Basic science connections between OMEGA / OMEGA EP and HIPER risk reduction

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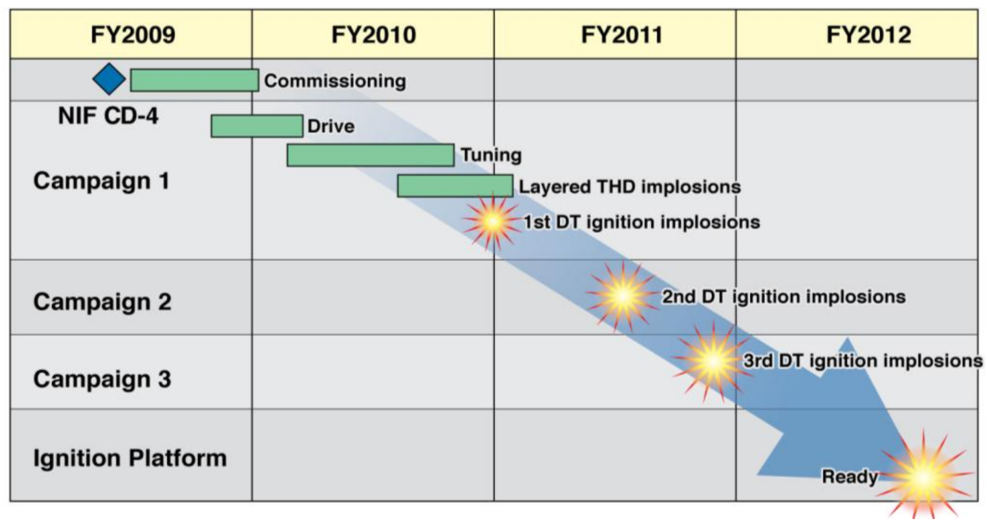
The fusion era is dawning …

- Demonstration of net energy production from laser fusion predicted within ~ **3 years** on the US National Ignition Facility
- **This is a fundamental step-change in our field**
- **Clear implications for our science and energy programmes**
- **A strategic way forward in Europe is now established**



HiPER European Consortium

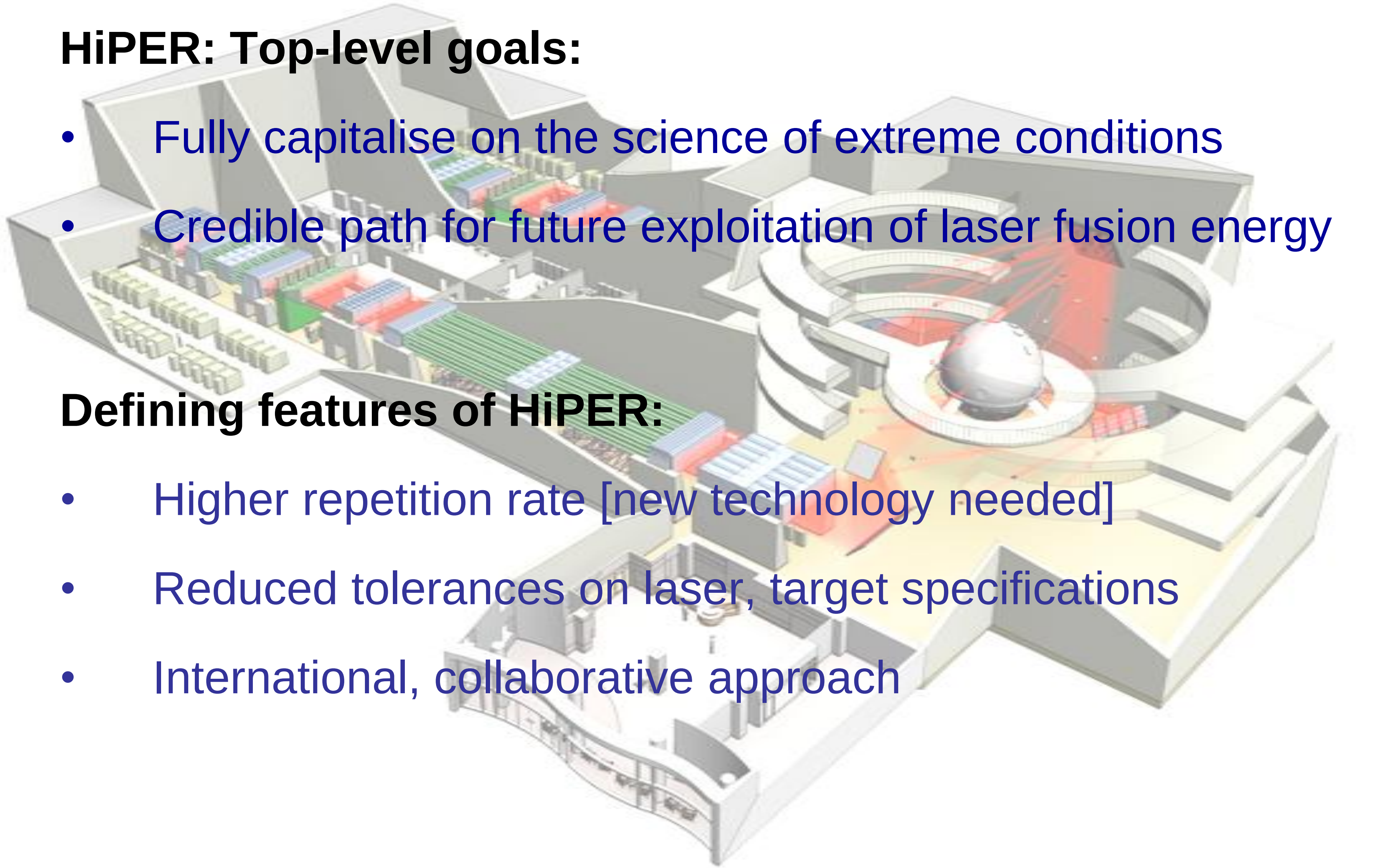
Funding Agency involvement by 9 partners

