Accelerator Physics Challenges for NSLS-II

Samuel Krinsky for NSLS-II Staff
PAC09, Vancouver, Canada
May 4-8, 2009

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

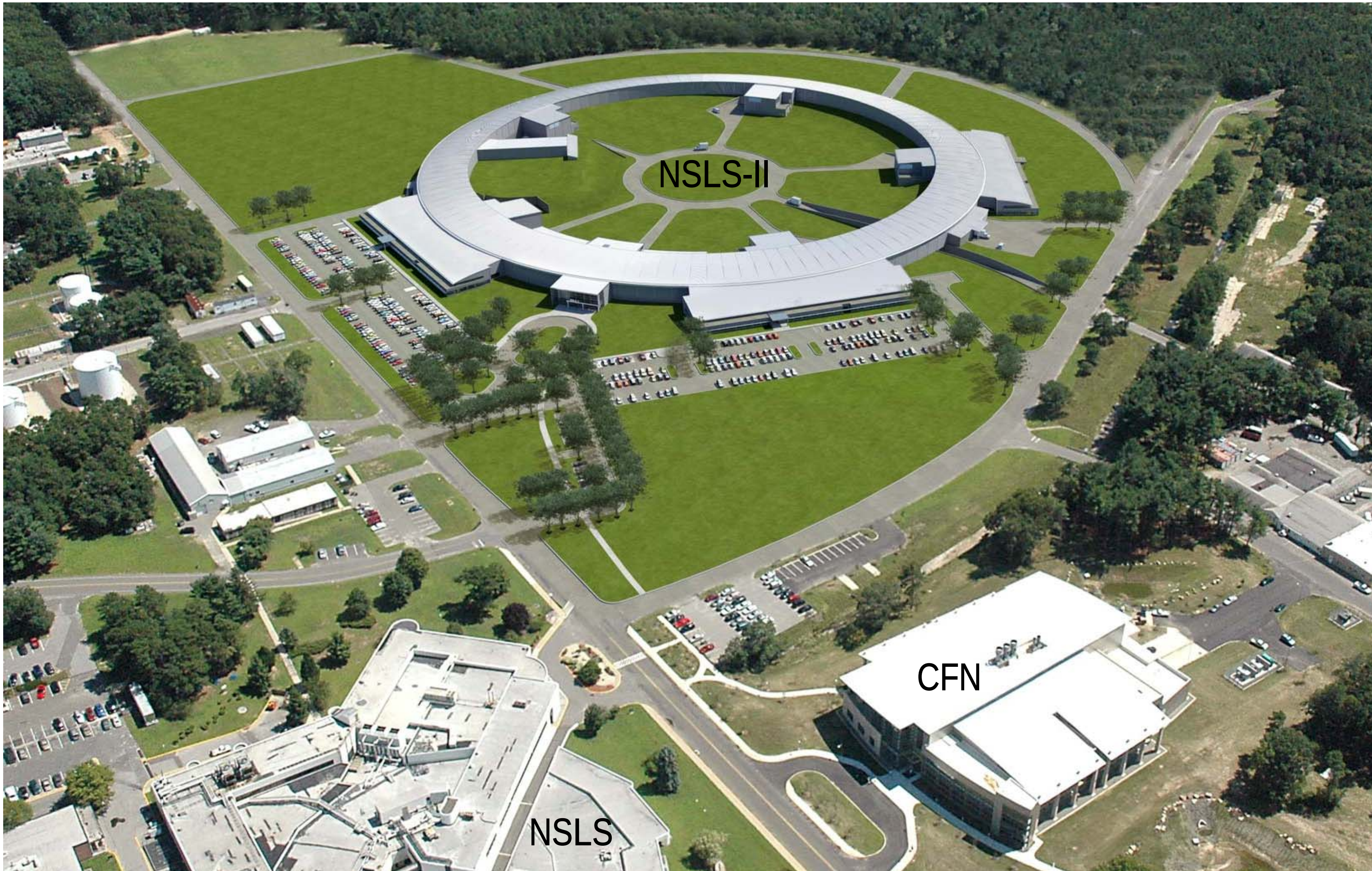
NSLS-II Accelerator Physics

J. Bengtsson, A. Blednykh, W. Cheng, R. Fliller, W. Guo, R. Heese,

S. Kramer, Y. Li, B. Nash, I. Pinayev, T. Shaftan, G. Wang, L.H. Yu

F. Willeke, S. Ozaki

Aerial View



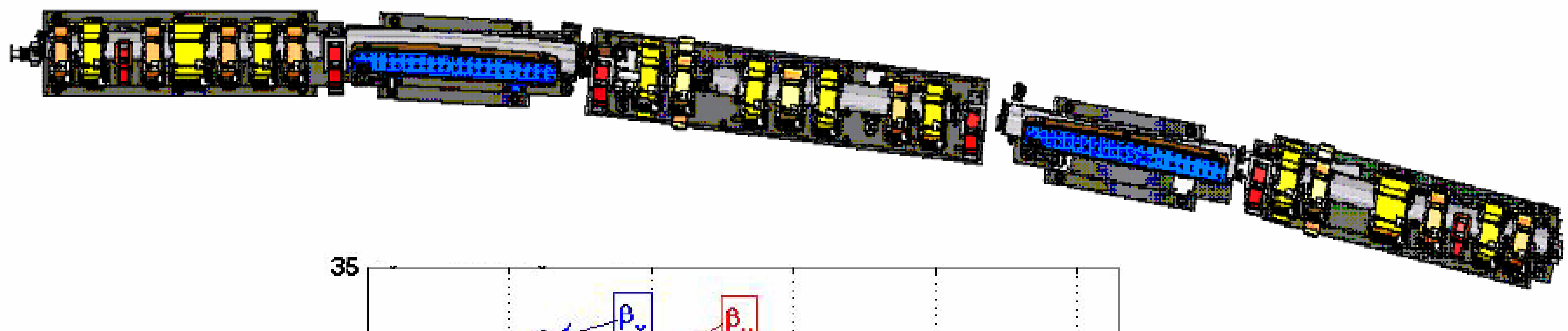
Some Basic NSLS-II Project Goals

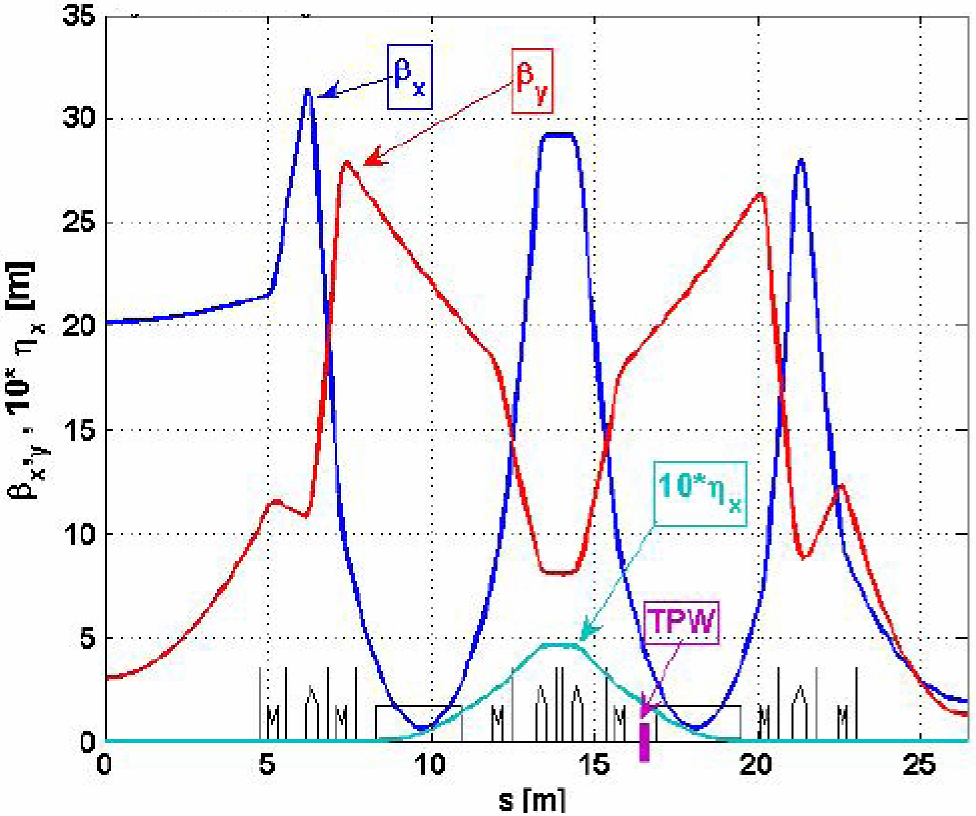
Beam Property	Goal
Horizontal emittance (nm-rad)	<1
Vertical emittance (nm-rad)	0.010
Average current (mA)	500
Straights for insertion devices	27
Orbit stability (% of beam size)	10
Touschek lifetime (hrs)	>3
Top-off injection frequency (/min)	<1

NSLS-II: Basic Parameters

Energy	3.0 GeV	Energy Spread	0.094%
Circumference	792 m	RF Frequency	~500 MHz
Number of Cells	30 DBA	Harmonic Number	1320
Length ID Straights	6.6 & 9.3m	RF Bucket Height	>2.5%
Emittance (h,v)	<1nm, 10pm	RMS Bunch Length	15ps-30ps
Momentum Compaction	.00037	Average Current	500ma
Dipole Bend Radius	25m	Current per Bunch	0.5ma
Energy Loss per Turn	<2MeV	Charge per Bunch	1.2nC
		Touschek Lifetime	>3hrs

