Linear Collider Overview

Status, challenges, R&D opportunities

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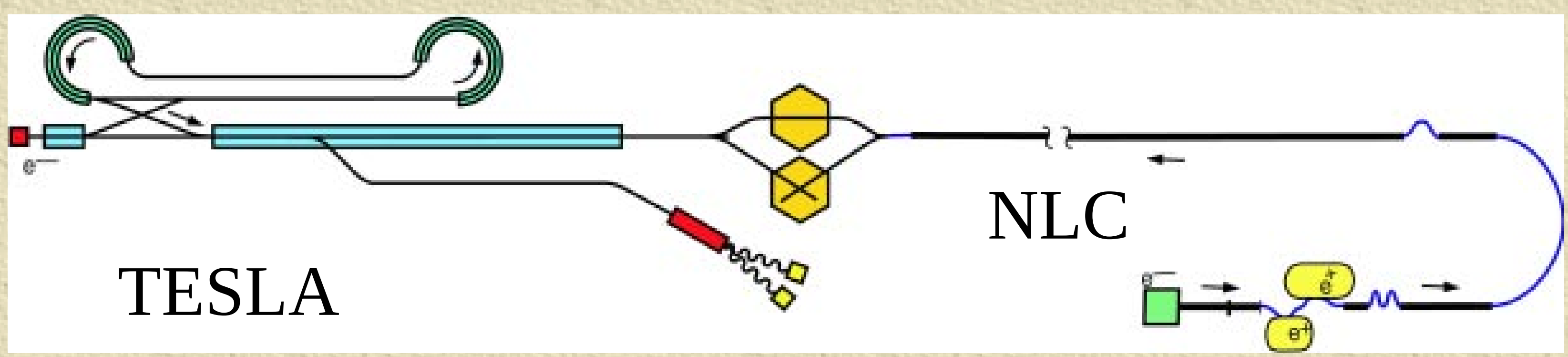
Contents

- NLC and TESLA status and comparison
  - Energy
  - Luminosity
- Some needed R&D



This Talk is Aimed at HEP experimentalists

- Accelerator experts can stay, but can’t ask questions.
- Why should you help with the accelerator?
  - Much of the technology is the same
  - Accelerators are even bigger toys than experiments.
  - You are needed.
  - Experiments can’t be done if the accelerator doesn’t get built and made to work.
- Won’t talk about why the LC is needed. Your presence indicates you know it is needed.

