

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

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M. Senniappan, S. Wagner, S. Zhu, (but not exclusively)
on behalf of the H.E.S.S. collaboration

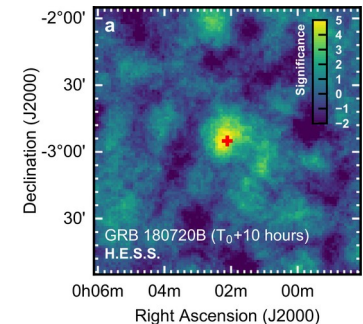


The long quest for the detection of GRBs at VHE

- During more than 20 years, numerous attempts to detect GRBs at VHE ($E > 100$ GeV) have been performed
 - Hint of signal for GRB 970417A in Milagro *(Atkins et al. 2000)*
 - 95 GeV photon detected by *Fermi*/LAT from GRB 130427A *(Ackermann et al. 2013)*

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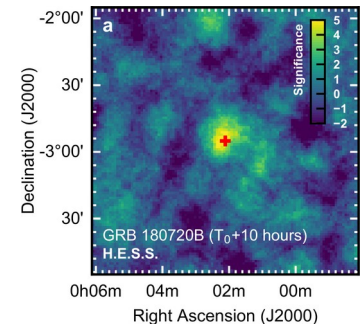
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- **First detection** at VHE achieved in **2018 by H.E.S.S. with GRB 180720B** (Abdalla et al. 2019)
 - Quickly followed by detections by H.E.S.S. and MAGIC of GRB 190114C, GRB 190829A and GRB 201216C
(MAGIC Collaboration 2019, H.E.S.S. Collaboration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



(Abdalla et al. 2019)

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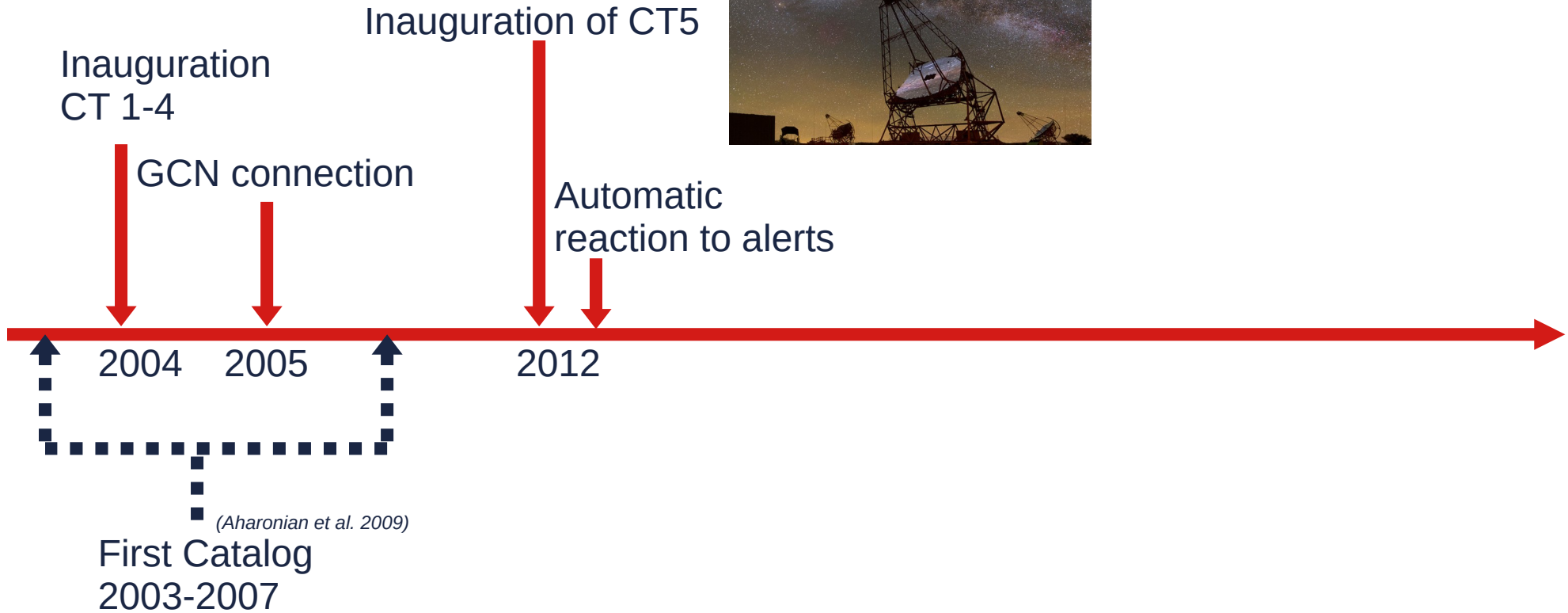
(Abdalla et al. 2019)

