High-energy spectral component of the prompt emission of GRBs

5^{th} October 2023, IV Gravi-Gamma-Nu Workshop

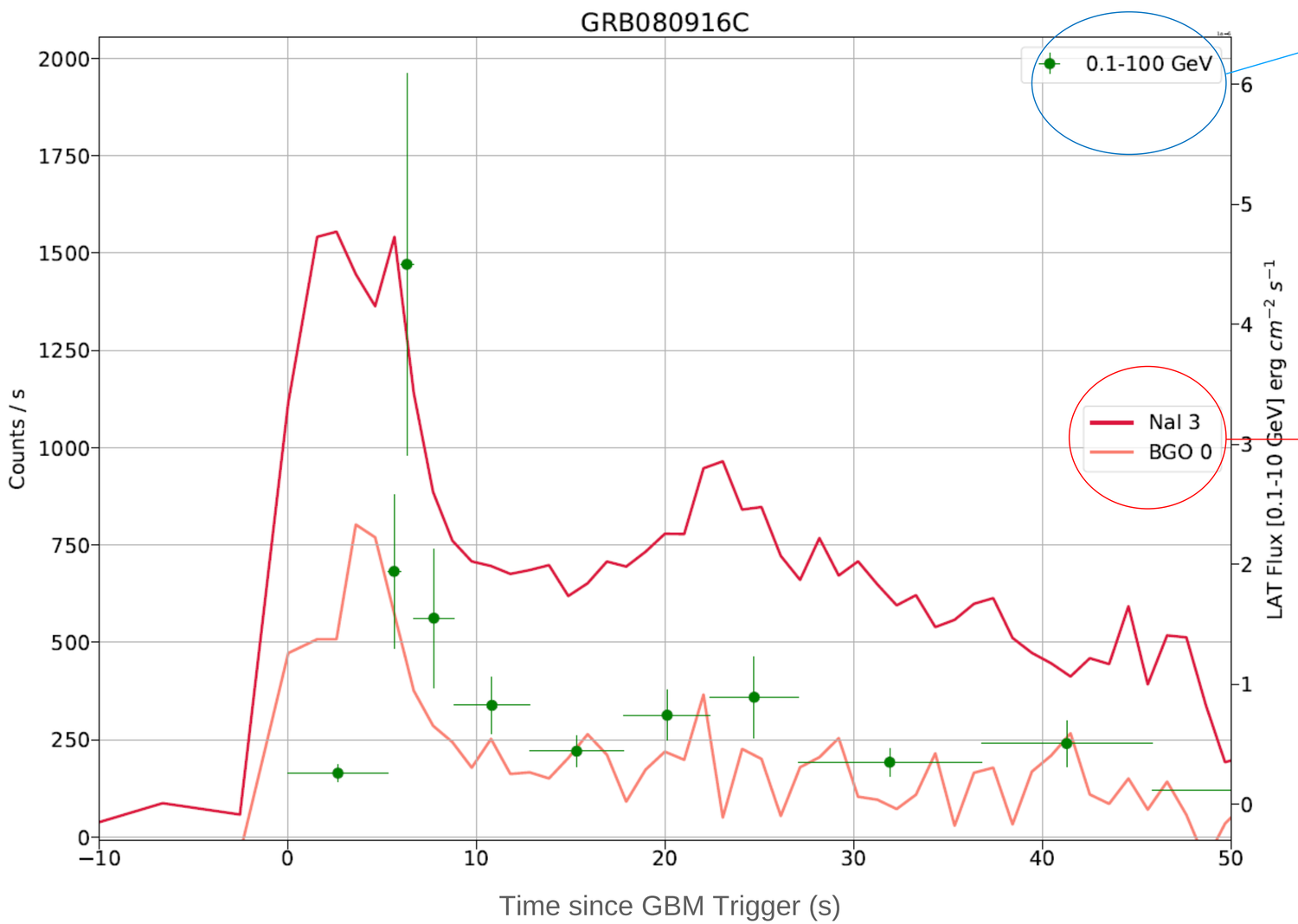
Samanta Macera, PhD Student

Istituto Nazionale di Fisica Nucleare

GRAN SASSO SCIENCE INSTITUTE

CENTER FOR ADVANCED STUDIES INFN

Nature of early GeV emission



Fermi-LAT
(> 10 MeV)

Fermi-GBM
(8 keV – 10 MeV)

Nature of early GeV emission

- High energy emission is delayed

  [Tajima et al. 2009 for GRB080916C**]**
  [Abdo et al. 2009 for GRB090902B**]**

- For some GRBs early GeV emission follows variability of prompt

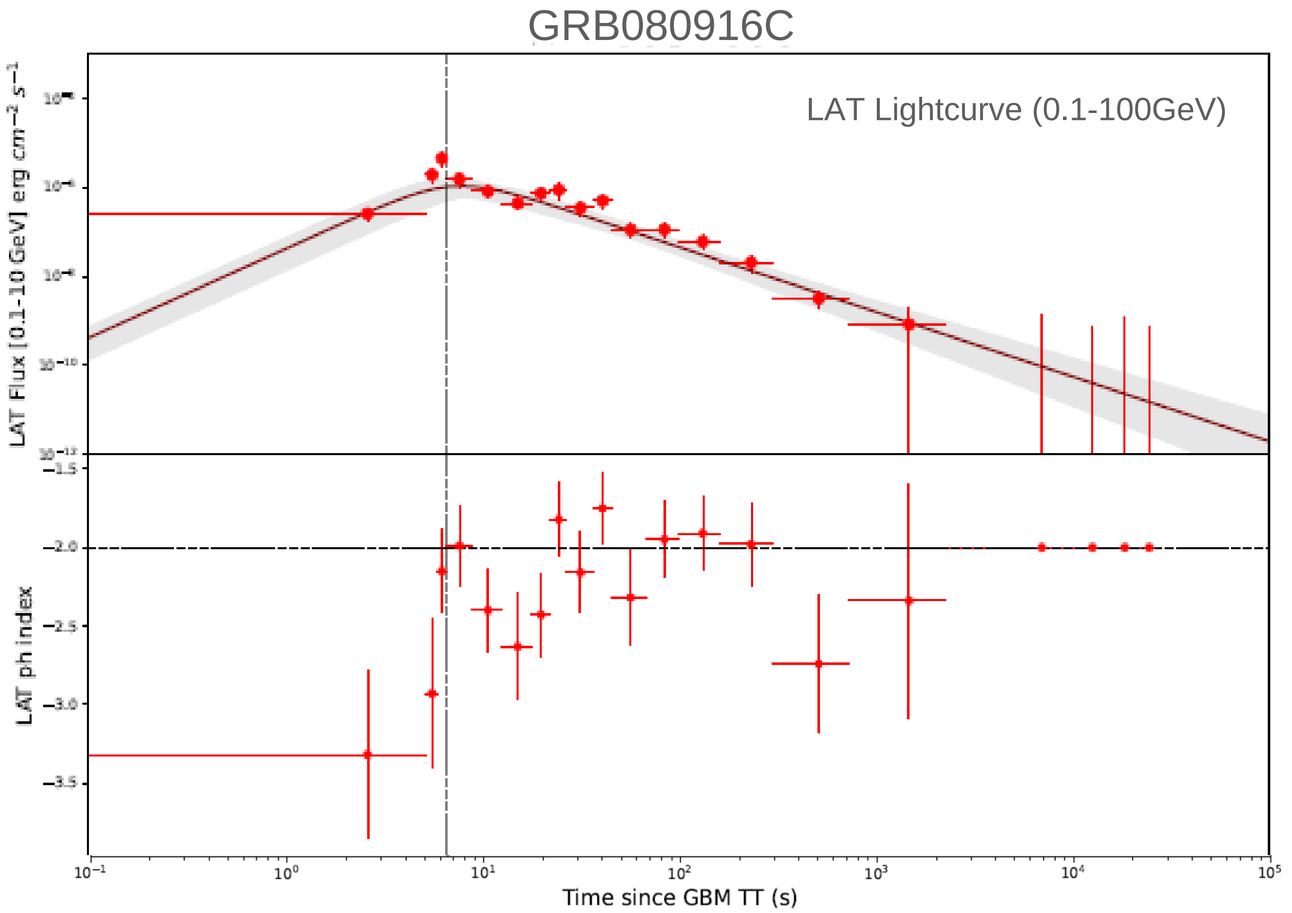
  [Zhang et al. 2011]

- Early Afterglow or Prompt origin?

  Ghisellini et al. 2009, Kumar & Barniol Duran, 2009
  Maxham et al. 2011

- What is the contribution of the keV-MeV prompt?

- Prompt second component?



