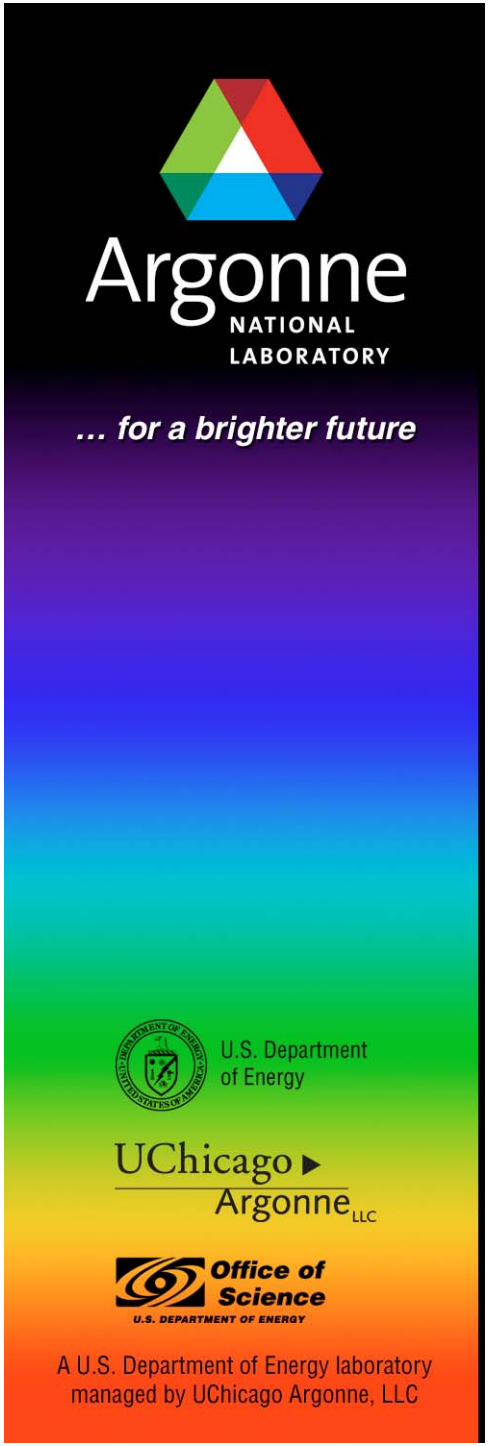


SPX Beam Diagnostics

Bingxin Yang, 2/15/2008

SPX Beam Diagnostics: Scope and Options

Optical Diagnostics:

- 7-BM vertical beam size ➔ tilt
- 7- BM vertical beam position ➔ Deflecting cavity phase
- 7-BM visible light to provide optical synchronization signal
- S35 high resolution / fast beam size measurement to monitor beam quality for non-SPX users

