FACET Diagnostics Experience

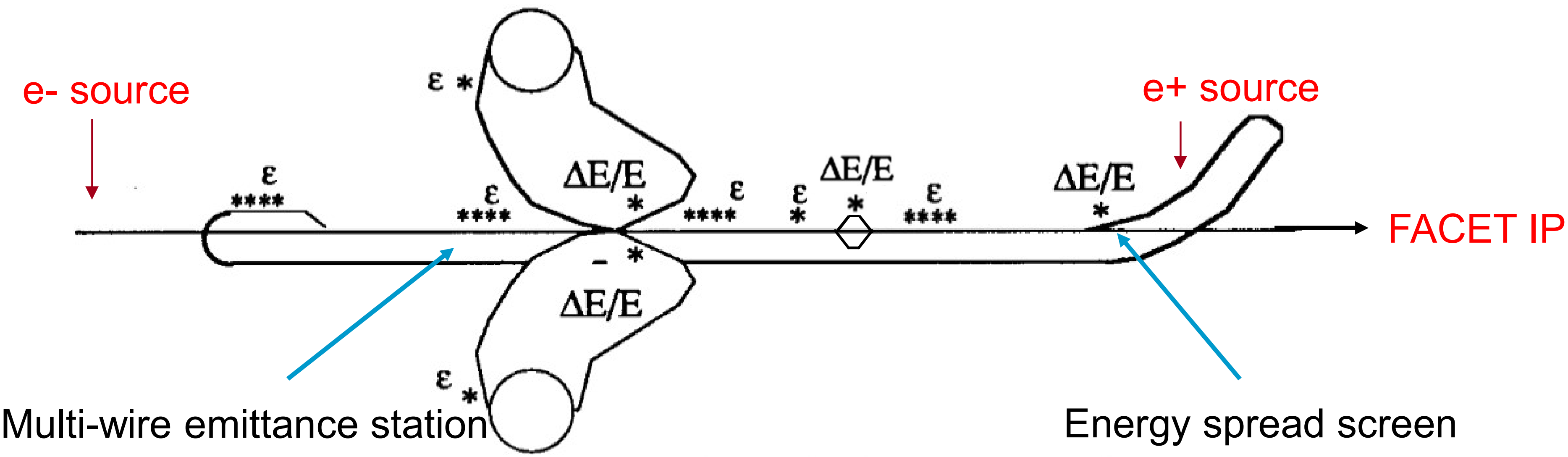
Nate Lipkowitz
FACET-II Science Workshop
October 18, 2016

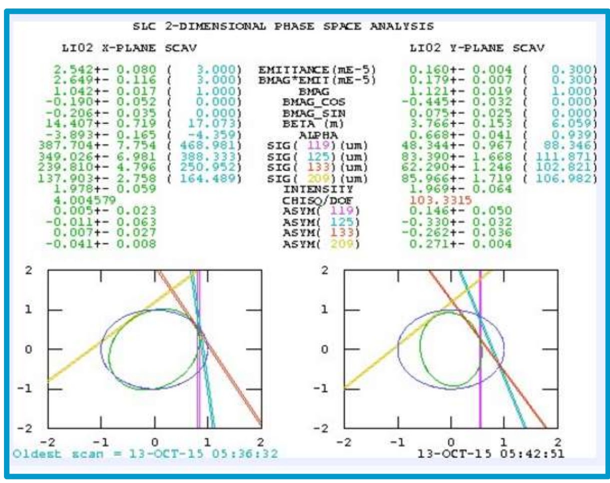
U.S. DEPARTMENT OF ENERGY
Office of Science

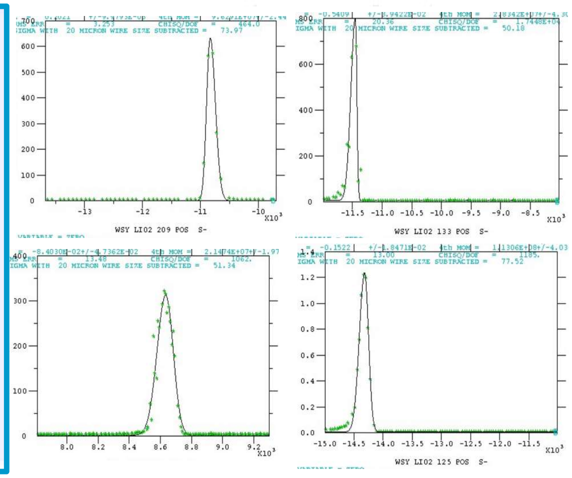
SLAC NATIONAL ACCELERATOR LABORATORY

Diagnostics at FACET

FACET Linac diagnostics were largely carried over from SLC:

