

Photon Science at DESY

Edgar Weckert

DESY, Hamburg



Nationally funded but
internationally used
research center

Staff: ~1700

Budget: ~170 M€

Users: ~3000 (> 2200 for
synchrotron radiation
experiments)

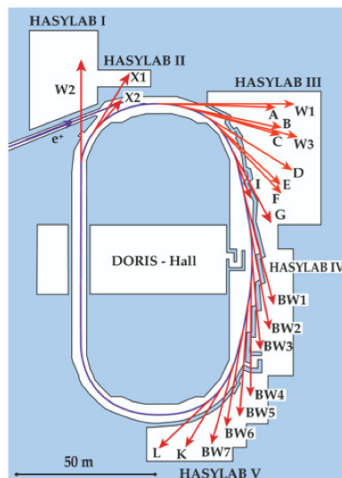
Hamburg

two sides

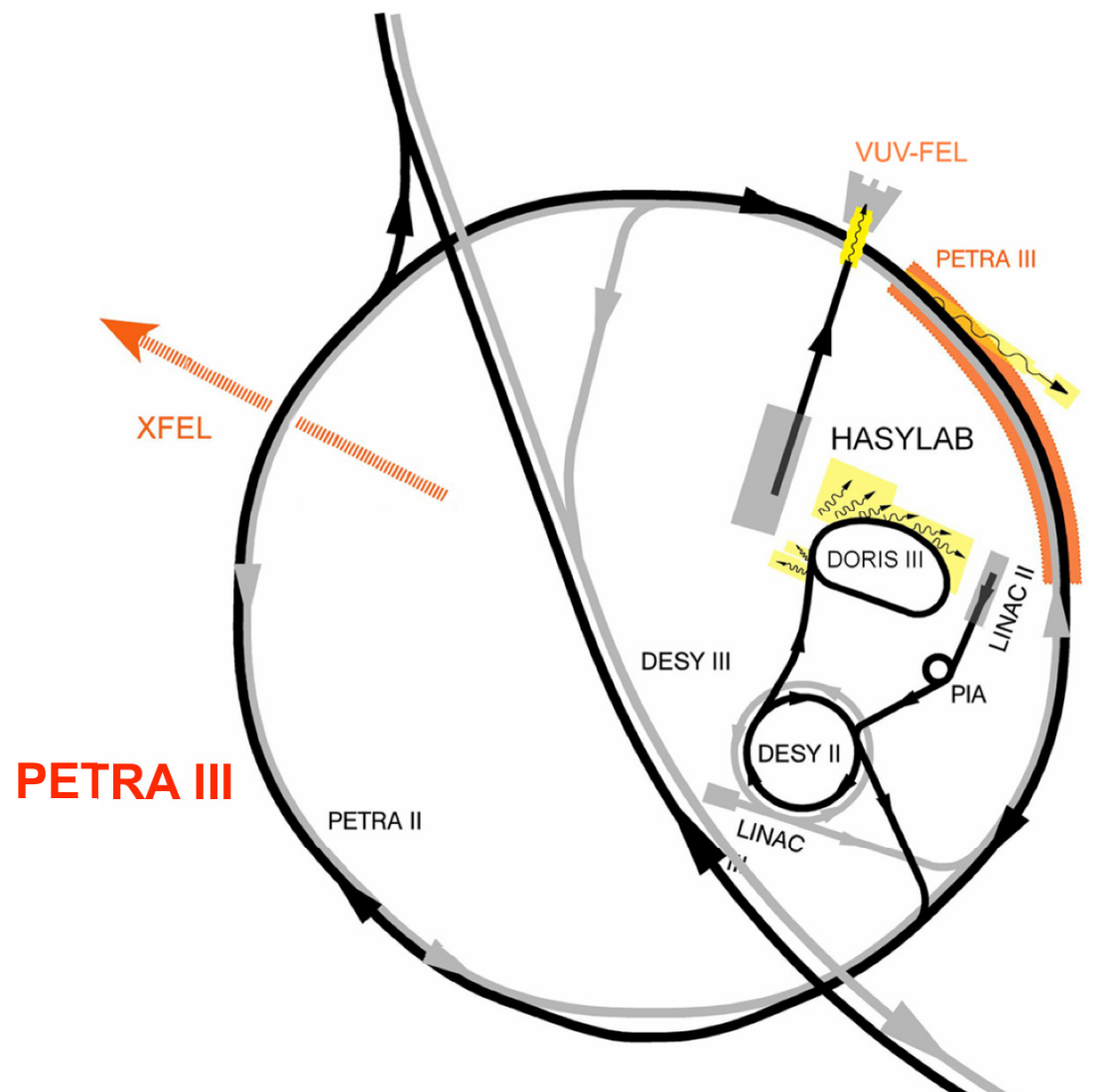
Zeuthen



DORIS III

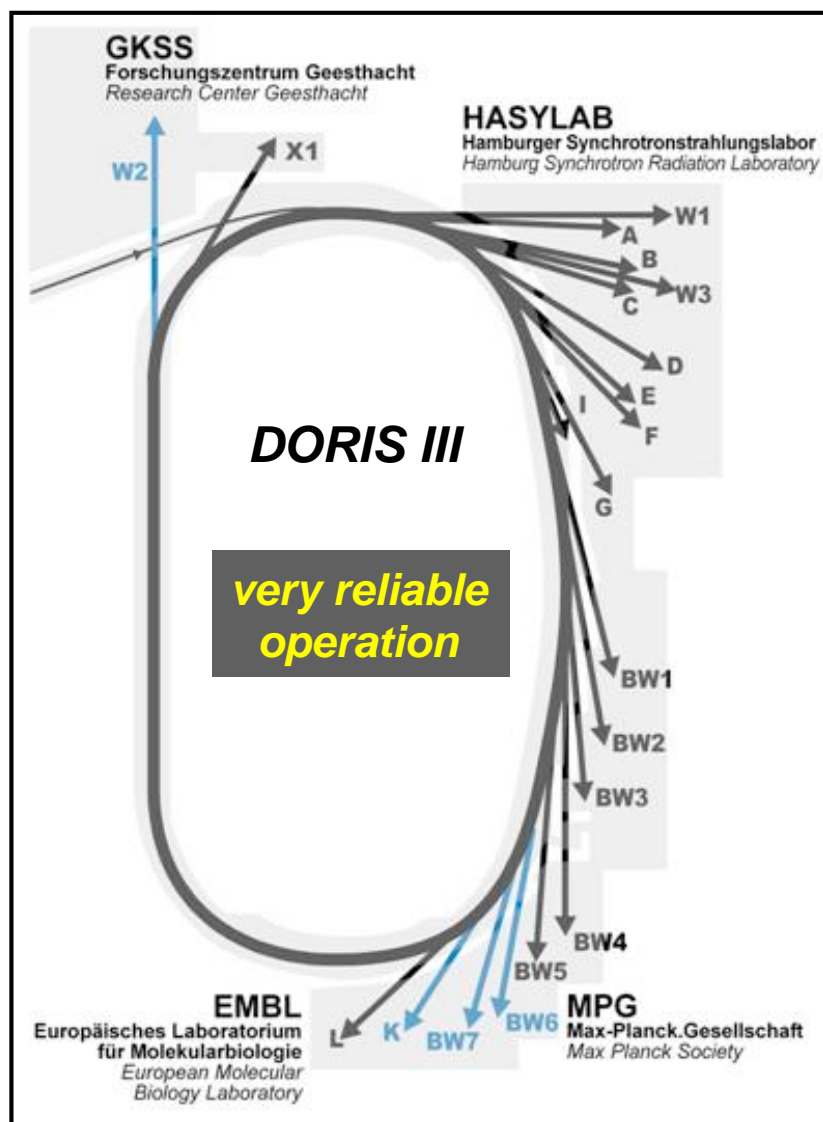


FLASH



PETRA III

European XFEL



Parameters:

4.3 GeV beam energy

140 mA max. current

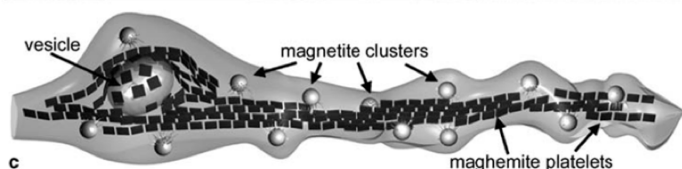
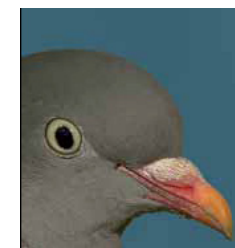
350 nmrad emittance

DORIS III is a well running storage ring with very efficient user operation including the **outstations** from EMBL, MPG, HGF (GKSS, GFZ) and University of Hamburg.

	<i>beamlines</i>
<i>HASYLAB + collaborations</i>	21
<i>outstations</i>	11
<i>special instruments</i>	5

*A novel concept of Fe-mineral-based magnetoreception:
histological and physicochemical data from the upper beak of homing pigeons*

Gerta Fleissner, Branko Stahl, Peter Thalau, Gerald Falkenberg, Günther Fleissner
Naturwissenschaften 94, 631 (2007), published online March 2007



maghemite:
 Fe^{2+} -deficient magnetite

*μ -fluorescence study at
Beamline L @ DORIS III*

Was featured worldwide

United Press International
Reuters
Scientific American (online)
Telegraph (UK)
New York Post
ABC News online
The Australian
... and MANY others

UPI press release:

Homing pigeons use beaks to get bearings

FRANKFURT, Germany, March 14 (UPI)

German scientists have found iron minerals contained in some birds' beaks might serve as a magnetometer, allowing the birds to use precise navigation.

Although scientists have long known birds can use the Earth's magnetic field for their navigation, the source of that ability was not known.

But a new study by [Gerta Fleissner and colleagues at the University of Frankfurt](#) determined iron-containing structures in the beaks of homing pigeons offers a promising insight into the complex topic.

In histological and physicochemical examinations [in collaboration with HASYLAB, a synchrotron laboratory based in Hamburg](#), iron-containing subcellular particles of maghemite and magnetite were found in sensory dendrites of the skin lining the upper beak of homing pigeons.

Researchers found those dendrites are arranged in a complex three-dimensional pattern and react to the Earth's external magnetic field in a very sensitive and specific manner, thus acting as a three-axis magnetometer.

The study suggests the birds sense the magnetic field independent of their motion and posture and thus can identify their geographical position.

The study appears online in the German journal Natural Sciences (Naturwissenschaften).

