Understanding the spectrum of Gamma-Ray Burst 190114C

Marc Klinger, Andrew Taylor, Walter Winter, Donggeun Tak, Sylvia Zhu

27.10.2021

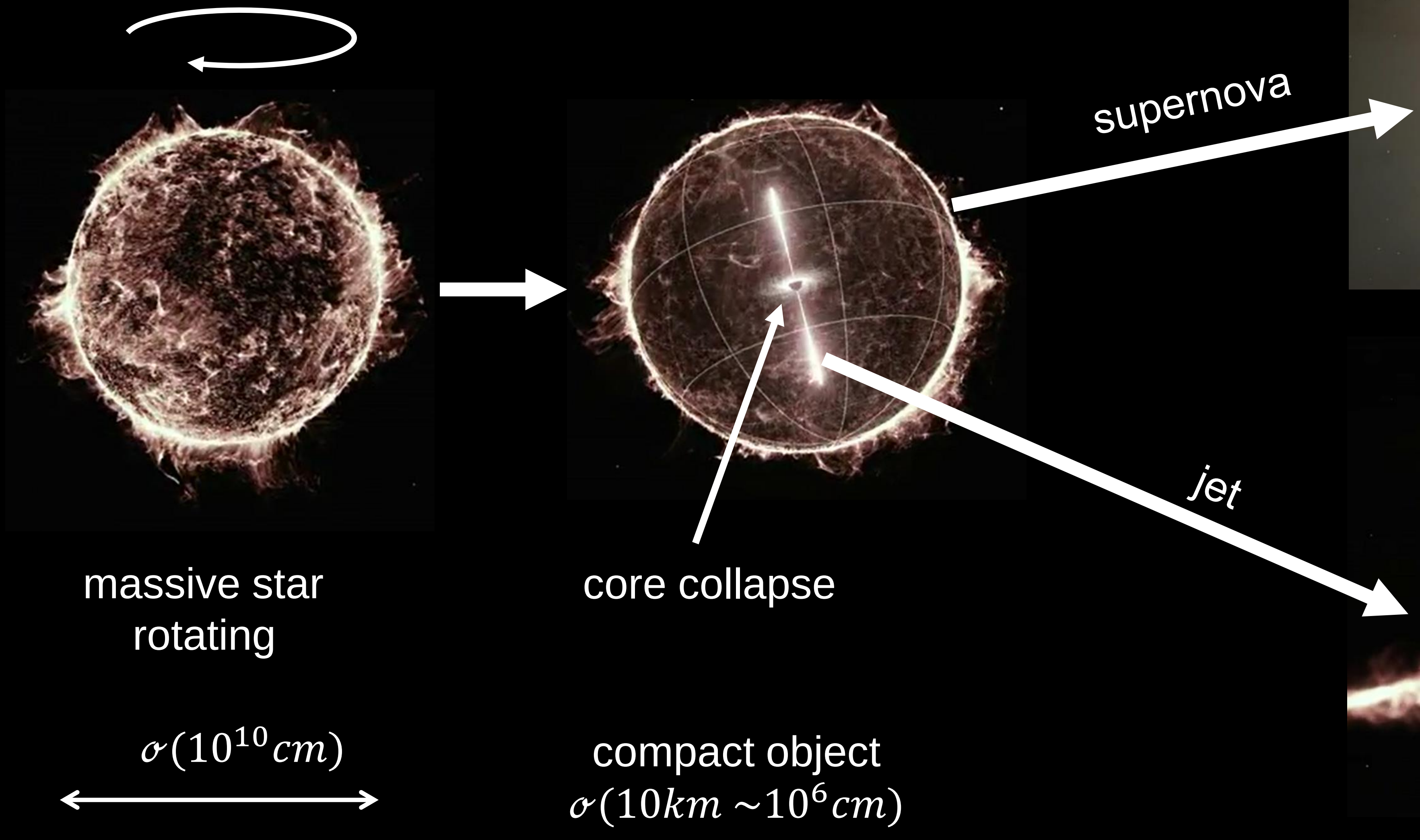
marc.klinger@desy.de

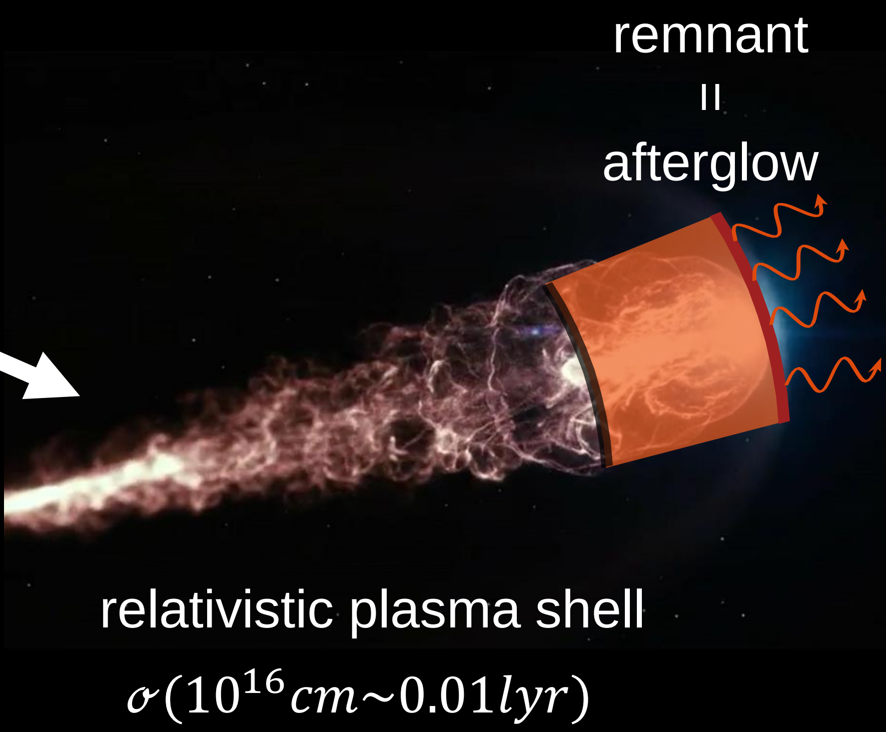
HELMHOLTZ WEIZMANN
RESEARCH SCHOOL
MULTIMESSENGER ASTRONOMY

