High and very-high-energy early emission of Gamma-ray bursts

Samanta Macera, PhD student at GSSI

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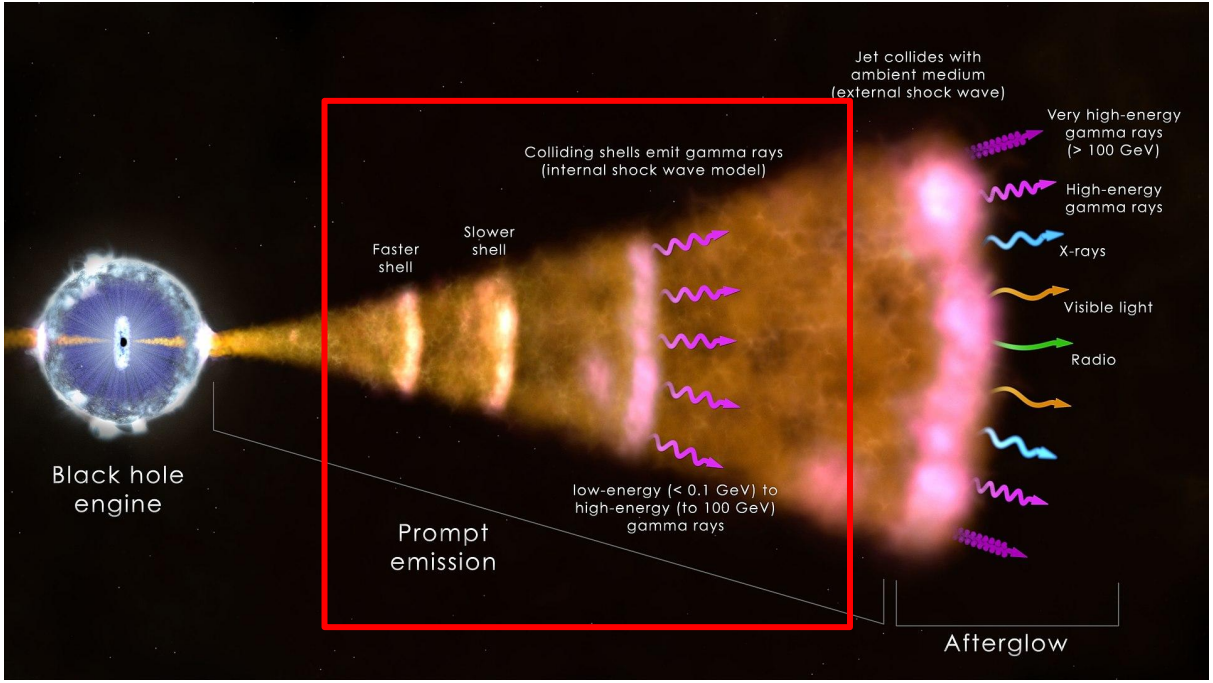
GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

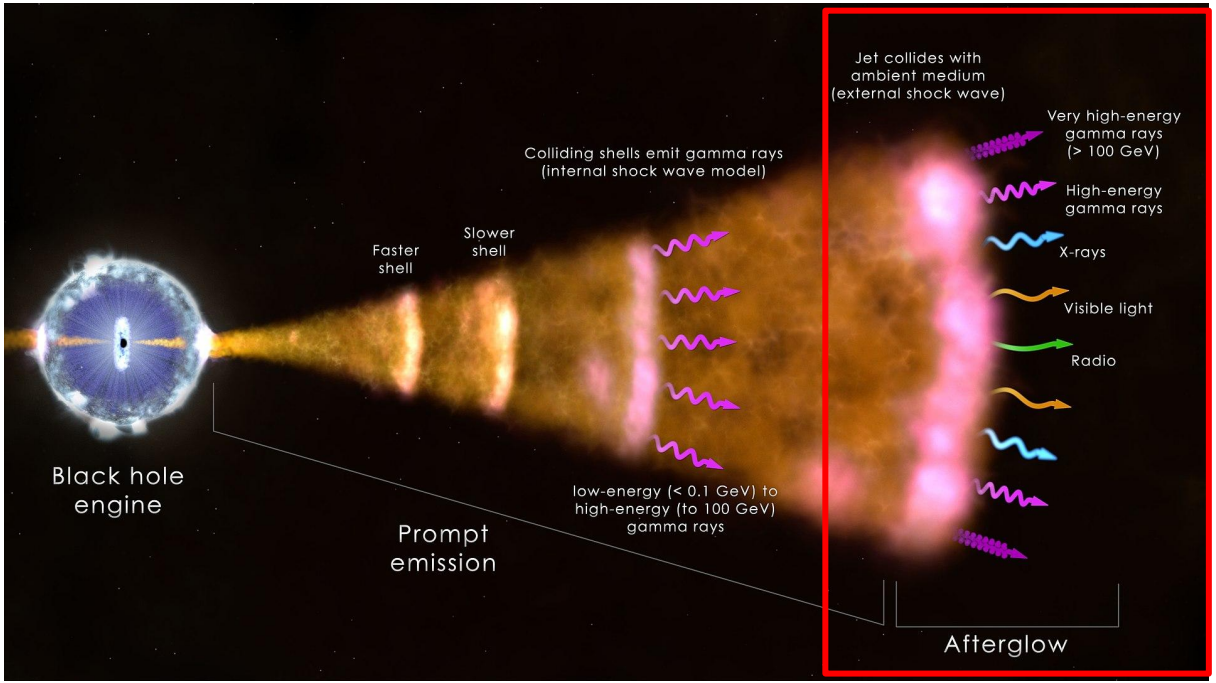
Gamma-ray bursts emissions



Prompt emission

- High variability
- Few seconds - minutes
- Energy range between few keV to 10 MeV
- Internal dissipation

Gamma-ray bursts emissions

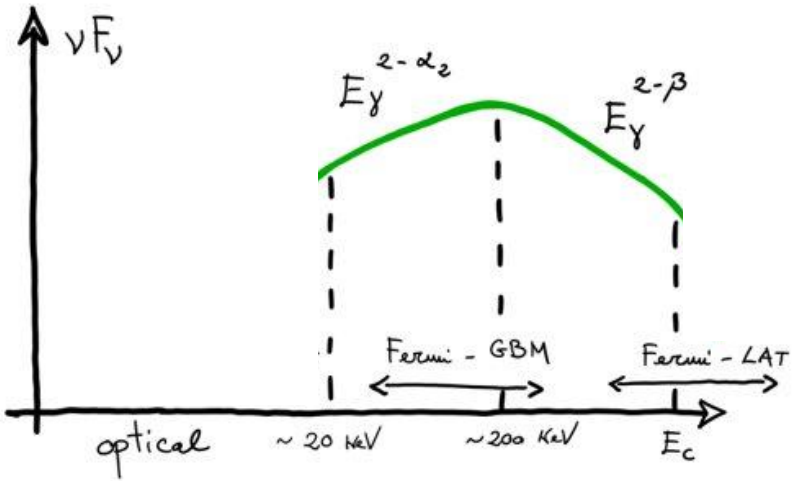


Afterglow emission

- Wide energy range (from γ to radio)
- Flux decays as a power law in time
- Can last from weeks to months
- External dissipation

