Insertion Devices & 3PW

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APS Upgrade Project

Contributions from numerous staff at APS

APSU Forum
February 12, 2015

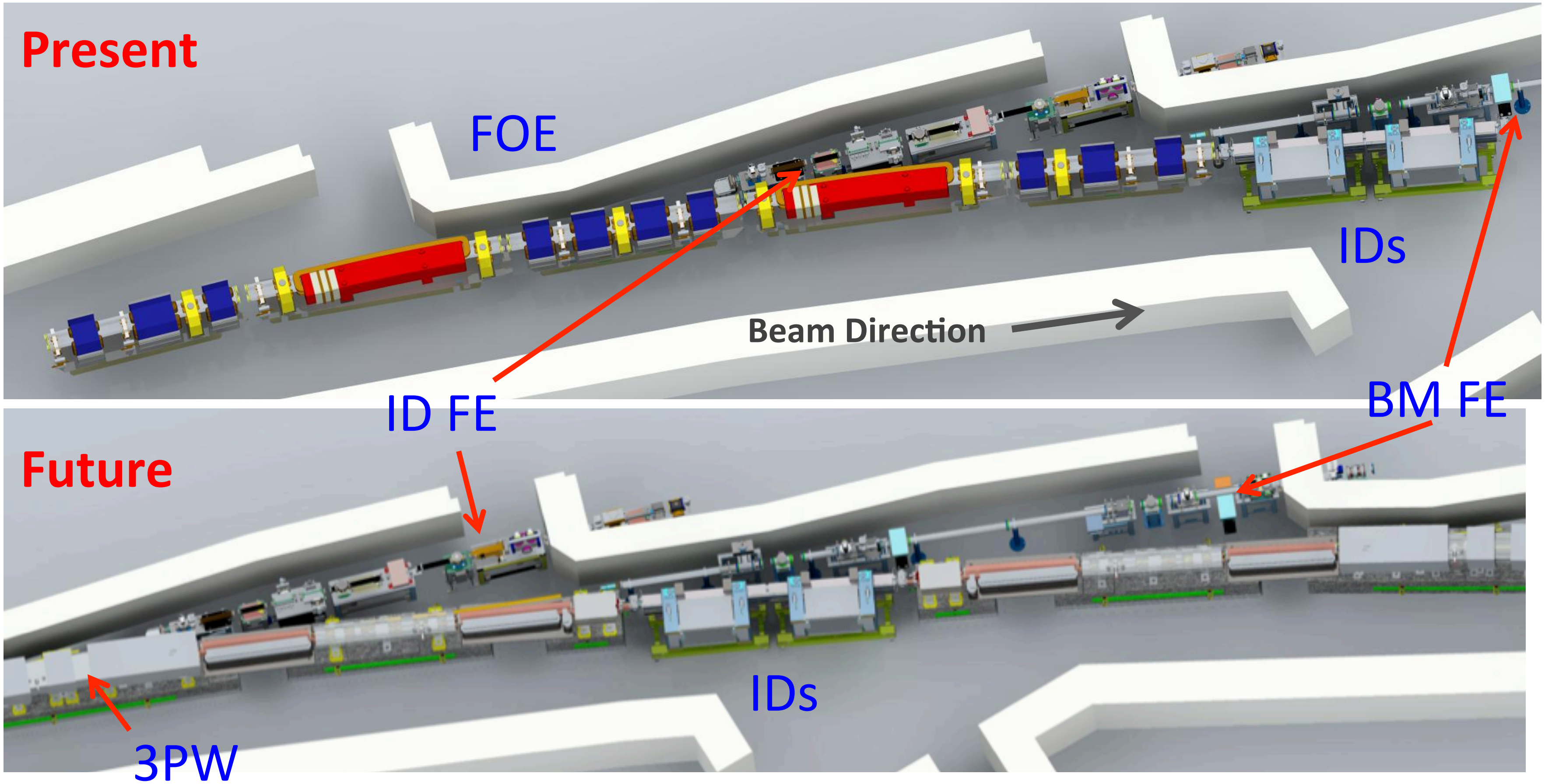
APS Upgrade Machine Parameters

Quantity	APS Now	APS MBA Timing Mode	APS MBA Brightness Mode	Units
Beam Energy	7	6	6	GeV
Beam Current	100	200	200	mA
Number of Bunches	24	48	324	
Bunch Duration (rms)	34	67	55	ps
Bunch Spacing	153	77	11	ns
Emittance Ratio	0.013	0.98	0.1	
Horizontal Emittance	3100	47	68	pm-rad
Horizontal Beam Size (rms)	275	18	22	μm
Horizontal Divergence (rms)	11	2.6	3.1	μrad
Vertical Emittance	40	46	6.8	pm-rad
Vertical Beam Size (rms)	10	10.6	4.1	μm
Vertical Divergence (rms)	3.5	4.3	1.7	μrad

