SiLC Simulation Status Report

an 18 minute, incomplete overview

M.Vos, IFIC Valencia, for the SiLC collaboration

What's SiLC?

Silicon for the **L**inear **C**ollider

As a truly “horizontal” R&D collaboration, SiLC members are from three continents, and are involved in LDC, SiD and GLD.

aims: to develop Silicon detector technology for tracking in the international linear collider experiments. Core activities include Front End chip design, sensor development, (hardware) alignment, mechanics AND simulation studies.

More information: http://silc.in2p3.fr/

National Centre for Micro-electronics, IMB-CNM, Barcelona (Spain)
Giulio Pellegrini (giulio.pellegrini@cnm.es)

Obninsk State University (Russia)
Valeri Saveliev (saveliev@mail.desy.de)

LPNHE, Paris, France
Mikael Berggren (Mikael.Berggren@cern.ch)
Wilfrid Da Silva (dasilva@in2p3.fr)
Frederic Kapusta (kapusta@in2p3.fr)

IPNP Charles University, Prague, Czech Republic
Zbynek Drasal (drasal@ipnp.troja.mff.cuni.cz)
Peter Kodys (kodys@ipnp.troja.mff.cuni.cz)

UCSC – SCIPP, Santa Cruz, USA
Bruce Schumm (schumm@scipp.ucsc.edu)

HEPHY, Vienna, Austria
Winfried Mitaroff (mitaroff@hephy.oeaw.ac.at)
Meinhard Regler (regler@hephy.oeaw.ac.at)
Manfred Valentan (valentan@hephy.oeaw.ac.at)

IFIC Valencia, Spain
Angeles Faus (Angeles.Faus@ific.uv.es)
Carmen Alabau (Carmen.Alabau@ific.uv.es)
Carlos Mariñas (carlos.marinas.pardo@cern.ch)
Marcel Vos (marcel.vos@ific.uv.es)

Simulation Task Force mission statement: a better understanding of the requirements for the various aspects and regions of an ILC tracker will provide guidance and direction to the detector R&D

SiLC assets: fast simulation

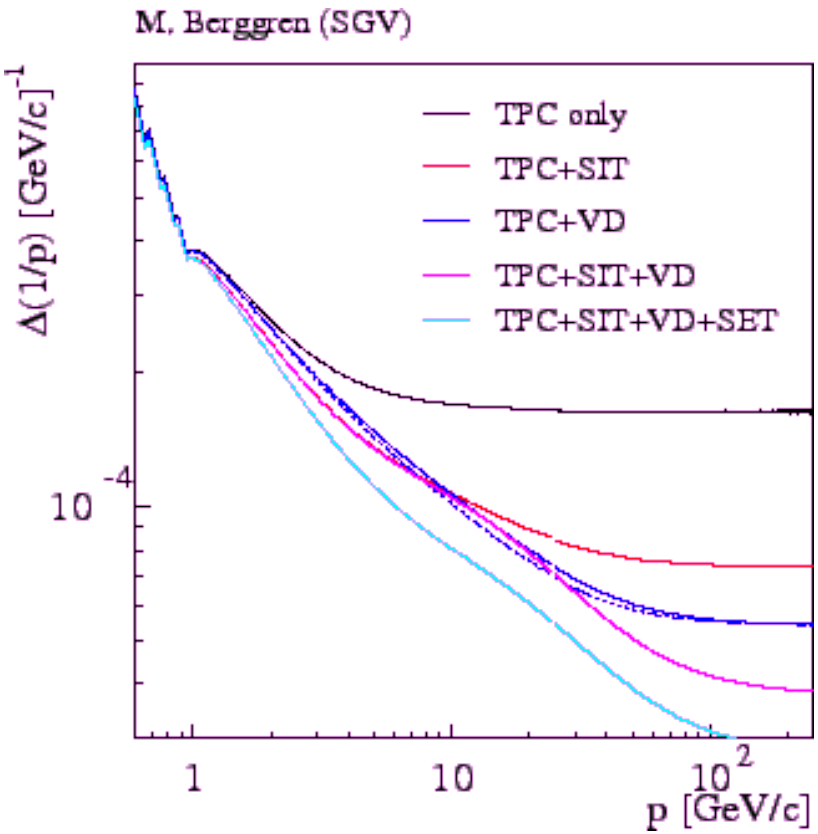
A basic understanding of the main design driver - track parameter estimate performance - is obtained by fast simulation:

SGV

LCDTRK

LiCToy (e.g. W. Mitaroff's presentation)

In 2007 we hope to complement the fast simulation picture by full simulation results.



SGV simulation (M. Berggren) of the LDC tracker central region.

http://silc.in2p3.fr/ Urgent simulation studies

(due by the end of 2007)

Tracking in mixed gas-silicon concepts. Especially important is the transition in the forward region between TPC and forward disks.

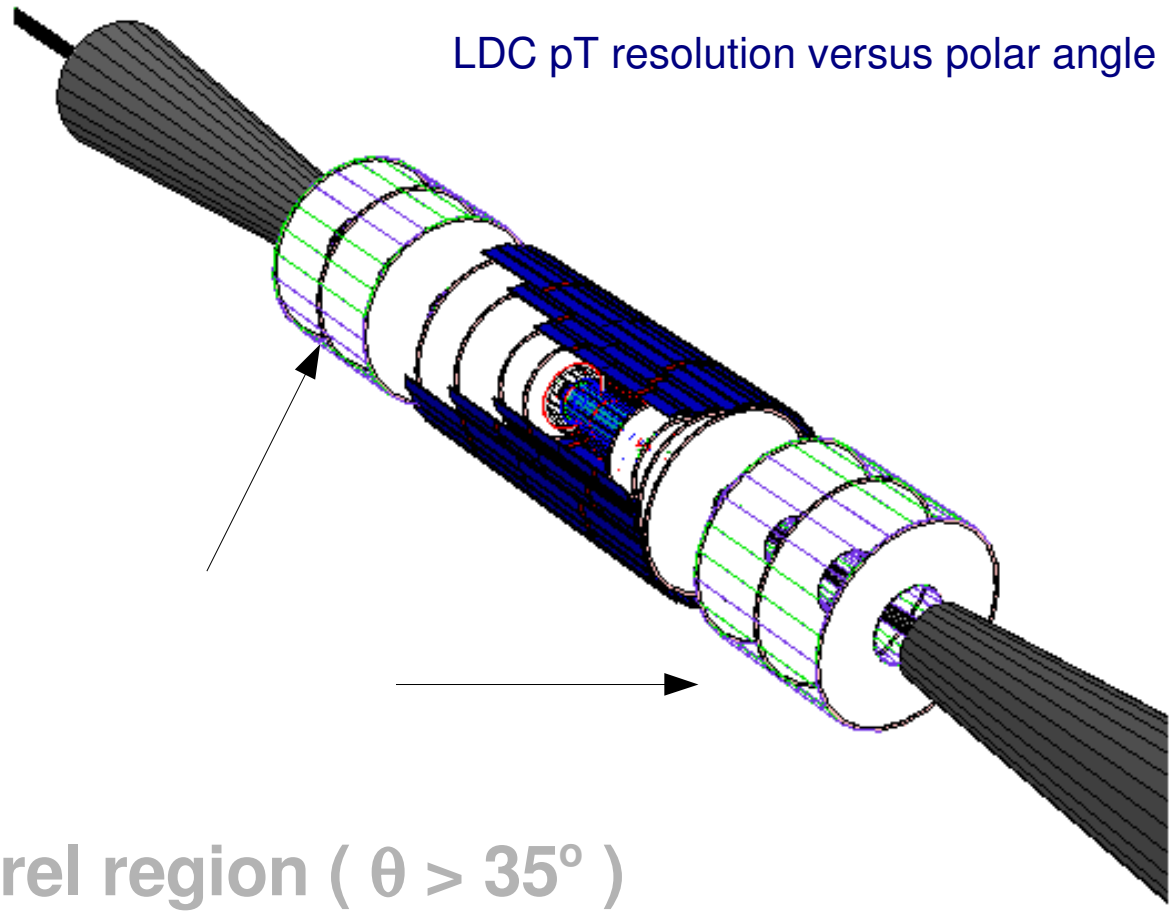
Machine and physics backgrounds and their impact on tracking in thevery forward and internal barrel regions. Study background levels in different detector, and study pattern recognition in the presence of this background.

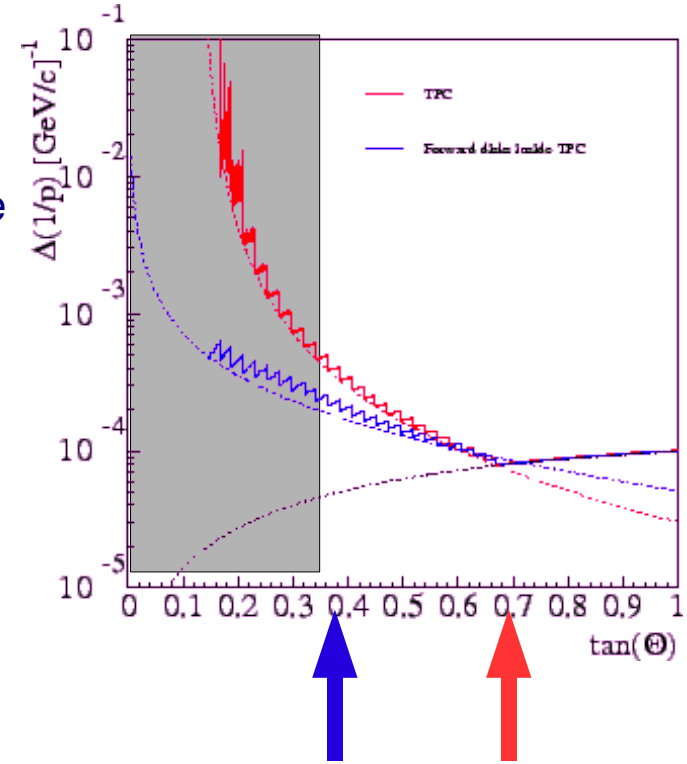
Pattern recognition the requirements that derive from pattern recognition are not well studied. This should tell us what granularity is needed in the different tracking regions to ensure that pattern recognition converges even for some of the toughest cases: in dense jet topologies and for non-prompt tracks.