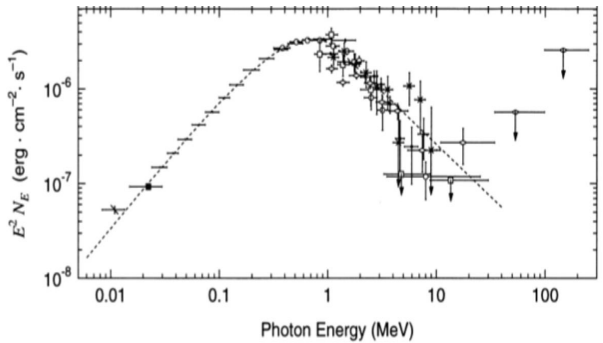
Physics of prompt: Band model

Spectrum consisting of two power laws smoothly connected



Typical energy range: few keV-10 MeV

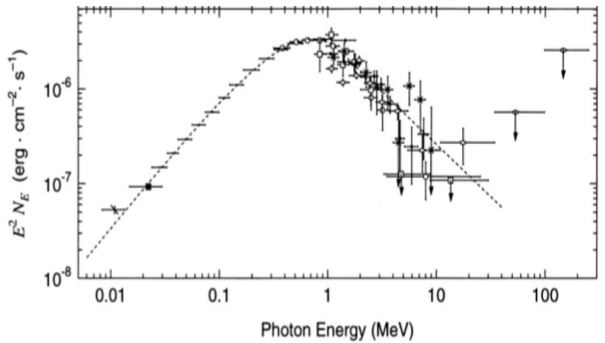
Physics of prompt: Band model



Briggs et al. 1999

$$\langle \alpha \rangle_{Band} \sim -1 \longrightarrow \begin{array}{l} \alpha_{fast\ cool} \sim -1.5 \\ \alpha_{slow\ cool} \sim -0.6 \end{array}$$

Physics of prompt: energy breaks



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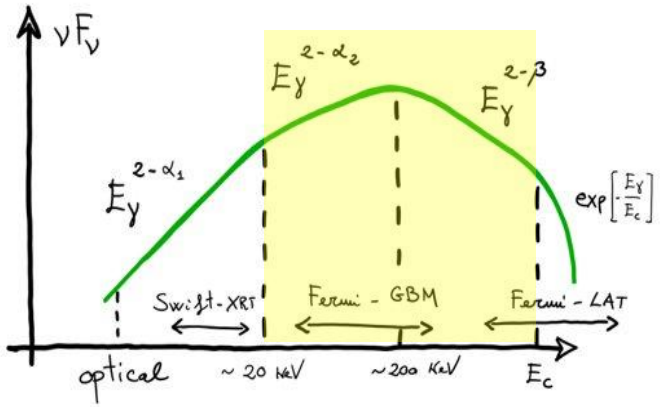
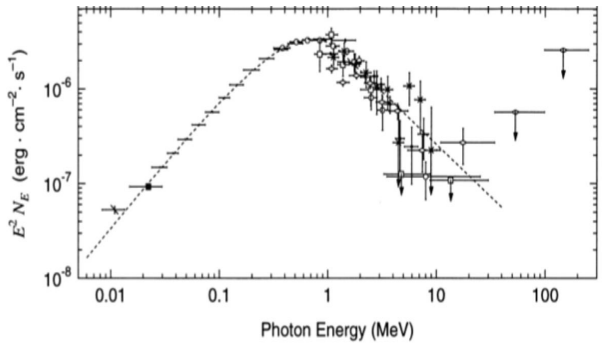
$\langle \alpha \rangle_{Band} \sim -1 \longrightarrow \begin{matrix} \alpha_{fast\ cool} \sim -1.5 \\ \alpha_{slow\ cool} \sim -0.6 \end{matrix}$

Broad-band GRB spectra
(from X-ray up to MeV)



Including also lower and higher energies, energy breaks appear in the spectrum

Physics of prompt: energy breaks



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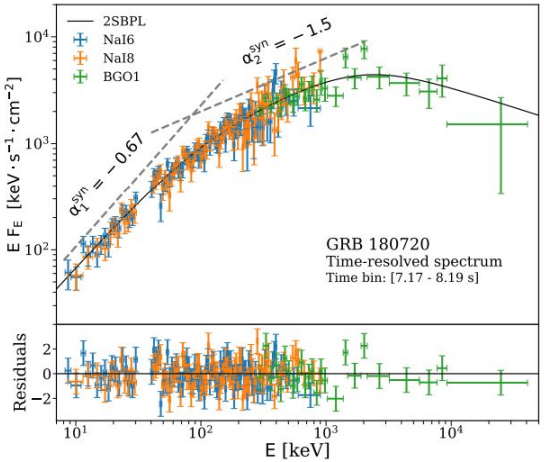

Ravasio et al. 2018

Low energy breaks
empirically
consistent with Synchrotron

Oganesyan et al. (2017, 2018)

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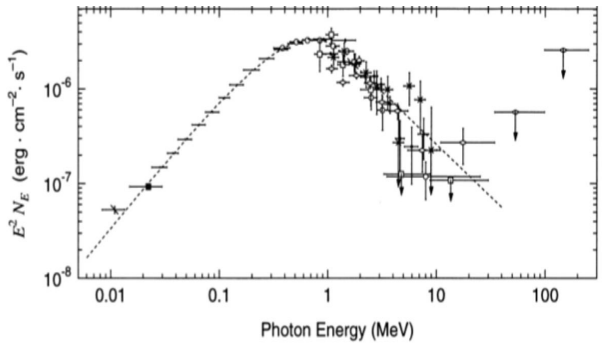

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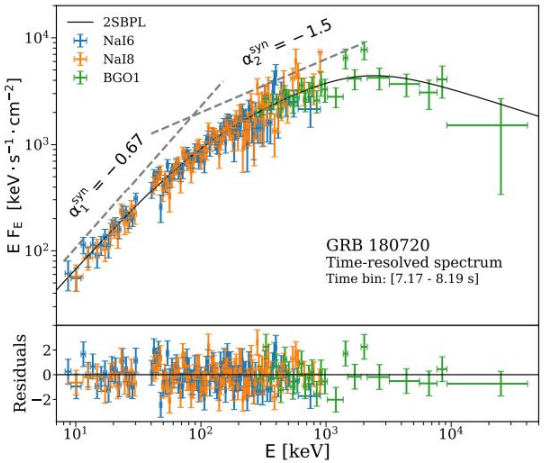

