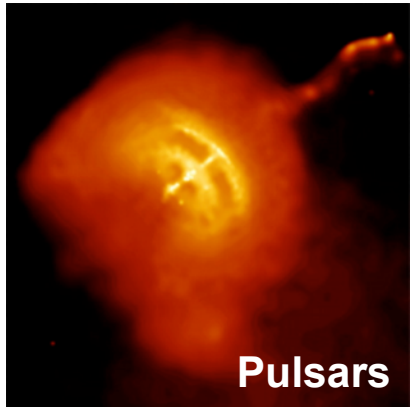
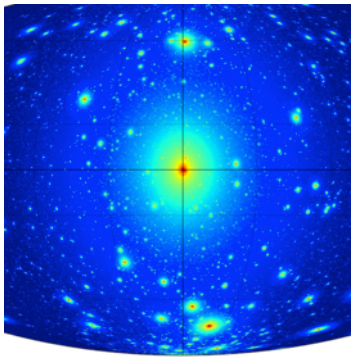
Gamma-ray astroparticle physics

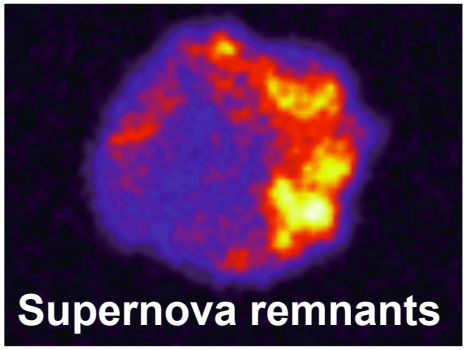
Gianluca Giavitto
83rd PRC Meeting
Hamburg, 21th March 2017

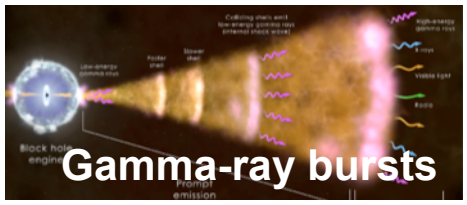
What do we do: state of the art gamma-ray astrophysics

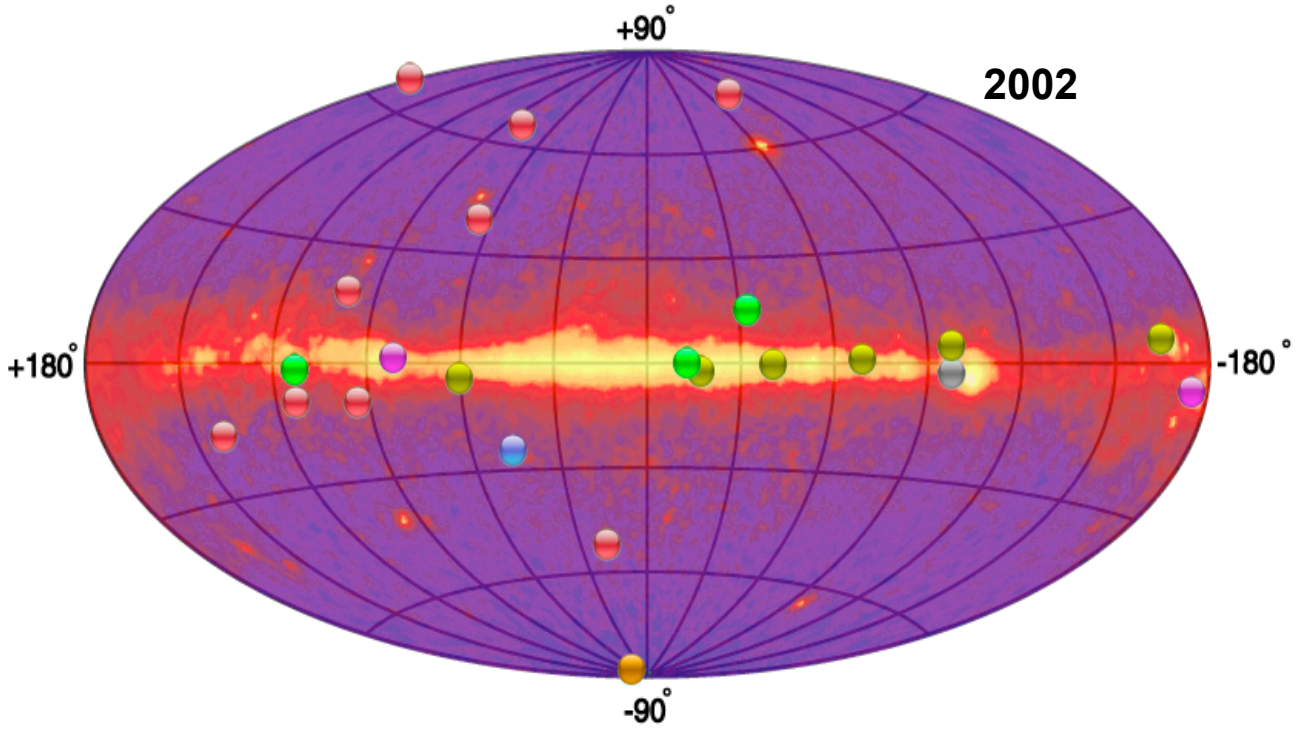
- Cosmic accelerators
- Extreme environments
- Frontiers of physics











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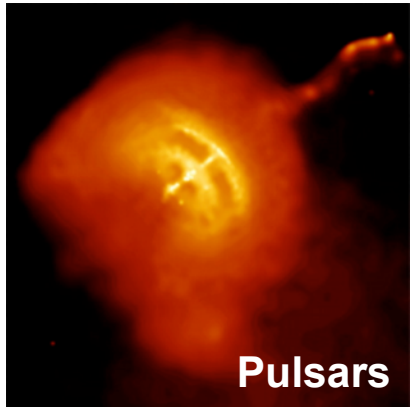
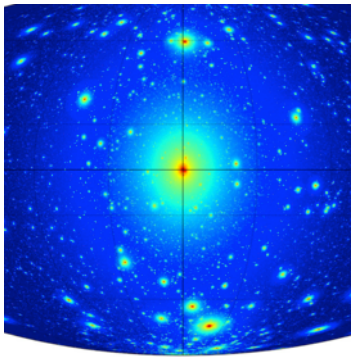
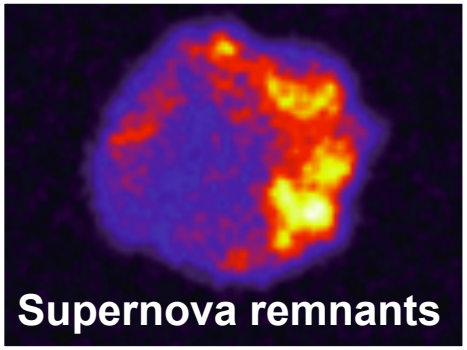
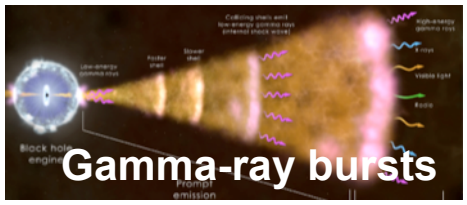
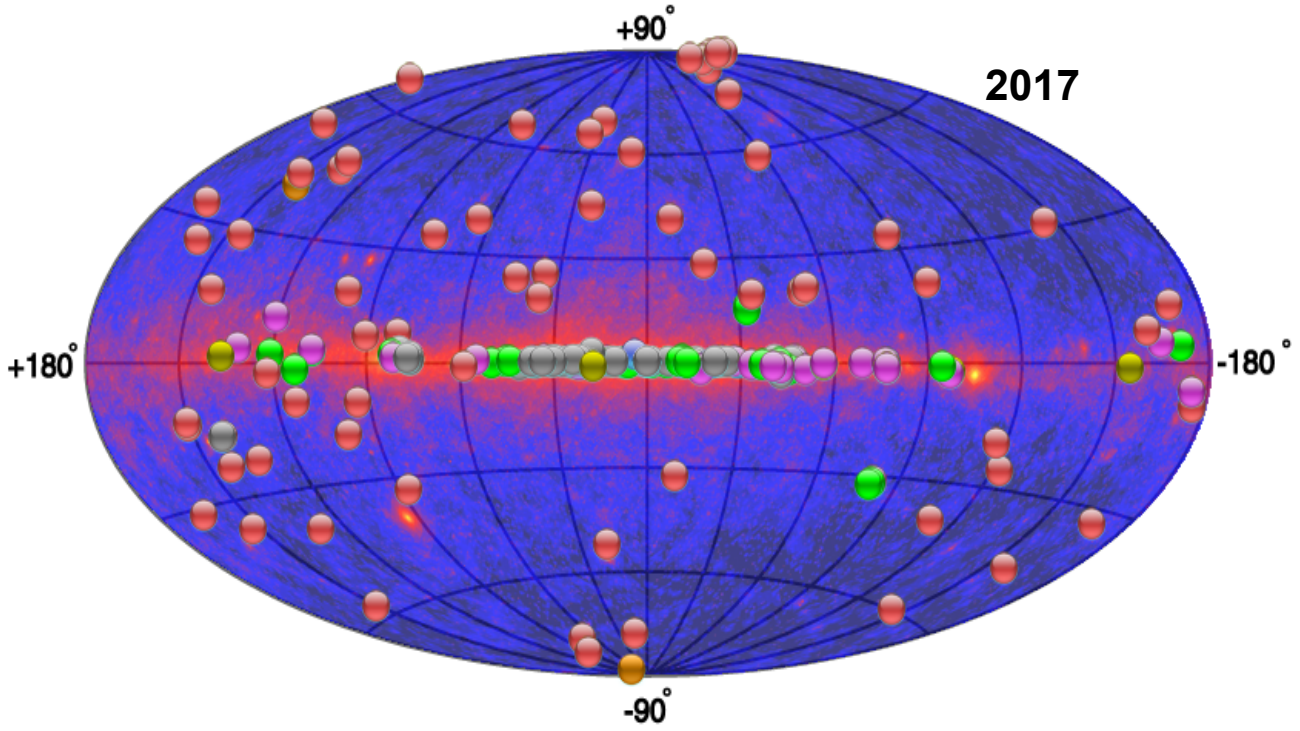






