Simulating Critical Processes

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Santa Cruz '02

Overview

- Provide full simulation capabilities for Linear Collider physics and detector program:
  - Physics simulations
  - Detector designs
  - Backgrounds
  - Reconstruction and analysis
- Whole world of accelerator simulations ignored!

Linear Collider Environment

- Detectors designed to exploit the physics discovery potential of e^+e^- collisions at $\sqrt{s} \sim 1\text{TeV}$.
- Will perform precision measurements of complex final states.
- Need fairly mature reconstruction and analysis frameworks to study.
- Must be robust against both physics and machine backgrounds.

Current Activities

- Generate full suite of SM physics processes.
  - No longer sitting on the Z resonance!
- Concentrate on full detector simulation.
  - GEANT4
- Include backgrounds.
  - Irreducible physics, $\gamma\gamma \to$ hadrons.
  - Machine backgrounds
- Emphasize full reconstruction results.
- Iterate detector design based on above.

"Standard LC MC Sample"

- Generate an inclusive set of MC events with all SM processes represented.
- Used for realistic physics analyses and will represent a "standard" sample.
  - Canonical background for Beyond-SM searches.
- Samples will be generated at several points to systematically study the benefits of higher energy.
  - 0.5, 0.8, 1.0, 1.2, 1.5 TeV cms

Physics Sample Generation

- WHIZARD, a generic MC generator for multi-particle processes at high-energy colliders, is being used to generate all of the following SM processes:

  $$e^+e^- \rightarrow f_1f_2,\ f_1f_2f_3f_4,\ f_1f_2f_3f_4f_5f_6$$

- PANDORA being used for 8 fermion $t\bar{t}$ processes.
- CIRCE is being used to model the beam- and brems-strahlung spectra.
  - Parameterizations available for latest NLC/JLC configurations at 0.5, 0.8, 1.0, 1.2 and 1.5 TeV thanks to Torsten Ohl.
  - PANDORA now includes CIRCE beamstrahlung as an option.
- Events can be used for TESLA studies simply by reweighting.

Physics Sample Generation II

- Electron and positron polarizations of 100% are assumed in event generation.
  - Generate all four configurations
  - Simulate arbitrary polarizations by sampling from e^-_L/e^+_R, e^-_R/e^+_L , …
- PYTHIA used for final state QED and QCD parton showering, fragmentation and decays.
- $\gamma\gamma \rightarrow e^+e^-$ and $\gamma\gamma \rightarrow$ hadrons will be overlaid.
- PYTHIA and HADES is being used to incorporate the $\gamma\gamma \rightarrow$ hadrons backgrounds.

Canonical SM sample

- A 1-2 ab^{-1} sample will be generated at each of the cms energies.
- Almost finished with first data point.
- Developing techniques to serve up correct mix of processes.
  - Weight >1 for some events (e.g. Bhabha's)
- Appreciate strong SCS support
  - Batch queues for generation
  - Disk space for storage (~1.5 TB/point)
- Terrific work by Tim Barklow.

Detector Design

- Perception that LC detectors are trivial to build.
- Much R&D has been done for SSC/LHC, but optimizations are different.
- Hadron colliders have large cross sections, enormous backgrounds and QCD processes
  - Complex triggering and radiation damage crucial
  - Jet energy resolutions limited by QCD radiation
- LC much smaller event rates and data sizes and small backgrounds.
- Robustness vs precision

Detector Design Comparison

	CMS	ATLAS	LC
Tracker Thickness	0.3	0.28	0.05
VXD layer thickness	1.7%	1.7%	0.06%
VXD Granularity	39 MPixels	100MPixels	800 MPixels
ECAL granularity	76,000	120,000	32,000,000

Jim Brau

Detector Design (GEANT 4)

- De facto standard for HEP physics simulations.
- We have made the transition to GEANT4 as the full simulation engine (Toshi Abe).
  - Uses existing XML detector description as input.
  - Currently writes output in ROOT format.
  - Should have SIO output soon.
  - SIO2ROOT and SIO2LCD exist.
- Flexibility imposes some restrictions on complexity of detector descriptions.