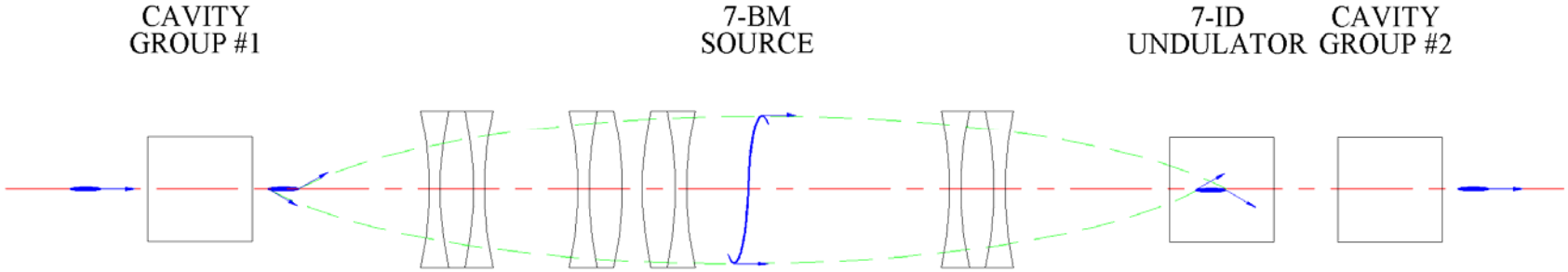
RF tilt meter R&D

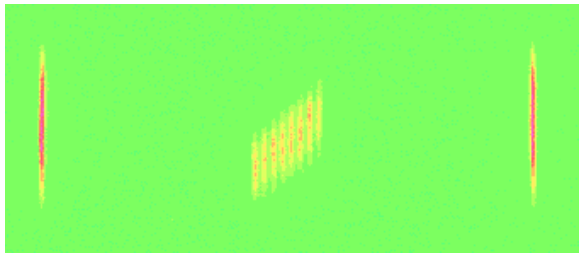
- S-band cavity tilt meter

RF BPM Enhancement

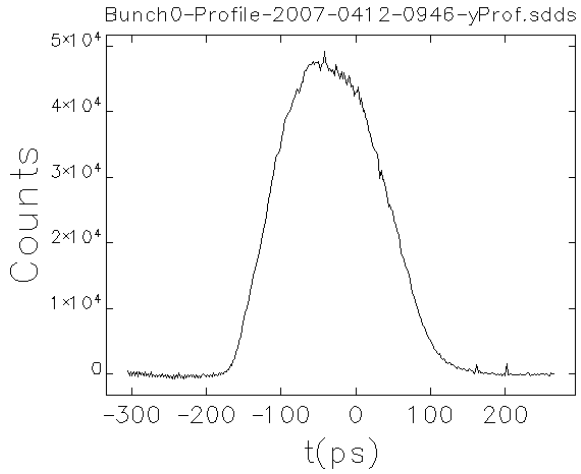
- Flexible acquisition and advanced digital signal processing for single pass measurement is essential for supporting the SPX operation