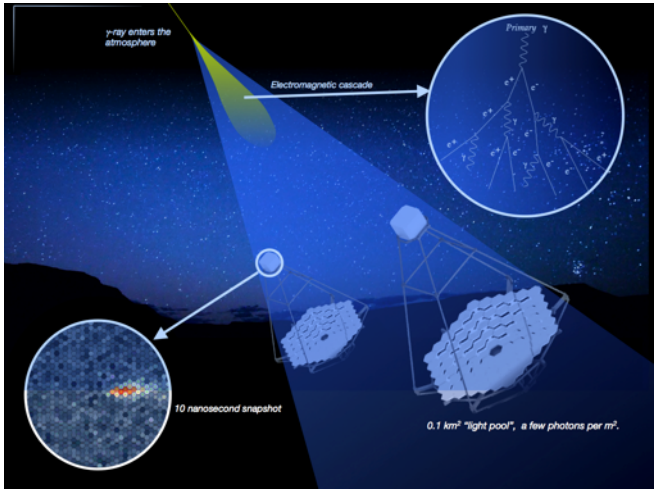




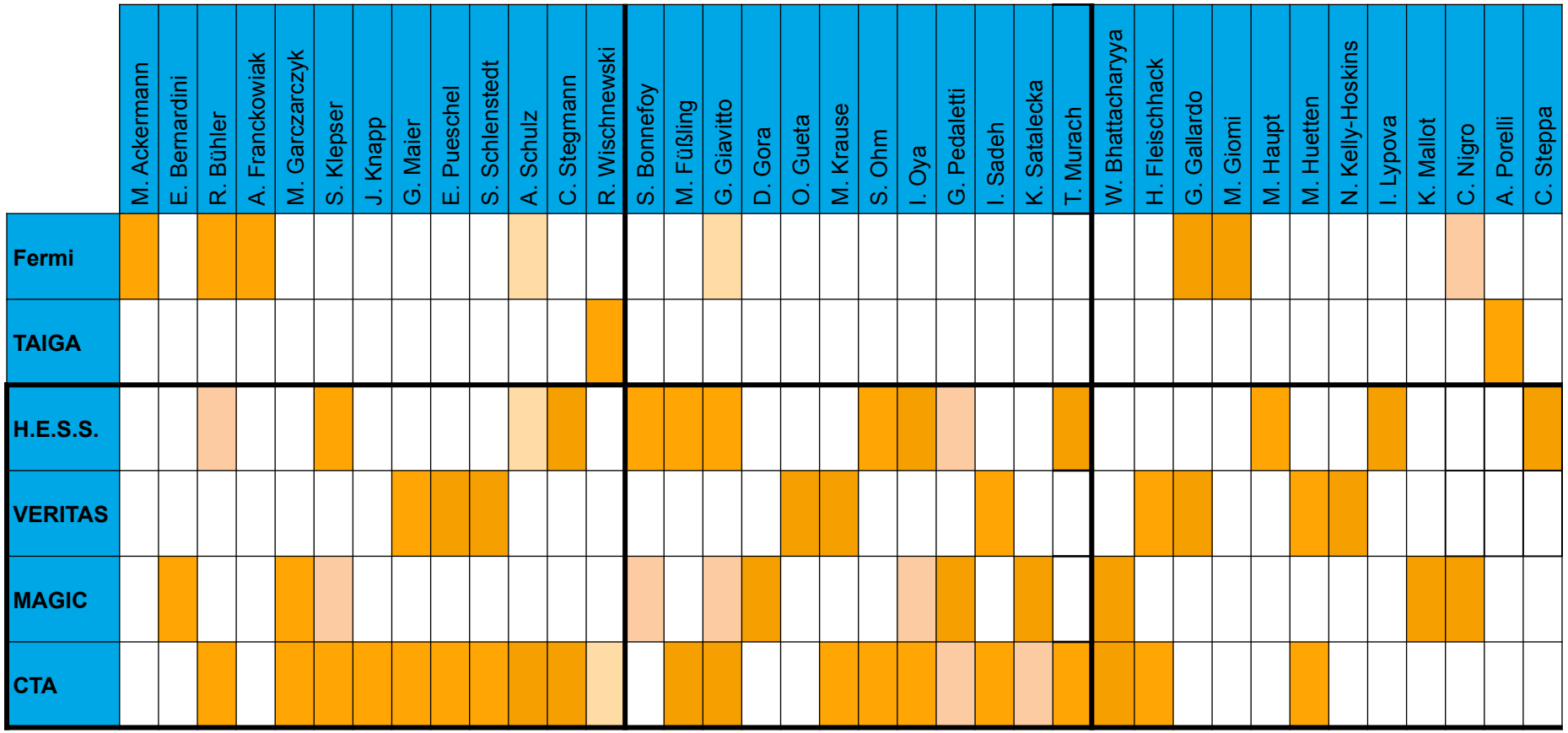
What do we use: gamma-ray instruments

	Ground-based imaging atmospheric Cherenkov telescope arrays (IACTs)	Space-borne pair-conversion gamma-ray satellites
Energy range	~20 GeV to 100 TeV (VHE)	~20 MeV to 300 GeV (HE)
Collection Area	10^5 m^2	1 m^2
Field of View	3-5 degrees	60 degrees
Angular resolution	0.1 degrees	6 to 0.3 degrees
Energy resolution	20%	10%

+ non-imaging arrays of Cherenkov detectors



Who we are: the DESY gamma-ray team (+2 since last PRC)



- 6 groups
- 13 staff
- 12 post-docs
- 12 PhD students

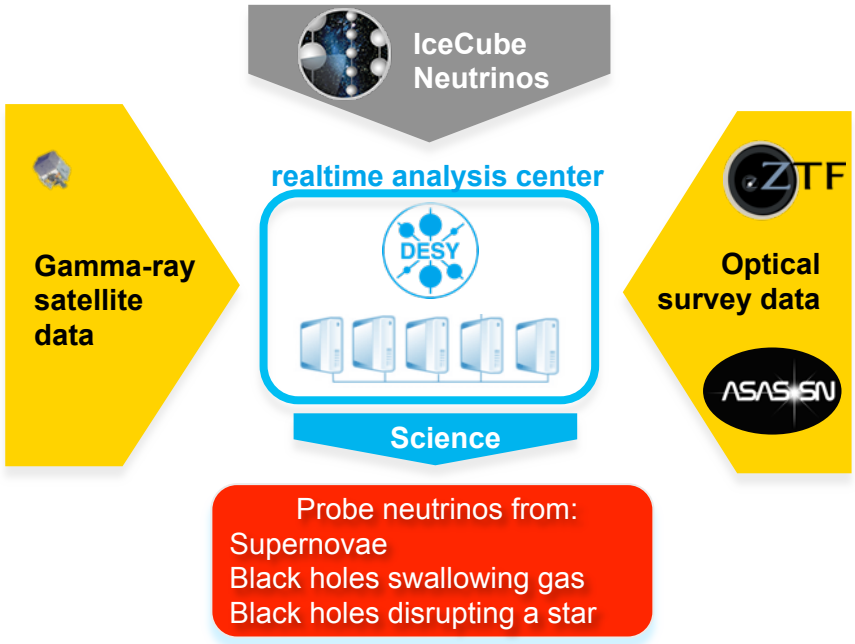
Table Legend	
Currently active	
Former member	

Young Investigator Groups

> Anna Franckowiak

"Identifying the sources of high-energy neutrinos with **multi-messenger** observations"

