Tracking Strategy for SiD

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Tracking Review
ILC Detector R&D Panel
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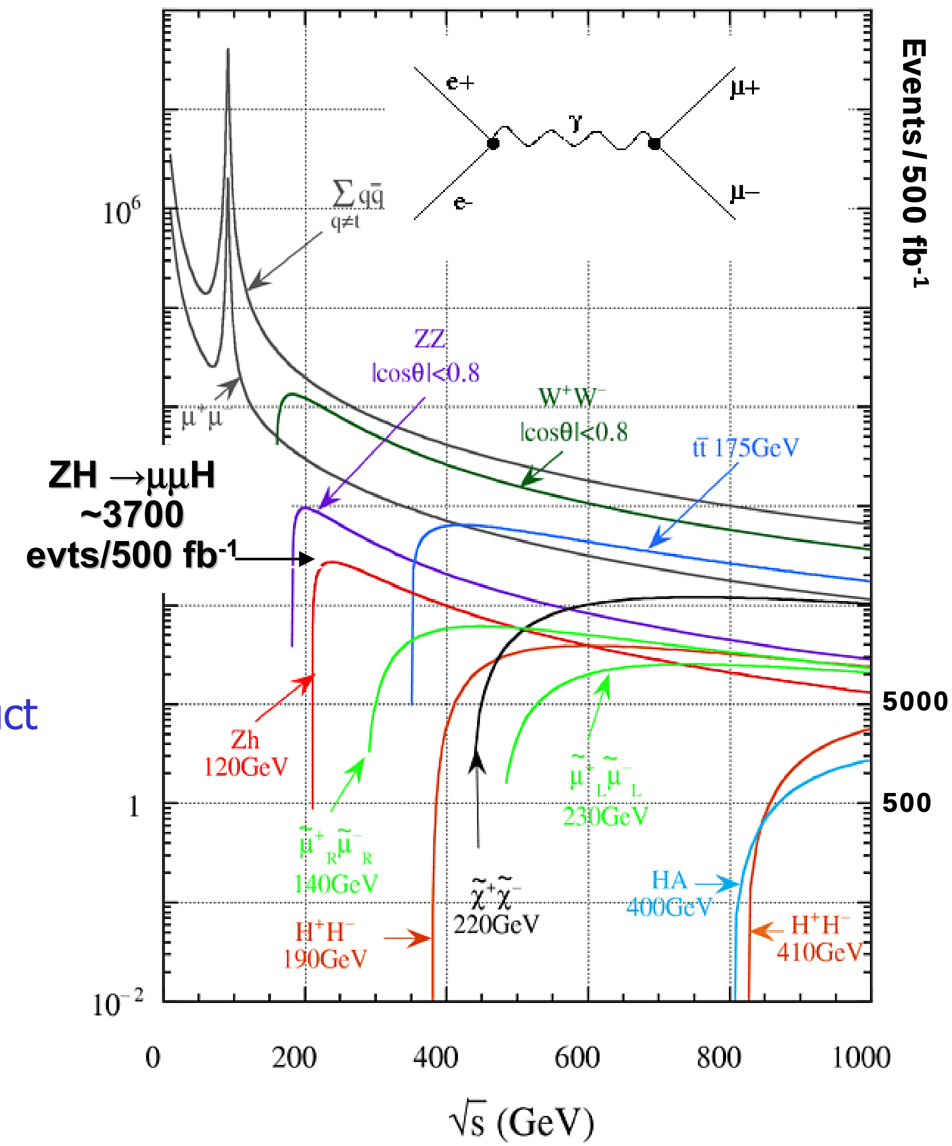
ILC Physics Characteristics

- Machine design luminosity
  $\mathcal{L} = 2 \times 10^{34}\ cm^{-2}s^{-1}$ ($\sqrt{s}$ = 500 GeV)
- Processes through s-channel spin-1 exchange: $\sigma \sim 1/s$
  - Cross sections relatively democratic
  - Cross sections are small
  - Angular distribution: $(1 + \cos^2\theta)$
    - Premium on forward region
    - Hermetic detectors
  - Relatively large backgrounds
    - 100k e^+e^- - pairs per bunch crossing
- W and Z bosons in all decay modes become the main objects to reconstruct
  - Discriminate W and Z in hadronic decay mode
- Highly polarized e^- beam: ~ 80%
  - To employ discriminating power requires running at both polarities
- Every event counts !

