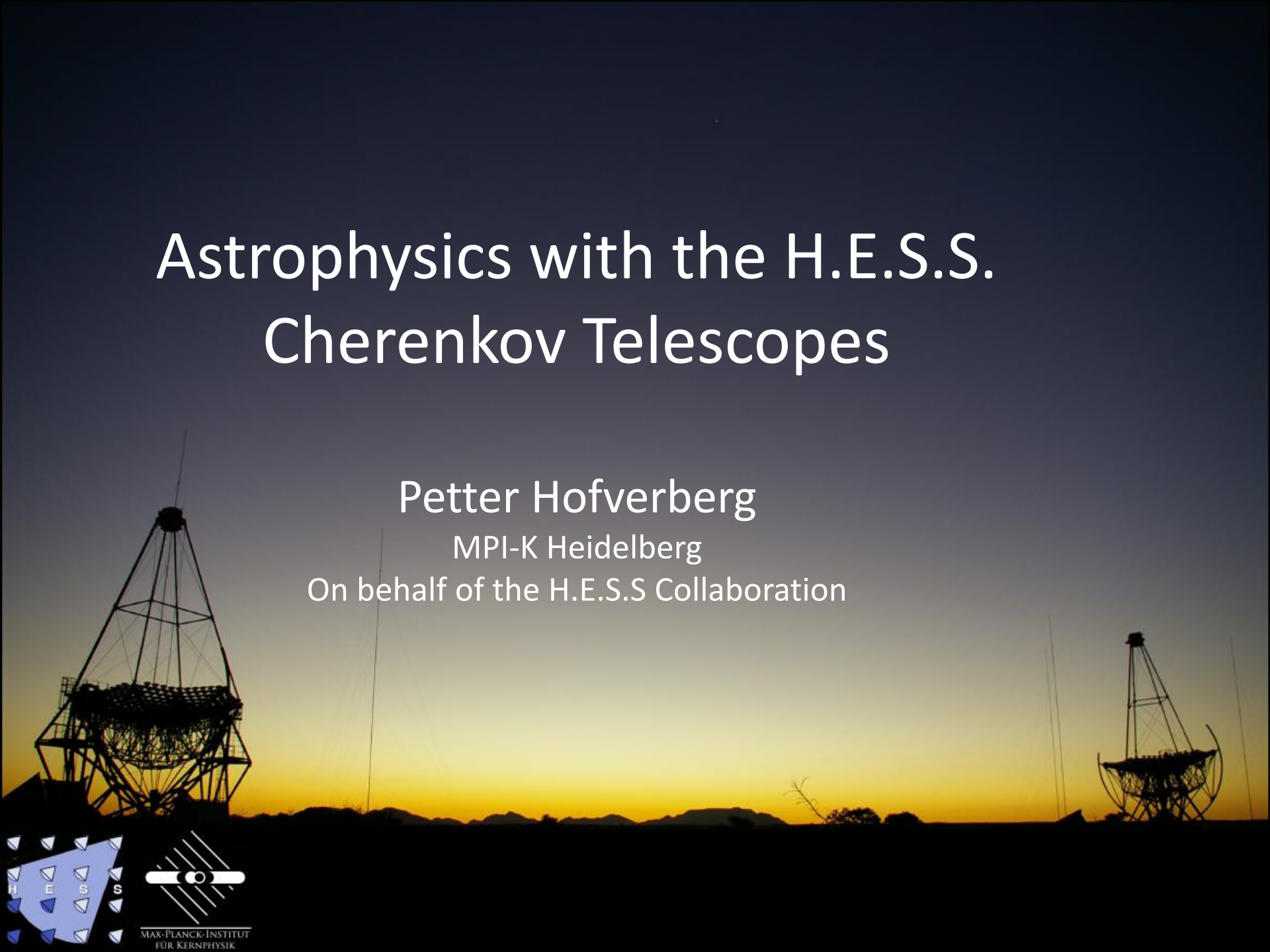
Astrophysics with the H.E.S.S. Cherenkov Telescopes

Petter Hofverberg
MPI-K Heidelberg
On behalf of the H.E.S.S Collaboration



VHE Gamma-ray astronomy with Imaging Atmospheric Cherenkov Telescopes

Cherenkov light pool (2km)

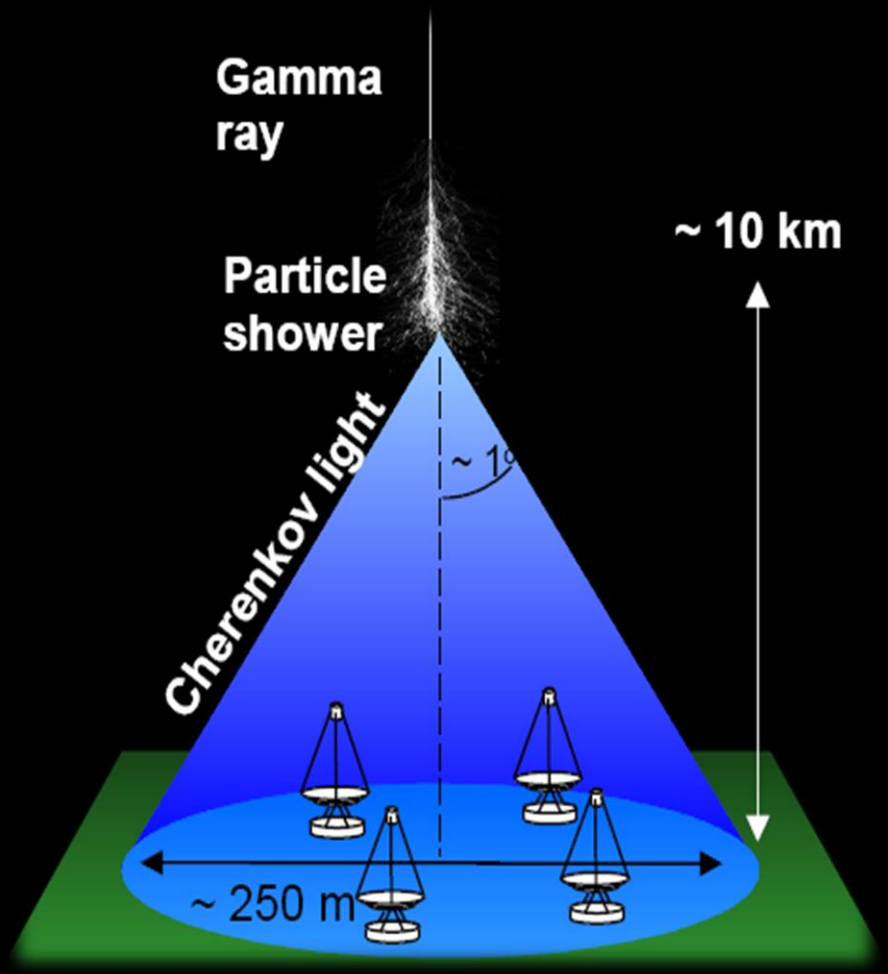
Radius ~ 120m
Thickness ~ ns
Spectrum peak 300-350 nm
~100 photons/(m^2*1TeV)

Observables

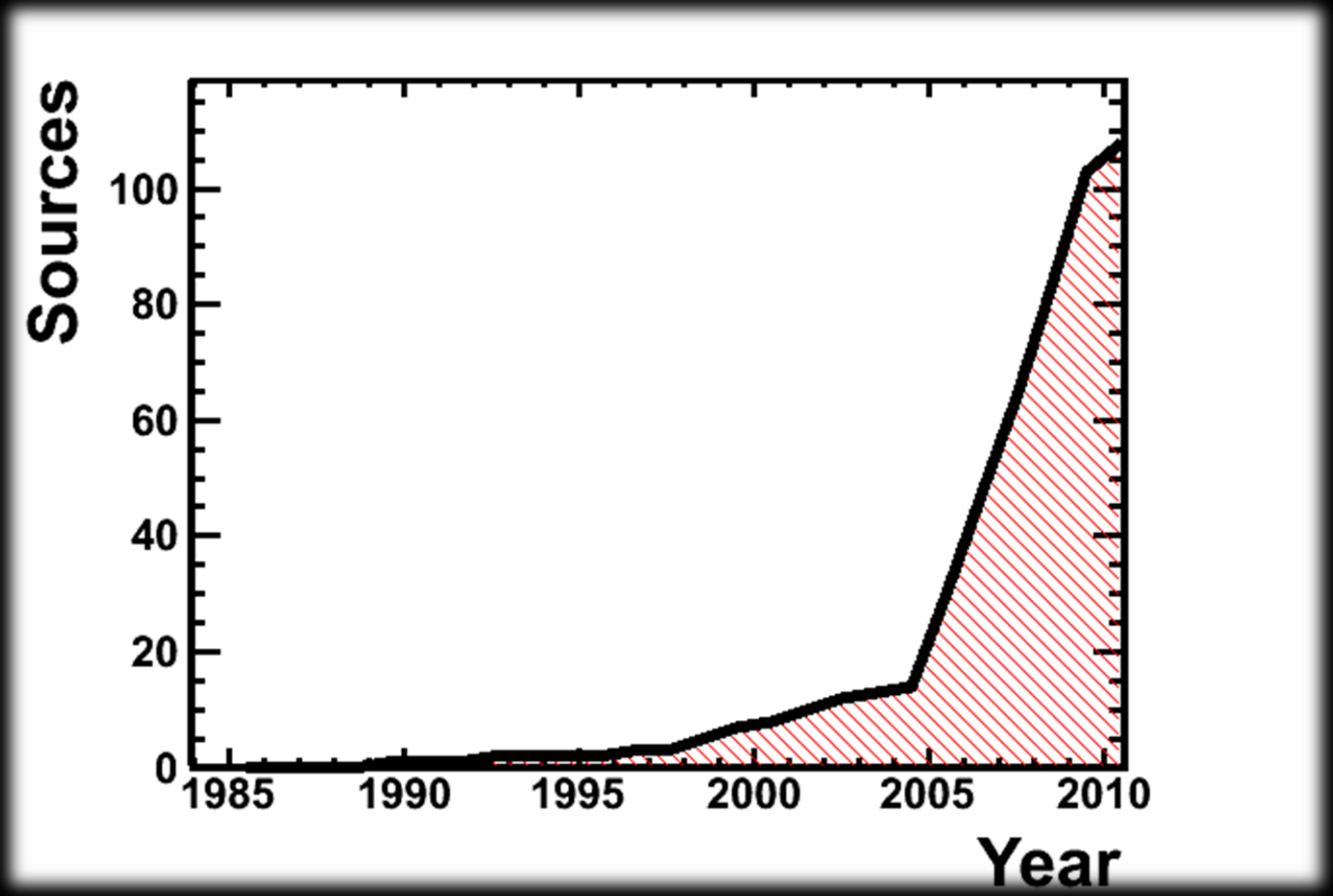
image intensity -> primary energy
image orientation -> arrival direction
image shape -> origin (photon, hadron)

Performance

Energy range: few GeV -> >100 TeV
Large detection area
Duty time <1000 h / year



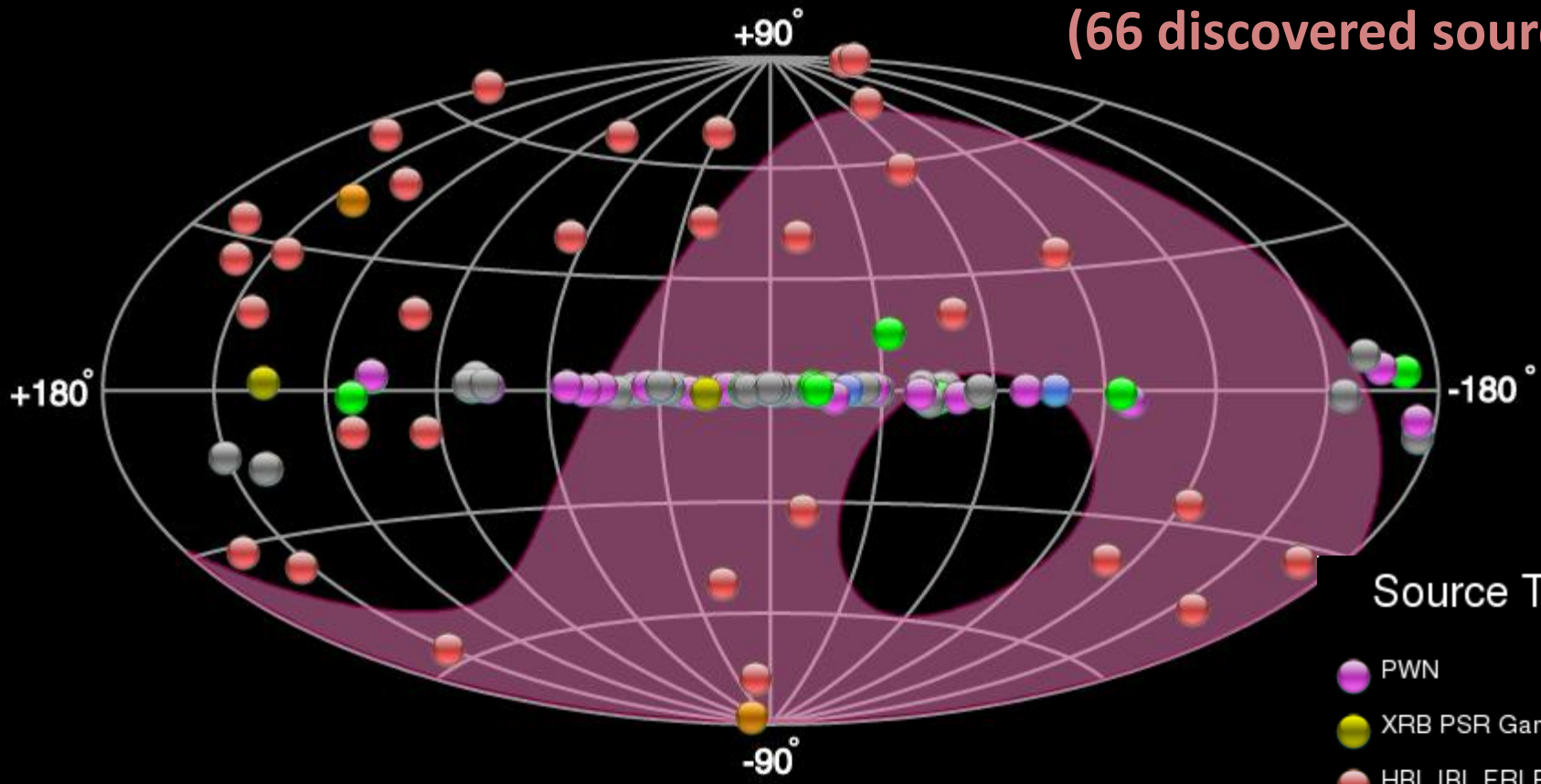
From source hunting to astrophysics



Cangaroo, Magic, Veritas, **HESS**, Mark 6 Telescope, Milagro, Telescope Array, Whipple

