University of California at Berkeley – Space Sciences Laboratory

Geomega: MEGAlib's geometry and detector description tool for Geant3, MGGPOD, and Geant4

A. Zoglauer (UCB), R. Andritschke (MPE), F. Schopper (MPE), C.B. Wunderer (UCB)

Abstract

The Medium Energy Gamma-ray Astronomy library MEGAlib[1,2] is a set of software tools for the analysis of low to medium energy gamma-ray telescopes, especially Compton telescopes. It comprises all necessary data analysis steps from simulation/measurements via event reconstruction to image reconstruction and enables detailed performance assessments.

An integral part of MEGAlib is Geomega, its tool for geometry and detector description, which provides volume, material, detector, and trigger information to the various simulation programs such as Geant3, MGeant/MGGPOD[3] and Geant4[4], provides visualization of the detector as well as the detected (and reconstructed) events, and serves as geometry foundation for all higher-level tools of MEGAlib.

Geomega and MEGAlib have been successfully applied to a wide variety of hard X-ray and gamma-ray telescopes such as MEGA[5], NCT[6], ACT[7], GRI[8], etc.

Geometry description:

Geomega provides many of the geometry features which Geant3, MGeant/MGGPOD, ROOT[9] and Geant4 have in common:

- A set of volumes: boxes, spheres, tubes, various trapezoids, polygones, polycones, etc., which can be positioned, rotated, etc.
- Virtual volumes: Container volumes which are allowed to overlap and allow for easy packaging of the volumes, but which are removed from the final geometry before actual display and simulation
- Complete material description

Geomega does not allow divisions of volumes or overlaping volumes (MANY keyword in Geant3)

In addition Geomega provides a set of useful features such as

- Scaling, i.e. enlarging or shrinking a volume including all daugther volumes
- Including geometries from different files
- Global definition of constants
- Handling of all mathematical operations known to ROOT
- For-loops, etc.

These features enable the construction of a completely flexible, scalable geometry controled by a small set of constants.

Finally, MEGAlib's Geomega contains several tools to verify the geometry during its construction phase, such as:

- Zoomable geometry display with axes (inherited from ROOT)
- Display of the whole geometry or a subset in a common mother volume
- Total mass calculations for main volume or a subset
- Overlap detection (with some limitations)

This geometry description is an independent part of MEGAlib and thus can be used to easily generate geometries for external simulation programs such as MGGPOD!

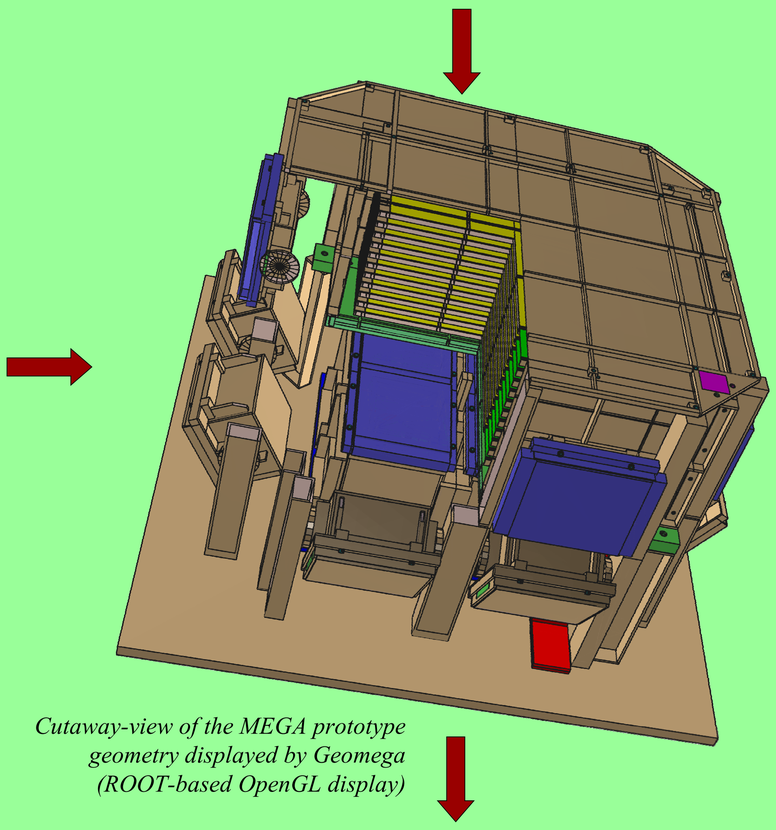
Detector and Trigger description:

Geomega knows a set of predefined detector types such as

- scintillators (single volume, Anger camera, MEGA-type calorimeters)
- strip/voxel detectors (with and without depth resolution)

In combination with the full MEGAlib framework, for all those detectors energy resolutions (as function of energy and interaction depth), position resolutions (as a function of energy), trigger thresholds, noise threshold, overflows, defective pixels, etc. can be defined

In addition Geomega allows to define trigger and veto criteria (e.g, "Use the event if there are no hits in this (veto) volume, but at least two of these detector volumes need to have a certain amount of channels triggered.").



