Silicon Strip Signals:  
*The Long Shaping-Time Limit*

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Long Shaping-Time Simulation

Outline

- Introduction and Motivation
- Effects Simulated
- Initial Results
- Present Status
Choosing a shaping time:
- consider pulse evolution → resolution
- consider noise

Noise is improved with longer shaping time, but can we retain requisite resolution?

Good news for simulation:
Long shaping time eliminates need for weighting fields and potential-relaxation methods because all charge is collected!

→ Develop a simulation to explore this design model
Detector modeled as series of identical, electrostatically decoupled cells of variable thickness and width

Track described by two orientation angles and an impact parameter
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Energy Deposition

- Bulk subdivided to allow position-dependent charge carrier drift
- Uncorrelated slab depositions verified
- Landau distribution preserved
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Trajectory of Charge Carriers

We approximate the electric field as having z-component only because we are interested only in which cell it is finally collected.

Thus, final positions are calculated from simple geometric consideration.

For diffusion effects, we need to know how long the charge carriers are in the bulk.

\[ t = \int_{z_0}^{0} \frac{dz}{v_z(z)} \]

\[ v = \mu * E \]

Since the static electric field is a linear function of position, depletion and bias voltages, and thickness, this is a simple analytic calculation.
Diffusion and Instantaneous Charge Expansion

\[ P(r, t) \propto \exp \left\{ -\frac{1}{4} \frac{r^2}{D_q(t + t_0)} \right\}, \quad \quad D_q = \left( \frac{kT}{q} \right) \mu_h \]

- Diffusion smears charge in Gaussian form with variance \(2(D \cdot t_{drift})\)
- Instantaneous charge expansion can be parameterized as offset (0.65 ns) to drift time (cf. Belau et al.)
- Integrated signals simply error functions of cell boundaries
Fractional distribution of charge among strips for straight-through, \(<\text{min-i}\)> tracks due to diffusion, charge expansion, and B-field (5T) deflection. (No capacitive coupling.)

<table>
<thead>
<tr>
<th>s (μm)</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>-24.5</td>
<td>0%</td>
<td>4.5%</td>
<td>85.7%</td>
<td>9.8%</td>
<td>0%</td>
</tr>
<tr>
<td>0.0</td>
<td>0%</td>
<td>0%</td>
<td>44.8%</td>
<td>55.2%</td>
<td>0%</td>
</tr>
<tr>
<td>24.5</td>
<td>0%</td>
<td>0%</td>
<td>5.3%</td>
<td>86.7%</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

Cell width of 50μm, bulk thickness of 300μm. Noise is omitted.

However, these are mean values—non-uniformity of deposition patterns cause fluctuations that we would like to retain in a Monte Carlo detector simulation.
To first order, this simulation can just be wrapped up and integrated into the Monte Carlo of the LC detector.

The major issue is of energy conservation within events: if total event deposition energy is provided by Geant4, Landau fluctuations at the sub-bulk level are lost.

Solution being developed is to modularize the simulation, and for min-i events match the total deposition energy at the 1% probability level.

This means we flatten the Landau distribution, and rethrow slab depositions until there is a bin-match between the bulk total and the Geant4 input.

Result is energy conservation to ~0.5% for typical min-i tracks.
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Present Status

- SCIPP has begun an R&D program with current efforts on both simulation and hardware prototypes (chip fab. on the way)
- The SCIPP long shaping time simulation is being incorporated into the LC Geant4 Monte Carlo project at SLAC
- Simulation code is being modularized/customized for SLAC group’s application