VHE Gamma Sources

HESS Acceptance
(66 discovered sources)



Source Types

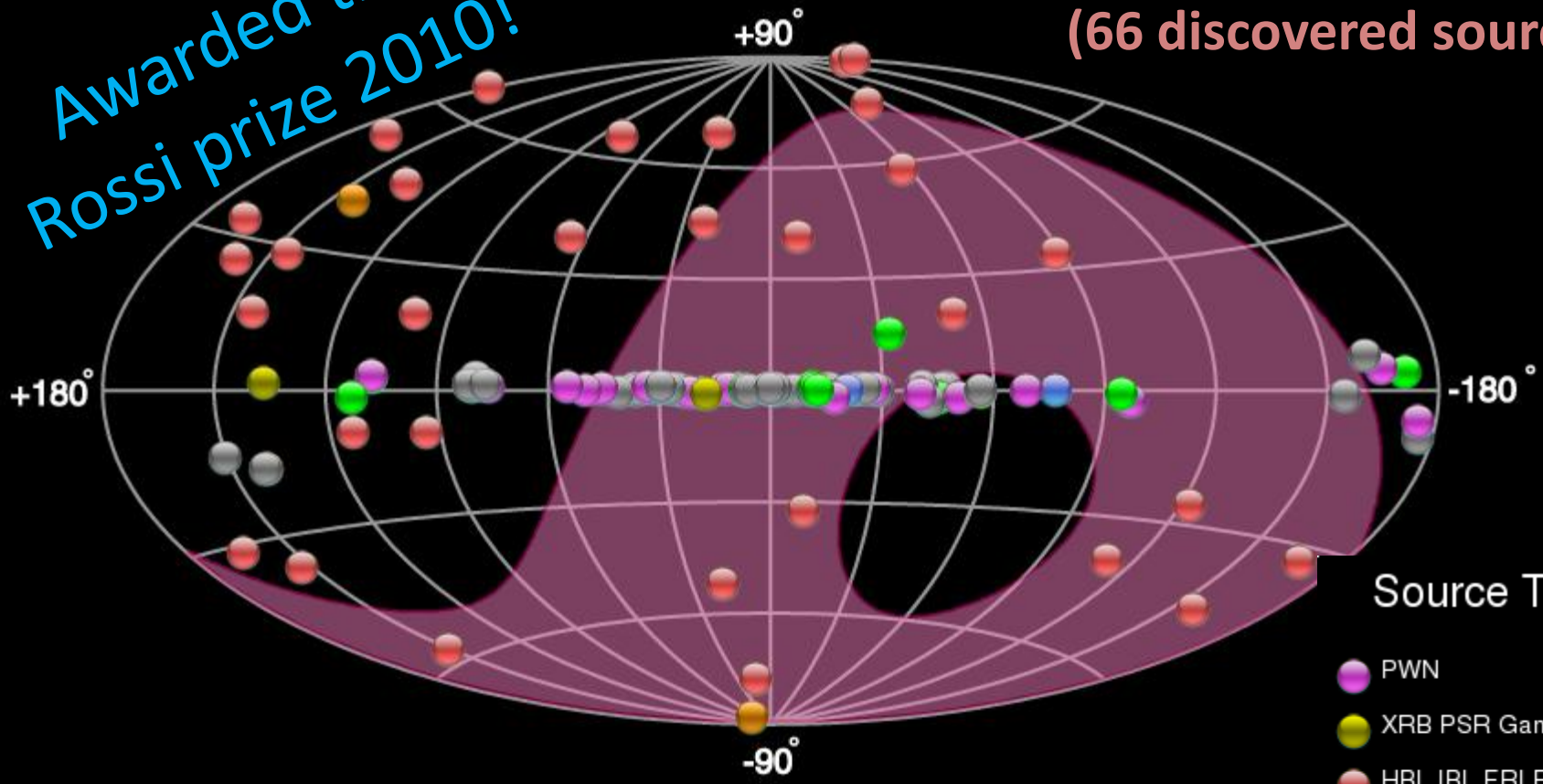
- PWN
- XRB PSR Gamma BIN
- HBL IBL FRI FSRQ LBL
- Shell
- Starburst
- DARK UNID Other
- uQuasar Cat. Var. BIN WR

http://tevcat/uchicago.edu/

VHE Gamma Sources

Awarded the Rossi prize 2010!

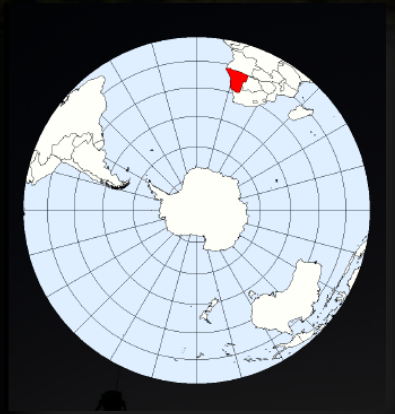
HESS Acceptance (66 discovered sources)



http://tevcat/uchicago.edu/

The H.E.S.S. Experiment

Energy threshold	100 GeV
Energy resolution	20%
Field of view	~ 5 deg
Angular resolution	<0.1deg
Sensitivity	1 Crab in 30 sec

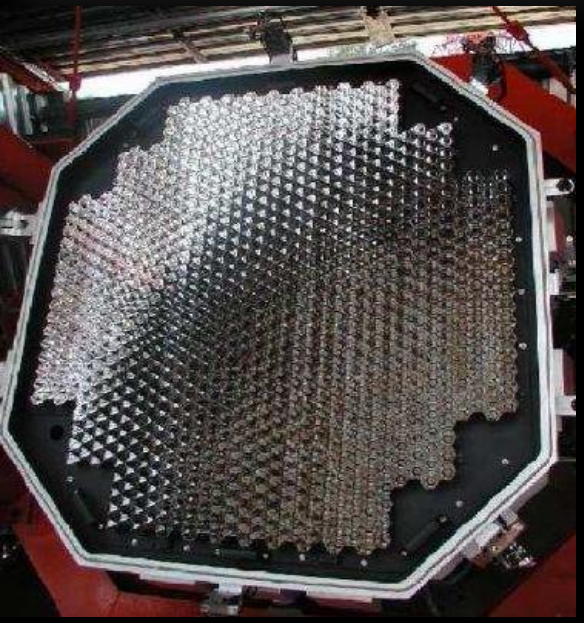


The H.E.S.S. Experiment

Key features

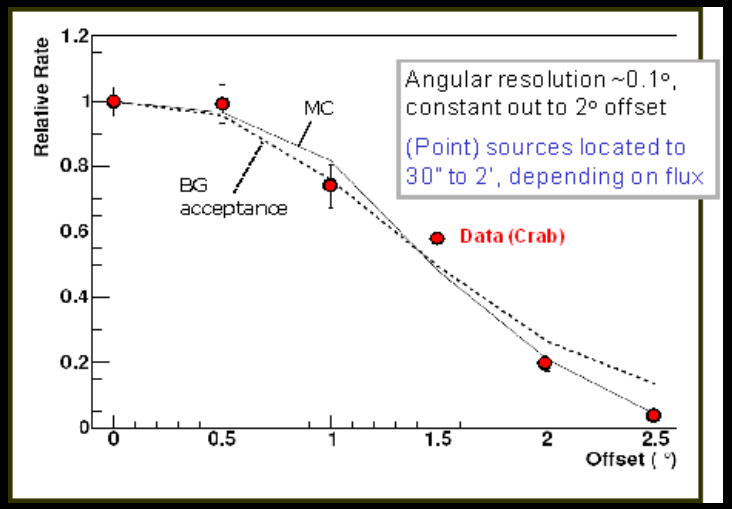
- Access to the inner Galaxy
- Large field of view with good off axis imaging
- Stereoscopy

Field of view, off axis performance



- Dish: Davies-Cotton design
  - good off-axis imaging
  - marginal rms time spread of ~1.4 ns
  - focal length/diameter = 15/13 = 1.2
- Camera: Large field-of-view
  - 960 pixels (PMTs), each 0.16° FoV
  - Total FoV 5°

Off axis performance



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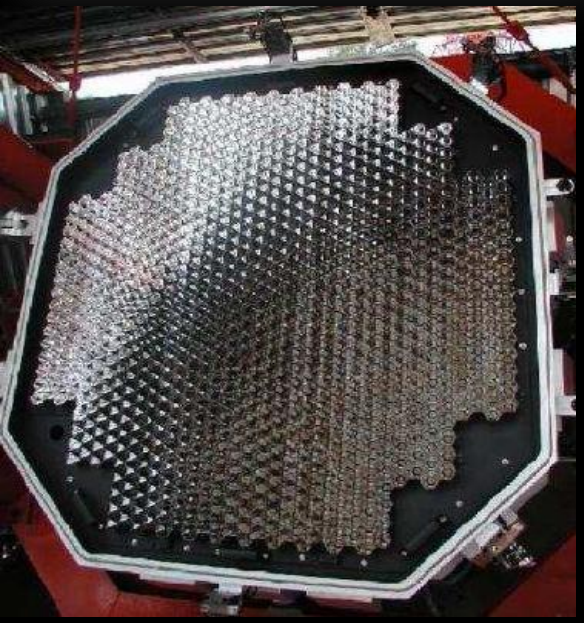
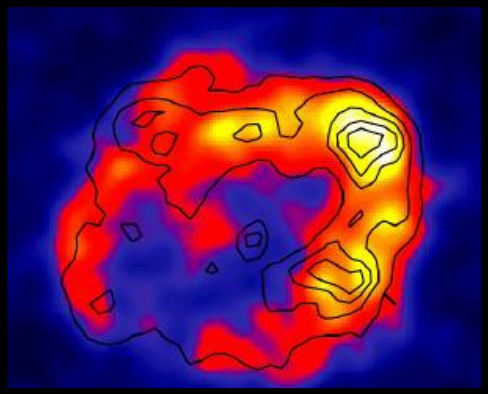
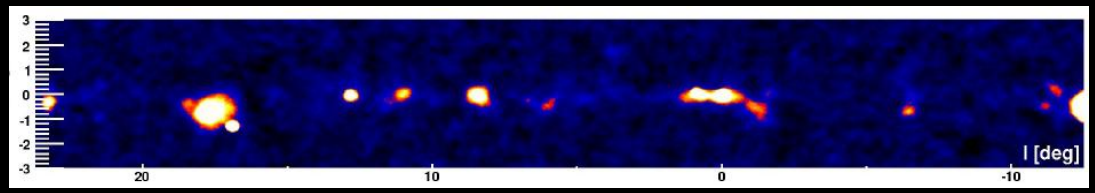


Well suited for:

✓ Extended sources

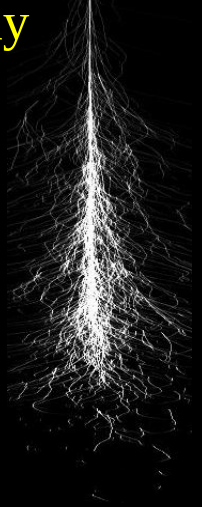
✓ Surveys





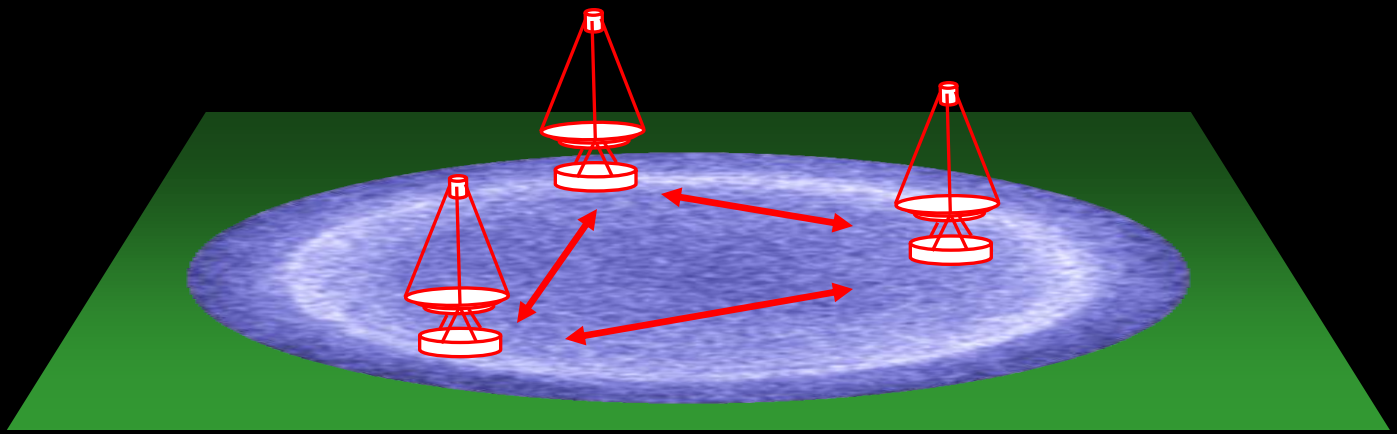
Stereoscopy

γ- Ray

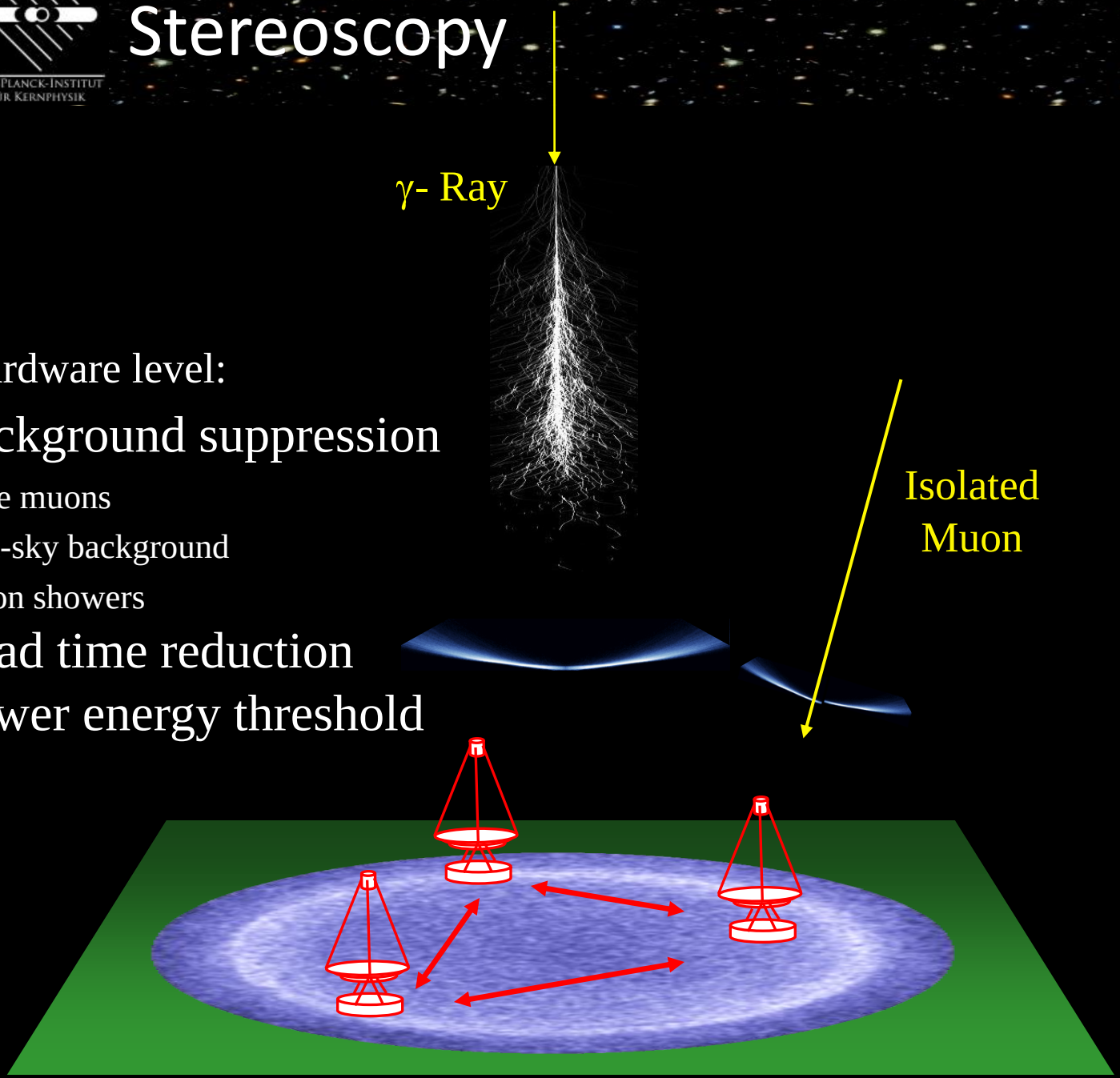


On a hardware level:

- ✓ Background suppression
- ✓ Dead time reduction
- ✓ Lower energy threshold



Stereoscopy

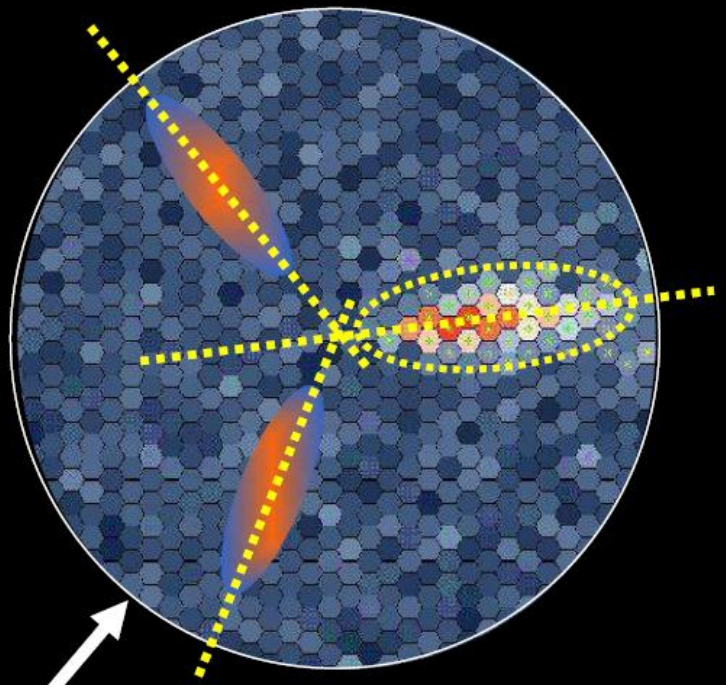


On a hardware level:

- ✓ Background suppression
  - single muons
  - night-sky background
  - hadron showers
- ✓ Dead time reduction
- ✓ Lower energy threshold

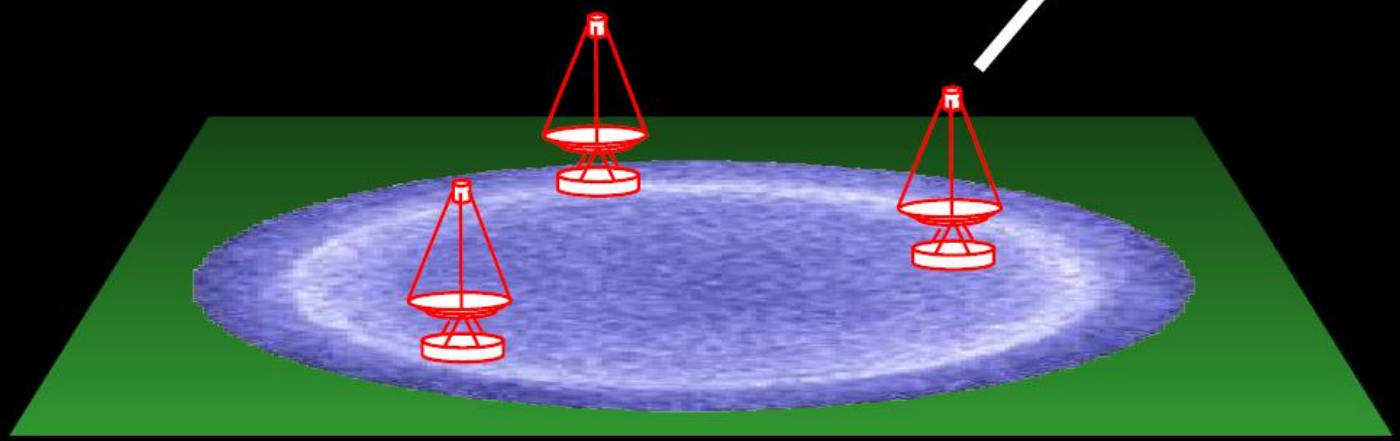
Stereoscopy

γ- Ray
(100 GeV)



On analysis level:

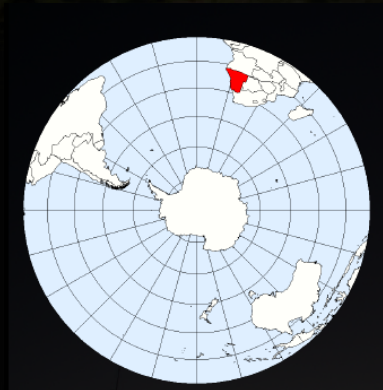
- ✓ Angular resolution
- ✓ Energy resolution
- ✓ Background rejection
- ✓ Sensitivity



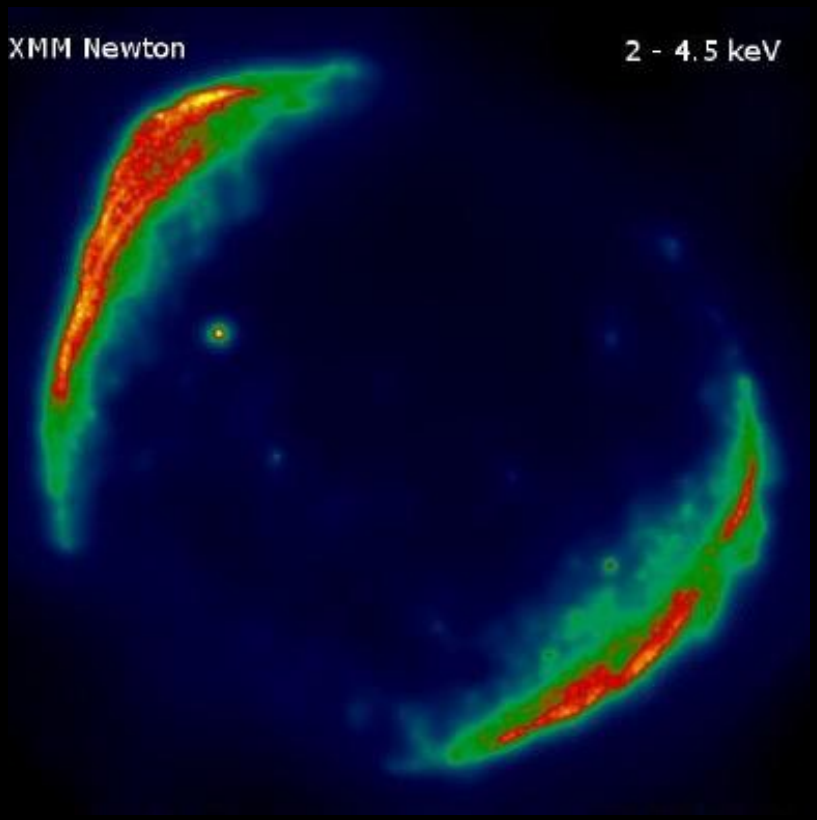
The H.E.S.S. Experiment
- In full stereo mode since 2004

Recent physics highlights

- SN1006: A shell type SNR
- Detection of a Starburst galaxy in VHE g-rays
- The H.E.S.S. Galactic Survey



Shell type supernova remnants: SN 1006



SN1006

Type 1a supernova

Non-thermal X-ray emission observed from the rims

Suggests shock accelerated electrons > 100TeV

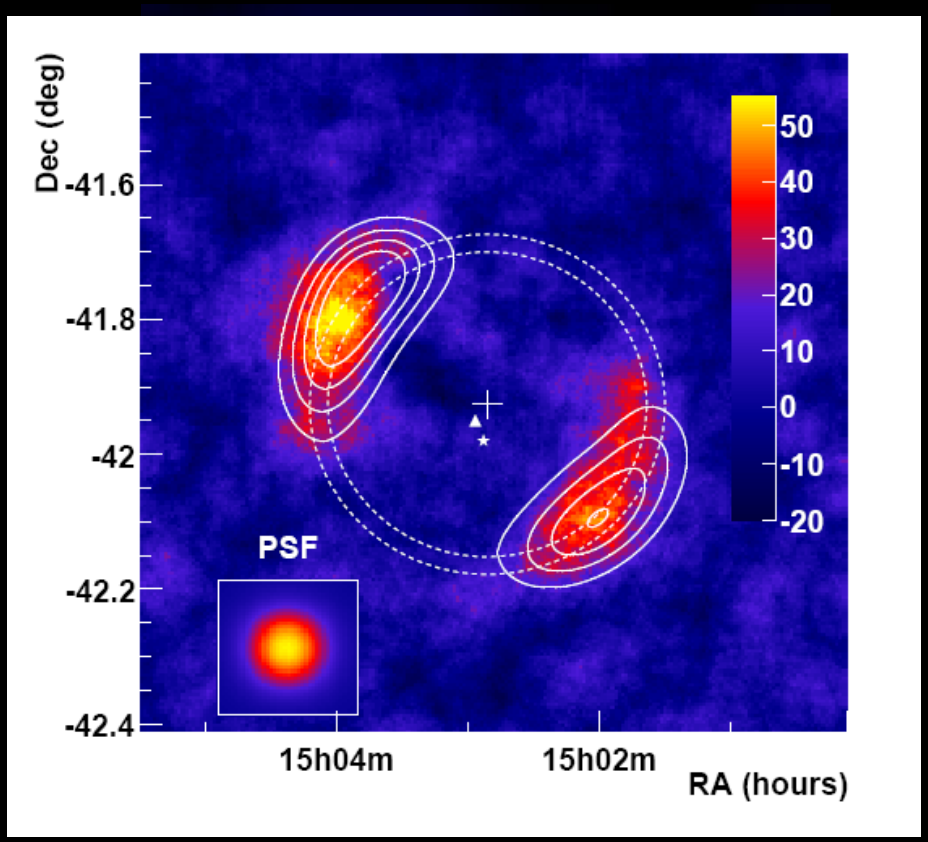
HESS observations

- Bipolar morphology, rim thickness compatible with PSF
- Morphology strongly correlated with non-thermal X-rays

Suggests a common origin

- Ambiguity between leptonic and hadronic acceleration scenarios

Shell type supernova remnants: SN 1006



arXiv:1004.2124v1, accepted for publication in A&A

SN1006

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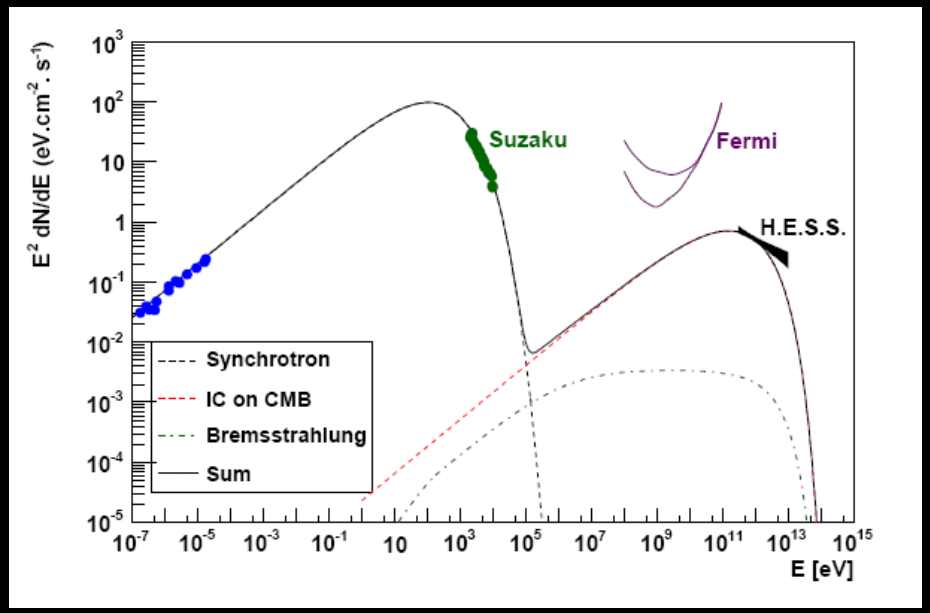
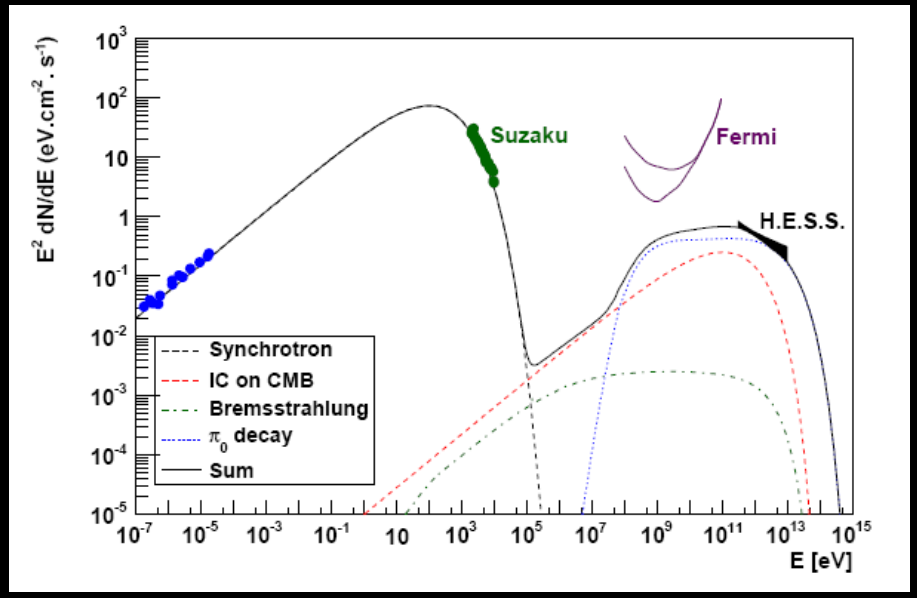
Shell type supernova remnants: SN 1006

