LiC Detector Toy 2.0

Tracking detector optimization with fast simulation and its application to the ILD design

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Abstract

The "LiC Detector Toy" allows investigation of the track parameter resolution via Monte Carlo, for the purpose of optimizing a detector set-up. It features:

- Simulation of the track sensitive part of a ring or linear collider detector with a solenoid magnetic field, and its material budget;
- Support of measurements by semiconductor pixel and strip detectors, and a TPC;
- Track reconstruction by a Kalman filter, including tests of goodness of the fits.

Written in **MatLab**® (a language and IDE by MathWorks).

Version 2.0 available for **GNU Octave**

Motivation

- Compare track parameter resolutions of various detector set-ups, for both barrel and forward/backward regions;
- Optimize size and position of the track sensitive devices, and of the 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 demonstration at a conference possible;
- An integrated graphics user interface (GUI) available;
- Ideal tool for investigating the effect of local variations.

Program Features
(general)

- Single or double silicon strip layers, pixel layers, TPC;
- Efficiencies uncorrelated (strips), or strictly correlated (pixels); passive layers defined by zero efficiency;
- Homogeneous magnetic field (by a solenoid), rotational symmetry w.r.t. the z-axis of the detector set-up;
  - However, an asymmetry w.r.t. the z coordinate possible;
- Start parameters for simulated tracks are user-defined:
  - Vertex position range,
  - Transverse momentum range,
  - Range of polar angle θ,
  - Number of tracks from the vertex.

Program Features
(Simulation)

- Exact helix track model, with kinks for multiple scattering;
- Data corruption by measurement errors, multiple scattering and detector inefficiencies (systematic and/or stochastic);
- Measurement errors Gaussian (e.g. for TPC) or uniformly distributed (uncorrelated or correlated in case of 2D);
- Material budget assumed to be concentrated in “thin” layers, no special treatment of electrons:
  - Multiple scattering: |p| conserved, correct path length traversed;
  - Thickness of scatterers given in radiation lengths;
  - Scattering angles Gaussian distributed in the track’s local coordinate frame (Rossi-Greisen formula with Highland’s term);
  - No energy loss (by ionisation or bremsstrahlung) simulated.

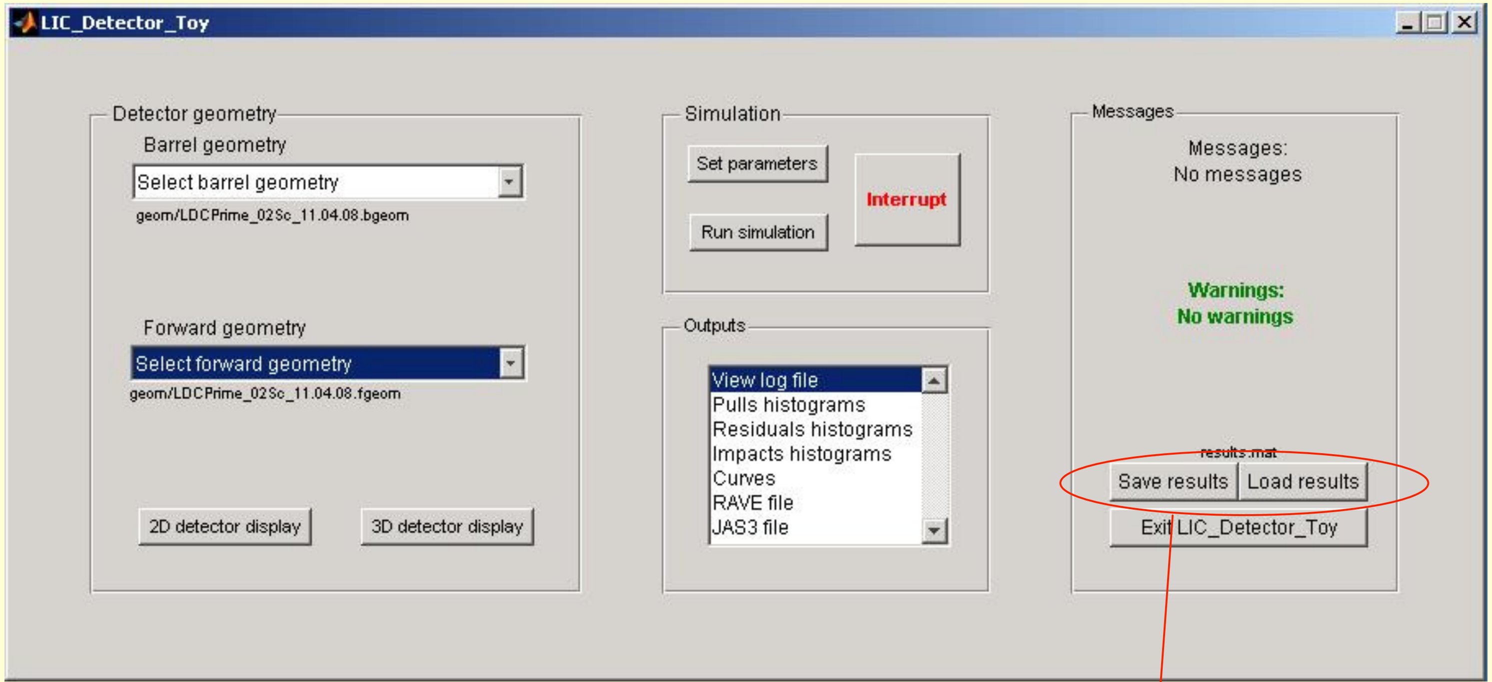
Program Features
(Reconstruction)

