Update on the UK's New Light Source Project

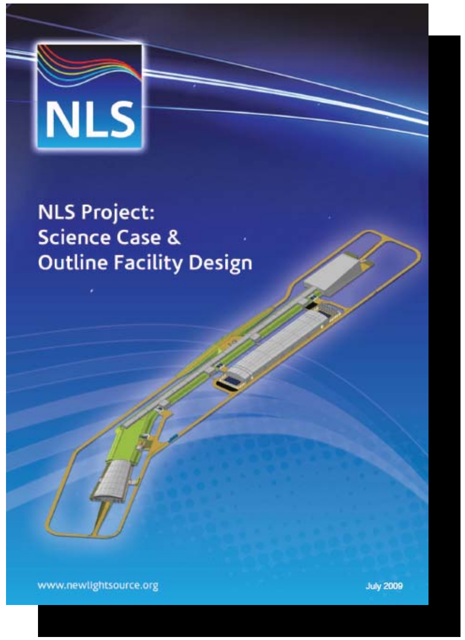
R. P. Walker, Diamond Light Source

http://www.newlightsource.org

ESLS-XVII, DESY, 26th-27th November 2009

New Light Source Project Progress

- Official Launch of the NLS Project,   April '08
- Science Workshops,   May - June '08
- Draft Science Case published,   Sep. '08
- Science Case approved by the Physical And Life Sciences (PALS) committee and Science Board of the STFC,   Oct. – Nov. '08
  → approval to proceed to the design stage
- Science Community Meeting,   April '09
- 1st Technical Advisory Committee,   June '09
- Science Case and Outline Facility Design,   July '09
- Review by STFC,   Oct. – Dec. '09



Baseline Specification for NLS to Match the Science Case

- High brightness (>10^{11} photons/pulse) in 50eV – 1keV range
- Harmonic radiation to 3keV (>10^8 ph/pulse) and 5keV (>10^6 ph/pulse)
- Short pulse duration ~20fs
- Smooth wavelength scanning across entire spectral range
- Synchronized to ultra-fast light sources covering THz- deep UV
- 1KHz repetition rate with even pulse spacing initially, increasing to 10 – 100 kHz in the future
- Fully coherent (transverse and longitudinal), reproducible pulses

Meeting the Baseline Specification

- **Free-Electron Lasers to cover the range 50 eV to 1 keV :**

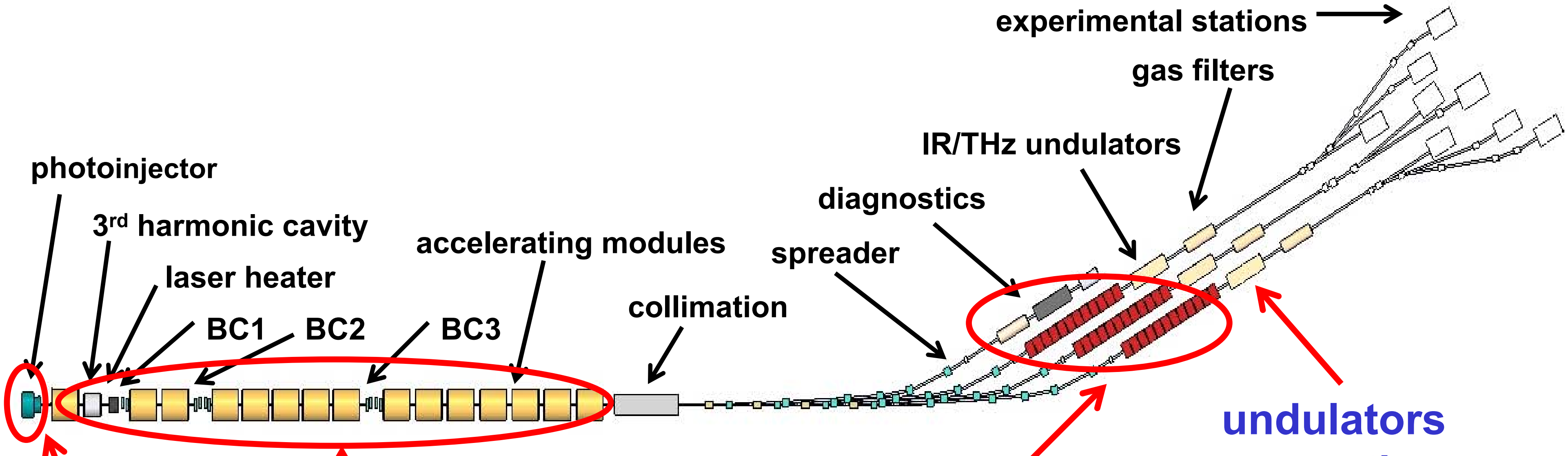
  FEL1: 50 - 300 eV FEL2: 250 - 850 eV FEL3: 430 - 1000 eV

- **harmonics up to 5 keV**
- **independently tuneable through undulator gap variation**
- **variable polarization using APPLE-II undulators**
- **seeded in order to provide longitudinal coherence, in 20 fs pulses**

- **Conventional laser sources + HHG for 60 meV (20 μm) – 50 eV**

- **IR/THz sources, e- beam generated and synchronised to the FELs, from 20 – 500 μm**

Schematic Layout



2.25 GeV cw superconducting linac

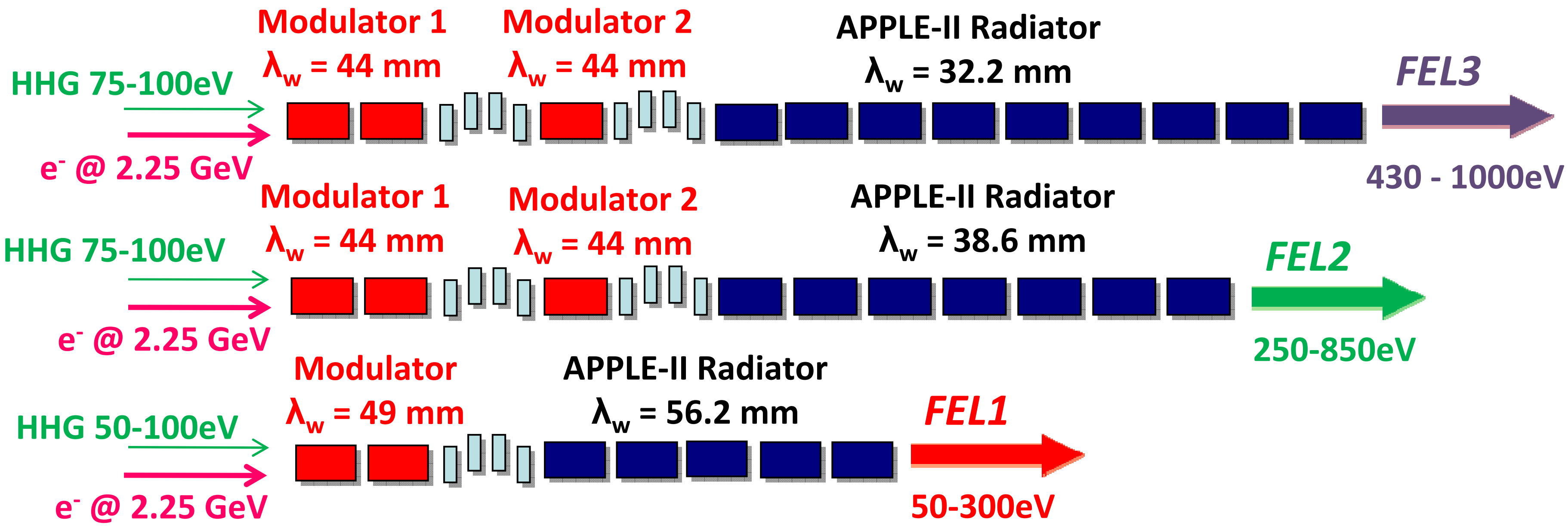
3 free-electron lasers covering 50 eV–1 keV,

undulators generating THz/IR radiation synchronised to the FELs

high brightness electron gun, operating initially at 1 kHz

Recirculating linac option being studied in parallel (talk by D. Angal-Kalinin).

