Status of Fast Detector Simulation

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Outline

The need for fast simulation

- We have very good full simulation now.
- So why bother about full simulation ?
- Answer:
  - Light-weight: run anywhere, no need to read tons of manuals and doxygen pages.
  - Anyhow, the LOI exercise showed that for physics, the fastSim studies were good enough.

But most of all:

Fast simulation is Fast !

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Cross-section and event-generation time

PYTHIA obtains a total cross-section for $e^+e^- \rightarrow \gamma\gamma e^+e^- \rightarrow q\bar{q}e^+e^-$ at $E_{CMS} = 500$ GeV of 28371 pb
(+ another 7170 pb if the diffractive and elastic components are included, but these classes do not contribute to high $P_{T\ miss}$-events)

- $\int \mathcal{L}dt = 500$ fb^{-1} $\rightarrow$ 14 $\star 10^9$ events are expected.
- 10 ms to generate one event.
- 10 ms to fastsim (SGV) one event.

10^8 s of CPU time is needed, ie more than 3 years. This goes to 3000 years with full simulation.

Clearly, there is need to reduce this number by one or two orders of magnitude, by using generator level cuts.

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SUSY parameter scans

Simple example:

- MSUGRA: 4 parameters + sign of μ
- Scan each in eg. 20 steps
- Eg. 5000 events per point (modest requirement: in sps1a' almost 1 million SUSY events are expected for 500 fb^{-1} !)
- = $20^4 \times 2 \times 5000 = 1.6 \times 10^9$ events to generate...

Slower to generate and simulate than $\gamma\gamma$ events

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Fast simulation

Different types, with different levels of sophistication:

- 4-vector smearing.
- Parametric. Eg SIMDET
- Covariance matrix machines. Eg. LiCToy, SGV

Common for all:

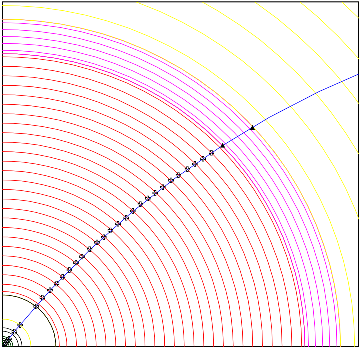
Detector simulation time $\approx$ time to generate event by an efficient generator (PYTHIA 6, SUSYGEN)

I will talk about SGV.

SGV: How it works

SGV is a machine to calculate covariance matrices

Tracking: Follow track-helix through the detector, to find what layers are hit by the particle.



- From this, calculate cov. mat. at perigee, including effects of material, measurement errors and extrapolation. NB: this is exactly what Your track fit does!
- Smear perigee parameters accordingly, with Choleski decomposition (takes all correlations into account)
- Information on hit-pattern accessible to analysis. Co-ordinates of hits accessible.

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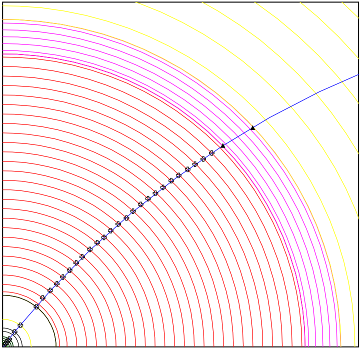

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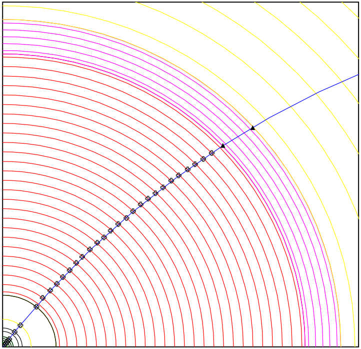

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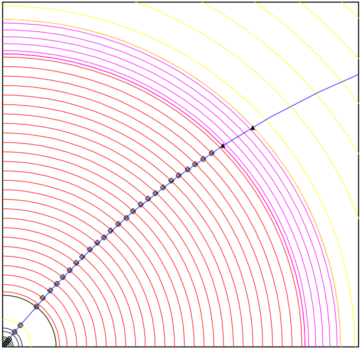

