Australian Government

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The Next Generation Australian Synchrotron

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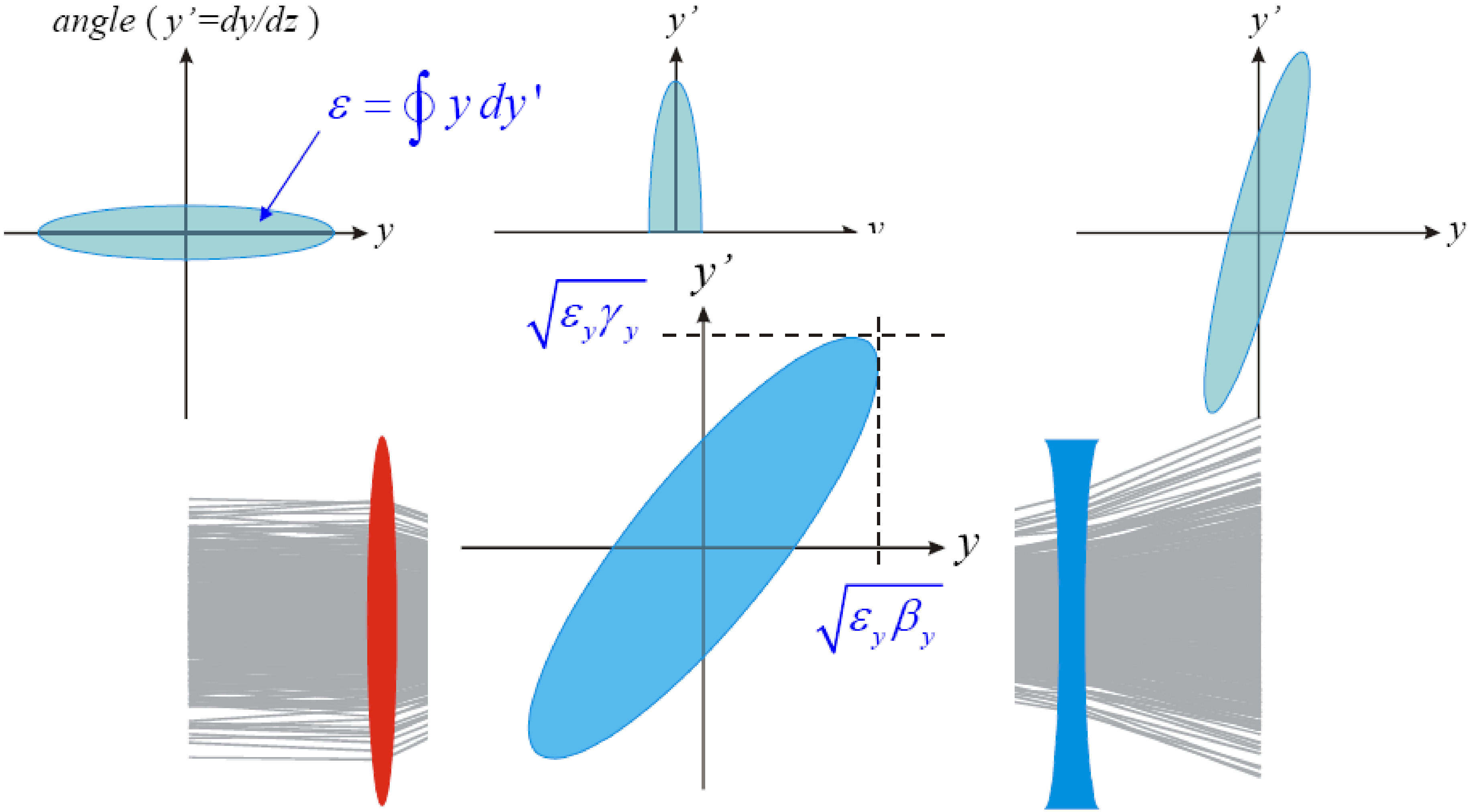
Science. Ingenuity. Sustainability.

Overview

- Introduction to emittance and lattice design
- Quick look at issues with upgrading the current lattice.
- Overview of our proposed design
- Comparison of optics parameters with existing Australian Synchrotron.
- Conclusion

Beam Basics – Phase space and emittance



Emittance in Storage rings.

- Horizontal emittance of a storage ring depends on the lattice, beam energy and bending angle. Lattice choice often a compromise of theoretical minimum emittance and other considerations.