FEL Scheme



- common electron energy for all 3 FELs, allows simultaneous operation

- HHG seeding with realistic laser parameters, up to 100 eV

- harmonic cascade scheme to reach up to 1 keV

N. R. Thompson, ASTeC

Upgrade Paths

- **Higher photon energies, at least to 1.5 keV, later > 2 keV**

  - space will be left for an extension of the linac to reach higher energy

- **Increased rep. rate, ≥ 10 kHz, up to 1 MHz**

  - requires higher repetition rate gun, lasers (photocathode, seeding and pump-probe), switching magnets <u>but the basic linac and infrastructure remain the same</u>

- **Shorter pulses, ≤ 1 fs**

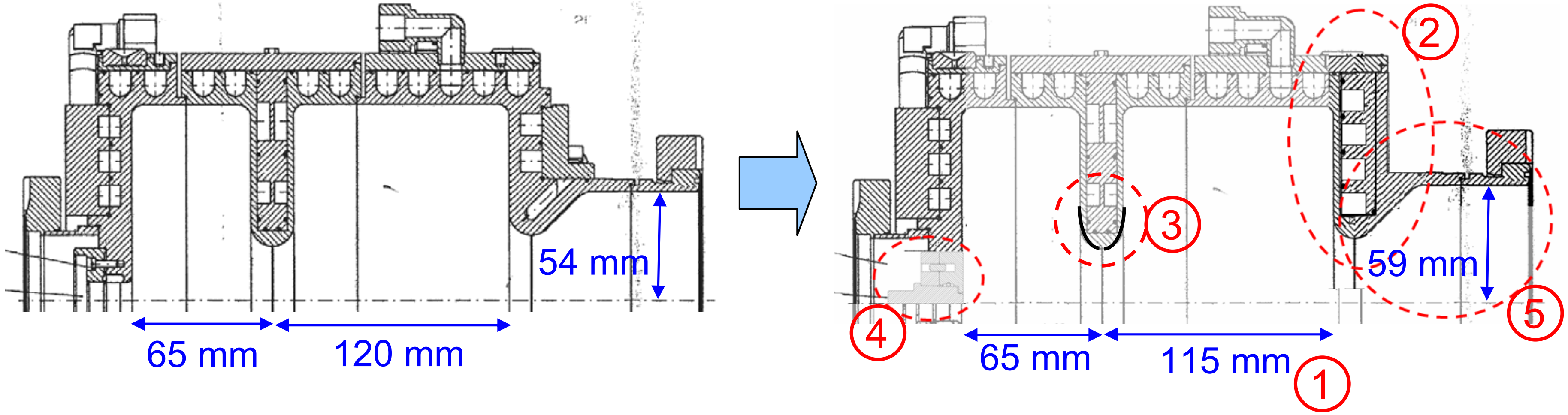
  - space will be left to incorporate laser slicing or other techniques

- **Additional FELs and experimental stations**

  - space will be left for a second FEL and experimental hall

Stage 1 Injector: modified FLASH/PITZ N/C L-band Gun

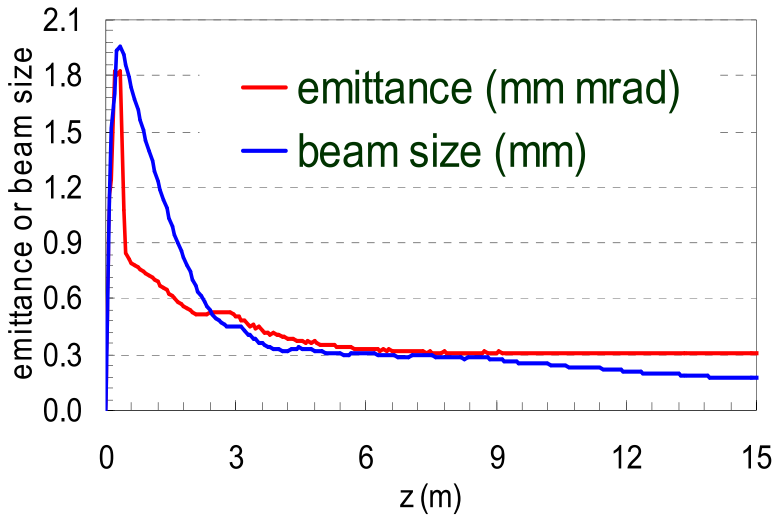
PITZ Gun4 (DESY) NLS Gun1



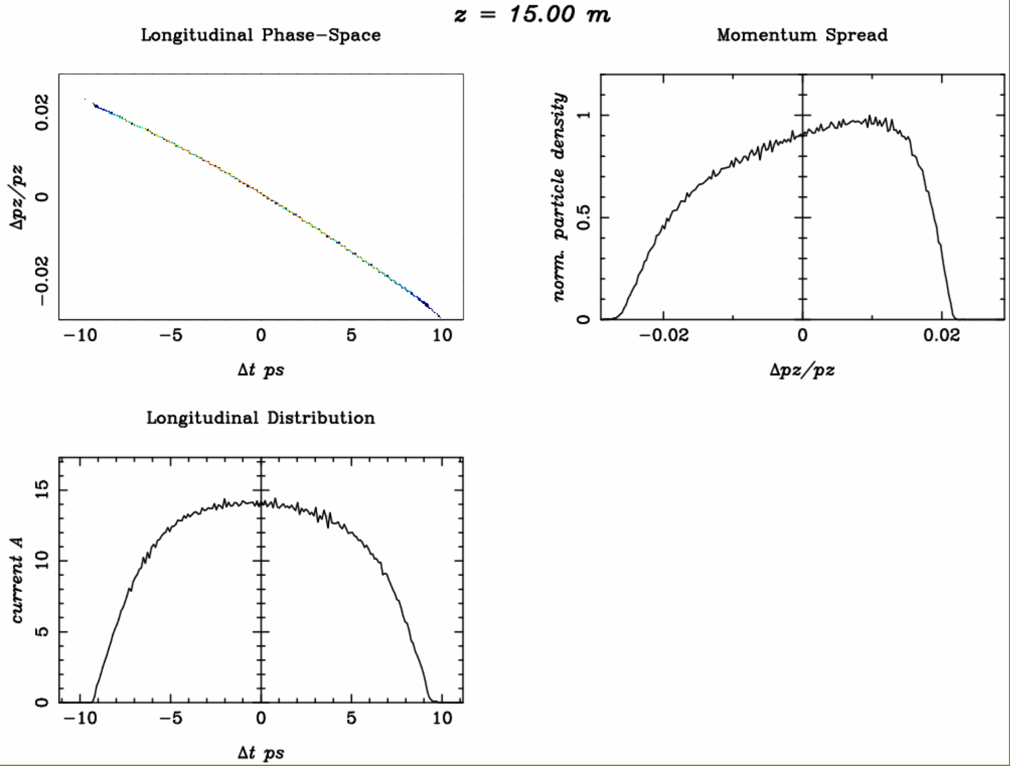
1. Cell lengths optimised for smaller emittance
2. Minor improvement of cooling-water channel
3. Iris shape to be elliptic for less surface field
4. Opening for cathode insertion improved for no scratch on the plug
5. Larger coupler radius for reducing wakefield

