Status of the Diamond Light Source upgrade

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Diamond Light Source
and
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EuCARD2 topical workshop
Barcelona, 23 April 2015

Outline

Diamond “10 years vision”

Lattices for the upgrade

The DDBA project

Conclusions

Motivation

Diamond operates since 2007 with nominal parameters

- 2.7 nm H emittance, 300 mA, 8pm V emittance in 2009

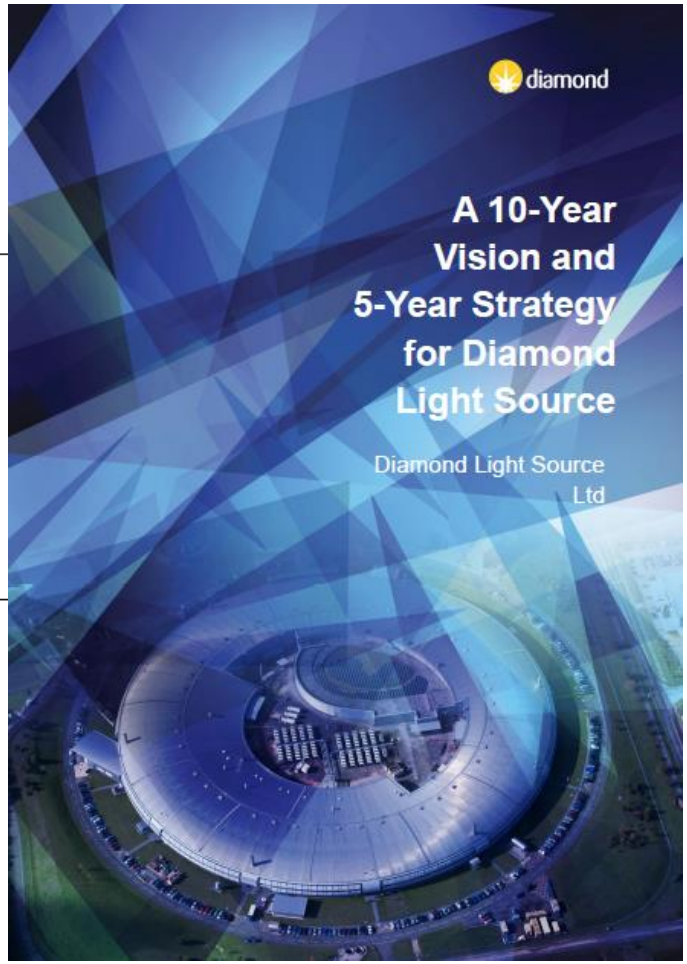
However:

- 2010 Petra-III was commissioned → 1 nm H emittance
- 2011-12 SLS and ASP ~1 pm V emittance (best achieved)
- 2012 ESRF et al. operate with 8pm V emittance
- 2013 ALS upgraded to a 2 nm H emittance lattice
- 2014 NSLS-II started operation → 0.5 nm H emittance
- 2014 Petra III has tested a 160 pm lattice at 3GeV
- 2016 MAX IV 300 pm H emittance lattice
- 2019 ESRF II 140 pm H emittance lattice
- APS, SPRING-8, ALS, SLS, ELETTRA, ANKA, CLS, SOLEIL are looking at lattice upgrades

10 years vision

Diamond Light Source

Strategic Plan 2015 - 2020
Preferred and Prioritised Plan: Sources



Discussion initiated by A. Harrison April 2014
Draft document – October 2014
November: presented and discussed at the SAC
Internal release in March 2015

Version 3, 29/10/14

10 years vision

Science driven (7 key scientific areas: biomaterials, chemistry, condensed matter, earth science, integrated structure biology, heritage, soft condensed matter)

- **beamline development (optics, detectors, stability, …)**
- **machine development**