Lattice Functions for One Cell





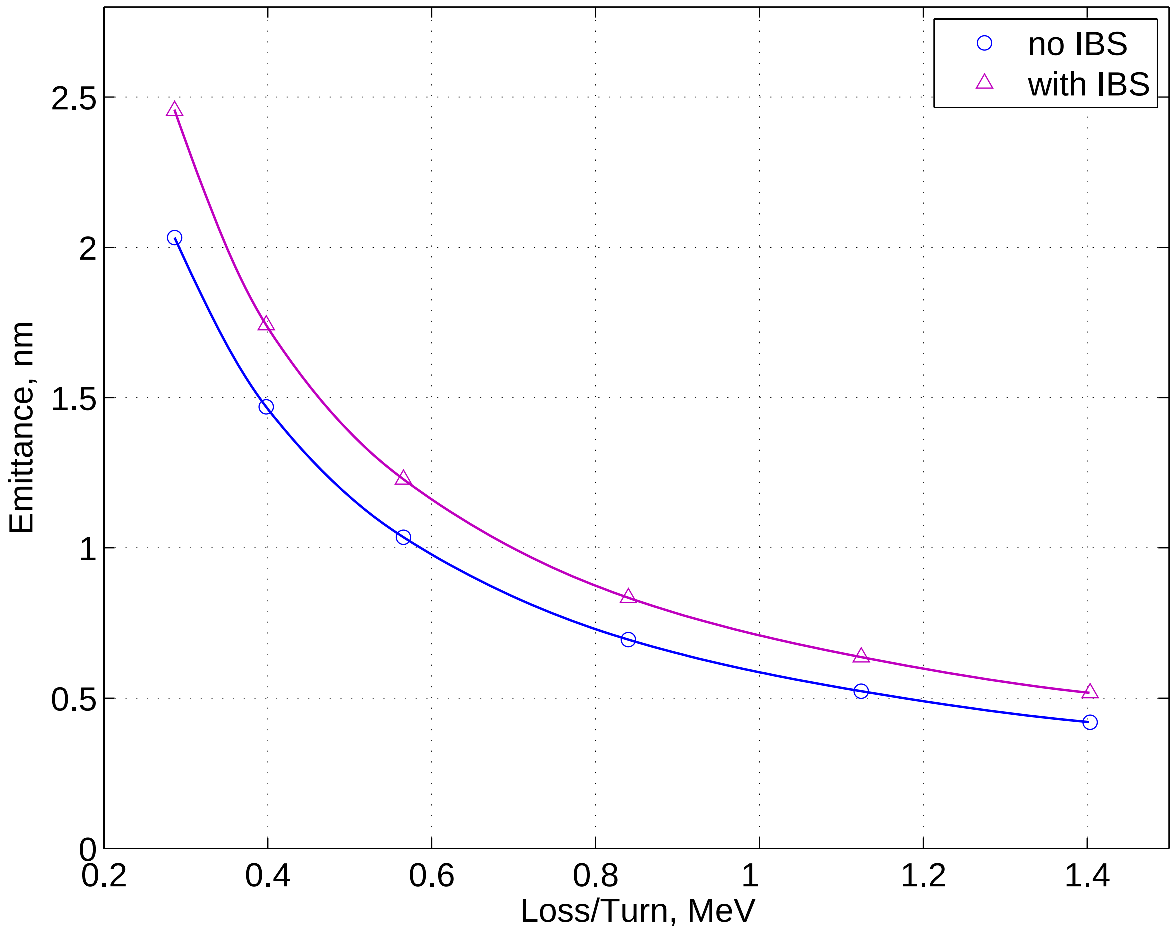
S. Kramer

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Reduction of Emittance with Damping Wigglers

Intra-Beam Scattering has Small Effect



B. Podobedov

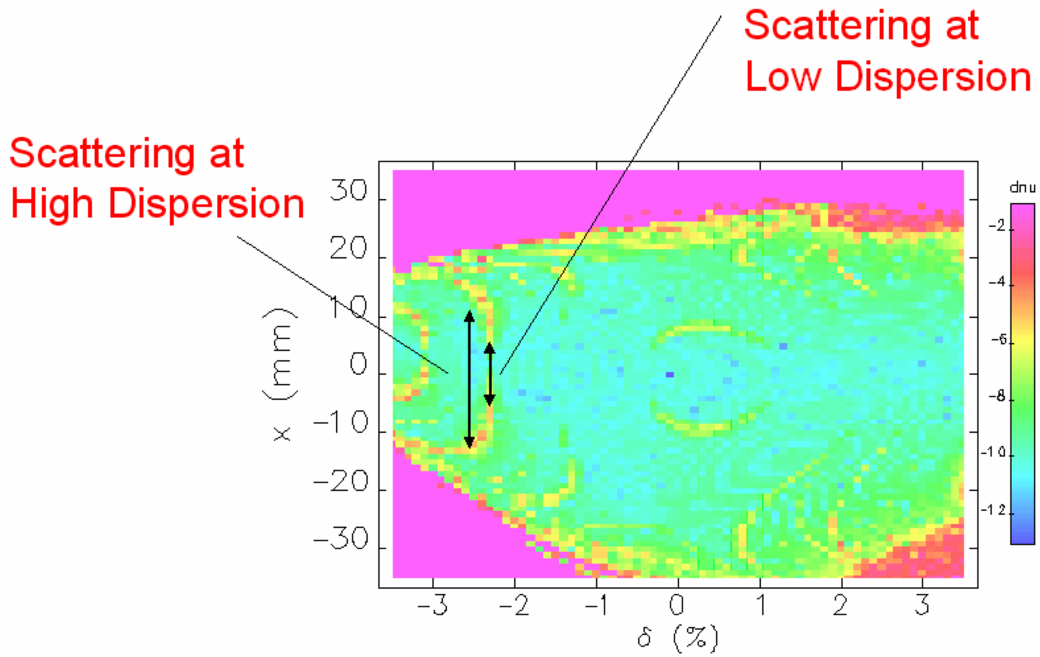
Key Project Milestones

Aug 2005	CD-0, Approve Mission Need	(Complete)
Jul 2007	CD-1, Approve Alternative Selection and Cost Range	(Complete)
Jan 2008	CD-2, Approve Performance Baseline	(Complete)
Jan 2009	CD-3, Approve Start of Construction	(Complete)
Feb 2009	Contract Award for Ring Building	(Complete)
Aug 2009	Contract Award for Storage Ring Magnets	
Mar 2010	Contract Award for Booster System	
Feb 2011	1st Pentant Ring Building Beneficial Occupancy; Begin Accelerator Installation	
Feb 2012	Beneficial Occupancy of Experimental Floor	
Oct 2013	Start Accelerator Commissioning	
Jun 2014	Early Project Completion; Ring Available to Beamlines	
Jun 2015	CD-4, Approve Start of Operations	

Touschek Scattering

Energy acceptance is smaller if electron is scattered at high dispersion

Scattering rate is smaller for high dispersion, since bunch volume bigger



Touschek Lifetime

σ_s=15ps w/o Landau Cavity

δ_{acc} Small η	δ_{acc} Large η	Lifetime (hrs)
3%	2.5%	5.5
2.5%	2.5%	3.3
2.5%	2.0%	2.9
2.5%	1.5%	2.3

B. Nash, TH6PFP064

Sources of Systematic and Random Multipole Errors

- For ideal, symmetric magnets, higher order multipoles consistent with symmetry ("allowed multipoles"): N(2m+1), m=0,1,2,…

