

Status and Execution of the Diamond-II Upgrade Project

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on behalf of the Diamond-II Machine Team

10th Low Emittance Rings Workshop 2025

DESY, Hamburg

October 8th, 2025

As requested: *“with an emphasis on the organizational and management aspects”*

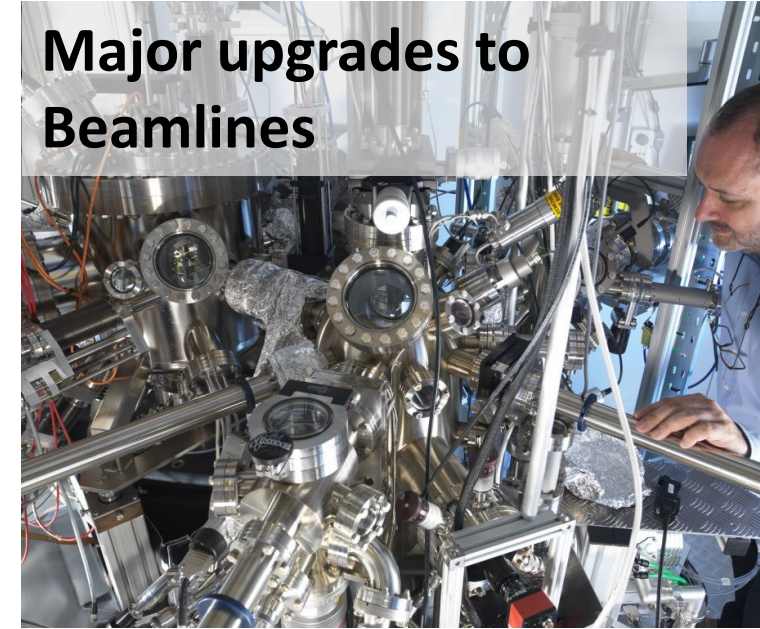
Diamond-II

- A coordinated development across 5 'pillars'.

New 4th Generation storage Ring



Major upgrades to Beamlines



Upgrades to software, controls and computing



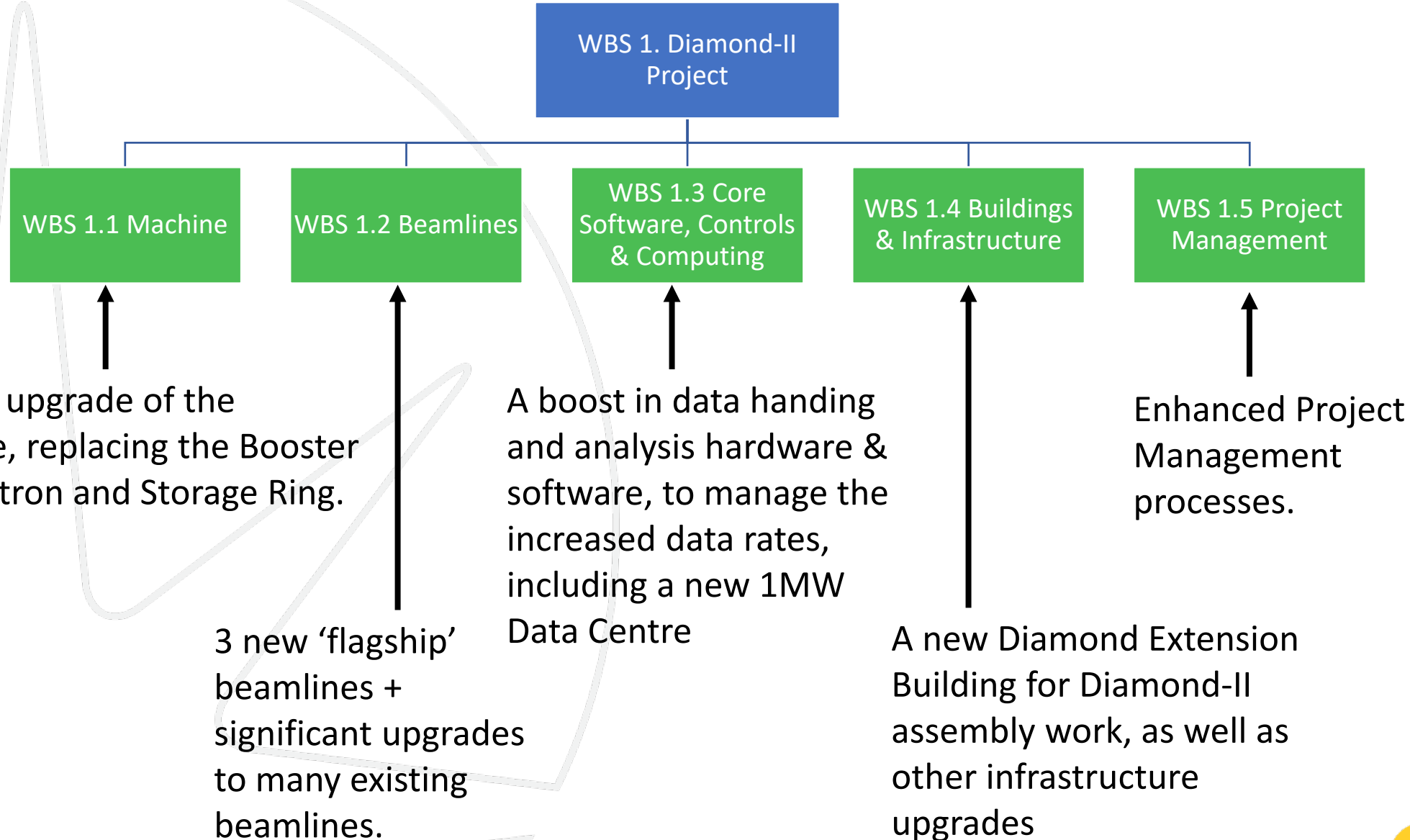
Diamond Extension Building and other infrastructure upgrades



Improved Project Management structure and processes



Diamond-II Project Structure



Diamond-II Governance

Meets 4 times a year

Diamond Light Source
Board of Directors

Meets 4 times a year before
the Board meetings

Diamond-II
Sponsor Group

Nominated by the Diamond Board, the
Sponsor Group provides project oversight,
'constructive challenge', and manages
release of contingency etc.

