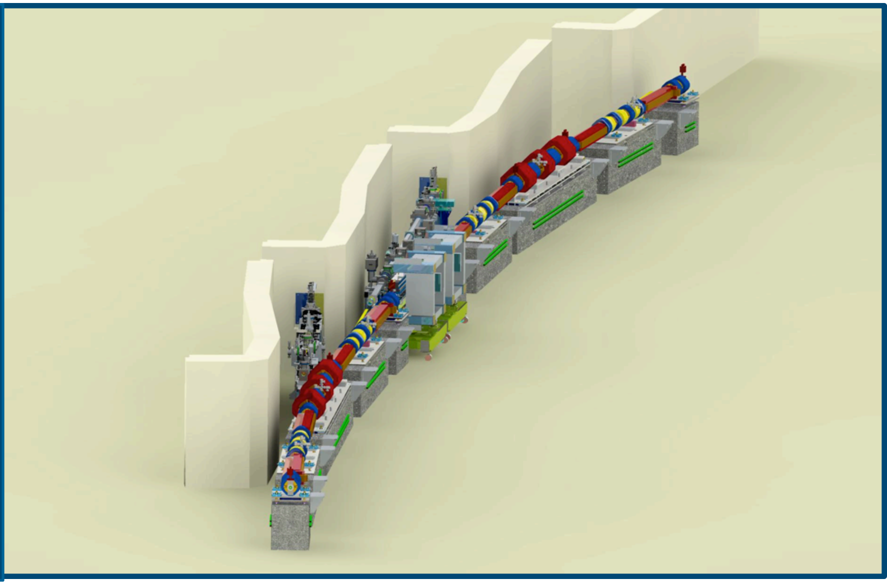
Bending Magnet Beamline Sources



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APS-U Forum
December 8, 2016

Outline

- BM beamline sources
- Source properties
- Flux comparisons
- Power load considerations
- Focused BM sources
- BM source – options
- Summary

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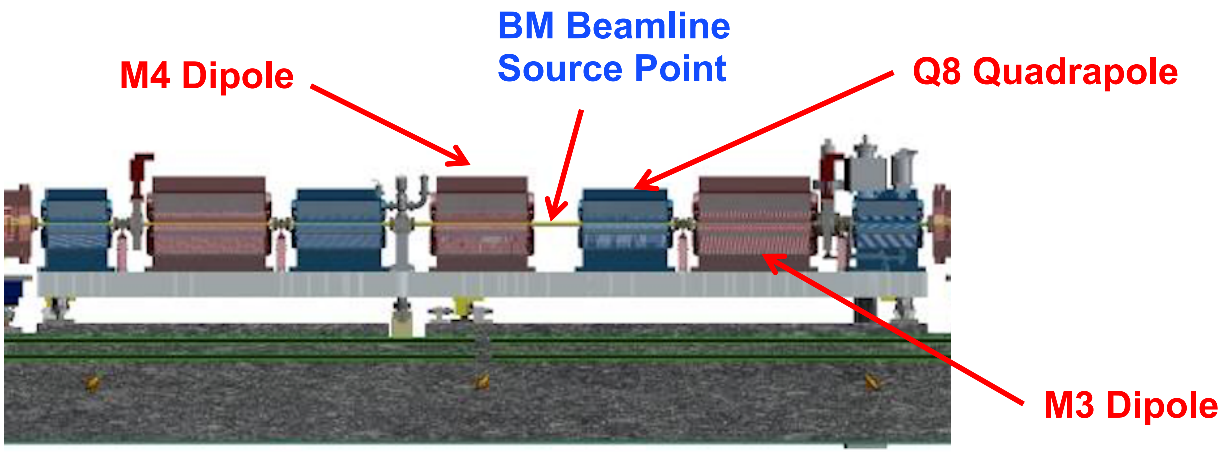
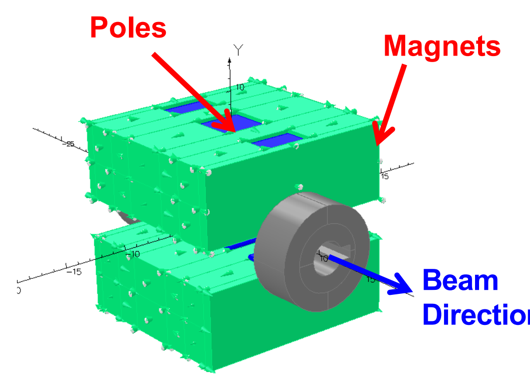
BM Beamline Sources

- MBA lattice poses new challenges for the existing BM source beamlines
- Current APS BM beamlines accepts 6 mrad fan (1/8 into the B dipole magnet)
- In the MBA lattice the same tangent point for the center of the fan is
  - Between M4 Dipole Magnet and Q8 Magnet in the FODO section
  - Space of about 250 mm is available for insertion of a 3 Pole Wiggler(3PW)
  - Minimum magnetic gap of 26 mm
  - The source point is shifted upstream 2.929 m
  - The source point is laterally shifted inboard by 43.4 mm
- Due to the shift in source point only 5.2 mrad can be extracted through the front end into the beamline FOE (defined by BM front end fixed mask 3 @ 18.513m)