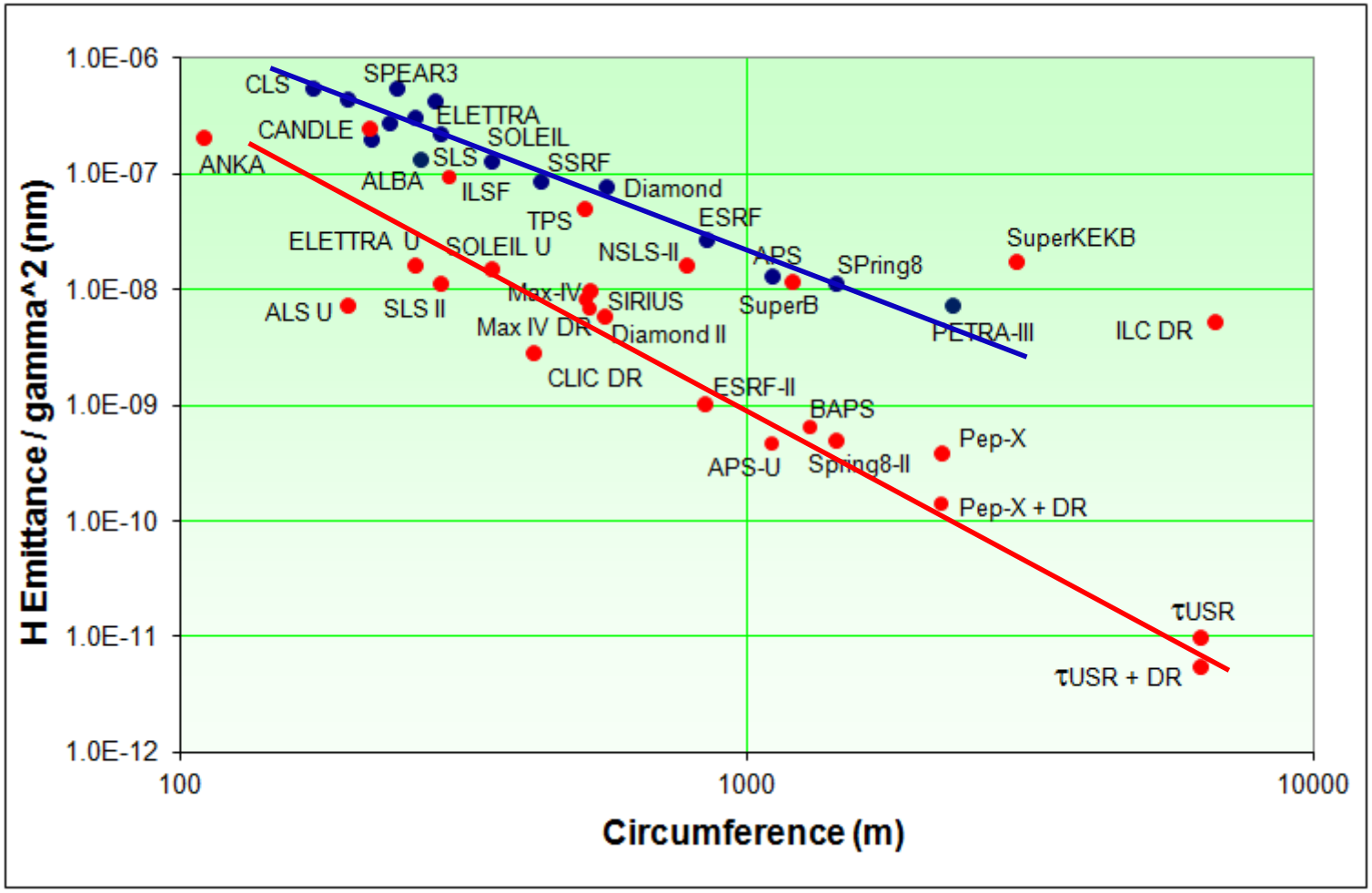
  reliability
  stability

- **source development**

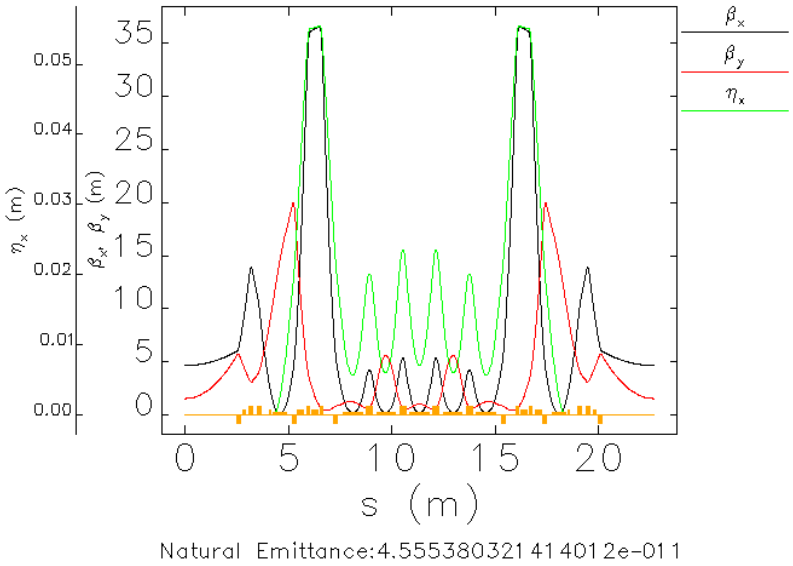
  CPMUs (in house)
  DDBA
  conceptual design for Diamond II

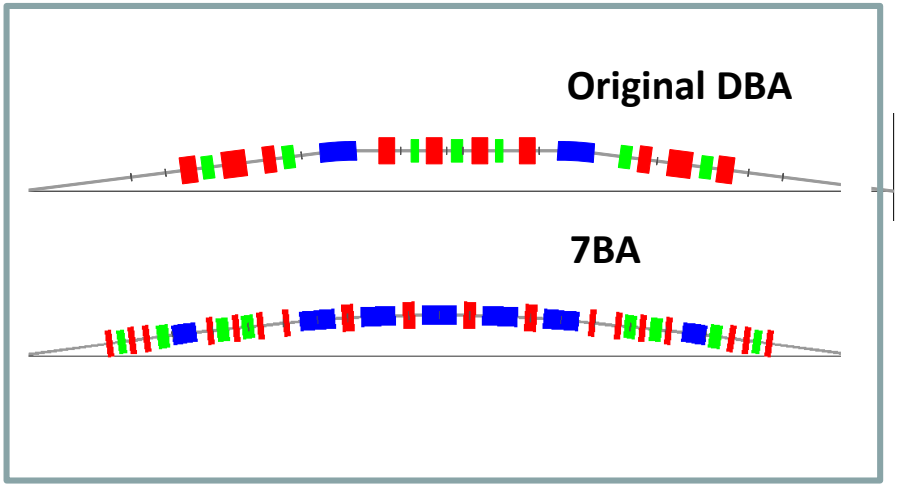
bid within next CSR – 2016; first beam >2021

Survey of low emittance lattices



Lattice design at Diamond





Nonlinear dynamics

7BA lattice	45 pm
5BA lattice	140 pm
4BA lattice	270 pm

DA achieved (WIP)

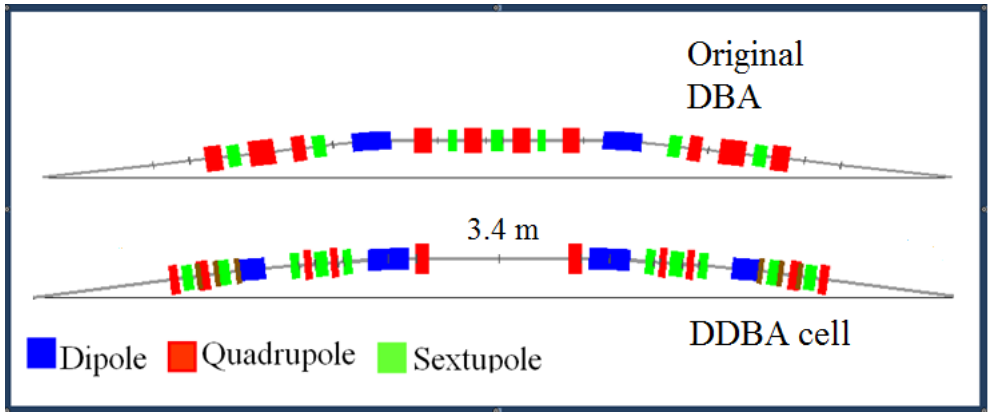
7BA DA ±1 mm
5BA DA ±3.5 mm
4BA DA ±5 mm

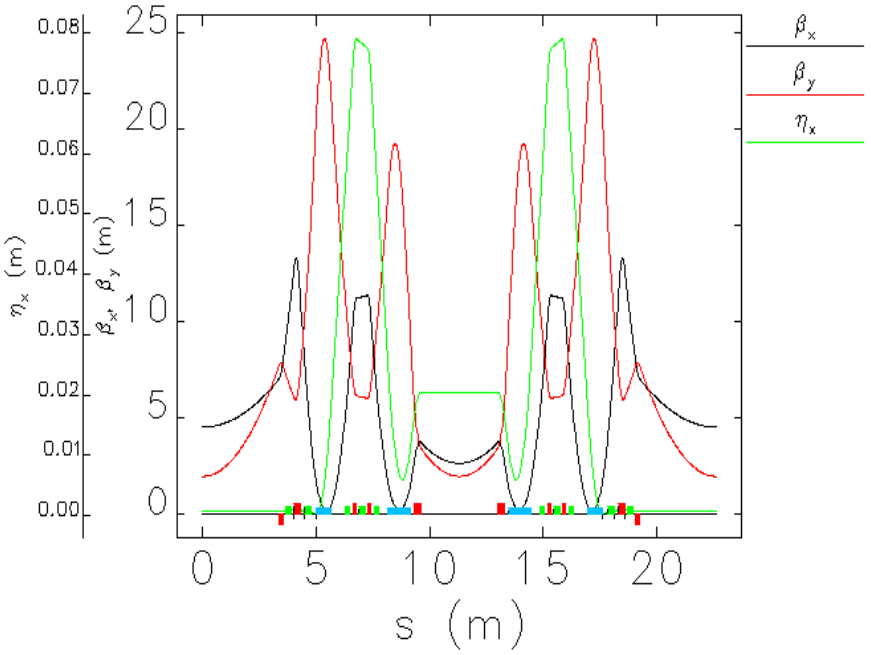
Fourth order and detuning terms very harder to compensate
Not enough freedom to set the cell phase advance as needed

