The *Simulation à Grande Vitesse* (SGV) Fast Simulation program

Mikael Berggren[1]

[1]DESY, Hamburg

LCWS, Sendai, Japan , Oct 2019

Outline

The need for fast simulation

- We have very good full simulation now.
- So why bother about fast simulation ?
- Answer:
  - R. Heuer at LCWS 2011: *We need to update the physics case continuously*.
  - Light-weight: run anywhere, no need to read tons of manuals and doxygen pages.
  - Anyhow, experience from both LOI and DBD showed that for physics, the FastSim studies often were good enough, if the FastSim has enough detail.

But most of all:

Fast simulation is Fast !

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$\gamma\gamma$ background

Total cross-section for $e^+e^- \to \gamma\gamma e^+e^- \to q\bar{q}e^+e^-$: 35 nb (PYTHIA)

- $\int \mathcal{L}dt = 500$ fb^{-1} $\to$ 18 $\star 10^9$ 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. But:This goes to 3000 years with full simulation.

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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} !)
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Fast simulation types, and the choice for ILC

Different types, with increasing level of sophistication:

- 4-vector smearing.
- Parametric. Eg.: Delphes
- Covariance matrix machines. Eg.: SGV

Common for all:

Detector simulation time $\approx$ time to generate event by an efficient generator like PYTHIA 6

For ILC:

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

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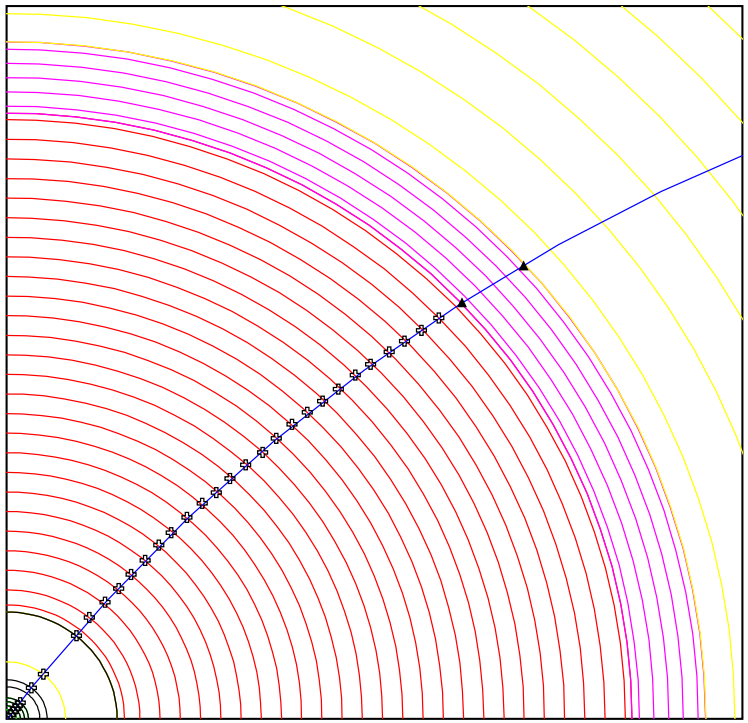
SGV: How tracking works

SGV is a machine to calculate covariance matrices

Tracking: Follow track-helix through the detector.



- Calculate cov. mat. at perigee, including material, measurement errors and extrapolation. NB: this is exactly what Your Kalman filter does!
- Smear perigee parameters (Choleski decomposition: takes all correlations into account)
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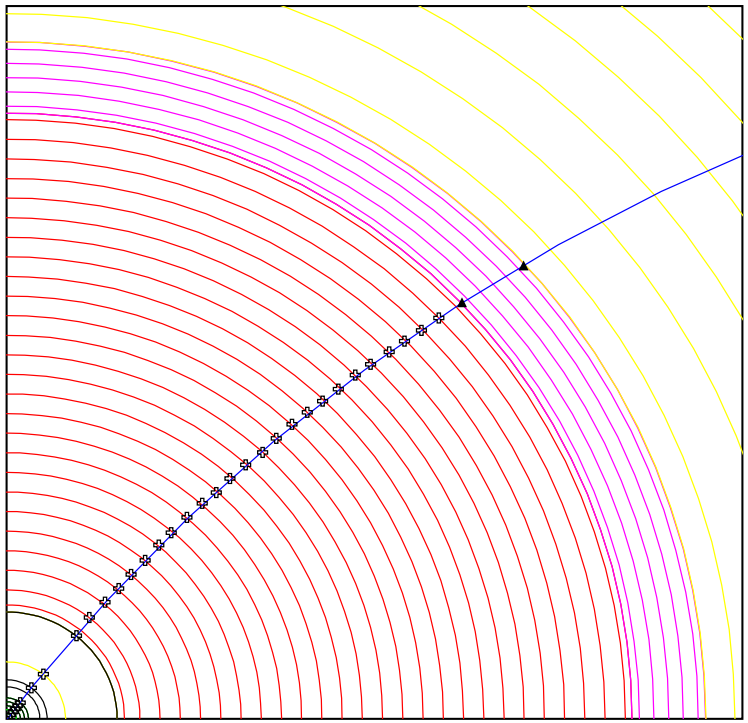

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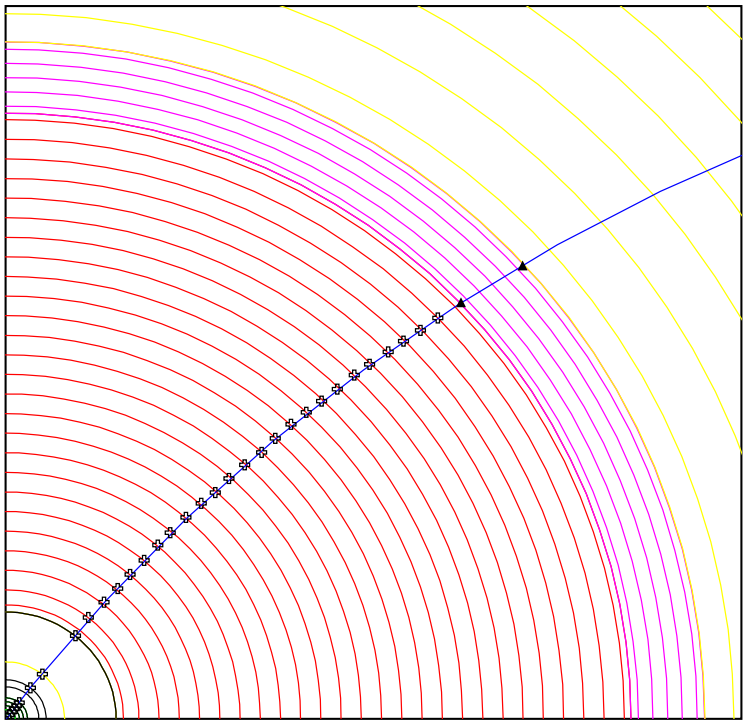

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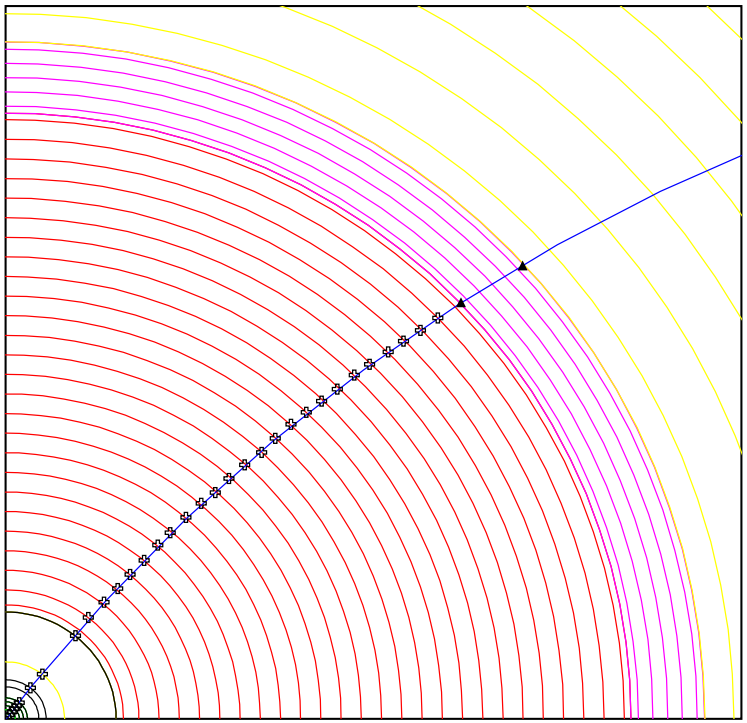

