SiLC optimization tools/plans

Marcel Vos – IFIC Valencia

for the SiLC collaboration

thanks to V. Saveliev, A. Savoy-Navarro

The SiLC simulation task force

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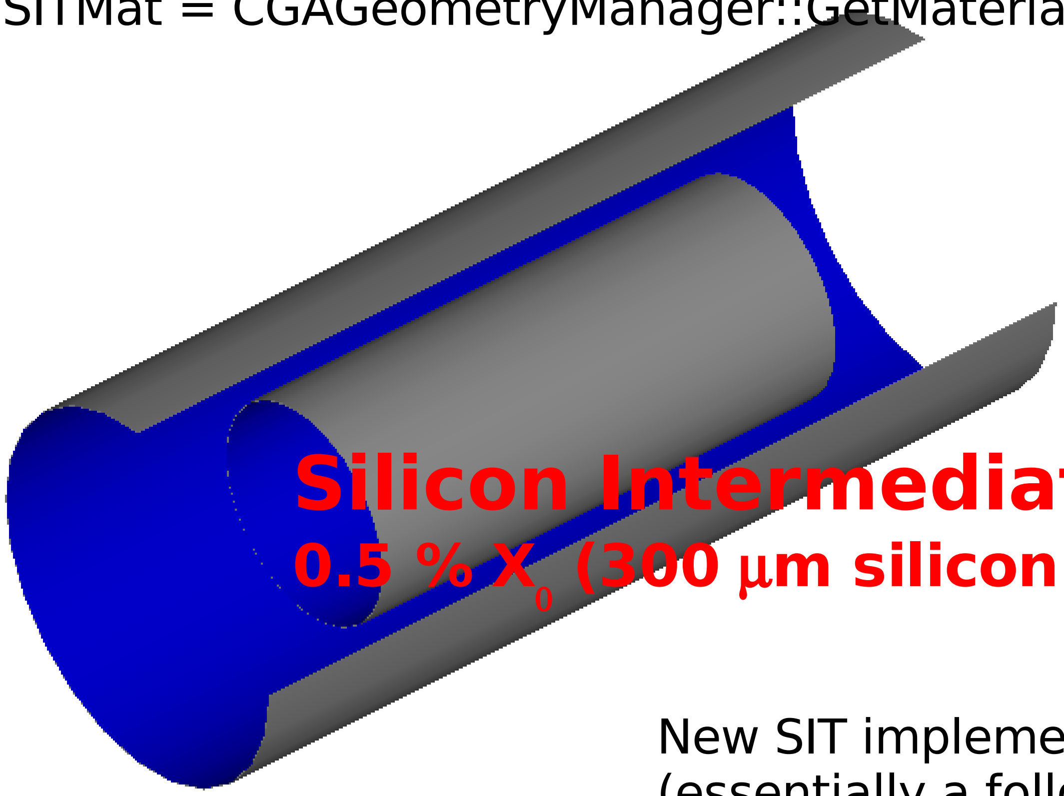
Korean Group (GLD)

Inner silicon: Mokka implementation SIT

```
// sensitive silicon cylinders...
G4Tubs *SitSolid = new G4Tubs("Sit",
              inner_radious, inner_radious+sensitive_thickness,
              half_z, start_phi, stop_phi);

SITMat = CGAGeometryManager::GetMaterial("silicon_2.33gccm");
```

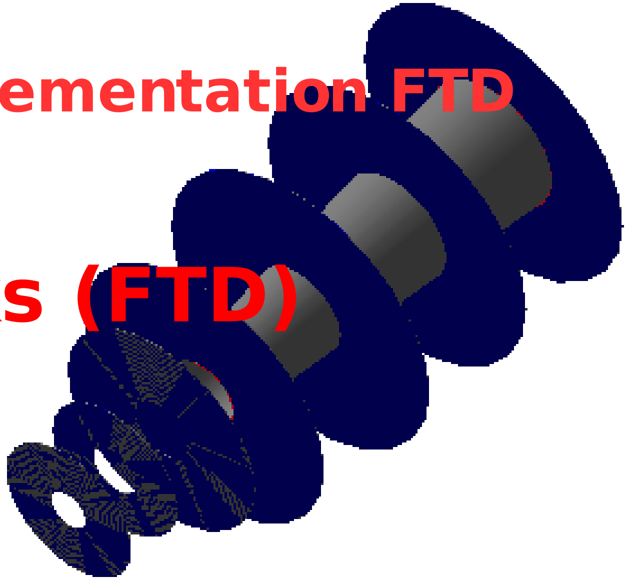


Silicon Intermediate Tracker (SIT)

0.5 % X_0 (300 μm silicon + C support)

New SIT implementation by Valeri Saveliev
(essentially a follow-up of Hengne Li's work)

