Insertion Device Development at the NSLS-II
Current Status and Future Plans

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PAC11
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Outline

- ID Development Strategy
- ID Table / Official Schedule for “Baseline” Project Scope
- Description on Each “Baseline” Device
- Future Devices
- R & D (PrFeB, IVMMS, AGU, VST)
- Conclusions

Acknowledgement:

ID group members: C. Kitegi, J. Rank, D.A. Harder, T. Corwin, P. Cappadoro, G. Rakowsky

Part-time members: O. Chubar, C. Spataro, P. He, F. Huston

Accelerator Physics: J. Bengtsson, S. Krinsky, A. Blednykh, L.H. Yu

Vacuum Group: Dick Hseuh

Mechanical Group: V. Ravindranath

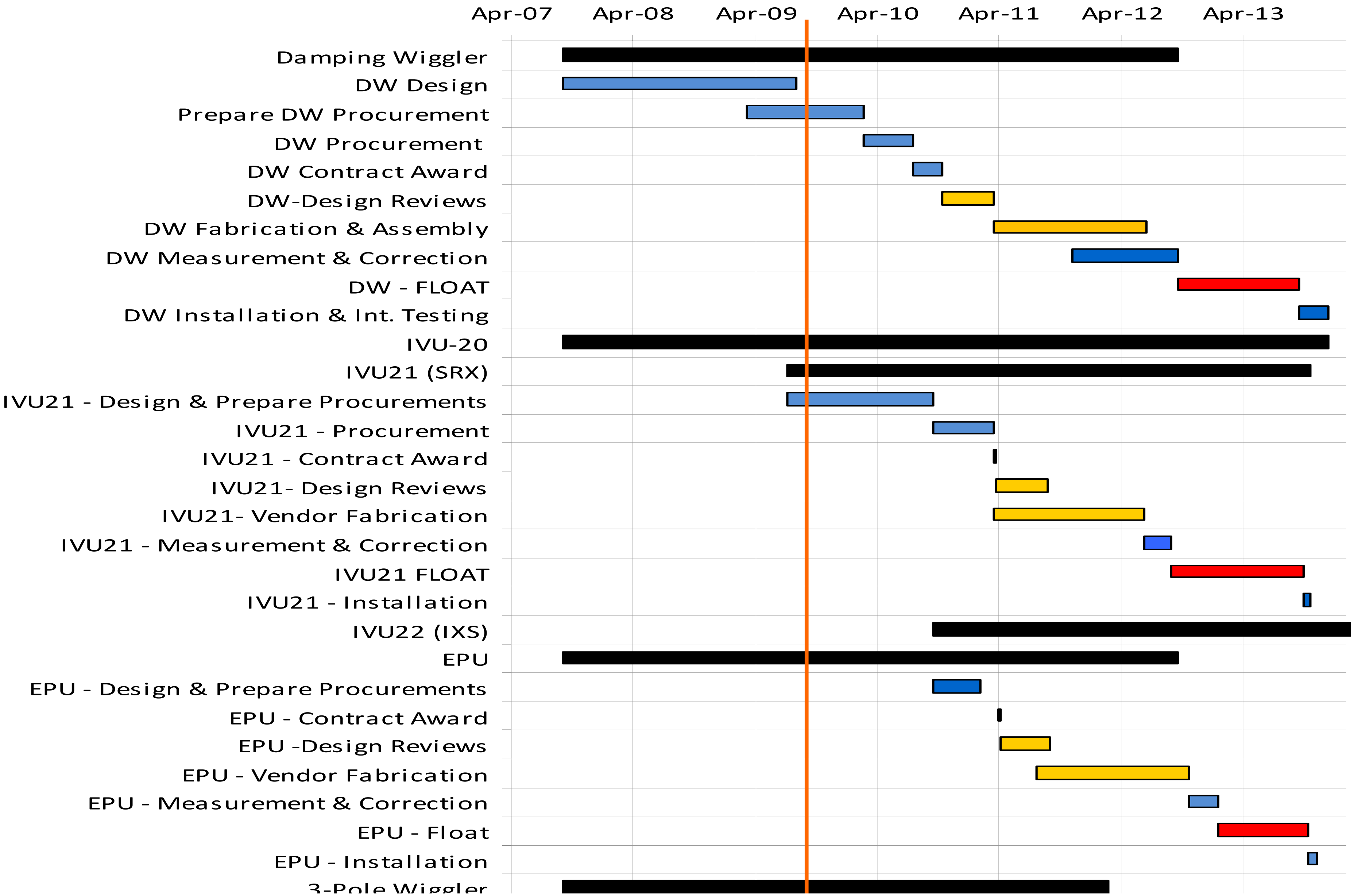
ID Development Strategy

- **No internal resources for "conventional device production"**
  - Baseline Devices are close to what are commercially available.
  - BNL's internal regulation on volume production makes cost and schedule difficult to control.
  - Baseline labor profile does not provide enough labor for in-house production.
- **Effort is concentrated on the first class measurement facility and R&D**
  - Improving measurement accuracy is not trivial task and no vendors are willing to invest.
  - In-house measurement capability should be superior to that of vendors so that proper certification of device can be made.
  - R&D subjects include PrFeB based Cryo-Permanent Magnet Undulator (CPMU), Adaptable Gap Undulator (AGU) and Super Conducting Undulator (SCU)

