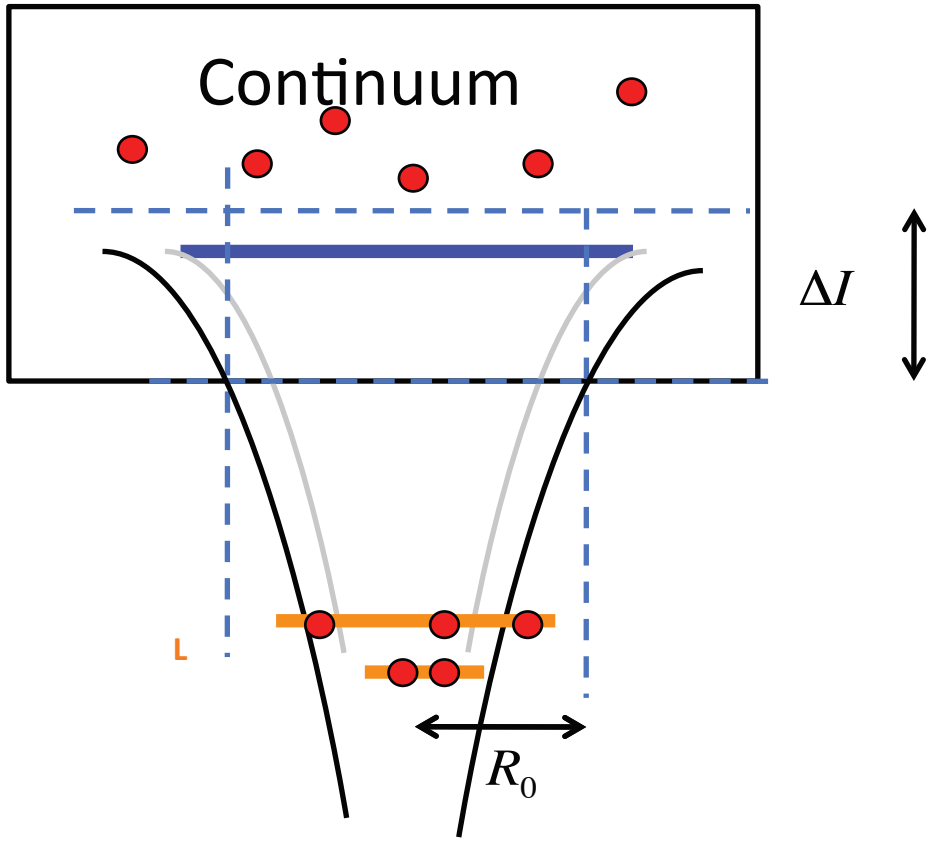
The "Ion Sphere" Model of IPD for a plasma

