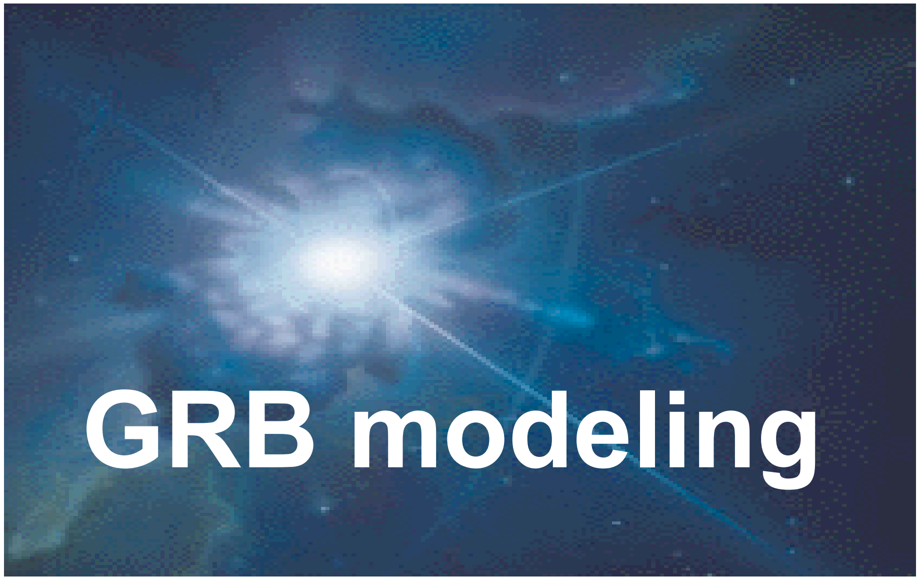

GRB modeling

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On behalf of the GLAST GRB and Solar Flare Science Team

On going GRB activities in Italy

- Simulation:
  - GRB modeling
  - On board fast reconstruction
  - Trigger and alerts
- Science Tools development
  - Visualization
  - Physical model fitting engine
- Quantum Gravity study

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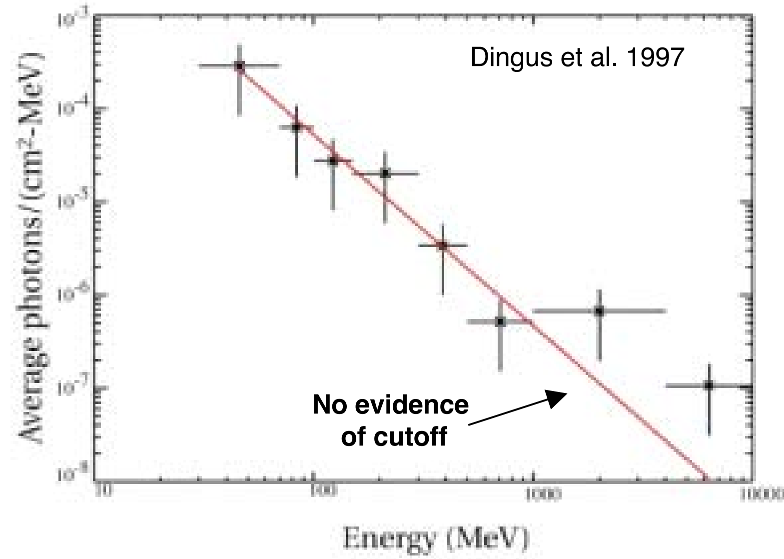
GRB physical modeling

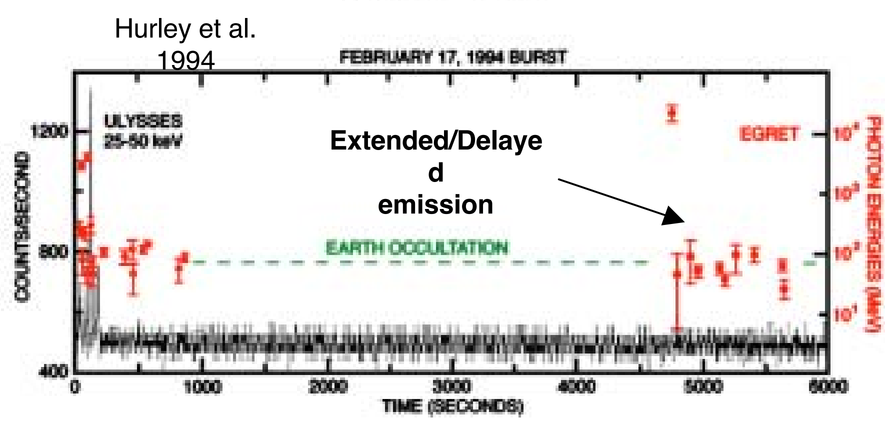
- Need to simulate LAT GRB photons for trigger decision and development of analysis tools
- Two approaches available
  - Phenomenological (J.Norris' approach)
  - Physical (based on shock models)
- More physics and new results on GRB at high energies (eg. Gonzales et al. 2003) to be included

GLAST and Gamma-Ray Bursts

- Little is known about GRB emission in the >50 MeV energy regime
- EGRET detected ~5 high-energy bursts, but suffered from:
  - Small field of view (~40°), so few bursts were detected
  - Small effective area (~1000 cm^2), so few detected photons per burst
  - Large deadtime (~100 ms/photon), so few prompt photons were detected
- Prompt GeV emission with no high-energy cutoff (combined with rapid variability) implies highly relativistic bulk motion at source: G > 10^2–10^3
- Extended or delayed GeV emission may require more than one emission mechanism

Composite spectrum of 5 EGRET Bursts





GRB theory

Standard Fireball Model:

- Relativistic motion of the emitting region
- Shock mechanism converts the kinetic energy of the shells into radiation.

Soft Energies:

Internal Shocks

- Synchrotron Emission
- Rapid time Variability
- Low conversion efficiency

High Energy:

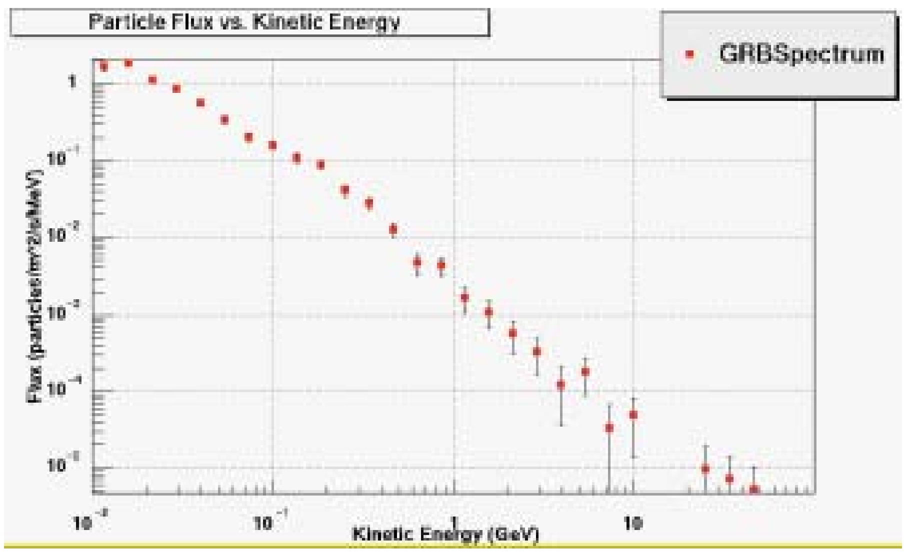
External Shock

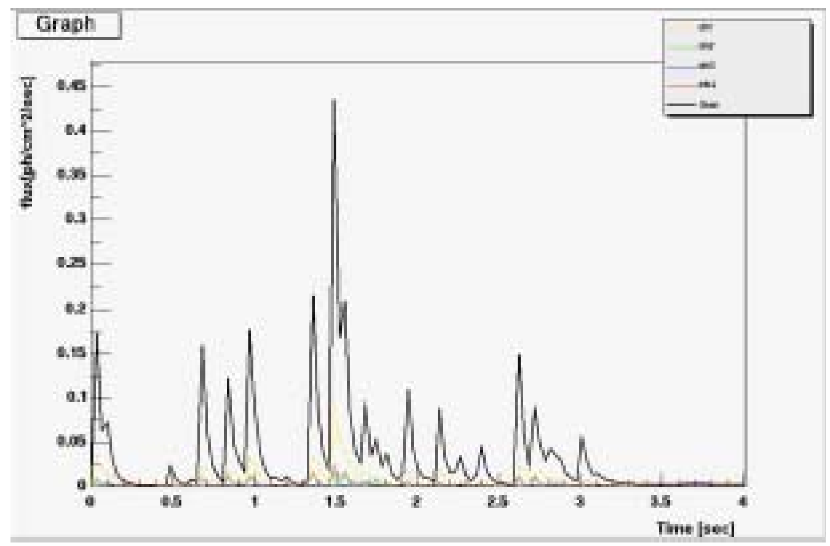
- Synchrotron & SSC
- High conversion efficiency
- Not easy to justify the rapid variability

Interaction Between the high energy particles produced
in the first stage with the external e.m. field (Background Radiation)
Delayed MeV-GeV photons

GRB package

- GRB model:included in Gleam
  - Shell collision: Different Lorentz factor
  - Jet geometry
  - Synchrotron & Inverse Compton emission
- Temporal evolution:
  - Detection of transient signals





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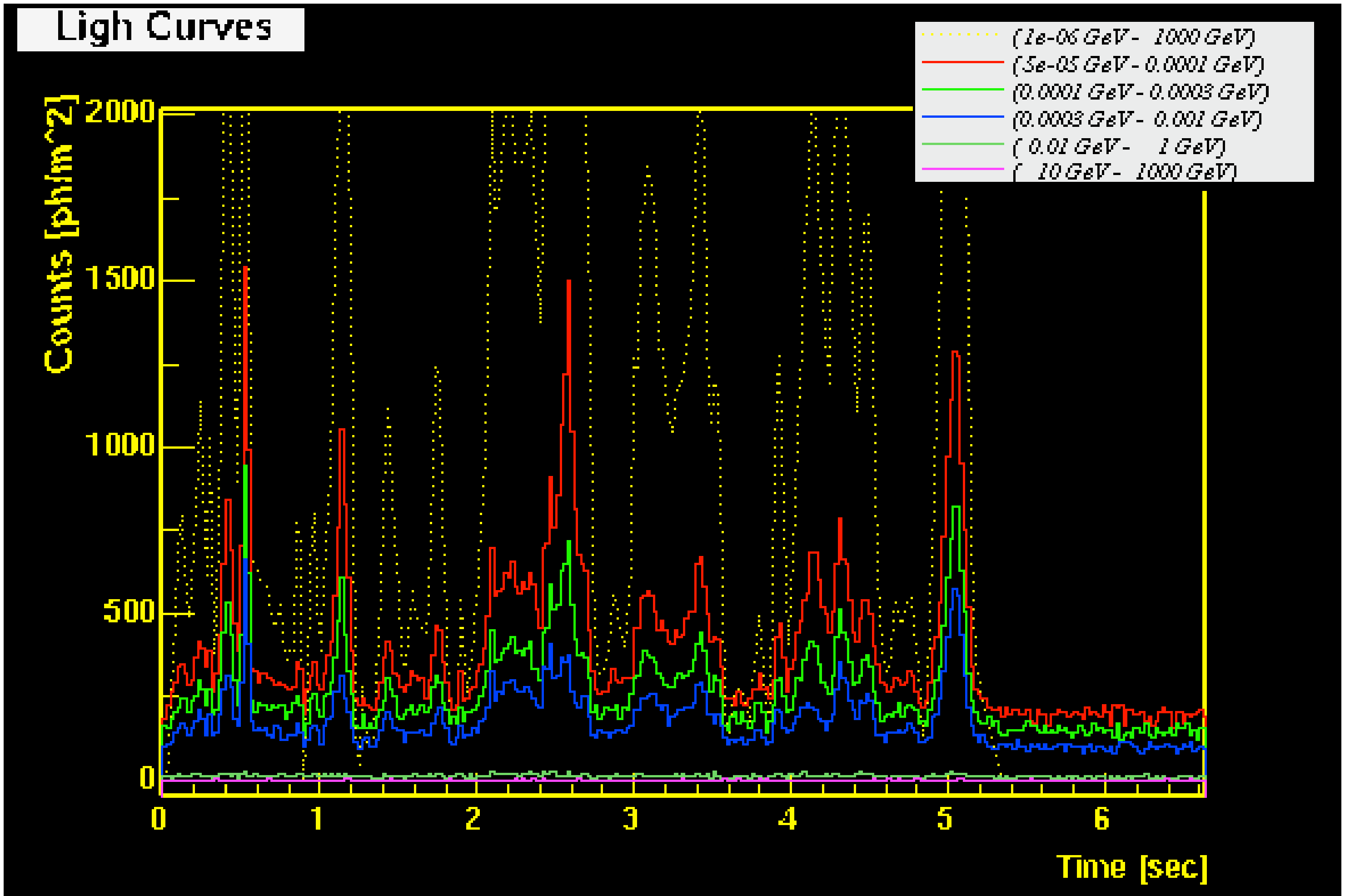
GRB modelling



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Simulations: a new model developed

- Starting from the experience of the development of the GRB physical model (GlastRelease/GRB) a new parametrization based on Ryde and Svensson models
- **Purpose**: Using the model to feed the LAT simulation

