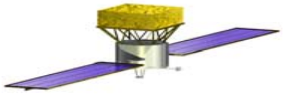


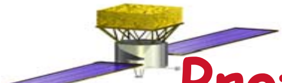
GLAST - an astroparticle mission to explore the gamma ray sky

Luca Latronico

INFN - sez. Pisa

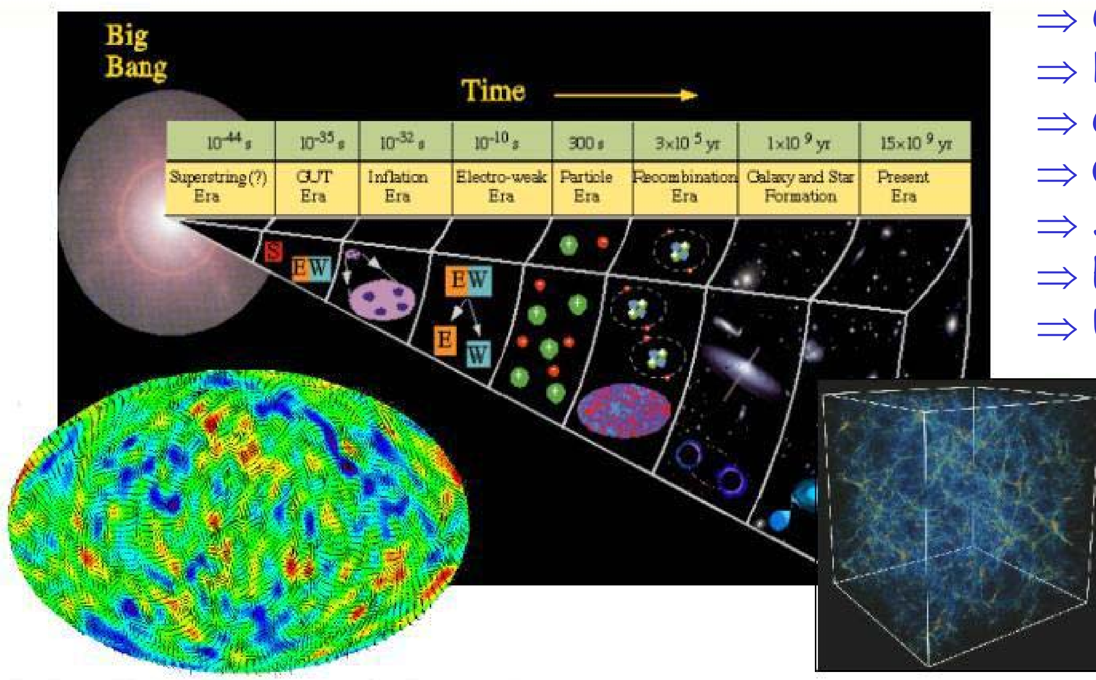
on behalf of the GLAST-LAT collaboration

31st International Conference on High Energy Physics
24-31 July 2002, Amsterdam



Profound Connection between Astrophysics & HEP

The fundamental theory of Cosmic Genesis and the quest for experimental evidence has led to new and potential partnerships between Astrophysics and HEP.



Some Areas of Collaboration:

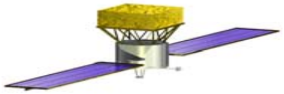
⇒ Origin of cosmic rays
⇒ Dark Matter Searches
⇒ CMBR
⇒ Quantum gravity
⇒ Structure Formation
⇒ Early Universe Physics
⇒ Understanding the HE Universe

Typical signatures

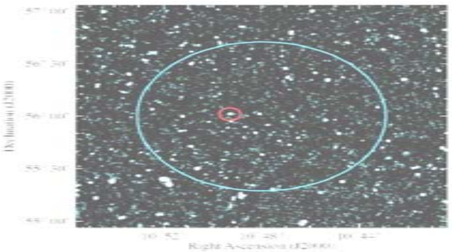
⇒ Ultra HE cosmic rays
⇒ gamma-rays
⇒ ν
⇒ antimatter

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

GLAST

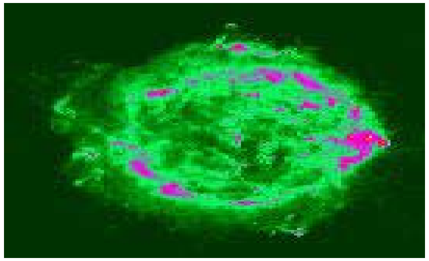


GLAST science - the sky above 100 MeV

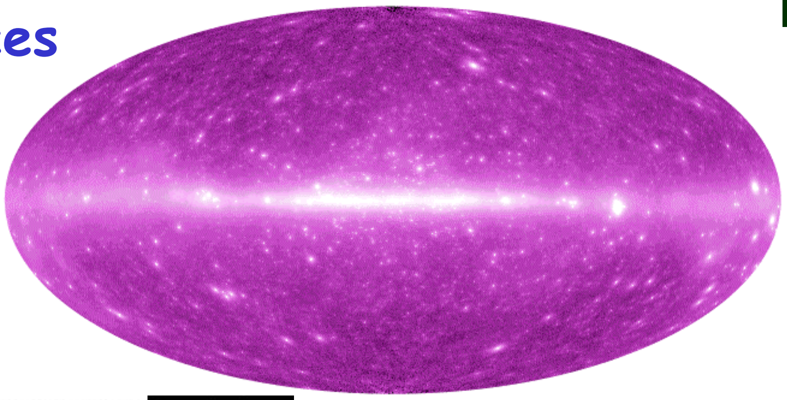


Unidentified sources

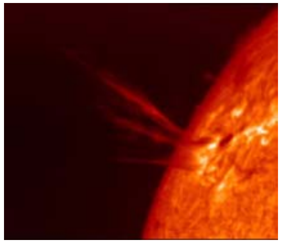
Active Galactic Nuclei



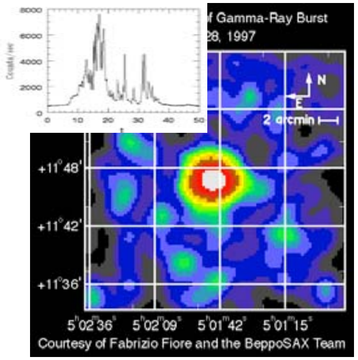
Cosmic ray acceleration



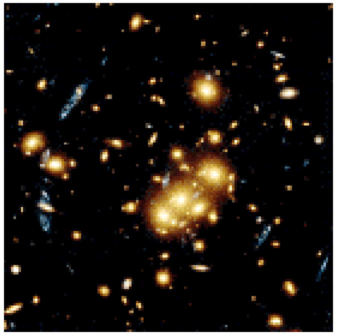
Pulsars



Solar flares

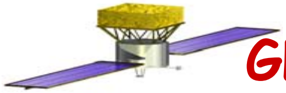


Gamma Ray Bursts



Dark matter

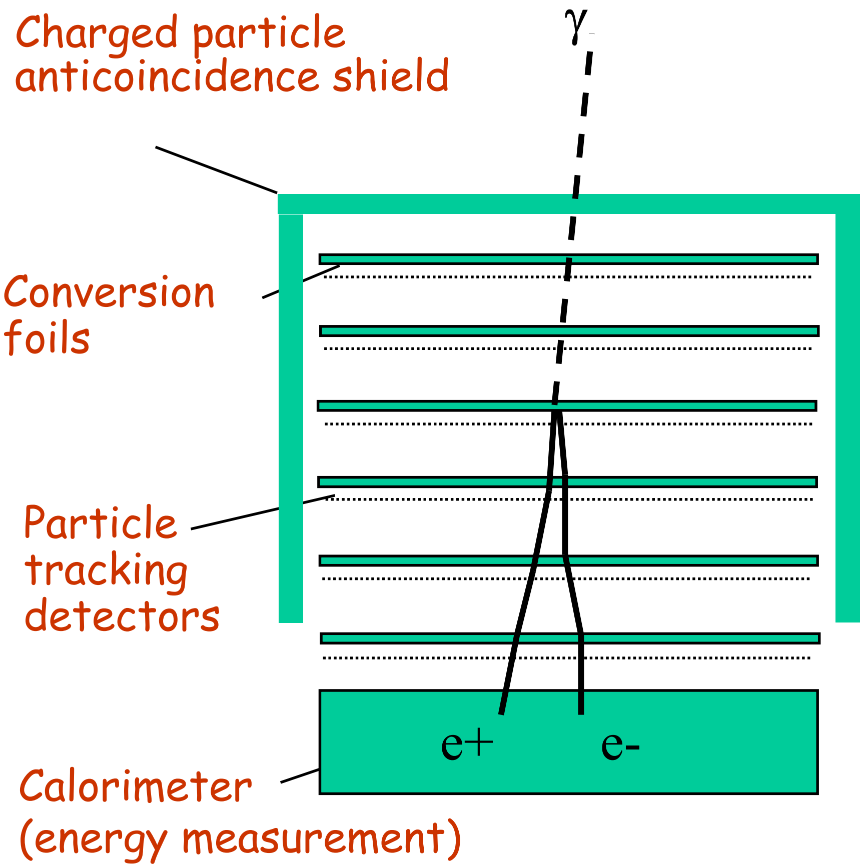
0.01 GeV | 0.1 GeV | 1 GeV | 10 GeV | 100 GeV | 1 TeV



