SGV fast detector simulation program : Tutorial

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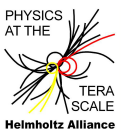
IDT-WG3 SGV tutorial, Online, 13 October, 2021





Outline

Fast simulation types, and the choice for ILC

Different types, with increasing level of sophistication:

- 4-vector smearing.
- Parametric, needing input from FullSim: Delphes
  - Ignores correlations, eg. between p measurement and ip:s.
  - Hard to handle confusion in high granularity calorimeters.
  - No dE/dx, secondary vertices, effect of hit level inefficiencies ....
  - But very fast, and very condensed output.
  - By theoreticians, for theoreticians.
- Covariance matrix machines, not needing input from FullSim:SGV
  - Full covariance matrix available for each track-helix.
  - Individual shower shape and position generated $\Rightarrow$ can approximate confusion.
  - Hit patterns known $\Rightarrow$ dE/dX and hit-level efficiencies doable.
  - Covariance matrices available $\Rightarrow$ vertex fitting.
  - Anything up to DST-level detail can be output.
  - As fast as Delphes.
  - By experimetalists, for both exprimetalists and theoreticians.

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For ILC:

Only Covariance matrix machines have sufficient detail. Here, I'll cover "la Simulation à Grande Vitesse", SGV.

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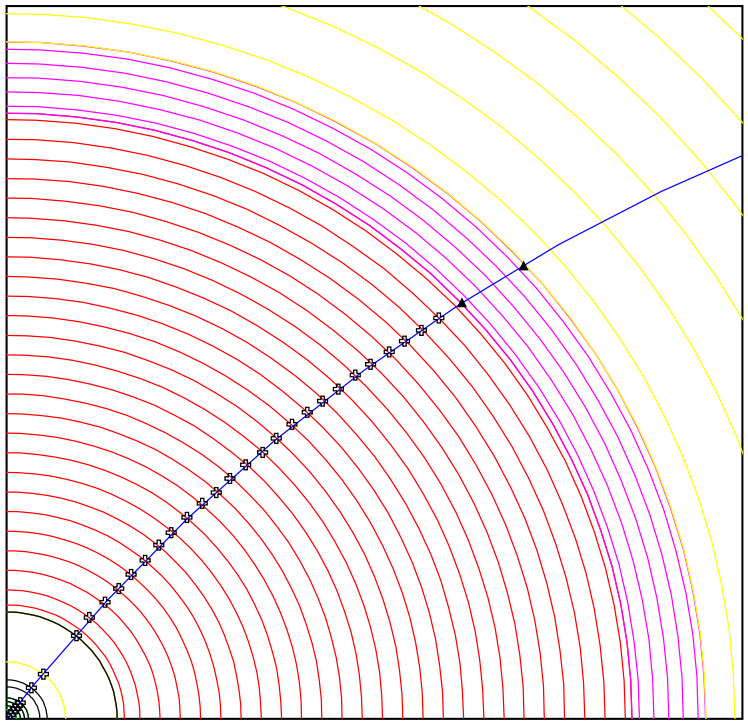
SGV: How tracking works

SGV is a machine to calculate covariance matrices

Tracking: Follow track-helix through the detector.



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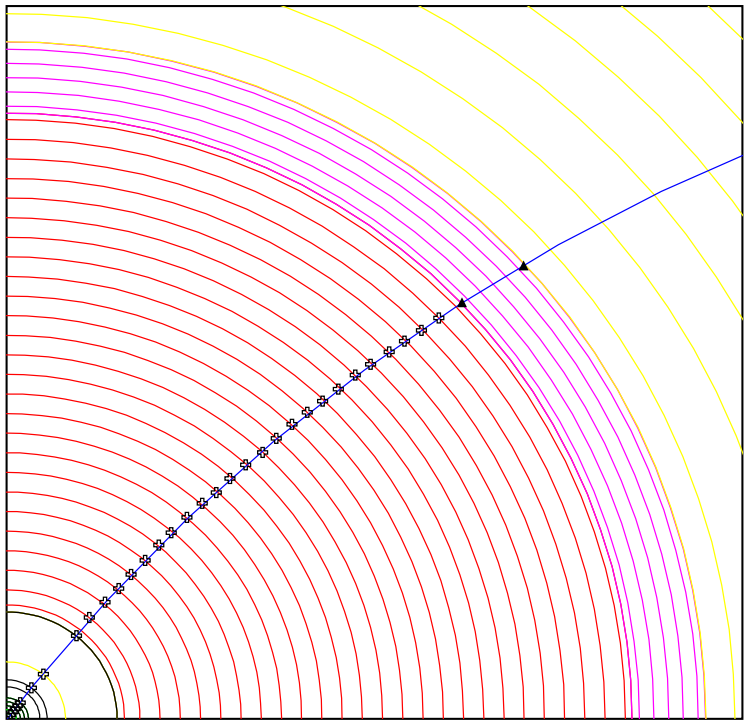