- **No pattern recognition !**
- Single track fit by an exact Kalman filter:
  - Multiple scattering accounted for as “process noise”;
  - Fitting performed from outside inwards;
- Linear track model: expansion point is a “reference track”;
- Fitted parameters defined at the inside of the innermost layer:
  - $\{ \Phi, z, \theta, \beta = \varphi - \Phi, \kappa = \pm 1/r_H \}$ with $\mathrm{sign}(\kappa) = \mathrm{sign}(d\varphi/ds)$, and the corresponding 5x5 covariance matrix;
  - Interface to the RAVE vertex reconstruction toolkit via VERTIGO;
- Goodness of the fit monitored by pull quantities and χ^2.

What's new in LDT 2.0?

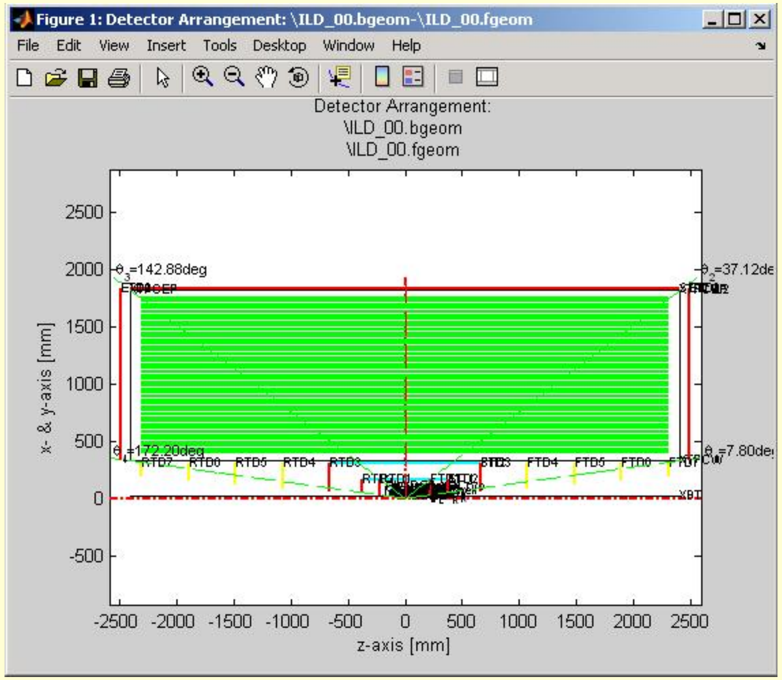
- New Graphic User Interface (GUI)
- 3D detector display
- Simulation of complex intermediate region
- Updated TPC resolution including drift
- Automatic loops over start parameters and/or geometry
- Command line based for GNU Octave