Feedback to global layout optimization. Optimize the overall design based on physics requirements. Special attention to the material budget.

SGV simulation (M. Berggren) of the

LDC pT resolution versus polar angle





Barrel region ($\theta > 35^o$)

Forward region ($20^o < \theta < 35^o$)

Far forward region ($5^o < \theta < 20^o$)

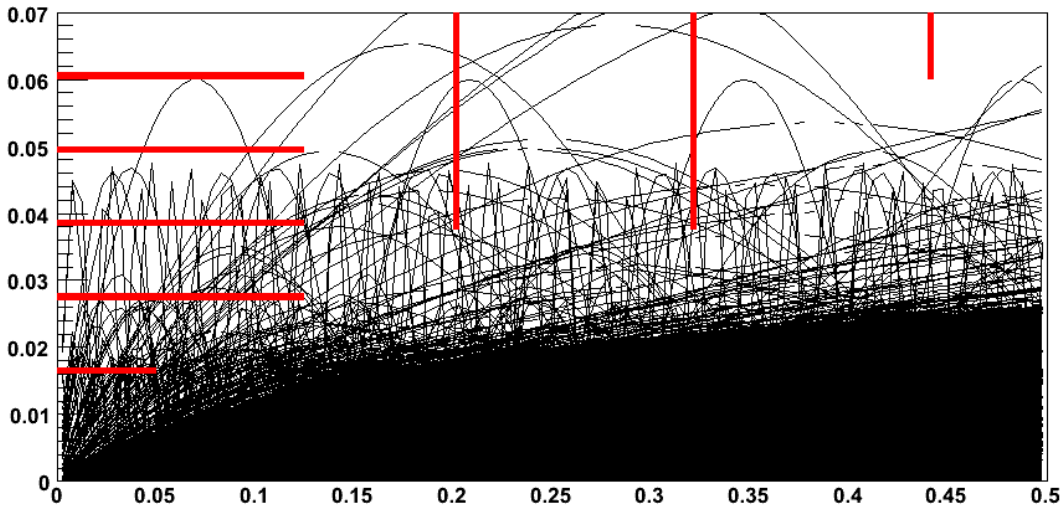
Regional idiosyncrasies: Far Forward

There are several motivations to single out the Far Forward region:

- **special physics (not the subject of this talk)**
- **“unfortunate” field orientation requires special effort to reach momentum resolution**
- **large occupancy from machine background**
- **relation to long barrel VXD: for low-angle tracks forward disks provide the innermost measurement.**
- **historical tendency to accumulate material**
- **relatively small size (especially of innermost layers)**
- **time stamp**

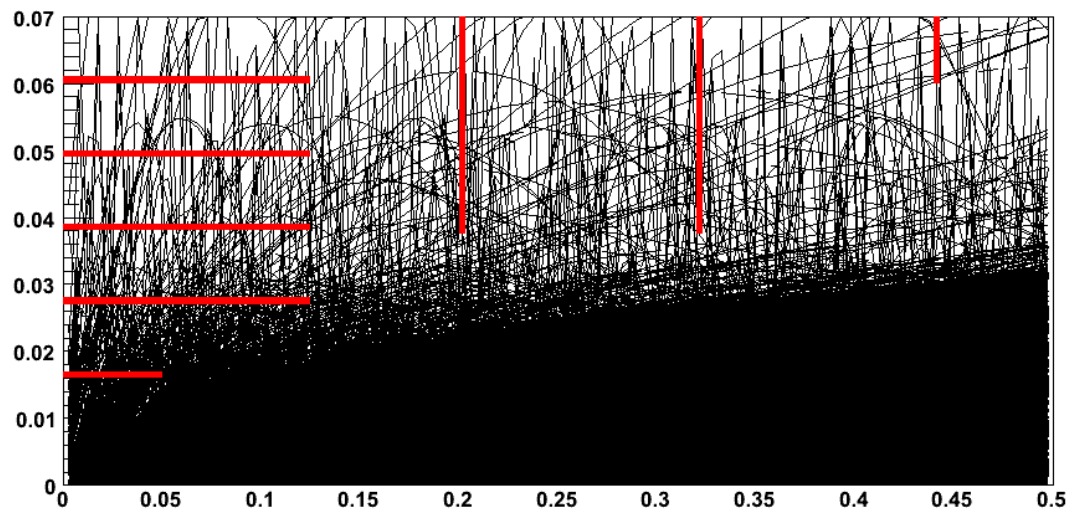
A dedicated study is ongoing to determine the tracker requirements in the Far Forward region. A SiLC document to be expected by the end of 2007.

Fast (simple helix) simulation of pair background as it comes out of Guinea Pig (thanks to Cecile Rimbaud)



