High Energy Gamma Rays Physics with GLAST

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Outline

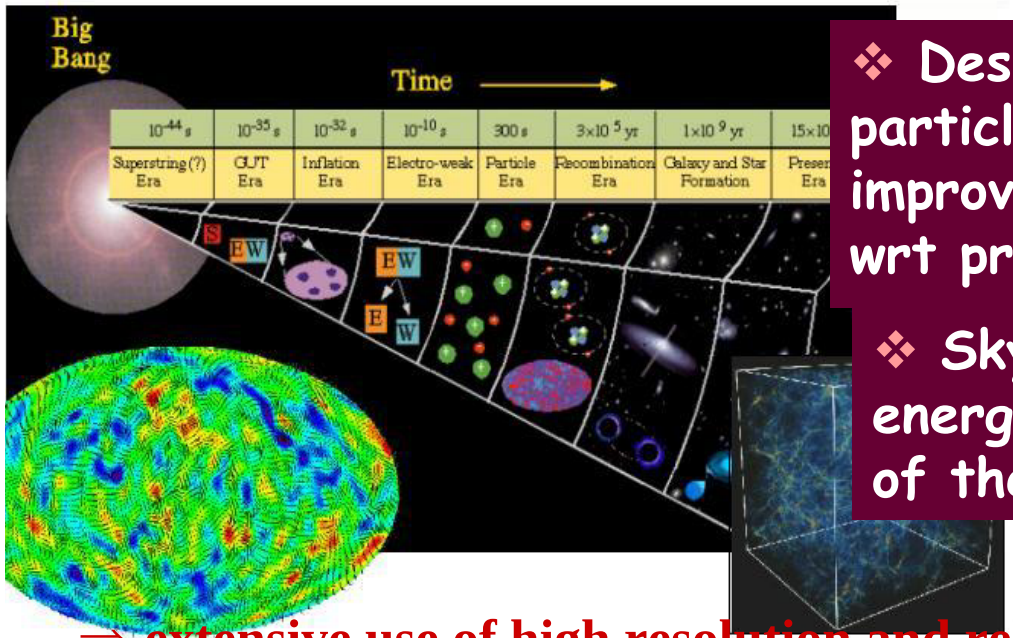
- Motivations and goals
- Overview of the GLAST Observatory
  - (Two instruments GBM and LAT)
- GLAST SCIENCE
  - Instrument capabilities
  - Physics topics:
    - Particle accelerations
      - AGN's
      - Supernova Remnants
    - GRB's
    - Dark Matter searches and New Physics
- Status of the mission
- Conclusions

GLAST : Motivations and Goals

Study of the origin of the Universe and its evolution :

strong connection between Astrophysics and HEP with many areas of collaboration

GLAST is a partnership of HEP and Astrophysics communities sharing scientific objectives and technology expertise:



- Designed to use very performant particle detectors order of magnitude improvement in sensitivity and resolution wrt previous missions
- Sky survey in the 10 keV – 300 GeV energy range (poorly observed region of the electromagnetic spectrum)

⇒ extensive use of high resolution and reliable particle detectors now possible in space after long and successful experience in particle physics

The GLAST mission

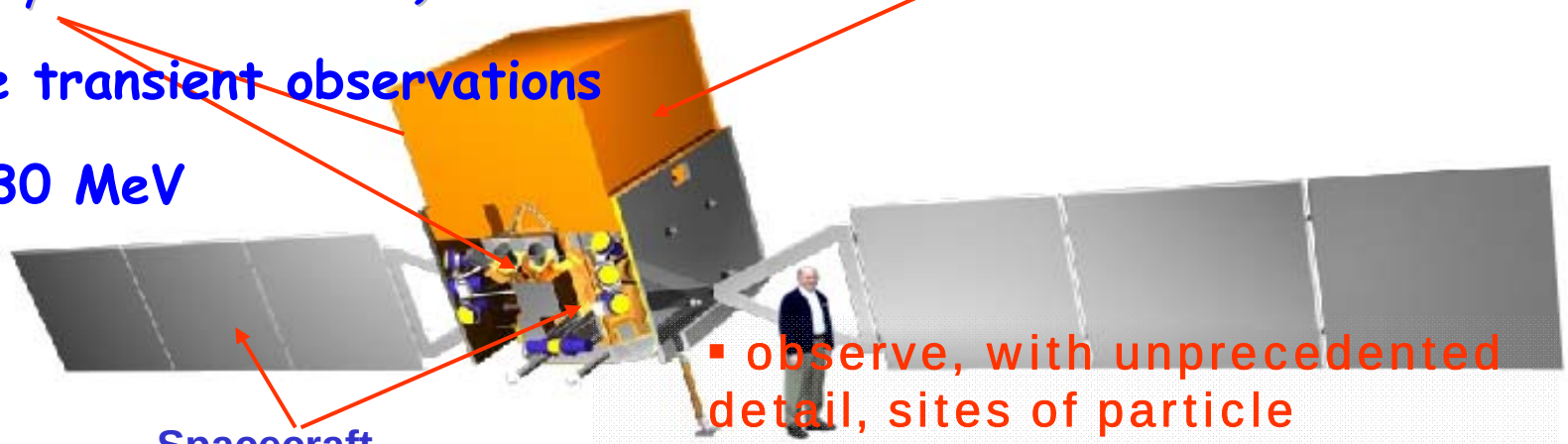
- High energy Gamma Ray observatory 2 instruments:
  - --Large Area Telescope (LAT)
  - --Gamma Ray Burst Monitor (GBM)

(Gamma Ray Burst Monitor) GBM:

correlative transient observations

~5 keV – 30 MeV

LAT: ~20 MeV - >300 GeV



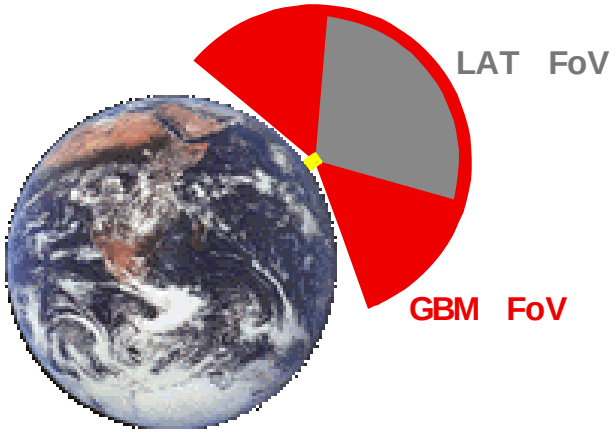
Spacecraft

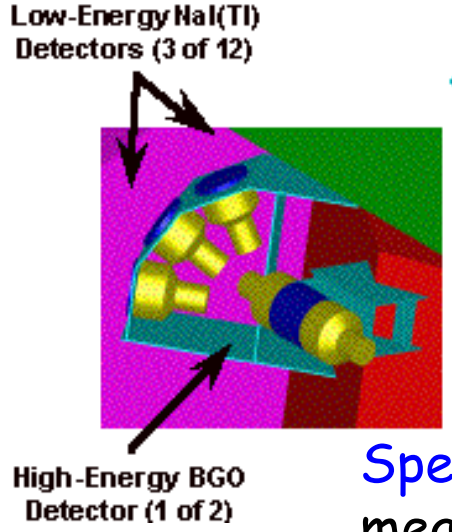
- -Launch August 2007
- -Delta II class
- -Orbit 565 Km, 28.5° inclination
- -95 min orbit period
- -Lifetime 5 years (minimum)
- -Observing mode:
  - All sky survey
  - Pointed observations

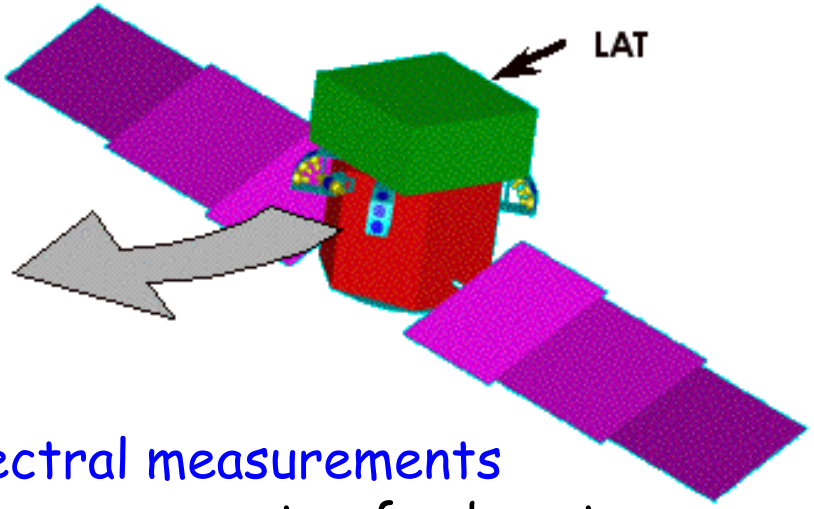
- observe, with unprecedented detail, sites of particle acceleration in the Universe
- explore Nature's highest energy processes (10 keV – 300 GeV)
- answer to important outstanding question in high energy astrophysics raised by results from EGRET

Glast Burst Monitor

NaI and BGO counters exposed to the entire sky







Spectral measurements
measures spectra for bursts
connects with LAT measurements

NaI crystals (12)
low energy spectral coverage
~10 KeV - ~1 MeV
rough burst location

BGO crystals (2)
High energy spectral coverage
~150 KeV – ~30MeV

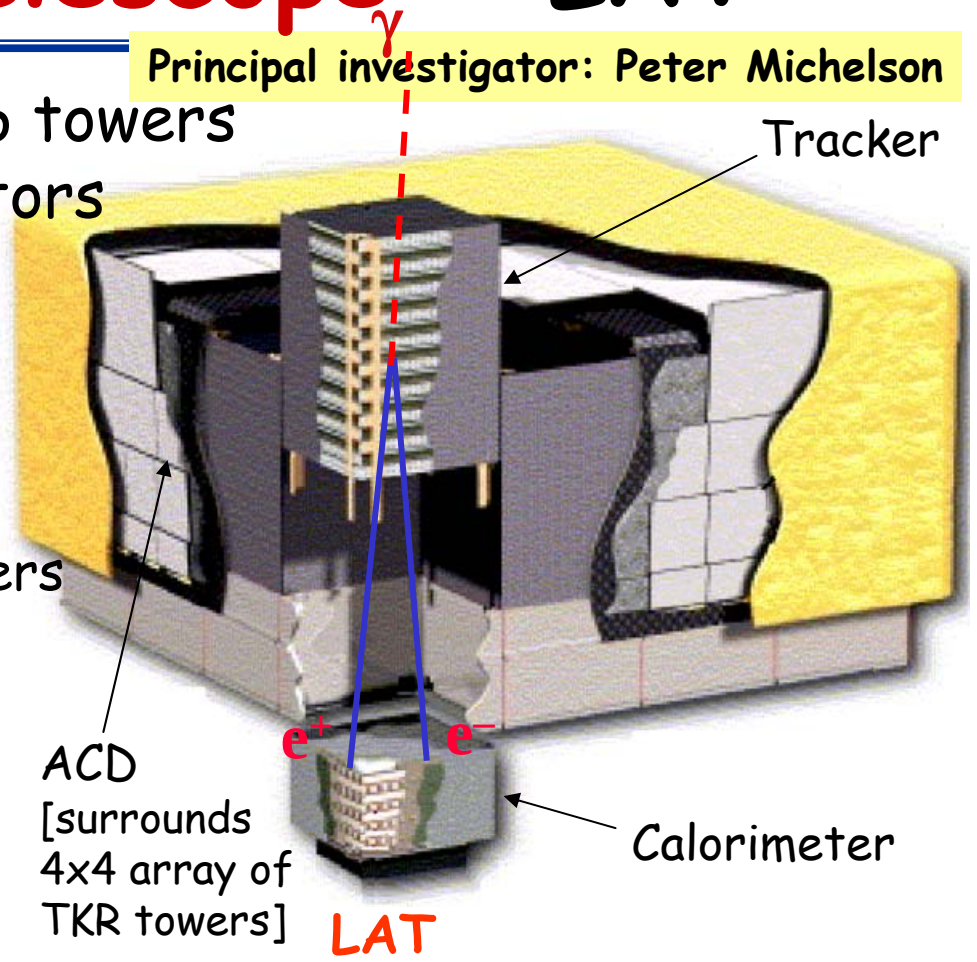
Afterglows in GRB
Wide Sky Coverage (8sr)
Autonomous repoints for exceptionally bright bursts outside LAT field of view