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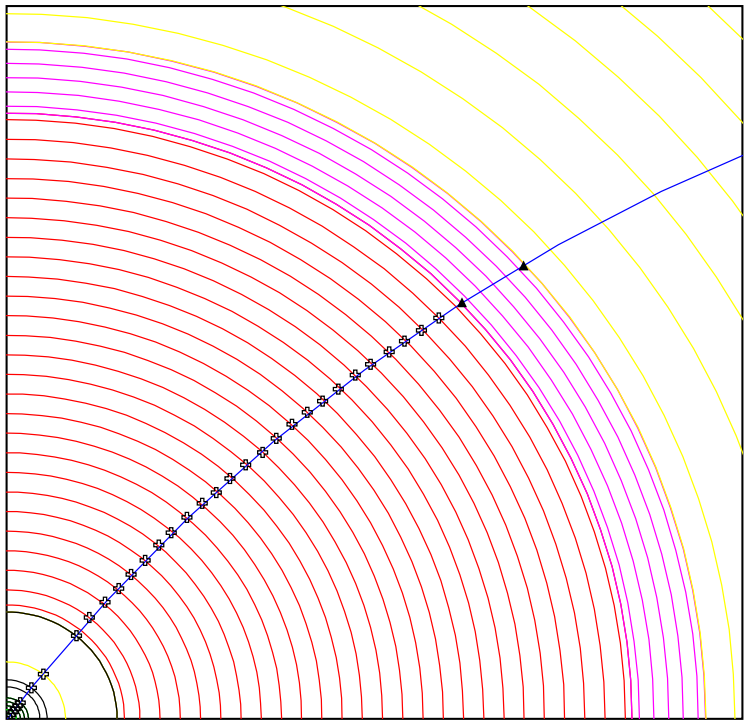

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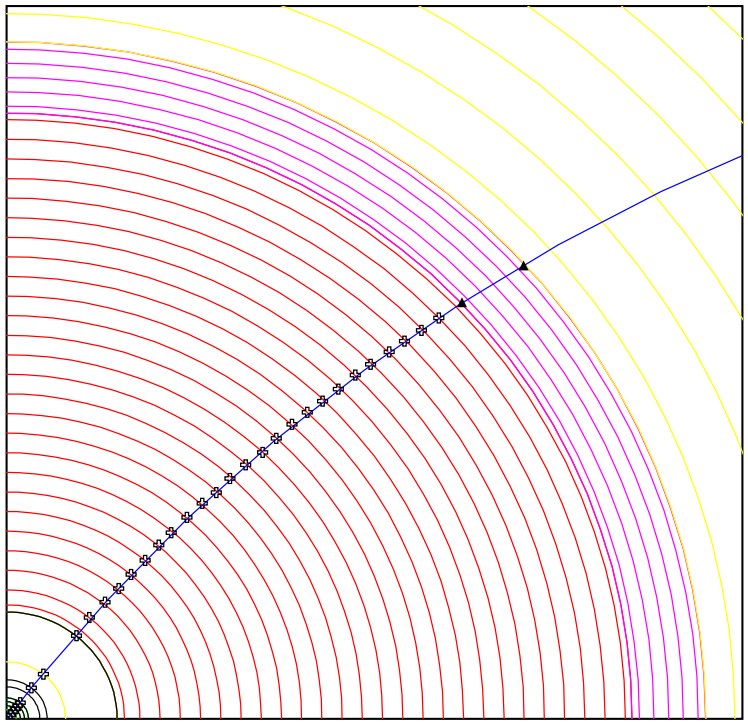

