News on Linear Collider Studies in the US

DESY-ECFA Workshop in Hamburg
Slawek Tkaczyk
22 September 2000.

- Current Activities

  NLC
  Physics WG

- Thanks to:
  Andreas Kronfeld,
  Michael Peskin, Tor Raubenheimer,
  Lynne Orr, Joanne Hewett
  Rick van Kooten, Dave Gerdes,
  and other WG group conveners

NLC Collaboration

- MOU signed with KEK to pursue common R&D towards LC
  - Focused on rf development and ATF at KEK
  - ISG progress report: SLAC-R-559 or KEK-Report-2000-7
- MOUs signed with LBNL, LLNL, and FNAL
  - Berkeley concentrating on magnet design and damping ring issues
  - Livermore focusing on solid-state modulators
- Fermilab taking responsibility for main linac beamline:
    - Emittance preservation, structure design, optics layout
    - Structure manufacture, magnet design, vacuum systems
- 1st US collaboration meeting at SLAC in January with all parties
- 1st MAC meeting in June at Fermilab; 2nd MAC meeting in October at SLAC

Parameters for 500 GeV and 1 TeV

IP Parameters for the JLC / NLC (2/24/00)	500 GeV				1 TeV			
	A	B	C	H	A	B	C	H
CMS Energy (GeV)	510	500	482	490	1022	1000	964	888
Luminosity (10^{33})	5.3	5.4	5.5	[illegible]	10.6	10.8	11	[illegible]
Repetition Rate (Hz)	120	120	120	120	120	120	120	120
Bunch Charge (10^{10})	**0.7**	**0.82**	**1**	**0.75**	**0.7**	**0.82**	**1**	**0.75**
Bunches/RF Pulse	95	95	95	190	95	95	95	190
Bunch Separation (ns)	2.8	2.8	2.8	1.4	2.8	2.8	2.8	1.4
Eff. Gradient (MV/m)	**58.7**	**57.3**	**55.2**	**50.2**	**58.7**	**57.3**	**55.2**	**50.2**
Injected $\gamma\varepsilon_x / \gamma\varepsilon_y$ (10^{-8})	300 / 3	300 / 3	300 / 3	300 / 2	300 / 3	300 / 3	300 / 3	300 / 2
$\gamma\varepsilon_x$ at IP (10^{-8} m-rad)	400	450	500	360	400	450	500	360
$\gamma\varepsilon_y$ at IP (10^{-8} m-rad)	6.5	8.5	12	3.5	[illegible]	8.5	12	3.5
β_x / β_y at IP (mm)	12 / 0.12	12 / 0.12	13 / 0.15	8 / 0.10	12 / 0.12	12 / 0.15	13 / 0.15	10 / 0.12
σ_x / σ_y at IP (nm)	310 / 4.0	330 / 4.6	366 / 6.2	245 / 2.7	[illegible]	235 / 3.2	260 / 4.4	200 / 2.2
σ_z at IP (um)	90	120	140	110	90	120	140	110
Υ_{ave}	0.11	0.09	0.08	0.11	0.32	0.25	0.23	0.26
Pinch Enhancement	1.46	1.35	1.39	1.43	1.46	1.35	1.39	1.49
Beamstrahlung δB (%)	3.2	3	3	4.6	8.3	8.1	8.4	8.8
Photons per e+/e-	0.86	0.96	1.05	1.17	1.12	1.25	1.38	1.33
Two Linac Length (km)	5	5	5	5.4	9.9	9.9	9.9	9.9

