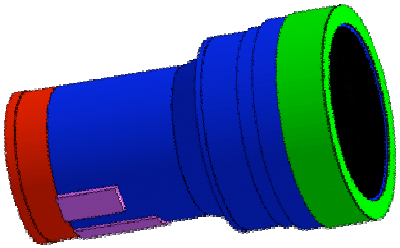
GBM Simulation and Instrument Response



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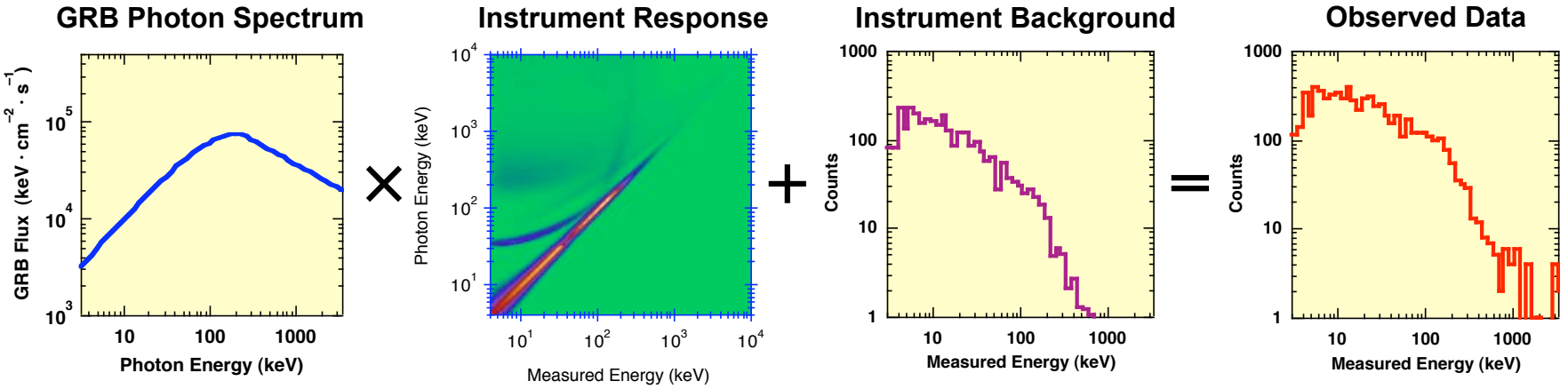
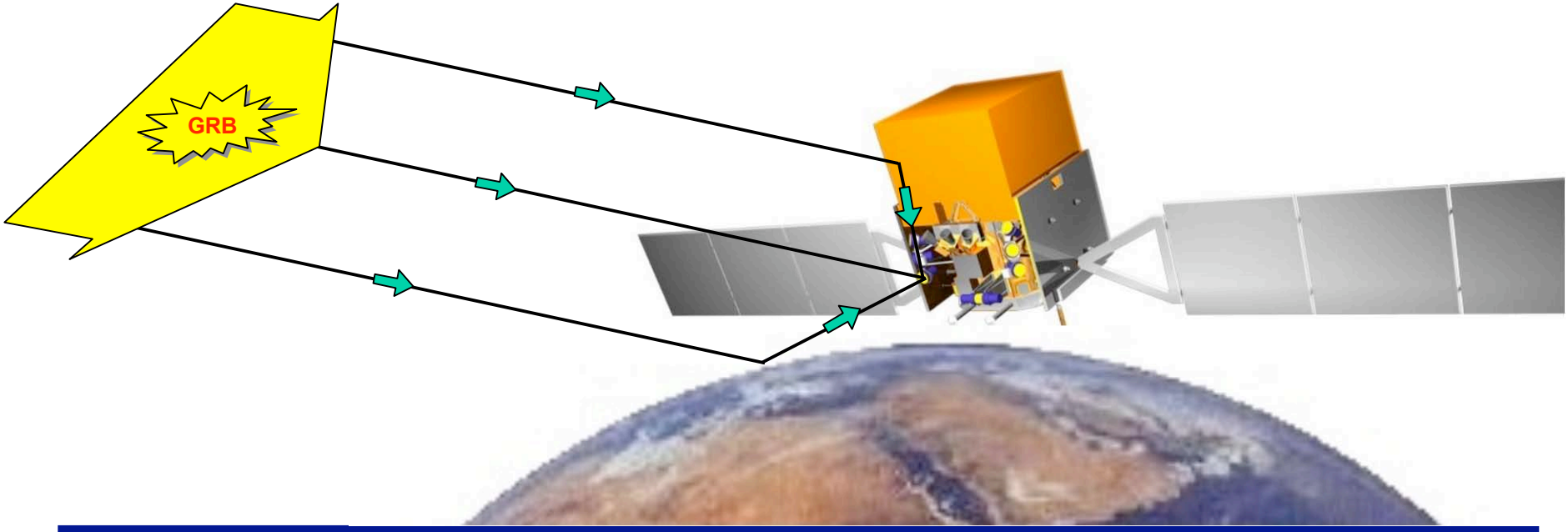
GBM Detector / Instrument Response

