Two Bunches in Two RF Buckets
Setups for Different Experiments

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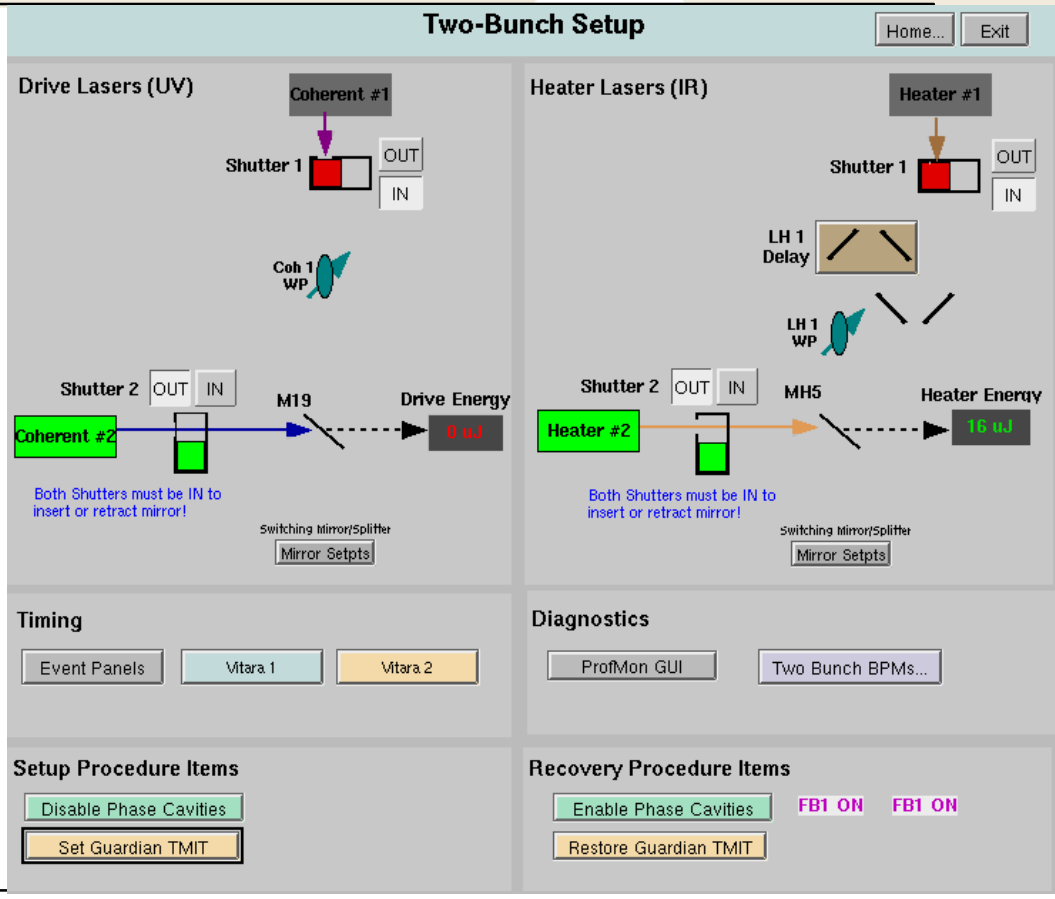
1. There were four experiments in 2016 (May, June, July, Oct) which had two bunches with up to 122 ns separation
2. What was done for the two different setups of pump-probe and probe-probe

Outline

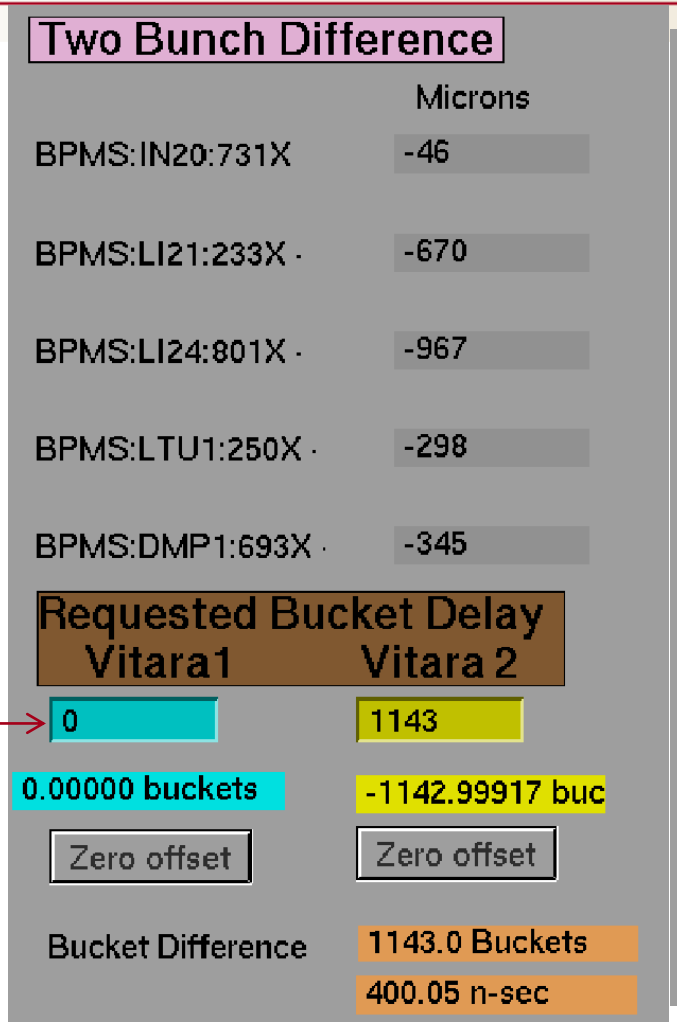
- Lasers
- Bucket Control
- RF
- BPMs
- Measurements
- Photon measurements
- Summary

Lasers: Coherent 1 and 2, Laser Heater 1 and 2

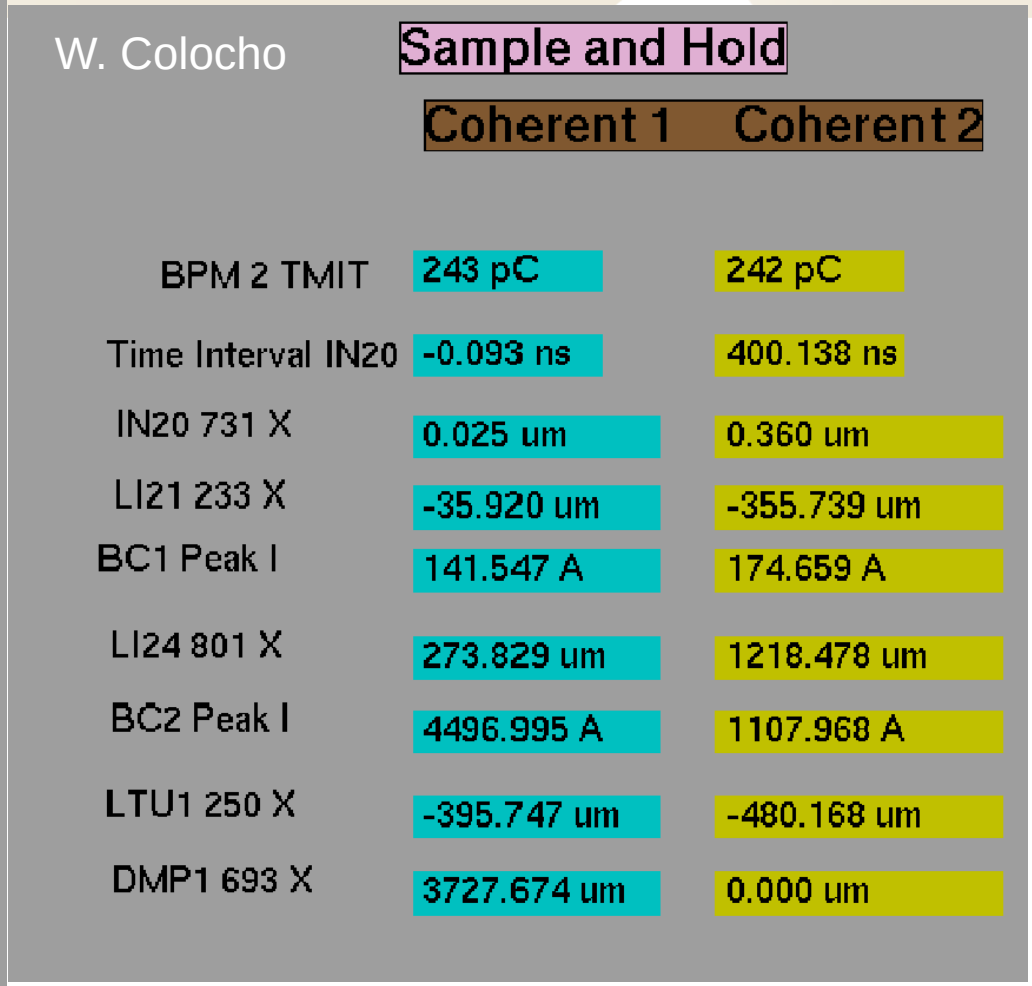
- "Mirrors" M19 and MH5 are now beam combiners
  - controls also overlap
    ~~[too coarse, need pico-motors]~~
    no: just dead band number 5 → 1 µm
- Coh 1 WP (wave-plate), LH 1 WP and LH1 Delay
  - added for independent intensity control
- Shutters to suppress one or the other (or …)