  & to fit GBM and LAT signals: -> Parametric Model
- **Ideas:**
  - A burst is composed by different peaks. ***Each peak***:
    - **Time resolved spectra:** Optically thin thermal bremsstrahlung (OTTB) combined with a power law at high energies (= Band function.)
    - **Tim**

$$N(t,e) = \frac{N(t)}{A} \cdot \begin{cases} (e/e_p(t))^a \exp(-e/e_p(t)) & e < e_p(t)(a-b) \\ C \cdot (e/e_p(t))^b & e > e_p(t)(a-b) \end{cases} \qquad [ph/cm^2/s/keV]$$

–The peak energy and the fluence of the time resolved spectra decays as a function of the time

$$e_p(t) = e_p(0)/(1+t/\tau)^d$$

$$N(t) = N(0)/(1+t/\tau)$$

–**Source model:** Photons are extracted accordingly with the theoretical flux and the GLAST simulator (Gleam) processes them. (Montecarlo, Digitization, Reconstruction…)

·**The model compute the spectrum also at GBM energies**

·**It could be used for A10 Fitting engine**

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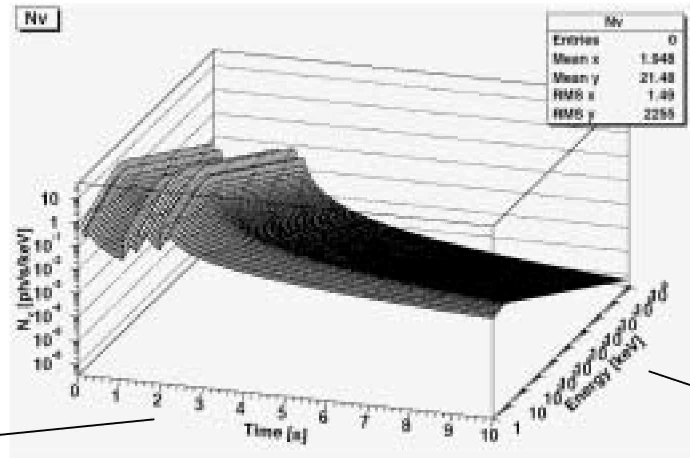
Simulations: a new model developed

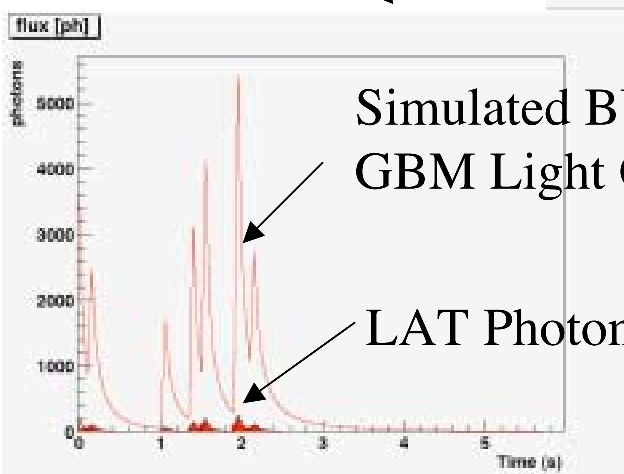
The time resolved spectrum is computed

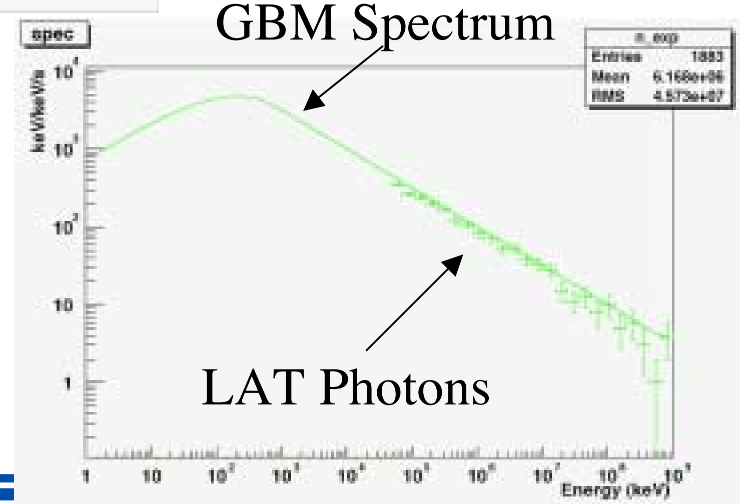
- Photons with energy greater then a fixed minimum energy are extracted (LAT photons).



Spectrum as a function of time

The 2D histogram contains all the information needed to compute the photon list

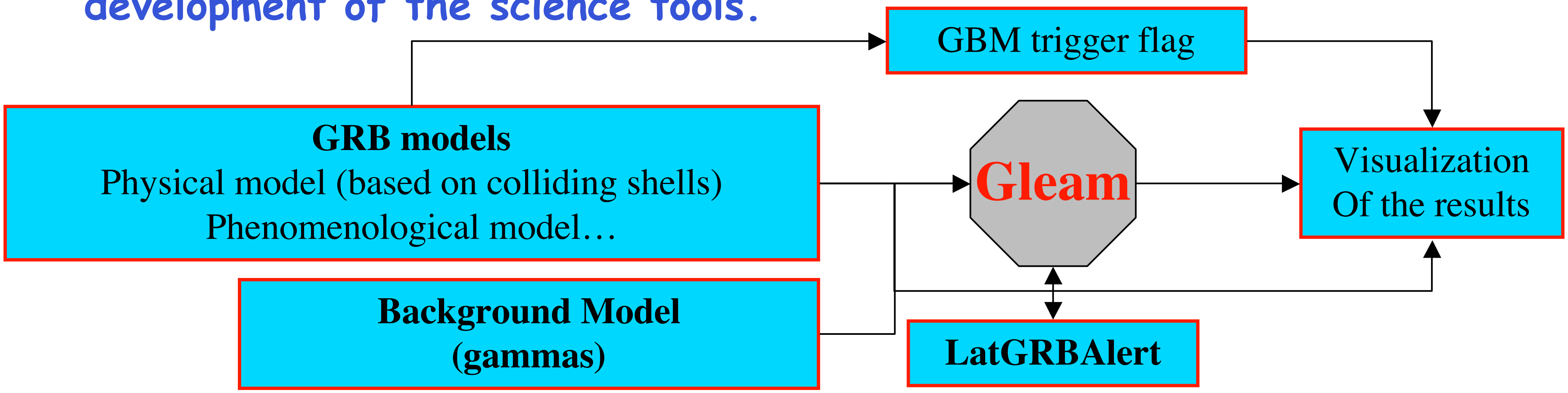




Time integrated spectrum

GRB "Use Cases"

In order to test and study the GRB world, we are creating a testbanch for simulating LAT signal, and for helping in the development of the science tools.