Pure electron population



➢ Fails to reproduce the slope of the VHE spectrum

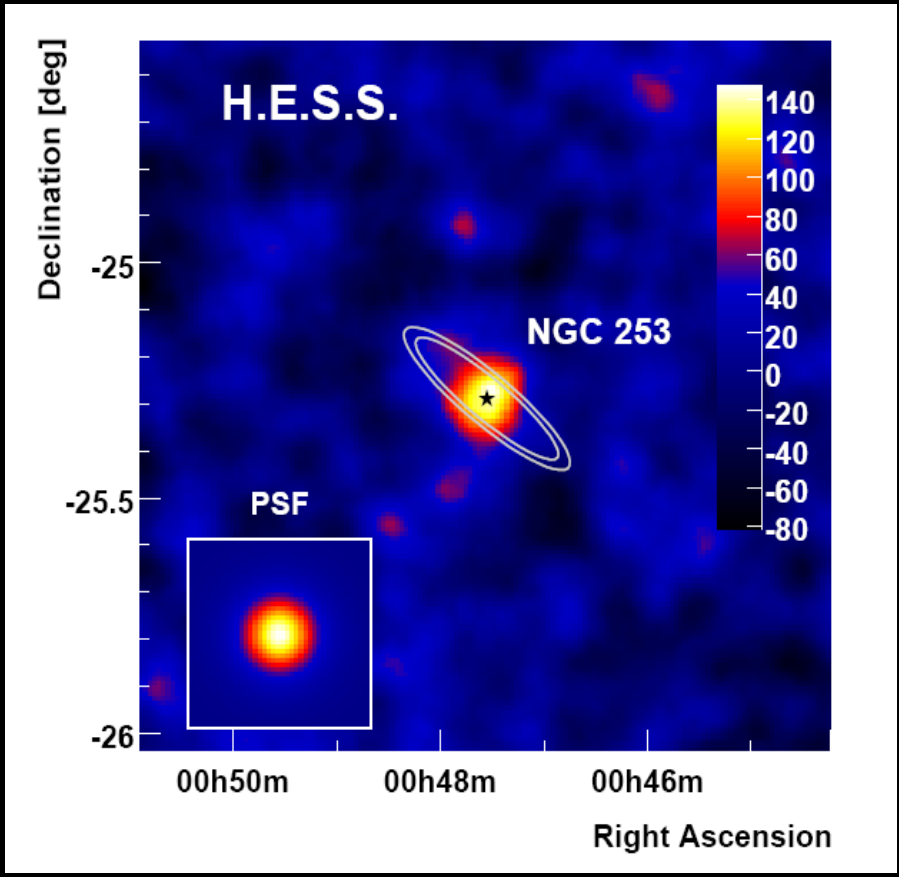
Electron+proton population



➢ Possibly to reproduce all multiwave data!

Lower energy data crucial!

Detection of the Starburst galaxy NGC253 in VHE gamma-rays



H.E.S.S. 2009, Science 326, 1080

The starburst galaxy NGC253

Spiral galaxy at 2.6-3.9Mpc

SNR rate in central 100pc ~0.03 SN/y

Predicted gamma ray emitter

Does not contain a significant active galactic nucleus!

The observations

Detected flux 0.3% of Crab, close to model predictions

Detection imples a very high density of CR:

EpNp(>1.3TeV)=6eV/cm^3, >1000 x in our own galaxy

A new class of gamma ray emitter, but faintest source detected yet!

H.E.S.S. as a survey instrument:

The initial TeV galactic plane survey (2004)

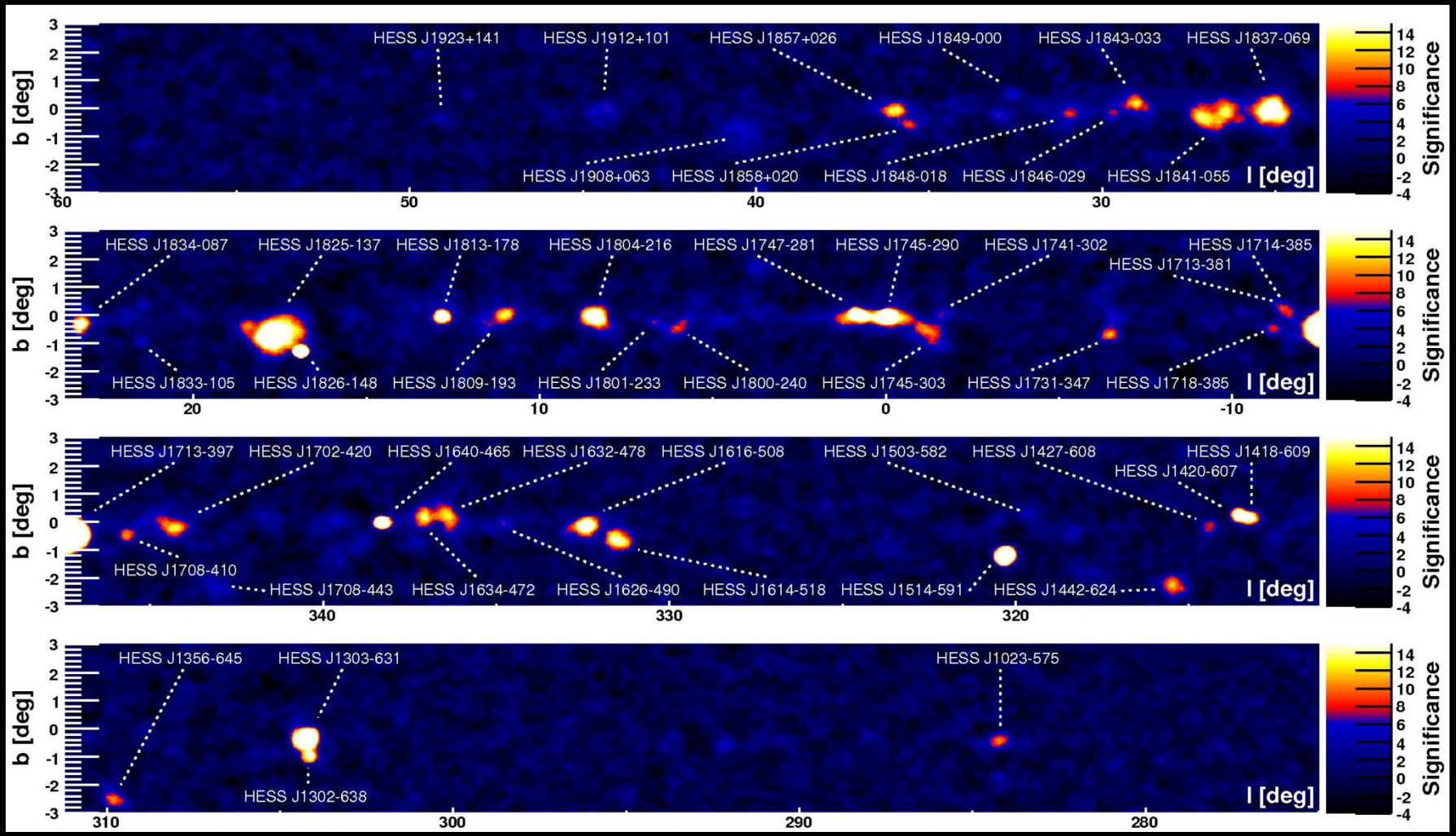
- Exposure ~95h + ~135h follow-up/dedicated
- Discovered 14 Galactic sources of TeV radiation

The extended H.E.S.S. Galactic plane survey (2005-2009)

- A much deeper exposure: 1400+h , + dedicated observations
- A more uniform exposure
- Discovered a total of 56 Galactic sources of TeV radiation

Aharonian et al. 2005 Science, 307 Aharonian et al. 2006, ApJ, 636
Chavez et al. 2009, ICRC Proc.

H.E.S.S. as a survey instrument: A deeper, wider TeV survey



Significance [σ]

Source catalog:
http://www.mpi-hd.mpg.de/hfm/HESS/pages/home/sources/

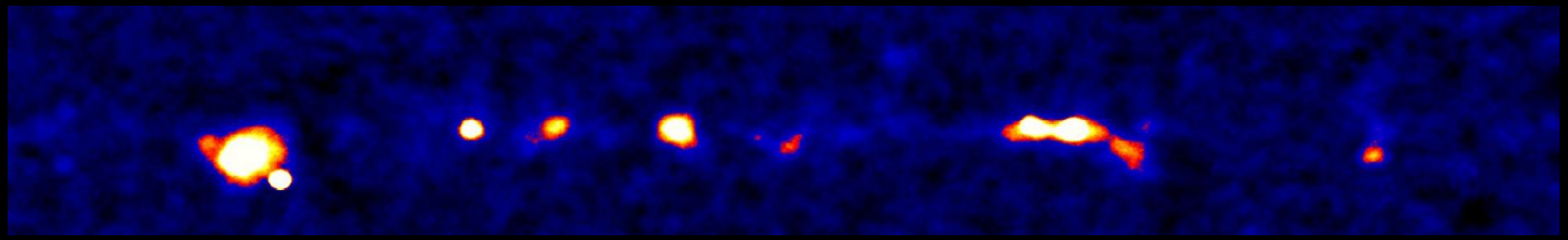
H.E.S.S. as a survey instrument

“ The H.E.S.S. Legacy Survey”

2010-2011

- Increase the uniformity of sensitivity of the H.E.S.S. Galactic Plane Survey to enhance the legacy of the TeV survey dataset

- Goal: 1% sensitivity within 1° of the galactic plane
- Coverage out to 4° of the galactic plane



The H.E.S.S. Experiment: Upgrades

- H.E.S.S. I Mirror refurbishment
- H.E.S.S. Phase II

Mirror refurbishment

Average loss of reflectance per year: 4-5%

Direct impact on energy threshold and sensitivity!

2 new mirror coatings are being tested

- 3-layer protective coating (SiO_2 , HfO_2 , SiO_2)
- dielectric coating (no Al)

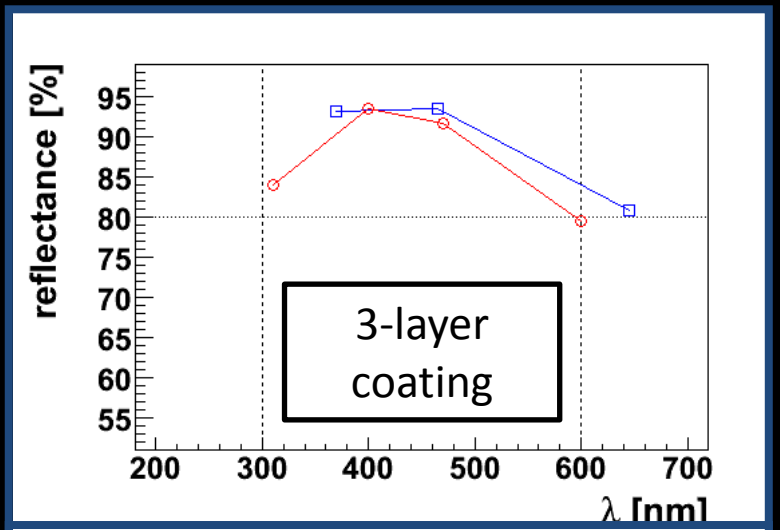
Old mirror coating

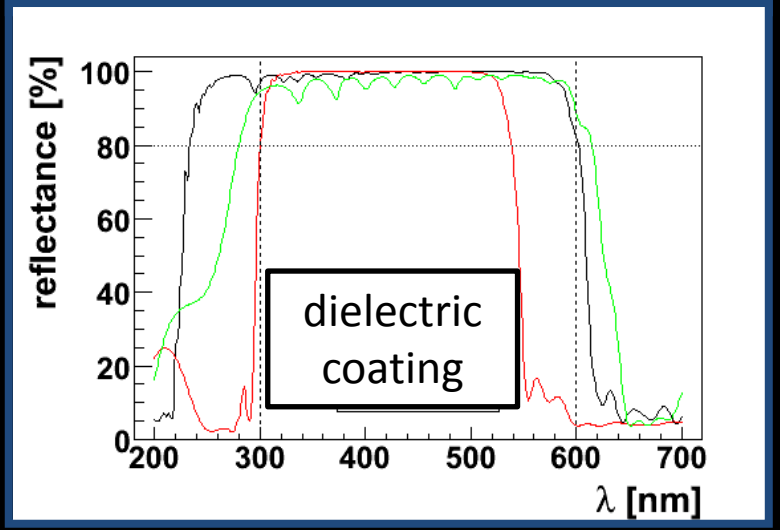
- Al/SiO_2 (reflectance ~85%)