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SGV: How it works

Calorimeters:

- Follow particle to intersection with calorimeters. Decide how the detectors will act: MIP, EM-shower, hadronic shower, below threshold, etc.
- Simulate response from parameters.
- Merge close showers
- Easy to plug in other (more sophisticated) shower-simulation

Other stuff:

- EM-interactions in detector material simulated
- Plug-ins for particle identification, track-finding efficiencies,...
- Scintilators and Taggers

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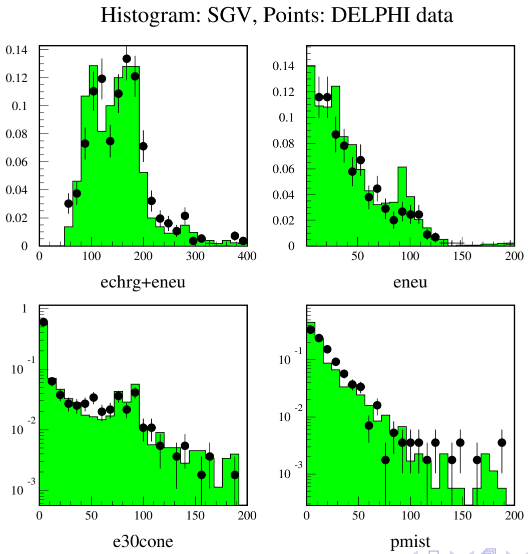
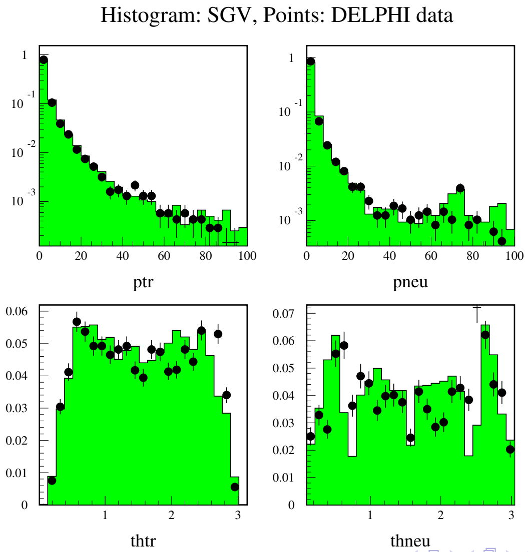
SGV physics performance

Some examples from DELPHI and ILD

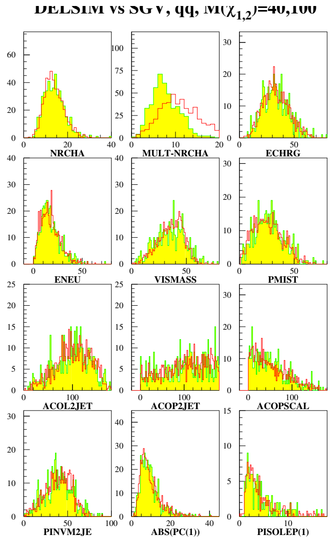
SGV and Real Data from DELPHI: Global variables

