

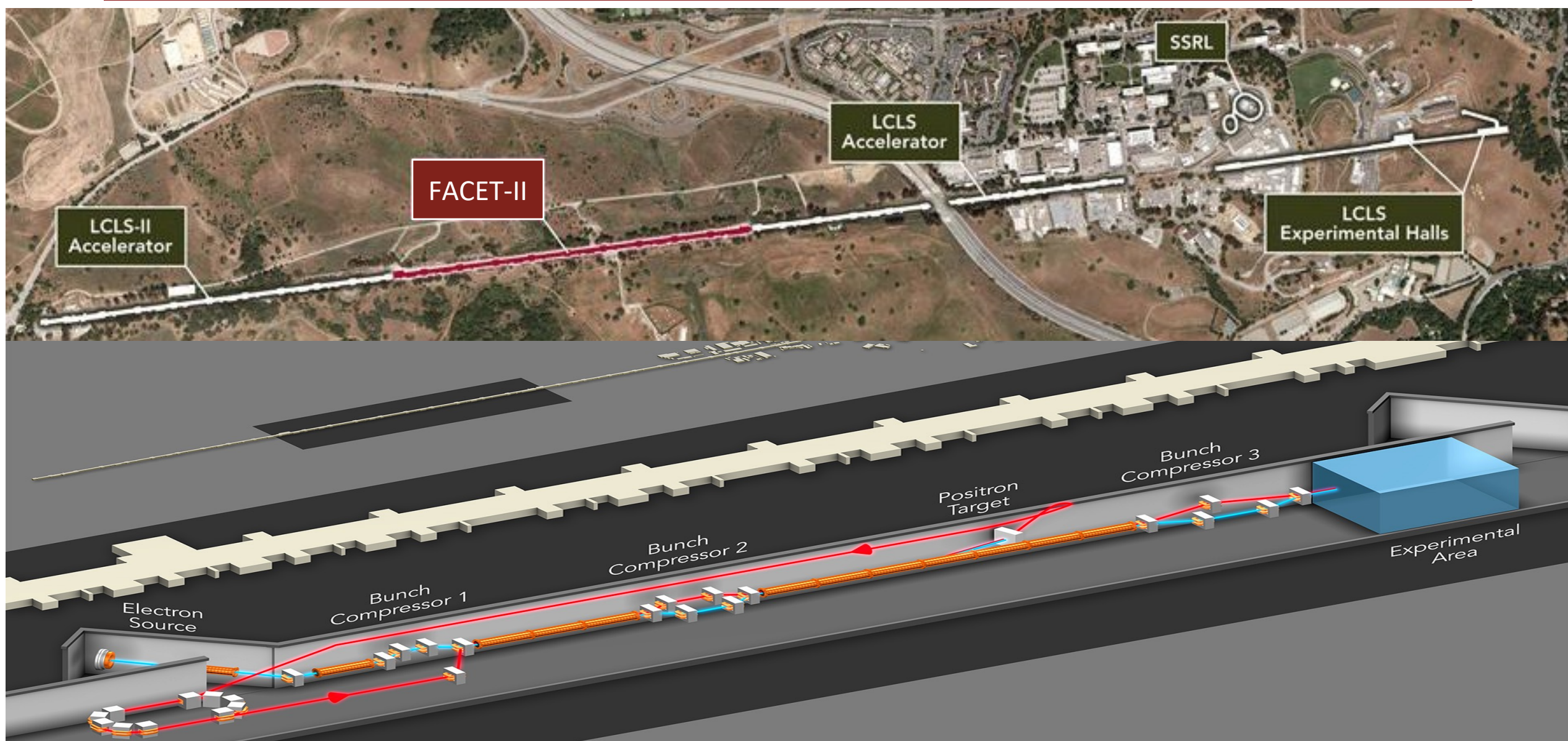
Electron Source Development and Charge Scaling



Facility for Advanced
Accelerator Experimental Tests

Brendan O'Shea / Division Director / FACET and Test Facilities
PhASE 2026 – September 21, 2026