MBA lattice opens up some new opportunity for novel sources for beamlines

Michael Borland will talk on March 12, 2015 on the lattice

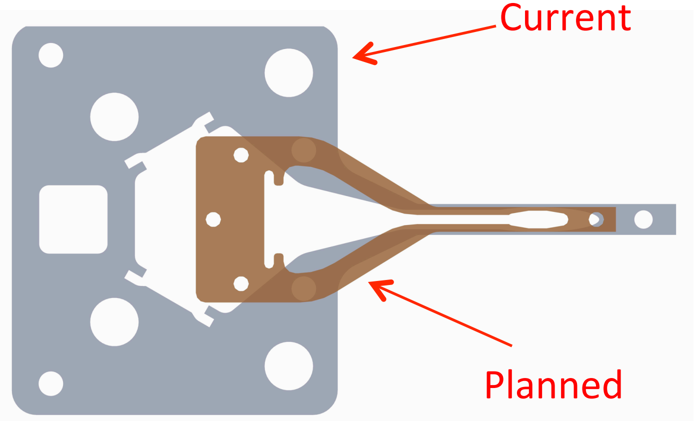
Storage Ring Layout



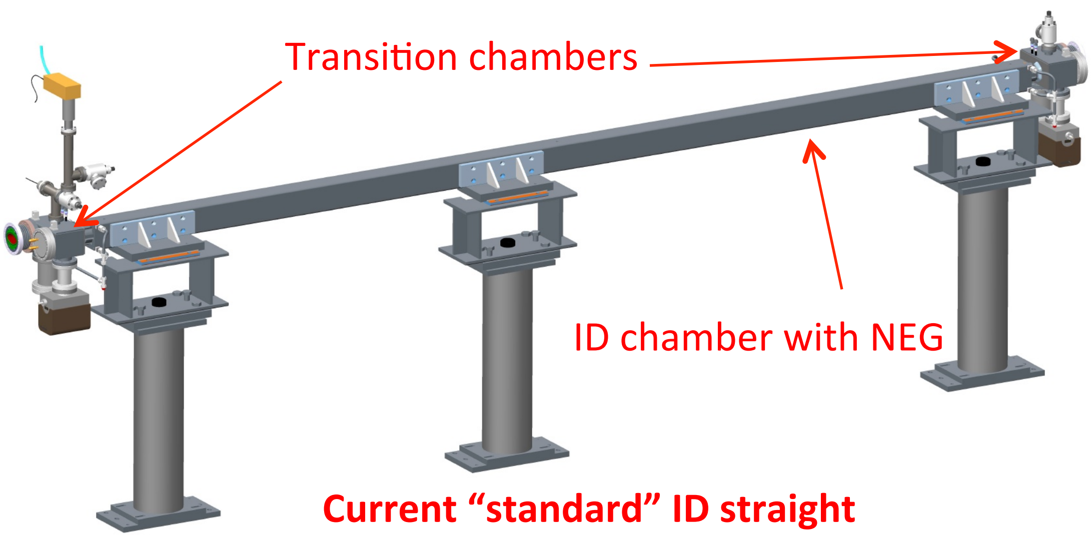
MBA lattice will preserve the 4.8 m ID lengths and provide a new source (3 pole Wiggler) for BM source

Insertion Device Vacuum Chamber

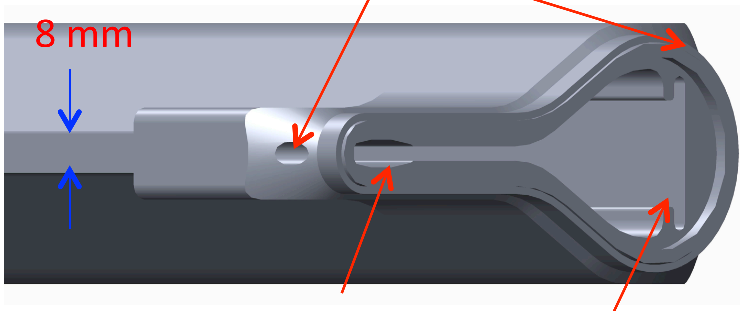
- The current ID vacuum chamber has a internal vertical aperture of 8 mm allowing for minimum undulator gap of 11 mm
- The current ID vacuum chamber transitions from 84 mm (H) x 42 mm (V) to 40 mm (H) x 8 mm (V)
- APSU will have a 22 mm diameter round chamber and will transition to 20 mm (H) x 6 mm (V) at the straight section of the IDs
- APSU will allow for routine minimum ID gap operation of 9.0 mm compared to current 11mm



Existing vs planned ID extrusions



Current “standard” ID straight section



Planned ID chamber extrusion

Courtesy: G.Wiemerslage, J. Lerch

Insertion Devices

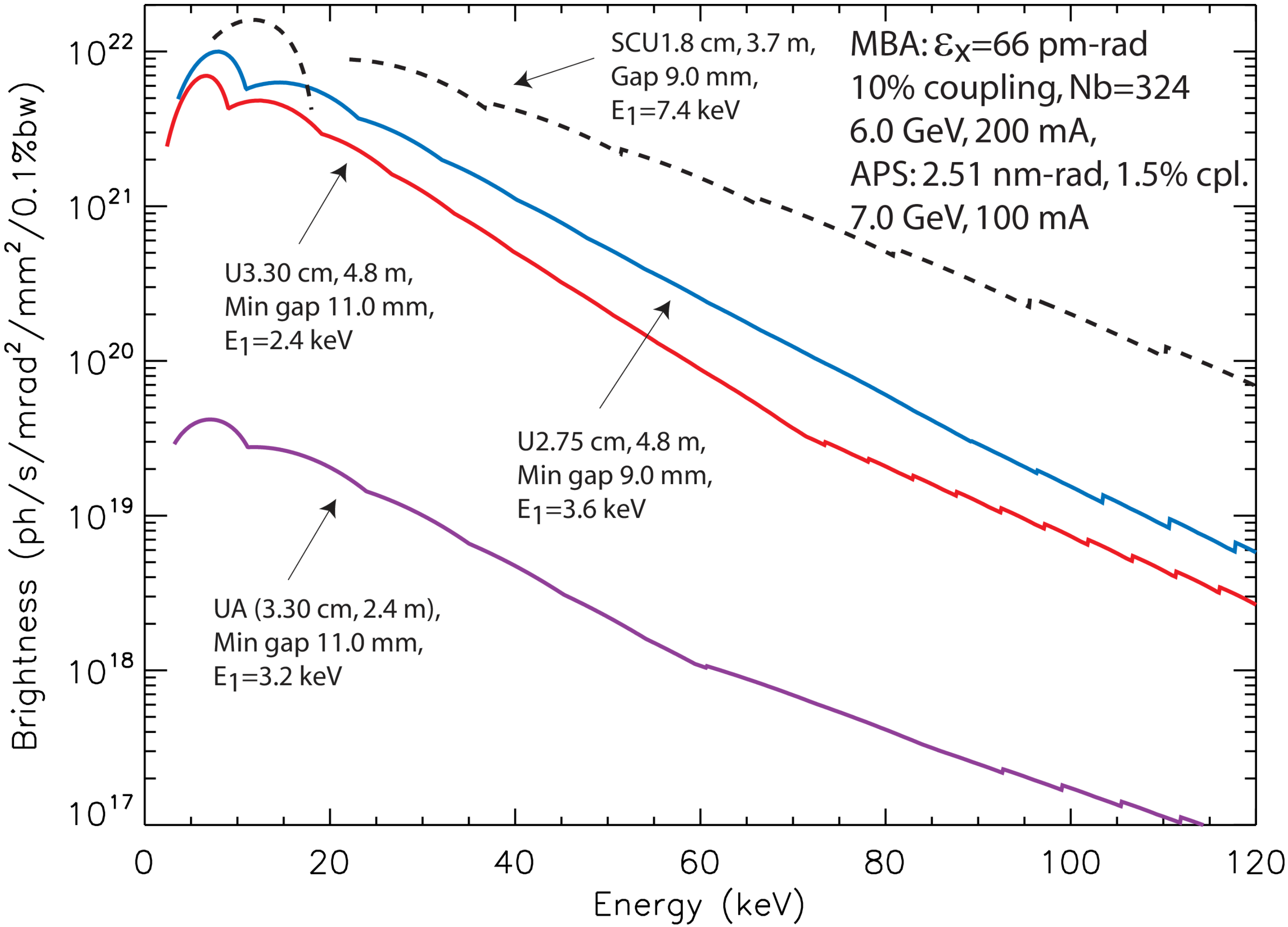
The reduction of Storage Ring energy from 7 GeV to 6 GeV will require reevaluation of undulator periods for APSU

Source (period)	Maximum K	Minimum ID Gap (mm)	Minimum Energy (keV)	Power (kW)	Power Density ($kW/mrad^2$)
APS* 3.3cm	2.66	11.0	3.2	5.45	158
APSU 3.3cm	2.66	11.0	2.4	8.0	171
APSU 3.3cm	3.33	9.0	1.7	12.52	215
APSU 2.75cm	2.29	9.0	3.6	8.55	212

