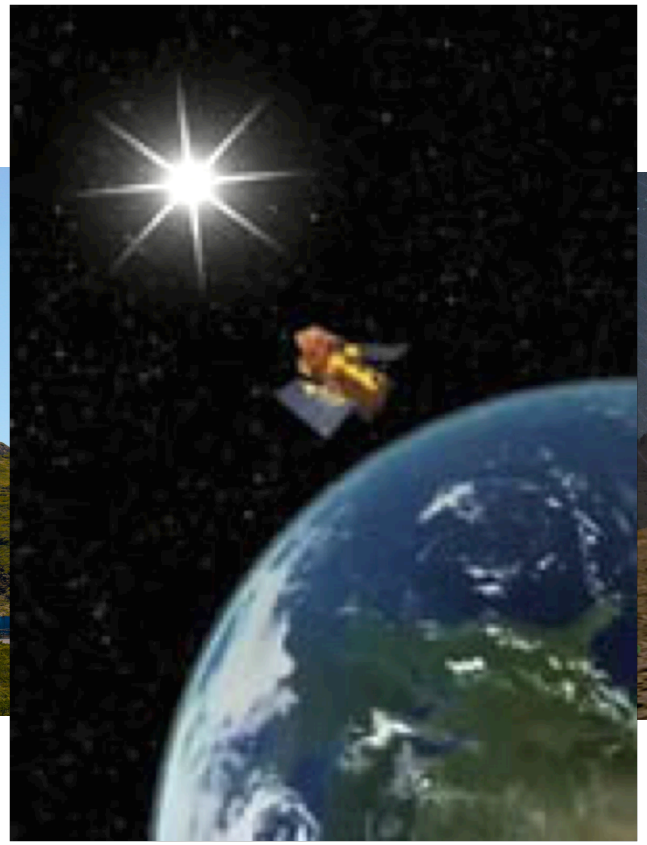
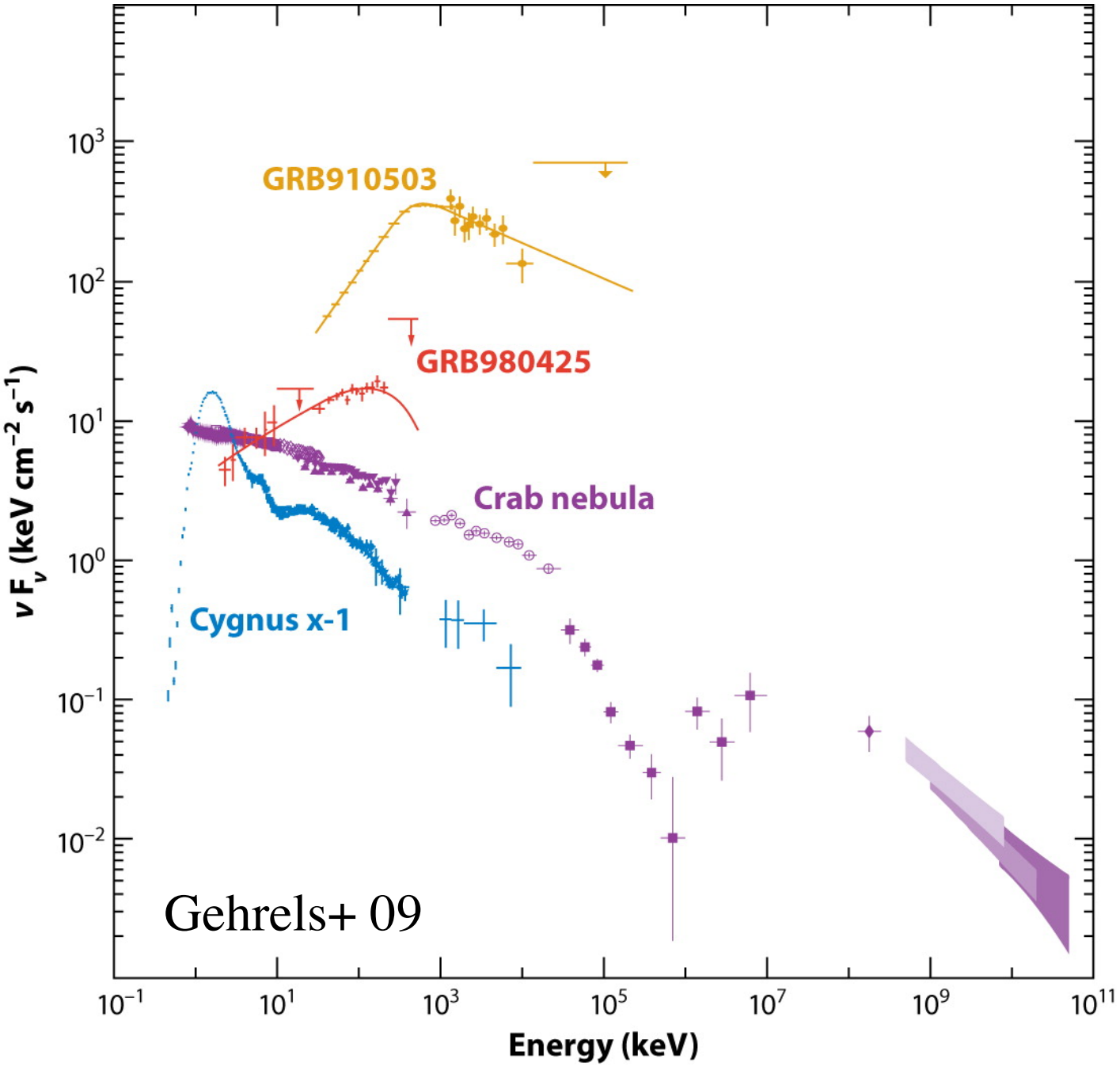
(Very) high energy emission from GRBs: challenges and prospects

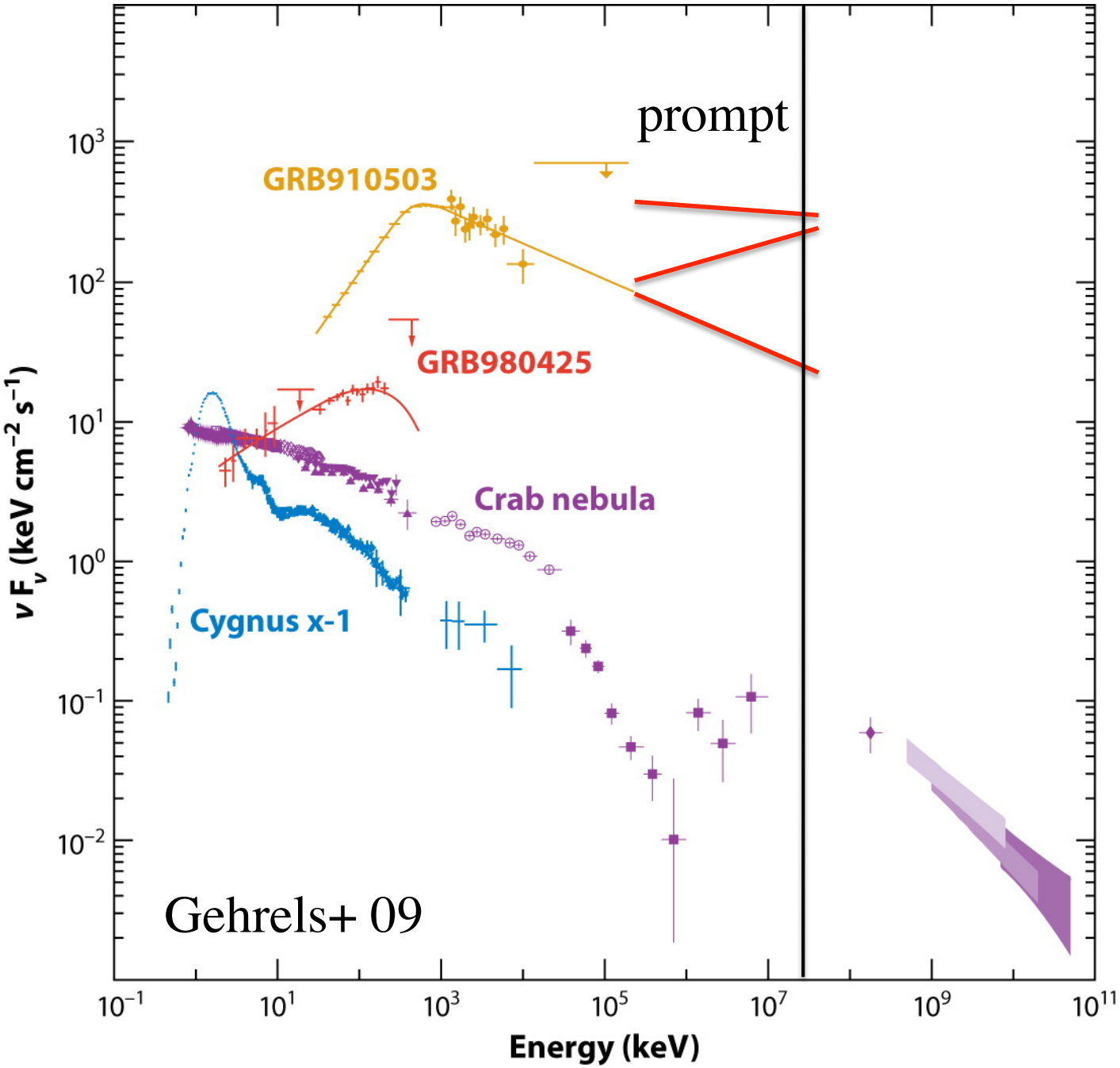
Susumu Inoue (RIKEN)
on behalf of many collaborators