7-BM Photon Diagnostics: Expected bunch profiles

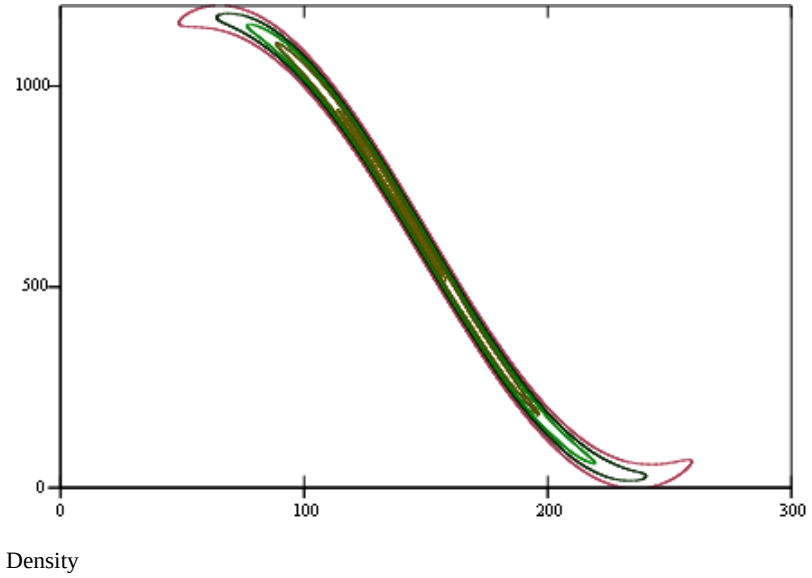




$$\left[\frac{dt}{dy}\right]_{y=0} = 10 \text{ ps/mm}$$

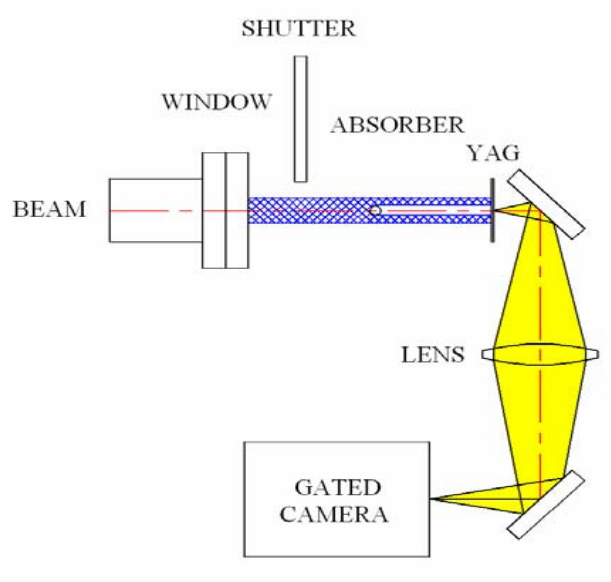


Bunch pattern / Super bunch profile



Side view of the super bunch in 7-BM

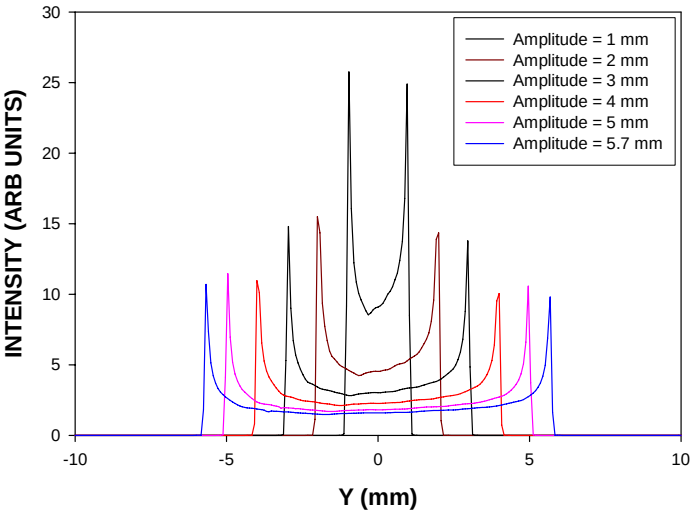
Vertical tilt diagnostics (Projected vertical beam size)

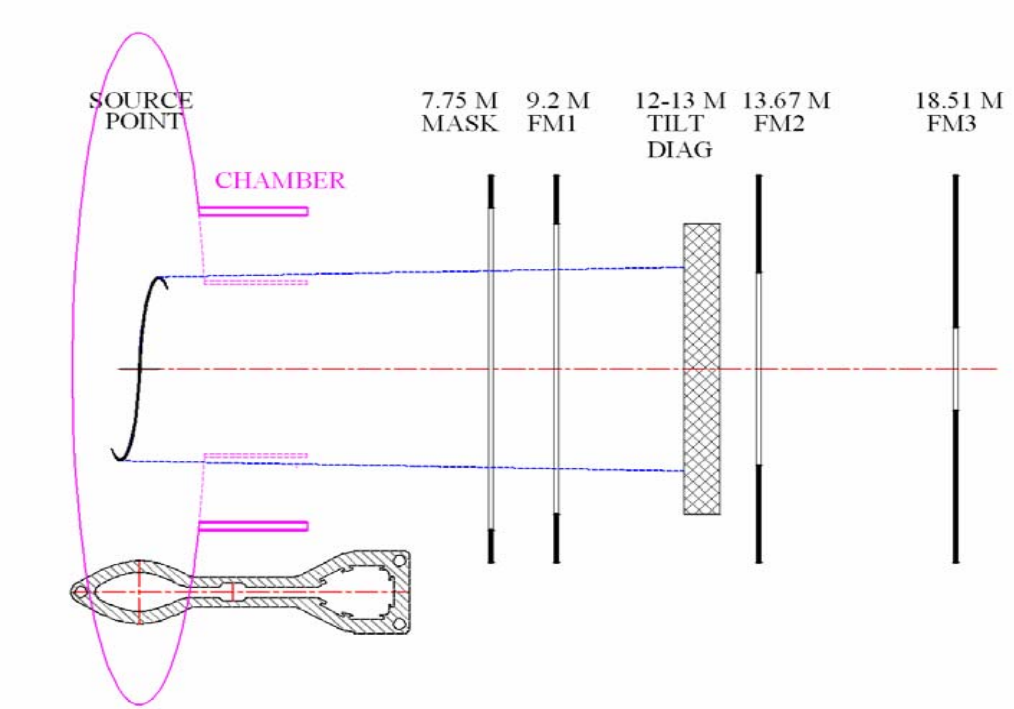


(1) Block off on-axis x-rays from undeflected beam
(2) Use gated camera to acquire image during kicks
(3) Use a shutter to protect the scintillator / optics from damages by vertically displaced beam.