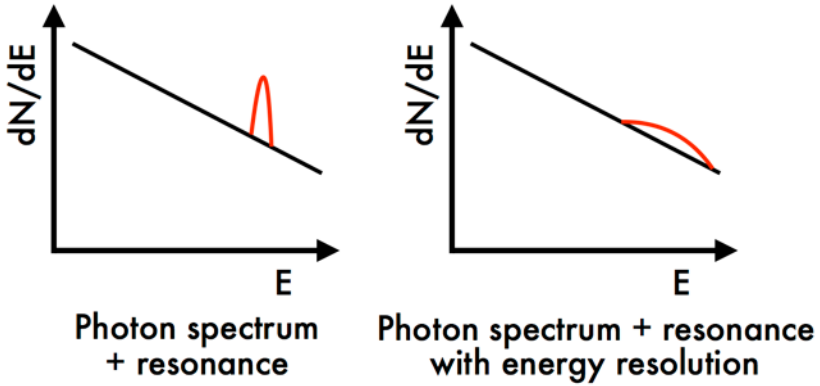
- Connecting gamma rays, optical and neutrino astronomy



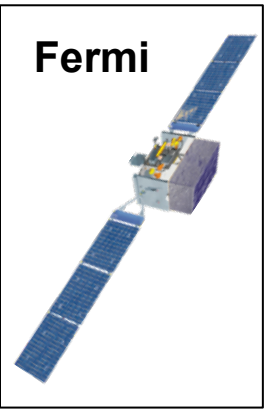
> Elisa Pueschel

"Astrophysical search for physics beyond the Standard Model of particle physics"

- Connecting gamma-ray astrophysics and particle physics

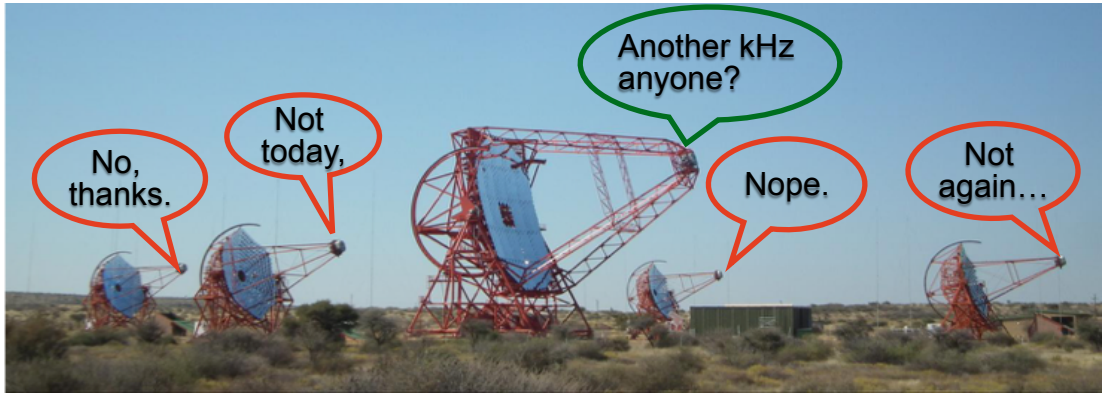


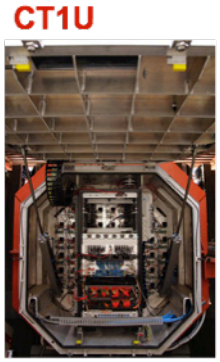
Highlights from currently operating installations

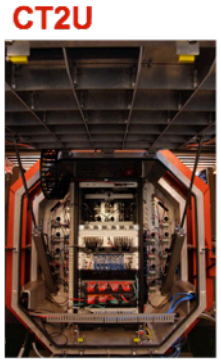


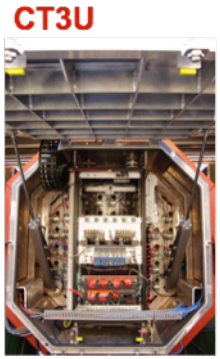
H.E.S.S.-I camera upgrade

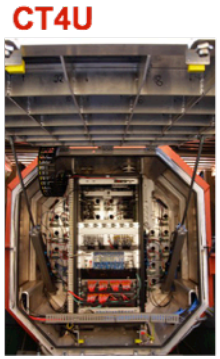
- Improves performance and reliability of array
- First camera in 2015
- Other three in 2016
- 10 people from DESY involved, leading





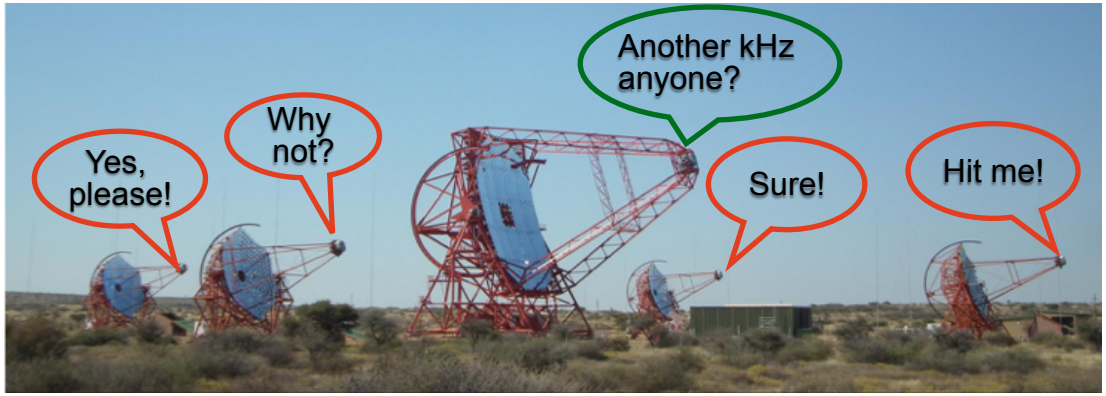


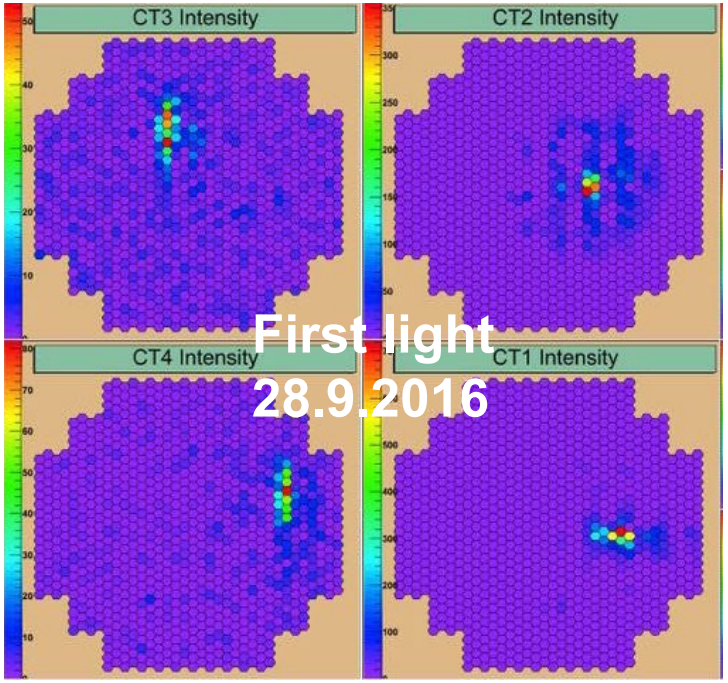




H.E.S.S.-I camera upgrade: finished!

- Improves performance and reliability of array
- First camera in 2015
- Other three in 2016
- 10 people from DESY involved, leading
- First light on 28.9.2016
- Commissioning done
- Hand-over on 31.01.2017

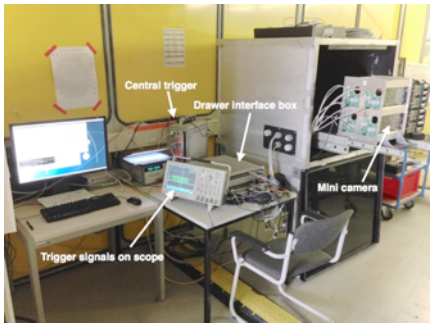


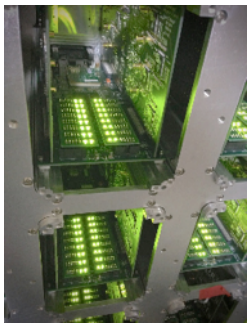
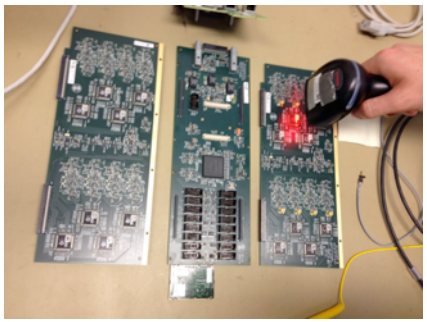
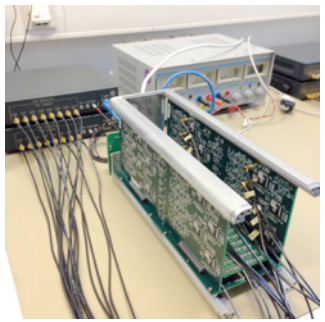


H.E.S.S.-I camera upgrade: a major undertaking

4 cameras, 4 years, ~800 boards, 7680 channels, new trigger, new software, full commissioning ...