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

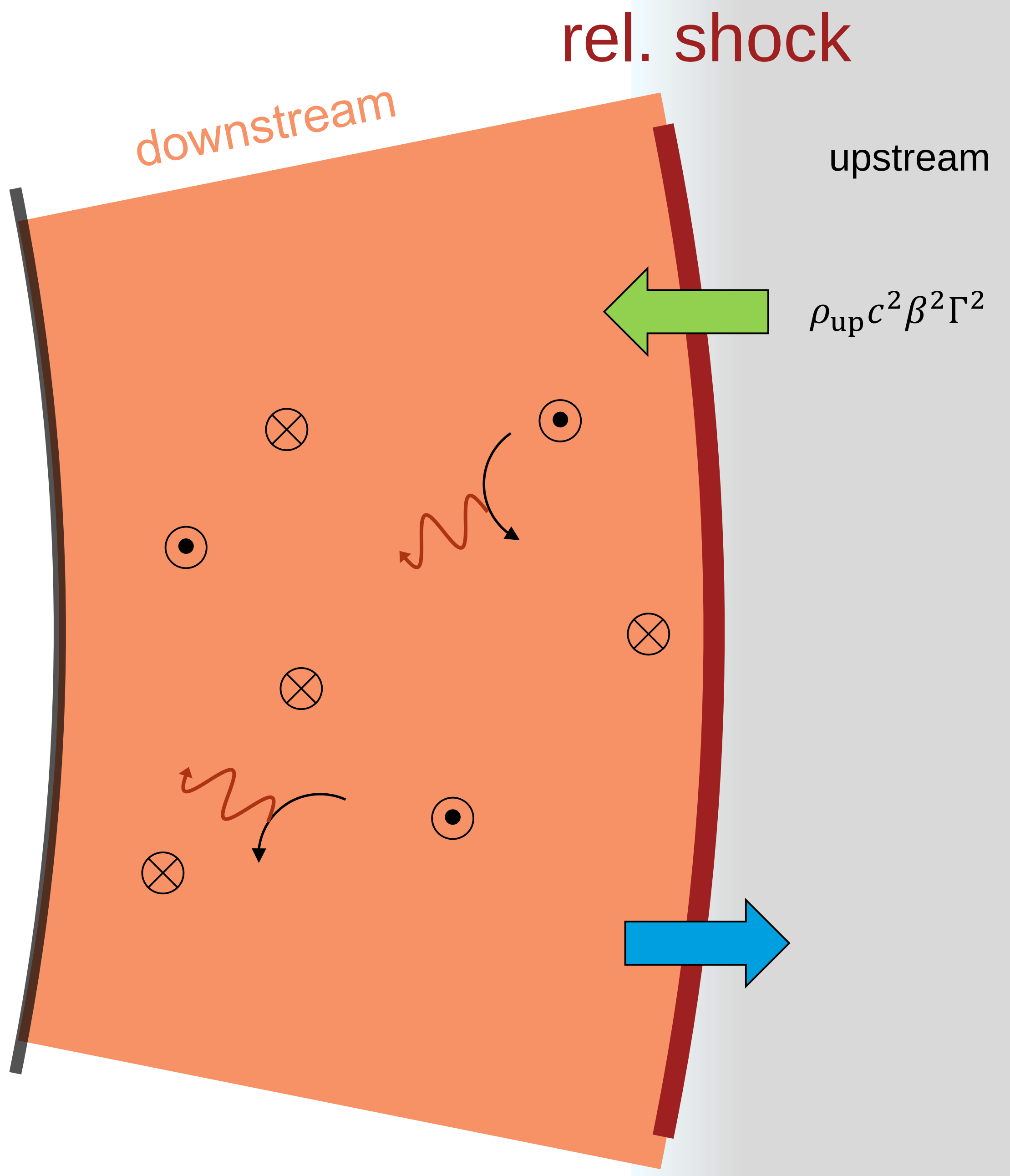
Standard model: Long GRB





Simple Box Assumption

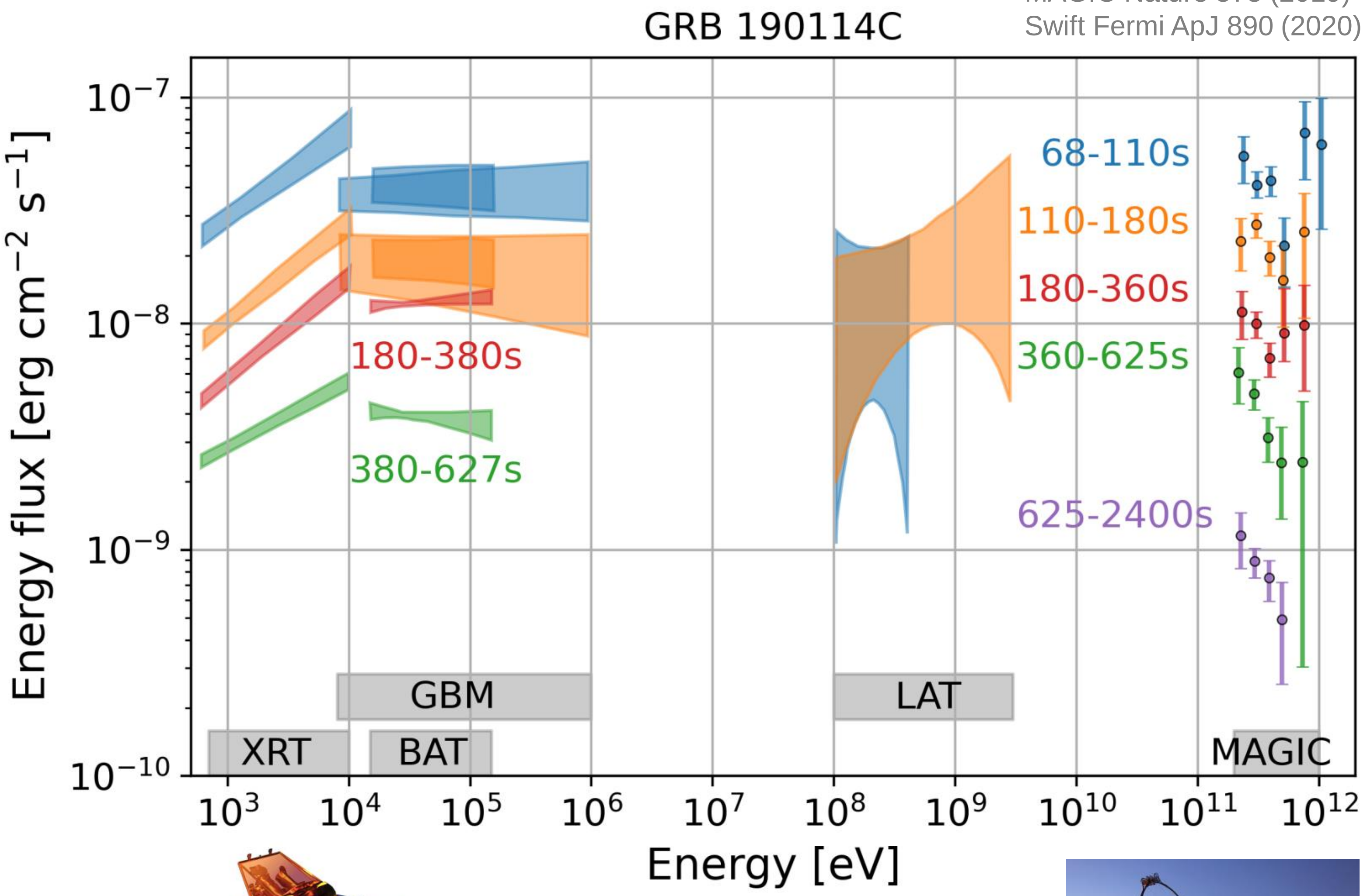
- Homogeneous shell of electrons/positrons and photons
- relativistic shock
  - → injection of non-thermal particles (ε_e, ζ_e)
  - → turbulent magnetic fields (ε_B)
- particles cool
- photons escape



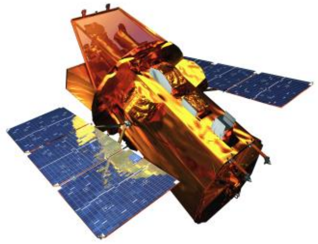
see e.g. Piran 2005 for a detailed review

GRB 190114C - Afterglow

MAGIC Nature 575 (2019)