External

Meets monthly
week 4

Diamond-II
Project Board chaired by
Project Director

Internal

Meets monthly
week 3

Pillar Coordination
Committee

The PCC is a working meeting not part
of the formal management structure,
with Project Director, Pillar Leads,
Finance, Procurement and Planners

Pillar Boards
Meet
monthly
week 2

Pillar 1.1
Machine

Pillar 1.2
Beamlines

Pillar 1.3 Core
Software, Controls
and Computing

Pillar 1.4
Buildings &
Infrastructure

Pillar 1.5
Project
Management

Diamond-II Key Project Milestones

Milestone	Date
Project approval	Jul. 2023
Completion of the Diamond Extension Building	Oct. 2025
Start of the Diamond-II shutdown (“dark period”)	Dec. 2027
Start of machine commissioning	Dec. 2028
Start of regular beamline X-ray commissioning	Jun. 2029
First phase of operational beamlines	Sep. 2029
First User on a flagship beamline	Jan. 2030
Diamond-II Project completed	Mar. 2030

Diamond-II Beamlines

- ❑ **3 new “Flagship” Beamlines**
 - SWIFT: Fast Operando Spectroscopy
 - K04: Ultra-high throughput for MX and Xchem
 - CSXID: Coherent Soft X-Ray Imaging and Diffraction
- ❑ **4 Bending Magnet Beamlines converting to ID Beamlines**
 - B07: Versatile Soft X-ray (VerSoX) Beamline
 - B16: Test Beamline
 - B18: Core XAS
 - B21: High-throughput small-angle X-ray scattering
- ❑ **3 Bending Magnet Beamlines with extensive front-end changes**
 - B22: Multimode InfraRed Imaging and Microspectroscopy
 - B23: Circular Dichroism
 - B24: 3D Correlative Cryo-Imaging
- ❑ **Critical Beamline Upgrades**
 - Upgrades required to optics, shielding, slits, diagnostics, collimators, windows etc., to enable the beamlines to operate in Diamond-II.



K04 Hutch

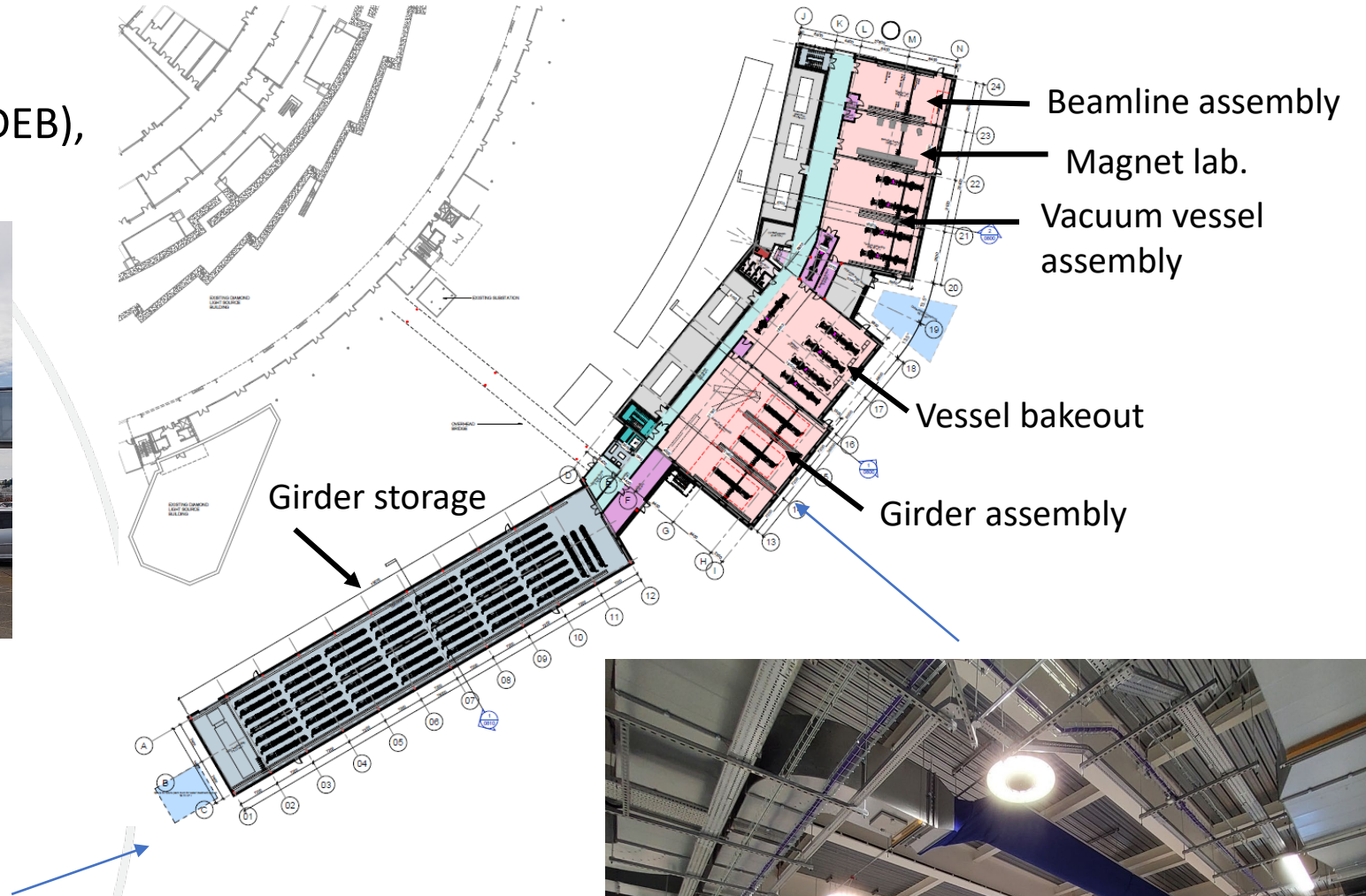


SWIFT Experimental Hutch and Transfer Pipe



Diamond-II Buildings

The new Diamond Extension Building (DEB), very near to Hand-over:



Diamond-II Infrastructure

Demin. Pipework
upgrade: 15 of 24 cells
completed



Process cooling
water pump
upgrade
completed



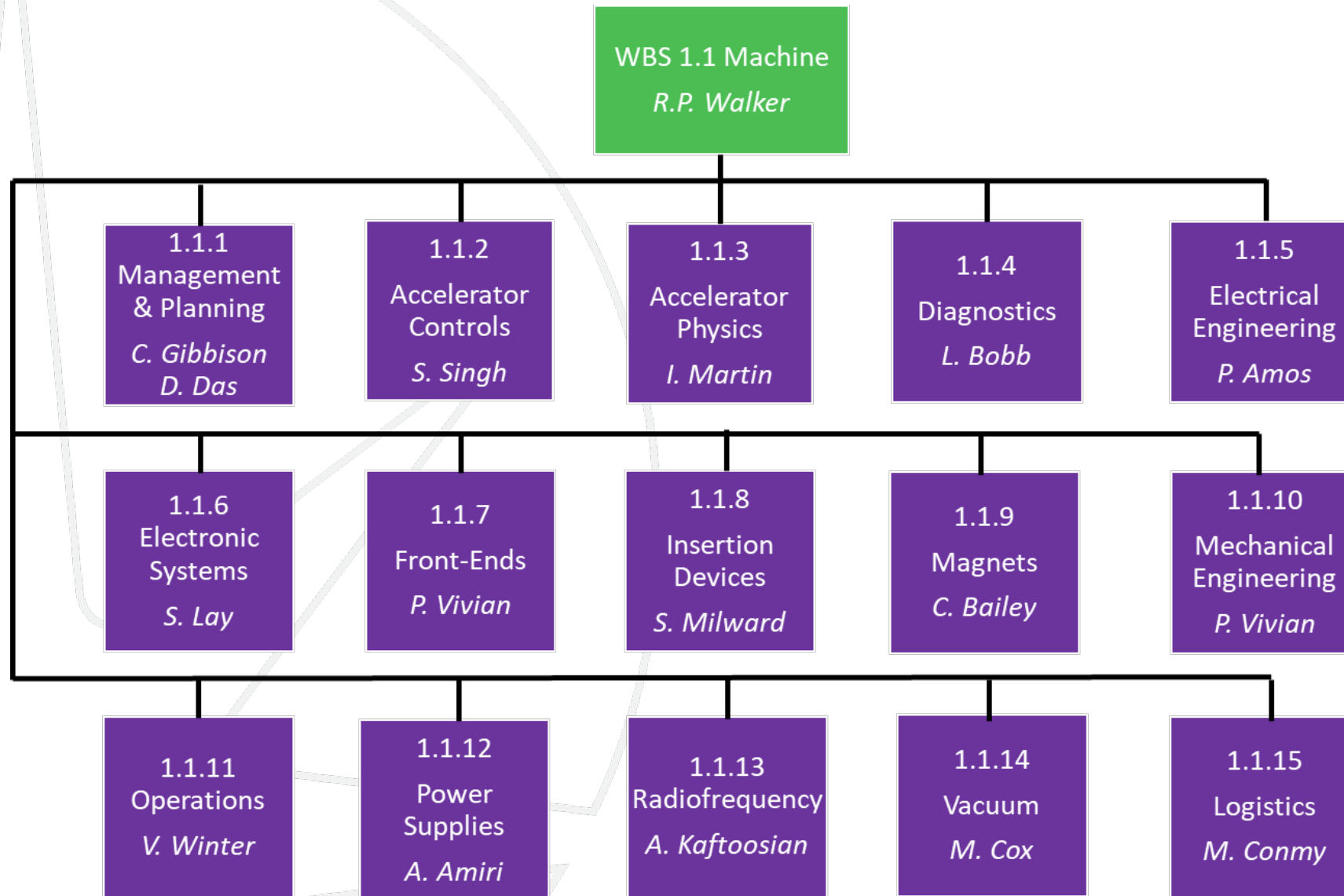
New HV transformer
installed for new RF
systems



First RF platform
for hosting new
solid-state
amplifiers together
with waveguide
penetrations
completed



