Astroparticle physics: gamma rays

HELMHOLTZ ASSOCIATION

Igor Oya Vallejo

82nd PRC Meeting

Berlin, October 20th 2016

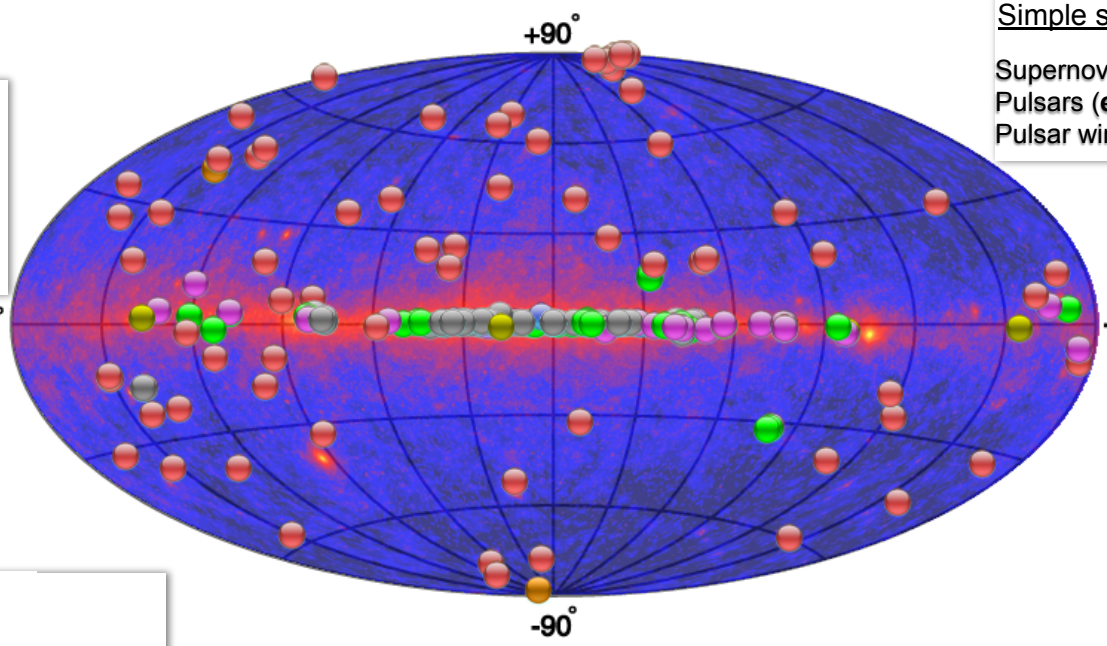
DESY

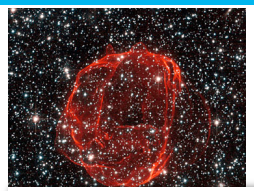
Gamma-ray astronomy: exploring the non-thermal Universe

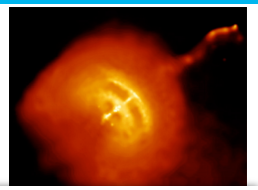
Black hole powered

The Galactic Center
Active galactic nuclei; (**e±, p**)

Almost 200 sources at ≥60 GeV
and 3000 at ~1 GeV

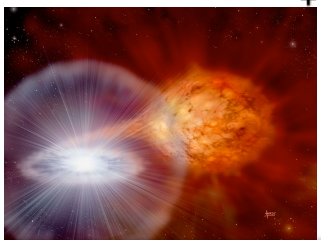






Simple stellar origin

Supernova shell (**e±, p**)
Pulsars (**e±**)
Pulsar wind nebulae (**e±**)



Complex stellar origin

X-ray Binaries
Microquasars
ms pulsars
Novae
Other binaries
Gamma ray bursts
Molecular clouds (**p + molecular clouds**)

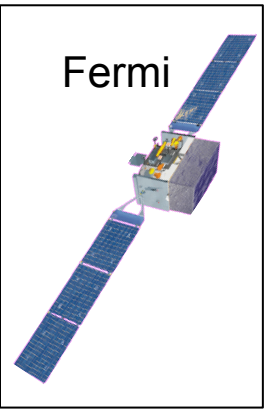
Collective Phenomena

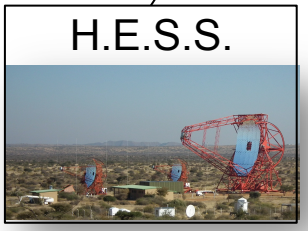
Star forming regions/clusters
Starburst galaxies
Super-bubbles
Diffuse Galactic emission (**e±, p**)
Diffuse extra-galactic emission