Swift Fermi ApJ 890 (2020)



- triggered:
  - → Swift satellite (**BAT**, XRT)
  - → Fermi satellite (**GBM**, LAT)
- rapid follow up by MAGIC
  - → **VHE afterglow** observed up to 40 minutes
- intermediate redshift $z = 0.42$


NASA


NASA


MAGIC Coll.

Characteristic values of blast wave parameters

- energy conservation:

  $\rightarrow E_{iso} = \Gamma^2(t_{obs})\, M_{sw}(t_{obs})\, c^2$

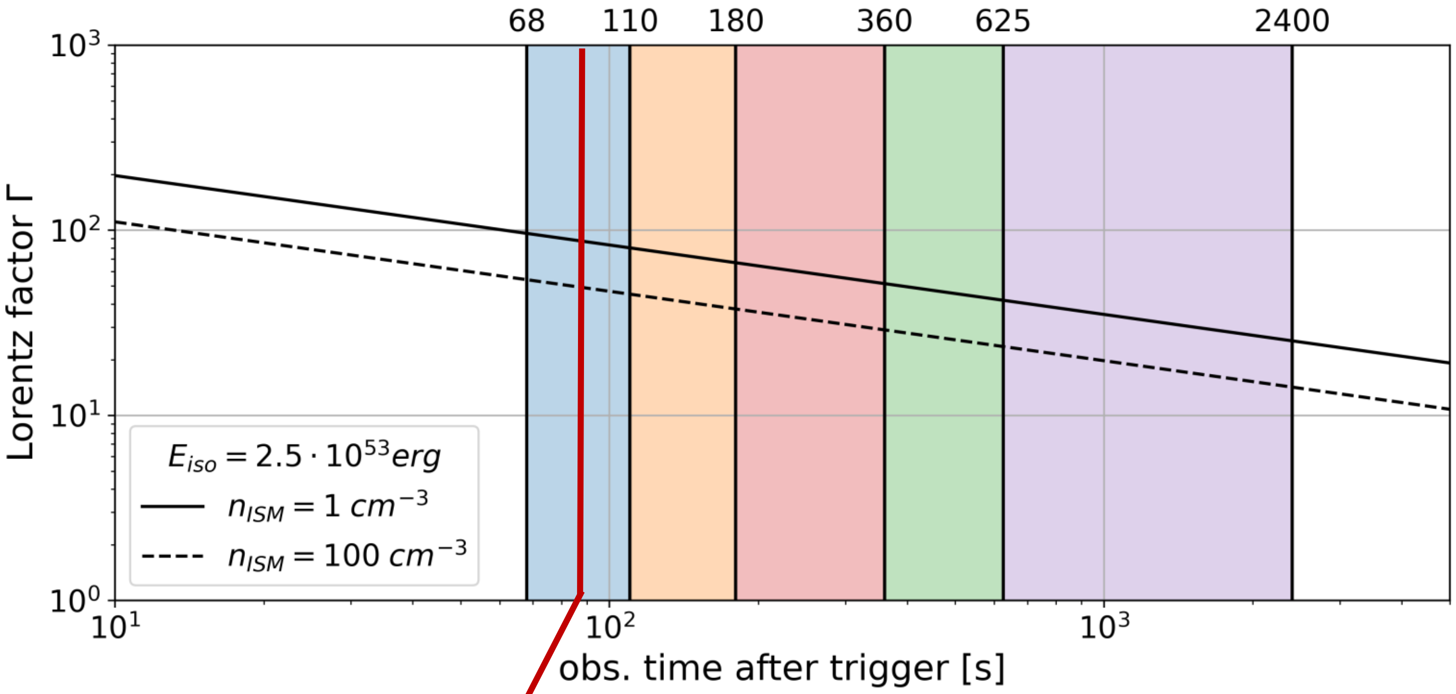
  $\rightarrow \Gamma(t_{obs} = 86s, n_{ISM} = 1cm^{-3}) = 90$