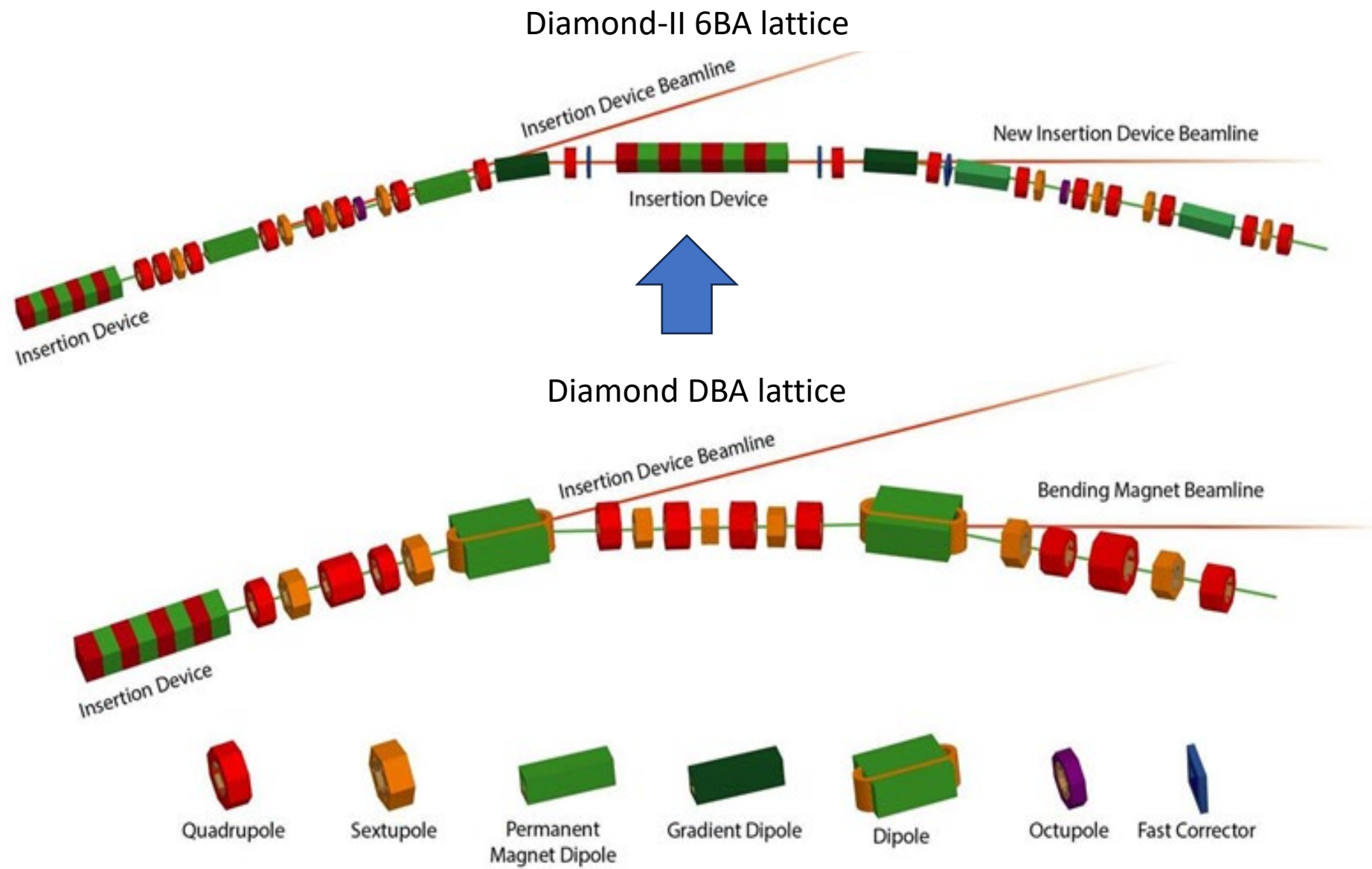
Diamond-II Machine: Work Packages



Diamond-II Machine: Design Goals

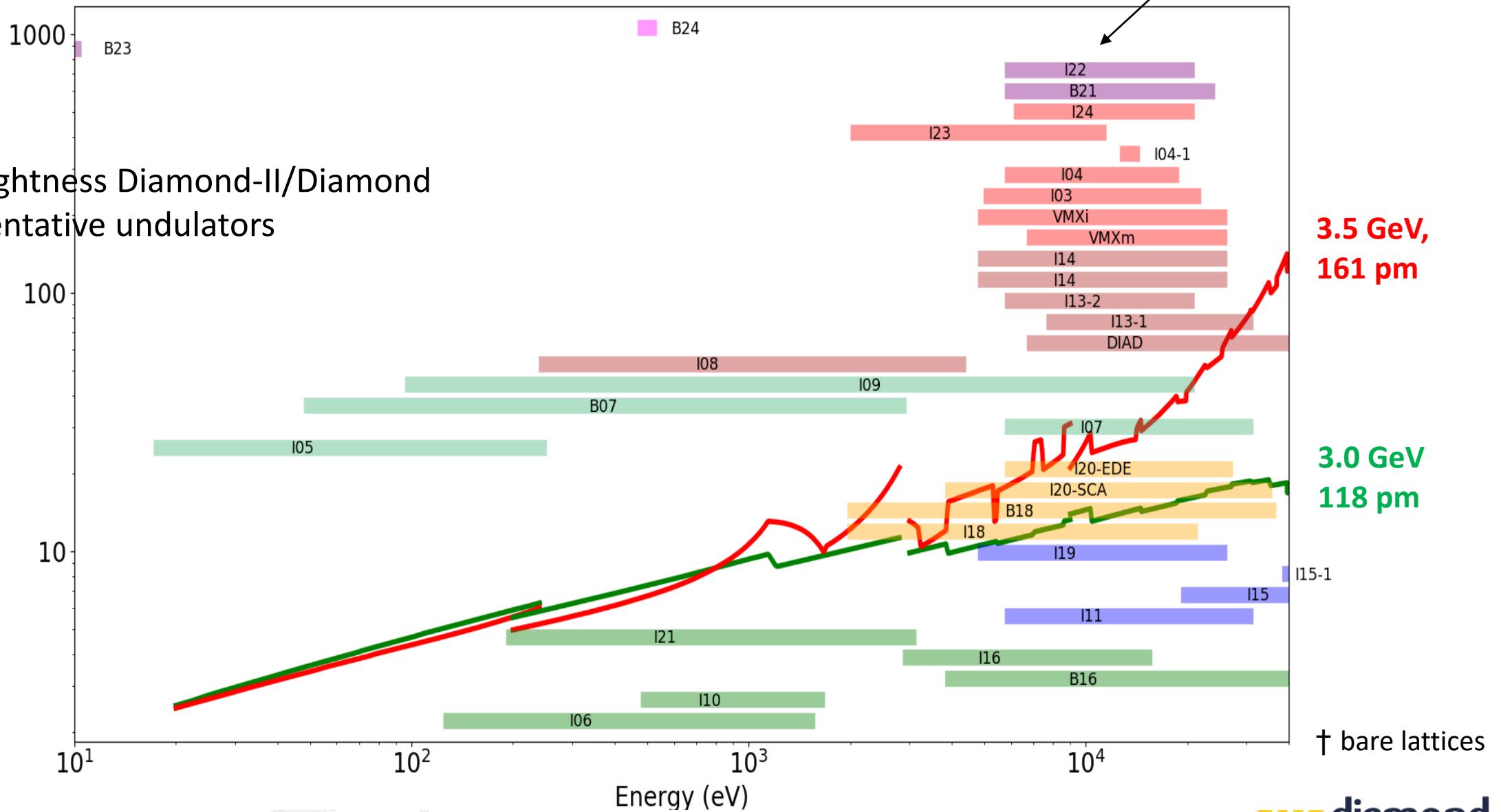
- ❖ Increased brightness and coherence
 - low emittance MBA lattice
 - increase in energy from 3 GeV to 3.5 GeV
- ❖ Increased capacity for insertion devices
 - inclusion of 'mid straights' in a 6BA lattice
- ❖ Maintain ID source points where possible
 - adjustment of straight section lengths
- ❖ Minimise downtime
 - do what is possible before the dark period
many activities already well underway
- ❖ Improved beam stability – < 3% of beam size integrated motion up to 1 kHz, with improved orbit feedback system
- ❖ Improved transparency of top-up operation – using a novel injection scheme