Two Bunch Critical Parameter Display: Sum and Single



or 0.5 to turn off



E at:

DL1

BC1

BC2

DL2

Difference BPM Orbit

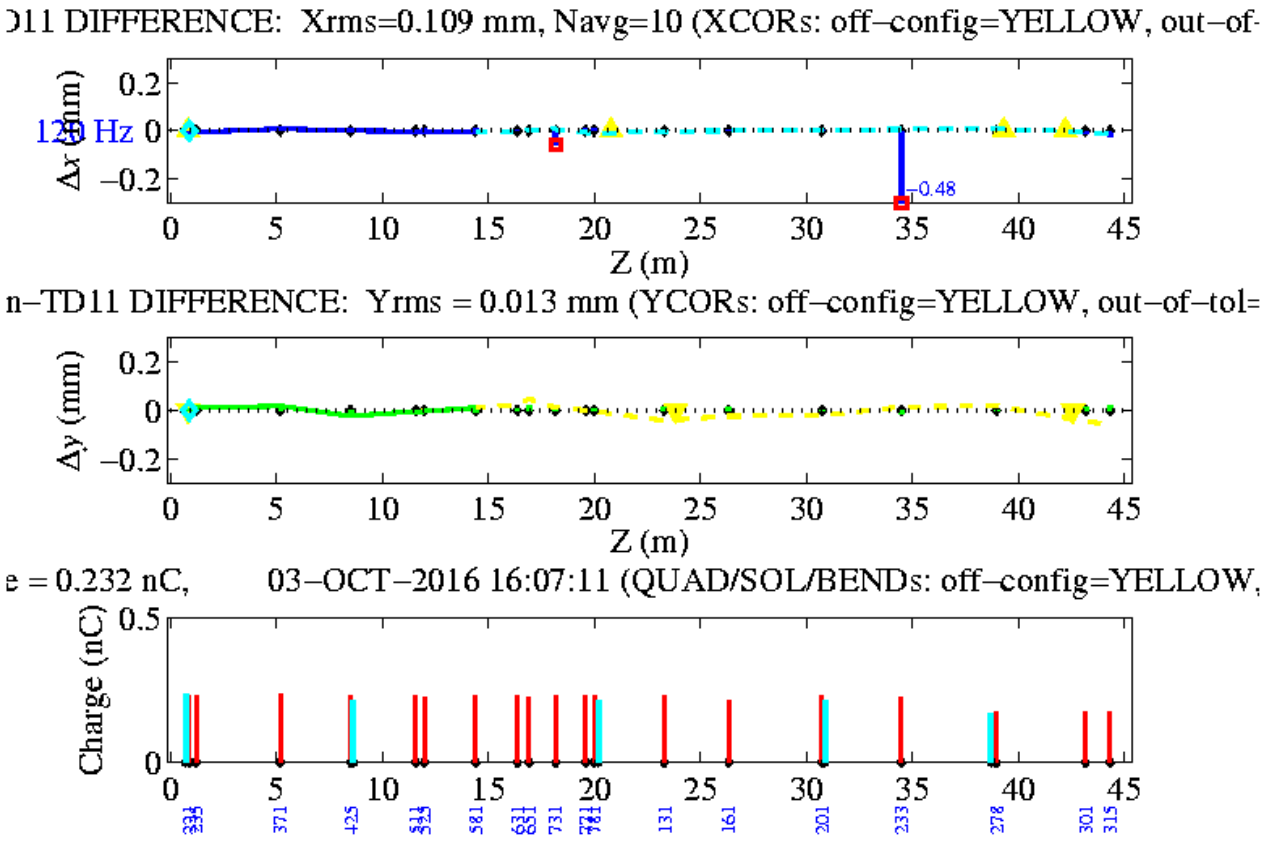
- Coh 2 only - Coh 1 only (0 bucket each)

  < 30 um in *x* and *y*

- 250 pC each

- BC1 collimators in

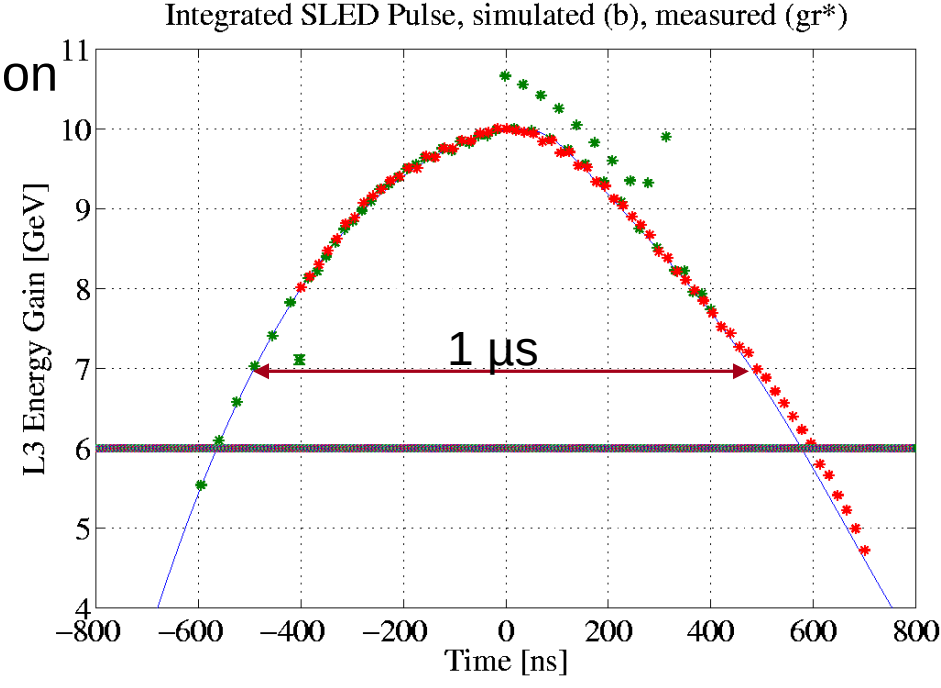
- (*E* in BC1 not yet)



