

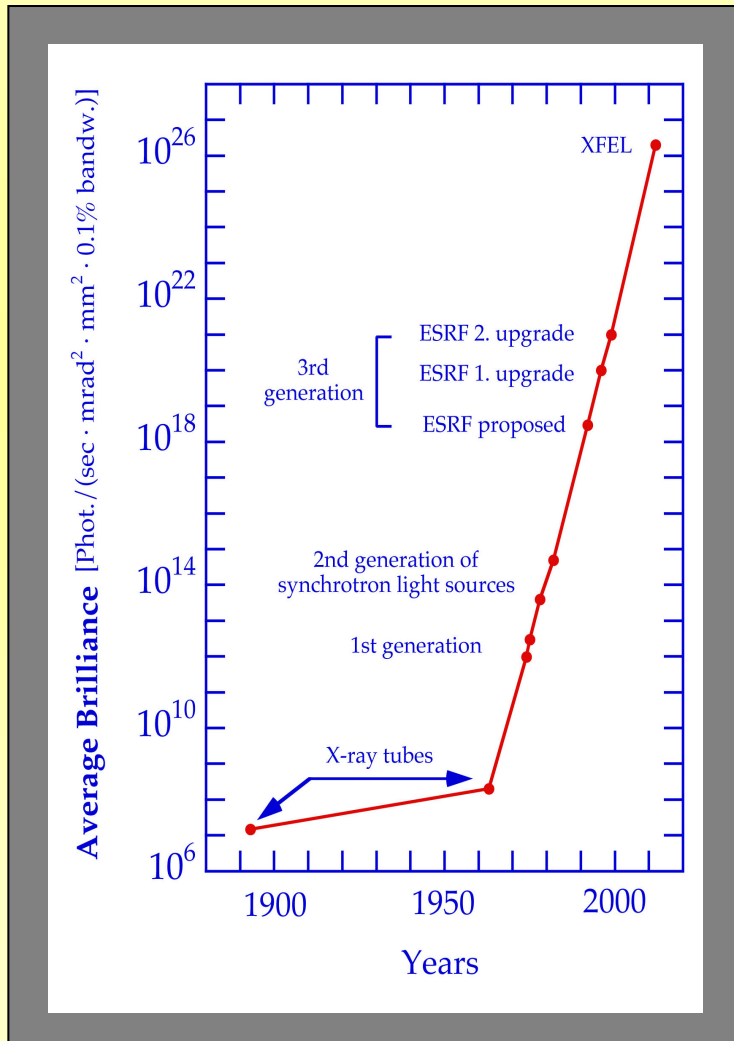
***ESFRI workshop on
Technical Challenges at the Proposed European XFEL Laboratory
30-31 October 2003***

XFEL project overview

Jochen R. Schneider (DESY)

- ***Scientific motivation for XFELs***
- ***Development of the Hamburg project (TESLA collaboration)***
- ***Current status of the European XFEL project at DESY***
- ***Goal of the workshop as defined by ESFRI***

Development of the brilliance of X-ray sources



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

Each new generation of facilities has brought up new applications, without making established methods less valuable.

However, today's storage ring technology approaches its theoretical limits.

Probing matter with atomic resolution

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

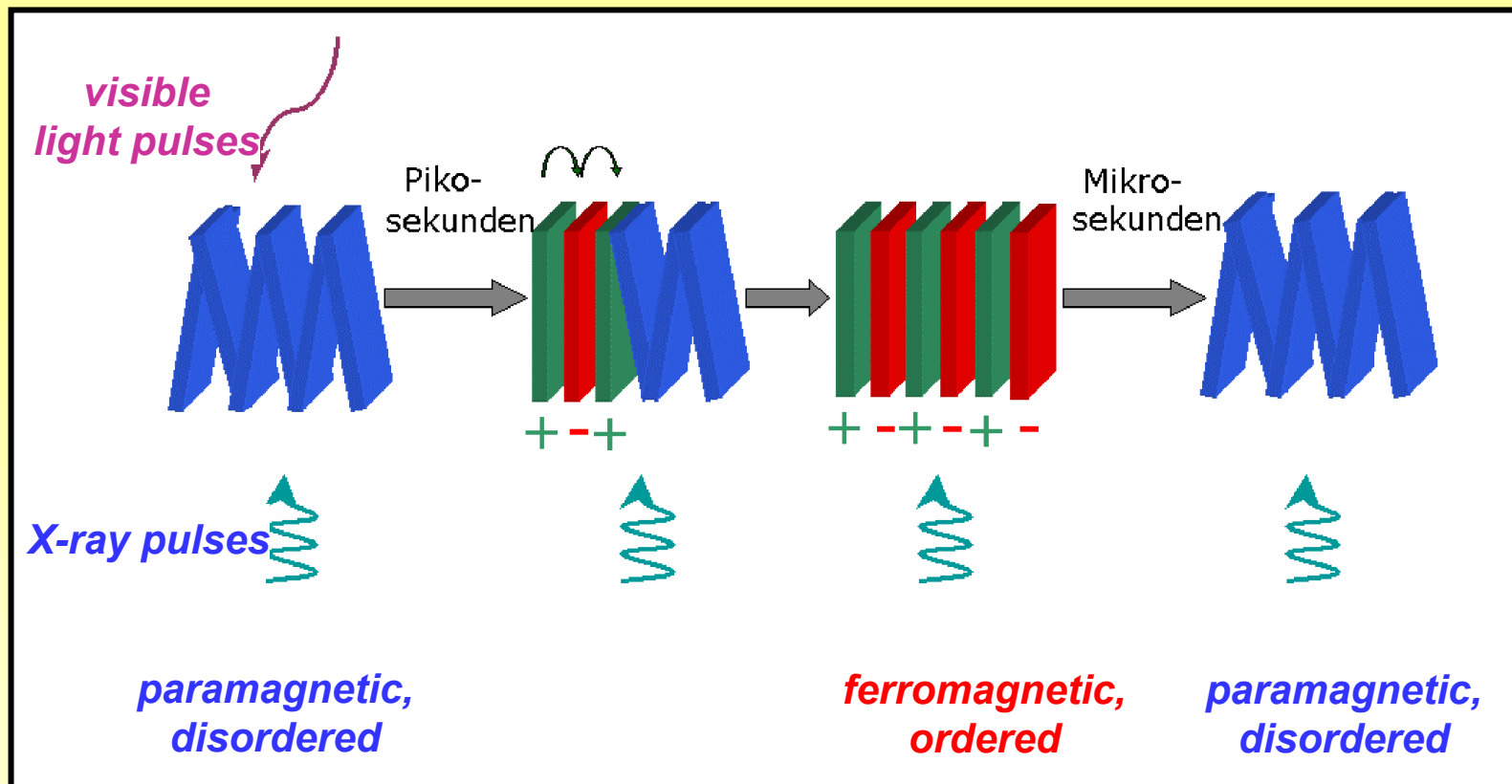
The next goal is to probe the **dynamic state of matter** with atomic resolution in space and time in order to allow for studies of **non-equilibrium states**, and very fast transitions between the different states of matter.