Connection to the ground network of telescopes
Bursts alerts to the LAT and ground Telescopes within seconds

Large Area Telescope - LAT

Principal investigator: Peter Michelson

Pair conversion telescope of 16 towers
Surrounded by plastc scintillators



Silicon Microstrip Tracker

~80m^2 of silicon
8.8 x 10^5 readout channels
strip pitch 228 μm
xy layers interleaved with W converters
Total Rad Lenght ~1.5 X_0

Calorimeter

Hodoscopic array
1536 CsI(Tl) crystals in 8 layers
Total Rad Lenght ~8.5 X_0

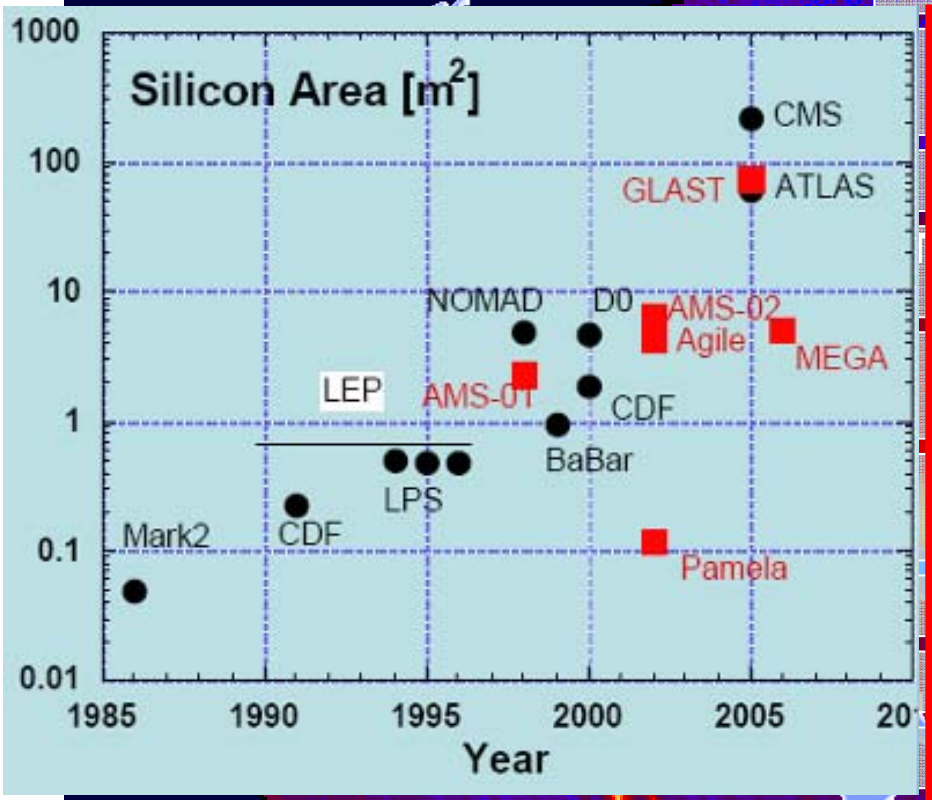
Anti coincidence detector

89 scintillator tiles
segmented design

3000 kg, 650 W (allocation)
1.8 m x 1.8 m x 1 m
20 MeV - 300 GeV
Currently there is no other telescope covering this range

TRACKER

INFN/ASI responsabilities for the LAT-TKR construction



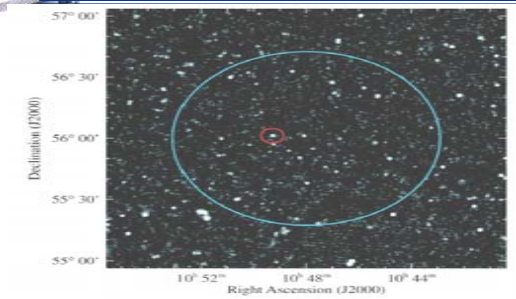
SSD procurement and test

We have met the very ambitious goal of building and qualifying for space in one year the LAT tracker, by far the largest silicon tracker ever built!

This result has been accomplished thanks to the dedication of the INFN teams, the coordination between ASI/INFN and the pool of Italian industries involved.

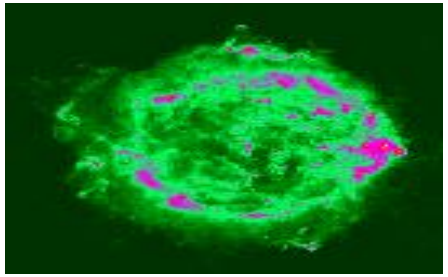
(Alcatel Alenia Space)

