TESLA

Progress Towards the Linear Collider in Germany

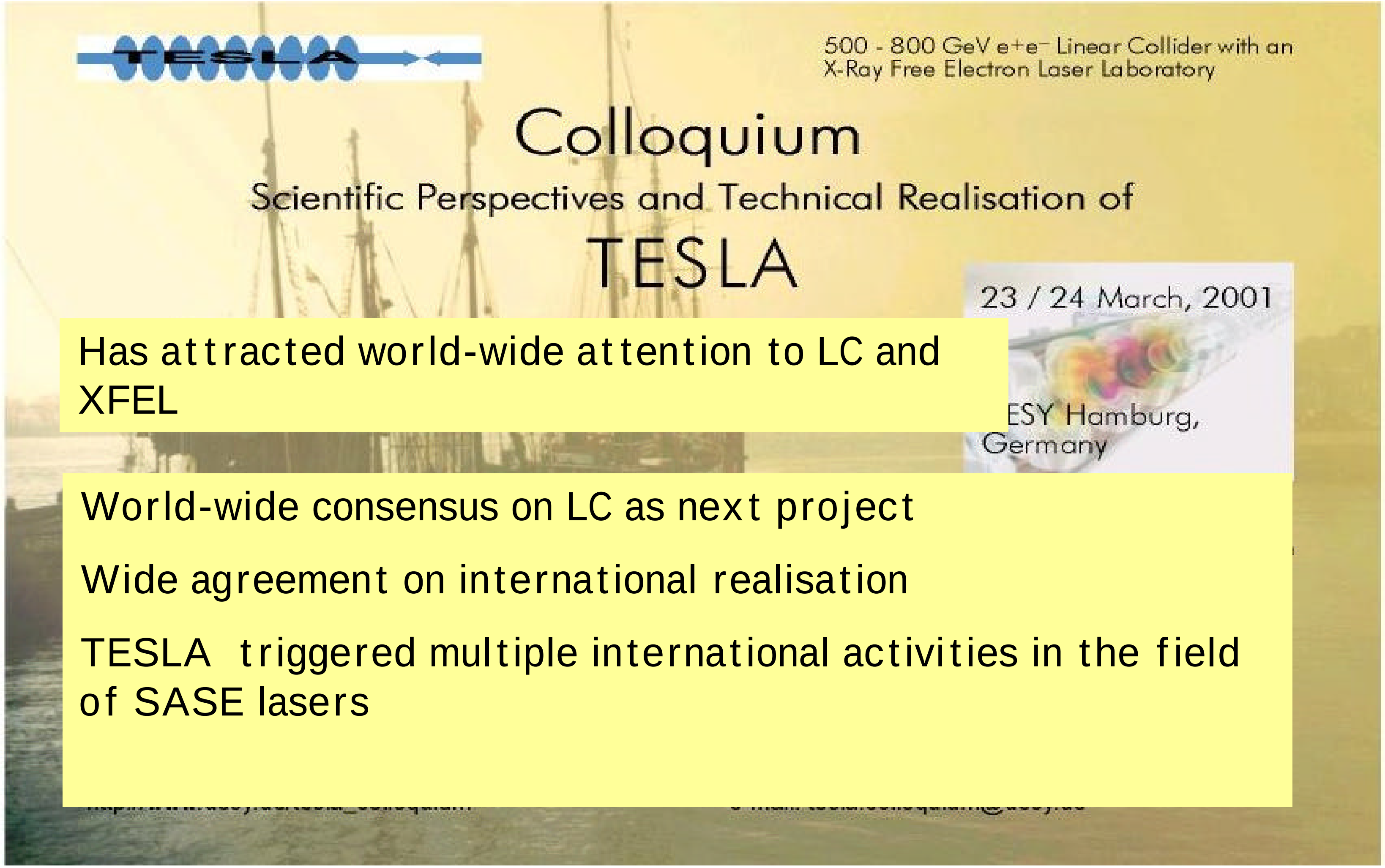
- What is new at TTF?
- Status of TESLA
- European Steering Committee
- Evaluation in Germany

(For technology aspects see talks by G. Dugan and H. Weise)

Albrecht Wagner

DESY and University of Hamburg

TESLA: One Year after TDR



- Has attracted world-wide attention to LC and XFEL
- World-wide consensus on LC as next project
- Wide agreement on international realisation
- TESLA triggered multiple international activities in the field of SASE lasers

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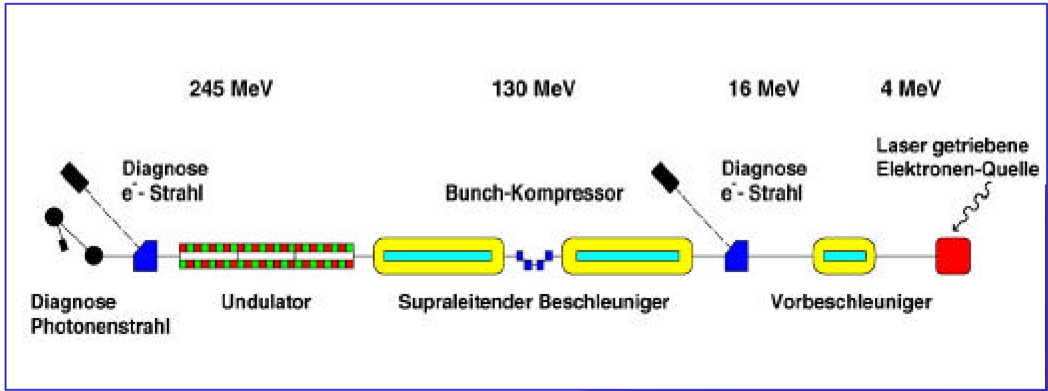
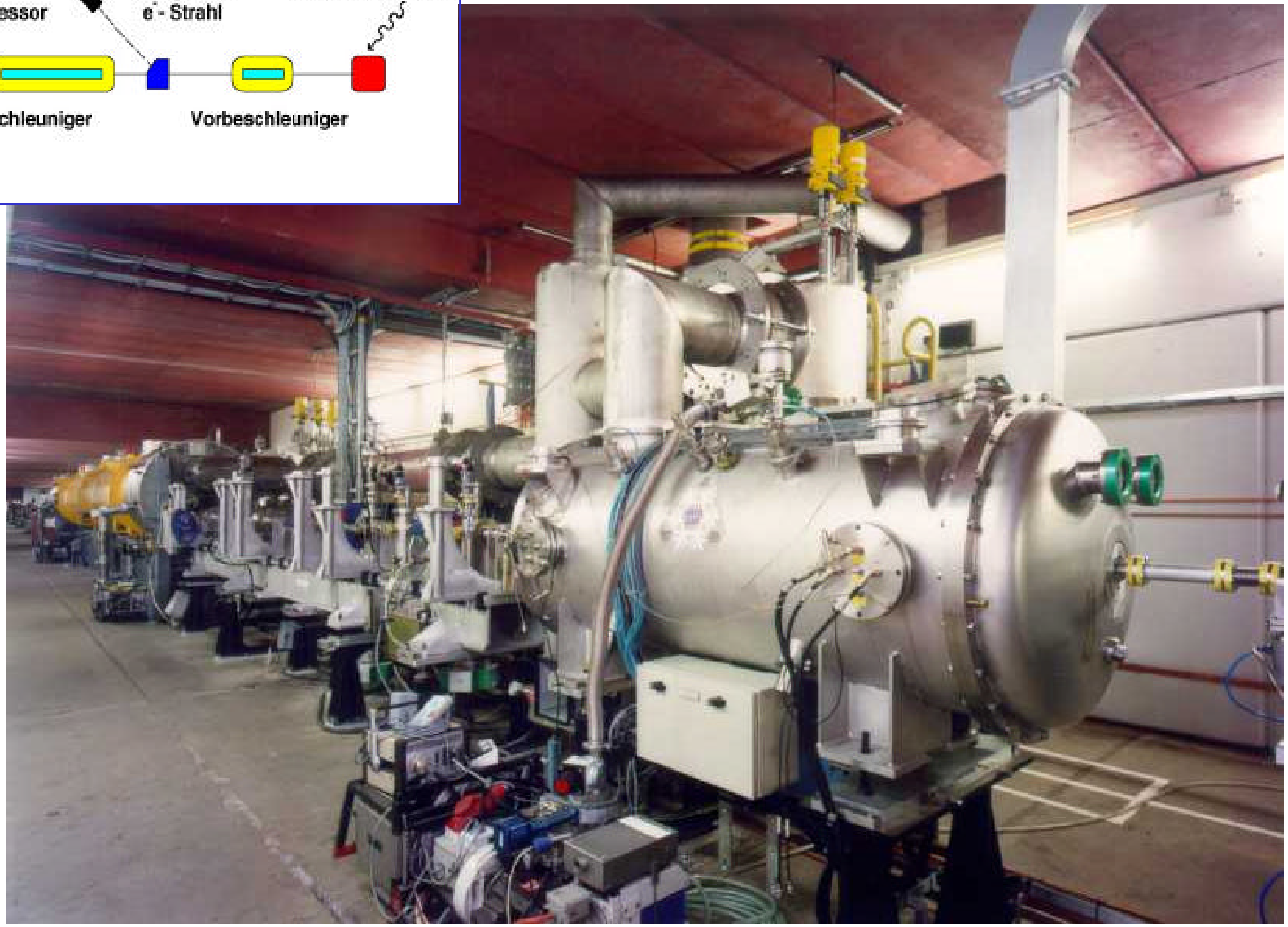
The TESLA Test Facility



Construction of a prototype accelerator:



Tasks:

Test of all components

Operation for > 13 000 h

Base for costing

Conclusion:

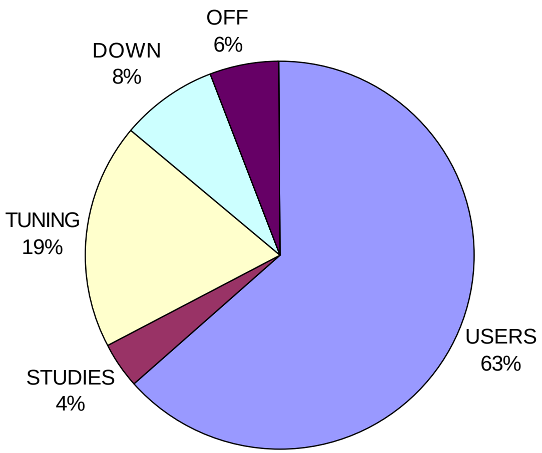
The technical readiness has been demonstrated

TTF Operation for Experiments and Beam Studies

Overview of TTF Operation from August 2001 to May 2002:

