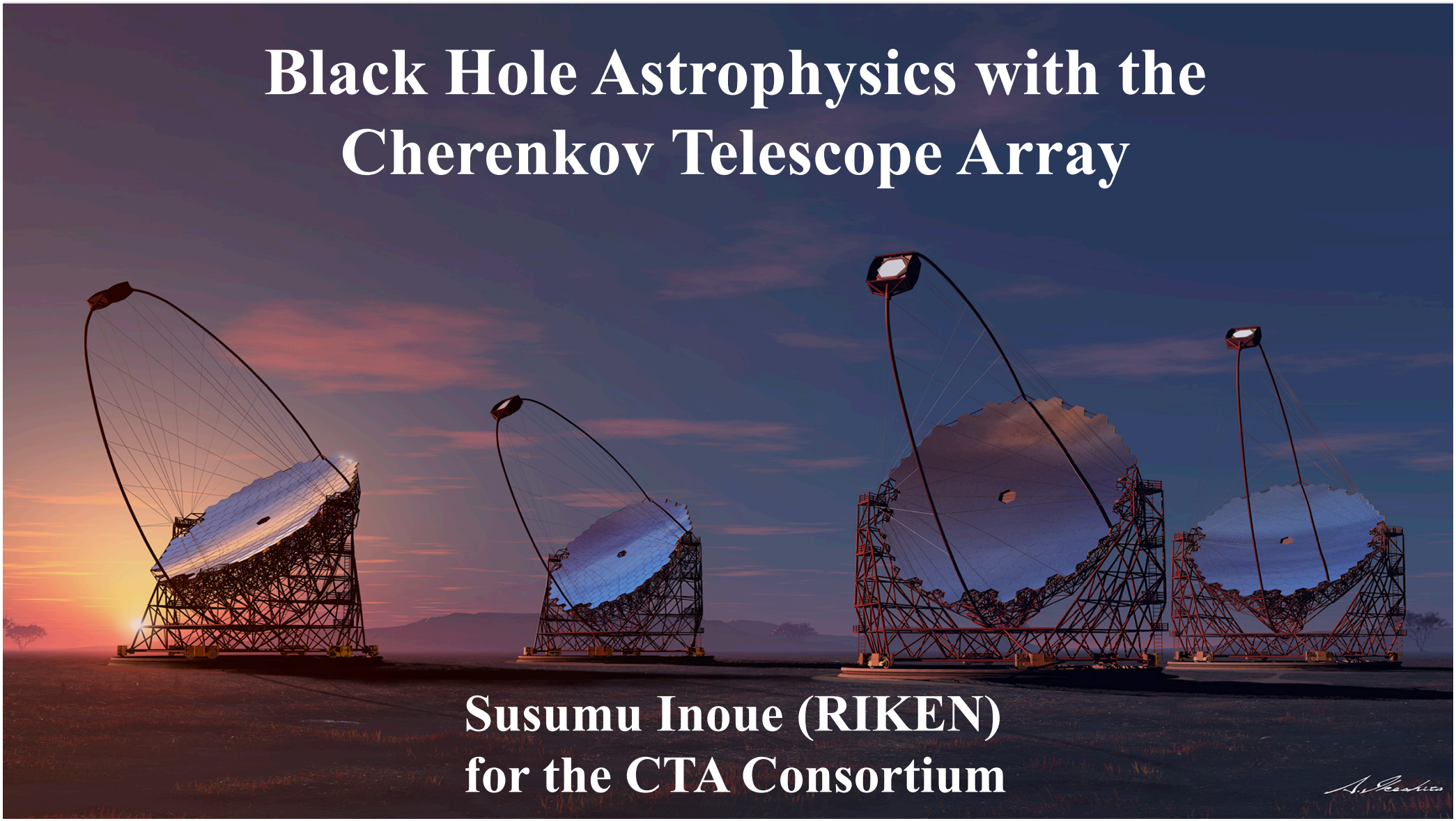
cherenkov telescope array

Black Hole Astrophysics with the Cherenkov Telescope Array



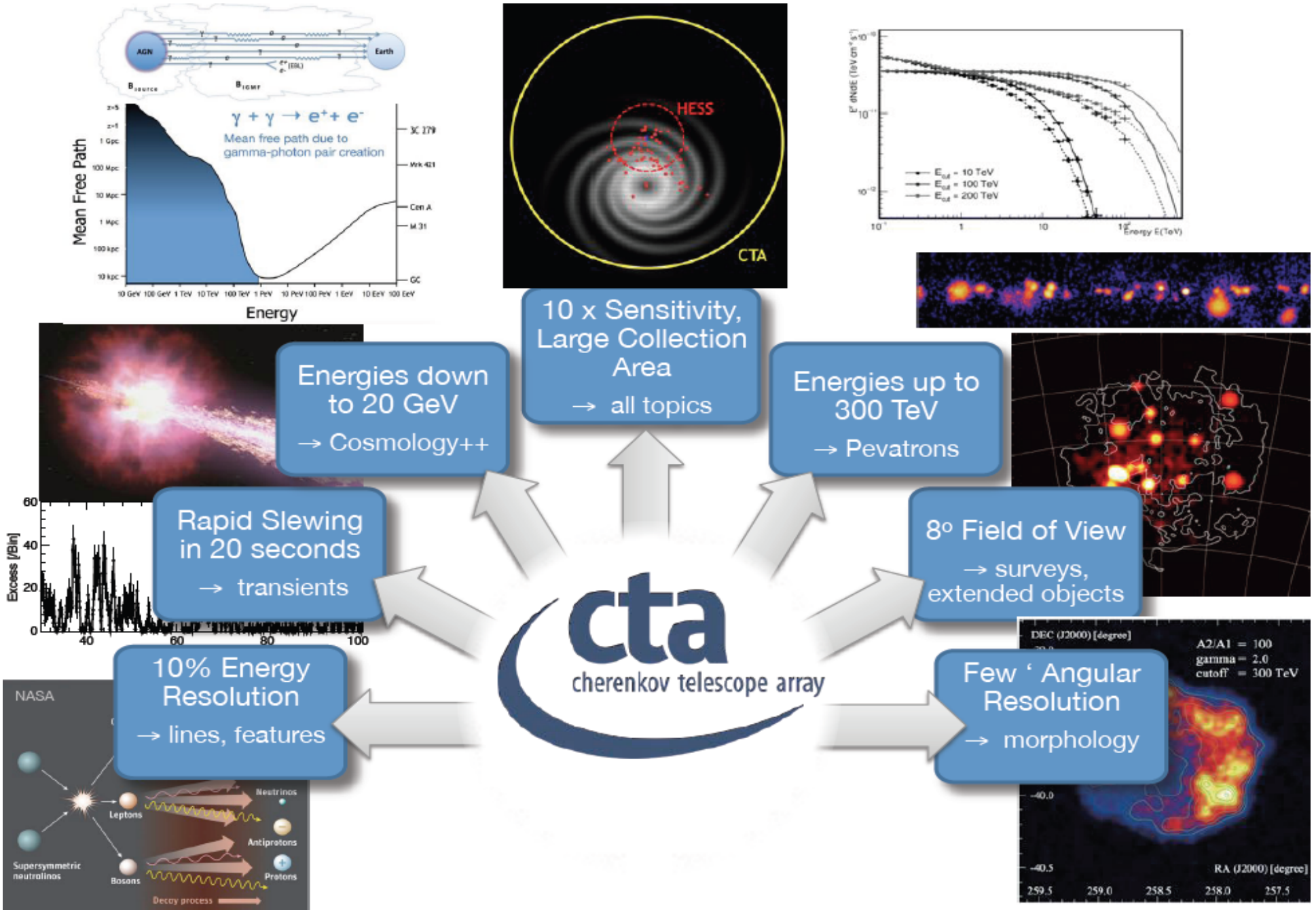
Susumu Inoue (RIKEN)
for the CTA Consortium

Outline

- **The Cherenkov Telescope Array**
- **Active Galactic Nuclei**
- **Gamma-Ray Bursts**
- **Microquasars, Other Transients**
- **Extragalactic Survey**
- **Summary**

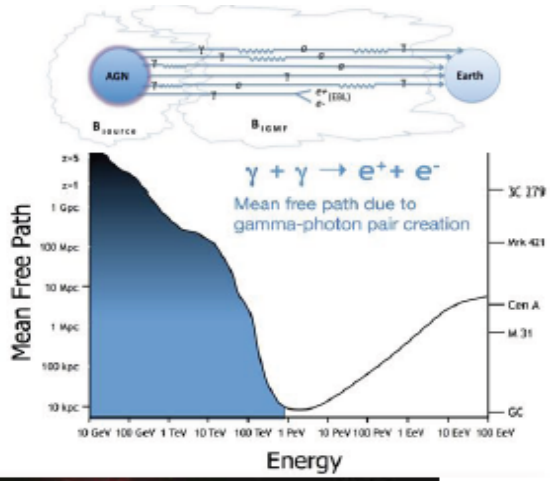
Figures from “Science with CTA” document
(to be published soon) unless noted otherwise

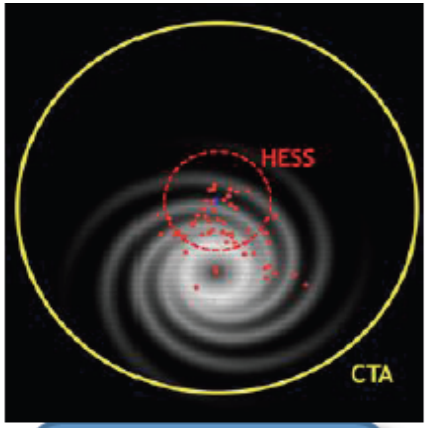

The Cherenkov Telescope Array
- Array of state-of-the-art IACTs
- Combination of large-, middle-, small-sized telescopes for wide energy coverage
- 2 sites in N & S for all-sky coverage
- Open observatory for the community (some fraction of time allocated for Consortium Key Science Projects)
LSTs: 4 N, 4 S
20 - 200 GeV
4.5 deg FoV
MSTs: 25(+24)S, 15 N
100 GeV - 10 TeV
8 deg FoV
SSTs: 70 S
few TeV - 300 TeV
9-10 deg FoV
adapted from W. Hofmann, S. Vercellone

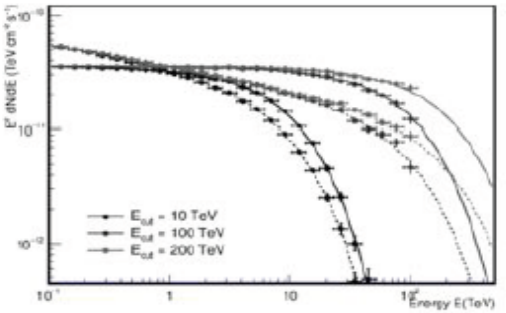


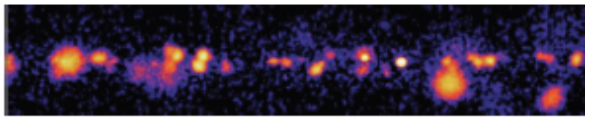
CTA vs current IACTs

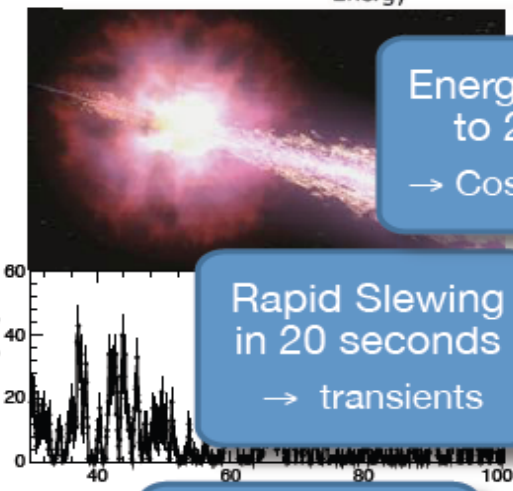
from W. Hofmann

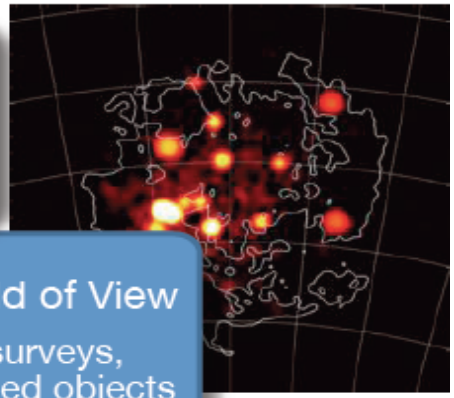












Energies down to 20 GeV
→ Cosmology++

10 x Sensitivity, Large Collection Area
→ all topics

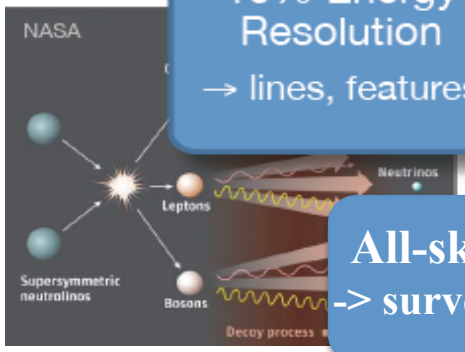
Energies up to 300 TeV
→ Pevatrons

Rapid Slewing in 20 seconds
→ transients

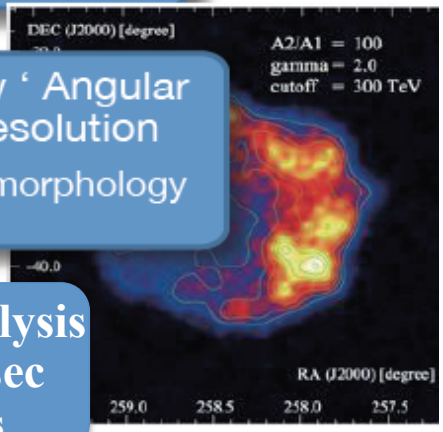
8° Field of View
→ surveys, extended objects