IBS emittance

7BA	45 pm → 90 pm @ 300 mA	relative increase 100%
5BA	140 pm → 180 pm @ 300 mA	relative increase 30%
4BA	270 pm → 280 pm @ 300 mA	relative increase 5%

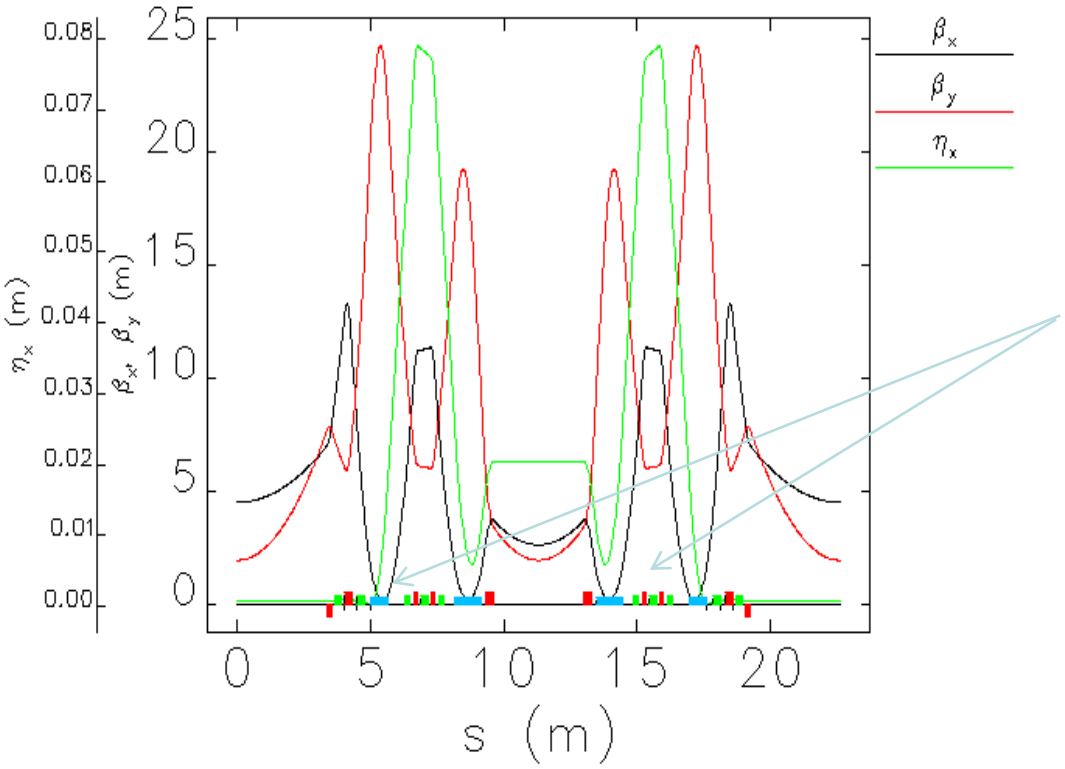
A modified 4BA lattice for Diamond-II





- Increase dispersion at chromatic sextupoles
- Optimize magnets positions and length leaving more distance between dipoles (no coil clash)
- removed sextupoles in the new straight
- Longer mid-cell straight section from 3m to 3.4 m – longer is unmanageable

Issues with cell design

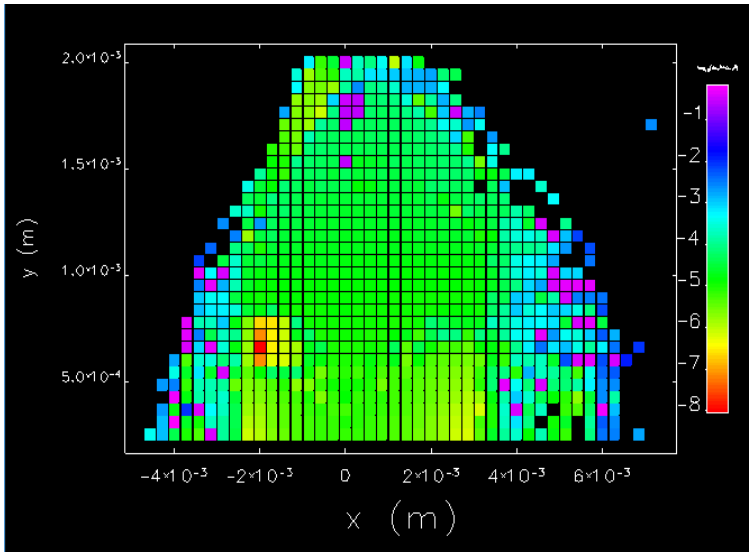


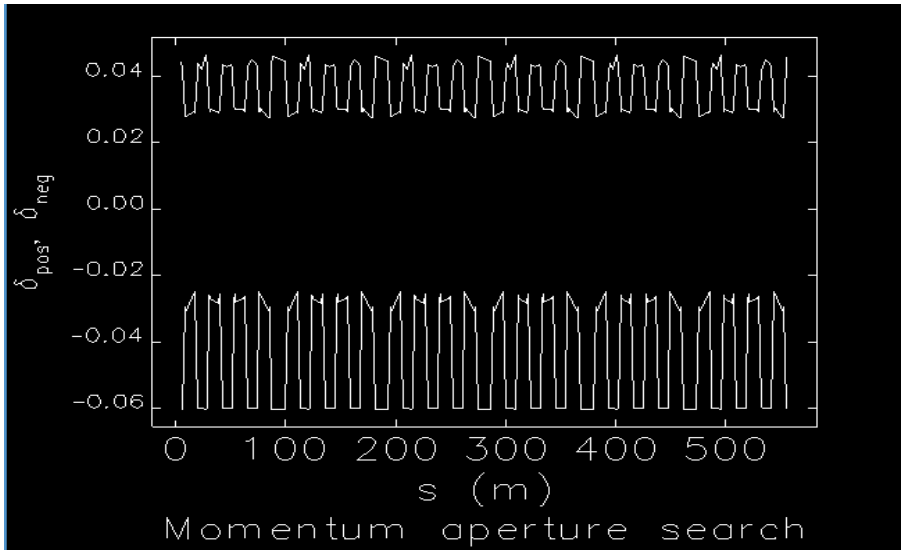
H phase advance is ~ 2π*0.8

Optics function tailored to add one more in-vacuum ID in the mid straight
Hard control of phase advance between chromatic sextupoles

MOGA optimisation for DA and lifetime (4BA)

Nonlinear beam dynamics optimised mostly with MOGA and resonance driving terms compensation