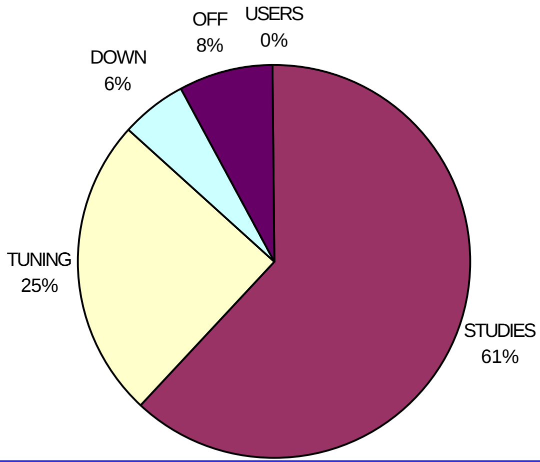
Total hours of operation: **4080**

Beam Uptime = hours allocated to the users, accelerator studies, and overall tuning: 89% (after October 2001)



FEL experiments

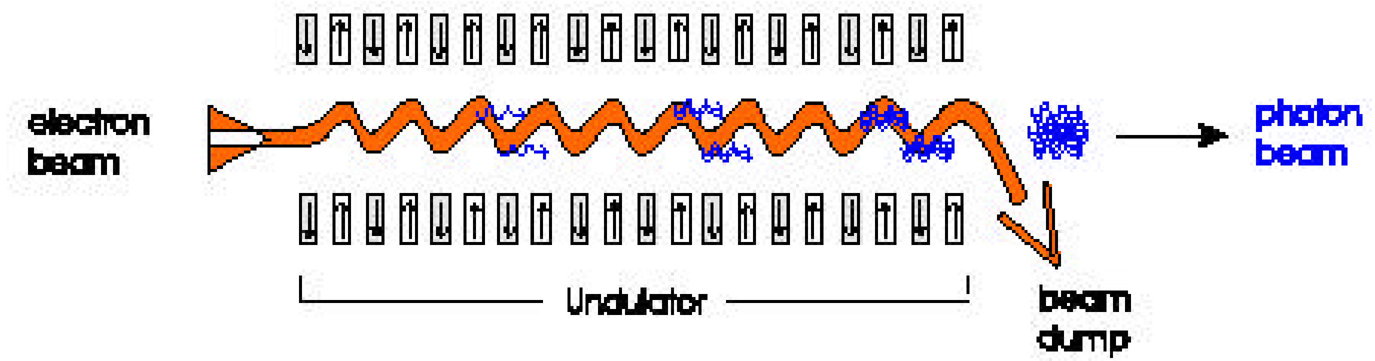
14.01.02 - 20.01.02



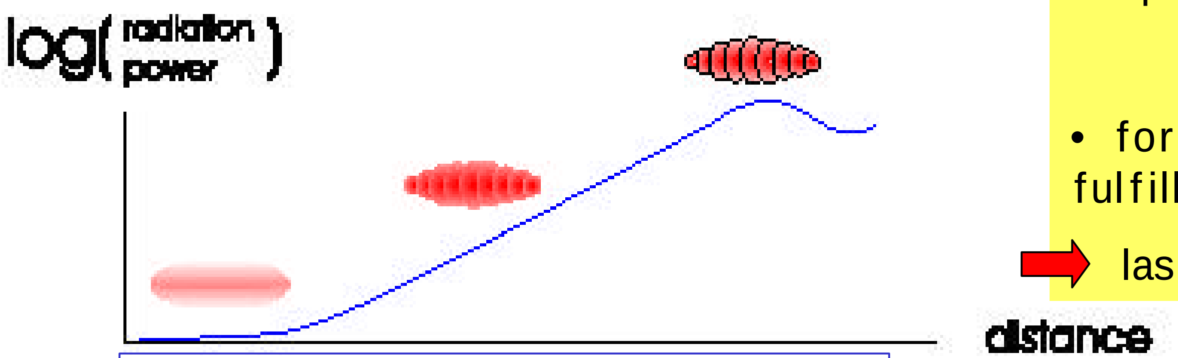
Linac studies

11.02.02 - 17.02.02

SC Linac as Base for an X-FEL

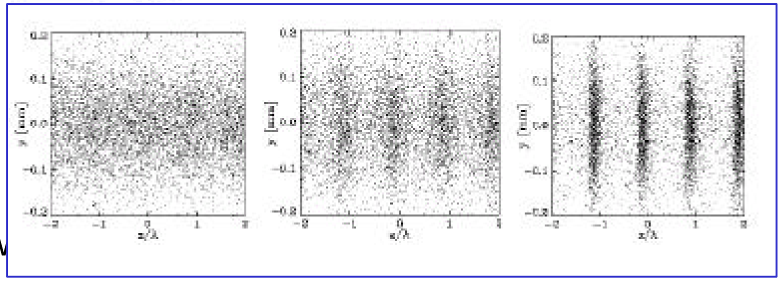


Self
Amplified
Spontaneous
Emission
(Kondratenko, Saldin 1980)



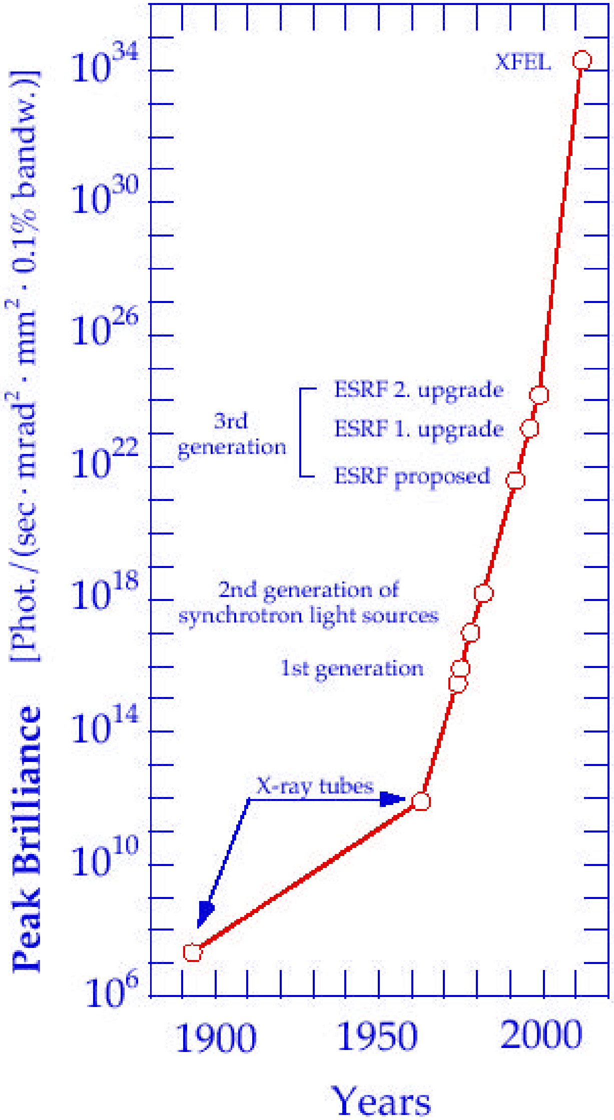
- Spont. Emission
- for certain wave lenghts, fulfilling a resonance condition

→ lasing



requires small emittance electron beam

Properties of the X-ray Laser



- Wavelength of atomic dimensions

  > 0.1 nm
- Highest brilliance

  ~ 10^9 times that of sources of the 3. generation
- Very short pulselength

  100 fs
- Tunable in wavelength
- Coherence

Synchrotron radiation power P of an incoherent electron distribution: $P \sim N_e$

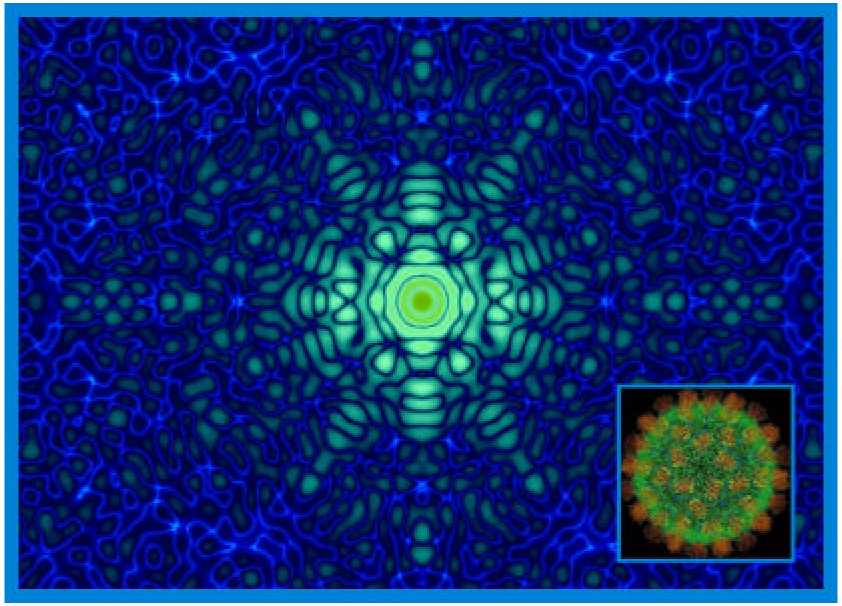
Radiation from a point charge (bunch length $< \lambda_{radiation}$): $P \sim N_e^2$