  dipole: 1,3,5,7, …

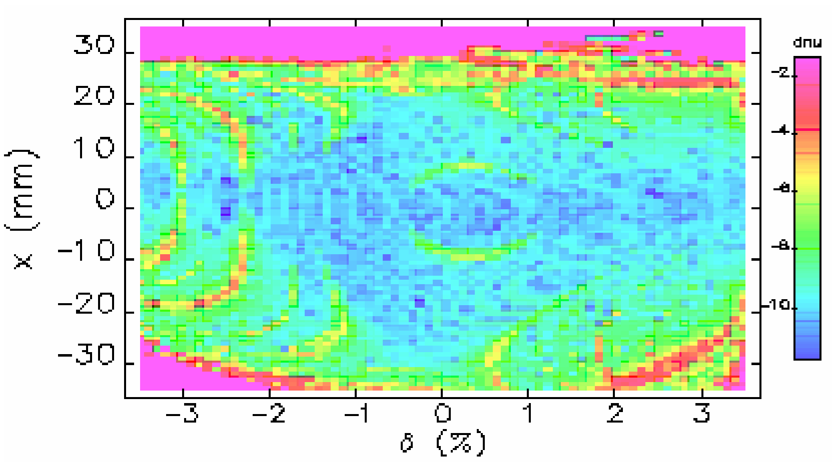
  quadrupole: 2, 6, 10, 14, …

  sextupole: 3, 9, 15, 21, …

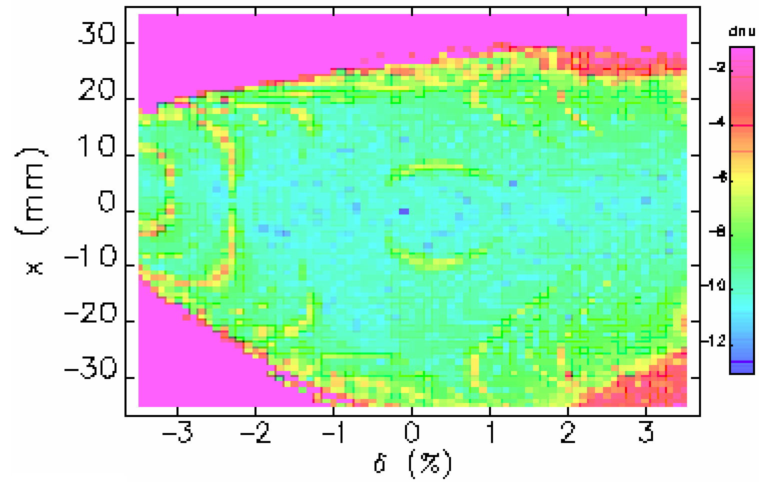
- Random Errors from manufacturing tolerances

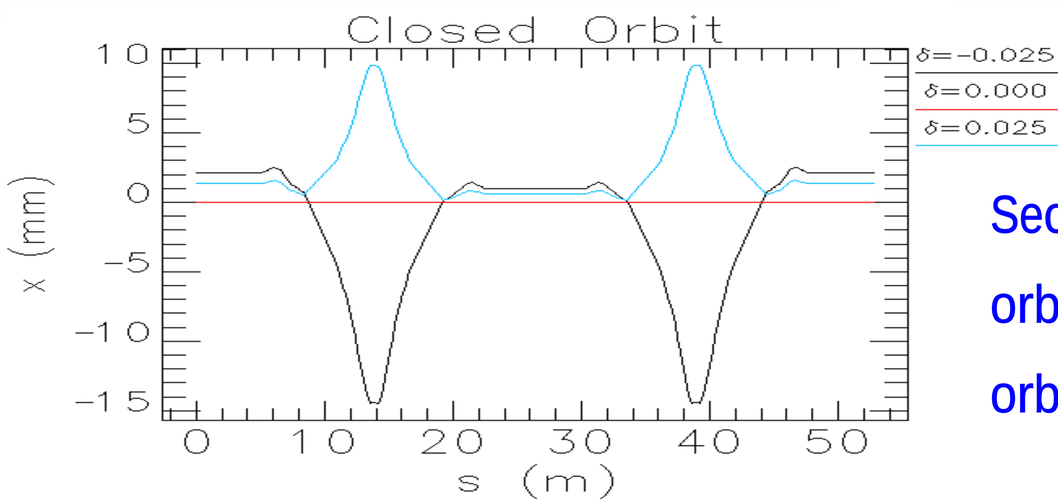
Systematic multipole errors reduce dynamic aperture for negative momentum deviation

No Multipole Errors



With Multipole Errors





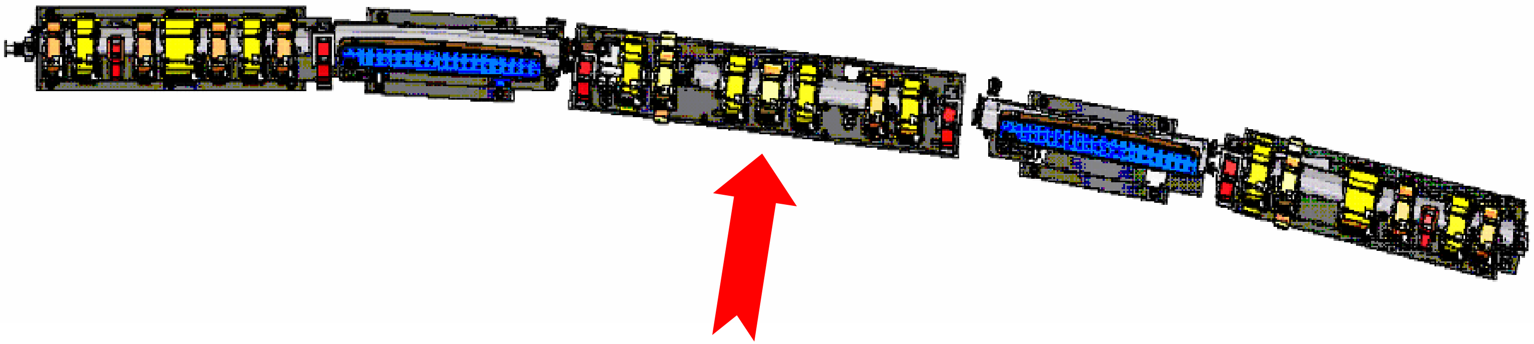
Second-order dispersion increases orbit deviation for **δ**<0 and decreases orbit deviation for **δ**>0

B. Nash, TH6PFP065

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

For the quadrupoles and sextupoles at highest dispersion, we have increased magnet aperture to reduce higher-order multipole components



x 10^4	NSLS-II regular	NSLS-II Large Aperture	SOLEIL	CELLS	SLS
B_2^6	1	1	1	2	1.1
B_2^{10}	3.3	0.5	0.2	4	-2.5
B_2^{14}	3.5	0.1	0.1		
B_3^9	1	0.5	-1	5	-2
B_3^{15}	1	0.5	-0.5	7	6.9
B_3^{21}	4	0.5			