- ram pressure (SRF):

  $\rightarrow p_{ram} = m_p c^2 n_{up} \beta^2 \Gamma^2$

- magnetic field?

  $\rightarrow \frac{B^2}{8\pi} = \varepsilon_B\, p_{ram}$



$\rightarrow \varepsilon_B \sim 10^{-4} \rightarrow B(t_{obs} = 86s, n_{ISM} = 1cm^{-3}) \sim 0.1G$

$\rightarrow \varepsilon_B \sim 10^{-2} \rightarrow B(t_{obs} = 86s, n_{ISM} = 1cm^{-3}) \sim 1G$

Electron spectrum

- smoothly broken power law, slow cooling:

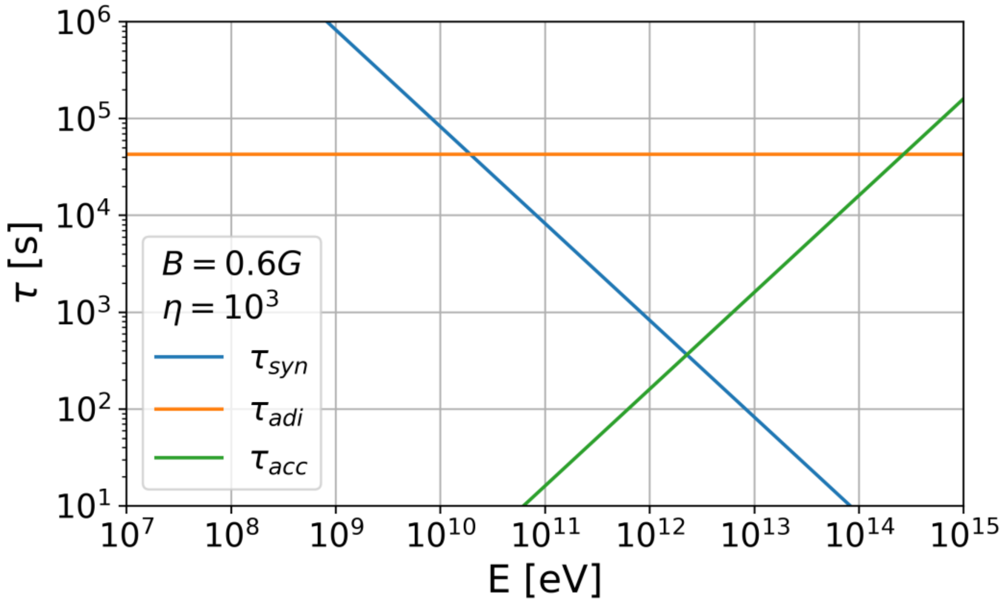
$$\rightarrow \frac{\mathrm{d}N}{\mathrm{d}E} \propto \left(\frac{E}{E_0}\right)^{-p} \left[1 + \left(\frac{E}{E_\mathrm{b}}\right)^{s}\right]^{-\frac{1}{s}} e^{-\frac{E}{E_\mathrm{max}} - \left(\frac{E_\mathrm{min}}{E}\right)^{\chi_\mathrm{on}}}$$

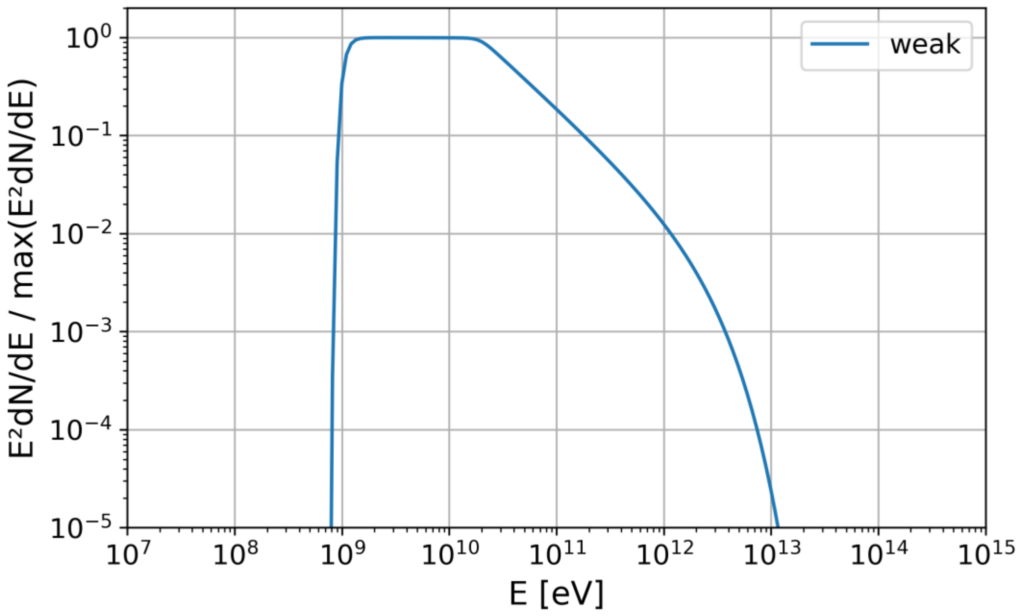
- $E_\mathrm{b} = \frac{9}{8\pi}\frac{h}{\alpha}\left(\frac{B_\mathrm{c}}{B}\right)^2 \frac{1}{\tau_\mathrm{adi}}$