Gain: $\sim N_e = 10^9 \ldots 10^{10}$

Scientific Applications of a 0.1 nm Laser

The applications make use of the different features of the laser

- Atomic and molecular physics
- Biology
- Chemistry
- Material science
- High field- and plasma physics



movies of chemical reactions

real-time studies of formation of condensed matter

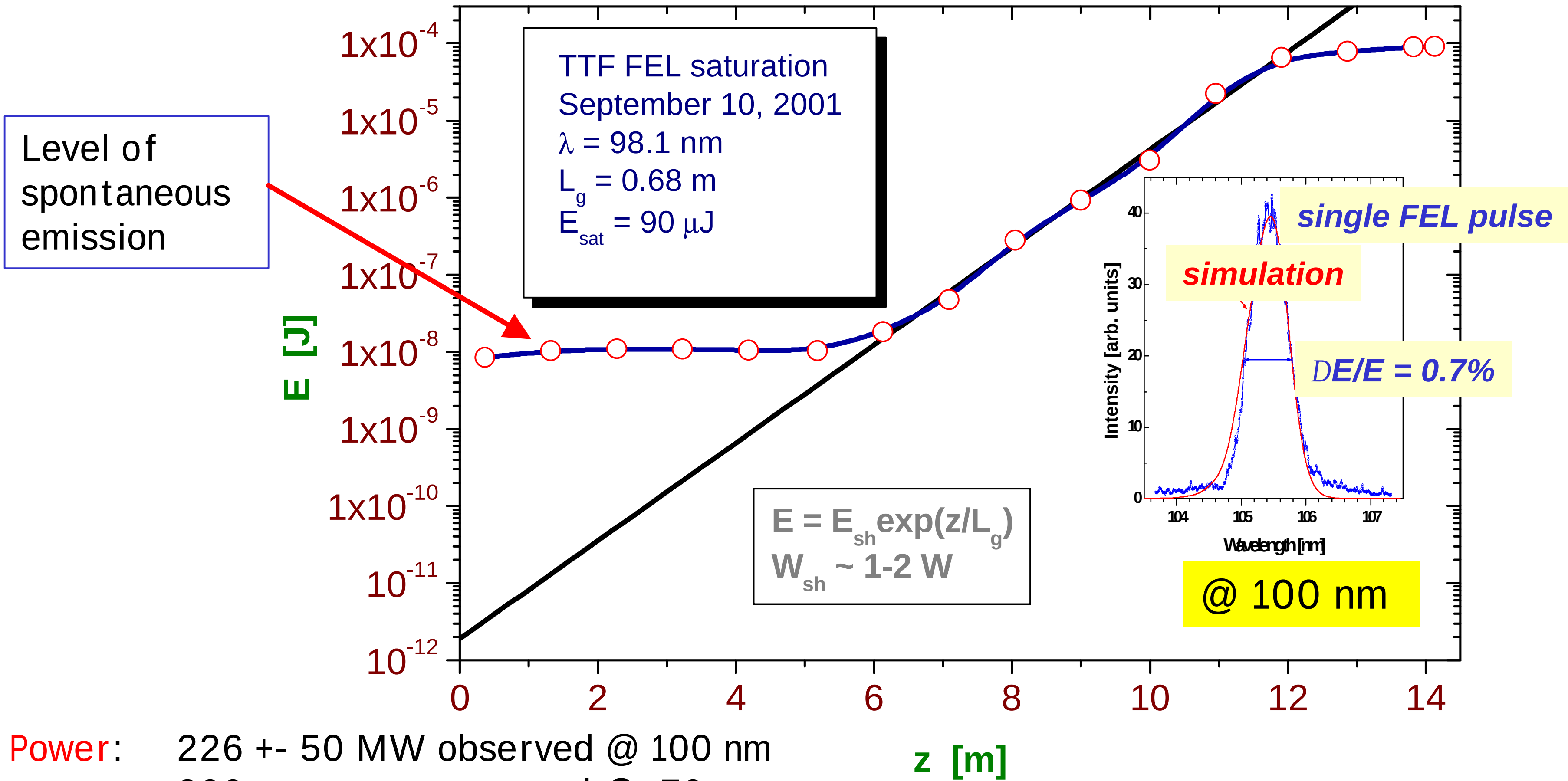
imaging of bio-molecular assemblies with atomic resolution

Key role for pump-and-probe experiments

Properties of the Laser

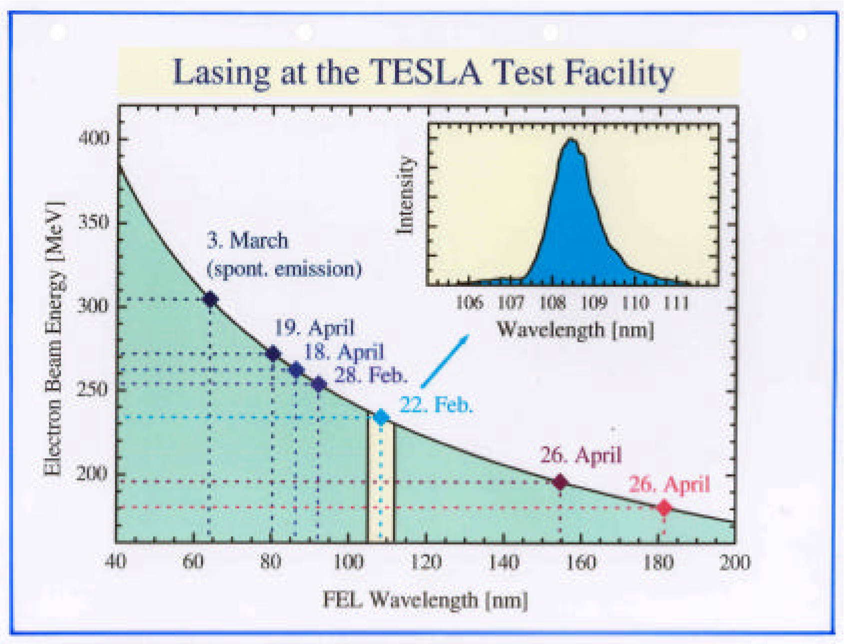
All measured properties of the laser agree with the theoretical predictions, e.g. saturation (gain: 10*10^6)

by far the most brilliant VUV light source world-wide

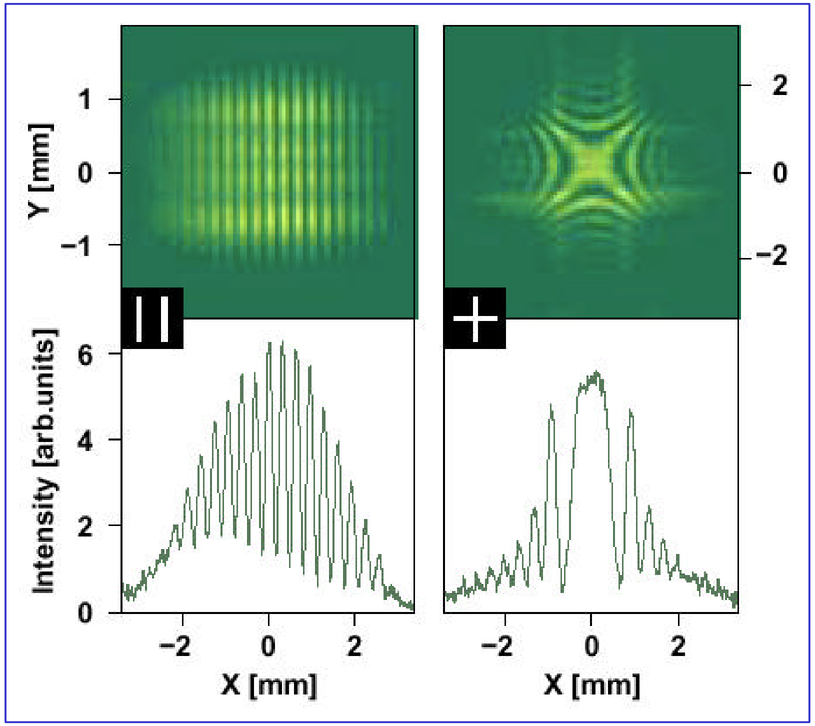


Power: 226 +- 50 MW observed @ 100 nm
200 expected @ 70 nm

Tunability and Coherence



$$l \propto 1/E^2$$



→Transverse coherence

Also seen in opening angle of radiation at saturation

Slit distance: 3 mm

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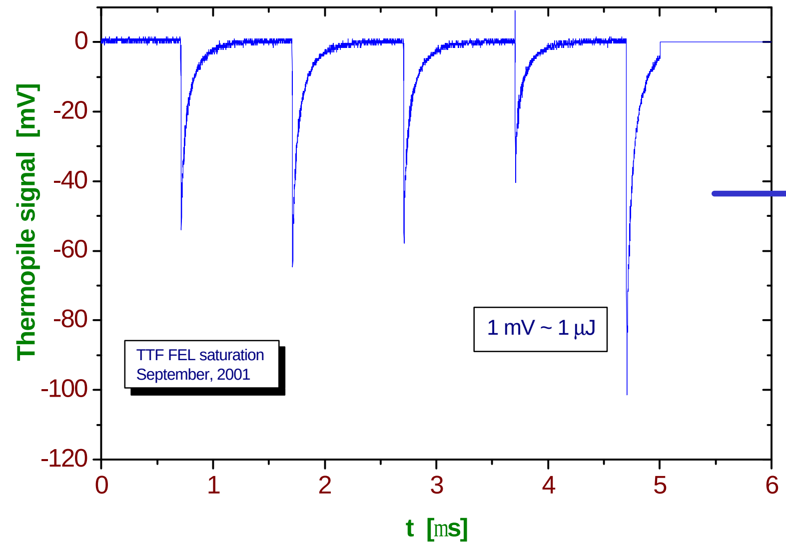
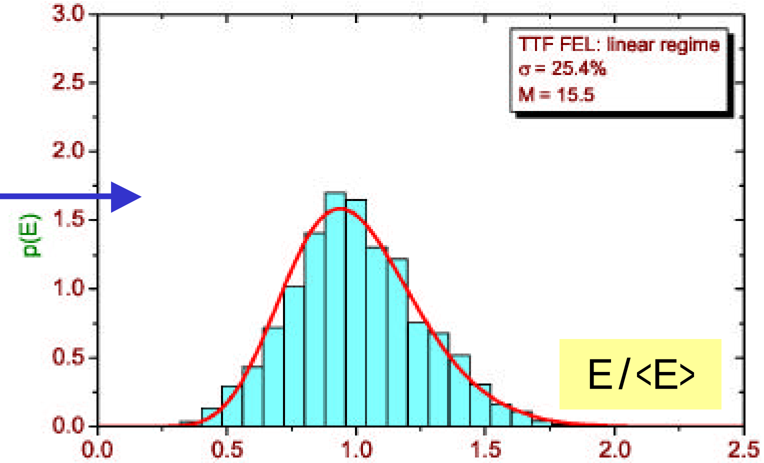
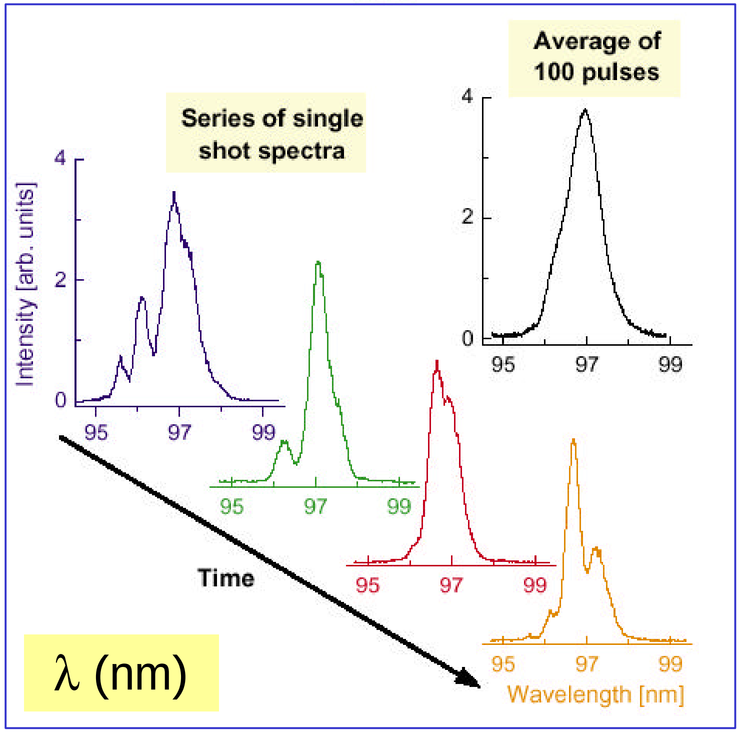
Fluctuation properties of SASE radiation at TTF