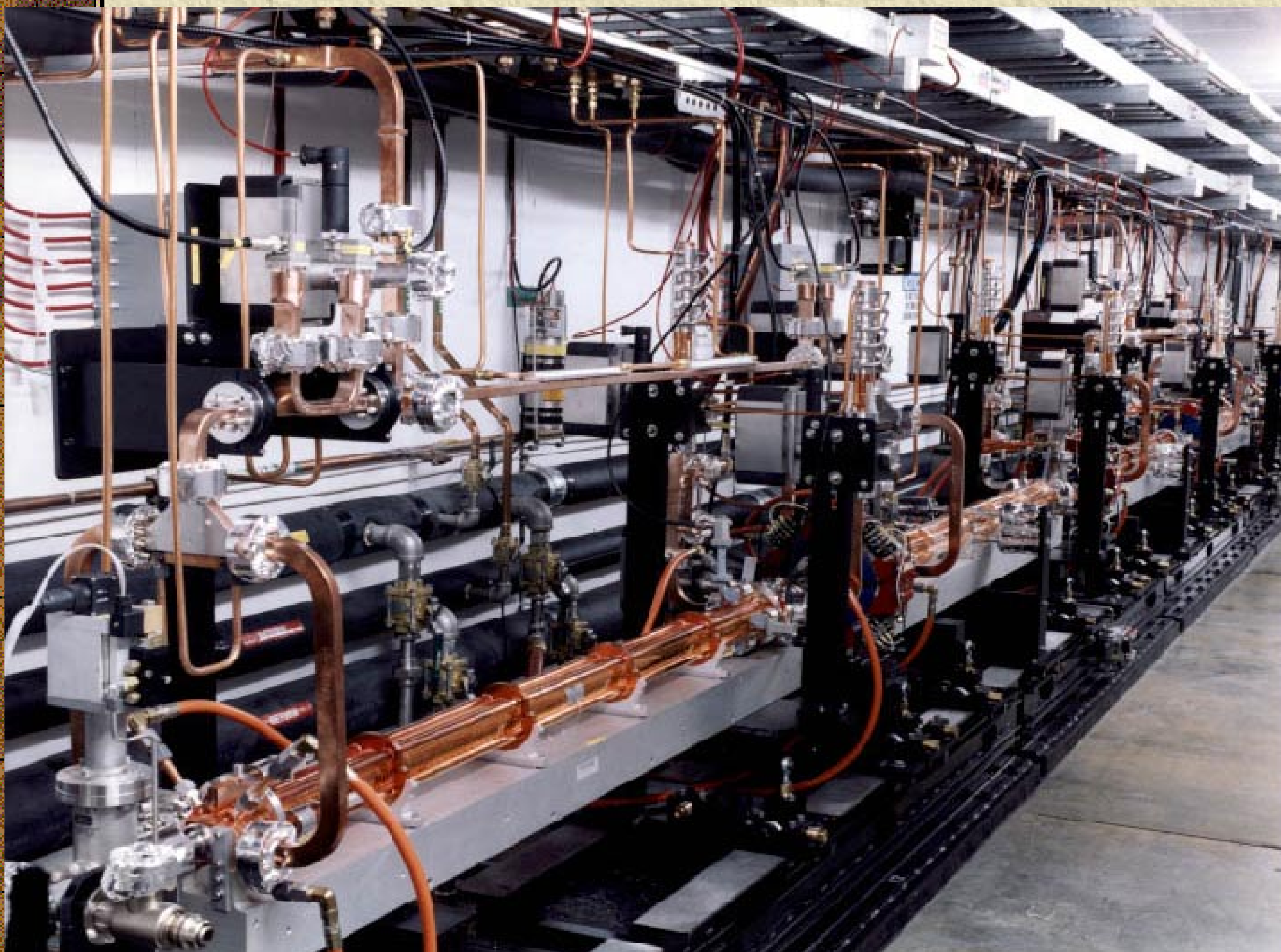
Selected Parameters

Parameter	TESLA	NLC	Pro/con of TESLA
Energy (GeV)	500-800	500-1000	- Less max energy due to lower gradient
RF Frequency (GHz)	1.3	11.4	+ Less wakefields and hence looser alignment tolerances
Repetition rate (Hz)	5	120	- Beam moves 20 sigma in 1/5 seconds.
# bunches/pulse	2820	192	- Needs very fast DR kicker
# bunches/sec	23,040	14,100	
Time between bunches (ns)	337	1.4	+ Allows easier intra-train feedback; + Less pile-up in the detector

Selected Parameters (cont)

Parameter	**TESLA**	**NLC**	**Pro/con of TESLA**
# particle/bunch	2	0.75	
Beam power (MW)	11.3	6.9	+ Allowed by higher RF to beam efficiency
Peak Luminosity (10^{33} cm^{-2} s^{-1})	34	20	+ Allowed by higher beam power
Total length (km)	33	32	Nearly identical!
RF structure temperature (degrees K)	2	380	- Cryostat makes alignment harder
σ_x / σ_y	553 / 5	243 / 3	Not very different
DR circumference (m)	17000	300	- Caused by large number of bunches

