Science & Technology Facilities Council

STFC Facility Update

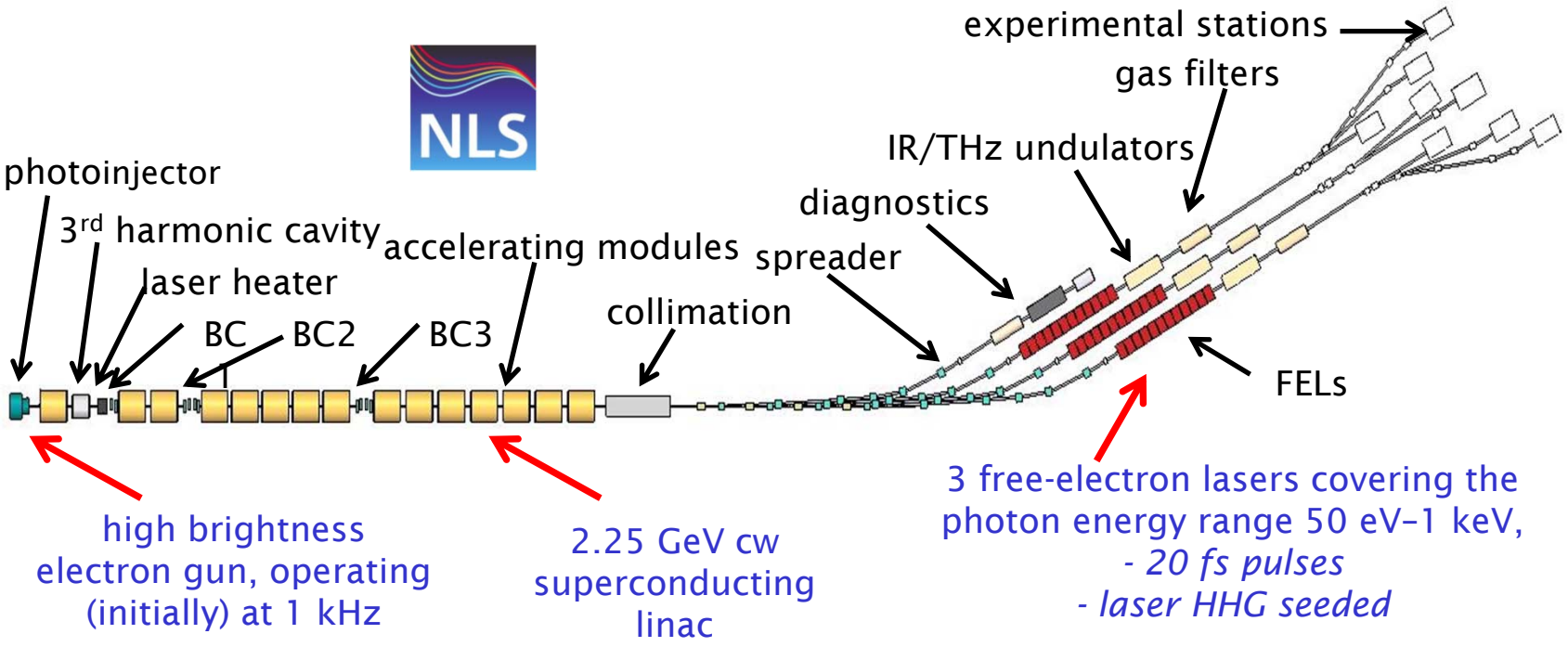
IRUVX Annual Meeting 2011

Neil Thompson

Outline

- Status of the **N**ew **L**ight **S**ource (NLS) Project
- ALICE (**A**ccelerators and **L**asers **I**n **C**ombined **E**xperiments)
  - Brief ALICE Overview
  - Results from the ALICE IR-FEL
  - Future Plans for the ALICE IR-FEL
- Future Plans

NLS Status



- As reported at last IRUVX meeting, although STFC recognised that NLS would have "*Very High Impact*", the project was put '*on ice*' for 3-5 years due to lack of funds
- Conceptual Design Report was completed in May 2010, available from http://www.newlightsource.org/
- No specific effort since then, and none anticipated.

ALICE Overview

- *However*, Accelerator R&D was recognised as being of major importance to STFC
- ALICE, the electron test accelerator at Daresbury, was supported as core to the UK accelerator R&D programme
- ALICE was originally known as ERLP, and was set up as an ERL Prototype for 4GLS
- There are many ALICE programmes, including
  - EMMA: a non-scaling FFAG prototype
  - **Electro-Optic Diagnostics**
  - **THz for Cell Experiments**
  - **Compton backscattering**
  - **Intra-Red Free Electron Laser**

ALICE Milestones

Aug 06: First Electrons

Oct 08: First Booster Beam

Dec 08: Full Energy Recovery

Feb 09: Coherently Enhanced THz

Nov 09: CBS X-Rays

Feb 10: IR-FEL Spontaneous Em.