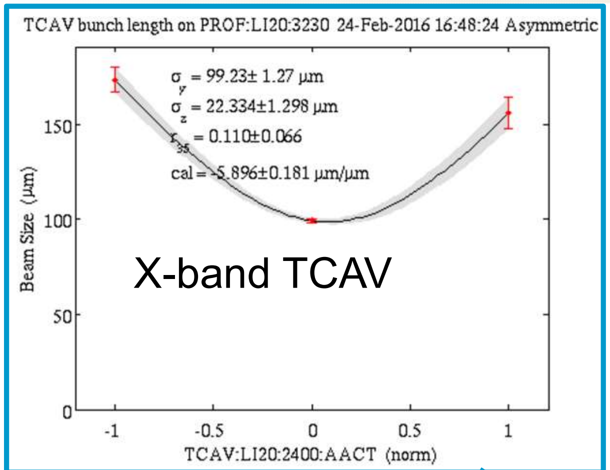


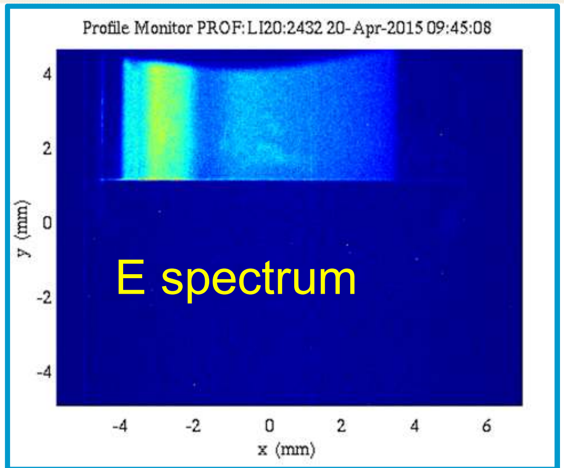


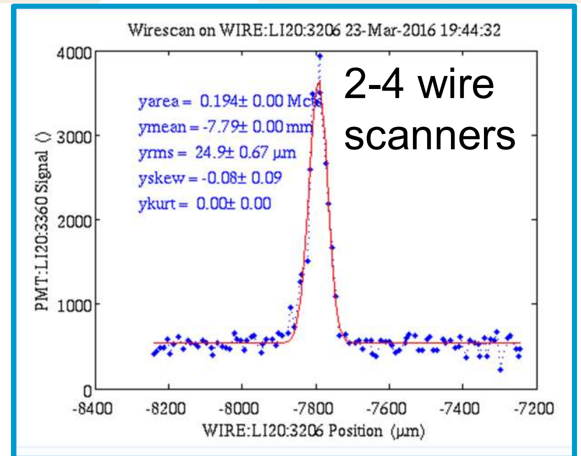


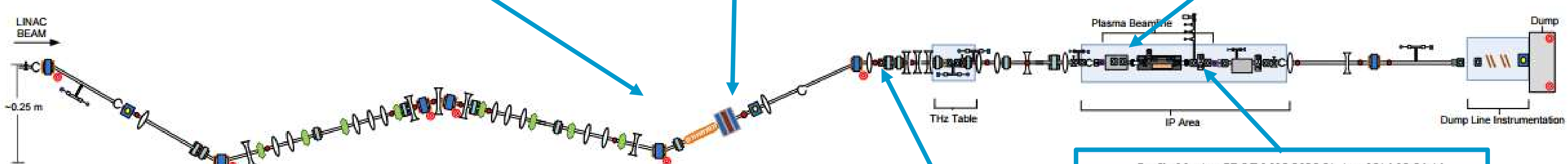
Diagnostics at FACET

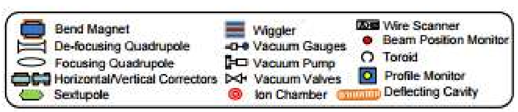
SLAC



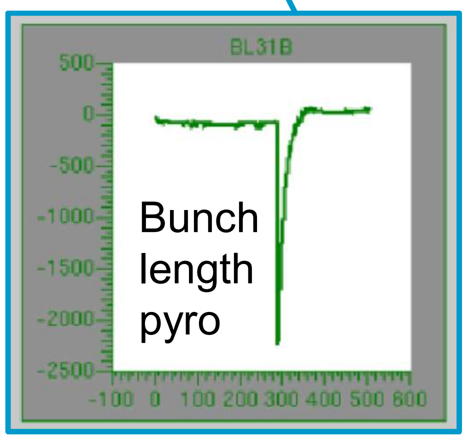


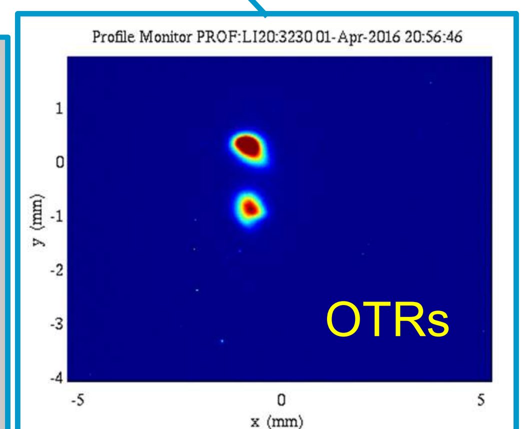






W chicane and IP area diagnostics all new for FACET.

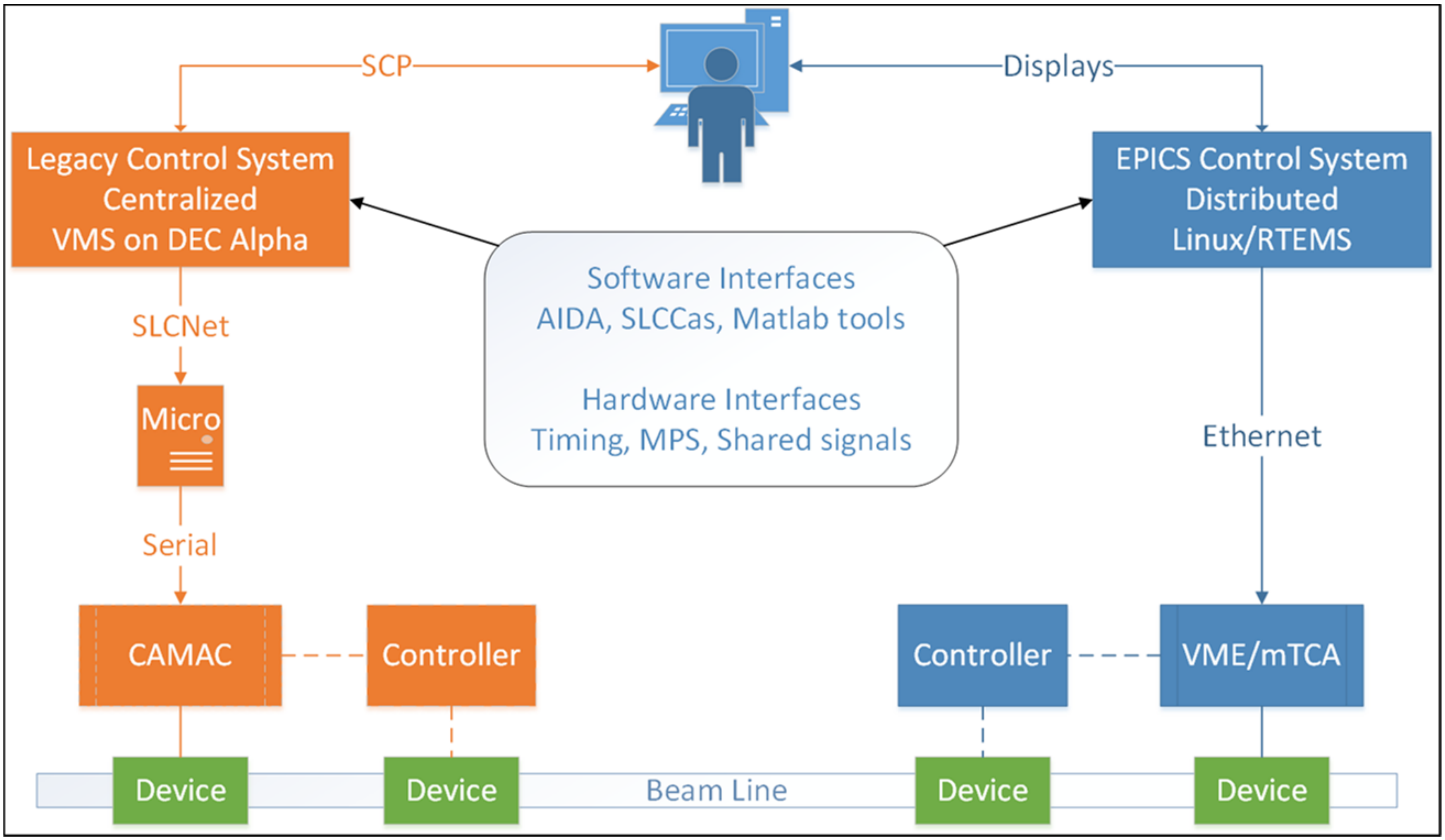




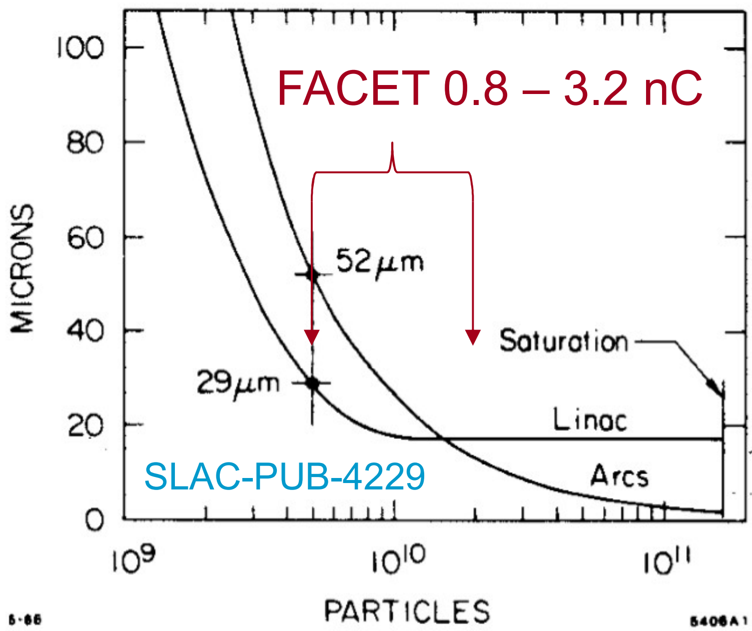
FACET Hybrid Control System Architecture

