Optimization study of the LDC forward tracker

Based on the Vienna Fast Simulation Tool for Charged Tracks ("LiC Detector Toy")

TILC '08 Workshop, Sendai, 3-6 March 2008

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presented by **W. Mitaroff**

Why fast simulation?

- Achieve quick response to local detector modifications, but not intended to replace full simulation
- Effect of various detector modifications can quickly be resolved
- Human readable, simplified detector description should be standardized to make results comparable
- The Vienna Fast Simulation Tool for Charged Tracks ("LiC Detector Toy")
  - Detector design studies
    - Geometry: cylinders (barrel) or planes (forward/rear)
    - Material budget, resolutions, inefficiencies
  - Simulation using solenoid magnetic field, helix track model
    - Multiple scattering, measurement errors and inefficiencies
  - Reconstruction via Kalman filter
    - 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)					Silicon Inner tracker (SIT)	
Name	XBT	VTX1	VTX2	VTX2	VTX4	VTX5	SIT1	SIT2
R [mm]	$14_{[1]}$	$16_{[1]}$	$26_{[1]}$	$37_{[1]}$	$48_{[1]}$	$60_{[1]}$	$160_{[3]}$	$270_{[3]}$
z_{max} [mm]		$50_{[1]}$	$120_{[1]}$	$120_{[1]}$	$120_{[1]}$	$120_{[1]}$	$380_{[3]}$	$660_{[3]}$
z_{min} [mm]		$-50_{[1]}$	$-120_{[1]}$	$-120_{[1]}$	$-120_{[1]}$	$-120_{[1]}$	$-380_{[3]}$	$-660_{[3]}$
Stereo angle		$(\pi/2)_{[1]}$	$(\pi/2)_{[1]}$	$(\pi/2)_{[1]}$	$(\pi/2)_{[1]}$	$(\pi/2)_{[1]}$	$0°/90°_{[3]}$	$0°/90°_{[3]}$
d [%X_0]	0.25	$0.14_{[2]}$	$0.14_{[2]}$	$0.14_{[2]}$	$0.14_{[2]}$	$0.14_{[2]}$	$0.5_{[4]}$	$0.5_{[4]}$
Pitch [µm]	passive	$24x24_{[2]}$	$24x24_{[2]}$	$24x24_{[2]}$	$24x24_{[2]}$	$24x24_{[2]}$	$50/50_{[3]}$	$50/50_{[3]}$
Remarks		$Pixels_{[1]}$	$Pixels_{[1]}$	$Pixels_{[1]}$	$Pixels_{[1]}$	$Pixels_{[1]}$	$Double\text{-}sided\ strips_{[3]}$	$Double\text{-}sided\ strips_{[3]}$

[1]: Detector Outline Document (DOD) for the LDC, Aug. 2006
[2]: M. Vos: Pixel R&D at IFIC Valencia, SiLC Meeting, Torino, Dec. 2007
[3]: V. Saleviev, A. Savoy-Navarro, M. Vos: Silicon Tracking, ILD Meeting, Zeuthen, Jan. 2008
[4]: M. Vos: The silicon tracker elements, SiLC phone conference, 06.02.2008

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Basic detector description (TPC, SET)

Description	Inner wall	196 pad rings				Outer wall	Silicon External Tracker	
Name	XTPCW1	TPC1-TPC196[1]				XTPCW2	SET1	SET2
R [mm]	300[4]	300[4] – 1580[4]				1580[4]	1600[3]	1610[3]
z_{max} [mm]	2160[4]	2160[4]				2160[4]	2500[3]	2500[3]
z_{min} [mm]	-2160[4]	-2160[4]				-2160[4]	-2500[3]	-2500[3]
Stereo angle		(π/2)					0°/90°[3]	0°/90°[3]
d [%X_0]	3[4]	0.00125 (for each layer)				3[4]	0.65[3]	0.65[3]
Errors [µm] $\sigma^2 = \sigma_0^2 + \sigma_1^2 \cdot \sin^2\beta + c_{Diff}^2 \cdot 6mm/h \cdot \sin\vartheta \cdot \Delta z[m]$, h = padrow pitch [5]	passive		σ_0 [µm]	σ_1 [µm]	c_{Diff} [µm/√m]	passive	Double-sided strips 50 / 50[3]	Double-sided strips 50 / 50[3]
		RΦ	50[5]	900[5]	53[5]			
		z	400[6]	0	800[6]			

[5]: R. Settles: E-mail communication, 25.01.2008
[6]: R. Settles: E-mail communication, 22.02.2008

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Basic detector description (forward) = 7 discs

Description	Forward Tracker Discs Pixels			Forward Tracker Discs Strips			
Name	FTD1	FTD2	FTD3	FTD4	FTD5	FTD6	FTD7
z [mm]	$\pm 220_{[3]}$	$\pm 350_{[3]}$	$\pm 500_{[3]}$	$\pm 850_{[3]}$	$\pm 1200_{[3]}$	$\pm 1550_{[3]}$	$\pm 1900_{[3]}$
R_{max} [mm]	$140_{[3]}$	$140_{[3]}$	$210_{[3]}$	$270_{[3]}$	$290_{[3]}$	$290_{[3]}$	$290_{[3]}$
R_{min} [mm]	$29_{[3]}$	$32_{[3]}$	$35_{[3]}$	$51_{[3]}$	$72_{[3]}$	$93_{[3]}$	$113_{[3]}$
Coord. angle δ_1/δ_2 [°]	0/90	0/90	0/90	±10	±10	±10	±10
d [%X_0]	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Pitch [µm]	$35x35_{[3]}$	$35x35_{[3]}$	$35x35_{[3]}$	$35/35_{[3]}$	$35/35_{[3]}$	$35/35_{[3]}$	$35/35_{[3]}$
Remarks	Pixels	Pixels	Pixels	Strips	Strips	Strips	Strips