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



MbCO photodissociation dynamics

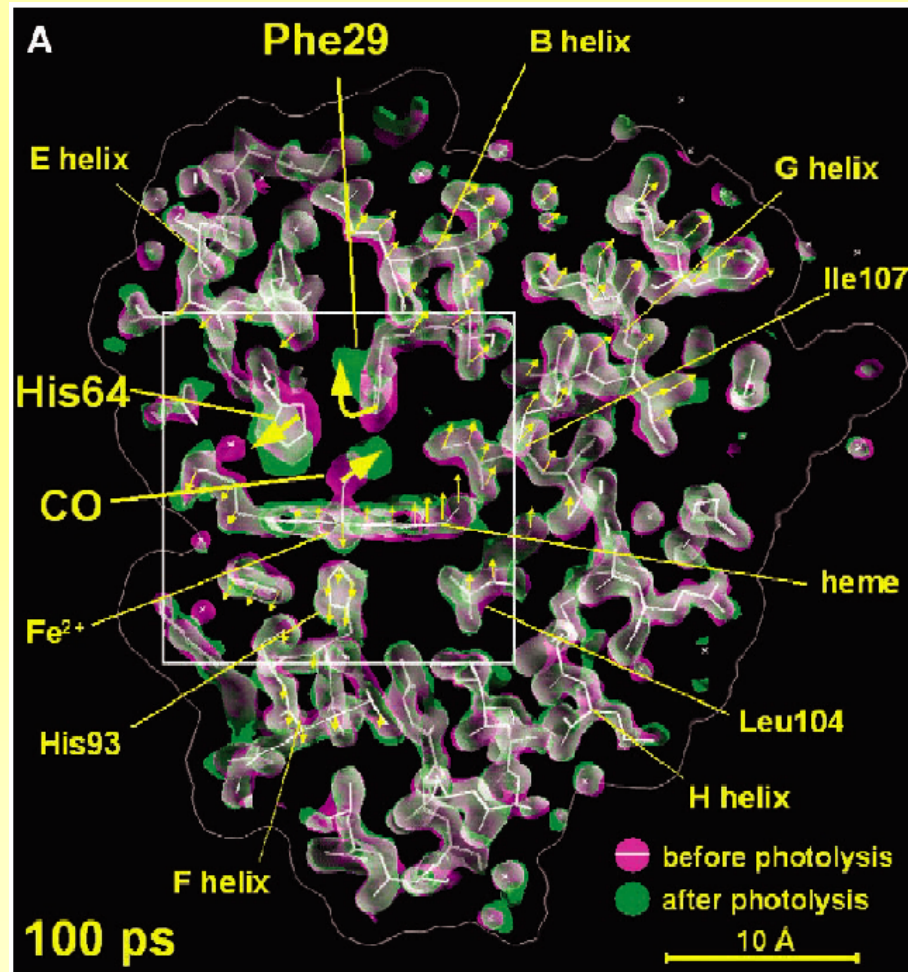
ID 09 B

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

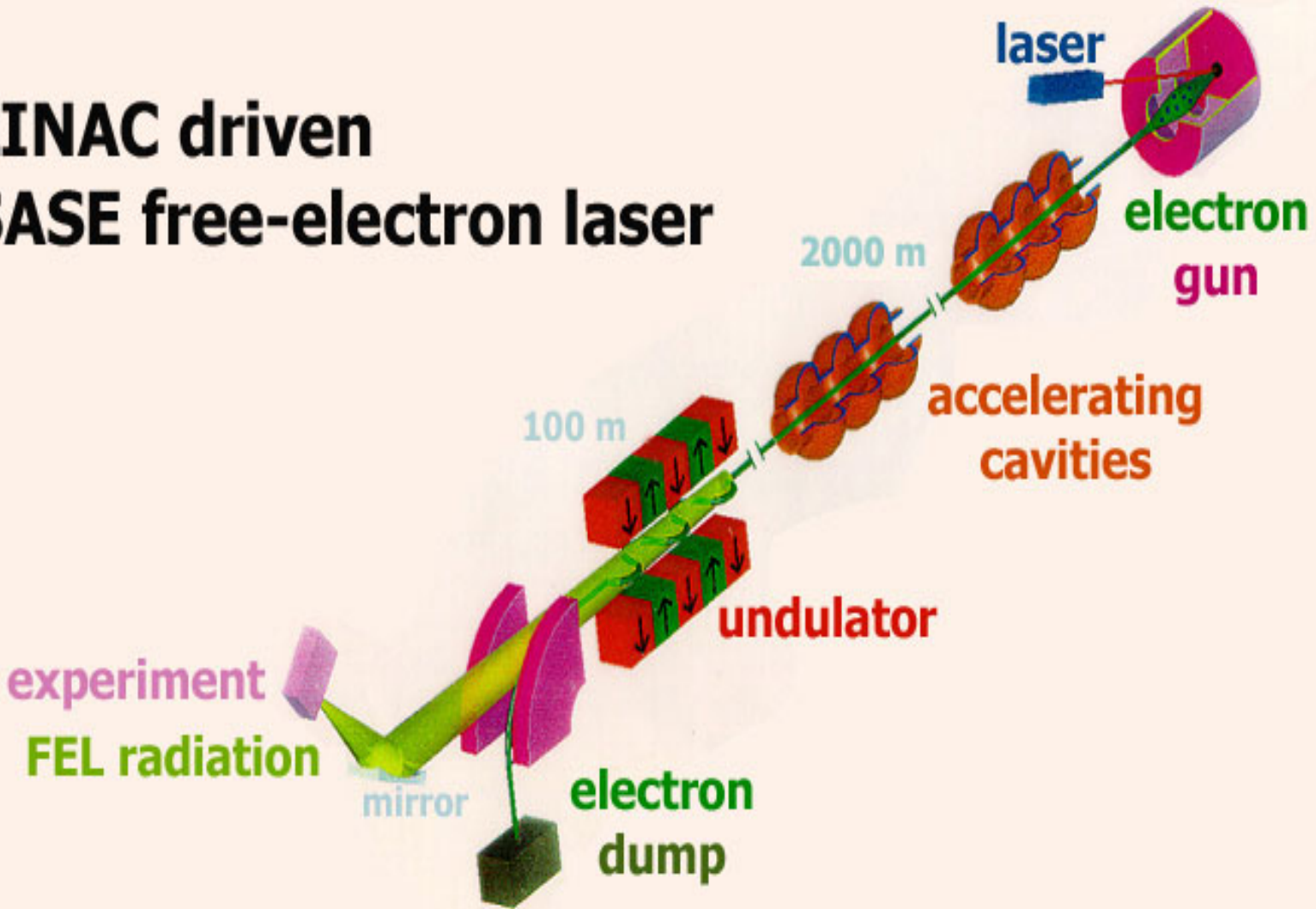
Friedrich Schotte,¹ Manho Lim,² Timothy A. Jackson,³ Aleksandr V. Smirnov,¹ Jayashree Soman,⁴ John S. Olson,⁴ George N. Phillips Jr.,⁵ Michael Wulff,⁶ Philip A. Anfinrud¹

X-ray pulses (~150 psec, ~1010 photons, 0.1mm²)

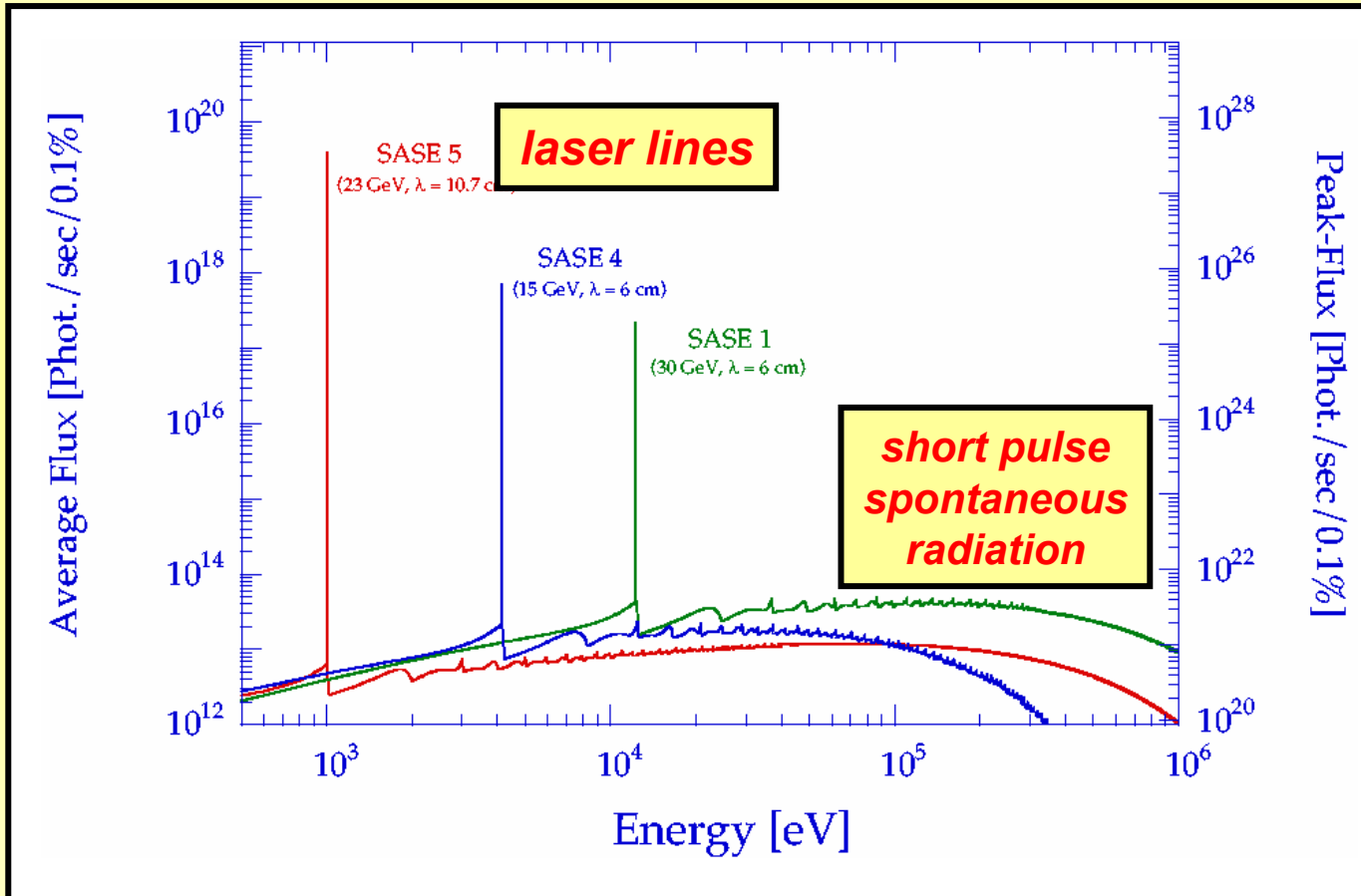
Laser pump pulses (570 nm, 1 psec, 23 μJ) induced photodissociation, better than 50 psec time jitter.