Route to High Luminosity in NLC

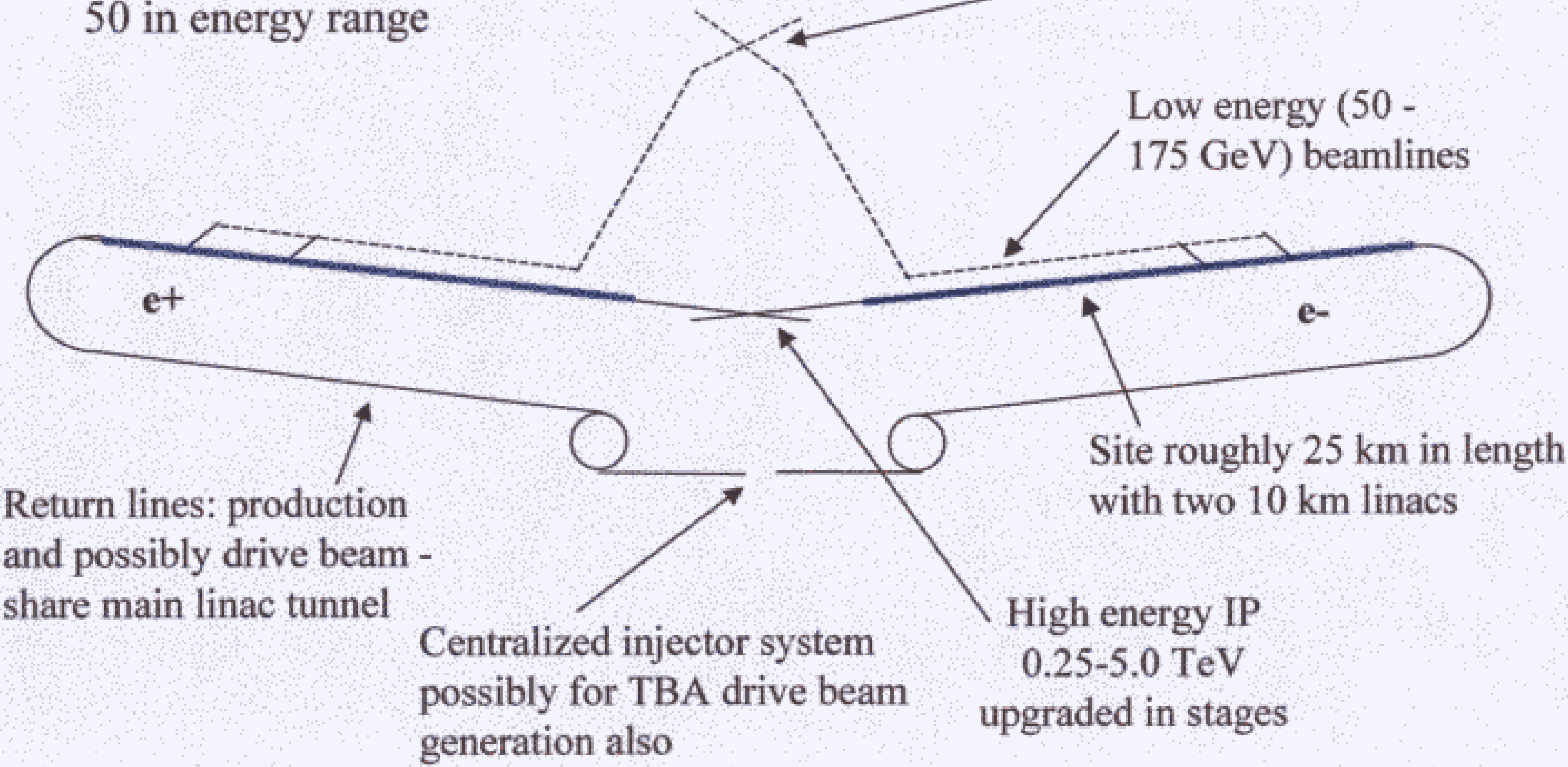
- NLC design has built-in margins to cover nominal operating plane including 50% charge overhead and 300% ε dilution
  - NLC damping rings spec. to produce 0.02 mm-mrad although design requires 0.03 mm-mrad
  - SLC used 'emittance bumps' to reduce emittance dilution from 1000% to 100%—technique not included in NLC emittance budgets
  - Use margins to achieve higher luminosity
- Present prototypes and R&D results are better than initial specs (see RDDS cell frequencies and DDS3 alignment & S-BPM)
  - $\Delta\varepsilon_y < 25\%$ in linac if production components are similar to prototypes

$\Rightarrow$ Both will lead to increased luminosity (34×10^{33} at 880 GeV)

NLC is designed for high luminosity (similar to TESLA) ***however*** neither design has much margin at these parameters

A Multi-TeV LC Facility

A poorly drawn schematic of a LC facility with an factor of 50 in energy range



Two Interaction Regions at NLC

- First - dedicated to running at the highest energy
- Second - dedicated to precision measurements
- Low energy region will use beam extracted at various points along the machine
- Designed to operate between 90 - 250 GeV
- Physics program includes: running at the Z-pole or at the Higgs or WW thresholds
- Lively discussion expected at LCWS2000

Multi-TeV Colliders

- Need improvements in rf technology to make higher energy cost effective:
  - multi-beam klystrons, active rf pulse compression, or TBA
- Need high gradients to keep length reasonable and balance cost of rf system
  - At 35 MV/m (SC max gradient), 3 TeV linac would be 110 km
  - Optimum gradient in NLC is between 75 and 100 MV/m depending on how components scale with rf power

  ⇒ Normal conducting cavities with lower cost rf system and higher gradient of 100 ~ 200 MV/m
- Need very small beam emittances and small spots to achieve luminosity – injection complex similar to present NLC
- Reuse next-generation LC injection system and beam delivery, and use linac tunnels with modified components

IR Layout Issues

- Final focus aperture is set by low energy beams $\sigma \sim 1/\sqrt{\gamma}$ but magnet strength is limited by highest energy operation
  - Final focus has limited energy range without rebuilding magnets and vacuum system
- Simplify design by dedicating one IR to 'low' energy operation and one to 'high' energy operation
  - 'Low' energy range of 90–350? GeV
  - 'High' energy range of 250–1000 GeV
  - Need to specify reasonable ranges!
- High energy beamline would have minimal bending to allow for upgrades to very high collision energies
  - 'High' energy BDS could be upgraded to multi-TeV operation!