All ID are 2.4 m long APS*: 7 GeV 100 mA APSU : 6 GeV 200 mA

All front ends in APSU will be upgraded to handle maximum power of 20 kW
Allows for full 4.8 m of ID inline or Two 2.1 m long ID in canted

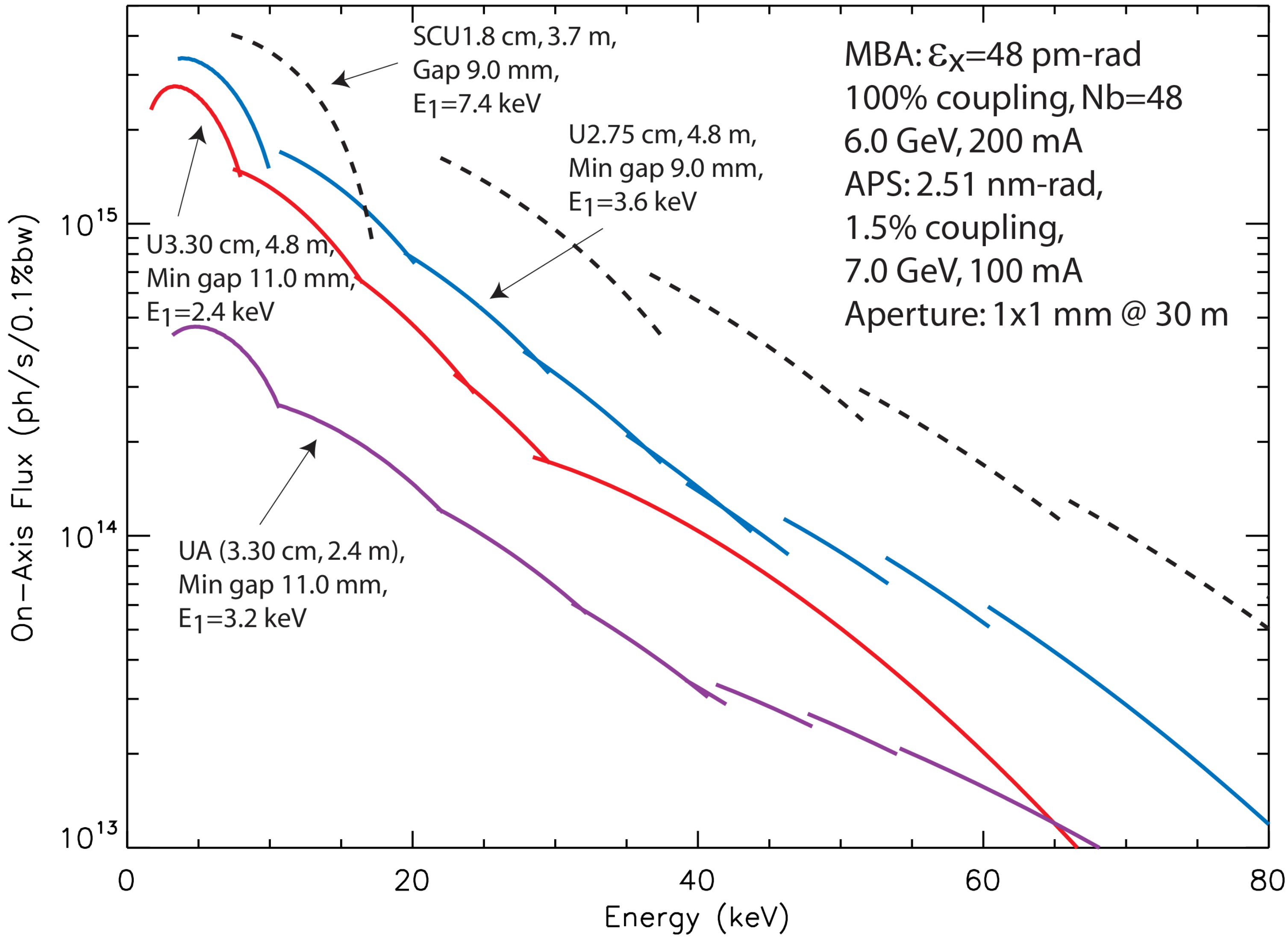
Insertion Devices - Brightness



The 2.75 cm period device will provide the optimum energy tunability

Courtesy: R. Dejus

Insertion Devices – Flux thru 1x1mm @ 30 m



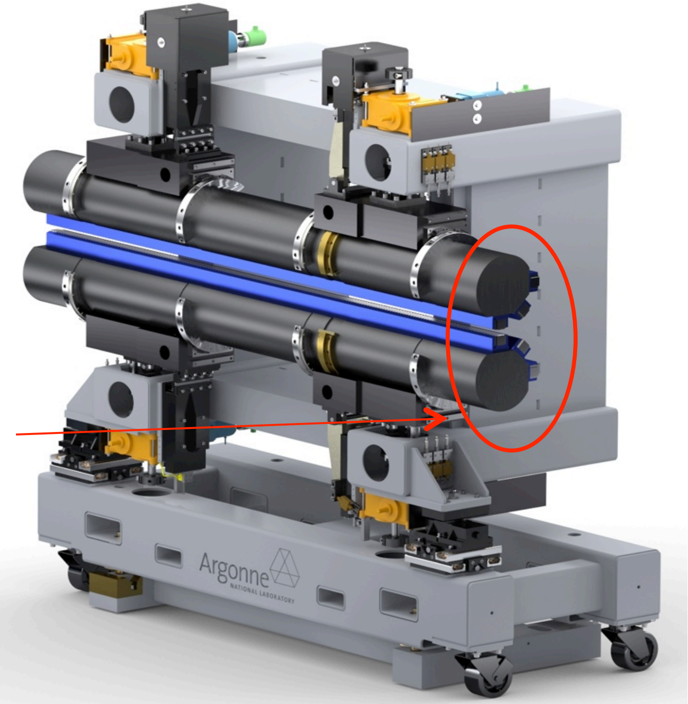
The 2.75 cm period device will provide excellent flux with full energy tunability