GRBs: Fermi results

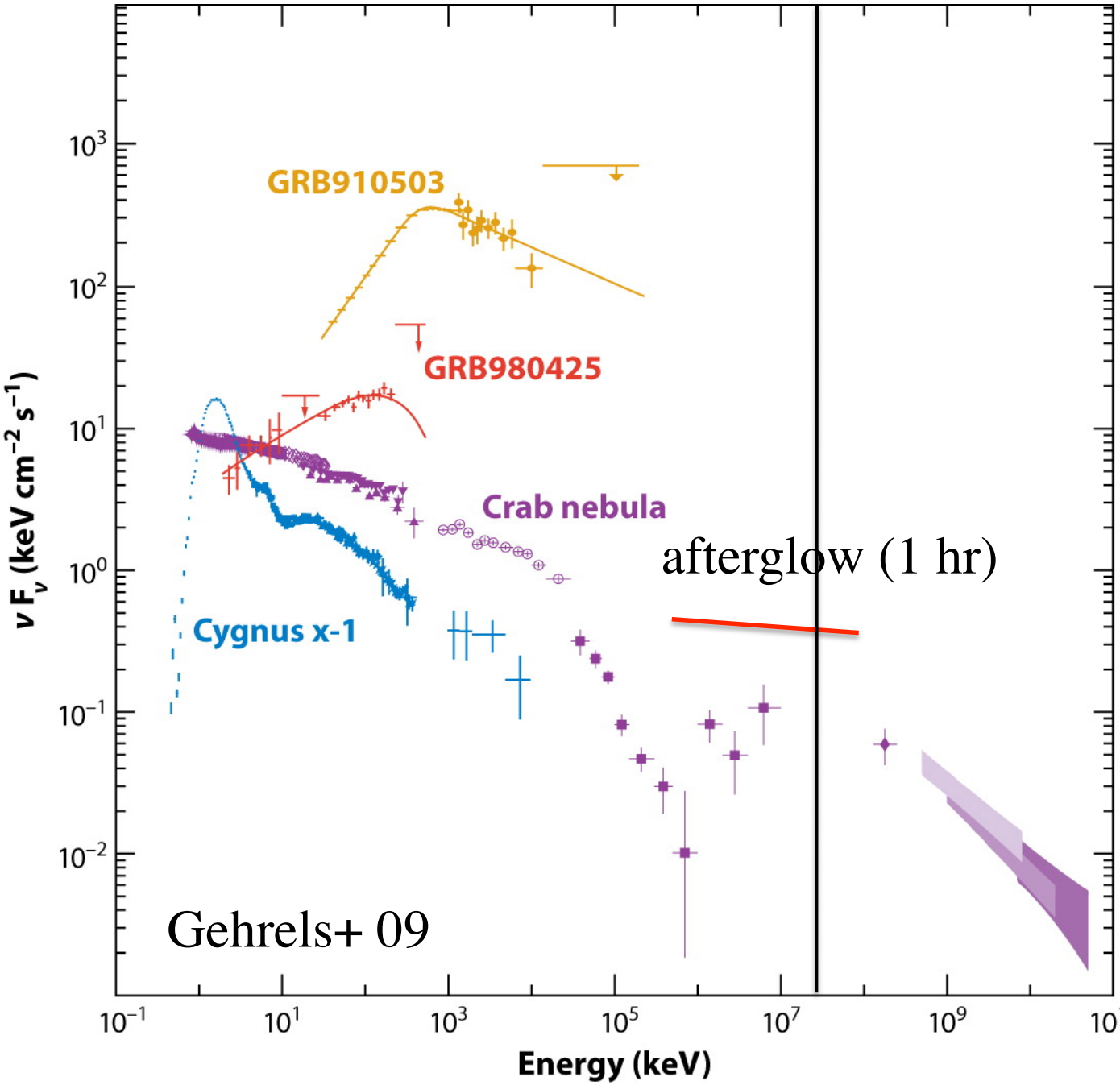


GRBs: Fermi results



- prompt GeV in bright GRBs
- MeV extension at least to 10-30 GeV
- excess hard compt. for brightest GRBs
- both long (few 100s), short (few s)

GRBs: Fermi results

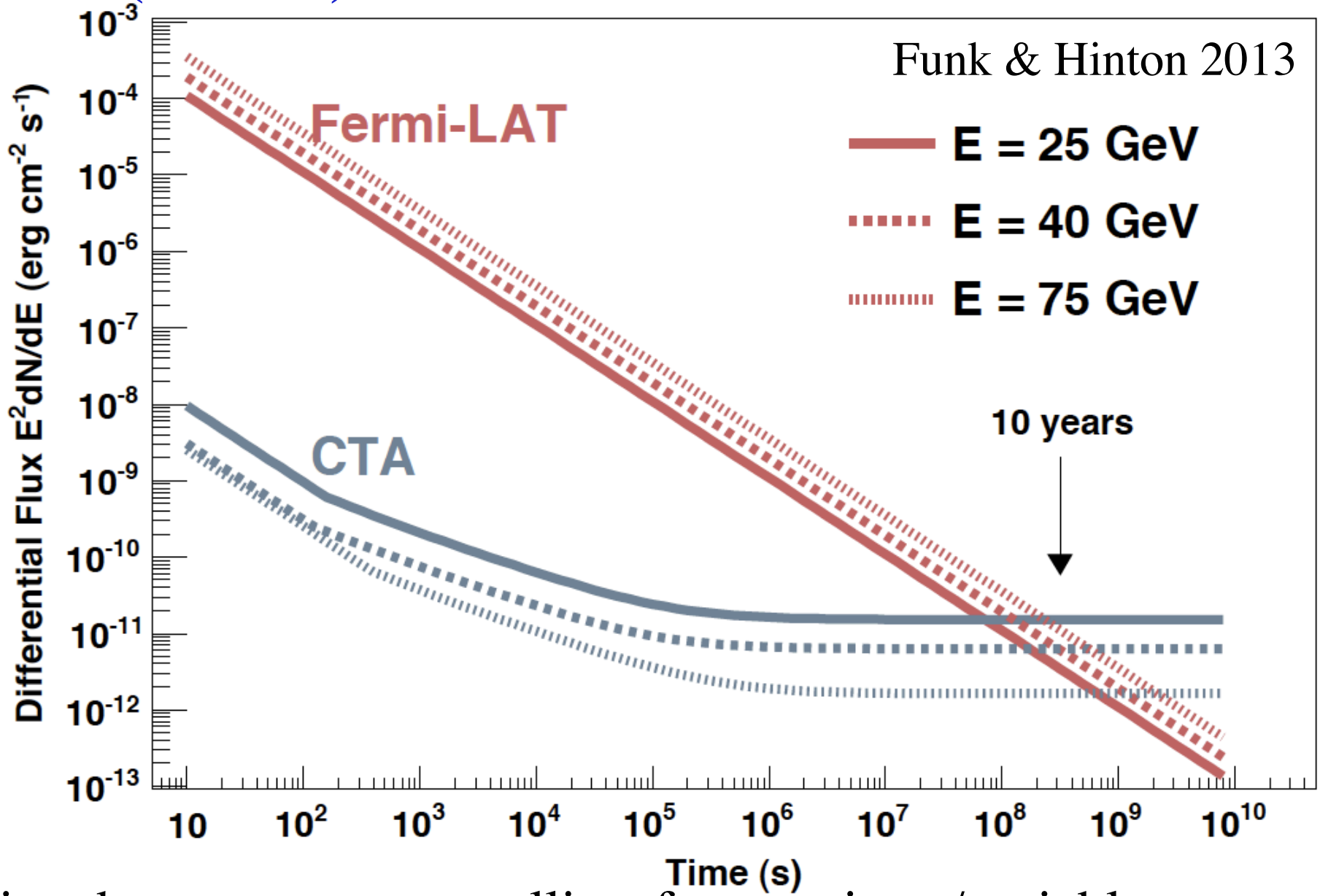


- GeV afterglow up to few ks $\propto t^{-1.2}$-$t^{-1.5}$

- consistent with most GRBs having GeV prompt+afterg. (evidence for break in ~20% of bright GRBs)

- BUT physics unclear due to low GeV photon statistics

CTA (IACTs) vs Fermi



big advantange over satellites for transients/variables:
effec. area ~10^4 x LAT@30GeV