GLAST science - the sky above 100 MeV

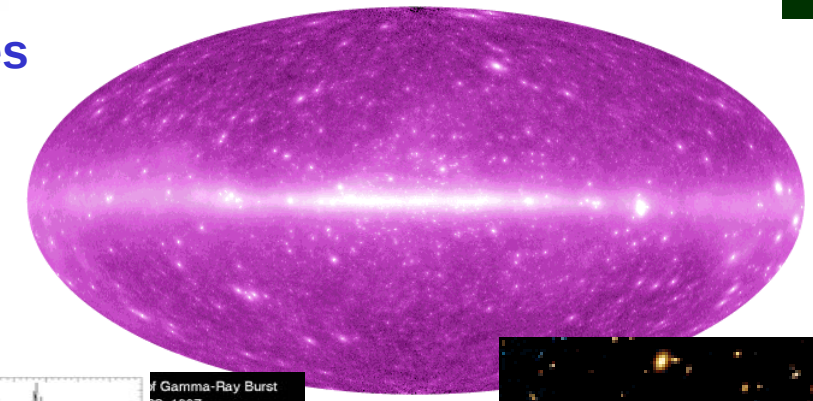


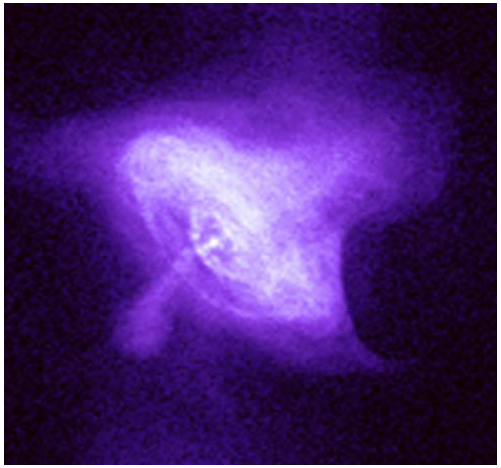
Unidentified sources

Active Galactic Nuclei

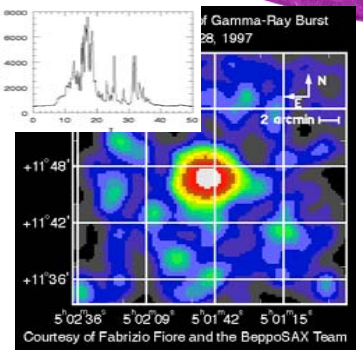


Cosmic ray acceleration

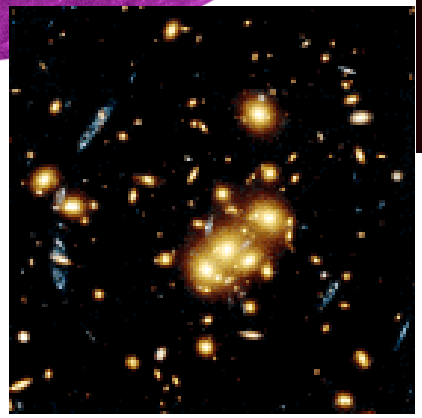




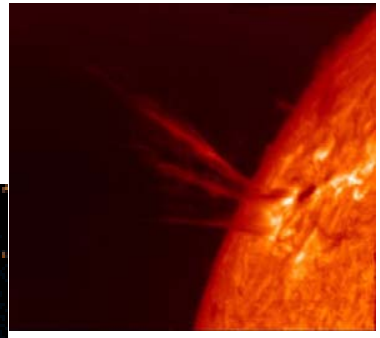
Pulsars



Gamma Ray Bursts



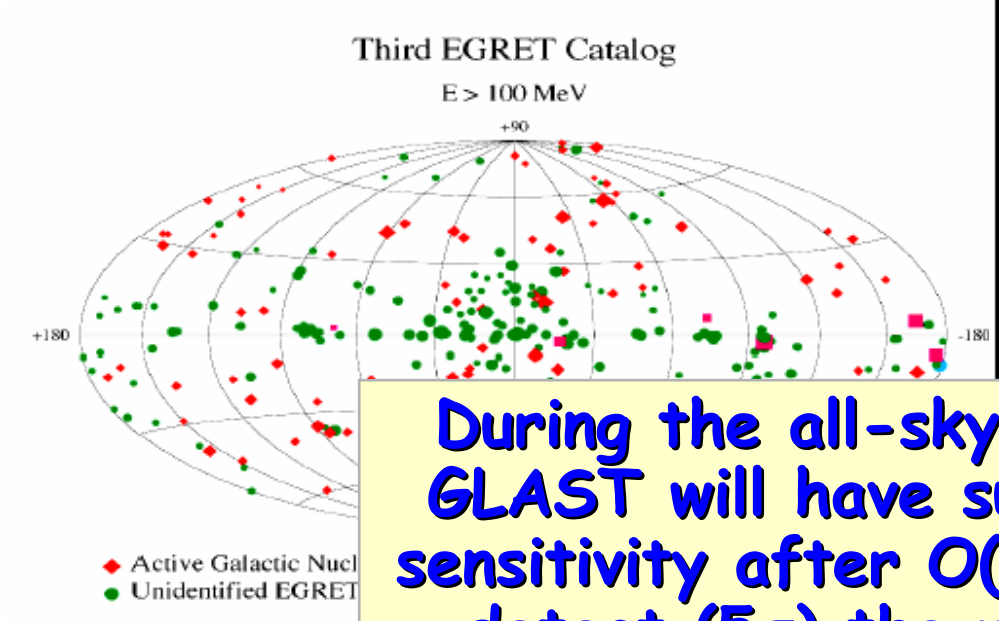
Dark matter



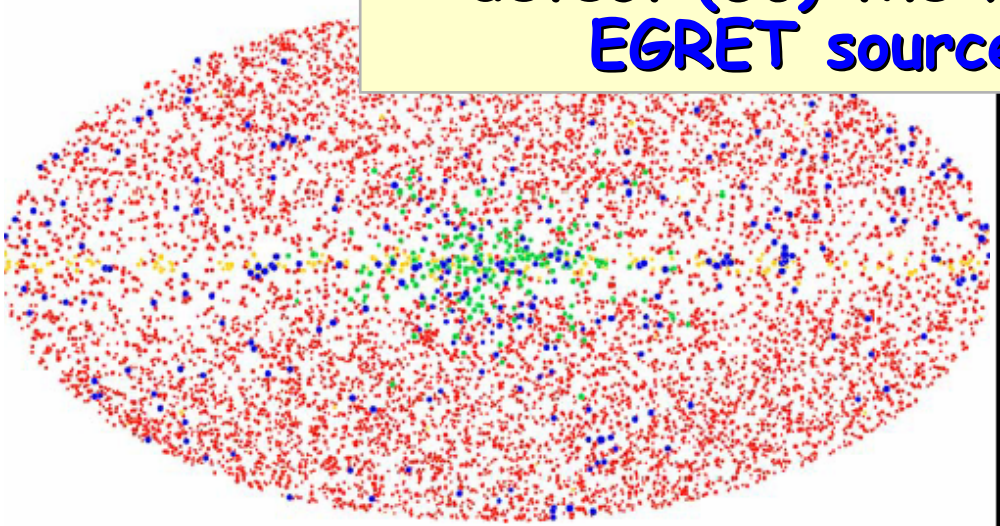
Solar flares

0.01 GeV | 0.1 GeV | 1 GeV | 10 GeV | 100 GeV | 1 TeV

LAT will rediscover the Gamma Ray Sky

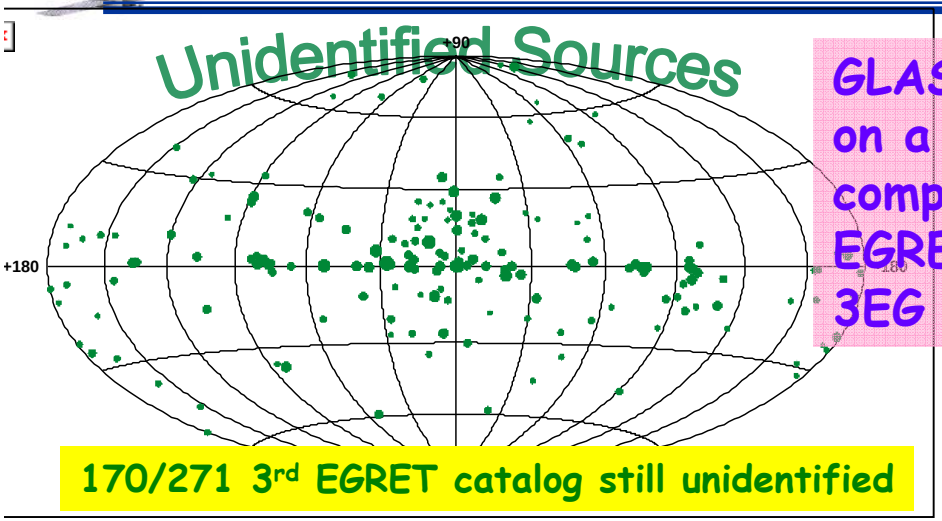


During the all-sky survey, GLAST will have sufficient sensitivity after O(1) day to detect (5σ) the weakest EGRET sources!!!



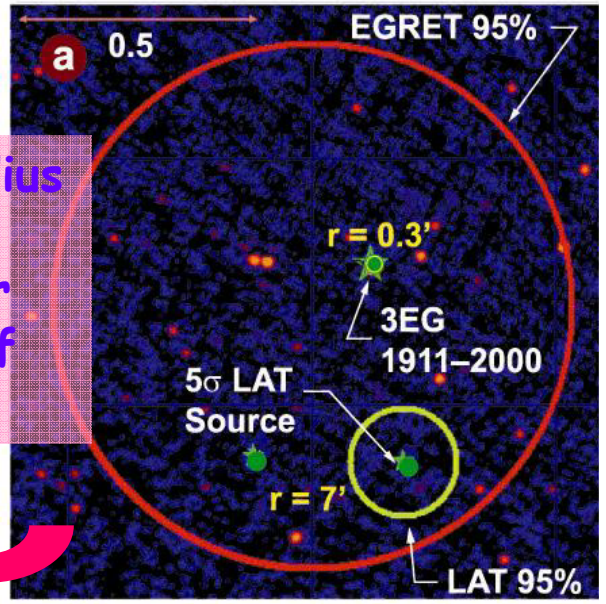
Source class	Seen by EGRET	Predicted with GLAST
Unidentified sources	170	?
Rotation powered pulsars	3-6	100-500
	50-80	>2000
ies	2	4-5
rsts	5	>500
ions	1-5	>10
Radio galaxies	1-1	?
X ray binaries/microquasars	1-1	?
Starburst galaxies	0	?
Cluster of galaxies	0	?

Unidentified sources



170/271 3rd EGRET catalog still unidentified

GLAST 95% C.L. radius on a 5σ source, compared to a similar EGRET observation of 3EG 1911-2000

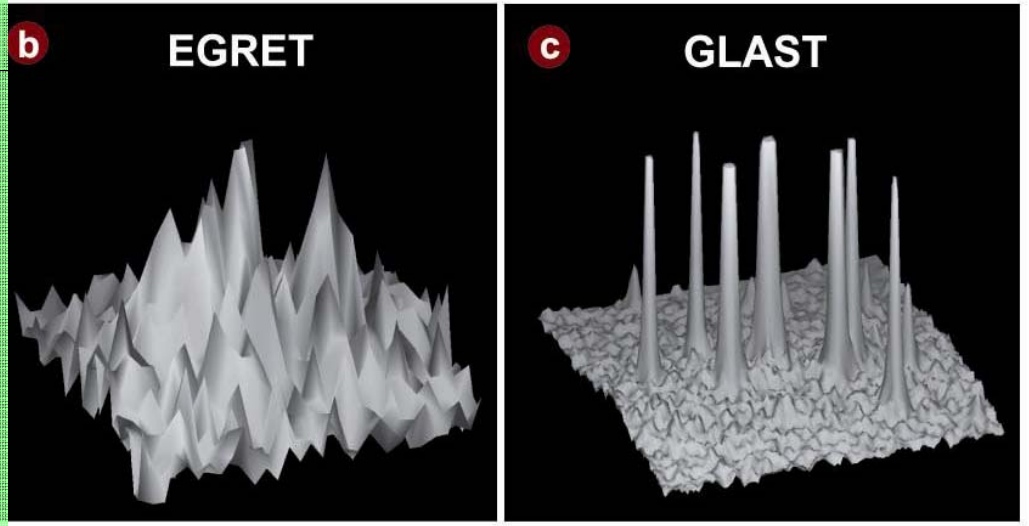


- Rosat or Einstein X-ray Source
- 1.4 GHz VLA Radio Source

GLAST high angular resolution and sensitivity:

- provide source localization at the level of arc-minute
- determine Energy spectra over a broad range and Time variability on many scales

correlate γ-ray detections with sources in other wavebands and discriminate between source models

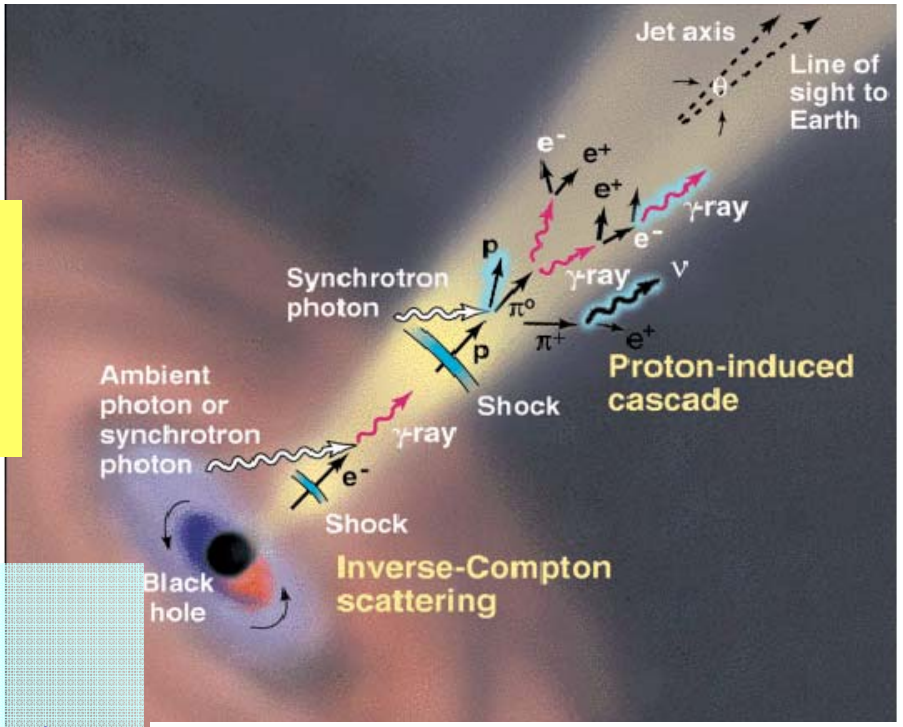


Cygnus region (15^0 x 15^0), Eg > 1 GeV

AGN(Blazars): Emission Mechanism

EGRET discovery:

AGN are bright and variable sources of high energy γ-rays



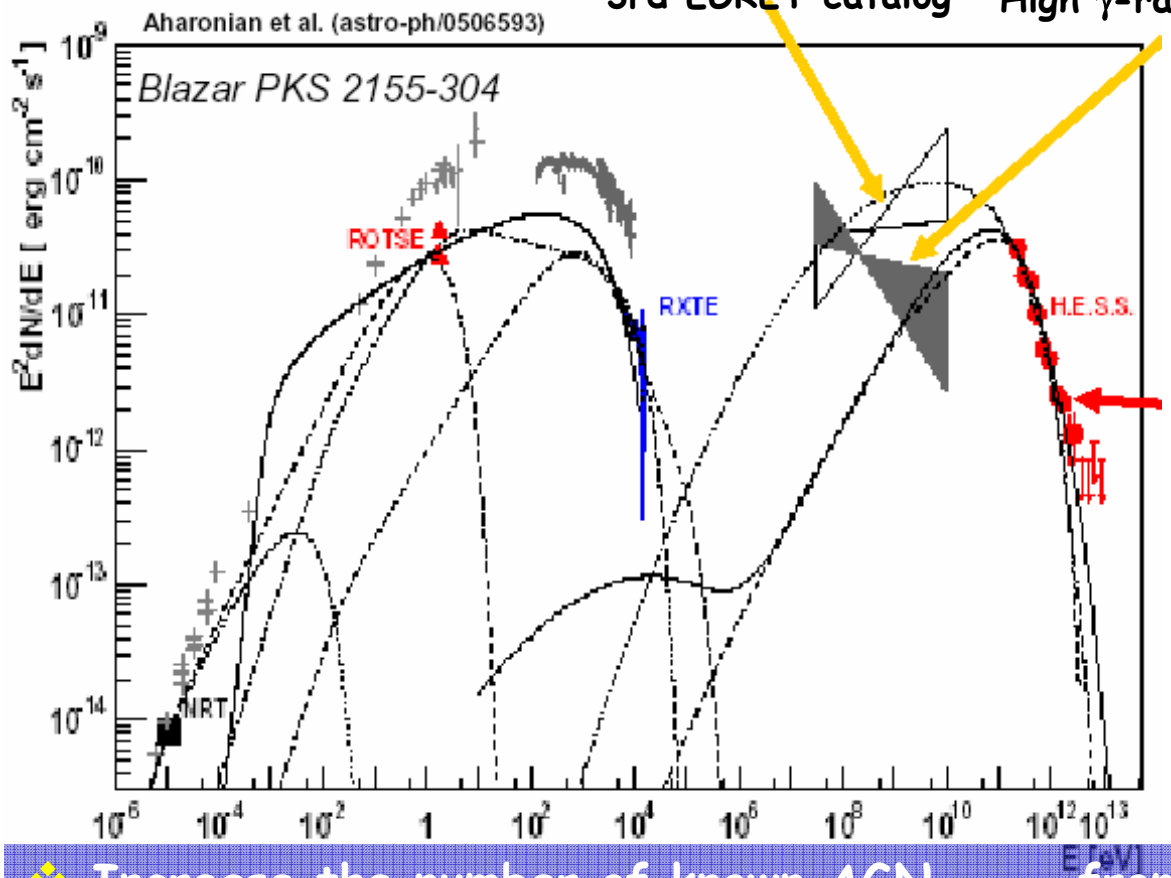
AGN signature

- vast amounts of luminosity (10^{49} erg/s) and energy (spectra extending to GeV and TeV regions) from a very compact central volume
- high variability on a time scale <1 day
- highly-collimated relativistic particle jets