  → weak accelerating magnetic field required to fit synchrotron break

- $E_\mathrm{max} = \left(\frac{9}{4}\frac{1}{\alpha}\frac{1}{\eta}\frac{B_\mathrm{c}}{B}\right)^{1/2} m_\mathrm{e}c^2 \sim 1\mathrm{TeV}$

acceleration efficiency



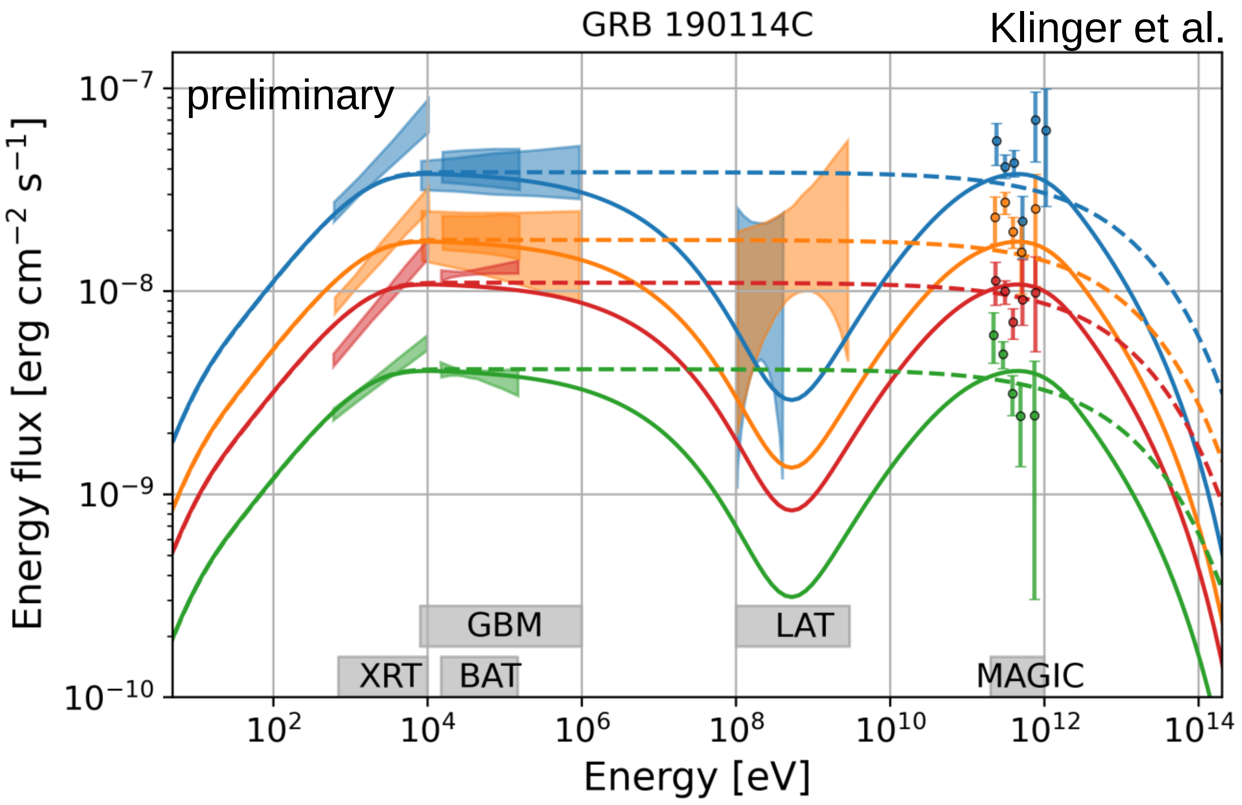


Photon spectrum: 2 types of solutions

→ synchrotron self-Compton spectrum

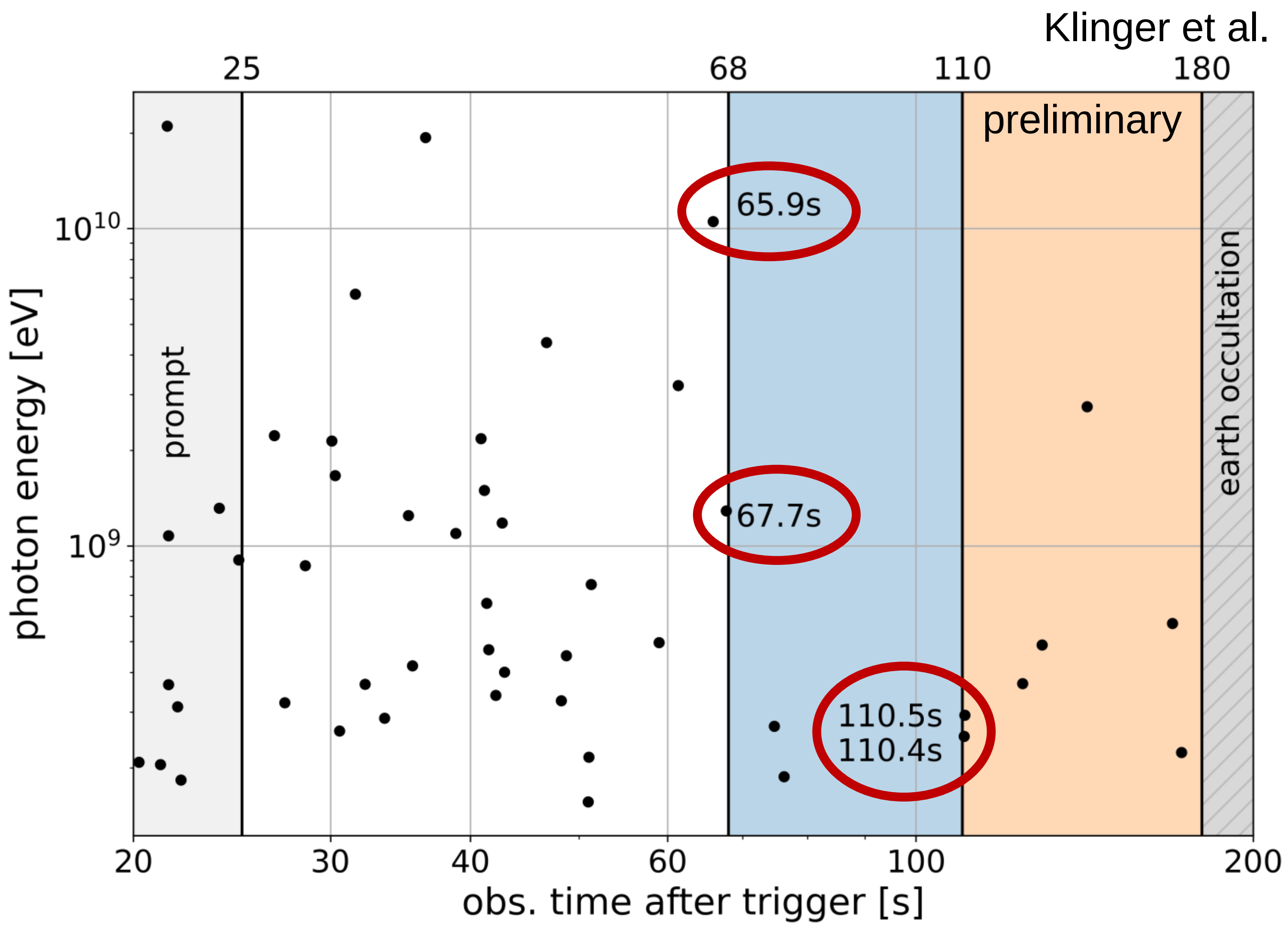
1. double hump solution:
   - → predicts dip: does this dip exist?
   - → is $\eta = 1000$ plausible?
   - → naturalness of similar heights?
2. single hump solution (syn. only)
   - → predicts no dip
   - → syn. burn off limit requires 2 field strengths, is this plausible?

