Photons at DESY:
A coherent and bright perspective

Jochen R. Schneider

X-rays

Wilhelm Conrad Röntgen

X-rays have a wavelength of the same order of magnitude as the distance of atoms in matter

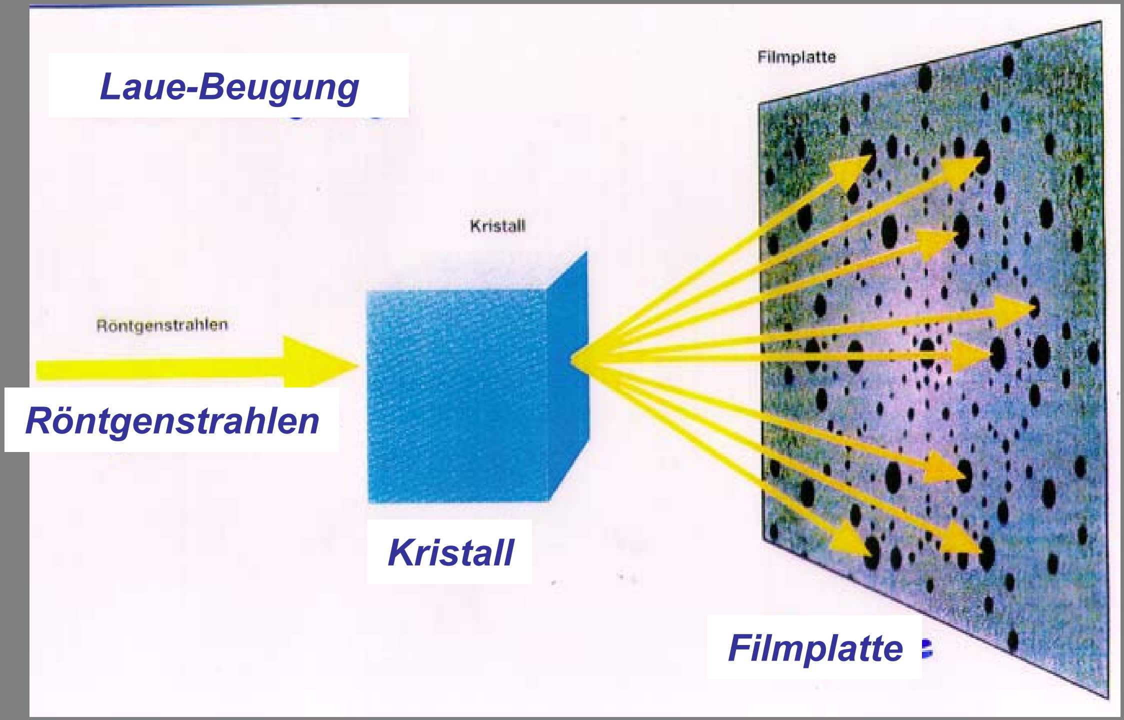
X-rays interact with the electrons

X-rays penetrate matter

X-rays are used to study the electronic and geometrical structure of matter

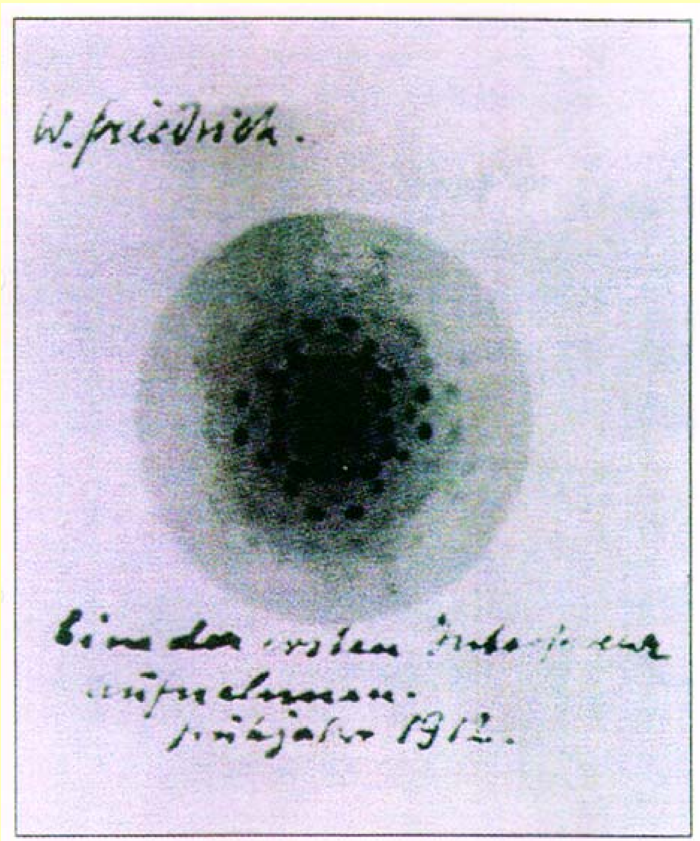
X-rays are applied in basic research and engineering science as well as in medicine

Röntgen-Strukturbestimmung

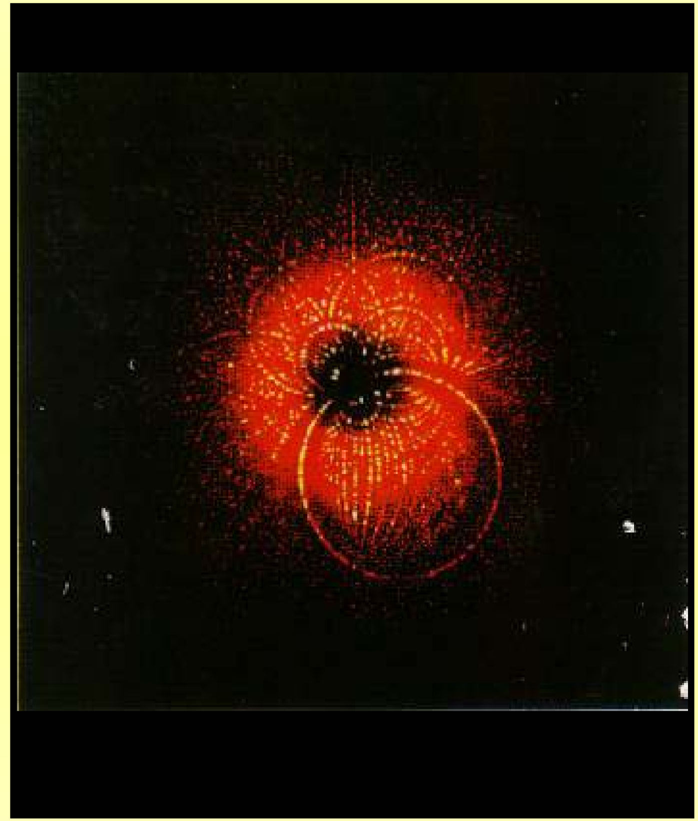


Bestimmung der Atomlagen aus den Intensitäten der Bragg-Reflexe

Laue Beugungsdiagramme

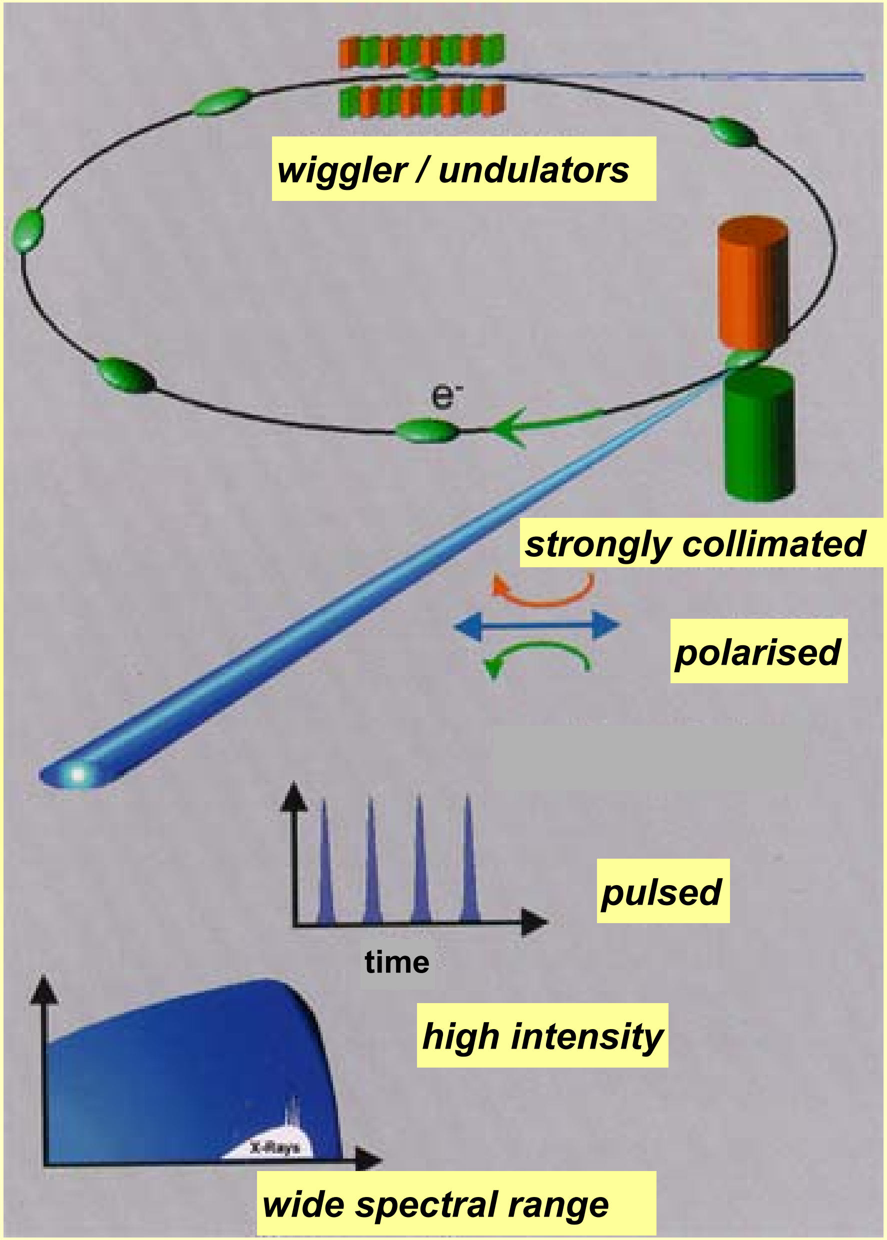


Erste Laue-Aufnahmen von
W. Friedrich, P. Knipping und M. von Laue
*an Mineral-Einkristallen im **Frühjahr 1912***



Laue-Aufnahme an
*Kohlen-Monoxyd-Myoglobin in **150 psec***
(M. Wulff et al., ESRF-Grenoble)

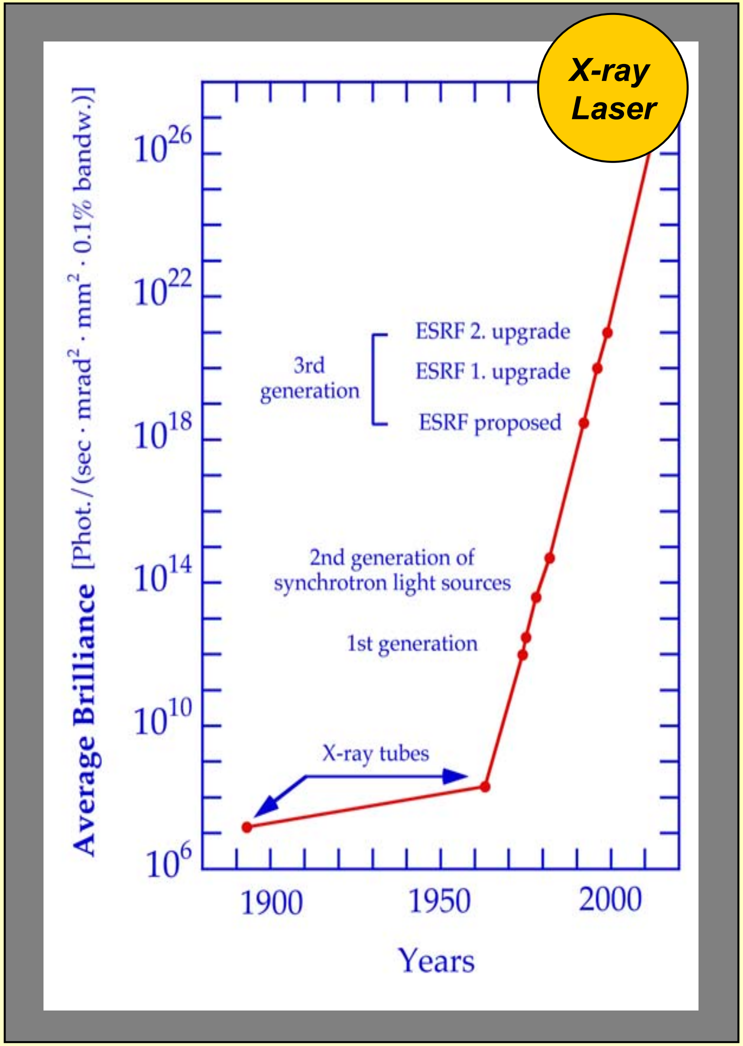
So far, the pace of progress in X-ray sciences has been closely tied to the development of ***synchrotron radiation sources****,*
where 3 orders of magnitude in brilliance were gained every 10 years since 1960.



European Synchrotron Radiation Facility

European flagship for hard X-ray sciences

Development of the brilliance of X-ray sources



Since the discovery of X-rays in 1895 the brilliance increased by more than 3 orders of magnitude every 10 years

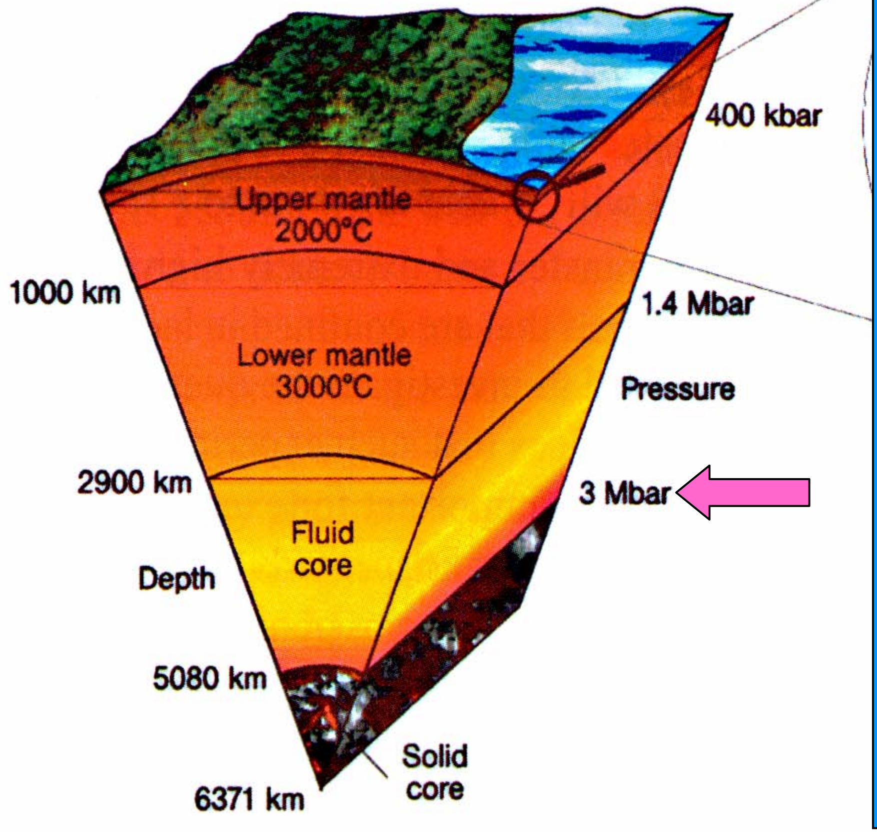
New generations of X-ray sources

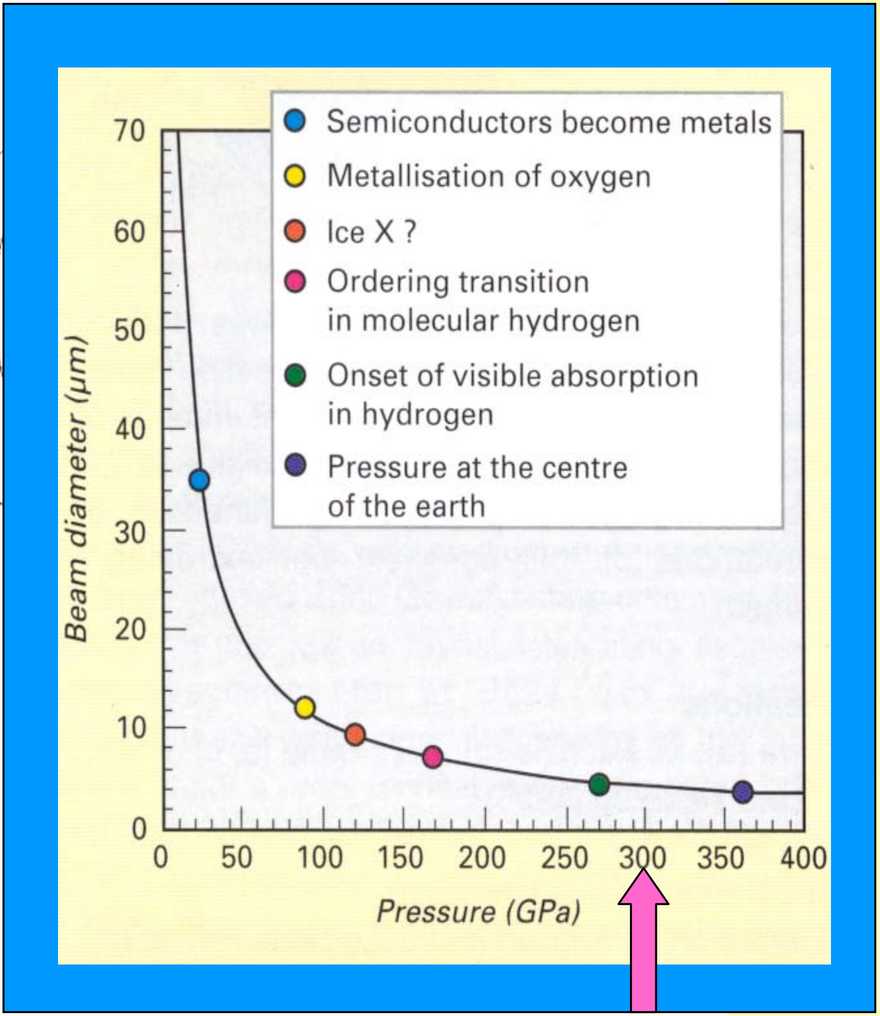
Open new opportunities for sciences without making the established work on older facilities less valuable

As a result: steady increase of synchrotron radiation users

Diffraction under extreme pressure

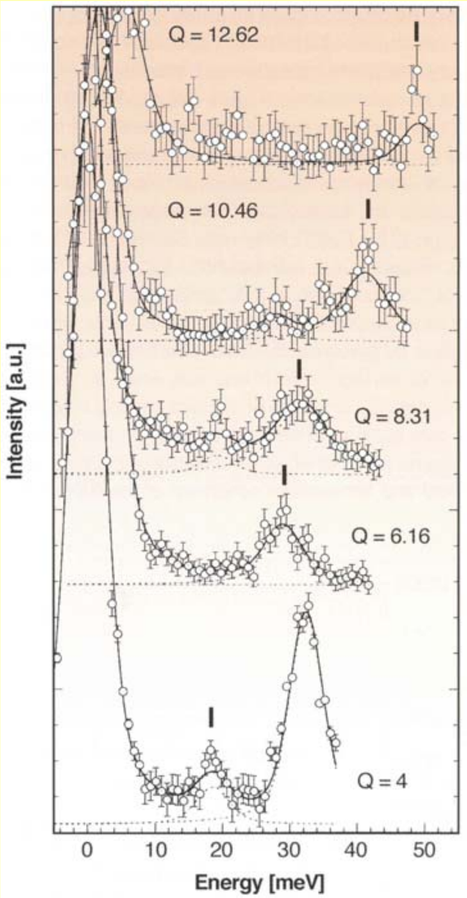
The smaller the sample the larger is the achievable pressure



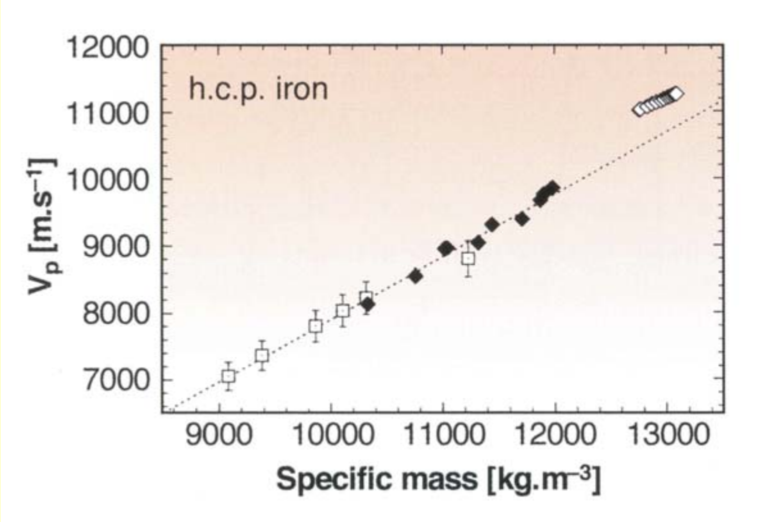


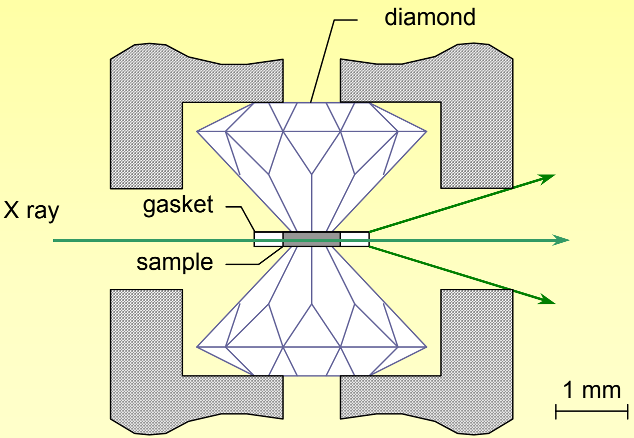
Inelastic scattering under high pressure

Speed of sound of Fe under pressure (ESRF: 2 ph/min)



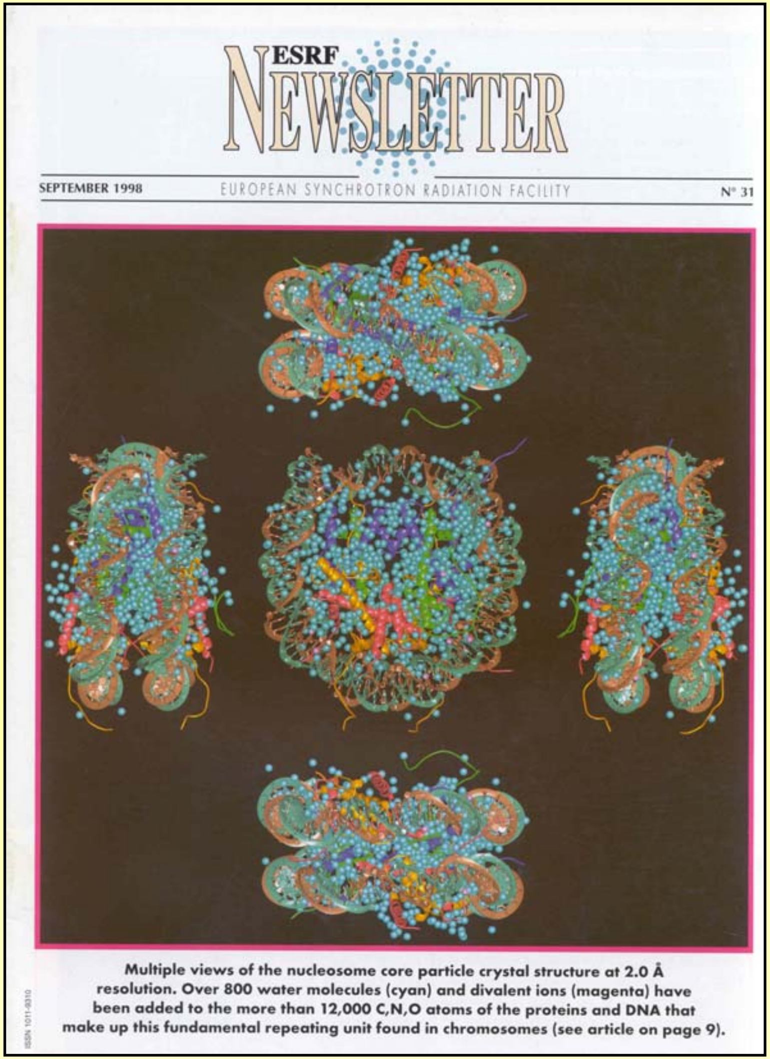
P=28GPa





G. Fiquet et al., Science (accepted)

Microfocus application (diffraction)