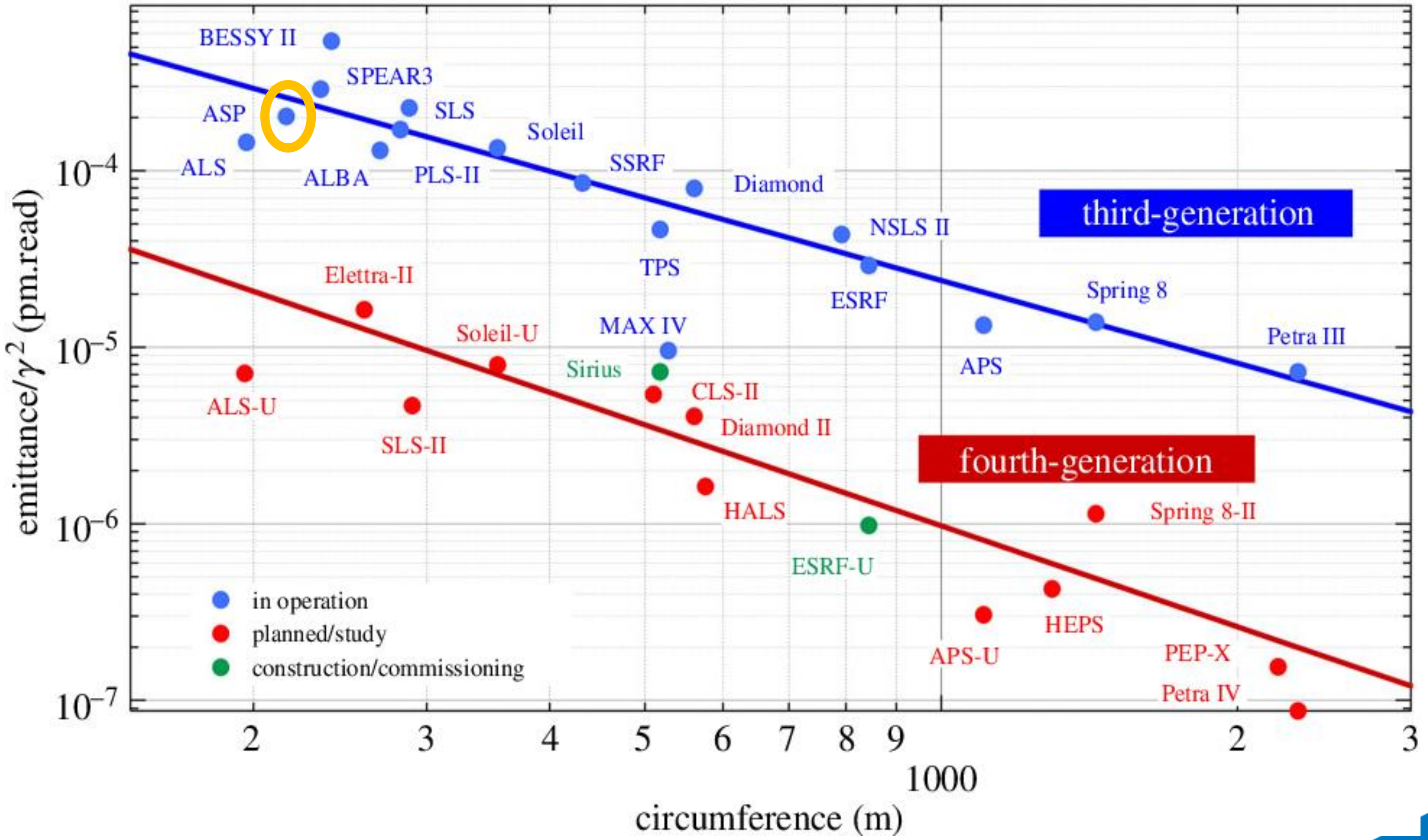
Lattice Energy 1/Circumference

Table 1: Minimum natural emittance in different lattice styles for electron storage rings: for each lattice style, the minimum natural emittance is given by $\boxed{\mathcal{F} C_q \gamma^2 \theta^3}$, where $C_q \approx 3.832 \times 10^{-13}$ m and γ is the relativistic factor for the beam. The dipoles have length L and bending angle θ, and no quadrupole component.

Lattice style	$\mathcal{F}$	Conditions
90° FODO	$2\sqrt{2}$	$f = L/\sqrt{2}$
137° FODO	1.2	Minimum emittance FODO
DBA	$\frac{1}{4\sqrt{15}}$	$\eta_{x,0} = \eta_{px,0} = 0, \quad \beta_{x,0} \approx \sqrt{12/5}L, \quad \alpha_{x,0} \approx \sqrt{15}$
MBA	$\frac{1}{12\sqrt{15}}\left(\frac{M+1}{M-1}\right)$	M dipoles (with same radius of curvature) per cell
TME	$\frac{1}{12\sqrt{15}}$	$\eta_{x,\min} \approx \frac{L\theta}{24}, \quad \beta_{x,\min} \approx \frac{L}{2\sqrt{15}}$

Emittance vs. Circumference.

- Emittance scales as Energy^2/Circumference^3
- Ways to reduce emittance:
  - Lower energy
  - Raise circumference
  - New lattice technology
- However circumference is a major cost driver of a facility due to civil engineering costs



Survey of Some 4th Generation Light Source Lattice Parameters

- Table contains Main physics parameters of 4th Generation light source lattices, both built and planned.
- To be competitive on brightness, we need to be > 0.2 nmrad Horizontal emittance.
- 3 GeV sources are all 500m+ circumference.

Lattice	MAX IV	HMBA	SIRIUS	DDBA	DTBA	S6BA	SLS-II	SOL-2
Circumf. (m)	528	506.28	518.4	561	561	259.2	290.4	354.7
Periods	20	22	20	24	24	12	12	20
Achr.-Length (m)	26.4	23.013	25.92	23.375	23.375	21.6	24.2	17.735
Energy (GeV)	3	3	3	3	3	2	2.4	2.75
Emittance (pmra	328	141	250	272	101	255	102	72
Tune_Qx	44.06	53.6	48.1	51.21	57.45	33.1	37.2	55.2
Tune_Qy	17.76	15.43	13.17	17.31	20.362	9.2	15.3	18.2
Chrom._ξx	-51.47	-87.86	-124.4	-129	-78.15	-75	-95	-134
Chrom._ξy	-51.37	-70.78	-79.9	-93.51	-109.7	-51	-35.2	-125

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Designing a ring

- Lattice optimisation needs to take into account
  - Ring circumference,
  - Energy
  - Desired photon energy range
  - Dynamic aperture and momentum acceptance (injection and lifetime)
  - Available technology (especially magnets)

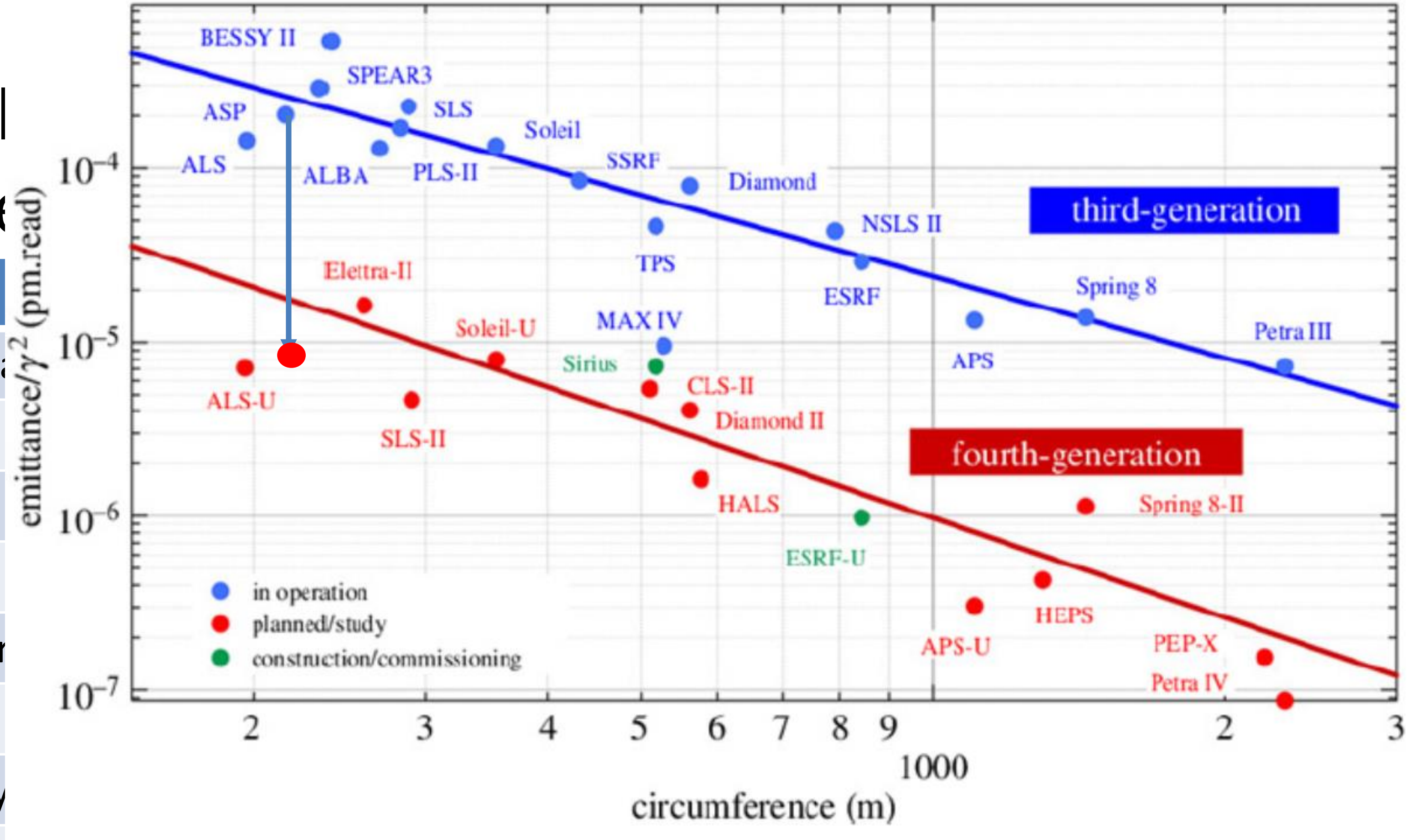
- What is optimal for one facility does not necessarily translate to another.

