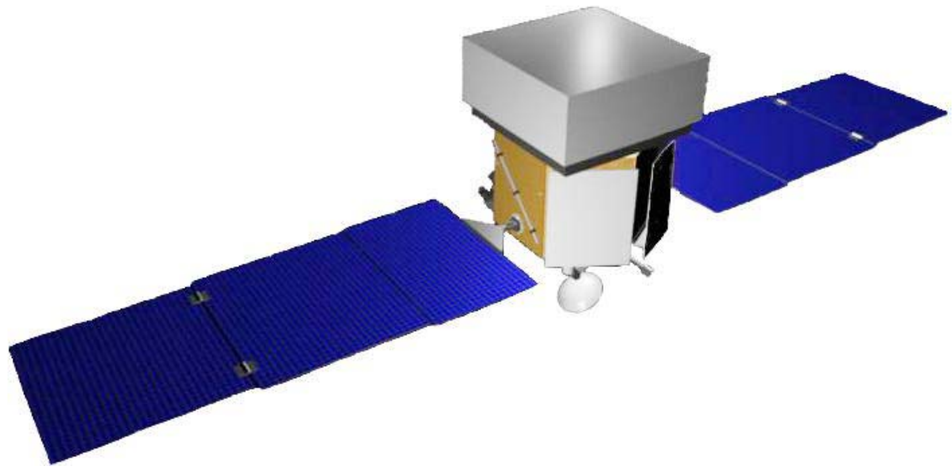


Simulation of GLAST

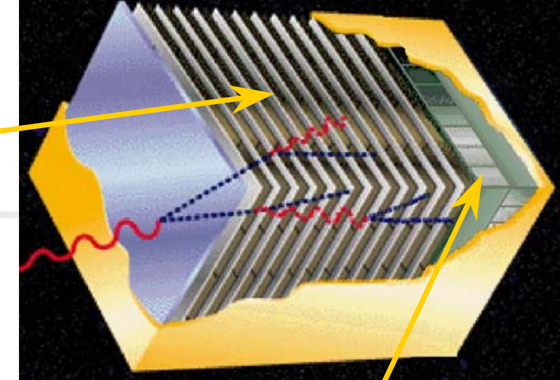
Alessandro de Angelis
University of Udine and INFN Trieste

SLAC, February 21, 2002

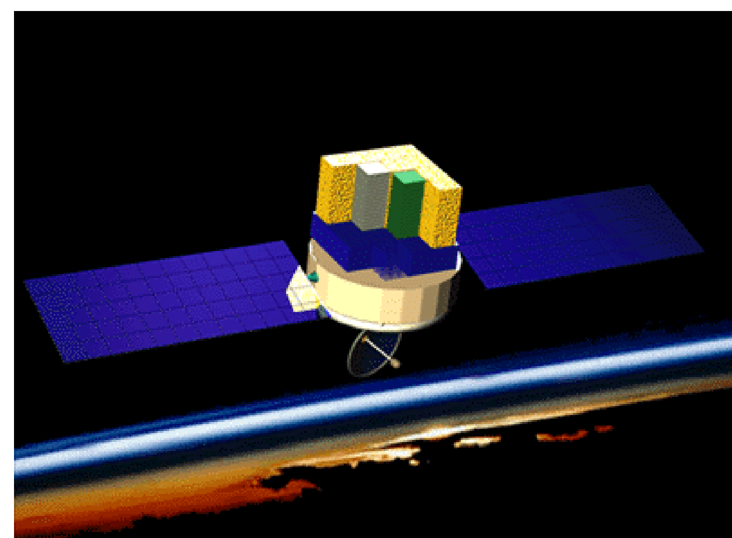
Layout of the presentation

- GLAST
  - Characteristics and requirements and their impact on the simulation
- Structure of the GLAST software
  - and its impact on the simulation
- From GISMO to G4
- The G4-based simulation
  - Framework & data exchange
  - Geometry
  - Flux generation
  - Digitizations
  - Interaction with analysis & event display tools
- Physics validation
- Simulation gallery
- Next steps

GLAST

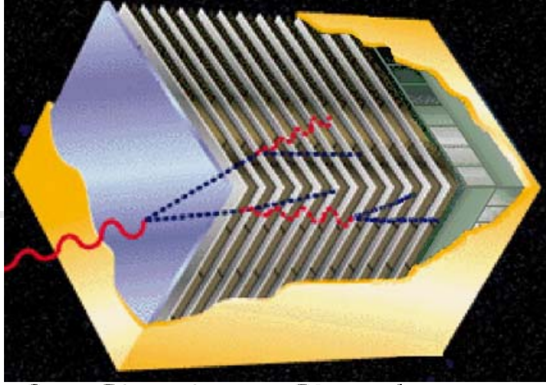


- γ telescope on satellite for the range 20 MeV-300 GeV
  - hybrid: tracker + calorimeter
- International collaboration NASA + US-Italy-France-Japan-Sweden
  - Broad experience in high-energy astrophysics and particle physics (science + instrumentation)
- Timescale: 2006-2010 (->2015)
- Wide range of physics objectives:
  - Gamma astrophysics
  - Fundamental physics



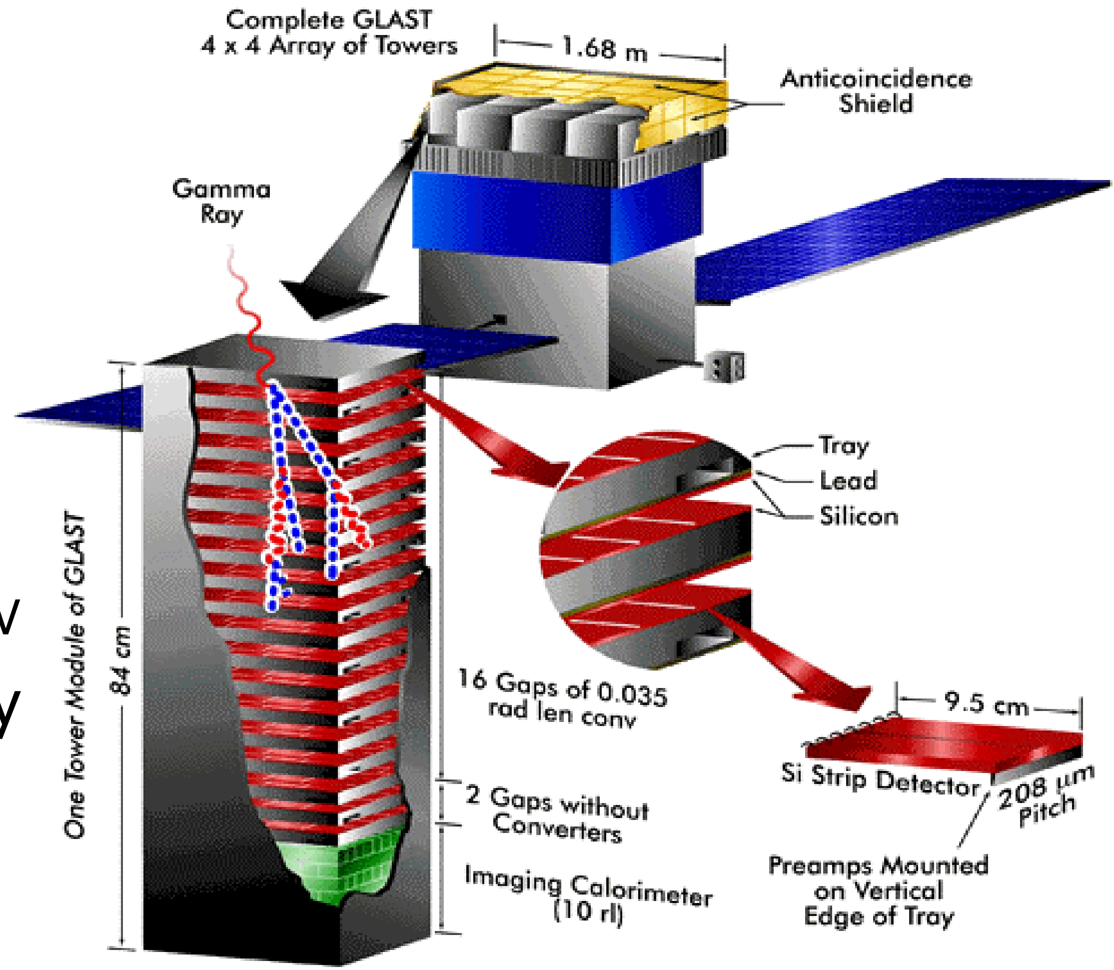
A HEP / astrophysics partnership

GLAST: the instrument

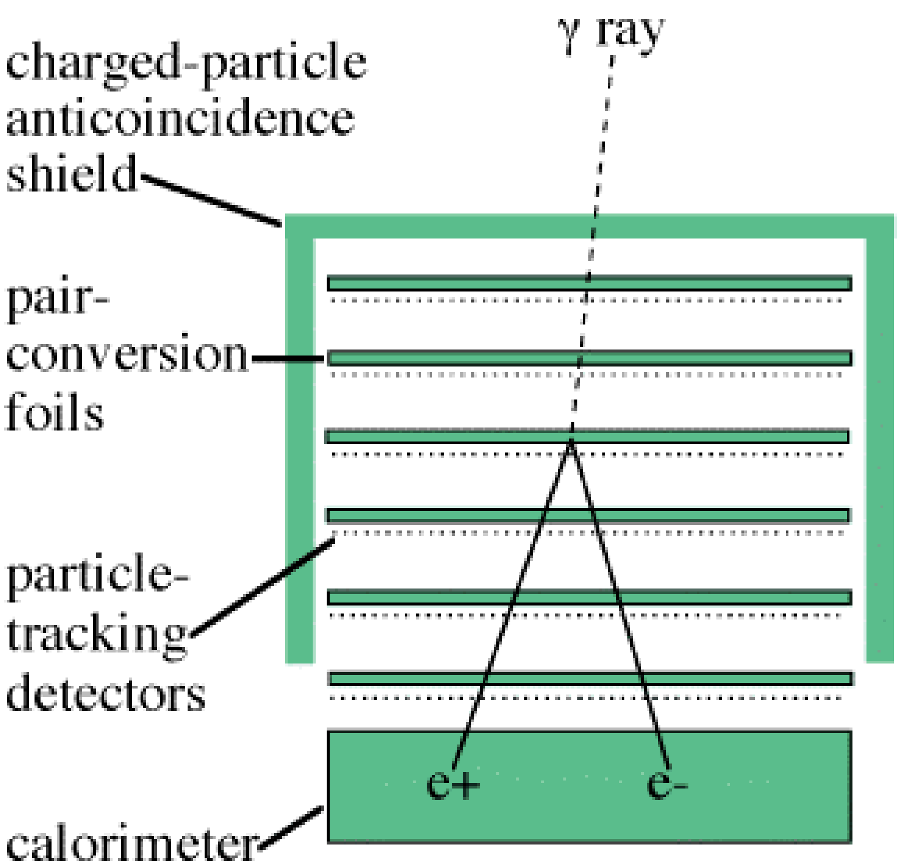


Some Dimensions are Distorted
for Clarity of Presentation

- Tracker (pair conversion telescope)
  Si strips + converter
- Calorimeter
  CsI with diode readout
  (a classic for HEP)
- 1.7 x 1.7 m^2 x 0.8 m
  height/width = 0.4 $\Rightarrow$ large FOV
- 16 towers $\Rightarrow$ modularity