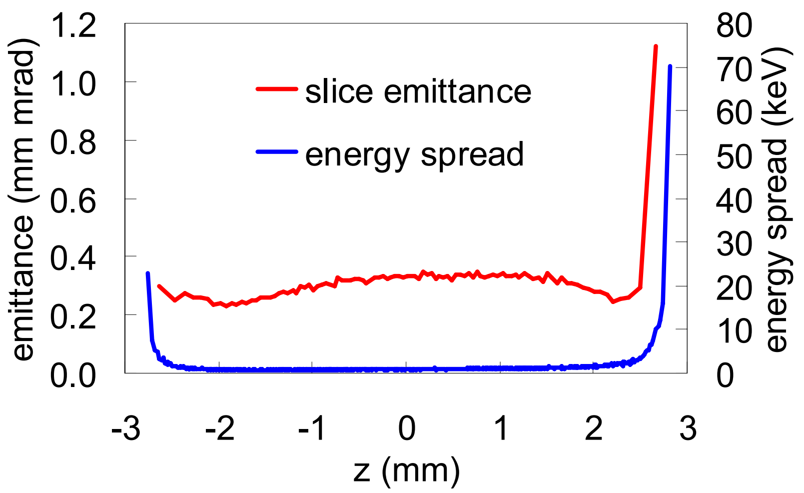
J-H. Han, DLS

Injector Optimisation Example (200 pC)



longitudinal phase space





core emittance:	**0.304 (100%)**
(mm mrad)	**0.227 (95%)**
	0.194 (90%)
	0.145 (80%)

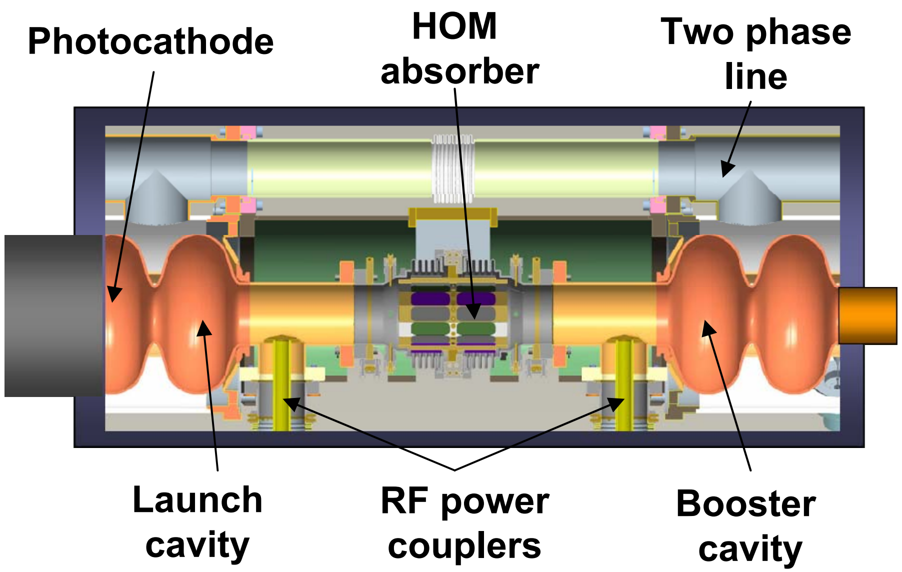
J-H. Han, DLS

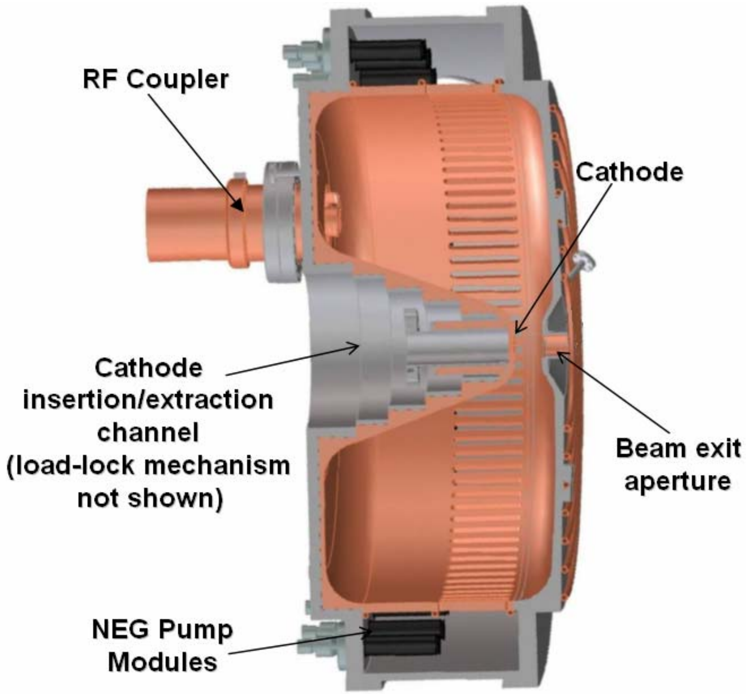
Stage 2 Injector

Two options are being considered:

1) LBNL normal conducting VHF gun cw 187 MHz

2) Superconducting L-band gun





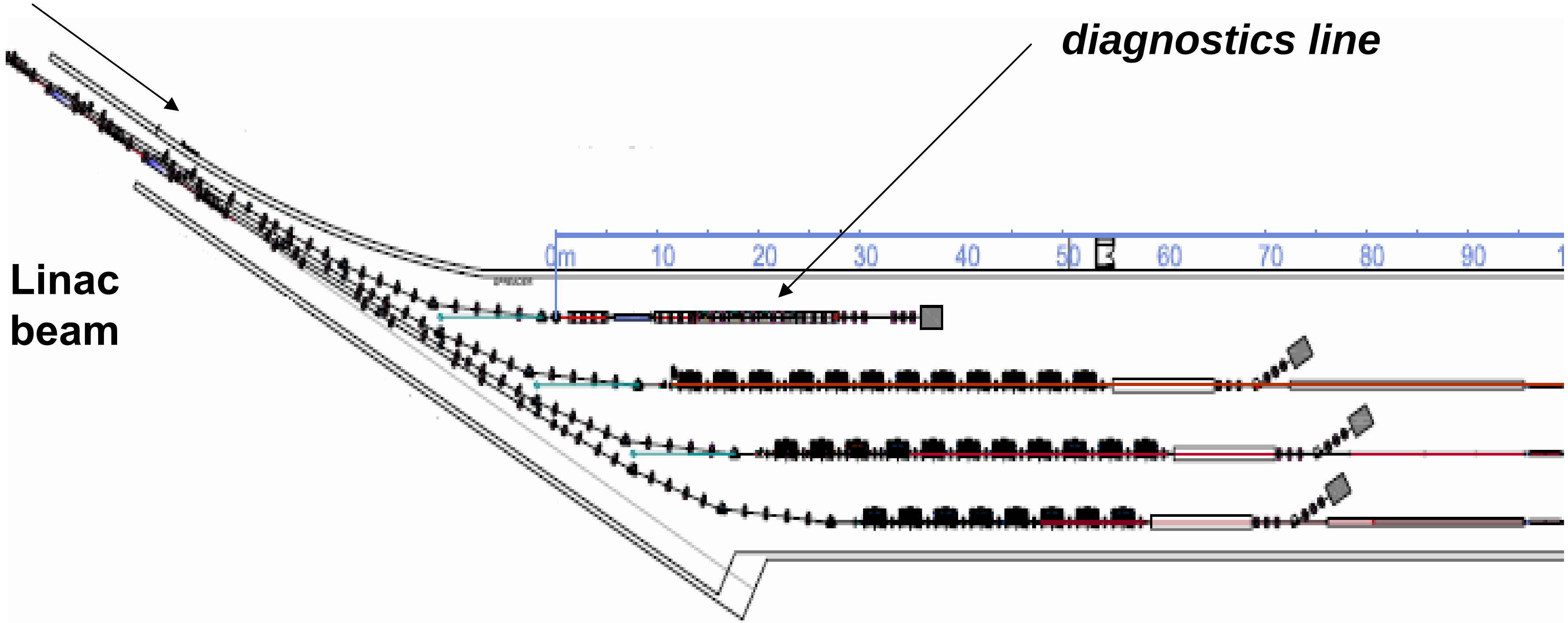
MOPC066 Proceedings of EPAC08, Genoa, Italy