Fundamental physics

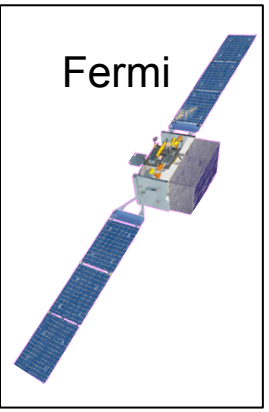
Dark Matter
Cosmological Fields
Primordial black holes
Quantum gravity

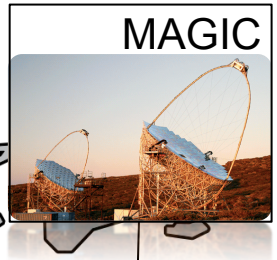
Gamma-ray astronomy installations & DESY (Now)

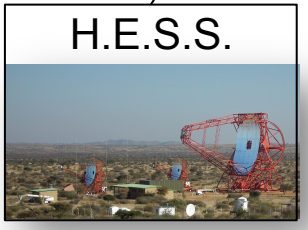




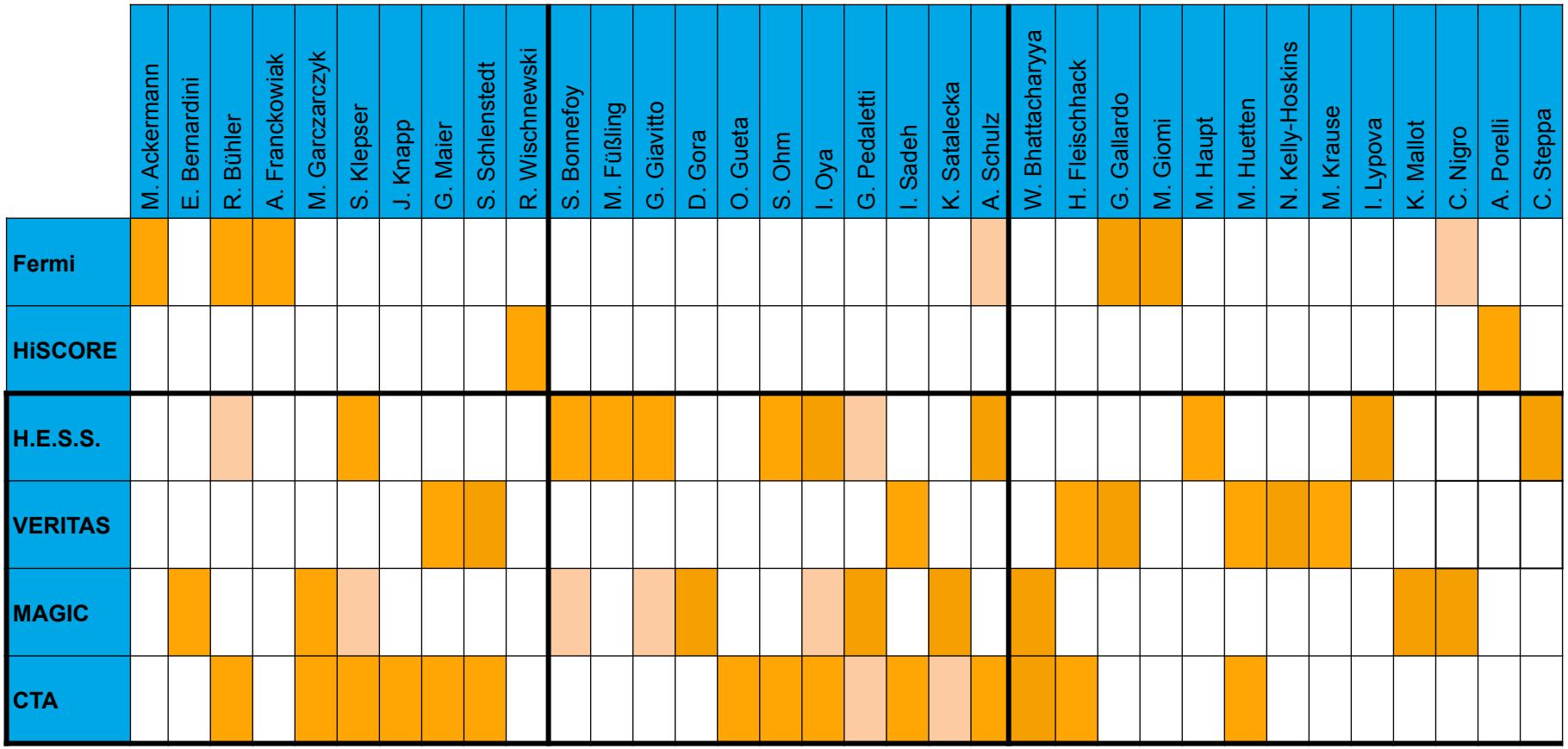
Gamma-ray astronomy installations & DESY (Now + Future)





