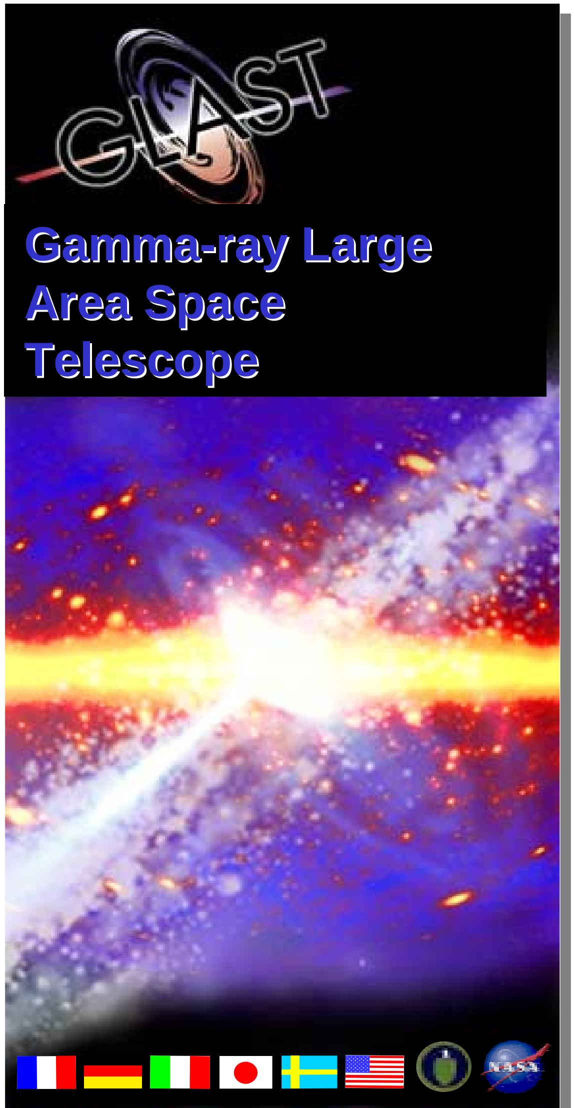


GLAST LAT G4 simulation

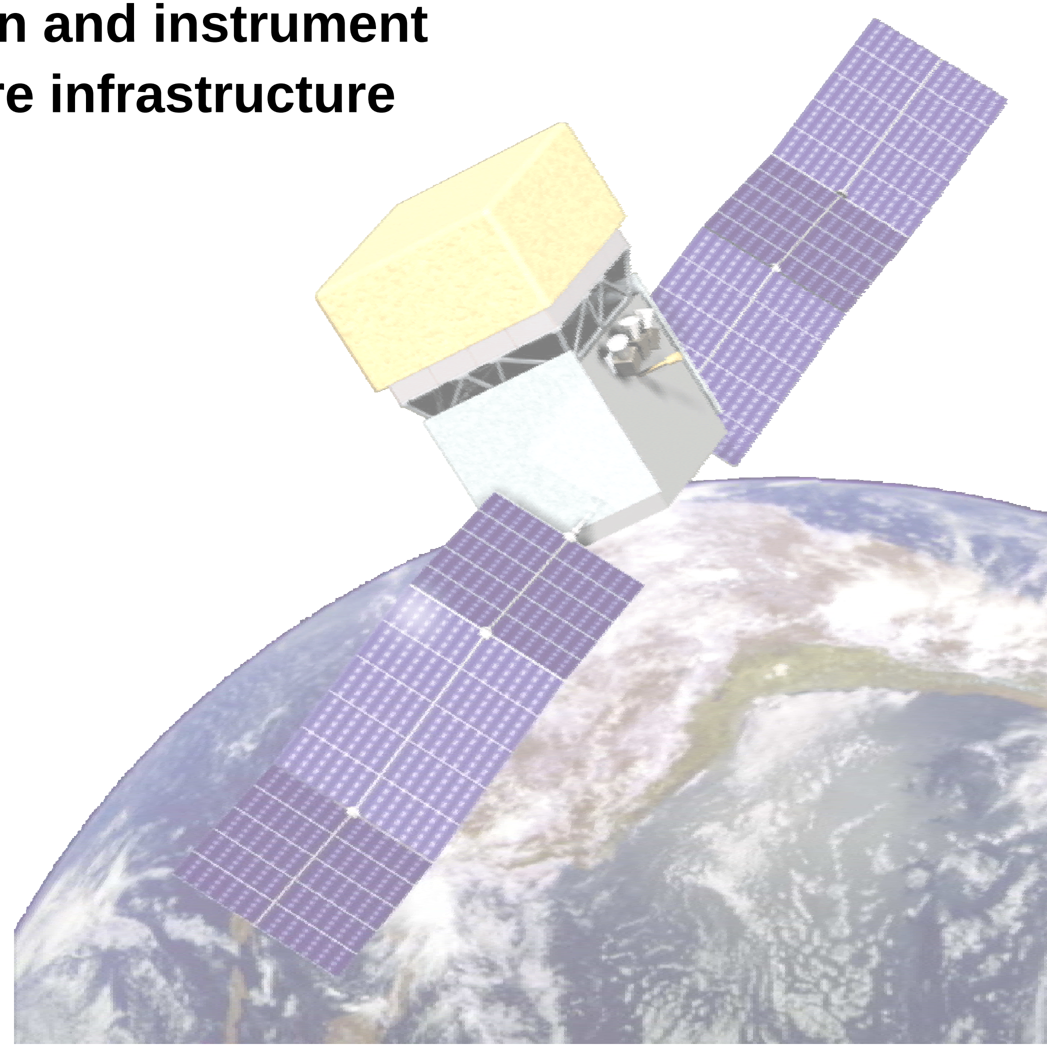
Francesco Longo
University and INFN, Trieste, Italy
francesco.longo@ts.infn.it

thanks to T.Burnett, X.Chen, E. do Couto e Silva, R.Dubois, R. Giannitrapani, B.Lott, H.Kelly, N.Omodei, S.Ritz, L.Rochester, T.Usher

On behalf of the GLAST LAT collaboration

Outline

- Description of the mission and instrument
- Science Analysis Software infrastructure
- G4 simulation
- Data Challenge 1