cta
cherenkov telescope array

10% Energy Resolution
→ lines, features



Few ' Angular Resolution
→ morphology



All-sky Coverage
-> surveys, transients

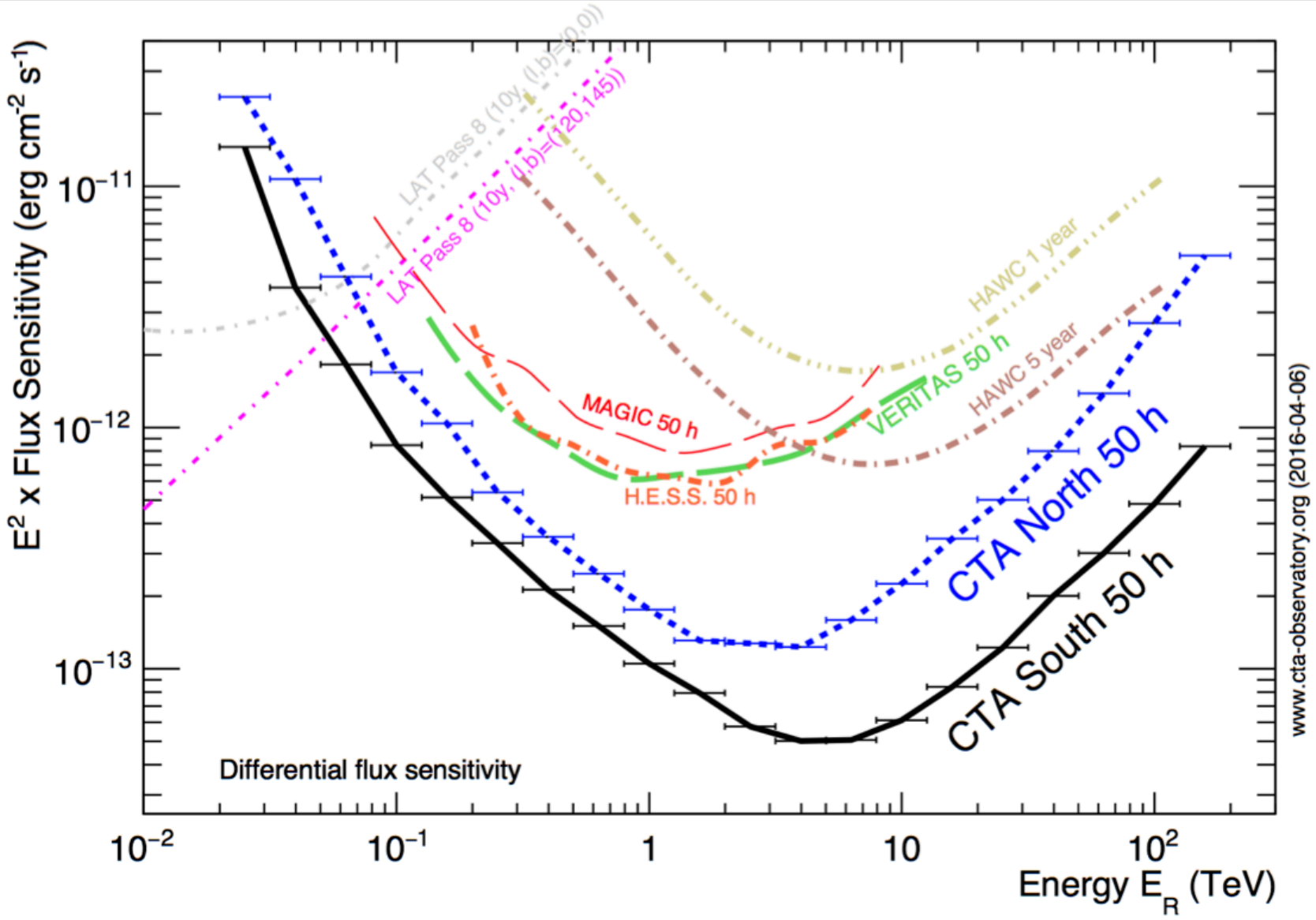
Versatile Pointing
(subarrays, divergent)
-> surveys, transients

Real Time Analysis
Alerts in 30 sec
-> transients

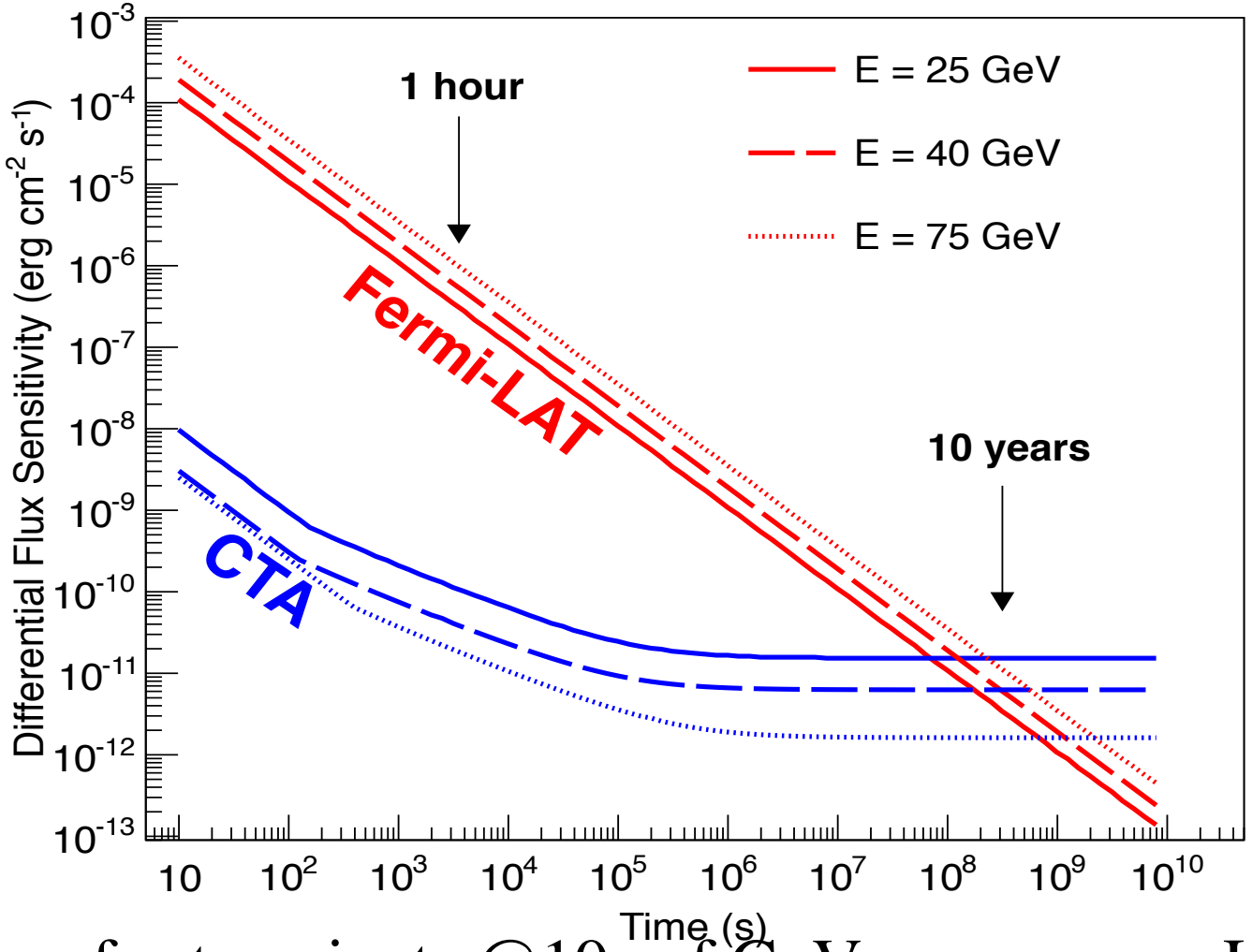
CTA vs current IACTs

adapted from W. Hofmann

CTA Sensitivity (steady sources)



CTA Sensitivity vs Fermi



Pros:

Big advantage for transients @10s of GeV

effective area ~10^4 x LAT@30GeV

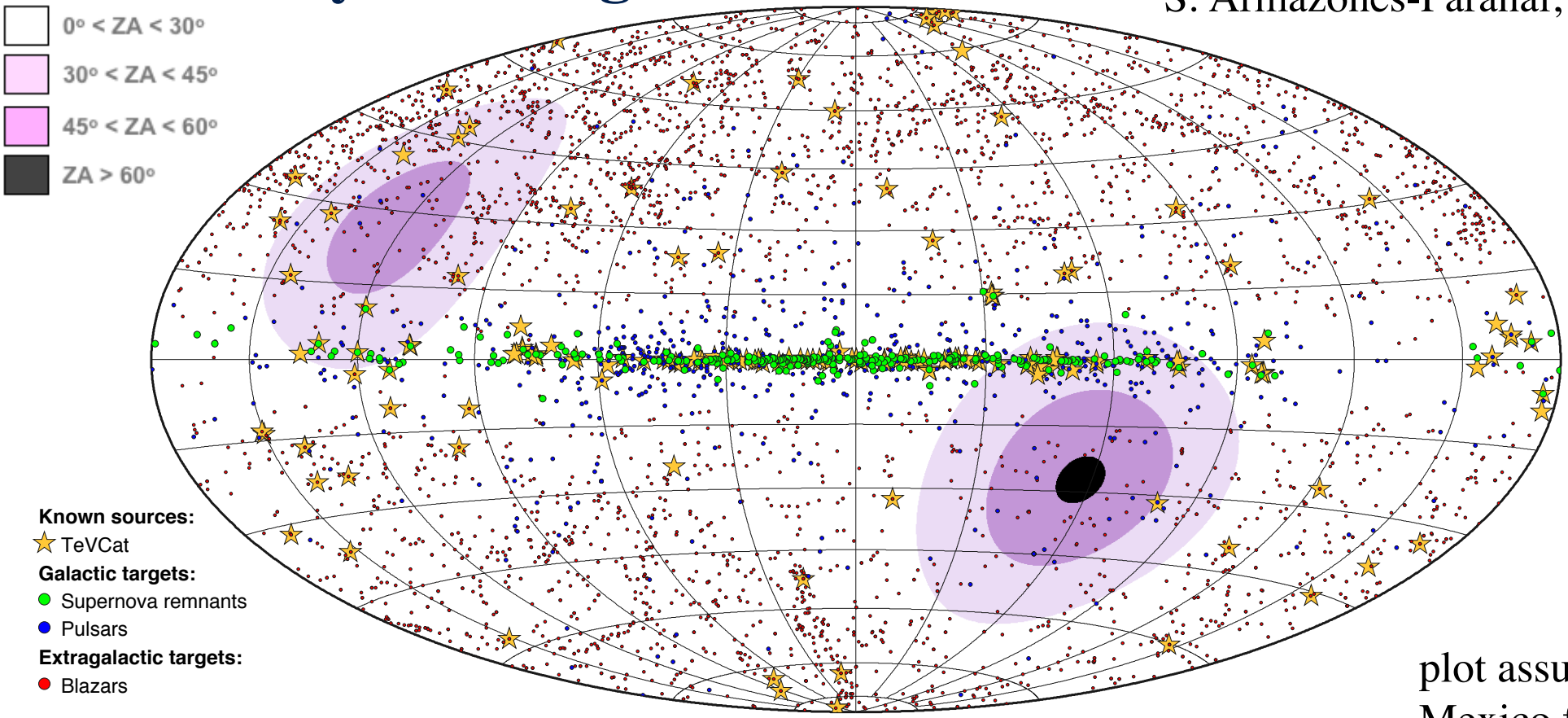
Cons:

Limited FoV

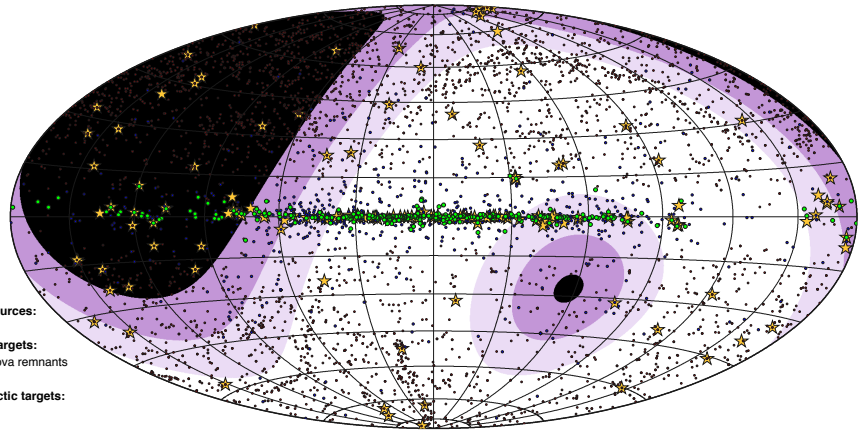
Limited duty cycle

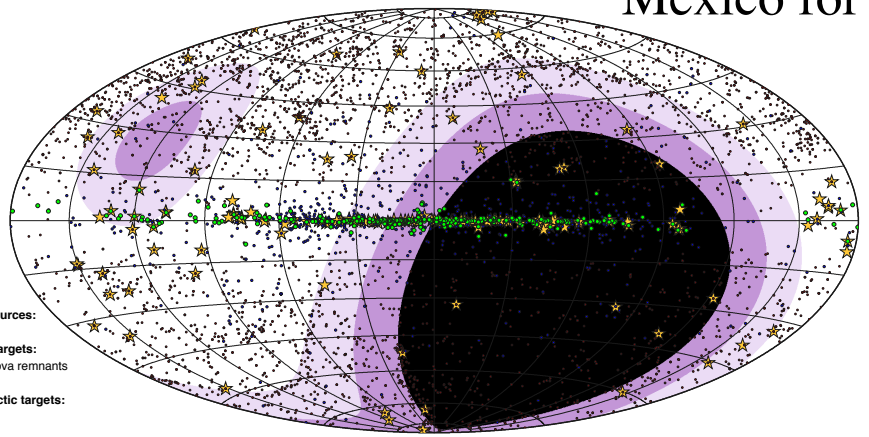
All Sky Coverage

N: La Palma, Canary Is.
S: Armazones-Paranal, Chile

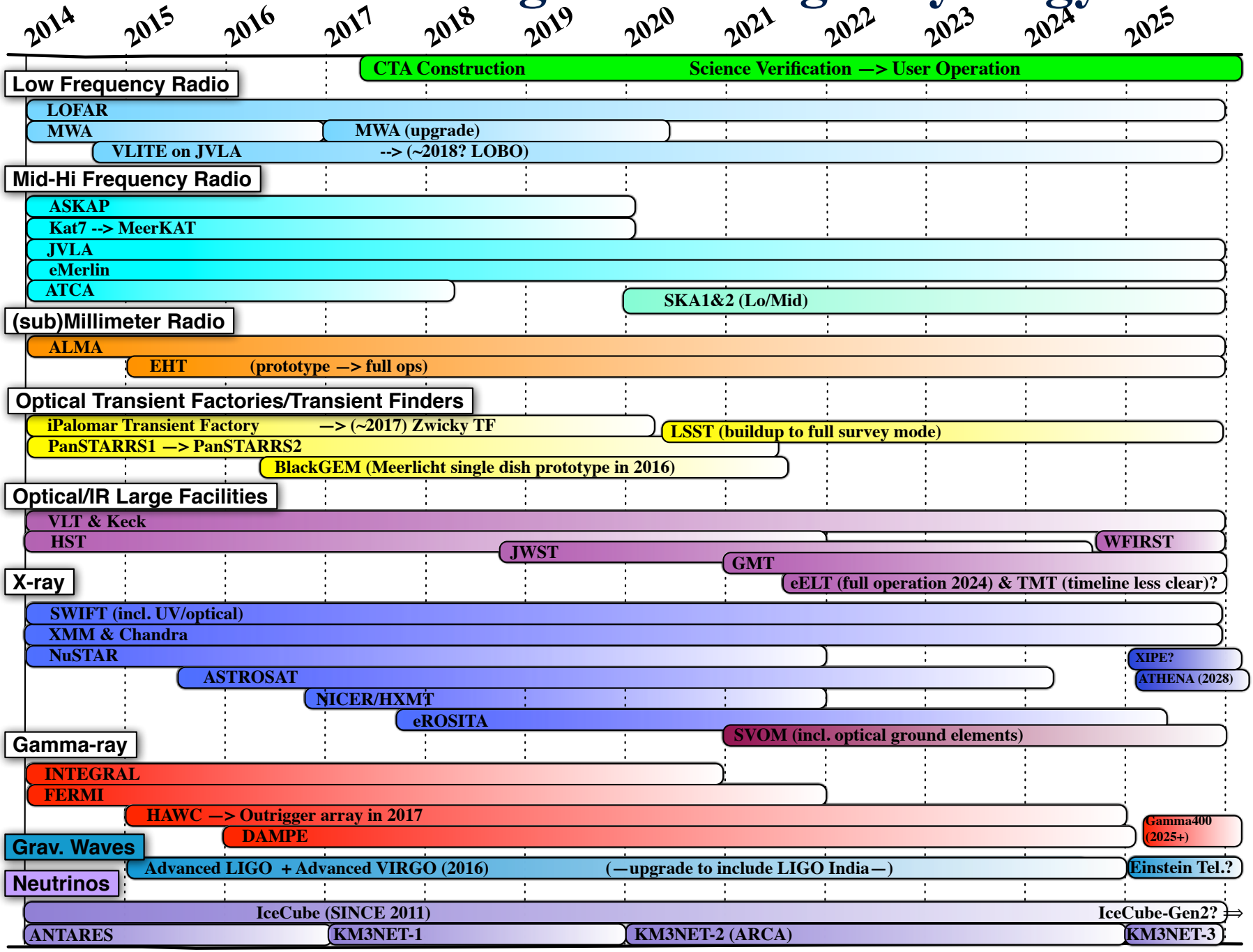


plot assumes
Mexico for N





Multi-wavelength/messenger Synergy



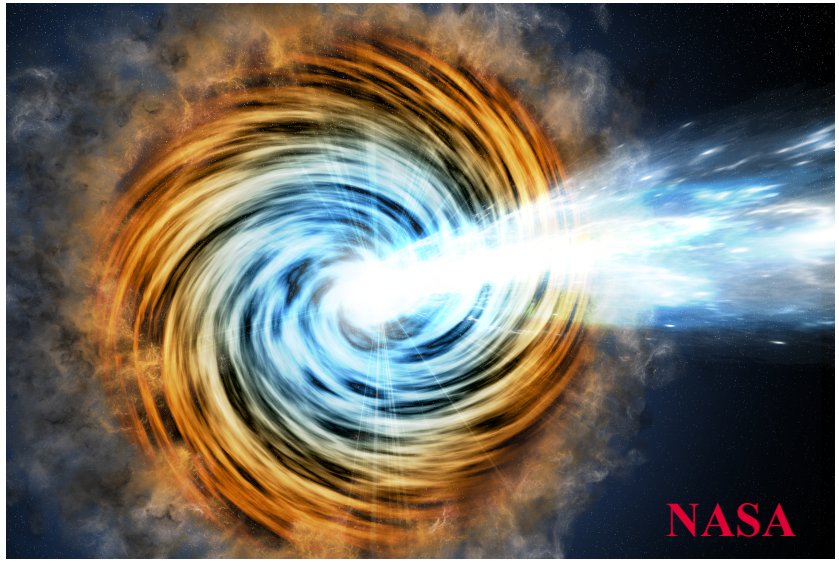
CTA Key Science Projects

- **Dark Matter Programme**
- **Galactic Centre**
- **Galactic Plane Survey**
- **Large Magellanic Cloud Survey**
- **Extragalactic Survey**
- **Transients**
- **Cosmic Ray PeVatrons**
- **Star Forming Systems**
- **Active Galactic Nuclei**
- **Clusters of Galaxies**
- **Non-Gamma-ray Science**

Details in document
"Science with CTA"
to be published on arXiv

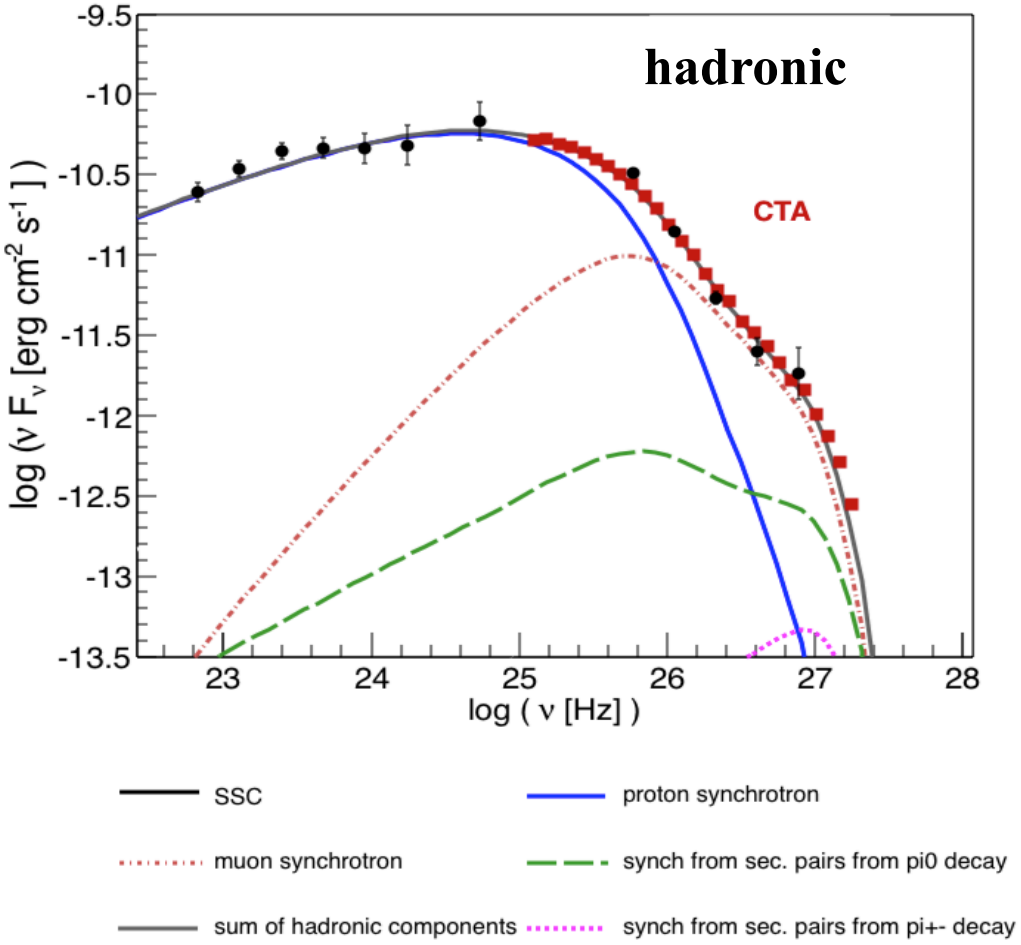
Active Galactic Nuclei

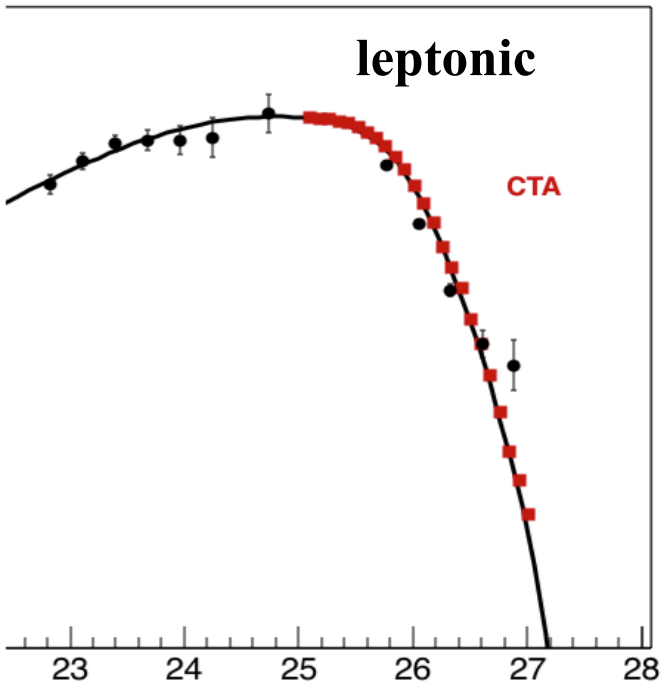
- **Physics of relativistic jets from supermassive BHs**
  - Mechanisms: emission, particle acceleration, energy dissipation, jet formation
  - Demography: origin of diversity, search for new classes
- **Tools to probe the Universe**
  - Extragalactic background light (star formation history, etc)
  - Intergalactic magnetic fields
- **Tests of UHECR origin, fundamental physics**
  Search for signatures of:
  - Accelerated hadrons
  - Lorentz invariance violation, Axion-like particles



