Investigations of Wakefields and HOMs in the Tesla-type Cavities at FAST

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Higher Order Modes (HOMs)

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- HOMs are induced by off-center steering in rf cavity.
- Investigate long range deflecting dipole mode acting within the macropulse; ~10-μs range. Vary bunch #.
- The magnitude of the HOMs can be increased by steering transversely off axis in cavity, intentionally or unintentionally, Q dep., and result in emittance growth.
- Commissioned HOM detectors in CC1 and CC2. (New filters have been ordered) (2)
- Perform initial long range effects search with HOM detectors, various offsets, charges, and beam size/pos. tracking after CC2 in X107, X108, X121 .CC1,CC2 Transfer matrix input? (2)
- Bunch by bunch rf BPM readings requested. CCD gates.

Short-range Dipole Wake Fields

- Investigate short range deflecting dipole mode wake field **acting within a single micropulse**; **1-20 ps range.**
- Use 1-10 micropulses to look for effects initially.
- The magnitude of this wake field can be increased by steering transversely off axis in cavity, intentionally or unintentionally, Q dep., and results in emittance growth.
- Perform initial short range wake field search with (HOM detectors), various offsets, charges, and beam size/pos. tracking after CC2 in X107, X108, X121. CC2 Transfer matrix input? (2)
- X107 slit images would help on emittance evaluation.
- If/when correlated beam size growth with offsets seen at X121, then pursue the streak camera studies to clarify.

Streak Camera Measurements of Dipole Kicks

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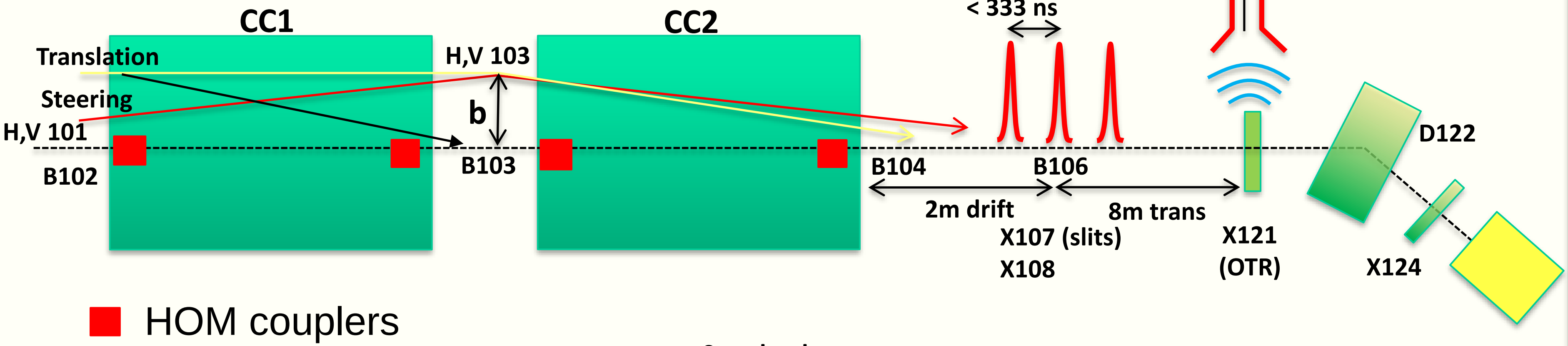
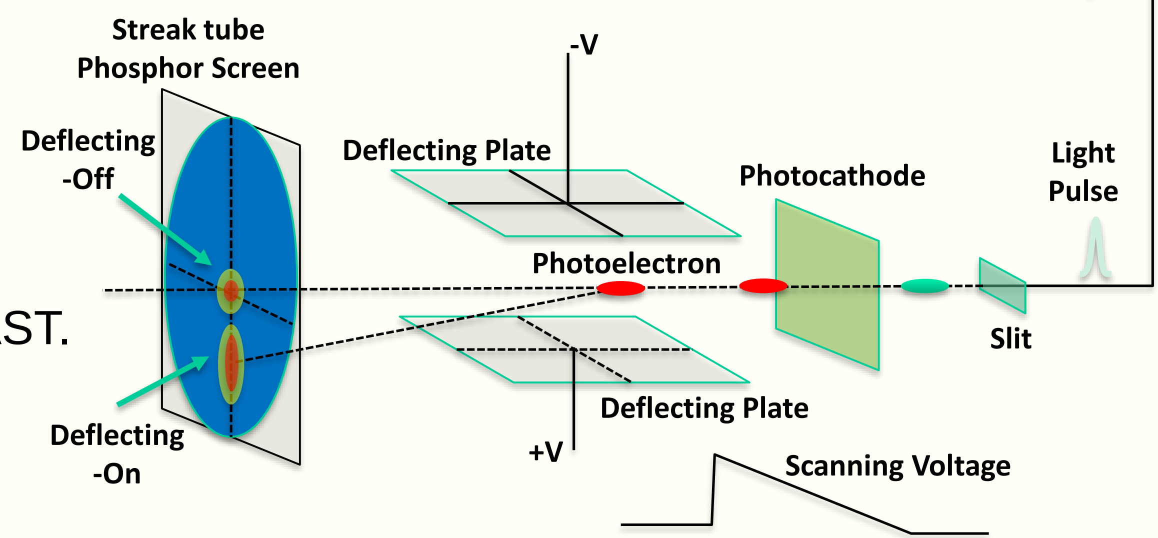
Some Kick and translation options, need b = 0 – 5 mm offsets at B103 between cavities or in cavities.