FACET-II Facility



FACET-II Electron Beam Parameters

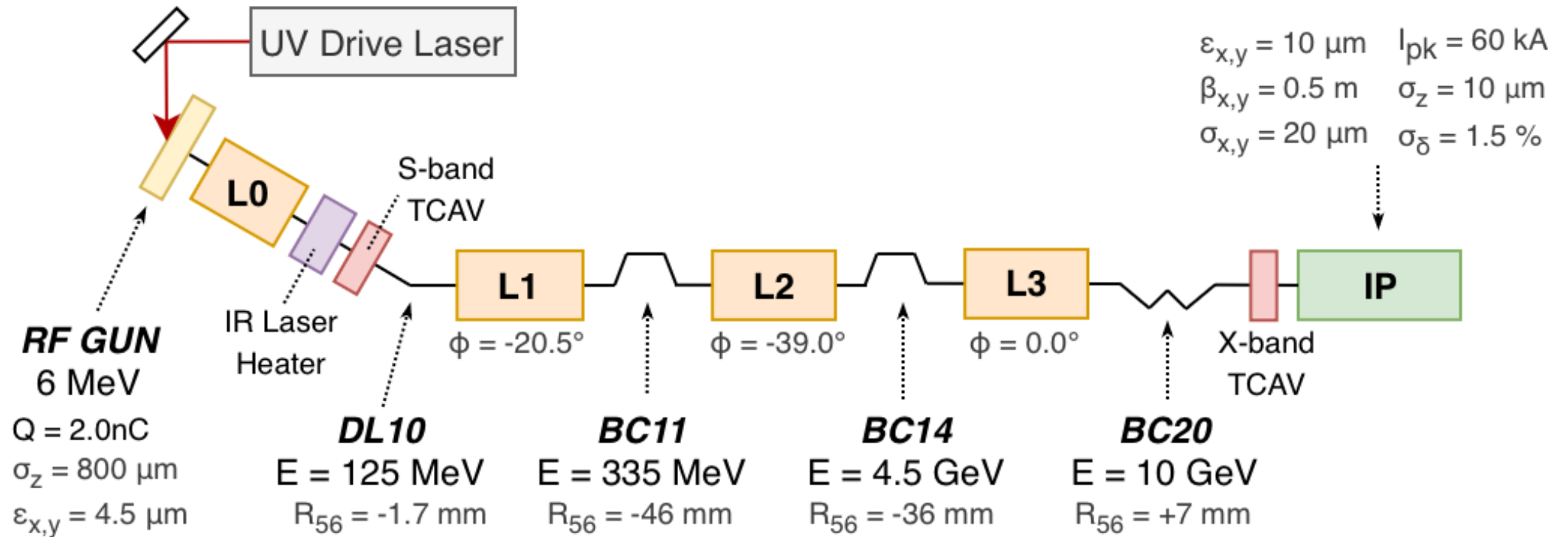
- Three beam configurations:
Long bunch, short bunch
and two bunch
- Parameters are not all
independent!
- + indicates more values
outside experience are
possible, but no one has
asked

Parameter	Units	Nominal	Range
Repetition Rate	Hz	10	1 - 30
Charge	nC	1.6	0.7 - 5
Energy	GeV	10	4 - 13.5
Bunch Length	μm / fs rms	20 / 67	20 / 67 - 150 / 500+
Transverse Size at IP	μm	20	10 - 100
Beam Current	kA	10	1 - 100+
Normalized Emittance	μm	10	—
Energy Spread	%	2	—

FACET-II targets high-charge, high-current operation

FACET-II Layout

FACET-II (SLAC Linac Tunnel Sectors 10 - 20)