GLAST γ detection technique – pair conversion telescope

Pair production is the dominant photon interaction above 10MeV:

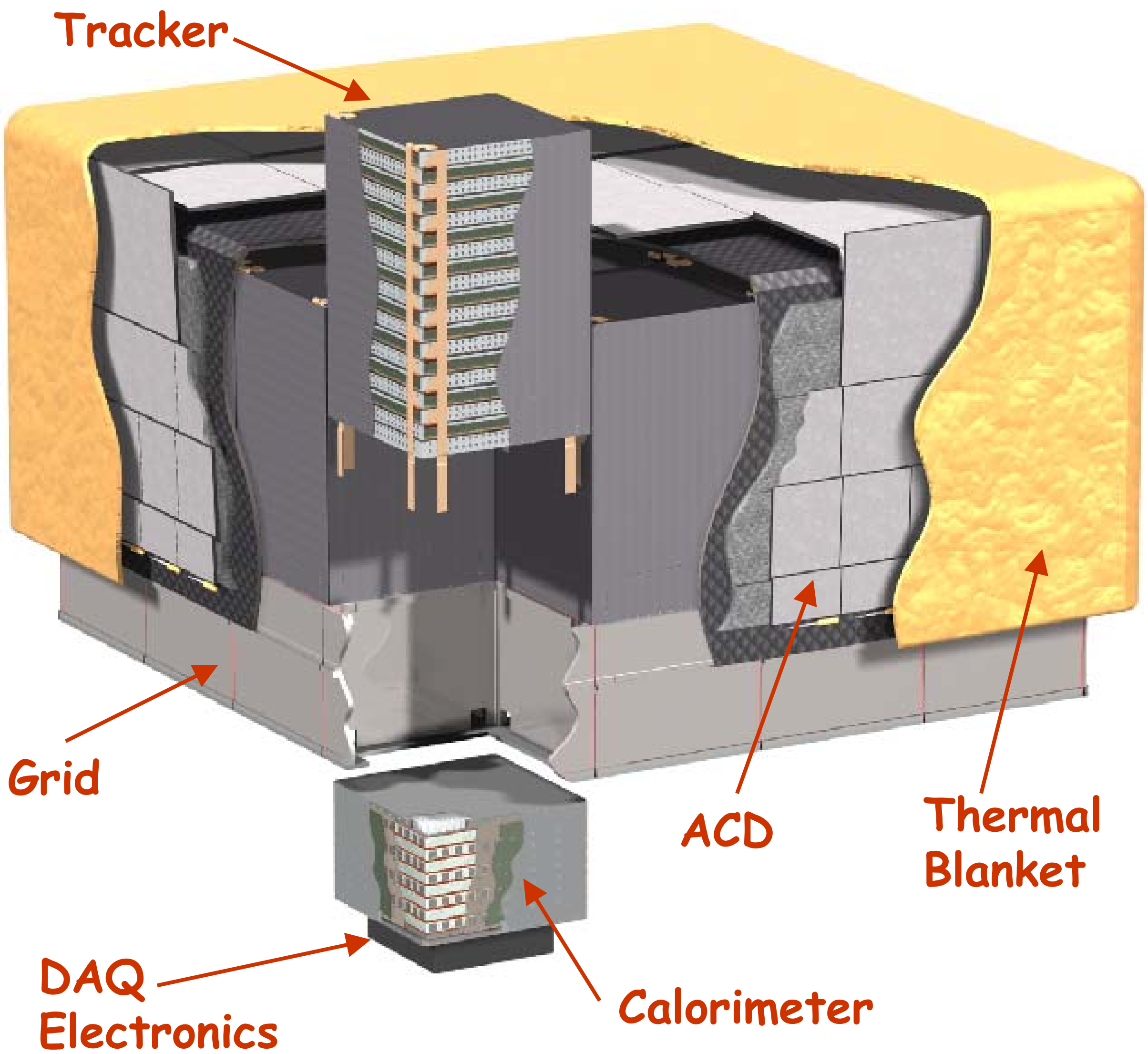
$$E_\gamma \rightarrow m_{e+}c^2 + m_{e-}c^2$$



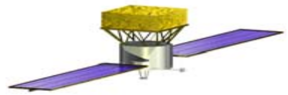
GLAST Concept

- Low profile for wide f.o.v.
- Segmented anti-shield to minimize self-veto at high E.
- Finely segment calorimeter for enhanced background rejection and shower leakage correction.
- High-efficiency, precise track detectors located close to the conversions foils to minimize multiple-scattering errors.
- Modular, redundant design.
- No consumables.
- Low power consumption (580 W)

GLAST Instrument: the Large Area Telescope (LAT)

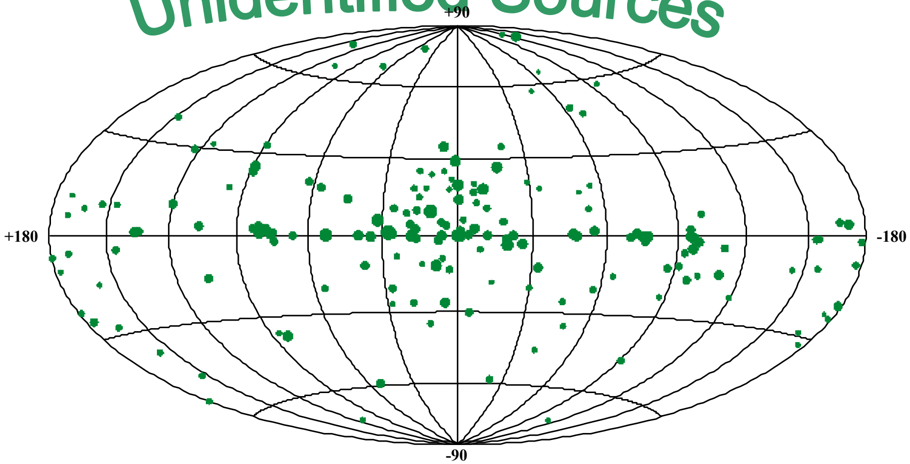


- Array of 16 identical "Tower" Modules, each with a tracker (Si strips) and a calorimeter (CsI with PIN diode readout) and DAQ module.
- Surrounded by finely segmented ACD (plastic scintillator with PMT readout).
- Aluminum strong-back "Grid," with heat pipes for transport of heat to the instrument sides.