For a complete review see: **Nava, 2018** and the references therein

Nature of early GeV emission

- High energy emission is delayed

  [Tajima et al. 2009 for GRB080916C**]**
  [Abdo et al. 2009 for GRB090902B**]**

- For some GRBs early GeV emission follows variability of prompt

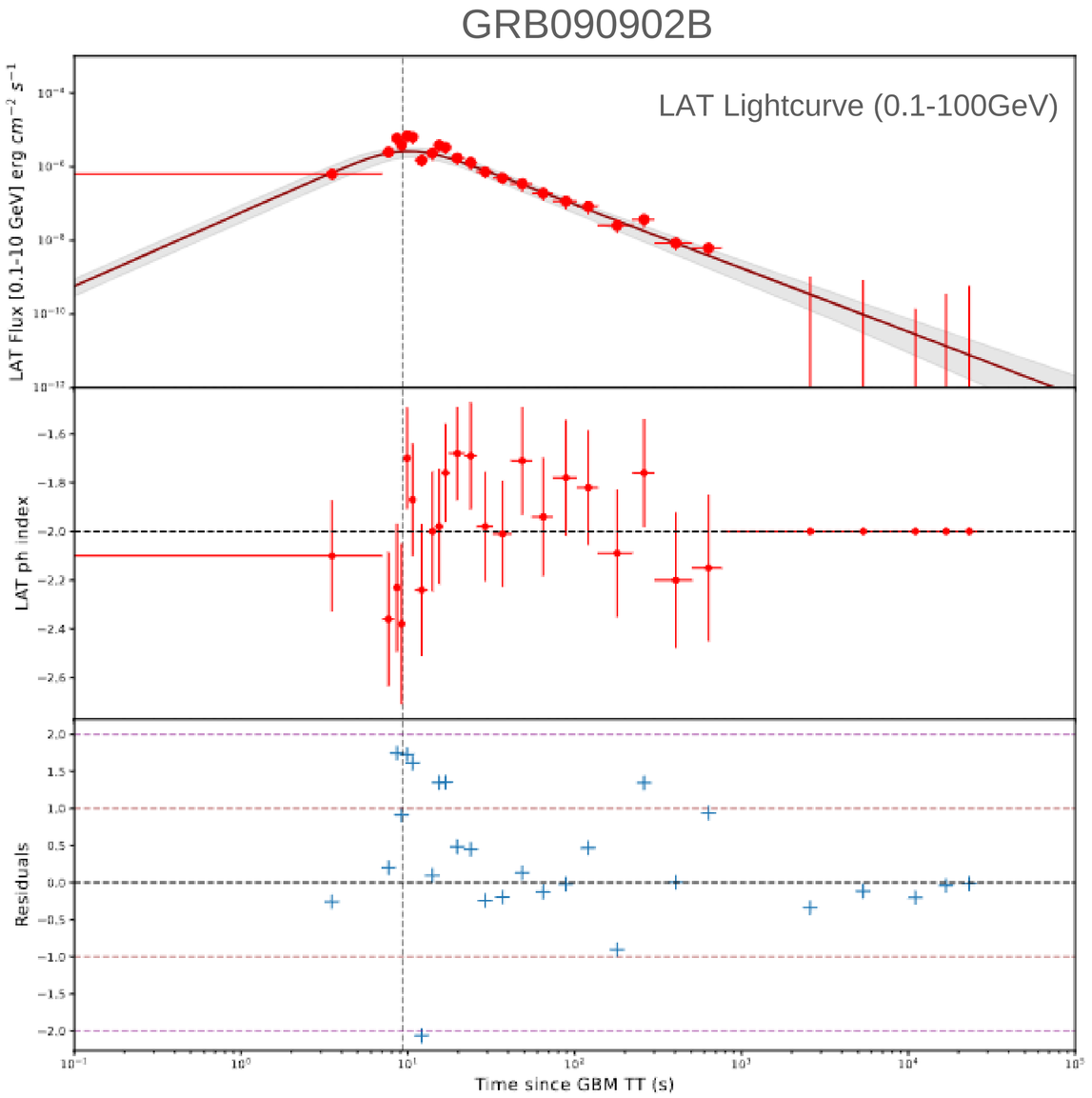
  [Zhang et al. 2011]

- Early Afterglow or Prompt origin?

  Ghisellini et al. 2009, Kumar & Barniol Duran, 2009
  Maxham et al. 2011

- What is the contribution of the keV-MeV prompt?

- Prompt second component?



For a complete review see: **Nava, 2018** and the references therein

Sample and Spectral Analysis

Selection Criteria:

- At least three significant temporal bins (>5 σ detection) simultaneous with Fermi/GBM
- GRBs with and without redshift up to year 2023
- At least 20 photons within 10° of region of interest around the GRB location

Time resolved analysis of 80 spectra and 14 GRBs

GBM + LLE + LAT

+ Physical model for Prompt emission

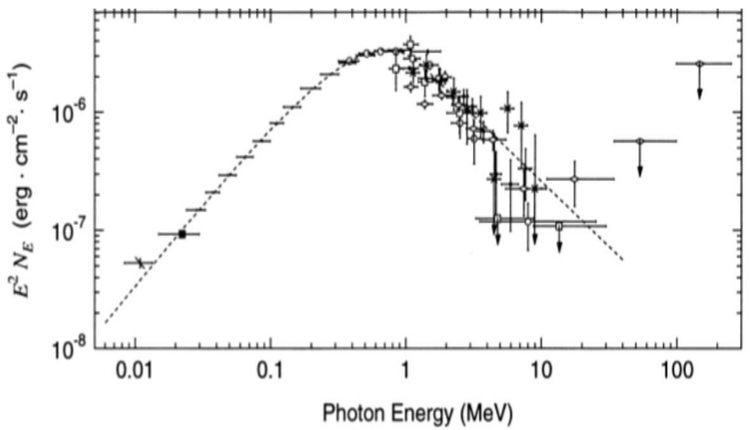
Zhang et al. 2010, joint analysis of Fermi GBM and Fermi LAT with Band Model

Guiriec et al. 2015, three-components model (Band, BB, PL)

Sample

GRB080916C
GRB090323
GRB090510
GRB090902B
GRB090926A
GRB110731A
GRB150523A
GRB160509A
GRB160625B
GRB170214A
GRB190114C
GRB221023A
GRB221009A

1990s - now
Band model



Briggs et al. 1999

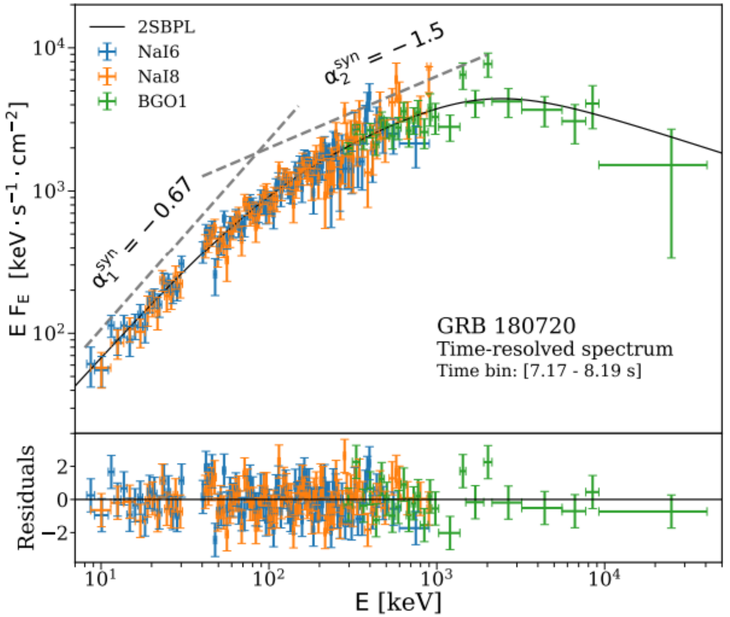
$$\langle \alpha \rangle_{Band} \sim -1$$

$$\alpha_{fast\ cool} \sim -1.5$$

$$\alpha_{slow\ cool} \sim -0.6$$

Broad band GRB spectra

(from X-ray up to MeV)



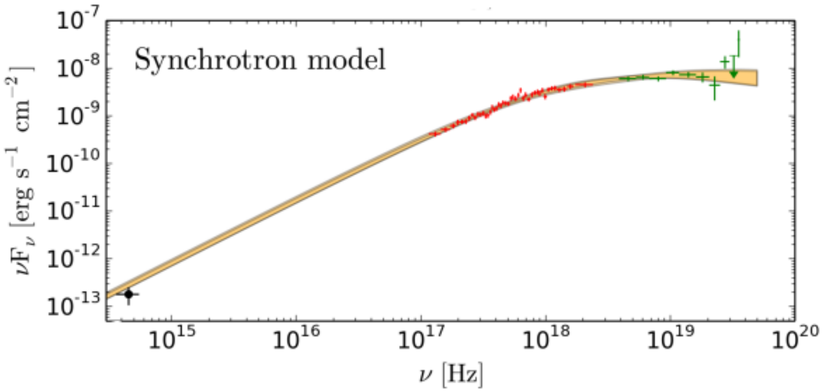
Ravasio et al. 2018

Low energy breaks empirically consistent with Synchrotron

Zheng et al. 2012 (for GRB 110205A)
Oganesyan et al. (2017, 2018) (soft X-ray breaks Swift BAT+XRT + Fermi/GBM sample)
Ravasio et al. 2019 (hard X-ray breaks Fermi/GBM sample)

Synchrotron model

(from optical to MeV)