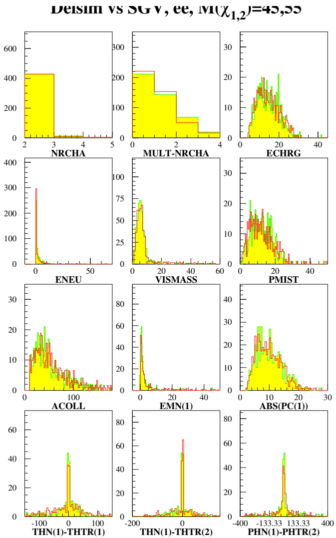


SGV and Real Data from DELPHI: Particle variables



SGV and DELSIM: Neutralino search





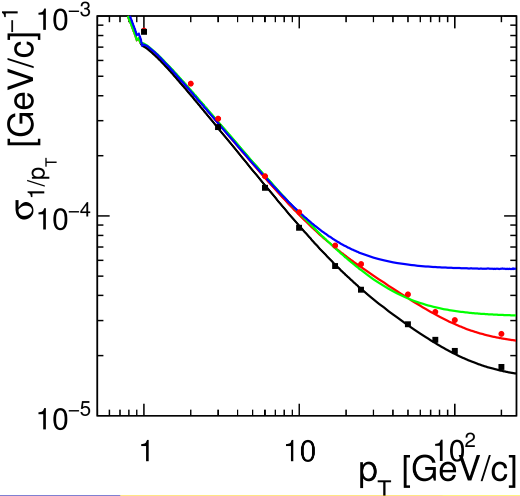
SGV for the LC: TESLA/LDC/ILD

- Used for fastsim physics studies, eg. arXiv:hep-ph/0510088, arXiv:hep-ph/0508247, arXiv:hep-ph/0406010, arXiv:hep-ph/9911345 and arXiv:hep-ph/9911344.
- Used for flavour-tagging training.
- Used for overall detector optimisation, see Eg. Vienna ECFA WS (2007), See Ilcagenda > Conference and Workshops > 2005 > ECFA Vienna Tracking
- GLD/LDC merging and LOI, see eg. Ilcagenda > Detector Design & Physics Studies > Detector Design Concepts > ILD > ILD Workshop > ILD Meeting, Cambridge > Agenda >Sub-detector Optimisation I

The latter two: Use the Covariance machine to get analytical expressions for performance (ie. *not* simulation)

SGV and FullSim LDC/ILD: momentum resolution

Lines: SGV, dots: Mokka+Marlin



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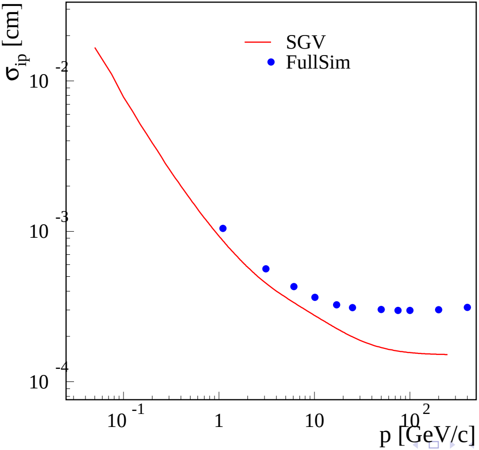

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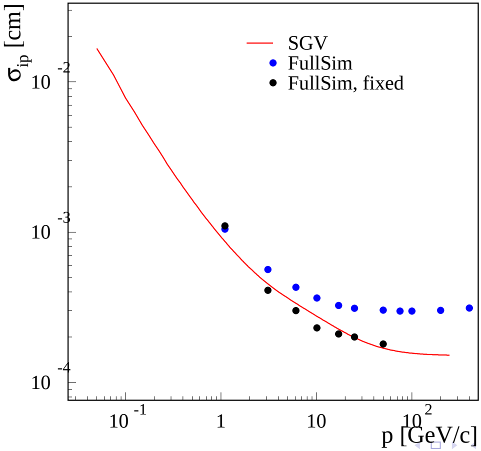

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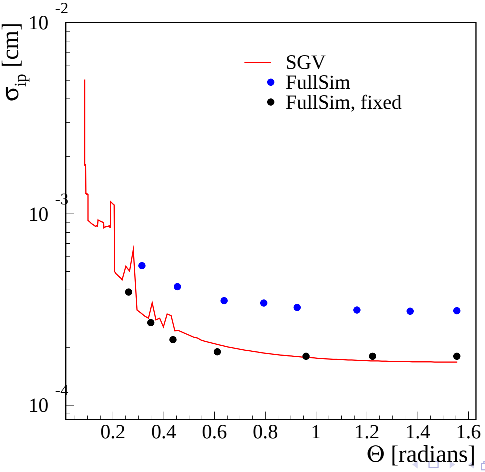

In the past

In the past (up to v. 2.32):

