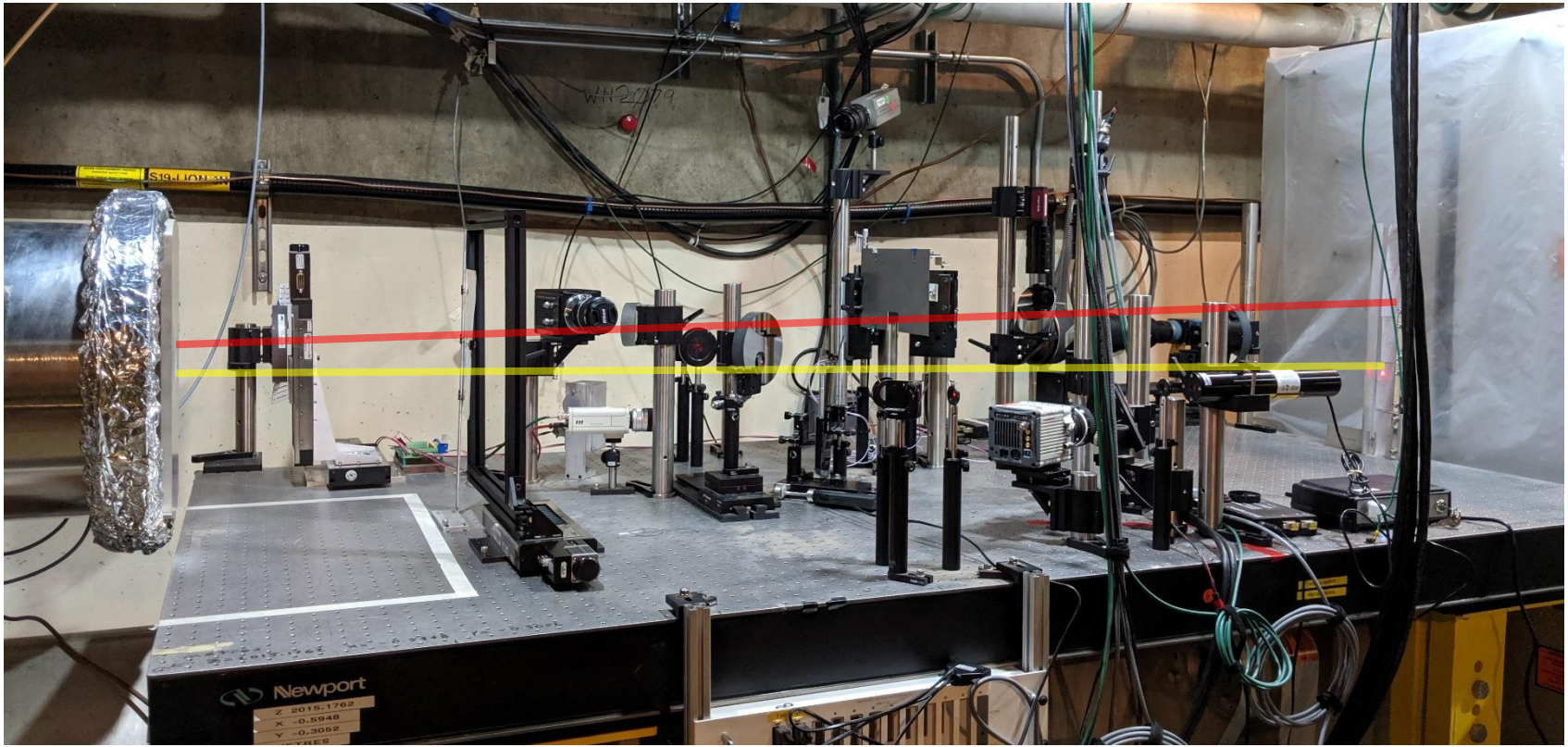
The plan:



Current status:



Electron Diagnostics



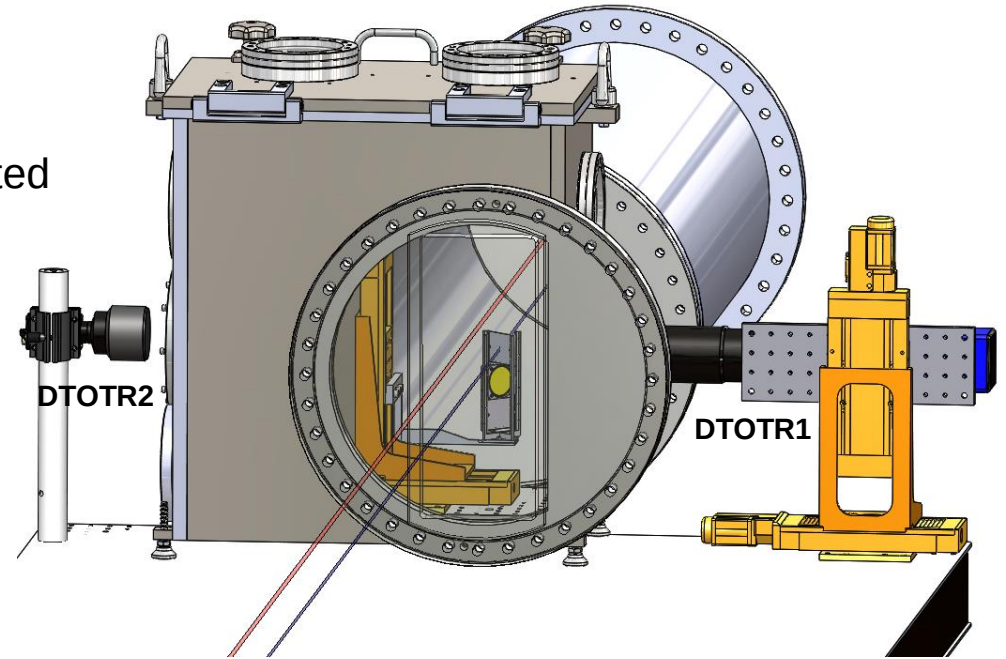
In-vacuum electron diagnostics

DTOTR1: high resolution in-vacuum e- OTR profile monitor

- PCO Edge5.5 w. Nikon Nikkor 200mm f/4
- Polished Ti OTR target, 0.5mm thick
- FOV = 7 mm x 8.4 mm ($\pm$30mm)
- Imaging resolution: 4.5 µm, diffraction limited
- Energy resolution at nominal dispersion of $D_0 = 60$ mm, $\sigma_{res,E} \cong 0.01\%$

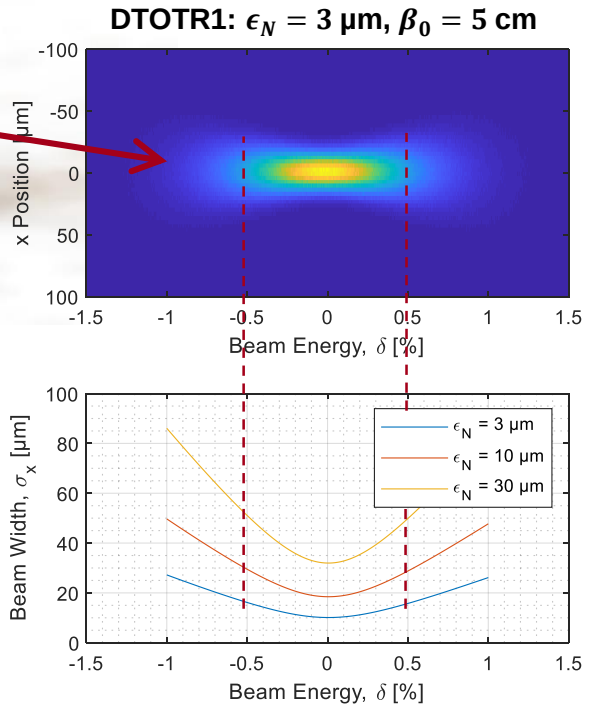
DTOTR2: large FOV e- detector

- AVT Manta w. Nikon Nikkor 50mm f/1.2
- Polished Ti OTR or 50 µm thick YAG:Ce
- FOV = 26 mm x 38.5 mm
- Resolution: ~50 µm, limited by pixel size



Note: Only one OTR may be viewed at a time.
YAG may be viewed simultaneously by both cameras

Butterfly emittance measurement



Butterfly measurement technique:

- Beam is reimaged from waist at plasma exit to DTOTR1, after the spectrometer dipole
- Horizontal beam width is fit to the function:

$$\left(\sigma_x(\delta)\right)^2 = \frac{\epsilon_n}{\gamma_b}\left[M_{11}(\delta)^2\beta_0 - 2M_{11}(\delta)M_{12}(\delta)\alpha_0 + M_{12}(\delta)^2\left(\frac{1+\alpha_0^2}{\beta_0}\right)\right]$$

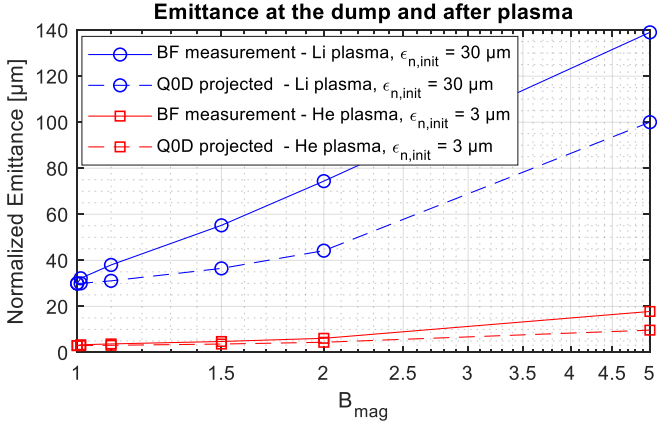
- Fit parameters ϵ_n, β_0, and α_0 at the plasma exit
  - Resolution: Can extract ϵ_n to within ~5% (matched PWFA)
  - Chromatic effects and phase mismatch can introduce further uncertainty (next)