$$\frac{4\pi R_0^3}{3} = \frac{z^*}{n_e} = \frac{1}{n_i}$$

$$\Delta I = C\frac{z^* e^2}{4\pi\varepsilon_0 R_0}$$



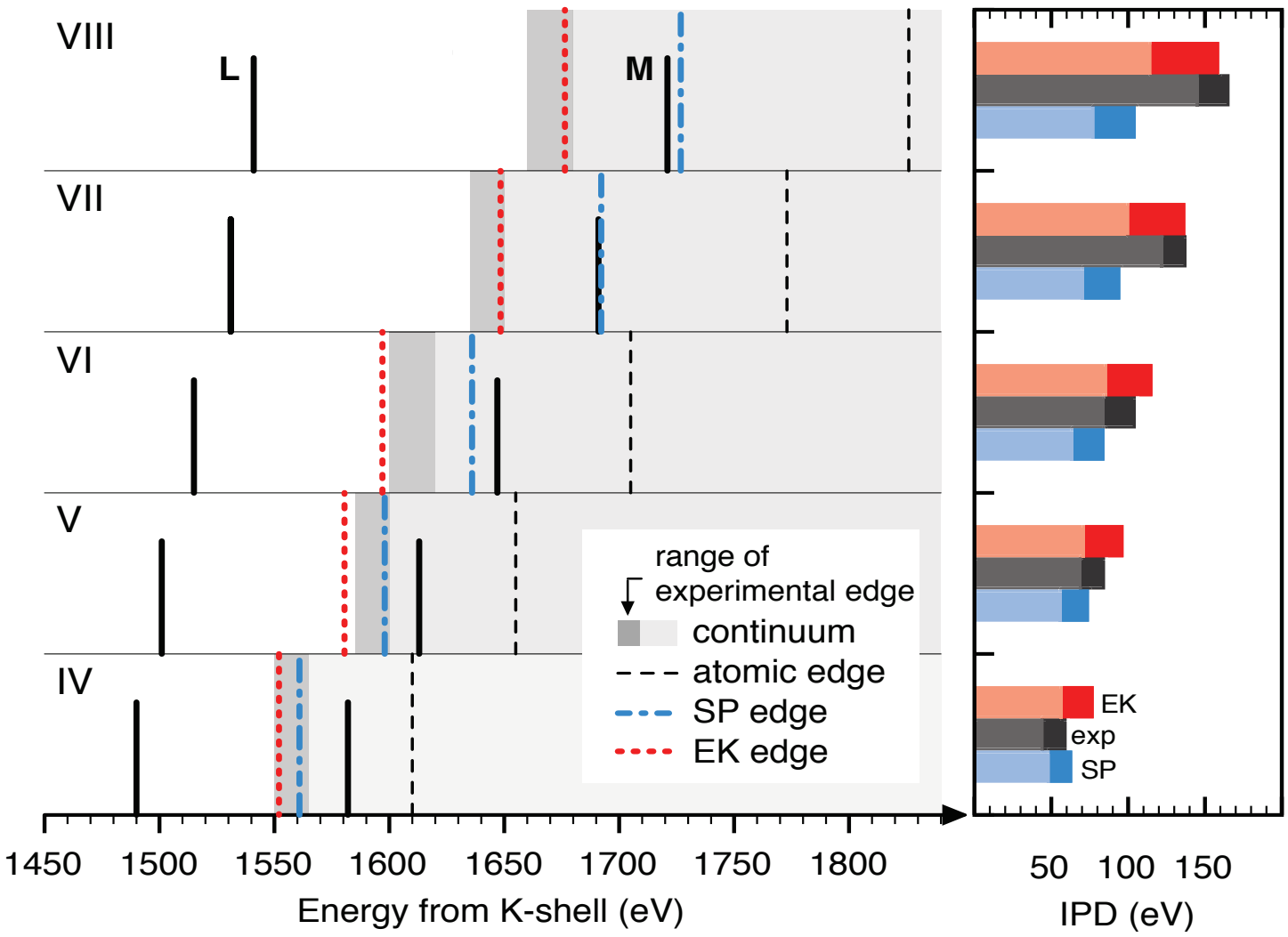
The "Ecker-Kroll" Model of IPD

- In 1963, three years before Stewart and Pyatt put forward their model, Ecker and Kroll argued that the relevant distance for determining the IPD was the mean distance between the total number of particles in the system:

$$\frac{4\pi R_{EK}^3}{3} = \frac{1}{(n_i + n_e)} \qquad \Delta I = \frac{z\ e^2}{4\pi\varepsilon_0 R_{EK}}$$