- STFC (UK)
- CEA, CNRS and CRA (France)
- MSMT (Czech Republic)
- GSRT (Greece)
- MEC and CAM (through UPM) (Spain)
- ENEA and CNR (Italy)

Institutional involvement by 17 other partners

- IST Lisbon (Portugal)
- CNSIM (Italy)
- TEI, TUC (Greece)
- IOP-PALS (Czech Republic)
- IPPLM (Poland)
- FVB, FSU Jena, GSI, TUD (Germany)
- Lebedev Physical Institute, Institute of Applied Physics-RAS (Russia)
- Imperial College London, Universities of York, Oxford, Strathclyde, Queens Belfast (UK)

Next step (after fusion ignition)



HiPER: Top-level goals:

- Fully capitalise on the science of extreme conditions
- Credible path for future exploitation of laser fusion energy

Defining features of HiPER:

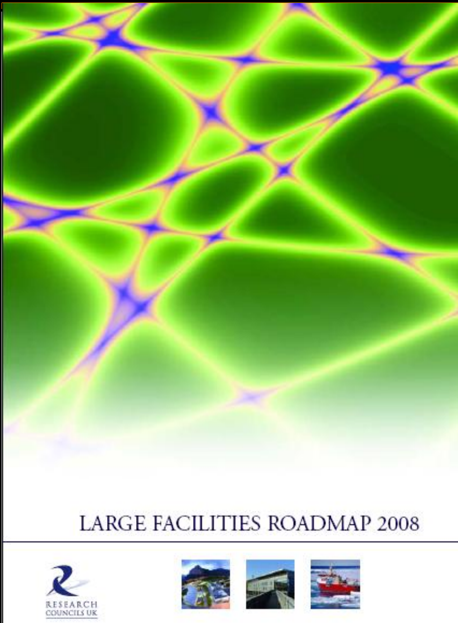
- Higher repetition rate [new technology needed]
- Reduced tolerances on laser, target specifications
- International, collaborative approach

HiPER

Signing Ceremony

Timeline for HiPER

- **2-year conceptual design phase (2005,6)**
- **Included on European roadmap (Oct 06)**
- **UK endorsement – coordinators (Jan 07)**
- **Preparatory Phase Project (2008 – 2011)**
- **Demonstrator and Definition (2011-2015?)**
  - ***PETAL, DPSSL and facility design***
- **Construction phase (2015 – 2020?)**



Expect the unexpected

Three examples:

Energy conversion efficiency experiment
double heating pulse observed

Fast electron transport in warm compressed plasma
range in Cl-doped foams reduced with increasing density

Channelling in underdense plasma with 30 ps relativistic laser pulses
0.1 n_c channels observed over 2mm distance