Diamond-II Layout



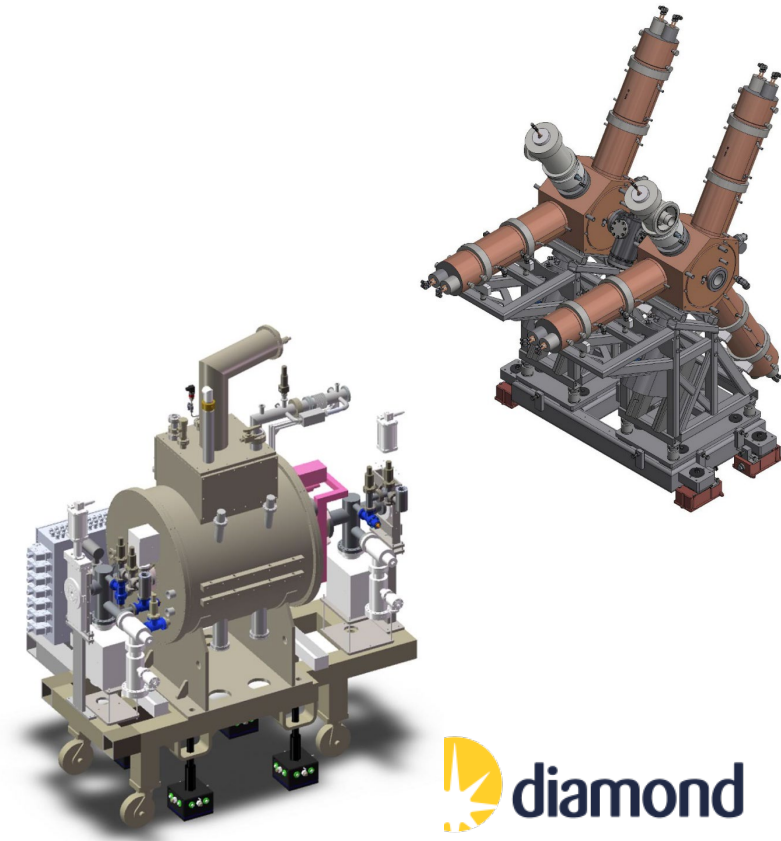
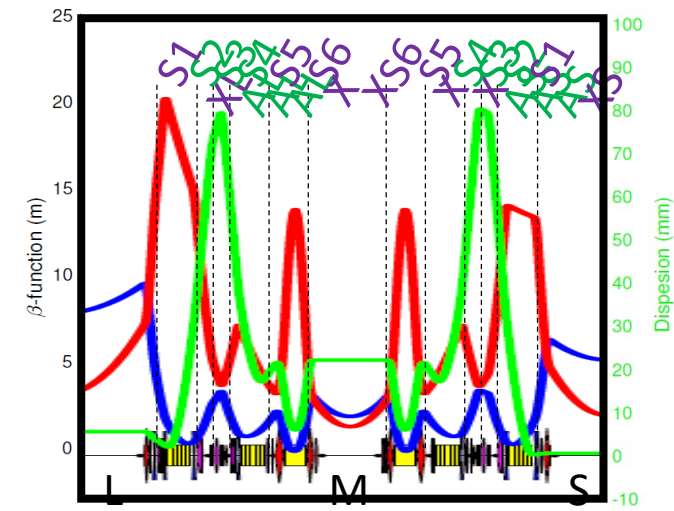
Diamond-II Brightness