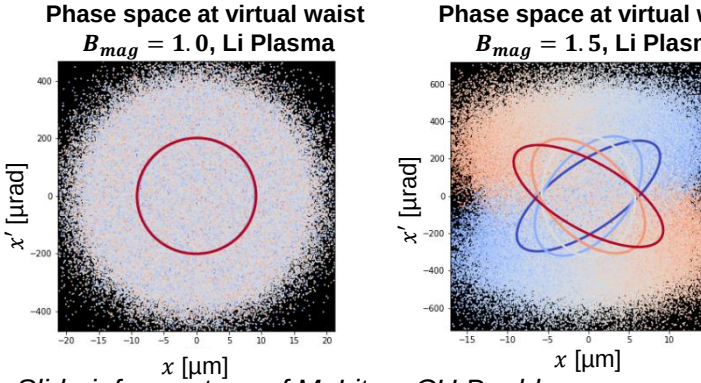
Effect of mismatch on PWFA emittance measurement

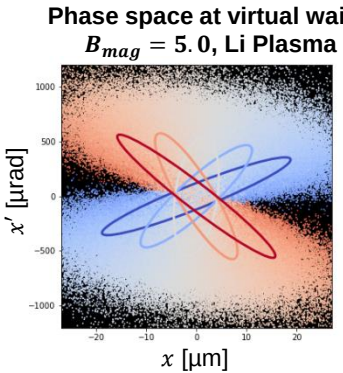
Witness beam tracked though plasma to DTOTR using Mike's non-PIC PWFA code to see the effect of phase mismatch

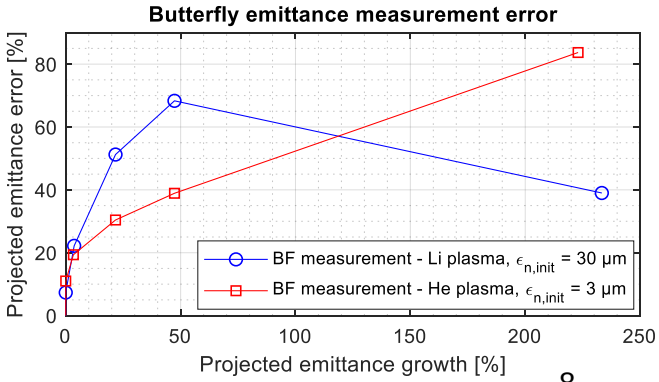
Findings:

- BF measurement will give an upper limit to emittance growth
- BF fit resolution is $\sigma(10\%)$ when the real emittance growth is $< 10\%$
- Can perform a quad scan or attempt to correlate with betatron signal to improve measurement performance









Slide info courtesy of M. Litos, CU Boulder

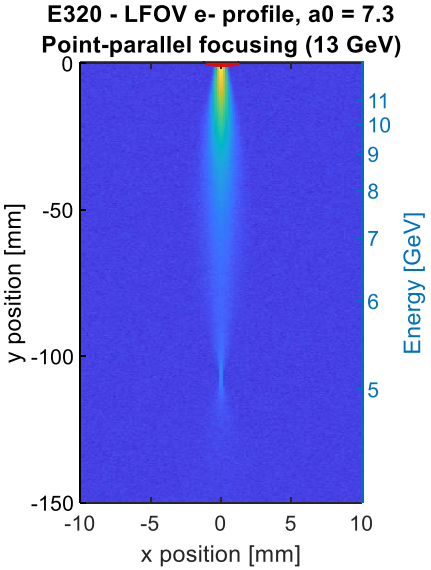
Large Field of View profile monitor

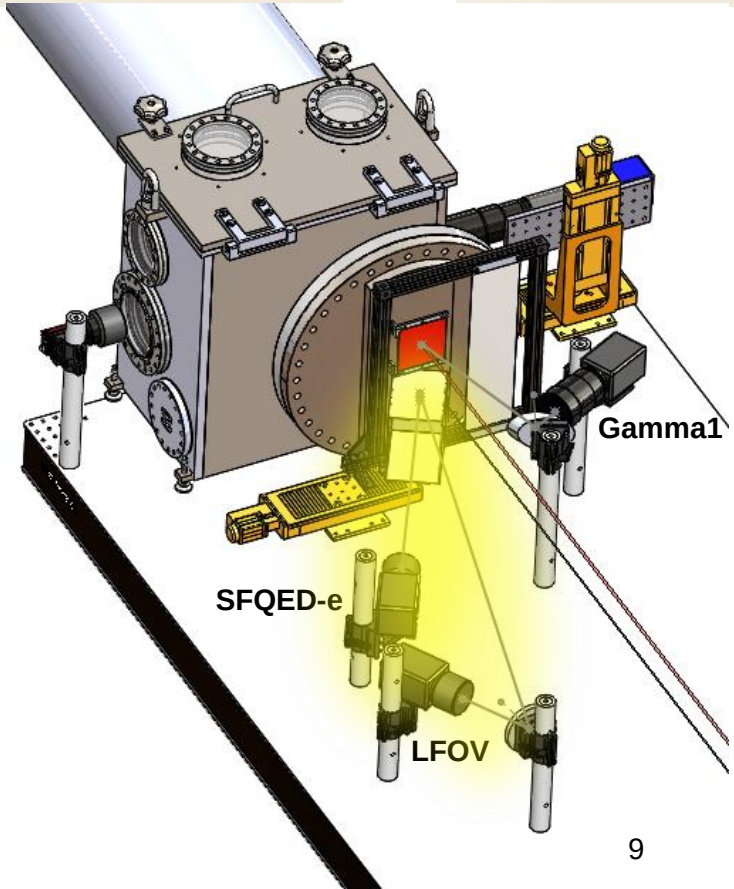
LFOV (Previously WLAN): very large e- Field of View

