4GLS: A Facility for the Generation of High Brightness, Variably Synchronised Sources from THz into the XUV

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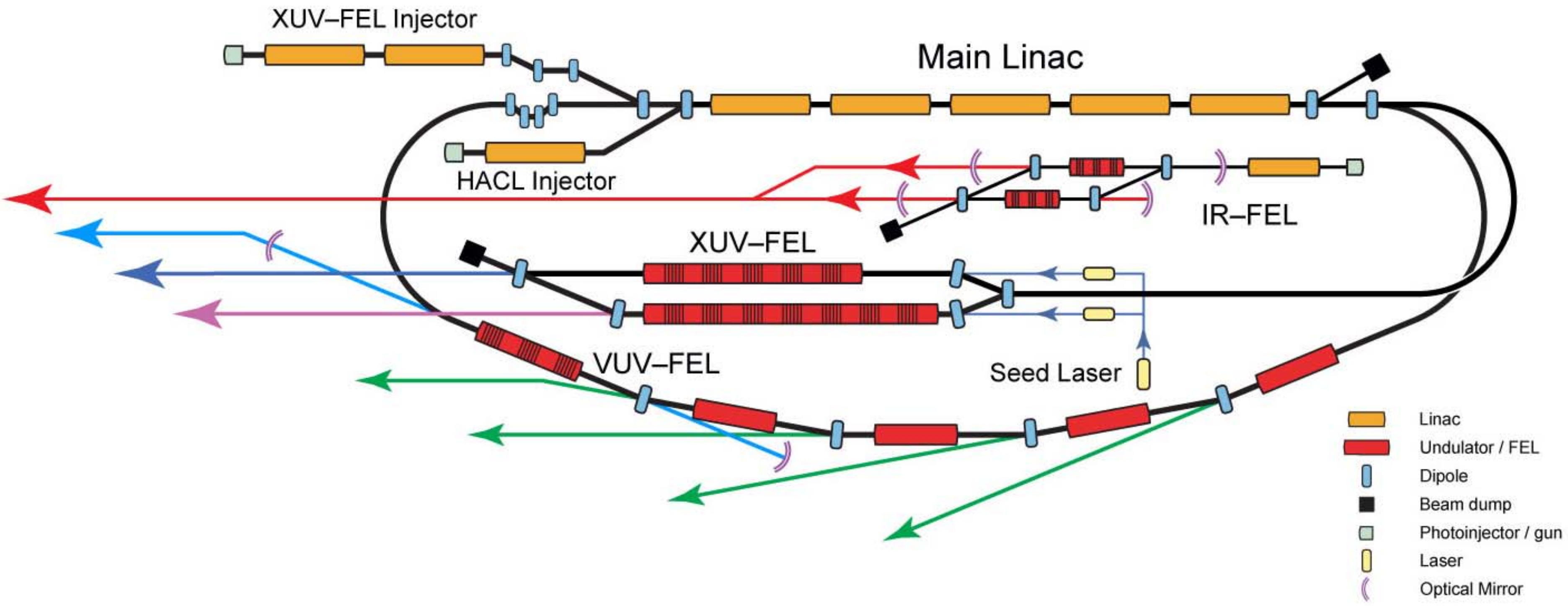
on behalf of Brian McNeil and
All of the 4GLS Design Team

4GLS

The 4GLS Concept

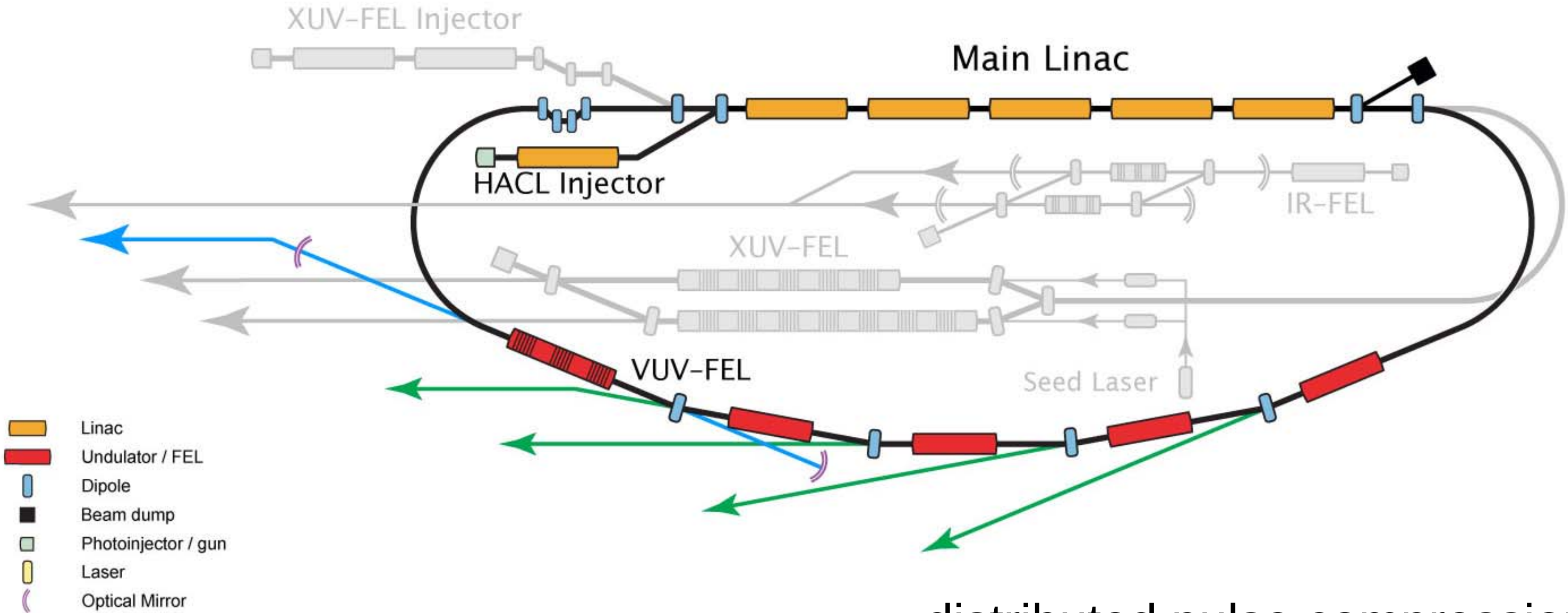


4GLS combines superconducting ERL, short pulse SR, lasers and FELs in a fully integrated, multi-source, multi-user facility