Key issues to be addressed

- Energetics of the source
- jet formation
- jet collimation
- nature of the plasma
- particle acceleration

AGN Physics with GLAST



Multiwavelength studies will continue to be key to understanding how the engine works

For E>O(100) GeV measure light emitted at the atmpsphere

Models: same population of HE electrons produces both components

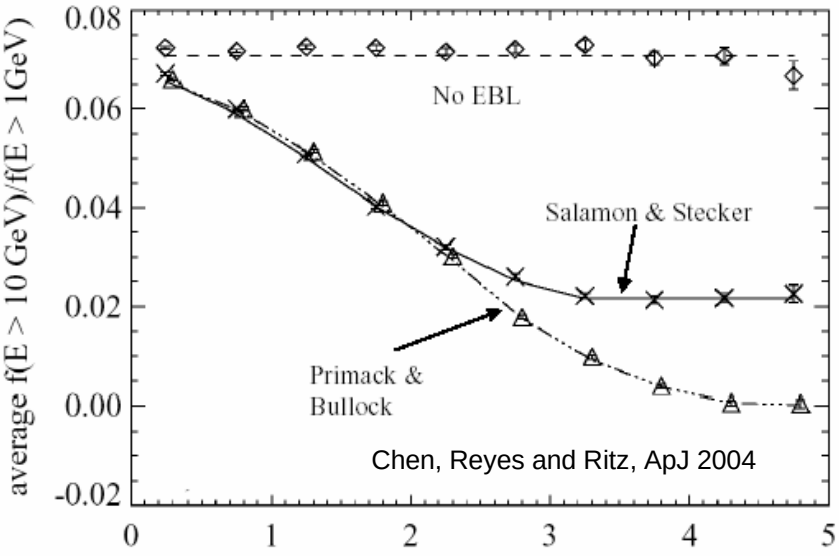
- Increase the number of known AGN from ~80 to ~5000
- Distinguish leptonic (SSC/ECS) and hadronic (pp / pγ) models of jets by detailed spectra studies of emitted gammas
- Multiwavelenght analysis combining timing and spectral information to determine acceleration and emission sites in the jet

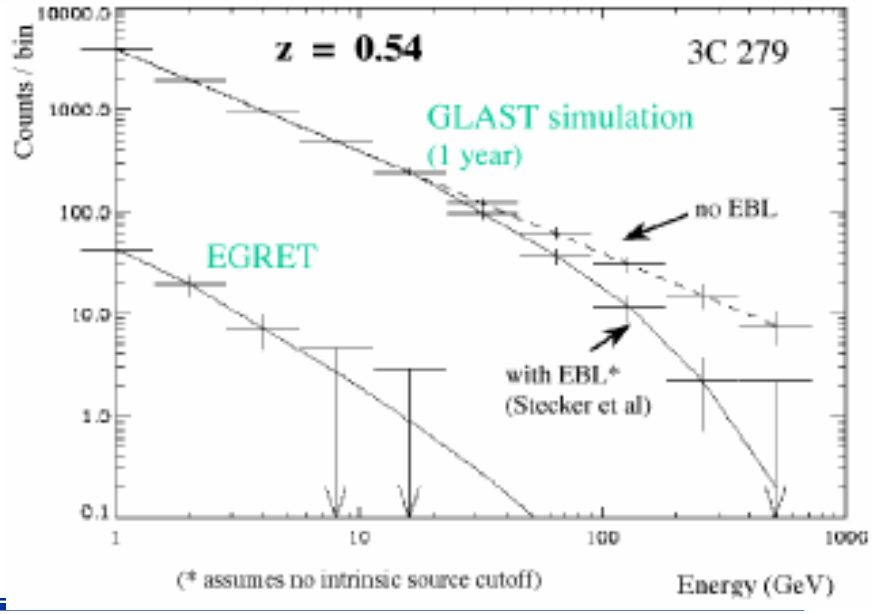
AGN and EBL

Photons with E>10 GeV are attenuated by the diffuse EBL

Effect is model dependent

Dominant factor in EBL model is the time of galxy formation
Attenuation measurements can help distinguish models



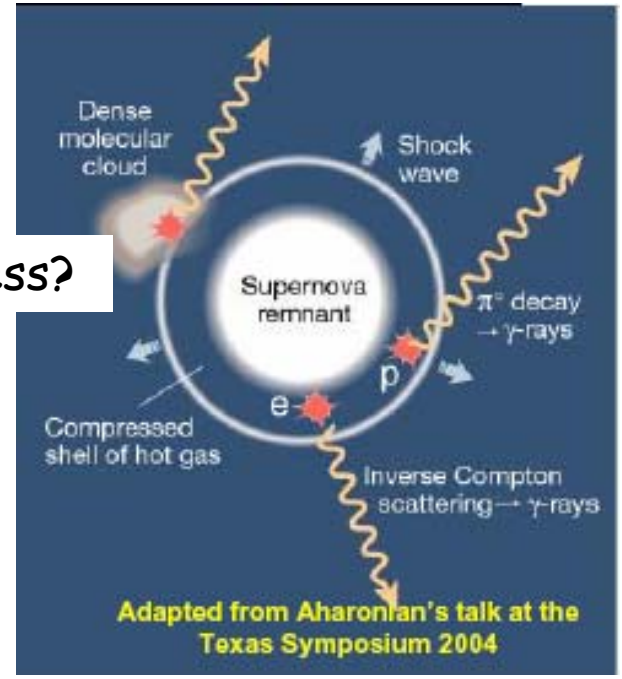


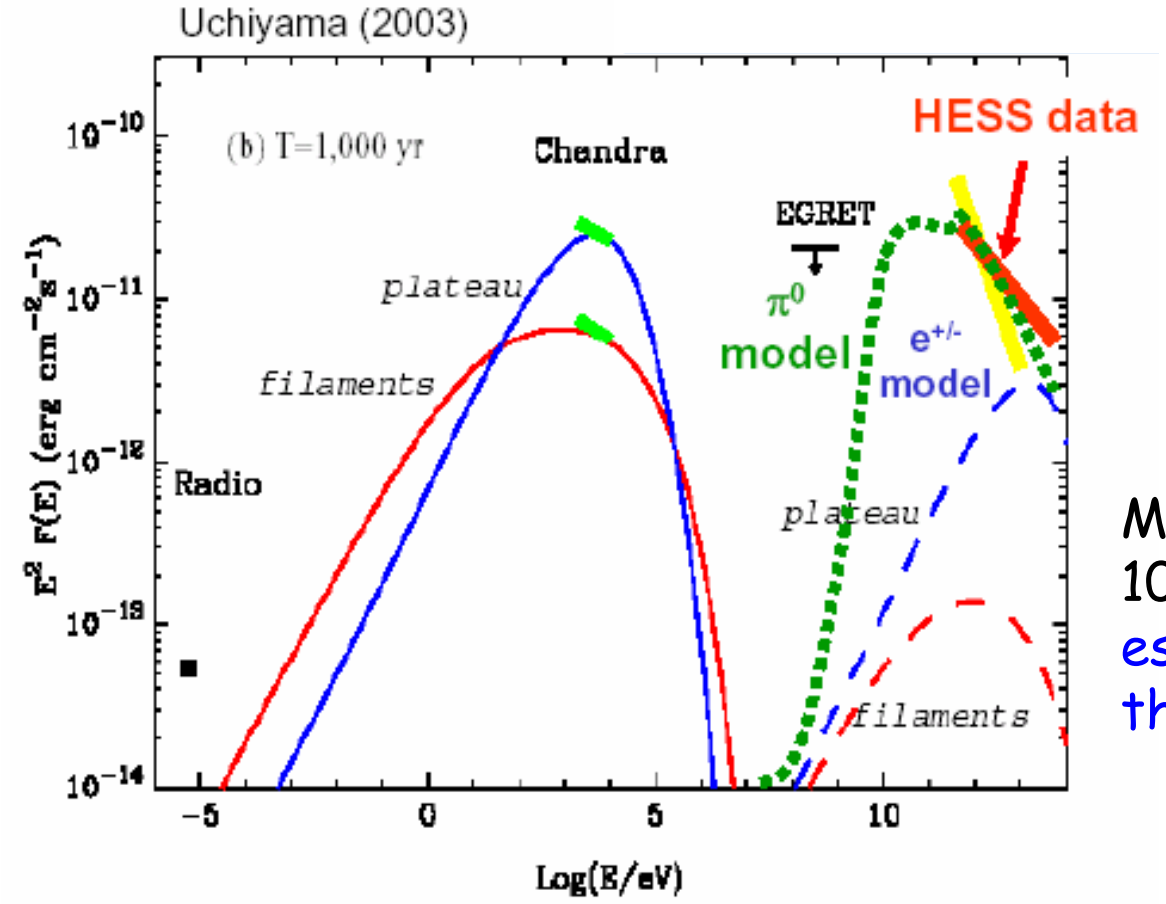
- **Strong dependence on the distance from the source**
- **Study the redshift dependence of cutoff in the γ-ray spectra at large z to probe interaction with extragalactic background light (EBL)**

SNR: sites of hadronic accelerations

- SNR could be be the source of CR proton acceleration after shell interaction with interstellar medium
- EGRET: π^0 bump in the galactic spectrum
- HESS: recent detection of TeV γ-rays

Question: do γ originate from hadronic or leptonic process?