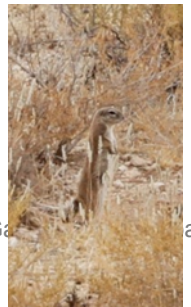











H.E.S.S.-I camera upgrade: first detected source!

> Camera ready for scientific operation – 25.12.2016

ACCELERATORS | PHOTON SCIENCE | PARTICLE PHYSICS

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

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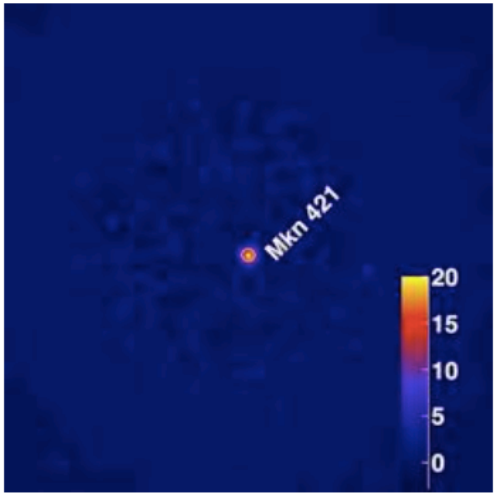
Back

New eyes for the gamma-ray sky

Final milestone for the upgraded H.E.S.S. telescopes in Namibia

The newly refurbished cameras of the H.E.S.S. gamma-ray telescopes in Namibia have detected their first signals from a cosmic particle accelerator: The new cameras recorded Markarian 421 as their first target, a well-known blazar in the constellation of Ursa Major. The active galactic nucleus, 400 million light years away, was detected during an active state and at high significance. After four years of development, testing, production and deployment, this is the last big milestone of the H.E.S.S. I camera upgrade project, which was led by DESY. The success is also an important test for the next generation gamma-ray observatory, the Cherenkov Telescope Array CTA, which will use the same camera technology.

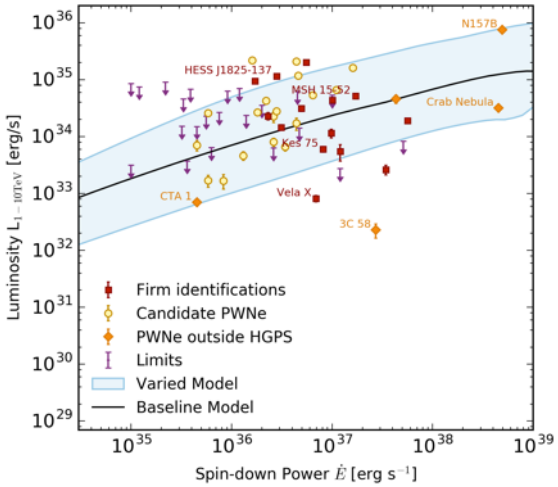


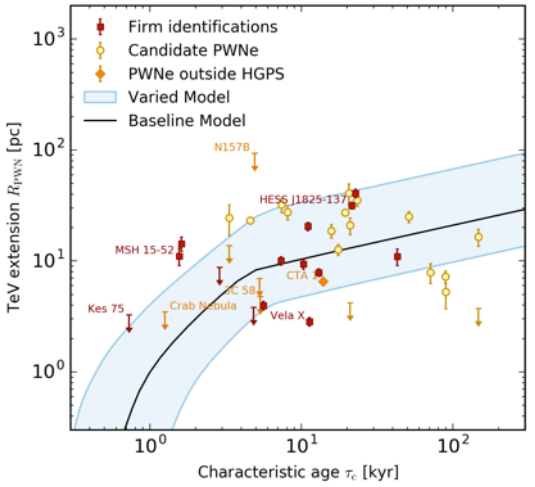
Download [182KB, 1024 x 1024]

When H.E.S.S. explores the mysteries of the high-energy sky, it actually does not look into the Universe, but at the upper atmosphere. Cosmic gamma-rays are absorbed there and produce short, faint

Other H.E.S.S. group highlights

- H.E.S.S. legacy paper on the population of TeV pulsar wind nebulae
- PWN get faint when they age
  - electron synchrotron cooling
- PWN expand as they age
  - electron diffusion
- Pulsar offsets for older PWN are larger than expected
  - inhomogeneity of interstellar medum
- Bonus: Statistics paper on source detection
  - arXiv:1701.047371

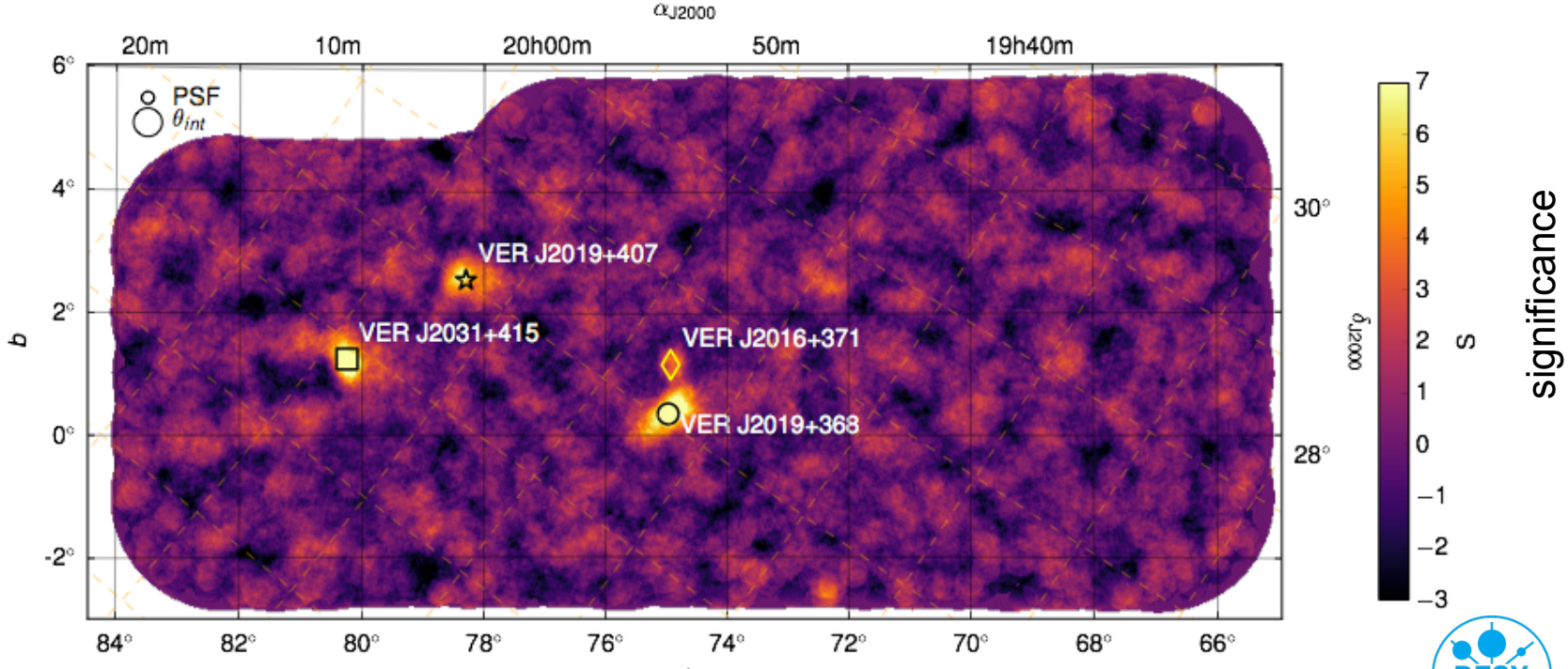




arXiv:1702.08280

The VERITAS Survey of the Cygnus Region

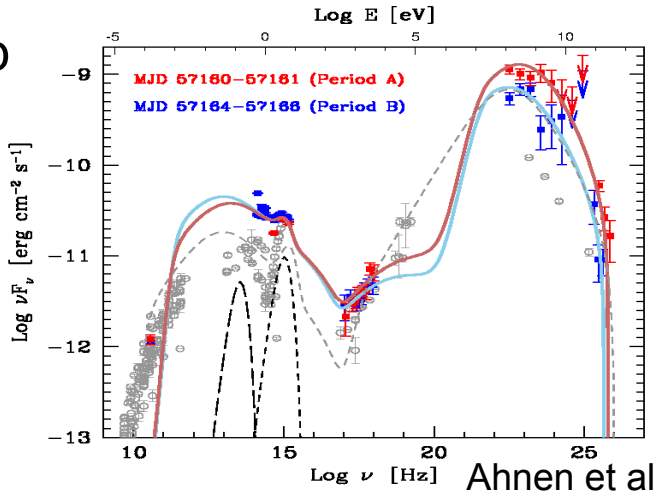
- First deep survey of the Cygnus region at energies above 100 GeV
- Brightest region of diffuse gamma rays in the Northern sky
  - wealth of cosmic-ray accelerators: >10 supernova remnants, >14 pulsars, active star forming region
- Analysis of all 300 h of VERITAS data with advanced analysis methods
  - detection of four gamma-ray sources and flux U.L. for the whole region on the level of <2% Crab

