

IBIC 17

INTERNATIONAL BEAM
INSTRUMENTATION CONFERENCE

Grand Rapids,
Michigan, USA
20-24 August 2017



Beam Diagnostics Challenges for **FACET-II**

Facility for Advanced Accelerator Experimental Tests

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SLAC National Accelerator Laboratory

August 21, 2017

FACET-II: Premier R&D Facility for PWFA

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FACET Highlights:

- Apr. 2012 – Apr. 2016 Experimental program
- High impact results on efficient acceleration of e^- and e^+ in plasma
- Mono-energetic e^- acceleration
- High efficiency e^- acceleration (*Nature* **515**, Nov. 2014)
- First high-gradient e^+ PWFA (*Nature* **524**, Aug. 2015)

FACET-II Timeline:

- ✓ Nov. 2013, FACET-II proposal, Comparative review
- ✓ CD-0 Aug. 2015
- ✓ CD-1 Oct. 2015
- ✓ CD-2/3A Sept. 2016
- CD-4 2022

FACET-II will operate as a National User Facility with experimental program between 2019 and 2026

PWFA Research Priorities at FACET-II

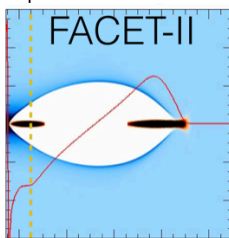
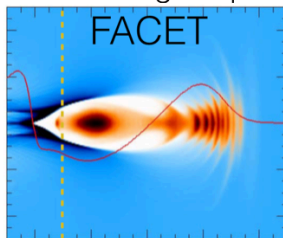
Emittance Preservation with Efficient Acceleration

FY19-21

- High-gradient high-efficiency (instantaneous) acceleration has been demonstrated @ FACET



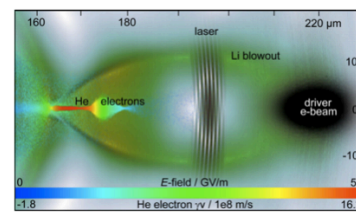
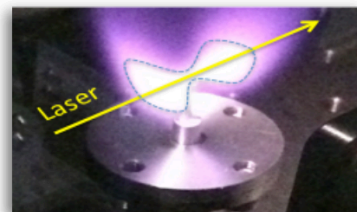
- Full pump depletion and preservation of emittance at μm level is planned as the first high impact experiment



High Brightness Beam Generation & Characterization

FY20-22

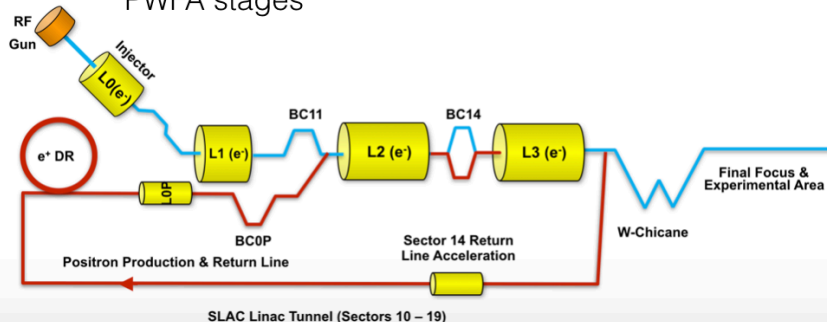
- 10's nm emittance preservation is necessary for collider applications
- Ultra-high brightness plasma injectors may lead to first applications of PWFA technology