SLAC

Tools exist to pull data from legacy system diagnostics, correlate with EPICS measurements, scan magnets etc. Little support remaining, and slow, but it works → data rate limitations



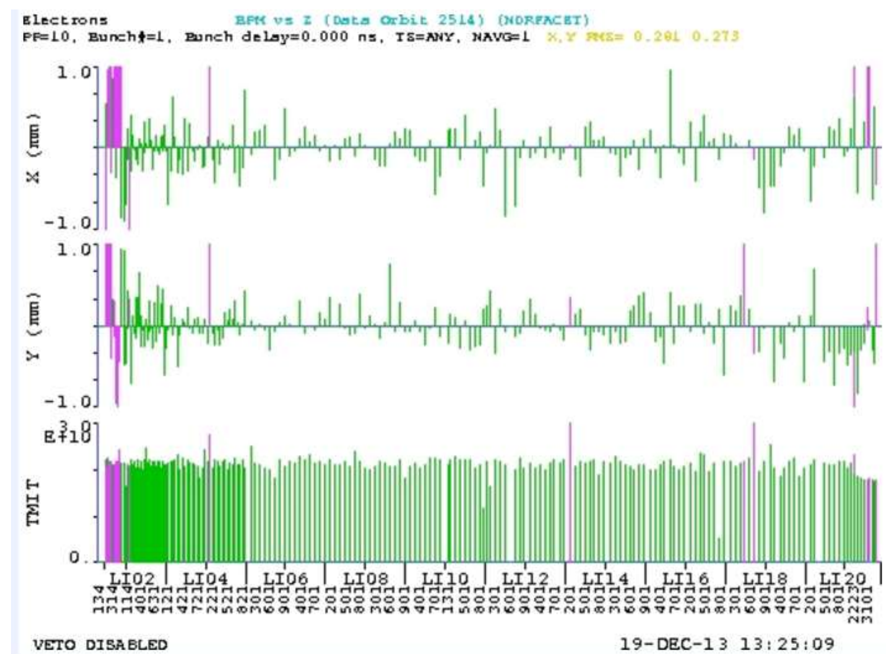
Stripline BPMs



SLC-era BPM processors in injector, DR, linac

- Resolution ~ 20 μm acceptable for linac steering at high charge
- Performance degrades rapidly below 1e10 e-

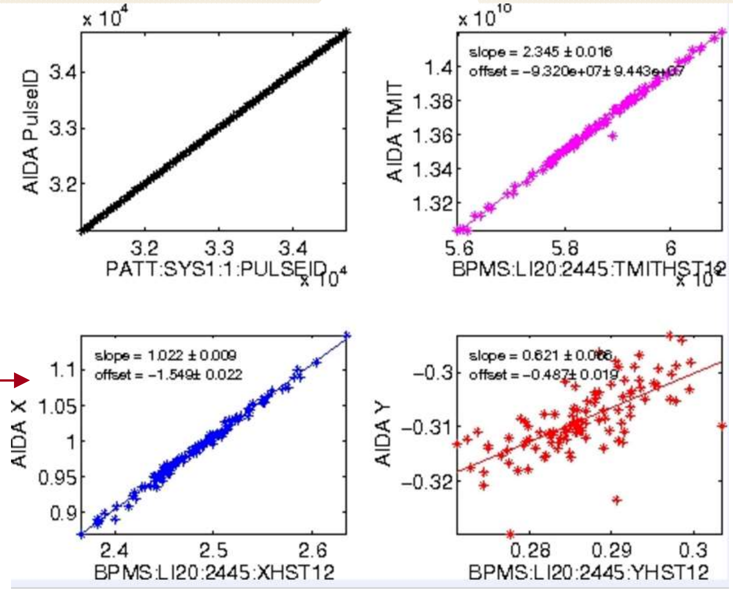
- Susceptible to scale and offset creep, jumps due to electrical interference
- Triggering scheme works poorly at low rep rates (<5 Hz) and software interface is aging
- Software work-arounds exist



Stripline BPMs

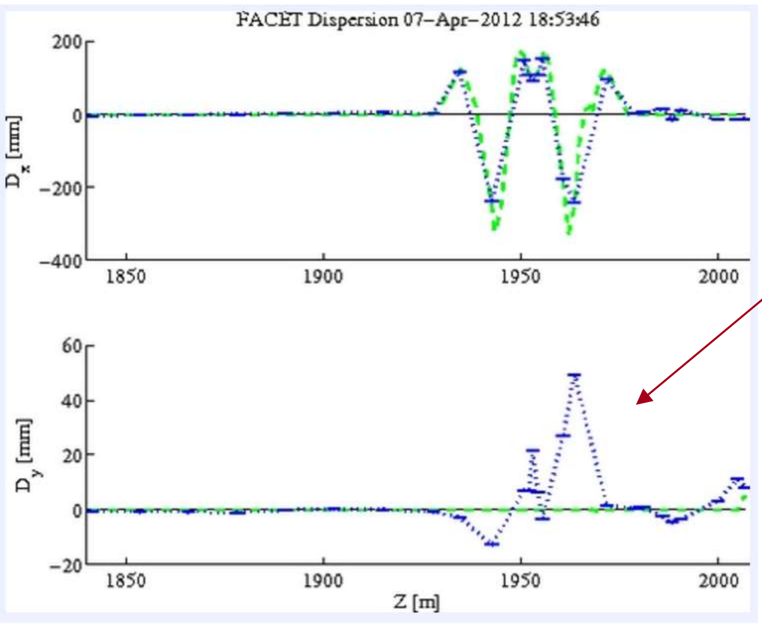
FFTB-style BPM processors in Sector 20 have better resolution, but same software limitations and frequent hardware failures.

Around IP, 4 BPMs have signals split into EPICS processors for fast diagnostics, feedback and easy DAQ by experimenters.

