The LiC Detector Toy

A mini simulation and track fit program, written in MATLAB, for fast and flexible detector optimization studies

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ILC software packages

	Description	Detector	Language	IO-Format	Region
Simdet	fast Monte Carlo	TeslaTDR	Fortran	StdHep/LCIO	EU
SGV	fast Monte Carlo	simple Geometry, flexible	Fortran	None (LCIO)	EU
Lelaps	fast Monte Carlo	SiD, flexible	C++	SIO, LCIO	US
Mokka	full simulation – Geant4	TeslaTDR, LDC, flexible	C++	ASCI, LCIO	EU
Brahms-Sim	Geant3 – full simulation	TeslaTDR	Fortran	LCIO	EU
SLIC	full simulation – Geant4	SiD, flexible	C++	LCIO	US
LCDG4	full simulation – Geant4	SiD, flexible	C++	SIO, LCIO	US
Jupiter	full simulation – Geant4	JLD (GDL)	C++	Root (LCIO)	AS
Brahms-Reco	reconstruction framework (most complete)	TeslaTDR	Fortran	LCIO	EU
Marlin	reconstruction and analysis application framework	Flexible	C++	LCIO	EU
hep.lcd	reconstruction framework	SiD (flexible)	Java	SIO	US
org.lcsim	reconstruction framework (under development)	SiD (flexible)	Java	LCIO	US
Jupiter-Satellite	reconstruction and analysis	JLD (GDL)	C++	Root	AS
LCCD	Conditions Data Toolkit	All	C++	MySQL, LCIO	EU
GEAR	Geometry description	Flexible	C++ (Java?)	XML	EU
LCIO	Persistency and datamodel	All	Java, C++, Fortran	-	AS,EU,US
JAS3/WIRED	Analysis Tool / Event Display	All	Java	xml,stdhep, heprep,LCIO,	US,EU