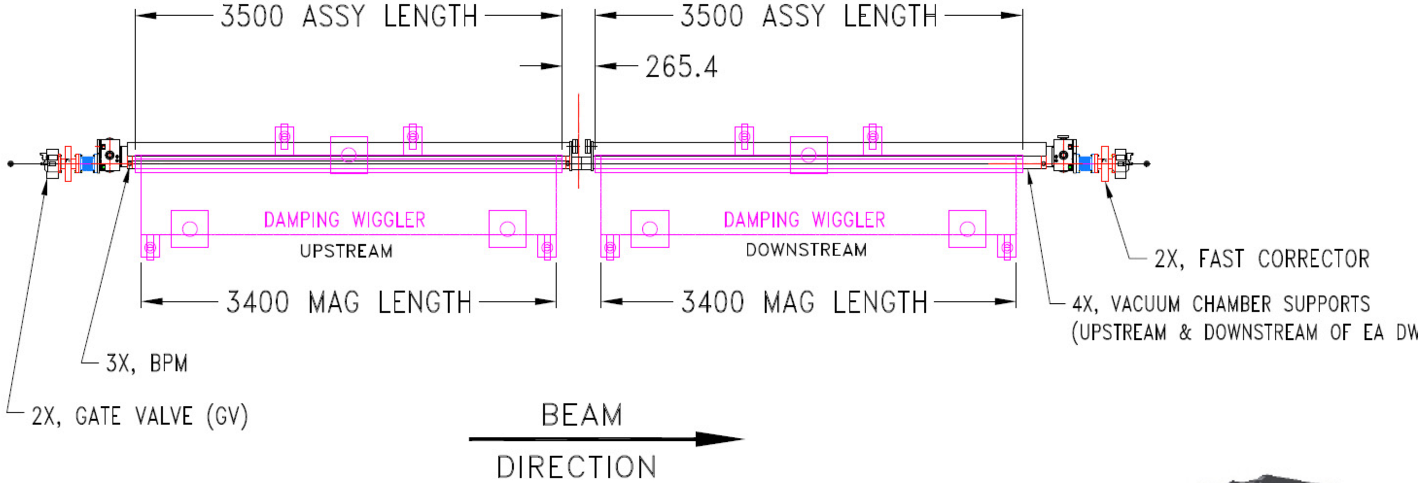
NSLS-II Insertion Devices (Baseline Project Scope)

Name	U20	U22(IXS)	EU49	U21(SRX)	DW-1.8T	3PW
Type	IVU	IVU	EPU	IVU	PMW	PMW
Photon energy range	Hard x-ray (1.9-20keV)	Hard x-ray (9.1keV)	Soft x-ray (250eV-1.7keV)	Hard x-ray (1.9-20keV)	Broad band (<10eV-100keV)	Broad band (<10eV-100keV)
Type of straight section	Short	Long	Short (canted)	Short (canted)	Long (in-line)	near 2nd Dipole
Period length (mm)	20	22	49	21	100	-
Length (m) & Number of Devices	3.0 x 2	3.0	2.0 x 2	1.5	3. 5 x 6	0.25
Number of periods	148	135	36 x 2	69	34 x 2	0.5
Magnetic gap (mm)	5	7.0	11.5	5.5	15.0	28
Peak magnetic field strength B (T)	1.03	0.78	0.57(Heli) 0.94 (Lin) 0.72(vlin) 0.41 (45°)	0.9	1.80	1.14
Keff	1.81	1.52	2.6(Heli) 4.3 (Lin) 3.2(vlin) 1.8 (45°)	1.79	18.0	-
hν fundamental, eV	1620	1802	230 (Heli) 180 (Lin) 285(vlin) 400 (45°)	1570		
hν critical, keV					10.7	6.8
Total power (kW)	8.0	4.7	8.8	3.6	64.5	0.32

