Prospects for Gamma-Ray Burst detection by the Cherenkov Telescope Array

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Goals

- **Understand the possibility of detecting GRB with the full CTA array using `ctools`**
- **Detection of GRB with LST**
- **Better estimate of the GRB rate for CTA**

GRB with CTA

- This work focuses on Fermi-like GRBs with measured redshift
- Main goal:
  - Setting up a library of GRBs as observed by LAT simulated at different epochs for CTA
- Procedure:
  - Extrapolation of the LAT flux to CTA energies
  - Flux estimation at different post triggers epochs, taking into account the flux temporal evolution
- Preliminary results
  - Proceedings of RICAP16 & Scineghe16 conferences (Bissaldi +16, Bissaldi+17)

Previous work

Prospects for Gamma-Ray Bursts detection by the Cherenkov Telescope Array

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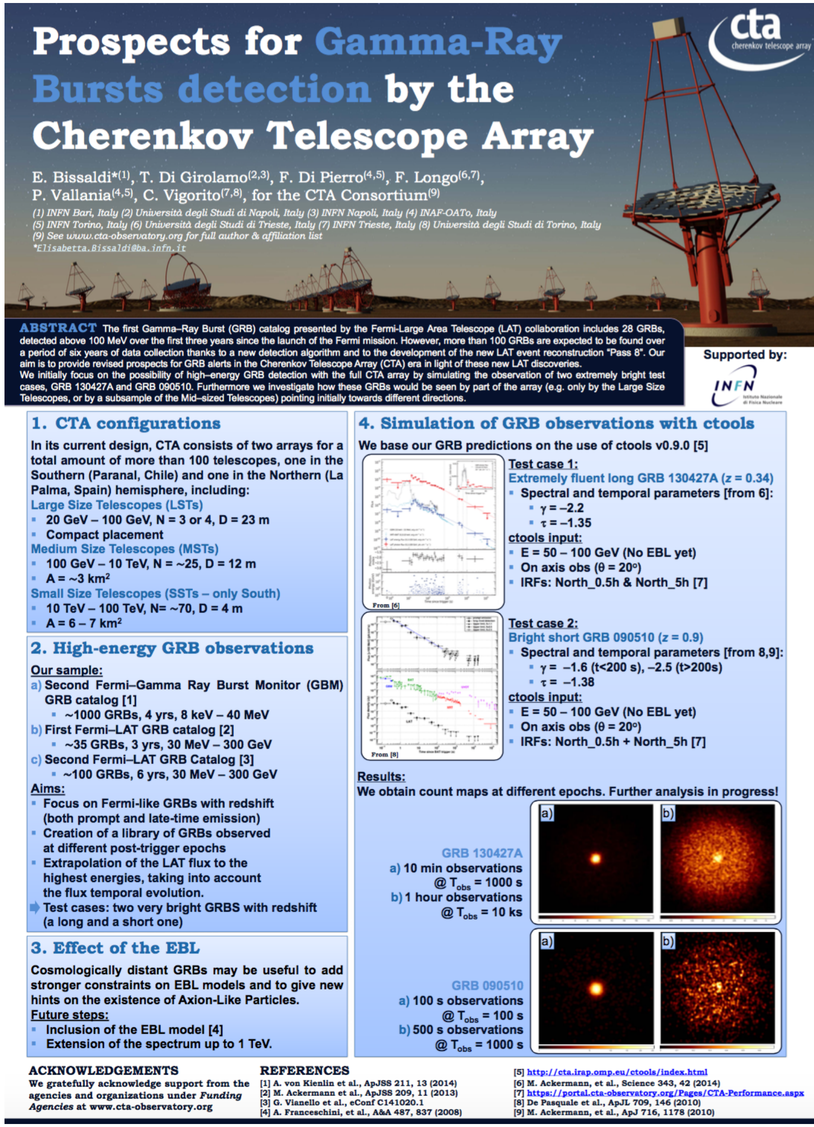
(Submitted on 4 Sep 2015)

The first Gamma-Ray Burst (GRB) catalog presented by the Fermi-Large Area Telescope (LAT) collaboration includes 28 GRBs, detected above 100 MeV over the first three years since the launch of the Fermi mission. However, more than 100 GRBs are expected to be found over a period of six years of data collection thanks to a new detection algorithm and to the development of a new LAT event reconstruction, the so-called "Pass 8." Our aim is to provide revised prospects for GRB alerts in the CTA era in light of these new LAT discoveries. We focus initially on the possibility of GRB detection with the Large Size Telescopes (LSTs). Moreover, we investigate the contribution of the Middle Size Telescopes (MSTs), which are crucial for the search of larger areas on short post trigger timescales. The study of different spectral components in the prompt and afterglow phase, and the limits on the Extragalactic background light are highlighted. Different strategies to repoint part of – or the entire array – are studied in detail.