Active Galactic Nuclei

- **Clarify physics of emission, particle acceleration**
- **Test UHECR origin** high S/N spectra + variability



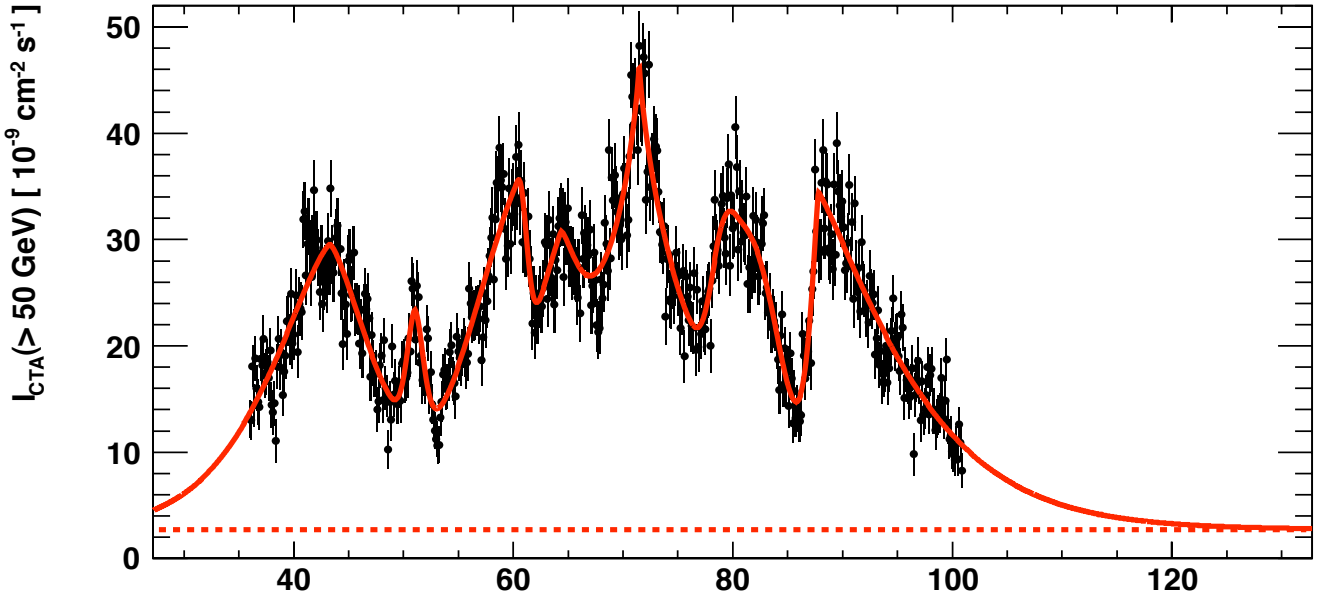


PKS 2155-304

- H.E.S.S. data
- 33hr CTA simulation

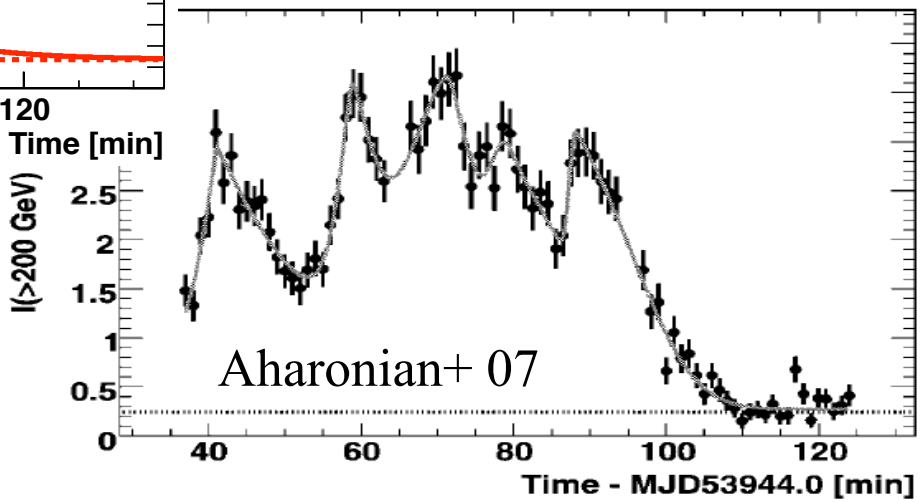
Active Galactic Nuclei

- **Clarify physics of emission, particle accel., energy dissipation**
- **Test LIV** high S/N light curves



CTA simulation
Δt_{min}~25 sec

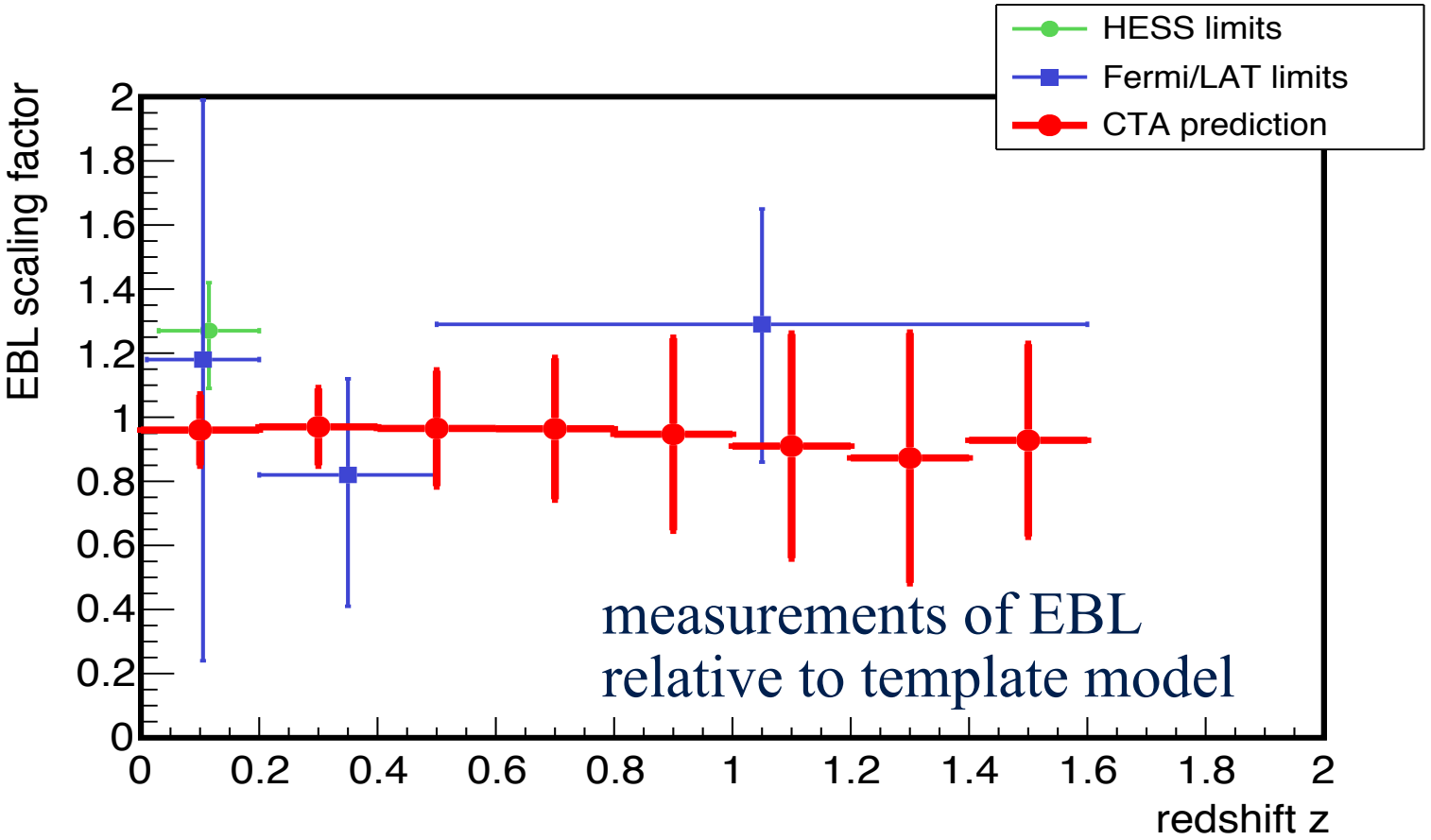
PKS 2155-304
HESS obs.
Δt_{min}~3 min

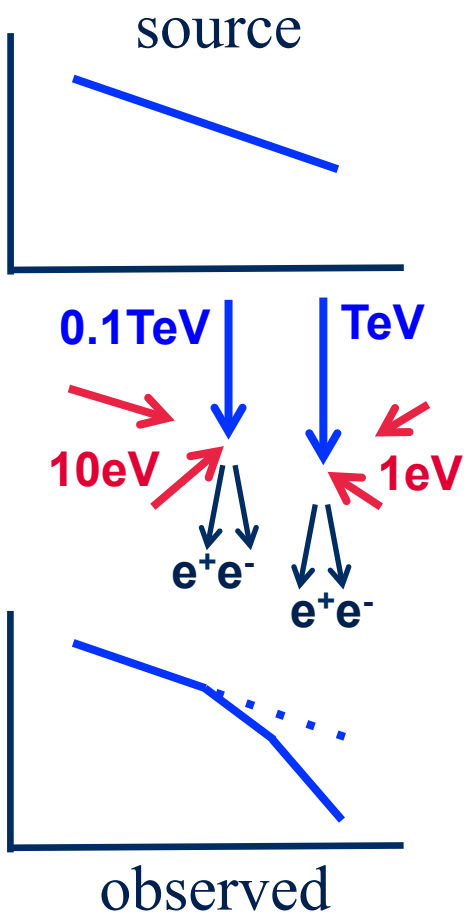


Active Galactic Nuclei

- **Probe evolution of optical/IR EBL via γγ spectral attenuation global view of star/galaxy formation & evolution**

high S/N spectra for large sample with different z



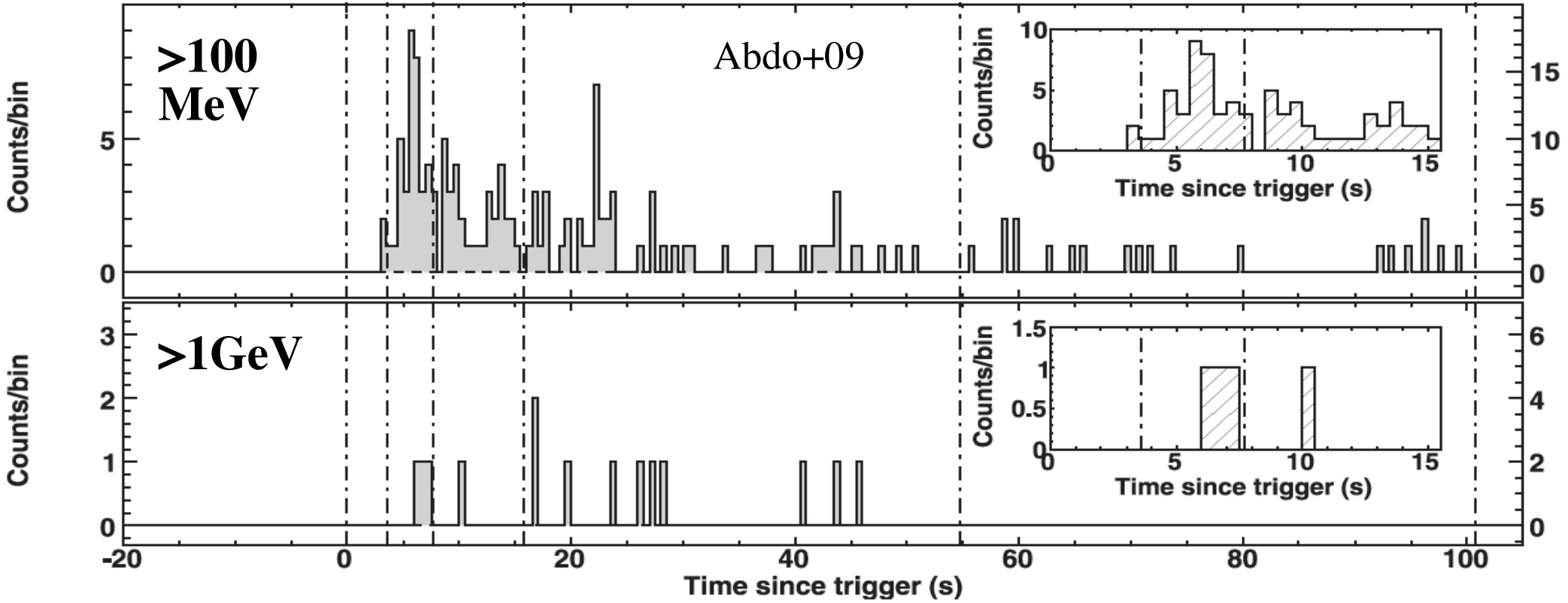


Gamma-Ray Bursts

- **Physics of GRBs**
  - Prompt: mechanism, jet properties, central engine (NS or BH?)
  - Early afterglow: mechanism (plateau phase), particle acceleration, B field generation
- **Tools to probe the Universe**
  - Extragalactic background light (deeper than AGN)
  - Intergalactic magnetic fields
- **Tests of UHECR origin, fundamental physics**
  Search for signatures of:
  - Accelerated hadrons
  - Lorentz invariance violation