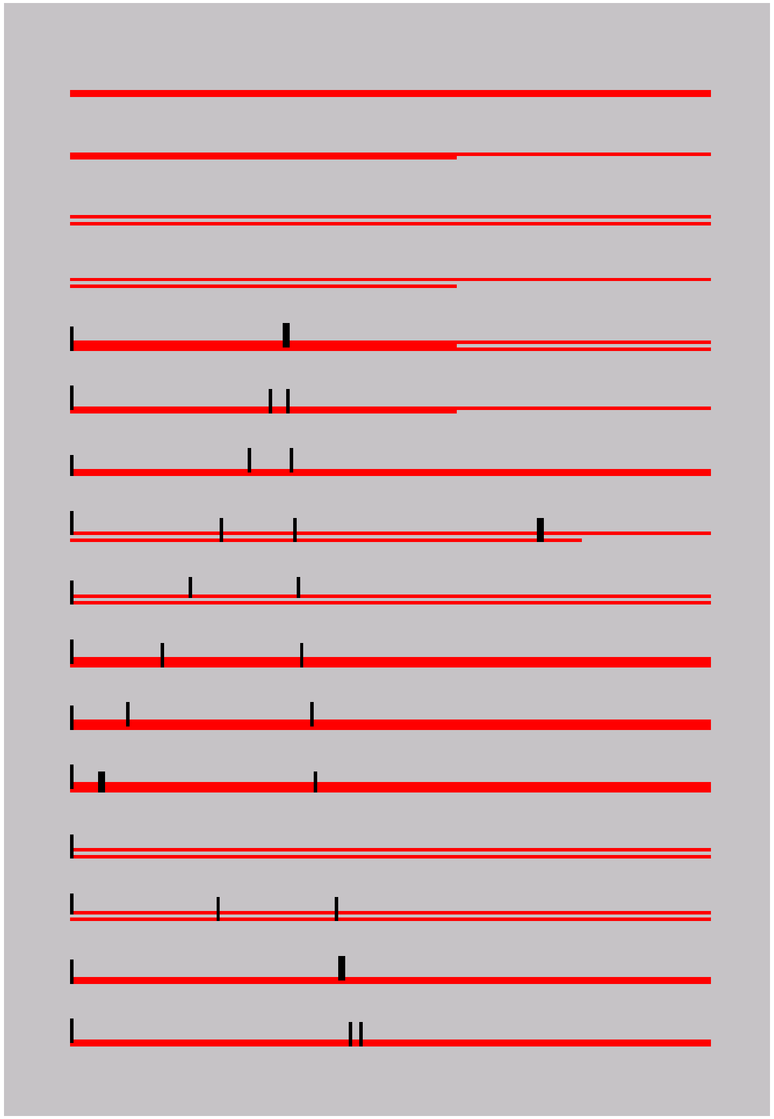
GLAST: the tracker

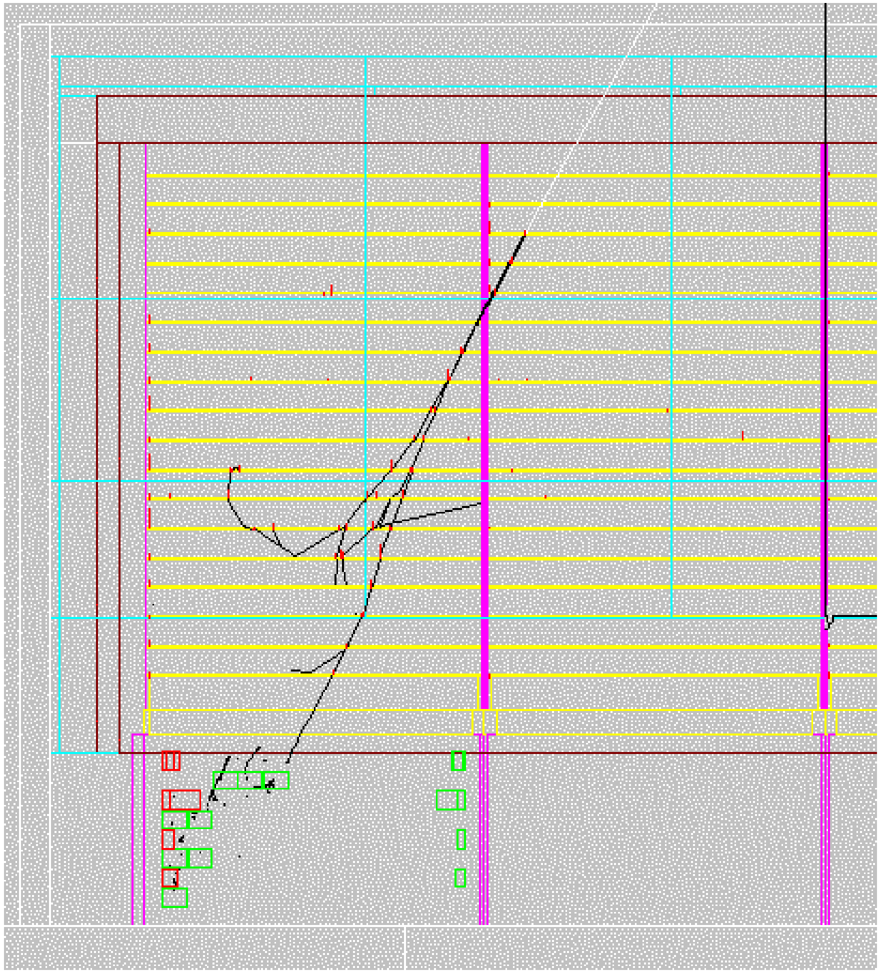


Si strips + converter
- High signal/noise
- Rad-hard
- Low power

- 4x4 towers, of 37 cm × 37 cm of Si
  - 200 μm pitch
- 18 *x,y* planes per tower
  - 19 "tray" structures
- Electronics on the sides of trays
  - Minimize gap between towers
- Carbon-fiber walls to provide stiffness

A real event and a reconstructed γ conversion

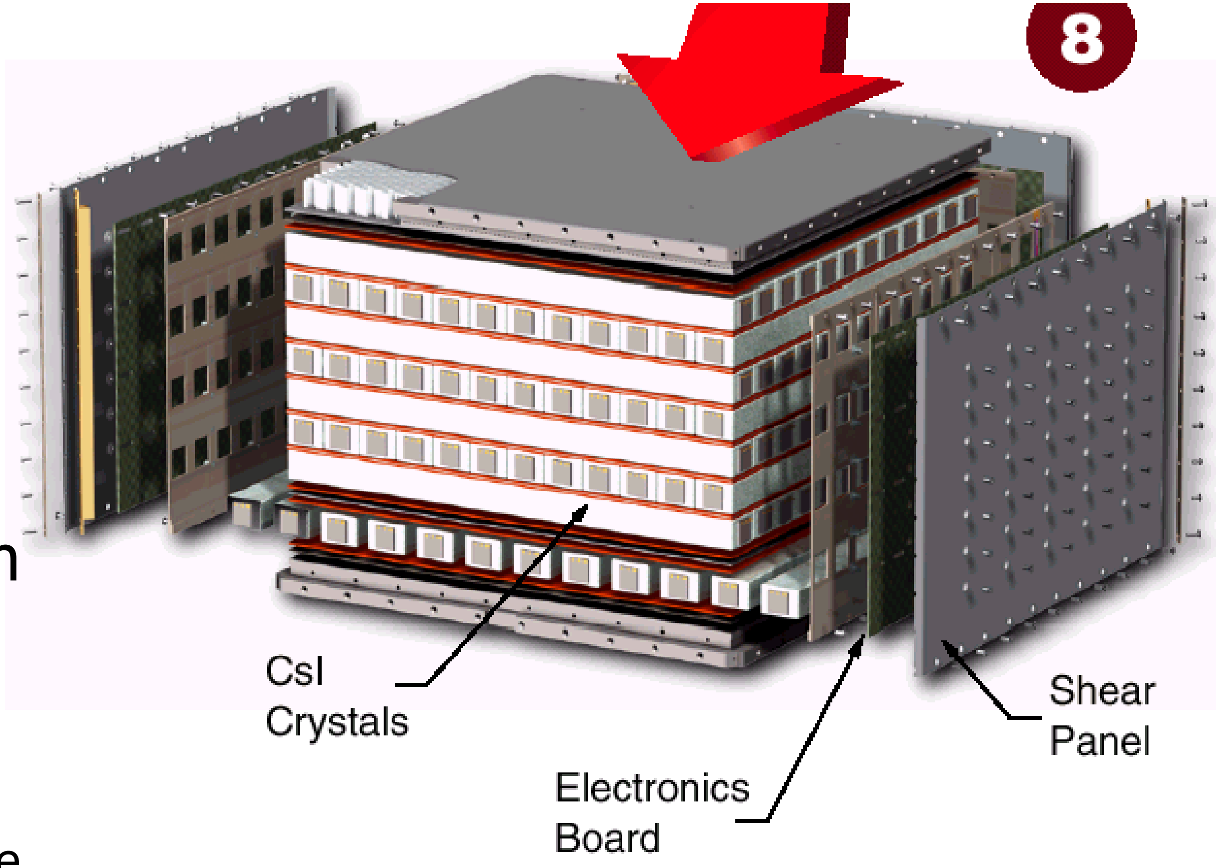




GLAST: the calorimeter

CsI with diode readout

- Good E resolution
- High signal/noise
- Hodoscope: good position determination & leakage correction



- 4x4 arrays of CsI (Tl) crystals
- Thickness of 10 X_0
  - ~27x20 mm^2 transv size

Key science objectives

- Resolving the γ ray sky: AGN, diffuse emission & unidentified sources
- Particle acceleration mechanisms
- High energy behavior of γ ray bursts & transients
- Dark matter: probing WIMPs
- Solar flares
- New fundamental physics (the "unexpected")

Make happy both the HEP and the astrophysics community...

From S. Ritz 2001

A few definitions…

Effective area

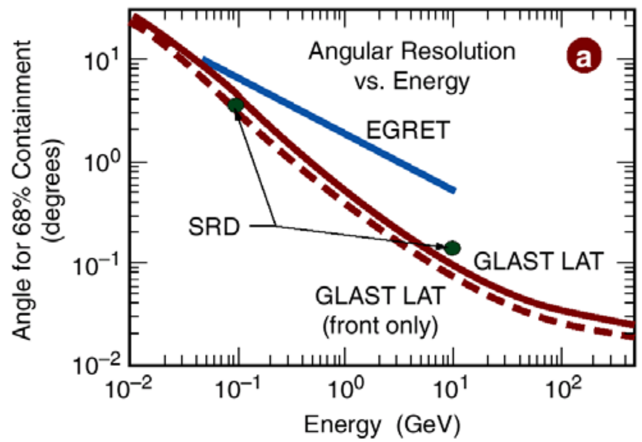
(total geometric acceptance) • (conversion probability) • (all detector and reconstruction efficiencies). Real rate of detecting a signal is (flux) • A_{eff}

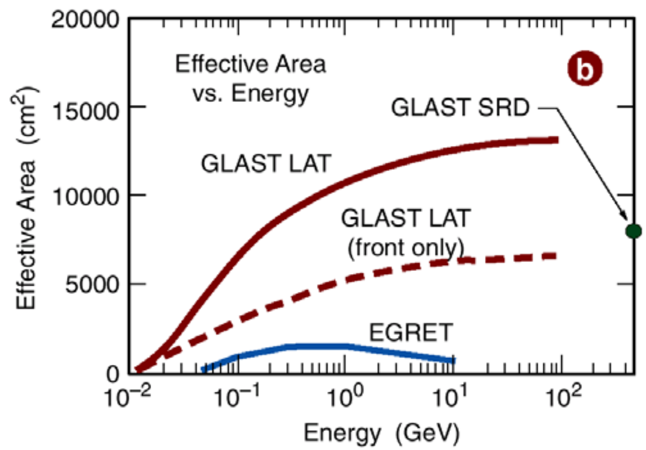
Point Spread Function (PSF)

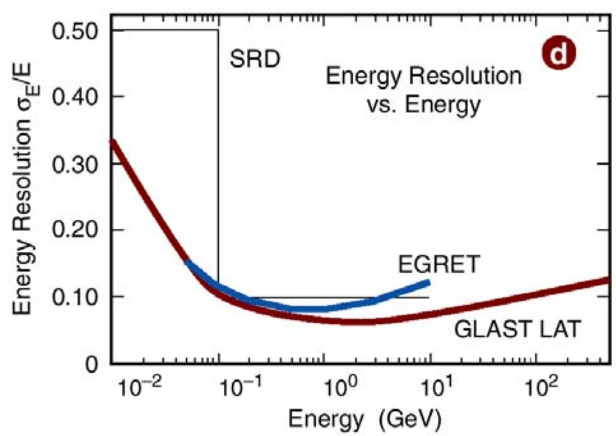
Angular resolution of instrument, after all detector and reconstruction algorithm effects.

Performance (compared to EGRET)

Quantity	GLAST	EGRET
Energy range	20 MeV- > 300 GeV	20 MeV- 30 GeV
Energy resolution	10 % (E>100 MeV)	10%
Peak Effective Area	> 8000 cm^2 (E>1 GeV)	1500 cm^2
Single photon angular resolution (68%, on-axis)	<3.5 deg (100 MeV) <0.15 deg (E>10 GeV)	5.8 deg (100 MeV)
*Field of view (FOV)	> 2 sr	0.5 sr
Time resolution	10 microseconds	0.1 milliseconds
Dead time	< 20 microsec/event	100 ms/event

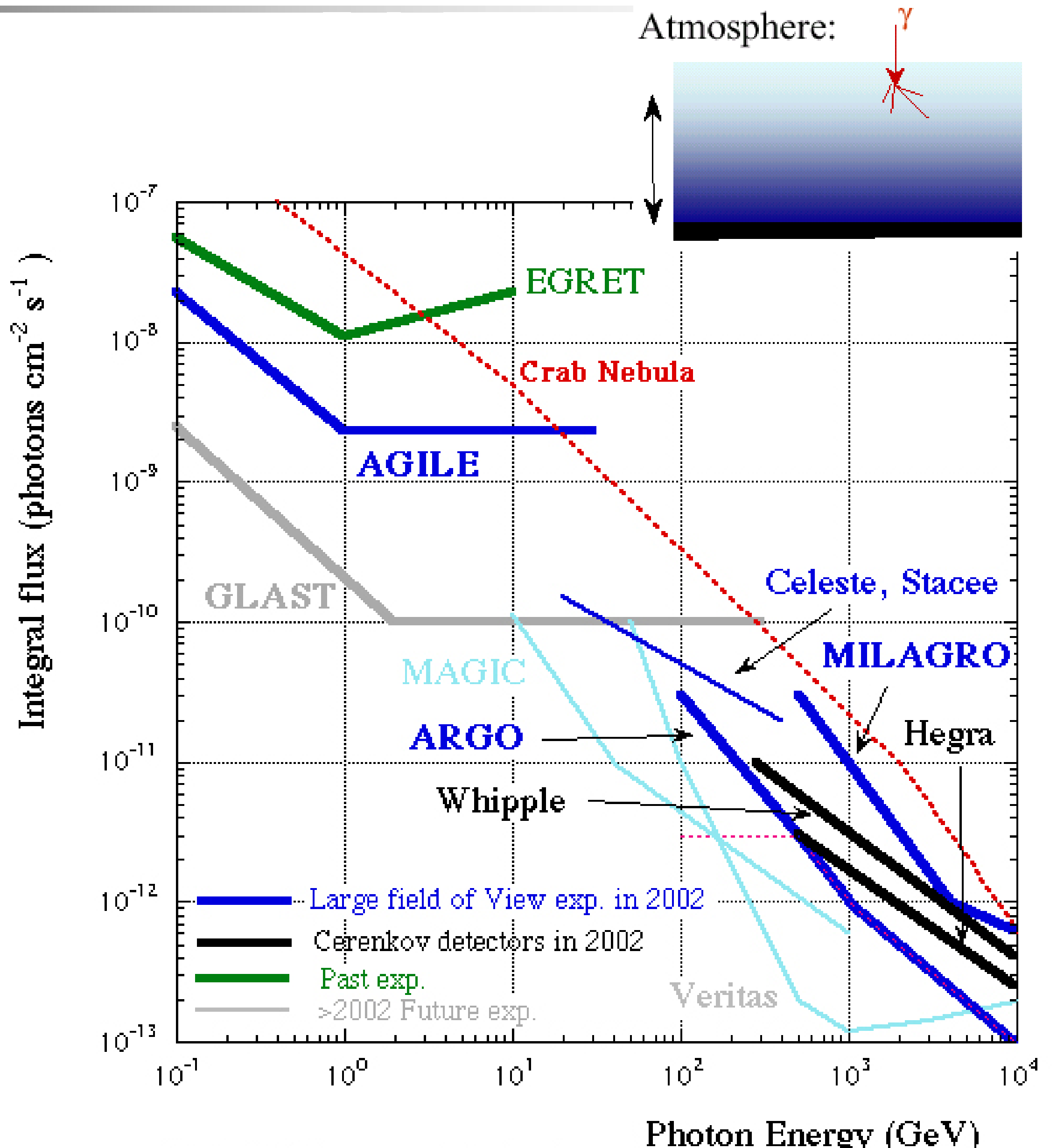






Sensitivity compared to present & future detectors

- Complementary to ground-based
- GLAST is a key element of the γ astrophysics program
  - Large area
  - Low deadtime (20 μs)
  - Energy range to >300 GeV
  - Large FOV



