New ultrashort OPCPA petawatt class beamline for Vulcan laser facility

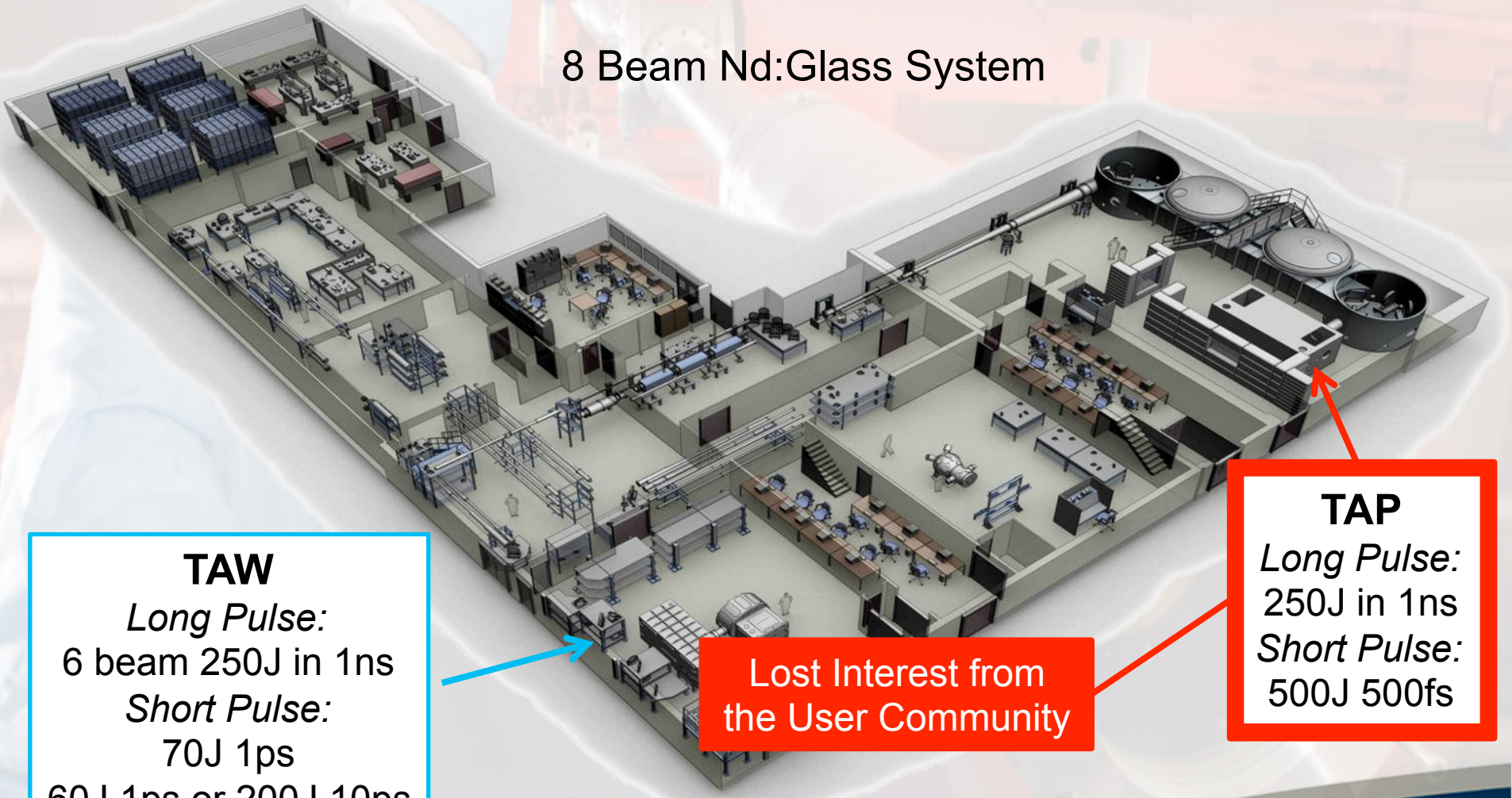
Marco Galimberti

UK Research and Innovation

Science & Technology Facilities Council

Vulcan Laser System

8 Beam Nd:Glass System

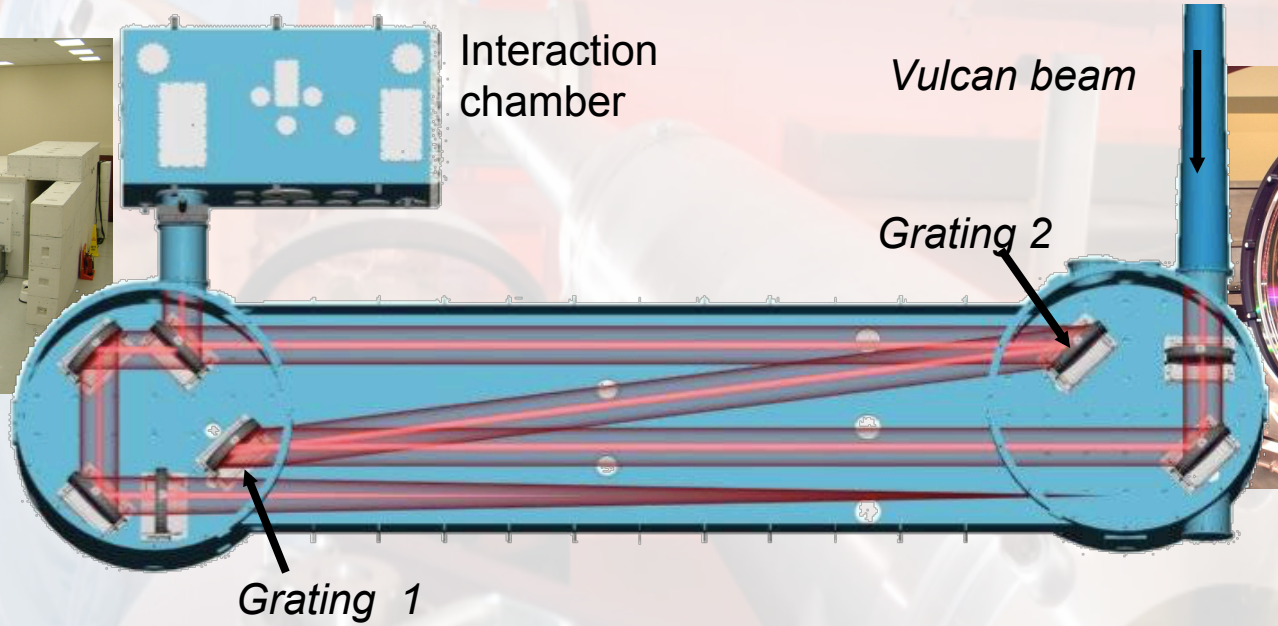


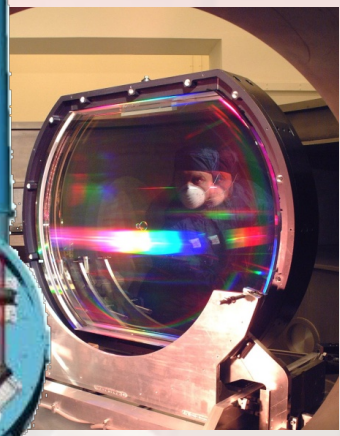
TAW
Long Pulse:
6 beam 250J in 1ns
Short Pulse:
70J 1ps
60J 1ps or 200J 10ps

Lost Interest from the User Community

TAP
Long Pulse:
250J in 1ns
Short Pulse:
500J 500fs

Target Area Petawatt





Maintain existing TAP beam (500J 500fs + 250J 1ns)

Add new beamline to increase scientific capabilities

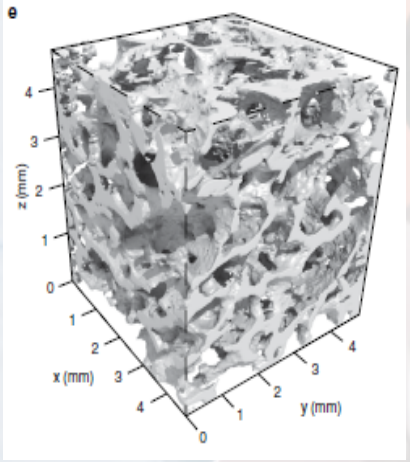
Requested Specification: ~40J, <30fs, 1 Shot / 5 min

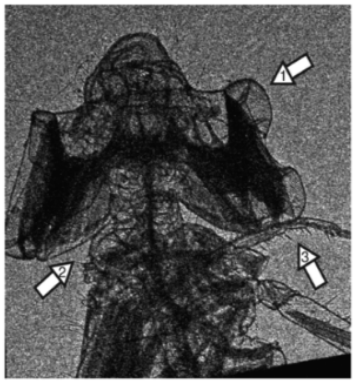
Look to provide enhanced long pulse capability (~1kJ 1ns)

New imaging capabilities

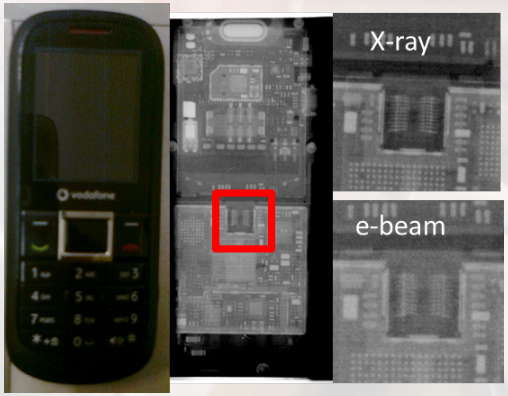
Complimentary beamline with the space in TAP will enable the development novel imaging capabilities for applications and science

Betatron/ X-ray Imaging

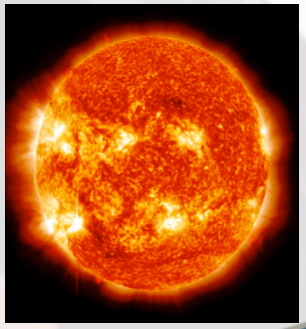


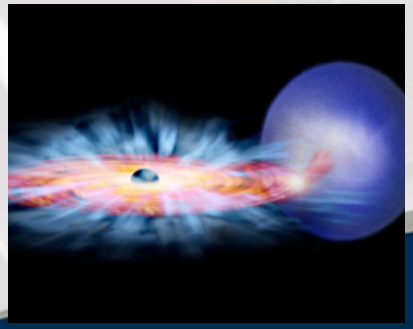


E-beam imaging



Imaging laser driven shocks “on-the fly”