N.B. Unique Cavity Configuration and Diagnostics capabilities at FAST.



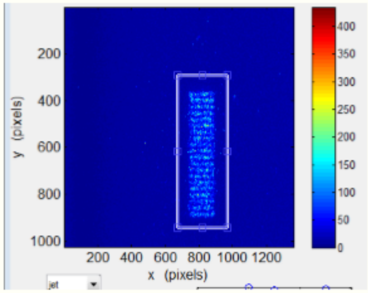
YMS Slide design

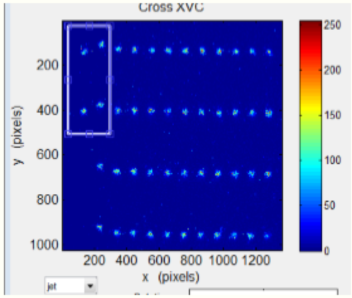
Streak Camera Modes

- **With slow vertical unit, streak camera in framing mode.**

Effect	Mode	Temporal resolution	Spatial res. (µm, est.*)	Wake Range
Sub-Micropulse, y-t	Synchroscan,V	1ps	50-100	short
Sub-macropulse, y-t,T	dual sweep,H,V	1ps, H axis selectable	50-100	short
Sub-macropulse, y-T	Slow sweep,V	100 ps	50-100	long
Sub-macropulse, x,y-T	Framing Mode	100 ps	50-100	long

UV laser pulse train demos





*Bunch-by-bunch techniques can be applied to IOTA beam turn by turn.

Preliminary OTR Data: Dual-Sweep Streak and Framing Images

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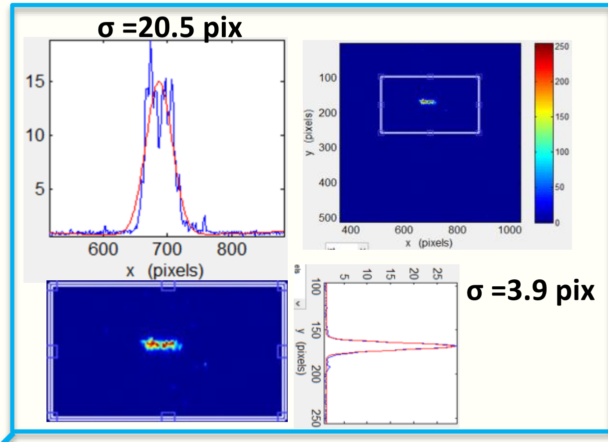
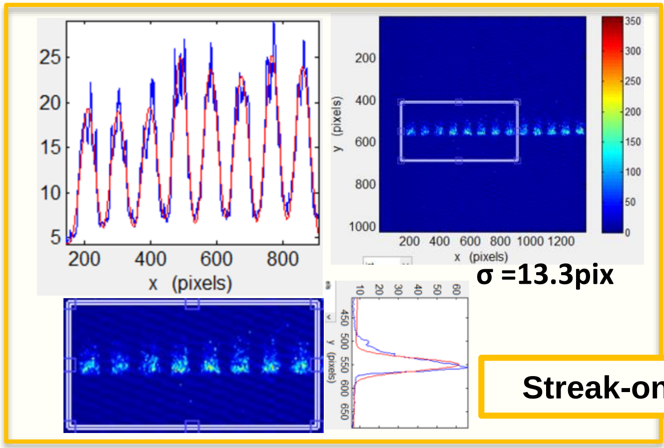


Short Range

Long range

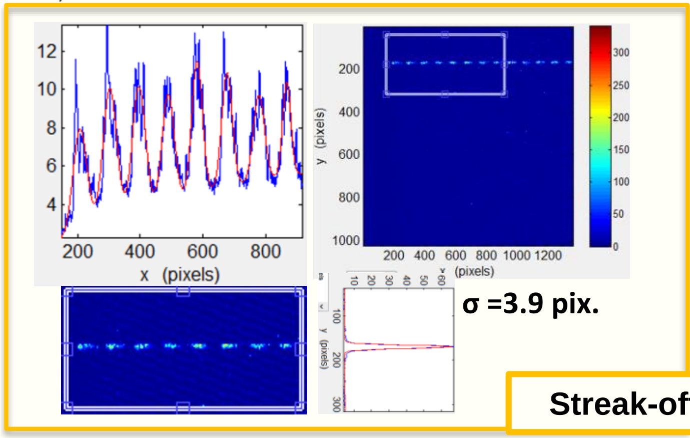
Dual-Sweep Streak Image

- R1 - 5μs, 330 pC, 13/18b, MCP = 55, CCD-G=10.5 image ave.
- 1.5 degree instr. axis tilt removed. Last bunch at left.
- σ_t = 4.7 ps - Apertured, 25 DOC R1cal=0.38 ps/pix