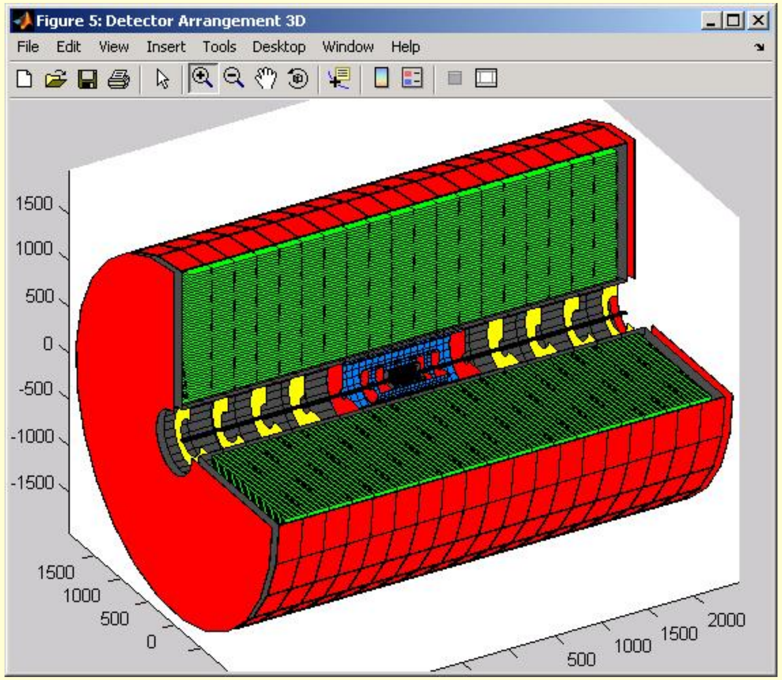
New Graphic User Interface (GUI)



Possibility to save simulation results for later use

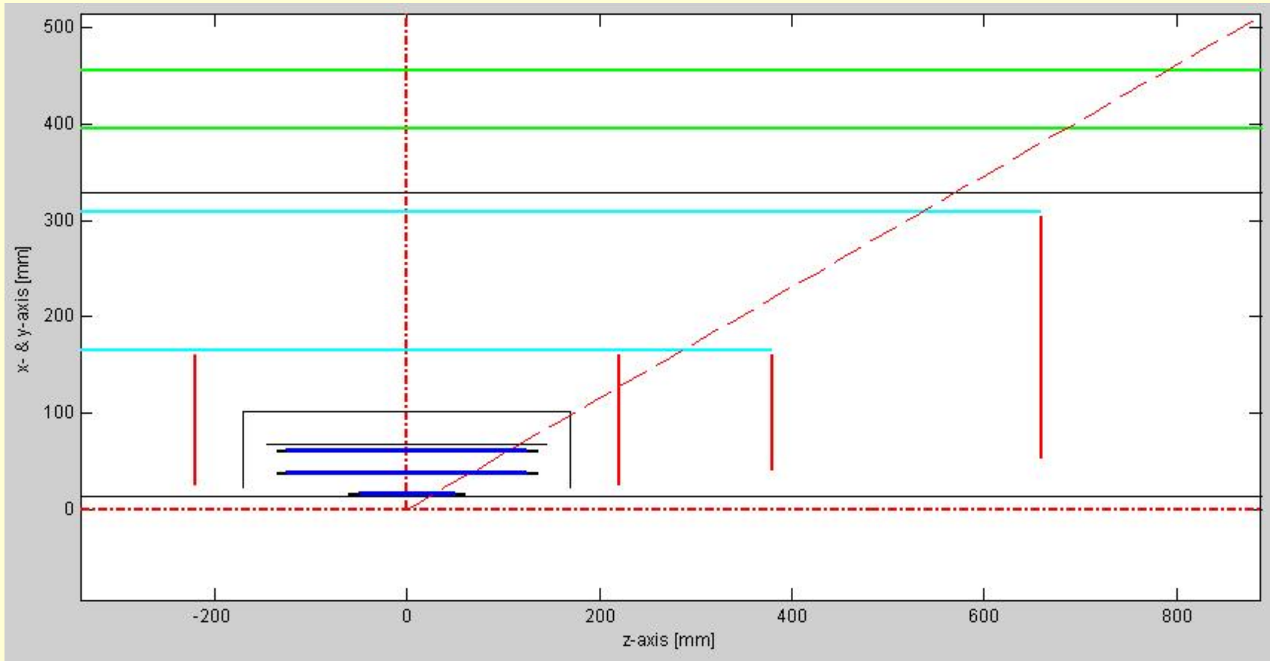
2D and 3D Detector Display
(ILD_00, October 2008)