Gamma-Ray Bursts

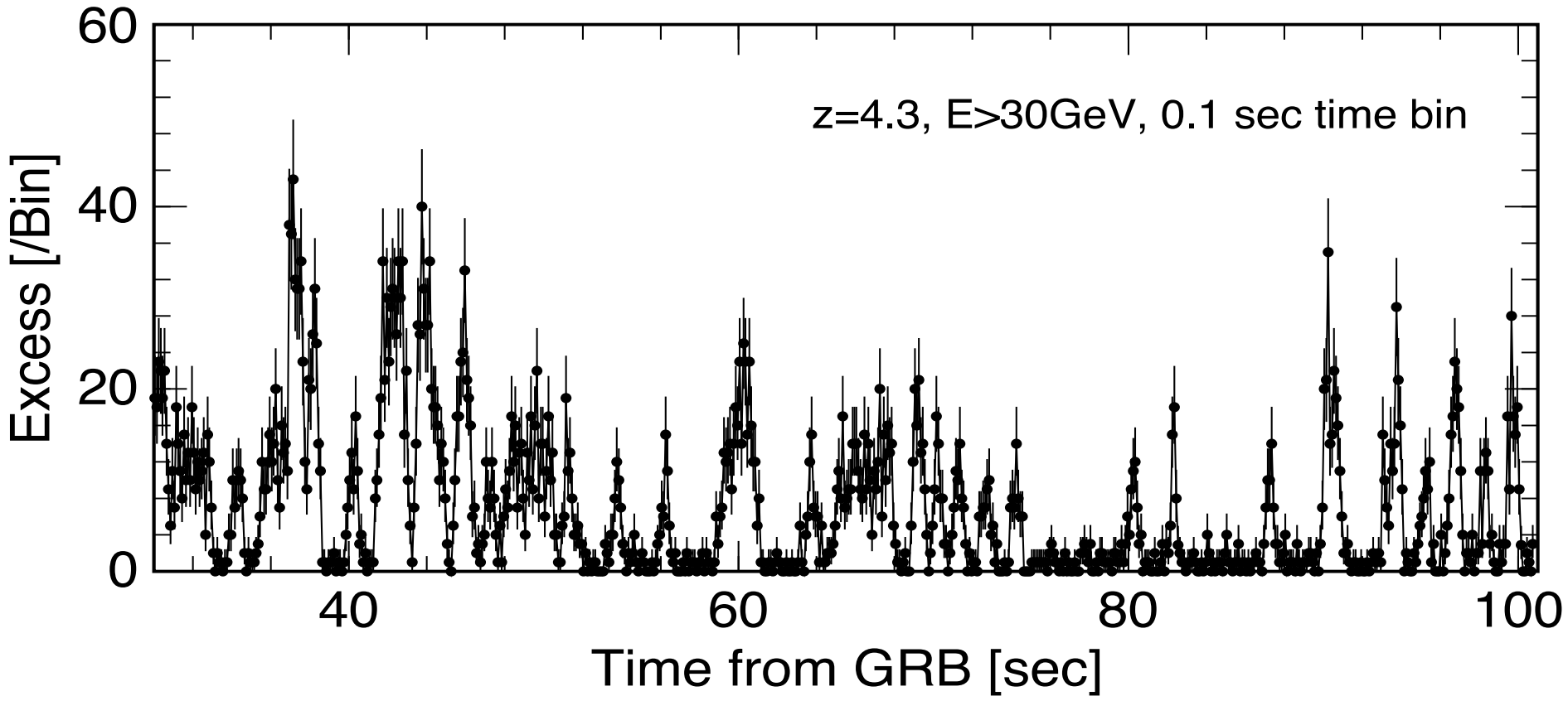
Fermi-LAT observations **GRB 080916C**



Gamma-Ray Bursts

- **Clarify physics of emission**
- **Test UHECR origin, LIV**
  high S/N, E-dependent light curves