Oganesyan et al. 2019

Synchrotron can predict the optical flux

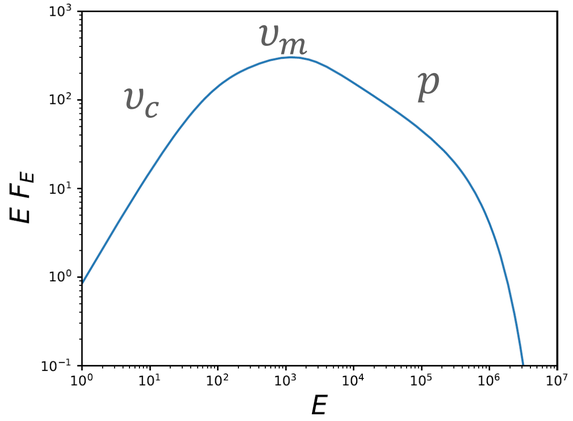
Tested Models

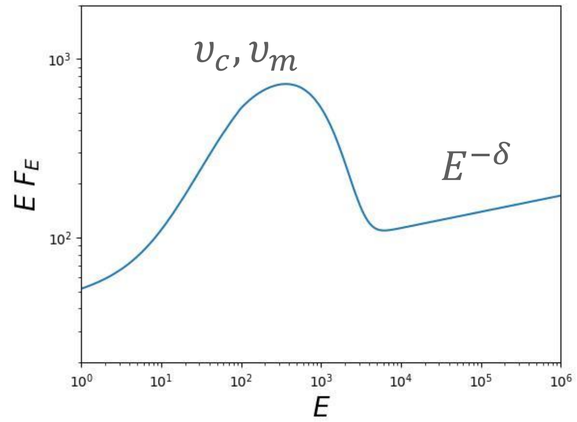
Synchrotron x High Energy Cutoff

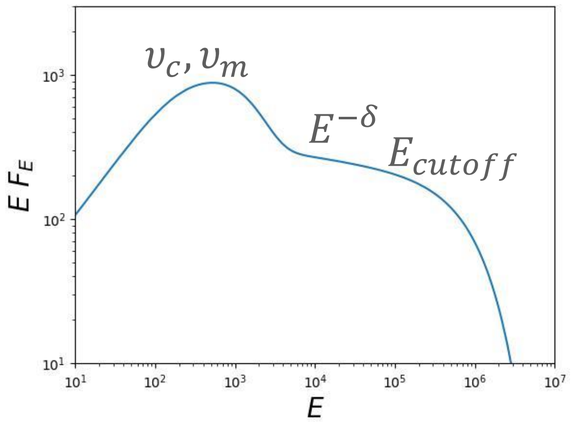
Synchrotron x HECut + Power Law

Synchrotron x HECut + Cutoff Power Law

+ Band-model comparison with only Fermi-GBM data







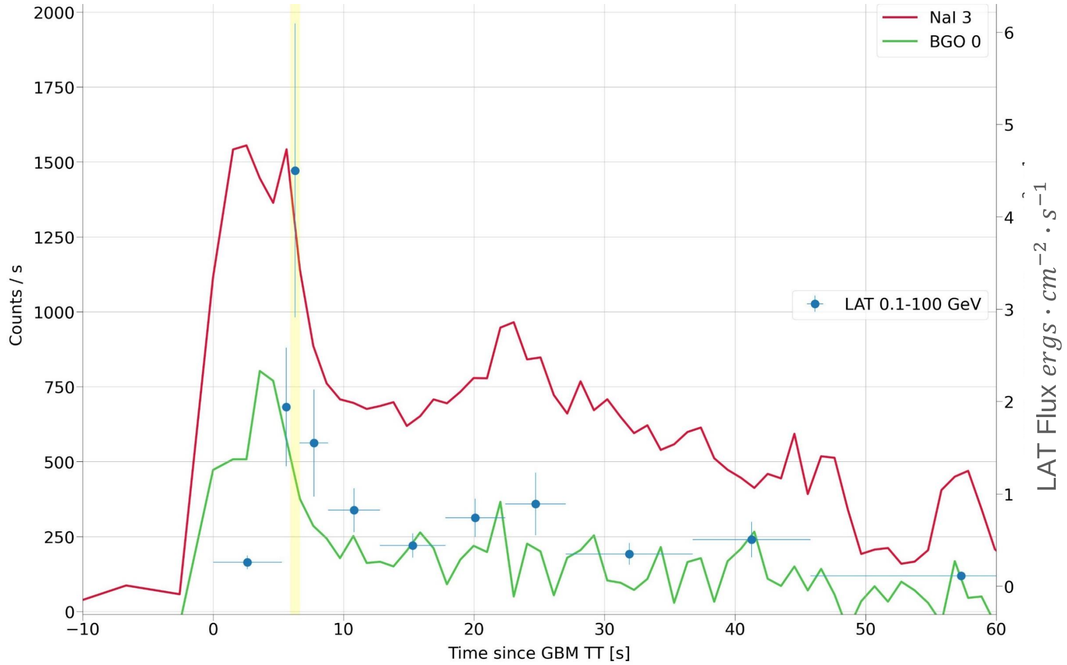
Group I : Synchrotron

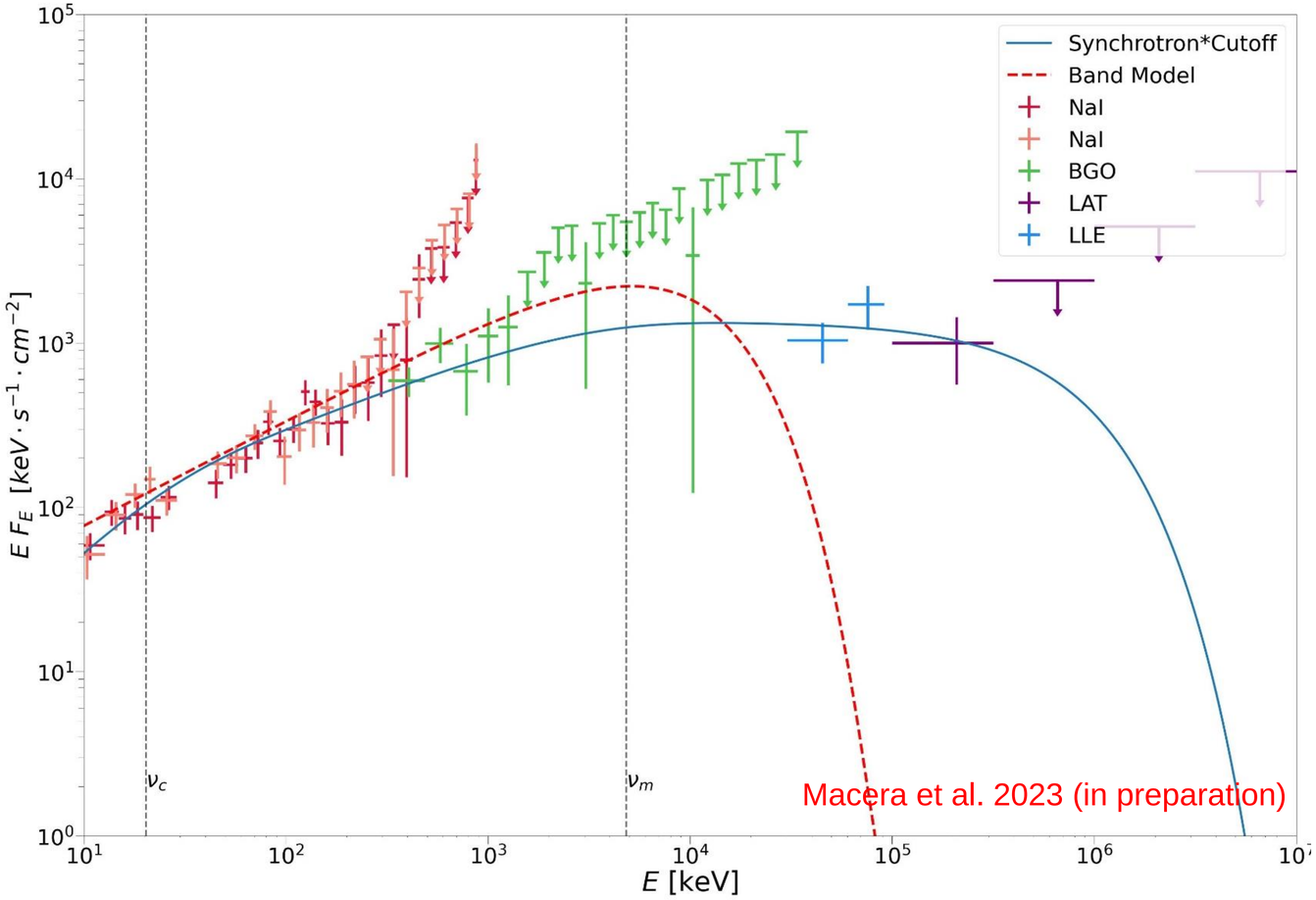
