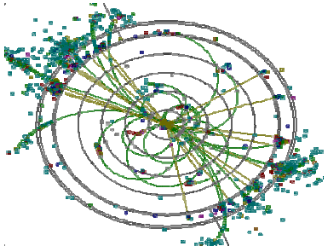
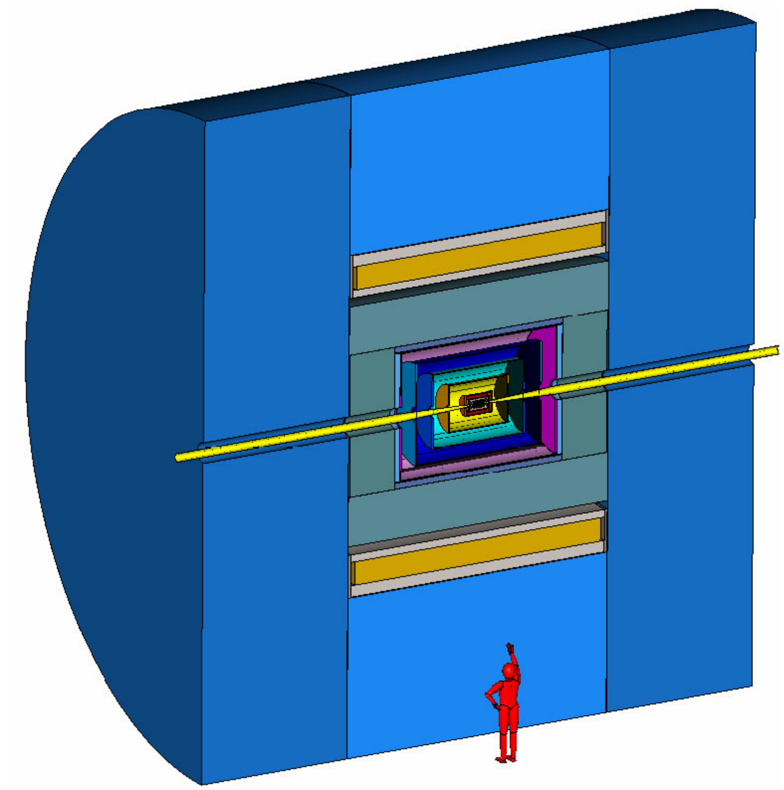


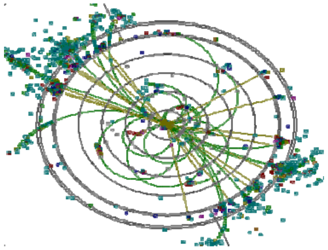
WHY SiD FOR AN ILC DETECTOR?

J. Brau

March 11, 2006

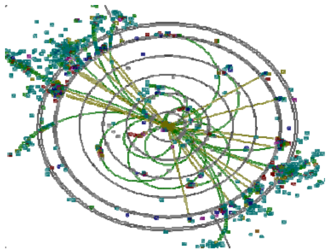
Bangalore - LCWS 2006





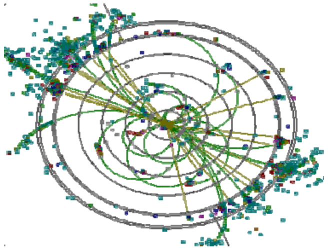
Physics Goals

- SiD has been designed to address questions of fundamental importance to progress in particle physics:
  - The mechanism responsible for electroweak symmetry breaking and the generation of mass
  - The unification of the forces
  - The structure of space-time at small distances
  - The connections of the nature of the fundamental particles and forces to cosmology
- These are addressed through precision measurements by SiD at the International Linear Collider (ILC) of the following:
  - Higgs boson properties
  - Strong coupling effects
  - Effects resulting from the existence of extra dimensions
  - Studies of supersymmetric particles
  - Top quark studies
- Cost Constraint important concern from start.