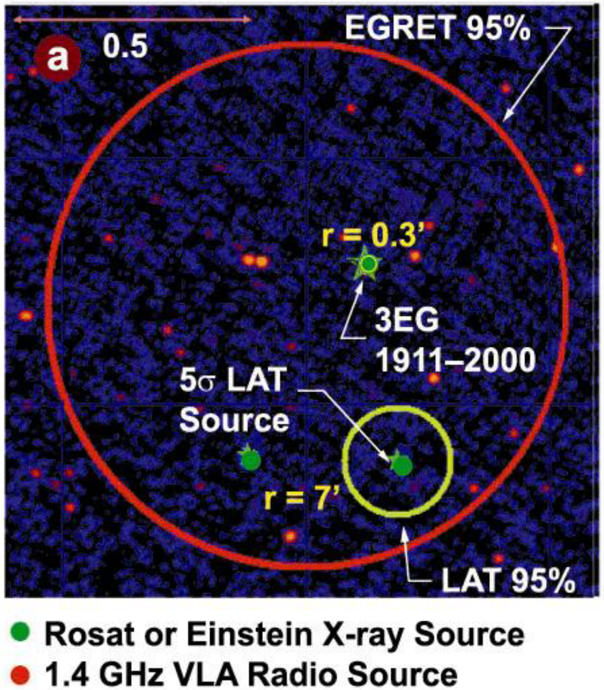
Identifying Sources

Unidentified Sources



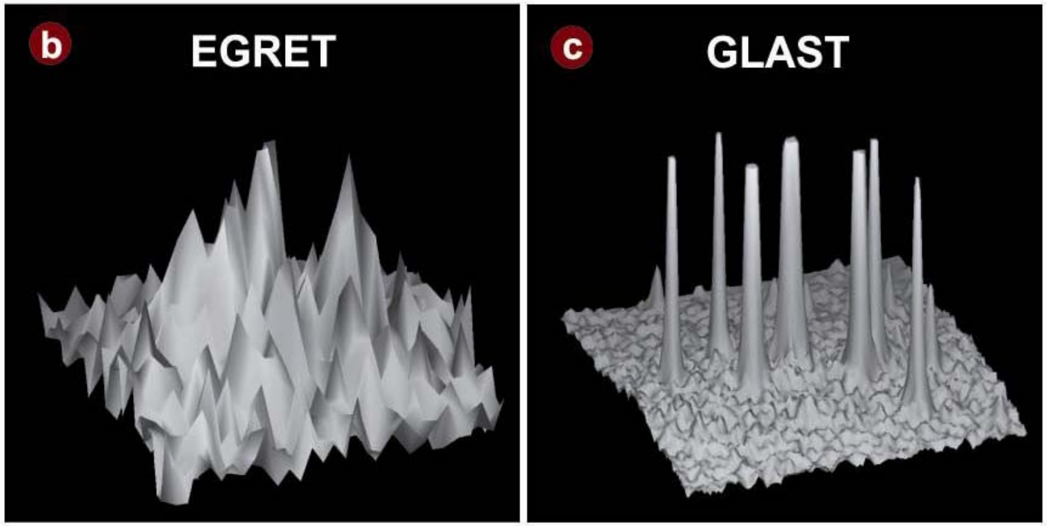
170/271 3rd EGRET catalog still unidentified

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



GLAST high resolution and sensitivity will

- resolve gamma-ray point sources at arc-minute level
- detect typical signatures (e.g. spectra, flares, pulsation) for identification with known source types

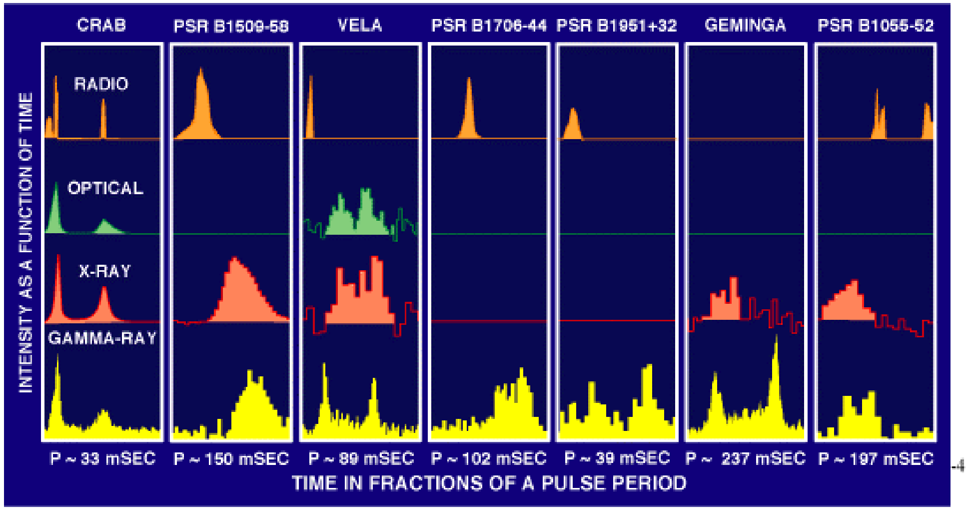


Cygnus region ($15^0 \times 15^0$), Eg > 1 GeV

GLAST

Pulsar physics with GLAST

known gamma-ray pulsars



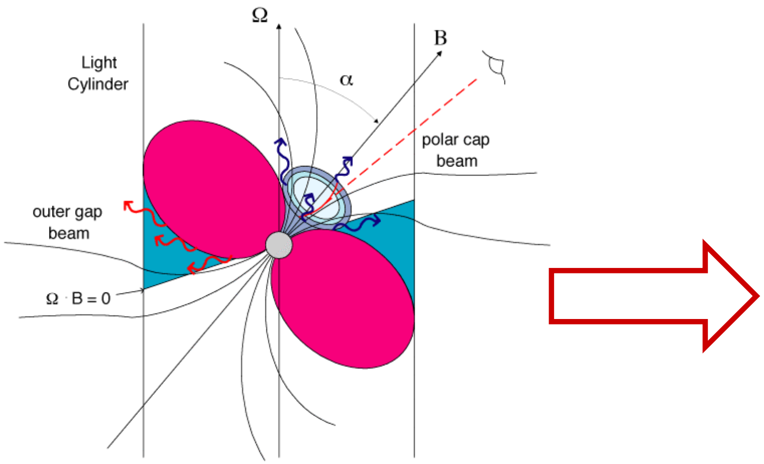
direct pulsation search in the γ-ray band

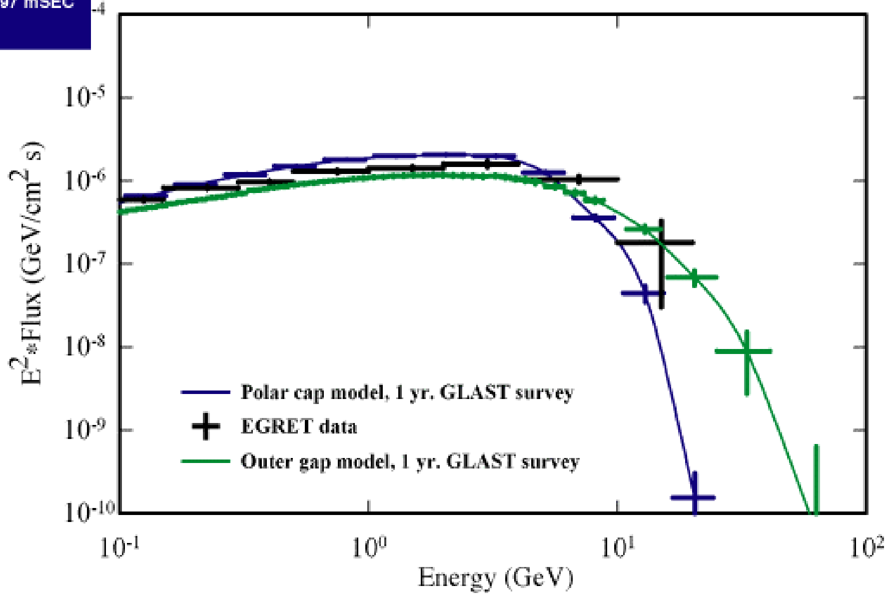
$\Rightarrow$ high time resolution

detect new gamma-ray pulsars (~250)

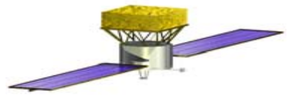
precise test of polar cap vs outer gap emission models

$\Rightarrow$ large effective area





GLAST

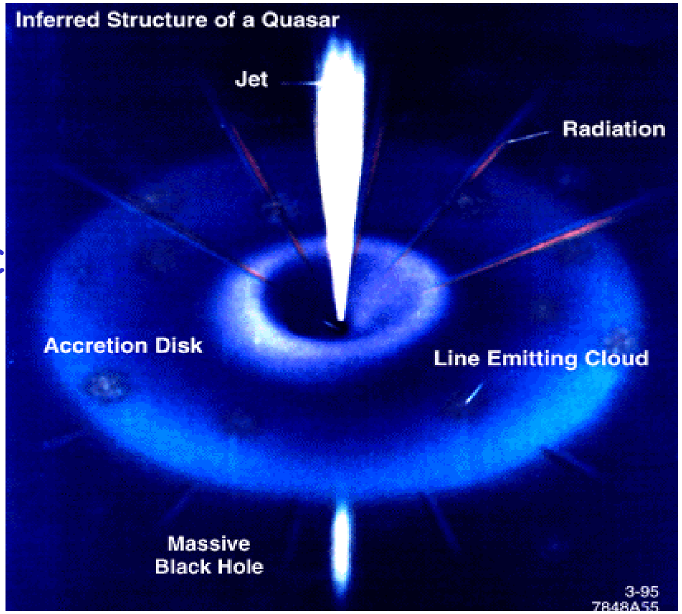


Active Galactic Nuclei

AGN signature

- vast amounts of energy (10^{49} erg/s) from a very compact central volume
- large luminosity fluctuations in fractions of a day
- energetic (multi-TeV), highly-collimated, relativistic particle jets