ESRF NEWSLETTER

SEPTEMBER 1998 — EUROPEAN SYNCHROTRON RADIATION FACILITY — N° 31

Multiple views of the nucleosome core particle crystal structure at 2.0 Å resolution. Over 800 water molecules (cyan) and divalent ions (magenta) have been added to the more than 12,000 C,N,O atoms of the proteins and DNA that make up this fundamental repeating unit found in chromosomes (see article on page 9).

nucleosome core particle

K. Luger, A.W. Mäder, R.K. Richmond, D.F. Sargent and T.J. Richmond, Nature, 389, 251-260 (1997).

Life sciences/Structural Biology

30S ribosomal subunit:

Small crystals:

- Micro focus and still small divergence

Large complexes:

- Extremely intense and parallel radiation

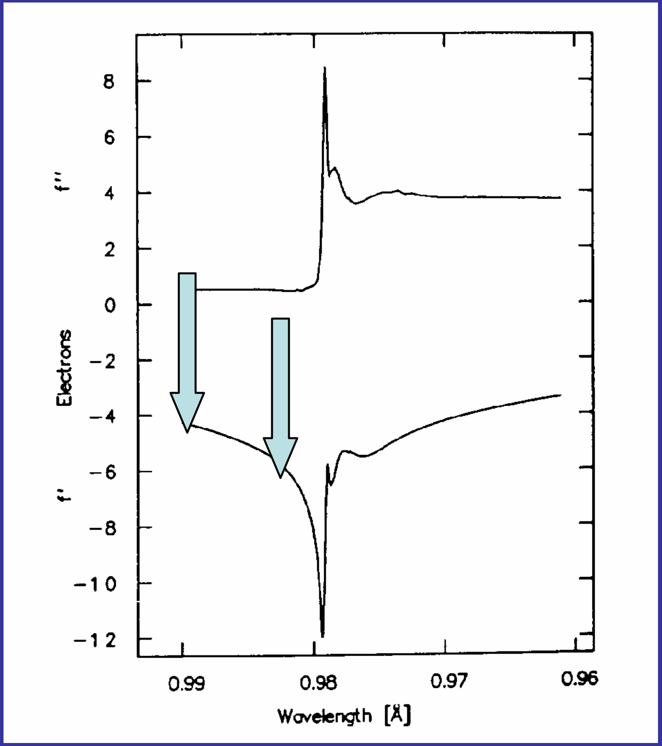
Optimum anomalous signal:

- High energy resolution and stability

F. Schlünzen, R. Zarivach, J. Harms, A. Bashan, A. Tocilj, R. Albrecht, A. Yonath, Nature 413 (2001) 814-821

Beugungsexperimente mit Synchrotronstrahlung

Resonante Streuung am Se Atom



Wellenlänge →

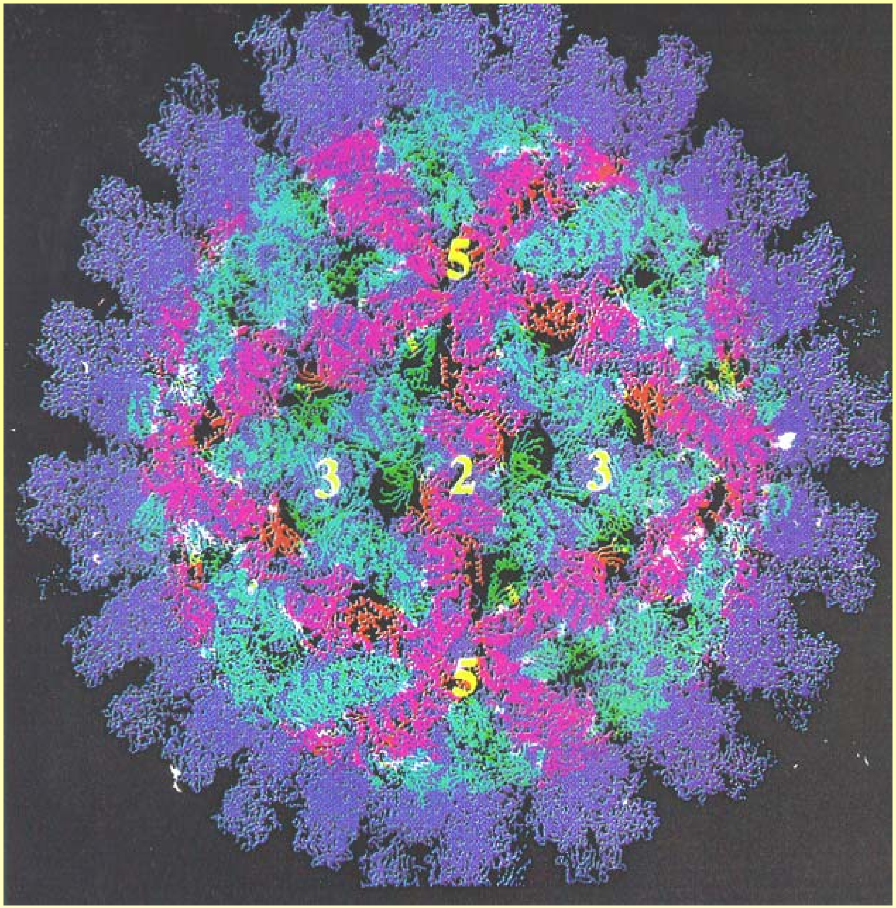
Mittlere Leuchtstärke

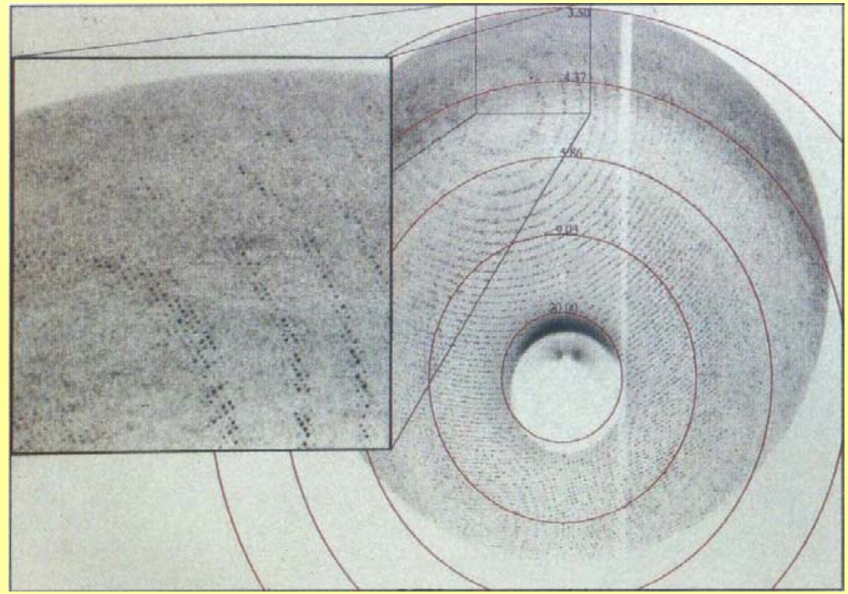
~10^{21} Photonen/sec/#

Energieauflösung ΔE/E im 0,001 Bereich

~10^{13} Photonen/sec auf Probe

Structure of a Virus

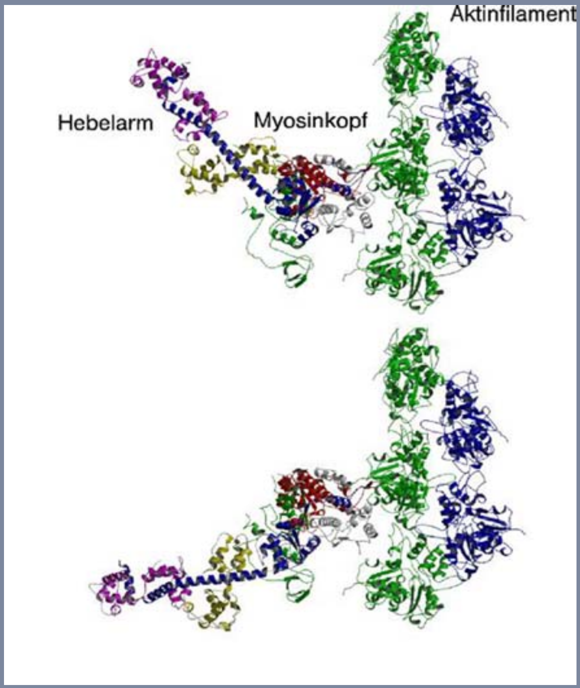




core particle of the
blue-tongue virus
David Stuart et al., ESRF data

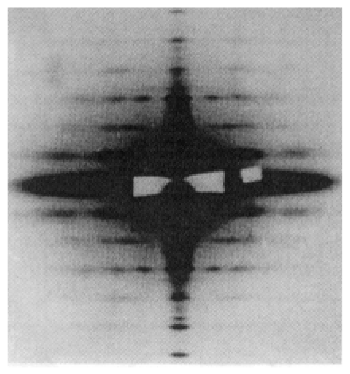
Synchrotron-Strahlung in der Biologie

Muskeln bewegen alles,
aber wie bewegt sich ein Muskel?



es begann bei DESY:

G. Rosenbaum, K.C. Holmes & J. Witz
Nature 230 (1971) 434-437



Zeit aufgelöste Klein-Winkel-Streuung

History

1964 1^{st} SR Laboratory at DESY Synchrotron

1973 1^{st} EMBL Laboratory at DESY

1974 SR Laboratory at DORIS storage ring

1981 HASYLAB experimental hall

1986 HARWI experimental hall

1987 MPG unit for structural molecular biology

1991 Start of operation of DORIS III

1992 HASYLAB wiggler laboratory

1993 DORIS III becomes dedicated SR source

1995 SR from an undulator at PETRA II

2000 Demonstration of SASE at TESLA Test Facility

2001 1^{st} experiment at TTF SASE FEL

2003 Decision of German Government to support PETRA III and the European XFEL Laboratory in Hamburg

Some early scientific highlights

- *First precise determination of absorption coefficients*
- *X-ray small angle scattering from muscles*
- *Photo-electron yield spectroscopy*
- *X-ray interferometry*
- *X-ray microscopy with zone plates*
- *Mößbauer spectroscopy with synchrotron radiation*
- *Scattering from liquid surfaces*
- *Studies of surfaces and interfaces with standing waves*
- *Inelastic scattering at eV and meV resolution*
- *Spin dependent absorption spectroscopy*
- *Coronary angiography*

Careers starting at DESY-HASYLAB

- *Wolfgang Eberhardt (Director BESSY)*
- *Wolfgang Gudat (Director BESSY)*
- *Ruprecht Haensel (Director General ESRF)*
- *Ernst E. Koch (Director BESSY)*
- *Helmut Krech (Admistrative Director BESSY, DESY, ESRF)*
- *Christof Kunz (Research Director ESRF)*
- *Gerhard Materlik (CEO Diamond)*
- *Gottfried Mühlhaupt (Machine Director BESSY, ESRF, SLS)*
- *Volker Saile (Director CAMD)*
- *Alwin Wrulich (Machine Director Elettra, SLS)*

Professors at Universities:

R. Frahm (Wuppertal), T. Brückel (FZJ-Aachen), J. Falta (U. Bremen),

Research with Photons at DESY

Storage ring based facilities

DORIS III:
Experiments needing high photon flux

PETRA II:
high brilliance test beamline

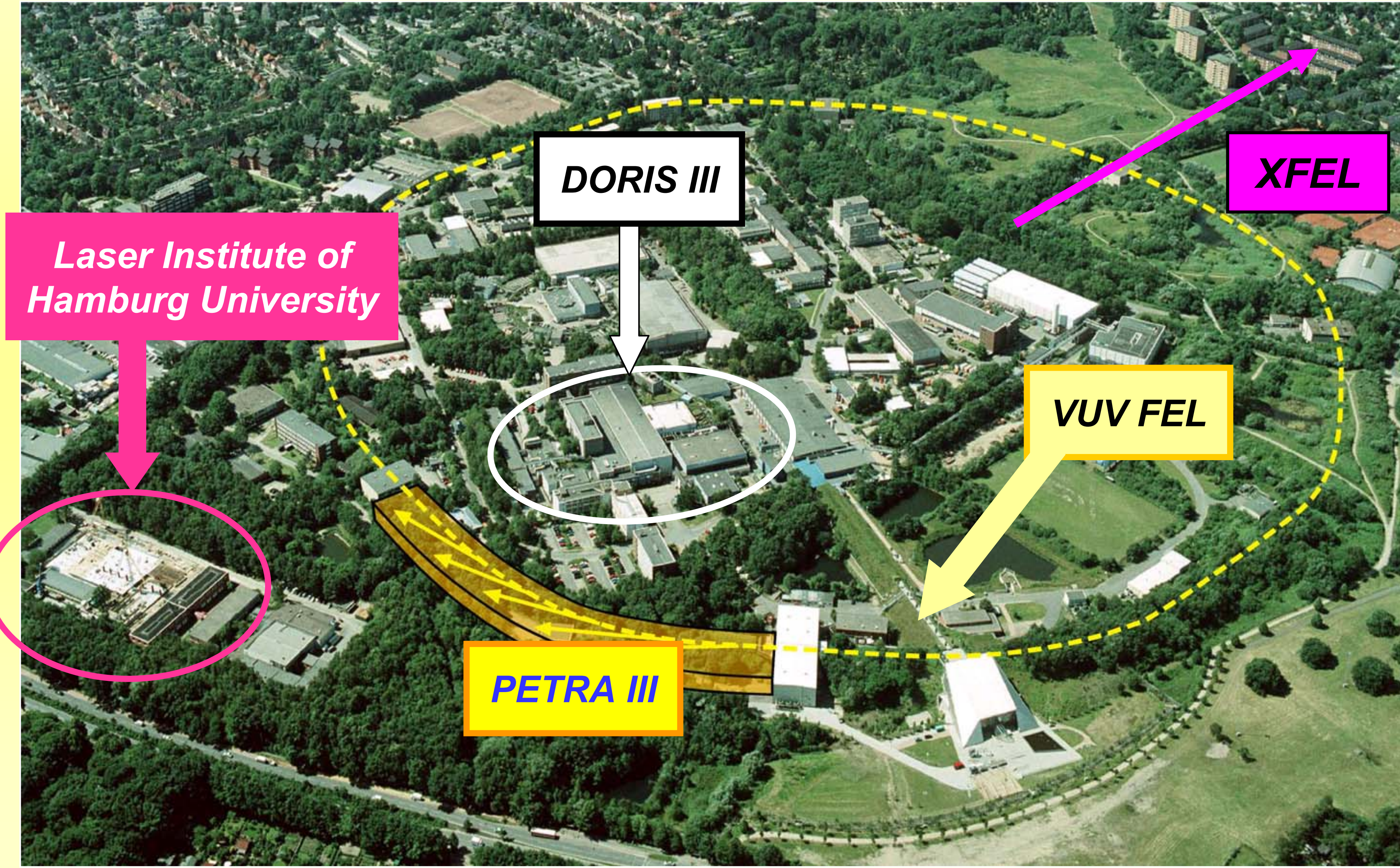
PETRA III:
Project
Optimized for high brilliance

LINAC based facilities

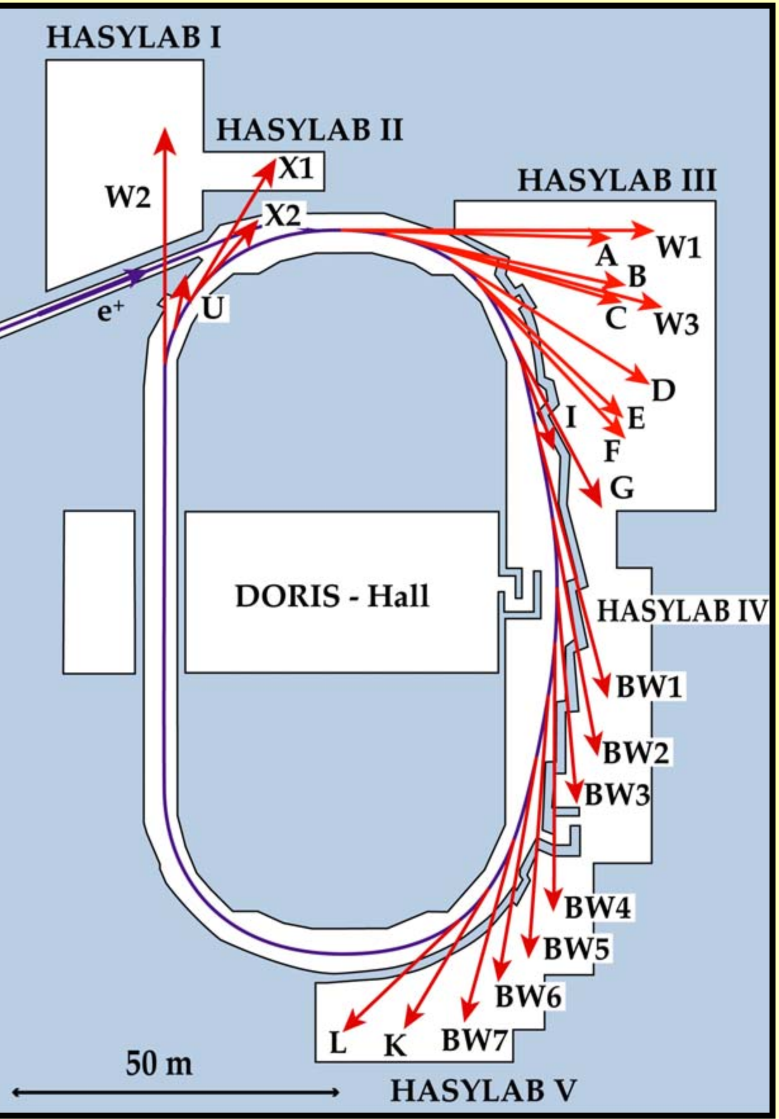
VUV FEL:
wavelengths from ~6 to 100 nm

European X-FEL Laboratory:
Project
wavelengths from ~0.085 to 6 nm

Research with photons at DESY



HASYLAB operation



DORIS III:

40 beamlines
76 experimental stations

7 stations operated by EMBL Outstation

1 station operated by MPG

10 stations operated with support from external institutions (Verbundforschung)

PETRA II:

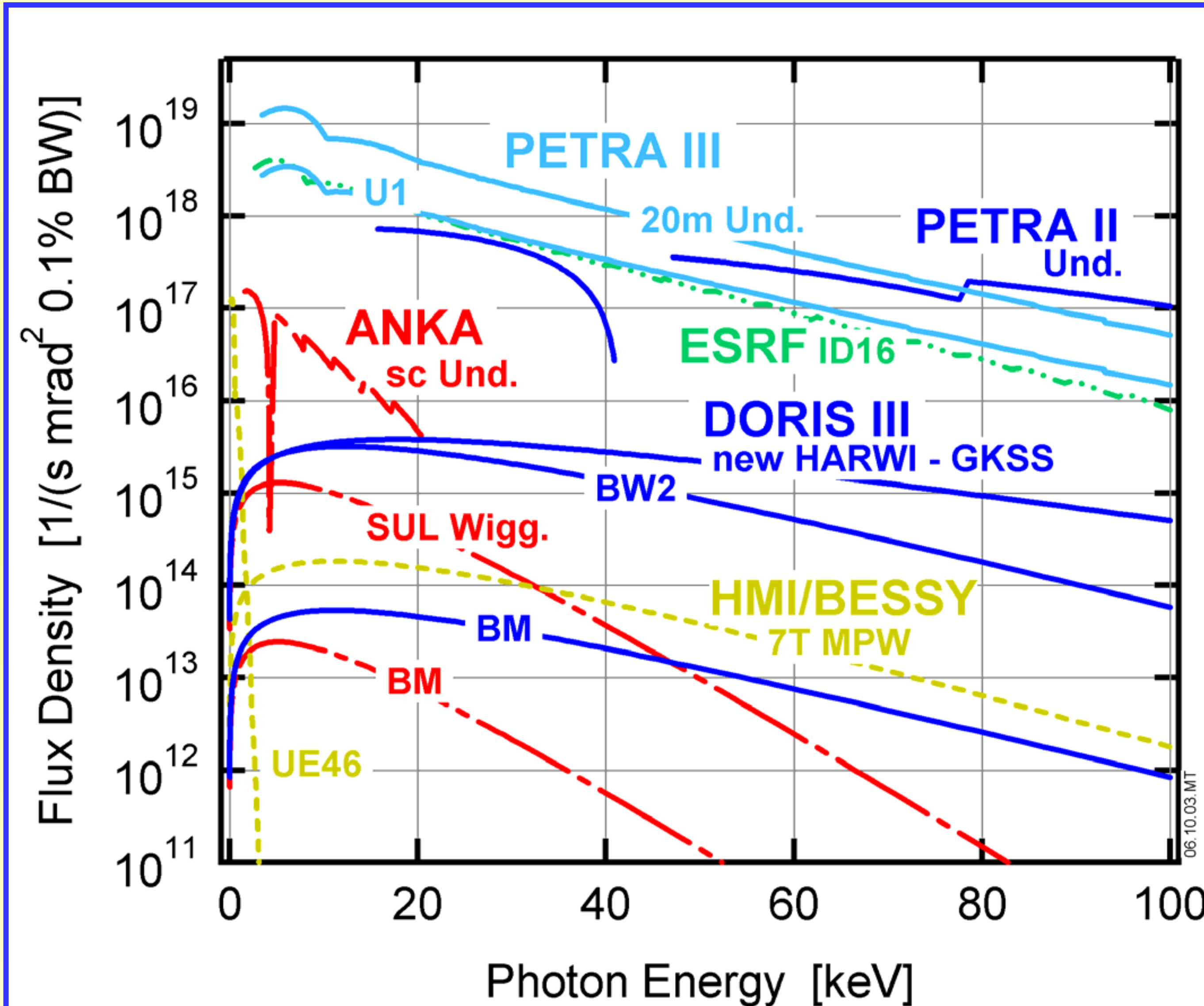
1 test beamline
2 experimental stations

HASYLAB staff in 2003

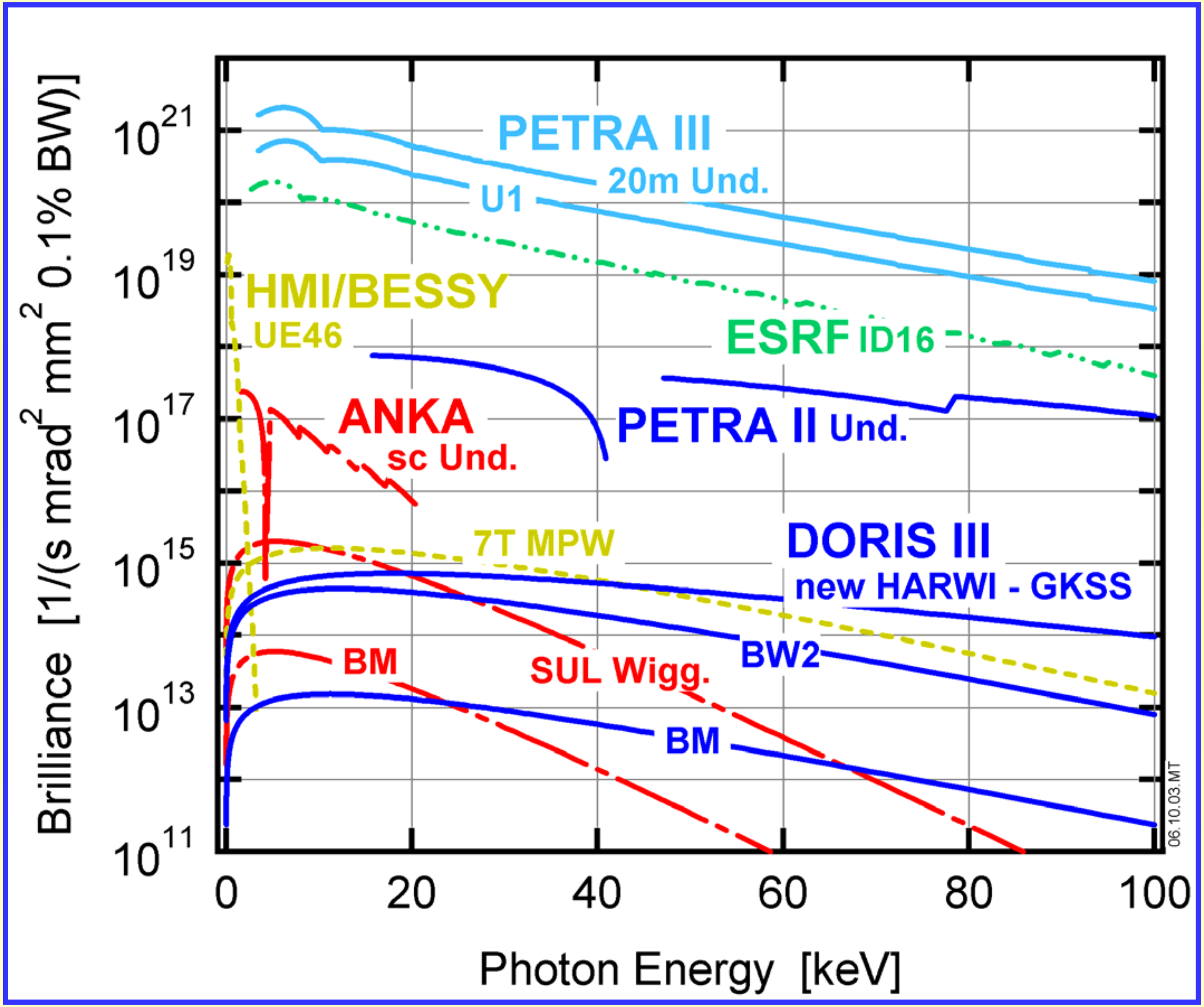
27 (17) scientists
31 (6) engineers and technicians
6 management, administration, secretariat