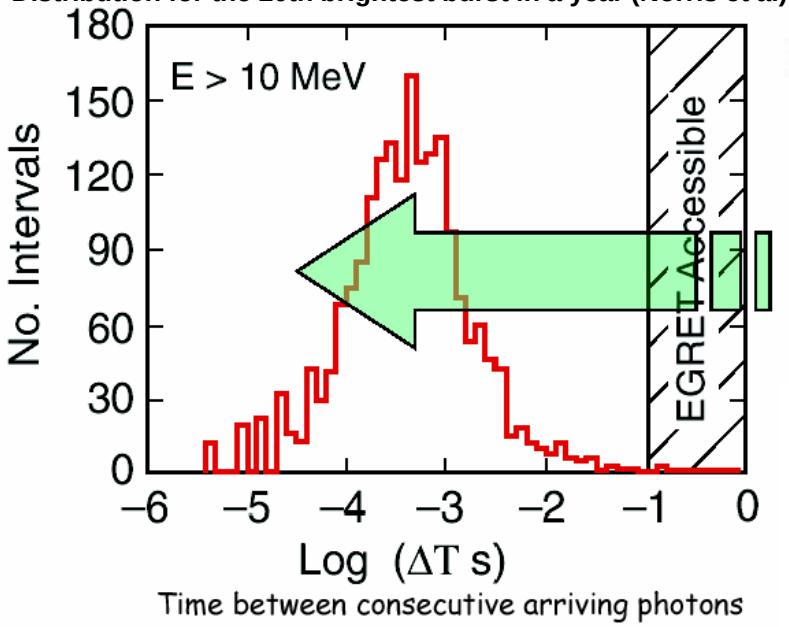
Measurement between 100 MeV – 100 GeV essential ingredient to resolve the origin (p vs $e^{+/-}$)

Gamma Ray Bursts: GBM and LAT

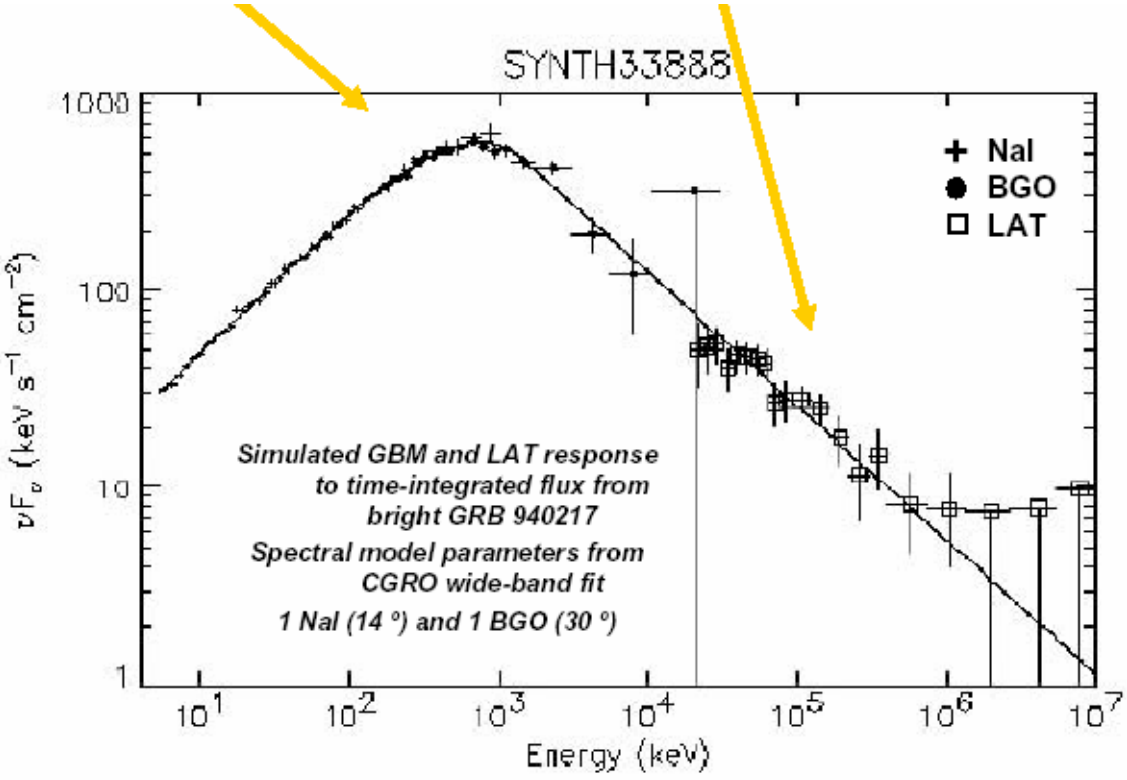
- most distant and intense sources of high energy γ-rays
- cosmological distances (afterglow redshift up to z=5)
- isotropic distribution in the sky
- transient signal ~ 100 μs time scale

EGRET: few statistics @ E>50 MeV, no temporal studies at high energies (large dead time)

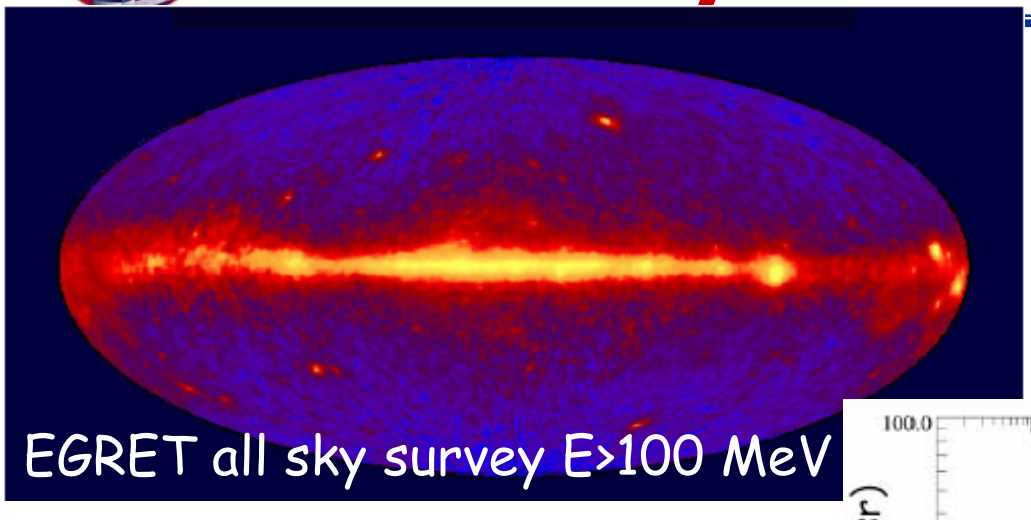
Distribution for the 20th brightest burst in a year (Norris et al)



- **GBM**
  Huge field of view (8sr)
  Measure spectra from bursts
  From 10 KeV to 30 MeV
- **LAT**
  Wide field of view (>2sr)
  Extend spectral coverage to higher energies



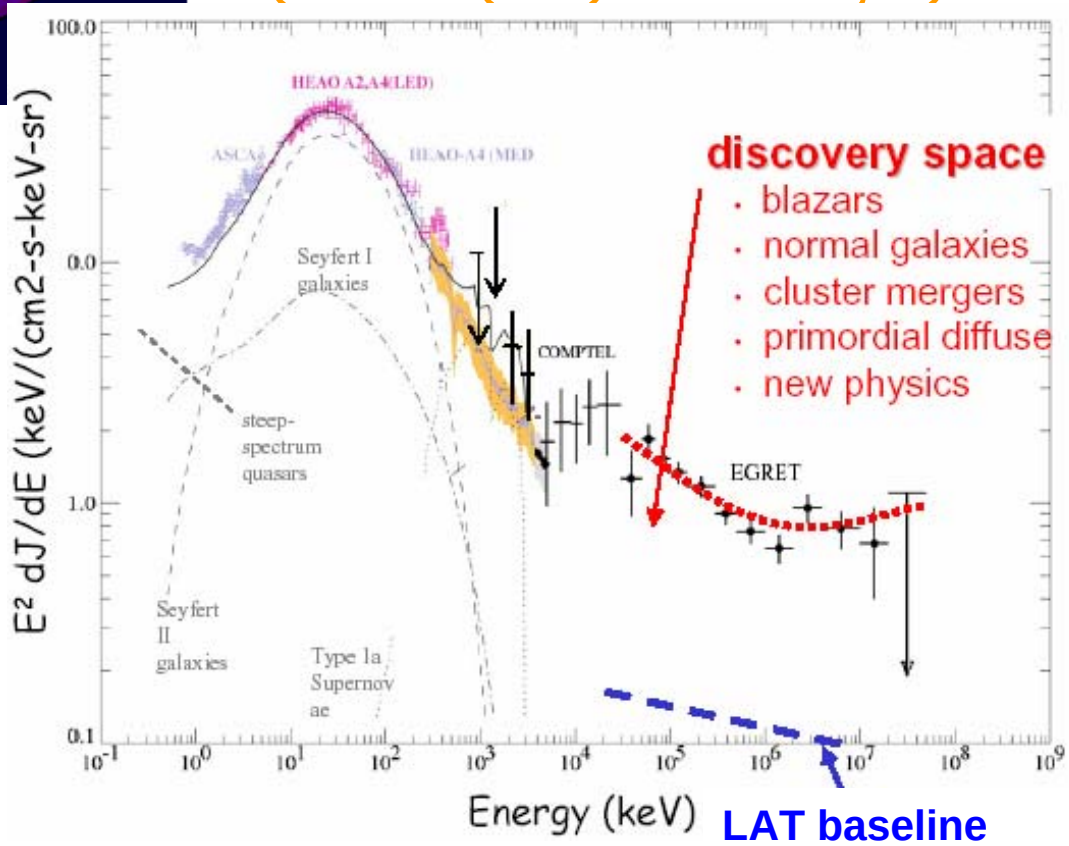
Gamma Ray Background radiation



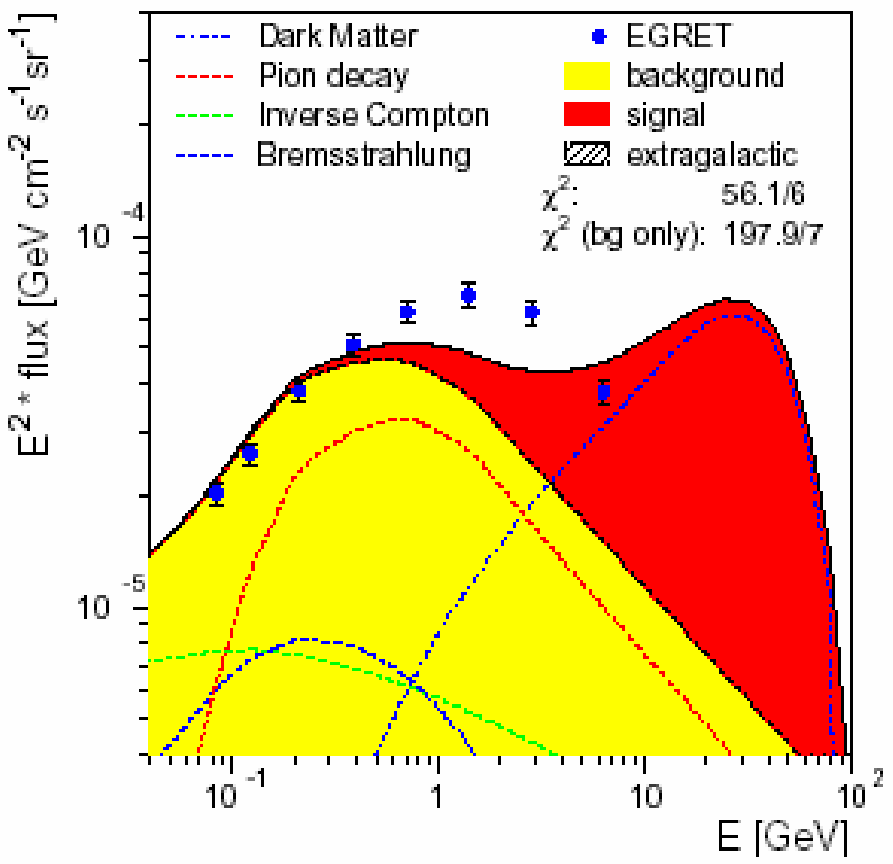
Diffuse extragalctic background
(flux 1.5 x 10^{-5} cm^{-2} $s^{-1}sr^{-1}$)

