Exploring Gamma-Ray Burst at Very High Energy : Insights from 15 Years of H.E.S.S. Observations

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for the H.E.S.S. collaboration

The long quest for the dectection of GRBs at VHE

- **During more than 20 years, numerous attempt to detect GRBs at VHE have been performed**
  - Hint of signal for GRB 970417A in Milagrito *(Atkins et al. 2000)*
  - 95 GeV photon detected by Fermi/LAT from GRB 130427A *(Ackermann et al. 2013)*

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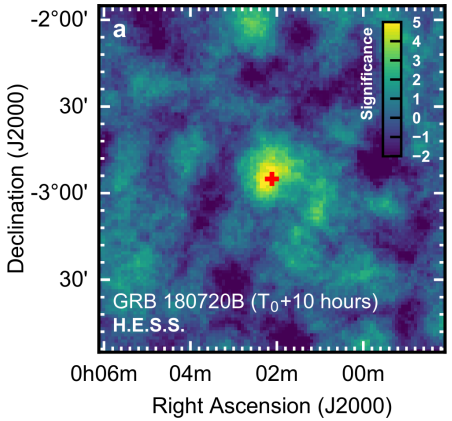
- **First detection** at VHE achieved in **2018 by H.E.S.S. with GRB 180720B** (*Abdalla et al. 2019)*
  - Quickly followed by detections by H.E.S.S. and MAGIC of GRB 190114C, GRB 190829A and GRB 201216C
    (MAGIC Collaboration 2019, H.E.S.S. Collaboration 2021, MAGIC Collaboration 2021)
  - More recently, detection by LHASSO of the BOAT, GRB 221009A
    (LHASSO Collaboration 2023)



Abdalla et al. (2019)

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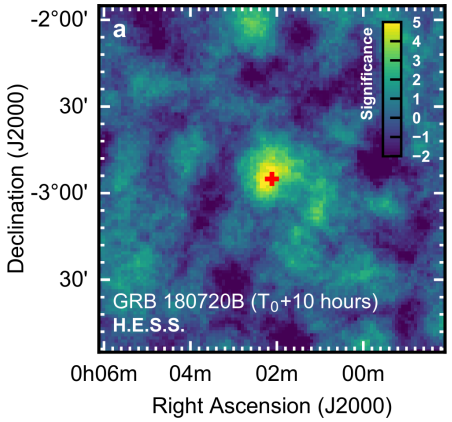

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Why so many detections in the recent years and none before ?

H.E.S.S. GRB program

- **H.E.S.S is performing follow-up observations of GRBs since the start of the operation in 2004**
  - Trigger conditions for follow-up has evolved across time
  - **Follow-up of alerts from various instrument :**
    - HETE 2
    - Swift/BAT
    - Fermi/GBM
    - Fermi/LAT
    - INTEGRAL
    - ….

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- Construction in 2012 of CT5,
  the central 28m telescope,
  allowing for a much lower energy threshold

Analysis of archival data

- **Cross-match GRBs catalogue and H.E.S.S. observation database**
  - Considering data taken between January 2004 and October 2019
  - Standard H.E.S.S. GRB quality check
    - Each single run is verified manually
    - Unblinding of the data only after data quality

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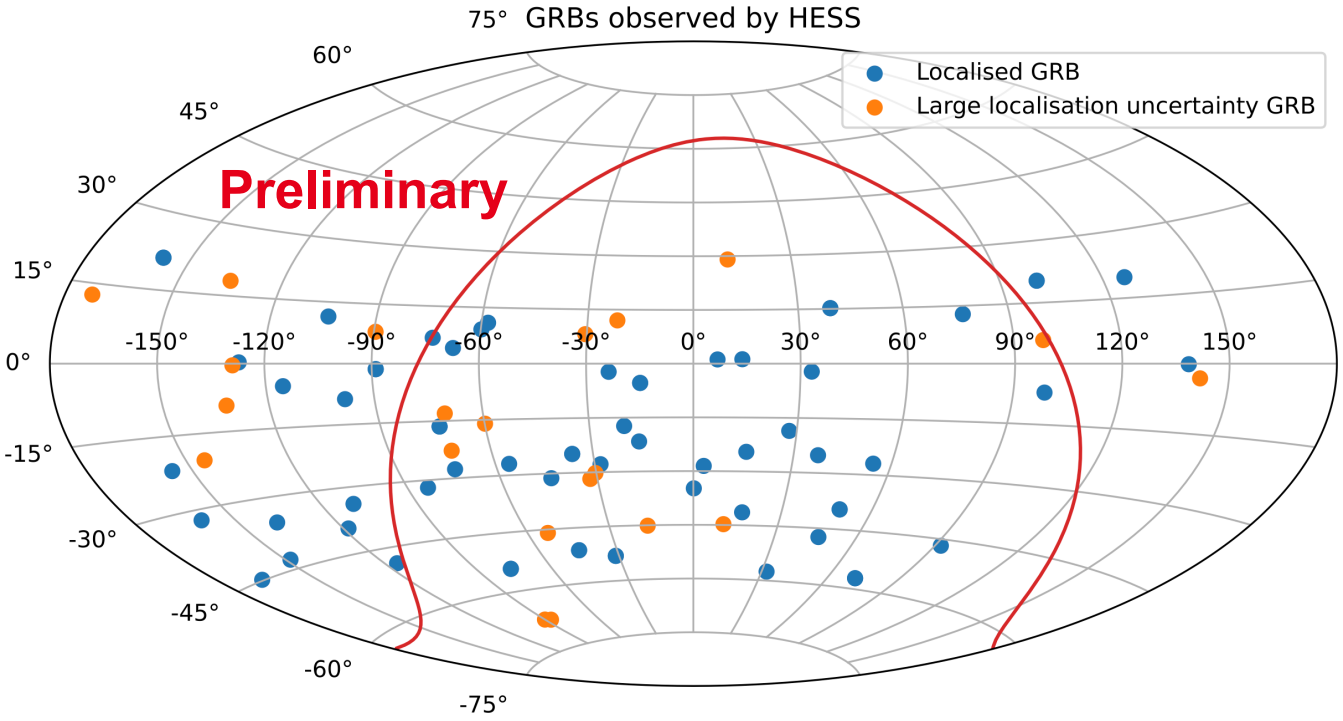
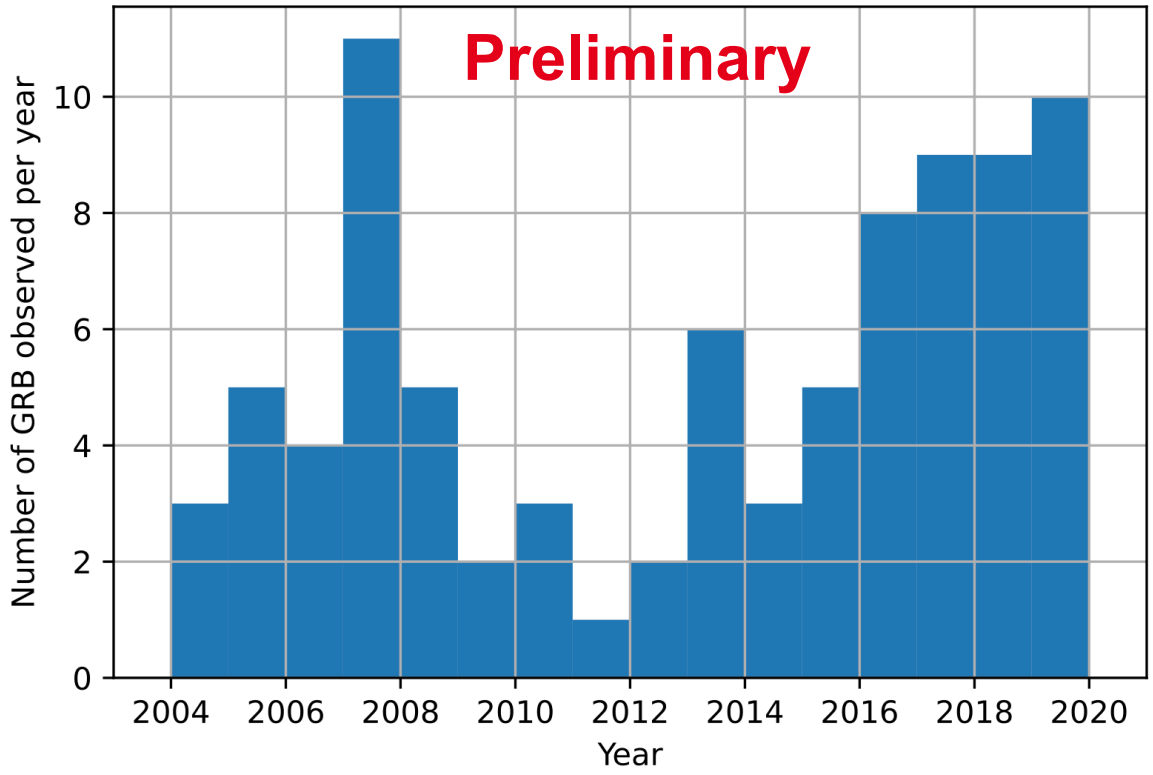
- **Analysis of observations of 63 GRBs**
- Separated in two groups :
  - GRB with poor localisations (mainly Fermi/GBM), **10 GRBs, 19.0 h of observations**
  - GRB with precise localisations, **53 GRBs, 81.3 h of observation**