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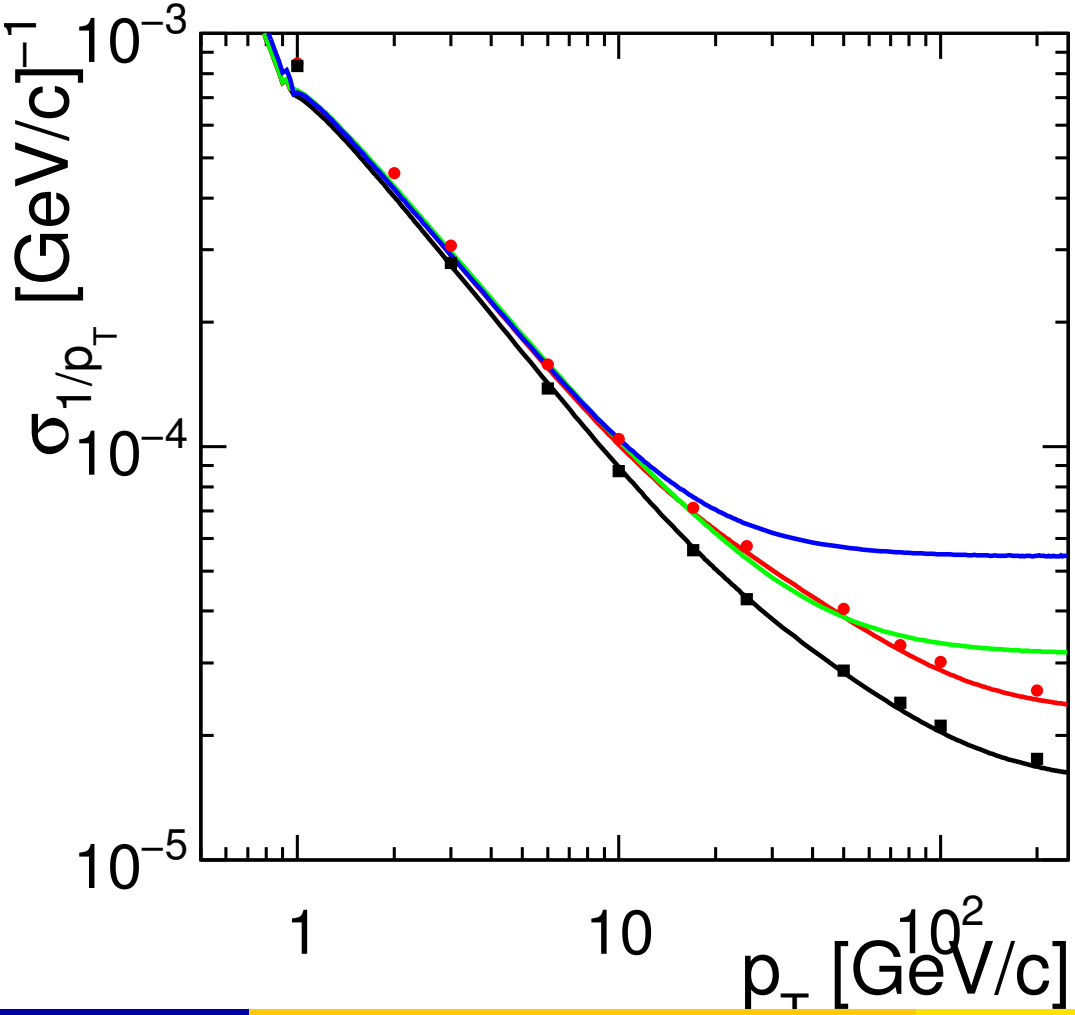
SGV and FullSim LDC/ILD: momentum resolution

Lines: SGV, dots: Mokka+Marlin



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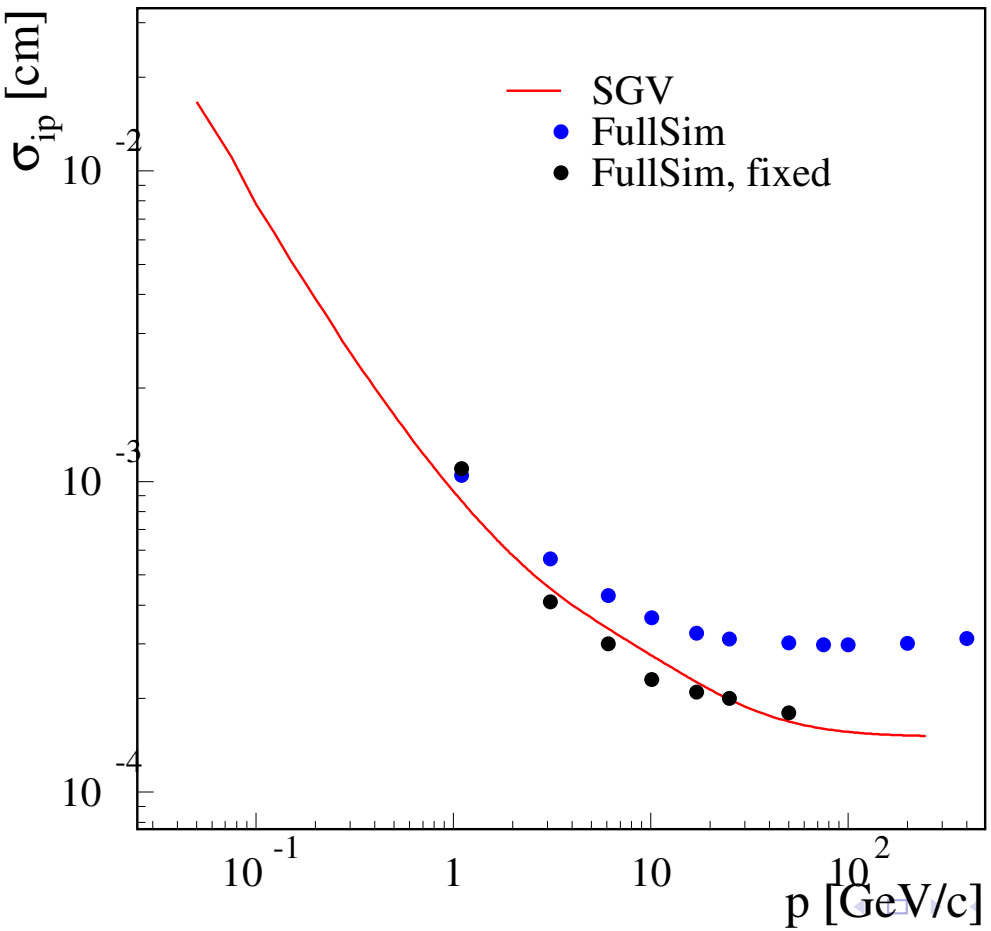
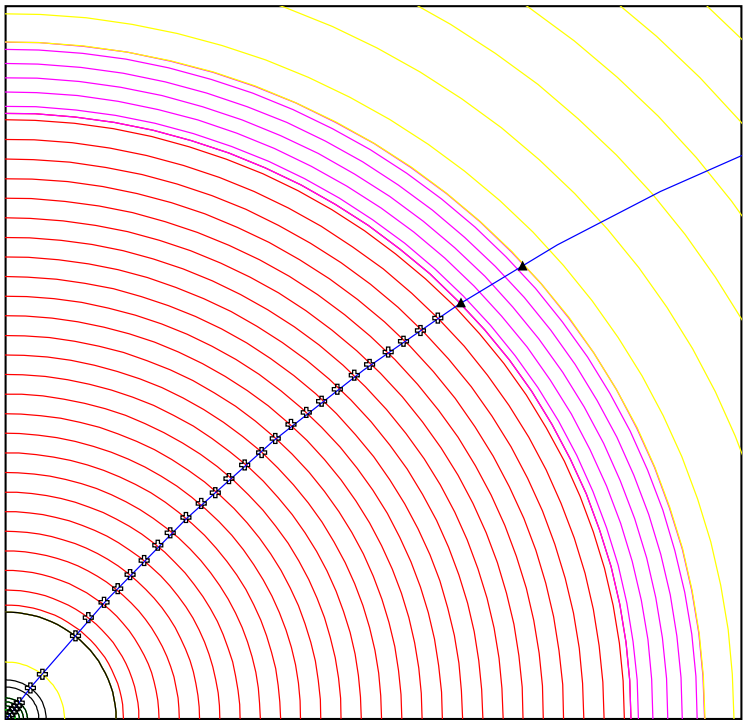