Pure synchrotron from 8 keV to 100 GeV

52 spectra, 10 GRBs

Preliminary results

GRB080916C

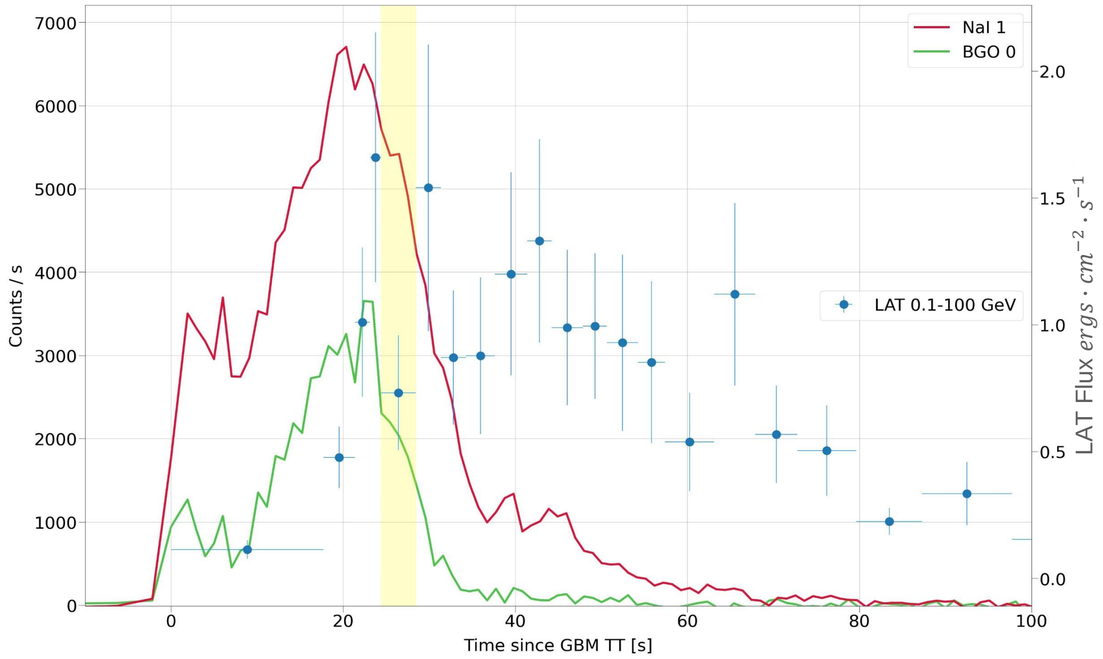




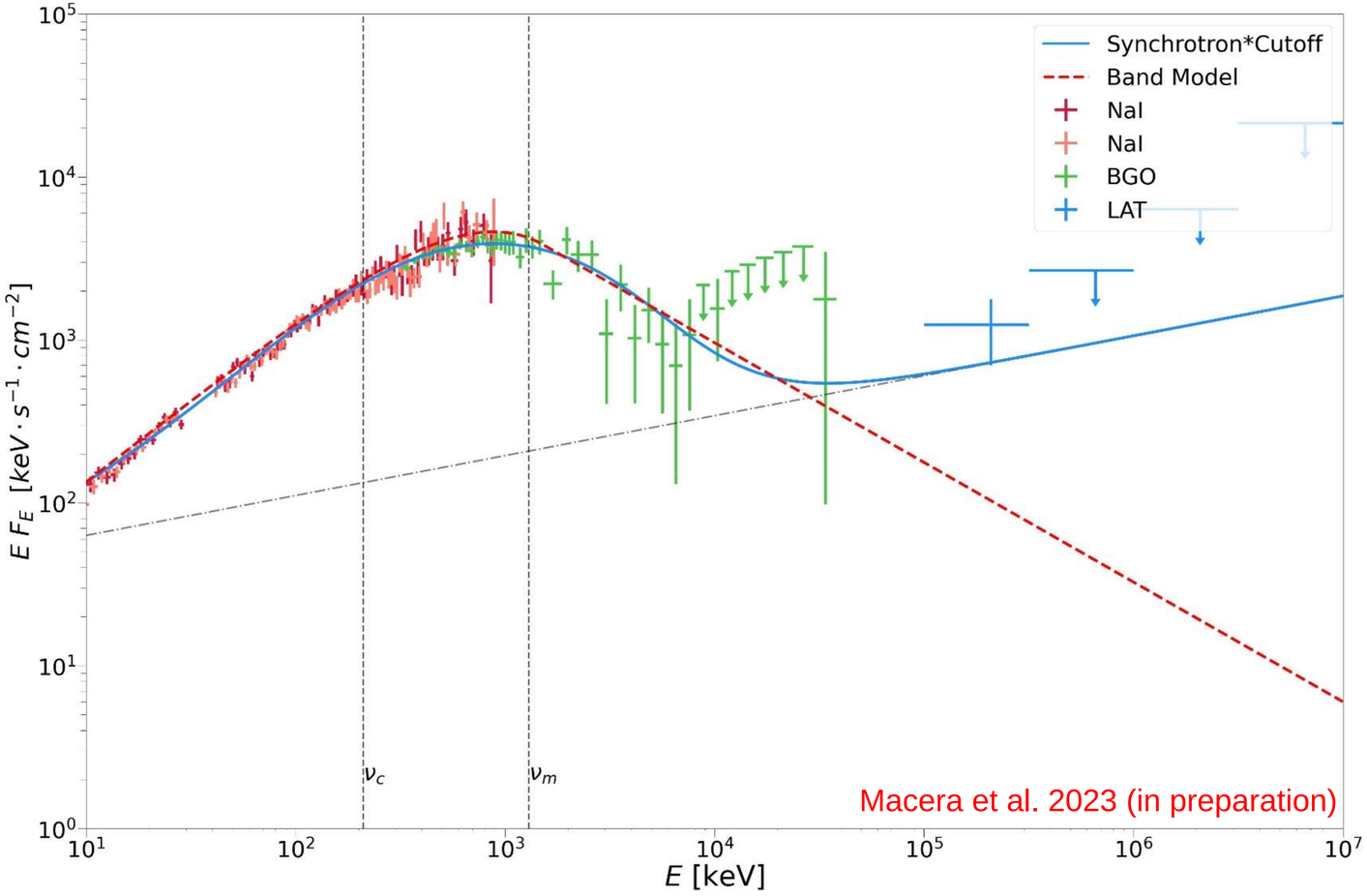
Group II : Synchrotron + Power Law

Synchrotron still working

13 spectra, 4 GRBs



GRB221023A



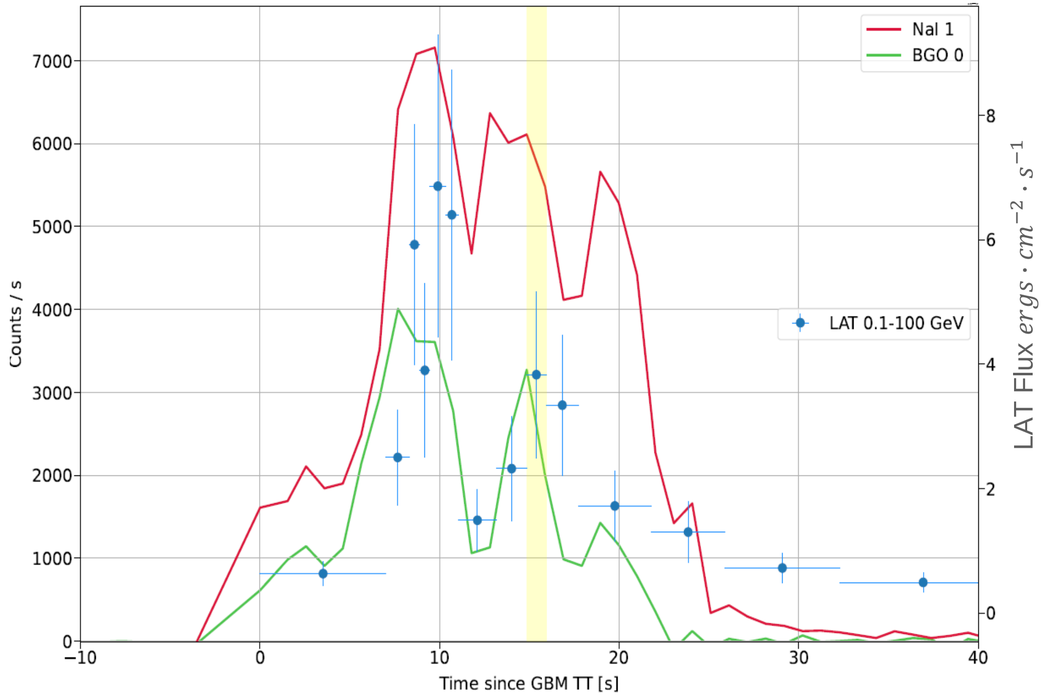
Group II : Synchrotron + Power Law → Sharp Cutoff

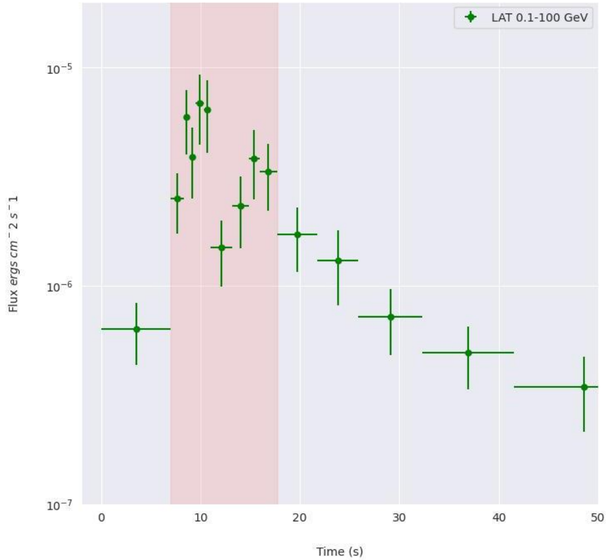
GRB090902B (similar to GRB190114C)