LINAC driven SASE free-electron laser



SASE X-FEL: Spectral flux



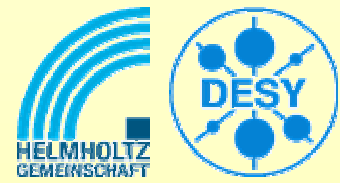
Spectral distribution of angle integrated SASE FEL radiation

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)

*The XFEL will not replace the storage facilities,
it opens the door to new science*



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***

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

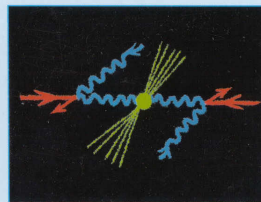
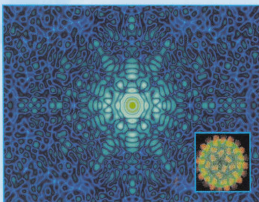
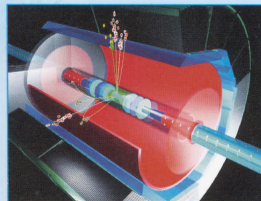
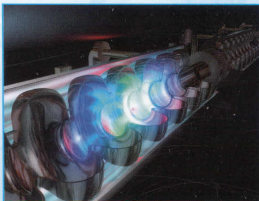


TESLA

The Superconducting Electron-Positron
Linear Collider with an Integrated
X-Ray Laser Laboratory

Technical Design Report

Part I Executive Summary



DESY 2001 - 011 • ECFA 2001 - 209
TESLA Report 2001 - 23 • TESLA-FEL 2001 - 05

March
2001

Members of the TESLA Collaboration

- | | | | |
|---|---|---|--|
|  | Yerewan Physics Institute, Yerewan |  | Institute of Nuclear Physics, Cracow
University of Mining and Metallurgy,
Cracow |
|  | Institute for High Energy Physics (IHEP), Academia Sinica, Beijing
Tsinghua University, Beijing |  | Sultan Institute for Nuclear Studies,
Cracow/Busiek |
|  | Institute of Physics, Helsinki |  | High Pressure Research Center,
Polish Academy of Science, Warsaw |
|  | CEA/DSM DAPHNE, CE-Saclay,
Orsay-Yvette
Laboratoire de l'Accélérateur
Linéaire (LAL), IN2P3, Orsay
Institut de Physique Nucléaire
(IPN), Orsay |  | Institute of Physics, Polish Academy
of Science, Warsaw
Polish Atomic Energy Agency
Warsaw
Faculty of Physics, University of
Warsaw |
|  | Rheinisch-Westfälische Technische
Hochschule, Aachen
Berliner Elektronenspeicher-
Gesellschaft für Synchrotronstrahlung,
BESSY, Berlin
Helmholtz Institut Berlin
Max-Planck-Institut, Berlin
Technische Universität Berlin
Technische Universität Darmstadt
Technische Universität Dresden
Universität Frankfurt
GSI-Forschungszentrum
Gesellschaft
Deutsches Elektronen-Synchrotron
DESY in der Helmholtz-Gemeinschaft,
Hamburg und Zeuthen
Universität Hamburg
Forschungszentrum Karlsruhe
Universität Konstanz
Bergische Universität-GH Wuppertal |  | 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), Novosibirsk
Institute for High Energy Physics
(IHEP), Protvino
Institute for Nuclear Research (INR),
Russian Academy of Science, Troitsk |
|  | CCLRC-Daresbury and Rutherford
Appleton Laboratory, Chilton
Royal Holloway, University of London (RHUL)
Queen Mary, University of London (QMUL)
University College London (UCL)
University of Oxford |  | Centro de Investigaciones
Energéticas, Medioambientales
y Tecnológicas (CIEMAT), Madrid |
|  | 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), Rome II
Istituto Nazionale di Fisica
Nucleare (INFN), Trieste |  | 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 |

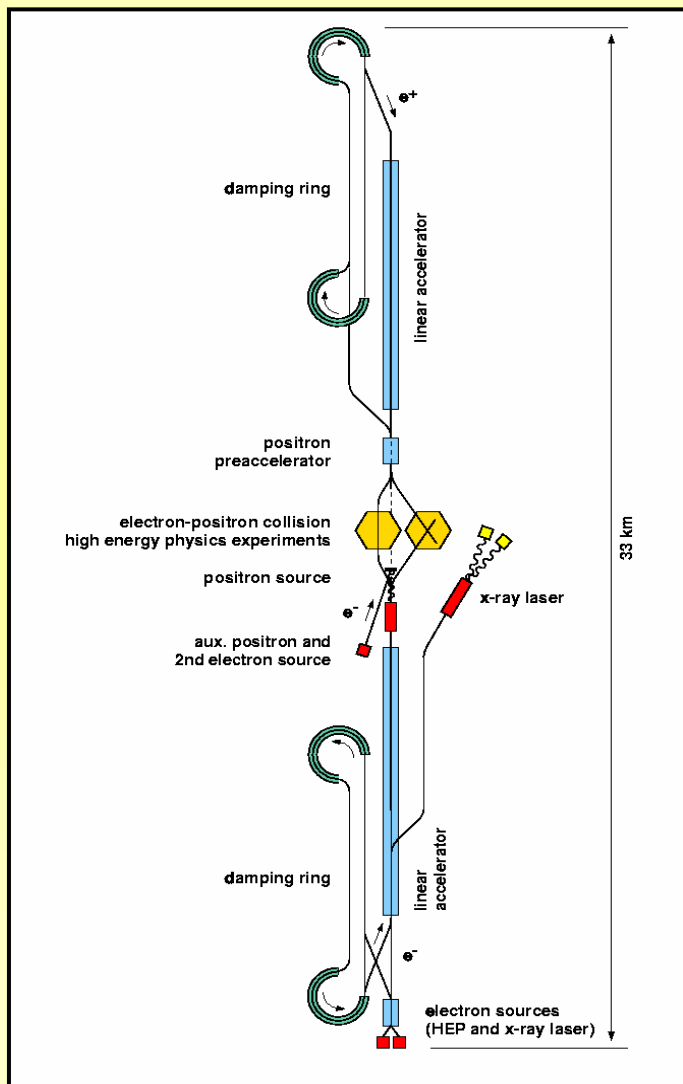
*bottom up
collaboration initiated
by particle physics*