- Language: FORTRAN77
- Code management: PATCHY
- Depends on CERNLIB
- Distributed as: Single compressed file (Gzip), self-installing. Download from http://berggren.web.cern.ch/berggren/sgv.html.
- 35 000 lines, installed 2.9 MB (including 1.1 MB documentation)

Recent developments

- Transformed to Fortran 95.
- Removed most CERNLIB dependence. Mostly by using Fortran 95's built-in matrix algebra.
- Managed in SVN.Install script included.
- Removed some options: PYTHIA pre version 6, SUSYGEN.
- Added several features:
  - Callable Whizard.
  - Input from stdhep.
  - Output of generated event to PYJETS or stdhep.
  - Sample subdirectory with steering and code for eg. scan single particles, create hbook ntuple with "all" information (can be converted to ROOT w/ h2root). And: output LCIO DST.
  - Development on calorimeters (see later)
- Tested to work on both 32 and 64 bit out-of-the-box.
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Future developments

- Update documentation and in-line comments, to reflect new structure.
- Consolidate use of Fortran 95/203/2008 features:
  - Use of user-defined types.
  - Use of PURE and ELEMENTAL routines,
  - Optimal choice between pointer, allocatable and automatic and/or assumed-size, assumed-shape, and explicit arrays.
- I/O over FIFO:s to avoid storage and I/O rate limitations.
- The Grid.
- Investigate running on GPU:s.
- Possibly - when gcc/gfortran 4.4 (ie. Fortran 2003) is common-place - Object Orientation, if there is no performance penalty.

ILD-specific Calorimeter simulation

The issues:

- Clearly: Random E, shower position, shower shape.
- But also association errors:
  - Clusters might merge.
  - Clusters might split.
  - Clusters might get wrongly associated to tracks.
- Consequences:
  - If a (part of) a neutral cluster associated to track → Energy is lost.
  - If a (part of) a charged cluster not associated to any track → Energy is double-counted.
  - Other errors (split neutral cluster, charged cluster assoiated with wrong track ....) are of less importance.
- These features are expected to depend on
  - The 4-mom of the incomming particle.
  - The calorimeter entry point of the particle.
  - The shape of the cluster
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Implementation of these mechanisms in SGV:

- SGV already
  - knows about where the particle hits the calorimeters.
  - has procdures to generate energy, position and shower-axes from geometry file input parameters.
  - has procedures to merge clusters based on generated shower positions and axes steerable by steering file.
  - has procedures to associate clusters to tracks, also steerable.
- So what is needed is mostly to determine sensible parameters:
  - Cluster energy, position and axis distributions, given 4-mom of entering particle.
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Input: From full simulation and/or test-beam:

- E error for isolated (hadronic and em). Done.
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Some development to SGV from this:

- NB: zdcalo is a user-routine (with a sensible default supplied), so code-wise one can do “anything” at the level of the single incomming particle.
  - Eg.: Splitting of clusters
- In SGV core:
  - Different properties neutral-charged originator.
  - More intricate track-cluster matching (or always correct?)
  - Handling splitting: one particle in to zdcalo, several out.

Tuning to Mokka+Marlin: Pandora effects

Use LOI sample (6k udsc), compare PandoraPFO:s to MCParticles

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- Fraction the energy in the smaller cluster
- Distribution of fraction vs E
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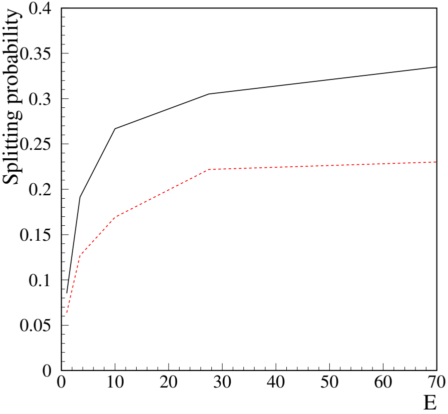
- ... and EM