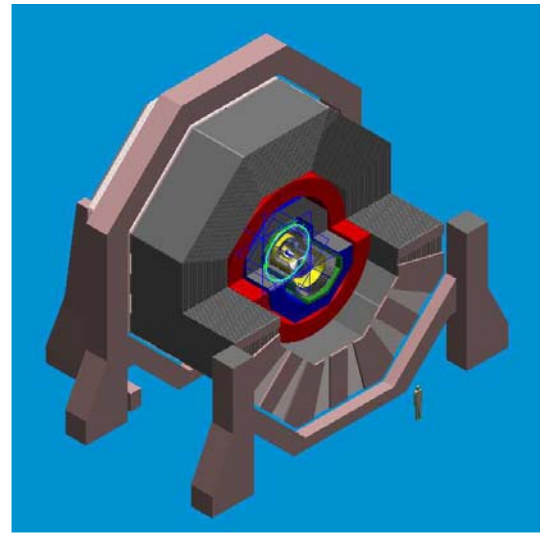
ILC Detector Requirements

- **Two-jet mass resolution comparable to the natural widths of W and Z for an unambiguous identification of the final states.**
- **Excellent flavor-tagging efficiency and purity (for both b- and c-quarks, and hopefully also for s-quarks).**
- **Momentum resolution capable of reconstructing the recoil-mass to di-muons in Higgs-strahlung with resolution better than beam-energy spread.**
- **Hermeticity (both crack-less and coverage to very forward angles) to precisely determine the missing momentum.**
- **Timing resolution capable of separating bunch-crossings to suppress overlapping of events .**



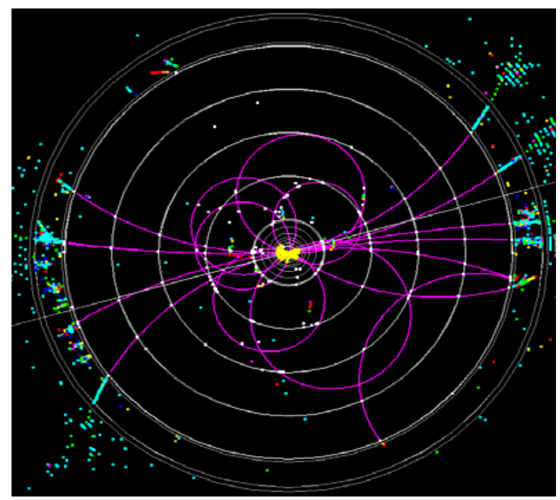
SiD (the Silicon Detector)

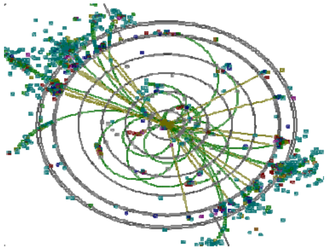
CALORIMETRY IS THE STARTING POINT IN THE SiD DESIGN



assumptions

- Particle Flow Calorimetry will result in the best possible performance
- Silicon/tungsten is the best approach for the EM calorimeter
- Silicon tracking delivers excellent resolution in smaller volume
- Large B field desirable to contain electron-positron pairs in beamline
- Cost is constrained





ILC Environment

- SiD has been designed to operate optimally in the ILC environment.

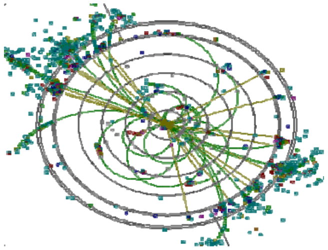
  Limiting sensitivity to particles generated in a selected, single bunch crossing is a critical goal, and central to the SiD philosophy.

- Collisions of bunches at the IP occur every 308 nsec (or less).

- Bunch trains consisting of 2820 bunches in each beam pass through the IP five times per second.

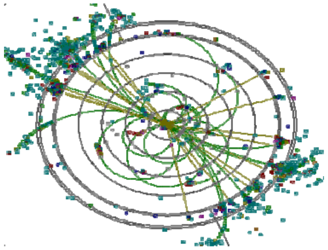
- Consequently, the bunch trains are 868 msec long, separated by 199 msec.

- The design luminosity is 2×10^{34} cm^{-2} sec^{-1}.