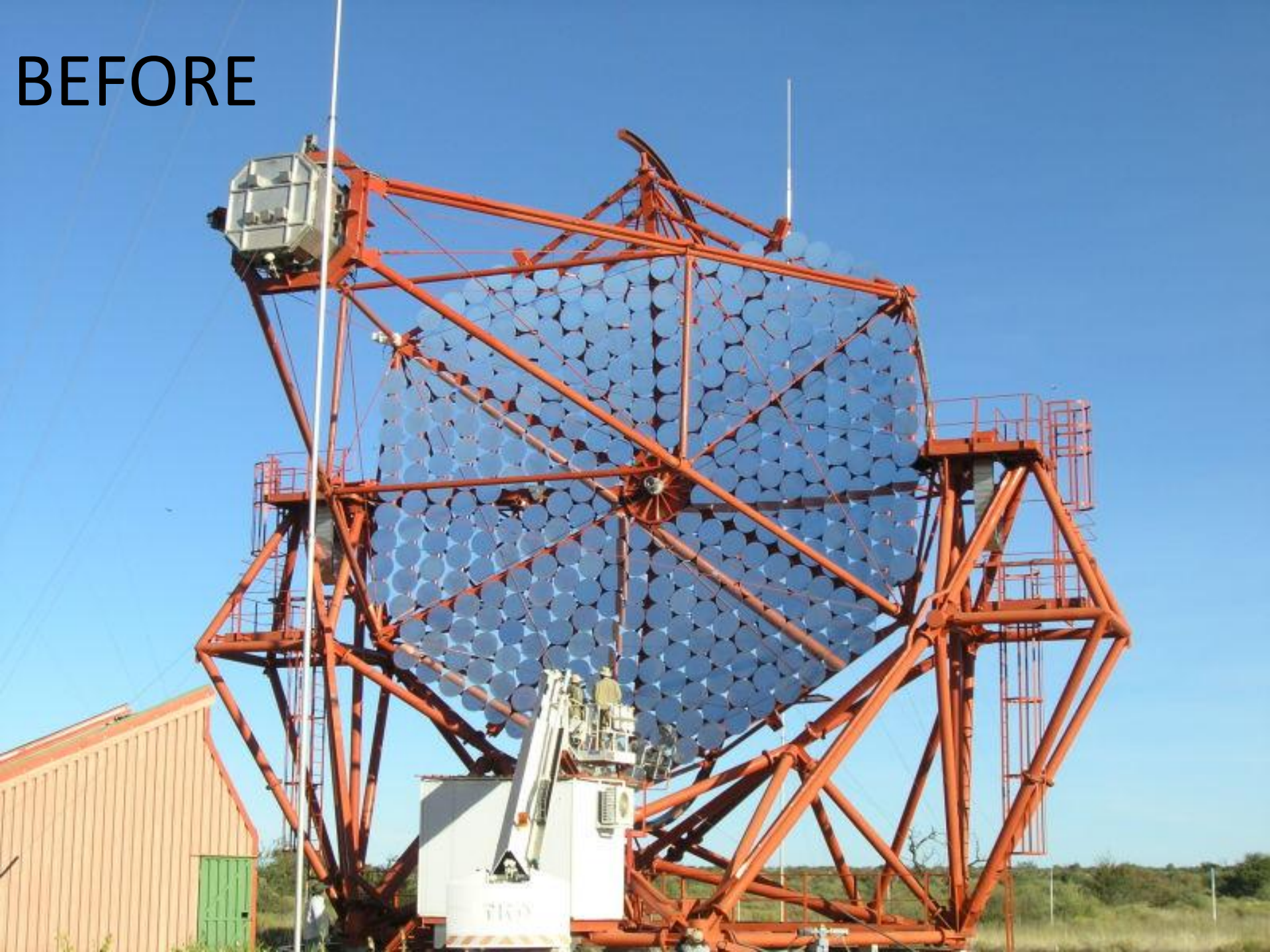
Already started

- CT3 finished two days ago
- One telescope every ~6 months

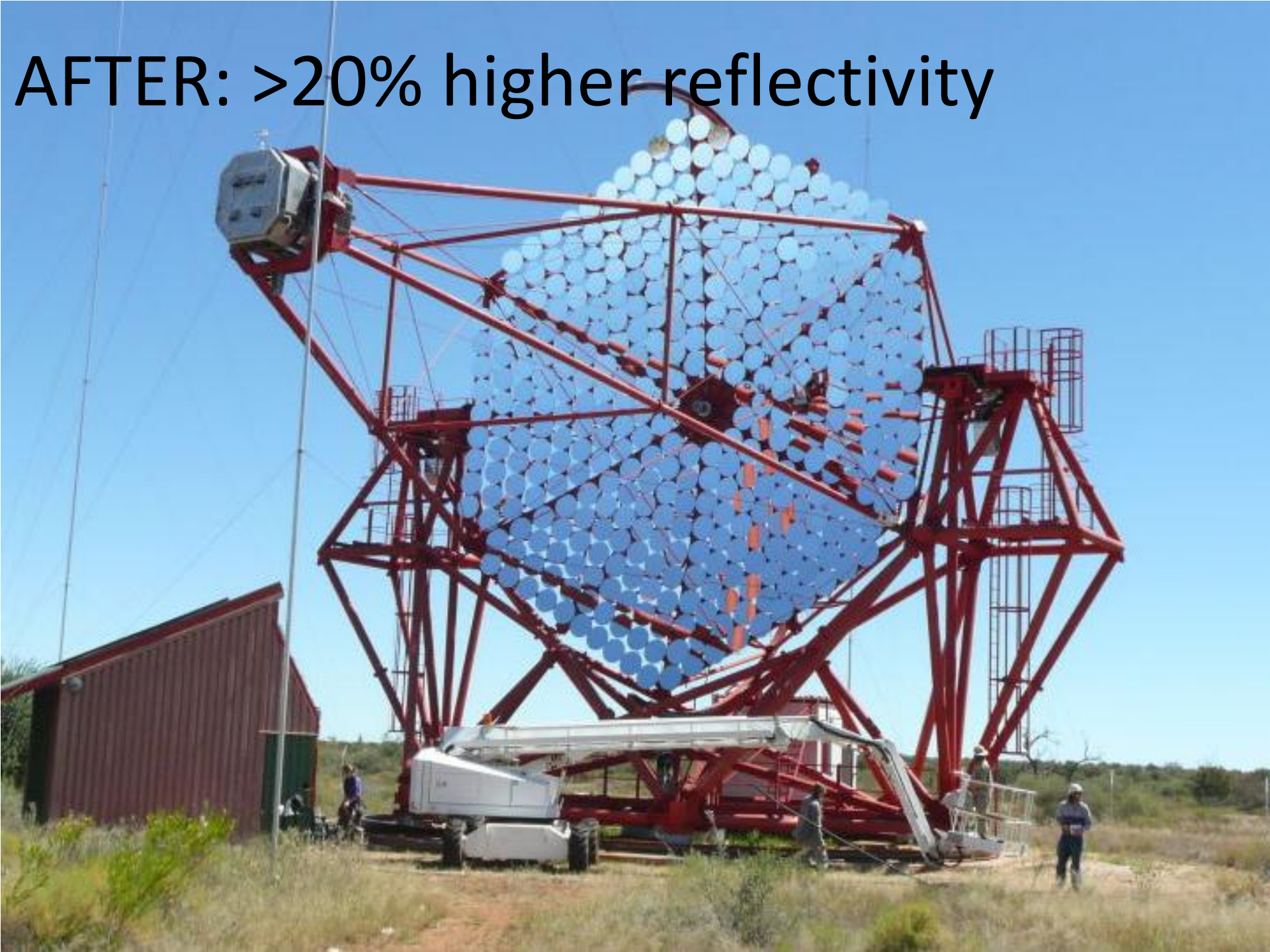
> 5% improvement in reflectivity than the currently used coating






BEFORE

AFTER: >20% higher reflectivity



HESS Phase II: Where to go next?

Goals

1) Improve the sensitivity in the current energy domain x2
   - Starburst galaxies, radio galaxies, galaxy cluster
2) Lower energy threshold
   - Less absorption → Can access more distant objects
   - Pulsars will be accessible
   - Test emission models in greater detail (hadronic/leptonic scenarious in SNR)
   - Overlap with Fermi!

Ok, how?

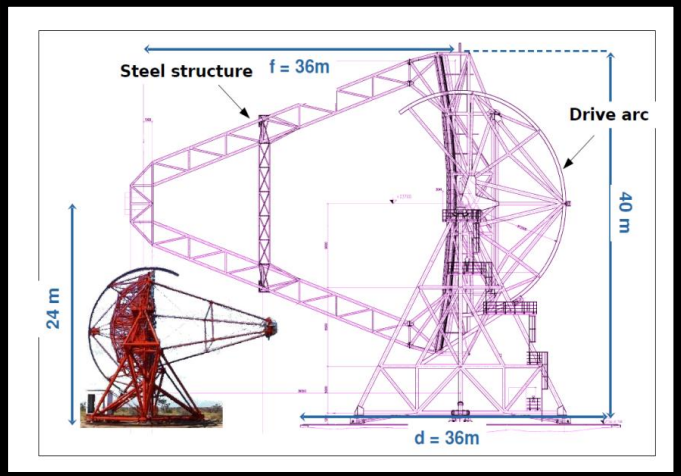
$$E_{thr} \sim \frac{1}{\sqrt{A}}$$

Add a (much) larger telescope!

HESS Phase II – A fifth large telescope in the centre of the array

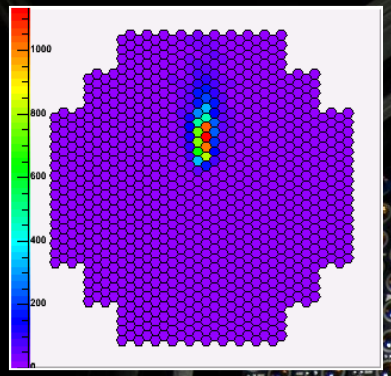
Biggest Cherenkov telescope ever built!

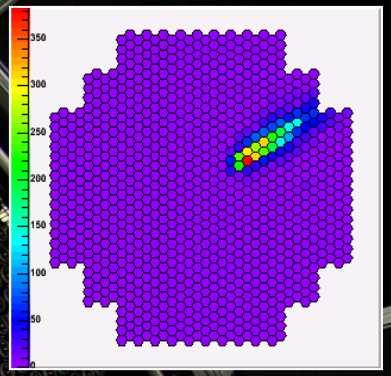
Mirror area:	600 m^2
Energy threshold:	≈20 GeV
Focal length:	36 m
Weight:	500 tonnes
Reflector:	Parabolic
FoV:	3.2°

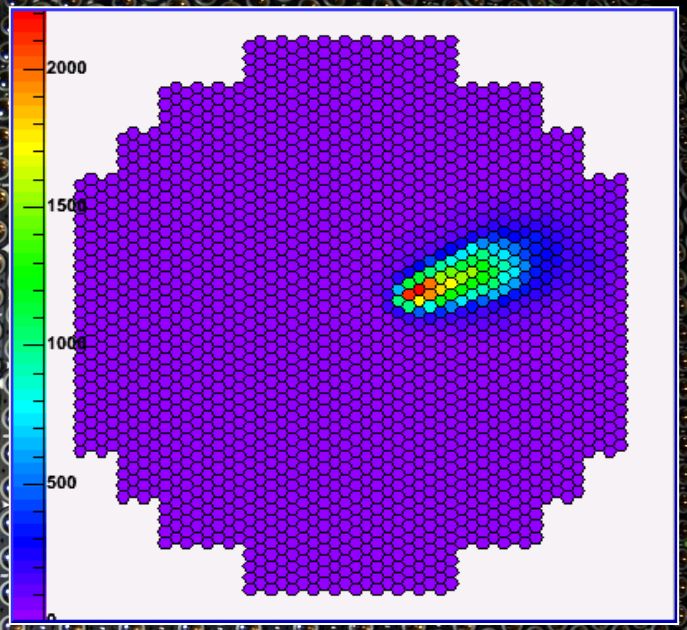


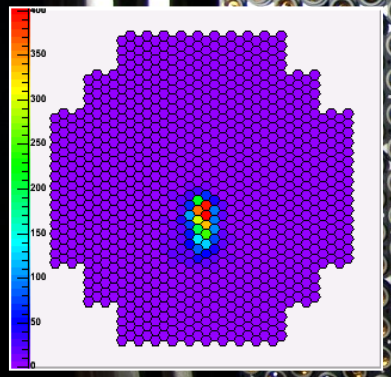
HESSII Camera

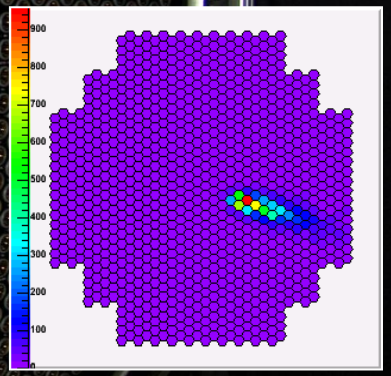
	HESSI	HESSII
#PMTs	960	2048
PMT FoV	0.16°	0.07°





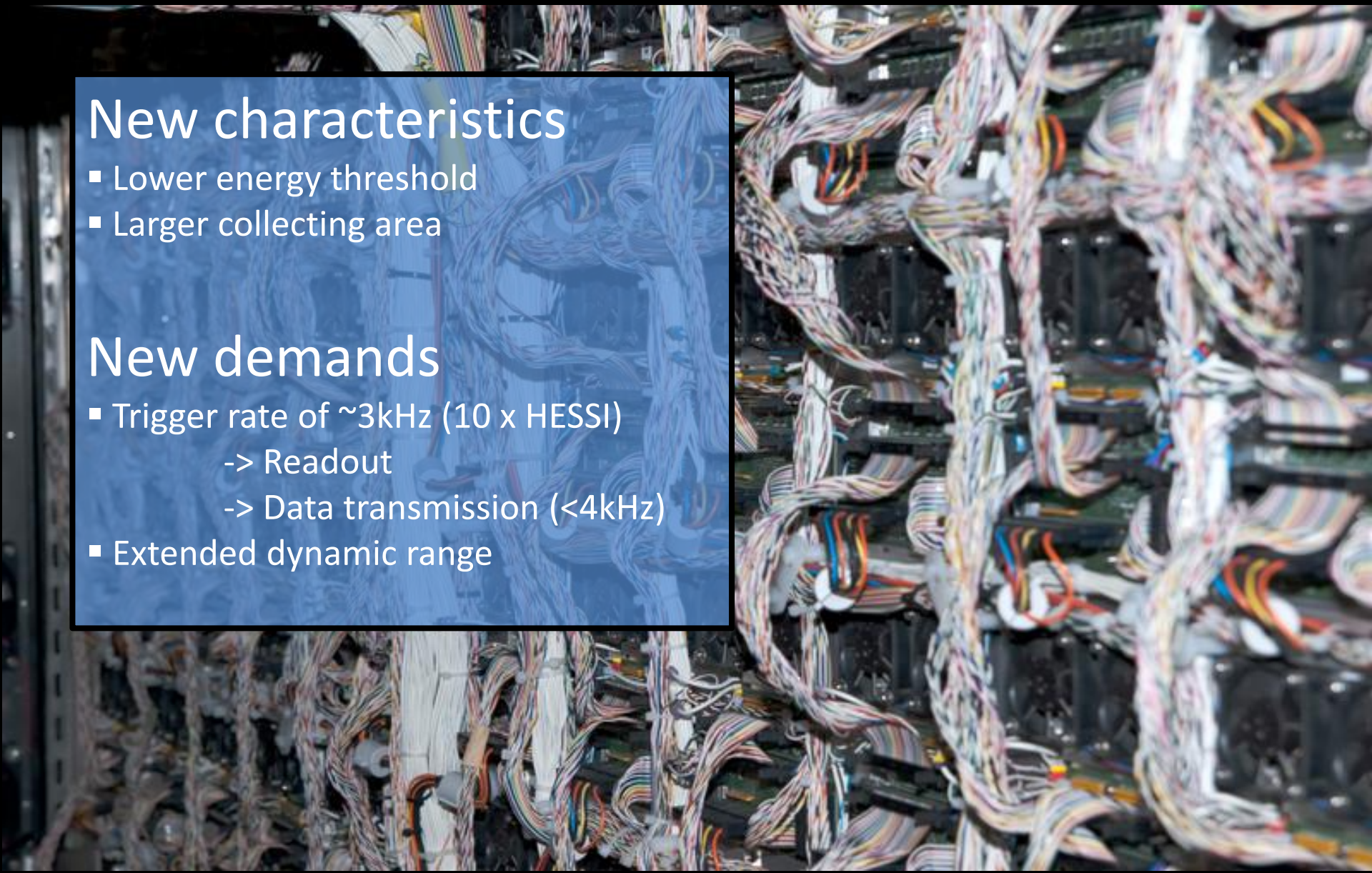






For the same energy, better definition of the shower image

HESSII Camera Electronics



New characteristics

- Lower energy threshold
- Larger collecting area

New demands

- Trigger rate of ~3kHz (10 x HESSI)
  - -> Readout
  - -> Data transmission (<4kHz)
- Extended dynamic range