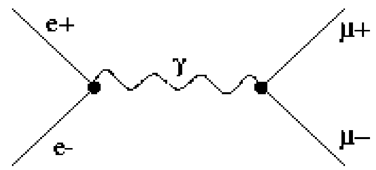


Polarization at the ILC

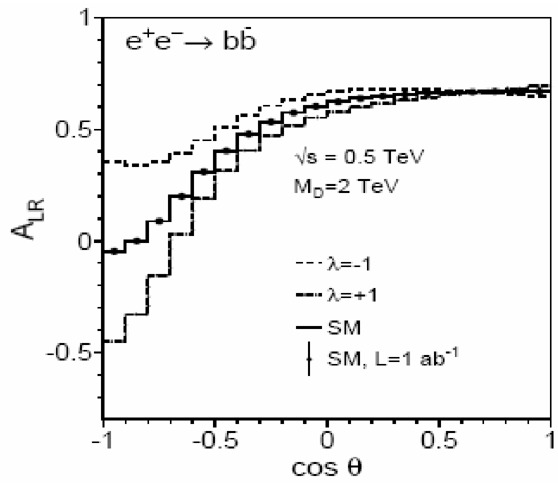
- Highly polarized e^- beam: ~ 80%

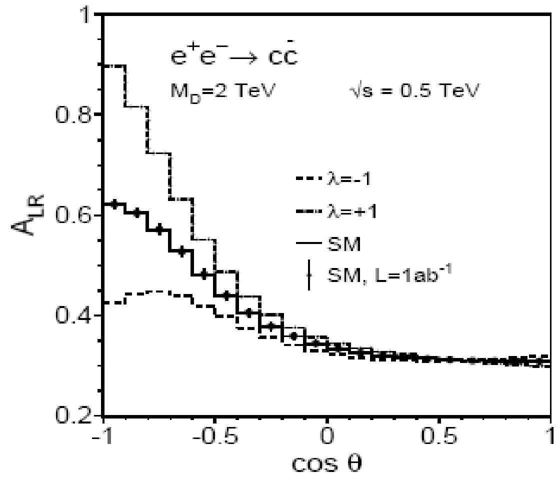
$$\frac{d\sigma_{f\bar{f}}}{d\cos\theta} = \frac{3}{8}\sigma_{f\bar{f}}^{tot}\left[(1-\mathcal{P}_e\mathcal{A}_e)(1+\cos^2\vartheta)+2(\mathcal{A}_e-\mathcal{P}_e)\mathcal{A}_f\cos\vartheta\right]$$

$$\mathcal{A}_f = \frac{2g_{Vf}\,g_{Af}}{g^2_{Vf}+g^2_{Af}} \qquad \mathcal{A}_b = 0.94 \quad \mathcal{A}_c = 0.67 \quad \mathcal{A}_l = 0.15$$



- Analyzing power of
  - Scan in center of mass energy
  - Various unique Asymmetries
    - Forward-backward asymmetry
    - Left-Right Asymmetry
  - Example: Model with extra dimensions
    - Coupling of graviton in 4-dimensions proportional to λ/M^4_D
    - Largest effects for b-quarks
      - $\sqrt{s}$ = 500 GeV, M_D = 2 TeV
      - $\mathcal{P}_e$ = 0.8, $\mathcal{L}$ = 1 ab^{-1}
    - Sensitivity is in the far backward region
    - No sensitivity for leptonic final states (A_e = 0.15)
- Hermetic detectors with uniform strengths
  - Importance of forward regions
  - b/c tagging and quark identification in forward region