NLC Test Accelerator



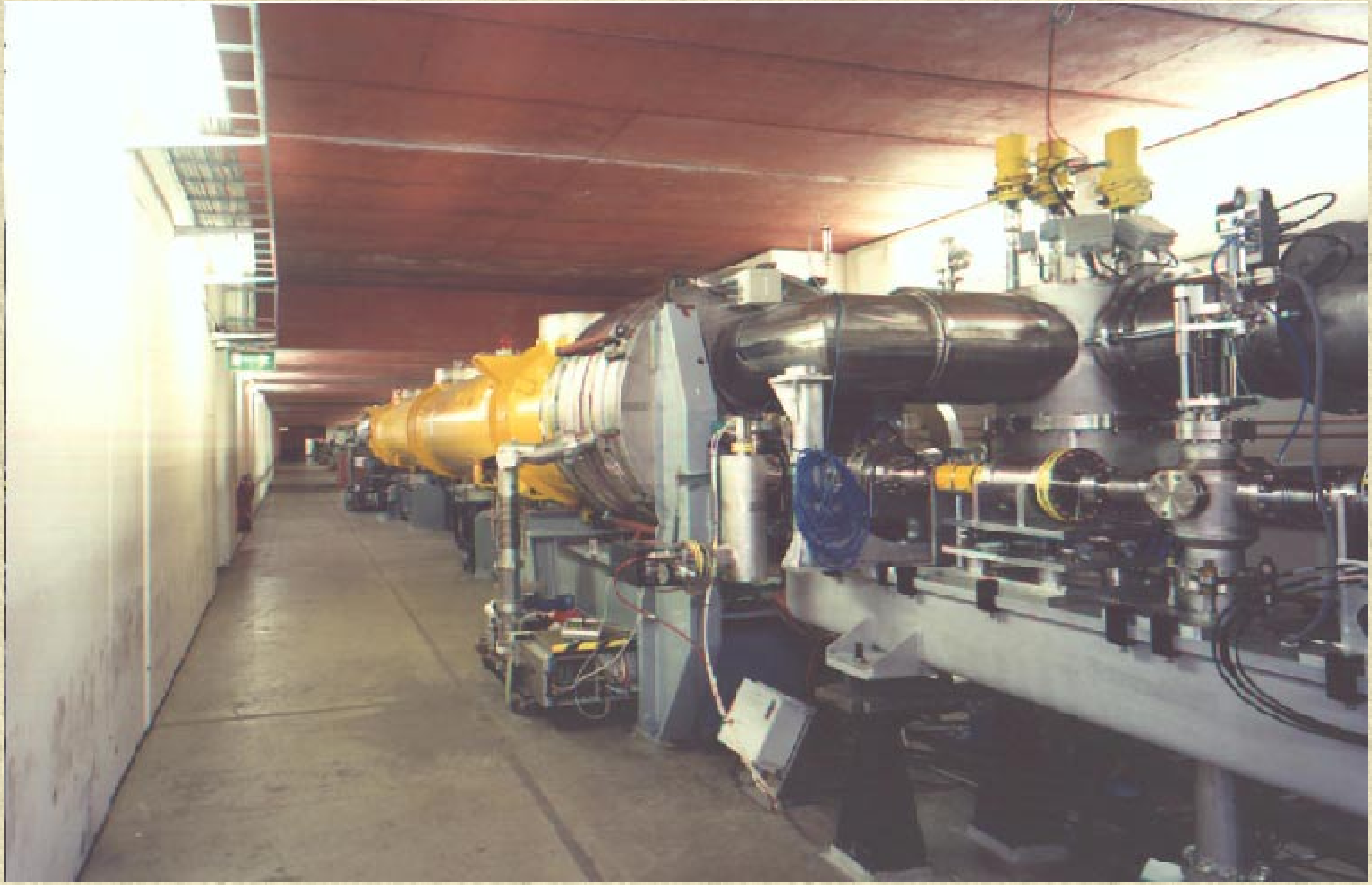
Operated since 1996

5000 hrs just this year

Essentially NLC-500 rf system from 1996:

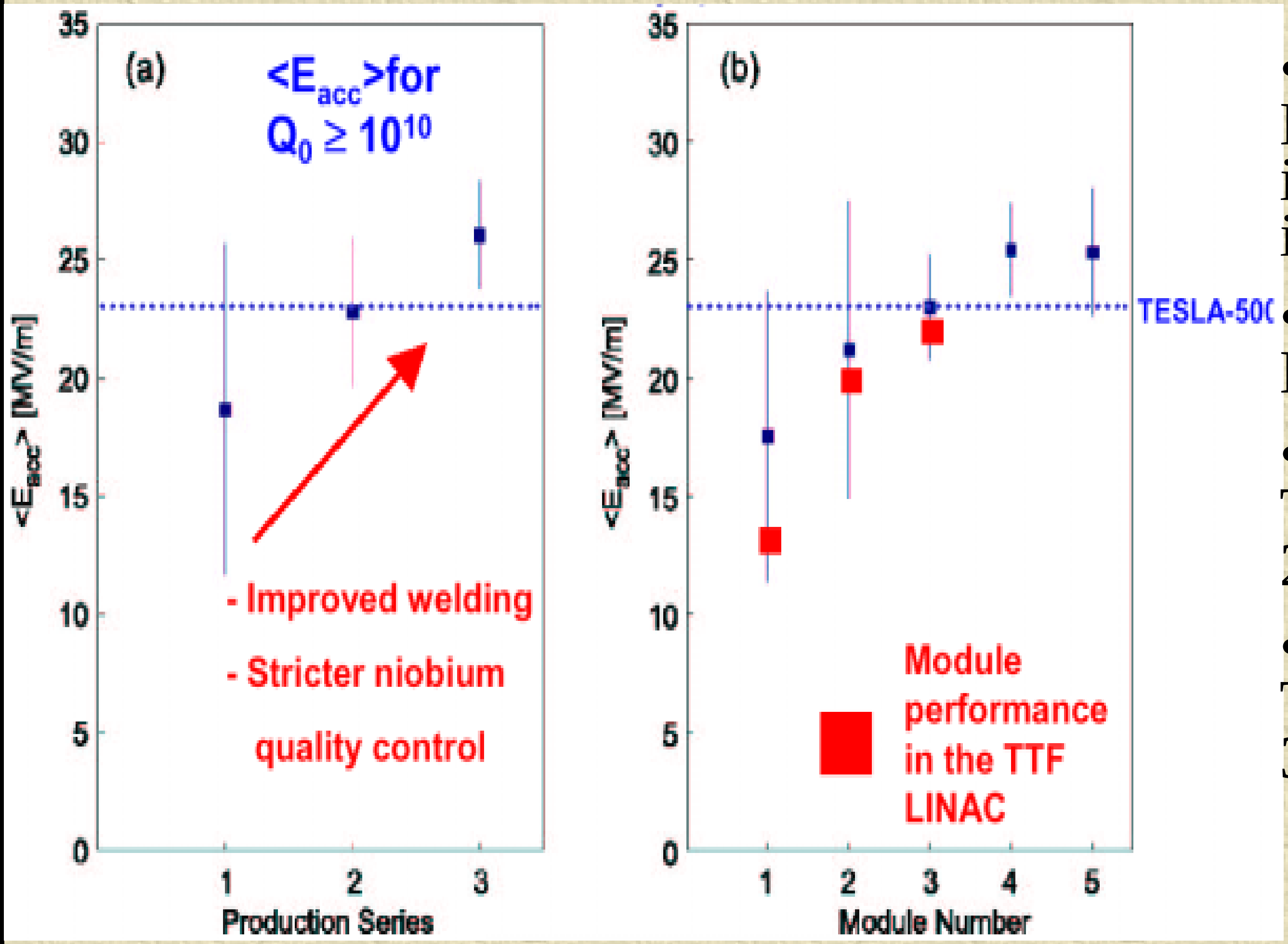
- Dual 50MW klystrons
- SLED-II
- 1.8 m long structures

TESLA Test Facility



Operated since 1997. Used to run an FEL.

TESLA Gradient Achievements



- Yield with E_{acc} > 23 MV/m in 3rd production is ~ 90%
- TTF runs at 17 MeV/m
- 500 GeV TESLA needs 23 MeV/m
- 800 GeV TESLA needs 35 MeV/m