Frank Gaede, ECFA ILC Workshop, Vienna, Nov 14-17, 2005

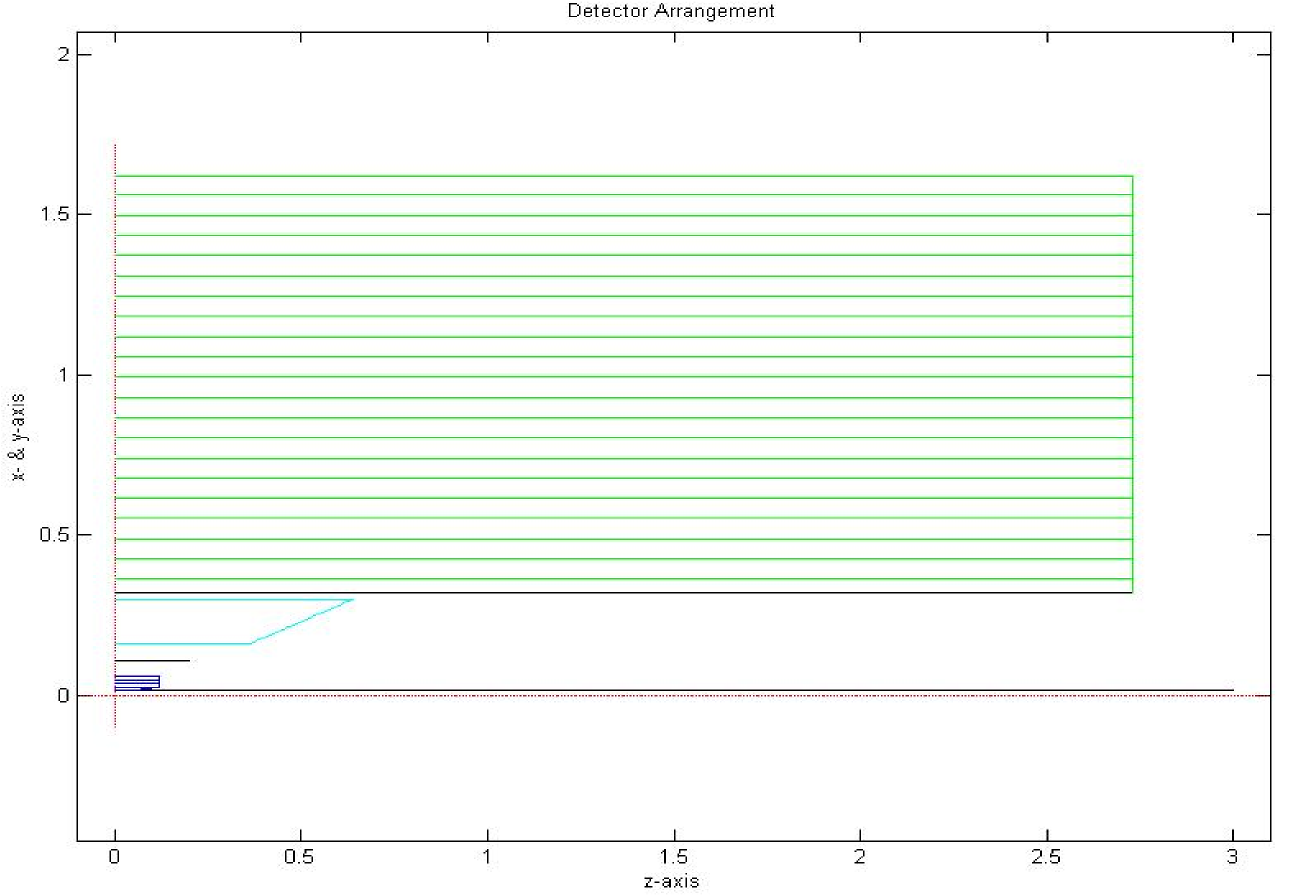
Program Features

- Simulation:
  - Single tracks coming from vertex (0,0,0)
  - Exact helix track model, including kinks for multiple scattering
  - Measurements of two coordinates, one for RΦ, one along a helix (incl. z) at coaxial cylinders, arranged in 3 groups (e.g. VD, IT, TPC), and additional passive layers (e.g. inner wall of TPC or beam tube)
  - Multiple scattering at discrete layers (material budget averaged over whole layer, correct path length traversed, scattering angles normally distributed (in the track system) with σ according to Highland)
  - Resolution of TPC measurements may be dependent on z (e.g. to account for diffusion)
- Reconstruction:
  - Exact Kalman filter with inclusion of multiple scattering (process noise), fitting from outside inwards
  - Linear track model; expansion point at a reference track (similar to DELPHI)

Program Features

- Program:
  - Written in MATLAB
  - Simple, for quite general use, may run on a laptop
  - Easy to read, implementing changes for individual needs
  - General facility should stay simple
    (e.g. use for multi track prong should be treated by a steering loop from outside)
  - Errors: normal or uniform (strips, or pads with double layer strip trick)
  - Flag to cope for inefficient detector layers
  - Orientation of one strip per detector may allow for any stereo angle
- Parameters:
  - Fitted parameters defined at the inside of the innermost layer
  - DELPHI-like coordinates (Φ, z, θ, $\beta=\varphi-\Phi$, 1/R with sign)
    5x5 error matrix
  - Cartesian coordinates (x, y, z, p_x, p_y, p_z)
    6x6 error matrix of rank ≤ 5, e.g. for CMS

Detector Setup



Input Sheet

- Vertex Detector (VD)

Number of layers:	5	
Radii [mm]:	15, 26, 37, 48, 60	
Lengths in z [mm]:	50, 120, 120, 120, 120	
Strips or pads:	1	(0: strips, 1: pads)
if strips: alpha [Rad]:		
Thickness [rad. lengths]:	0.002	
error distribution:	1	(0: normal, 1: uniform)
if normal: $\sigma(R\Phi)$ [μm]:		
$\sigma(z)$ [μm]:		
if uniform: $d(R\Phi)$ [μm]:	25	
$d(z)$ [μm]:	25	

