GLAST Large Area Telescope:

Data Challenge 2

Getting Ready for Science

Richard Dubois
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A Glimpse of the Future
Organizing Science in the Collaboration

Analysis Coordinator
Julie McEnery
GSFC

Calibs
Analysis
W. Atwood (UCSC)
S. Ritz

Instrument analysis

Astro analysis

Blazars/AGNs
B. Lott
P. Giommi
R. Dubois

Catalogues
S. Digel (SLAC)
E. Bloom (SLAC)
A. Morselli

Dark Matter
E. Bloom (SLAC)
A. Morselli

Diffuse And Molecular Clouds
S. Digel (SLAC)
I. Grenier

Gamma Ray Bursts
N. Omodei
J. Norris

Pulsars, SNRs
R. Romani (Stan)
D. Thompson

Solar System
G. Share

Unidentified\ O. Reimer (Stan)
P. Caraveo

3/42
Pair production is the dominant photon interaction in our energy range

- Reconstruction Goals:
  - Incident Gamma Direction and Energy
  - Reject Backgrounds
- Incident Gamma converts in the tracker
  - In particular, conversion occurs in one of the converter foils – ie at a well defined location
- Resulting electron-positron pair range out of tracker (TKR)…
  - No magnetic field, tracks are “straight lines”
  - Resulting two tracks “point” back to incident Gamma
- And into the CsI Calorimeter (CAL)
  - Measures total energy of electron-positron pair
  - = Gamma energy
- Surrounding Anti-Coincidence Detector (ACD) vetoes any wayward charged particles
GLAST Reconstruction

What makes it challenging…

- Track Opening Angle ~0
  - Resolve
    \[ \sim 2 \times 228 \text{ um} / 30 \text{ mm} = \sim 15 \text{ mr} \]

\[ \text{Strip Pitch} \quad \sim \text{Tray Spacing} \]

< ~50 MeV photons to resolve tracks without “help”

- Looking for “v”\(’\)s may not be the correct strategy for gamma direction reconstruction
  - Well… see next slides…

T.Usher
GLAST Reconstruction
What makes it challenging...

- **Tracker has a lot of material**
  - Actual tracker is ~ .3 rl
    - Could live with this...
  - Converter foils are ~ 1.1 rl
    - Love them: convert gamma
    - Hate them: tracking electrons
  - Total ~ 1.4 rl
    - For particles traversing active area of tracker
    - Does not include walls between towers, etc.

- **Issues to deal with**
  - Gammas can (and do) convert outside the foils
  - $e^+e^-$ pair interact with tracker
    - Multiple scatter
    - Primary $e^+$ or $e^-$ can stop in the tracker
    - $e^+$ and $e^-$ radiate energy
    - etc.

T.Usher

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**Incident Gamma**

**1 GeV Gamma**

- $e^+e^-$ pair in there

**Radiated gammas** (from Bremstrahlung)

- Note flow of energy in direction of incident Gamma

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R.Dubois
GLAST Reconstruction

What makes it challenging...

- Calorimeter Issues
  - Measure Event Energy – Not Track Energy(ies)
    - Don’t have resolution to separate
    - Large fraction of measured energy from Brems
    - Implications for determining gamma direction when you do have two track events...
  - Measure Fraction of Event Energy
    - Energy “loss”
      - in tracker
      - Leaking out of Calorimeter
    - Significant contribution at
      - lower energies (e.g. < 1 GeV)
      - for conversions starting higher in the tracker
    - Must augment total energy determination with contribution from tracker

T.Usher
Background Rejection
Example: Charged Particles in Tracker

- Project Track to plane of struck tile
- Calculate distance to nearest edge
- Sign
  Positive if track projection inside the tile
  Negative if track projection outside the tile
- Reject if inside the tile

“Active Distance”

no tile hit

outside tile boundary
inside tile boundary

R.Dubois
T.Usher
## Sim/Recon Toolkit

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
<th>Provider</th>
<th>Status</th>
</tr>
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<tbody>
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<td>ACD, CAL, TKR</td>
<td>Data reconstruction</td>
<td>LAT</td>
<td>90% done In use</td>
</tr>
<tr>
<td>Recon</td>
<td></td>
<td></td>
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<tr>
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<td>G4 worldwide</td>
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<td>Parameters</td>
<td>World standard</td>
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<tr>
<td>Root 5</td>
<td>C++ object I/O</td>
<td>HEP standard</td>
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<td>Gaudi</td>
<td>Code skeleton</td>
<td>CERN standard</td>
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<td>doxygen</td>
<td>Code doc tool</td>
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<td>In use</td>
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<td>Visual C++/gnu</td>
<td>Development envs</td>
<td>World standards</td>
<td>In use</td>
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<td>HEP standard</td>
<td>In use</td>
</tr>
<tr>
<td>ViewCvs</td>
<td>cvs web viewer</td>
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<td>In use</td>
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<tr>
<td>cvs</td>
<td>File version mgmt</td>
<td>World standard</td>
<td>In use</td>
</tr>
</tbody>
</table>
Instrument Simulation and Reconstruction