http://www-project.slac.stanford.edu/lc/Project_List/intro.htm T. Himel 4/5/02

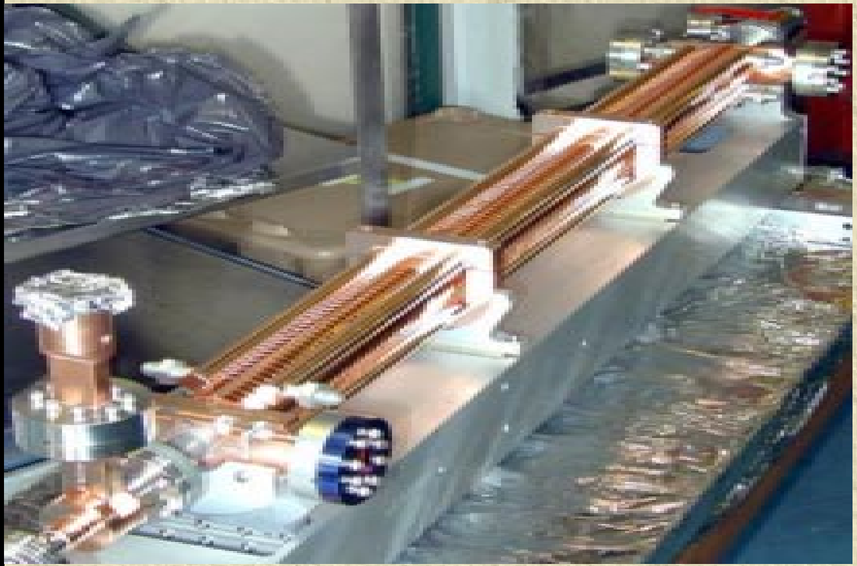
NLC Accelerator Structures

- Not near gradient limits for copper
  - Single cell cavities hold gradients of ~ 200 MV/m
  - ‘Short’ structures processed rapidly to >100 MV/m
- Built many 1.3-m ~ 1.8-m structures
  - Meet fabrication tolerances
  - Studied wakefield damping extensively – damping sufficient although not at desired values due to trivial errors, solutions in-hand
  - Stable operation limited to 40 ~ 45 MV/m
- Processing model – increase voltage until breakdown
  - Not strongly coupled to cleanliness - different than SC models
  - Small arcs clean surface / large arcs damage surface
  - Difference between the two is how much energy is deposited → low vg
  - Some ‘damage’ is acceptable however need to extrapolate out 10~20 years
  - Other models predict constant damage – inconsistent with single cell data

NLC Low Group Velocity Structures

DS2S
52 cells DS2

20 cm test
5% to 4% v_g



105 cm test
5% to 1% v_g

Built 9 traveling wave test structures

Rapid processing to >70 MV/m

DS2S 1500 hrs @ 50-70 MV/m

Vg 5% 500 hrs @ 65-75 MV/m

Two subsequent traveling wave structures operated at 70 MV/m with peak 85 MV/m

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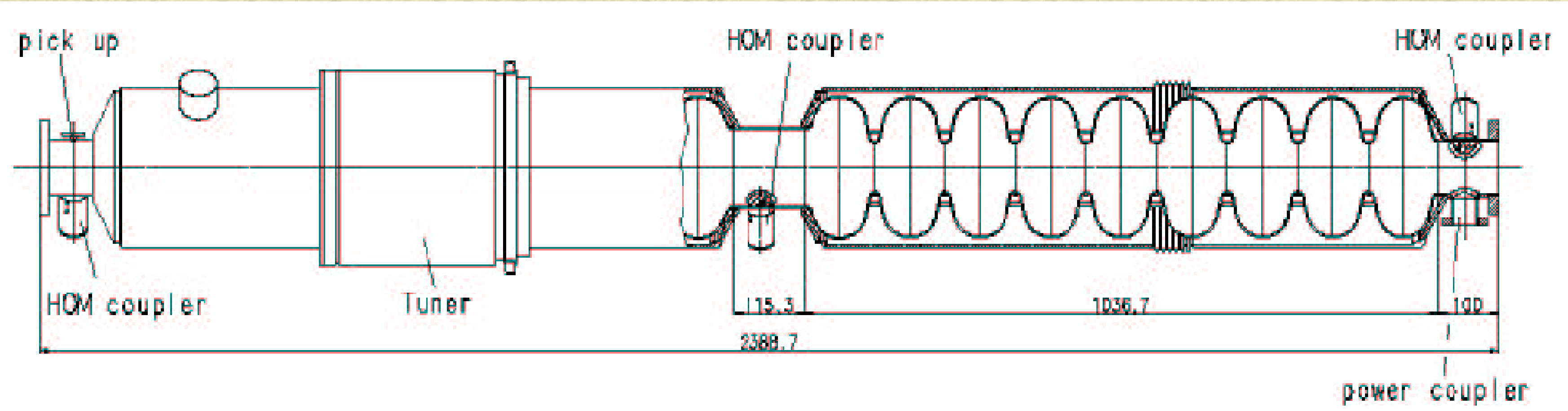
NLC RF system

- 3rd iteration on NLC rf system driven by cost reduction and results from R&D program
  - 1st iteration built into NLCTA which started operation in 1996
    - Conventional modulators; XL-4s with 50 MW PPM demonstrated summer on 1996; SLED-II 4x power compression; 1.8-m damped detuned accelerator structures
  - 2nd iteration adopted in 1998
    - Conventional modulators; 75 MW PPM klystron with 1.5 us pulse width; DLDS 4x power compression; 1.8-m damped rounded detuned accelerator structures (gradient and wakefields)
  - 3rd iteration adopted in 2000
    - Solid state modulators; 75 MW PPM klystron with 3 us pulse width; DLDS 8x power compression; 0.9-m rounded damped detuned accelerator structures (gradient and wakefield)