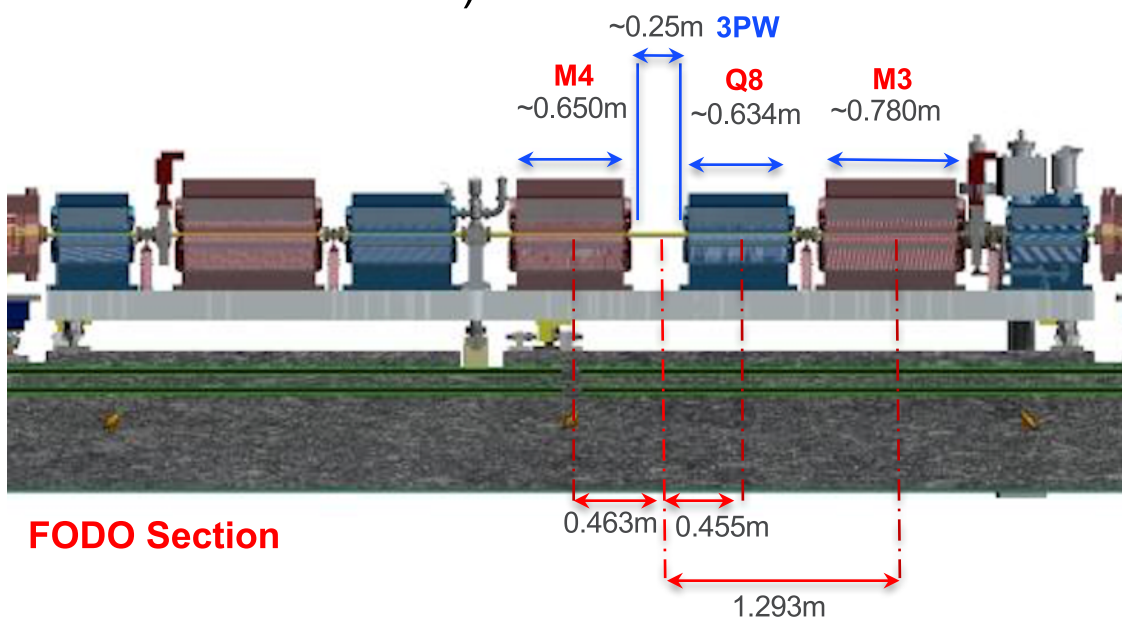
FODO Section



3 Pole Wiggler

BM Beamline Sources

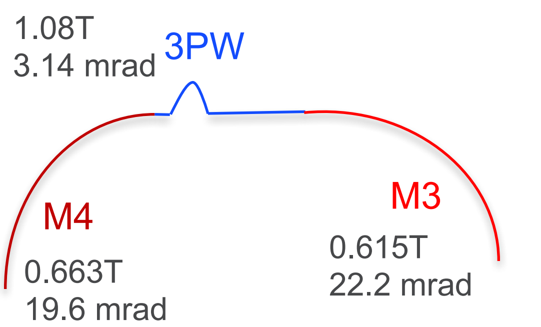
- Any Wiggler inserted in the small space of 250 mm cannot produce the required 6 mrad fan
- The BM radiation fan will be a combination of the two dipoles on either side, the Q8 Quadrapole and the 3 pole wiggler
- Two alternates were explored for the source point:
  - 3PW center as center of fan will result in a parallel translation of 43.4 mm inboard
  - Shift the fan center upstream by 1.2 mrad into M4 magnet results in a lateral shift of 17.5 mm inboard at fixed mask 3 @ 18.513m and is displaced 20 mm outboard @ 50 m (APS current distance)

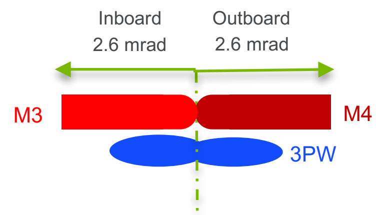


BM Beamline Sources - Schematic

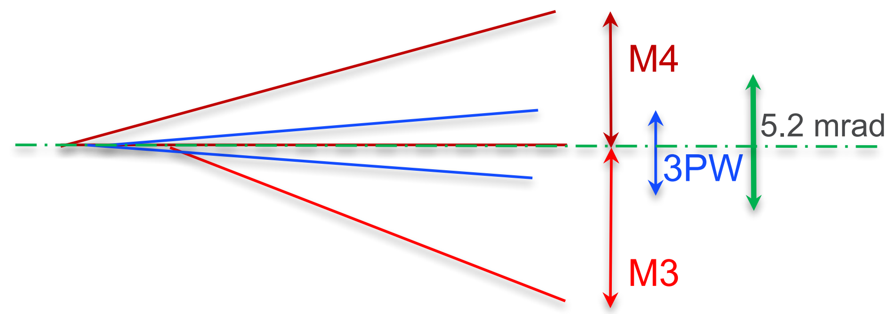
APS Upgrade is in the process of finalizing on a new 41 pm Reverse Bend Lattice