Inner silicon: Mokka implementation FTD

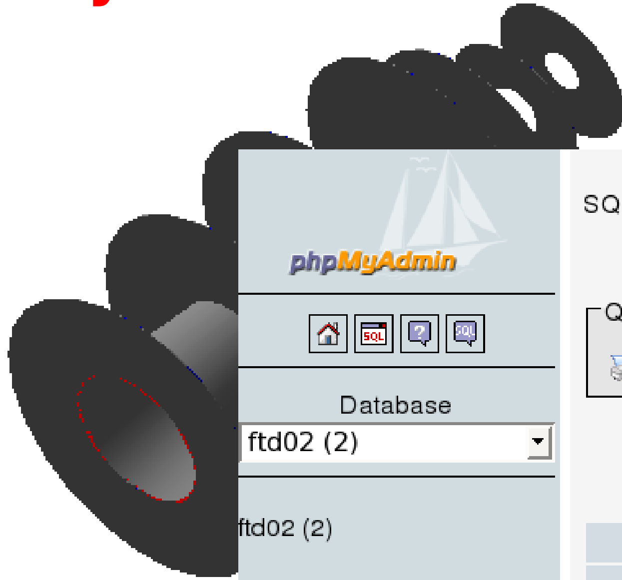


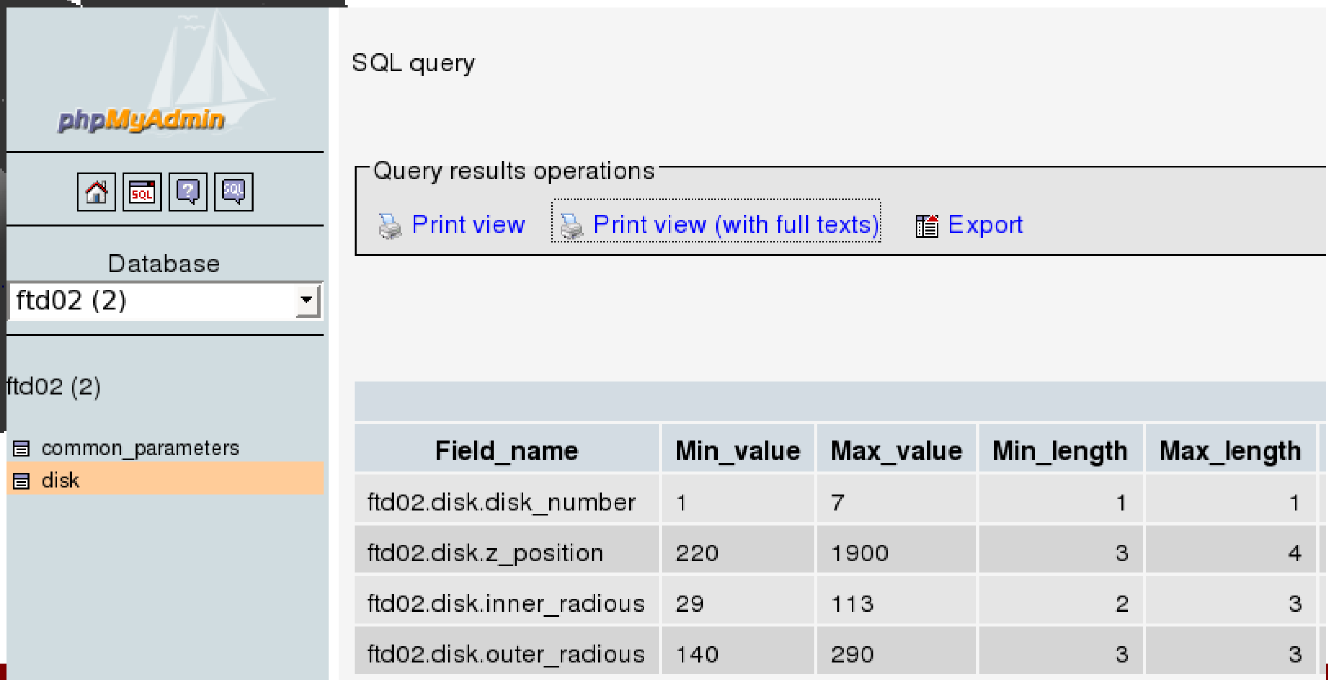
Forward Tracking Disks (FTD)

3 pixel disks (1 % X_0)

4 strip disks (0.5 % X_0)

extended layout wrt TESLA

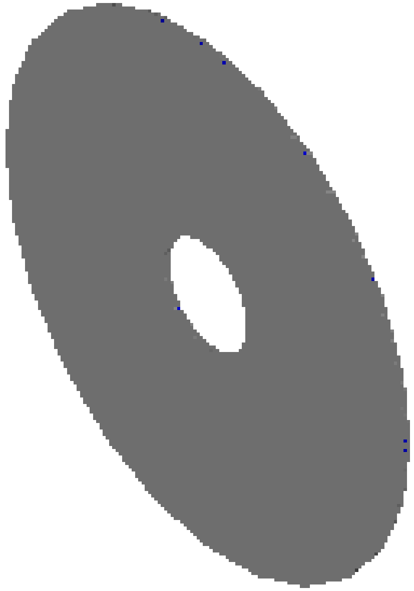


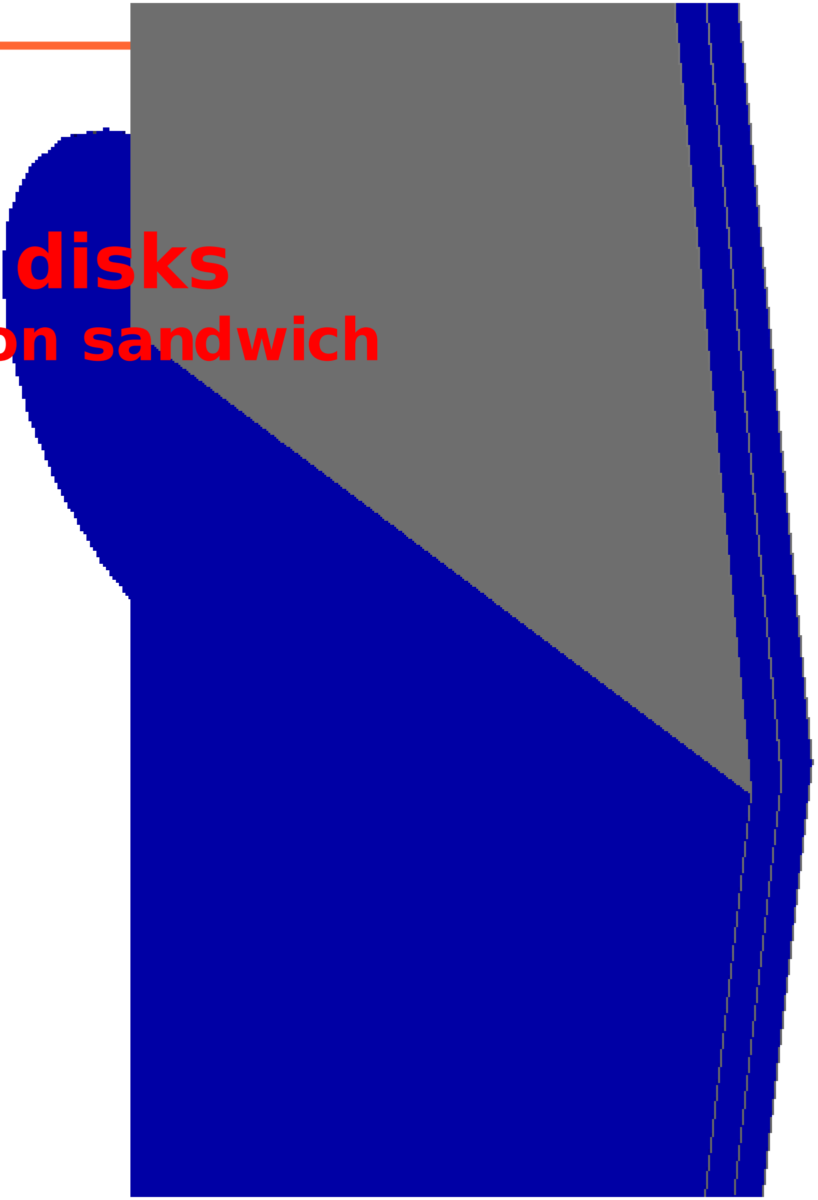


Field_name	Min_value	Max_value	Min_length	Max_length
ftd02.disk.disk_number	1	7	1	1
ftd02.disk.z_position	220	1900	3	4
ftd02.disk.inner_radious	29	113	2	3
ftd02.disk.outer_radious	140	290	3	3