GLAST in summary…

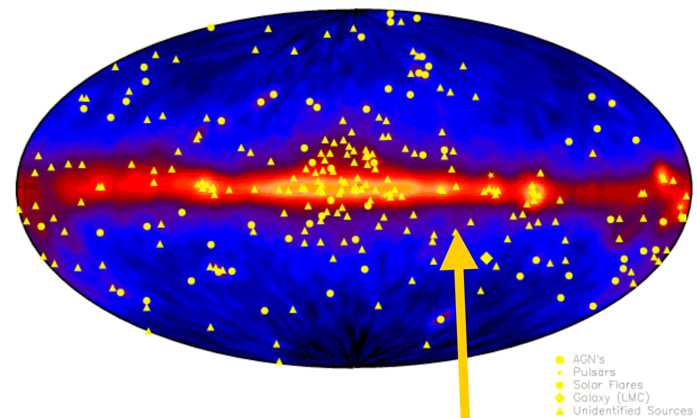
- Huge FOV (~20% of sky)
- Broadband

  (4 decades in energy, including unexplored region > 10 GeV)
- Unprecedented PSF for gamma rays

  (factor > 3 better than EGRET for E>1 GeV)
- Large effective area (factor > 4 better than EGRET)
- Results in factor > 30-100 improvement in sensitivity
- No expendables: long mission without degradation

GLAST: signal and backgrounds

- Main signal: gamma rays
  - Detect conversion in the tracker
    - Typical cutoff ~ 10 keV
  - Shower in the calorimeter
    - Availability of a fast simulation
- Main background is charged cosmics
  - Veto with ACD
  - Possible classification using Multiple Scattering
  - Track signature
- S/B ratio is very low!
  - CR protons and He [(differential flux up to 5 order of magnitude than the high latitude diffuse γ radiation (at 30 GeV)]
  - CR electrons (up to 10^3 times more abundant)
- Need for a very efficient Bckg Rejection up to ~10^{-6}
- Diffuse γ modelling needed for source detection



Galactic diffuse Emission

Simulation: physics requirements

- Accuracy in the simulation of EM interactions, down to low energies
  - Availability of a fast simulation in the calorimeter

- Reasonable simulation of hadronic interactions, rather fast
  - Availability of a fast simulation for hadrons

- *Plus technical requirements: a well written code*
  - *Modularity*
  - *Good documentation*
  - *Maintenability*

GLAST: structure of the offline sw

- Worldwide distributed sw dev’t (weekly VRVS meetings for cohesion)
  - CVS for concurrent developing
  - CMT for configuration management
- Strictly OO code (mainly C++, possibly some part in Java in the future)
- Code subdivided in packages
  - Clear division of the responsibilities
  - Easier to manage
- Three official platforms (Windows 2000/NT, Linux, Sun)
- A lot of applications in event production & analysis
  - Flux generation
  - MC propagation
  - Digits from hits
  - Reconstruction
  - Analysis
  - Event display
  - Databasing, …

how to deal with all of them in a structured way?

The GAUDI framework

- First GLAST simulation/analysis programs evidence the need for modularity, scalability, maintainability

=> a well structured (& well documented) framework: **GAUDI**

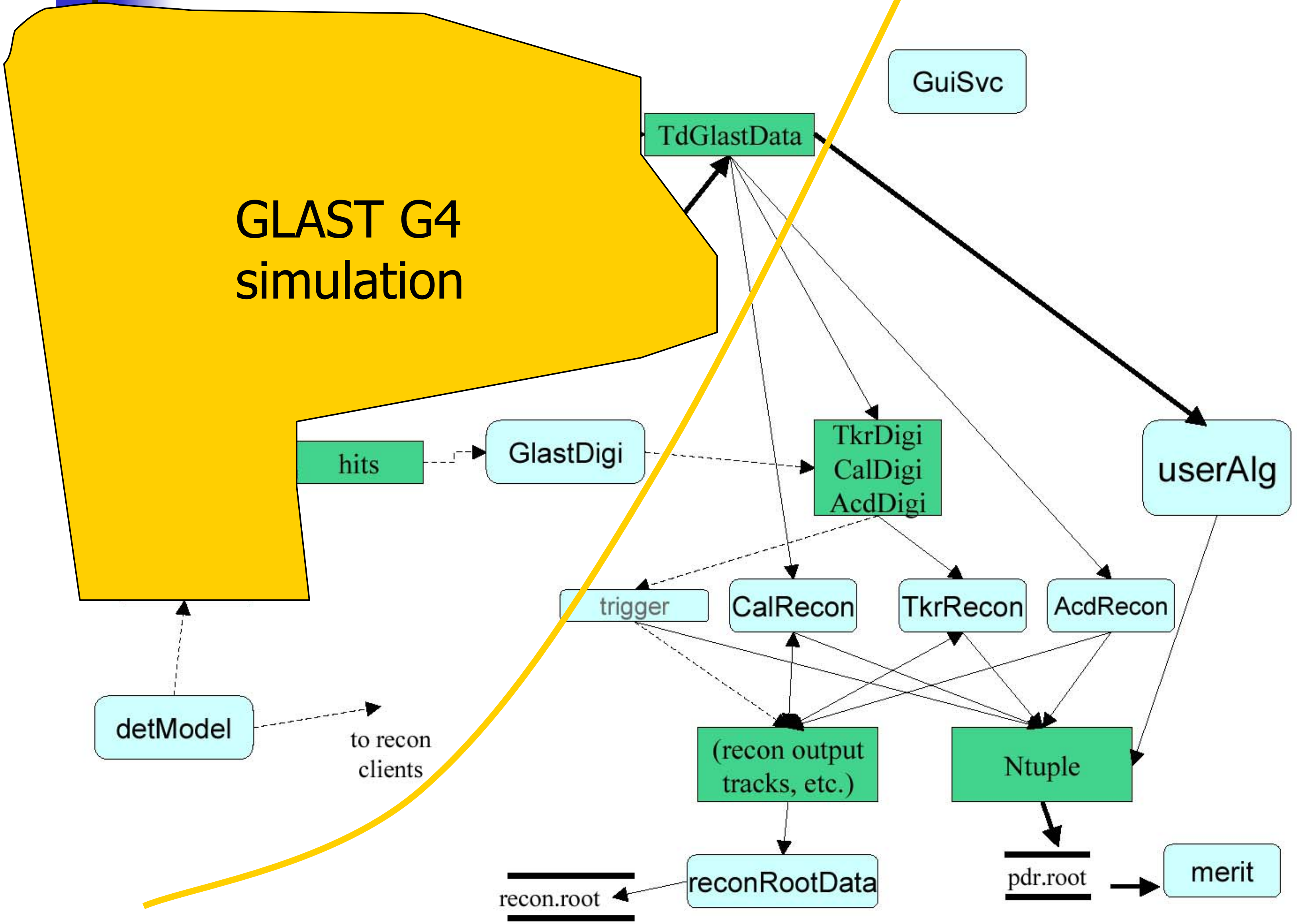
  - An application framework designed to facilitate event-oriented analysis, allowing modular development & deployment of processing algorithms
  - Open source project supported by (committed to) LHCb and ATLAS, hopefully guaranteeing long term support

- GLAST sim/rec/analysis is integrated in GAUDI

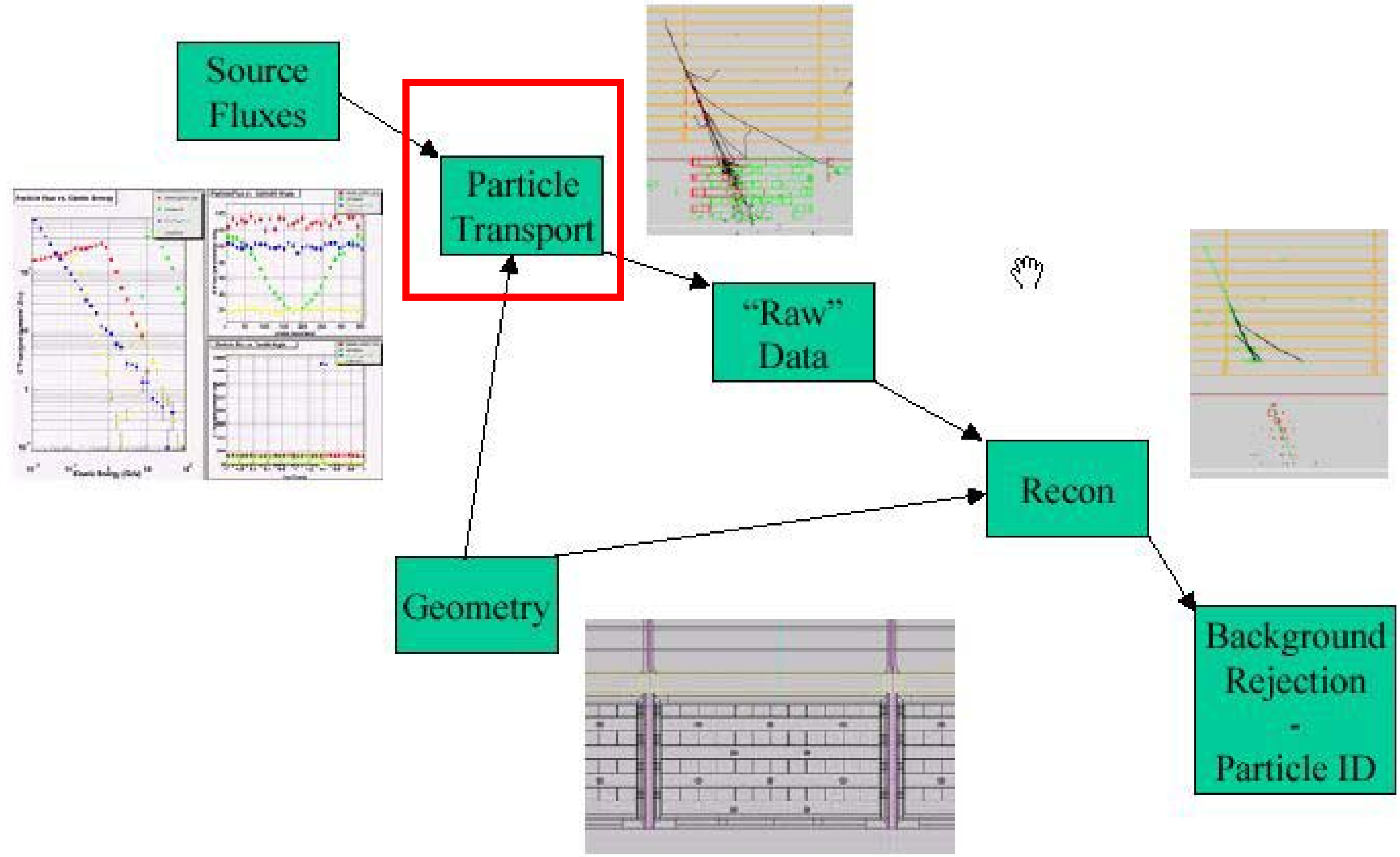
  The MC simulation (G4 for example) is a transport algorithm in the framework, not a standalone application

- See tomorrow's talk
  - Connecting G4 to the GLAST infrastructure: geometry and GAUDI, by Riccardo Giannitrapani (Udine)

Architecture plan



The simulation chain in GLAST

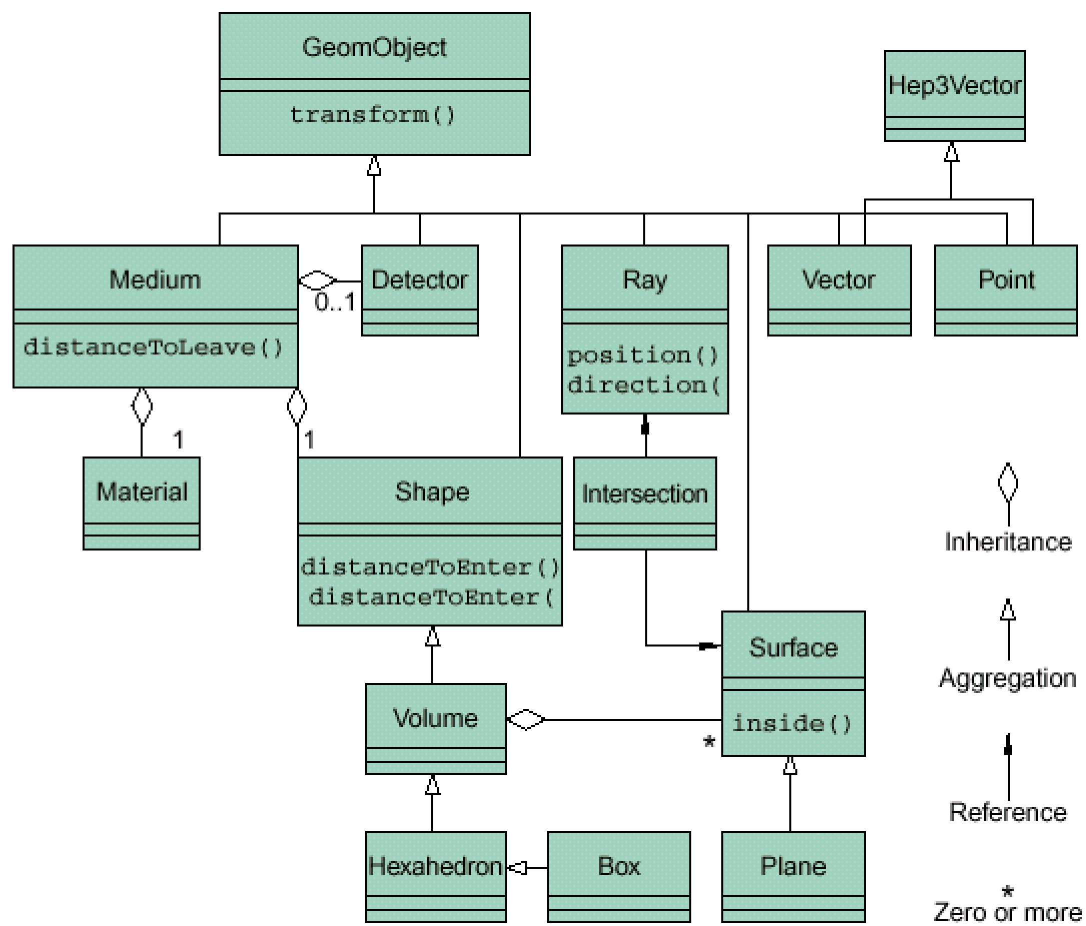


The beginning: GISMO

- The GLAST simulation has been done, from the beginning, using C++ and with OO technologies in mind
- GISMO was the choice
  - No other candidate at that moment (apart from standard Fortran MC)
  - GLAST core software group already experienced with GISMO

