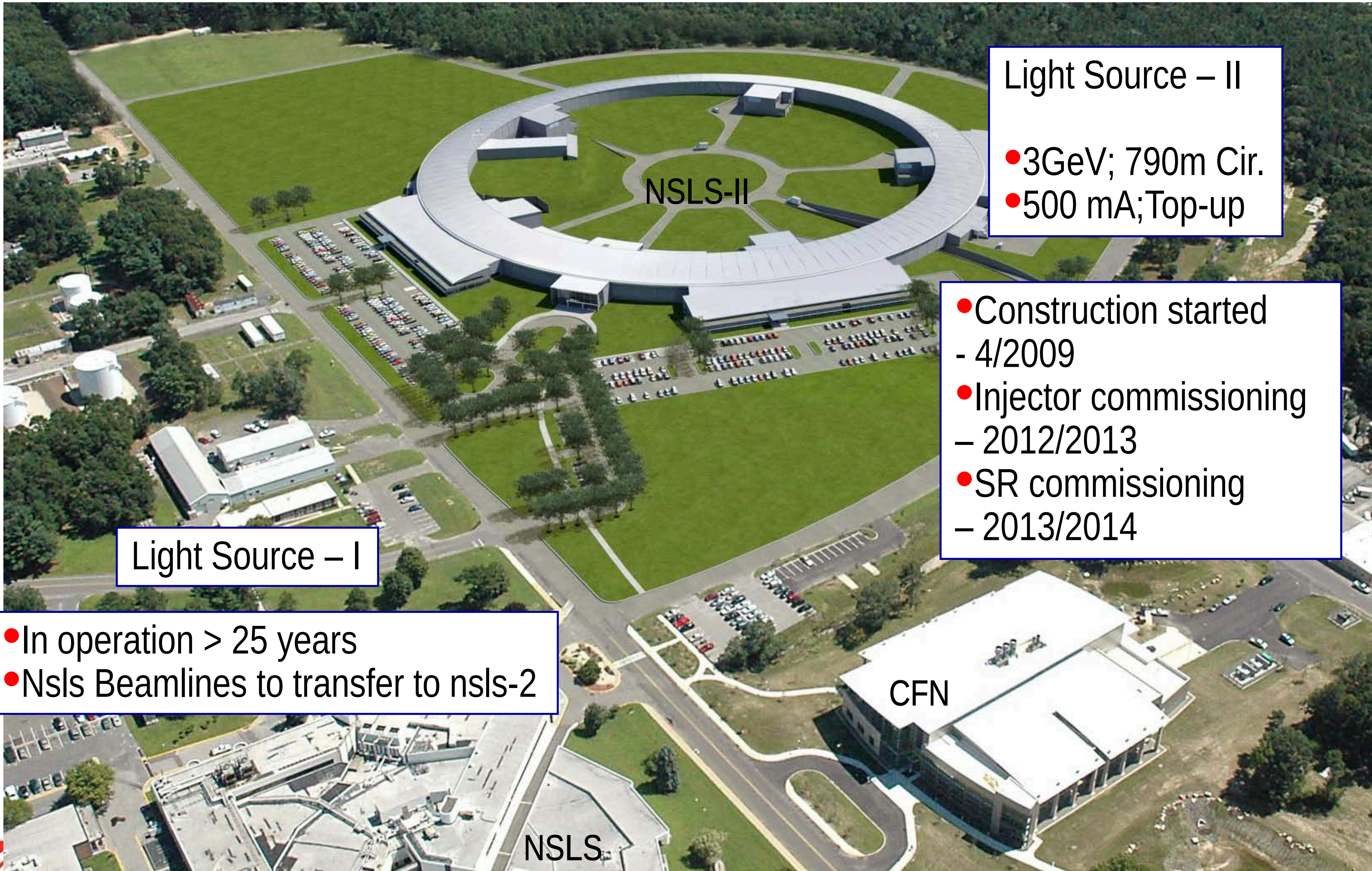
NSLS-II Closed Orbit BPM Project

Om Singh
Libera Users Meeting - June 22-23, 2009
ESRF, Grenoble, France

Outline

- NSLS-II Project Overview
- Closed Orbit Correction Strategy
- Libera Brilliance Test Results with Beam
- Summary

Aerial View



Light Source – II

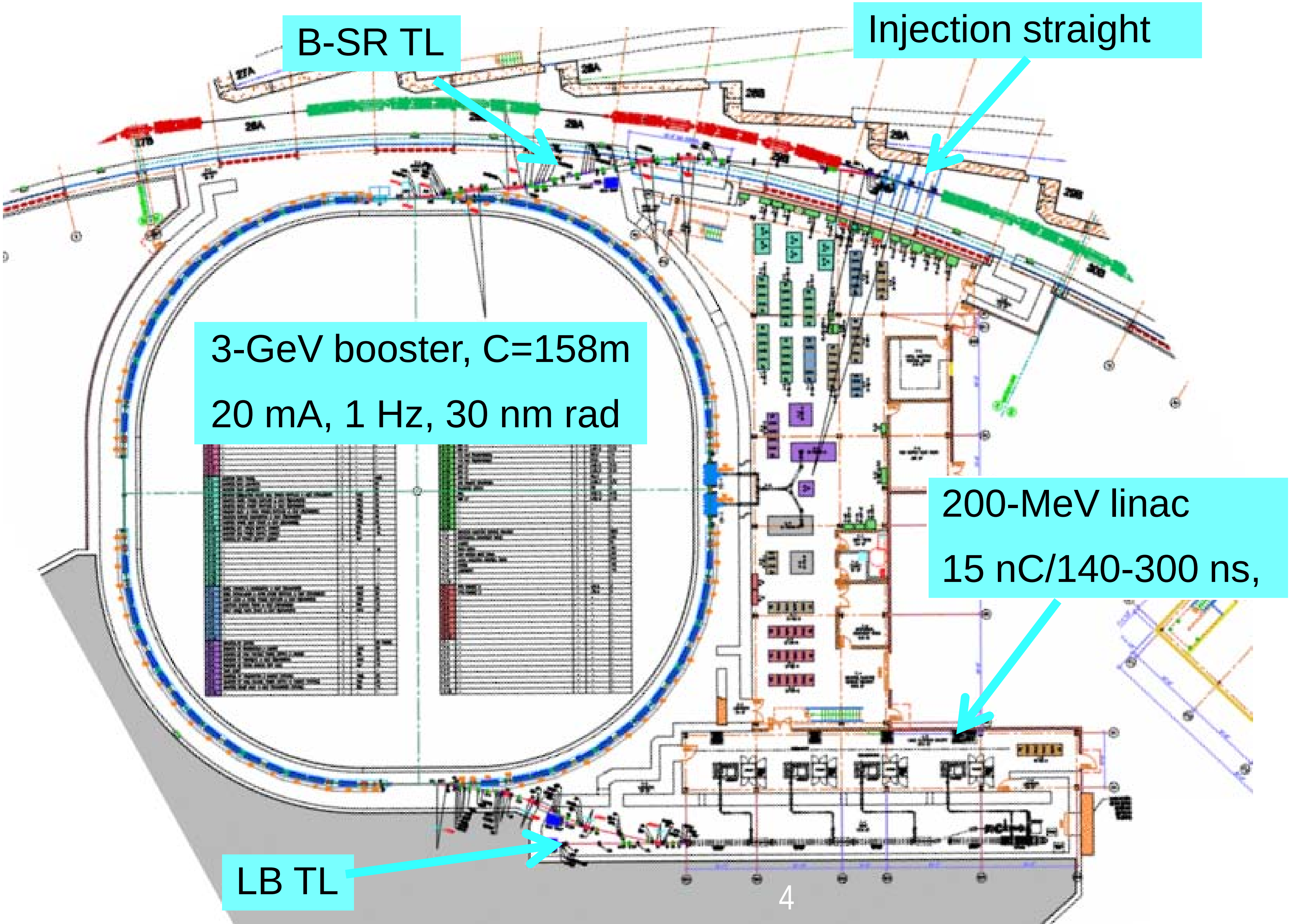
- 3GeV; 790m Cir.
- 500 mA;Top-up

- Construction started - 4/2009
- Injector commissioning – 2012/2013
- SR commissioning – 2013/2014