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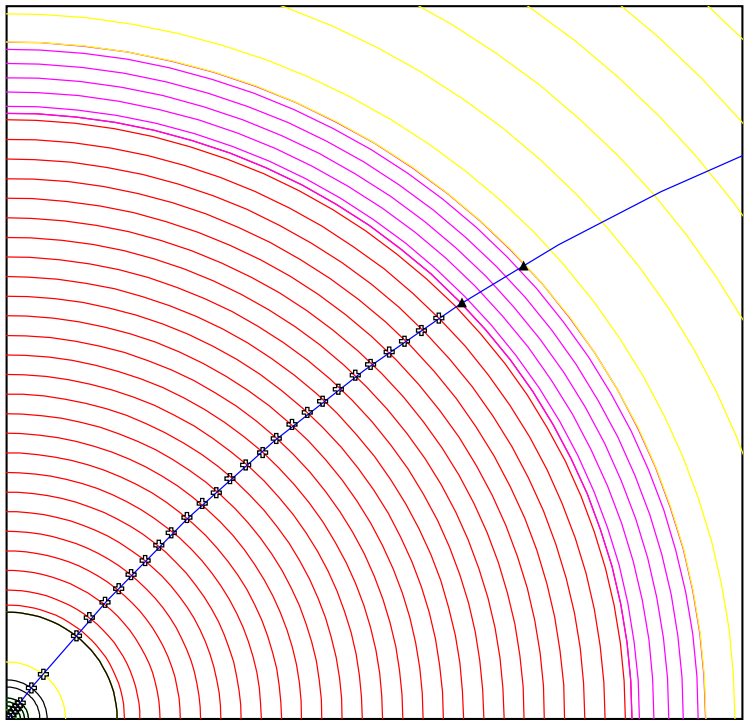

- Response type: MIP, EM or hadronic shower, below threshold, etc.
- Simulate single particle response from parameters.
- Easy to plug in more sophisticated shower-simulation.

Other stuff:

- EM-interactions in detector material simulated
- Plug-ins for particle identification, track-finding efficiencies,...
- Information on hit-patterns accessible to analysis.

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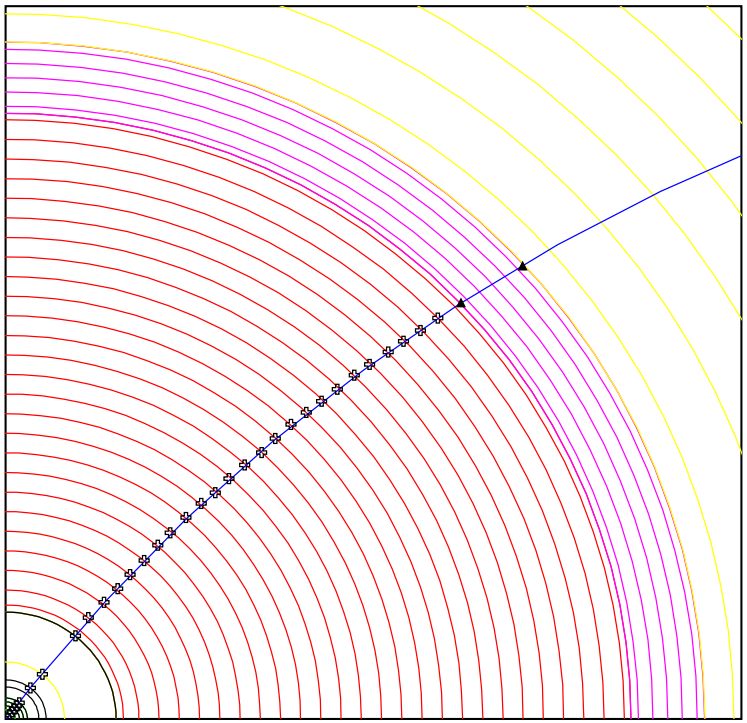

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- User data, delivered in Module-global arrays:
  - Extended 4-vectors .
  - Track helix parameters with correlations.
  - Calorimetric clusters.
  - When relevant: true values.
  - Auxiliary information on particle history, detector-elements used etc.
  - Event-global variables.
- User Analysis tasks :
  - Jet-finding.
  - Event-shapes.
  - Primary and secondary vertex fitting.
  - Impact parameters.

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SGV at work

SGV has been used to produce ILD LCIO DST:s for the full DBD benchmarks- several times.

- 43 Mevents.
- $\sim$ 1 hour of wall-clock time (first submit to last completed) on the German NAF.
- SUSY slepton scan: Generate 1000 events at all possible slepton and LSP masses on a 1 GeV $\times$ 1 GeV grid @ E_{CMS} 500 GeV (=31 000 points) $\Rightarrow$ 31 Mevents.
- Used to filter out the *seeable pairs* in 100 000 bunch-crossings from GuineaPig.

More performance in talks at eg.

KeyForHEP | LCWS2021

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Technicalities

- Written in Fortran 08, a re-write of the Fortran77-based SGV2 series.Managed in SVN.Install script included.
- Requires:
  - Fortran compiler, e.g. gfortran - any version between 4.7 and 10 ($\Rightarrow$ future-proof!).
  - Standard Linux math: `blas` and `lapack`.
  - PYTHIA vers 6 (even if not needed for event-generation: SGV uses many PYTHIA6 extras).
  - To produce the doc's during installation: `TexLive` and `pandoc`
- Features:
  - On-demand memory allocation.
  - Callable PYTHIA, Whizard 1.x, ...
  - Input from Hepevt/PYJETS, stdhep, slcio, HepMC2/3, GuineaPig.
  - Output of generated event to PYJETS, stdhep, slcio, or HepMC2/3.
  - No imposed format of reconstructed events. Code to make LCIO-DSTs or ROOT trees supplied.
- Typical generation+simulation+reconstruction time $\mathcal{O}(1)$ ms.