3 GeV gamma interaction

Source Fluxes → Particle Transport → "Raw" Data → Recon

Geometry → Instrument data

Full geometry in xml with C++ interface
G4 discovers instrument from the xml

CAL Detail

3 GeV gamma recon

Background Rejection - Particle ID
Science Tools

• The ‘Science Tools’ are the high-level analysis tools for astronomy
• The core analysis tools have been defined and developed jointly with the GLAST Science Support Center (NASA/GSFC)
  – NASA staffed the GSSC early with this intent
  – These tools all adhere to the HEASARC FTOOL standards
• To the extent possible we have reused code from existing tools
  – Most notably for pulsar timing, e.g., barycenter arrival time corrections
• For source detection and characterization, the science tools use Instrument Response Functions (PSF, effective area, and energy dispersion as functions of relevant parameters), effectively abstracting the reconstruction and classification process
  – The greatest differences from the formalism for EGRET analysis is that the LAT will almost always be slewing, so that the response functions that apply to any given source also change continuously
Science Tools (2)

- After a period of definition and review, the tools have been developed incrementally, with the milestones for evaluation
  - Data Challenges (see later) as major milestones and ‘Science Tools Checkouts’ (3 so far) as intermediate ones

- The core Science Tools are
  - `gtlikelihood`, `gtexpmap`, and numerous associated utilities – for defining a model of a region of the sky and fitting it via maximizing the likelihood function
  - `gtrspgen`, `gtbin` – for generating response matrices and counts spectra for analysis of GRBs in XSPEC, including jointly with GBM data
  - `gtbary`, `gtpphase`, `gtpsearch` – and associated utilities for pulsar timing, periodicity tests
  - `gtobssim`, `gtorbsim` – fast and flexible observation simulator using the IRFs, and an orbit/attitude simulator.
Automated Pipeline Processing

• What is the pipeline?
  – Envisaged as tool to provide a tree of processing on a given input dataset
  – Handle multiple “tasks” concurrently, eg LAT commissioning, DC2 Monte Carlo runs
  – Full bookkeeping to track what happened
  – Archive all files touched

• Used by whom?
  – Online
    • for sweeping integration data out of the clean room and to tape
    • populate eLogbook
  – SVAC (Science Verification and Calibrations)
    • for doing digi, recon
    • creating reports
    • Preparing for calibrations
  – Generic MC
    • DC2, background runs etc etc
  – ISOC (Instrument Science Operations Center)
    • Flight operations: Level 1 and 2
    • environmental testing, at Spectrum Astro, KSC
    • Data reprocessing
Sample Processing Chain

NRL → Fast Copy → CCSDS → FC Archive → FastCopy.out

Digi

Digi.Root → DigiReport → DigiReport.out

Recon1 → Recon2 → ... → ReconN

Recon1.root → Recon2.root → ... → ReconN.root

Recon.root → ReconReport → ReconReport.out
Web Monitoring of Pipeline Progress

Task in question
Processing step in chain
Filter queries

Access control by user

GLAST Pipeline

Runs for process: mc1step

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<thead>
<tr>
<th>Run</th>
<th>Status</th>
<th>Submitted</th>
<th>Memory (MB)</th>
<th>CPU (secs)</th>
<th>Job Id</th>
<th>Links (?)</th>
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<td>565</td>
<td>2035</td>
<td>100544</td>
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</tbody>
</table>
Pipeline 2