arXiv:1509.01438

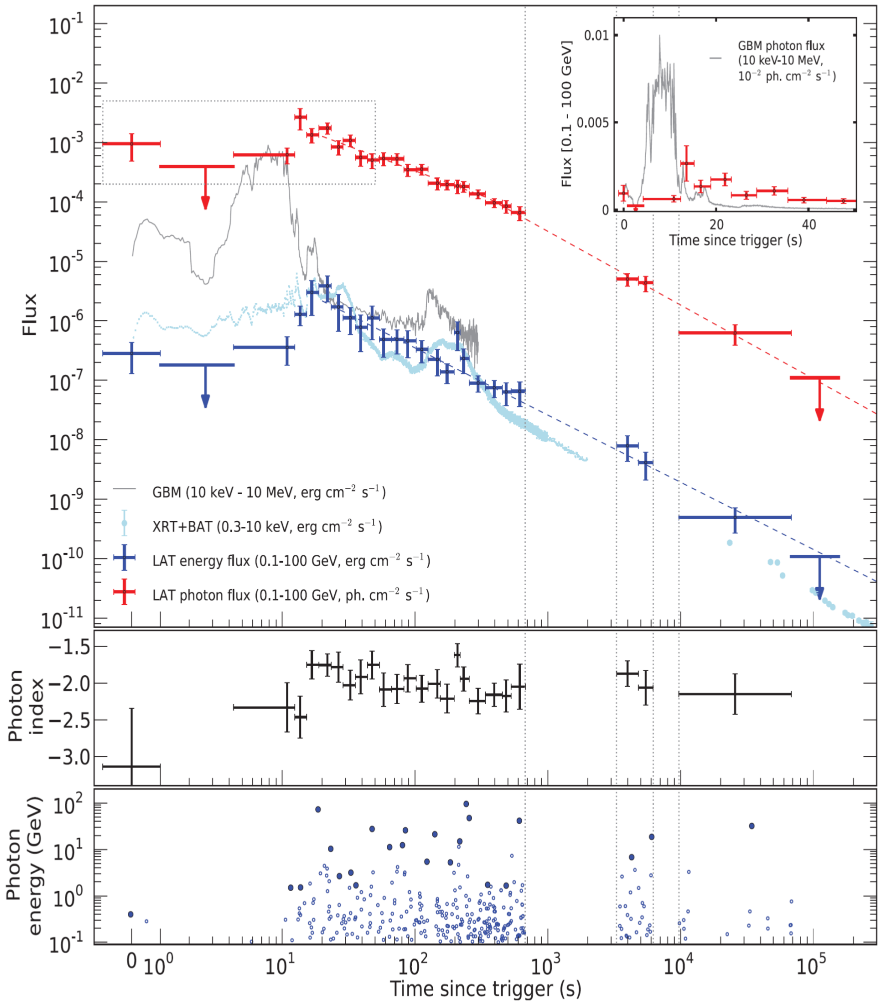
Work for the FermiSymposium

- Poster at the Fermi Symposium
- Short GRB 090510



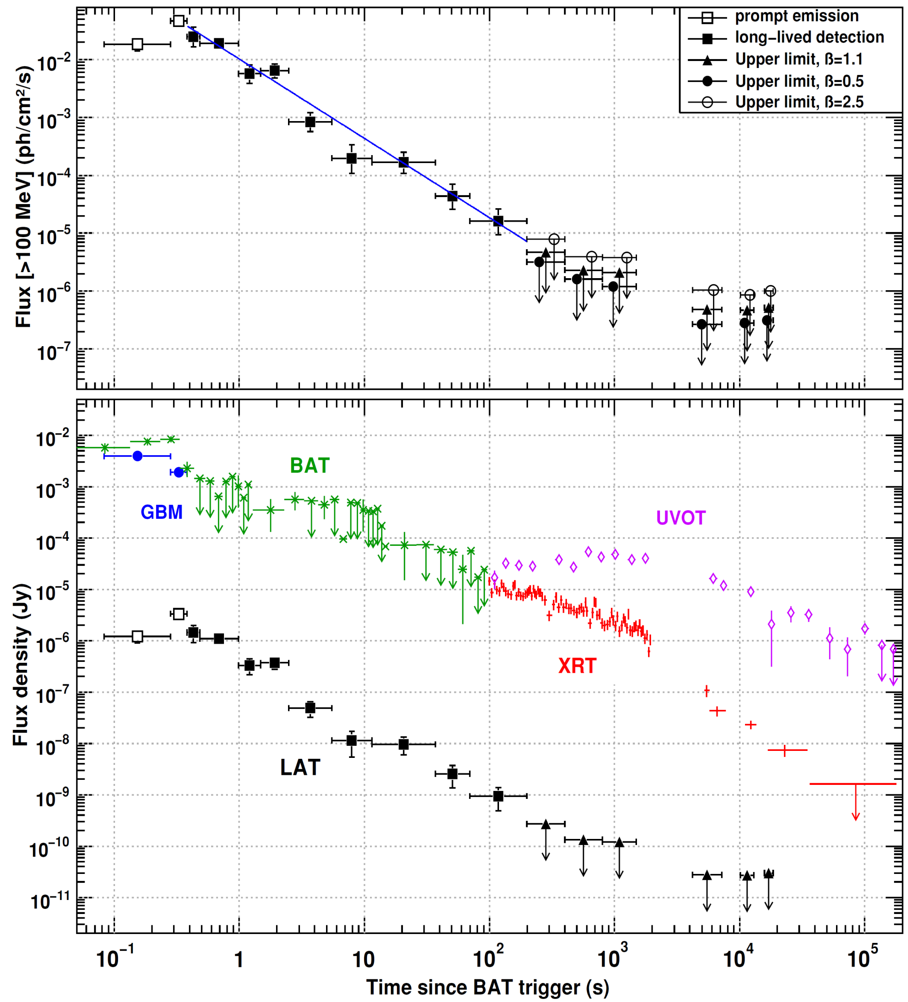
Test cases

1. **GRB 130427A**
   - Long GRB
   - Max photon energy: 95 GeV (current record!)
   - Redshift z = 0.34
   - Spectral index $\gamma = -2.2$ (almost constant from 400 s up to 70 ks after the trigger)
