### Electron and positron sources

<table>
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<tr>
<th>Requirements</th>
<th>Status of R&amp;D</th>
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#### Linac

- Developing expertise
- Tools and algorithms
- Development of diagnostic and tuning
- Modeling of beam dynamics

D. Rubin, Cornell University
<table>
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<tr>
<th>Requirements</th>
<th>NLC</th>
<th>TESLA</th>
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<tr>
<td>Bunches/sec</td>
<td>23,040</td>
<td>14,100</td>
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<tr>
<td>Pulse length</td>
<td>70 ns</td>
<td>950 ns</td>
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<tr>
<td>Bunch spacing</td>
<td>1.4 ns</td>
<td>337 ns</td>
</tr>
<tr>
<td>Electrons/bunch</td>
<td>(0.75 \times 10^{10})</td>
<td>(2 \times 10^{10})</td>
</tr>
<tr>
<td>Bunches/pulse</td>
<td>120</td>
<td>5</td>
</tr>
<tr>
<td>Repetition rate [Hz]</td>
<td>192</td>
<td>2820</td>
</tr>
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</table>
Electron source status

TTF RF photoinjector gun

- No polarization
- Collider requirements
- Delivers to TTF charge distribution comparable to
- 10 ps pulse length
- Laser: Nd:YLF rods lase at 1.047 μm (~270)
- CsTe photocathode, quantum efficiency ~ 1%
- 4 MeV electrons
- 35 MV/m
- 1.5 cell L-band

Electron source status
Spread out spot to get sufficient charge

- Dependence of quantum efficiency and polarization on laser wavelength
- Quantum efficiency for GaAs ~0.1%
- Recovery time for cathode 10-100ns/pulse
- Low voltage limits current (space charge)
- Minimize dark current to protect cathode (low fields)
- 1.8MV/m DC instead
- Vacuum requirement incompatible with RF gun
- GaAs cathode (and ultra high vacuum > (10^-11) mbar)

Polarization

TESLA/NLC require 10X electron production of SLC

STC gun yielded 80% polarization

Polarized electron source
Polarization and QE as a function of wavelength measured in the CTS lab.
April 19, 2002

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T. Maruyama (SLAC)–2.2(10)¹² electrons/pulse with 14mm laser spot–4.5(10)¹² with 20mm spot

NLC needs 2.7(10)¹²

Cathode can deliver charge

Ti:sapphire is usual choice for polarized source

No such laser is commercially available

2800 pulses and 5 pulses/pulse

Requires ~1ms laser pulse train

TELA bunch spacing presents challenge for laser

Train bunch structure

NLC needs 2.7(10)¹² with 20mm spot – 4.5(10)¹² with 4mm spot – 2.2(10)¹² electrons/pulse with 14mm laser spot

T. Maruyama (SLAC)
Electron source - flat beam gun

and polarized electrons

Needs "emittance compensation"

Flat emittance ~1μm (50 times too big)

50:1 transverse emittance ratio of 1MeV beam

Experiments with AO photoinjector at FNAL

- Transform to emittance asymmetry with quadrupole optics
- Beam emerges with angular momentum
- Solenoid field at cathode

Proposed by Brinkermann, Derbenev, and Flottmann

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Flat Beam Experiment at A0/FERMILAB
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Conventional positron production limited by stress in target
Alternative?

Conversion of high energy undulator radiation in thin target

250 GeV electron beam through ~100m (.75T) undulator

Yields 28 MeV photons

2.7 mm rad spot \( 0.7 \text{ mm} \)

\( 0.4 \times 10^0 \) \( \text{X} \) \( 0.4 \text{ cm} \) Ti rotating target 350m from undulator

Conversion of positron production limited by stress in target
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Positron source

- Polarized positrons
  - Replace planar undulator with helical undulator

- Polarized photons
  - 1 mm period, B=0.5 T, 1 m long helical undulator

- Polarized photons/electron (Sheppard/Pitthan)
  - 3 x (10^-3) positrons/electron

- Test

Requires small electron beam divergence since only near-axis photons are polarized.

Undulator parameters

- B ~ 1.3 T
- 1 cm period
- 1 m period

Polarized photons in polarized positions

Position source

Test
And instrumentation to measure polarization?

Effect of position capture solenoids on polarization?

Off-axis photons collimated (100 kW)?