Complex intermediate region

- Arbitrary sequence of cylindric and plane detector layers



Updated TPC resolution

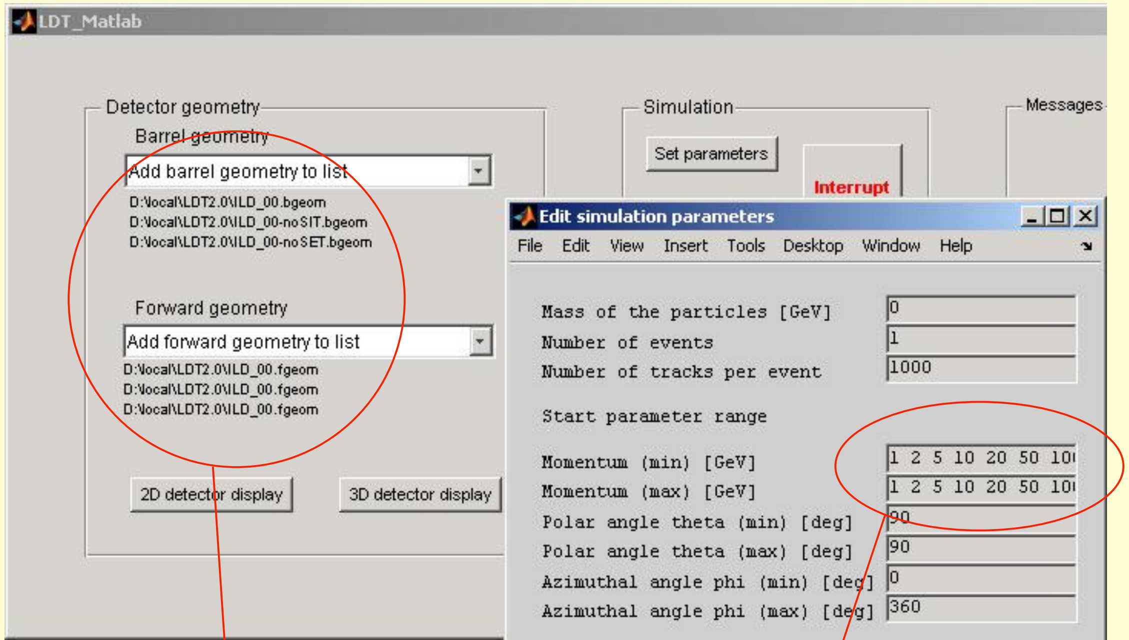
- TPC resolution as commented by Ron Settles:

$$\sigma_{R\Phi} = \sqrt{\sigma^2_{R\Phi,0} + \sigma^2_{R\Phi,1} \cdot \sin(\beta) + C^2_{R\Phi} \cdot \sin(\vartheta) \cdot \frac{6mm}{h[mm]} \cdot \Delta z[m]},$$

$$\sigma_z = \sqrt{\sigma^2_{z,0} + C^2_z \cdot \Delta z[m]},$$

- Includes:
  - Constant point resolution of endplates,
  - Term dependent on angle β between projected track and normal vector of cylindrical layer,
  - Term dependent on polar angle θ and charge spreading.