CONCEPTUAL DESIGN OF A HIGH AVERAGE CURRENT SRF GUN

C. D. Beard[#], J.W. McKenzie, B.L. Militsyn, B.D. Muratori, STFC Daresbury Laboratory, Warrington, WA4 4AD, UK

B.L. Militsyn, ASTeC

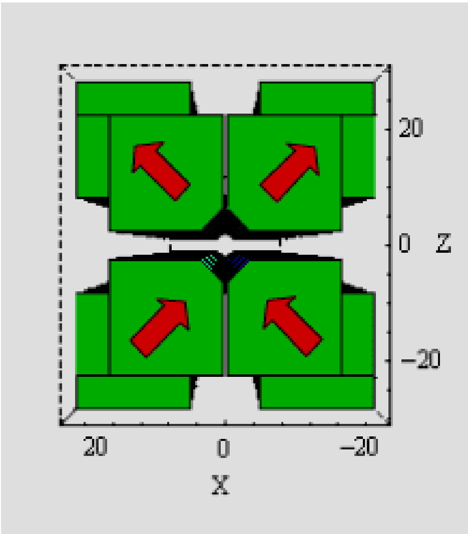
Beam Spreader



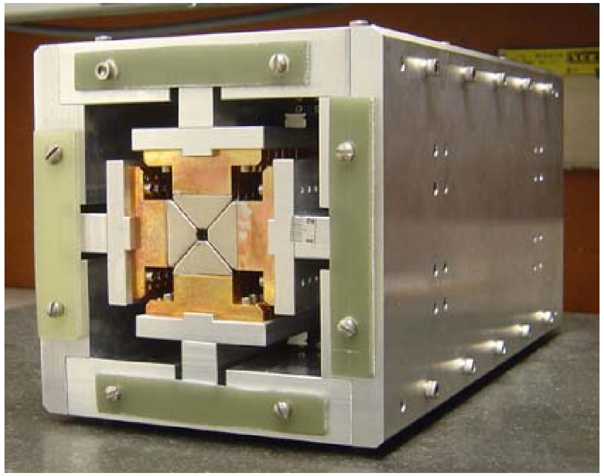
D. Angal-Kalinin et al., ASTeC

Undulator

- APPLE-II is the current choice
- Crossed undulator scheme studied but rejected
- APPLE-III and DELTA designs, as well as in-vacuum solutions, are also being considered
- Effects of wakefields are also being assessed



~ 40% higher field but:
- unproven

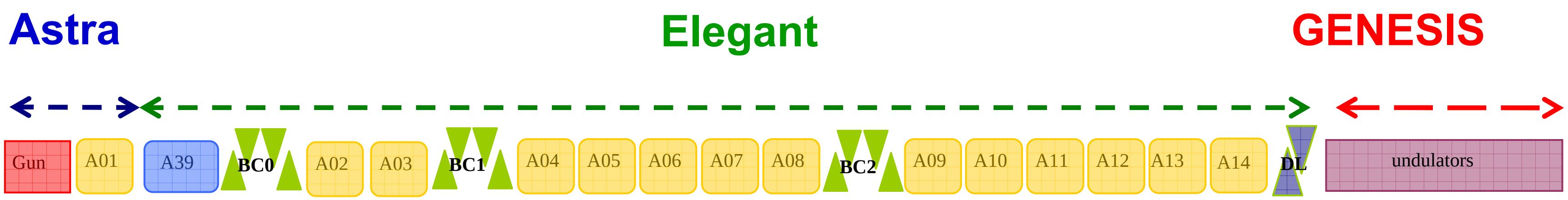


(A. B. Temnykh, PRSTAB 11, 120702, 2008)

~ 70% higher field but:
- short prototype only exists
- difficult to measure
- how to shim ?

J. Clarke, ASTeC

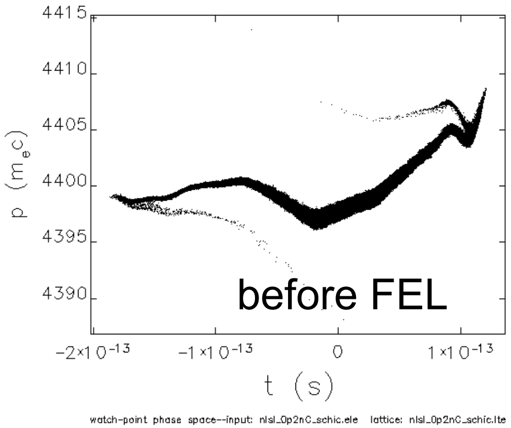
“Start-to-End” Optimisation

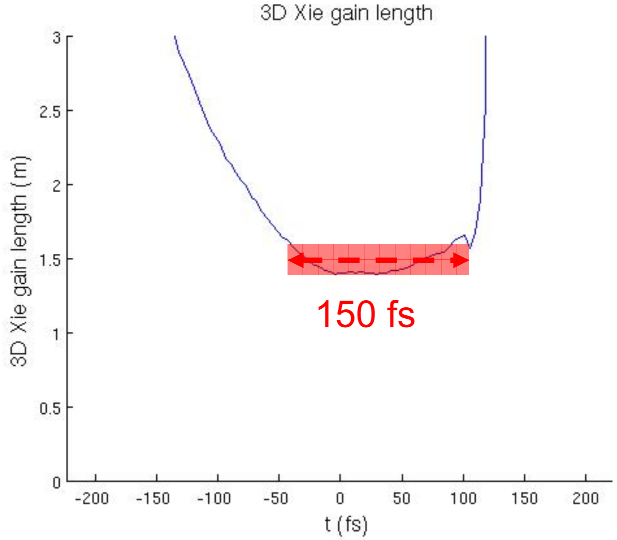


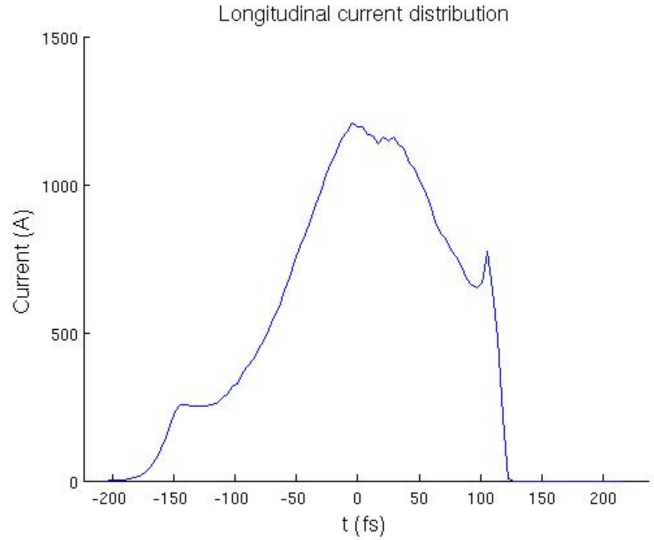
- **Astra calculations to optimise the injector including space-charge effects.**
- **Elegant calculations to optimise the beam quality at the beginning of the undulators including CSR, longitudinal space charge, wake-fields.**
- **GENESIS calculations of the FEL to validate the optimisation with full start-to-end time dependent simulations.**