+ DESY infrastructure, machine operation and general administration

Flux density at storage ring facilities

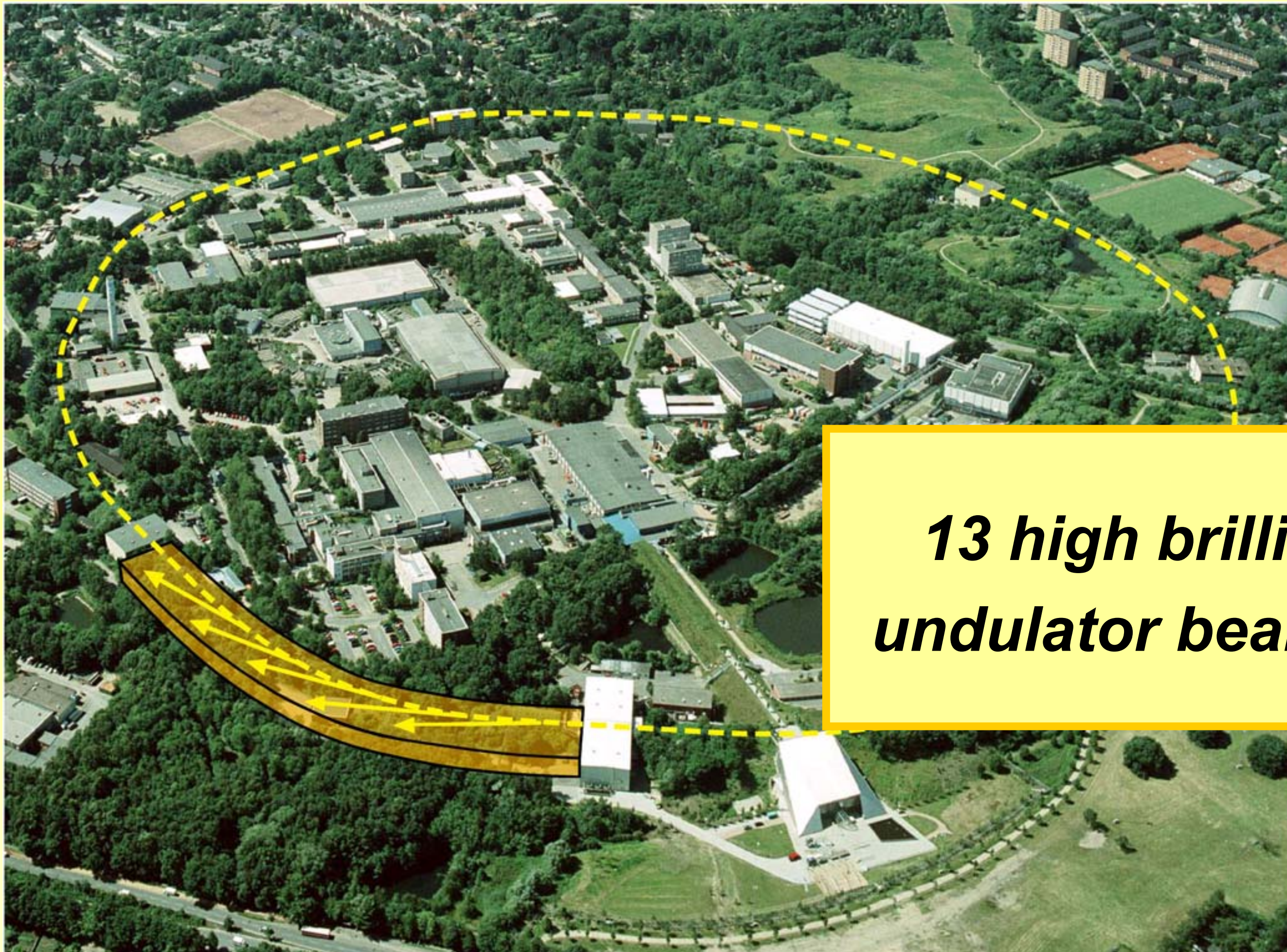


Brilliance at storage ring facilities



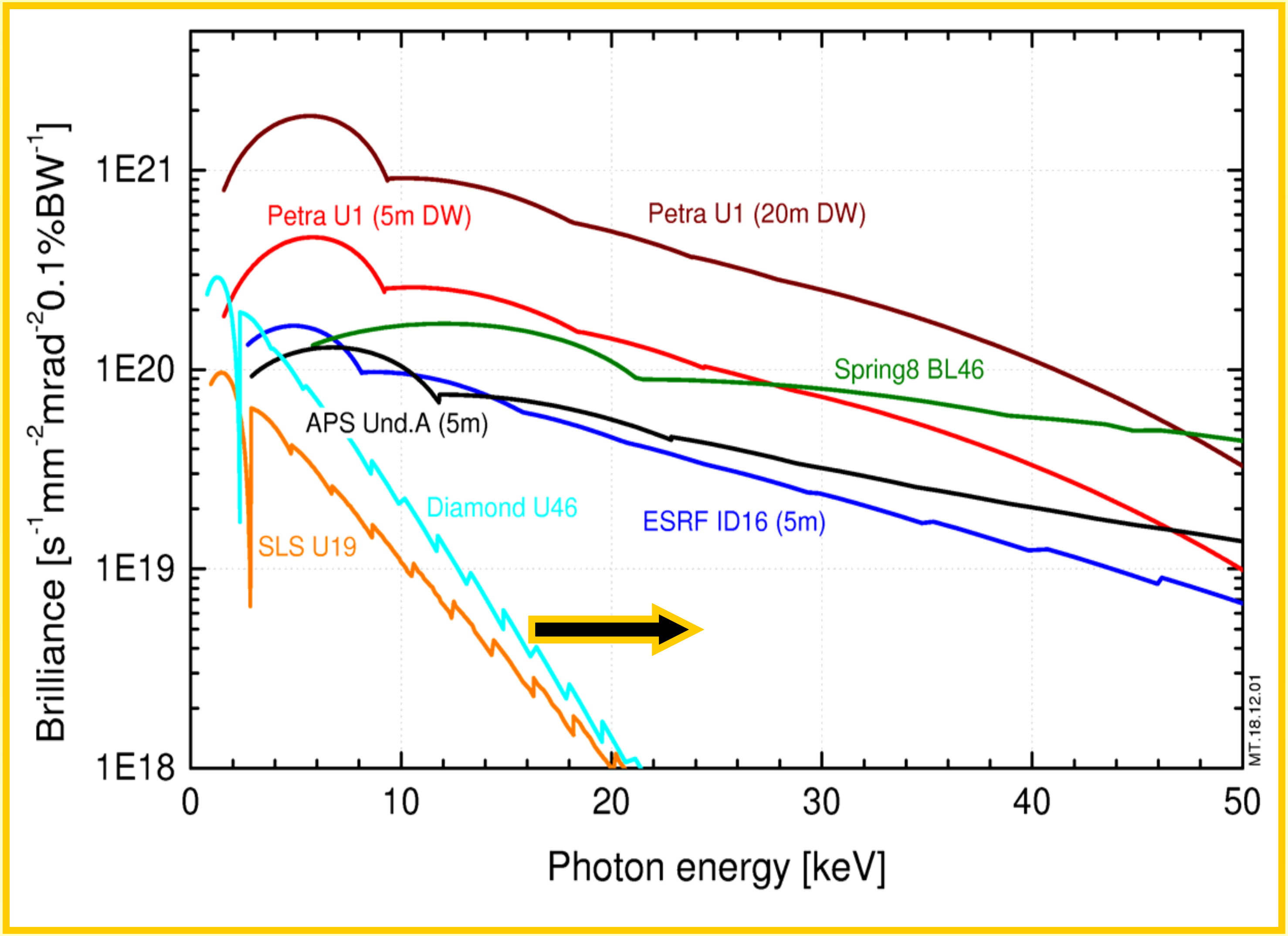
Project

PETRA III synchrotron radiation facility



13 high brilliance undulator beamlines

PETRA III: brilliance comparison



Time Resolved Studies

Probing matter with atomic resolution

Present day X-ray and neutron experiments probe in most cases equilibrium states of matter.

The next goal is to probe the dynamic state of matter with atomic resolution in space and time in order to allow for studies of non-equilibrium states, and very fast transitions between the different states of matter.

Schotte et al., Science 300, 1944 (2003)

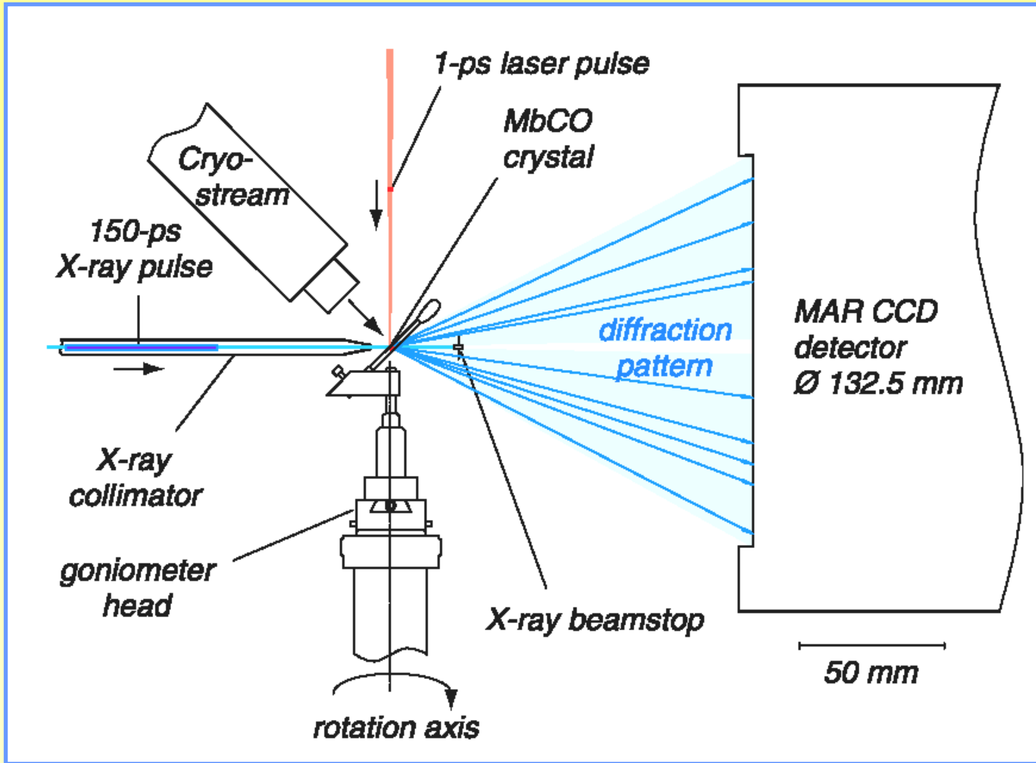
ID 09 B

Watching a Protein as it Functions with 150-ps Time-Resolved X-ray Crystallography

Friedrich Schotte,[1] Manho Lim,[2] Timothy A. Jackson,[3] Aleksandr V. Smirnov,[1] Jayashree Soman,[4] John S. Olson,[4] George N. Phillips Jr.,[5] Michael Wulff, [6] Philip A. Anfinrud[1]

X-ray pulses (~150 psec, ~1010 photons, 0.1mm²) from ESRF ID09B in “single bunch” mode.

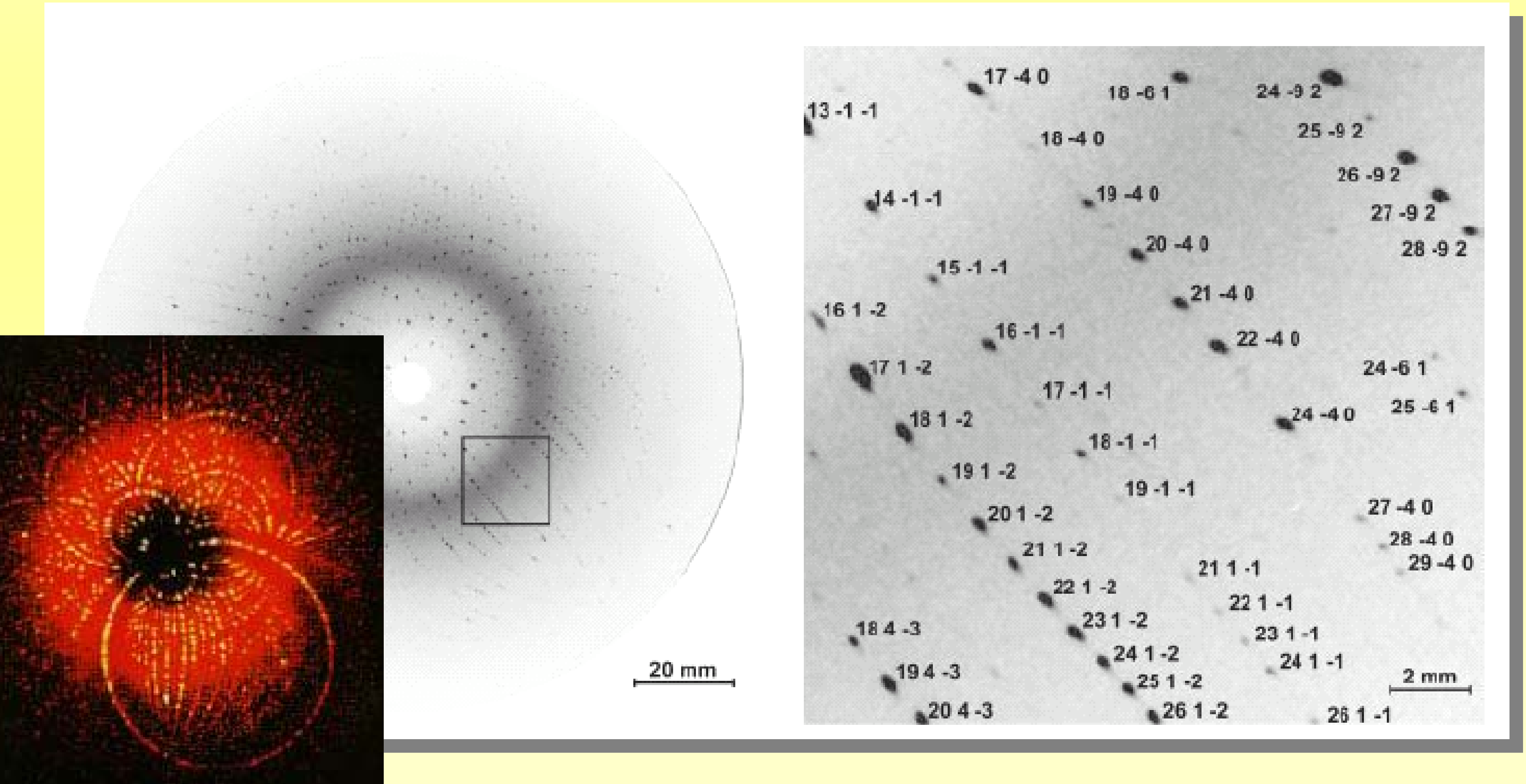
Laser pump pulses (570 nm, 1 psec, 23 µJ) induced photo-dissociation, better than 50 psec time jitter.



Schotte et al., Science 300, 1944 (2003)

MbCO photodissociation dynamics

Myoglobin Laue data (3.5% bw, 15.6 keV) recorded on CCD



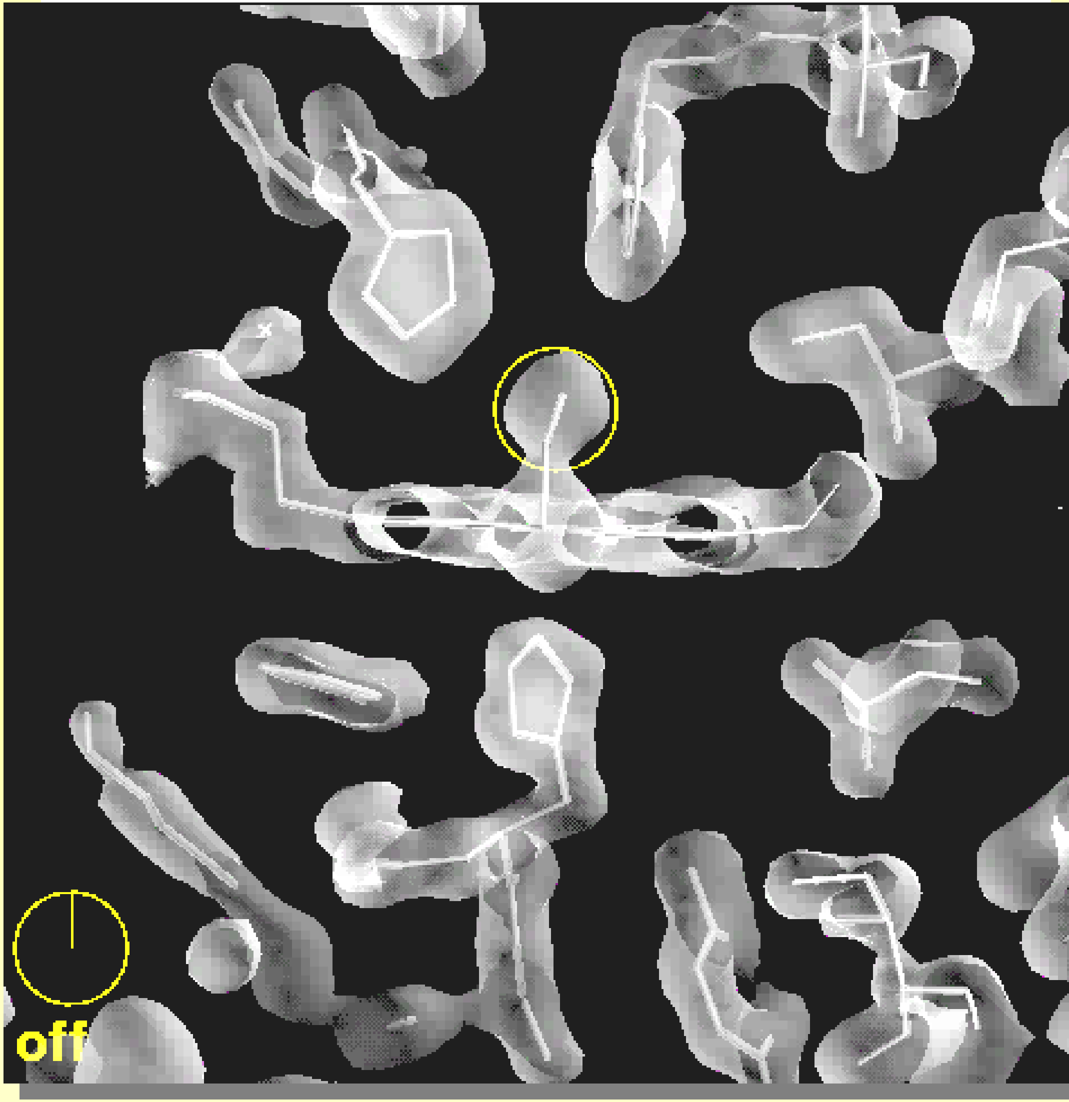
Schotte et al., Science 300, 1944 (2003)

MbCO photodissociation dynamics

Myoglobin

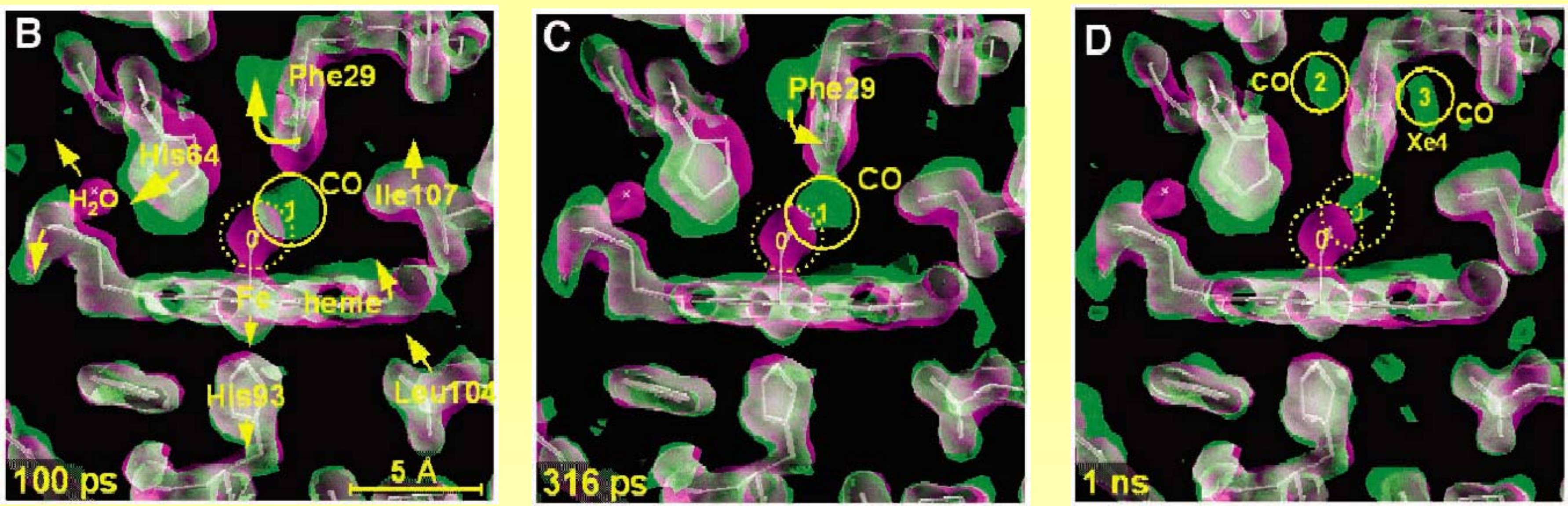
Correlated motions of heme, protein backbone and side chains already evident at 100 psec

Early displacements of side chains much more dramatic than static differences between Mb and MbCO



Schotte et al., Science 300, 1944 (2003)