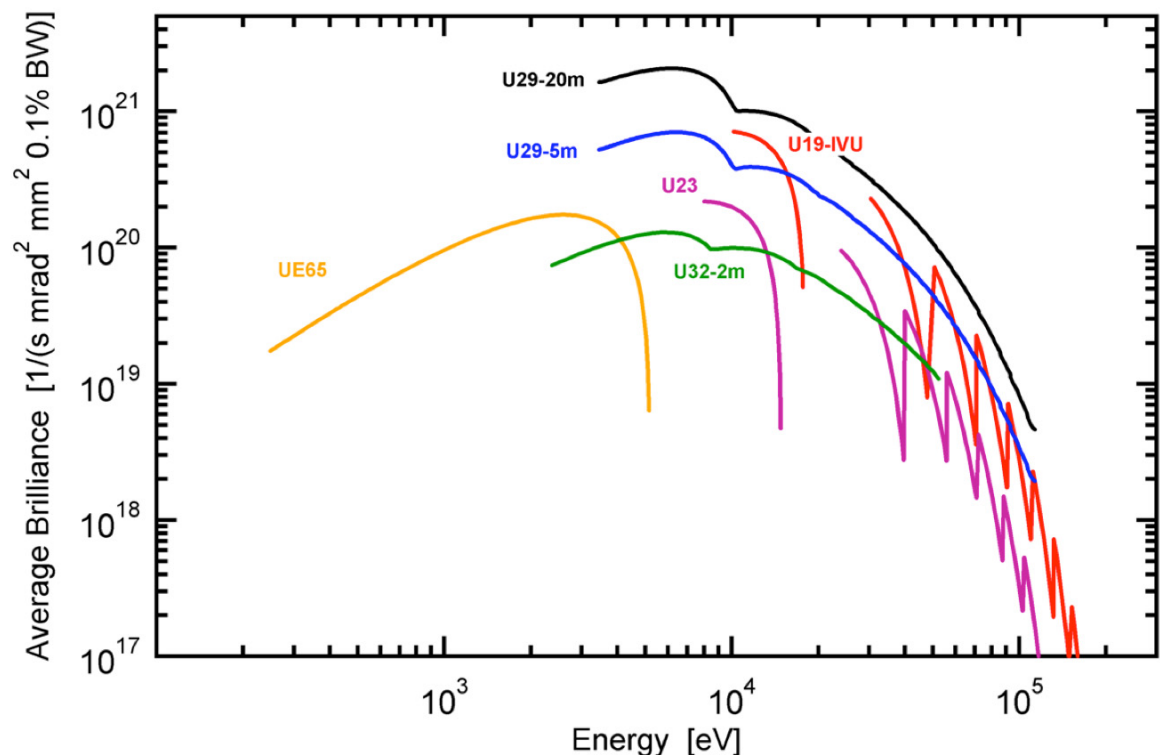
PETRA III: Summary



- rebuild of **1/8** of the **2304m** circumference
- refurbishment of 7/8 of the storage ring
- refurbishment of pre-accelerator chain
(also used by DORIS III)
- construction of a **300m** long new experimental hall
- installation of **80m** of **damping wigglers**
- top up operation mode

key parameters:

- **particle energy:** **6GeV**
- **current:** **100mA (200mA)**
- **horizontal emittance:** **1 nmrad**
- **No. of undulators:** **14 (incl. canted)**
- **undulator lengths:** **2-10(20) m**
- **no bending magnet beamlines**



1nmrad
1% coupling

- coherent flux @12keV ($B(\lambda/2)^2$):
 - 2m ID: $\sim 4 \times 10^{10}$ ph/s/0.01%BW
 - 5m ID: $\sim 1 \times 10^{11}$ ph/s/0.01%BW
 - 20m ID: $\sim 2.5 \times 10^{11}$ ph/s/0.01%BW

Photon beam parameters at 12keV:

	β_x [m]	β_y [m]	σ_x [μm]	σ_y [μm]	$\sigma_{x'}$ [μrad]	$\sigma_{y'}$ [μrad]	ID-length [m]
low- β 5 m	1.3	3	35.9	5.7	28	5.0	5
high- β 5 m	20	2.38	141	5.2	8.6	5.2	5

Horizontal β -function of each straight section can be selected individually and is changeable ($\beta_x = 1.3\text{m}$ or $\beta_x = 20\text{m}$)

Beamlines for PETRA III were selected according to user demands and driven by novel scientific applications in order to use the **high brilliance and capabilities for μ - and nano-focusing** in a best possible manner.

Number	Name	ID-type	Energy range	Comment	Kontakt
P01	NRS, ps-time resolved, IXS	10 m U	6 - 40 keV		H. Franz, DESY
P02	Hard X-ray scattering/diffraction	2 m U23	30 - 100 keV	straight	NN, DESY
P03	Micro SAXS/WAXS	2 m U29	8 - 23 keV	down	S. Roth, DESY
P04	Variable Polarization XUV	5 m UE65	0.2 - 3.0 keV		J. Viefhaus, DESY
P05	Micro- and nano-tomography / imaging	2 m U29	8 - 50 keV	side	A. Haibel, GKSS
P06	Micro/nano-spectroscopy / fluorescence	2 m U32	2.4 - 50 keV	straight	G. Falkenberg, DESY
P07	High energy materials science and diffraction	4 m U19	30 - 150 keV		N. Schell, GKSS/DESY
P08	High resolution diffraction	2 m U29	5.4 - 30 keV	top	O. Seeck, DESY
P09	Resonant scattering / diffraction	2 m U32	2.4 - 50 keV	straight	J. Stremper, DESY
P10	Coherence applications	5 m U29	4 - 25 keV		O. Leupold, DESY
P11	MX-diffraction / biological imaging	2 m U32	8 - 25 keV	side	NN; MPI, HGF, DESY
P12	BioSAXS	2 m U29	4 - 25 keV	straight	M. Rößle, EMBL
P13	Macro molecular crystallography I	2 m U29	8 - 16 keV	side	M. Cianci, EMBL
P14	Macro molecular crystallography II	2 m U29	5 - 35 keV	straight	G. Bourenkov, EMBL