GRB science prospects for IACTs

higher photon statistics >tens of GeV

origin of GRBs

- measurements of bulk velocity (intrinsic γγ cutoff)
- mechanisms of prompt emission, early afterglow (broadband spectra, variability)

origin of cosmic rays

- signatures of UHECR/ HE neutrino production (proton synchrotron, pγ cascade components, …)
- delayed cascade radiation

observational cosmology

- probe extragalactic background light (EBL) at high-z (γγ absorption)
- probe weak intergalactic magnetic fields (pair echos)

fundamental physics

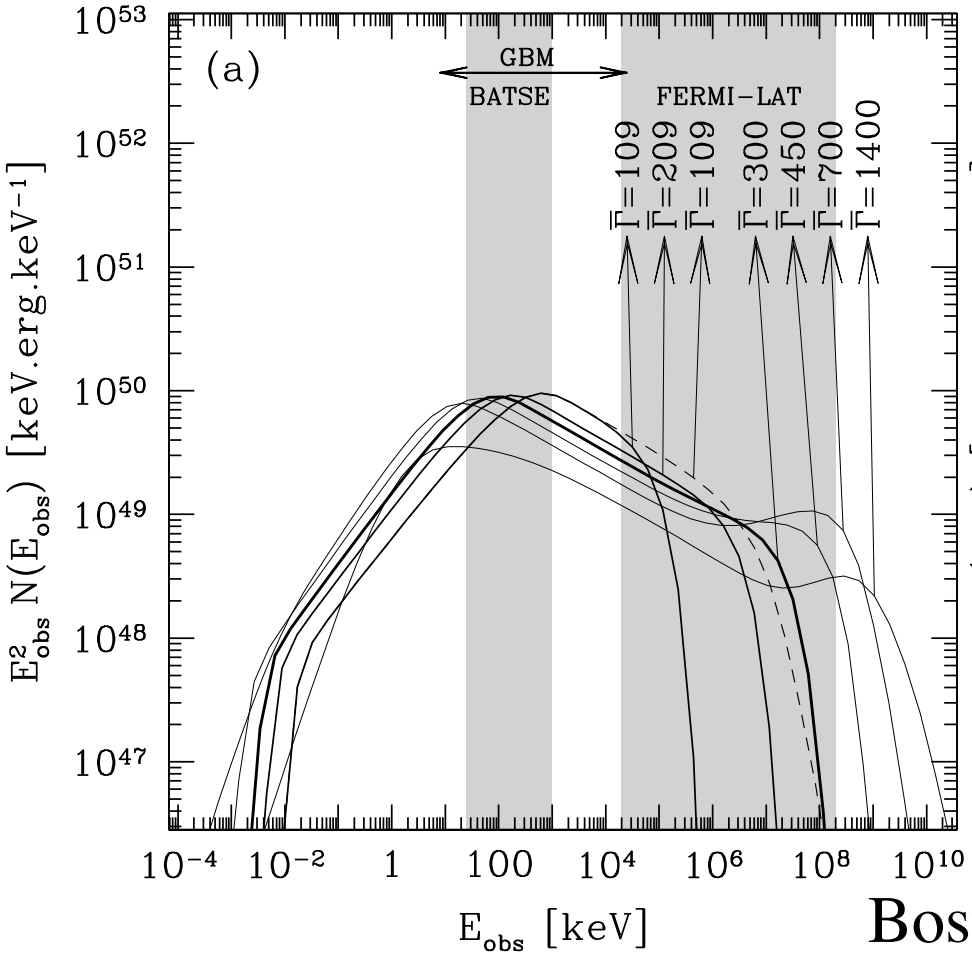
- probe Lorentz invariance violation
- constrain axions/nonstandard particles

prompt emission at HE

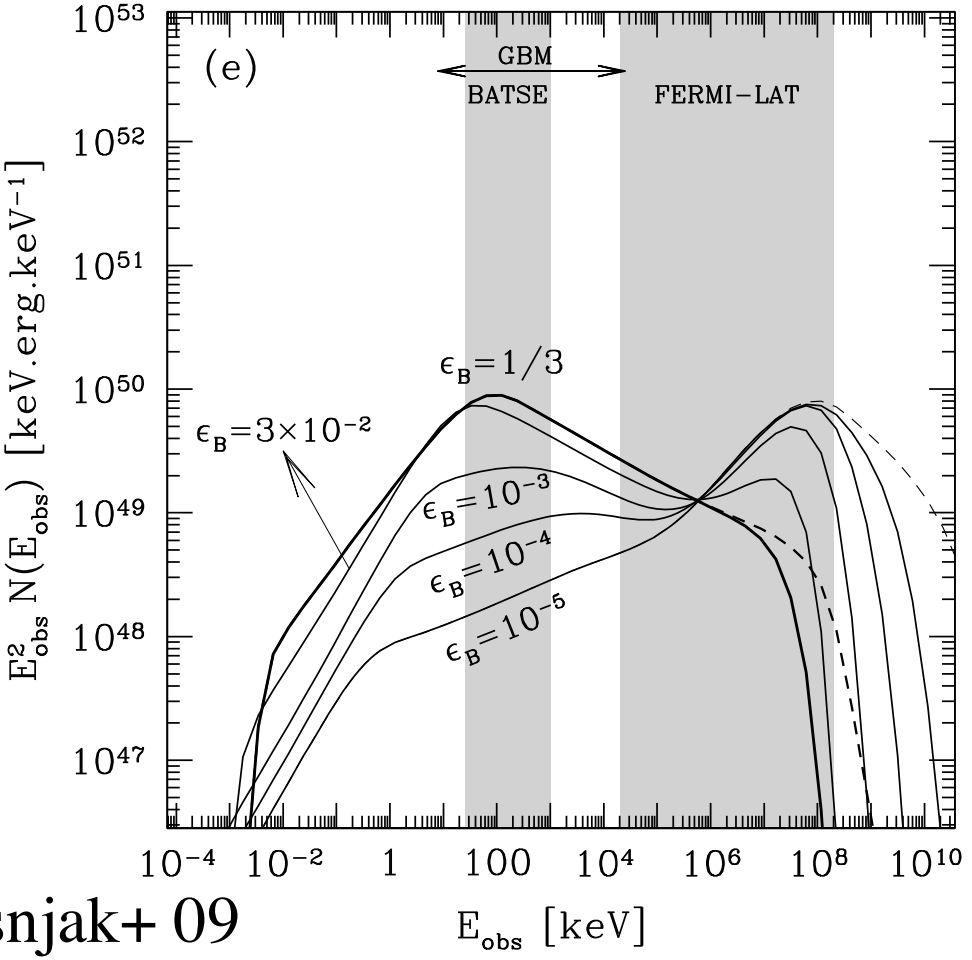
- bulk Lorentz factor: jet physical conditions, formation mechanism
- emission mechanism: internal shock? photosphere? B reconnection? …
- hadronic processes (UHECR/neutrino production)

heart of the action, but poorly understood

Bulk Lorentz factor

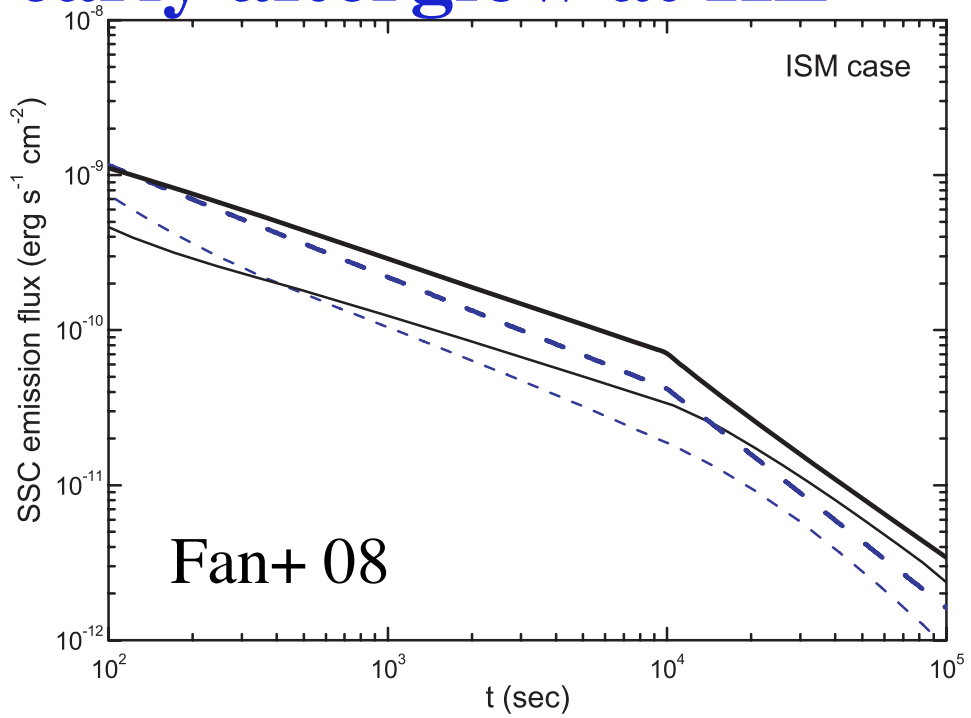


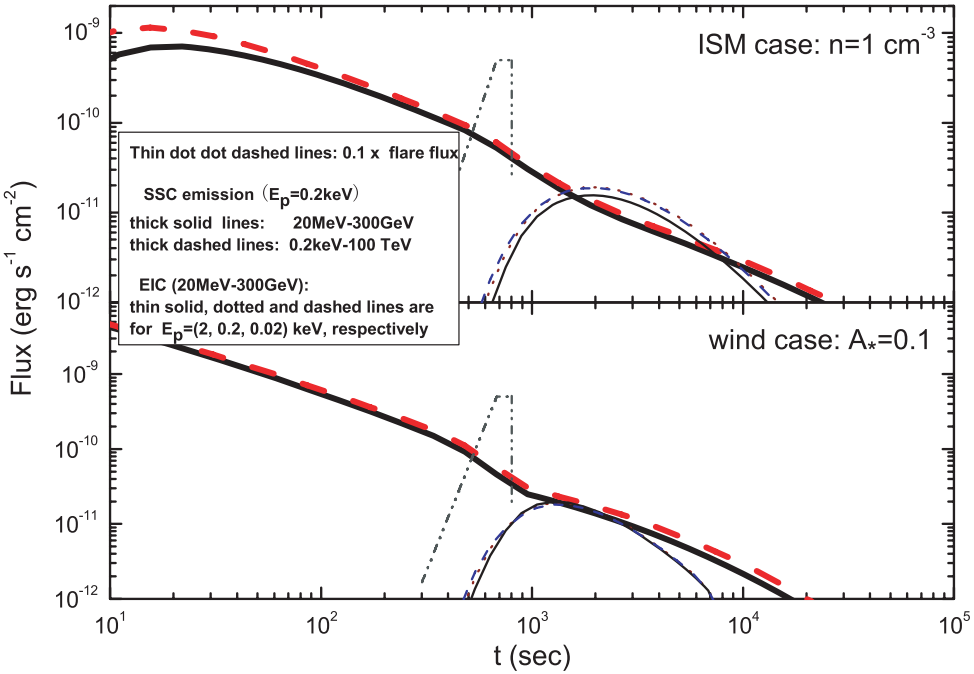
Fraction of energy injected in the magn. field