Mar 10: EMMA Injection Line Beam

Apr 10: First THz Cell Exposures

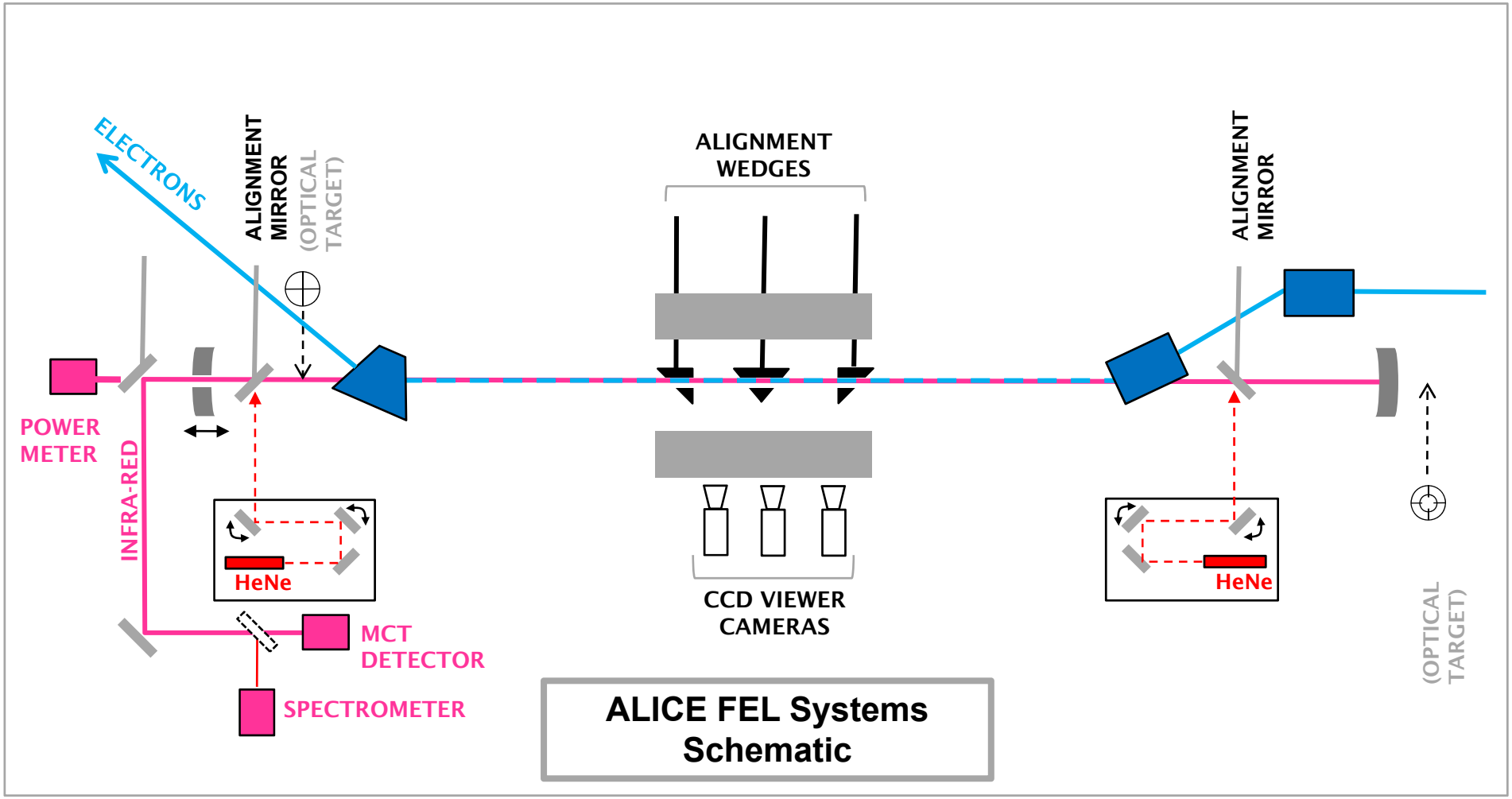
Aug 10: EMMA Ring 1000s turns

Oct 10: IR-FEL First Lasing

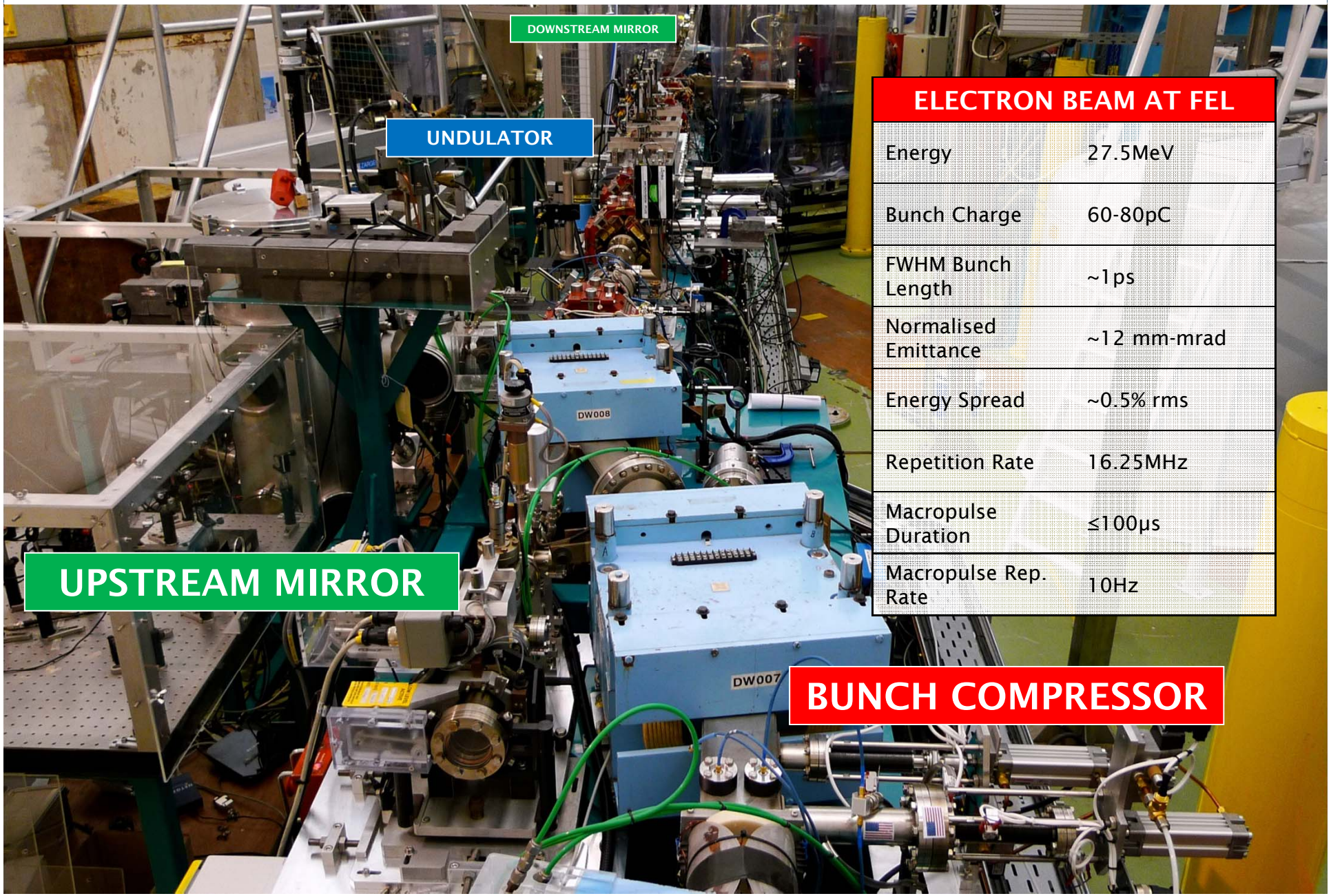
History of the ALICE IR-FEL

- **2003**:
  - ERLP proposed as a prototype for 4GLS.
  - IR-FEL was planned
    - To test energy recovery with a large FEL-induced energy spread
    - To start to develop UK FEL expertise
- **2010**
  - **January**: FEL Undulator and Cavity Mirrors installed and aligned.
  - **Throughout 2010**: FEL/THz/CBS programmes proceeded in parallel with installation of EMMA. One shift per day of beamtime for commissioning. Of available beamtime, FEL programme gets 12%.
  - **February**: First observations of undulator spontaneous emission.
    - **Stored in cavity immediately, indicating transverse pre-alignment reasonable.**
    - **Analysis of spontaneous emission used to optimise steering and focussing**
    - ***BUT NO LASING!*** Problem was that we were limited to 40pC: above 40pC @ 81.25Mz beam loading prevented constant energy along 100μs train.
  - **17th October:** we installed a Burst Generator to reduce laser repetition rate by a factor of 5, from 81.25MHz to 16.25MHz. This enabled us to increase the bunch charge to 60pC+.
  - **23rd Oct 2010:** achieved first lasing @ 8μm
  - **November/December 2010: Shutdown**
- **2011**
  - Lasing regularly, from 8.0-5.0μm

