ILC Cost Versus Performance (Parameter Choices)

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Most slides from September 2006 MAC meeting

Motivation for Parameters

- Parameter plane established at KEK ILC mtg
- TESLA TDR pushed parameters:
  - **Emittance dilution**
  - **Disruption and kink instability**
  - **Luminosity enhancement**
- Parameter plane established for flexibility in achieving goal of 500 fb-1 in 4 years
  - **Accelerators rarely optimize at design parm.**
    - SLC, HERA, PEP-II, KEKB, DAPHNE, …
  - **Linear collider has fewer options for optimization**
    - Already used most tricks to maximize specific luminosity

Parameters

TESLA peak luminosity

3×10^{34}

parameter space

- Possible due to very high beam-beam disruption (D_y~25)
- Well into kink-instability regime (unstable)
- Little head room to play with

ILC peak luminosity

2×10^{34}

parameter space

Schematic from Nick Walker, LCWS 2005

Luminosity Expressions

- Well known luminosity expressions:

$$L = \frac{f_{rep}}{4\pi}\frac{n_b N^2}{\sigma_x \sigma_y} H_D \quad \Rightarrow \quad L = \frac{P_b N}{4\pi mc^2}\frac{H_D}{(\beta_x \beta_y)^{1/2}(\gamma\varepsilon_x \gamma\varepsilon_y)^{1/2}}$$

- Can also be written in term of δ_B, n_γ, or D_y:

$$L \propto \frac{P_{beam}}{E_{cms}}\sqrt{\frac{\delta_B \sigma_z}{\gamma\varepsilon_y \beta_y}} H_D \left(1+(1.5\Upsilon)^{2/3}\right) \qquad L \propto \frac{P_{beam}}{E_{cms}}\sqrt{\frac{1}{\gamma\varepsilon_y \beta_y}} n_\gamma H_D$$

$$L \propto \frac{P_{beam}}{E_{cms}}\frac{D_y}{\sigma_z} H_D$$

(blue circle) ~ main parameters

(red circle) ~ backgrounds

(yellow circle) ~ IP dynamics

$$\delta_B \propto \frac{N^2 \gamma}{\sigma_z(\sigma_x+\sigma_y)^2}\frac{1}{\left(1+(1.5\Upsilon)^{2/3}\right)^2} \qquad n_\gamma \propto \frac{N}{\sigma_x}\frac{1}{\sqrt{1+\Upsilon^{2/3}}}$$

Parameter Plane

- Nominal – reduced Dy and more reasonable ε budget → 2×10^{34} with similar *L* spectrum
- Provide paths to deal with:
  - **IP: kink instability → Lower Dy (LowQ)**
  - **IP: beamstrahlung → Lower dB (LowQ)**
  - **Dumps or losses → lower power (LowP)**
  - **RF pulse length → shorter pulse (LowP)**
  - **RF peak power → lower current (LowP)**
  - **LET: emittance preservation → (LargeY)**
  - **DR: SBI → Lower bunch charge (LowQ)**
  - **DR: CBI or kicker → fewer bunches (LowP)**
  - **DR: bunch length → dual stage BC**

Example Parameter Sets

Parameter range established to allow operating optimization

		nom	low Q	lrg Y	low P	High L
N	$\times 10^{10}$	2	1	2	2	2
n_b		2820	5640	2820	1330	2820
$\varepsilon_{x,y}$	µm, nm	9.6, 40	10, 30	12, 80	10, 35	10,30
$\beta_{x,y}$	cm, mm	2, 0.4	1.2, 0.2	1, 0.4	1, 0.2	1, 0.2
$\sigma_{x,y}$	nm	543, 5.7	495, 3.5	495, 8	452, 3.8	452, 3.5
D_y		18.5	10	28.6	27	22
δ_{BS}	%	2.2	1.8	2.4	5.7	7
σ_z	µm	300	150	500	200	150
P_{beam}	MW	11	11	11	5.3	11
Lumi	10^{34}	2	2	2	2	5