Bosnjak+ 09

early afterglow at HE





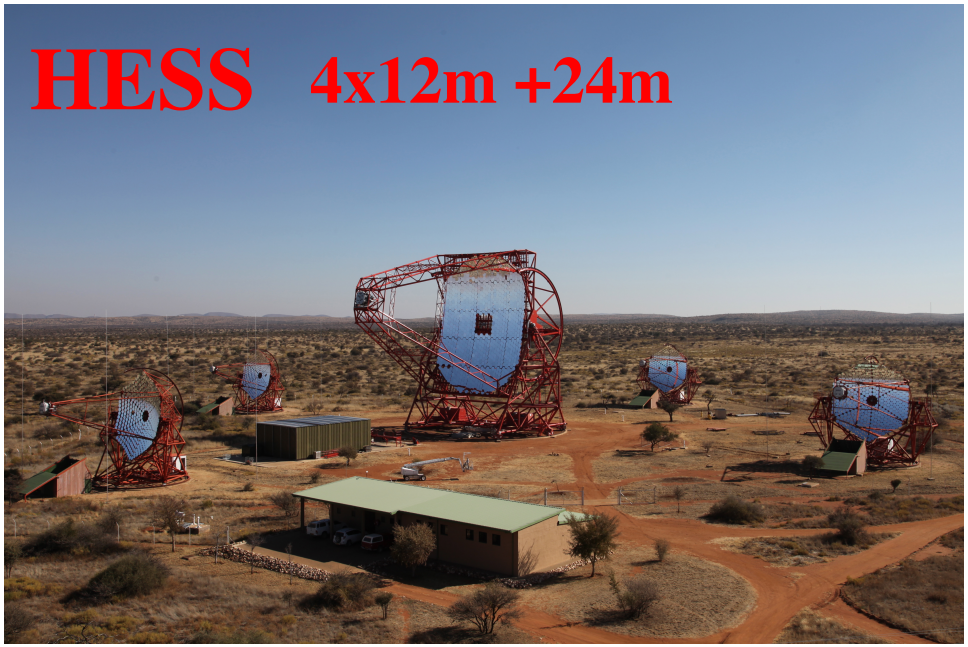
unsolved afterglow puzzles
shallow phase, flares…

solid: late-time energy injection
dashed: varying electron efficiency

flare EIC component

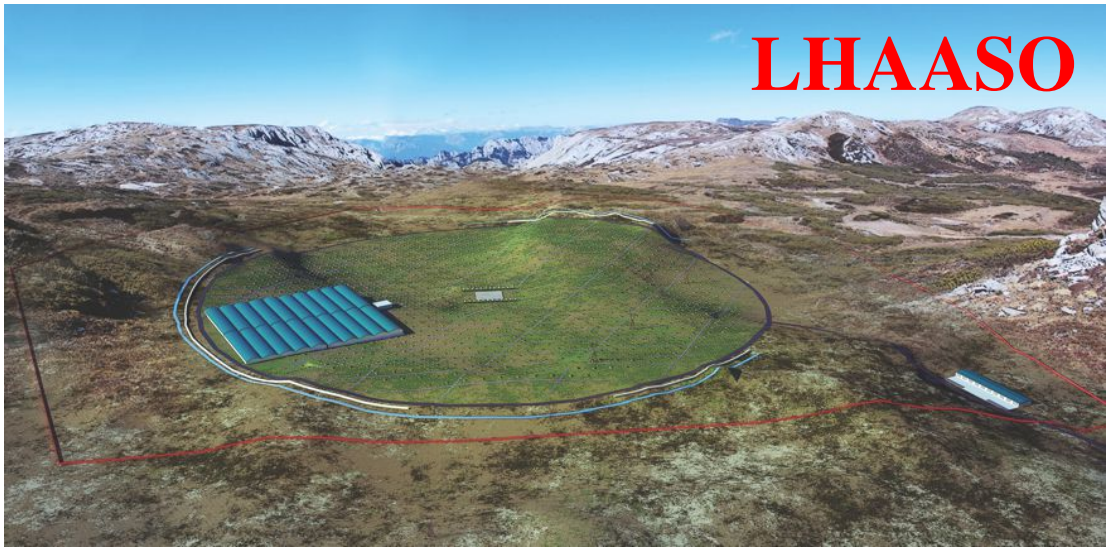
model-dep. GeV-TeV expectations
but not much progress with Fermi
->
clarify physics of early afterglow (+ engine) via VHE observations

ground-based gamma-ray telescopes: present IACTs



ground-based gamma-ray telescopes: present

ground-based gamma-ray telescopes: future



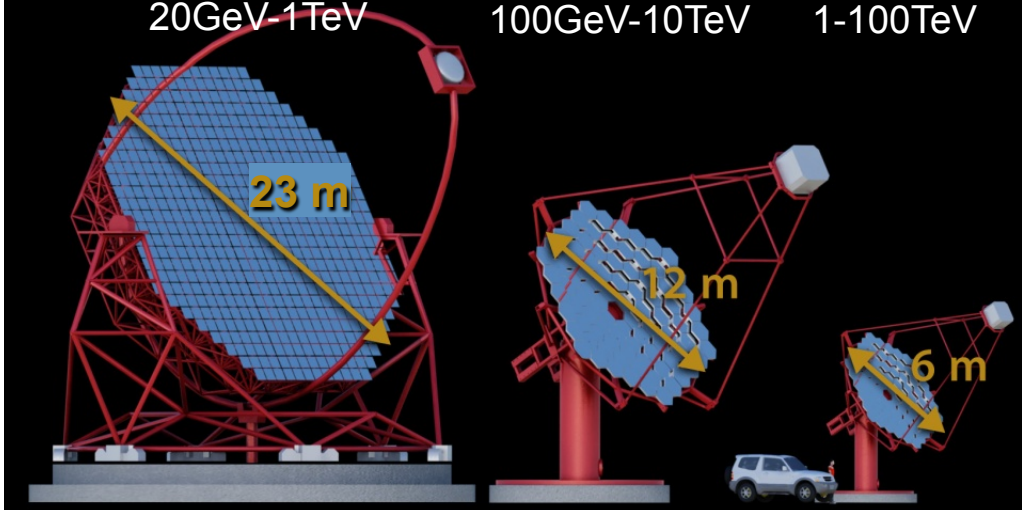
Cherenkov Telescope Array (CTA)

major, next generation
gamma-ray observatory

~20 GeV - 100 TeV+

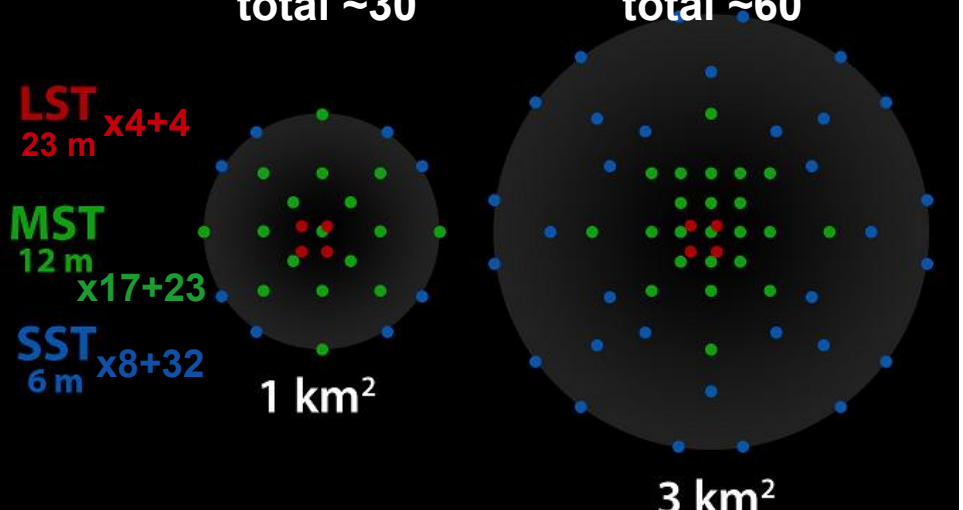
2015- begin construction
2016- early operation
2020- open observatory

