Insertion Devices

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Diamond-II: challenges and novel solutions for upgrading the national synchrotron light facility

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diamond

IDs for Diamond-II

What are insertion devices (IDs)?

What changes Diamond ⇨ Diamond-II?

Mitigations for low energy photons

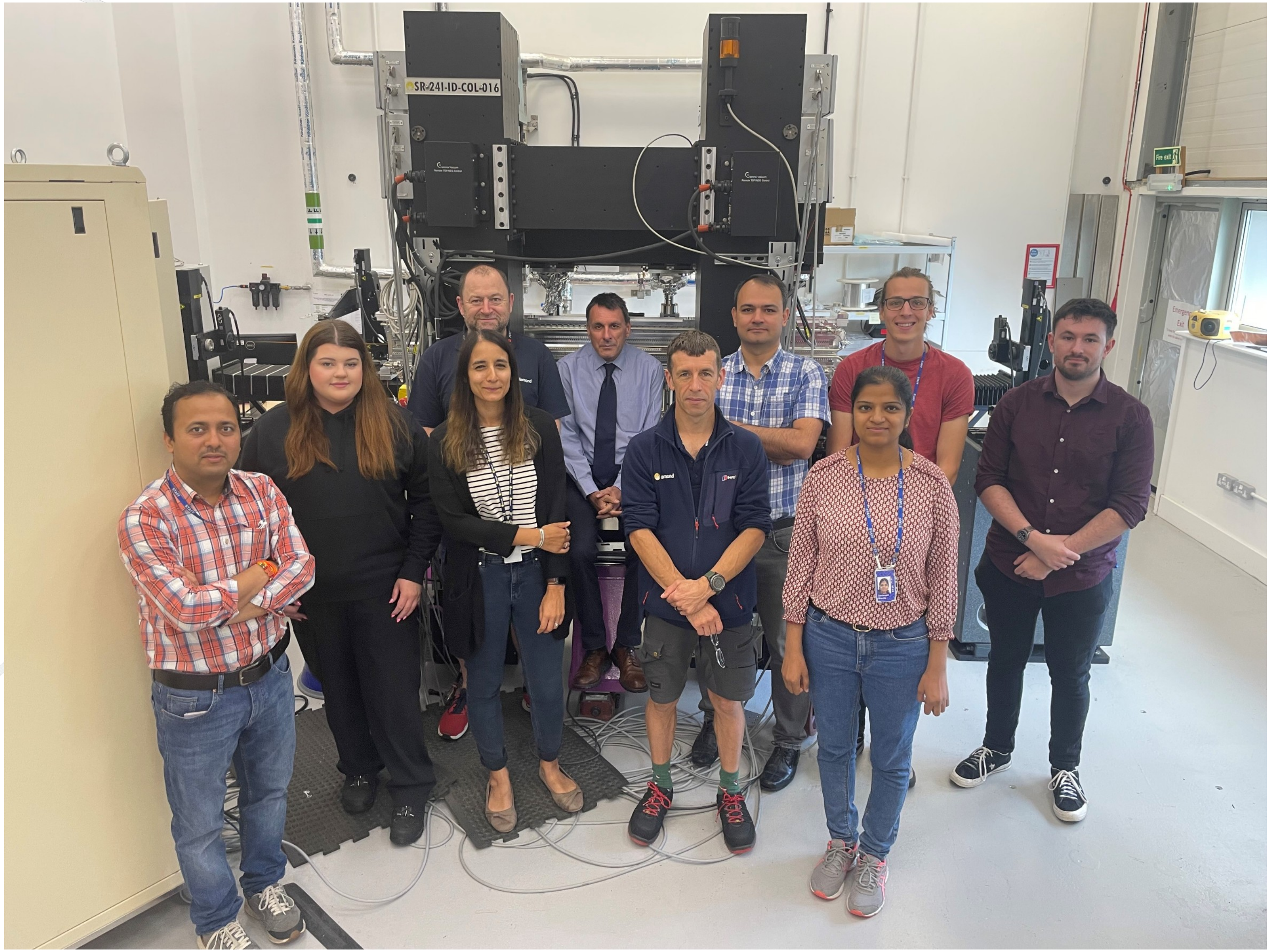
Exploiting higher energies

Fast Polarisation switching

New IDs for Diamond-II

Other challenges

Diamond ID Group



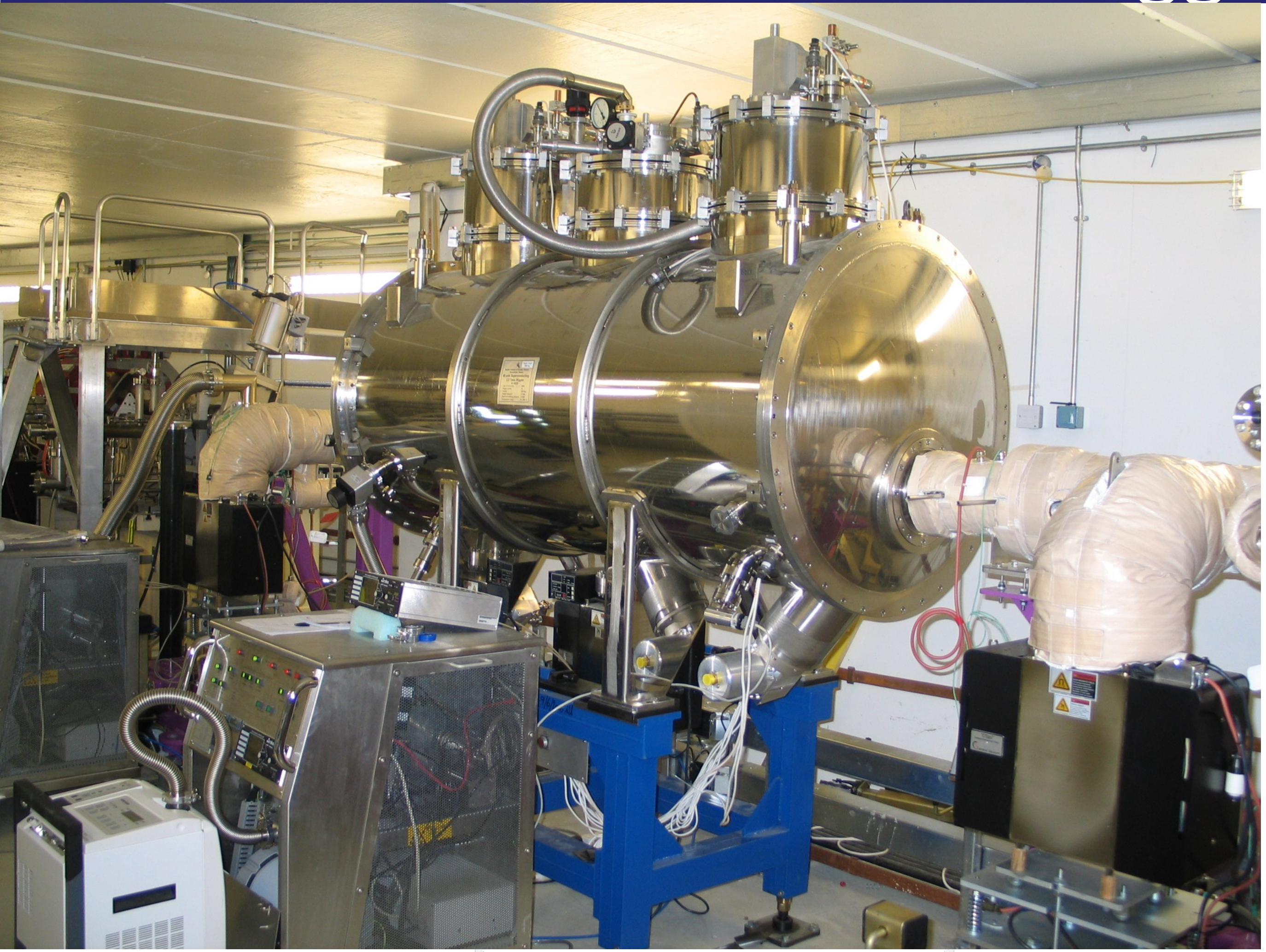
Crash Course on IDs

Insertion devices are magnet arrays inserted into electron storage rings to generate synchrotron radiation

Two broad classes according to deflection parameter K $\propto$ B x λ:

- **Wigglers**
- Higher magnetic fields (B) at larger periods (λ) = Large K
- Larger electron deflection
- Continuous photon spectrum over a wide fan
- Permanent magnet and superconducting
- **Undulators**
- Smaller magnetic fields (B) and smaller periods (λ) = Small K
- Small electron deflection
- Exploit constructive interference ⇨ line spectrum narrow bright beam
- Linear, helical, in-vacuum, out of vacuum. Exclusively permanent magnet at Diamond.