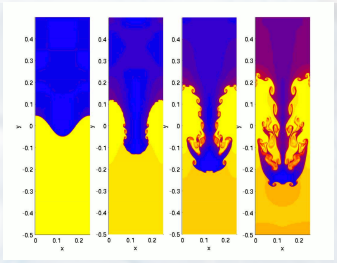
UK Research and Innovation

Science & Technology Facilities Council

Multi-beam capabilities

Combinations of complimentary beamline, existing PW and additional Long pulse will enable pump-probe experiments to reveal dynamics of extreme states of matter

Study of instabilities

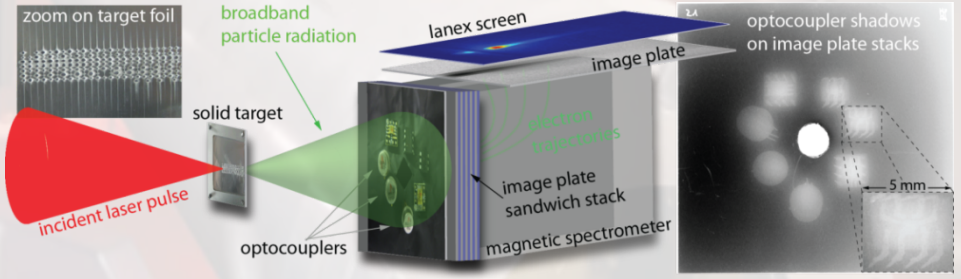


Kelvin-Helmholtz >

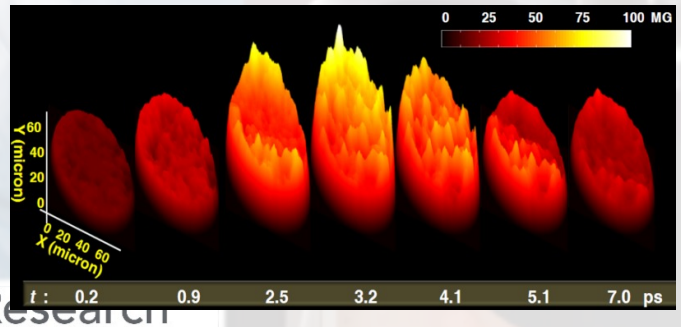
< Rayleigh-Taylor

Experiments combining e^- and p^+:

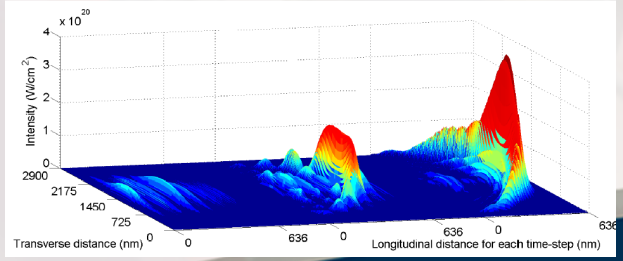
Radiation Hardness Testing
Space Radiation Reproduction



Temporal evolution of the B-field inside the laser spot



Raman Amplification



UK Research and Innovation

Science & Technology Facilities Council

Laser Technology

TiSa forces wavelength to 800nm, require more space (multipass) and development (transverse lasering mitigation)

OPCPA more flexible on wavelength and requires less space.

800nm Bandwidth 100nm case

Crystals	Centre Wavelength (nm)	Bandwidth (nm)	Output Energy (J)
DKDP 95%	838	66	26
LBO	806	102	58
DKDP 95%	920	177	40
LBO	877	224	58
Ti:S (Gemini)	800	40	15 (on target)

Optimal Spectral region for LBO

Preferred Option: OPCPA with LBO

Laser Specification

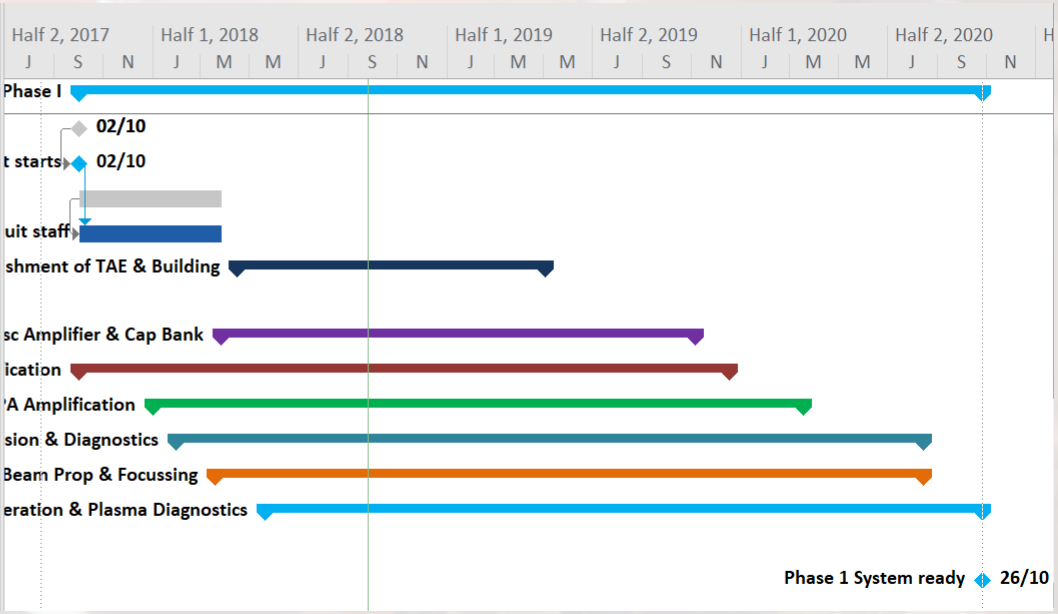
Project Split in 3 Phases to provide new capability to TAP quickly

	Phase I	Phase IIa	Phase IIb
Pulse Length	<30 fs		
Spectral Bandwidth	768 nm – 973 nm		
Final Beam Size	200 mm		
Final Beam Shape	Round	Round	Square
Energy on Target	~7 J	~30 J	~40 J
Rep. Rate	5 min	20 min	5 min

Project Plan

Internally Funded

Task Name	Finish
TAP Beamline Phase I	**Mon 26/10/20**
Project starts	Mon 02/10/17
Project starts	Mon 02/10/17
Recruit staff	Mon 26/03/18
Recruit staff	Mon 26/03/18
WP1 PhI Refurbishment of TAE & Building	**Thu 02/05/19**
WP2 PhI Disc Amplifier & Cap Bank	**Tue 05/11/19**
WP3 PhI Relocation and modification	**Tue 17/12/19**
WP4 PhI OPCPA Amplification	**Wed 18/03/20**
WP5 PhI Compression & Diagnostics	**Fri 14/08/20**
WP6 PhI Beam Prop & Focussing	**Fri 14/08/20**
WP7 PhI Source Generation & Plasma Diagnostics	**Mon 26/10/20**
Phase 1 System ready	**Mon 26/10/20**



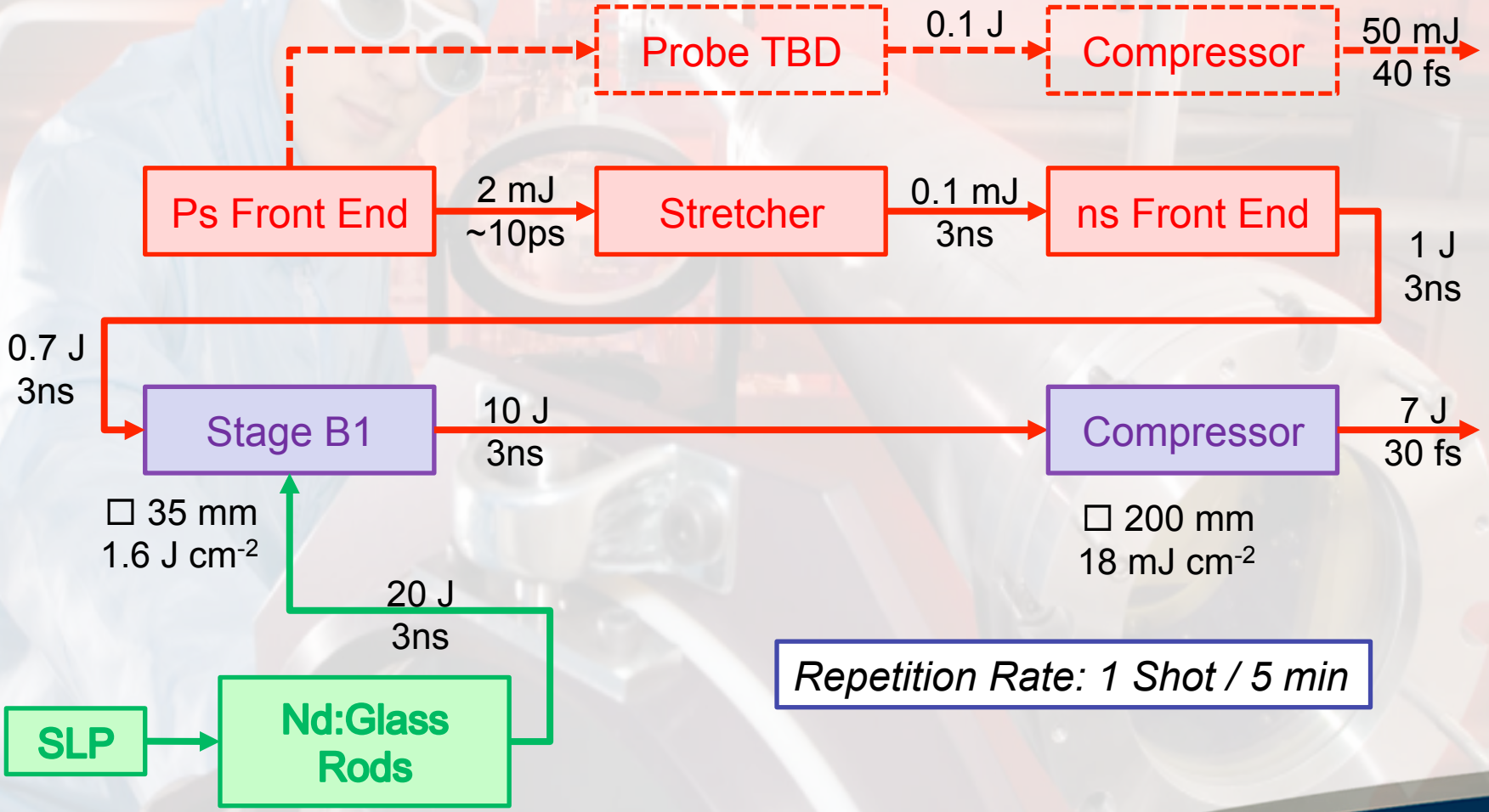
Phase I expected to be completed at the end of 2020

