4GLS

Project Update

SRI 2003, San Francisco

Strategy for new low energy light source

- The UK has strong communities exploiting existing advanced storage ring and 'table top' laser facilities (SRS, ESRF, CLF)

- DIAMOND will serve the x-ray community from 2007 (XFEL ?)

- Low energy (< 100 eV) requires a separately optimised source

- Users have identified the need to supplement transverse brightness by compression longitudinally - fs pulses

- Many scientific applications need multiple sources
  - **eg pump-probe**

original aims (1993)

- Third generation, high brightness storage rings covering
  - Low energy, 1 GeV, IR - 100 eV
  - Medium energy, 3 GeV, 100 - > 30,000 eV
  - High energy covered by 6 GeV ESRF

- Medium energy ring now funded; DIAMOND under construction at RALsite

storage ring issues

- Equilibrium beam dimensions set by radiation emission
- beam lifetime limits bunch density (10^{11} turns)
- demanding UHV environment
- undulator sources restricted
- most issues worse at low energies needed for optimum low energy performance (< 1GeV)

linac sources

- Linacs can deliver very high quality electron beams
- temporal pulse pattern flexibility
- performance being driven by Linear Colliders and FELs
- high average flux requires Energy Recovery
- superconducting RF can be exploited
- high average brightness guns are an essential development

- economy comes from energy recovery

ERL advantages

- Removes storage ring restrictions
- dramatic increase in flexibility
  - lattice dynamics (but isochronous)
  - ID and BM sources (variable optics)
  - source dimensions
  - temporal patterns, pulse tailoring
  - upgrades (no symmetry restrictions)
- high performance FELs can be incorporated

World ERL Projects

• J-Lab (exists)	50 MeV	High power IR
• JAERI (exists)	17 MeV	Ditto
• Cornell	100 MeV	Demonstrator
• KEK	300 MeV	Test Facility
• 4GLS	600 MeV	IR/UV/XUV
• LBNL	2.5 GeV	X-ray
• PERL	3(7) GeV	X-ray

4GLS proposal

- Multiple sources, stimulated and spontaneous used in combination and with conventional lasers
  - undulators
  - FELs
  - bending magnets
- ERL based
- 600 MeV superconducting linac
- two photo-cathode guns
  - high average current
  - high peak current