Image / profile information:

- Vertical beam size ➔ Total tilt
- Vertical beam centroid ➔ RF phase.

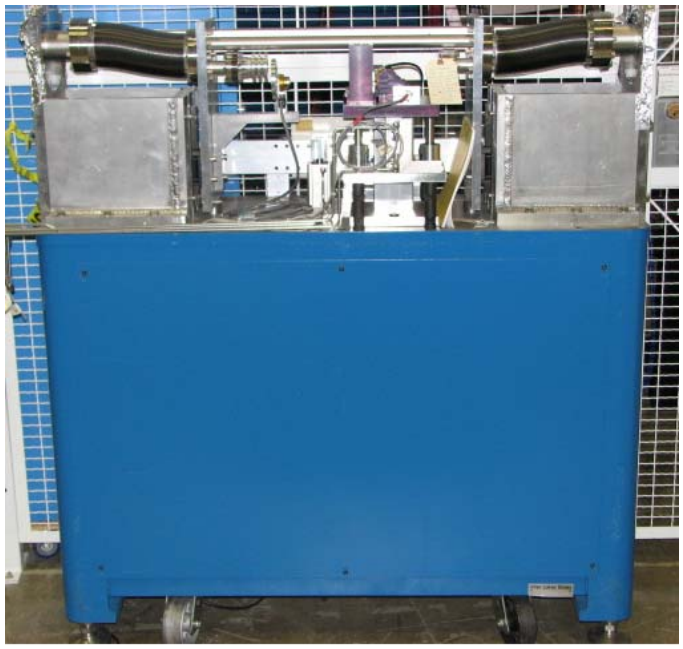


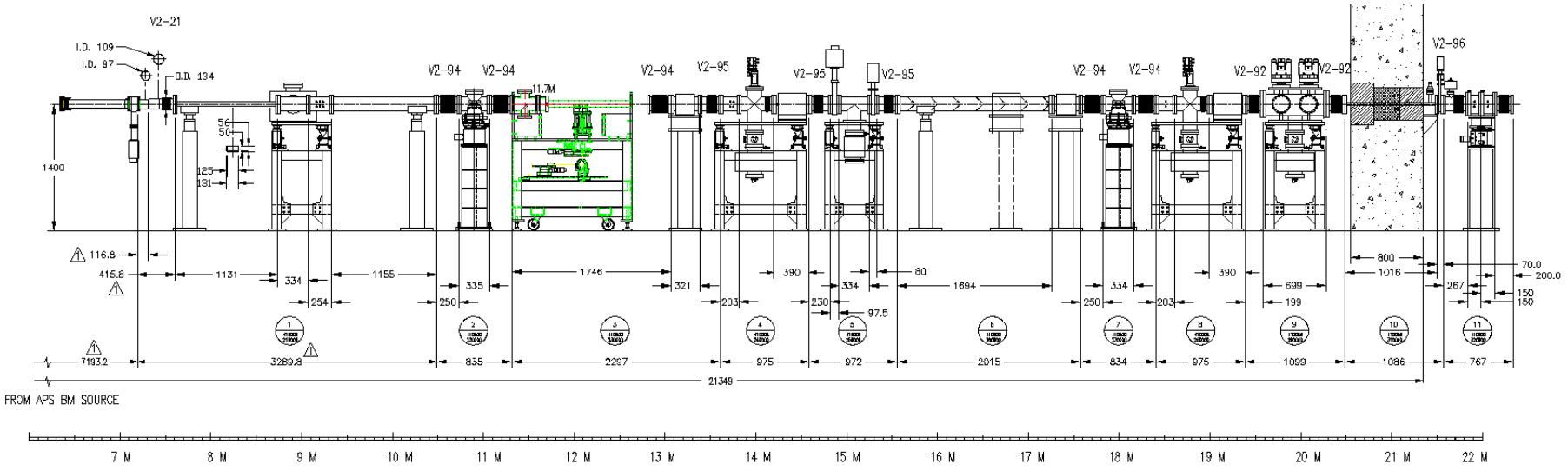


Where do we put the diagnostics?