Prevailing idea: accretion onto super-massive black holes (10^6 - 10^{10} solar masses)



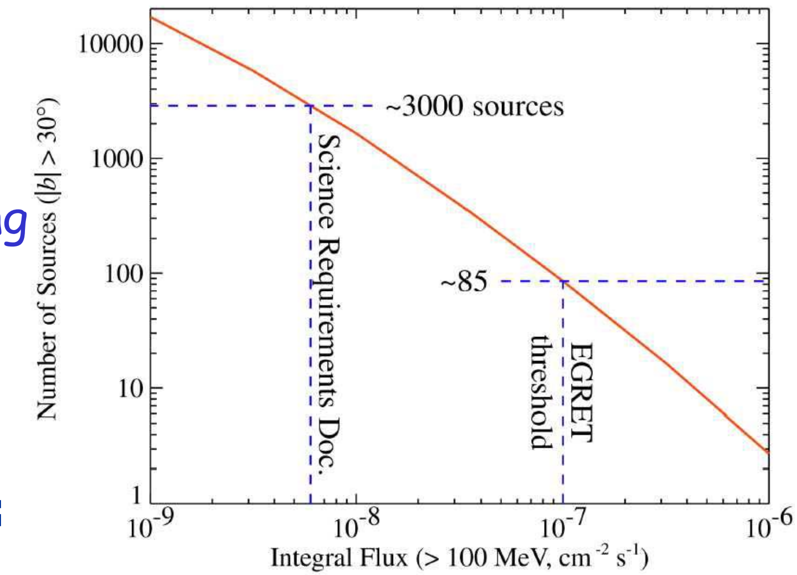
AGN physics *to-do* list

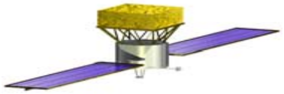
- catalogue AGN classes with a large data sample (~>3000 new AGNs)
- distinguish different emission models studying high statistics spectra
- resolve diffuse background
- study redshift dependence of spectra exploiting overlap with other wavelength observations and alert capabilities

$\Rightarrow$ high sensitivity

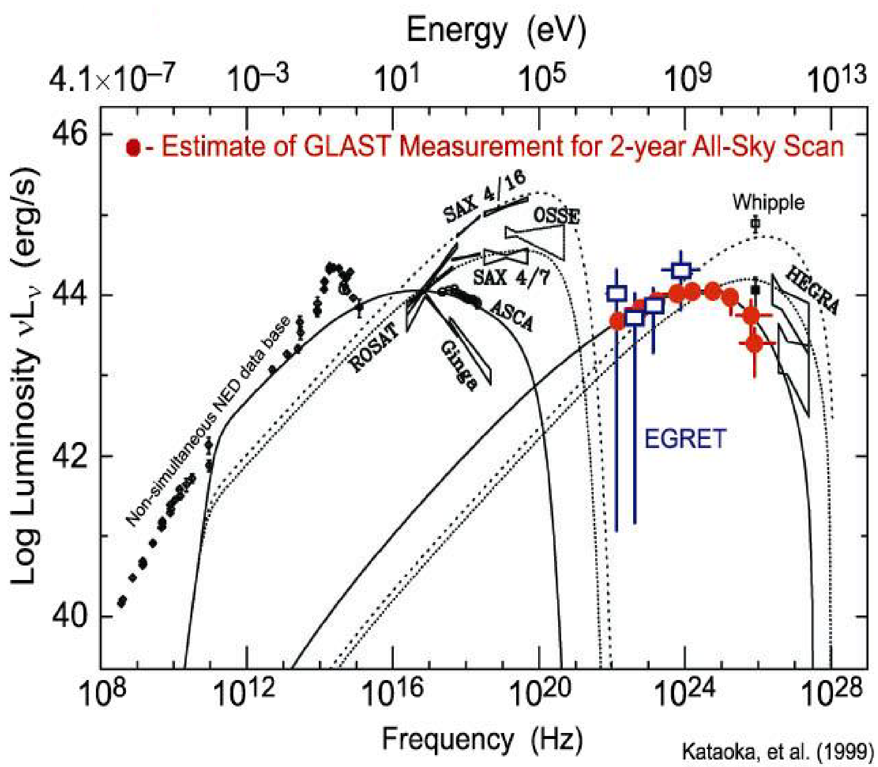
$\Rightarrow$ large effective area

$\Rightarrow$ small PSF





Active Galactic Nuclei physics with GLAST

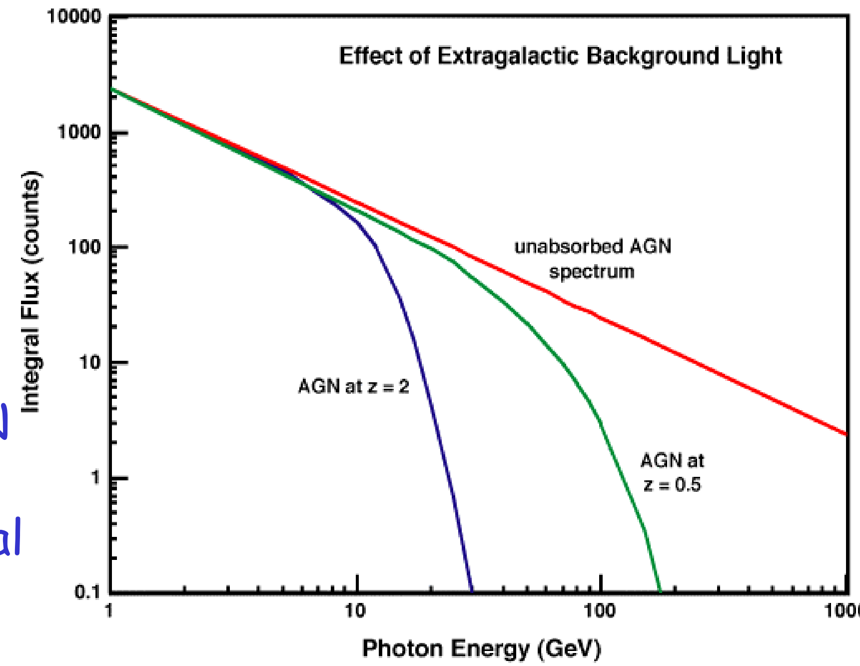


Blazar physics

- measure spectrum in uncovered gamma-ray energy band
- identify leptonic (SSC/ESC) and hadronic (π^0 decay) contributions
- track flares (time scale of minutes) and correlate to other wavelengths

Cosmology models

Roll-offs in the γ-ray spectra from AGN at large z probe the extragalactic background light (EBL) over cosmological distances and may help to distinguish models of galaxy formation