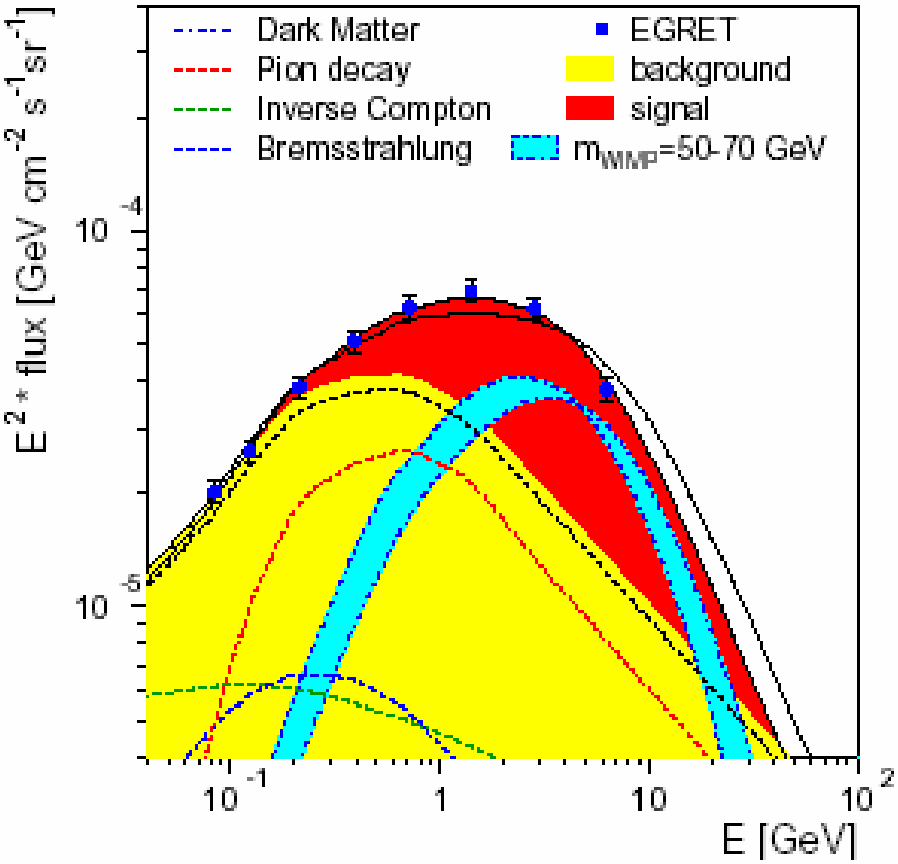
Galactic diffuse
(flux ~O(100) times larger)

Origin of extragalactic diffuse radiation: mistery!
Sources there for GLAST to resolve OR truly diffuse flux from the early Universe



Dark matter search: the EGRET excess





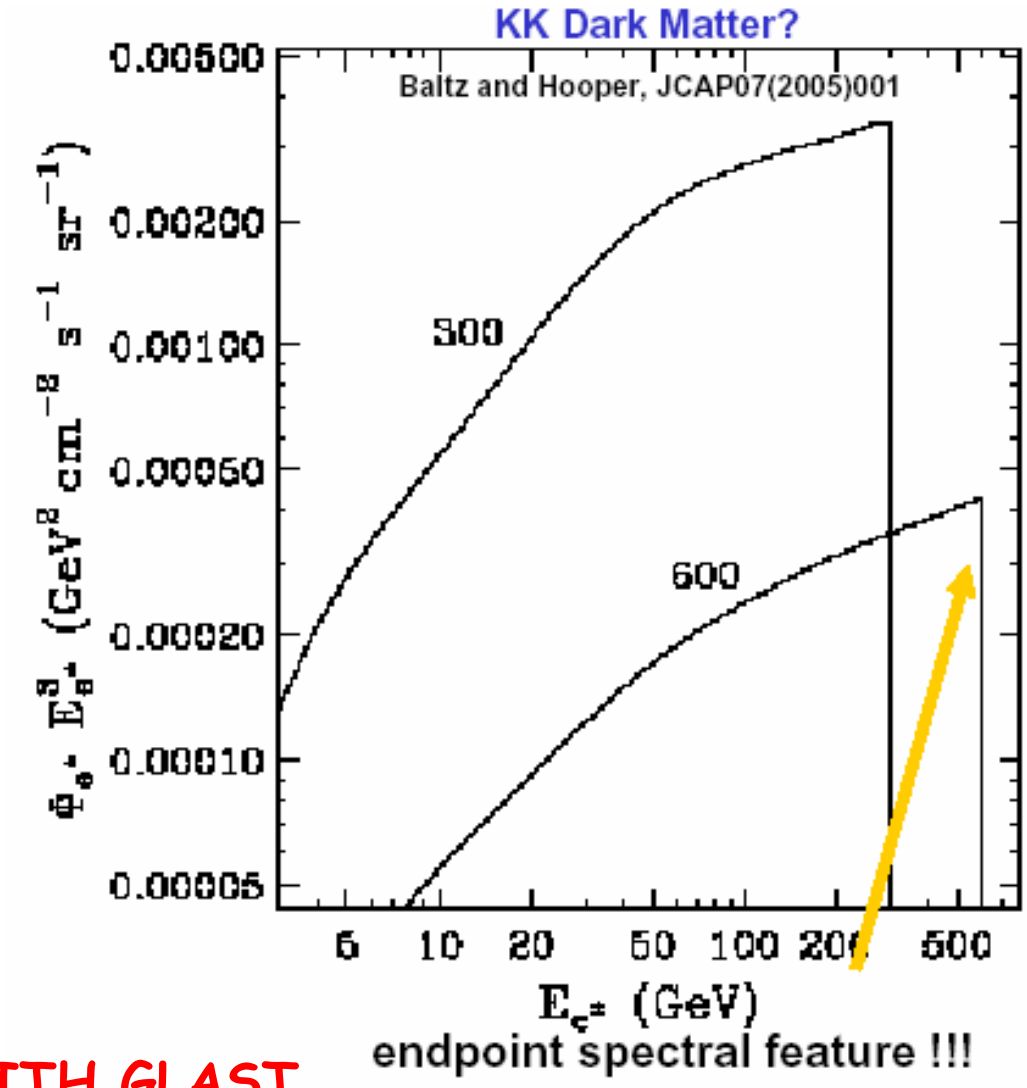
GLAST will investigate this excess with much better accuracy

W. De Boer et al. 2006

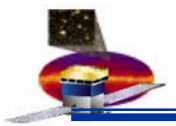
Dark Matter

- WIMP annihilations (SUSY)
  - continuum γ from π^0
  - lines (2γ, γZ)
    - Neutralino search for photons

- KK DM scenario (Extra dimensions)
  - Lightest Kaluza-Klein particle
    B1
  - search for photons and leptons
    charged leptons not helicity suppressed



LIMITED STATISTICS WITH GLAST



LAT Performances

Parameter	SRD Value	Present Design Value
Peak Effective Area (in range 1-10 GeV)	>8000 cm^2	10,000 cm^2 at 10 GeV
Energy Resolution 100 MeV on-axis	<10%	9%
Energy Resolution 10 GeV on-axis	<10%	8%
Energy Resolution 10-300 GeV on-axis	<20%	<15%
Energy Resolution 10-300 GeV off-axis (>60°)	<6%	<4.5%
PSF 68% 100 MeV on-axis	<3.5°	3.37° (front), 4.64° (total)
PSF 68% 10 GeV on-axis	<0.15°	0.086° (front), 0.115° (total)
PSF 95/68 ratio	<3	2.1 front, 2.6 back (100 MeV)
PSF 55°/normal ratio	<1.7	1.6
Field of View	>2sr	2.4 sr
Background rejection (E>100 MeV)	<10% diffuse	6% diffuse (adjustable)
Point Source Sensitivity(>100MeV)	<6×10^{-9} $cm^{-2}s^{-1}$	3×10^{-9} $cm^{-2}s^{-1}$
Source Location Determination	<0.5 arcmin	<0.4 arcmin (ignoring BACK info)
GRB localization	<10 arcmin	5 arcmin (ignoring BACK info)

LAT meets all requirements and analysis improvements are underway

Data Challenges

- "End-to-end" testing of analysis software
- Feedback on what works and what is missing from data format and tools

-DC1

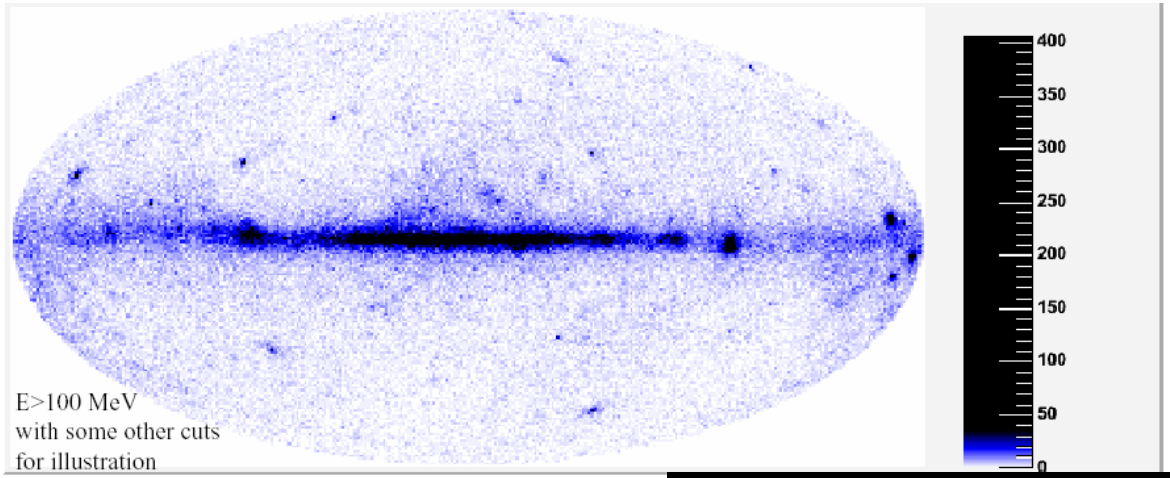
- 1 simulated day all sky survey
- find sources including GRB's
- exercise: exposure, orbit/attitude handling, data processing pipeline, analysis tools

-DC2

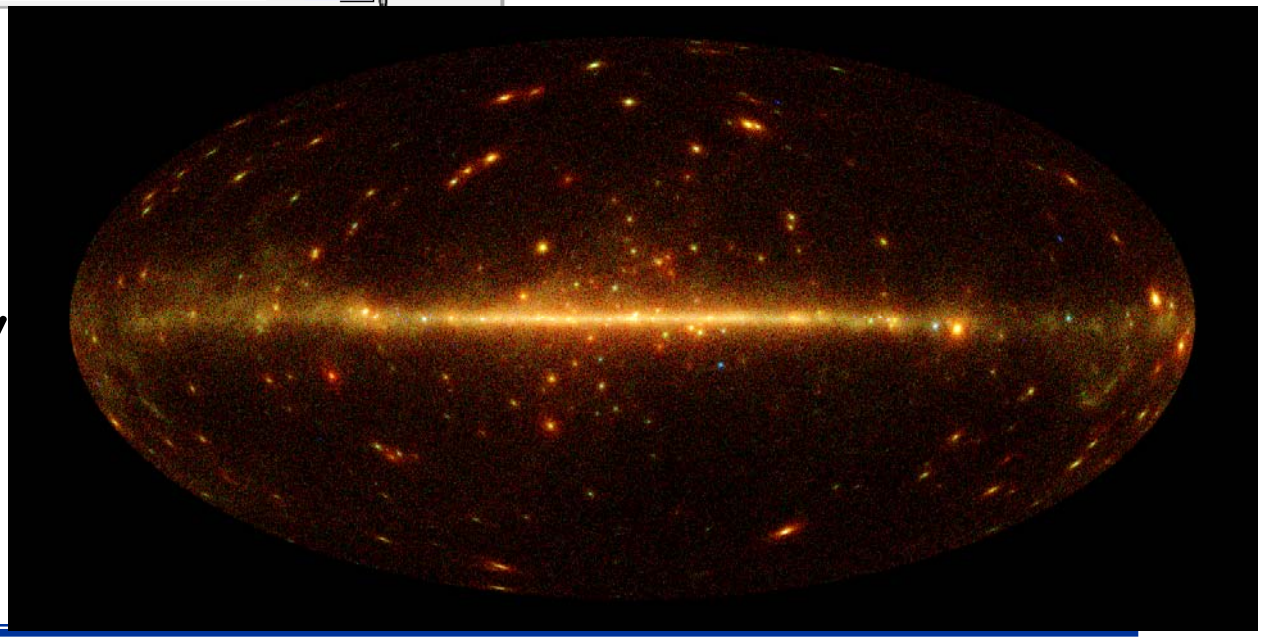
- kickoff meeting March 1st 2006
- toy 1 month catalog
- add source variability
- closeout meeting end of May