Studies of rf Structures

- Workshop held at SLAC on August 28-30, 2000.
- 50 participants from all major world labs
- Damage caused by breakdowns
- Much discussion on importance of cleanliness during the fabrication, as learned by work on cold rf cavities.
- Hypothesis that damage can be minimized by reducing rf group velocity in structures, e.g., harder for energy to flow to site of breakdown
- SLAC testing theory and first results expected in a month
- Proceedings of the Workshop:

http://www-project.slac.stanford.edu/lc/wkshp/RFBreakdown/

Studies of rf Structures

- Damage Appears as Erosion of Irises introducing a phase shift that eventually makes structures De-accelerate.
- NLC observed structure damage after 1000 hours of high power operation in the NLCTA
- Similar damage seen on CLIC Structures
- Short structures (few cells) do not show damage

American Working Group Interim Organizers

Study of the Physics and Detectors for Future Linear e+e- Colliders

Paul Grannis and Charles Baltay, Coordinators

1. **Detector & Physics Simulations**

   Norman Graf, Mike Peskin, Adam Para

2. **Vertex Detector**

   Jim Brau

3. **Tracking**

   Keith Riles, John Jaros

4. **Particle I.D.**

   Hitoshi Yamamoto, Bob Wilson

5. **Calorimetry**

   Ray Frey, Frank Porter, Andre Turcot

6. **Muon Detector**

   Dave Koltick, Gene Fisk

7. **Data Acquisition, Magnet, and Infrastructure**

   Tony Barker, Marty Breidenbach

8. **Higgs**

   Rick Van Kooten, , Howie Haber, Andreas Kronfeld

9. **SUSY**

   Frank Paige, Jim Wells, Uriel Nauenberg

10. **Other New Particles and Alternative Theories**

Slawek Tkaczyk, Joanne Hewett

11. **Top Physics**

    Dave Gerdes, Uli Baur

12. **QCD, Two Photon**

    Bruce Schumm, Lynn Orr

13. **Precision Electroweak, Strong Gauge Interactions**

    Tim Barklow, Bill Marciano, Bogdan Dobrescu

14. **e-e-, e-gamma, gamma-gamma Options**

    Karl Van Bibber, Clem Heusch

15. **Interaction Regions, Backgrounds**

    Tom Markiewicz, Stan Hertzbach

Home

Simulations

- Studies of benefits from aggressive Vertex Detector designs

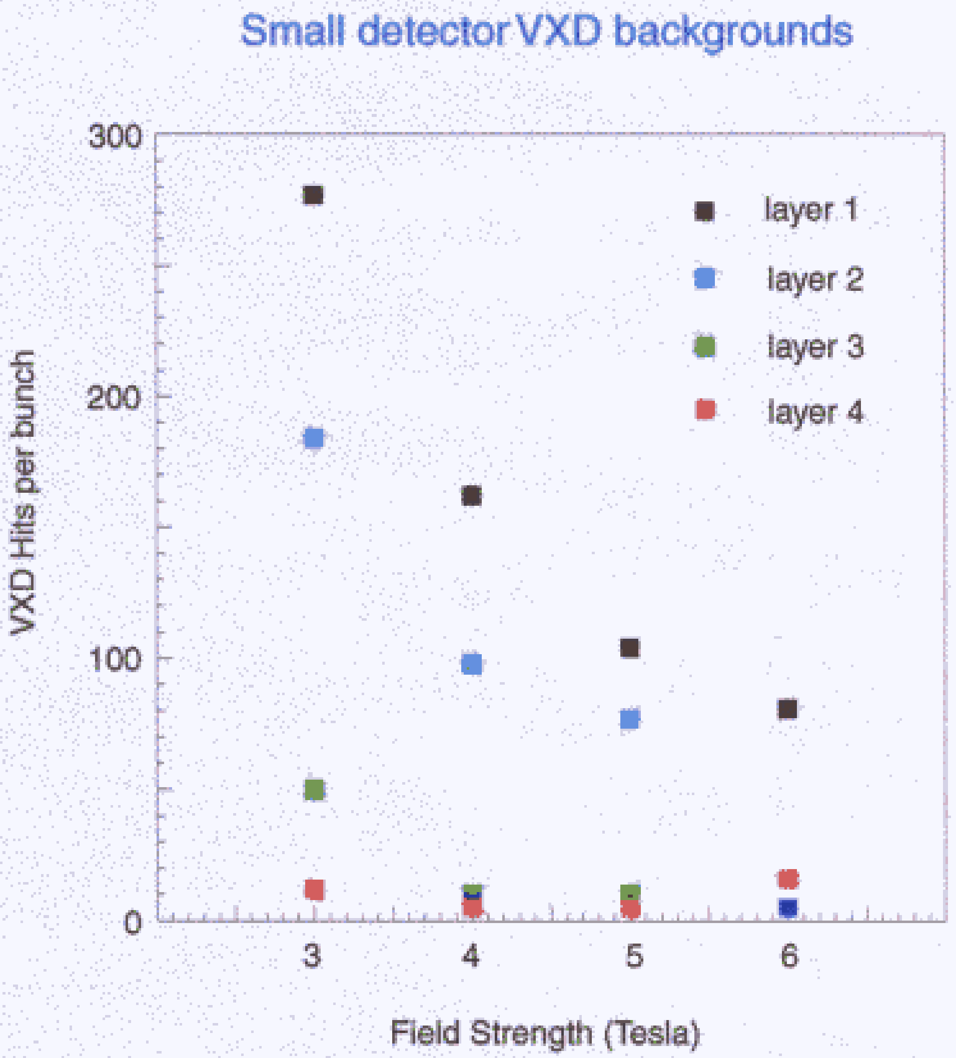
  http://blueox.uoregon.edu/jimbrau/LC/lcd-vxd-8-00.PDF