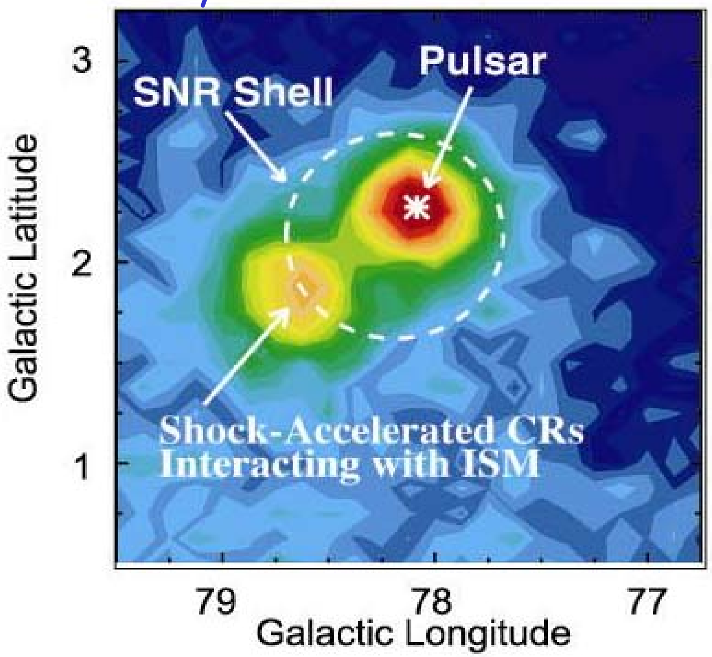


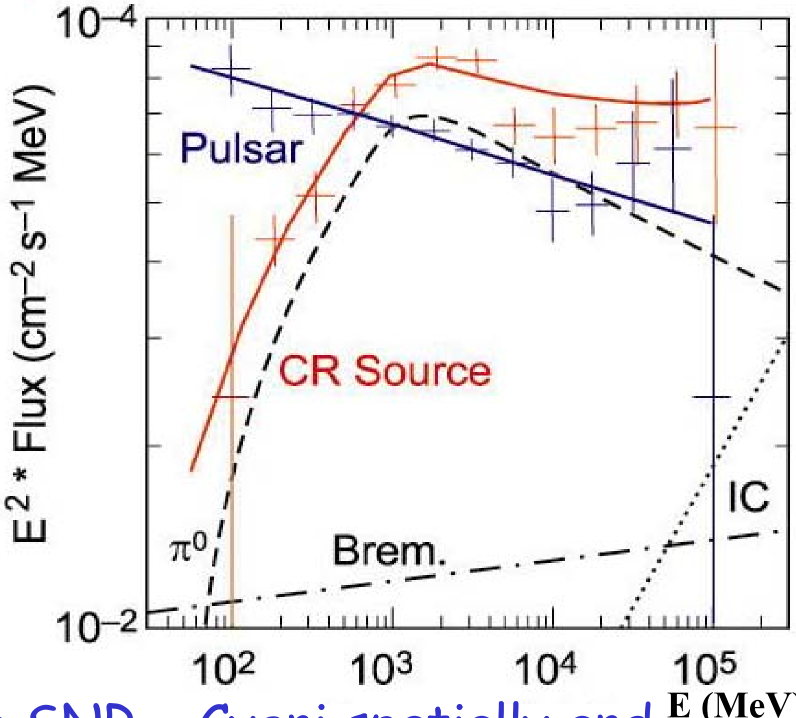
GLAST

Cosmic-Ray production and acceleration in SNR

- SNR widely believed to be the source of CR proton acceleration after shell interaction with interstellar medium
- π^0 bump in the galactic spectrum detected by EGRET

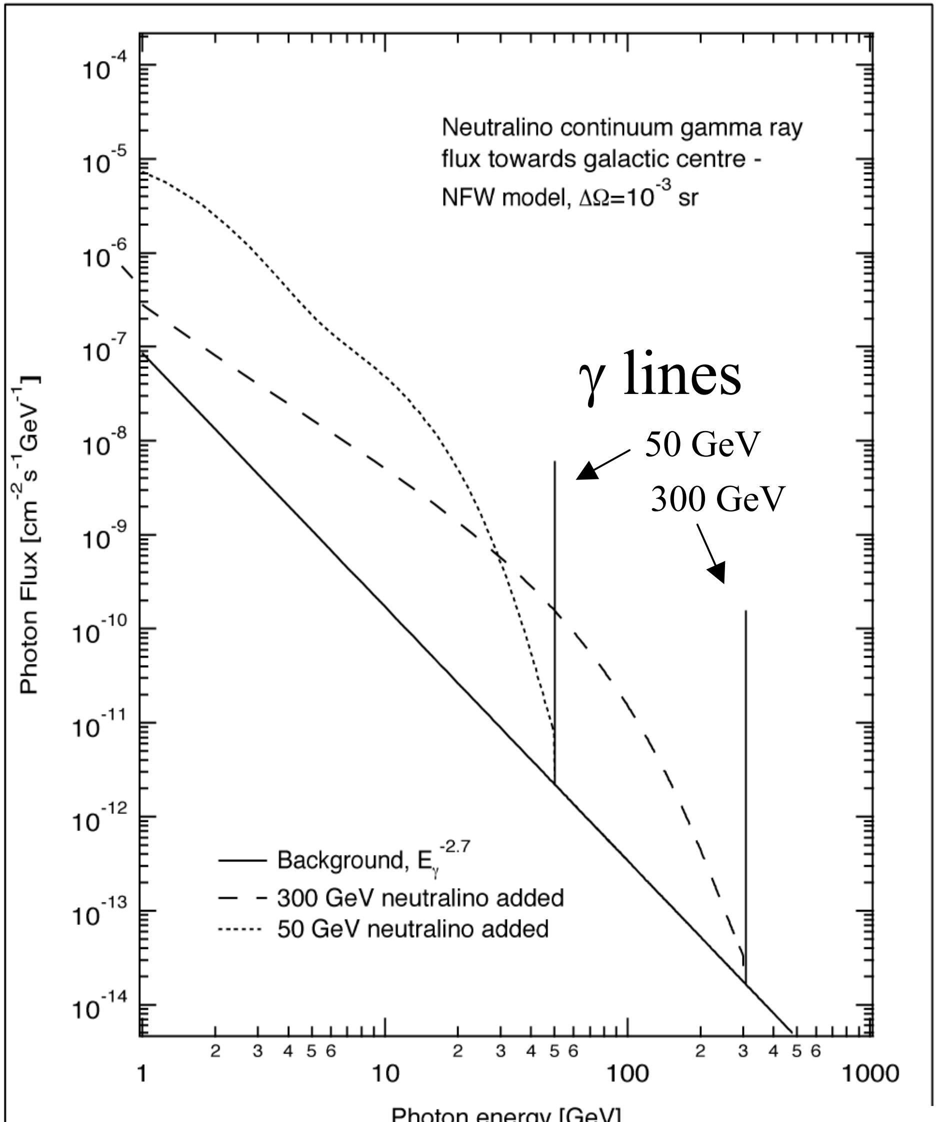
GLAST will
- locate SNR
- resolve SNR shells at ≈10′ level
- measure SNR spectra





GLAST simulations showing SNR γ-Cygni spatially and spectrally resolved from the compact inner gamma-ray pulsar – a clear π^0 decay signature from the shell would indicate SNR as a source of proton CR

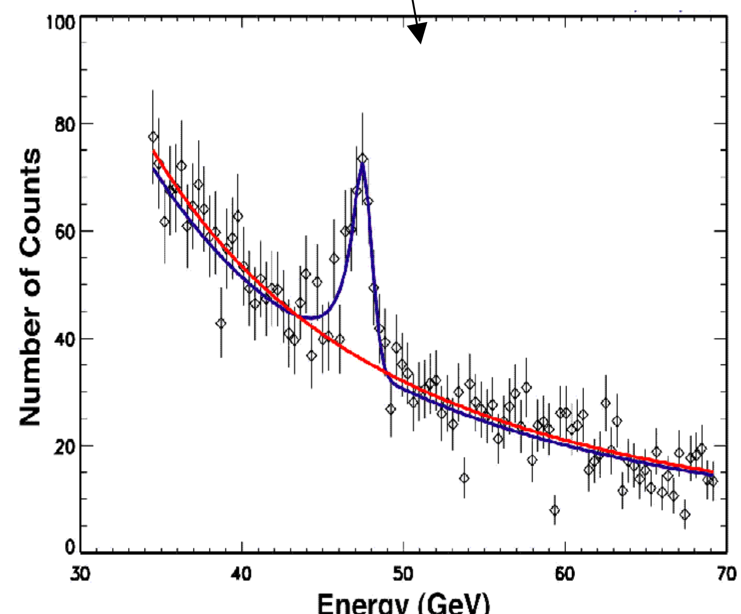
Supersymmetric Cold Dark Matter searches with GLAST



Total photon spectrum from galactic centre with $\chi\chi$ annihilation contribution

