

GLAST Large Area Telescope:

Status of System-level Performance Simulations

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For status see:

<http://www-glast.slac.stanford.edu/software/PDR/>



System-level Performance Simulations

Outline

- ❑ Introduction, Summary of requirements
- ❑ Description of simulation and reconstruction
 - ❑ history, overall architecture and components
 - ❑ geometry, background models
 - ❑ trigger and reconstruction
- ❑ Background rejection
- ❑ Results: status, issues, and plans
- ❑ Next steps:
 - ❑ failure modes modeling
 - ❑ plans

Result of much work by many people: Toby, Richard, Heather, Sasha, Ian, Karl, Leon, Tracy, Eduardo, Arache, Regis, ...

Note that there is a large amount of work being done on the simulation, reconstruction and other aspects of SAS not covered here (see SAS PDR in August). Only the most relevant parts for these studies described here.



Summary of Requirements

We use the simulation to evaluate the expected performance of the instrument design:

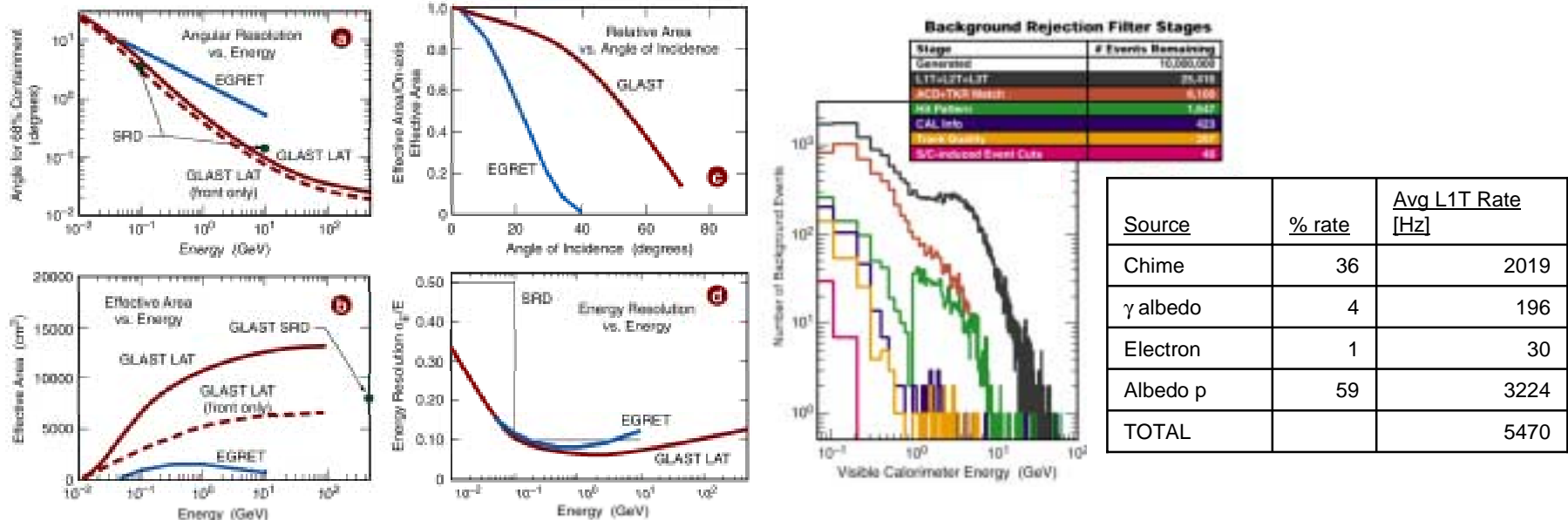
- **Effective Area as a function of energy**
- **FOV (Effective Area as a function of angle)**
- **Energy resolution**
- **PSF (68%, 95%) as a function of energy and angle. Make parameterization for physics studies.**
- **Background rejection (and all of the above after background rejection selections)**
- **Trigger rates and data volume after L1T and L3T**

We use the beam tests and other measurements to verify the simulation.



Work done for proposal

- We did this work for the proposal:



- Why do it again for PDR/Baseline?

- quantitative assessment of performance impact of incremental design changes
- better modeling of backgrounds
- check results and make improvements. move analysis forward.
- side benefits: opportunity to use and improve tools. simulation and reconstruction have undergone major architectural changes -- lost some functionality but gained much more solid foundation. this is an opportunity to pull everything back together.



PDR Simulation Work Requirements (2/2001)

For PDR, we must present the basic performance parameters of the instrument and show they meet the relevant LAT Performance Specifications.

The following elements must be in place to begin this evaluation process:

- updated, validated, and documented geometry to match the current design, along with configuration control of the design parameters; review noise and threshold parameters;
- updated source fluxes, incorporating the improved understanding;
- a documented release of the simulation and reconstruction in the new framework, including the new event storage format;
- a version of the event display that is compatible with the new simulation, reconstruction, and event storage format;
- machinery in place to generate the necessary statistics of signal and background events. We specify a requirement of >10 million background events, with a goal of 100 million background events generated and analyzed. The machinery must include a simple mechanism to identify each event uniquely, and the capability to produce from an event list files with a subset of the full event sample;
- an updated version of merit, or an equivalent tool, to run in the new environment. Ideally, this tool could run both on the stored events and on a new standard tuple. Depending on the size of the full events, a standard tuple may be a practical necessity.
- a basic analysis framework to operate on the new event stores.