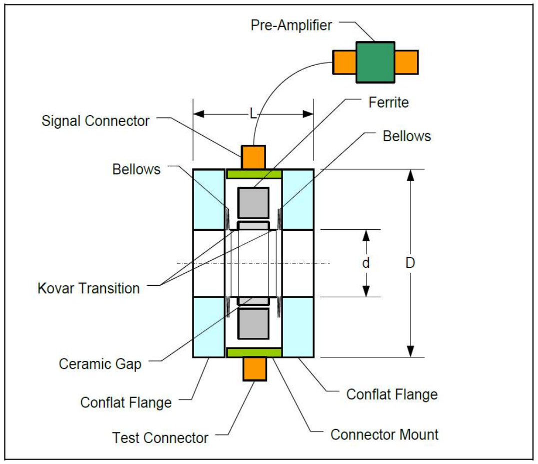


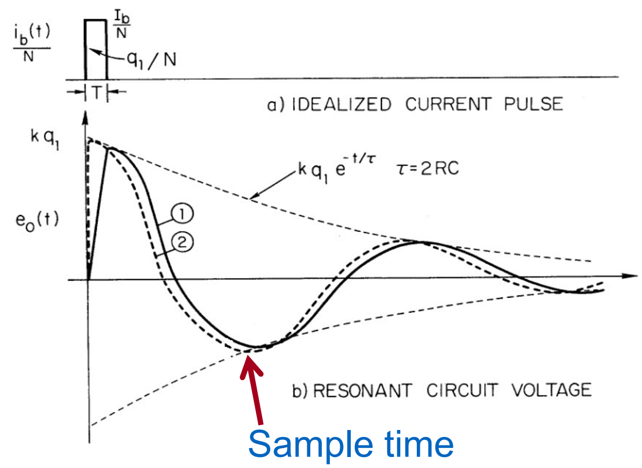
Sometimes the diagnostic <u>is</u> the problem:

- Apparent large vertical dispersion in the Sector 20 chicane
- Much hunting for optics errors and stray magnetic fields
- Careful measurement and correction of BPM x-y coupling (roll) up to 5 deg fixed most of this



Charge Monitors

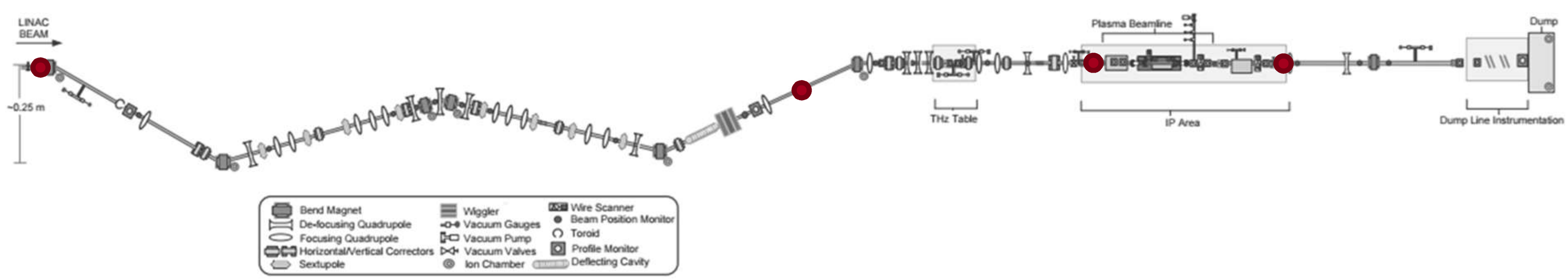




Typically:

- 8-turn signal
- 1-turn calib.
- f ~ 50 kHz

- CAMAC TCM module + SLAC preamp
- Rectifier to S&H circuit to 10-bit gated ADC, ~ 5% absolute accuracy and precision
- Finicky calibration and ADC precision limits measurement for e.g. plasma charge injection experiments
- Signal from toroids near IP split, fed to 16-bit EPICS ADC channels

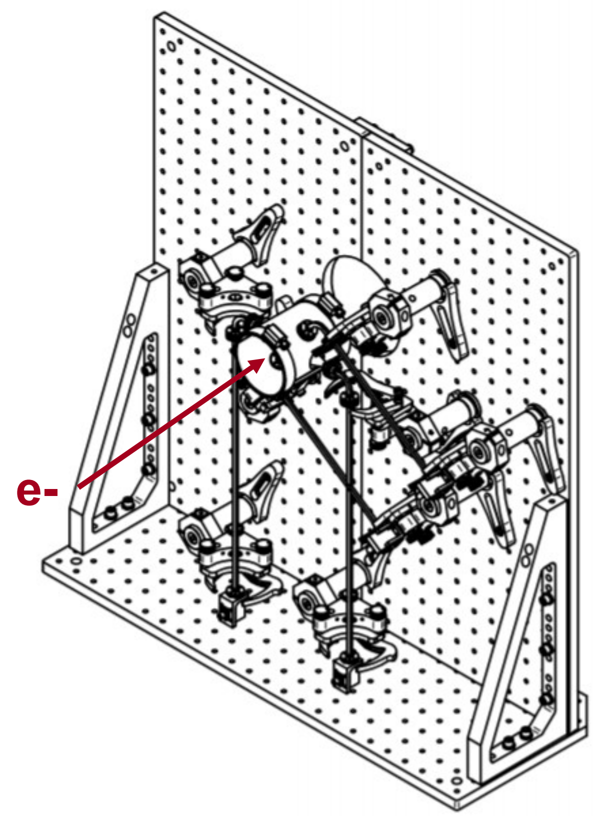


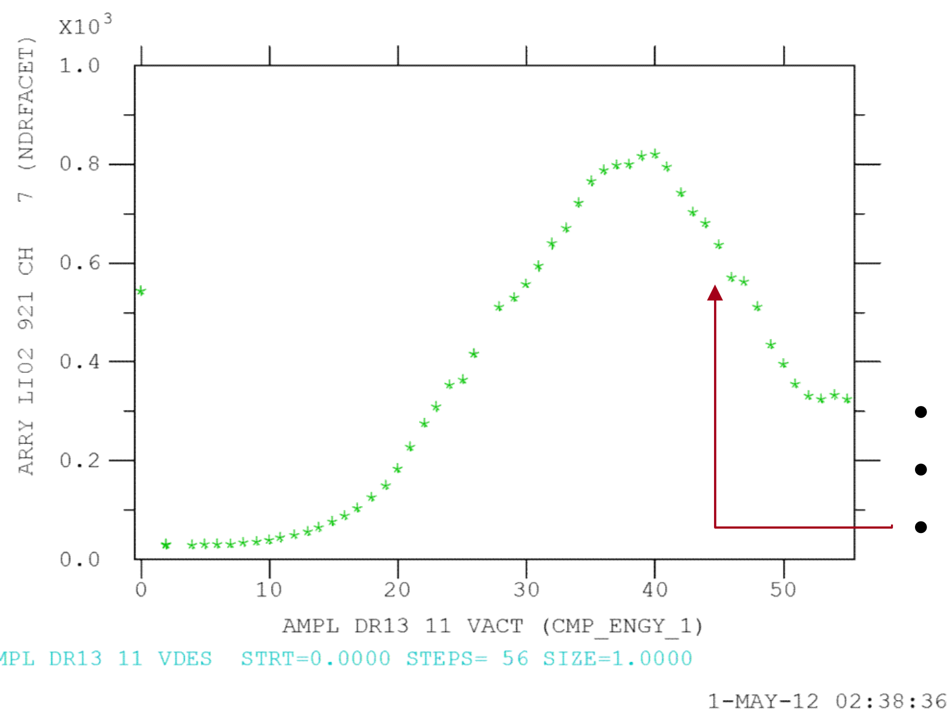
Bunch Length Monitors

SLAC

Simple ceramic gap radiating into waveguide-coupled diodes (30-60 GHz) for bunch length monitoring 0.5 – 5 mm before injection into linac.