ETD Mokka implementation

End-cap tracking disks
Silicon – carbon – silicon sandwich

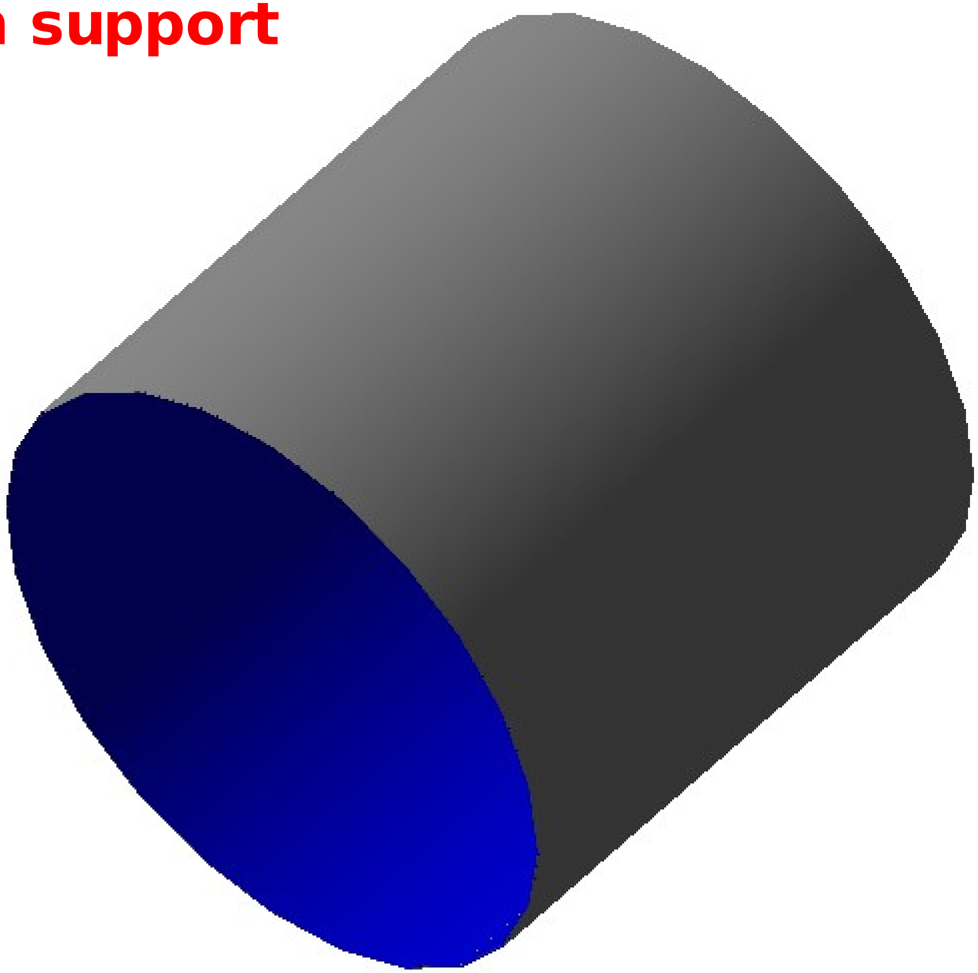




ETD Mokka implementation

Silicon Envelope Tracker

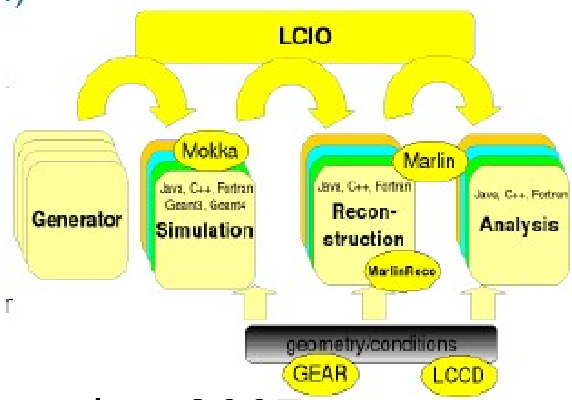
Silicon + carbon support



Digitization

ILC Software – Basics

- Baseline sofware:
  - ***Mokka***: Geant 4 based, full simulation tool using a realistic detector geometry available via a MySQL database; to access the database and construct the detector geometry the C++ driver is needed; output in ASCII or **LCIO** file
  - ***LCIO***: Linear Collider I/O framework, which defines a data model for ILC; as a concrete data format an implementation of Serial Input/Output (***SIO***) is used → output in ****.slcio files***
  - ***Gear***: geometry description toolkit for ILC analysis and reconstruction software; when specified in Mokka the geometry ****.xml*** file is created; the file contains simplified detector geometry (testbeam geometry ...)
  - ***Marlin***: ILC Modular Analysis & Reconstruction tool; enables ***modular approach*** to development of reconstruction and analysis code based on LCIO; data in LCIO format are processed using so-called ***processors***; processor parameters set via a steering file; (***digitization package*** represents one of Marlin processors)