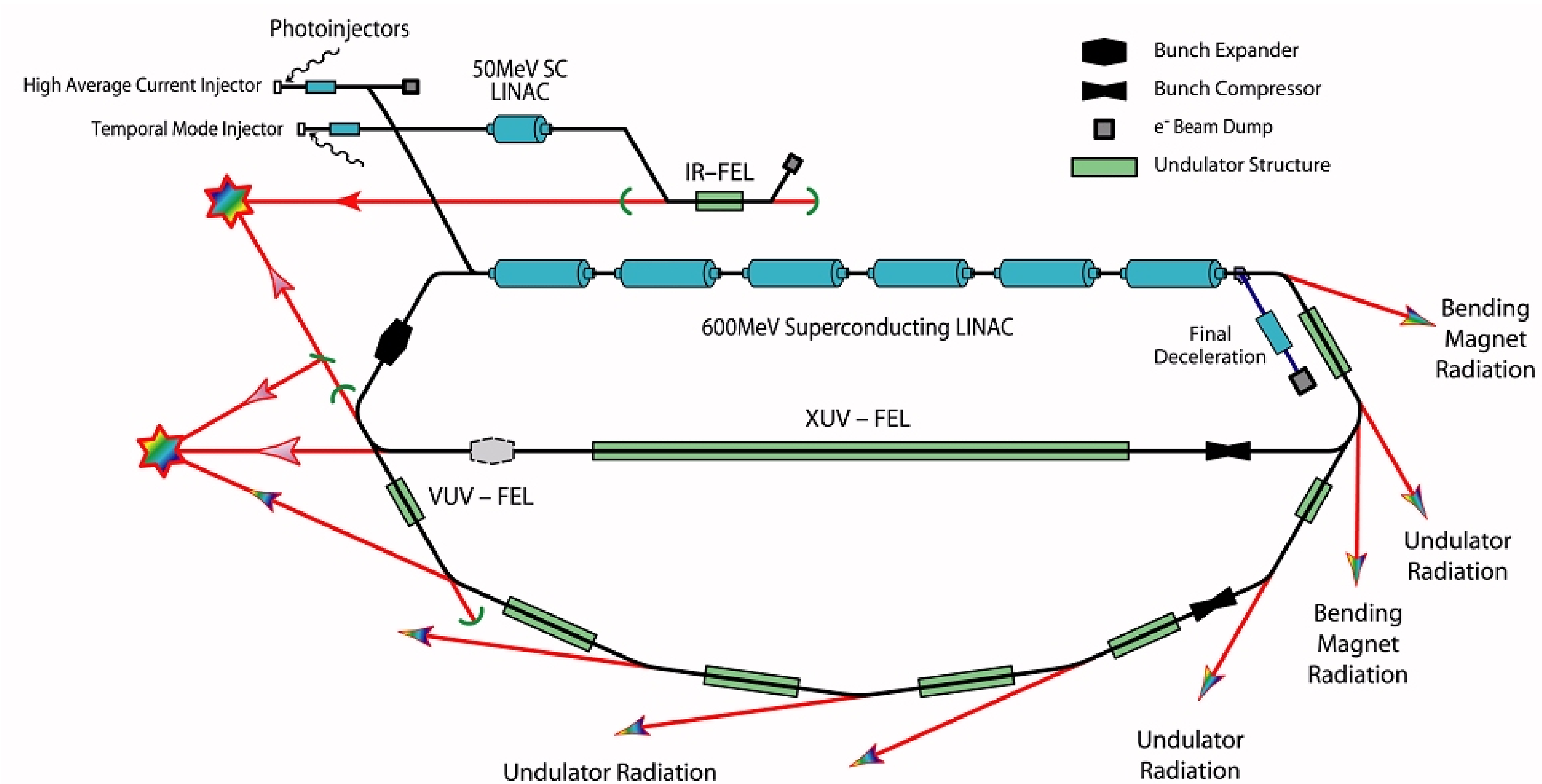
Emittance < 1nm-rad

bunch length 50fs-5ps

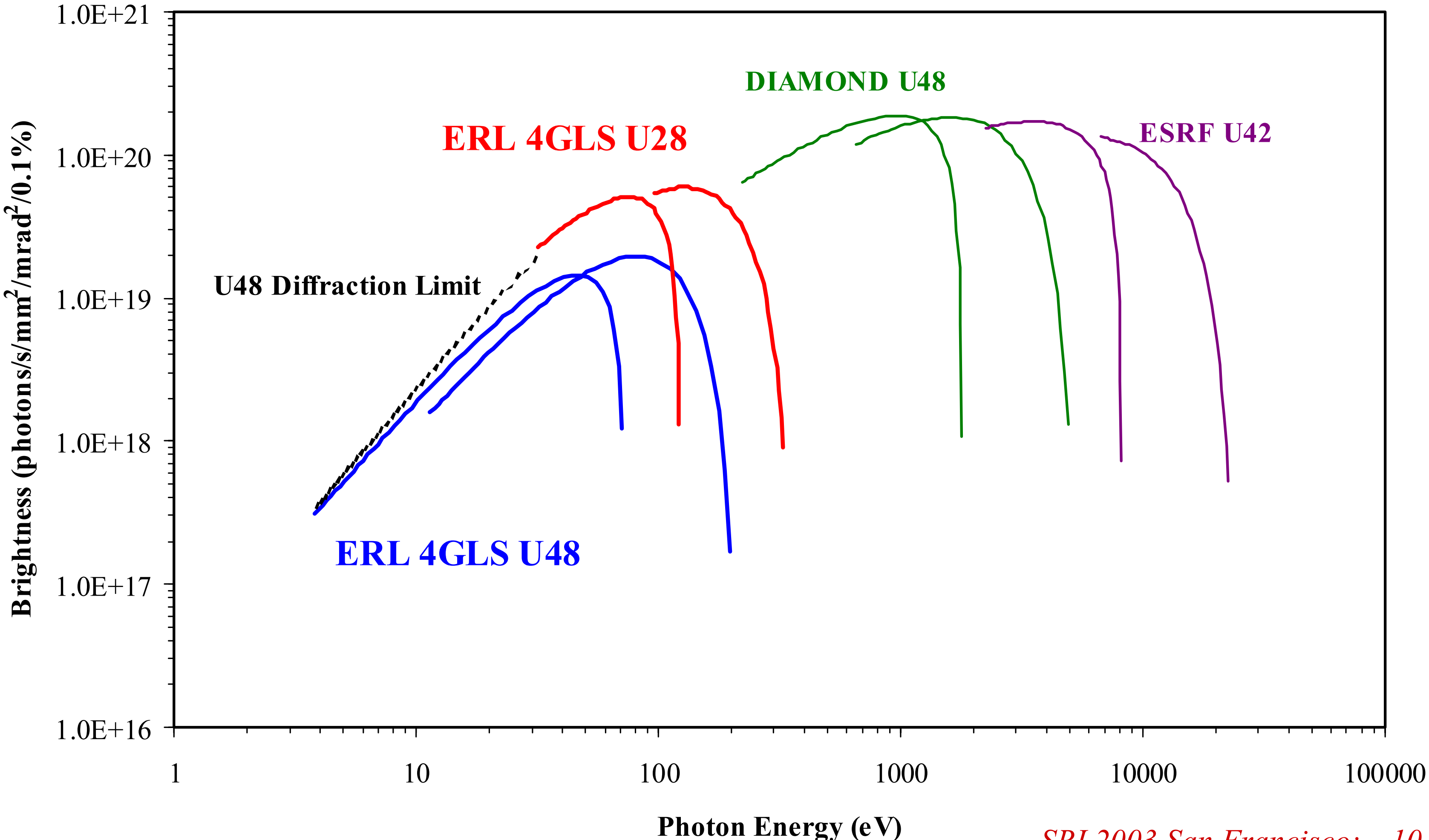
bunch separation 1-1000ns

target current 100mA

schematic layout



4GLS average undulator brightness



FEL opportunities

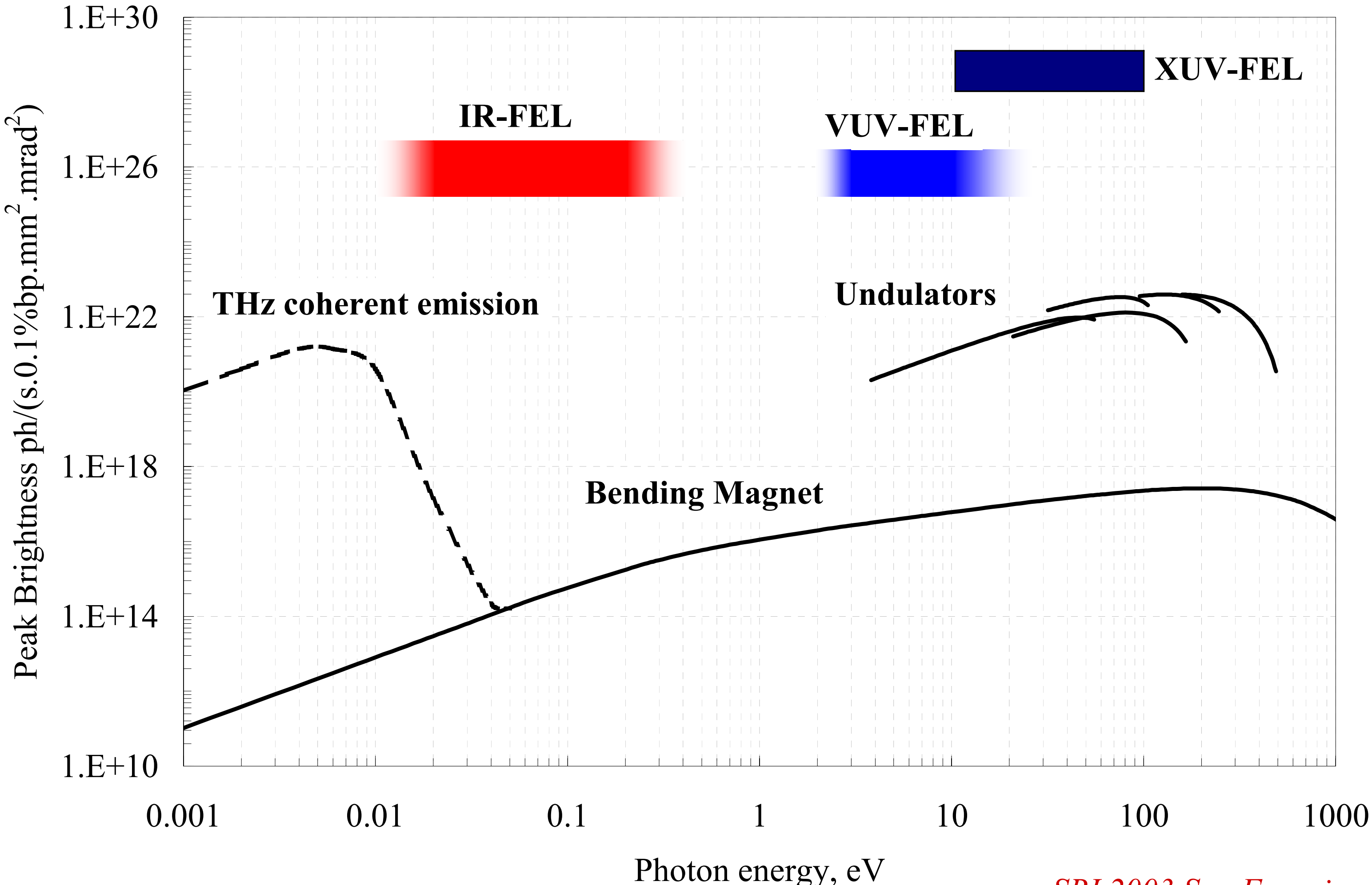
- IR oscillator FEL; 50 MeV electrons,
  - 5-75μm; variable polarisation
  - micropulse ~ 75 μJ
  - repetition rate 10MHz
- VUV oscillator FEL
  - 3-10 eV
  - 10^{13} photon/pulse ==15 μJ
  - repetition rate 6.25 MHz
- XUV single pass (sase or seeded)
  - 10-100 eV
  - 10^{14} photons/pulse == 2mJ
  - repetition rate; microbunch 65 MHz, macrobunch tens of Hz

multiple sources

• Undulators	3-100 eV (plus harmonics)
• IR FEL	3-75 μm
• VUV-FEL	3-10 eV
• XUV-FEL	5-100 eV
• bending magnets	THz-1keV