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Steering SGV

Two steering files...

- Program steering:
  - Single file, with sections for general, generator, detector and analysis steering.
  - Many examples included.
  - Extensive comments in these.
- Geometry description:
  - Described by cylinders and planes.
  - Attach material properties (rad. length, material, int. length, ...)
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The User's Guide

All the details can be found in:

https://www.desy.de/~berggren/sgv_ug/

Summary

- SGV is a full-blown fast detector simulation, not just a parameterised four-vector smearer
  - Comparisons to FullSim can be shown to be quite good, also for complicated features like h.f. tagging.
  - A pre-existing full simulation is not needed to get realistic results. Descriptions of e^+e^- detectors available after installation.
  - Still: SGV is as fast as eg. `Delphes`.
- Many input-methods (internal and external). No output format imposed on the user, plugins for LCIO and Root output available.
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Hands-on

If you have checked the system requirements explained on Indico, you can now get your hands on SGV. Now do this:

- Download `tutorial-step-by-step` from Indico.
- Start viewing the file in a separate window - that can be with `more, less, cat` - whatever. Or in the editor.
- ∼Everything in the file that is flush-left can be cut'n'pasted to the command line.
- I will share my desktop and go through the steps with you ...
  - My desktop is a brand-new Ububtu 20.04, running in VirtualBox.
  - I only did the explained preliminaries - including LCIO and root setup.
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Let's go !

Gotchas, updates, out-look

- Stay up-to-date ! Regularly do
  - `svn update`
  - `makesgvlibs (library)`
  - `. ./sgvenv.sh`
    - If `(library)` is an existing one, only changed files, and possible dependencies, will be recompiled. If it is not, a new library is created, and added as the last definition of `SGV_LIB` in `sgvenv.sh`
- `sgvenv.sh` issues
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  - If you do `makesgvlibs [a new directory]`, the new directory will be appended to `sgvenv.sh`
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  - $\Rightarrow$ Check your soft-links and steering file!
  - If that isn't the problem: re-compile with debug, to localise the point-of-failure:

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cd $SGV_DIR
makesgvlibs [you library] debug
. ./sgvenv.sh d
cd [your working directory]
cresgvexe merge [your program] "debug [+ any other compile optinons]"
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    - The `debug` argument to `makesgvlibs` sets the options, and also creates a *different* sub-directory for debug-libraries (by default `[you library]/deb`). The `d` as the second argument to `sgvenv.sh` will set `SGV_LIB` to this.

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  - If that isn't the problem: re-compile with debug, to localise the point-of-failure:

```
cd $SGV_DIR
makesgvlibs [you library] debug
. ./sgvenv.sh d
cd [your working directory]
cresgvexe merge [your program] "debug [+ any other compile optinons]"
```

    - The `debug` argument to `makesgvlibs` sets the options, and also creates a *different* sub-directory for debug-libraries (by default `[you library]/deb`). The `d` as the second argument to `sgvenv.sh` will set `SGV_LIB` to this.

Gotchas, updates, out-look

- There is more features, not covered in this tutorial. Check the READMEs:
  - BCal: look in `samples/usercalo`.
  - HepMC: look in `samples/hepmc` (Note that HepMC itself needs a patch for this)
  - Confusion in the calorimeters: look in `samples/pflow`.
  - Whizard: look in `samples/whizard`. Only Whizard v1 for now ...
  - Filtering: Select generated events to output after generation, or simulation, or analysis. Look in the `global_generation_steering` section of any example steering file.
- To come: SGV4
  - Move to git (GitHub or GitLab).
  - Tidy up comments, docs, conditional code, scripts, ... from all CERNLIB/Fortran 77 references.
  - Modernise the steering state-structure

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Need a Fortran95 crash-course?
Here it is:

▸ WikiPedia

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Reminder: Installing SGV

Do

svn co https://svnsrv.desy.de/public/sgv/trunk/ sgv/

Check that `lapack` and `blas` installed. If PYTHIA6 is not installed, run `bash sgv/install-pythia` to get it from HepForge.

Then

cd sgv ; . ./install[1]

This will take you about 30 seconds ...