Energy fluctuation in saturation < 20%

Measured spectrum agrees with simulated spectrum, based on measured fluctuations of pulse energy



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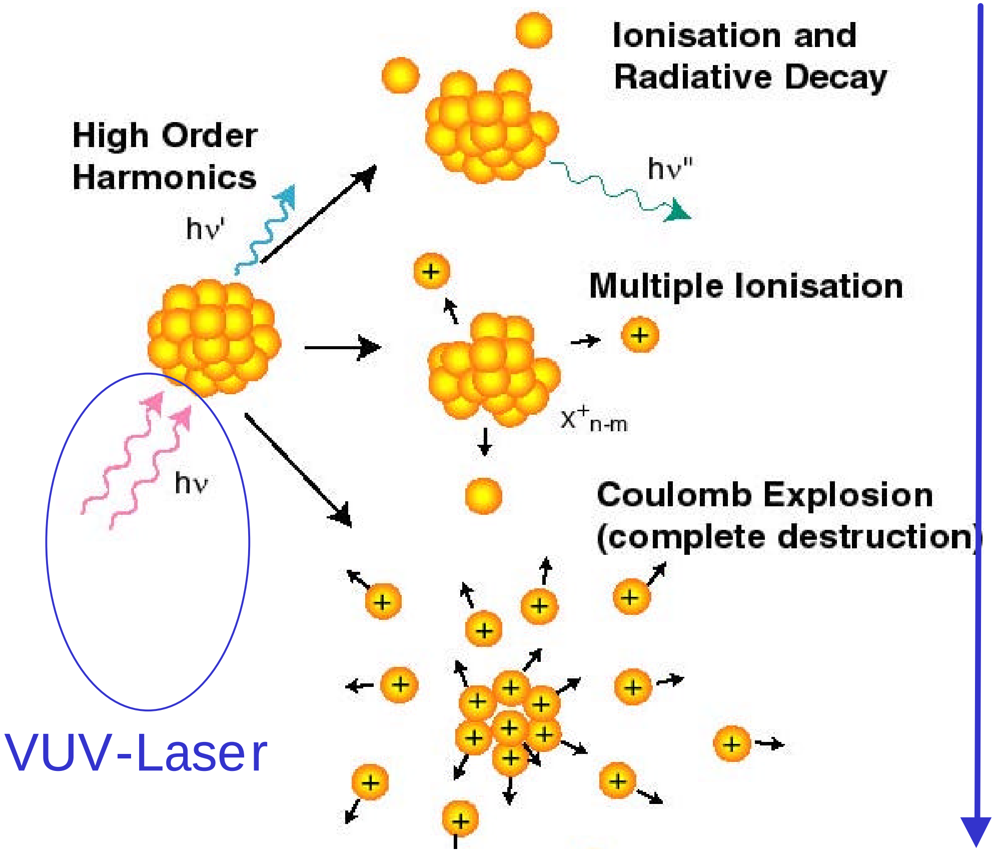
First Experiments at TTF



Interaction of Intense Radiation (100 nm) with Matter

Measurement of

- multi-photon processes
- cross sections
- life time of intermediate states
- Coulomb explosion

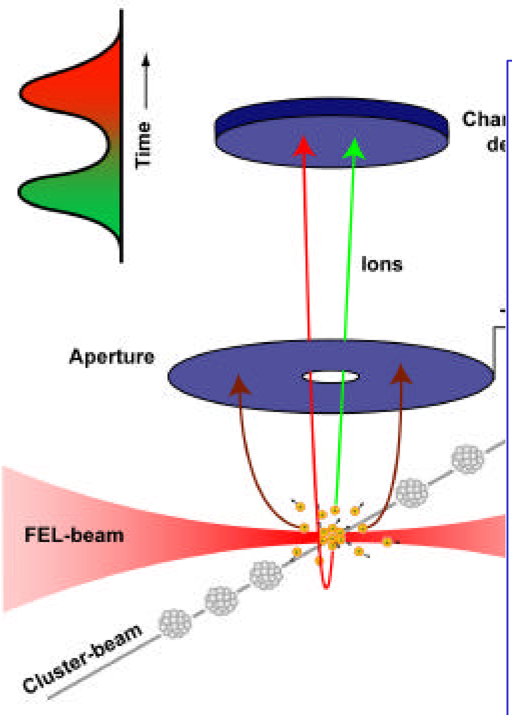
as function of intensity

Increasing intensity

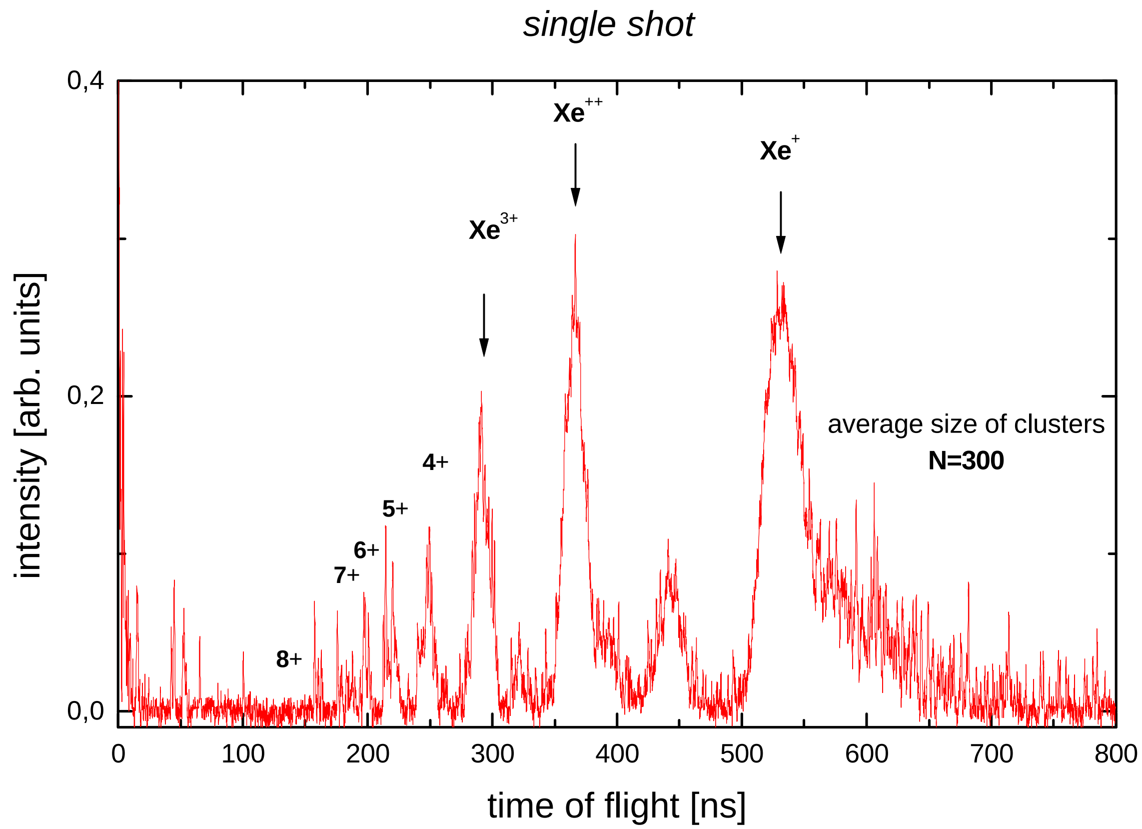
First Results

(Th.Möller et al.)