Positron Acceleration

FY21-24

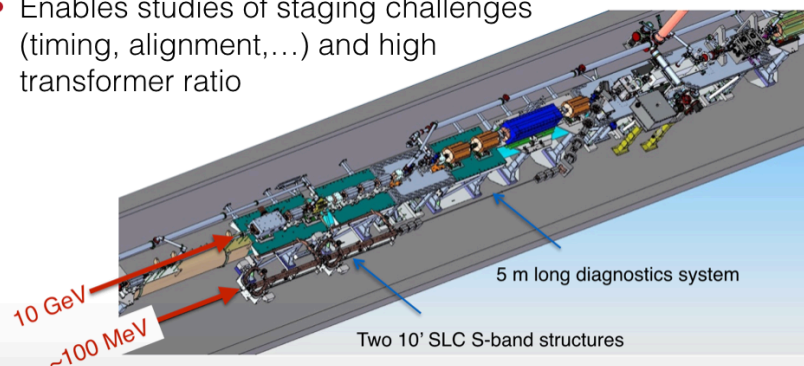
- Only positron capability in the world for PWFA research will be enabled by Phase II
 - Develop techniques for positron acceleration in PWFA stages



Staging Studies

FY22-25

- Independent witness injector planned to be added to FACET-II as an AIP project
- Enables studies of staging challenges (timing, alignment,...) and high transformer ratio

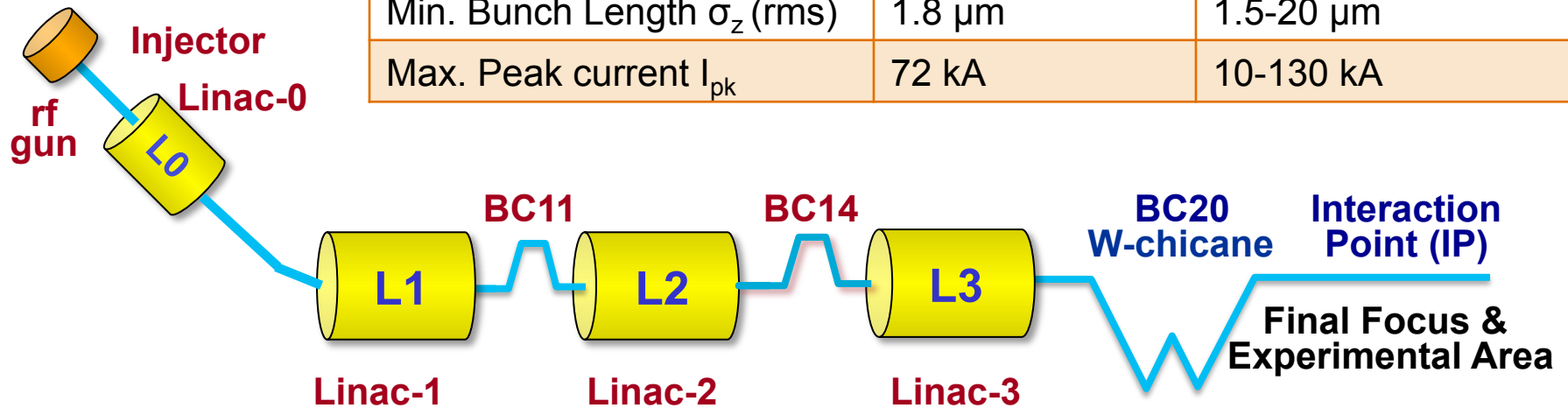


Broad User Community is engaged in FACET-II Science Program Planning with Workshops: Oct. 12-16, 2015, Oct. 17-19, 2016, Oct. 17-20, 2017

