Some European Thoughts on Technology Options

- The TESLA cost estimate
- The US study from the TESLA perspective
- Variants of the TESLA baseline design
- Next steps

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The TESLA Collaboration

- The TESLA Collaboration:

at present 55 Institutes in 12 countries

These institutes have contributed through ideas, hardware, and manpower to the TESLA Test Facility and share the know-how concerning the construction and operation of the SC linac

TESLA Cost Determination

- All major subsystems costs are based on evaluations by industry
- With the exception of the Cavity preparation, the module assembly and beam position monitors everything of the TTF linac has been produced in industry
- many off-the-shelf items,
- substantial manufacturing experience (e.g. cryo-plant nearly identical to the one which has recently been built for LHC).
- There are **prototypes** for all systems needed for the cold linear accelerator, **fabricated in industry**
- Cost evaluation is based in most cases on **3 years** for **production** plus one year for startup; considered feasible by companies
- Several institutes of the TESLA collaboration were involved in cost evaluations

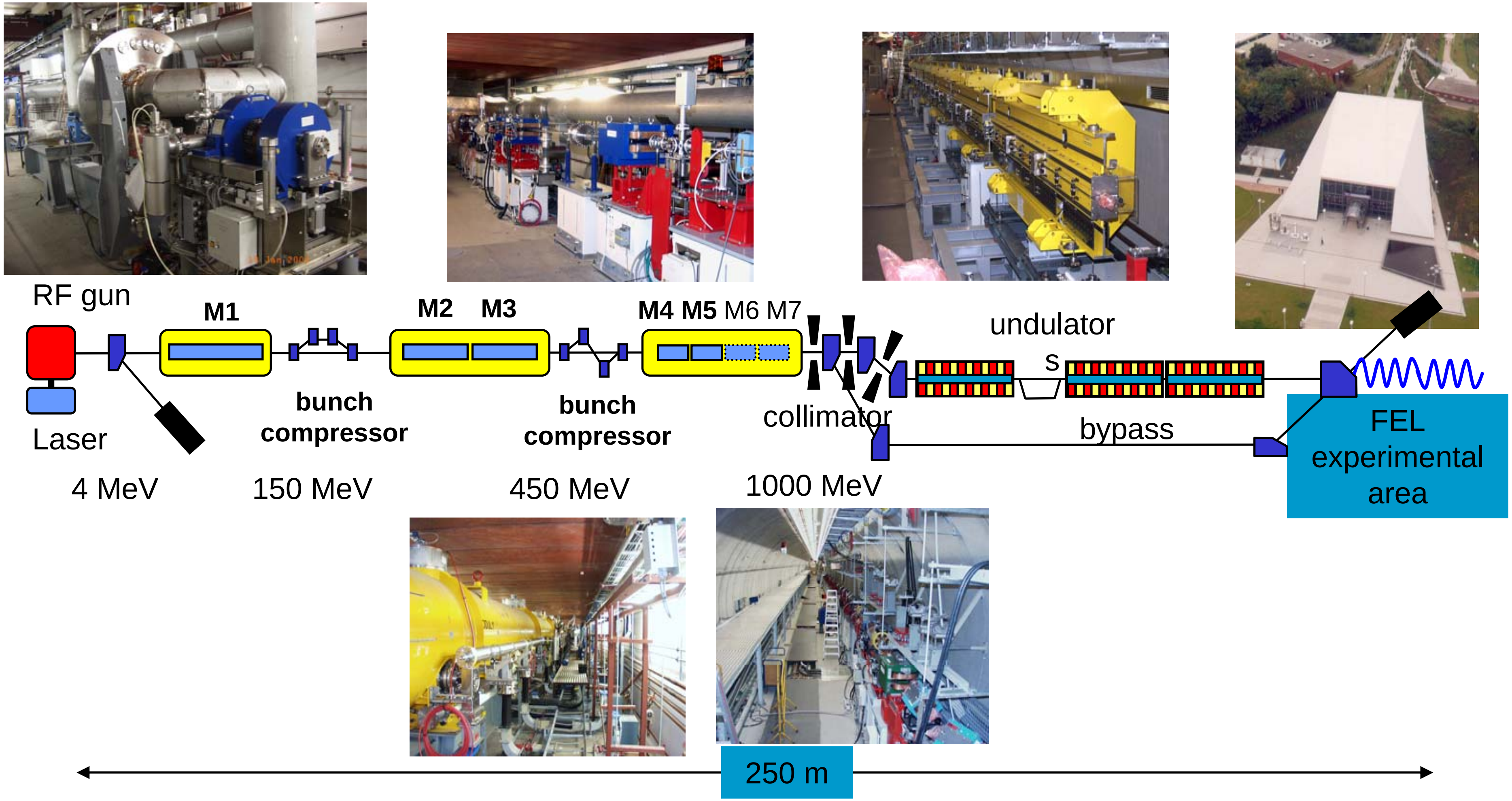
TESLA Cost Determination

No extrapolation factors are used. The uncertainty is minimised by having enabled several companies to bid competitively.

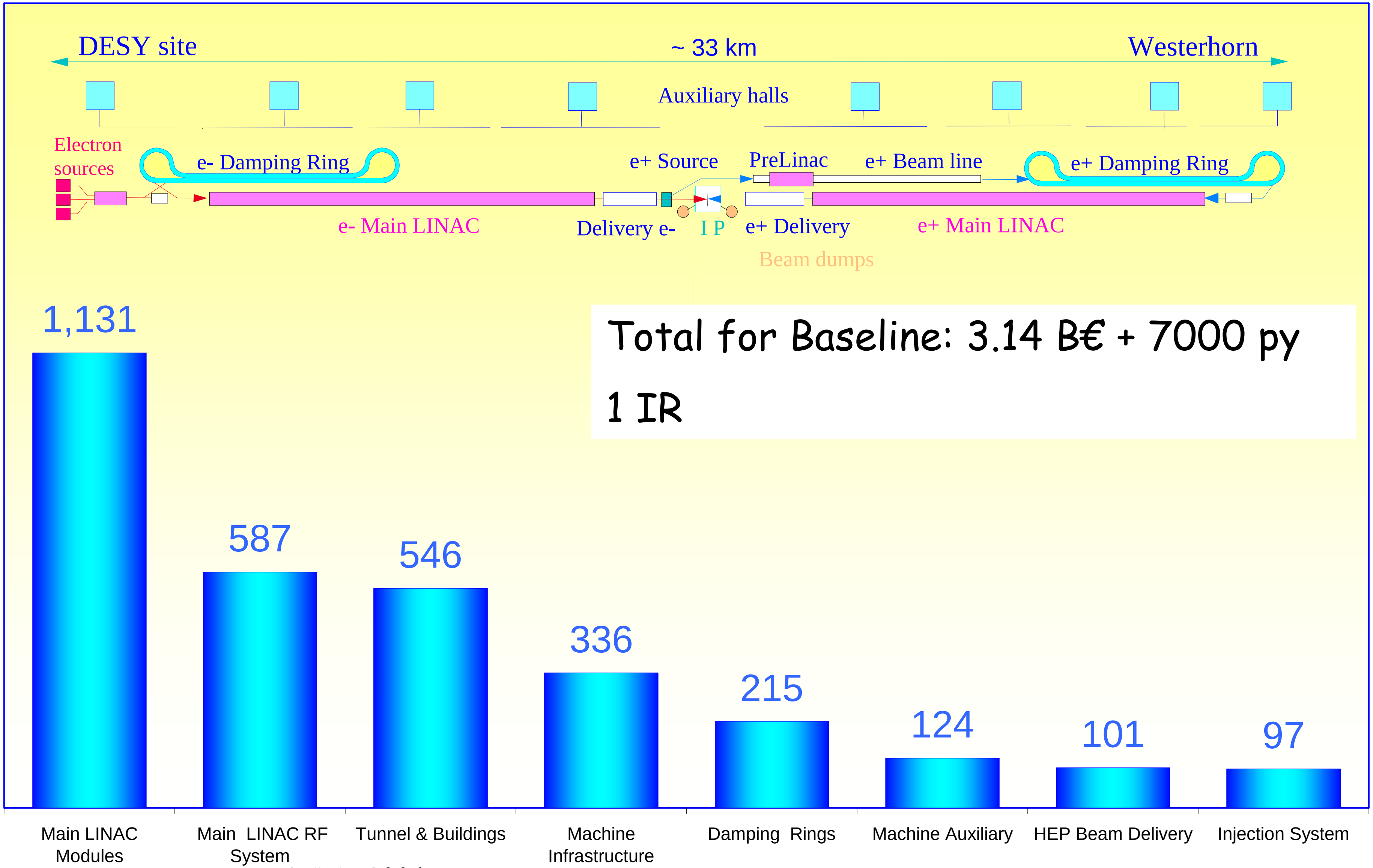
The TESLA cost figures have been severely scrutinised by colleagues from the US and Japan who have endorsed the methodology of the TESLA costing.