FEL Systems Simplified Schematic

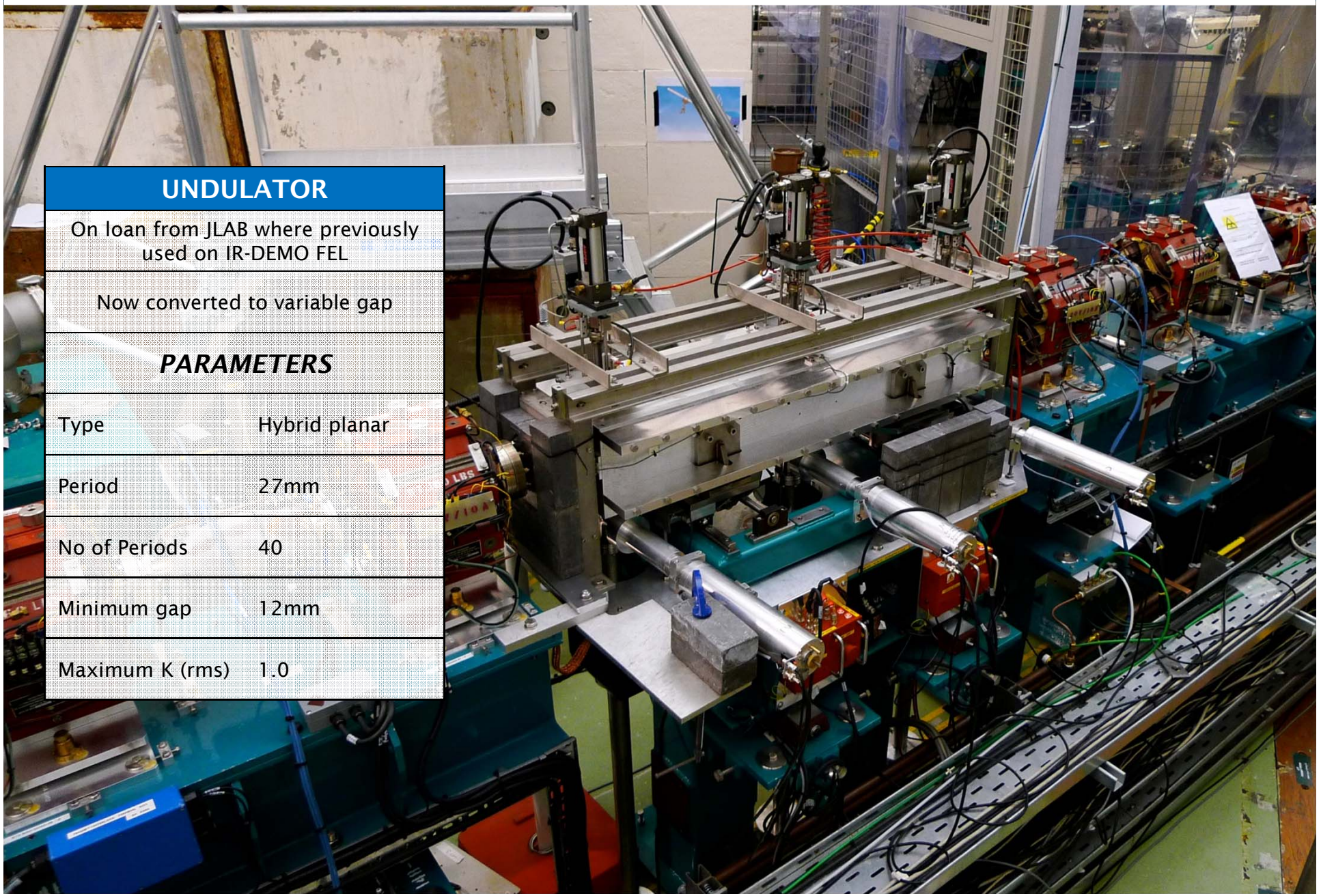


FEL Overview



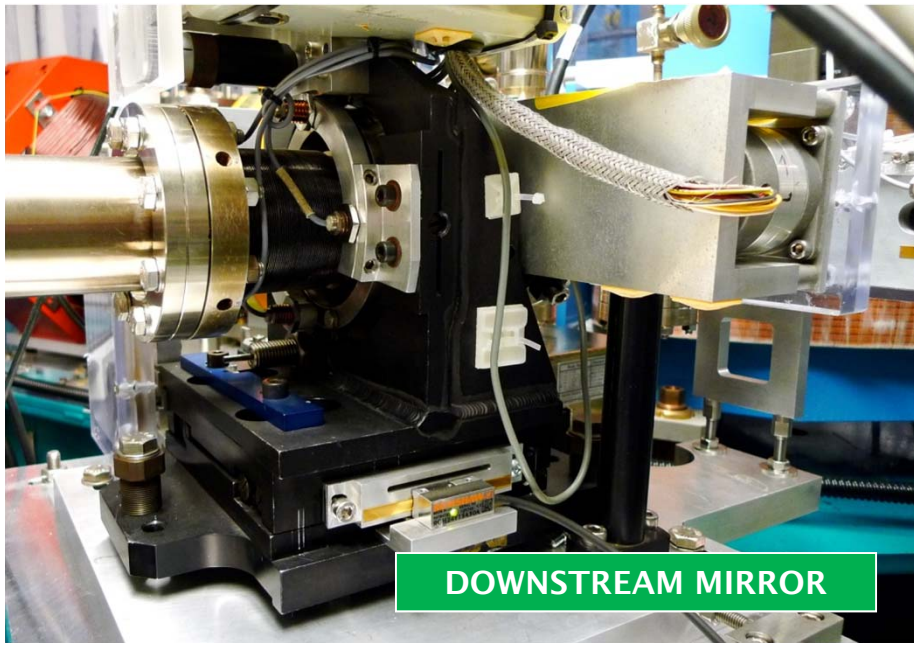
ELECTRON BEAM AT FEL	
Energy	27.5MeV
Bunch Charge	60-80pC
FWHM Bunch Length	~1ps
Normalised Emittance	~12 mm-mrad
Energy Spread	~0.5% rms
Repetition Rate	16.25MHz
Macropulse Duration	≤100μs
Macropulse Rep. Rate	10Hz

FEL Undulator



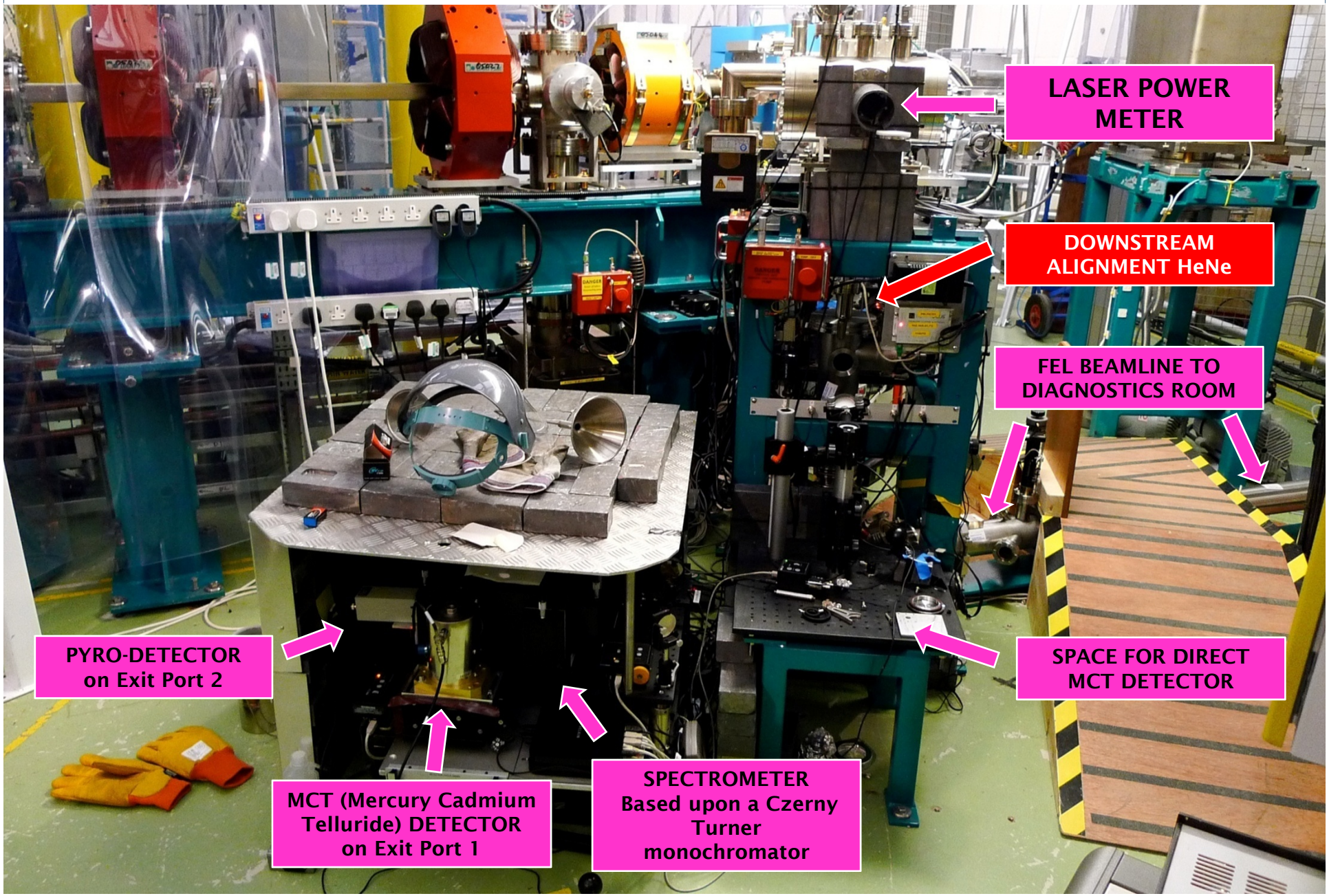
UNDULATOR	
On loan from JLAB where previously used on IR-DEMO FEL	
Now converted to variable gap	
PARAMETERS	
Type	Hybrid planar
Period	27mm
No of Periods	40
Minimum gap	12mm
Maximum K (rms)	1.0