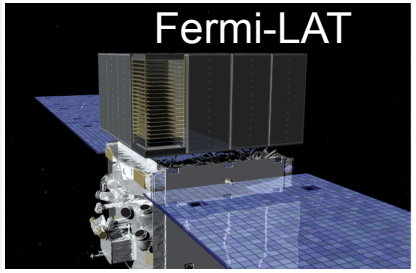


The DESY gamma-ray astronomy team



- In addition, invaluable contribution by:
  - Member from other departments as (Mechanics, Computer Center, Electronics, …)
  - Theory group members
- Key group within CTA, leading the MST and ACTL work packages, significant contribution to physics and analysis groups

Table Legend	
Currently active	
Former member	



A selected list of highlights from the contributions of DESY to:

CURRENTLY OPERATING INSTALLATIONS + R&D

New cameras for the H.E.S.S. Telescopes

- First camera was installed July 2015
- Remaining three cameras were installed September 2016
- 10 people from DESY were involved and led the efforts
- Installation campaign finished in time
- Commissioning is on-going

CT1U

CT2U

CT3U

CT4U

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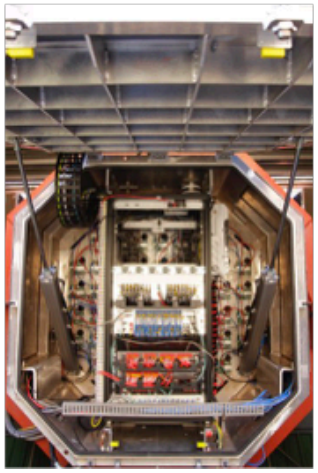


CT4U

New plaques for the H.E.S.S. Telescopes

H.E.S.S. Group news

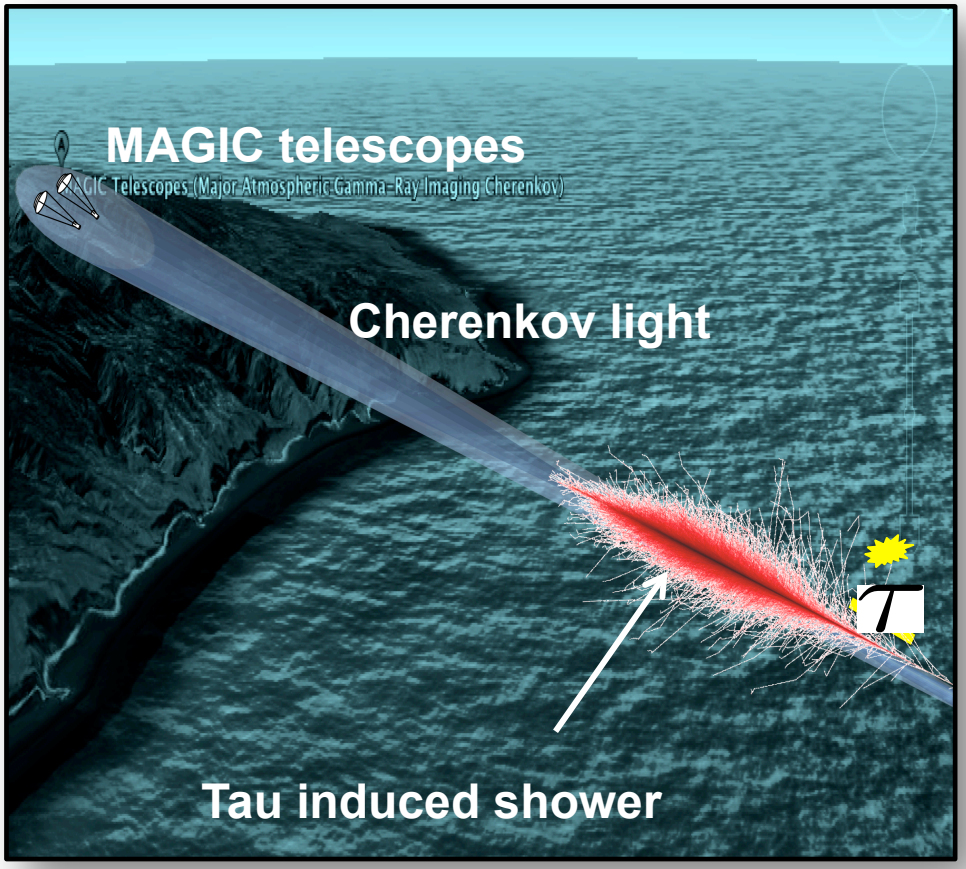
- Major H.E.S.S. legacy paper on pulsar wind nebula population submitted for publication in A&A (S. Klepser)
  - *The Population of TeV Pulsar Wind Nebulae in the H.E.S.S. Galactic Plane Survey*