- Inner Tracker (IT)

Number of layers:	2	
Radii [mm]:	160, 300	
Lengths in z [mm]:	360, 640	
alpha [Rad]:	pi/2	
Single layer:	0, 0	(0: double, 1: single)
if single: measured coor.:		(0: $R\Phi$, 1: z)
Thickness [rad. lengths]:	0.0175	
error distribution:	1	(0: normal, 1: uniform)
if normal: $\sigma(R\Phi)$ [μm]:		
$\sigma(z)$ [μm]:		
if uniform: $d(R\Phi)$ [μm]:	50	
$d(z)$ [μm]:	50	

Input Sheet

- Time Projection Chamber (TPC)

Number of layers:	200
Radii [mm]:	362, 1618
Lengths in z [mm]:	2730
Thickness [rad. lengths]:	0.00005
$\sigma 1(R\Phi)$ [μm]:	50 ($\sigma=\sqrt{[\sigma_1^2 + \sigma_2^2 \lvert z-z_{max} \rvert]}$)
$\sigma 2(R\Phi)$ [μm]:	40
$\sigma 1(z)$ [μm]:	200
$\sigma 2(z)$ [μm]:	1000

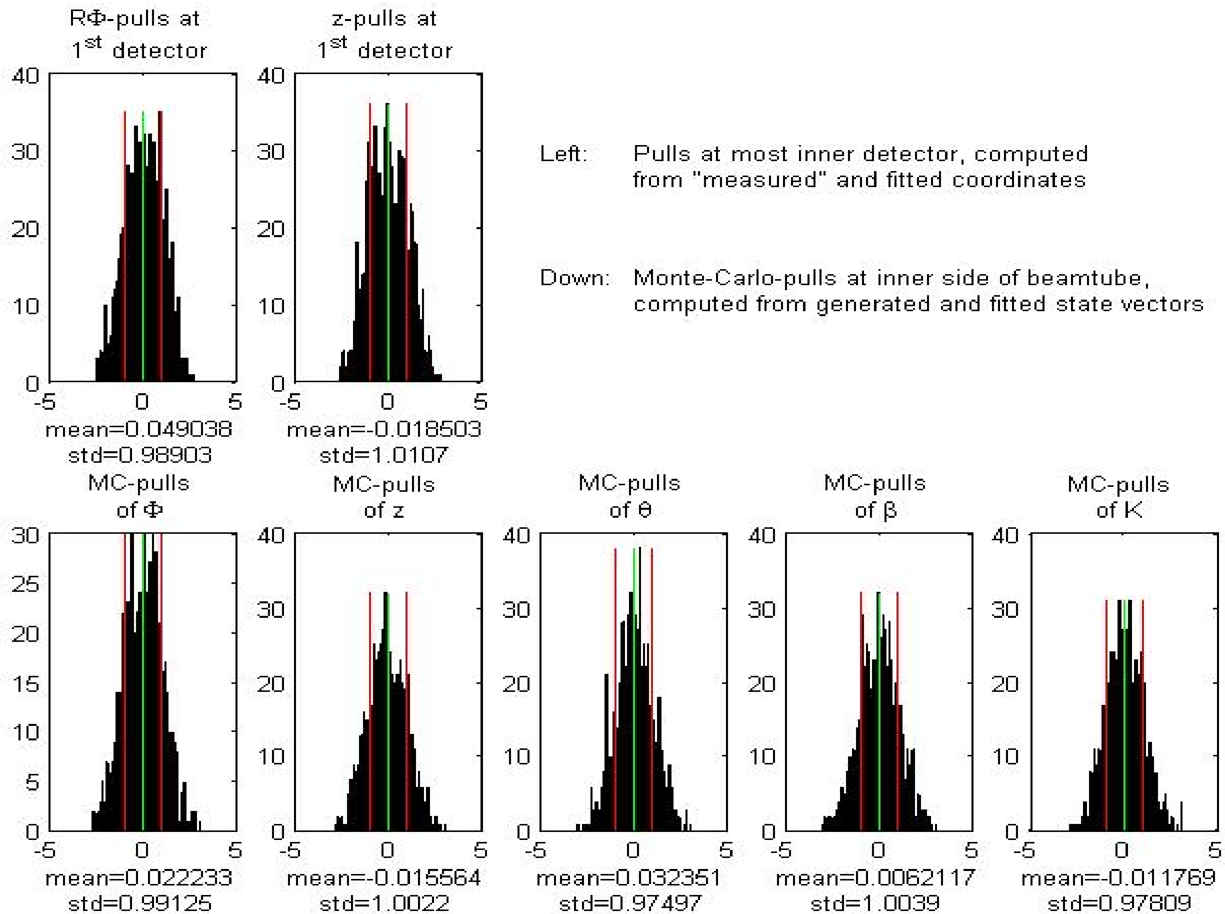
- Passive Scatterers (PS)