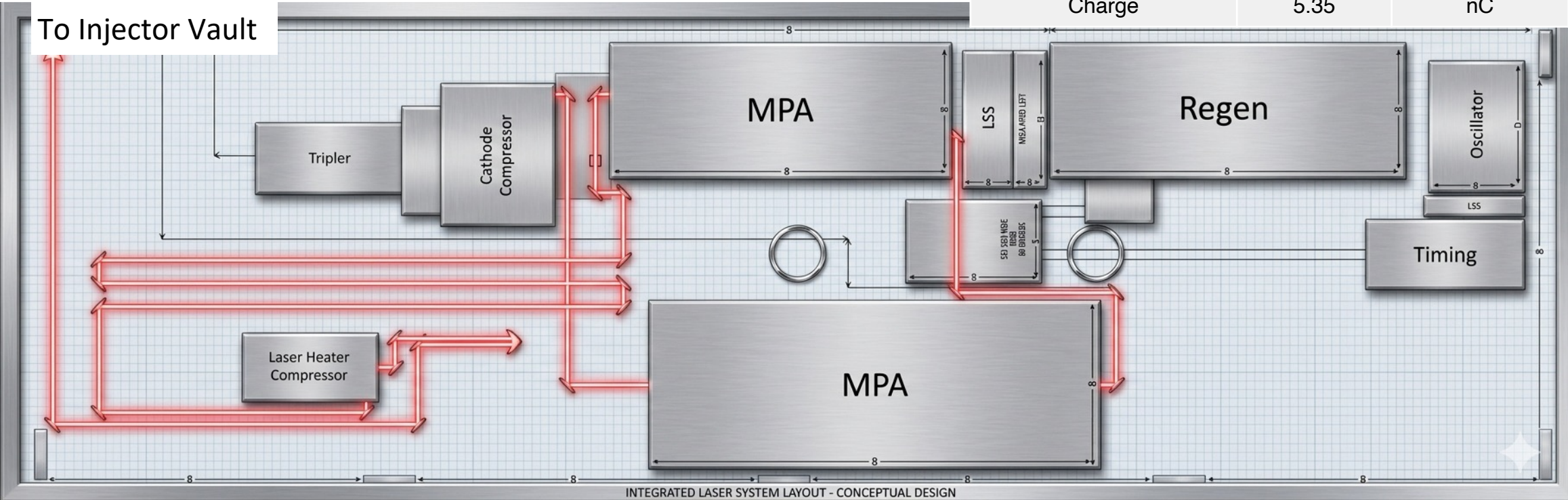


FACET-II targets high-charge, high-current operation

Laser System

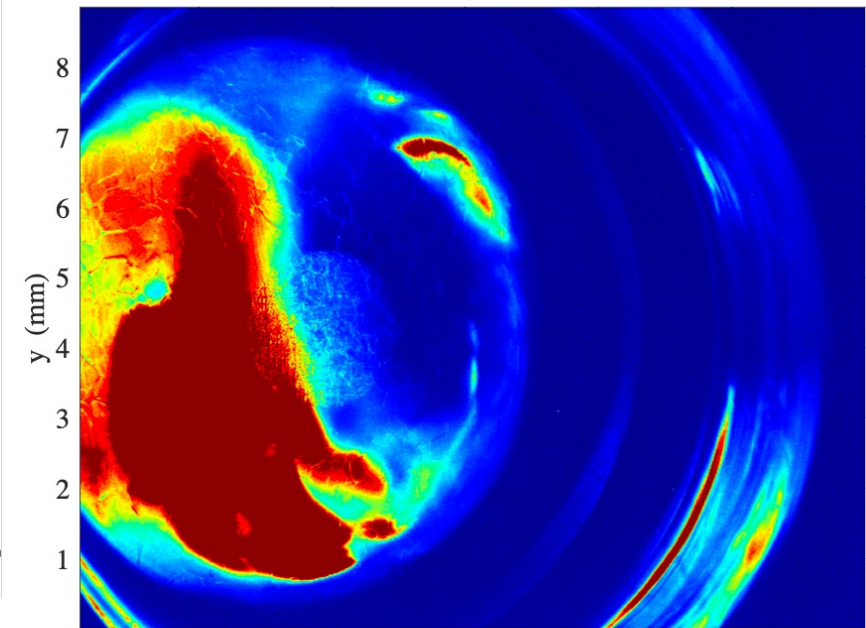
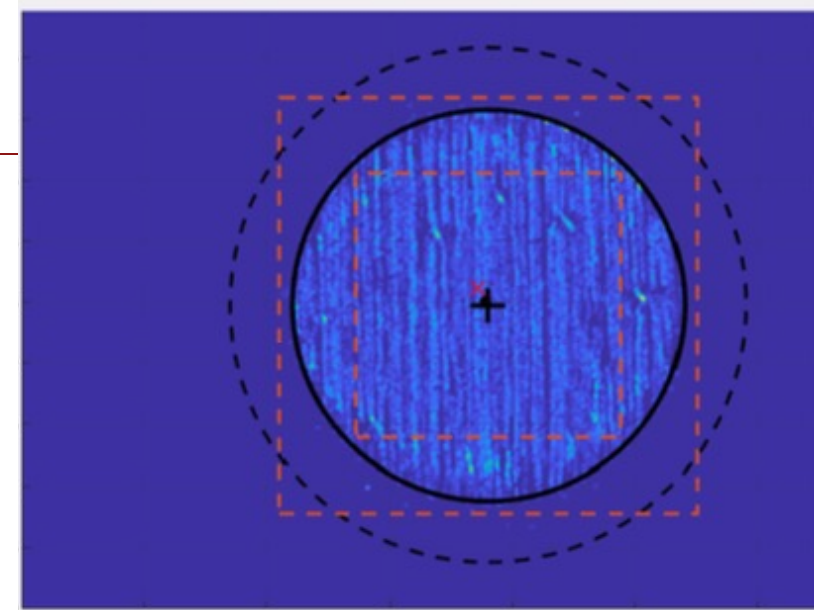
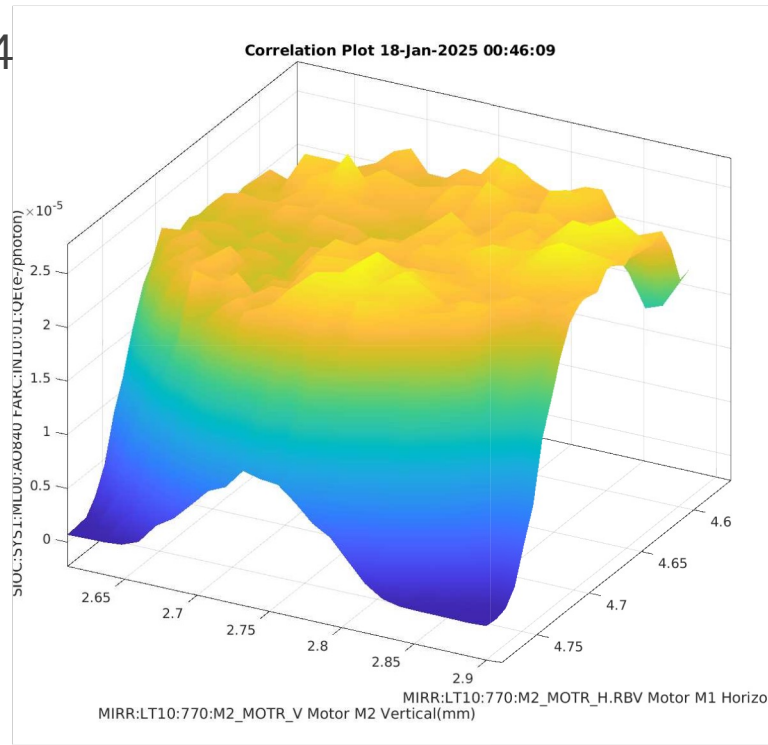