Charge sensitive (~q^2) but cheap, simple and very robust.



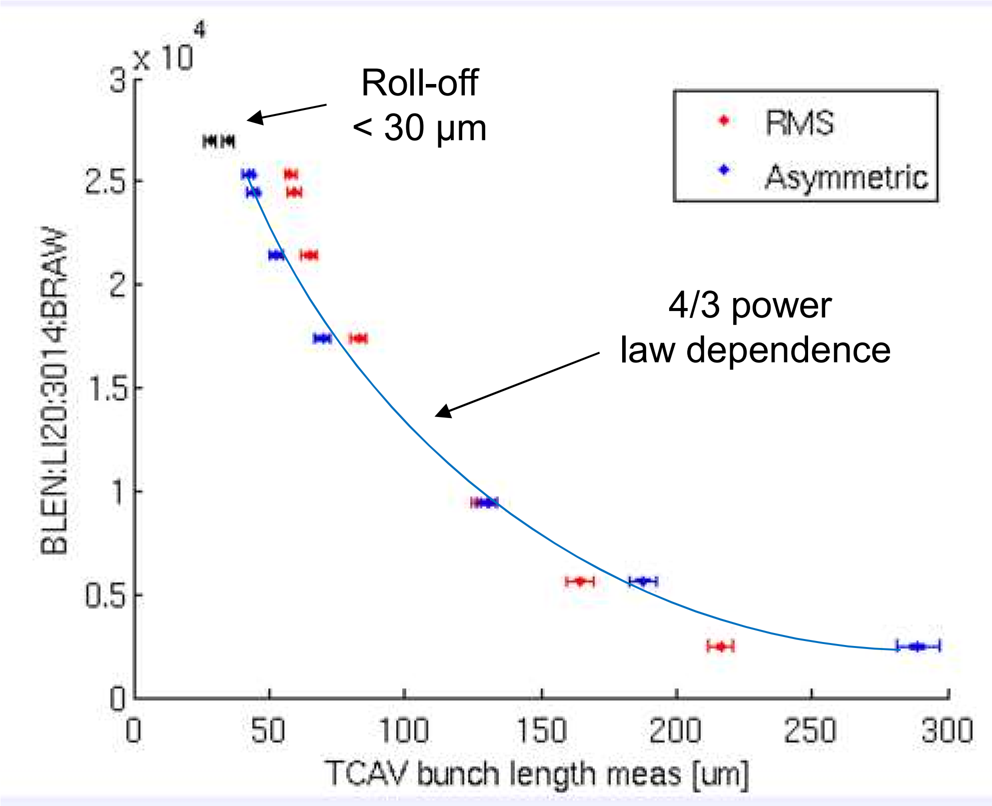


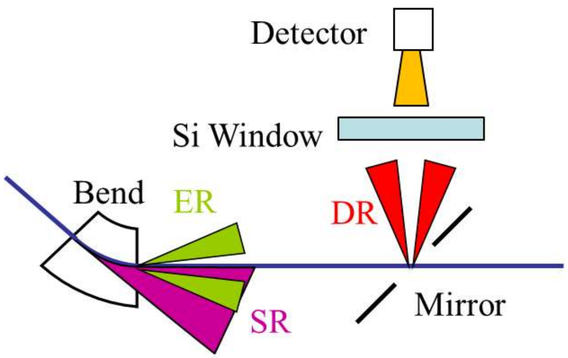
- Scan compressor voltage
- Find maximum
- Operate at offset ~ 80% from peak

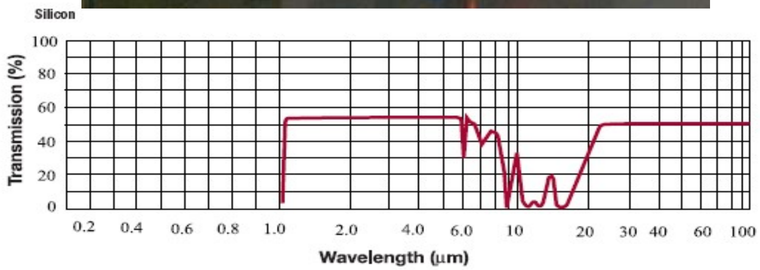
Bunch Length Monitors

Pyroelectric bunch length monitor modeled after LCLS BC1/BC2.

Relative diagnostic, works well for finding and maintaining peak compression.