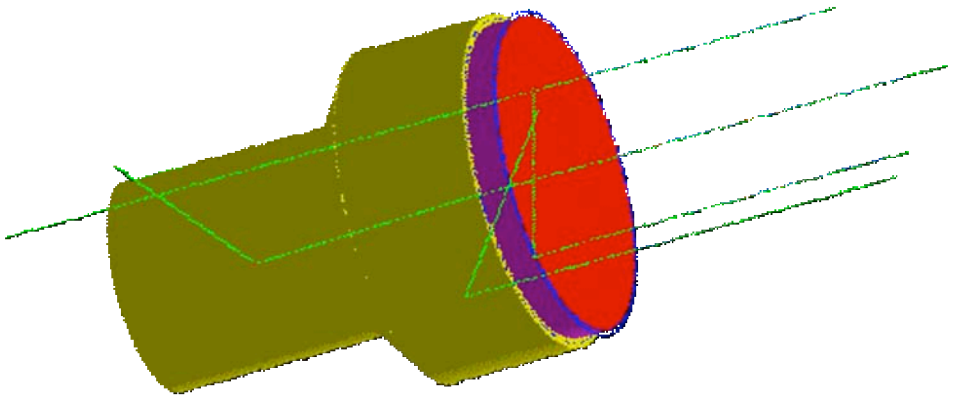




Simulation and Detector Response Software

- **Definition:** Multi-purpose software suite that computes the physical and instrumental response of the GBM instrument system
  - **Primary purpose**: generate *detector response functions* critical to the analysis of flight science data
  - **Other uses**: instrument design; interpretation of calibrations; design of flight and ground analysis algorithms & s/w

- **Technique:** Numerical simulation — Monte Carlo radiation transport
  - ***Verified through, and incorporating results from experimental calibration***



Major Components

- Mass model (geometry + composition)
- Incident particle distributions
- Radiation transport physics
- Instrumental/calibration effects
- DRM database
- DRM synthesizer/generator

Key Functional Specifications

GBM SIM/DRM S/W Functional Specs

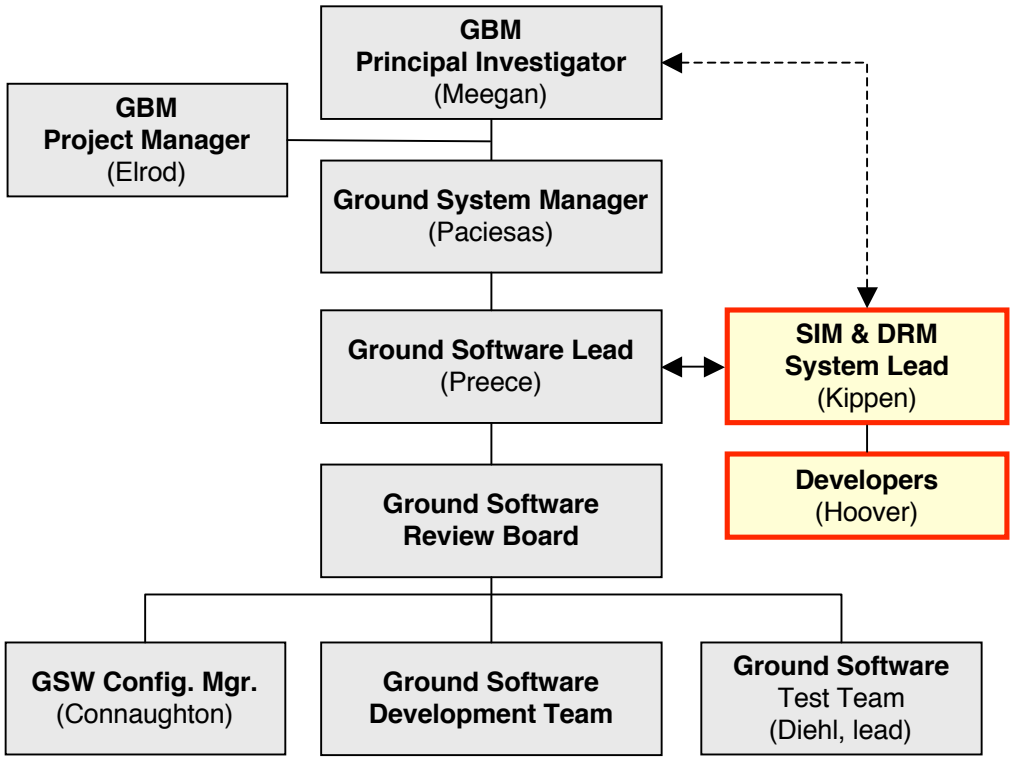
GBM-SPEC-1025 (reviewed at GSW PDR)

GBM IODA S/W Functional Specs

GBM-SPEC-1031 (reviewed at GSW PDR)