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

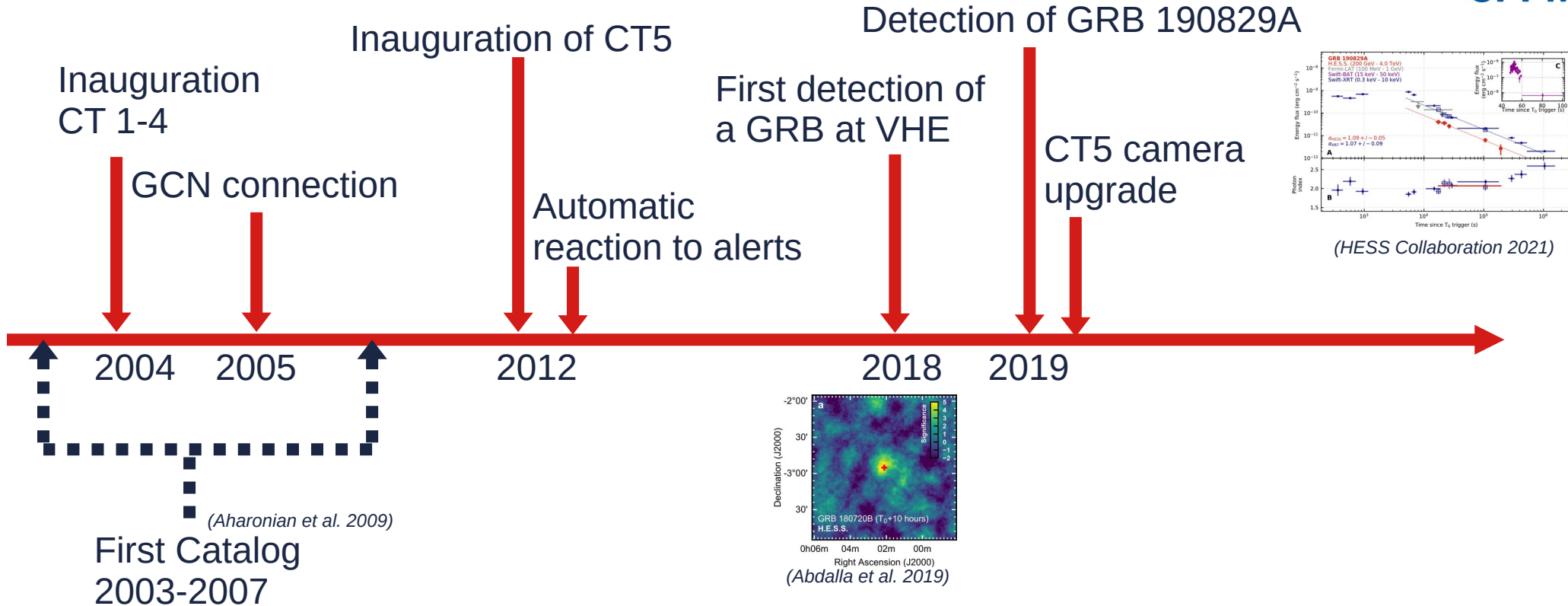
Timeline of the H.E.S.S. GRB program



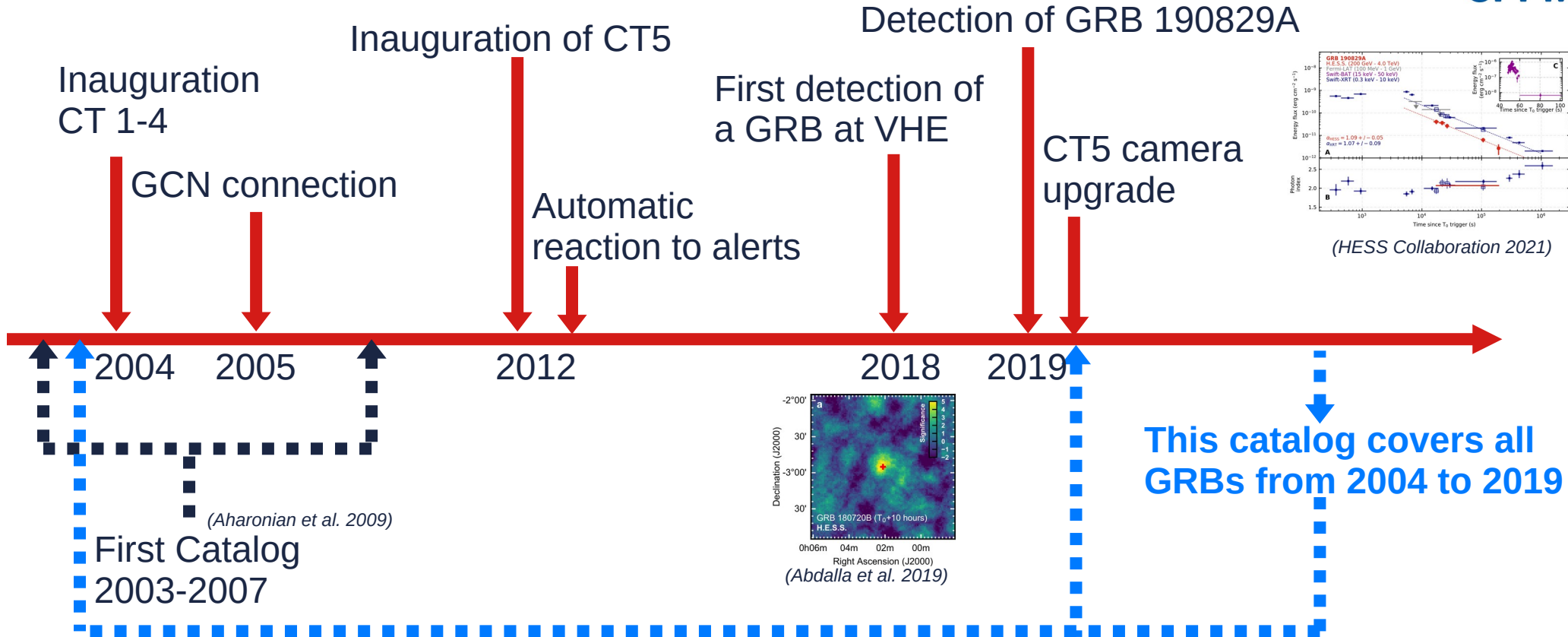
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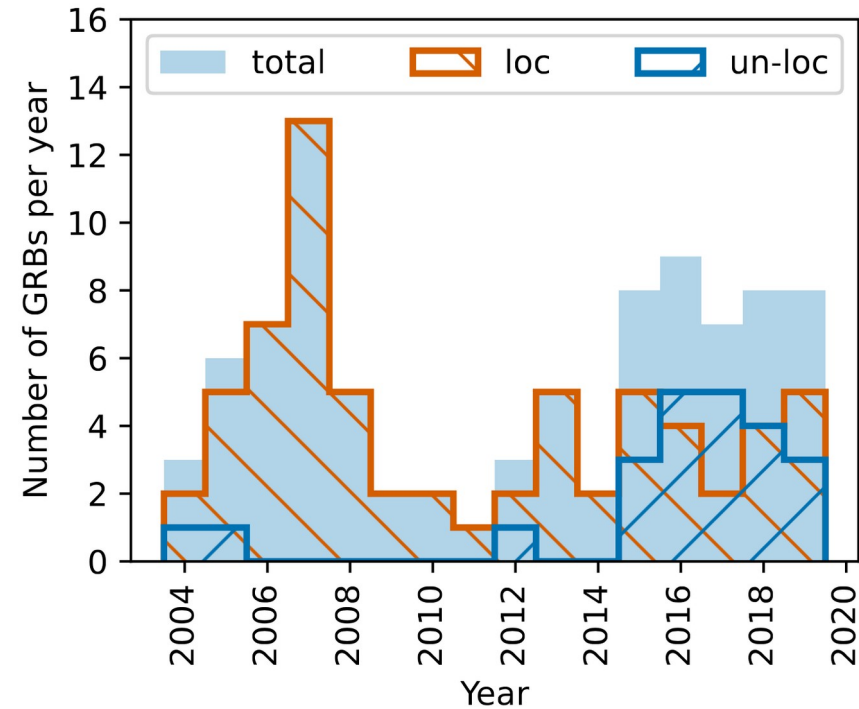
Timeline of the H.E.S.S. GRB program