Backgrounds

- Backgrounds generated by stray beam particles upstream, and collisions of the bunches themselves (beamstrahlung and beam-beam interactions), consist of large numbers of low energy (~MeV) photons, and electron-positron pairs.
- Additionally, the hadronic collision rate itself, including the two-photon events, is about 200 events per bunch train.
- Other than the two-photon events, high energy interactions comprise only one event in about every ten bunch trains.
- Therefore, the pile up of the two-photon events could significantly confuse detection of the principal signal of interest unless the detector can cleanly select single bunch crossings, which SiD is designed to do.
- For example, only a few Higgstrahlung events per hour, or less, might be produced, motivating clean separation of the overriding two-photon events, and the lower energy backgrounds.



Background Sources

IP Backgrounds

- Beam-beam Interactions
  - Disrupted primary beam
    - Extraction line losses
  - Beamstrahlung photons
  - e+e- pairs
- Radiative Bhabhas
- $\gamma\gamma \rightarrow$ hadrons/μ+μ-

Somewhat manageable -

- Scale with luminosity
- Transport them away from IP
- Shield sensitive detectors
- Exploit detector timing

- Reliable simulations.

Machine backgrounds

- Muon production at collimators
- Collimator edge scattering
- Beam-gas
- Synchrotron radiations
- Neutrons from dumps/extr. line

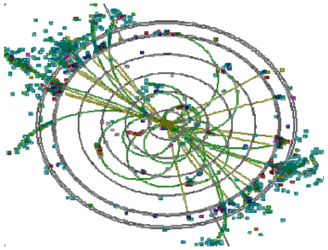
Harder to handle -

- Don't make them
- Keep them from IP if you do

- Dominated by beam halo
- Dependent on assumptions

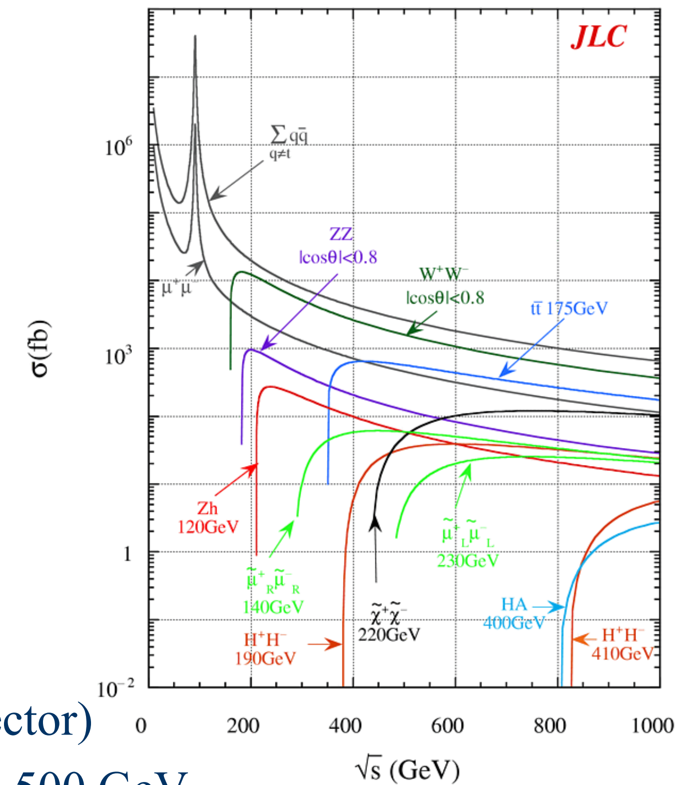
Backgrounds

- The electron-positron pairs, largely produced in beam-beam interactions, while soft, are a particularly major problem for the most inner layers of the detector.
- SiD's high solenoidal field is an effective protection from the bulk of these pairs, and allows the smallest possible beam pipe radius, optimizing vertexing resolution.