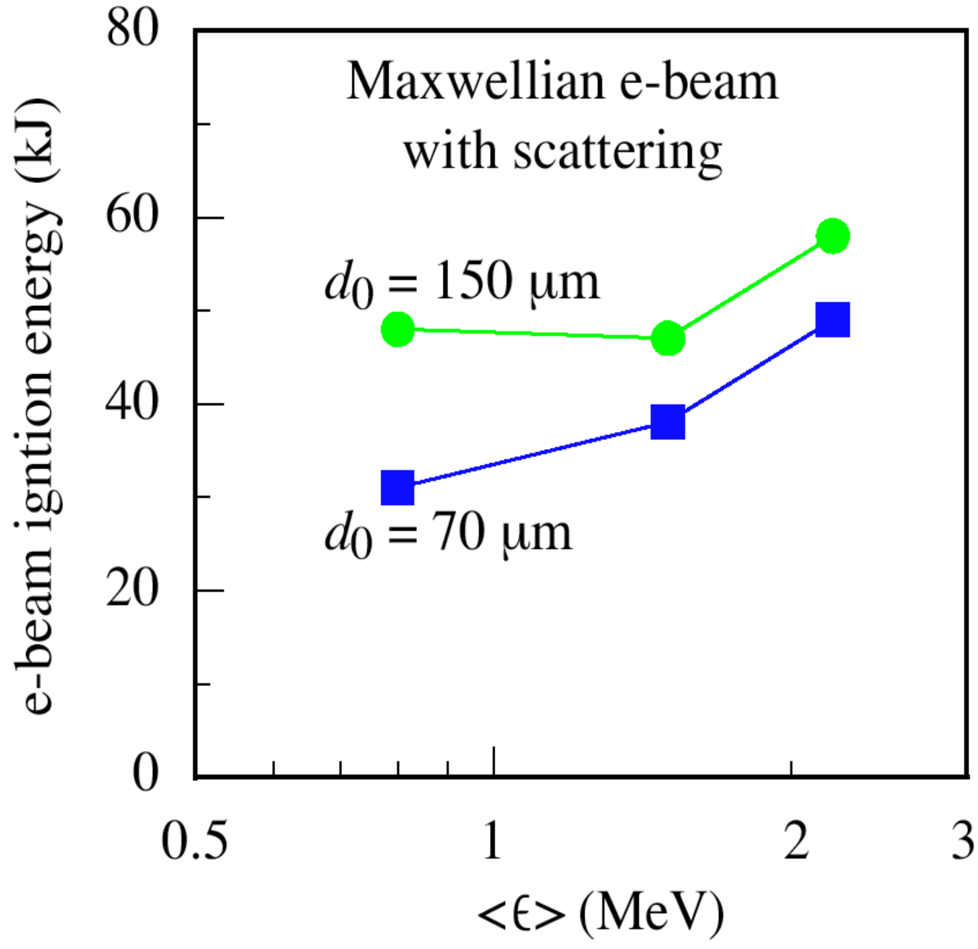
Please bear in mind some of the data in this presentation is PRELIMINARY and HOT OFF THE PRESS!

More detailed analysis is now underway.

Baseline target requirements

New calculations of electron beam ignition energy that include more accurate stopping powers for HiPER baseline target design

Puts stringent requirement on both the conversion efficiency to electrons and mean energy



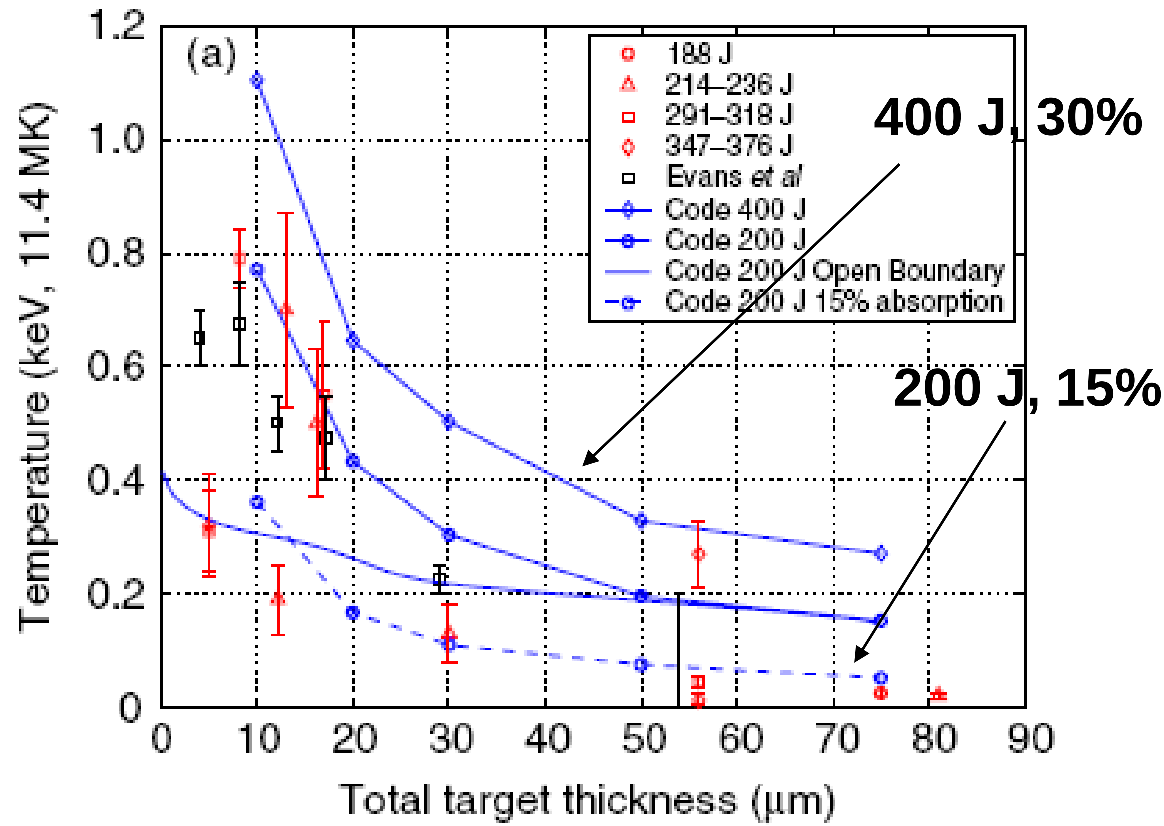
Courtesy of Stefano Atzeni

Absorption and mean energy

•Quantitative agreement of Vulcan PW rear surface temperature measurements with modelling

• Refluxing is important to explain the two temperature slope to the measurements.