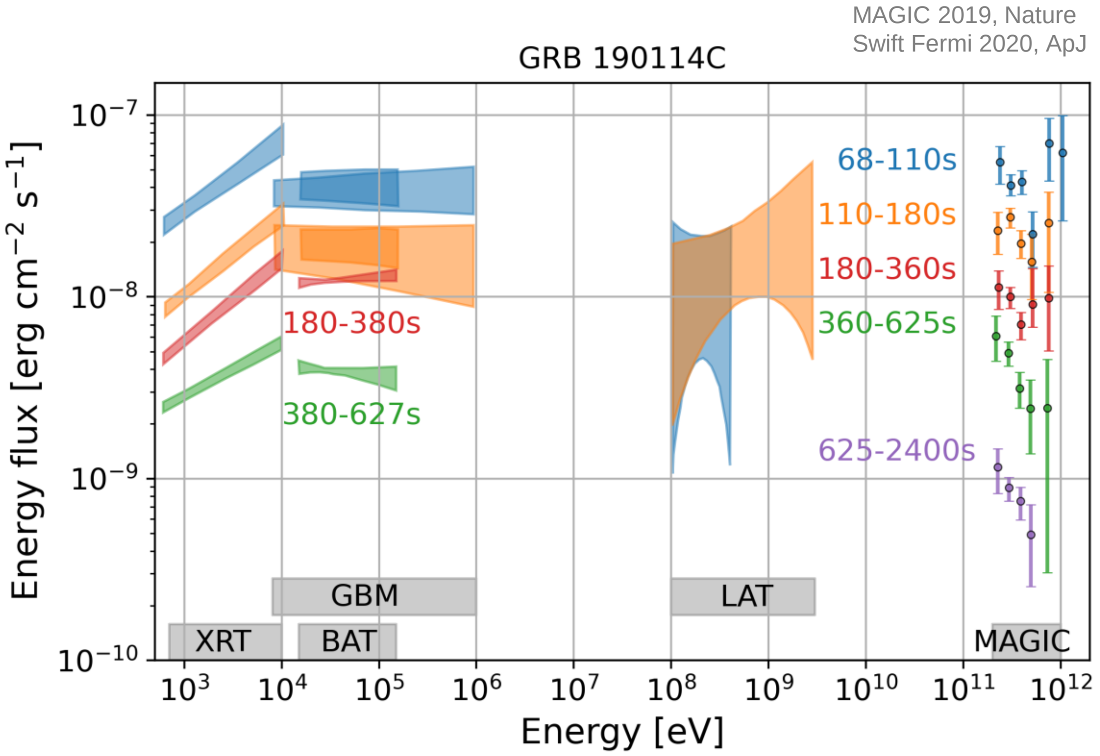
see also GRB 190829A



→ LAT data crucial to distinguish! Are statistics good enough?

LAT photons – peculiar binning?

