New LDC optimization studies based on the “LiC Toy tool”

Interplay of TPC and SET: influence on the momentum resolution, and complementary study on the effectiveness of the SIT

ILD Workshop, DESY-Zeuthen, 14–16 Jan. 2008

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presented by W. Mitaroff

Why fast simulation?

- **Not intended to replace full simulation, but to achieve quick response to local detector modifications**
- Simple to use, even by non experts
- Doesn't demand much preparation time
- Quick results, can be installed on a laptop
- Differences between various detector setups can be resolved quickly
- **Human readable, simplified detector description should be standardized** (contents see slide at the end)

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The LiC Detector Toy Software

- Simple, but flexible and powerful tool, written in MatLab
- Detector design studies
  - Geometry: cylinders (barrel) or planes (forward/rear)
  - Material budget, resolutions, inefficiencies
- Simulation
  - Solenoid magnetic field, helix track model
  - Multiple scattering, measurement errors and inefficiencies
  - *No further corruption, therefore no pattern recognition*
  - Strips and pads, uniform and gaussian errors (in TPC with diffusion corr.)
- Reconstruction
  - Kalman filter
  - *Optimal linear estimator according to Gauss-Markov (no corruption)*
  - Fitted parameters and corresponding covariances at the beamtube
- Output
  - Resolution of the reconstructed track parameters inside the beam tube
  - Impact parameters (projected and in space)
  - Test quantities (pulls, χ^2, etc.)

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Basic detector description (VTX, SIT)

Description	Beam pipe	Vertex detector (VTX)					Inner tracker	
Name	XBT	VTX1	VTX2	VTX2	VTX4	VTX5	SIT1	SIT2
R [mm]	14	16	26	37	48	60	150	290
z_{max} [mm]		50	120	120	120	120	200[*]	390[*]
z_{min} [mm]		-50	-120	-120	-120	-120	-200[*]	-390[*]
Stereo angle		(π/2)	(π/2)	(π/2)	(π/2)	(π/2)	0°/10°	0°/10°
d [X_0]	0.0025	0.002	0.002	0.002	0.002	0.002	0.0175	0.0175
Pitch [μm]	passive	25x25	25x25	25x25	25x25	25x25	50/50	50/50
Remarks		pixels	pixels	pixels	pixels	pixels	strips	strips

[*]: For this study, values changed w. r. t. the layout defined in the DOD, in order to cover the range θ > 39°