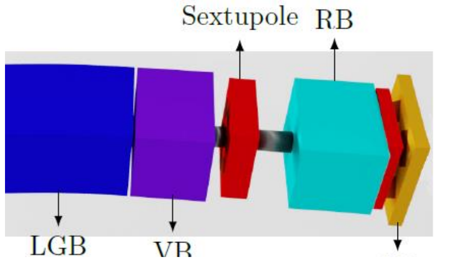
- Choice of prioritisation of needs to be led by a Science strategy
  - What I will present today is a preliminary design.

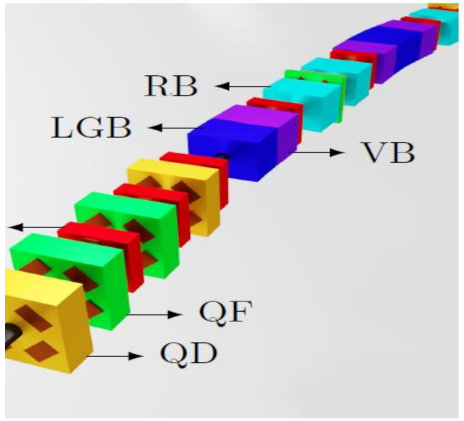
Upgrade design of exisiting 216m Storage Ring

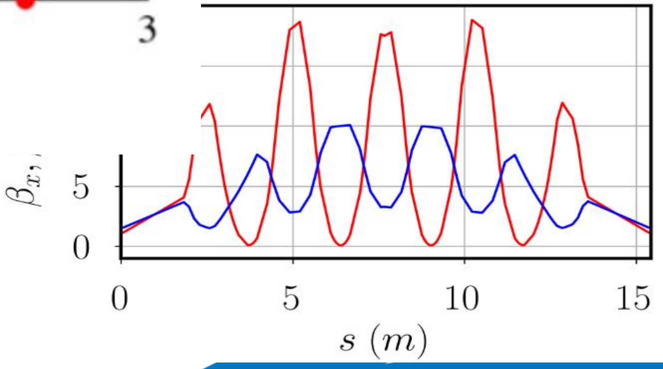
- Design foll
  ‘reverse be

Parameter		
Hor. Emittance (nm.ra		
E Loss Per Turn (KeV)		
Energy Spread (%)		
Bunch Length [ps]		
Tousheck Lifetime (hr		
Coupling (%)		
Dipole Critical Energy		
Straight σx [um]	322.75	19.115
Straight σy [um]	17.464	5.317
Straight Length (m)	4.5	3.0