Characteristics of GISMO

- Takes care of tracking, Eloss etc.
- Secondary processes: EGS4, GHEISHA wrapped in



From GISMO to G4

- Why
  - GISMO is no more officially supported (and developed)
  - Physics needed some manpower
  - GEANT4 has arrived in the meanwhile
    - More flexible & maintainable
    - Well supported and used by several experiments
    - Continuously developed: 2 major releases each year + monthly internal tag (frequent bug fixes, new features, new examples)
    - Proved reliable for space applications (XRayTel and GammaRayTel)
- Groups involved (4-5 FTE)
  - Italy
  - Japan

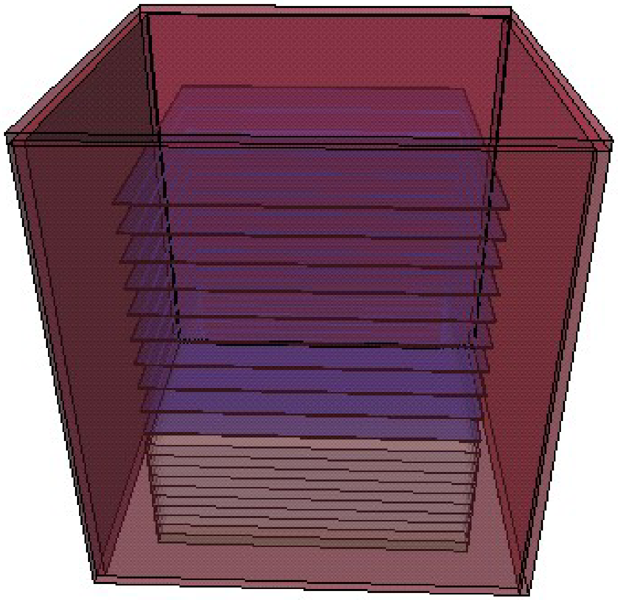
Why G4 is the solution

- Satisfies the technical requirements
  - C++, Object Oriented
  - Modular, scalable, extendable

- Lot of care on physics processes
  - A lot of physics processes available
    - Electromagnetic and hadronic processes in the same toolkit, no need for external packages
  - Possibility to act on the physics behind in an easy way
  - EM processes well simulated in the range of energies relevant for GLAST
  - The physics is tested in a lot of collaborations: bugs will have short life

GammaRayTel

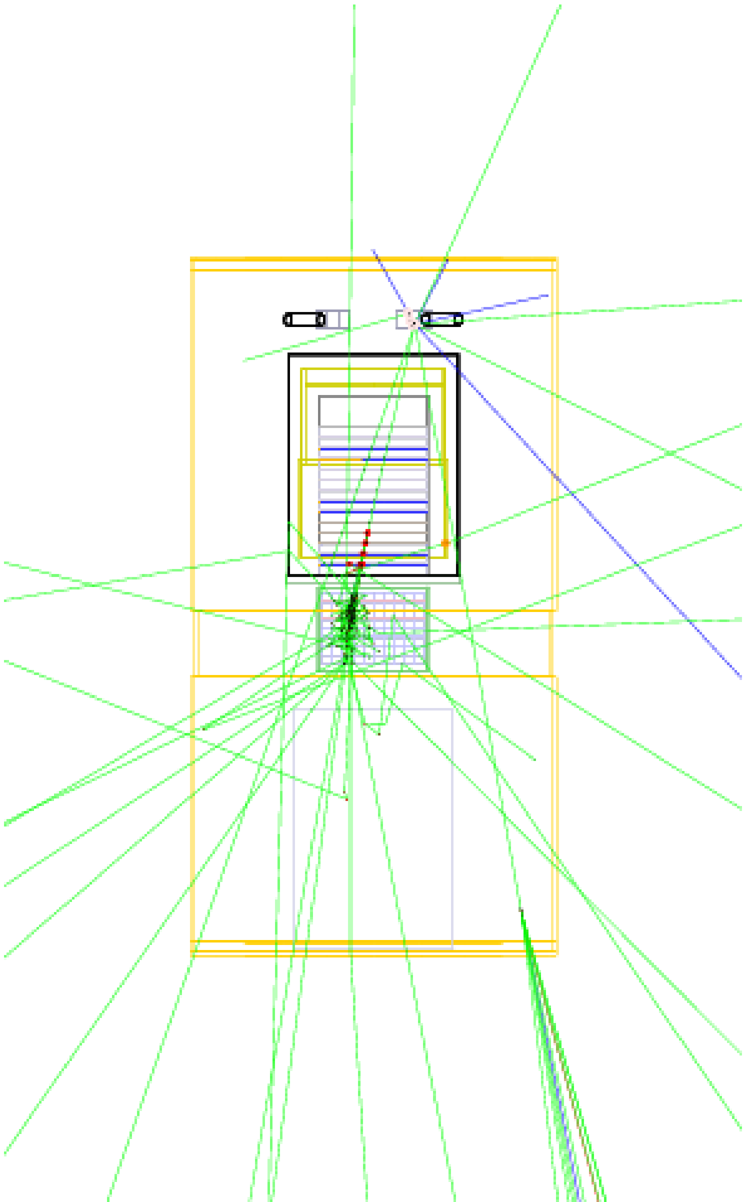
- A good workbench for GLAST needs and features
  - An advanced example of the G4 toolkit distribution
  - “Inspired” by GLAST and other similar experiments (AGILE)
    - One tower, with an ACD, a silicon strips tracker and a CsI calorimeter
    - The geometry is simplified wrt a GLAST tower
  - Example of use of Visualization, Analysis, Hits and Digits, UI and other features of G4
  - Is a standalone simulation (no GAUDI integration)



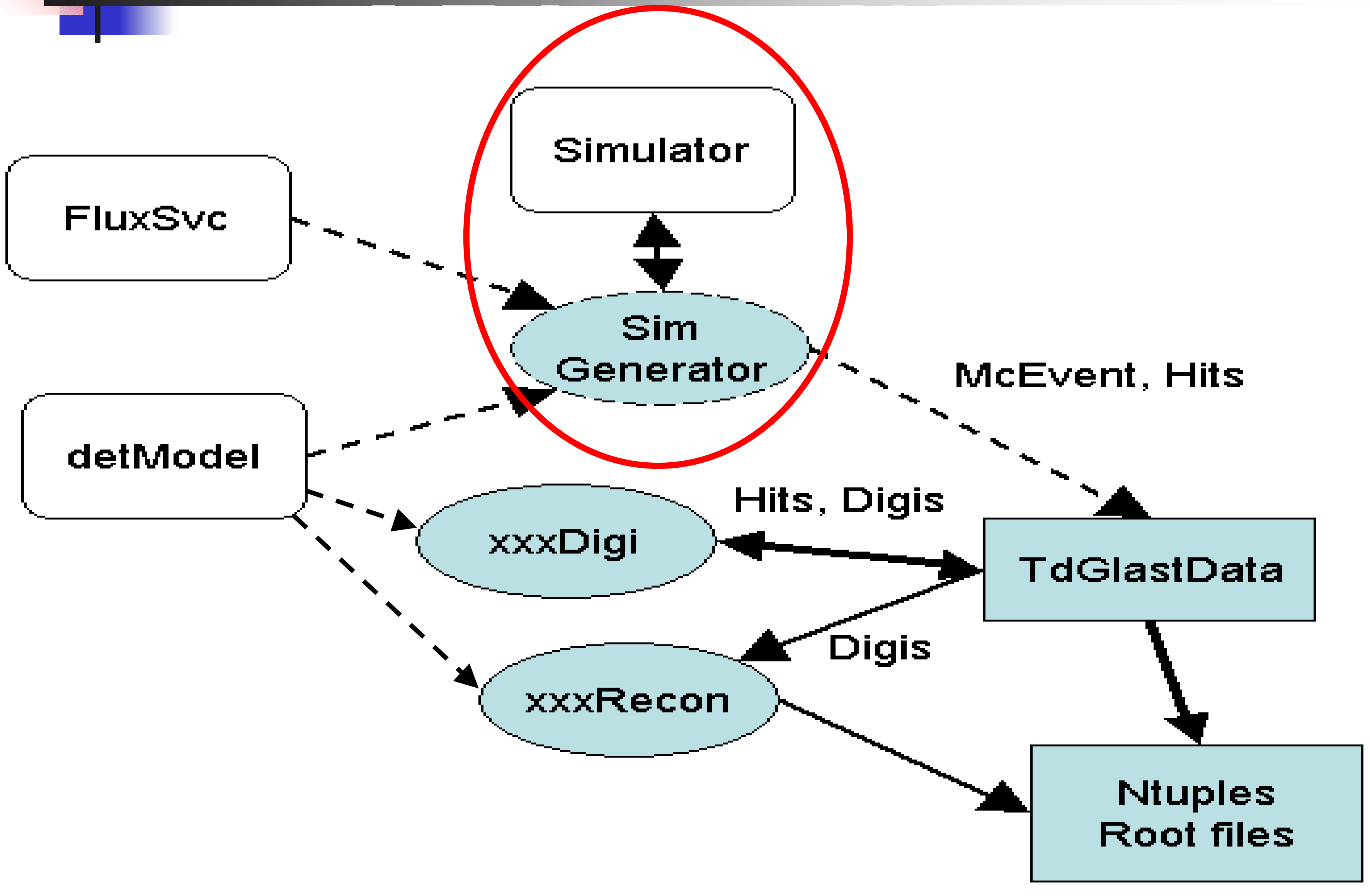
Playground for the GLAST G4 simulation

- Tested on data from a balloon flight (2001) and beamtest

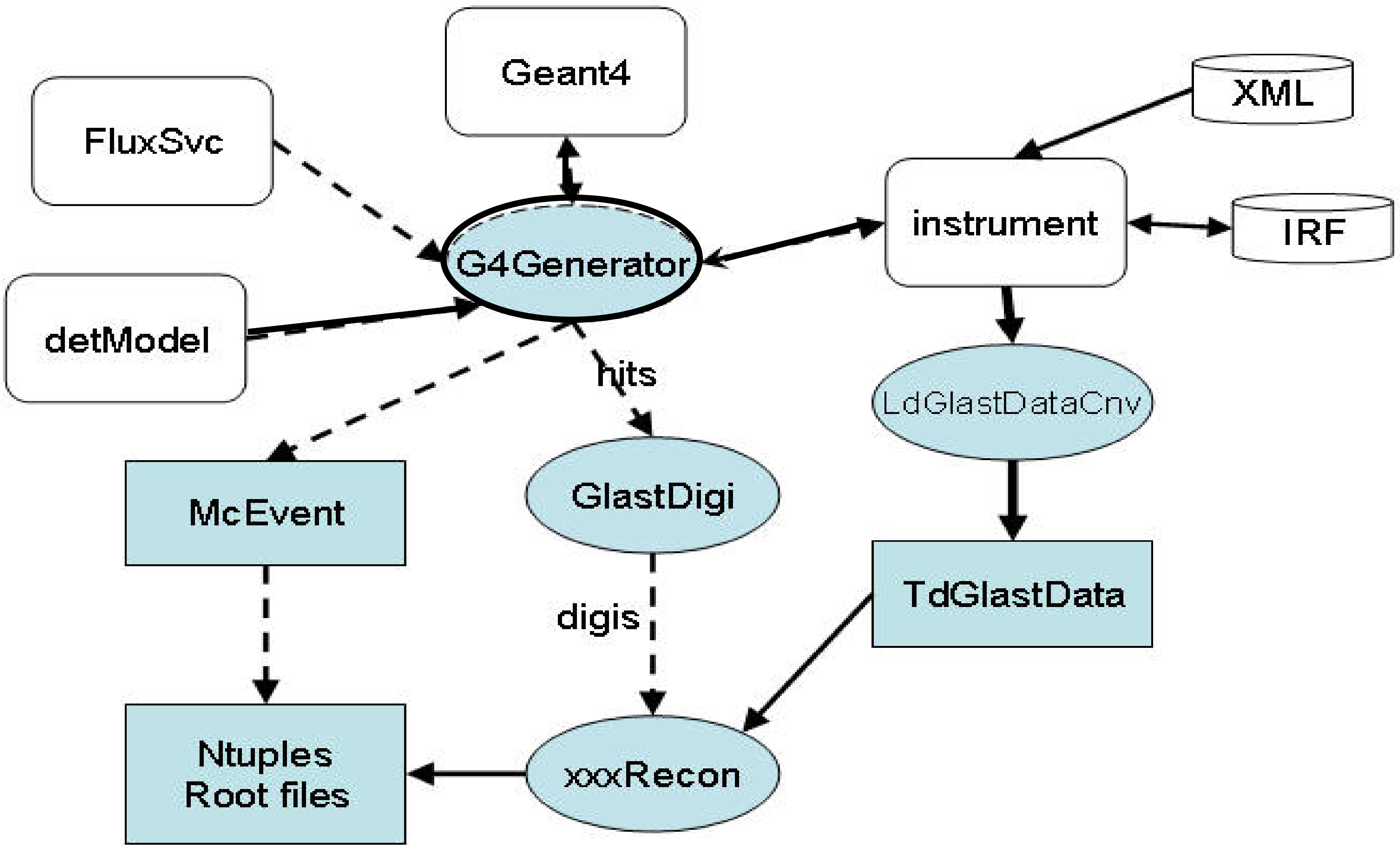
- See tomorrow's talk
  - Study of the GLAST balloon prototype data based on Geant4 simulator, by Tsunefumi Mizuno (Hiroshima/SLAC)