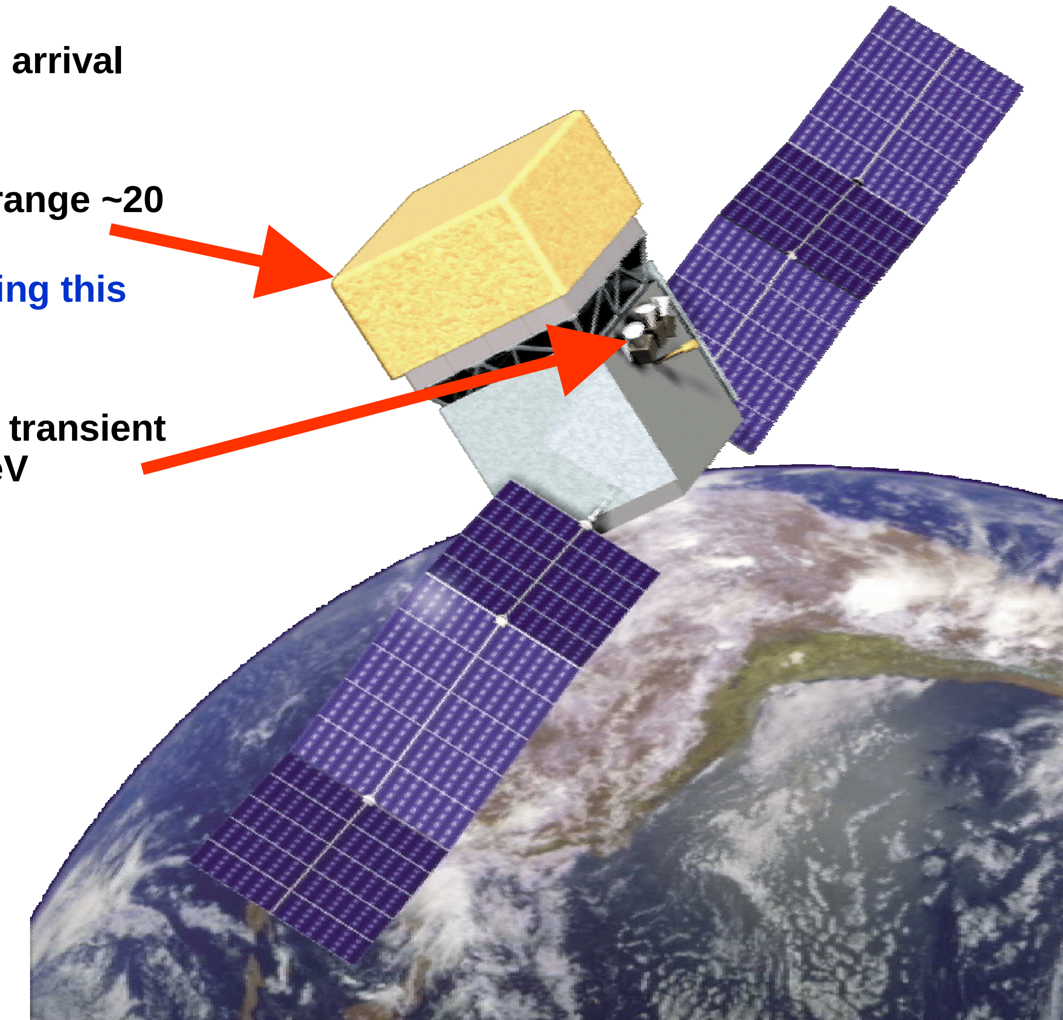
The GLAST Mission

GLAST measures the direction, energy and arrival time of celestial gamma rays

-LAT measures gamma-rays in the energy range ~20 MeV - >300 GeV

- There is no instrument now covering this range!!

- GBM provides correlative observations of transient events in the energy range ~20 keV – 20 MeV



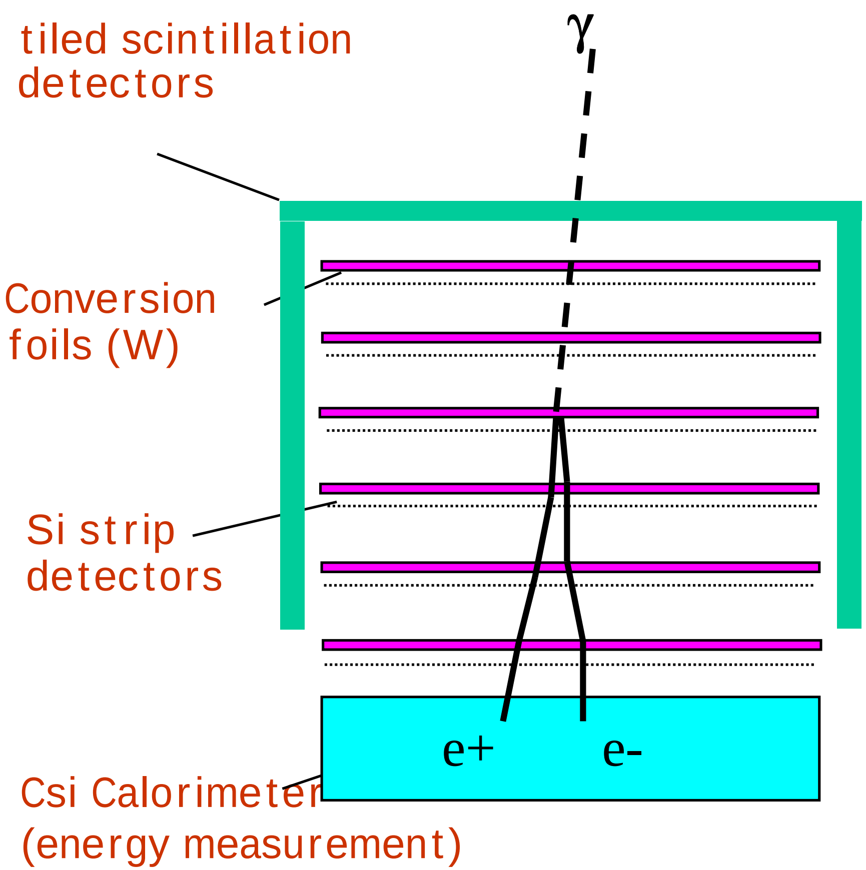
Launch: February 2007
Florida

Orbit: 550 km,
28.5° inclination

Lifetime: 5 years
(minimum)

γ-pair conversion "telescope"

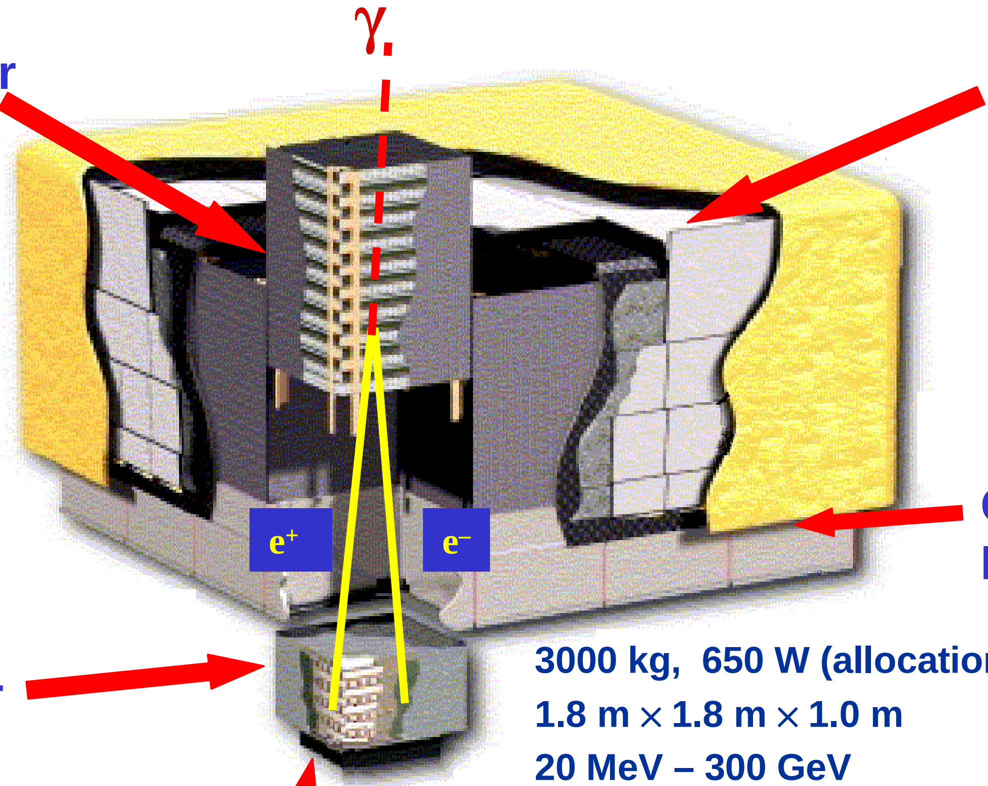
Pair production is the dominant photon interaction above 10 MeV