The GRB sample of the second H.E.S.S. catalog

- GRB from bookkeeping,
Cross matching GRBs database with obs. database
 - **Loc:** Pointing distance $< 2^\circ$, delay $< 48\text{h}$
 - **Un-loc:** Cover $> 10\%$ prob. region, delay $< 24\text{h}$

Stage	<i>loc</i> GRBs	<i>un-loc</i> GRBs	Total
Follow-up observations	-	-	107
Selected for analysis	66	23	89
Retained after quality selection	48	15	63
Flux ULs determined	48	1	49

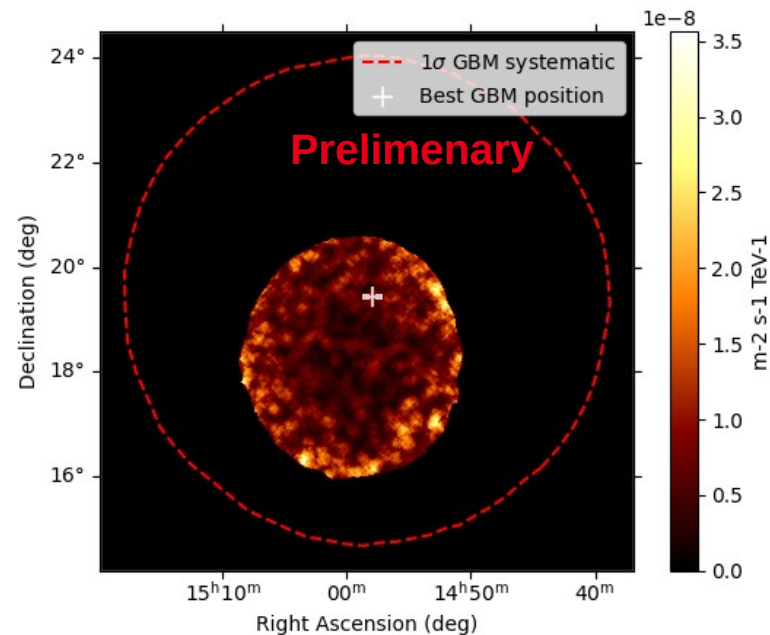
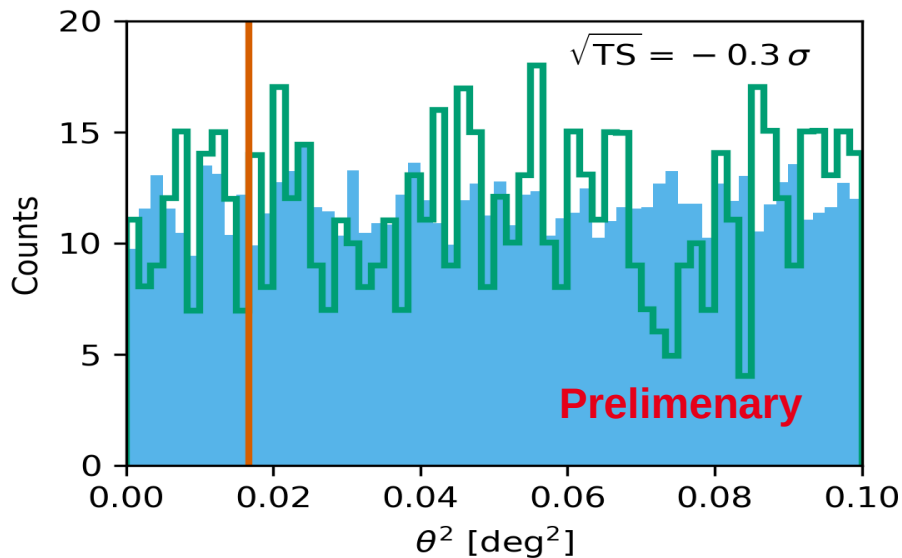


GRB 180720B and GRB 190829A are not included as they have dedicated publications

Individual analysis for each GRB

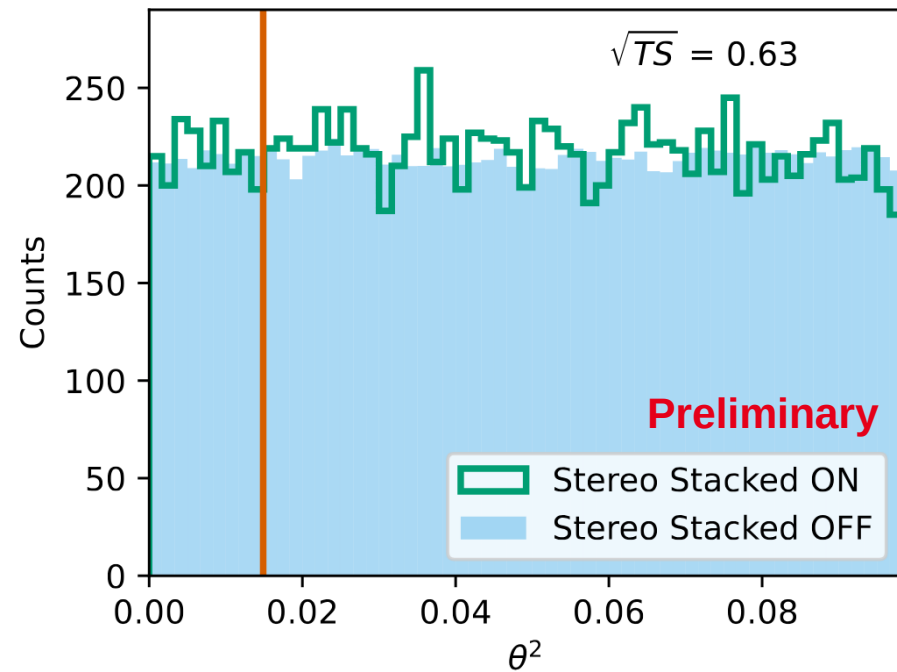
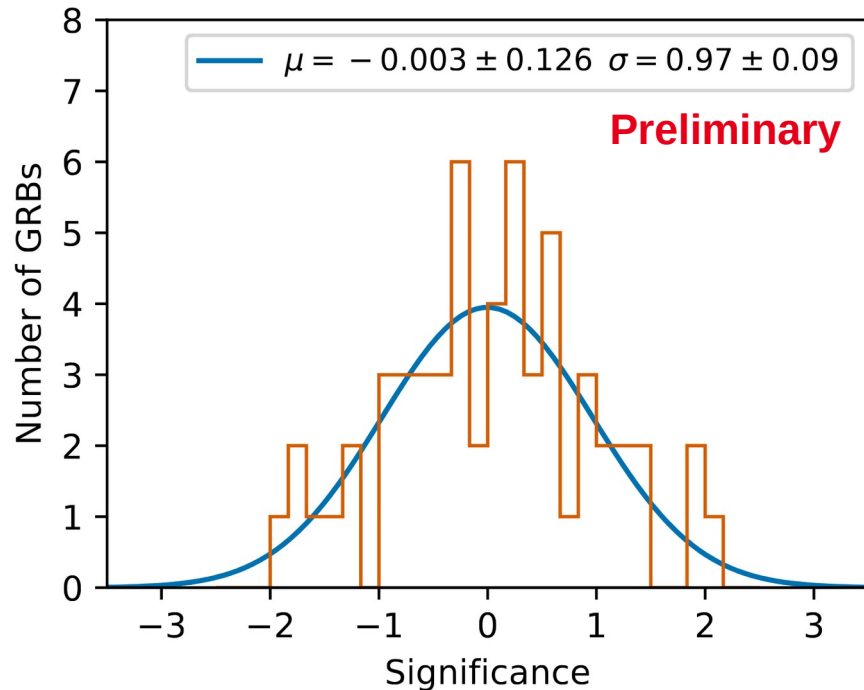
■ Type of information in the catalog :