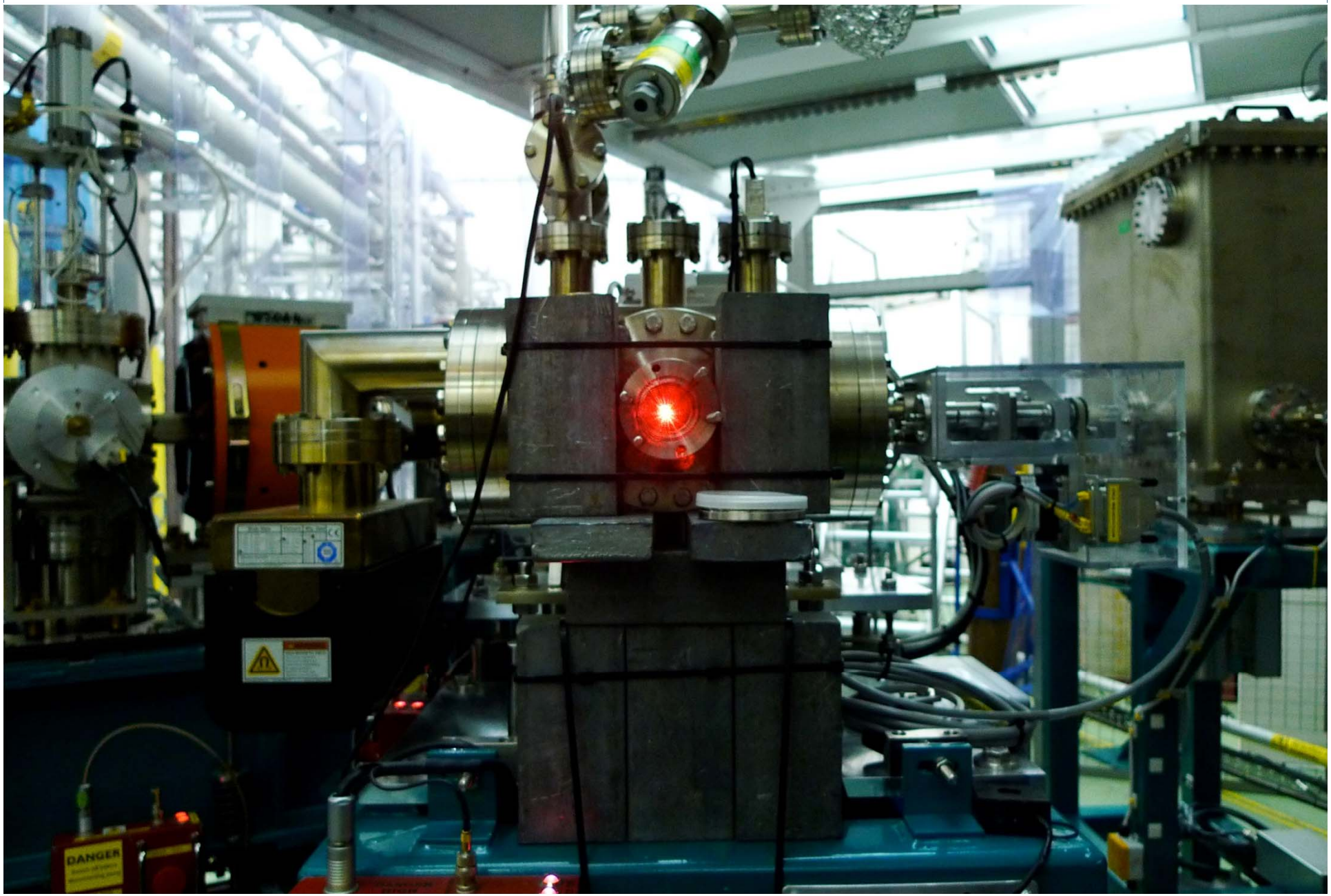
FEL Resonator



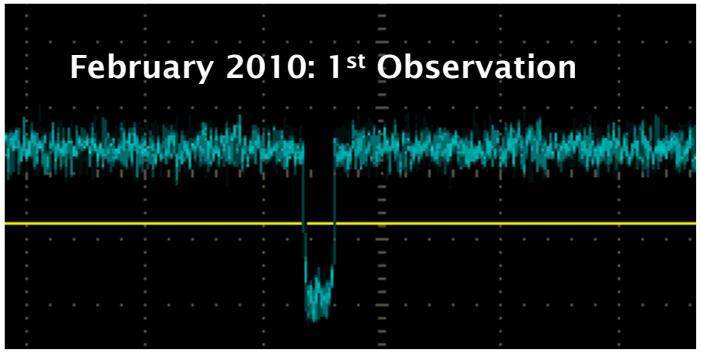
RESONATOR	
Mirror cavities on kind loan from CLIO.	
Previously used on Super-ACO FEL	
PARAMETERS	
Type	Near Concentric
Resonator Length	9.2234m
Mirror ROC	4.85m
Mirror Diameter	38mm
Mirror Type	Cu/Au
Outcoupling	Hole
Rayleigh Length	1.05m
Upstream Mirror Motion	Pitch, Yaw
Downstream Mirror Motion	Pitch, Yaw, Trans.

FEL Local Diagnostics



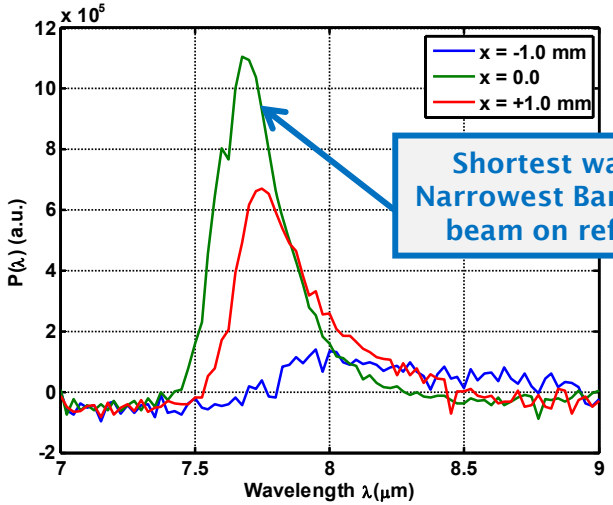

DANGER

Spontaneous Emission as a Diagnostic

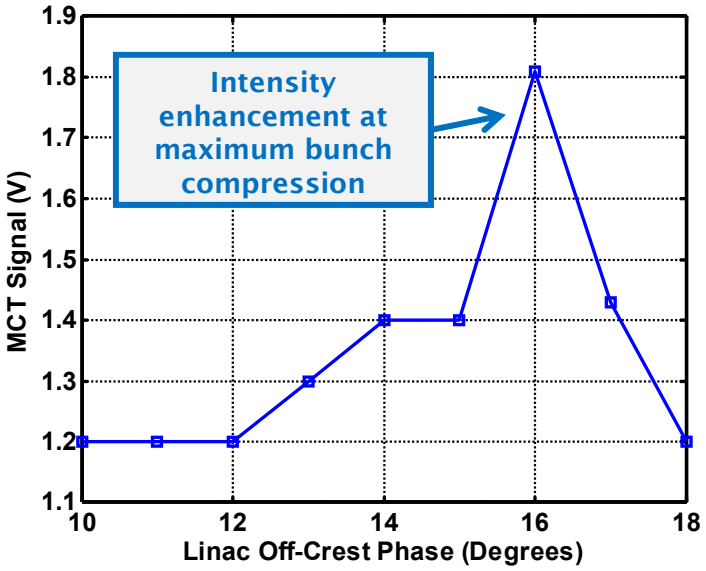


Spontaneous emission has been a useful diagnostic

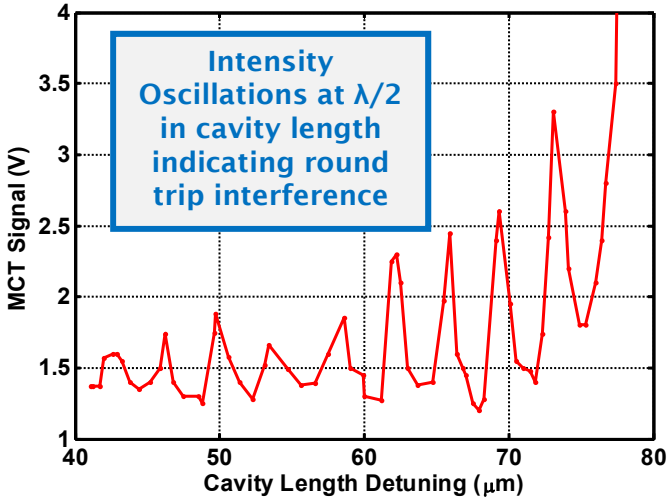
1. Spectrum used to optimise steering in undulator