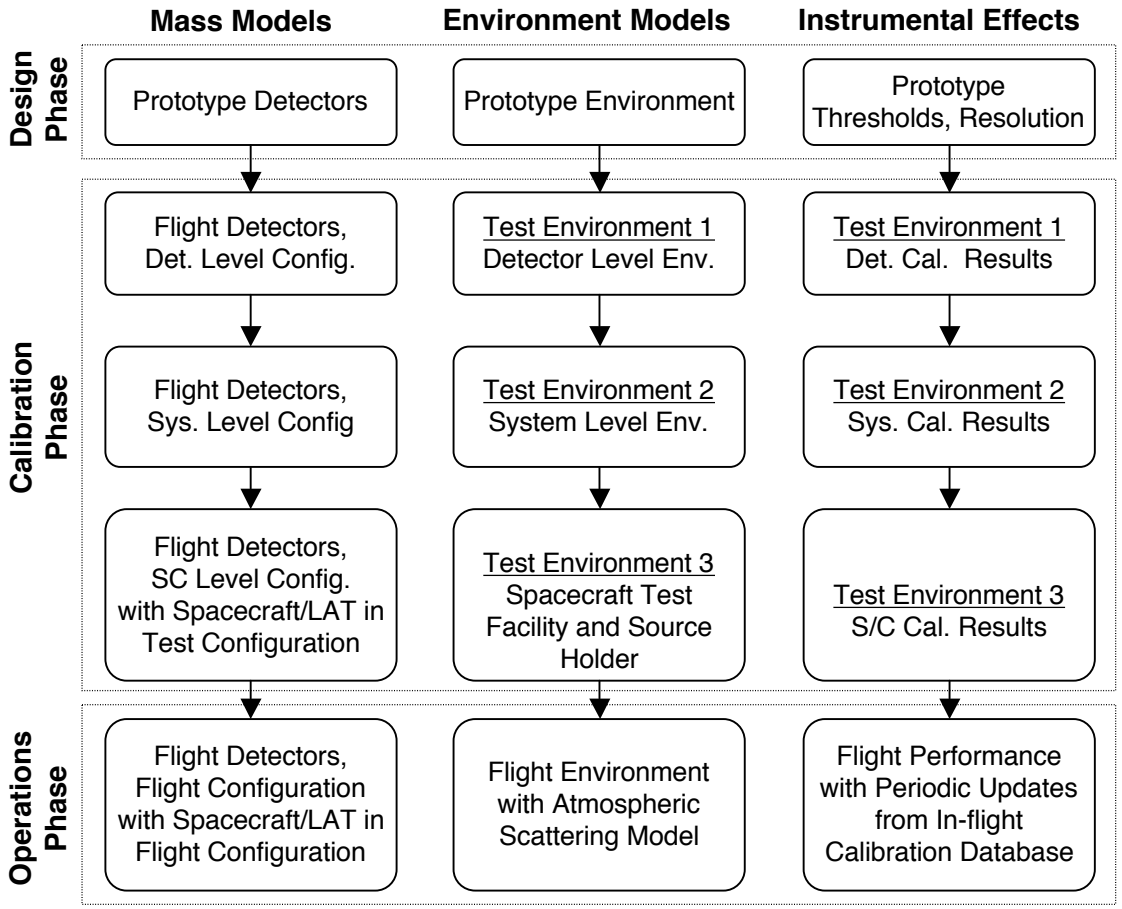
- **Complete and accurate interaction physics (included in core simulation package — GEANT4)**
- **Accurate mass models, environment models, and instrument models (but not overly complex)**
- **Later stages of development require S/C models (including LAT model)**
- **Verification through comparison with experimental data**
- **Final DRMs must include contribution from atmospheric scattering (+direct detector and S/C scattered response)**
- **GLAST S/C will have rapid slew capability — different DRMs are required whenever aspect changes by > 1°**
- **DRM generation s/w is part of GBM IODA s/w and subject to the same requirements for standards, configuration control, etc.**

Development Organization



- SIM/DRM software designed and developed at LANL in collaboration with GBM PI and GSW lead
- Development process falls under GSW Development Plan (GBM-PLAN-1023)
- Final products (s/w and data) delivered to GBM PI at NSSTC (also available to MPE and other interested parties)

Phased Software/Model Development



- **Software and models require cross-validation with calibration data**
- **Three phases of SIM/DRM sw/model development**
  - **Design**
    - **Simulate prototype detectors**
  - **Calibration**
    - **Simulate three levels of calibration/test**
      - *Detector level*
      - *GBM system level*
      - *On-spacecraft level*
  - **Operation**
    - **In-flight configuration appropriate for analysis of science data**
    - **DRM generation**