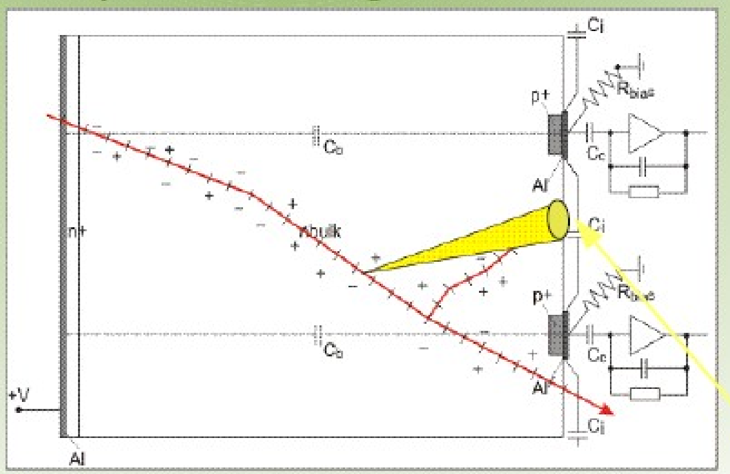
Zbynek Drasal, SiLC meeting, Torino, December 2007

Digitization

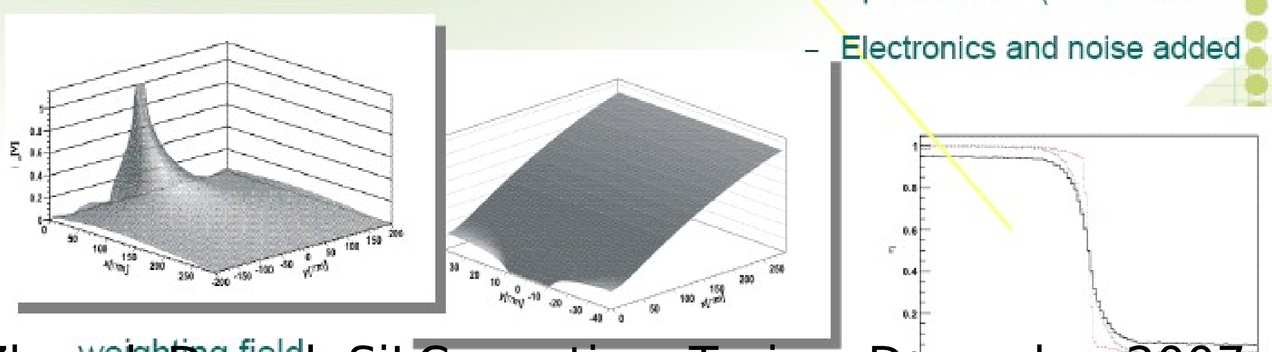
Digitization 5

SiStripDigi Package - Introduction

- Strip detector digitization



- steps = 25 µm (50 µm ~ 2x faster)
  - calculated manually from Geant4 hits
- E_{eh} = 3.65 eV (energy for an e-h pair creation)
- physical processes:
  - Drift in el. field (4th order Runge-Kutta method or Predictor – Corrector method)
  - Diffusion (smear position with Gauss distribution)
  - Lorentz shift in magnet. field (Romberg numerical integration method)
  - "η correction" (crosstalk included – AC or DC)
  - Electronics and noise added



weighting field

Zbynek Drasal, SiLC meeting, Torino, December 2007

LDC/GLD convergence to ILD

LDCPrime

Sub-Detector	Parameter	GLD	LDC	GLD'	LDC'
TPC	R_{inner} (m)	0.45	0.30	0.45	0.30
	R_{outer} (m)	2.00	1.58	1.80	1.80
	Z_{max} (m)*	2.50	2.16	2.35	2.35
Barrel ECAL	R_{inner} (m)**	2.10	1.60	1.85	1.82
	Material	Sci/W	Si/W	Sci/W	Sci/W
Barrel HCAL	Material	Sci/W	Sci/Fe	Sci/Fe	Sci/Fe
Endcap ECAL	Z_{min} (m)***	2.80	2.30	2.55	2.55
Solenoid	B-field	3.0	4.0	3.50	3.50
VTX	Inner Layer (mm)	20	16	18	18

From Frank Gaede, December 6th.

Convergence for detector parameters linked to B or R. TPC inner radius or innermost silicon unchanged in "Primed" layouts

Silicon tracker parameters for optimization

The questions we would like to see answered in the next year(s)

Parameter	Affects	Changed in	LDC/GLD differences
Material	Overall performance, PatRec	Mokka description	All
Number of layers	All aspects	Mokka description	SIT, ETD
Layout	Momentum resolution	Mokka description	FTD
Rϕ resolution	Momentum resolution	Digitizer	FTD, ETD
R/z segmentation	Pattern recognition	Digitizer	SIT, FTD

Given limited time/resources, concentrate on tracker material, a key parameter in the global detector performance

Comparison of physics impact of optimistic/pessimistic scenarios for material in SIT/FTD, integrated scenarios for TPC endplate material (ETD), VXD services (FTD)

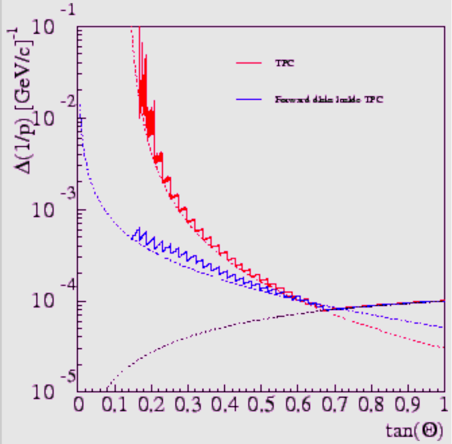
Other parameters: small-scale dedicated productions could be very interesting.

