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Revisiting $e^- e^-$ Switchover in the NLC Linac

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Abstract

This paper is an extension of a talk given in December 1999 which discussed various options for reconfiguring magnets and power sources to convert the NLC to $e^- e^-$ operation. At that time three different configurations were examined and a Directional Reversal model was recommended in order to avoid the difficulties of polarity reversal with permanent magnets anticipated in the main linac at that time. Since permanent magnets are no longer in the baseline, a Polarity Reversal scheme becomes more attractive.

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REVISITING $e^- e^-$ SWITCHOVER IN THE NLC LINAC[1]

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1. 1999 Discussion of Configuring a Linear Collider for e– e– Collisions

The basis issues and background were reviewed in the 1999 paper on the same subject[2]. In that paper three operational requirements were considered:

- Modest additional capital cost
- Quick changeover to $e^- e^-$
- Quick return to $e^+ e^-$ operation.

It was assumed that $e^- e^-$ operation would take place alternately with standard $e^+ e^-$ operations and with minimum interference in terms of changeover times.

The main hardware addition to the machine was another e- source for polarized electrons. The basic technical components were:

- Add a new polarized e^- source
- Bypass line for positron target
- Reversal scheme for all magnets where e^- will travel through e^+ sections *in the same direction*
- Fully automated or semi-automated electromagnetic polarity reversal
- Re-match phase at injection to the e^+ main linac.

Most of the changes lie in the Positron Injection area. Main Linacs primarily have only quads that do not have to be reversed. The Beam Delivery area is long but relatively sparsely populated compared with Injection. The Positron Injection magnets in the baseline model of the NLC are summarized in Table 1[3].

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[1] This work supported by U.S. Department of Energy Contract DE-AC03-76SF00515.
[2] $E^- E^-$ Switchover In The NLC Linac, R.S. Larsen, Stanford Linear Accelerator Center, February 2000, Int.J.Mod.Phys.A15:2477-2483,2000.
[3] Private communication, J. Sheppard, SLAC.

Magnet Type	PSOURCE	PBOOST	PPL	PLTR	PPDR	PXFER	PDR	PBC1	PBC2	TOTALS
Bends	6			13	18	2	36	26	188	289
Quads	46	123	91	36	78	4	136	95	263	872
Sextupoles			15		48		120		136	319
Corr./Trims	40	312		20		4		20		396
Septa					2		4			6
Kickers					6		6	1		13
Spin Rotators						2				2
Wigglers					8		20			28
										0
Totals	92	435	106	69	160	12	322	142	587	1925

Table 1: Positron Injection Magnets (Approx.)

Legend: PL=Pre-Linac, PDR=Pre-Damping Ring, LTR=Linac-to-Ring, DR=Damping Ring, XFER=Transfer, BC=Bunch Compressor

2. Discussion of Three $e^- e^-$ Models

As discussed in the 1999 Paper, the Injection area can be implemented in the following ways:

- *Reverse polarities* of all magnets in the path of the polarized e^- beam
- *Reverse the direction* of the new polarized e^- beam so that ideally no polarity reversals are required
- *Design an independent system* for polarized e^- injection that can operate alternately or in tandem with the planned e^+ system.

The three models are shown in Figures 1-3. A brief description and discussion of each accompanies the Figures. The models are not offered as solutions but as general concepts to illustrate the problems to be investigated.