Ratio (x10^4) of multipole field to design quadrupole or sextupole field at reference radius: R = 25 mm

Local Compensation of Damping Wigglers

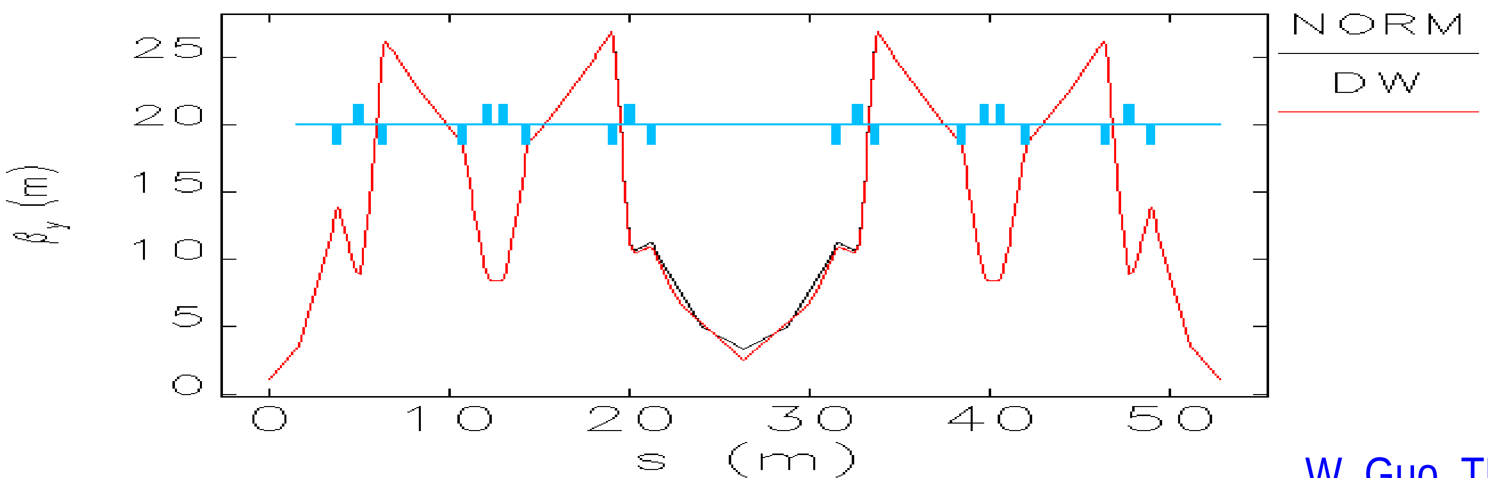
Damping wigglers: length=7m, magnetic field=1.8T

Perturbation on linear optics is important to control.

Quadrupole triplets bounding long straight are used to satisfy:

α_x =0, α_y =0, $\Delta\mu_x$ =0 (at insertion center)

Resulting perturbation of betay is small



W. Guo, TU5RFP008

Office of Science
U.S. DEPARTMENT OF ENERGY

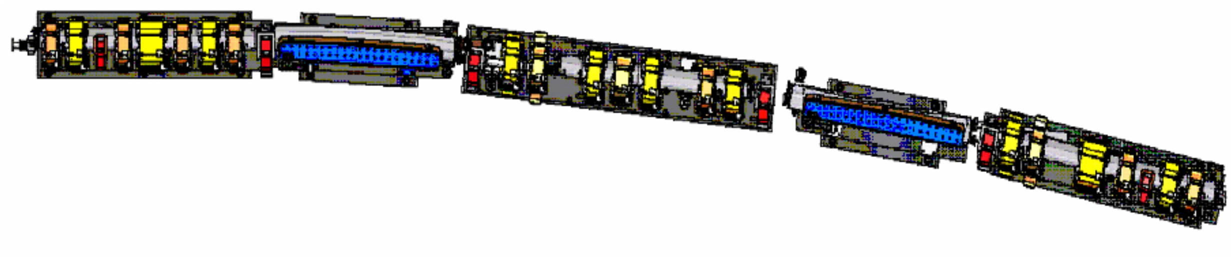
BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

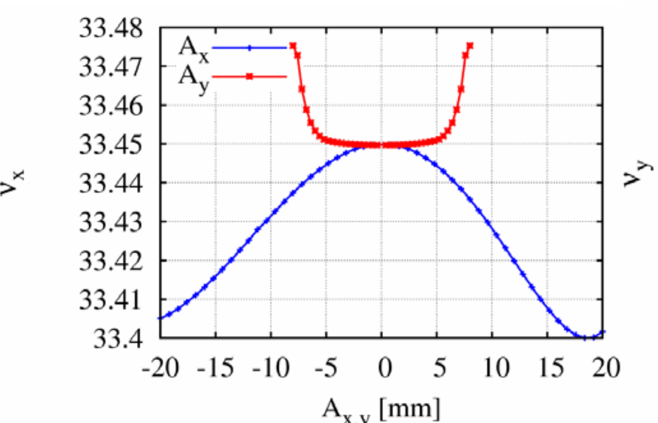
Introduction of Third Chromatic Sextupole Knob

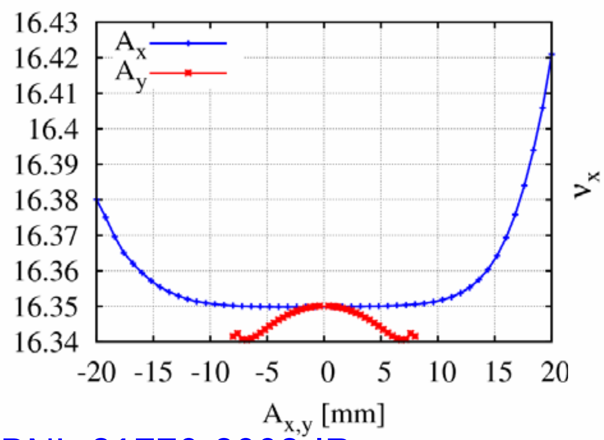
Allows reduction of second order horizontal chromaticity while maintaining flexibility in Geometric sextupoles to correct the tune-shift with amplitude.