- Significance
- Energy threshold
- Integral UL, index -2.5 and 5



Stacking of localized GRBs

- **No hint of signal** in any of the analyzed GRBs
- No hint of signal with the stacking of all GRBs



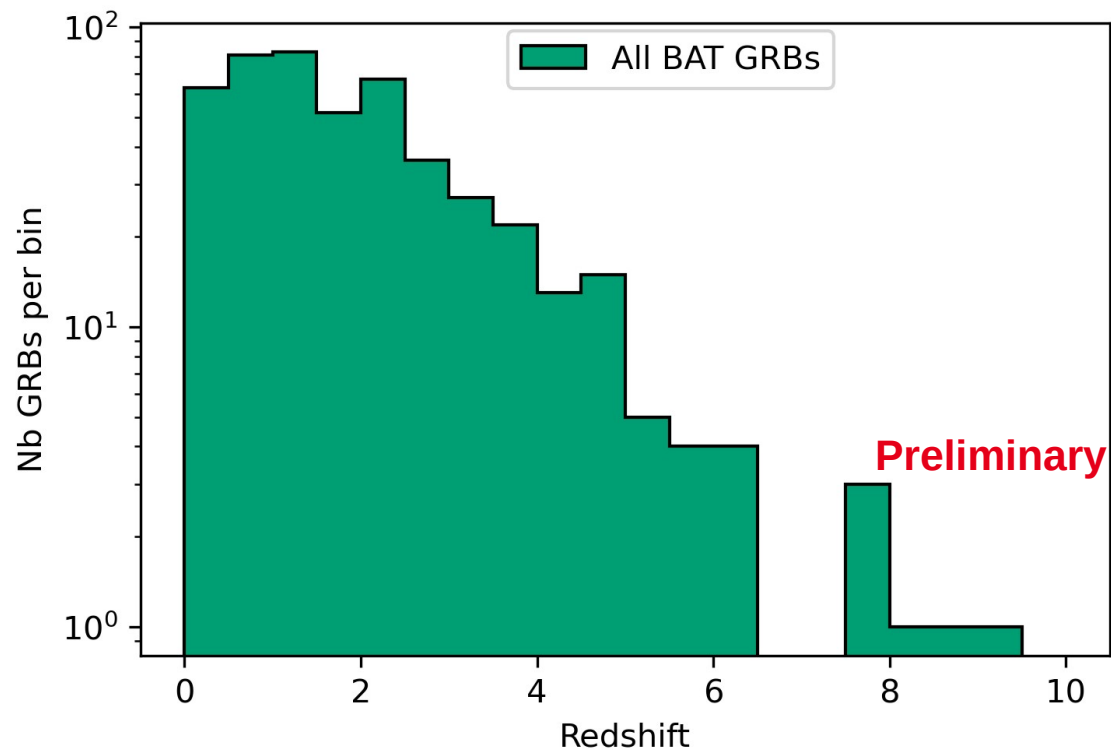
Population studies

■ **Aim : Do GRBs detected at VHE have specific properties ?**

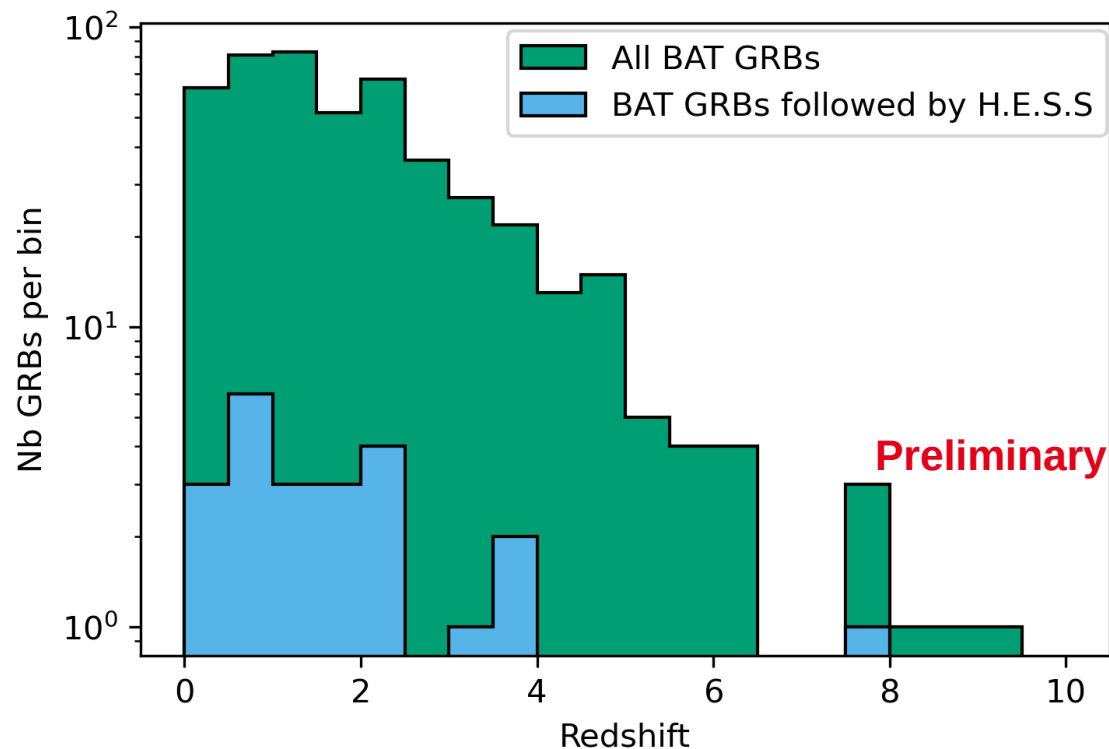
■ **Method :**

- Compare **GRBs followed by H.E.S.S vs. the full GRB population**
(Search for deviation due to follow-up strategy)
- Compare **GRBs detected at VHE vs. the full GRB population**
(Search for deviation specific to VHE detected GRBs)
- Use *Swift*/BAT for the prompt and *Swift*/XRT for the afterglow
- Comparison with the Kolmogorov-Smirnov test