Characteristics

- **Low profile for wide f.o.v.**
- **Segmented anti-shield to minimize self-veto at high E.**
- **Finely segmented calorimeter for enhanced background rejection and shower leakage correction.**
- **High-efficiency, precise track detectors located close to the conversions foils to minimize multiple-scattering errors.**
- **Modular, redundant design.**
- **No consumables.**
- **Low power consumption (580 W)**

GLAST Large Area Telescope (LAT)



Si Tracker Tower

pitch = 228 µm
5.52 10^4 channels
12 layers × 3% X_0
+ 4 layers × 18% X_0
+ 2 layers

ACD

Segmented scintillator tiles
0.9997 efficiency
⇒ minimize self-veto

Grid (& Thermal Radiators)

CsI Calorimeter

Hodoscopic array
8.4 X_0 8 × 12 bars
2.0 × 2.7 × 33.6 cm
⇒ cosmic-ray rejection
⇒ shower leakage correction

Data acquisition

3000 kg, 650 W (allocation)
1.8 m × 1.8 m × 1.0 m
20 MeV – 300 GeV

16 identical towers
300 Hz average downlink

Why we need Simulation

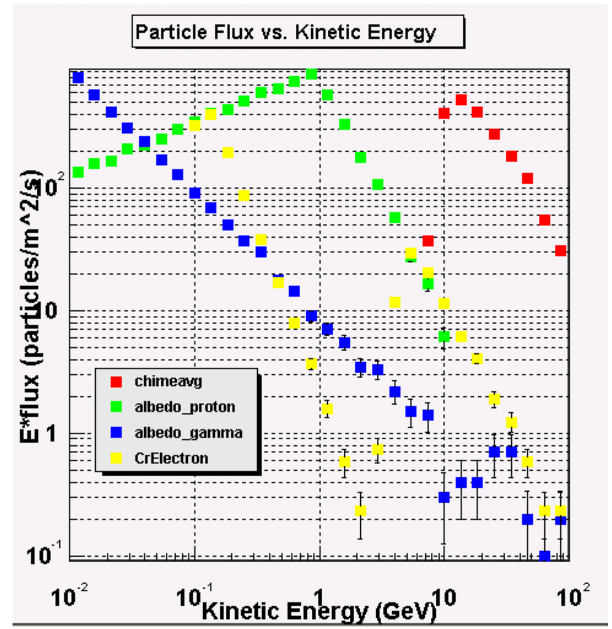
- Calibration, assessment of pattern recognition, track fitting strategies
- Predict the following figures of merit, depend on incoming photon energy $E\gamma$ and angle θ:
  - Effective area A_{eff}: depends on geometric area, conversion probability, reconstruction efficiency
  - Point Spread Function (PSF): depends on multiple scattering, detector resolution, pattern recognition accuracy
- Develop a strategy and assess its effectiveness in suppressing the background from hadronic interactions. (Average trigger rate: 4 kHz: science rate: <10 Hz)

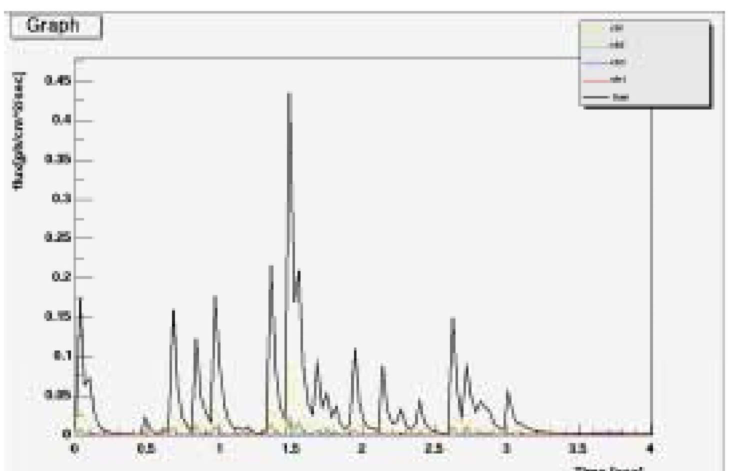
How we are (not) using G4

- The incident flux is modeled by a dedicated package
- Geometry database is XML based, independent
- We have our own graphics, GUI.
- The event loop is controlled by our framework, Gaudi (G4 is invoked event-by-event from an *Algorithm*)

Sources: Incident Flux

- Types that must be available:
  - Primary and secondary GCR
  - Albedo gammas
  - Galactic point & diffuse sources
- Distributions of energy spectra
- Various angles distribution
  - Zenith, spacecraft galactic or celestial coords
- Keep track of time
  - Orbit, rates, deadtime
  - Transients

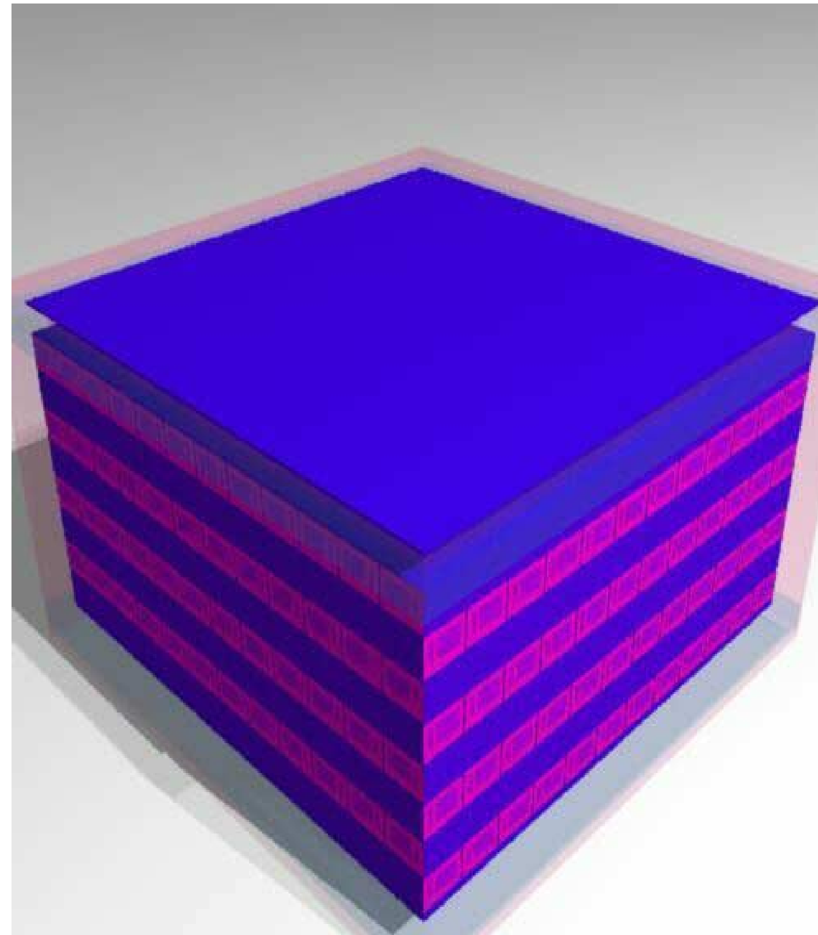




- GRB physical model
  - Shell collision: Different Lorentz factors
  - Jet geometry
  - Synchrotron & Inverse Compton emission
  - Temporal and Spectral Evolution