GBM external trigger: uses starting time of the simulated Burst (reference value) the real one to be implemented by GBM

GRB and Background are mixed via the **"GRB_library.xml"**

The **LatGRBAlert** algorithm compute the **joint likelihood** (spatial and temporal)

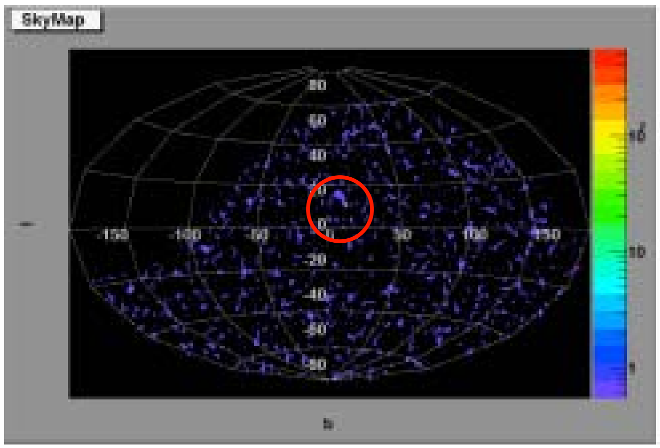
We use **LatGRBAlert** in **real time** (to be put in **GlastRelease**). It works with a **buffer of events** *(some refinement and test are needed)*

This scheme works fine with the **full reconstruction** -> we need a **Fast on-board reconstruction for GRBAlertTrigger (*OnboardFilter*).**

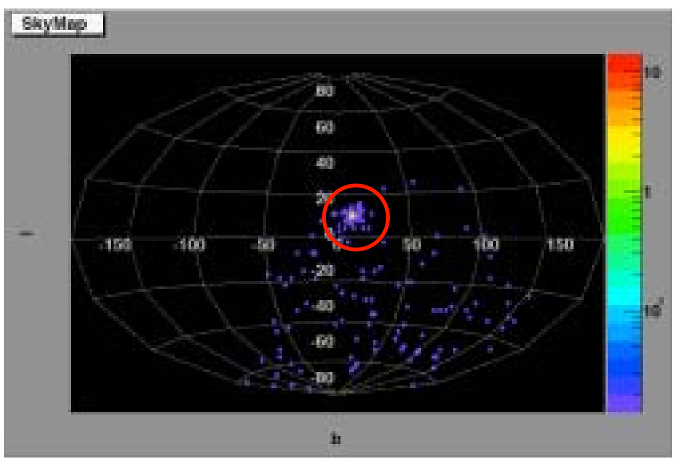
Visualization based on ROOT

Preliminary results

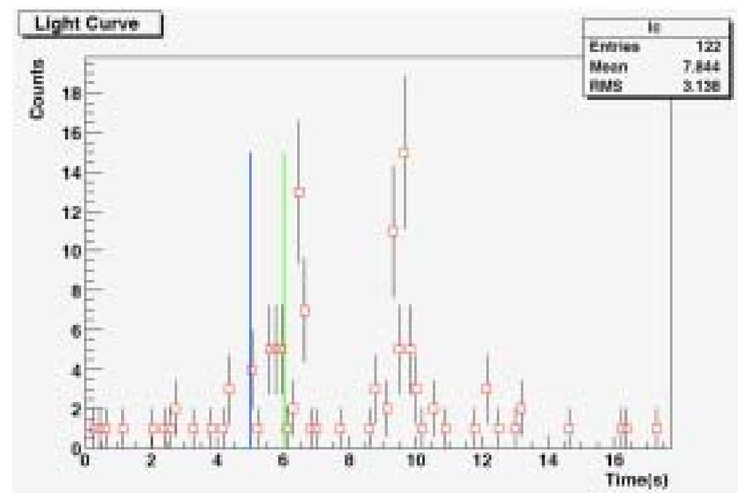
- Photons coming from the GRB and from the diffuse background are processed by the Montecarlo.
- A buffer is filled by N evens -> LatGRBAlert searches aggregation of events in time and space.
- A signal of alert is given



SkyMap of the **incoming events**



SkyMap of the **reconstructed events**



Reconstructed events as a function of time. The simulated burst starts at *t* ~5 and the alert is given at *t* ~ 6…

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A fast reconstruction method for Onboard GRB Alert

- In the **full reconstruction** most of computing time is spent in find good tracks candidates (Pattern Recognition)

  Simple and fast way to select the candidates tracks

- Reduce the number of iterations over the points

  Differents filters to select only interesting candidates.

- Identification of general classes of events based on different phenomenology of the shower

  Very simple and specific methods for finding direction of gamma.

1. **In the GRBs spectrum we expect many events with low energy (20-100 Mev), and consequently not too many hits in the TKR.**
2. **We want to reduce the error due to propagation of particles in the detectors (multiple scattering, Compton, etc..)**

AND

1. **Reduce the number of iterations operations between the points**

   we use only the first layers hit.

Phase 0: Retrieve initial data

(Hits on Tkr from the 3-In-A-Row)

↓

Phase 1: Find candidates

(triplets of points aligned on x and y projection ('***SimpleTracks***'))

↓

Phase 2: Merging of tracks

(few SimpleTracks obtained from merging closest tracks)

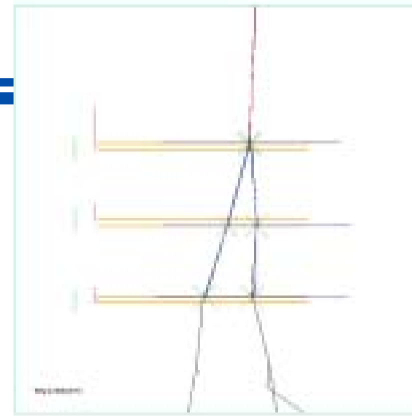
↓

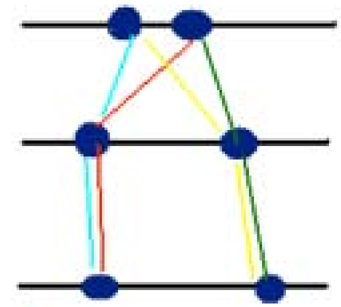
Phase 3: Vertexing

(Simple geometrical strategies In order to have directions)

How it works: some preliminary results

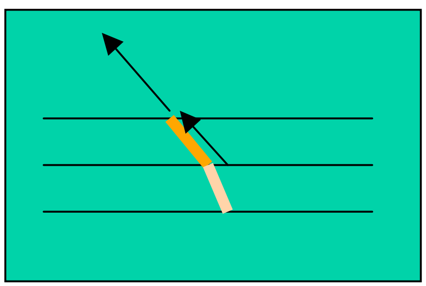
1) We start from 4 SimpleTracks
(4 possible combinations of aligned triplets)



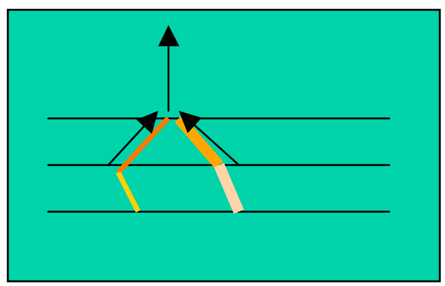


2) Then we merge (0,2) and (1,3)