High Average Current Loop

100mA, **550 MeV**, 2 mm mrad normalised emittance

1.3 GHz, 77 pC, CW

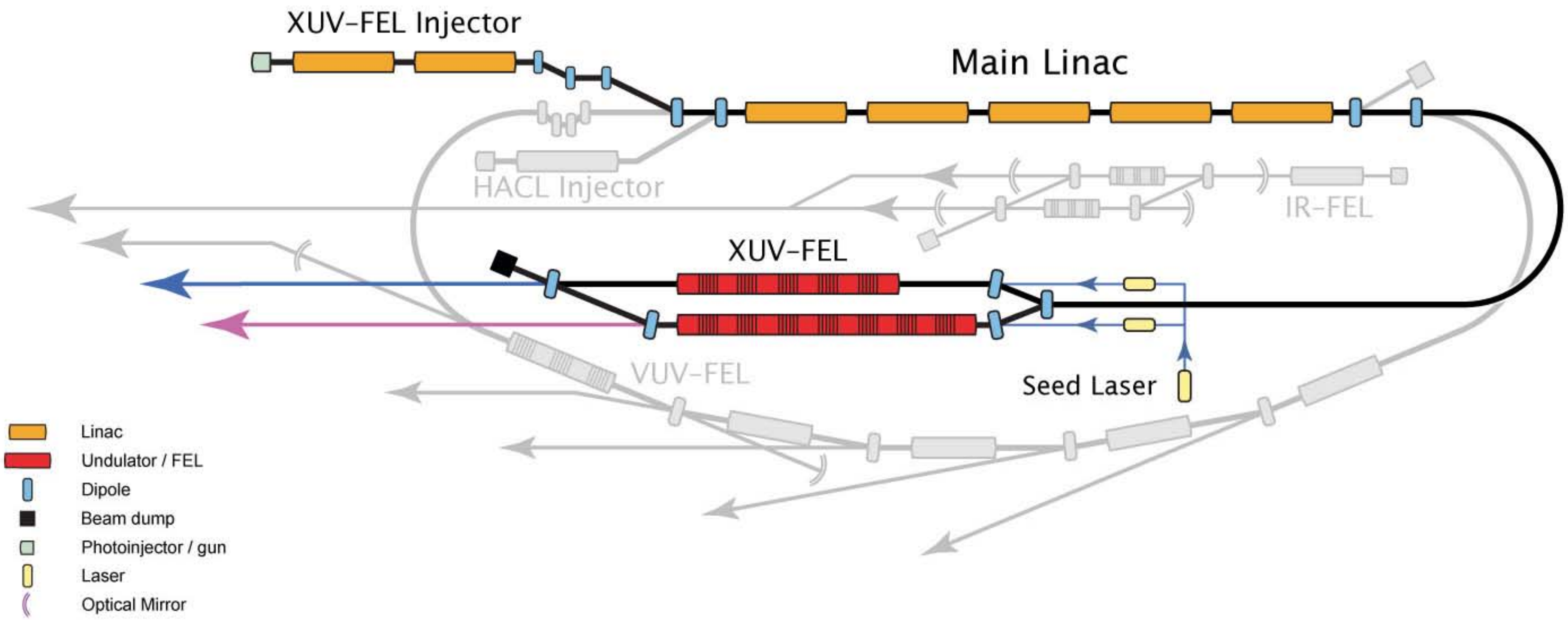


distributed pulse compression

Undulator sources and VUV-FEL

Progressive compression, ~1 ps to 100 fs

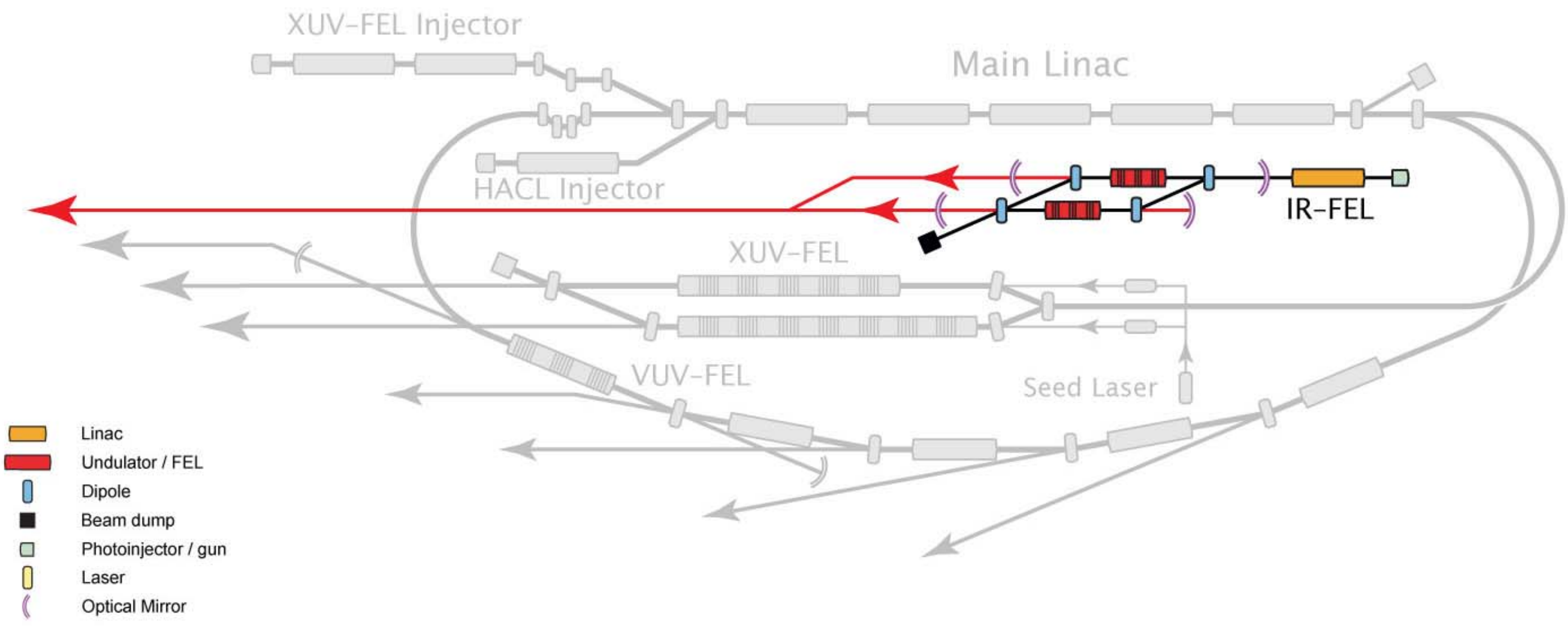
XUV-FEL Branch



1 nC, **750 MeV**, 2 mm mrad normalised emittance,
1 kHz, 1.5 kA

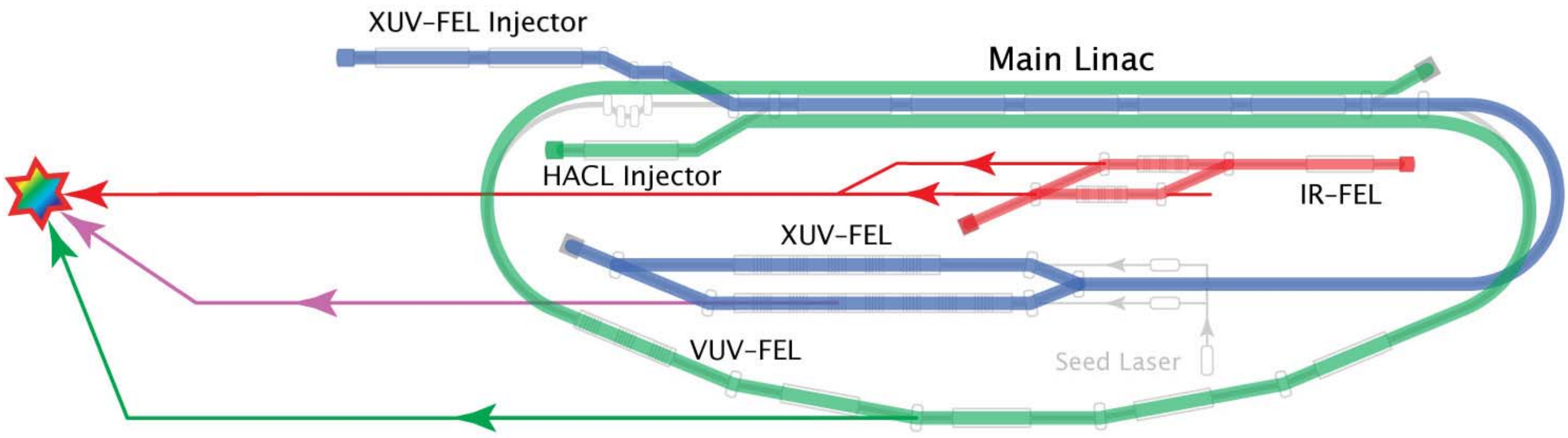
2 Branches

IR FEL

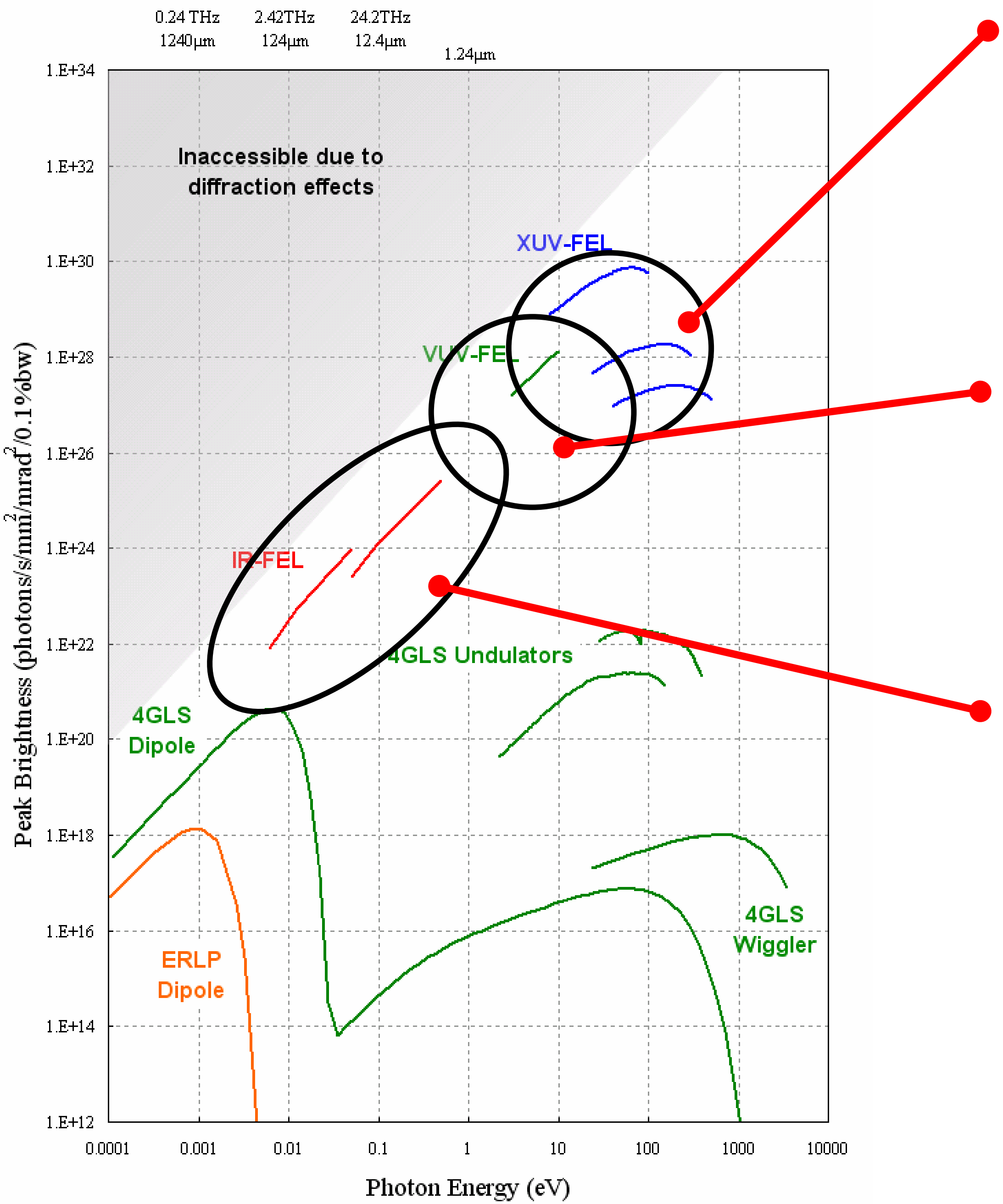


XUV-FEL Injector
Main Linac
HACL Injector
IR-FEL