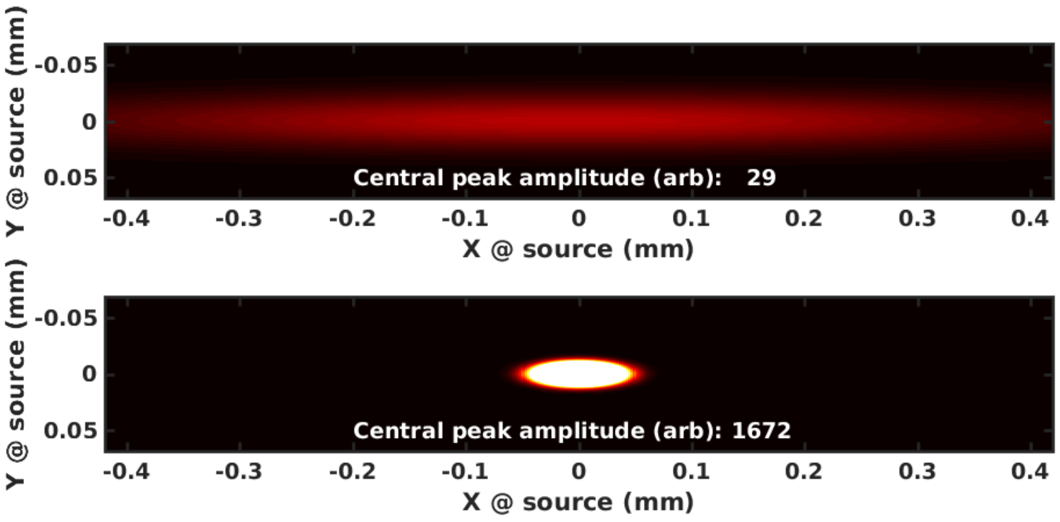


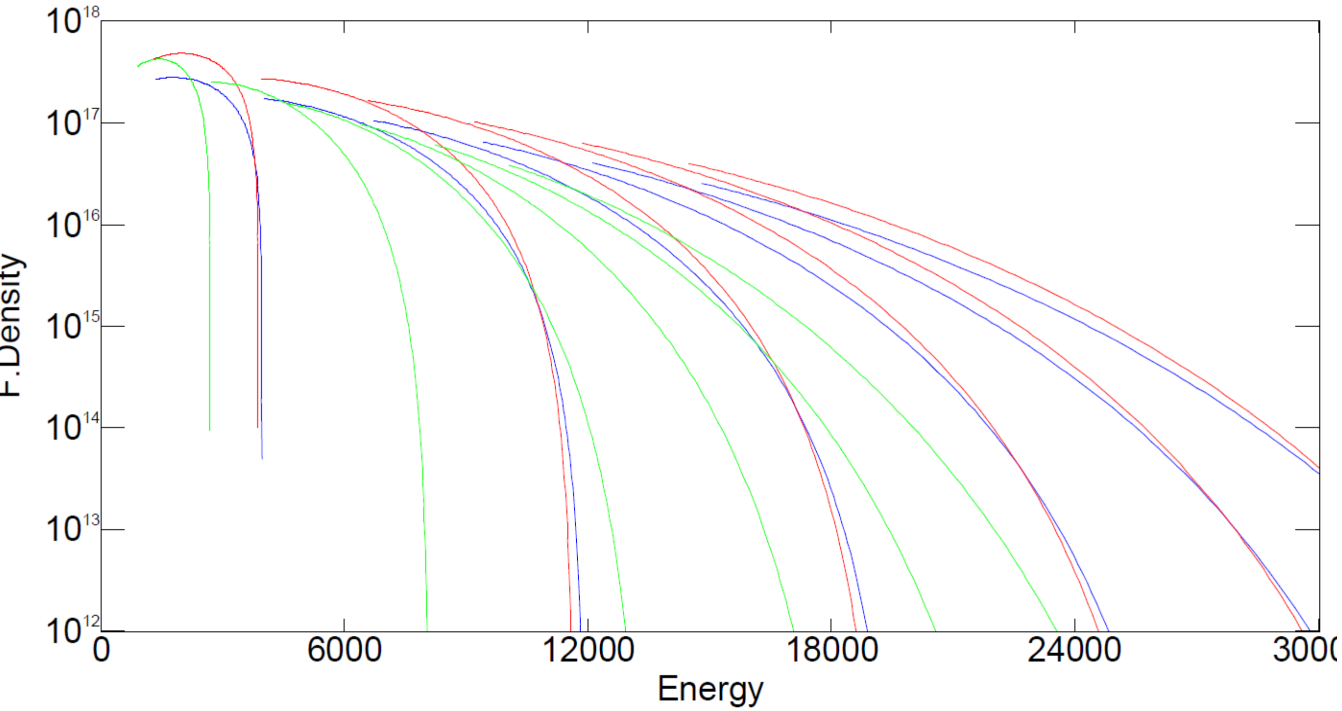


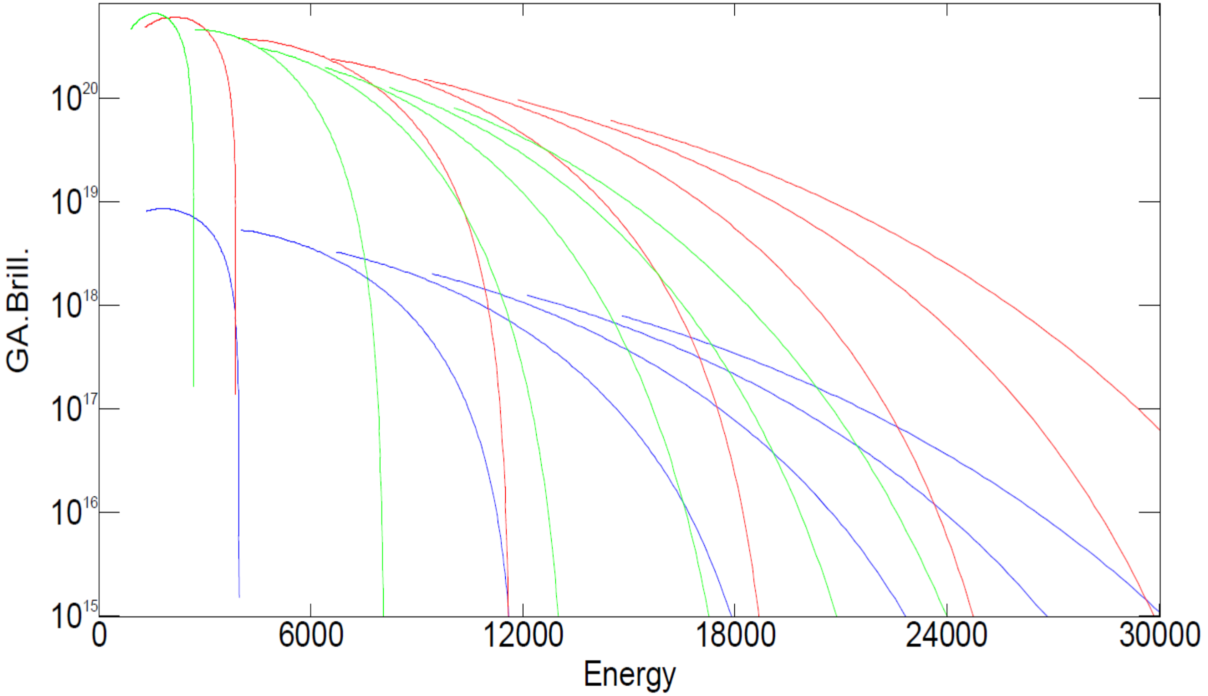
Expected ID Flux/Brilliance 216m AS-U

- Undulators, flux density and brightness.

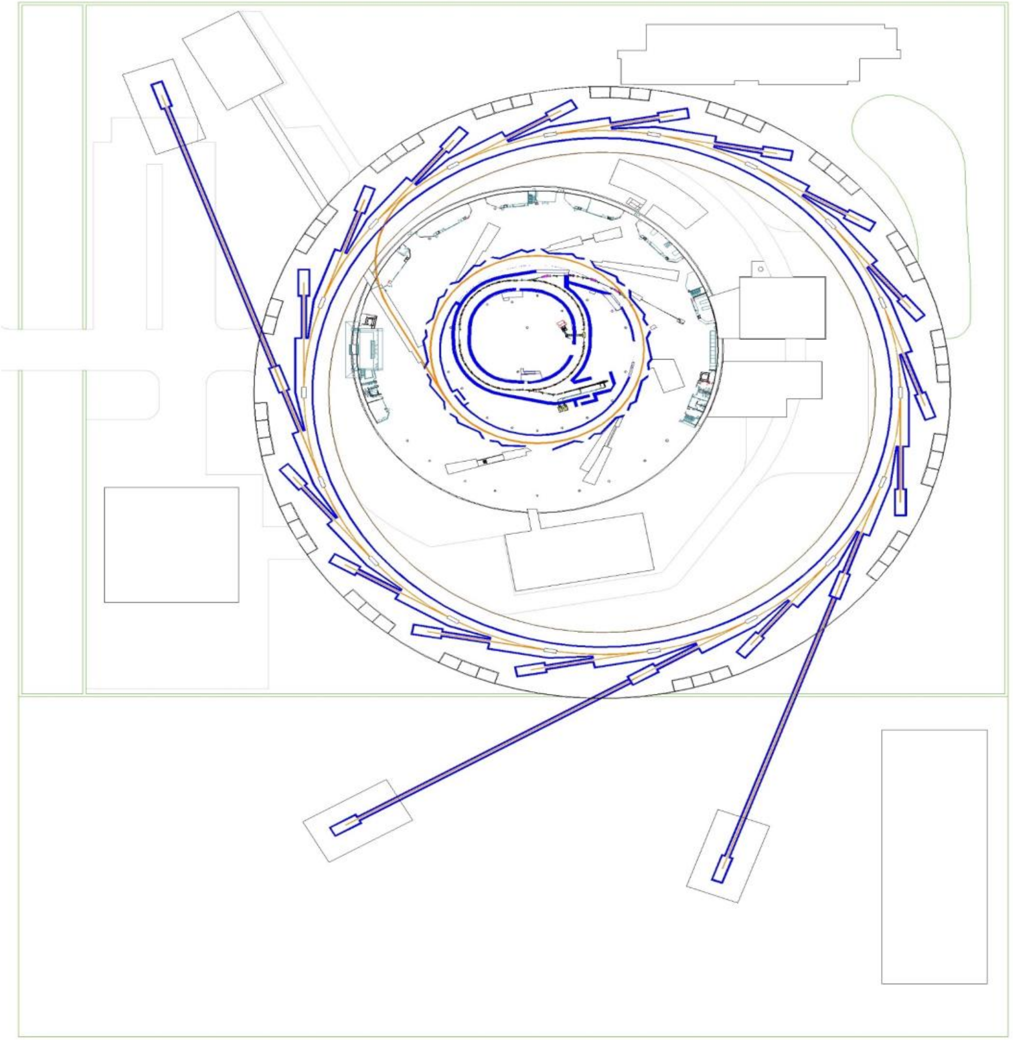
Blue– AS, Red 3GeV AS-U, Green 2.5 GeV AS-U