Population studies, Redshift

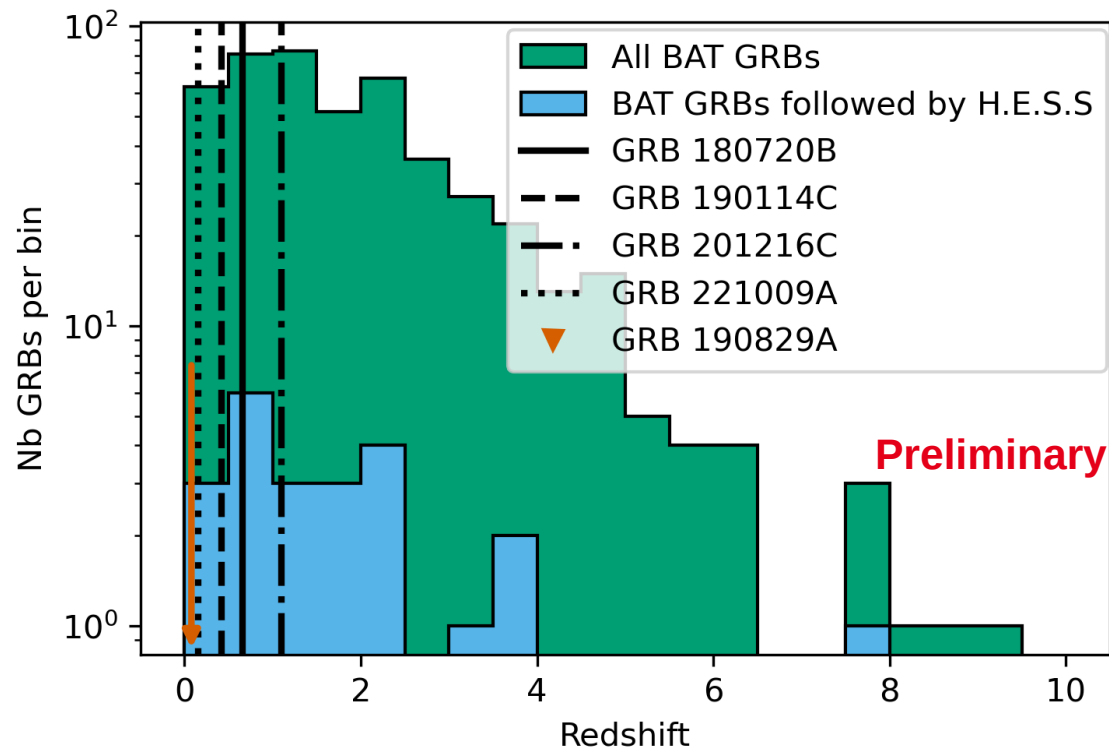


Population studies, Redshift



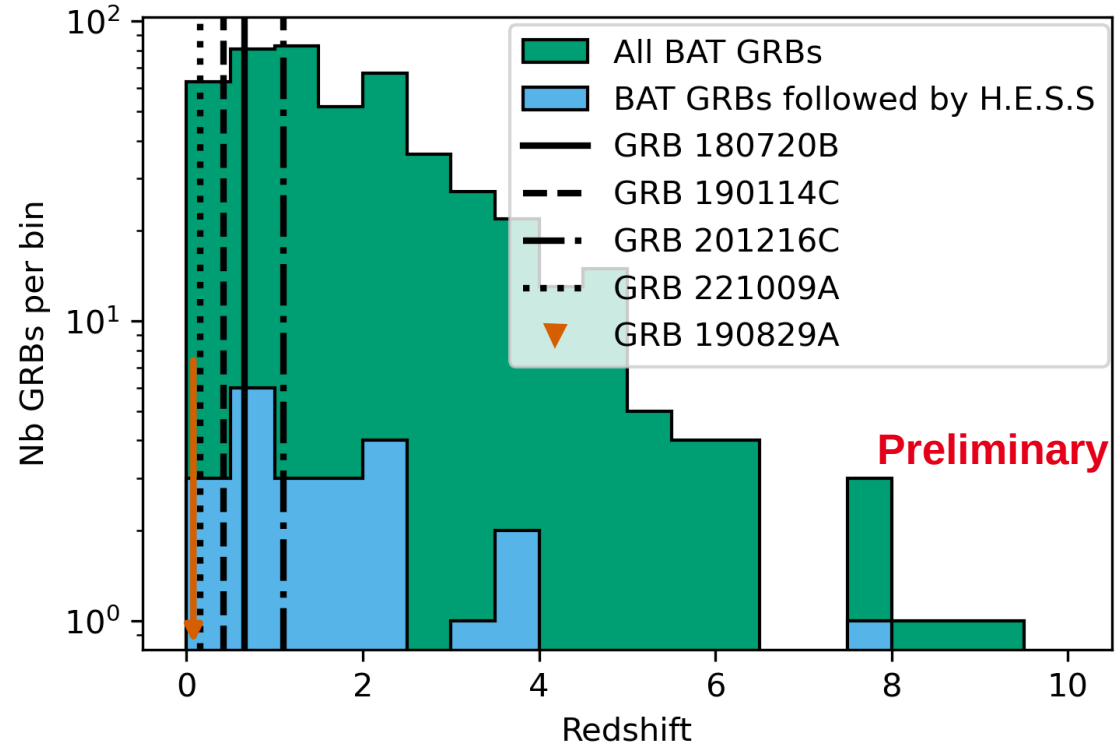
Preliminary

Population studies, Redshift



Population studies, Redshift

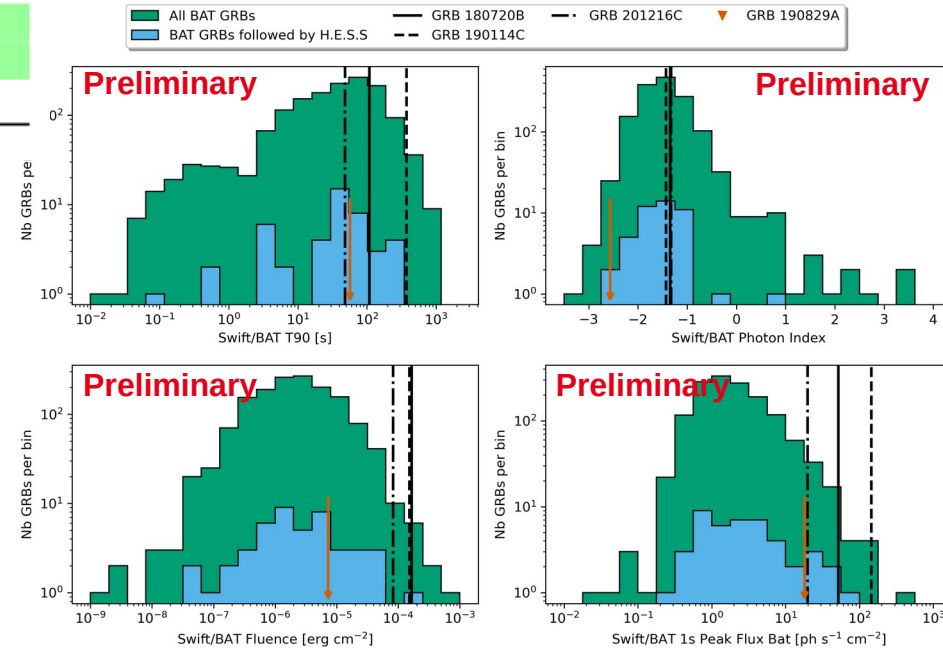
- Only 1/3 of the sample have redshift
- ~ 2 sigma deviation for all comparisons
- Expected bias for detection due to EBL
- Expected bias at the time of follow-up due to decision of favoring low redshift



Population studies, Prompt : *Swift*/BAT