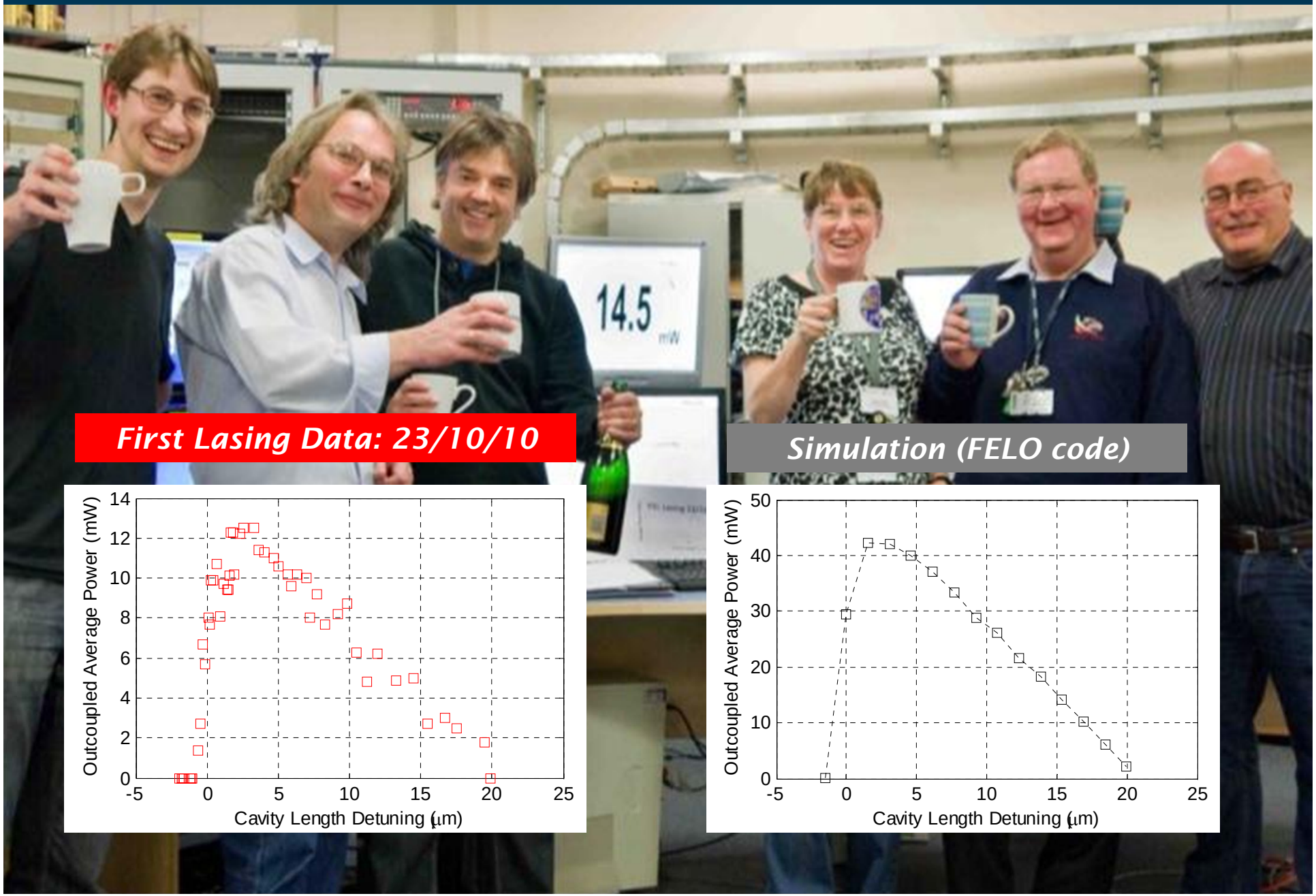
2. Coherent enhancement used to set minimum bunch length



3. Interference of coherent SE used to set correct cavity length



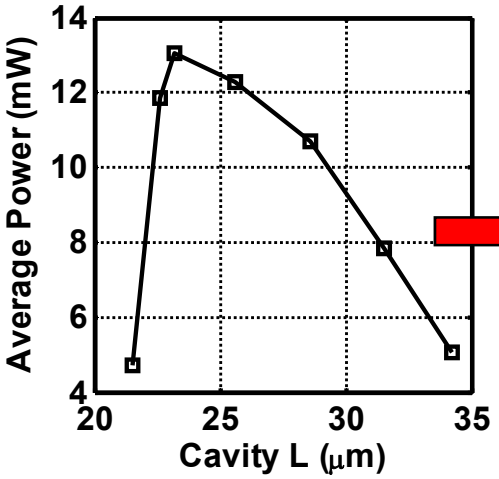
ALICE IR-FEL: First Lasing

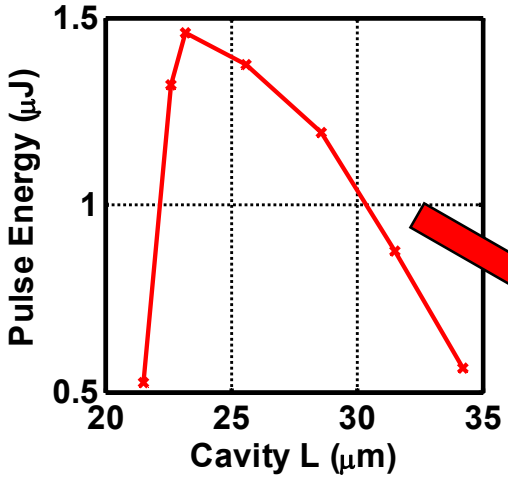


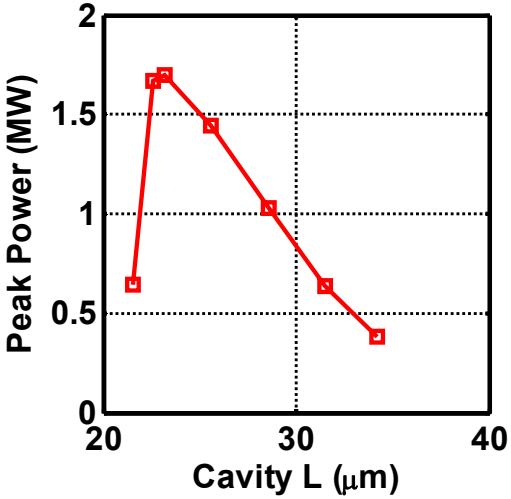
First Lasing Data: 23/10/10

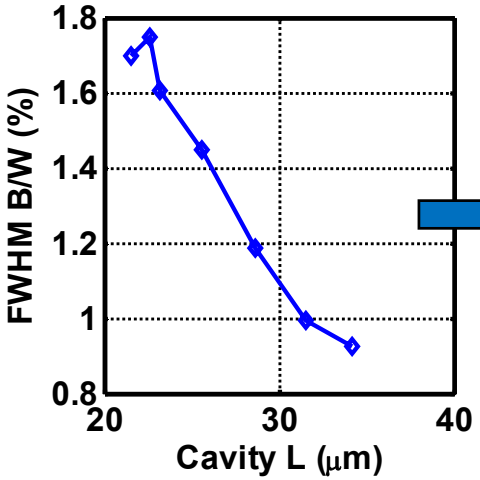
Simulation (FELO code)