Forward tracking: interplay with TPC

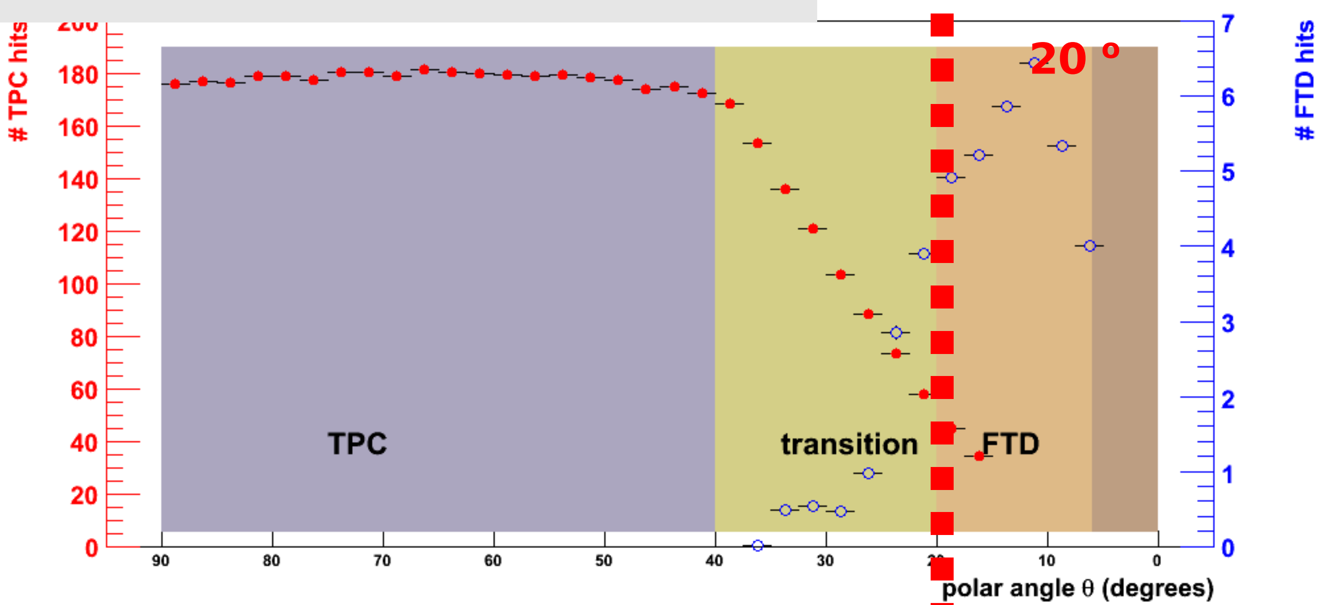
(Very) forward tracking in a gaseous + silicon tracker

For track polar angles below 40º reduced TPC coverage
Below ~ 30º FTD starts to contribute
Below ~ 20º FTD dominates the measurements

TPC/FTD hits vs. polar angle Large Detector Concept (Tesla layout of FTD)



SGV momentum resolution



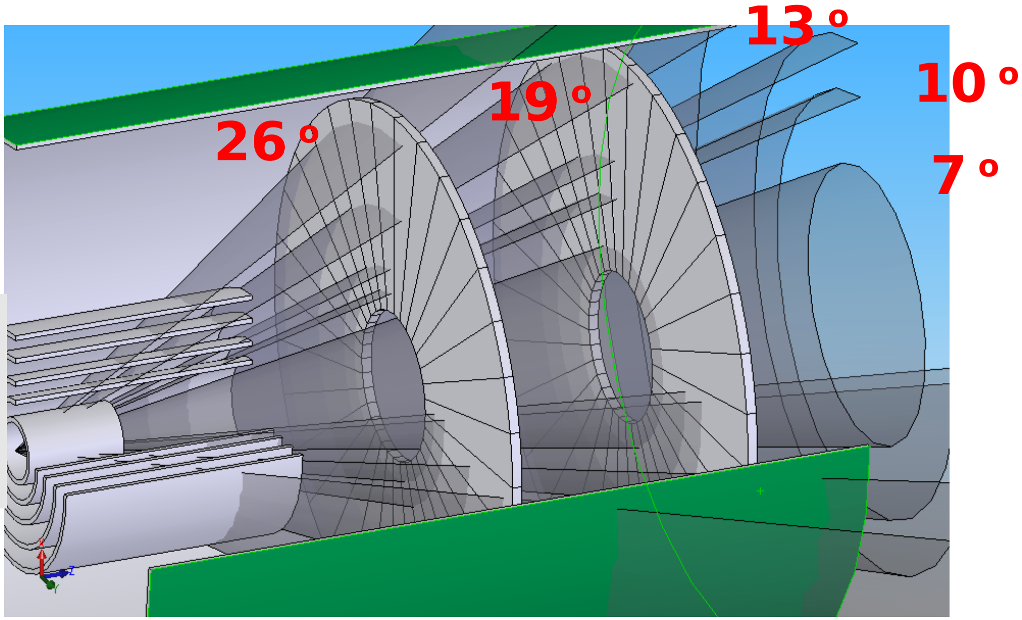
Full Mokka simulation + Marlin reconstruction

Forward tracking: interplay with VXD

Concept	Magnetic Field	Angular Coverage 5-point	3-point
SiD	5 T	12.5 (43 barrel)	9
LDC	4 T	26	19
GLD	3T	26 (6 points)	18 (4 barrel + 2 disk)

Long barrel layout (LDC, GLD) has limited coverage for angular region from 7° to 25°

(Very) forward tracking with a "Long barrel" vertex detector



LDC inner tracker layout:

VXD (cylinders)
SIT (green)
FTD disk 1 and 2

Tools – track fitting

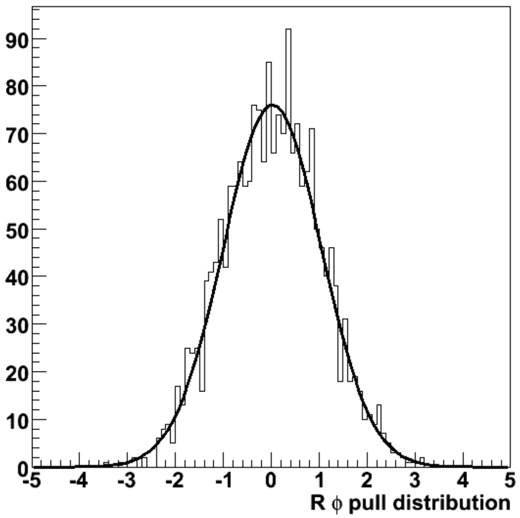
CMS Kalman filter tool-kit.

The result of years of work by a lot of people. Validated in large-scale MC productions.