Two Buckets

RF Longer Pulse Separations, SLED vs. UnSLEDed

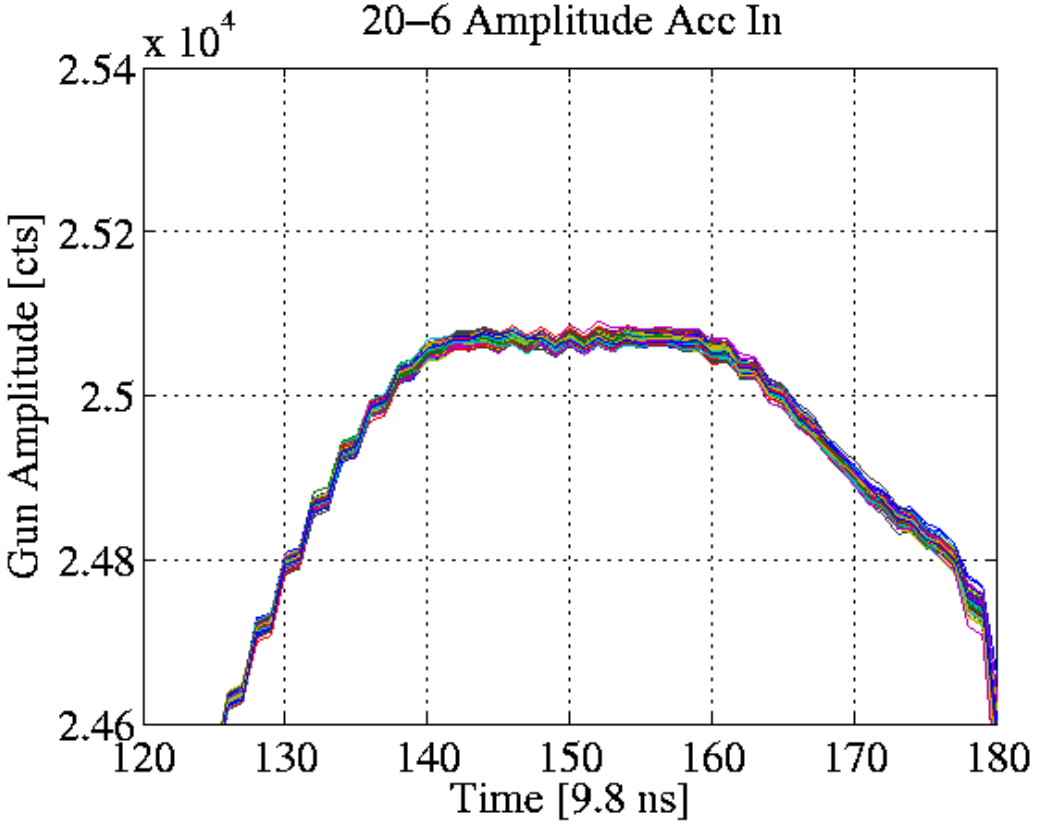
- Most RF is lengthened to allow 150 ns bunch separation
  - (L0B 1.8 µs (needs 2 µs), Gun and L1X need double pulse for longer separations)
- SLEDed RF in L2 and L3 needs timing adjustment about half of bunch separation
  e.g.: 200 ns would require
  +100 ns on PSK_L2 and PSK_L3
- A long range PSK scan revealed that up to 1100 ns might be possible with SLEDed setup
- UnSLEDed will give about 1/1.65 less energy (e.g.: 6 instead of 10 GeV) corresponds to 4 instead of 11 keV



Gun RF Flattened

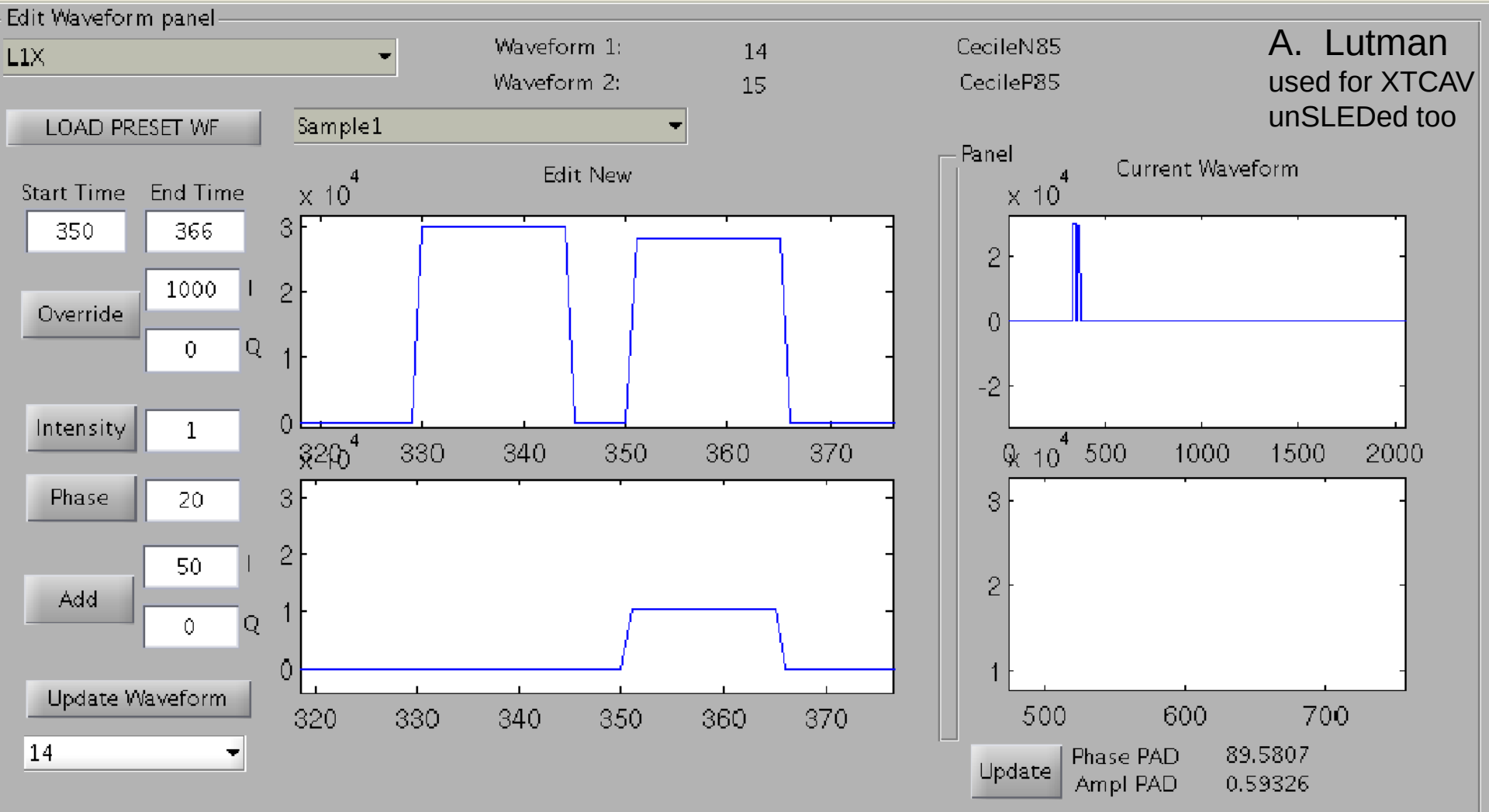
- RF should be flat for about 200 ns (maybe till 400 ns o.k.)

- Further fine adjustments necessary
- Longer delay requires double pulsing like L1X



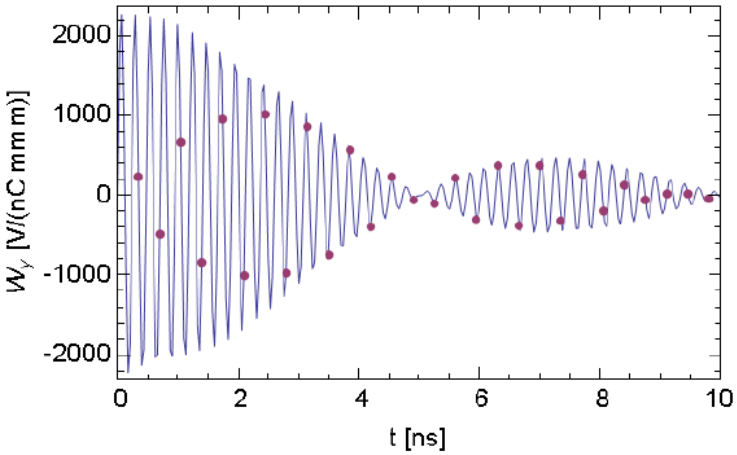
Two Buckets

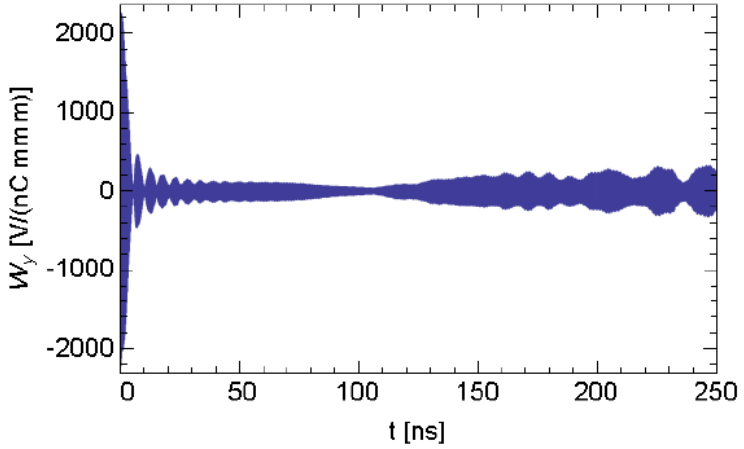
RF Waveform Modification to Adjust Phase and Amplitude of Second Bunch (e.g.: L1X)



