R&D ISSUES and PLANS for a SILICON μSTRIP CENTRAL TRACKER

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Sitges Linear Collider Workshop

4/99

Unique Properties of Linear Collider

- Low duty cycle

  TESLA: $< 10^{-2}$ NLC: $< 10^{-4}$

- Separation between bunches

  TESLA: ~300 nsec NLC: ~3 nsec

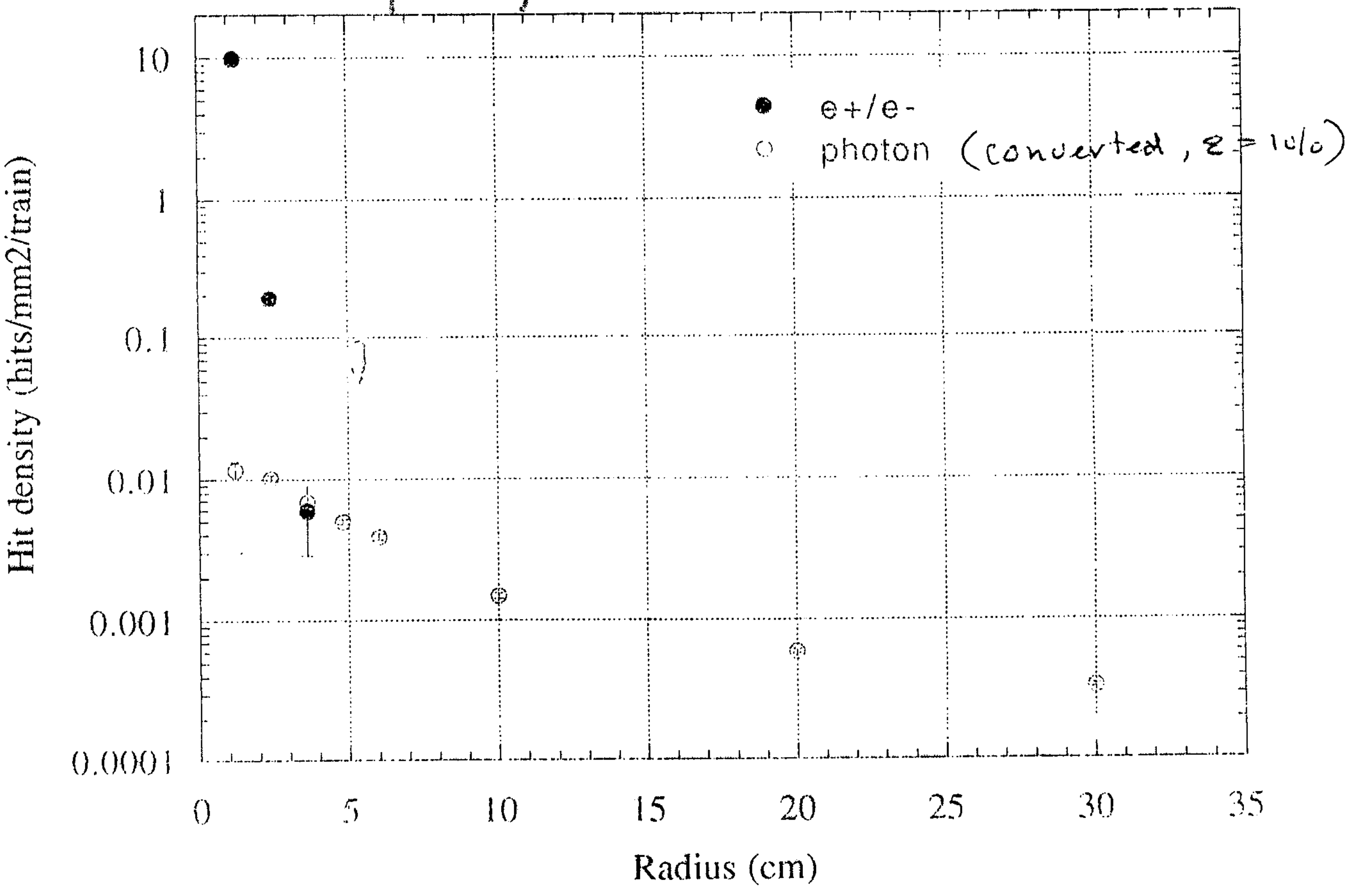
- Notoriously bad backgrounds

- High magnetic field (if ultraprecise vertexing is desired)