Geometry Repository

- A complex instrument: GLAST geometry is formed by more than 40000 volumes.
  - A typical problem in HEP experiments (and GLAST is not so big)
- The geometry database in GLAST is in XML, a quite common choice (LHCb, Atlas and more) today
- detModel is a set of C++ classes to parse and represent in memory such XML description
- Used by various clients (reconstruction algorithms, MonteCarlo simulation, graphics etc. etc)

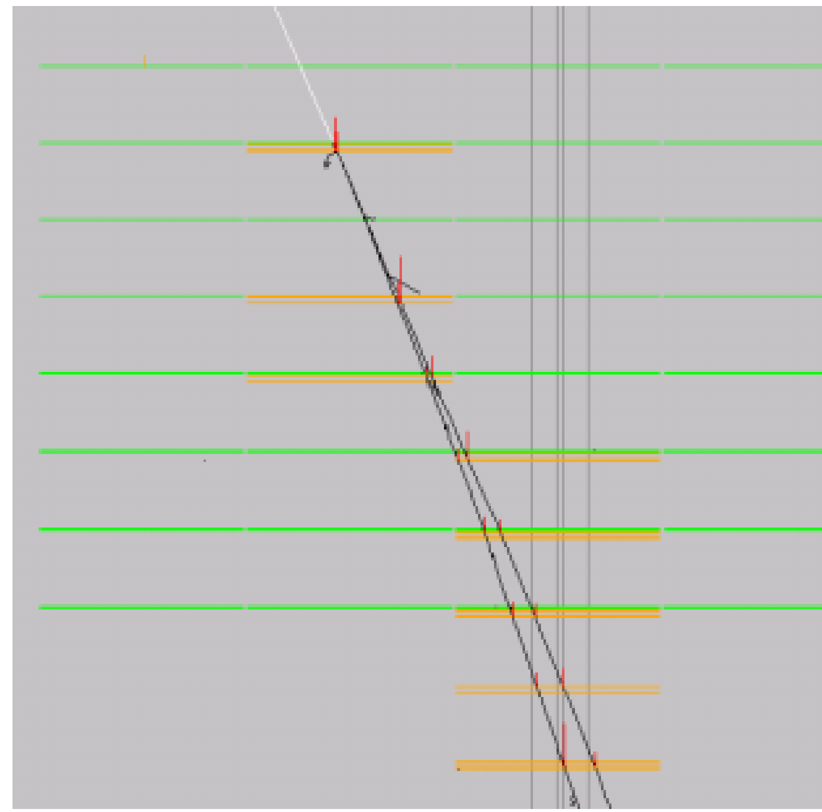


GLAST G4 physics

- Photon processes: Photoelectric, Compton Scattering and Pair Production
- Cross Section, Angular and Energy Distribution
- Charged particles processes
- Ionisation
  - Landau and Bethe Bloch
  - Range, Straggling, Stopping Power
- Multiple Scattering
  - Angular distribution, Energy Dependence
- Bremsstrahlung
  - Cross Section, Angular and Energy Distribution
- Delta Ray production
  - Energy distribution, Multiplicity
- Positron Annihilation
- EM shower development
- Muon-nucleus interactions
- Neutron interactions
- HE hadron-nucleus interactions
- Nucleus-nucleus elastic scattering
- Hadronic showers in CsI
- Radioactive decay

Requirements: EM processes
Tracking region: small scale

- Physics processes:
  - Pair conversion
  - Bremsstrahlung
  - Multiple Scattering
    - MCS in the W layer determines the angular resolution!
    - Discover problem at MCS in version 5.*
    - Back to MCS v3.2 on the basis of experimental data

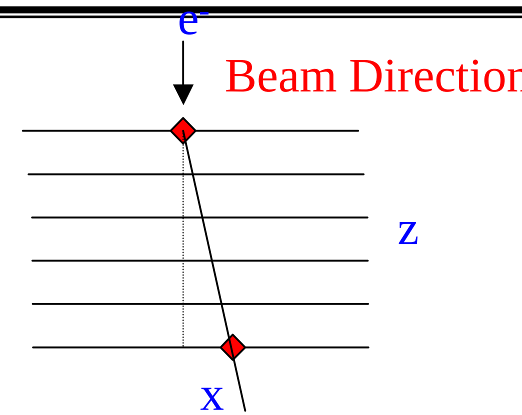


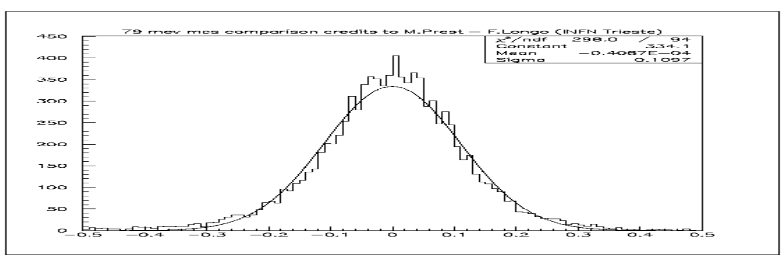
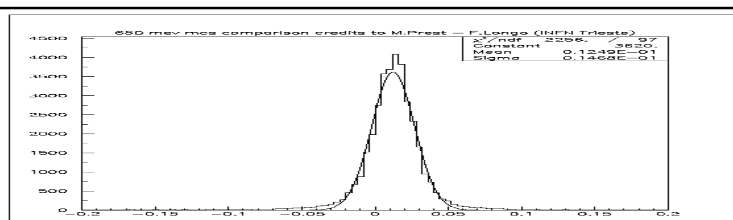
Secondary gammas not shown

white: incoming photon
black: electron, positron
green: W
orange: hit Si wafers
red: strip energy
Note: other gamms not shown

Multiple Scattering validation

- Electron test beam at Frascati for AGILE (2003)
- Geometry:
  - 6 planes with 300 μm of W
  - Inter-plane distance 1.6 cm
- Analysis:
  - Require single cluster on the 1st and 6th plane
  - plot x/z



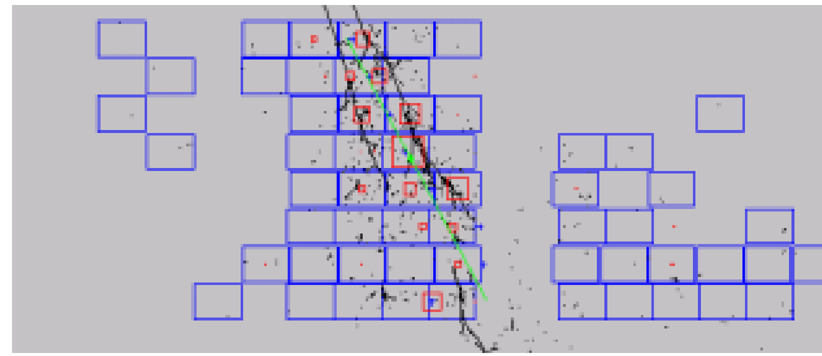
Energy (MeV)	Data: x/z distribuition	Fit sigma deflection (mrad)			
		Expt	G3	G4 5.2	G4 3.2
79		109	104	81	101
650		14.6	13.3	8.4	14.2