- Study README do get the first test job done (another 30 seconds)
- Look README in the samples sub-directory, to enhance the capabilities, eg.:
  - Get ROOT interface set up, and produce you first ROOT tree.
  - Get the LCIO, HepMC, and/or STDHEP i/o set up.
  - Make you first LCIO DST.

[1] Under bash. Under c-shell, do `bash install ; source sgvenv.csh`

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Thank You !

Backup

BACKUP SLIDES

... a tool for rapid LC studies?

Peer-reviewed papers using SGV

- Phys. Rev D101 (2020) 7, 075053
- ILD-PHYS-2019-001 (Accepted by Phys. ReV. D)
- Eur.Phys.J.C 76 (2016) 4,183
- Eur.Phys.J.C 75 (2015) 12, 617
- Phys. Rev D 91 (2015) 113007
- Phys. Rev D 90 (2014) 114029
- Phys. Rev D 89 (2014) 11, 113006
- Eur.Phys.J.C 73 (2013) 12,2660
- Eur.Phys.J.C 72 (2012) 2213
- Phys. Rev. D 82 (2010) 055016
- NIM A 579 (2007) 750
- Eur. Phys. J. C 31 (2003) 421
- Eur. Phys, J. direct (2000) 1

+ innumerable theses, reports, arXiv submissions and conference proceedings. Including the Tesla TDR, LoI, TDR, the IDR and ILC/ILD inputs to EPPSU and Snowmass 2013.

... a tool for rapid LC studies ?

SGV was used for

- Defining the forward tracking geometry of LDC:
  - Vienna 2005. ▸ LDC and ▸ tracking
- The utility (or not) of the silicon envelope
  - ▸ Valencia 2006
- Merge of LDC and GLD into ILD
  - ▸ Cambrige 2008
- Define the options for the IDR
  - ▸ KEK 2015
- Also: SGV is part of the FullSim machinery: It is used to select which part of the pairs-background to overlay.

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Calorimeter simulation: SGV strategy

- Concentrate on what really matters:
  - True charged particles splitting off (a part of) their shower: double-counting.
  - True neutral particles merging (a part of) their shower with charged particles: enetgy loss.
- Don't care about neutral-neutral or charged-charged merging.
- Nor about multiple splitting/merging.
- Then: identify the most relevant variables available in fast simulation:
  - Cluster energy.
  - Distance to nearest particle of "the other type"
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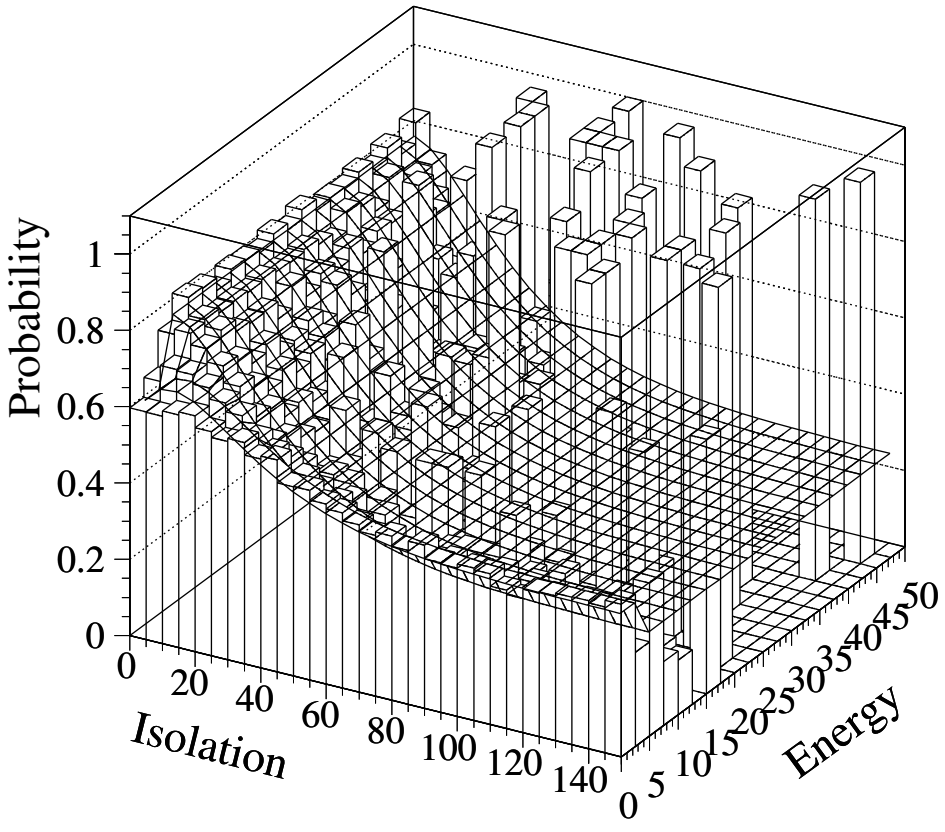
Observed distributions

- Probability to split (charged had or γ)
- Fraction the energy vs distance
- ... and vs E
- Fit of the Distribution of the fraction
- Average fraction vs. E and distance.