Courtesy: R. Dejus

Insertion Devices - Opportunities

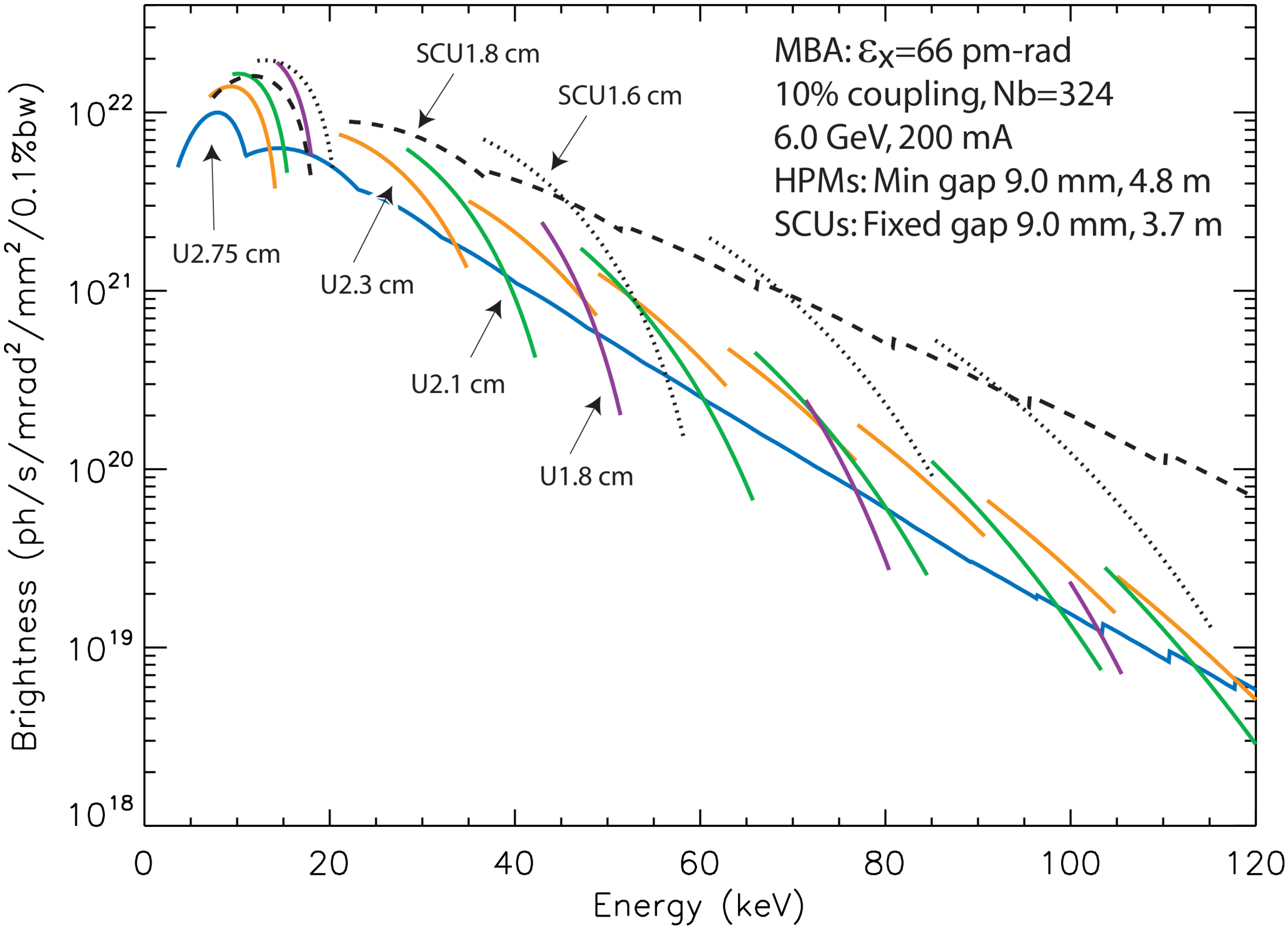
- Most of the hardware from the existing undulators will be reused
- New strong backs with new magnetic arrays will be fabricated and swapped out
- Existing hardware with new period and smaller gap will provide optimized ID's
- New ID vacuum chamber will accommodate a 3-headed revolver
  - 3 different periods on the same device to provide maximum brilliance over a large tuning range

Only new component



Courtesy: J. Grimmer, J.Mulvey, O. Schmidt

Revolvers – Maximize Brightness



Revolvers with 2 or 3 different periods will allow for maximizing the brightness at select energies while the power is low

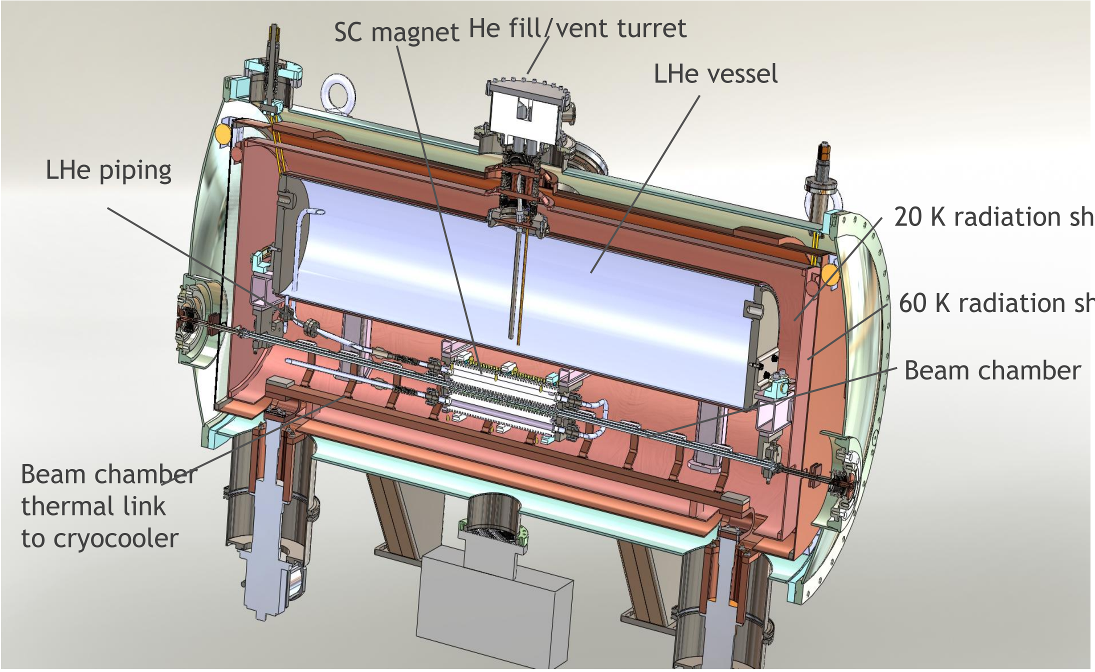
Courtesy: R. Dejus

Super Conducting Undulator

SCU0 Design Conceptual Points:

- Cooling power is provided by four cryocoolers
- Beam chamber is thermally insulated from superconducting coils and is kept at 12-20 K
- Superconducting coils are indirectly cooled by LHe flowing through the channels inside the coil cores
- LHe is contained in a 100-liter buffer tank with which the LHe piping and the cores make a closed circuit cooled by two cryocoolers
- Two other cryocoolers are used to cool the beam chamber that is heated by the electron beam