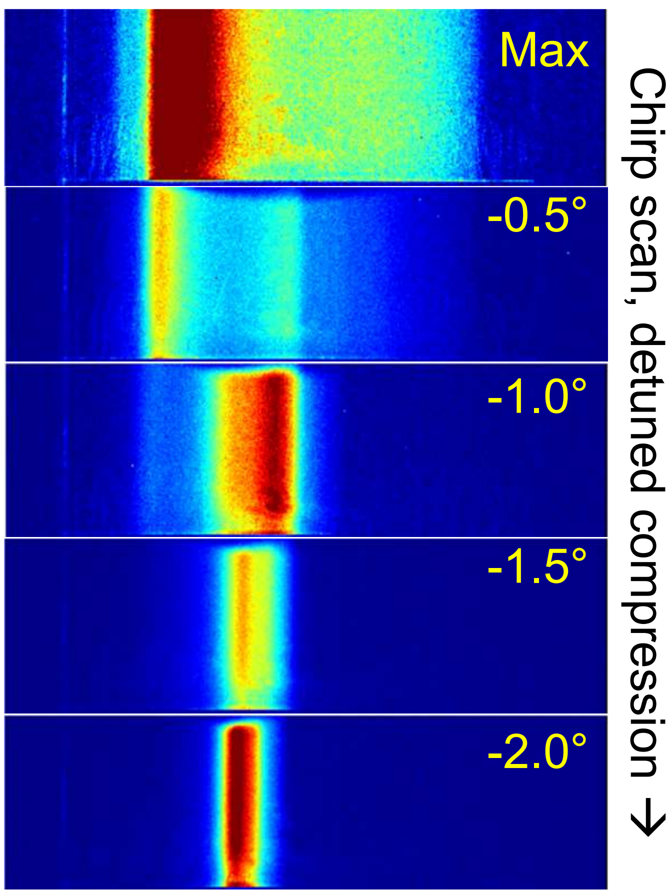




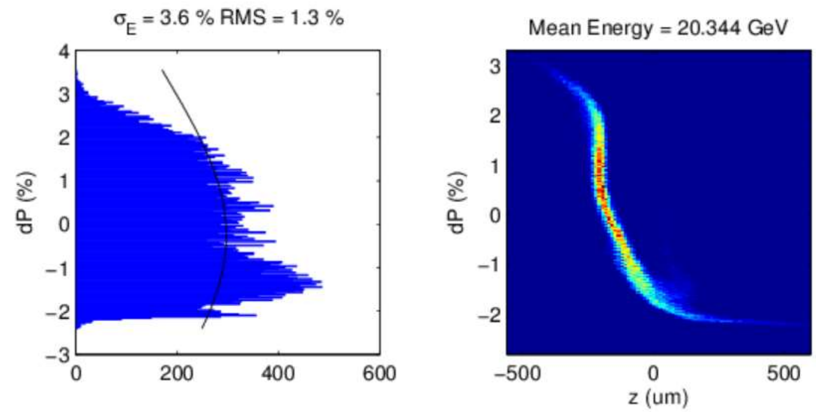


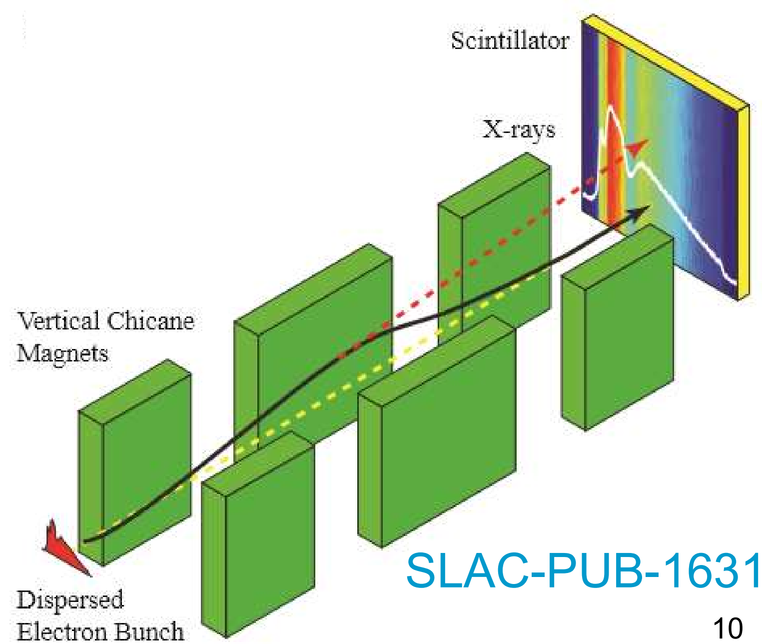
SYAG wiggler stripe spectrometer

Always-on, non-invasive
energy spread measurement



Higher energy →





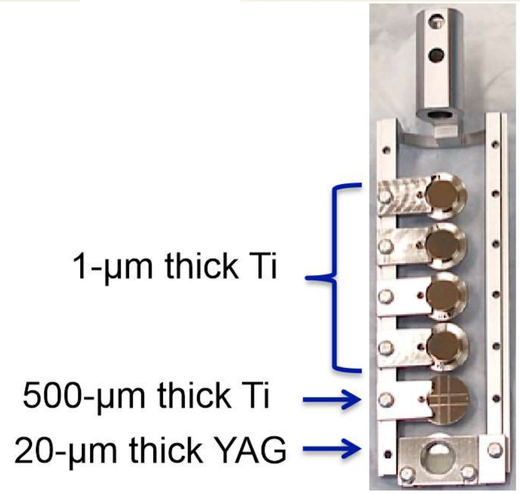
SLAC-PUB-16310

Profile Monitors

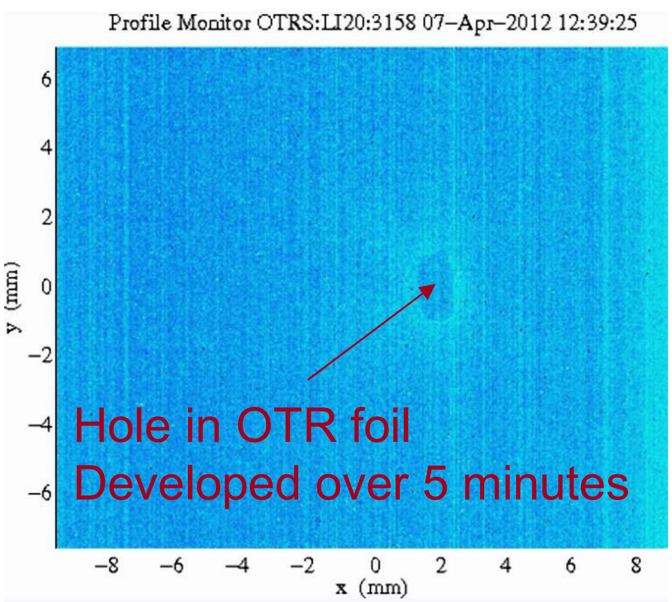
OTR foils (and wires, and windows, etc) near FACET IP very susceptible to damage from high I_{pk} (~10 kA) beam at focus.

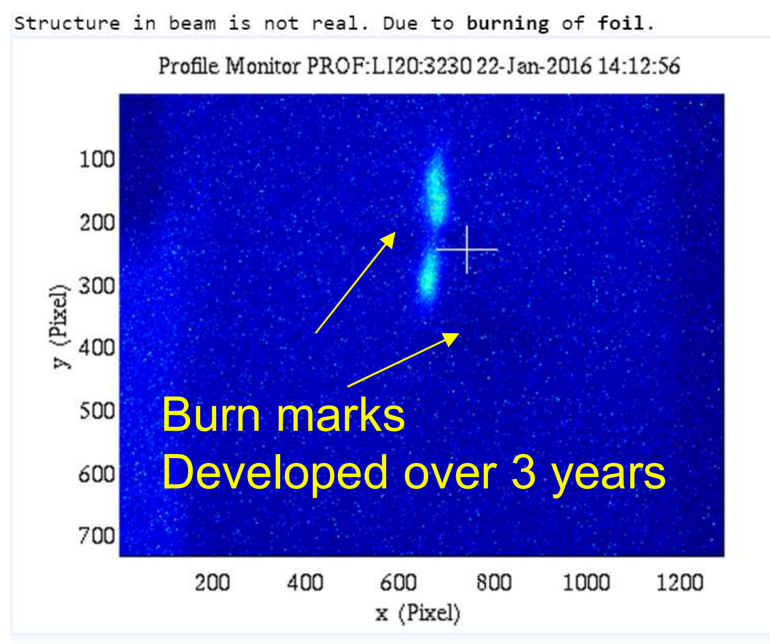
Still useful for imaging unfocused beam: away from waist, in conjunction with TCAV, energy dispersed, etc.

YAG & phosphor screens saturate; nevertheless give qualitative information, steering/alignment and tail hunting.