FACET-II Accelerator & Beam Parameters for Electrons

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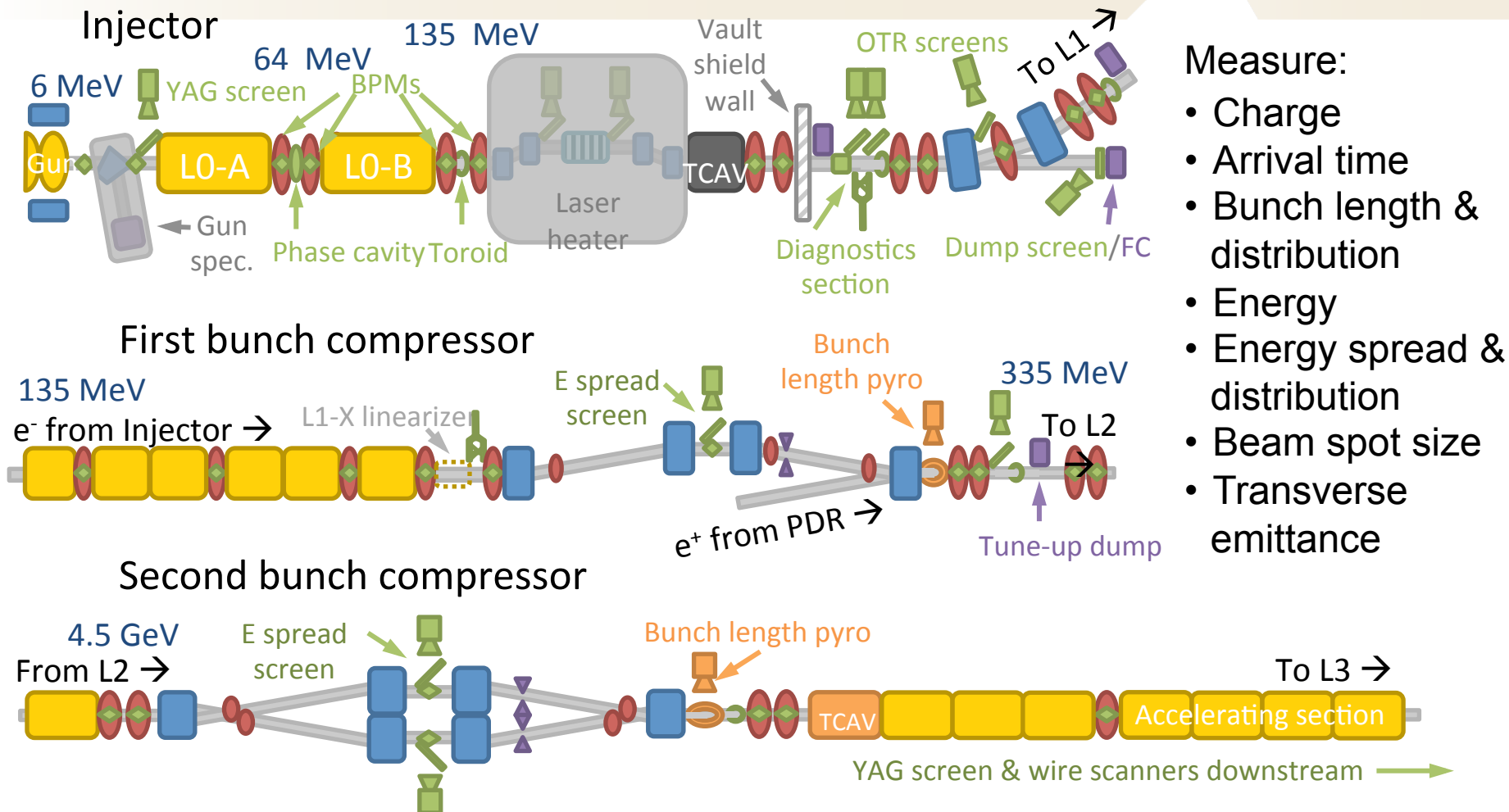
Beam Parameter	Baseline Design	Operational Ranges
Final Energy	10 GeV	4.0-13.5 GeV
Charge per pulse	2 nC	0.7-5 nC
Repetition Rate	30 Hz	1-30 Hz
Norm. Emittance $\gamma\epsilon_{x,y}$ at S19	4.4, 3.2 $\mu\text{m-rad}$	3-6 $\mu\text{m-rad}$
Spot Size at IP $\sigma_{x,y}$	18, 12 μm	6-20 μm
Min. Bunch Length σ_z (rms)	1.8 μm	1.5-20 μm
Max. Peak current I_{pk}	72 kA	10-130 kA



SLAC Linac Tunnel (Sectors 10 – 19)