Light Source – I

- In operation > 25 years
- Nsls Beamlines to transfer to nsls-2

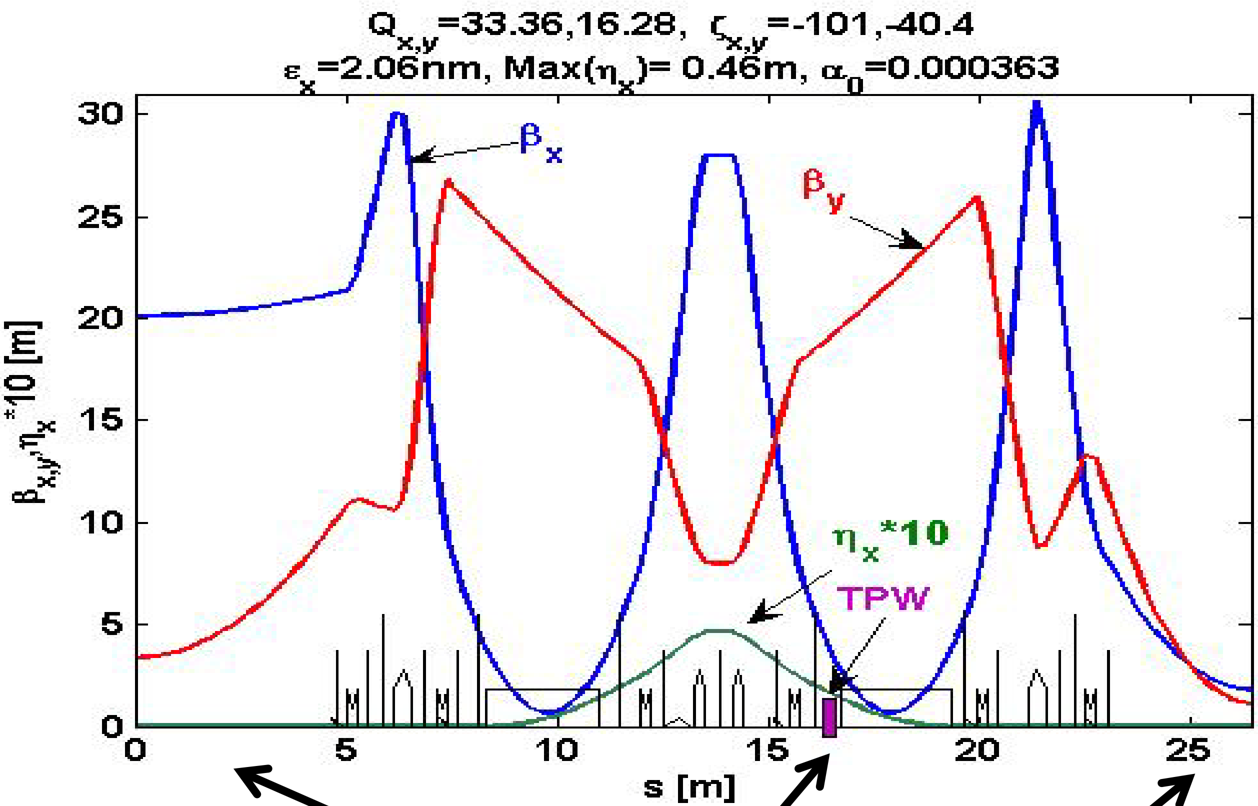
NSLS-II Injector Complex Overview



SR Lattice & Electron Beam sizes/divergences

Lattice

Functions



Electron Beam Sizes

& Divergences

Types of source	8.6m 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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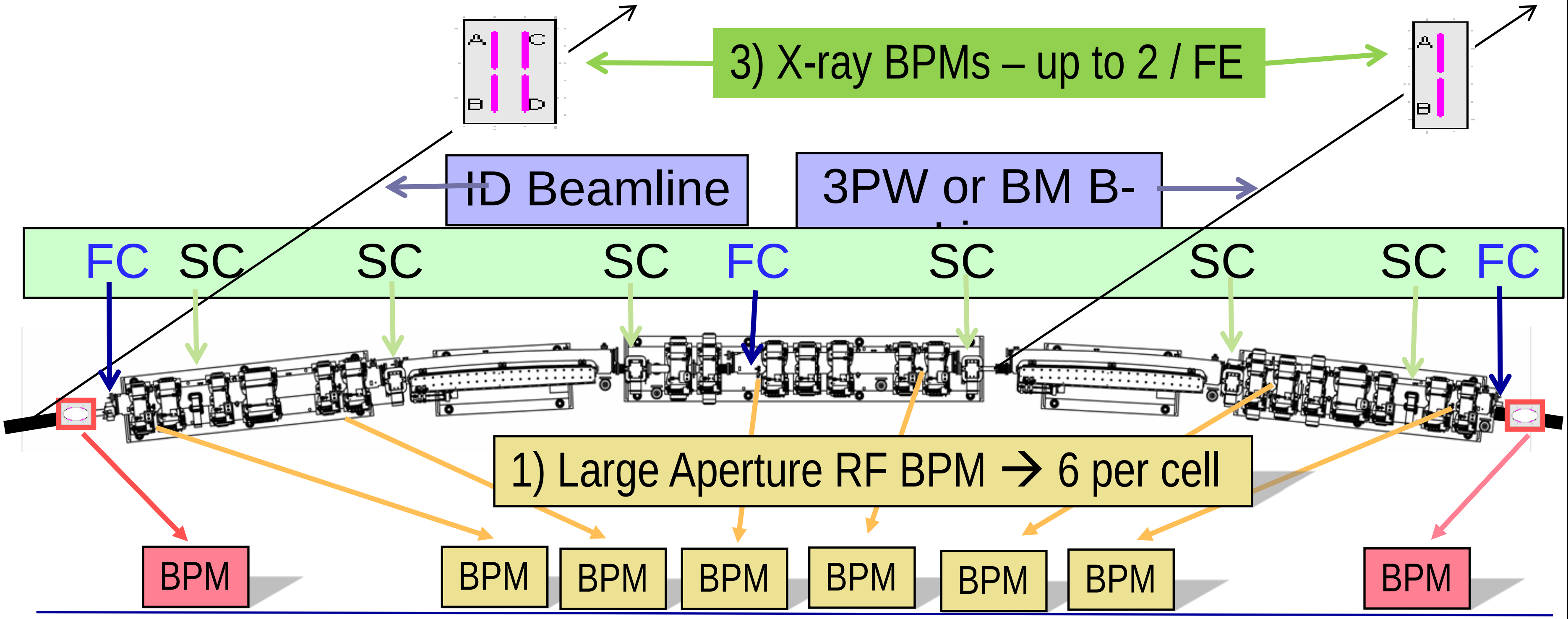
SR Diagnostics