Horizontal-Sweep Demo for HOMs/IOTA

- Focus Mode (L) and Hor.=5 μs (R), 170 and 1000 pC/b, MCP=55, CCD-G=10.
- Focus 3.87 pix. Slit=35 μm (Optics rotated image 90 deg.) @ X121 station
- σ_x = 25 μm, σ_y = 135 μm, X,Y cal = 6.6 μm/pix

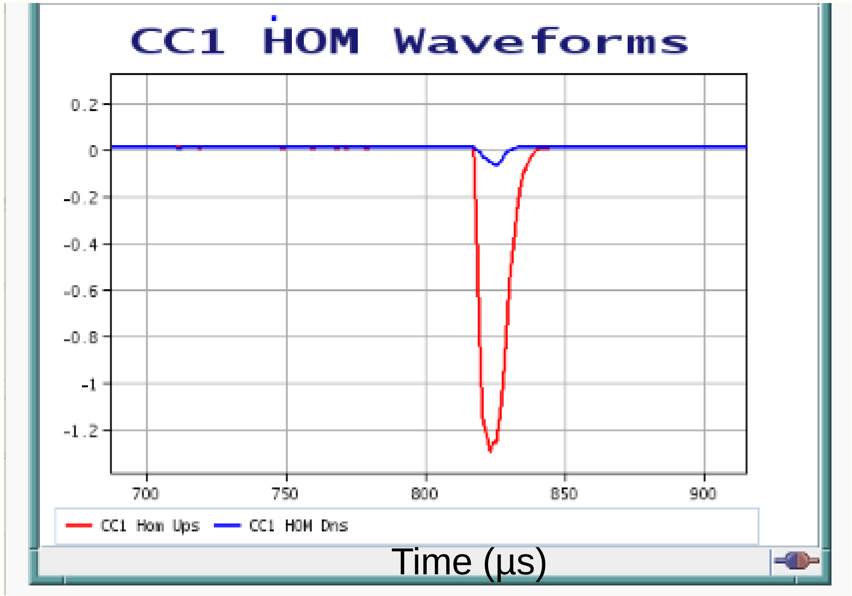


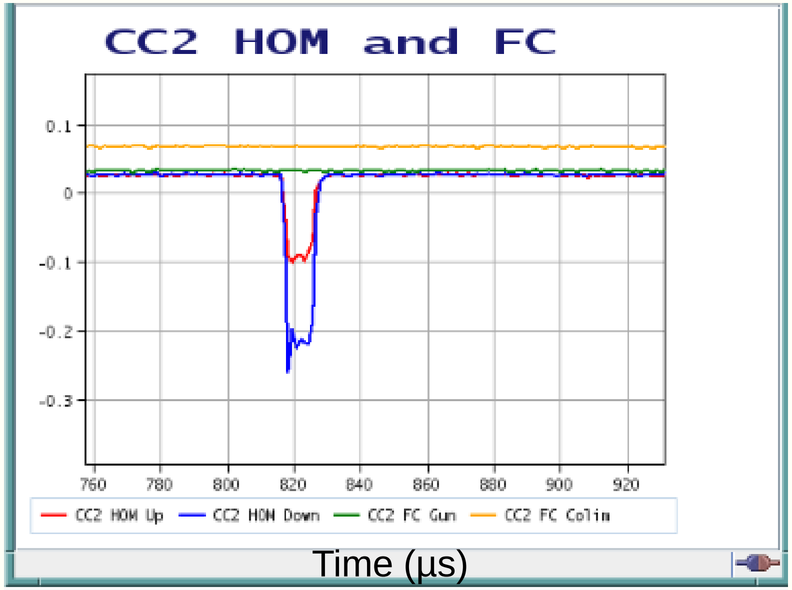
HOM Detector Updates

- **HOM detector circuits were revised twice by Peter on 7/22/16 from earlier version with beam-based tests.**
- **With band pass filters available near 1.7-1.8 GHz we targeted the expected HOM dipole modes from Tesla cavities. (New set of notch and wider BP filters ordered)**
- **Both CC1 and CC2's upstream and down stream detectors were functioning with the strongest signal in CC1 upstream.**
- **Resteered the beam with H,V101-3 correctors to reduce the CC1 and CC2 HOM signals.**
- **Emittance reported to be improved by 30% at low charge by Philippe and Jinhao a few days later using reduced HOM setup, but *no* high charge cases done yet.**

HOM Detector Signals (7-22-16)