Number of layers:	3
Radii [mm]:	14, 110, 320
Length in z [mm]:	3000, 200, 2730
Thickness [rad. lengths]:	0.14, 0.001, 0.02

- Start parameter range

Transverse momentum range [GeV/c]:	5, 20
Angular range theta [Rad]:	pi/2, 3*pi/2

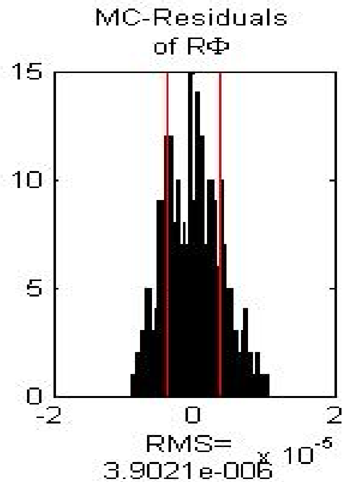
Pulls

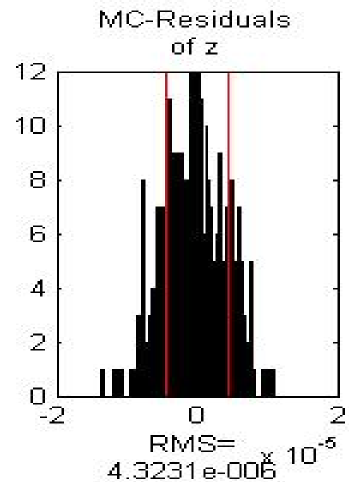


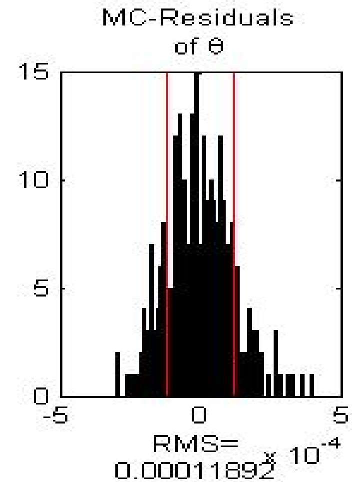
Left: Pulls at most inner detector, computed from "measured" and fitted coordinates

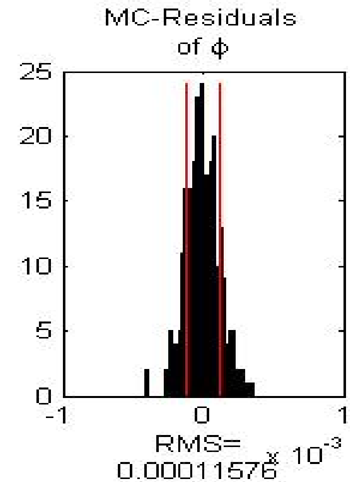
Down: Monte-Carlo-pulls at inner side of beamtube, computed from generated and fitted state vectors