Structure: goal



Temporary structure

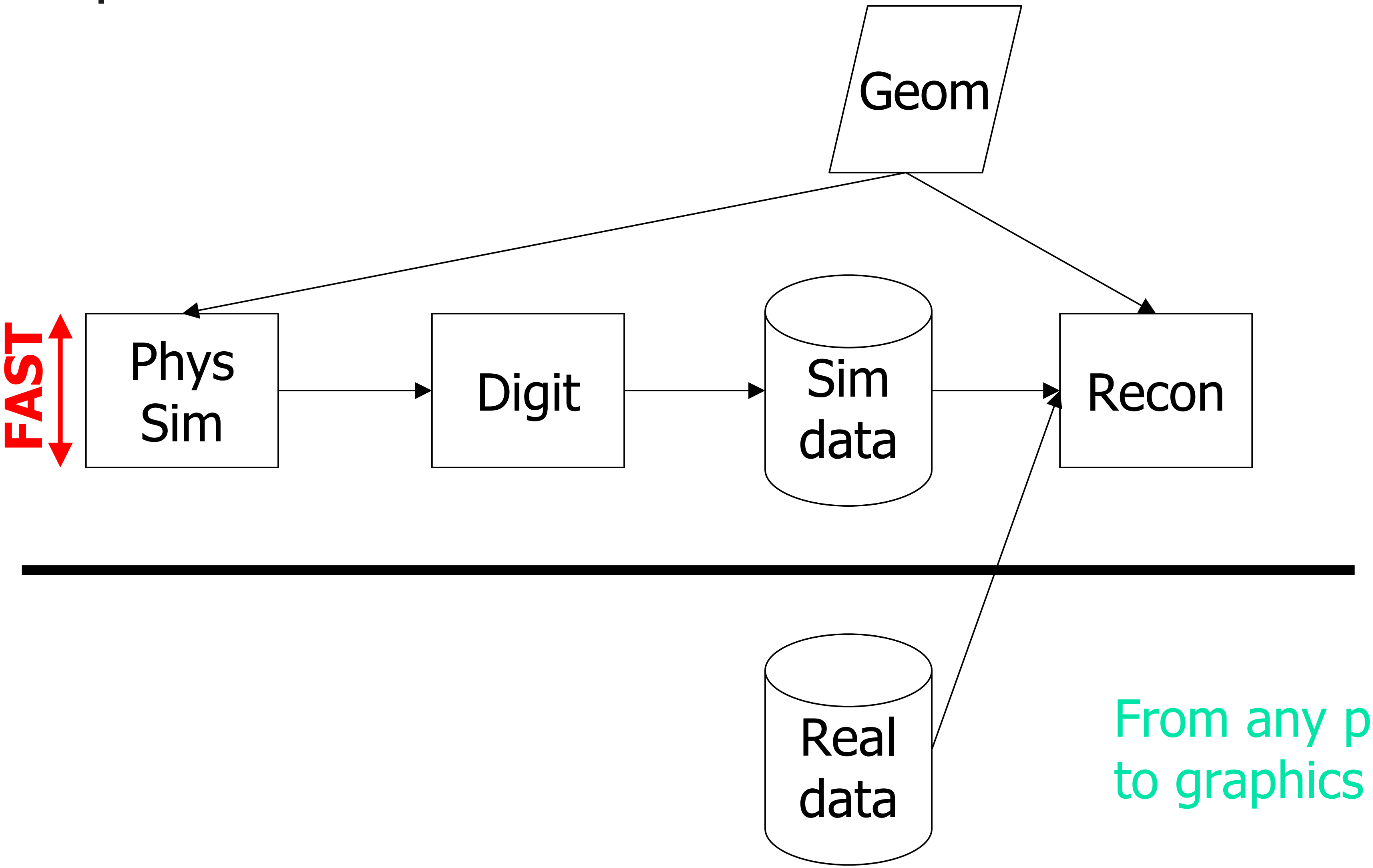


Implementation of the GLAST G4 simulation

- A GAUDI algorithm (G4Generator)
- Incoming flux: a GAUDI service FluxSvc (see later) independent of G4
- Geometry from XML file (see later) and a GAUDI service (DetModelSvc)
- Parameters of the simulation can be set a la GAUDI (via a jobOptions file)
- Interfaced with the GLAST own 3D representation and GUI
  - Ongoing project: integrate with other event display solutions (see later)
- Results (hits) saved in the Transient Data Store (work in progress)
  - Can then be used by digit algorithms and later by reconstruction and analysis in a G4 independent way

- G4 simply used for propagation; input and output externally dealt
  - We can use other MC algorithms (like GismoGenerator) in a complete interchangeable way

COMMENTS: Digits outside code Geometry outside code



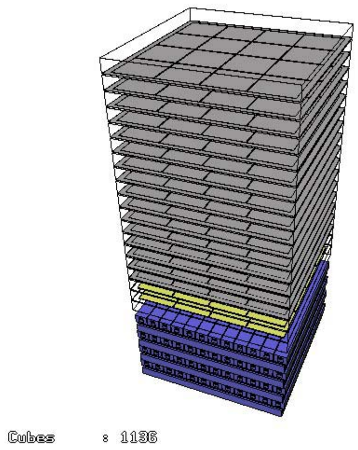
From any point to graphics

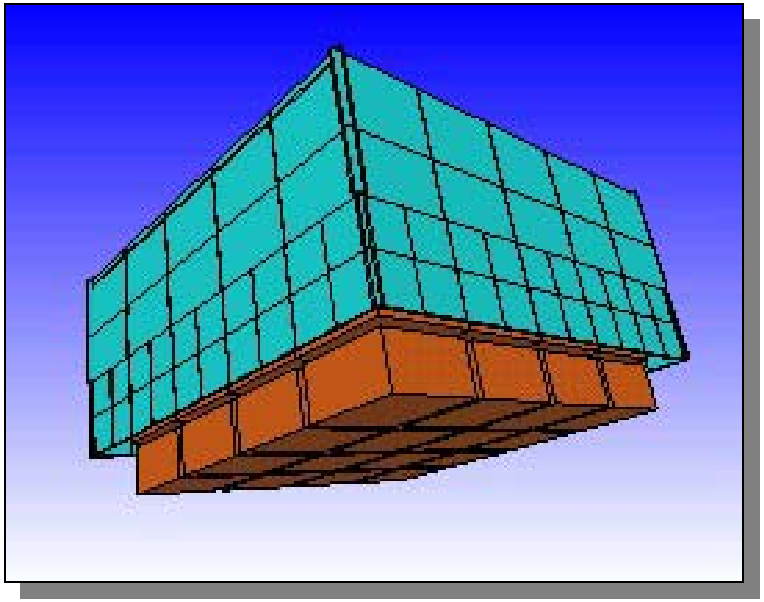
Solution for geometry: XML persistency

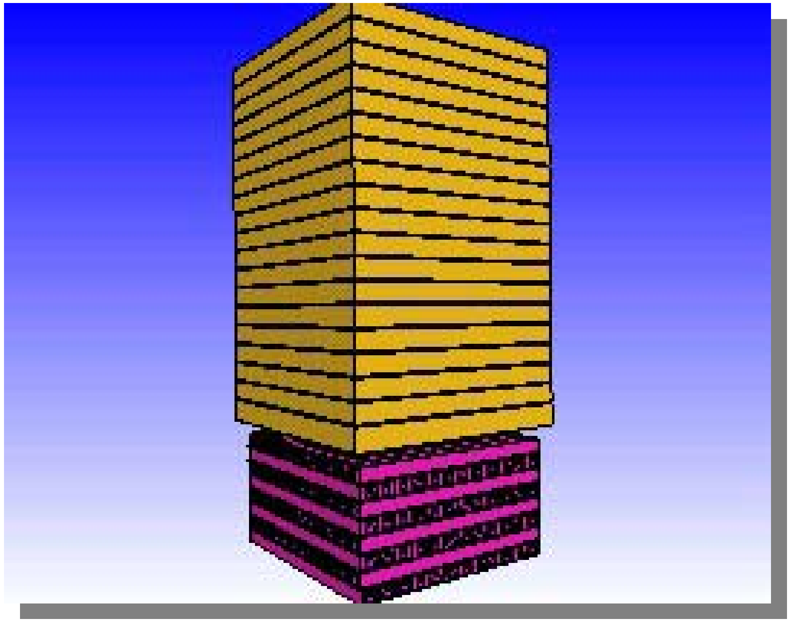
- A specific DTD for the GLAST geometry (derived from the ATLAS one)
  - Geometry description + materials
  - Constants, Identifiers
- A C++ hierarchy of classes for the XML interface (detModel)
- A GAUDI service to wrap such a hierarchy (DetModelSvc)
- Many clients
  - Simulation
  - Reconstruction
  - Analysis
  - Event display
- Interfaces for
  - VRML output for the geometry
  - HTML constants documentation
  - GEANT4 and GISMO geometry description
  - ROOT
  - HepRep (work in progress)

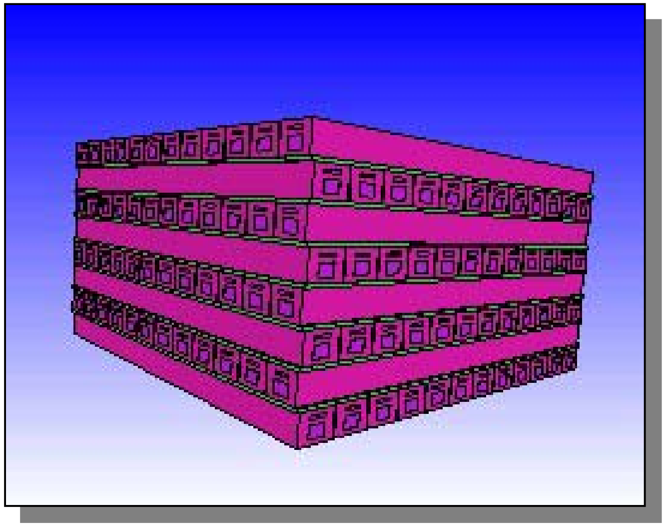
- See tomorrow's talk
  - Connecting G4 to the GLAST infrastructure: geometry and GAUDI, by Riccardo Giannitrapani (Udine)

XML: VRML output

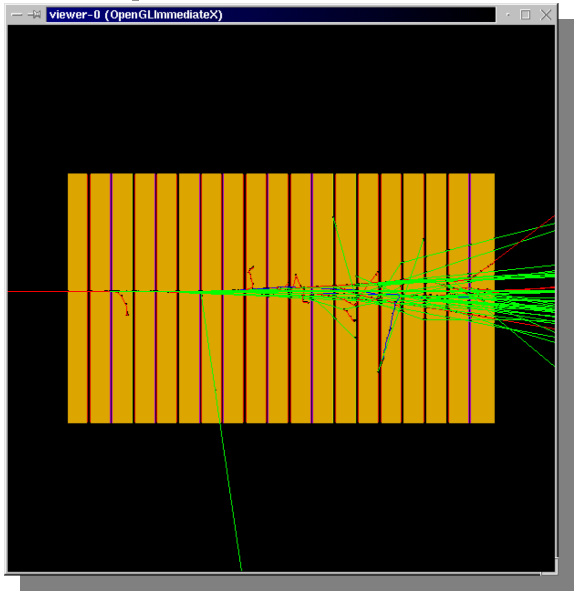


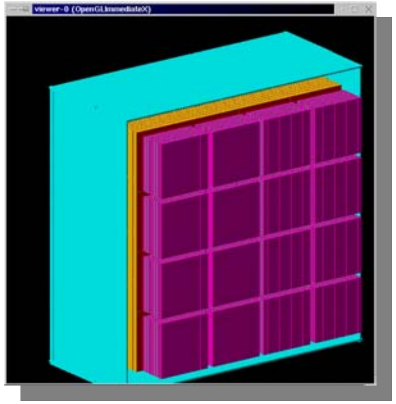


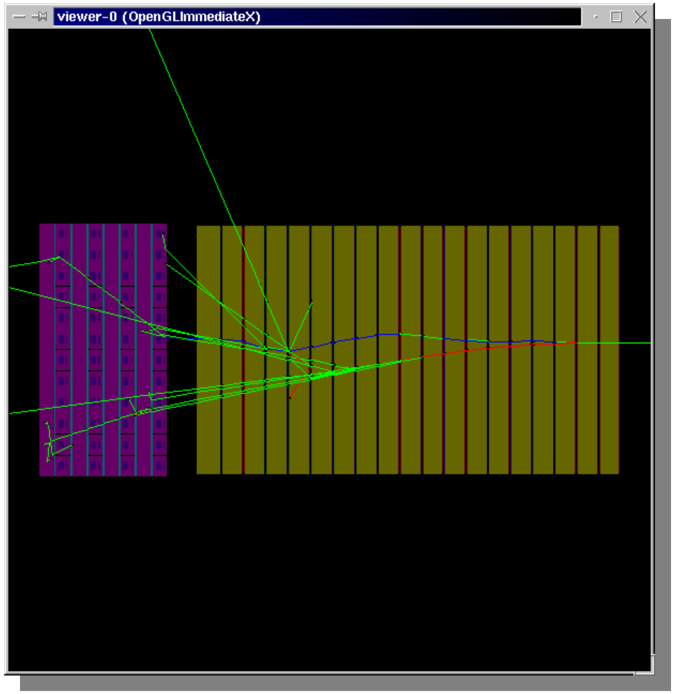


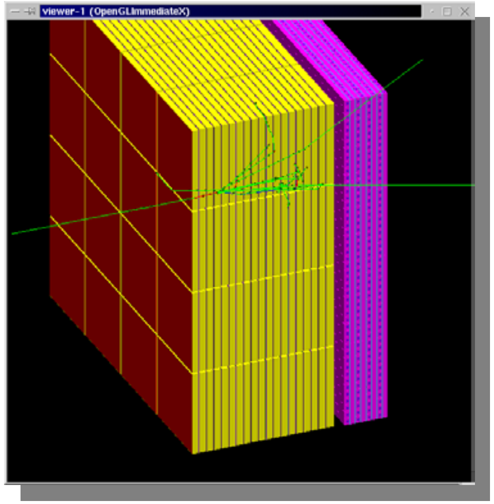


XML: GEANT4 interface



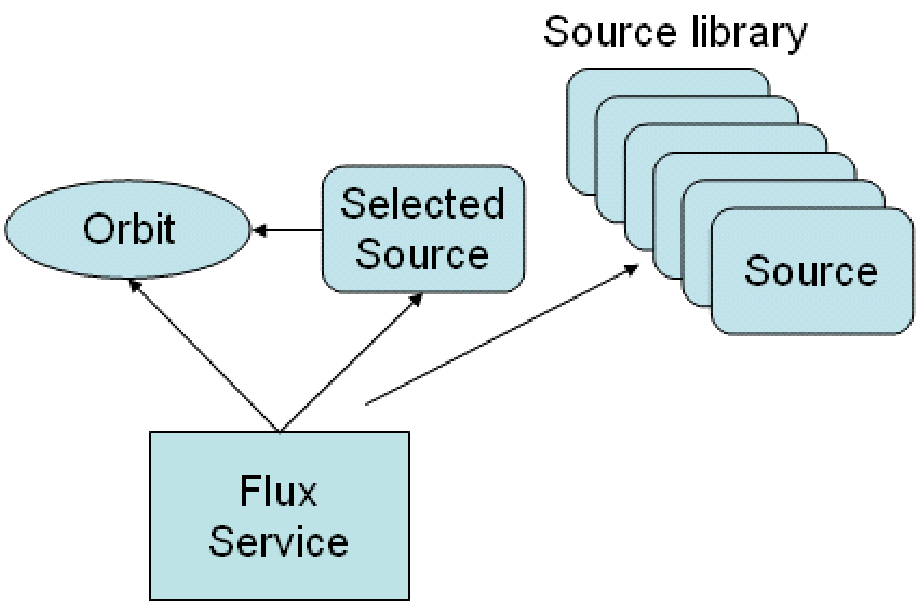






Flux Generator (Flux Service)