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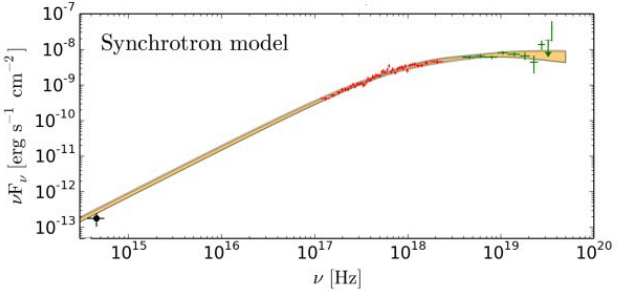
Synchrotron model

(from optical to MeV)



Oganesyan et al. 2019

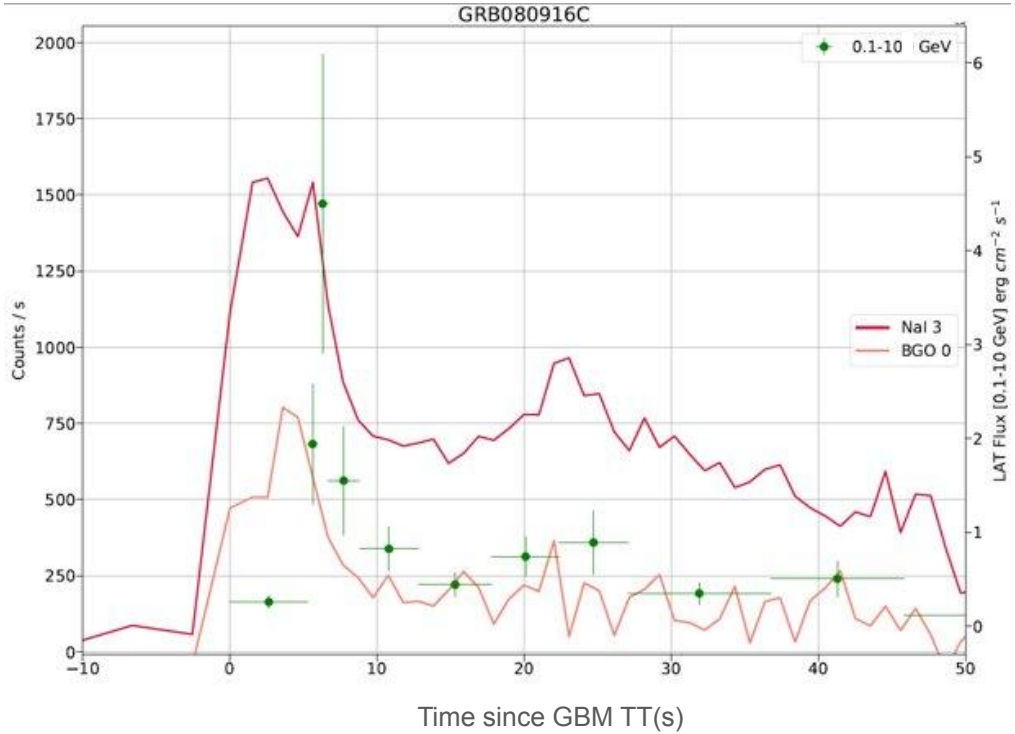
Synchrotron can predict the optical flux

Early GeV emission

- GeV emission temporally coincident with prompt
- Follows prompt (Fermi-GBM) variability

→ Prompt or afterglow related?

Fermi-GBM + Fermi-LAT lightcurves

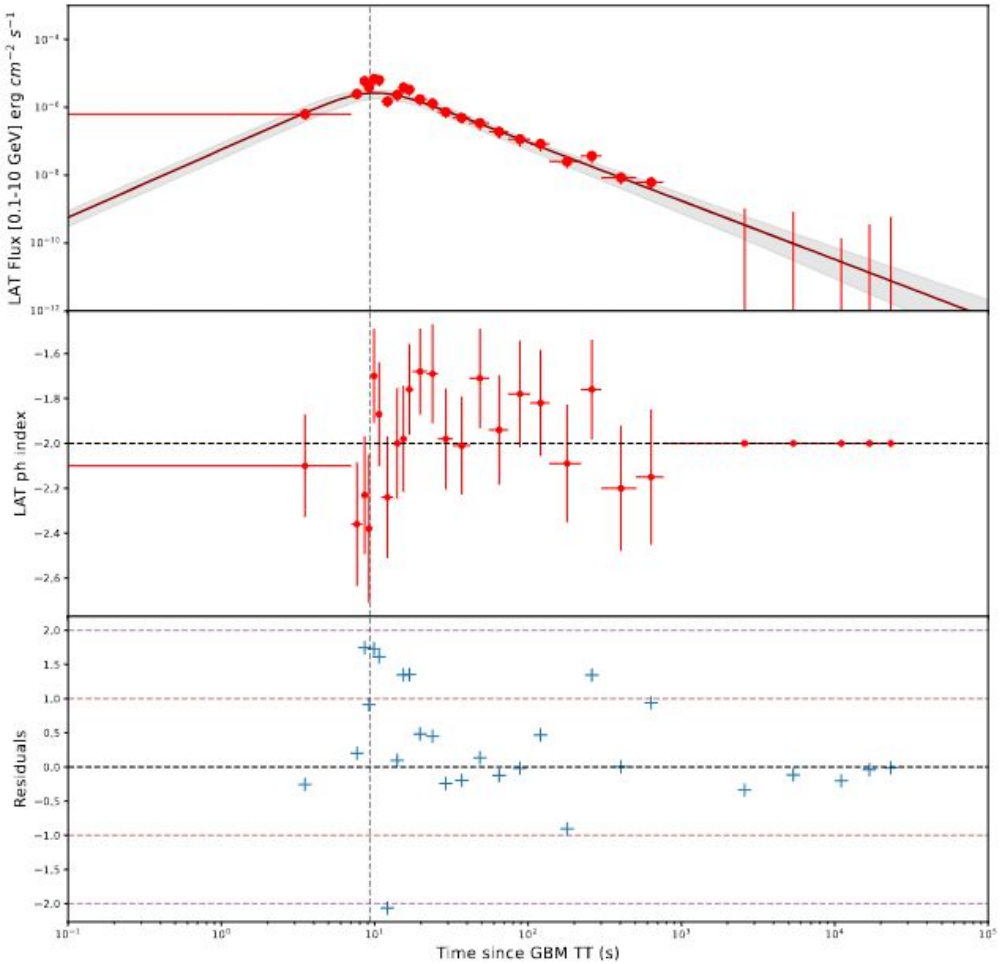


Macera et al, in preparation

Early GeV emission

Temporal analysis:

→ Does the emission follow the afterglow LC time-evolution?