   - Temporal index $\tau = -1.35$ (valid for t > 380 s)



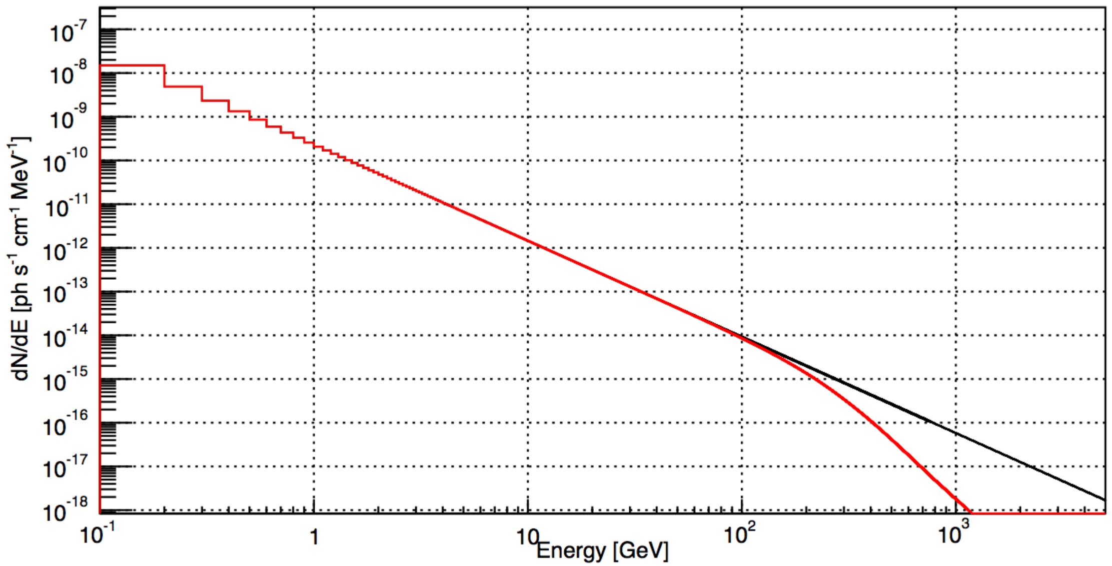
Test cases

2. **GRB 090510**
   - **Short GRB**
   - **Max photon energy: 31 GeV**
   - **Redshift z = 0.9**
   - **Spectral index**
     $\gamma_1 = -1.6$ (for t<200 s)
     $\gamma_2 = -2.5$ (for t>200 s)
   - **Temporal index**
     $\tau = -1.35$