fast slew 180deg/20s



La Palma

CTA - North
total ~30



Paranal

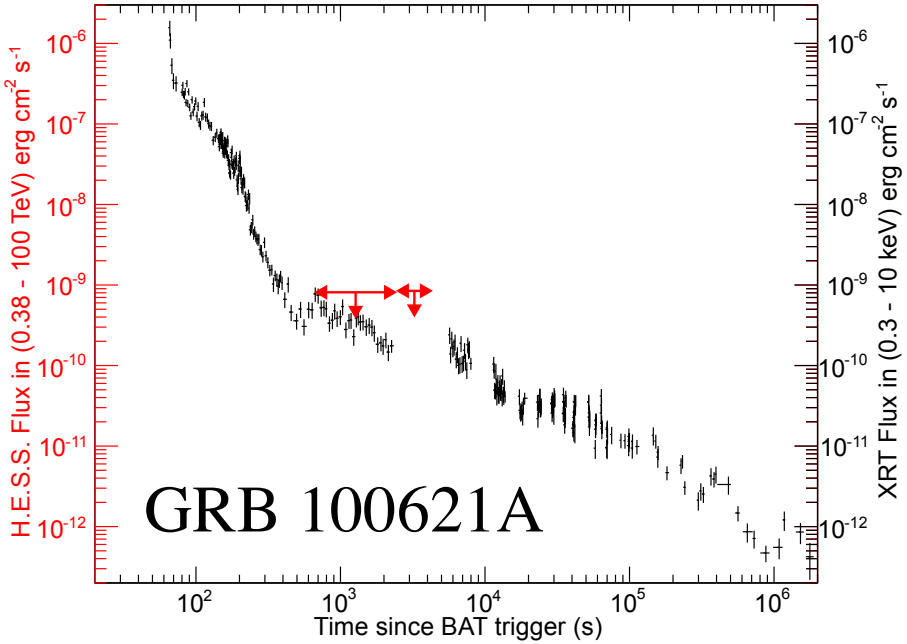
CTA - South
total ~60

ground-based gamma-ray telescopes: present results

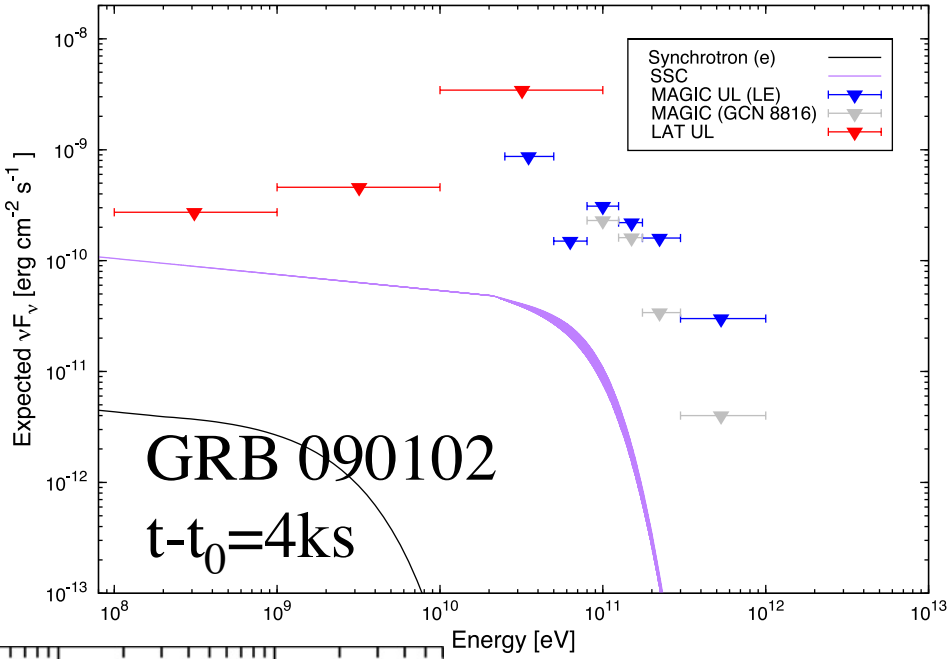
No detections so far…

ground-based gamma-ray telescopes: present results

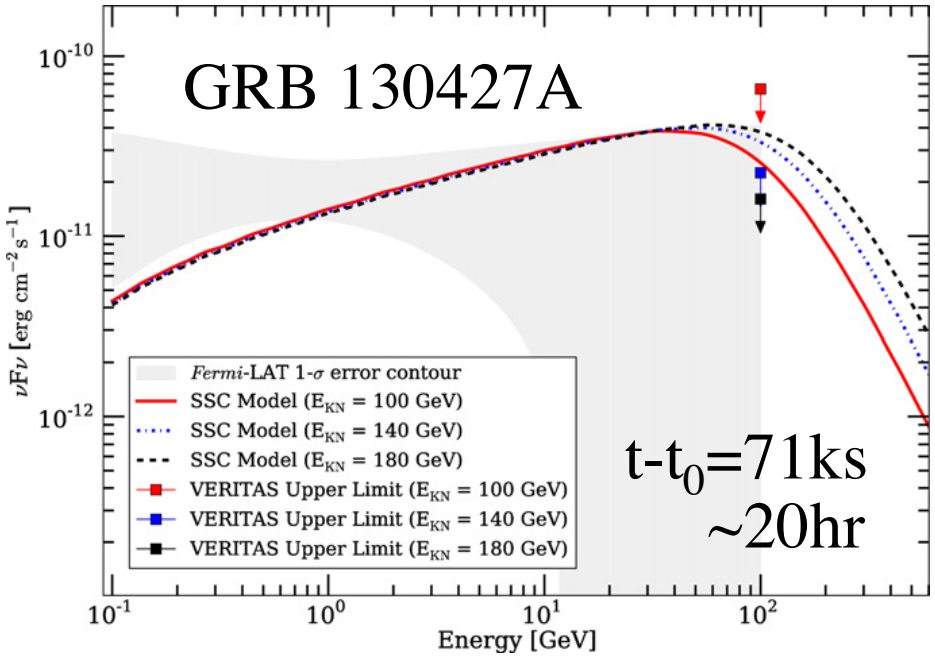
HESS Abramowski+ 2014



MAGIC+Fermi Aleksic+ 2014



VERITAS
Aliu+ 2014



GRB detection rate expectations

Kakuwa+ 12 Gilmore+ 13
SI+ 13

per site, x2 for N+S sites

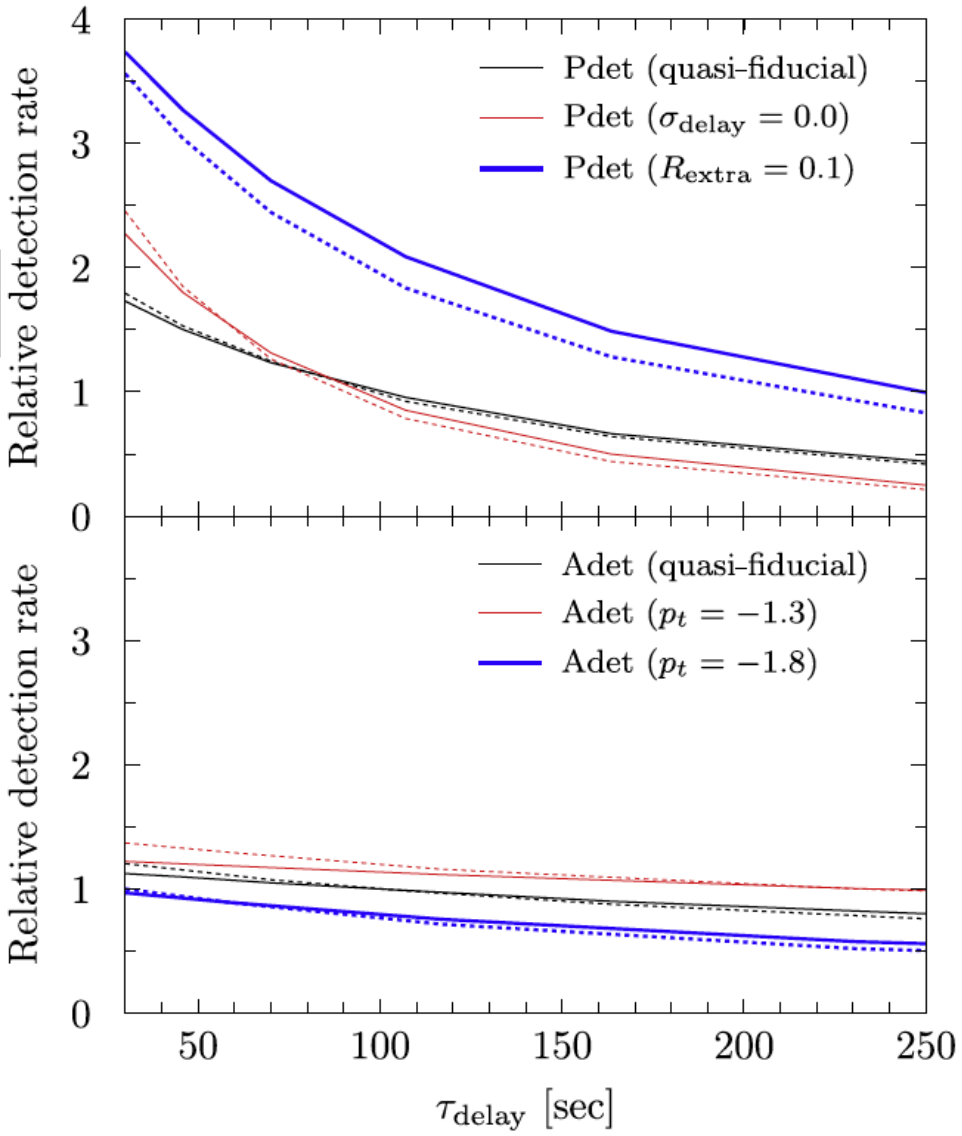