R. Bartolini, DLS

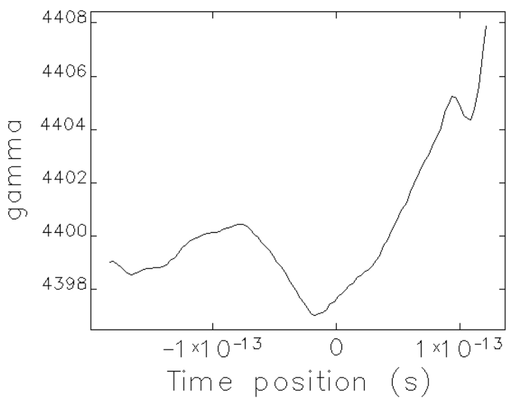
0.2 nC Standard Bunch

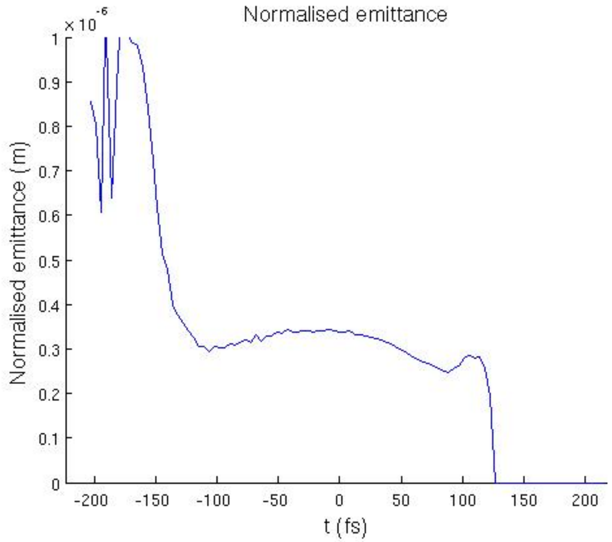


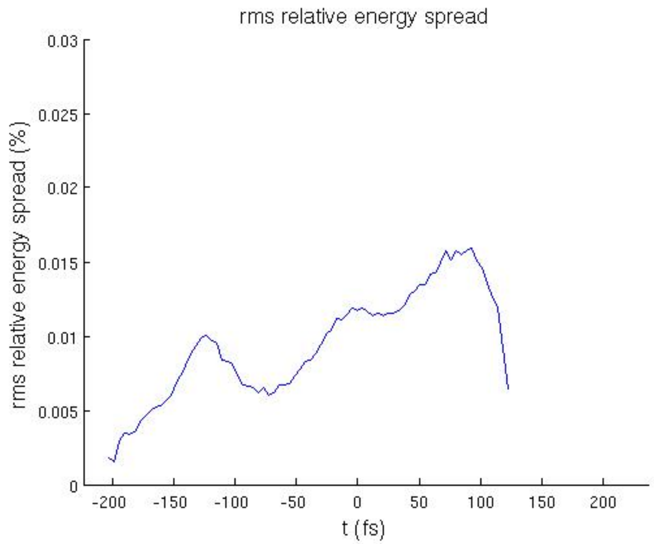




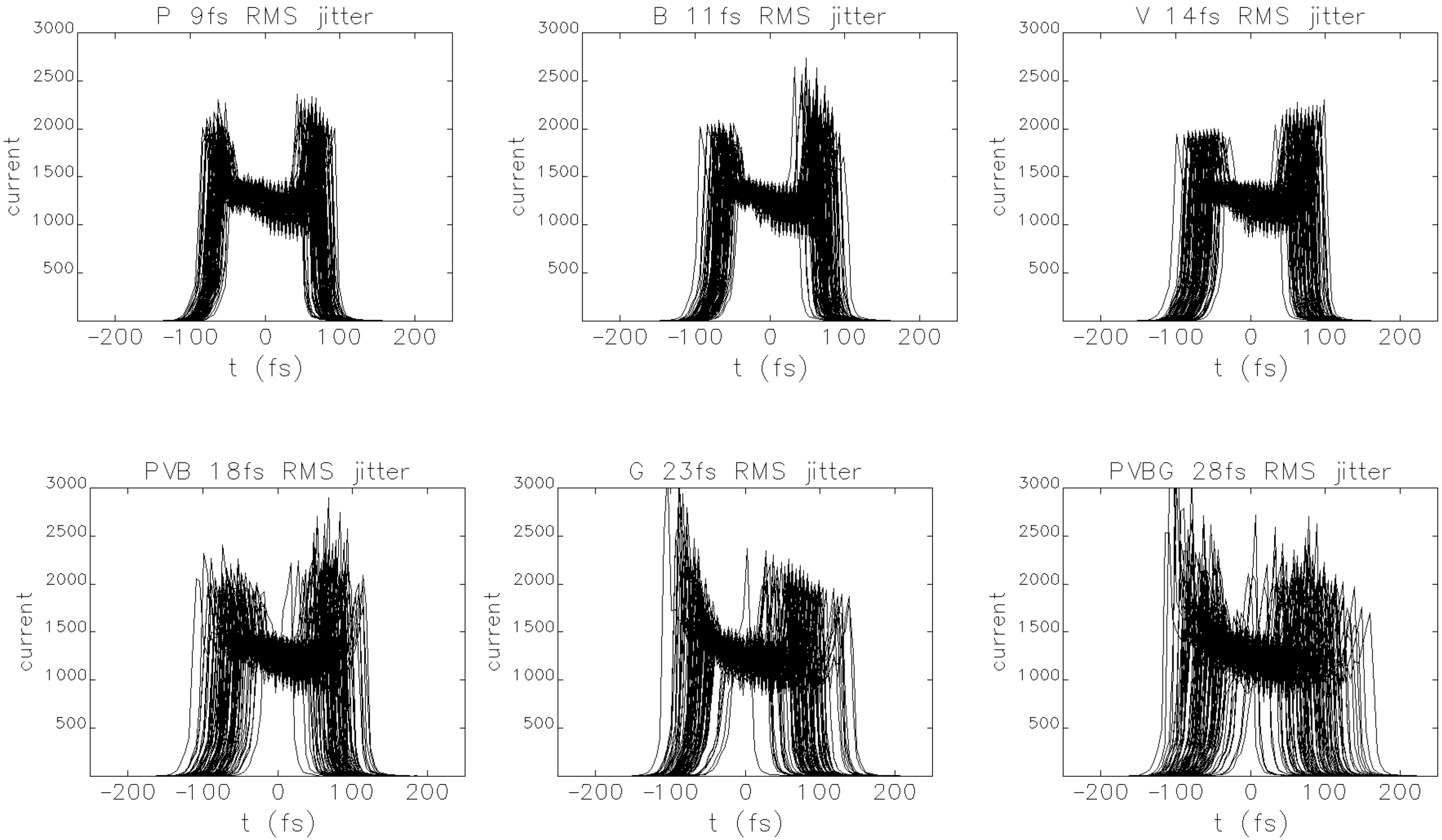
energy







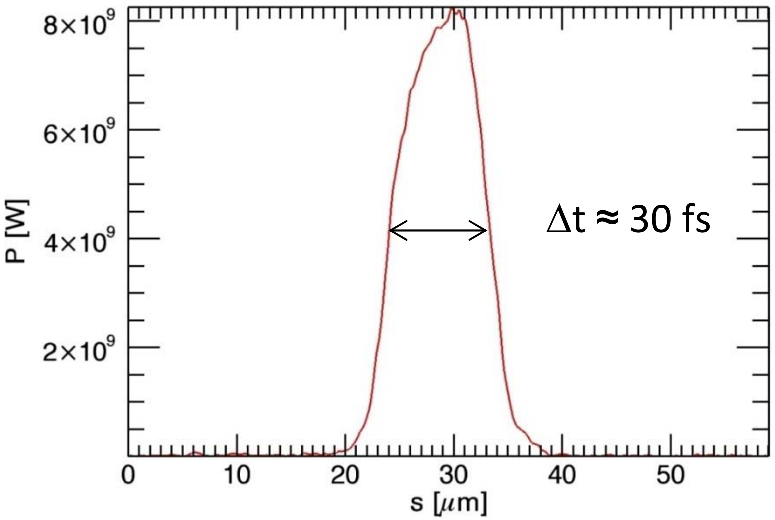
Jitter Calculations (Gun+Linac)