• The energy going into the forward going fast electron beam is bounded between 15% at 200 J and 30% at 400 J on target.



• **Hybrid code simulations were performed by Jonathan Davies**

M. Nakatsutsumi et al., New J. Physics 10, 043046 (2008)

Experimental Setup

Laser

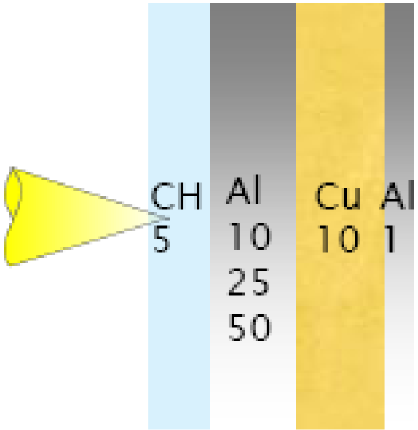
- LULI 2000 at the Ecole Polytechnique, Paris
- Central wavelength 1057nm
- Focusing parabola f/4
- 50 J in 800 fs focused to ≈12 μm
- $I\lambda^2 = 2.3\times10^{19}$ $Wcm^{-2}\mu m^2$

ASE width (ns)	Contrast Ratio
0.8	2.50×10^{-6}
1.4	3.40×10^{-6}
3.5	2.30×10^{-6}

Pre-Pulse Characteristics

Instrumentation

- HISAC (rear surface thermal emission, 22.5° off laser axis)
- Aluminium & Copper K-α (2D and spectrometer)
- Streaked spectrometer (3rd & 4th harmonic on front surface)
- Interferometry
- Optical Transition Radiation with Gated Optical Imager



Target Design

Next experiments

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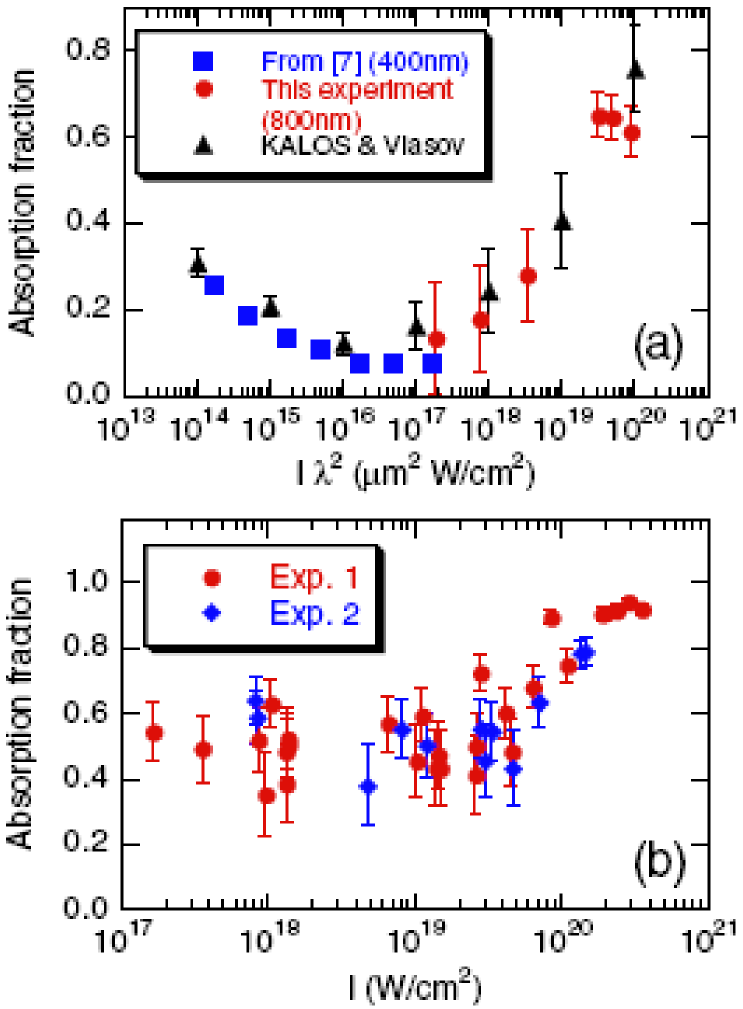
- Absorption measurements using 150 fs laser pulses at LLNL. Excellent agreement over 6 orders of magnitude with modelling

- Is there a transport barrier preventing entry of fast electrons?