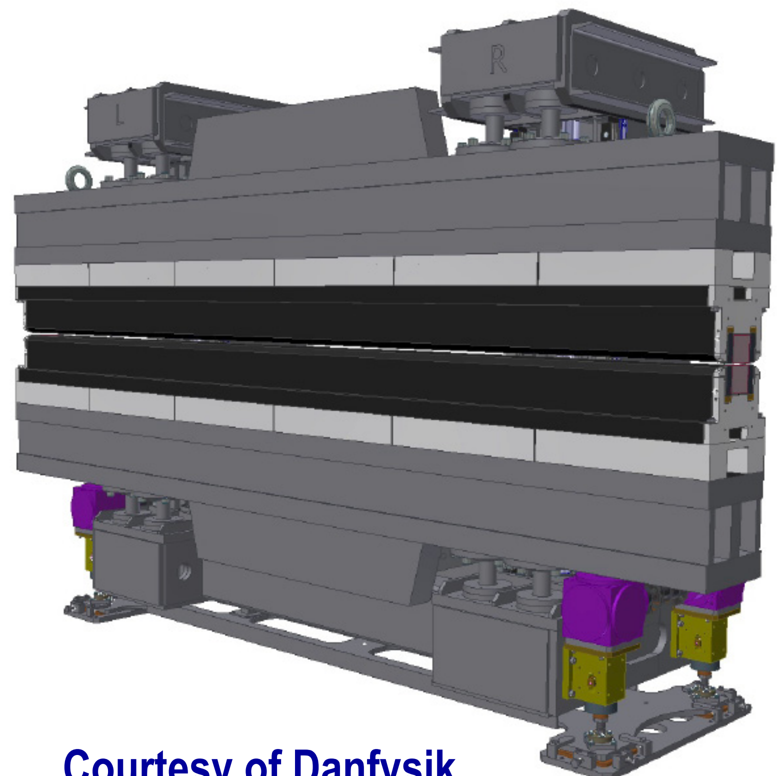
Official Schedule



DW Preliminary Design



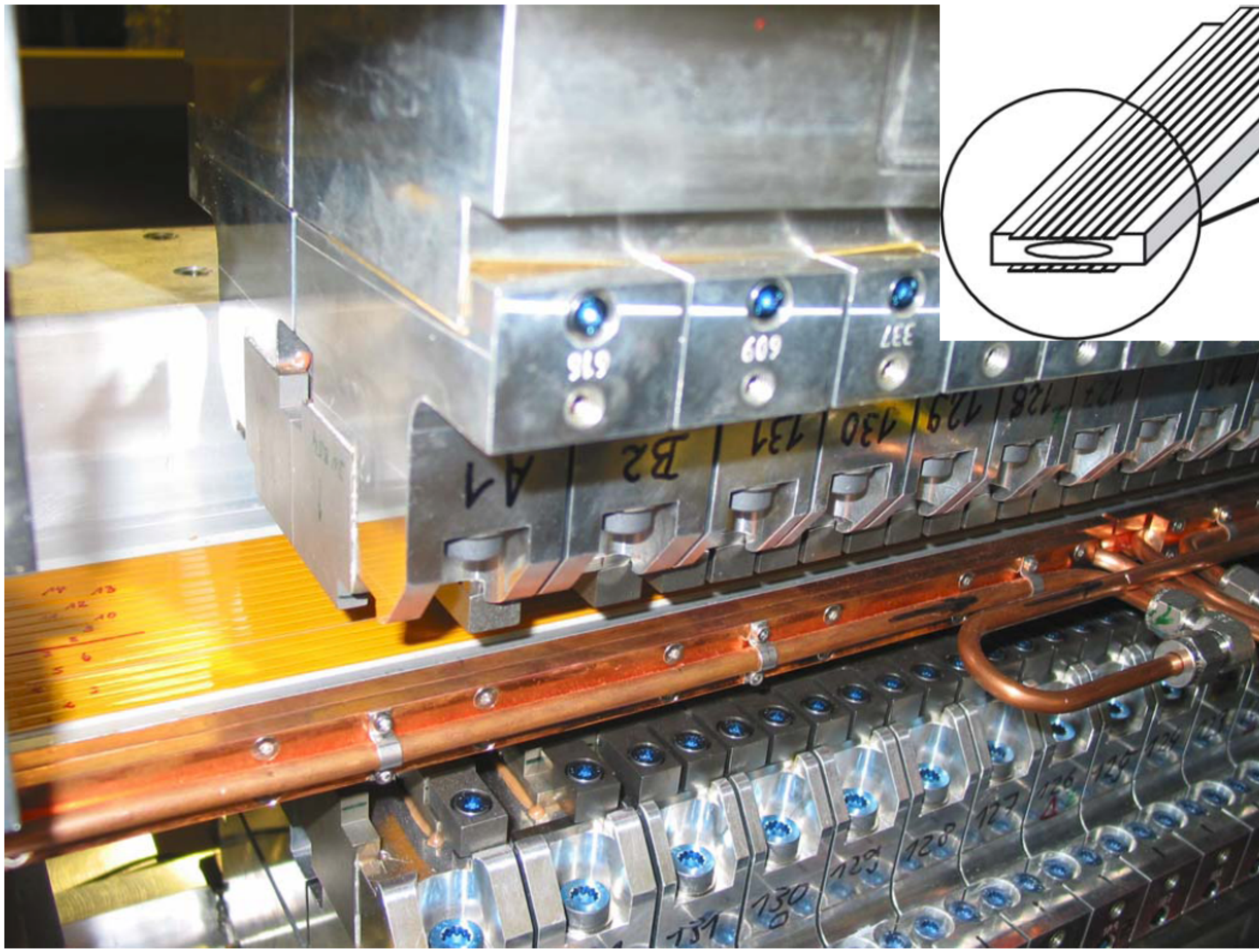
Item	Parameter
Magnetic length	>3.4 m
Period Length	100 mm
Minimum Pole Width	90 mm
Operational Magnetic Gap (Design Gap) Minimum Fully Separated Gap (Fully Open State)	15.0 mm >150 mm
Nominal Peak Field	1.8 T
Integral of By2 on-axis for one period in longitudinal direction	Minimum: 0.158 T^2.m
1st and 2nd Integral Error Requirement (|x|<15mm, |y|<4mm), gap =12.5mm AND fully extracted positions:	
$\int_{-\infty}^{\infty} By(x,y,z)dz$ (without correction coils)	<50 G.cm (|x|<15 mm, y = 0 mm), <100 G.cm (|x|<15 mm, |y| = 3 mm)
$\int_{-\infty}^{\infty} Bx(x,y,z)dz$ (without correction coils)	<30 G.cm (|x|<1 5 mm, y = 0 mm), <60 G.cm (|x|<15 mm, |y| = 3 mm)
$\int_{-\infty}^{\infty}\int_{-\infty}^{z} By(x,y,z')dz'dz$ (without correction coils)	<10,000 G.cm.cm (|x|<15 mm, y = 0 mm),
$\int_{-\infty}^{\infty}\int_{-\infty}^{z} Bx(x,y,z')dz'dz$ (without correction coils))	<5,000 G.cm.cm (|x|<15 mm, y = 0 mm),
On-axis Electron Trajectory Requirements for E=3GeV at any longitudinal position	|x|<60 µm, |y|<5 µm and |y'|<10 µrad

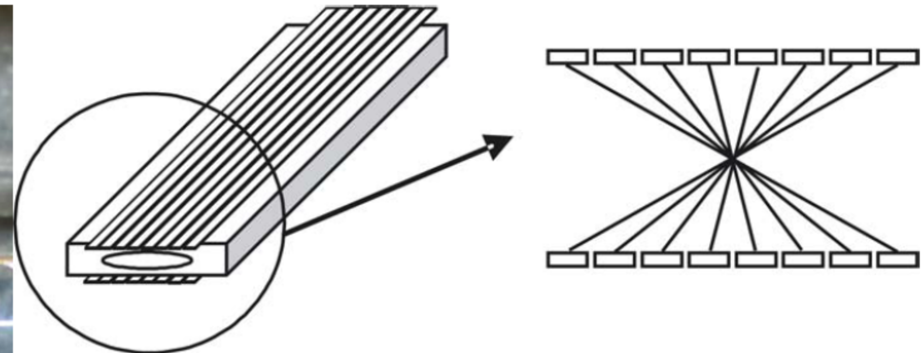


Courtesy of Danfysik

EPU Active Compensation (à la BESSY)

active compensation of dynamic field components in the linear/inclined mode





28 flat wires along the ID-chamber with 14 PS

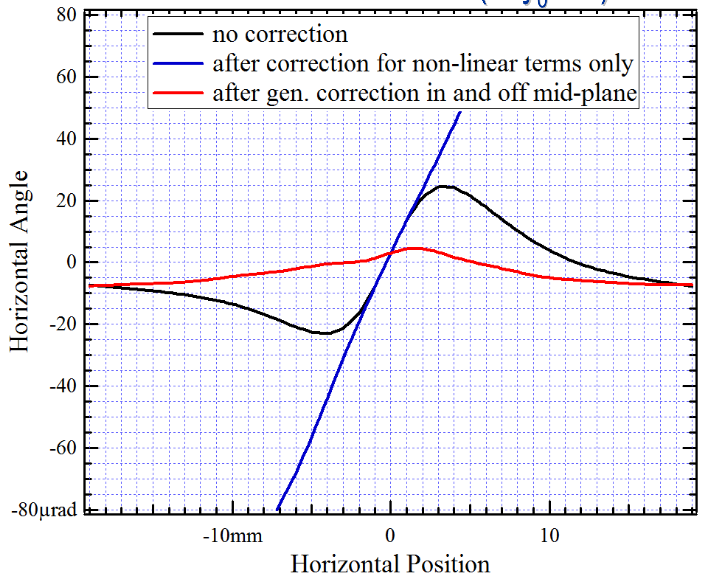
maximum current; 16A,
wire diameter; 3x0.3mm^2
wire separation: 4mm