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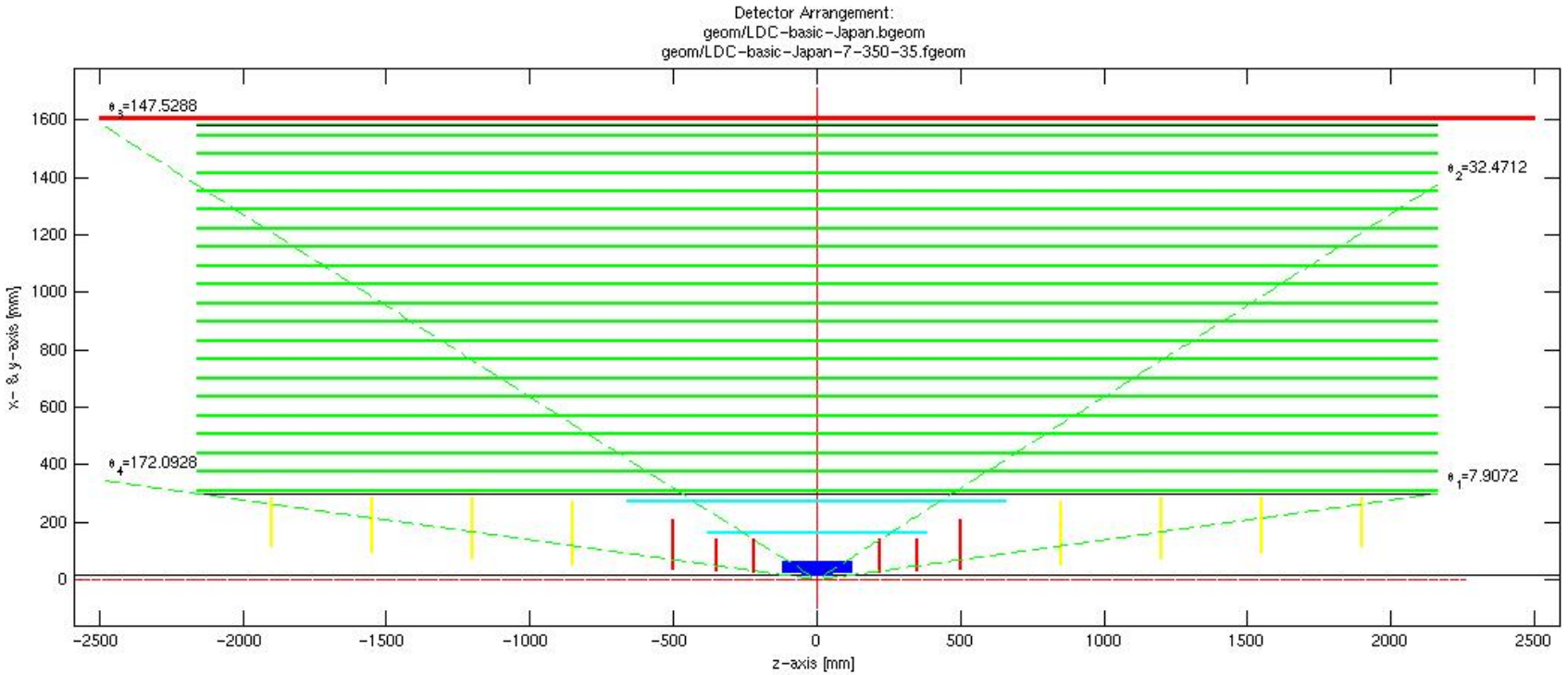
Display of basic detector description



$\theta < \theta_1 = 7.9°$: Forward hits only

$\theta > \theta_2 = 32.5°$: Barrel hits only

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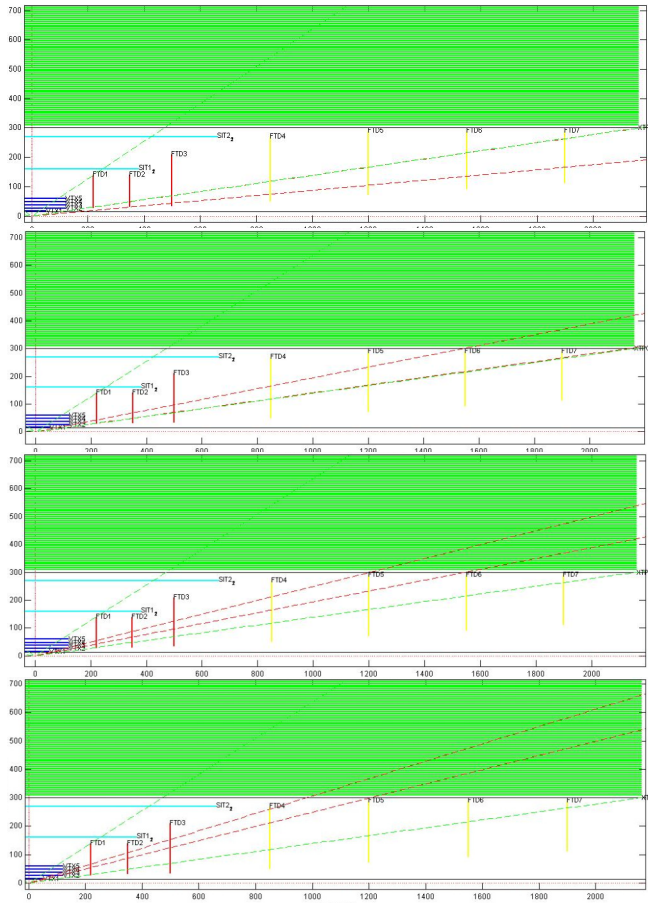
Basic Setup = 7 fwd. discs