Substantial cost savings expected due to the SC XFEL activities world-wide and the X-FEL, as these activities will pay for a substantial part of the R&D and industrial development efforts.

The Basis for the TESLA Costing



TESLA Cost Distribution



Operating Cost

Consumables:	Electrical power	35 Mio Euro
	140 MW 5000h/year @0.05 Euro/KWh	
	Klystrons	7 Mio Euro
	78 per year $\frac{1}{2}$ new $\frac{1}{2}$ refurbished @ 2/3 price	
	Helium losses, cooling water, outsourcing of operation…	8 Mio Euro
	Sum	50 Mio Euro
Maintenance and repair		
	2% of investment cost	70 Mio Euro
Total Operation Cost		120 Mio Euro

Personnel cost for operation has not been analysed yet

Due to the lower power consumption and the considerably smaller number of consumables (mainly klystrons) the operation cost for a cold machine is lower than for a warm machine.

Areas of possible Cost Increase compared to TDR

Two issues have been identified since the publication of the TDR in 2001:

- Damping ring vacuum needs to be improved by factor 10 due to ion instability
- Detailed engineering design of buildings (access halls, support buildings ect), combined with an in-depth analysis of the required floor space, done in preparation of the legal implementation process, have led to a *greater request* than specified in the TDR (e.g. 2nd IR)

The resulting cost increase is in the order of a few %.

Comments concerning the US Cold Warm Comparison

General Comments

A great amount of valuable work has been done for this study.

The whole community can benefit from it.

The cold proponents can benefit from addressing the criticisms that are directed toward the cold design.

The study advances and sharpens the thought processes associated with LC issues.

The cold collider version is not TESLA, but an NLC type layout using the cold technology

The warm collider is NLC with undulator source at 150 GeV

The study is a first attempt at an in-depth reliability/availibility analysis

General Comments - 2

In view of existing international efforts, it would have been preferable had the study been done internationally, under the guidance of the ILCSC. This view is shared by the Asian colleagues.

There are at least two reasons for this:

- It is extremely important to build and strengthen the spirit of international co-operation and collaboration, and not to have unilateral and polarizing activities.

- The second reason is technical. The members of the study with cold expertise were limited to 4 out of a total of 28. One of these four had not been part of the TESLA effort, but rather had independent experience with the cold technology cost. A more balanced working group would have reduced the potential for a bias in the study.

Issues and Differences

For the cold version the US study makes a number of assumptions, such as increased spare allocations, cryogenic contingency etc., which altogether lead to a cost differential of 1.25+-0.10

I will discuss 2 assumptions next (energy overhead, second tunnel),

Another cost factor is for example the positron source:

TESLA:	undulator, requiring + 250m tunnel
US cold:	undulator (at 150 GeV), requiring an 850 m insert, a separate tunnel and 1 km cryo by-pass

Many such items have to be revisited in a design and optimisation which will be done globally.

Energy Overhead

The 2% energy overhead of TESLA is considered sufficient in view of the fact that the collider most of the time does not run at the energy limit, and in view of scheduled access days. (2% was based on 40 khr life time, companies now estimate 100 khr cathode lifetime).

The energy overhead influences the availability only when operating at the maximum energy of the collider.

The US study assumes a 8% overhead for the one tunnel option, which leads to a larger number of klystrons, modulators etc.

Second Tunnel and Reliability

The TESLA design is based on one tunnel, as this is the most cost effective solution. Due to the number of klystrons and their lifetime, this option is only possible in the cold option.

To guarantee high availability the TESLA design incorporated redundancy for the components in the tunnel (power supplies, LLRF etc).