TESLA kick-off meeting March 2001



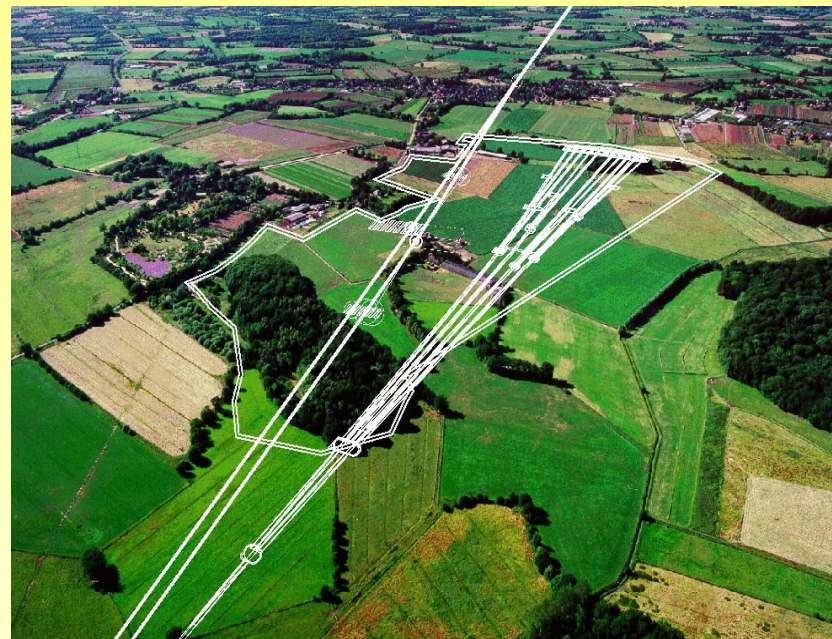
TESLA:

Linear Collider with integrated X-ray laser laboratory

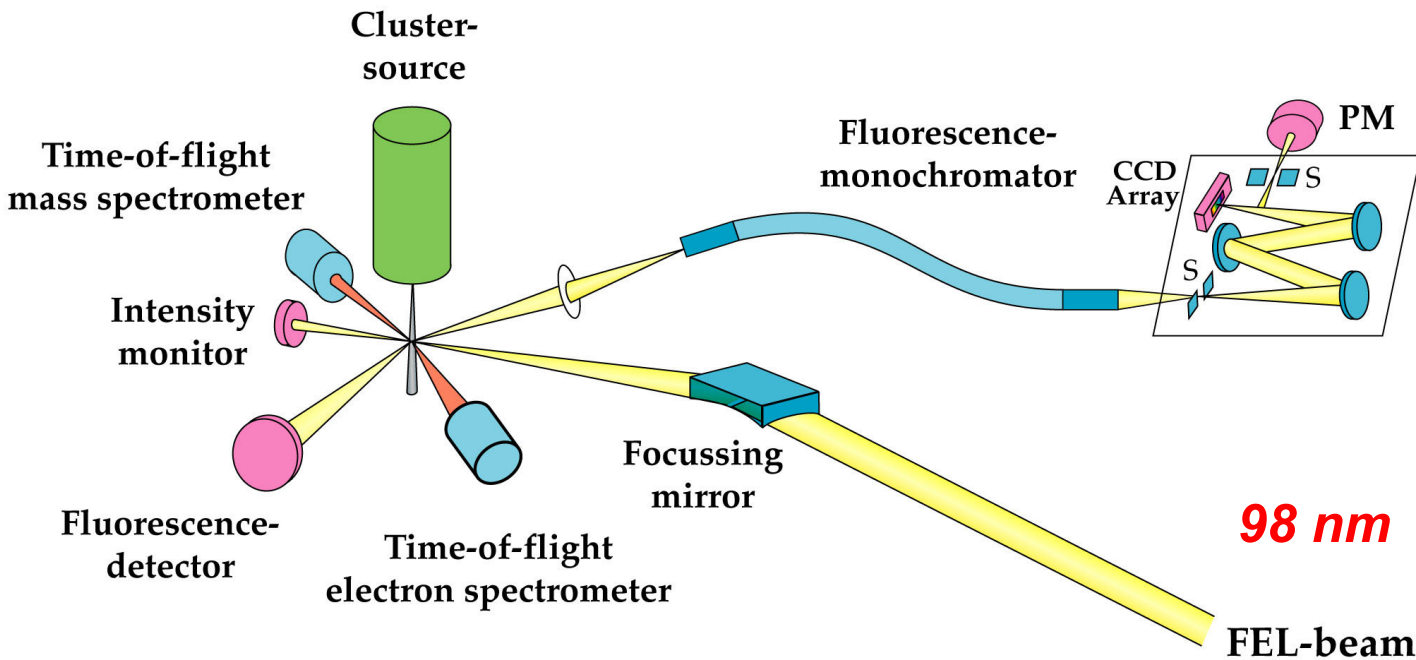


<i>500 GeV linear collider</i>	<i>3136 Mio Euro</i>
<i>Detector for particle physics</i>	<i>210 Mio Euro</i>
<i>Accelerator components for X-FEL</i>	<i>241 Mio Euro</i>
<i>X-ray laser laboratory</i>	<i>290 Mio Euro</i>
<i>7000 person years</i>	

**March
2001**



FEL Cluster Experiment at 100 nm



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

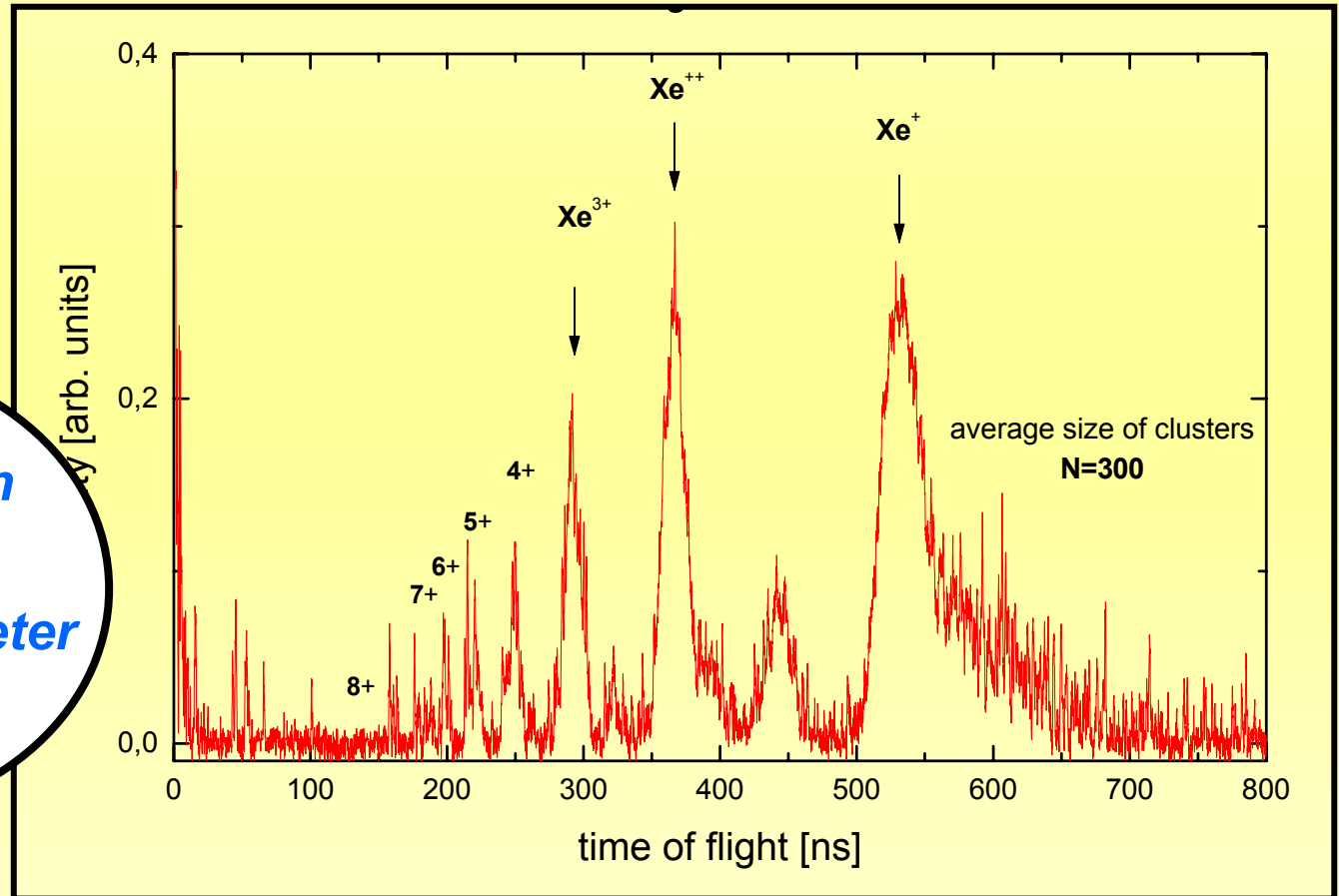
50 μ J, 50 fsec

up to power densities of 10^{14} W/cm²

Single shot time-of-flight spectrum

$I_{p_{Xe}} = 12.1 \text{ eV}$
 $E_{phot} = 12.8 \text{ eV}$

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



Coulomb explosion of Xenon clusters with ~ 300 atoms

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

Step wise approach for construction and usage

FEL at TTF Phase I (1999 - 2002):