Watching a protein as it functions



100 psec

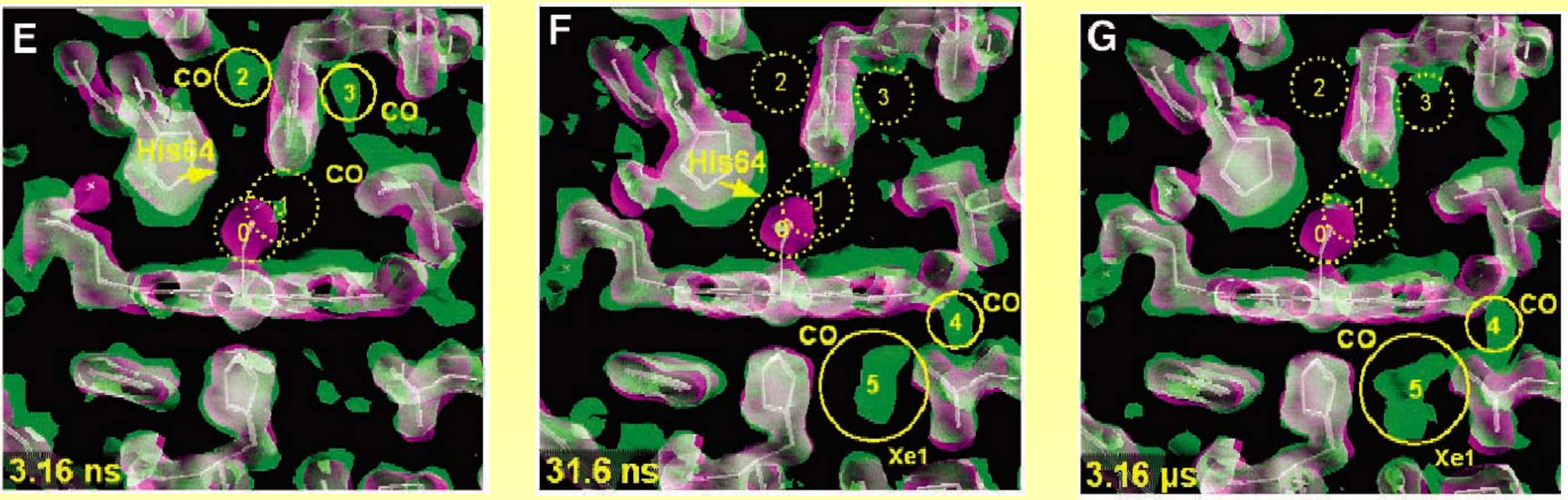
316 psec

1000 psec
1 nsec

MbCO photodissociation dynamics

Schotte et al., Science 300, 1944 (2003)

Watching a protein as it functions



3.6 nsec

31.6 nsec

3160 nsec
3,16 µsec

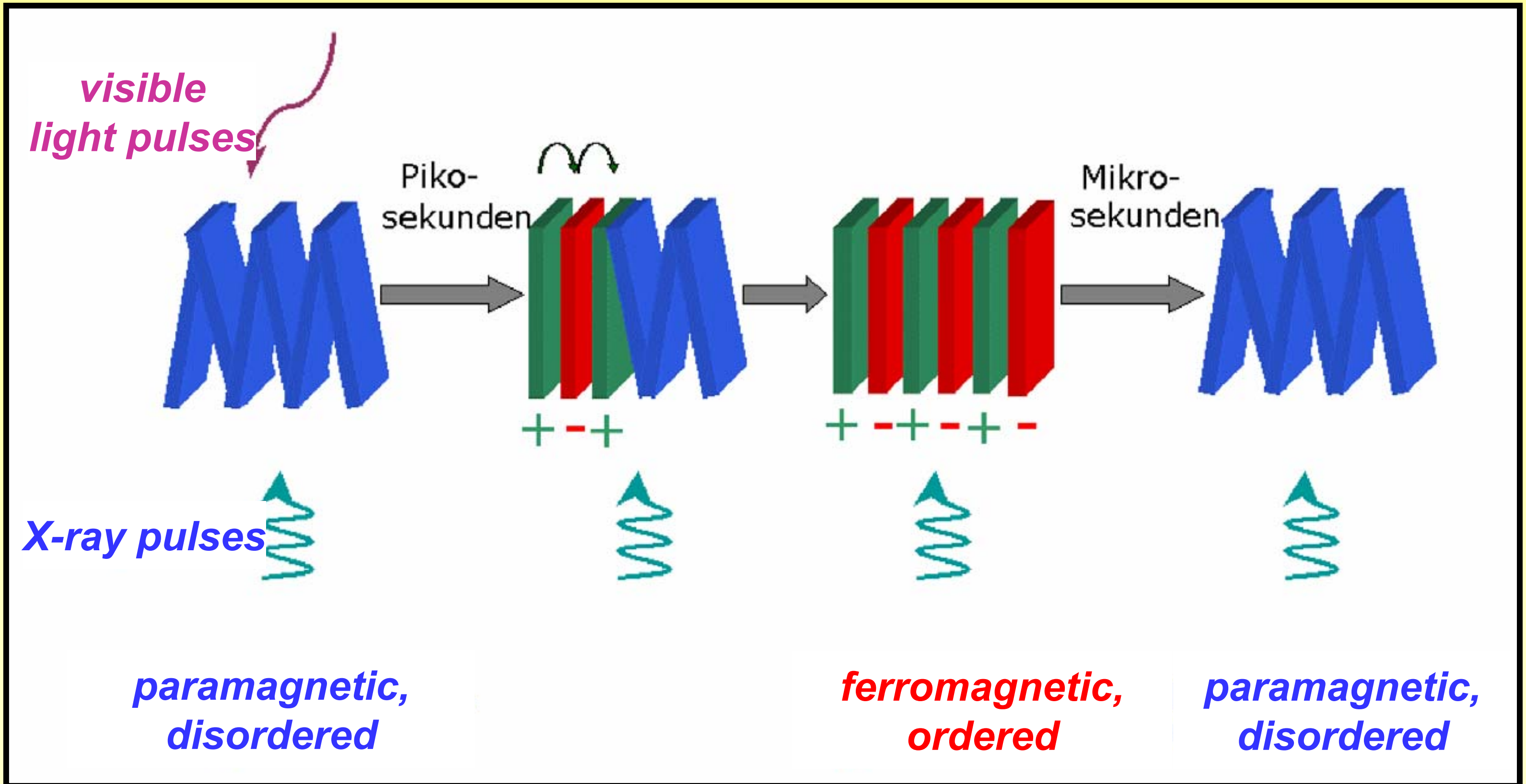
MbCO photodissociation dynamics

Laser-induced ferroelectric structural order in an organic charge-transfer crystal

tetrathiafulvalene-p-chloranil

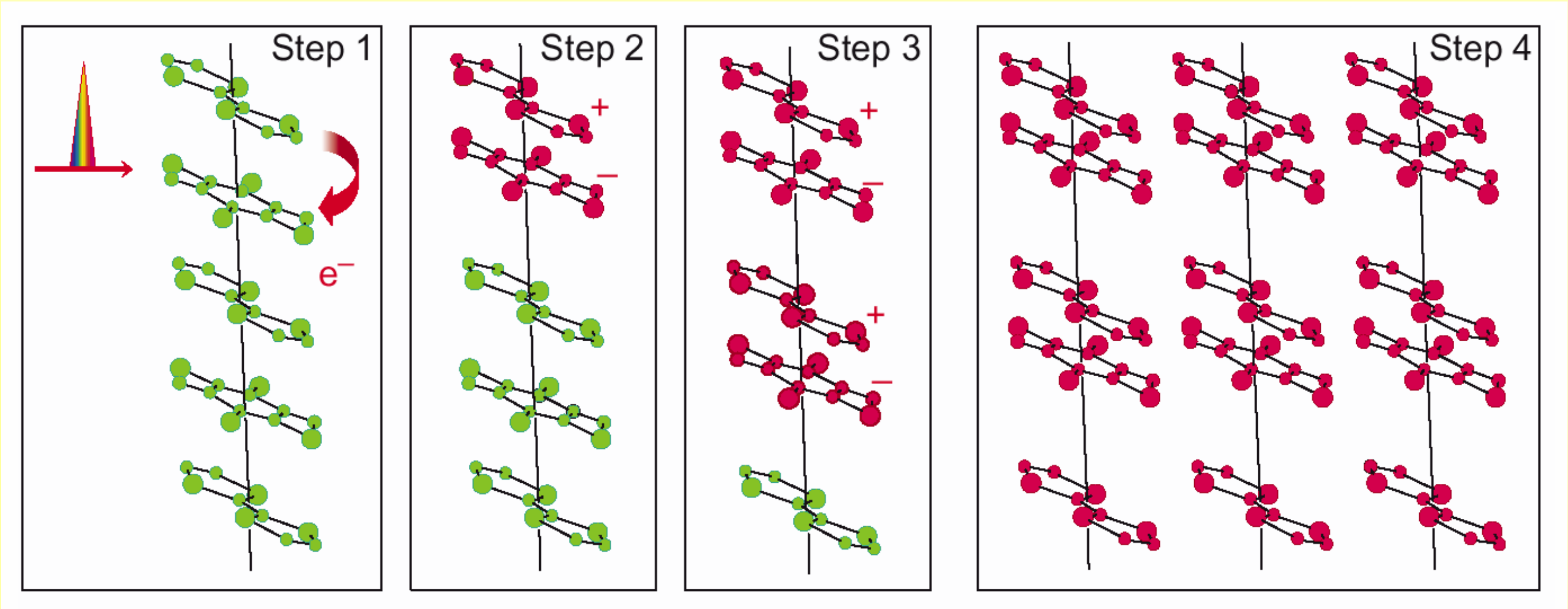
E. Collet, M.-H. Lemée-Cailleau, M. Buron-Le Cointe, H. Cailleau, S. Techert, M. Wulff, T. Luty, S.-Y. Koshihara, M. Meyer, L. Toupet, P. Rabiller

Science, Vol. 300, 25 April 2003, 612



Laser-induced ferroelectric structural order in an organic charge-transfer crystal

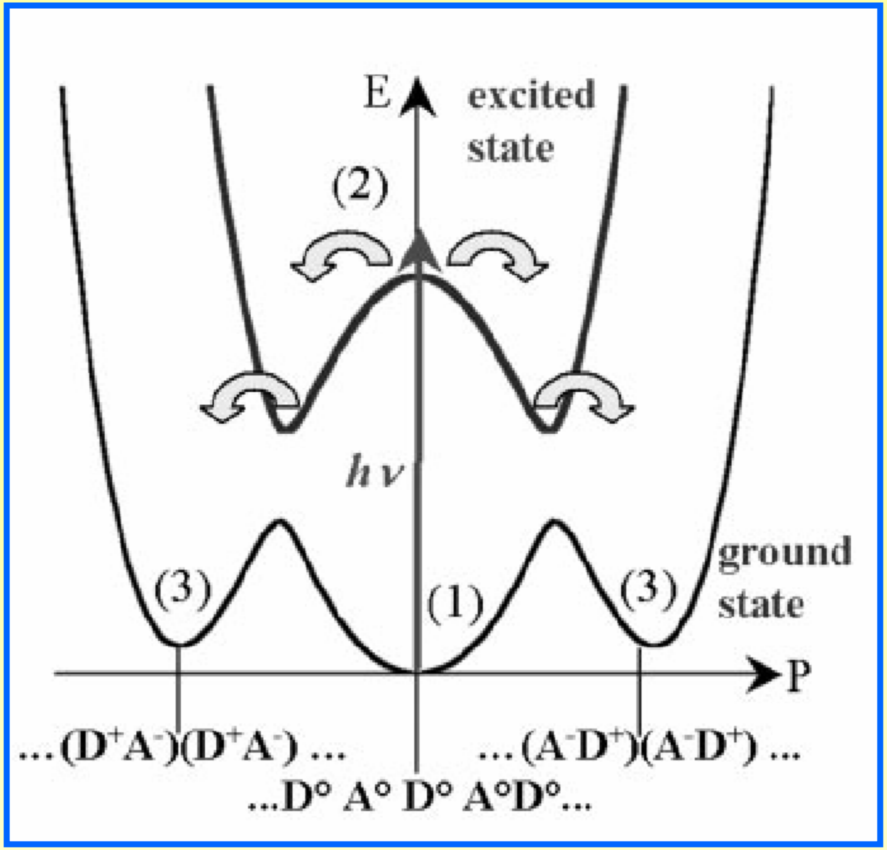
Collet et al, Science, Vol. 300, 25 April 2003, 612



1. an optical pulse excites a molecule
2. an intermolecular charge transfer occurs accompanied by a lattice relaxation, i.e. a dimerization process trapping the excitation
3. cooperative phenomena take place with the self-multiplication of the excited molecule in the stack
4. interstack interactions lead to the 3D ordering of the dimers, with a photon efficiency so high that one photon transforms a few hundred molecules

Photoinduced neutral-to-ionic transformation path along the polar order parameter P

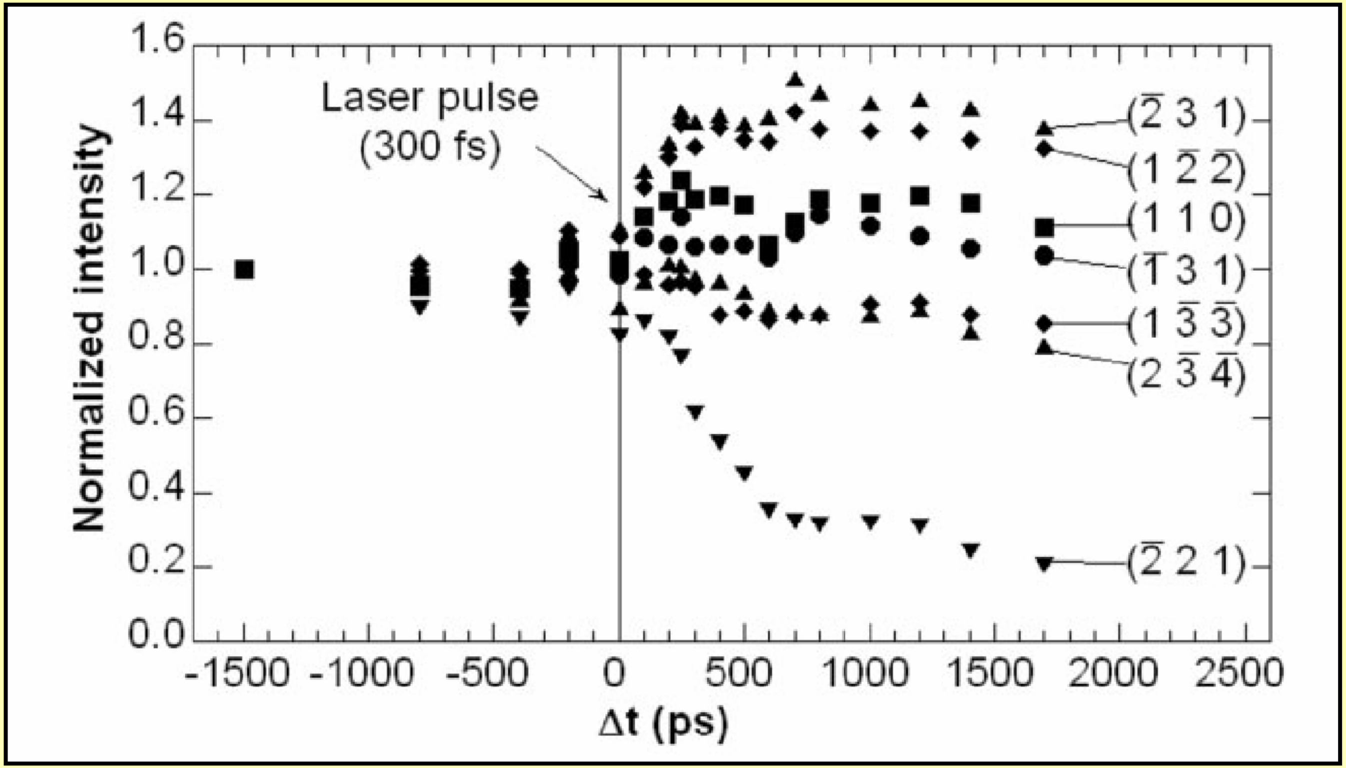
Collet et al, Science, Vol. 300, 25 April 2003, 612



1. *The stable neutral state is made of homogeneous, nonpolar neutral chains where electron donar (D) and acceptor (A) molecules are regularly stacked.*
2. ***Photons excite DA pairs into an ionic state inducing a lattice relaxation.***
3. *The coupling between the relaxed species makes the system switch to a metastable macroscopic state.*

Laser-induced ferroelectric structural order in an organic charge-transfer crystal

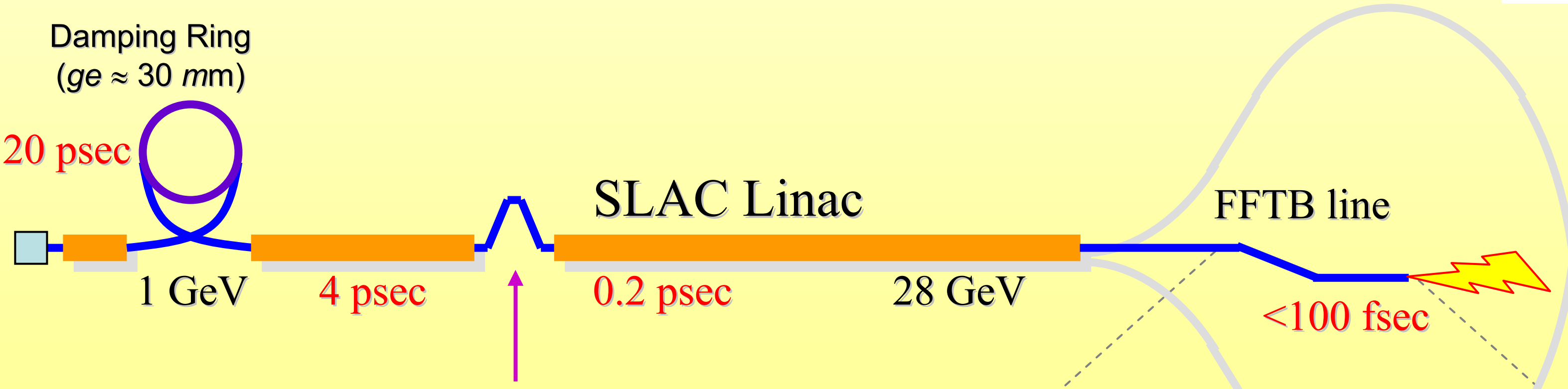
Collet et al, Science, Vol. 300, 25 April 2003, 612



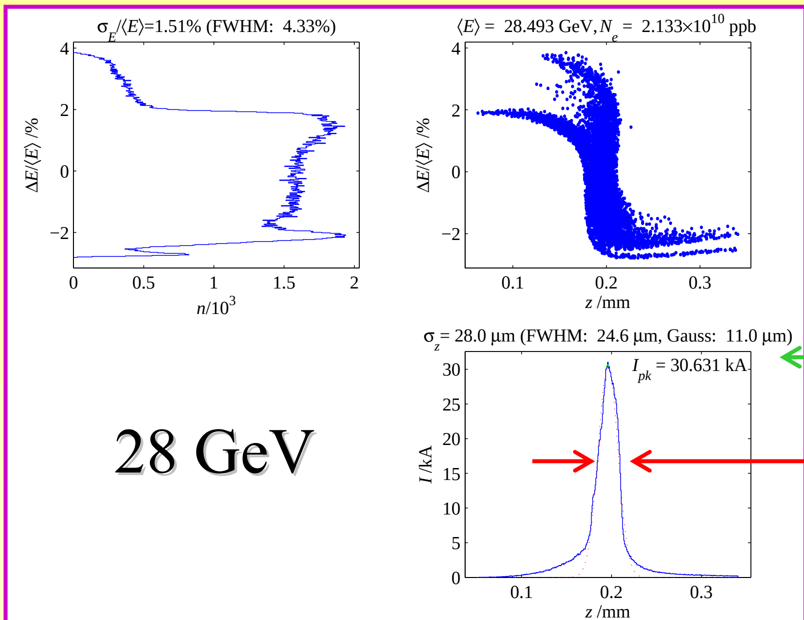
Relative intensity of some single crystal Bragg peaks versus the delay time between the laser pump and the X-ray probe. After about 500 ps the light-driven metastable state is established.

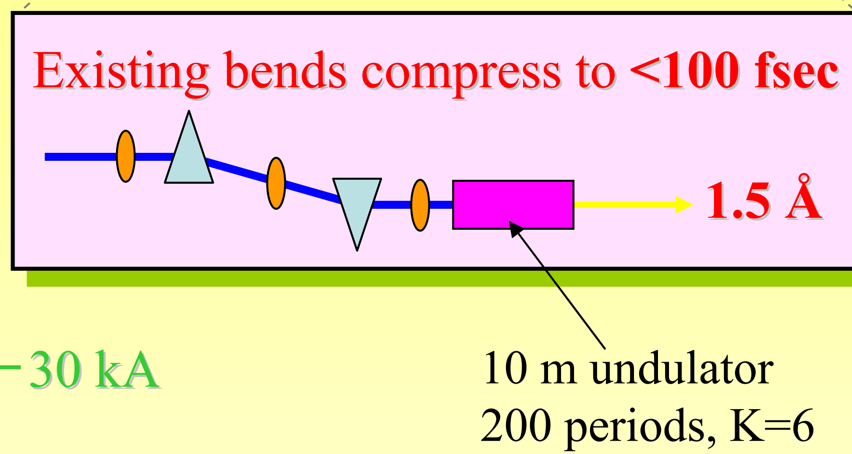
ID 09 B

Sub-Picosecond Pulse Source (SPPS) R&D Program
(a Component of the LCLS R&D Effort)



Add 12-meter chicane compressor in linac at 1/3-point (9 GeV)



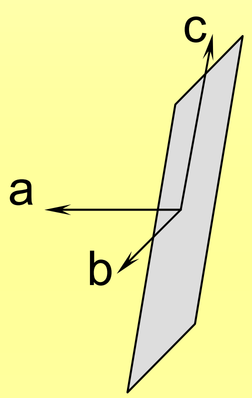


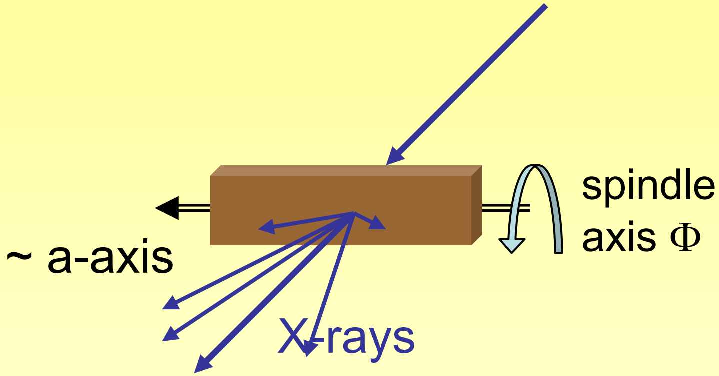
TTF-CA

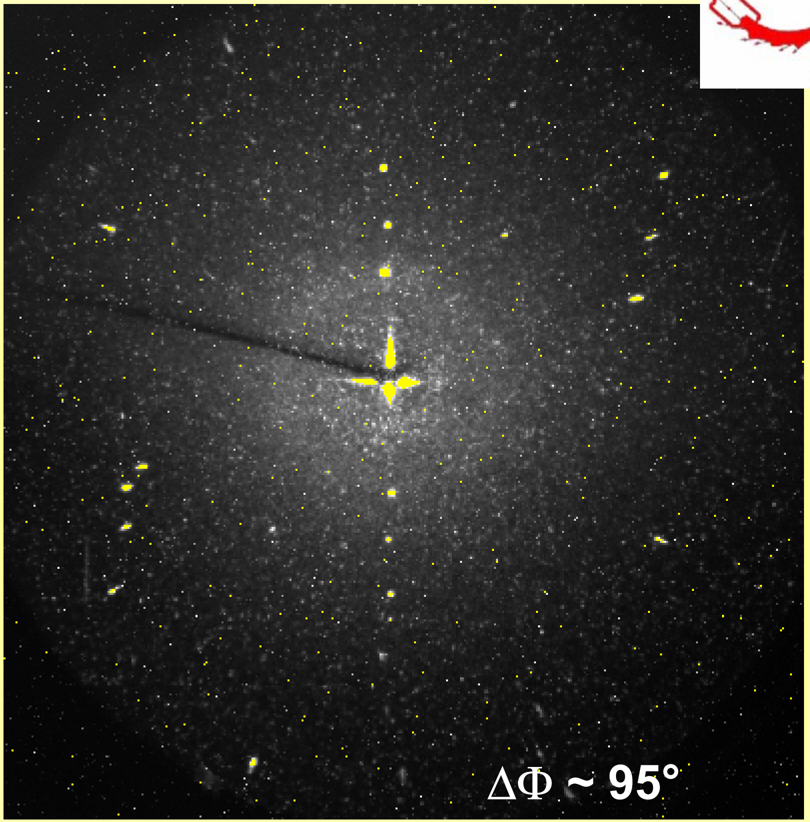
Tetrathiafulvalene-p-chloranil

SPPS

$C_6H_4S_4 \cdot C_6Cl_4O_2$
Monoclinic
$P2_1/n$
a=7.2182 Å
b=7.586 Å
c=14.474 Å
$\alpha=\chi=90°$
$\beta=99.14°$