A large number of observed GRBs



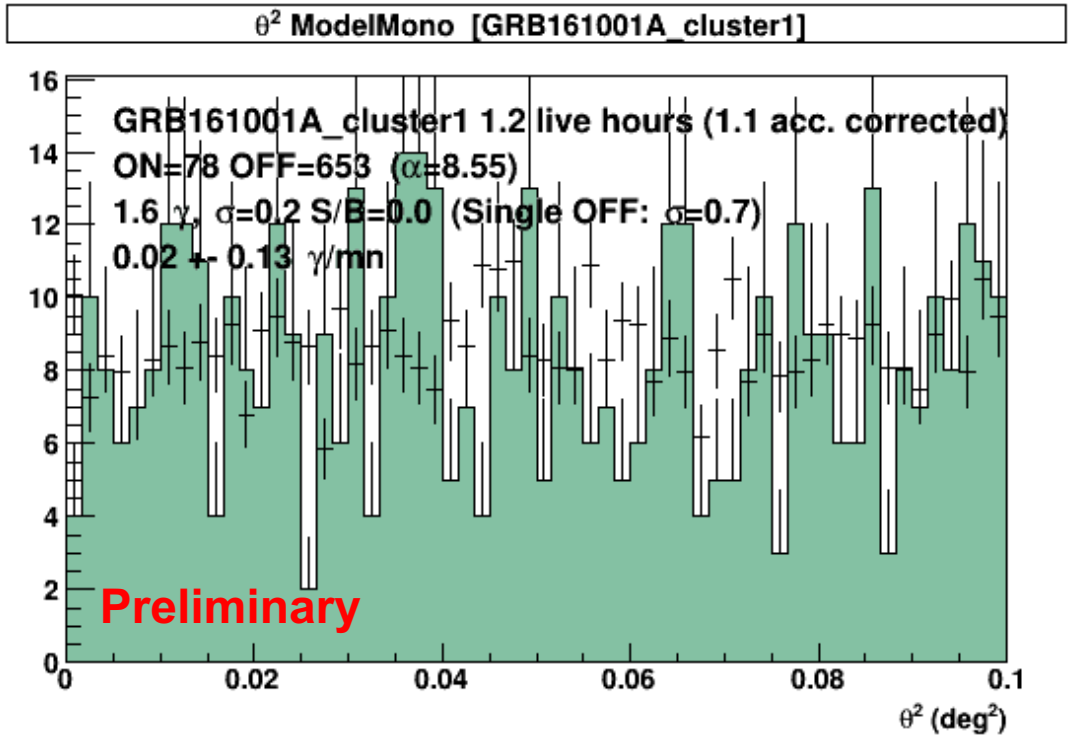


Analysis of each GRB

- **An individual analysis is performed for each GRB**

  GRBs without precise localisation :

  Theta2 and integral upper limit



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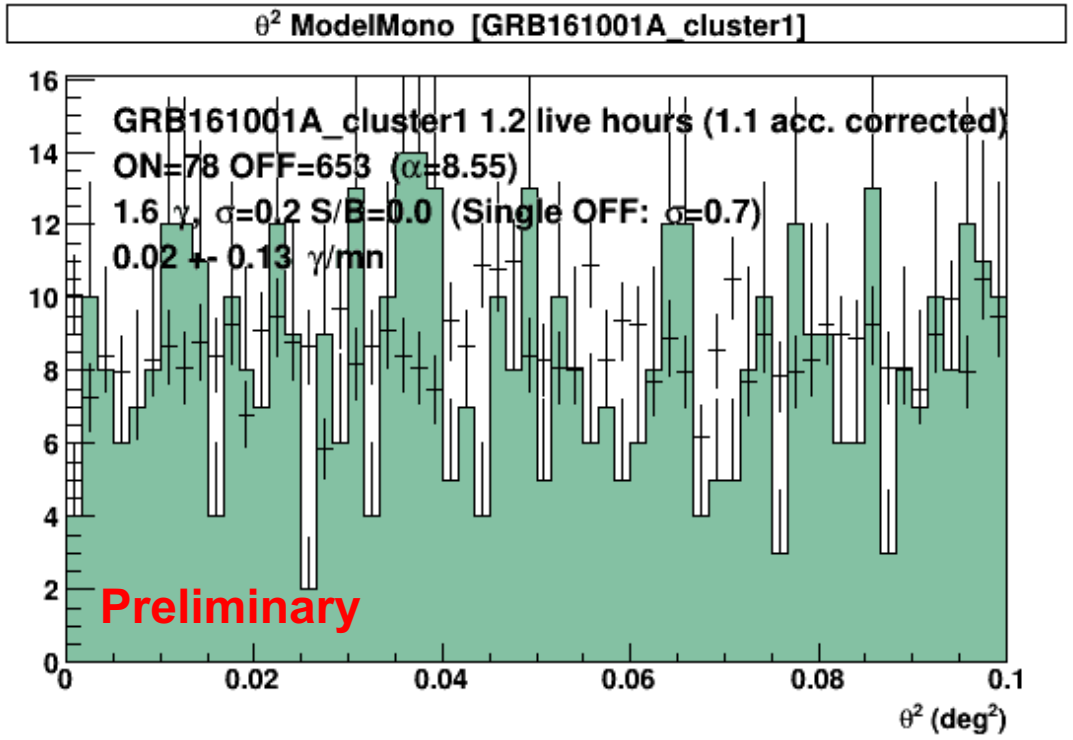
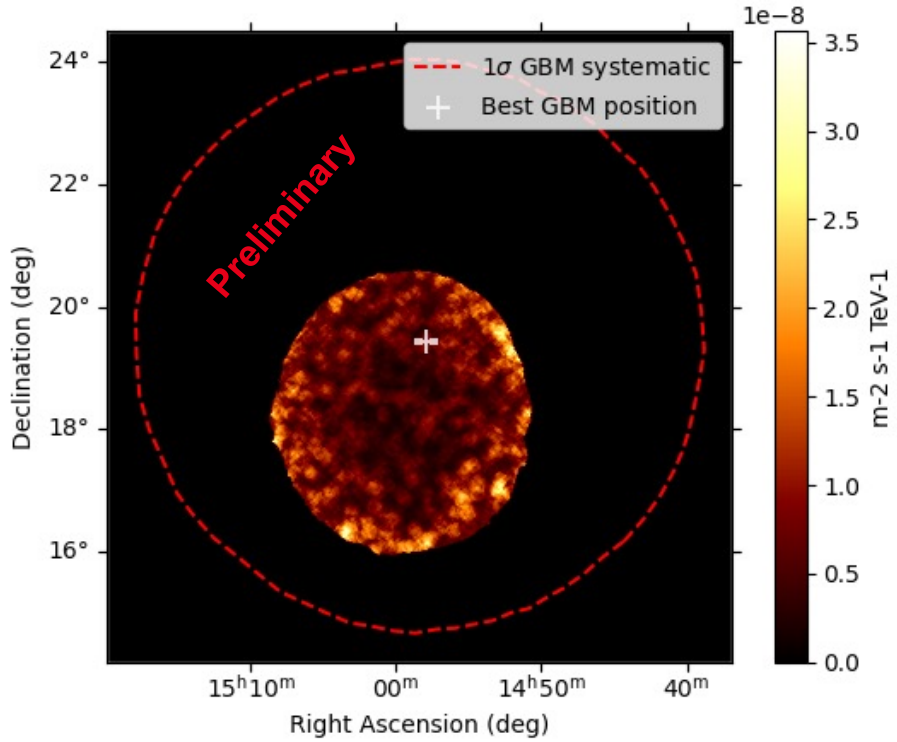
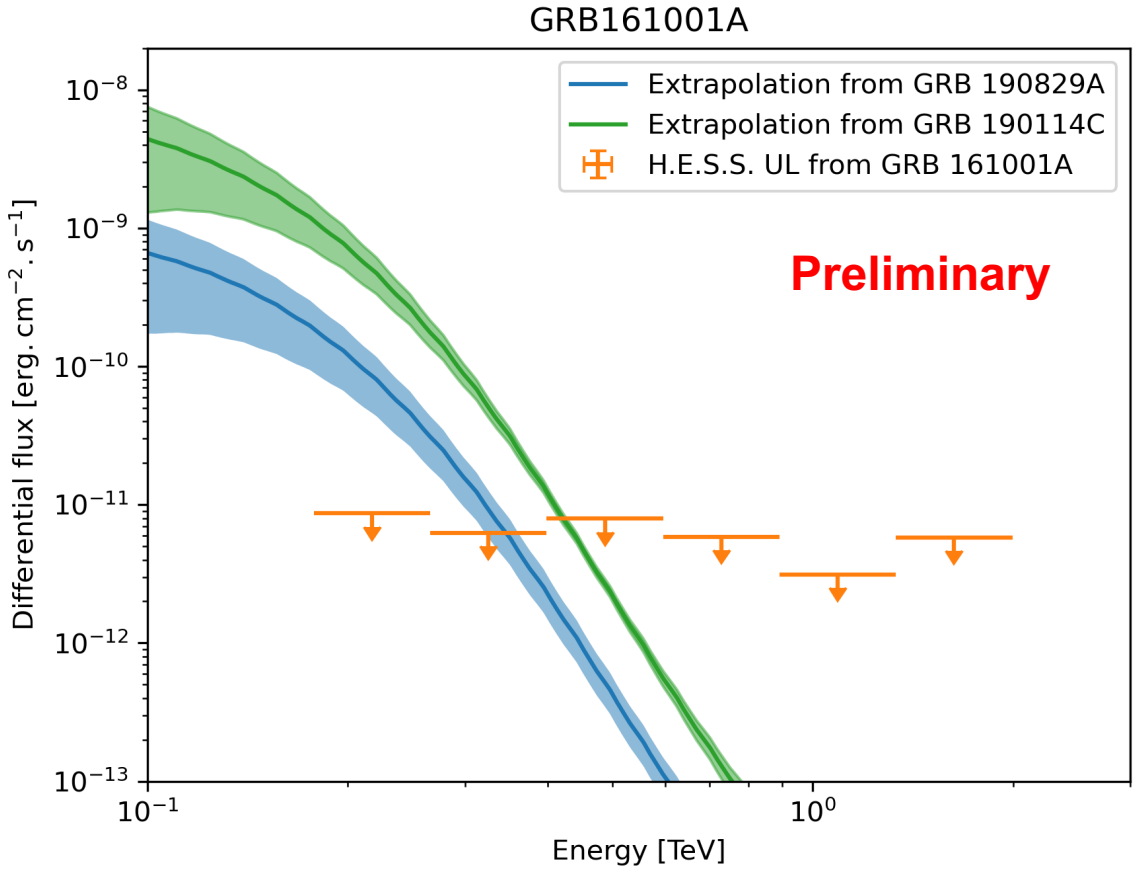


GRBs without precise localisation :
significance map and integral upper limit map