Cluster-Ion Detector



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

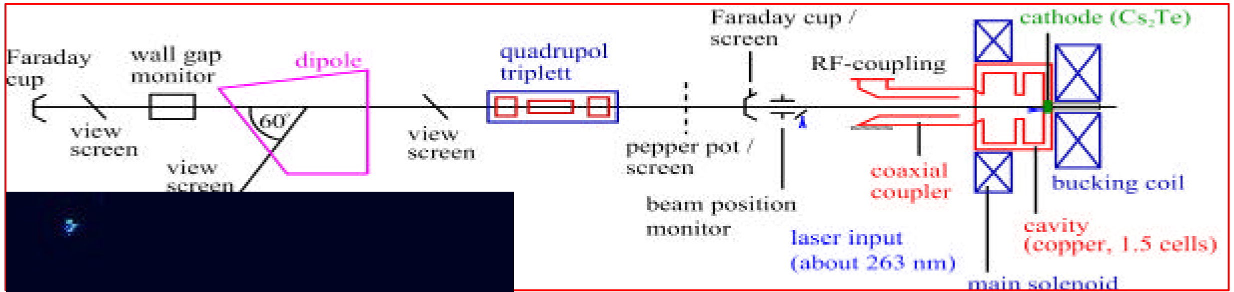


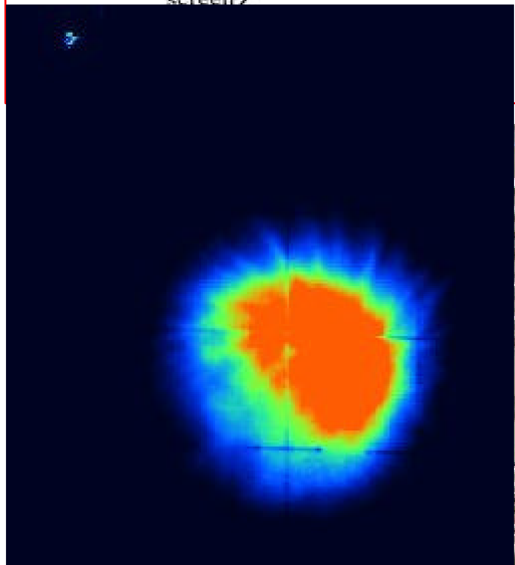
The Photo-Injector in Zeuthen

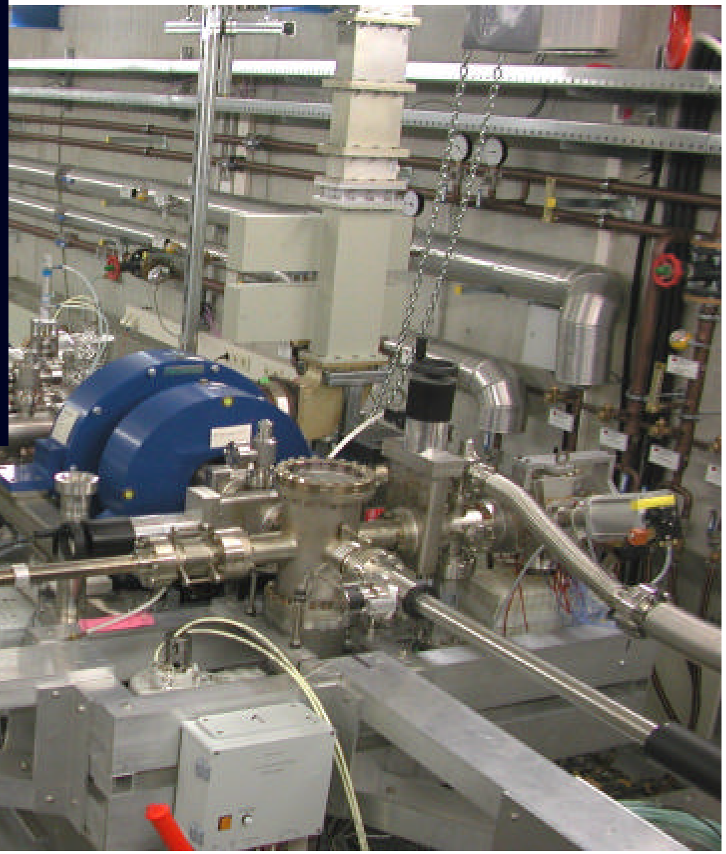
In collaboration with BESSY, MBI, TUD

Start of operation on 30 January 2002

Experience at TTF1 have again underlined the key importance of the RF gun development







TTF Full Performance Test

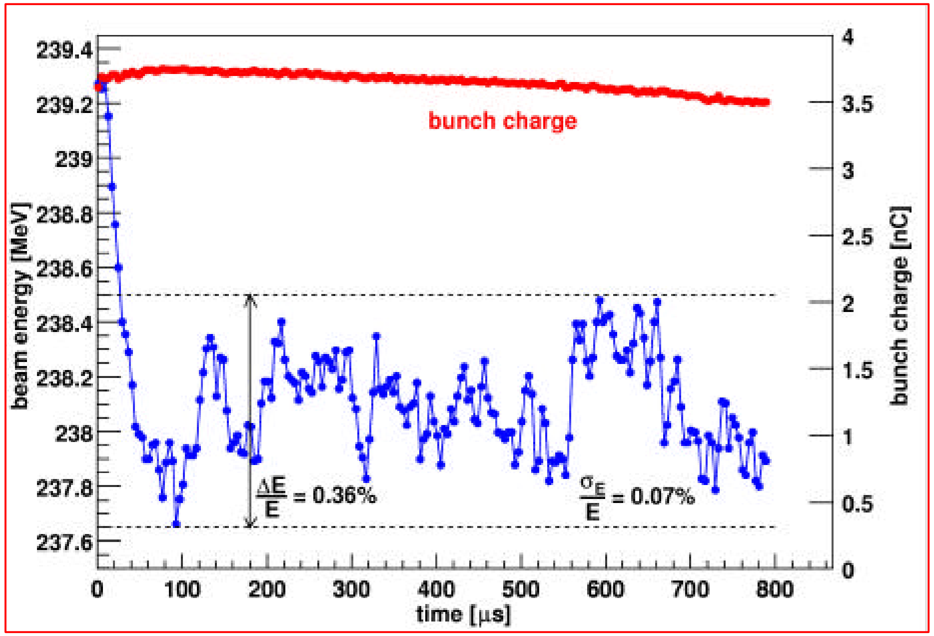
Goal:

Operate module close to TESLA specifications and for long period

One module with gradients of close to 23 MV/m (TDR: 23.4 MV/m)

Run RF with 5 Hz (TDR: 5 Hz)

Run with long pulse trains: 800 μs,
> 3 nC/bunch (TDR: 3.2 nC)



TESLA High Gradient & Full Beam Loading

Module #3 quench limit: 22.7 MV/m

Total time of run: 49 days (18.03.02 - 05.05.02)

Module operation at 5Hz: 39 days (~ 19.5 MV/ m)

Module operation at 1Hz: 4 days (~ 20.0 MV/ m)

Module operation at 1Hz: 6 days (~ 21.5 MV/ m)

~ 5 % below quench limit

The up time of the module was about 90 % average during the test.

Down time never due to the module itself.

No difference in cavity performance with and without beam.

Next Steps at TTF

At present TTF is being reconfigured (until July):

- Install one new module which reaches the TESLA design gradient of 23.4 MV/m
- Test of one 'superstructure' (higher cavity packing density)

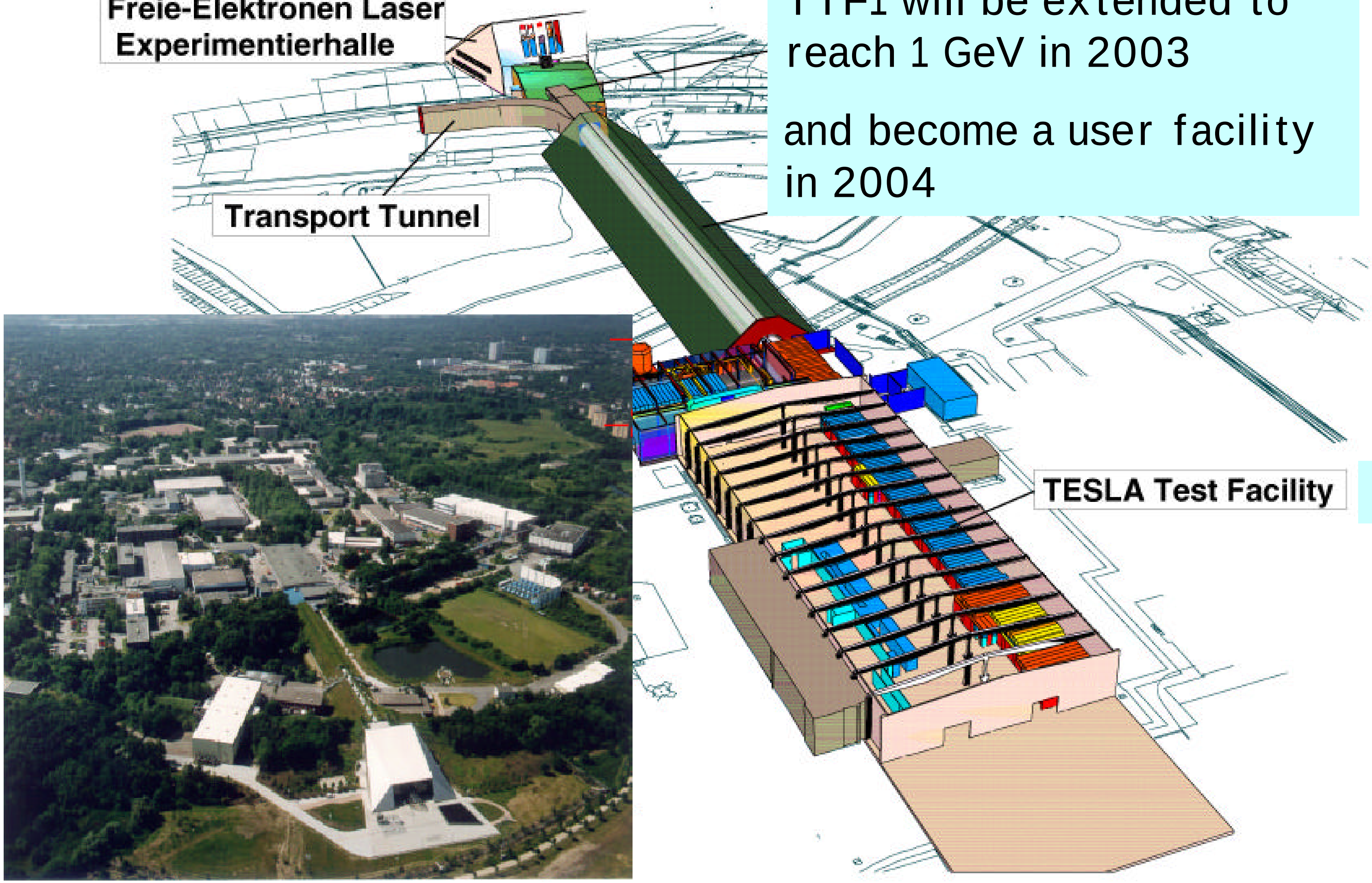
Run TTF from July to November to gain further experience with these systems

Then reconfigure for TTF2, a 1 GeV VUV FEL and LC test bed.