Provides incoming particles for simulation



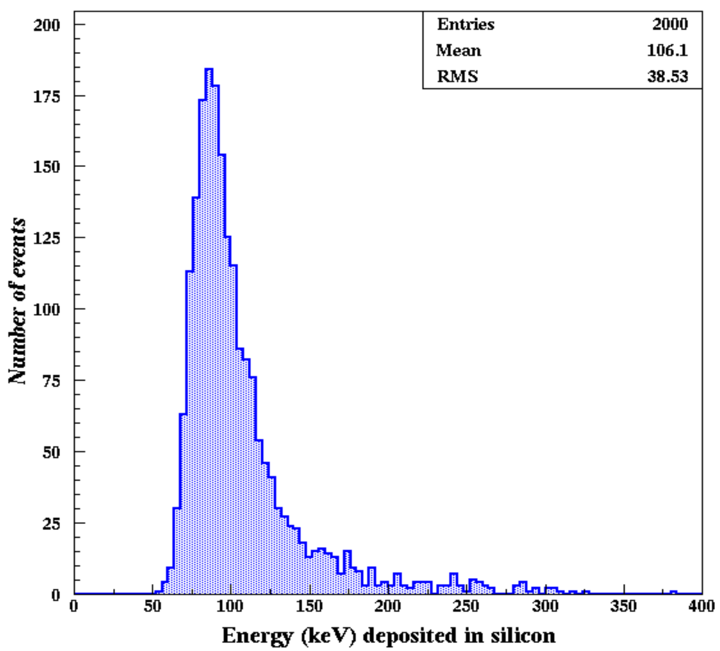
Flux Service:

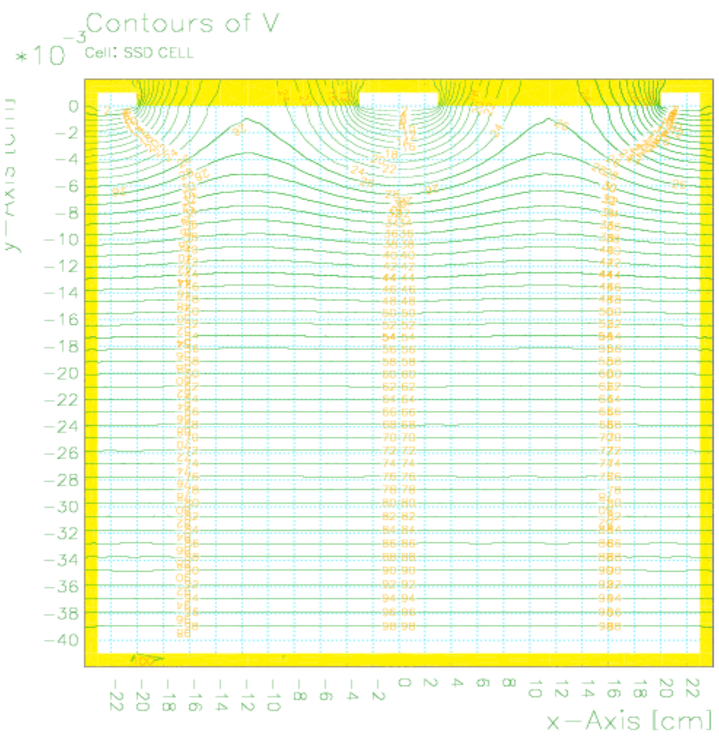
- Selects from library (XML spec)
- Manages orbital parameters
- Returns particles generated by selected source, depending on the orbit

- Types that must be available:
  - Single γs for testing resolution
  - Primary and secondary Galactic Cosmic Rays (p,e)
  - Galactic gamma point sources
  - Galactic diffuse sources
  - Albedo gammas
  - Transient sources
- distributions of energy spectra
- angles with respect to:
  - local zenith
  - spacecraft
  - galactic or celestial coordinates
- Keep track of time
  - for measurement of rates
  - pile-up or deadtime correction
  - for turn-on of transients

Digitizations

- Choice: parametrization to be interfaced to the G4 simulation
  - Speed/accuracy constraints
- For an accurate digitization of the tracker signal
  - Electron motion in Si: simulation using HEED + GARFIELD/MAXWELL
    => charge sharing



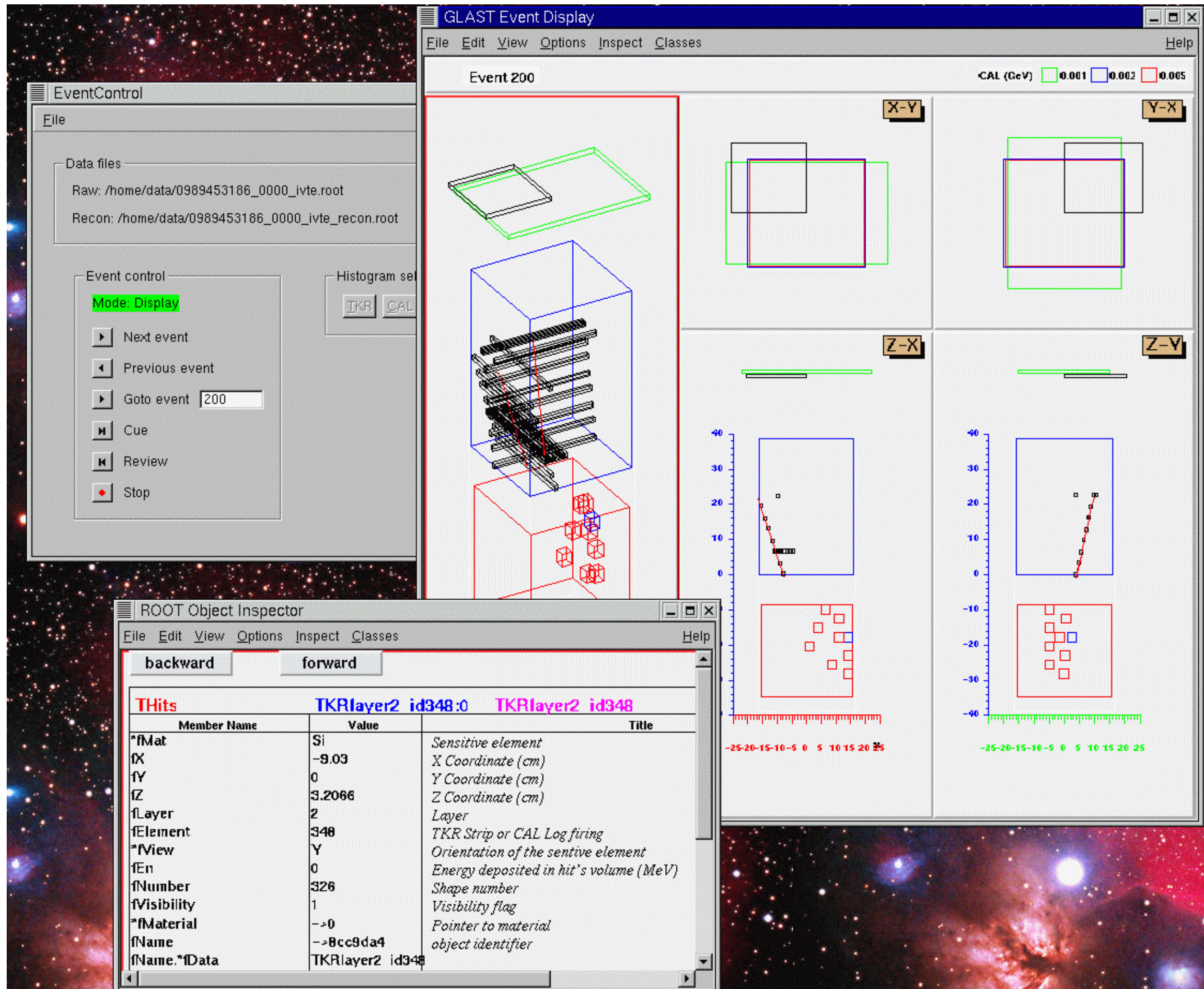


Interaction with analysis and event display tools

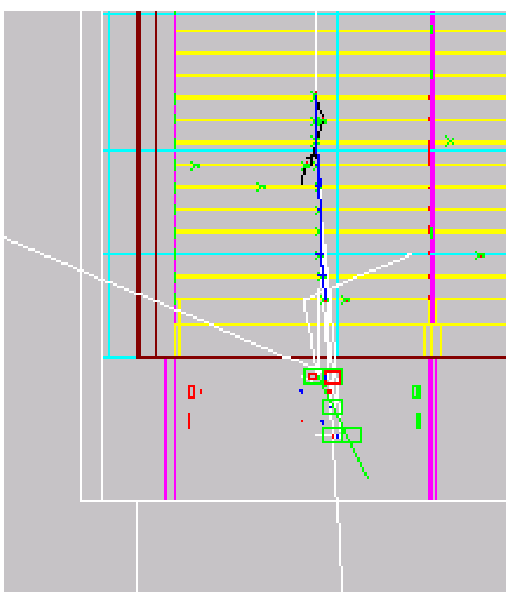
- Analysis is decoupled from MC
  - Hits and digits in the GAUDI TDS from the G4Generator (or GismoGenerator) algorithm
  - Available for reconstruction and analysis algorithms
  - Analysis mainly in Root for now, but architecture open to other tools (IDL, JAS, other)
- Event display
  - A simple 3D representation with GUI is built in the GLAST software
  - Good experience with the Balloon event display made in Root
  - In the near future a complete support for HepRep data representation
    - Open to WIRED or other future HepRep clients
  - Events will be analyzed during MC run or later from the GAUDI permanent data store with a server-GAUDI client