high beta section

142x5 μm

low beta section

35x6 μm

PETRA III: Start of construction

2nd July, 2007







Experimental floor: Base plate



Experimental floor: now



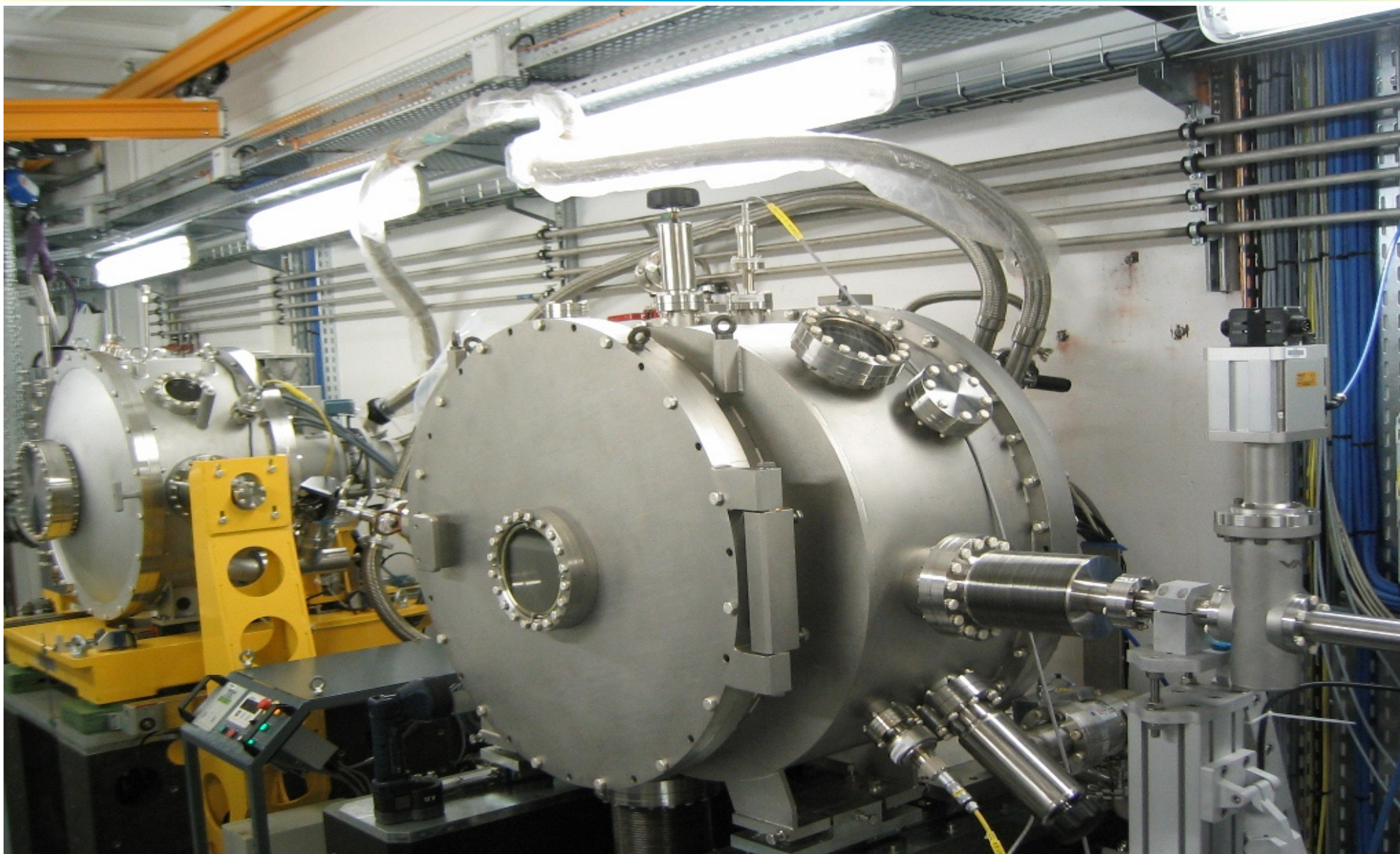
PETRA III: Status last week

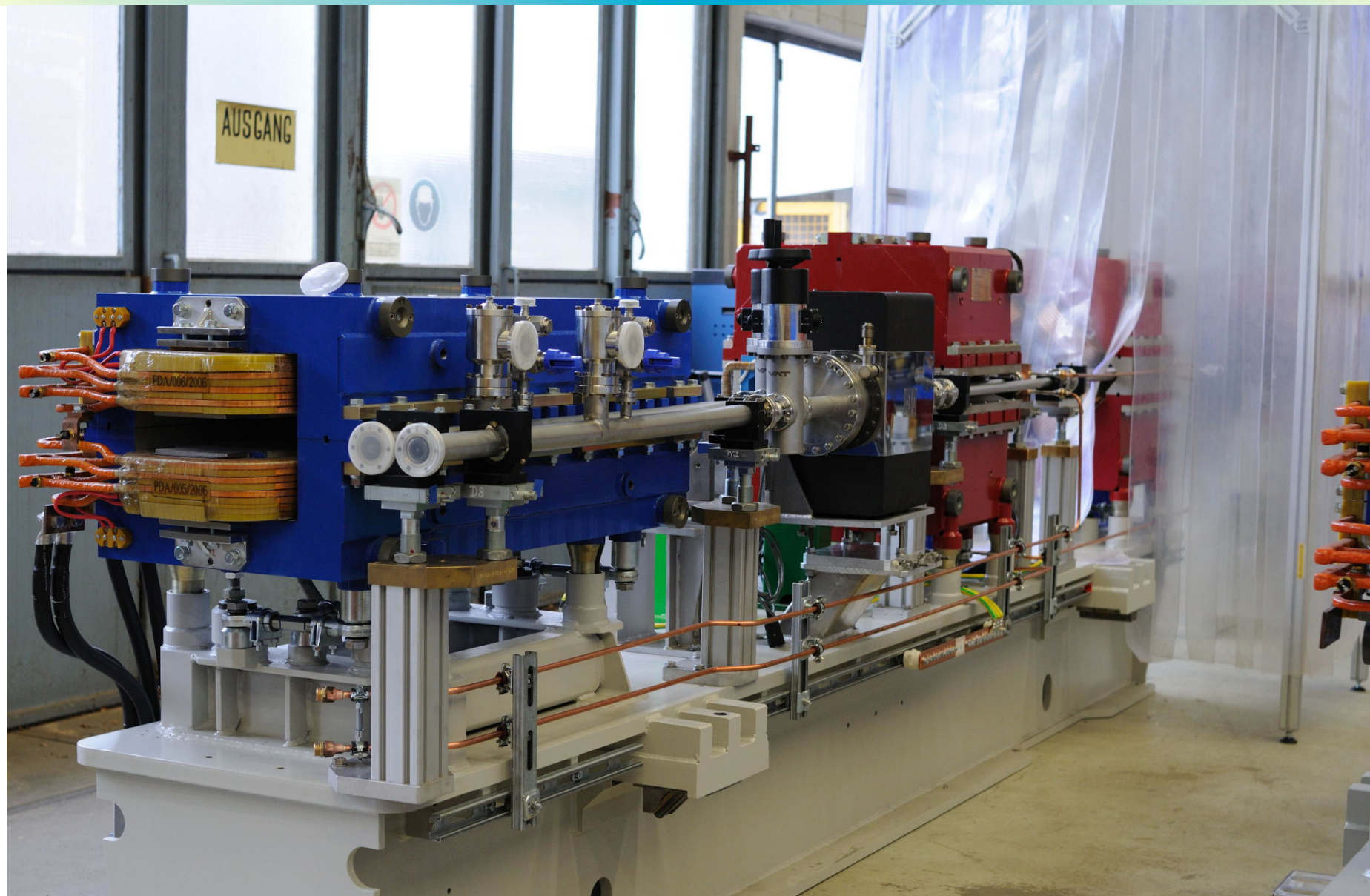




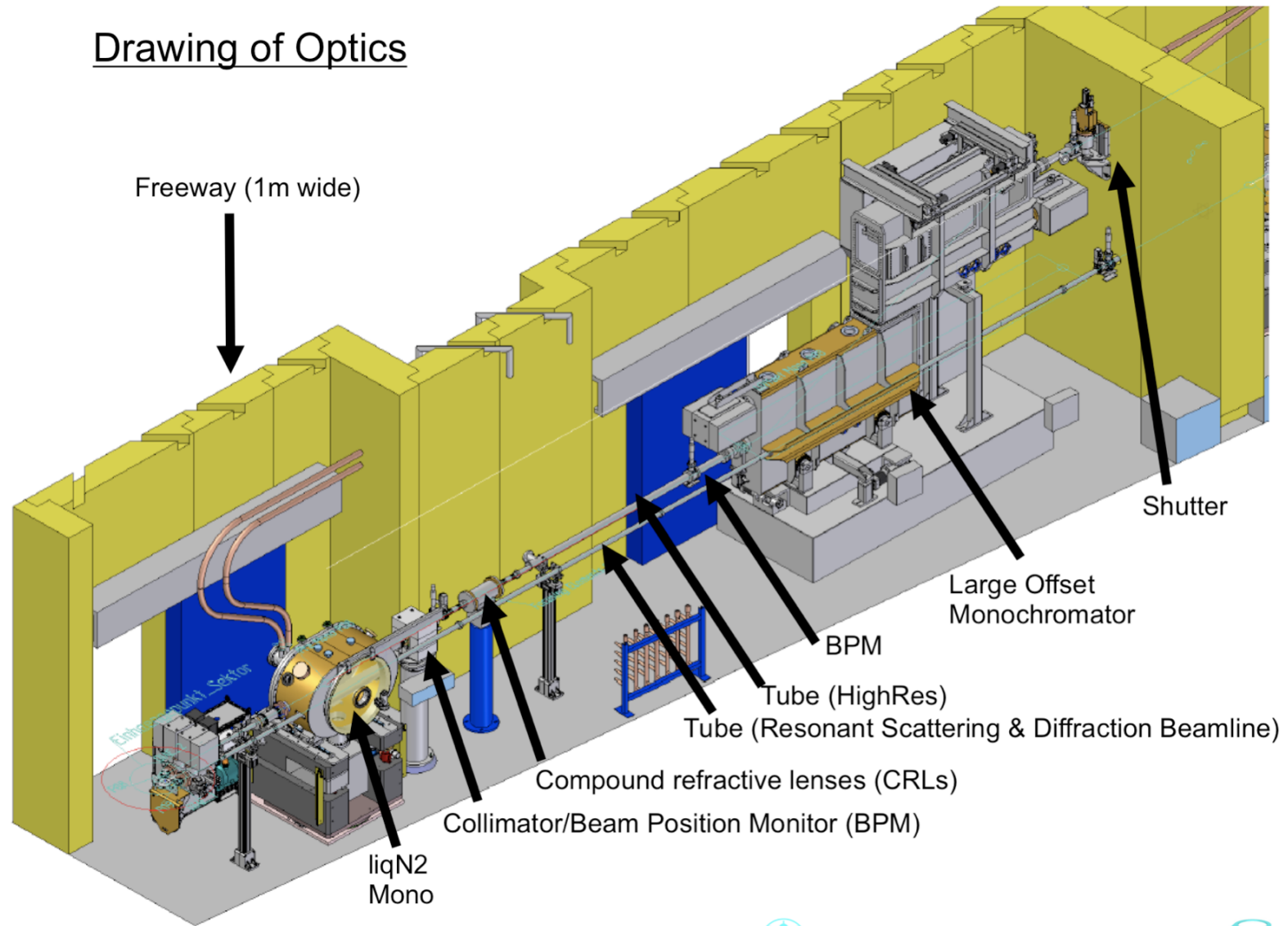
***>90% of all magnets
already reinstalled***







Drawing of Optics



11



The High Resolution Diffraction Beamline

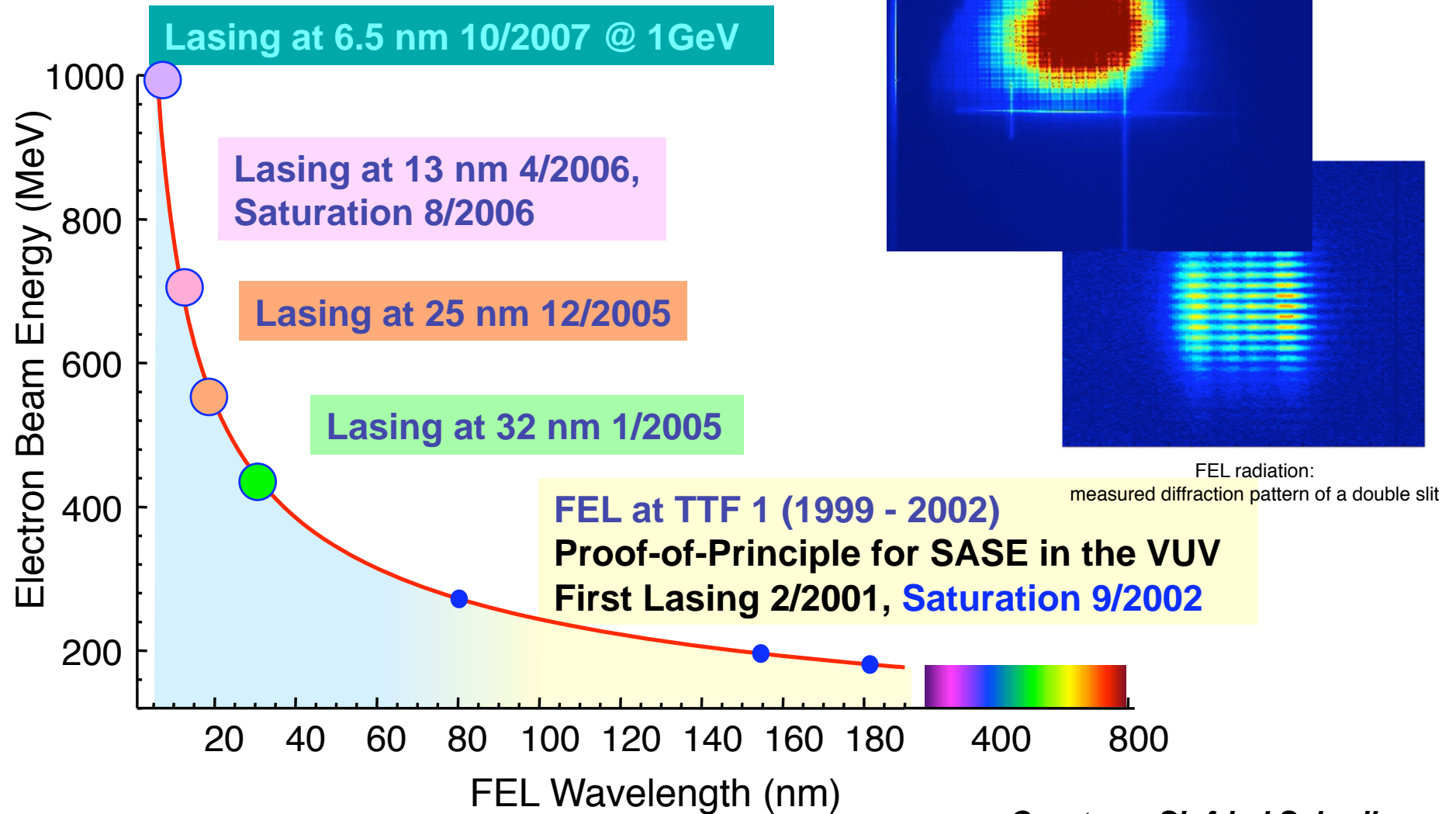


First construction work	already started
End of HERA operation, start of dismantling	July 2 nd , 7:00
laying of the foundation stone	second week of September
casting of experimental floor plate finished	14./15. December
handing over of the experimental floor	first week April 2008
end of construction work	end of June 2008
start of beamline construction	mid 2008
start technical commissioning of the storage ring	October 2008
start of beamline commissioning	begin 2009
first (friendly) users	sometimes in 2009