- Basic Setup:
  - as seen in the basic detector description
- Modifications of forward discs:
  - 500 μm Si (0.50% X_0) instead of 350 μm Si (0.35% X_0)
  - 50 μm pitch instead of 35 μm pitch
- Evaluation
  - Plot RMS of $\Delta p_t/p_t^2$ for
    - p_t = 1, 3, 5, 10, 15, 20, 25, 35 GeV
    - θ = 5-8°, 8-11°, 11-14°, 14-17°
  - 1000 tracks per p_t and θ range



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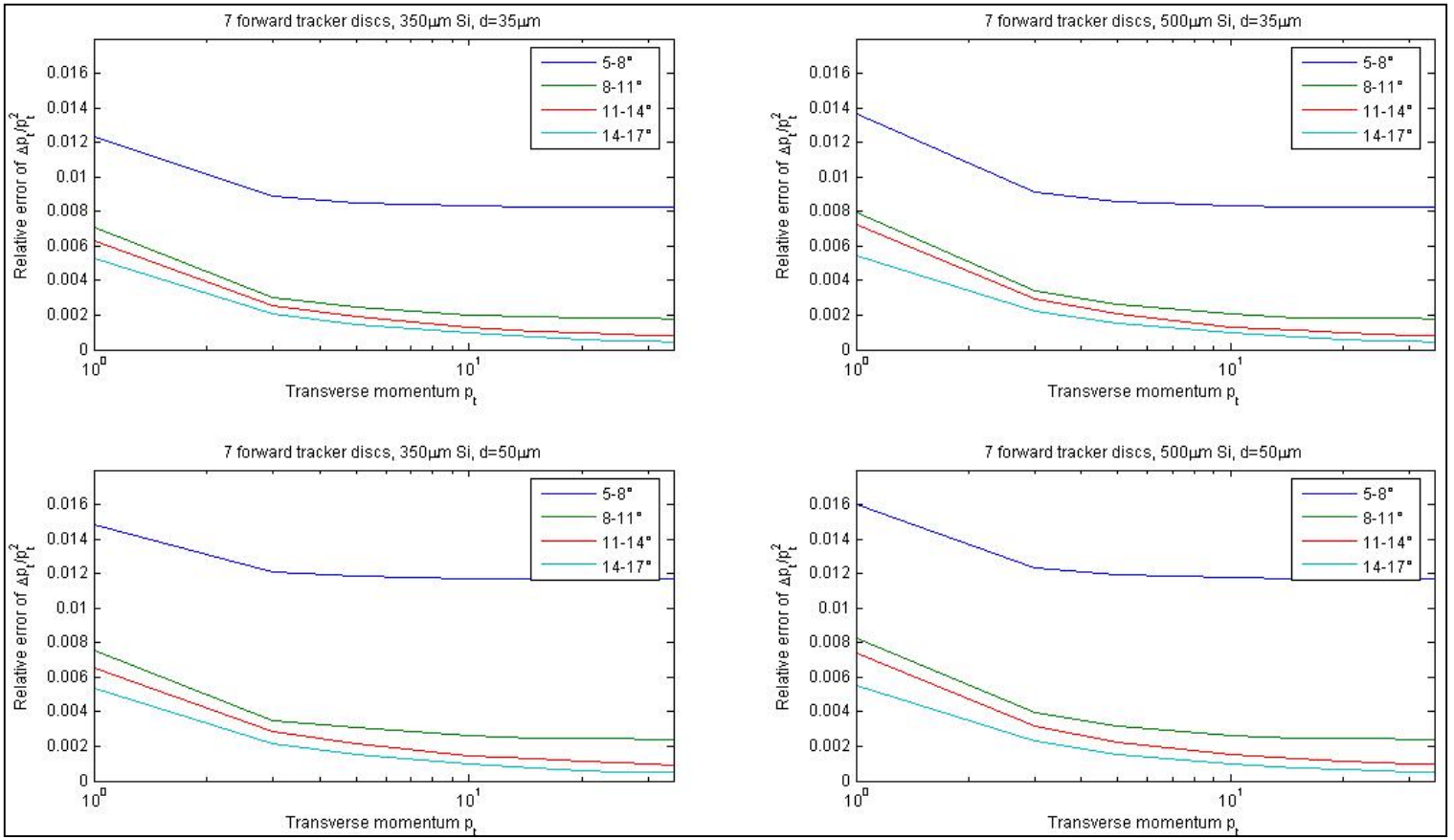
Study 1 (basic Setup), results