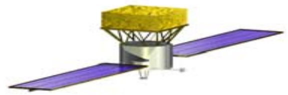
infinite energy resolution

finite energy resolution



2-year scanning mode

GLAST



EGRET/GLAST sensitivity to dark matter cusp candidates

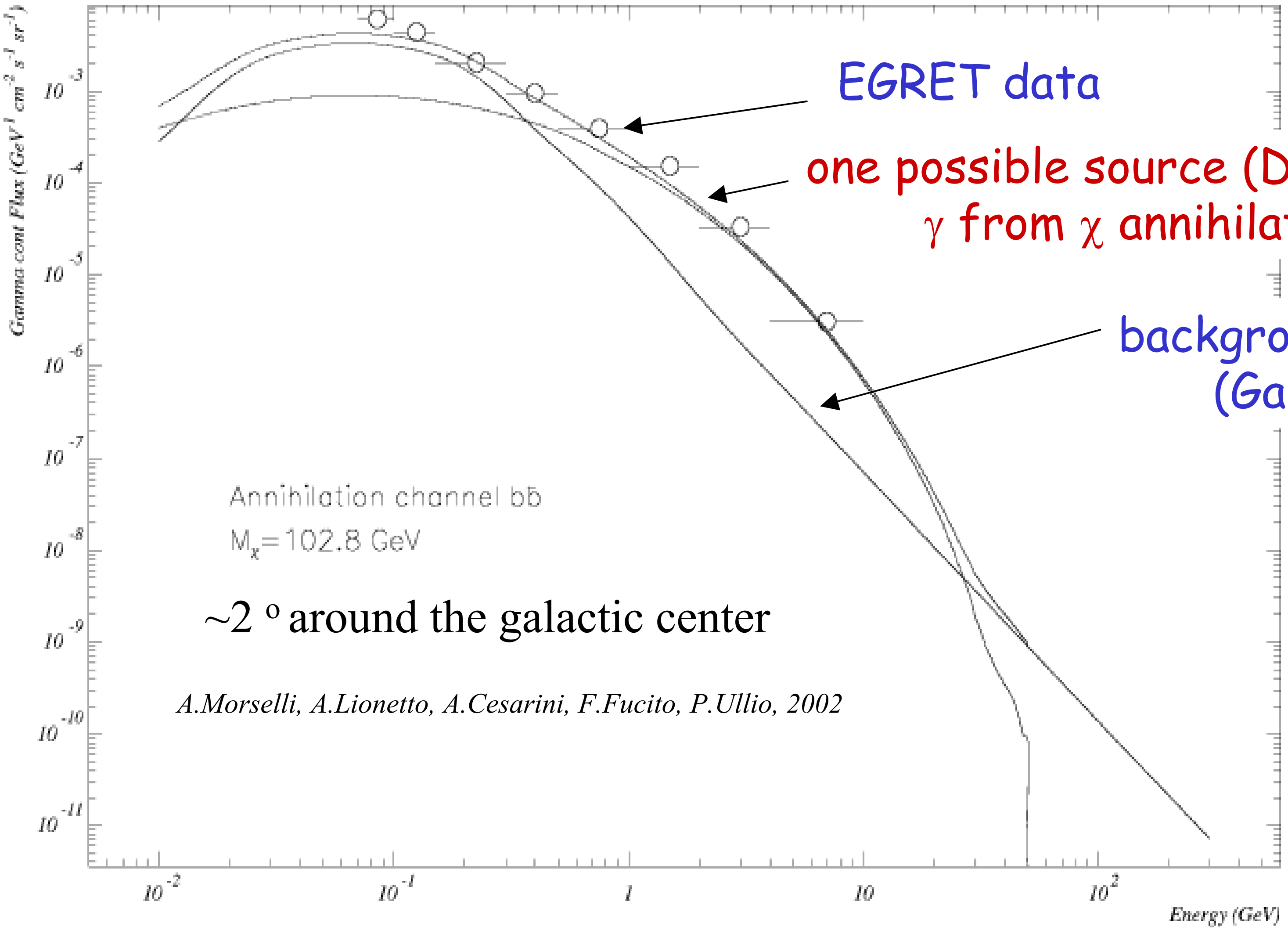
Name	Location	Distance	$<\sigma v>_{\chi\chi}$ sensitivity[3] for m_χ=100GeV (cm^3s^{-1})
Galactic Center[1]	$b=0^0$, $l=0^0$	8.5 kpc	EGRET: 2e-27 GLAST: 2e-29
Large Magellanic Cloud[1]	$b=-32.09^0$, $l=279.73^0$	50 kpc	EGRET: 7e-26 GLAST: 7e-28
Draco[2]	$b=34.71^0$, $l=86.37^0$	79 kpc	EGRET: 2e-24 GLAST: 2e-26

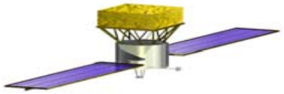
1. Calcaneo-Roldan & Moore, PRD 62, 123005 (2000); "Moore" cusp, 200pc core
2. Tyler, C. PRD 66, 023509 (2002); Singular Isothermal Sphere, 0.1pc core
3. Note: Ω_χ=0.3 corresponds to 2e-26 cm^3s^{-1}

GLAST

EGRET data & Susy models

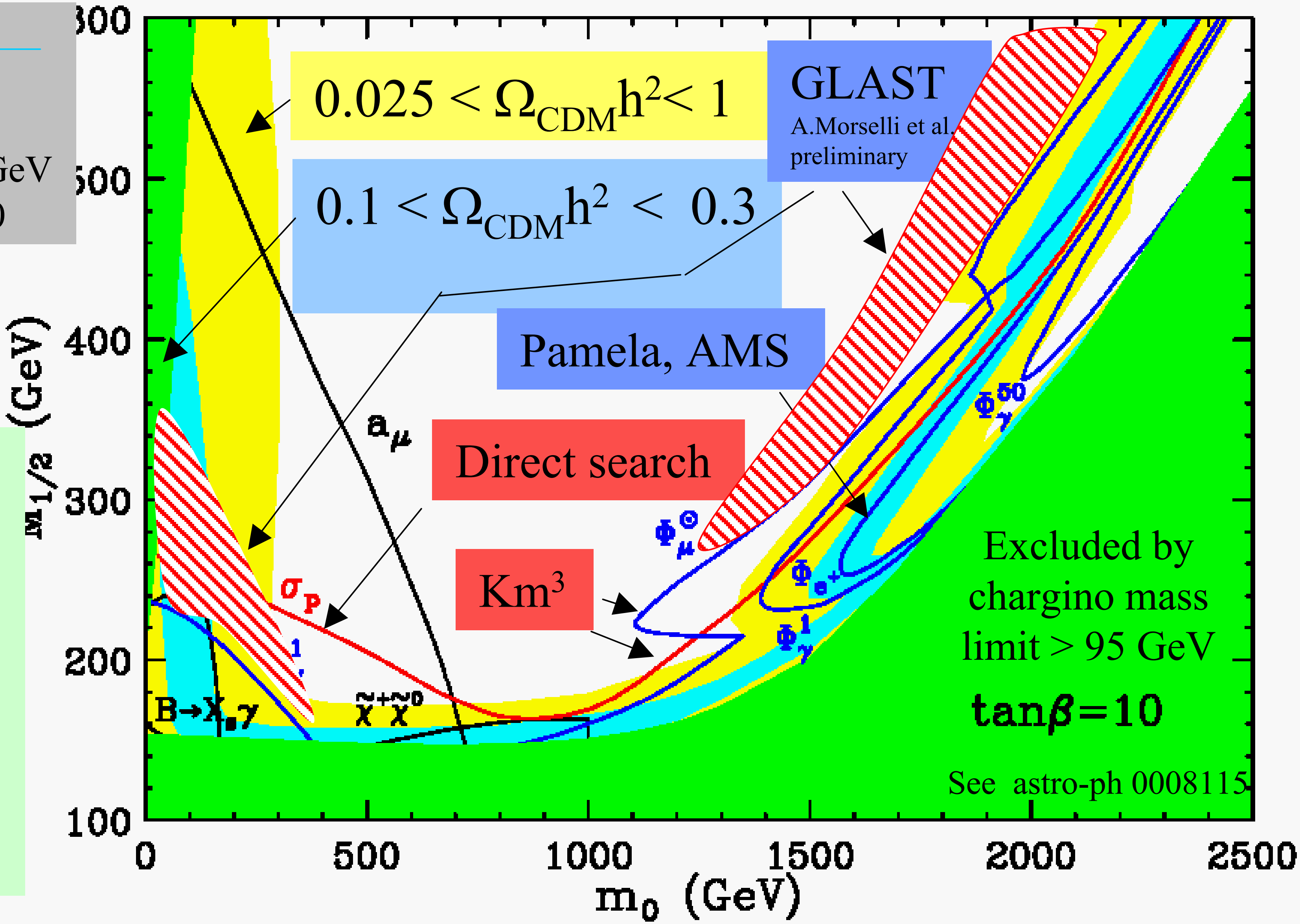
(www-glast.slac.stanford.edu/ScienceWorkingGroups/DarkMatter/default.asp)