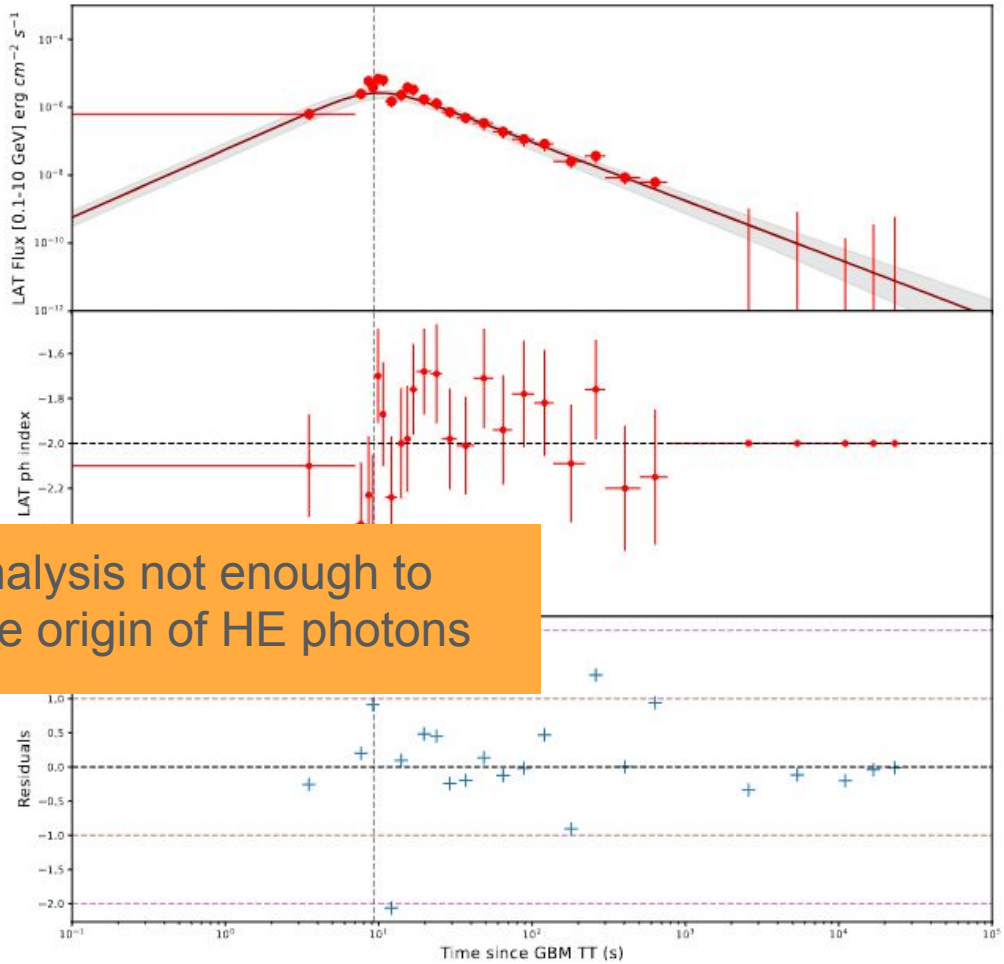
Macera et al, in preparation

Early GeV emission

Temporal analysis:

→ Does the emission follow the afterglo[illegible] time-evolution?

Temporal analysis not enough to understand the origin of HE photons



Macera et al, in preparation

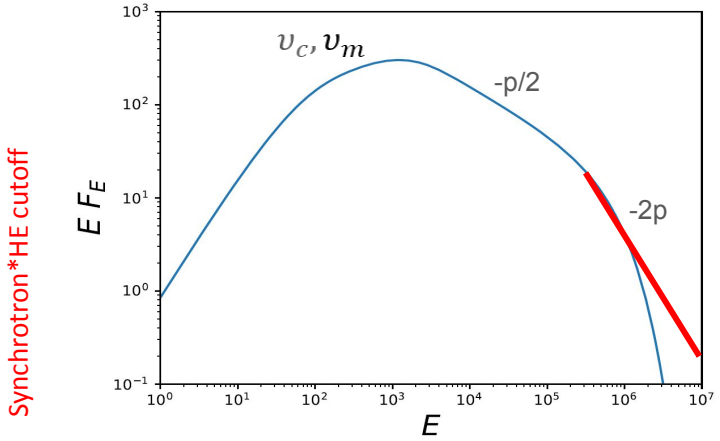
Study of the early GeV emission and the physics of prompt

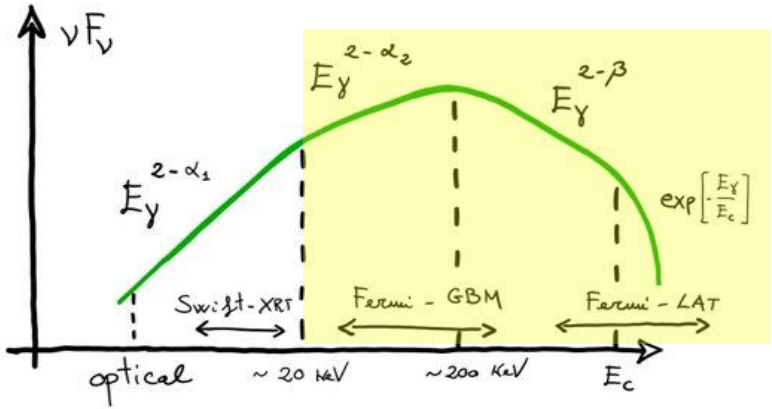
- Extend energy band to Fermi-LAT energy range

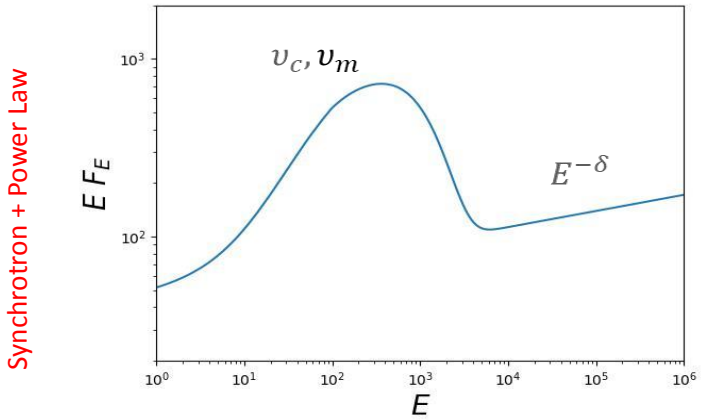
  → <u>total energy range covered: 8 keV - 10 GeV</u>

- Use a physical model for the prompt emission

  → <u>adopt physical models based on synchrotron</u>







Sample selection

- 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
- GBM + LLE (when possible) + LAT

Sample 1

Time resolved spectral analysis of 14 GRBs, 80 spectra

- One 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
- GBM + LLE (when possible) + LAT