Long-range Transverse Linac Wakefields

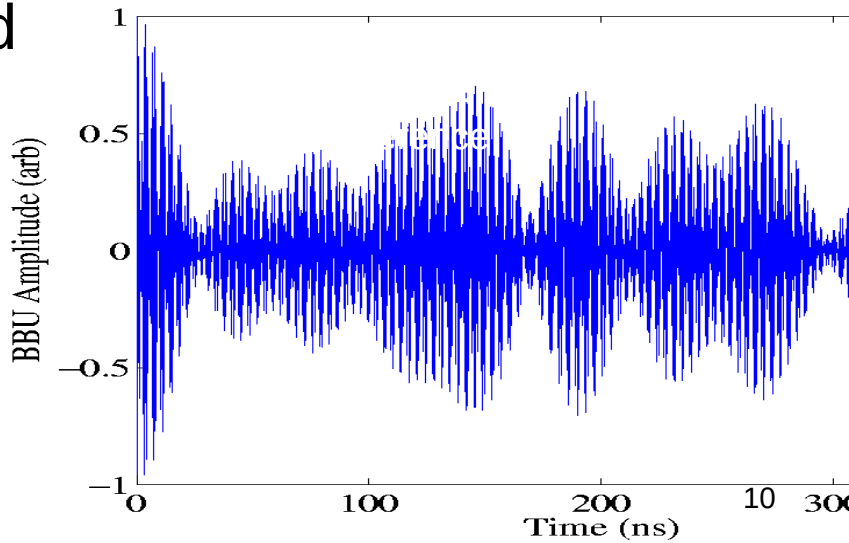
K. Bane





- The biggest transverse kick should be at about 2 ns

- Five transverse modes combined:



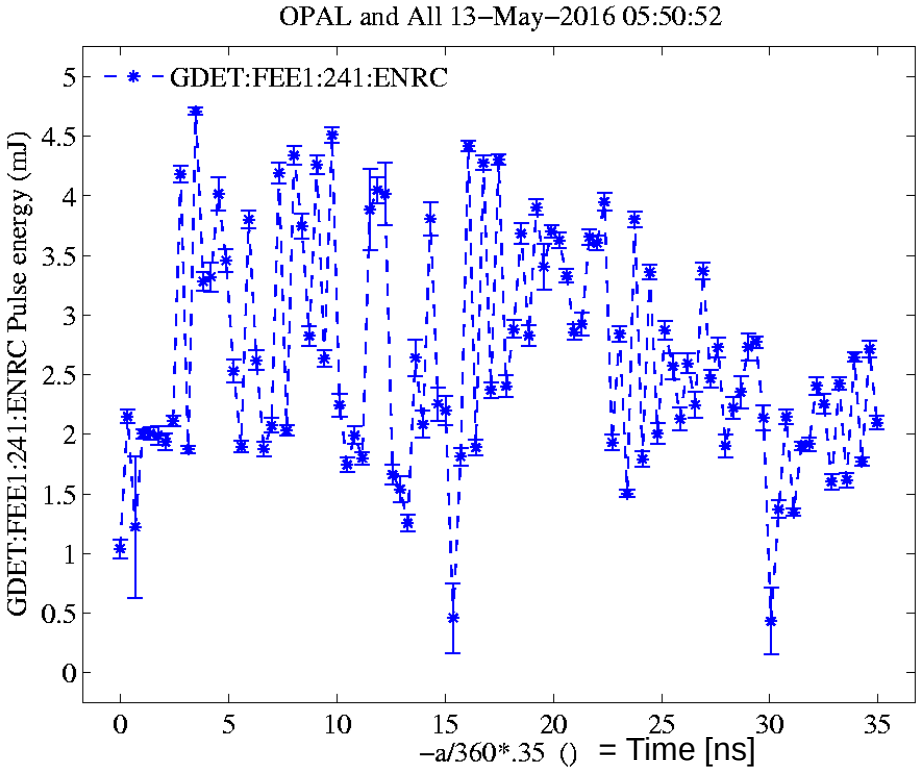
Long-range Timing Scan of Two Bucket Separation

- Gas detector sees rapid up-down (two bunch (4 mJ) then one bunch (2mJ) lasing) consistent with 4.3 GHz transverse mode

- [Every 14.7 ns (= 1/68 MHz) there is a jump (or need to wait longer in scan)]

- Time beyond 25 ns require additional tuning

- We use this to bring both beam together with L2 launch set points

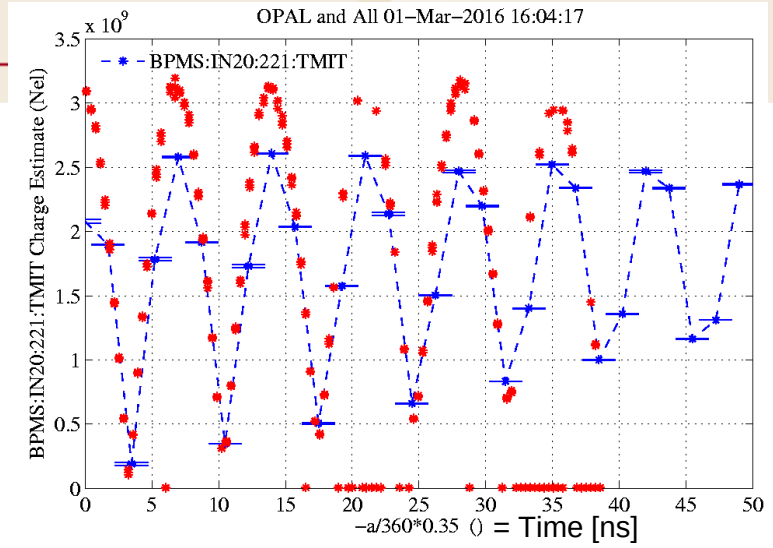


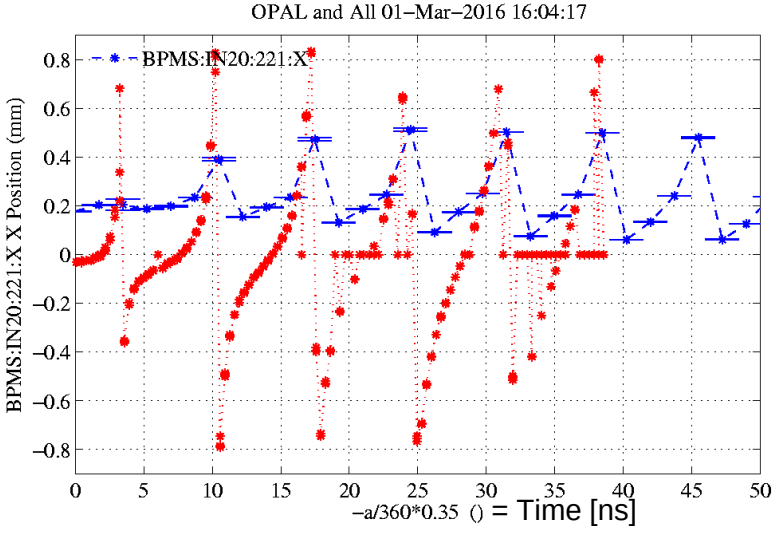
BPM Response at Low Measured Charge Questionable

- Measured beam trajectory o.k. if measured charge is >30% sum of real charges: 0, 7, 14, 21, 28, … ns
  [Just don't ask for 10 ns separation]

- Why does it change for different measurements? [Coh 1 vs. Coh 2]
  Why does slope near zero change?