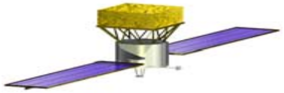


Estimated reaches before LHC

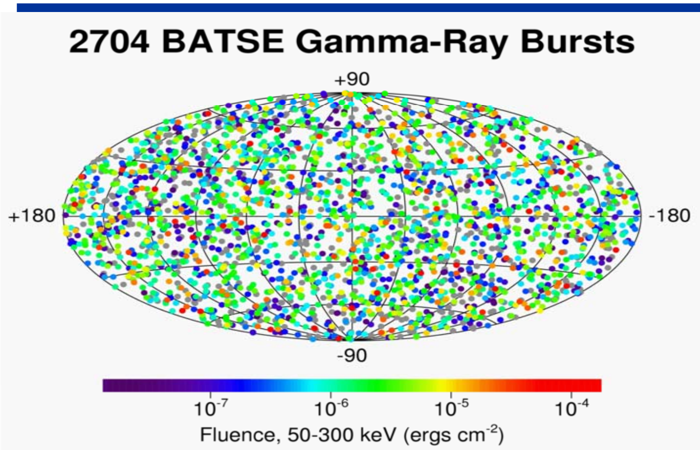
MSSM
$A_0 = 0$
$\mu > 0$
$m_t = 174$ GeV
$\tan\beta = 10$



2 years exposure. Fixed Halo profile, indirect limits better if halo is clumpy



Gamma-Ray Bursts and GLAST



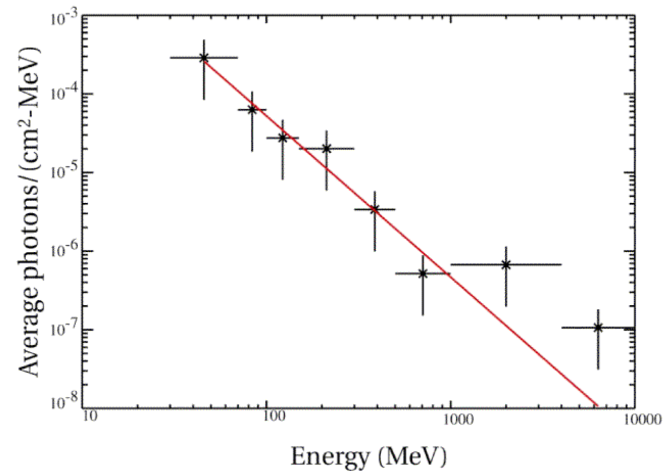
- observed Φ_γ ~ (0.1-10) x 10^{-6} erg/cm^2 ($\Omega/4\pi$)
- little data > 50MeV
- isotropic distribution in the sky
- cosmological origin from afterglow redshift
- spectacular energies ~ 10^{51} - 10^{52} erg (!)

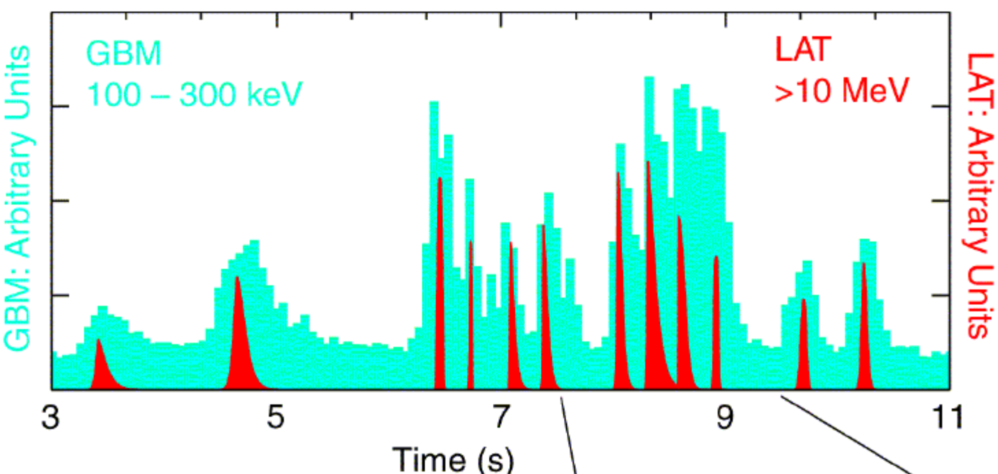
$\Rightarrow$ **large effective area, high angular resolution**

spectral studies for

- non-thermal emission model (synchrotron, ICS)
- fireball baryon fraction

$\Rightarrow$ **high energy resolution**



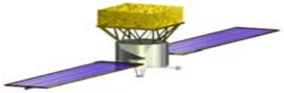


- transient signal, ~ 100 μs time scale
- light curves vs energy

$\Rightarrow$ fast response/ short dead time

GLAST

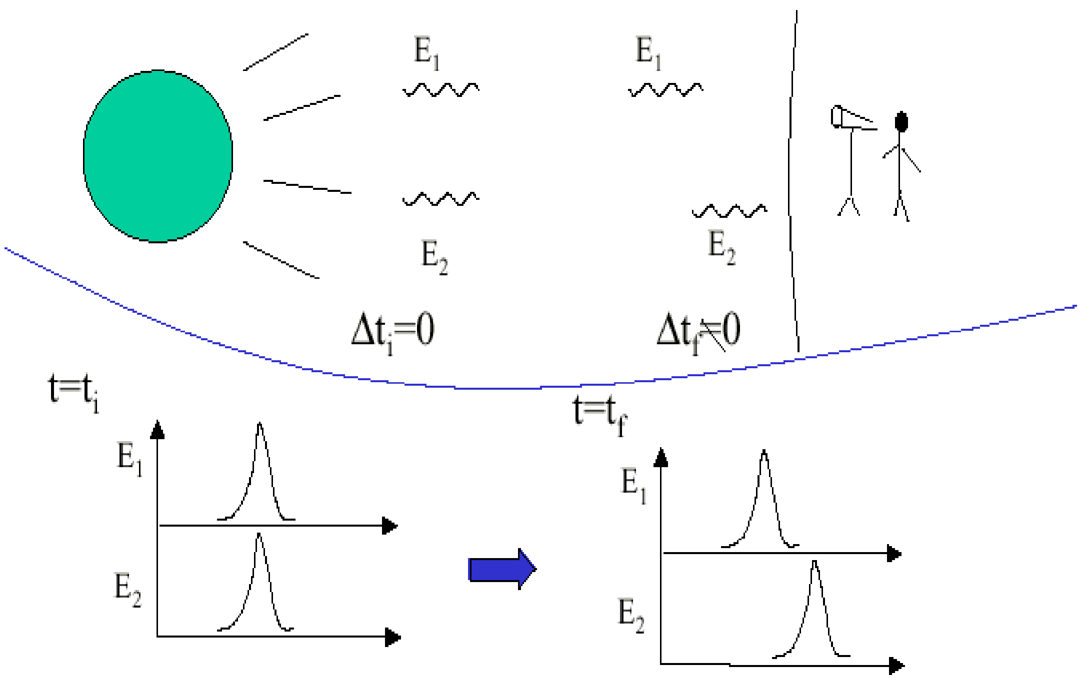
Luca Latronico – INFN Pisa

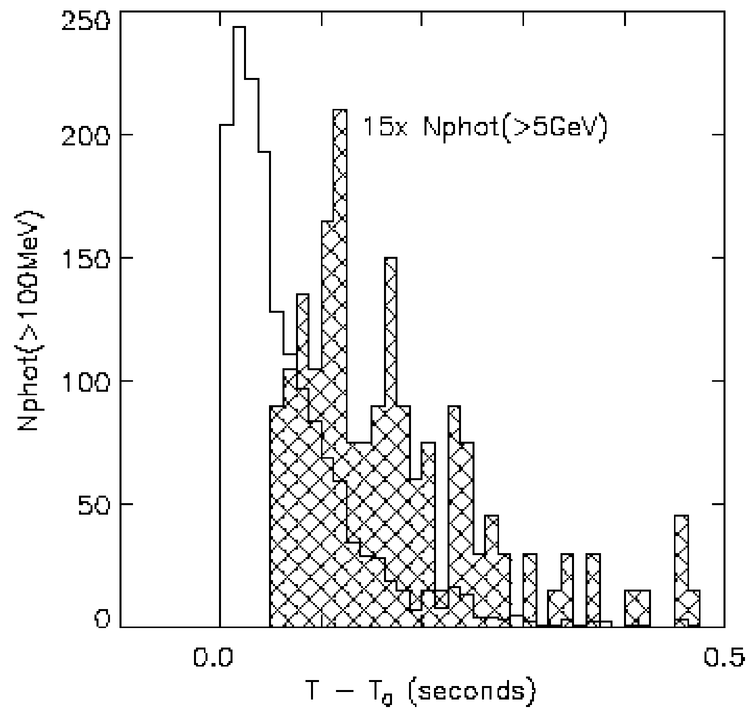


GRBs to probe Quantum Gravity

Using only the 10 brightest bursts yr^{-1}, GLAST would easily see the predicted energy- and distance-dependent effect.