THESE PRESENT OPPORTUNITIES and CHALLENGES FOR THE DESIGN OF A SOLID STATE TRACKER

Beam-beam Backgrounds

Maruyama, Markiewicz for JLC/NLC



Effect of γ-background in μ-strips is understood:

There is a hit
-or-
There is no hit } Occupancy is only issue (fluence is not intimidating)

Nominal occupancy $r = 30$ cm (Maruyama, Markiewicz)

3×10^{-4} mm^{-2} (per train)

⇒ assumes 1% conversion rate

Nominal μstrip sensitive area: 20 cm × 50 μm = 10 mm^2

⇒ 3×10^{-3} occupancy at 30 cm.

HOW RELIABLE IS THE 1% CONVERSION RATE?

- Photon spectrum / absorption lngth vs. E_γ
- Photon incident angle
- Low energy cutoff (~1fC thresh)

Could use refinement.

Short Shaping Time Limit - Background Immunity

- Strip segmentation already good for background rejection

- further rejection by <u>timing</u> within pulse train

STRAIGHTFORWARD FOR TESLA (Δt = 337. nsec.)

MORE CHALLENGING FOR JLC/NLC (Δt = 2.8 nsec.)

- n-side signal is fast (~10 nsec). Could possibly improve with:

  Increased detector bias

  Thinner detectors

  Optimized electronics

- Resolve pulses to within 2-3 JLC/NLC buckets (extra ×30 background suppression)

Exploit Duty Cycle to Limit Power Dissipation

- Develop "switchable" chip which is biased only during beam spills

⇒ reduce power consumption by $> 10^3$

- Eliminates need for active cooling (material, complexity)

- Electronic stability? (tempurature cycling)

Example of Long Shaping Time Chip

The AMS chip (M Pauluzzi, NIM 383, p 35, 1996)

$$\sigma_N = 350 + 4 \cdot \overset{\sim 1.4\,\text{pF/cm of detector length}}{\overset{\downarrow}{C}} \quad \text{electrons equivalent}$$

⇒ ladder lengths in excess of 150 cm conceivable

⇒ thinner detectors for inner layers conceivable

Optimistic long-shaping design:

R	$\% X_0$ (total!)
14 cm	0.11
28	0.21
42	0.21
57	0.32
71	0.32

Space frame? Also conceivable (Hytec INC; SBIR interest)

Noise Considerations

Typically, trigger at ~1 fC to have efficient detector (Lorentz charge spreading ?!)

$$1\,fC = 6{,}250\ e^-$$

Noise (1σ) in electrons for fast (20 nsec τ_R) amp:

$$N = 600 + 30 \cdot C$$

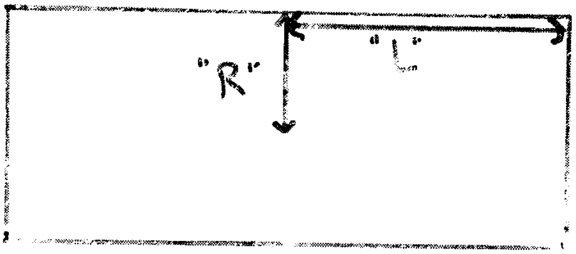
↑ reduce to optimize for long detector

and $C \cong 1.4\,pf/cm$. Solving, the detector length associated w/ a 4σ (10^{-4} occupancy) threshold is

$$\ell = \left[\left(\frac{6250}{4}\right) - 600\right] / 42 = \boxed{23\ cm}$$

On the other hand, the ASPECT RATIO (L/R) of a detector w/ $\cos\Theta = 0.9$ coverage is 2.1 : 1.