UK Research and Innovation

Science & Technology Facilities Council

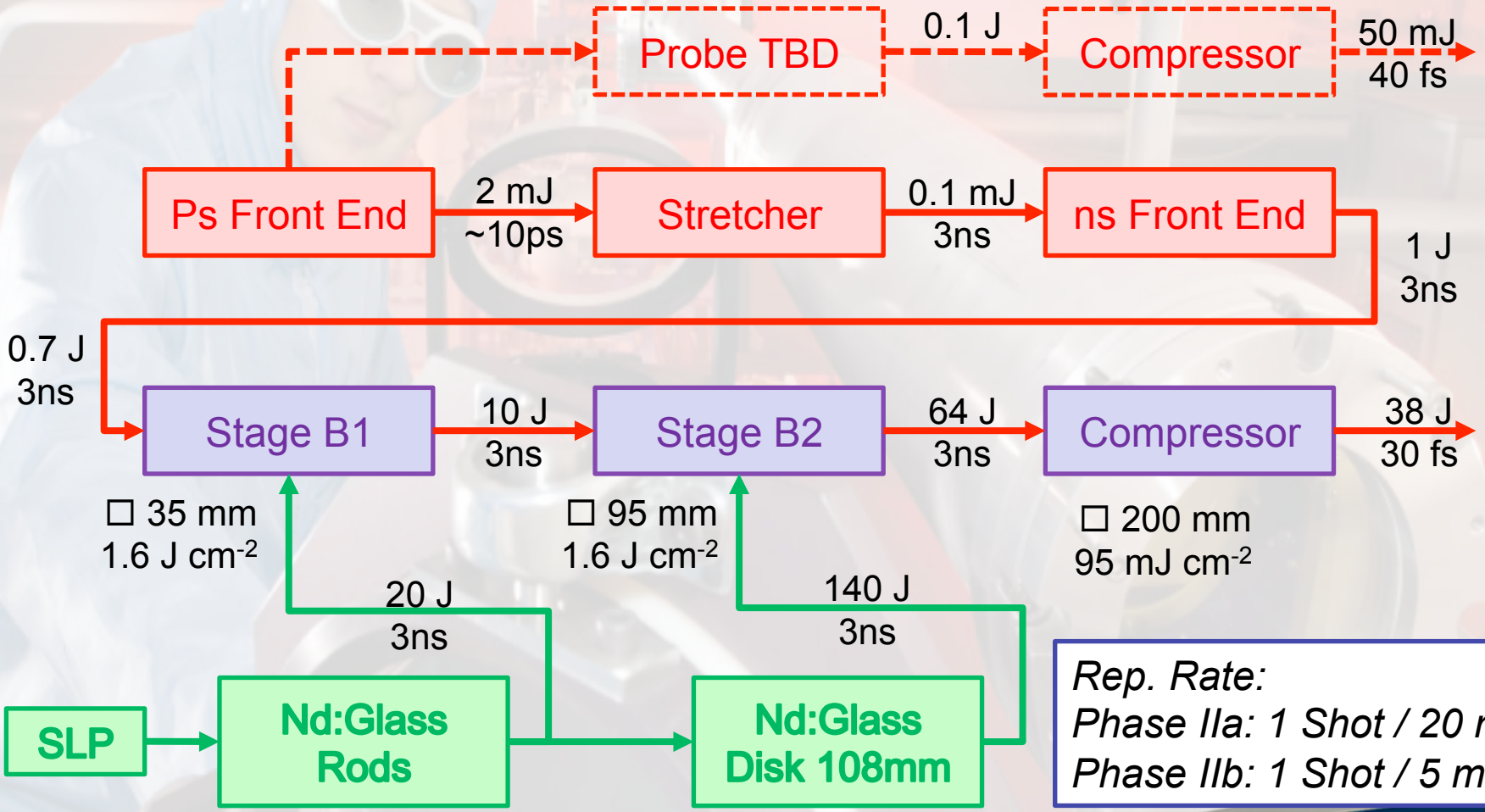
LASER DESIGN

Beamline Layout – Phase I



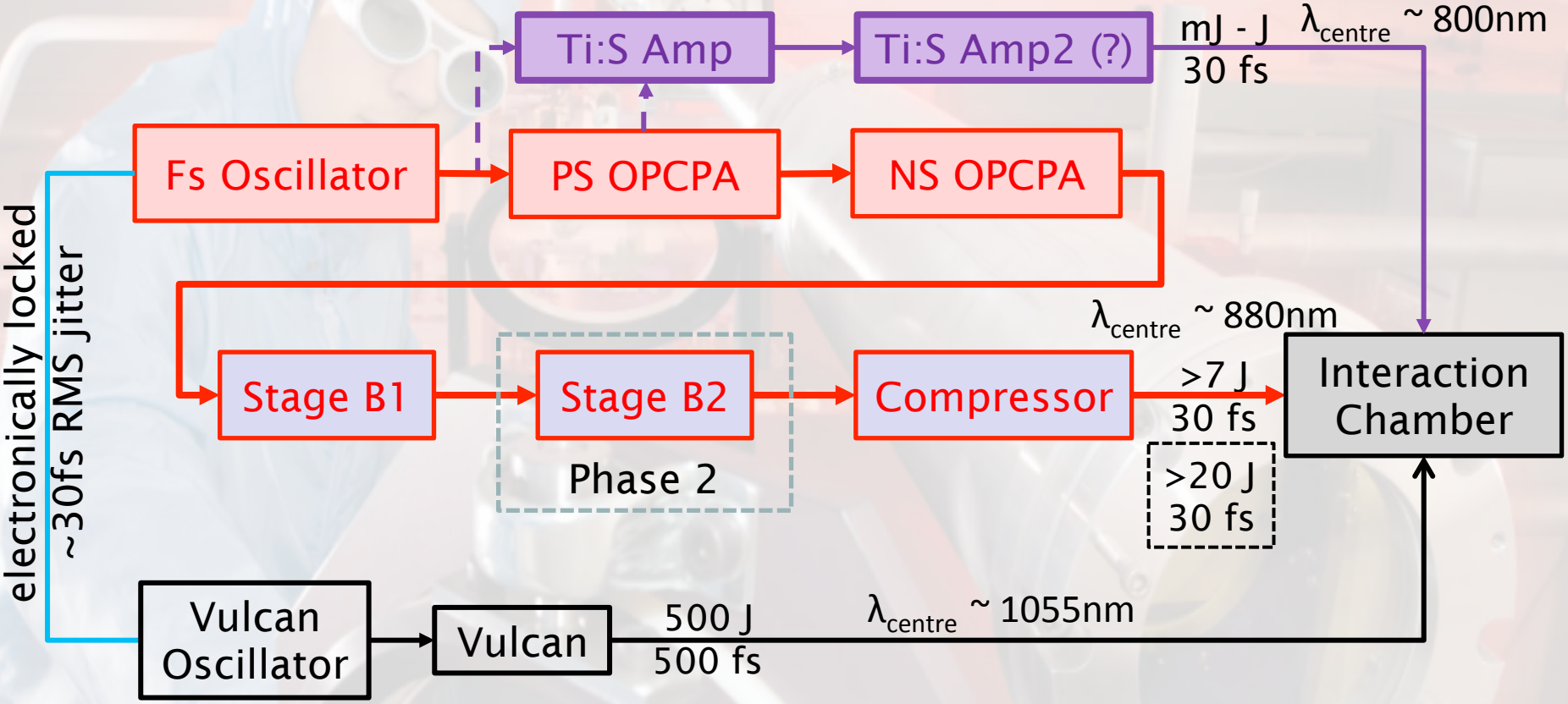
Repetition Rate: 1 Shot / 5 min

Beamline Layout – Phase II



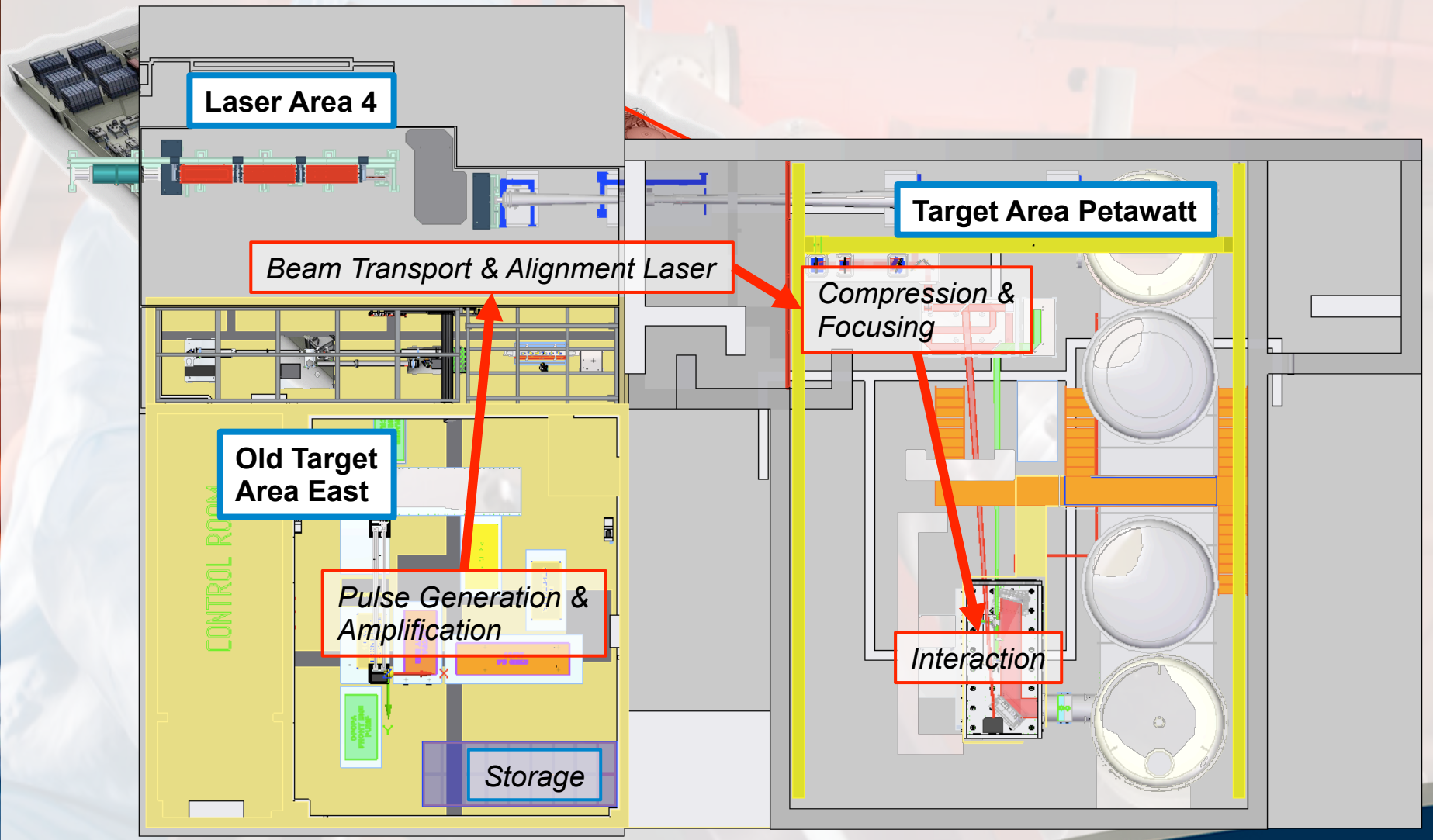
Rep. Rate:
Phase IIa: 1 Shot / 20 min
Phase IIb: 1 Shot / 5 min

Probe and Synchronisation

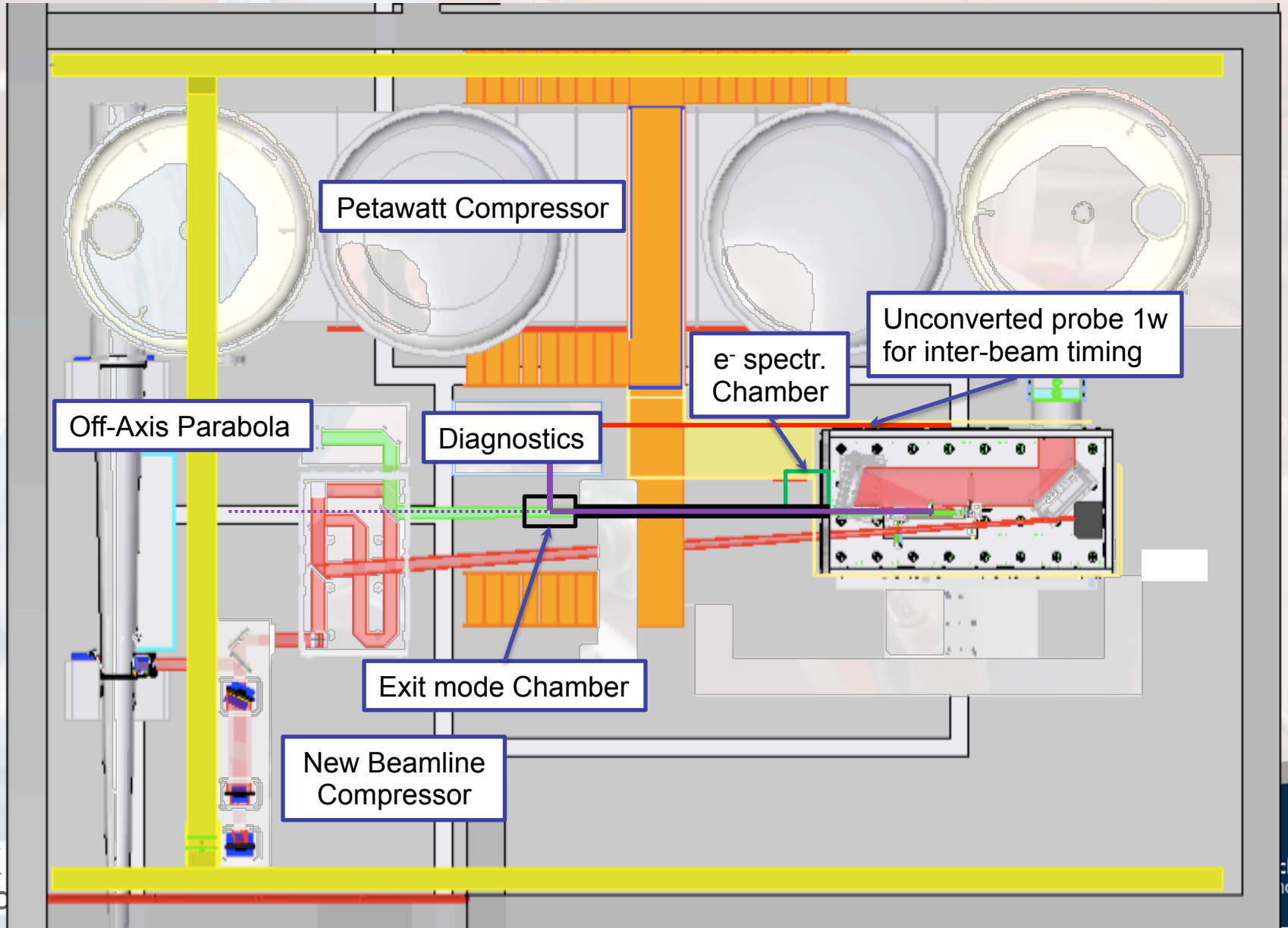


Seed for probe taken from either seed for new beamline or out of the ps OPCPA
Beam path lengths are likely require stabilisation