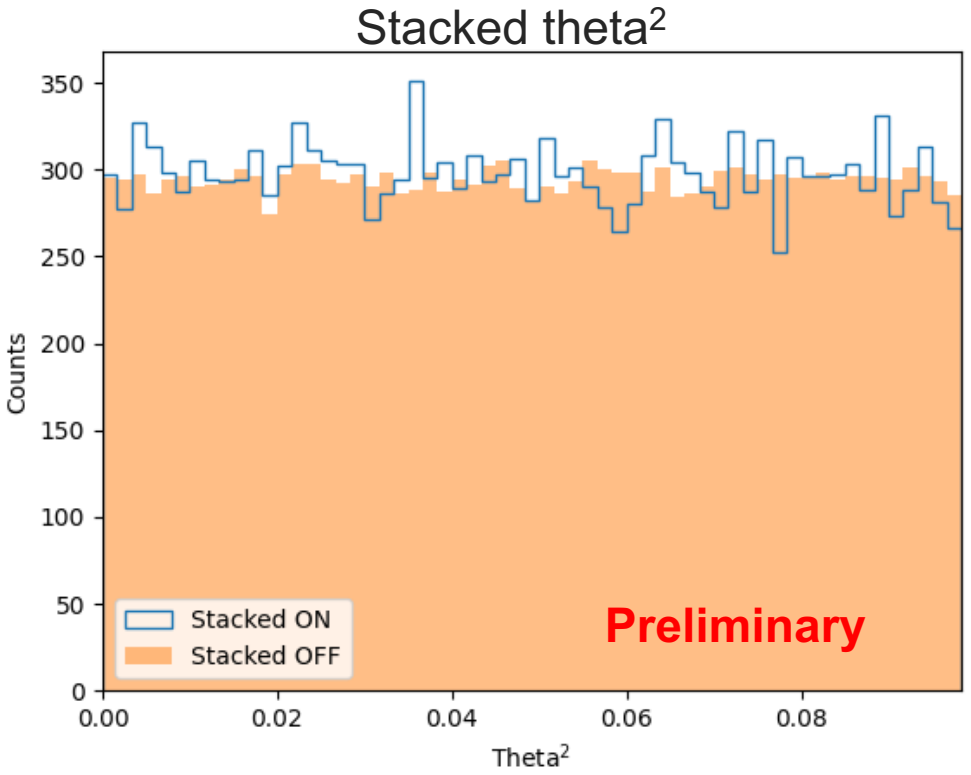


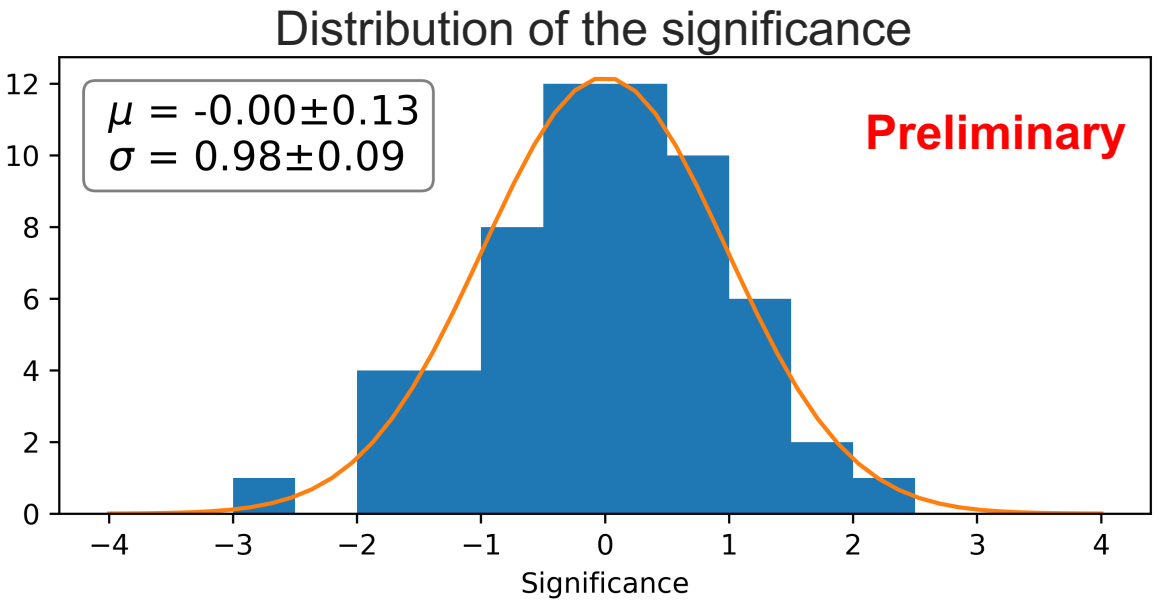
Possible to reject emission as bright as VHE detected GRBs

- **Extrapolation of the spectra of GRB 190829A and GRB 190114C to observation of GRB 161001A**
  - Correction for difference of EBL absorption due difference of redshift
  - Correction for difference of delay and observation window



Analysis results of all localized GRBs

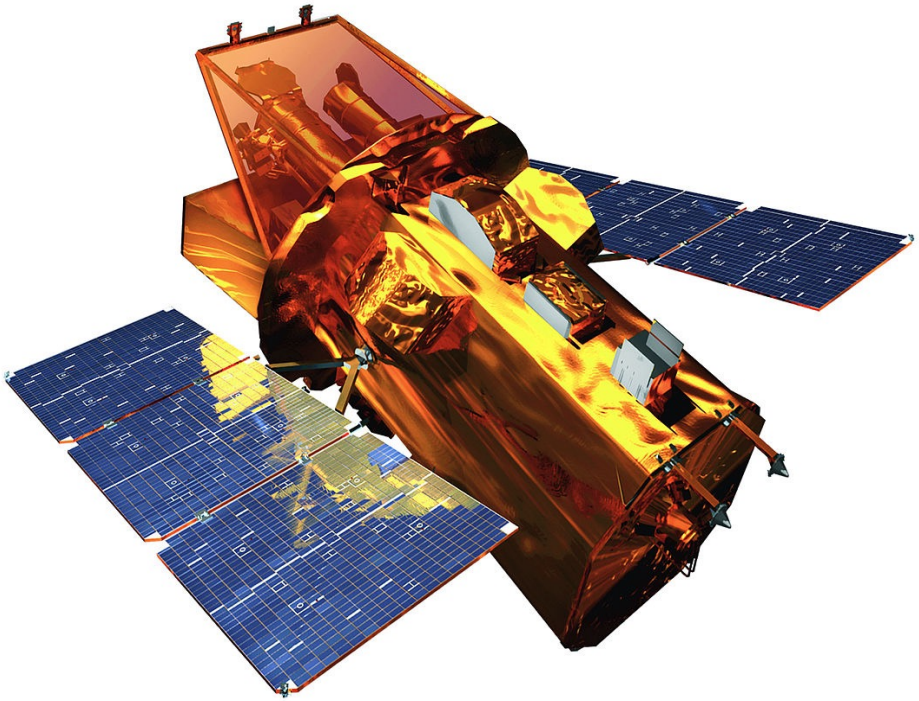




No hint of signal

Population studies : Swift/BAT and XRT GRBs

- **Most GRBs detected by Swift/BAT and Swift XRT**
  - Large sample of GRBs, **properties of the prompt and afterglow phase**



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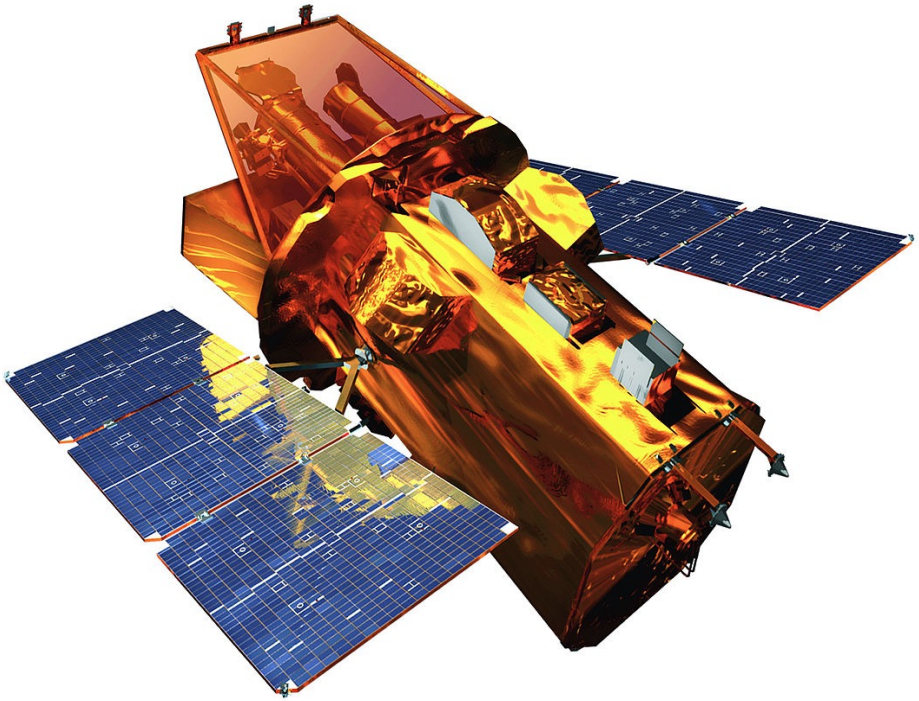

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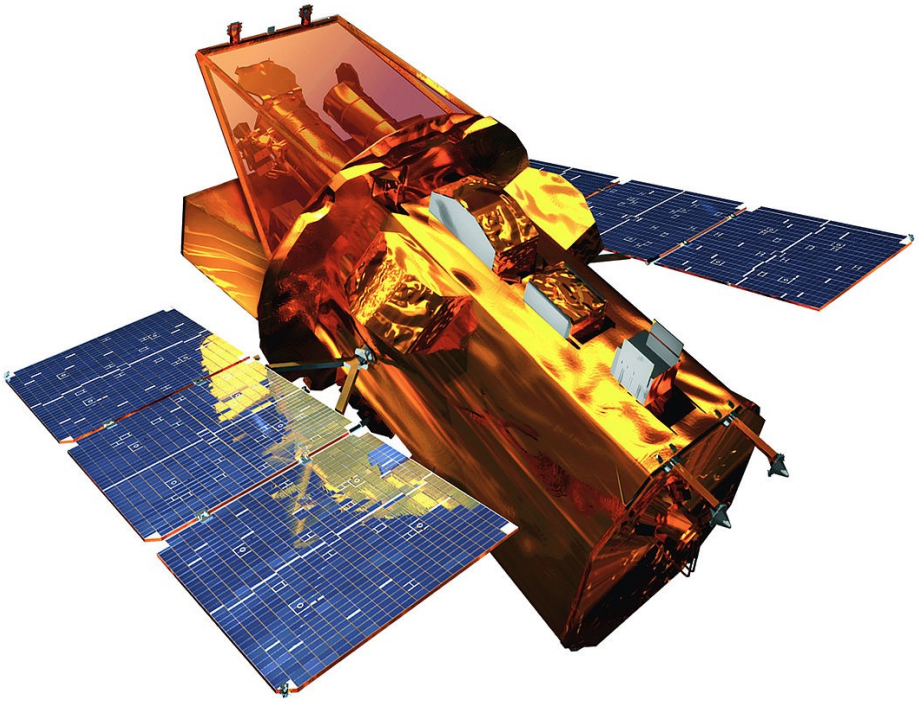