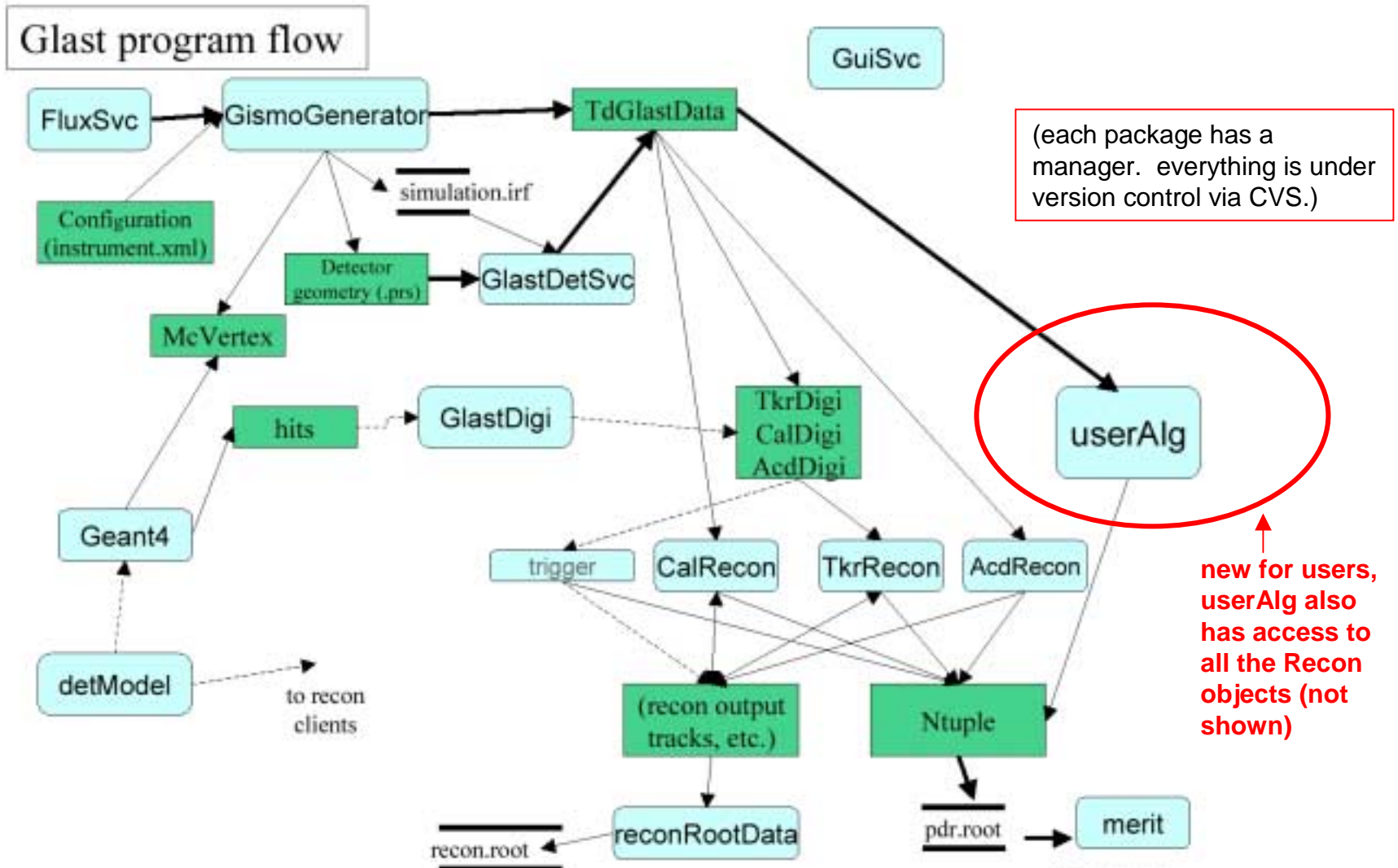


Some history

- **AO Glastsim + AO Recon – 1998-1999**
 - the original line of tools started in 1992
- **TBSim + TBRecon – Jan-Aug 2000**
 - New branch:
 - Special version of Sim for test beam geometry
 - Repackage Recon based on Gaudi concepts
 - Separate algorithms and data
 - Transient and persistent stores (Root as persistent store)
 - Centrally supplied services (geometry, messaging, I/O...)
- **Gaudi-ized Glastsim+TBRecon – Aug 2000 to present**
 - Merge the separate branches
 - Fully adopt Gaudi and implement main features, modularity \longleftrightarrow flexibility
 - Port TB Recon to Gaudi
 - much better support for additional reconstruction algorithms and analysis improvements [usefulness already demonstrated]
 - Port Gismo to Gaudi
 - will be able to switch between Gismo and Geant4