Courtesy of J. Bahrdt

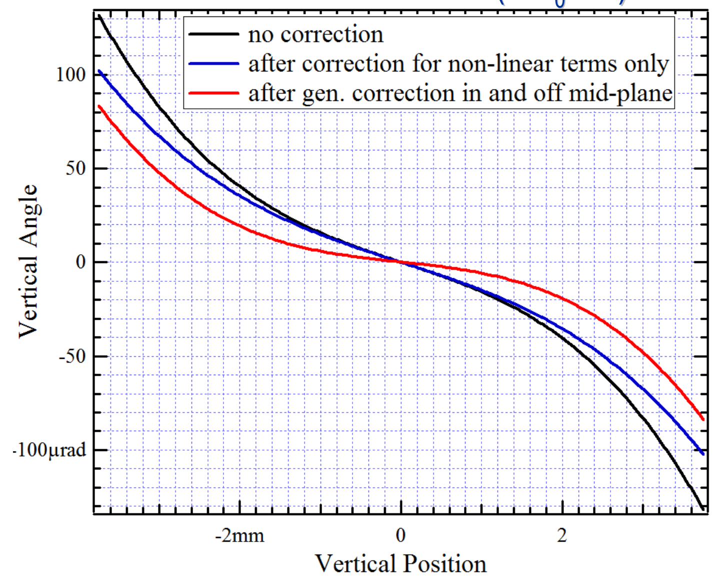
Testing Efficiency of Current Strip Based Correction Scheme for APPLE-II (EPU49) in Linear Vertical Polarization Mode

- Electron Trajectory Angles at Exit of 2 m Long EPU49 at Different Initial Transverse Positions

Resulting Horizontal Angle vs Horizontal Initial Position in Horizontal Mid-Plane (at $y_0 = 0$)



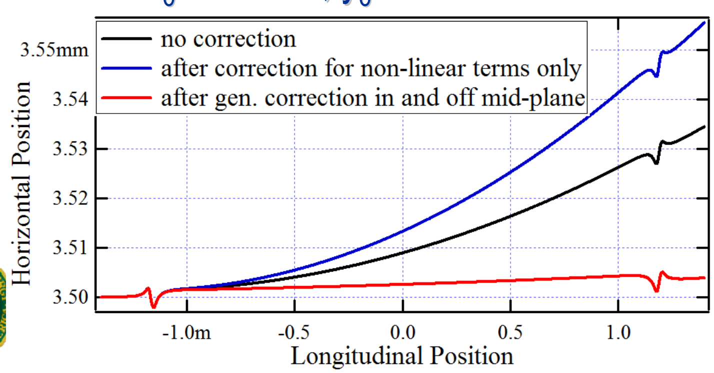
Vertical Angle vs Vertical Initial Position in Vertical Mid-Plane (at $x_0 = 0$)



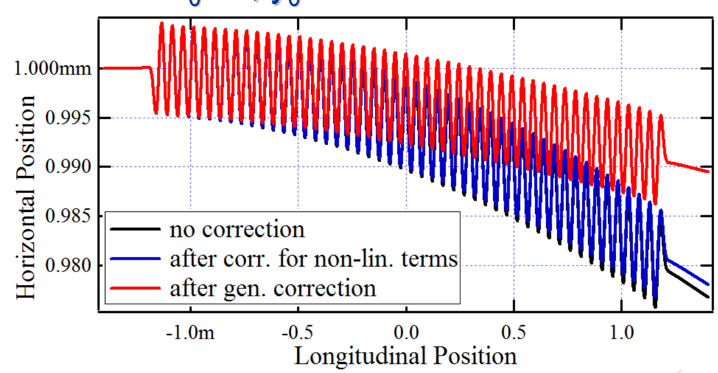
Number of Strips: 2 x 20
Dims: 2 mm x 0.3 mm x 2 m
Hor. Gap bw Strips: 1 mm
Vert. Gap bw Strips: 10.7 mm
APPLE-II Vert. Gap: 11.5 mm
Electron Energy: 3 GeV

- Electron Trajectories in 3D Magnetic Field Without and With Correction

Horizontal Projections at x_0= 3.5 mm, y_0= 0 before Undulator

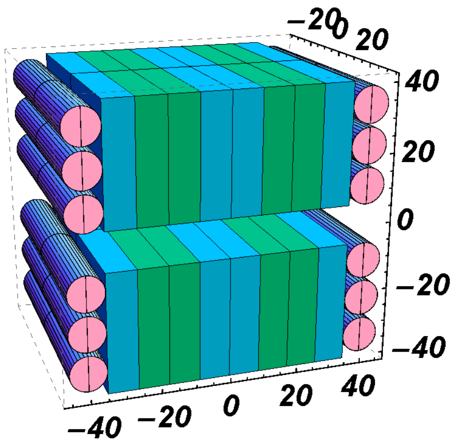


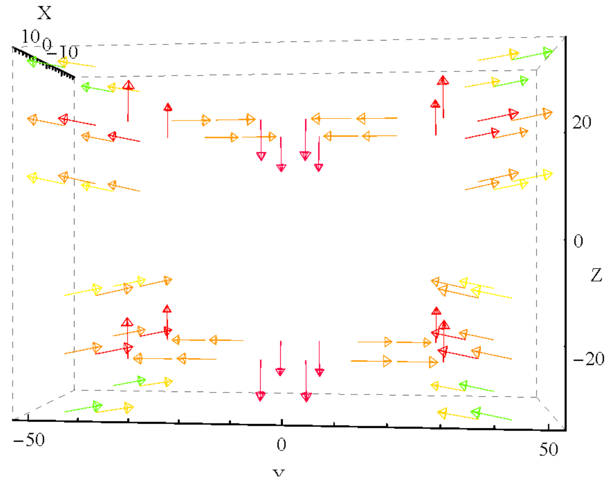
Vertical Projections at x_0= 0, y_0= 1 mm before Undulator