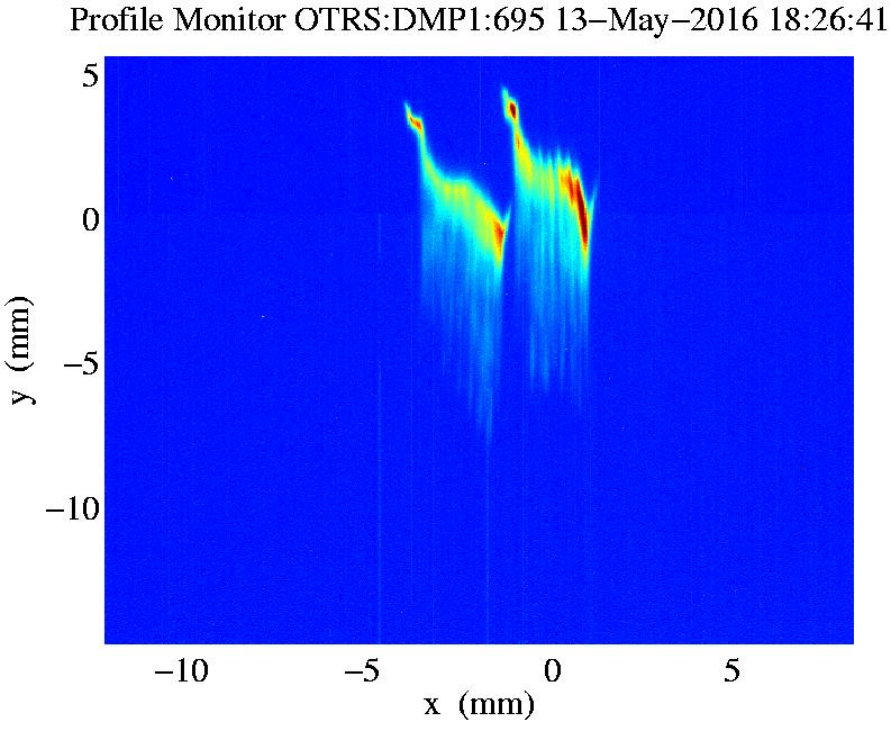
- [Bunch separations at low charge points should be with FBs off (or regold)]

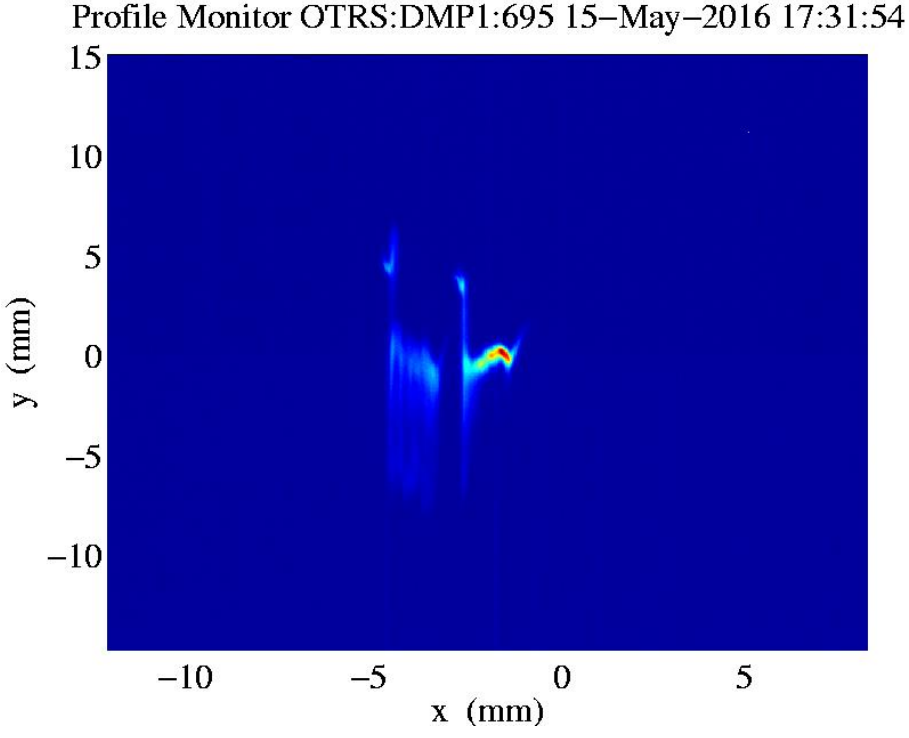




Measurement Diagnostics: XTCAV

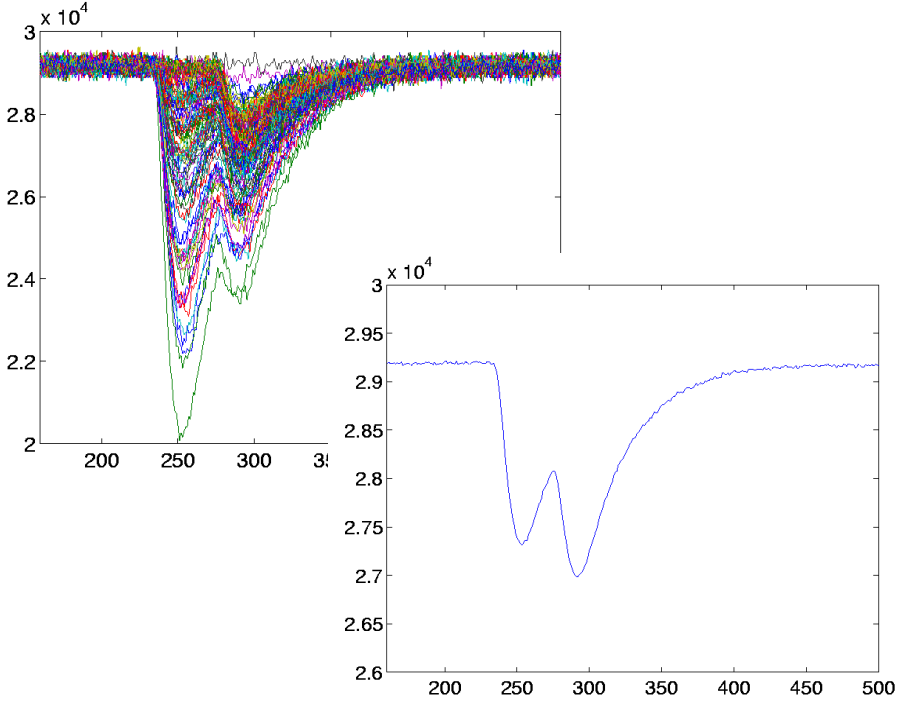
- XTCAV and OTRDMP show energy (equal) and lasing
  - Good lasing in both bunches Coh 1 (right) barely lases



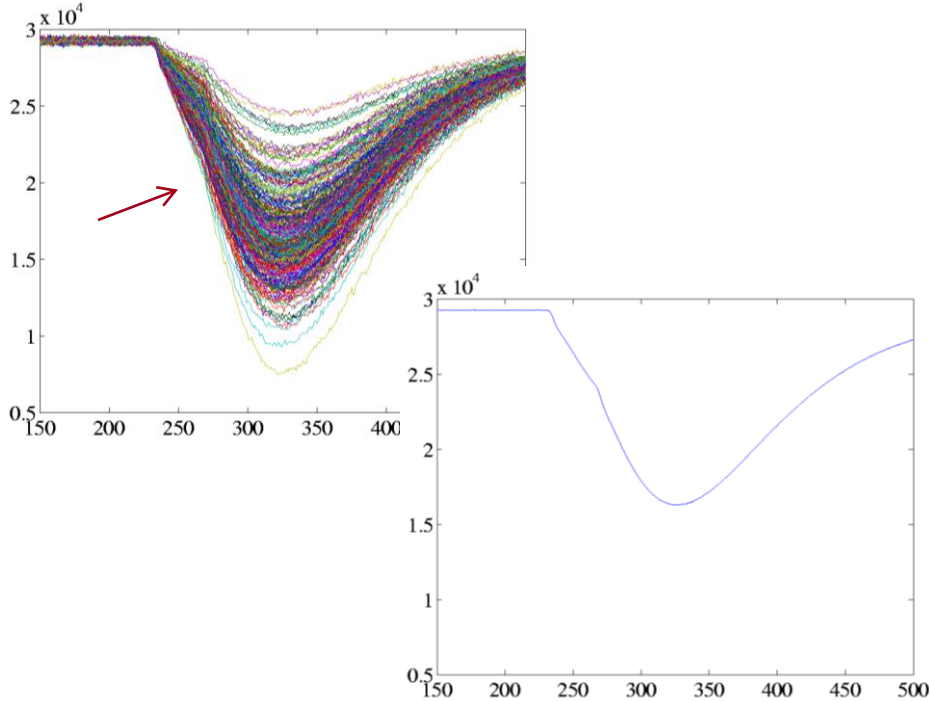


Measurement Diagnostics: Gas Detector

- Gas Detector can measure intensity at hard x-ray and long delays (41 ns)



- tricky at 1.2 keV (31 ns)