Test of Quantum Gravity $\Delta t = \sim \alpha\, E/E_{QG}\, D/c$



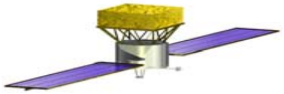


$D \sim 2\ 10^{28}$ cm $E_{QG} \sim 10^{19}$ GeV $c \sim 3\ 10^{10}$ cm ➡ $\Delta t(ms) \sim 60\ \Delta E(GeV)$

even at pulsars distance: $D \sim 6\ 10^{21}$ cm $\Delta t(\mu s) \sim 100$ ➡ $E_{QG} \sim 10^{14}$ GeV

Arrival time distribution for two energy cuts 0.1 GeV and 5 GeV(cross-hatched)

GLAST

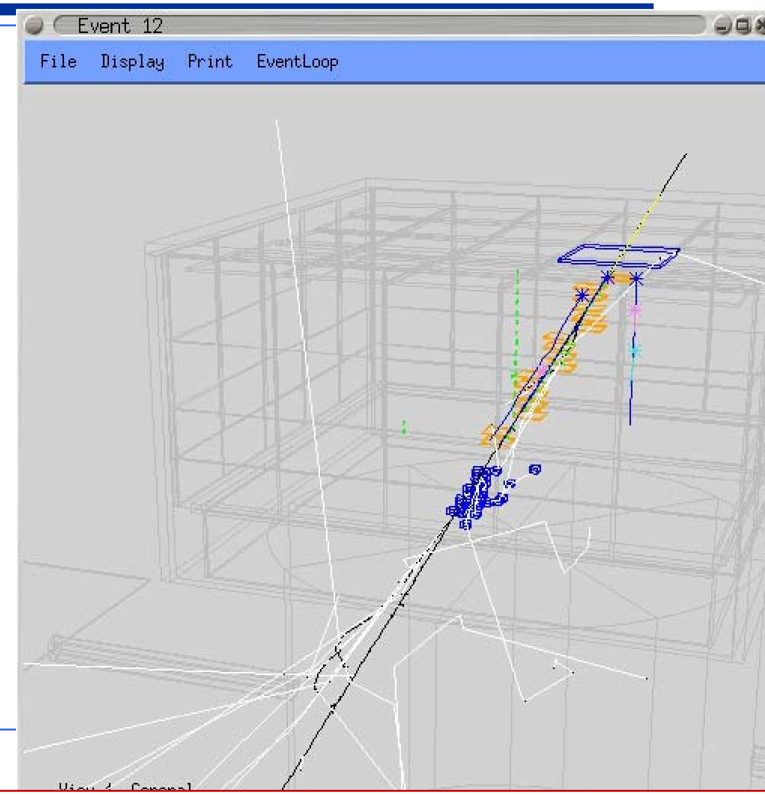


GRB Simulation

(http://glast.gsfc.nasa.gov/science/grbst/ for details)

source signal - two different approaches:

- *phenomenological*: extrapolation of the high energy spectrum from data collected in the previous experiments (J. Norris et al.)
- *physical* : based on the fireball description of GRBs (expanding shells) it computes the evolution of the spectrum taking care of all the emission processes that can be involved in GRB physics (N. Omodei et al.)
- both reproduce GRB spectral and temporal variability

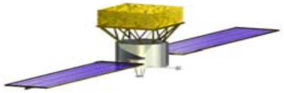


simulation of GLAST response

- Montecarlo Simulation (Geant4, Gismo)
- tracks reconstruction
- full event reconstruction

Analysis

- direct comparison with the previous experiments (BATSE)
- investigate Trigger strategies
- develop of the scientific analysis tools (Spectral fitting engine, Light Curves visualization and pulse decomposition)



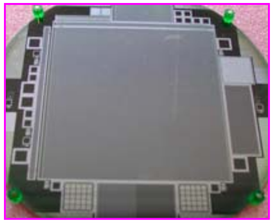
GLAST Tracker Design Overview

- 16 "tower" modules, each with 37cm × 37cm of acti cross section
- 83m^2 of Si in all, like ATLAS
- 11500 SSD, ~ 1M channels
- 18 *x,y* planes per tower
  - 19 "tray" structures
    - 12 with 3% W on bottom *("Front")*
    - 4 with 18% W on bottom *("Back") - SuperGlast*
    - 3 with no converter foils
  - Every other tray is rotated by 90°, so each W foil is followed immediately by an *x,y* plane of detectors
    - 2mm gap between *x* and *y* oriented detectors
- Trays stack and align at their corners
- The bottom tray has a flange to mount on the grid.
- Electronics on sides of trays:
  - Minimize gap between towers
  - 9 readout modules on each of 4 sides

One Tracker Tower Module

Status of the Tracker construction

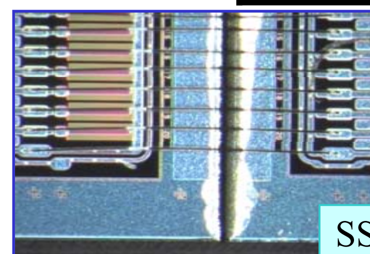
SSD Procurement, Testing
(Japan, Italy, SLAC)



- 3400 flight SSD produced (HPK)
- 2200 tested (~20% total production)
- < 1.3% failure rate

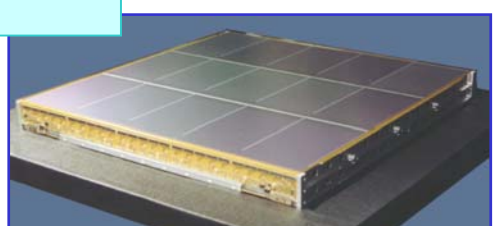
	μ	σ
I_{leak}	100nA	50nA
V_{dep}	70V	20V
C_{bulk}	1800 pF	10pF ~2μm
Wafer cut		~2μm

- 140 *mechanical* assembled to tune production, with wafer σ_{align} ~5.5 μm
- 300 *flight* in production for EM (1tower with 4fully operational trays, due March 2003)



SSD Ladder Assembly
(Italy)

Tray Assembly and Test
(Italy)

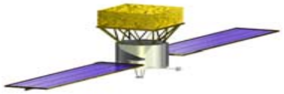


- superGlast tray design approved
- thermal and vibrational tests on prototypes
- tower assembly technique and tools finalized

EM prototypes production of hybrids and F.E.

Electronics Design, abrication
& Test
(UCSC, SLAC)

GLAST



Conclusions

- GLAST is a partnership of HEP and Astrophysics communities sharing scientific objectives and technology expertise
- GLAST will survey the sky in the 20MeV~1TeV γ-ray band, where the most energetic and mysterious phenomena in nature reveal their signature
- GLAST is equipped with state-of-the-art particle detectors, resulting in an order of magnitude improvement in sensitivity and resolution with respect to previous missions
- the GLAST-LAT construction has started with very promising results
- GLAST will therefore:
  - detect thousands of new and unknown γ-ray sources
  - identify the correct emission models for known classes of sources
  - probe the supersymmetric phase space in search for WIMP decay and neutralino annihilation signals
  - provide significant data on the origin and evolution of GRBs
  - help building a new cosmological theory with key observation on the nature of dark matter, presence of an extra-galactic background light, quantum gravity effects

……. *much anticipation awaits GLAST on its way to discoveries that will change our knowledge of the Universe*

GLAST