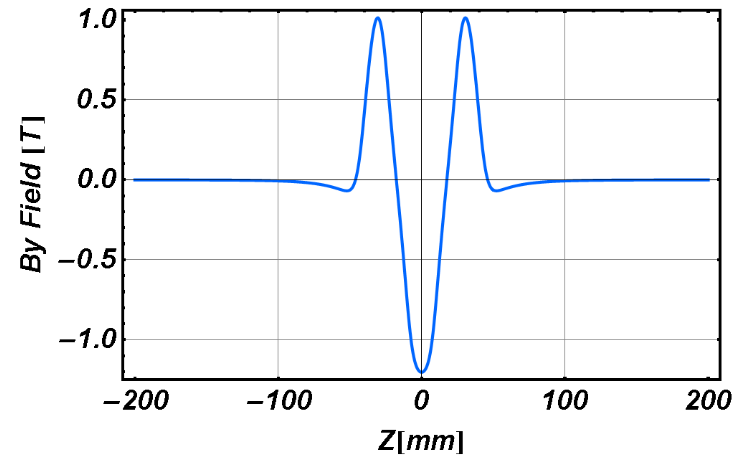


O.Chubar

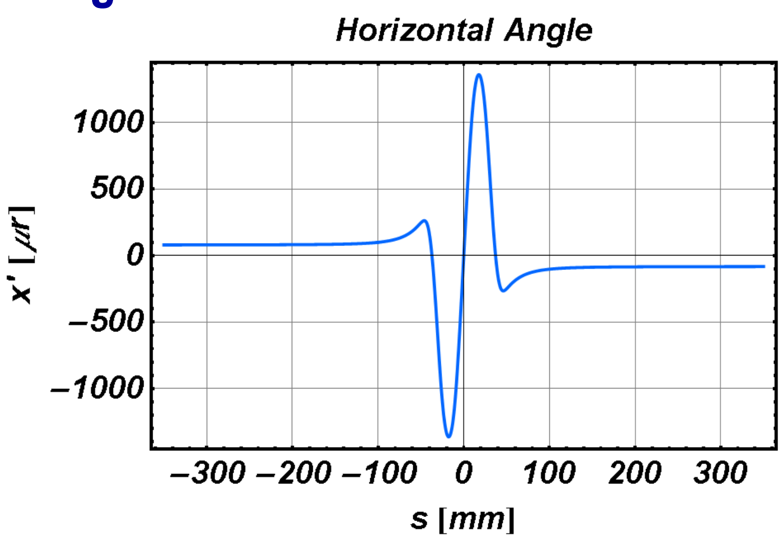
EPU Phasing / Canting Magnet Design

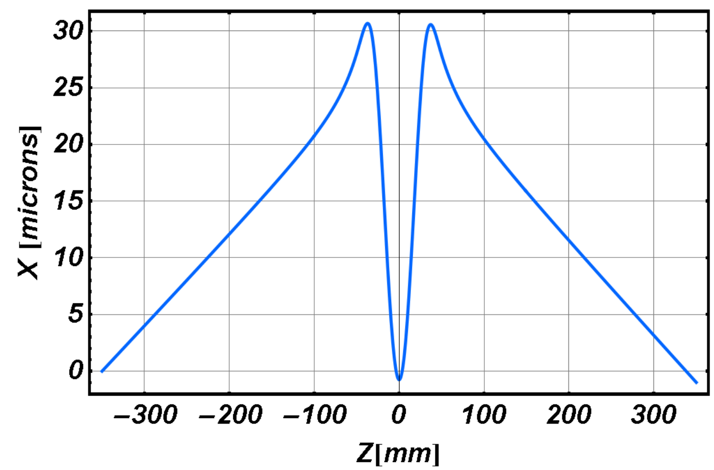






C. Kitegi





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Canting Mode Example

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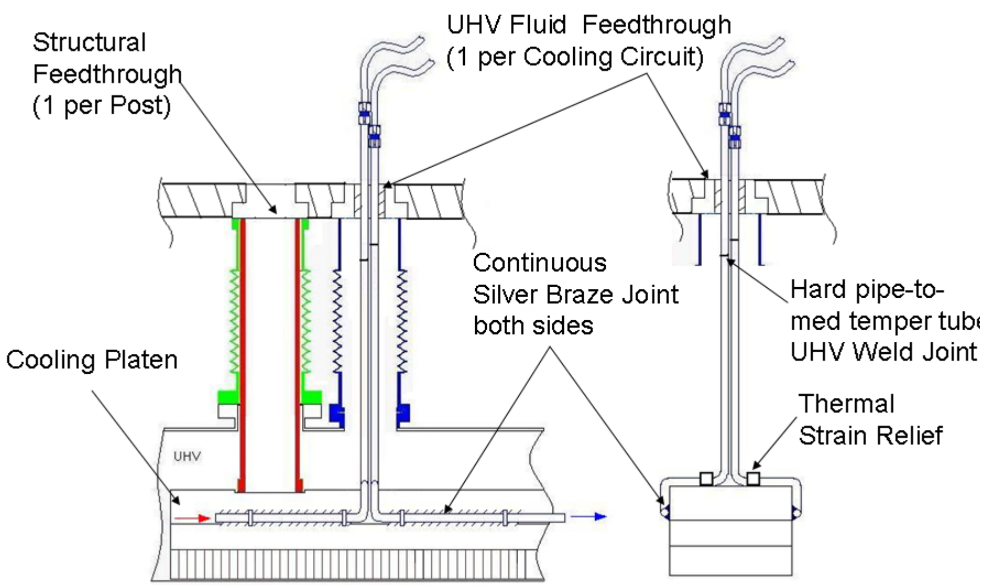
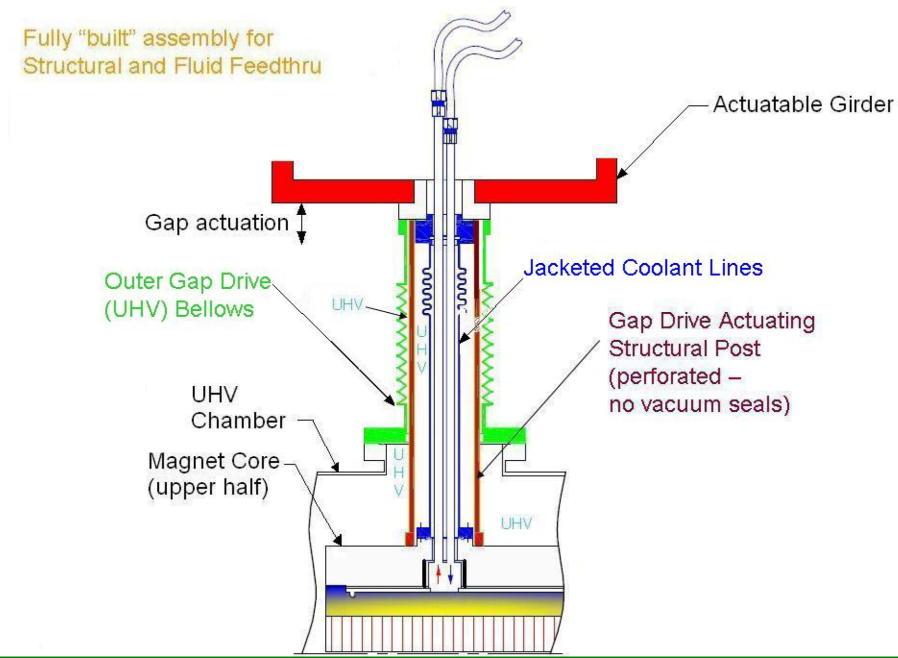
IVU Array Cooling Scheme