350 µm Si | 500 µm Si

35 µm pitch

50 µm pitch



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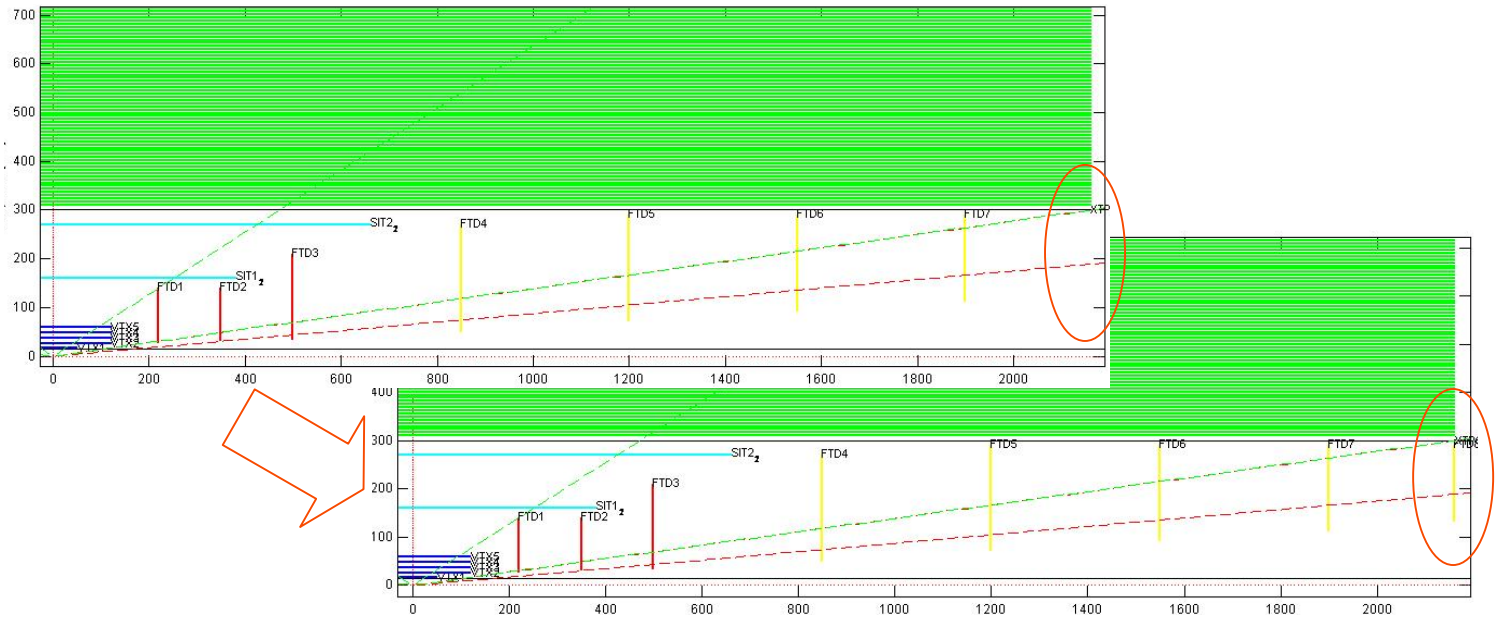
Setup 2 = 8 fwd. discs

- Basic setup + additional forward disc at z = 2160 mm
  (affects only θ = 5-8°)



- Same modifications and evaluation as before

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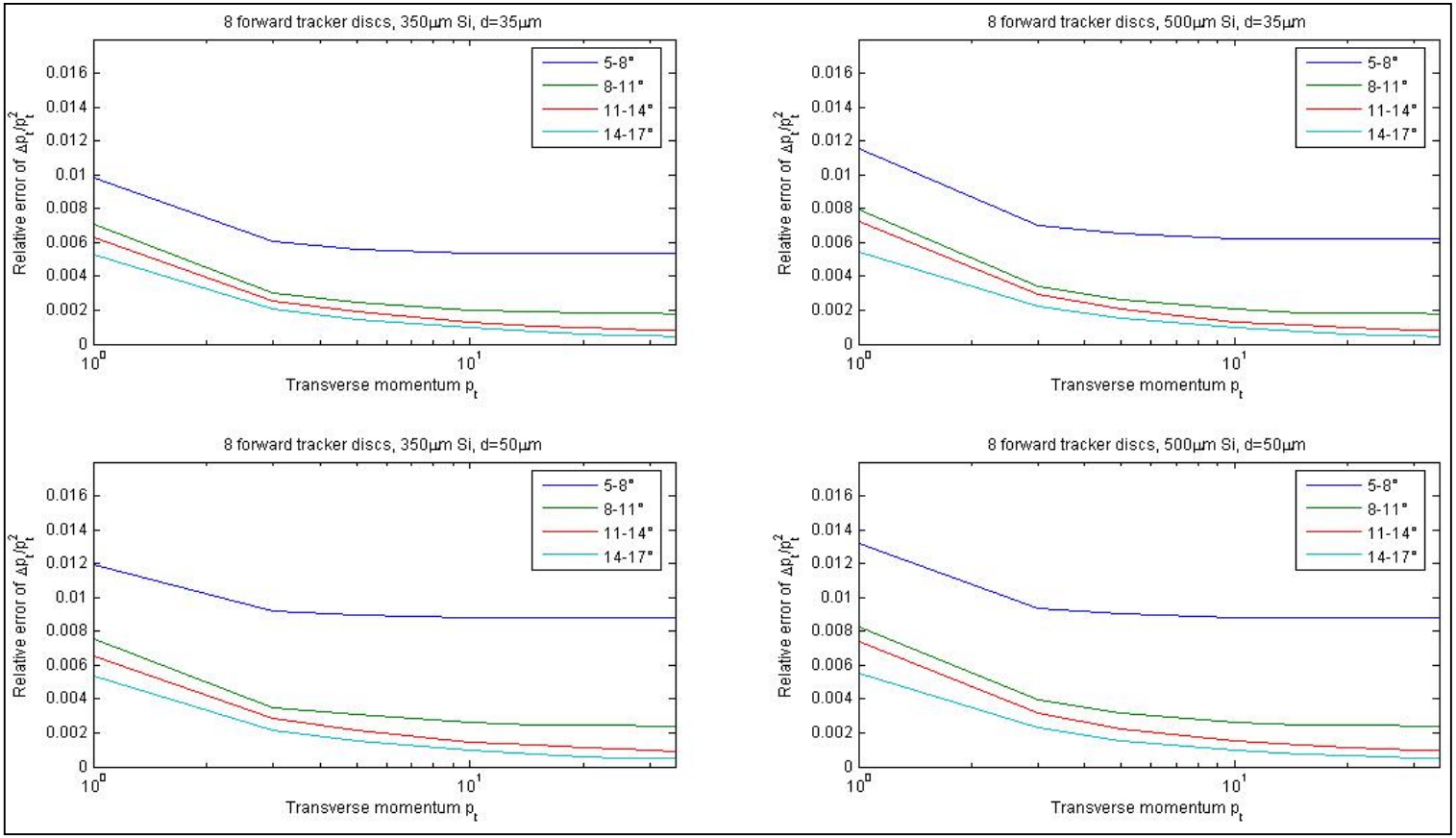
Study 2 (Setup 2), results