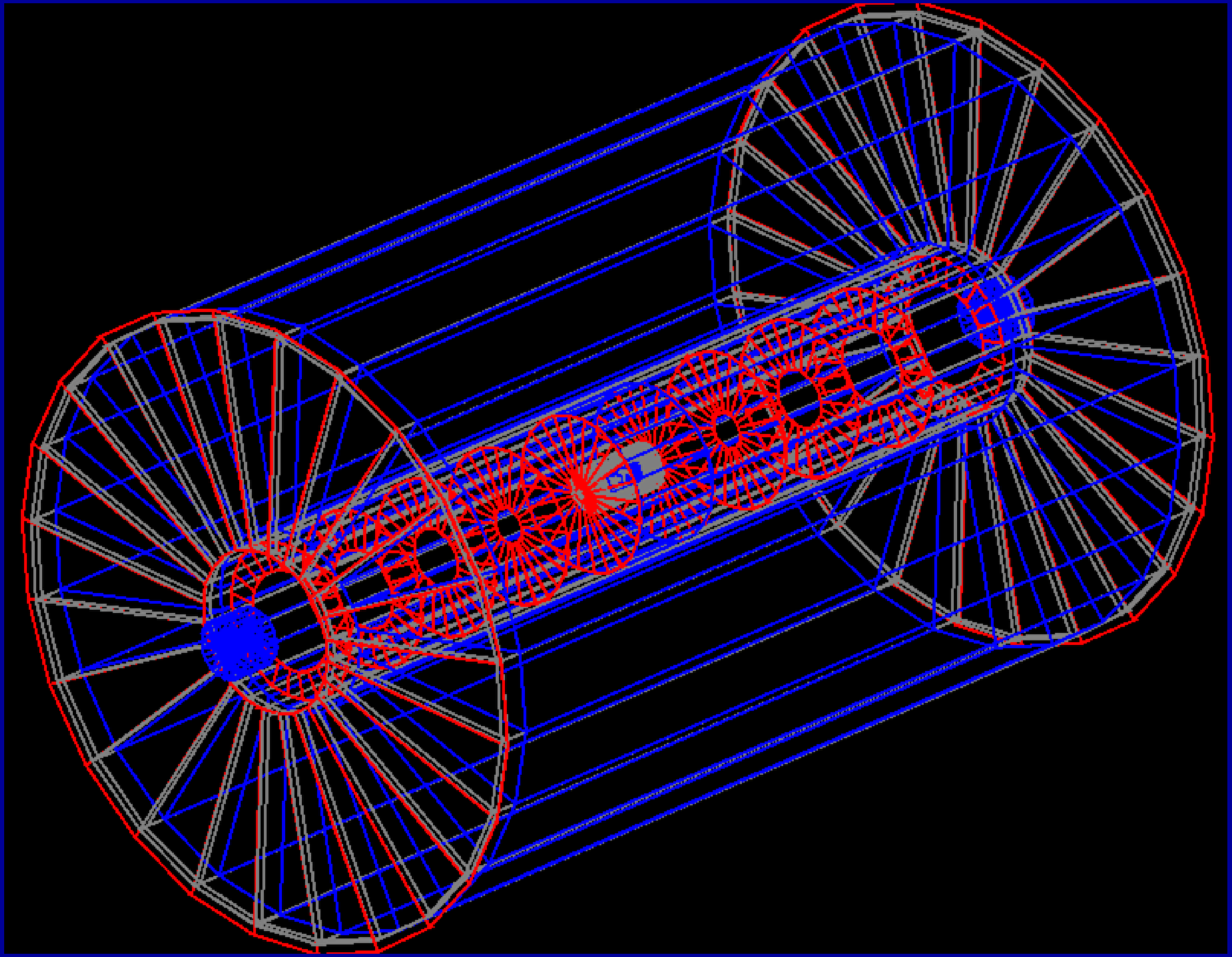
Improved Generic Detectors

- Investigating alternate schemes for describing detector geometries.
  - e.g. NICADD group installed MOKKA
- ATLAS and CMS have XML-based designs
  - Not commensurate with each other!
- CERN/IT working on common solution
  - GDML looks very promising
- Hoping GEANT4 adopts & supports a generic solution