SGV: How the rest works

SGV is a machine to calculate covariance matrices

Calorimeters: Follow particle to intersection with calorimeters.



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

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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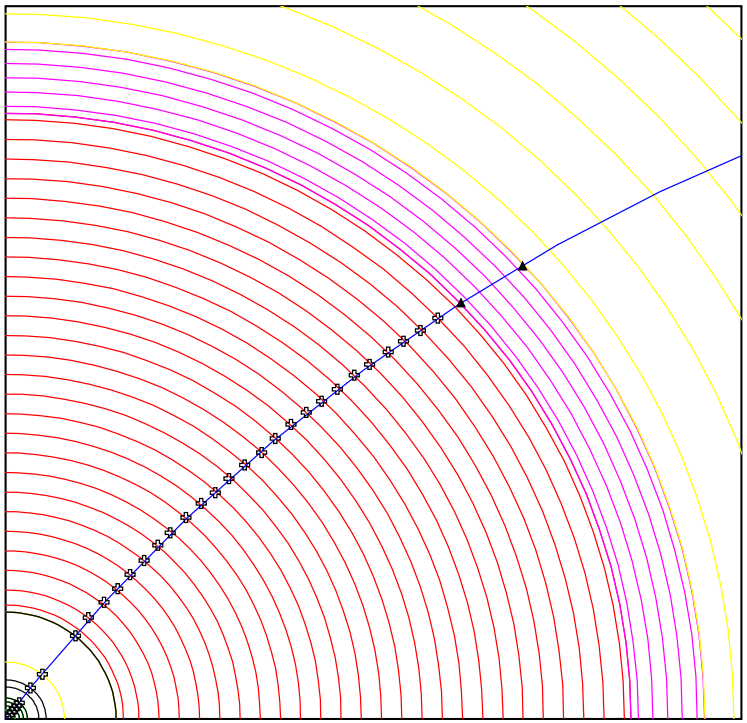

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Something about vertex fits and all that

- 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.
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Calorimeter simulation

The issues:

- Clearly: Random E, shower position, shower shape.
- But also association errors:
  - Clusters might merge,split, or get wrongly associated to tracks
- Will depend on Energy, on distance to neighbour, on EM or hadronic, on Barrel or forward, ...
- 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.
- Parametrisation:
  - Look at how PFA on FullSim has associated tracks and clusters: link MCParticle -> Track and/or true cluster -> Seen cluster.
  - Found that sets of p.d.f.'s with 28 parameters × 4 cases (em/had × double-counting/loss) can do this.

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Proof of principle of the parametrisation

Feed exactly the same physics events through FullSim or SGV.

- Overall:
  - Total seen energy
- $e^+e^- \rightarrow ZZ \rightarrow$ four jets:
  - Reconstructed M_Z at different stages in FullSim.
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- *Zhh* at 1 TeV:
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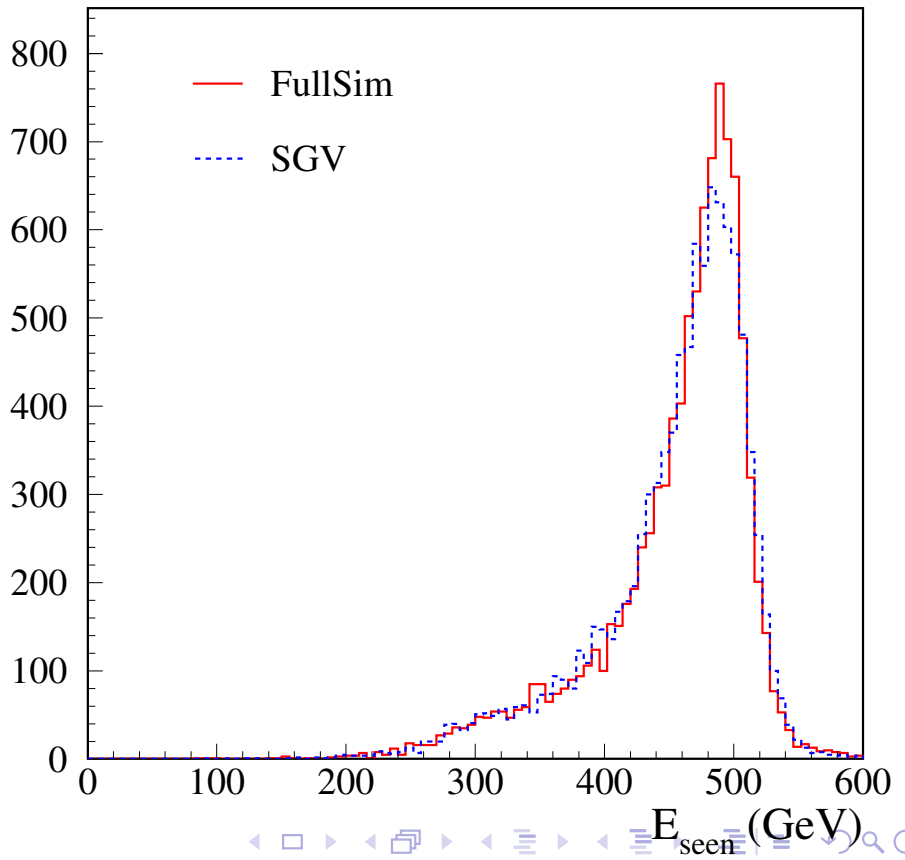