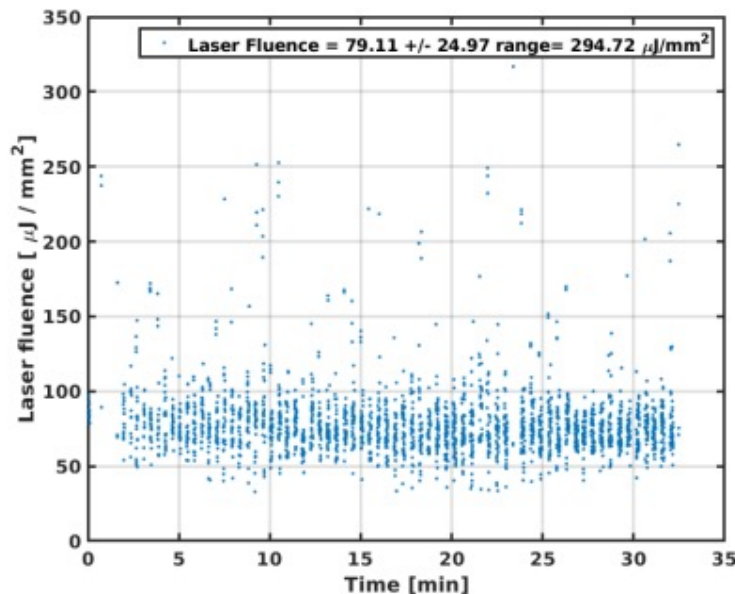
- Ti:Sapphire system tuned to 760 nm
- Oscillator and Regen split to feed two MPA
 - Cathode and Laser Heater Sections
- Pay attention to your mirrors!