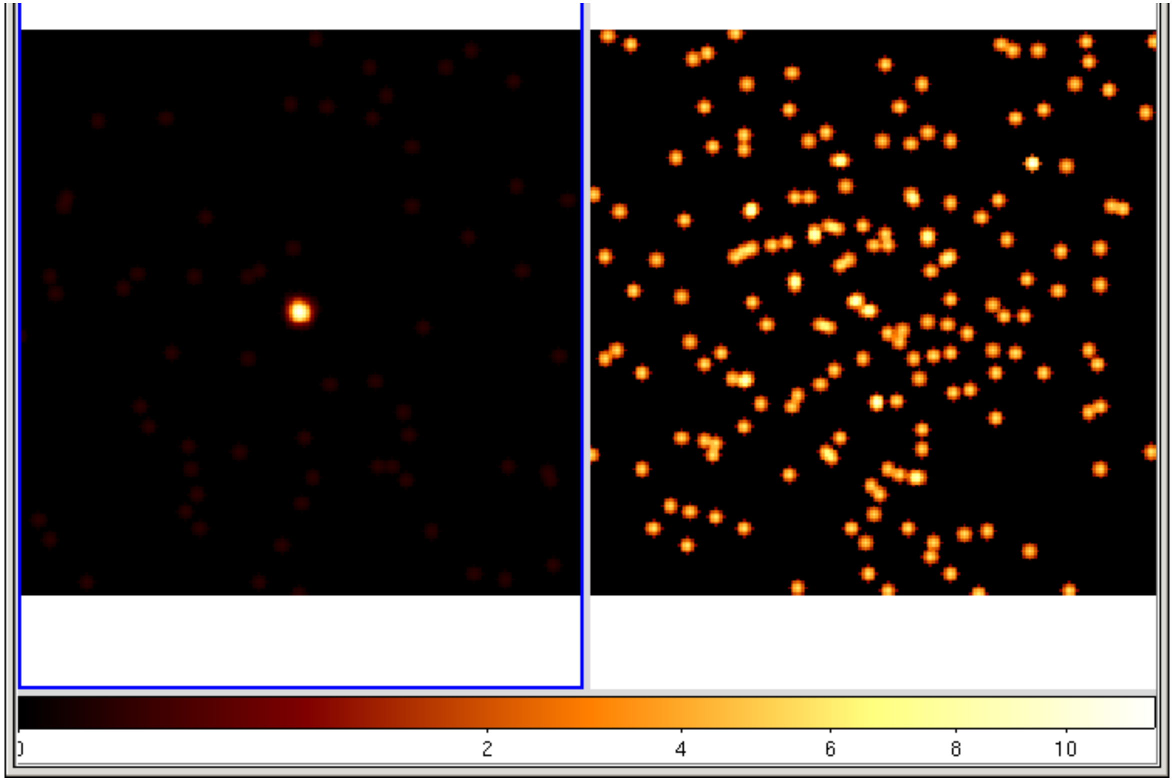
Past work

- Code to include the effect of EBL absorbtion (C.Vigorito)
- Table of EBL model provided by T.Di Girolamo



GRB 130427A at 10000s with EBL effect included (z = 0.34)

Test on EBL absorbtion



On the left the simulation with no EBL
On the right the simulation with EBL

- Energy bin (1 TeV – 1.60 TeV)

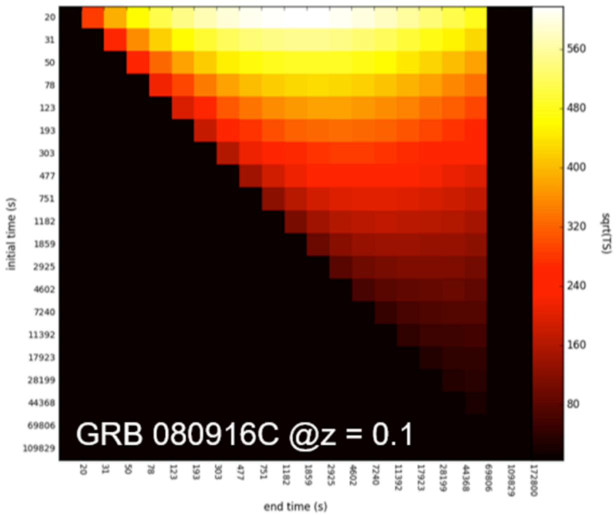
Plans for GRB simulations

- GRB library – Fluxes and spectral shapes from LAT
- GRB temporal shapes – (short, long)
- EBL attenuation – set of GRB at different z
- ctlike analysis