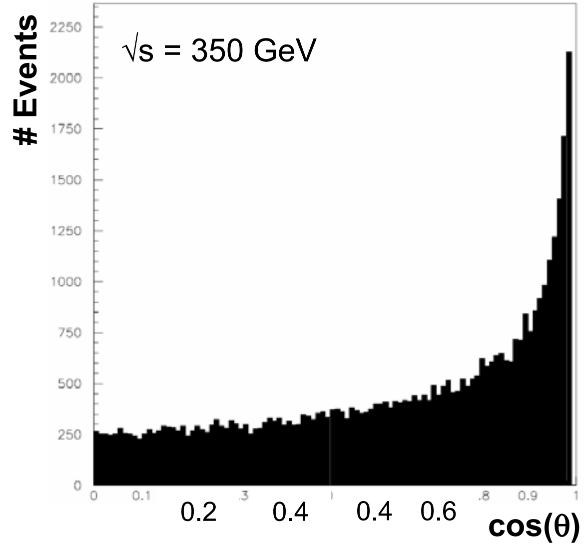


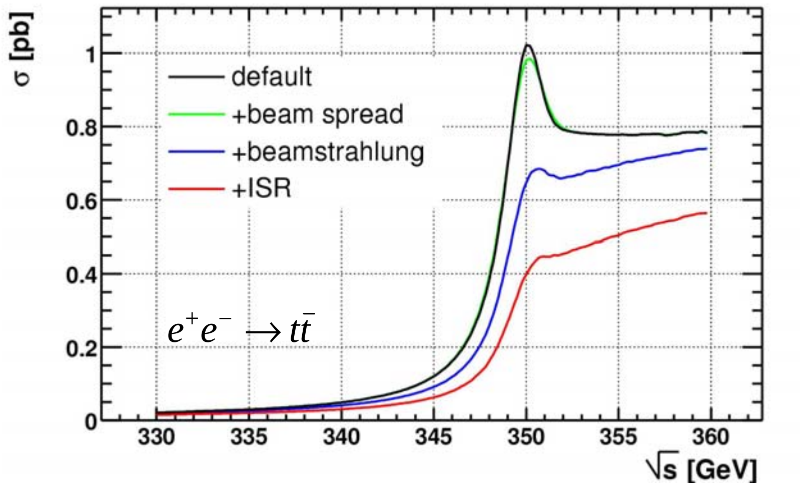


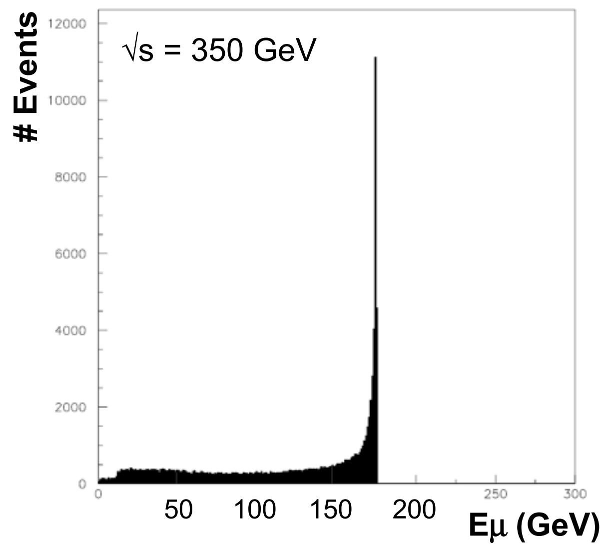
E_{CM} Determination

- Center of mass energy requirements
  - Top mass: 200 ppm (ΔM_t=35 Mev)
  - Higgs mass: 200 ppm (ΔM_H=60 MeV; m_H=120 GeV)
  - Giga-Z program: 50 ppm
- Determine E_{CM} from $e^+e^- \rightarrow \mu^+\mu^-\gamma$
  - $e^+e^- \rightarrow \mu^+\mu^-\gamma \qquad at\sqrt{s} = 350\,GeV, \mathcal{L} = 100\,fb^{-1}$
  - Events predominantly forward
- Determination of the Luminosity spectrum
  - top-quark pair production threshold scan