Conventional Design



Note: Copper tube not to contact stainless components to avoid galvanic corrosion.

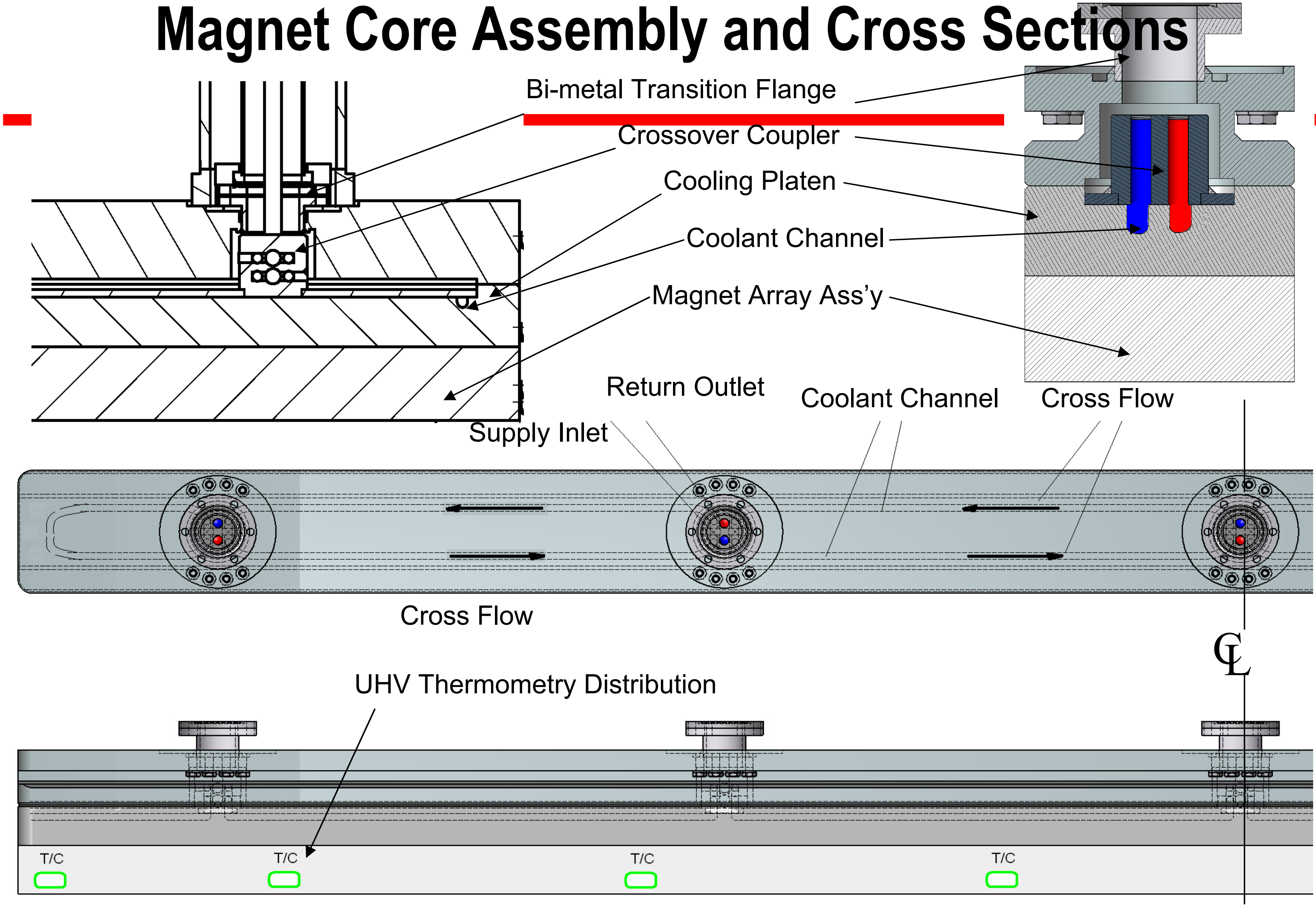
BNL Design



- Slightly fewer shop fabricated parts
- Slightly Simpler to Assemble
- Repair of major leak may not require breakdown of magnet core

- Structural and fluid connections share common feedthrough
- Negligible probability of water-to-UHV leak
- Cooling channel leak is to ambient room only and may usually be repaired without breaking vacuum
- No fatigue stress induced in thin wall tubing
- Allows for magnet array upgrade to CPMU with small increase in cost

Magnet Core Assembly and Cross Sections



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Three Pole Wiggler (3PW)

- Requirements:
  - More than 2 mrad of radiation fan above 1T field
  - Use a special inconel (25 mm outer vertical) chamber
  - Fixed gap and removable from one side of the chamber
  - Simple and economical