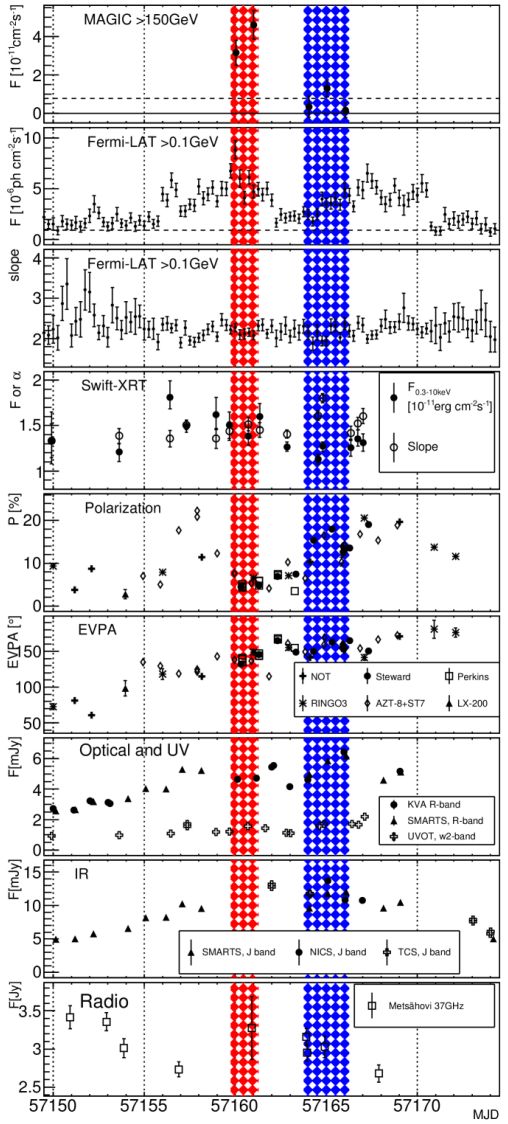


PhD M.Krause, To be published in *The Astrophysical Journal (2017)*

MAGIC: PKS 1510-089 Very High Energy variability

- First Flat Spectrum Radio Quasar detected in VHE gamma rays
- MAGIC data reveal significant variability in May 2015 flare for first time in this source, unexpected
- Constraints on location and size of emission region
- Variability can be explained by small changes in B-field and e-distribution in EC model
- MAGIC DESY group involved in data analysis

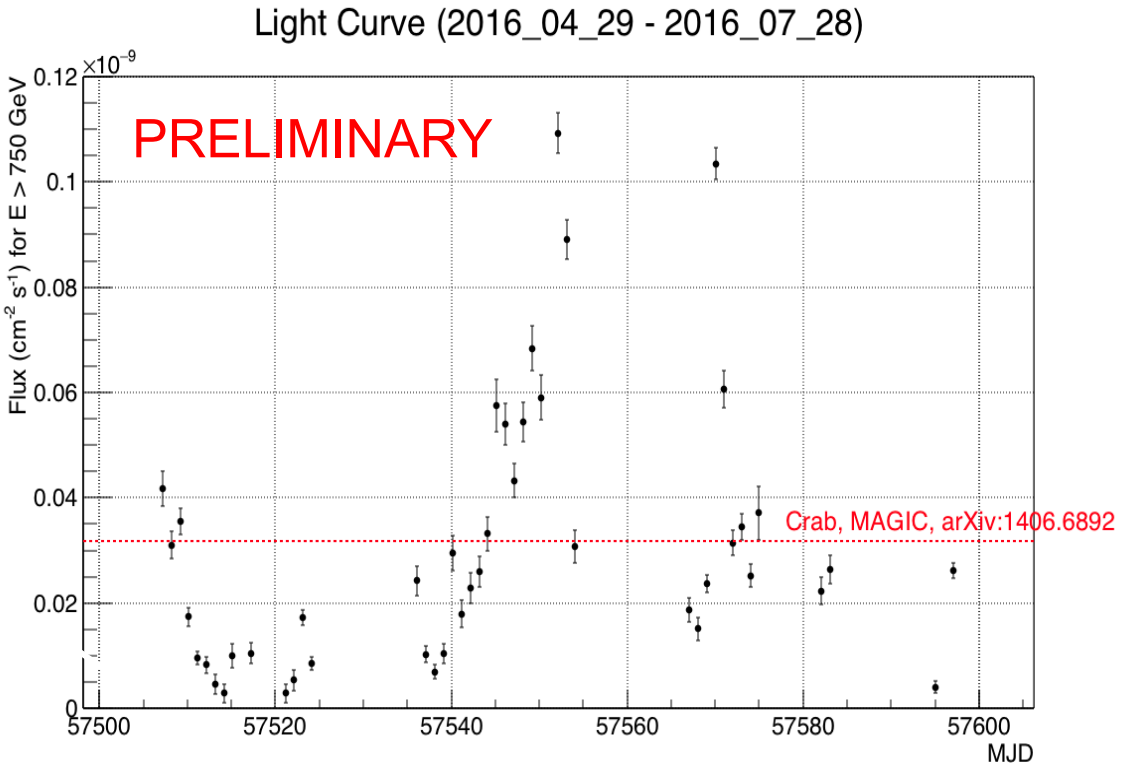




Ahnen et al. 2017 A&A

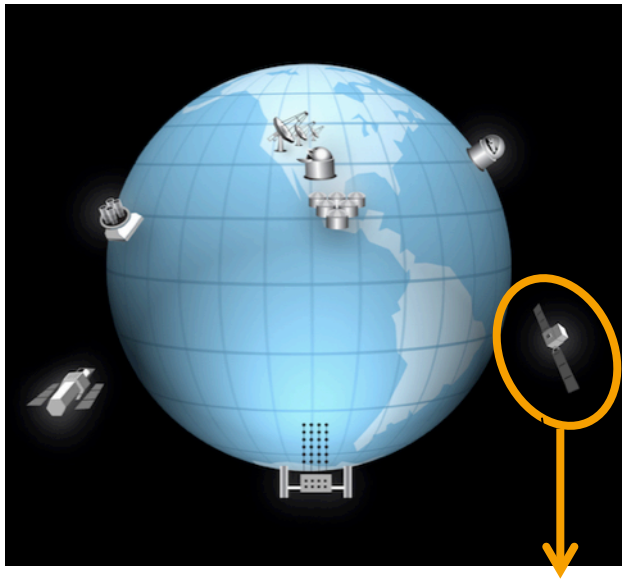
MAGIC: 1ES 1959+650 – a dormant blazar flares again!

- 1ES 1959+650, one of the first VHE gamma ray sources discovered, laid dormant since 2002…
- April – July 2016 long flaring period with VHE gamma ray fluxes ~3.0 x Crab Nebula flux!
- Input to joint analysis with neutrino data from IceCube to test hadronic emission
- **MAGIC & IceCube DESY** groups involved in data analysis and interpretation



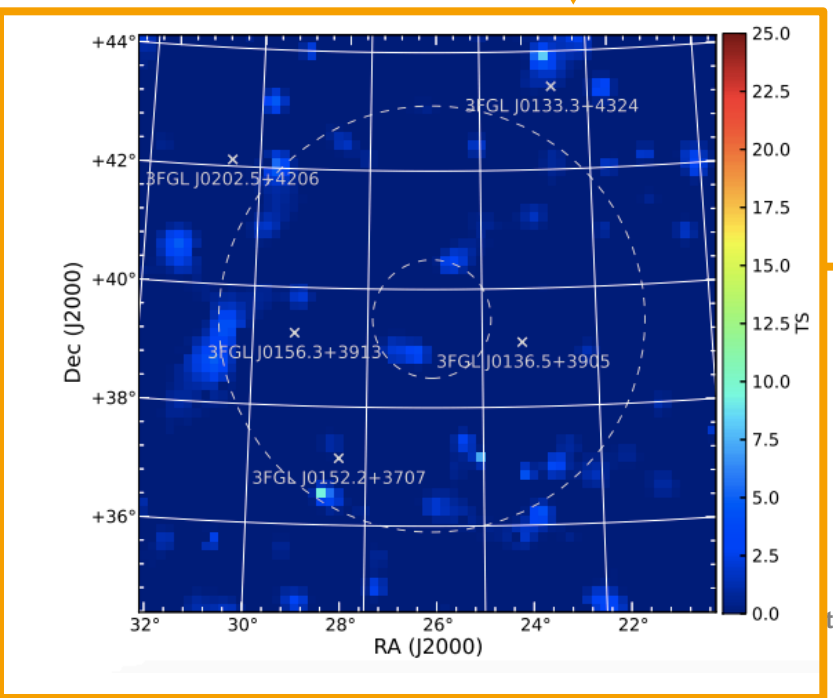
W. Bhattacharyya: flare advocate (ATel #9010) and data analyzer