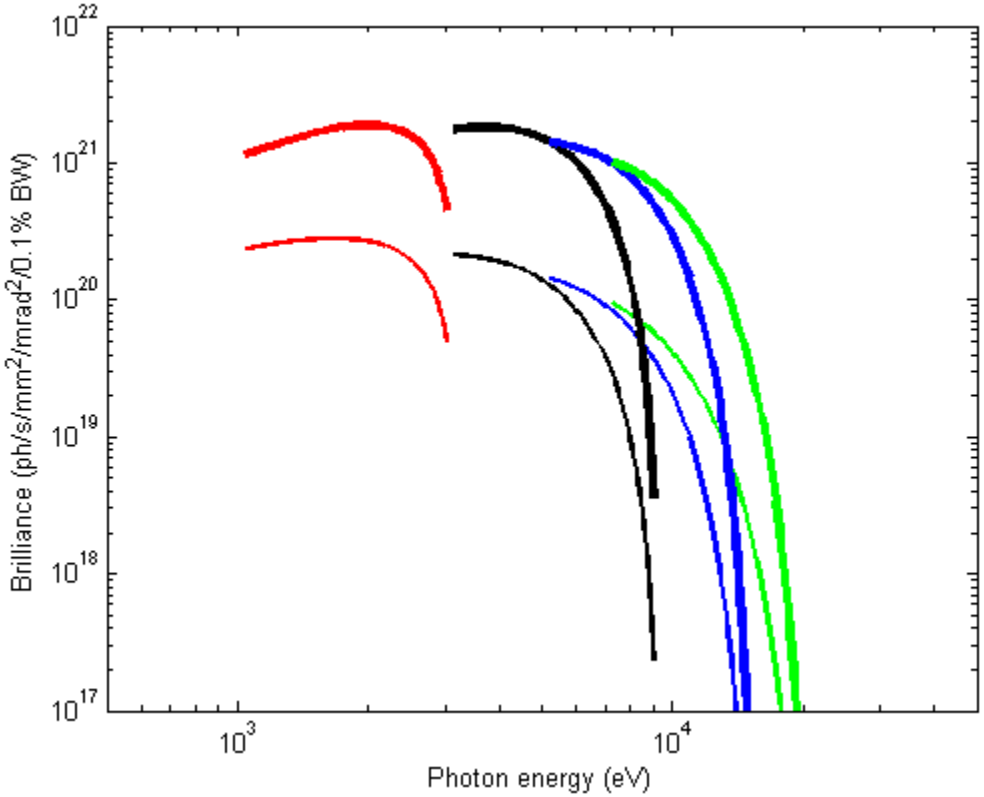




DA still under optimisation - ~5 mm (WIP)
Touschek lifetime ~ 7h without harmonic cavities

upgrade with Diamond-II (200pm): 300mA and 1%K

Brilliance plot using U27 – 72 periods 2 m long with Kmax = 2.02



Tuning curves computed with Spectra 8.0

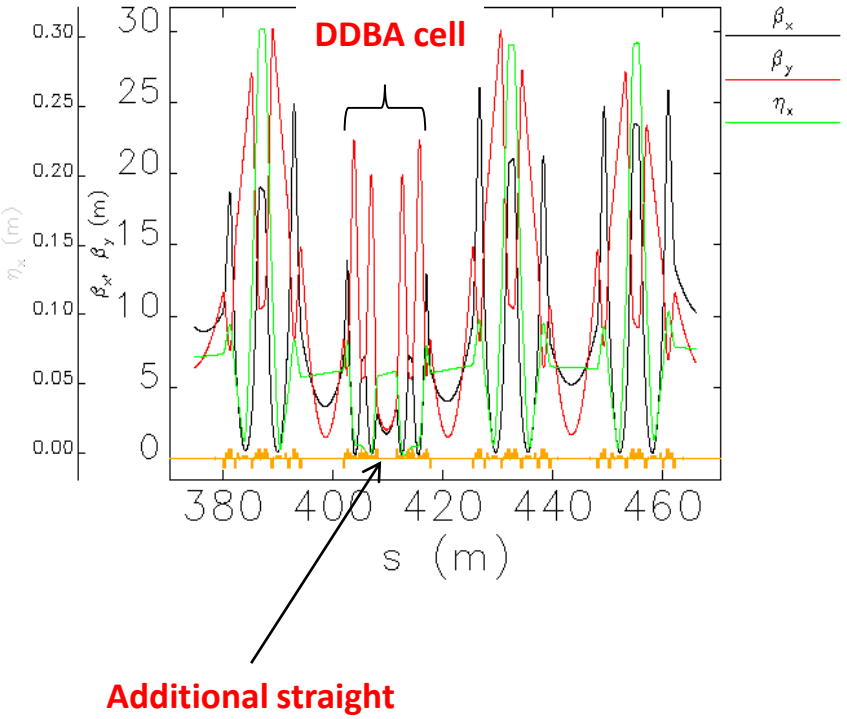
Lattice design at Diamond

One (or more) modified 4BA cells in the present lattice (called DDBA)