XUV-FEL
VUV-FEL
Seed Laser
Linac
Undulator / FEL
Dipole
Beam dump
Photoinjector / gun
Laser
Optical Mirror

Simultaneous Operation



Short pulses and combined sources are key to 4GLS



XUV FEL
Range: fundamental 8-100 eV
Photons per pulse: 10^{14}
Pulse energy: ~0.3 mJ
Pulse length: <50 fs
Variable polarisation
Repetition rate: 1 kHz

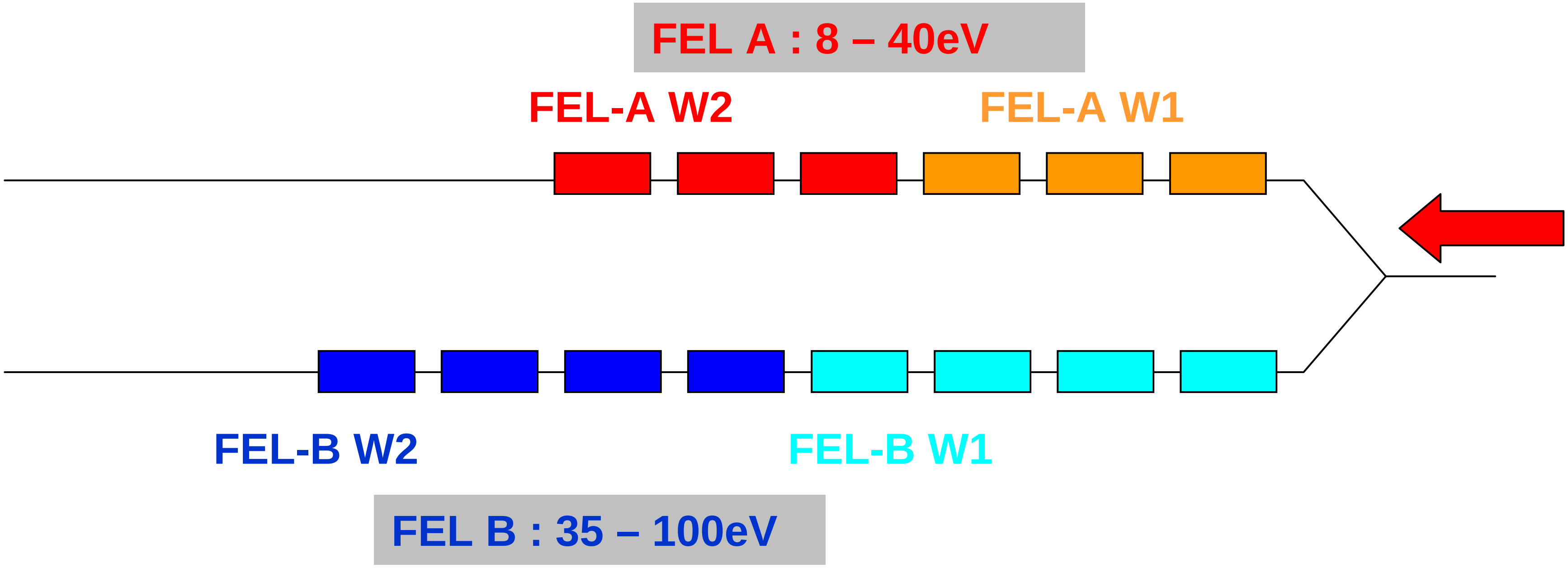
VUV FEL
Range: 3-10 eV
Photons per pulse: 10^{13}
Pulse energy: ~60 µJ
Pulse length: 25 - 170 fs
Variable polarisation
Repetition rate: 4.33 MHz