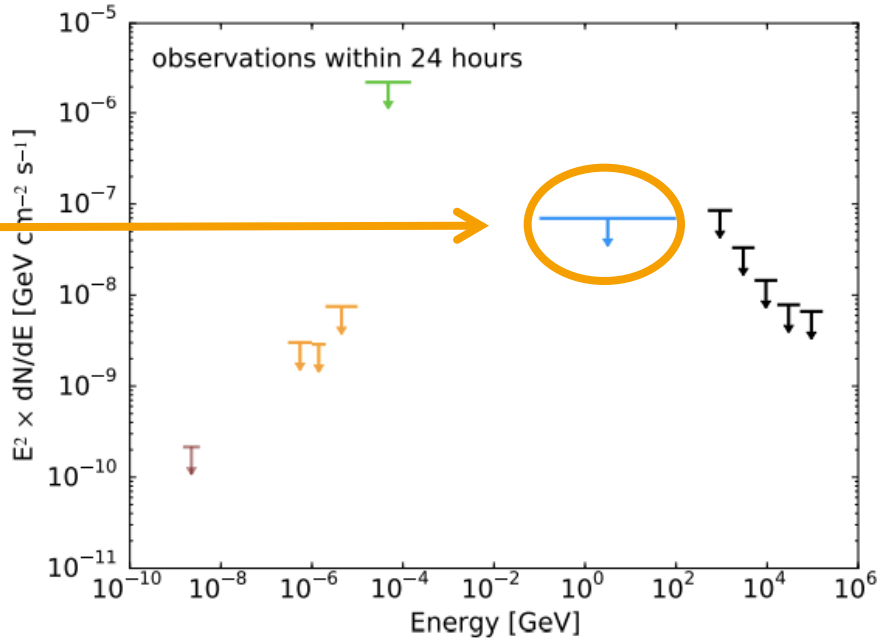
Fermi: Gamma-Ray Follow-Up of Neutrino Multiplet



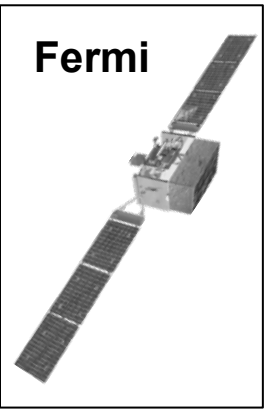
- Paper lead by Nora Strotjohann on the detection of 3 neutrino candidates within 100 seconds → follow-up in several wavelengths
- Search for gamma-ray counterpart with Fermi-LAT in collaboration with Fermi team at NASA

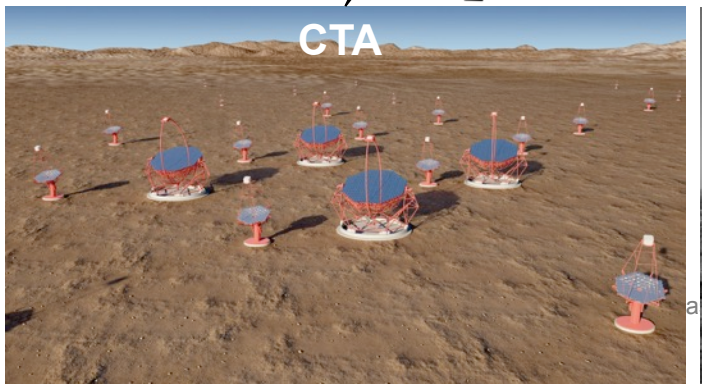
arXiv:1702.06131





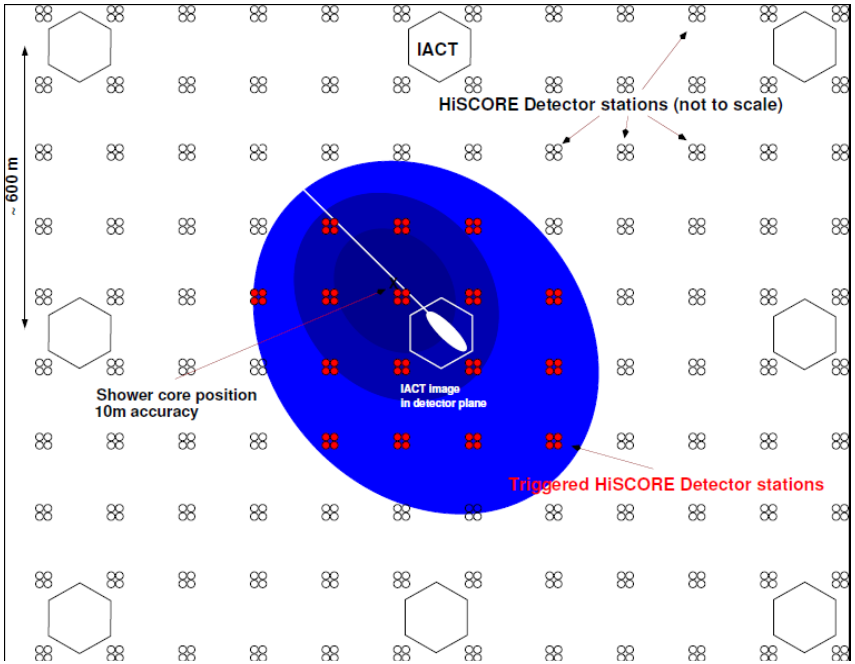
Highlights from future installations



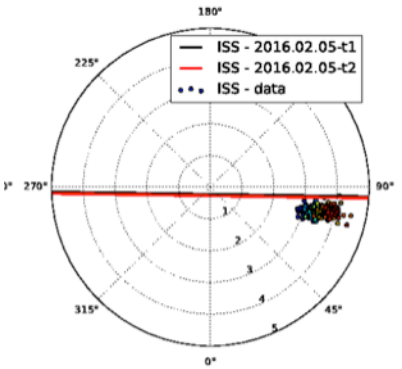


TAIGA: TeV / PeV Astronomy R&D in Siberia

- Combine imaging & non-imaging tech
  - HiSCORE: 1 km^2 of wide-angle non-imaging Cherenkov detectors, reconstruction by timing
  - Several (up to 9) imaging telescopes (IACT)
- Aims: low cost, higher energies (~PeV)
  - Complementary to CTA
- Status: 28 HiSCORE stations deployed, 1st IACT in commissioning (**DESY** PMTs)



- Bonus: HiSCORE sees the ISS – LIDAR
  Excellent calibration source, routinely detected