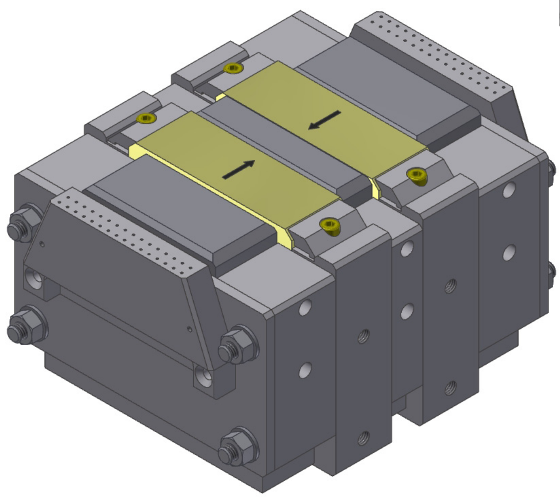
- Magnetic Design (Central Pole Gap=28mm)

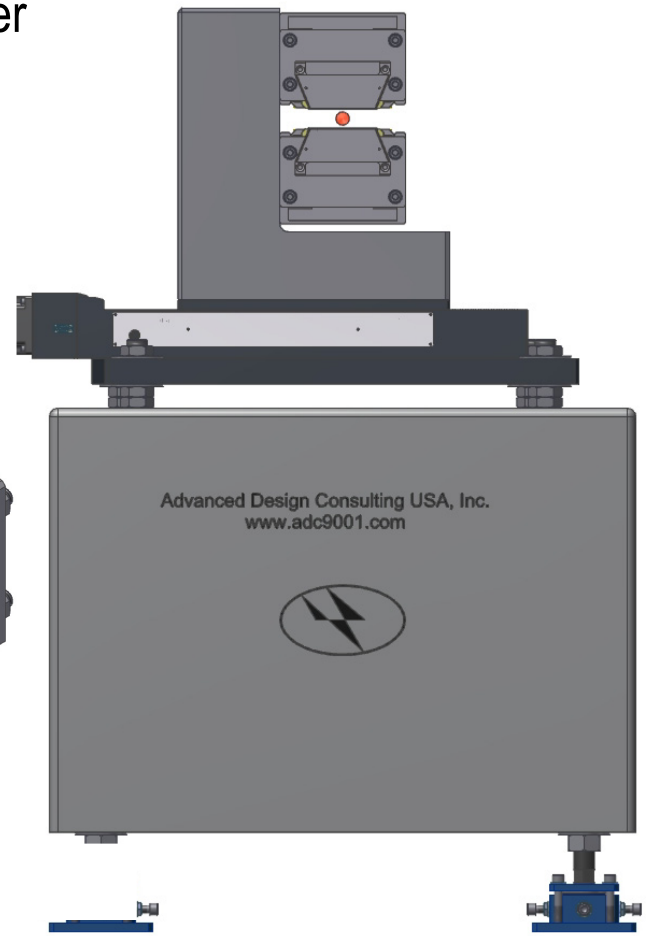
- **Br=1.25T**
- **Permendur Center Pole**
- **Soft Iron (1006) Side Poles**
- **Rectangular Magnets**

Main Magnets: 120 x 41. x 90 mm

Center Pole: 120 x 23 x 65 mm

End Poles: 101. x 45 x 86 mm





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List of "Off-baseline" Devices

- **IVUs for NIH Funded Beam Lines (funded)**
  - 2 Canted IVUs in a short straight section similar to SRX
  - One standard U20
  - Another device to be specified
- **NEXT-MIE Devices (near term: details T.B.D)**
  - Several standard IVUs (expected)
  - SCW (1m long, 80mm period at 4.5T)
  - Long Period EPU?
- **Type-II Beamlines**
- **NEXT-II**
- **NxtGen**
- **Biological and Environmental Research (BER)**

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New Technology (Off-baseline)

- **Adaptive Gap Undulator**
  - Different period length / gap depending on the magnet position in Z
  - Various issues such as impedance effect by the steps and kick compensation in each joint section, etc. remain to be solved.
- **CPMU (PrFeB)**
  - Proto-type test shows 19% increase of Br from RT to 77K
  - 17mm period, Br (@77K)=1.45T, 2.7m long
  - Bakeable magnet arrays are being fabricated for baking test
- **SCU**
  - Goal: 14mm period, B=1.68T, 2m long
  - APC NbTi wire is now available
  - Both LTS/HTS version will be investigated.

PrFeB shows no SRT

- NdFeB magnets exhibit “Spin Reorientation Transition (SRT) which will change the magnet’s permeability at low temperature. PrFeB has no SRT.

5–1 Nd(Tb)FeB系磁石　減磁曲線(低温:85K,180K)

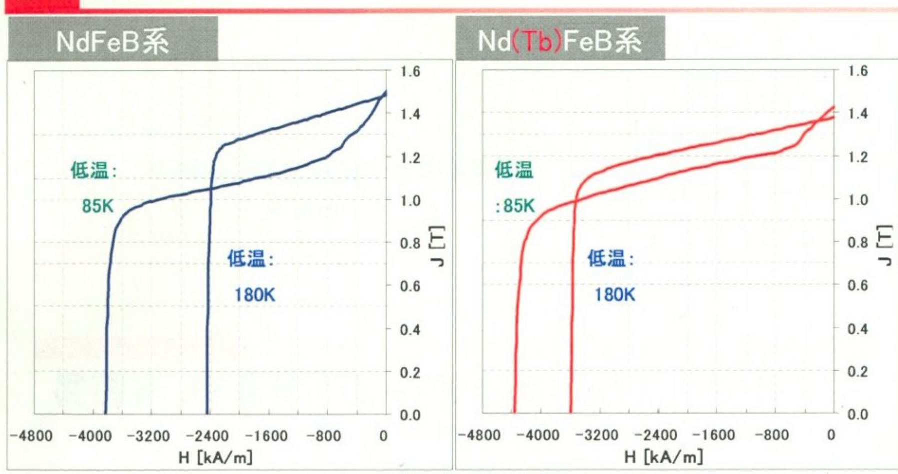


Fig. 減磁曲線 (低温比較)

VSM	B_r [T]			H_{cJ} [kA/m]		
85K、180K	85K	180K	300K	85K	180K	300K
NdFeB	1.48	1.49	1.39	3819	2437	1109
Nd(Tb)FeB	1.41	1.38	1.30	4363	3588	2020

Materials Mag!c
Hitachi Metals

NEOMAX Magnetic Materials Research Laboratory

5–2 Pr(Tb)FeB系磁石　減磁曲線(低温:85K,180K)

