NSLS-II Requirements and Plans

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Diagnostics & Instrumentation
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Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
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Outline

- Overview – Machine Parameters
- Stability Requirements
- NSLS-II BPMs
- Motivation for XBPM
  - APS Operation Experience
- NSLS-II XBPM Plan

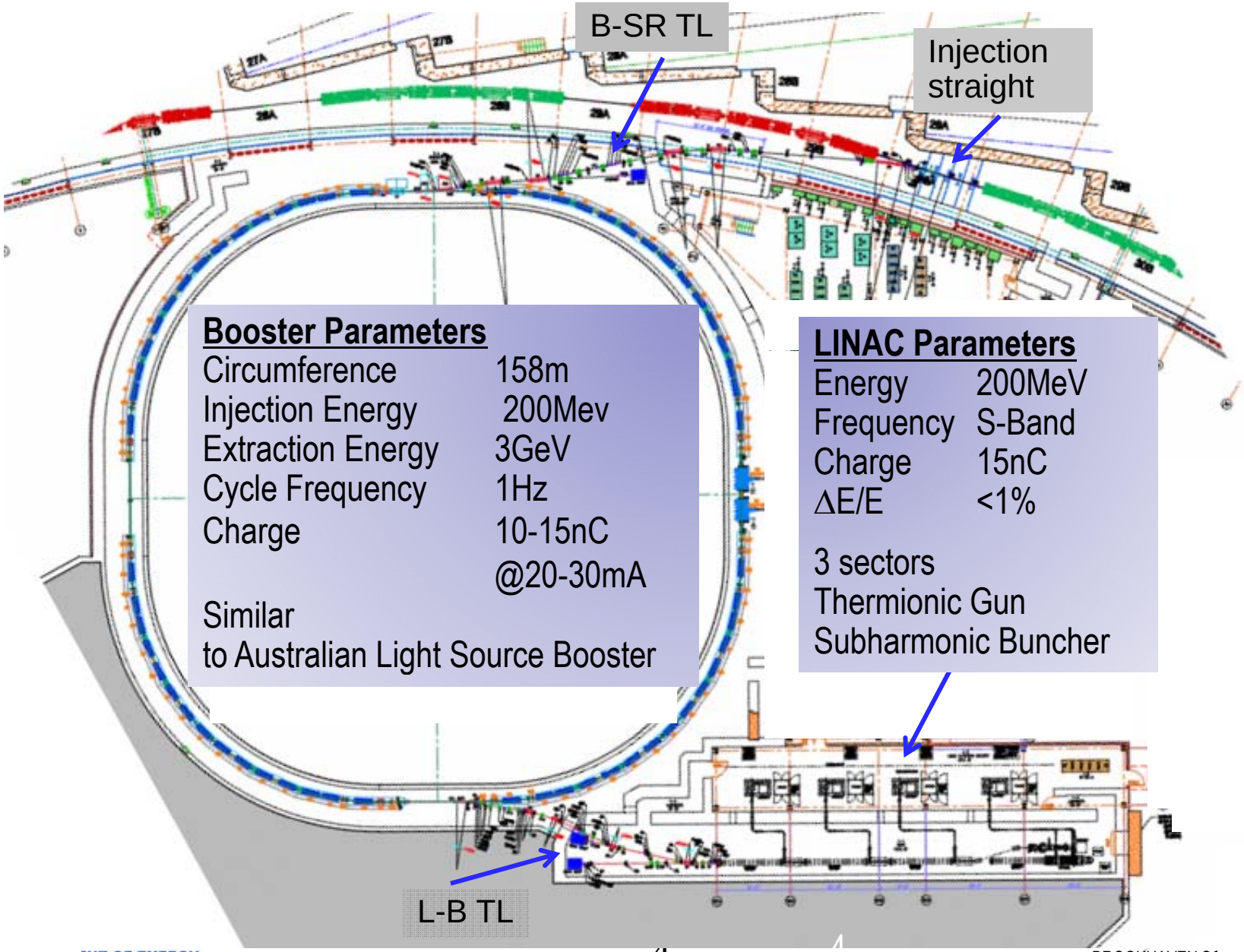
Key SR Parameters

Parameter	Nominal Value
Energy	3.0 GeV
Stored Beam	500 mA; $\Delta I/I = 1\%$
RF frequency	499.68 MHz
Circumference	792 m
Revolution period, T_0	2.642 μs
Harmonic number	1320
Number of bunches filled	1056 (~80%)
Tunes - Q_x, Q_y	33.36, 16.28
Emittance Bare Lattice ε_0 (H/V)	2.0 /0.01 nm-rad
Emittance with 8-DWs ε (H/V)	0.60/0.008 nm-rad
Bunch length	15-30 ps
9.3 m & 6.6 m straight sections	15/15 (30 cells)
β-function at 9.3m ID (β_x, β_y)	20.8/2.94 m
β-function at 6.6m ID (β_x, β_y)	2.02/1.0 6m
X,Y,E Damping times at 3 GeV	5.4/5.1/2.5 ms
Synchrotron frequency, f_s	3.0-3.6 kHz

Top up every 1 minute

Bunch to bunch variation = 20%

NSLS-II Injector Complex Overview



Booster Parameters

Circumference	158m
Injection Energy	200Mev
Extraction Energy	3GeV
Cycle Frequency	1Hz
Charge	10-15nC @20-30mA

Similar to Australian Light Source Booster

LINAC Parameters

Energy	200MeV
Frequency	S-Band
Charge	15nC
$\Delta E/E$	<1%

3 sectors
Thermionic Gun
Subharmonic Buncher

Stability Requirements

$$\Delta x < 0.1\sigma_x \quad \Delta x' < 0.1\sigma_{x'}$$
$$\Delta y < 0.1\sigma_y \quad \Delta y' < 0.1\sigma_{y'}$$
$$\Delta\sigma_{x,y} < 0.1\sigma_{x,y}$$
$$\Delta p / p < 5\times 10^{-5}$$

In short insertion, $\sigma_y = 3\,\mu m$**, hence must hold orbit stable to** $0.3\ \mu\ m$

Orbit stability requirements can be met using orbit feedback

Skew quadrupoles at dispersive (15) and non-dispersive (15) locations used to correct for coupling errors.