e^{-} e^{-} SWITCHOVER IN THE NLC LINAC

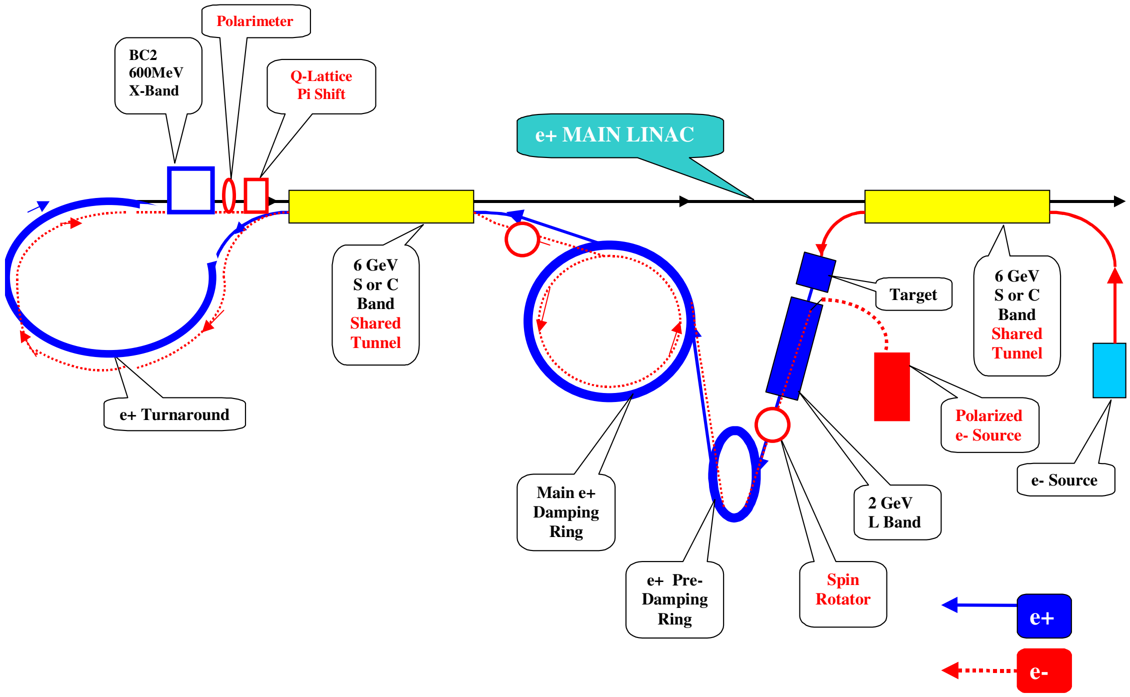

Fig. 1 Polarity Reversal Model

Description:

- New e^{-} Source installed near e^{+} vault bypasses target.
- Injects into 2 GeV pre-accelerator.
- New Spin Rotator and Polarimeter are added.
- Magnets reversed in ½ the PDR, the Main DR, Turnaround and all injection and extraction lines.
- New Q Lattice π Shift after Turnaround.

Features:

- Polarized e^{-} Source vault and transport line require new tunneling.
- Re-uses all e^{+} beamline components.
- Requires automated reversing of all electromagnets.
- Does not work for permanent magnets.
- Re-standardization of magnets and subsequent tuning required.
- Re-standardization must be performed in parallel for acceptable turn-around time.