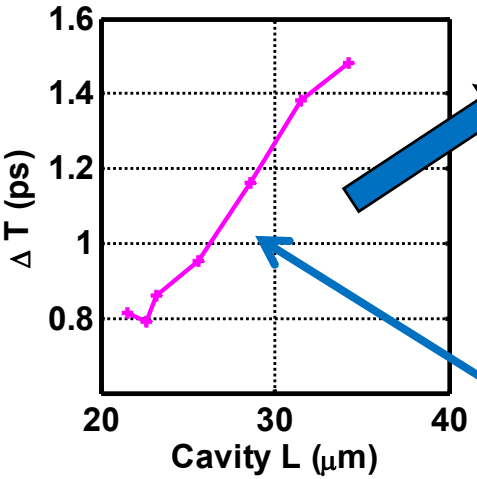
Results from First Lasing Period (23-31 October 2010)





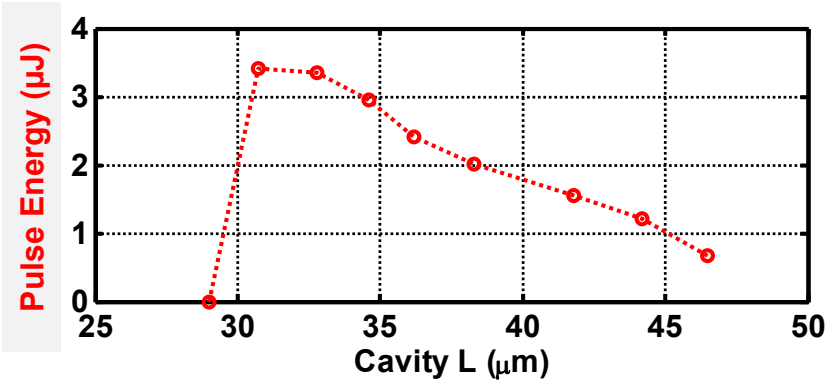




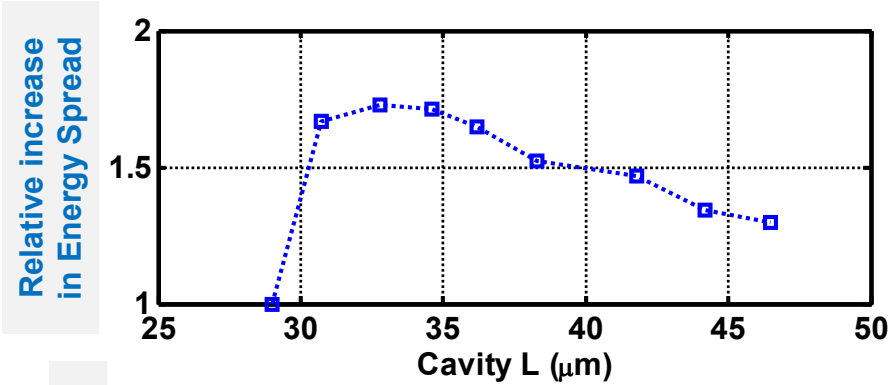


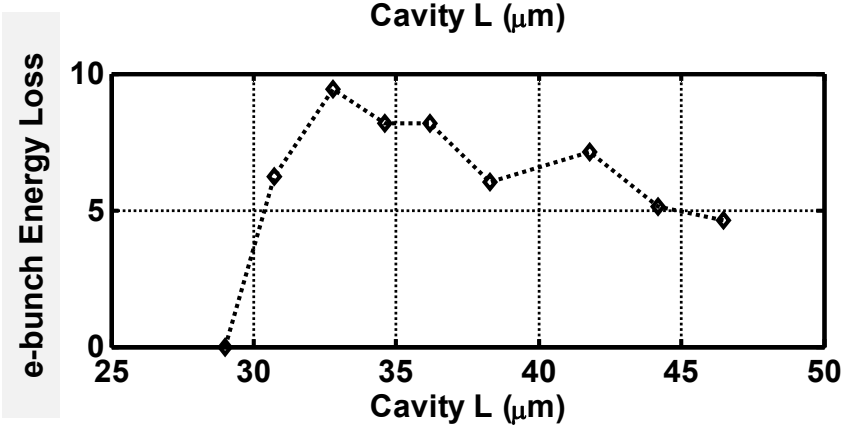
Implies electron bunch length ≈1ps, in agreement with previous EO measurements of a similar ALICE setup

Results from First Lasing Period (23-31 October 2010)



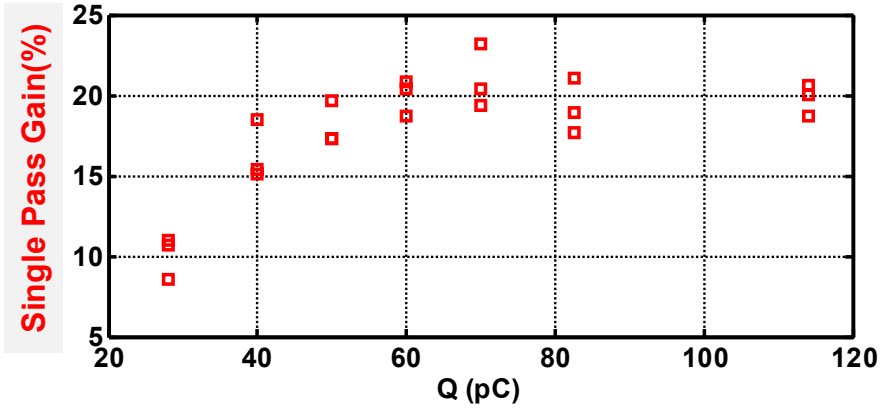
- Maximum pulse energy we've recorded so far is 3.3μJ
  - Current outcoupling hole is small, to give high Q for first lasing
  - Expect to get >10μJ with bigger hole

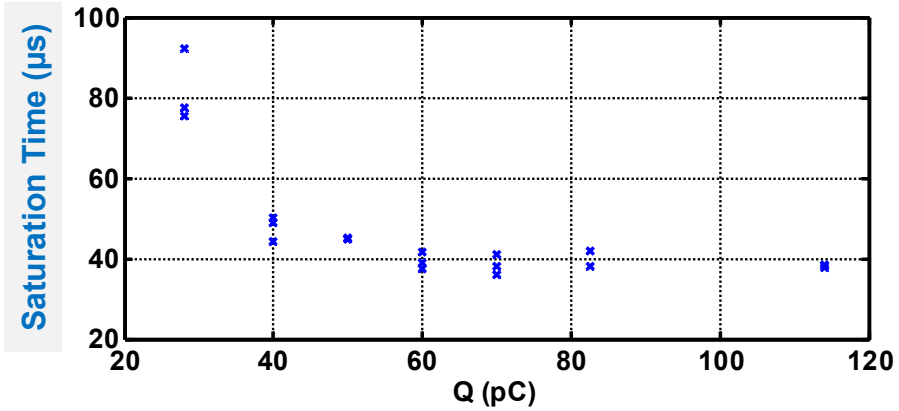


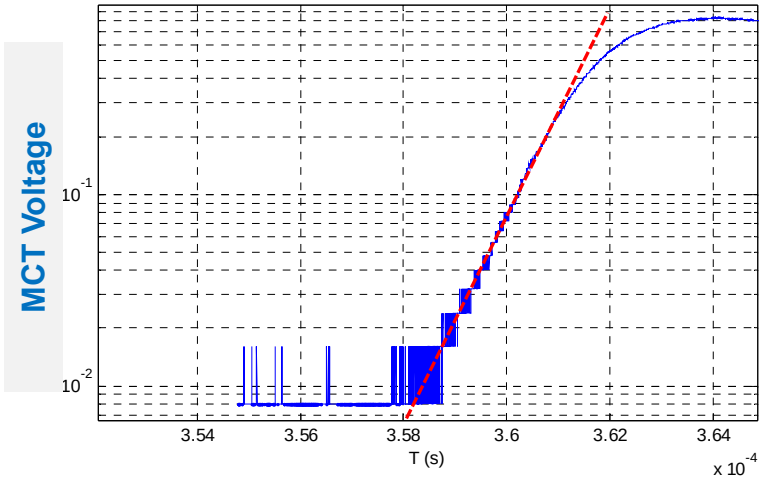


- Effect on electron beam studied post-FEL in dispersive section of return arc.
  - Maximum bunch energy loss is 10μJ.
  - Suggests ~1/3rd of energy extracted from electrons is outcoupled and detected
  - In agreement with expectations:
    - From size of hole and calculated size of TEM_{00} mode on mirror face, hole should give ~2% outcoupling
    - Mirror reflectivity ~98%, so 4% absorption
    - This adds up to the measured cavity loss of ~6.4% and means that ~1/3rd of power should be extracted