IR FEL
Range: 2.5-200 µm
Pulse energy: 50 µJ
Pulse length 0.3-10 ps
Variable polarisation
Repetition rate: 13 MHz

Main Parameters

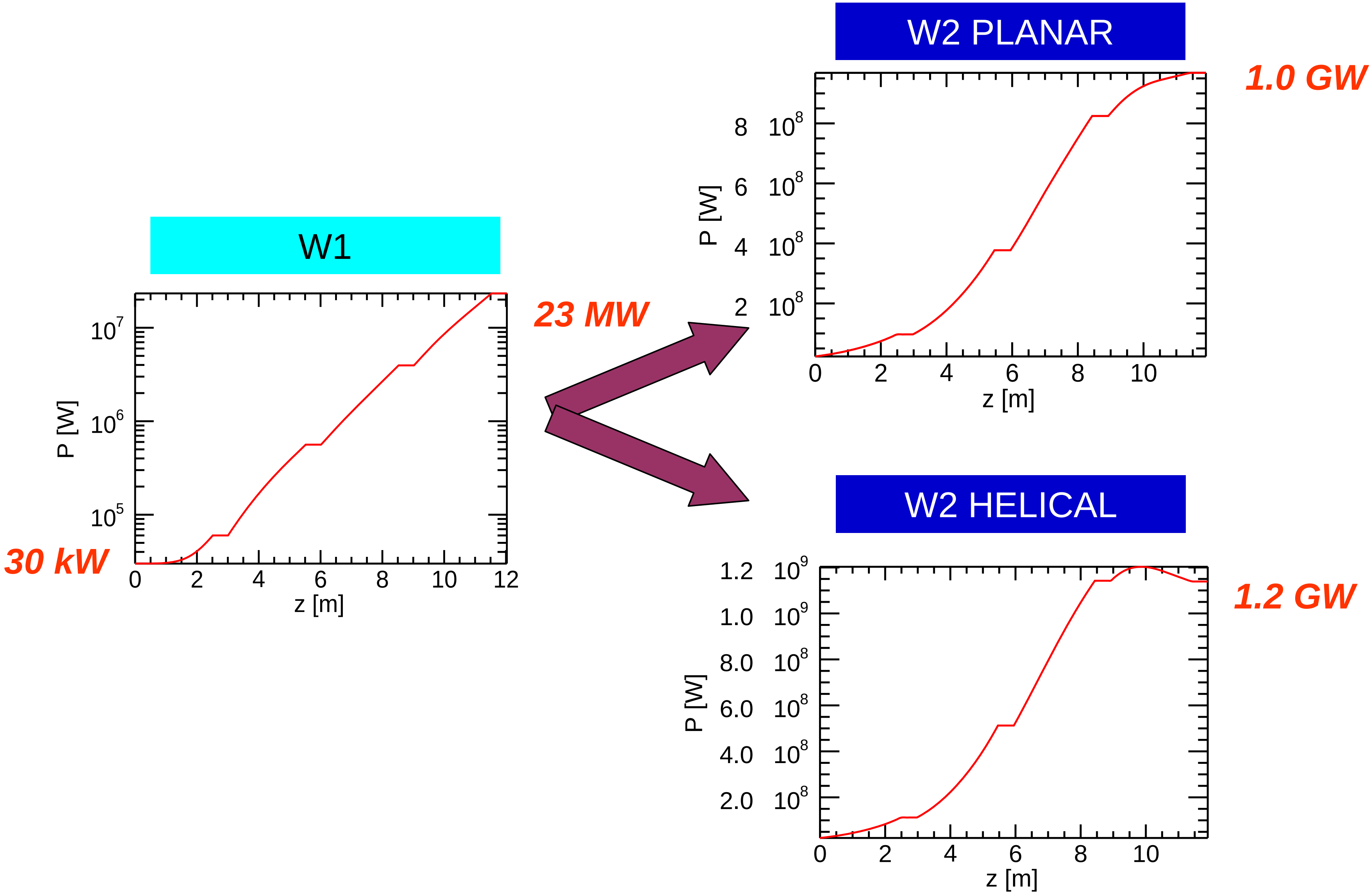
Bunch Parameter	*XUV-FEL*	*100 mA HACL Operation*	*VUV-FEL HACL Operation*	*IR-FEL*
Electron Energy	750 MeV	550 MeV	550 MeV	25 to 60 MeV
Normalised Emittance	2 mm mrad	2 mm mrad	2 mm mrad	10 mm mrad
RMS Projected Energy Spread	0.1 %	0.1 %	0.1 %	0.1 %
RMS Bunch Length	< 270 fs	100 to 900 fs	100 fs	1 to 10 ps
Bunch Charge	1 nC	77 pC	77 pC	200 pC
Bunch Repetition Rate	1 kHz	1.3 GHz	n x 4.33 MHz	13 MHz
Electron Beam Average Power	< 1 kW	55 MW	n x 183 kW	156 kW

XUV FEL Layout



	W2 *min gap 9mm*				**W1** *min gap 9mm*			
	Type	Period	No.	Length	Type	Period	No.	Length
FEL A **8 – 40eV**	APPLE-II	51 mm	3	2.5m	Planar PPM	46mm	3	2.5m
FEL B **35 -100eV**	APPLE-II	35 mm	4	2.5m	Planar PPM	31 mm	4	2.5m