HESSII Camera Electronics

New solutions

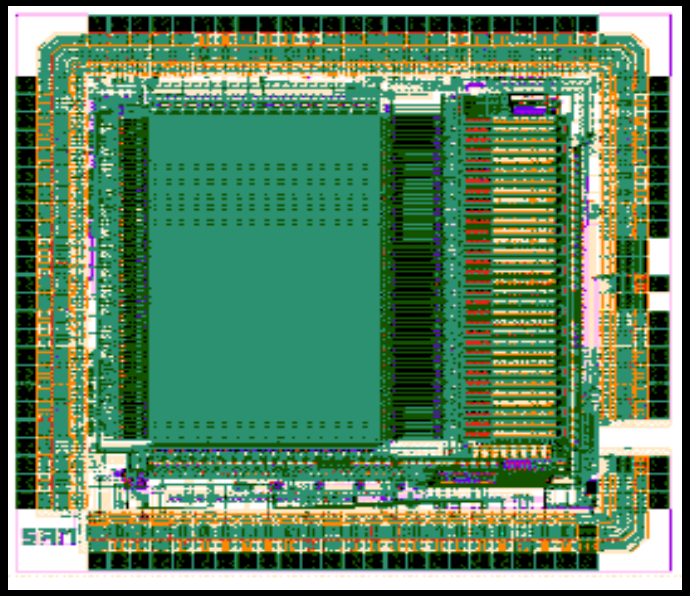
- A new ASIC chip for the analogue pipeline: *SAM (Swift Analogue Memory):*

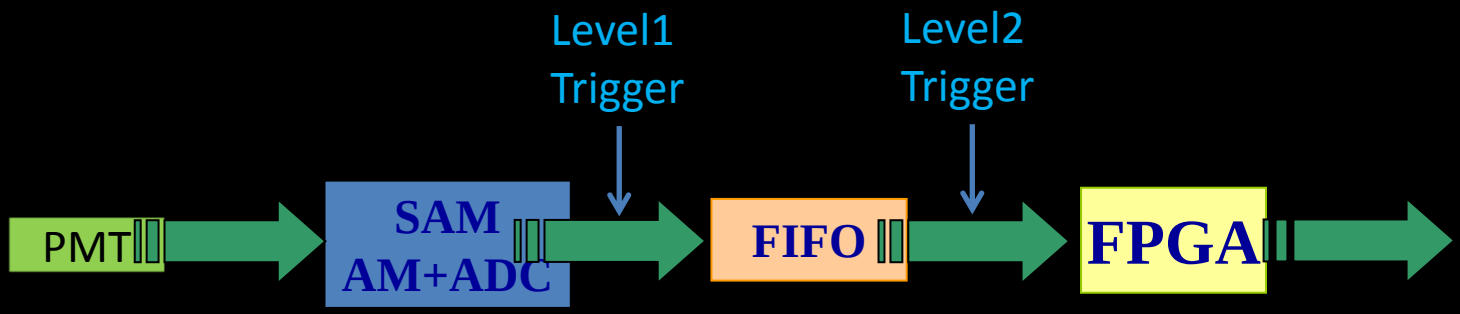
	SAM (HESSII)	ARS0 (HESSI)
Buffering	Matrix	Ring
Dynamic Range	1 pe → 6000 pe	1 pe → 1600 pe
Readout Time	1.6 µs	60 µs
Sampling Speed	2 GHz	1 GHz

Deadtime < 1% @ Trigger rate of 3kHz

- 2nd level trigger (under development)

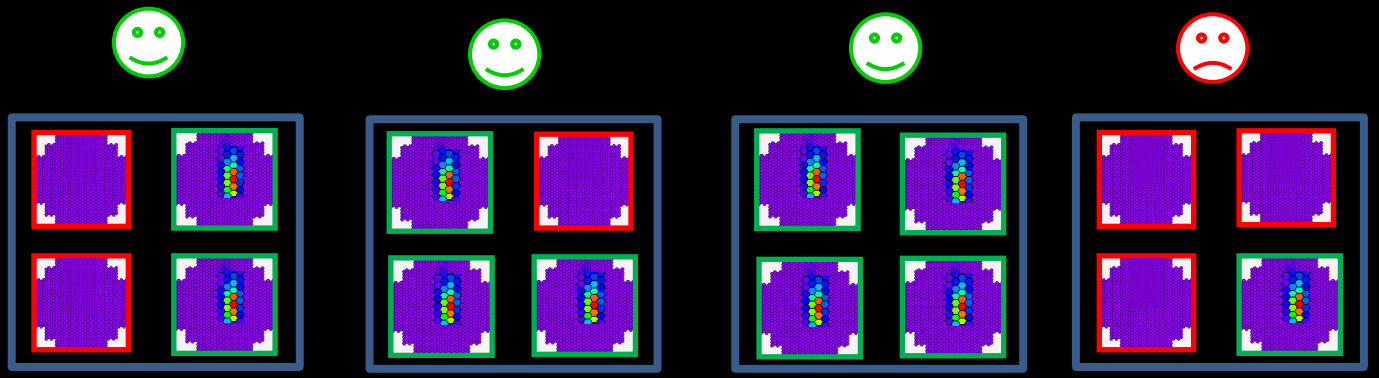
SAM: developed for HESSII by SEDI-Saclay