Coordination with 7-BM users:

- The 7-BM user beamline use 2 mrad x-ray fan outboard of the 7-BM axis.
- Tilt diagnostics uses 2 mrad x-ray fan on inboard side of 7-BM.
- Reserve space for pick-up mirror for visible synchrotron radiation.





Visible synchrotron radiation (option)

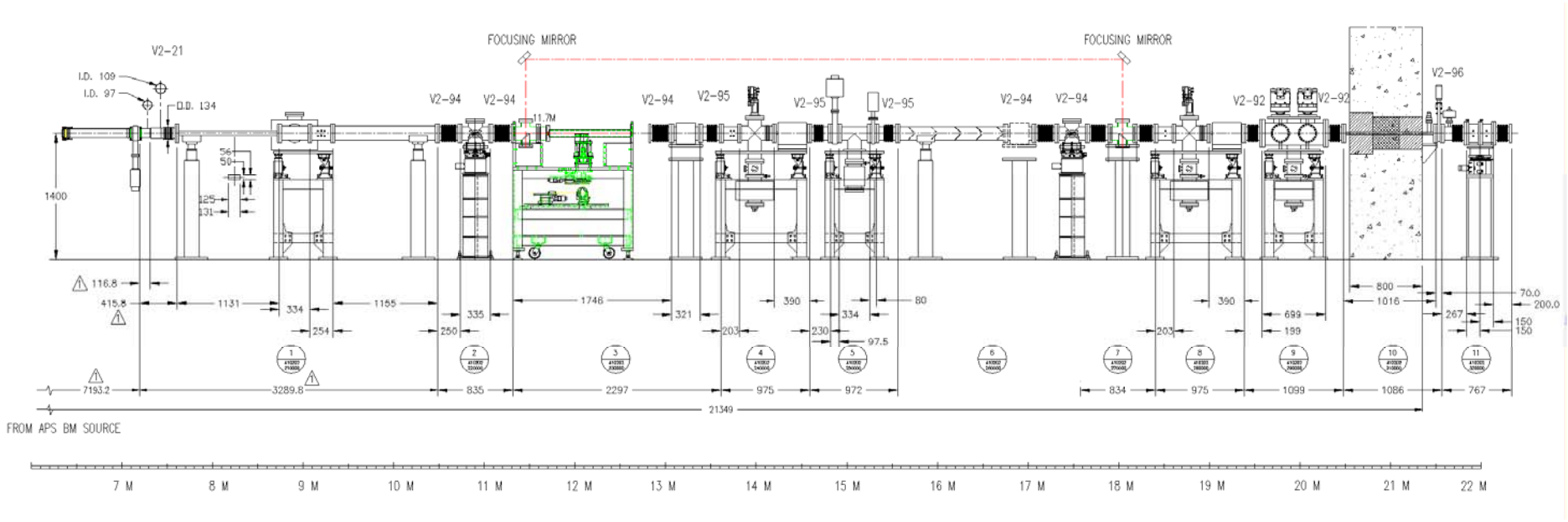
Usage for ps-long visible / UV light pulse:

(1) To generate real-time beam-derived timing signal for x-ray experiment

(2) To correlate with Sector 7 main laser pulse using nonlinear optics.

Optics:

- All mirror optics required to keep the light pulse short: Planar pick-off mirror + curved mirrors for imaging
- Space and cost constraints are the main limiting factors for design.



RF Tiltmeter R & D

Hardware candidate:

- Cavity BPM (proposed and demonstrated in SLAC & ATF)
- Button BPM (?)

Main Idea:

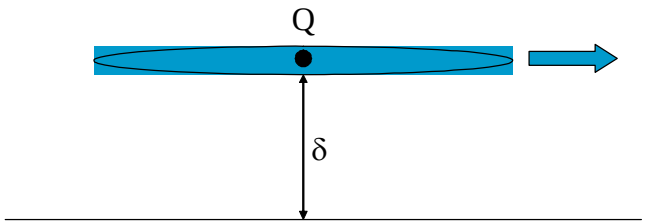
- Each electron produces a RF signal in the BPM. The amplitude of the signal is determined by displacement and its phase is determined by the electron's arrival time.
- Total signal is the superposition of RF signals from all electrons. For tilted bunch, phase and amplitude of the signal is a function of displacement and tilt.
- Appropriate signal processing electronics may sort out the displacement and tilt information