Implementation: GBM REsponse Simulation System

GRESS

gbmsim
GBM instrument physical simulator

calsim
Instrumental/calibration effects & data packager

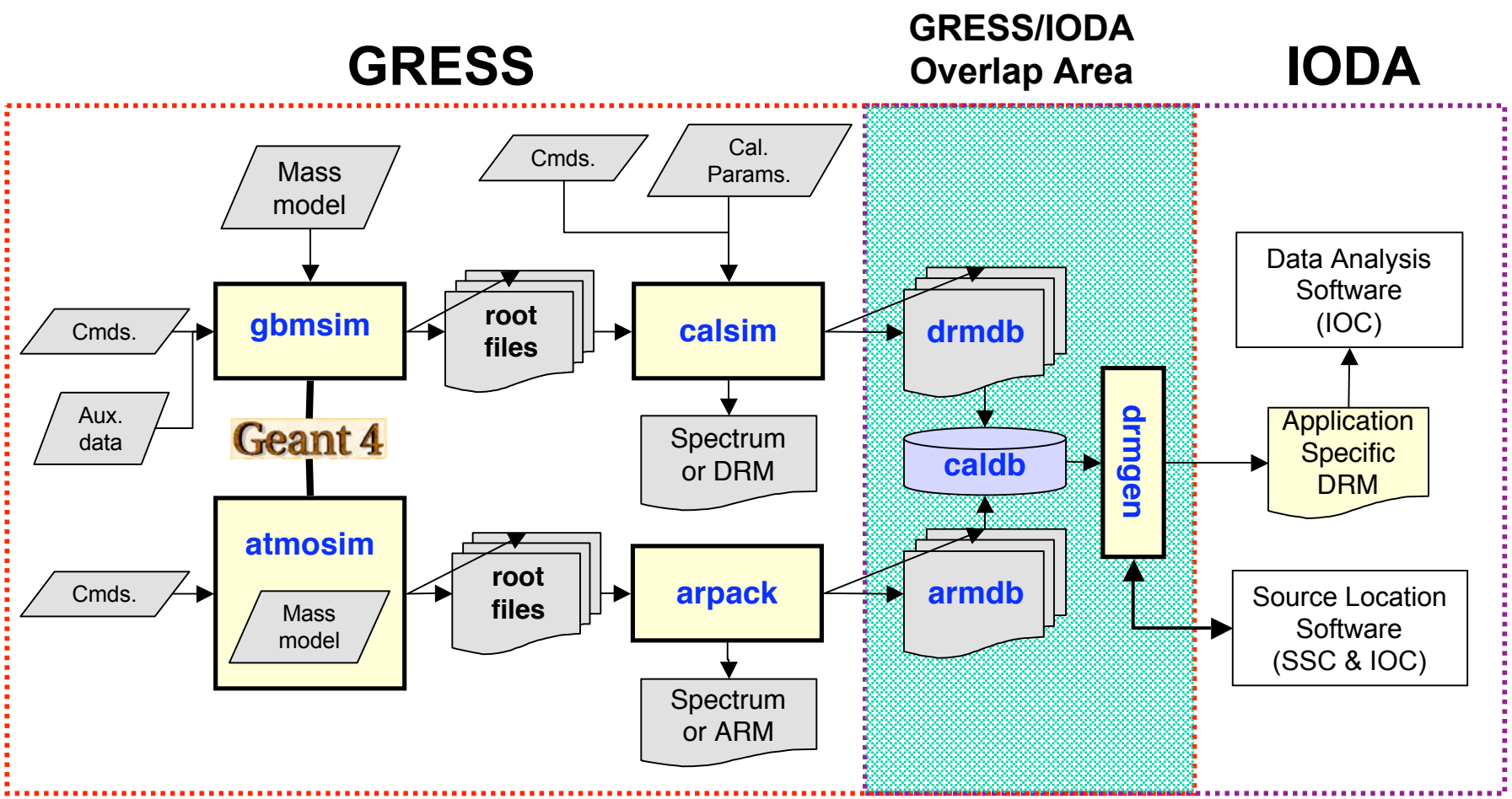
atmosim
Atmospheric scattering simulator

arpack
Atmospheric scattering data packager

drmgen
Application-specific DRM generator

- **Integrated package that will encompass all GBM instrument response software and data needs**
- **Configuration controlled as a single deliverable package with component software/data modules**
- **All packages (and their dependencies) use GNU compilers — mainly g++**
- **All data files have headers with detailed version & job tracking data**
- **Final phase package will be a subset of the GBM IODA software, cf. GBM-SPEC-1036 (GSW Arch. Design)**

Implementation: GBM REsponse Simulation System

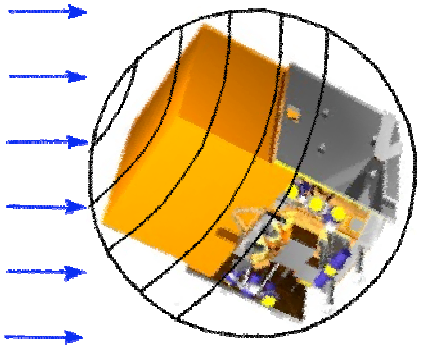


Note: a separate, reduced DRM/ARM database is used for BAP software (based on same simulation data)