Parameter	Value	Unit
MPA Output	22	mJ
Compressor Output	14.3	mJ
UV Conversion Efficiency	0.07	
UV (253)	1	mJ
Transport Efficiency	0.25	
UV on Cathode	250	uJ
QE	10 ⁻⁴	
Charge	5.35	nC



Laser cleaning Cu cathode

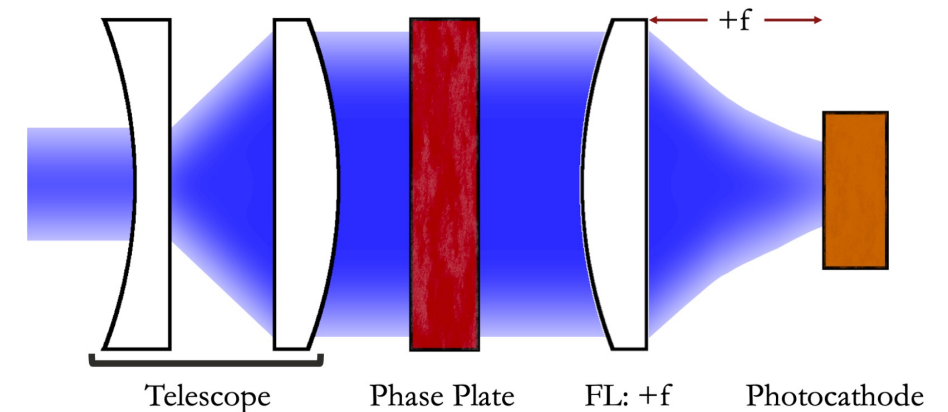
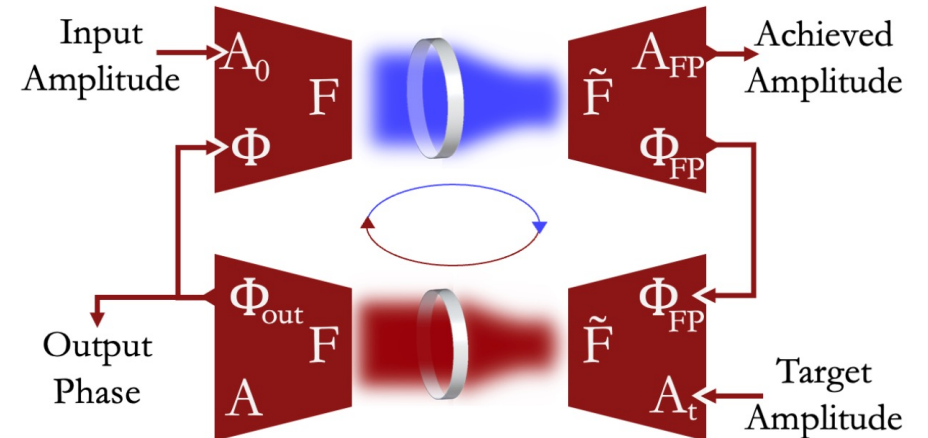
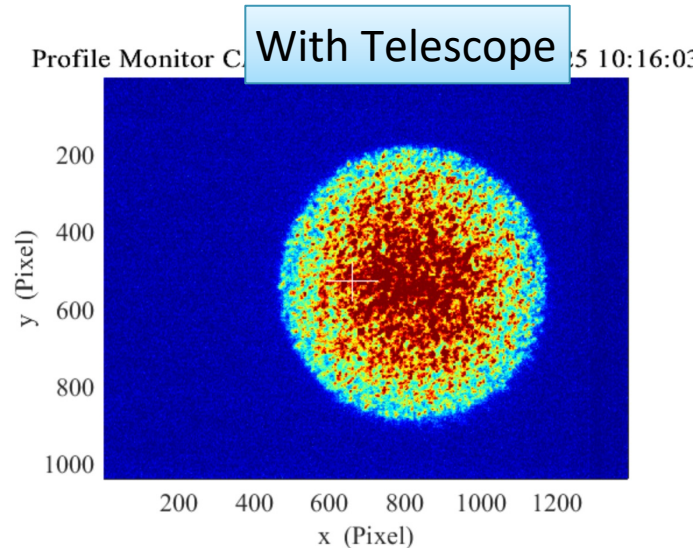
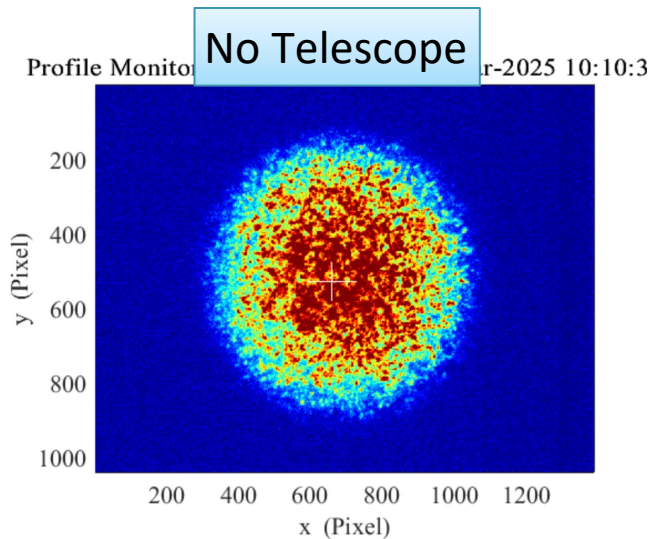
- Surprisingly little on laser cleaning in the literature
- We last laser cleaning October 29, 2021 to November 5, 2021
 - Yes, 8 days. It is a big spot.
- We have not laser cleaned since
- February 21, 2022: QE = 1.6×10^{-4}
- March 17, 2026: QE = 1.6×10^{-4}