Thus, a layer at 40 cm will have ~4 modules, and at 60 cm will have ~8 modules in each detector half ⇒ much material!



$L/R \approx 2.1$ for $|\cos\Theta| \approx .9$

L ~ 150 cm for 'S' outer layer

Long Shaping Time Limit - Momentum Resolution

- Can hope to completely remove electronics from the tracking volume
- In addition, can hope to thin inner layers

⇒ Momentum resolution essentially identical to gaseous tracker option

⇒ Lose ability to reject out-of-time hits within pulse train

MOMENTUM RESOLUTION vs.

BACKGROUND IMMUNITY

- Physics simulations should address this issue
- Interim R&D should pursue both paths
- Long shaping for barrel, short for disks?

Stereo Geometry

Performance of long-shaping detector predicated on single-sided readout.

⇒ What about :

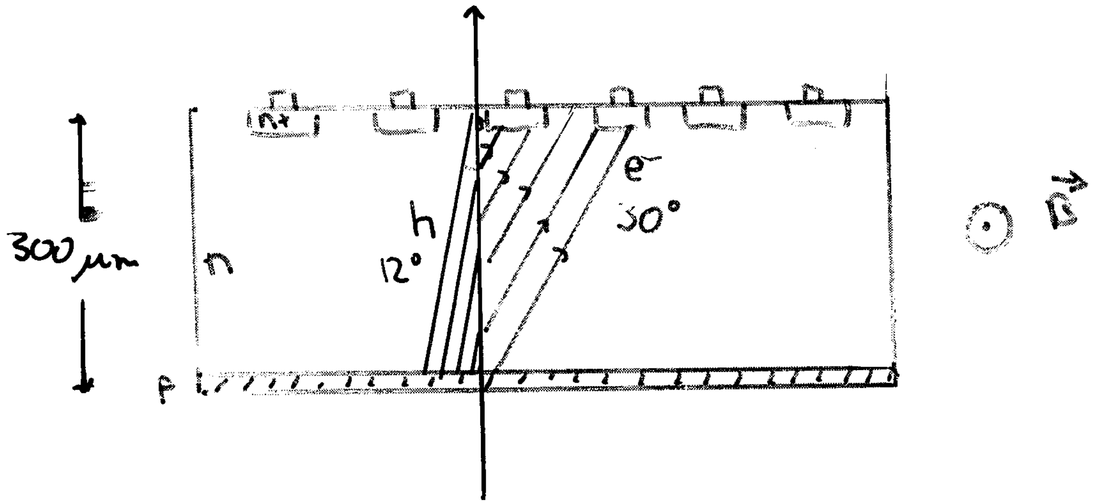
- All-axial detector (except perhaps outermost layer) ?

- All-stereo (alternating U-V) detector

SIMULATION MUST ALLOW STUDY / OPTIMIZATION OF THIS ISSUE!!

Lorentz Angle

$$\Theta_L = \begin{cases} 7.5^\circ \times B(T) & \text{electrons} \\ 3^\circ \times B(T) & \text{holes} \end{cases}$$



For a 300 μm detector, this corresponds to a 100 μm spread of charge ⇒ potentially degraded spatial resolution and S/N.

Q: How does this vary as detector is tilted?

Important design question! (may want to "give up" on p side - r-φ resolution much more critical!)

Spatial Resolution

Strawman design assumed single-hit resolution of 10μm in r-ϕ.

- Lorentz angle issues
- Narrower strip pitch?
- High cosΘ tracks?