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    - Comparing properties of our sample to all Swift/BAT GRBs
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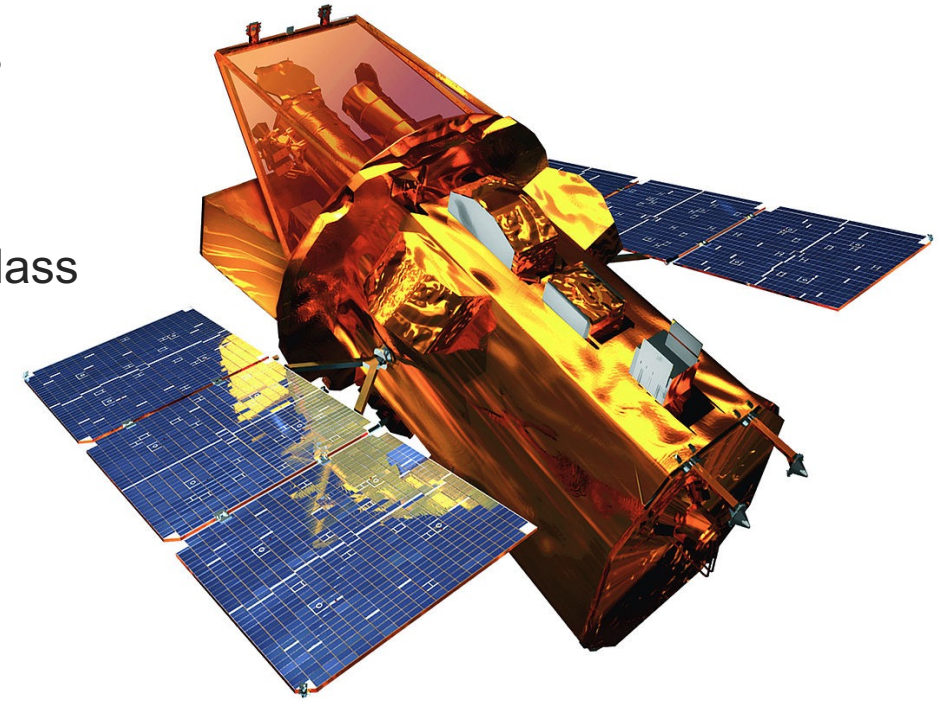
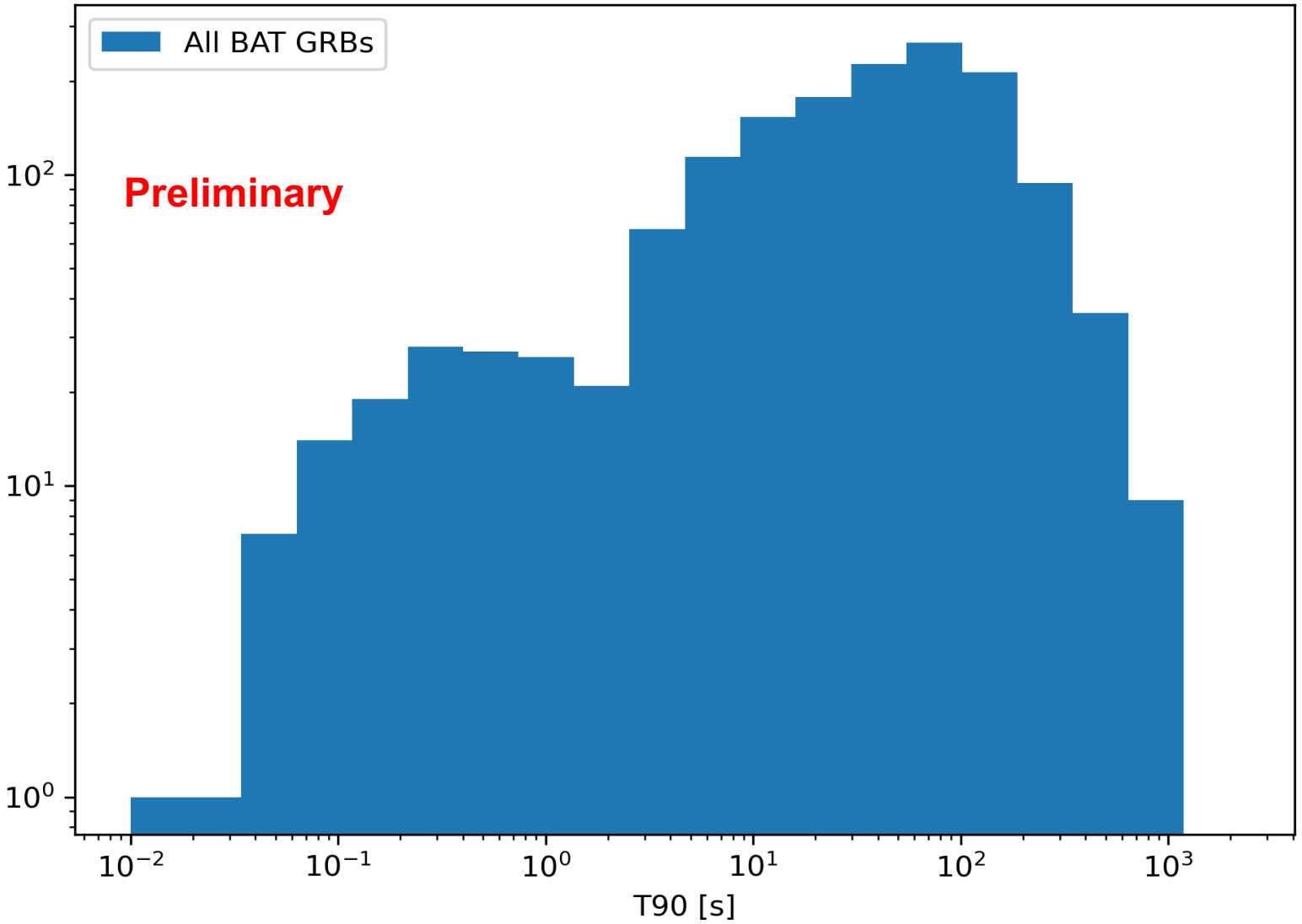
    - GRB 190829A is a candidate for the low luminosity GRB class
      - Will look at comparison with and without GRB 190829A



Prompt : T90 distributions



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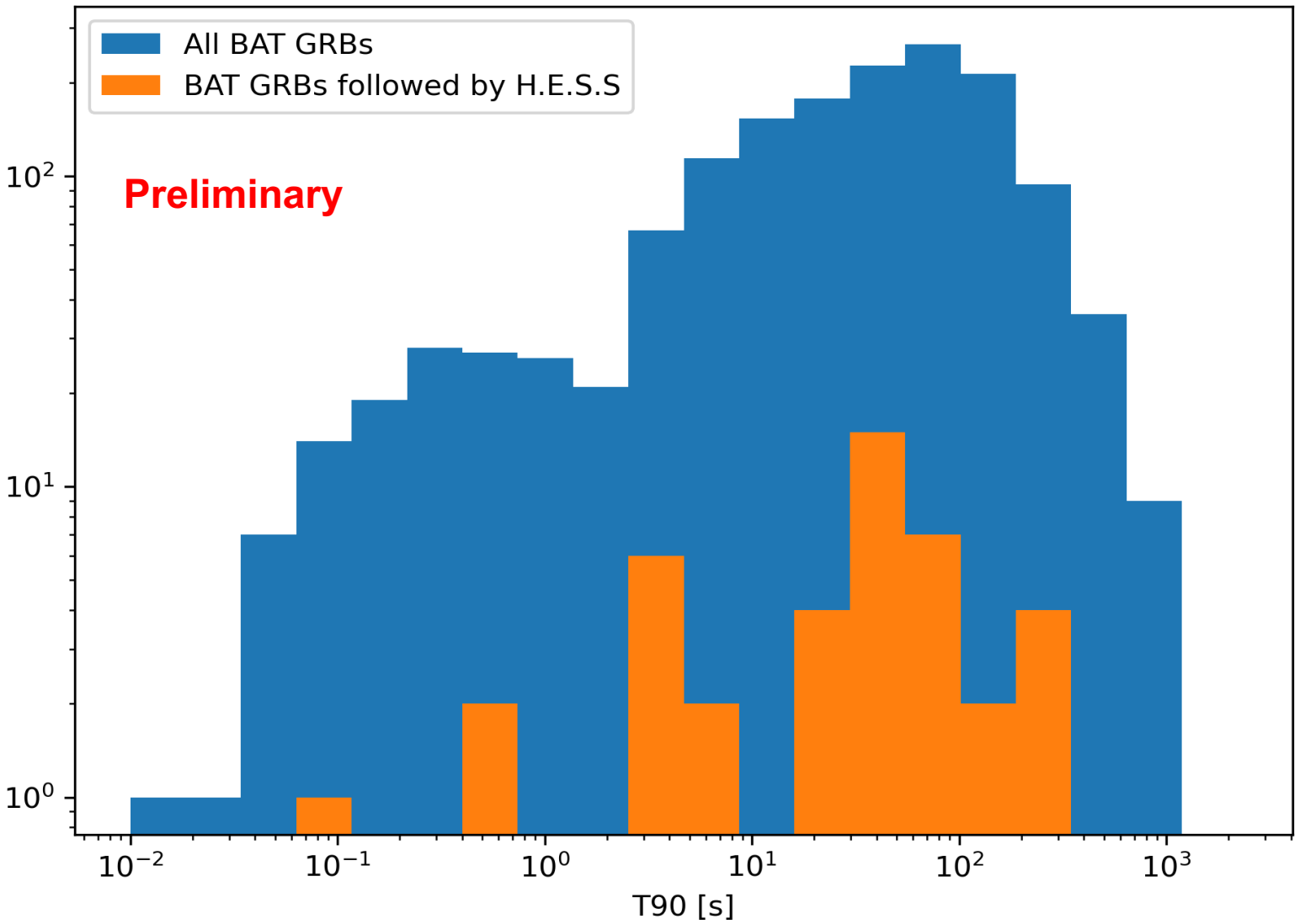

Distributions are compatible (Deviation at 1.4 σ)