Sample 2

Spectral analysis of 66 GRBs

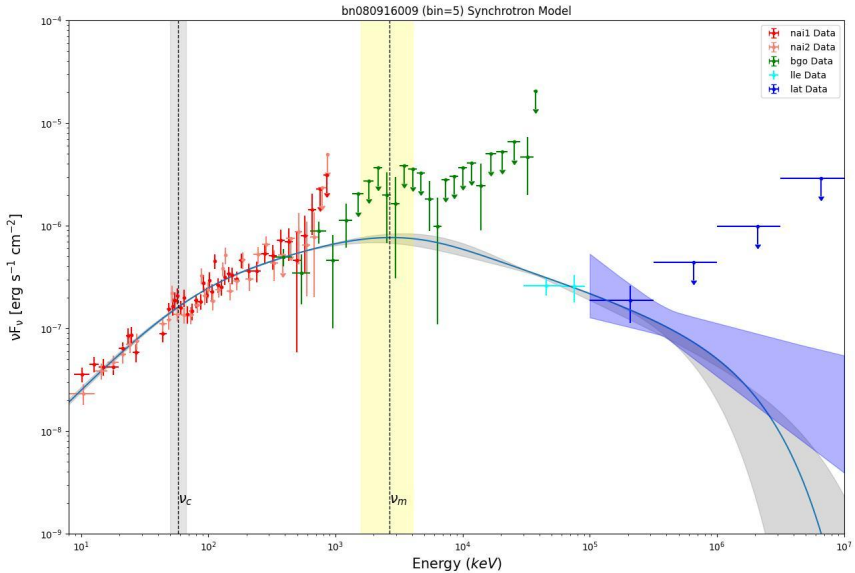
Total of 80 GRBs analysed in the energy range 8 keV - 10 GeV

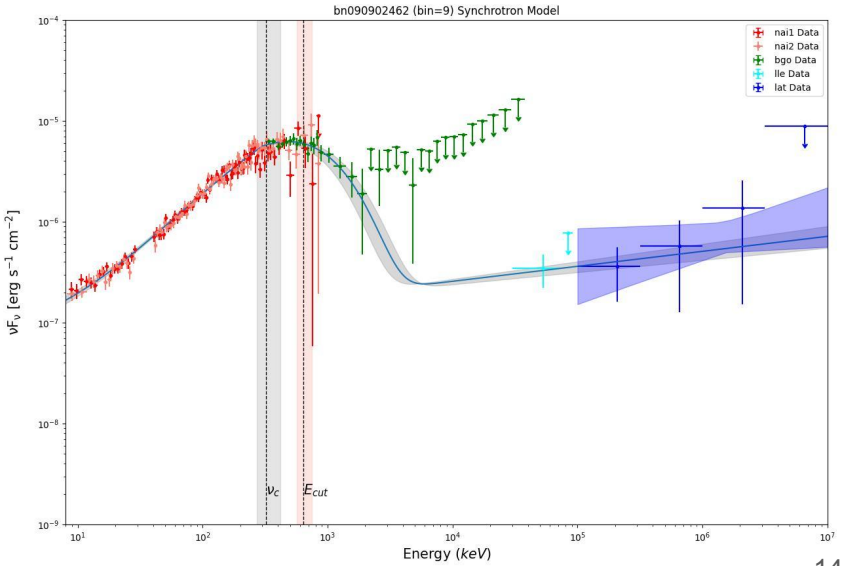
Results of the time-resolved spectral analysis

Sample divided in two groups

1 High-Energy emission dominated by synchrotron

2 High-Energy emission dominated by power law





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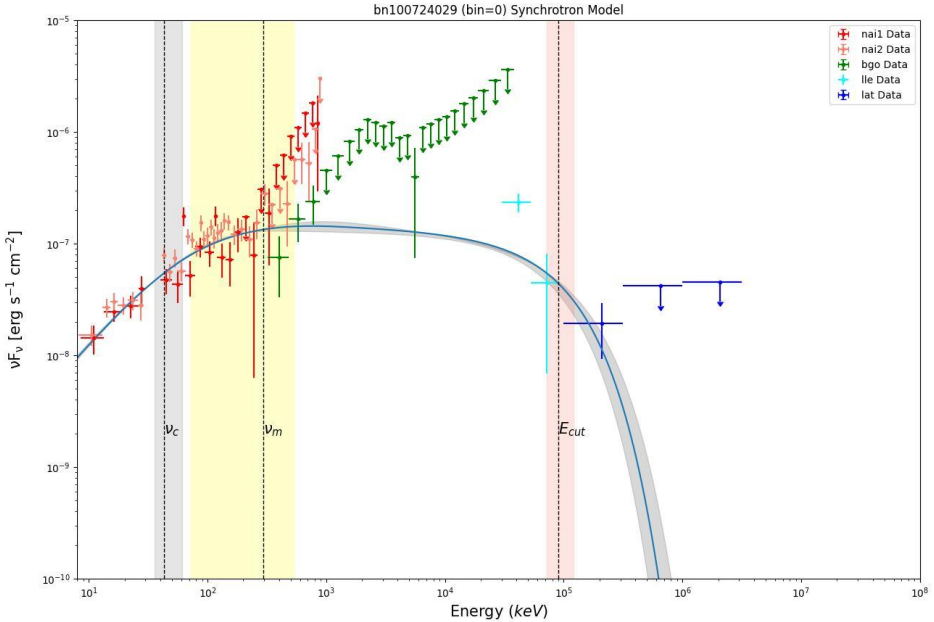
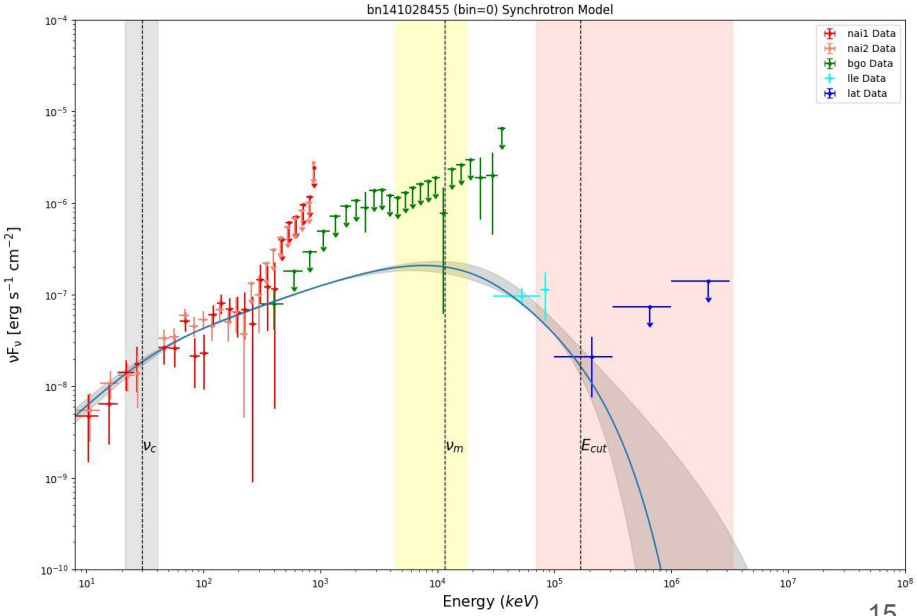
Results Group 1: Broad spectra, covering the entire energy range analysed