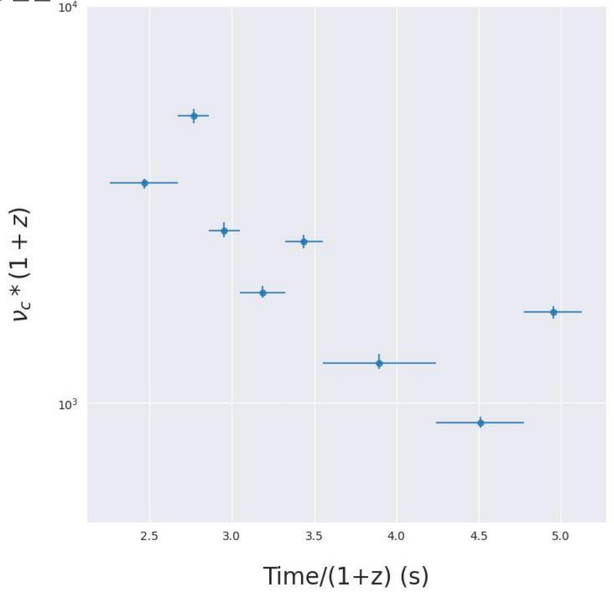
Synchrotron still working

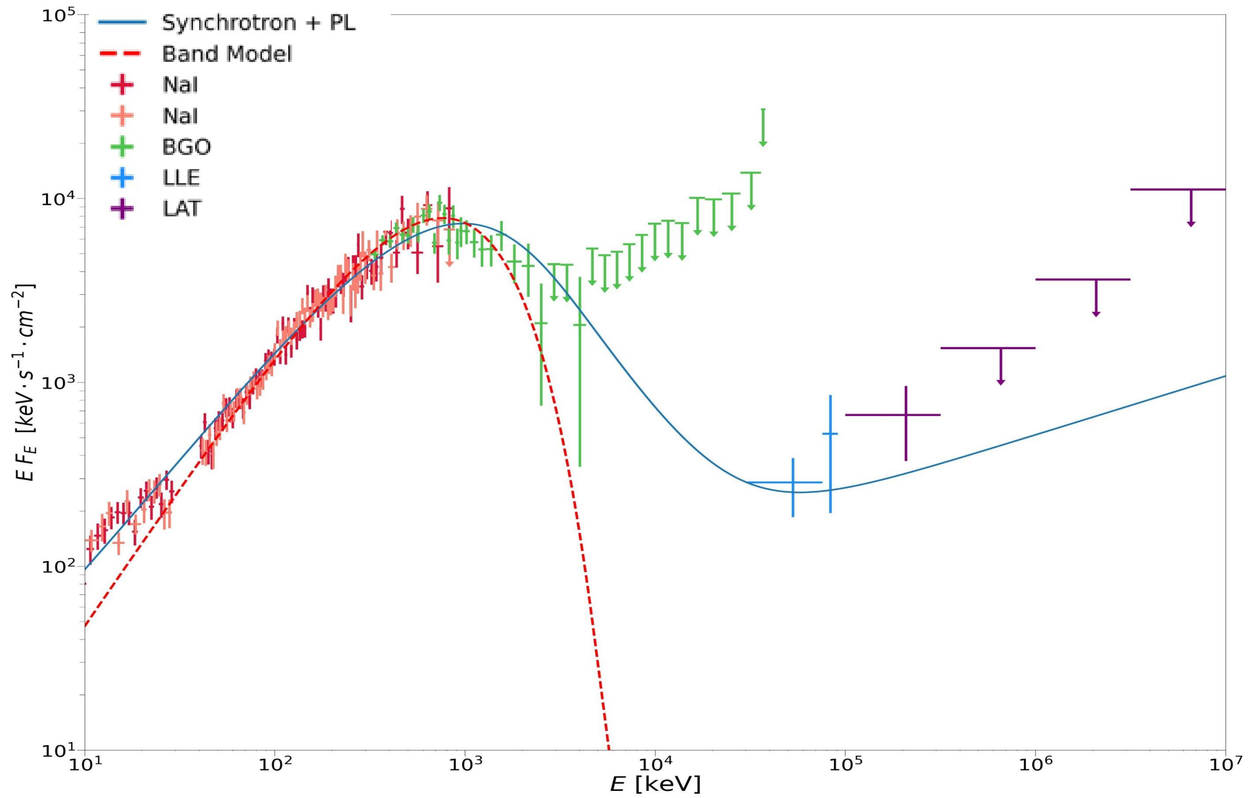
Peak at $\sim 0.1\ MeV$

15 spectra, 2 GRB









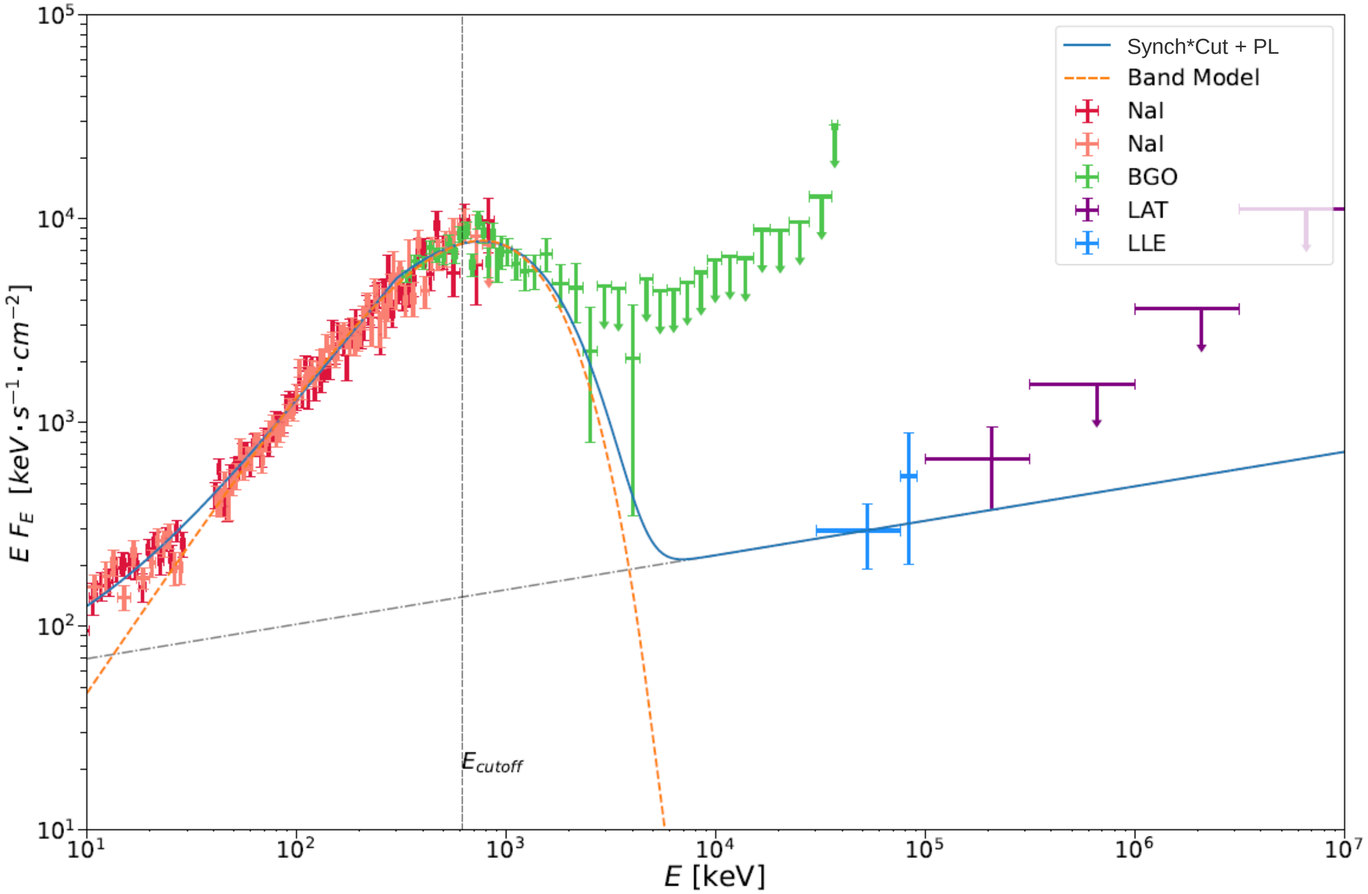
Group III : Synchrotron + Power Law → Sharp Cutoff