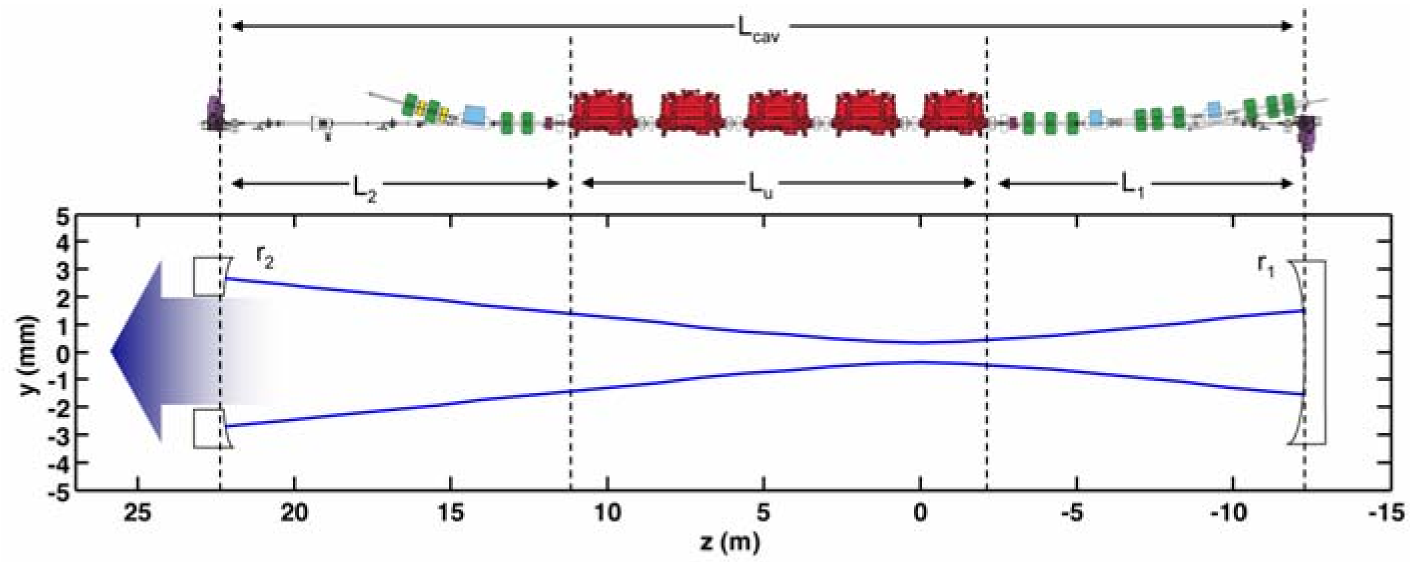
Example, 100eV FEL B



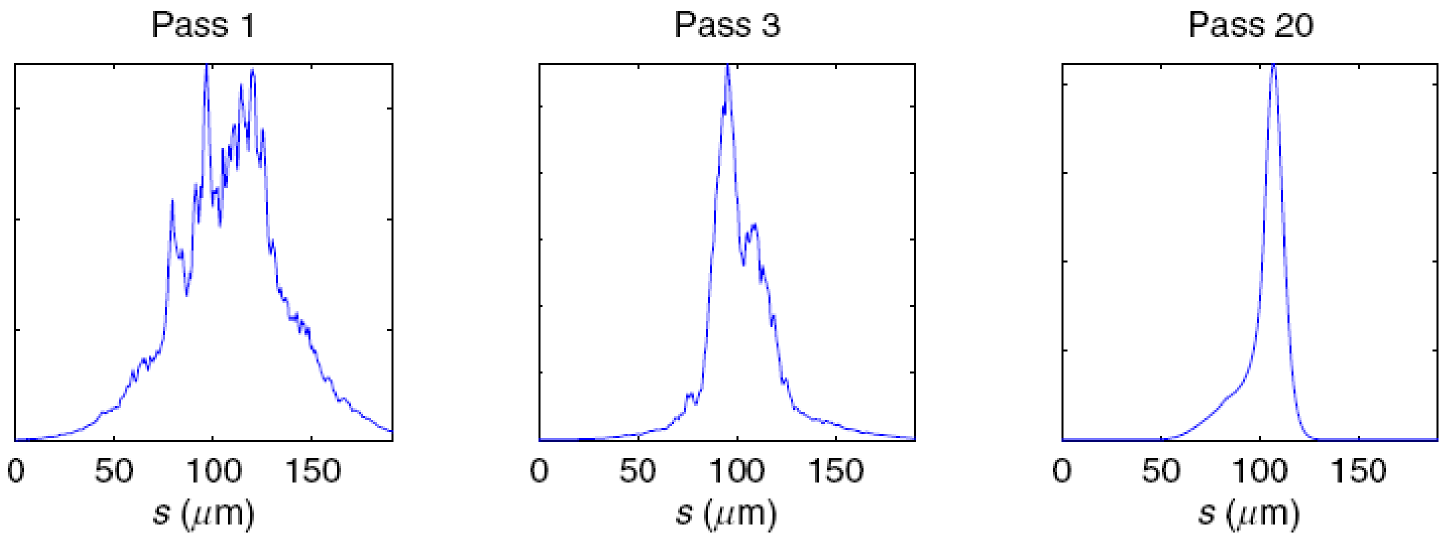
VUV-FEL

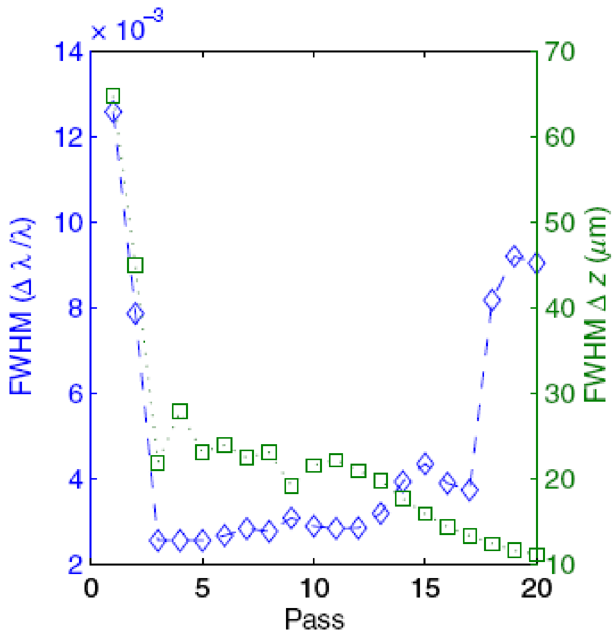
- 3 to 10 eV, ~500MW output
- Regenerative Amplifier system
- 4.33 MHz compared with 1 kHz XUV FEL
- Very tolerant to mirror degradation
- Reflectivity only 40 to 60% needed
- No seed
- 300 A peak current