67 pm lattice Orbit



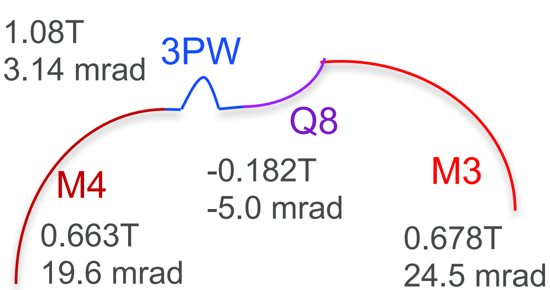


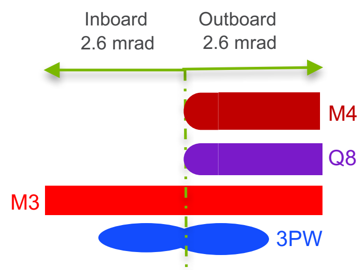
View from beamline



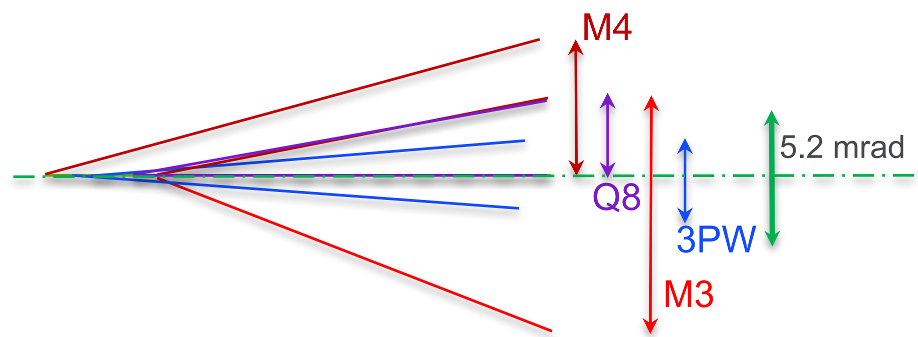
Radiation Fans

41 pm Reverse Bend lattice Orbit





View from beamline



The BM sources are a combination of multiple sources at different source distances (~ 1 m apart) and vary from inboard to outboard as well

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BM Source Properties

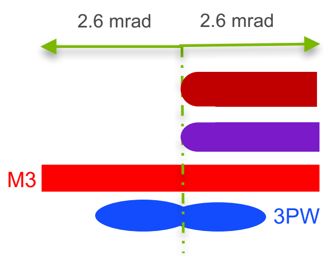
Magnet	Max Field (T)	Critical Energy (keV)	Horizontal Fan (mrad)	Ave Power/mrad (W)	Max Power Density (W/mm^2)
APS BM (current)	0.599	19.519	78.5	87	1.24
M4 Magnet Upstream	0.663	15.872	19.6	121	1.18
M3 Magnet Downstream	0.678	16.232	24.5	124	1.34
Q8	0.182	4.357	-5.0	33	0.33
3PW-1.08T	1.08	25.916	3.1	305	3.53
Outboard (M4+M3+Q8)			2.6*	278	2.85
Inboard (M3)			2.6*	124	1.34
Outboard (M4+M3+Q8+3PW)			2.6*	583	6.38
Inboard (M3+3PW)			2.6*	429	4.87

Power Density is at current 25 m point from the source (Current APS BM source)
All MBA sources have been adjusted to reflect the distance from sources (~ 3m upstream)
Magnets above are for APSU 6 GeV 200 mA except APS BM which is 7 GeV 100 mA
* Amount of radiation accepted by BM front end as determined by the fixed mask 3
Fields shown for M3, M4 and Q8 are higher than the lattice design to take into account the real magnet design and are approximate and expected to change

Existing BM front ends were designed for 261 W/mrad and can handle the combined power loads without the 3PW.

BM Sources- Flux Comparisons

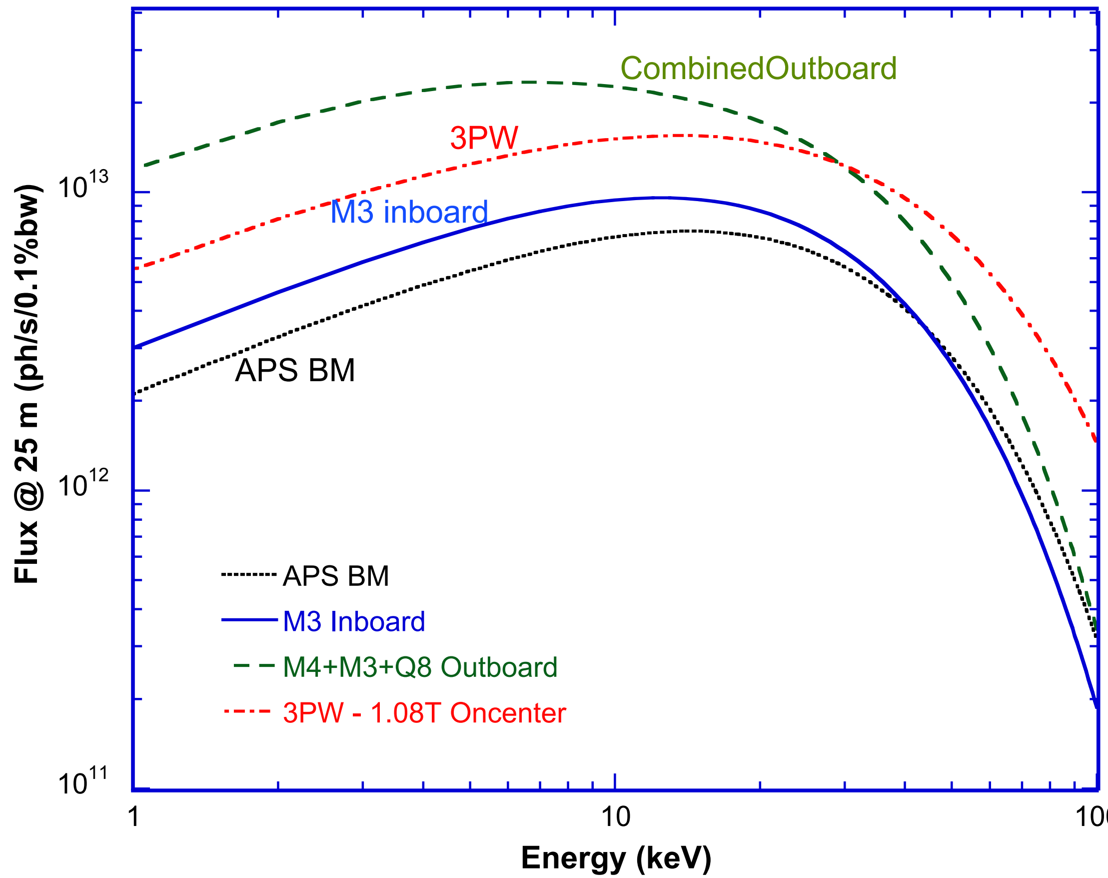
Flux through a 25mm H x 2mm V aperture at current 25 m point (Typical monochromators location). All sources distances has been adjusted