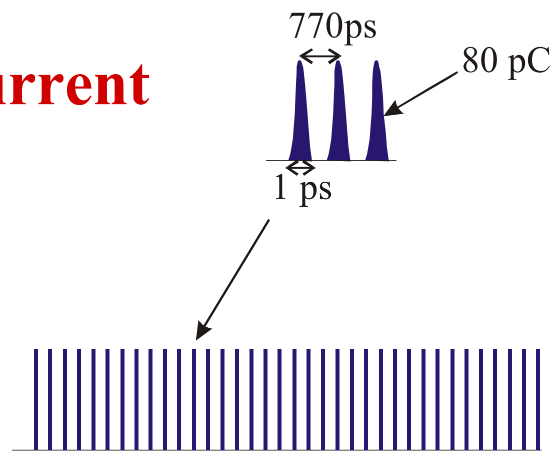
- coherent enhancment in THz range

peak brightness output

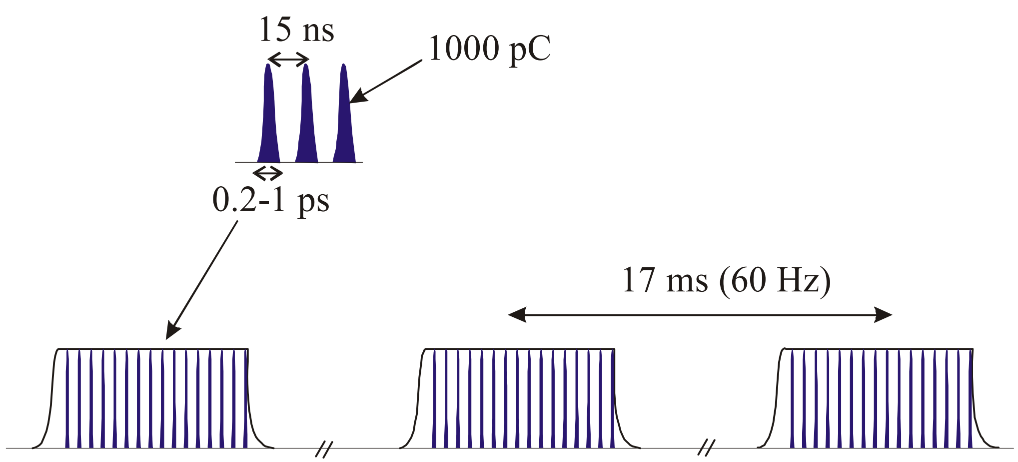


Pulse pattern: tailoring

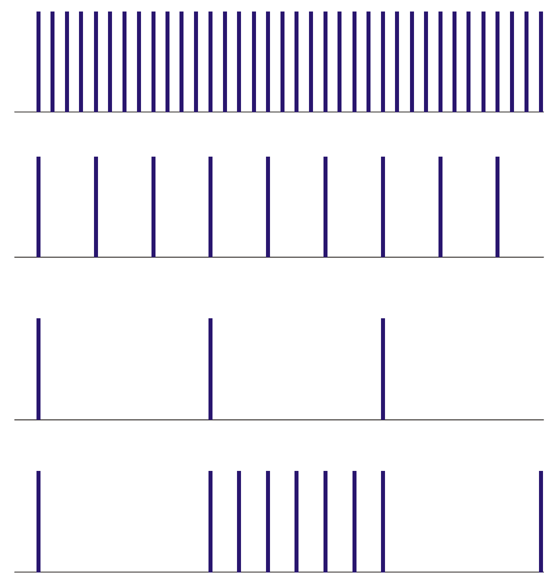
High average current



High peak charge



Range of pulse patterns



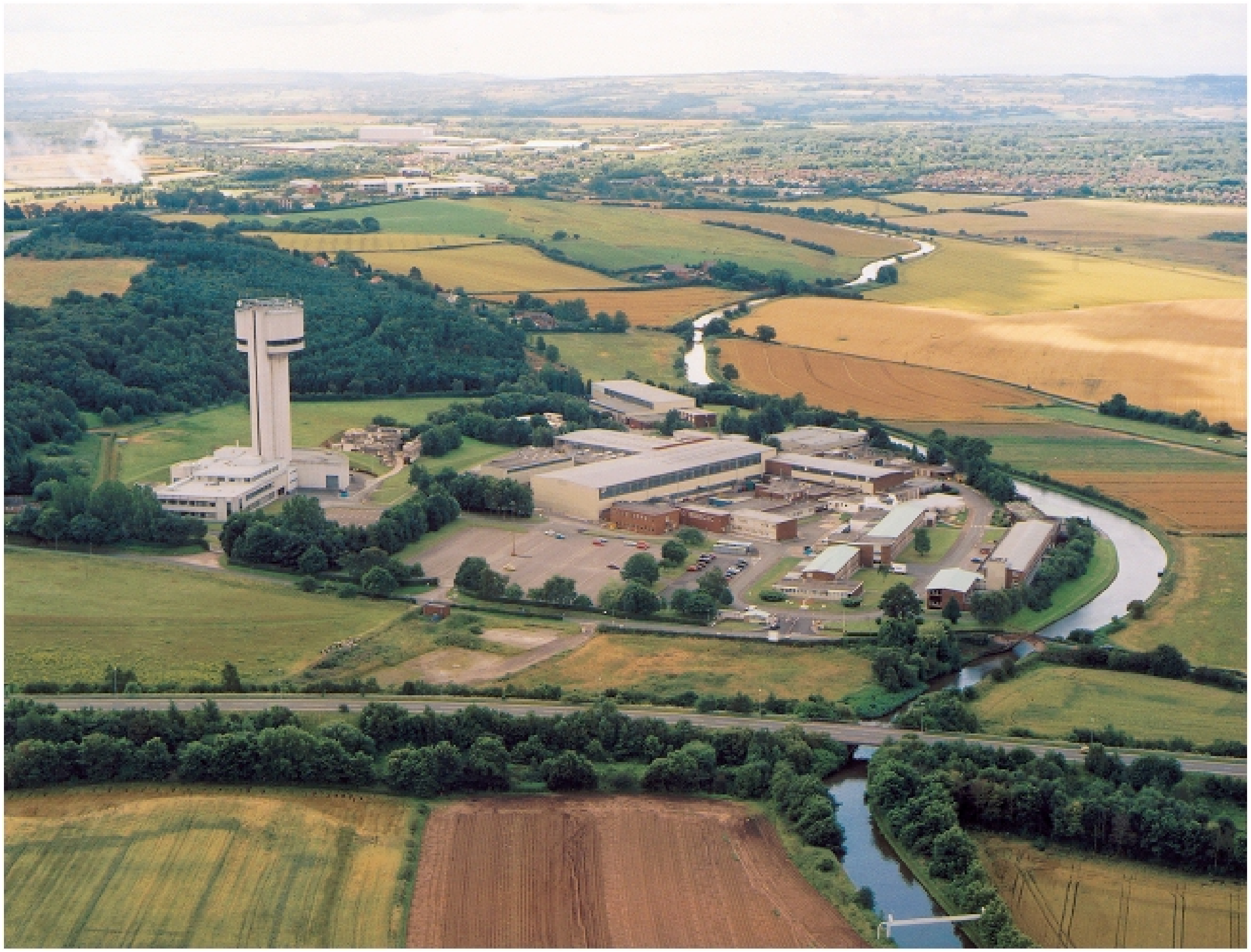
Summary

- Peak brightness up to **10^7** times 3rd generation sources
- short pulses down to **fs** regime
- **flexible** control of pulse structure
- flexible use of sources in combination; **multi-beams**
- coherence
- variable polarisation
- high power THz radiation (watts level)
- effectively **infinite** beam lifetimes
- multi-user access