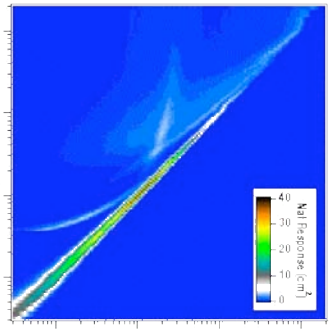
How – *Direct* Instrument Response

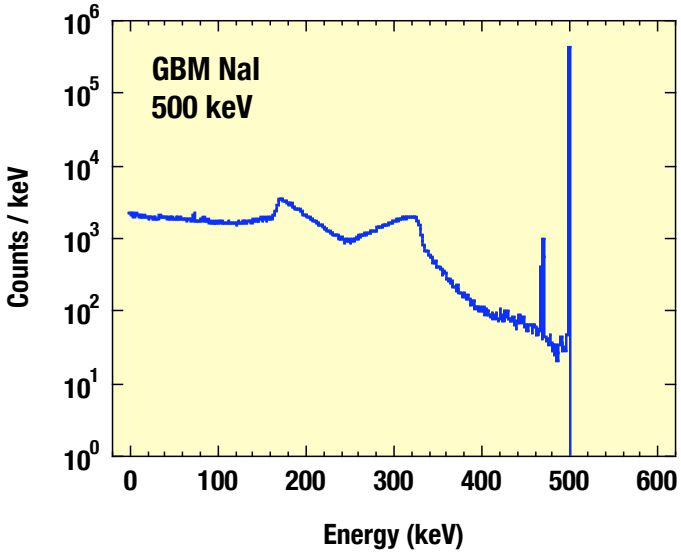
gbmsim — Raw "physical" data

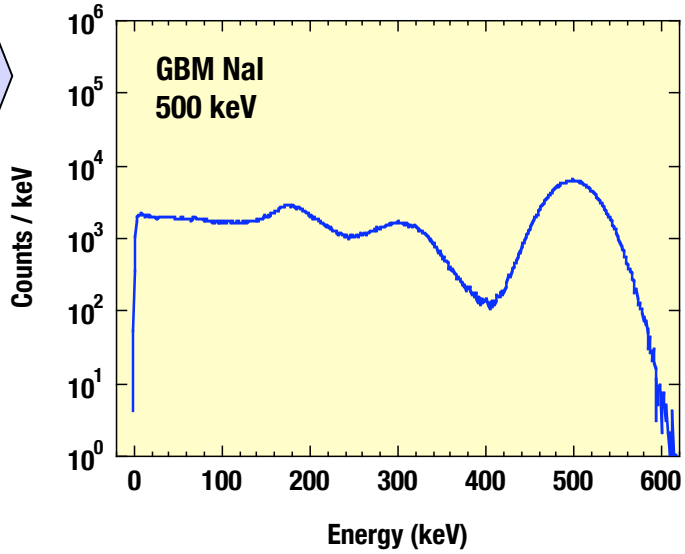
calsim — Packaged, instrument-like data



$$\Re_{\mathrm{D}}\left(\vartheta,\varphi,E_{\gamma},E_{m}\right)$$

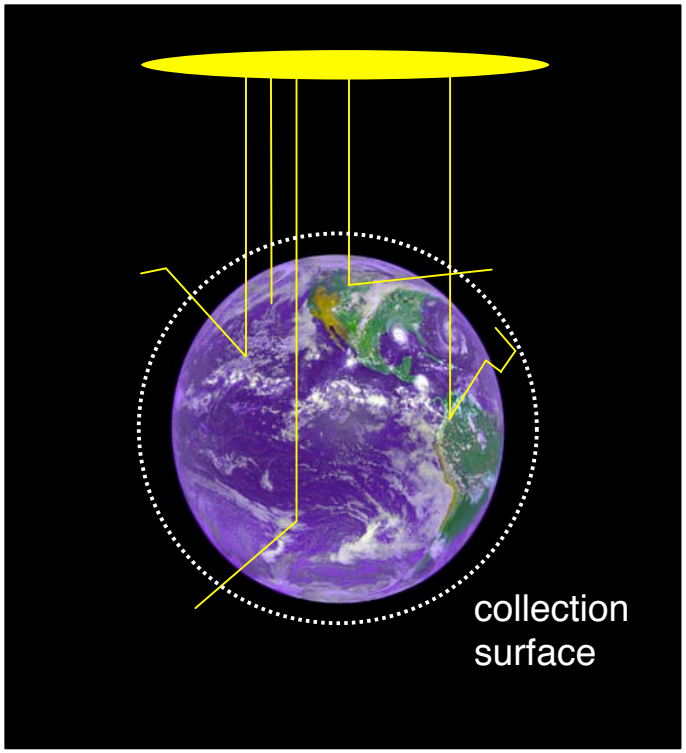






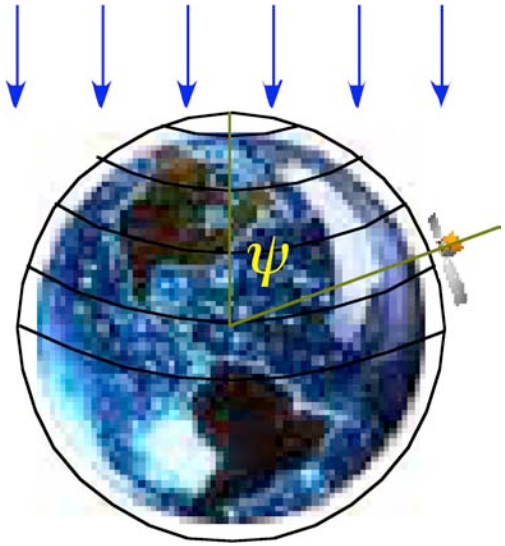
How – Atmospheric *Scattered* Response

atmosim — Raw "physical" data



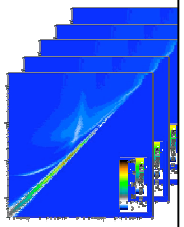
NRLMSISE-2000 atmospheric model used to create concentric shell mass model