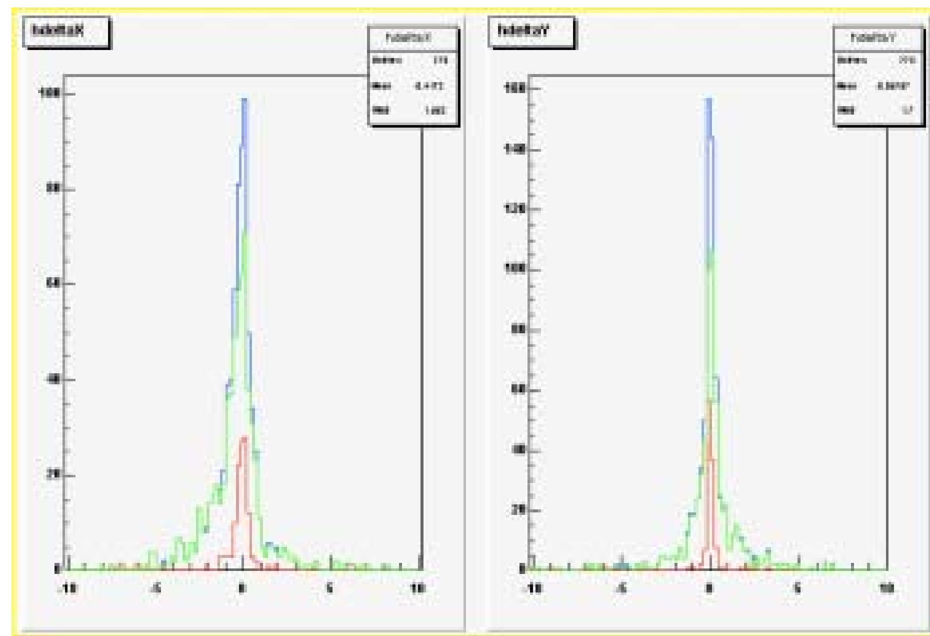
3) Then we find the direction depending on 2 types of event classes



Type 0 event:
1 track



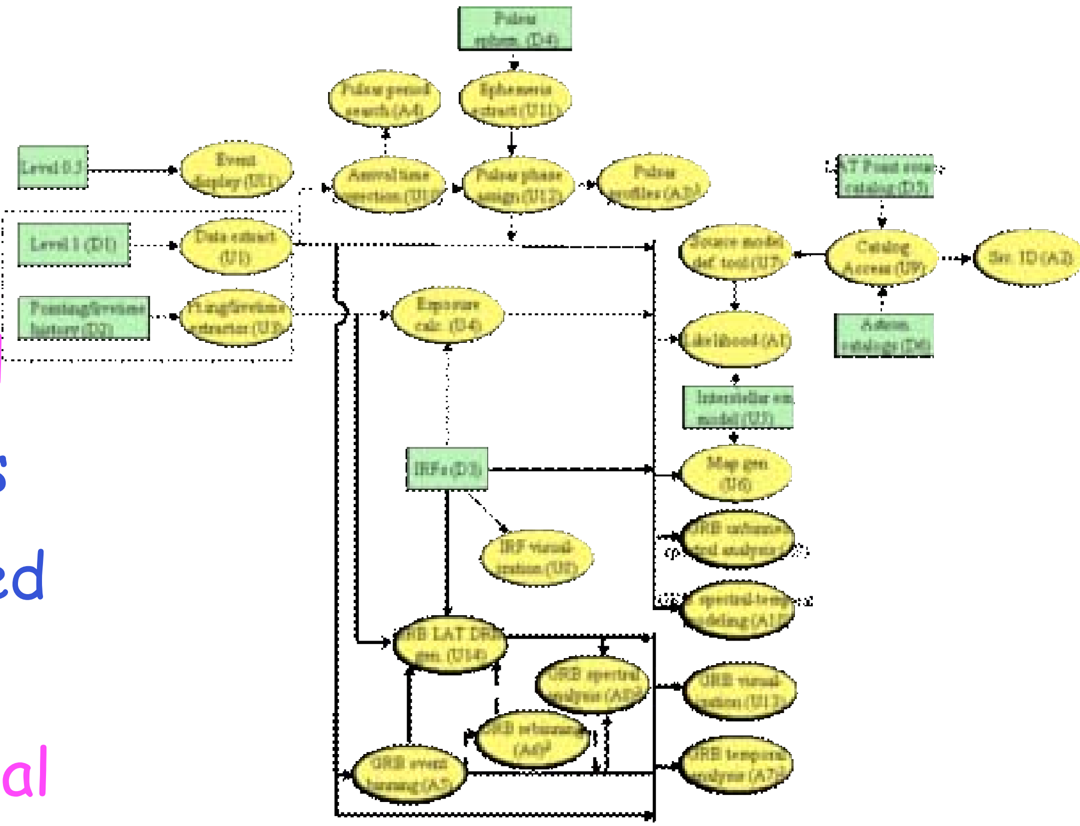
Type 1 event:
2 or more tracks



Angular distribution with fast reconstruction of a photon beam of 500 MeV (θ=0 deg, φ = 30 deg)
Red: Type 0; Green: Type 1; Blu: Type 0 + Type1

Overview of the GRB planned tools

- U14: DRM generator
- A5/6: Event Binning/Rebinning
- U13: Visualization tool
- A7: Temporal Analysis
- A8/9: Binned/Unbinned Spectral Analysis
- A10: Spectral Temporal Physical Modeling



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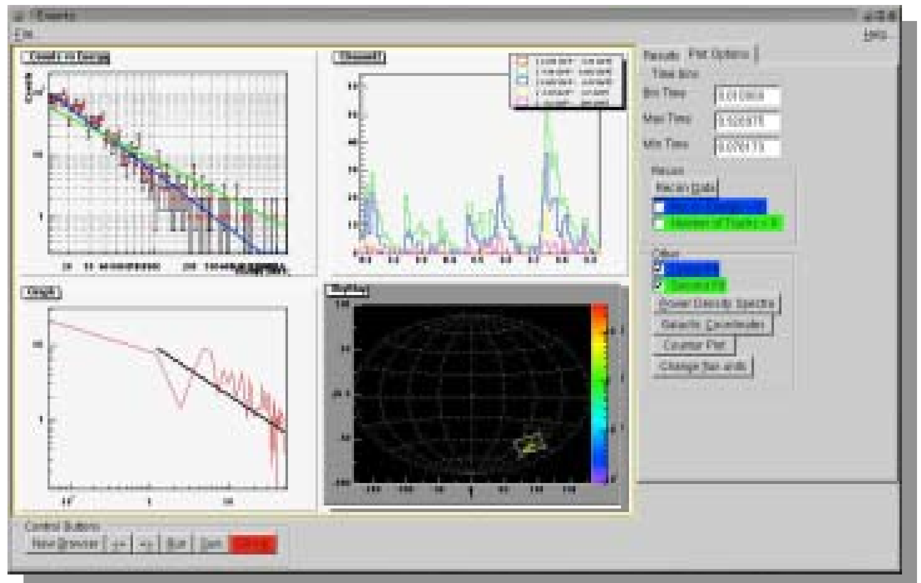
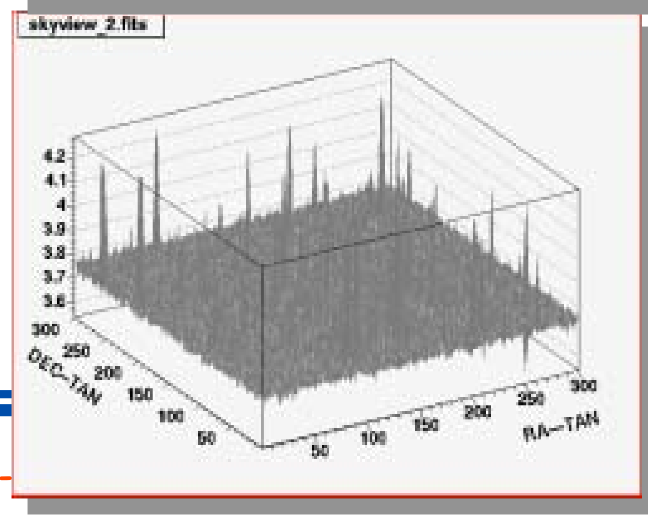
Visualization: current status