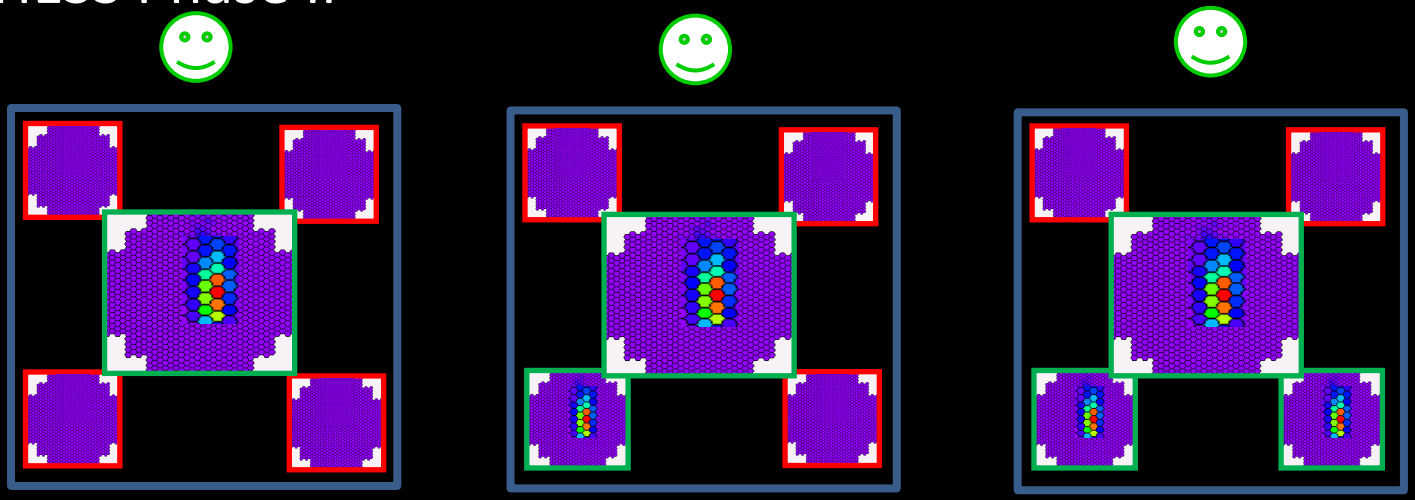


H.E.S.S. II Trigger: Operating Modes

- HESS Phase I: 2 fold coincidence

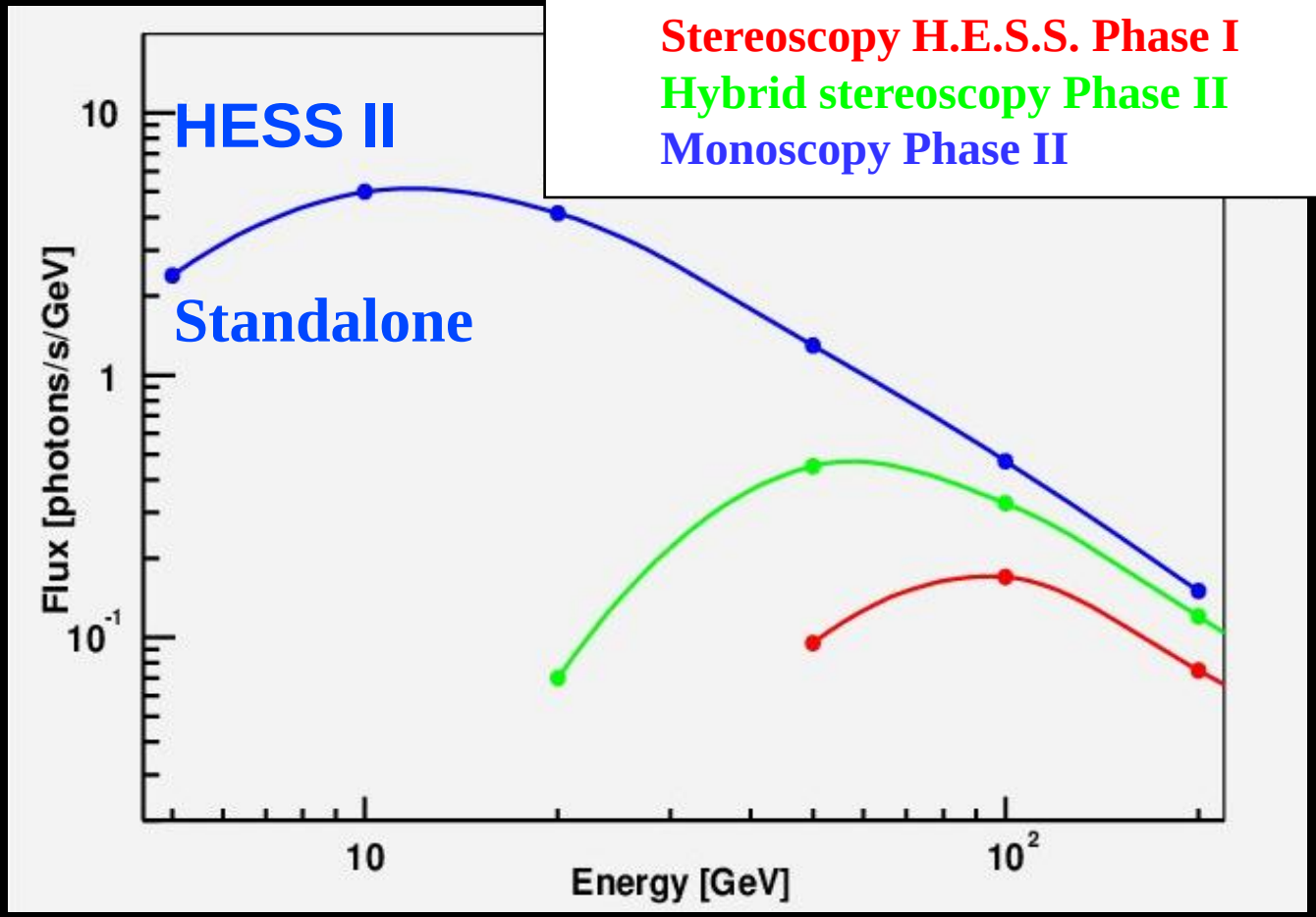


- HESS Phase II

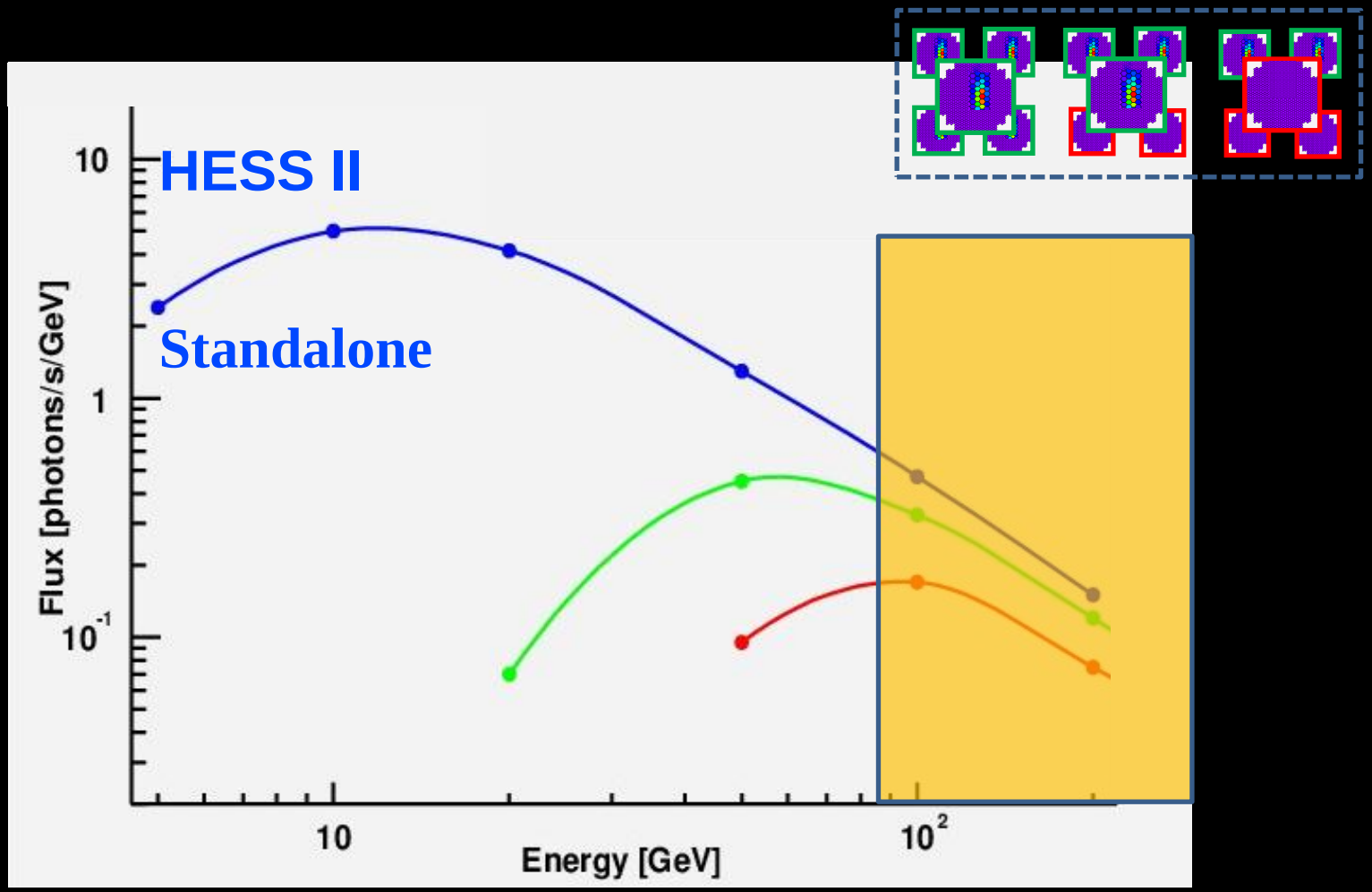


Mono Event | Stero Hybrid, Phase II | Stereo, Phase I

H.E.S.S. II Expected performance

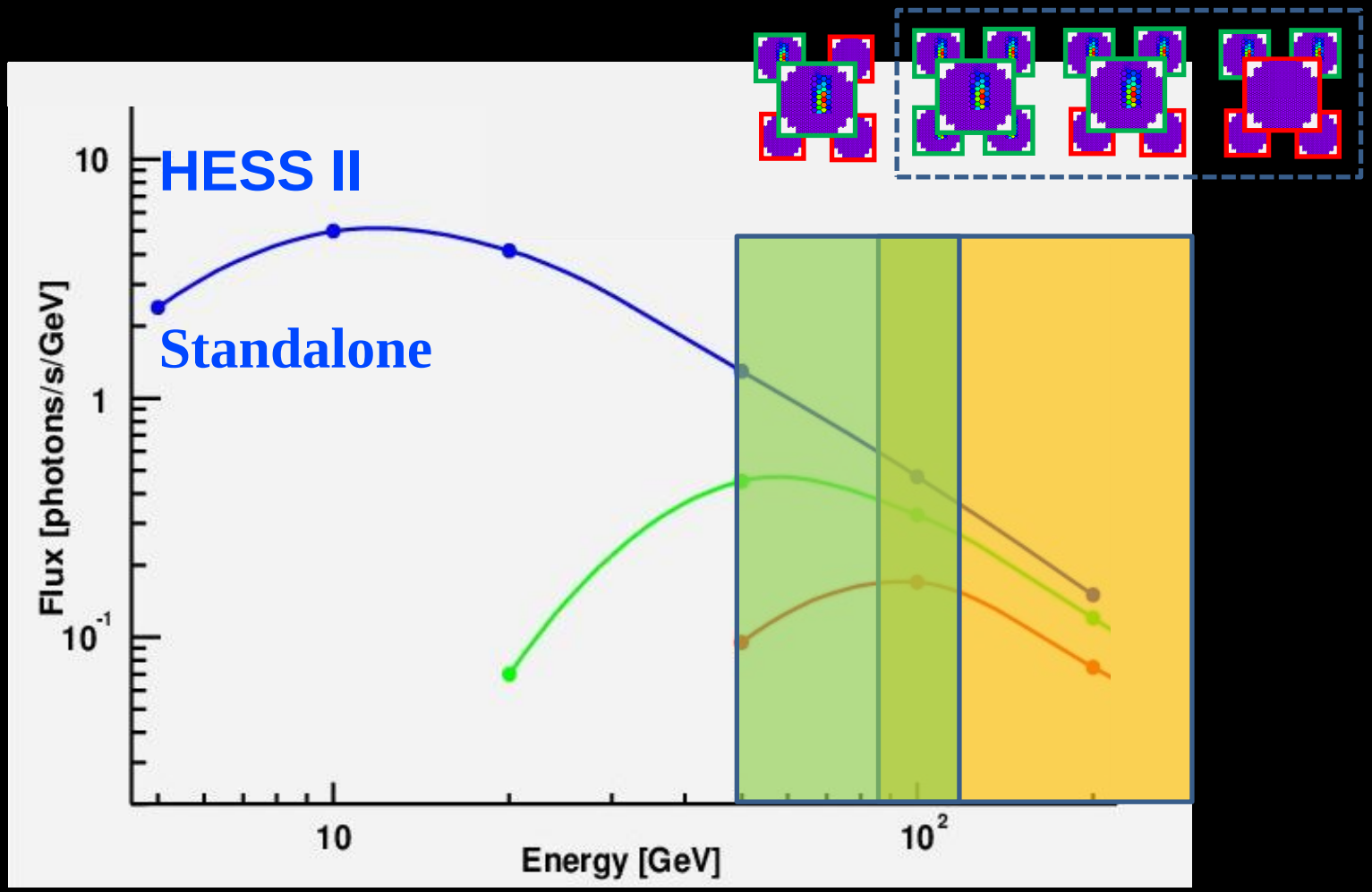


H.E.S.S. II Expected performance



Improved Sensitivity

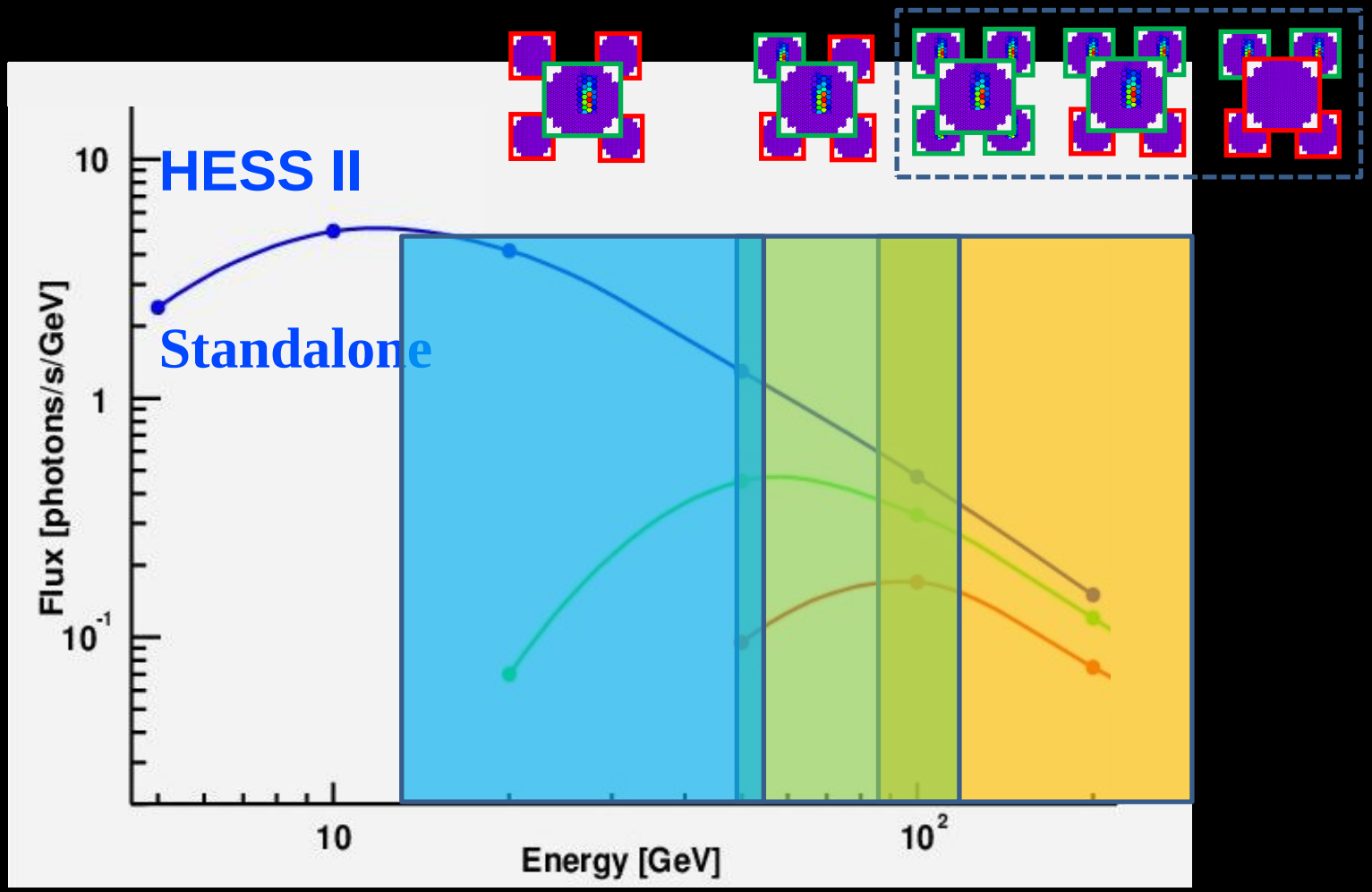
H.E.S.S. II Expected performance



New Stereo Window

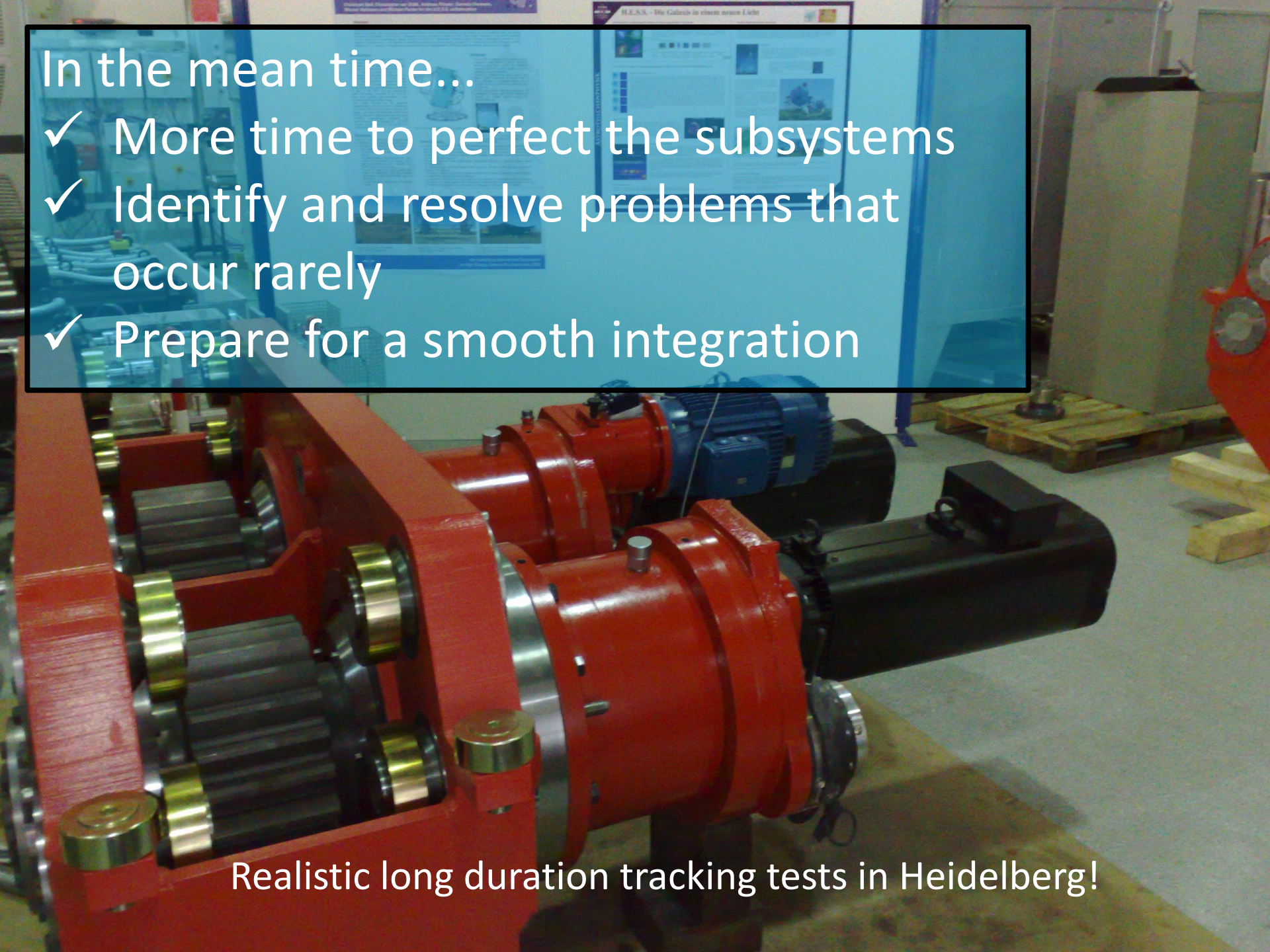
Improved Sensitivity

H.E.S.S. II Expected performance

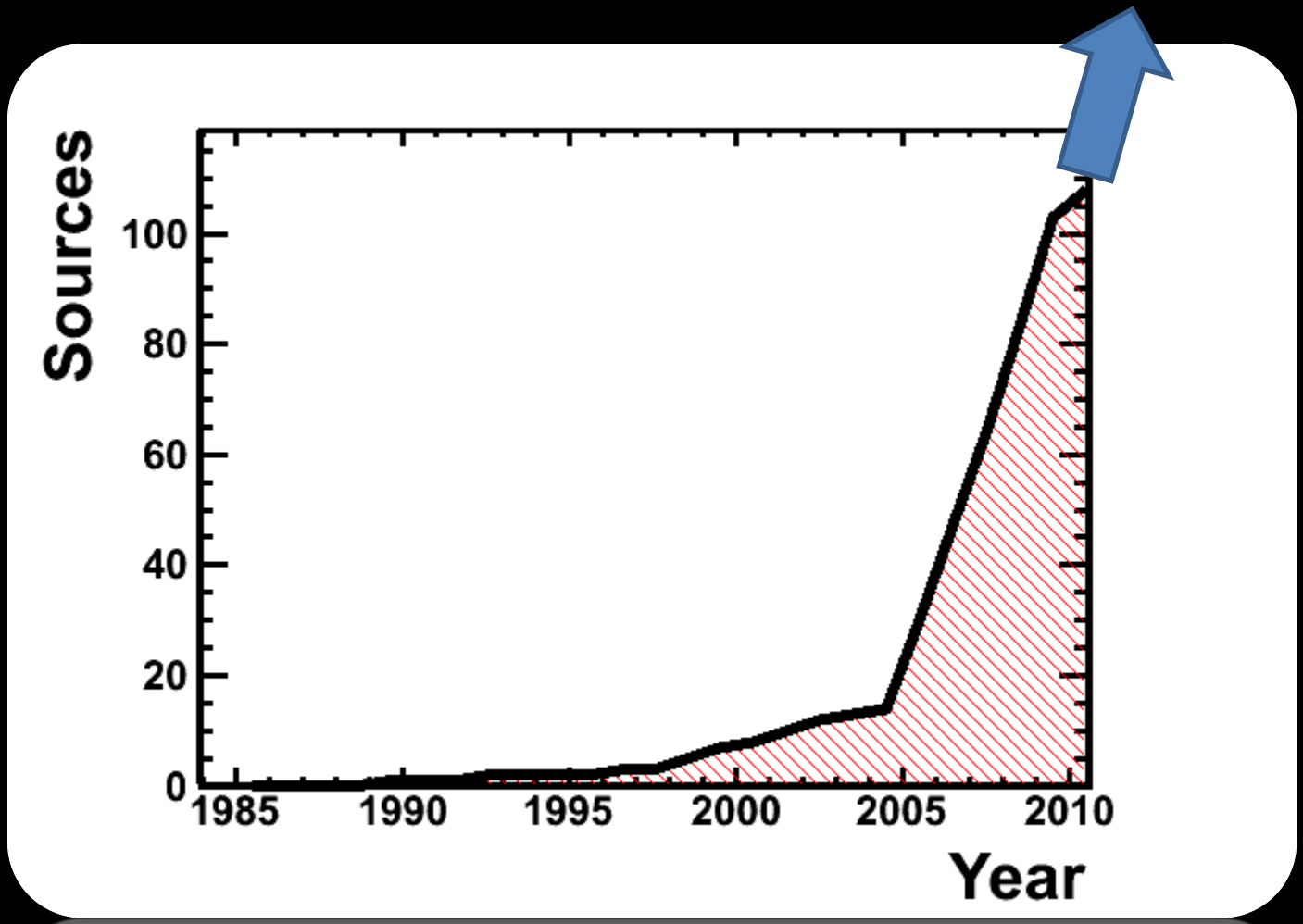


HESSII Status

- Work on steel structure stopped, contract with old company broken
- Tendering process ongoing, 2promising candidates
- Subsystems are ready to roll
- Hope to start integration in Namibia late 2011


In the mean time...
✓ More time to perfect the subsystems
✓ Identify and resolve problems that occur rarely
✓ Prepare for a smooth integration
Realistic long duration tracking tests in Heidelberg!