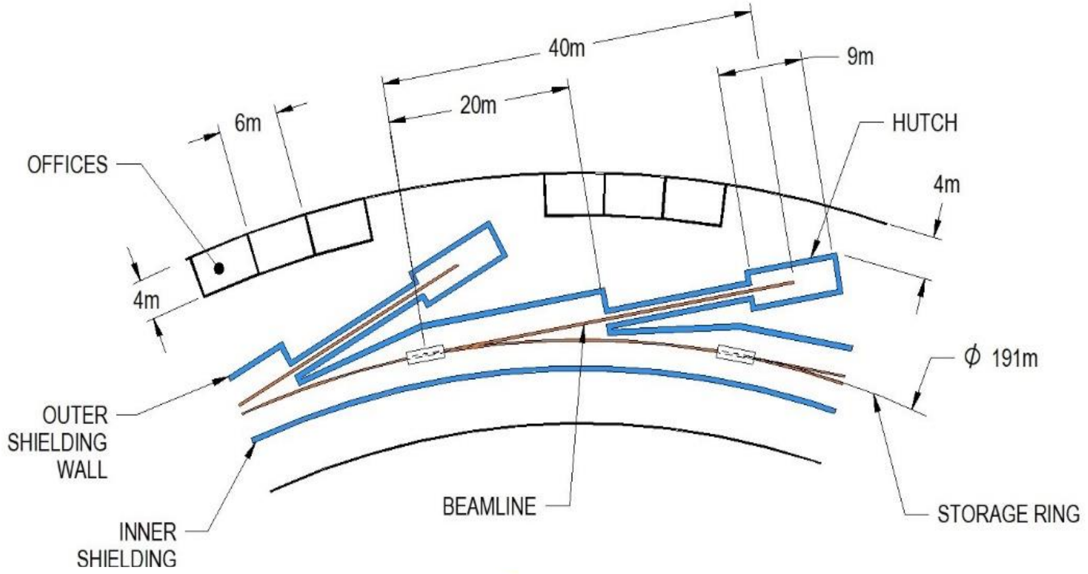


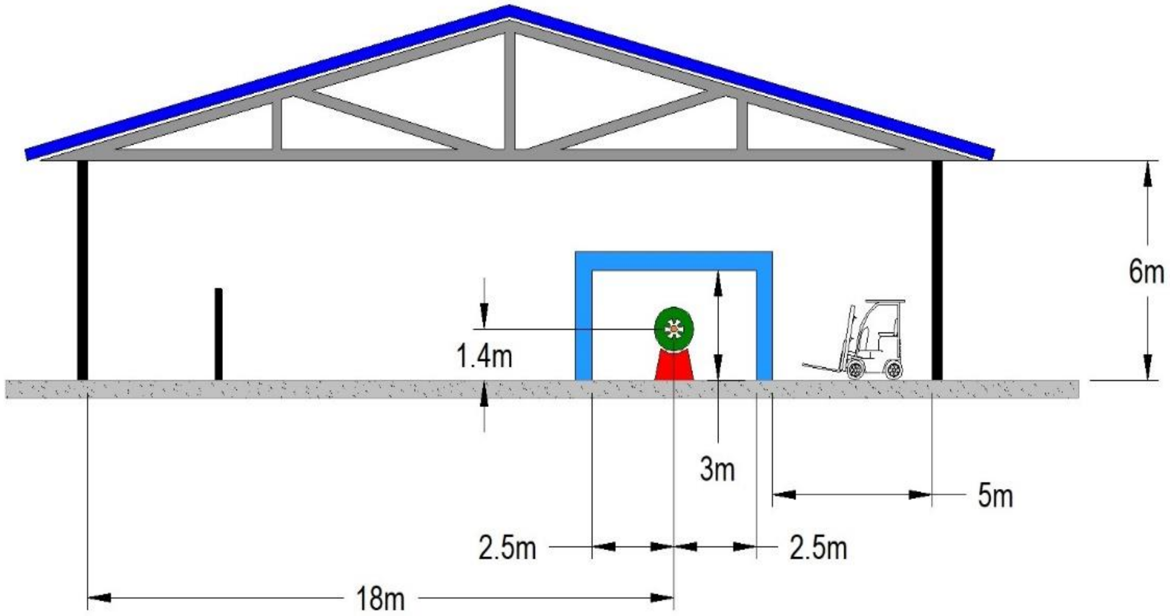




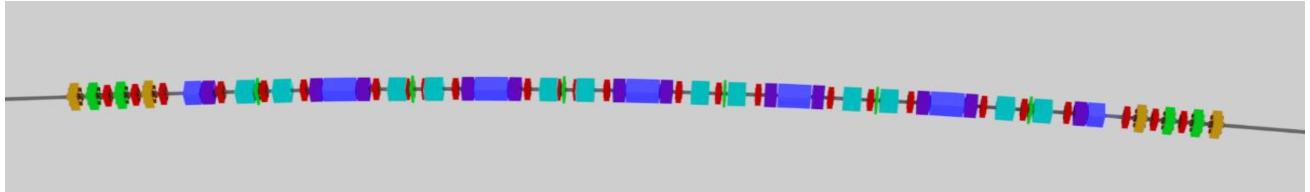
Concept design 600m Ring



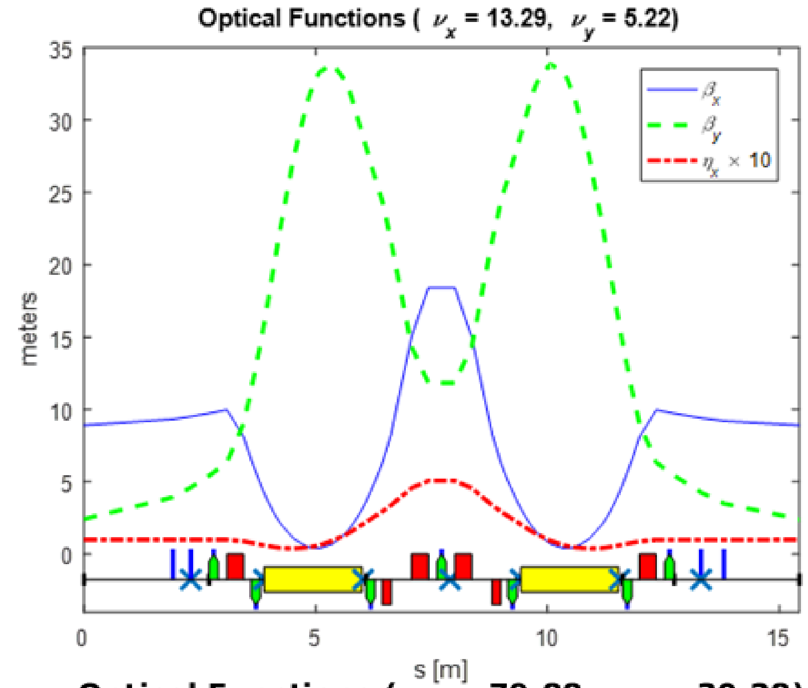




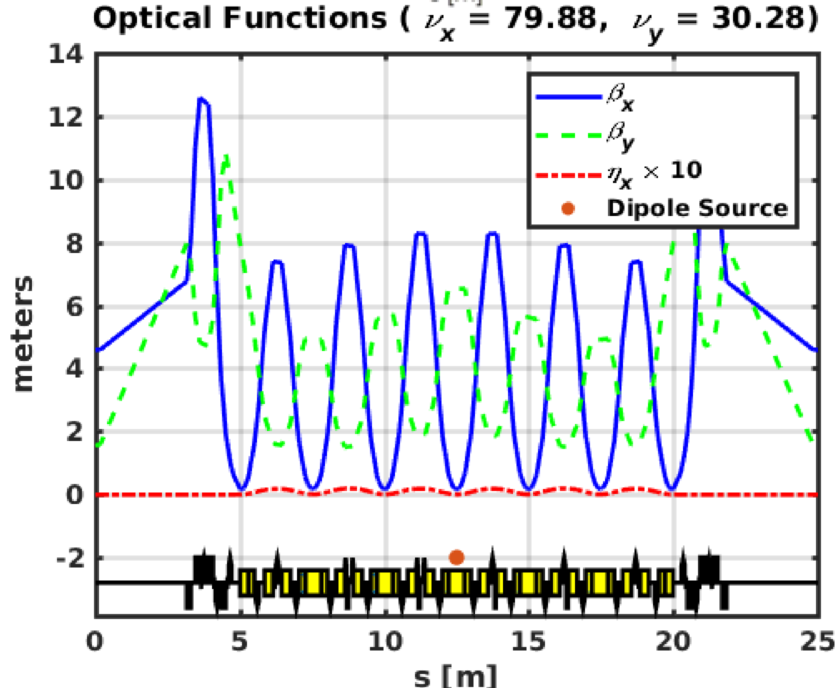
Lattice design - 9BA



Parameter	Current DBA	600m 9BA
Circumference (m)	216	600
Hor. Emittance (nm.rad)	10.5	0.007(no errors)
E Loss Per Turn (KeV)	932	387