Wiggler

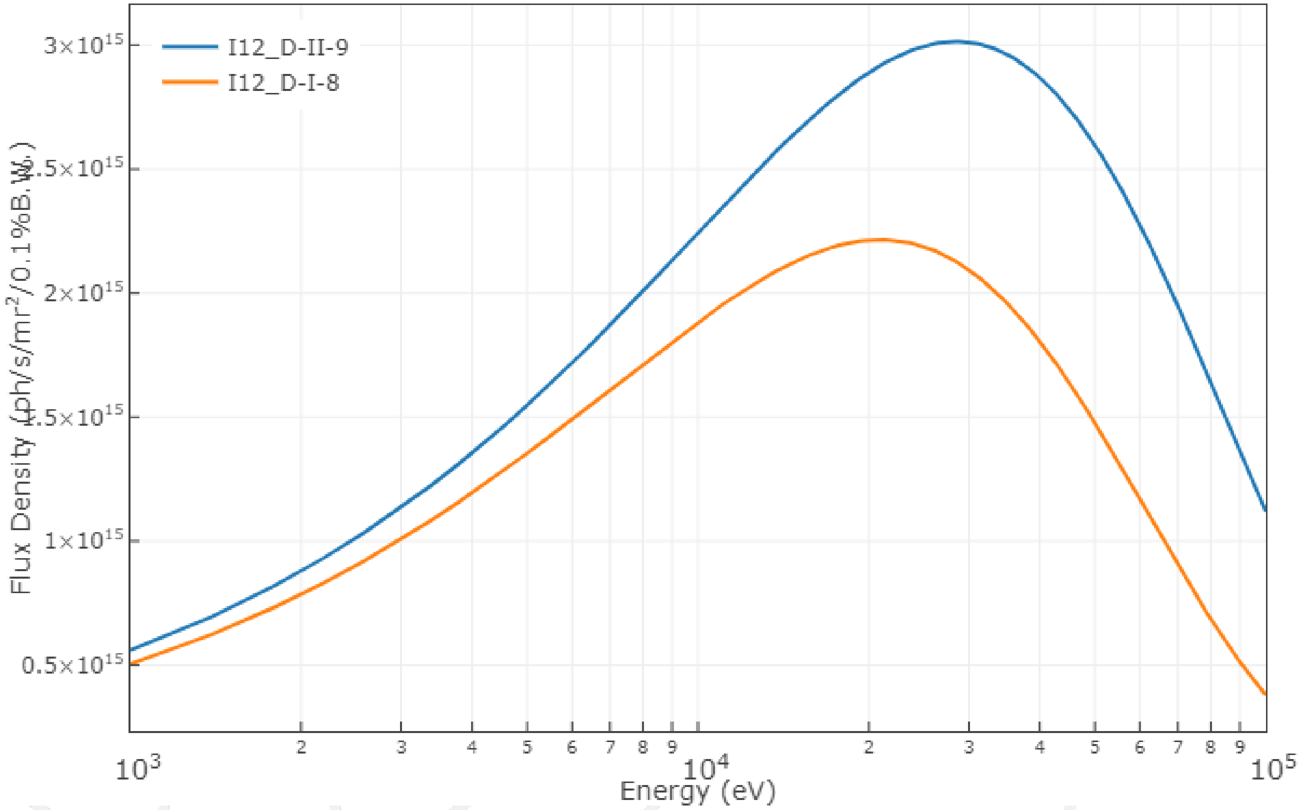


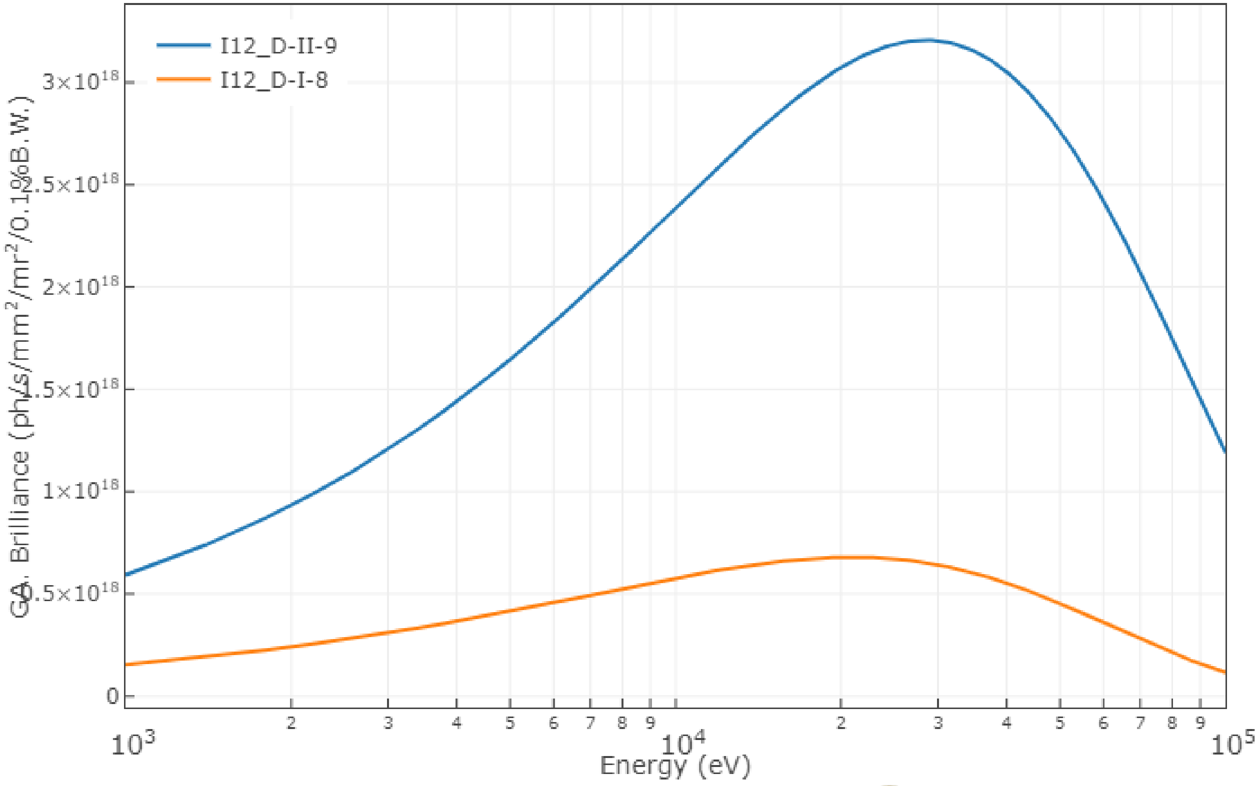
I12 SCW† Parameters	Diamond	Diamond-II
Beamline energy range (keV)	53 – 150	53 – 150
Field amplitude (T)	4.2	4.2
Period (mm)	48	48
No. of periods	22.5	22.5
Magnetic Length (m)	1.11	1.11
K	18.8	18.8
E_c (keV)	25	34
Total power (kW)	33.4	45.5