- Can it be controlled / removed?

- What happens to transport at higher energies on OMEGA EP ?



6°

45°

See Y. Ping et al., Phys. Rev. Lett. 100, 085004 (2008)

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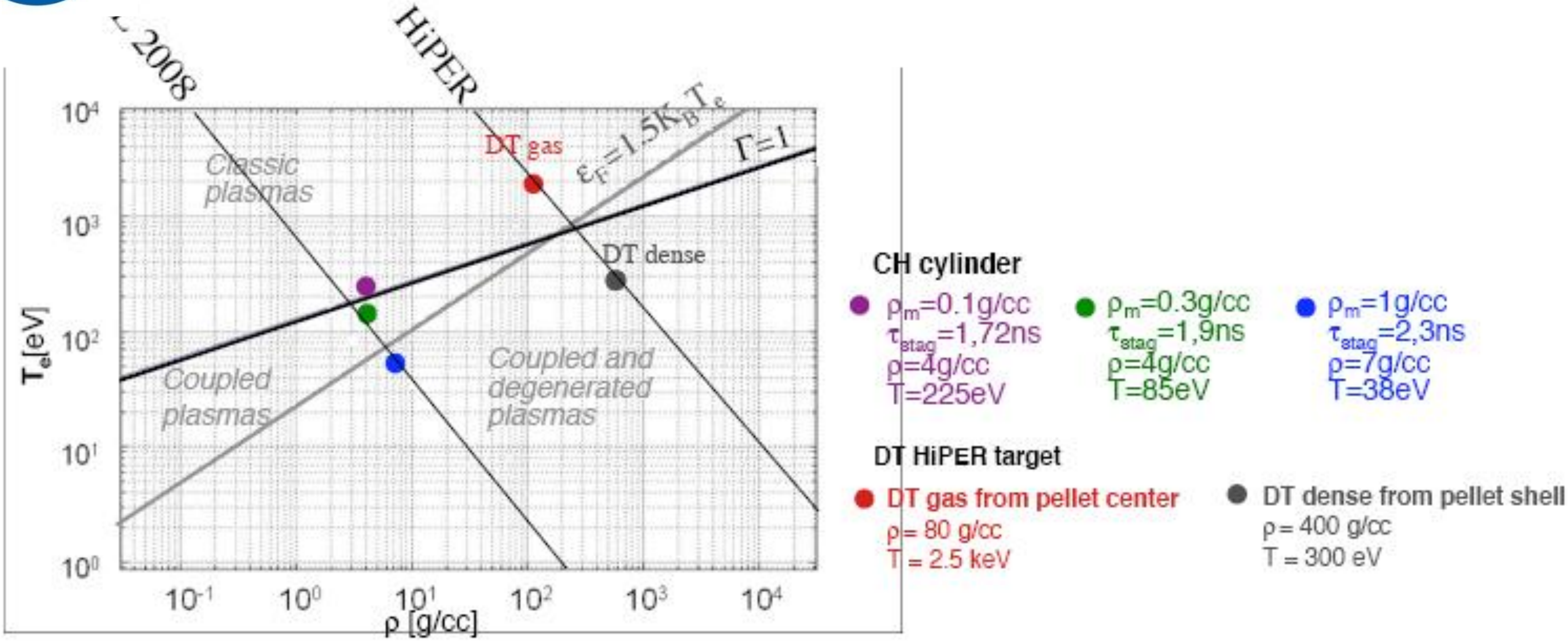
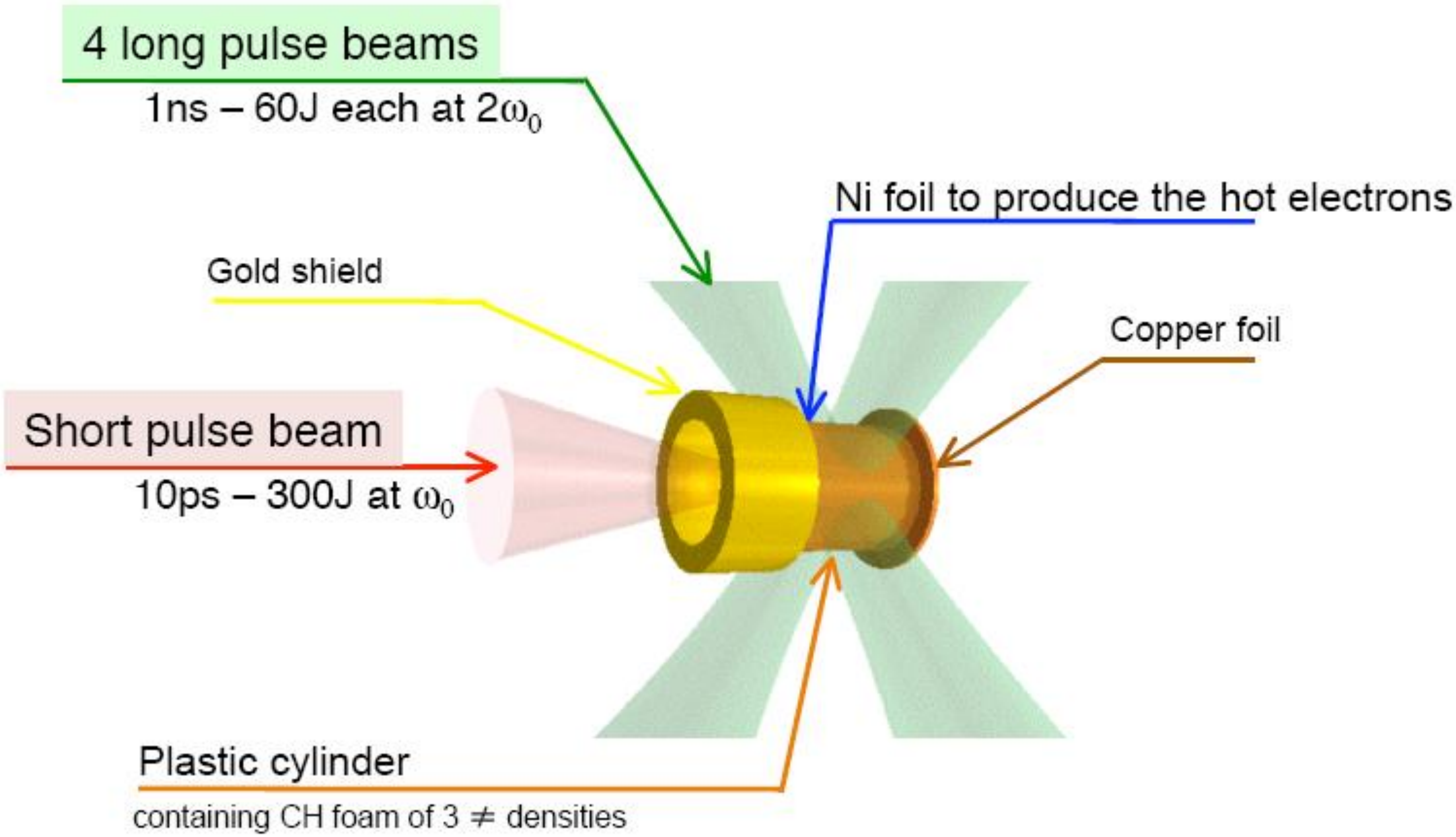
Transport of energy in warm matter



