The LiC Detector Toy

A mini simulation and track fit program tool for fast and flexible detector optimization studies

M. Regler, M. Valentan, R. Frühwirth
Austrian Academy of Sciences, Vienna

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

Motivation

- Compare track parameter resolutions of various detector setups (at present only in the „barrel region“);
- Optimize size and position of track sensitive devices and of detector material budgets;
- A simple tool easy to understand, handle and modify;
- Can easily be adapted to meet individual needs;
- Can be installed on a desktop or laptop PC;
- Quick results by „shorter than a coffee break“;
- Live demonstrations at a conference possible;
- Graphics visualisation interface planned in future release.

General Program Features

- Written in MatLab (a language and IDE by MathWorks);
- At present support for coaxial cylinder layers („barrel“) only; „forward region“ planes in next release;
- Arbitrary length and position of the layers;
- Inclusion of any number of passive layers;
- Measurements of two coordinates: one for azimuth $R\Phi$, one along the cylinder (z) for pixels or a TPC;
- Arbitrary stereo angle (z‘ instead of z) for strips;
- Inefficiencies uncorrelated (strips) or correlated (pixels);
- Resolutions of a TPC Gaussian, and may depend on z.

Specific Program Features

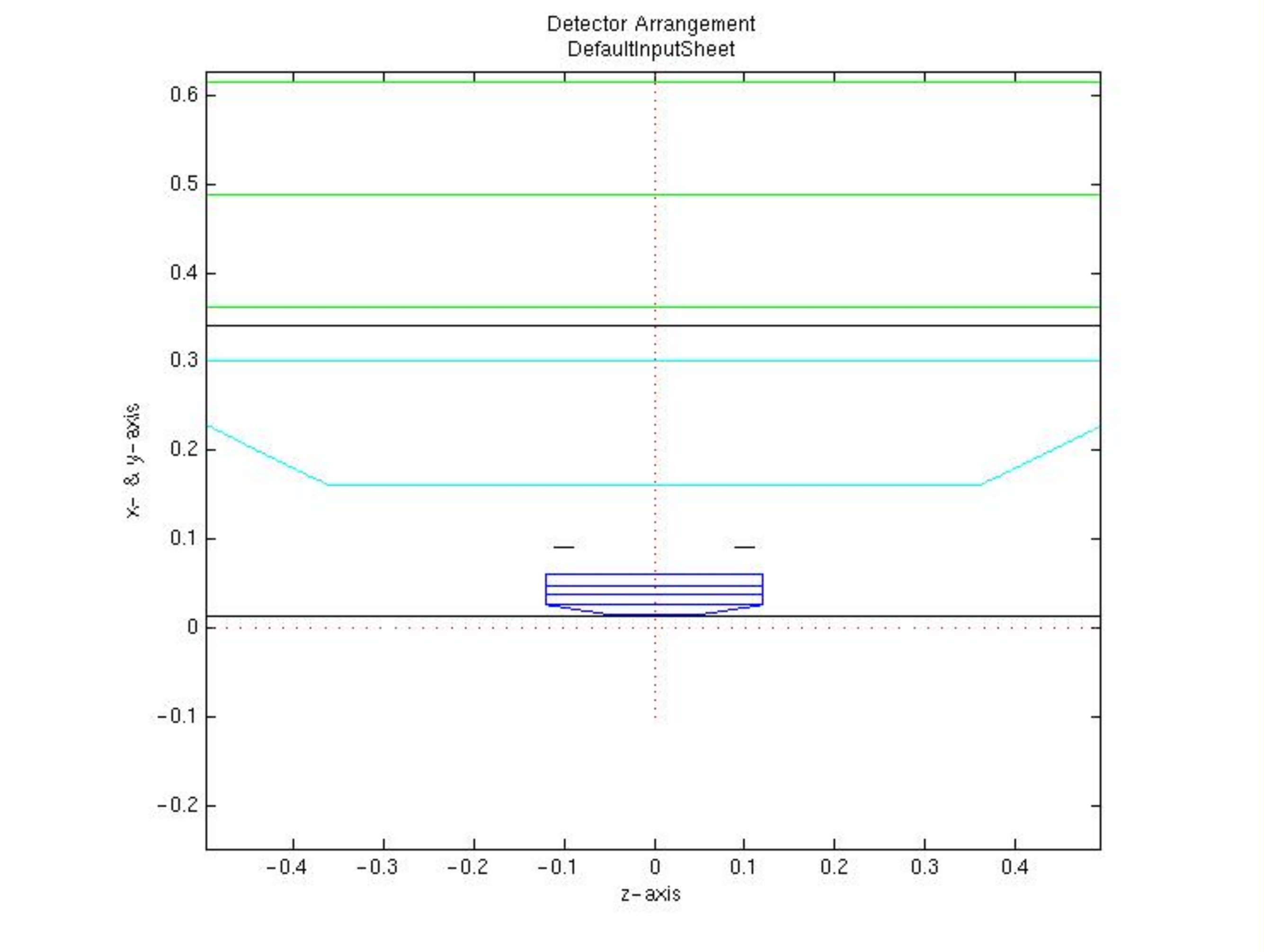
- **Simulation:**
  - Single tracks originating from a vertex, assumed at (0, 0, z);
  - Solenoid magnetic field, rotational symmetry w.r.t. z-axis;
  - Cylinders grouped in 3 modules with any number of layers; the 3rd module being either a TPC, or empty;
  - Exact helix track model, including kinks for multiple scattering;
  - Multiple scattering at discrete layers: correct path length traversed, material budget averaged over whole layer, scattering angles Gaussian distributed (in the track‘s local coordinate frame) according to the Highland formula;
  - Gaussian (TPC) or uniformly distributed measurement errors;
  - Systematic and/or stochastic inefficiencies included.