Monitor	Qty	Comment
RF BPM – TBT & Stored Beam	180	Itech – Brilliance
ID RF BPM	2 or 3 per ID	Itech - Brilliance
Photon BPMs (BM/ ID)	2 per BL	Workshop at NSLS-II
DC Current Transformer	1	Test @ SPEAR3
Tune Monitor	1	
Fill Pattern Monitor	1	WCM or Stripline
Fluorescent Screen	1 (3 position)	Injection straight
X-ray Radiation BL (BM/ 3PW)	2	Pin-hole simluations
Visible Radiation BL (BM)	1	
Transverse Feedback Systems	1 H & 1 V	Inst. Tech; Dimtel Inc.
Beam Loss Monitors	60	
Beam Scrapers (X & Y)	2 sets	
Bunch cleaner/bunch purity	1	Not in baseline

SR Cell BPM/Corrector Layout

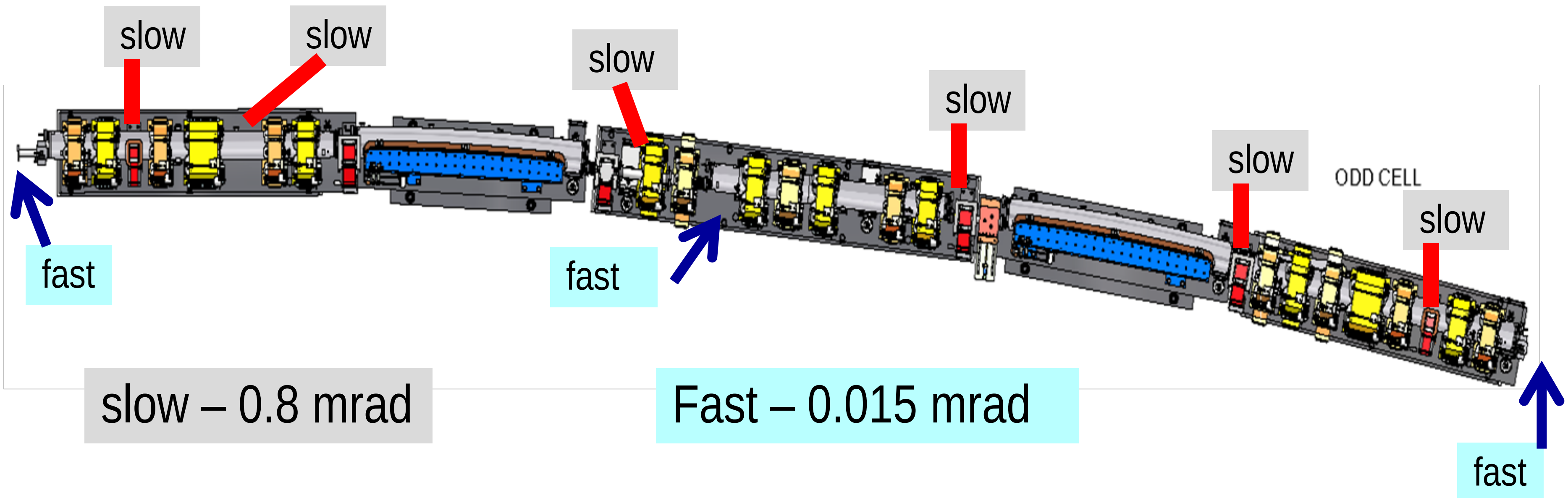


2) Small Aperture RF BPMs → 2 or 3 per Cell; Button Assembly on a Stand or ID Chamber

4) a-**Six slow correctors (SC)– 0.8 mrad;**

b-Three fast correctors (FC)– 0.015 mrad

Close Orbit Correction Strategy



- Include all available BPMs
- Slow correctors for close orbit correction (alignment)
- Fast correctors for fast orbit feedback
- Requires synchronous transfer at some interval of DC part from fast corrector to slow corrector - avoids saturation of fast corrector

RF BPM – R&D and Design

Key areas in RFBPM performance

1. RF Button Geometry
2. RF Button Mechanical Mounting Stability
3. Vacuum Chamber Microwave Modes
4. RF BPM Electronics

RF BPM System Baseline Requirement

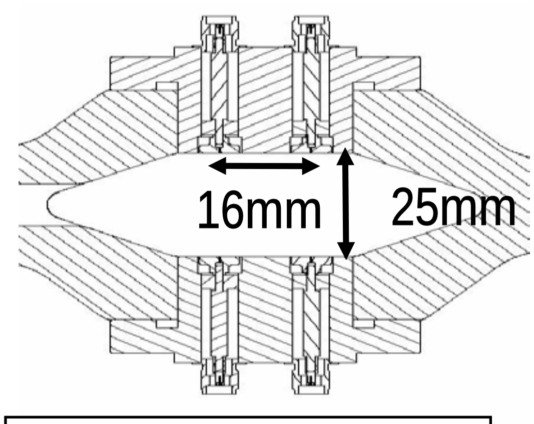
1. Diagnostics & position data (BPM Electronics)
   - Raw digitizer Data ~ 117 MHz
   - Turn by Turn ~ 400 kHz
   - Fast Orbit Feedback ~ 10 kHz
   - Slow Orbit ~ 10 Hz
   - Interlock data
2. Perform beam-based alignment
3. Calculate machine parameters during beam studies
   - β function, betatron phase advance
   - Dispersion, chromaticities, coupling

(On line calculation during operational beam highly desirable, but not in baseline – requirement being evaluated)