- Work on understanding machine backgrounds and their limiting function on the detector performance
- Work on pattern recognition using the SLD tool - ZVTOP.
- New release of linear collider event generator - PANDORA by Michael Peskin.
- simulations of the most important two-body SM processes in e^+e^-, e^-e^-, $e^+\gamma$, $\gamma\gamma$ collisions
- initial state radiation, beam polarization and final state spin correlations are included for all processes.
- Hadronization implemented with PYTHIA, using pythia-pandora interface package

http://www-sldnt.slac.stanford.edu/nld/new/Docs/Generators/PANDORA.

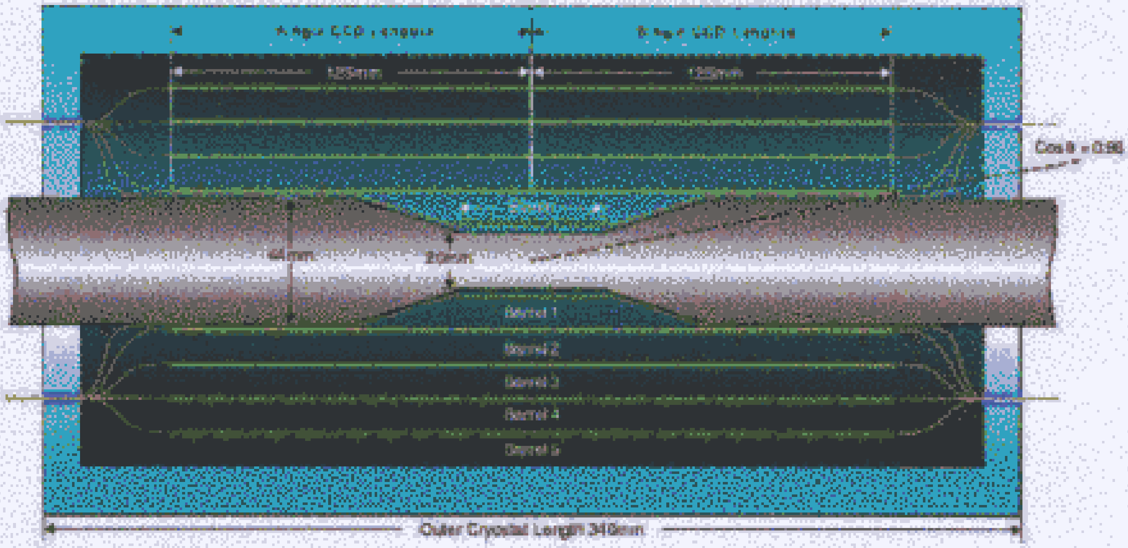
Vertex Detector WG

- Study of variation of detector backgrounds with magnetic field

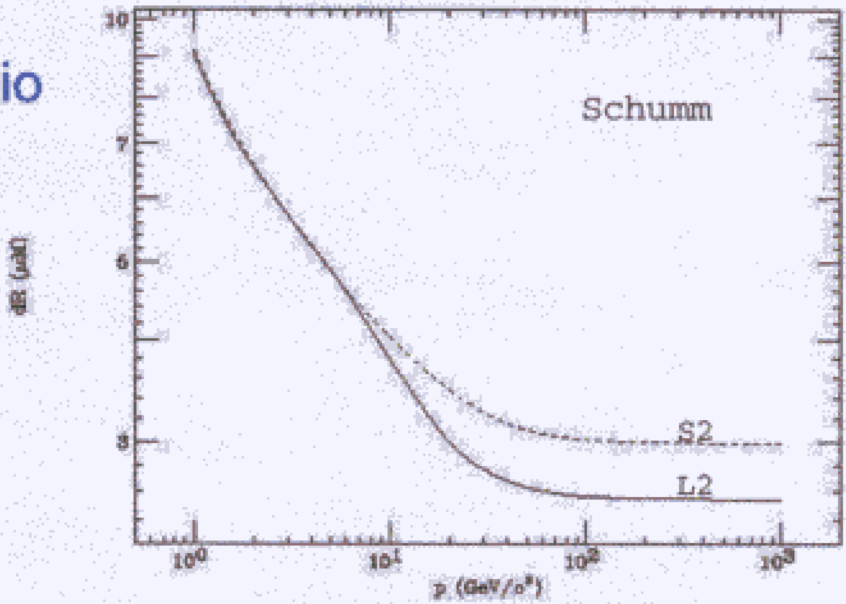


- Can layer 1 of a VXD be put at smaller radius for increased physics capability?