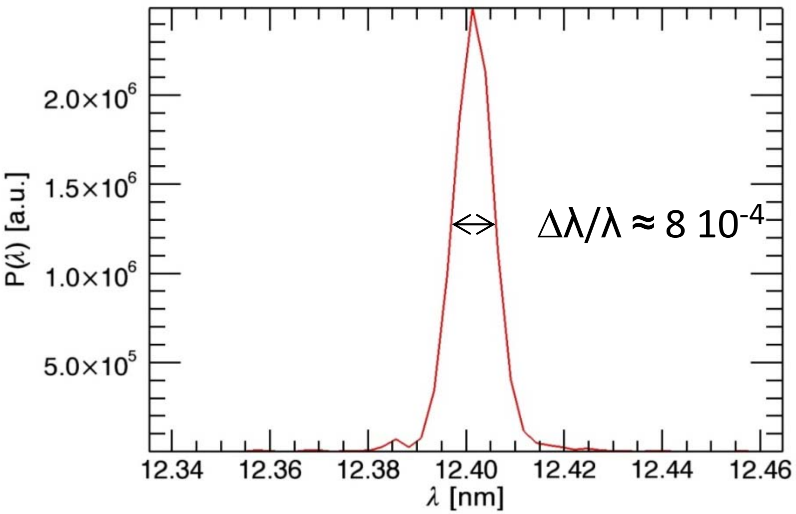


Full start-to-end jitter calculations in progress

Results of Start-to-End Simulations

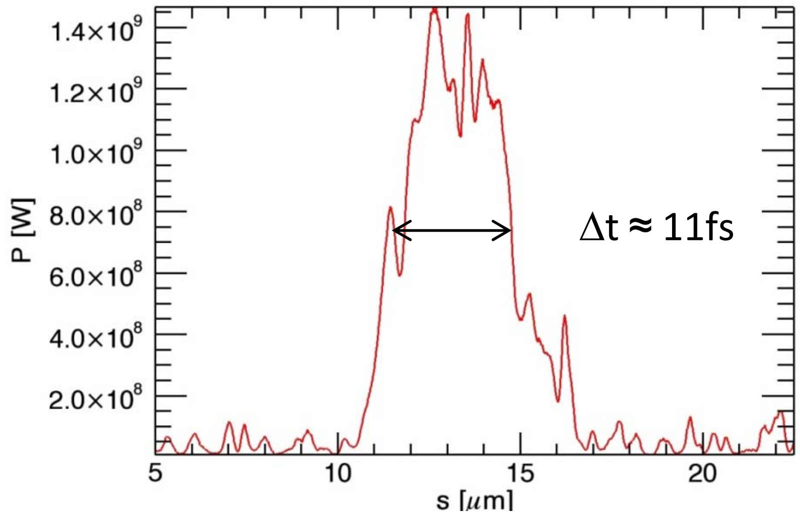
100 eV

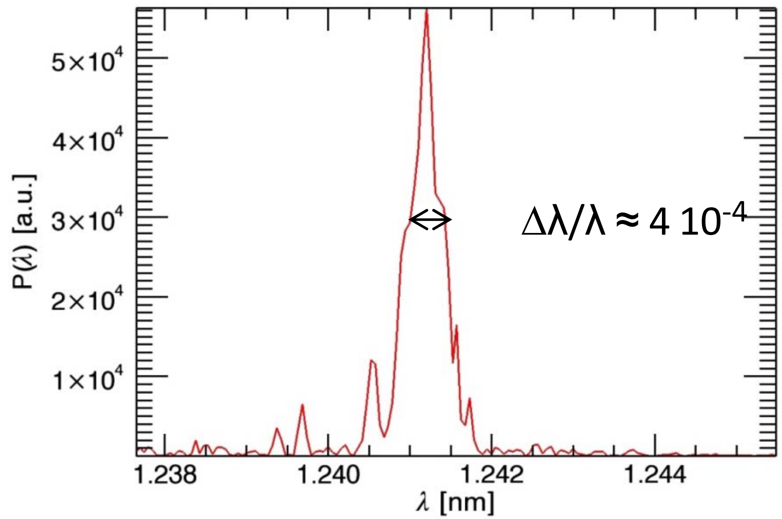




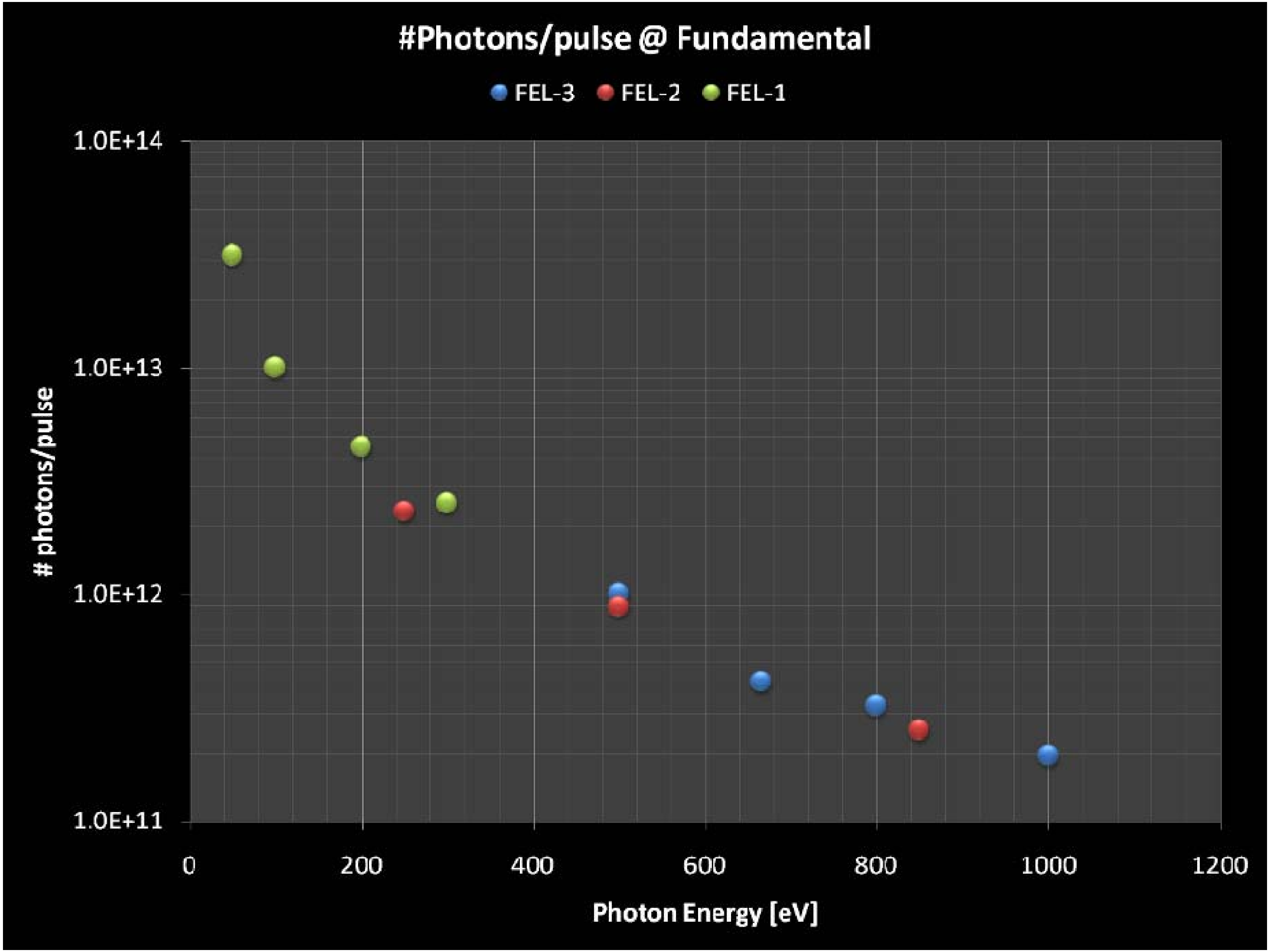
Time-bandwidth product ≈ 0.6

1000 eV

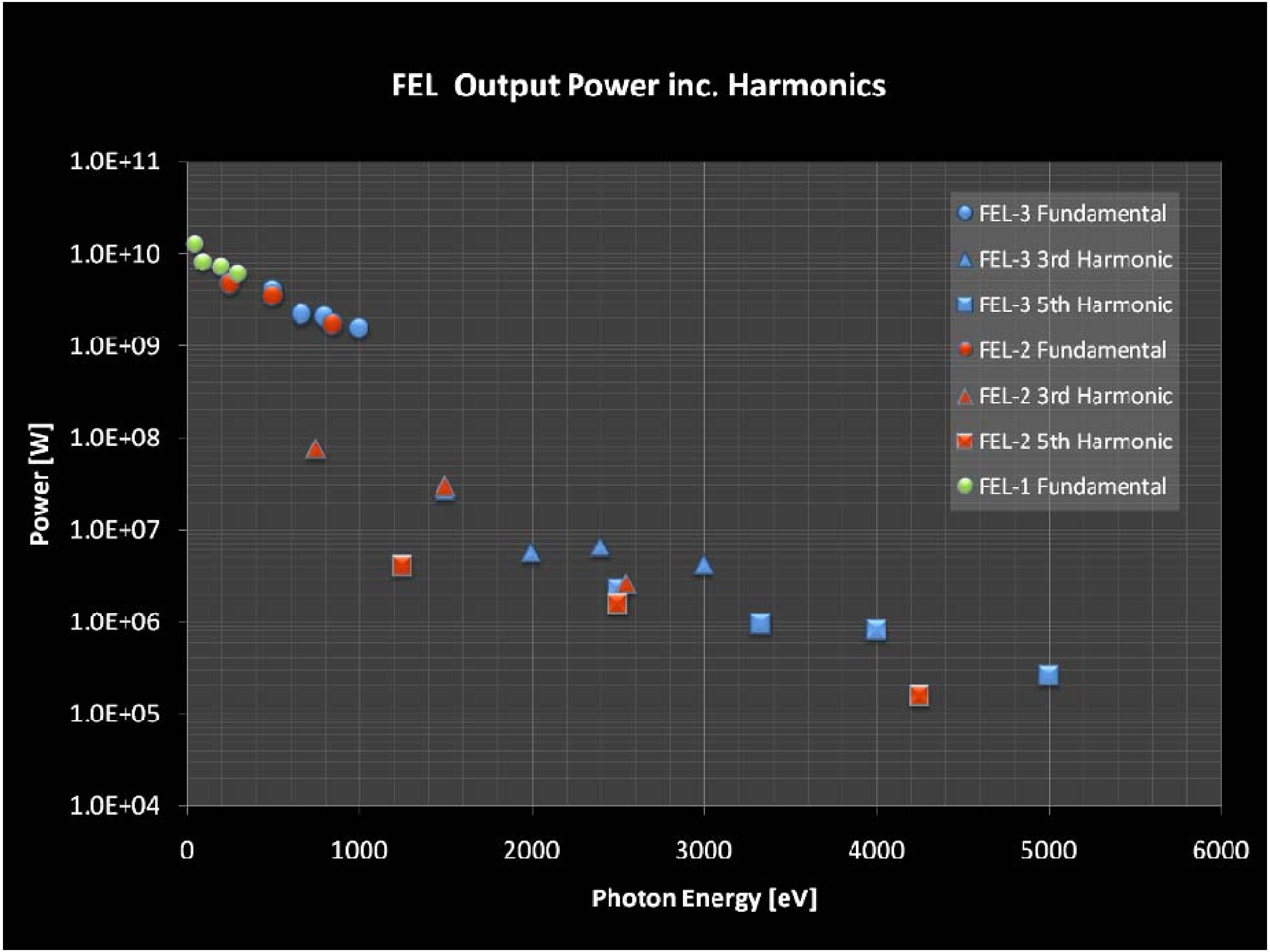




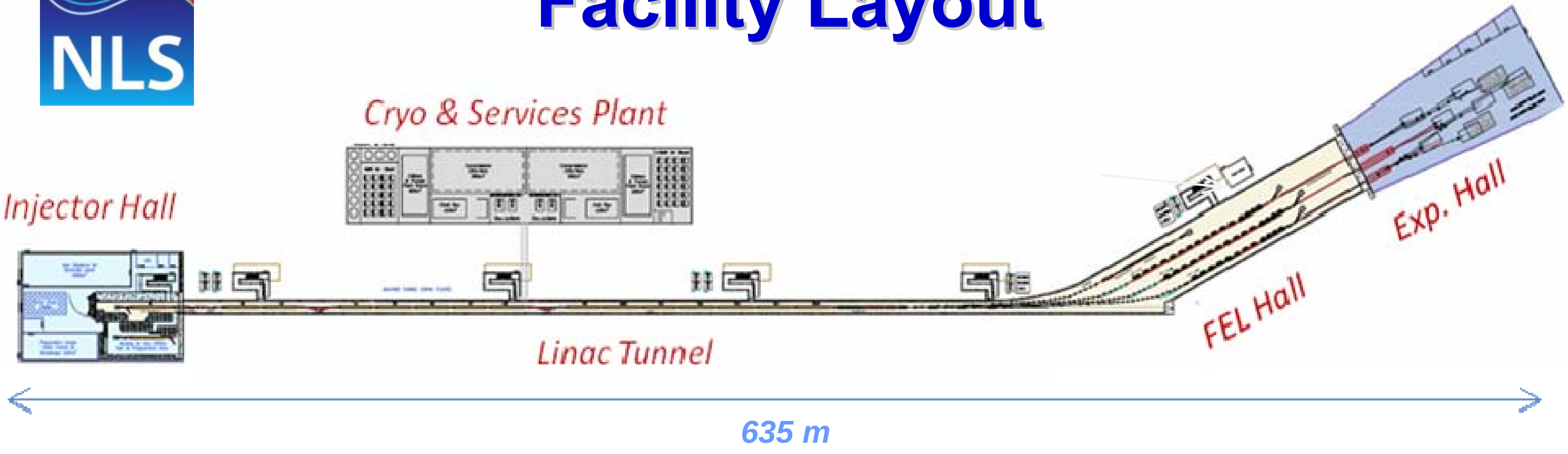
Time-bandwidth product ≈ 1

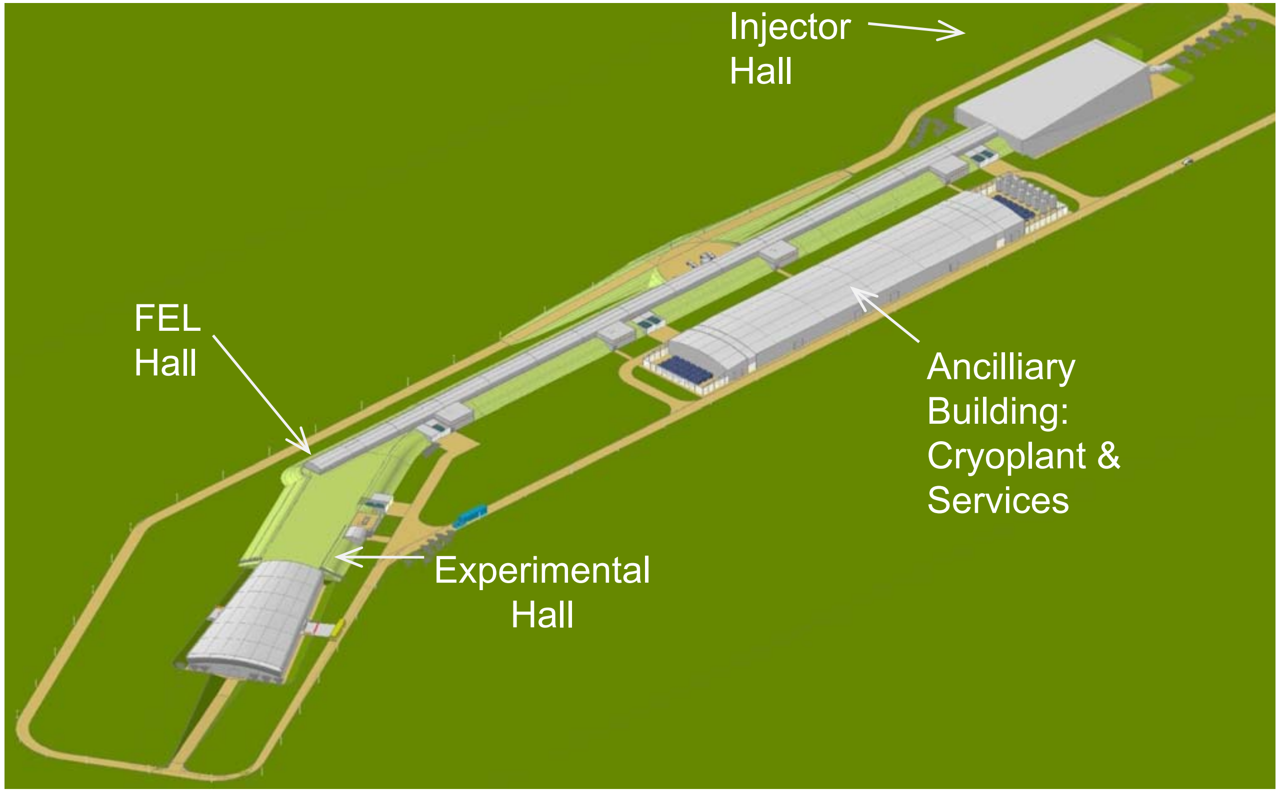


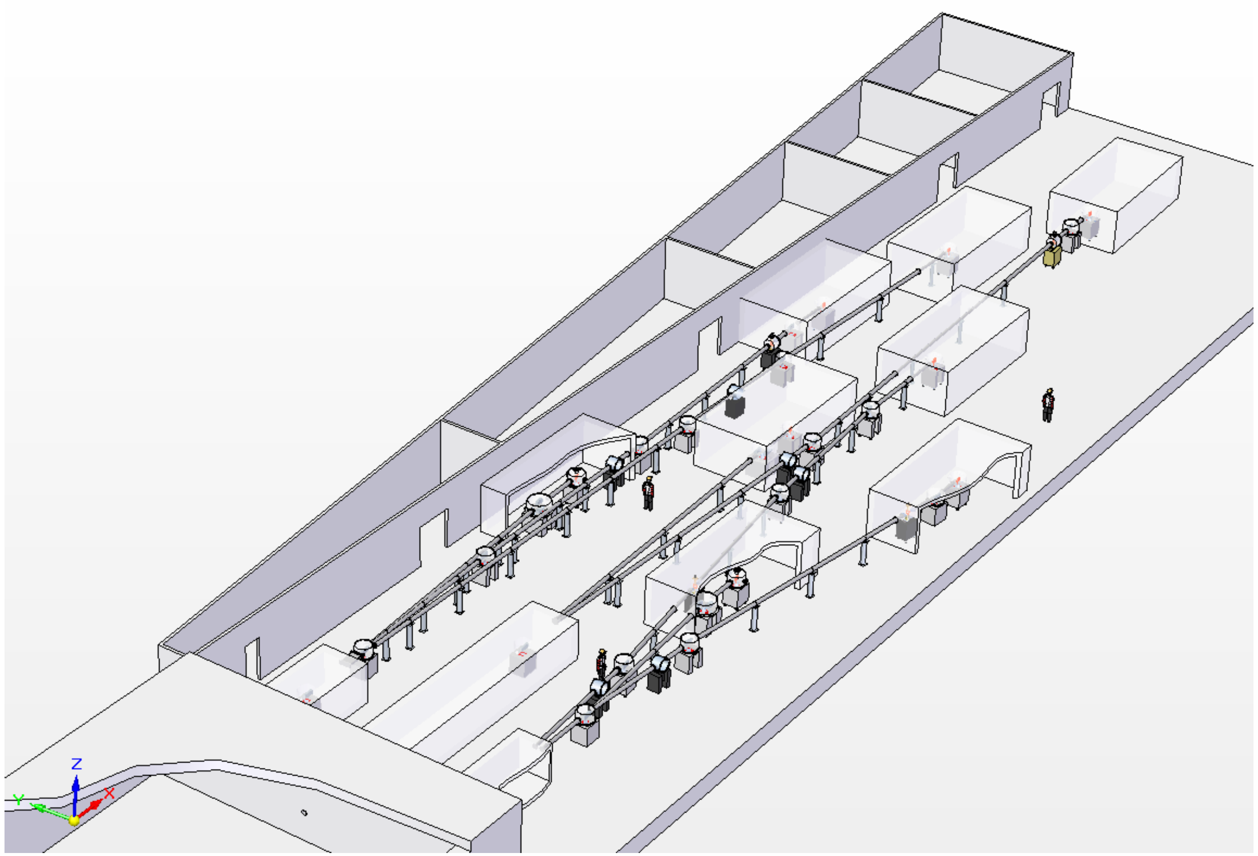
#Photons/pulse @ Fundamental
FEL-3
FEL-2
FEL-1
1.0E+14
1.0E+13
1.0E+12
1.0E+11
photons/pulse
0
200
400
600
800
1000
1200
Photon Energy [eV]

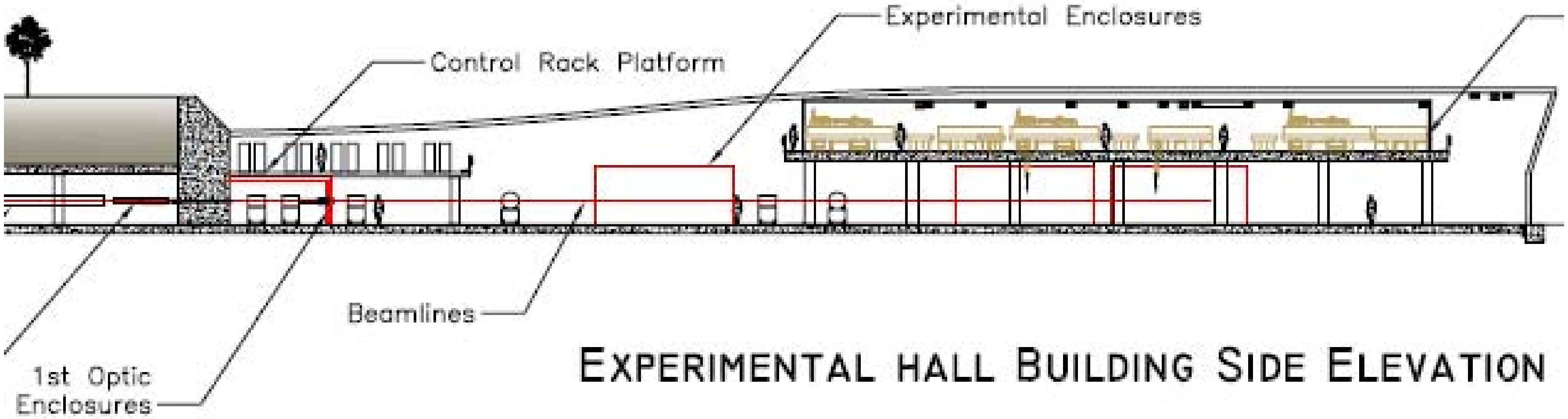

FEL Output Power inc. Harmonics
Power [W]
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