Multi-screen ladders mitigate damage





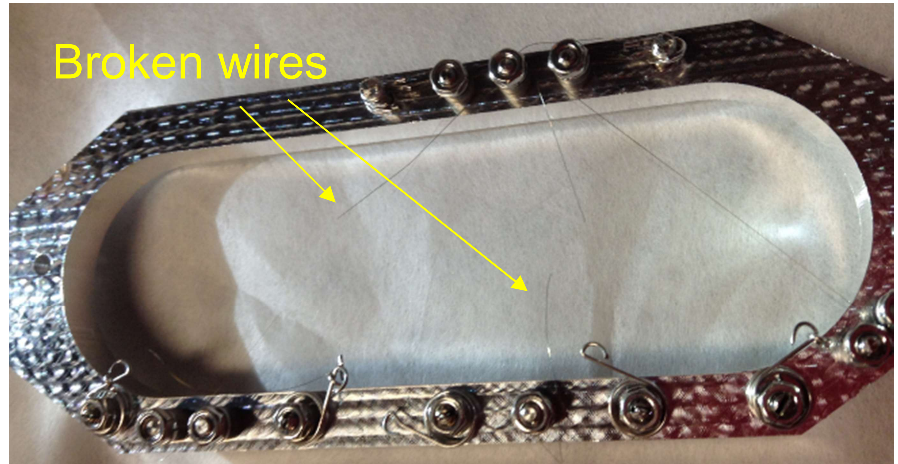
Wire Scanners

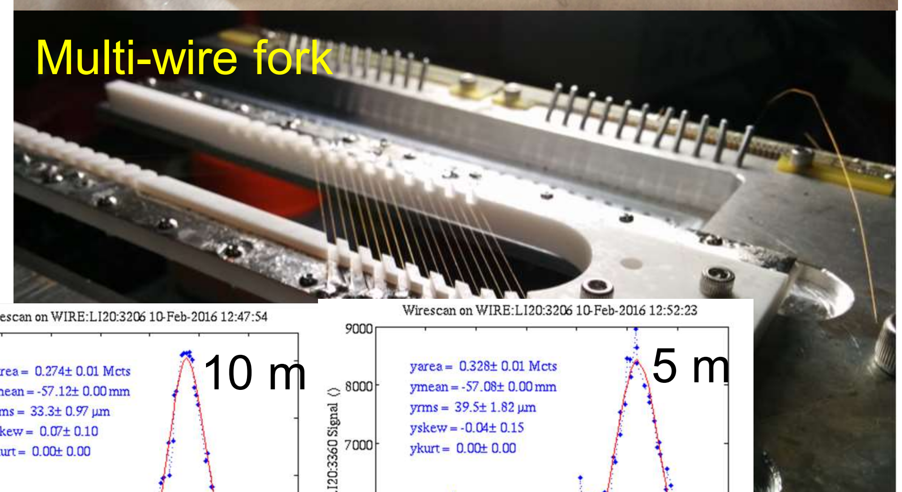
Wire scanners remain the best way to reliably measure transverse beam size, both in linac and at FACET IP.

Linac wire scanners are robust though slow - many hours spent scanning and tuning.

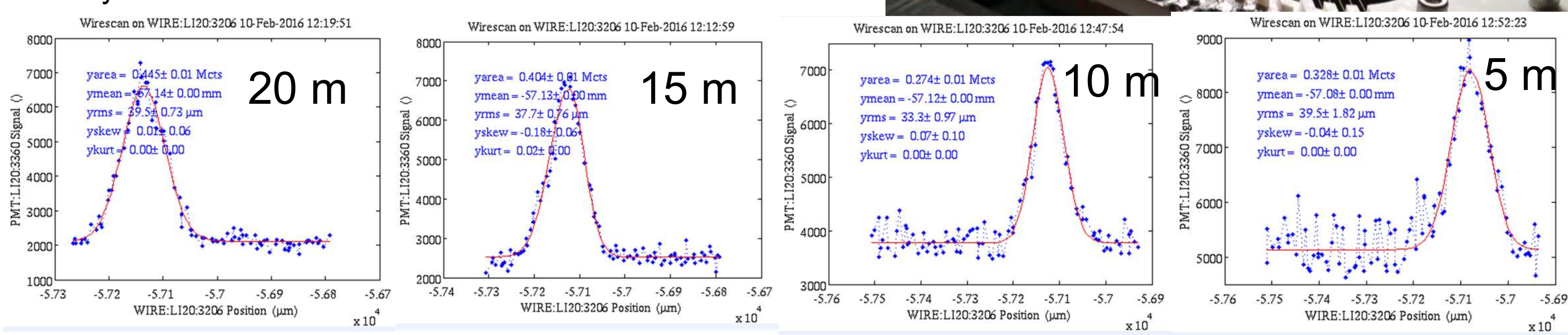
IP area wire scanners aren't perfect:

- Wires frequently broken by good beam
- Backgrounds due to FFS chromaticity





B*$_y$ scan →



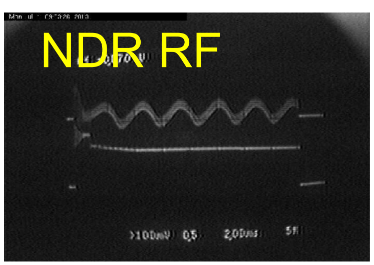
Other Diagnostics

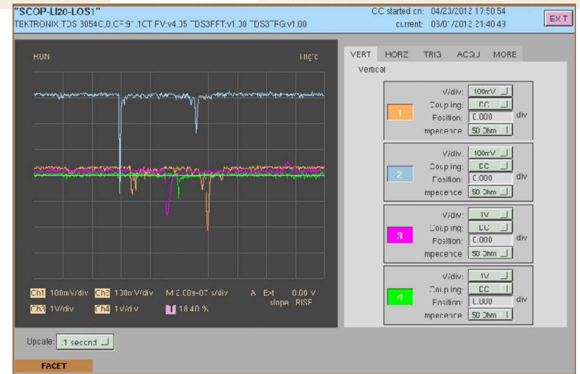
Beam loss fibers – useful during commissioning the W-chicane, but radiation damage turns them opaque.

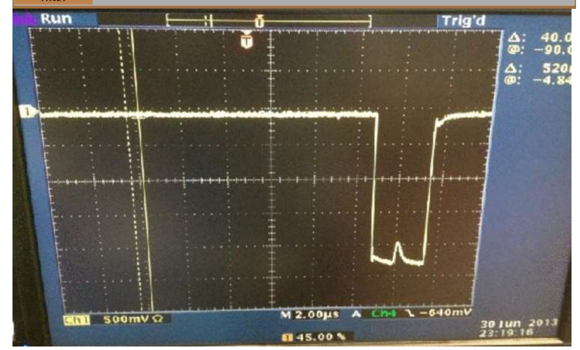
PLIC – MPS function, locates losses – useful for establishing first beam after a downtime, locating loss when BCS trips constantly.

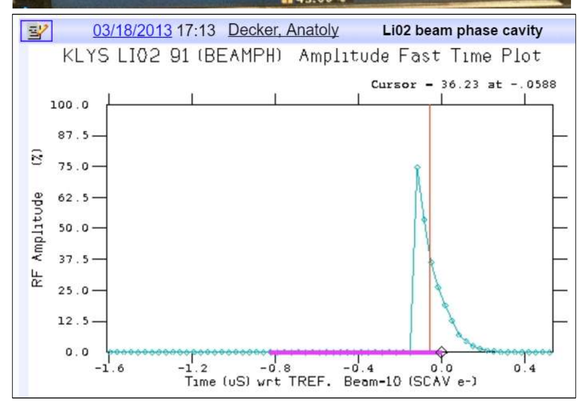
2-9 beam phase cavity, induced signal sampled and digitized by spare klystron PAD. Not used much.