DC1 and DC2 Sky

One day all sky survey, generated E>20 MeV



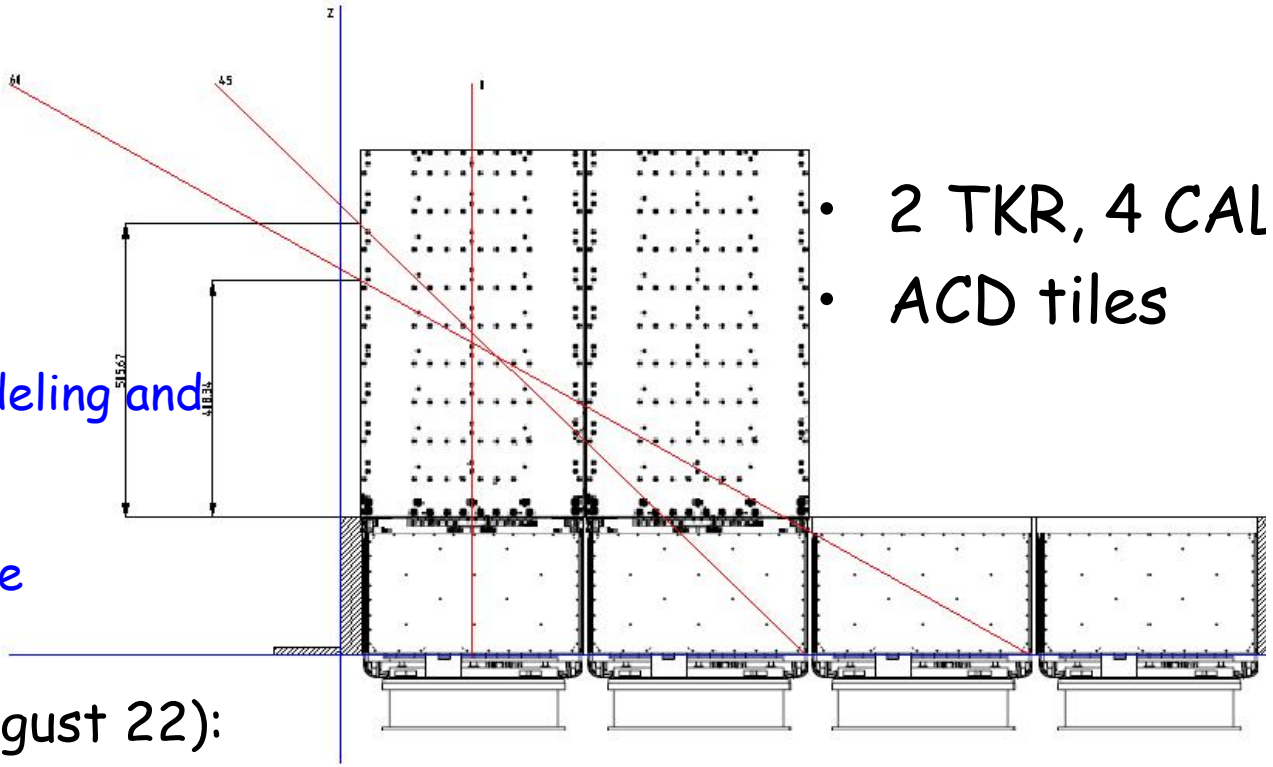
One month all sky survey



Beam test at CERN

GOALS:

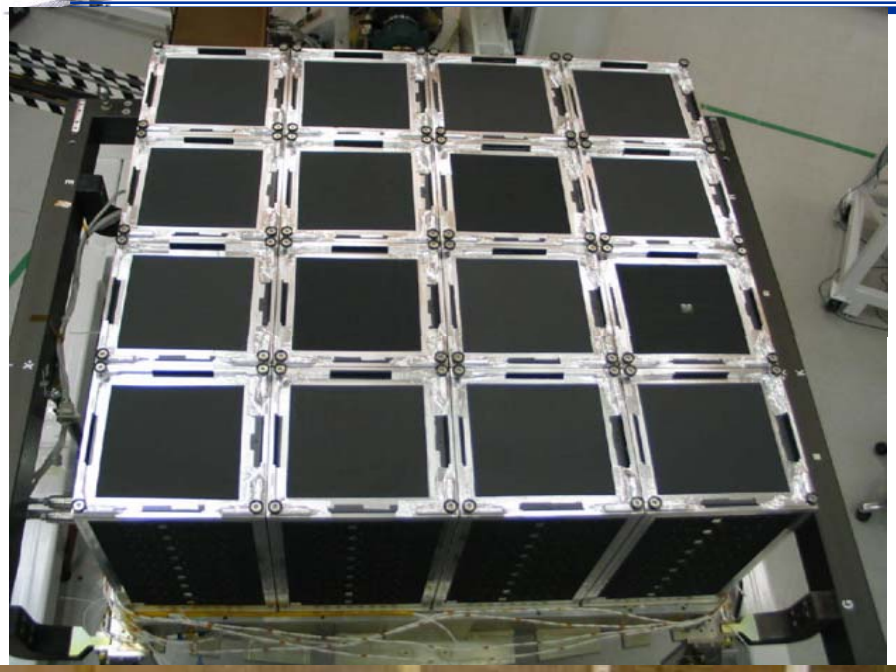
- PSF
- Effective Area
- Energy reconstruction
- Backsplash
- Hadronic interaction modeling and BG rejection
- G4 validation
- Flight electronic response



- 2 TKR, 4 CAL
- ACD tiles

- PS (4 weeks July 27-August 22):
  - e-, p+, p 300 MeV/15 GeV
  - tagged γ : ~50MeV/~2 GeV
- SPS (2weeks+1day 4-18 September):
  - e-, p^+, p 10 GeV/300 GeV

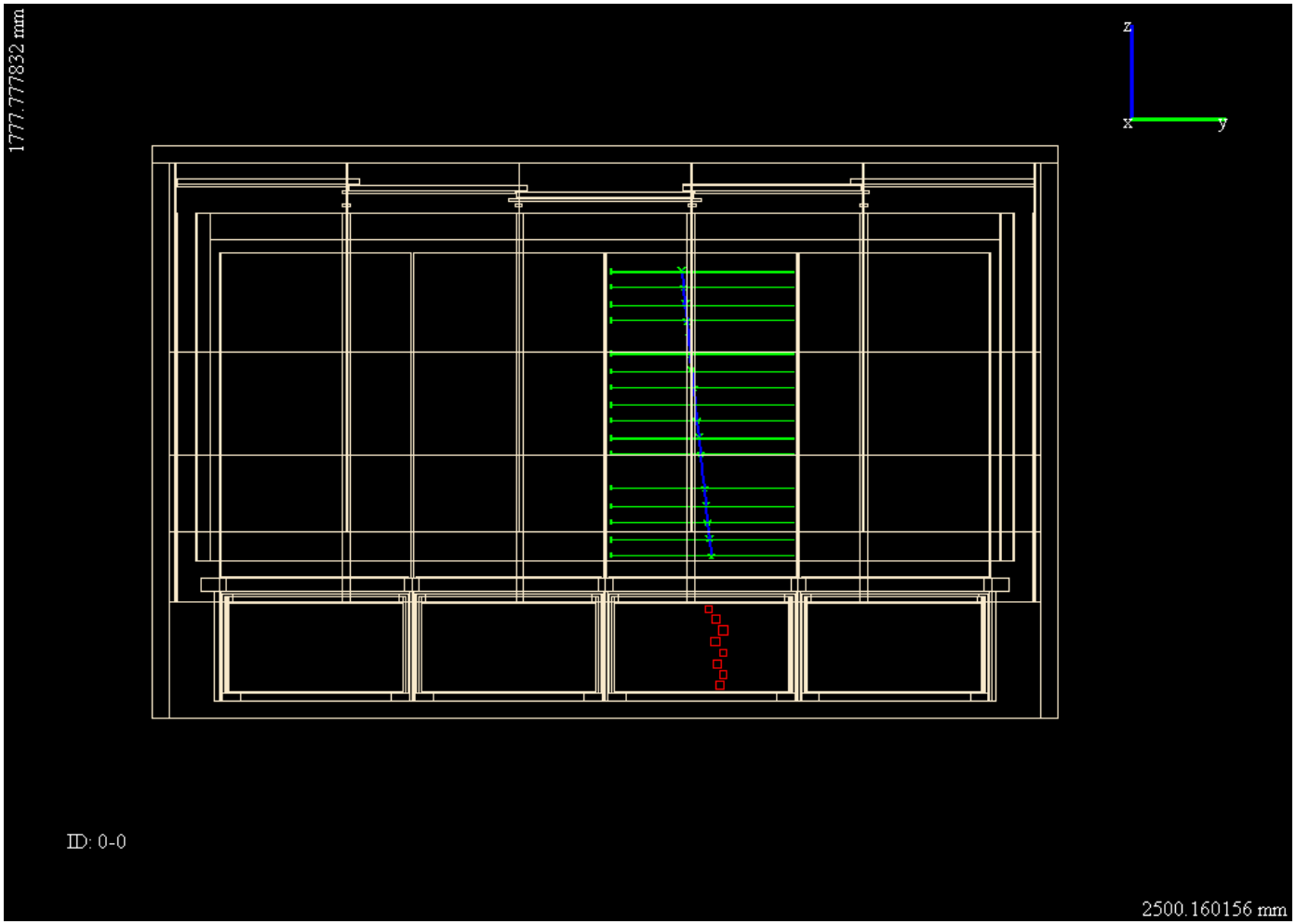
LAT STATUS



- The LAT is completed
- The flight software being integrated
- The LAT will be shipped to NRL for environmental testing
- LAT and GBM assembly complete by mid 2006 → shipment to SpectrumAstro for integration to the spacecraft
- Beam Test planned for this summer at CERN