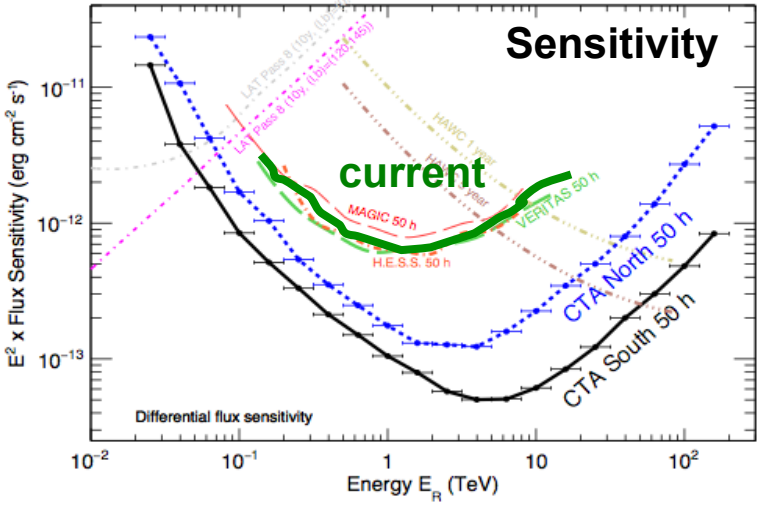


Cherenkov Telescope Array

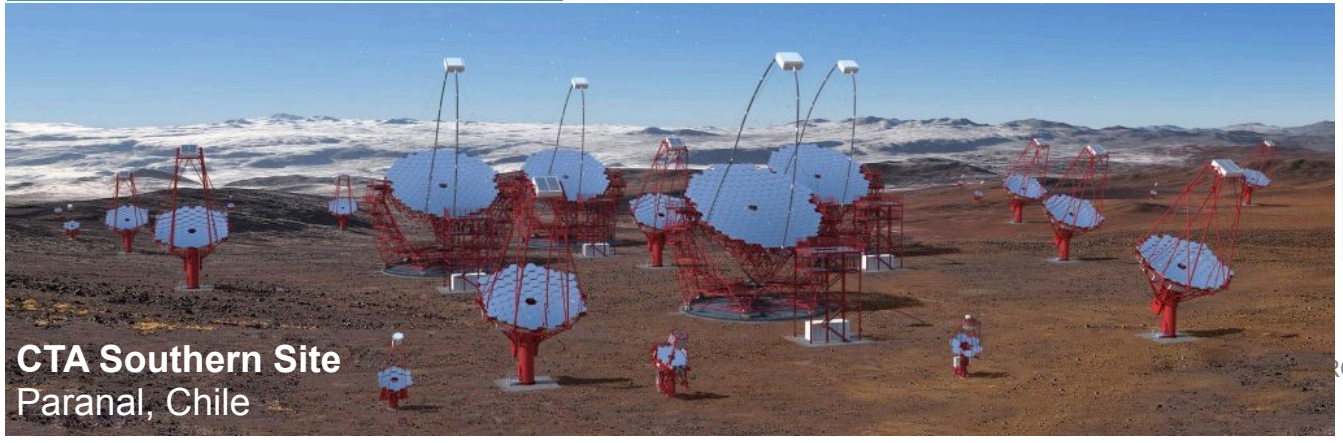
Status:
Pre-production, about to start construction

SDMC: DESY

HQ: Bologna



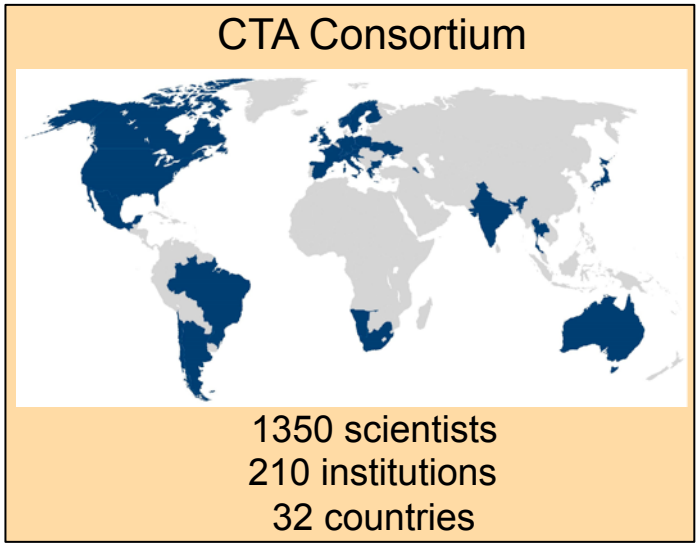
Energy range: 20GeV : 300TeV
Sensitivity: x10 better
Field of view: x2 - x3 larger
Fast slewing for transients
Angular res.: x5 - x10 better

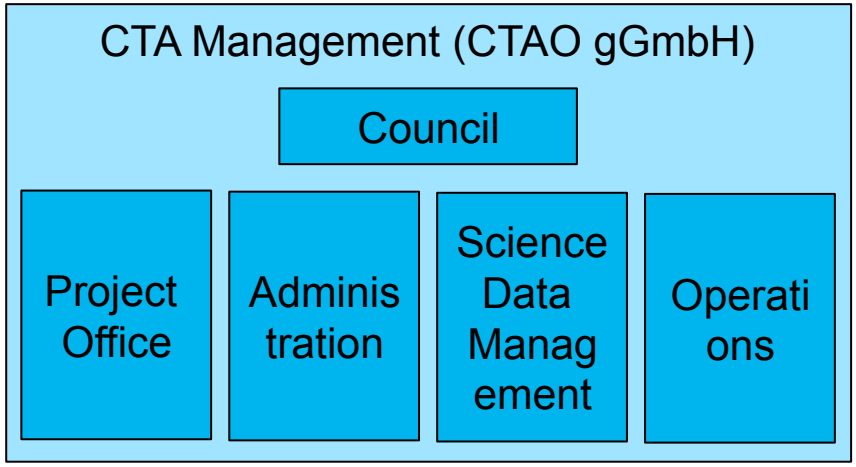


The egg-laying wool-milk sow

Role of DESY in CTA

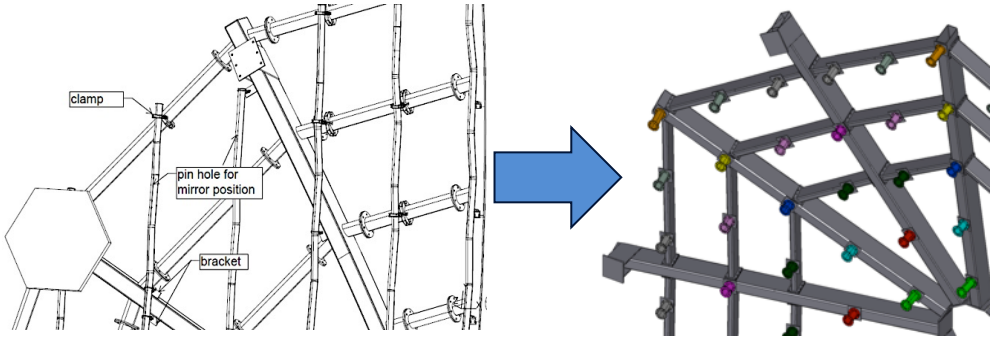
- Key group within CTA with 19 people working on it
- CTA Consortium is restructuring
  - Introduction of work packages (WP)
- Strong involvement in CTA Construction
  - Leading Mid Size Telescope WP
- Strong involvement in CTA Science
  - Lead of analysis, calibration & simulation WP: **G. Meier**
  - Lead of cosmic-ray science WP: **S. Ohm**
- Strong involvement in CTA Management
  - Shareholder of CTAO gGmbH
  - In project office:
    Software Coordinator: **M. Füßling**
    On-site ITC planning: **P. Wegner**





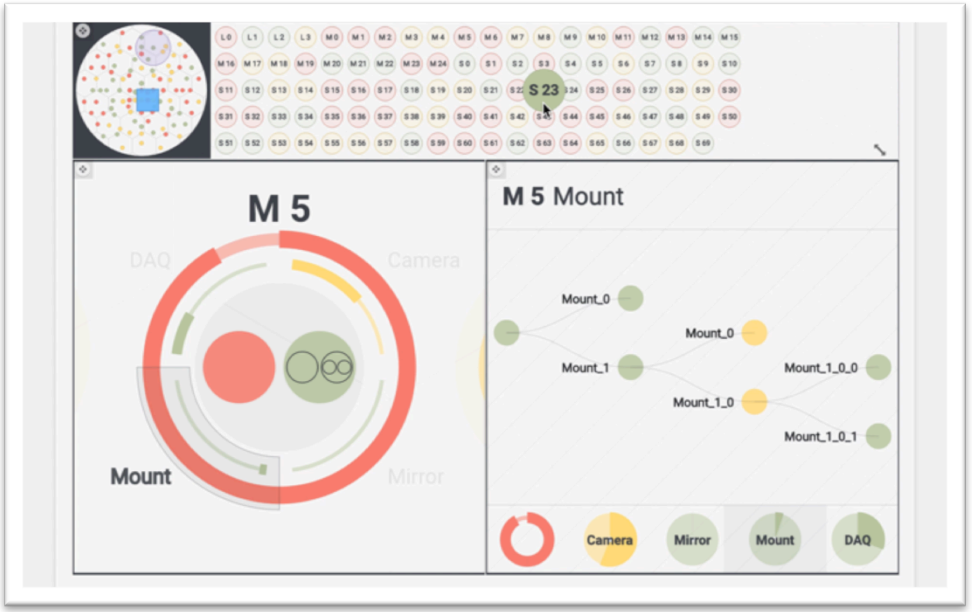
CTA Work Package: Mid Size Telescope

- DESY Prototype
  - Dish optimization done: better performance (PSF)
  - Control software commissioning & continuous improvement (saftety, pointing, mirror alignment)
  - Integration tests with gamma-ray camera after summer
- Measurement on mirrors
  - 3 vendors, reflectivity of individual facets + point spread function
- Preproduction:
  - Next CTA phase: plan for 2 MSTs in South, 1 in North, first in 2018
  - Data from prototype goes in documentation for preproduction readiness review



CTA Work Package: Array Control & Data Acquisition

- DESY leads the CTA software effort
  - Leadership, systems engineering, project management
  - Software Architect: I. Oya
- First version of CTA software architecture
  - Restructure all CTA software sub-projects
- Operator GUI: Novel technologies and visualization procedures