Event display: first steps

The BALLOON ROOT Event Display

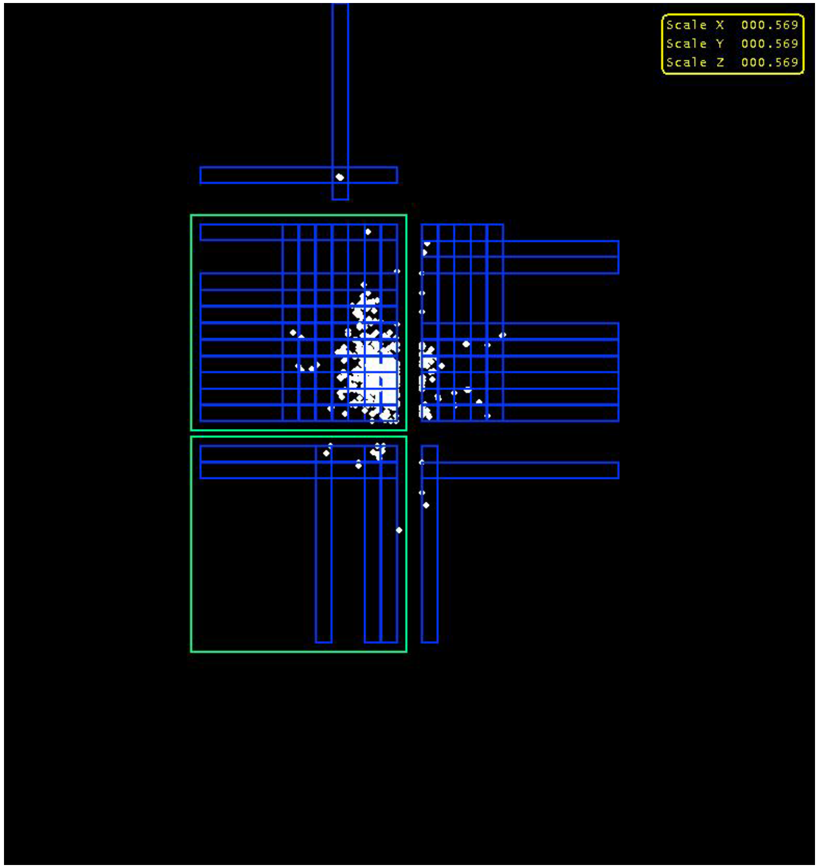


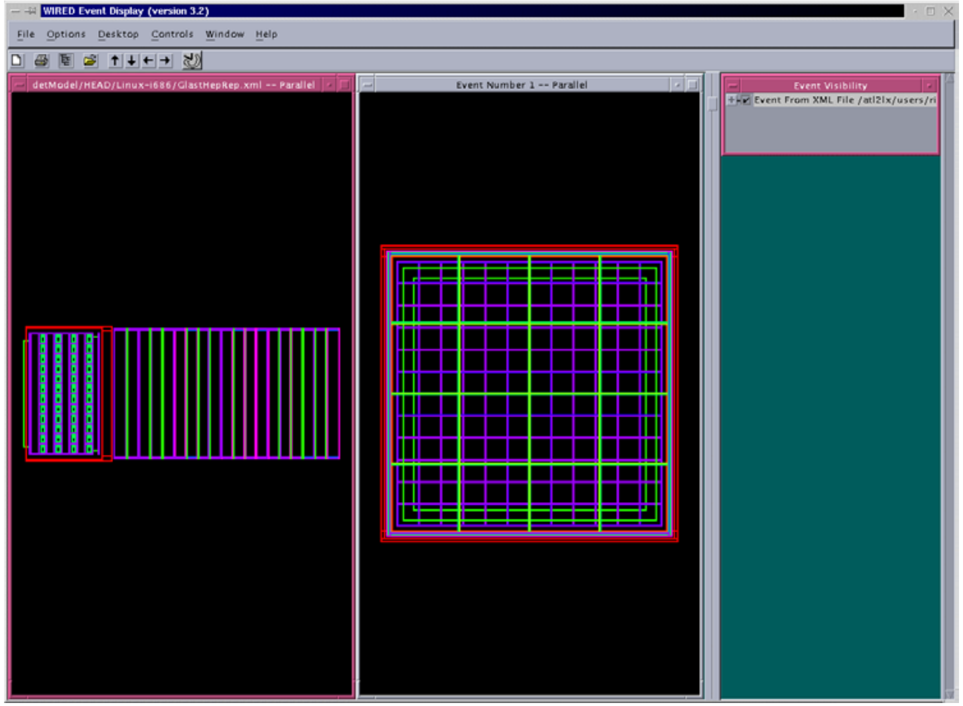
The in-house GLAST 3D



HepRep output from G4Generator in Wired

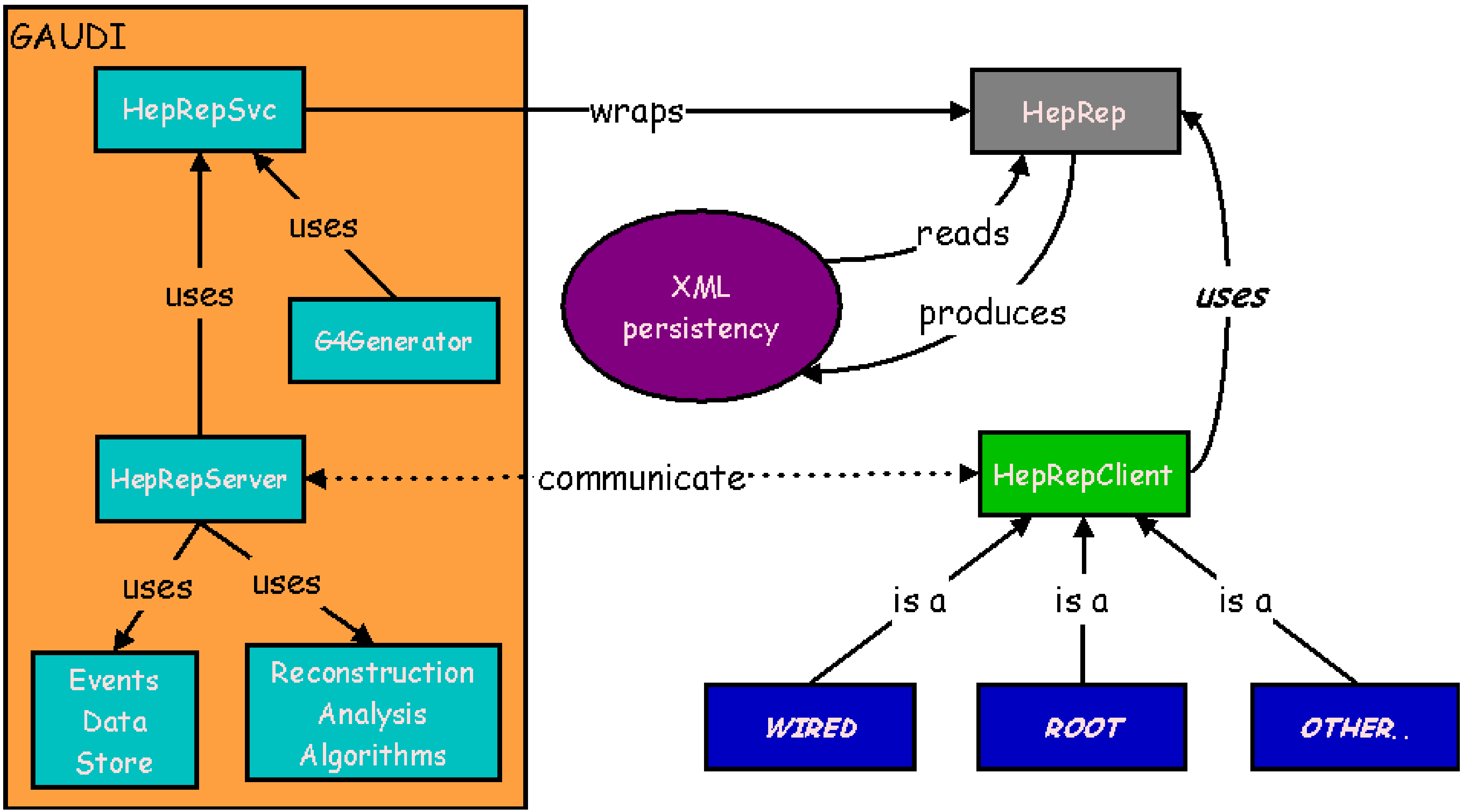
A top-view of an event: the detectors with energy released are displayed along with hits





A full tower (tracker + calorimeter) geometry

HepRep in GLAST



GEANT4 physics validation

- Many users => good debugging
- Quite a lot of manpower; would profit for more people concentrating on basic processes and simple geometries

Conclusions *(Taken from K. Amako, jun 2001)*

- Study of electomagnetic processes
  - Large progress in understanding them since the beginning of the project.
  - However, there are still a lot of issues remain to be solved.
- Study of hadronic processes
  - Now we started to focus on this subject.
  - We expect it is much harder than the electromagnetic case.

Conclusions *(Taken from T. Kamae, nov 2001)*

- GEANT4 is as good as any existing EM simulator now.

Physics validation: the GLAST contribution

- Although the validation is done locally (Japan/Italy), many people involved belong to the G4 core

- Activity started in 2001
  - ~1.5 FTE taken from 6 people
    - "Low" level validation (comparison with G3, EGS4 & analytical formulae)
    - "High" level validation (comparison with balloon and test beam data; folded with digitizations)
  - Already obtained: positive feedback on the EM routines

- See tomorrow's talks:
  - Validation of the EM part of Geant4, by Tune Kamae (SLAC)
  - Study of the GLAST balloon prototype data based on Geant4 simulator, by Tsunefumi Mizuno (Hiroshima/SLAC)

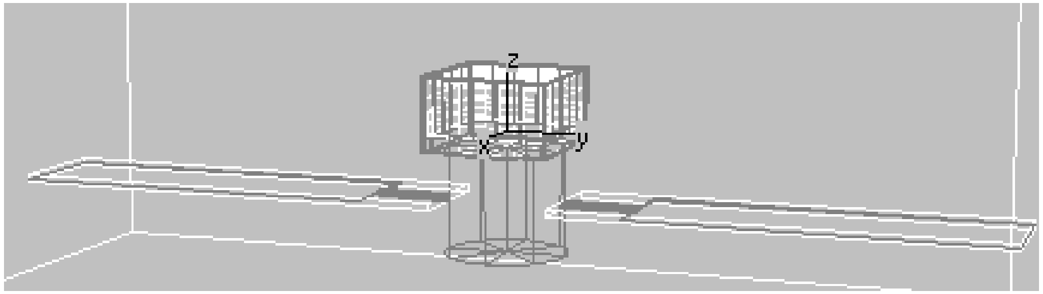
Crew

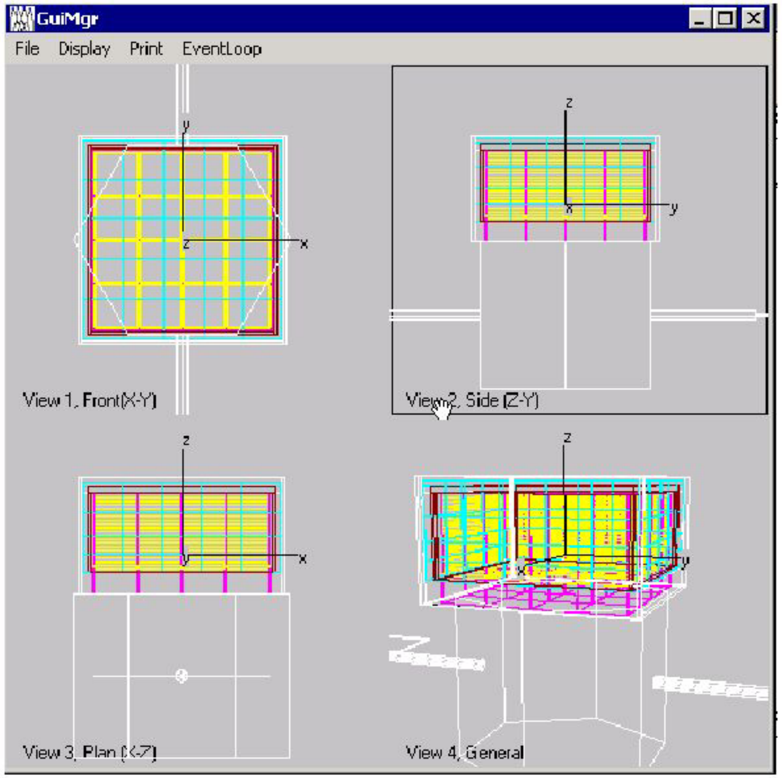
- Italy
  - Bari (M. Brigida, N. Giglietto, F. Loparco, N. Mazziotta)
  - Perugia (C. Cecchi, C. Cestellini, P. Lubrano)
  - Padova (D. Bastieri)
  - Pisa (J. Cohen-Tanugi, L. Latronico, N. Omodei, G. Spandre)
  - Udine/Trieste (AdA, D. Favretto, M. Frailis, R. Giannitrapani, F. Longo)
- Japan
  - Hiroshima (Y. Fukazawa, T. Mizuno, H. Mizushima)
  - ISAS (M. Ozaki)
- USA
  - Goddard (H. Kelly)
  - SLAC (J. Bogart, R. Dubois, T. Kamae, H. Tajima, K. Young)
  - Washington State (T. Burnett)

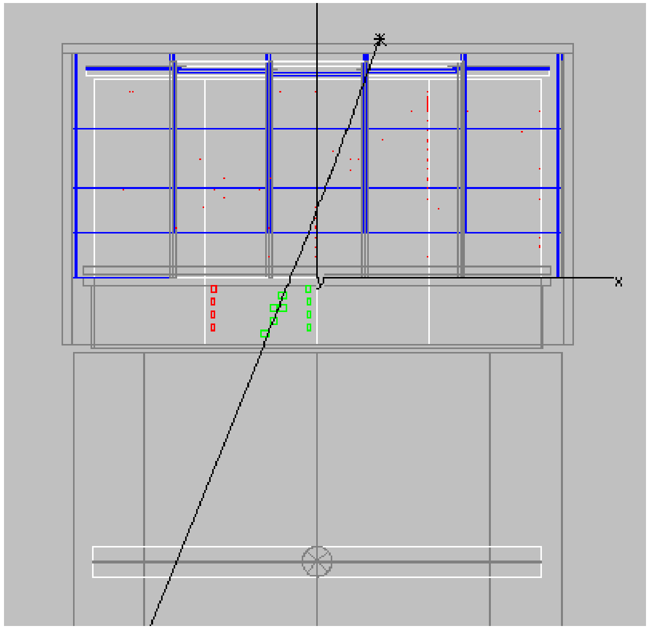
CREDITS: S. Ritz, L. Rochester, K. Amako

Simulation gallery

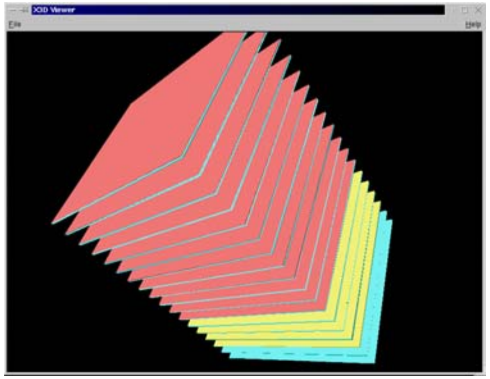
PDRAPP (GISMO)

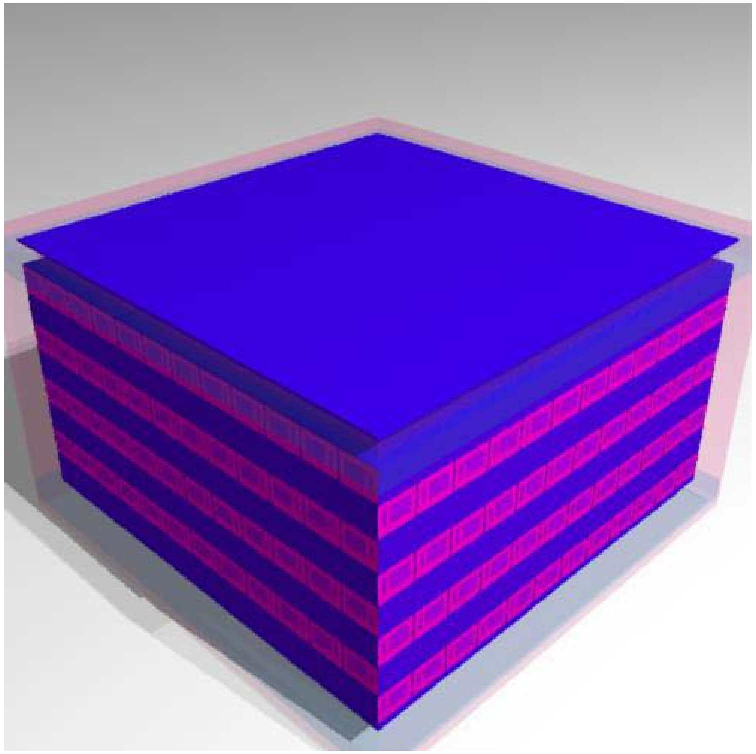


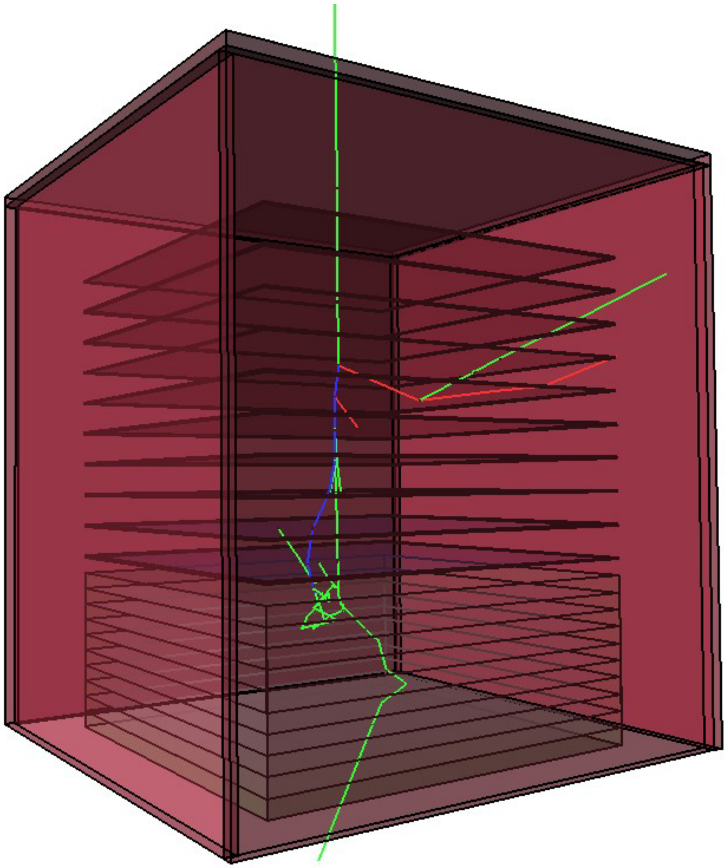




Simulation gallery (cont'd)