- Hamamatsu Orca Flash V2 w. Nikon Nikkor 50mm f/1.2
- DRZ-Fine, 40 cm x 10 cm
- FOV = 30cm x 30cm
- Resolution: ~150µm pixel size

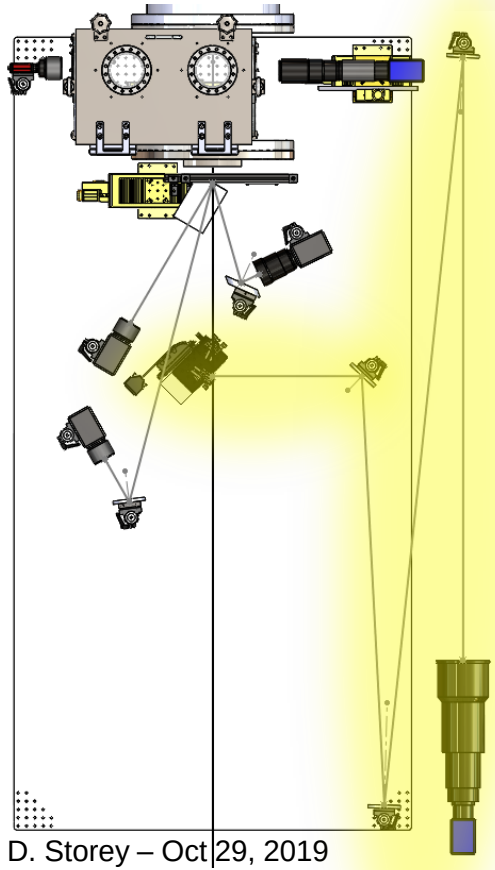
SFQED-e: Brighter, higher res.

- Same camera and lens
- Shorter working distance
- Scintillators: Shielded DRZ-High and/or CsI array
- Hole added to allow main beam to pass through