CTA simulation
GRB 080916C

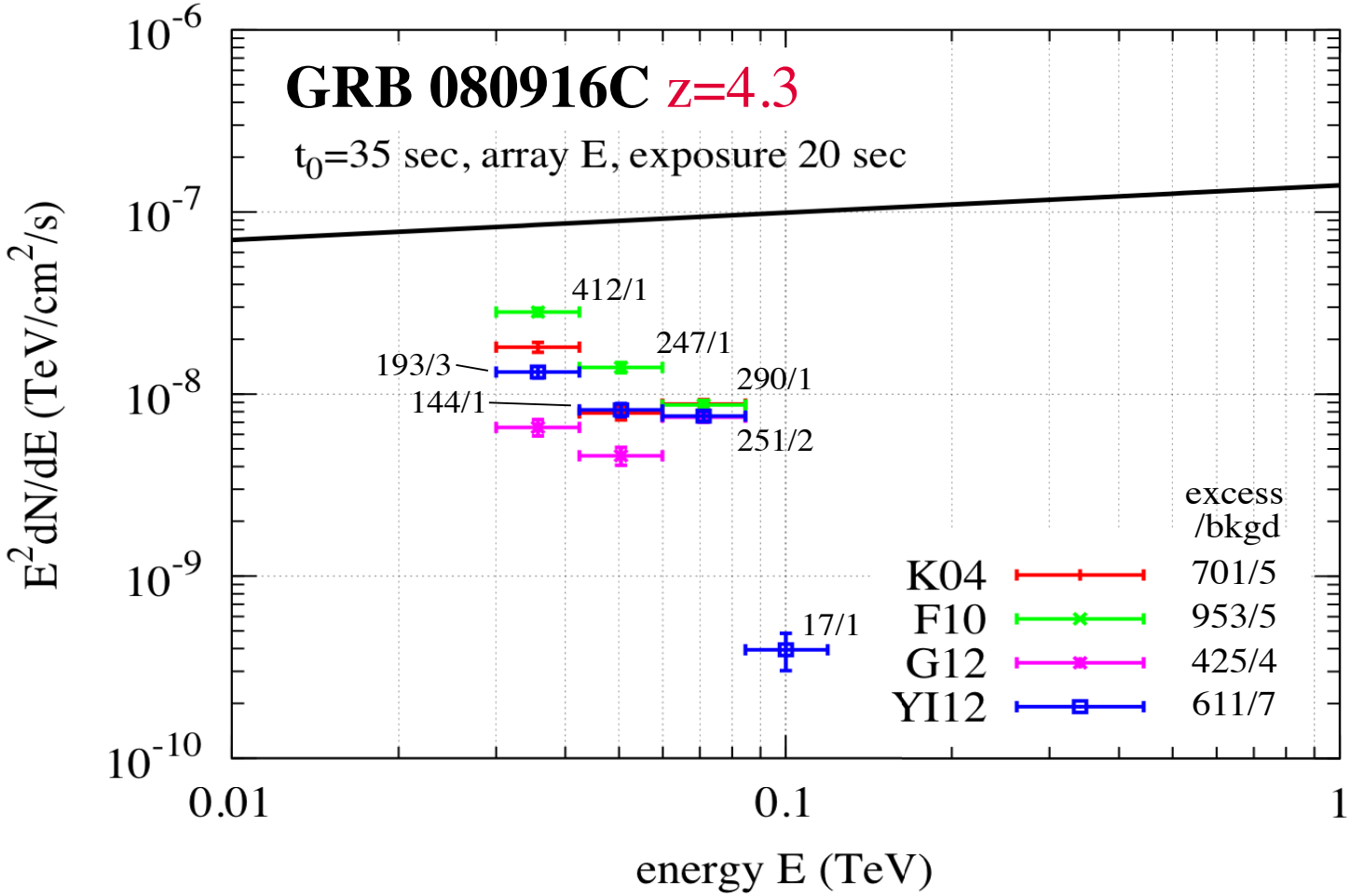


Gamma-Ray Bursts

- Probe high-z UV EBL via γγ spectral attenuation

high S/N spectra

CTA simulation

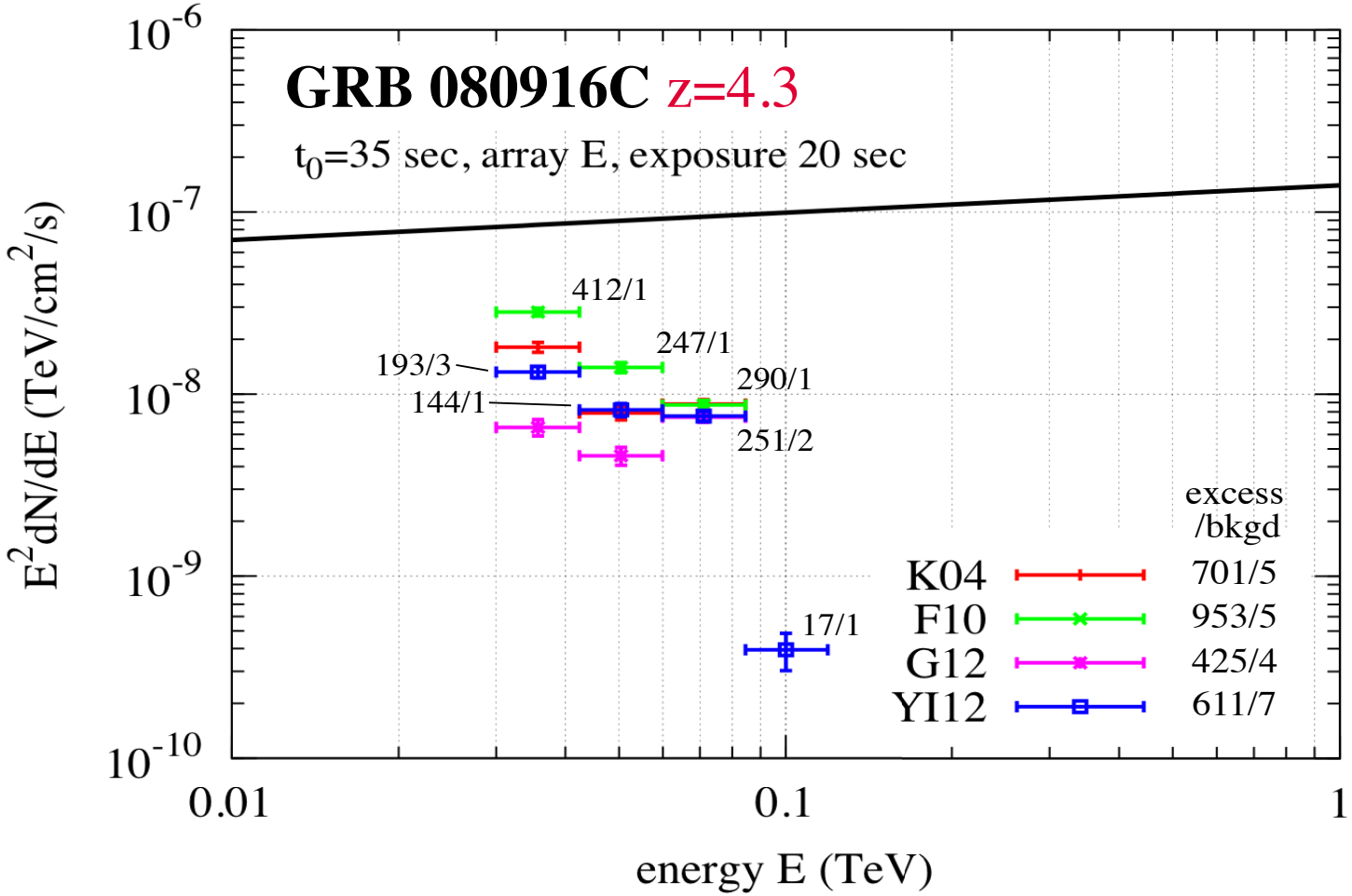


Gamma-Ray Bursts

- Probe high-z UV EBL via γγ spectral attenuation

high S/N spectra

CTA simulation

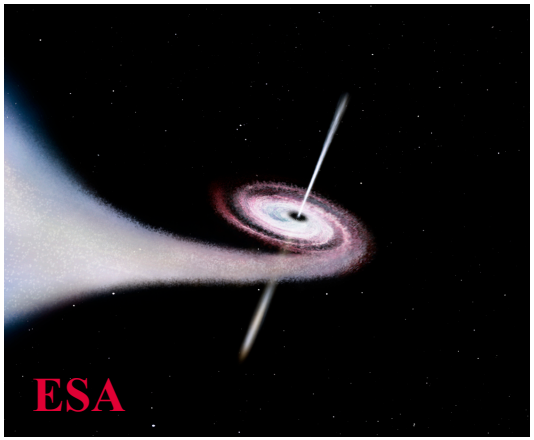


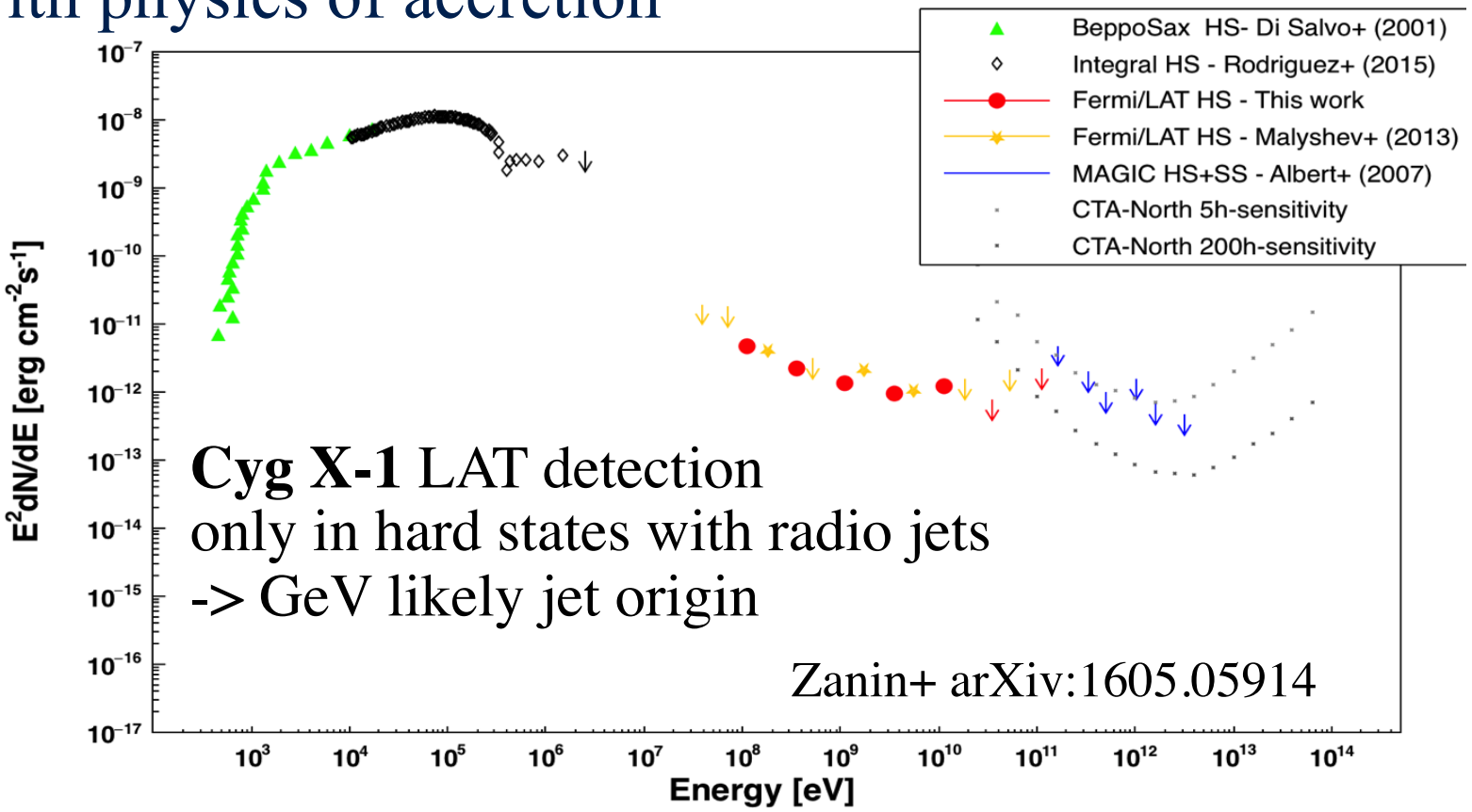
expected total detection rate:
~1-2 /yr/site
~<15% prompt rest afterglow

Kakuwa+ 12
Gilmore+ 13
SI+ 13

Microquasars

- **Physics of relativistic jets from stellar mass BHs**
  - Mechanisms: emission, particle acceleration, energy dissipation, jet formation
  + connection with physics of accretion





Other Transients

Follow-up of Alerts:

- **High-Energy Neutrinos**
- **Gravitational Waves**
- **X-ray/Optical Transients**
  - Tidal Disruption Events
  - Supernova Shock Breakout Events
  - …

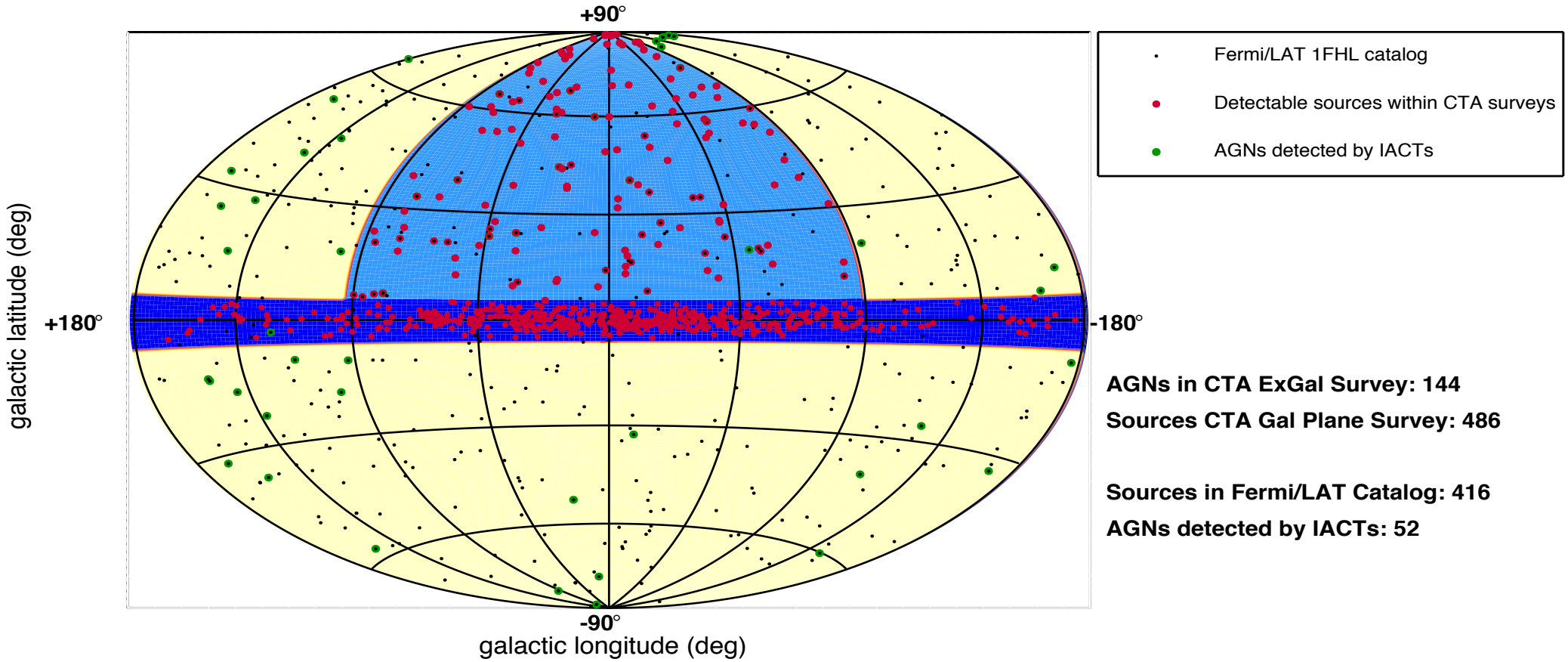
  possibly with subarrays
- **Radio Transients**
  - Fast Radio Bursts
  - …

Serendipitous Transients

via real time analysis, alerts with ~30 sec latency
-> CTA as transient factory

Extragalactic Survey

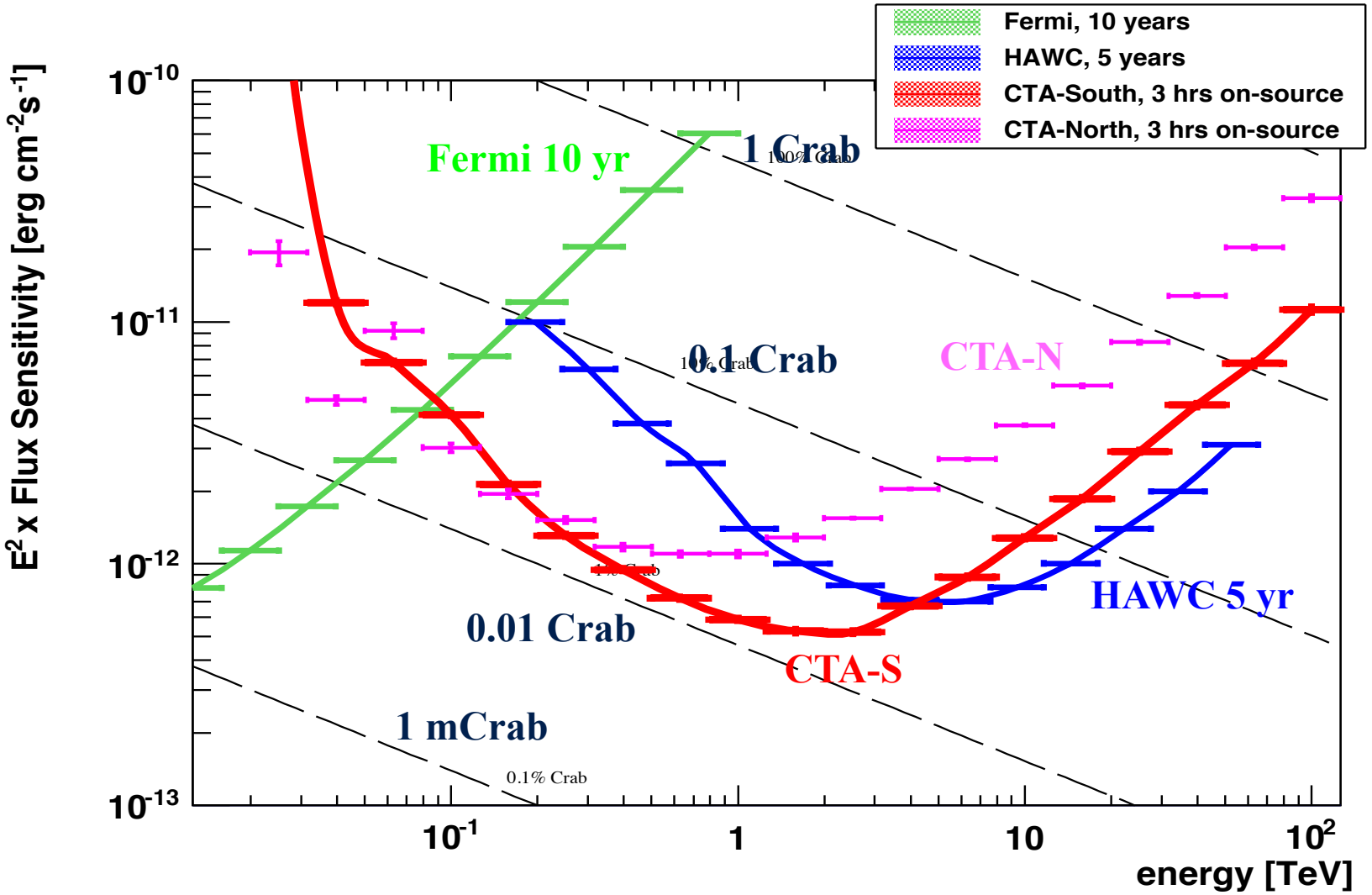
Unbiased survey for 1/4 sky (~10^4 deg^2) to flux limit ~5mCrab