Build on experience from #1

- #1 now robust, but lacking in areas of flexibility

- Revisited requirements:
  - Task scheduling should be more flexible than current linear chain
    - Should support parallel execution of tasks
    - Should allow dependency chain to be more general than the input file requirements
    - Should support parallel sub-tasks, with number of sub-tasks defined at runtime
    - Perhaps support conditions based on external dependencies
  - Should allow for remote submission of jobs
    - Perhaps using GRID batch submission component, or Glast specific batch submission system
    - Will need to generalize current system (e.g. get rid of absolute paths)
  - Support reprocessing of data without redefining tasks
    - Need way to mark Done task as "ReRunnable"
    - Need to support multiple versions of output files
  - Ability to Prioritize tasks
  - Ability to work with "disk space allocator"
  - Would be nice to set parameters (env vars) in task description
  - Would be nice to be able to pass in parameters in "createJob"
  - Ability to suspend tasks
  - Ability to kill tasks
  - Ability to throttle job submission (ie max number of jobs in queue)
  - Ability to map absolute path names to FTP path names (site specific)
  - Would be nice to remove need for "wrapper scripts"
  - Ability to specify batch options (but portability problems)

- Redesigning database schema now
- Targeting beamtest for production use
**Instrument Data Access**

**Select detailed event data**

**Batch data for user: richard**

Task type: **pruner** batch number: **126191**

Please edit data and then press the 'Proceed' button

<table>
<thead>
<tr>
<th>Batch Parameters</th>
<th>Parameter Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Name</td>
<td>interleavedC2-GR-v7.3p21</td>
</tr>
<tr>
<td>E-mail</td>
<td><a href="mailto:richard@slac.stanford.edu">richard@slac.stanford.edu</a></td>
</tr>
<tr>
<td>Tcut</td>
<td>CTBGM&gt;0</td>
</tr>
<tr>
<td>Min Run Number</td>
<td></td>
</tr>
<tr>
<td>Max Run Number</td>
<td></td>
</tr>
<tr>
<td>Debug mode</td>
<td>false</td>
</tr>
<tr>
<td>User Comment</td>
<td>10-day test prune</td>
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<tr>
<td>Batch Options</td>
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</tr>
<tr>
<td>Max Filesize [MB]</td>
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</tbody>
</table>
Data Challenges

- Ground software is amalgam of HEP instrument software and Astro FTOOLS

- Adopt HEP’s “Data Challenges” to create a series of end-to-end studies: create a progression of ever more demanding studies

- Originated by the Mark2 experiment at SLAC while waiting for the SLC accelerator to deliver data
  - Test and oil the data analysis system from simulating the physics through full blown analyses
  - Details of physics and detector performance not revealed to the collaboration until closeout
  - Engage the collaboration and get it thinking science

- ISOC is an integral part of the collaboration
  - Exercise its part and interactions with the rest of the collaboration
Data Challenges: Three Rounds

  - 1 simulated day all-sky survey simulation
  - find GRBs
  - recognize simple hardware problem(s)
  - a few physics surprises
  - Exercise all the components

- DC2, kickoff Mar 1. More ambitious goals. Encourage further development, based on lessons from DC1. Two simulated months.
  - DC1 +
    - Much more data
    - Backgrounds included
    - More realistic GRBs
    - Pulsars, variable AGNs
    - More and more elaborate surprises

- DC3, in CY07. Support for flight science production.
DC Components

• Focal point for many threads – “end to end system test”
  – Orbit, rocking, celestial coordinates, pointing history
  – Plausible model of the sky
  – Background rejection and event selection
  – Instrument Response Functions
  – Data formats for input to high level tools
  – Use of Science Tools
  – Generation of datasets
  – Populate and exercise data servers at SSC & LAT
  – Code distribution on windows and linux

• Involve new users from across the collaboration

• Teamwork!
Preparations for DC2

- Full background analysis this time!
  - Tremendous collaboration effort to reduce the backgrounds to Science Requirements levels
  - Revision of background model – x4 higher than DC1 estimate
  - Detailed skymodel
    - Flaring objects; pulsars; joint GBM data(!); etc etc
  - Mechanically a huge change from DC1
    - Have to simulate backgrounds $10^3 \times$ signal
    - 100,000 CPU-hrs to simulate 1 day of background: 5 billion events
    - Machinery to randomly interleave that day 55 times, while simulating full rate deadtime effects
    - High-stress test of processing pipeline
      - ~400 CPUs running simultaneously for a week for the backgrounds runs
      - ~200,000 batch jobs total for DC2
  - Many scaling problems fixed
Monitoring Pipeline Throughput

Pipeline Statistics

- CPU time
- Memory
- "Wait" time for jobs
- Ratio wall clock to CPU

Summary

- CPU Used (secs)
- Memory Used (MB)
- Wall Clock time (secs)
- Pending time (mins)

Graphs showing statistics for CPU and memory usage, as well as waiting times and ratio wall clock to CPU. R. Dubois June 7, 2006.
## Monitoring Disk Farm via SCS Tools

**sulky35.slac.stanford.edu Overview**

This host is up and running.