Event Rates and Backgrounds

- **Event rates (Luminosity = 2 x 10^{34})**
  - $e^+e^- \rightarrow$ qq, WW, tt, HX
    - **~ 0.1 event / train**
  - $e^+e^- \rightarrow e^+e^- \gamma\gamma \rightarrow e^+e^-$ X
    - **~ 200 /train**

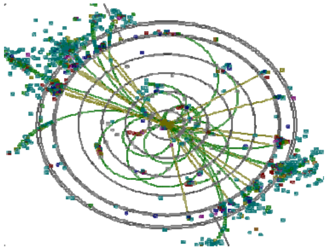


- **Background**
  - 6 x 10^{10} γ / BX (from synchrotron radiation, scatters into central detector)
  - 40,000-250,000 e^+e^- / BX (90-1000 TeV) @ 500 GeV
  - Muons: < 1 Hz/cm^2 (w/ beamline spoilers)
  - Neutrons: ~3 x 10^8 /cm^2/ yr @ 500 GeV

Ref: Maruyama, Snowmass 2005

Important Lesson of SLC, the 1st Linear Collider

- At SLC, bunch-to-bunch variations in the beam parameters were large, and hard to predict, model, and control.
- Individual bunches with anomalous backgrounds were problematic to operation of the SLD detector.
- Significant precautions are being taken at ILC to deal with this, but experience suggests the need for robust detectors.
- SiD's reliance on silicon sensors for vertexing, tracking, and electromagnetic calorimetry promises the needed robustness.
- Sensitivity to single bunch crossings, made possible by silicon detectors, is the key to immunity.

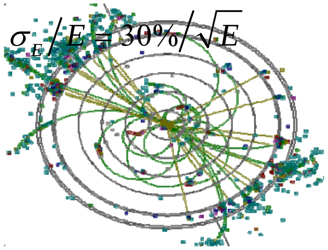


The S in SiD

- **SiD is a detector concept based on silicon tracking and a silicon-tungsten sampling calorimeter, complemented by a powerful silicon pixel vertex detector, and outer hadronic calorimeter and muon system. Optimized forward detectors are deployed.**

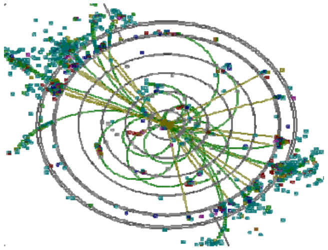
- **In order to meet the ILC physics goals, SiD is designed as a general purpose detector taking full advantage of the silicon technology.**

- **Silicon detectors are fast, robust against machine-induced background, fine in segmentation and, by now, a mature technology.**



Detector Performance

- The detector performance required for the ILC physics goals includes
  - i) unprecedented jet energy resolution of $\sigma_E/E = 30\%/\sqrt{E}$, where E is the jet energy in GeV,
  - ii) a superb momentum resolution $\sigma(1/p_T) = 5 \times 10^{-5}$, where is the momentum perpendicular to the beam axis measured in GeV/*c* and
  - iii) the impact parameter resolution of $\sigma_{r\phi} \approx \sigma_z \approx 5 \oplus 10/(p \sin^{3/2}\theta)\ \mu m$, where *p* is the momentum of the charged track in GeV/*c* and is the polar angle with respect to the beam axis.
- The jet energy resolution, a factor of 2 better than SLC/LEP calorimeters, and comparable to ZEUS uranium-plastic scintillator calorimeter, for multi-jet final states.
- The momentum resolution required is a factor of 10 better than LEP experiments and a factor of 3 better than CMS at LHC.
- The impact parameter resolution, which is a factor of 3 better than what SLD achieved, for flavor (b or c origin) tagging of jets.



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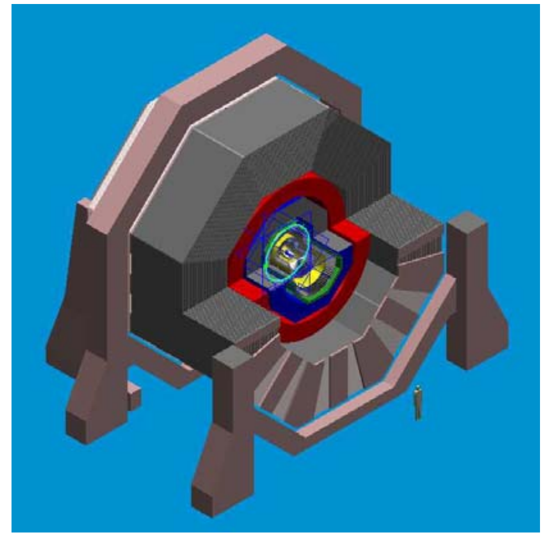