~10^6 photons/pulse
1 x 1 mm^2
1% bandwidth
300 s, 10 Hz

9.3 keV
image int. CCD
at 110 mm

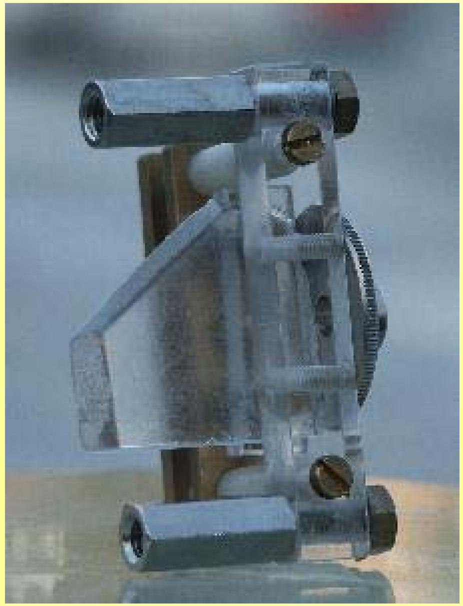
T. Tschentscher, H. Schulte-Schrepping, S. Techert, SPPS-Team (J. Hastings)

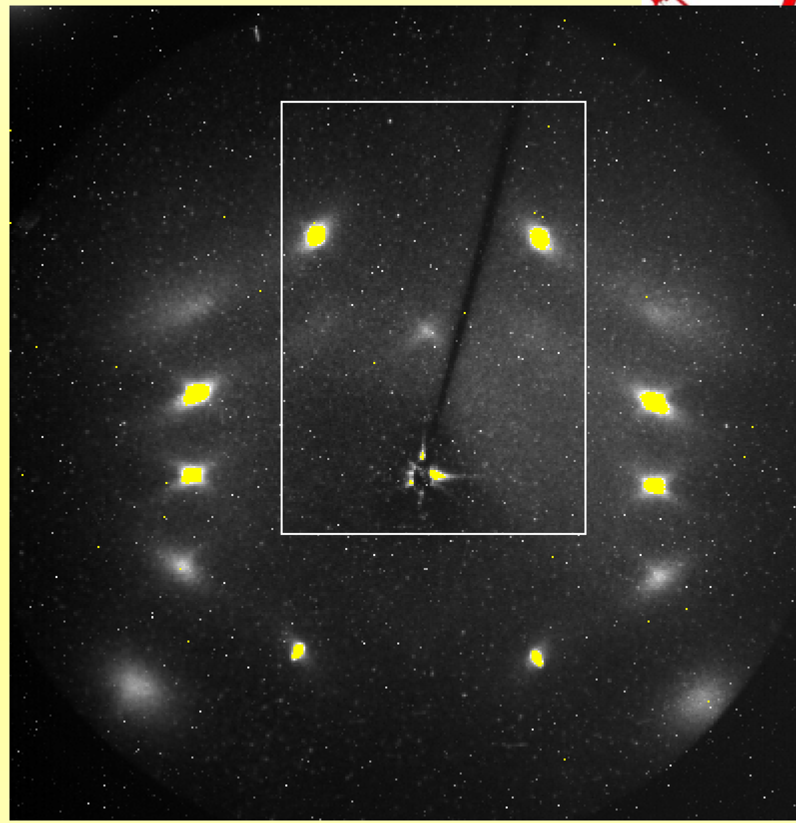
Diffraction from Salol

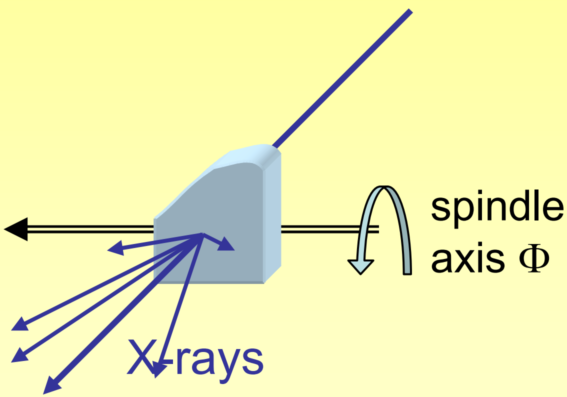
SPPS

Phenylsalicylate

$C_{13}H_{10}O_3$
Orthorombic
Pbca
a=7.961 Å
b=11.258 Å
c=23.402 Å
$\alpha = \beta = \gamma = 90°$
$\Delta\theta$ (0 16 0)=0.3 mdeg







~10^6 photons/pulse
1 x 1 mm^2
1% bandwidth
300 s, 10 Hz

9.365 keV
image intensif. CCD
at 120 mm

T. Tschentscher, H. Schulte-Schrepping, E. Weckert, SPPS-Team (J. Hastings)

LINAC driven

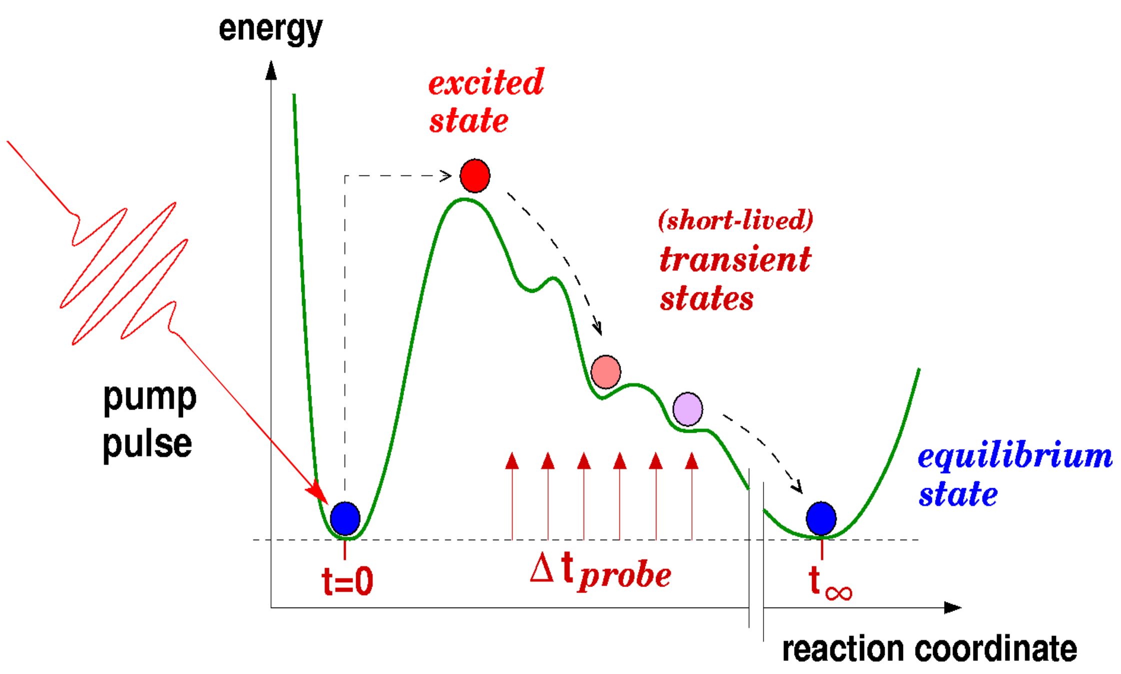
SASE FEL

Probing matter with atomic resolution

Present day X-ray and neutron experiments probe in most cases equilibrium states of matter.

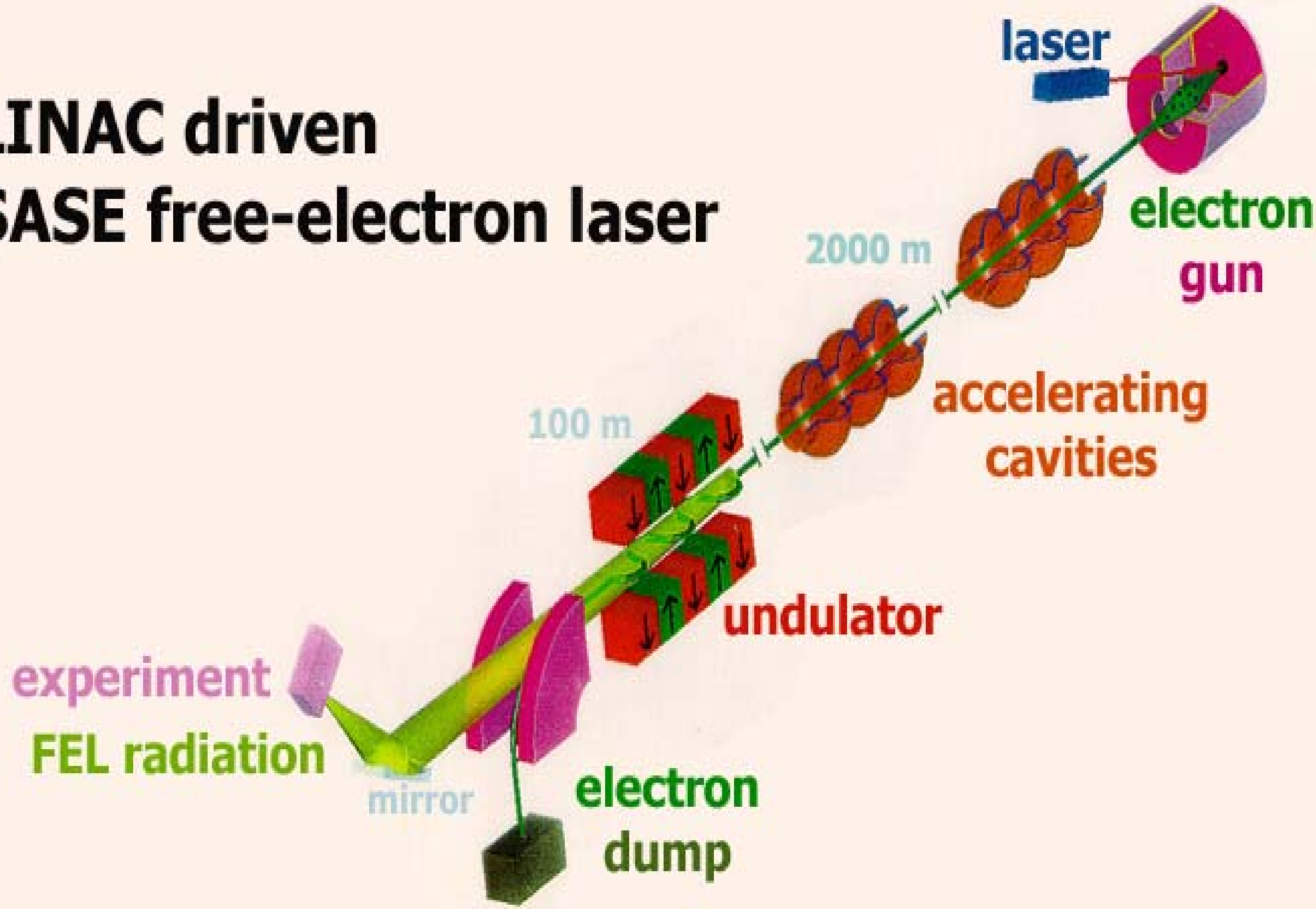
The next goal is to probe the dynamic state of matter with atomic resolution in space and time in order to allow for studies of non-equilibrium states, and very fast transitions between the different states of matter.

Take a movie of chemical reactions

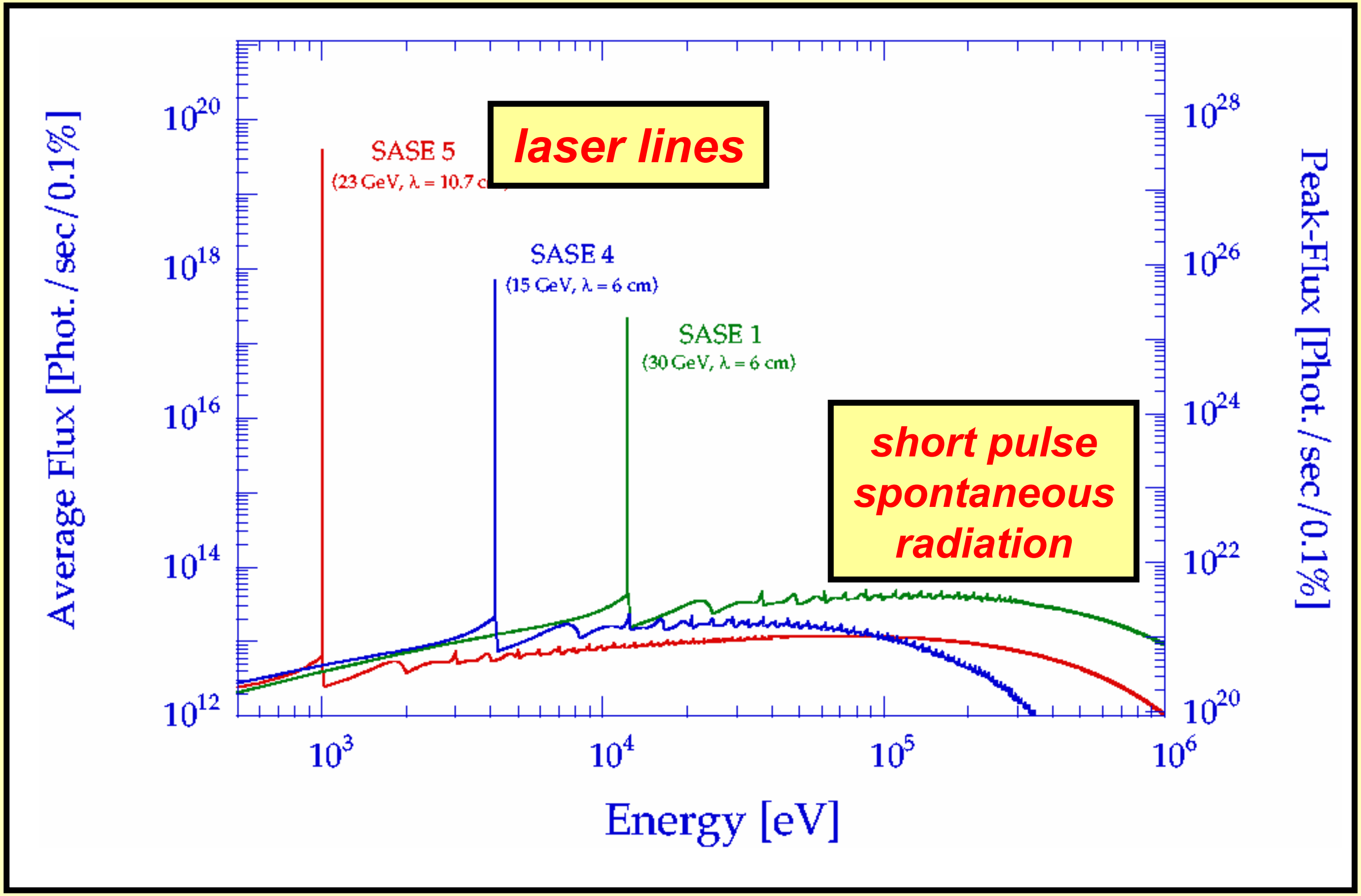


Schematic presentation of transition states in a chemical reaction

LINAC driven
SASE free-electron laser



SASE X-FEL: Spectral flux



Spectral distribution of angle integrated SASE FEL radiation

European X-FEL Laboratory

Compared to 3rd generation storage ring based synchrotron radiation facilities, the **gain factors** are:

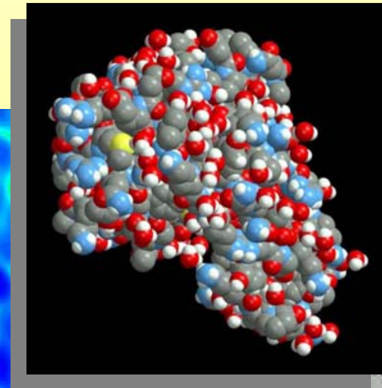
- peak brilliance: 10^9 at the FEL line
  10^4 for spontaneous radiation
- average brilliance: 10^4 at FEL line
- coherence: 10^9 at FEL line
  (numbers of photons per mode)

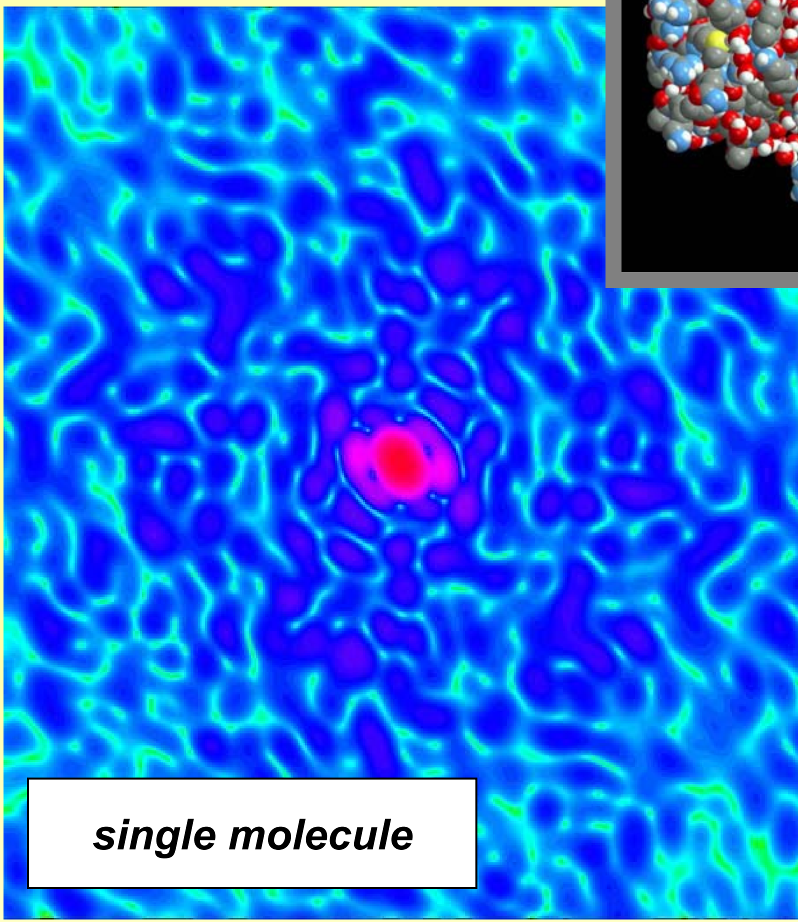
With gain factors of 10^4 … 10^9 the scientific case is based on extrapolation from today's needs and/or on wild dreams

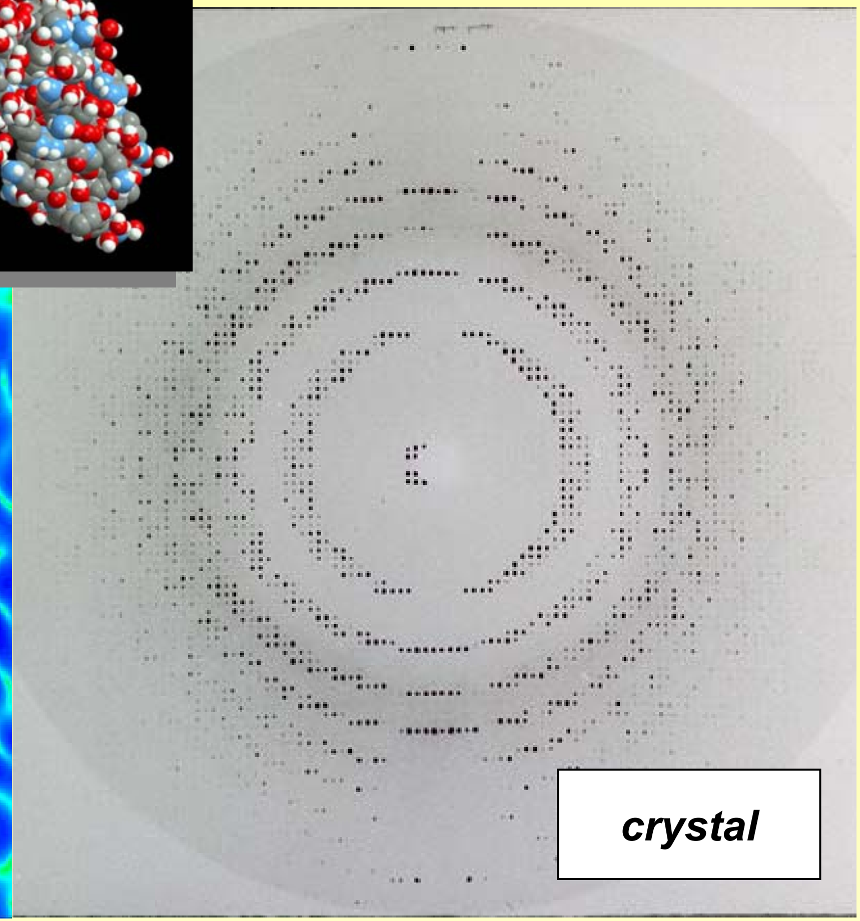
Imaging of a single bio-molecule

with atomic resolution

Lysozym







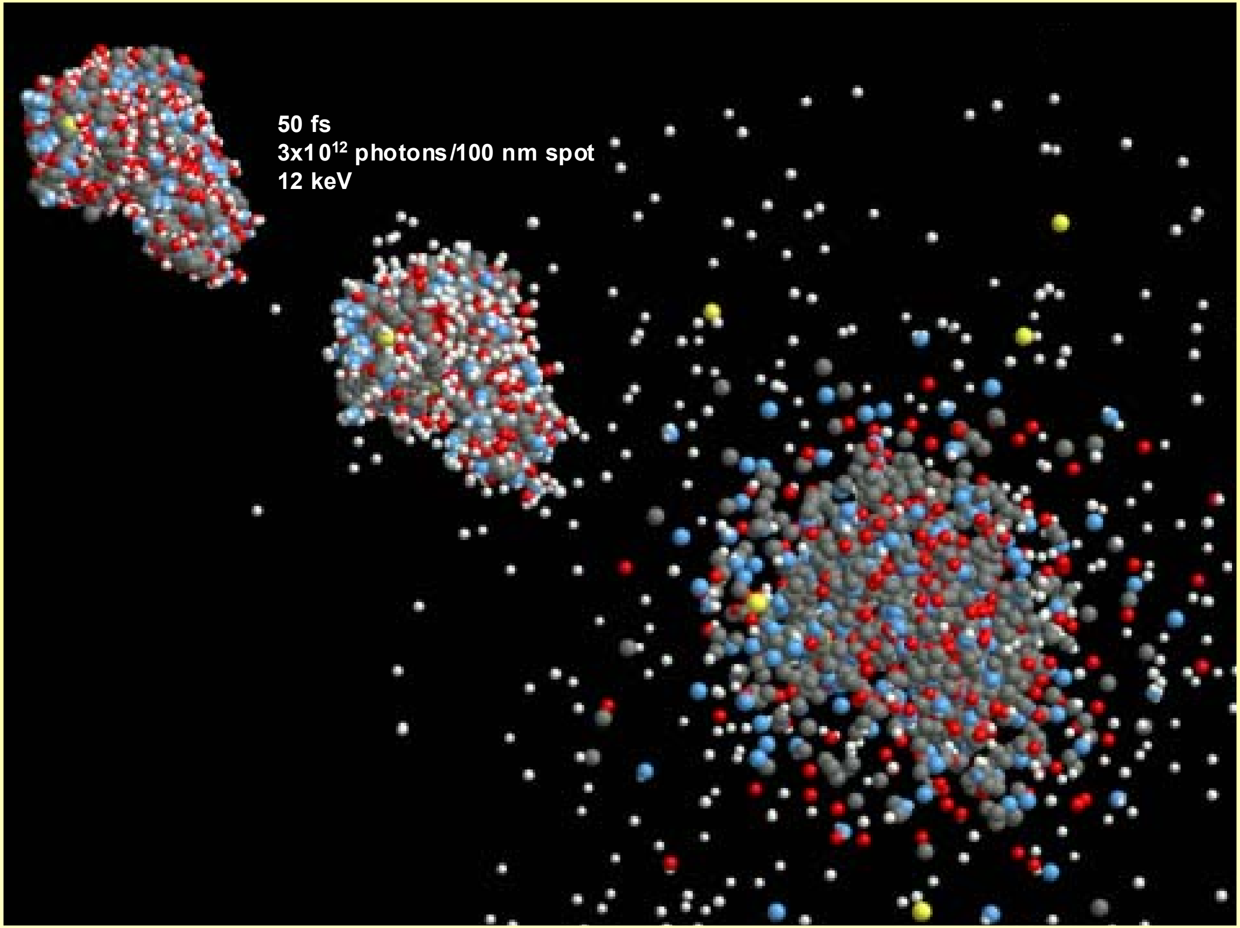
Oversampling: J. Miao, K.O. Hodgson and D. Sayre, PNAS 98 (2001) 6641-6645

Coulomb Explosion von Lyzosym

t=0

t=50 fsec

t=100 fsec



R. Neutze, R. Wouts, D. van der Spoerl, E. Weckert, J. Hajdu: ***Nature 406 (2000) 752-757***

European XFEL Laboratory

Main fields of application

- *atomic, molecular and cluster phenomena, plasma physics*
- *non-linear processes and quantum optics*
- *condensed matter physics and materials science*
- *ultra-fast chemistry and life-sciences*