- “H.E.S.S. prize” to G. Giavitto
  - For Vela PSR discovery and invaluable work in H.E.S.S. upgrade software & commissioning
  - Awarded twice a year for outstanding technical work by H.E.S.S. collaboration board

- Activation of real-time analysis and new alert system in Namibia (S. Ohm, M. Füßling + external collaborators)
  - Already caught 2 alarms

MAGIC neutrino hunt – tau neutrino (D.Góra)

> MAGIC telescopes can point down to the Sea and act as a tau neutrino detector!
> Data can be collected during nights with high clouds – saves “expensive dark time”



D. Góra et al, for MAGIC Collaboration, Proceed. of NEUTRINO 2016 and GAMMA 2016
Similar study for CTA: D. Góra and E. Bernardini, Astropart. Phys. 82 (2016) 77

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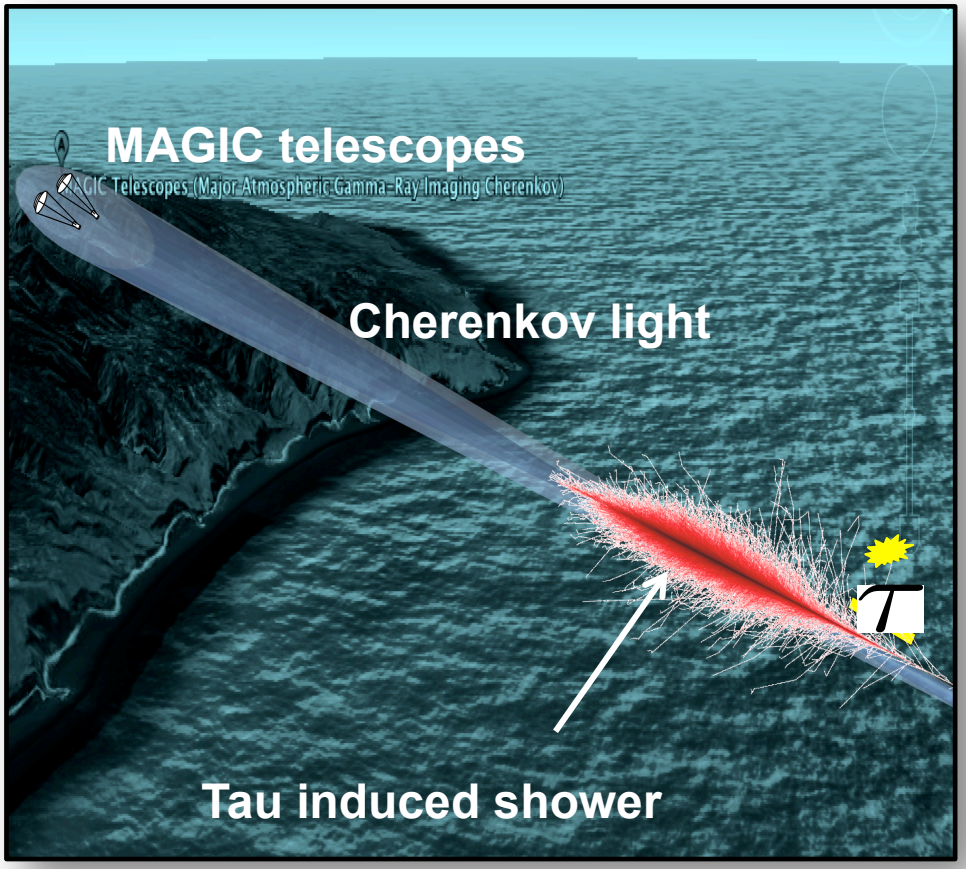
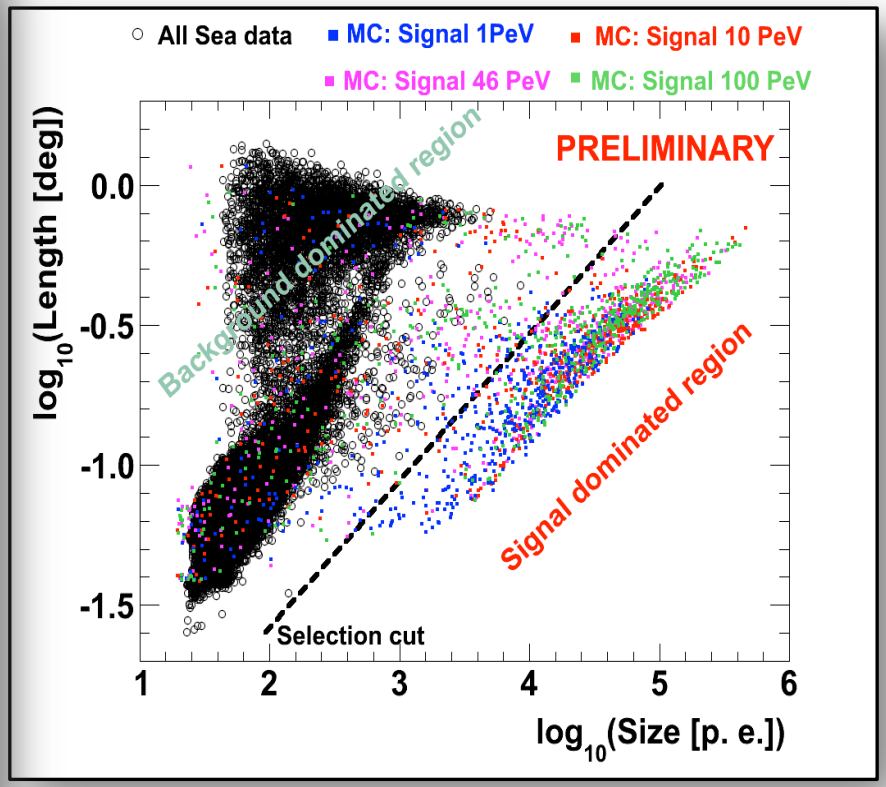
> Special MC chain & analysis