alert rate GRB facility

× θ_{zenith} fraction $0.25(\theta_{zen}<60)$

× duty cycle 0.1

× slewing+detection efficiency

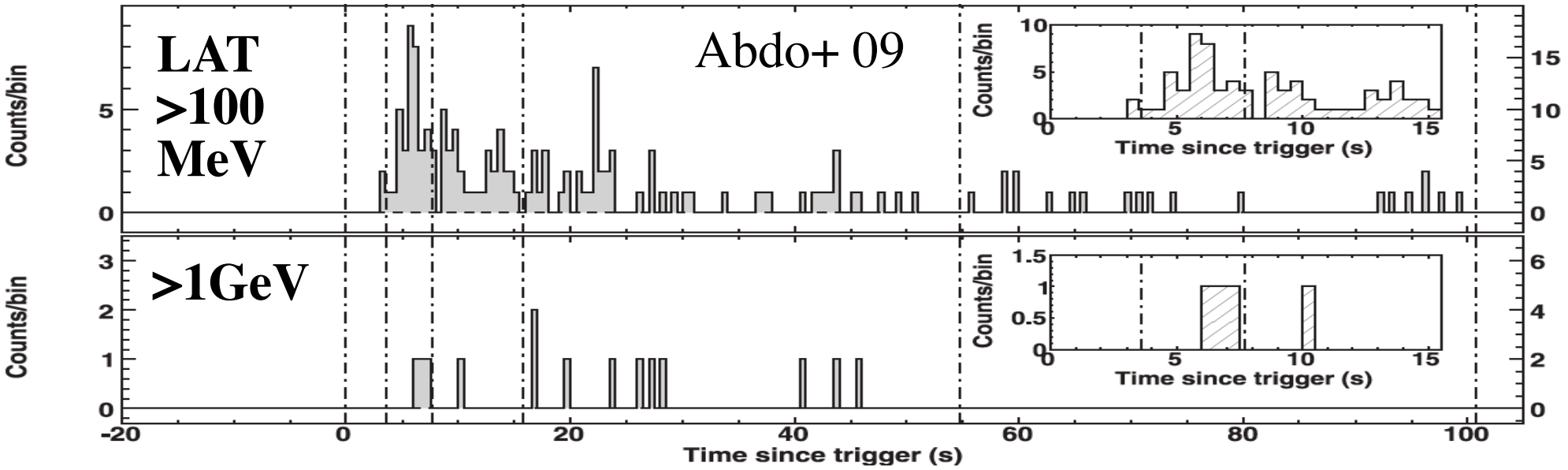
spectrum, T_{90} , luminosity, z dist.
EBL attenuation



of order ~1 detection/yr/site
mostly early afterglow phase
small fraction prompt phase

GRB light curve: Fermi vs CTA

GRB 080916C



GRB light curve: Fermi vs CTA

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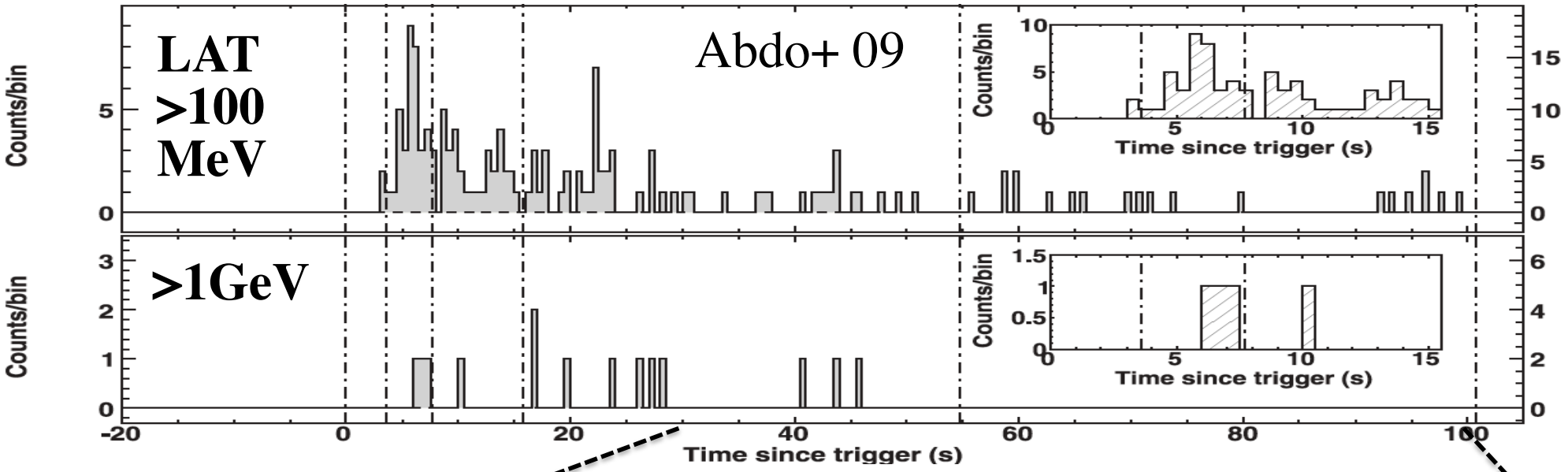
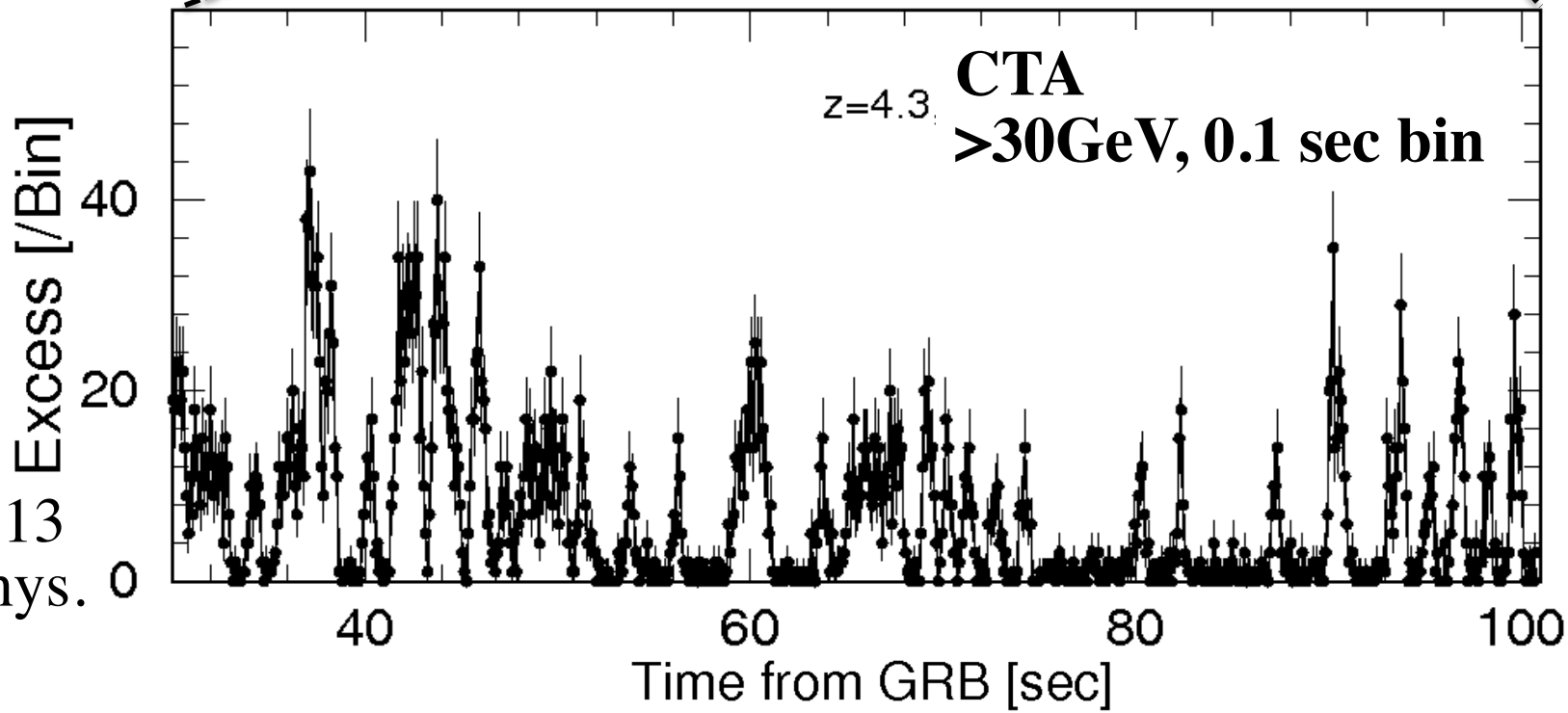
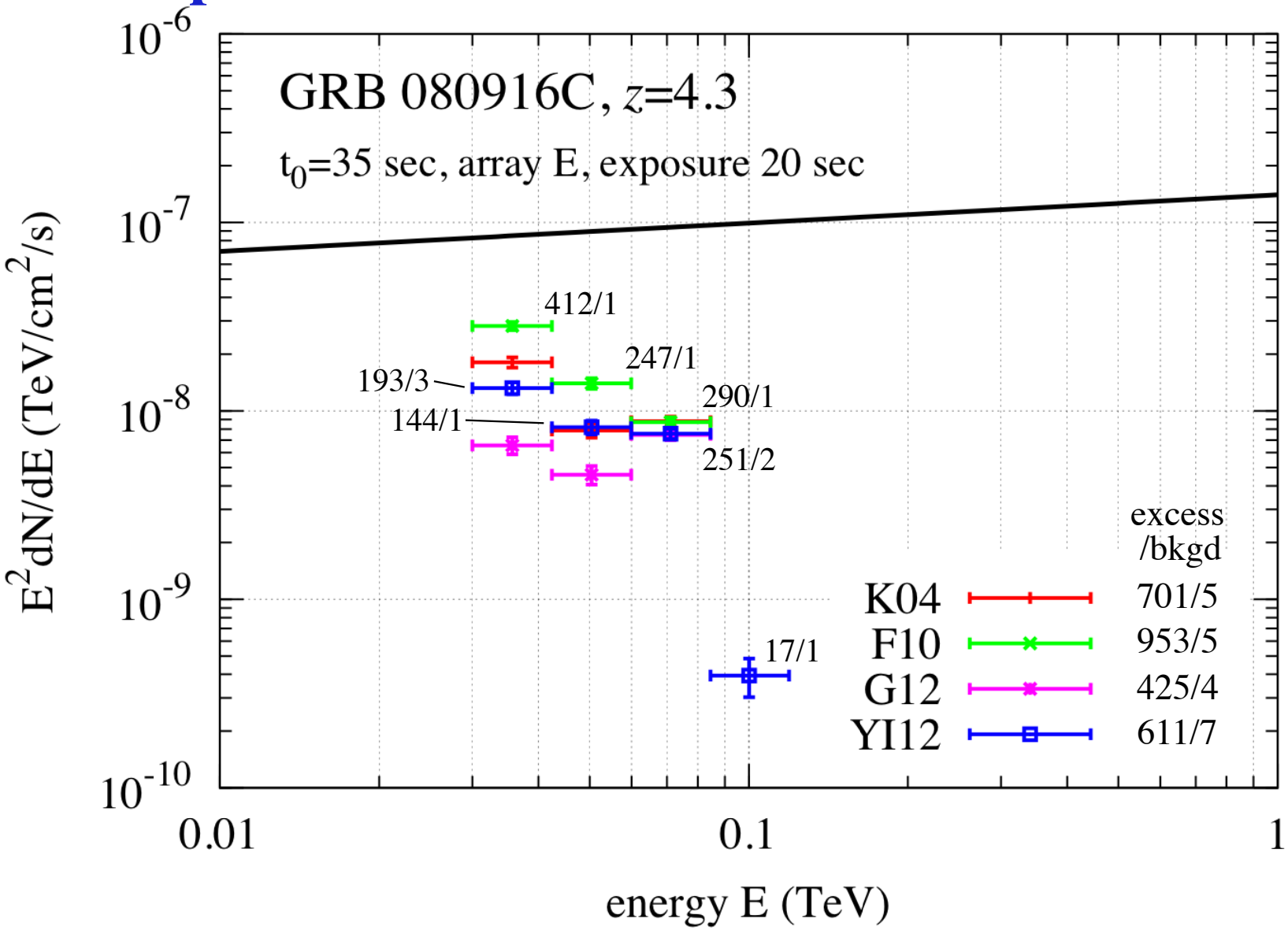