Suggested layout of Vertex Detector for future e^+e^- Linear Collider (Updated November 1998)



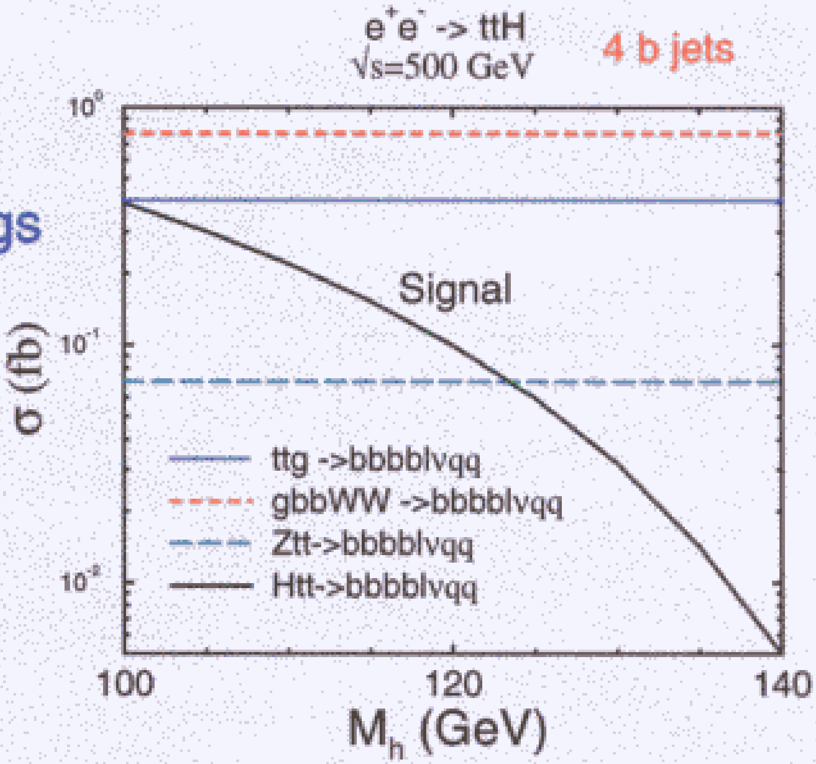
Vertex Detector Resolution

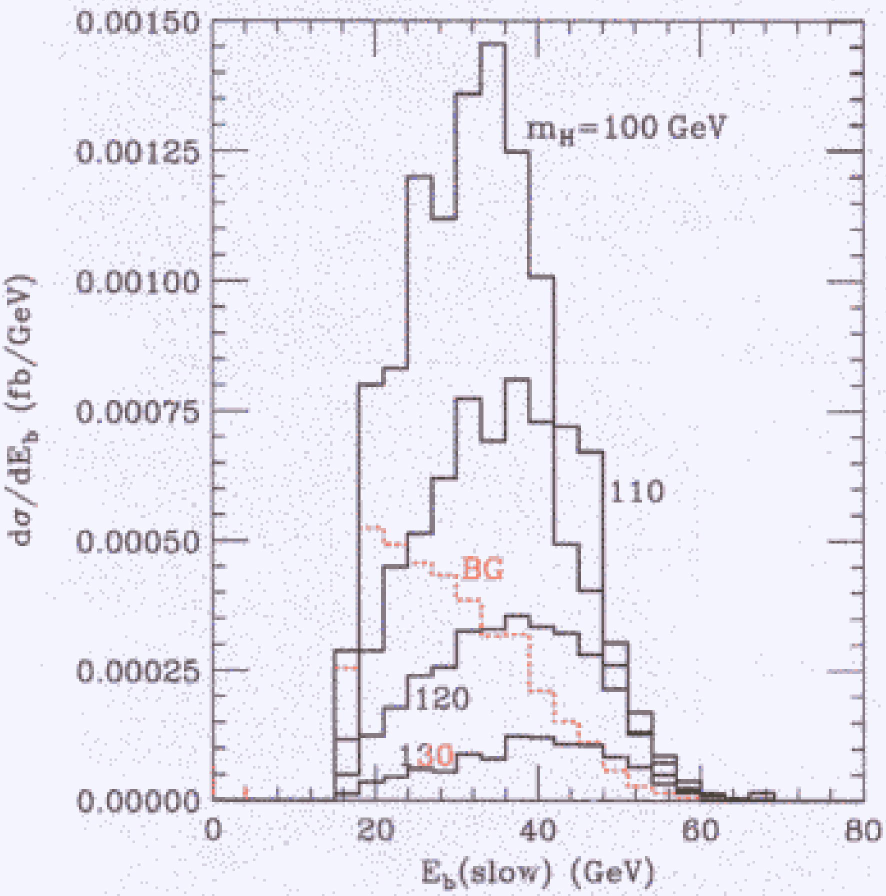


- Higgs branching ratio measurements and vertex detection (small and large NLC detectors) (Brau et al.)
- Implications of *Z*-factory option on Higgs sector
- Measuring *bb* branching ratio when small (Derwent/FNAL)
- Measuring angular distributions of Higgs production and decay (Para/FNAL)
- Measuring intermediate mass Higgs prop. (Wester/FNAL)