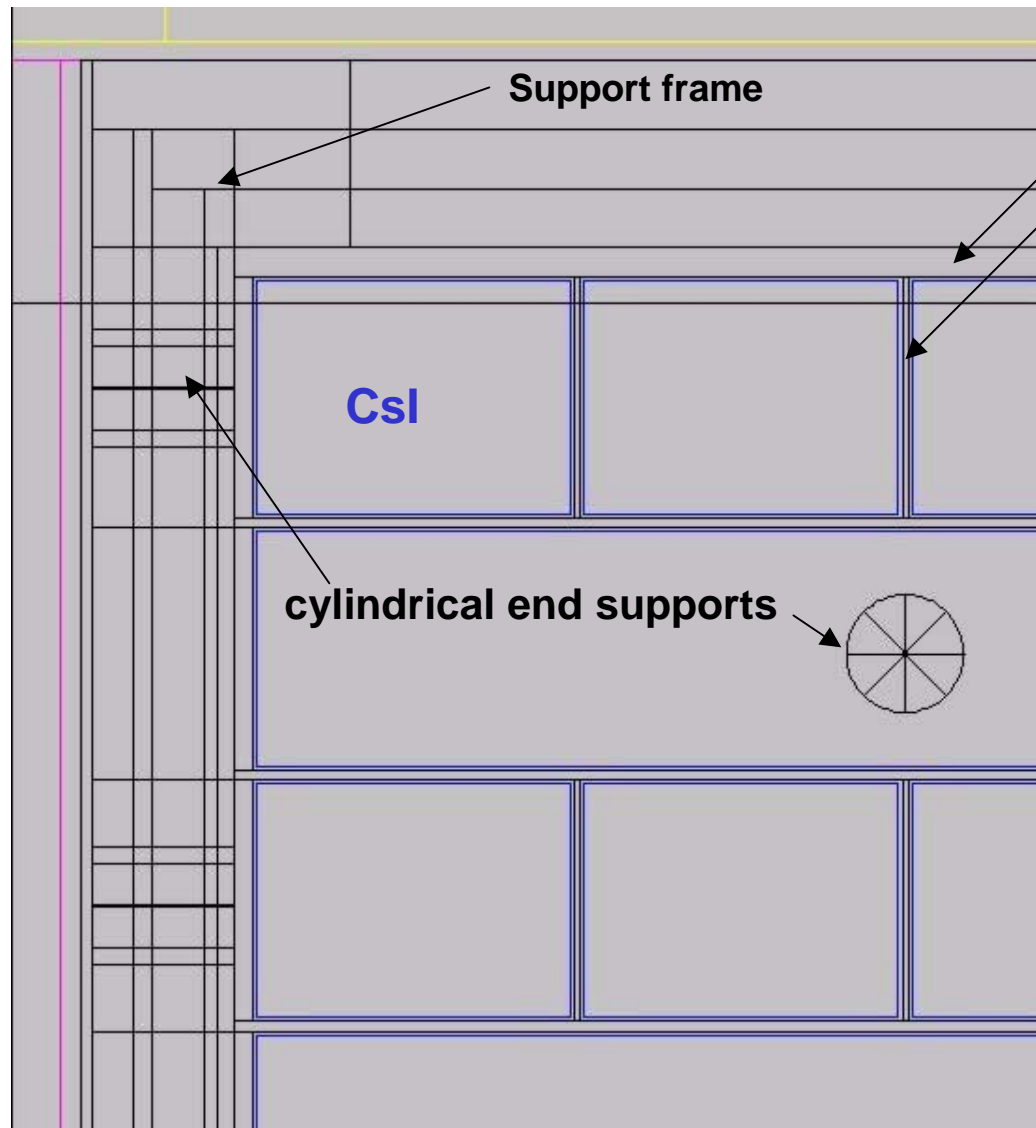
Architecture Plan



25 July 2001



CAL Geometry Update

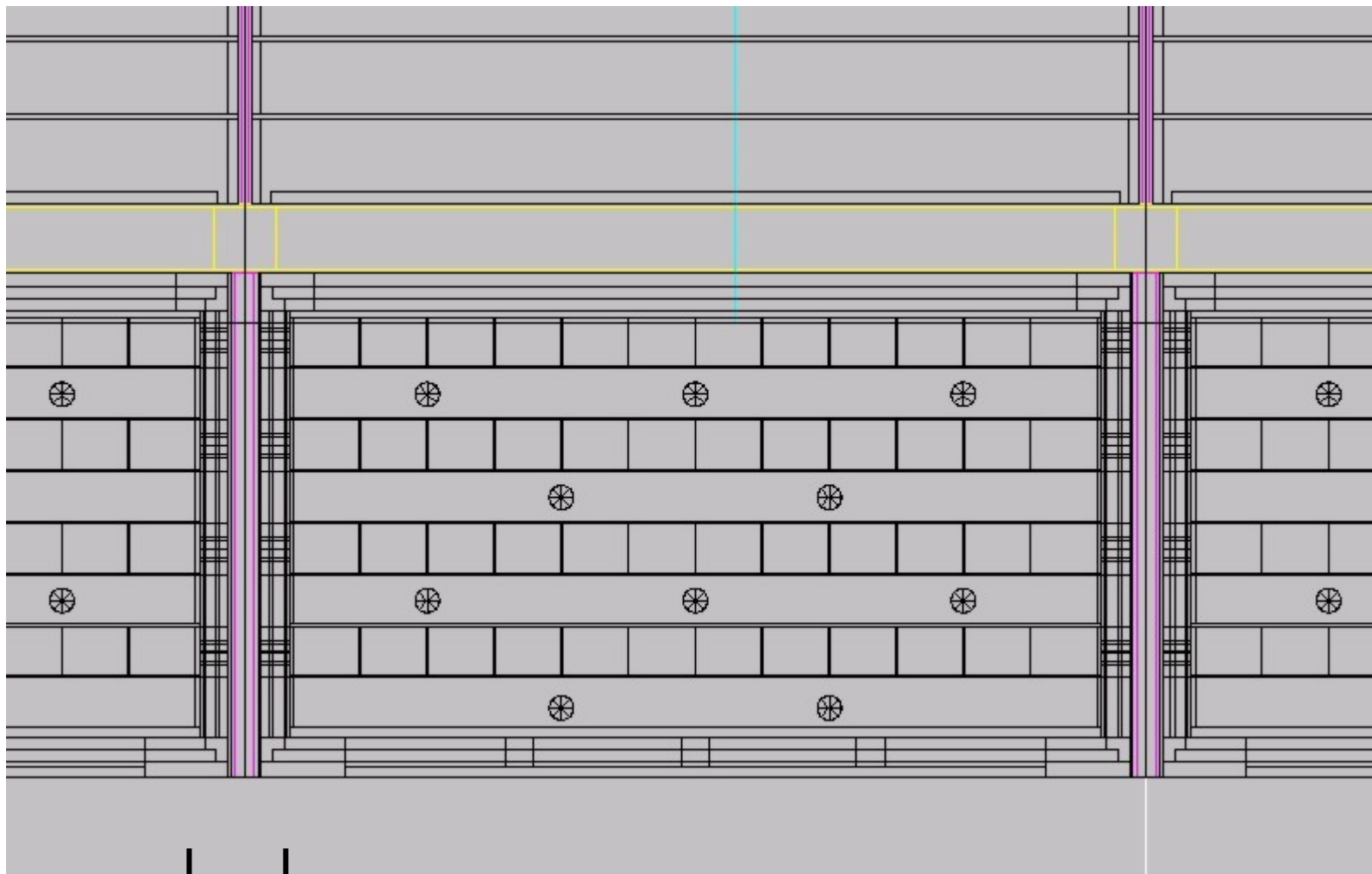


- new carbon cell design implemented
- detailed description of top and bottom supporting frames
- detailed description of cell closeout and electronics compartment at the sides of towers.
- all calorimeter dimensions are up-to-date.

Work done by Sasha (CAL group)



CAL Geometry Update (II)