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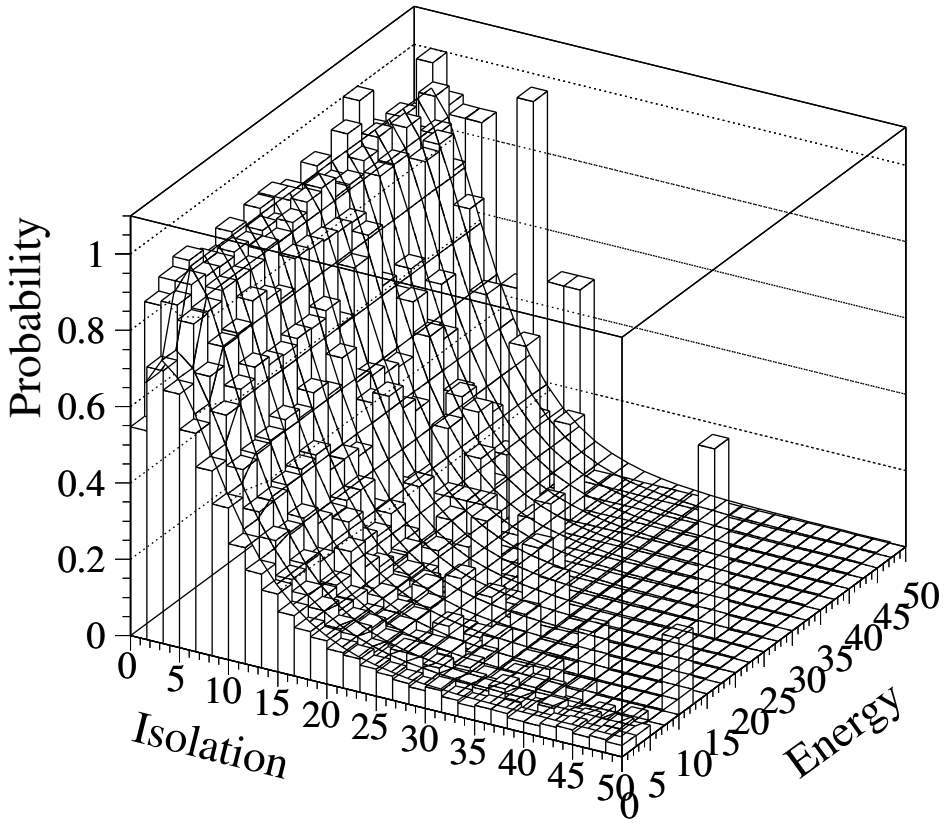

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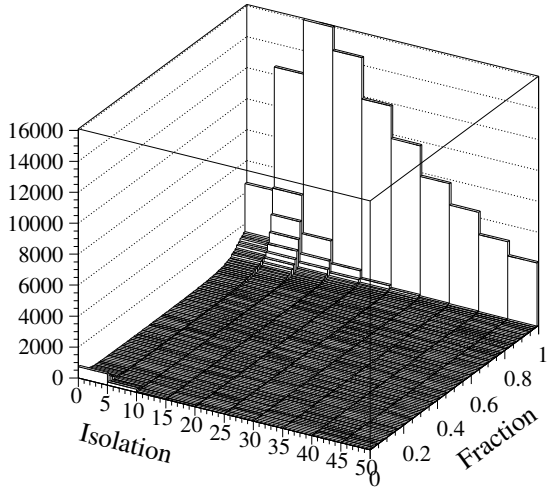