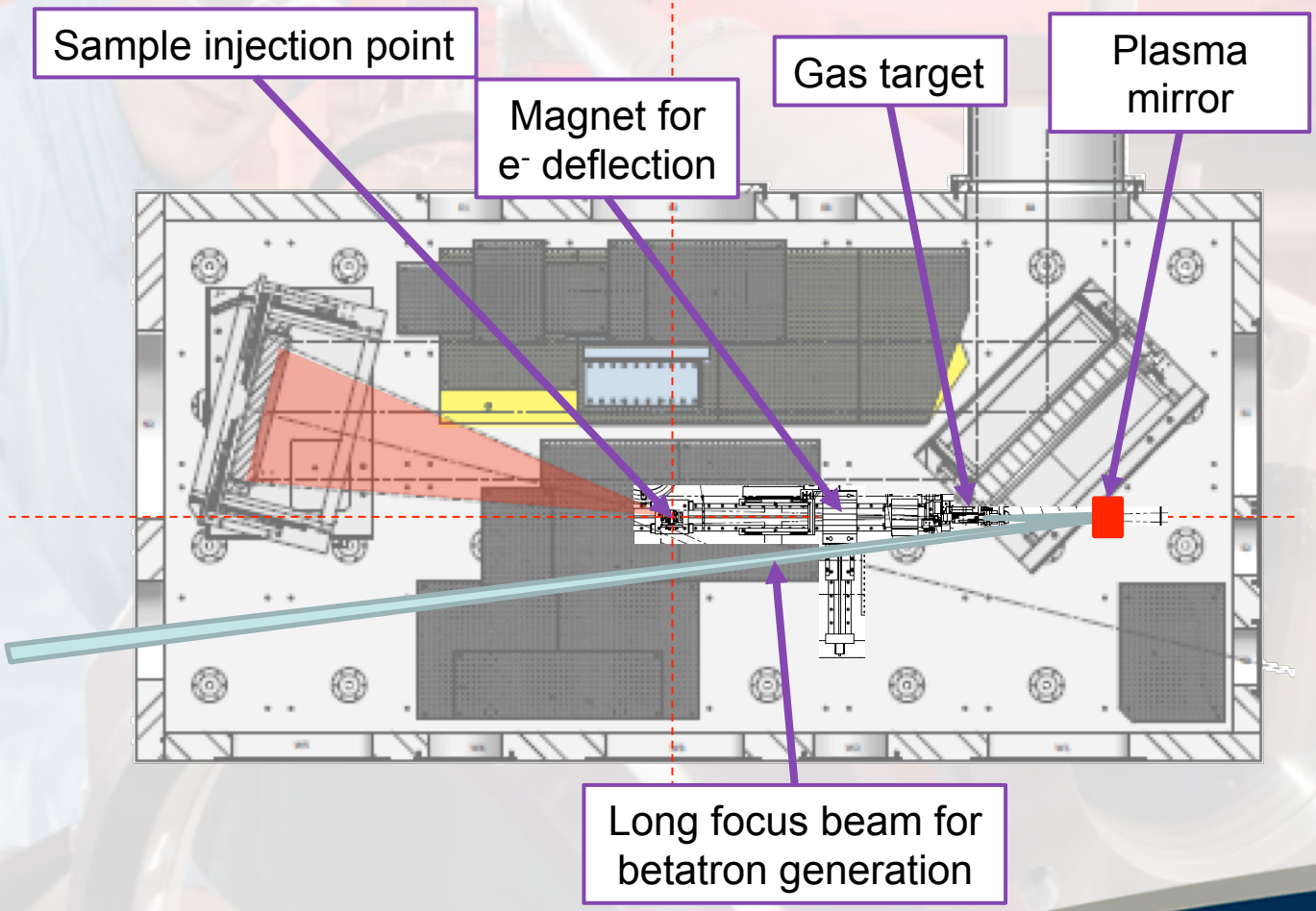
Basic Layout



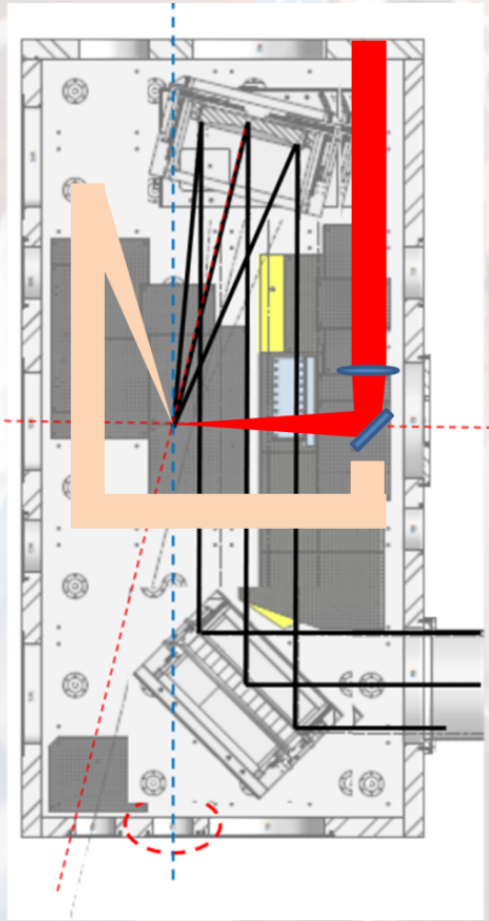
TAP New Layout



Betatron Imaging Setup



Future Long Pulse Options



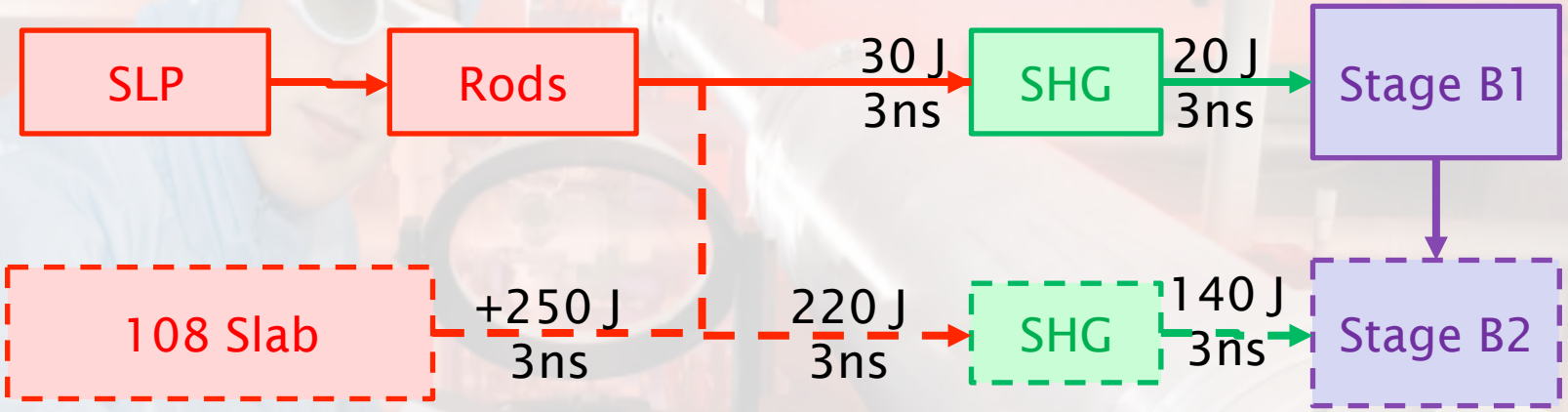
Currently have single LP 108 beam into TAP (250J 0.5-8ns).

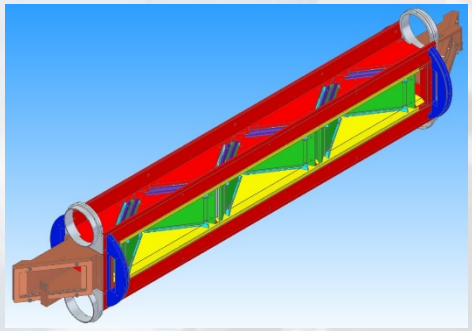
Planned to use the 208 Disk amplifier to deliver up to 1kJ

This will allows to study long pulse interaction using the new TAP beamline

LARGE OPCPA STAGES

Pump Laser





A multi-pass slab amplifier will be used to increase pump energy to +250J in the IR

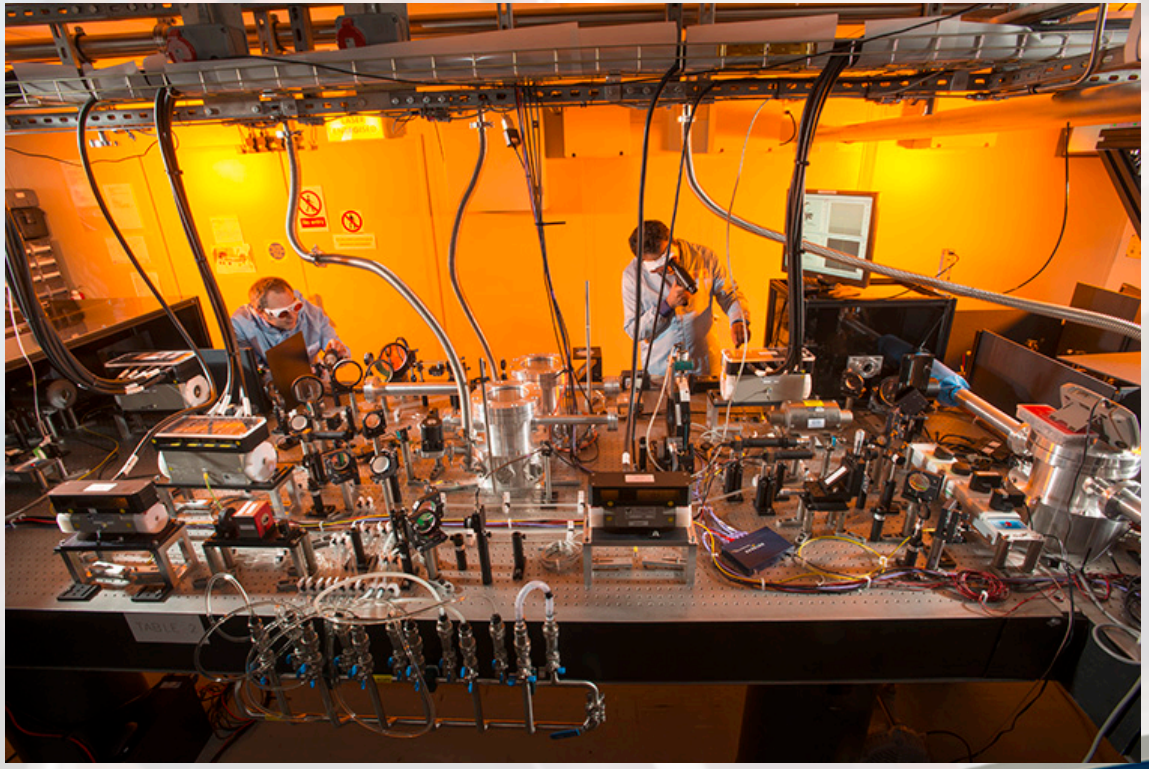
Air-cooled design is under development to increase rep. rate to 5min

Pump Laser

The rod chain has been commissioned

Output energy will be increased from 30J in the IR to ~50J

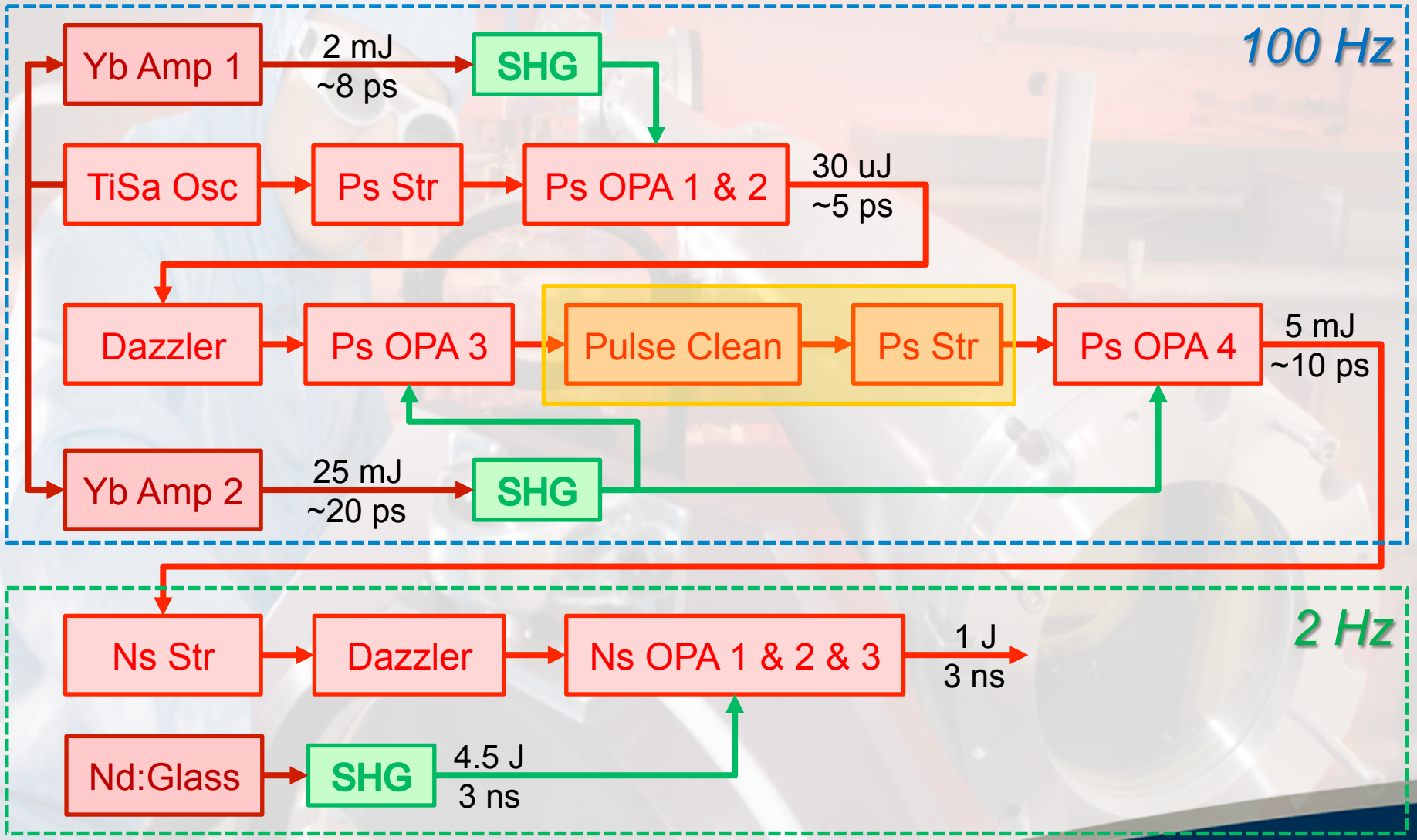
Work to increase conversion efficiency to 2ω