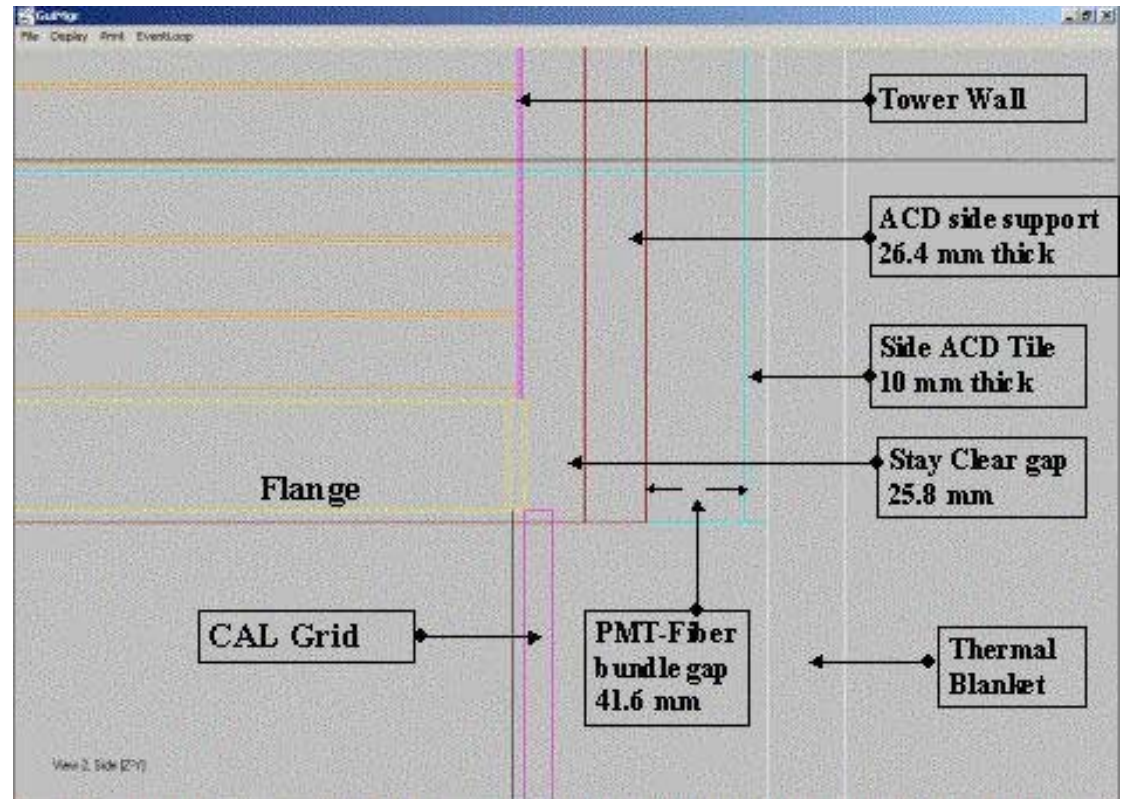


41.5 mm



ACD and GRID Geometry Updates

- ACD support structure consists of an approximated core material and two face sheets.
- The gap between the tiles and the towers reflects the current design.
- Thermal blanket is modeled as it was for the AO, using one average density material.

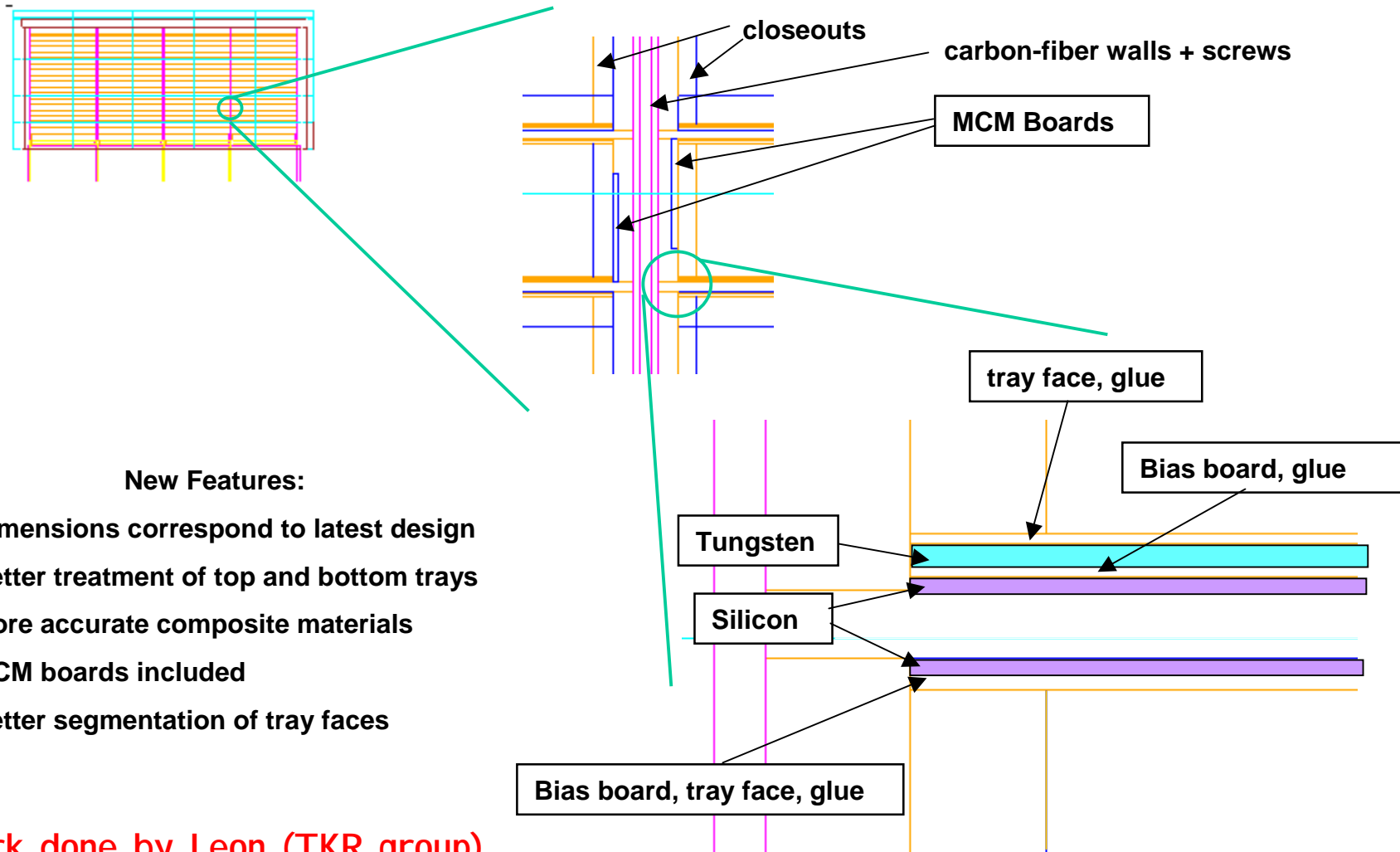


- GRID flange between TKR and CAL (treated as a separate volume) is undergoing modification to reflect the current design.
- Also adding ACD base frame.

Work done by Heather (ACD group) with help from Eduardo



TKR Geometry Update



New Features:

- ✓ Dimensions correspond to latest design
- ✓ Better treatment of top and bottom trays
- ✓ More accurate composite materials
- ✓ MCM boards included
- ✓ Better segmentation of tray faces

Work done by Leon (TKR group)