View from beamline

M3 Inboard radiation has a cross over with APS BM @ ~ 43 keV

Combined Outboard radiation has a cross over with APS BM @ 100 keV



Flux on BM beamlines is higher than existing BM source for all energies upto 100 keV without the 3PW and with very little increase in power and power density

BM Source: Power Load Considerations

Magnet	Max Field (T)	Critical Energy (keV)	Horizontal Fan (mrad)	Total Power (W)	Power Density (kW/mrad^2)
APS BM (100 mA)	0.599	19.519	6	522	0.780
APS BM (300 mA)	0.599	19.519	6	1566	2.342
M4 Magnet Upstream	0.663	15.872	2.6	315	0.937
M3 Magnet Downstream	0.678	16.232	2.6	322	0.958
Q8	0.182	4.357	2.6	86	0.256
3PW-1.08T	1.08	25.916	3.1	957	2.755
Outboard (M4+M3+Q8)			*2.6 (accepted)*	*723*	*2.151*
Inboard (M3)			*2.6 (accepted)*	*322*	*0.958*
Without 3PW			5.2	1045	2.151
Outboard (M4+M3+Q8+3PW)			*2.6 (accepted)*	*1202*	*4.906*
Inboard (M3+3PW)			*2.6 (accepted)*	*801*	*3.713*
With 3PW			5.2	2003	4.906

Need thermal simulations on front end masks and shutters and windows for determining the capability for handling 3PW power loads

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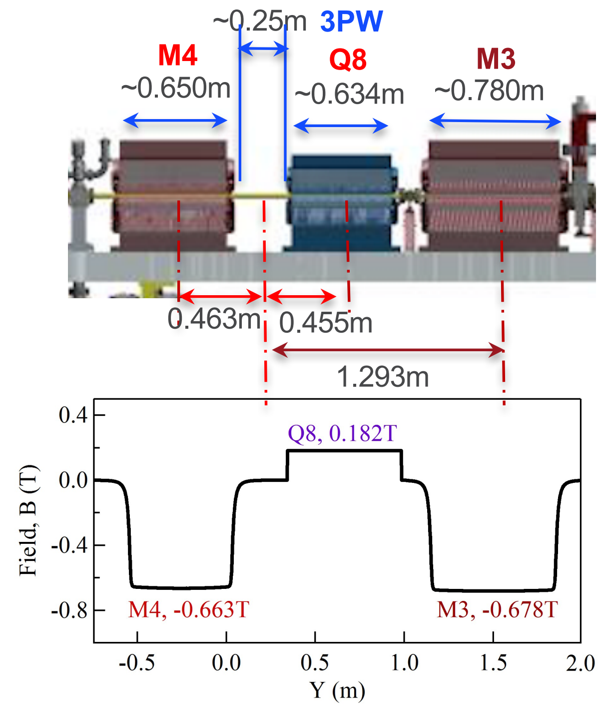
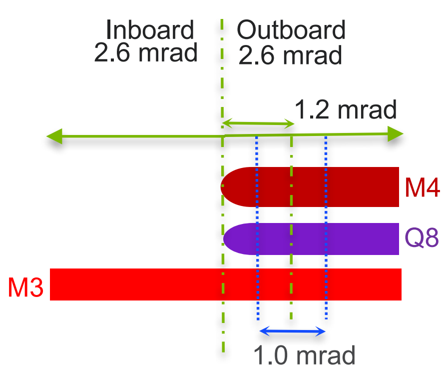
Shadow Simulations

- The source includes the M4, Q8 and M3 radiation
  - Transverse plane (x-horizontal, z-vertical), Propagation direction (y-longitudinal)
- Calculated energies: 5, 20, 50 keV
- Electron beam emittance
  - $\epsilon_x = 4\text{e-}11$ m·rad, $\epsilon_y = 4\text{e-}12$ m·rad
- Optics layout
  - Fixed mask (FM) at 18.5 m to cut the horizontal fan, Ideal mirror (1:1 focus) at 30 m to imaging the source