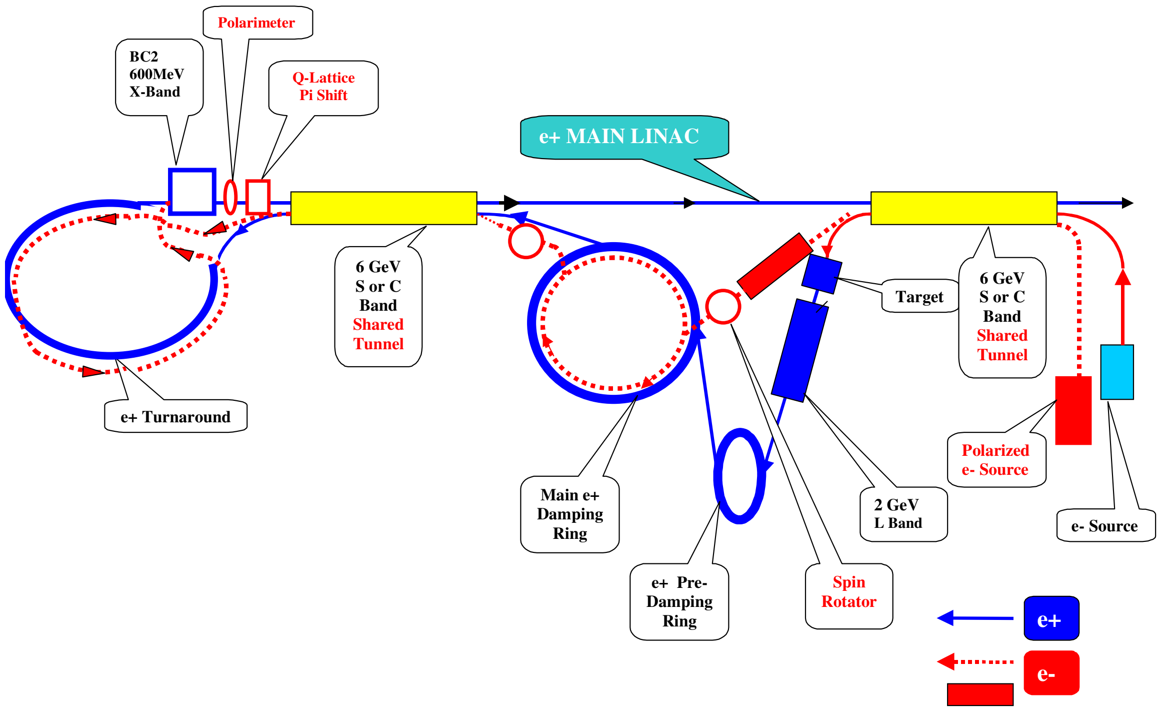

Fig. 2 Direction Reversal Model

Description:

- Add new Polarized e^- Source located near e^+ Source.
- Beam extracted from first linac at 2 GeV.
- New tunnel and transport line injects beam into the Main DR in *reverse direction*.
- Add new Spin Rotator and Polarimeter.
- Add new extraction line for reversed beam out of MDR.
- Beam injected into Turnaround in *reverse direction*.
- Reverse Polarity fast Kickers added (not shown).
- Launch into Q Lattice π Shift after Turnaround.

Features:

- Avoids polarity reversals of all magnets in MDR and Turnaround.
- Can accommodate permanent magnets.
- Avoids PDR bypass entirely.
- Switchover essentially automated and quick.
- Requires more tunneling than (1).
- Requires additional components for injection, extraction, kickers.
- More costly than (1).