We are implementing *fast prototypes* for testing the capability of ROOT

GRAPHICS:

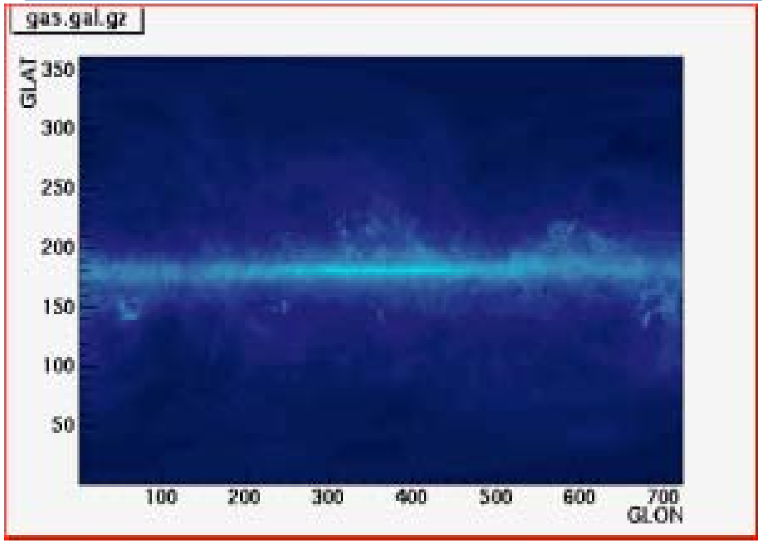
- Graph, 1D and 2D Histograms
- Fully editable interactively
- Re binning / variable bin size
- Easy to derive classes (sky map…)
- Scripting (root macro) C++ based, good for fast prototyping
- External libraries can be interfaced with the GUI (FFTw, AstroLib…)



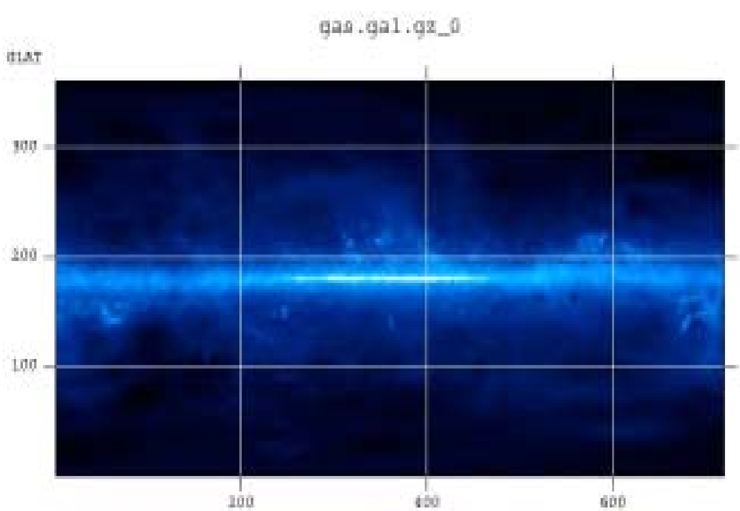


3D surface plot, sky view in J band (data from STScI)

ROOT and FITS



Displayed with AstroROOT



Displayed with fv

DATA HANDLING (FITS)

- AstroROOT can read/write the header of FITS files
- AstroROOT can read/write **ASCII** and **Binary** tables in the FITS file
- AstroROOT **creates a TTree from the data table in the HDU***
- AstroROOT **can read/write images, and display them using a TH2***

* = **not in** AstroROOT, **our implementation.**

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Scheduled work

Regarding the GRB source simulations:

- Put the new model in the repository (needs documentation, of course)
- I/O file definition (FITS). Interaction with GBM.

To be used as fitting engine: Implementing the fitting "procedure" (constrains from GBM and other experiments).

Trigger & alert: Refinement of the alert strategies, and studies the capability of the alert algorithm operating in the real-time.

- Efficiency as a function of the buffer length and of the threshold.
- On board fast reconstruction.

Scientific Tools Development:

- Development of Visualization tools with ROOT
  1. Load an input FITS file (CCFits), read it with ROOT, create a TTree, and browse it.
  2. Using a GUI to display some plots (counts vs time, counts vs energy, images).
  3. Try to interface ROOT with other tools (i.e. the rebinning tool).

Quantum Gravity Effect: Broken or Deformed Lorentz Symmetry?

1. Testing with GLAST
   - $p^2 \approx E^2 - m^2 + w\lambda_{pl}{}^n E^{2n}$: w > 0 for Broken symmetry, w < 0 for Deformed symmetry

- Development software and algorithm to detect the QG effect
- Start the simulated campaign for collecting enough statistics and test the algorithm

GLAST and GRB: probing the photon propagation over cosmological distances

Quantum Gravity effect

Within various theoretical frameworks:

- String Theory/ Loop Quantum Gravity
- Discretized or non-commutative spacetimes

A Lorentz invariance breaking dispersion law rises:

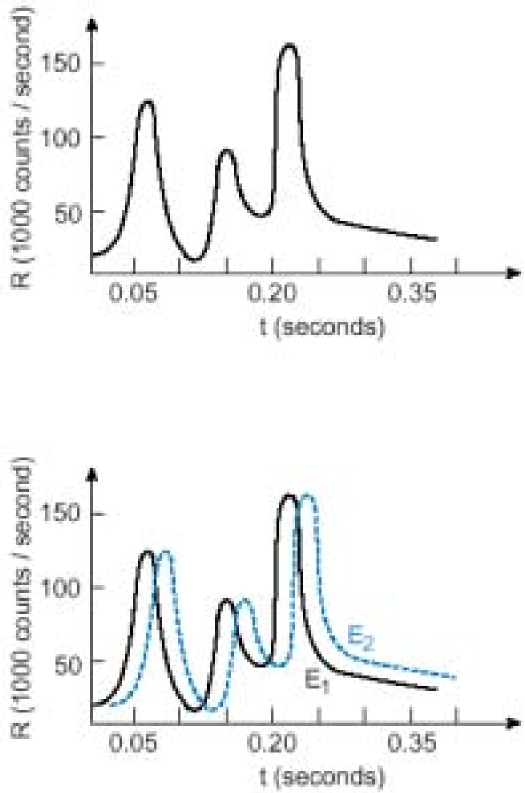
$$E^2 = m^2 + \vec{p}^2 + f\left(\vec{p}^2, E, m; M_p\right)$$

M_p is a mass scale ~ Planck Mass = 10^{19} GeV

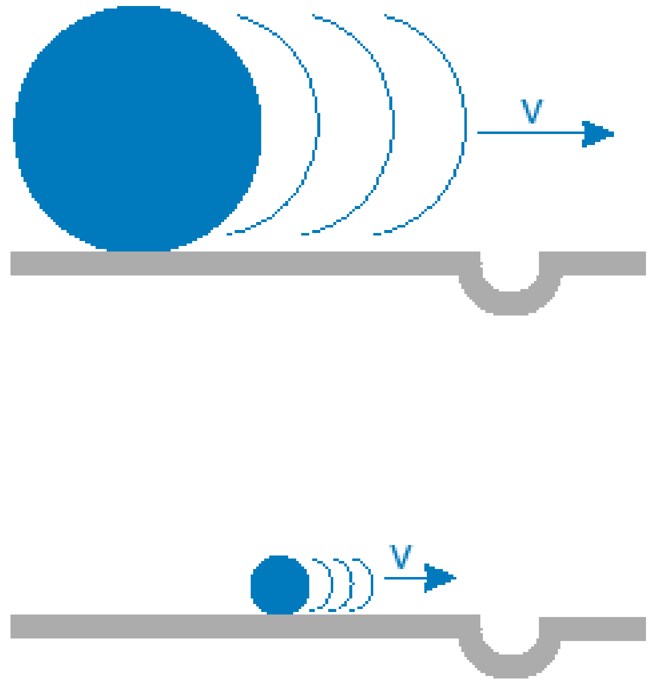
"Photons propagating in vacuum may exhibit non trivial refractive index"!

Quantum Gravity and HE photons

(Amelino-Camelia 1999)



Schematic representations of a GRB profile. The quantum nature of the space-time introduces a delay in the high energy pulses



Analogy between photons and spheres with wavelenght proportional to radius.The low energy photons are not affected by S/T structure

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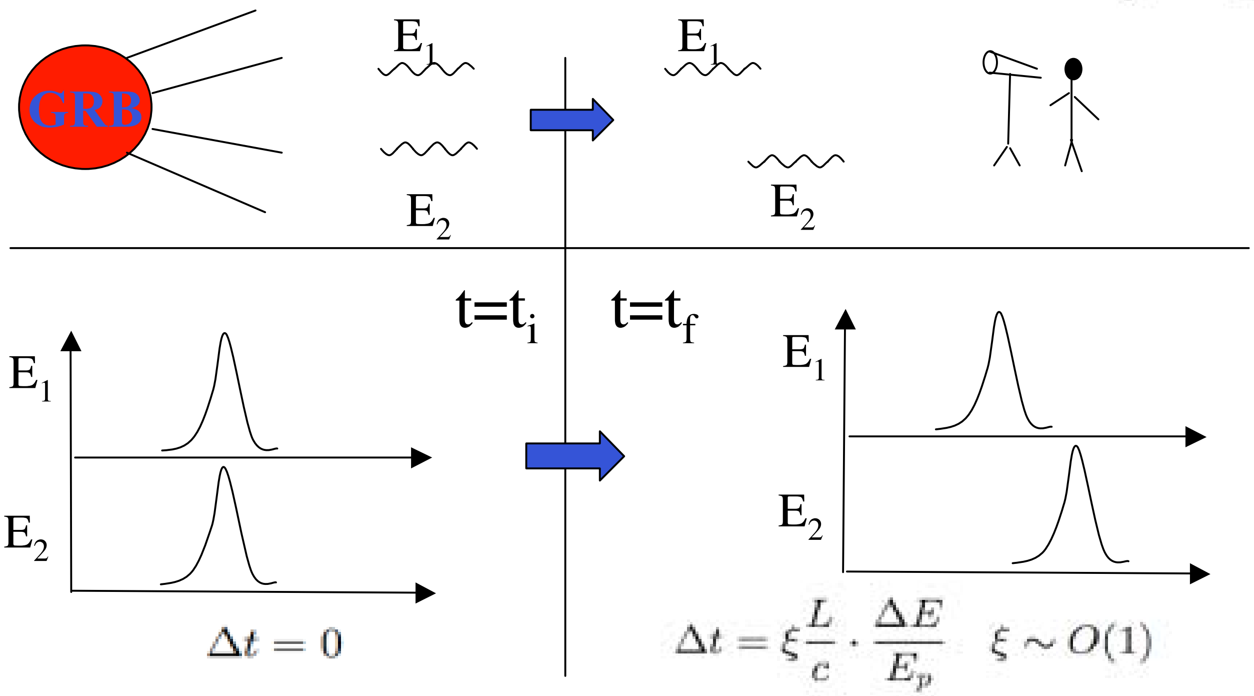
Phenomenology for photons

$$v \equiv \frac{\partial E}{\partial p} \approx c\left(1 - \xi \frac{E_\gamma}{E_p}\right)$$

2 photons, E_1 and E_2, emitted with delay δt will arrive with a delay:

$$\Delta t = \delta t + \xi \frac{L}{c} \cdot \frac{\Delta E}{E_p} \qquad \xi \sim O(1)$$



$$\frac{L \Delta E}{c \delta t}$$

measures sensitivity

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The case for GLAST

EGRET highest limit for E_{qg} (10^4 lower than GLAST)

$$\left(\frac{L\Delta E}{c\delta t}\right)_{EGRET} = \frac{(10^{28}cm)(10GeV)}{(10^{10}cm/s)(10^{-1}s)} = 10^{20}GeV$$

But, we have also to consider the low rates at high energies.