Stability Dependent on Conventional Facilities

- Stability goals driven by conventional facility design
  - Stability of storage ring tunnel floor
    - Vibration < 25 nm PSD from 4-50hz
  - Stability of experimental floor
    - Vibration level of < 25 nm PSD from 4-50hz for general floor area
  - Thermal stability of storage ring tunnel environment
    - +/- 0.1^{o} C for 1 hour time constant
  - Thermal stability of experimental floor environment
    - +/- 0.5^{o} C for 1 hour time constant

Magnet Alignment and Orbit Control

Multipole Alignment

Quadrupoles and Sextupoles on Girders	30 microns
BPM Initial Alignment	300 microns
Beam Based BPM Calibration	10 microns
Beam Centered in Sextupoles	50 microns

Orbit Correction

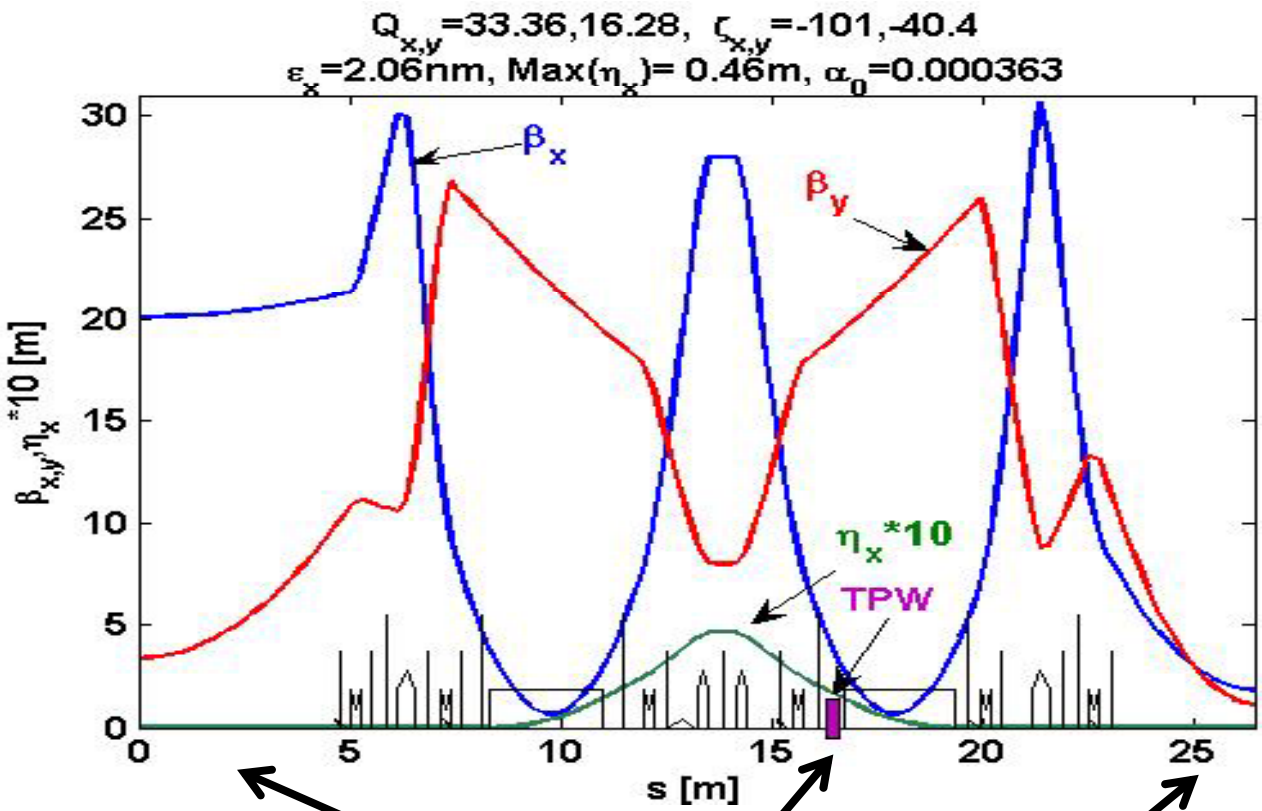
Six Correctors (Maximum strength of 0.8mrad)
+ Six BPMs per Cell+Two ID BPMs per Undulator
Feed forward using trims at ID ends to correct for gap change

Orbit Feedback

Four Fast Correctors per Cell
18 bit resolution
Noise level of 4 nrad (0.5-200 Hz)

SR Lattice & Electron Beam sizes/divergences

Lattice Functions



Electron Beam Sizes & Divergences

Types of source	9.3m ID	1-T 3-Pole wiggler	Bend magnet	6.6m ID
σ_x (μm)	108	175	44.2	29.6
$\sigma_{x'}$ (μrad)	4.6	14	63.1	16.9
σ_y (μm)	4.8	12.4	15.7	3.1
$\sigma_{y'}$ (μrad)	1.7	0.62	0.63	2.6

Most challenging Beam stability Requirements = ~ 0.31 μm

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NSLS-II SR RF BPM System – Performance Requirements