- **Normal steering for cavity settings, 25 b and 750 pC.**





Preliminary HOM CC1 Det 1 Results

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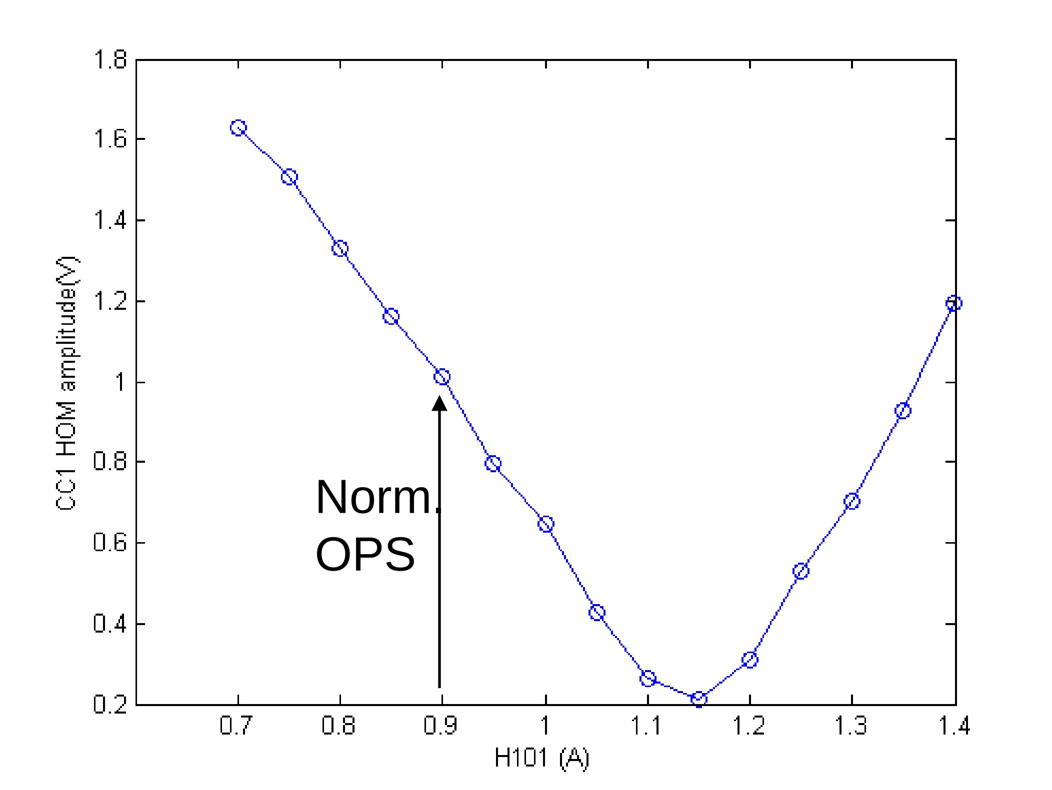
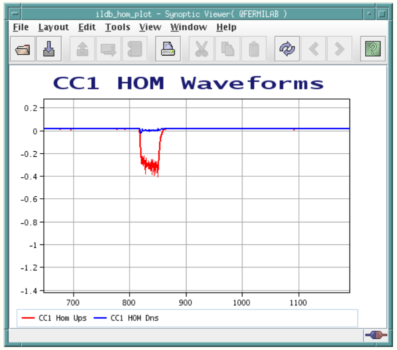
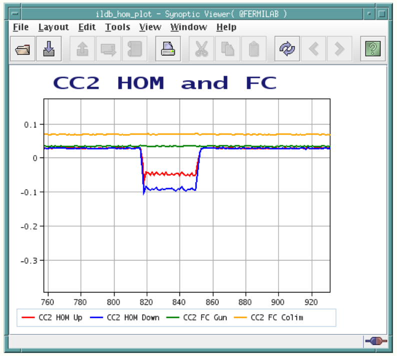
- **Initial look at CC1 HOM D1 signals with H101 steering.**
- **Normal current setting at 0.9 A. (7-22-16 elog entry)**