TTF2 VUV FEL

TTF1 will be extended to reach 1 GeV in 2003

and become a user facility in 2004

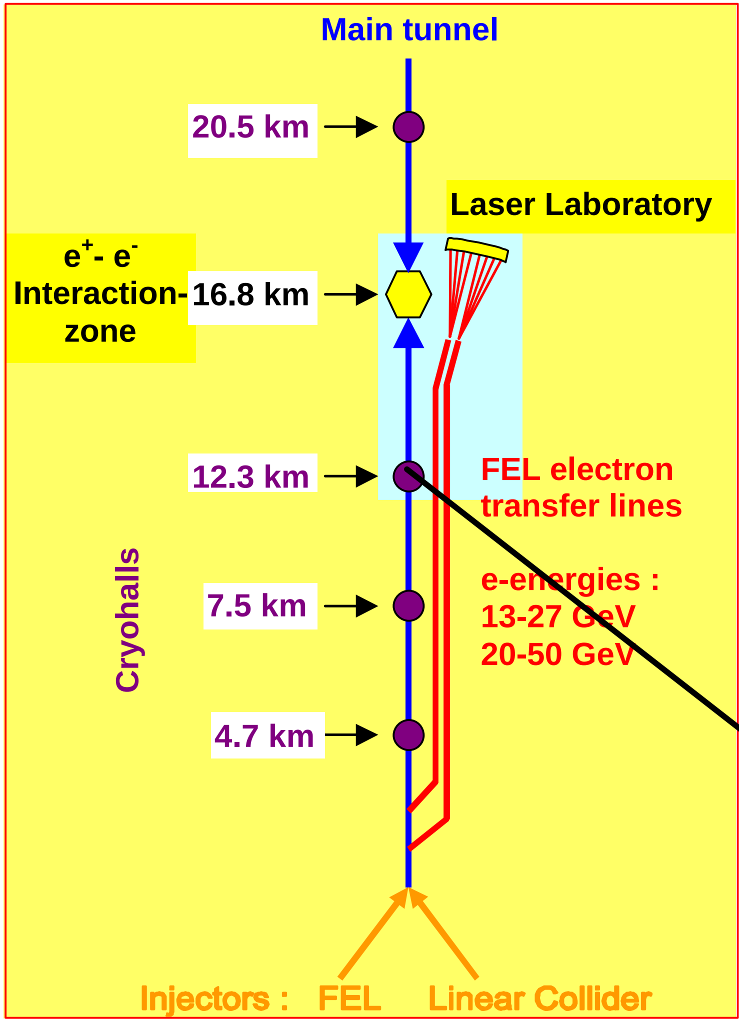


TTF1

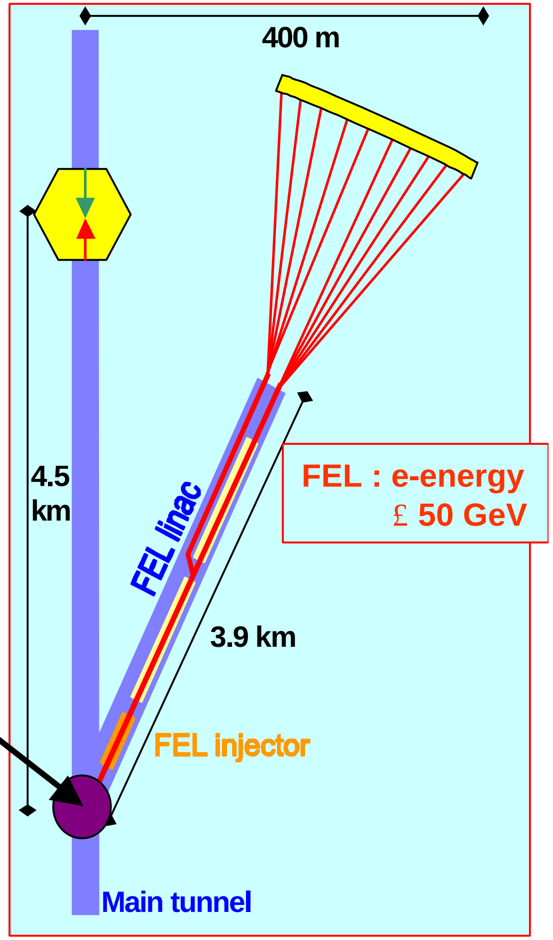
X-FEL Layout

TDR:

Collider and FEL use jointly the first section of the SC linac.

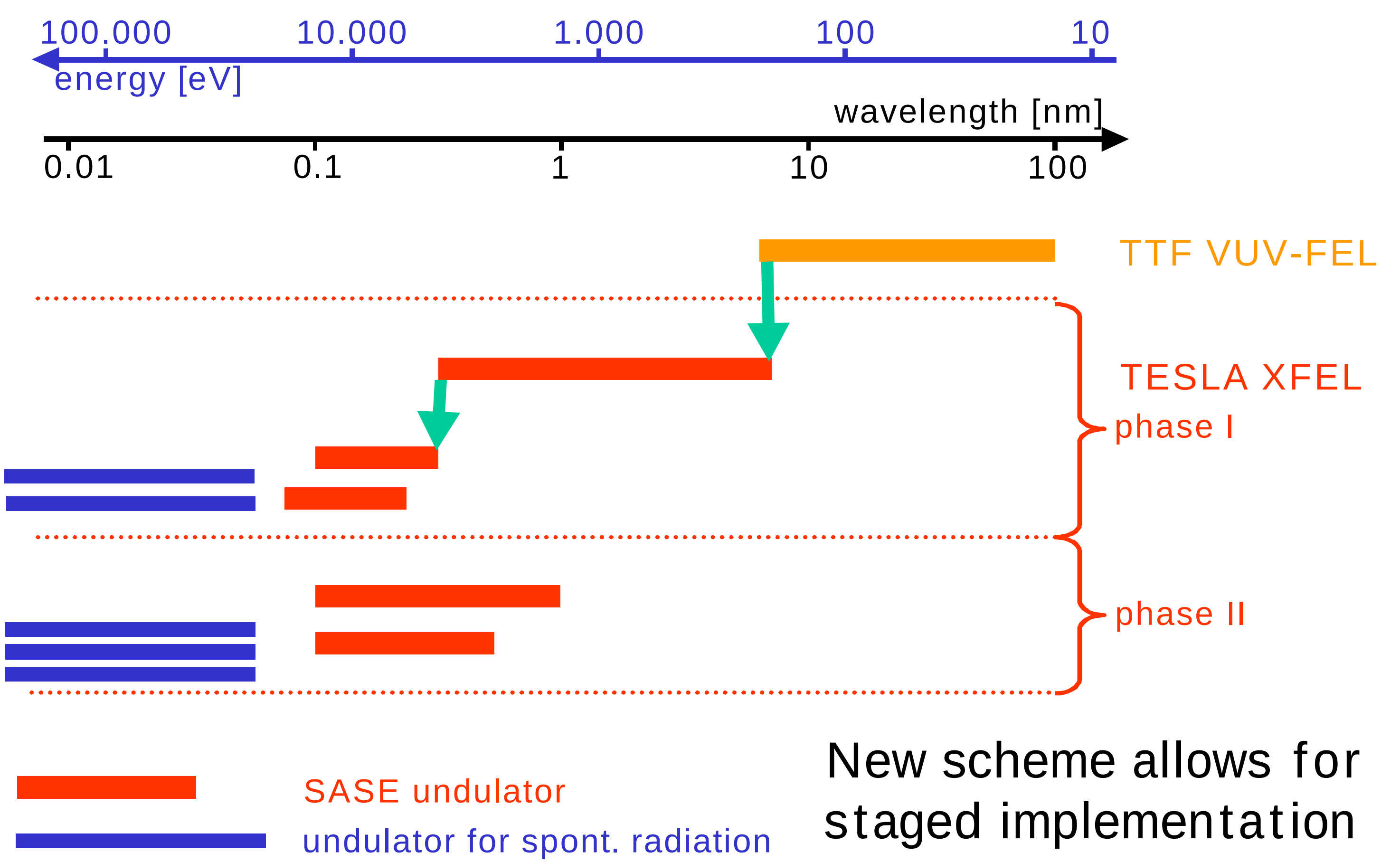


Following the recommendation by the Science Council, the planning is based on separate linac for X-FEL, using same technology and infrastructure



New scheme for implementation

Spectral distribution covered by TESLA



New scheme allows for staged implementation

Status of TESLA

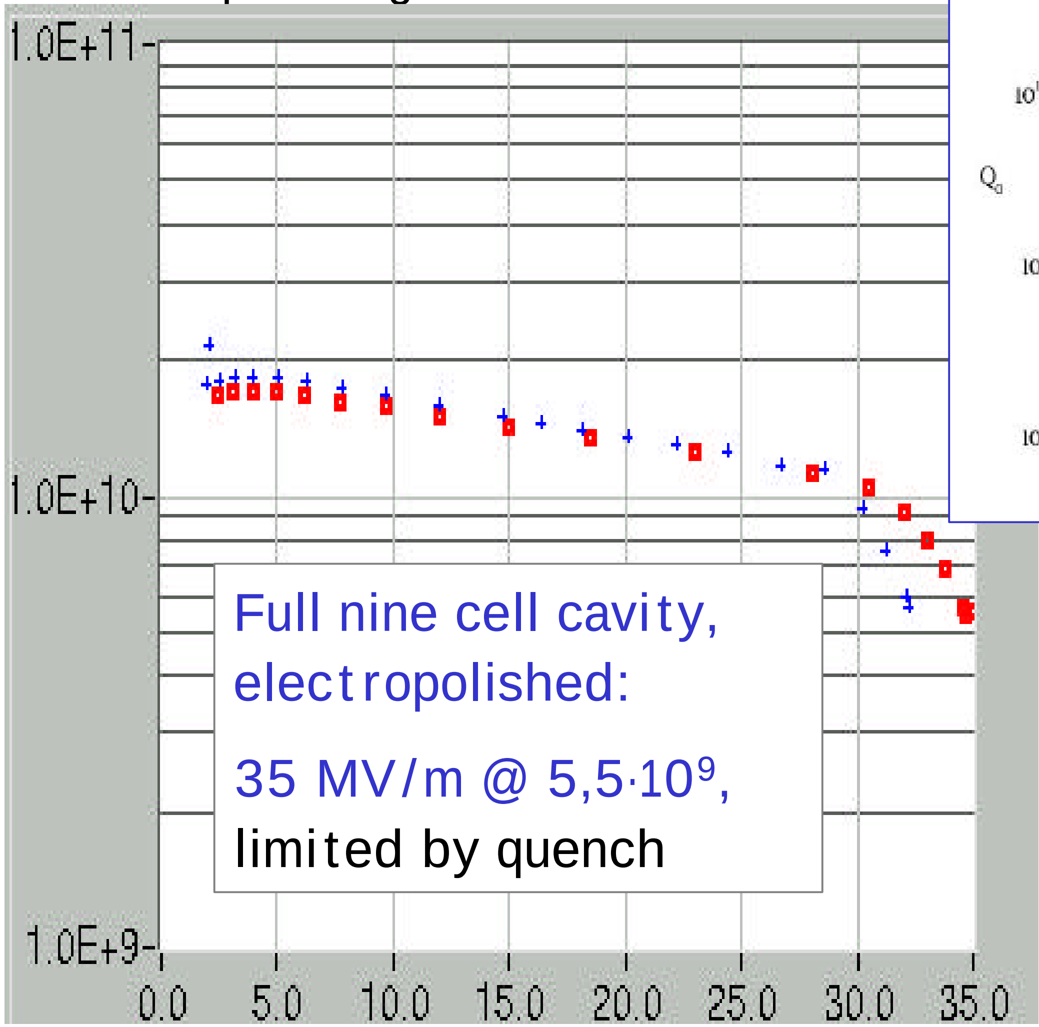
Major new results:

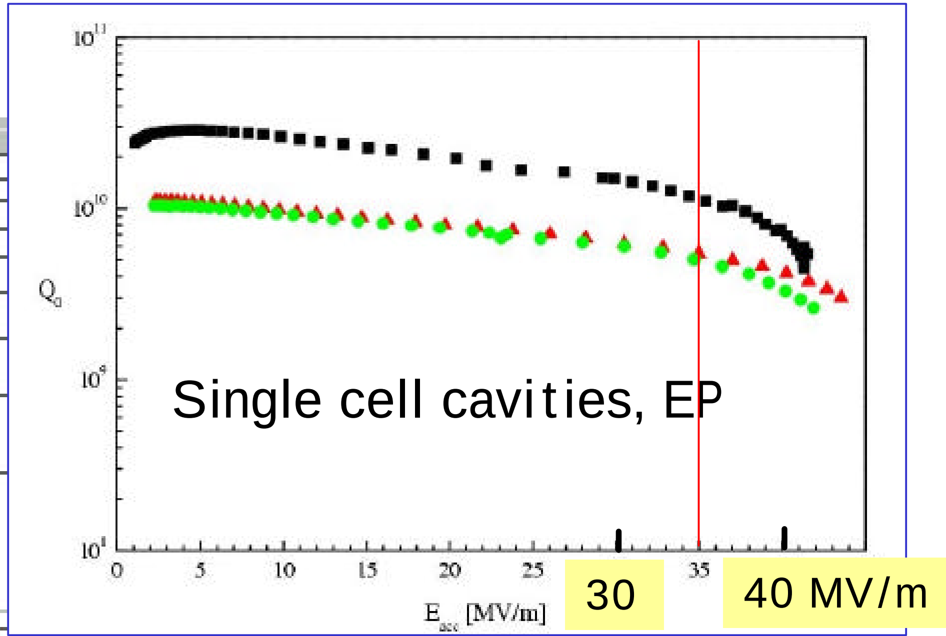
- Free Electron Laser works as user facility with high efficiency
- Promising development of cavities (gradient of gradient)
- High gradient operation of TTF works well
- Progress in ongoing other R&D (e.g. RF coupler, photoinjector)
- Improved theoretical understanding and tools
- Much better understanding of implementation issues

  (2. IR, separate laser linac, hall lay out…)
- New TESLA working groups: Commissioning, Risk and Reliability

On the Way to 35 MV/m

Improvement of surface quality with electro-polishing





Transition from single-cell results to multi-cell results has again been successful

Speed of progress presently limited by manpower and availability of infrastructure

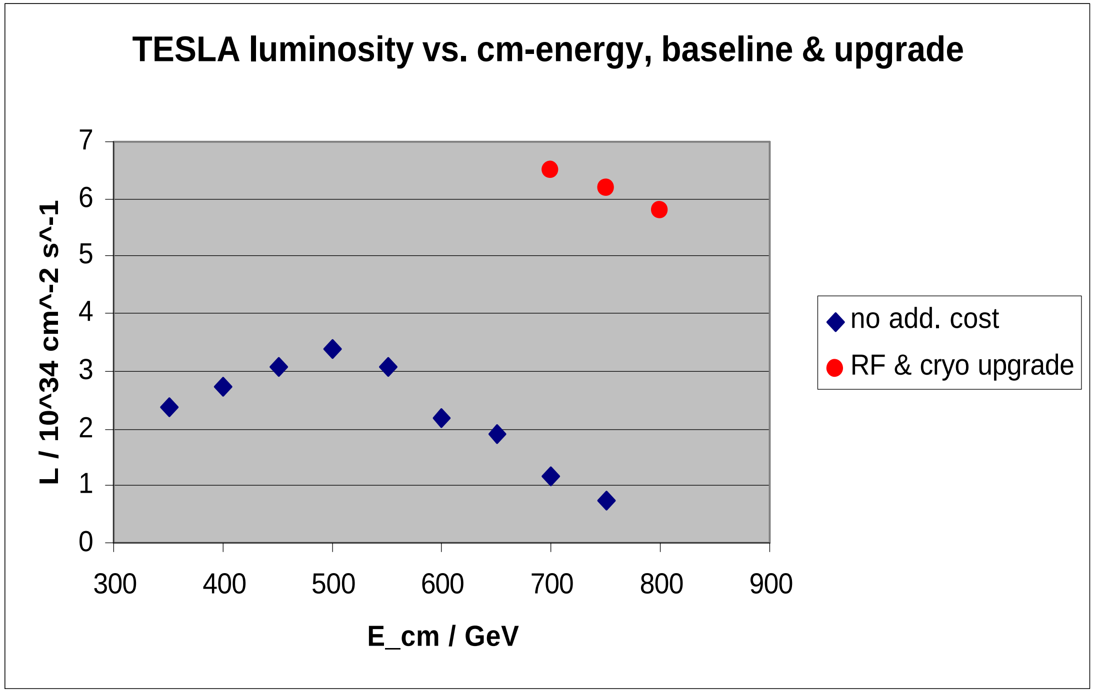
TESLA Energy Strategy

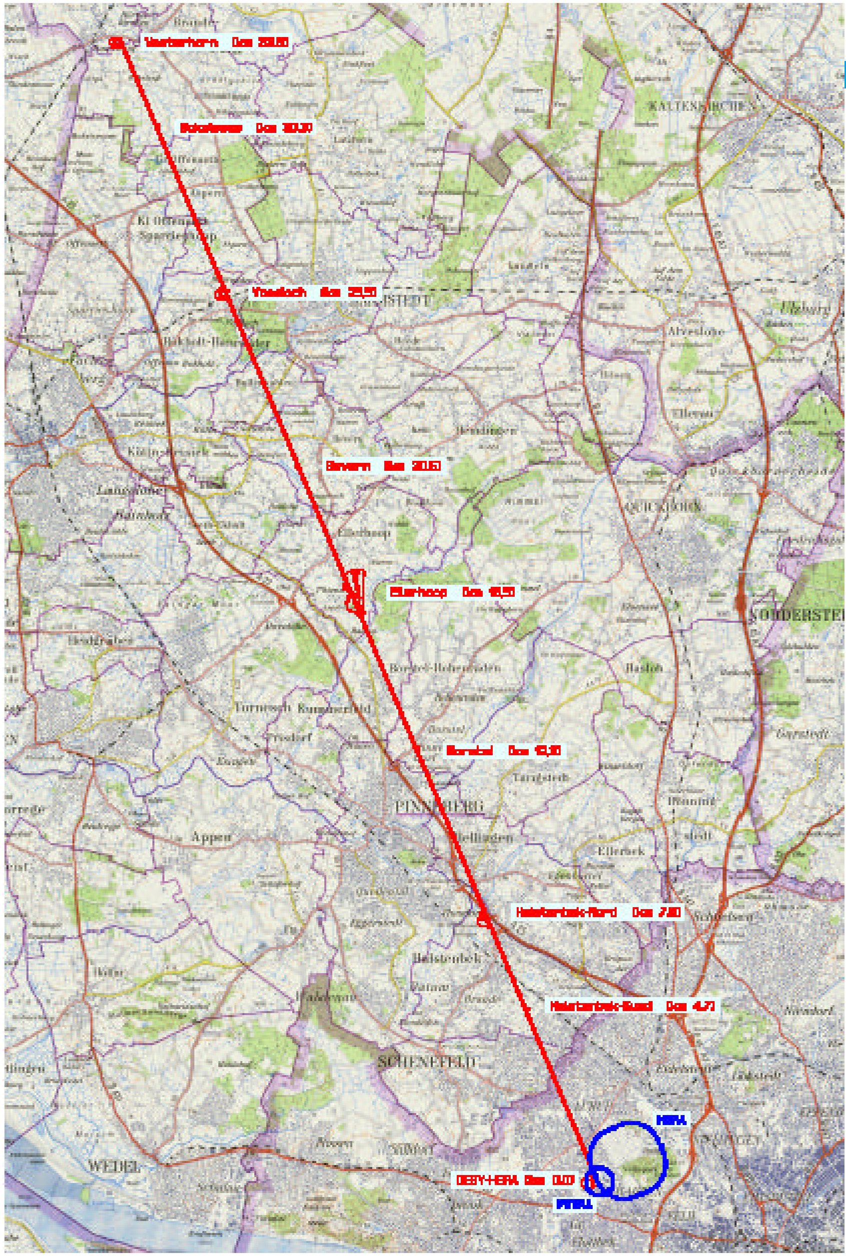
TDR (March 2001)

Base line design for 500 GeV, upgrade possibility outlined

- initially operate at an energy of about 500 GeV, to explore the Higgs and related phenomena, and then
- increasing the energy to 800-1,000 GeV, to more fully explore the TeV energy scale.

Assuming that cavities will reach 35 MV/m:





Site Planning Status

Agreement between the states Schleswig-Holstein and Hamburg for joint legal procedure

Environmental impact study is completed. It includes evaluations of

- noise protection
- electromagnetic pollution
- radiological risks
- hydro-geology

We prepare to start the legal procedure required for an implementation at the site in November 02, as part of the overall feasibility study

Cost and Time

Cost evaluation based on TTF prices and studies by industry (2000 prices)

Construction time: 8 years, Funding time: 10 years

Personnel:		7000 person years
1) 500 GeV Linear Collider with 1 experimental area		3136 MEuro
2) Incremental cost for X-FEL and laboratory		531 MEuro
3) One detector for particle physics		210 MEuro
	Sum	3877 MEuro
Annual cost during construction		400 ME/year
Cost **shared** between partners		
Civil engineering would be host responsibility		546 ME

Review of Cost

Review of costing by groups from Japan, US

The two reviews did not attempt to fully validate the cost, but rather the method of the cost estimates.

Both however validated the methodology and noticed

- A substantial difference in salary levels
- A difference in opinion and culture concerning contingency

The US review did also analyse the difference between US and European costing

"Manpower is expressed in person-years. This makes it easier to understand the resource requirements, and implicitly acknowledges the expected different labor basis from different collaborators."

Some Statements from the US Review (1)

The R&D associated with TTF (at ~250 MeV, a 0.1% scale proof of principle) has provided confidence in the superconducting RF as LC technology.

The TESLA TDR strategy (to initially operate at an energy of about 500 GeV and then to increase the energy to 800 GeV) is in full accordance with the recommendations by ACFA, ECFA, and HEPAP.

TTF must gain additional operational experience at a 23.4 MV/m gradient level.

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Some Statements from the US Review (2)

Strategy to reach 800 GeV assumes gradients of 35 MV/m obtained in mass production before the construction of the accelerator start. ....

Recently, a bare 9 cell RF cavity has been tested CW up to the required 35 MV/m gradient. Complete cryomodules and RF couplers have yet to be operated at this level with beam. Demonstration of this capability is the high priority of the TESLA Collaboration.

There has been little analysis of project risks and contingency in terms of schedule or scope.

There remain areas for continued review or further R&D and investigation. This would be true in any evolving project.

Open Accelerator Issues

Examples:

- module engineering - improved flange and interconnect designs, transportability;
- modulators – optimization and investigation of alternative technologies, and design of cost effective control and interlock, review of need of backup switch;
- low level RF systems - work on the design and prototyping of LLRF systems and frequency reference;

See list of Tom Himel for all projects:

http://www-project.slac.stanford.edu/lc/Project_List/intro.htm

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Some Statements from the US Review (3)

Certain conflict between

• the need to move ahead on project activities and decisions,
• getting collaborator participation in the decision processes at an early stage.

It is clearly understood by the TESLA collaboration that many aspects of the project will have to be reconsidered when the project collaboration is formed and new partners join.

We believe that the TESLA proposal is sound and developed to an appropriate level of detail for this stage in the project proposal process.