Requirements: EM processes

Calorimetry region: large scale

– **Basic shower properties for leakage correction**

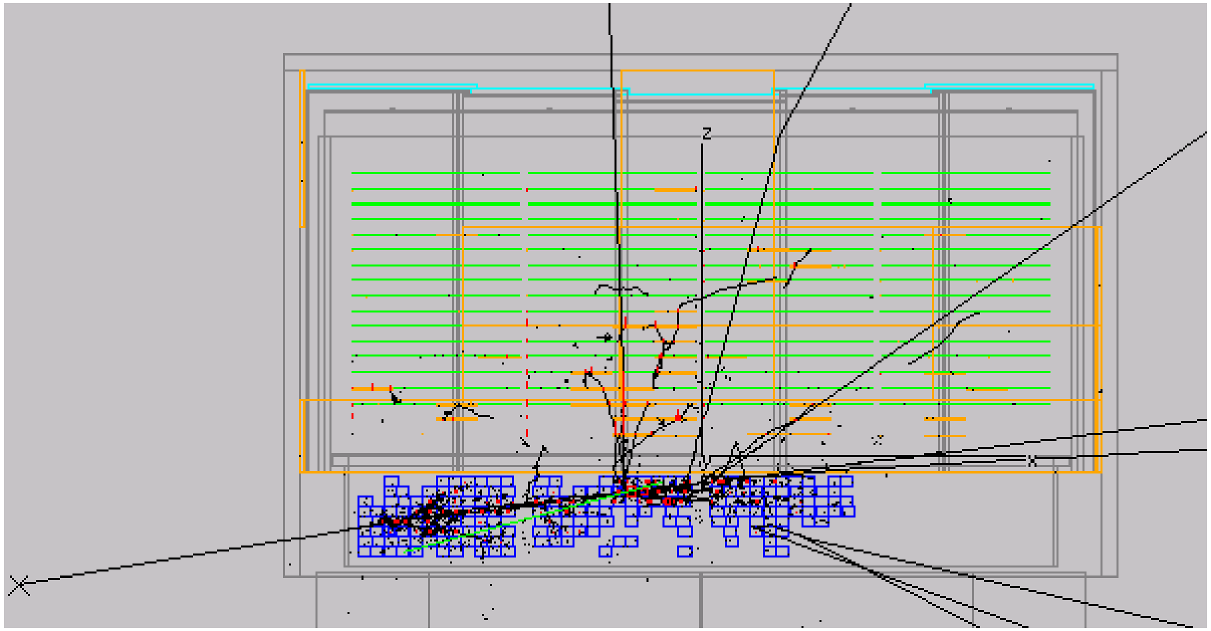
blue boxes: CsI segments
black: electrons and positons
red: light repsonse



not
much
lost on
this one!

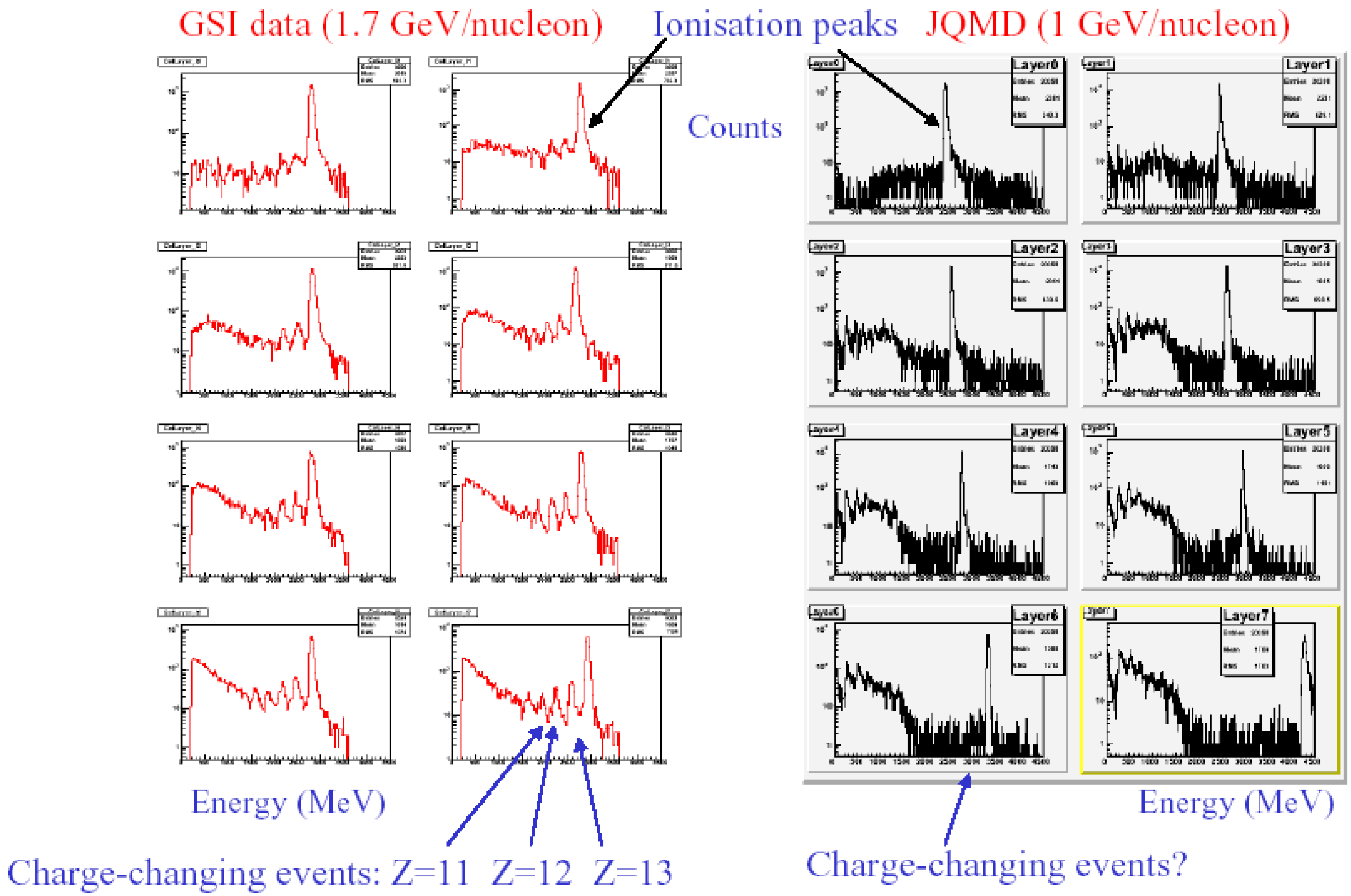
Requirements: Hadronic Processes

- **proton-nucleus cross sections, multiplicities**
- **Same for He, C, N, O, etc. (components of cosmic rays)**
- **E loss for min-I heavy nuclei (used to calibrate calorimeter)**