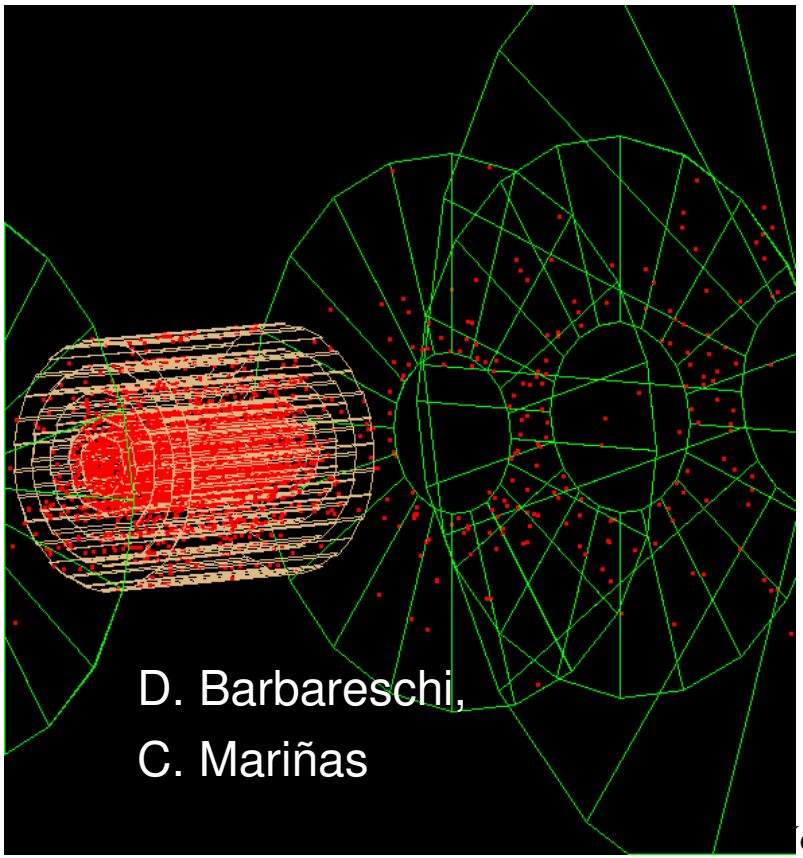
NOMINAL

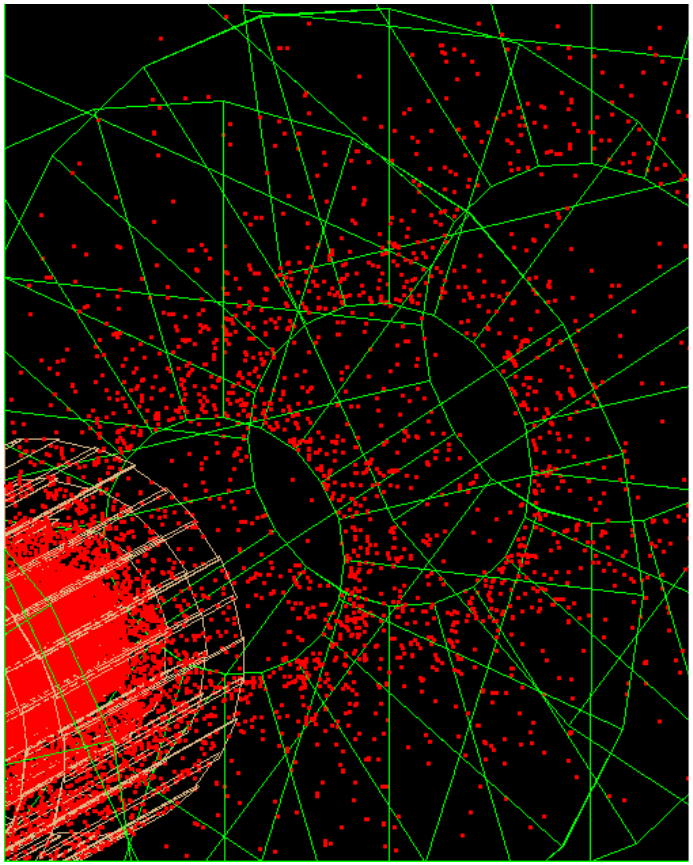
LOW-P



Fast (simple helix) simulation of pair background as it comes out of Guinea Pig

14 BX



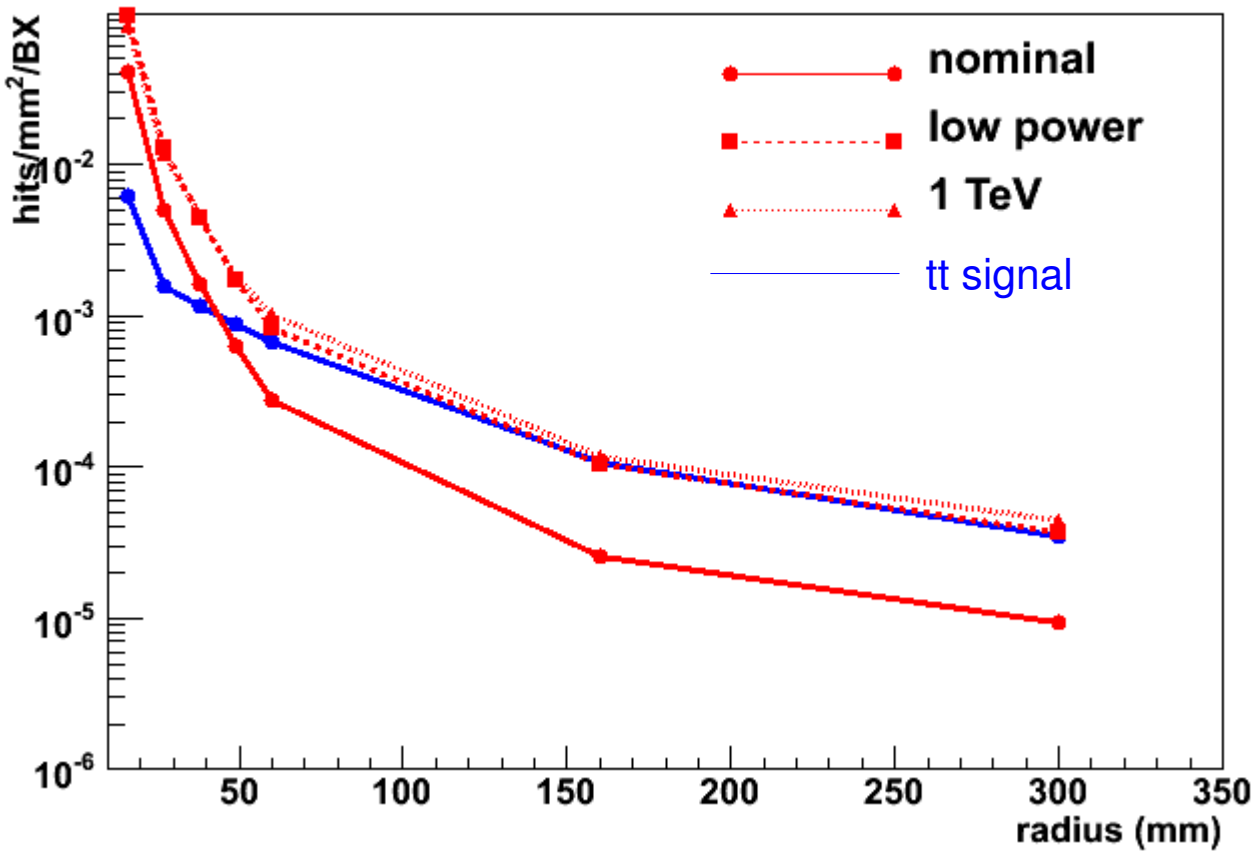


140 BX

Machine background: central tracker

Dense signal topology (tt events)

Pair production background due to beamstrahlung, (GUINEAPIG and Mokka simulation by A. Vogel)



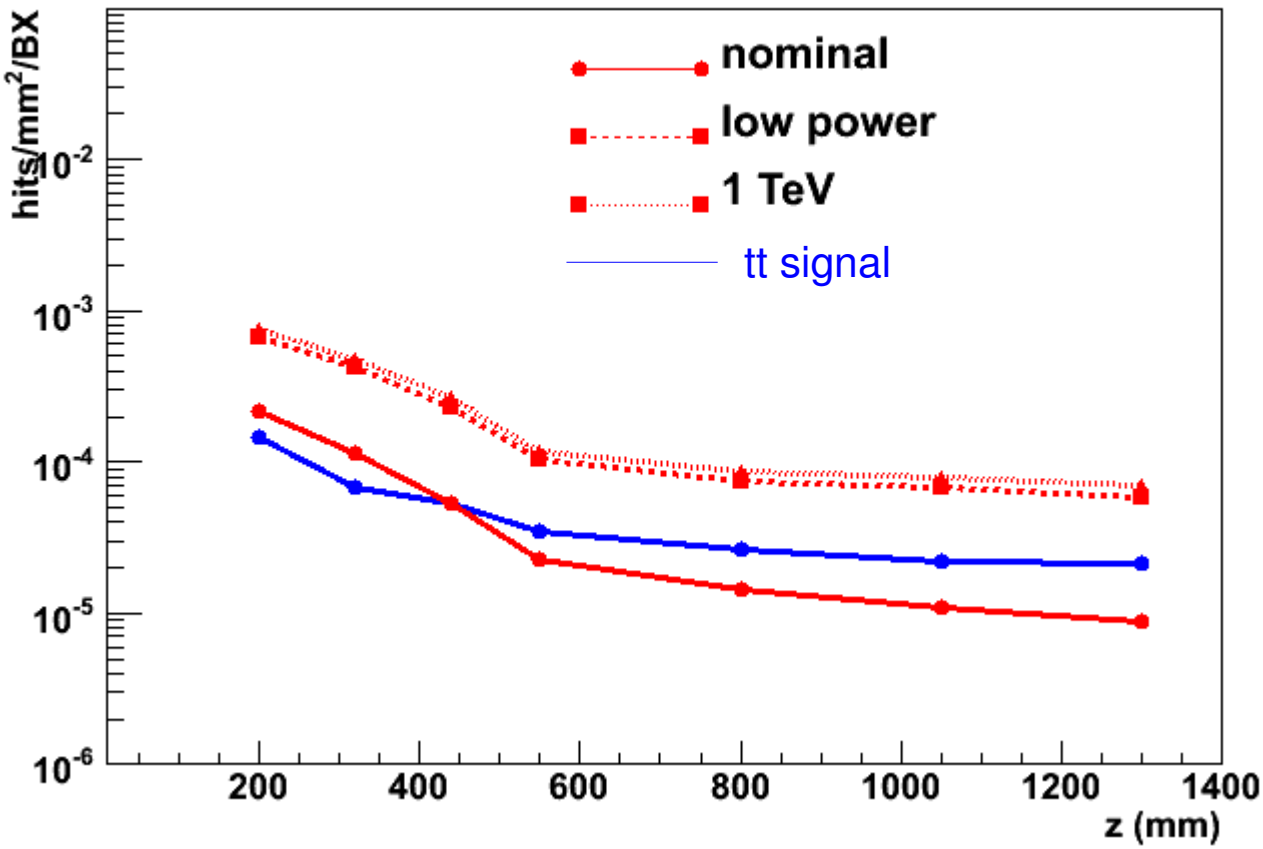
NOTE: low power option has double BX spacing

SIT hit density due to pair bkg an order of magnitude below that of outermost VXD layer (but cell size is of the order of 50 μm x 10 cm, 3 orders of magnitude larger)

Machine background: forward tracker

Dense signal topology (tt events)

Pair production background due to beamstrahlung, (GUINEAPIG and Mokka simulation by A. Vogel)