The scientific case has been discussed in recent reports from SLAC/SSRL, DESY/HASYLAB, BESSY, ELETTRA, SRS Daresbury, MIT Bates Lab

Strategy for the realization of hard X-ray FEL facilities at DESY

Step wise approach because of the challenges involved

FEL at TTF I (1999 - 2002):
Proof-of-Principle for SASE in 2001 at 80 – 120 nm,
first experiments in 2001/2

integrated system tests are needed

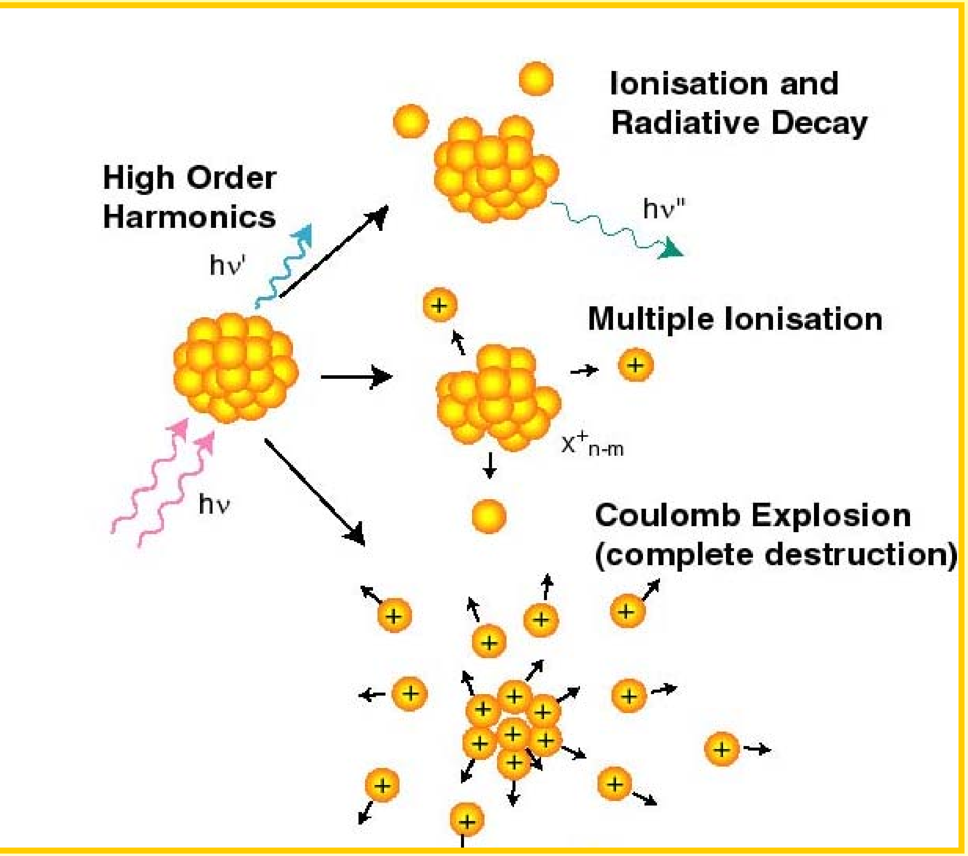
VUV FEL user facility (2005):
Soft X-rays in the 100 - 6 nm wavelength range

European XFEL Laboratory:
hard X-rays: 6 - 0.1 nm, funding under way, beam for users expected in 2012

VUV FEL

in TESLA Technology

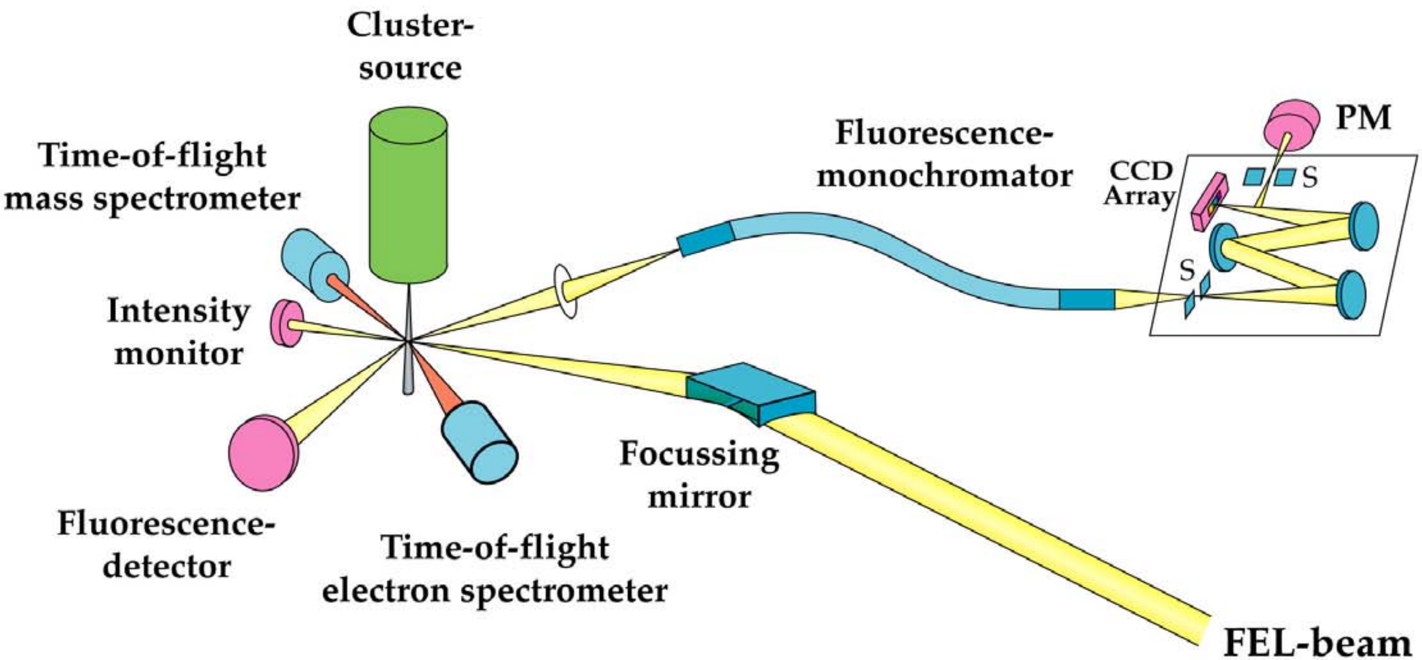
Goals of a cluster experiment



Questions asked:

- *which multi-photon processes are observed*
- *cross sections (surface, bulk)*
- *which ions are prepared (charge state, electronically excited states)*
- *life time of intermediate states*
- *high-order harmonic generation*

FEL Cluster Experiment at 100 nm



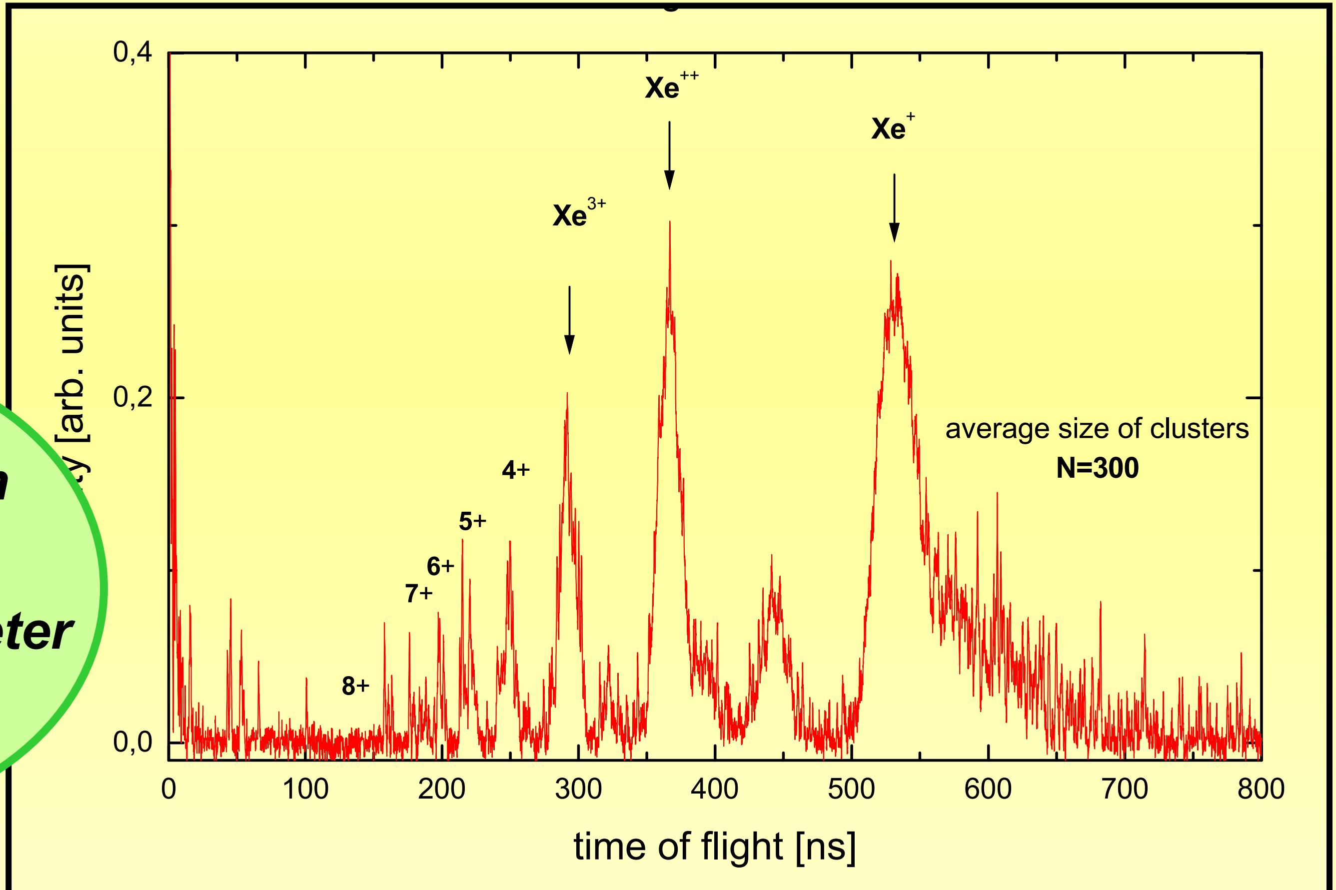
H. Wabnitz et al., Nature 420, 482 (2002)

50 μJ, 50 fsec
up to power densities of 10^{14} W/cm^2

H. Wabnitz et al., Nature 420, 482 (2002)

Single shot time-of-flight spectrum

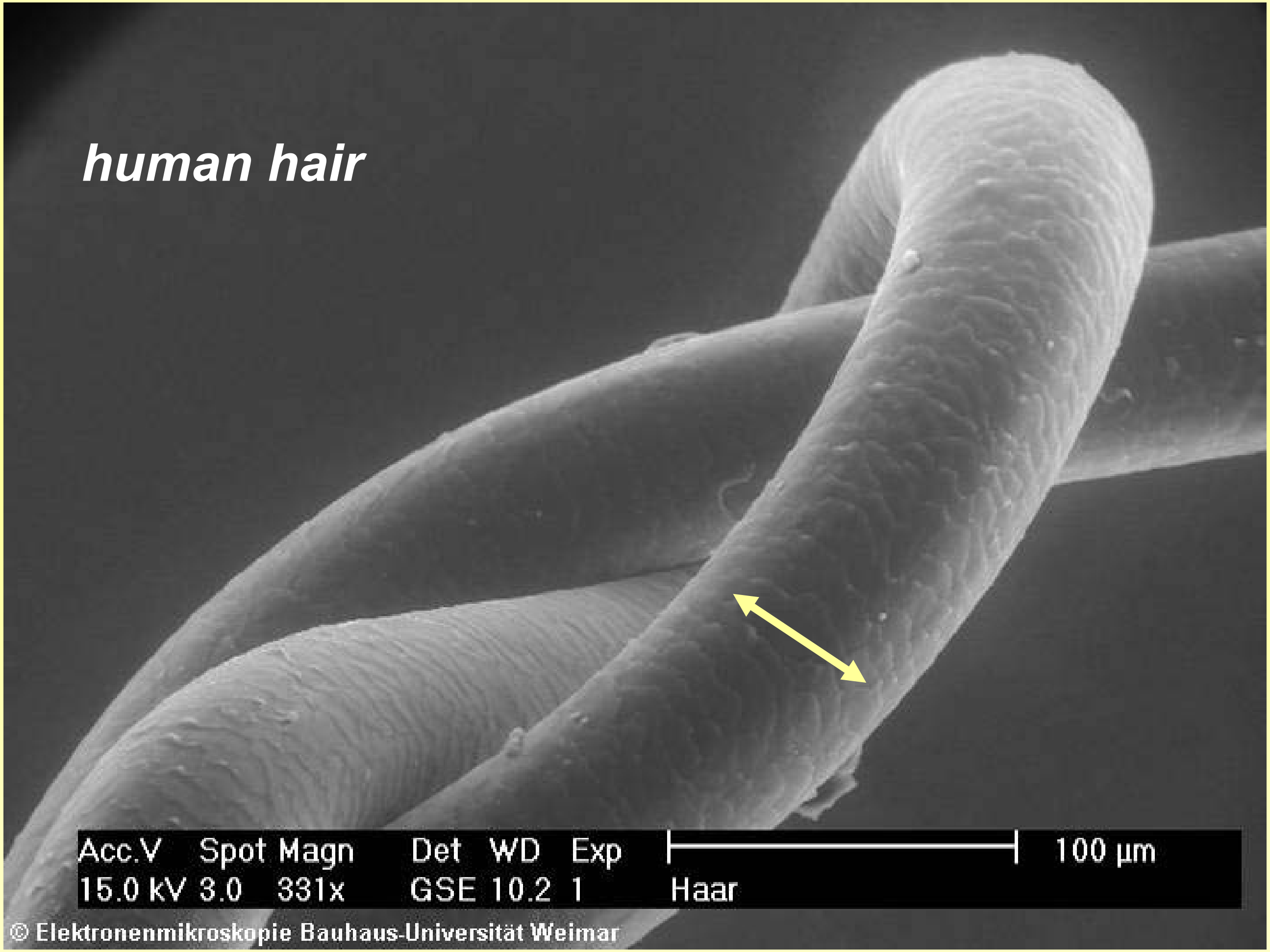
Ip_{Xe} = 12.1 eV
E_{phot}= 12.8 eV



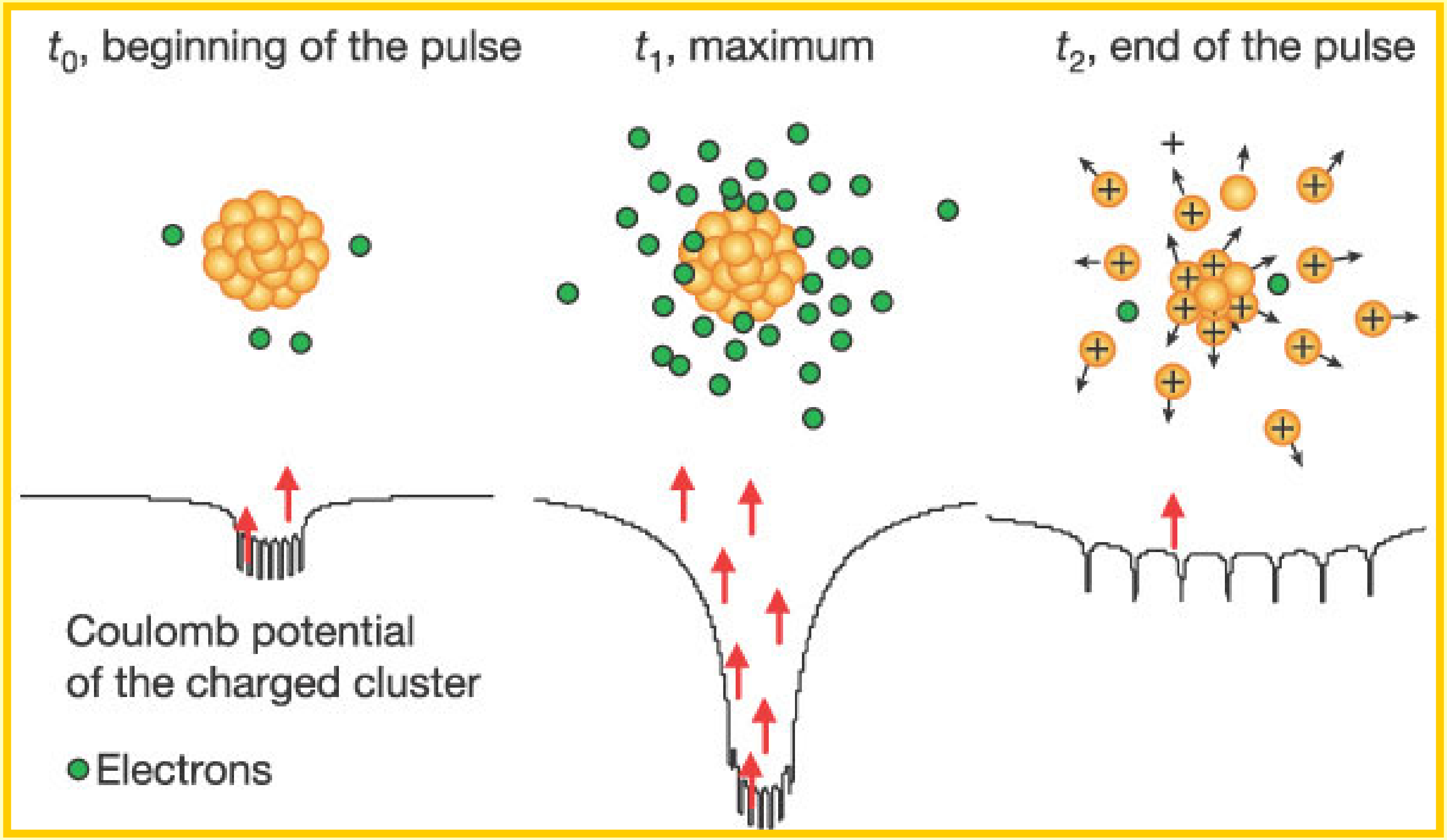
10^{13} photons in ~50 fsec in a 20 µm diameter focal spot

Coulomb explosion of Xenon clusters with ~ 300 atoms

100 femtoseconds ⟷ 30 µm

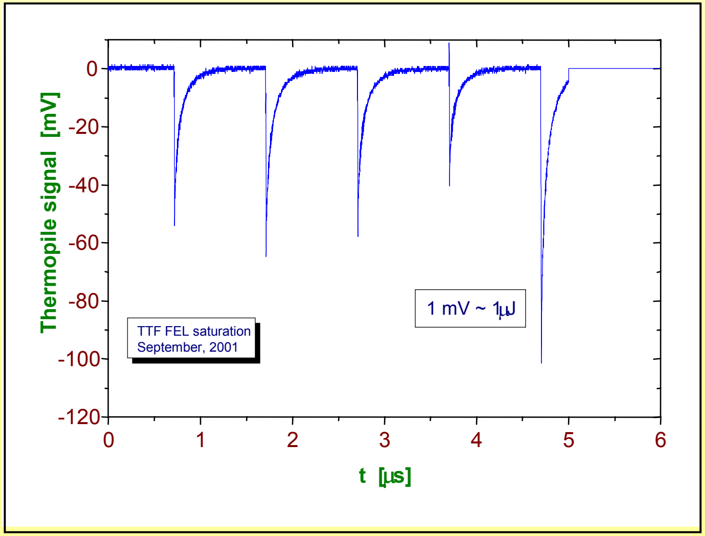


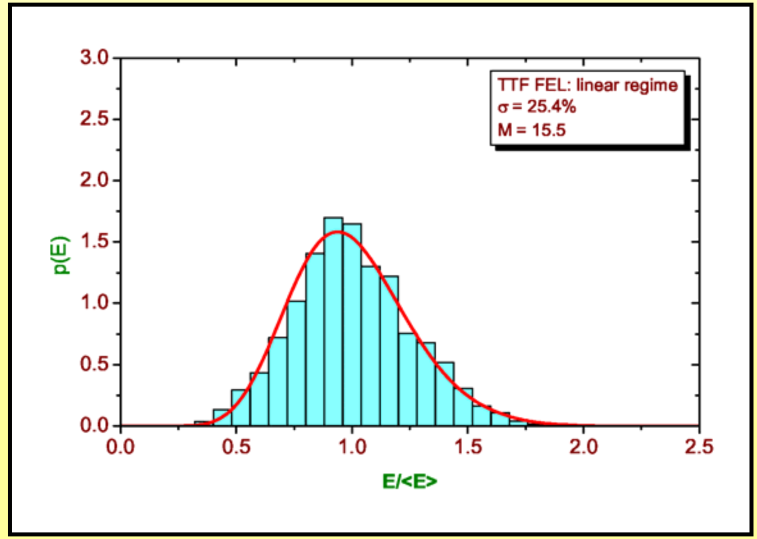
Coulomb explosion of clusters induced by multi-photon absorption



Th. Moeller et al.

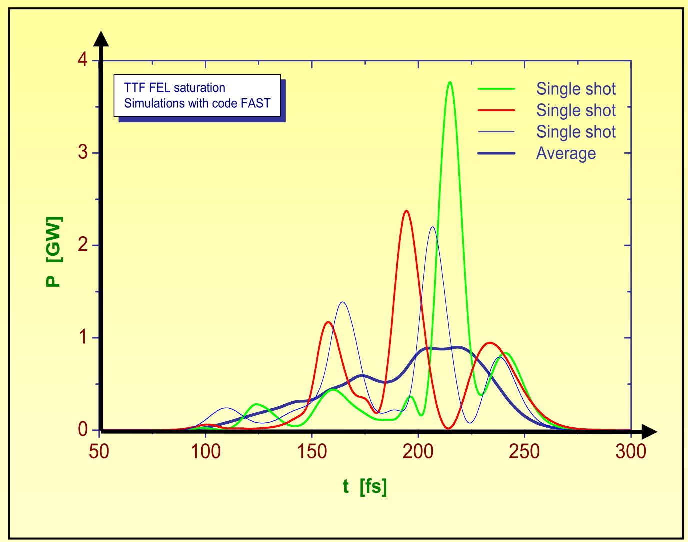
Fluctuation properties of SASE radiation at TTF