covers Virgo, Coma, Cen A, North Fermi Bubble

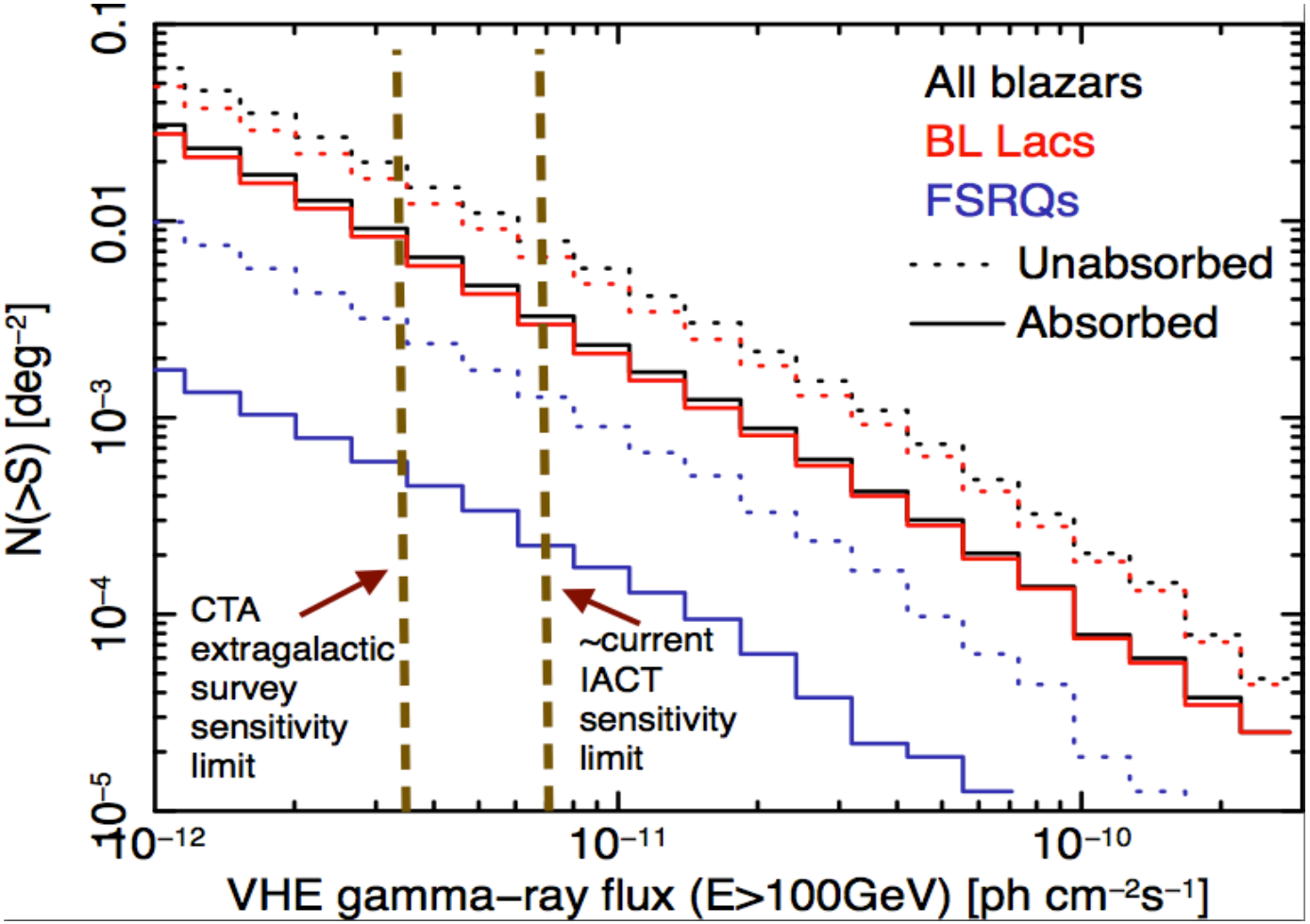
Extragalactic Survey

Unbiased survey for 1/4 sky (~10^4 deg^2) to flux limit ~5mCrab



Extragalactic Survey

Unbiased survey for 1/4 sky (~10^4 deg^2) to flux limit ~5mCrab

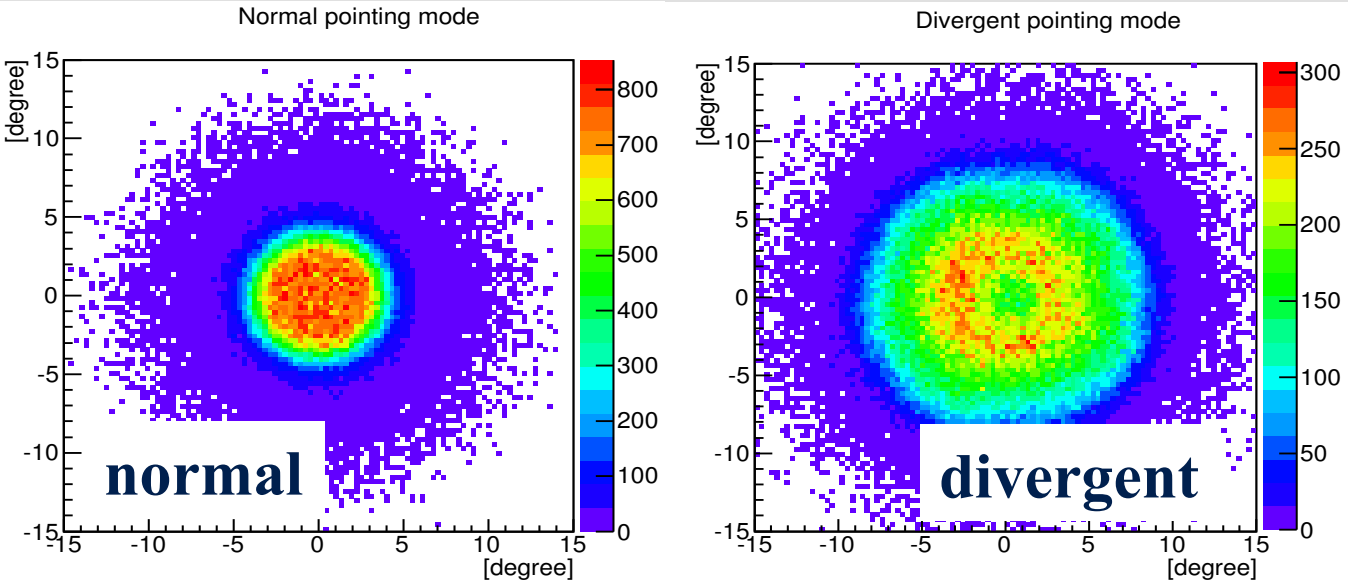


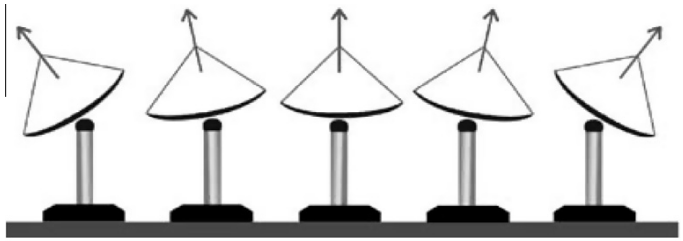
Padovani & Giommi 2015

Expect:
- 30-150 blazars
  (current total ~60)
  -> clarify AGN γLF,
  exgal. γ background
- new extreme blazars

Discover new phenomena?
c.f. HESS unID
Fermi Bubble

Extragalactic Survey: Divergent Pointing?

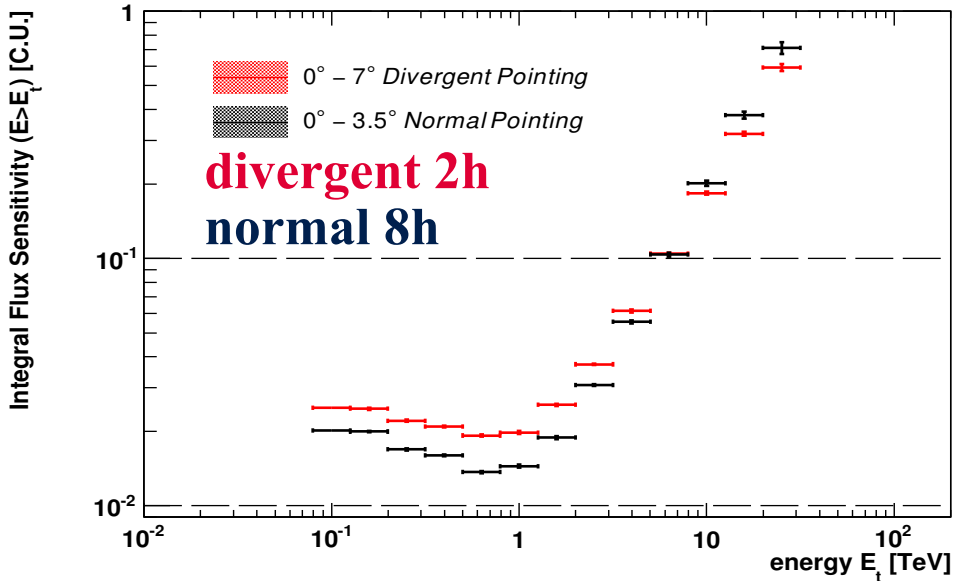




Szanecki+ 2015

Wider FoV at expense of angular/ energy resolution

Gérard+ 2015



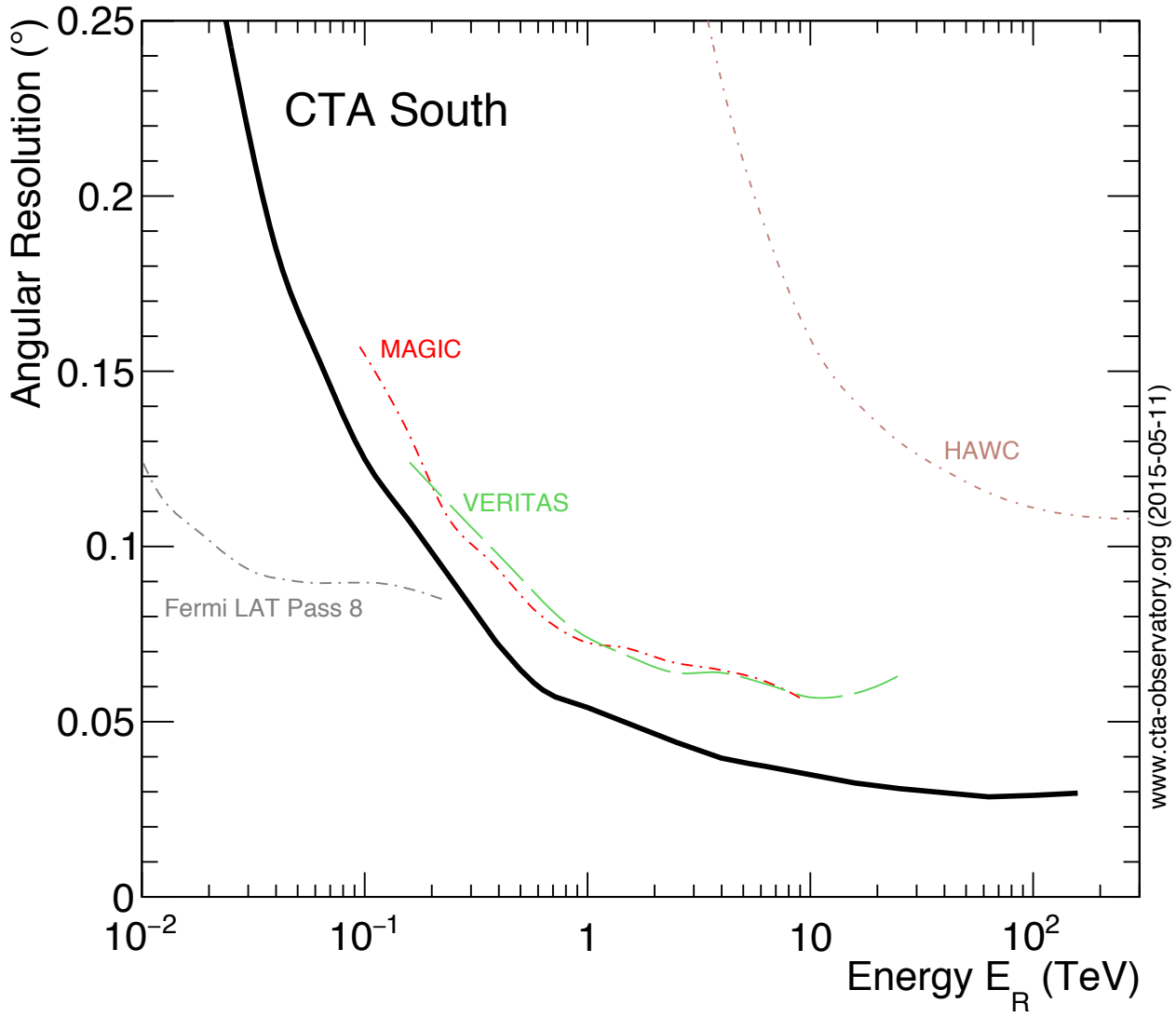
Preliminary studies: point source survey efficiency comparable? -> possibly interesting for commensal unbiased transient survey