Focus

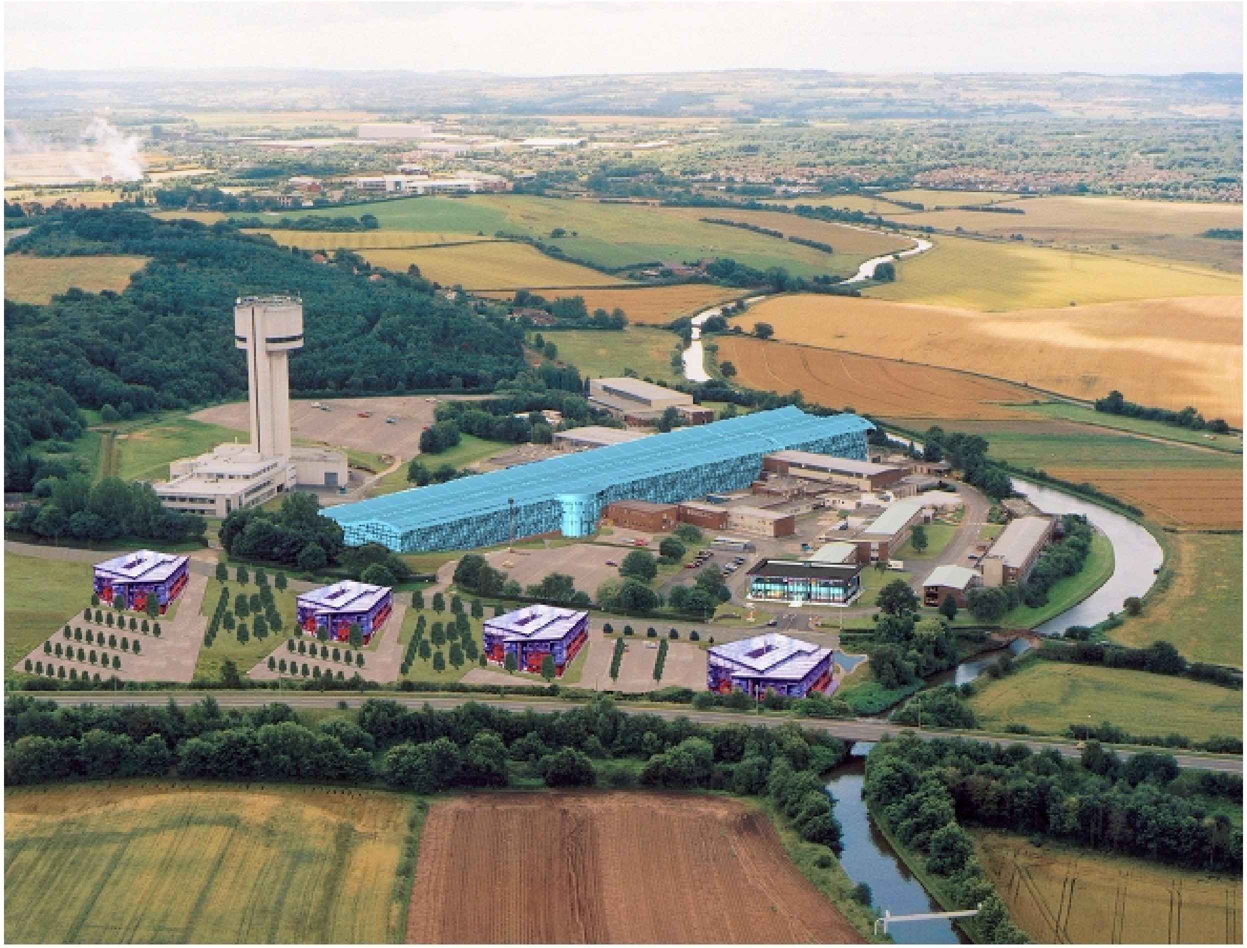
- 4GLS will be a multi-user, multi-source facility
- focus is on source quality and on flexible match to experiment/science needs (not simply high power)
- design phase is just starting; concept will evolve over next two-three years

Daresbury Site



Phase 1

Long term potential



project status

- December 2001 - Science case submitted
- April 2002 - **science case accepted** - RCUK recommend that 4GLS goes forward to Gateway 1
- Oct./Nov. 2002 - **business case accepted** - OGC Gateway 1 review status GREEN, NWDA committed £25M for building (lease-back)
- April 2003 - **R&D phase approved** - DTI announce **£11.5 Million** for R&D phase, NWDA committed **£4.5M** to 4GLS project

Funding: Deliverables

- For the research and development work needed for the design and exploitation of the 4GLS facility
- to establish an ERL prototype test facility
- to produce a detailed design report for 4GLS

ERL-Prototype Outline

- Photocathode gun test facility (initially DC)
- 50 MeV superconducting linac
- isochronous arc optics (Bates or TBA?)
- flexible bunch compression
- Infra-red FEL with J-Lab wiggler

ERL prototype

- Aim
  - to enable the development of core skills and to gain experience to meet the 4GLS challenge
- the work is cross-departmental, involving ASTeC, SRD, CLF, ED, ID, and HEIs
- the prototype will be housed in the Daresbury Tower experimental areas
- tenders are currently under negotiation for the principal components