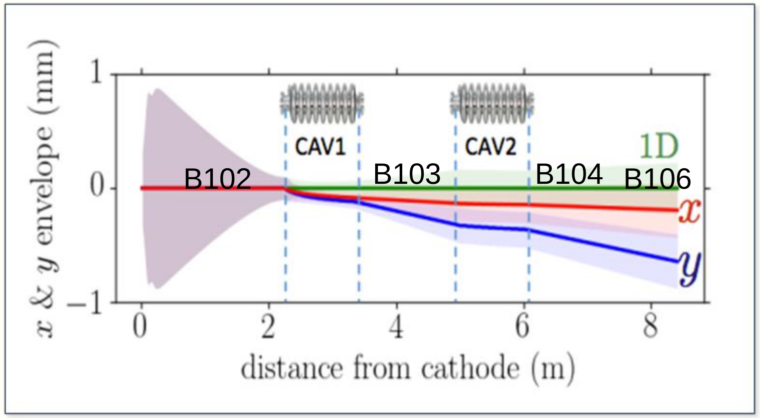


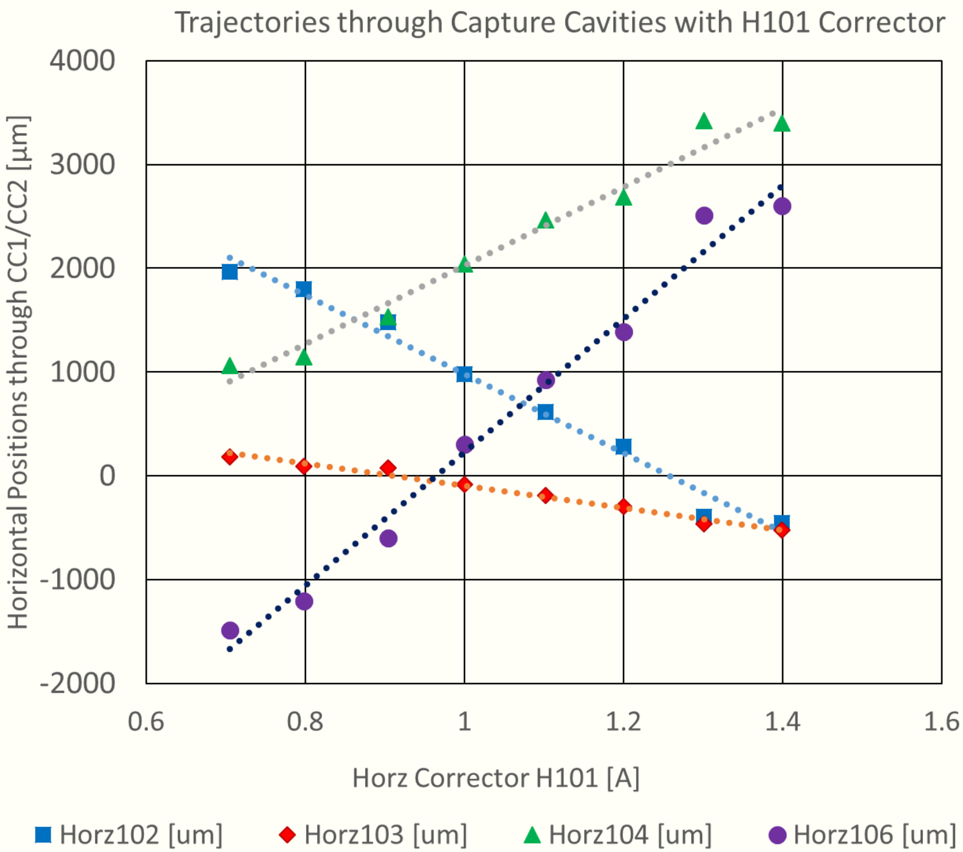


New Steering

Preliminary Trajectories Study

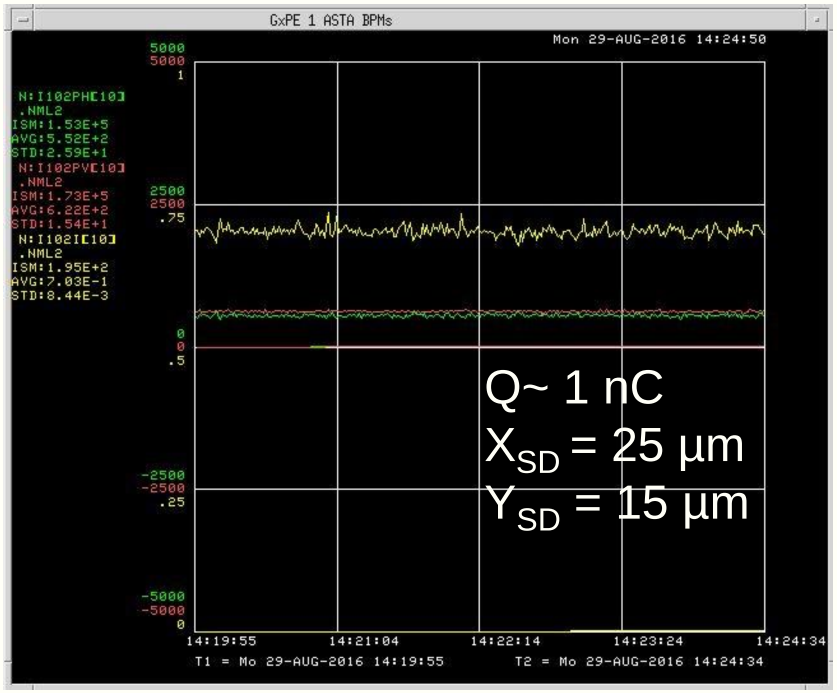
- **Tracked the rf BPM readings as a function of H101 corrector current. Significant offsets observed (7-22-16).**