†SCW = SuperConducting Wiggler
PMW = Permanent Magnet Wiggler

Diamond Wigglers:
2 x SCWs - I12 & I15
3 x PMWs I20, J20 & K11

Wiggler





E_e 3GeV ⇨ 3.5GeV means more flux at higher energy & more power onto FE & optics

In-Vacuum Undulator

In-Vacuum Undulator

CPMU† Parameters I24, I03, I04, (J02)	Diamond	Diamond-II
Beamline energy range (keV)	5 – 25*	5 – 30*
ID gap (mm)	28 – 4	28 – 4
Field amplitude (T)	0 - 1.4	0 - 1.4
Period (mm)	17.6	17.6
No. of periods	113	113
Magnetic Length (mm)	1988.8	1988.8
K	0 – 2.3	0 – 2.3
ε1st (eV)	1332	1813
Magnet material	PrNdFeB	PrNdFeB
Total power (kW)	6.5	20.3

*Typical

Diamond In-Vac. IDs:

5 x CPMU: I24, I03, I04, (J02) & I07

11 x PMU: I02, (J02), I09, I13-1&2, I14, I16, I18, I19, I22, I23

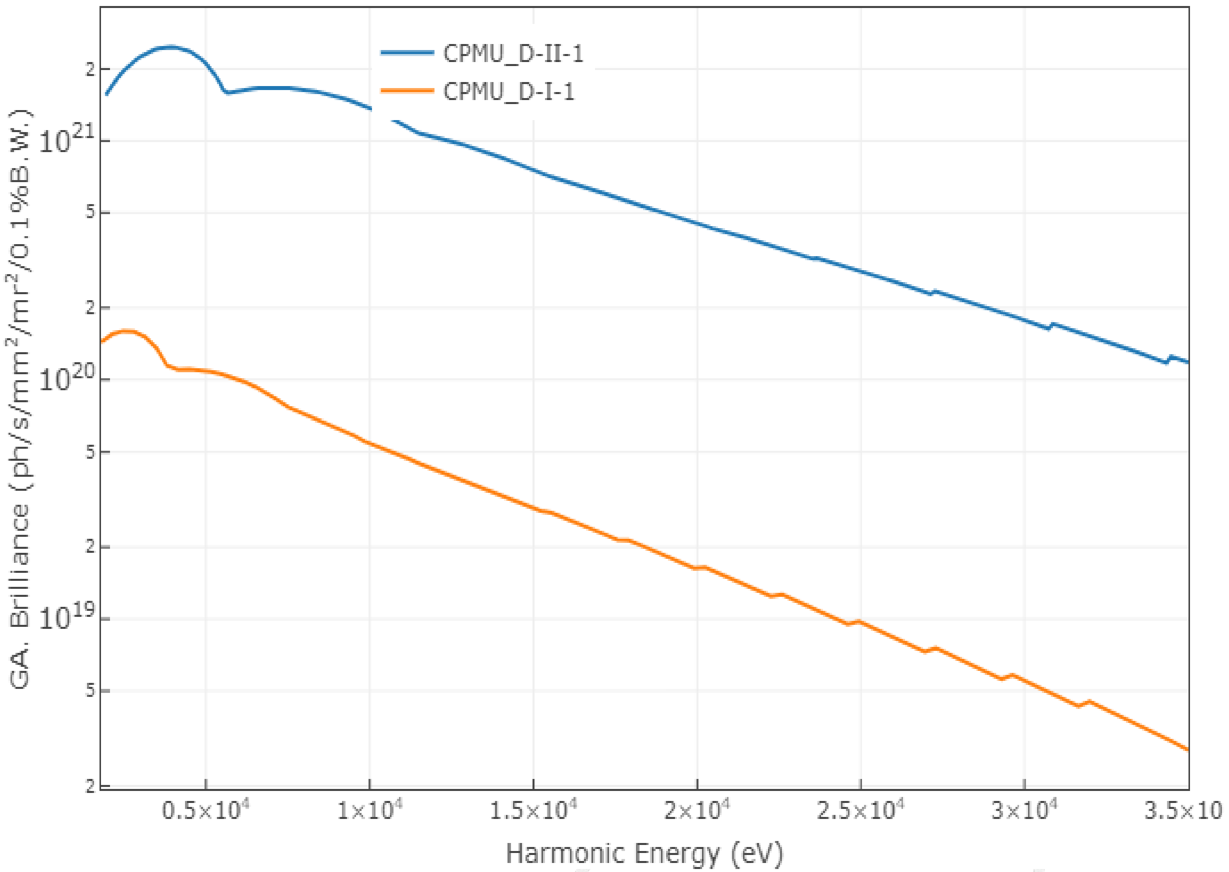
1 x HPMU: I04.1

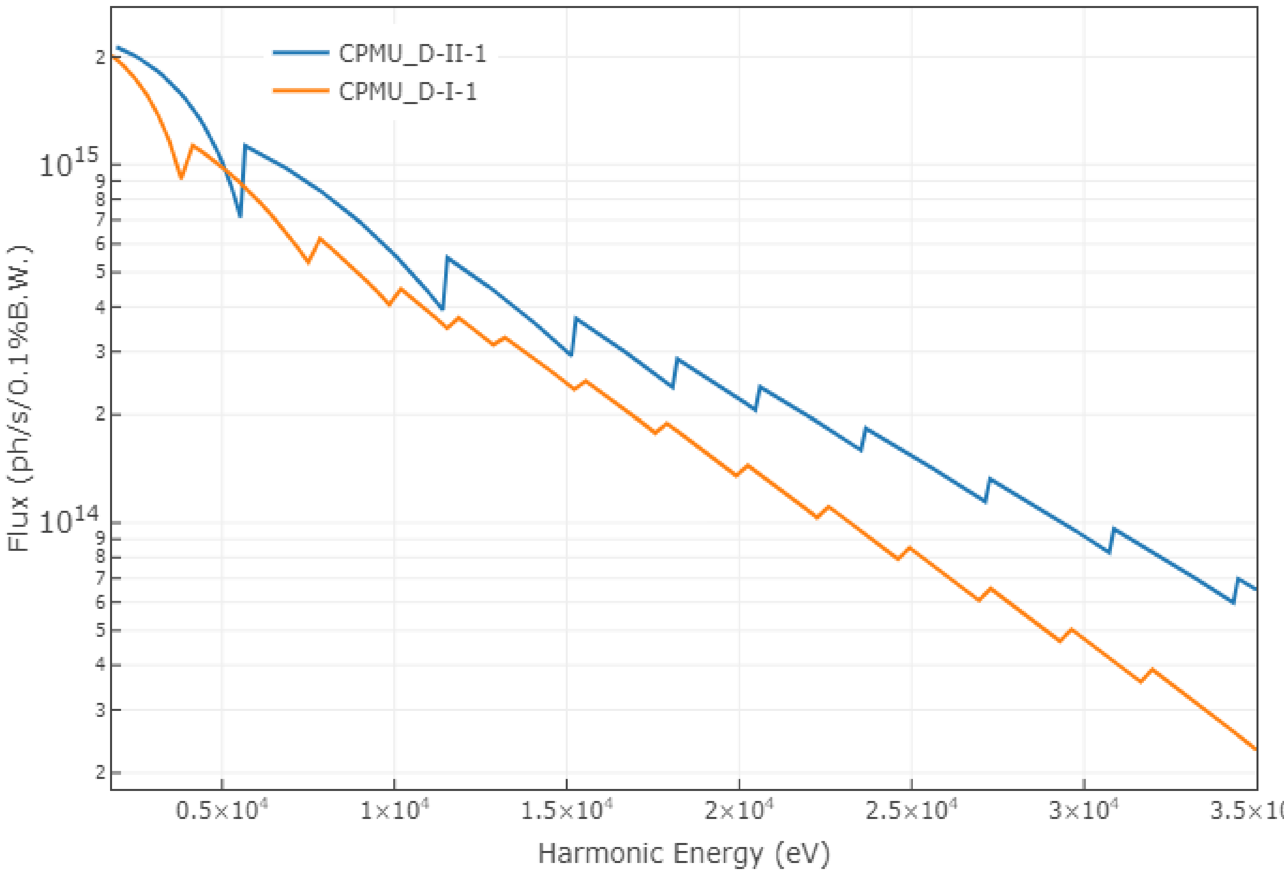
† CPMU = Cryogenic Permanent Magnet Undulator (cold magnets & poles)