SCU0 structure

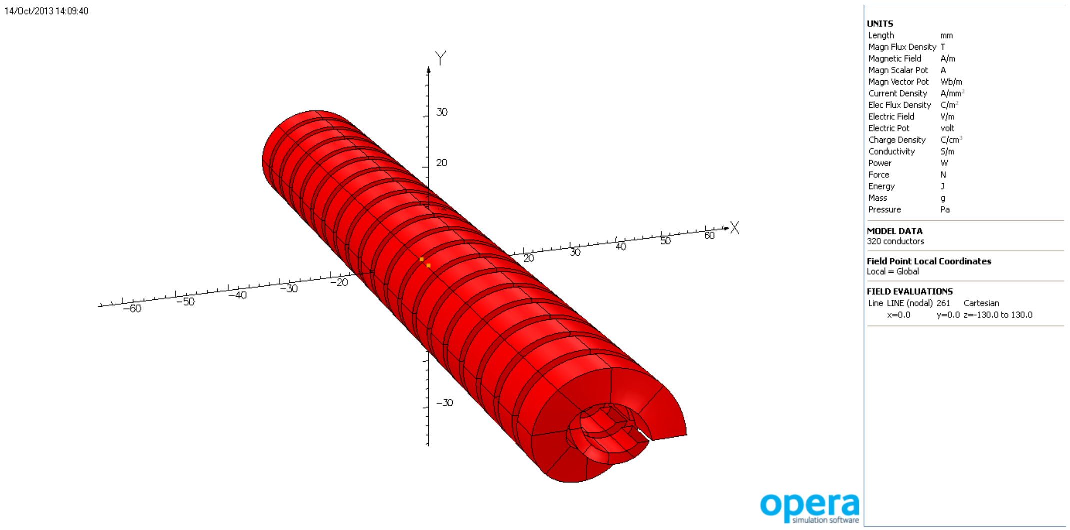


The design has been developed in the collaboration with the BINP, Novosibirsk

SCU1 of 1m has been built – MBA will take advantage of ongoing R&D for APS and LCLS

Courtesy: E.Gluskin

Helical Undulator – Concept for Variable Polarization



Inner bifilar coil:
Period: 16 mm
Winding bore: 6 mm
Winding: 6 mm (W) x 2mm (H)
Current density: 0 A/mm^2
or ±795.6 A/mm^2

Outer bifilar coil:
Period: 16 mm
Winding bore: 11 mm
Winding: 6 mm x 6 mm
Current density: 0 A/mm^2
or 1184.5 A/mm^2

Inner Coil	Outer Coil	Field Configuration
J = 795.6 A/mm^2	0	**Helical** B_y =0.68 T, B_x = 0.68 T
0	J = 1184.5 A/mm^2	**Helical (opposite helicity)** B_y =0.68 T, B_x = 0.68 T
J =795.6 A/mm^2	J = 1184.5 A/mm^2	**Vertical** B_y = 1.36 T, B_x = 0
J = - 795.6 A/mm^2	J = 1184.5 A/mm^2	**Horizontal** B_y = 0, B_x = 1.36 T

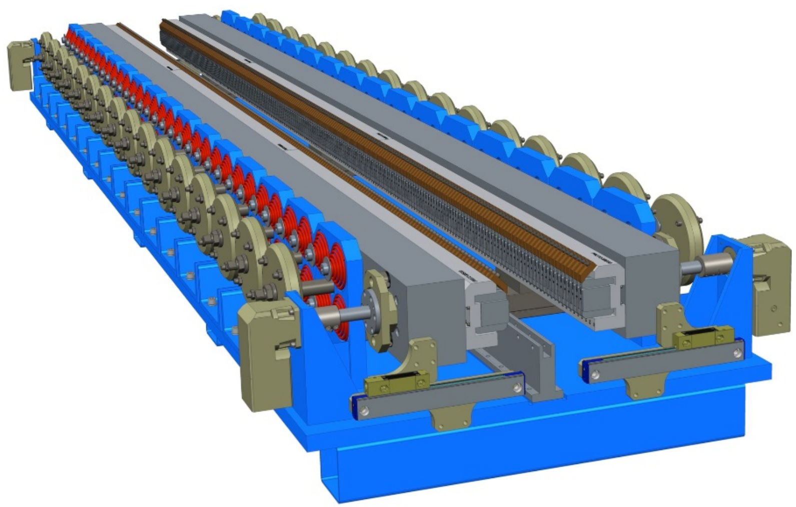
- This is a truly universal undulator that can create both planar and helical fields.
- All polarization modes could be switched with the frequency higher than 10 Hz.

MBA enables this type of device however engineering challenges exist

Courtesy: Y. Ivanyushenkov

Horizontal Gap Vertical Polarizing Undulator (HGVPU)

- Prototype built for LCLS
- MBA provides opportunity for HGVPU
- MBA lattice will allow for few rectangular ID chambers of internal aperture of 8 mm H x 6 mm V
- Possible 11 mm minimum ID gap