DE/DX

Nominally, good particle separation for $\beta \lesssim 0.7$

From B. Schumm BABAR NOTE #126

5 LAYER SI TRACKER (300μm/Lay)

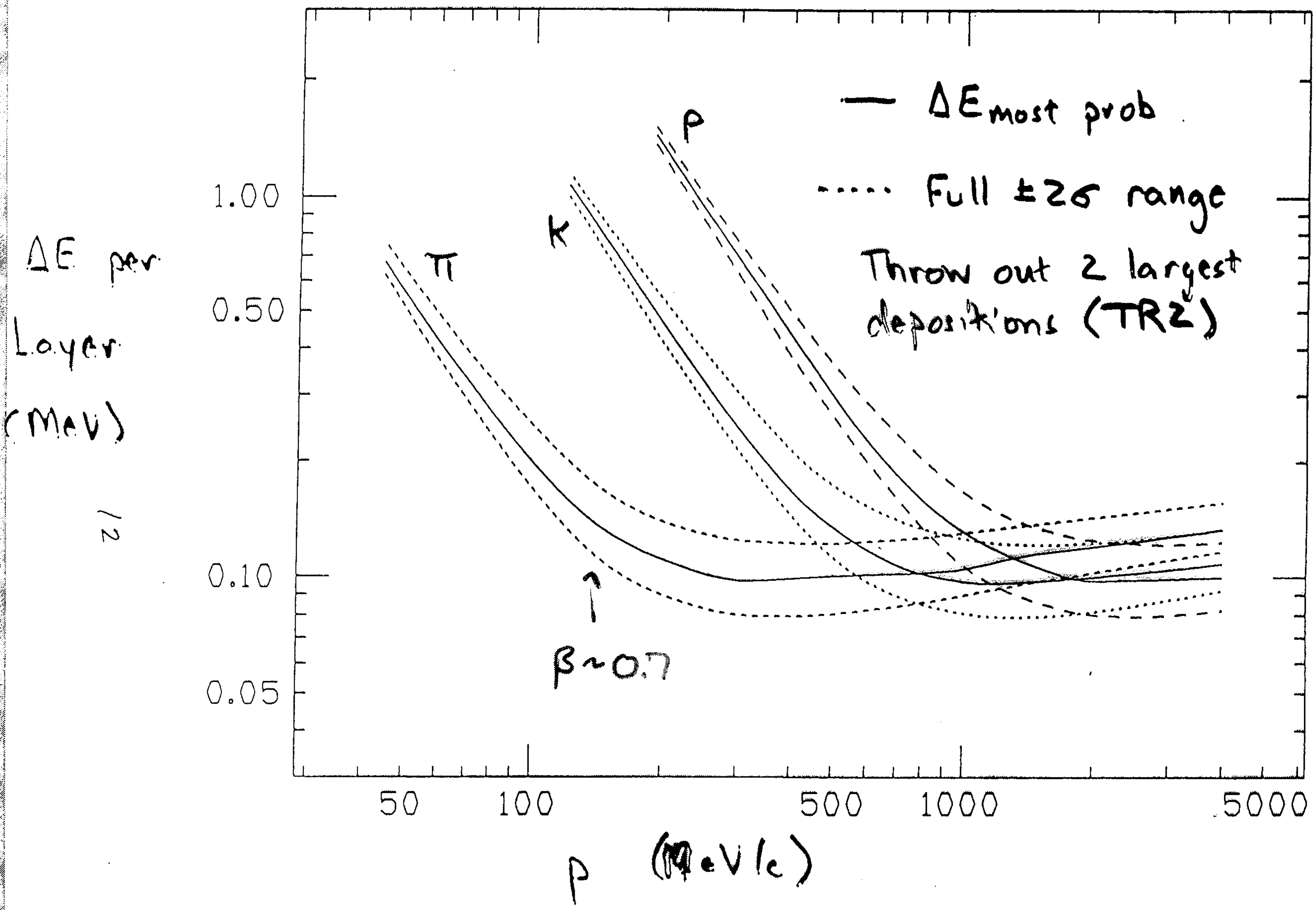


FIGURE 3

Short Term Program: Simulations