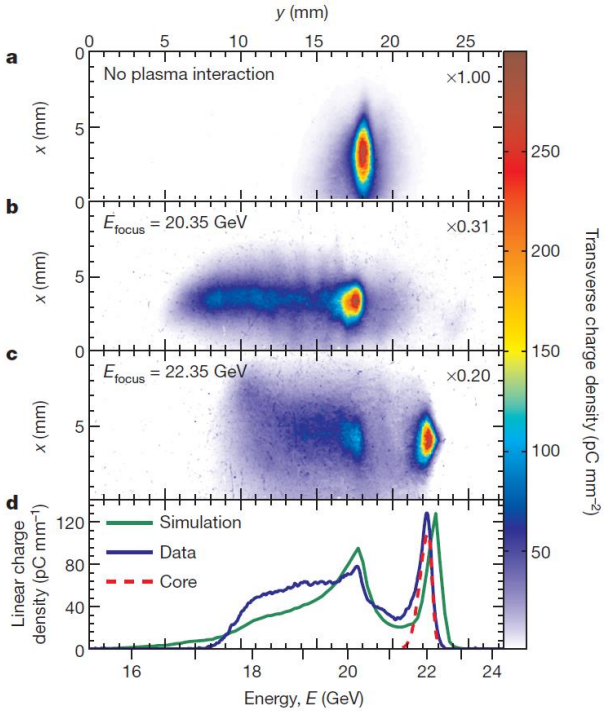
Cherenkov light spectrometer



CHER: e- spectrometer

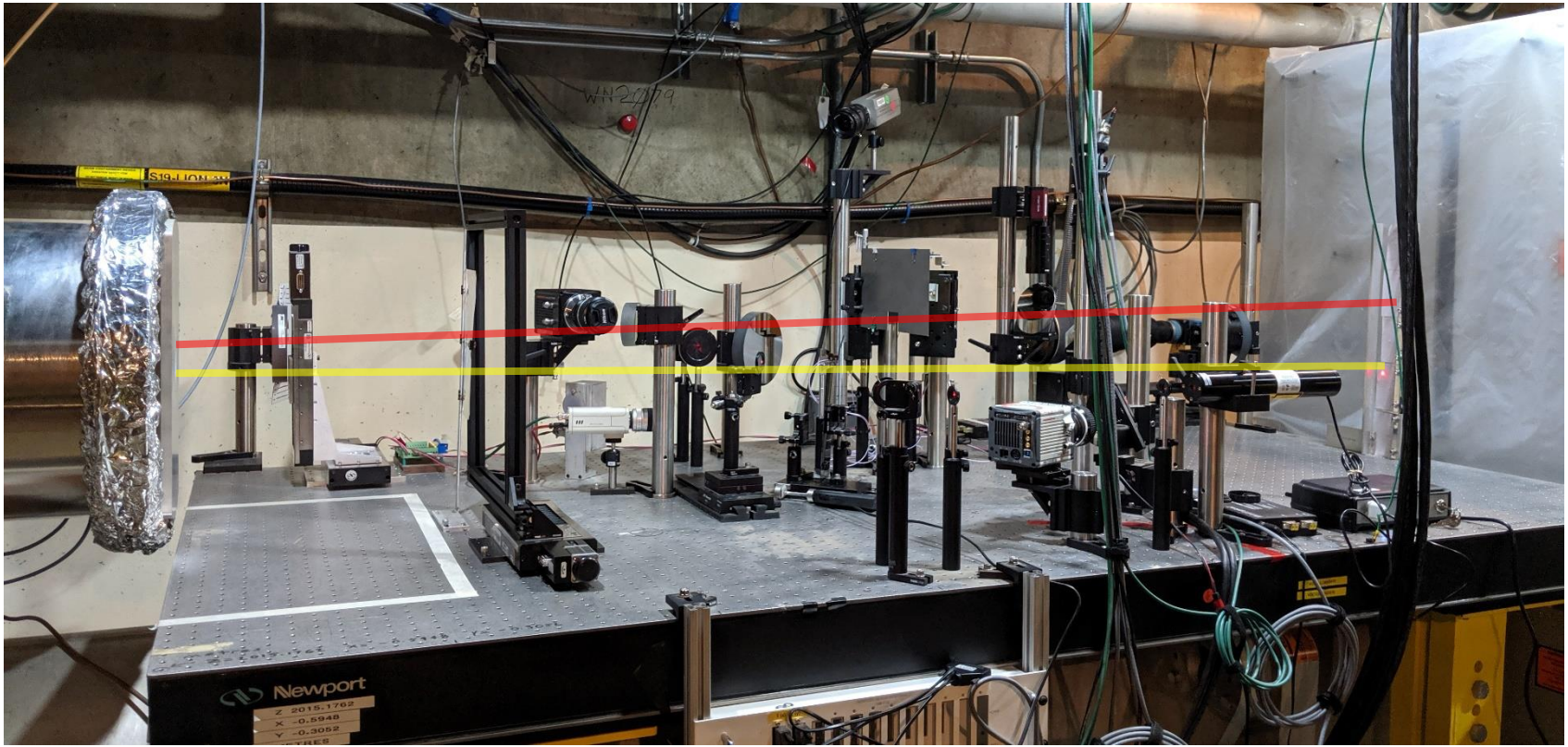
- PCO Edge5.5 w. Nikon Nikkor 600mm f/4 (new lens)
- Cherenkov light from 5cm gap
- FOV = 5 x 16 cm
- Imaging resolution: ~230 μm
  - Energy resolution at nominal dispersion of $D_0 = 62$ mm
    - $\sigma_{res,E} = \frac{\sigma_{res,y}}{D_0} E_0 = 0.4\%$