HiPER collaboration used the recently upgraded Vulcan laser for this study

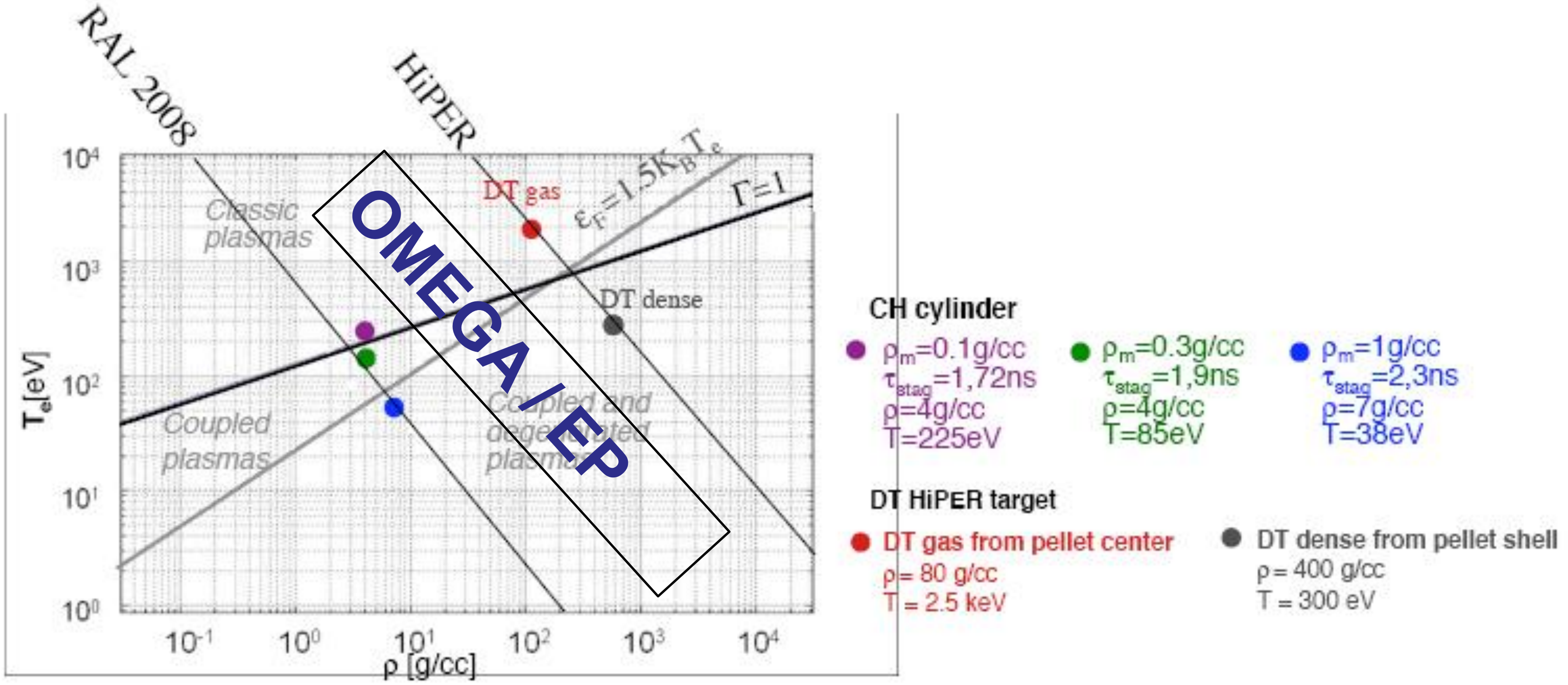
Ecole Polytechnique, the Universita di Milano-Bicocca, CELIA, RAL,Universita di Bologna, IPCF/CNR of Pisa, Universita di Roma Tor Vergata, University of York, University of California, San Diego, Lawrence Livermore National Laboratory and Universidad Politecnica de Madrid