Detailed simulation of Si signal pulse development

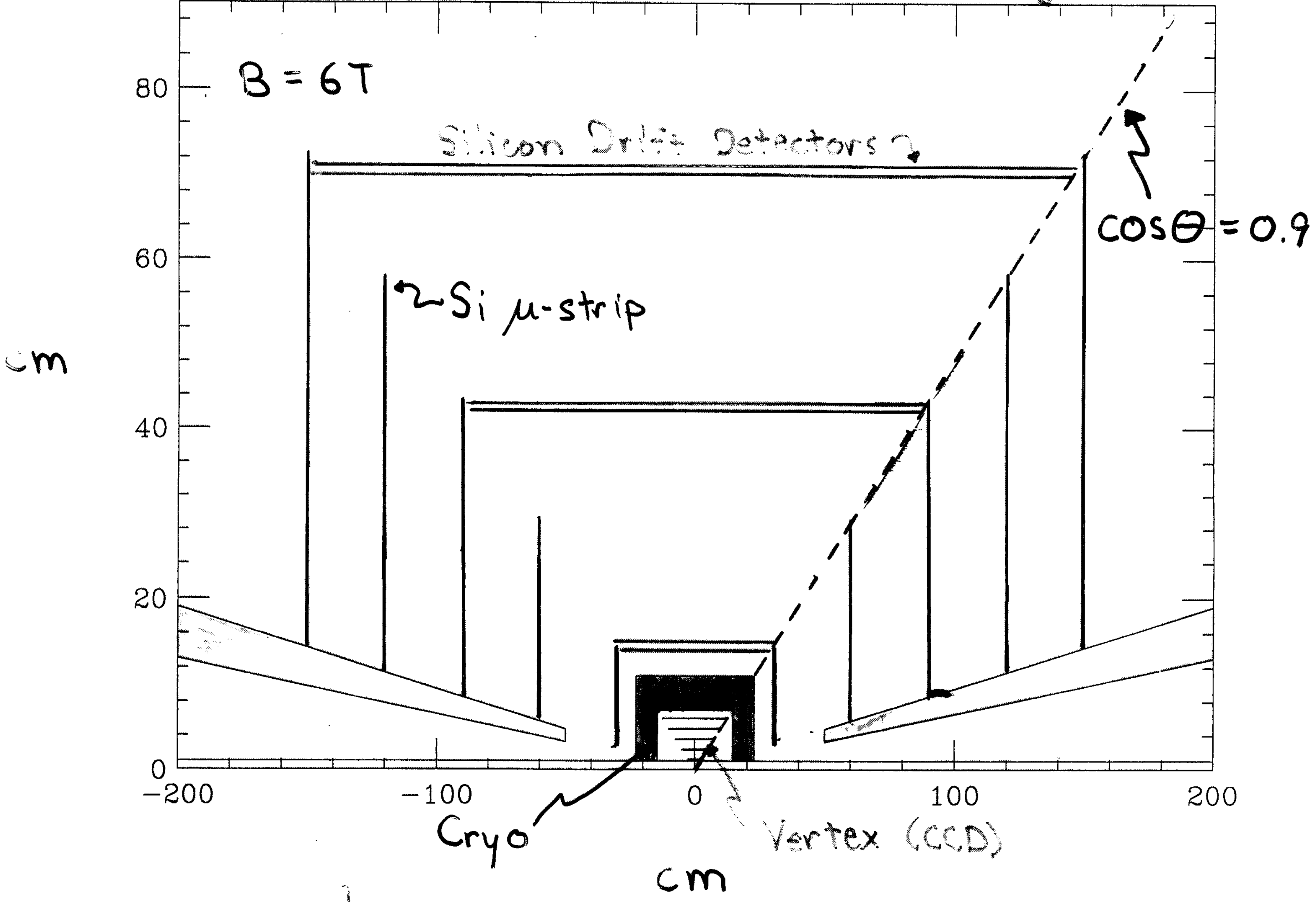
- Thinner detectors
- Higher bias
- Effects of strip resistance
- Lorentz angle, shingling, high cosθ tracks
- Narower strip pitch
- Landau fluctuations (S/N, and dE/dX)
- etc.