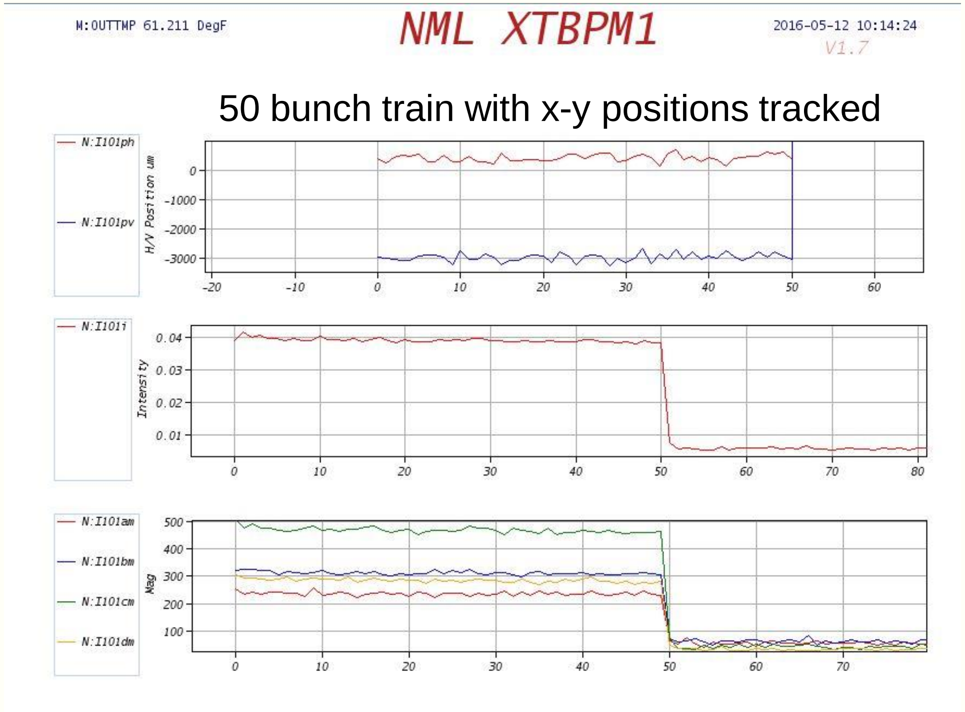




New rf BPM Results (8-29-16)

- Using the 4-MeV beam from the gun, the new lower noise BPM board was shown to significantly reduce noise at high (Left) and low charge.
- The firmware was also revised to allow bunch-by-bunch position plots through ACNET for 50 bunches (Right).
- Need several (all) injector rf BPM stations upgraded for HOM studies.





Courtesy of N. Eddy

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SUMMARY

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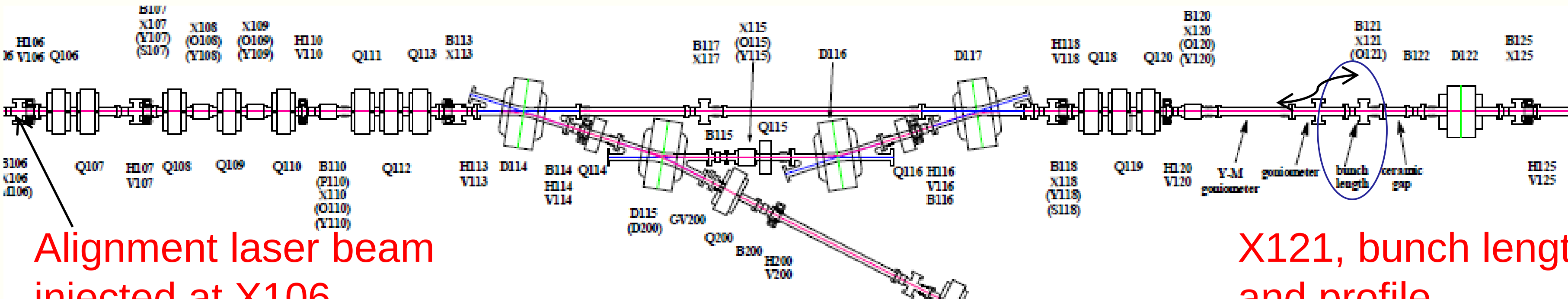
- Success on several counts:
- Demonstrated dual-sweep streak mode for phase and bunch-length tracking bunch by bunch. (y-t effects)
- Demonstrated horizontal sweep in semi-framing mode to track spatial position and profile bunch by bunch.

(Applications to X121 OTR (and OSR from IOTA ring))

- Demonstrated improved time resolution by speeding up Range 1 deflection circuit and adding 550 nm LPF.
- Observed sub-ps bunches at FAST with improved system. (see e-log) Also should run at 20-25 ps laser.
- Further HOM studies time will be requested for full test program. FAST and MaRIE, etc. relevance.
- Simulations of long-range wakefield effects needed.

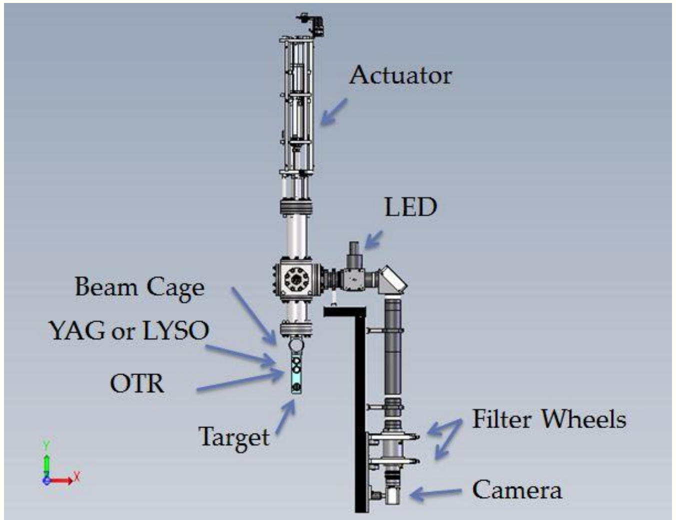
Injector Beamline After CC2

- **Diagnostics available for beam studies. X107, X108, X109,X110, X120, X121, X124, rf BPMs, loss monitor.**