Experiment design



Transport of energy in warm matter

Imperial College London



HiPER collaboration propose to extend these observations to OMEGA / OMEGA EP

Ecole Polytechnique, the Universita di Milano-Bicocca, CELIA, RAL,Universita di Bologna, IPCF/CNR of Pisa, Universita di Roma Tor Vergata, University of York, University of California, San Diego, Lawrence Livermore National Laboratory and Universidad Politecnica de Madrid

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Channel formation in fast ignition

Hole-boring is an alternative to cone-shell geometry

Easier to implement (target fabrication) for inertial fusion energy

No debris issues

HiPER team decided to investigate whether this approach was feasible

1. STFC Rutherford Appleton Laboratory, Didcot, UK
2. Blackett Laboratory, Imperial College London, UK
3. School of Mathematics and Physics, Queens University Belfast, UK
4. Lawrence Livermore National Laboratory, Livermore, CA, USA
5. Technological Educational Institute of Crete, Greece
6. GoLP, Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Lisbon, Portugal
7. Graduate School of Engineering, Osaka University, Osaka 565-0871, Japan
8. ETSI Industriales, Universidad Politécnica de Madrid, Spain

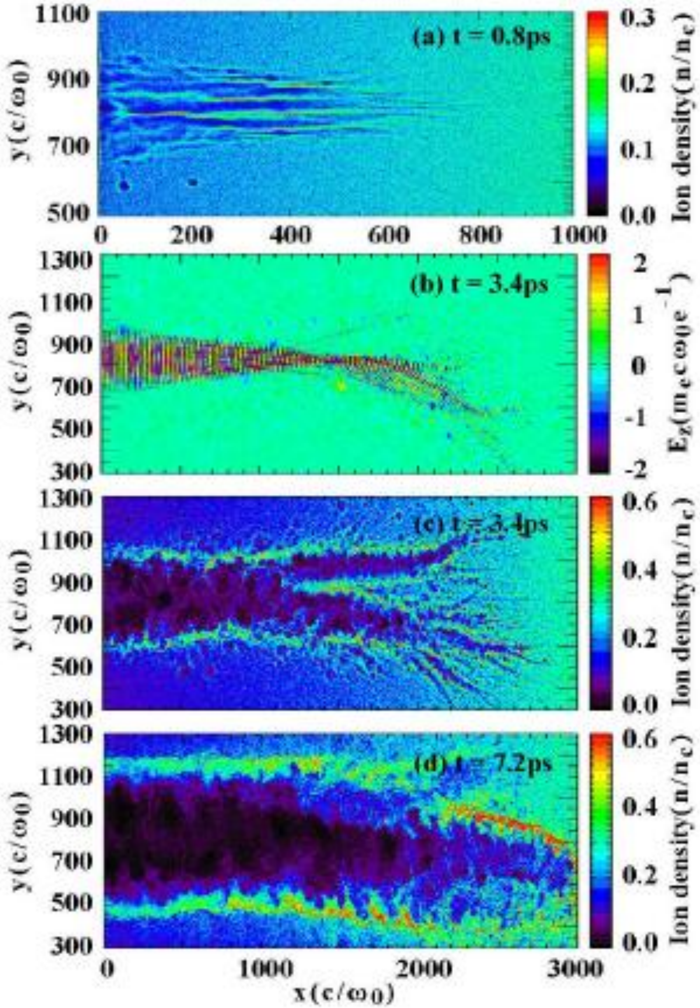
Hole boring re-visited

- Channelling recently been re-examined by colleagues in the US Fusion Science Center (Univ. Rochester and UCLA)