Proof-of-Principle for SASE in 2001, first experiments

*integrated
system tests
are needed*

FEL at TTF Phase II (2005):

Soft X-rays in the 100 - 6 nm wavelength range, *user facility*

TESLA XFEL with X-ray User Facility:

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

TESLA Test Facility LINAC

Beam Dumps

Protvino

Modul Cryostats

INFN

Magnets

**Fermilab, INFN,
Orsay, Protvino,
Yerevan**

Cryogenics

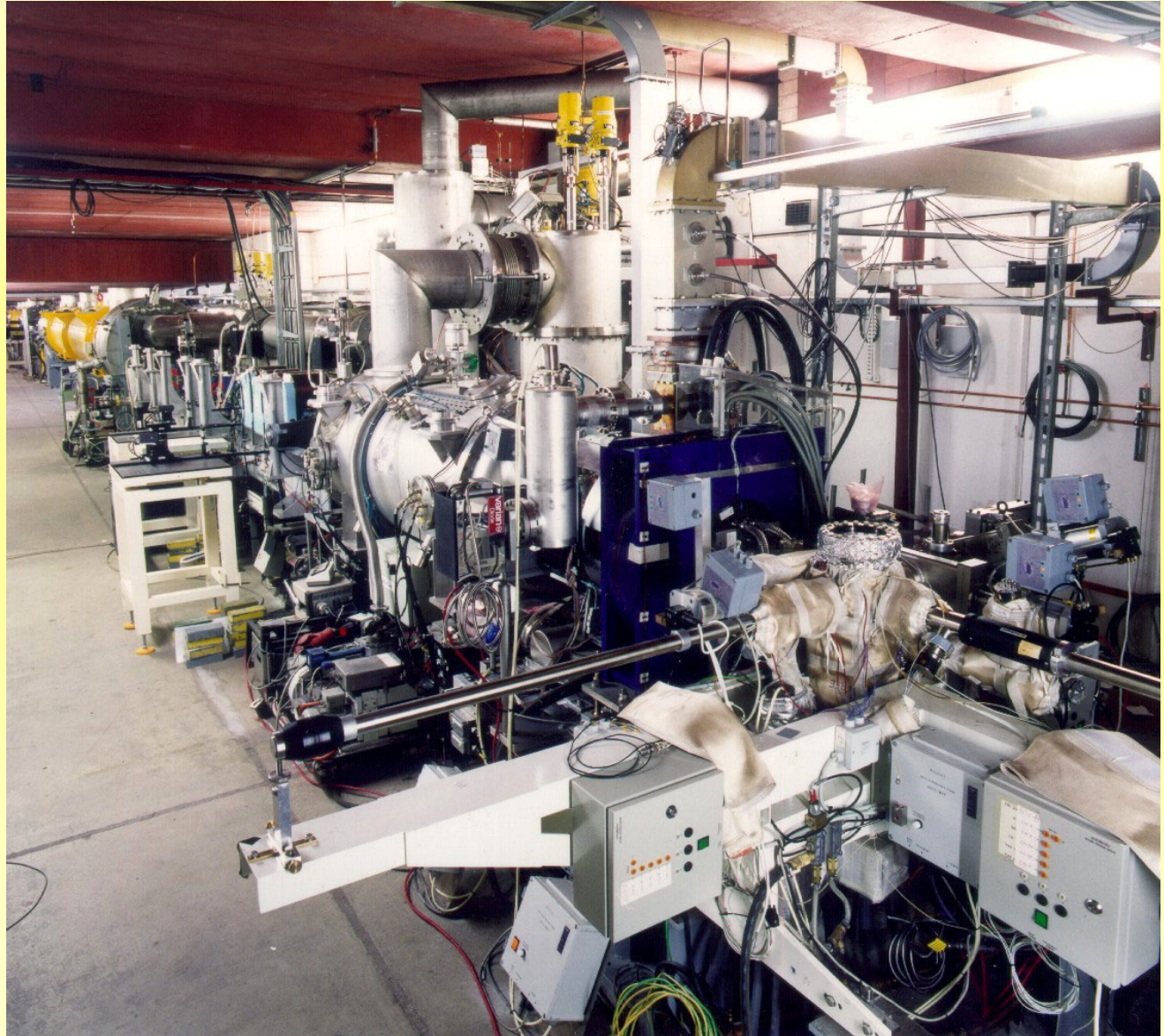
Fermilab, Orsay

Instrumentation

INFN, Orsay

Injector; RF-gun

**Orsay, Saclay,
Fermilab, INFN**



Performance of TESLA Test Facility VUV FEL

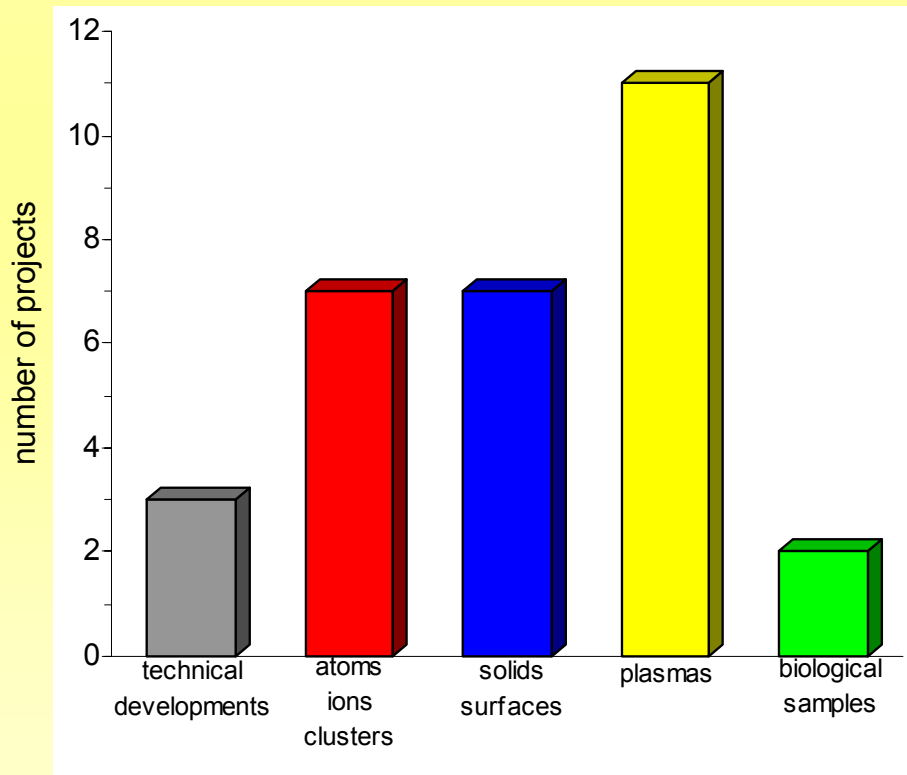
- ***saturation 80-120 nm***
- ***photon statistics***
- ***single pulse spectral distribution***
- ***lateral coherence***
- ***second harmonic***
- ***pulse length variation 50-150 fsec***