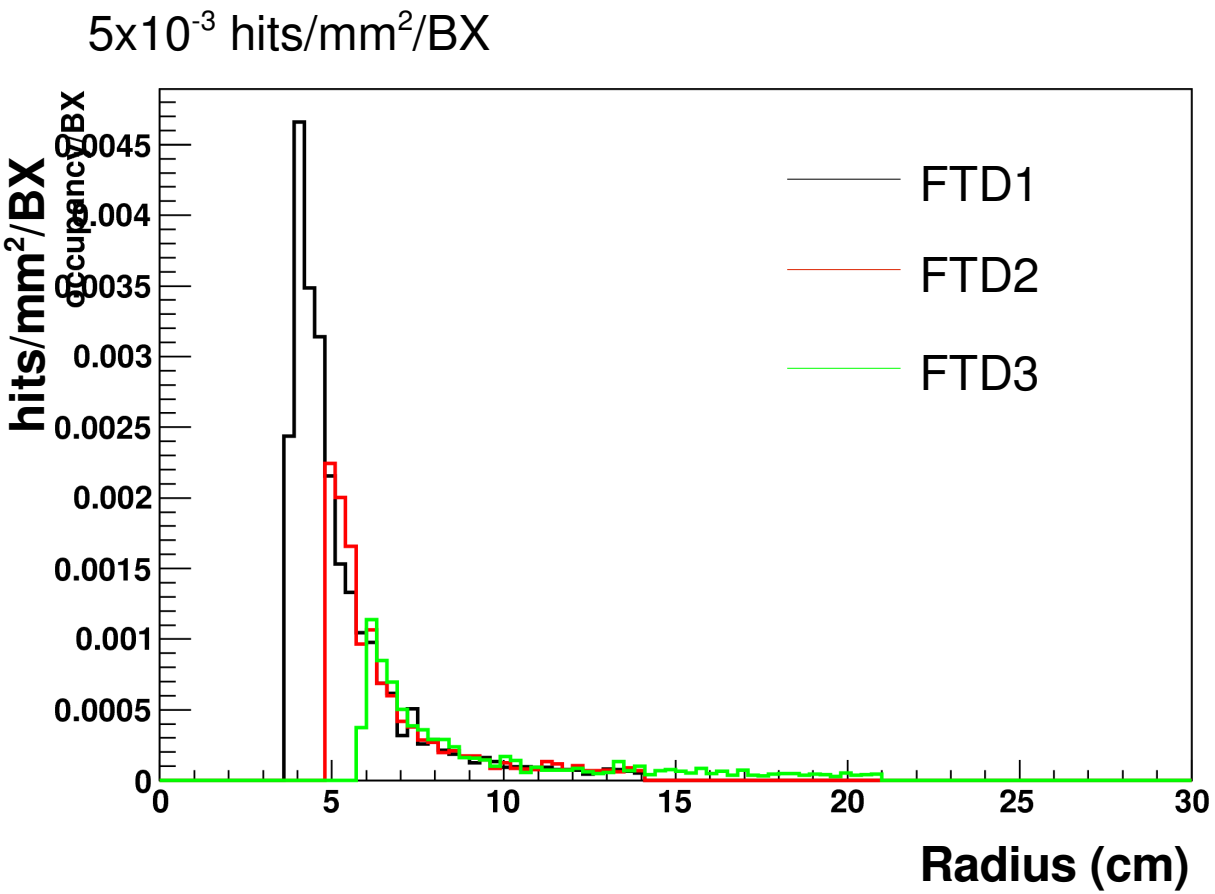
NOTE: low power option has double BX spacing

Inner rings of first 3 FTD disks suffer large hit density from pair bkg.

Machine background: forward tracker

Occupancy due to background highly non-uniform

On innermost ring locally an order of magnitude larger



Machine Background

Effect of machine parameters on background levels in different sub-systems

	Low power(*)	1 TeV
VTX	+20-50%	x2-2.5
SIT	x 2	x4
FTD	x 2	x 4

(*) per unit time, corrected to accomodate for factor 2 (BX frequency)

Sub-detector	% direct hits
VXD	73% (layer 1) - 55% (layer 5)
SIT	29 % (layer 1) - 26% (layer 2)
FTD	54 % (disk 2) - 40 % (disk 7)

Average background level in FTD1-3 ~ 10^{-4} hits/mm^2/BX (nominal)

locally an order of magnitude higher (inner ring FTD1-3

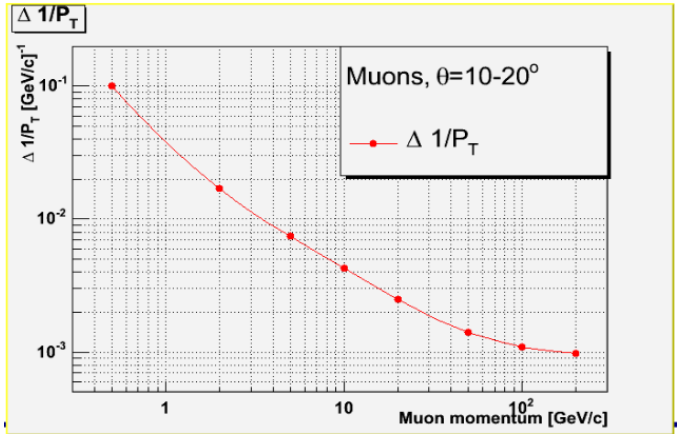
strongly dependent on machine parameters

over half of the hits due to backscatters

Far forward tracking: material budget

Transverse momentum resolution under stress from magnetic field orientation. Historically, forward tracking performance has been compromised even further by accumulation of material (services)

A. Raspereza, momentum performance of FullLDCTracking, yesterday's Simu/Reco meeting



Toy model, quite similar to a track at 20 degrees in LDC

Material: momentum resolution of a toy tracker in a 4 Tesla field:

- 3 VXD barrel layers (1.1 cm R spacing, 1.2 per mil X_0, 2 micron resolution in Rϕ, z)
- 3 pixel tracking disks (12 cm z spacing, 1.2 per mil/1.2 % X_0, 5 μm resolution in Rϕ, 50 μm in R)
- 4 DS strip tracking disks (25 cm z spacing, 8 per mil X_0, 10 μm resolution in Rϕ, 1 μm in R)

Far forward tracking: material budget

CMS KF track fit for θ = 20°

$\sigma(p_T)/p_T^2 = 1.8 \times 10^{-4} + 4.0 \times 10^{-3}/p_T$ *for 0.12 % X_0 FTD1-3*

$= 2.0 \times 10^{-4} + 5.8 \times 10^{-3}/p_T$ *for 1.2 % X_0 FTD1-3*

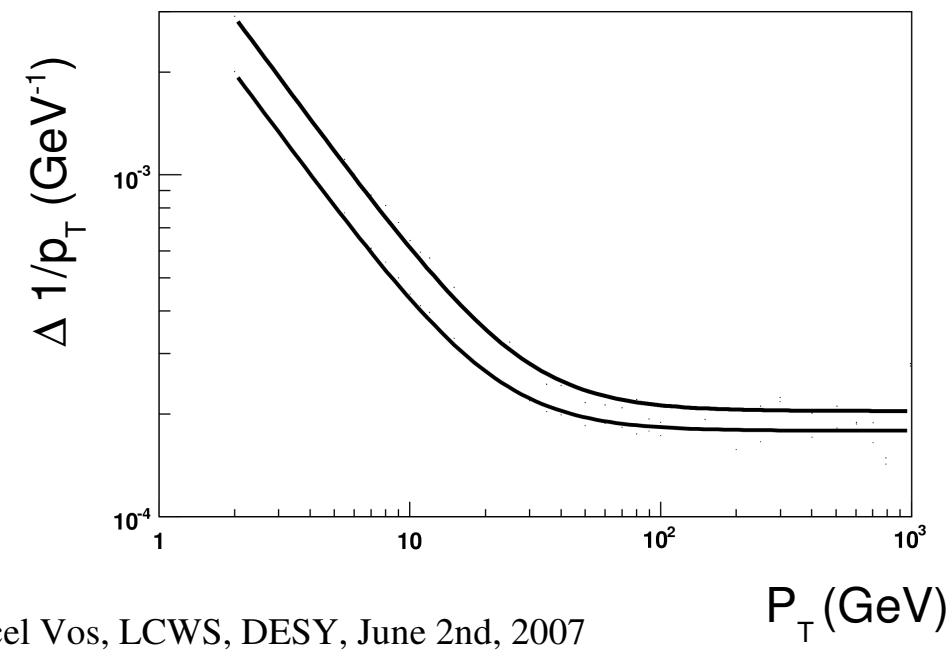
LiCToy (demonstrator version of Vienna instrumentation conference)

$\sigma(p_T)/p_T^2 = 1.8 \times 10^{-4} + 4.3 \times 10^{-3}/p_T$ *for 0.12 % X_0 FTD1-3*

$= 1.9 \times 10^{-4} + 6.2 \times 10^{-3}/p_T$ *for 1.2 % X_0 FTD1-3*

CMS KF fit on toy geometry (see previous slide for parameters)