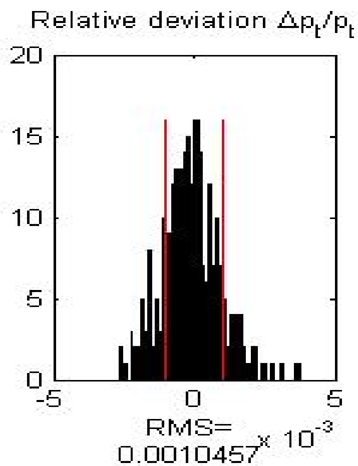
Residuals









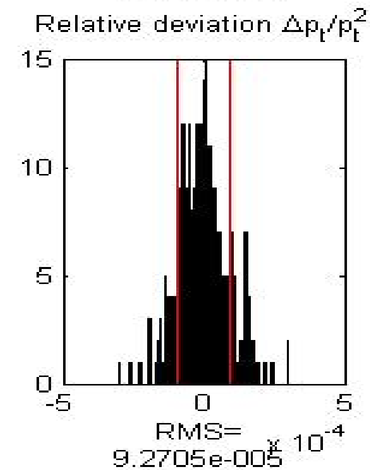


$0 \leq \lambda \leq \pi/12$

Up: Monte-Carlo-Residuals at 1st detector, computed from generated and fitted state vectors

Left: Relative deviation $\Delta p_t/p_t$

Right: Relative deviation $\Delta p_t/p_t^2$



Results

RMS		$0 \leq \lambda \leq \pi/12$	$\pi/12 \leq \lambda \leq \pi/6$	$\pi/6 \leq \lambda \leq \pi/4$
$R\Phi$	without IT	$3.95\ 10^{-6}$	$3.99\ 10^{-6}$	$3.98\ 10^{-6}$
	with IT	$3.90\ 10^{-6}$	$3.98\ 10^{-6}$	$4.33\ 10^{-6}$
	modified IT	$3.81\ 10^{-6}$	$3.87\ 10^{-6}$	$4.26\ 10^{-6}$
z	without IT	$4.35\ 10^{-6}$	$4.65\ 10^{-6}$	$4.88\ 10^{-6}$
	with IT	$4.32\ 10^{-6}$	$4.02\ 10^{-6}$	$4.26\ 10^{-6}$
	modified IT	$4.27\ 10^{-6}$	$3.97\ 10^{-6}$	$4.12\ 10^{-6}$
ϑ	without IT	$1.50\ 10^{-4}$	$1.46\ 10^{-4}$	$1.17\ 10^{-4}$
	with IT	$1.19\ 10^{-4}$	$1.17\ 10^{-4}$	$1.00\ 10^{-4}$
	modified IT	$1.14\ 10^{-4}$	$1.15\ 10^{-4}$	$0.967\ 10^{-4}$
ϕ	without IT	$1.14\ 10^{-4}$	$1.19\ 10^{-4}$	$1.27\ 10^{-4}$
	with IT	$1.16\ 10^{-4}$	$1.21\ 10^{-4}$	$1.27\ 10^{-4}$
	modified IT	$1.10\ 10^{-4}$	$1.16\ 10^{-4}$	$1.22\ 10^{-4}$
$\Delta p_t/p_t$	without IT	$1.06\ 10^{-3}$	$1.08\ 10^{-3}$	$1.16\ 10^{-3}$
	with IT	$1.05\ 10^{-3}$	$1.02\ 10^{-3}$	$1.05\ 10^{-3}$
	modified IT	$1.05\ 10^{-3}$	$1.03\ 10^{-3}$	$1.05\ 10^{-3}$
$\Delta p_t/p_t^2$	without IT	$1.02\ 10^{-4}$	$1.01\ 10^{-4}$	$1.14\ 10^{-4}$
	with IT	$0.927\ 10^{-4}$	$0.921\ 10^{-4}$	$0.977\ 10^{-4}$
	modified IT	$0.942\ 10^{-4}$	$0.931\ 10^{-4}$	$0.998\ 10^{-4}$