Parameter Trades

- Parameters can be traded against each other to maintain luminosity while overcoming specific difficulties → Parameter Plane
- Gradient impact is known although might want to revisit this
- Two main parameter-based issues (I think):
  - **Beam power and number of bunches per pulse and perhaps per second**
  - **Later relates to the minimum damping ring size**
  - **Former relates to the rf configuration**
    - Could imaging repackaging rf sources for higher rep rate or longer rf pulse length but lower pulse current (fewer sources for same P_{beam})

Parameter Limitations Opinions (1)

- Damping rings
  - **Average current is probably not at the limit**
  - **Bunch length may have further room**
  - **Single bunch charge is a question**
  - **Vertical emittance not limited**
  - **Damping times could be decreased**
  - **Kickers are pushed to limit**
- BC
  - **Two-stage can achieve the ~150 um bunches**
  - **Single-stage compressor with linearization might work**
  - **Might reduce initial collimation stages**

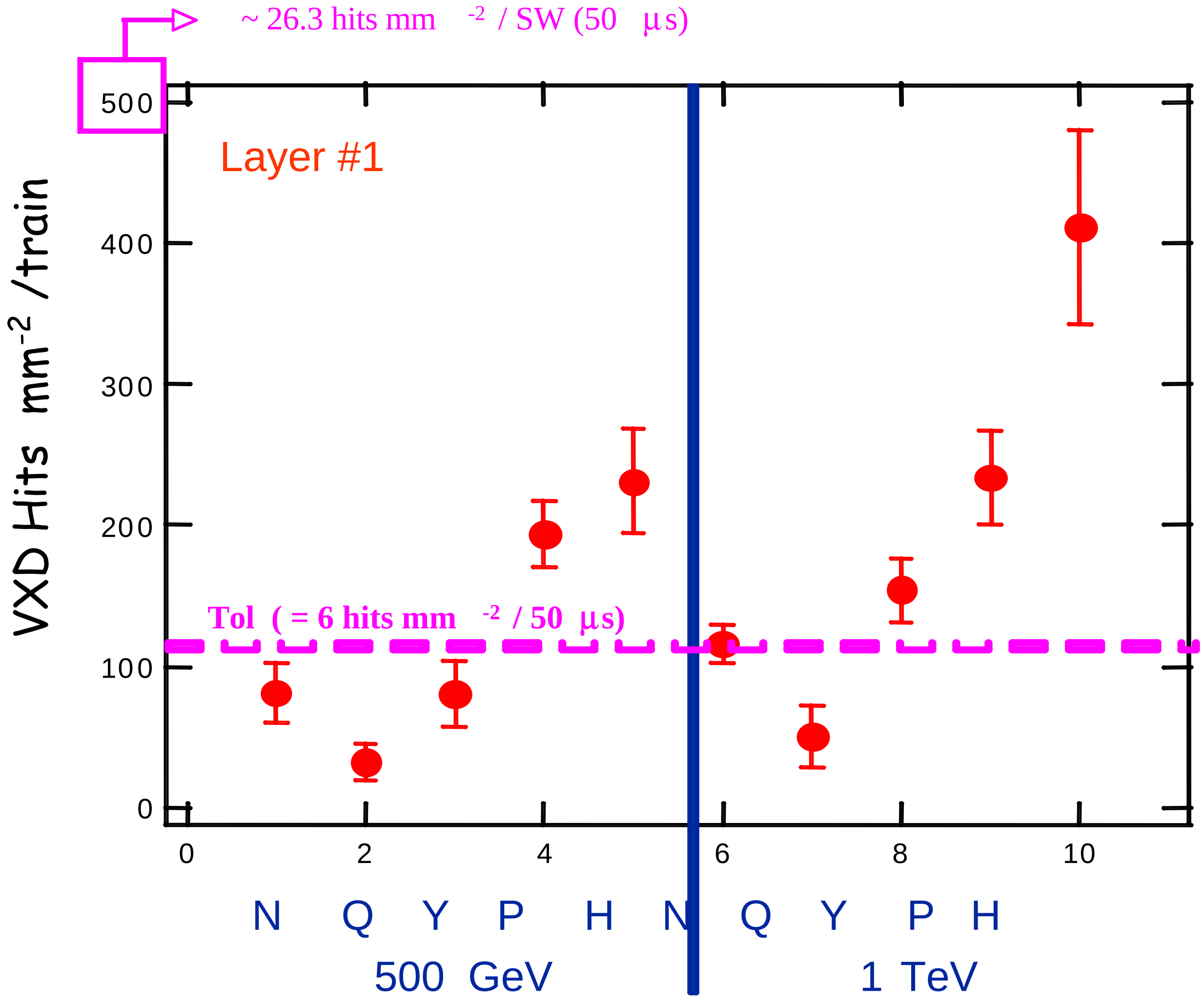
Parameter Limitations Opinions (2)