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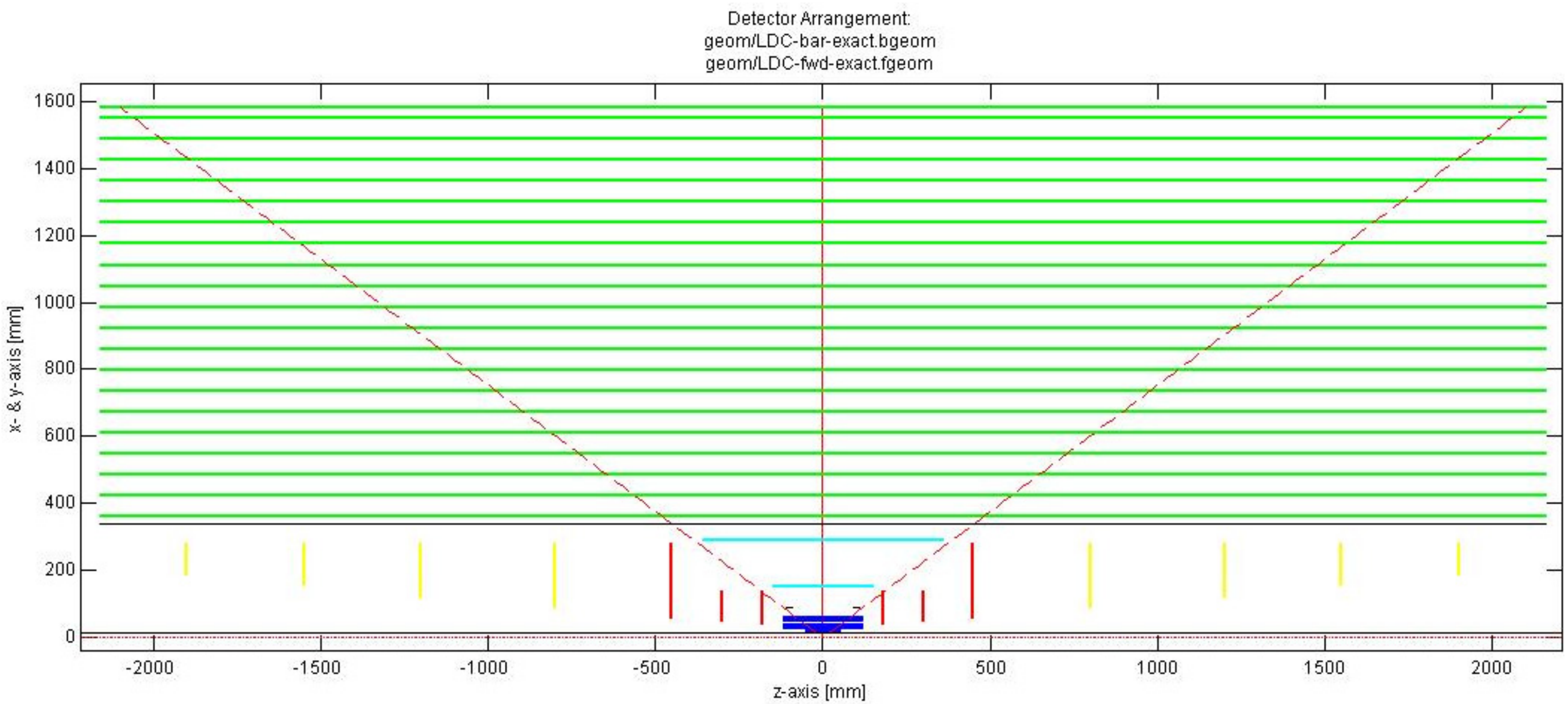
Basic detector description (TPC)

<table>
<tr><td>Description</td><td>Inner wall</td><td colspan="3">196 pad rings, or GEMs</td></tr>
<tr><td>Name</td><td>XTPCW1</td><td colspan="3">TPC1-TPC196</td></tr>
<tr><td>R [mm]</td><td>340</td><td colspan="3">362 – 1580</td></tr>
<tr><td>z_{max} [mm]</td><td>2160</td><td colspan="3">2160</td></tr>
<tr><td>z_{min} [mm]</td><td>-2160</td><td colspan="3">-2160</td></tr>
<tr><td>d [X_0]</td><td>0.01</td><td colspan="3">0.0000125 (for each layer)</td></tr>
<tr><td rowspan="4">Errors [μm]
$\sigma=\sqrt{(\sigma_1^2+\Delta z[m]*\sigma_2^2)}$</td><td rowspan="4">passive</td><td></td><td>σ_1 (pad size)</td><td>σ_2 (diffusion)</td></tr>
<tr><td rowspan="2">RΦ</td><td>Case 1: 50[1]</td><td rowspan="2">350[2] [$\mu m/m^{1/2}$]</td></tr>
<tr><td>Case 2: 2000/√12[2]</td></tr>
<tr><td>z</td><td>15</td><td>5800 [$\mu m/m^{1/2}$]</td></tr>
</table>

[1]: M. Dixit et al., Micromegas TPC studies at high magnetic fields using the charge dispersion signal, VCI 2007, p. 254
[2]: P. Colas, I. Giomataris, V. Lepeltier, M. Ronan, First test of a Micromegas TPC in a magnetic field, VCI 2004, p. 181

Display of basic detector description



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THIS STUDY

- **Basic setup:**
  - VTX, extended SIT, TPC*)
- **Modifications:**
  - Variant 1: VTX, extended SIT, TPC*), **SET**
  - Variant 2: VTX, TPC*) **(no SIT, no SET)**
- **Studies:**
  - Study 1: Compare variant 1 with basic setup
  - Study 2: Compare variant 2 with basic setup

*) TPC: case 1, case 2

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Modifications, variant 1: adding a silicon external tracker (SET)

(VTX, SIT and TPC see above)