### Time and String Metrics
- **boottime**: Sun, 5 Feb 2006 14:25:42 -0800
- **gexec**: OFF
- **last_reported**: 0 days, 00:07
- **machine_type**: sun4u
- **os_name**: SunOS
- **os_release**: 5.9
- **uptime**: 6 days, 18:20:32

### Constant Metrics
- **cpu_num**: 2 CPUs
- **cpu_speed**: 1503 MHz
- **mem_total**: 4010424 KB
- **swap_total**: 11805840 KB

### Gmetrics
GLAST Data Challenge II

Welcome to Data Challenge II!

Kickoff March 1-3, 2006

Key Links: Kickoff Agenda, DC2 Workshop, DC2 Users Forum, DC2 Analysis Results

Second in a sequence of 3 data challenges, DC2 will include extensive analysis of 55 days worth of realistic simulated data. Relative to DC1, many aspects of the simulated data have been improved:

- **Full and realistic detector simulation**, i.e., realistic in that simulations are imperfect, including things like dead strips, deadtime, etc.
- **Full reconstruction chain** from low level electronics quantities, to high level event information.
- **Updated and detailed background model**, including all the things that are not gamma-rays from celestial sources; also includes orbit variations.
- **Rich description of the gamma-ray sky**, including variable sources, pulsing sources and Gamma-Ray Bursts (GRBs).
- **Revamped event classification and background rejection analysis**, i.e., updated instrument performance plots.

DC2’s "Simulated Gamma-ray Sky" featured as APOD’s picture of the day: May 31, 2006.

Follow on lead from SLD, BABAR, but …

- work with Tech Writer
- skilled at extracting information from us wackos
- worries about layout, organization
- can write good
- we’re struggling with apparent conflict of web navigation vs “printed book”. Pursuing the former.
Code Distribution

- Tied in to Release Manager builds database
- Provide self-contained scripts to run executables sans CMT

Java WebStart app
GLAST plugin
GlastRelease config

Event control

Graphics tree

Graphics metadata: HepRep

3D controls

Multiple views

Fox/Ruby/C++ app

Event Display
DC2 Kickoff Meeting 1-3 March

112 registered attendees!

France: 13
Italy: 17
US: 71
Japan: 5
Sweden: 2
Germany: 4 (GBM)
Data Challenge II


Closeout Meeting: 31 May – 2 June
DC2 Coordinated by Julie McEnery, GSFC (I’m liberally swiping slides from her closeout talk!)
DC2 Goals, requirements and purpose

• 55 days of LAT data provide a deeper view of the high energy gamma-ray sky than has previously been achieved.
  – Results from previous gamma-ray missions provide, at best, an incomplete guide to the DC2 sky.
  – Part of the challenge of DC2 will be to figure out what was included in the sky model.
  – DC2 data has a fairly realistic level of detail which will support a wide variety of both science and instrument performance studies.
  – Exercise the science tools – but don’t feel restricted to them
  – Improve the documentation and analysis software from user feedback.
Gamma-ray sources in the DC2 Milky Way

- With the exception of Pulsars, which were based on a population model and a lot of research and fiddling, we included only likely examples each source class
  - Typically associated with an already-known source (sorry Olaf & Patrizia) without attempting a pop. synthesis
- ‘Other 3EG’ means that we included all non-spurious sources from the 3rd EGRET catalog (Hartman et al. 1999) even if we did not have a specific counterpart in mind

<table>
<thead>
<tr>
<th>Source Class</th>
<th># γ-rays (A+B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milky Way itself</td>
<td>1,704,807</td>
</tr>
<tr>
<td>Pulsars</td>
<td>140,596</td>
</tr>
<tr>
<td>Plerions</td>
<td>9,780</td>
</tr>
<tr>
<td>SNR</td>
<td>22,592</td>
</tr>
<tr>
<td>XRB</td>
<td>1,491</td>
</tr>
<tr>
<td>OB associations</td>
<td>295</td>
</tr>
<tr>
<td>Small molecular clouds</td>
<td>1,741</td>
</tr>
<tr>
<td>Dark matter (~2)</td>
<td>5,158</td>
</tr>
<tr>
<td>‘Other 3EG’ (120)</td>
<td>112,386</td>
</tr>
<tr>
<td>Sun (1 flare)</td>
<td>4,669</td>
</tr>
<tr>
<td>Moon (1)</td>
<td>10,523</td>
</tr>
<tr>
<td></td>
<td>*Out of 3,340,146</td>
</tr>
</tbody>
</table>