Parameter	Observed with H.E.S.S	Detected at VHE	Detected at VHE (except GRB 190829A)
	VS All GRBs	VS all GRBs	VS all GRBs
T_{90}	1.4σ	1.5σ	1.2σ
Fluence	0.8σ	2.9σ	4.7σ
1s Peak Flux	1.6σ	4.5σ	3.9σ
Spectral Index	1.2σ	0.6σ	1.2σ

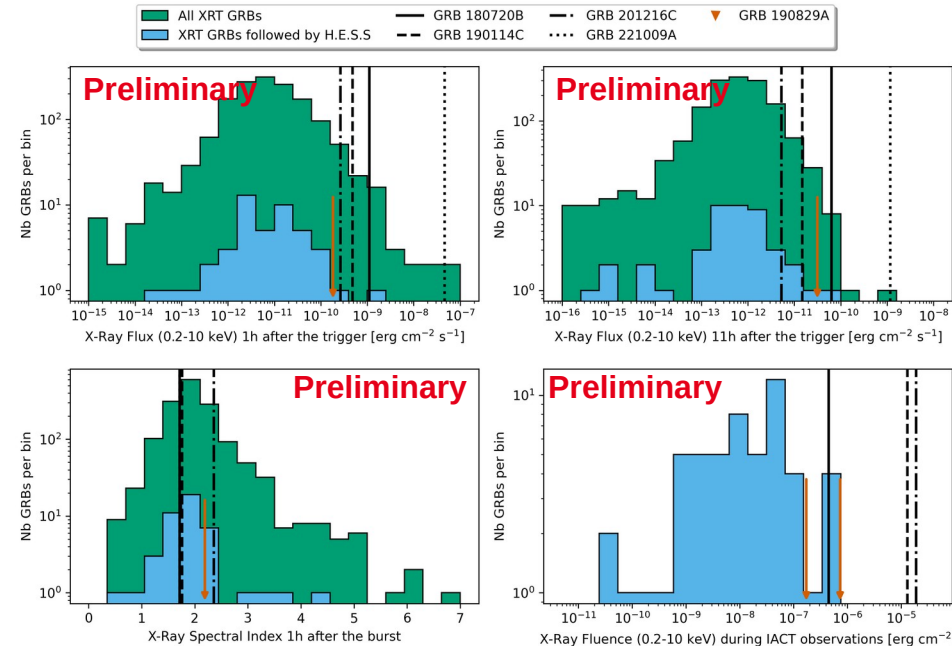
- No significant bias in the H.E.S.S sample
- GRBs detected at VHE show no deviation on spec. index
- GRBs detected at VHE show no deviation on duration
- **GRBs detected at VHE are brighter than the average**



