Working group 3 summary: ILC Injector

sources, kickers, damping rings, bunch compressors

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Outline

- Goals and organization
- Sources
- Kickers
- Damping rings
- Bunch compressors
- Post-SLAC, pre-KEK activities

Goals

Part of our charge:

- Review the technical issues with SC-LC;
- Develop a list of design elements that are:
  - non-controversial in concept and may only need optimization
  - should be considered open for evaluation from scratch;
- Present the topics the different groups are interested in…

How we organized things

Upstream to downstream, grouped by major subsystem:

- sources
- kicker
- damping rings
- bunch compressors

Presentations tended to describe:

- specific work already under way
- future directions and concerns

We discussed risks and current status of R&D status after presentations concerning each subsystem.

Branch points

Some topics will eventually lead to ILC configuration choices among very different machine possibilities:

- should there be an e^+ pre-damping ring or not?
- undulator or conventional e^+ source?
- fast pulsed asymmetric kicker, or some kind of RF device?
- 17 km dog bone damping ring, 6 km, or 3 km circular ring?
- generate e^+ using main linac beam, or build an independent linac?
- one-stage or two-stage bunch compressors?
- should there be a “feed-forward turnaround” (perhaps between damping ring extraction and main linac ejection)?

Estimates of risk and current R&D status

See http://awolski.lbl.gov/ILCAmericas/InjectorRiskIssues-Final.xls; please take the numbers with a grain of salt.

Performance impact:

0. No impact on overall machine performance, cost, or schedule
1. Minor impact
2. Significant impact
3. It’ll never fly, Orville

R&D status

0. We already know how to do it
1. Technology exists and we’re pretty confident it’ll work
2. There is a proposed solution, but it needs to be demonstrated
3. We are nearly clueless.

Example: kicker for 6 km damping ring

From http://awolski.lbl.gov/ILCAmericas/InjectorRiskIssues-Final.xls.

technical challenge	performance impact	R&D status
6 ns rise / 60 ns fall	2	2
kick angle	3	1
repetition rate	2	2
reflections	2	1
0.1% pulse-to-pulse stability	1	2
Contribution to ring impedance	1	1
Reliability/Long term stability	2	2

Sources

See ILC-Americas site for list of presentations.

Institutions interested in sources:

Argonne, Cornell, Fermilab, Jlab, LLNL, SLAC

Summary mostly from David Schultz.

ILC Source Issues

Polarized electron source

Polarized electron source technology well in hand.
R&D needed to:
- Develop laser system to meet specs.
- Tune photocathode to ILC pulse train spec.
- Improve photocathode polarization
- Improve source up-time
- Develop bunching system

Advanced sources:
- Polarized RF gun – large development effort needed

ILC Source Issues

Positron source

Positron source system needs to be better modeled (in progress)

- Yield calculation to be done, spanning large set of variables
- Technologies need to be developed (eg. Flux Concentrator)
    - to support the design
- DR dynamic aperture the largest factor in the Yield
    - Large aperture Pre-Damping Ring certainly preferred, maybe necessary

Conventional (e^- beam driven) source is possible

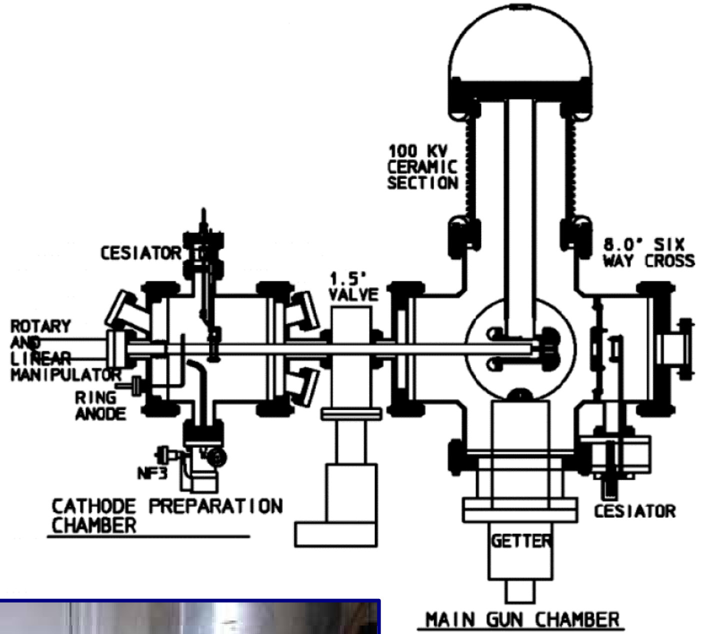
Undulator based systems much cleaner radiologically, and give spin polarization