Tim Barklow





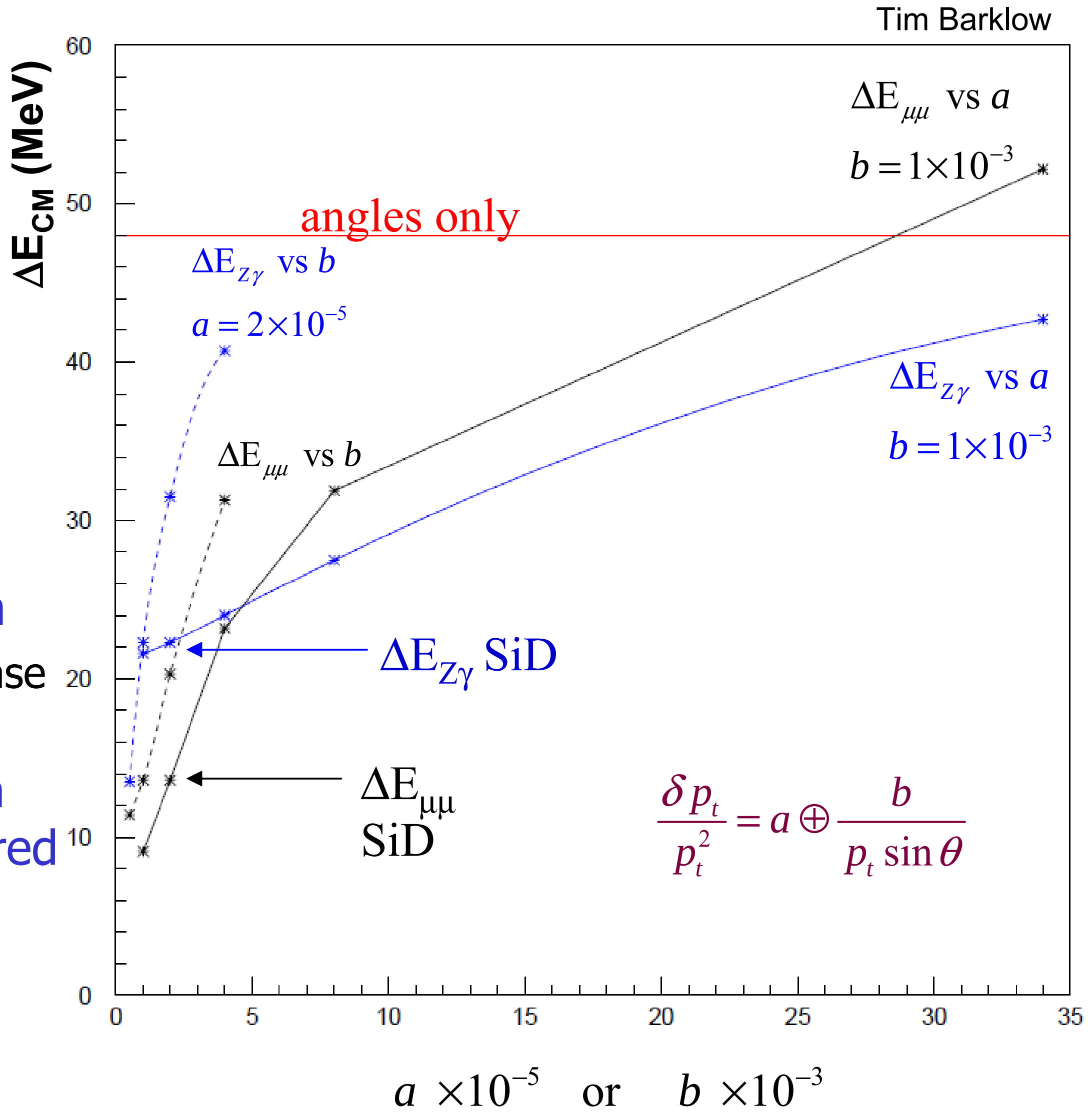


E_{CM} Determination

- Momentum resolution parametrization

$$\frac{\delta p_T}{p_T^{\ 2}} = a \oplus \frac{b}{p_T \sin \vartheta}$$

- Three options considered
  - Angles from $\mu^+\mu^-$ only
  - $\Delta E_{Z\gamma}$: $Z\gamma \to \mu^+\mu^-\gamma$
  - $\Delta E_{\mu\mu}$: $e^+e^- \to \mu^+\mu^-$ with μ^+/μ^- each the full beam energy
- Large sensitivity to MS term
  - 40% increase for x2 increase in b.
- Good momentum resolution and low mass tracker required over full angular region

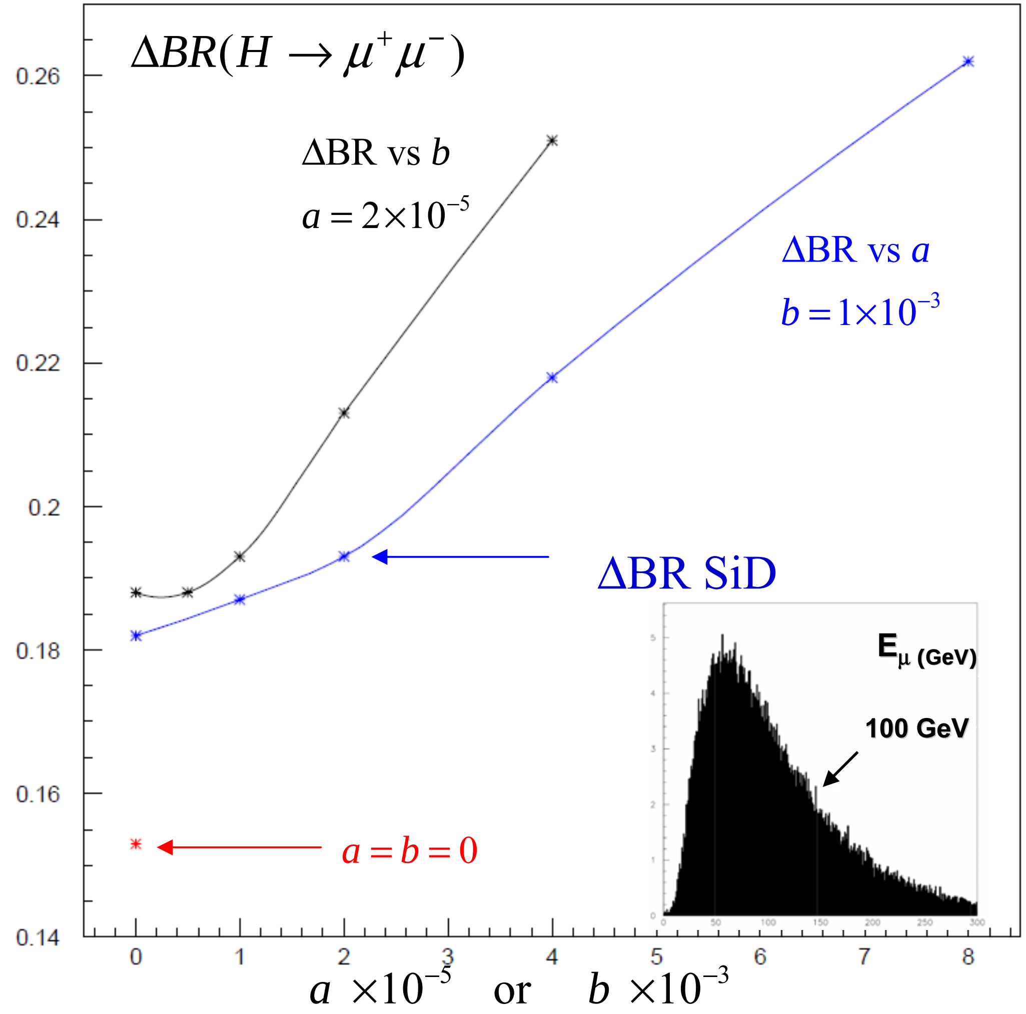


BR(H→μ⁺μ⁻)

- $e^+e^- \rightarrow \nu_e\bar{\nu}_e H \rightarrow \nu_e\bar{\nu}_e \mu^+\mu^- \quad at \sqrt{s} = 1TeV, \mathcal{L} = 1000\ fb^{-1}$

- Angular distribution follows ~ 1+cos(θ)
- Determine error on the branching ratio as function of momentum resolution parameters
- Surprising dependence on constant term in the p-resolution
- Low mass device needed over full angular coverage