Parameters/ Subsystems				Conditions	*Large Aperture RF BPM Resolution Requirement	
					Vertical	Horizontal
50 mA ** to 500 mA Stored beam resolution – 20% to 100 % duty cycle	BPM Receiver Electronics	Assuming no contribution from bunch/ fill pattern effects		0.017 Hz to 200 Hz	0.2 µm rms	0.3 µm rms
				200 Hz to 2000 Hz	0.4 µm rms	0.6 µm rms
				1 min to 8 hr drift	0.2 µm pk-pk	0.5 µm pk-pk
		Bunch charge/ fill pattern effects only		DC to 2000 Hz	0.2 µm rms	0.3 µm rms
	Mechanical motion limit at Pick-up electrodes assembly (ground & support combined)		Vibrations	50 Hz to 2000 Hz	10 nm rms	10 nm rms
				4 Hz to 50 Hz	25 nm rms	25 nm rms
				0.5 Hz to 4 Hz	200 nm rms	200 nm rms
			Thermal	1 min to 8 hr	200 nm pk-pk	500 nm pk-pk

* ID BPM system (small aperture RF BPM) resolution values will be smaller (factor of ~ 0.5)

** @ 5 mA – 50 mA stored beam, BPM receiver resolution values will be worse (factor of ~2)

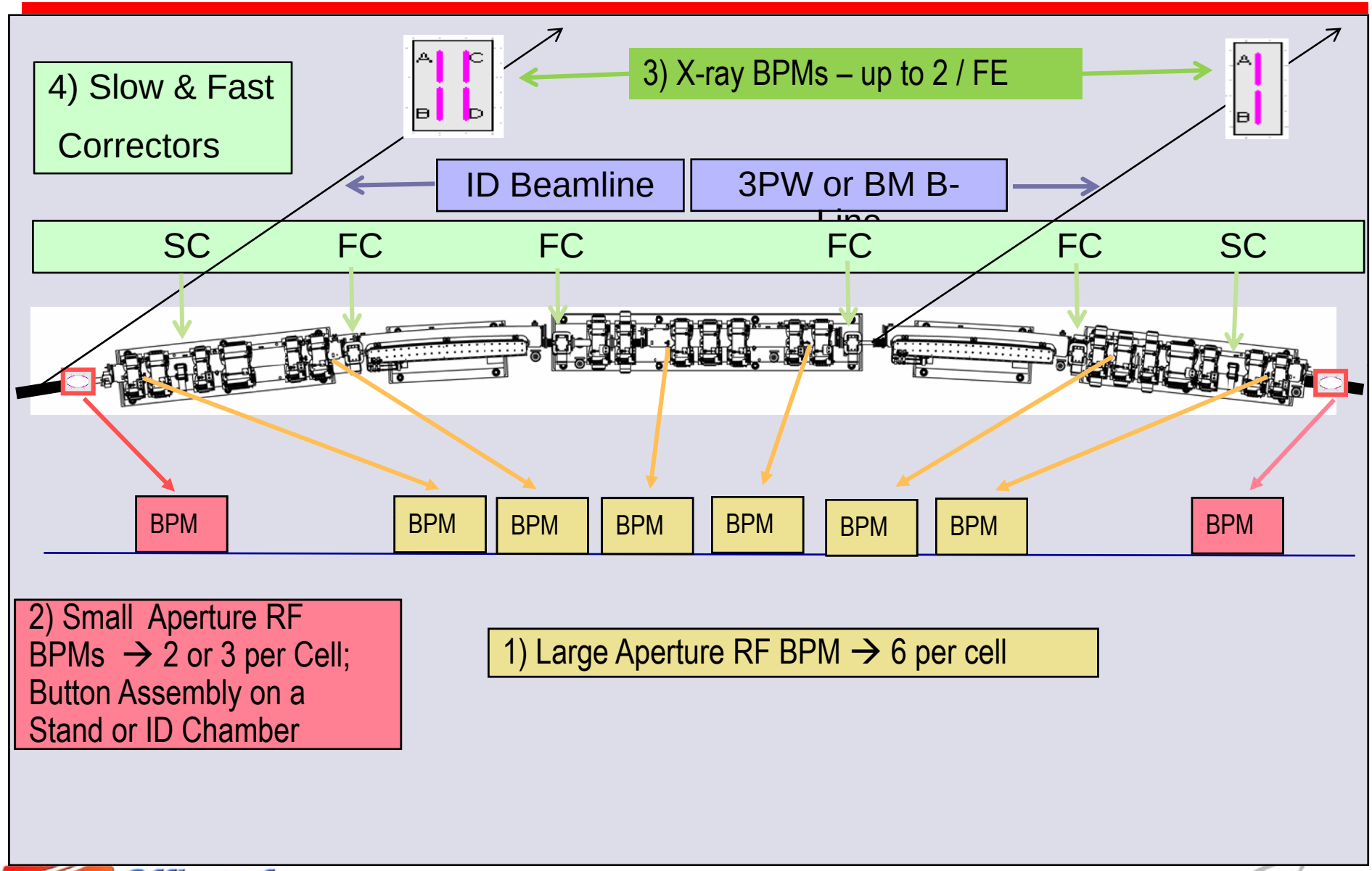
NSLS-II Diagnostics Sub-systems

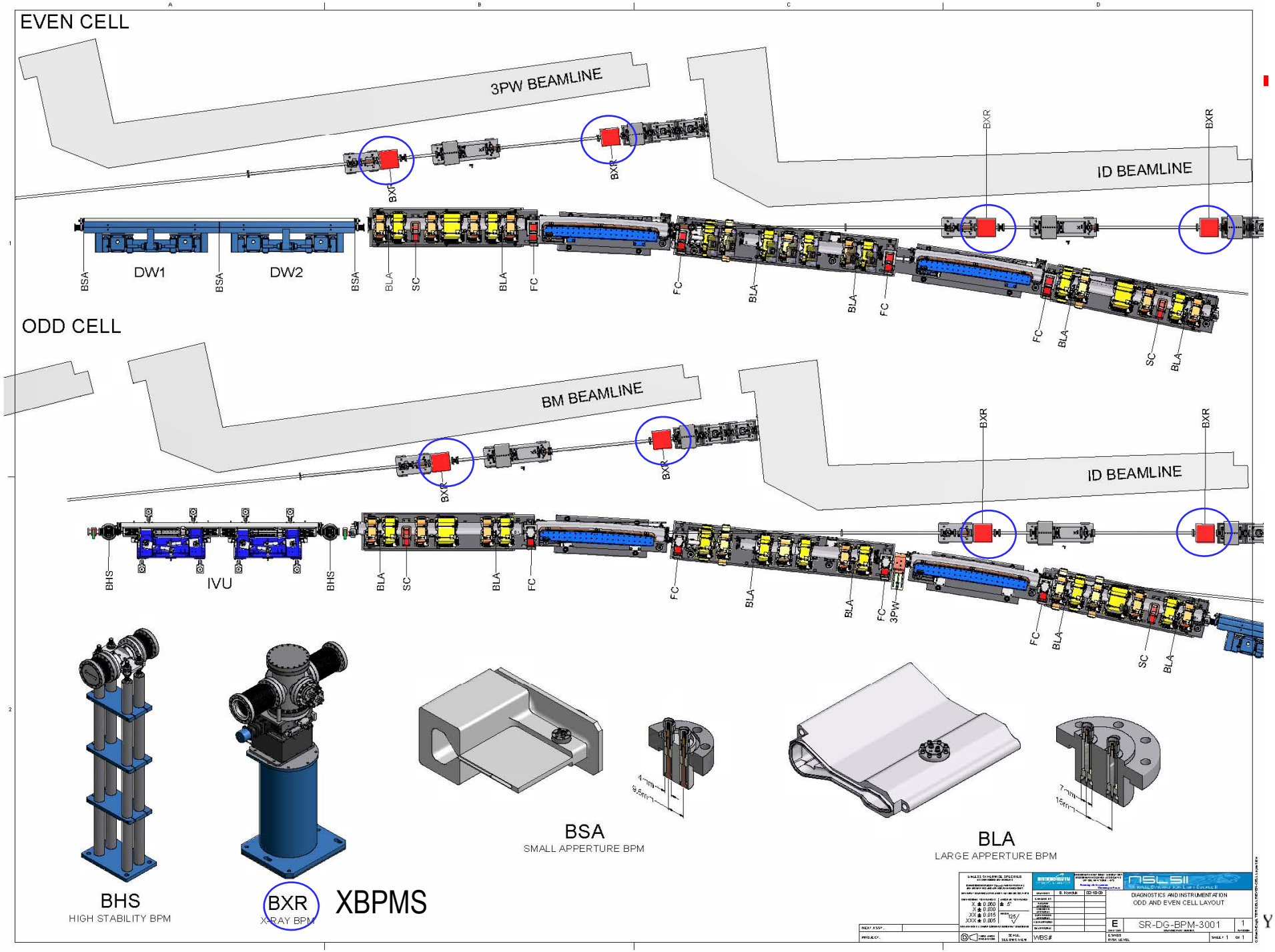
Monitor	Location					
	SR	BTS	Booster	LTB	Linac	Gun
Wall Current Monitor						3