- Beam splits up but eventually pushes material out of the way by the light pressure

- Hole is formed in the coronal plasma that is in the beam direction

- Tens of picosecond relativistic pulses are more stable to instabilities



G. Li, R. Yan, C. Ren, T.-L. Wang, J. Tonge, and W. B. Mori
Phys. Rev. Lett. 100, 125002 (2008)

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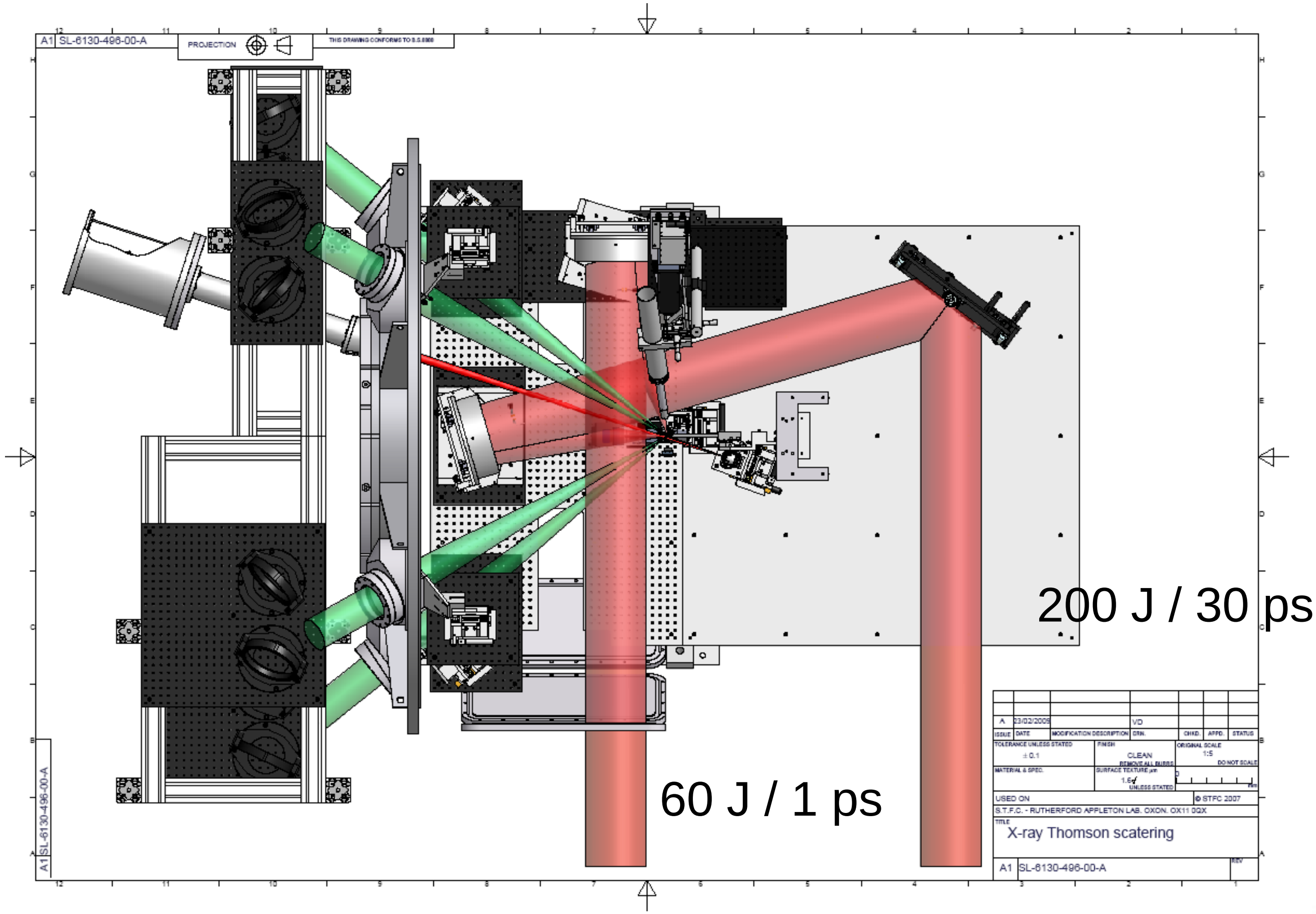
Top view of experiment layout



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Opportunities for focused EU/US collaboration

Co-ordinated experiments at European and US laser facilities

best use of EU and Univ. Rochester facilities

STFC and other HiPER consortia members are willing to fund seconded member(s) of staff to Univ. Rochester

part of agreed campaigns

Provide assistance with EU modelling capability in design of experiments

Target fabrication infrastructure

transition to quasi commercial operation

Diagnostic development

high resolution (1-2μm) X-ray zone plate imaging

British Embassy will fund joint workshop

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