Gain in Brightness Diamond-II/Diamond
for representative undulators



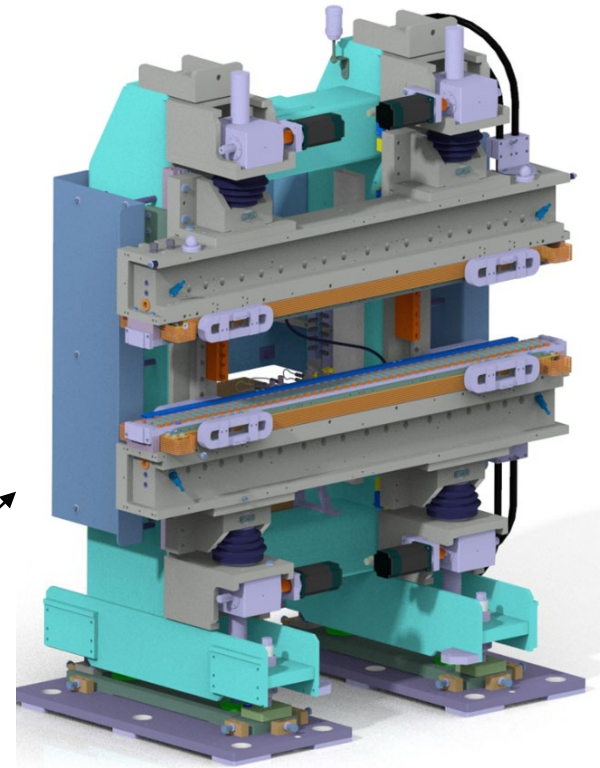
Diamond-II Machine: Main Features (i)

- Modified hybrid 6BA lattice – based on the ESRF H7BA; creates 24 new “mid straights”, 8 of which useable for insertion devices.
- Longitudinal gradient dipoles and transverse gradient dipoles (a la ESRF).
- Mainly NEG coated Cu vessels.
- 8 Normal Conducting Cavities, each with own Solid State Amplifier – *no more SC cavities and IOTs !*. Aiming for redundant operation – loss of 1 or 2 RF systems should not lose beam.
- Passive superconducting 3rd harmonic cavity.
- Fast Orbit Feedback integrating slow (in sextupoles, over Cu vessels) and fast (ferrite cored magnets over Ti vessels) corrector magnets.
- New pilot-tone injection BPM electronics, developed in-house.

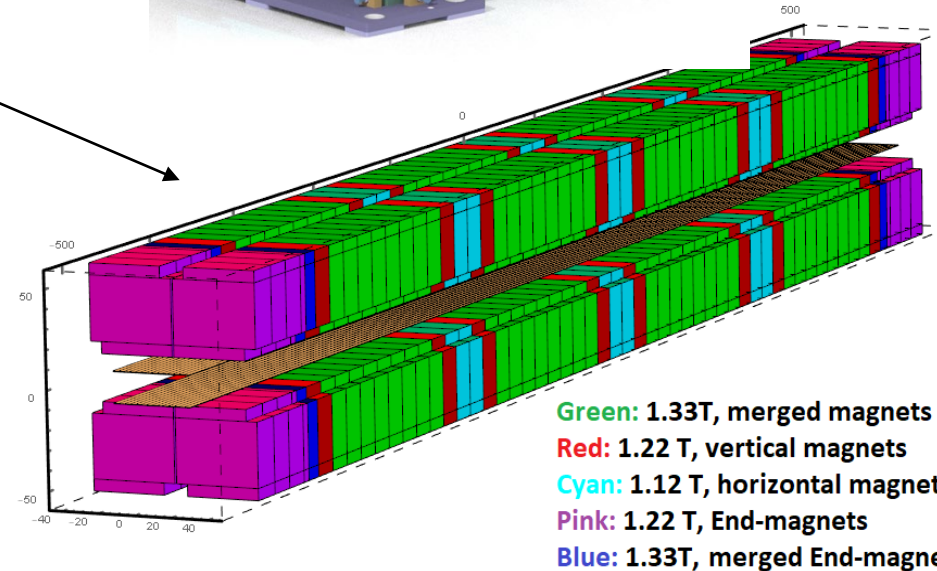


Diamond-II Machine: Main Features (ii)

- 12 new insertion devices:
 - 1 x CPMU ... under construction in-house
 - 2 x HPMU ... under construction in industry
 - 5 x APPLE-II
 - 1 x MPW
 - 1 x 3PW
 - 1 x EMPHU for circular polarization switching ... to be built in-house
 - 1 x APPLE-Knot (5m) to reach 10 eV with low on-axis radiation power in all polarization modes ... to be built in-house