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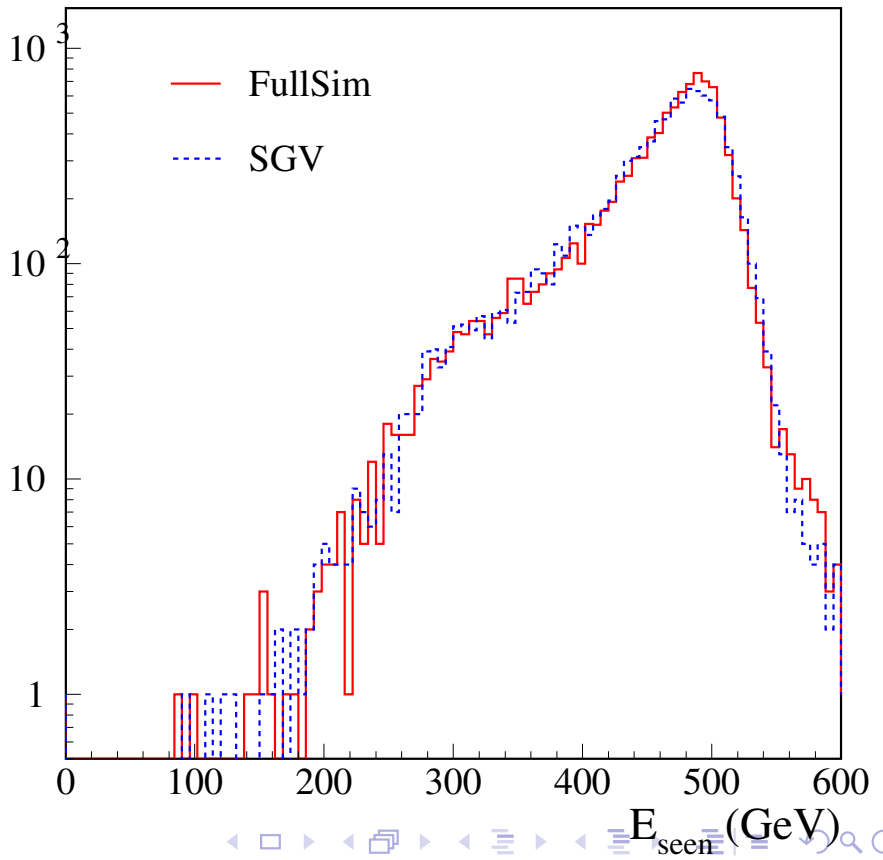

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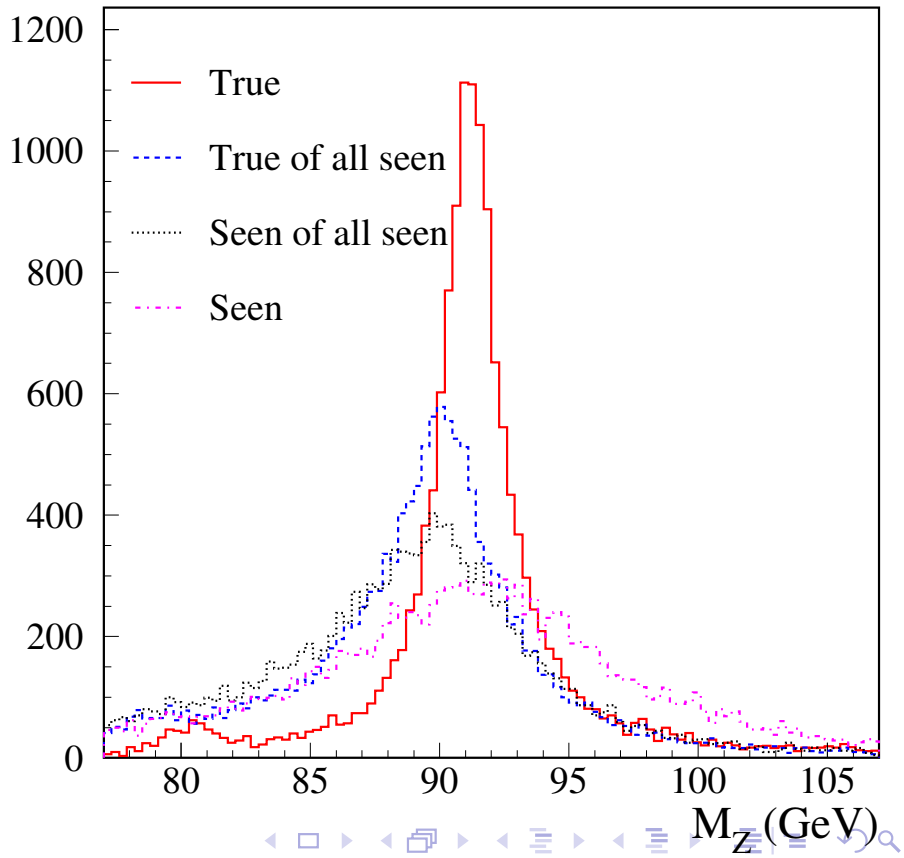

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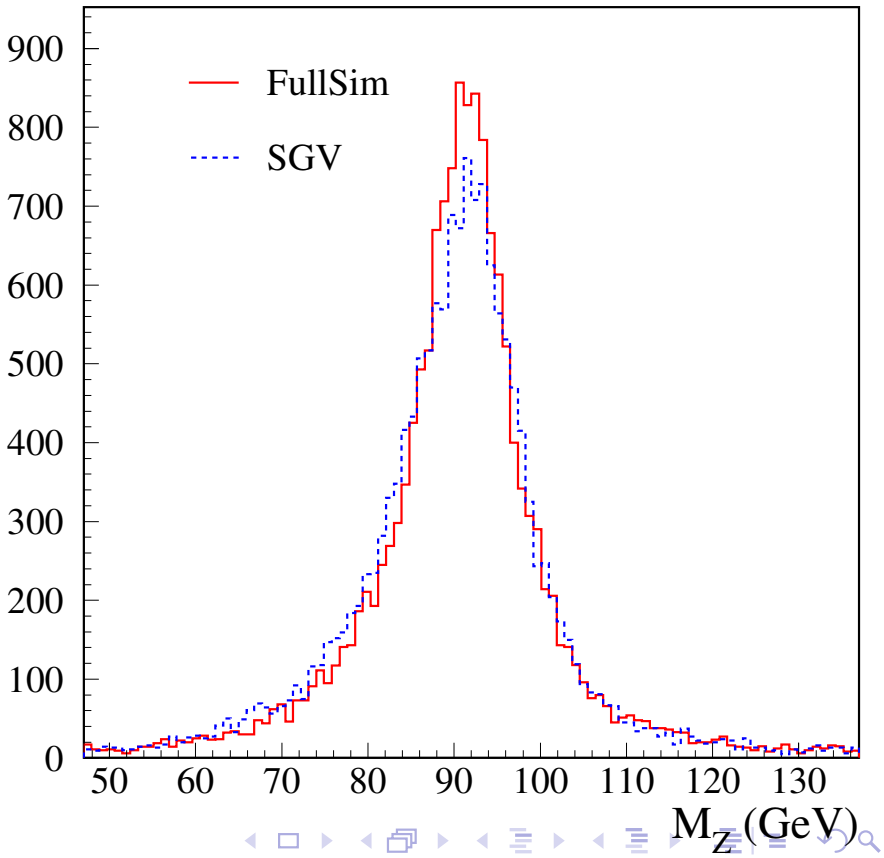

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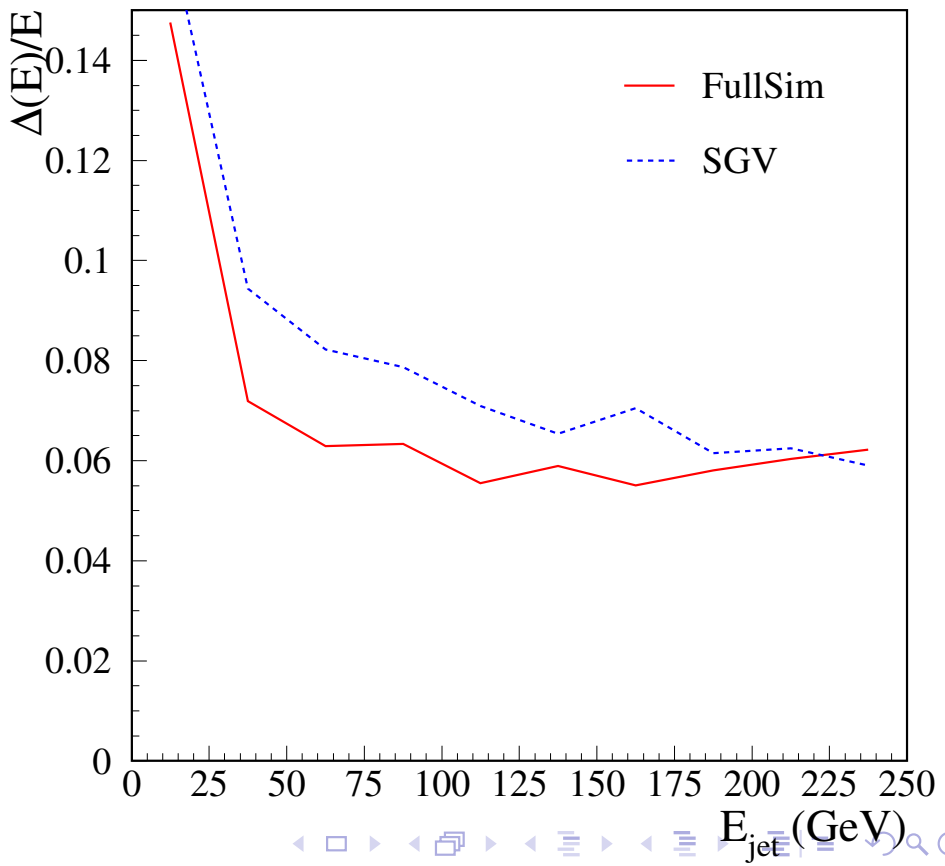