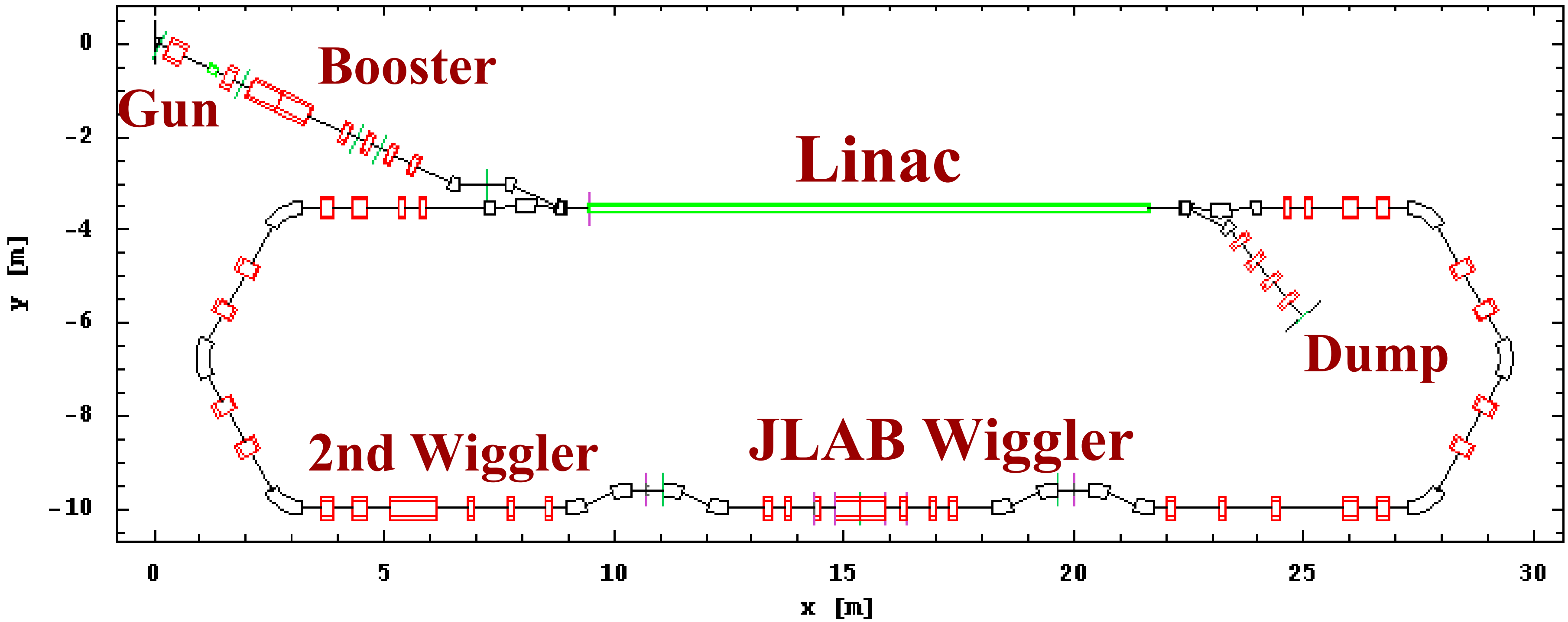
Principal Challenges

- High brightness guns
- high current superconducting linac
- beam transport optics (bunch compression, CSR, wakes)
- diagnostics