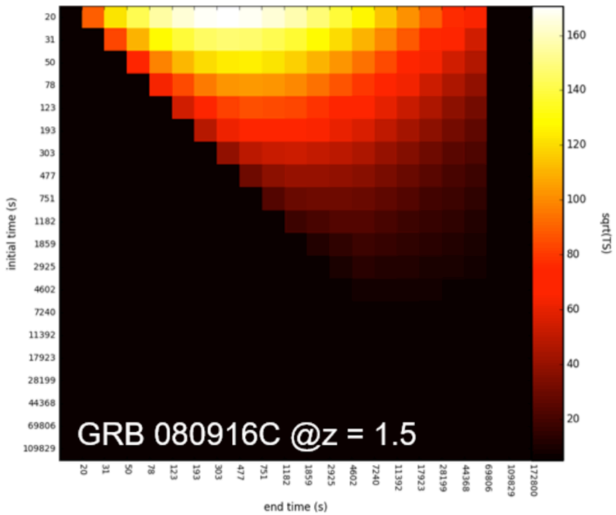
Time window optimization

GRB 080916C

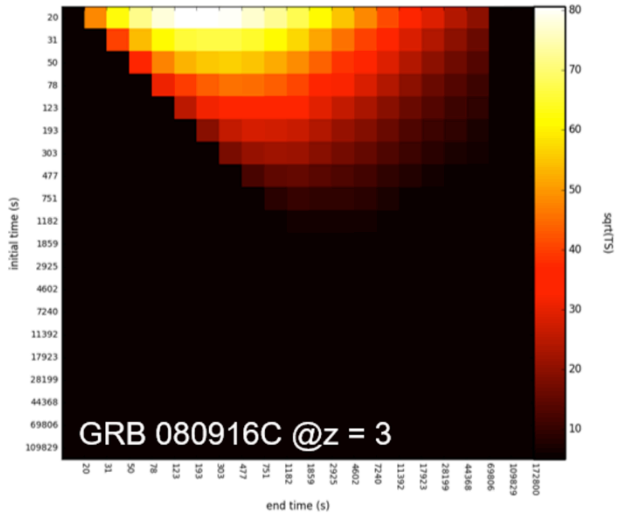
z = 0.1



z = 1.5



z = 3



Simplified procedure for this study

- Fermi-LAT measured HE flux and spectral index ("afterglow" phase)
- Place at Southern sky …
- Consider the flux at 20 GeV – 10 TeV (+EBL) in CTA energy range
- Calculate the TS and the flux obtained by CTA as function of the observation time (Tstart and Tstop)
- Concentration on "afterglow" detection …
- Simplified procedure – unique temporal index alpha = -1.7
- TS calculation at fixed times (t0 + 1h)
- Use of new IRFs !

Sample of GRBs

GRB	Redshift
080916C	4.350
090510	0.903
090902B	1.822
090926	2.1062
091003	0.89
110731A	2.83
130427A	0.340
130518A	2.49
131108A	2.4
131231A	0.642
141028A	2.33
160509A	1.17
170214A	2.53

Preliminary results for afterglow detection

GRB	Redshift	20s	60s	180s	1800 s	3600 s
080916C	4.350	320	159	71	4	0
090510	0.903	1281	905	471	75	34
090902B	1.822	1823	1601	957	175	88
090926	2.1062	1060	847	438	66	29
091003	0.89	291	213	97	10	3
110731A	2.83	190	96	38	1	0
130427A	0.340	3221	2848	1782	407	225
130518A	2.49	2	1	0	0	0
131108A	2.4	81	68	29	0	0
131231A	0.642	793	540	276	41	17
141028A	2.33	21	18	8	0	0
160509A	1.17	429	245	113	10	4
170214A	2.53	154	148	127	14	5

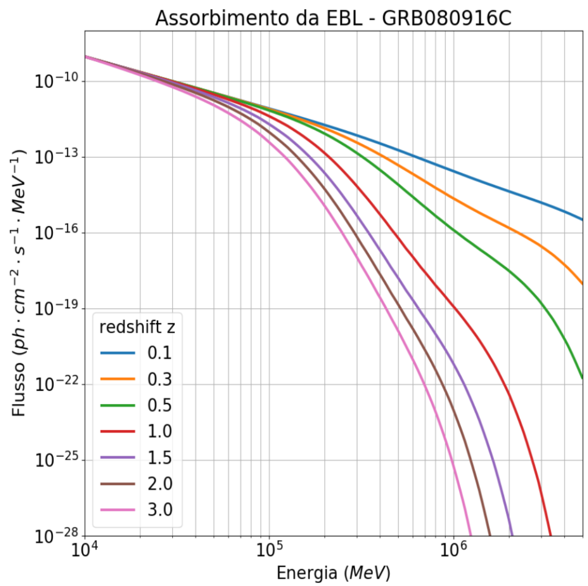
Procedure

- Fermi-LAT measured HE spectral index and time decay power law index (“afterglow” phase)
- Consider the flux at 20 GeV – 5 TeV (+EBL) in CTA energy range
- Calculate the TS obtained by CTA
- Simulate similar source at different redshift (to simulate the effect of EBL absorbtion – using Franceschini et al. 2008)

GRB with z sample

Name	F_p (ph/cm^2/s $\times 10^{-5}$)	En.index [β]	Time index [α]	$t_p(s)$
GRB080916C	500±100	2.05±0.07	1,37 ± 0.07	6,6 ± 0,9
GRB090323	6±3	2.3±0.2	1,0 ± 0.3	40 ± 30
GRB090328	9±4	2.0±0.2	1,0 ± 0.3	40 ± 30
GRB090510	3900±600	2,05±0.07	1,8 ± 0.2	0,9 ± 0,1
GRB090902B	600±100	1,95±0.05	1,56 ± 0.06	9 ± 1
GRB090926A	700±100	2,12±0.07	1,9 ± 0.2	11 ± 2
GRB091003	8±3	2,1±0.2	1,0 ± 0.2	22 ± 9
GRB100414	70±30	2.0±0.2	1,7 ± 0.3	20 ± 10
GRB110731A	220±60	2,4±0.2	1,8 ± 0.2	4,8 ± 0,7
GRB130427A	150±30	2.2±0.2	1.35 ± 0.08	20 ± 5