Automatic loops



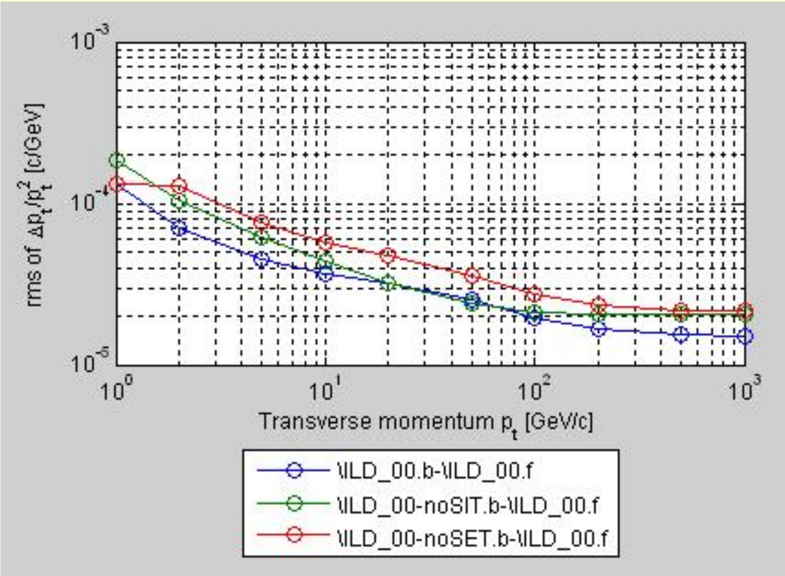
Several pairs of barrel and forward detector setups

Several different start values for the transverse momentum

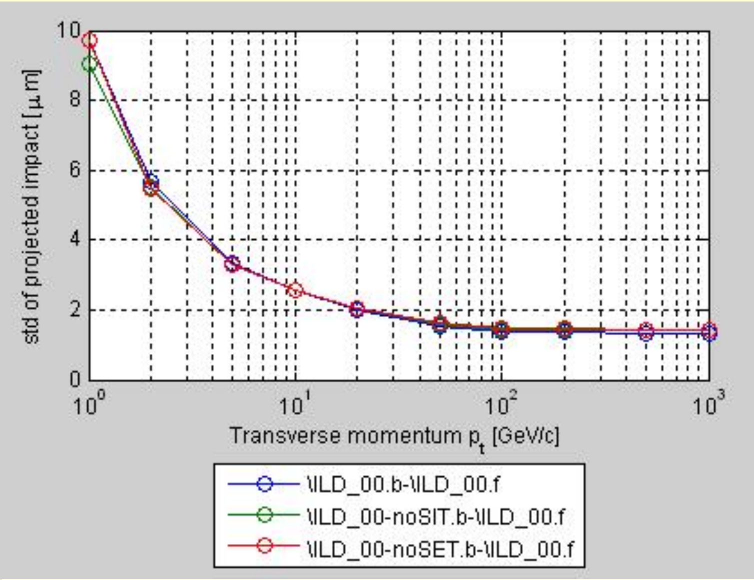
- Performance of
  - different detector setups
- as function of
  - momentum
  - polar angle