TESLA Super-Structures

- Super-structure will increase filling factor from 74% to 79%
  - TESLA-500 gradient would be 22 MV/m
  - TESLA-800 gradient would be 35 MV/m
- Super-structures reduce number of couplers by 50% and HOM couplers by 25%
- 2x7 super-structure to be tested next year and 2x9 later?
- Designing new couplers for super-structures



Upgrade Routes and Costs

- NLC and TESLA costs are similar in value for 500 GeV (the error on the costs is greater than the difference)
- NLC upgrade requires adding structures, klystrons, etc. in the 2^{nd} half of the linac tunnel
  - Cost to upgrade to 1 TeV is roughly 25% of initial TPC
- TESLA upgrade route: install 35 MV/m cavities at onset, double rf system, upgrade cryo plant
  - Assuming initial installation of 35 MV/m cavities, cost to upgrade to 800 GeV cms is 20% of initial project cost
  - Upgrade from 800 GeV to 1 TeV is another 25% for a total of 45% of the initial project cost
  - If cavities also have to be replaced, then the upgrade cost would be roughly 85% of the initial cost

Where does the x10^4 Luminosity increase come from?

$$L = \frac{f_{rep}}{4\pi}\frac{n_b N^2}{\sigma_x \sigma_y} H_D$$

$$\frac{1}{\sigma_{IP}} = \sqrt{\frac{\gamma}{(\gamma\varepsilon)_{DR} \cdot Dilution_{DR\rightarrow IP} \cdot \beta_{IP}}}$$

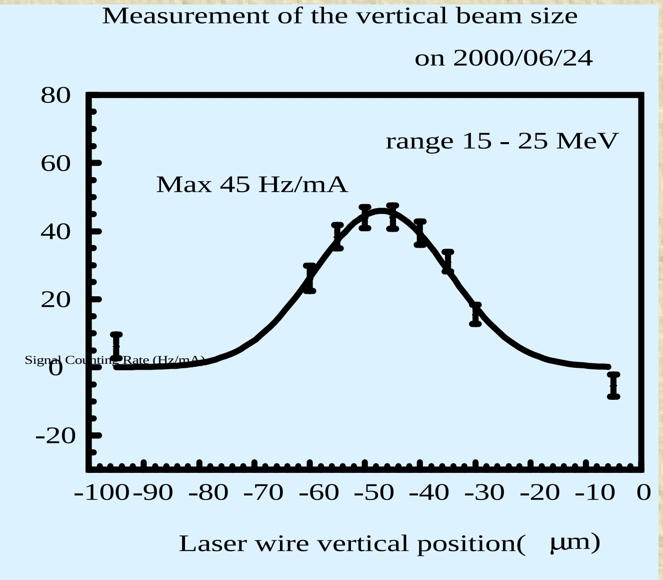
SLC Luminosity x10^4

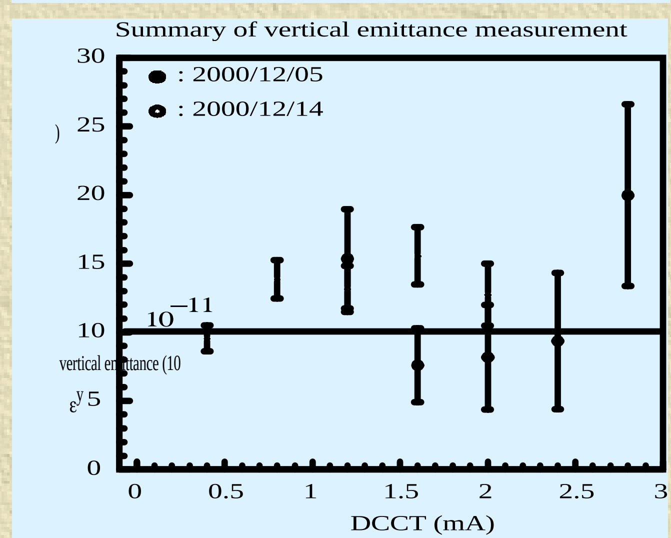
Where does it come from?