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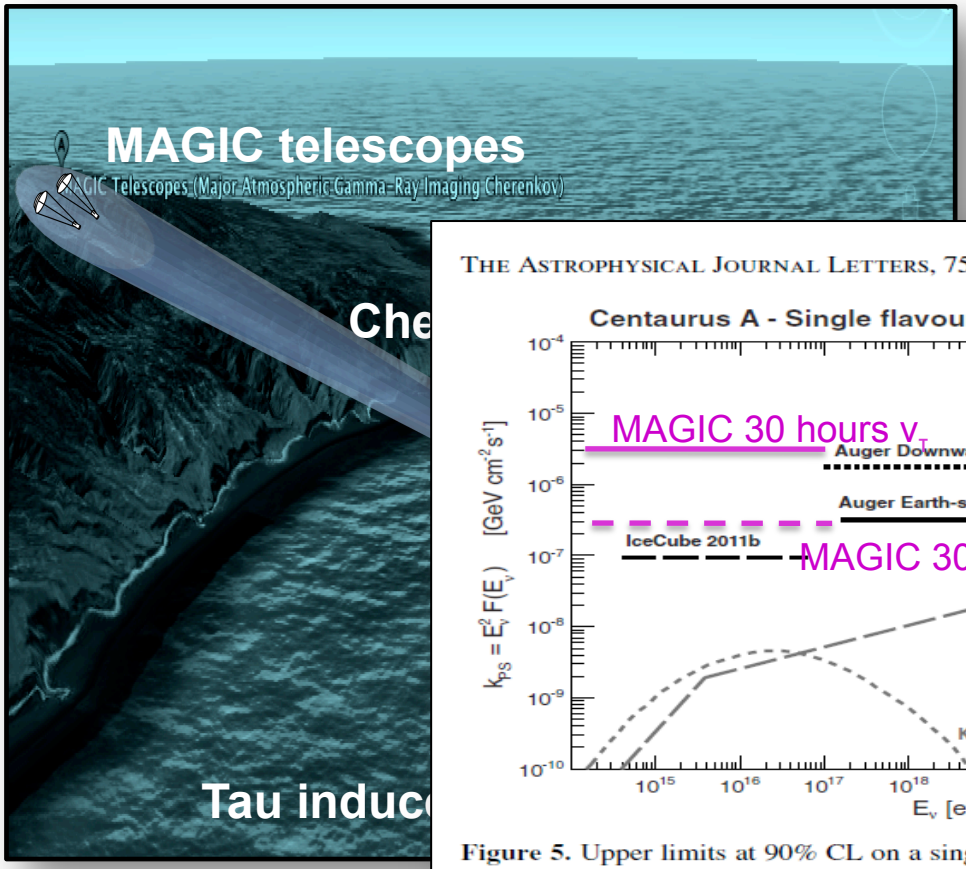
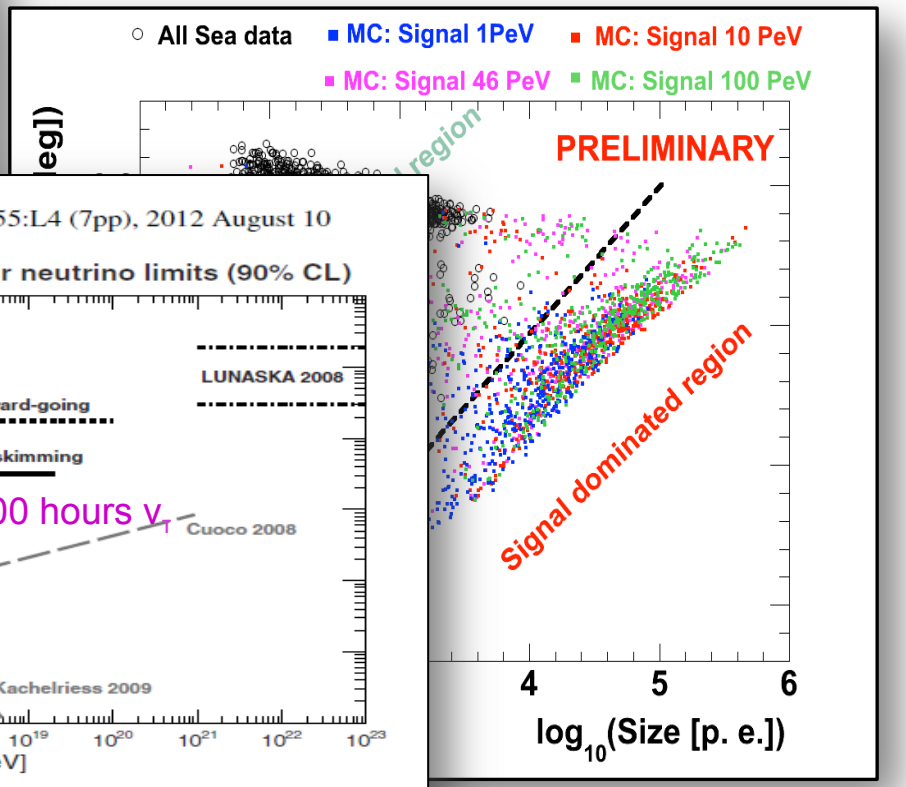
> Data can be collected during nights with high clouds – saves “expensive dark time”
> Special MC chain & analysis
> **30 h of data collected**