S. Inoue+ 2013
Astropart. Phys.
43, 252

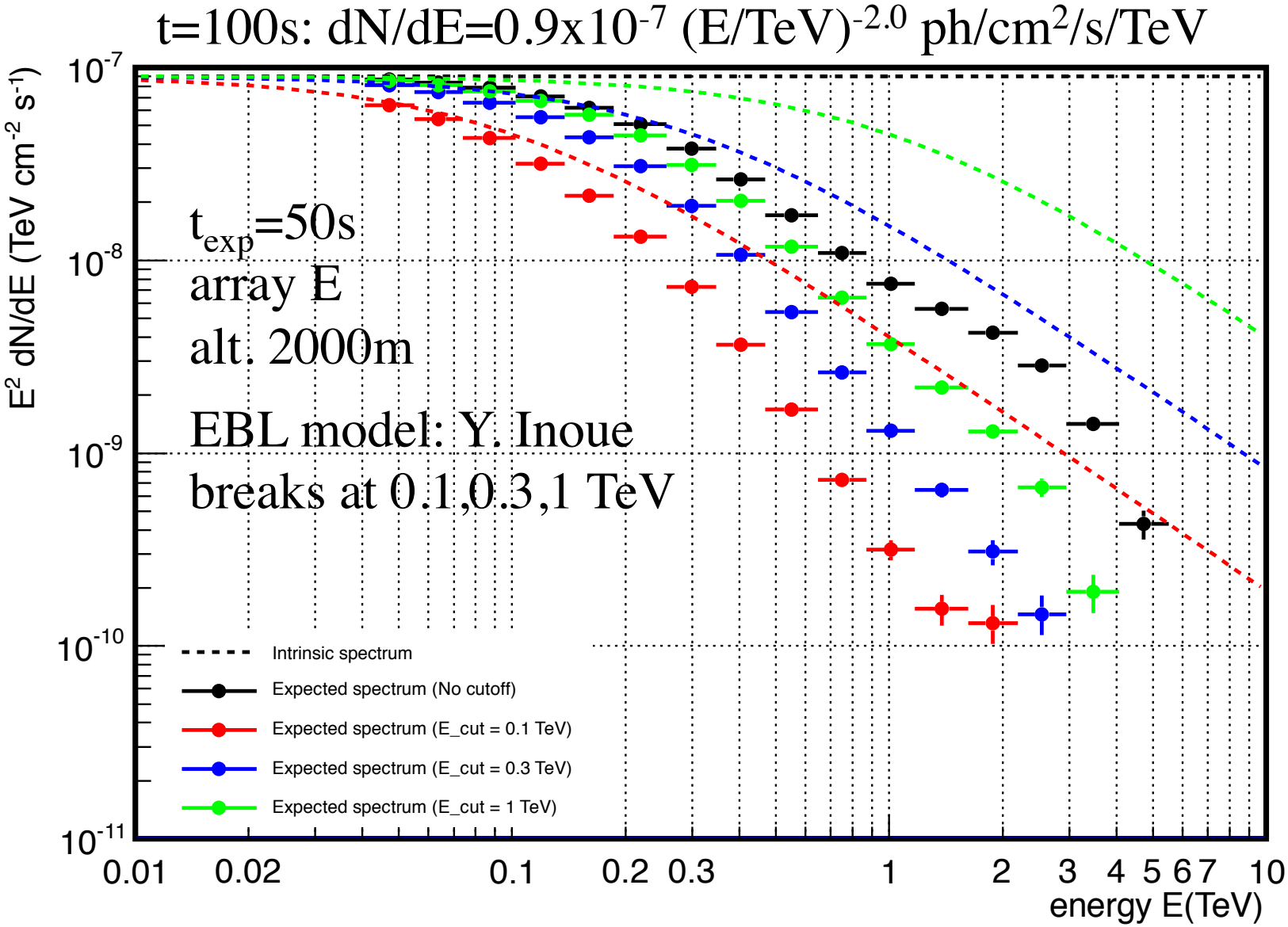
GRB spectra with CTA: GRB 080916C at z=4.3



Mazin+ 2013 Astropart. Phys. 43, 241

effective probe of extragalactic background light at high-z:
unique info on cosmic star/galaxy/QSO formation

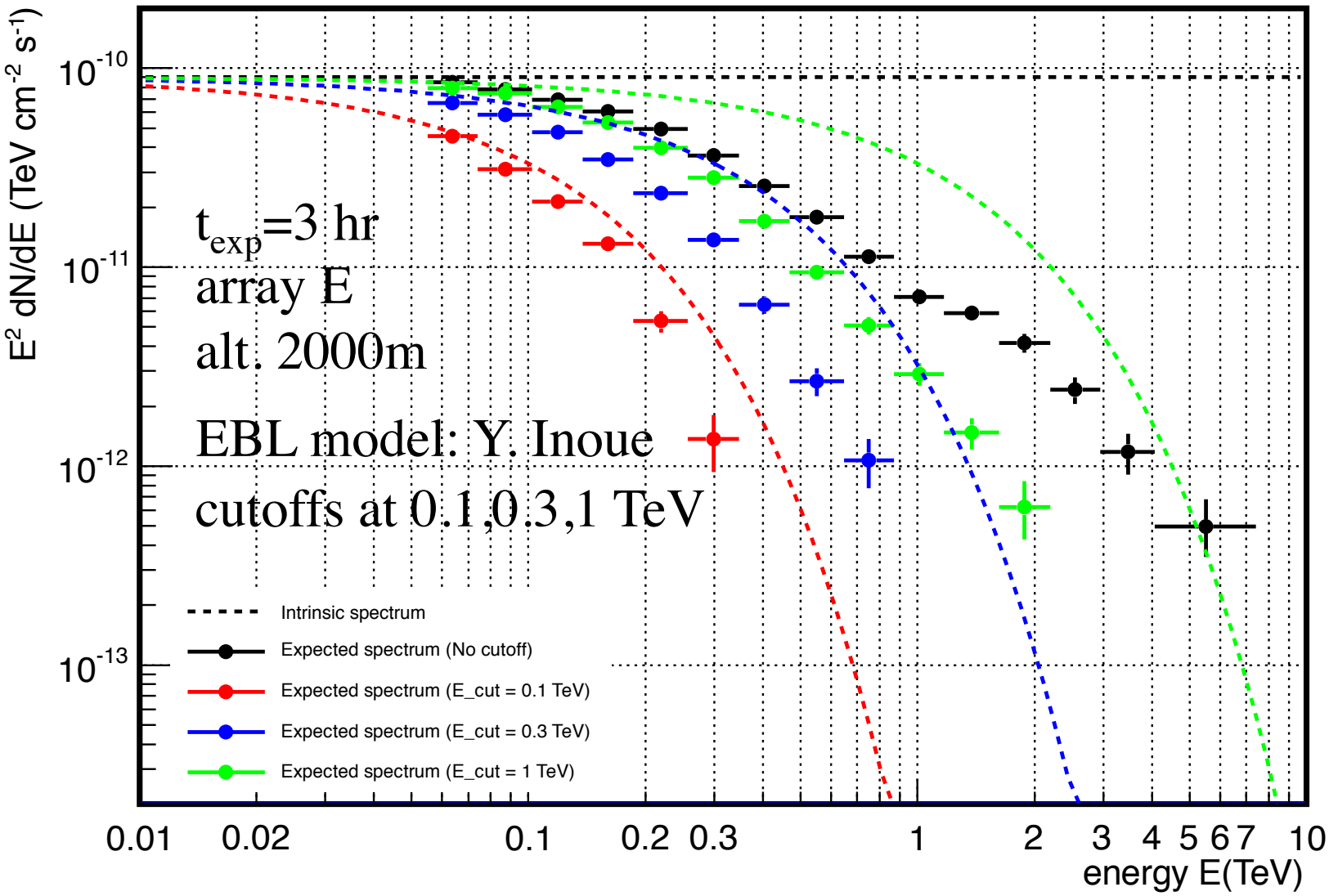
GRB spectra with CTA: GRB 130427A (z=0.34)