Results from First Lasing Period (23-31 October 2010)

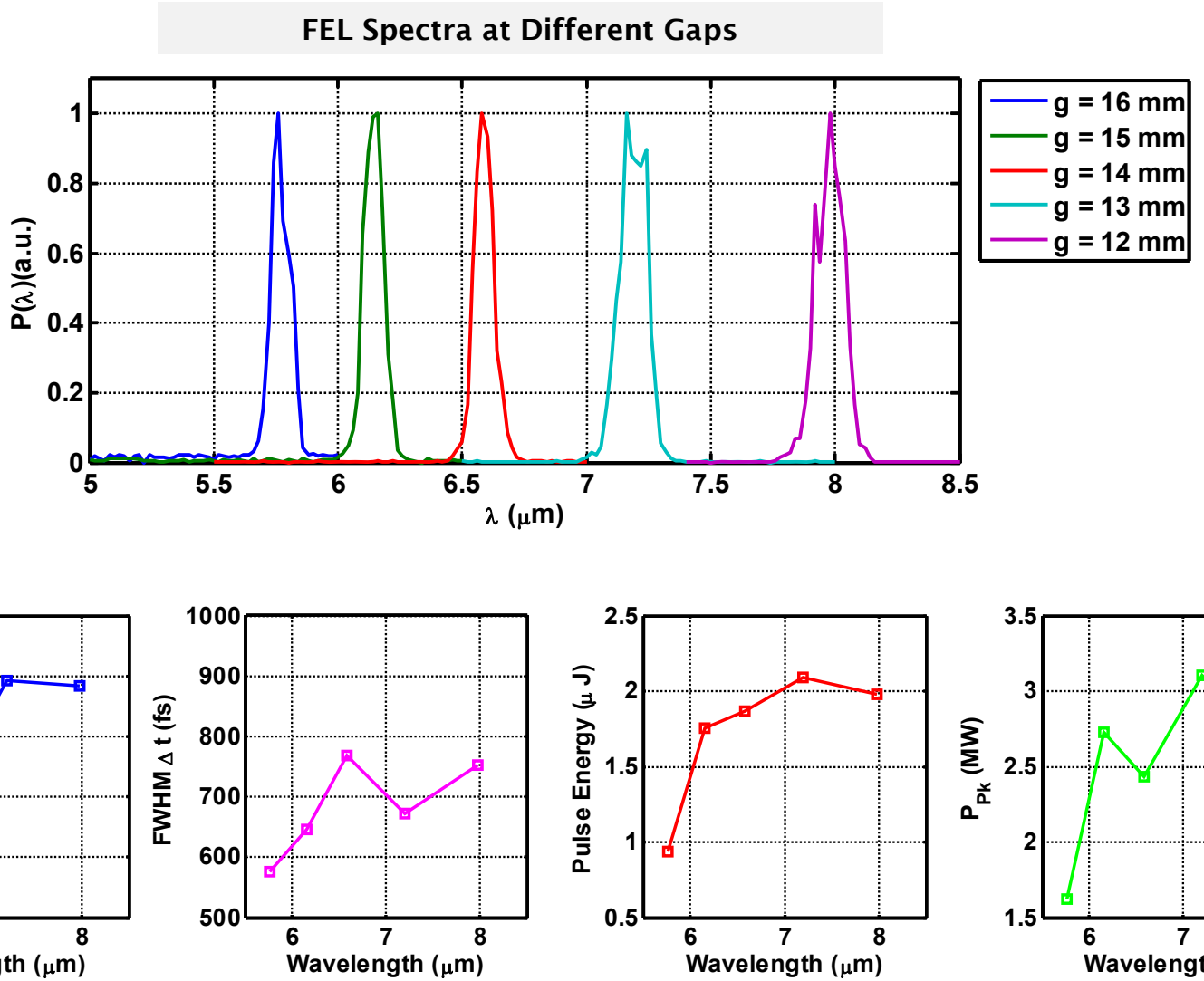






- Gain determined from cavity rise time
- From one pulse train to the next the **gain jitters**
  - Cause under investigation. *Phase jitter in pulsed RF? Laser jitter?....*
- On average the **gain is lower than we want**:
  - rms Energy spread of 0.5% is too big: degrades the gain significantly
  - Aim to halve energy spread and double gain
  - Can then change to outcoupler with larger hole for increased efficiency
  - Have already set up beam to achieve this (set injector to deliver shorter bunch to linac) but haven't yet lased with this setup – *still to be understood!* ***Should work, but doesn't!***

Results from February 2011: Gap Tuning

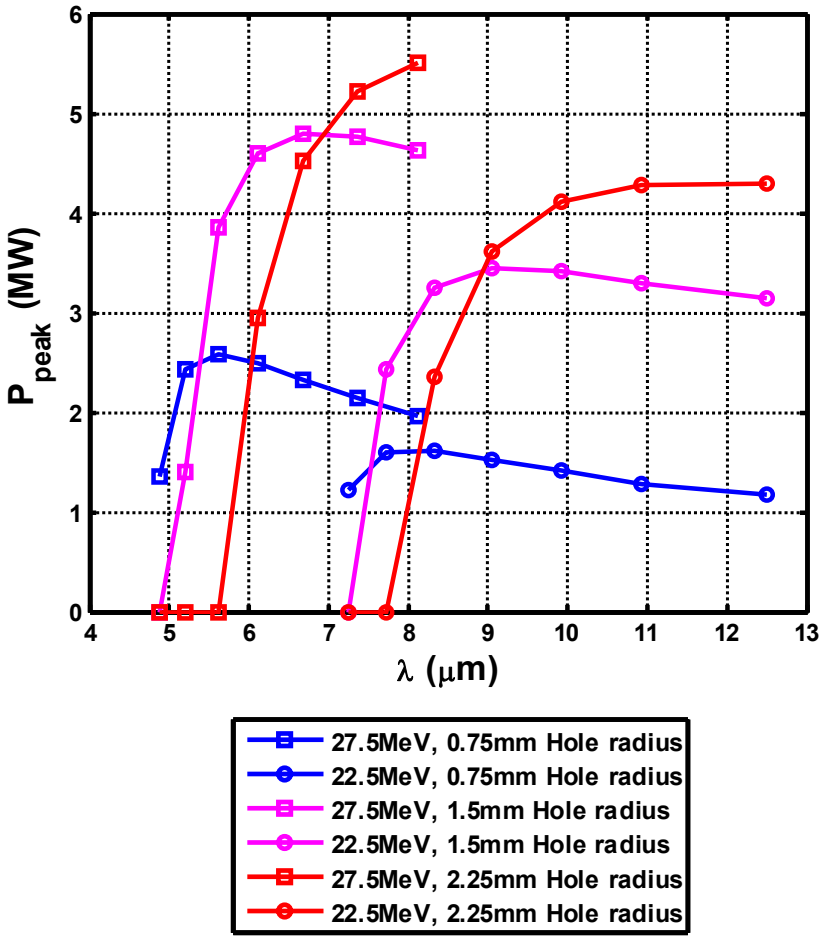


ALICE FEL Future Plans

- Improved electron beam set-ups with reduced energy spread and jitter.
- Transport of FEL beam to diagnostics room, then full output characterisation.
- Reduced Mirror ROC to improve gain, plus selection of outcoupling hole sizes to optimise output power.
- Plan to run and characterise at two different energies
  - 27.5MeV (5-8μm)
  - 22.5MeV (7-12μm)
- After characterisation, *future IR-FEL program depends on funding being obtained for specific FEL physics or exploitation programmes.*