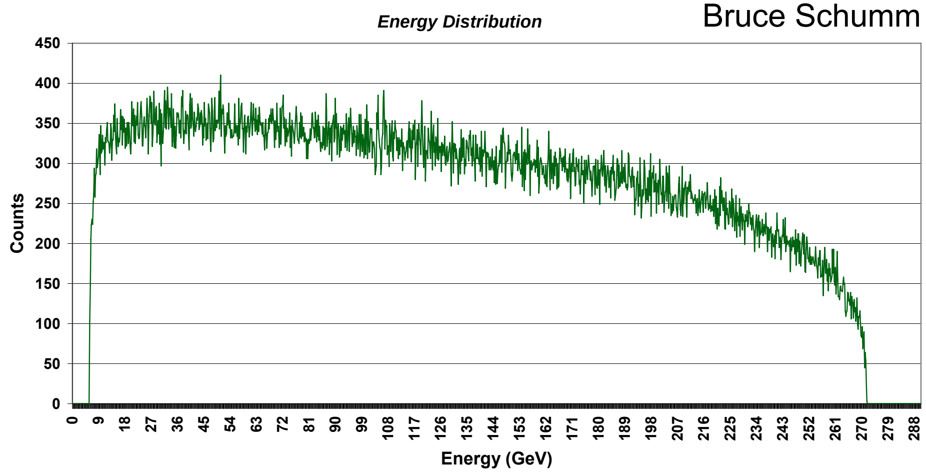
Tim Barklow

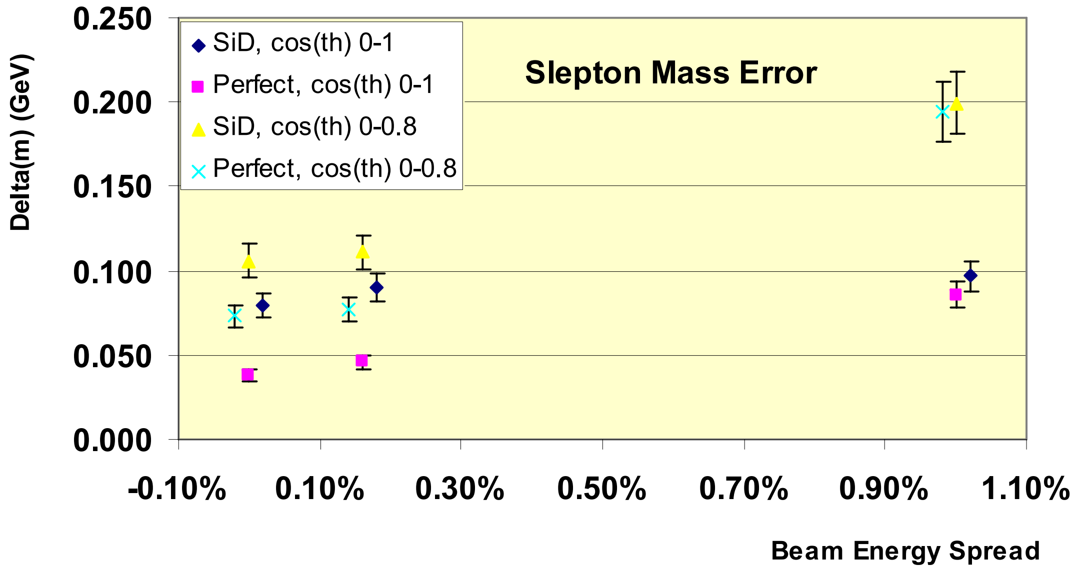


Slepton Mass Determination

- Selectron pair production at √s = 1 TeV
  - $m_{\tilde{e}} = 143\,GeV,\quad m_{\tilde{\chi}} = 96.1\,GeV,\quad P_{e^-} = 80\%$
- Angular distribution follows $1+\cos(\theta)$
- Selectron mass determination from Energy end-point spectrum
  - Benefits significantly from larger angular coverage
  - Benefits from improved momentum resolution