PMU = Permanent Magnet Undulator (just magnets)

HPMU = Hybrid PM Undulator (magnets & poles)

In-Vacuum Undulator





CPMUs allow short periods for more high energy flux

E_e 3GeV ⇨ 3.5GeV also gives more flux at higher energy. Plus more FE & optics power

Out of Vacuum Undulator

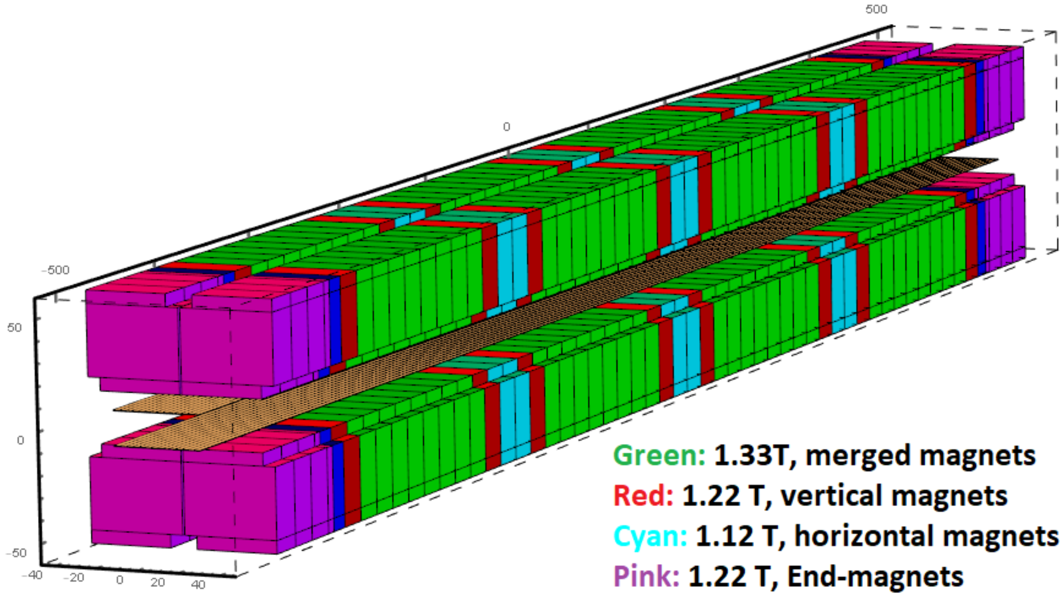
I05 Parameters	Diamond	Diamond-II
Beamline energy range (eV)	18 – 240 LV LH CP	10 – 240 LV LH CP
Configuration	APPLE†-II QP	APPLE-KNOT QP
ID gap (mm)	300 – 23.5	300 – 19
Field amplitude (T)	0.62 LV 0.62 LH 0.44 CP	0.98 LV 0.98 LH 0.69 CP
Period (mm)	140	140
No. of periods	33	33
Magnetic Length (m)	5	5
K	8.1/8.1/5.7	9.5/9.5/9.0
ε1st (eV)	18	10
Magnet material	NdFeB	NdFeB
Total power (kW)	3.0	10.3

†APPLE = Advanced Planar Polarized Light Emitter (Undulator) – variable polarisation

QP = Quasi-periodic

Out of Vacuum Undulator – Low Photon Energies

Diamond Out of Vac. IDs: 8 x APPLE-II: I05, I06A&B, I08, J09, I10A&B, I21.