Fast Current Transformer			1	1	2	
Integrating Current Transformer		1		2		
Fluorescent Screen						
Energy Slit						
Bunch Cleaner						
RF BPM – Single Pass						
RF BPM – TBT & Store						
ID RF BPM						
ID Photon BPM						
BM Photon BPM						
DC Current Transforme						
Fill Pattern Monitor Str						
Tune Monitor Stripline						
Emittance Monitor (3P						
Pinhole Camera (BM s						
Optical Ports for visib						
FireWire Camera	1		1			
Streak-camera	1					
Transverse Feedback Systems (Striplines & RF Amplifiers)	1 H & 1 V					
Beam Oscillations Monitor	1					
P-i-n Diode/ Scintillator Loss Monitors	60/20					
Beam Scrapers (X & Y)	2 sets					

Storage Ring BPM	#
RF BPM – TBT & Stored Beam	6 per cell
ID RF BPM	2 or 3 per ID
ID Photon BPM	1 per ID
BM Photon BPM	1 per BM*

*Not in the baseline

SR Cell BPM/Corrector Layout




EVEN CELL
3PW BEAMLINE
ID BEAMLINE
BXR
BSA
DW1
DW2
BLA
SC
FC
ODD CELL
BM BEAMLINE
BHS
IVU
3PW
BHS
HIGH STABILITY BPM
BXR
X-RAY BPM
XBPMS
BSA
SMALL APPERTURE BPM
BLA
LARGE APPERTURE BPM
DIAGNOSTICS AND INSTRUMENTATION
ODD AND EVEN CELL LAYOUT
SR-DG-BPM-3001