Issues like one or two tunnels and the required energy overhead will be considered again, as the design iterations proceed. The guideline will be to find the optimum in terms of cost and availability. This requires good understanding of the relative benefits or deficiencies of one vs. two tunnels.

Cost Comparison - Cold

The US study has used for the cold design directly the cost figures provided by the TESLA collaboration.

For the cold option, the areas that received further scrutiny were: linac components, refrigerator and damping rings.

In this effort the cost task force representatives made 3 separate visits to DESY, of 2- 3 days each to examine the methodology and look in detail at the industrial studies.

The cold damping ring was extensively re-evaluated by LBNL.

The refrigeration system was completely re-costed by Fermilab.

Cost Comparison - Warm

The Warm costing is base on scaling assumptions from one of a kind prototypes which lead to cost reductions in mass production of some factors. These extrapolation factors are assumed to be very large (up to 6) with a correspondingly large uncertainty.

There was no external review of the warm cost.

Therefore the warm costs deserve a much closer look than we understand was performed during the study.

Reliability Analysis

The study makes a first attempt for an in-depth reliability analysis and therefore is very welcome. This kind of study needs to be pursued in the global design.

Conclusion:

Reliability is a challenge for both machines

Reliability is correlated with cost (one can 'buy' reliability), but equally for cold and warm. It does not lead to a cost differential between both machines

A word of caution:

The model has not been tested against a real system

Attempts to model other accelerators (e.g. SR light sources, nuclear transmutation inacs) have failed to reproduce reality

Luminosity

The US study ignores the role that the higher intrinsic luminosity of the SC design plays in achieving the overall integrated luminosity goal.

Some luminosity is even artificially reduced (pg 130):

“The vertical waist is assumed to be at the IP. This change was made to facilitate a more direct comparison with the warm option.“

This change alone reduces the luminosity by 10%.

Nevertheless: L(cold) = 1.3 L(warm)

Conclusion on US Study

Important work, will be useful in future optimisation

The quoted cost differential of 1.25 is a product of many few % differences and depends on many detailed assumptions, on large cost extrapolations for the warm machine and has an error which is probably larger than the quoted 10%

The luminosity is > 1.3 times higher in a cold machine

The TESLA collaboration is impressed by the amount of effort that this study has put into trying to understand the TESLA design. However, a more equal and wider participation of cold experts would have led to a more balanced report

The operating cost is definitely lower in the cold machine

Again, as in previous studies, no major errors/cost discrepancies have been found in the TESLA case

If cost were to play an important role in the technology choice, a fully co-ordinated international cost estimate must be made

Variants to the TESLA Baseline Design

For TESLA there exists now a set of variants to the baseline design (TDR) with corresponding cost estimates.

Although the cost of the variants is not of the same accuracy as that of the baseline design, the study provides a good idea of the cost determining elements.

Assumptions:

- All technical systems identical to TDR
- Same RF station as TDR; scaling of stations for constant peak power; no optimization
- Scaling by power or length, if adequate
- For example mains power or water scaled with number of RF stations
- Injectors, damping ring and beam delivery unchanged with the exception of dump system

500 GeV Variants
and their Energy Reach at Reduced Luminosity

Baseline design in European accounting. In addition: 7000 py

operating Grad for 500 GeV (MeV/m)	Max Energy reach * (GeV)	Cost or % change wrt Baseline	Comment
24	~ 700	3.14 B€	Baseline
18	~ 900	+ 15%	2. tun'l + 350M
24	~ 700	+ 5%	
28	~ 630	+ 5%	
35	500	+ 5%	
35	500	- 5%	

With additional funds these options can be expanded to high luminosity operation at 800- 1000 GeV (see below)

* Assuming an installed gradient of 35 MV/m, High energy reach comes from trading energy against luminosity, no mod's of accelerator needed

Next Steps

The strength of our community is its ability to unite behind a project

ICFA and ILCSC are actively involved in moving the LC forward

We eagerly await the technology recommendation by the ITRP

We are getting ready to embark on a global design in phases

During the design process the work done in Asia, the US, and by the TESLA collaboration will be exploited as much as possible to obtain the highest performance and the most cost effective design of a TeV range LC.

To assure a healthy future of the field we need to concentrate the world-wide efforts on the common goal: commissioning of a LC in ~2015

It is high time to focus on these issues and not be side tracked.