August 12, 2000

DP 2000

Summary
The Linear Collider
Superconducting Cavity
T E S L A Collider

For the T E S L A collaboration
Winfried Decking, DESY - M P y

Challenges of the T E S L A Linear Collider Design
Challenges of the TESLA Linear Collider Design

**Swiss Challenges**
- INP Trench
- INP Testbeam
- INP Targetline
- INP Proton beam line

TESLA Collaboration

40 Institutions from 9 nations present, form the TESLA collaboration

**Participating countries**
- USA
- France
- Germany
- Italy
- Japan
- South Korea
- China
- Brazil
- Spain

**Institutions**
- CERN
- INFN
- DESY
- KEK
- SINQ
- SNB
- TESLA
- Future Petter

**Participants**
- W. Decking
- P. A. A. A.
- B. D. 4
- E. E. F.
- F. F. F.
- G. G. G.
Challenge of the TESLA Linear Collider Design

- Reduce cost through modular design and mass fabrication
- Increase gradient to 25 MV/m (35 MV/m)

Construct and build cheap (compared to today's installations) superconducting RF-cavities

Challenge #1

- Fast bunch-to-bunch orbit feedback
- Small wakefields ($\propto \frac{f^{2.5}}{\lambda}$)
- Long (1.1 ms) RF-pulses with low $\approx 200$ kW/3m peak power
- High AC-to-beam efficiency of 20%

Why Superconducting RF-cavities?

500 (800) GeV Linear Collider Based on Superconducting 1.3 GHz Cavities

The TESLA Concept
Superconducting Cavities

- Welding, hydroforming, spinning
- Fabrication technique: electron beam
- Conductivity (RRR300)
- Material: Niobium with high thermal conductivity
- Cavity bandwidth approx. 400 Hz
- Operation temperature 2 K
- Pi-mode operation
- Cavity frequency 1.3 GHz; standing wave
The TESLA Test Facility at DESY
Results from vertical tests

Results from vertical tests of assembled modules have been

- Emphasis on liquid operation
- High gradient (so far)
- Proportional and FEL studies, not on commissioning and FEL studies, not on
- 4-cell cavities
- 55 TESLA 9-cell cavities delivered by 4

Challenges of the TESLA Linear Collider Design

Module #

TESLA 500 GeV Goal

00/66 07/96 98/96

Gradient MV/m

W. Declair
B. Pfeifer
Challenges of the TESLA Linear Collider Design

- Seamless cavities from hydro-forming or spinning
- Electro-polishing
- Further increase of gradients with:
  - Higher gradients with present treatment and fabrication is not expected
  - Presently achieved level of technology in cavity production is adequate for construction
  - Proper fabrication and treatment of cavities yields gradient of 25 MV/m

Summary Cavity Development
The TESLA Linear Collider
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESLA 500</td>
<td>3570</td>
</tr>
<tr>
<td>TESLA 800</td>
<td>860</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lumin. L [1 × 10^{3} cm$^{-2}$s$^{-1}$]</th>
<th>Beamstrahlung [%]</th>
<th>Bunch Length [mm]</th>
<th>Spot size [um]</th>
<th>N_e/bunch [1 × 10^{10}]</th>
<th>Rep. Rate [Hz]</th>
<th>Bunch spacing [ns]</th>
<th># bunches/pulse</th>
<th>t_{pulse} [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2</td>
<td>0.3</td>
<td>391 / 2.4</td>
<td>5.5 / 5</td>
<td>15 / 0.4</td>
<td>10 / 0.3</td>
<td>2</td>
<td>37</td>
<td>800</td>
</tr>
<tr>
<td>32</td>
<td>3.3</td>
<td>15 / 0.4</td>
<td>33 / 7</td>
<td>2</td>
<td>5</td>
<td>337</td>
<td>2820</td>
<td>950</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>8 / 0.15</td>
<td>1 / 0.9</td>
<td>1 / 0.3</td>
<td>10 / 0.03</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4.7</td>
<td>0.3</td>
<td>15 / 0.4</td>
<td>33 / 7</td>
<td>2</td>
<td>5</td>
<td>337</td>
<td>2820</td>
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<td>5</td>
<td>337</td>
<td>2820</td>
<td>950</td>
</tr>
</tbody>
</table>

Number of cavities per linac
Number of klystrons

≈ 300 (≈ 600)

≈ 10000

Challenges of the TESLA Linear Collider Design
Challenges of the TESLA Linear Collider Design

- W. Decruyne
- W. Decruijn

Tunnel Layout

- Access and kryo hall every 5 km
- Tunnel hosts modules, klystrons, transfer lines, damping ring...
- 20 – 30 m below ground
- Diameter 5.2 m
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{beam}}$ [GeV]</td>
<td>250</td>
</tr>
<tr>
<td>$B_{\text{rms}}$ (wiggler) [T]</td>
<td>0.9</td>
</tr>
<tr>
<td>$L_w$ [m]</td>
<td>60</td>
</tr>
<tr>
<td>$\lambda_w$ [cm]</td>
<td>2.5</td>
</tr>
<tr>
<td>$\sigma_{x,y}$(target) [mm]</td>
<td>1</td>
</tr>
<tr>
<td>$\eta_{\text{capture}}$ [%]</td>
<td>17</td>
</tr>
<tr>
<td>$N_{e^+}/N_{e^-}$</td>
<td>2</td>
</tr>
<tr>
<td>$&lt;dE(e^-)/E&gt;$ [%]</td>
<td>-1.6</td>
</tr>
<tr>
<td>$\sigma_{E}(e^-)/E$ [%]</td>
<td>0.18</td>
</tr>
<tr>
<td>$\gamma \Delta \varepsilon(e^-)$ [m]</td>
<td>$&lt;10^{-8}$</td>
</tr>
</tbody>
</table>
is filled again after 1.5 turns. **Note:** Because of the TESLA position source scheme the position of an ejected bunch