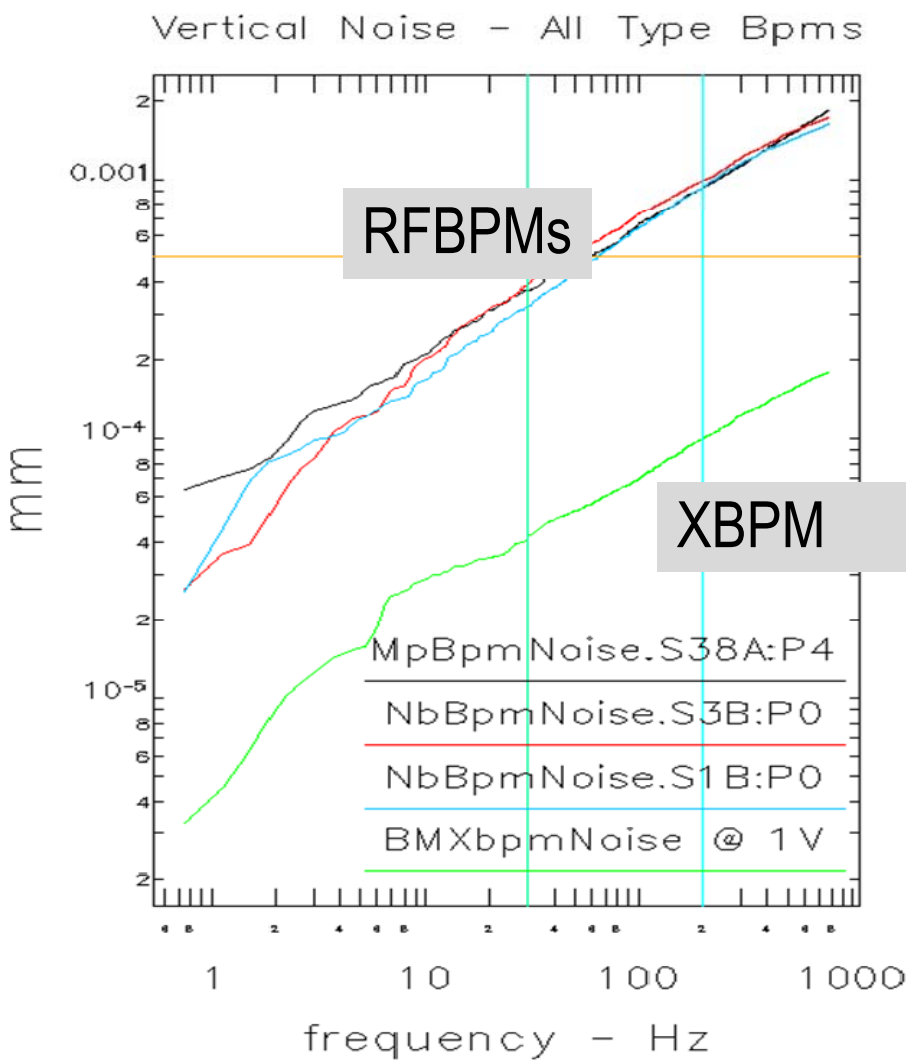
Motivation for XBPM & Operational Experiences at APS

1. Increase in BPM Resolution/ Linearity/ stability
   - Lever arm advantage over RFBPM – (17m/2.5m) S/N > 6
   - Operation range only +/- 1 mm; Δ/sum resolution < 10 nm
   - Beam normally parked at the center - better linearity
   - Mounted on a thermally stable stand - better stability
2. Decrease in bunch pattern dependence
   - Blade pre-amplifier signal response – tens of kHz; results in position averaging over tens of SR turns; bunch to bunch intensity variation effects drastically reduced
   - Excellent for restoring "golden" orbit, especially when fill pattern has significant changes – APS operation requires fill pattern changes on the average 2 per month.

Motivation for XBPM & Operational Experiences at APS - cntd

3. Provides first look at the photon beam position
   - ID Gap change effects photon beam position due to field errors, even if electron beam is stable at the end of ID chamber
   - Adds capability to compensate these changes with feed-forward algorithm using end ID trims
4. Decker Distortion at APS
   - Eliminates background stray radiation – enables to make ultra stable measurements when ID gap fully closed
   - Distortion also enables to make measurement at higher ID gap, but with reduced resolution.
   - 29 out of 31 ID beamlines have this distortion implemented – XBPMS are extremely valuable to recover golden orbit

RFBPM & XBPM Vertical Noise Baseline (APS)



200 Hz BW data

- RFBPMS – 1 micron

(new fpga based rfbpm data not included)

- XBPMs - 100 nm

(limited due to digitizing resolution)

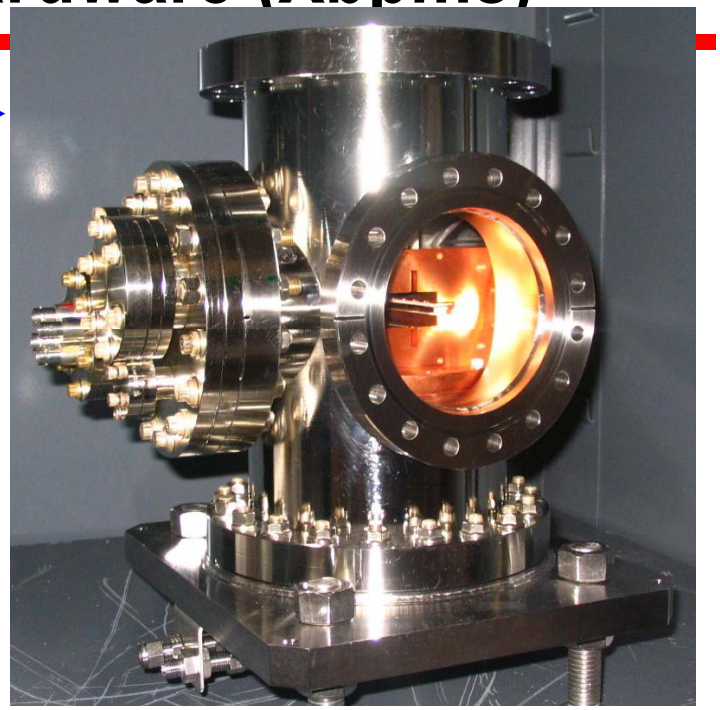
In Tunnel BPM Hardware (Xbpms)