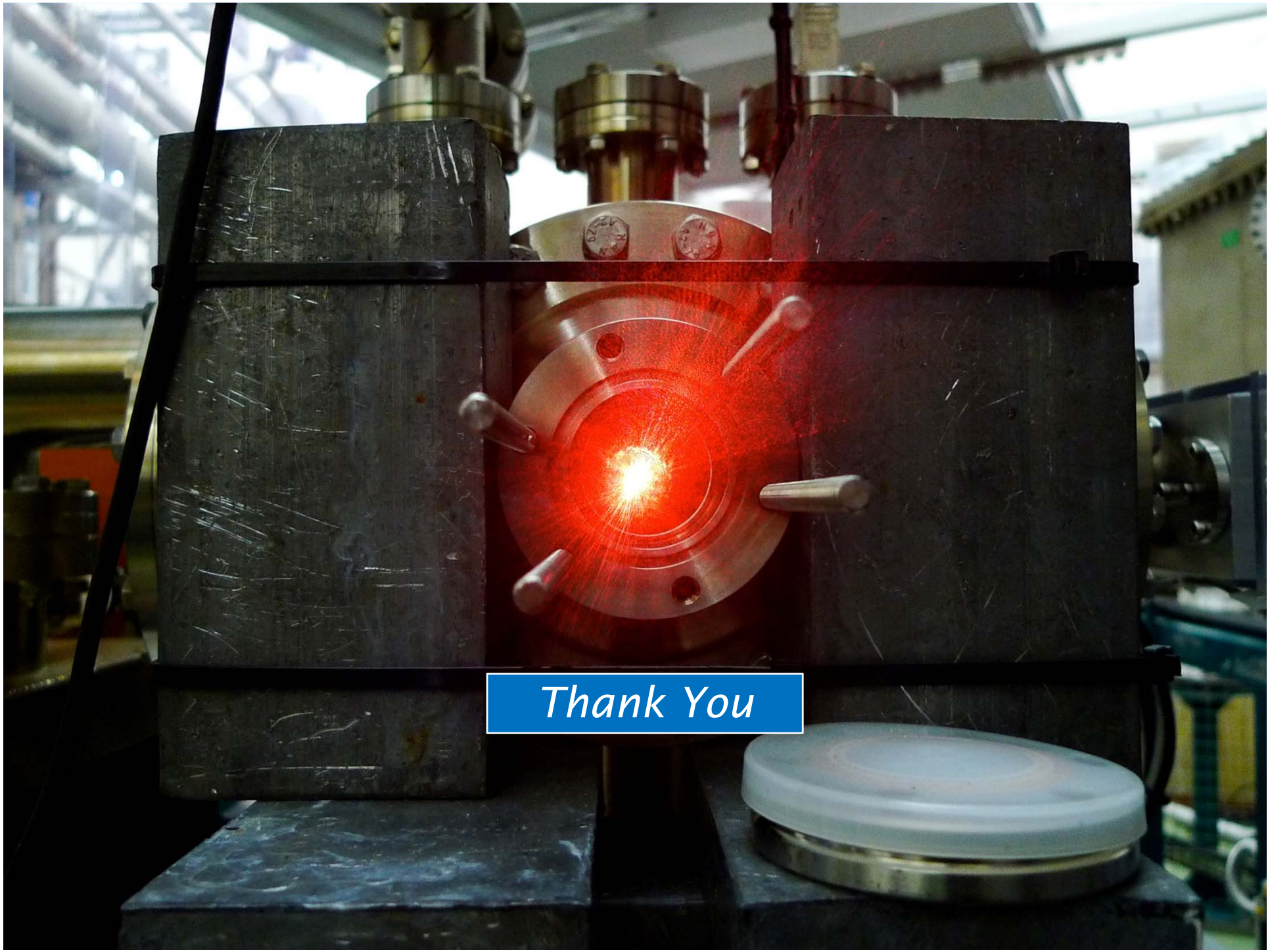
- But ALICE itself will not run indefinitely.
- We are now thinking beyond ALICE….

Simulation results

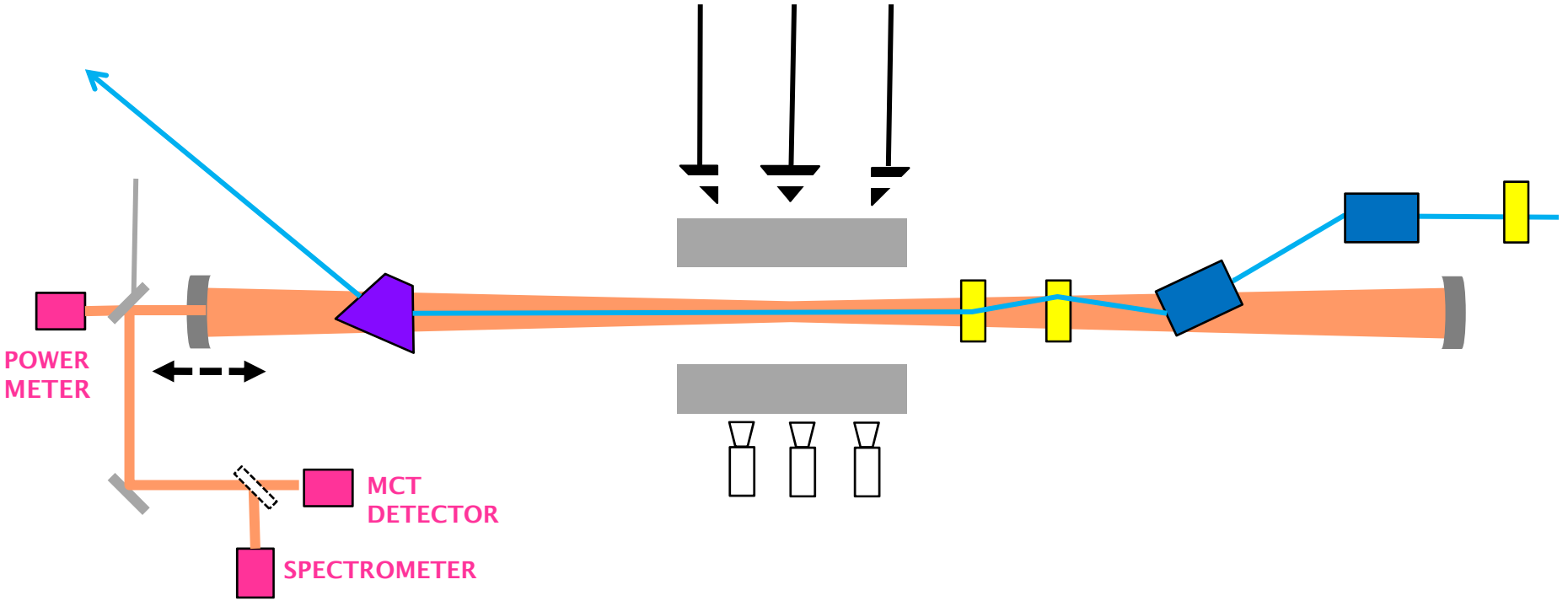


Development of Electron Test Accelerators

- Concepts for a post-ALICE hundred-MeV-scale electron test accelerator at Daresbury are currently under development.
- Approval for a new large-scale UK light source facility is extremely unlikely for several years, so the general theme for the test accelerator will be ***R&D on topics relevant to Future Light Sources***
- Potential topics of interest include:
  - *'Ultra-Cold' Injectors (Low emittance, velocity bunching…..)*
  - *Novel Acceleration (Laser plasma wakefield….)*
  - *More Compact FELs (Low emittance, short period undulators….)*
  - *Attosecond FEL pulse generation (slicing, mode-locking…)*
  - *Novel FEL seeding schemes (HHG, self-seeding, EEHG….)*
  - *Photon pulse diagnostics*
  - *Laser/Electron Beam interactions*
  - *…….*
- Nothing is yet ruled out, and nothing is yet confirmed….
- Will be a national and international collaboration taking 6-18 months to develop the proposed R&D programme.
- ***Watch this space…..***


Thank You

FEL SYSTEMS + Transverse/Longitudinal Alignment



6. Cavity length scanned looking for enhancement of spontaneous emission, then LASING.