RF BPM Hardware and Electronics

Large Aperture

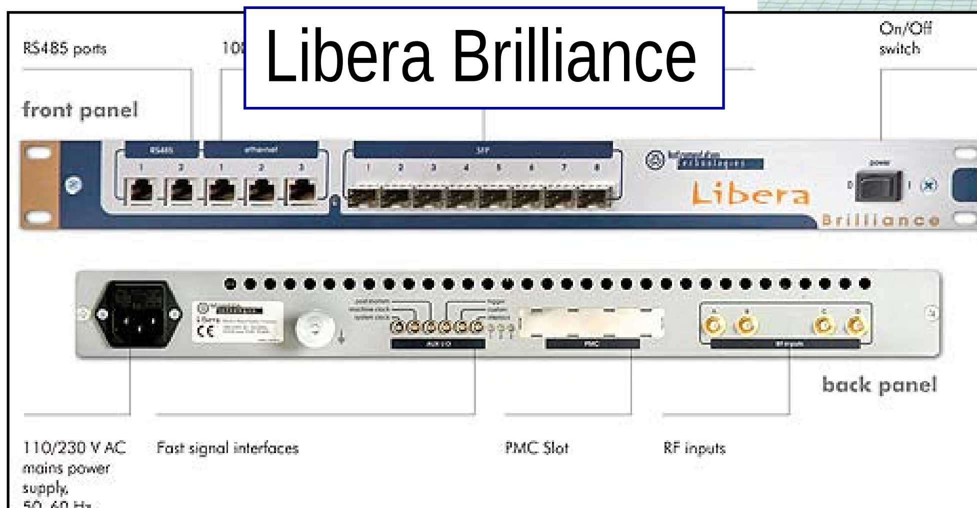
Small Aperture



Multipole Chamber

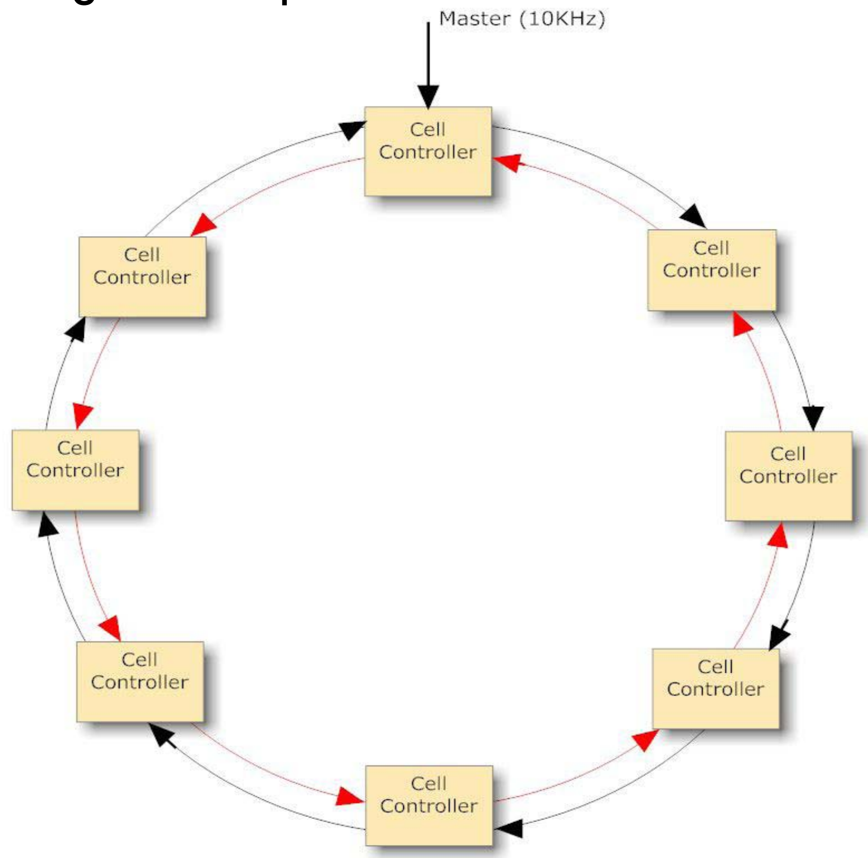
Shipped June 19, 2009

Libera Brilliance



Fast Orbit Feedback

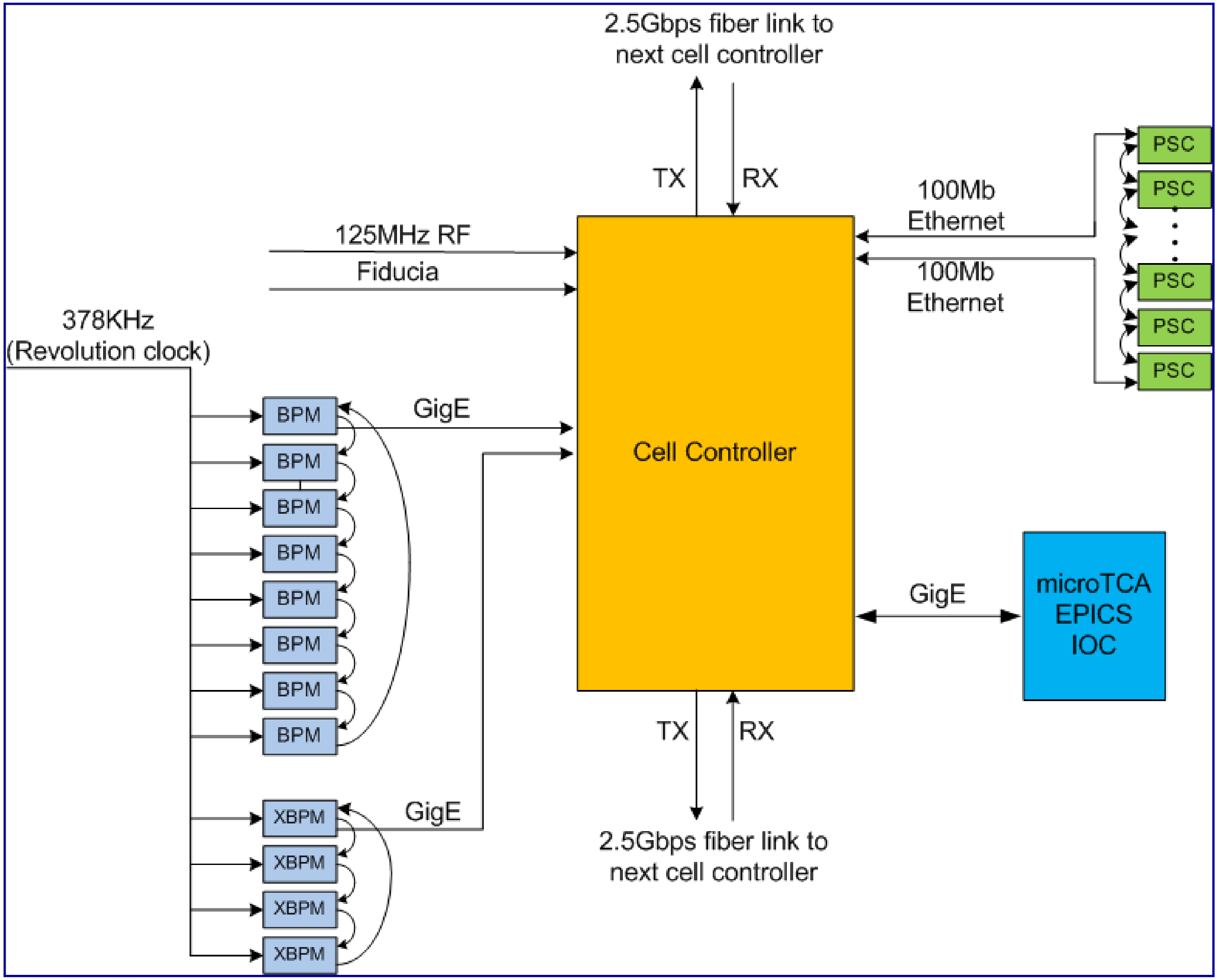
- Need to Circulates > 240 BPM data to all 30 cells at 10 kHz rate
  - ✓ Develop fast synchronous communication (FPGA based)
  - ✓ Architecture - synchronous, deterministic, fault tolerance
  - ✓ Provide BPM data to feedback / diagnostics processor



Collaboration –

L. Dolittle - LBL
Y. Tian – BNL NSLSII
J. Mead – BNL Instrumentation

FOFB Data Communication



Y. Tian

Brilliance Test at CESR Cornell (Multi-bunch)

RF frequency = 499.68 MHz;
Harmonic number = 1281
Minimum bunch separation = 14 ns

Setup –
-One button signal split to 4
- inserted attenuator for ~ 1mm Y offset

Bunch fill pattern	Total current, (mA)	Each bunch current (mA)	X, μ	Y, μ
45	35.9	~0.8	37.8	1120.5
9×5	44.3	~1.0	37.9	1120.5
9	44.0	~5.0	37.9	1117.8