Summary: CTA

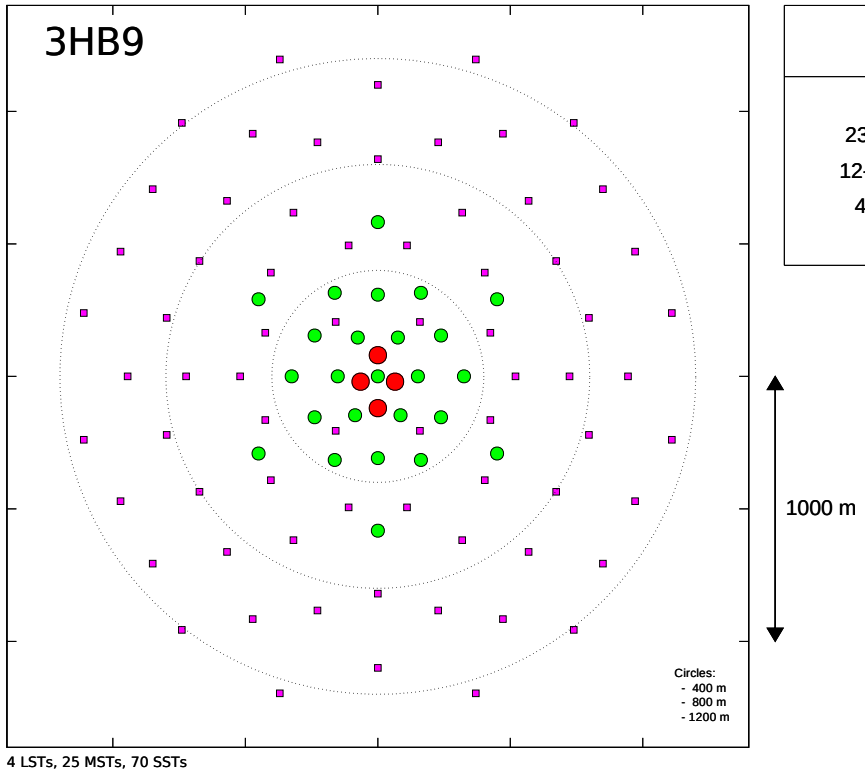
- **New ground-based gamma-ray observatory**
  - Open to the community
  - All-sky, high-sensitivity, wide-band (20 GeV - 300 TeV)
  - Rapid follow-up + rapid alerts for transients
  - Strong multi-wavelength/messenger synergy with concurrent projects
- **Powerful tool for black hole astrophysics**
  - New perspectives on physics of AGN, GRBs, μquasars, etc
  - New approaches to observational cosmology, test of fundamental physics, etc
  - High-quality spectra + light curves for individual objects
  - Large survey programs for population studies, new discovery space

Backup slides

CTA Angular Resolution

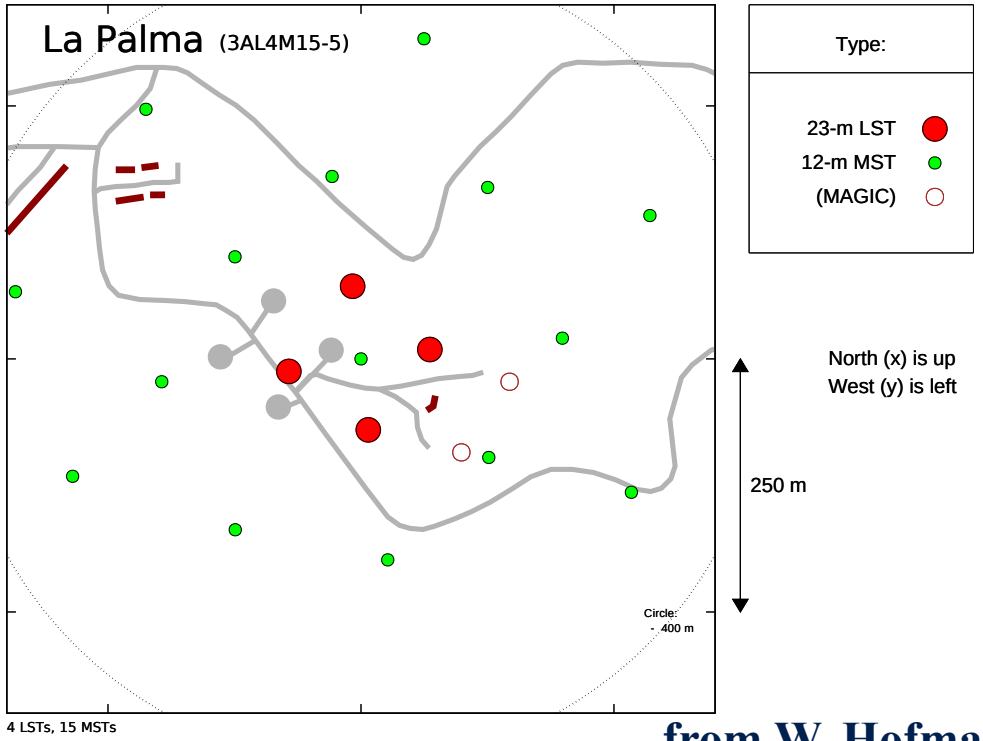


Baseline Array Layout



South:
4 LST
25 MST
70 SST

North:
4 LST
15 MST



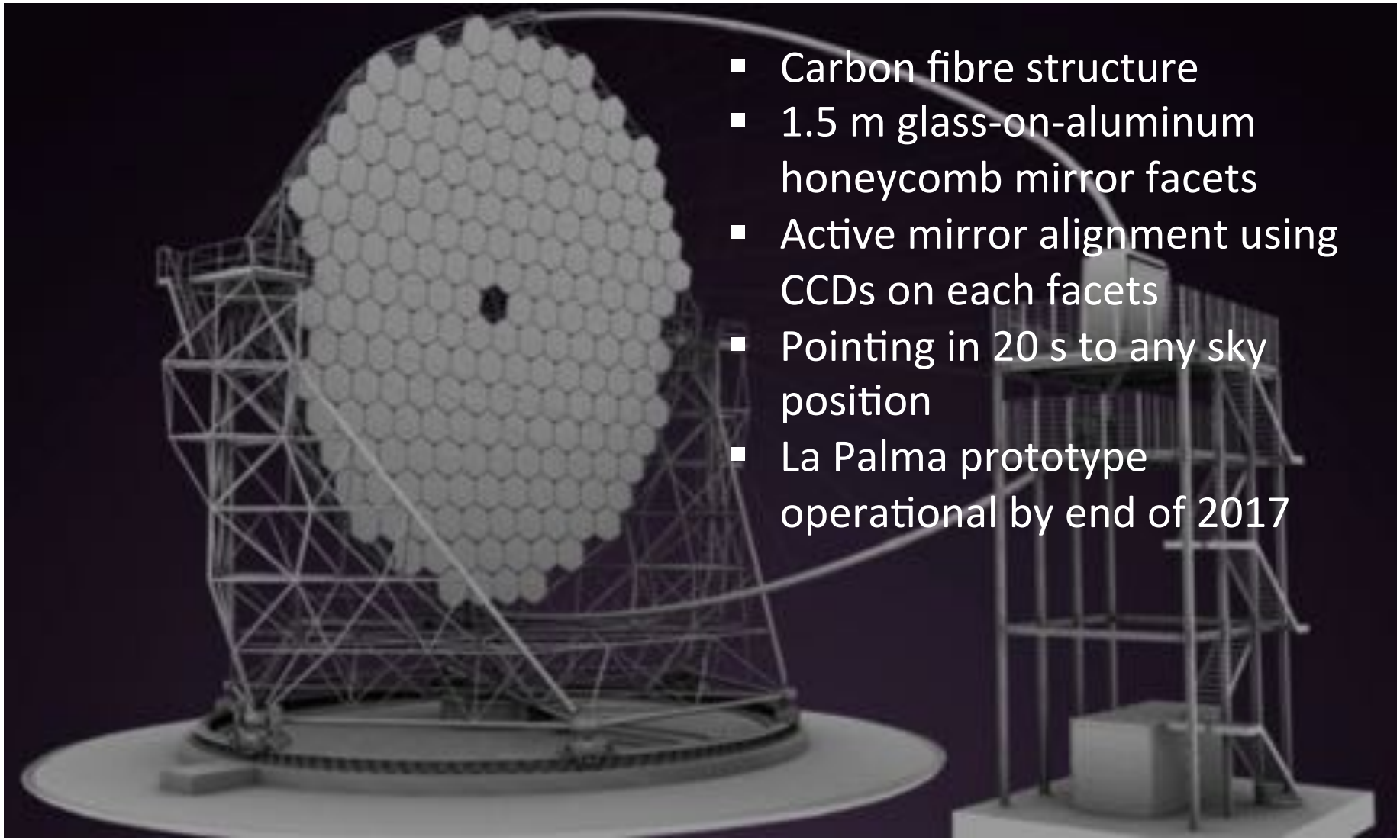
from W. Hofmann

Telescope Characteristics

Telescope	Large	Medium		Small		
	LST	MST	SCT	SST-1M	ASTRI SST-2M	GCT SST-2M
Number North array	4	15	TBD		0	
Number South array	4	25	TBD		70	
Optics						
Optics layout	Parabolic mirror	Davies-Cotton	**Schwarzschild-Couder**	Davies-Cotton	**Schwarzschild-Couder**	**Schwarzschild-Couder**
Primary mirror diameter (m)	23	13.8	9.7	4	4.3	4
Secondary mirror diameter (m)	–	–	5.4	–	1.8	2
Eff. mirror area after shadowing (m^2)	368	88	40	7.4	6	6
Focal length (m)	28	16	5.6	5.6	2.15	2.28
Focal plane instrumentation						
Photo sensor	**PMT**	**PMT**	**silicon**	**silicon**	**silicon**	**silicon**
Pixel size (degr.), shape	0.10, hex.	0.18, hex.	0.07, square	0.24, hex.	0.17, square	0.15-0.2, square
Field of view (degr.)	4.5	7.7/8.0	8.0	9.1	9.6	8.5 - 9.2
Number of pixels	1855	1764/1855	11328	1296	1984	2048
Signal sampling rate	GHz	250 MHz / GHz	GHz	250 MHz	S&H	GHz
Structure						
Mount	alz-az, on circular rail	alt-az positioner	alt-az positioner	alt-az positioner	alt-az positioner	alt-az positioner
Structural material	CFRP / steel	steel	steel	steel	steel	steel
Weight (full telescope, tons)	100	85	~85	9	15	8
Max. time for repositioning (s)	20	90	90	60	80	60

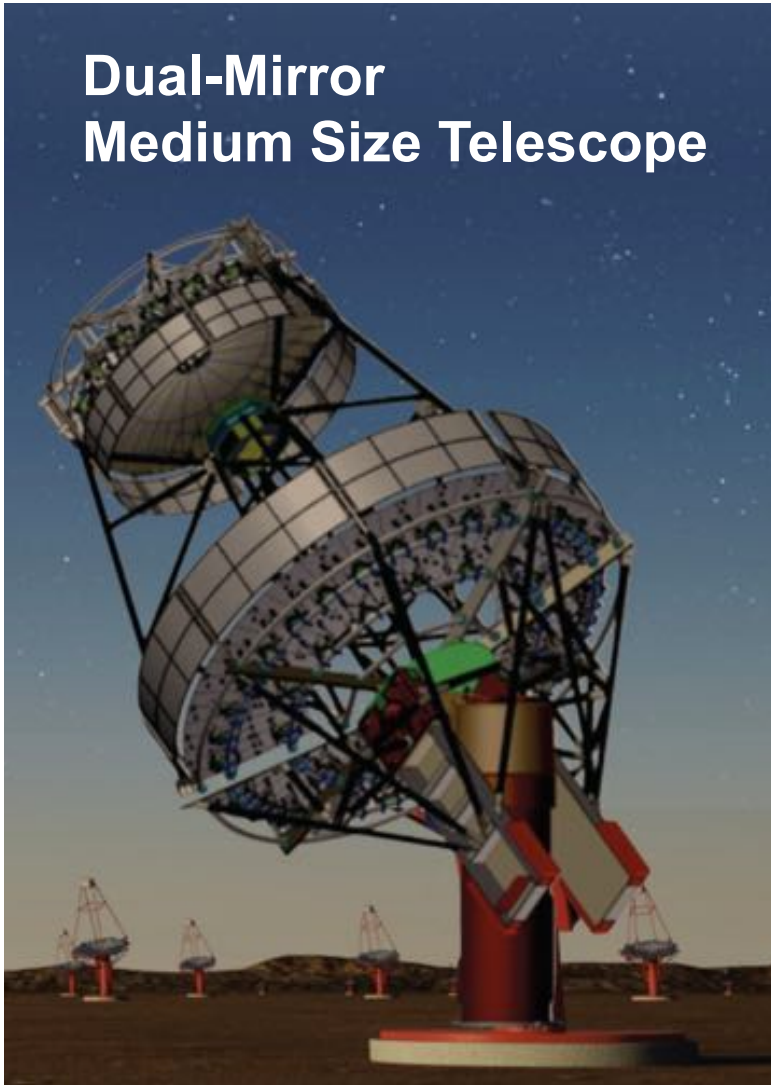
from W. Hofmann

Large Sized Telescope



from W. Hofmann

Middle Sized Telescopes



adapted from W. Hofmann

Small Sized Telescopes

adapted from W. Hofmann