Energy Spread (%)	0.1027	0.0788
Bunch Length [ps]	29.36	2.98
Tousheck Lifetime (hrs)	22	16.7
Coupling (%)	1	5
Dipole Critical Energy (KeV)	8.3	5.98
Straight σx [um]	322.75	5.574
Straight σy [um]	17.464	0.727
Straight Length (m)	4.7	5.65



Current DBA lattice cell



9DBA lattice cell

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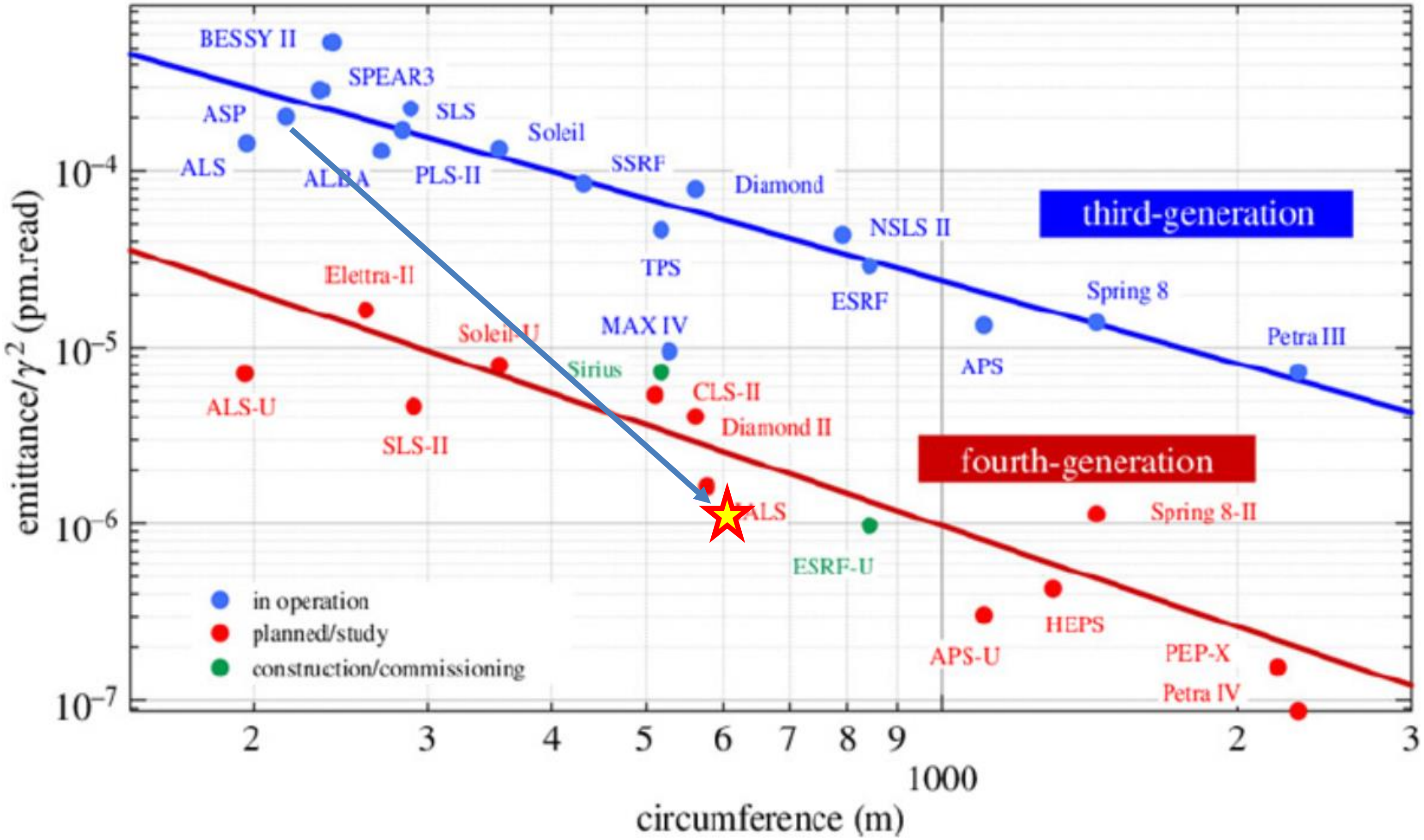
Where does this put us?