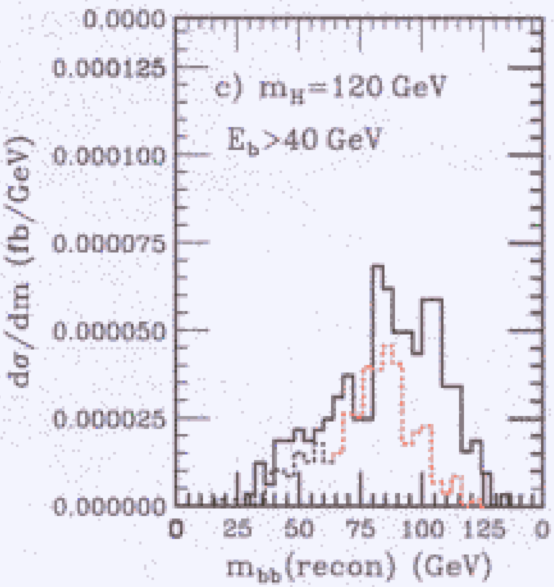
- Measuring Higgs to top quark Yukawa coupling (Dawson, Reina, et al.)

4 b jets





Energy of b jet



bb invariant mass, after top quark reconstruction

TOP and QCD and Two Photon WG
(Lynne Orr)

- Studies of QCD corrections to top production and decays
(gluon radiation)
- Work on accompanying NLO event generator with production-decay interference and all spin correlations
- Plans to advance studies of mass measurements in the dilepton mode and spin correlations
- Non-top QCD: Rapid progress on BFKL Monte Carlo for e^+e^-

TOP WG
(David Gerdes)

- Studies of $t\bar{t}$ reconstruction with fast/full simulation in the small and large detectors (Iwasaki/Frey)

- Studies of $t\bar{t}$ anomalous couplings (Ferretti/Gerdes; Han et al.)

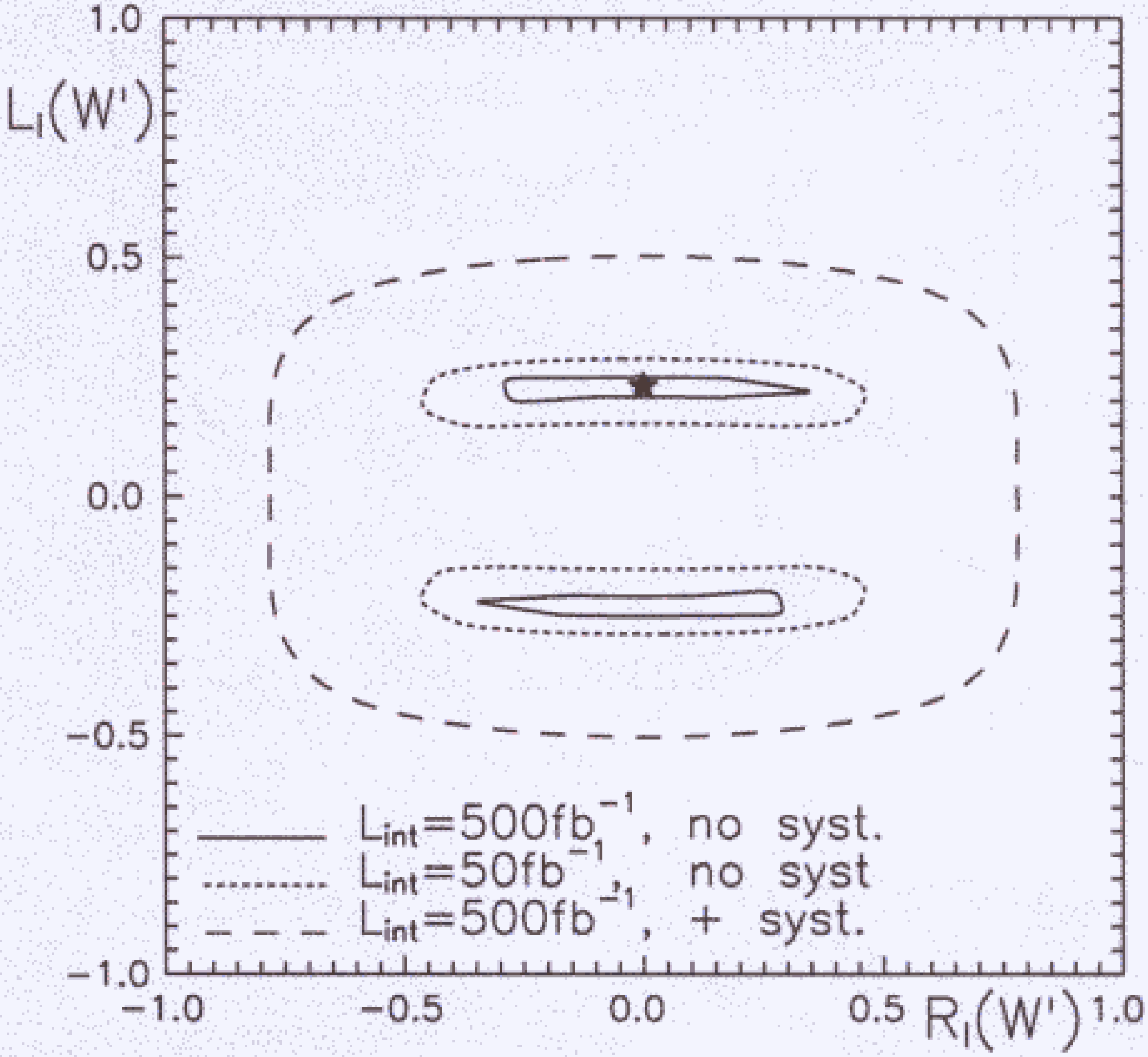
- $t\bar{t}$ threshold
  theory (Yakovlev), measurement of $d\sigma)/dL$ (Cinabro)