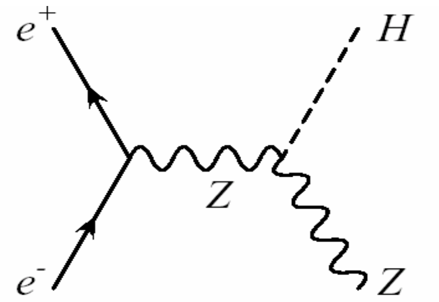
Bruce Schumm



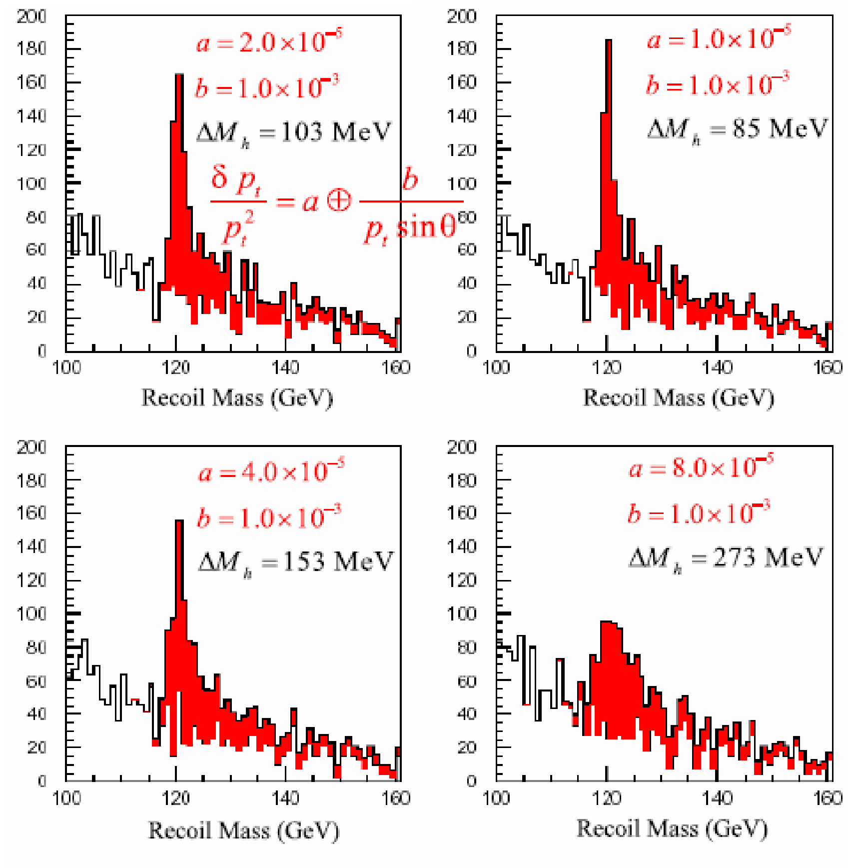


Higgs Recoil Mass

- Benchmark measurement is the measurement of the Higgs recoil mass in the channel $e^+e^- \rightarrow ZH$
  - Higgs recoil mass resolution improves until $\Delta p/p^2 \sim 2 \times 10^{-5}$
  - Sensitivity to invisible Higgs decays, and purity of recoil-tagged Higgs sample, improve accordingly.



- Example:
  - $\sqrt{s}$ = 300 GeV
  - 500 fb^{-1}
  - beam energy spread of 0.1%
- Goal:
  - $\delta M_{ll} < 0.1 \times \Gamma_Z$
  - δM_H dominated by beamstrahlung



Backgrounds

- "At the ILC the initial state is well defined …"

- Backgrounds from the IP
  - Disrupted beams
    - Extraction line losses
  - Beamstrahlung photons
  - e^+e^- - pairs

$\sqrt{s}$ (GeV)	Beam	# e^+e^- per BX	Total Energy (TeV)
500	Nominal	98 K	197
1000	Nominal	174 K	1042

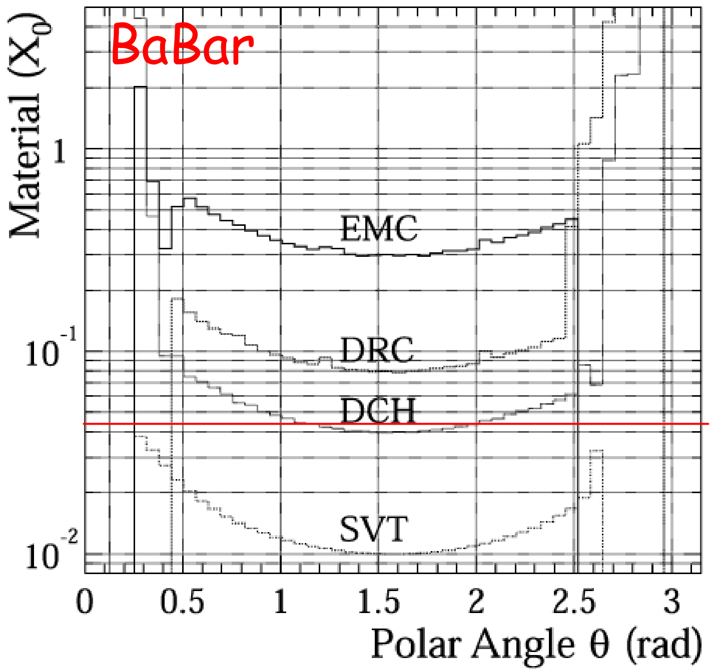
- Backgrounds from the machine
  - Muon production at collimators
  - Synchrotron radiation
  - Neutrons from dumps, extraction lines