From source hunting to astrophysics



Petter Hofverberg
On behalf of the H.E.S.S Collaboration

Shell type supernova remnants: SN 1006

Toy model for investigating VHE gamma origin

- One zone model
- Synchrotron, IC, Bremsstrahlung, π_0 decay
- Free parameters: power law index and exponential cutoff of particle population(s), magnetic field

Two Scenarious

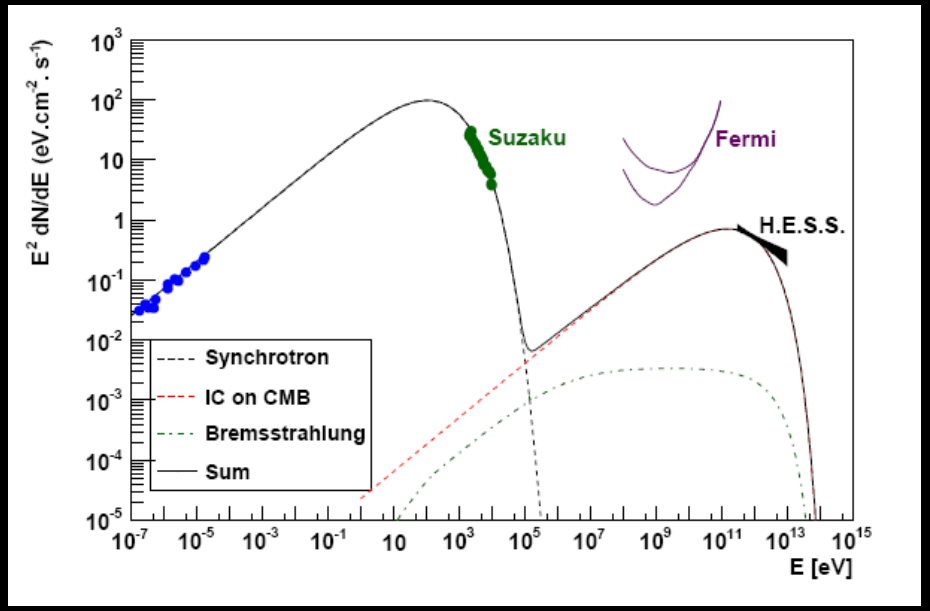
- Pure leptonic scenario

TeV γ from: IC scattering on CMB

- Mixed leptonic/hadronic scenario

TeV γ from: IC scattering + π_0 decay

Pure leptonic scenario



➢ Fails to reproduce the slope of the VHE spectrum

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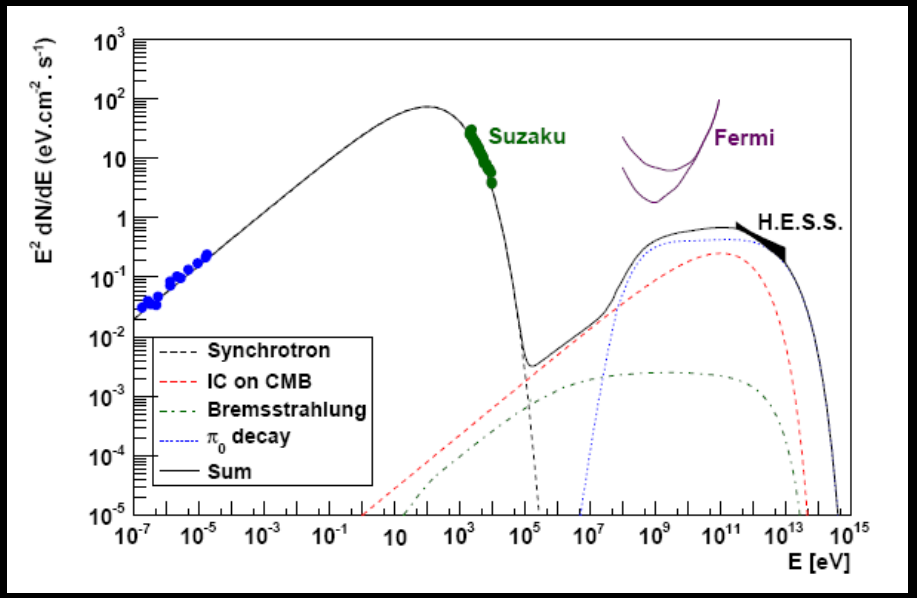
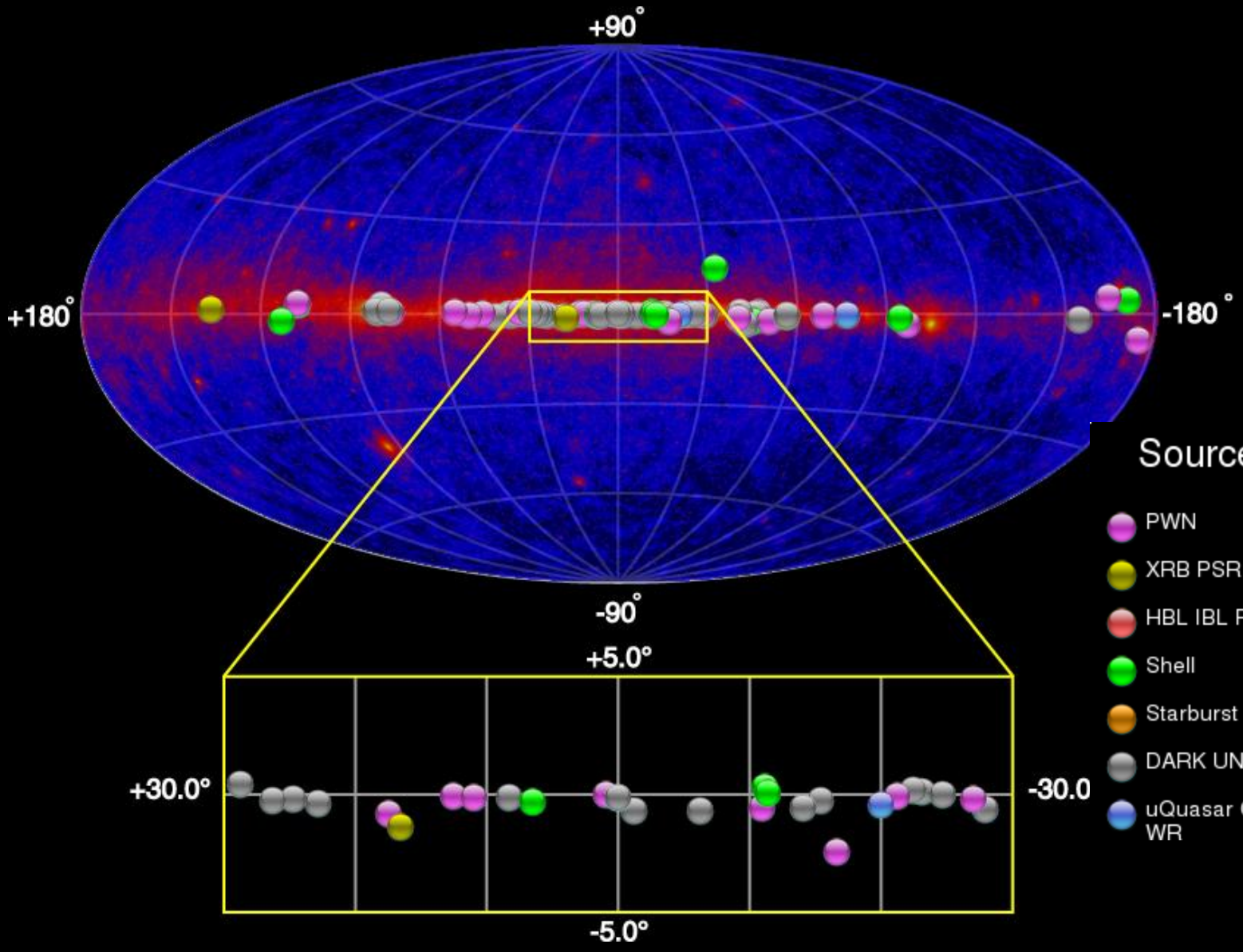
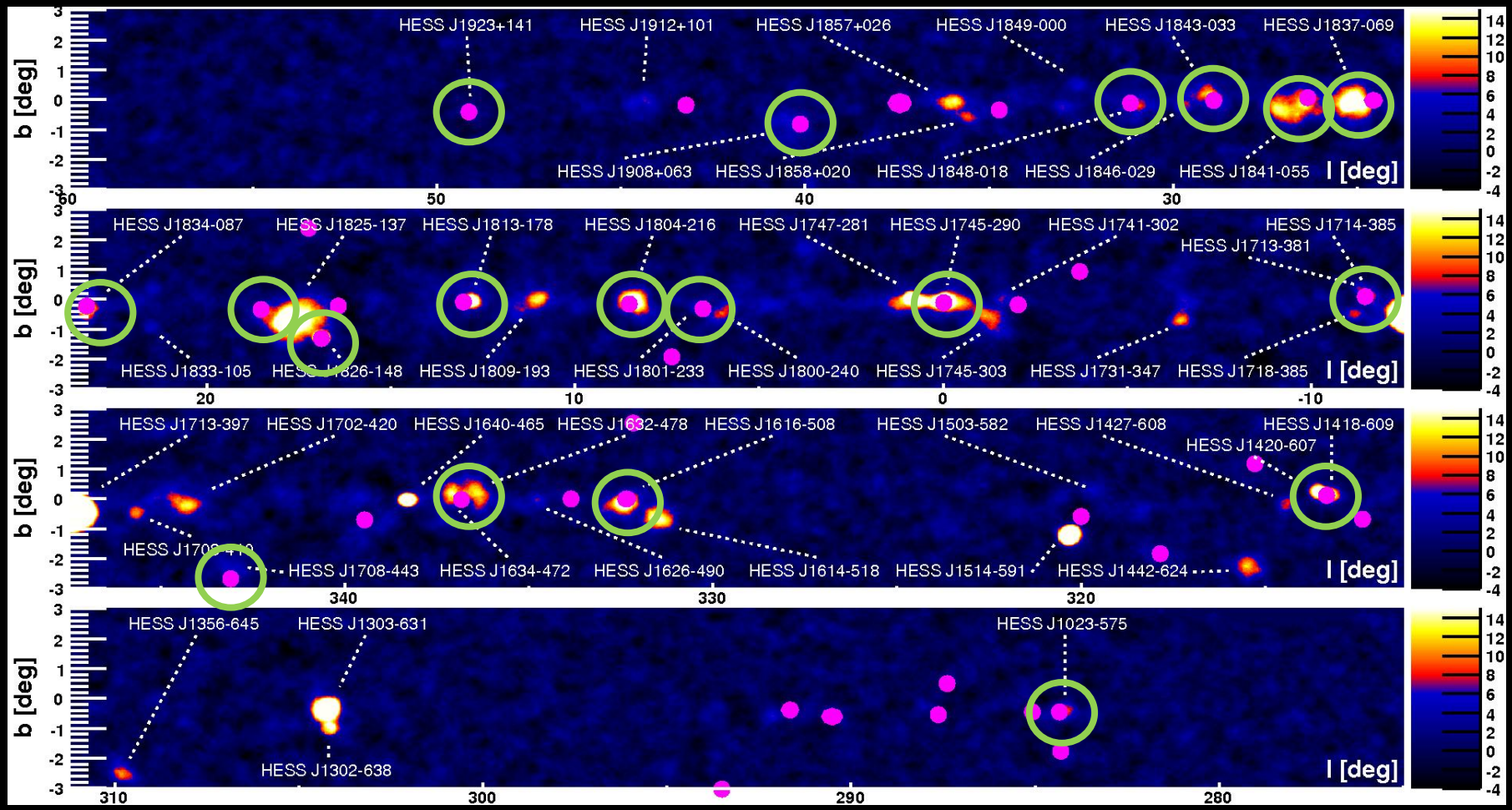


➢Possibly to reproduce all multiwave data!

H.E.S.S. as a survey instrument: A deeper, wider TeV survey



H.E.S.S. as a survey instrument: A deeper, wider TeV survey



GeV—TeV spatial associations

Significance [σ]