Careful cleaning and managing gun vacuum preserves long lifetime

Random Phase Plate (RPP)

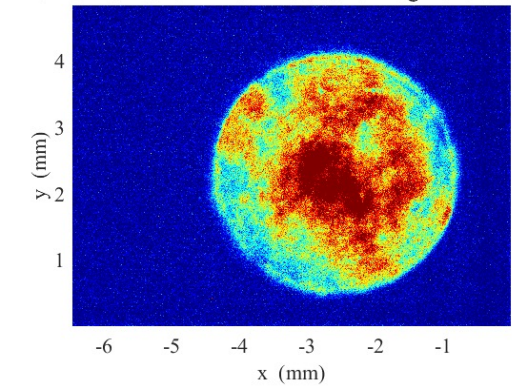
- Goal is to generate a cut Gaussian without diffractive and other effects
 - 33% better emittance performance compared to pure flattop
 - 5.85 μm $\rightarrow$ 4.7 μm demonstrated at FACET-II (20%) at 3 nC



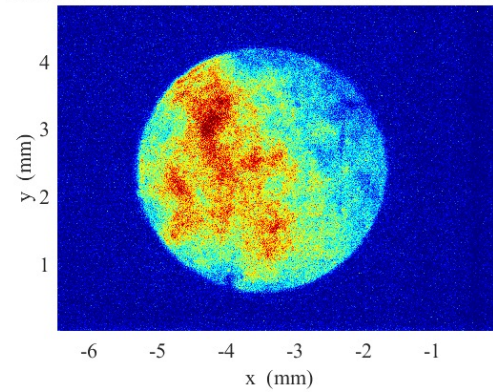
RPP based laser shape never changes, minimal tuning required day to day

RPP Performance

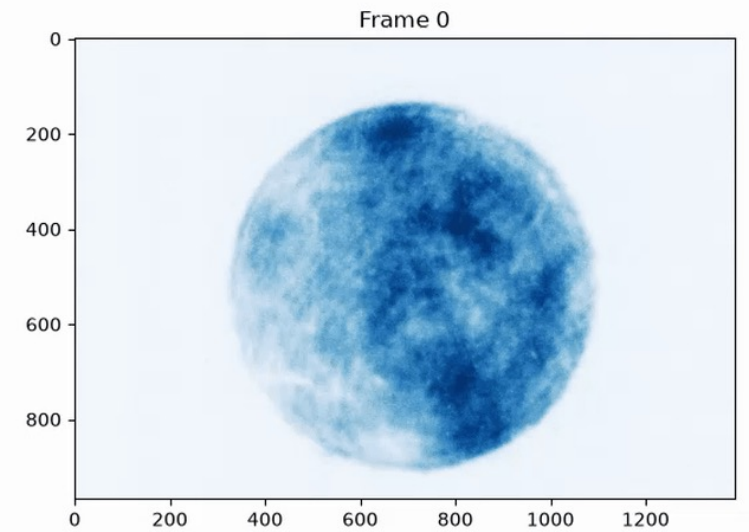
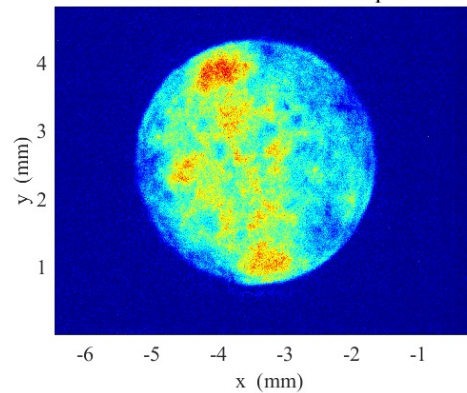
Profile Monitor CAMR:LT10:900 10-Aug-2023 09:32:39