Two Buckets

Photon Experiments and their Demands

Pump-probe

Probe-probe

SLAC

C. Stan, water droplets, May 2015, MEC, 8.9 keV

LI41: diff.: *t, E, I,* ***y***; same *y'* (*x, x'*), s.p. 25 ns

M. Seaberg, skyrmions, May 2016, SXR, 1.2 keV

LM23: diff.: *t* **only** 0.7, 4.6, 23, 49 ns

P. Fuoss, probe-probe, Jun 2016, XCS, 8.2 keV

LL25: diff.: *t* **only** mono, 4.6, 8.8, 24 ns

I. Schlichting, proteins, Jul 2016, CXI, 7.1 keV

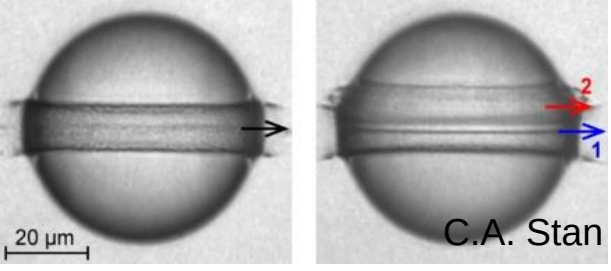
LM18: diff.: *t,* ***E****, y*; same *y', I,* (*x, x'*), s.p. 8.4 ns

Y. Feng, GDET **>122 ns**, Oct 2016, XCS, 7.0 keV

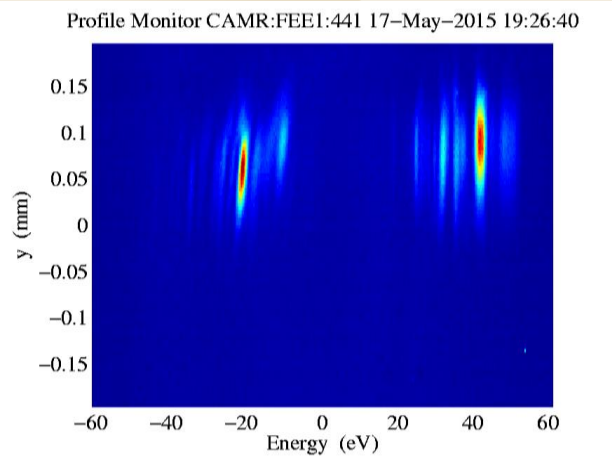
X119: diff.: *t* only, high *I*; same *x, y*; o.k. *E*, 122 ns

Two Bunch with many Differences: *t, E, I, y*

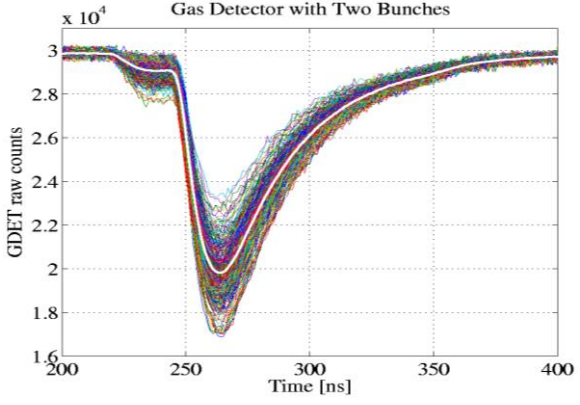
- Intendent differences:
  - Time: 25.2 ns (= 72*0.35 ns)
  - Energy: 60 eV
  - Y separation: 5 sigma
  - Intensity 1:10 ratio
  - Water droplets



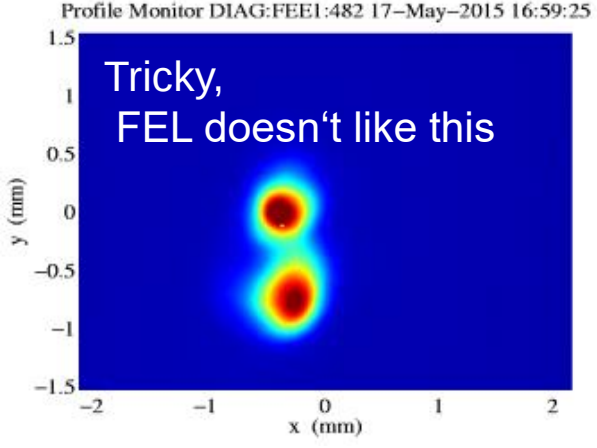
Two buckets



FEE spectrometer: E (+x)



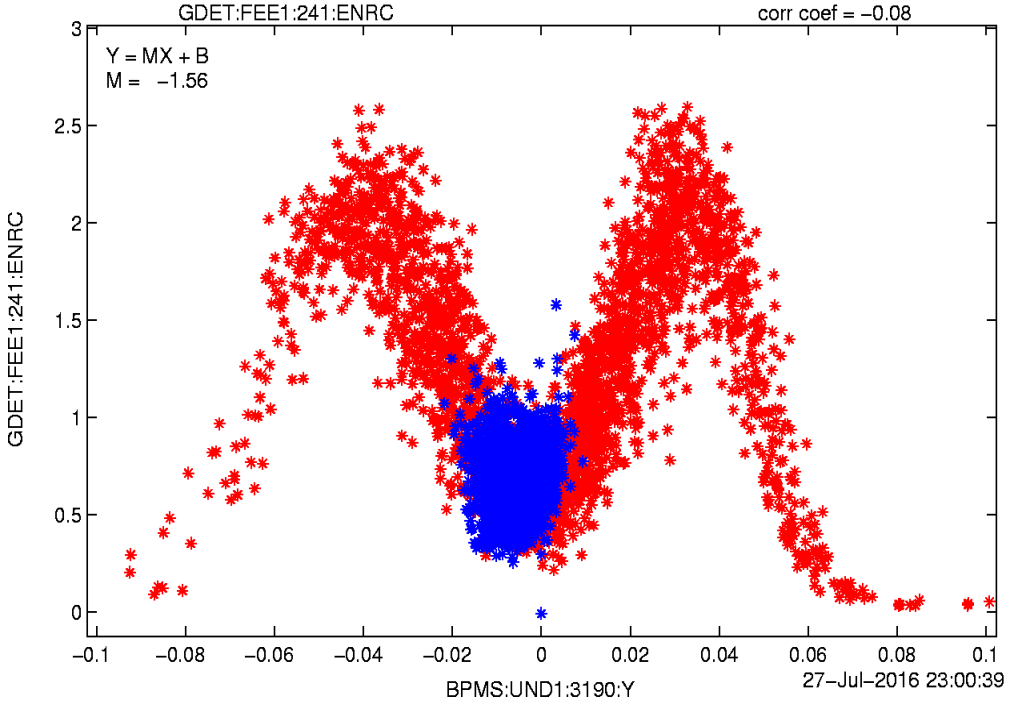
Gas Detector with 1:10 intensity



Direct Imager: x and y

Vertical Bunch Separation with TCAV3 (which is off-frequency)

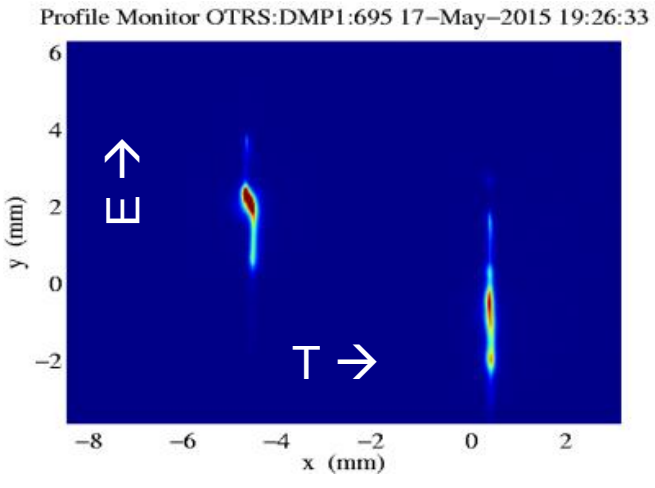
- Initially there was a 3.6 Hz line causing a huge jitter (red).
- This line got eliminated (blue) by running with somewhat higher RF amplitude and miss-timed.
- Since there is a vertical separation, both bunches are lasing **off** the peak in the center of the undulator
- Both bunches have equal peak performance (2 mJ)