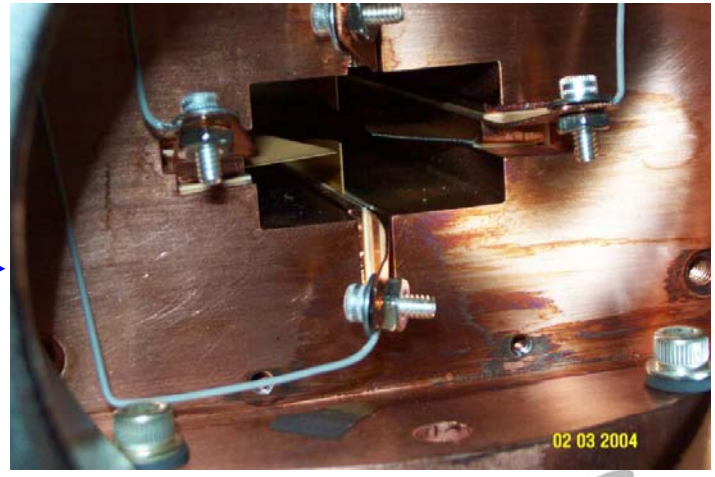
Xbpm Main Assembly

X-Y Translation Stages

Mounting Stand

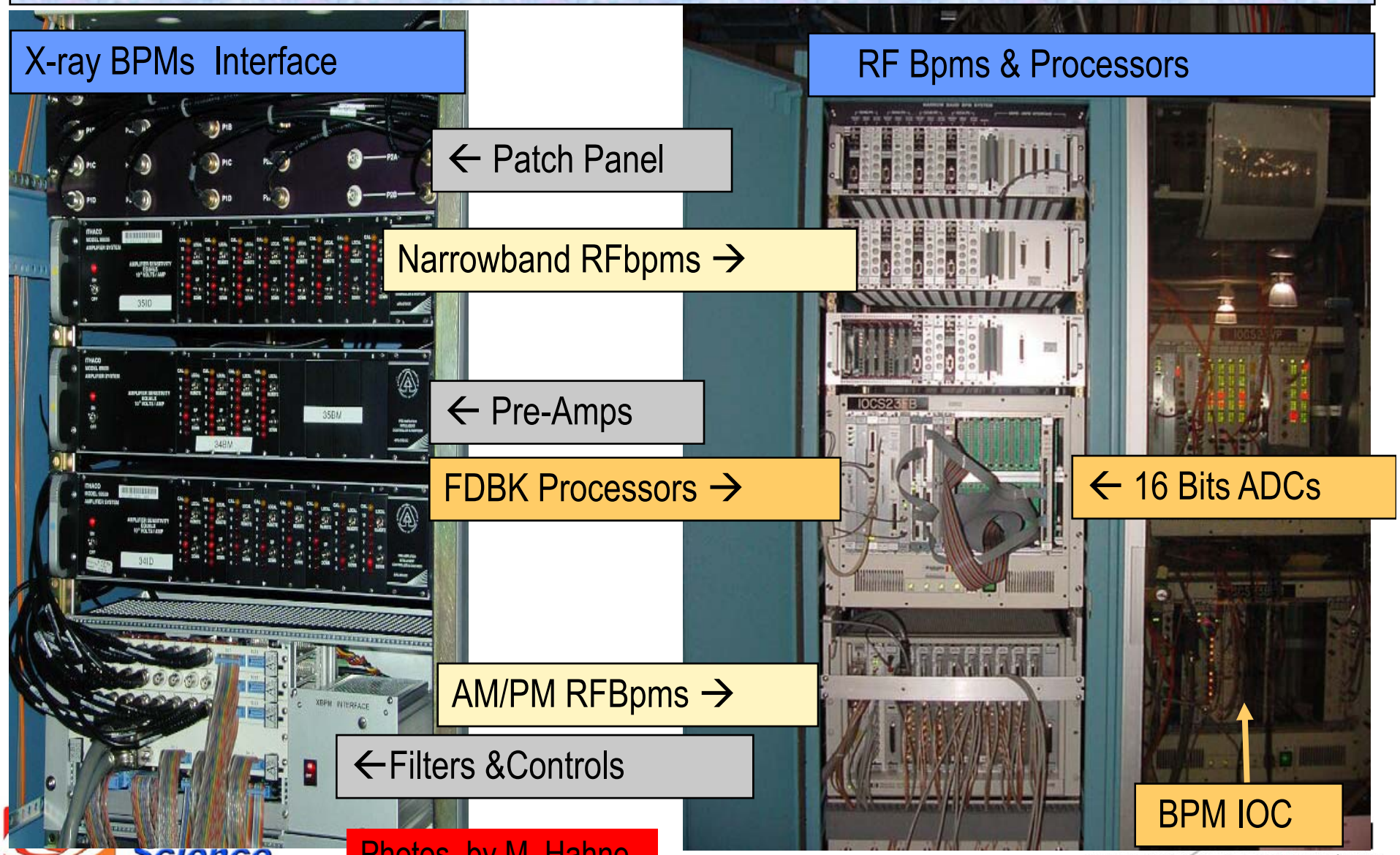
Xbpm Blades Assembly





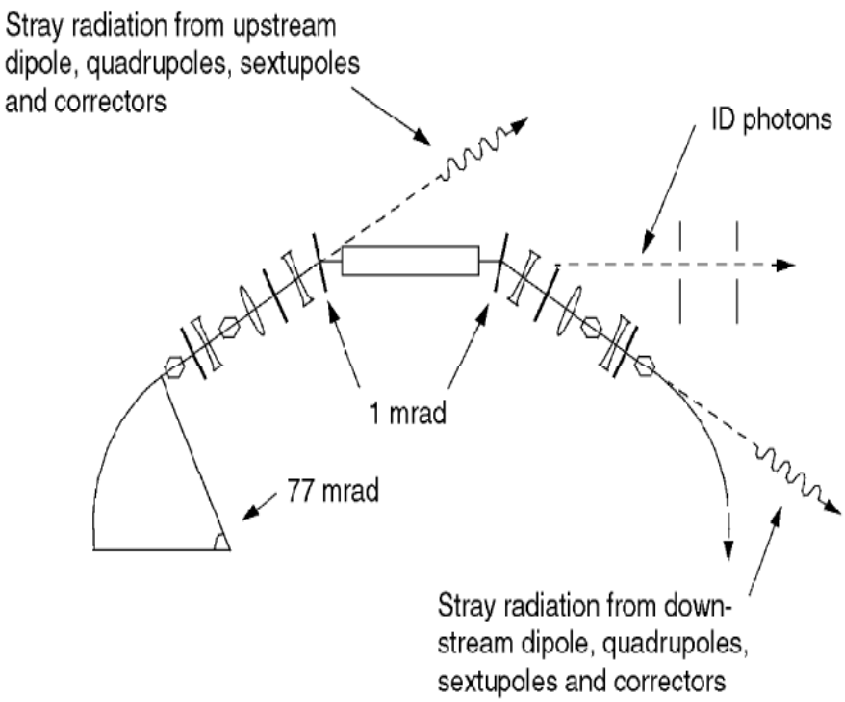
** Deming Shu -APS*

BPM Front-End Electronics and Processors – Two Sectors

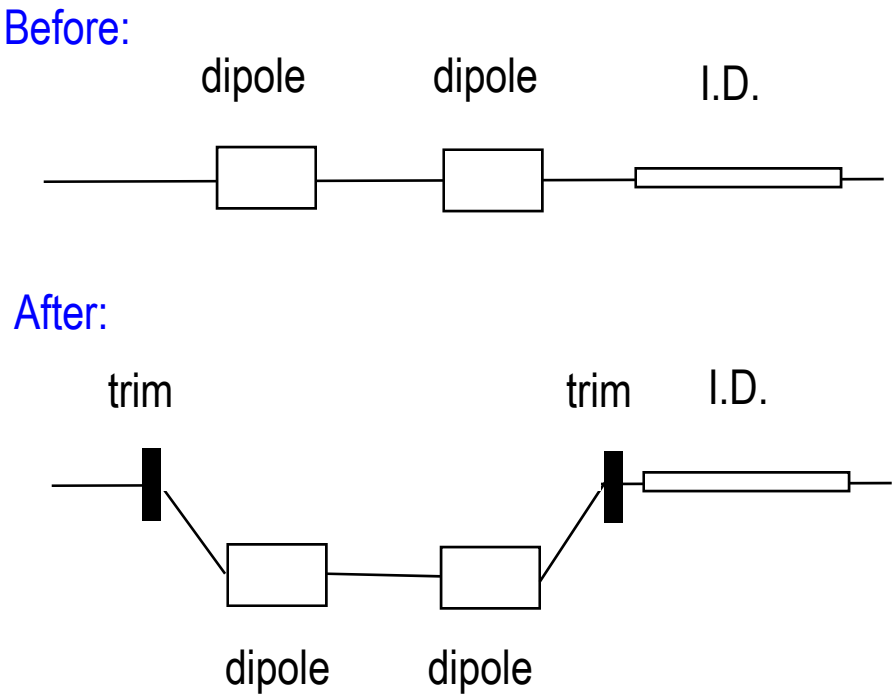


Photos by M. Hahne

Decker distortion at the APS



Stray radiation and Decker distortion

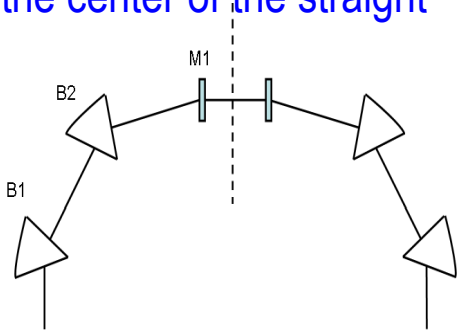


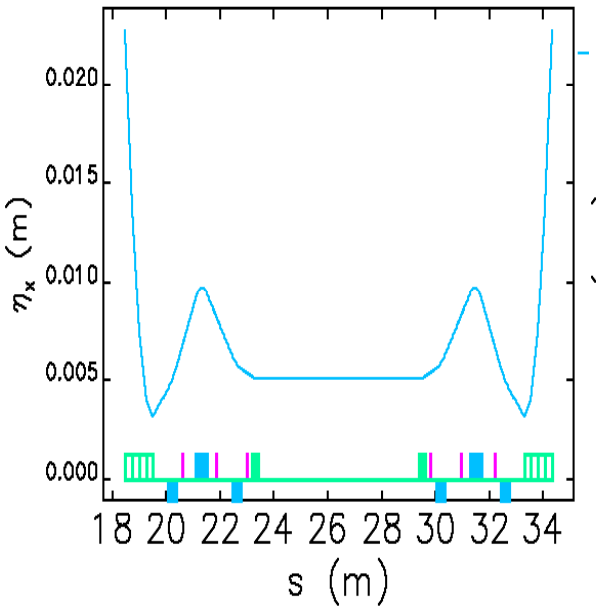