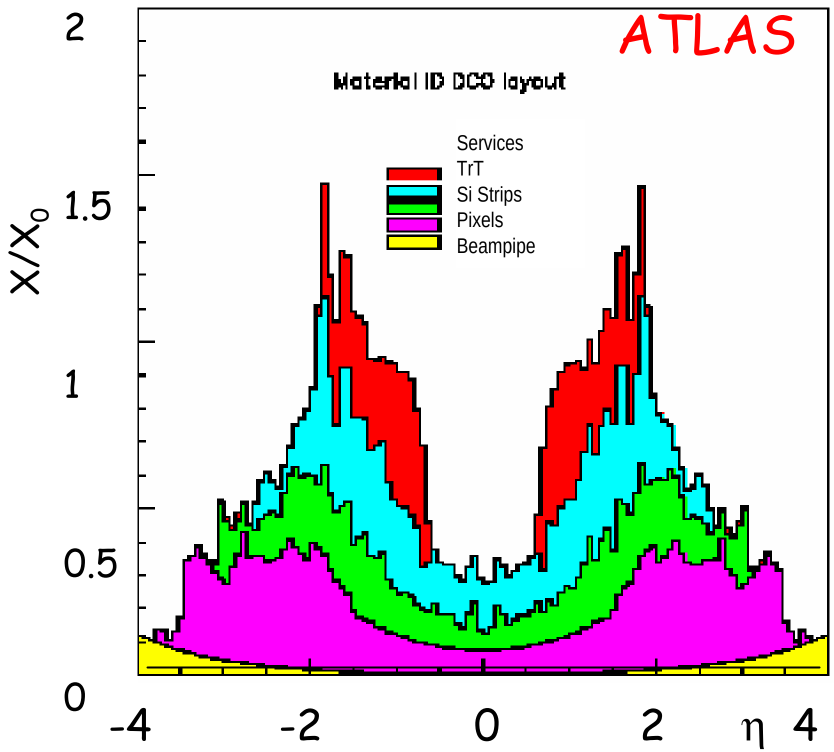
- For beam current of $I=2.8\ 10^{14}\ s^{-1}$
  - 0.1% of particles hits spoiler
  - $<N_\mu> = 4.6\ cm^{-2}\ sec^{-1}$, $<N_\gamma> = 4.7\ cm^{-2}\ sec^{-1}$
  - For 150 bunches, $<N\mu> = 0.0489\ cm^{-2}$ or 8855 muons in the tunnel aperture
  - Alleviated by muon spoilers in tunnel

- Monte Carlo simulations have reached very good predictive power, but one ought to be prepared for the unexpected
- A silicon based tracker has single bunch timing resolution

Material Budget

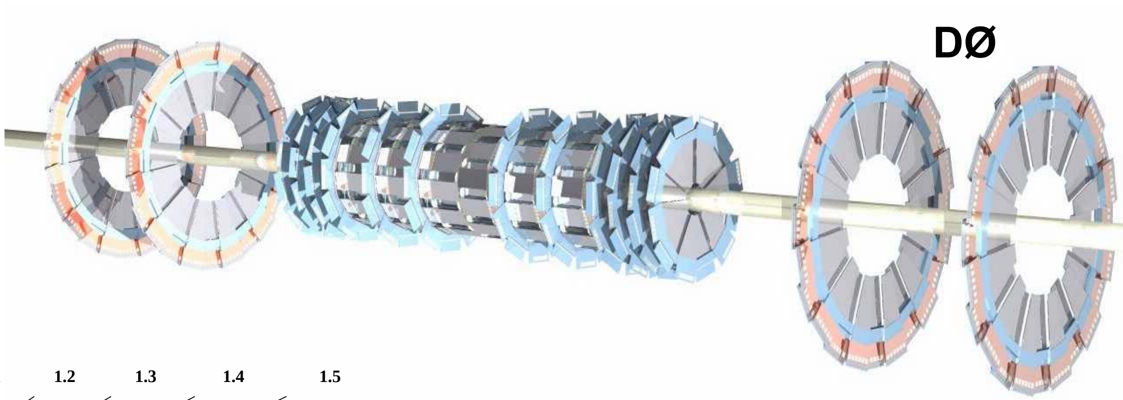
- Material budget, especially in the forward region, is a major issue
  - Babar: 5 layers of double-sided Si
  - Stays below 4% at normal incidence traversing SVT; average of 0.8% X_0 per layer
  - But, significant amount of material (far too much) in forward region
    - LHC type detectors would be inadequate