New Phenomena

- Supersymmetry may NOT be realized in Nature!
- We need to expect and be prepared for New Phenomena!
- This program is an integral part of physics justification for an LC!
- Issues:
- Discovery - fill in the gaps from the hadron collider
- Elucidation - LC strong point
- Impact on the detector design

Extra Gauge Boson - W′ Studies

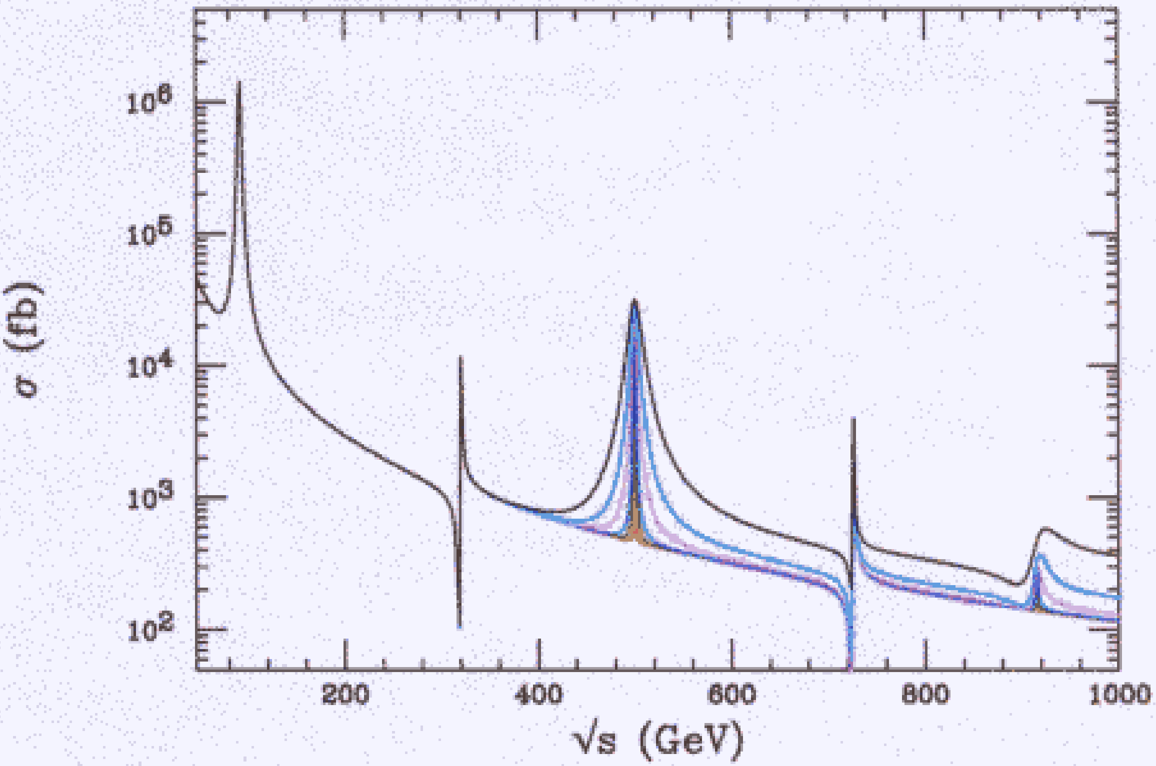
- Steve Godfrey et al. completed their analysis of W′ production in $ee \to \nu\bar{\nu}\gamma$
- Sensitivity to W′ masses up to several TeV, depending on energy, luminosity and models.



- New analysis of W′ production in $e\gamma \to \nu q + X$

Experimental Probes of Localized Gravity

- Hooman Davoudiasl, Tom Rizzo, and Joanne Hewett have looked at the signatures of localized gravity models (hep-ph/0006041).



- Many SM particles can propagate in other dimensions.
- Simultaneous production of graviton and gauge boson KK excitations.