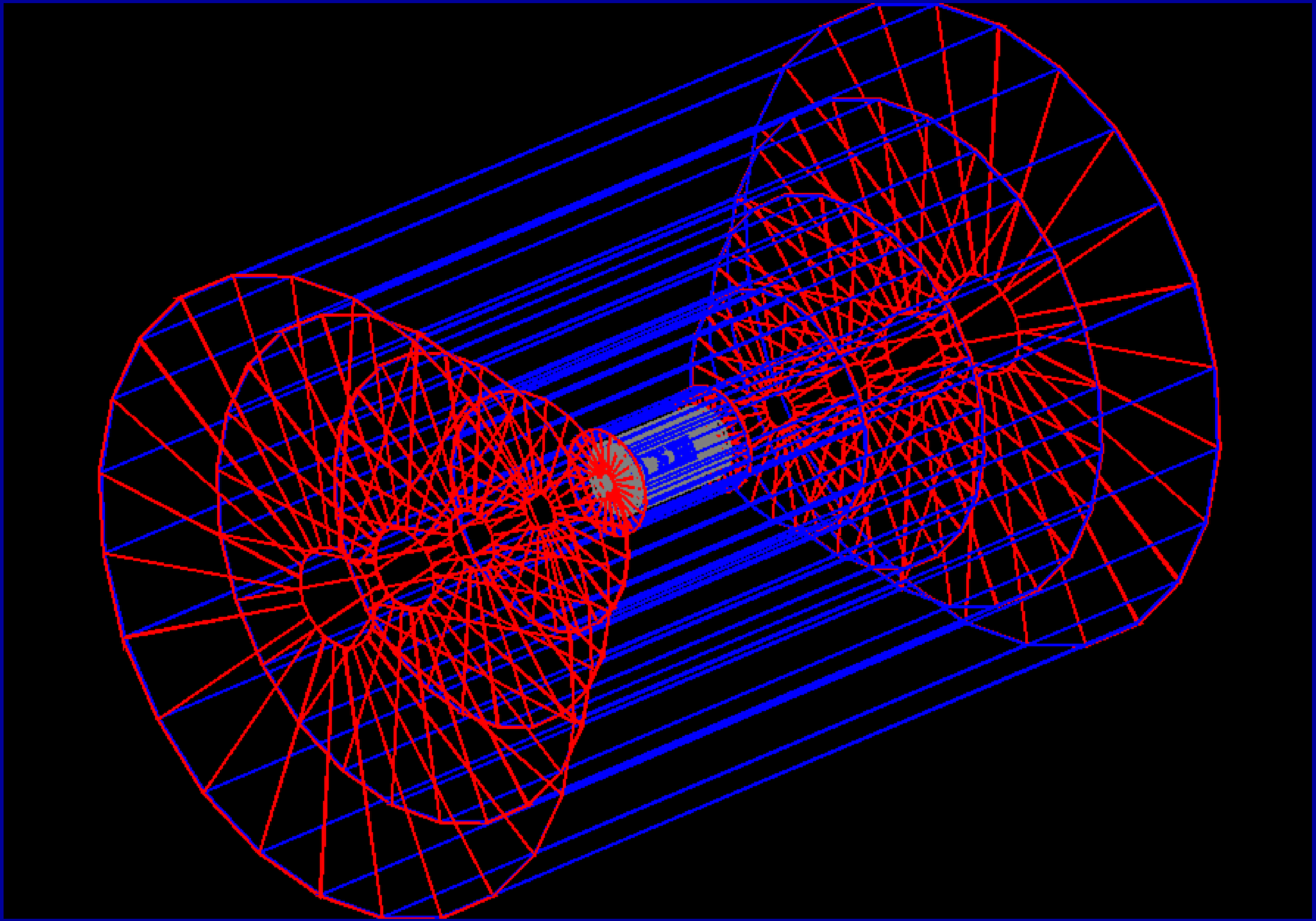
Strawmen Detectors

- Currently have two example detectors implemented.
  - LD
  - SD
- Can "roll your own" simply by editing ASCII file.
  - Change Calorimeter composition, segmentation
  - Introduce different tracker designs.
  - ...