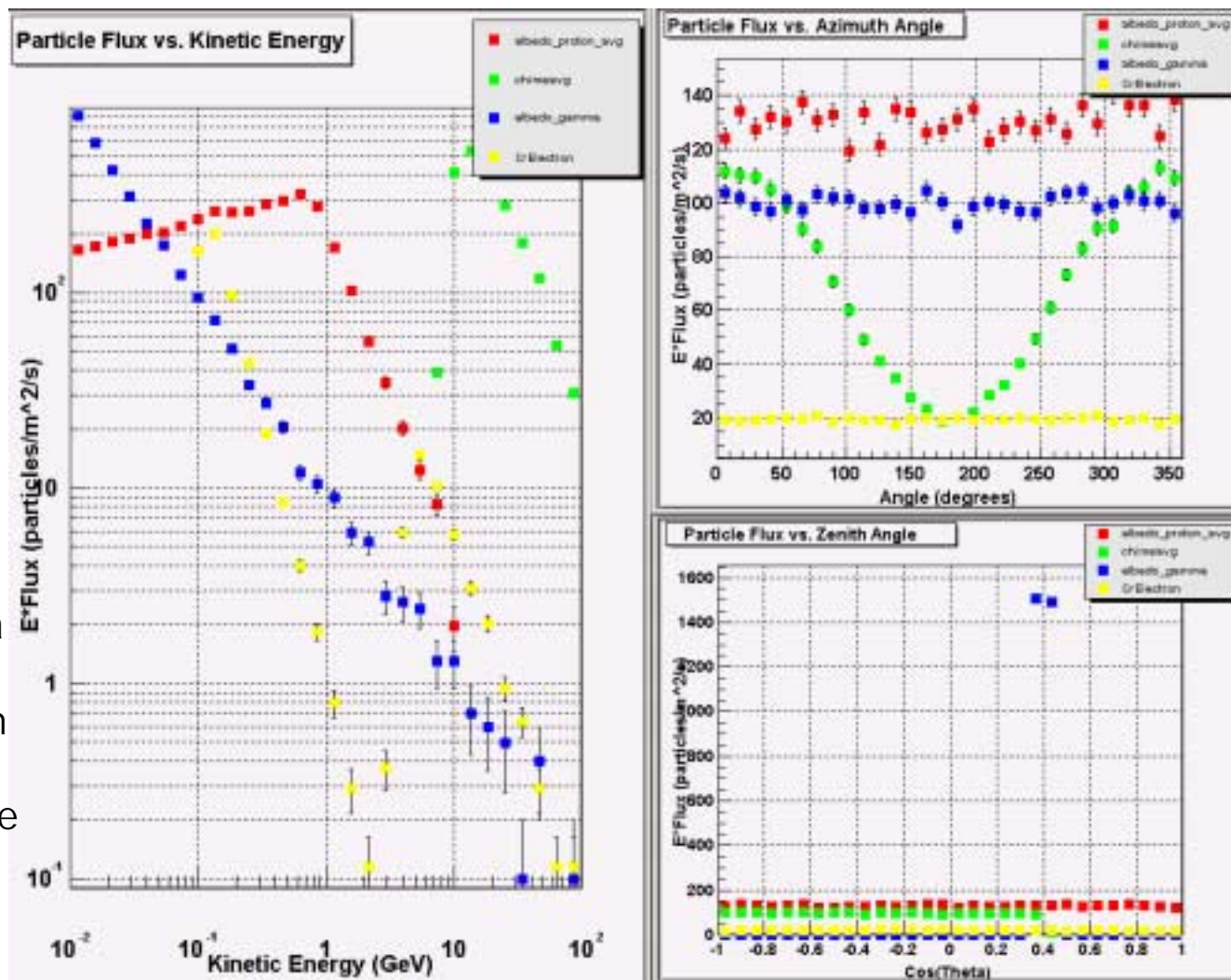
Background models

Implementation by Masanobu and Toby (updated 25 July!), reference LAT-TD-00250-01 (11 July 01) Mizuno et al.

Still needs review

Flux generator knows about orbit position

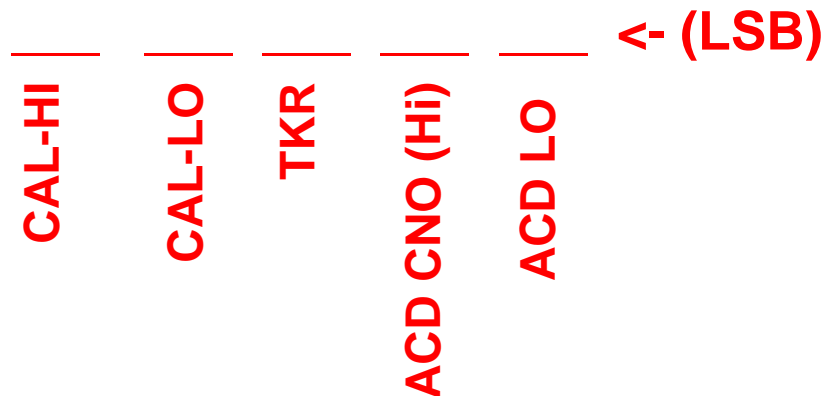
“avg” in this plot is just a point in orbit that has avg total rate - spectrum is not true average. Will implement better average spectrum for large generation runs (suggestions welcome)





Level 1 Trigger

- TKR 3-in-a-row
- CAL-LO = any single log with recorded energy > 100 MeV
- CAL-HI = any tower with 3-layers-in-a-row each with >0 logs with recorded energy > 1 GeV (**NEW!** see [LAT-TD-00245-01, 16 July](#))
- L1 Trigger word:



- Will continue to study details of performance of new CAL-HI proposal in this round of simulations.
- ACD throttle of L1T not yet implemented in release. (We anyway want to study the effects in the analysis step, but it should be implemented in the public release soon. Not essential for the mass generation – an advantage of ROOT: event lists!)



TKR reconstruction

- Full track info output to recon prototype ROOT structures (not extensively used yet).
- Sample of summary tuple quantities (also ROOT tuple, used by performance analysis):

<u>Item</u>	<u>Description</u>
TKR_No_Tracks	Total # tracks found
TKR__t_angle	Sine of angle between the best track and the reconstructed gamma direction (useful for trimming PSF tails)
TKR_First_Xhit	Layer number of first hit associated with best X track
TKR_Gamma_{xyz}dir	Direction cosines of reconstructed gamma
TKR_qual	Best track fit quality factors
TKR_Gamma_{xyz}0	Position for the reconstructed gamma

(see PDR prep website for full tuple description, Tracy Usher has taken over TKR Recon)



CAL reconstruction

- **CAL info output to recon prototype ROOT structures (not extensively used yet).**
- **Sample of summary tuple quantities (also ROOT tuple, used by performance analysis):**

<u>Item</u>	<u>Description</u>
Cal_Energy_Deposit	Total energy (MeV) as reconstructed by the CAL
Cal_eLayer0-Cal_eLayer7	Energy reconstructed (MeV) in each CAL layer
Cal_No_Xtals	Total number of logs with recorded energy above zero-suppression threshold (includes noise)
Cal_X, Cal_Y, Cal_Z	Position of energy centroid

(see PDR prep website for full tuple description, much work done by CAL software group on corrections for leakage and losses in TKR)



ACD reconstruction

- ACD info output to recon prototype ROOT structures (not extensively used yet).
- Sample of summary tuple quantities (also ROOT tuple, used by performance analysis):

<u>Item</u>	<u>Description</u>
ACD_DOCA	Distance of closest approach for all tiles, using all found tracks
ACD_GammaDOCA	DOCA for all tiles using reconstructed gamma trajectory
ACD_TopDOCA, ACDSnDOCA	Same as above, but using only top or side rows 0, 1, 2, 3
ACD_TileCount	Number of tiles above threshold

(see PDR prep website for full tuple description, ACD Recon by Heather)



System-level recon and MC_Truth info

- **Sample of summary tuple quantities (also ROOT tuple, used by performance analysis):**

<u>Item</u>	<u>Description</u>
Trig_Bits	Described in previous slide
REC_Surplus_Hit_Ratio	Used in background rejection analysis – average # hits/layer within 5 sigma of the best track (tells us if track is consistent with single prong)
REC_Csl_Corr_energy	CAL energy corrected for loss in TKR
Run_Number, Event_ID, etc.	Unique event ID info
MC_Energy, MC_Src_Id, etc	MC truth information about the event
MC_{xyz}Dir, MC_Gamma_Err	MC truth information about the incident particle direction and error in reconstructed direction.