***all measured quantities agree very well with
SASE FEL theory***

Review of VUV FEL Proposals

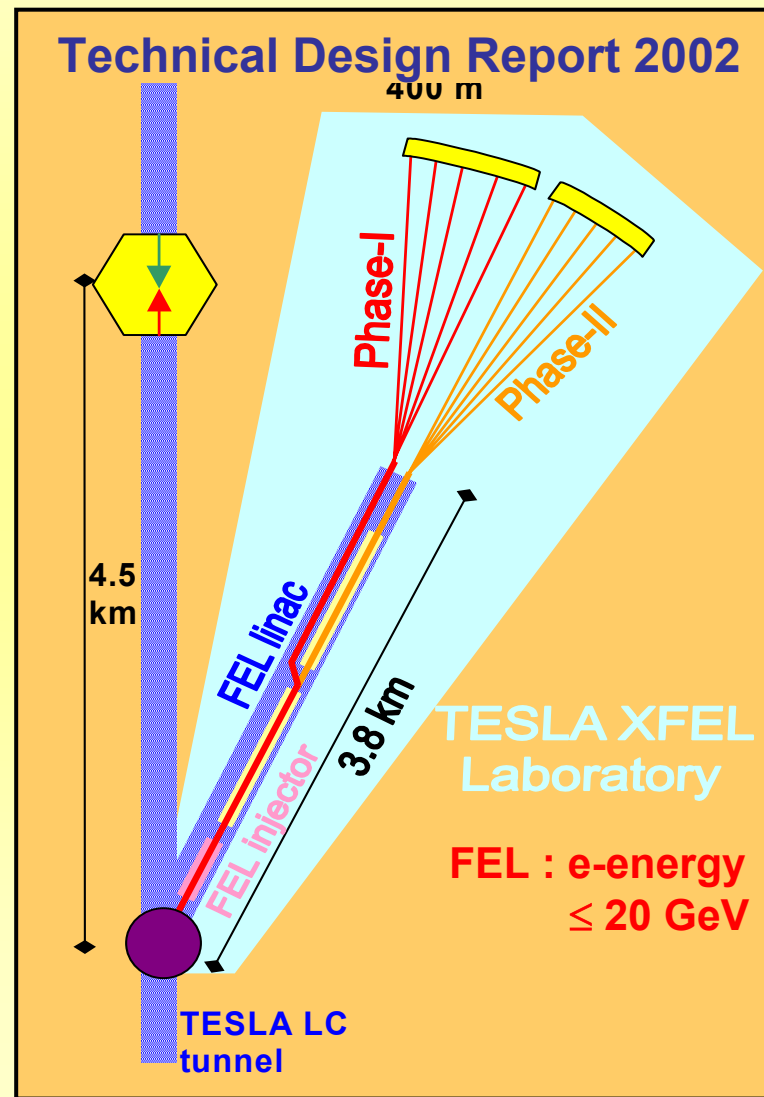
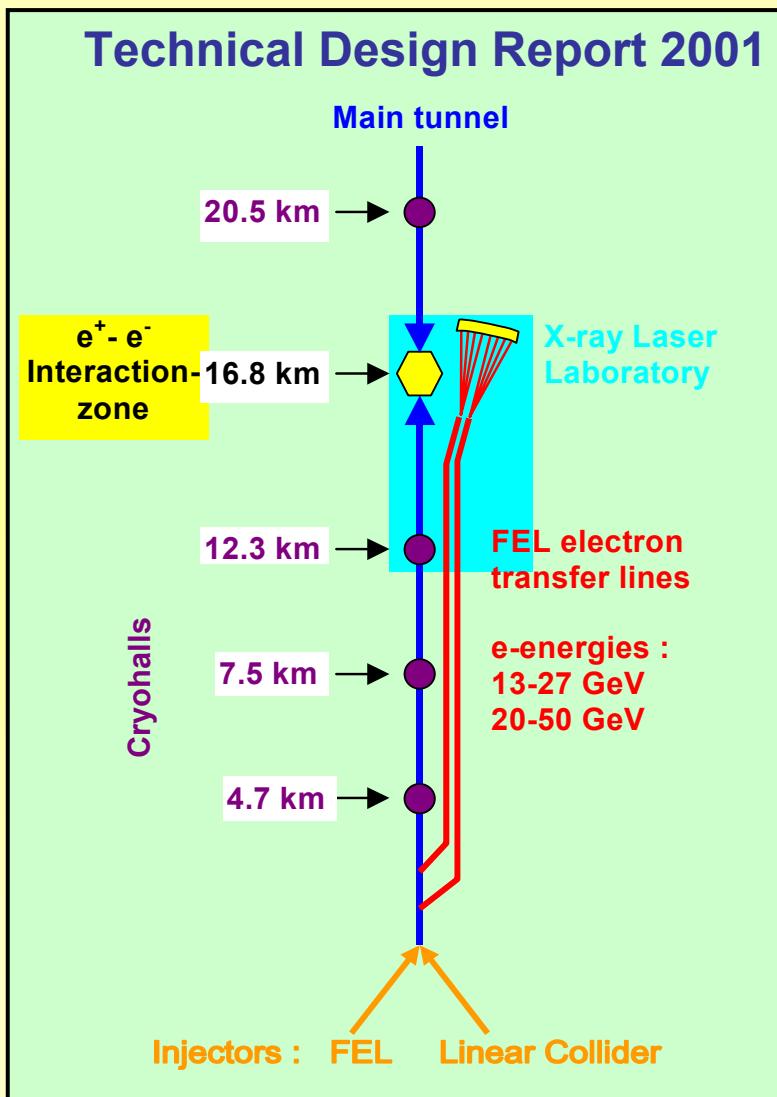
Sep. 25-27, 2002

Areas of Proposed Research



- *30 proposals submitted*
 - 18 individual projects*
 - plasma physics proposal with 12 projects*
- *about 200 scientists from 60 institutes in 11 countries involved*
 - optical lasers community: 18*
 - synchrotron community: 12*

Science Council evaluation of TESLA



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** which contains the integrated solution. This proposal should include a **cost evaluation**.*