Description	TPC outer wall	External tracker	
Name	XTPCW2	SET1	SET2
R [mm]	1600	1610	1620
z_{max} [mm]	2160	2160	2160
z_{min} [mm]	-2160	-2160	-2160
Stereo angle		0°/10°	0°/10°
d [X_0]	0.02	0.001	0.001
Pitch [μm]	passive	70/70	70/70
Remarks		strips	strips

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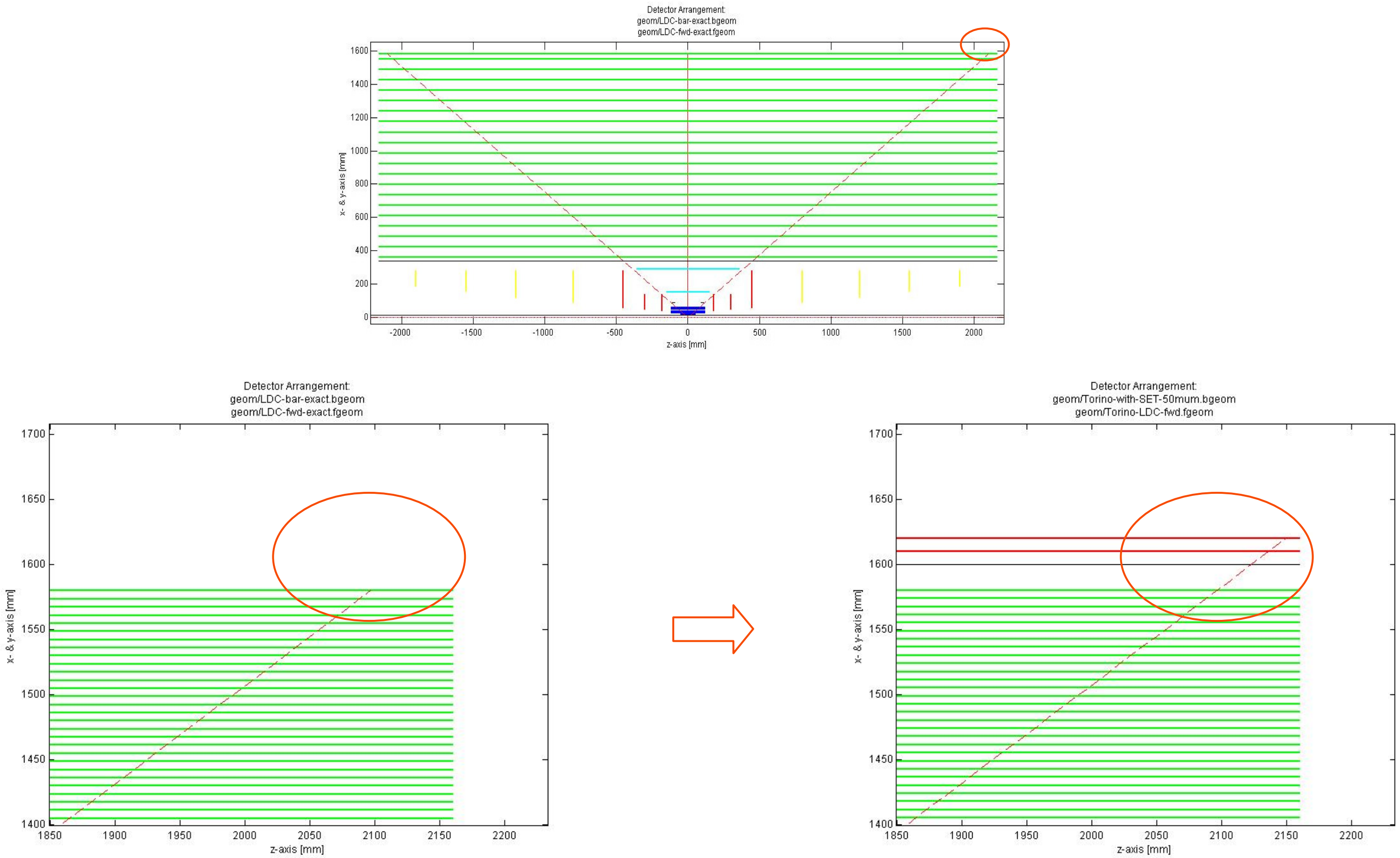
Display of modifications, variant 1: adding a silicon external tracker (SET)