(see PDR prep website for full tuple description)



Background Rejection Overview

- First developer of background rejection analysis: Bill Atwood (lots of work also by Jay, Toby, Heather, Cathie, Sawyer, Jose, Paul, Taro, SR, ...)
- Analysis done thus far for two main reasons:
 - (1) A reasonable way to quote our effective area.
 - (2) A proof of principle and a demonstration of the power of the instrument design.
- Not the final background analysis! Other techniques are available to reduce the backgrounds further with good efficiency (particularly using TKR pattern recognition). The analysis for the AO response was done in *triage* mode, and there is much to do now.
- Some science topics may require less stringent background rejection than others. Issues of duration, visible energy range, etc.

Same points also hold for the event reconstruction we have thus far.

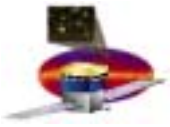


Background Analysis

Ideally (and usually) cut variable distributions are examined several ways, first to check the distribution is sensible and then for implementing the selections:

- 1) **raw** (after triggers, depending on tuple)
- 2) **cumulative** - the distribution of the next cut variable after all previous cuts. Note, this order is **arbitrary** (mostly) and the distributions can be misleading, so....
- 3) **“all but”**: look at each variable distribution with every cut but this one applied.
- 4) **niche areas**: check for effects of each cut in different energy ranges and different angles of incidence. (usually done with merit first)
- 5) **interplay with track quality cuts**: the effects of the track quality cuts and the background rejection cuts are not orthogonal: track quality cuts usually help in background rejection somewhat, and background cuts sometimes help clean up PSF. In one case, an **“all but”** background distribution was empty! Optimize these together.
- 6) **n-dimensionally** (usually 2 at a time) : look for correlations and domains of well-clustered S/B for like variables.

Note that a neural net very well addresses (3), (5) and (6). These cuts are not orthogonal, and there is a better space in which to make them.



Background Analysis (cont)

- try to keep the cuts away from steep areas, or right next to individual events (avoid fine-tuning).
- process is iterative:

With each variable, look at distributions for gammas and background and choose a preliminary cut value.

Scan remaining background events and lost gamma events for adjusting cut and to determine potentially new cut variables.

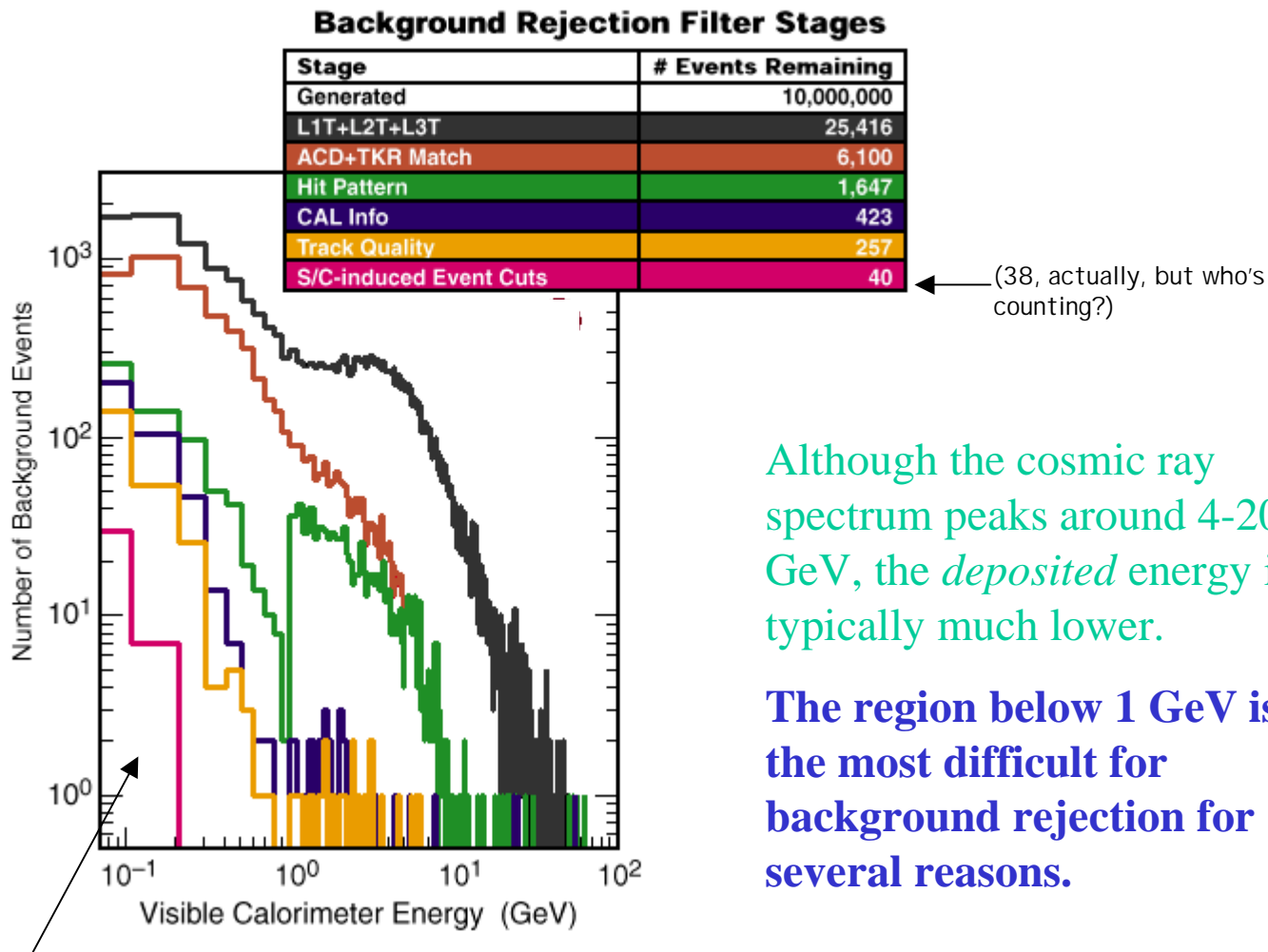
Check for cut redundancy and correlation. Check impact on instrument performance. Merit is particularly useful here.