S.Digel
Examples of Variable Sky

AGN: Mk 421

Pulsar

Sun

Integrated flux >10 MeV

Early figure – showing slewing and eclipse
Produce LAT point source catalog

- **Requirement:** Spectral index and flux (with associated uncertainties), location with 68% and 95% confidence ranges, flux in discrete energy bands.
- **Goal:** Variability index, flux history, peak flux, measure of whether a source is extended.

The catalog analysis and results proved to be an extremely important part of DC2. It provided a starting point for a large fraction of the more detailed source analysis and was a reference for people doing population/source detection type studies.

There was a somewhat higher rate of false detections than would have been expected (~10%), this needs to be understood.
LS 5039, LS I +615 & Friends
Micro-quasar candidates in DC2

Toby’s HEALPIX map + Saclay sources

Cyg X1, SS 433, GRS 1915+105, V 4641 Sgr, GRS 1758-258, GRO J1655-40, Circinus X1, XTE J1550-564, 1E 1740.7-294.2

LS I +615
$\Gamma = -2.75$

LS 5039
$\Gamma = -2.42$
Develop and test source detection algorithms

- Requirement: That these algorithms are tested and compared with one another in a systematic way using the DC2 data.
  - Many source detection methods developed – Stephens, Tosti, Burnett, Casandjian, Ballet, Romeo/Cillis
  - Compared with one another by Seth Digel
Pulsars

- Goal: blind periodicity searches on candidate DC2 pulsars
  - Use time differences to measure power
  - Look for frequency at peak power

Marcus Ziegler – lightcurves of pulsars without radio data.

Phased light curves for radio quiet pulsars

Epoch_MET = 220838550
F0 = 5.885928323969
F1 = -1.306230 e-012
F2 = 1.0 e-021

Epoch_MET = 220838550
F0 = 3.91691474178
F1 = -1.936137 e-013
F2 = 6.0 e-022

Epoch_MET = 220838550
F0 = 3.766282209980
F1 = -3.677283 e-013
F2 = -3.3 e-021
Extended sources

- Hiro studying how to improve images by deconvoluting with the PSF
  - Can we use event by event measured errors?

Before deconvolution

After deconvolution

Hiro Tajima
Variable sources

- Requirement: Produce lightcurves for at least 20 bright sources (from the data release plan, these are the sources we will release high level data from in year 1)
- Goal: look at lightcurves for many more sources

By Benoit Lott
Riccardo Rando found a source that appeared to consist of two components, a pulsed hard component and a soft, steady component.

Power-law point source + background model is a very poor fit to the data.

Refit with a composite source consisting of a power-law and a log normal component.

Phase vs energy plot shows that the pulsed emission dominates above 1 GeV.
Gamma-ray bursts

This was one of the “rejected” fits due to the strange spectrum. The cause is likely to be because this GRB was simulated with an additional “hard” extended component lasting for 400s.

GRB08015885 – Nukri Komin

132 generated in $4\pi$
64 bursts seen in GBM
25 in LAT; 16 with $> 4\gamma$

 Blind GRB Search

- spikes in LAT trigger rate $R = 10/\Delta t$ (rate for 10 events)
- 7 GBM bursts
- 3 new bursts
- 1 solar flare
Other sources

- Requirement: Identify at least one source that is not a pulsar, AGN or GRB (there are some that can be identified from the gamma-ray data)
- Moon (Tosti, Rando)
- Sun (Tosti, Chiang)
Diffuse sources

- Goal: Study flux, spectra and spatial distribution of the galactic diffuse and compare with the diffuse model provided for source analysis.
- Studied by Jean Marc Casanjian, Andy Strong and Larry Wai

Diffuse is background to non-line dark matter searches
DC2 and Beyond

• The DC2 sky is probably the best rendition to date of the gamma ray sky
  – LATers took up the challenge and didn’t just look for the obvious

• And… we now have a great dataset for future development!
  – 55 days of simulated downlink to practise with
  – Simulate downlink frequency
  – Test Data Monitoring
  – Develop Quicklook

• And then “DC3”