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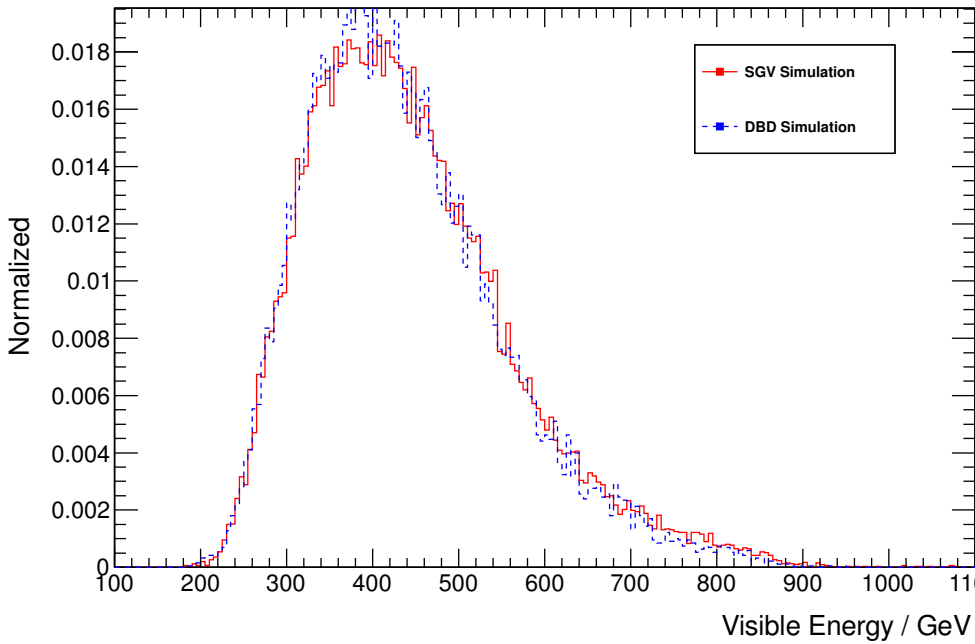

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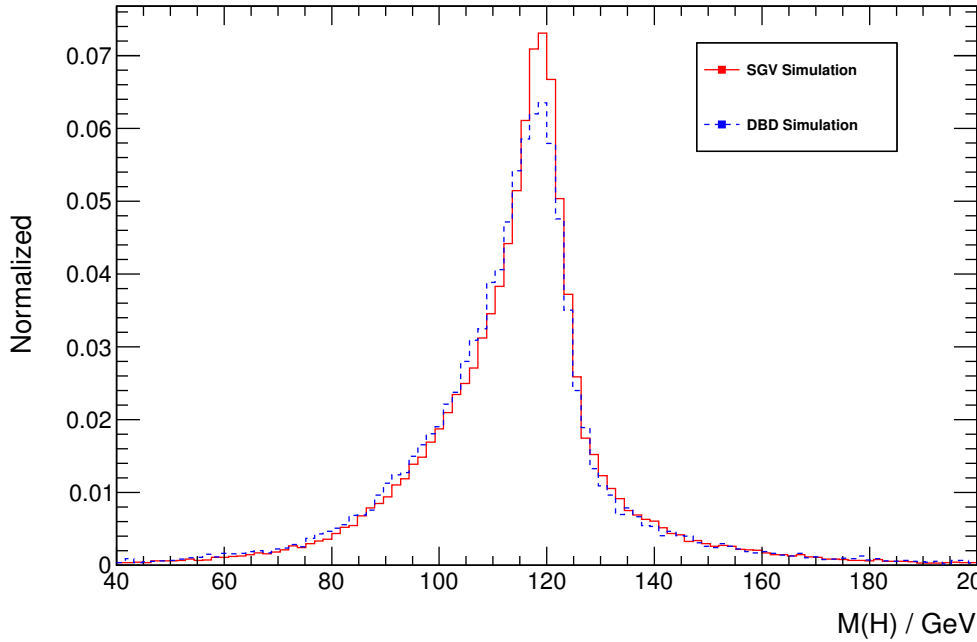

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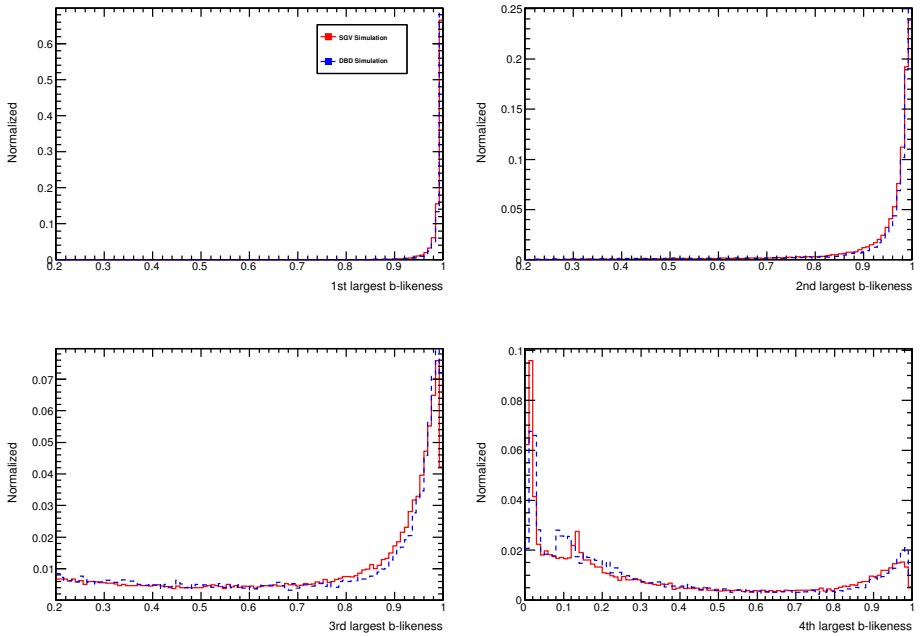