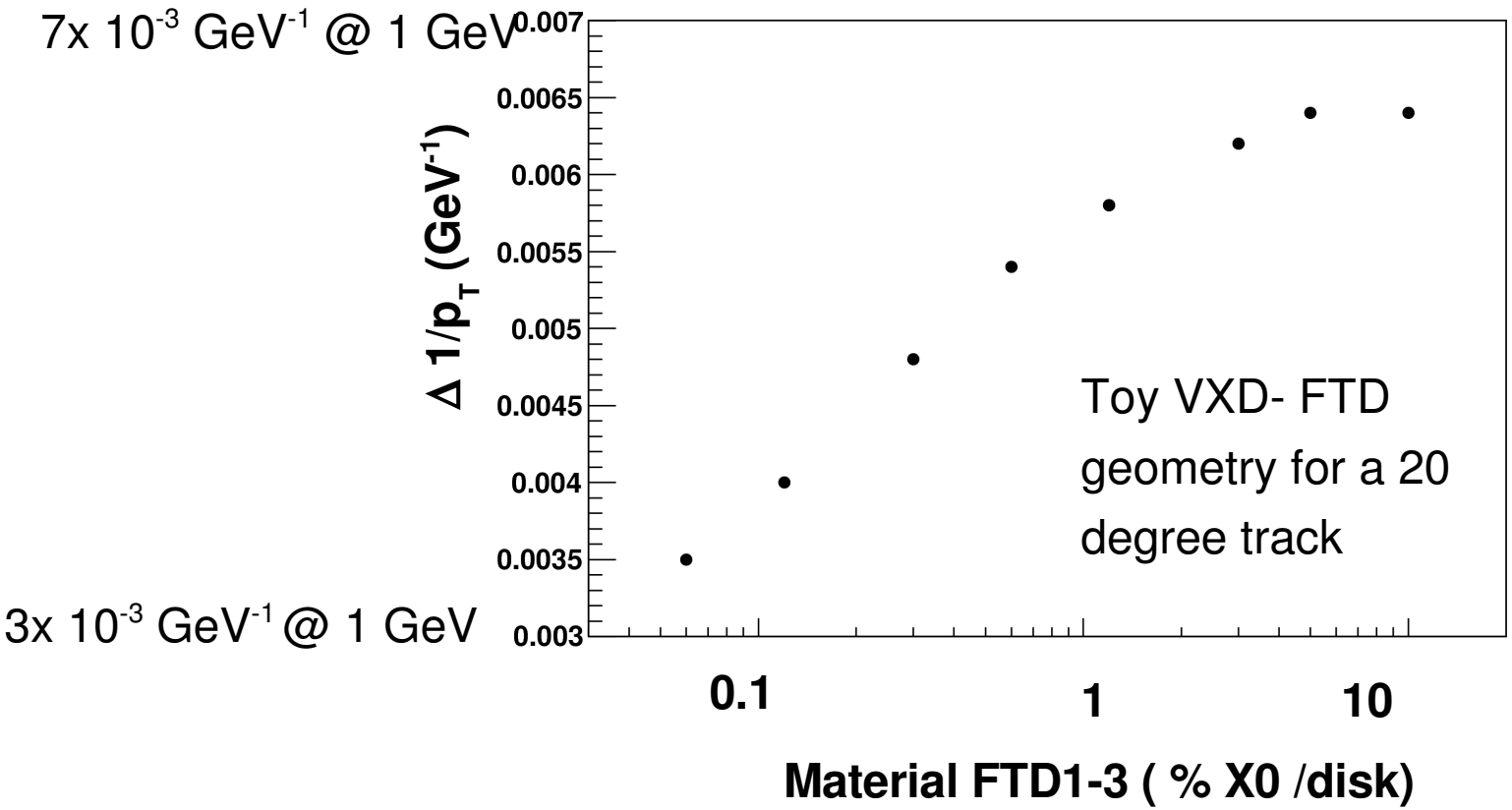
Want to see this in full simulation.
Want to see the effect of material on particle flow.



Far forward tracking: material budget

Impact of the material in the first three FTD disks on the tracking performance of low momentum tracks. Same setup as on previous slide. Track at 20 degrees polar angle.

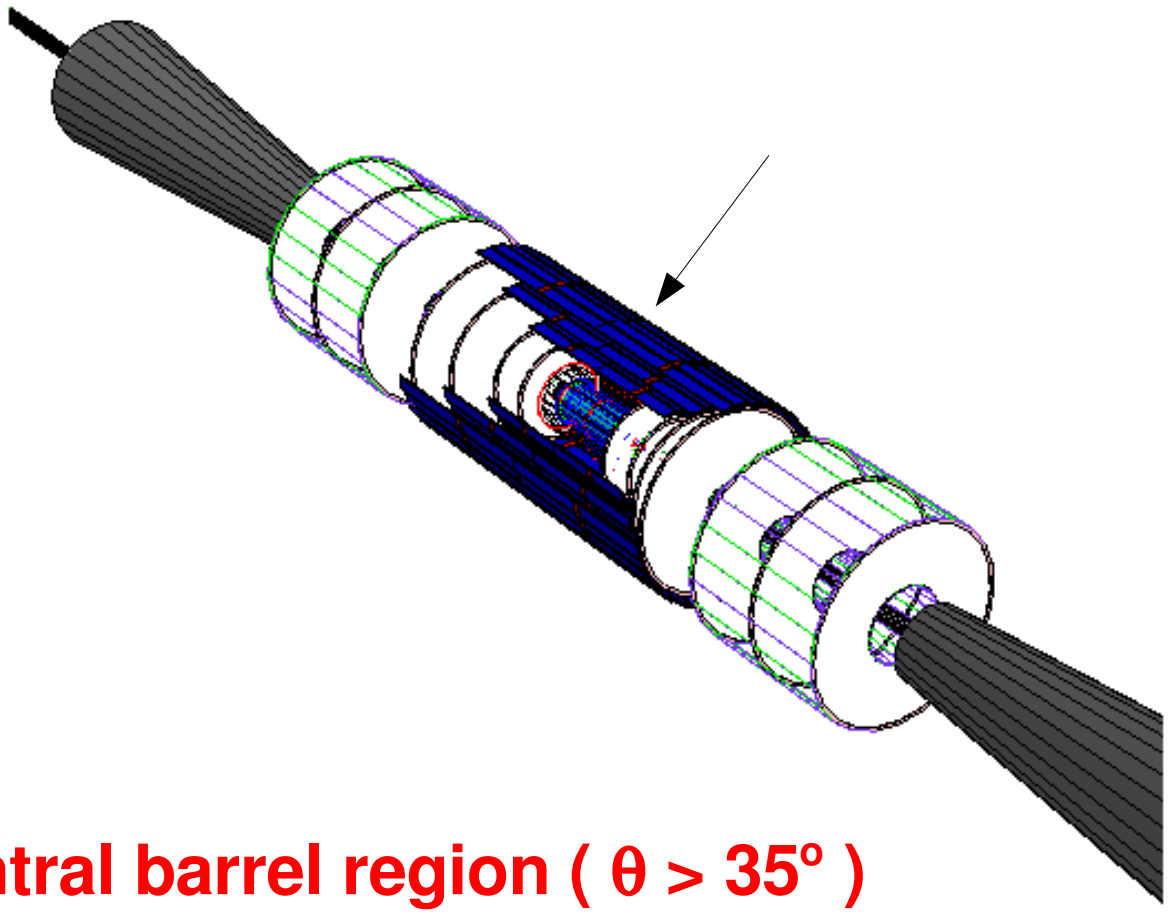
Vary material per layer from rather optimistic (factor two better than VXD layers) to disastrous (10% X_0).

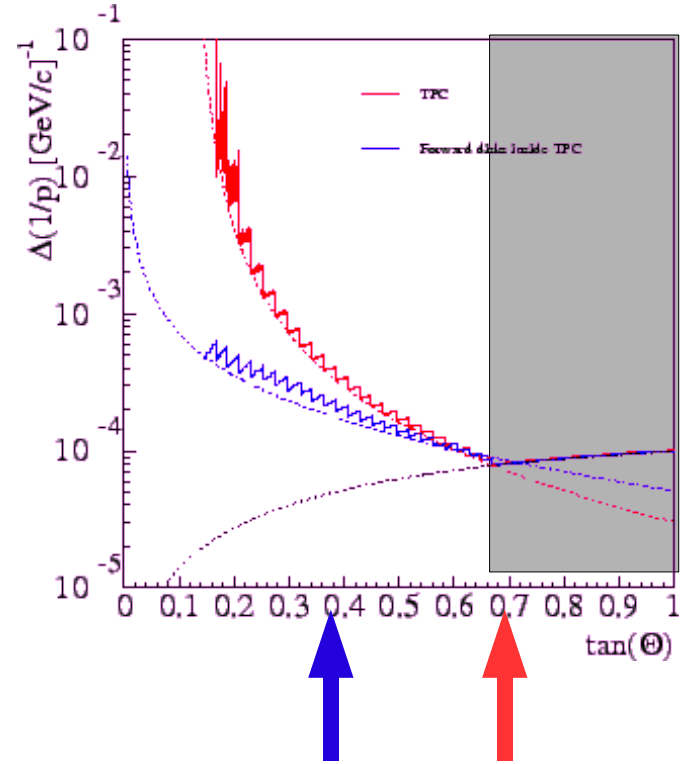


Far forward tracking

Machine background cannot be ignored (with the usual consequences for read-out speed and/or segmentation)

Parameter scan (δ (performance) / δ (material)) identifies material in FTD1-3 as a crucial parameter for momentum resolution of low momentum tracks. Much can be gained (or lost). Need a more detailed momentum resolution specification (based on physics, of course) to translate into detector requirements.





Central barrel region (θ > 35°)

Forward region (20° < θ < 35°)

Far forward region (5° < θ < 20°)

Regional idiosyncrasies: inner central

In GLD, LDC, SiD the thing a track sees after leaving the central VXD is more silicon.