Automatic loops

rms of $\Delta p_t/p_t^2$



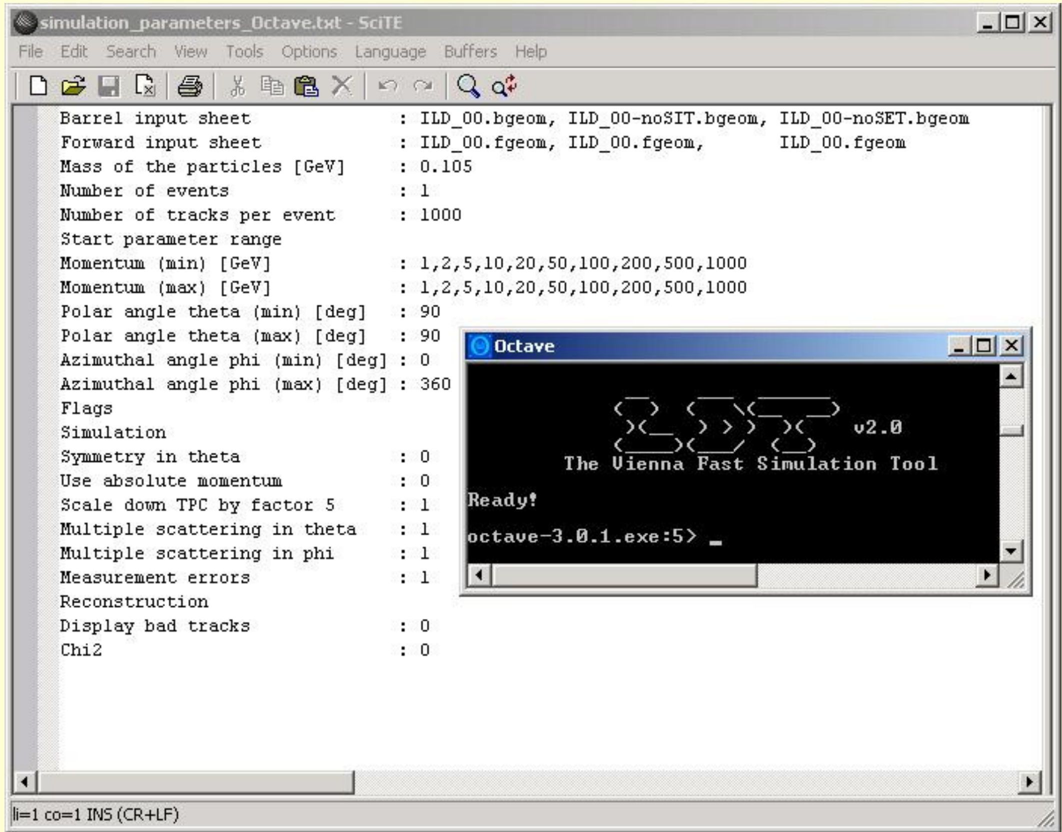
σ of projected impact



- blue: ILD
- green: ILD without SIT
- red: ILD without SET

These plots are direct outputs of the program!

LDT 2.0 for GNU Octave



- Octave is free
- Command line based (no GUI)
- All features except for 3D detector display
- Factor 10 slower

Validation and Outlook

- Successful validation against
  - Fullsim: Mokka/Marlin (Steve Aplin, Frank Gaede);
  - Fastsim: SGV (Mikael Berggren).
- Outlook to future features:
  - Optional fine-grained scan of parameter space, results using covariance matrix instead of distribution of fitted tracks;
  - Simulation of e^-/e^+energy loss by bremsstrahlung;
  - Continuous multiple scattering (e.g. inside calorimeters in front of muon detectors);
  - Flexible handling of subdirectories for input and output files.

Fastsim activities in 2008

– Mini Workshop, HEPHY Vienna, 26 - 28 March 2008;
– Brainstorming, DESY Hamburg, 29 Sept - 1 Oct 2008.

Repositories on the Web

http://wwwhephy.oeaw.ac.at/p3w/ilc/lictoy/

LDTsource_20.zip

UserGuide_20.pdf

http://wwwhephy.oeaw.ac.at/p3w/ilc/reports/
LiC_Det_Toy/Proceedings/…