As a practical matter, some days are spent mostly improving the rejection and other days are spent mostly improving the gamma efficiency.



AO Overview: Visible (CAL) Energy Distributions at Various Stages

Important: at the time of the large data set generation for the AO, the albedo proton flux was not implemented. It *was* implemented for the rate studies, but the energy spectrum was wrong. We *thought* this was pessimistic.



Although the cosmic ray spectrum peaks around 4-20 GeV, the *deposited* energy is typically much lower.

The region below 1 GeV is the most difficult for background rejection for several reasons.

Note, after all selections, no background events remain with visible energy greater than 200 MeV. This wasn't easy.



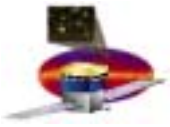
Some references (beyond meeting presentations):

- 1) DoE proposal (1998)
- 2) Note of 9 August 1999 (describes cuts and problem areas fairly well, needs distributions included)
- 3) AO response

however, better documentation is needed and will be done in this round of studies.

STEPS (note: description uses AO tuple variable names)

- The famous VETO_DOCA (only for $CsI_Energy_Sum < 20$) - getting better, but still somewhat *broca*. Needs improvement.
- "Hit pattern" - $Surplus_Hit_Ratio$, with an energy-dependent application.
 $Surplus_Hit_Ratio > 2.25 \parallel (CsI_Energy_Sum > 1 \& \&fst_X_Lyr > 13) \parallel CsI_Energy_Sum > 5.$



Background Analysis Steps (II)

STEPS (continued)

(Will work on making this one continuous in energy with a normalized moment)

- "CAL info" - CsI_Fit_errNrm, CsI_Xtal_Ratio -- **keep events w/no CAL info whenever possible.**

CsI_Xtal_Ratio>0.25||CsI_No_Xtals<1

(CsI_Energy_Sum<1.&&CsI_Fit_errNrm<10.)||CsI_Fit_errNrm<4.||CsI_No_Xtals<1

- "Track quality" (most recent selections developed by Jose)
- "S/C induced event cuts" - designed to remove cosmics whose primary interaction is in the S/C. This is our single largest residual background!

No_Vetos_Hit<1.5 || (CsI_Energy_Sum>1. && No_Vetos_Hit<2.5) || CsI_Energy_Sum>50.

CsI_eLayer8/CsI_Energy_Sum<0.08 || CsI_eLayer1/CsI_Energy_Sum>0.25 ||

CsI_Energy_Sum>0.35||CsI_No_Xtals<1

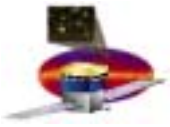
CsI_moment1<15. || CsI_moment1<80.&&CsI_Energy_Sum>0.35||CsI_Energy_Sum>1.||

CsI_No_Xtals<1

CsI_Z>-30.||CsI_No_Xtals<1 ← Surprisingly efficient even at high energy

CsI_No_Xtals_Trunc<20.||CsI_Energy_Sum>75.||fst_X_Lyr<12 ← Only needed in BACK

Quality_Parm>10 (composite track quality parameter, cut effective against low-energy stubs from splash-up)



Background Analysis To Do

Next steps:

- Use better background flux model. Low energy p and e albedo must be dealt with. Demonstrate high-energy electron rejection.
- Improve low energy Aeff, work on inefficiencies (Surplus_Hit_Ratio, CsI_Fit_errNrm)
- VETO_DOCA: needs work. Mainly a tracking issue. Seed tracks with hit tiles, track quality selections for loop.
- Document, put correct implementation into merit.
- Simplify analysis (make prettier, simpler). Bring in neural net. More sophisticated tracking (downward “ Λ ”) & CAL pattern recognition. (post-PDR)
- Further improvements in rejection (at time of AO, integrated residual background rate was $\sim 6\%$ of extragalactic diffuse rate). Also, study background rate differentially (by visible energy bin). More work on upward-going energy events.
- Evaluate impact of limited set of instrument failure modes (see end of talk)



Data set generation planning

- **Main challenge is generating backgrounds ~ 50M events**
 - At 0.1 sec/event, would take **58 days** to generate on 1 PC
 - Use SLAC batch (Linux/Solaris) system, requires **1 week**
 - **Linux build of pdrApp now running (7/24/01)**
 - Disk space (800 GB fileserver) is in place
 - DataManager ready to generate and book-keep events
- **Since early June, we have been generating increasingly larger photon and background data sets:**
 - iterate to find the bugs and missing pieces (inspect sets of events, study distributions, effects of cuts, use tools, ...)
 - complete and exercise the infrastructure
 - **Plan to generate the large batch of background events during the week of 13 August**

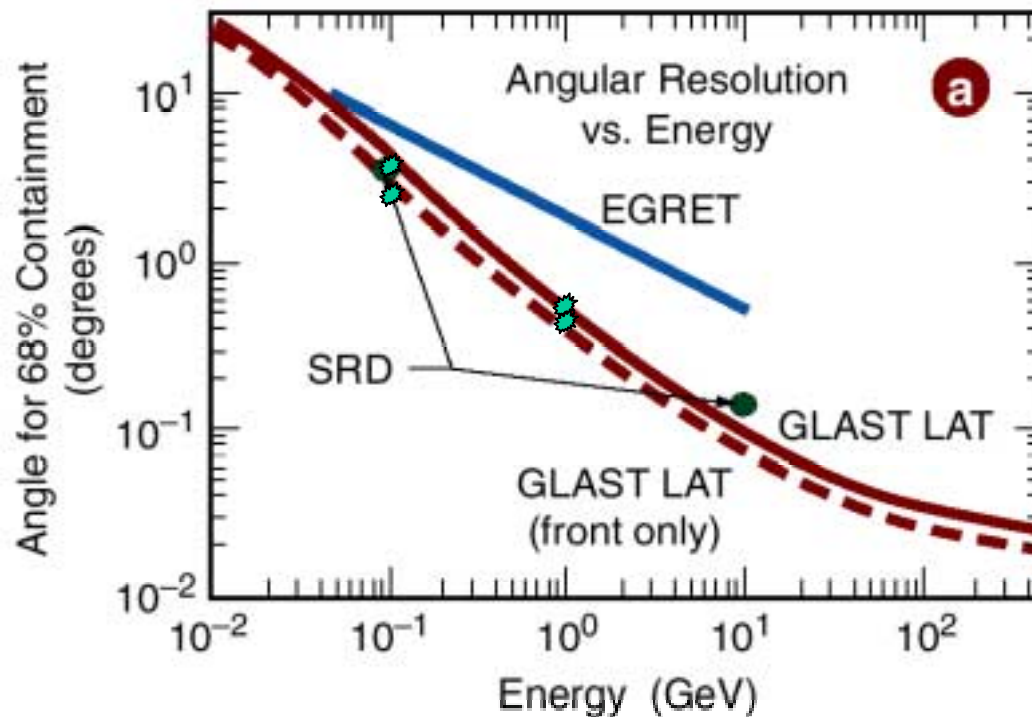


Results: status

- First peek at PSF looks ~not terrible (much to do!)

	total 68%	total 95%	front 68%	front 95%	back 68%	back 95%
100 MeV normal inc.	3.44		2.3	4.45	5.8	
1 GeV normal incidence	0.59	1.87	0.47	1.62	0.84	2.08

results are
pre-pre-pre-
preliminary!