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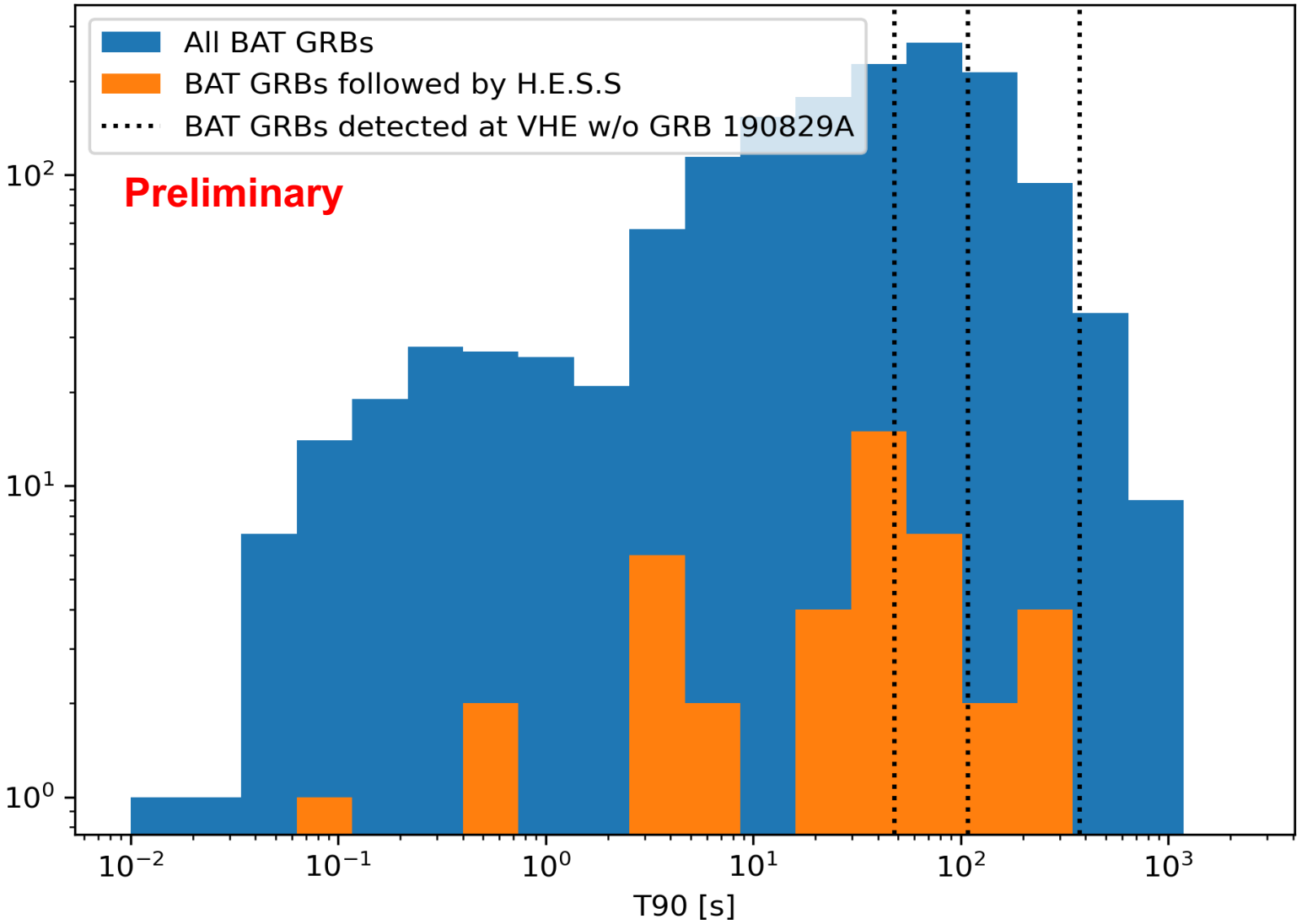

Only detected long GRBs
Statistical significance 2.1 σ

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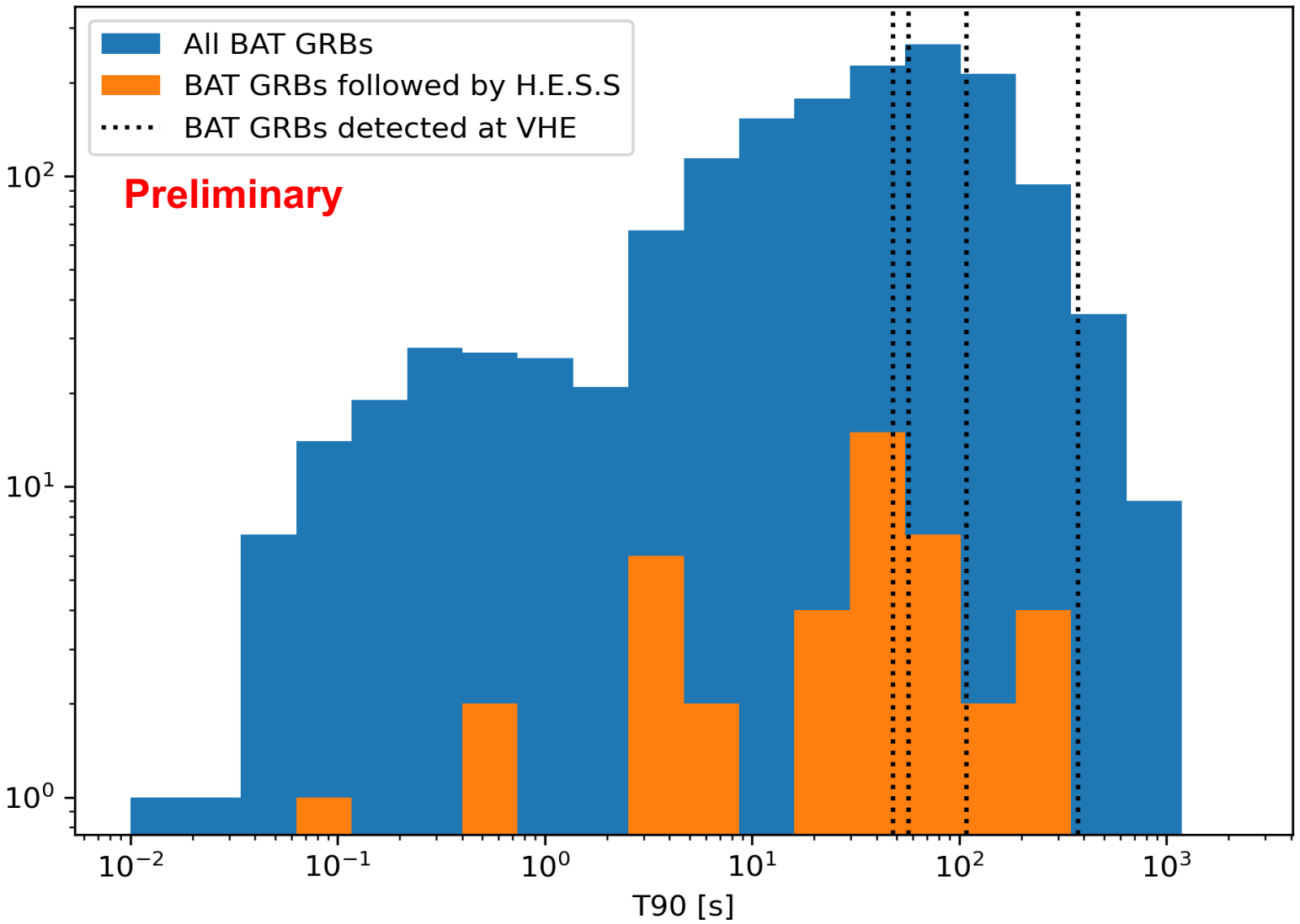