- Main linac
  - **Lower average beam current reduces the rf power requirements**
    - Usually lower current needs longer fill but some solutions
    - Want to maintain beam power and single bunch charge for luminosity but can reformat the bunch train with higher rep rate or longer rf pulse length
  - **Vertical emittance is not limited**
- Beam delivery system
  - **Length set by 1 TeV and collimation issues**
  - **Probably not background limited**
    - Extraction line can handle larger δ_B
    - Beta function could be reduced (increases L for same rf power or shorter bunch train)

Parameter Plane Costs

- Four main cost guesses (I don't know costs):
  - **Single stage BC (-1%)**
    - Eliminates options of LowP and LowN
    - Increases risk for DR, LET, abd BDS
  - **Reduced RF system (-2% and another -1% civil)**
    - Only allows LowP parameters at full energy
    - Increases risk in LET and BDS but reduces risk in DR
    - Possible to upgrade in quasi-adiabatic manner
  - **Smaller damping ring circumference (-2~4%)**
    - Eliminates LowQ or only allows LowP parameters
    - Increases DR risk – hard to upgrade
  - **Simpler extraction line design → (-0.3%)**
    - Increases risk in BDS; Eliminates option of LowP and limits peak luminosity

Luminosity & Backgrounds



K. Buesser, T. Maruyama, W. Kozanecki, etc.

Other Configuration Options

- Major scope/layout considerations
  1. **Centralized injector complex**
  2. **Common booster linacs**
  3. **Dog-bone damping ring**
  4. **Polarized RF gun**
  5. **Undulator vs conventional e+ source**
  6. **Single stage BC and other RTML options**
  7. **Lower current linac operation**
  8. **Lower linac energy**
  9. **Reduced linac overhead**
  10. **One vs two linac tunnels**
  11. **Beam Delivery System options (500 GeV max)**

ILC Summary

- Clear costs for maintaining parameter plane versus adopting lowP parameters
  - **How important is luminosity goal of 500 fb-1 in 4 years?**
    - Personally believe that operating space will be needed to meet design goals but can lower the goals
  - **How important is luminosity spectrum (Hitoshi's talk)?**
    - Which is preferable 7% reduced energy or LowP only?
    - Reduced RF with full DR → L ~ const vs Energy
  - **Still have parameter plane at reduced luminosity of ~1×10^{34} with reduced rf system**
    - Is 50% luminosity worth 3% TPC?
    - Would this be an acceptable option for experimentalists?

Final Personal Comments (1)

- Timescale for the ILC has been delayed
  - **Wait for LHC data ~2011**
  - **ILC TDP will be ready on similar timescale**
  - **ILC technical construction timescale is now ~2015**
- Want to have ILC project ***ready*** to start next phase when LHC data could motivate this
  - **However necessary energy reach will likely not be clear and the CLIC CRD will be complete around TDP timescale and will likely estimate a lower cost**
- What information would be desired to commit
  - **Better understanding of costs, risks, and timescales of both options**

Final Personal Comments (2)

- GDE has only considered SC RF thus far
- Costs are one ***major*** limitation for LC project
  - **Cost savings was estimated by USTOS for X-band**
    - 25% cost savings of X-band klystron-based system versus SC RF LC based on USTOS committee chaired by G. Dugan
      - Probably greater for CLIC X-band LC
  - **ITRP was not able to compare costs – needed costing done with common methodology**
- ITRP charge specified construction before 2010
- Given slower ILC schedule and advances of TBA technology, it is time for a cost study of both options using common methodology
  - **GDE is the only organization that can do this!**