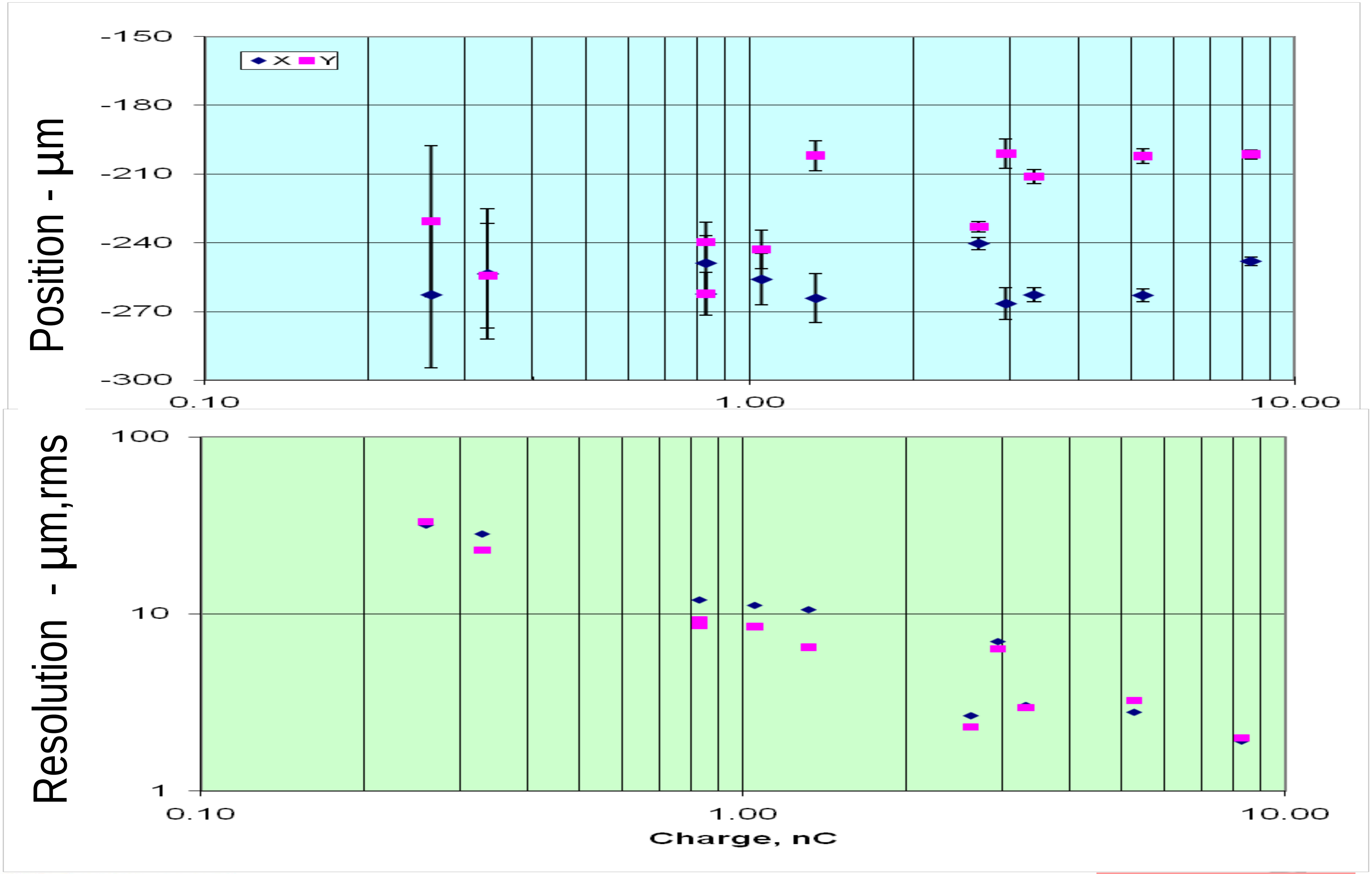
Conclusions

– Fill pattern dependence < 100 nm

- Intensity dependence < 3 micron with 5 fold change

I. Pinayev

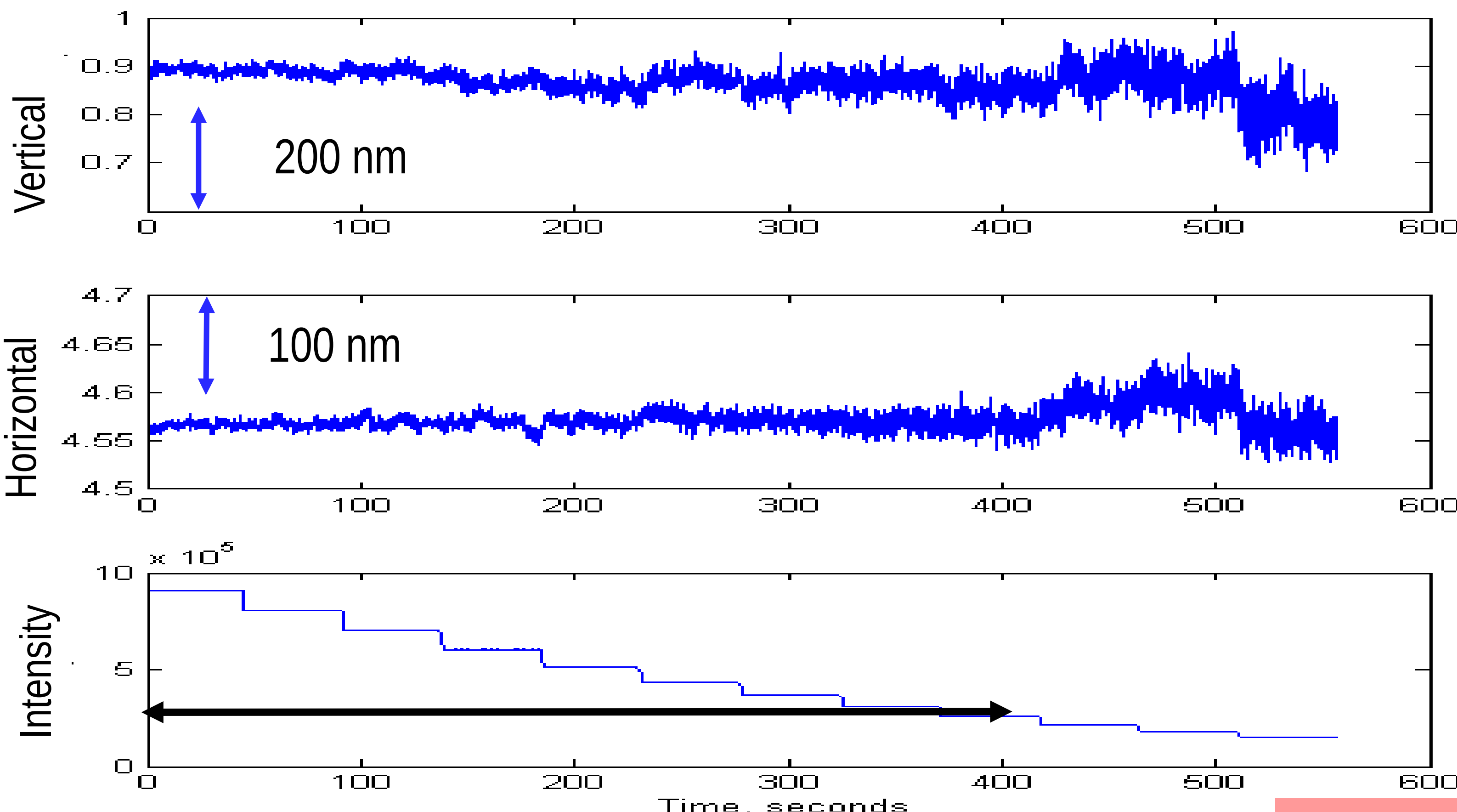
Brilliance Test at CESR Cornell (Single bunch)