Population studies, Afterglow : *Swift*/XRT

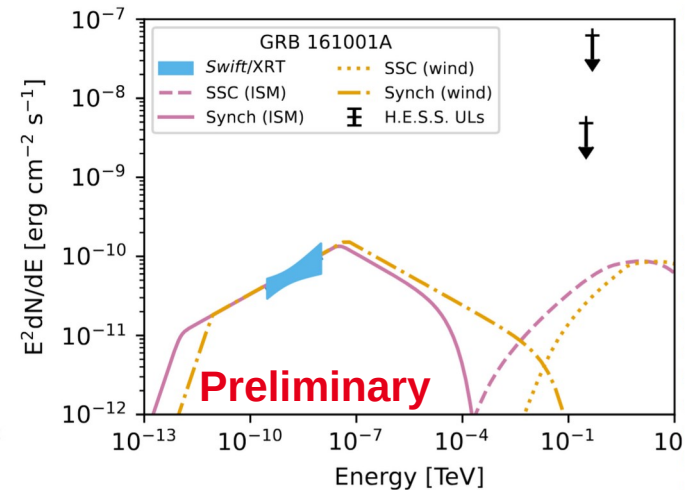
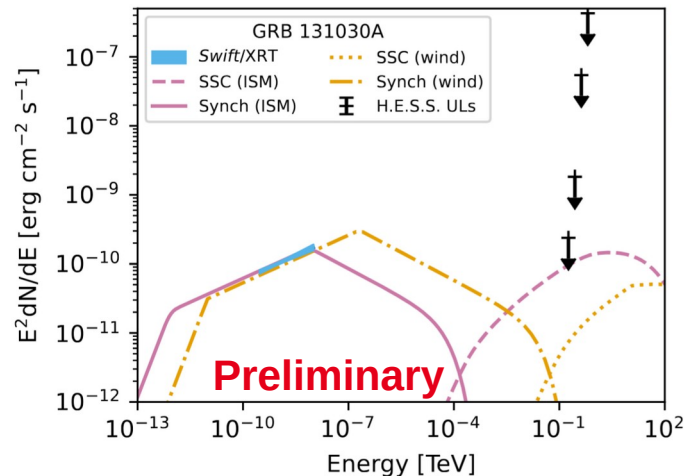
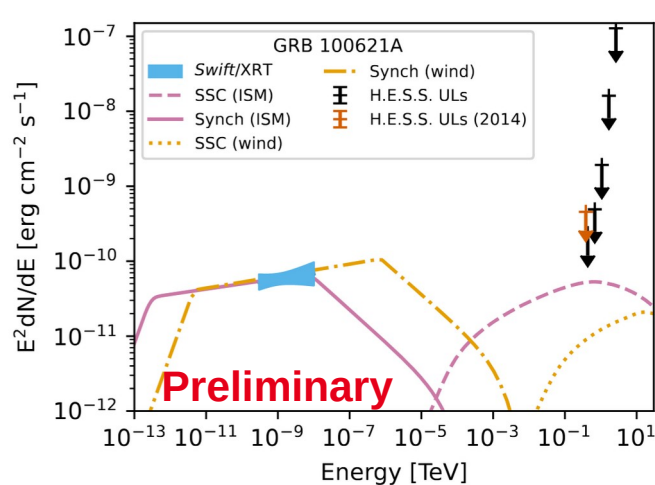
Parameter	Observed with H.E.S.S	Detected at VHE	Detected at VHE (except GRB 190829A)
	VS All GRBs	VS all GRBs	VS all GRBs
Fluence during obs.	N/A	4.0σ	4.1σ
Flux at 200 s	0.1σ	3.1σ	4.4σ
Flux at 1 h	0.1σ	4.0σ	4.5σ
Flux at 11 h	0.1σ	4.8σ	3.8σ
Flux at 24 h	0.1σ	4.1σ	3.6σ
Spec. Index at 200 s	0.04σ	0.5σ	1.1σ
Spec. Index at 1 h	0.7σ	0.4σ	1.0σ
Spec. Index at 11 h	0.3σ	0.3σ	0.2σ
Spec. Index at 24 h	0.3σ	0.3σ	0.9σ

- No significant bias in the H.E.S.S sample
- GRBs detected at VHE show no deviation on spec. index
- GRBs detected at VHE are brighter than the average



Modeling of specific GRBs

- Selected GRBs at low redshift, low delay and bright X-Ray flux
- Modeling from Huang et al. 2022
- H.E.S.S. UL are consistent with the standard SSC scenario**

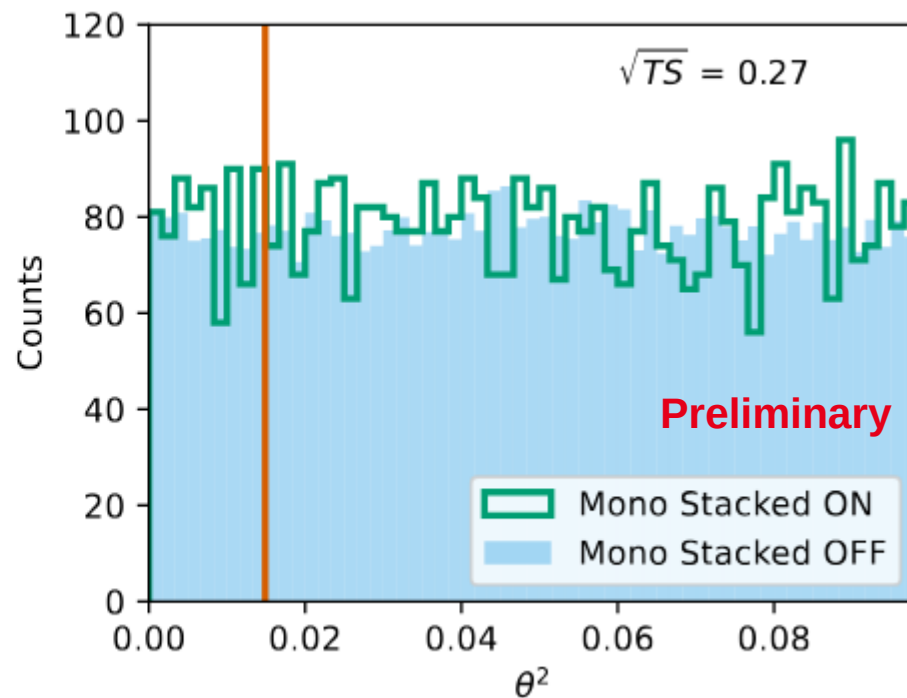
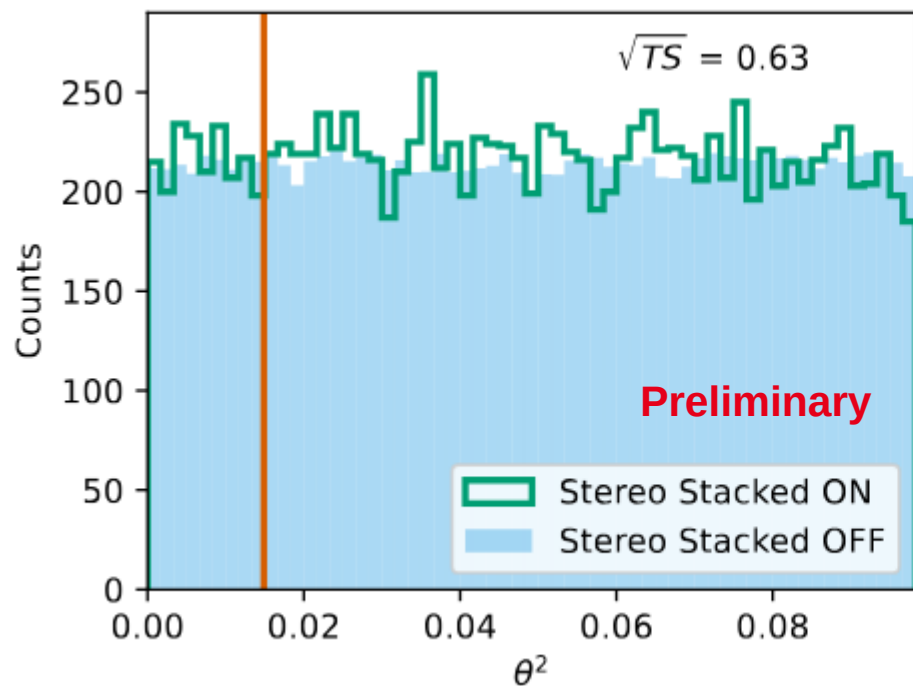