To have enough statistics: The CRAB (flaring)

$dt \sim 10^{-3}$

$$\left(\frac{L\Delta E}{c\delta t}\right)_{CRAB} = \frac{(10^{21}cm)(10^{2}GeV)}{(10^{10}cm/s)(10^{-3}s)} = 10^{16}GeV$$

The GRBs are dim sources, far and with a short time scale:

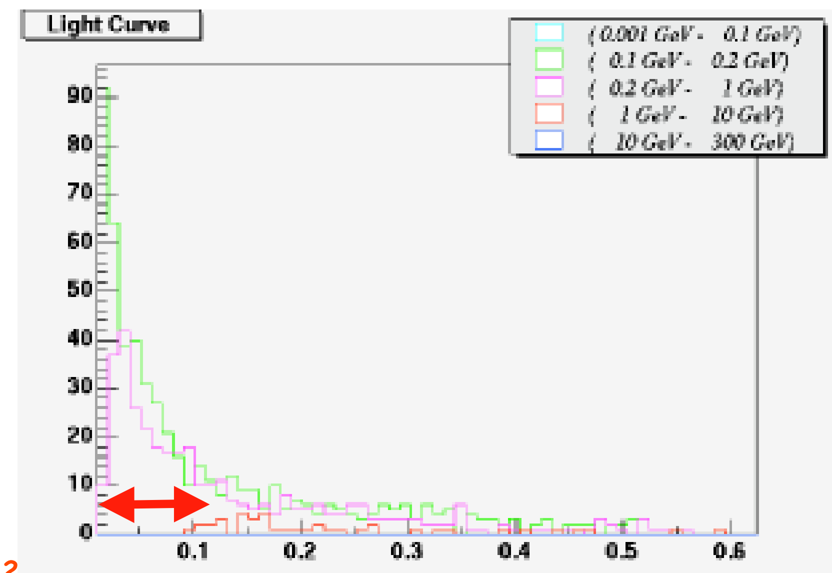
$$\left(\frac{L\Delta E}{c\delta t}\right)_{GRB} = \frac{(10^{28}cm)(10^{2}GeV)}{(10^{10}cm/s)(10^{-3}s)} = 10^{23}GeV$$

GRB are good candidates to probe the Quantum Gravity up to the Plank scale !!

QG observation?

Gamma-Ray Burst at z = 1.

1. Observing the burst at GBM energies:
   - For **Eqg~ 10^{19} GeV** ; at **100 KeV dt ~ 10^{-5} s**
   - All the delay will be intrinsic (different cooling time, geometry effects,…)!
2. Observing the burst at **LAT energies**:
   - For **Eqg ~ 10^{19}GeV**; at **10 GeV dt ~ 1 s, at 1 GeV dt ~ .1 s** !
   - Minimizing the uncertainties with
     - Physical GRB model (computes the intrinsic delay at high energy)
     - GRB statistics (different redshift → different QG effect, but same intrinsic delay)



The events at **LAT** energies reconstructed by **GLAST**:
For Energies up to **1GeV the peak is time resolved**!!
At **10 GeV only few photons**

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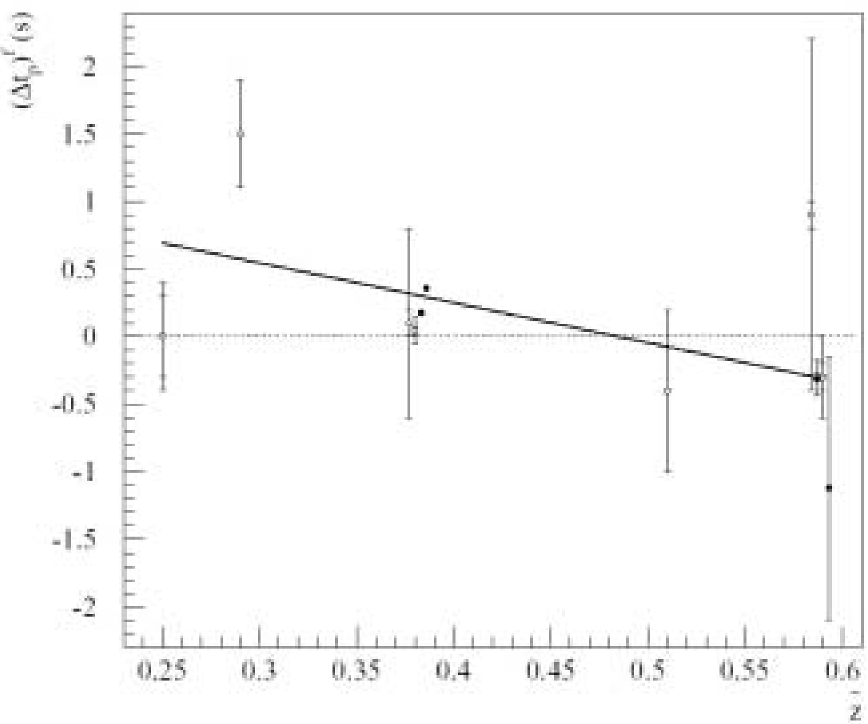
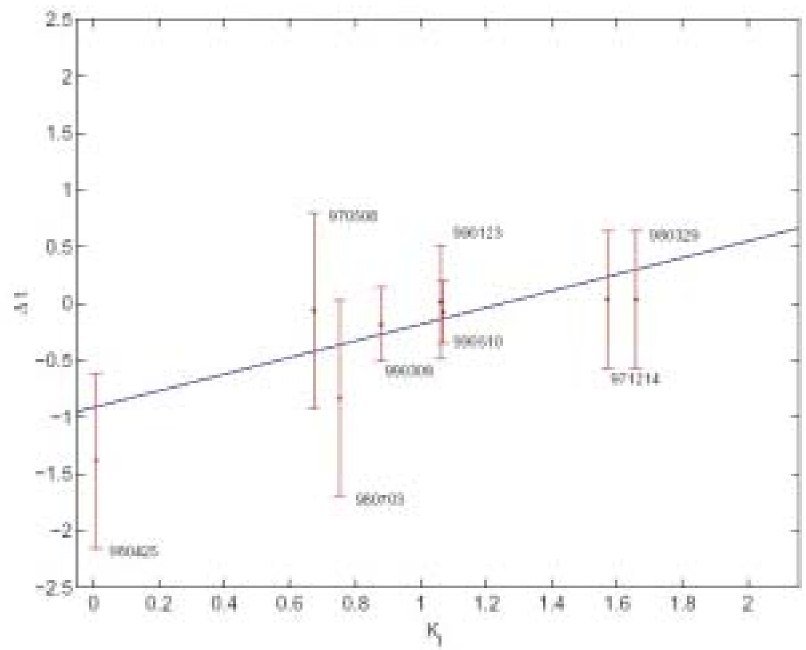
What has been already done?

Ellis et al. (00)

Ellis et al. (02)



Lags versus redshift for few GRB and fitting greatest pulses



Lags versus distance few GRB using wavelet analysis

$M > 10^{15}$ GeV

$M > 6.9 \cdot 10^{15}$ GeV

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Concluding remarks

- See Jacobson et al. (02) for complete analysis of different effects
- Observation of polarization has put strong constraints on QG effect
- Need confirmation of lag-luminosity or other intrinsic GRB properties
- Correlations with other astrophysical sources (AGN)
- Need correlated spectral-temporal analysis
- Correlation with Ground Based Telescopes

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