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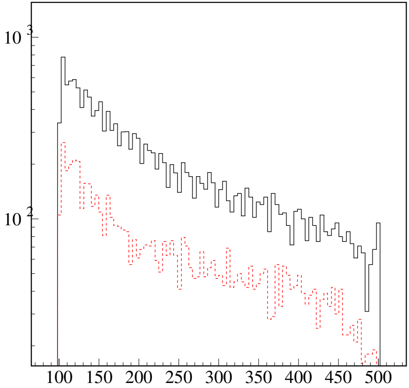

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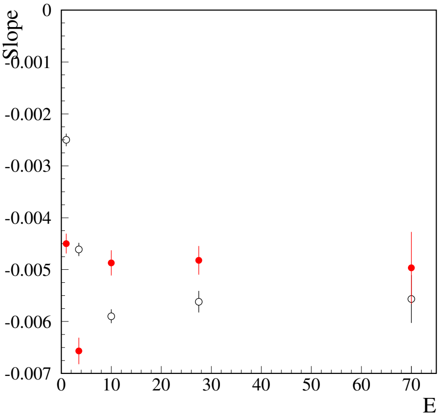
Use LOI sample (6k udsc), compare PandoraPFO:s to MCParticles

- Probability to split cluster in two vs E
- Fraction the energy in the smaller cluster
- Distribution of fraction vs E
- Distance beteen split hadron-showers
- ... and EM



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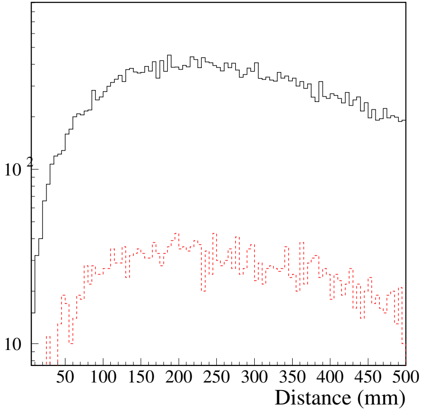

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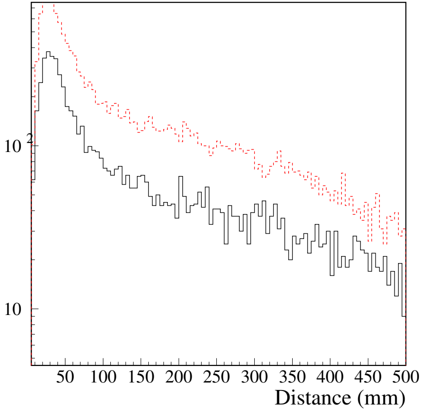

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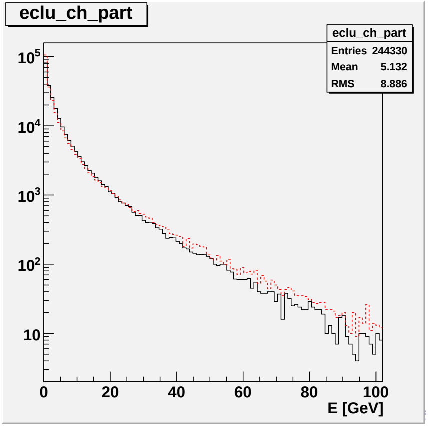
Tuning to Mokka+Marlin: Tentative settings

Compare Mokka+Marlin (Red) to LCIO-DST produced by SGV, with either perfect matching (but smeared meassurements) (Black), or with tentative cluster merging and EM-interations on (Blue). NB: no splitting, yet !

- Charged cluster energy.
- Neutral cluster energy.
- Unseen neutral energy, due to associating track to neutral
- Double-counted charged enegry due to un-associated cluster.