And necessarily small divergence

Beam requires 3mmX10mm aperture to be demonstrated

$\mathcal{L} = 1 \text{cm}, B = 1.37 \text{T}\) helical undulator has yet

Polarized positrons

Position source
Designed: Superconducting With Iron

- Designed for \( r_N = 12 \) mm, but
  - Fliptoman (WIP) DESY double helix design

NLC - The Next Linear Collider Project
Linac

Emittance preservation

Transverse wake $\sim 1/a^3$ ($a = \text{iris diameter}$)

Cavity and quadrupole alignment

TESLA ($a = 70\text{mm}$)

$5\text{ mm for RF structures}$

$0.5\text{ mm for cavities}$

$10\text{ mm for quadrupoles}$

NLC ($7.8\text{mm} < a < 11.2\text{mm}$)

$300\text{mm for quadrupole}$

$10\text{ mm for quadrupoles}$
From S. Smith LC02

Linac - Quad BPM

NLC Requirements

- Quantity: 3000
- Bunch spacing: 1.4 ns
- Charge dynamic range: \(5 \times 10^8\) to \(5 \times 10^{10}\) / bunch
- Position dynamic range: \(\pm 2\) mm
- Position accuracy: \(200\) mm
- Position stability: \(1\) mm over 24 hours
- Position re quad center of single bunch
- Resolution: \(300\) mm rms of \(10^{10}\) single bunch

Measure average position of bunch train and align quads
Linac - BPM

S. Smith LC02

- 300nm resolution
- 1.4μm apart
- 1.4ns apart

• Measure each bunch in train and correct trajectory

Multibunch BPM

- Resolution 5μm
- 22,000 required for NLC

• Alignment with beam
• And minimize transverse wakes to establish
• Modes in accelerating cavities
• Measure amplitude and phase of transverse
• Structure position monitor
Linac - modeling

Limited flexibility

Fixed bunch length

No multipoles

But not all...

Magnet movers

Structure wake fields

Accelerating fields

Magnetic guide field

Include lots of physics

(Merlin)

(LAIR Linear Accelerator Research Code)

Codes have been developed for detailed modeling

Linac - modeling
Linac - modeling

Modeling codes used to:
- Evaluate beam based alignment algorithms
- Determine adequacy of BPM, resolution, placement
- Develop commissioning strategy
- Diagnose problems and performance during startup and operation
- Anticipate instrumentation requirements
Linac - modeling

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Linac - modeling
- Existing codes are powerful but incomplete
- Many issues to explore
- Does beam based alignment of quadrupols to 300nm and cavities to 5\(\mu\)m in NLC converge?
- Is 0.5\(\mu\)m alignment of TESLA cavities really good enough?

By exercising modeling codes, we train ourselves (and our students) to use and interpret them. So we will be better prepared to address operational problems as they arise.
and performance

Significant implications for beam parameters (bunch length)

- The effect / corrective measures can (and should) be explored in
- And further compensated with tuning IR correctors
- And further compensated with feedback

It is suggested that the problem can be at least partially

Our understanding of the phenomenon is based on simulation.

\[ \frac{\lambda f}{\Box} = D \]

Instability in beam-beam interaction - when disruption is high

Relatively small correlated emittance growth can lead to

Example modeling and simulation project

Linac - banana instability
Beam centroids head on

Projected emittance growth

Y-Z correlation (equivalent to Few %

Nominal TESLA Beam Parameters +

Banana Effect - Beam-Beam Simulation
This is just an example what powerful knob at the SLC

phase by = 2.5 deg

Change of bunch compressor

Ideal machine

Gaussian bunch from DR

DR to IP Simulations

W. Decking LCO2
Linac - parameter space

- Explore possibilities
- Perhaps 10Hz X 425 m and smaller damping ring would be advantageous
- 15Hz rep rate with 950 m pulse length and large damping ring optimum
- Increase Q from 1 to 5x10^10, and gradient from 23 to 35 MV/m
  - Then 10Hz rep rate and 950 m pulse length
  - Increase Q from 1 to 5x10^10, and
  - Increase Q from 1 to 5x10^10, and
  - Implications of improvements in cavity performance (Padamsee)

Then 10Hz rep rate and 950 m pulse length

20% reduction in capital cost and no increase in operating cost

- Increase Q from 1 to 5x10^10, and gradient from 23 to 35 MV/m with 60% increase in wall plug power

- Twice the luminosity

- 20% reduction in capital cost and no increase in operating cost