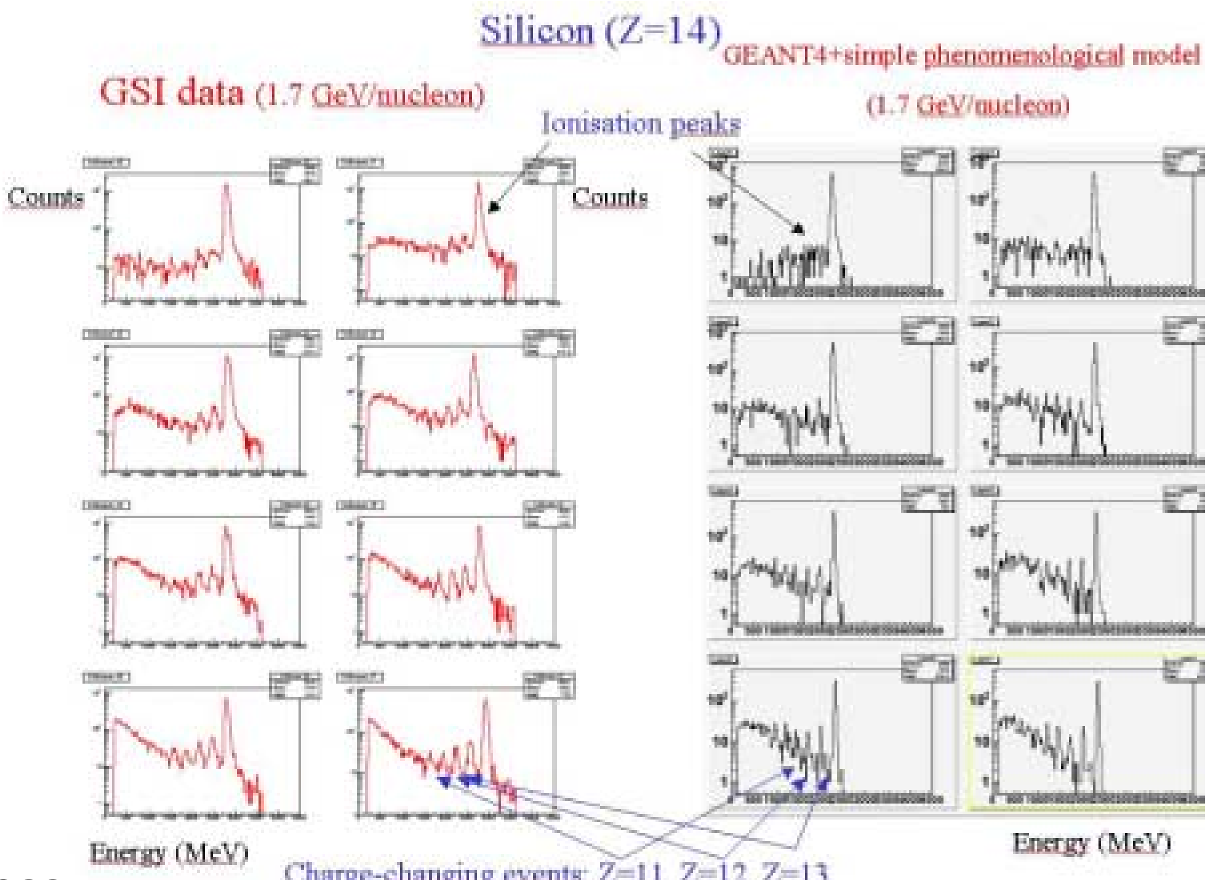
GLAST LAT full simulation

Heavy Ion Simulation



Heavy Ion Simulation

Test beam data and EPAX phenomenological model

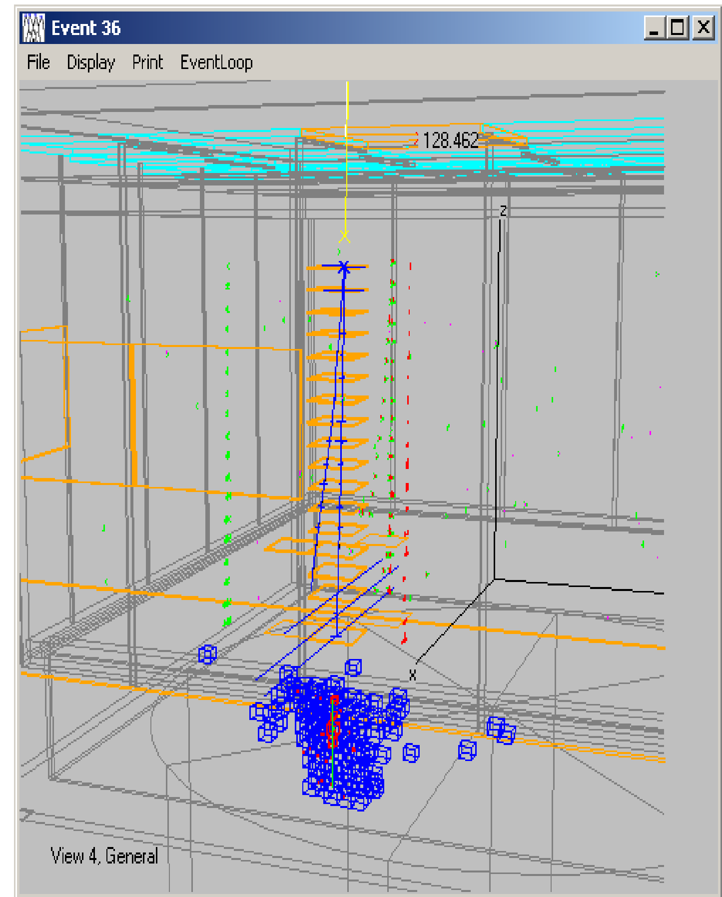


Work in progress

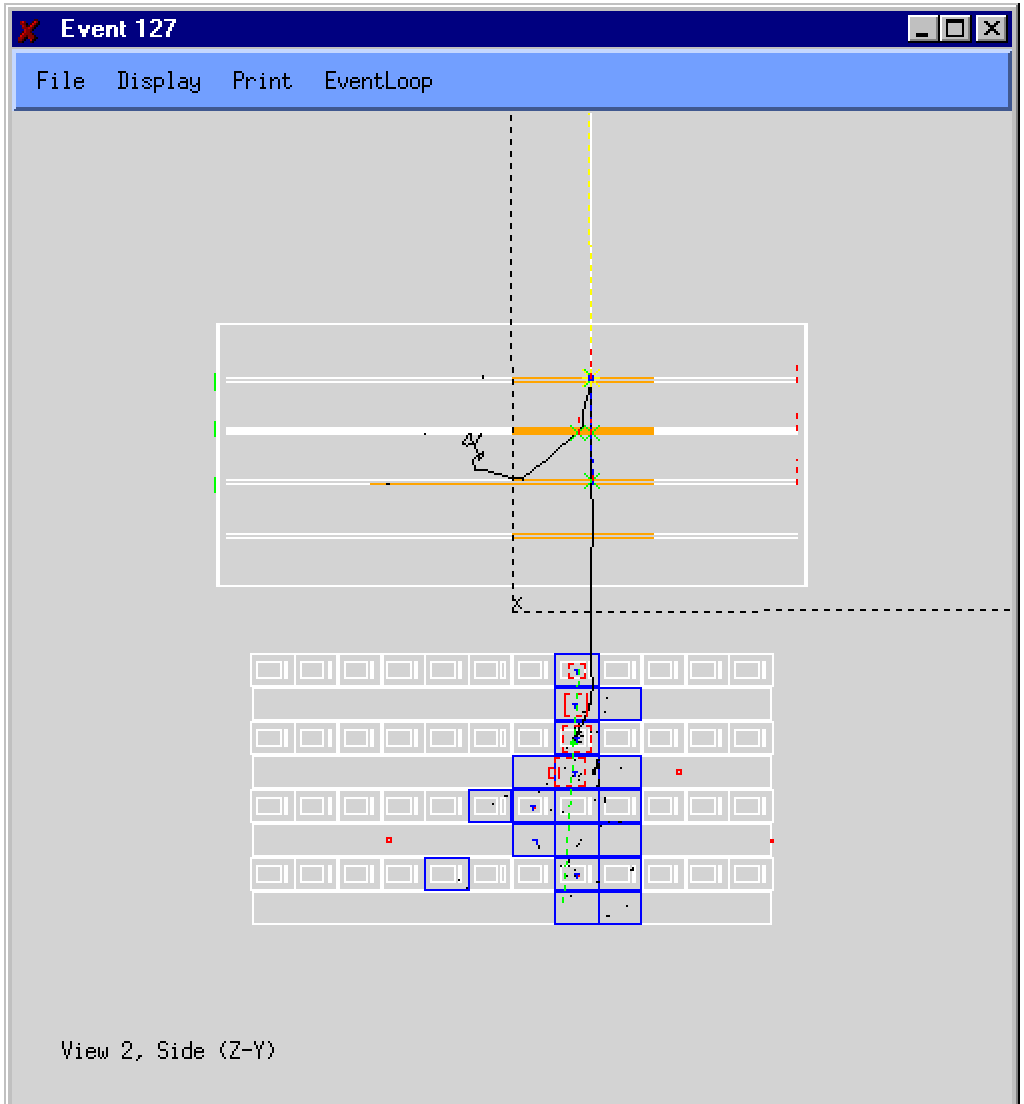
- Evaluation of G4 existing models
- New phenomenological models