	NLC/ SLC	TESLA / SLC	Basis for Confidence
Energy, Beam Power, Q/bunch	34.6	152	"Free" and "Guaranteed"
Disruption (H_d)	0.72	1	Guinea Pig Studies
Damping Rings Sqrt(ε_x ε_y)	41	25	ATF
Emittance Preservation Sqrt ($Dilution_x$ $Dilution_y$)	2.24 (x41)	2.38 (x25)	ASSET Beam Based Alignment Studies
FF Demagnification Sqrt ($\beta_x \beta_y$)	3.27	1.20	FFTB
Total	7400	11300	

NLC prototype Damping Ring at KEK (ATF)

Vertical emittance $3.5x10^{-8}$ measured with laser wire (~2 x NLC spec)





ATF not at full current
TESLA DR not prototyped at all

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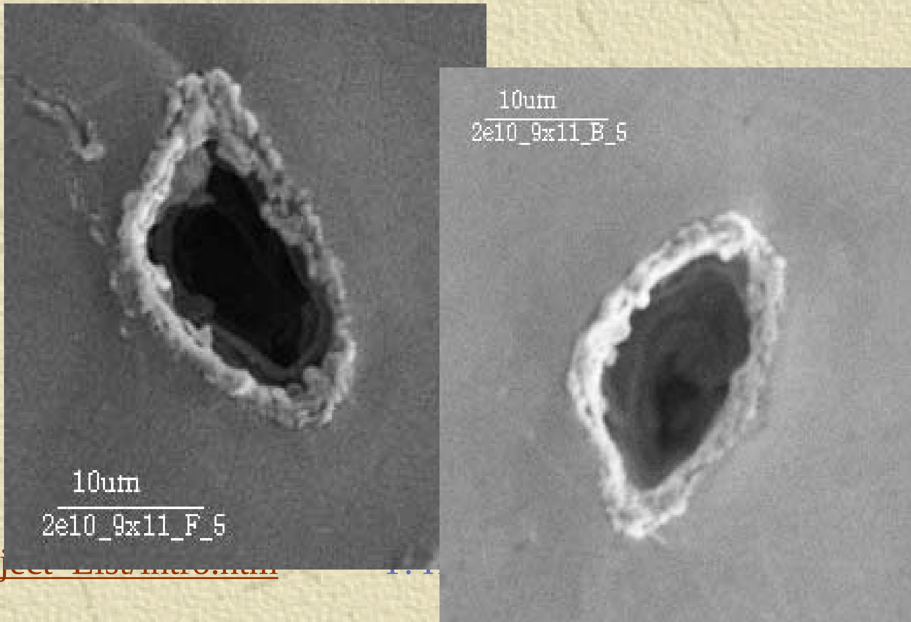
RF Cavity Alignment

- NLC structures (cavities) must be aligned to beam within 10 μm rms for 20% Δε
  - Every structure has two rf-BPMs with better than 2 μm accuracy
  - Short-range wakefields depend on average of structure offset
  - Average position of the 6 structures on an rf girder and move girder end-points with remotely controlled movers
- TESLA cavities must be aligned with 500 μm rms for 15% Δε
  - Achieved +/- 250 μm alignment within cryostat
  - But effects add → tolerance for 12 cavities in cryostat ~ 140 μm
  - Effect is worst at $\frac{1}{4}\lambda_\beta$ = 150 m → tolerance for cryostats ~ 45 μm
  - Either add read-backs on HOM dampers and steer beam to center of cavities or use global emittance bumps like those used in SLC to cancel dilutions
  - RF deflections imposes 100 μrad tolerance on cavities for 5% Δε

Need for Hazard Avoidance Logic (HAL)

- Single bunches will likely damage any material at the end of the linac or in the beam delivery
  - Complicated turn-on process to prevent damage
  - Complicated MPS system with diagnostics on all components that can change from pulse-to-pulse
  - Some impact on operation not yet fully quantified
  - Problems are similar for TESLA and NLC!

Damage from 13 pC/μm^2 (2x10^9 e$^-$)



http://www-project.slac.stanford.edu/lc/Proj

List of Extra R&D needs

- I'm walking on a tight rope
  - Want to convince you there are interesting, challenging R&D projects
  - Without convincing you the LC cannot be built.
- Very high priorities are being done: gradient, power source, FF design: not on project list.
- On list are items that if they can be done will decrease cost or improve reliability.
- Many items on list are challenging but pretty clearly doable. Doing them makes the CDR that much more definite and convincing, refines the cost estimates and gets work going that needs to be done.

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

THE LIST of projects

- In capitals. It has been dominating my life the last few weeks.
- http://www-project.slac.stanford.edu/lc/Project_List/intro.htm
- Input from SLAC, FNAL, Cornell. I just organized it.
- Dave Finley's and Marc Ross' projects (in following talks) are on it.
- Wide range of skills, project sizes and priorities. Something suitable for everyone.