e- beam profiles on CHER_FAR – E200

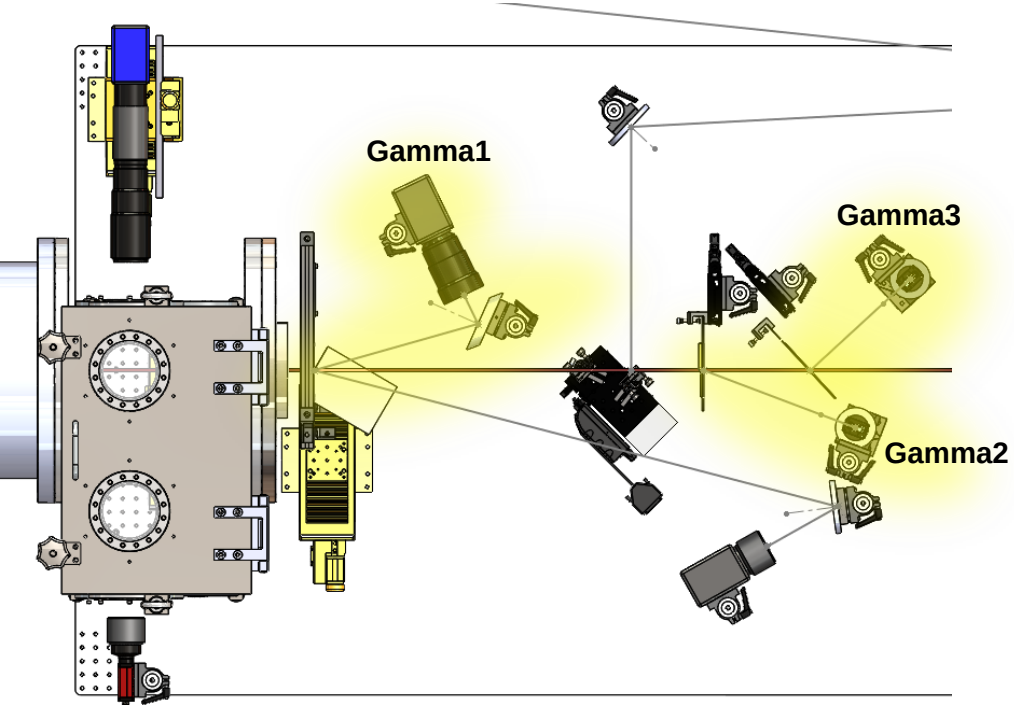


*Litos et al, Nature, **515** 92 (2014)*

Gamma Diagnostics



Gamma diagnostics



Gamma1: Photon profile monitor

- Hamamatsu Orca Flash V3
  w. Nikon Nikkor 50mm f/1.2
- DRZ-Fine or CsI array
- FOV = 10cm x 10cm
- Resolution: ~50 µm pixel size (~2 µrad)

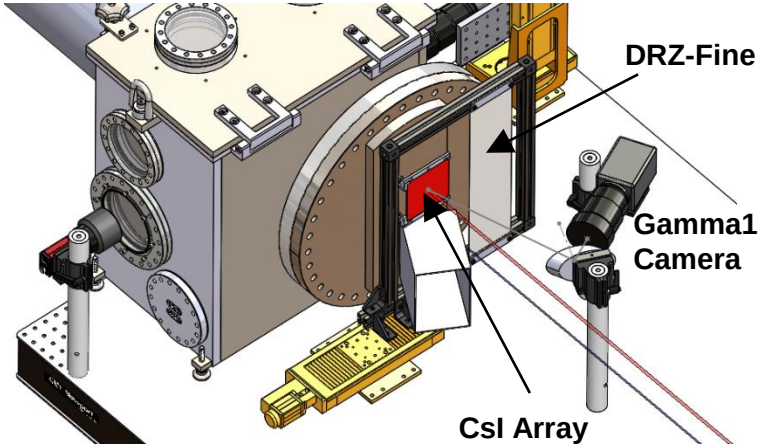
Gamma2/3: Photon spectrometer

- Manta G125B w. 13-130 Computar Lens
- DRZ-Fine with preceding Ross/Step filter
- Resolution: ~50 µm pixel size

Gamma1 overview

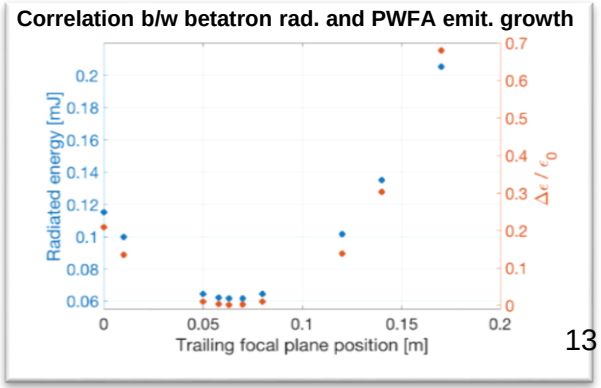
Gamma1 will act as a photon profile monitor:

- 2 different scintillators set-ups
  - Pixelated CsI Array – 0.5x0.5x3 mm
  - DRZ-screens (+ converter if needed)



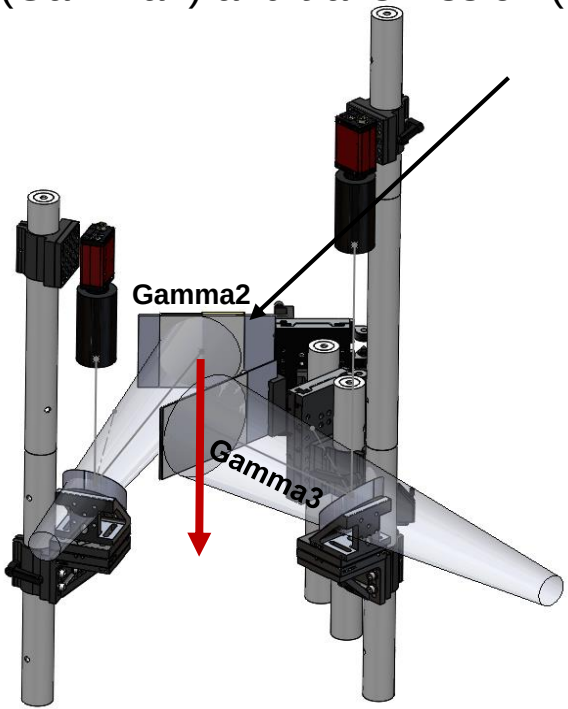
Gamma1 information:

- Photon integrated signal:
  - PWFA: Correlated with beam matching dynamics.
  - Spatio-temporal alignment.
- Photon angular distribution:
  - PWFA: e^- beam *x-y* symmetry and trailing beam offsets.
  - E320 - SFQED: a_0 value.