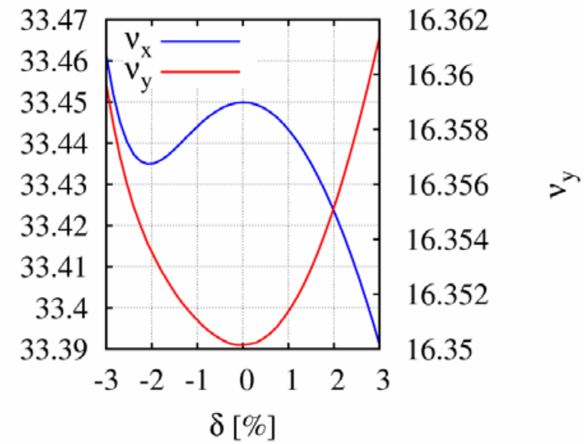
Two approaches: (1) add additional sextupole in dispersive region

(2) move one of the defocusing chromatic sextupoles toward max dispersion









J. Bengtsson, BNL-81770-2008-IR

W. Guo, TU5RFP008

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Stability Requirements

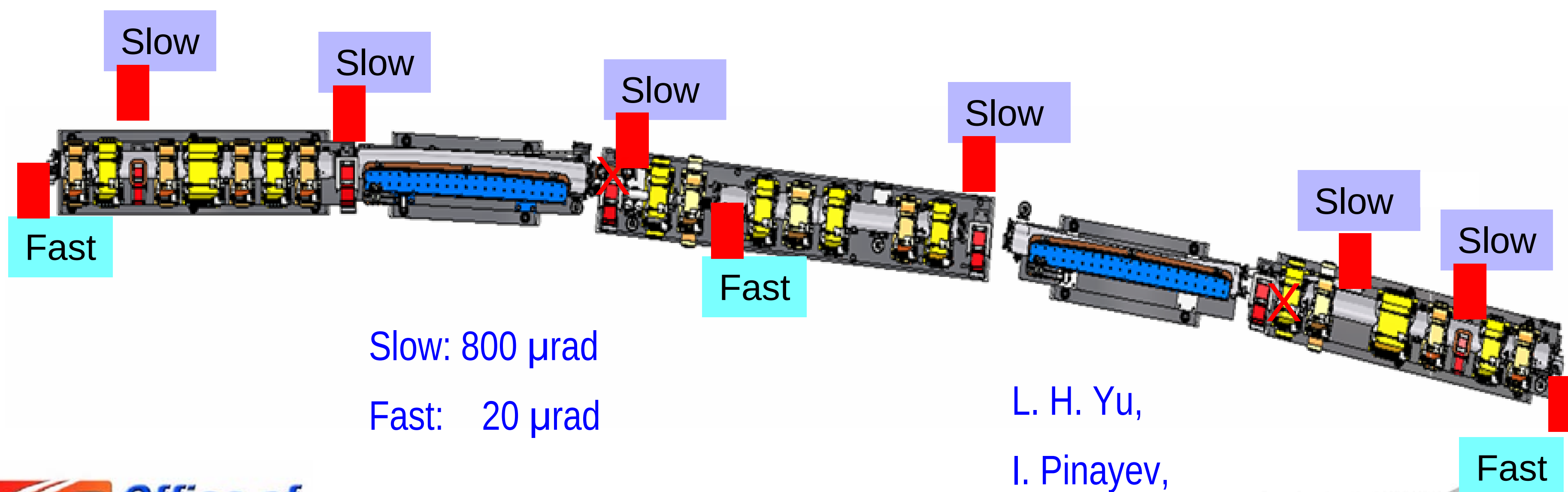
$$\Delta x < 0.1\sigma_x \quad \Delta x' < 0.1\sigma_{x'} \quad \Delta\sigma_{x,y} < 0.1\sigma_{x,y}$$

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

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.