TPC Tracker, Si Disks, CCD VTX



All Si Tracker, CCD VTX



GEANT4 plans

- Next version due out imminently.
- Default hadronic showering code is a simple rewrite of GHEISHA into C++.
- Problems uncovered and discussed by Gary Bower and Ron Cassell in Chicago also present in GEANT4.
- Hope to expedite fixes locally.
- Make available to others in LC community.

Towards Internationalization

- Suggest that Tesla, NLC and JLC full simulation groups could run a single GEANT4 executable.
- Geometry determined at run-time (XML).
- Write out common "ideal" hits (~flat-file).
- Digitize as appropriate with plug-ins.
- Enormous savings in effort.
- Makes comparisons easy.
- "You don't have to build it to use it."

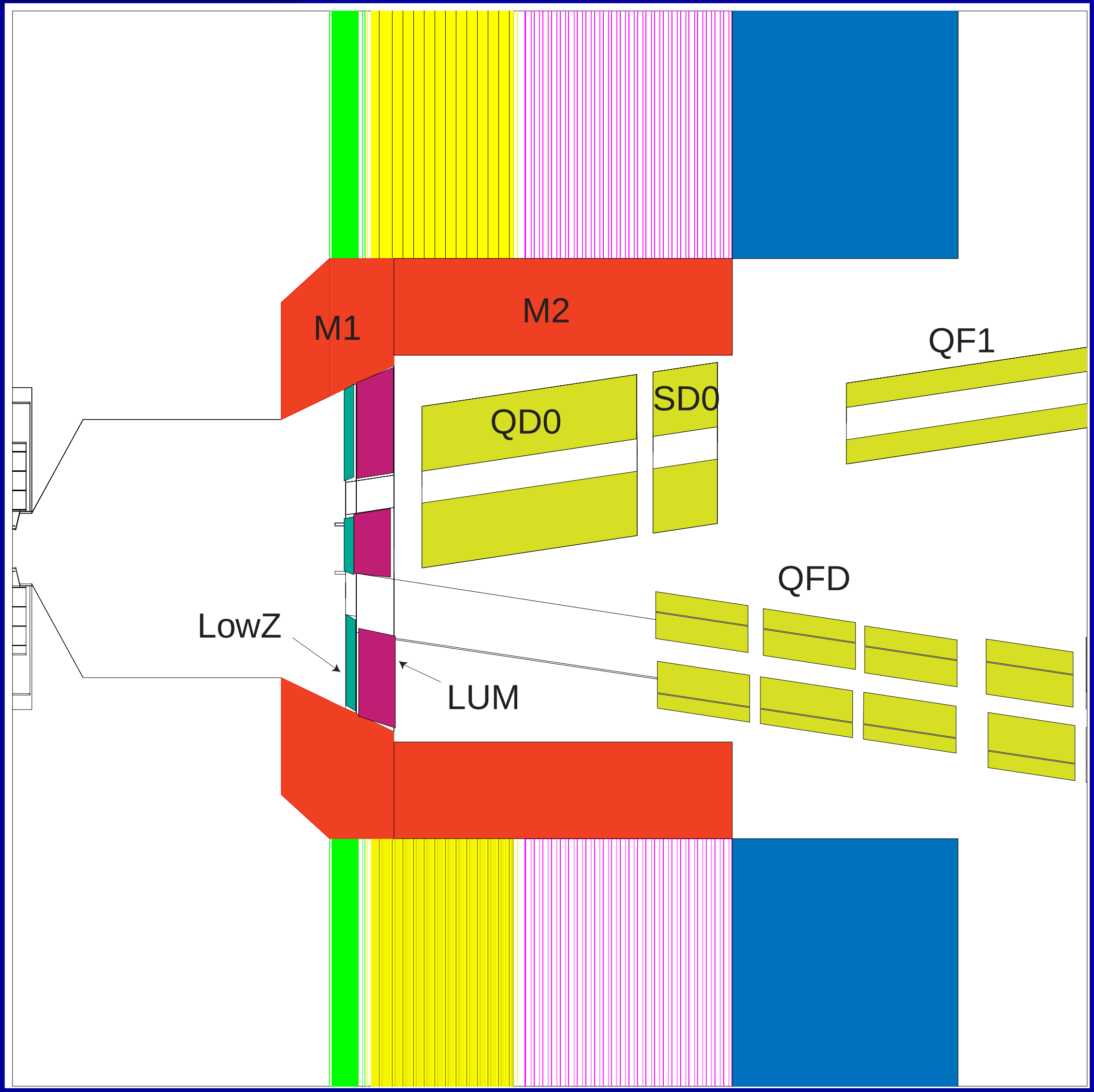
Backgrounds

- Essential that detector design be robust against machine backgrounds.
- Crucial to undertake physics studies in the correct context of irreducible physics backgrounds.
  - Can no longer simply float k_T to get 2 jets!
- Correctly simulate and overlay backgrounds on signal, event-by-event.