Sectors 20

Diagnostics for FACET-II Accelerator

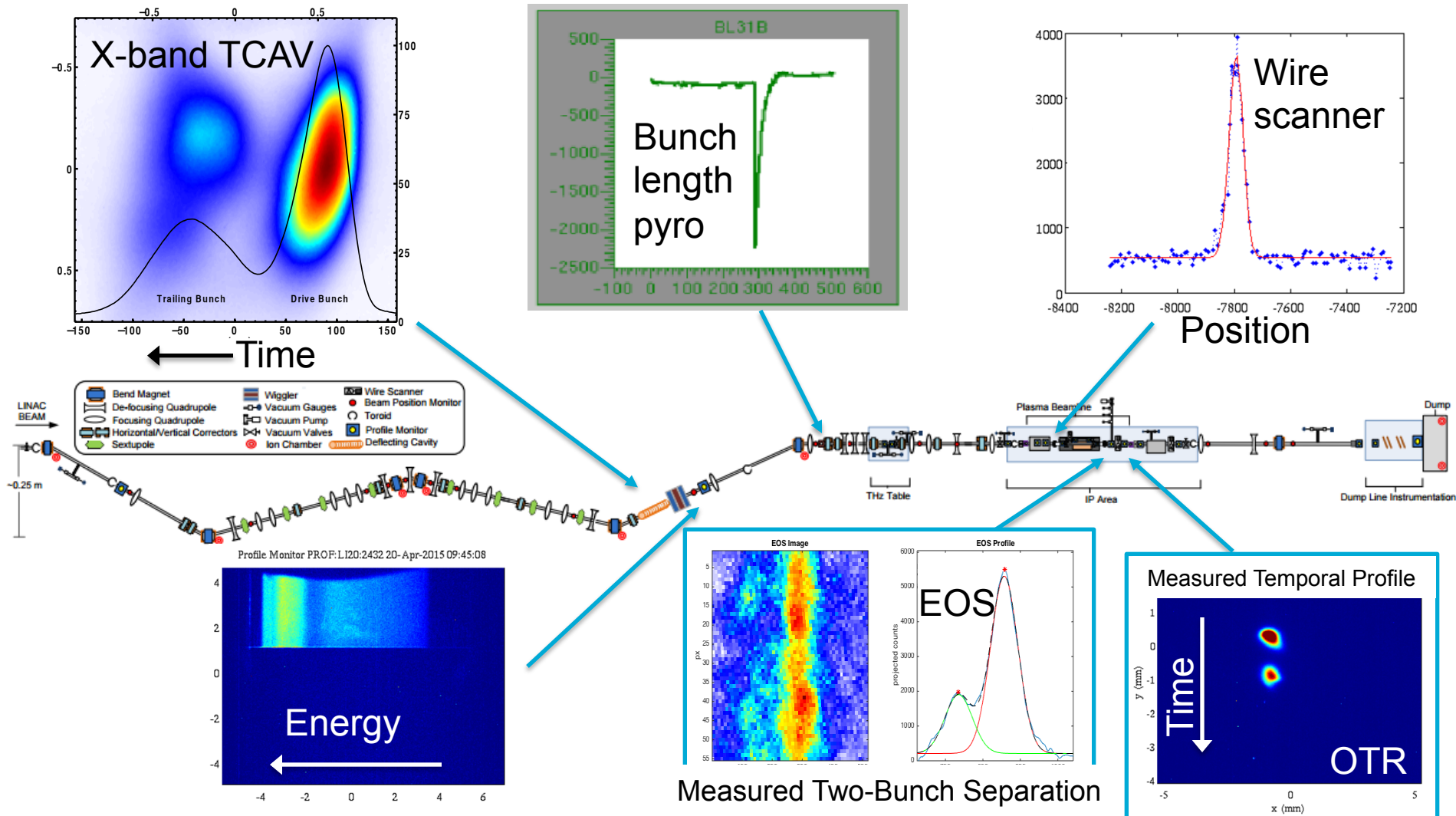


(See details in P. Krejcik's LCLS talk on 8/23)