Cavity BPM Response to Two Macro Particle Beam

From Steve Smith (SLAC), NLC Snowmass 2001

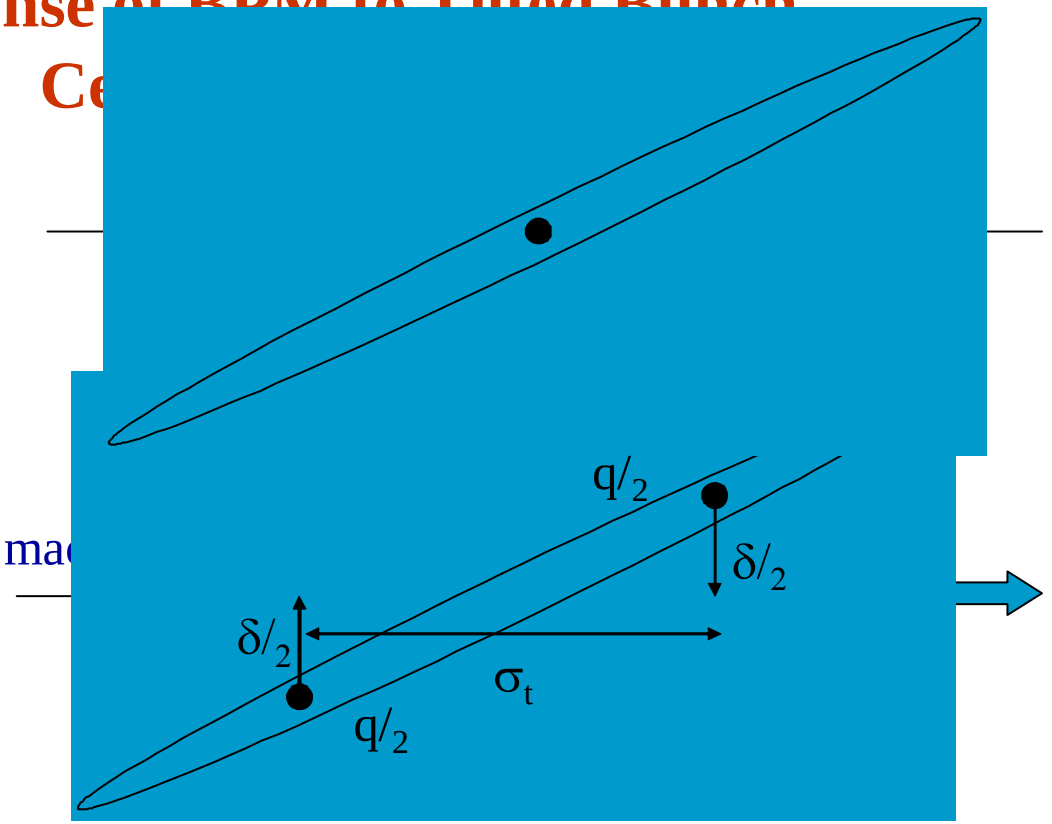
Response of BPM to Tilted Bunch

Ce



$$V(t) = aq\delta\sin(\omega t)$$

Treat as pair of ma



$$V(t) = a\frac{q}{2}\frac{\delta}{2}\sin\omega(t-\frac{\sigma_t}{2}) - a\frac{q}{2}\frac{\delta}{2}\sin\omega(t+\frac{\sigma_t}{2}) = \frac{a\delta q}{2}\cos\omega t\sin\frac{\omega\sigma_t}{2}$$

Cavity BPM Response to Two Macro Particle Tilt

- Point charge offset by δ

$$V_y(t) = aq\delta \sin(\omega t)$$

- Centered, extended bunch tilted at slope δ/σ_t

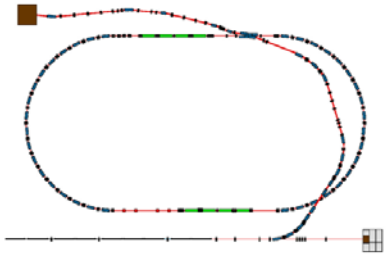
$$V_t(t) = \frac{a\delta q}{2} \sin\frac{\omega\sigma_t}{2} \cos\omega t$$

- Tilt signal is in *quadrature* to displacement. It can be enhanced for cavity wavelength comparable with the bunch length. For the APS bunch length of ~ 2 cm, the wavelength of 10 – 20 cm is compatible with the storage ring aperture.