Event Reconstruction

- **Sequence of operations, each implemented by one or more** Algorithms, **using TDS for communication**
  - **Trigger analysis: is there a valid trigger?**
  - **Preliminary CAL to find seed for tracker**
  - **Tracker recon: pattern recognition and fitting to find tracks and then photons in the tracker (uses Kalman filter)**
  - **Full CAL recon: finds clusters to estimate energies and directions**
    - **Must deal with significant energy leakage since only 8.5 X_0 thick**
  - **ACD recon: associate tracks with hit tiles to allow rejection of events in which a tile fired in the vicinity of a track extrapolation**
  - **Background rejection: consistency of patterns:**
    - **Hits in tracker**
    - **Shower in CAL: alignment with track, consistency with EM shower**



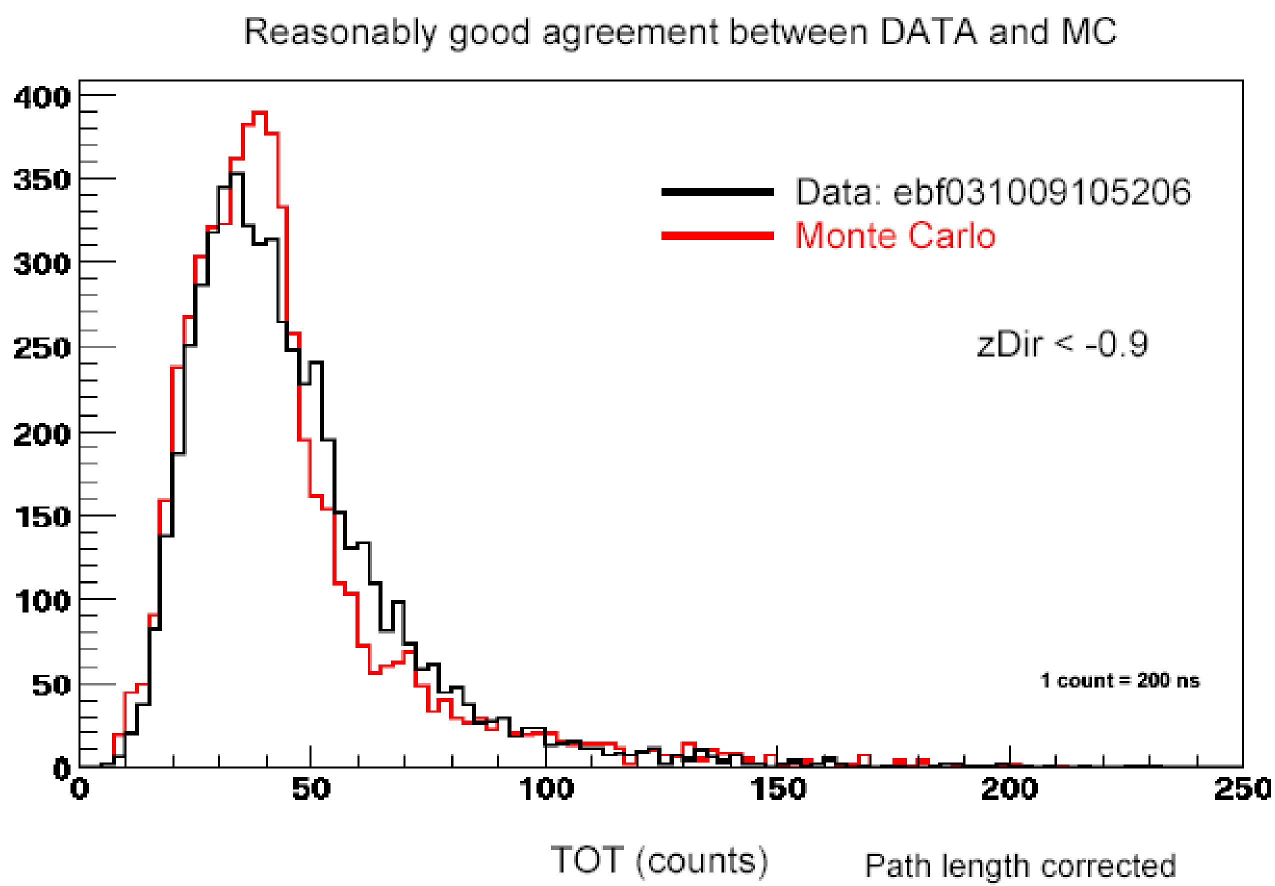
Geant4 simulation



- 18 MeV on-axis photon
- Engineering Model
  - Mini-Tower
- EM Data Analysis
  - Calibrate CAL and TKR
  - Measure the energy spectrum of van de Graaff photons (17.6 MeV)
  - Exercise flexibility of geometry input for the Monte Carlo simulations