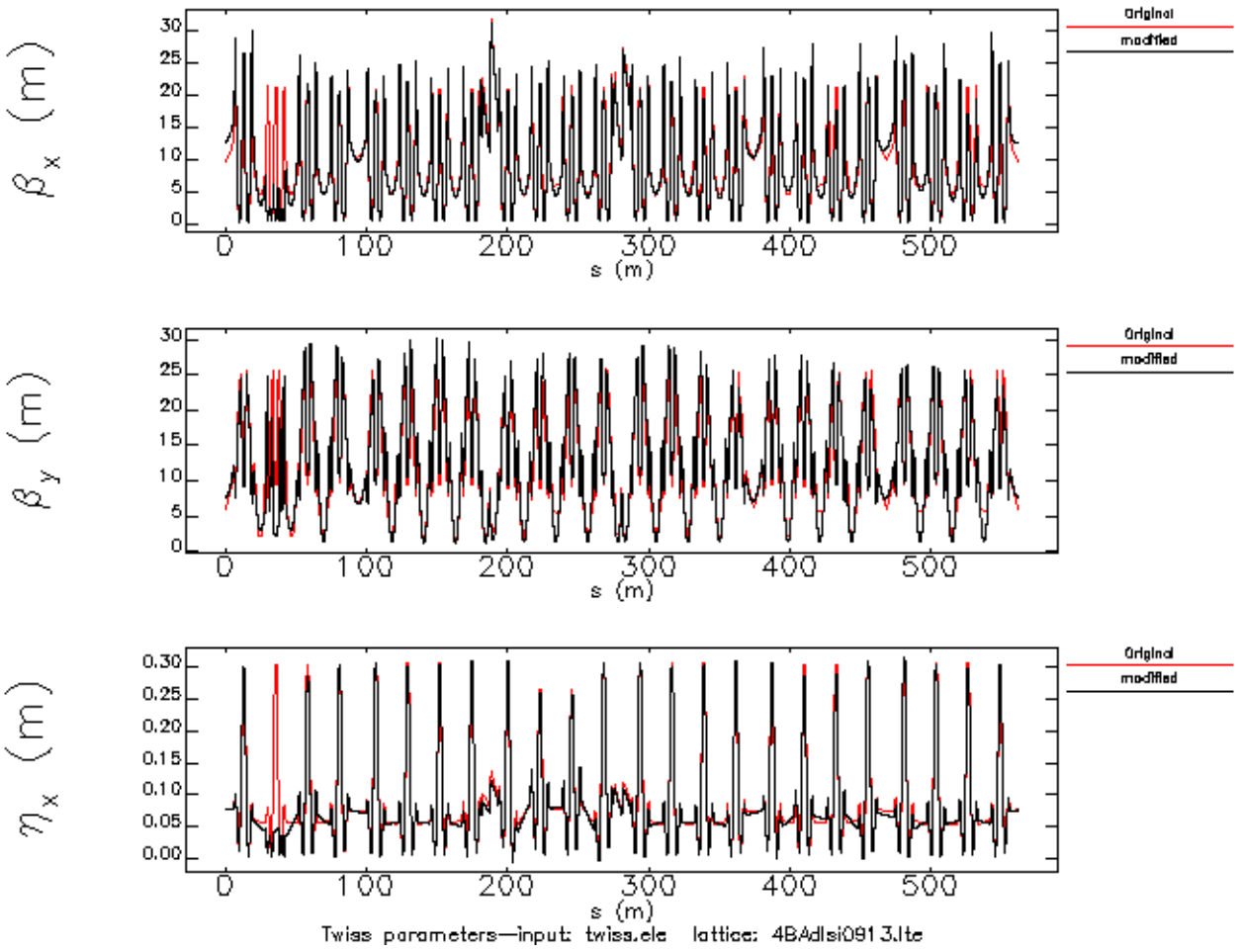
One DDBA cell in the existing lattice

Replacing the existing cell2 with a DDBA cell

- **Introduces an additional straight section (beamline upgrade bending magnet to ID beamline)**
- **Serves as a prototype for low emittance lattice upgrade**
- **Lots of R&D required (magnet design challenging, vacuum with small apertures, engineering integration, etc)**



Ring optics with and without the DDBA cell in cell2

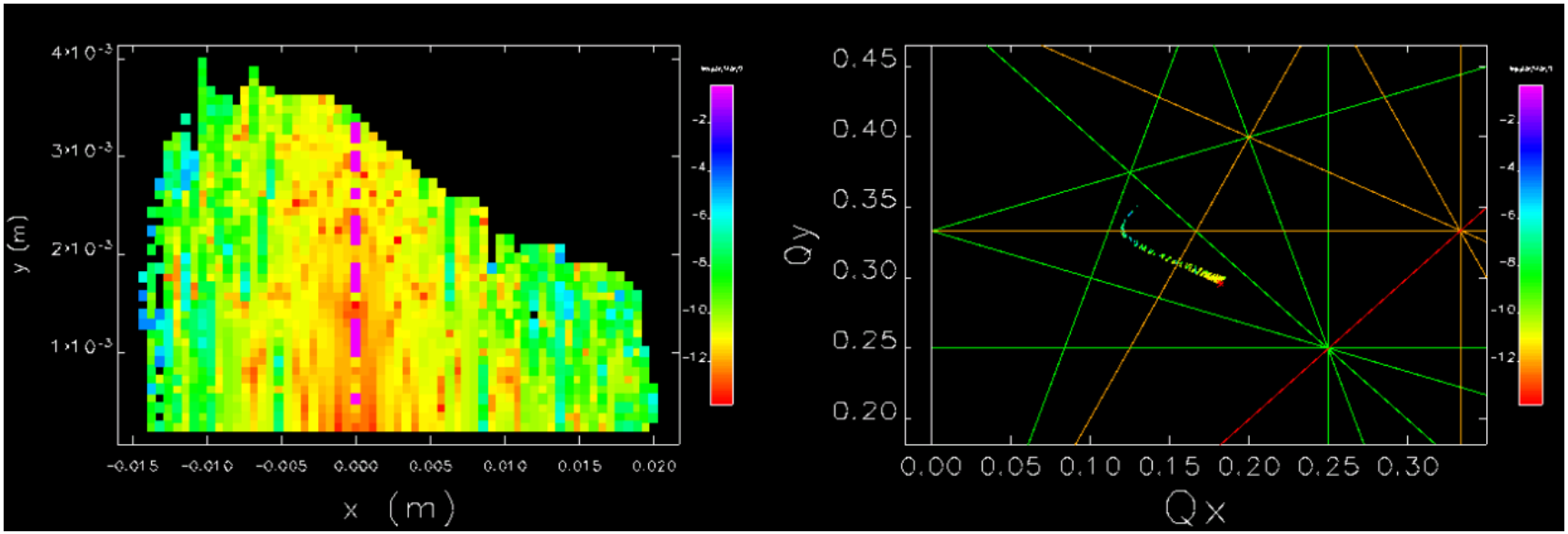


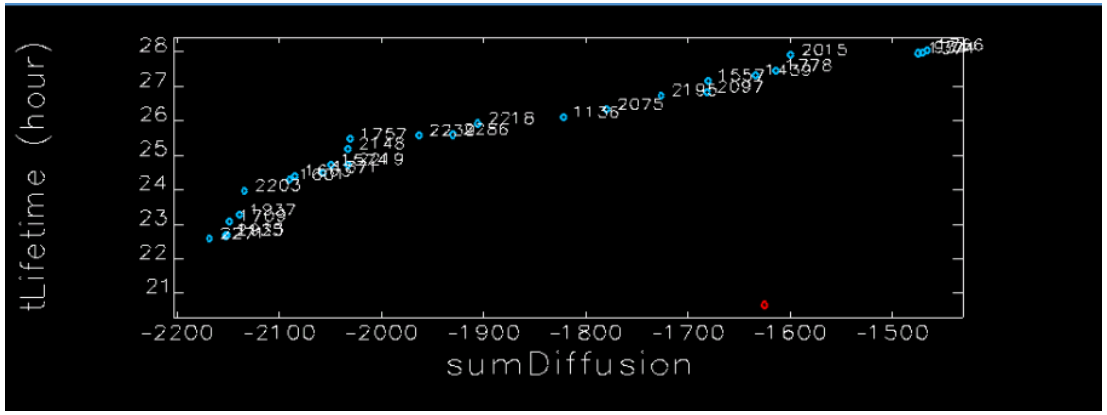
red = present lattice

black = new lattice with modified cell2

Optics optimised with very modest perturbation to adjacent straight sections

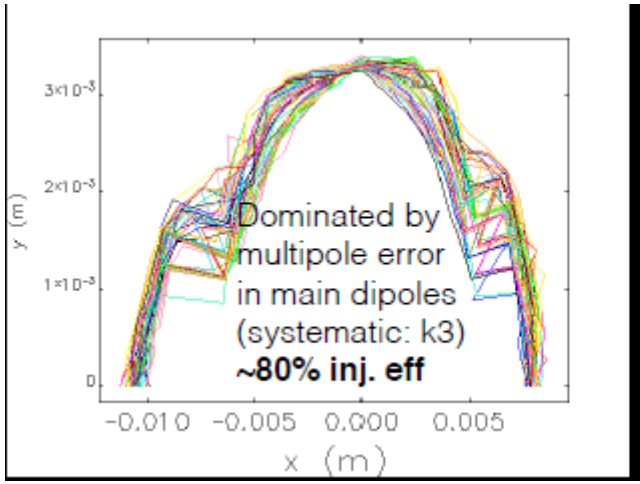
One DDBA: dynamic aperture and lifetime with MOGA