➔ **Example study of EBL absorption for GRB 080916C placed at 7 different redshifts (z = 0.1 – 3)**



TS calculation

GRBs
GRB080916C (z=4.35)
GRB090510 (z=0.90)
GRB090902B(z=1.82)
GRB090926A(z=2.11)
GRB110931A (z=2.83)
GRB130427A (z=0.34)
GRB091003 (z=0.98)

IRFs
Nord
Nord LST
Nord Threshold
Sud
Sud Threshold
Sud Threshold MST

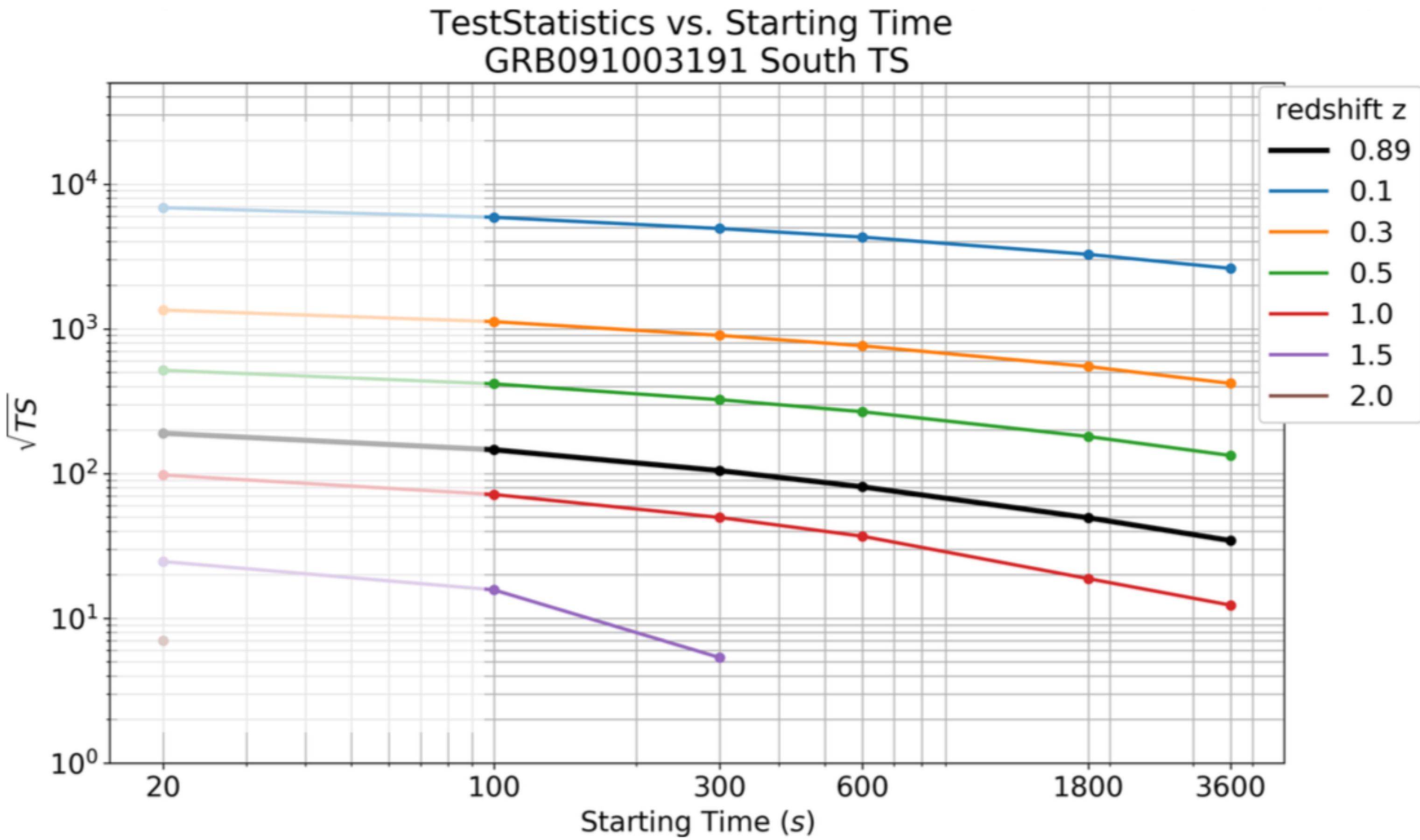
Redshift z
0.1
0.3
0.5
1.0
2.0
3.0

T start
20
100
300
600
1800
3600

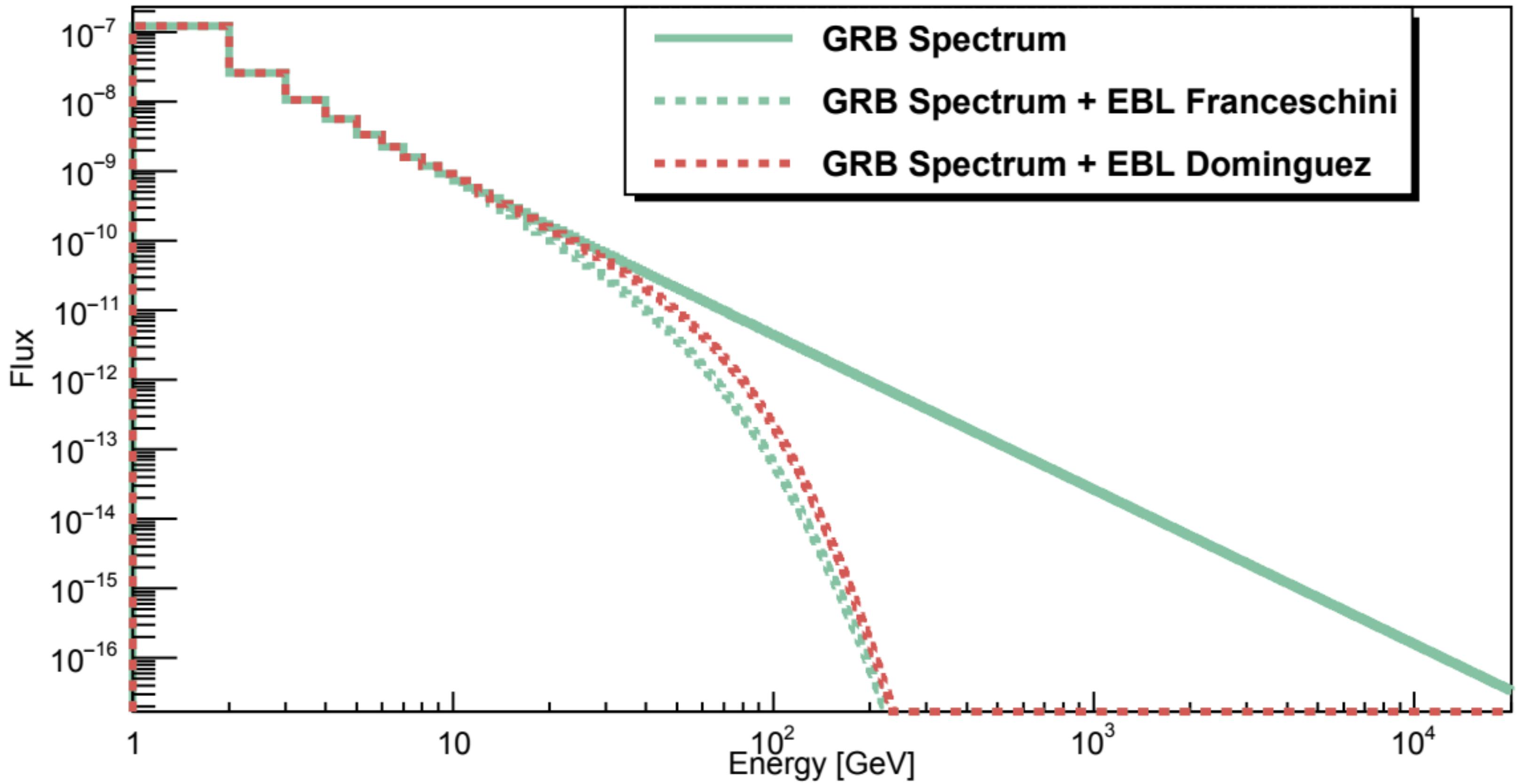
Workflow for TS calculation

ctobssim → ctselect → ctlike