FACET-II accelerator uses similar diagnostics as LCLS

Diagnostics at FACET Experimental Area

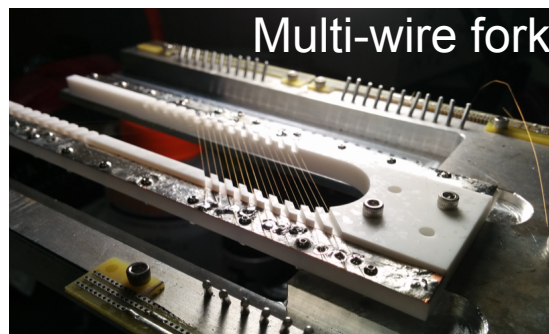
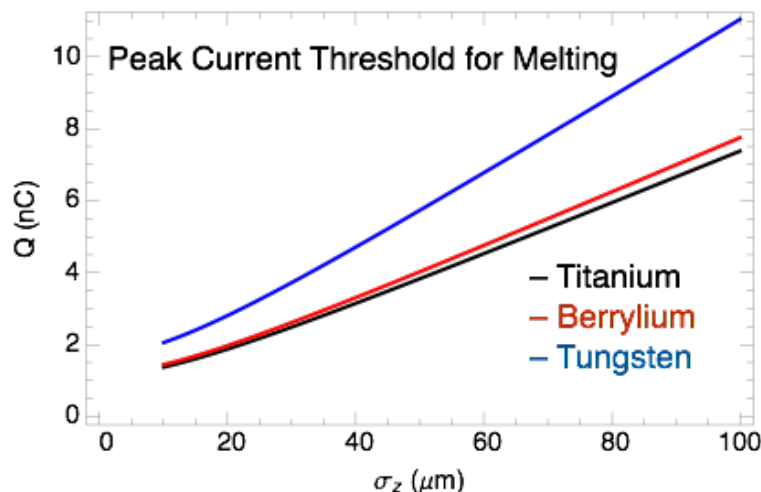
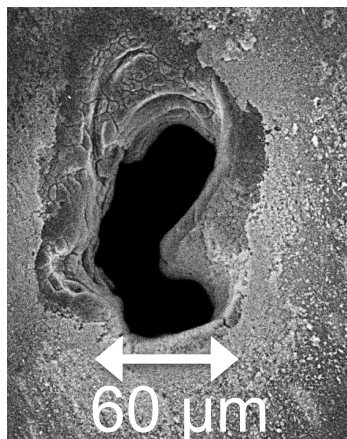
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FACET-II will inherit and improve FACET's diagnostics

Extreme Beams: A Challenge and Opportunity

- Extreme beam densities at FACET-II allow experiments to access new regimes & create diagnostic challenges as anything intercepting the beam will be damaged

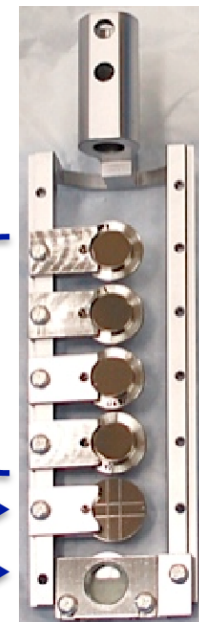


- Use of multi-screen OTR ladders & multi-wire fork wire scanners away from beam waist mitigates damage

1- μm thick Ti

500- μm thick Ti

20- μm thick YAG



$$P \propto \frac{Q^2}{\sigma_r^2 \sigma_z^2} F(\sigma_r / \sigma_z)$$

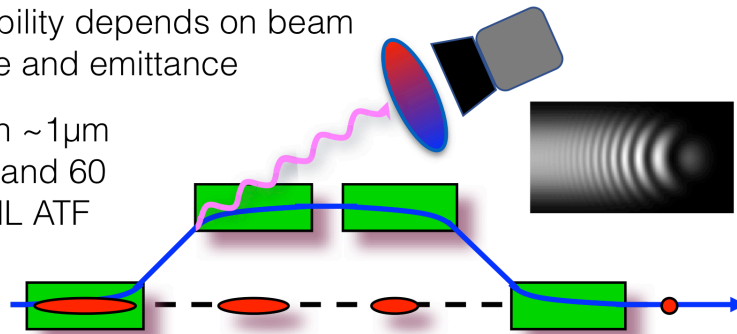
FACET-II needs to develop diagnostics not intercepting the high-density beam