I. Pinayev

Brilliance Test at APS ANL – Intensity Dependence

With intensity changes from 9 a.u. to 3 a.u
1) DC Offset < 100 nm; 2) AC Noise 10nm → 20nm (10 Hz BW)



G. Decker, APS

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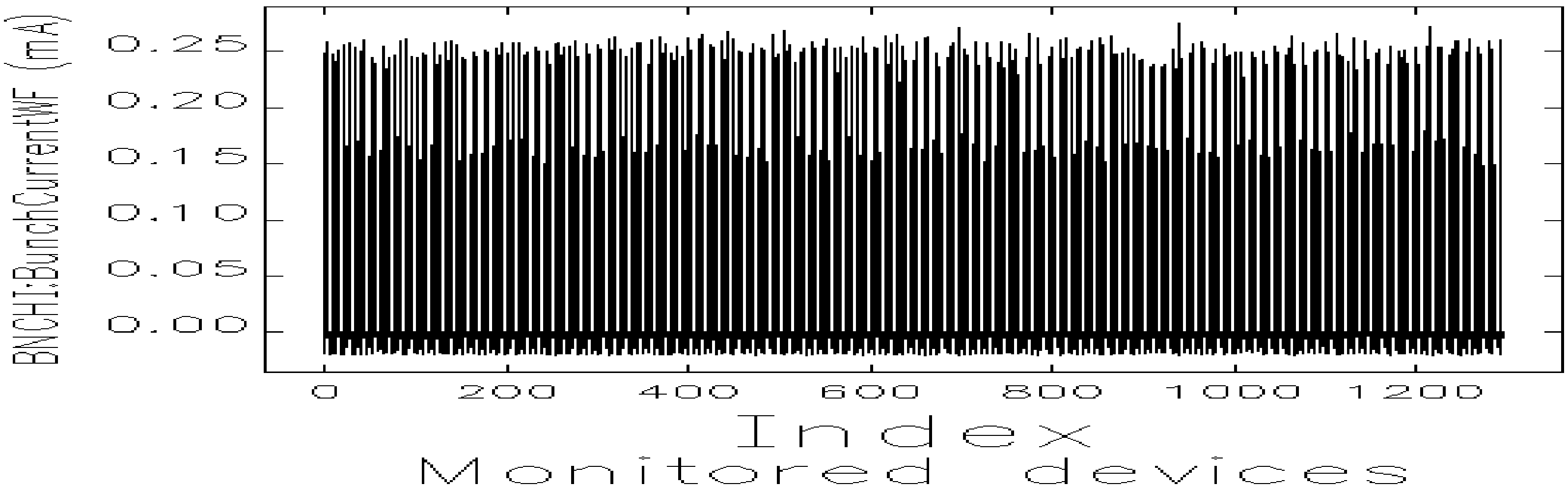
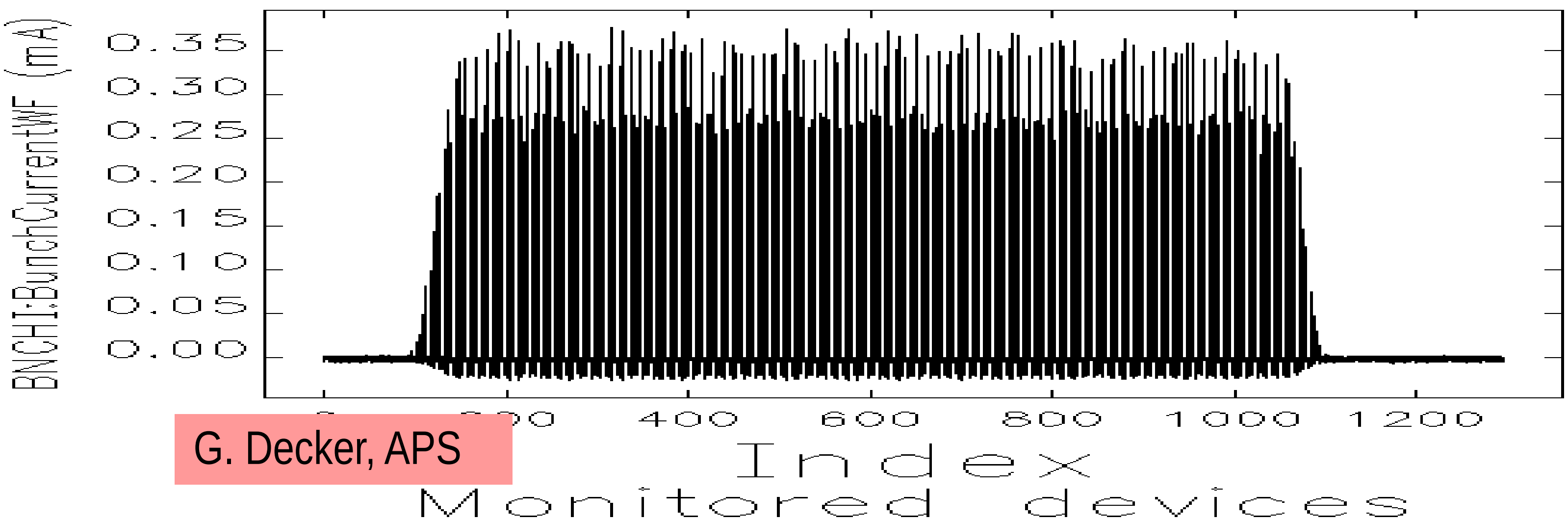
Brilliance Test at APS ANL – Bunch Fill Dependence

With fill pattern change from 100% to ~ 80 % - DC Offset < 100 nm





G. Decker, APS

Summary

1. Made good progress on RF BPM infrastructure
2. Closed orbit strategy is well defined for both alignment as well as fast correction
3. RF BPM Electronics