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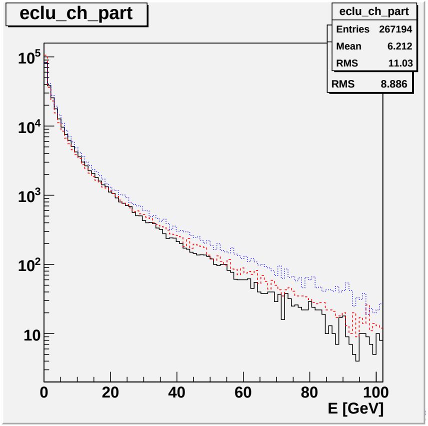

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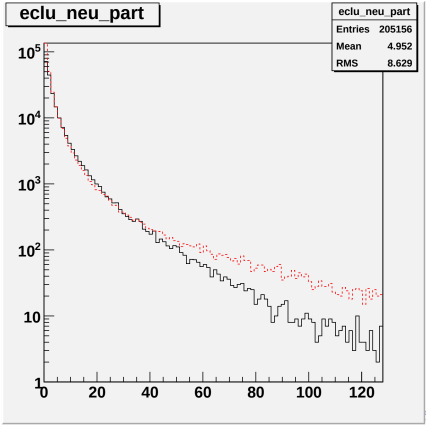

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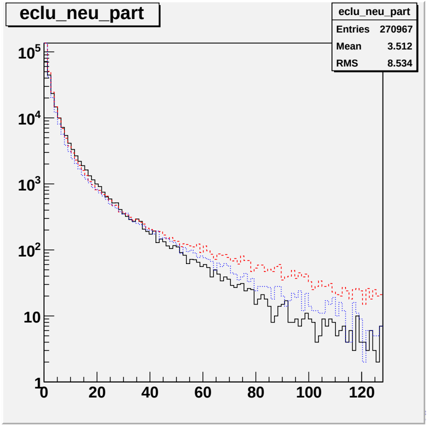

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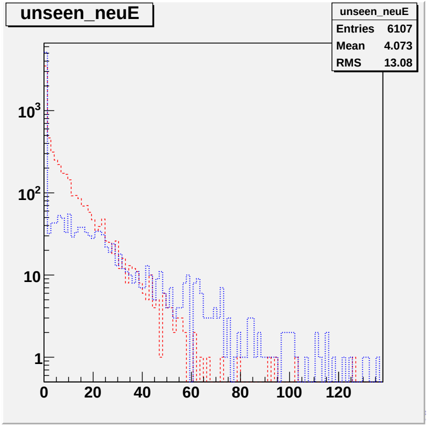

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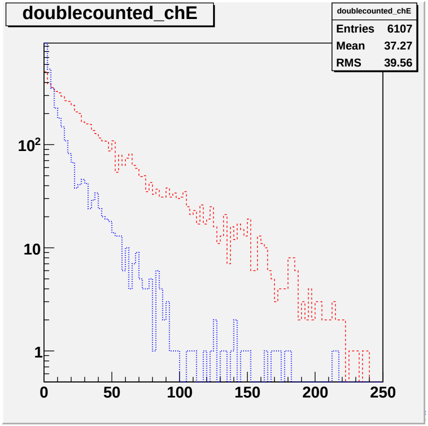
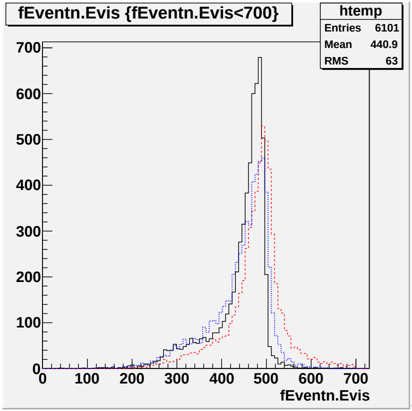


Tuning to Mokka+Marlin: Tentative settings

Resulting Total visible energy

Degradation seen in Full simulation reproduced. Not enough double counting, but cluster splitting not yet included.



Conclusions

- The need for FastSim was reviewed:
- Large cross-sections ($\gamma\gamma$), or large parameter-spaces (SUSY) makes such programs obligatory.
- The SGV program was presented, and (I hope) was shown to be up to the job, both in physics and computing performance.
- The new developents were presented: Code over-haul: F77->F95, calorimeter parametrisation, extended generator-set, and full LCIO-DST as an output-format option.
- The near future plans for SGV were presented: Further improvment in confusion simulation by allowing for splitting, and by more precise parameters. Roll-out of the SGV 3.0 SVN. Longer term plans was also mentioned.
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