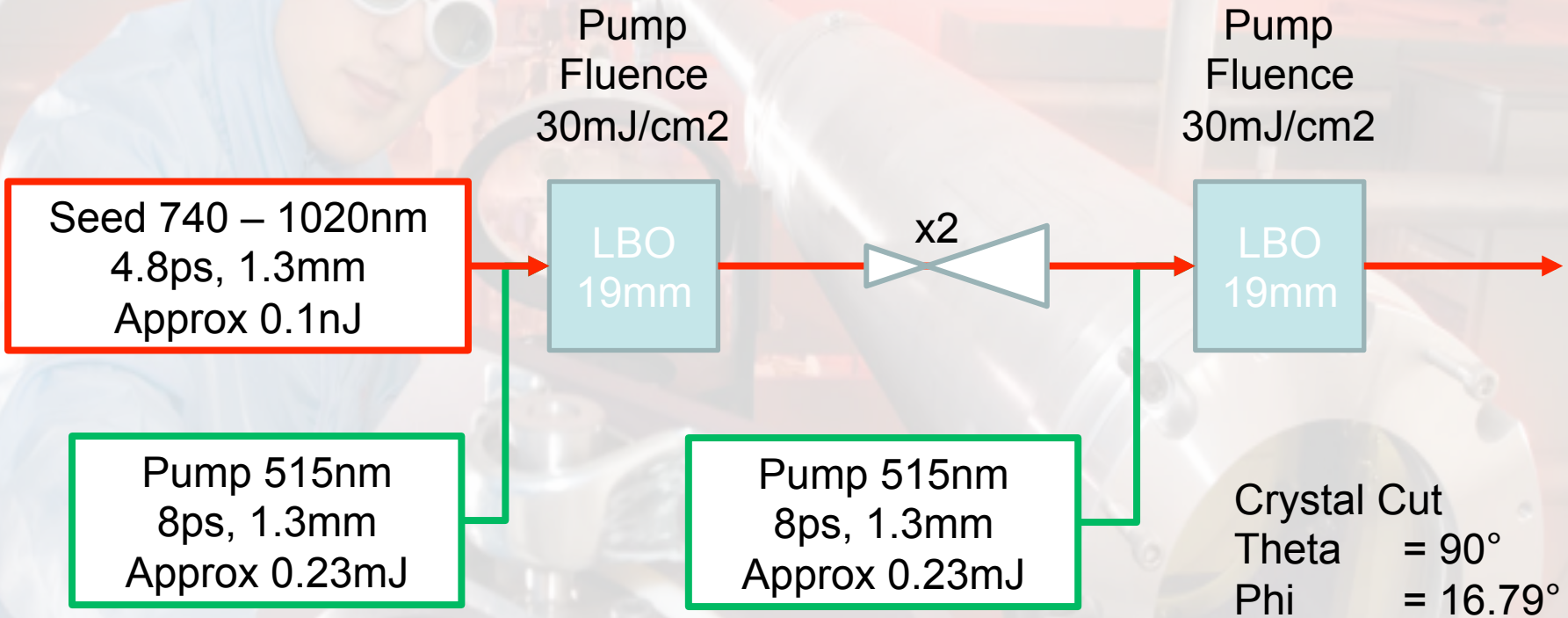
Giedre Archipovaite, Mario Galletti, Pedro Oliveira

FRONT END

Front End Schematic

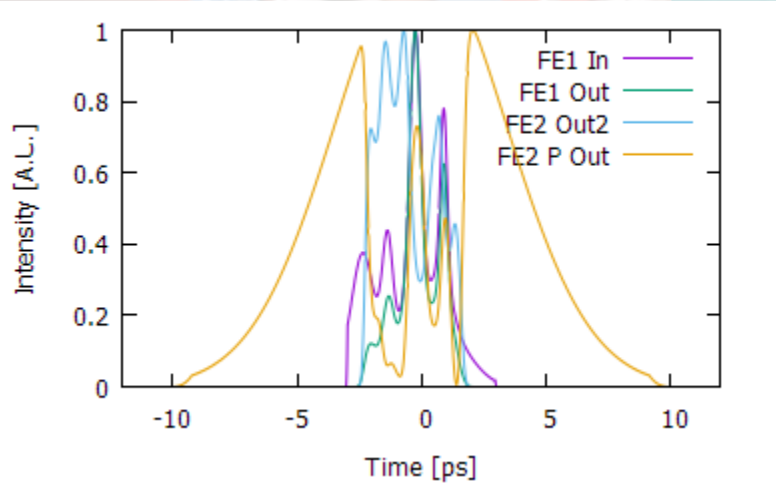


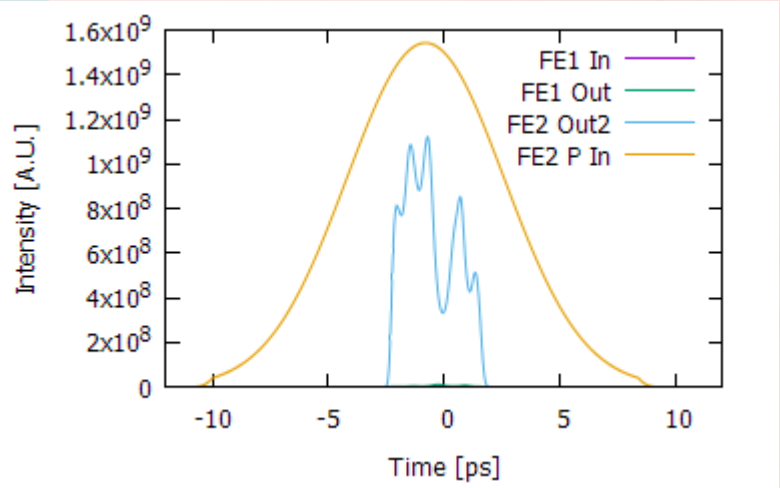
Ps OPA 1 & 2 Simulation

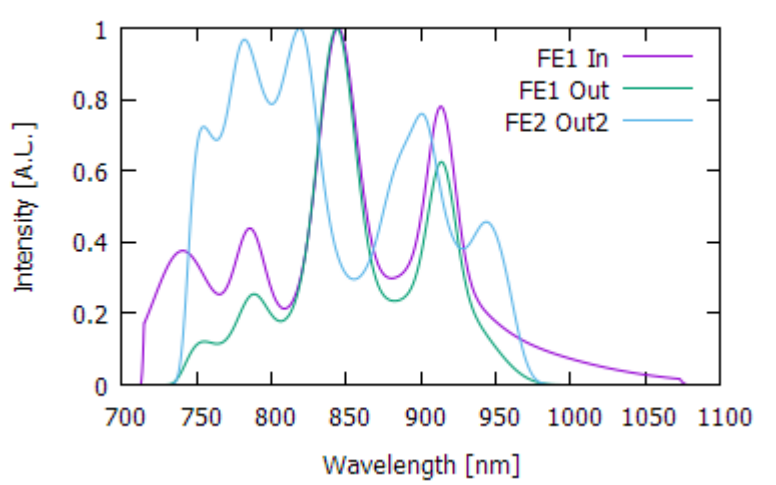


Crystal Cut
Theta = 90°
Phi = 16.79°
ThetaP = 1.56°

1D Simulation Result







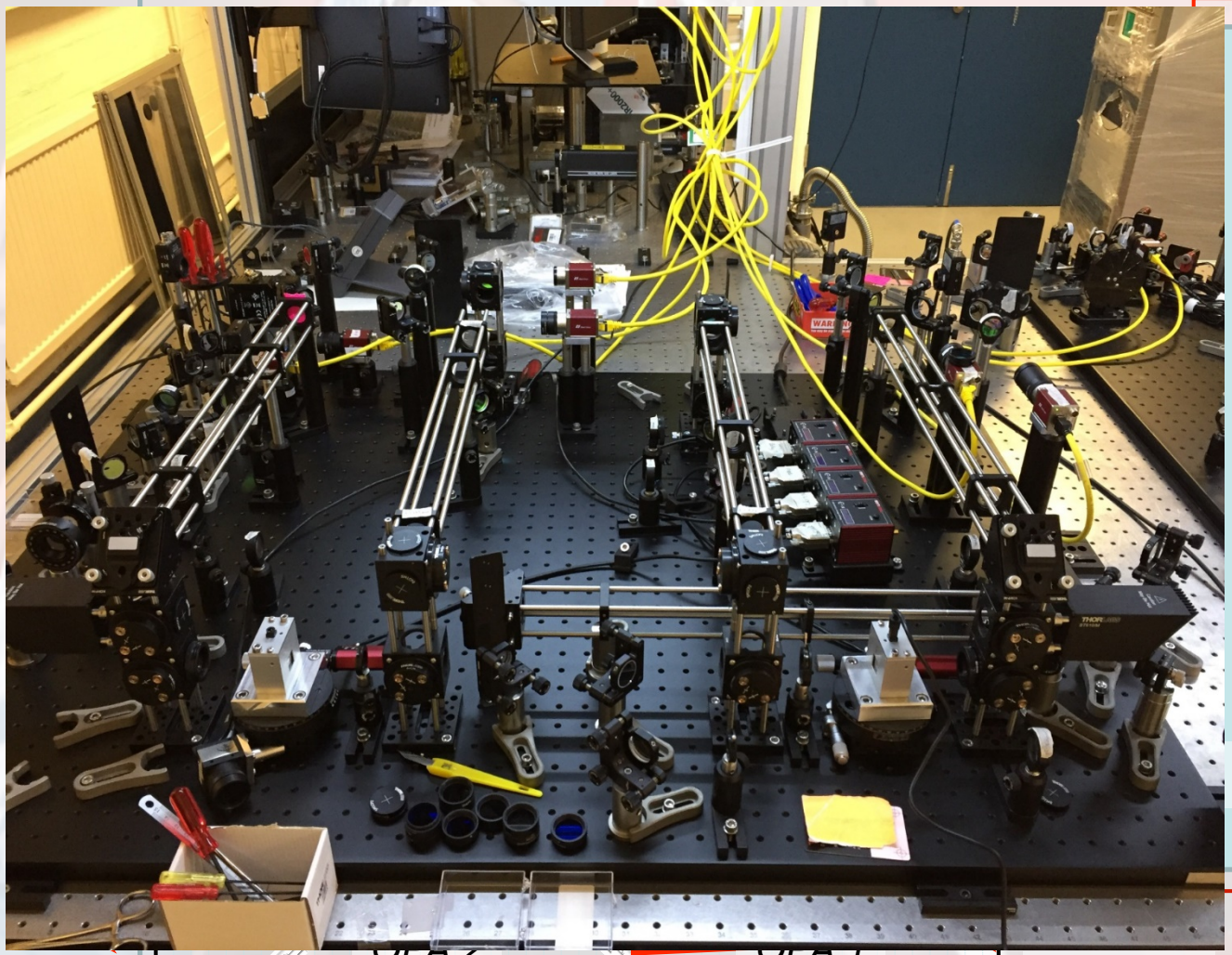
Pump:

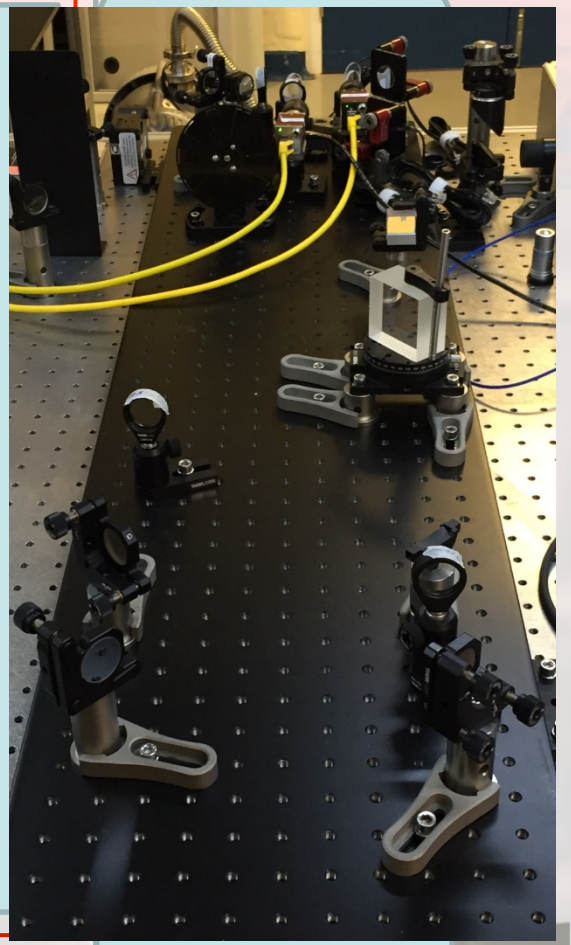
- Size 1.3mm
- Duration 8ps
- Energy 0.23mJ

Signal:

- Size 1.3mm
- Duration ~4.8ps
- Energy In 0.1nJ
- Energy Out 47uJ

Ps OPCPA 12 Layout

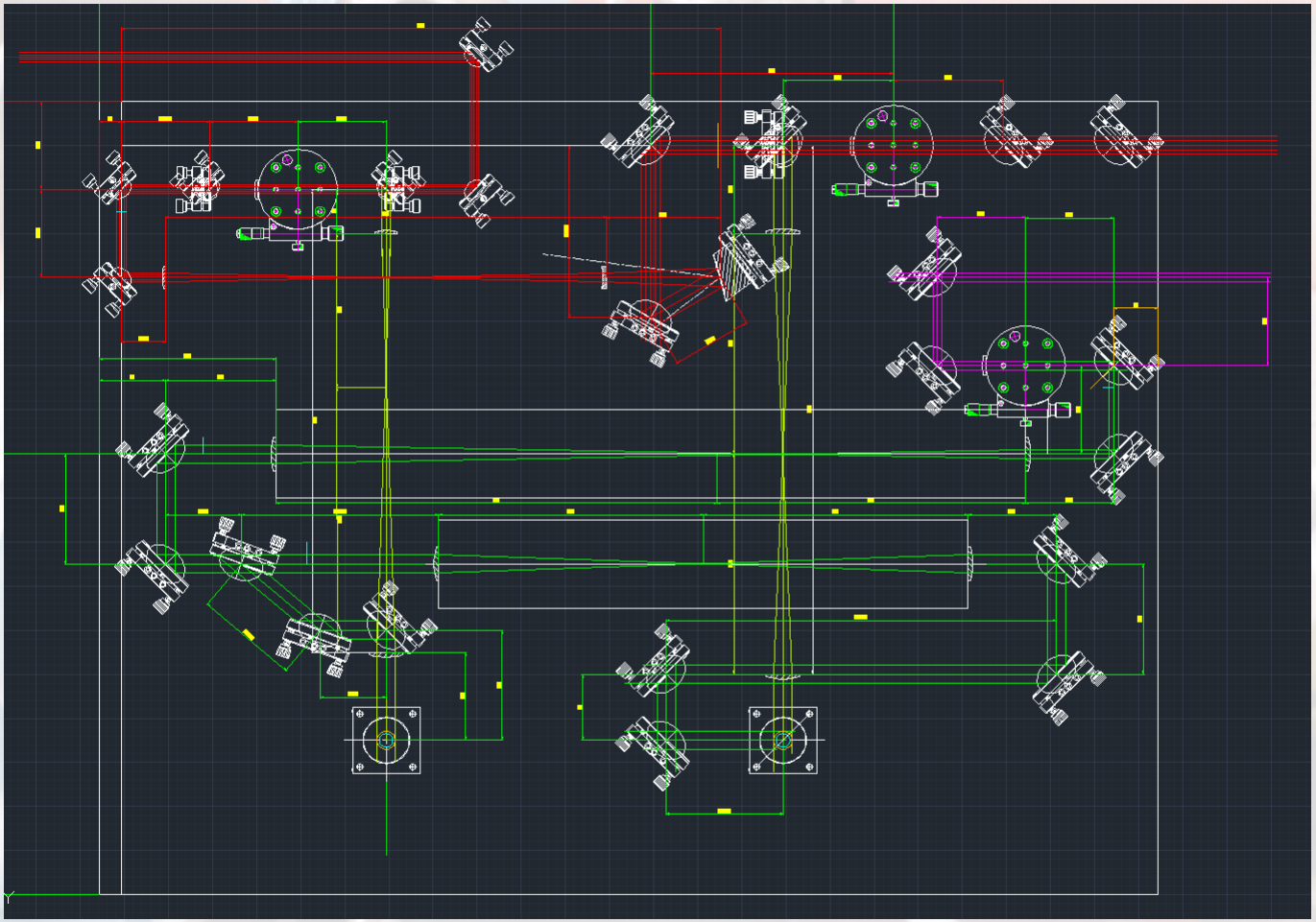




OPA 2 OPA 1

Signal In

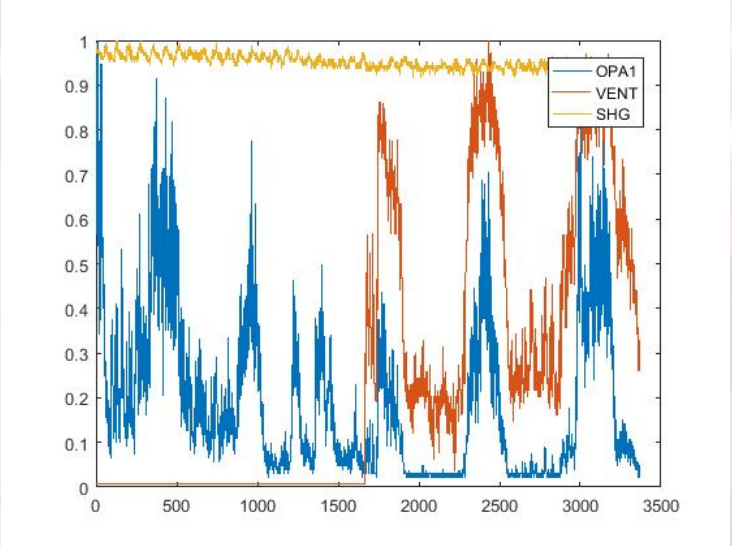
Ps OPCPA 34 Layout



Pump laser is coming

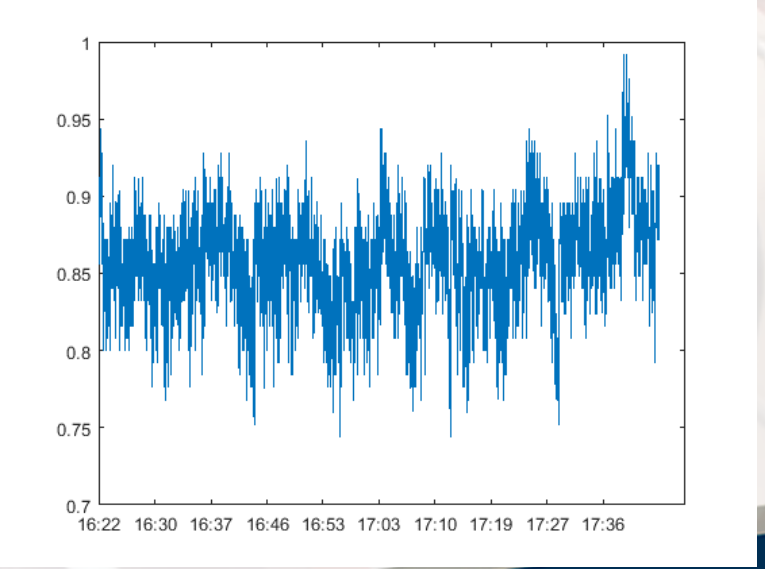
Require Vacuum Telescope for Pump Beams

Ps OPCPA 12 Stability



Output signal was not stable over timescale of few minutes

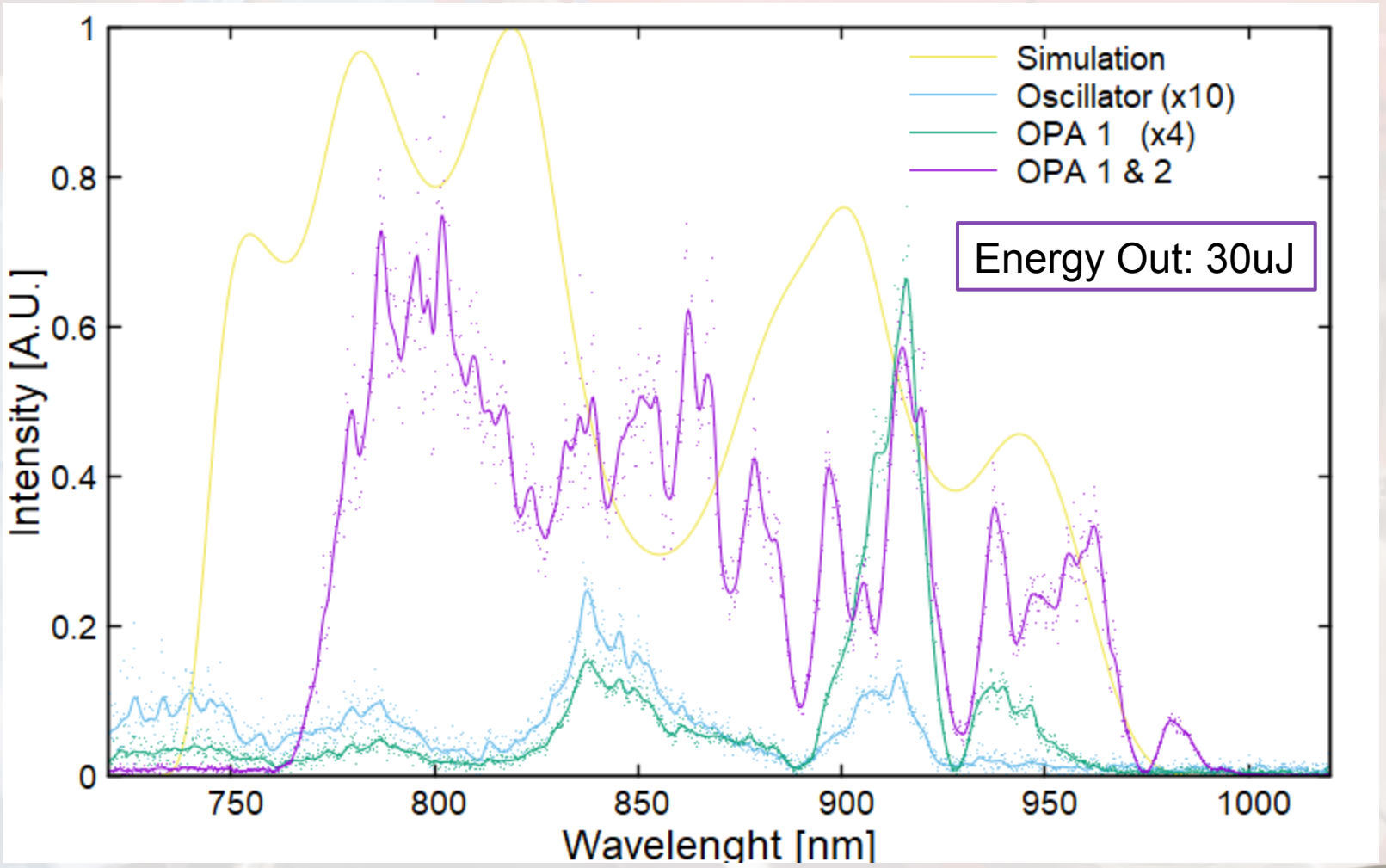
Investigation identified a timing shift between pump and seed



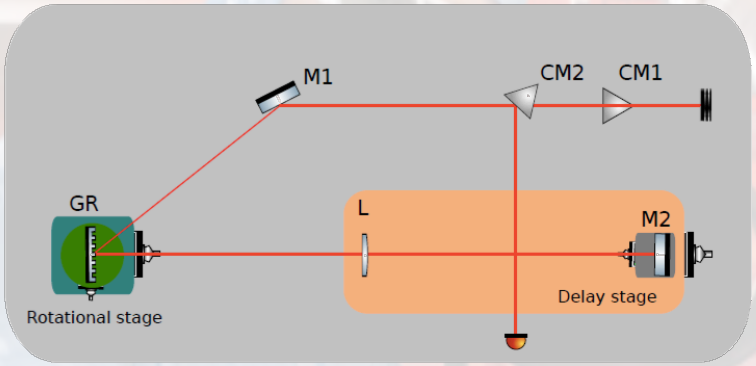
"Crude" automatic timing was implemented

Proper automatic timing system is on order

Ps OPCPA 1&2 Output



Test Compression

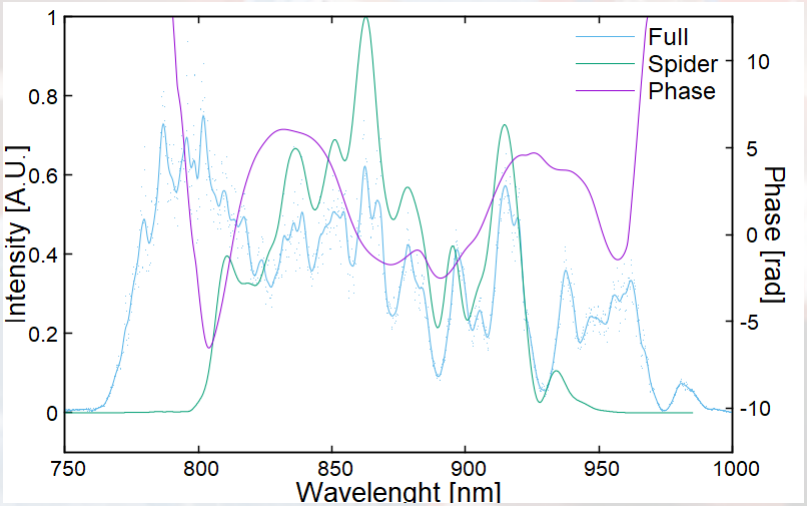