Full LCD simulation studies

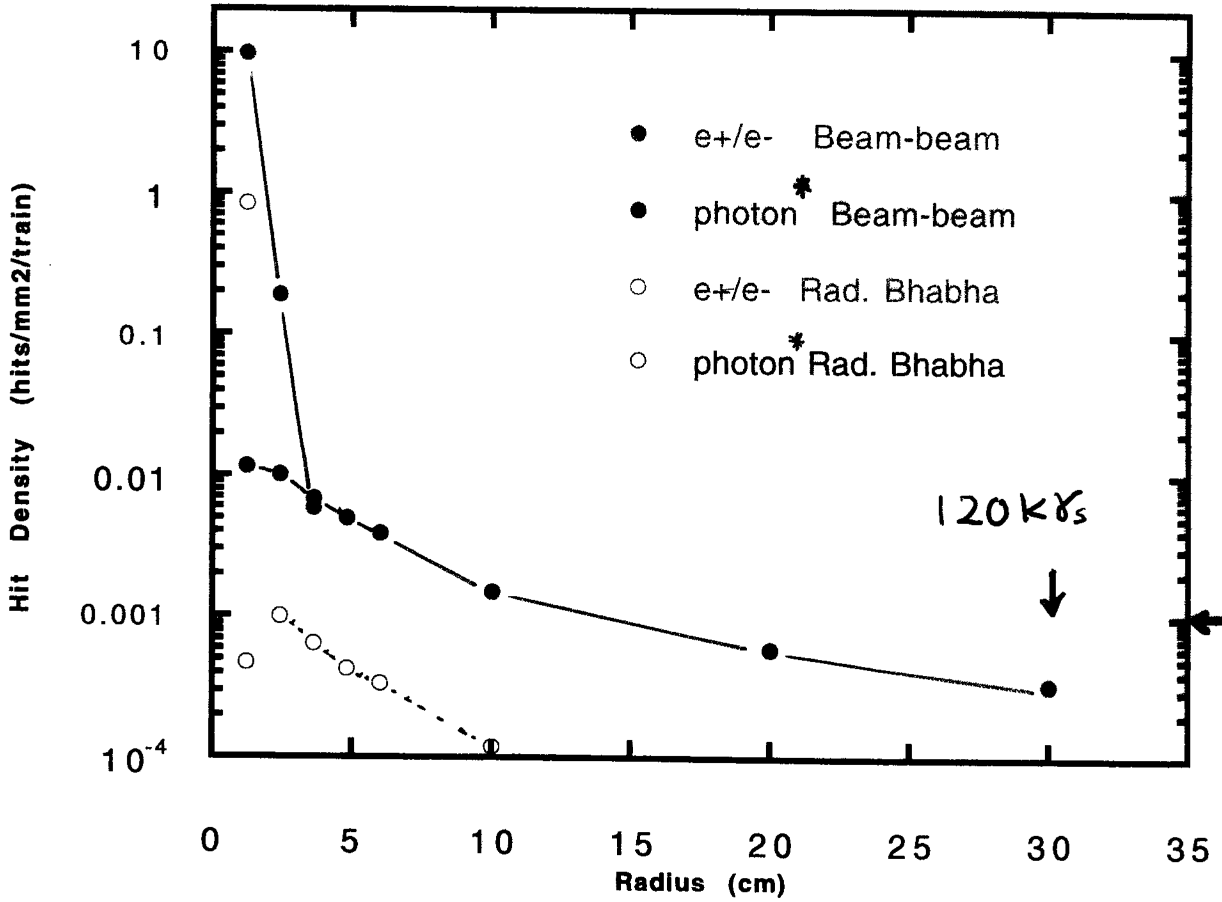
- Momentum-resolution defining reactions.
- Stereo geometry + pattern recognition
- Layer distribution (doublets vs. evenly spaced)
- Realistic hit simulation in package
- Backgrounds!!

Component level electronic design, prototyping, and testing are for the future.

North American 'S' Detector Tracking



Hit Density in LCD Small Detector



* converted photons

ε = 1%

← 0.1% occupancy

for 50μm × 20cm

Si strip