Geant4 Simulation of EM

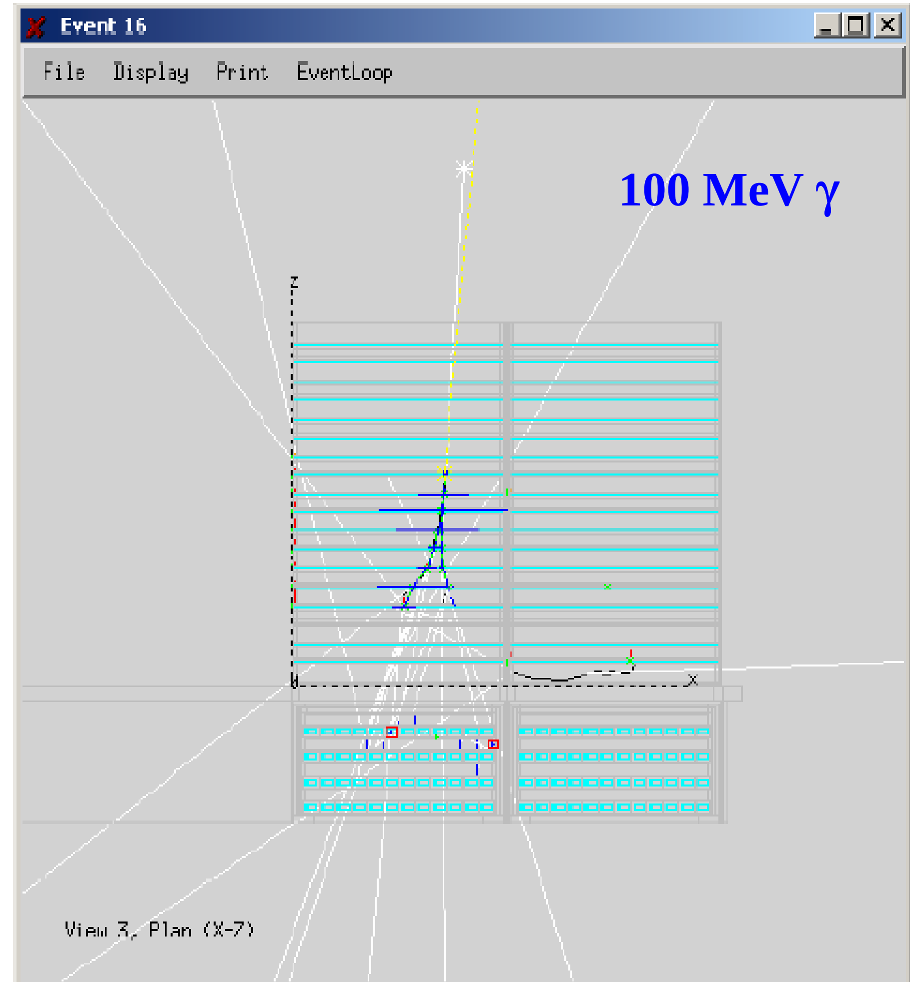
ToT ~ Estimate of Deposited Charge in Si Layer



Geant4 simulation

Common sets of MC events for tower integration foreseen for this summer

- **100 MeV photons on axis**
- **Surface muons (all angles)**
- **Van de Graaff photons (all angles)**

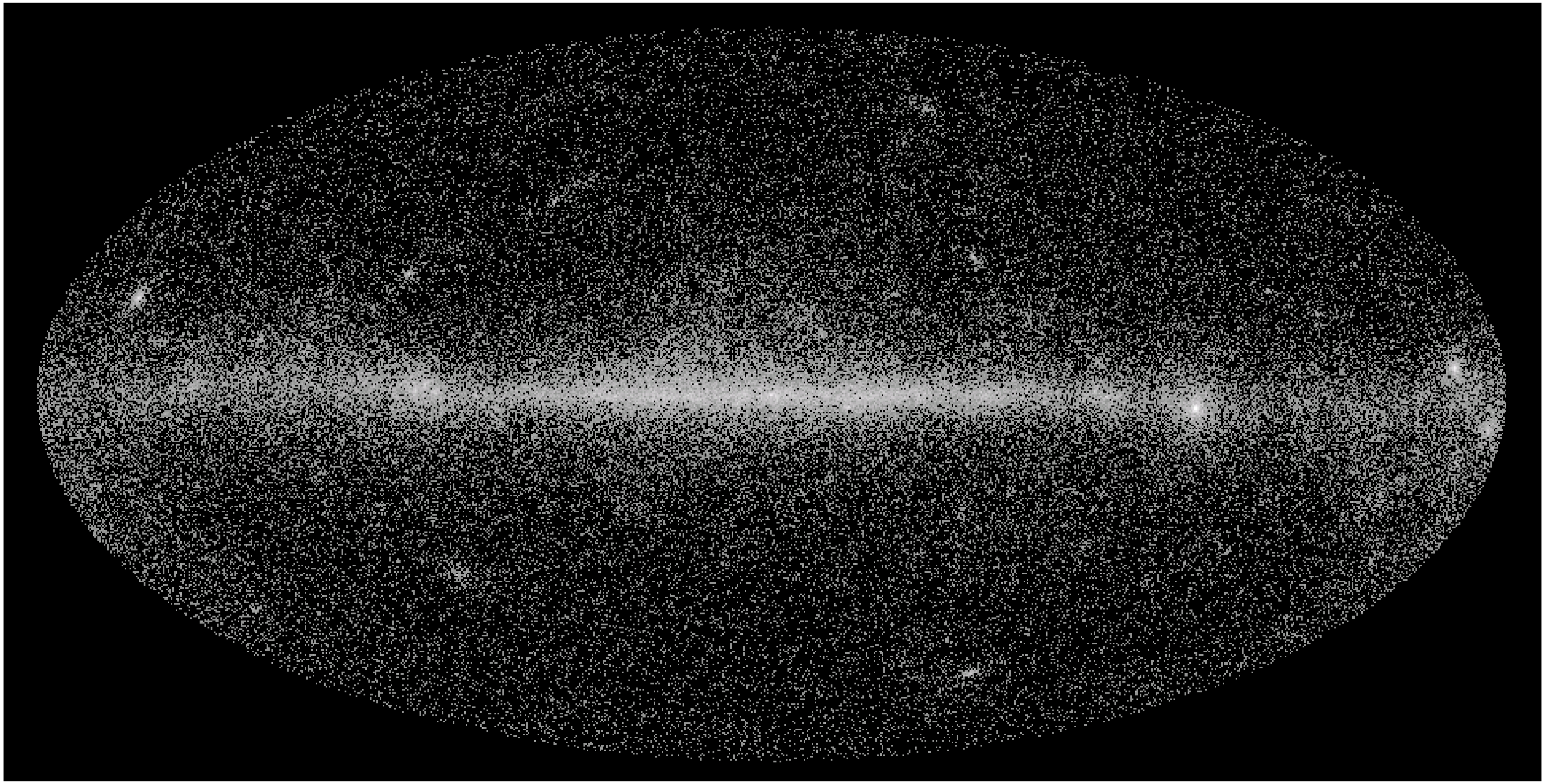


1st two towers simulation

Data Challenges

- **Support readiness by launch time to do all first-year science.**
  - **"End-to-end" testing of analysis software.**
  - **Familiarize team with data content, formats, tools and realistic details of analysis issues (both instrumental and astrophysical).**
  - **If needed, develop additional methods for analyzing LAT data, encouraging alternatives that fit within the existing framework.**
  - **Provide feedback to the SAS group on what works and what is missing from the data formats and tools.**
  - **Uncover systematic effects in reconstruction and analysis.**
- **DC1 - December 2003 – February 2004**
  - **Modest goals. Contains most essential features of a data challenge.**
    - **1 simulated day all-sky survey simulation**
      - **find GRB**
      - **a few physics surprises**
      - **exercise:**
        - » **exposure, orbit/attitude handling, data processing pipeline components, analysis tools**
- **DC2, start beginning of 2005. More ambitious goals. Encourage further development, based on lessons from DC1. One simulated month.**
- **DC3. Support for flight science production.**

DC1 gamma-ray sky-map



Conclusions

- Geant4 adopted as GLAST MC simulator
- Independent packages interacting with MC simulations
- Need reliable heavy ion simulation
- Need to trust releases of G4. Better validation procedure?
- Starting phase of massive MC data production for flight integration
- Data Challenge 1 completed
- Mission to be launched in 2007!