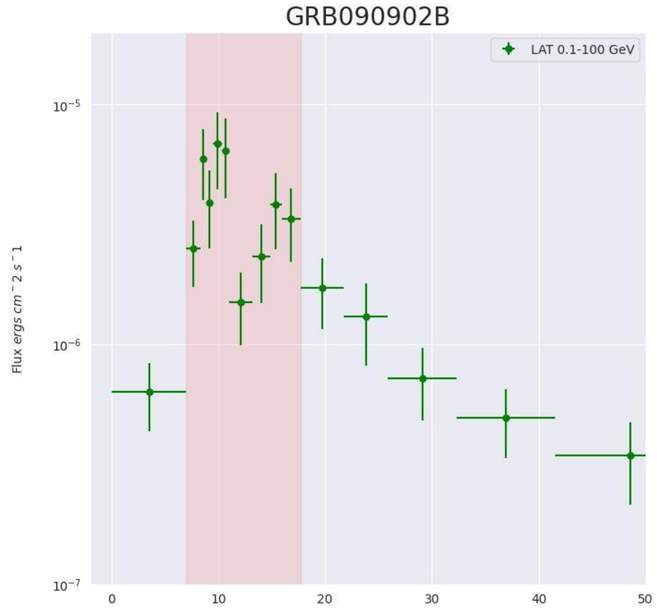
GRB090902B

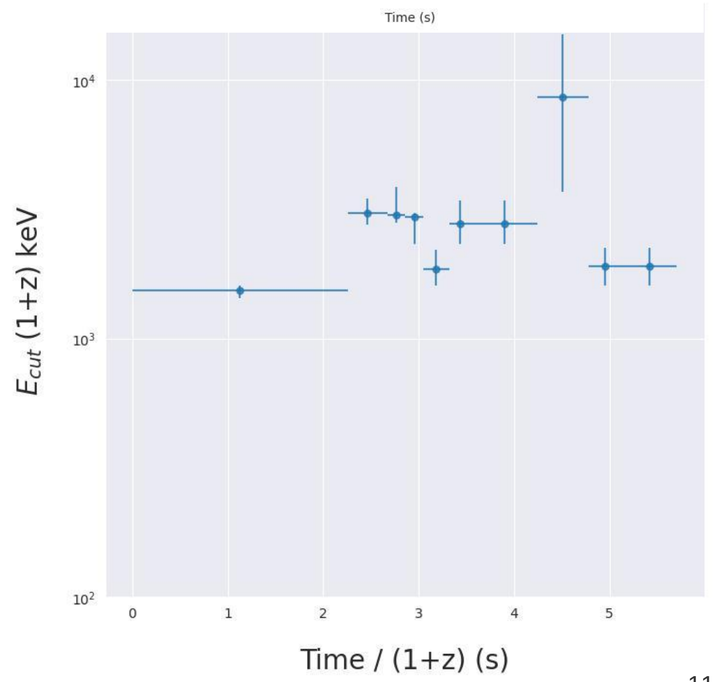
Synchrotron still working

Sharp cutoff at Energies above 0.1 MeV

$$E_{cut}\,(1+z) \sim [1-6\ MeV]$$

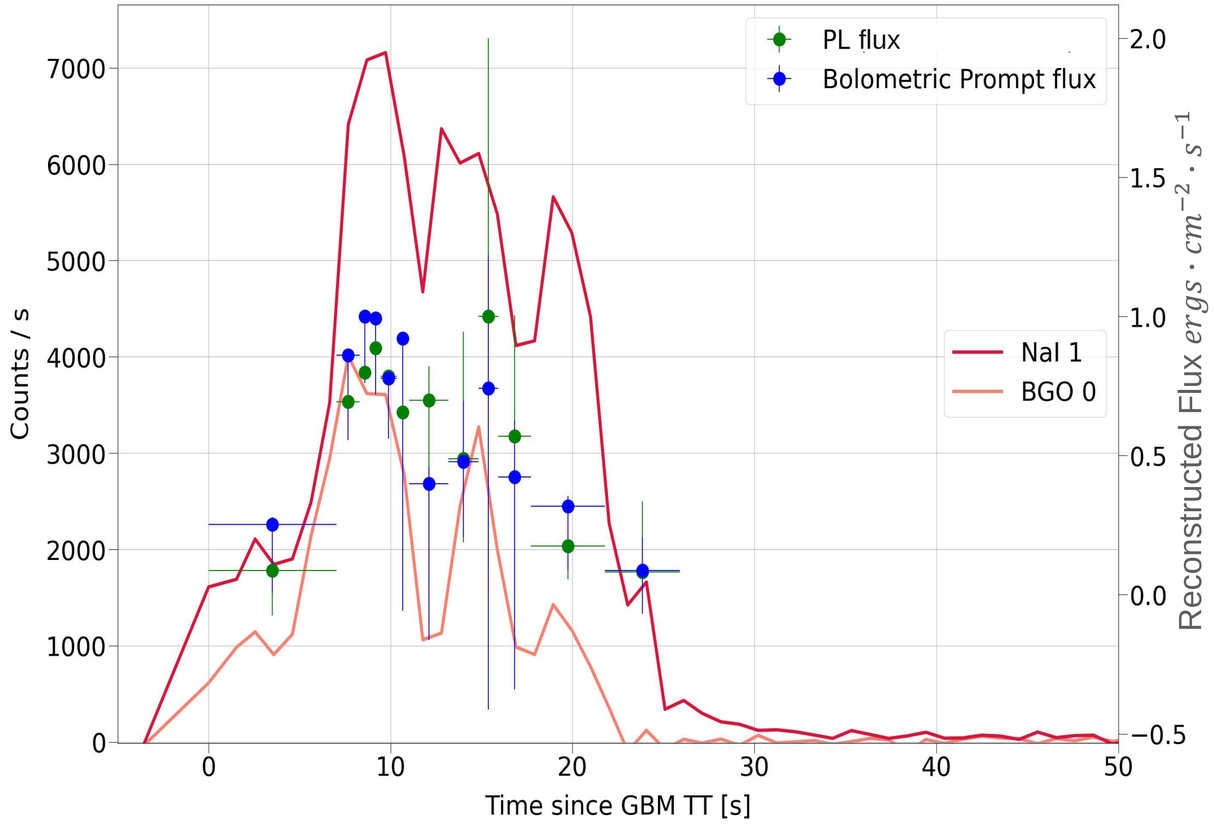






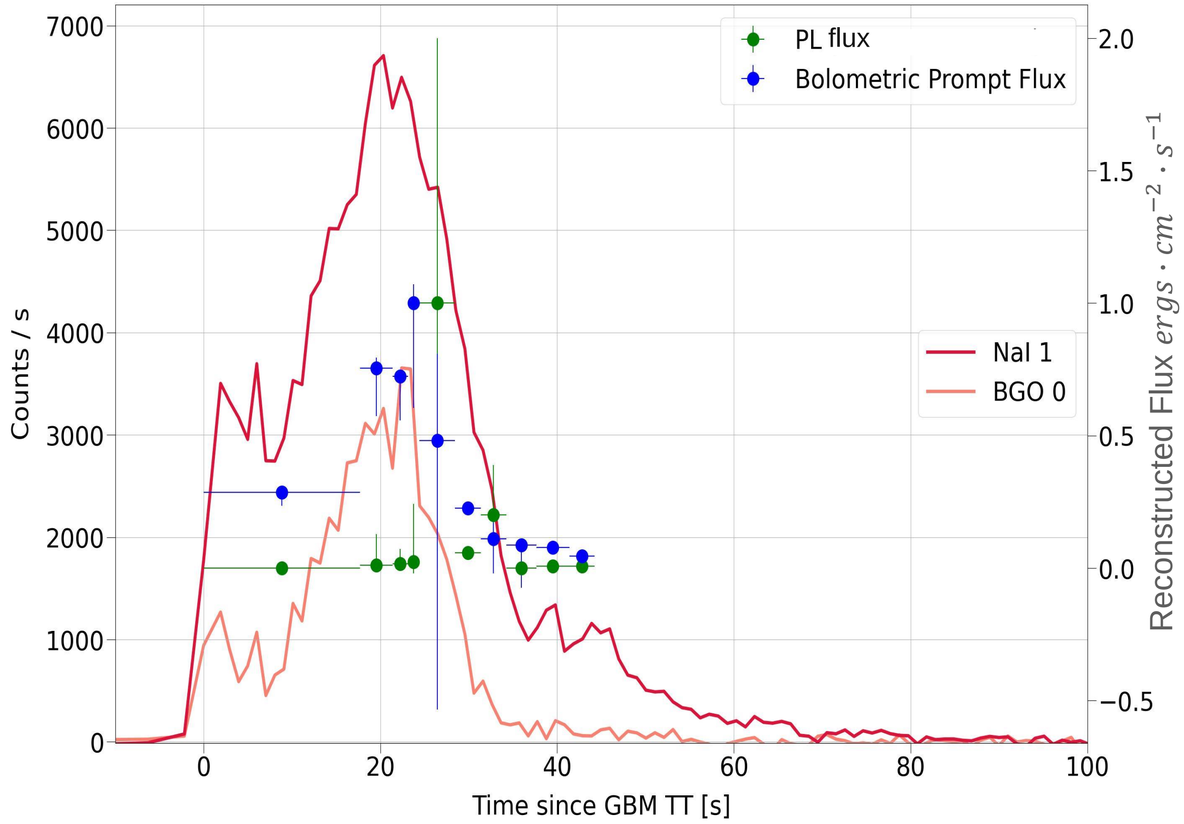
Nature of early GeV emission

GRB090902B



PL component following Synchrotron evolution

GRB221023A



PL ~ Constant → Afterglow ?

Nature of early GeV emission

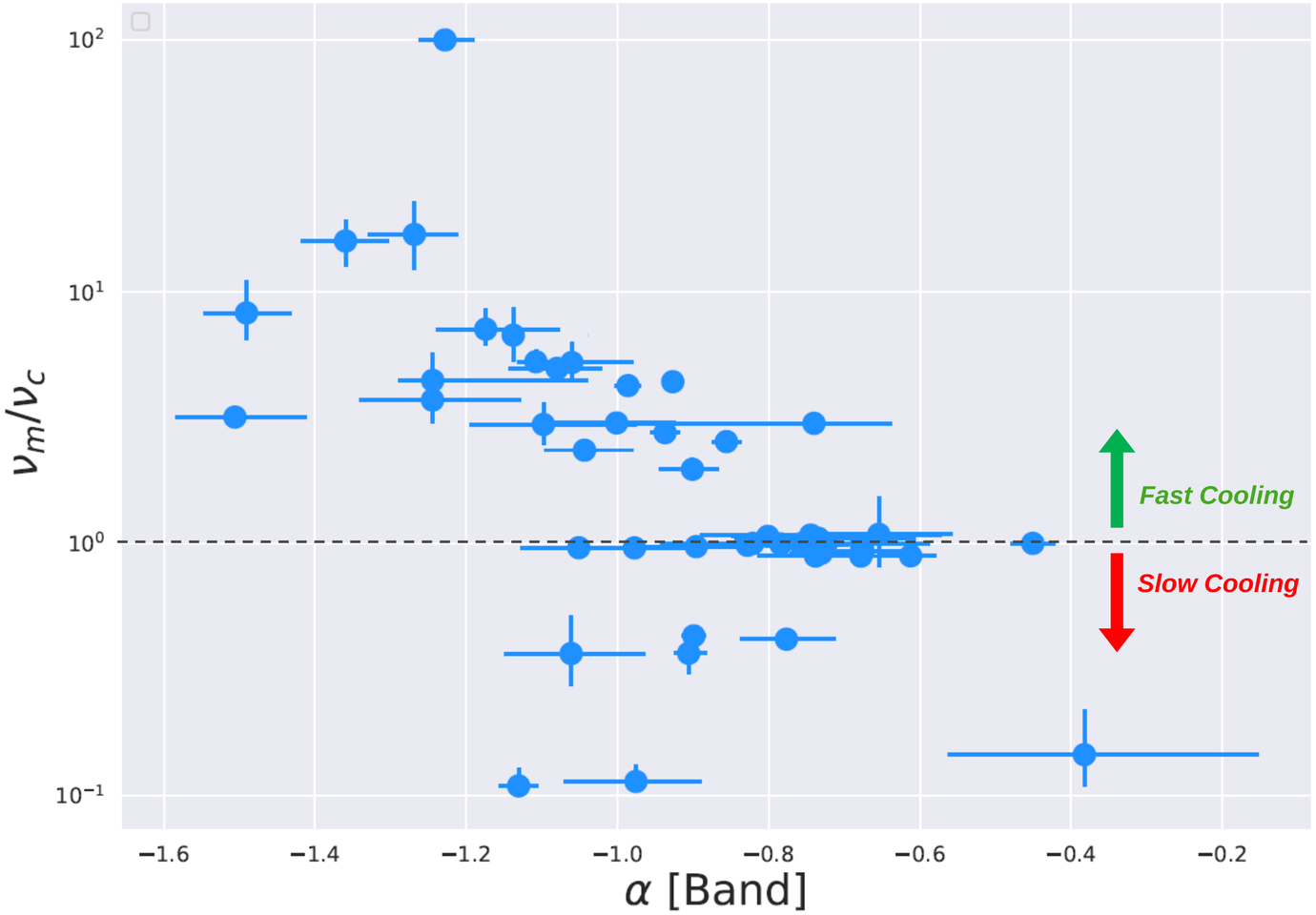
❖ In the majority of cases early GeV emission is dominated by Synchrotron radiation

→ If prompt emission is synchrotron, GeV early emission is produced by prompt

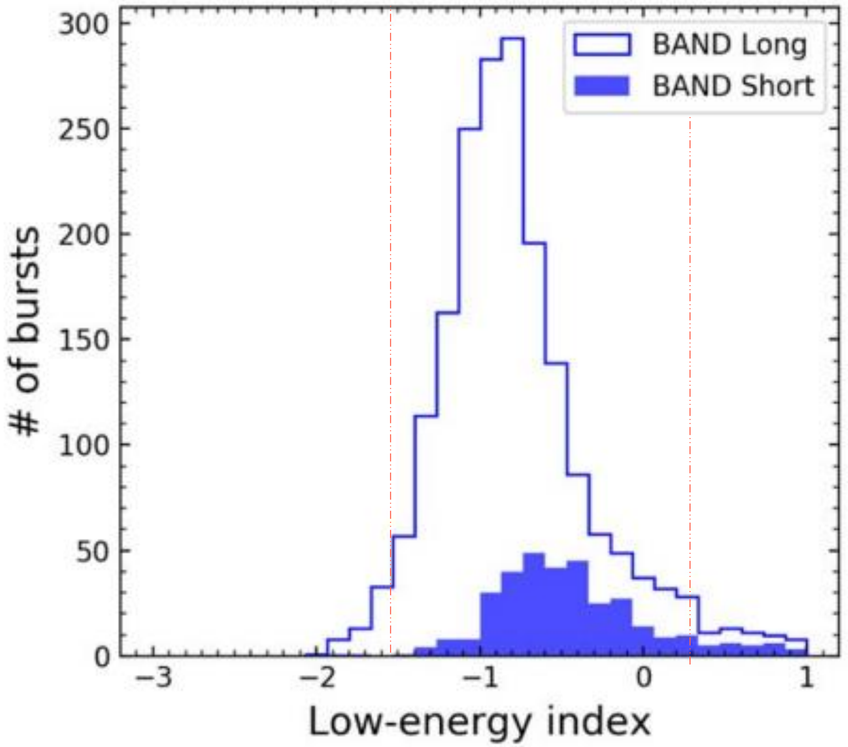
❖ In 4 GRBs the second component is significant, but still unclear origin