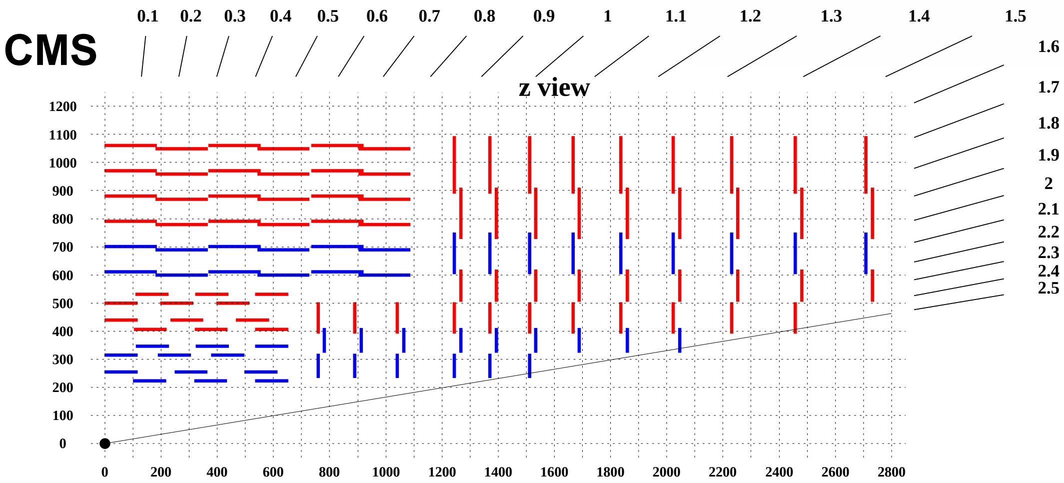


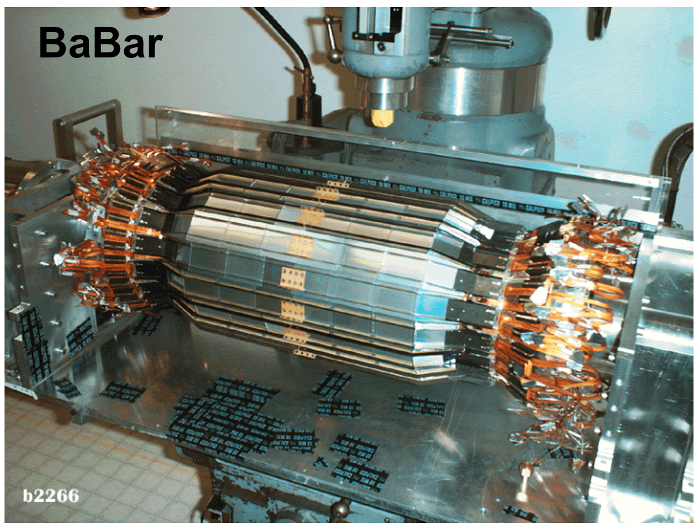


Tracking Strategies

- Many experiments have come up with quite different tracking strategies
  - What drives the determination of the tracking strategy?
  - What are the external constraints?

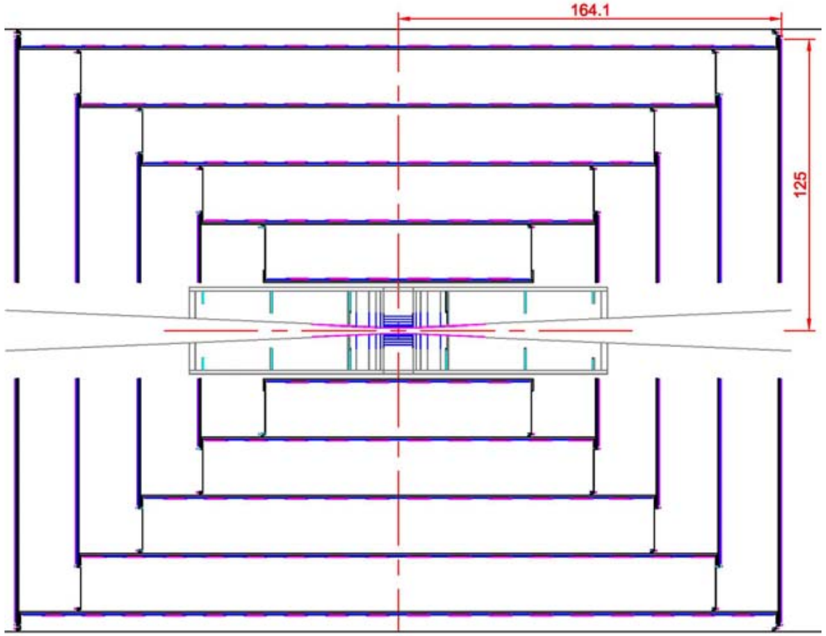






SiD Design Concept

- Detector is conceived as an integrated detector
  - Vertex detector for track seeding and initial pattern recognition
  - Momentum measurement in tracker
  - Integration with calorimeter
- Detector design premises:
  - Expect best performance with uniform technology throughout the detector
  - Silicon and carbon fiber support allows for uniform transparency of the detector over full angular range (~0.8% X_0 per layer)
  - Silicon and carbon fiber support allows for easy optimization of the design
  - Silicon provides for superior momentum resolution 2 10^{-5} (GeV^{-1})
  - Silicon provides for single bunch crossing timing
  - Robust against (unforeseen) beam backgrounds and beam induced backgrounds
  - Retains stand-alone tracking capability



Concluding Remarks

- SiD tracker conceived as integral part of the full detector
- Basic premise is that a silicon based tracker is the most promising technology that can address the issues facing a linear collider detector
- The R&D that is needed for the design, and to further optimize it, will be covered in the subsequent talks
  - Mechanical Design and R&D – Bill Cooper
  - Sensor and Module Design and R&D -- Tim Nelson
  - SiD-related University R&D -- Rich Partridge

- R&D Goals:
  - Establish feasibility of current design both mechanical, detector and readout
  - Develop and demonstrate feasibility of various approaches to tracker design
  - Optimize design with benchmark physics processes

- This review is a review of the tracker sub-system R&D only
  - The interplay between vertex detector, tracker, calorimeter and the implications of the tracker on, for example, particle flow calorimetry, is not quantified.