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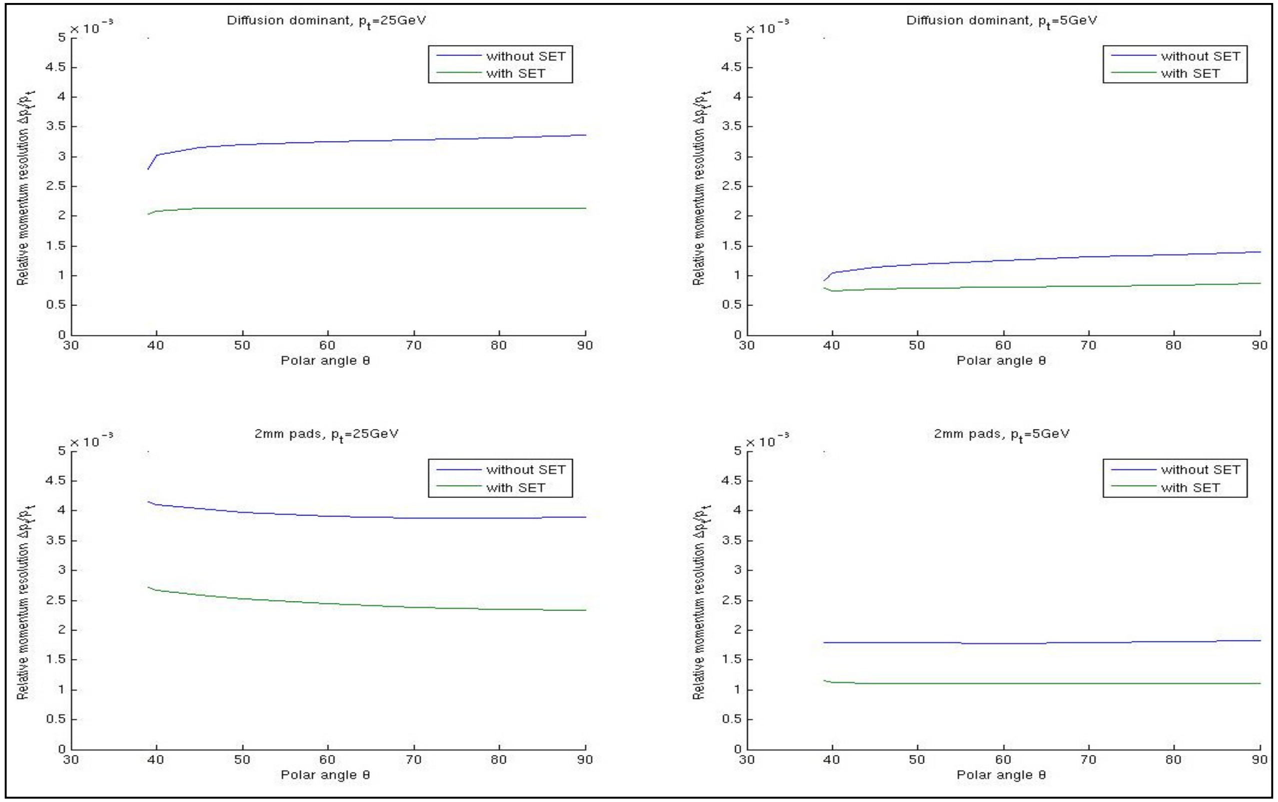
Effect of adding the SET

Comparison of modification variant 1 with basic setup

P_t = 25 GeV P_t = 5 GeV

Case 1:
Diffusion dominant
(σ_1=50 [μm]
σ_2=350 [μm/√m])

Case 2:
2mm pads
(σ_1=2000/√ 1 2
[μm]
σ_2=350 [μm/√m])



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Modifications, variant 2: remove the silicon inner tracker (SIT)