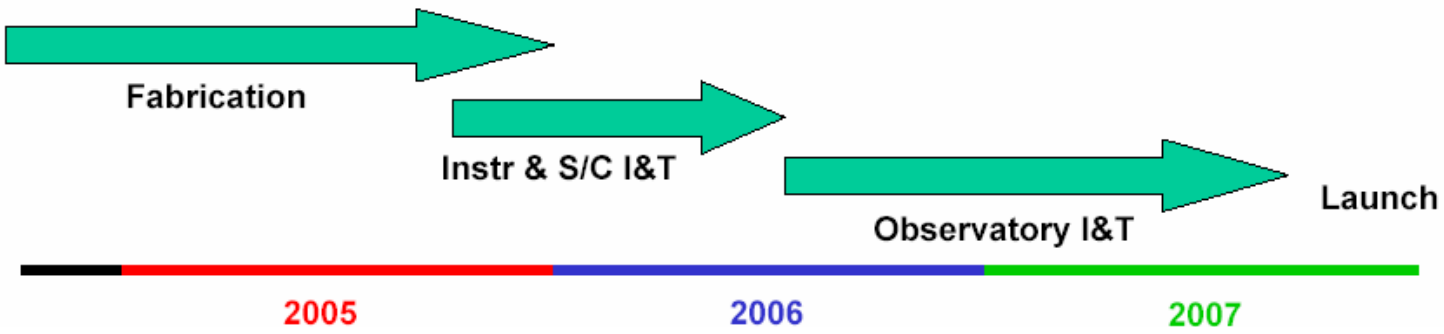
Status of the LAT

LAT completely assembled at SLAC
Data taking: cosmic muons with FSW



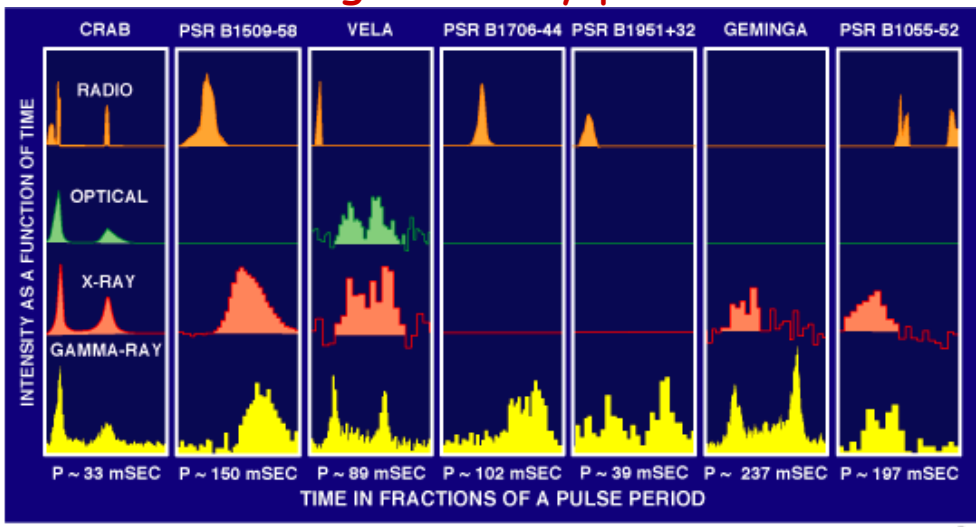
Conclusions

- **GLAST will address many important questions:**
  - How do nature's most powerful accelerators works?
  - What are unidentified sources found by EGRET?
  - What is the origin of the diffuse background?
  - What is the origin of cosmic rays?
  - What is the high energy behaviour of Gamma Ray Bursts?
  - What else out there is shining gamma-rays?
- **First year of science operations : all-sky survey**
  - detailed instrument characterization,
  - refinement of the alignment,
  - key projects needed by the community (LAT catalog, diffuse bckgd models)
  - data on transients to be released *with caveats.*
  - *repoints for bright bursts/burst alerts enabled.*
  - *limited first-year guest observer program*
- **Subsequent years** : all data released



Pulsar Physics with GLAST

known gamma-ray pulsars



LAT high time resolution and detection efficiency

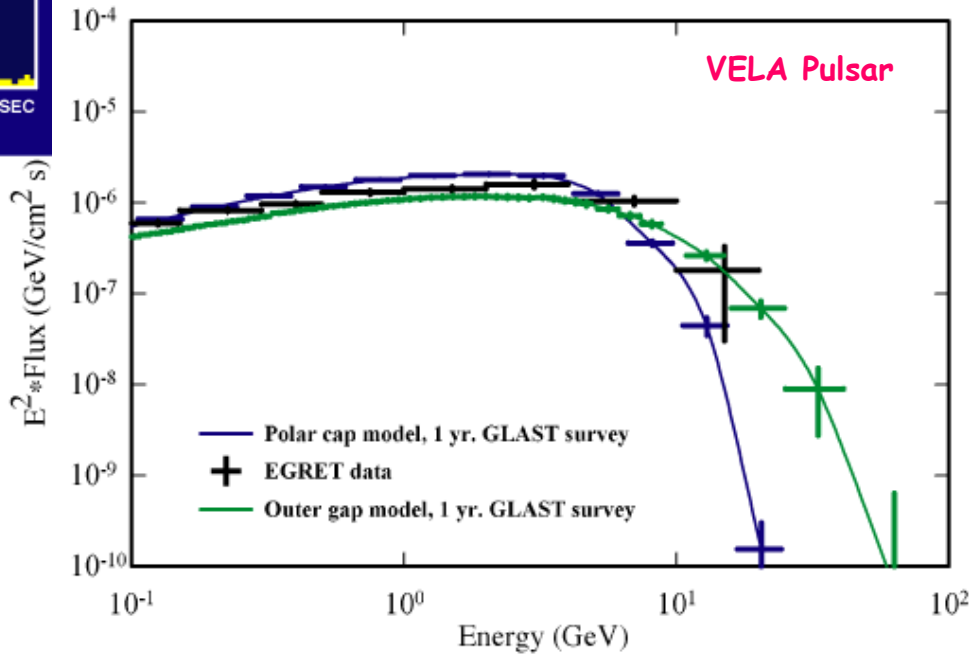
Direct pulsation search in the γ-ray band in all EGRET unidentifyed sources

➢ Detect ~250 new gamma-ray pulsars

LAT large effective area

High photon statistics, detailed spectra

➢ Discriminate between polar cap and outer gap emission models of γ-ray production



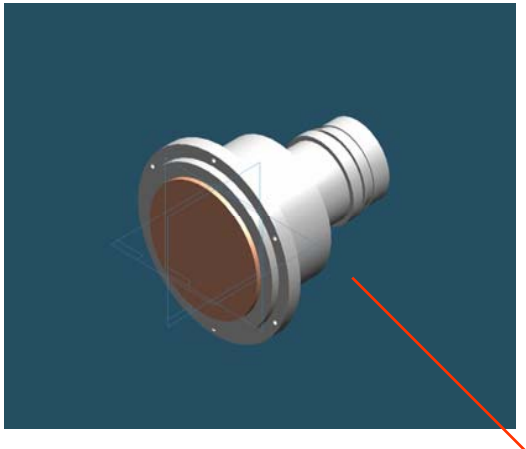
γ-ray beams broader than their radio beams ➡ many radio quiet pulsars to be discovered

EGRET / LAT Properties

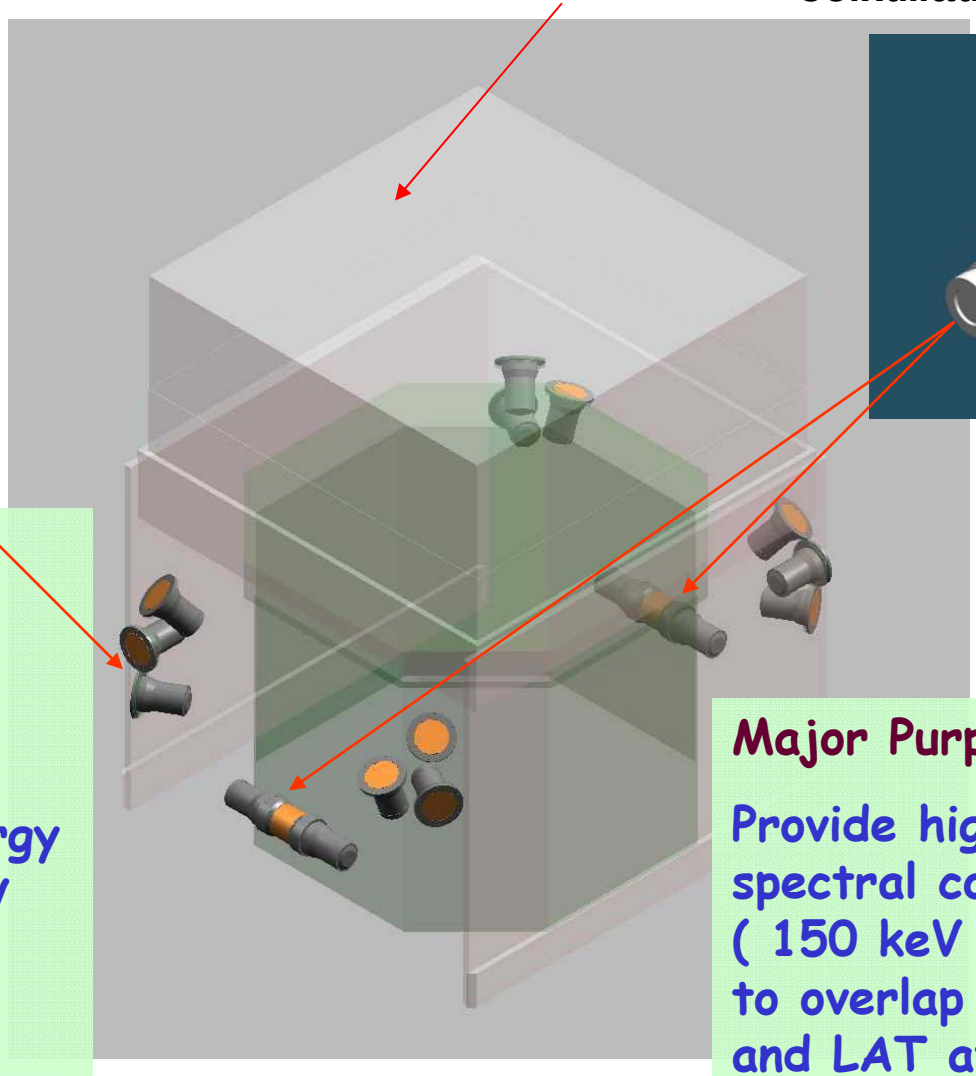
	EGRET	LAT
Energy range	20 Mev – 30 GeV	20 Mev – 300 GeV
Energy resolution	10 %	9 %
Effective Area	1500 cm^2	10000 cm^2
Angular resolution	5.8^0 - 0.3^0	3.4^0 - 0.09^0
Field of View	0.5 sr	2.4 sr
Flux sensitivity (E>100 MeV)	10^{-7} cm^{-2} s^{-1}	$2 \cdot 10^{-9}$ cm^{-2} s^{-1}
Dead Time	100 ms	10 μs

The GBM Detector

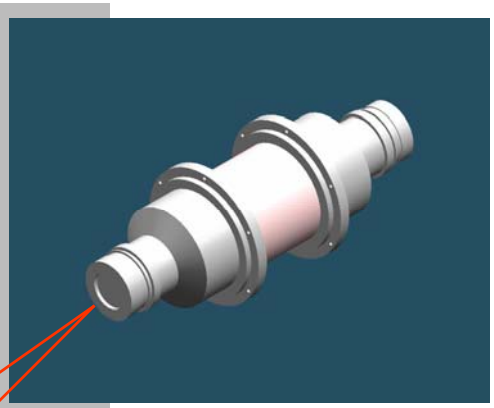
12 Sodium Iodide (NaI) Scintillation Detectors



LAT



2 Bismuth Germanate (BGO) Scintillation Detectors



Major Purpose

Provide low-energy spectral coverage (10 keV – 1 MeV) in the typical GRB energy regime over a wide FoV

Provide rough burst triggers and locations

Major Purpose

Provide high-energy spectral coverage (150 keV – 25 MeV) to overlap NaI at lower and LAT at high range