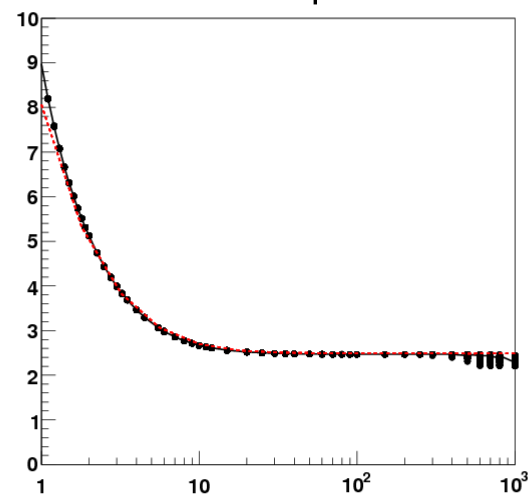
Extracted all relevant code in a series of libraries with limited external dependencies (CLHEP, ROOT).

Interfaced to toy geometries in standalone programme. Tested results for internal consistency and against existing fast-simulation packages.

Interfaced to MarlinReco (GEAR geometry, LCIO hits)



pull distribution R ϕ coordenate at last measurement plane



LCDTRK vs. KF: Transverse impact parameter resolution vs p_T

Momentum resolution

Δ(1/p_T) @ 10 degrees :

Reference (TESLA) set-up

$1.8\times10^{-3}\oplus1.3\times10^{-2}/ p_T$

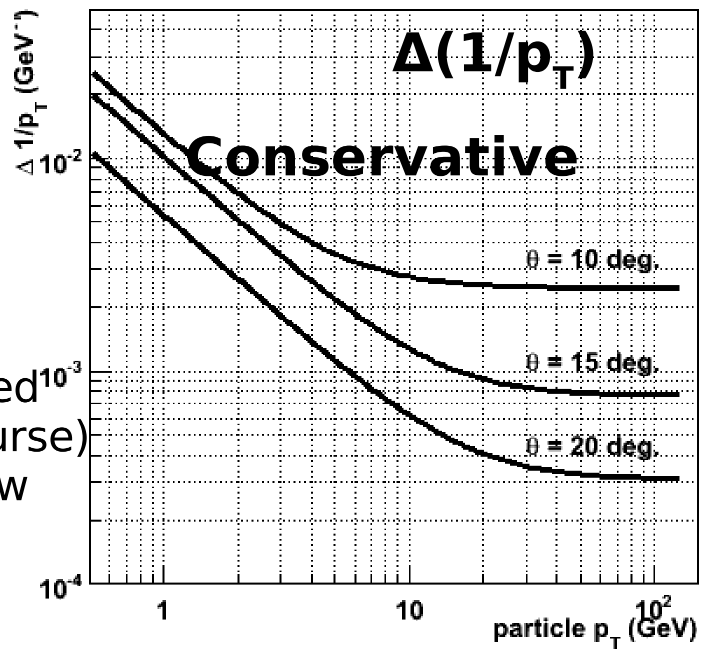
Challenging setup

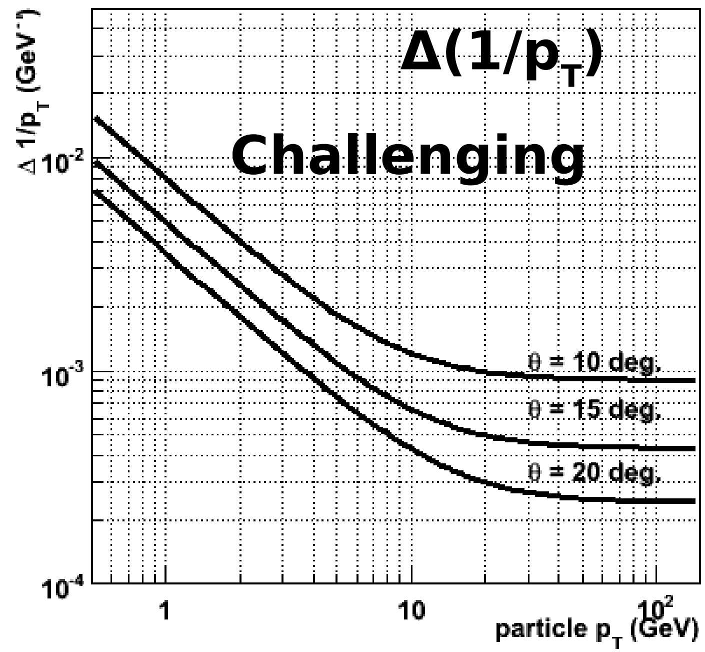
(5 µ m Rφ resolution, 1.2 ‰ X0/disk for FTD1-3, 4 ‰ X0/disk for FTD4-7)

$\Delta(1/p_T)=0.9\times10^{-3}\oplus0.8\times10^{-2}/ p_T$

Detector	*R ϕ (µm)*	*z/R (µm)*	*Material (% X_0)*
VXD	*5*	*5*	*0.12/layer*
FTD1-3	*10*	*50*	*1.2/layer*
FTD4-7	*10*	*1000*	*0.8/layer*
TPC	*120*	*300*	*1 (field cage)*

CAVEAT; extended geometry (of course) does better at low angle





Momentum resolution

In the very forward tracker the momentum resolution ($\Delta(1/p_T)$) is inevitably degraded by the less favourable orientation of the B-field