Description	Inner tracker	
Name	SIT1	SIT2
R [mm]	150	290
z_{max} [mm]	200	390
z_{min} [mm]	-200	-390
Stereo angle	0°/10°	0°/10°
d [X_0]	0.0175	0.0175
Pitch [µm]	50/50	50/50
Remarks	strips	strips

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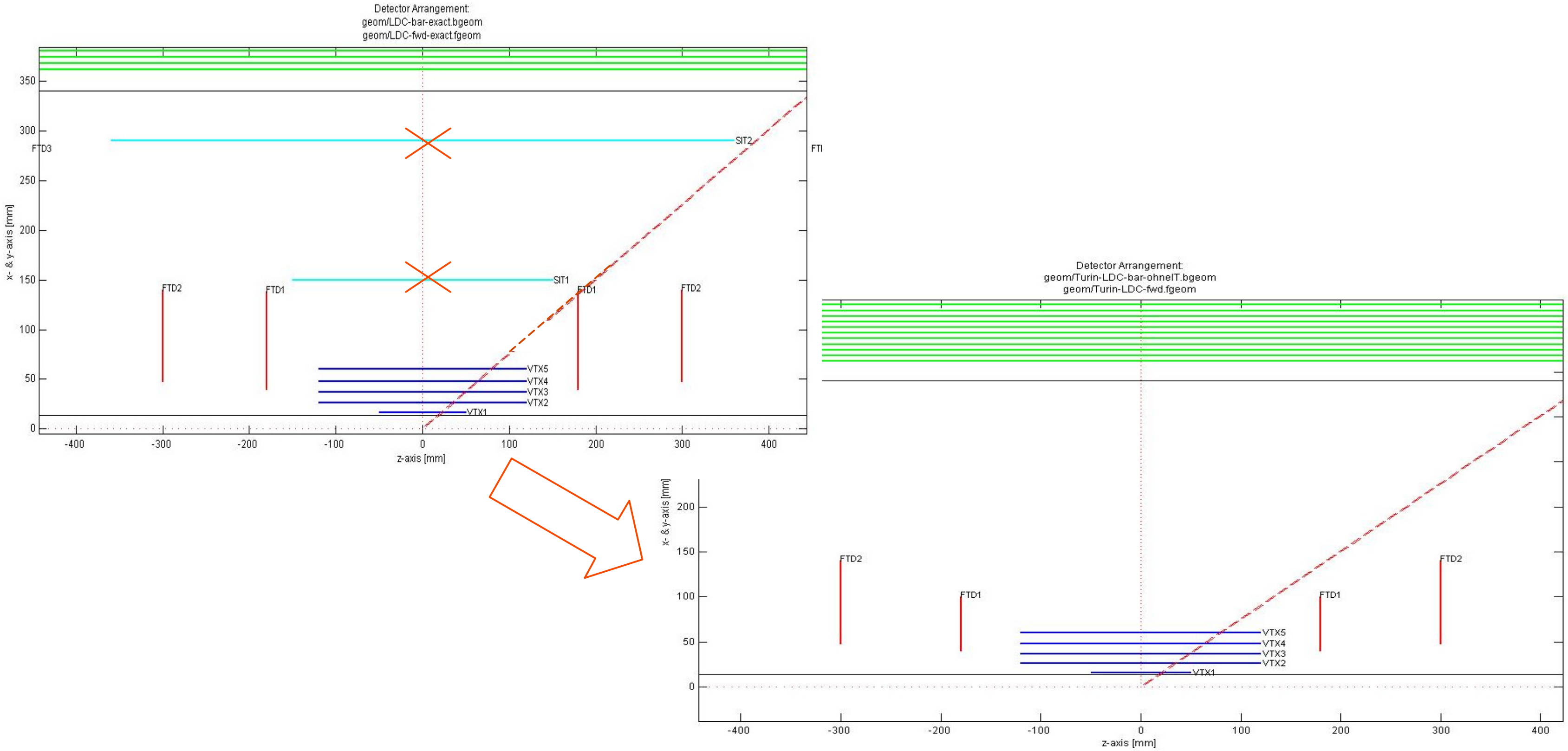
Modifications, variant 2:
remove the silicon inner tracker (SIT)