FLASH: VUV free electron laser

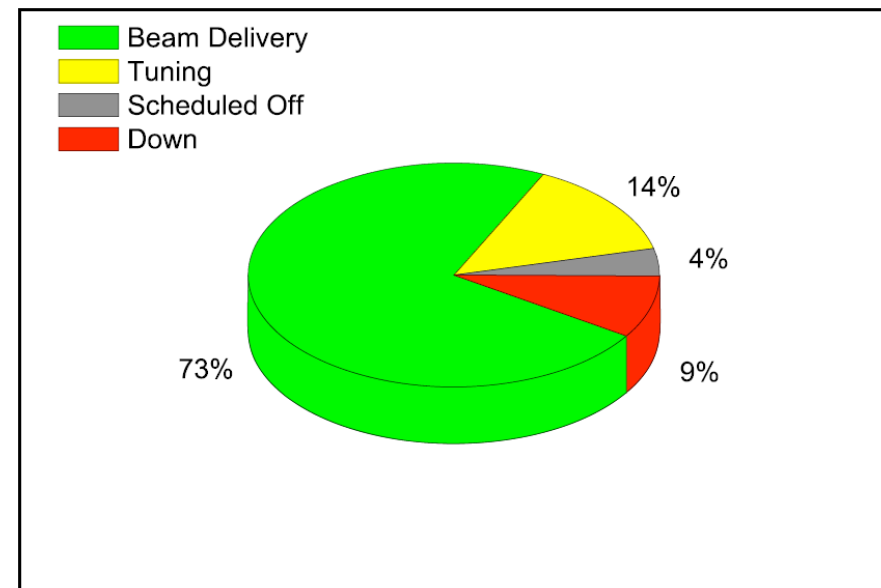
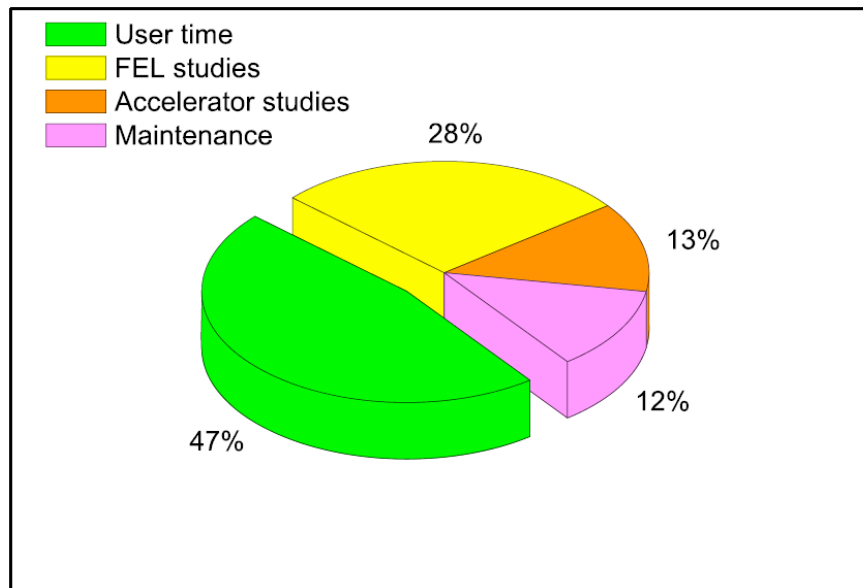
electron energy:	1 GeV
wavelength:	6.5-47 nm
average pulse energy:	2-70 μJ
peak pulse energy:	170 μJ
pulse duration:	10-25 fs
average power (700 pulses / s):	20 mW
peak power:	3-10 GW
peak brilliance	$1-10 \cdot 10^{29}$
divergence (@13nm):	90 μrad
spectral width:	0.7-1%



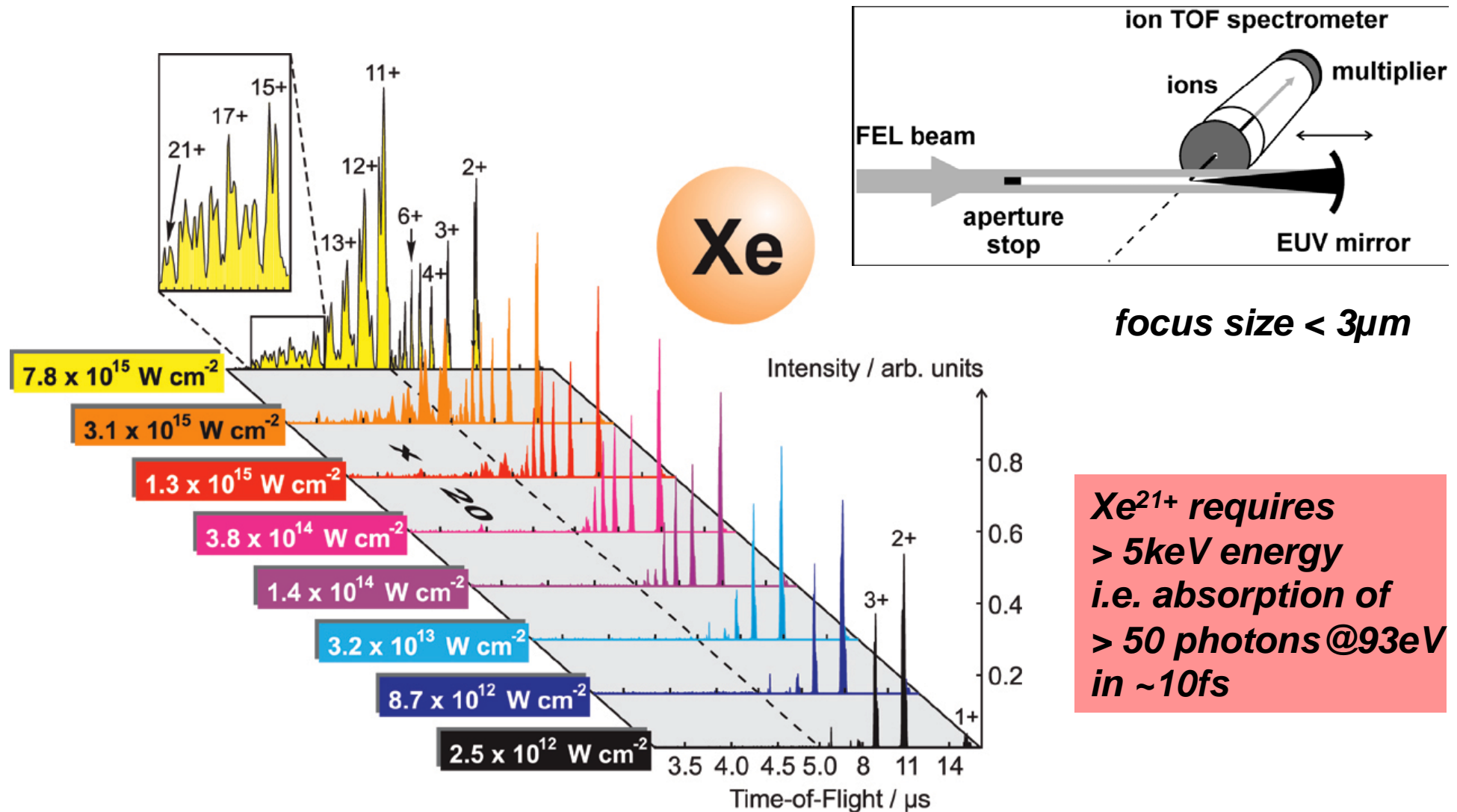


Courtesy: Sigfried Schreiber

- **Run 2: May 2006 to Mar 2007**
→ 45 weeks or 7728 h
- **User experiments had 3840 h of beam time (47 %)**
- **with 2798 h of actual beam delivery (73%)**





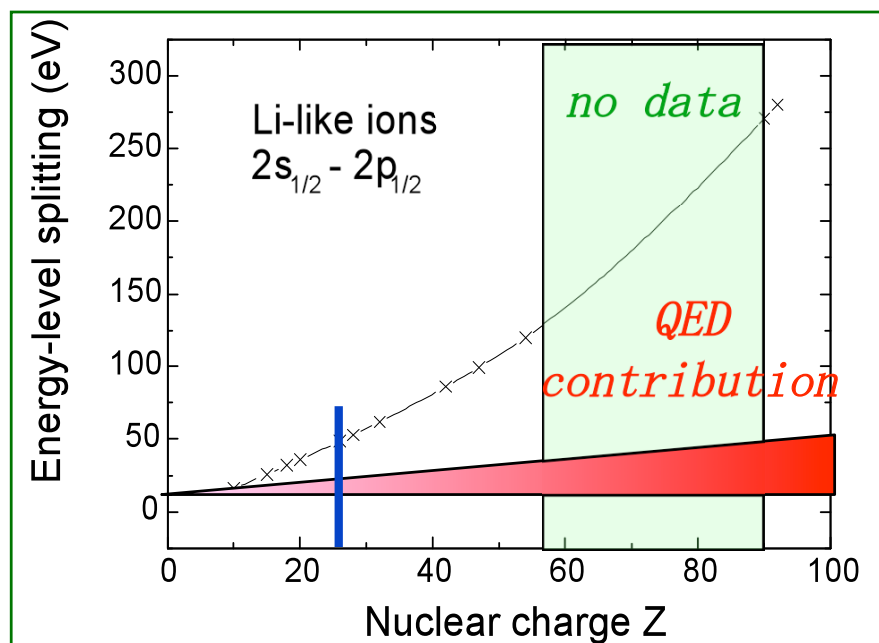


A. A. Sorokin et al., Photoelectric Effect at Ultrahigh Intensities, PRL 99, 213002 (2007) collaboration
PTB, Ioffe Institute, Fraunhofer Jena, DESY



Precision Spectroscopy on Highly-Charged Ions

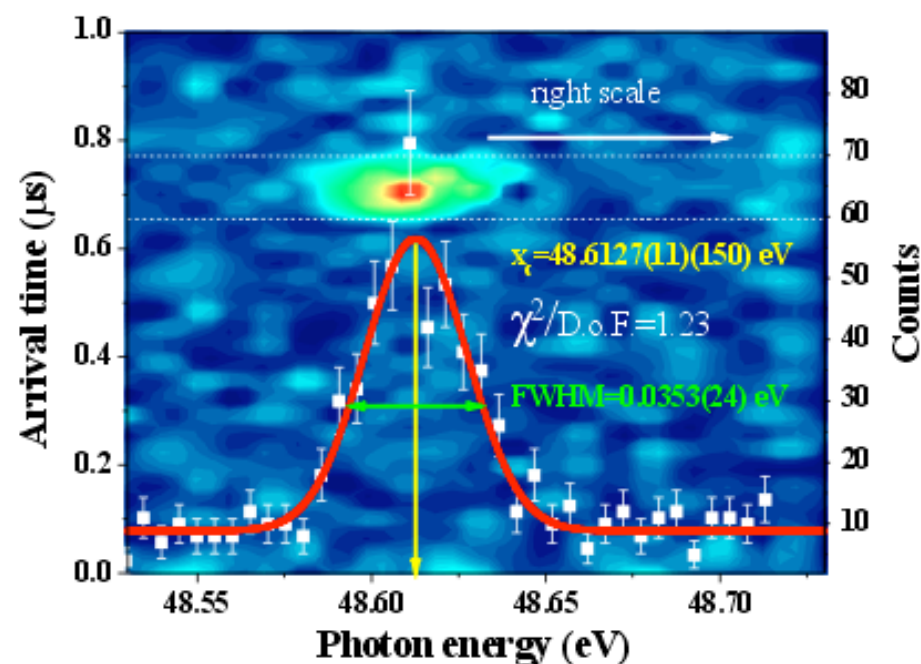
- *fundamental tests of QED with Li-like ions: Ar^{15+} - U^{89+}*
- *precision data for fusion research*