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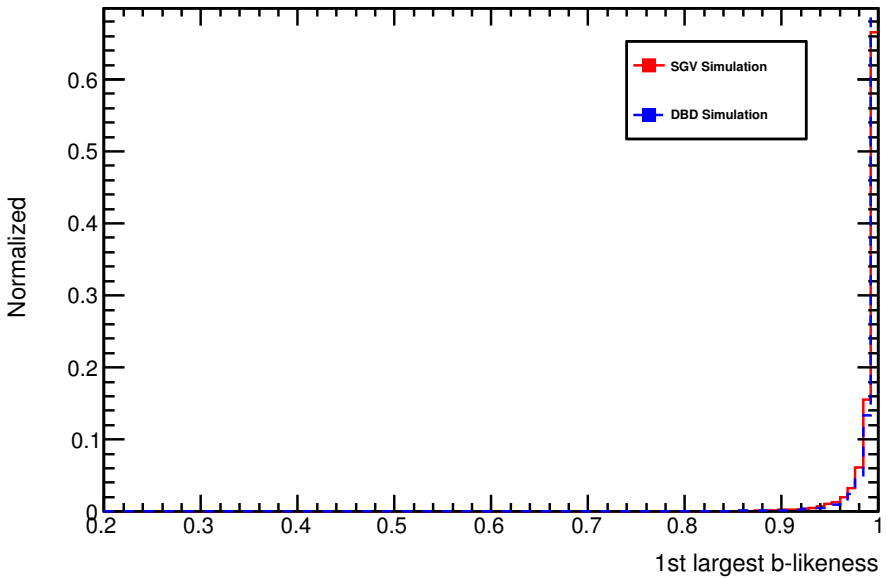
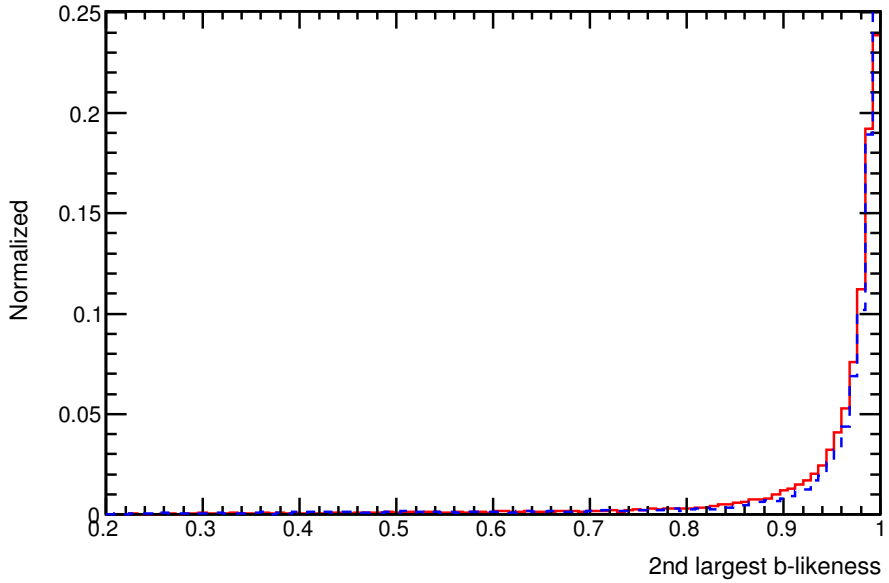

SGV Simulation
DBD Simulation
Normalized
1st largest b-likeness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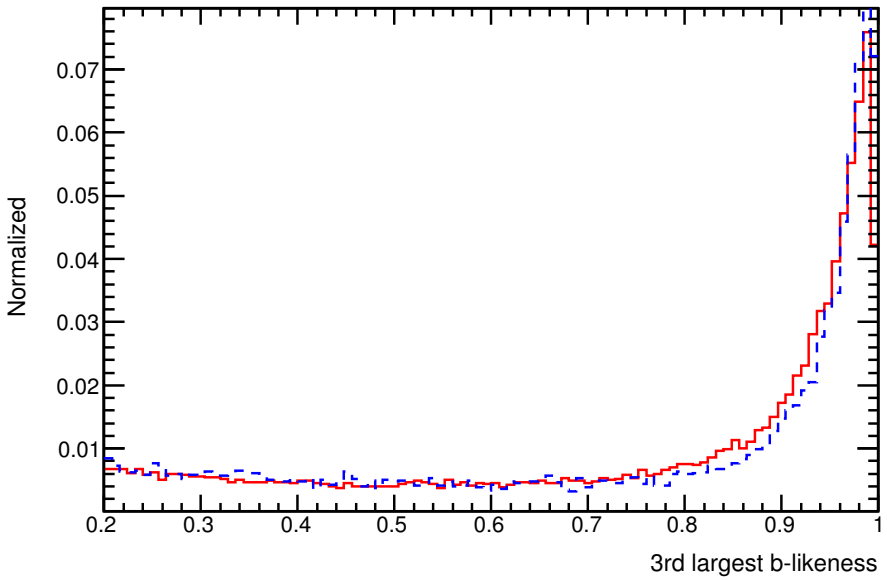
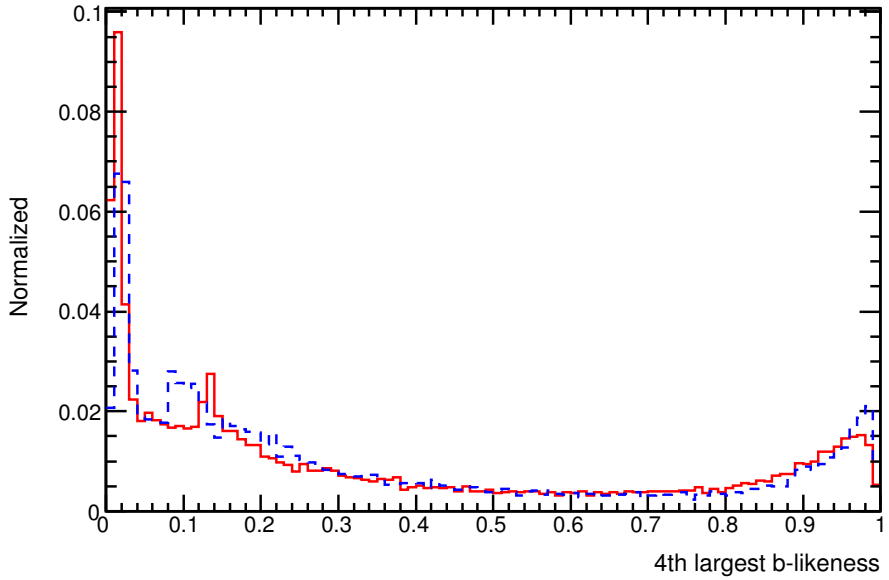

Normalized
3rd largest b-likeness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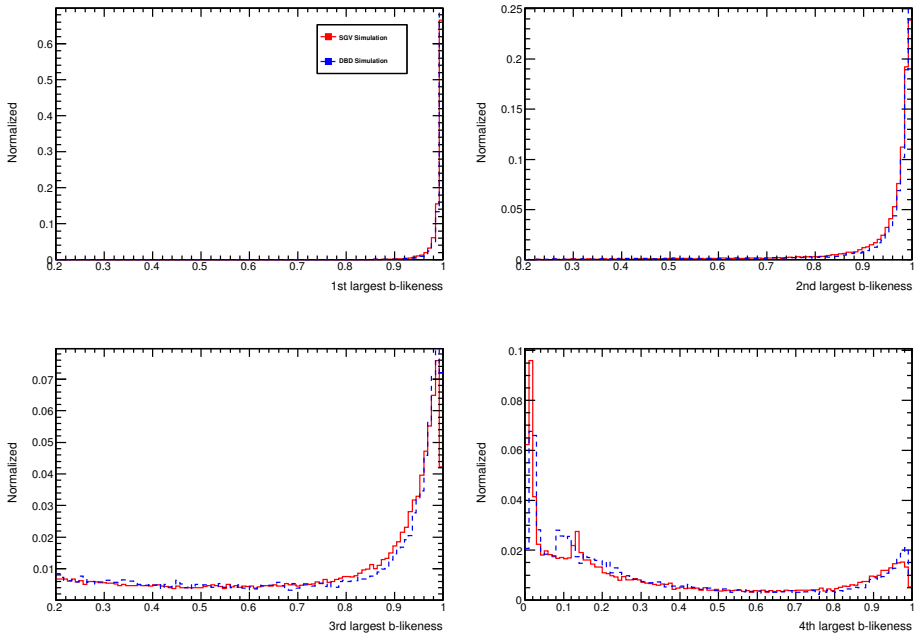

Technicalities

- Written in Fortran 08, a re-write of the Fortran77-based SGV2 series.
- Managed in SVN.Install script included.
- Features:
  - Callable PYTHIA, Whizard (v. 1.x, only, since v2.x is not yet callable as a subroutine).
  - Input from PYJETS, stdhep, slcio, GuineaPig.
  - Output of generated event to PYJETS, stdhep or slcio.
  - Produce LCIO-DST look-alike of reconstructed events.
  - samples subdirectory with steering and code for eg. scan single particles, create ntuples with "all" information (right now, as hbook ntuples, so need CERNLIB for this, can be converted to ROOT w/ h2root. Direct Root interface comming) .
  - Development on calorimeters (see later)
- Typical generation+simulation+reconstruction time $\mathcal{O}(10)$ ms.