Scheme at the APS

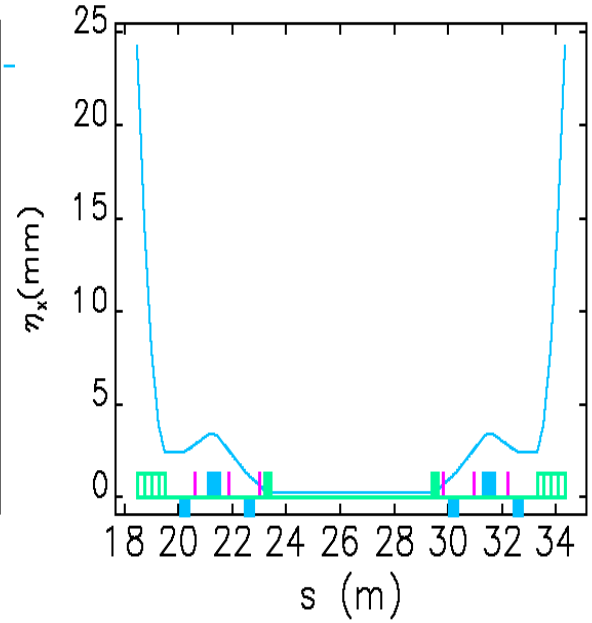
Weiming Guo

Decker distortion for NSLS-II

Reflection symmetry about the center of the straight







Requirements:

1)Orbit stay on-center

2)Dispersion enclosed

$$\begin{cases} \eta = 0 \\ \eta' = 0 \\ \sum \theta = 0 \end{cases}$$

$\Delta B_1 = -1.727$ mr

$\Delta B_2 = 0.727$ mr and M1=1 mr

No change on quadrupole setting

$\Delta B_1 = -0.28$ mr

$\Delta B_2 = -1.02$ mr

M1 = 1.31 mr

$|\Delta K_1 / K_1| \leq 0.1$

Straights will be moved!