- *typical present accuracy:*
 $\Delta\lambda/\lambda = 10^{-3}-10^{-4}$

• **FLASH:** $\Delta\lambda/\lambda = 10^{-5}-10^{-6}$

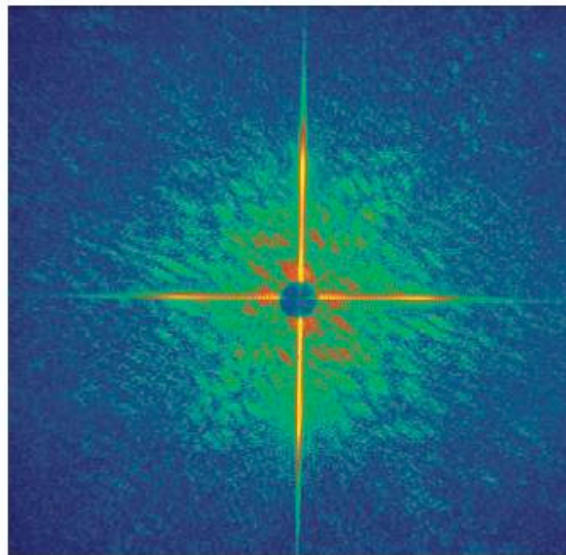
Li-like Fe^{23+}



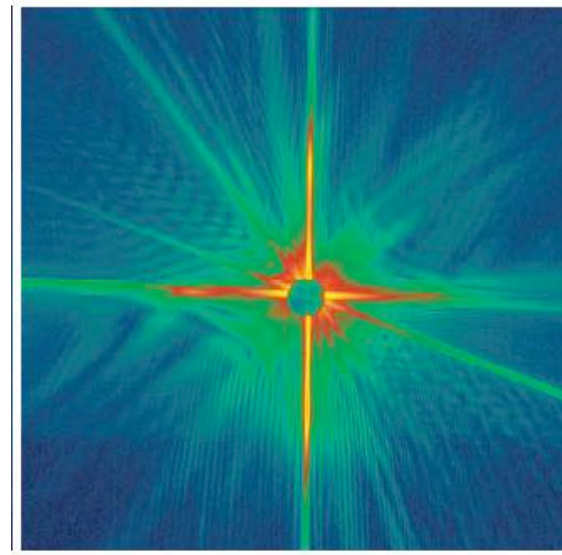
*High average brilliance is
crucial for success !*