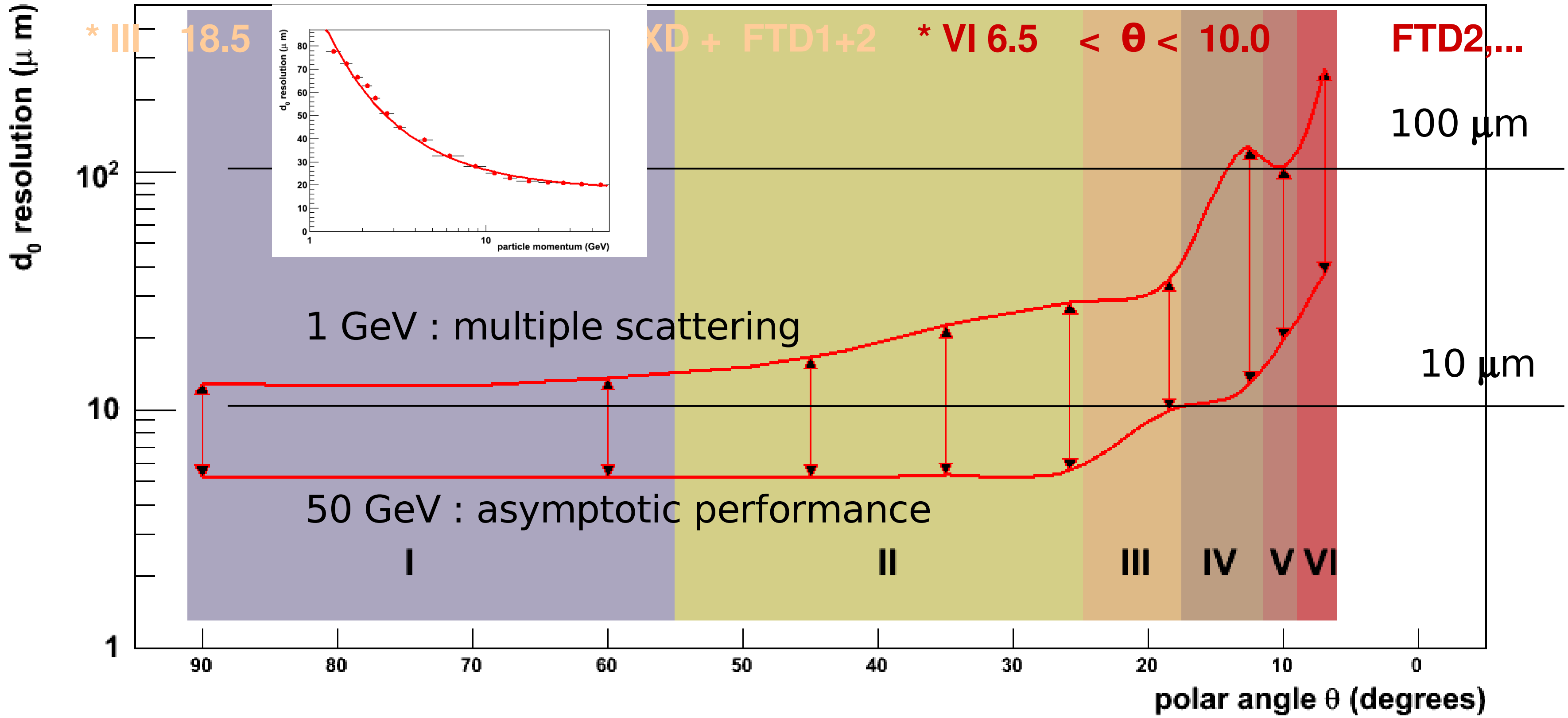
Excellent instrumentation allows to regain part of the lost performance: with a combination of a very challenging material budget and very good $R\phi$ resolution a factor two improvement is achieved throughout the momentum range.

Vertexing with forward tracks

* I 35 < θ < 90 5 VXD + SIT * IV 12.5 < θ < 18.5 VXD2 + FTD

* II 25.8 < θ < 35 5 VXD + FTD1 * V 10 < θ < 12.5 FTD1,...

* III 18.5 ... XD + FTD1+2 * VI 6.5 < θ < 10.0 FTD2,...



Vertexing with forward tracks

For very forward tracks (< 12º) the innermost measurement is provided by Forward Tracking Disks.

d_0 resolution well below the ct of B-hadrons possible, provided:

- *very little material in/before first tracking disk,*
- *excellent R f resolution,*
- *smallest possible z-distance first disk.*

Region V **θ = 10 degrees**	σ (d0) @ 50 GeV (μm)	σ (d0) @ 1 GeV (μm)
Reference geometry	**20**	**120**
FTD material = 1.2 % X0	**21**	**290**
R ϕ resolution = 5 μm	**12**	**104**
Z (FTD1) = 15 cm	**17**	**82**

Reference geometry: “long barrel” VXD with 5 μm resolution and 0.12 % X_0 material and LDC FTD with 10 μm resolution and 0.12 % X_0 material

Pattern recognition - tools

Combinatorial algorithm based on KF kit

The baseline algorithm of the ATLAS (arXiv:0707:3071) and CMS (NIM A 559 143) experiments

Standalone FTD reconstruction implemented in MarlinReco processor

Run on tt events with superposed pair background.

Reference FTD (TESLA layout)

10 μm R-ϕ resolution

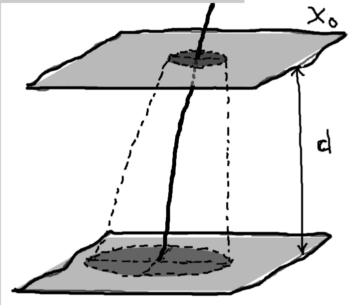
1.2 % X_0/disk (1-3) and 0.8 % X_0/disk (4-7).

Several scenarios for R-resolution, from pixel to single-sided strip.

CSIC

IFIC

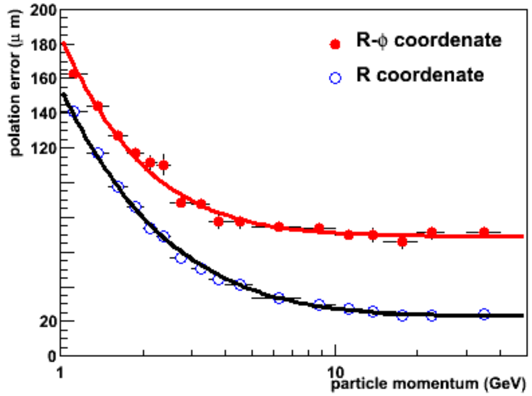
Pattern recognition

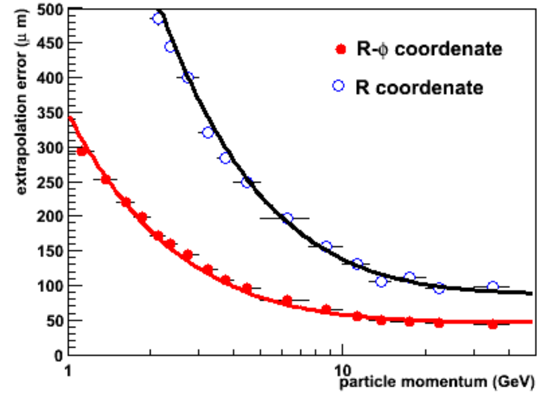


Extrapolation precision

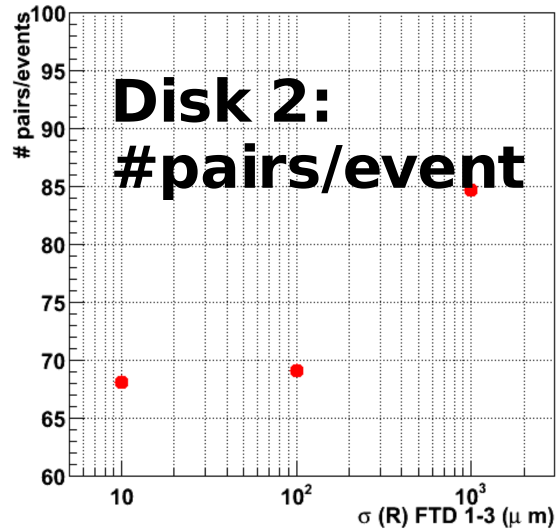
Innermost disks
R very precise (pixel detectors)
R ϕ -> weakly constrained p_T