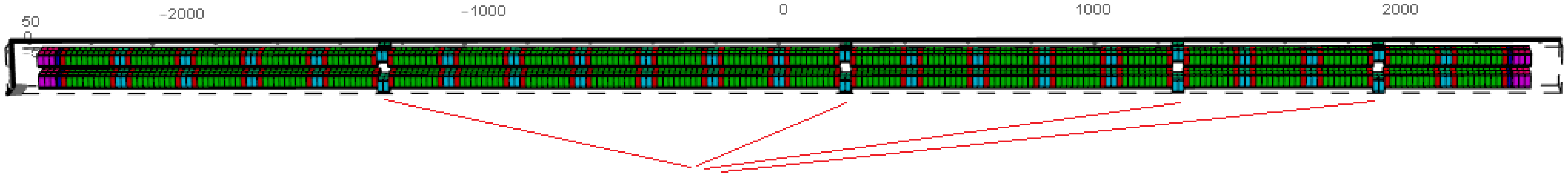


Green: 1.33T, merged magnets
Red: 1.22 T, vertical magnets
Cyan: 1.12 T, horizontal magnets
Pink: 1.22 T, End-magnets
Blue: 1.33T, merged End-magnet

X-separation	1 mm
Magnets dimensions	45mm*45mm*17.45 mm
Magnets grades	1.33T, NdFeB 1.22T, NdFeB 1.12T, NdFeB
Force	8.4 tonnes per 5 m beam

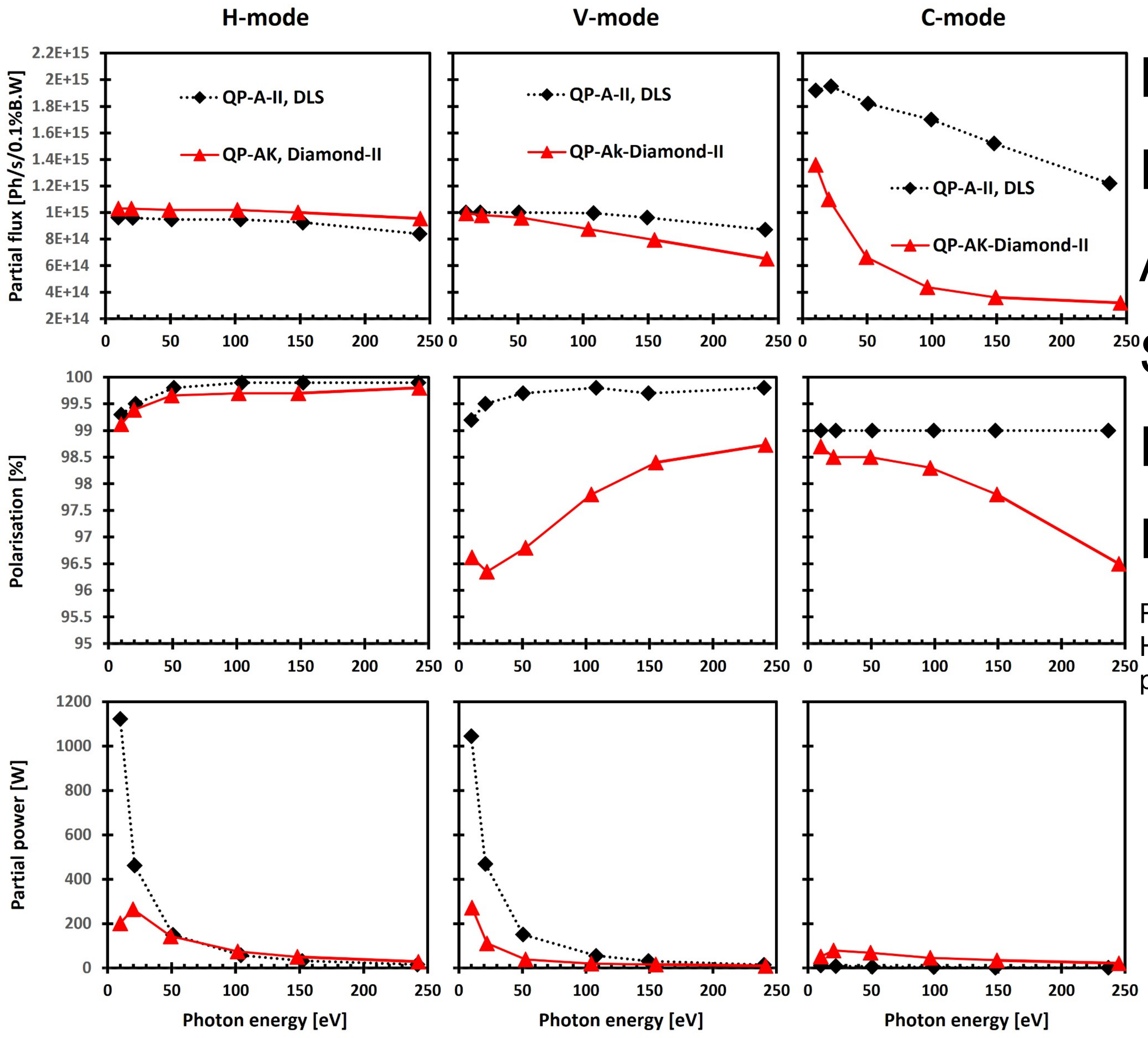
APPLE-Knot ID for I05 in Diamond-II

Uses compound angle magnets = higher magnetic field for lower photon energy without excessive power on optics