Specific Program Features

- **Reconstruction:**
  - No PR; track fit by exact Kalman filter with inclusion of multiple scattering (process noise), fitting from outside inwards;
  - Linear track model: expansion point is a reference track (method similar to that of the DELPHI experiment).
- **Parameters:**
  - Fitted parameters defined at the inside of the innermost layer;
  - DELPHI-like parameter vector and error matrix:
    $\{ \Phi, z, \theta, \beta = \varphi - \Phi, \kappa = \pm 1/R_H \}$ with $\mathrm{sign}(\kappa) = \mathrm{sign}(d\varphi/ds)$,
    and corresponding 5x5 covariance matrix;
  - Optional CMS-like Cartesian parameters and errors:
    $\{ x, y, z, p_x, p_y, p_z \}$ with a 6x6 covariance matrix of rank 5.

Sample Detector Setup

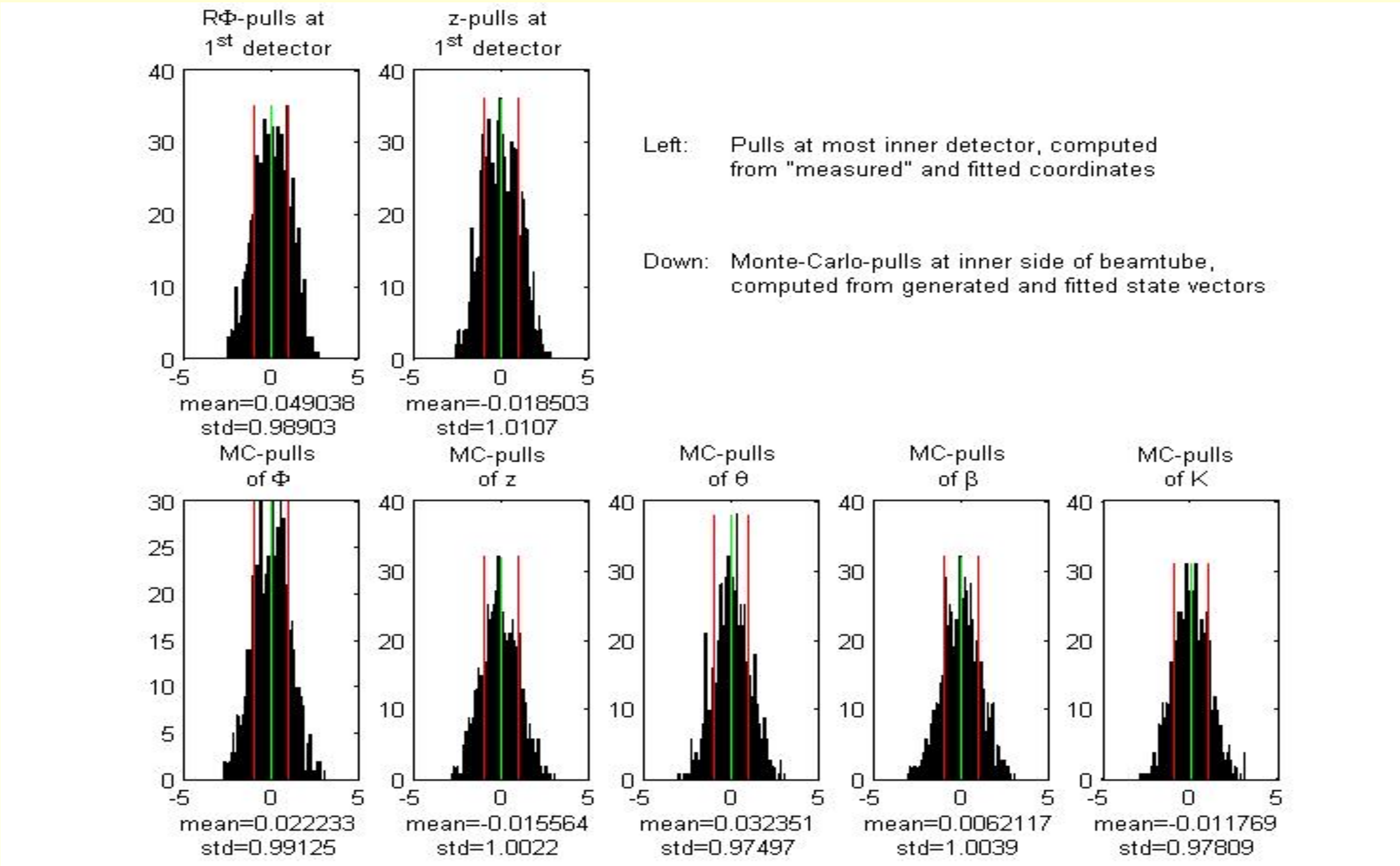
Inspired by the LDC concept
with „Paris“ TPC
(scale units in m)