LC Physics Studies at Fermilab

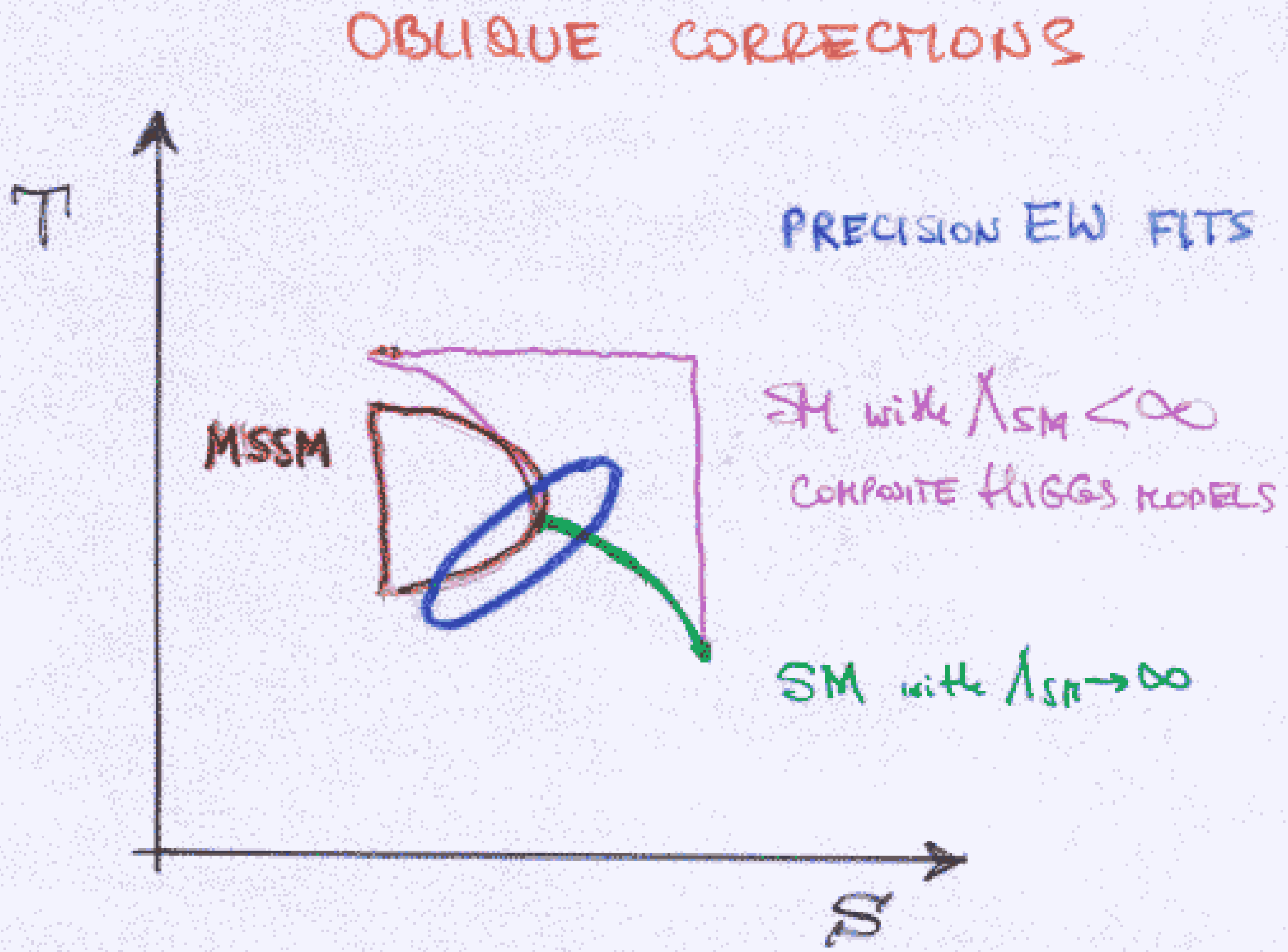
- Charge from the Directors:
  - Study Higgs and EWSB - physics from ≈250 GeV = $<\phi>$ up to few TeV - hierarchy/fine tuning
- Many theories covered:
  - SM Higgs
  - SUSY
  - Composite Higgs, ...
- Studies done in Working Groups by people actively working on RunII:
  - Light Higgs: $b\bar{b}$, $c\bar{c}$,$\tau\bar{\tau}$,...
  - Intermediate Higgs: WW, ZZ
  - Heavy Higgs: WW, ZZ, $t\bar{t}$

LC Physics Studies at Fermilab
Higgs

- SM gauge sector well tested, very successful.
- Higgs sector indirectly tested, only *vev* known.
- Triviality: SM Higgs sector breaks down at $\Lambda_{SM} < \infty$ (well studied, e.g., Lüscher and Weisz)
- SM Higgs sector is an effective theory

LC Physics Studies at Fermilab
Higgs

- Taking $\Lambda_{SM} < \infty$, modifies EW fits, and weakens bound on m_H.



- Many models (topcolor, top seesaw, extra dimensions,...) populate red box. In all, Higgs is a bound state.

LC Physics Studies at Fermilab
Higgs

- Composite models can have m_H up to $\sim 500 - 700$ GeV and satisfy precision EW measurements.
- Typically their phenomenology is rich.
- LC is excellent for distinguishing them from SUSY.
- They add to a case for LC,
  at expense of a belief in light Higgs.

LC Physics Studies at Fermilab
Beyond SM

- Superpartners, KK excitations from extra dimensions, and non-Higgs composites can all be studied at LC.

- Difficult to anticipate how many of them have mass below/above 1 TeV.

- Value of LC increases with energy,
  in the absence of a signal.

- If RunII sees a squark, a KK graviton, or the Higgs, a high-luminosity e^+e^- collider in the 0.5-1.0 TeV range would be a very valuable machine for elucidating its properties.