350 µm Si | 500 µm Si

35 µm pitch

50 µm pitch



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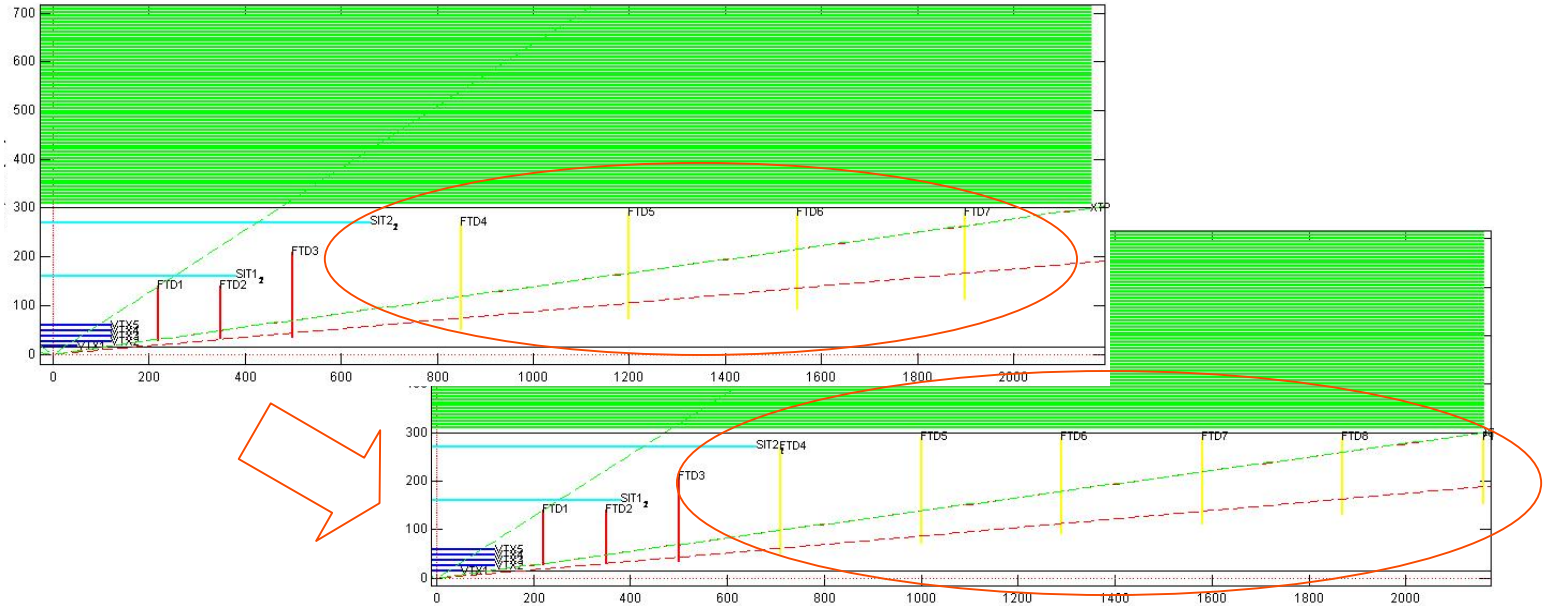
Setup 3 = 9 fwd. discs

- Basic setup => forward discs FTD4 - FTD7 replaced by 6 discs, distributed evenly in the range z = 710 – 2160 mm