S. Epp, J. Crespo López-Urrutia, J. Ullrich et al., PRL 98, 183001 (2007)

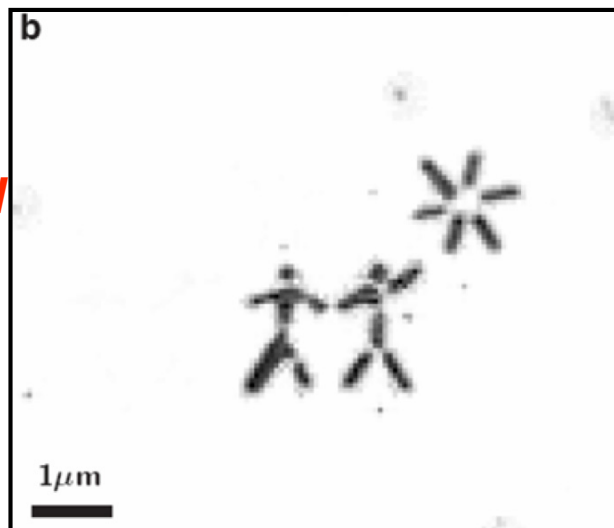
*diffraction
pattern from
first pulse*



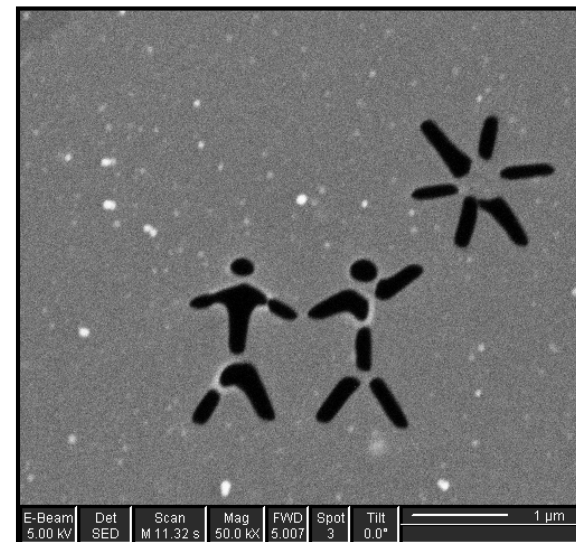
*diffraction
pattern from
second pulse*



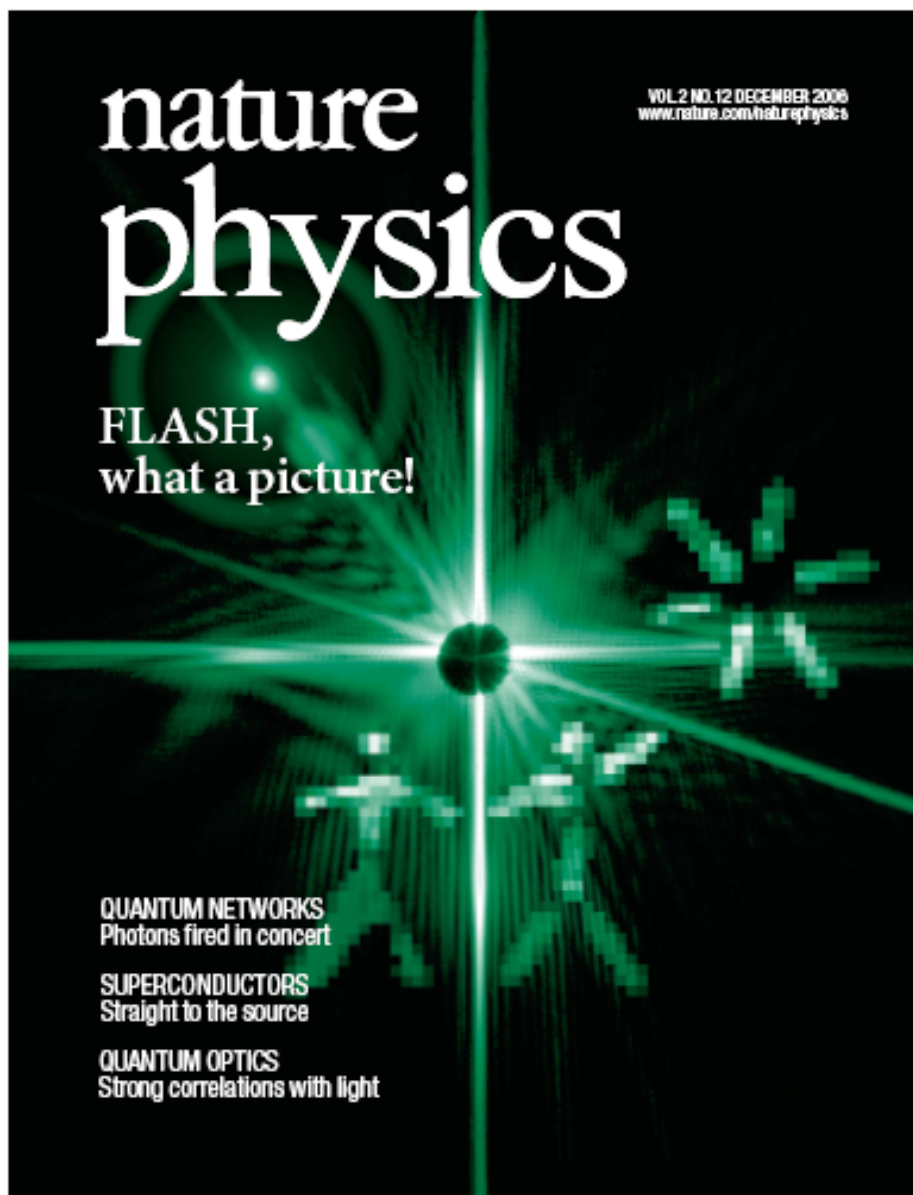
*reconstructed
picture*



*TEM picture
from original
structure*



H. Chapman, J. Hajdu et al.



***International collaboration lead by
Henry Chapman (LLNL) and
Janos Hajdu (Uppsala University)***

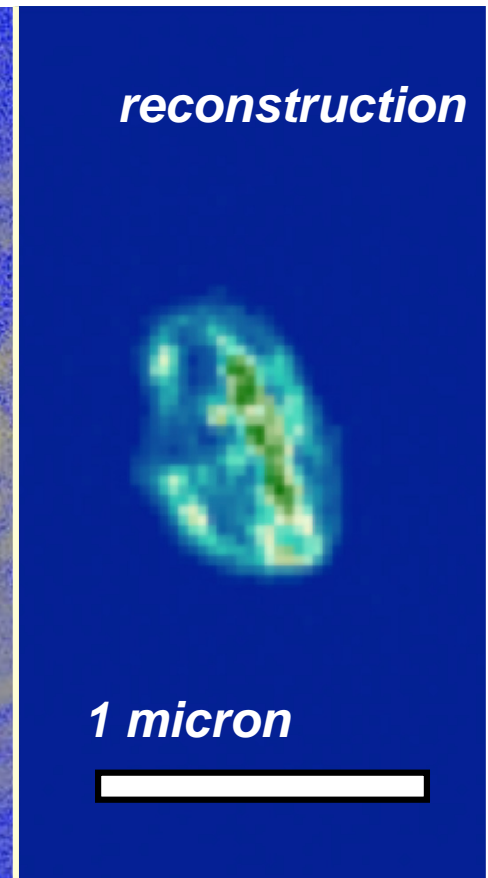
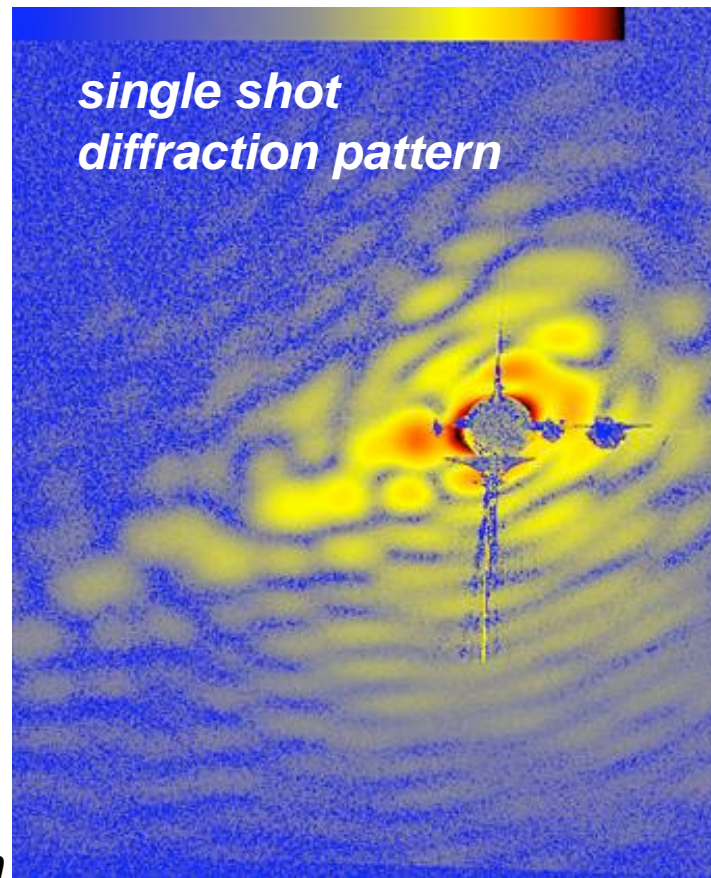
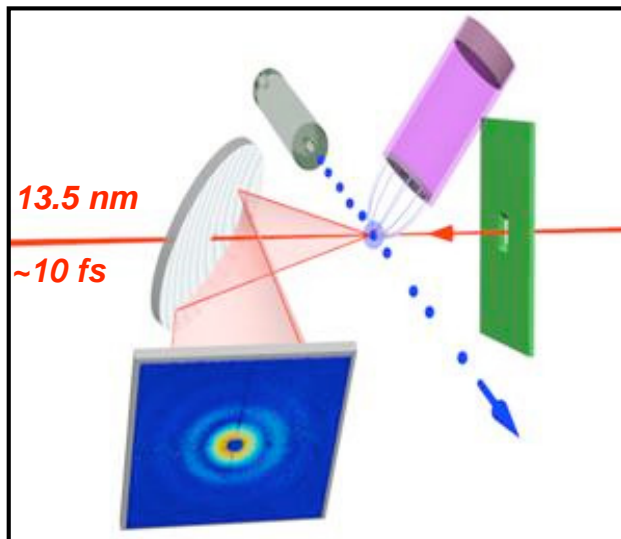
HENRY N. CHAPMAN^{1,2*}, ANTON BARTY¹, MICHAEL J. BOGAN¹, SÉBASTIEN BOUTET^{1,3,4},
MATTHIAS FRANK¹, STEFAN P. HAU-RIEGE¹, STEFANO MARCHESINI^{1,2}, BRUCE W. WOODS¹, SAŠA BAJT¹,
W. HENRY BENNER¹, RICHARD A. LONDON^{1,2}, ELKE PLÖNJE⁵, MARION KUHLMANN⁶, ROLF TREUSCH⁶,
STEFAN DÜSTERER⁵, THOMAS TSCHENTSCHER⁵, JOCHEN R. SCHNEIDER⁶, EBERHARD SPILLER⁶,
THOMAS MÖLLER⁷, CHRISTOPH BOSTEDT⁷, MATTHIAS HOENER⁷, DAVID A. SHAPIRO²,
KEITH O. HODGSON³, DAVID VAN DER SPOEL⁴, FLORIAN BURMEISTER⁴, MAGNUS BERGH⁴,
CARL CALEMAN⁴, GÖSTA HULDT⁴, M. MARVIN SEIBERT⁴, FILIPE R. N. C. MAIA⁴, RICHARD W. LEE^{1,4},
ABRAHAM SZÖKE^{1,4}, NICUSOR TIMNEANU⁴ AND JANOS HAJDU^{3,4*}



Imaging **picoplankton** organism “on the fly”

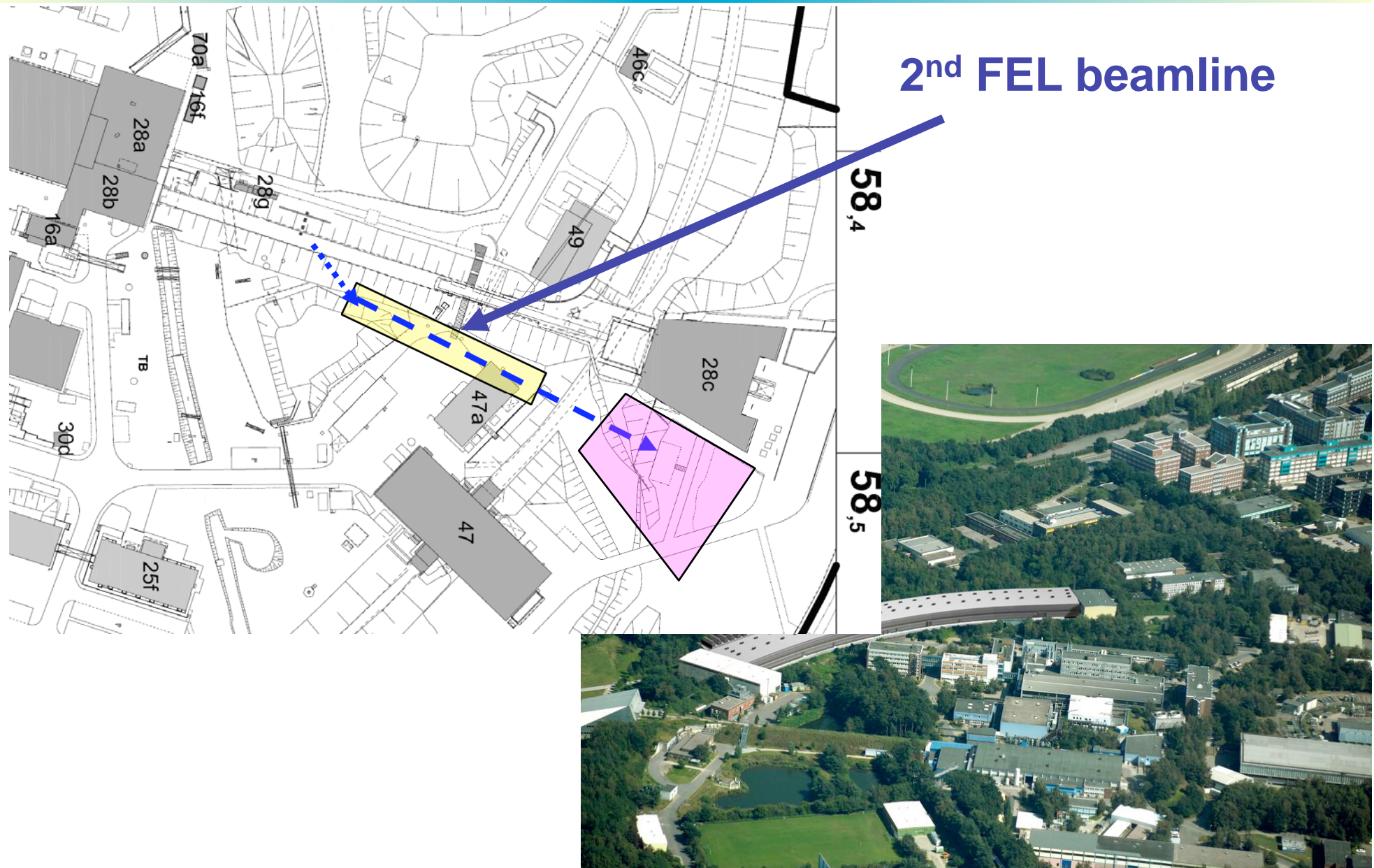


PICOPLANKTON are the most abundant **photosynthetic cells** in the oceans (discovered in 1988)



This cell was injected into vacuum from solution, and shot through the beam at 200 m/s

H. Chapman, J. Hajdu et al. (2007)

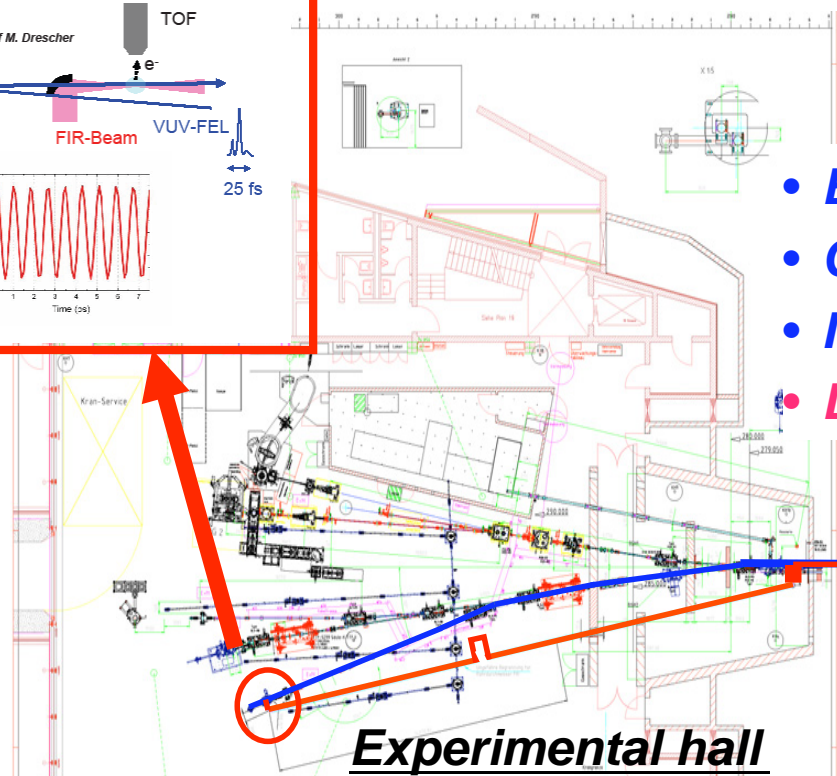
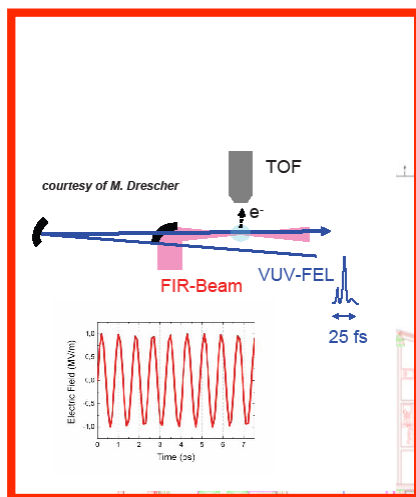


Uni HH + DESY

50 – 200 μm at BL3!