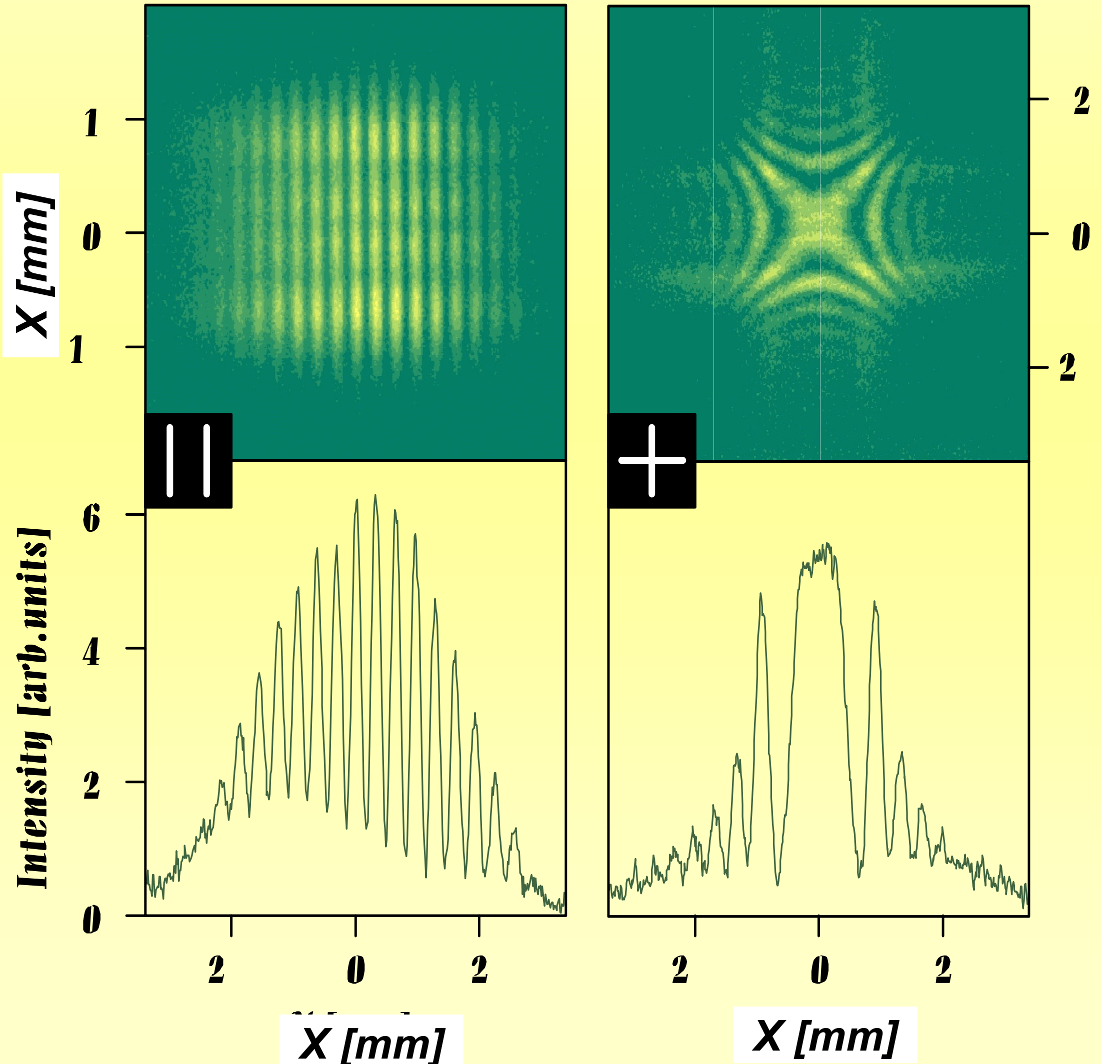


Simulated spike structure in SASE saturation

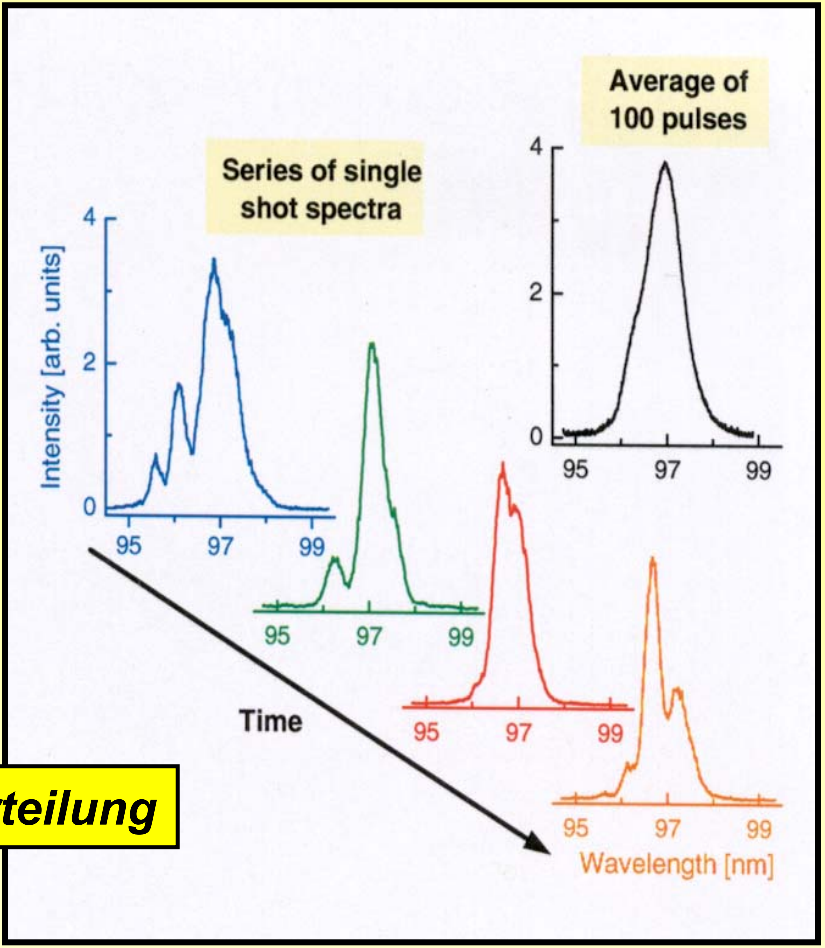
based on measured fluctuations of the pulse energy



Transversale Kohärenz



SASE FEL: Start aus dem Rauschen



Spektralverteilung

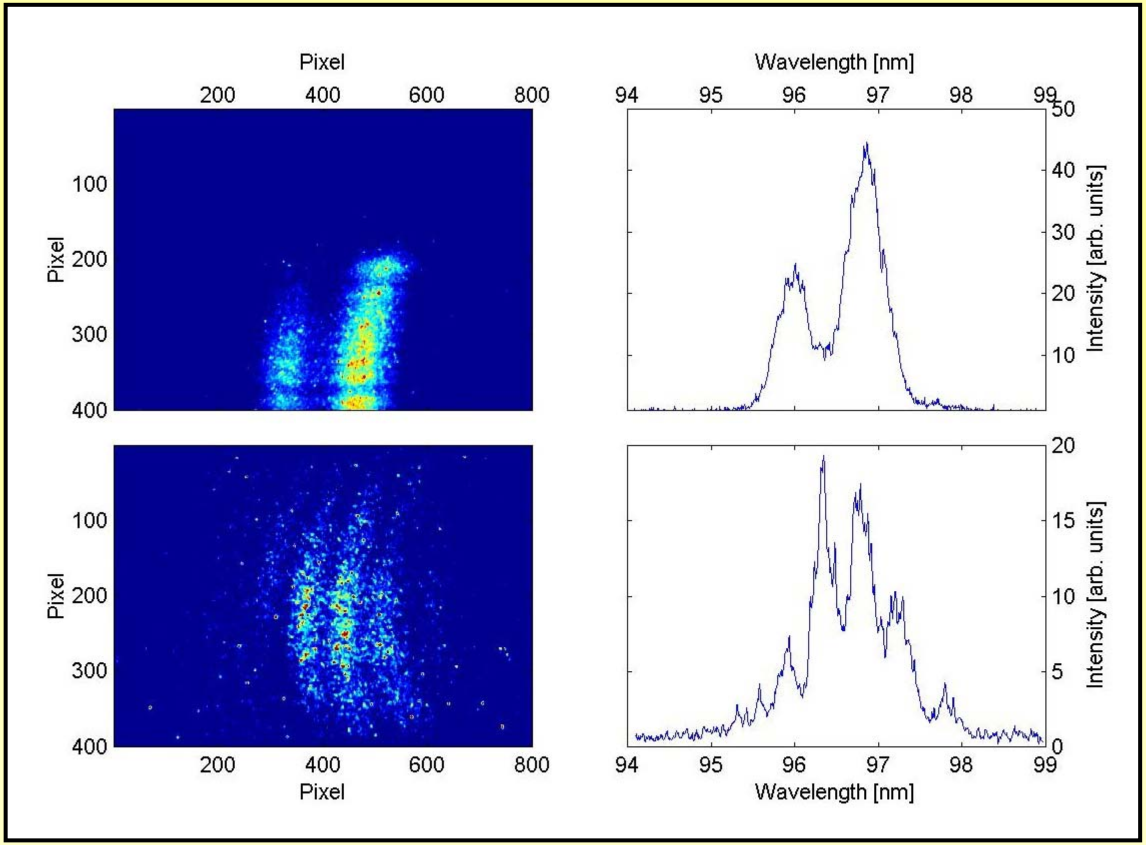
Pulsdauer zwischen 50 und 100 fsec

TTF Phase I

Pulse length variation via bunch compressor (BC1)

BC1 off

BC1 on



~50 fses

Modes:
M ≅ 2 - 3

Modes:
M ≅ 7 - 10

~150 fses

Performance of TESLA Test Facility VUV FEL (80-100 nm)

- saturation
- photon statistics
- single pulse spectral distribution
- lateral coherence
- second harmonic
- pulse length variation 50 – 150 fsec

all measured quantities agree very well with SASE FEL theory

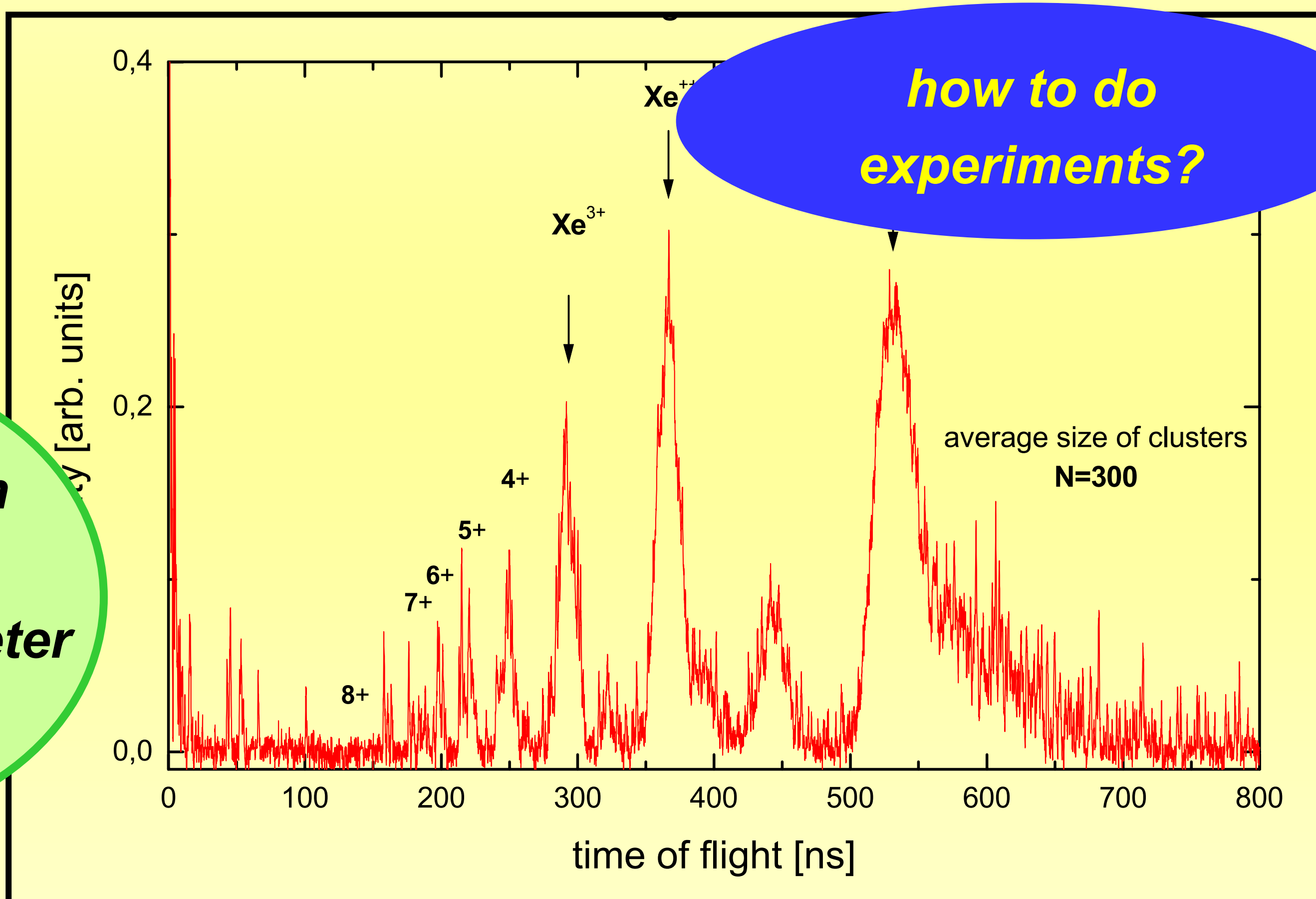
H. Wabnitz et al., Nature <u>420</u>, 482 (2002)

Single shot time-of-flight spectrum

Ip**$_{Xe}$ **= 12.1 eV

E**$_{phot}$**= 12.8 eV

how to do experiments?



10^{13} photons in ~50 fsec in a 20 µm diameter focal spot

Coulomb explosion of Xenon clusters with ~ 300 atoms

VUV FEL User Facility at DESY

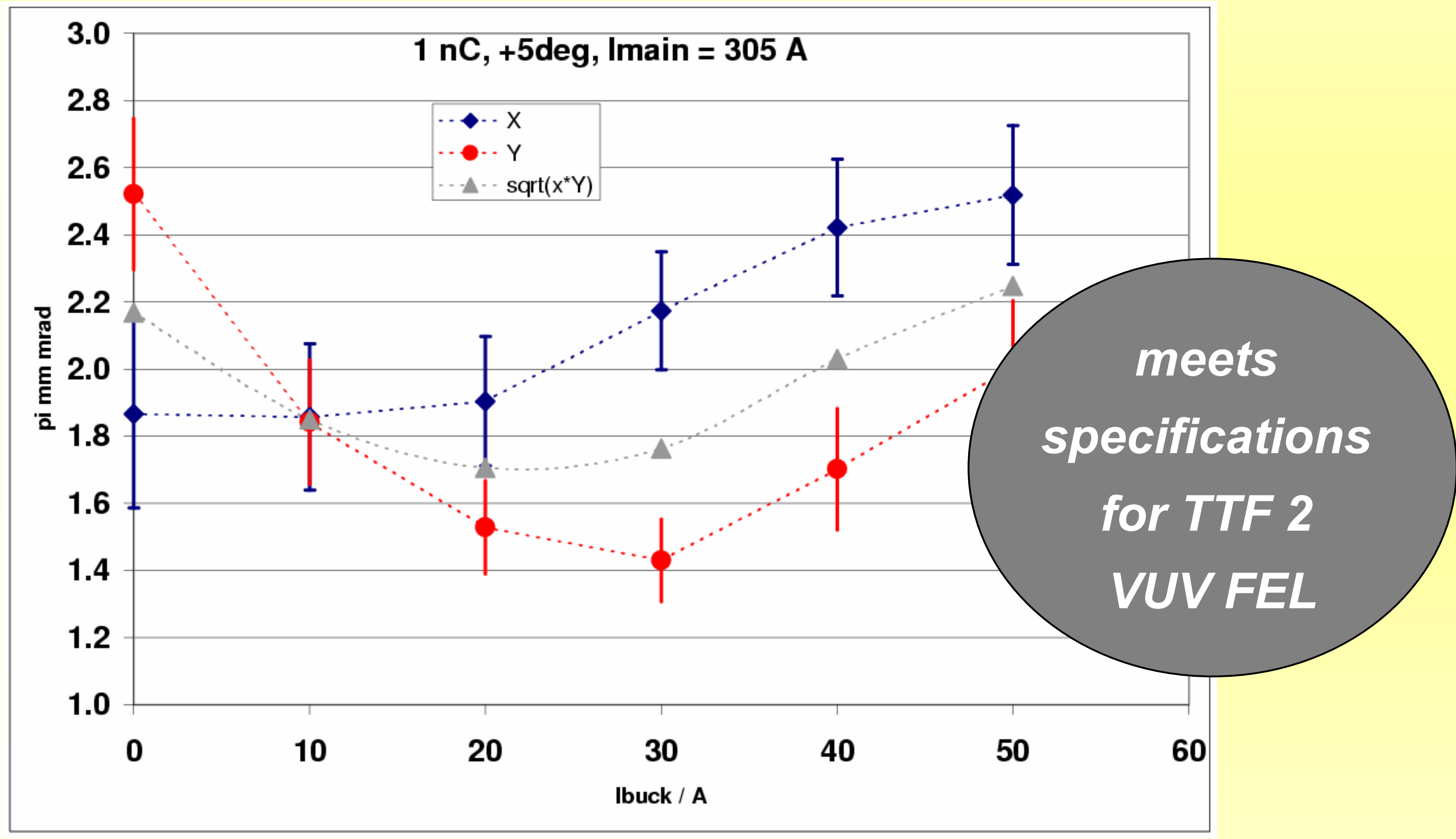
TTF 1

TTF 2

experimental hall

start of operation in 2004

Latest results from PITZ



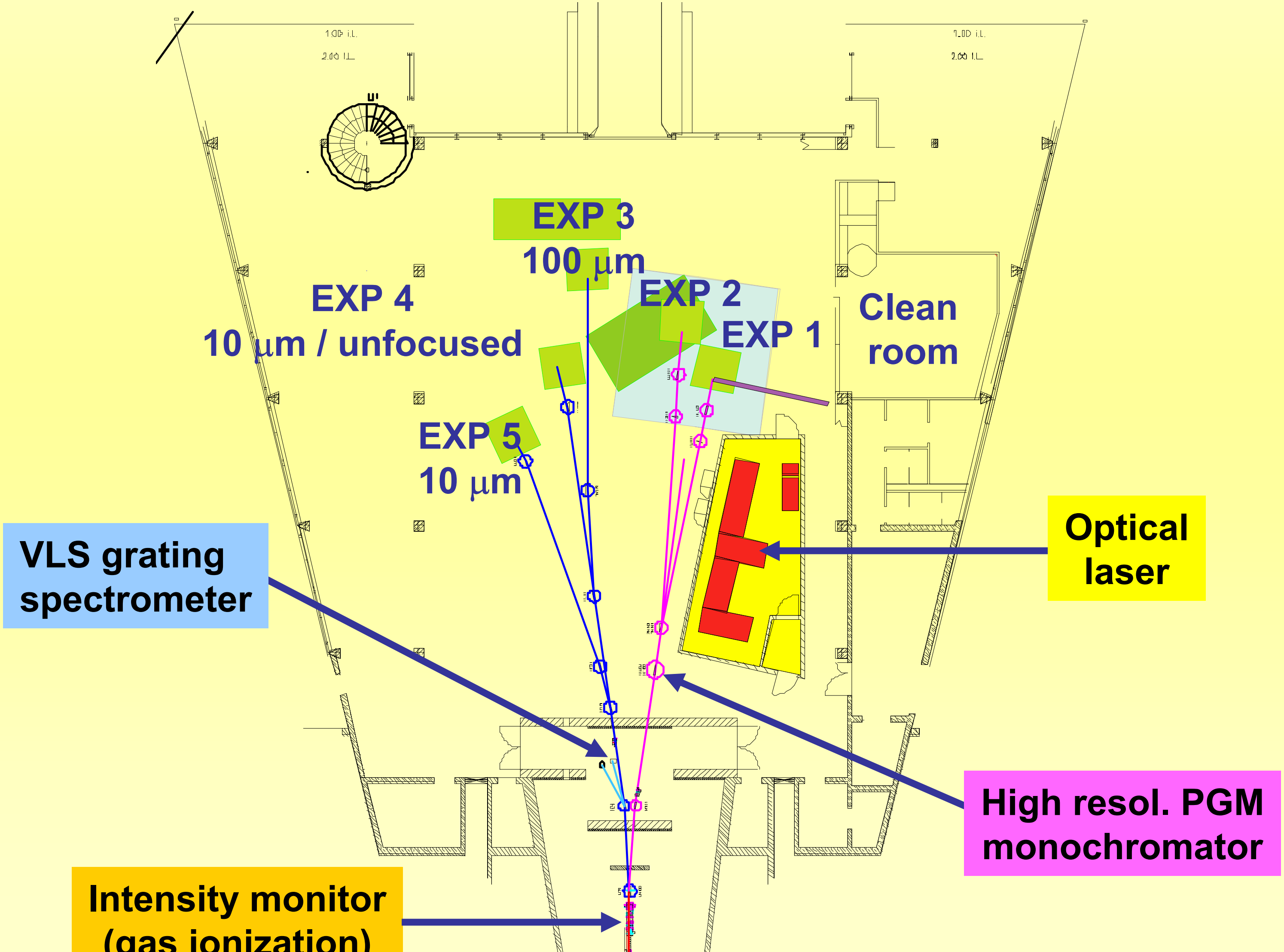
current in the solenoid compensating the magnetic field at the cathode

VUV FEL at TTF

undulators

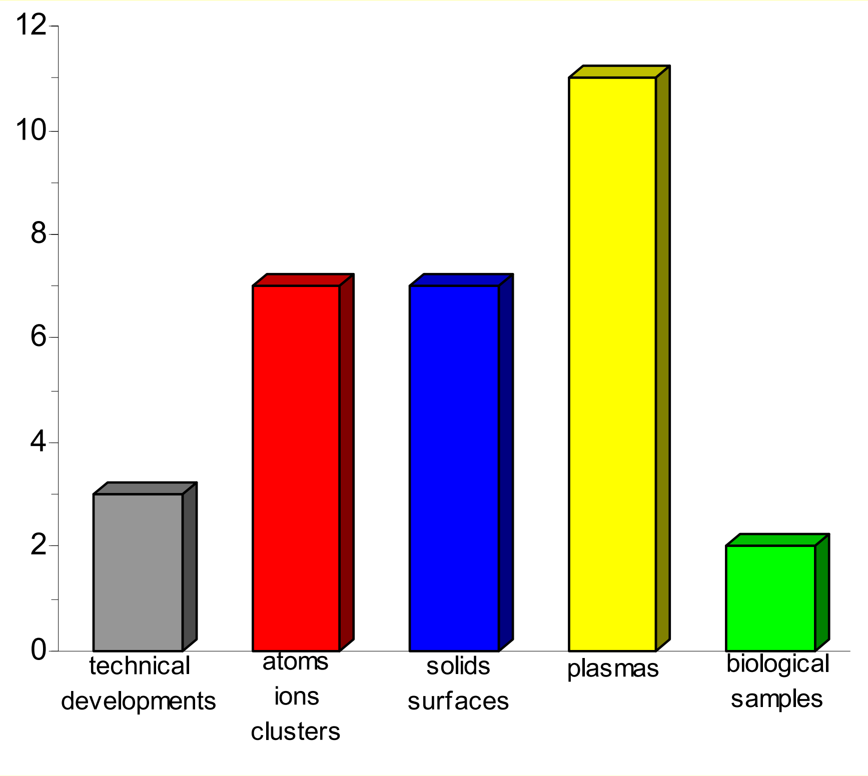
Layout of VUV FEL user facility

5 experimental stations



Review of VUV FEL Proposals
Sep. 25-27, 2002

Areas of Proposed Research



- 30 proposals submitted
- about 200 scientists from 60 institutes in 11 countries involved

optical lasers community: 18

synchrotron community: 12

European XFEL Laboratory

DESY's formula for success:

Particle Physics

↕

Accelerator
science, construction, operation

↕

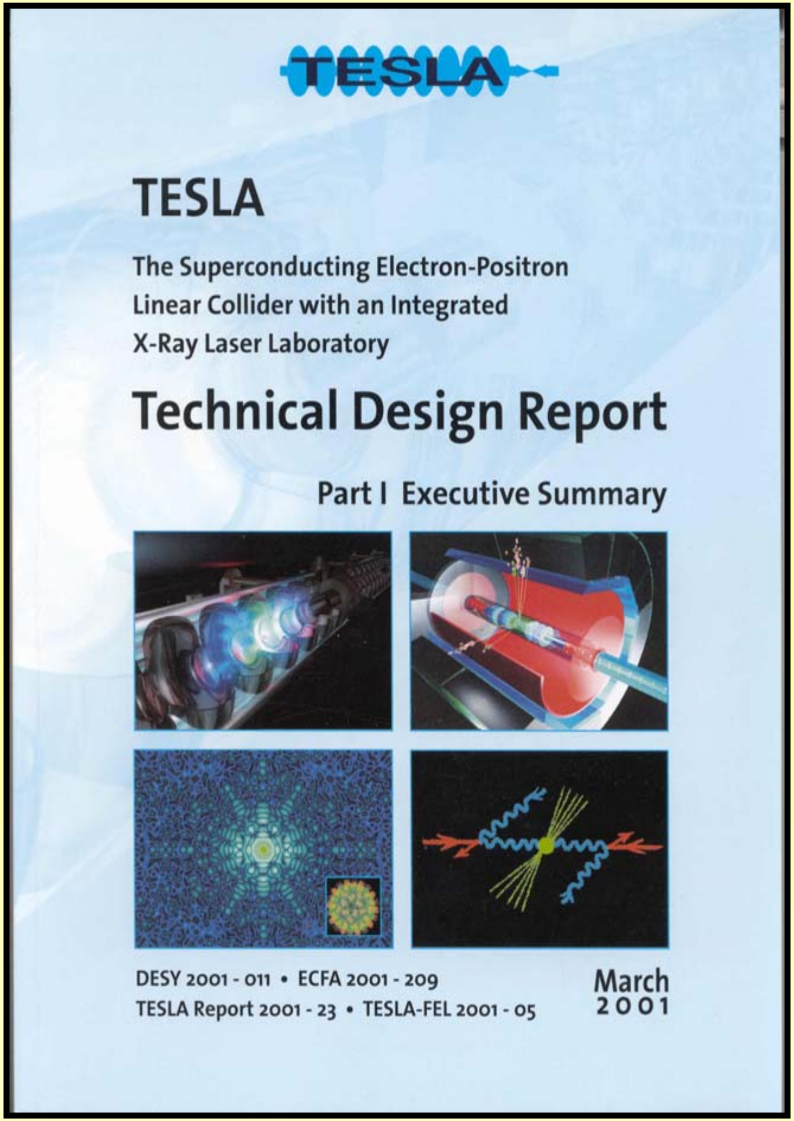
Research with photons

1992: The vision for DESY's future

Björn H. Wiik

TESLA: A linear e^{+}-e^{-} collider with incorporated X-ray laser based on a super conducting linear accelerator