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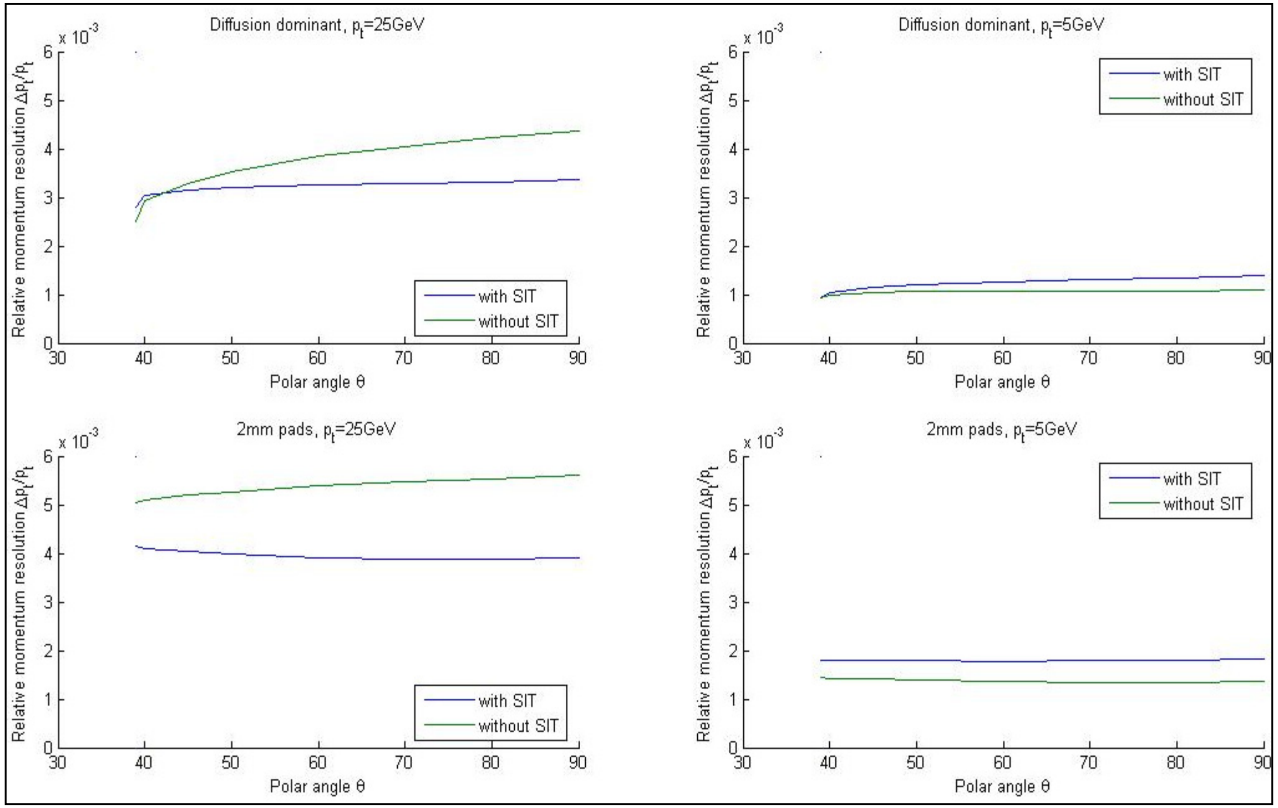
Effect of removing the SIT

Comparison of modification variant 2 with basic setup

$P_t = 25$ GeV — $P_t = 5$ GeV

Case 1:
Diffusion dominant
(σ_1=50 [μm]
σ_2=350 [μm/√m])

Case 2:
2mm pads
(σ_1=2000/√12 [μm]
σ_2=350 [μm/√m])



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Remarks on general behaviour

- The momentum resolution improves when approaching the endplate of the TPC (small θ) because of the suppression of the diffusion effect. However, multiple scattering gains a stronger influence.
- In case of pad readout the z dependence is suppressed by the poor performance of the pad pitch.
- The greatest impact of poor resolution has of course been observed for high momentum tracks.