- Need to weigh the operational impacts vs. additional costs

E166 to run again in Jan. – demonstration of LC polarized positron production

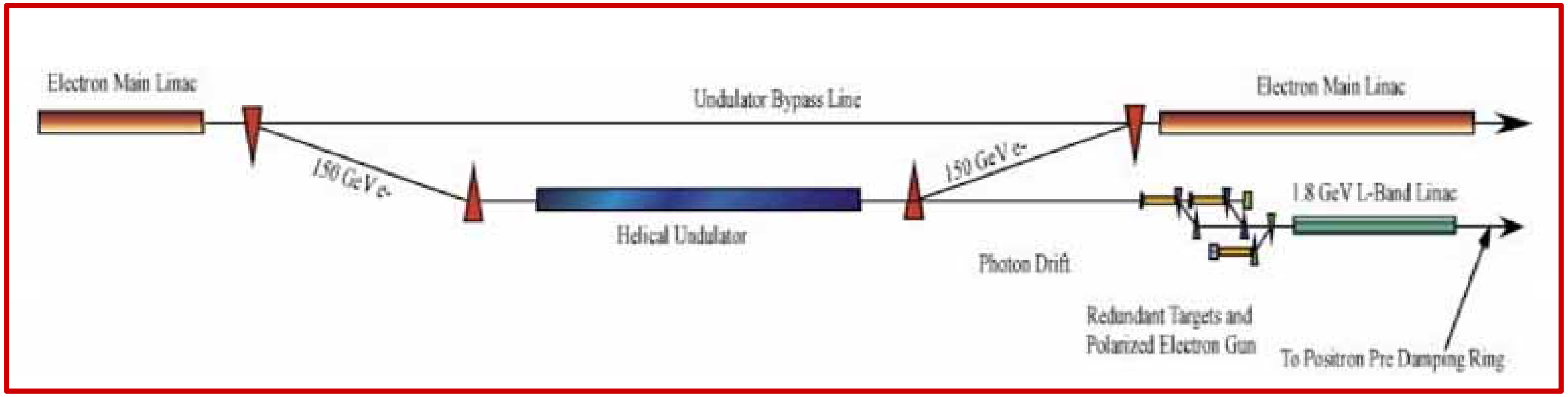
ILC Source Issues

J-Lab polarized gun design: 100kV



ILC Source Issues

Undulator scheme



Two e+ source options have some common issues

- We evaluated performance impact and R&D status in four categories:
  - Radiation damage (to target)
  - Radiation environment (of system)
  - Yield
  - Target engineering
- Most of the issues have the potential for a major impact on machine performance.
- R&D specifically required for
  - Radiation damage
  - Yield

Kickers

Institutions interested in kickers: Cornell, Fermilab, University of Illinois, LLNL, SLAC.

Basic choice seems to be between a fast pulsed kicker (using some sort of stripline geometry) and a more exotic device, using RF to kick, or otherwise manipulate bunches.

Issues for pulsed kicker: switch speed, stability.

Issues for RF kickers (*e.g.*, pulse compression kicker): stability, general proof of concept.

Issues for all: impedance impact, reflections and ringing.

Kickers

Confidence in our ability to find/develop a satisfactory "switch" varies considerably from person to person.

General consensus is that fast on/not-so-fast off is a good idea. This goes well with inclusion of gaps in bunch train to help clear electron cloud.

It is the kicker that led to a 17 km TESLA dog bone. How small a ring would be possible with a so-fast-you-can't-believe-it kicker? Probably smaller than 6 km, maybe as small as 3 km. Other effects (higher current, for example) will begin to dominate.

17 km ring: < 20 ns rise time.
6 km ring: < 6 ns rise time, < 60 ns fall time.

The specs

Kicker specs depend, in part, on beam dynamics: phase space volume occupied by a just-kicked bunch must be well separated from that of an unkicked bunch.

Dog bone (TESLA TDR) kicker specs:

- impulse: 100 G-m (3 MeV/c) ± 0.07 G-m (2 keV/c)
- residual (off) impulse: 0 ± 0.07 G-m (2 keV/c)
- rise/fall time: < 20 ns

Perhaps larger (but less precise) impulse at injection, smaller (but more precise) impulse at extraction will be desirable.

Small ring kicker rise, fall times can be asymmetric: leading edge < 6 ns, trailing edge < 60 ns

What’s happening

Fermilab is presently gearing up to study a pulse compression kicker module using the A0 16 MeV beam.

Some investigation of how well-suited A0 is for this purpose will begin early in 2005.

Thinking about pulsed kickers is going on too.

Damping rings

Summary from Andy Wolski.