Retracted H-blocks in Quasi periodic design

Out of Vacuum Undulator – Low Photon Energies



$E_{ph} \propto E_e^2/\lambda_u(1+(\lambda_u \times B_u)^2..)$

For Diamond-II: E_e 3GeV ⇨ 3.5GeV

And: E_{ph} 18eV ⇨ 10eV

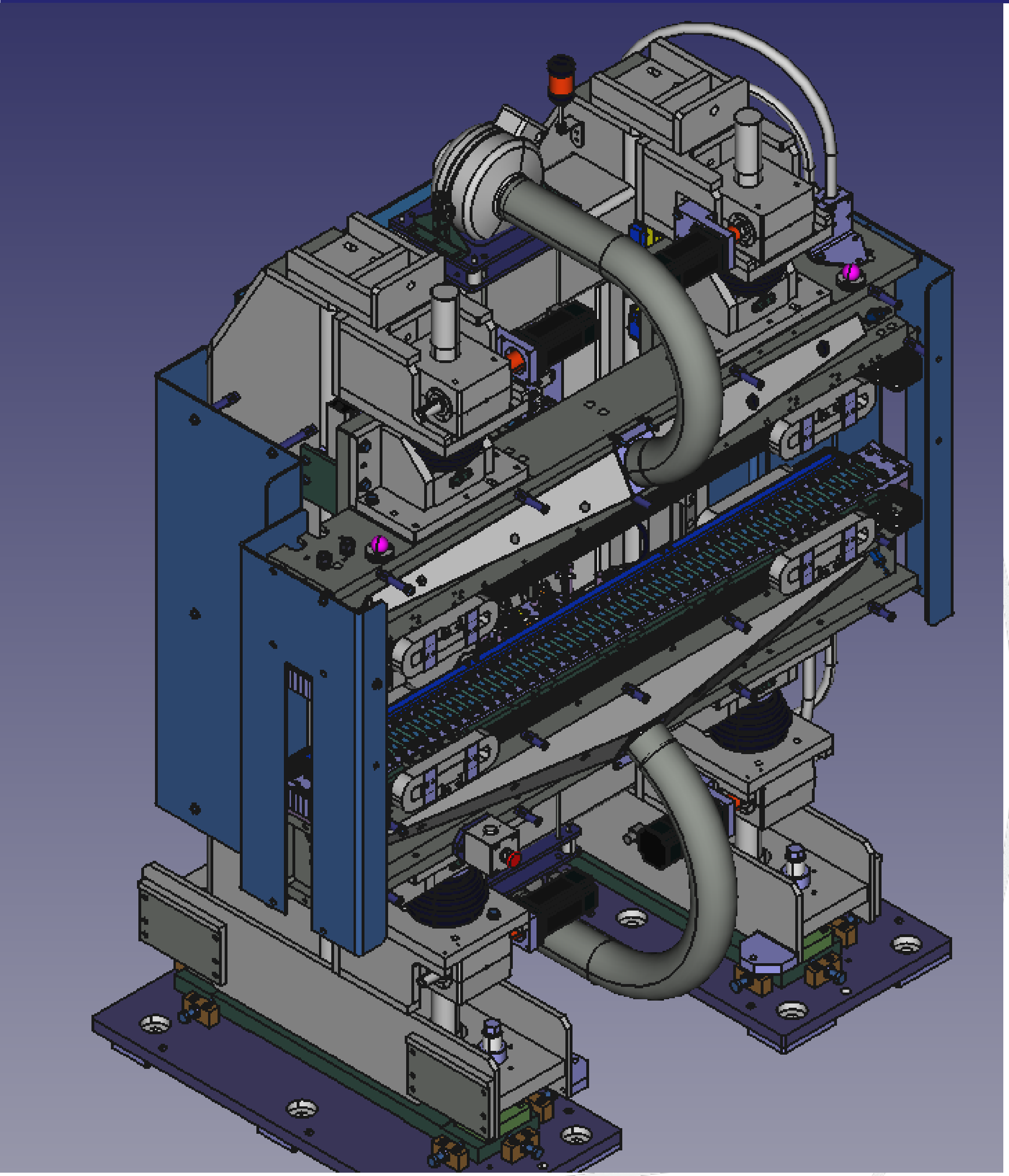
So: B_u must be larger

However: Power $\propto E_e^2 \times B_u^2$

Hence: APPLE ⇨ APPLE-KNOT

Ref.: e.g. S. Qiao, D. Ma, D. Feng, S. Marks, R. Schlueter, S. Prestemon, and Z. Hussain, "Knot undulator to generate linearly polarized photons with low on axis power density," Review of Scientific Instruments 80, 085108 (2009).