Gamma2 and 3 overview

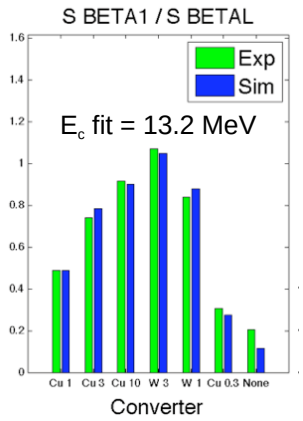
Gamma2 and 3 measure photon spectral information by measuring conversion (Gamma2) and transmission (Gamma3) rates of gammas through a set of filters.

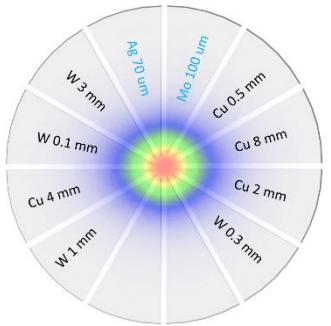


Gamma2,3 information:

- Photon spectral information:
  - PWFA: ω_c measurements, correlated with beam matching dynamics.
  - E305 - Filamentation: instability growth.
- Filter set-up:
  - Step filters: conversion (100's keV-10's MeV) and transmission (50-100's keV)
  - Ross filters: energy bands (<100 keV)

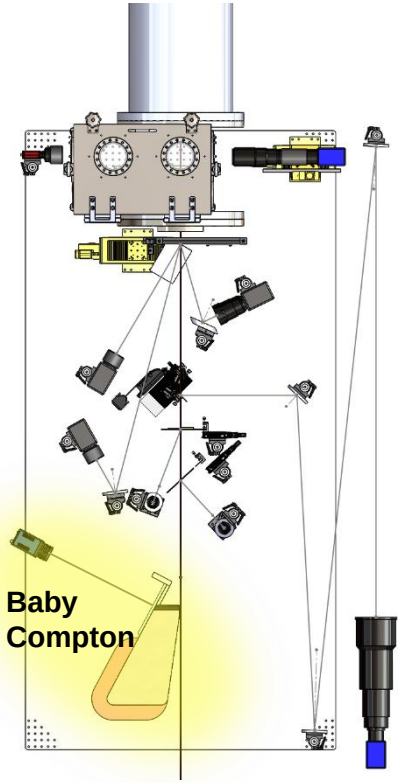
Note: Geometry and choice of filters depend on gamma ray features.

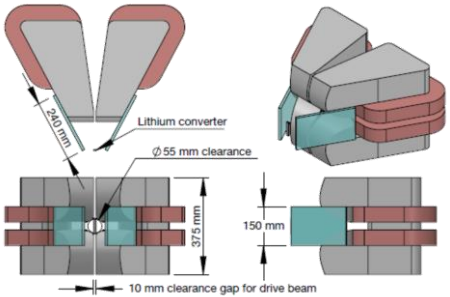




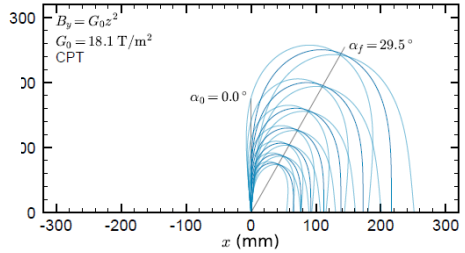
Sketch of filters for E300 30μm emittance beams, together with betatron angular distribution.

Compton Spectrometer (UCLA)

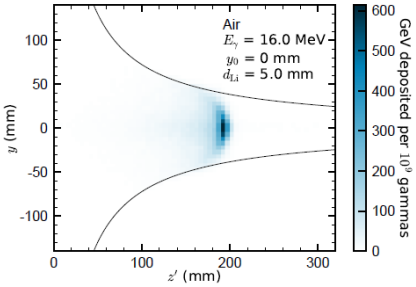




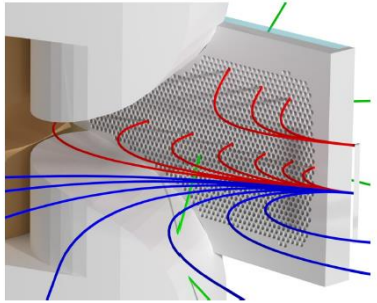
Dimensions including optional positron readout