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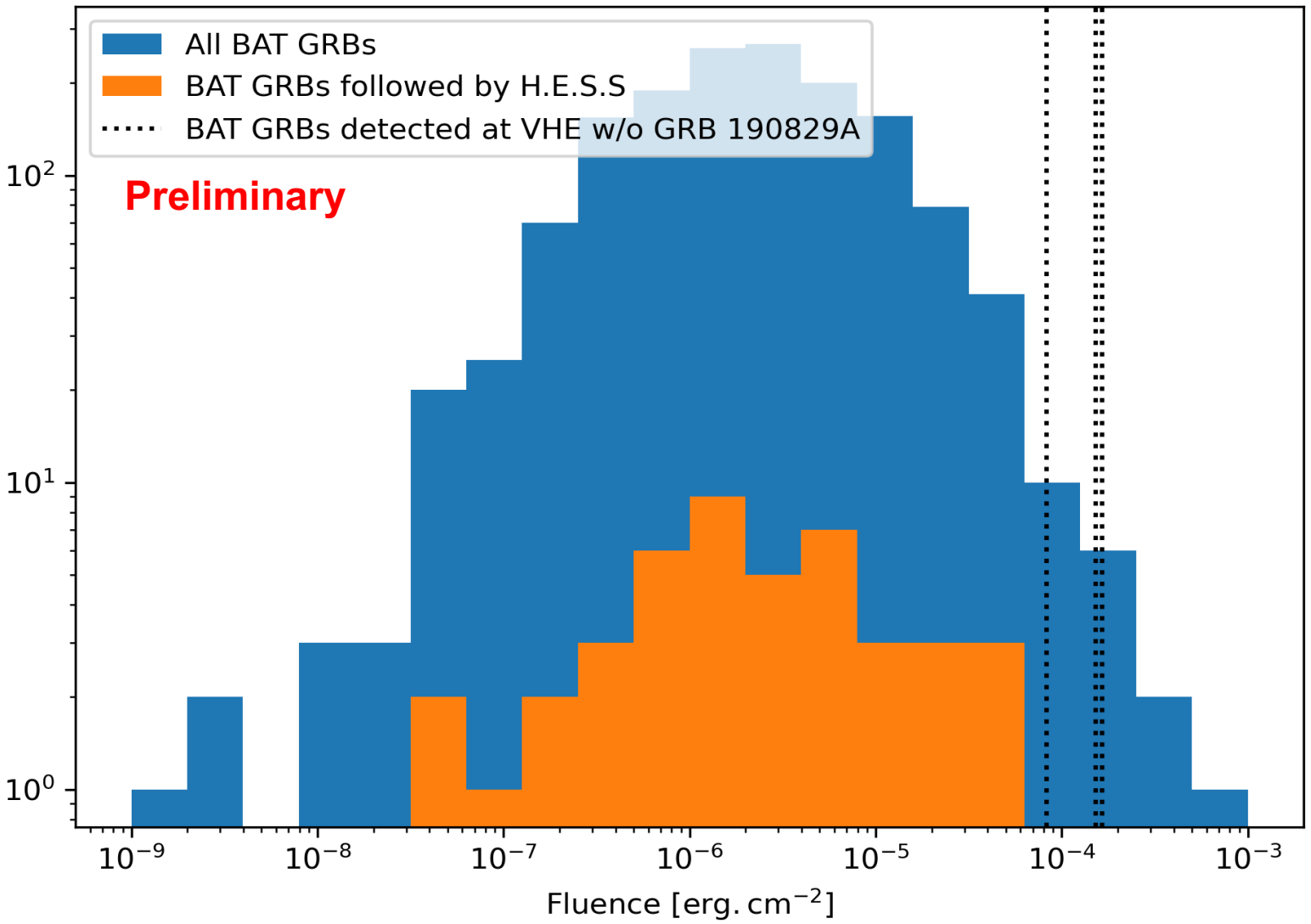
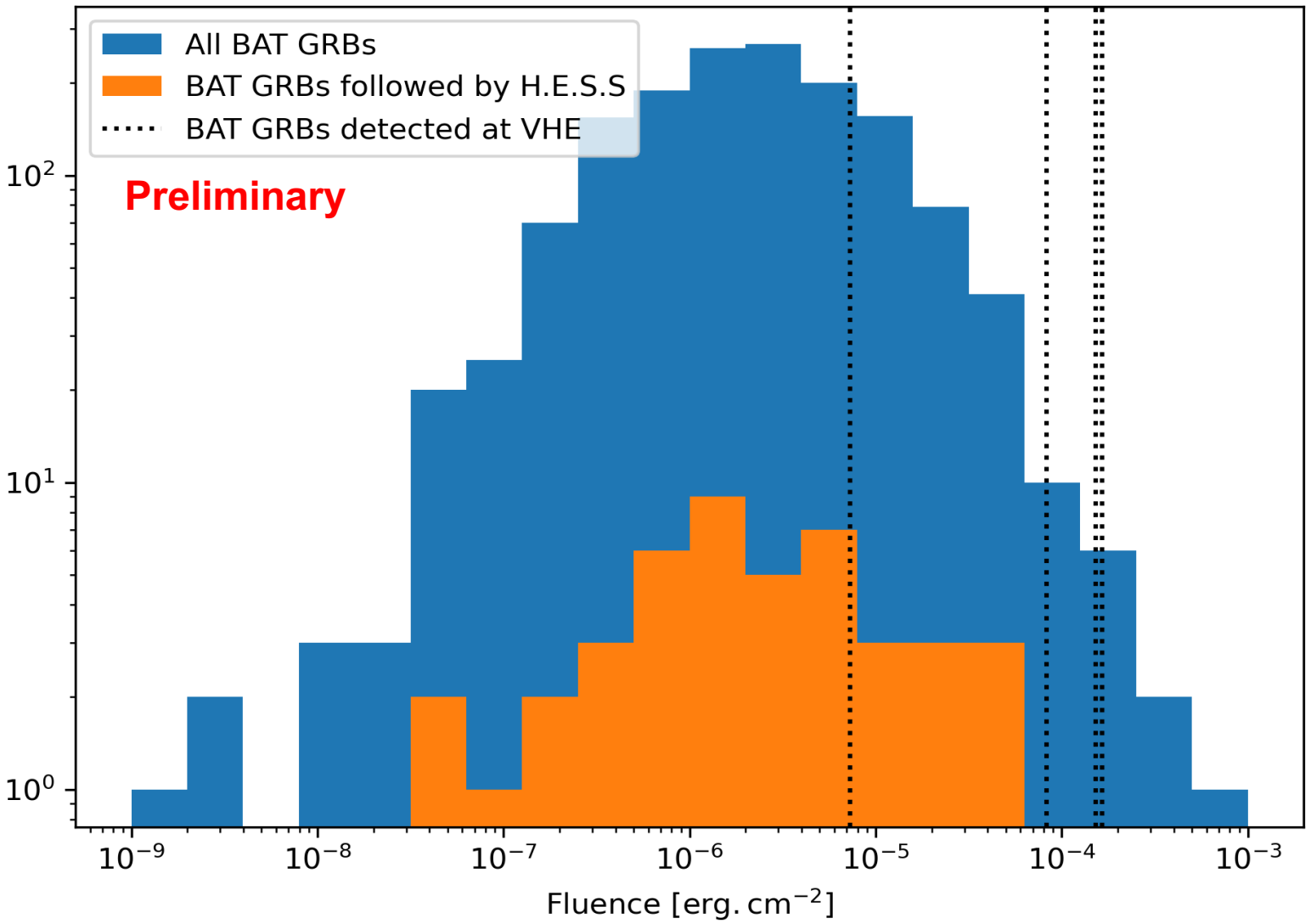