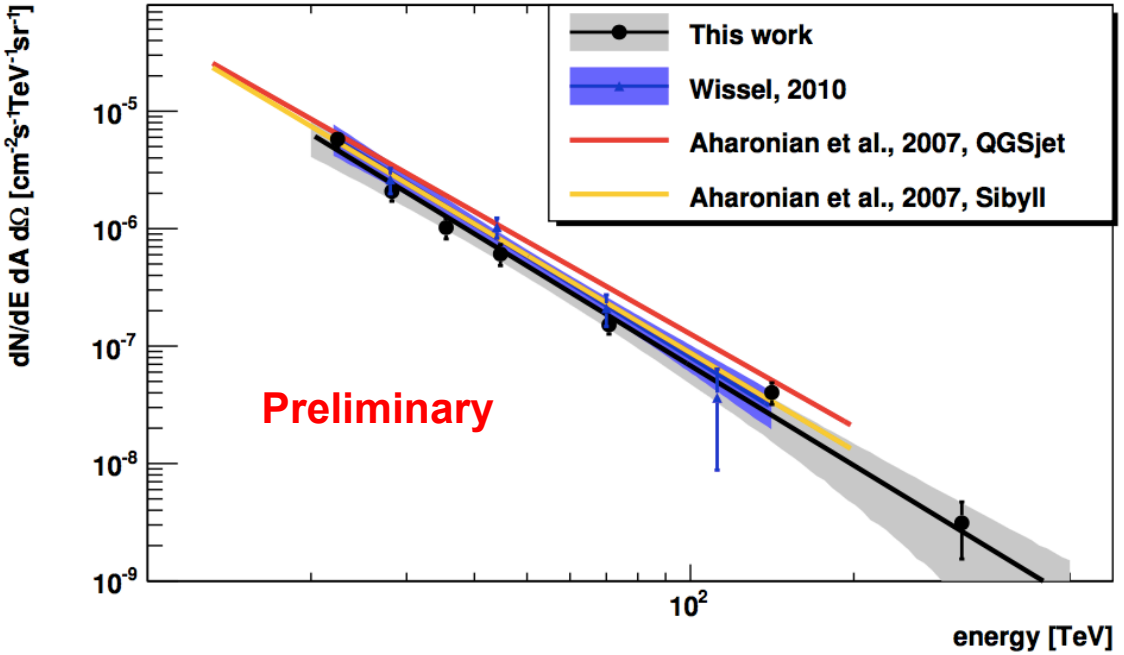
THE ASTROPHYSICAL JOURNAL LETTERS, 755:L4 (7pp), 2012 August 10

Figure 5. Upper limits at 90% CL on a single flavor E_ν^{-2} flux from the active galaxy Centaurus A from the Earth-skimming and downward-going neutrino analyses, together with bounds from the IceCube Neutrino Observatory (Abbasi et al. 2011b) and LUNASKA (James et al. 2011). The predictions for two models of UHEν production—in the jets (Cuoco & Hannestad 2008), and close to the core of Centaurus A (Kachelriess et al. 2009)—are also shown.