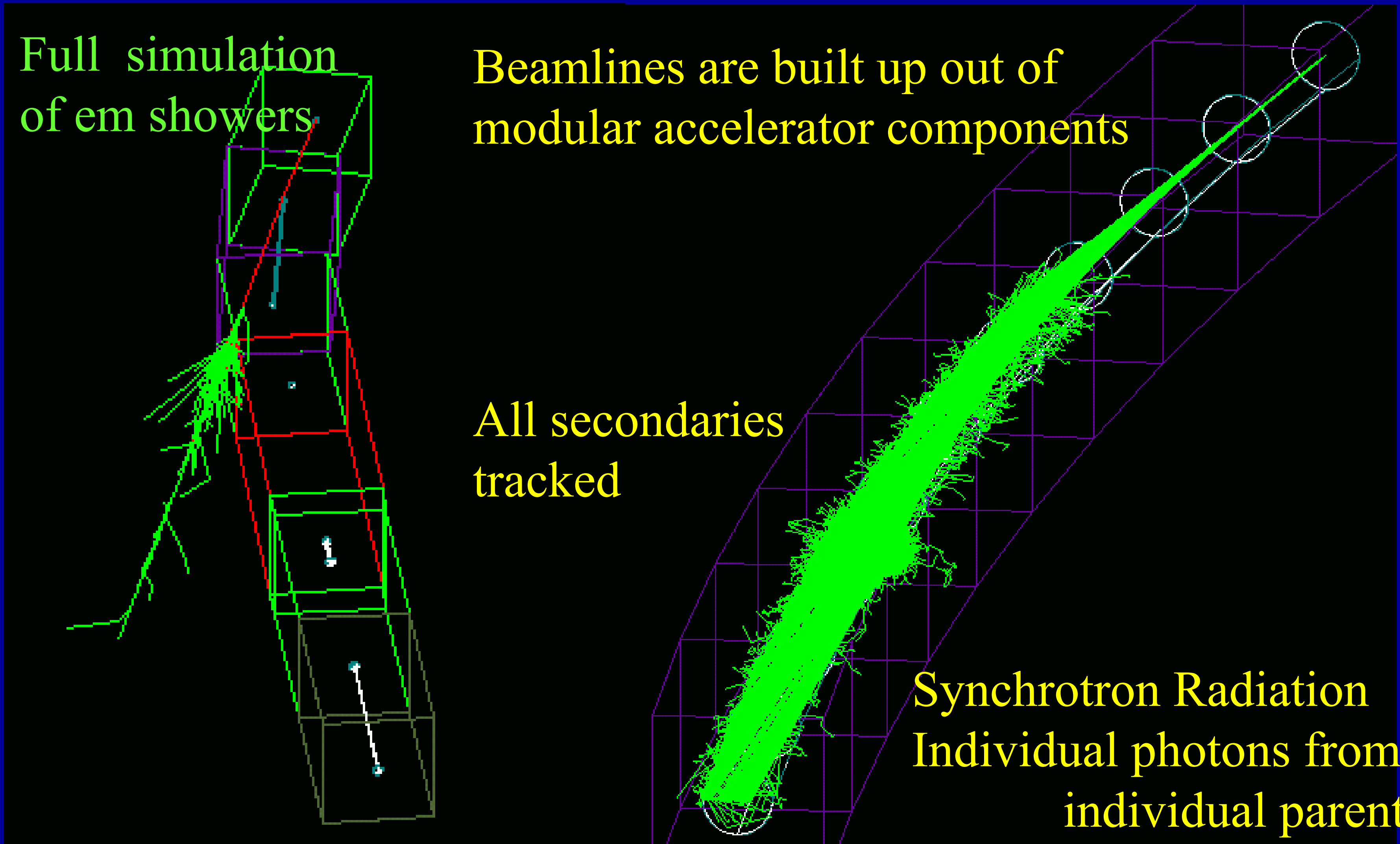
Machine Backgrounds

- Beam Delivery System group has sophisticated simulation of interaction region
- See plenary talk by Jeff Gronberg
- Run GuineaPig simulations of beam interactions.
- Follow all the particles.
- Record those which register hits in detector scoring planes.

BDS Simulation (GEANT3)



BDS in GEANT4 (G. Blaire)



Machine backgrounds

- e+e- pairs from beam-beam interactions (T. Maruyama)
  - Generating large samples of events
  - Have added 192 bunches worth to some signal events, started tracking investigations
- Muons from collimator halo (L. Keller)
  - Event samples generated
  - Will be generated and available for overlay soon.
- See talks by Takashi Maruyama (|| Session II) and Mike Ronan (|| Session III)

Underlying Physics Processes

- Dominant background due to $\gamma\gamma \to$hadrons resulting from beam- and brems-strahlung photons.