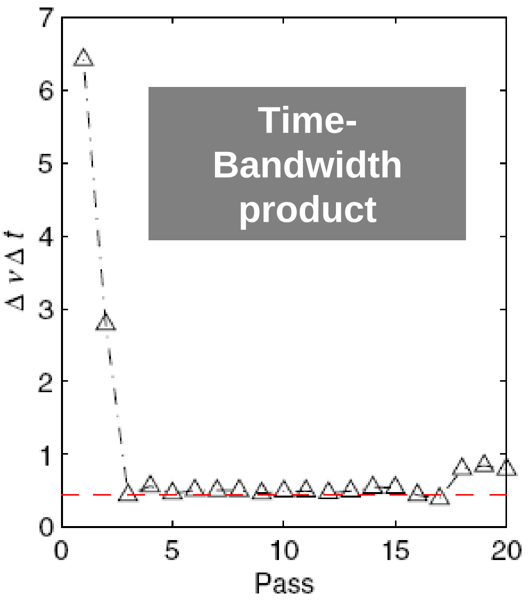
electrons



3D Time Dependent Simulations: Genesis/OPC

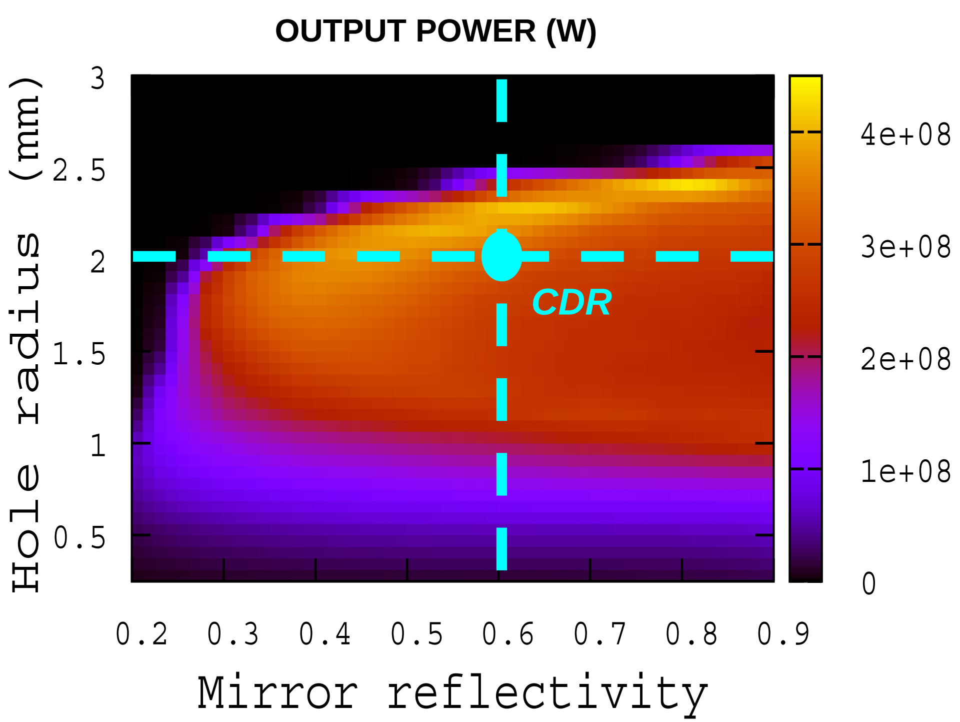






Optimisation of Cavity Parameters

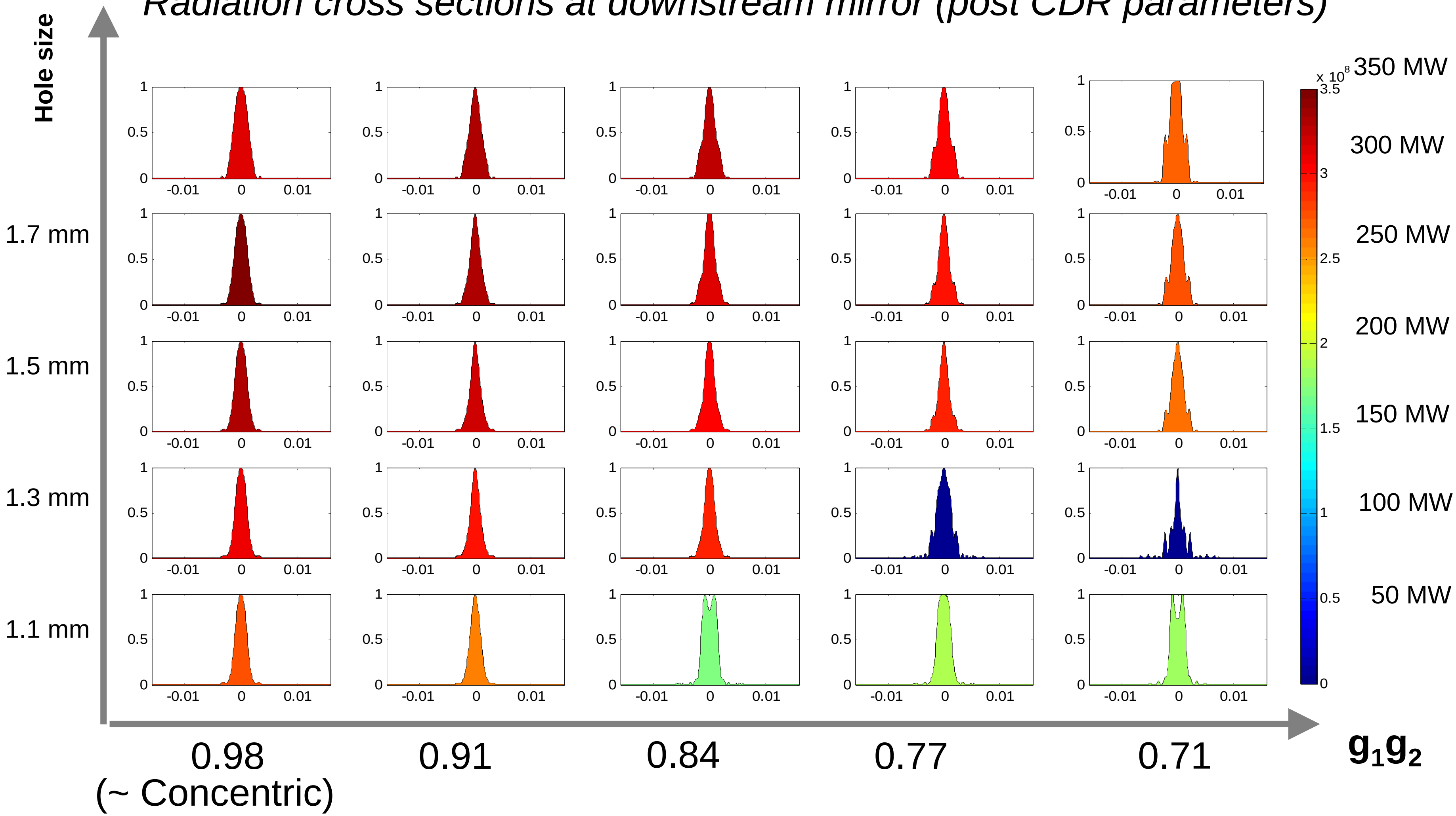
- Scans using Genesis/OPC of hole radius, mirror reflectivity and cavity geometry (changing mirror ROC to adjust waist radius and position of fundamental cold cavity mode).



- *Example: Hole Radius vs Reflectivity:*
  - Output power relatively INSENSITIVE to reflectivity
  - Reflectivity REDUCTION gives small power INCREASE
  - Consistent with 1D simulations used during CDR

RAFEL Sensitivity to Cavity Geometry

Radiation cross sections at downstream mirror (post CDR parameters)