Two Buckets

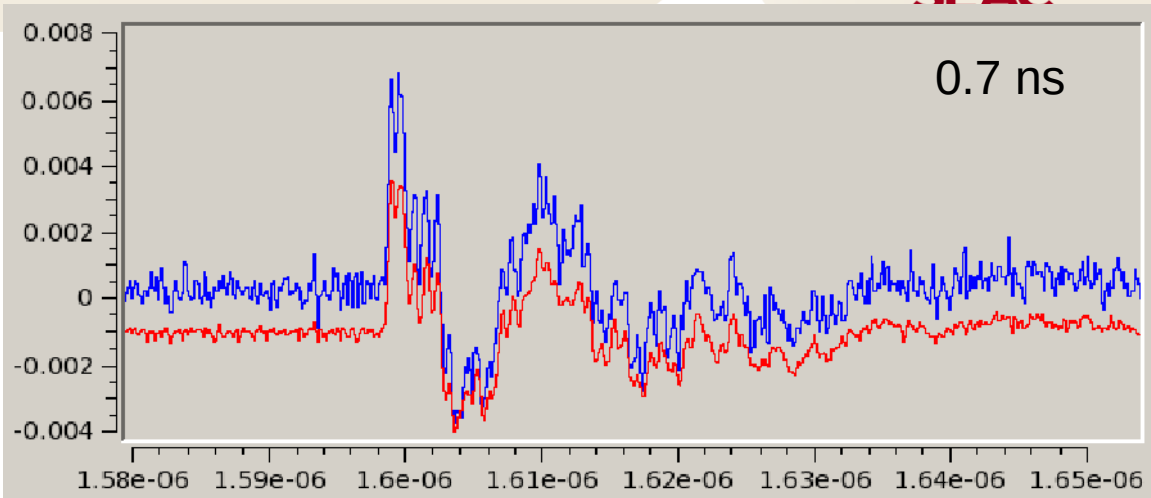
Same parameters or un-intendent differences

- Often the other parameters except time should be the same:
  E, I, x, x', y, y', σ_x, σ_x', σ_y, σ_y', source point, bunch length, …
- Difference in e.g.:
  - Bunch length: long short
  - Phase (?)
    from XTCAV
  - Source point?



Measurement Diagnostics: Photon MCP Multi Channel Plate

- Even two bucket 0.7 ns could be measured
- Used for equalizing intensity and correlation



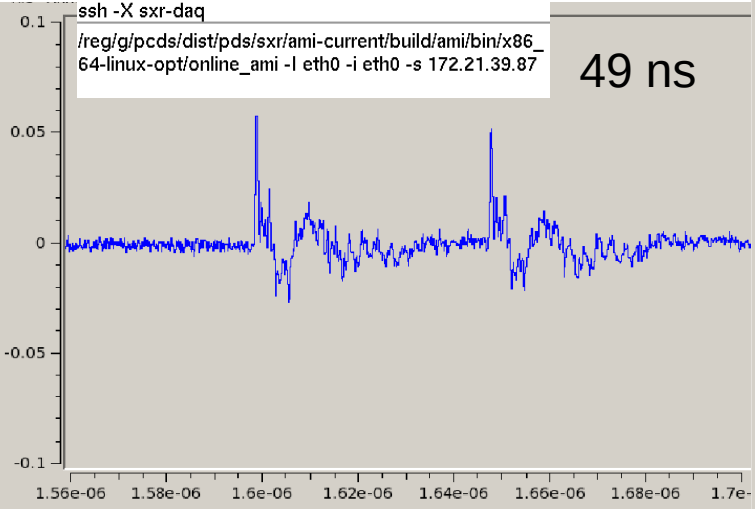
Micro Channel Plate GUI: <-- Launch it!

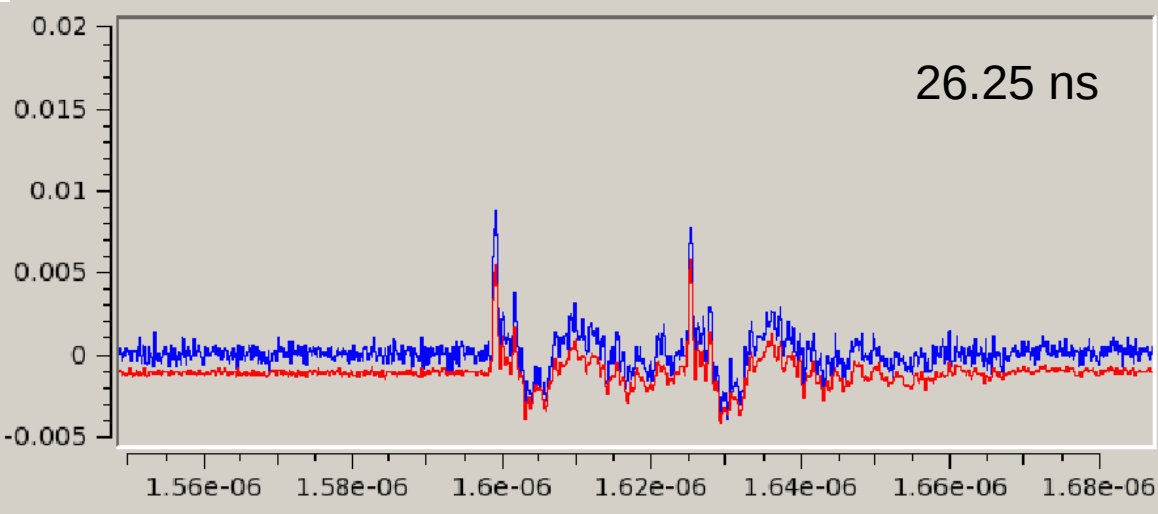
ssh mcclogin

ssh -X psdev

ssh -X sxr-daq

/reg/g/pcds/dist/pds/sxr/ami-current/build/ami/bin/x86_64-linux-opt/online_ami -I eth0 -i eth0 -s 172.21.39.87

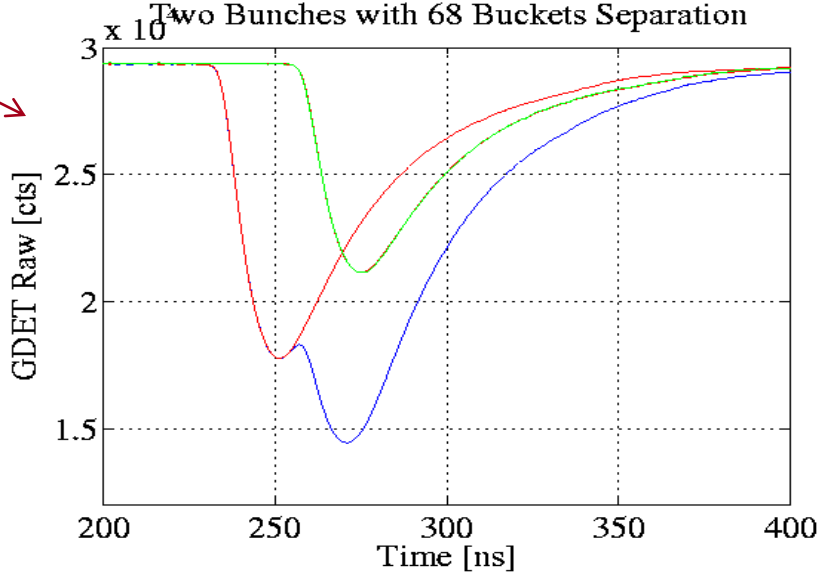




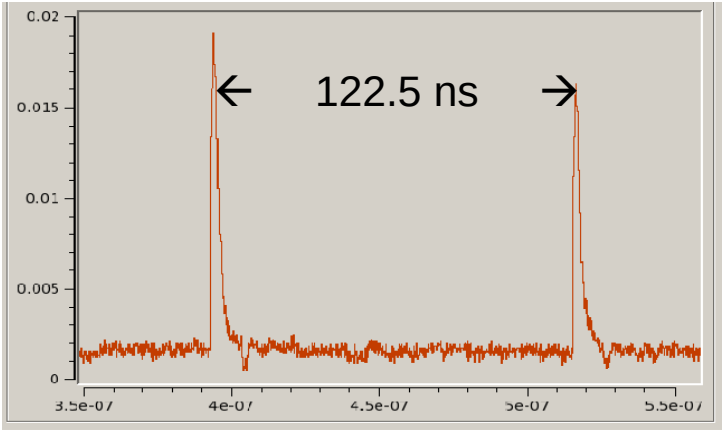
Quantifying FEL Intensity of each of Two Bunches

Gas detector raw waveform

Blue is the combined signal of two bunches with 23.8 ns separation (68 buckets). By subtracting a fitted single bunch response (red) the signal of the second bunch gets achieved (green).