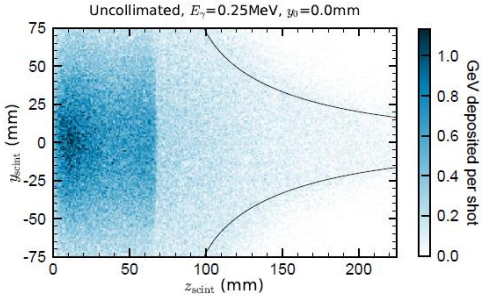
Focusing in horizontal plane



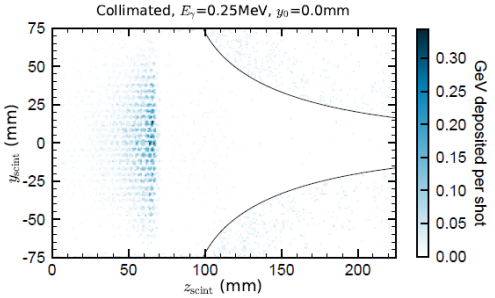
16 MeV gammas incident on lithium



Electron collimator (3D printed tungsten)



250 keV gammas (without collimator)



250 keV gammas (with collimator)

- Nominal gamma spectroscopy range from 200 keV through 20 MeV.
- Optional positron readout to subtract pair background from Compton spectrum.
- Sextupole design allows compact spectrometer with high dynamic range.
- Lengths scale with cube root of electron momenta.

Slide courtesy of B. Naranjo, UCLA

Status of dump table diagnostics installation

Diagnostic	e-/γ	Current Status	Work remaining	Complete
DTOTR	e-	• All components fabricated • Resolution and alignment tests complete	• Chamber ships today • OTR to be polished • Installation	80%
LFOV	e-	• Course install on table	• Final alignment	95%
CHER	e-	• Course install on table	• Install wafers and filter • Final alignment	90%
Gamma1	γ	• Course install on table	• Final alignment	95%
Gamma2/3	γ	• Course install on table	• Camembert fabrication	80%
Baby Compton	γ	• Design stage	• Review, fabrication • Installation	

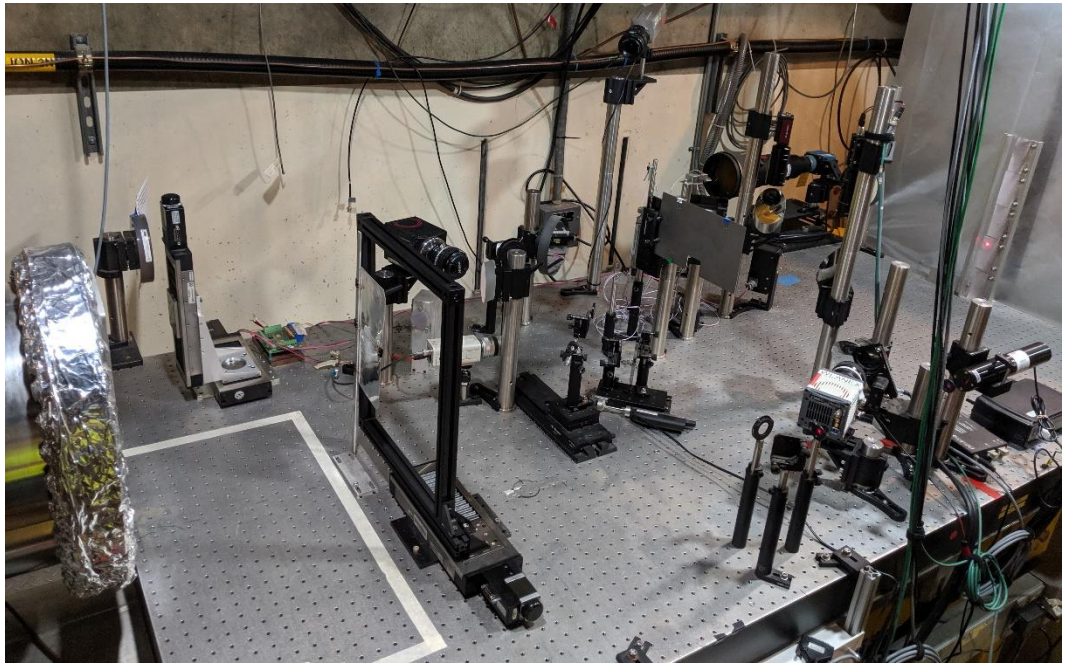
Other remaining work:

- New framegrabbers for 2 camera servers, 1 new sCMOS camera channel
- New optical fibers in tunnel
- Motor and camera commissioning in tunnel

Dump table diagnostics expected to be completed and ready to see beam by Dec. 2019

Summary

- Dump table provides a suite of post-interaction diagnostics for both electrons and gammas.
- Dump table diagnostics installation >80% complete.
- Expected to be ready to see beam by Dec. 2019.
- Thanks to all collaborators for helping to make this all come together!



Thanks for your attention!

Questions?

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