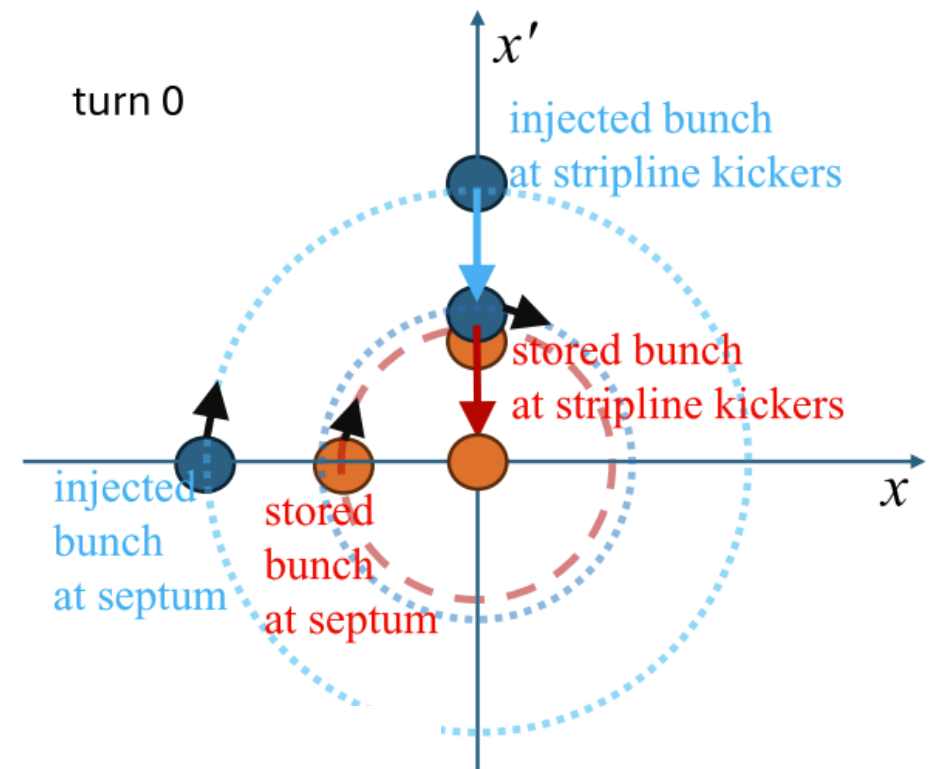
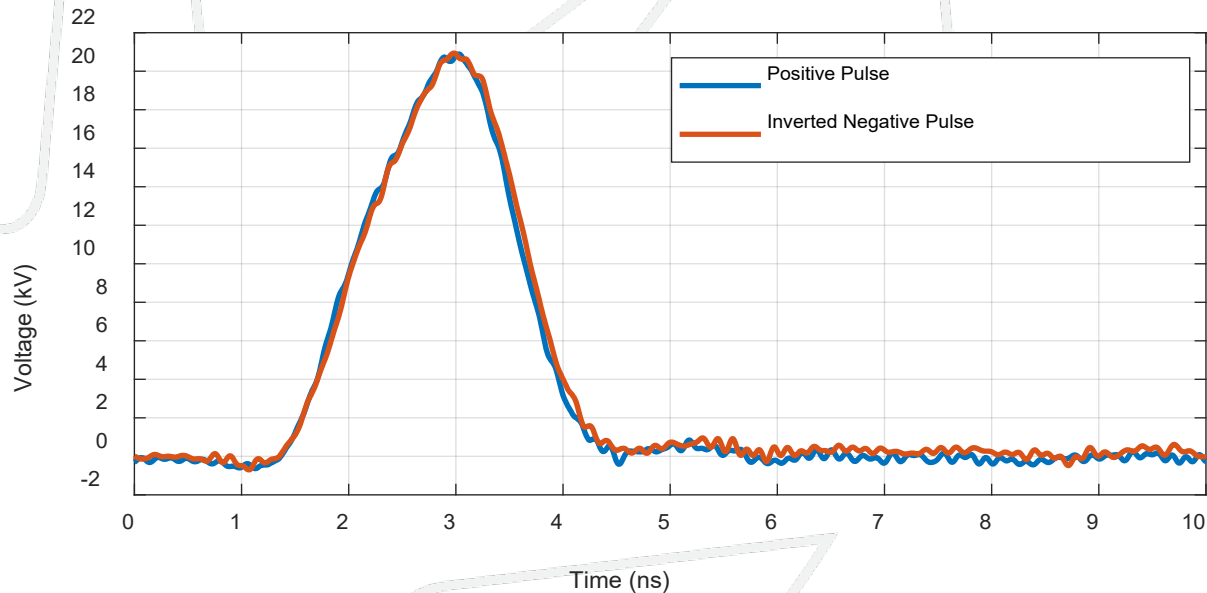


*Based on the SOLEIL
Electro-Magnetic
Permanent magnet
Helical Undulator*

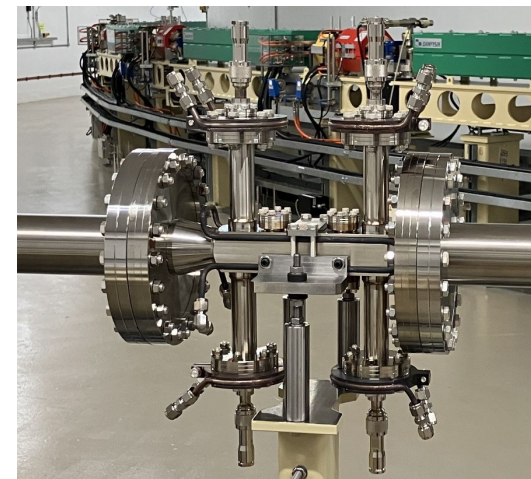


Diamond-II Machine: Main Features (iii)

- Double injection scheme:
 - classic 4-kicker bump and
 - new transparent single-bunch **“kick-and-cancel” injection scheme** using stripline kickers with novel high voltage fast double-pulse power supply, developed together with Kentech Instruments (UK)
- multiple, ± 20 kV pulses, < 3 ns 95% width



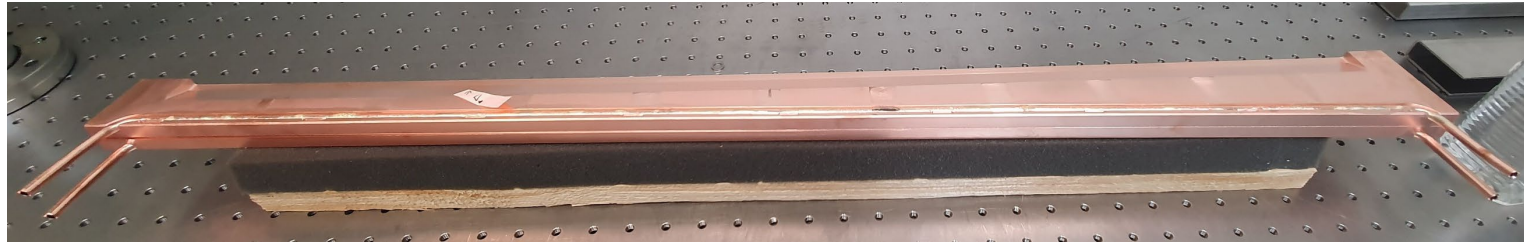
Phys. Rev. Accel. Beams **28**, 060701, June 2025