~43000-110000 photons, significance ~210-330 sigma

GRB spectra with CTA: GRB 130427A (z=0.34)

t=1 day: $dN/dE=0.9\times10^{-10}\ (E/TeV)^{-2.0}$ ph/cm^2/s/TeV

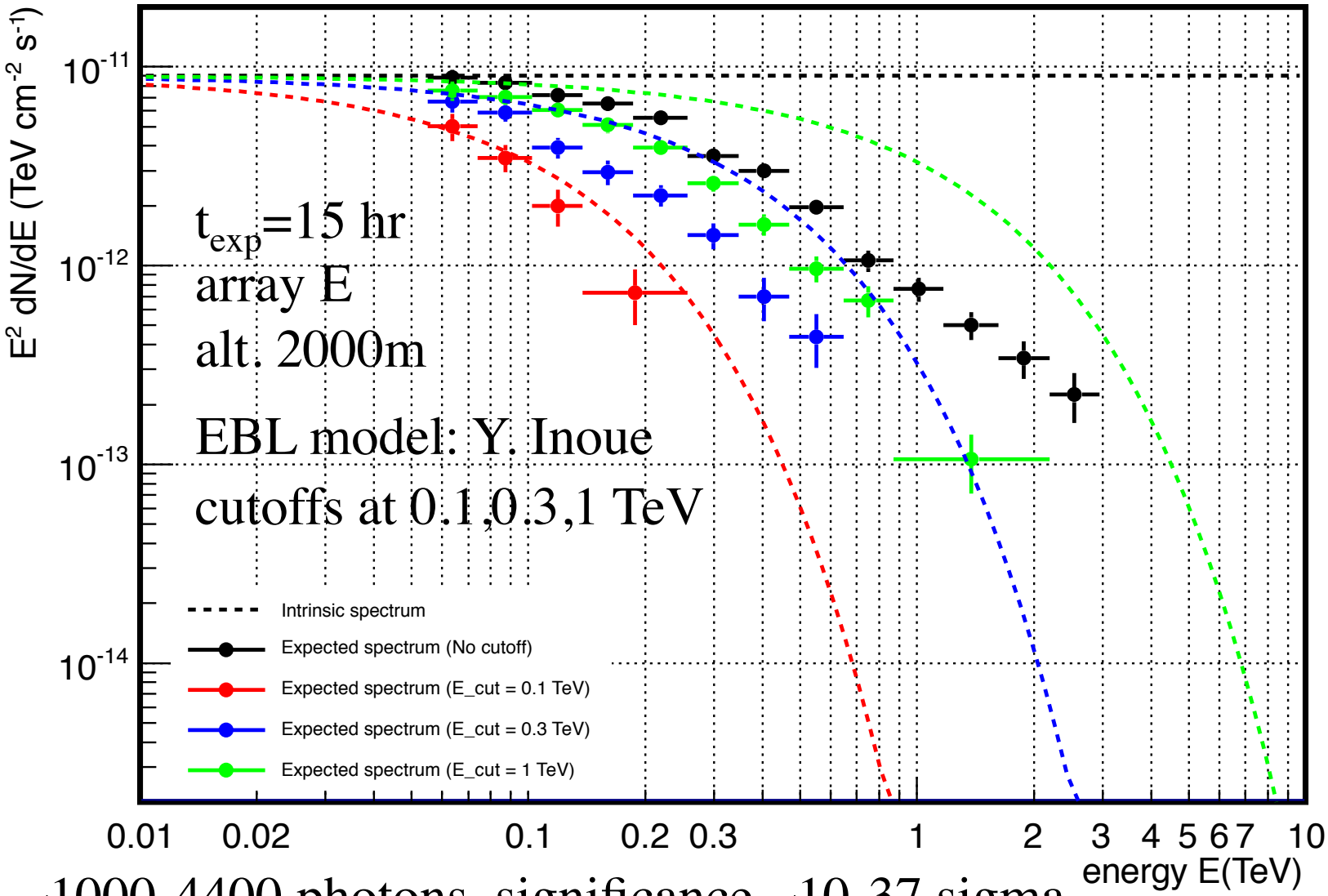


~2000-8400 photons, significance ~30-80 sigma

array B+3700m -> ~8500-10000 photons

GRB spectra with CTA: GRB 130427A (z=0.34)

t=10 day: $dN/dE=0.9\times10^{-11}\ (E/TeV)^{-2.0}$ ph/cm^2/s/TeV

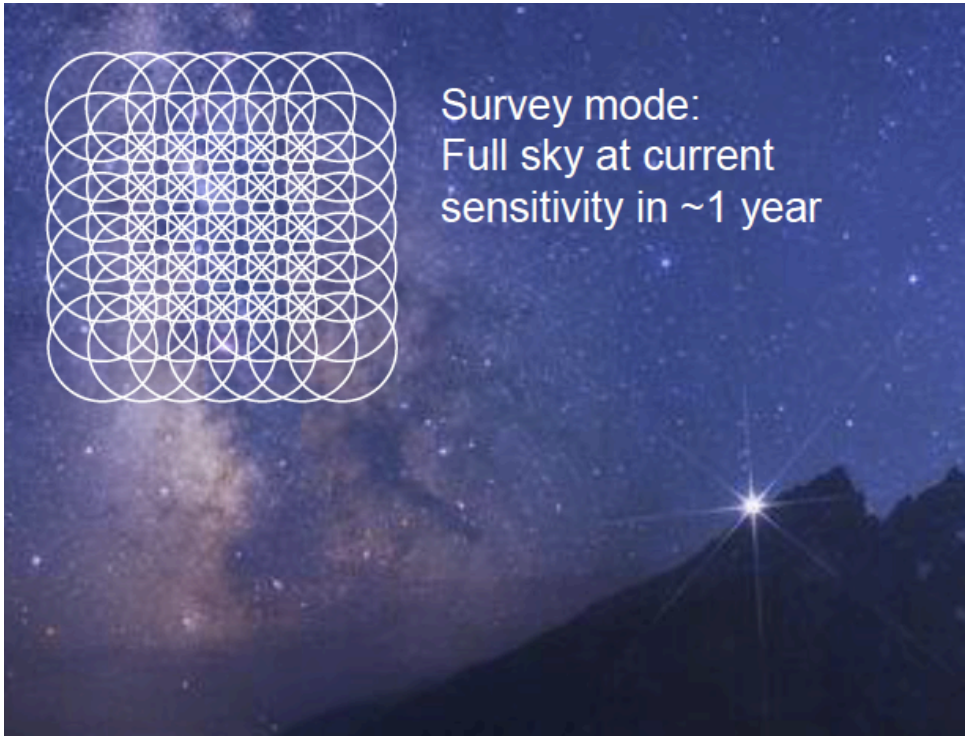


~1000-4400 photons, significance ~10-37 sigma

array B+3700m -> ~1100-5400 photons

detectable by current IACTs, under new Moon??

divergent pointing mode observations



- more effective for surveys of persistent point sources

- GRBs from onset
  prompt emission physics
  (crucial but poorly understood)
- short GRBs
  Lorentz inv. violation
  (big improvement over Fermi)
- unbiased transient survey
  e.g. fast radio bursts

GRBs occurring in FoV (not necessarily detectable):
GRB rate all sky ~800/yr (BAT), ~600/yr (GBM)
field of view ~1000 deg^2 (0.025 sky; 25MSTs, no gap)
duty cycle 10%
-> ~0.2-0.3 /100 hr -> ~1-2 GRBs /600 hr

summary

- IACTs much better sensitivity than Fermi for short exposures >tens of GeV
- solid science cases
  prompt+afterglow physics, UHECRs, high-z EBL, LIV…
- no detections yet by current facilities, but limits improving
- modest expected event rate
- even with ~event/year, with perseverance, great prospects for CTA as well as current facilities