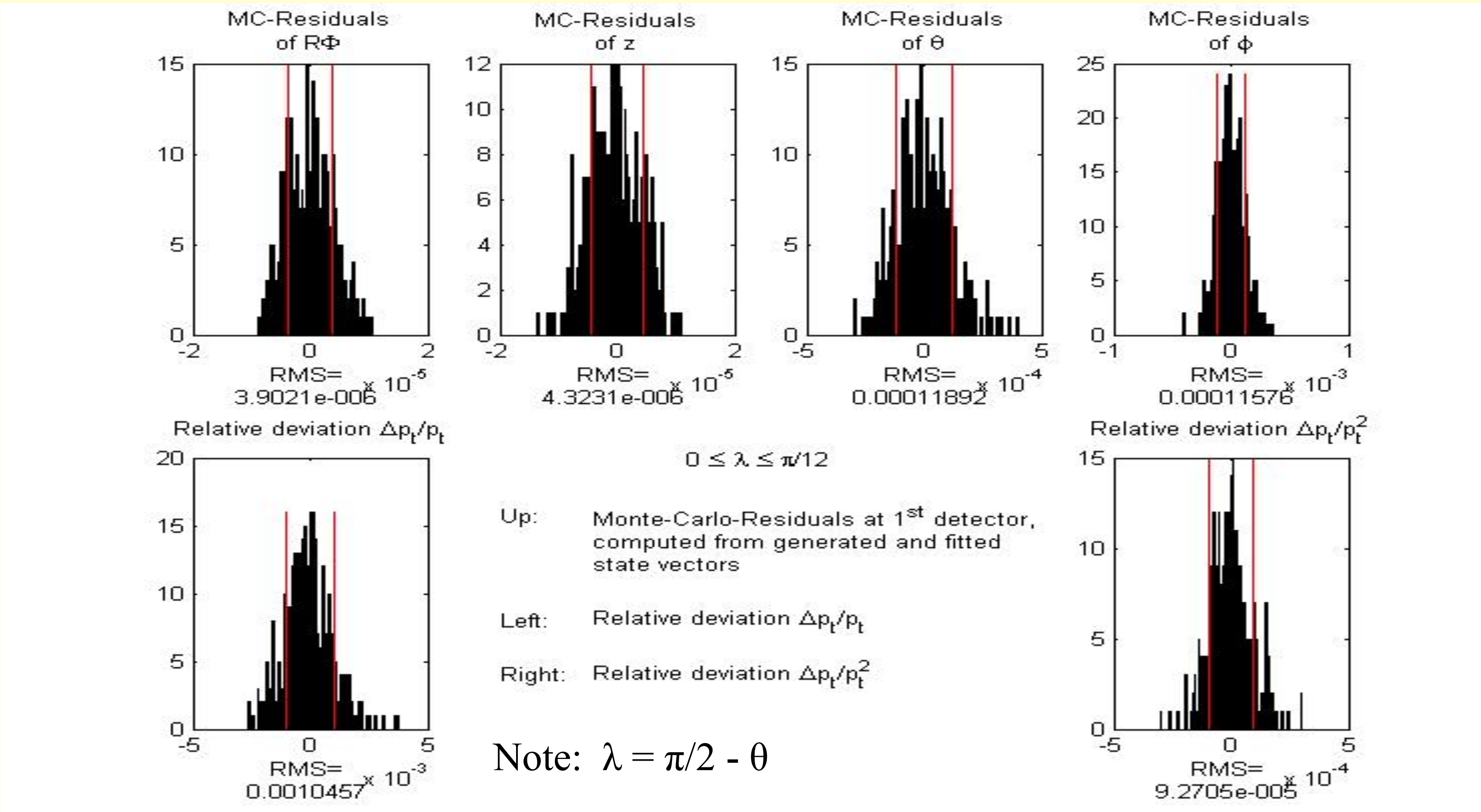
Corresponding Input Sheet

```
01 LiC Detector-Toy (barrel)
02 Default Input Sheet
03
04 Vertex Detector (VD)
05
06 Number of layers:             6
07 Radii [mm]:                   14,15,26,37,48,60
08 Upper z limit [mm]:            3000, 50, 120, 120, 120, 120
09 Lower z limit [mm]:           -3000,-50,-120,-120,-120,-120
10 Efficiency RPhi:              0,0.9,0.9,0.9,0.9,0.9
11 Efficiency 2nd:               -1
12 Stereo angle alpha [Rad]:     pi/2
13 Thickness [rad. lengths]      0.14,0.05,0.05,0.05,0.05,0.05
14 Error distribution:           1
15 0 normal sigma(RPhi) [1e-6m]:
16          sigma(2nd)  [1e-6m]:
17 1 uniform d(RPhi)  [1e-6m]:   25
18           d(2nd)   [1e-6m]:   25
19
20 Inner Tracker (IT)
21
22 Number of layers:             5
23 Radii [mm]:                   90,90,160,300,360
24 Upper z limit [mm]:            110,-90, 360, 640, 2730
25 Lower z limit [mm]:            90,-110,-360,-640,-2730
26 Efficiency RPhi:              0,0,0.9,0.9,0
27 Efficiency 2nd:               -1
28 Stereo angle alpha [Rad]:     pi/2
29 Thickness [rad. lengths]:     0.14,0.14,0.0175,0.0175,0.14
30 Error distribution:           1
31 0 normal sigma(RPhi) [1e-6m]:
32          sigma(2nd)  [1e-6m]:
33 1 uniform d(RPhi) [1e-6m]:    50
34           d(2nd)  [1e-6m]:    50
36 Time Projection Chamber (TPC)
37
38 Number of layers:              100
39 Radii [mm]:                    362, 1618
40 Upper z limit [mm]:             2730
41 Lower z limit [mm]:            -2730
42 Efficiency RPhi:               0.95
43 Efficiency z: 0.95