Sample DB entry

ID: 16 **Priority:** Medium **project_size:** Large **skill_type:** physicist

short project description: superconducting quadrupole vibration test

Detailed project description: There are two options for the final doublet magnets: permanent and superconducting. The main concern about the superconducting method is that coils will vibrate too much since a strong support to the cryostat would cause a big heat leak, and boiling helium may jiggle the coils. Either by calculation, or finding an appropriate magnet, convince people that the quadrupole fields center will move by less than a nm relative to the outside of the cryostat.

Needed by who: NLC and TESLA **present status:** good idea needed
Needed by date: 6/1/2005

ContactPerson1: Joe Frisch **WorkPhone1:** 6509264005
EmailAddress1: frisch@slac.stanford.edu

ContactPerson2: **WorkPhone2:** **EmailAddress2:**

Background Calculation and Reduction in the IR.

- Priority: Medium
- Size: Medium
- Skill: Simulations
- Needed for NLC and TESLA
- There are many types of backgrounds: Halo muons, low energy e+e- pairs, synchrotron radiation.
- Use existing simulation tools (and perhaps write new ones) to calculate the background levels and to design shielding and masks to minimize it.\
- A fair amount of work has been done, but more is needed.

Low level RF 500 MHz digitizer

- Priority: Medium-High
- Size: Large
- Skill: Electronics
- Needed for NLC
- There are many channels of this, so it must be CHEAP.: $100 per channel instead of the present $10,000. One idea is to develop an analog waveform recording chip and then do the digitizing more slowly after the pulse has gone by.
- The present RF system down-mixes the RF signals from the structures and diagnostics to an IF in the ~100-500MHz range. This must be digitized at ~500MHz, for the length of the RF pulse (up to 3.2 microseconds), at 12 bits (possibly 8 is ok?).

DR beam size monitor

- Priority: Medium-Low
- Size: Medium
- Skill: Physicist
- Needed for NLC and TESLA
- The beam height in the damping ring will be about 4 microns. We need to non-disruptively measure this on an individual turn in the ring. Traditionally this is done with a synchrotron light monitor. The spot here is so small that one must go to very short (x-ray) wavelengths to get the necessary resolution. We would like a conceptual design of some way to do this. It would then be evaluated whether a prototype is needed

Design and prototype RF BPM both mechanical and electronic

- Priority: Medium
- Size: Large
- Skill: Electronics and Mechanical
- Needed for NLC
- Reads out a small RF x band cavity. Gives a position that must have a precision of 1 micron and a drift of less than 1 micron per day.
- We think that by using the quadrature signal from the BPM that the tilt from the front to the back of the beam (x-z and y-z correlations) can be measured. This would be an enormous bonus, letting us directly measure the wakefield tail as it forms.

Flow switch

- Priority: Medium
- Size: Small
- Skill: Electronics and Mechanical
- Needed for NLC and TESLA
- High reliability, cheap, rad-hard flow switch. Should not trip when a bubble goes by, should not be the smallest aperture in the system so that it gets plugged up. Should both have a trip point and a flow readout so marginal flow can be detected before it causes a trip.

Fast communications to check pulsed devices (part of HAL)

- Priority: Medium-Low
- Size: Small
- Skill: Electronics and Mechanical
- Needed for NLC and TESLA
- Part of HAL that must check that all pulsed devices (modulators and kickers) are ready to fire just before the particles are extracted from the damping rings. If too many things aren't ready (a few bad modulators may be OK) then DR extraction is aborted. This must be very fast (speed of light should account for most of the delay), so simple logic and wires or fibers must be used. Design such a system to be highly reliable and have necessary diagnostics and readout of what caused the fault. Only a conceptual design is needed at this point.

Summary of LC status

- TESLA and NLC designs are more similar than they are different.
- No showstoppers!
  - Many outstanding problems in both designs
  - 2nd generation prototype hardware still needs demonstration
  - Most failures can be worked around
    - Example: don't get to full gradient, make it longer.
- At this point the designs will reach conclusion faster than any political process
  - Believe this is true for both NLC/JLC and TESLA designs
  - Need to go into the construction phase to stop the design improvements.
- Lots of challenging, fun, useful R&D projects to do.
- Let's get to work!!