- Collaboration of DESY and external companies (Fraunhofer, INRIA, Cosylab), applying the best practices to CTA

CTA Science Data Management Center at DESY

- Coordinate science operations and make CTA's science products available worldwide, including data management and observatory data services
- Personnel: 20 FTEs + 10 guests
- Hosting agreement with CTAO drafted
- Negotiations for construction to be started after those for the headquarters

Conclusion

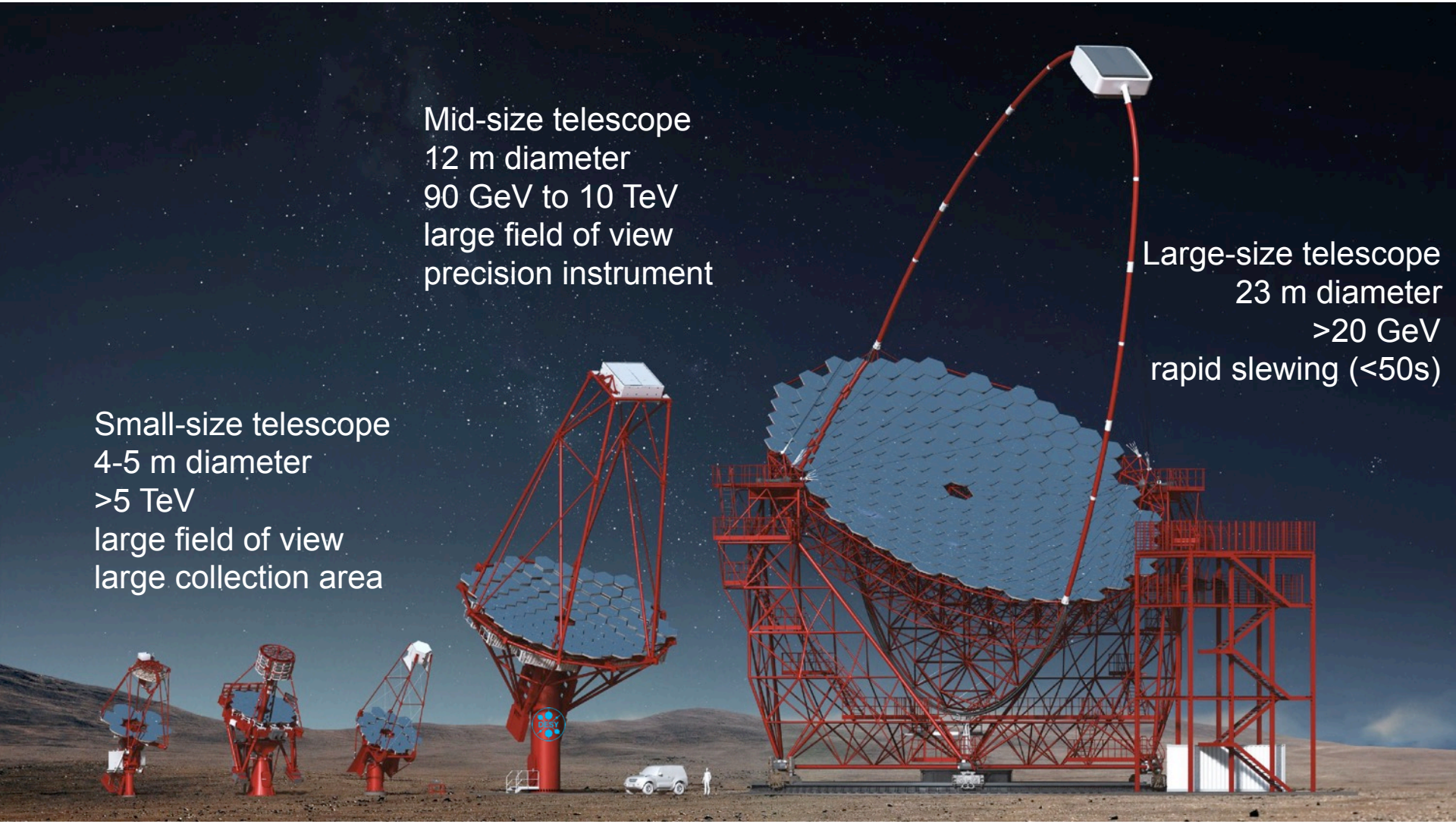
- DESY is a unique center for gamma-ray astroparticle physics
  - Important contributions to all major running gamma-ray experiments
  - Excellent and continuous scientific output in the field
- DESY plays a leading role within CTA
  - Know-how gathered @ DESY is invaluable for CTA efforts
  - Leading WP Medium Size Telescope and Array Control and Data Acquisition
  - Important contributions to preparation for key science exploitation, performance and array layout characterization
- A bright future ahead for DESY in gamma-rays:
  - 2 new young investigator groups just started
  - DESY will host the CTA Science Data Management Center

Backup

HELMHOLTZ ASSOCIATION

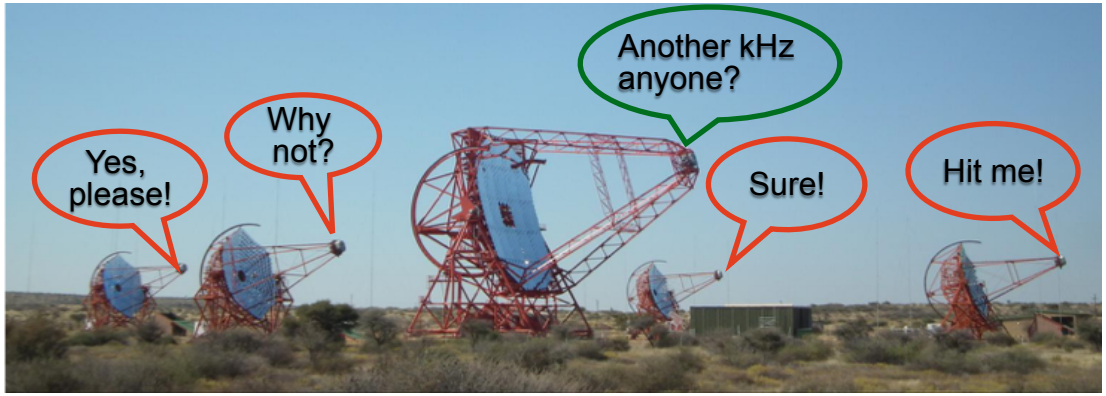
DESY

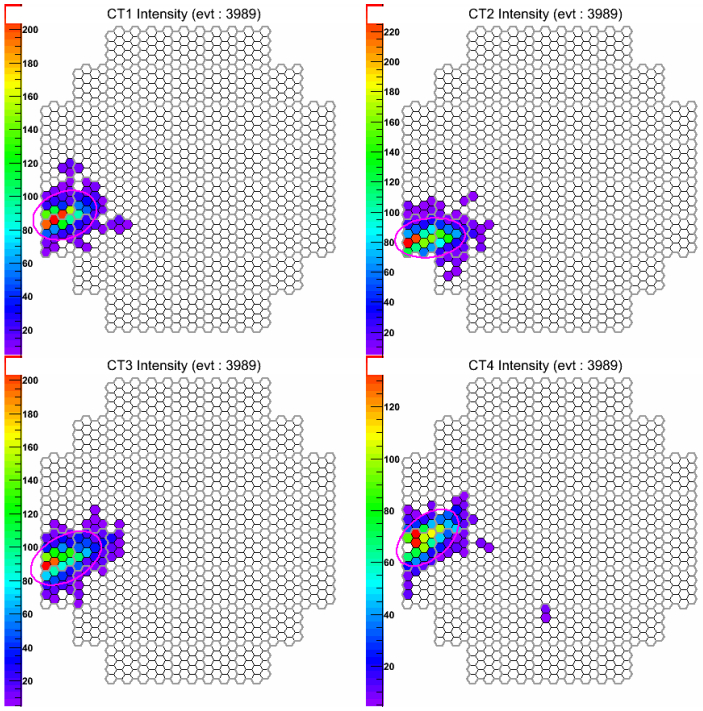
CTA Telescopes



H.E.S.S.-I camera upgrade: finished!

- Improves performance and reliability of array
- First camera in 2015
- Other three in 2016
- 10 people from DESY involved, leading
- First light on 28.9.2016
- Hand-over on 31.01.2017





Development of DESY time-dependent hadronic model
(C. Nigro, W. Bhattacharyya, G.Pedaletti, K. Satalecka)

- Aim is to develop a time-dependent self-consistent hadronic blazar emission model
- Apply the model to selected source class where exists a possibility of hadronic particle acceleration (for eg: sources with history of orphan VHE flares)
- **Present status : Synchrotron Self Compton + modules for best fit and uncertainty distribution of spectral model parameters (chi-sq minimization method)**