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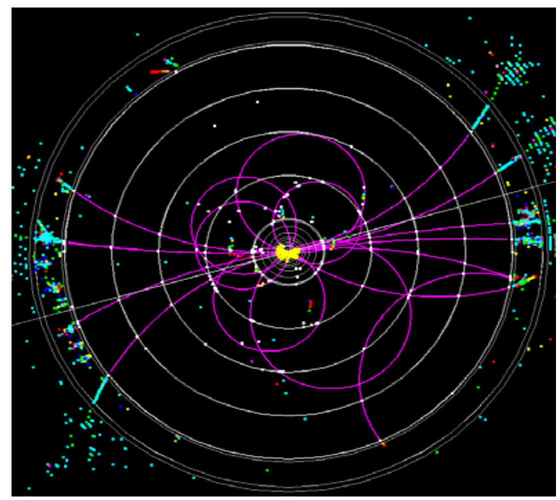
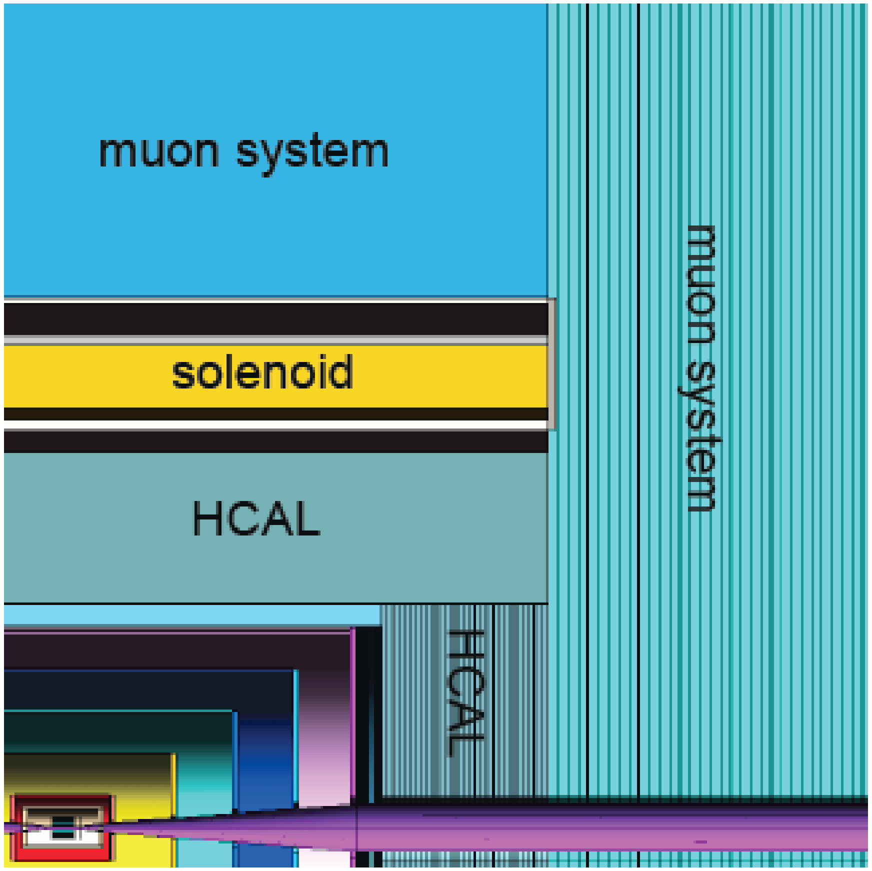
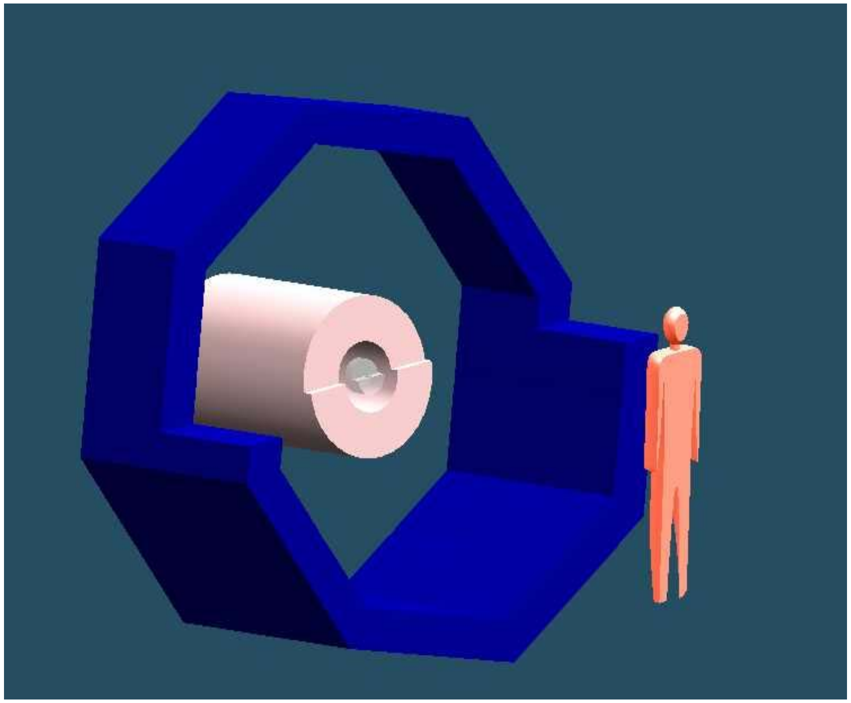