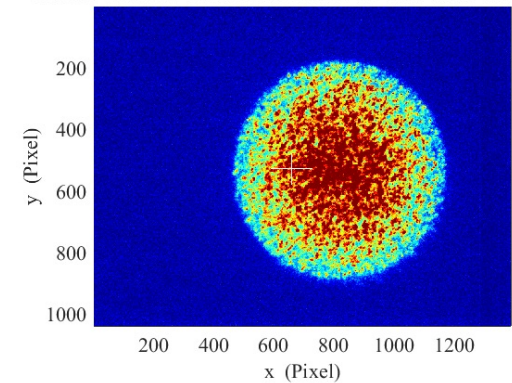
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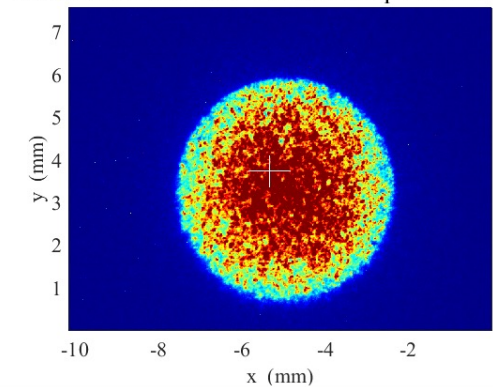
Profile Monitor CAMR:LT10:900 11-Apr-2024 16



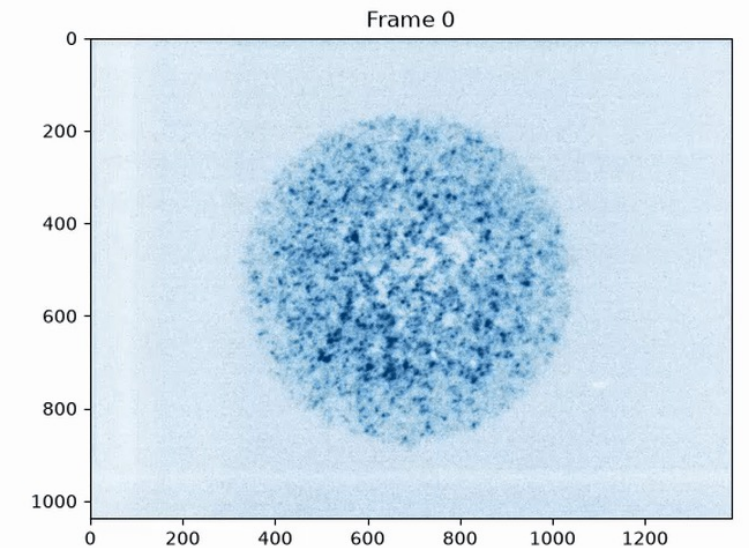
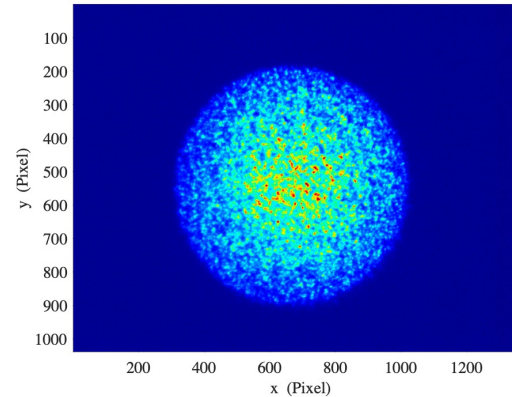
Profile Monitor CAMR:LT10:900 01-Mar-2025 10:16:05