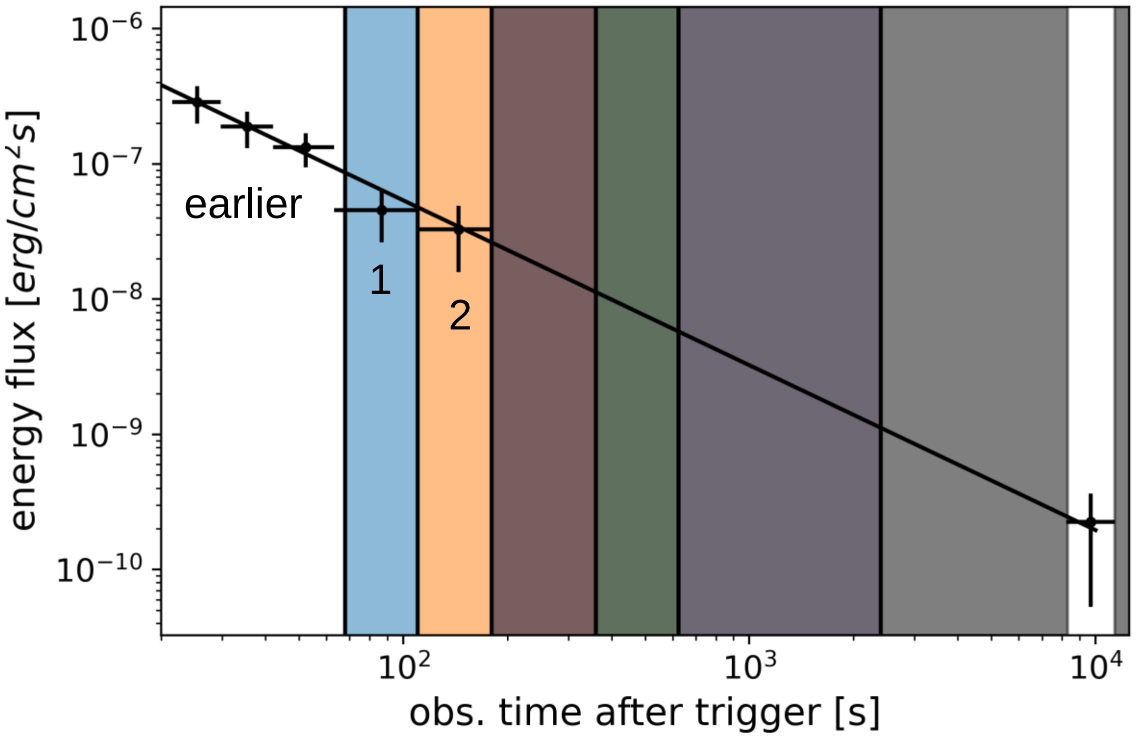




→ unlucky temporal binning?

How many LAT photons do we expect?

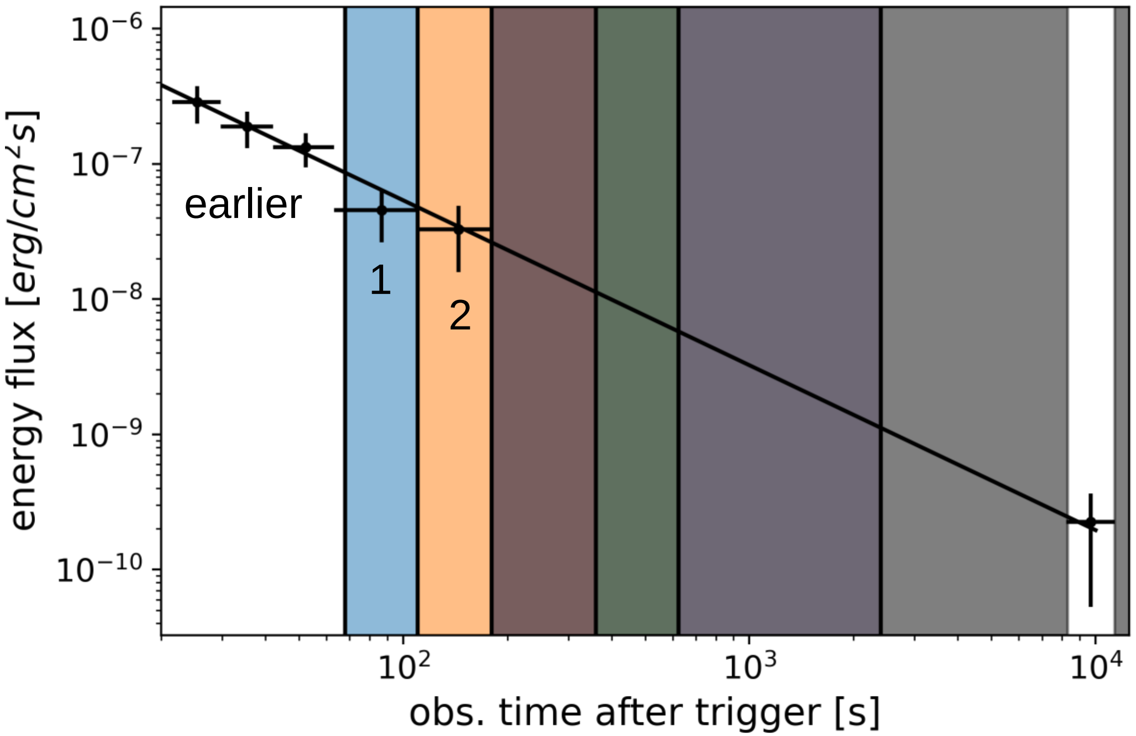
Swift Fermi ApJ 890 (2020)