Many other legacy diagnostics particularly in damping rings and e+ system still relied on – relatively simple setups with e.g. an oscilloscope interface.









Diagnostic challenges FACET-II

High-brightness electron beam from RF photocathode gun will pose similar challenges to those at LCLS:

- Coherent OTR emission from screens due to microbunching. No clear solution to this (use wires).

- Sensitivity to cathode laser profile changes:

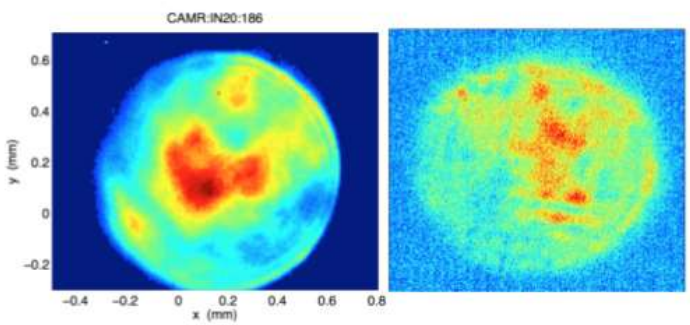
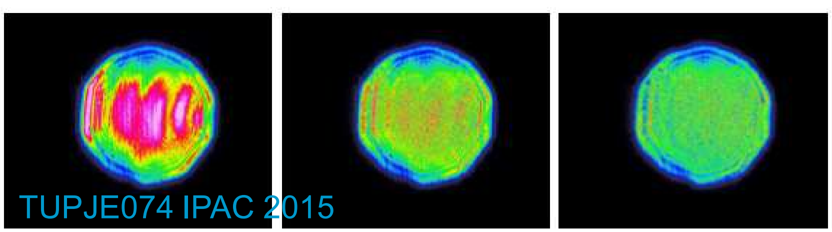
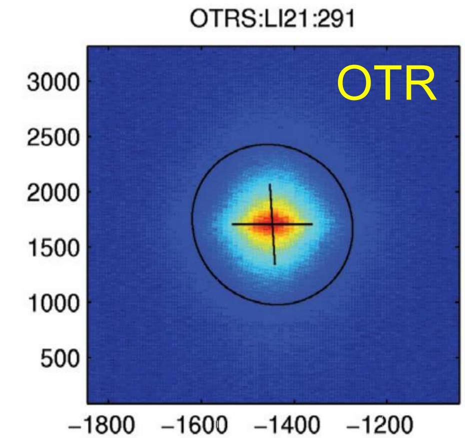
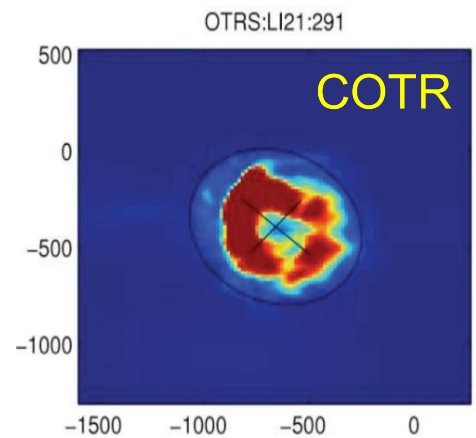


Figure 1: Example of LCLS injector laser transverse profile (left). Example of electron beam transverse profile (right).



Laser shaping with adaptive optics





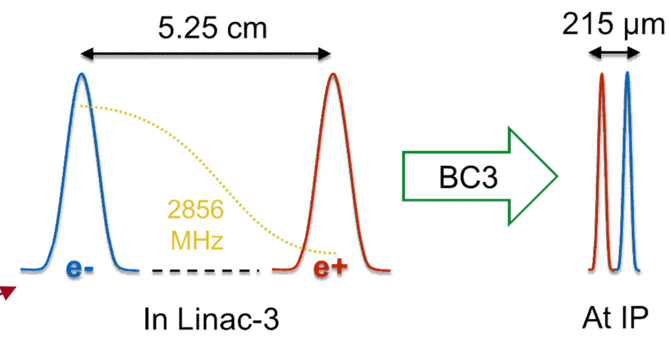
Possible hints of this at FACET?

Diagnostic challenges FACET-II

Proposed future operational modes:

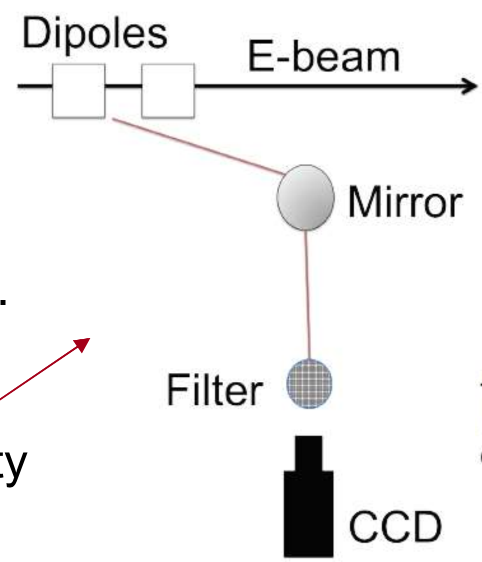
Two-bunch operation in two distinct regimes:

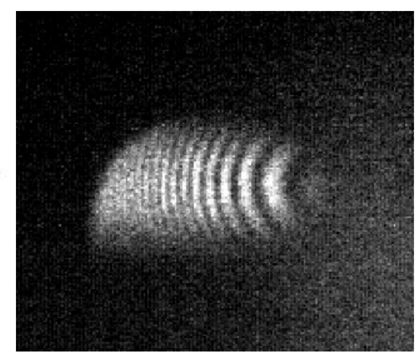
- e- / e- (60 ns) – bunch spacing comparable to SLC; similar to current LCLS two-bunch operation.
- e- / e+ (100 ps) – much harder, high bandwidth processing needed for many signals.

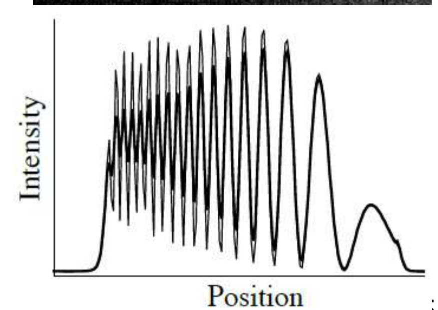


Extremely high peak current ~100 kA focused beam is imagined to damage beam-intercepting devices (screens, wires, windows..). Not clear how to measure this.

Non-intercepting methods e.g. edge radiation interferometry are a possibility but need some study.







Lessons learned

Managing and controlling the configuration across maintenance days and experiment installation is important for meaningful results.

Modern, supported diagnostics controls go a long way towards solving many of the limitations and headaches involved with data collection and analysis.

Stability across shifts remains a problem at FACET and probably FACET-II:

- Many drift sources are hard to identify (RF, alignment, BPM…)
- Feedback is only as good as the measurement, and can mask or worsen problems
- Source beam stability is paramount for experiments and for machine studies
- Archive everything - finding correlations is an art, could be improved with some software development effort.

Diagnostics generate lots of information:

- Data storage and access often a limitation - plan for more than you expect
- Users and operations have different use cases and data flow needs, both should be considered