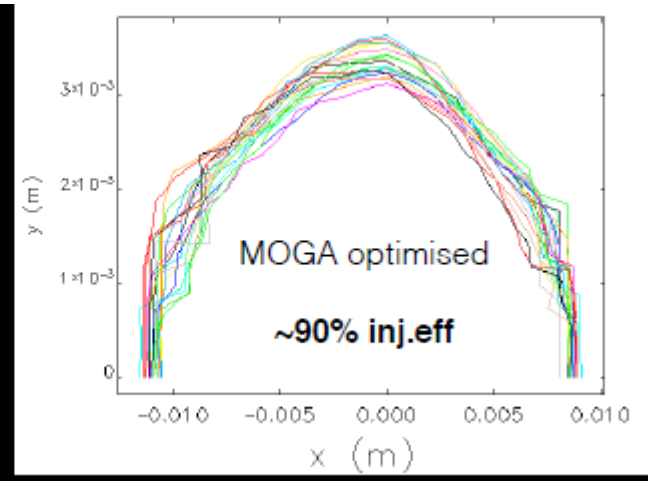




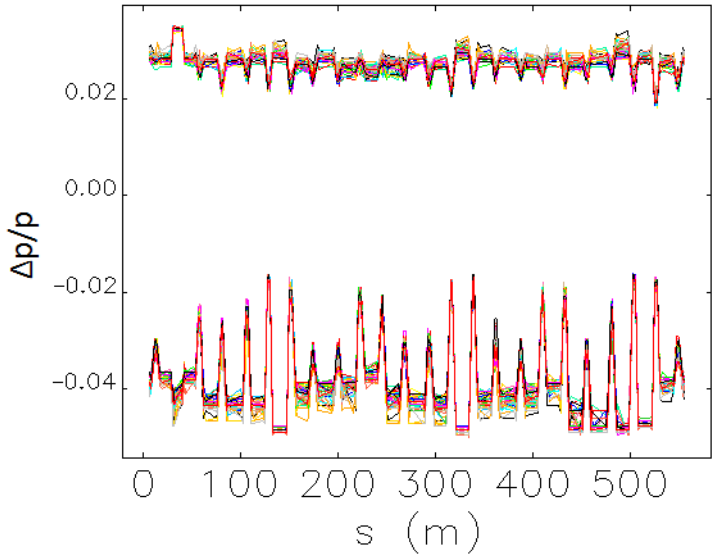
Parameters	
Emittance [m-rad]	2.5e-9
Tune x	28.18
Tune y	13.29
Chromaticity	2,2
Lifetime [h]	*27* (29)

DDBA DA with engineering apertures and errors





*Operation with 300 mA, 900 bunches, 0.3 % coupling, 2.6 MV, with engineering apertures, with errors, orbit and tune corrected



DA slightly reduced
+8mm -12mm one DDBA cell
+12mm – 15mm for the existing machine

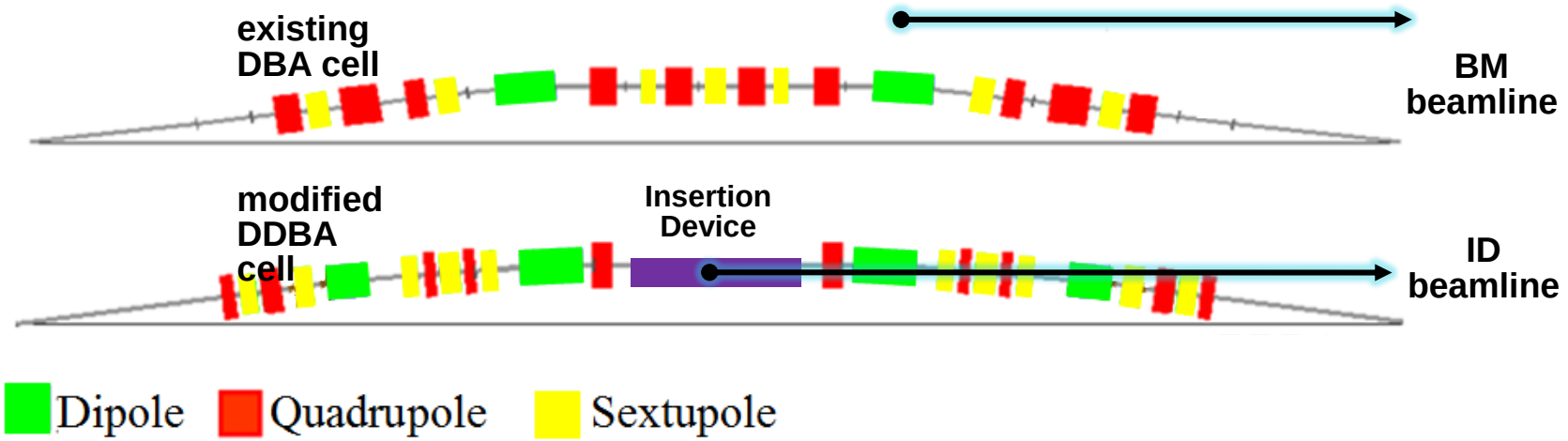
Injection efficiency ~90%
with injection point at -6.8 mm

Touschek lifetime
(300 mA, 686 bunches, 1 % coupling),
16.5 h one DDBA cell
19.6 h for the existing machine

The optimisation will continue

DDBA

Modifying one straight section to add an ID – DDBA cell



Magnets, vessel , BPM buttons contract placed
now progressing reasonably well towards their FDR

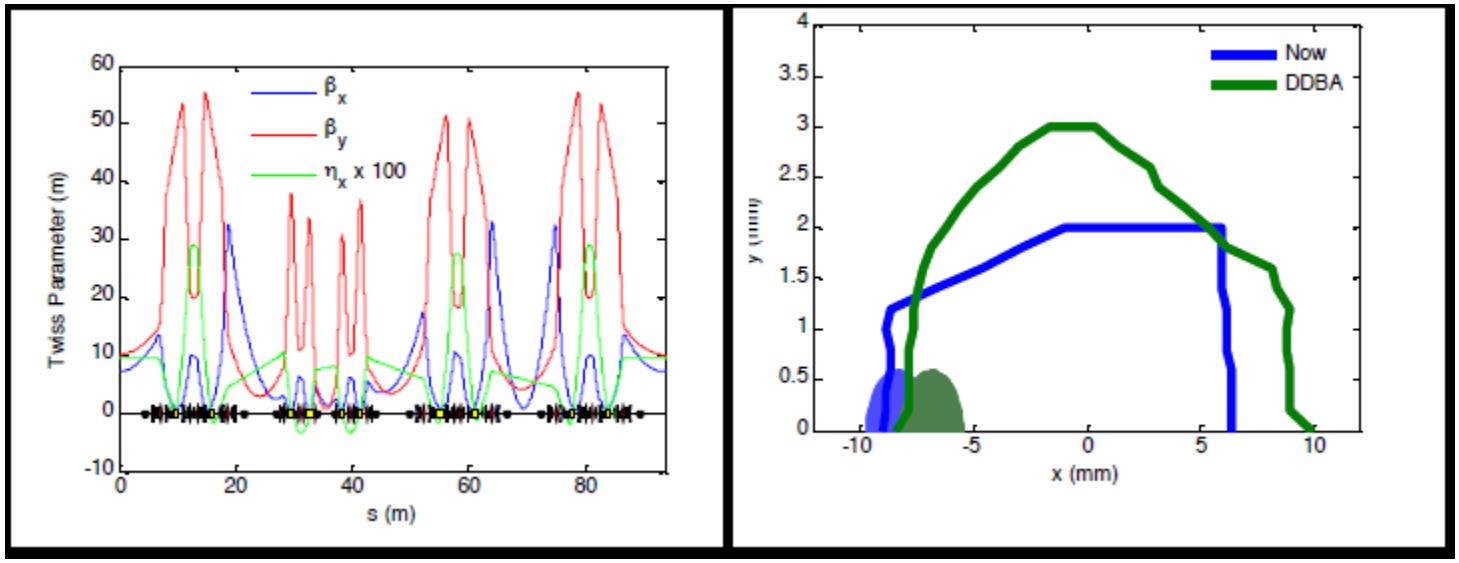
Magnets due in November 2015 – installation 8 weeks SD in August 2016
Beam back November 2016 (one week AP commissioning time)