Slow: 800 µrad

Fast: 20 µrad

L. H. Yu,

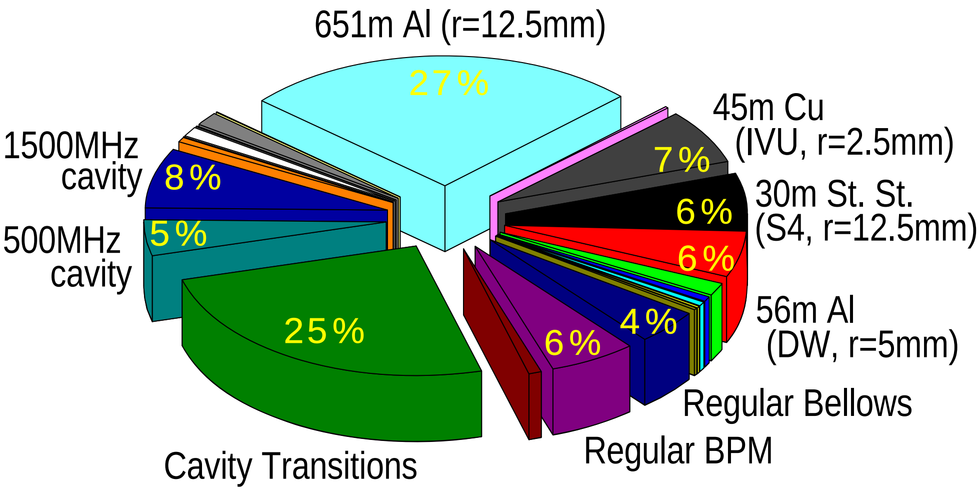
I. Pinayev,

EPAC08

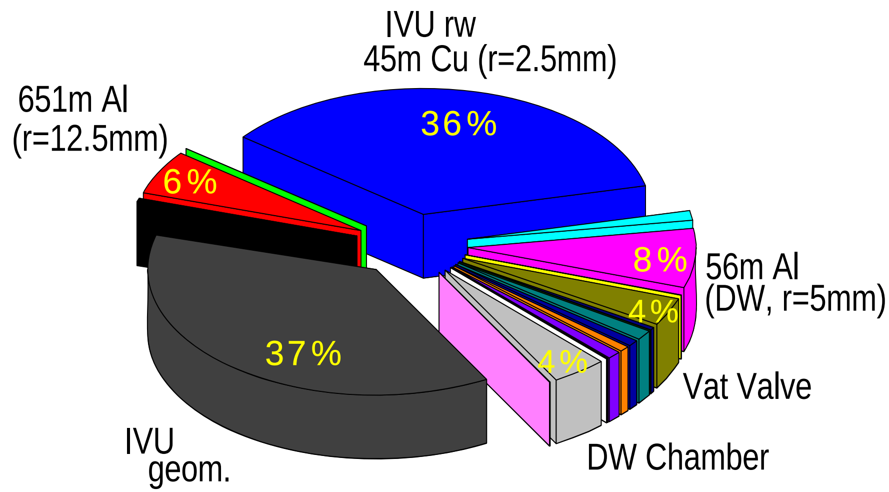
Collective Effects

- We have estimated instability thresholds based on an impedance budget suggested by experience at ESRF and APS.
- We are calculating the impedance of the NSLS-II components using GdFidL. Calculated results obtained thus far lie within the budget.
- Calculations are first performed using a 3 mm Gaussian bunch. Next we plan to calculate the wakefield for a 0.5mm bunch for use as a pseudo Green's function for tracking simulations.
- In order to carry out the GdFidL calculations for a 0.5mm bunch, we require improvements in the code (W. Bruns) and increased computing power (upgrade of our cluster).
- Single bunch (0.5 mA) and average current (500 mA) goals are achievable
- Bunch to bunch vertical feedback required for resistive wall and fast-ion instability

Contributions to Total Impedance



Longitudinal Loss Factor



Vertical Kick Factor

A. Blednykh, FR5RFP031

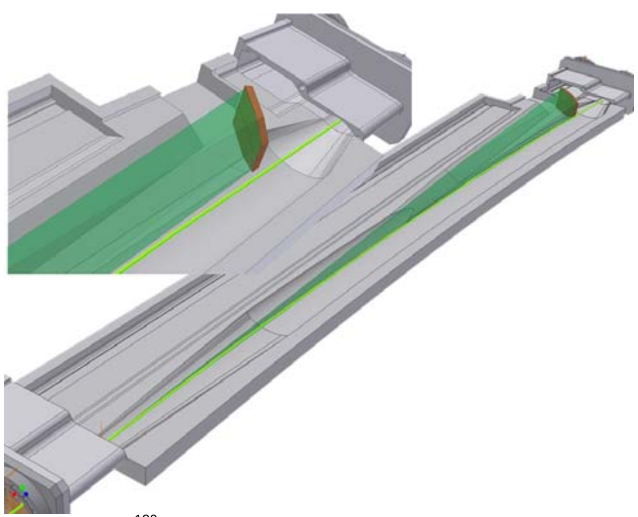
Office of Science
U.S. DEPARTMENT OF ENERGY

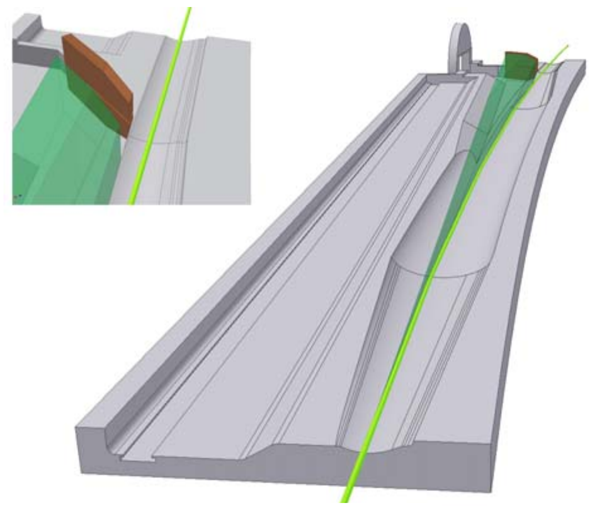
BROOKHAVEN
NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

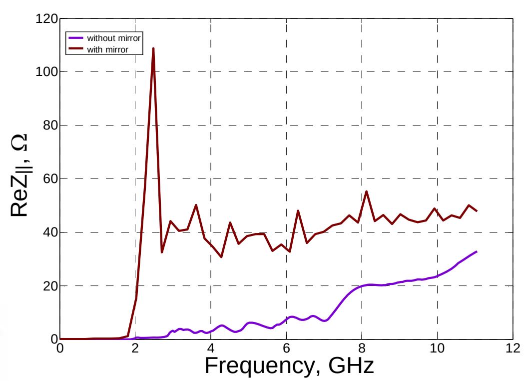
Impedance of Infra-red Extraction Chamber

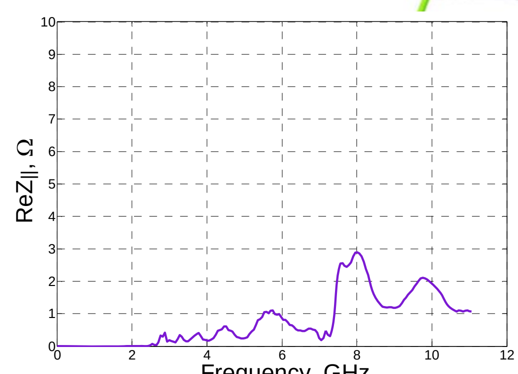
There are 54 regular dipoles with a gap of 35mm