	# layers	radii (cm)	baseline technology
GLD	4	9, 18.5, 28.0, 37.5	Double Sided μ-strips
LDC	2	16,30	Double Sided μ-strips
SiD	5	22, 47, 72, 97, 122	Single Sided μ-strips

In mixed solid-gaseous tracker concepts, the Inner Central Tracker provides the "connection" between VXD and TPC

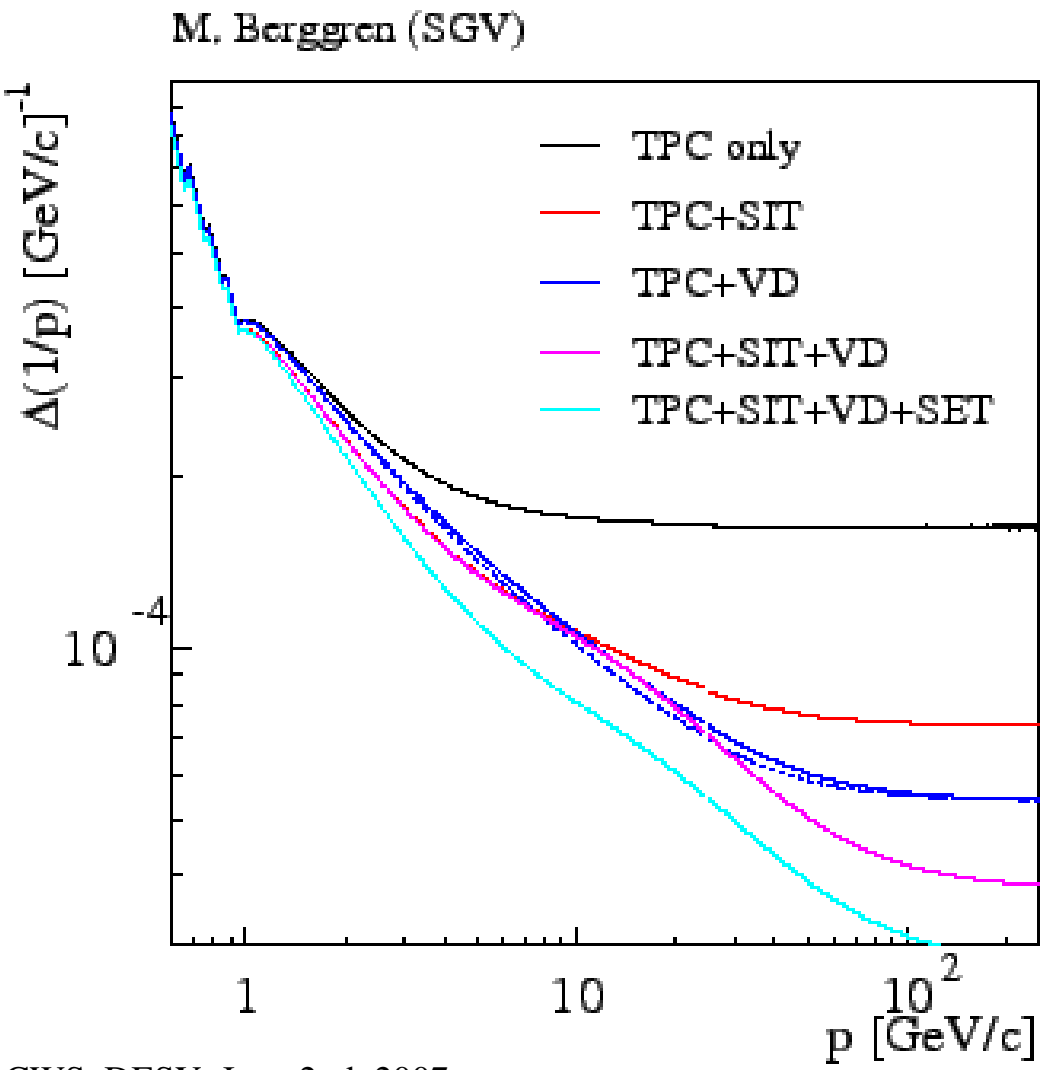
The innermost central tracker layers plays the role of a pattern recognition "tail catcher" for tracks not reconstructed in the VXD (non-prompt tracks) or outer tracker (low momentum tracks)

Time stamp

Inner tracker contribution to momentum resolution

SGV fast simulation (M. Berggren) of the LDC tracker central region

Silicon envelope for the TPC: a precise measurement extending the lever arm improves resolution for large momentum.

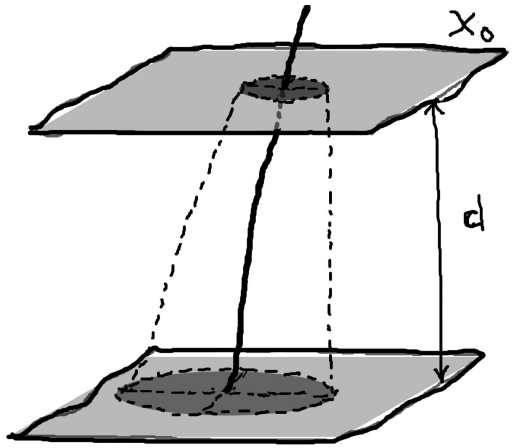


Pattern recognition

Studies into pattern recognition requirements are ongoing.
The aim is to establish a requirement for the segmentation of the innermost tracker layers.

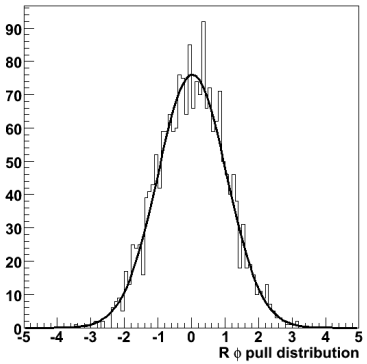
- Search windows for track stub extrapolation
- Occupancy
- Contamination

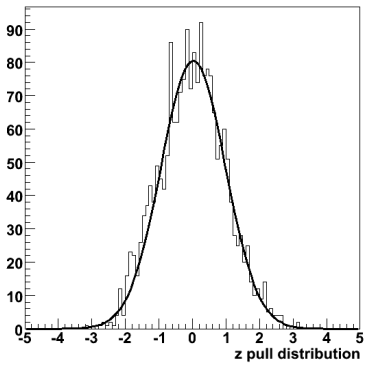
Success to add correct hit to track stub depends on contamination (occupancy ⊗ compatible window)



Tool: full (CMS) Kalman Filter-based track fitting suite on toy geometries. In the near future this should be extended to “full” reconstruction of signal topologies in the presence of realistic background.

Search window





Internal consistency check

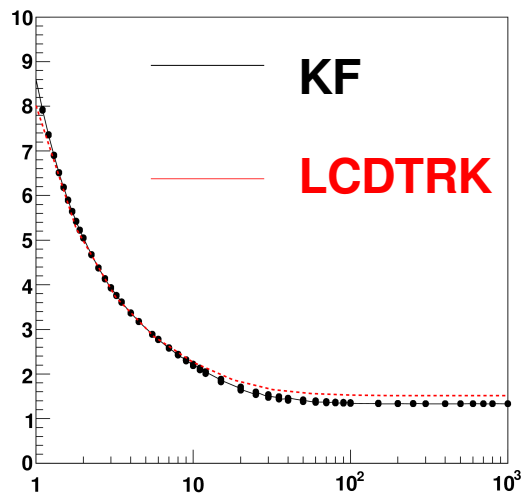
Pull distribution for R-ϕ and z coordinates.

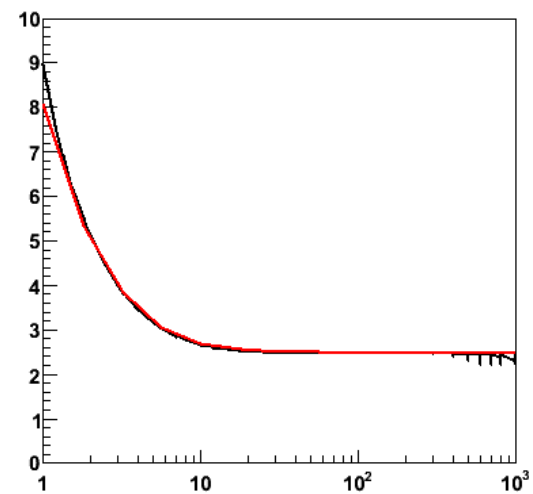
Mean and RMS compatible with 0 and 1.

Cross-check a few scenarios in detail:

d_0 for VXD + SIT

z_0 for VXD + SIT

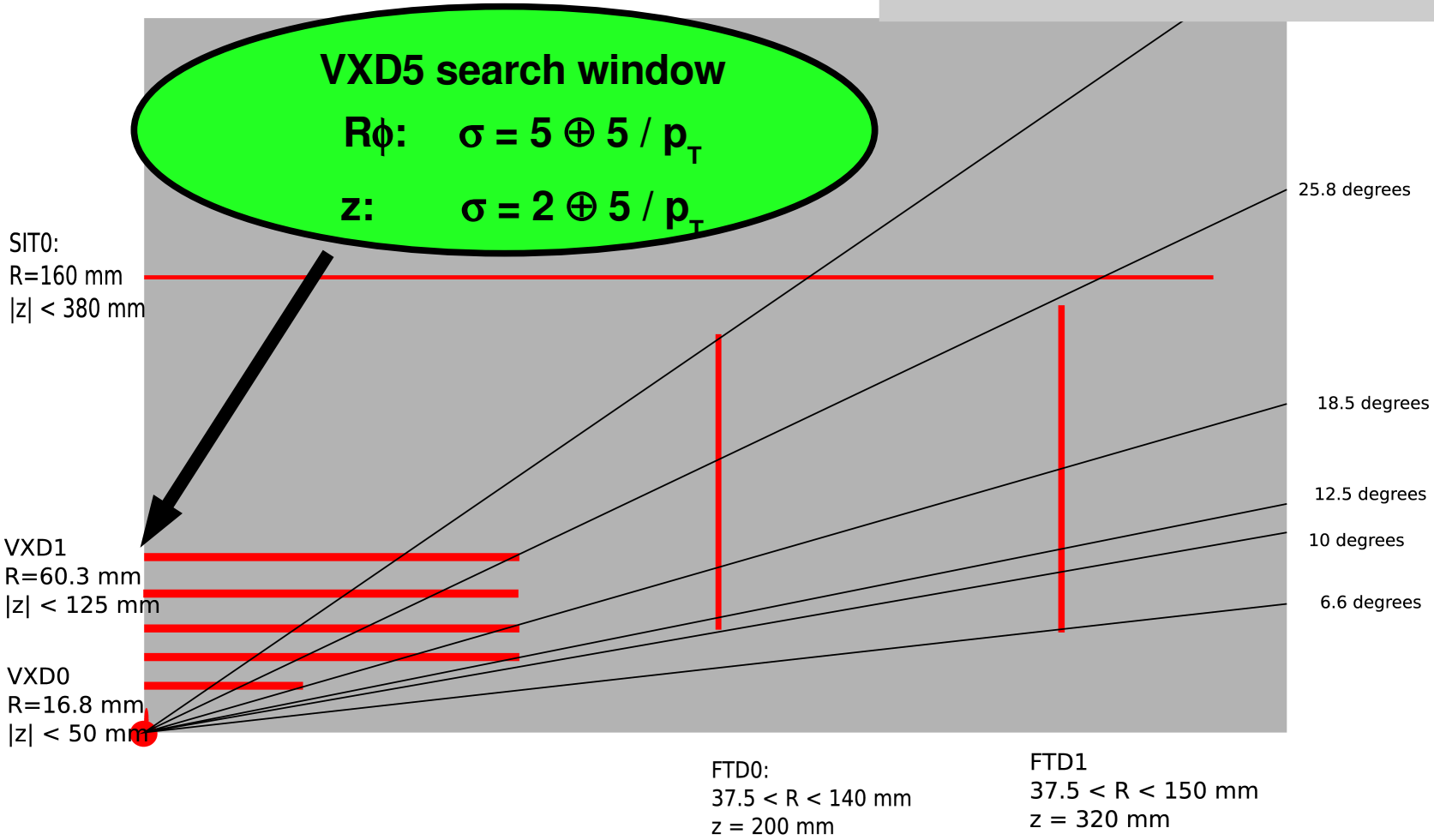




Extrapolation precision

Simplified geometry: Gaussian smearing of points, ideal silicon layers characterized by material thickness

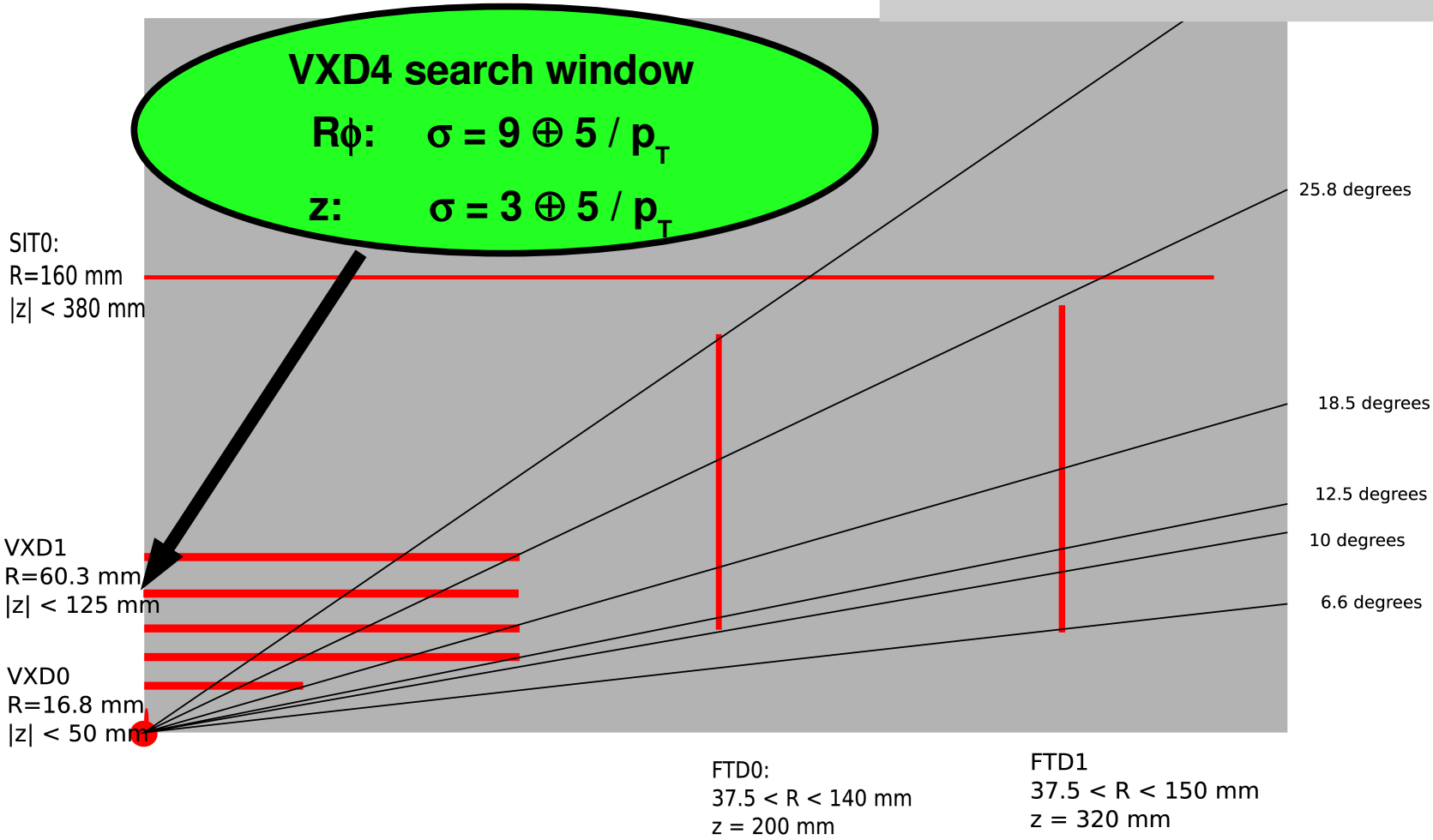
	VXD	SIT
σ rϕ (μm)	2	5
material (‰ X_0)	1.2	8



Extrapolation precision

Simplified geometry: Gaussian smearing of points, ideal silicon layers characterized by material thickness

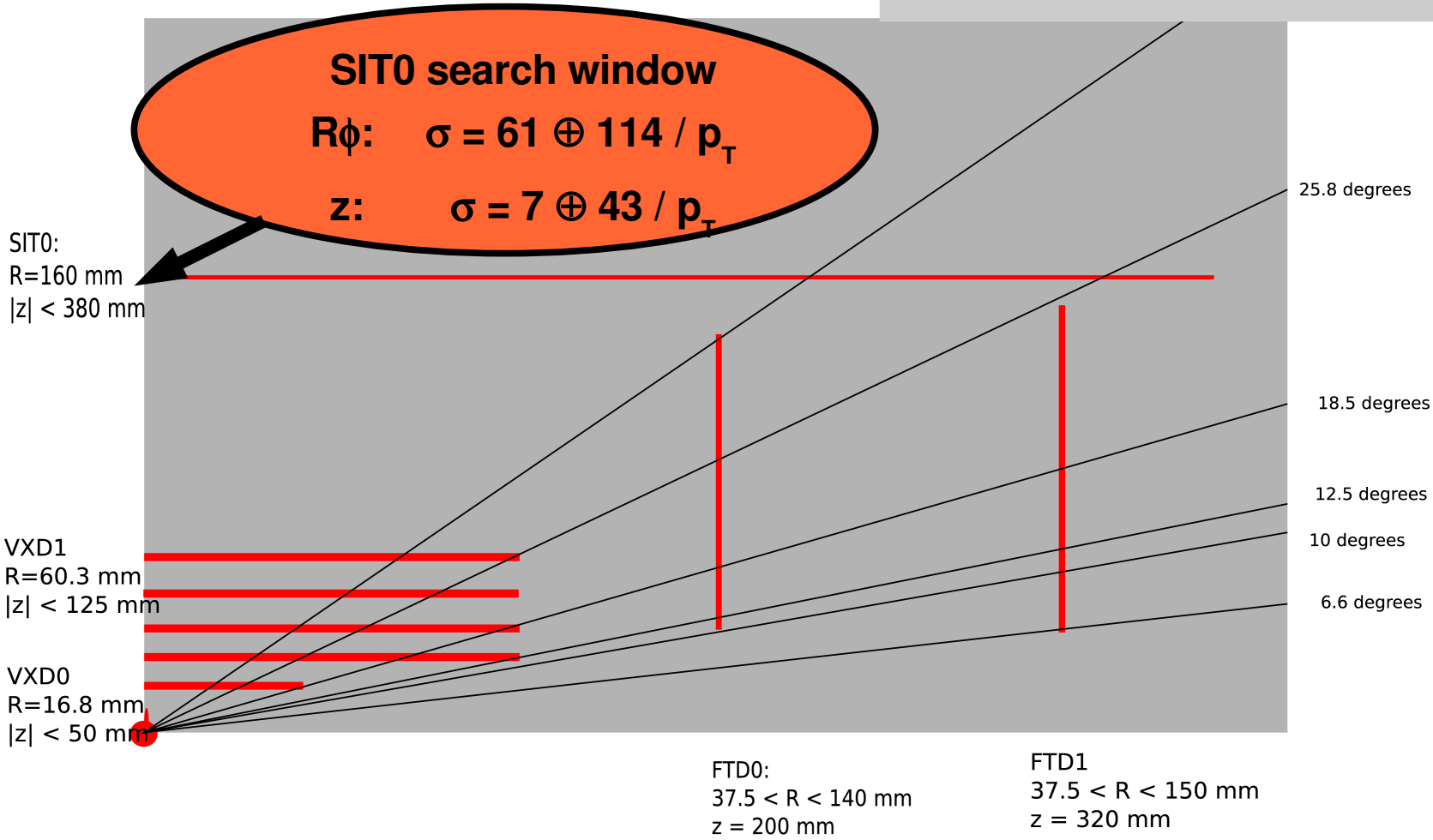
	VXD	SIT
σ rϕ (μm)	2	5
material (‰ X_0)	1.2	8