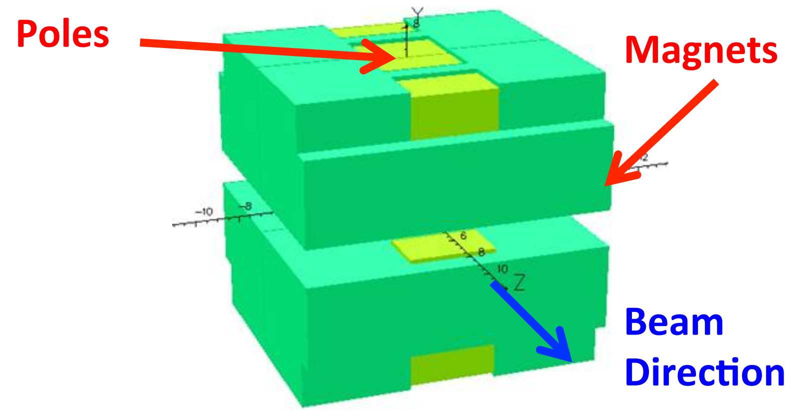


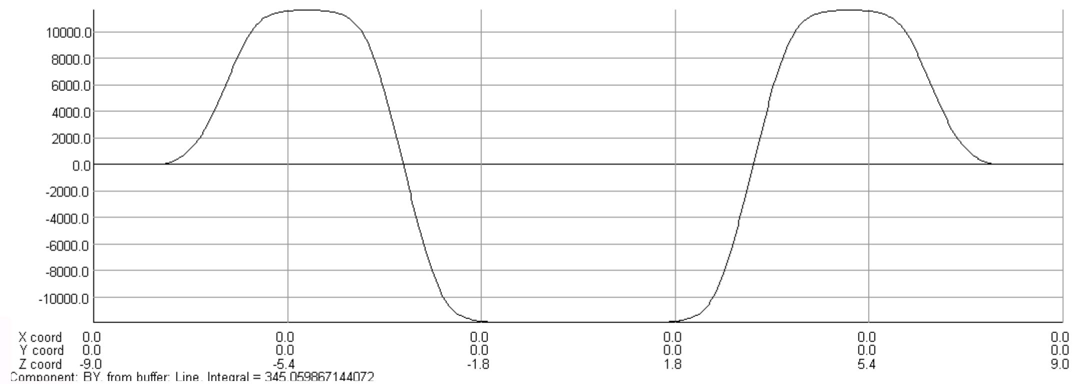
Synchrotron management challenges exist

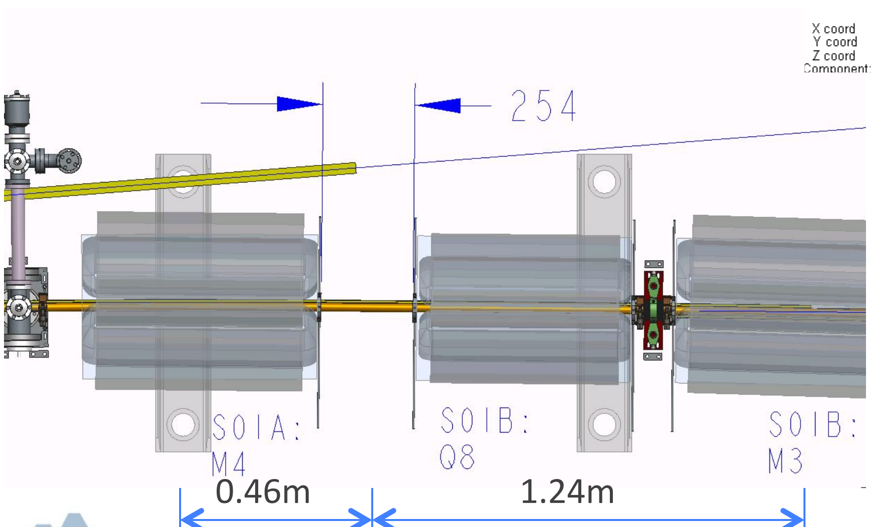
Courtesy: E. Gluskin

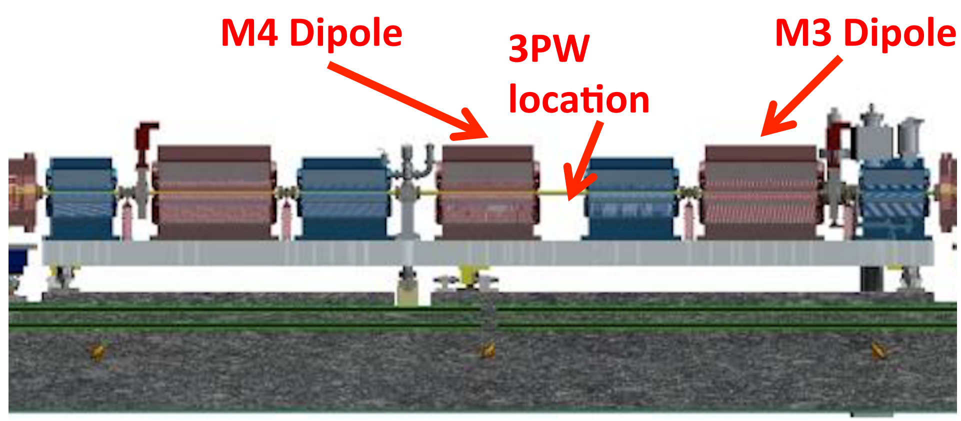
3-Pole Wiggler

- Provide a new source using a 3PW in place of a BM source
  - Available space of about 250 mm in the FODO section
  - Minimum magnetic gap of 26 mm
- Transverse gradient dipoles on either side of 3PW (M4 and M3)
- M4 has 0.66T and M3 has 0.6T peak fields









Courtesy: M.Abliz, B.Stillwell, J.Collins, B.Turner

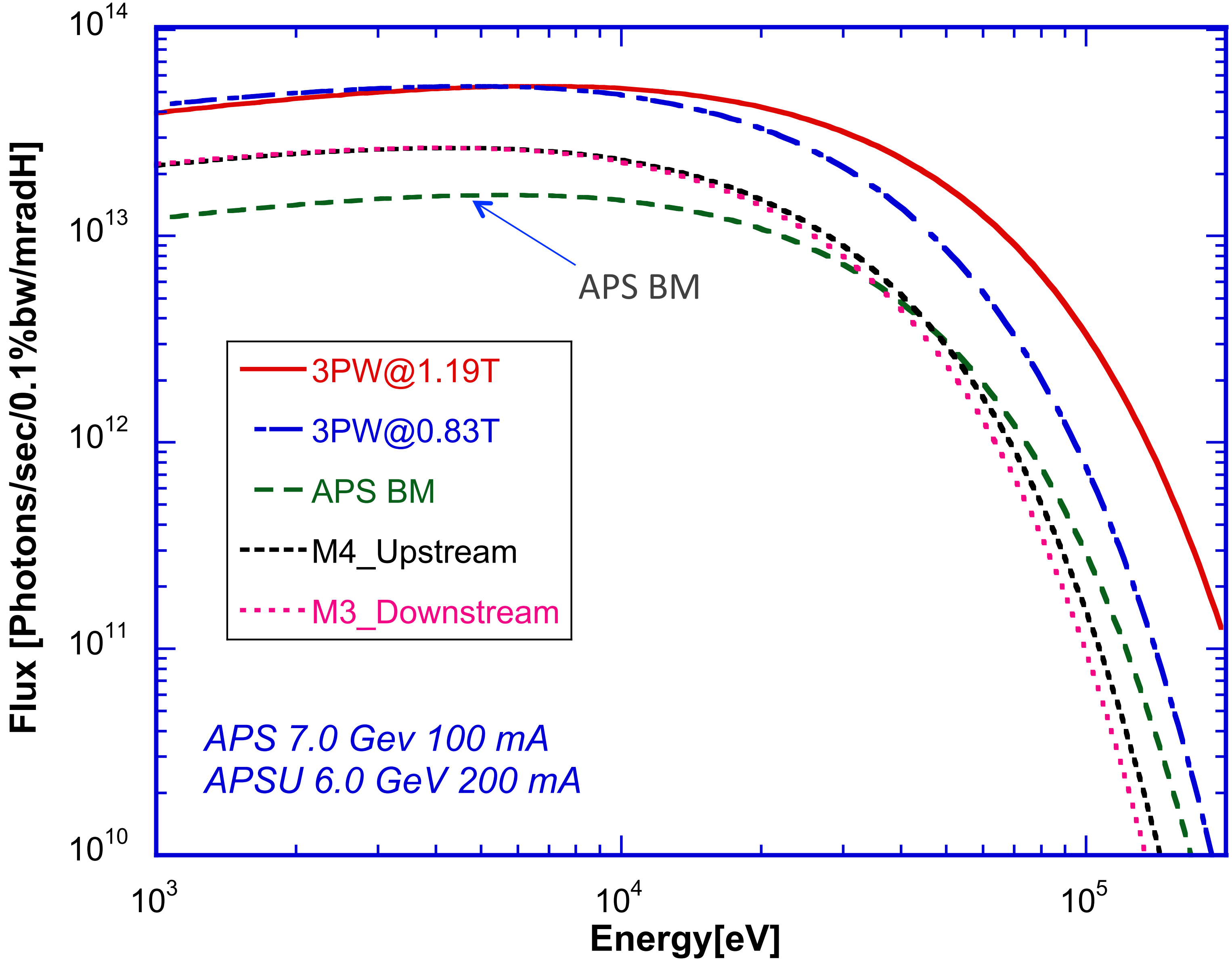
3-Pole Wiggler

The 3PW radiation fan will have contribution from the M4 magnet(located upstream) on the outboard side and the M3 magnet on the inboard side