44 Thickness [rad. lengths]:0.00005
45 sigma1(RPhi) [1e-6m]:          50
46 sigma2(RPhi) [1e-6m]:          40
47 sigma1(z)       [1e-6m]:       200
48 sigma2(z)       [1e-6m]:       1000
49
50 Start parameter range
51
52 Transverse momentum [GeV/c]:   5,20
53 Angular range in theta [Rad]:  pi/4, 3*pi/4
54 Range in z [mm]:               0,5
55
56 Flags (0 disabled, 1 enabled)
57
58 Sketch of arrangement:         0
59 Simulation:                    1
60 Multiple scattering:           1
61 Measurement errors:            1
62 Reconstruction:                1
63 Tests:                         1
64 Chi2:                          1
65 Display bad pulls:             0
66 Pulls histograms:              1
67 Residuals histograms:          1
68
69 Number of tracks:              1000
```

Results: Pull Quantities



Results: MC Residuals



Note: $\lambda = \pi/2 - \theta$

Summary of various setups and λ parameter regions

RMS		$0 \le \lambda \le \pi/12$	$\pi/12 \le \lambda \le \pi/6$	$\pi/6 \le \lambda \le \pi/4$
$R\Phi$	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	$0.942\ 10^{-4}$	$0.931\ 10^{-4}$	$0.998\ 10^{-4}$

Subsequent Vertex Fit

- Fitted tracks as input to the VERTIGO/RAVE toolkit;
- Interface is the Harvester's standard CSV format;
- Successfully tested with 10- and 1000-prong events.

References

- http://forum.linearcollider.org ==> Fast Simulations
  ==> LiC Detector Toy (permanently kept up-to-date);
- http://wwwhephy.oeaw.ac.at/p3w/ilc/reports/LiC_Det_Toy/UserGuide.pdf (User Guide);
- Forthcoming visit of M. Valentan in Valencia (last week of Nov. 2006).