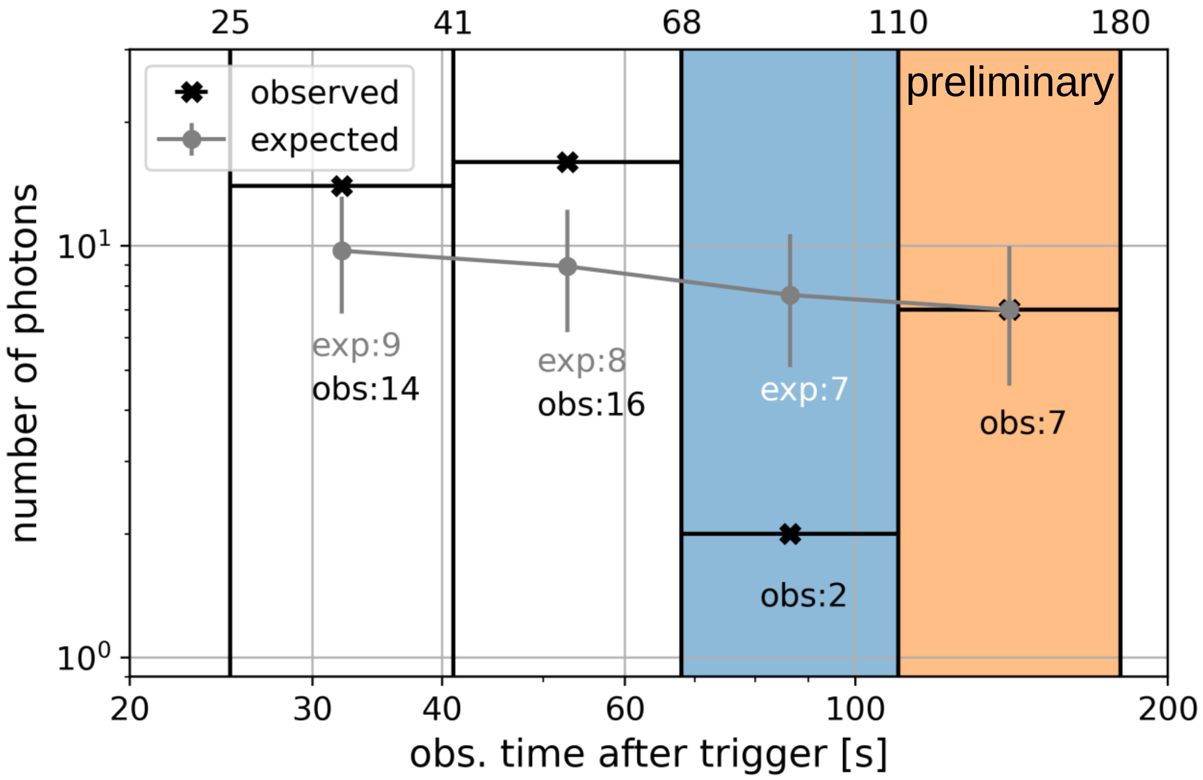
→ LAT data follows a power law with index $\alpha = -1.22$

How many LAT photons do we expect?

Swift Fermi ApJ 890 (2020)



Klinger et al.



→ LAT data follows a power law with index $\alpha = -1.22$

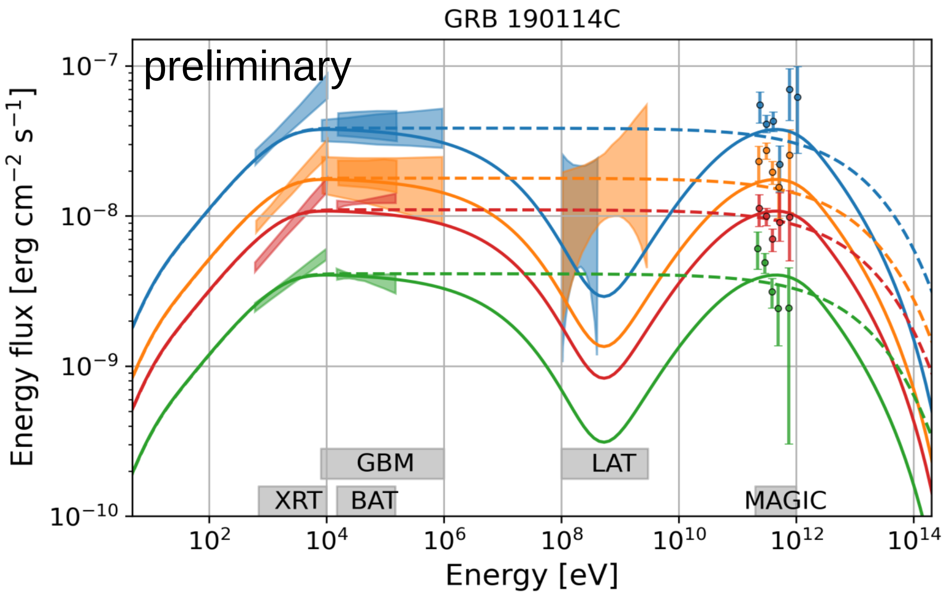
→ underfluctuation !

Conclusions

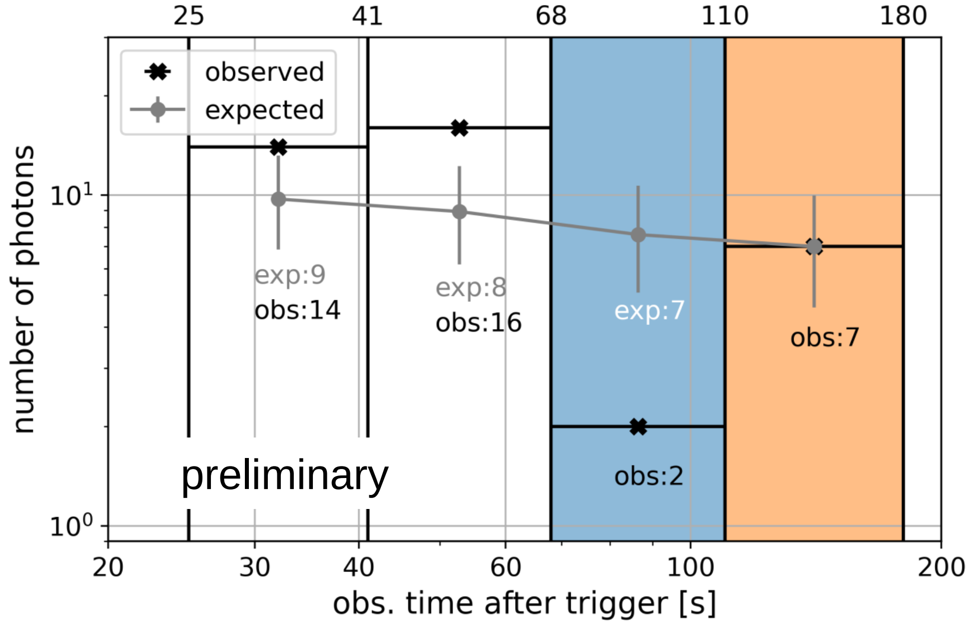
- 2 types of solutions

  → LAT data crucial to distinguish

  → statistics will decide



- large underfluctuation of LAT data in first time bin of MAGIC analysis



Thank you for your attention!

marc.klinger@desy.de