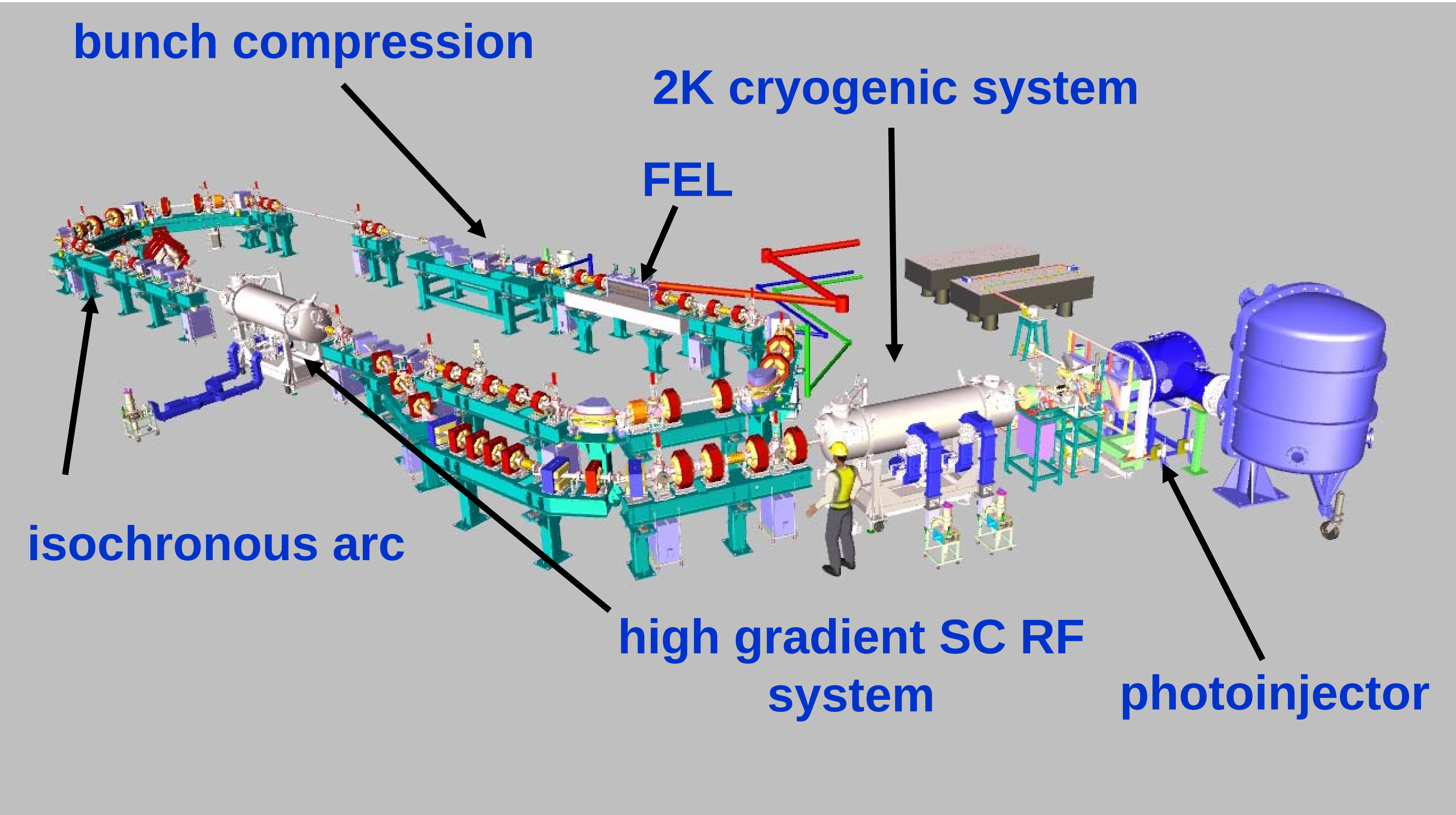


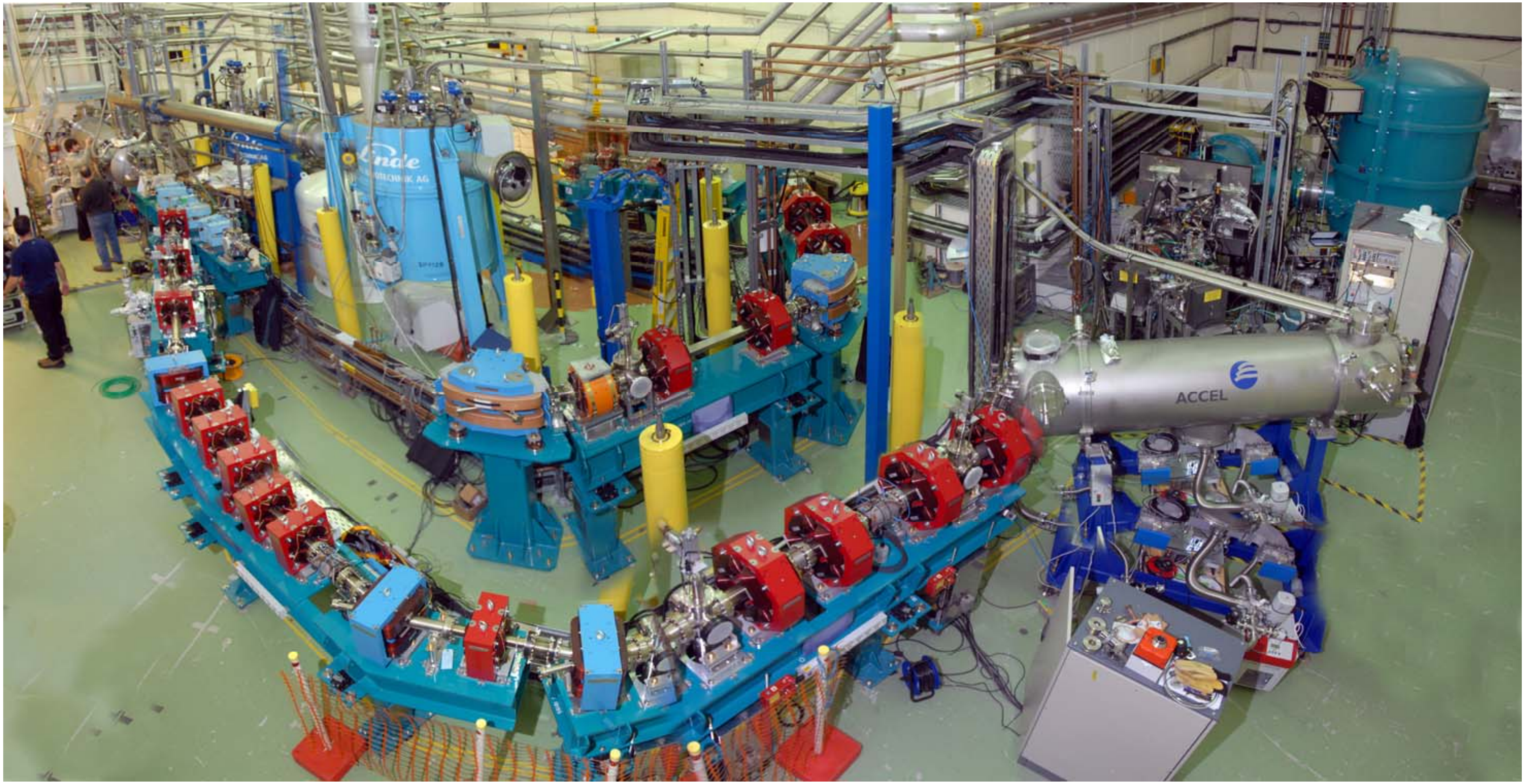
R & D Studies

- In preparation for 4GLS we have constructed a prototype ERL
- In addition to this we have started the construction of a prototype SC linac suitable for CW-mode operation
- We are also actively designing a high average current photoinjector capable of 100mA operation

ERLP: All the major components of a 4th Generation ERL driven FEL

Designed, procured, assembled, installed and being commissioned




ACCEL

Achievements so far

- Beam energy 350 kV (spec value)
- Maximum voltage achieved 450 kV
- Bunch charge 11 pC (ultimate target 80 pC)
- Quantum efficiency measured in the gun 1.2%, measured in the lab 3.5% (ultimate target ~few percent)
- Bunch train length 100 μs (spec value)
- Train repetition rate 20 Hz (spec value)

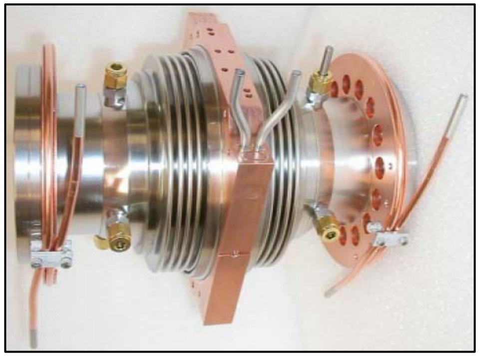
- All other components installed
- Cryosystem commissioned for 2K
- High Power RF conditioning underway