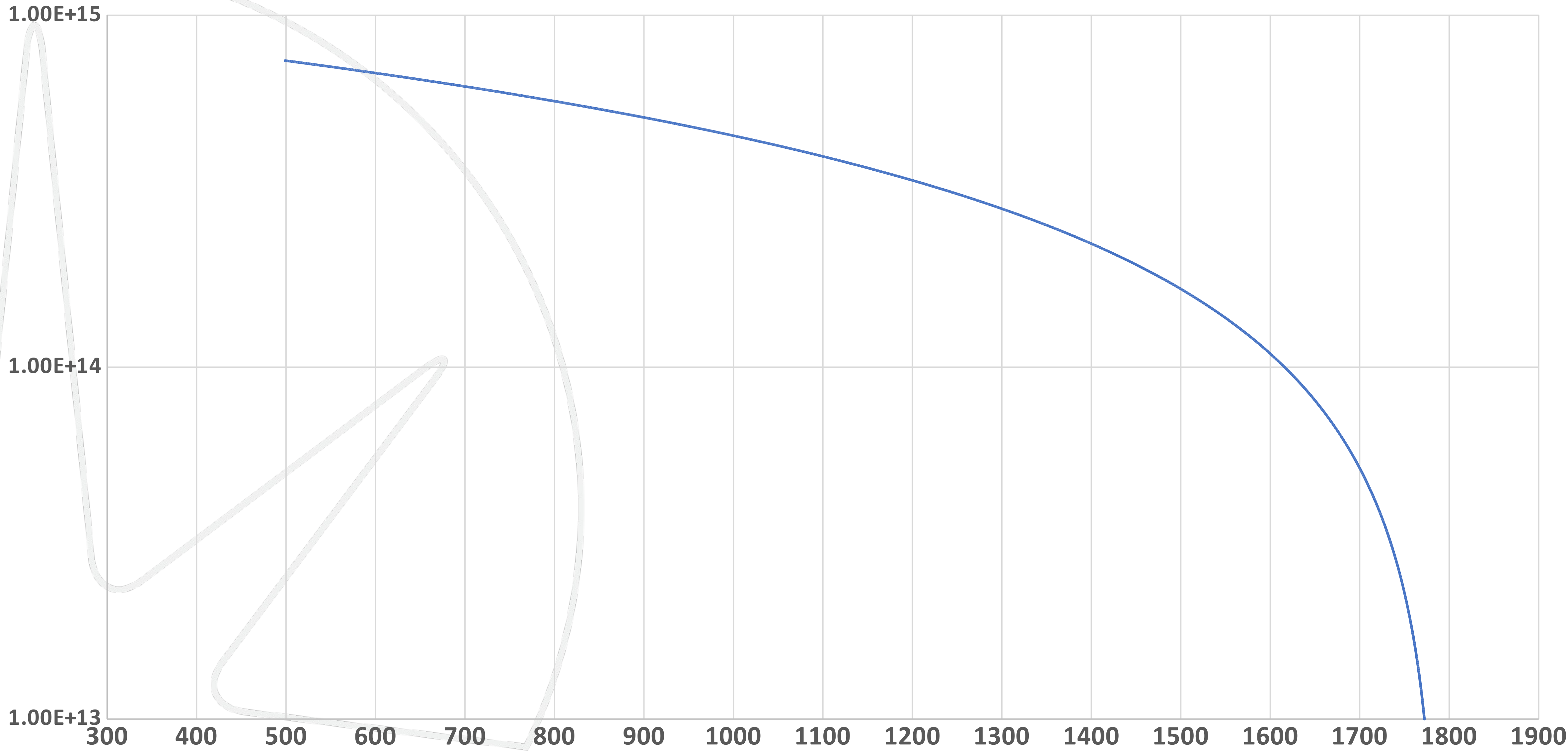
Fast Polarisation Switching



Beamline	I06
Device type	EMPHU
Minimum gap	12.5mm
Period length	65mm
Number of periods	24
Device length	1.75m
Max. effective magnetic field	0.265T
Energy range for beamline	0.5-1.7keV
Total power W	500
Polarisation switching rate	~ 5 Hz

Courtesy Fabrice Marteau, Synchrotron-Soleil

Fast Polarisation Switching



New IDs for Diamond-II

*Provisional
⚐ In-House
Ind Industry

	Beamline	ID type	Period* (mm)	N	L (m)	Min. Gap (mm)	B (T)	In-house
1	K02 (VMXm)	CPMU	17.6	85	1.5	4	1.4	⚐
2	I09.1	HPMU	23	87	2	6.4	0.97	⚐
3	K21	HPMU	18.7	80	1.5	4	1.17	Ind
4	K16	HPMU	18.7	80	1.5	4	1.17	Ind
5	I05	APPLE-K	140	35	5	19	0.98	⚐
6	I06	APPLE II	56	44	2	19.5	0.732	Ind
7	I08	APPLE II	56	70	3.97	19.5	0.732	Ind
8	I10	APPLE II	56	70	3.97	23	0.6	Ind
9	K07(B07-2)	APPLE II	64	28	1.94	18	0.87	Ind
10	I17 CSXID	APPLE II	52	94	5	16.5	0.82	⚐
11	K18	3PW	-	1	2	12	1.4	Ind
12	K14 SWIFT	MPW	116	6	0.7	15	1.3	
13	I06	EMPHU	65	24	1.75	12.5	0.265	⚐

Other Diamond-II Challenges

- Capacity of ID industry to supply 8 IDs in time available
- Impact of fast polarisation switching on stored beam stability
- Motor drive architecture & obsolescence
- Synchronising ID gap & phase motion with optics for spectroscopy experiments
- Commissioning many beamlines with new IDs in a short time