Button BPM signal will also be affected by the bunch tilt. It can be extracted with more sophisticated signal processing.

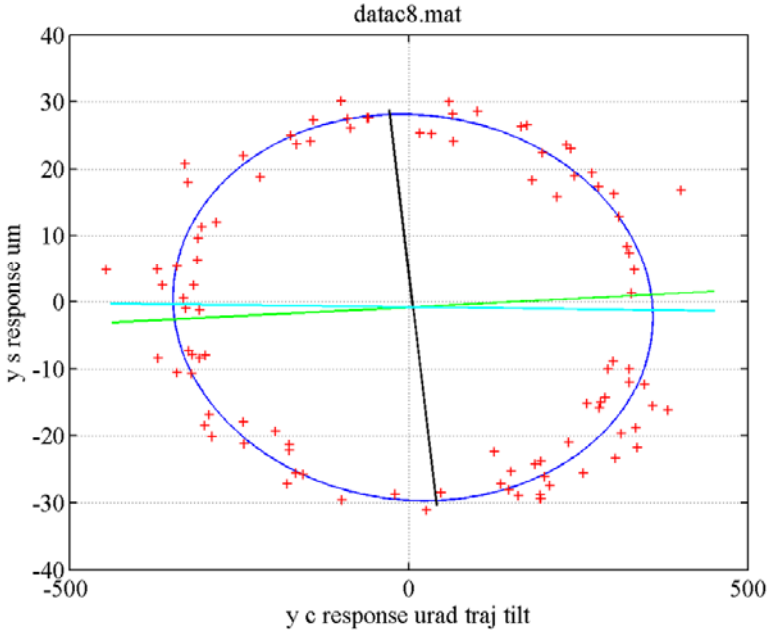
Cavity BPM Tiltmeter test at the ATF

From Marc Ross (SLAC/ATF), KEK-SLAC ISG9 Meeting 12/2002



- I/Q cavity response with deflection cavity at full voltage
- Axes show directions of pure displacement (black) and pure angle (bluish) (green is 90 from pure displacement)
  - Tilter motion is not quite orthogonal
- Ellipticity is the ellipse aspect ratio (*jiyouou*)
- This plot shows equivalent 'angle trajectory'

Deflection cavity on



11.12.02 *ISG 9 at KEK* Marc Ross/SLAC 17

Demonstrated sensitivity < 0.2 mrad, compared to the SPX beam tilt of 0.5 rad.

RF BPM Enhancement (in progress)

Requirements (Om Singh, SPX diagnostics discussion 1/07)

- Maintain ***absolute*** orbit in the deflecting cavities to within 100 microns during SPX operations
- Resolution of the straight section BPMs (P0) = 1 micron for 1 sec. average, 10 microns for single pass (?)

RF BPM enhancement:

- Mono-pulse receiver upgrade allows flexible acquisition mode, including simultaneous measurement of beam position of different bunches
- Understanding and quantify systematic effects, such as charge-dependence and tilt dependence of the BPM signal is important in meeting the resolution requirements
- Advanced digital signal processing is an absolute necessity.

Summary

Diagnostics to implement with source development:

- Simple optical diagnostics measures x-ray beam vertical profile will be used to obtain information of e-bunch tilt and rf deflection cavity phase.
- RF BPM upgrade is crucial in maintaining / controlling electron beam trajectory during SPX operation.

R & D

- RF electron bunch tiltmeter

Options for enhancing user operation

- Visible light can be extracted from the source for beam-derived timing signals / experiments

Acknowledgements

Glenn Decker
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Om Singh
(SPX diagnostics planning / slides, 1/2007)

A.H. Lumpkin, E. C. Landahl, and E. M. Dufresne
(PAC'07 coauthors for SPX Diagnostics Design Studies)

J. Wang
(7-BM front end planning)