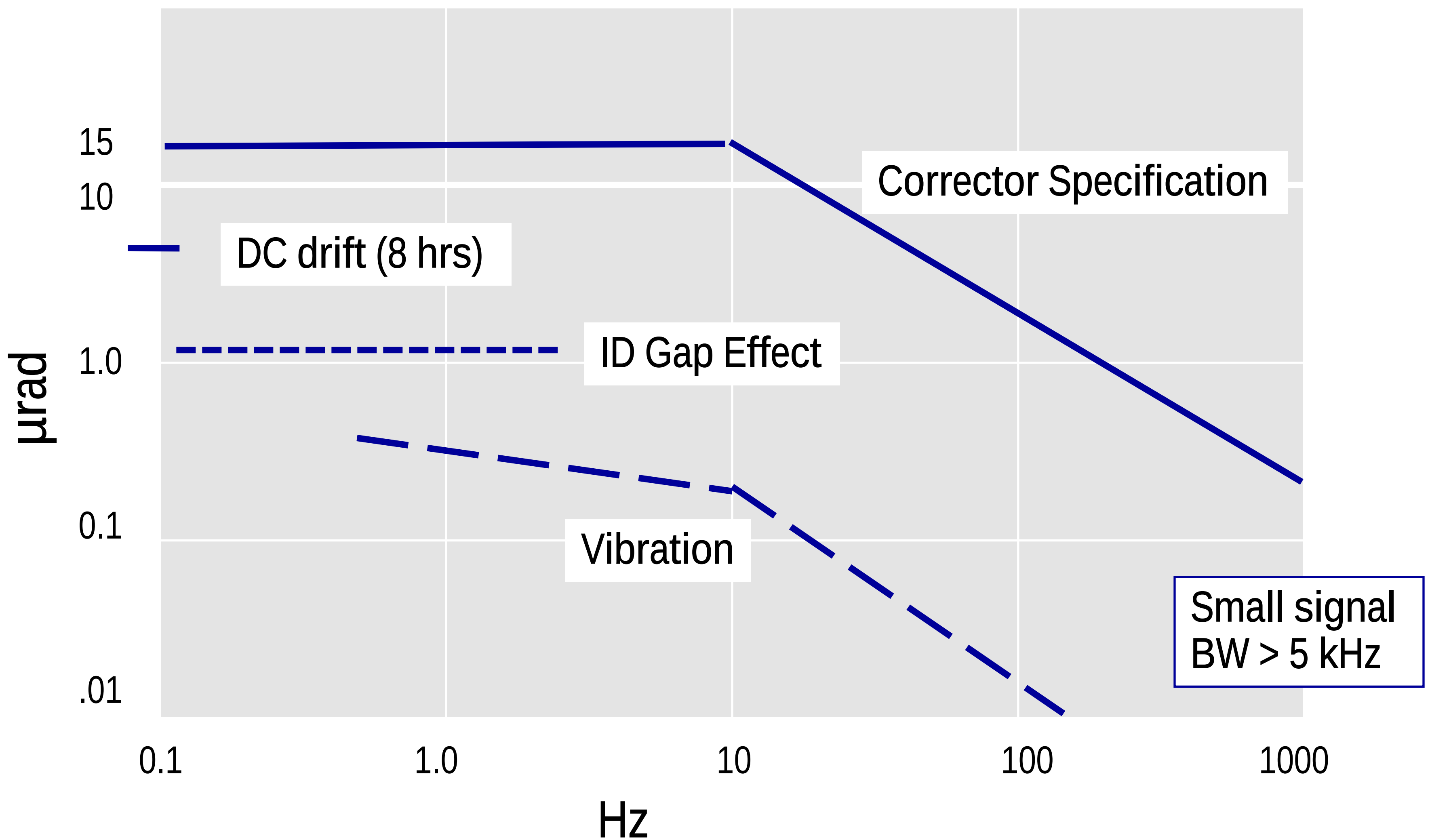
   - Libera Brilliance meets or exceeds NSLS-II baseline measurement resolution and stability requirement.
   - Issues with Libera Brilliance currently under evaluation
     - Use of Virtex-2 FPGA technology – not current
     - Limited FPGA capacity to add on future applications

Acknowledgment

R. Alforque, B. Bacha, A. Blednykh, P. Cameron, W. Cheng, L.B. Dalesio, A.J. Della Penna, L. Doom, R. P. Fliller, G. Ganetis, R. Heese, H-C Hseuh, E.D. Johnson, B.N. Kosciuk, S.L. Kramer, S. Krinsky, J. Mead, S. Ozaki, D. Padrazo, I. Pinayev, V. Ravindranath, J. Rose, T. Shaftan, S. Sharma, J. Skaritka, T. Tanabe, Y. Tian, F.J. Willeke, L-H Yu

Backup Slides

Fast Corrector Requirement vs Noise Sources



RF BPM System – Performance Requirements - I

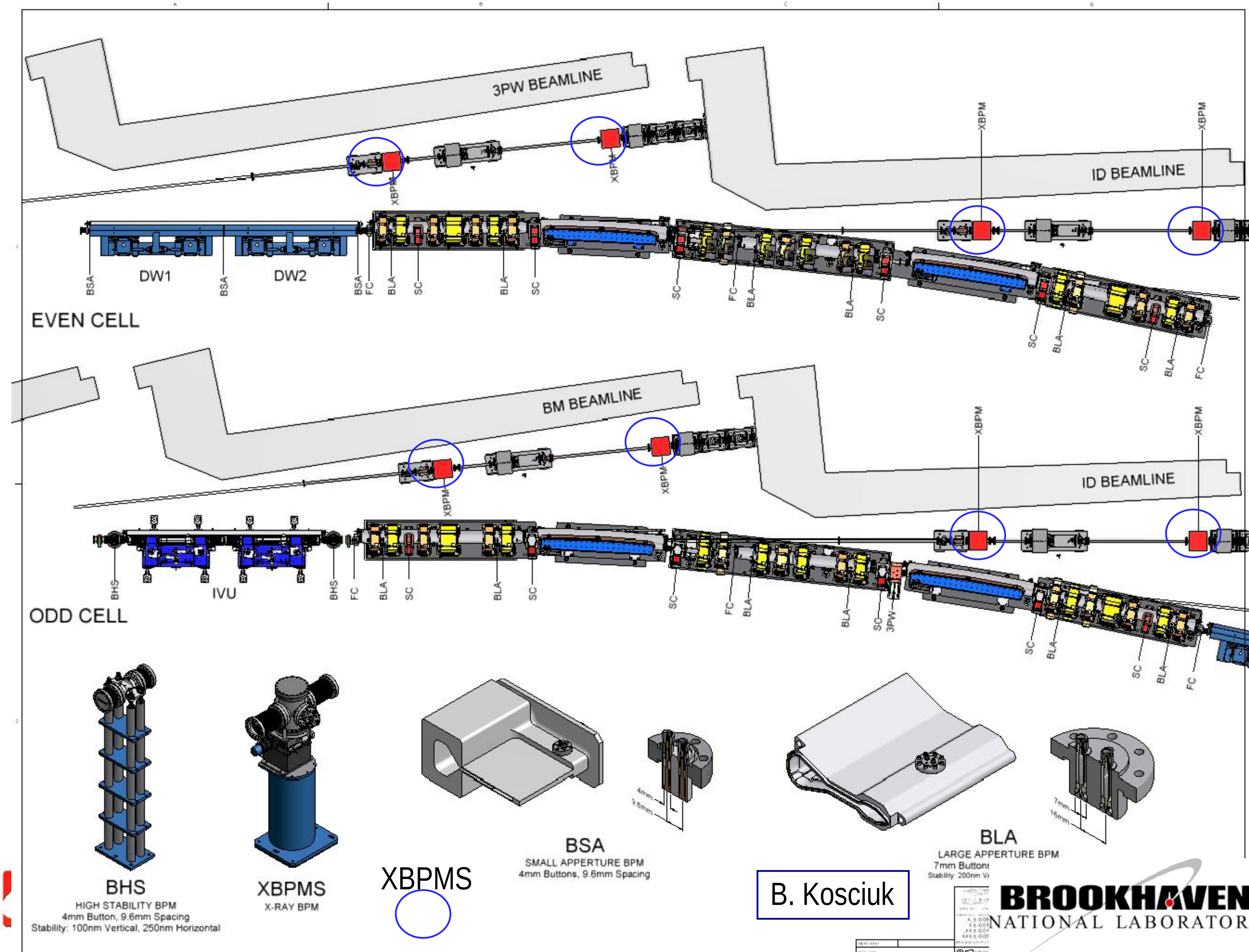
Parameters/ Subsystems	Conditions	*Large Aperture RF BPM Resolution Requirement	
		Vertical	Horizontal
Single bunch, Single turn resolution (@ 378 kHz)	0.05 nC charge	500 µm rms	500 µm rms
	5.0 nC charge	20 µm rms	20 µm rms
Single bunch stored beam resolution (0.017-200 Hz BW)	0.02 mA current	10 µm rms	10 µm rms
	2.0 mA current	1 µm rms	1 µm rms