arpack — Packaged data matrix



$$\Re_{\mathrm{A}}\left(\psi, A, \vartheta', \varphi', E_\gamma, E_s\right)$$

How — Putting it all Together

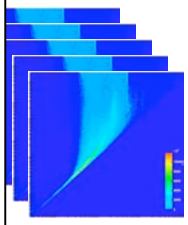


drmdb — direct response db

$$\Re_{\mathrm{D}}\left(\vartheta,\varphi,E_{\gamma},E_{m}\right)$$

armdb – Atmos. Resp. db

$$\Re_{\mathrm{A}}\left(\psi,A,\vartheta',\varphi',E_{\gamma},E_{s}\right)$$



drmgen — burst-specific response generator

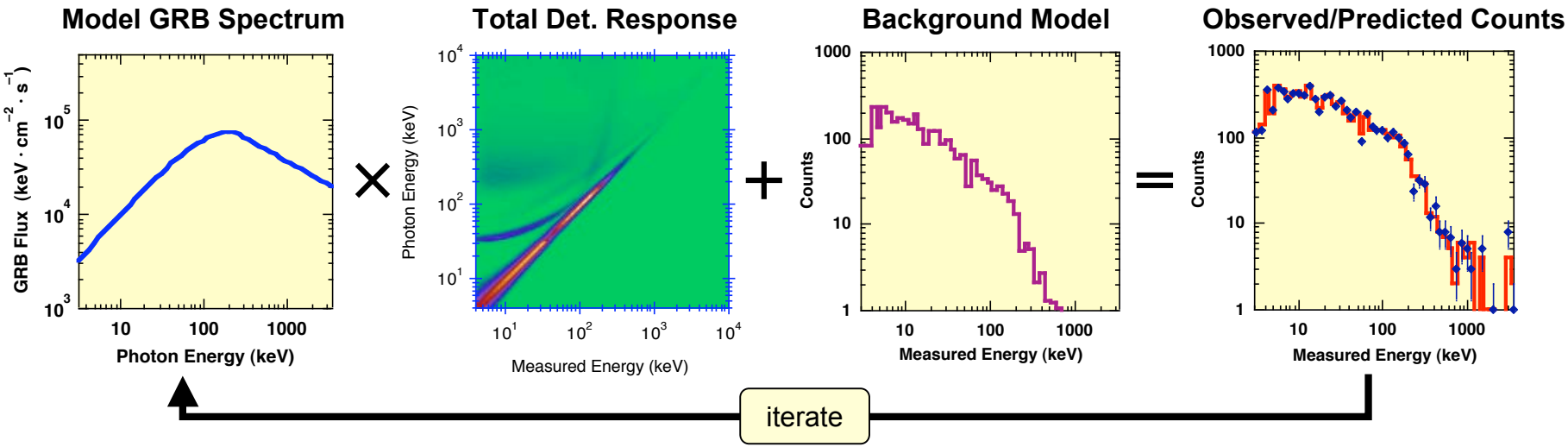
$$\Re_{\mathrm{T}}\left(\boldsymbol{E_{\gamma}},\boldsymbol{Ch}\right)=\Re_{\mathrm{D}}\left(\vartheta_{\mathrm{o}},\varphi_{\mathrm{o}},E_{\gamma},Ch\right)+\iint\Re_{\mathrm{A}}\left(\psi_{\mathrm{o}},A_{\mathrm{o}},\vartheta',\varphi',E_{\gamma},E_{s}\right)\cdot\Re_{\mathrm{D}}\left(\vartheta',\varphi',E_{\gamma},Ch\right)\,\mathrm{d}\Omega'$$

Data Analysis – spectral fitting and localization

$$C_{i}=\int f\left(E_{\gamma}\right)\cdot\Re_{\mathrm{T}}\left(E_{\gamma},Ch\right)\,\mathrm{d}E_{\gamma}$$

How — Response used for Spectral Analysis

rmfit/xspec — spectral model "hypothesis testing"