Parameter Space of Synchrotron

Synchrotron parameters

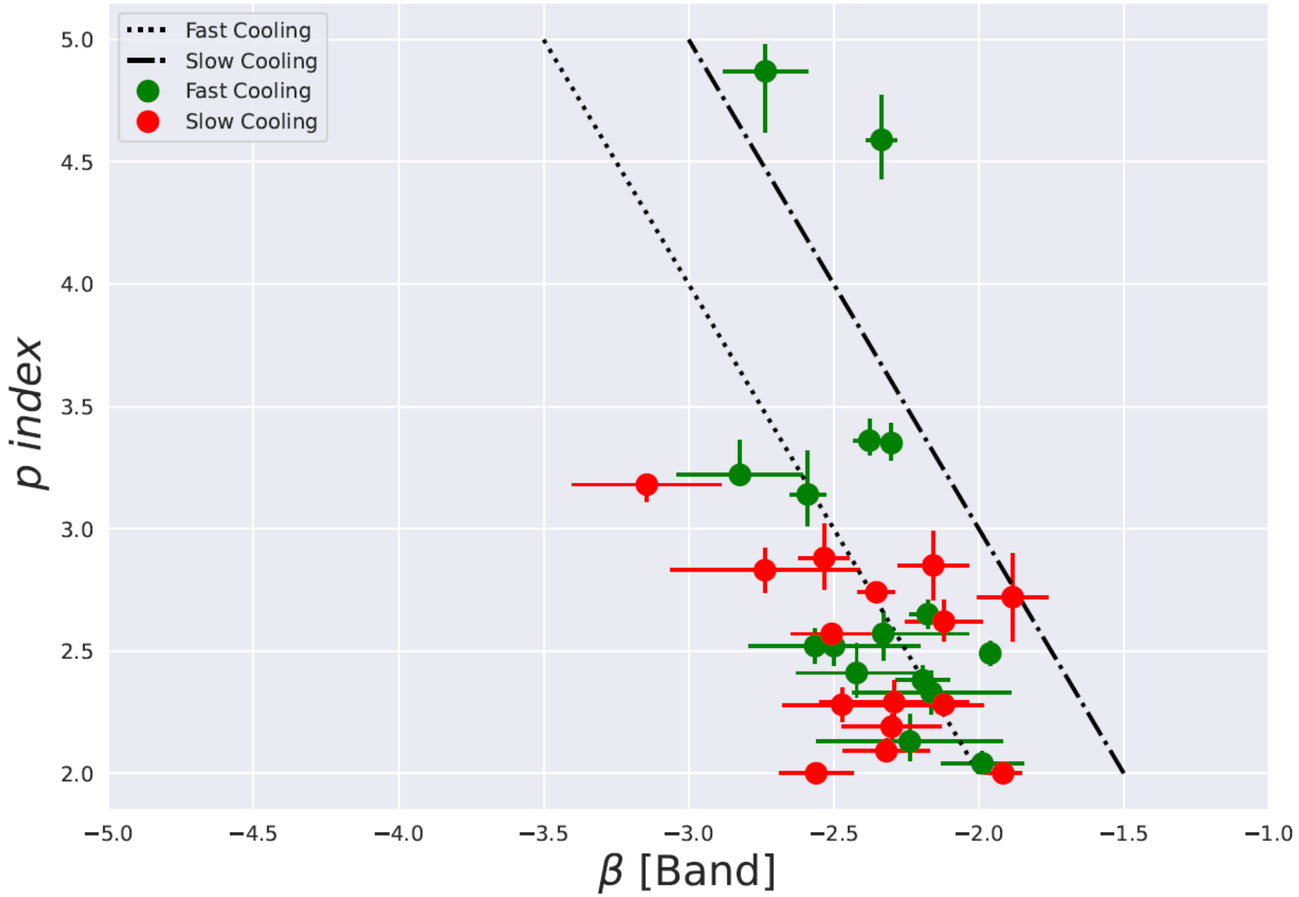


Macera et al. 2023 (in preparation)