TS calculation



Check of EBL models



GRB Data Challenge proposal

- Population of GRBs
  - Simple GRID of GRBs
  - Flux, Spectral shapes, Duration (from LAT?)
  - CTA survey observation simulation scheme
  - “Some” Physical motivated scenario …
  - Inclusion of Real Time Analysis SW
  - Opportunity to test the Detection and Analysis SW?

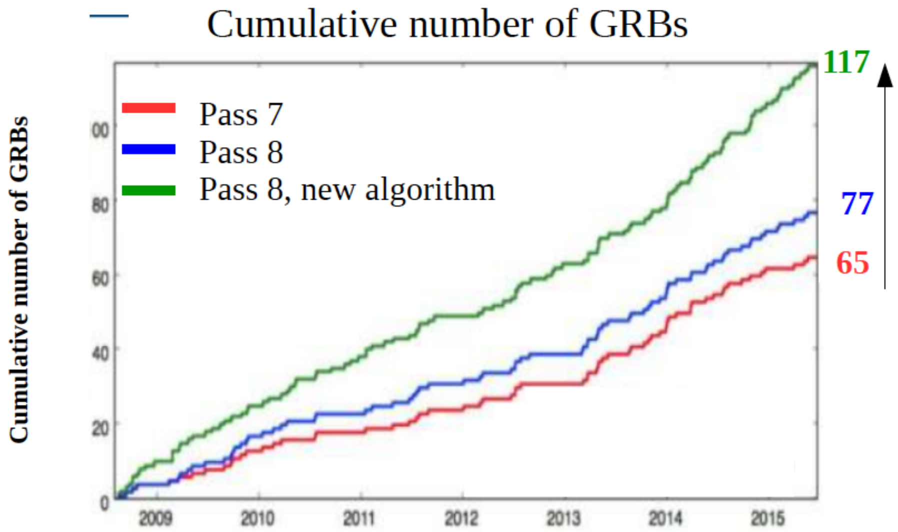
- Proposal
  - Organization of a small group of “sky-master” to prepare the GRB Data Challenge
  - Timeframe: Ready by April 2018?