D. Góra et al, for MAGIC (2016
Similar study for CTA: D. (

VERITAS measurement of cosmic ray iron spectrum
(H. Fleischhack et al.)

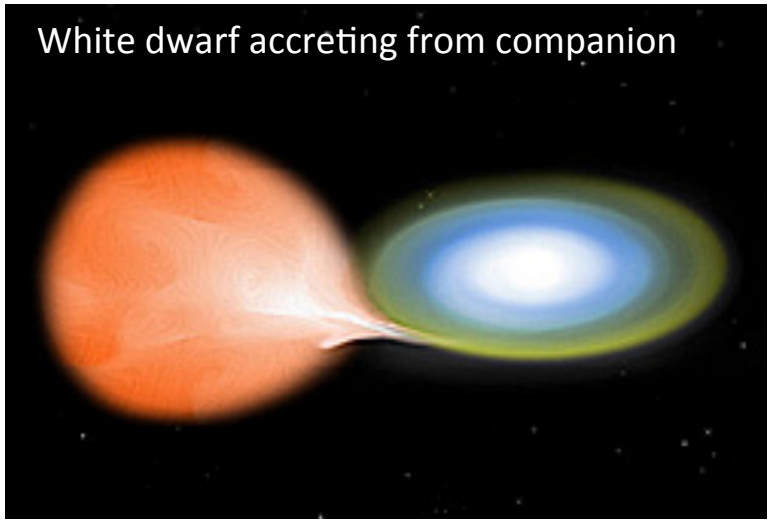
- Identification of heavy nuclei by direct Cherenkov light emitted before the first interaction
- Novel analysis using template likelihood method plus boosted decision tree classification
  - >30% improved collection area
  - 50% better energy resolution
  - significantly extended energy range
- Proof of principle study with VERITAS data shows:
  CTA will be able to provided detailed measurements of the shape of the heavy-nuclei cosmic ray energy spectra to at least 1 PeV
- Henrike Fleischhack; Thesis at HU (submitted)
- In connection CTA cosmic ray science working group, led by S. Ohm

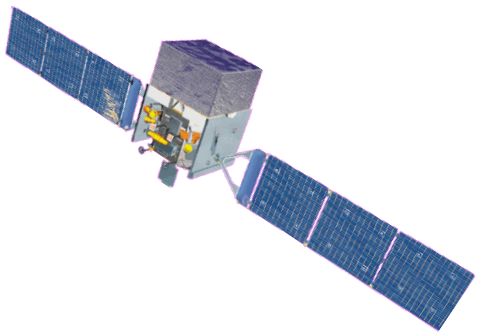


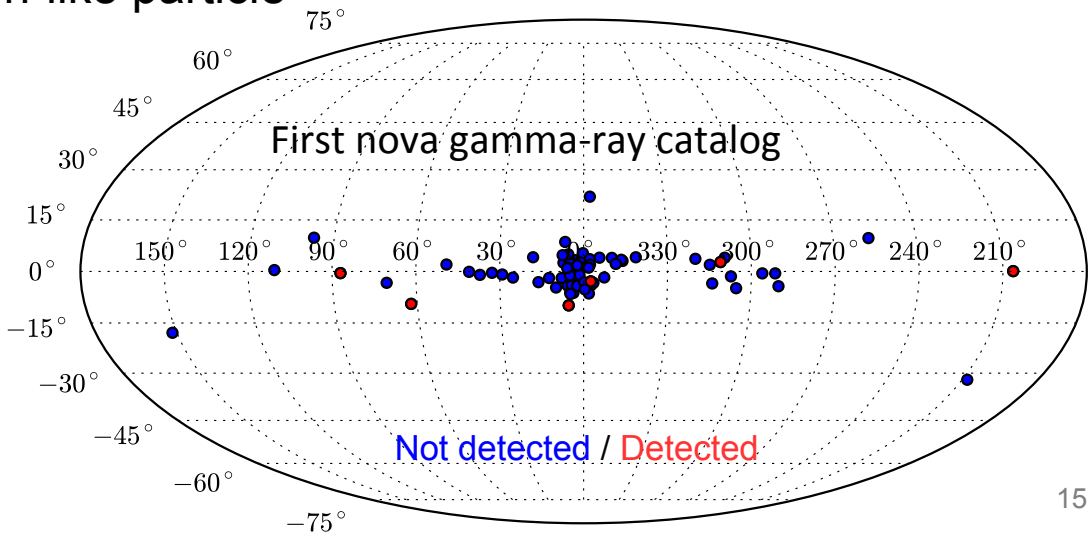
DESY contribution to the Fermi Large Area Telescope

(M. Ackermann, R. Bühler, A. Franckowiak, et al.)