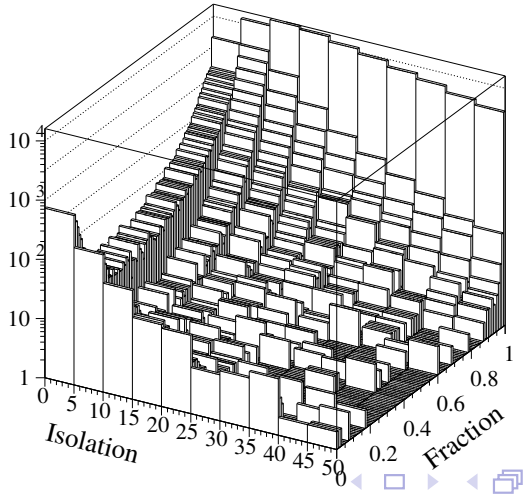

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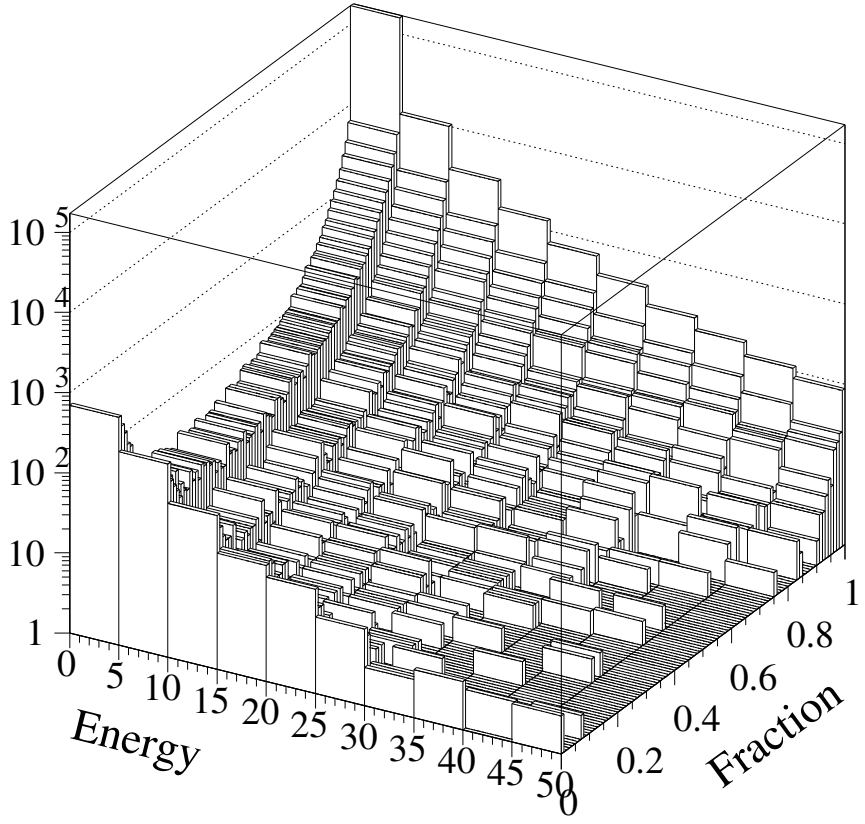

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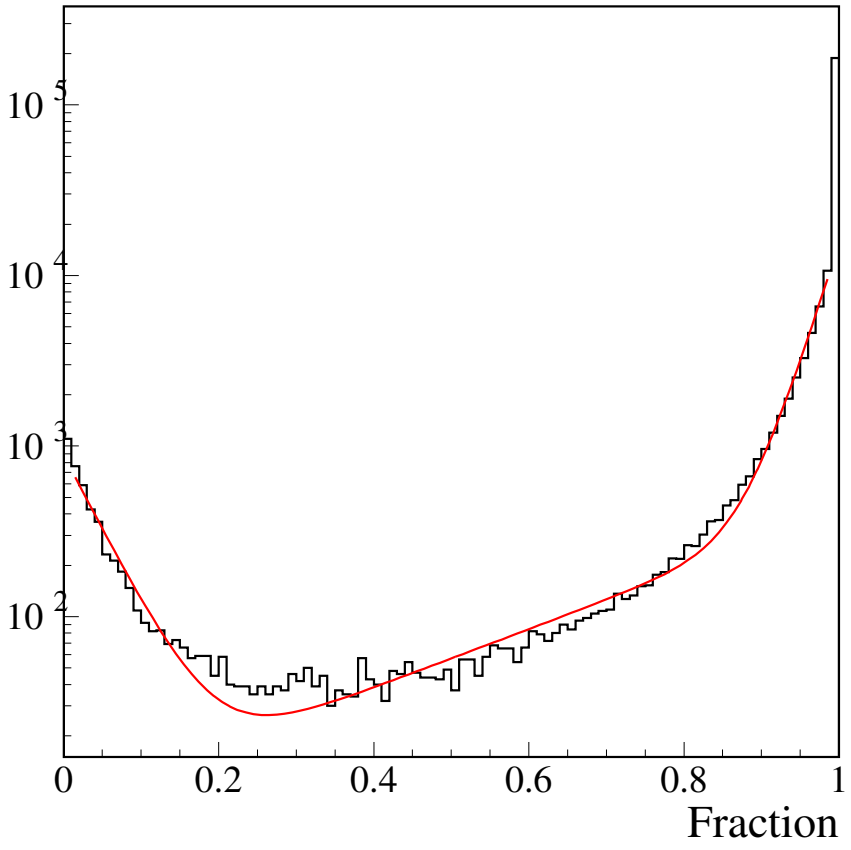