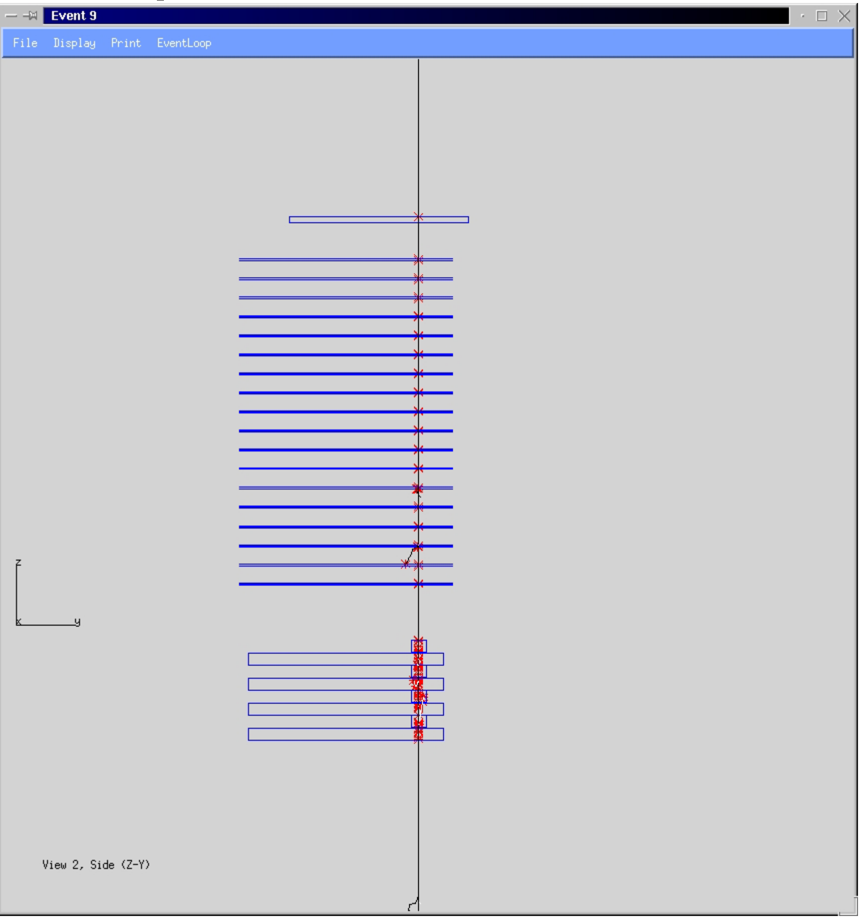


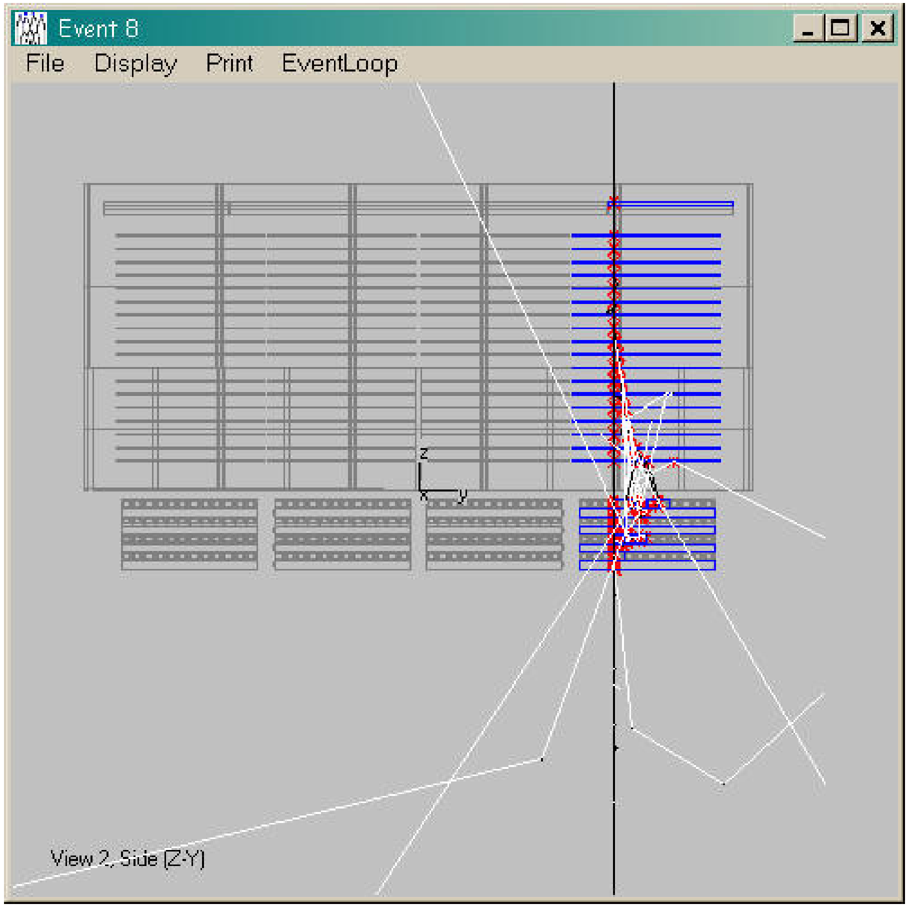




ROOT, GAMMARAYTEL, RAYTRACING

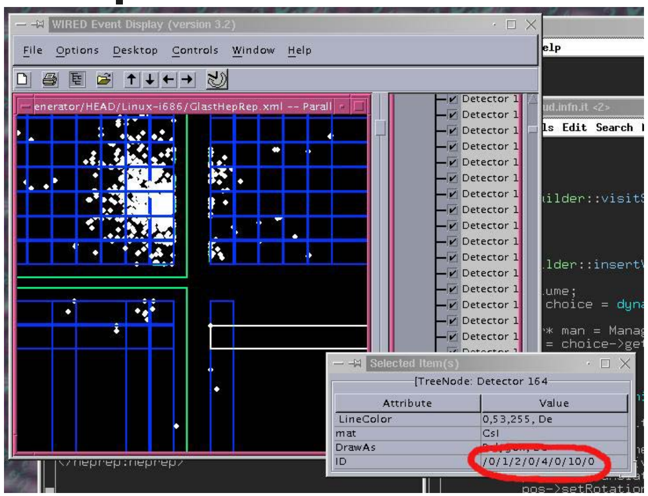
Simulation gallery (cont'd)

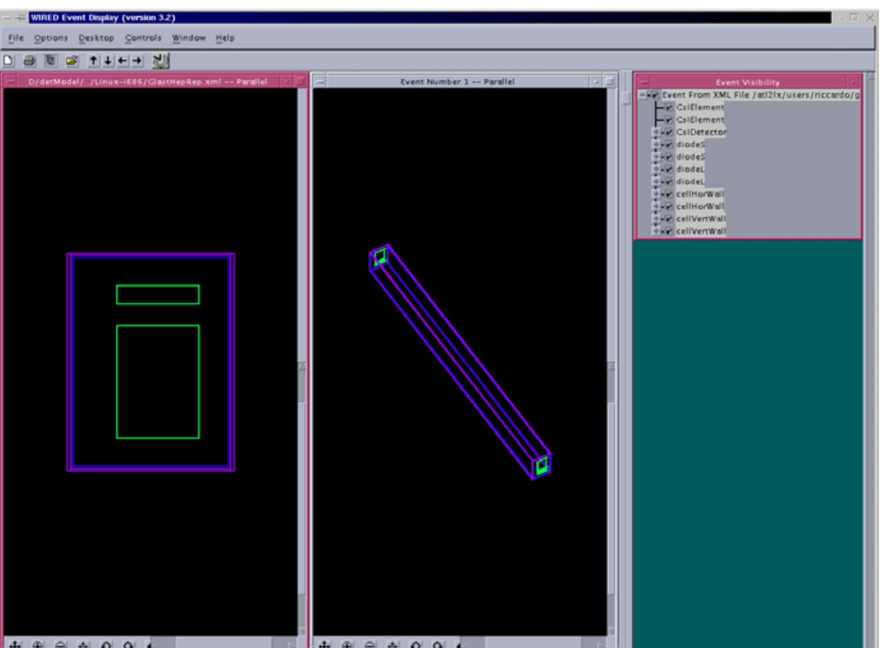


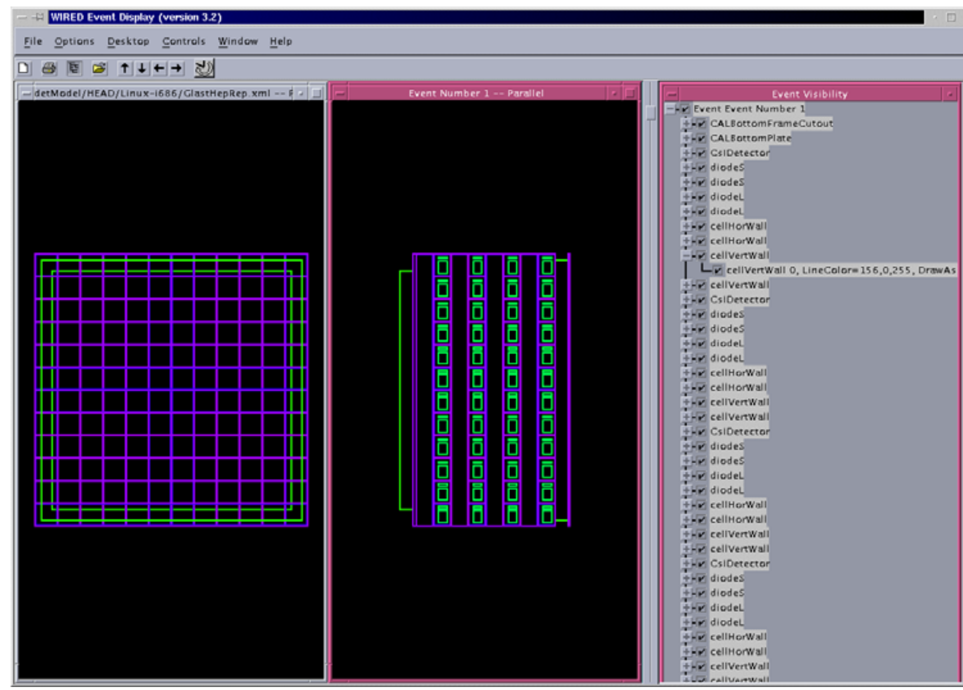


Simulation gallery (cont'd)

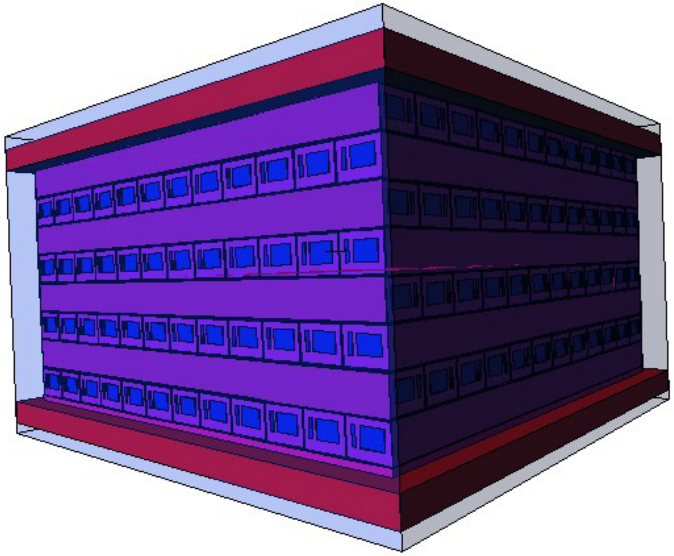
WIRED

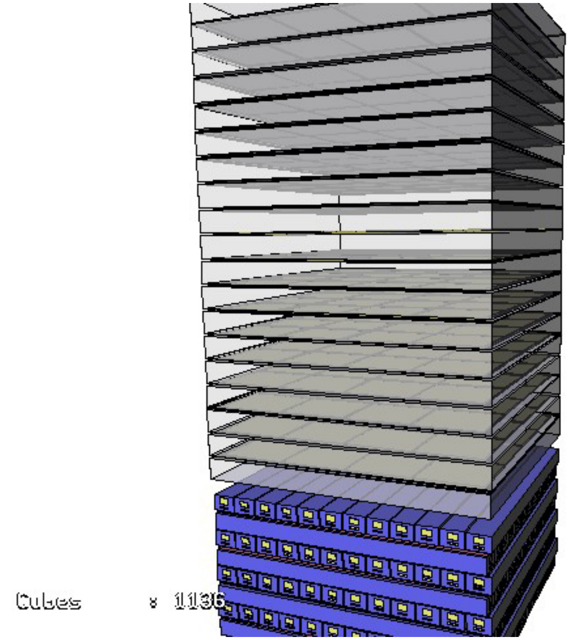


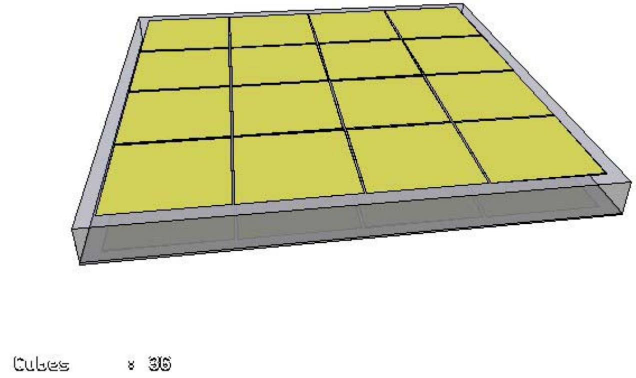




Simulation gallery (cont'd)







VRML

Next steps

- Technical
  - G4 tuning
    - Choice of physics models, cutoffs & physical parameters
  - Finalize the Transient Data Store MC data saving
  - Finalize and test the Tracker Digits algorithms
  - Test the HepRep framework
    - with existing clients (WIRED)
    - with new clients (ROOT, OpenGL, other)
- Physics
  - Conclude the validation of EM processes
  - Start the hadronic validation
  - Start the implementation of fast simulations