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Backup

BACKUP SLIDES

Observed distributions

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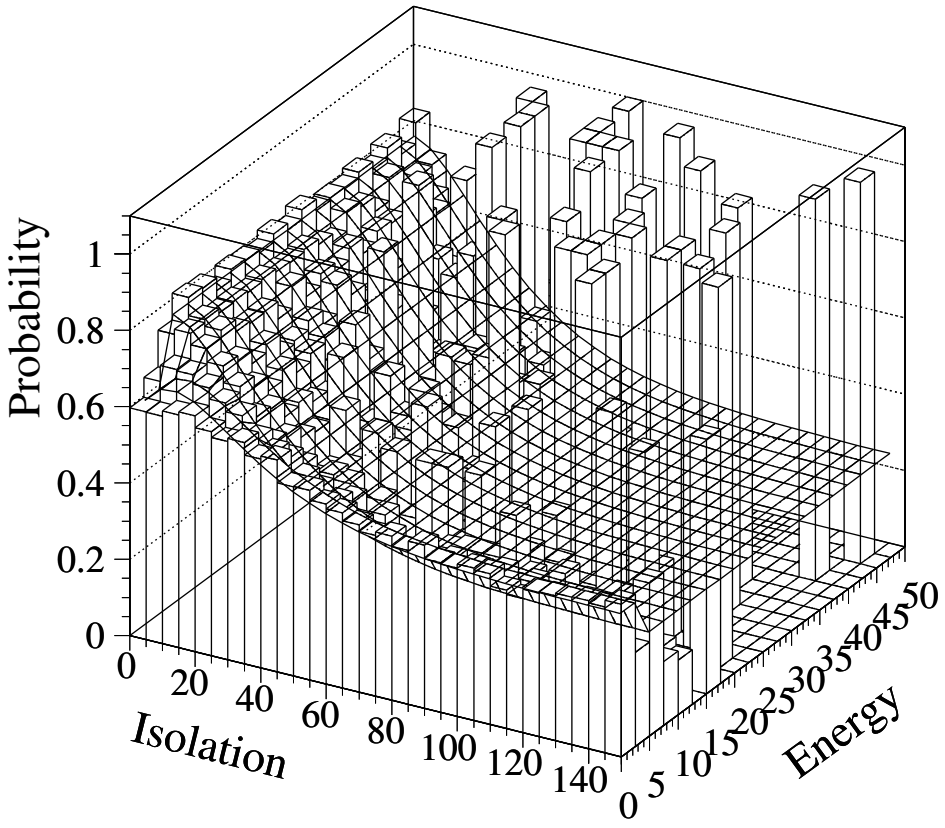

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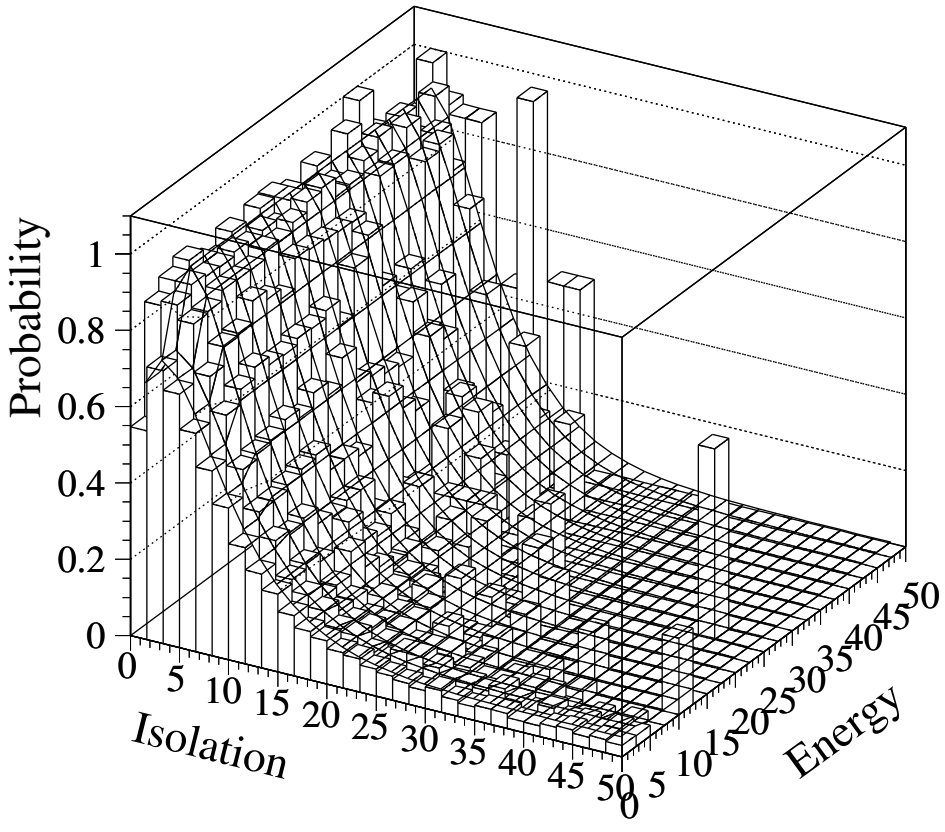

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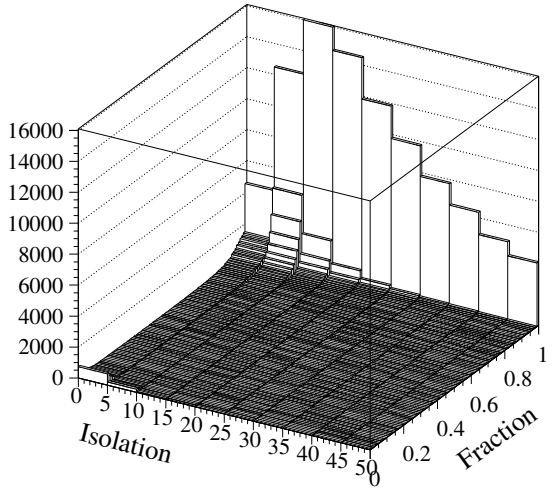