HE emission dominated by synchrotron → Prompt related





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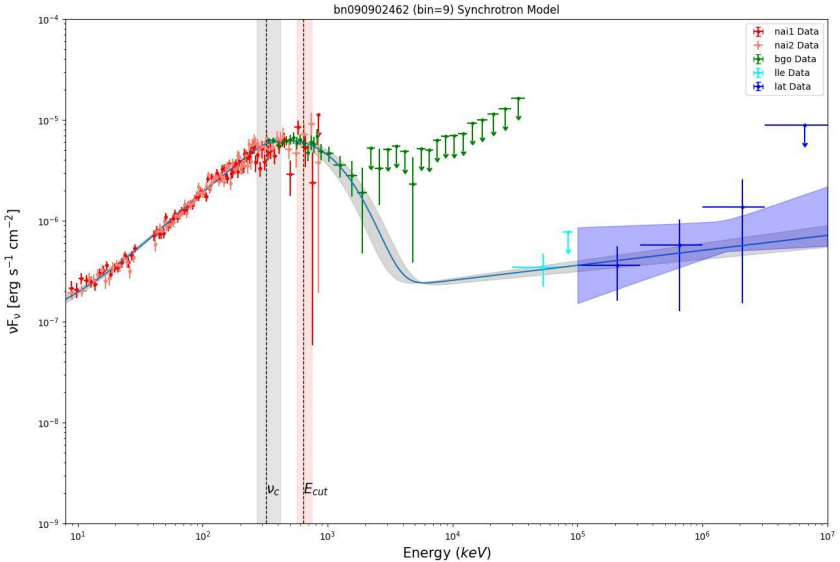
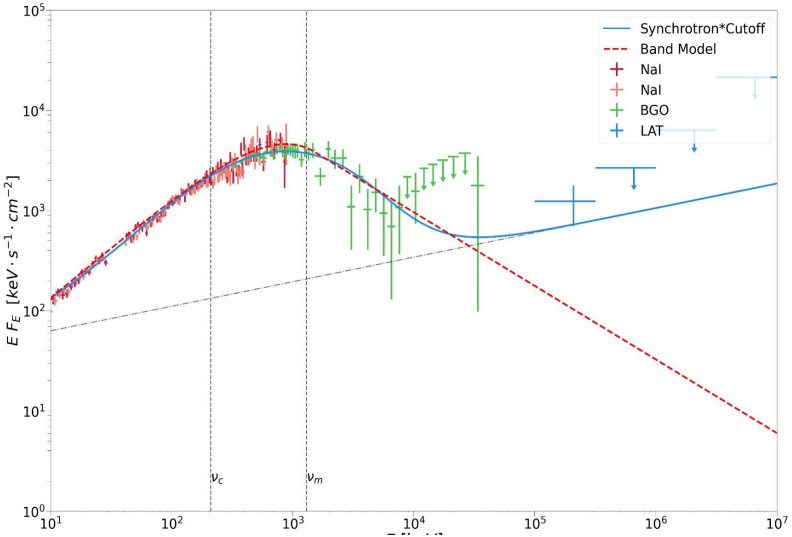
Results Group 2: Power law needed to account for HE photons

GRB 090902B



GRB 221023A



- PL flux follows the variability of prompt emission → Most likely prompt related

- PL flux almost constant in time → Afterglow related?

Results Group 2: Power law needed to account for HE photons

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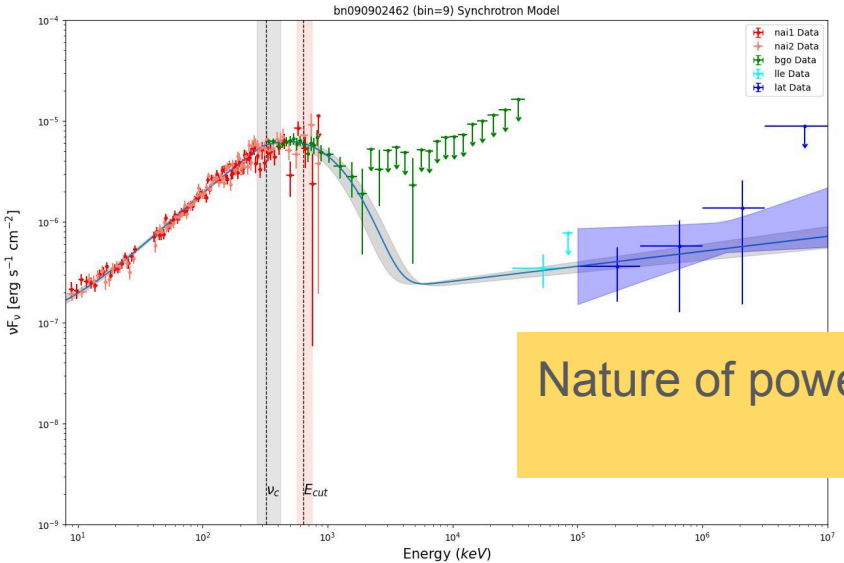

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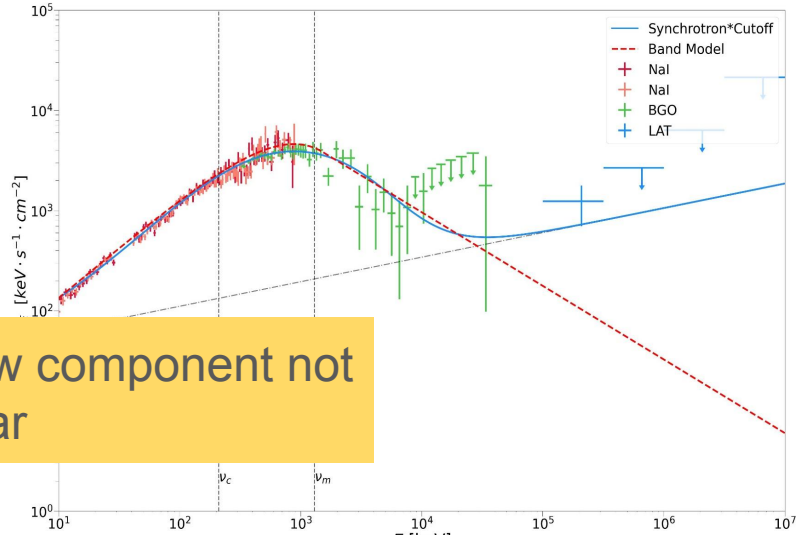
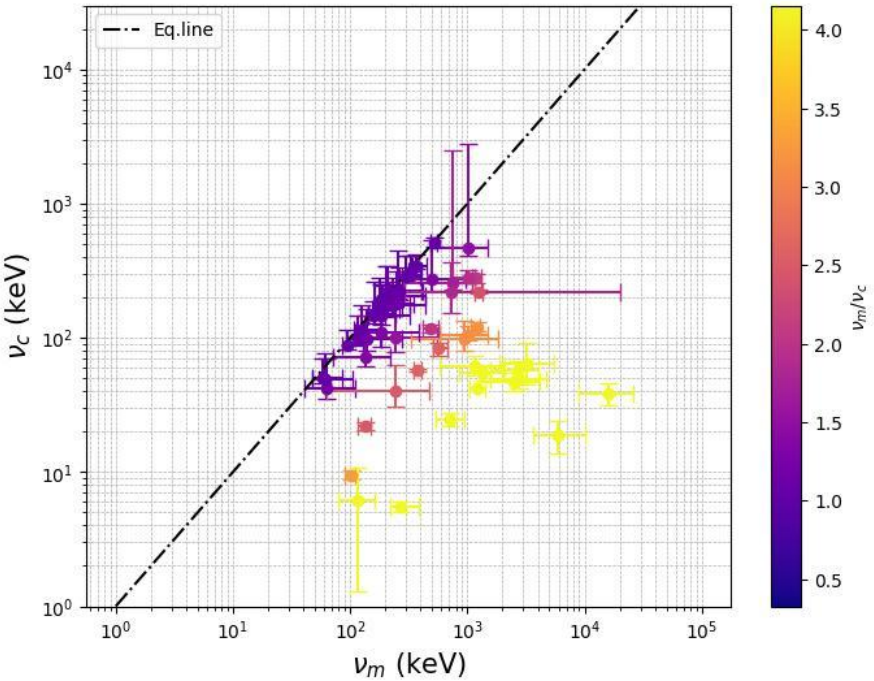