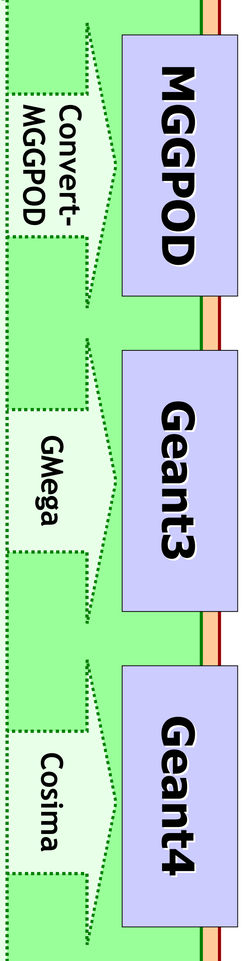
Cutaway-view of the MEGA prototype geometry displayed by Geomega (ROOT-based OpenGL display)

Interface to simulation programs:

Geomega provides material, volume, geometry, detector and trigger information to the various simulation programs/interfaces: For MGeant/MGGPOD and Geant3/GMega the MEGAlib type geometry is directly converted into files readable by those programs, while the Geant4-based code Cosima is able to directly link the Geomega library, and thus can directly read the Geomega file format.

MGGPOD and Geant4 can be used in a way that only the geometry reading and conversion steps of Geomega are performed allowing to combine Geomega with third party software.

In the MEGAlib context, all three programs generate the same file format readable by higher level programs of MEGAlib.



Instrumental effects engine:

Within the full MEGAlib framework, Geomega allows to apply

- Gaussian/Lorenzian noise
- Noise and trigger thresholds
- Overflows
- defective pixels
- trigger criteria, etc.

to the simulation data, in order to adapt it to reality.

High level tools for high level data analysis:

Absorption probabilities along path of photons, hit-detector assignment, visualization of geometry and events during event reconstruction, etc.

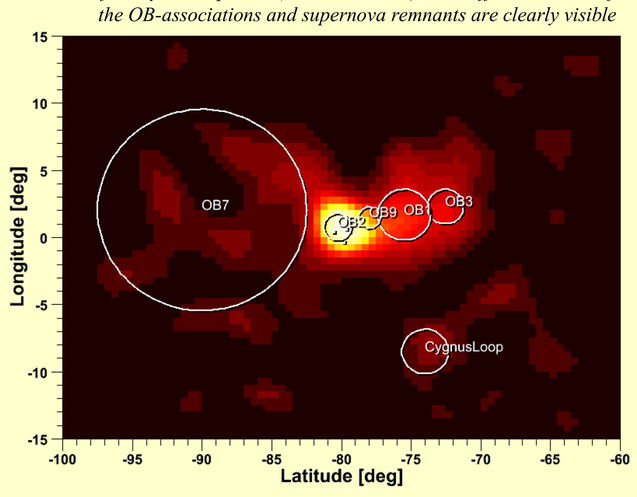
MEGAlib's high-level data analysis tools (e.g. Mimrec & Revan) utilize all of Geomega's features

Mimrec:

Mimrec includes modules for:

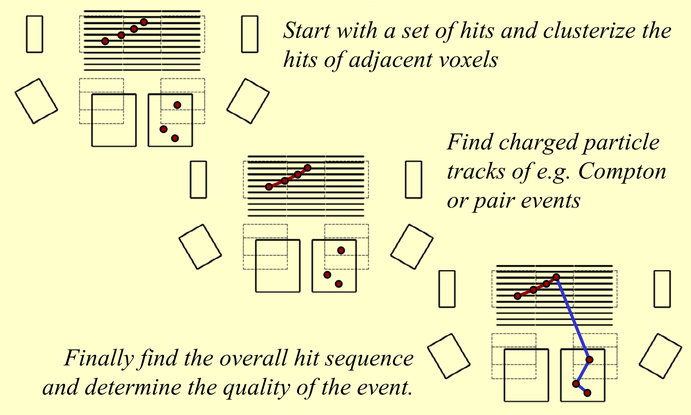
- Event selections of all performance-relevant parameters of Compton and pair telescopes/cameras (e.g. energies, interaction distances, scatter or opening angles, etc.)
- List-mode likelihood image reconstruction in spherical as well as Cartesian coordinates (2D, 3D) including different response calculation approaches for Compton and pair creation events
- General Compton detector analysis (angular resolution energy dispersion, scatter angle distributions, etc.)
- Performance assessment of event reconstruction algorithms
- Sensitivity and background calculation tools
- and many more

Image obtained by simulations of the Cygnus region in the light of ^{26}Al after 2 years exposure (MEGA detector): The diffuse emission of the OB-associations and supernova remnants are clearly visible



Revan: Event reconstruction

All event reconstruction algorithms have the following steps in common to find the correct ordering of the hits:



MEGAlib base library – C++, completely object-oriented, utilizes ROOT (http://root.cern.ch). Supported operating systems: Linux and Mac OS X.

References:

[1] A. Zoglauer et al. "MEGAlib – The Medium Energy Gamma-ray Astronomy library", NewAR, 2006, in press
[2] A.Zoglauer, "First Light for the Next Generation of Compton and Pair Telescopes", Doctoral thesis, TU München 2005
[3] G. Weidenspointner et al. "MGGPOD – a Monte Carlo Suite for Modelling...", ApJS, 156, 2005
[4] S. Agostinelli et al. "Geant4 – a simulation toolkit", NIM A506, 2003
[5] G. Kanbach et al. "Development and calibration of the tracking Compton and Pair telescope MEGA", NIM A541, 2005
[6] S.E. Boggs et al. "Overview of the Nuclear Compton Telescope", NewAR 28, 2004
[7] C.B. Wunderer et al., "The ACT vision mission study simulation effort", NewAR, 2006, in press
[8] J. Knödelseder et al. "GRI – the Gamma-Ray Imager mission", SPIE 6266, 2006
[9] R. Brun and F. Rademakers, "ROOT – An Object Oriented Data Analysis Framework", NIM A 389, 1997

The latest version of Geomega and MEGAlib (v2.14) can be found at www.mpe.mpg.de/mega/megalib.html, *or contact:* zog@ssl.berkeley.edu