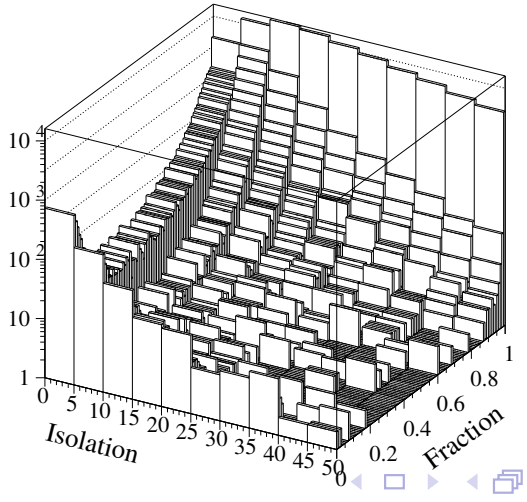

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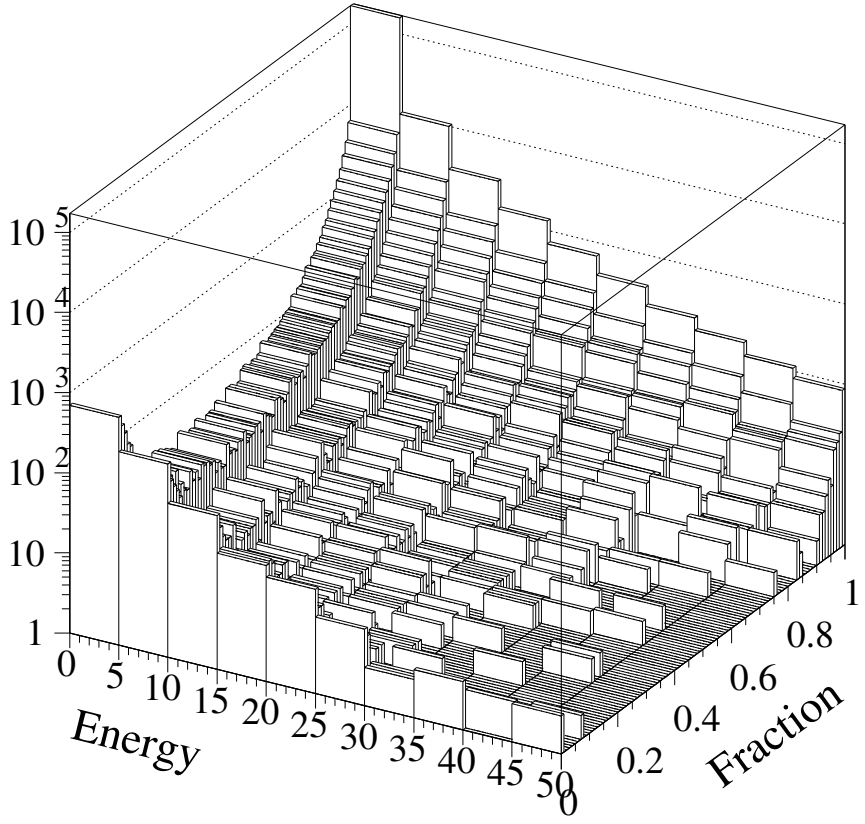

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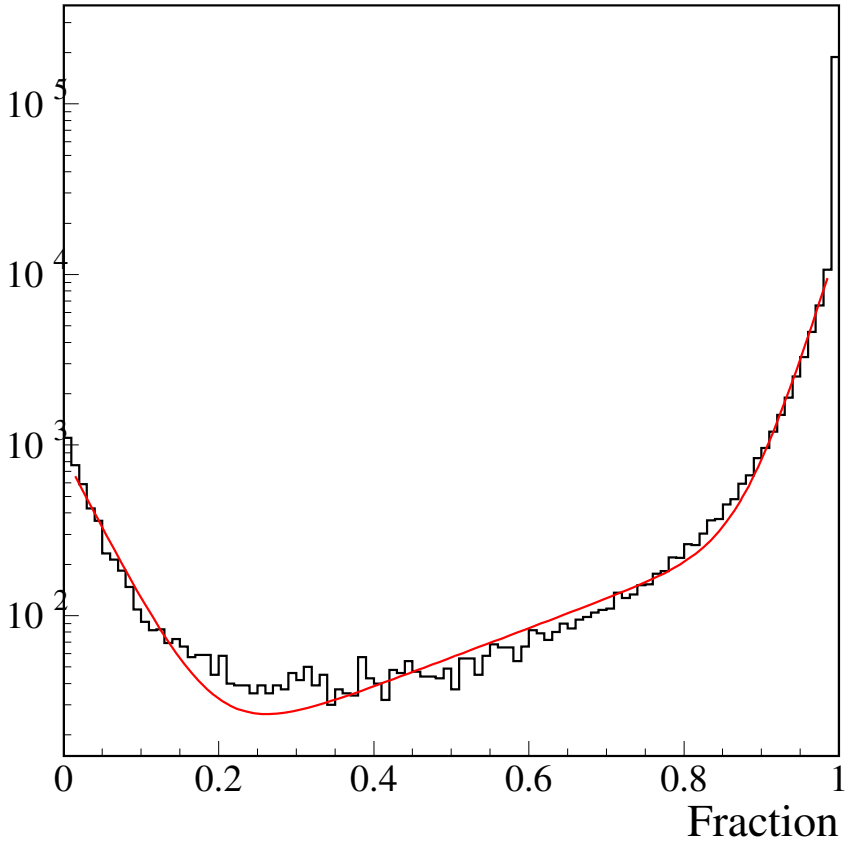

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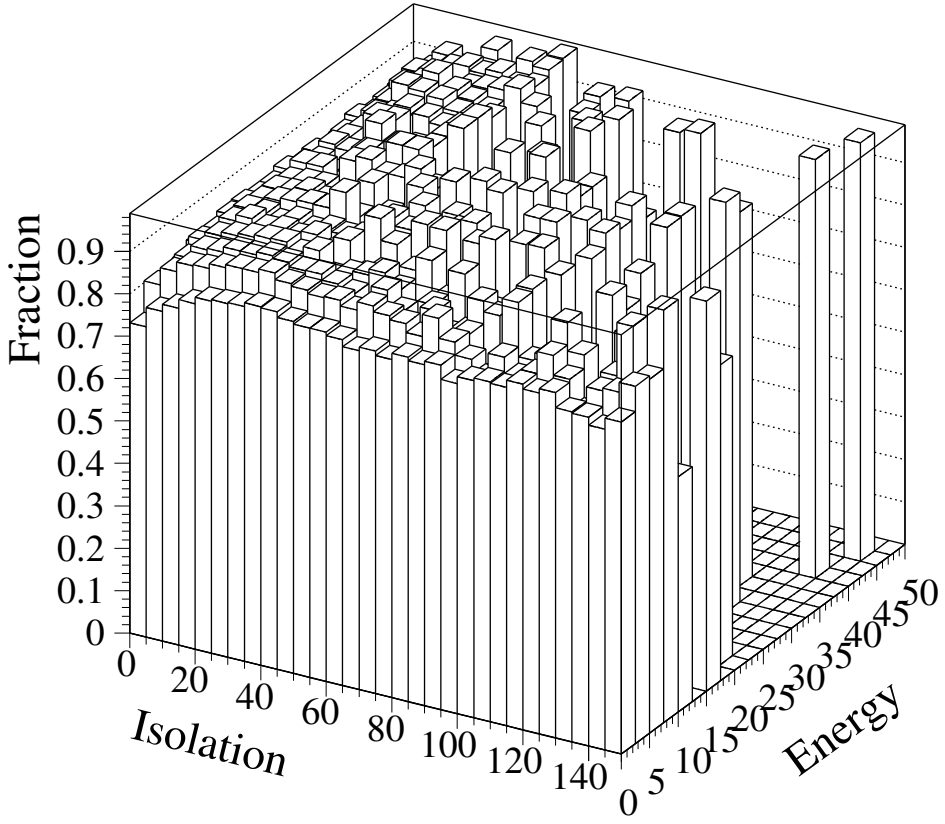

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Total cross-section for $e^+e^- \to \gamma\gamma e^+e^- \to q\bar{q}e^+e^-$: 35 nb (PYTHIA)

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Simple example:

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- Eg. 5000 events per point (modest requirement: in sps1a' almost 1 million SUSY events are expected for 500 fb^{-1} !)
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Use-cases at the ILC

- 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)

White paper

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- Concentrate on what really matters:
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  - True neutral particles merging (a part of) their shower with charged particles: enetgy loss.
- Don't care about neutral-neutral or charged-charged merging.
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Collections

- 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.

Outlook

- Include a filter-mode:
  - Generate event inside SGV.
  - Run SGV detector simulation and analysis.
  - Decide what to do: Fill some histos, fill ntuple, output LCIO, or better do full sim
  - In the last case: output STDHEP of event
- Update documentation and in-line comments, to reflect new structure.
- Consolidate use of Fortran 95/203/2008 features. Possibly - when gcc/gfortran 4.4 (ie. Fortran 2003) is common-place - Object Orientation, if there is no performance penalty.
  - 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.

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