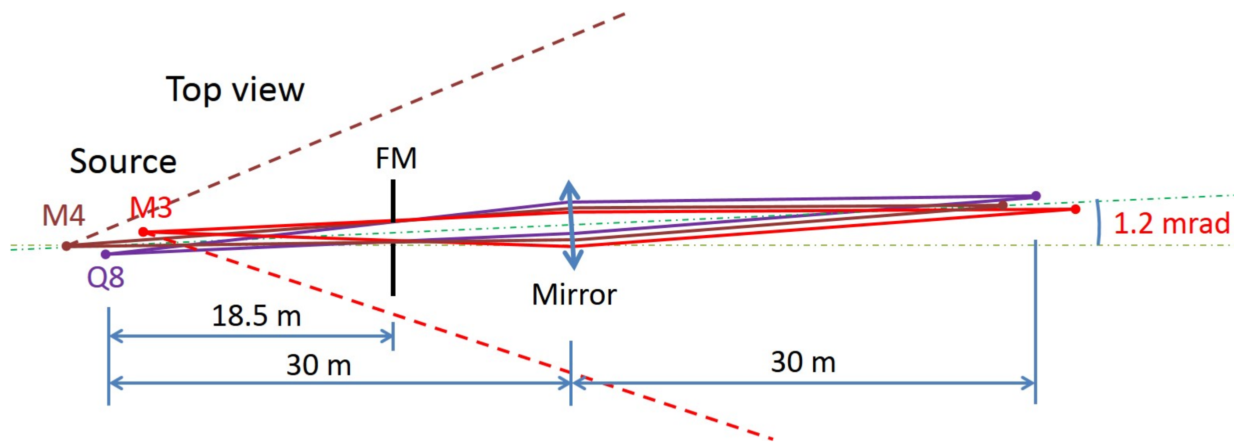
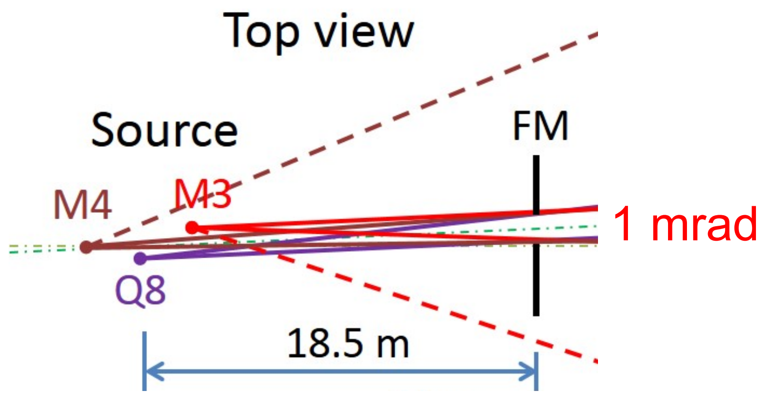
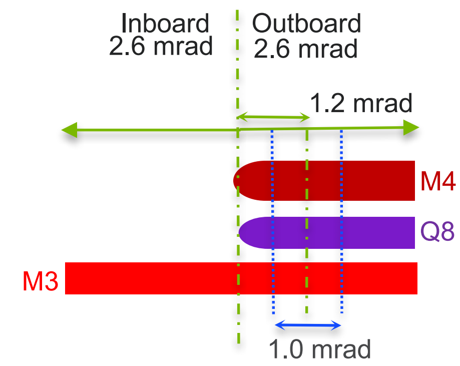


Image M4-Q8-M3 unfocused beam





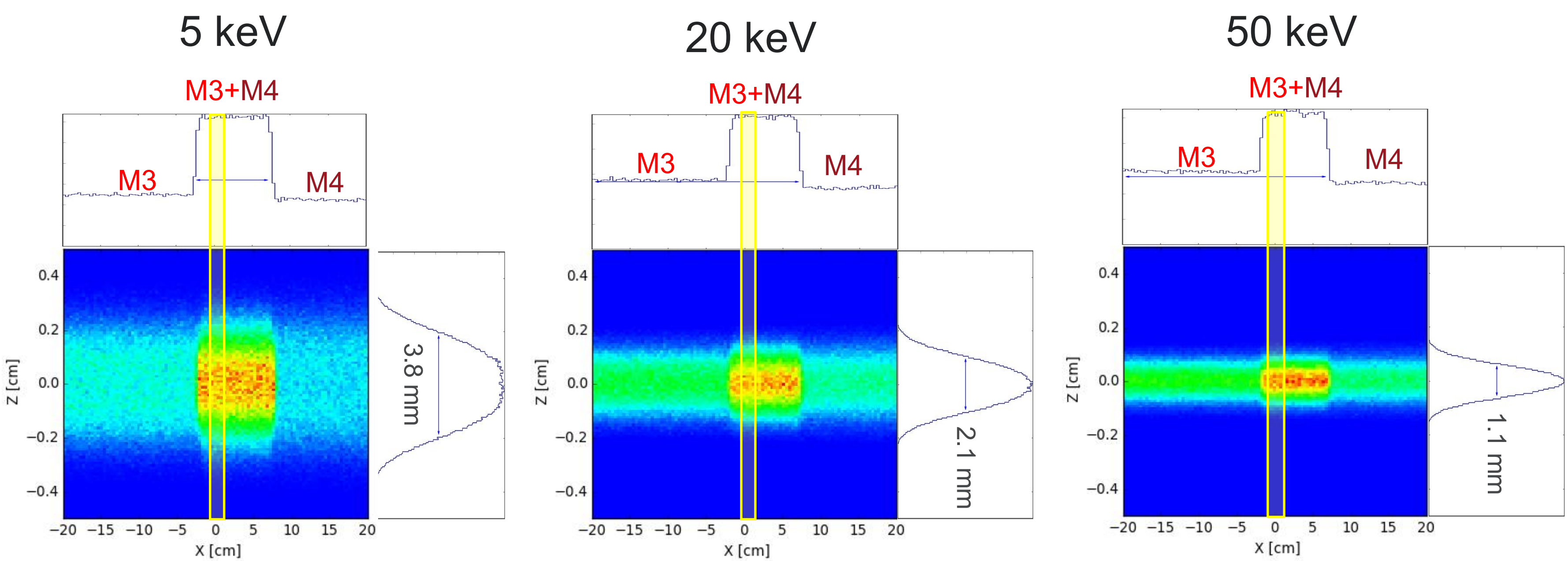


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Image M4-Q8-M3 focused beam

- Shadow simulation at 20 keV, beam centered at 1.2 mrad outboard, Fixed mask takes 1 mrad beam.