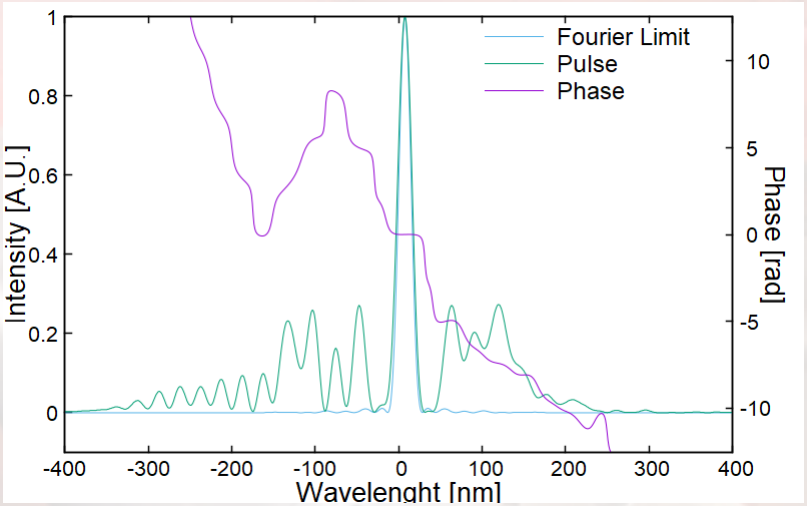
Simple Test Compressor Using off-shelf achromatic lens and grating

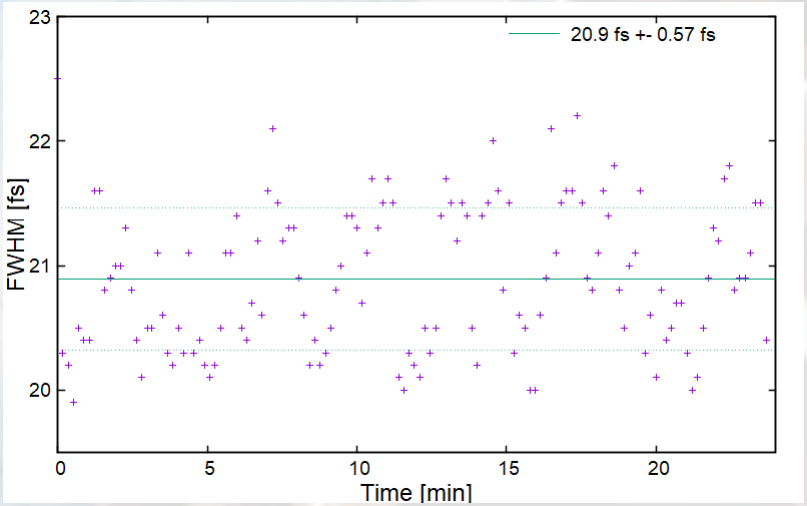
Use of the DAZZLER to control spectral phase not possible

Pulse measured using SPIDER from Gemini laser system, unable to handle full bandwidth

Compression Results







Compressed down to 19.4fs (20.9fs Avg)

Only used ~120nm bandwidth

Pulse length stable over 20min

UK Research and Innovation

Science & Technology Facilities Council

Conclusion

Imaging Capability is Required on the Target Area Petawatt at Vulcan Facility

Proposed New Beamline of ~40J <30fs, 1 Shot / 5 min

Full OPCPA Based Laser System

New ps OPCPA Under Development

Beamline is Planned to be Delivered in 2020 (Phase I)