Nature of power law component not clear

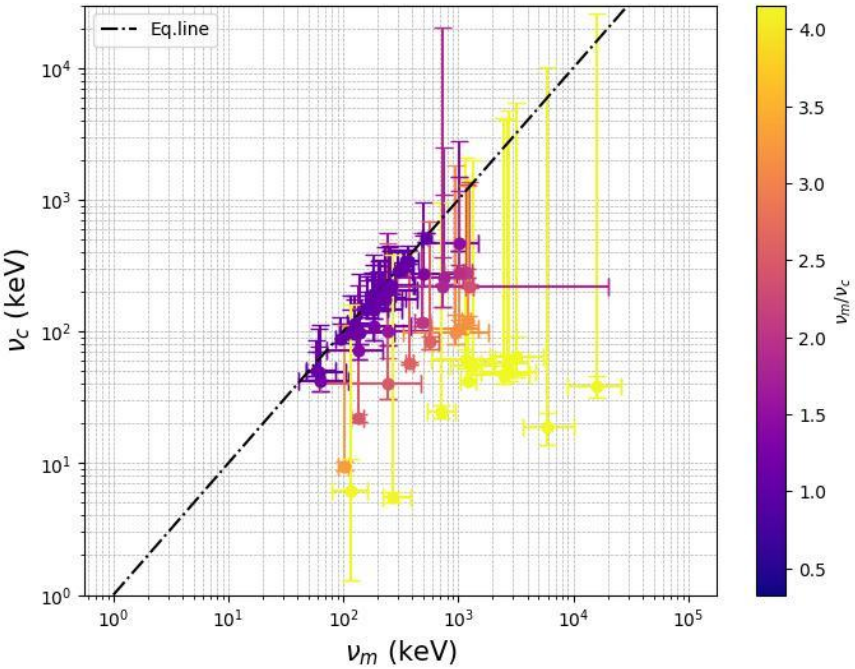
- PL flux follows the variability of prompt emission → Most likely prompt related
- PL flux almost constant in time → Afterglow related?

Results: Synchrotron parameter space

Sample 1



Sample 2



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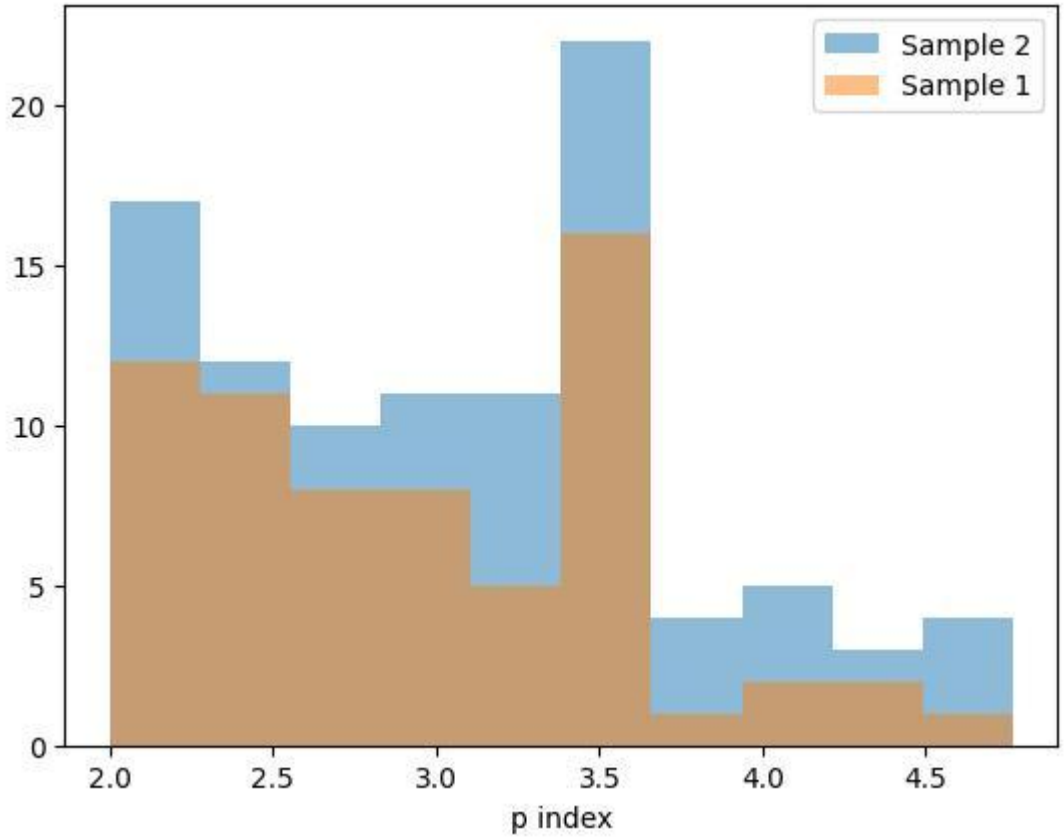


Better p-index constraints with Fermi-GBM + Fermi-LAT and LLE data, but better data at HE needed