TESLA

TESLA X-FEL
First Stage of the X-Ray Laser Laboratory

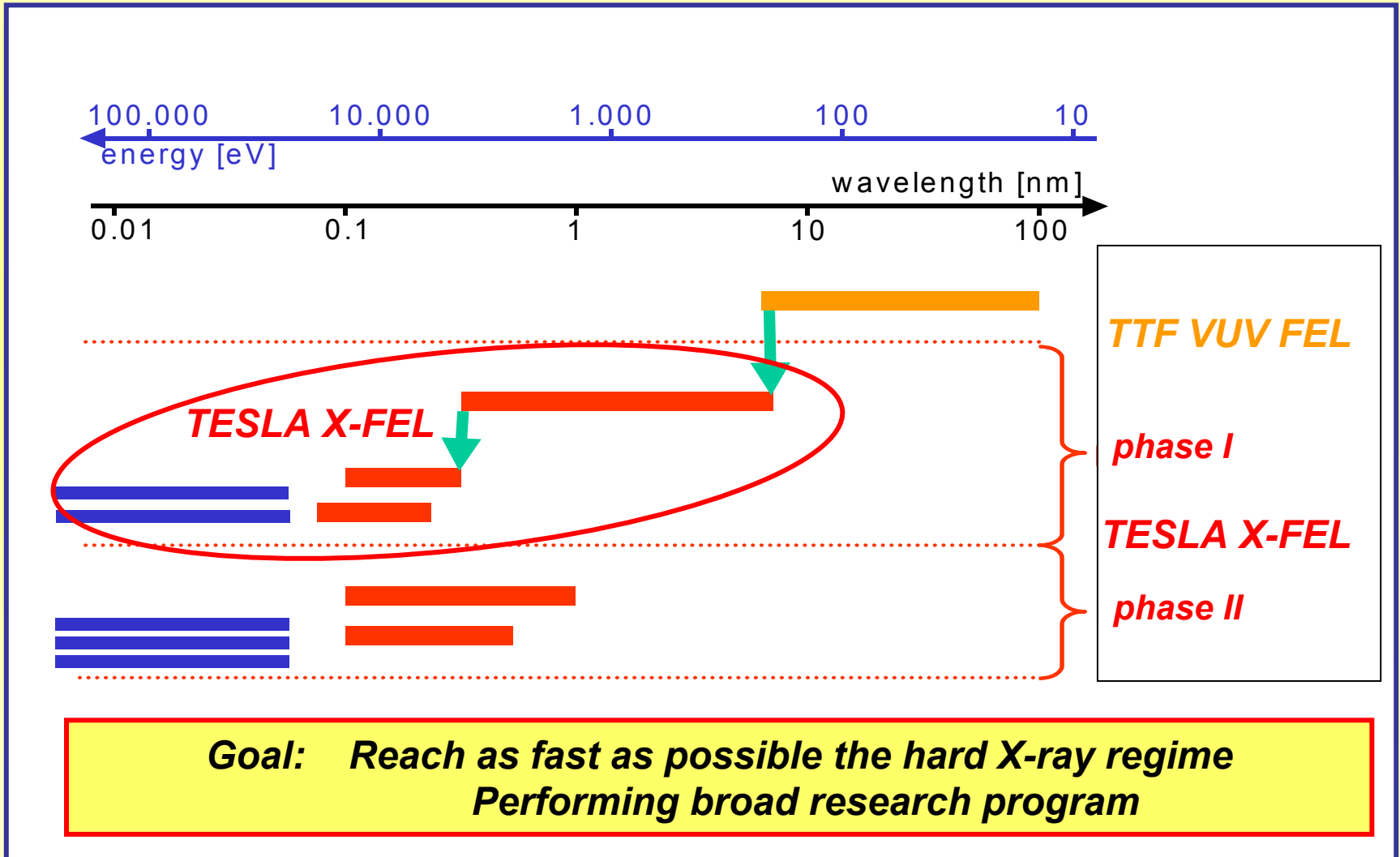
Technical Design Report
Supplement

DESY 2002 -167

October
2002

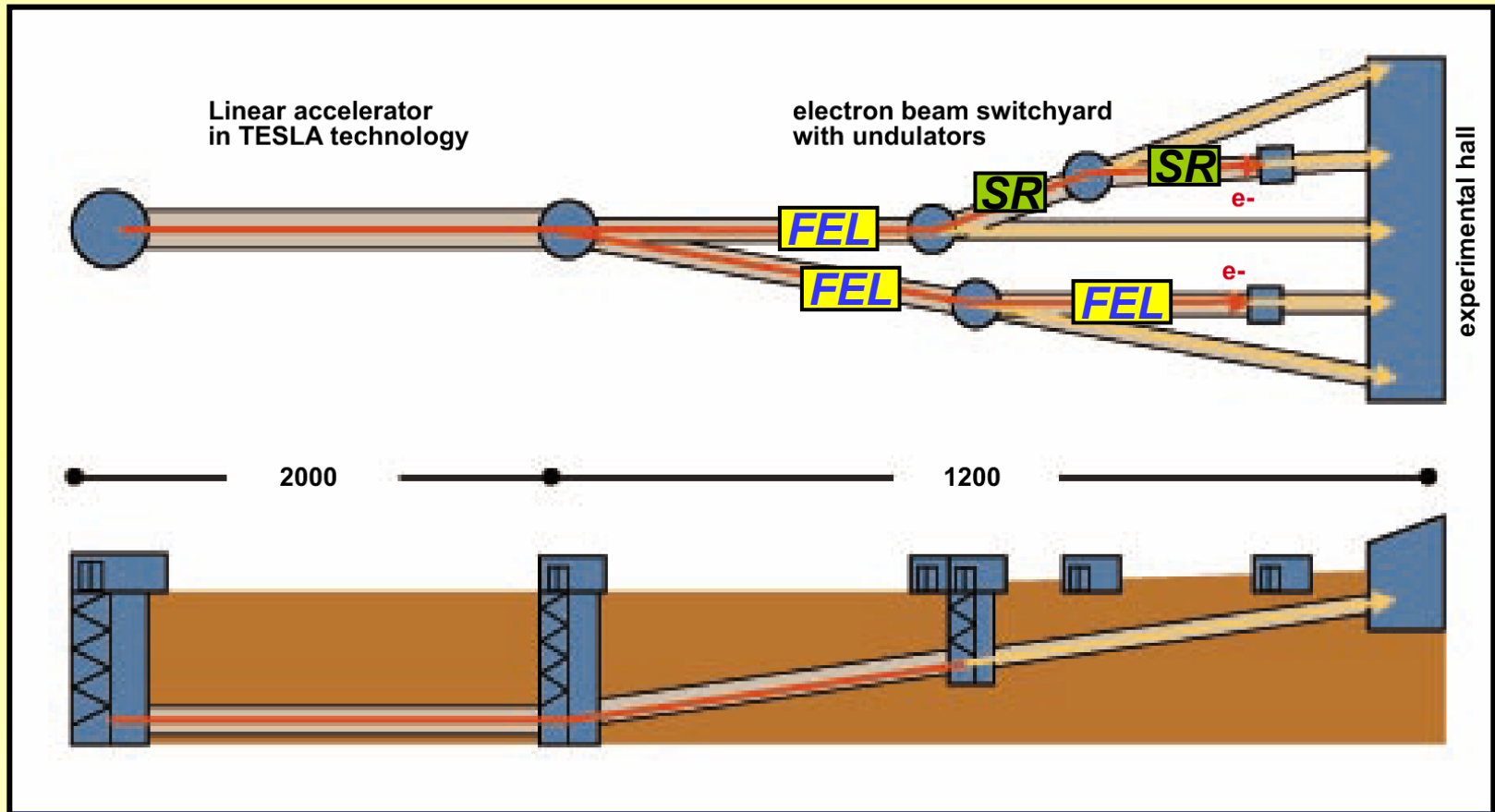
stand alone facility

Spectral distribution of TESLA XFELs

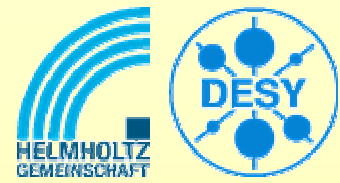


Project

European XFEL Laboratory



**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***

Government activities

for promotion of the European XFEL Laboratory project

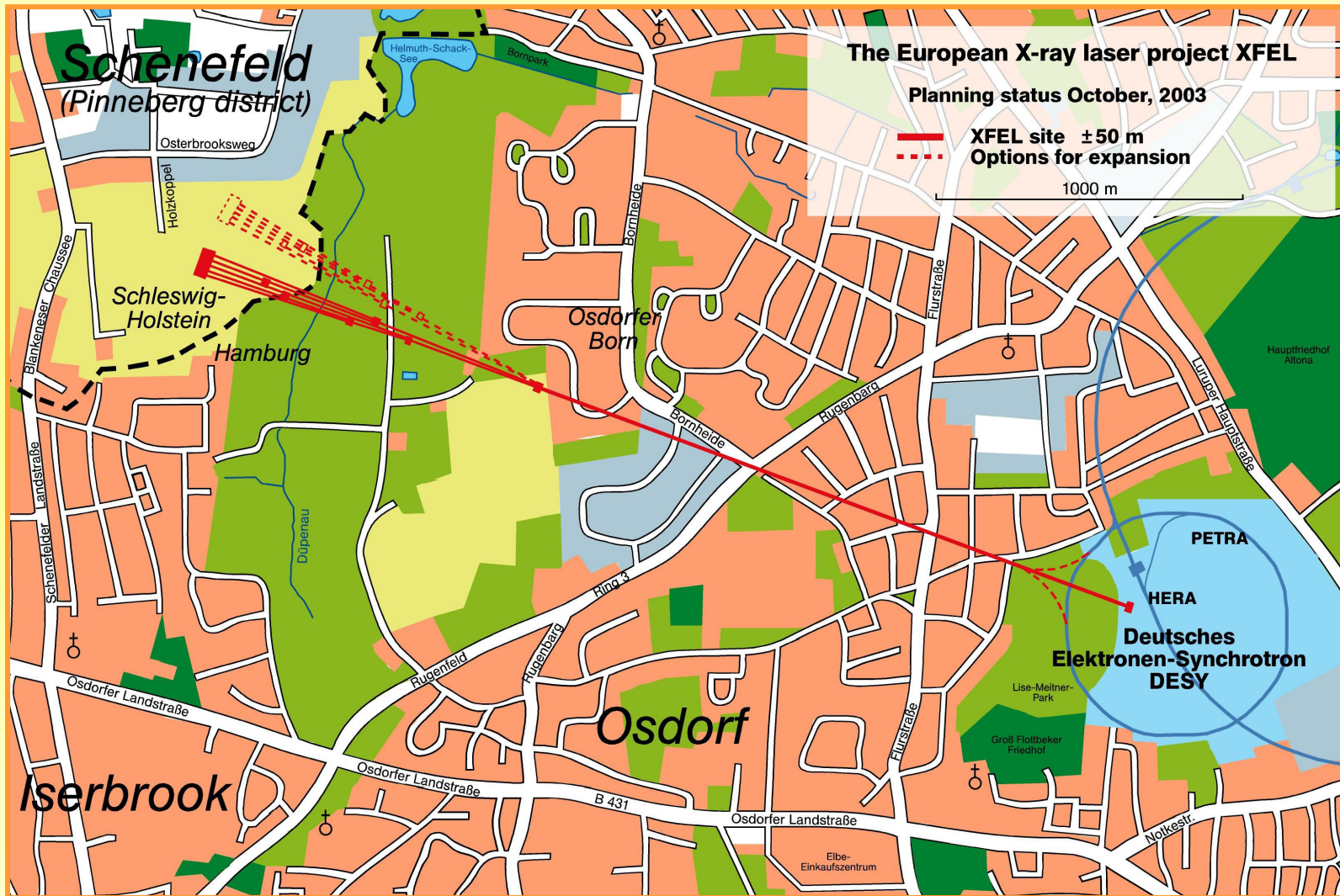
Mrs. Edelgard Bulmahn, German Minister for Education and Science, wrote letters to her colleagues (countries represented in ESFRI plus Switzerland and Russia) inviting them to join *two working groups*:

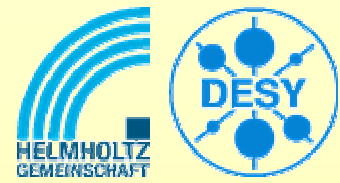
- **Working Group dealing with *scientific and technical matters* of the project**
- **Working group dealing with the *administrative matters* of the project**

**Site, facility layout
and some of the technical
parameters for the XFEL Laboratory
are currently reconsidered**

Positive response from at least 7 European countries

European XFEL Laboratory – Site Proposal





Photon Science at DESY

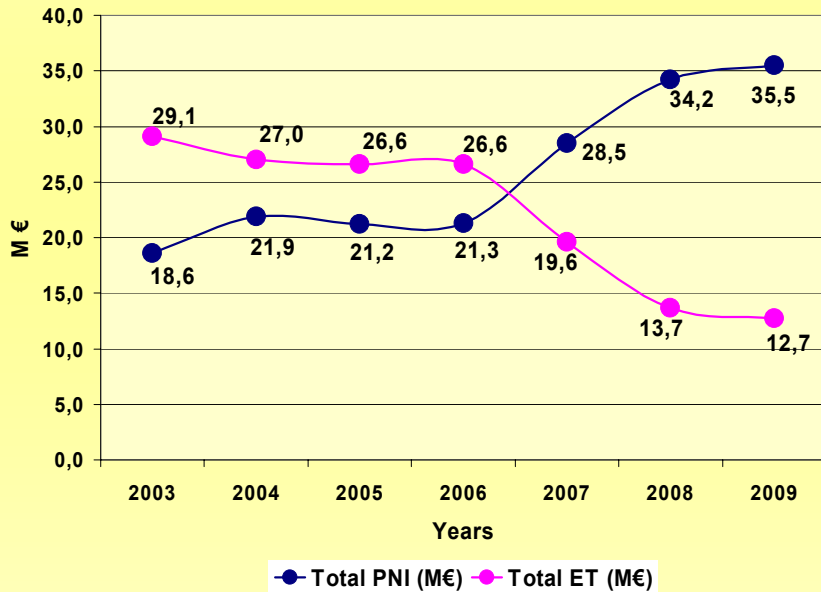
With the VUV FEL, PETRA III and XFEL project DESY will thus provide a **unique spectrum of outstanding facilities** for research with X-rays to the national and international science communities.

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.

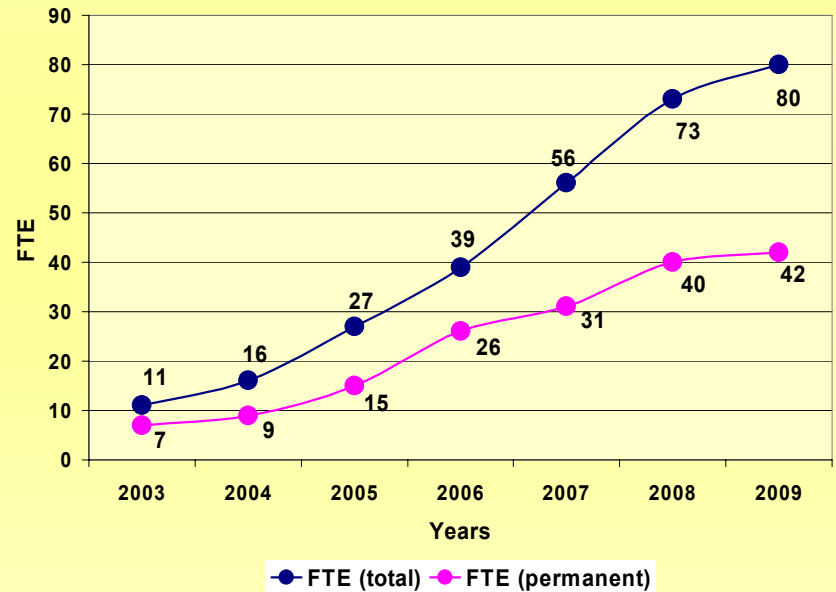
DESY research programs and resources

DESY research budgets (without infrastructure)



Elementary Particle Physics
Photon Science

Full Time Equivalents PS in-house research



Photon Science
total # FTE
(permanent)



ESFRI

EUROPEAN STRATEGY FORUM on RESEARCH INFRASTRUCTURES

Fifth meeting

Brussels, Monday April 28, 2003 (09:30-17:00)

5. X-ray FEL at DESY

a - presentation of proposal by J. Schneider (DE)

b - discussion

6. Working groups on Free Electron Lasers

a - presentation of report by M. Poole and C. Rizzuto

b - discussion

c - conclusions and follow-up

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): discussio*
- b - conclusions and follow-up*

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



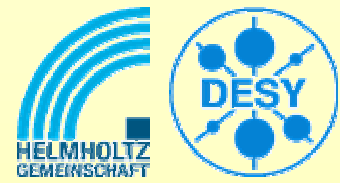
ESFRI workshop on

Technical Challenges at the Proposed European XFEL Laboratory

30-31 October 2003

Thursday, 30 Oct. – Accelerator-related aspects of the XFEL project

- | | | |
|---------------|---|--------------------------|
| 14 hrs | Opening | A. Wagner |
| 14:10 | XFEL project overview | J.R. Schneider |
| 14:40 | Roadmap towards hard X-ray FELs | J. Galayda (SLAC) |
| 15:10 | Accelerator layout and parameters | R. Brinkmann |
| | Coffee break | |
| 16:00 | Injector concept and expected performance | K. Flöttmann |
| 16:30 | Advanced laser technology – Challenges and solutions | W. Sandner (MBI) |
| 17:00 | Operation experience at TTF | H. Weise |



***ESFRI workshop on
Technical Challenges at the Proposed European XFEL Laboratory
30-31 October 2003***

17:30-19:00 Poster session for accelerator aspects

RF gun and cathode operation

Cathode laser operation

Cavities

Couplers

Accelerator modules

Power RF klystrons and modulators

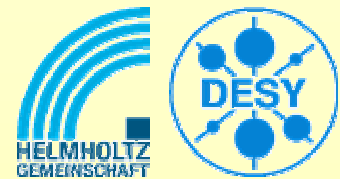
Low-level RF

Electron beam diagnostics

Electron beam stabilisation

Start-to-end simulations for the XFEL

Start-to-end analysis for TTF-1



ESFRI workshop on

Technical Challenges at the Proposed European XFEL Laboratory

30-31 October 2003

Friday, 30 Oct. – FEL radiation-related aspects of the XFEL project

- | | | |
|---------------------|---|--------------------------------|
| <i>9:00</i> | <i>Parameter choice and radiation properties</i> | <i>M. Yurkov</i> |
| <i>9:30</i> | <i>Photon beam diagnostics</i> | <i>J. Feldhaus</i> |
| <i>10:00</i> | <i>XFEL laboratory concept</i> | <i>Th. Tschentscher</i> |

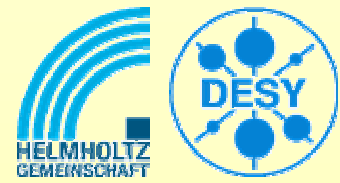
Coffee break

10:30-12:00 ***Poster session for FEL radiation aspects***

12:00-13:30 ***Lunch break***

13:30 ***Final conclusions*** ***J.R. Schneider***

13:45-15:15 ***Discussion round*** ***M. Altarelli***



ESFRI workshop on
Technical Challenges at the Proposed European XFEL Laboratory
30-31 October 2003

10:30-12:00 ***Poster session for FEL radiation aspects***

Details of SASE FEL radiation parameters

Parameters and realization of FEL undulators

Photon-beam based diagnostics for undulator alignment

X-ray photon diagnostics

FEL photon beamline concept

X-ray optics requirements

Seeding project for the VUV-FEL

Experimental hall concepts

FEL-based pump-probe experiments

The experiments challenge at TTF-1