0
1000
2000
3000
4000
5000
6000
Photon Energy [eV]
FEL-3 Fundamental
FEL-3 3rd Harmonic
FEL-3 5th Harmonic
FEL-2 Fundamental
FEL-2 3rd Harmonic
FEL-2 5th Harmonic
FEL-1 Fundamental

Facility Layout









EXPERIMENTAL HALL BUILDING SIDE ELEVATION

Summary

- A World-class Facility - *the <u>only</u> facility providing:*

  - soft X-ray operation up to 1 keV in the fundamental
  - high repetition frequency of regularly spaced pulses
  - multiple FELs operating independently
  - synchronised THz/IR + conventional lasers + FELs
  - seeded operation providing longitudinal coherence

- Baseline requirements can be met by a machine that is essentially buildable “now”, based on proven technology but with some further development to optimise performance, reduce costs and risk.

- Designed-in upgradeability for higher rep. rate, increased number of beamlines, higher photon energy etc.

Next Steps

- Science case and outline design under review by STFC PALS Committee & Science Board, as part of an overall prioritisation exercise. Result expected Dec. 16th.
- 2nd NLS TAC meeting, Dec. '09
- Conceptual Design Report in March 2010.
- Initiate a 2-year Preparation Phase in April 2010 (hopefully):

  - Technology Development in key areas to mitigate risks, reduce costs and optimise the design.

  - Extend national and international engagement.

  - Develop a fully costed proposal and business case.

  - Decide on location.

NLS Source Design Team

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