- Same modifications and evaluation as before

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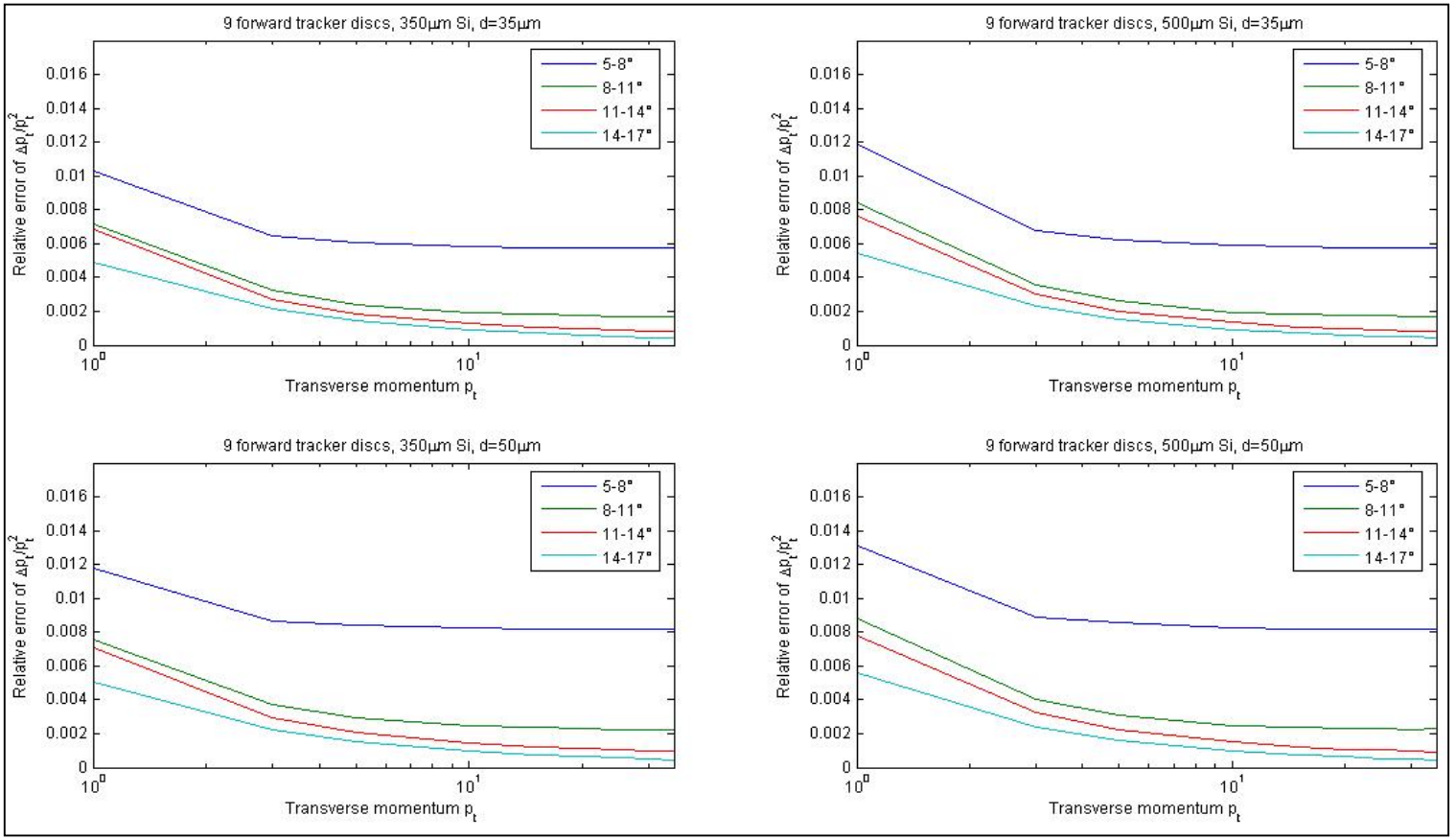
Study 3 (Setup 3), results

350 µm Si | 500 µm Si

35 µm pitch

50 µm pitch



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Optimizations of Setup 2

- From now on: only 350 μm Si (0.35% X_0) and 35 μm pitch
- Best choice up to now: Setup 2
  - Setup 2: Basic setup with additional 8th forward disc at z = 2160 mm
  - Yielded improved momentum resolution for tracks NOT hitting the TPC, with an additional measurement at higher z (bigger lever arm)
  - But: tracks with θ < 8° miss FTD1!
- 1st optimization:
  - **Setup 4 (8 fwd discs)**: Reduce inner radius of FTD1 from 29 mm to 19 mm to cover tracks with θ down to 5° (ignoring radiation problems resulting in higher inefficiency, cluster size, etc.)
- 2nd optimization:
  - **Setup 5 (9 fwd. discs)**: Setup 4 => add one more forward disc with even bigger lever arm at z = 2290 mm (just in front of ECAL at z = 2300 mm[4])

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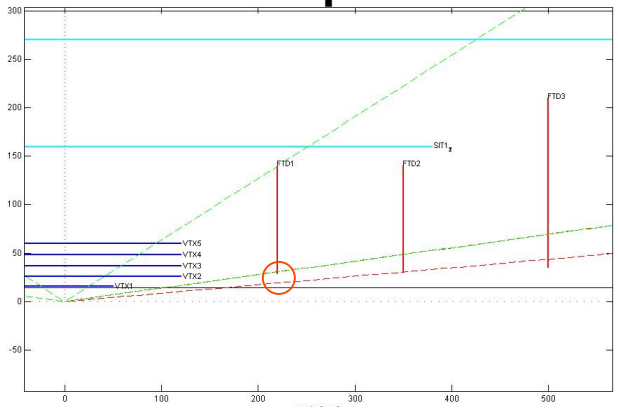
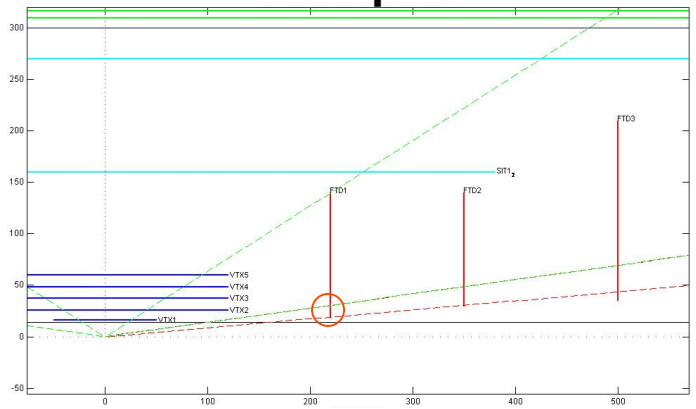
Optimized Setups 4 and 5