Alignment laser beam injected at X106

X121, bunch length and profile

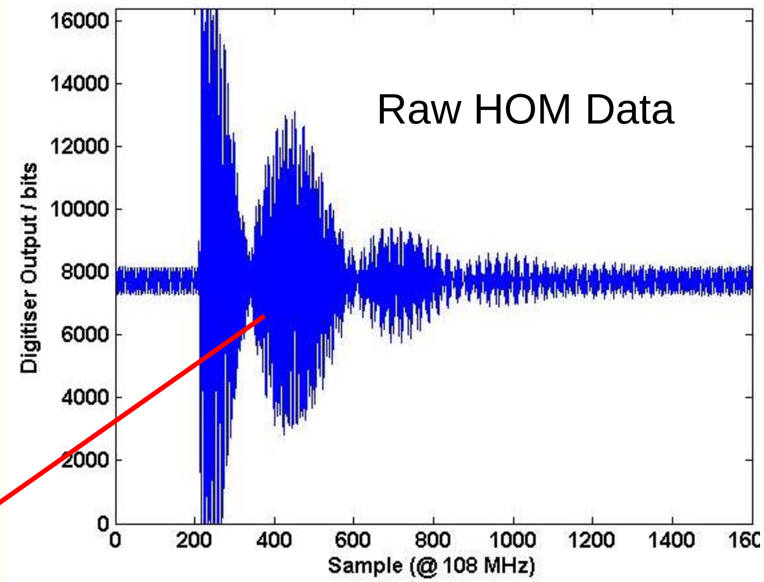


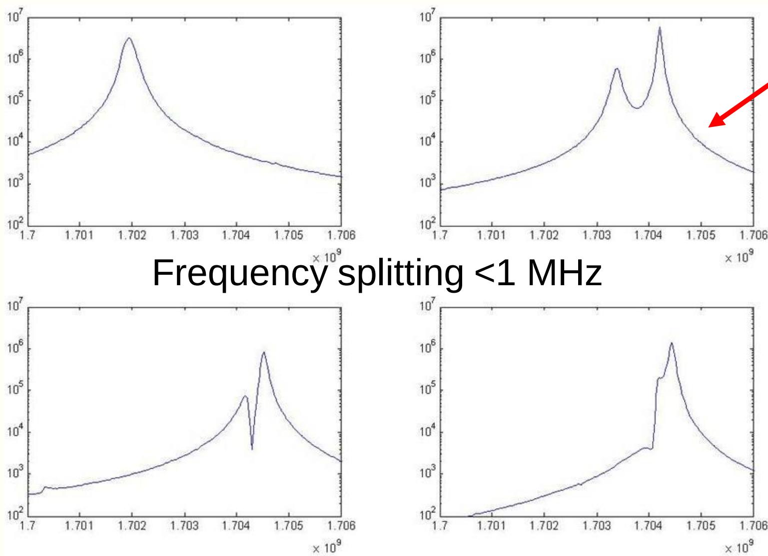
Narrow-band BPM System

Dipole modes exist in two polarisations corresponding to orthogonal transverse directions.

The polarisations may be degenerate in frequency, or may be split by the perturbing affect of the couplers, cavity imperfections, etc.

Makes determination of mode amplitudes difficult using traditional techniques





Frequency splitting <1 MHz

Mode Splitting in Different Cavities

Need to calibrate the HOM response against positions from the BPMs

Use SVD to find orthogonal modes then regress the mode amplitudes against BPMs to determine calibration matrix

Multi-bunch data requires subtracting predicted amplitudes from previous bunch

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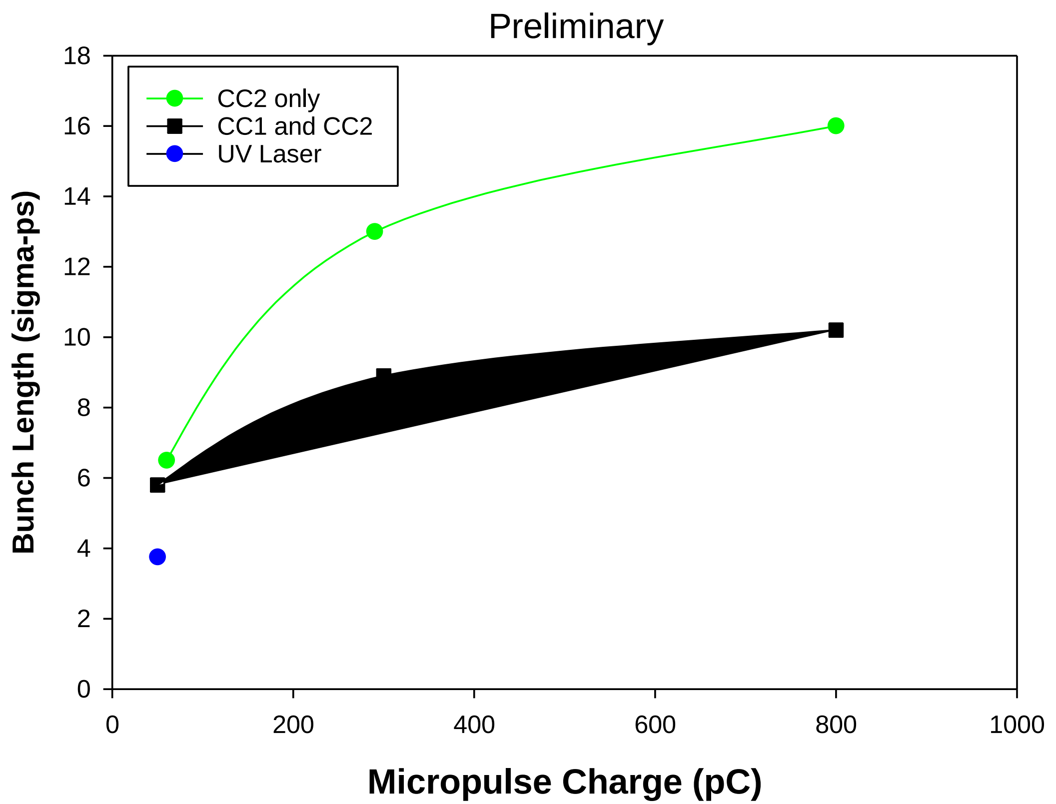
Some Results