Concepts for Novel Beam Diagnostics at FACET-II

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Interference of Dipole Edge Radiation – Monitor for Beam Divergence

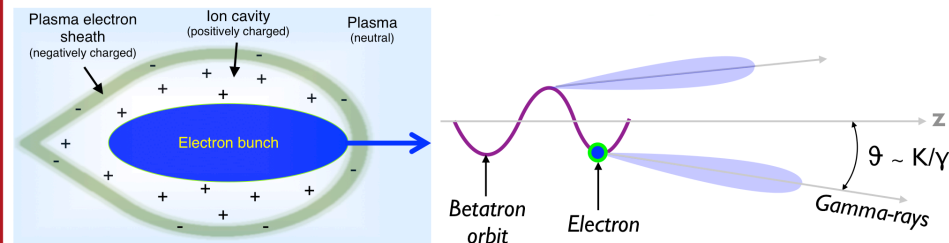
- Fringe visibility depends on beam divergence and emittance
- Tested with $\sim 1\mu\text{m}$ emittance and 60 MeV at BNL ATF



O. Chubar PhD thesis 1990

Betatron Radiation for Measuring Ultra-low Emittance

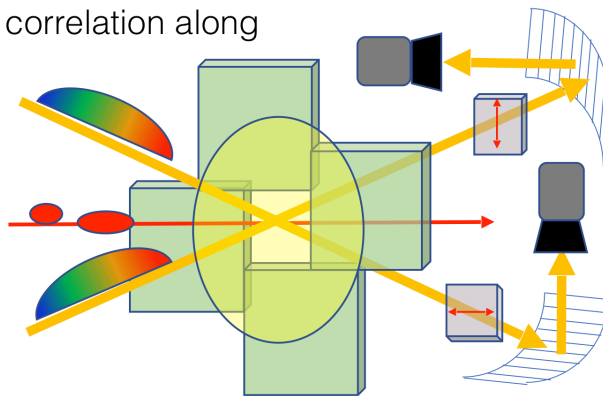
- Central betatron wavelength proportional to beam energy
- Linewidth of the radiation proportional to beam emittance



J. Rosenzweig, 2016 FACET-II Science Workshop

Quadrant EOS to Measure r-t Beam Correlations

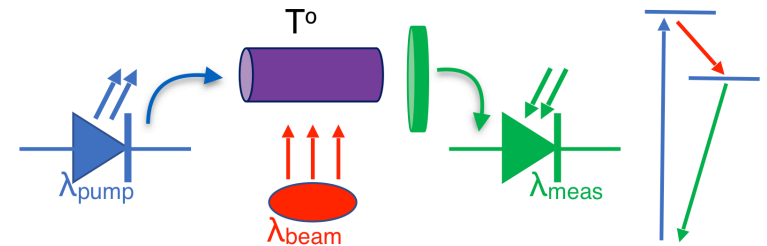
- Goal is to measure correlation along $\sim 1\text{ps}$ long bunch
- Spectrally encoded EOS with imaging spectrometer enable non-destructive measurement of correlations



V. Yakimenko, Private comm.

Bunch Length Monitor for 3-30fs Long Bunches

- Laser light resonantly pumps gas to excited state
- Relaxation to intermediate state triggered by beam field
- Emission rate from intermediate to ground state depends on temporal spectrum of the beam field



M. Zolotarev, Private comm.

Unprecedented beams at FACET-II provide exciting diagnostic challenges for the accelerator community

Conclusion

- FACET-II will deliver unprecedented high density electron and positron beams for advanced accelerator R&D
- Diagnostics for accelerator operation are well developed
- Diagnostics at the experimental area are challenging and need to be developed
- FACET-II will operate as a National User Facility
 - Users are invited to develop & test beam diagnostics at the FACET-II beamline
 - FACET-II Science Workshop Oct. 17-20, 2017
<https://conf.slac.stanford.edu/facet-2-2017/>

End of Presentation