Detected only the brightest GRBs

Statistical significance 5.0 σ

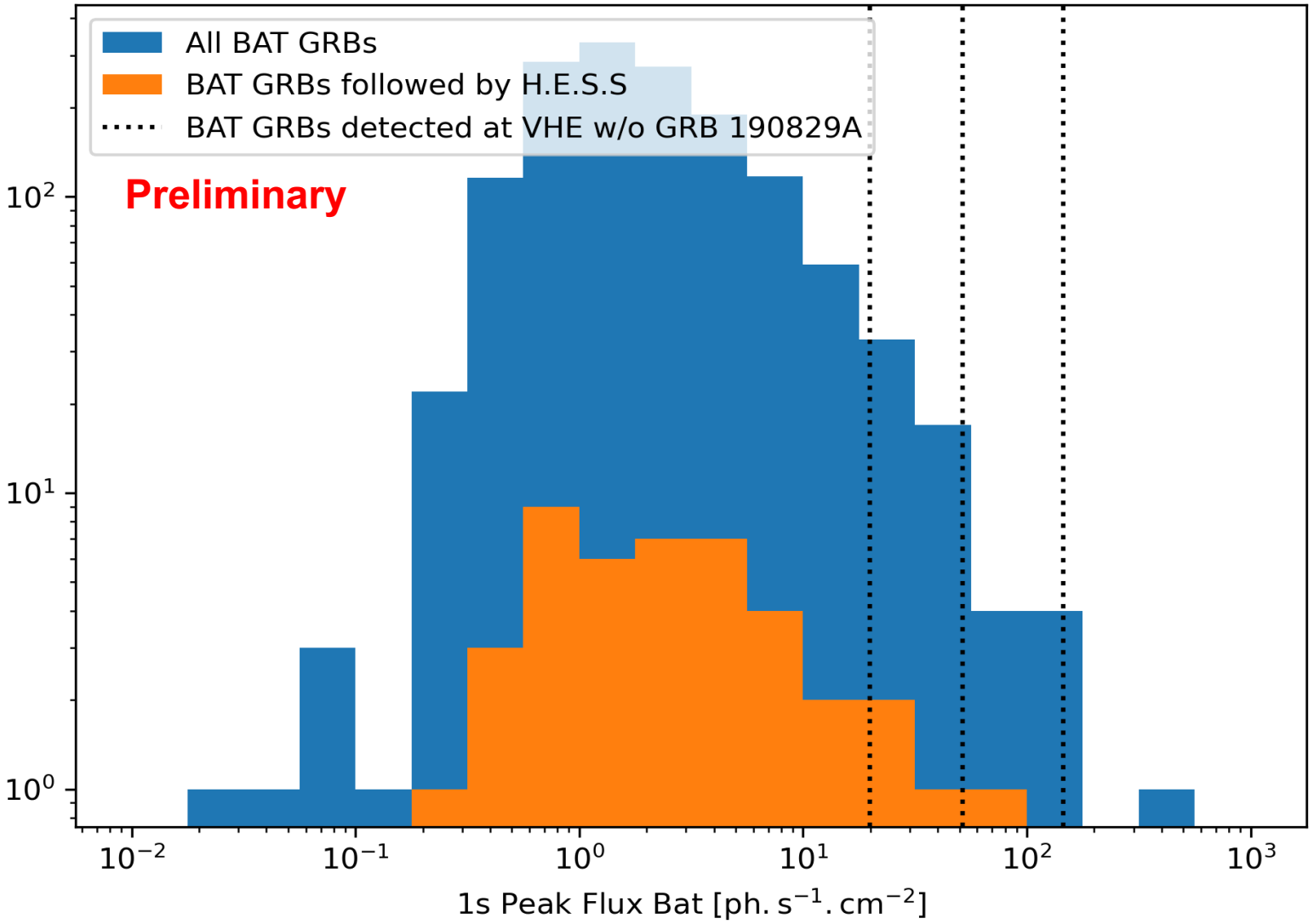
Prompt : Fluence distributions



Detected only the brightest GRBs

Statistical significance 3.1 σ

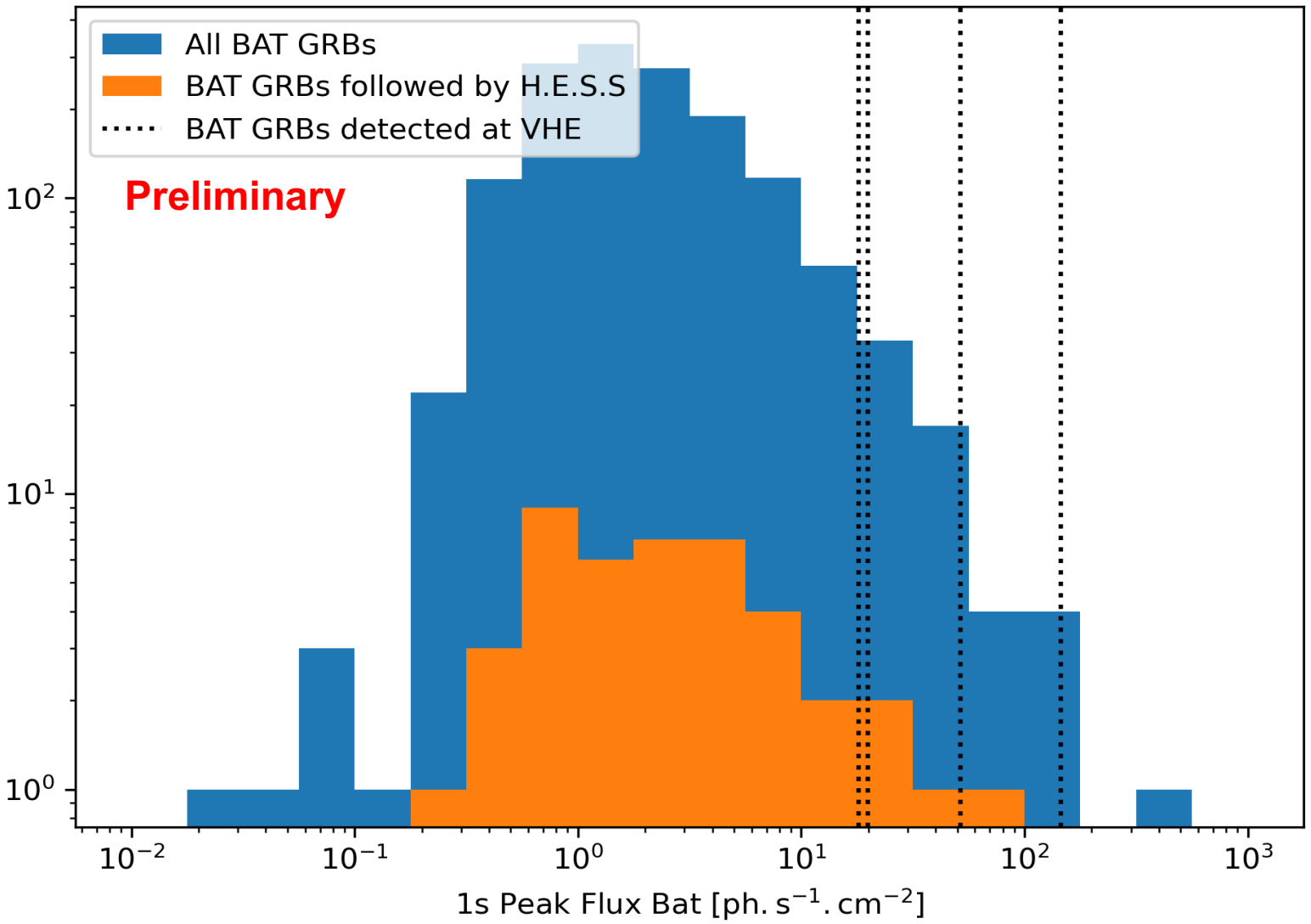
Prompt : Peak flux distributions



Detected only the brightest GRBs

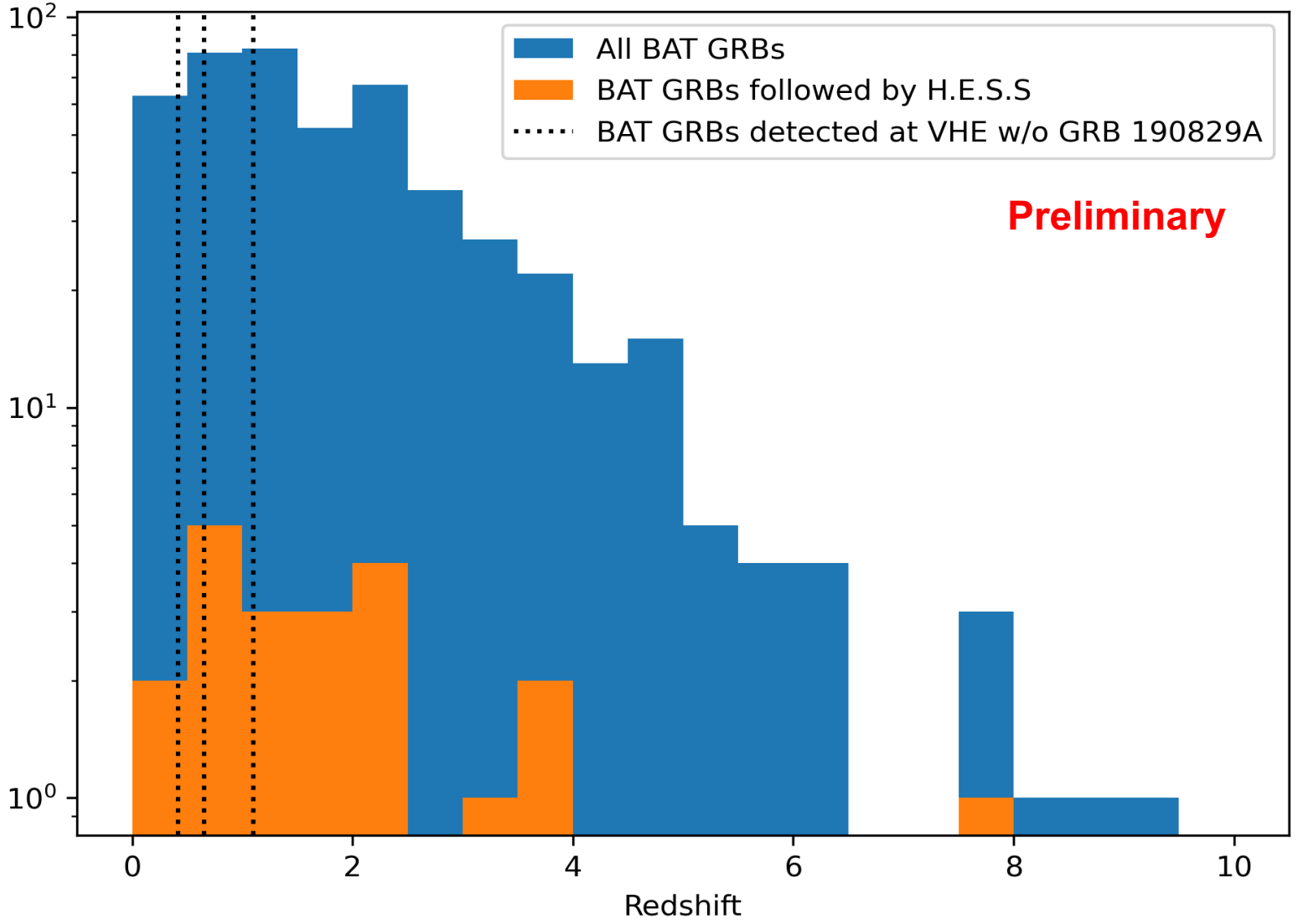
Statistical significance 4.1 σ

Prompt : Peak flux distributions



Detected only the brightest GRBs
Statistical significance 4.7 σ

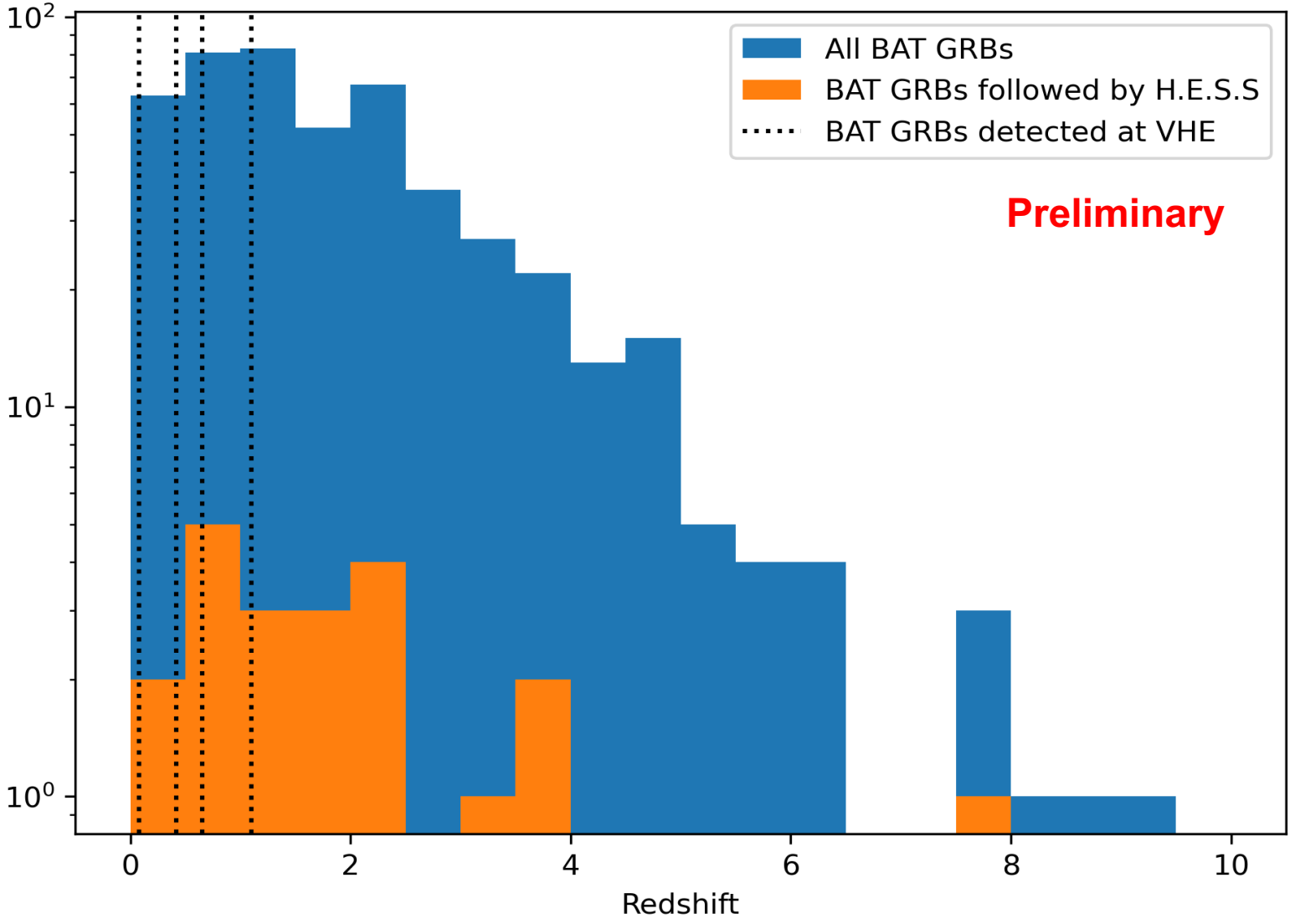
Prompt : Redshift



GRBs observed deviate from the BAT distribution at 2.2 σ

GRBs detected deviate from the BAT distribution at 1.9 σ

Prompt : Redshift



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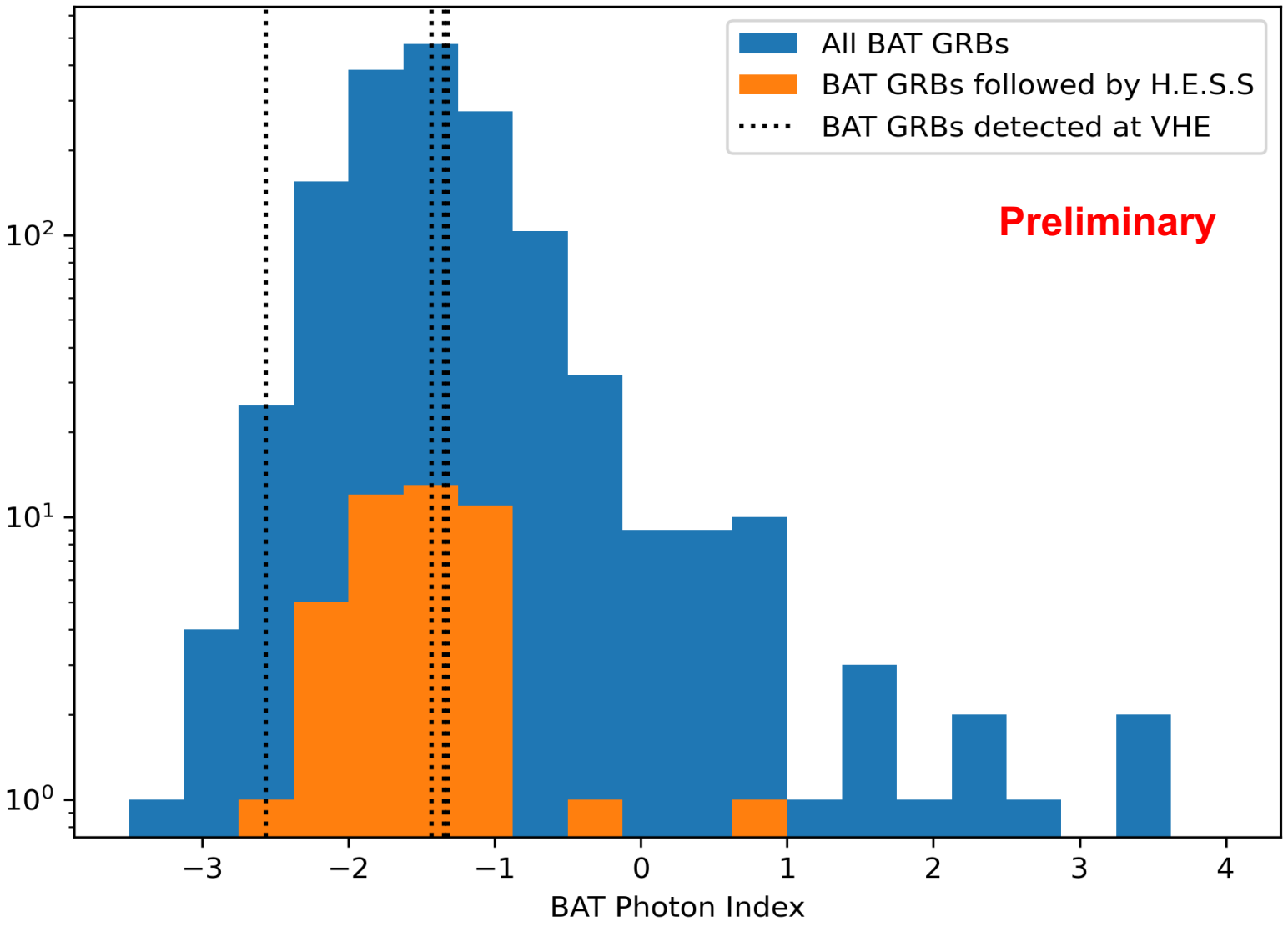