- Places us in a competitive spot on the world stage for brightness
- RF power requirements are much lower
- 24 Sectors with long straights



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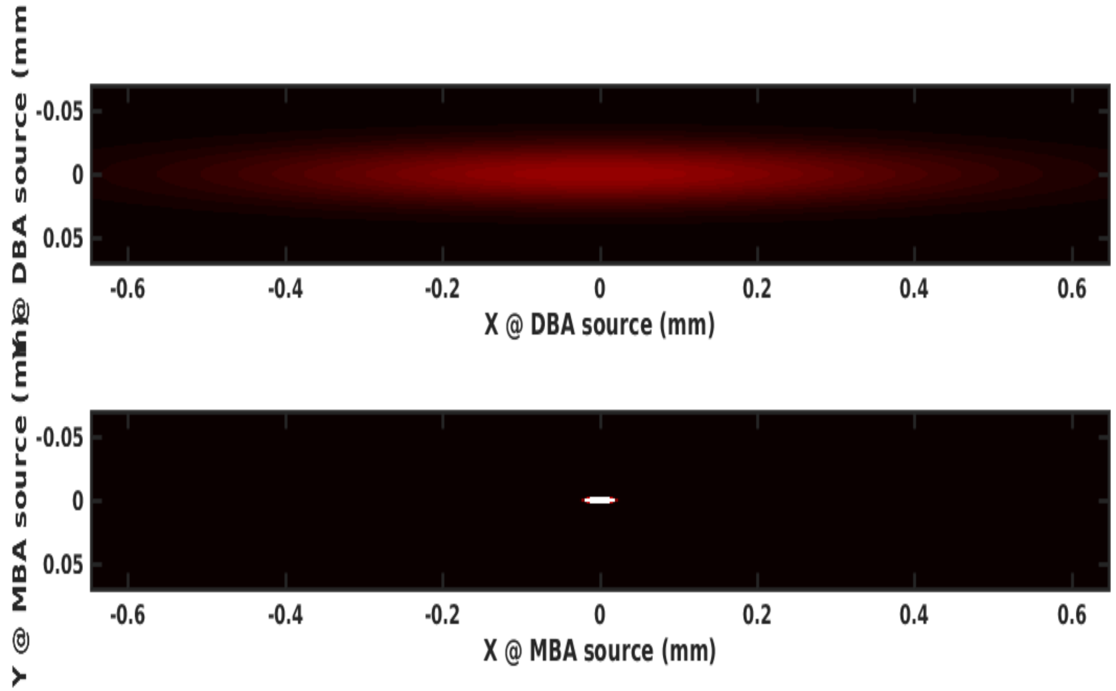
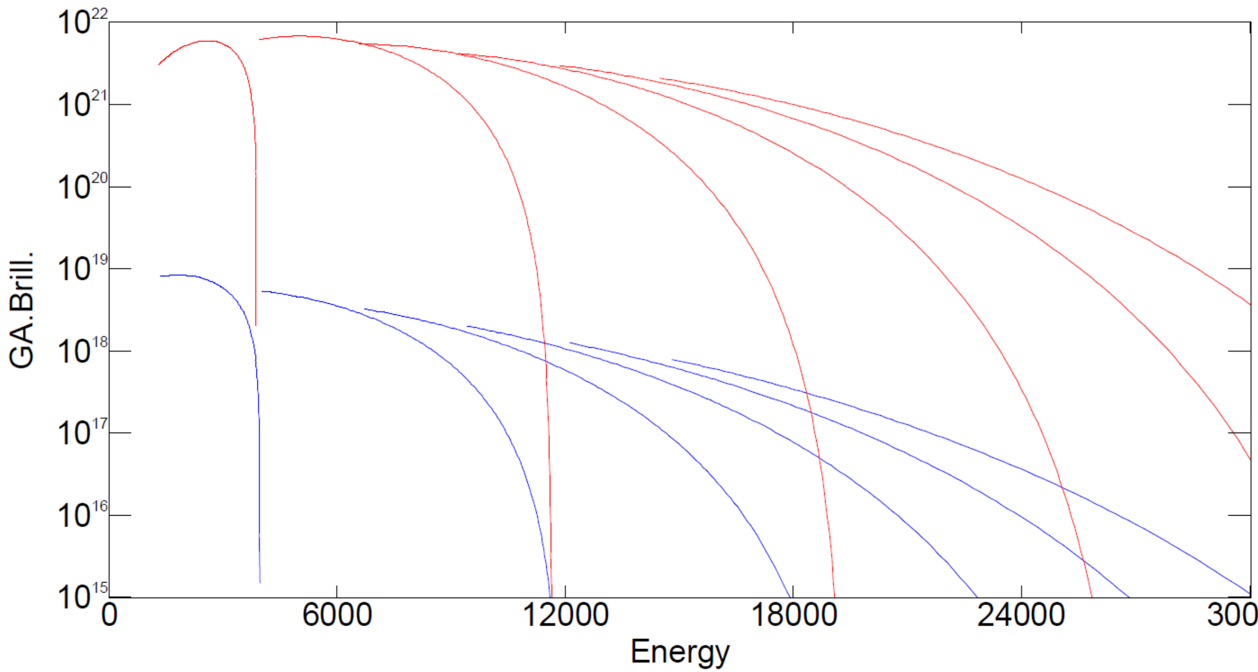
Expected ID Brilliance
600m 9BA