Baseline ID Beamlines & XBPM Plan

Baseline Beamlines		Device	H or L - β Straight	Canting (mrad)	ID RFBPM	Decker Distortion	ID XBPM
IXS	Inelastic X-ray scattering	U20	H	0	yes	yes	yes
HXN	HXN Hard X-ray nanoprobe	U20	L	0	yes	yes	yes
CHX	Coherent Hard X-ray scattering	U20	L	0	yes	yes	yes
SRX	Sub-micron resolution x-ray spectroscopy	U22	L	2.0	yes	yes	yes
CSX	Coherent Soft X-ray scattering	EU55	L	0.25	yes*	no	no
XPD	X-ray Powder Diffraction	DW	H	0	yes*	no	no

- XBPM plans

* mounted on ID chamber

- Space in accelerator tunnel for 2 XBPMs in each ID & BM beamline
- Decker distortion plan has been mitigated
- Collaborate with XFD & others to develop state-of-the-art accelerator XBPMs

NSLS-II Job Posting

Instrumentation Physicist - Synchrotron Radiation Diagnostics (S-1/S-2/S-3) – Job No. 14733. Log in to the Candidate Gateway to apply for this position

The National Synchrotron Light Source II Project is seeking an experienced physicist or engineer with expertise in the design of x-ray beamlines and optical instrumentation for synchrotron radiation diagnostics. Responsibilities include the design and commissioning of synchrotron radiation diagnostics for the NSLS-II accelerator systems as well as the opportunity to carry out R&D on x-ray beam position monitors. This position requires: PhD degree in physics or engineering At least two years postdoctoral experience in accelerator instrumentation. Expertise in the design and use of optical, x-ray and electronic instrumentation. A successful track record in the development and use of advanced instrumentation. Reports to the Accelerator Physics Group Leader. National Synchrotron Light Source II.

Acknowledgements

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NSLS-II SR RF BPM System – Performance Requirements

Parameters/ Subsystems				Conditions	Large Aperture RF BPM Resolution Requirement	
					Vertical	Horizontal
Single bunch, Single turn resolution (@ 378 kHz)				0.05 nC charge	500 µm rms	500 µm rms
				5.0 nC charge	20 µm rms	20 µm rms
Single bunch stored beam resolution (0.017-200 Hz BW)				0.02 mA current	10 µm rms	10 µm rms
				2.0 mA current	1 µm rms	1 µm rms
50 mA *** to 500 mA Stored beam resolution – 20% to 100 % duty cycle	BPM Receiver Electronics	Assuming no contribution from bunch/ fill pattern effects		**0.017 Hz to 200 Hz	0.2 µm rms	0.3 µm rms
				200 Hz to 2000 Hz	0.4 µm rms	0.6 µm rms
				**1 min to 8 hr drift	0.2 µm pk-pk	0.5 µm pk-pk
		Bunch charge/ fill pattern effects only		DC to 2000 Hz	0.2 µm rms	0.3 µm rms
	Mechanical motion limit at Pick-up electrodes assembly (ground & support combined)		Vibrations	50 Hz to 2000 Hz	10 nm rms	10 nm rms
				4 Hz to 50 Hz	25 nm rms	25 nm rms
				0.5 Hz to 4 Hz	200 nm rms	200 nm rms
			Thermal	**1 min to 8 hr	200 nm pk-pk	500 nm pk-pk

** ID BPM system (small aperture RF BPM) resolution values will be smaller (factor of ~ 0.5)

*** @ 5 mA – 50 mA stored beam, BPM receiver resolution values will be worse (factor of ~2)

In Tunnel BPM Hardware (Rf Bpms)

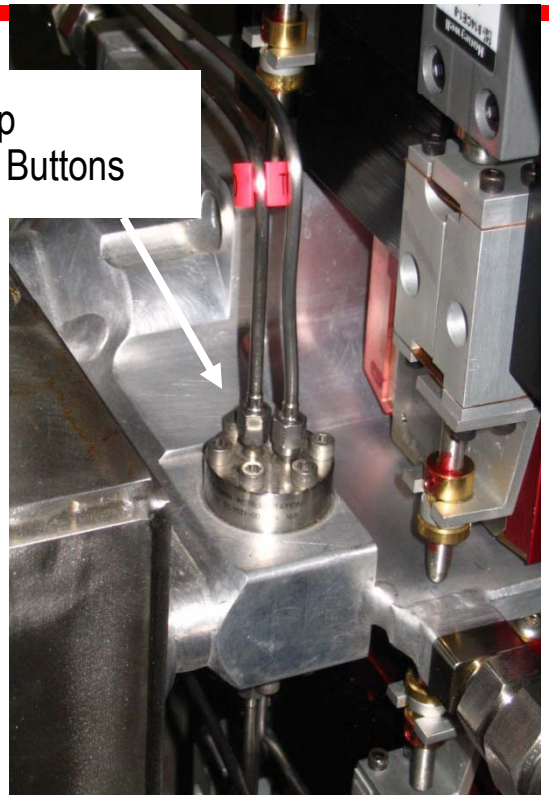

Photo – M. Hahne