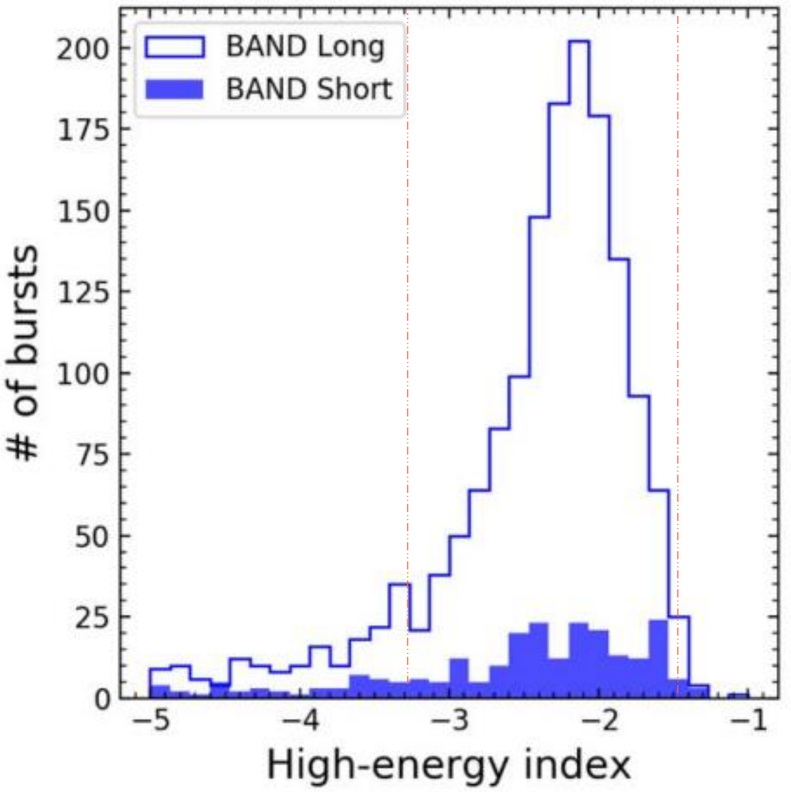


Poolakkil et al. 2021

Synchrotron parameters

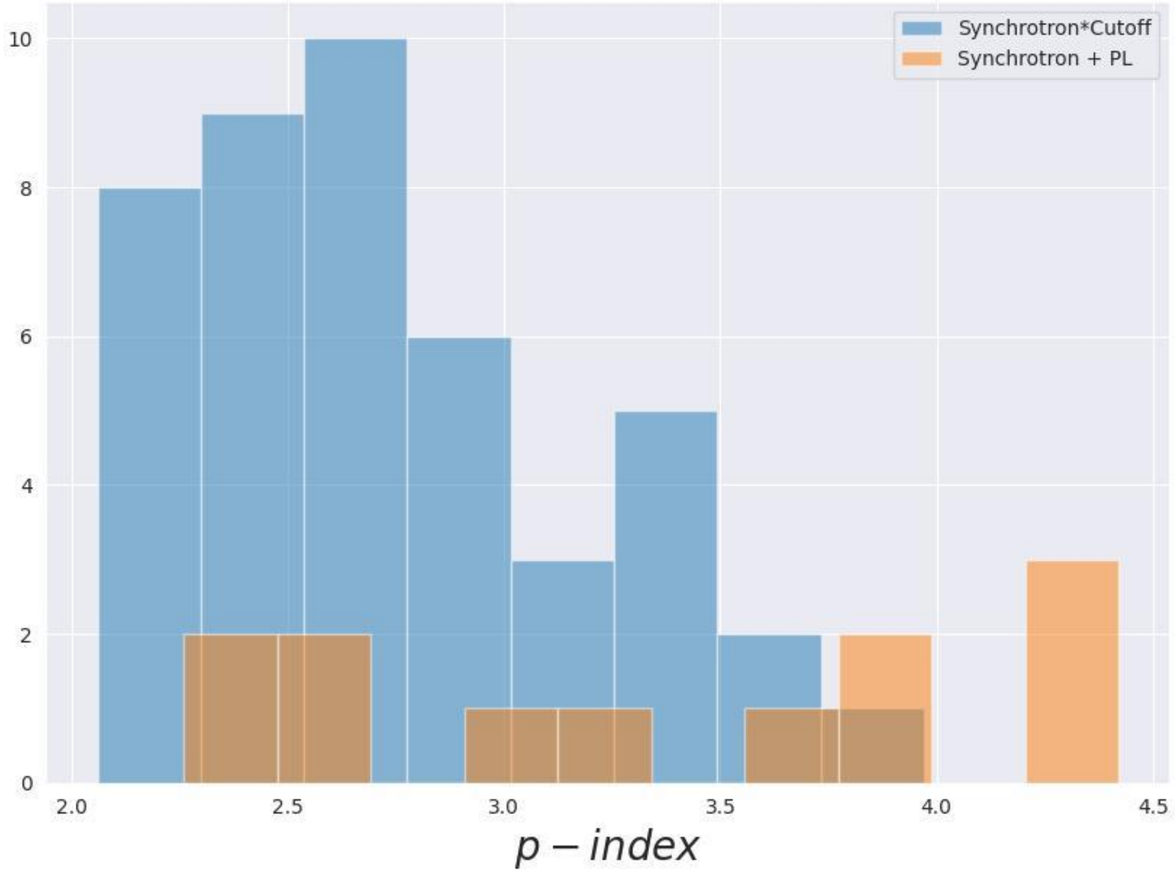


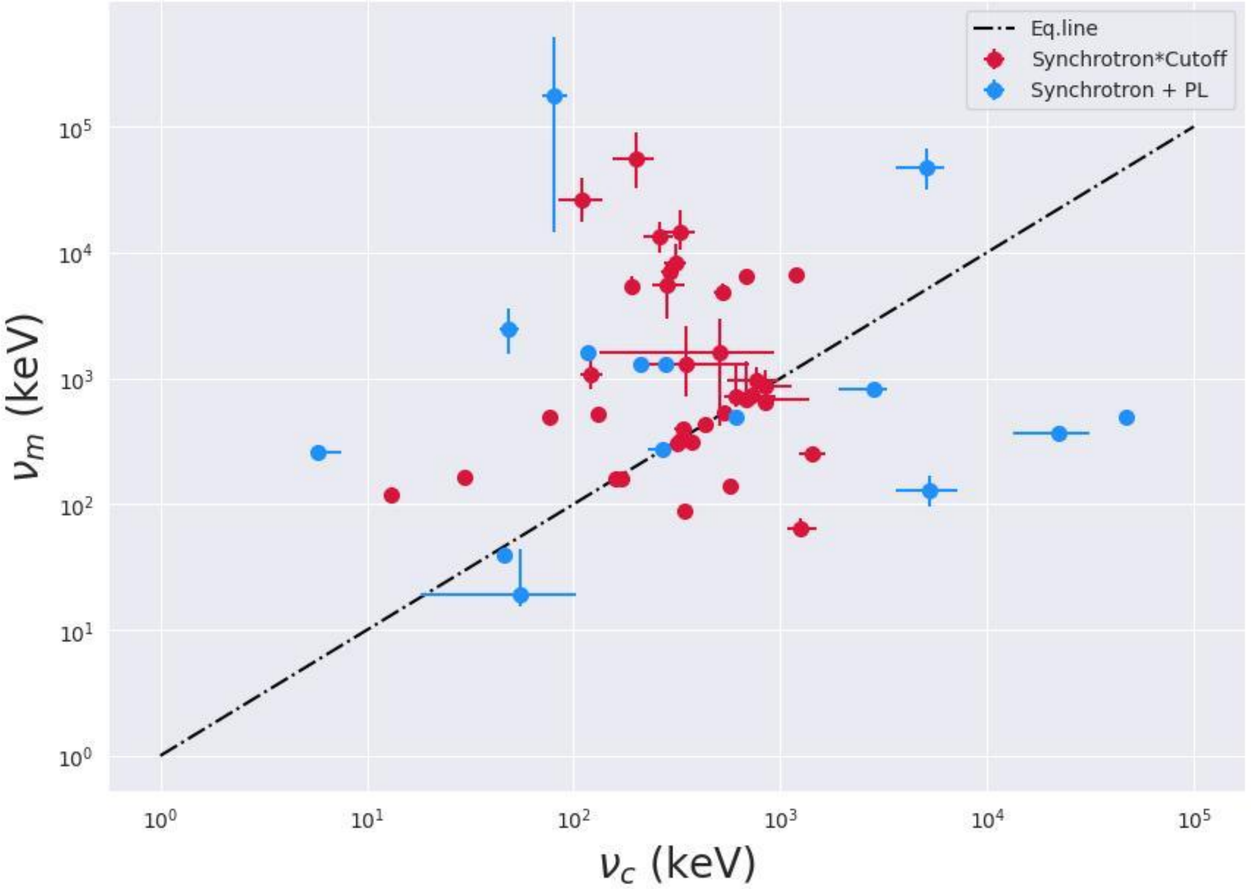
Macera et al. 2023 (in preparation)



Poolakkil et al. 2021

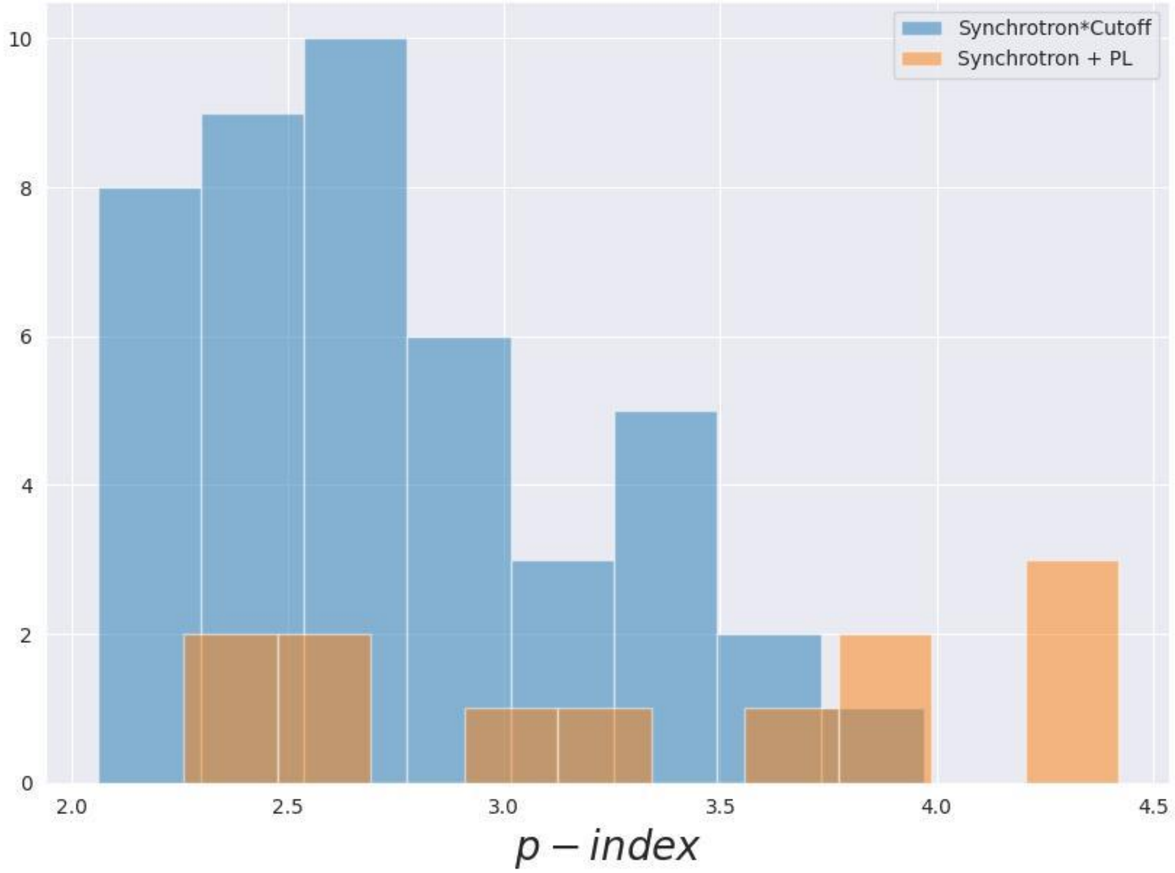
Synchrotron parameters

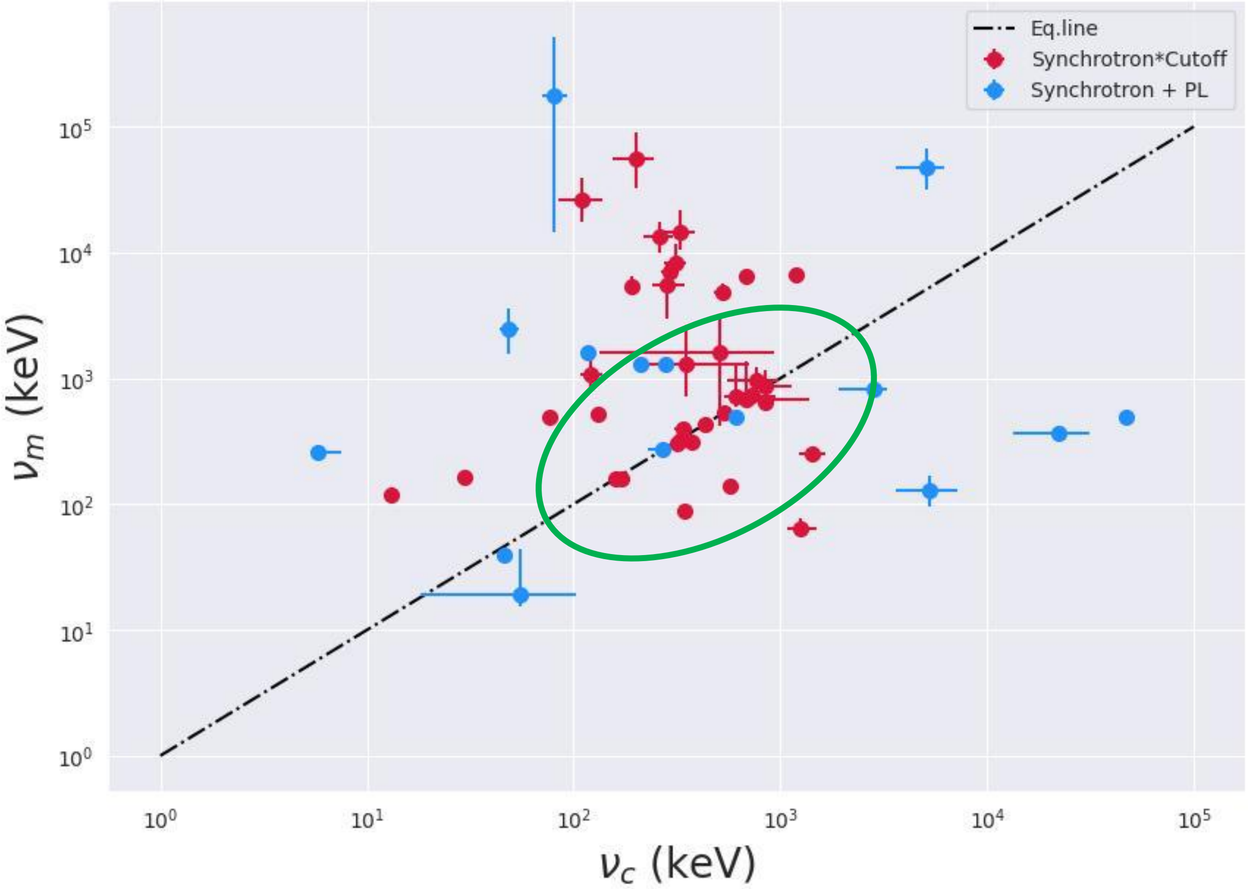




Macera et al. 2023 (in preparation)

Synchrotron parameters





Macera et al. 2023 (in preparation)

Conclusions

- ❖ All the spectra analyzed are consistent with synchrotron origin
- ❖ Few GRBs require second spectral component to explain the GeV emission, but with a still unclear nature
- ❖ High energy data allows to probe synchrotron model over 7 orders of magnitude
- ❖ Exceptional case GRB090902B $E_{cut}(1+z) \sim [1 - 6\ MeV]$ → Pair loaded afterglow? **[Beloborodov, 2002]**
- ❖ Unclear the common marginally/slow cooling origin of prompt emission