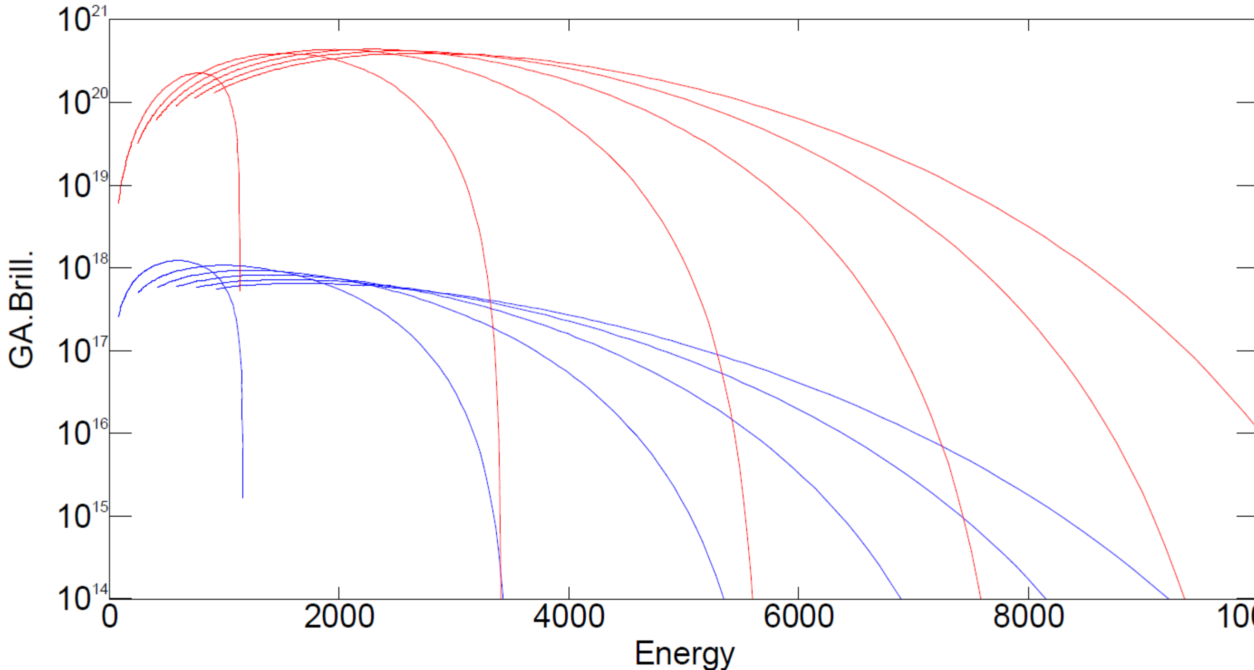
Blue– AS, Red (9BA)

IVUs top plot

APPLE-II bottom plot





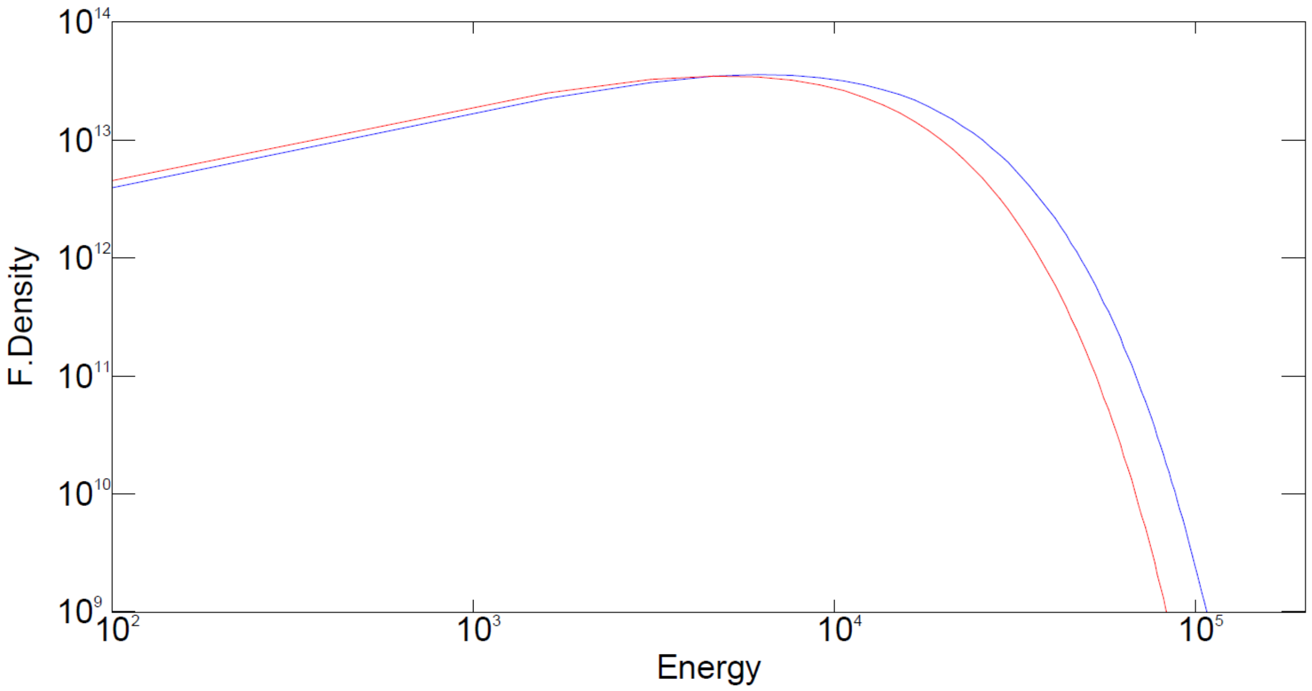


Expected Dipole Flux 600m 9BA

Blue– AS, Red (9BA)

Dipoles flux density (largely driven by bend field)

However coherence fraction will be significantly higher



Photon Energy/Source	Coh. Frac. DBA	Coh. Frac. 9BA	Increase factor
1 keV Straight	0.00224	0.70128	312.781
1 keV Dipole	0.00085	0.66264	781.278
5 keV Straight	0.00018	0.38864	2135.253
5 keV Dipole	0.00005	0.35958	7196.464
10 keV Straight	0.00005	0.2729	5029.318
10 keV Dipole	0.00001	0.25510	18937.647

Conclusion

- We investigated a lattice upgrade of the existing facility and there are some significant technical challenges
  - Even with those challenges solve, we would still be ‘back of the pack’
- A new, 600m ring lattice has been explored and is very promising.
- Further design work will be done on this proposal and will seek to incorporate your input on the science case into the accelerator design.

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