Extrapolation precision

Simplified geometry: Gaussian smearing of points, ideal silicon layers characterized by material thickness

	VXD	SIT
σ rϕ (μm)	2	5
material (‰ X_0)	1.2	8



Inside-out track search starting out from a stub in 5 VXD barrel layers (1.1 cm R spacing, 1.2 per mil X_0, 2 micron resolution in Rϕ, z)

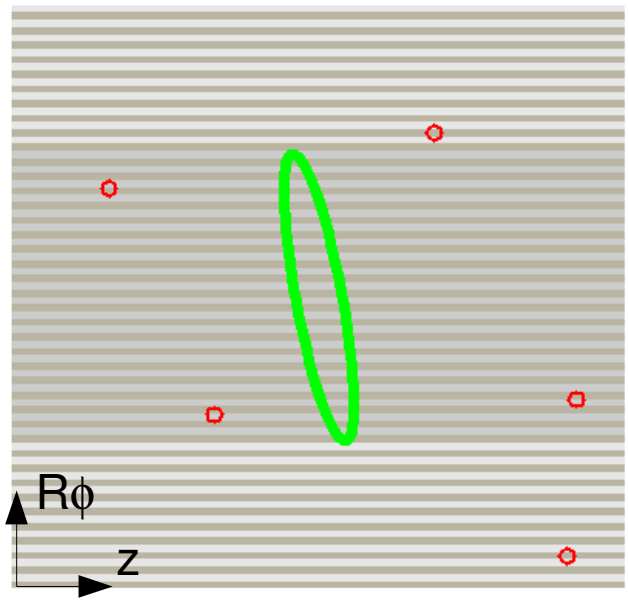
Radius first barrel tracking layer (cm)	**Rϕ extrapolation uncertainty (μm)**		
LDC nominal	**61**	$\oplus$	**114 / p_T**
material X 2	61	$\oplus$	**166 / p_T**
space point resolution X 2	**122**	$\oplus$	**117 / p_T**
one layer less:	**105**	$\oplus$	**134 / p_T**
All together:	**211**	$\oplus$	**199 / p_T**

Extrapolation precision dependence on Vertex Detector parameters

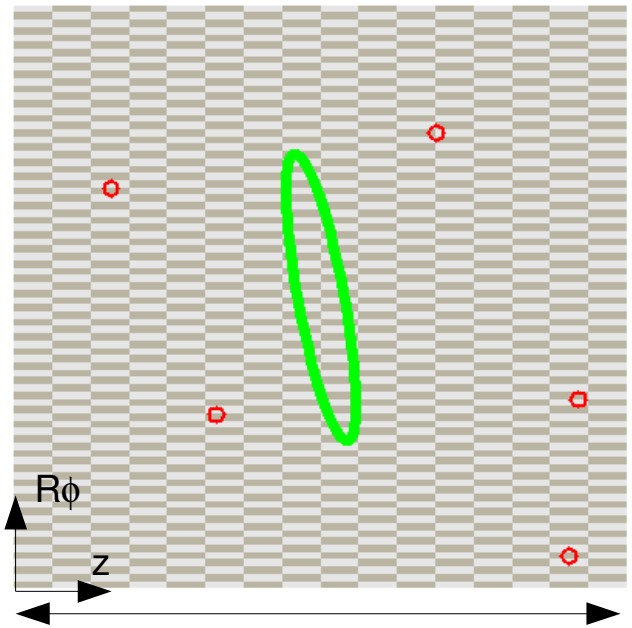
Radius first barrel tracking layer (cm)	**Rϕ extrapolation uncertainty (μm)**		
12	**27**	$\oplus$	**47 / p_T**
16 (LDC nominal)	**61**	$\oplus$	**114 / p_T**
20	**108**	$\oplus$	**215 / p_T**
30	**279**	$\oplus$	**624 / p_T**

Extrapolation precision dependence on VXD-SIT distance

Contamination = Search window ⊗ occupancy ⊗ technology



vs.



Legend: extrapolated search window, hits, compatible area 1 cm

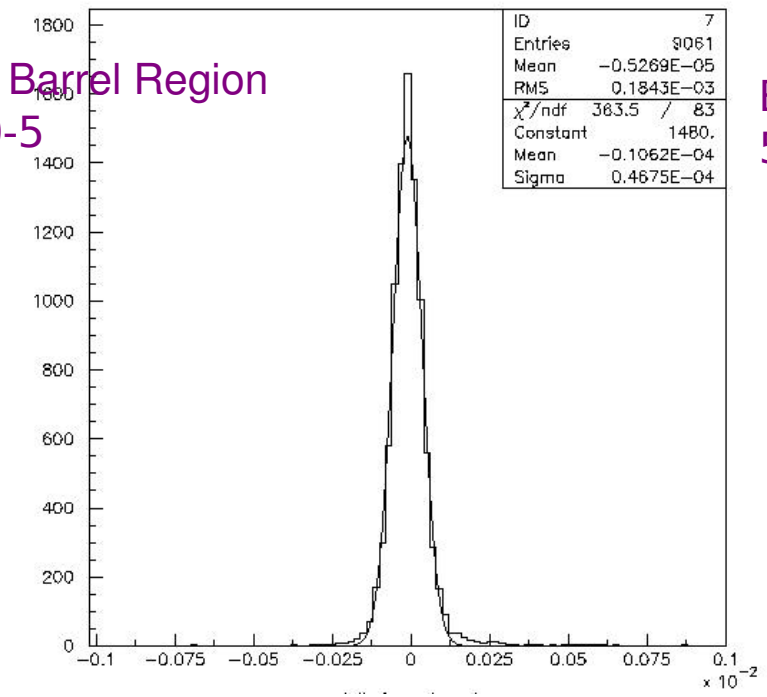
Contamination as a quality marker of the contribution of a given layer in the global pattern recognition (quantitative results for several technologies are being prepared)

Towards full simulation

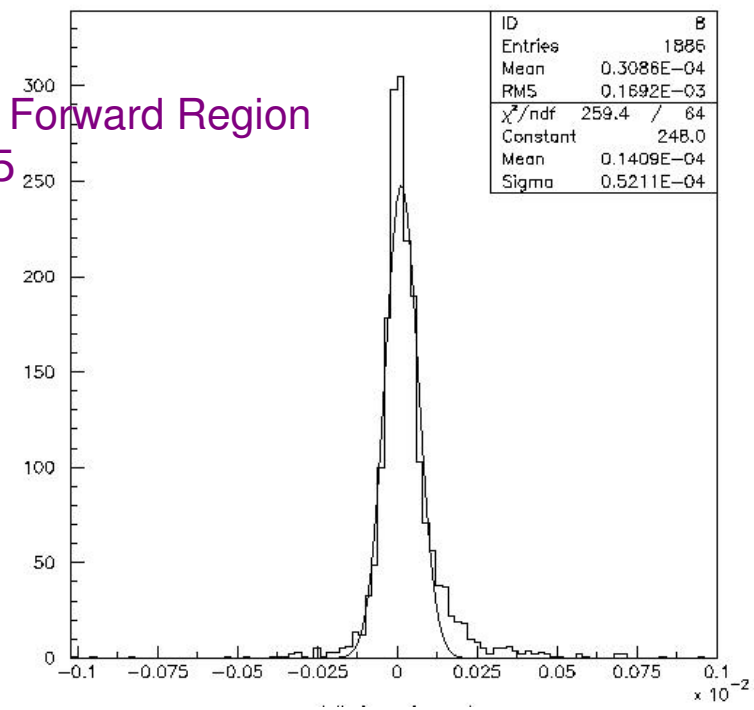
TRACK RECONSTRUCTION (V. Saveliev) (Marlin implementation)

- LEP Tracking Algorithm is implemented in the MARLIN Reconstruction Framework and shows Reasonable Results

Central Barrel Region
4.7x10-5



End Cap Forward Region
5.5x10-5



Conclusions

Ongoing SiLC effort to understand requirements of central, end-cap and far-forward regions of the ILC tracker... complementing the fast simulation with full simulation/reconstruction

Many items not treated in this talk (LiCToy, W. Mitaroff, SiD non-prompt tracks, B. Schumm), but also work in Paris on forward tracking, in Prague on digitization, etc...

Not quite there yet, but progress on full reconstruction is very encouraging.

Outside-in track search starting out from a track with $\Delta (1/p_T) = 10^{-4}$

TPC inner field cage material	z **extrapolation uncertainty (μm)**		
1 % X_0 , no SIT	70	⊕	**211 / p_T**
5 % X_0 , no SIT	63	⊕	**630 / p_T**

Extrapolation precision dependence on material

TPC inner field cage material	**Rϕ extrapolation uncertainty (μm)**		
1 % X_0 , no SIT	57	⊕	**483 / p_T**
5 % X_0 , no SIT	56	⊕	**1000 / p_T**
5 % X0, 2 layer SIT	**7**	⊕	**155 / p_T**

Extrapolation precision dependence on material and on the presence of SIT