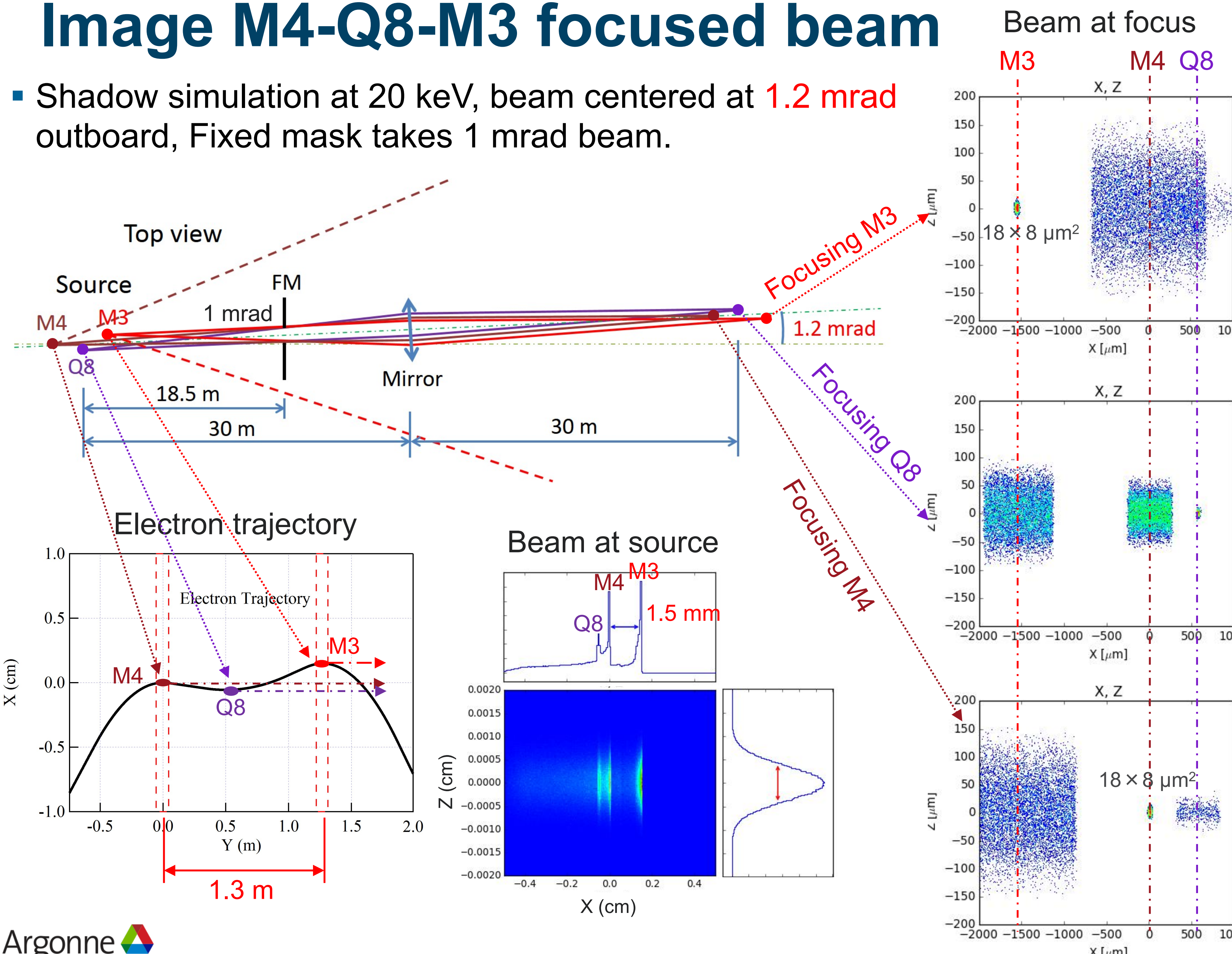
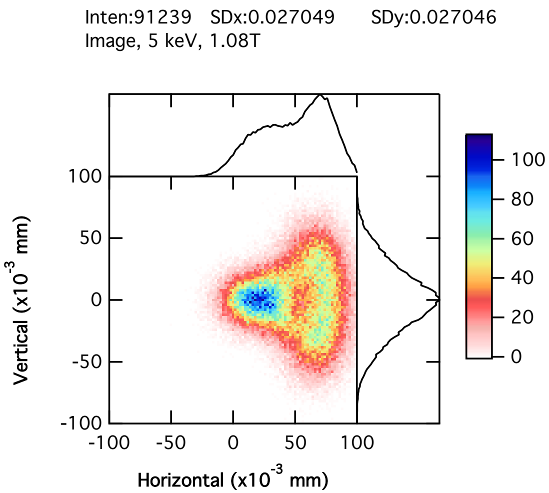
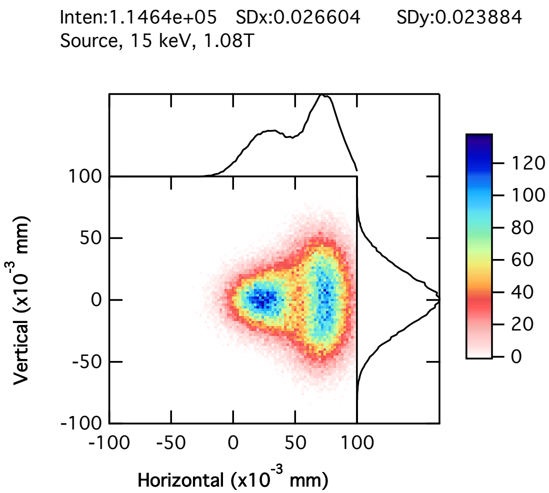