- We have obtained clear sub-ps pulse generation and streak camera sub-ps resolution by speeding up R1 and adding a long pass filter (LPF) on OTR input.
- We have obtained clear dual-sweep streak images for looking for short range wakefields. See single bunches at 330 pC/b.
- We have also obtained first semi-framing camera mode for bunch by bunch profile and position with X121 OTR.
- Comparison to images at X121 YAG indicate spatial resolution at about 10 microns, much better than our conservative estimate of last Feb.
- Since beam was apertured to 25 x 135 μm^2 we probably can operate below 200 pC per micropulse if focused.

Electron-beam Elongation

- **Comparison of the electron beam elongation in z vs. micropulse charge without and with CC1 installed.**
- **Synchronous sum of 20 micropulses except lowest Q.**

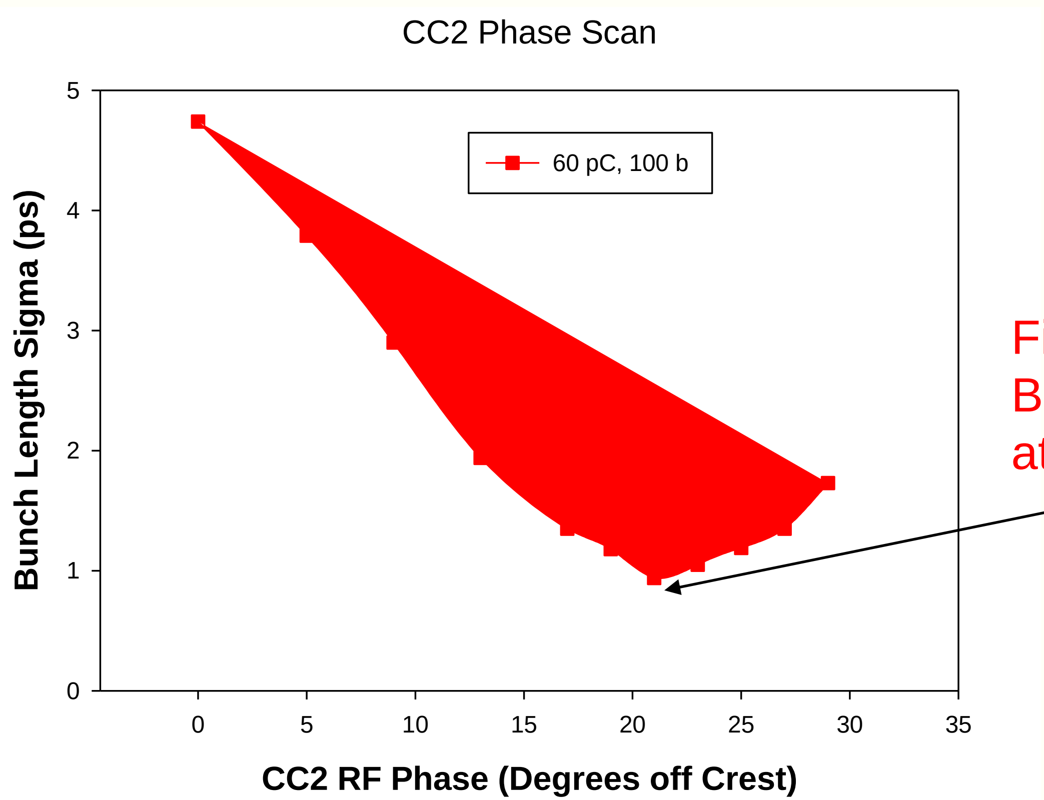


*Also should run at 20-25 ps laser pulse lengths for Wakefield studies.

Electron-beam Compression

- **Comparison of the electron beam bunch length versus CC2 rf phase noted as degrees off crest (DOC).**
- **60 pC micropulse charge, synchronous sum of 100 b.**

1.New R1 cal:
0.10 ps/pix
2. BandWidth
term subt.
3. 7-13-16 Data



First sub-ps
Bunch length
at FAST