Profile Monitor CAMR:LT10:900 09-Apr-2025 14:09:20



Profile Monitor CAMR:LT10:900 01-Mar-2025 11:38:25



RPP based laser shape never changes, minimal tuning required day to day

RPP and Beam Performance



No RPP

With RPP

RPP based laser shape never changes, minimal tuning required day to day

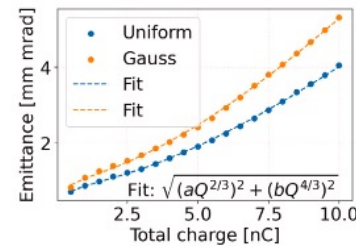
High Charge Beam Performance

Parameter	Unit	RPP	RPP	RPP	RPP	RPP	RPP		No RPP	No RPP	No RPP
Charge	nC	1.6	2.0	2.5	3.0	3.5	3.8		1.6	3.0	3.0
Laser Power	uJ	65	78	101	132	145	182		52	93	85
Flat top Spot Size	mm	5.5	5.5	5.5	5.5	5.5	5.5		5.5	5.5	5.5
Pulse Length (rms)	ps	1.2	1.2	1.2	1.2	1.2	1.2		1.1	1.1	1.1
Emittance X/Y (@135 MeV)	μm	4.4/4.4	4.3/4.7	4.1/4.7	4.5/4.9	6.3/5.6	5.5/6.1		3.2/3.2	5.9/5.8	7.5/5.4
Effective QE	10^{-4}	1.2	1.26	1.21	1.11	1.18	1.02		1.51	1.58	1.72

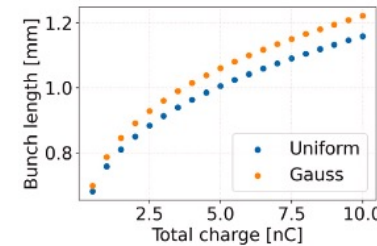
Performance repeatability huge benefit in two bunch operation

Future plans + experiments

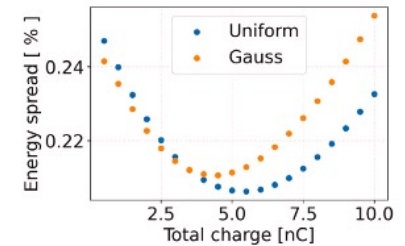
- Characterize beam parameters at design value of 5 nC
- Measure emittance and match for multiple laser beam sizes and charge values
 - Aiming for FCC relevant values
- Install method for changing beam size at 100 Hz
 - Spatial Light Modulator
 - Deformable Mirror
- Image electron beam back to cathode and optimize laser shape to QE
- Use two laser pulses to measure charge emission from Cu cathodes



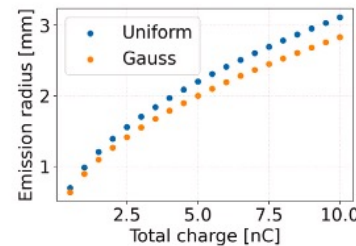
(a) Rms normalized transverse emittance.



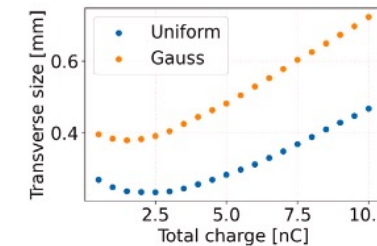
(b) Rms bunch length.



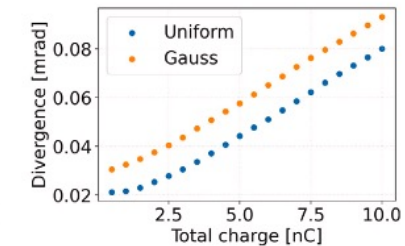
(c) Rms energy spread.



(d) Emission radius.



(e) Rms transverse beam size.



(f) Rms beam divergence.

Bunch parameter	Simulation	Target
Transverse emittance	3.14 mm.mrad (rms) Assumed 3.2 mm.mrad (rms)	< 4 mm.mrad
Bunch length	0.96 mm (rms)	1 mm
Final energy	190 MeV	200 MeV
Energy spread	0.2% (390 keV)	< 0.5 %
Bunch charge	5 nC	5 nC



Thank You!