Image the 3PW source (1:1)

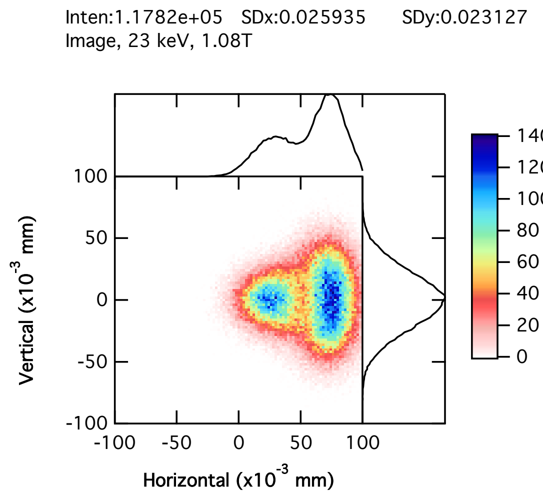
5 keV



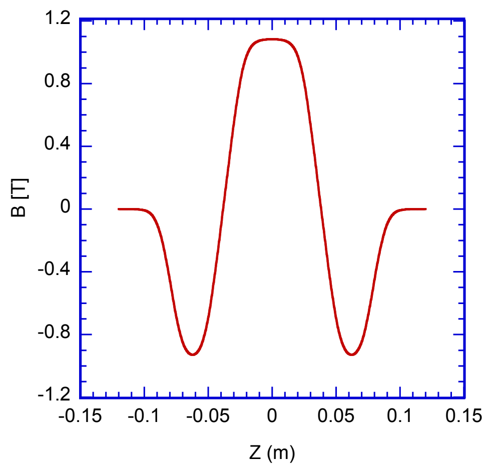
15 keV



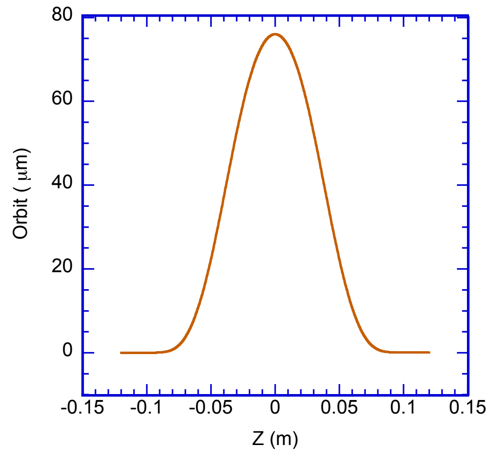
23 keV



3PW Field



Electron Orbit



3PW Radiation Fan

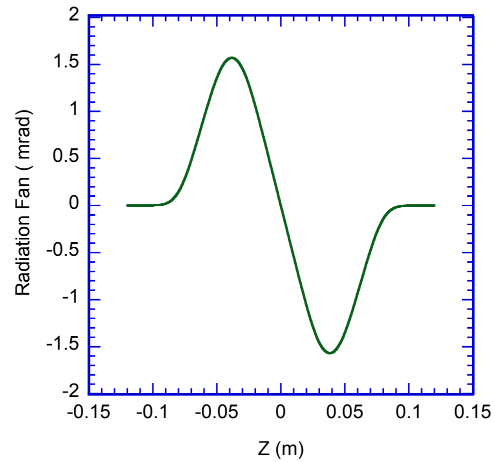


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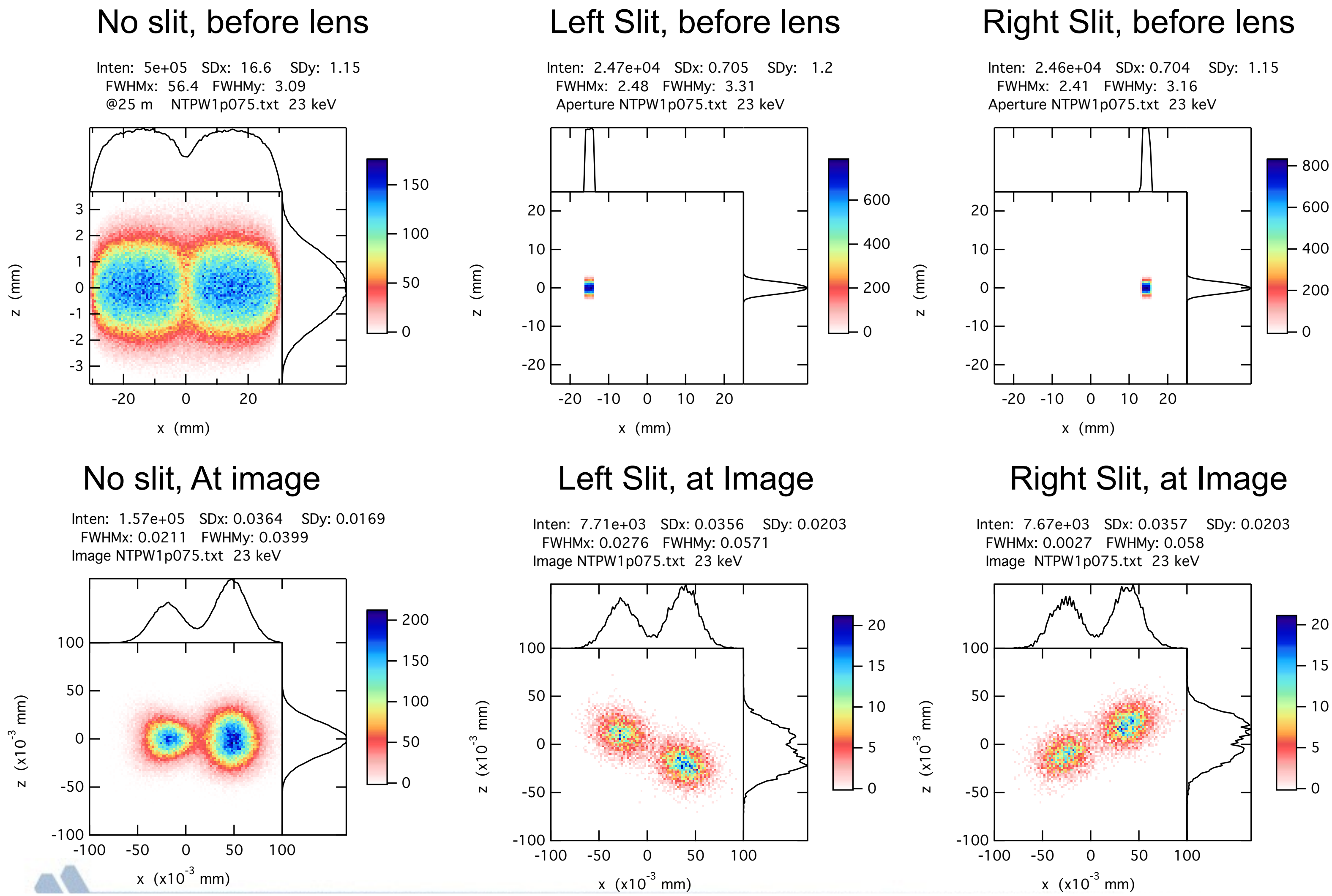
Image the 3PW with and without slits

Beam @ 25 m 1:1 mirror position and at Focus for 23 keV



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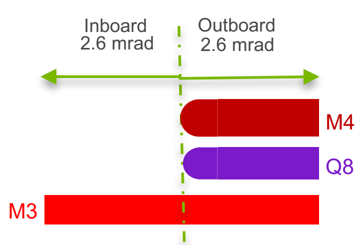
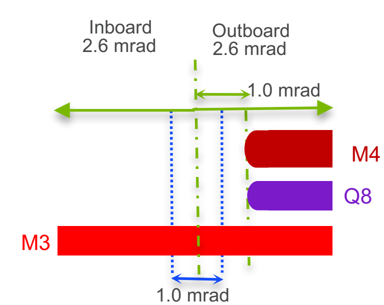
Courtesy : Ruben Reininger

BM Beamline Source Options

- If the 3PW as a source is not considered as an option there are few choices on the selection of the source point.
- Keep the radiation fan center at 3PW source point
  - Whole beamline laterally shifted 43.5 mm inboard
  - 2.6 mrad of clean M3 radiation on inboard side
  - About 0.5 mrad of edge radiation starting from the center and towards outboard
- Shift the radiation fan center downstream by 1.0 mrad away from M4 Magnet
  - Whole beamline will be rotated 1.0 mrad inboard with the 25 m point shifted laterally inboard by ~ 71.3 mm
  - Outboard fan of 1.6 mrad will be combination of M3 M4 and Q8 and 1 mrad of clean M3. The 1.6 mrad of combined fan will have about 0.5 mrad of edge radiation from Q8 and M4
  - Inboard will be 2.6 mrad of clean M3.
- Modify the lattice to weaken the M4 and increase the M3 to
  - Shift the combined radiation away from the center by upto 1 mrad
  - Keep the center of the radiation a lateral shift only by < 50 mm inboard
  - Advantage in this scheme is the clean M3 radiation in the central 1 mrad without any edge effect



Centered on 3PW



Shifted downstream 1 mrad

Summary

- The MBA lattice does not have a clear dipole source for existing BM beamlines
- The 41 pm Reverse Bend Lattice provides a BM source combined from multiple magnets
- The new source point has shifted further upstream by 2.929m relative to the current source
- The spectral and spatial properties of the radiation fan for the new BM source will be different on the inboard and outboard sides
- The dipoles sources do provide a good source with a modest increase of power and power densities
- The 3PW source poses challenges for front ends and beamlines with a large increase in power and power densities
- Space available for 3PW is still being determined – Poses challenges on a clean 3PW design
- The 3PW source lies on top of M3 radiation on one side and combined radiation on the other side. Focusing any of the combined sources will result in separate focus spots
- The inboard clean M3 radiation will focus clearly without any interference
- More work needed to optimize the lattice and improve the M3 radiation to increase critical energy to provide higher flux at higher energies