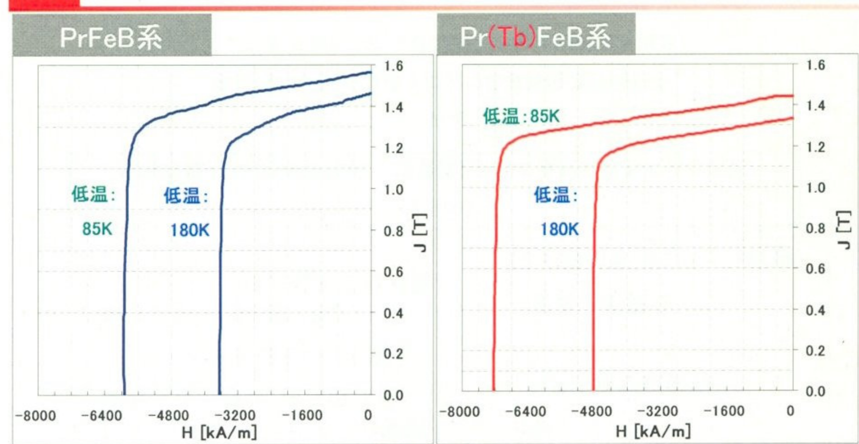


Fig. 減磁曲線 (低温比較)

VSM	B_r [T]			H_{cJ} [kA/m]		
85K、180K	85K	180K	300K	85K	180K	300K
PrFeB	1.57	1.47	1.35	5925	3630	1470
Pr(Tb)FeB	1.44	1.35	1.25	7207	4843	2400

Materials Mag!c
Hitachi Metals

NEOMAX Magnetic Materials Research Laboratory

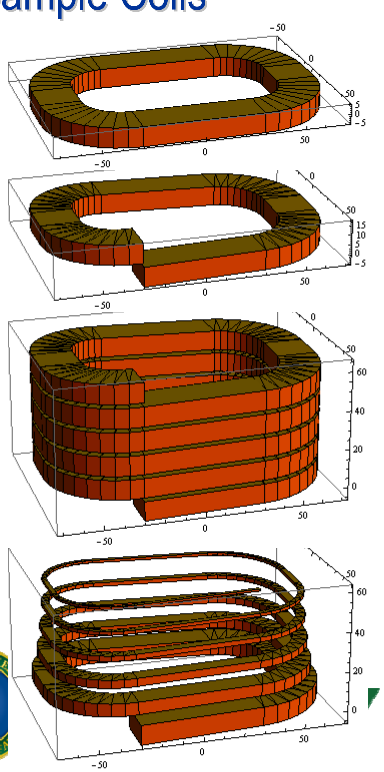
Courtesy of Hitachi Metal, USA.

Radia Updates

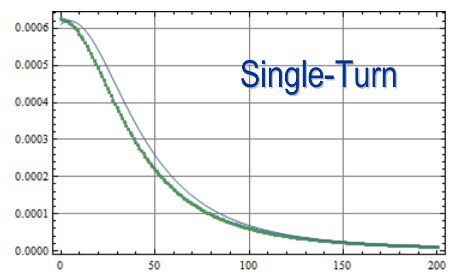
RADIA and SRW are supported and further developed by NSLS-II / BNL (O. Chubar) and ESRF (P. Elleaume, J. Chavanne)

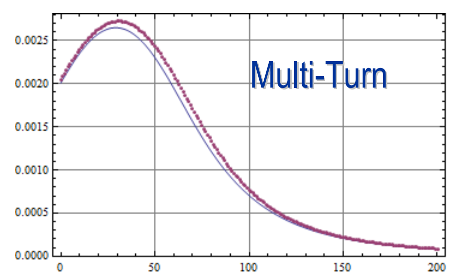
Recent Developments in RADIA (v. 4.29, 64-bit, available on all platforms):
- Implementation of Polyhedrons with constant or linearly-varying Current Density
- New function for generating Coils by Generalized Extrusion

Sample Coils

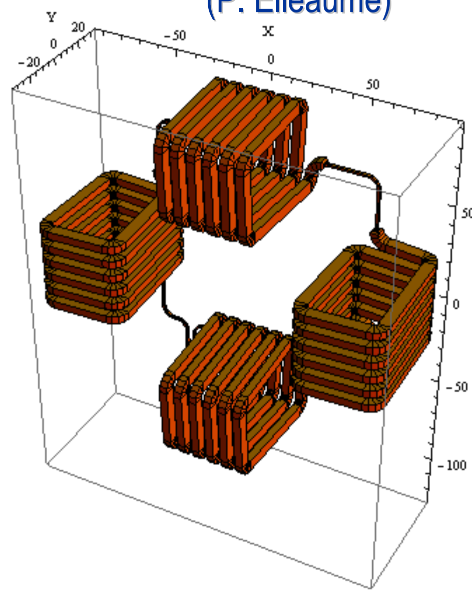


On-Axis Vertical Magnetic Field
vs Vertical Position

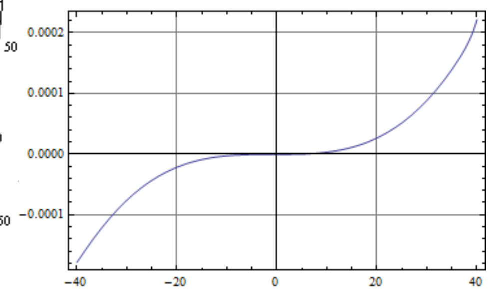




Inductor Example
(P. Elleaume)



Vertical Magnetic Field
vs Horizontal Position



Summary

- ***Damping Wigglers:*** Preliminary design is almost complete. Final design review will be conducted by May, 2011.
- ***3PW :*** A vendor has been selected. Completed contract is imminent.
- ***EPU***
  - A vendor has been selected. Completed contract is imminent.
  - Active correction scheme using current strips will be further optimized to reduce tune foot print by the devices.
- ***IVU:*** RFP for 1.5m SRX-IVU will be issued shortly. 3m standard IVU20 and 3m IXS-IVU will follow.
- ***ID-MMF:*** Hall probe bench is in place and Integrated Field Measurement System will be ready by May.
- ***R&D and Future Devices***
  - PrFeB based CPMU R&D is being carried out.
  - In-Vacuum Magnetic Measurement System (IVMMS) is in design stage.