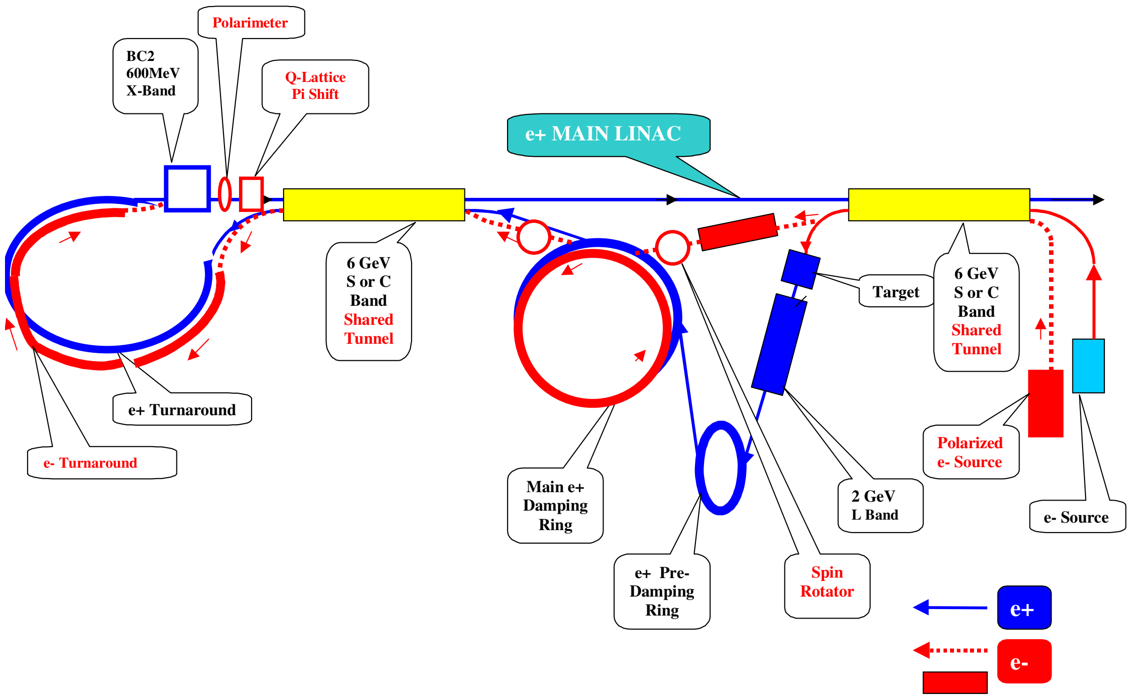

Fig. 3 Independent Systems Model

Description:
- Add new Polarized e⁻ Injection system, tunneling completely independent up to Main Linac.
- Add Spin Rotator, Polarimeter and Q Lattice π Shift
- Diagram shows shared or parallel housings but could be completely separated to eliminate interference during construction of second complex.
- Linacs are shared to reduce cost.
- Could couple upgrade with 2nd IR Detector.

Features:
- Systems switchover requires zero down time.
- Systems are always tuned.
- True parasitic running possible.
- Interleaved ML operation possible (though perhaps too complex in reality).
- More physics options available in one or both IR's.
- Initial civil work if on same side would be less costly.
- Construction at later date could be completely non-interfering.
- Flexibility of programming and operational non-interference is optimized.
- An ideal solution if money were no object. Since e⁻ e⁻ is supposed to be low cost parasitic feature, relatively high cost probably rules out.

3. New Considerations Since 1999

In 1999 and 2000 there was a large R&D investment in permanent magnets to cut costs by eliminating power systems and cabling. Since that time, these efforts have been curtailed because of the difficult mechanical requirements for permanent magnet alignment and trimming, the latter requiring a complex mechanical mover. In the end there was no clear cost advantage. At the same time, electromagnets were shown able to meet the NLC alignment requirements and therefore are still the Baseline model.

If one adopts a rule that there will be no permanent magnets in the Injection system, then *Fig. 1, the Polarity Reversal Model*, becomes the system of choice. To reverse electromagnets, all of these magnets could be driven from bipolar power supplies of an H-bridge IGBT design, such that mechanical reversing involving cables is avoided entirely. This efficient design can be accomplished at an acceptable additional cost over a unipolar supply, although power supplies will be somewhat bulkier due to requiring a line-transformer for isolation rather than running a switching inverter right off the AC line[4].

4. Discussion

It is unlikely that $e^- e^-$ operation would run parasitically, as once envisaged, i.e. operating during downtimes in $e^+ e^-$ operation. The fact that $e^- e^-$ would share most of the critical parts except for the target, and that a redundant target is planned for just such an eventuality, suggests that $e^- e^-$ will operate on a regular program schedule with a negotiated priority.

The polarity reversal model appears to be the easiest and possibly lowest cost solution if the following rules are adopted:

1. Use only electromagnets in sections requiring polarity reversal (no permanent magnets in P/MDR, turnaround bends & correctors.)
2. Use modern IGBT switched H-bridge power supplies to drive either polarity smoothly with modest additional cost.*

Re-standardization upon switching polarity can be accomplished quickly if built into initial design of control system. With the machine already warm, and with stored configurations downloadable, tuning after switchover should be recoverable relatively quickly. Studies of controls models should be carried out to confirm these assumptions.

3. Recommendations & Conclusions

The following tasks are recommended to qualify the $e^- e^-$ system concept, identify performance issues and R&D tasks for the near term, and quantify estimated costs:

1. Select most viable operation option(s) for detailed analysis.
2. Perform lattice studies to qualify various options.
3. Investigate hardware issues including R&D on bipolar power supplies.
4. Identify civil design effort and work to be done at initial construction.
5. Scope costs of options including life cycle cost considerations
6. Identify incremental costs of additions.
7. Estimate Civil costs

[4] Private communication, Paul Bellomo, Power Conversion Dept., Stanford Linear Accelerator Center.

8. Estimate additional capital costs
9. Select final option for proposed system.
10. *Make early proposal to USLCSG to include preferred design in Baseline, or preserve upgrade options in Civil design.*

Since the LC has progressed tremendously since 1999 and appears to have a good chance of being built, it is time to invest effort into a serious conceptual design and cost model for the e- e- upgrade.

Acknowledgement

Paul Bellomo, Head of Power Conversion Department, SLAC, provided valuable information on the merits of H-Bridge bipolar power supplies.