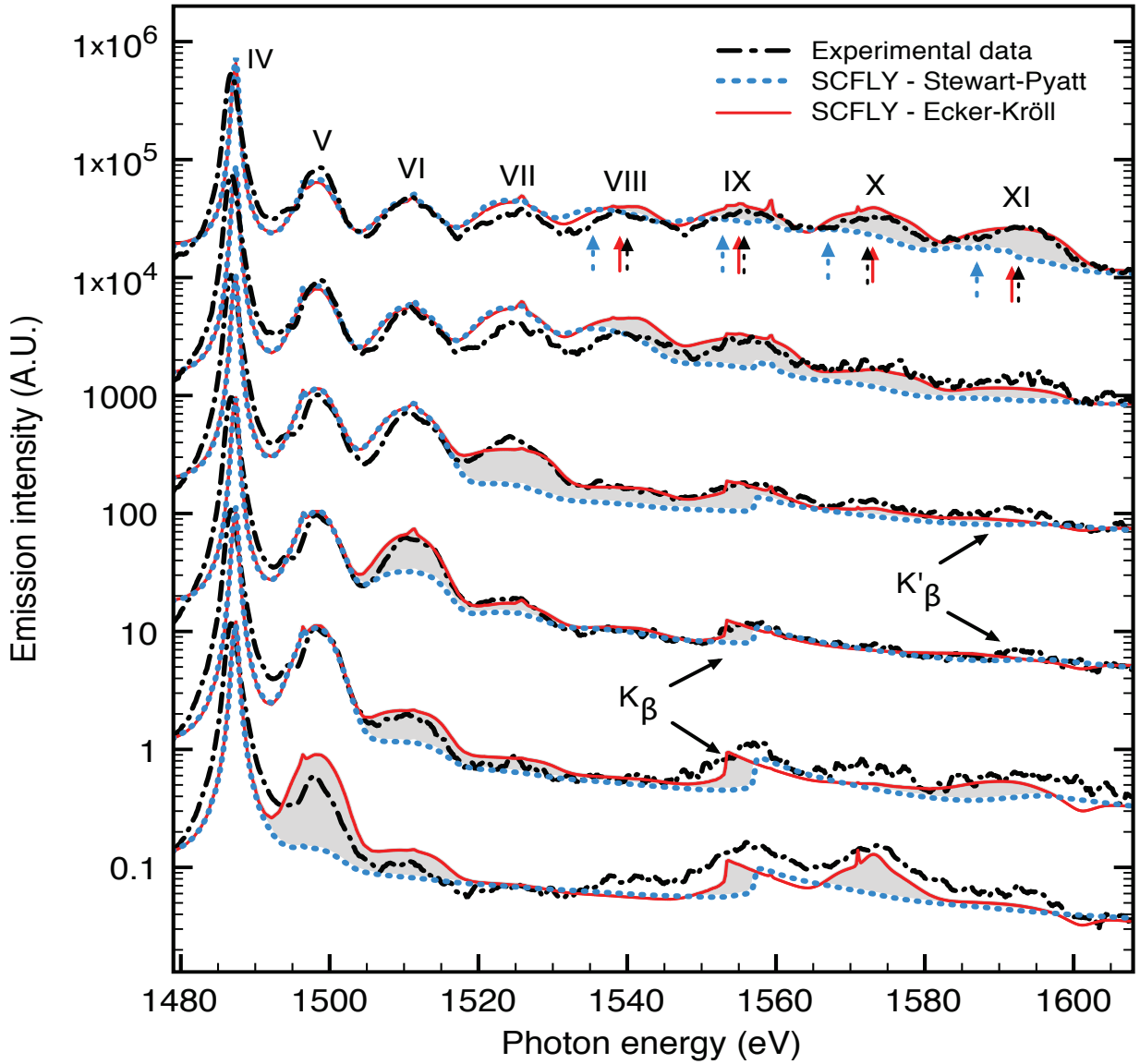
- The E-K model predicts significantly larger values of the IPD as the charge states increase, scaling with an extra factor of $z^{1/3}$. G. Ecker and W. Kroll, Phys. Fluids 6, 62 (1963).
- It has been largely ignored since being 'superceded' by Stewart-Pyatt.
- Stewart-Pyatt is extensively used in the vast majority of plasma physics codes that model the atomic kinetics of dense plasmas – e.g. LASNEX, CRETIN, FLYCHK, SCFLY.

Measured and Calculated Depressions



(PRL, Ciricosta *et al, 109, 065002* – 10th August, 2012)

Measured and Calculated Spectra



Summary

- Our first experiment at LCLS allowed us to heat a solid within 80-fsec (no time for hydro motion) to close to 200 eV by focussing the FEL beam to a small micron scale spot (~ 10^{17} Wcm^{-2}).