**DOG-BONE**

To avoid excessive additional tunnel cost build most part of the ring in the Linac tunnel:

Assume kicker raise/fall time of 20 ns → circumference = 2820 m due to

Circumference is now given by the achievable kicker raise/fall time

Compress bunch train with smaller bunch spacing in damping ring

Long TESLA bunch train (2820 bunches, 337 ns bunch-spacing) would require a 280

**Damping Ring**
R&D ongoing for kicker system with 20 ns raise/fall time
Reduce space charge time shift through energy increase and local coupling

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Incoherent space charge time shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>$\frac{J}{F_{\text{r}-\text{vol}}}$</td>
</tr>
<tr>
<td>3.25</td>
<td>$p_{\text{rad}}$</td>
</tr>
<tr>
<td>1.60</td>
<td>$I_{\text{beam}}$</td>
</tr>
<tr>
<td>20.3</td>
<td>$\frac{I_{0}}{\text{turn}}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transverse damping time $t_{\text{D}}$</th>
<th>Longitudinal damping time $t_{\text{L}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$28 \times 10^{-3}$ s</td>
<td>$1.3 \times 10^{-8}$ s</td>
</tr>
<tr>
<td>$1.9 \times 10^{-6}$ m</td>
<td>$9 \times 10^{-6}$ m</td>
</tr>
<tr>
<td>17 km</td>
<td>17 km</td>
</tr>
<tr>
<td>5.0 GeV</td>
<td>5.0 GeV</td>
</tr>
</tbody>
</table>
Beam Delivery System

- Luminosity detector
- Background from pair production, neutrons, synchrotron radiation...
- Detector and interaction region layout including masking

Accelerator-Detector Interface (ECFA/DESY study):
- Non-linear energy collimation scheme
- Include slow and fast orbit feedbacks
- Inclined e+ production on the electron side
- Head-on collision
- Inclined e- production on the electron side
<table>
<thead>
<tr>
<th>Beam-Gas</th>
<th>Beam-Shielding</th>
<th>Source</th>
<th>Beam-Gas</th>
<th>Beam-Shielding</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.95</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
<td>2.1</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
</tr>
<tr>
<td>2.0 - 1.0</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
<td>2.1</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
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<td>2.0 - 1.0</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
<td>2.1</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
</tr>
<tr>
<td>2.0 - 1.0</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
<td>2.1</td>
<td>2.1 - 1.2</td>
<td>2.1 - 1.2</td>
</tr>
</tbody>
</table>

Summary of 500 GeV Background

Challenges of the TESLA Linear Collider Design
Major concern: Offset of Final Doublet Transfers

\[ \Delta \sigma \leq 0.2 \text{ mm} = 10\% \]
\[ \Delta \gamma \leq 0.5 \text{ mm} = 10\% \]

\[ \Rightarrow \]

Luminosity Loss/Bunch crossing \( > 10\% \)

Luminosity Versus Beam Separation at IP
Challenges of the TESLA Linear Collider Design

Fast Bunch-to-Bunch Feedback

Correction from Bunch to Second Bunch Feasible

due to strong beam-beam detection:
Separations in nanometer range detectable

Need of intra bunch Train Correction @ 3MHz:
\[ \gamma^2 = 20^\circ \] HERA Final Doubler (3.4m, C. Monteiro)
\[ \gamma^2 > 35^\circ \] Train-to-Train Jitter (N. Walker)
\[ \gamma^2 = 10^\circ \] within bunch train

- Reduction by 1000
  After 30 Bunches:

Add. distance \( \gamma^2 = 100^\circ \), \( \alpha = 10^\circ \): \( 9\% \)

3. e+ e- Feedback: Beam Separation
Challenges of the TESLA Linear Collider Design

2003 Begin of construction (6-8 years)
2003 Approval as an international project
2001 Evaluation of TESLA project by the German Science Council
2001 Presentation of Technical Design Report including cost and schedule
1997 First beam in TESLA test facility
1997 Publication of Conceptual Design Report
1994 Formal start of the TESLA collaboration

TESSA Schedule
Challenges of the TESLA Linear Collider Design

- Emphasize on TESLA: X-ray FEL and Linear Collider
- EXPO 2000 in Hanover
- DESY exposition "Light for the New Millennium" in Hamburg parallel to world exhibition

Challenge #5: Get support from politicians and the public

A possible TESLA site at DESY in Hamburg
Thanks to all colleagues within the TESLA collaboration for support and information.

- Detailed cost and schedule by end of this year
- Cavity development for 800 GeV option underway
- With luminosity of $\mathcal{L} \approx 3.4 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}

TESLA technology and layout ready for a 500 GeV linear collider

After decade of cavity development and parallel linear collider R&D

Conclusion