Conclusion

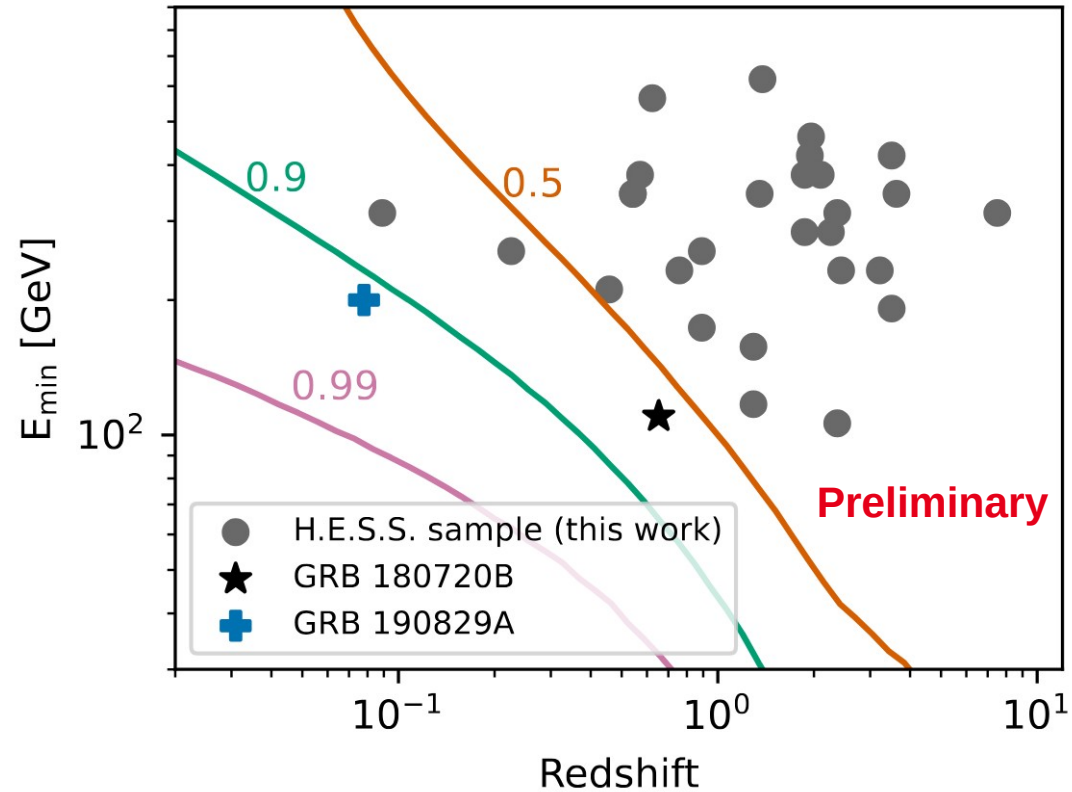
- Analysis of 15 years of GRB follow-ups with H.E.S.S.
 - Largest sample of GRBs observed at VHE
- No hint of signal from any GRBs
- Population studies:
 - H.E.S.S. sample is not significantly biased
 - GRBs detected at VHE are very bright in X-Ray
- CTA should allow to probe lower-luminosity GRB
- Publication submitted to journal
 - Will contain more details on all the results presented here
 - Will contained individual results for each GRB

Backup

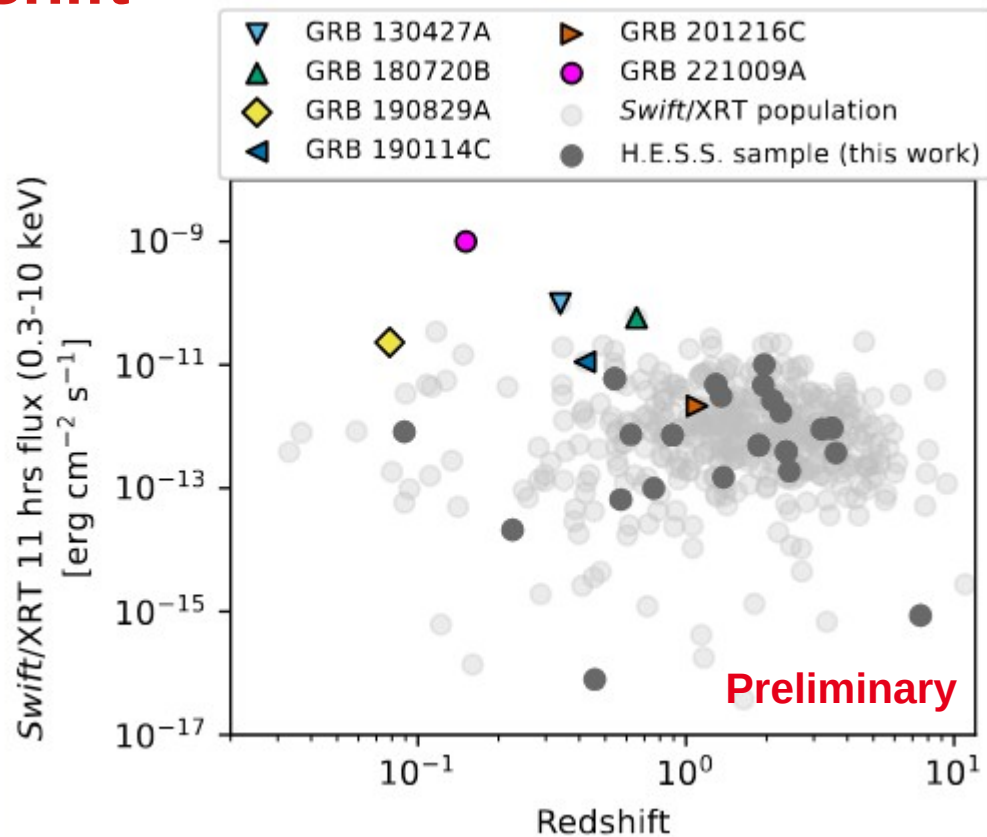
Stacked analysis



EBL absorption



X-Ray flux and redshift



Zenith and delay