- Parameterized spectral models
- Built-in models or "custom" models

- From drmgen
- Updated automatically when S/C pointing changes

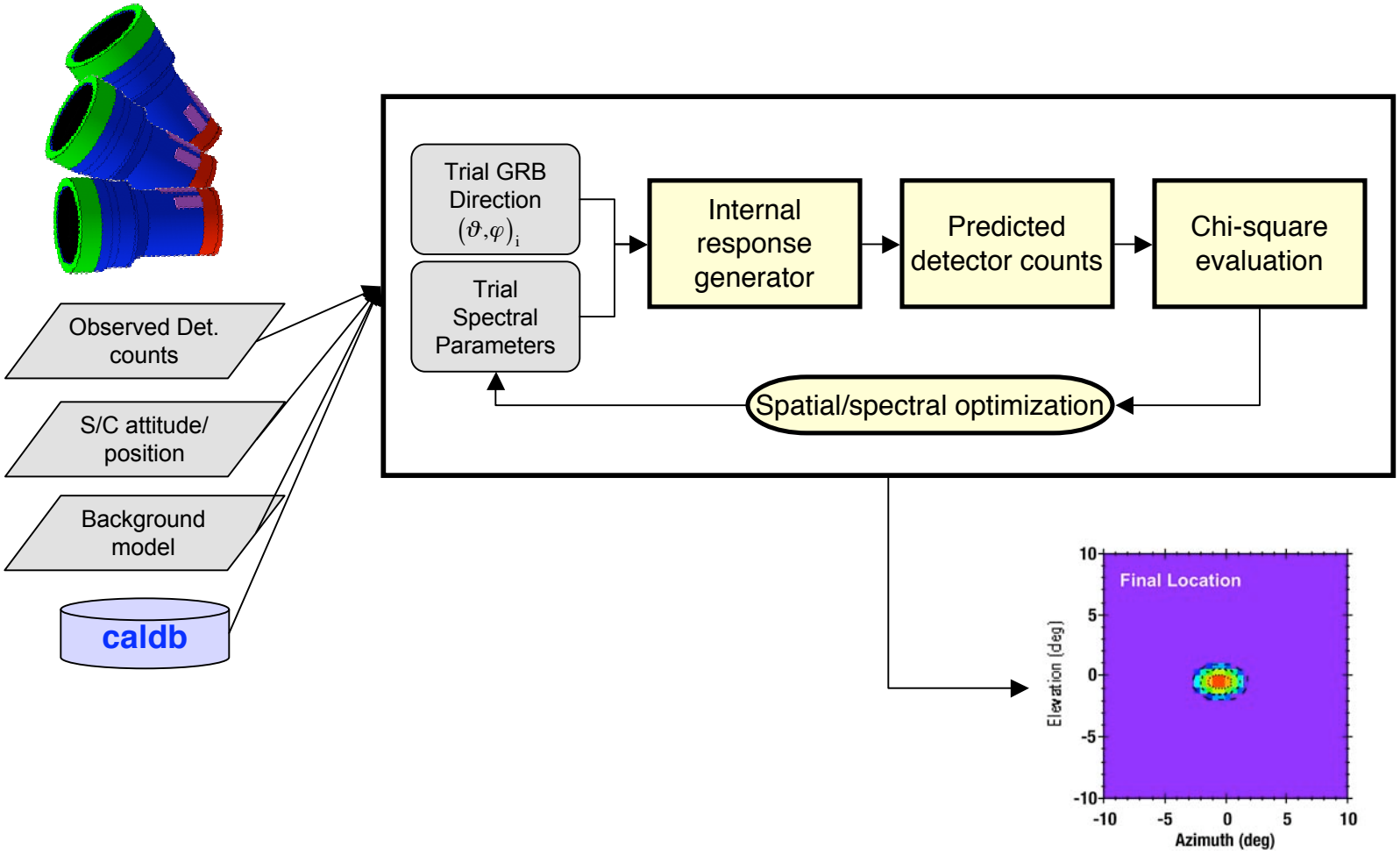
- Empirical, time-dependent model based on data before and after burst

- Observed and predicted counts compared via test statistic
- Chi-squared (Gaussian) or Poisson log Likelihood
- Optimize test Stat. iteratively

Process is extended to simultaneously include multiple GBM detectors (Incl. NaI and BGO) or other instruments (e.g., LAT, Swift, etc.)

How — Response used for Localization

Simultaneous spatial/spectral model “hypothesis testing”



Development Status

- SIM/DRM development is affected by:
  - **Delivery of GBM detector design data/drawings (received June 2004, three months behind original schedule)**
  - **Delivery of GLAST spacecraft design data/drawings (expected July 2004, three months behind original schedule, initial delivery August 2004)**
  - **Schedule of GBM calibrations**
    - **Required to verify SIM/DRM s/w and models**
    - **Detector level (MPE), system level (NSSTC), spacecraft level (Spectrum) — all slipped due to launch slip.**

- Development status:
  - **Preliminary versions of GRESS software complete (several months ahead of schedule)**
  - **Detector model development nearing completion (3 months behind)**
  - **Spacecraft model development starting (3 months behind)**
  - Result: able to meet required delivery schedule