Prototype striplines
tested in the Booster-To-
Storage ring transfer line

Diamond-II Machine: Status (i)

- Procurement contracts in place for:
 - all SR lattice magnets
 - all SR standard arc vacuum vessels
 - SR girders
 - RF cavities, SSAs, 3HC
 - Booster girder assemblies (integrated girders, magnets, vacuum vessels – ready to install)
 - Main Booster magnet power supplies
- Main remaining procurement:
 - Pulsed magnets and power supplies
 - Special vacuum vessels
 - Straights vacuum vessels ... (many different versions, Diamond-II has 48 straights!)
 - Off-site storage (imminent)



Pre-series vacuum vessels



Pre-series girder fabrications



First of 7 x 120 kW solid-state amplifiers delivered to Diamond



Diamond-II Status: (ii)



Prototype girder with dummy magnets for vibration and alignment tests



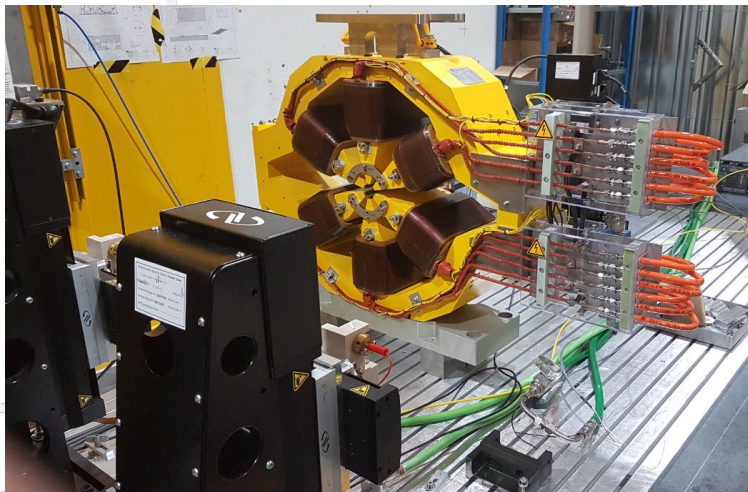
Prototype transverse gradient dipole magnet (DQ)



Longitudinal gradient dipole magnet (DL)



Full prototype girder vacuum vessel string



Pre-series sextupole magnet at Diamond



Prototype ceramic kicker vessels)

Diamond-II Machine: Key Outstanding Technical Issues

- Achieving an acceptable collimation and beam dump strategy (see Ian Martin's talk tomorrow a.m.).
- Supply of ceramic vessels for injection kickers – prototype injection kicker vessel with brazed flanges due this month.
- Supply of ceramic vessels for beam dump kickers – feasibility and possible supplier still to be identified (required dimensions challenging).
- Supply of extruded copper vessels for out-of-vacuum IDs – prototype due this month.
- Prototype injection stripline testing with ± 20 kV pulses – lab. tests this month, to be followed by active tests in the storage ring.

Project Management

- Key Project Milestones (KPMs)
 - High level KPMs reported to the Sponsor Group
 - Pillar level KPMs reported to the Project Board
 - Work Package KPMs reported to the Pillar Boards
- Contingency
 - Originally £93.1m (21.8%)
 - Amount of release of contingency regulated by the Sponsor Group based on quantitative residual risk calculation; decision on how it is used is delegated to the Project Board.
- Reserves
 - Created by costs being under budget > £100k: 50% retained by the Pillar, 50% by the Project.
 - Delegated authority to Pillar Leads to use (if < £100k), otherwise Project Board.
- Change Requests
 - for changes to scope, time, cost, with levels set for approval by Pillar Board, Project Board, Sponsor Group.

Procurement

Critical components for girder assembly	Delay to pre-series Factory Acceptance Tests
DQ (gradient dipoles)	3½ months
Quadrupoles	7 months
Sextupoles	1½ months ✓
Octupoles	2½ months
DL yokes & poles	3 months ✓
Group A arc vacuum vessels	10 months
Group B arc vacuum vessels	8 months
Group C arc vacuum vessels	7 months
Group D arc vacuum vessels	5 months
Group E arc vacuum vessels	3 months

✓ = now complete

- Regular contact with suppliers, weekly in the case of vacuum vessel contracts by video call, with occasional visits.
- Inspection service set-up for magnets with a UK company which has agents in various countries and this is being considered for vacuum vessel contracts.

Diamond-II Lessons Learned ... *so far!*

- Beam loss management is a much bigger issue than we ever envisaged.
- We underestimated the effort needed in some areas especially in Mechanical & Electrical Engineering, mainly due to: more complexity than envisaged, more special vessels than expected, more FEA needed than expected.
- Effect of overlap with beamline work ... a complete unknown at the start and still being detailed. Would be better to get a grip on this earlier.
- Procurement contracts often run late (not really a surprise ..). Do what you can to expedite progress .
- Don't rely on contractor experience – e.g. Follow-up on material certification (recent bad experience).
- Have buffer in the schedules and/or backup plans.
- Do whatever you can before the 'dark period'.
- Manage expectations for beamline start-up conditions from the beginning and regularly update beam parameters including reliability.

Conclusion

- ❑ Diamond-II has challenges around procurement delays and the remaining design work, but we currently have margin in the programme to accommodate these and so ...
- ❑ We are on track for the start of the Diamond-II shutdown in Dec. 2027
- ❑ Advice/collaborations welcome on:
 - Pulsed magnets & power supplies
 - Beam loss management - collimation and beam dumps



Brighter Times Ahead !

Thanks for Your Attention