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ECFA/DESY Study III

St. Malo, April 2002

~ 180 participants, 18 from North America, 1 from Asia

A lot of new work on physics, detectors since TDR and Cracow

Next ECFA/DESY workshop in fall, location to be decided (Prag)

Concluding conference/workshop of the ECFA/DESY III study planned for spring 2003

In view of the International Consensus and the International Steering Group a continuation of this workshop beyond 2003 is envisaged.

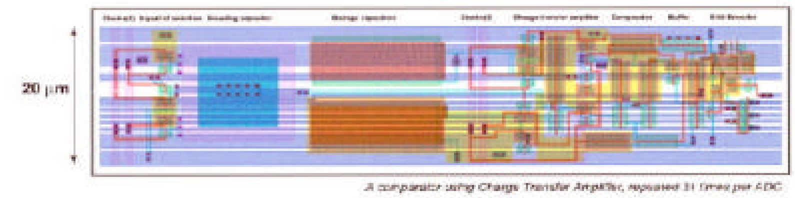
TESLA related R&D for Detectors

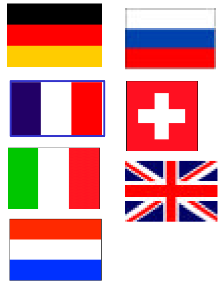
- Calorimeter R&D:
  (CALICE collaboration):

  (CALEIDO):

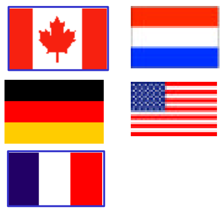
- Vertex Detector R&D: (CCD, CMOS technologies)

CCD readout chip mask





- Main Tracking Detector (TPC) R&D:



Formal review procedure provided by DESY PRC

How to Realise Big Accelerator Projects?

Global Accelerator Network

- Collaboration of interested accelerator laboratories and institutes world-wide with the goal to build, operate and utilise large new accelerators

- Follows major detector collaboration in particle physics

- Partners contribute in full responsibility through components or subsystems

- Facility is common property
- Responsibility, cost are shared
- Remote operation
- Project of limited duration (~ 25 years)

Important to work out the detailed management issues

GAN

Remote operation will very likely be of key importance for the future operation of large facilities.

Key issues:

- social aspects
- identify exciting issues, challenges

Tests in this area are ongoing or planned (TTF, A0, LINX, PI3…)

The GAN workshop was an important start for an in-depth study of the critical issues and for real experiments

Remote Control for Experiments

Likely scenario for accelerator control:

Have several control rooms around the globe

Suggestions:

- Adapt model of several control rooms also for control room(s) of experiment(s)
- Combine them with the accelerator control rooms at the same locations

Advantage:

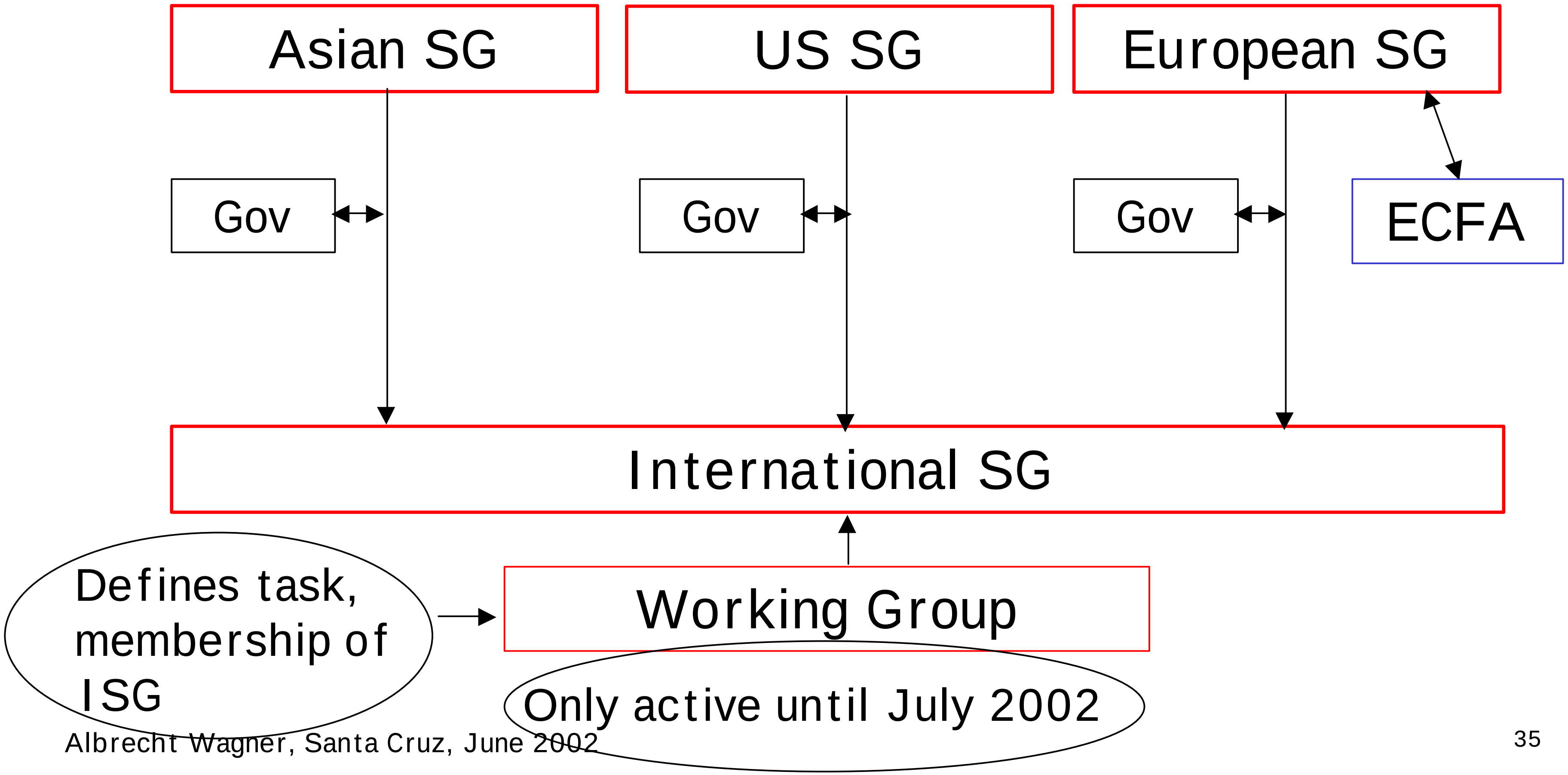
Close interaction between experimenters and machine operators

Visible presence of experiment(s) in the regions

Of course a certain on-site shift crew will be also required

LC Steering Groups

ICFA initiative:



Composition of the European Steering Group

RECFA has endorsed the formation of an ESG and its mandate at its May 2002 meeting

The ESG has the following composition:

- ECFA chair (Brian Foster)
- Chair of the ECFA LC physics study group (David Miller)
- One representative of CERN (Luciano Maiani)
- One representative of DESY (AW)
- Two persons representing the other European laboratories active in linear collider work (e.g. in France, Italy, UK) (F. Richard, S. Bertolucci)

The committee will be chaired by the chair of ECFA.

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OECD Consultative Group

Principal Conclusions Regarding the Road Map:

- The Consultative Group concurs with the world-wide consensus … that a high-energy electron-positron linear collider is the next facility.

- There should be a significant period of concurrent running of the LHC and the LC, requiring the LC to start operating before 2015. Given the long lead times for decision-making and for construction, consultations among interested countries should begin at a suitably-chosen time in the near future.

- The cost of the LC will be broadly comparable to that of the LHC, and can be accommodated if the historical pattern of expenditure on particle physics … l resources that … ide.

Request by the US representatives to continue the group in one form or the other after summer 2002

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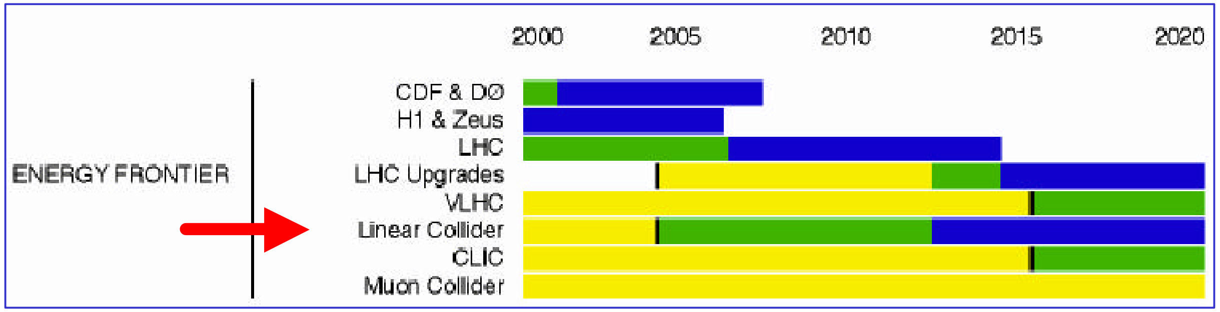
The Time Line

We must keep the time line in mind in our next steps:



The synergy between the LHC and the linear collider argues for an early start. The linear collider should be ready to begin construction in 2005.

Need to converge towards one project soon to meet challenges

International technical review helps to clarify issues, but will not provide a recommendation

What can we do to be able to begin construction in 2005?

Evaluation by German Science Council

Context: Large Scientific infrastructure proposals

Working Groups have been established, started to work:

- TESLA Linear Collider
- Free Electron Lasers
- etc.

Final evaluation/recommendation by fall 2002

Decision by German government expected in 2003

Oral Briefing by Science Council after Site Visit

TESLA Linear Collider:

The LC answers key questions, is complementary to LHC, is next accelerator to be built

The technical preparation is excellent, TTF is impressive and a great engineering achievement. TTF is not only a test of components but of a system.

Recommendation: 35 MV/m should have highest priority

Strong support for concept for international realisation

TESLA X-FEL:

Scientific potential excellent.

Impressed by technical preparation and results

The Next Steps

Continue to convince all interested governments to invest in a joint international project, e.g. through the mechanism of a Global Accelerator Network or alike.

The choice of site will be primarily a political decision, determined by which country/region is willing to host the facility. The host has to make a major investment and a long term commitment.

The political decision might speed up the technology choice.

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Conclusion

The particle physics case for a LC is compelling and timely

Unique capabilities and complementary to LHC, being now analysed in much more detail

X-FEL will provide 0.1 nm light with very high peak brilliance

Many fields of science will greatly benefit

Superconducting technology provides excellent experimental conditions and is mature and cost effective

Scientific recommendation on LC and XFEL in 2002

Political decision expected in 2003

A Last Word

Need to make progress on

international collaboration

to meet

the technical challenge and the time line