- Extensively studied at LEPII, particularly by OPAL.
- Event generators usually considered:
  - PHOJET
  - PYTHIA
  - HERWIG

$\gamma\gamma$ Generators

- Latest version of PYTHIA includes improved support for $\gamma\gamma$ processes.
  - Will use as default unless objections.
  - Does as well as PHOJET at LEPII.
  - PHOJET needs PYTHIA fragmentation.
- Use CIRCE to provide input γ spectrum.
- PYTHIA allows event-by-event specification of cms energy.
- Generate inclusive $\gamma\gamma$ processes.

Overlaying Background Events

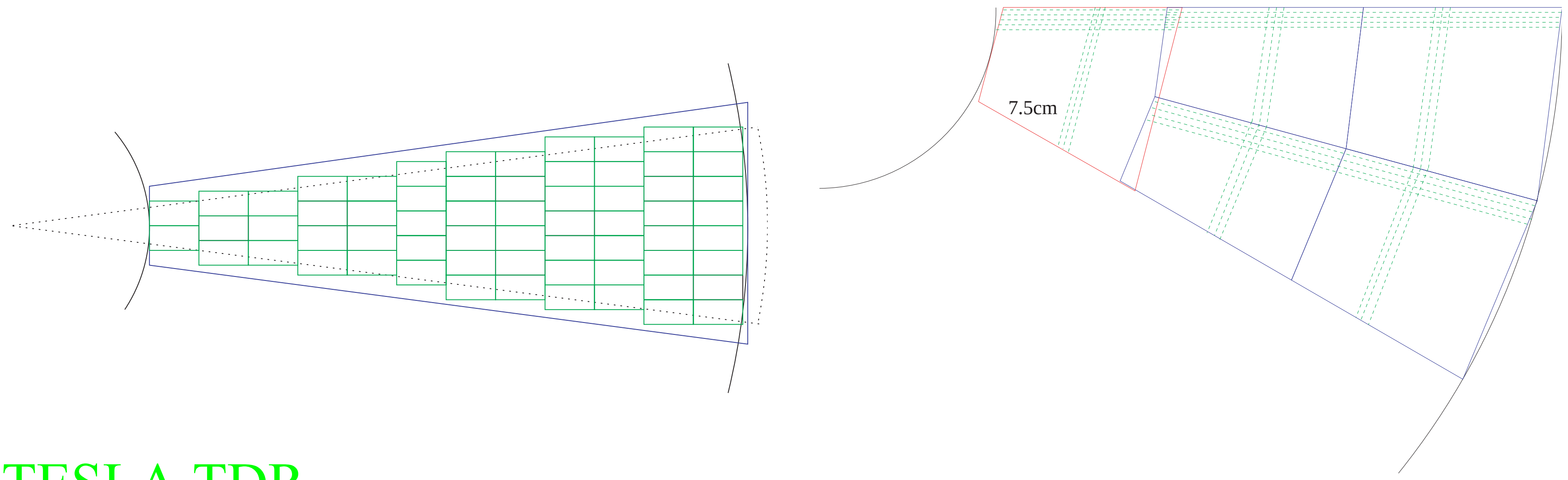
- Process background events through full simulation.
- Merge with fully simulated signal events.
  - Add appropriate number of beam bunches.
- SIOMerge combines MC particle heirarchy, tracker and calorimeter hits.
  - Renumbers MC particles, etc.
  - Does not yet account for time offsets in time-sensitive detectors (e.g. TPC).