Institutions interested in the rings:

Argonne, Cornell, Fermilab, University of Illinois, LBNL, LLNL, SLAC

Damping Rings have a wide range of difficult issues

- Performance specifications were placed in five categories
  - Injection/extraction stability
  - Injection efficiency
  - Beam emittance
  - Beam stability
  - Beam polarization
- All the issues in these categories have a potentially significant impact on machine performance.
- Injection efficiency and beam stability have a potentially major impact on machine performance.
- R&D required for many of the beam dynamics issues, particularly:
  - Achieving sufficient dynamic aperture for positron beam
  - Alignment and coupling correction for 2 pm emittance
  - Suppression of electron cloud
  - Prevention of fast-ion instability
- Some R&D also required for:
  - Damping wiggler design
  - Bunch-by-bunch feedback system

Present options for Damping Rings range from 17 km to 3 km

- Larger circumference has some advantages:
  - Operational flexibility
    - e.g. reduced bunch charge with reduced bunch spacing (depending on kicker performance) providing same charge per pulse.
  - Easier to prevent electron-cloud with larger bunch separation.
- Smaller circumference has some advantages:
  - Reduced wiggler length reduces risk of impact on dynamics.
  - Some benefits for operation with smaller number of components in ring.
  - Possible cost savings.
- **There is no obvious choice at present.**
  - Continuing comparative studies are needed.
- A serious concern for all rings is the limited dynamic aperture.
  - Strong chromatic sextupoles are needed in low-emittance rings.
  - Acceptance is probably not sufficient for 0.01 m positron beam from undulator-based source.
  - Acceptance is certainly not sufficient for larger positron beam from conventional source.
- Acceptance concerns can be addressed with a predamping ring.

Predamping ring can have major benefit for positron sources

- Dynamic aperture can be much larger in a ring with a larger natural emittance.
  - Lower chromaticity and larger dispersion lead to weaker sextupoles.
- Several schemes are possible. One example:
  - 6 km main damping ring in tunnel separate from main linac, storing one full bunch train
  - 6 km predamping ring in same tunnel as main damping ring, storing a second full bunch train
  - On each machine pulse:
    - Fully damped beam extracted from main damping ring
    - Partially damped beam extracted from predamping ring and injected into main damping ring
    - Undamped beam injected directly from source into predamping ring
- Tolerances on predamping ring (beam emittance and stability) are significantly relaxed compared to main damping ring.
- Implications of different predamping ring schemes for sources and for main damping ring need further study.

Different injection and extraction schemes are also possible

- Injection/extraction from any position in bunch train.
  - Requires kicker with fast fall time as well as fast rise time.
  - Conceptually simple, no issues with beam loading compensation.

- Injection/extraction always at end of bunch train.
  - Allows a kicker with relatively slow fall time (several 10's of ns).
  - Beam loading compensation necessary to prevent phase-jitter in extracted bunches. Either:
    - compensate RF in storage ring cavities directly, or...
    - ...use a small 'auxiliary' ring sharing RF with main damping ring.

- ...other schemes?

Bunch compressor

So far only SLAC and LBNL are thinking about this.

Short bunches are better: wake field, energy spread considerations.

Leaving damping ring: 6 mm bunch length.

0.3 mm bunch length is desired at IP.

Summary from Gerry Dugan.

Bunch compressor issues

- Baseline (TDR) 20X single stage system performance:
  - Compression ratio 20X:
  - Input: 6 mm (rms) bunch length, 0.13% rms energy spread, vertical polarization
  - Output: 0.3 mm rms bunch length, 2.8% rms energy spread, horizontal polarization

- Principal issues in baseline design:
  - Tuning and operation not fully simulated: errors may lead to emittance growth (R&D needed)
  - Spin rotator solenoids enormous
  - At the performance limit of a single stage system
  - No margin for reduced output bunch length
  - Large output energy spread results in dispersive emittance growth in the main linac
  - IP beam phase sensitive to small phase errors in compressor RF
  - Design for pre-linac collimation system missing (R&D needed)

Bunch compressor issues

Dual stage bunch compressor option:

Two 90 degree compressors, with compression ratios of ~9, ~6; separated by acceleration (to 10 GeV).

Pros:

- Output bunch length 0.15 mm or less: reduces disruption parameter=>less sensitivity to kink instability, enables smaller beta-star=> more luminosity
- Reduced output energy spread=>less dispersive emittance growth in linac=> more luminosity

Cons:

- DR output beam phase jitter becomes IP beam phase jitter
- May need 3.9 GHz RF. Gradient limited, R&D needed, emittance growth in BC may be increased

Interested groups: SLAC, LBNL

ILC-America + ILC-global near-term goals

Possible goals and timelines:

- pre-KEK: discuss tentative plans for injector R&D with our colleagues in America, Asia, and Europe to have a sense of who would like to do what.
- at KEK: rough-out an R&D plan aimed at choosing a kicker technology in ~2 years
- at Snowmass (August, 2005): small workshops with international participation to assess how well we've gotten started, and what we have learned?

End notes

The kicker and damping ring scare the daylights out of me.

We must build one and make it work before the ILC main linac is completed.

More information:

- *Studies Pertaining to a Small Damping Ring for the International Linear Collider*, FERMILAB-TM-2272-AD-TD
- ILC Damping Rings web site: http://awolski.lbl.gov/ILCDR/