Fast diode signals at experiment

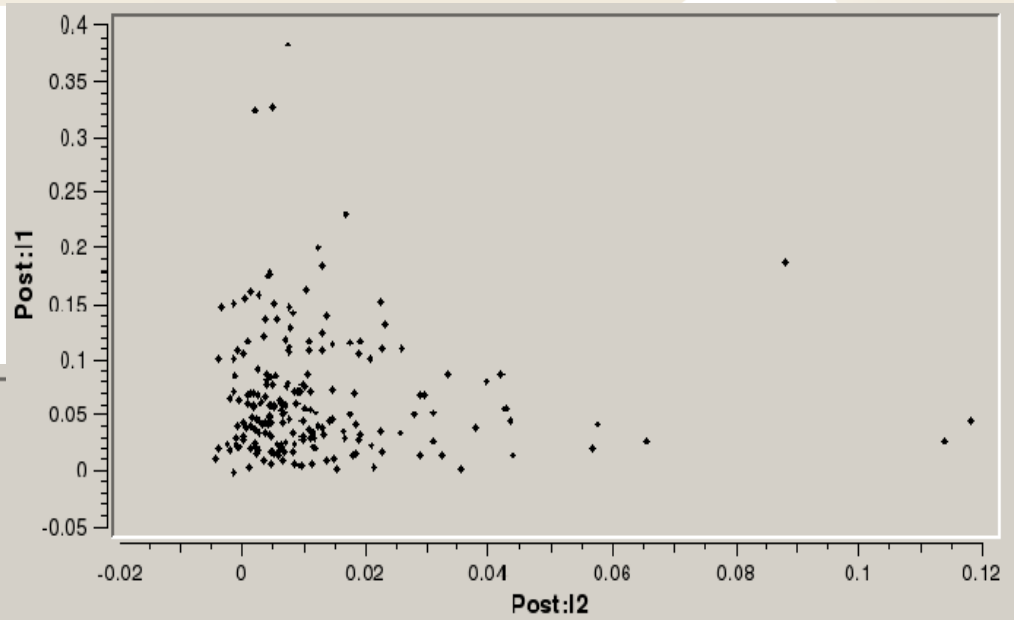


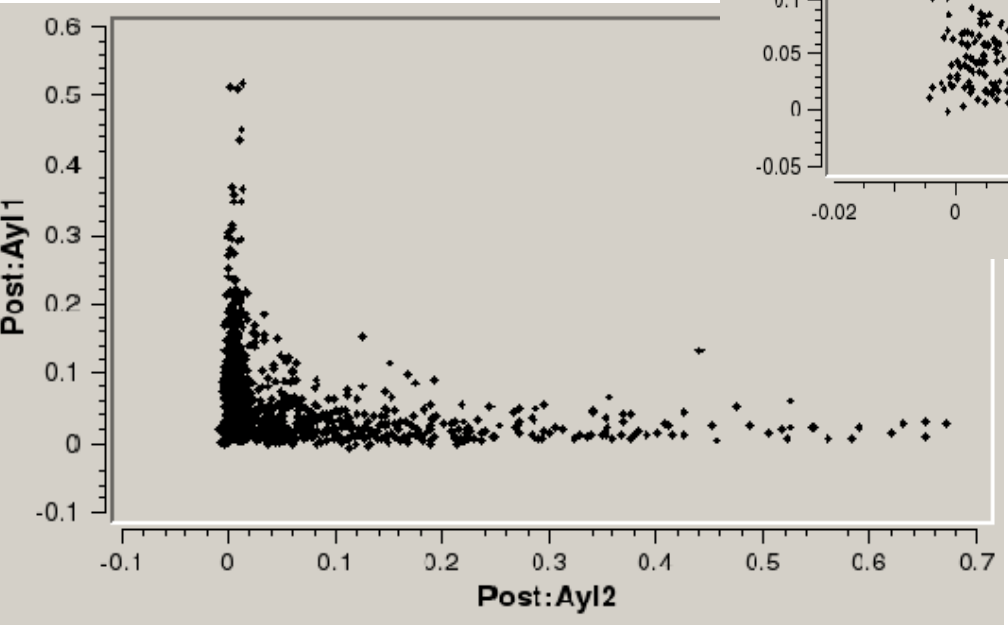
Two Buckets

Fast diode signal helps to identify: intensity, steering and energy issues

Fast diode signal:
anti-correlation (orbit diff.)

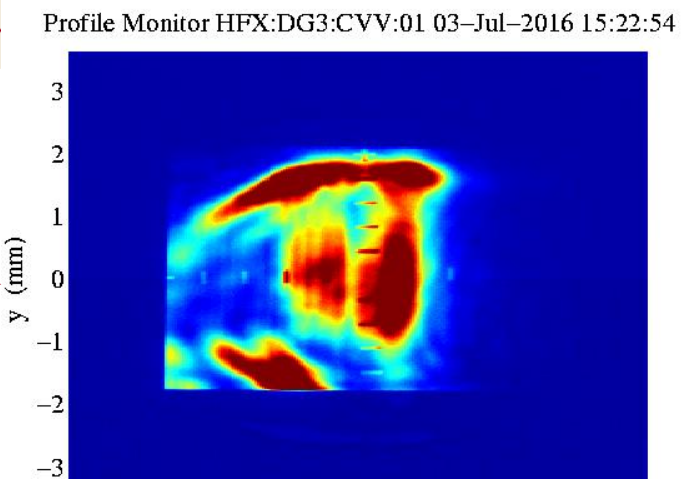
L-shaped (energy diff. + monochromator)



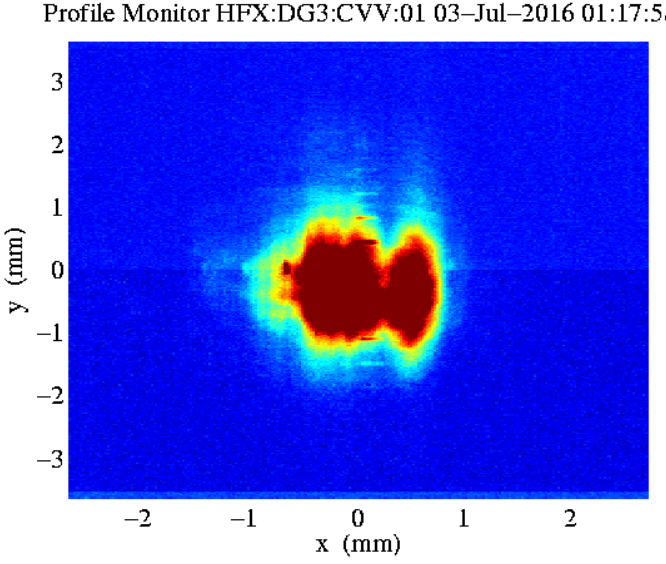


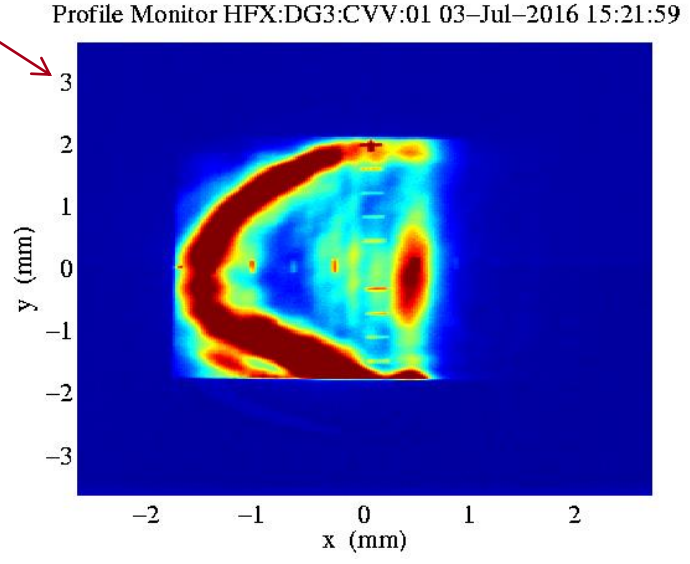
More Differences: divergence and spot size (or mode)

- Transverse distribution at the end of the XRT
- Second bunch too long: donut shaped lasing



- First bunch:





Two Buckets

Summary

- Besides “Two-Buckets” (0.35 to 200+ ns) we have also “Twin Bunches” and “Fresh Slice” setups (both 120 fs (hard) to 900 fs (soft x-rays))
- Pump-probe “typically” requires a few other different parameters beside Δt: ΔE, Δy, (ΔI)
- Probe-probe “typically” just Δt and mono-chromatic beams
- Many “equal” parameters have to be watched:

  E, I, x, x', y, y', σ_E, σ_I, σ_x, $\sigma_{x'}$, σ_y, $\sigma_{y'}$, source point, bunch length, …
- To Do List:
  - Get betatron phase advance adjustment from TCAV3 to undulator source point
  - BPM raw signal into two-bunch difference orbit
  - + seeding
  - Longer delays and reliable transverse adjustments (kickers?)