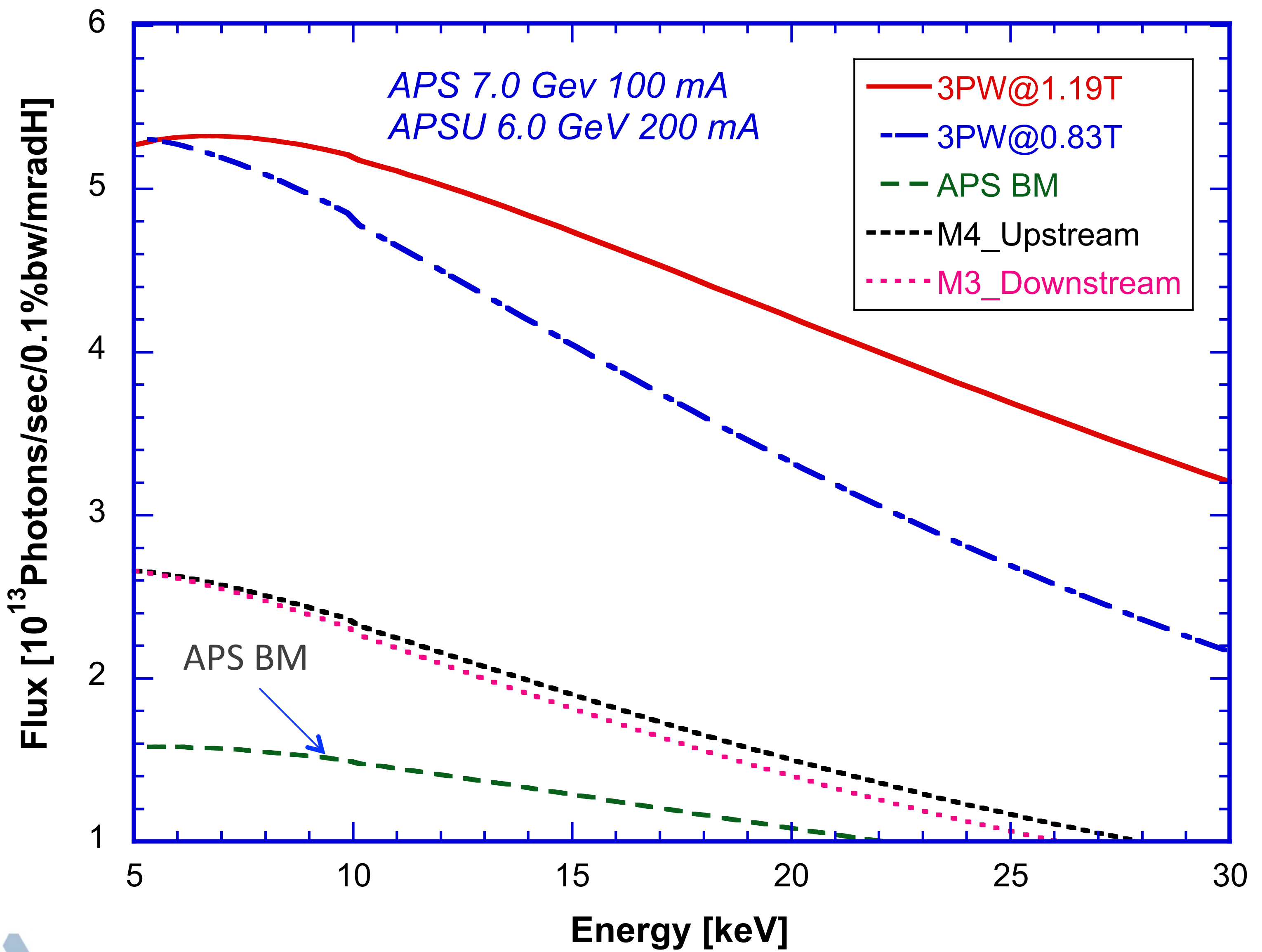
Magnet	Max Field (T)	Critical Energy (keV)	Horizontal Fan (mrad)	Total Power (W)	Power/mrad (W)
M4 Magnet Upstream	0.66	15.927	19.66	2303	117
M3 Magnet Downstream	0.60	14.776	22.18	2426	109
3PW-1.19T	1.19	28.494	3.35	1288	385
3PW-0.83T	0.83	19.874	2.34	627	268
APS BM (current)	0.599	19.519	78.5	6822	87

Current BM FE allows horizontal fan of 6 mrad
Magnets above are for APSU 6 GeV 200 mA except APS BM which is 7 GeV 100 mA