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Conclusions on SET (study 1)

- Including the silicon external tracker (SET) improves the momentum resolution over the full angular range. This is of course especially relevant for high momentum.
- As expected, the results show slightly better momentum resolution for tracks near the endplate, where diffusion is less important. Nevertheless, the SET should cover the full length of the TPC.
- For endplates with 2mm pads the SET is a must.
  - Resolution improvements like charge spreading by a resistive foil and calculating the barycenter, are under discussion.

Conclusions on SIT (study 2)

- Removing the silicon inner tracker:
  - At 5 GeV the information gain of the SIT and the information loss due to multiple scattering compensate.
  - Simulation at 25 GeV shows clearly that the information obtained from the SIT is missing.
  - This is less obvious for optimal resolution at the endplate (GEM), but for poor resolution (2mm pads) this is crucial.

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DETECTOR DESCRIPTION FOR FAST SIMULATION

- Parallel to full detector description, define a basic detector description, limited to cylinders in the barrel and planes in the forward region.
- It should serve as a starting point for local detector studies of the trackers.
- Without agreement on a common starting version results of different detector optimization studies will never be comparable.
- Increases productivity and yields useful and comparable results, which may subsequently be refined by full simulation.
- The studies shown above can be reproduced within a few hours! For a demonstration please contact the authors.

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ILD basic detector description

Vertex Detector (VTX)

Radius									
z_{min} / z_{max}									
Φ_{min} / Φ_{max}									
Efficiency RΦ / z									
Stereo angle									
Xlen									
Pixels, Strips									
Errors RΦ / z									
function $\sigma(\theta,\beta)$									
function σ(clustersize)									

Silicon Inner Tracker (SIT)

Radius									
z_{min} / z_{max}									
Φ_{min} / Φ_{max}									
Efficiency RΦ / z									
Stereo angle									
Xlen									
Pixels, Strips									
Errors RΦ / z									
function $\sigma(\theta,\beta)$									
function σ(clustersize)									

Time Projection Chamber (TPC) $\sigma=\sqrt{(\sigma_1^2+\Delta z[m]*\sigma_2^2)}$

# layers	R_{min}	R_{max}	z_{min}	z_{max}	Eff. RΦ	Eff. z	Xlen (per layer)	σ_1 (RΦ)	σ_1 (z)	σ_2 (RΦ)	σ_2 (z)

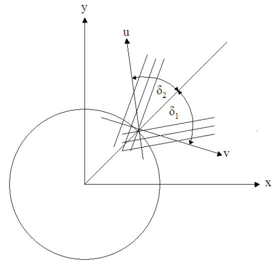
Silicon External Tracker (SET, cylinder approximation)

Radius									
z_{min} / z_{max}									
Φ_{min} / Φ_{max}									
Efficiency RΦ / z									
Stereo angle									
Xlen									
Pixels, Strips									
Errors RΦ / z									
function $\sigma(\theta,\beta)$									
function σ(clustersize)									

Passive scatterers and support structures – barrel region

Radius									
z_{min} / z_{max}									
Φ_{min} / Φ_{max} (VTX)									
Xlen									

Definition of fwd/bwd coordinates:



Forward Layers

z position										
R_{min} / R_{max}										
Φ_{min} / Φ_{max}										
Efficiency u / v										
Coord. angle δ_1 / δ_2										
Xlen										
Pixels, Strips										
Errors u / v										
function $\sigma(\theta,\beta)$										
function σ(clustersize)										

Backward Layers

z position										
R_{min} / R_{max}										
Φ_{min} / Φ_{max}										
Efficiency u / v										
Coord. angle δ_1 / δ_2										
Xlen										
Pixels, Strips										
Errors u / v										
function $\sigma(\theta,\beta)$										
function σ(clustersize)										

Passive scatterers and support structures – fwd/bwd region

z position										
R_{min} / R_{max}										
Xlen										

Mini workshop in Vienna?

- Suggest to set up a small ad-hoc working group (a few key persons) for LDC/ILD optimization, based on fast simulation.
- Goal: agree on a basic detector description.
- Invitation to an OPTIMIZATION "brain-storming jamboree" in Vienna (2-3 days in February or March 2008).

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LiC Detector Toy on the web

http://stop.itp.tuwien.ac.at/websvn/

=> lictoy

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