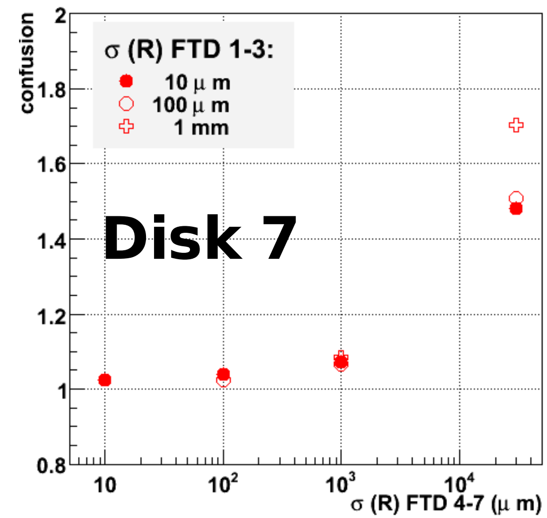
Outermost disks
R degraded (single sided strips)
R ϕ -> OK





Confusion





Pattern recognition

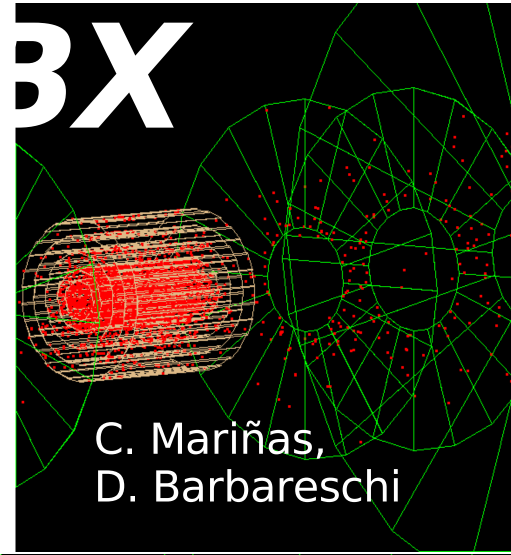
Low momentum tracks are a real challenge!

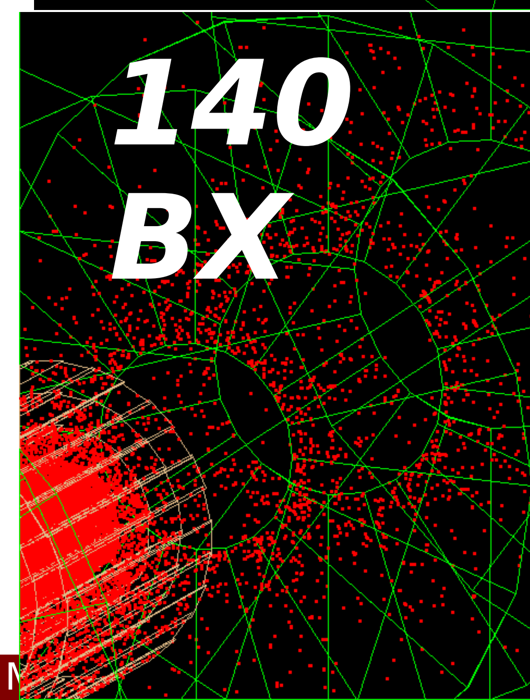
The stand-alone FTD is able to resolve patterns down to a p_T of 100 MeV, provided:

R-segmentation: in innermost disks < 500 μm, in outermost disks O(1cm)

Read-out speed: beyond O(10) bunch crossings the density of low momentum tracks prevents algorithm convergence

Material: an increase of the material beyond 1%/disk has dramatic consequences on pattern recognition





Forward tracking: challenges

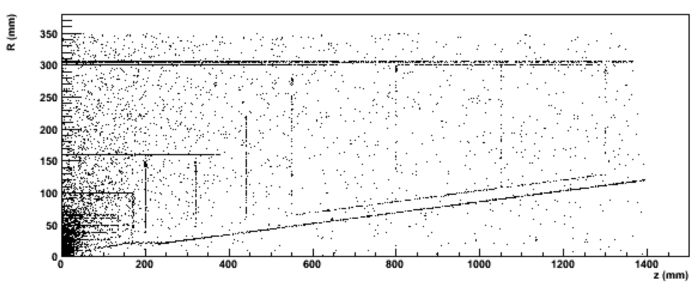
Forward Tracking disks must provide:

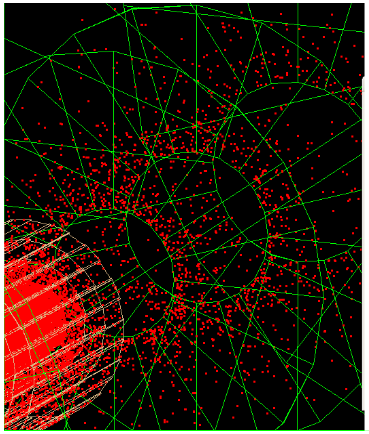
- superb momentum resolution in unfavourable field orientation

- impact parameter measurement for very forward tracks

- standalone pattern recognition in presence of background and low momentum tracks

- minimal distortion of particles





Conclusions

Drivers for SIT, FTD, SET and ETD have been provided

Many silicon tracker parameters to be optimized for ILD,
concentrate on the global performance impact of tracker material

SiLC simulation task force committed to actively participate in ILD optimization