TESLA project



Members of the TESLA Collaboration

Yerevan Physics Institute, Yerevan

Institute for High Energy Physics (IHEP), Academia Sinica, Beijing

Tsinghua University, Beijing

Institute of Physics, Helsinki

CEA/DSM DAPNIA, CE-Saclay, Gif-sur-Yvette

Laboratoire de l'Accélérateur Linéaire (LAL), IN2P3, Orsay

Institut de Physique Nucléaire (IPN), Orsay

Rheinisch-Westfälische Technische Hochschule, Aachen

Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung, BESSY, Berlin

Hahn-Meitner Institut Berlin

Max-Born-Institut, Berlin

Technische Universität Berlin

Technische Universität Darmstadt

Technische Universität Dresden

Universität Frankfurt

GKSS-Forschungszentrum Geesthacht

Deutsches Elektronen-Synchrotron DESY in der Helmholtz-Gemeinschaft, Hamburg and Zeuthen

Universität Hamburg

Forschungszentrum Karlsruhe

Universität Rostock

Bergische Universität-GH Wuppertal

CCLRC-Daresbury and Rutherford Appleton Laboratory, Cheshire

Royal Holloway, University of London (RHUL)

Queen Mary, University of London (QMUL)

University College London (UCL)

University of Oxford

Laboratori Nazionali di Frascati, INFN, Frascati

Istituto Nazionale di Fisica Nucleare (INFN), Legnaro

Istituto Nazionale di Fisica Nucleare (INFN), Milan

Istituto Nazionale di Fisica Nucleare (INFN), Roma II

Sincrotrone Trieste

Institute of Nuclear Physics, Cracow

University of Mining and Metallurgy, Cracow

Soltan Institute for Nuclear Studies, Otwock-Swierk

High Pressure Research Center, Polish Academy of Science, Warsaw

Institute of Physics, Polish Academy of Science, Warsaw

Polish Atomic Energy Agency, Warsaw

Faculty of Physics, University of Warsaw

Moscow Engineering and Physics Institute, Moscow

Institute for Theoretical and Experimental Physics (ITEP), Moscow

Budker Institute for Nuclear Physics (BINP), Novosibirsk

Budker Institute for Nuclear Physics (BINP), Protvino

Institute for High Energy Physics (IHEP), Protvino

Institute for Nuclear Research (INR), Russian Academy of Sciences, Troitsk

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Madrid

Paul-Scherrer-Institut (PSI), Villigen

Argonne National Laboratory (ANL), Argonne IL

Fermi National Accelerator Laboratory (FNAL), Batavia IL

Cornell University, Ithaca NY

University of California, Los Angeles CA

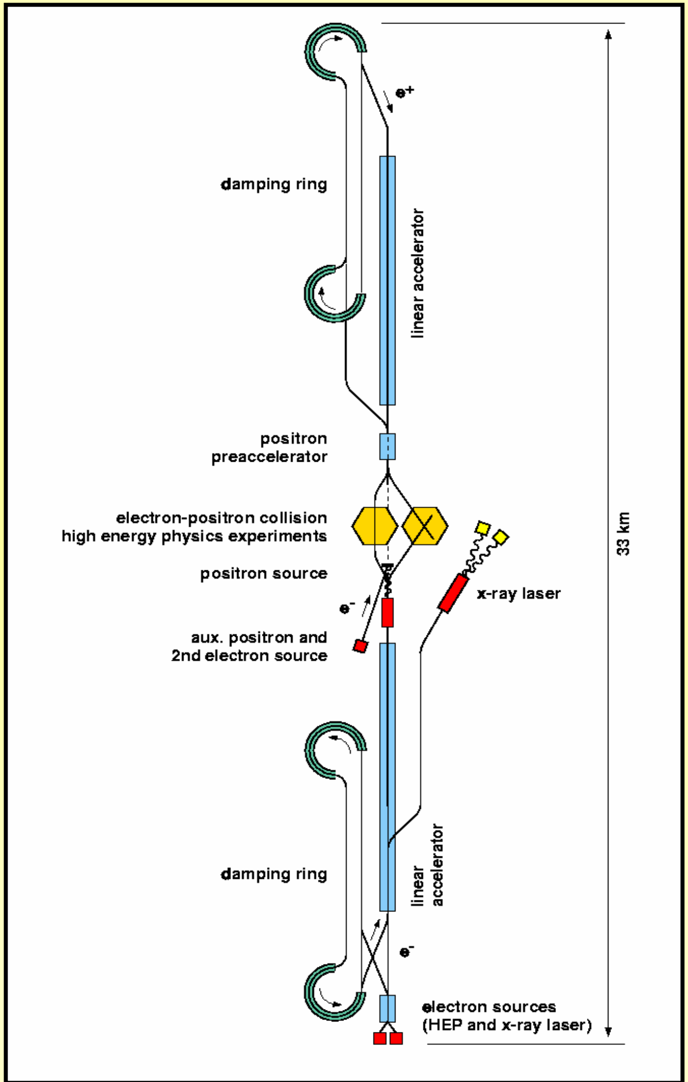
Jefferson Lab, Newport News VA

Joint Institute for Nuclear Research (JINR), Dubna

September 2002

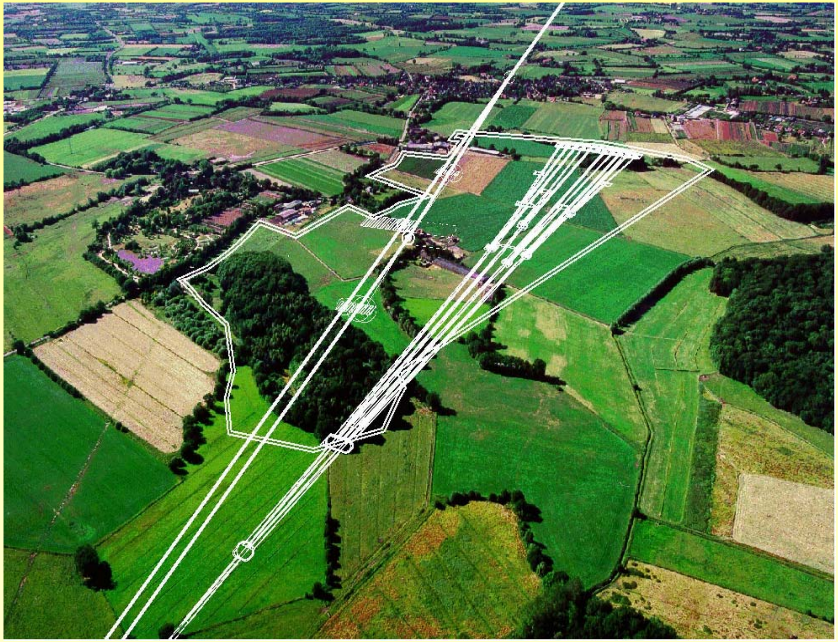
TESLA:

Linear Collider with integrated X-ray laser laboratory



500 GeV linear collider	3136 Mio Euro
Detector for particle physics	210 Mio Euro
Accelerator components for X-FEL	241 Mio Euro
X-ray laser laboratory	290 Mio Euro

7000 person years

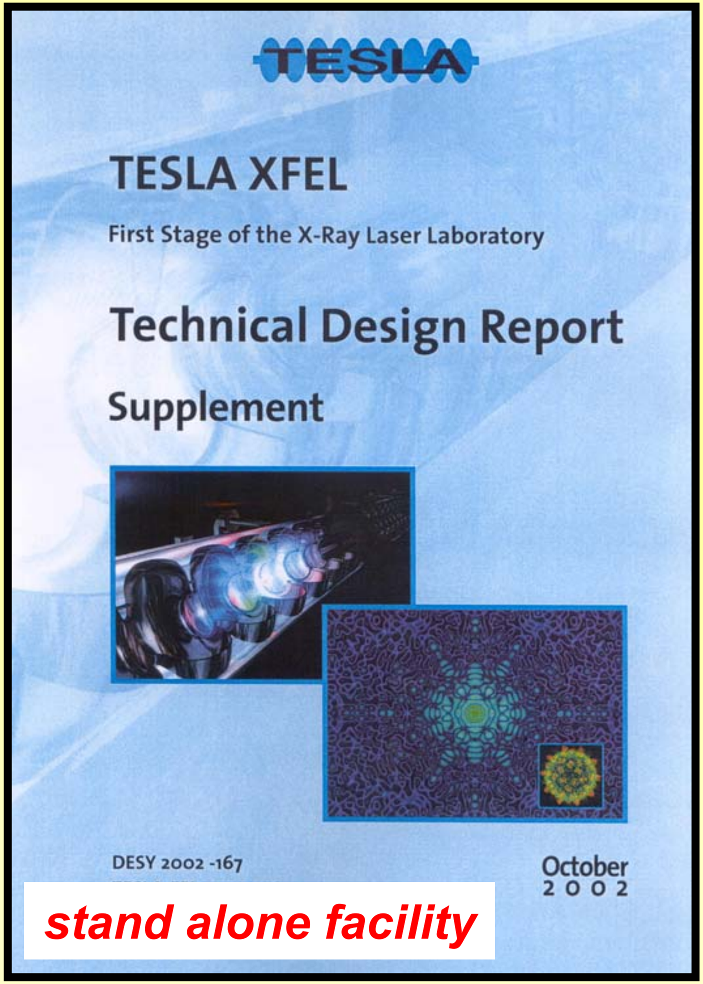


German Science Council

Statements concerning the X-FEL

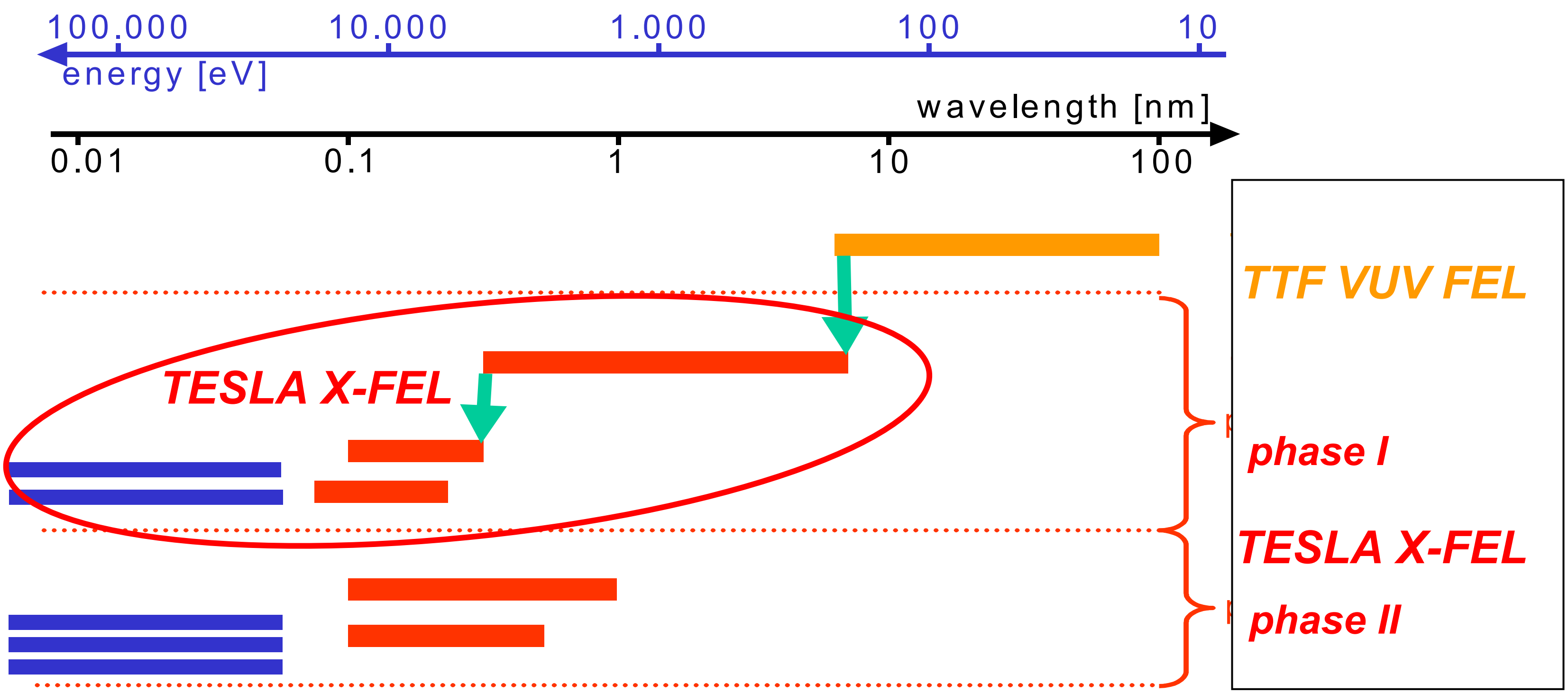
DESY and the TESLA collaboration are asked to present as soon as possible a technical proposal which is optimised for the X-FEL, based on the existing Technical Design Report for the integrated solution.

This proposal should include a cost evaluation.



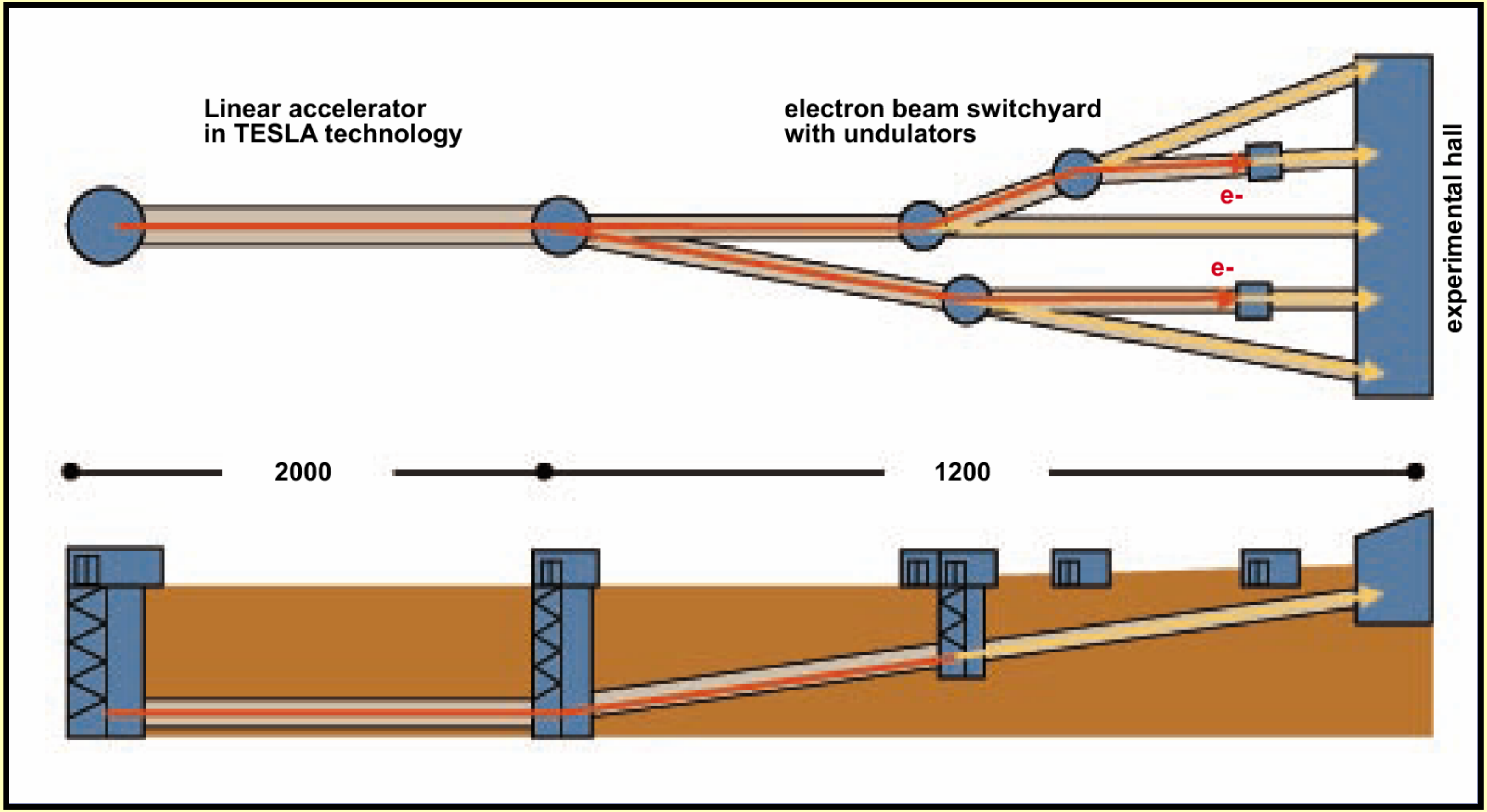
stand alone facility

Spectral distribution at XFELs in Hamburg



Goal: Reach as fast as possible the hard X-ray regime
Performing broad research program

European XFEL Laboratory (Oct. 2002)



3 FEL and 2 beamlines for spontaneous synchrotron radiation with 10 independent experimental stations

European XFEL Laboratory

Cost estimate at year 2000 prices

Linear accelerator including 110 million EUR for personnel

446 million EUR

XFEL Laboratory with beamlines and 10 experimental stations including 30 million EUR for personnel

238 million EUR

Project preparation

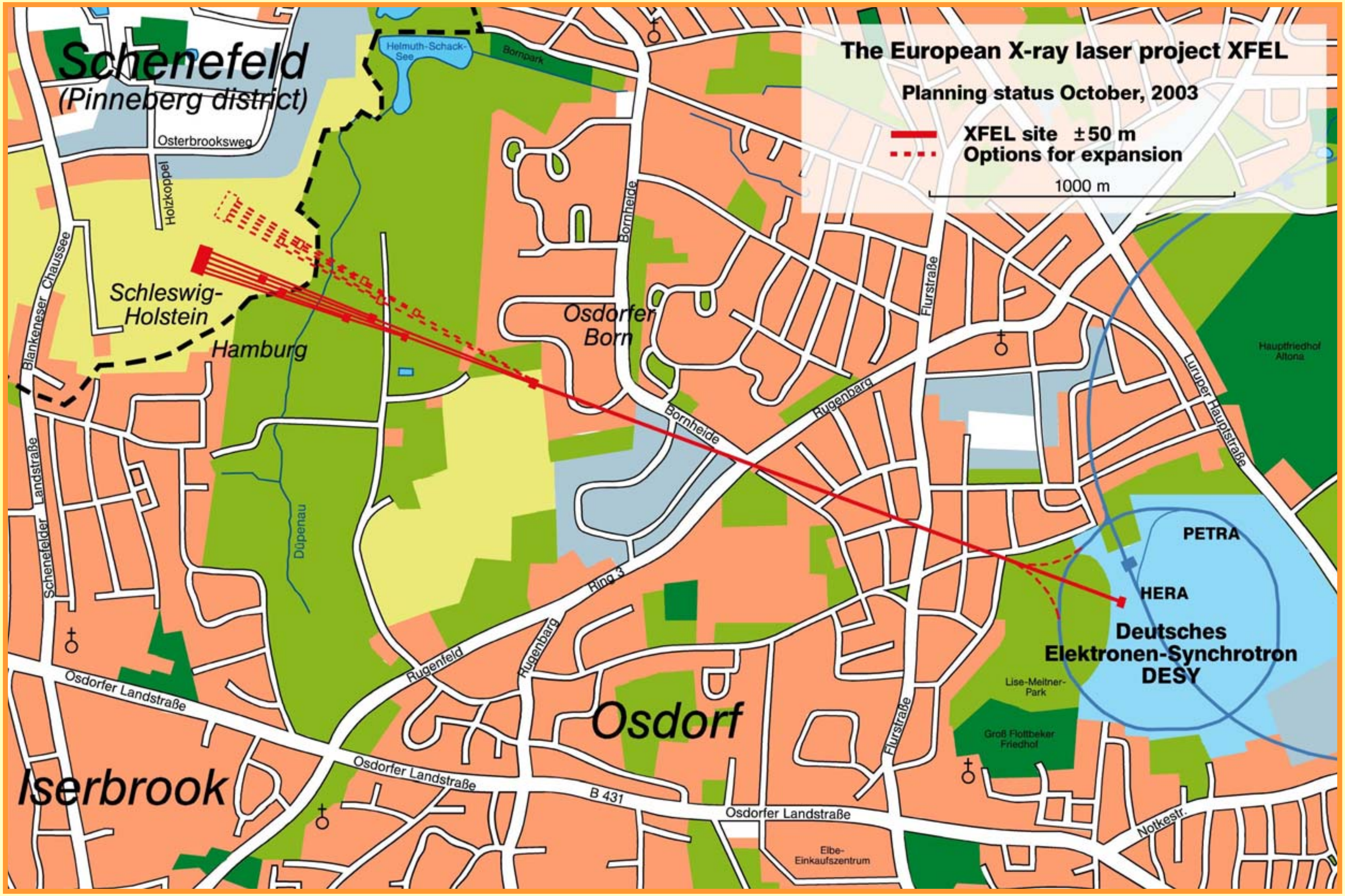
25 million EUR

Decisions by German Government on Large Scale Facilities for Research

announced 5 February 2003

- *50 % of the investment costs of 673 MEuro for a European XFEL Laboratory*
- *120 MEuro for upgrade of PETRA storage ring*
- *No comment on possible sites for TESLA Linear Collider, DESY encouraged to continue strong program in particle physics*

European XFEL Laboratory – Site Proposal



Discussions in Europe

ESFRI

EUROPEAN STRATEGY FORUM on RESEARCH INFRASTRUCTURES

Sixth meeting

Brussels, Friday July 4, 2003 (09:30-17:00)

5. ***X-ray FEL at DESY***

   a - issues encountered by delegations considering the question "whether or not to join?" (science case, technical case, business case)

   b - exchange of views and experiences

   c - conclusions with respect to continuation of negotiations

6. ***Working groups on Free Electron Lasers***

   a - final version of joint report (I, UK): discussion

   b - conclusions and follow-up

Suggestion: Workshop on the
Technical Challenges at the Proposed European XFEL Laboratory

Conclusions of ESFRI workshop

- A lot more needs to be done, but technical solutions are in reach to meet the parameters of the proposed European XFEL Laboratory in due time
  - photo-cathodes, injectors
  - optimization of Linac, however, it is already clear today that the TESLA technology is flexible enough to be able to profit from progress expected in the coming years for different sub-systems
  - fast switching within a bunch train preserving the beam quality
  - electron and photon beam diagnostics
  - synchronization
  - X-ray optics, instrumentation, detectors

Discussion at ESFRI - Trieste 20. Nov. 2003

- ***Ministers have on the table a German proposal for a European hard X-ray FEL facility in Hamburg. Declarations of interest by various Member States justify continuing along the following lines:***
    - ***setting up of a European working group for engineering design***
    - ***update of the science case, with the view of starting construction in about two years***

- ***For the VUV/soft X-ray regime there are several initiatives from various countries, exploiting different technologies and leading to complementary applications:***

Trieste FEL (IT), VUV FEL at TTF-2 (DE), 4GLS (UK), Max4 Laboratory (SE), BESSY-FEL (DE), Arc-en-Ciel (FR)

Discussion at ESFRI - Trieste 20 Nov. 2003

- ***Most initiatives are at various stages of maturity, but the majority of projects can start within 2-3 years: for example the TTF-2 soft X-ray facility will start as a user facility in Hamburg in 2005. R&D has already taken place on practically all proposed facilities.***

- ***A joint project for advanced R&D on key technological issues, covering both the hard X-ray and the VUV/soft X-ray regimes, is intended to start within months.***

"EC Call for Design Studies"

EUROPEAN INITIATIVE FOR GROWTH

QUICKSTART PROGRAMME

This Quick-start programme identifies key areas for investment in network and knowledge.

The projects, where work and investment can be under way within three years, accelerate progress towards achieving existing EU goals.

The total volume of investment that this Initiative mobilises will be around €60 billion between now and 2010 and, in some cases, beyond.

The specific projects foreseen cover:

- ***nanoelectronics***
- ***next generation lasers (VUVs and XFEL in Hamburg)***
- ***use of hydrogen as a source of energy and electricity***

Photons at DESY:

A coherent and bright perspective

With the VUV FEL, PETRA III and XFEL project DESY will provide a unique spectrum of outstanding facilities for research with X-rays to the national and international science communities.

DESY's accelerator department will focus more and more on the development, construction and operation of accelerator based light sources.

Together with its international partners, especially in the TESLA collaboration, DESY has an extraordinary potential to promote progress in accelerator based light sources and photon sciences as a whole.