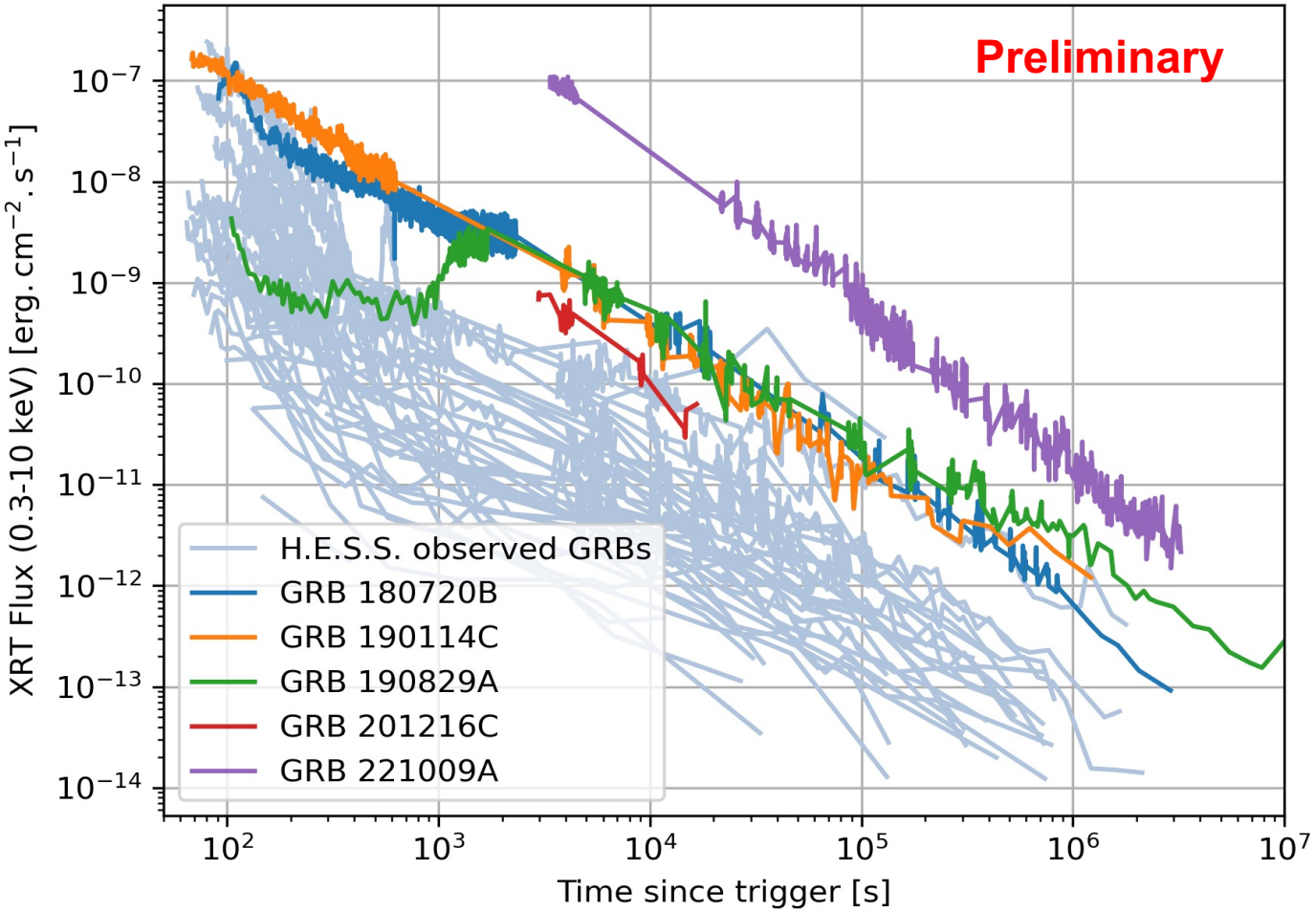
GRBs detected deviate from the BAT distribution at 2.1 σ

Prompt : Photon index



No significant effect

Afterglow : X-Ray Light Curve



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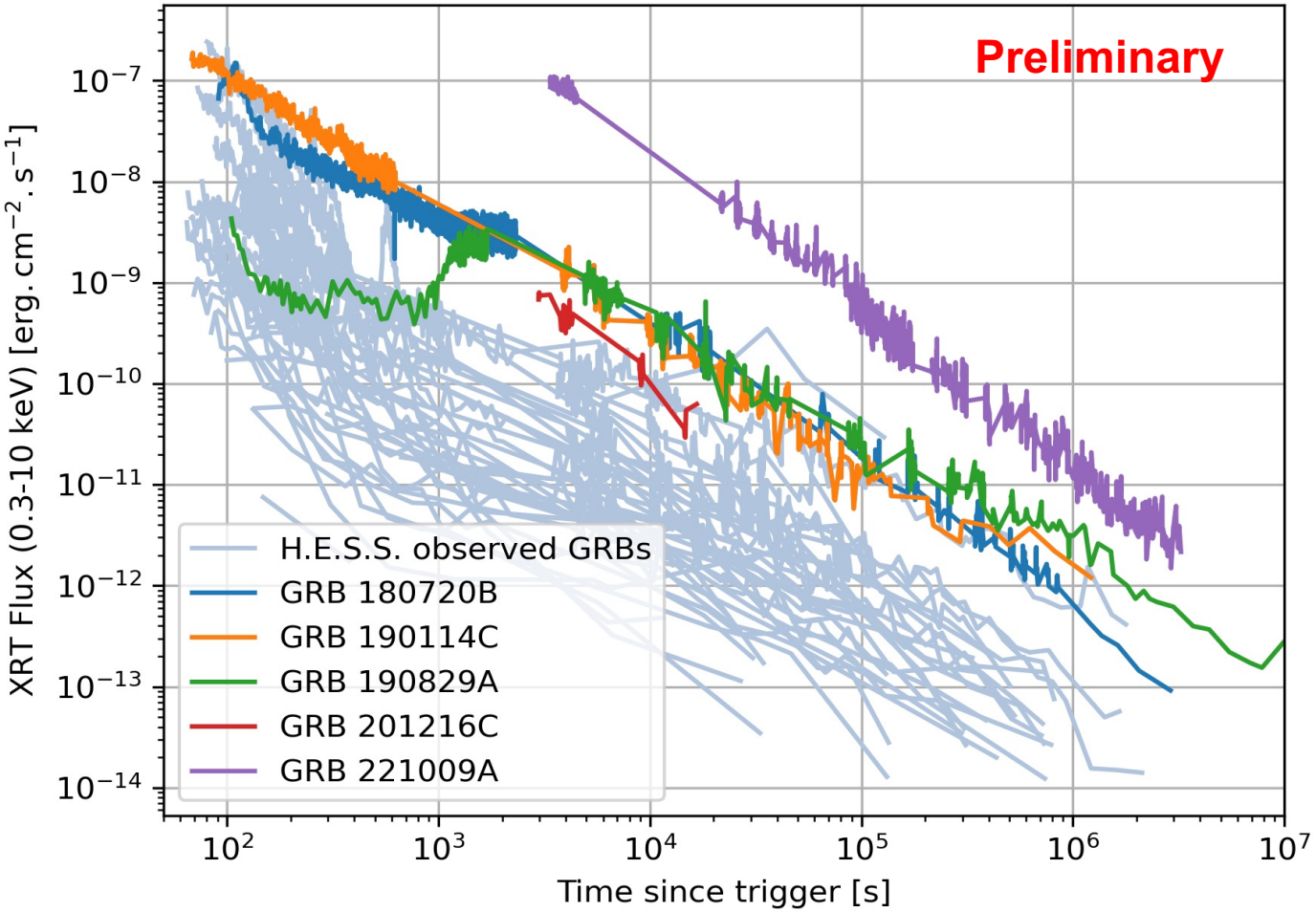

Detected only the brightest GRBs

Conclusion

- Analysis of **15 years of GRBs observations** by H.E.S.S.

- **No hint of signal** from any GRBs

- Population of GRBs detected by Swift :
  - **Unbiased sample of GRBs**
  - **GRBs detected at VHE are :**
    - **Long GRBs**
    - **Close-by GRBs**
    - **Extremely bright (Prompt and Afterglow)**

- Publication in preparation

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Thanks for your attention

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