The 2nd LAT GRB catalog

Towards the 2nd Fermi/LAT GRB catalog

- New event reconstruction and classification algorithms **"Pass 8"**
- Development of a new detection algorithm for GRBs: LTF (LAT Transient Factory, *Vianello et al. 2015*)

Increase by >50% of the rate of LAT-detected bursts

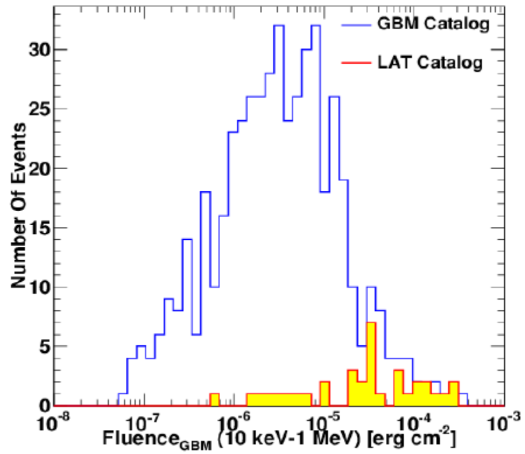


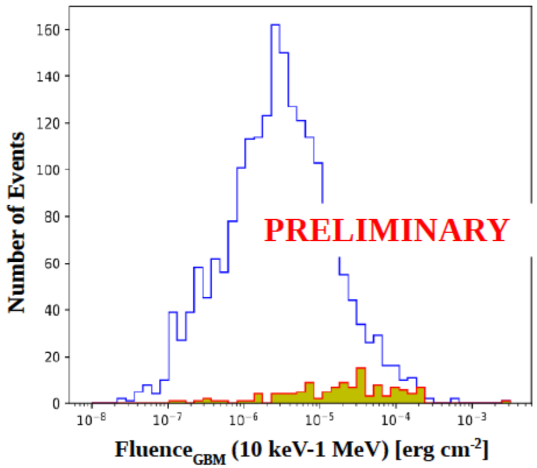
Omodei et al. 2016

The 2nd LAT GRB catalog

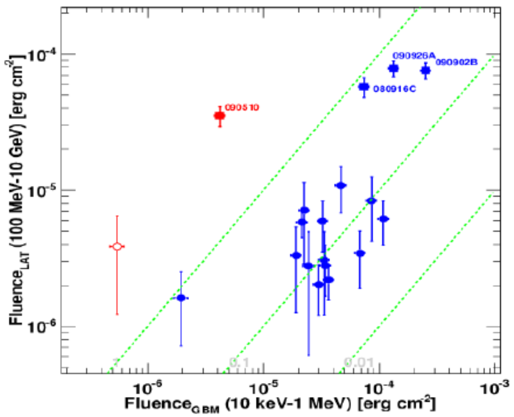
Towards the 2nd Fermi/LAT GRB catalog

1st LAT GRB catalog → 2nd LAT GRB catalog

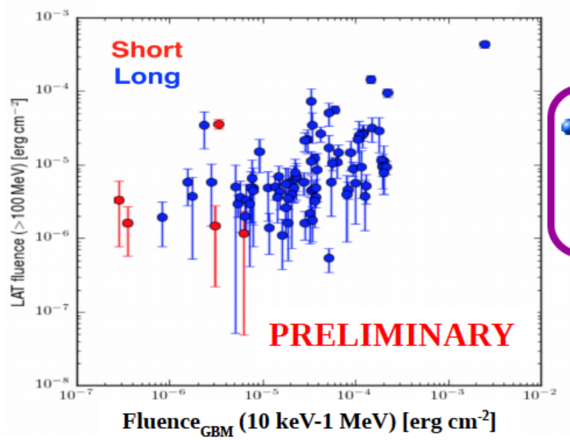




- Broader fluence range
- Similar fluence distribution



Ackermann et al. 2013



Vianello et al. 2017

- No difference between short and long GRB fluences

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Prospects

- Update the GRB library
  - Need to include the most updated LAT results
- Need to build a realistic redshift distribution for LAT GRB
  - Correct use of EBL absorbtion models