- By tuning the FEL photon energy, we can directly measure the K-edge of highly charged ions in the dense plasma, and test >50 year old theories of ionisation potential depression.

- This is the first direct measurement of IPD in a very strongly-coupled plasma. We find the model used in almost every kinetics code is wrong under these conditions. Subsequent measurements on other elements have confirmed very high IPDs.

- Current work is underway to try to understand why the ionization energy is reduced so much.

- These results are important, as the ionization potential determines the opacity and equation of state, and indeed all of the thermodynamics of dense plasmas.

- Further information - see S. Vinko *et al*, Nature **482**, 59 (2012), O. Ciricosta *et al*, Phys. Rev. Lett. **109**, 065002 (2012), B.-I.Cho *et al*, Phys. Rev. Lett. **109**, 245003 (2012)

Helmholtz-Beamline at European XFEL – Institutions & Topics

Germany: 20

CFEL, DESY, EMMI-GSI, GFZ-Potsdam, GSI, HI-Jena, HZDR, MBI, MPIK-HD, MPQ, OncoRay, Uni Bayreuth, TU Darmstadt, TU Dresden, Uni's Frankfurt, Freiburg, IOQ-Jena, LMU-Munich, Rostock, Siegen

Europe: 24

PSI (CH); FZU-PALS (CZ); CLPU-Salamanca (ES); IRAMIS-CEA, CEA-Arpajon, LULI, CELIA-Bordeaux, UPMC (FR); Univ Pecs (HU); Uni Roma (IT); MUT-Warsaw (PL); JIHT-RAS (RU); Stockholm, Umea, Uppsala (SE); Edinburgh, IC, QUB, UCL, Oxford, Plymouth, SUPA, Strathclyde (UK); European XFEL

Asia: 8

IOP-CAS, Peking Univ., SJTU, SIOM (CN); Tata IFR (IN); ILE-Osaka, JAEA-Kansai, Univ. Kyoto (JP);

US: 11

Carnegie Inst. Wash., General Atomics, LANL, LBNL, LLNL, ORNL, Ohio State, Rockefeller Univ, SLAC-LCLS, UCSD, UNR

		Nr	%	%
DE	HGF	74	10.9	33.3
	DE	152	22.4	
EU	UK	73	10.8	33.9
	FR	39	5.8	
	ES	29	4.3	
	SE	28	4.1	
	CH	10	1.5	
	CZ	10	1.5	
	PL	10	1.5	
	RU	10	1.5	
	HU	9	1.3	
	IT	6	0.9	
	XFEL	6	0.9	
Asia	CN	94	13.9	17.8
	JP	22	3.2	
	IN	5	0.7	
US	US	101	14.9	14.9

>85 Groups, 63 Institutions, ~360 faculty/scientists, ~300 students

Structural dynamics – Materials / Bio	21 groups
Relativistic Laser Matter Interaction	32 groups
Magnetic Materials* (recent)	2 groups
High Pressure Physics	16 groups
Strong field & nuclear physics	16 groups
Warm dense matter	26 groups

Faculty/Groups	86
Institutions	63
Faculty/Staff/Students	678

The ‘UK Position’

- UK Consortium formed as part of HiBEF (Edinburgh, IC, UCL, Oxford, SUPA, Plymouth, York, Strathclyde, QUB, Cambridge, Warwick)

- A formal approach has been made to EPSRC (by JSW) to re-engage via the HIBEF project by providing funding for the DiPOLE laser from RAL CLF