- *Electromagnetic undulator*
- *Coherent radiation 1-200 μm (at 500 MeV)*
- *IR radiation source, pump/probe expts.*
- *Longitudinal beam diagnostics*



perfectly synchronized !!

- 2nd line of variable gap undulators 20m + 10m (helical?) long
- test bed for various seeding schemes:
 - HHG
 - HGHG
- test bed for critical XFEL components
- quasi – simultaneous operation at 2 different wavelengths
- enhances user capacity by a factor 2
- provide space for further extensions



**Technical Design
Report published
in July 2006**

**Plan approval
procedure finished**

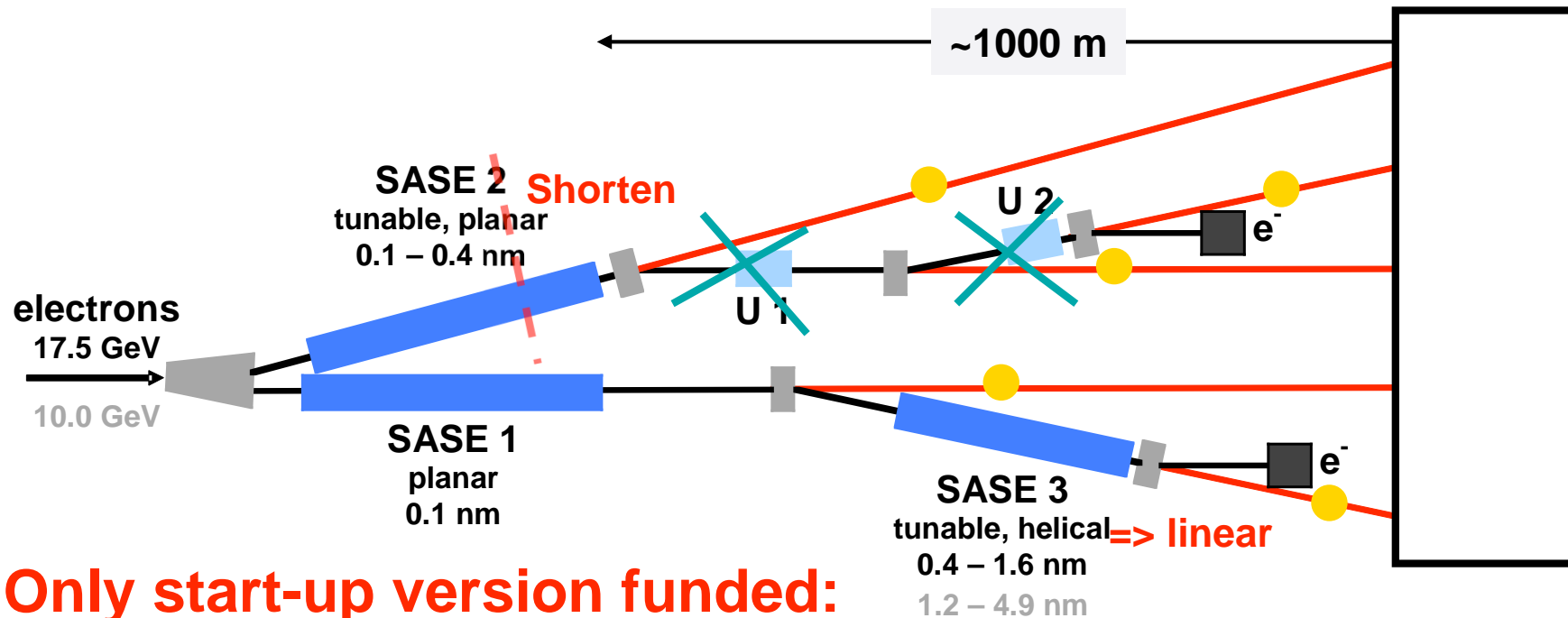
**kick-off at ECRI
press conference
5 June 2007**

Realization as European Facility in 2 steps

- 1. step: 3 radiators with 6 experimental stations (850 M€ in 2005 prices)**
- 2. step: Full facility (TDR) with 5 radiators and 10 experimental stations
(construction cost 986 M€ in 2005 prices)**

Foundation of XFEL Limited Liability Company envisaged for mid 2008





Only start-up version funded:

Accelerator up to 17.5 GeV only

3 Undulator systems

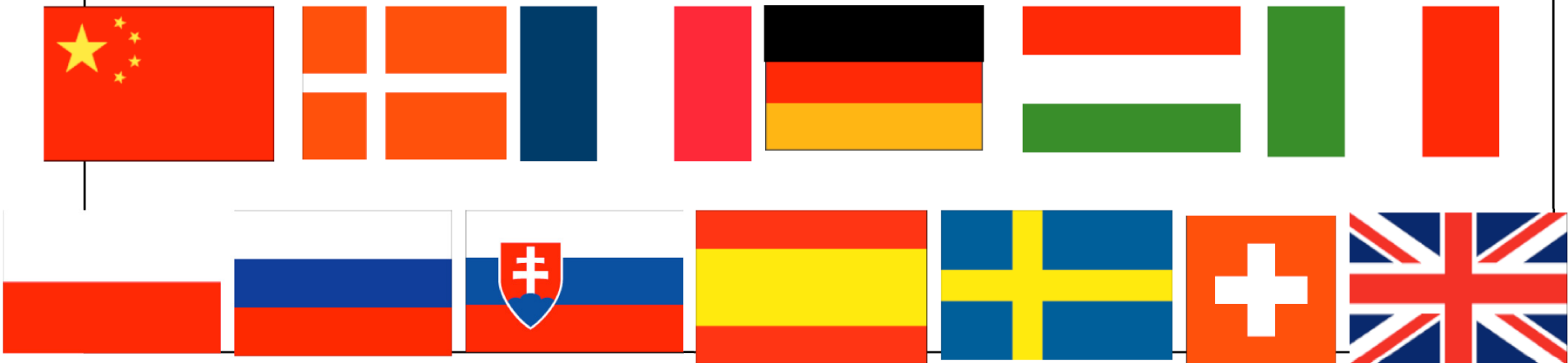
3 Photon diagnostics

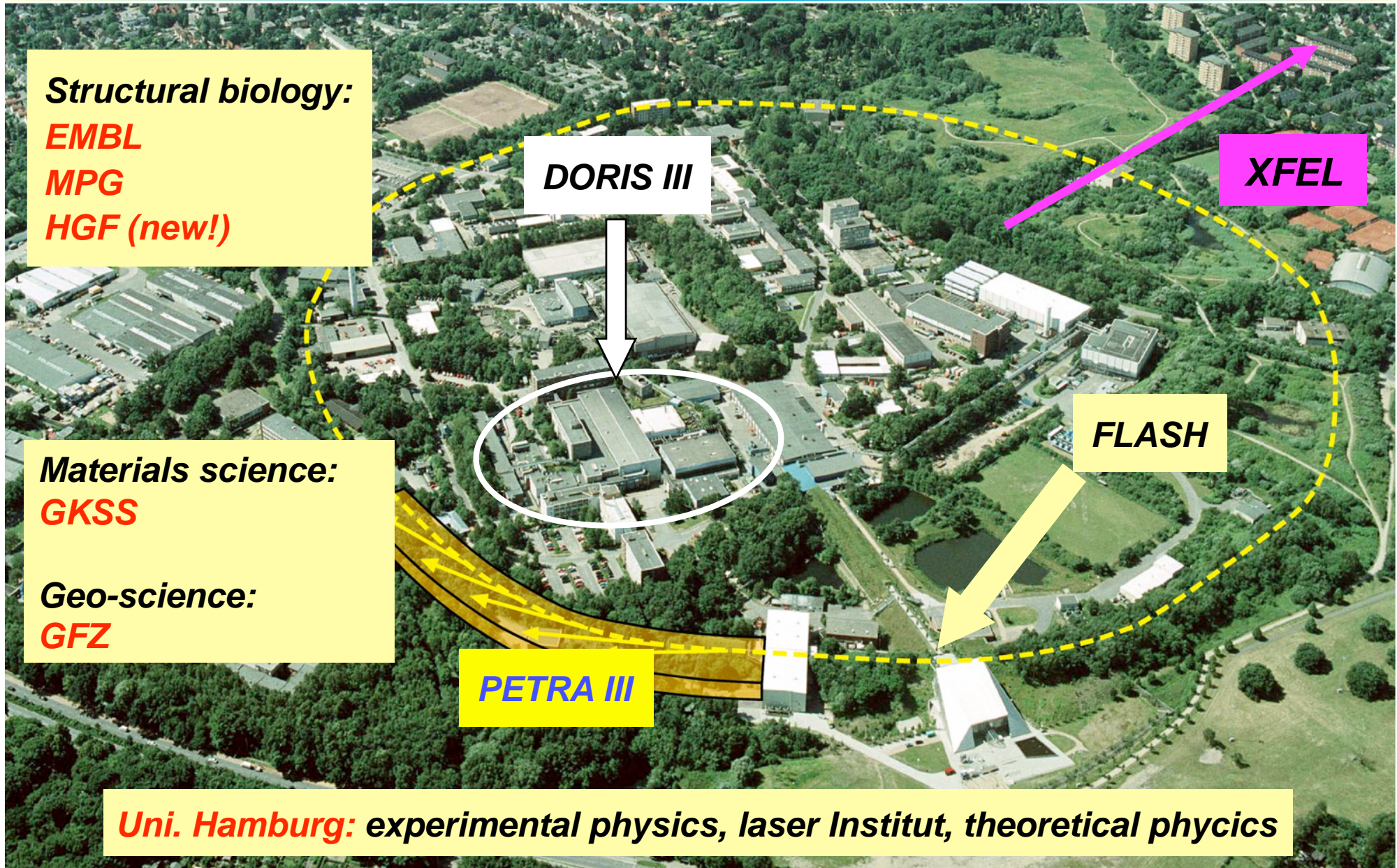
3 Photon beamline

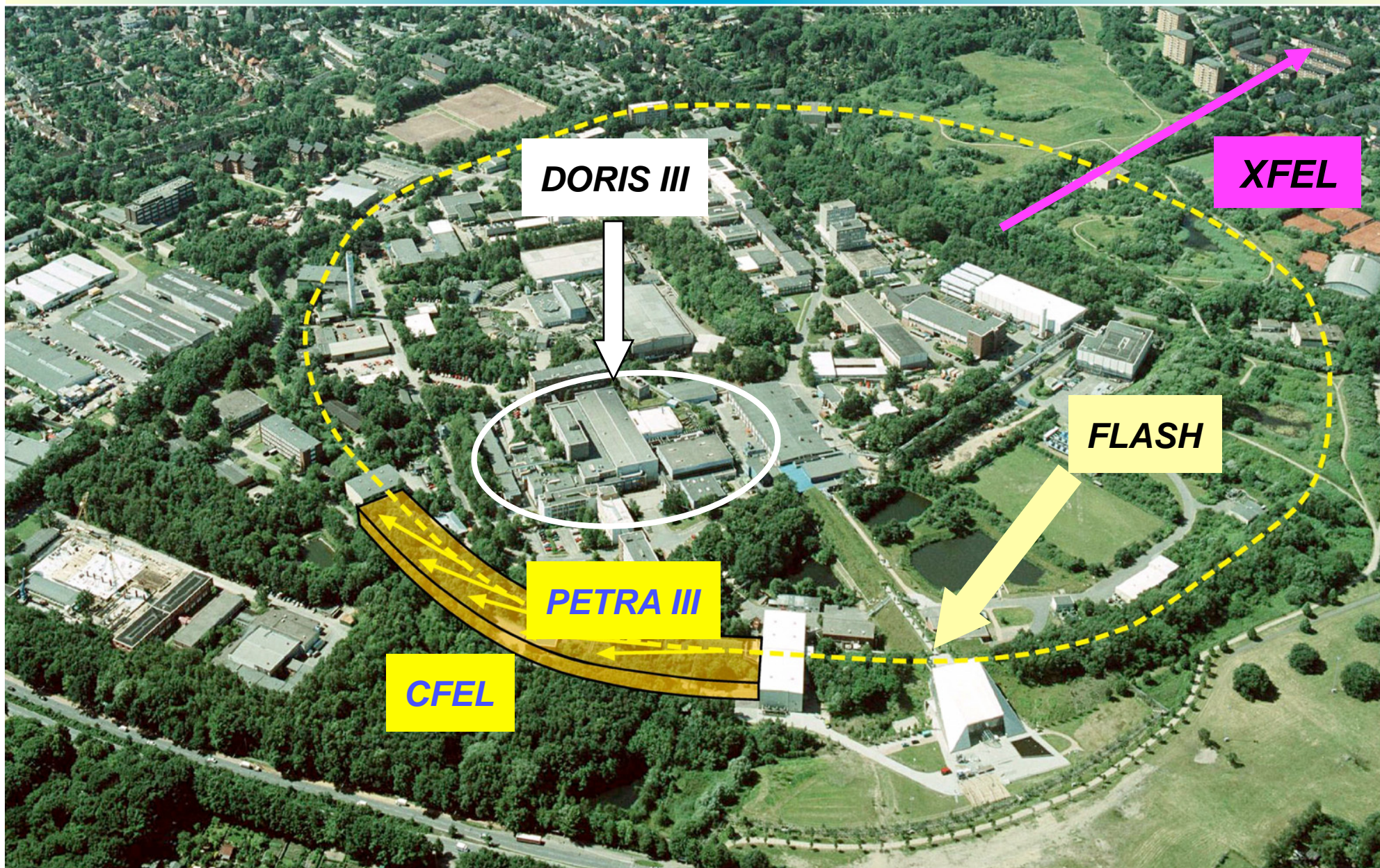
6 Instruments

2 Detectors (2D-area)

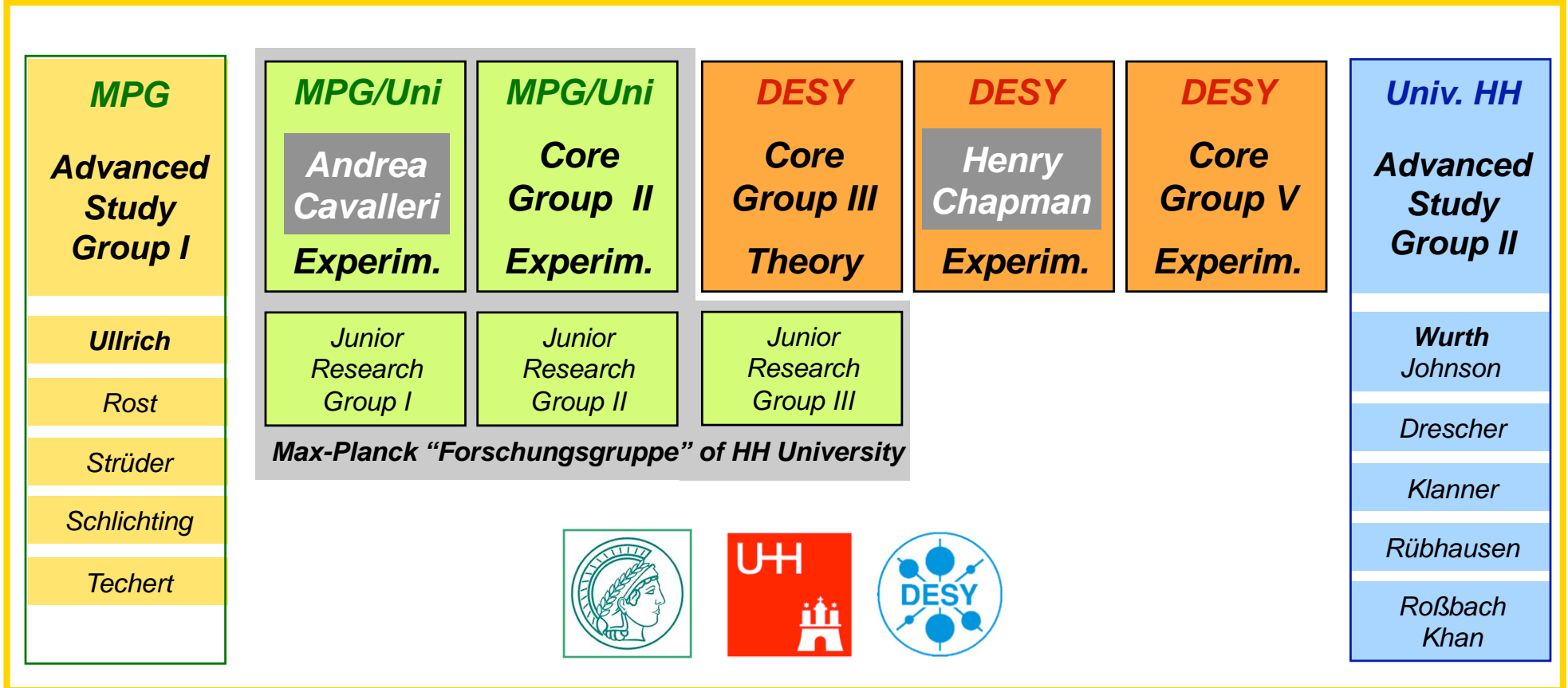
- Preparations are underway for the foundation of a company with research institutes of the different countries as shareholders, the European XFEL GmbH (probably June 2008)
- Construction and operation of the XFEL is entrusted to this company





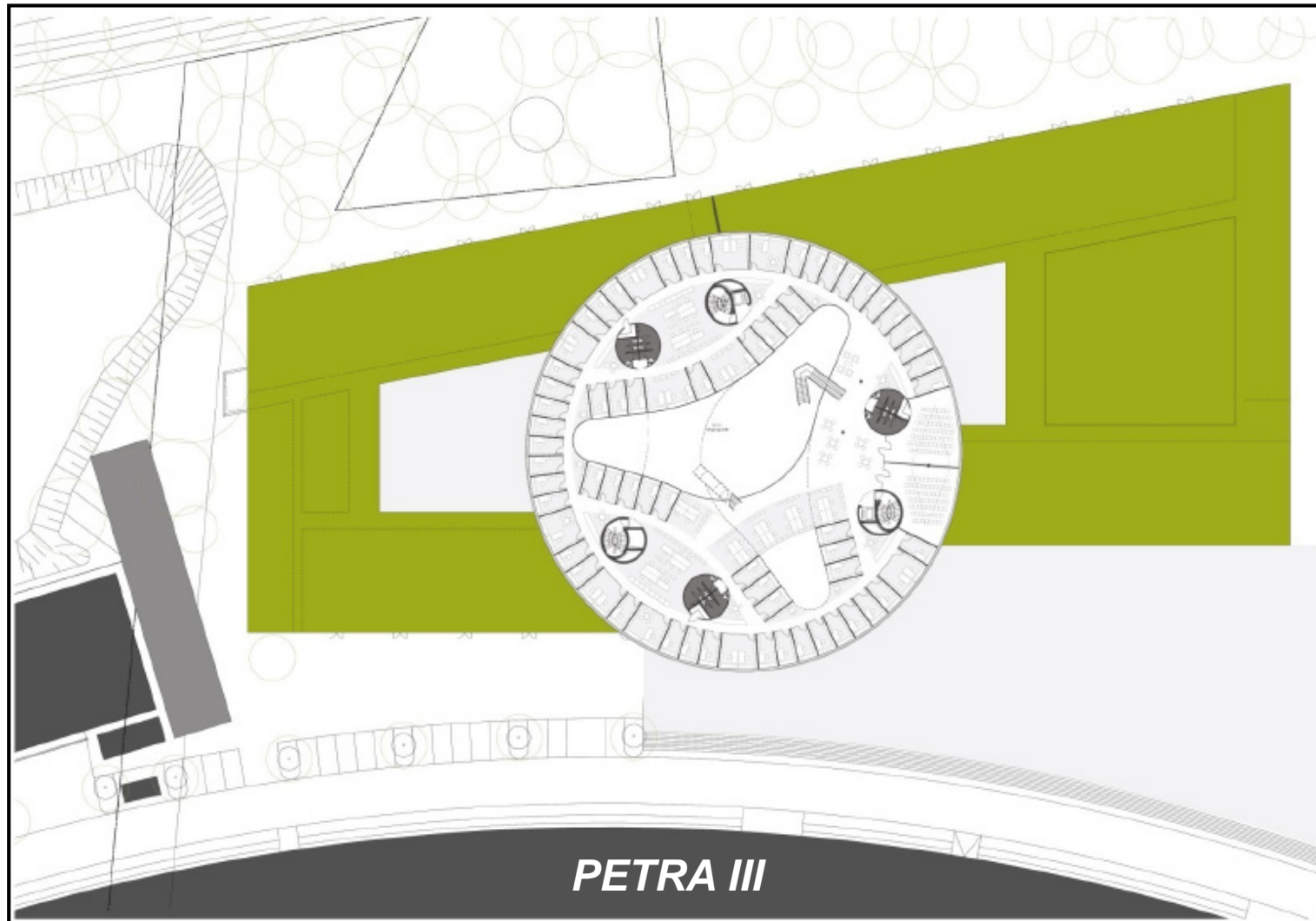


Center for Free-Electron Laser Science (CFEL) MPG, DESY, and University of Hamburg



In 2010 a new building available for ~300 people, annual budget ~15 M€

CFEL building



hammeskrause architekten

CFEL building



hammeskrause architekten

- **Brilliant future for photon science at DESY**
- **Storage ring based sources for high flux as well as high brilliance applications**
- **FELs in the soft X-ray and hard X-ray regime for:**
 - **time resolved studies**
 - **coherence applications**
 - **ultra high intensity applications**
- **build up of an appropriate scientific environment**