Detector Issues

- Current simulations are good enough for many studies, but room for improvement.
- Need more detailed/realistic subdetector designs.
  - Current detectors are floating cylinders!
  - Luminosity monitors and masks neglected.
  - Calorimeters simple absorber/readout
  - Only projective tower geometry supported.
- Subdetector integration needs attention.

Tracking Detector Issues

- Forward tracking system very idealized
  - Simple disks providing 2D hits
  - Need wafer proposal and supports



TESLA TDR

Tracking Detector Issues

- Tracker MC hits all smeared with same resolutions (but see D. Karlen's talk).
- Currently don't merge tracker hits.
  - Need to digitize signals or simulate.
    - Axial Si μ strips
    - "ghosts" from forward stereo disks
  - Need to assign appropriate errors to merged hits.
- Don't simulate detector inefficiencies.
- Don't add detector noise.

Reconstruction Issues

- Most physics analyses based on fast MC.
  - Highly idealistic, assumes perfect pattern recognition and perfect resolutions.
  - Goal towards which to strive.
- Full reconstruction fundamentals available but not fully characterized or developed.
  - Track pattern recognition and fitting in central region (e.g. VXD+TPC)
  - Nearest Neighbor calorimeter clustering

Reconstruction Issues II

- Forward tracking and central region axial tracking still needed.
  - See talks in Tracking Session.
- Track-Cluster association and neutral hadron identification still needs a lot of work. “Energy Flow” being worked on.
  - See talks in combined Sim/Calor Session.
- Particle ID (see PID Session, R. Wilson)
  - Do we need it?
  - How good is TPC dE/dx?

Reconstruction Issues III

- In order to correctly judge the capability of detectors to accomplish the physics goals and the effect of backgrounds on the detector designs, we need capable, robust, believable event reconstruction.
- The only way to convince ourselves that this is true is to use it!
- Much is available, but there are many places where groups and individuals can plug in and contribute.

Summary

- Canonical SM Physics sample available soon.
  - Need to coordinate usage with physics groups.
- Background samples available.
  - Impact on detectors and physics only as good as the quality of the reconstruction.
- Detector descriptions need to become more Realistic & Detailed
  - R&D program?

Summary II

- Full reconstruction available, but underutilized.
  - What functionality do you need?
  - What functionality can you provide?
- Personal definition of “critical processes.”
  - What did I forget?

Informational Mailing Lists

- lcd-sim
  - This list is directed to those **using** the simulation, reconstruction and analysis software.
- lcd-dev
  - This list is directed to the simulation and analysis software **developers**.

URL

- American Linear Collider Detector simulation efforts are documented at:

  www-sldnt.slac.stanford.edu/nld

- Binaries, full source, API, tutorials, etc.
- Thanks to:

  T. Abe, G. Bower, R. Cassell, M. Iwasaki,

  A. Johnson, M. Ronan, B. Schumm, N. Sinev, W. Walkowiak, *et al.*

- Mail to: Norman.Graf@slac.stanford.edu