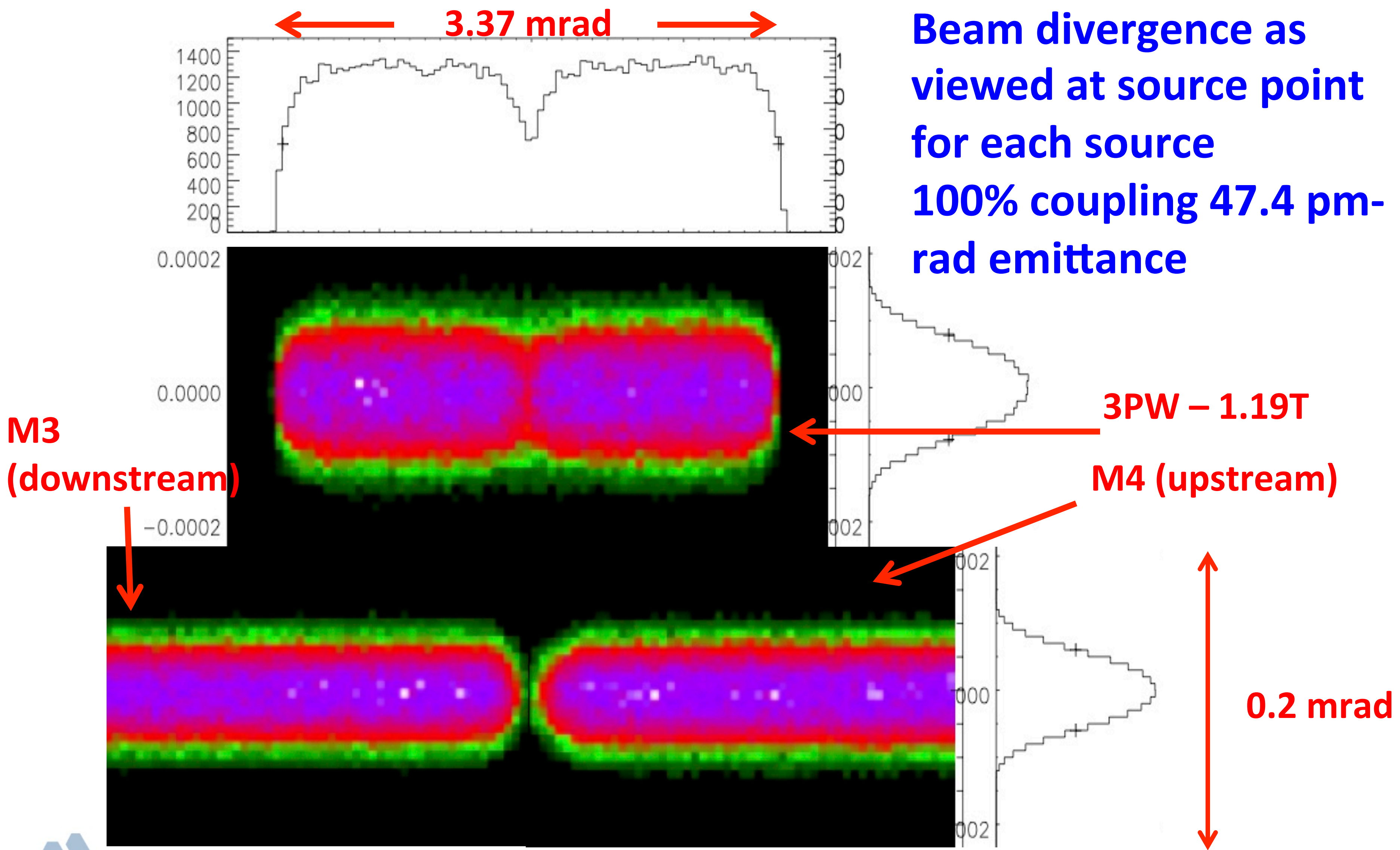
3-pole Wiggler – Flux Comparisons



3-pole Wiggler – Flux Comparisons over 5-30 keV

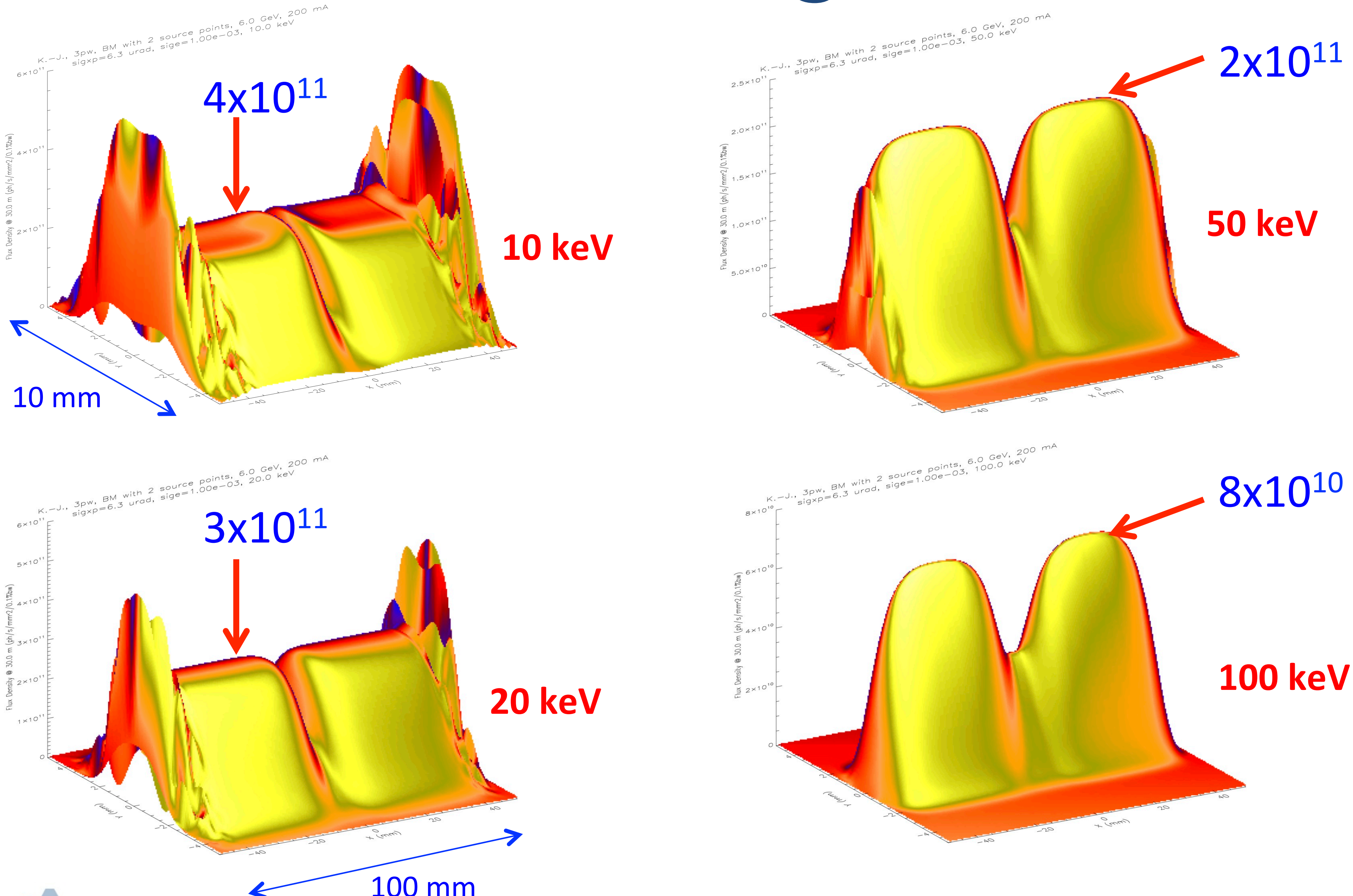


3-Pole Wiggler – Flux Distribution @ 20 keV



Beam divergence as viewed at source point for each source 100% coupling 47.4 pm-rad emittance

Flux Densities for 3PW-1.19 T @ 30 m



Courtesy: R. Dejus

Summary

- Work on optimization of ID's has started
- Opportunity for customization of ID's to suit user needs
- Design concepts for 3-pole wiggler exist
- Optimization of 3PW has started

- Good handle on understanding the challenges
- Planning underway to tackle some of the challenges…