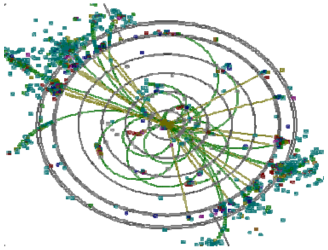
SiD Configuration



5 Tesla



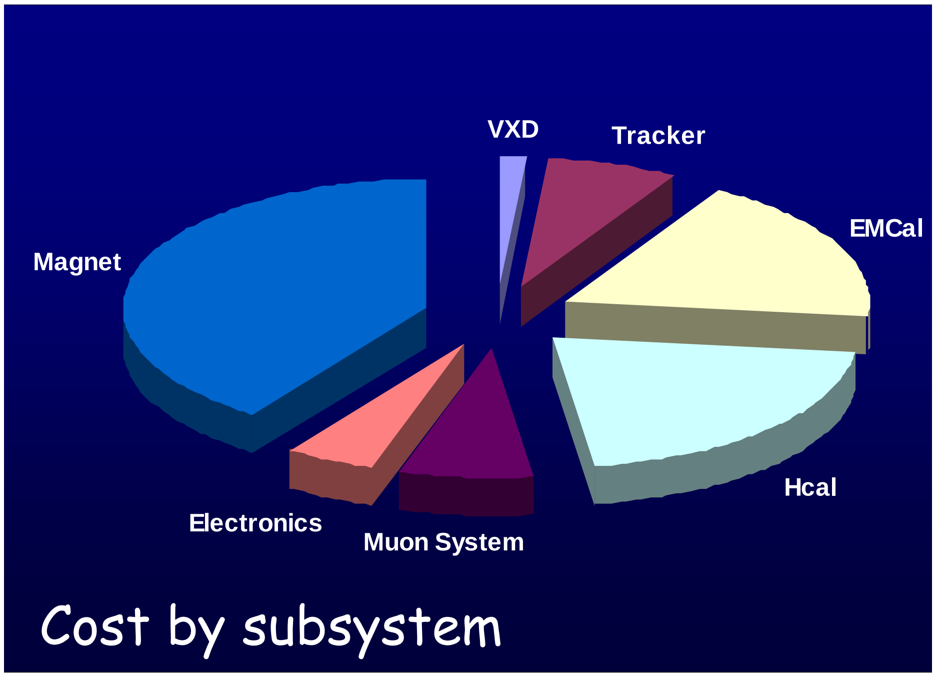
Scale of EMCal
& Vertex Detector

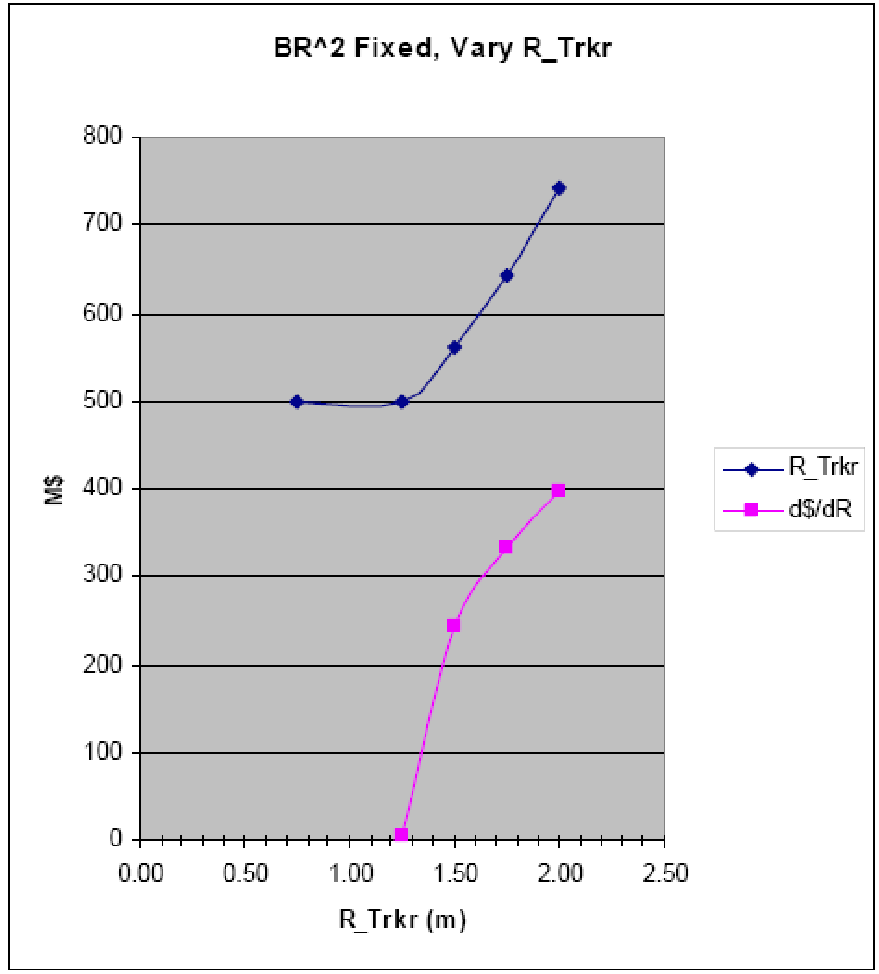


Cost

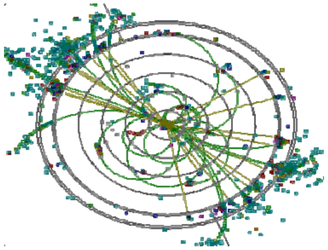
Parametric Cost Model

Cost = f (B-field, R_{TRK}, ….)





Cost vs. tracker radius



Summary

- **The ILC detector must have the capability to identify the bunch crossing, in which the recorded collision event has occurred.**
- **ILC bunches are separated by 308 ns, or less (150 ns).**
- **SiD identifies the ILC bunches separated by as little as 150 ns.**
- **SiD is a state-of-the-art detector meeting all physics requirements**
  - **built-in robustness against machine-induced backgrounds**
  - **large field coil located outside calorimeter for optimal PFA**
  - **finely granular calorimeter to achieve optimal particle flow calorimetry,**
    - silicon-tungsten electromagnetic calorimeter.
    - compact geometry since Si-W expensive
    - tracking in compact configuration with **large magnetic field** and silicon
    - ancillary benefit of the large magnetic field is small beampipe/very close vxd
- **Designed with Cost Constraint from Start**