*Small aperture RF BPM requirements specified to be better by a factor of 2

RF BPM System – Performance Requirements - 2

<table>
<tr><th colspan="4" rowspan="2">Parameters/ Subsystems</th><th rowspan="2">Conditions</th><th colspan="2">*Large Aperture RF BPM Resolution Requirement</th></tr>
<tr><th>Vertical</th><th>Horizontal</th></tr>
<tr><td rowspan="8">50 mA to 500 mA Stored beam resolution – 20% to 100 % duty cycle</td><td rowspan="4">BPM Receiver Electronics</td><td colspan="2" rowspan="3">Assuming no contribution from bunch/ fill pattern effects</td><td>0.017 Hz to 200 Hz</td><td>0.2 µm rms</td><td>0.3 µm rms</td></tr>
<tr><td>200 Hz to 2000 Hz</td><td>0.4 µm rms</td><td>0.6 µm rms</td></tr>
<tr><td>1 min to 8 hr drift</td><td>0.2 µm peak</td><td>0.5 µm peak</td></tr>
<tr><td colspan="2">Bunch charge/ fill pattern effects only</td><td>DC to 2000 Hz</td><td>0.2 µm rms</td><td>0.3 µm rms</td></tr>
<tr><td colspan="2" rowspan="4">Mechanical motion limit at Pick-up electrodes assembly (ground & support combined)</td><td rowspan="3">Vibrations</td><td>50 Hz to 2000 Hz</td><td>10 nm rms</td><td>10 nm rms</td></tr>
<tr><td>4 Hz to 50 Hz</td><td>25 nm rms</td><td>25 nm rms</td></tr>
<tr><td>0.5 Hz to 4 Hz</td><td>200 nm rms</td><td>200 nm rms</td></tr>
<tr><td>Thermal</td><td>1 min to 8 hr</td><td>200 nm peak</td><td>500 nm peak</td></tr>
</table>

*Small aperture RF BPM requirements specified to be better by a factor of 2



XBPMS

B. Kosciuk

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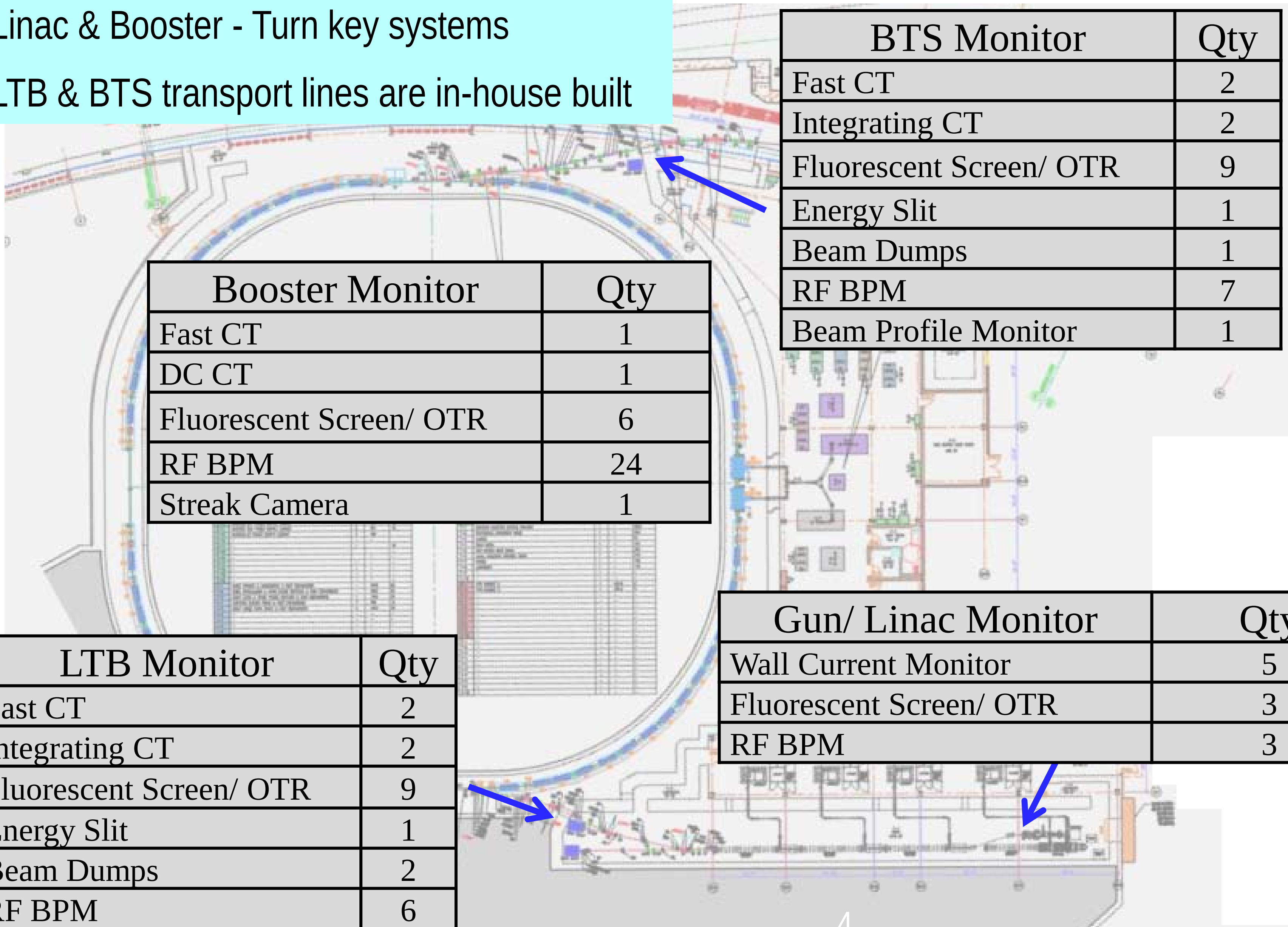
NSLS-II Injector - Overview

- Linac & Booster - Turn key systems
- LTB & BTS transport lines are in-house built



BTS Monitor	Qty
Fast CT	2
Integrating CT	2
Fluorescent Screen/ OTR	9
Energy Slit	1
Beam Dumps	1
RF BPM	7
Beam Profile Monitor	1

Booster Monitor	Qty
Fast CT	1
DC CT	1
Fluorescent Screen/ OTR	6
RF BPM	24
Streak Camera	1

Gun/ Linac Monitor	Qty
Wall Current Monitor	5
Fluorescent Screen/ OTR	3
RF BPM	3

LTB Monitor	Qty
Fast CT	2
Integrating CT	2
Fluorescent Screen/ OTR	9
Energy Slit	1
Beam Dumps	2
RF BPM	6

Slow / Fast Corrector Power Supply Requirement

New configuration – FOF feedback consists of dedicated fast corrector system. This results in an economical power supply design for fast corrector.

Corrector type	Full Scale strength	DC Stability	AC Noise	DAC Resolution	Small Signal BW
Alignment	800 µrad	20nrad	1.6 nrad	3nrad	100 Hz
		25ppm	1.9ppm	3.8ppm	
Fast	15 µrad	1.5 nrad	<<1.6nrad	0.22nrad	>5 kHz
		100ppm	1.9ppm	15ppm	

G. Ganetis, L-H Yu