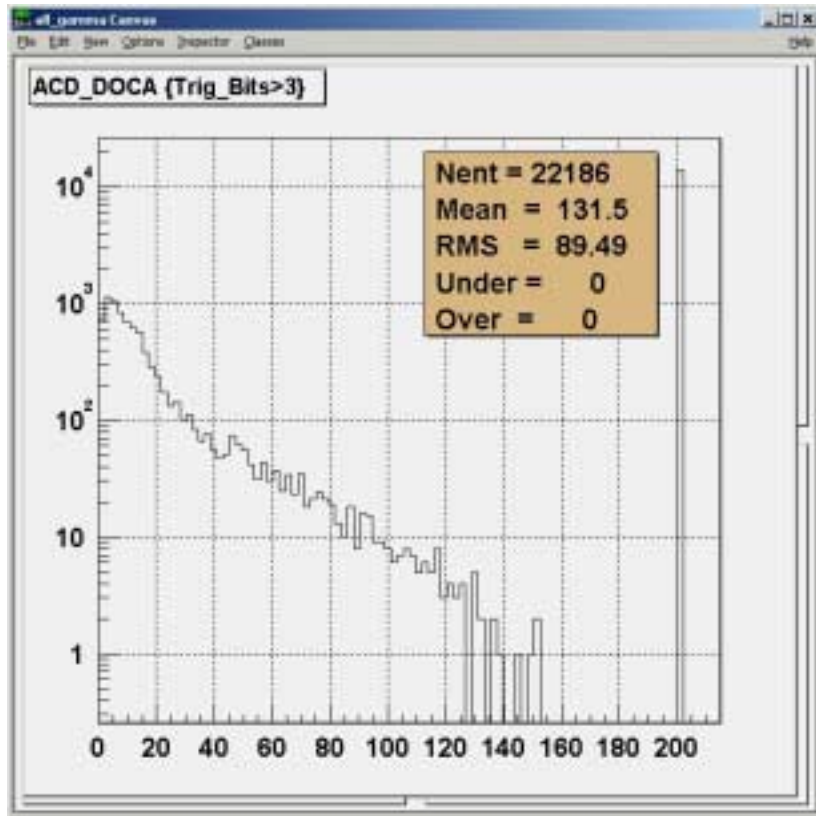


Note: normal incidence PSF is not particularly relevant for physics – just a well-defined comparison point for performance changes and code checking. “Normal” in Table means 0-8 deg bin.

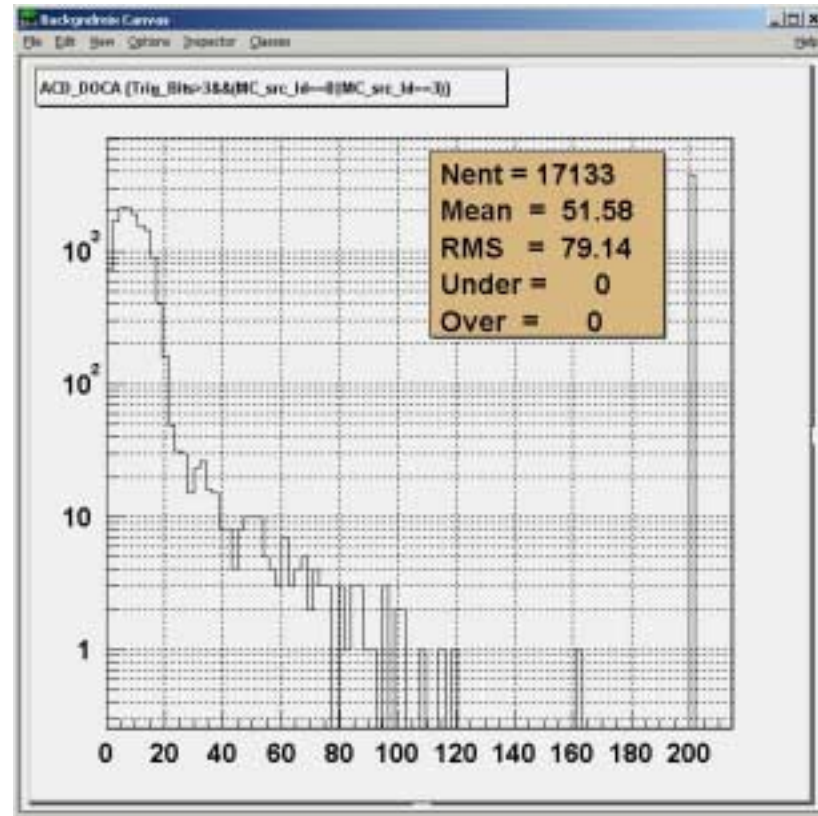


Results: status

- **Effective area calculation is still not ready. This requires every distribution to be correct (for background selections). Still working on these – tools are in place to do this.**



all_gamma



backgndmix



Failure Modes Modeling

- Now part of our regular planning (see, e.g., study on using ACD as L1T throttle). Loss of functionality will be handled in the simulation as an “after-burner” analysis on the large data set. Difficult part is putting awareness into the reconstruction (as we would if failure really happens) – results for PDR will be rudimentary.
- **ACD: loss of a single tile in three locations (front corner, front middle, side)**
- **TKR+CAL: loss of a corner tower; loss of a central tower**
- Not possible to explore the infinite combinatorics. Need best judgment of the subsystem managers and system engineering team. Still time to put in your requests prior to PDR/Baseline review, but please keep it limited to key design questions.



Next Steps

- review implementation of all fluxes, choose “avg” and “max” spectra; first check of L1T rates (by 1 August).
- fix remaining tuple variables (by 10 August)
- one more check of geometry with subsystems, r.l. audits (by 6 August)
- exercise SLAC batch facility, check random number service implementation, event ID, DataManager, write/readback/re-analyze events. (happening now, results reported by 31 July)

Schedule to start mass generation on 13 August.

- provides full month of September for background rejection re-analysis and PSF tail improvements, plot generation.