There are 6 special dipoles with large gap 90mm









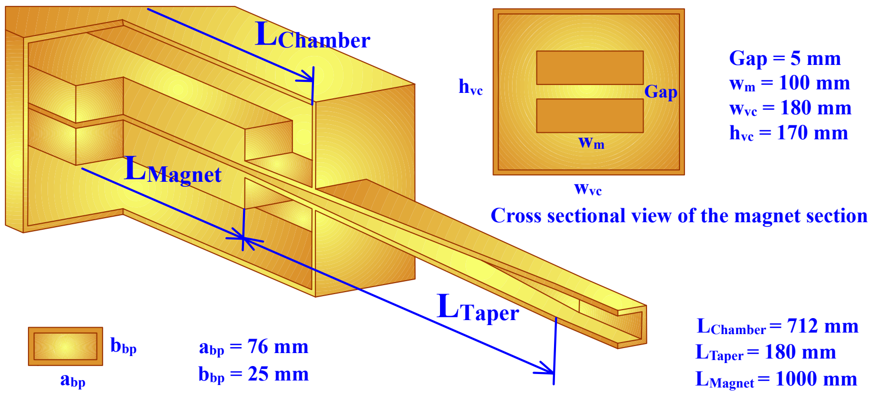
A. Blednykh,

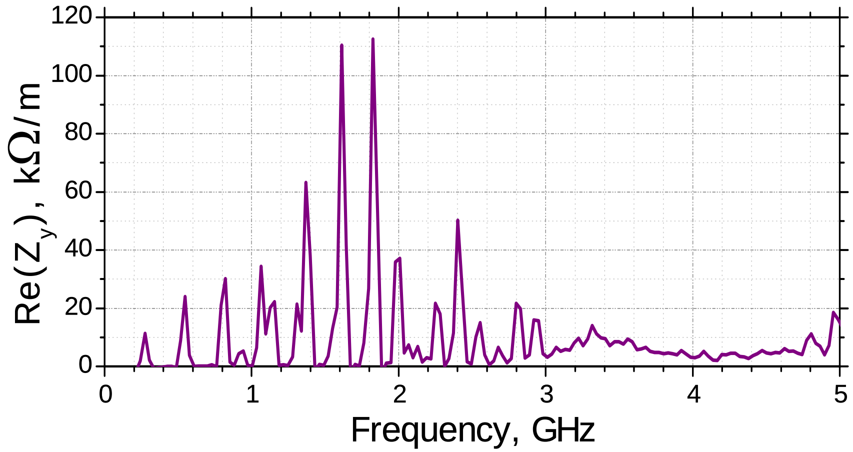
FR5RFP032

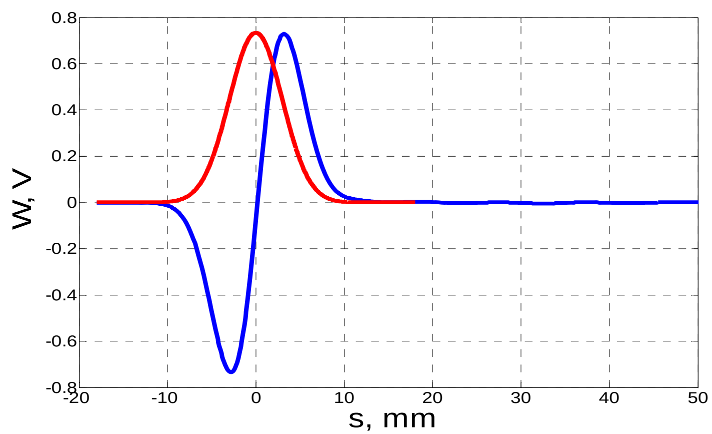
Office of Science
U.S. DEPARTMENT OF ENERGY

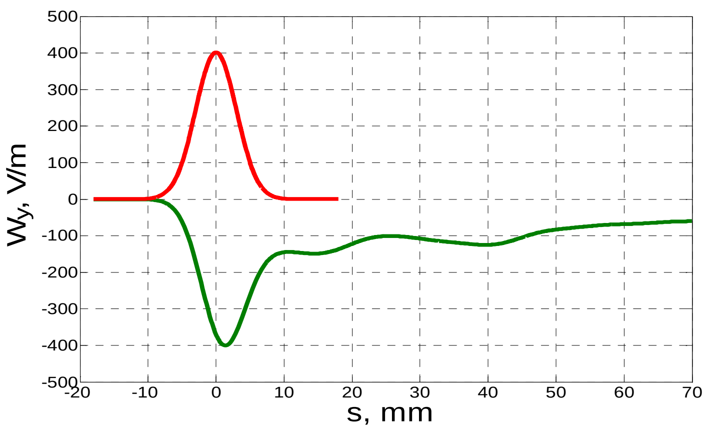
BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Impedance of Invacuum Undulator (IVU)





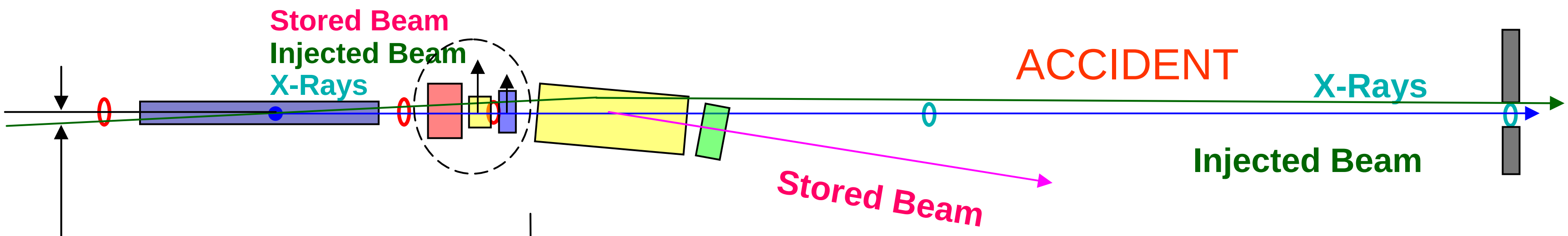




A. Blednykh, EPAC06

Top-Off Safety Analysis

Require Proof that injected beam cannot pass through beamline beyond safe point inside shielded area.



Combination of

- Bad Steering
- Bad Lattice Settings (conspiracy of magnets)

Simulation is necessary!

courtesy Bob Hettel (SLAC)