SIM/DRM Revised Delivery Schedule

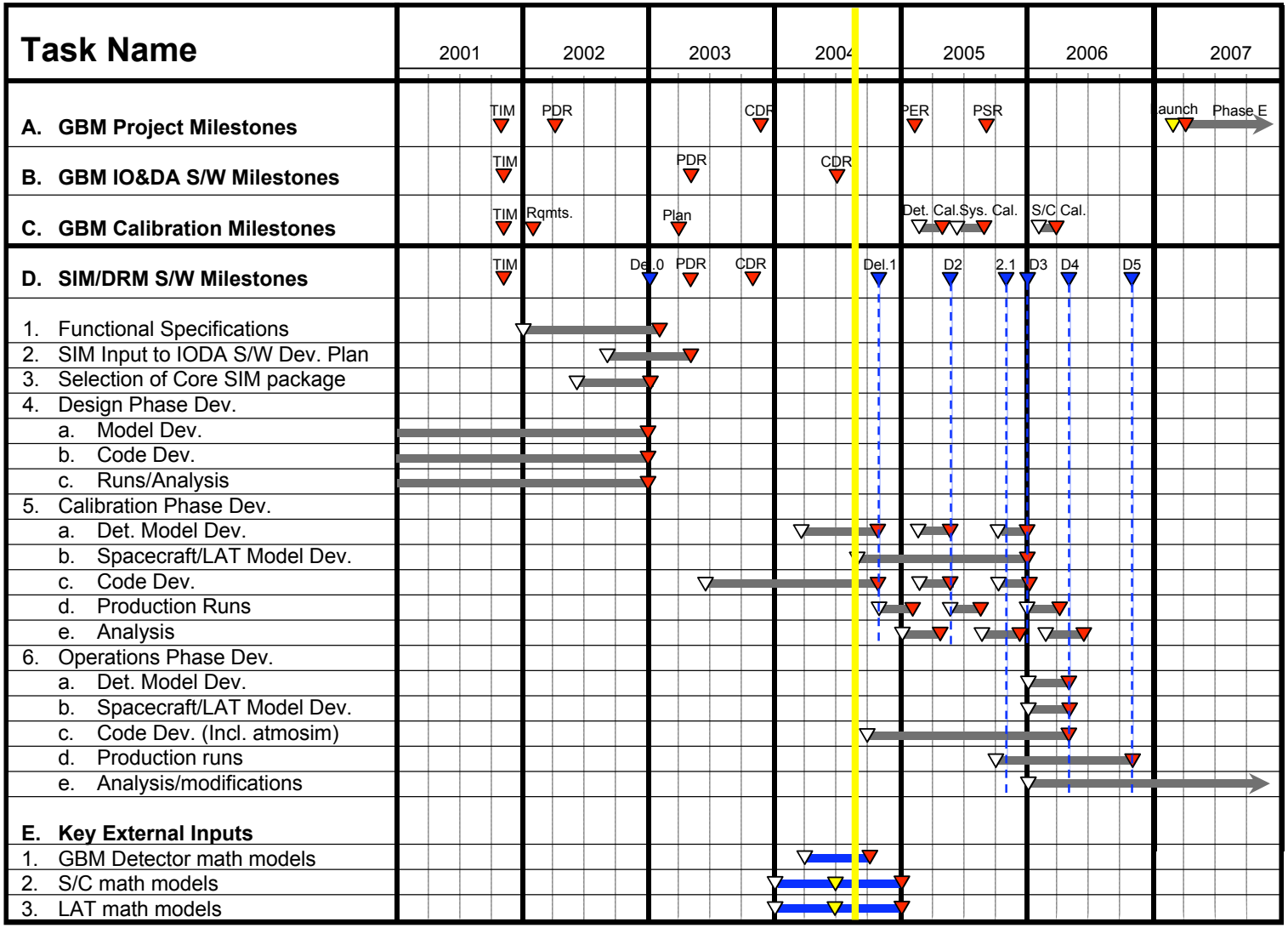
Stable since GBM System CDR June 2004

Milestone	Date†	Driver	Date
SIM/DRM Delivery 1 (Det.-level s/w & models)	Nov. 1, 2004 (Δ+4 mo)	Verify s/w & models with GBM detector-level calibrations	Feb. 2005 – Mar. 2005
SIM/DRM Delivery 2 (Syst.-level s/w & models)	Jun. 15, 2005 (Δ+3 mo)	Verify s/w & models with GBM system-level calibrations	Jul. 2005 – Sep. 2005
SIM/DRM Delivery 2.1 (preliminary CALDB/DRM)	Nov. 1, 2005 (new)	Support IODA Release 2.2 & 2.3, and Data Challenge 3	Nov. 1, 2005; Dec. 1, 2005
SIM/DRM Delivery 3 (S/C-level s/w & models)	Jan. 2, 2006 (Δ+3 mo)	Verify s/w & models with GBM spacecraft-level source survey	Feb. 2006
SIM/DRM Delivery 4 (Ops. phase s/w & models)	Apr. 14, 2006 (no change)	Support IODA Release 3 (launch-ready software)	Sept. 1, 2005
SIM/DRM Delivery 5 (Final DRM/CALDB database)	Nov. 1, 2006 (no change)	Support Phase E science/Ops.	Post-launch

* All deliveries from LANL to NSSTC

† Schedule changes from ground s/w CDR reflect changes in the GBM calibration schedule (affected by launch slip)

SIM/DRM Schedule



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