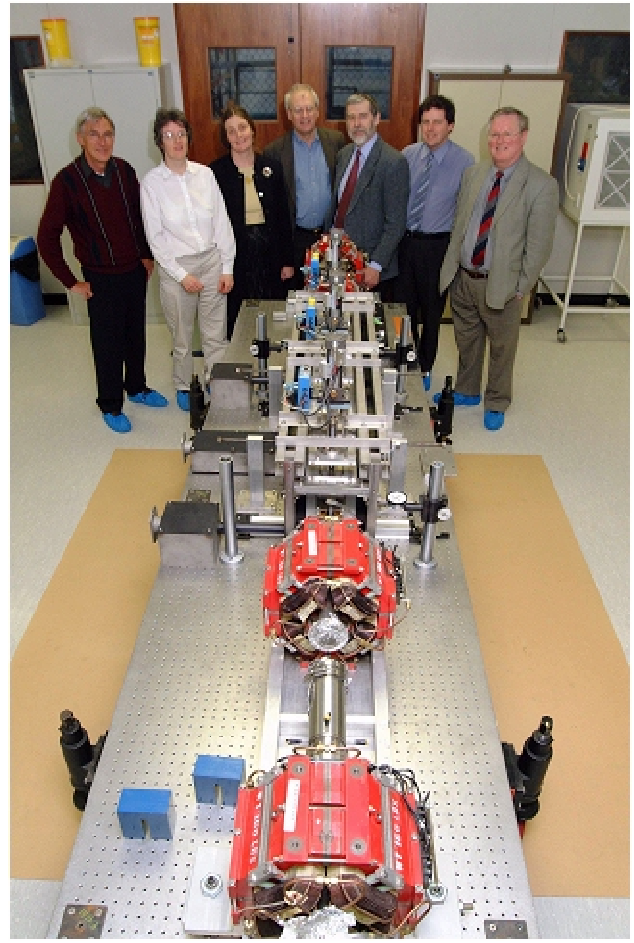
and

- lack of experience

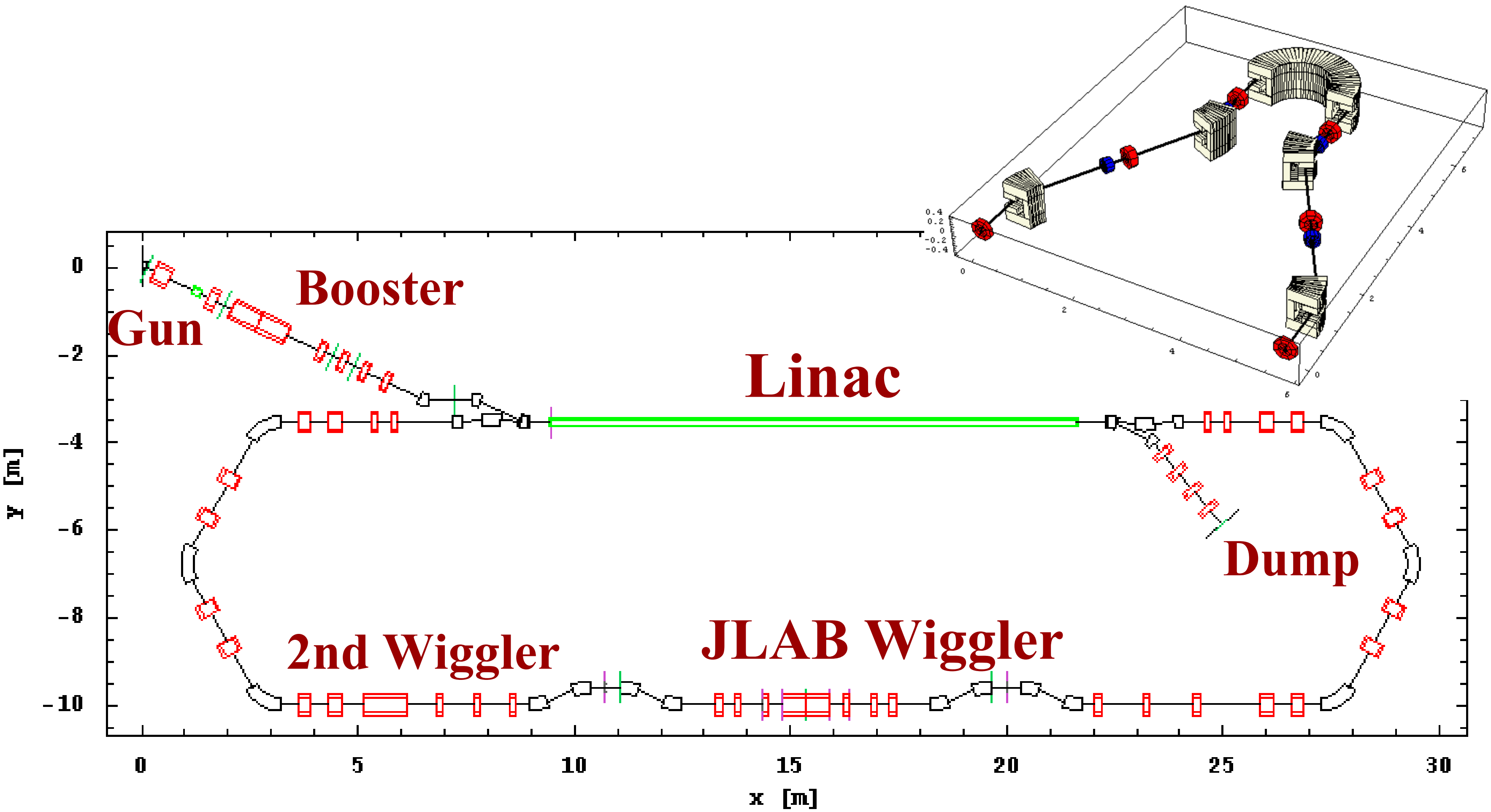
ERL-P schematic layout



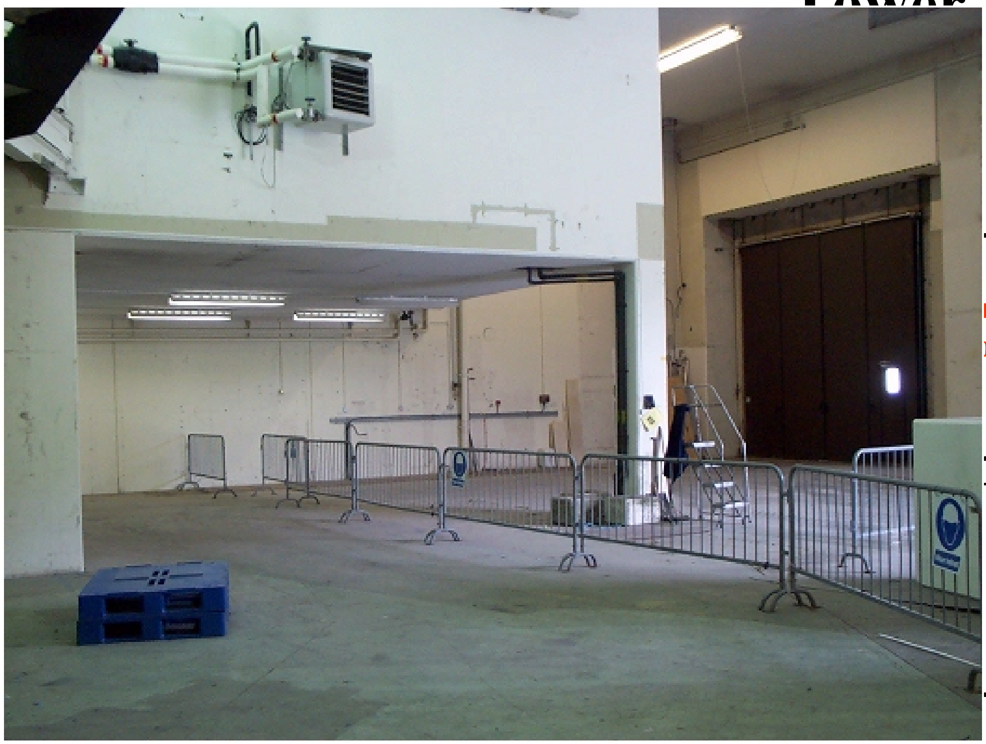
J-Lab undulator



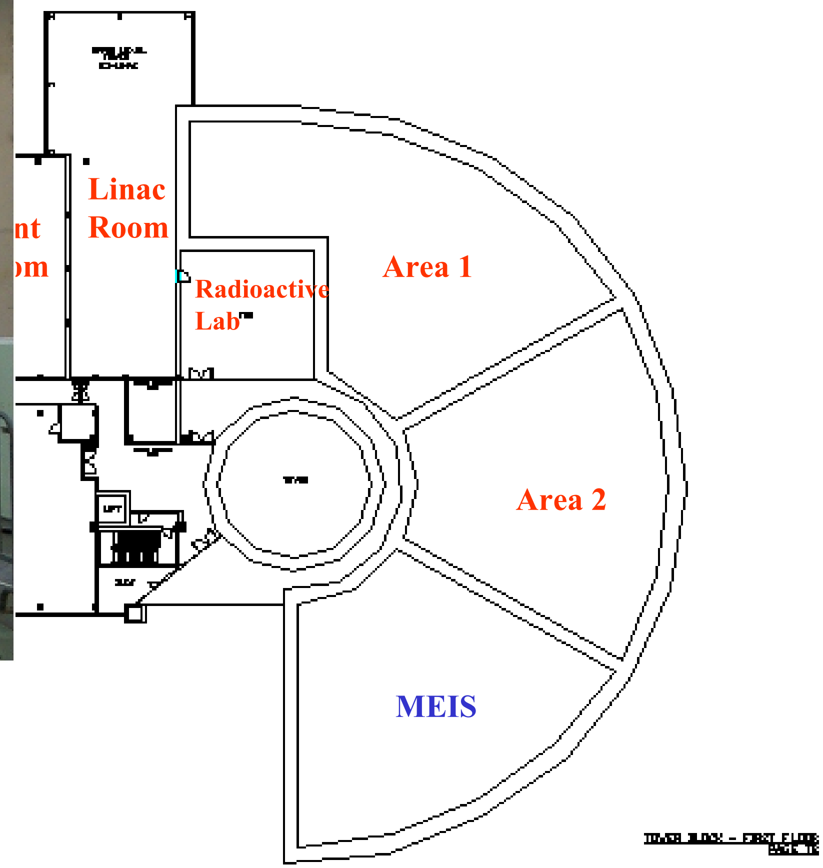
bend options: Bates or TBA



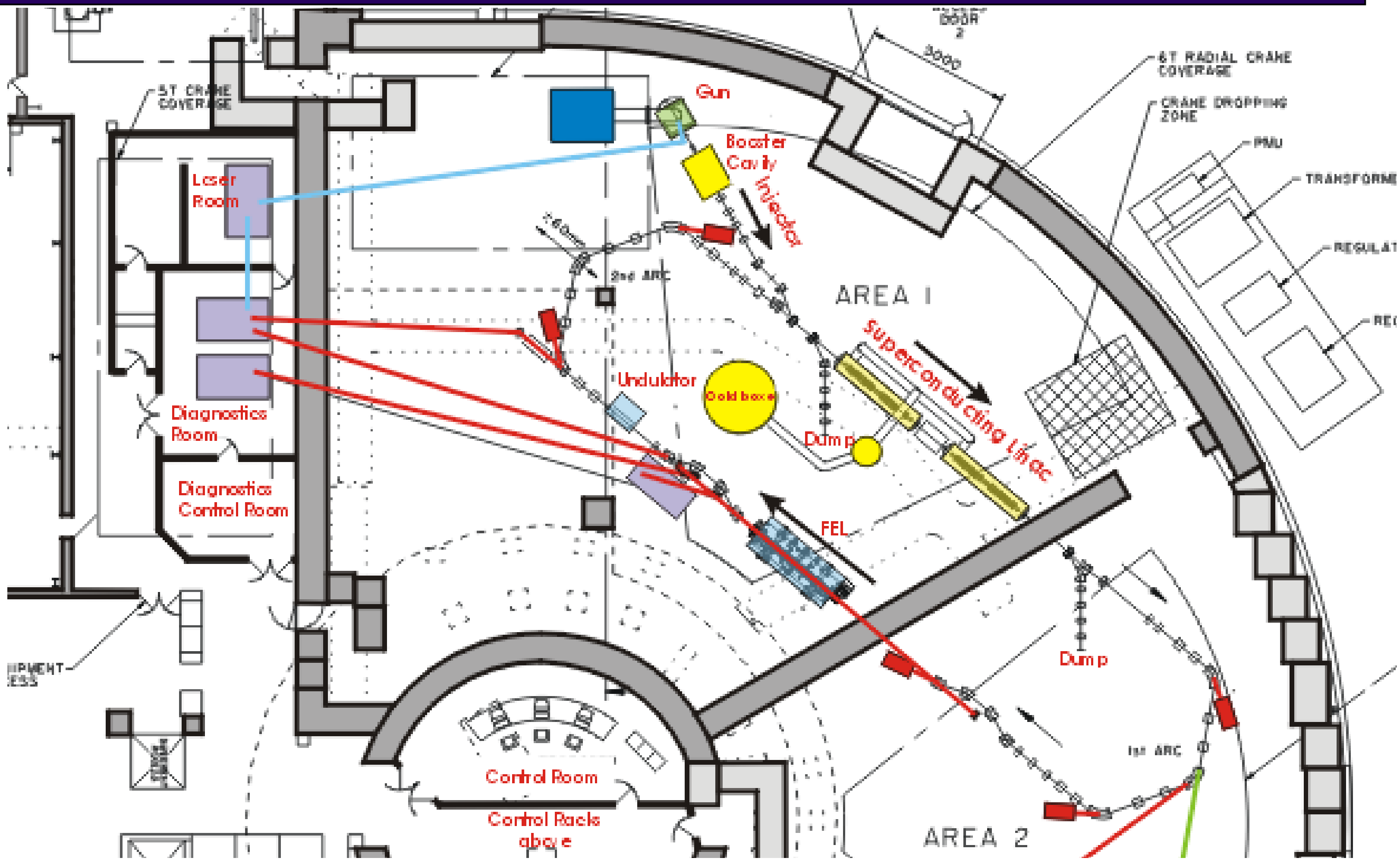
Tower experiment areas



Tower 1st Floor Plan



ERL-P layout in NSF



4gls *possible* programme

- 2003-6
  - ERL-prototype (gun and laser 2004,Linac 2005)
  - 4GLS design studies
- 2006/7
  - new building
- 2008
  - ERL operational
- 2009
  - FELs commissioned
- 2010
  - full specification

Collaboration

Too numerous to mention individually:-

- CLRC
  - DL - SRD, ASTeC, ED, ID
  - RAL - Central Laser Facility
- UK HEIs -
- Jefferson Laboratory
- DESY
- NorthWest Development Agency

Further collaborations evolving……..

Further Information

- Elaine Seddon (CCLRC Daresbury Laboratory - SRD)
- Wendy Flavell (University of Manchester Institute of Science and Technology)
- Peter Weightman (University of Liverpool)

- Mike Poole (CCLRC Daresbury Laboratory - ASTeC)