Low-alpha and DDBA

The DDBA design must be compatible with low -alpha operation for THz and short X-ray pulses users.

The existing low-alpha has reduced injection efficiency (~20%). This was maintained. The injection point was shifted form 8.3 mm to 6.8 mm

Unclear if this can be kept for the full upgrade as well



Future work on Diamond II

DLS will produce a Conceptual Design report for Diamond II ~2016

Initial studies are based on MBA (modified 4BA or 5BA – 140-270 pm)
Making a strong effort to tailor the machine design to the user requirements

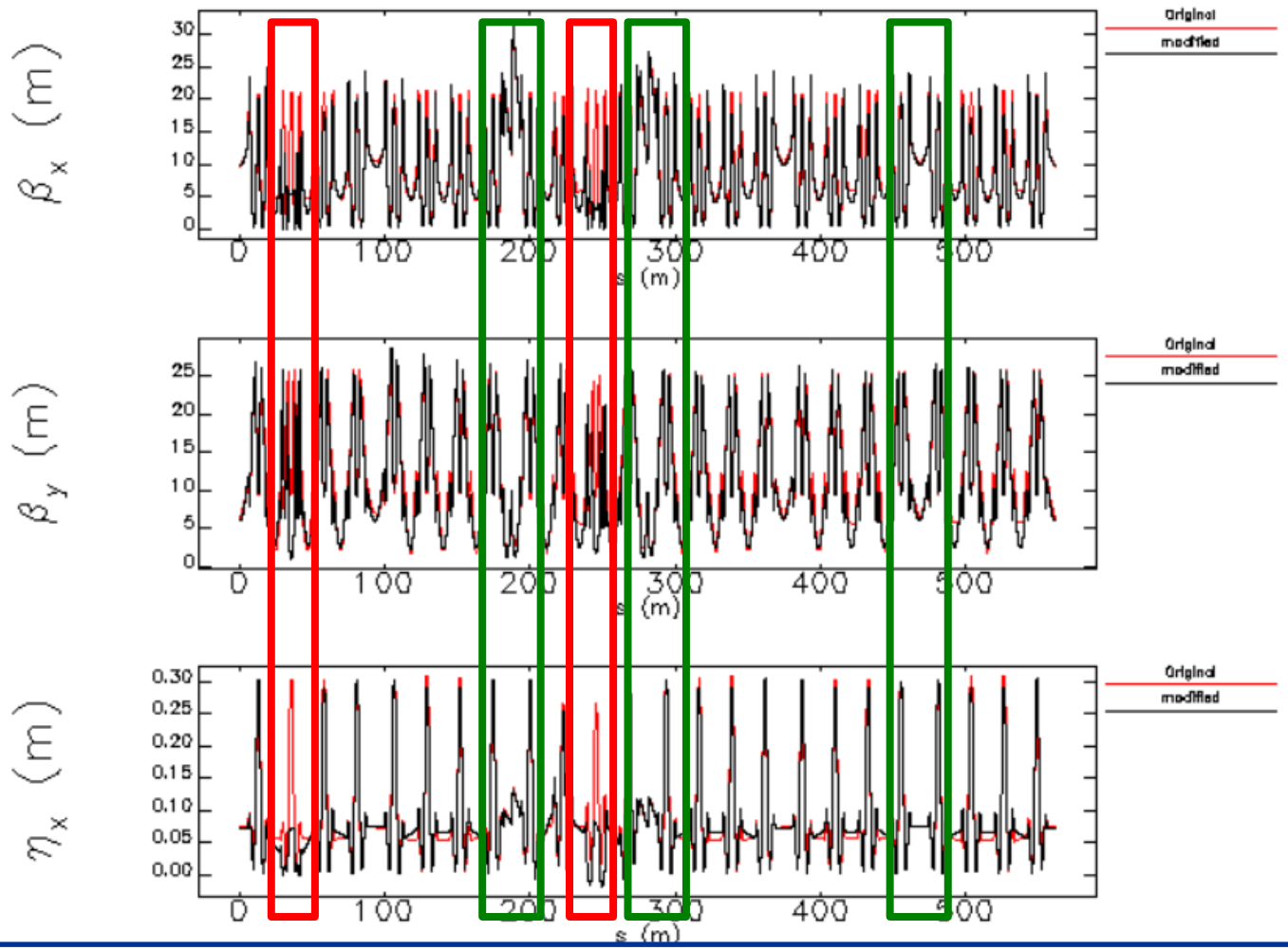
- **customised optics**
- **length of the shutdown is not a settled questions yet…**

Most of technological choices and engineering issues are expected to be similar to the single cell DDBA

Possible new are of development (wrt to DDBA)

- **magnet design – permanent magnet – longitudinal gradient**
- **vacuum chamber design and vacuum system (antechamber - NEG)**
- **diagnostics for stability (including electron and photons)**