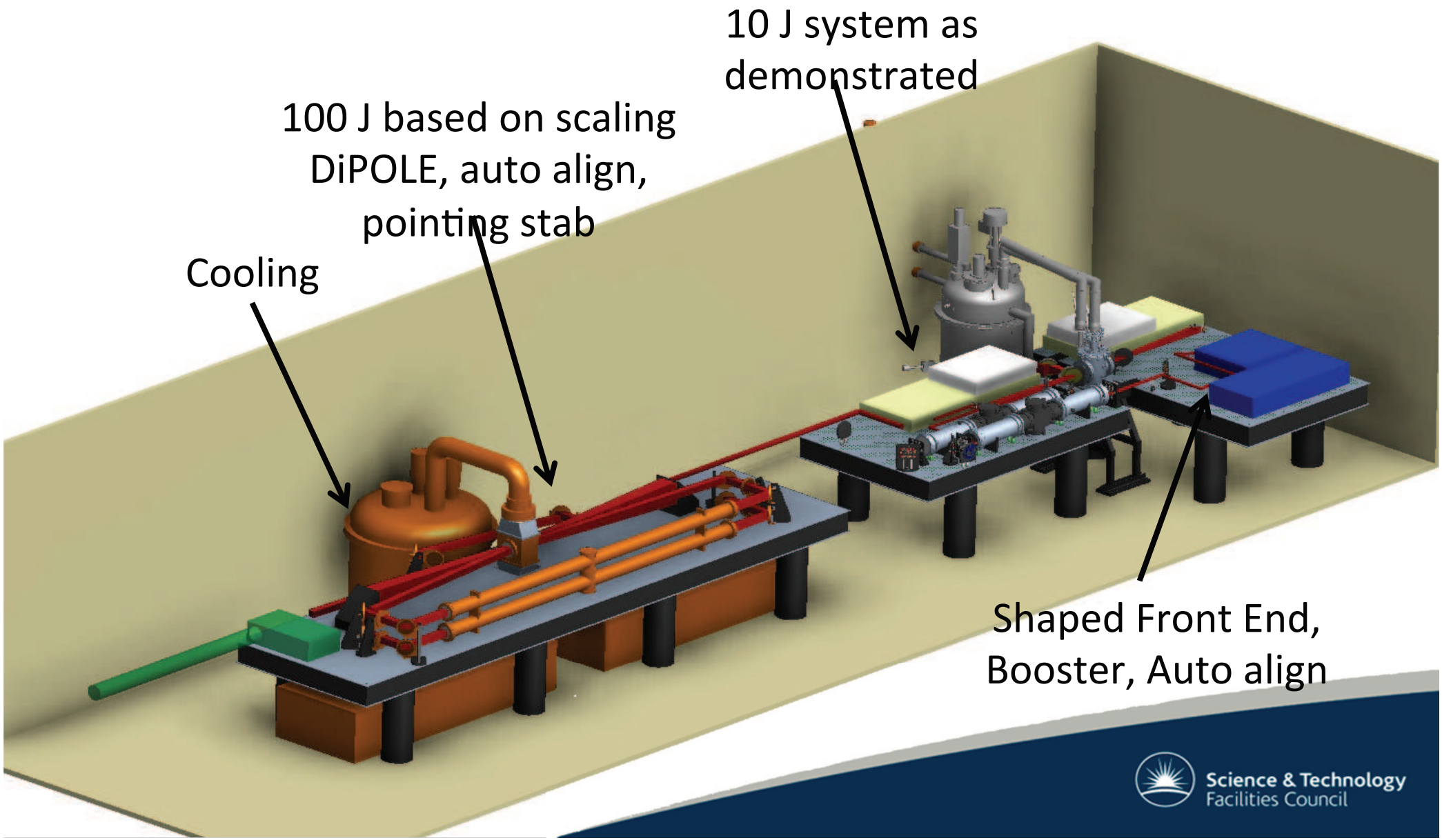
- Capital contribution of ~55% of DiPOLE costs (£3.5M + VAT)

- Pre-proposal for strategic equipment funding submitted May 2013 (should hear if we jumped that hurdle soon).

- EPSRC have also been consulted and ‘primed’ for a larger UK Consortium bid (~£7M) early next year. ‘Best-Science’ case to be formed over coming months in the light of ideas presented at the HiBEF kick-off meeting earlier this month.

- The landscape could change rapidly over the coming weeks depending on outcomes regarding capital expenditure.

Shaped 100J



Science & Technology Facilities Council