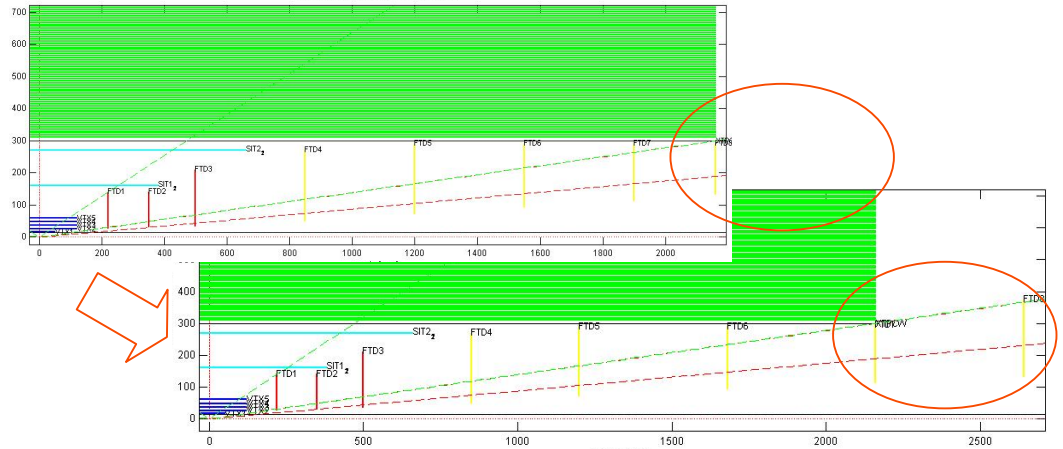
Setup 2:



Setup 4:



Setup 4:



Setup 5:

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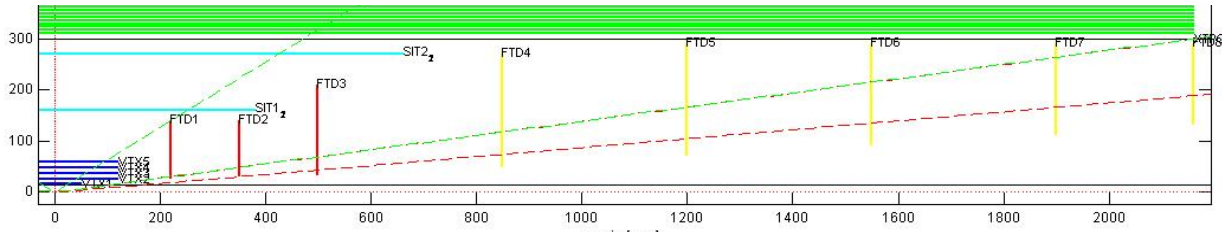
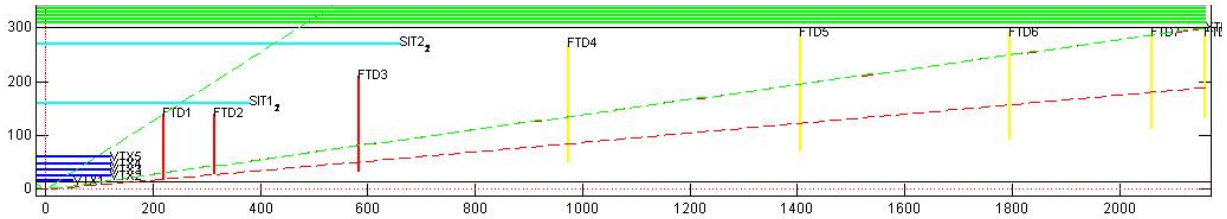
Further optimization of Setup 2

- 3rd optimization:
  - **Setup 6 (8 fwd. discs)**: Setup 4 => rearrange the detector positions such that they are distributed according to a cosine distribution
  - i.e. more discs at both ends, less discs in the middle
  - No further modifications (material, pitch). Evaluations as before

Setup 4:



Setup 6:



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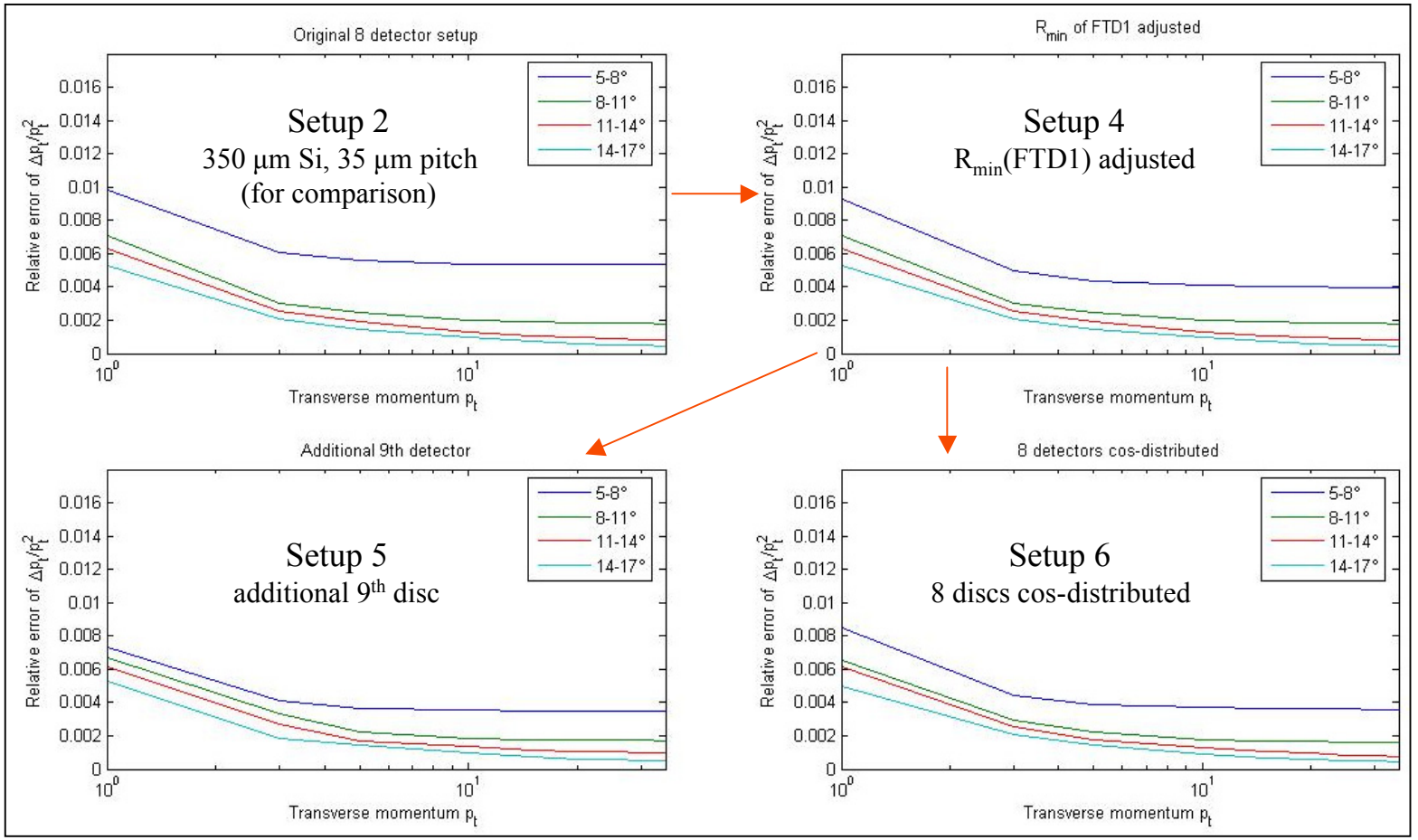
Study 4 (Setups 4, 5, 6), results



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Conclusions Study 1

- Study 1: Basic Setup (7 fwd. discs)
- Optimization is strongly conditioned by the range $\theta = 5 - 8°$ (no hits in TPC and FTD1)
- 500 μm Si instead of 350 μm Si:
  - 15% resolution loss for low p_t, no change for high p_t
- 50 μm pitch instead of 35 μm pitch:
  - 20% resolution loss for low p_t, 30% resolution loss for high p_t
- For larger angles ($\theta > 8°$) TPC starts to dominate the momentum resolution rather soon, thus the optimization must essentially cover the range at small angles and the transition region
  - accurate measurements of the TPC available; inclusion of the VTX, but loss of outer forward chambers
  - however, in the transition region the measurements inside and outside the TPC's inner wall are quite decoupled due to multiple scattering (large scattering for small θ)

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Conclusions Study 2

- Setup 2 (8 fwd. discs): additional disc at z = 2160 mm
- Clear improvement of momentum resolution of tracks missing the TPC
  - (Those tracks also miss the Vertex Detector and the innermost Forward Pixel Disc!)
  - 15% gain for low p_t
  - 20% gain for high p_t
- Same impact of material budget and pitch as before
  - therefore adding an 8^{th} disc is not yet an "overinstrumentation"

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Conclusions Study 3

- Setup 3 (9 fwd. discs): FTD4-FTD7 replaced by 6 discs, distributed evenly in the range z = 710 – 2160 mm
- Overinstrumented when using 500 µm Si!
  - No resolution gain compared to Setup 2
- Material budget starts to dominate even when using 350 µm Si
- Using 8 forward discs seems to be the best choice!

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Conclusions Study 4

- Optimization of Setup 2 (8 fwd. discs)
  - Setup 4 (8 fwd. discs): R_{min} of FTD1 adjusted, neglecting radiation problems
    - clear improvement for tracks with $\theta < 8°$:
      - 7% resolution gain for low p_t
      - 25% resolution gain for high p_t
  - Setup 5 (9 fwd. discs): add. disc at z = 2290 mm
    - further improvement for tracks with $\theta < 8°$:
      - 15% resolution gain for low p_t
      - 10% resolution gain for high p_t
  - Setup 6 (8 fwd. discs): cos-distributed
    - no more improvement in the forward region

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DETECTOR DESCRIPTION FOR FAST SIMULATION

- BASIC IDEA:
  - 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 (neither with fast simulation, nor with MOKKA/MARLIN).
  - Increases flexibility and speed, and yields useful and comparable results, which may be validated by full simulation once in a while.
- OPTIMIZATION MINI-WORKSHOP ("brainstorming jamboree") in Vienna, 26-28 March 2008 (participation by invitation only):
  - Suggest to set up a small ad-hoc working group (a few key persons) for LDC/ILD optimization, based on fast simulation. Goals:
    - agree on a basic detector description for fast simulation
    - make it also readable for MOKKA (validitation with corrupted data)?!

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The Vienna Fast Simulation Tool for charged tracks (LiC). Info on the web:

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

==> lictoy

Acknowledgements

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