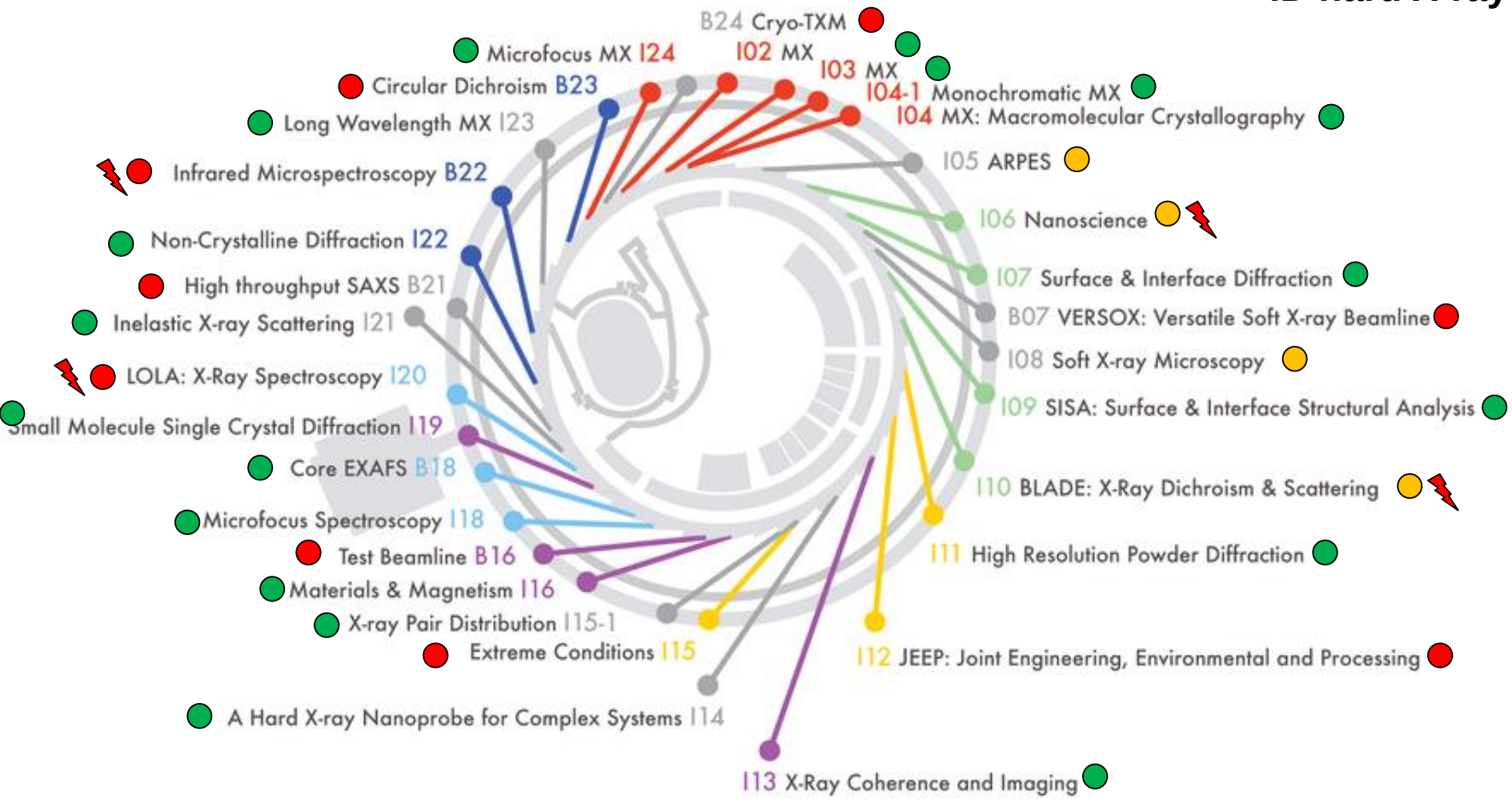
Breaking the symmetry of the lattice



(preliminary) SAC feedback

SAC requested a clear assessment of the overall benefit of a low emittance upgrade beamline by beamline

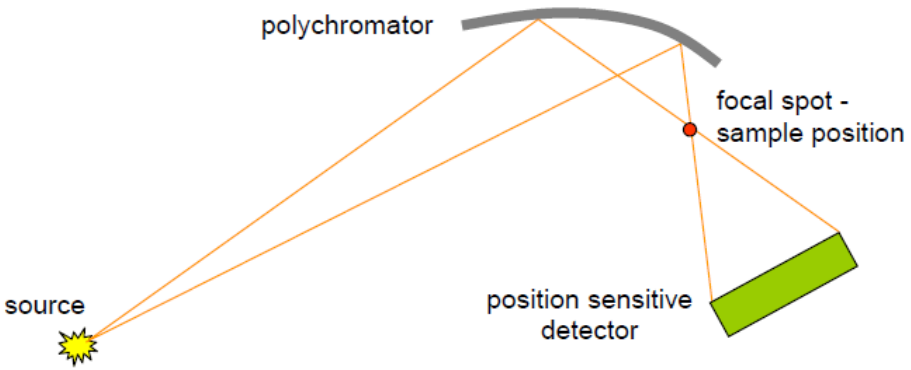
- bending
- ID soft X-ray
- ID hard X-ray

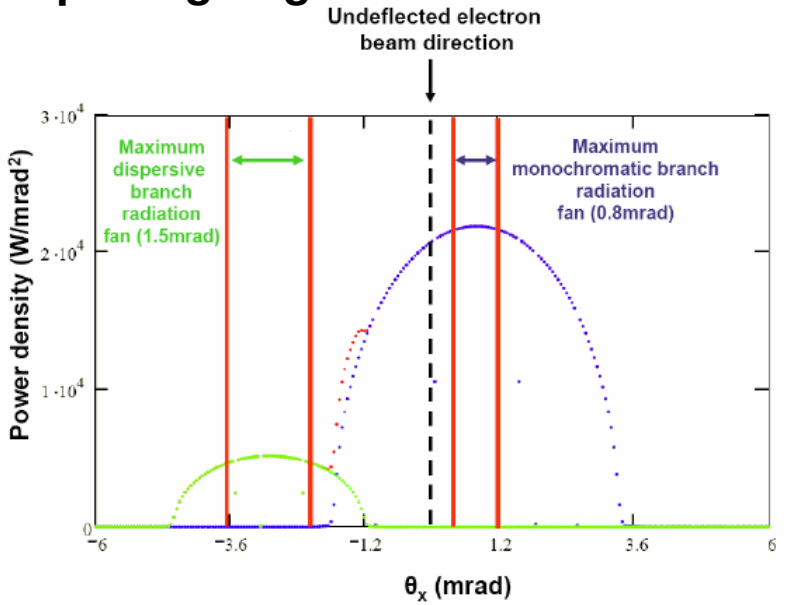


An example: dispersive branch in I20 (WIP)

This beamline requires large horizontal divergence in order to have a large photon energy span at the sample
The energy range is correlated with the angle of incidence on the polychromatic mirror (dispersive beamline)

Source divergence defined by the slits opening angle in the FE if ID (wiggler) radiation fan has divergence >> than the slit opening angle





Design the straight section with large electron beam divergence + use a wiggler? May prove sufficient…

Conclusions

Various MBA options are under analysis.

Some of the designs have still lots of flexibility in the technical choices

Need input from PBSs and Users
what emittance?
are round beams needed?
alternate high beta – low beta ?
operating modes (e.g. low alpha, …)?
… still open for any exotic ideas?

AP should explore tailoring the design to their specific beamlines

New low emittance lattice by 202?

A possible time plan

The respective timescales for the ESRF Upgrade (start of shutdown October 2018, return of User Mode June 2020) and a possible Diamond-II (start of shutdown January 2021, in order to not overlap with ESRF shutdown) are as follows:

	ESRF	ESRF + 2y/3mo
White paper endorsed by Council	Nov. 12	Feb. 15
1st APAC	Sep. 13	Dec. 15
lattice frozen (S28)	Jan. 14	Apr. 16
draft TDS	Apr. 14	Jul. 16
formal approval	Nov. 14	Feb. 17
start of detailed design	Jan. 15	Apr. 17
calls for tender	Jul. 15	Oct. 17
production	Jan. 16-Jul. 18	Apr. 18-Oct. 20
start of shutdown	Oct. 18	Jan. 21

This timeline could be shortened if we were to select the modified 4BA option for which much prototype work has already been done