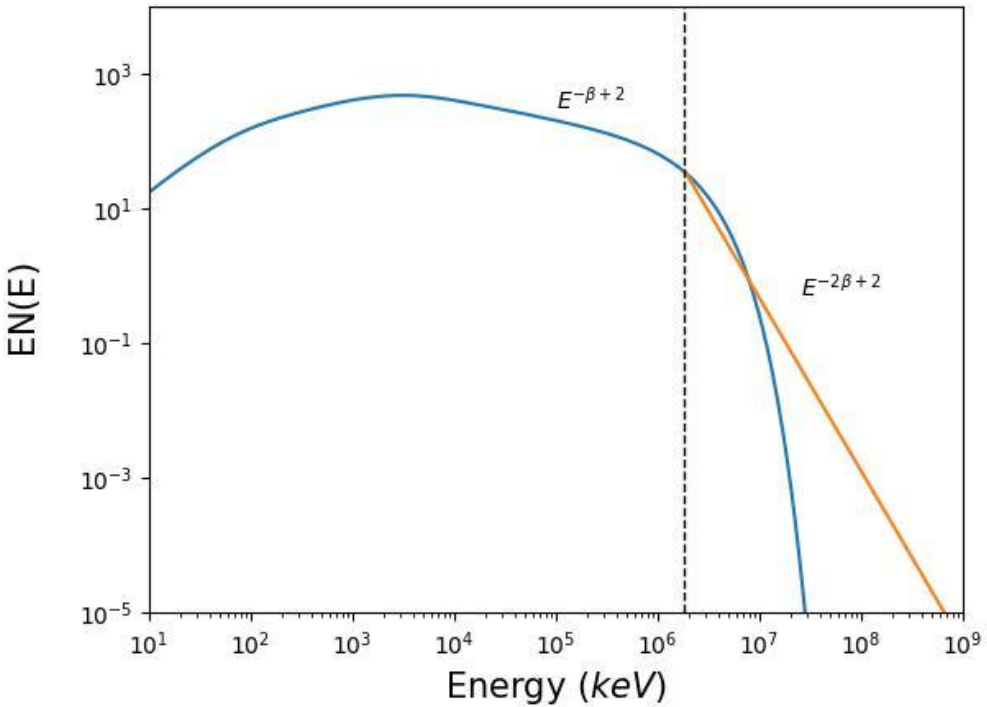
Conclusions

- Synchrotron prompt spectra are broad, covering the energy range 8 kev-10 GeV
  - A possible second component (if present) should appear at VHE
    - CTA needed to detect this component
- Second power law component is very rare
  - With Fermi-LAT data is difficult to resolve in time
    - CTA can help in understanding the nature and the physics of this component

→ CTA early observations are needed to understand better the physics of prompt emission and the nature of the early HE emission in GRBs

Backup slides

Extrapolation to VHE

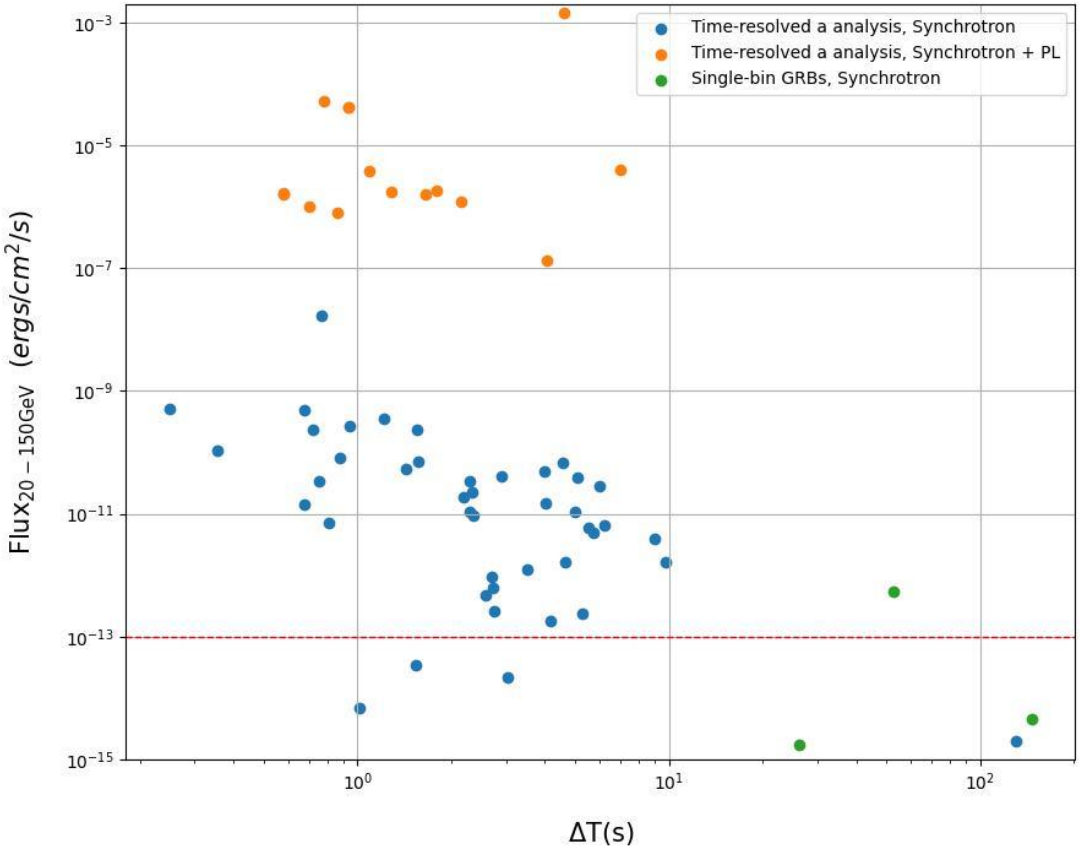


→ Above the threshold for pair production

Spectrum should evolve as $E^{-2\beta}$

- If we know the cutoff energy, we can extrapolate the flux expected at LST energies (20-150 GeV)

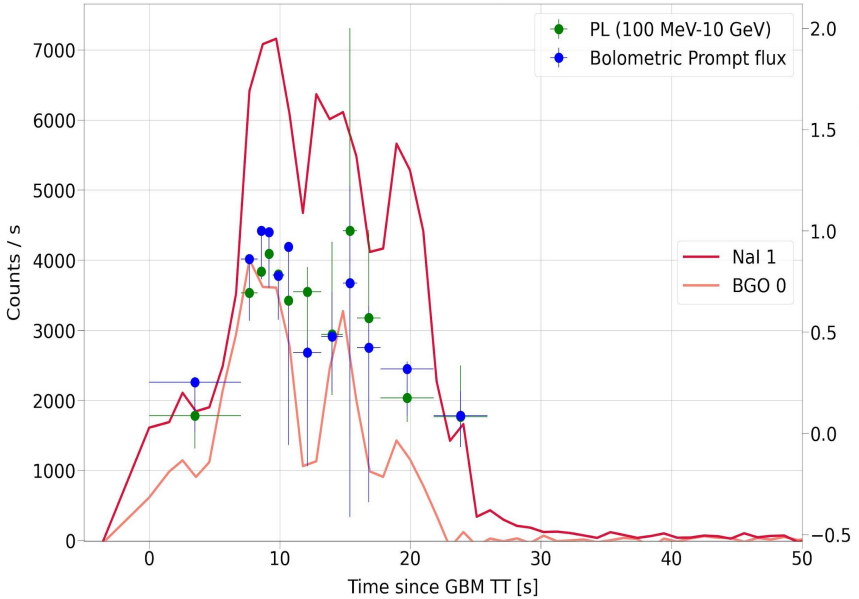
Extrapolation to VHE



- GRBs with PL should be bright in LST
- GRBs with single synchrotron component might be detected by LST

Power law flux evolution: two cases

GRB090902B



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