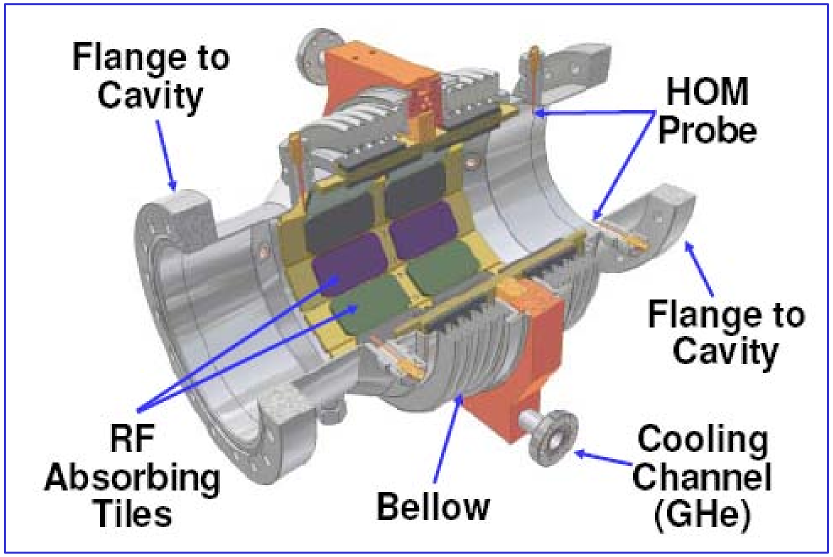
ERL Accelerator Cryomodules

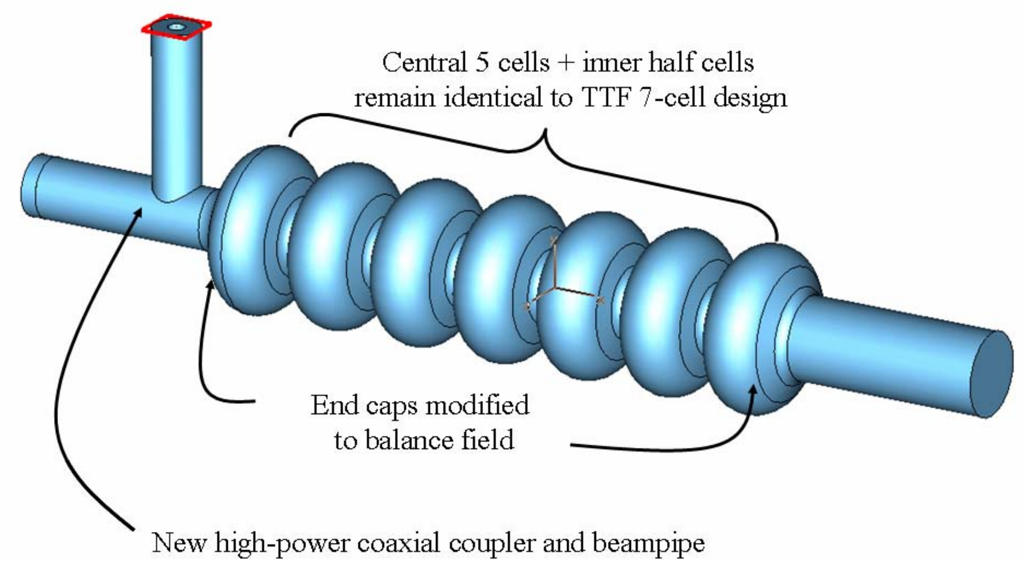
- ILC Cryomodules are not suitable for high average current ERL operation
  - HOMs need to be reduced
  - CW Input power capability needs to be increased
- Collaboration established to develop a prototype cryomodule
  - Daresbury, Cornell, Stanford, Rossendorf, and Berkeley
- Design requirements:
  - $E_{acc} > 20$ MV/m @ $Q_o > 10^{10}$
  - Couplers capable of up to 25 kW CW
  - Large HOM damping capability
- The 2-cavity cryomodule will be validated on ERLP and later Cornell ERL injector.

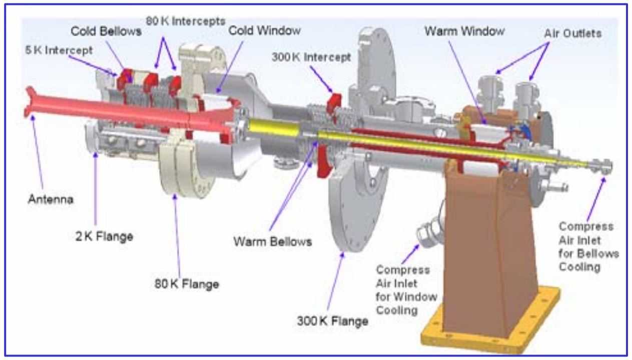
Major changes

- Cavity changed from 9 cell to 7 cell
- New HOM absorbers installed between cavities
- High power (CW) couplers installed

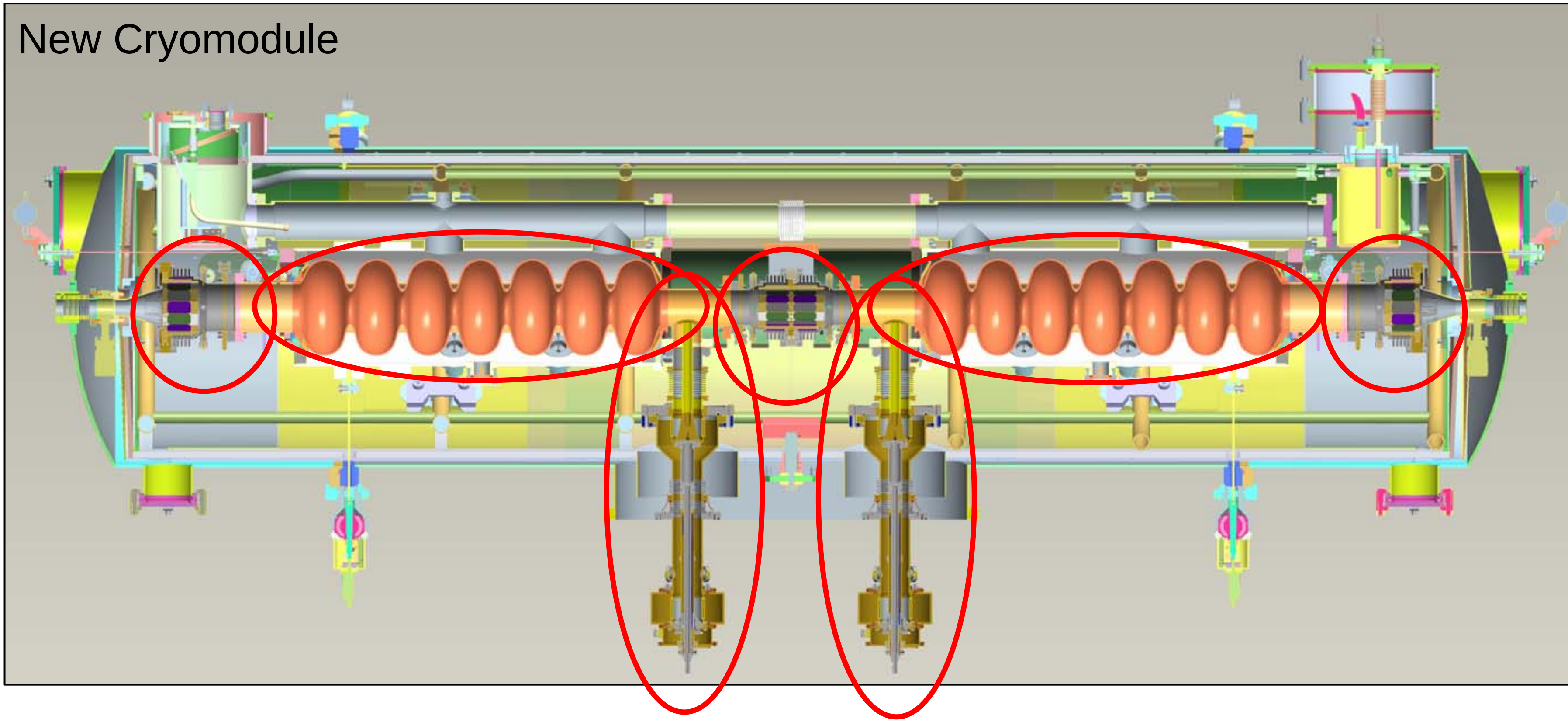








Cryomodule Evolution



Cryomodule to be ready for beams tests on ERLP by Q4 2008.
Cryomodule to be ready for beam tests on Cornell ERL injector by Q4 2009.

Summary

- 4GLS Design continues to be refined
- Technical Design phase is underway (CDR published 2006)
- Major R & D activities also ongoing in parallel
  - ERLP being commissioned
  - CW cryomodule being constructed
  - High average current photoinjector being designed