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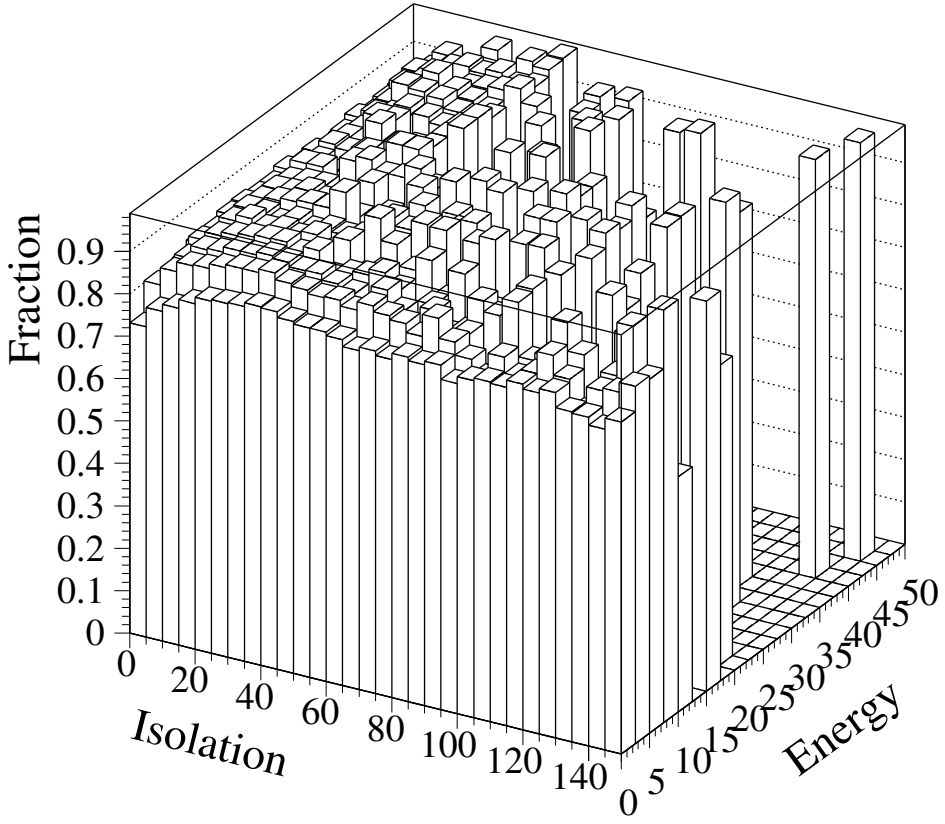

LCIO Collections with DST output

- Added sensible values to all collections that will (probably) be there on the DST from the fullSim production.
  - BuildUpVertex
  - BuildUpVertex_RP
  - MarlinTrkTracks
  - PandoraClusters
  - PandoraPFOs
  - PrimaryVertex
  - RecoMCTruthLink
  - MCParticlesSkimmed
  - V0Vertices
  - V0RecoParticles
  - BCALParticles
  - BCALClusters
  - BCALMCTruthLink
  - PrimaryVertex_RP
- Also added more relation links:
  - MCTruthRecoLink
  - ClusterMCTruthLink
  - MCTruthClusterLink
  - MCTruthTrackLink
  - TrackMCTruthLink
  - MCTruthBcalLink

Comments

Secondary vertices (as before):

- Use true information to find all secondary vertices.
- For all vertices with ≥ 2 seen charged tracks: do vertex fit.
- Concequence:
  - Vertex *finding* is too good.
  - Vertex *quality* should be comparable to FullSim.

In addition: Decide from parent pdg-code if it goes into BuildUpVertex or V0Vertices !

MCParticle :

- There might be some issues with history codes in the earlier part of the event (initial beam-particles, 94-objects, ...)

Comments

Clusters:

- Are done with the Pandora confusion parametrisation on.
- Expect $\sim$ correct dispersion of jet energy, but a few % to high central value.
- See my talk three weeks ago.
- Warning: Clusters are always only in one detector , so don't use E_{had}/E_{EM} for e/π: It will be $\equiv$ 100 % efficient !

Navigators

- All the navigators that the TruthLinker processor makes when all flags are switched on are created:
  - Both Seen to True and True to Seen (weights are different !)
  - Seen is both PFOs, tracks and clusters.
  - The standard RecoMCTruthLink collection is as it would be from FullSim ie. weights between 0 and 1.