- Fermi All-sky Variability Analysis FAVA monitor and catalog
  - http://fermi.gsfc.nasa.gov/ssc/data/access/lat/FAVA/
  - *Ackerman et al, Second FAVA catalog, LAT internal review; M. Giomi PhD Thesis*
- Preparing the first gamma-ray catalogue of novae
- Extragalactic gamma-ray background and neutrino connection
  - *Ackermann et al. ApJ 799 (2015), Ajello et al. ApJ 800 2 (2015)*
- G. Gallardo started PhD on axion-like particle search
  - VERITAS-LAT data
  - Financed by DSF



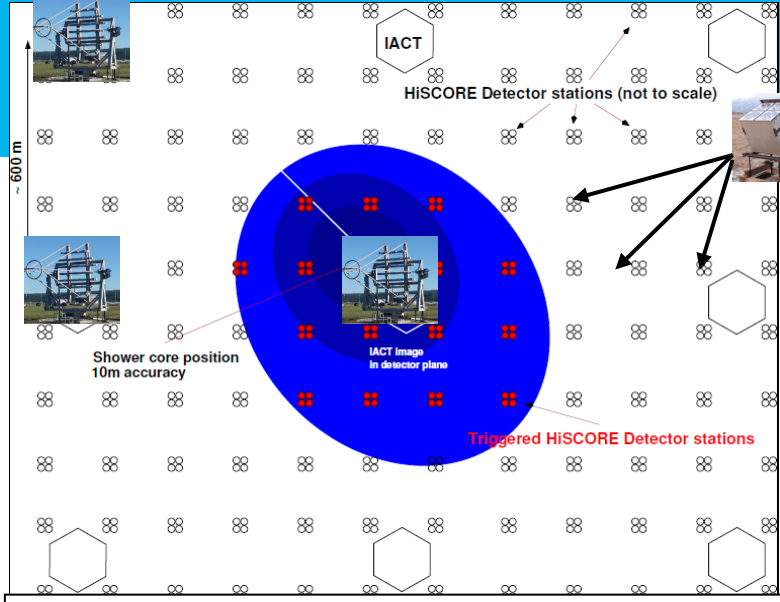




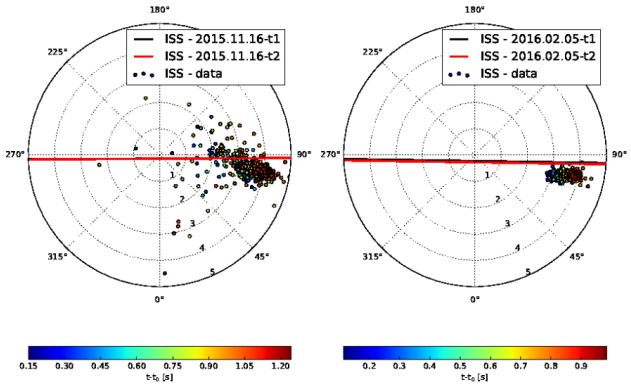
TeV / PeV Astronomy: HiSCORE – R&D

TAIGA: Combine imaging (IACT) & non-imaging techniques

- Complementary to CTA
  - Aiming for energy ranges above CTA, low-cost project
- HiSCORE: 1 km^2 array of wide angle non-imaging Cherenkov detectors
  - 28 station array already deployed (0.25 km^2)
  - Double the installation next year
- 1st IACT in commissioning (DESY PMTs)
- DESY:
  - Data analysis, shower reconstruction
  - Sub-nsec array timing (Rb-GPS, Stations): White-Rabbit
- HiSCORE sees the ISS - Laser: 10 nsec 1 mJ Flashes (A. Porelli)
  - Serendipitous discovery. Next occurrence predicted and verified 2 weeks after.
  - Detected: 4 times in 2015/16, for ~1 s duration each
  - Excellent HiSCORE calibration source, interesting prospects for IACTs



HiSCORE: Shower reconstruction by timing (core, direction, E)
IACT: γ-Hadron separation by shower image



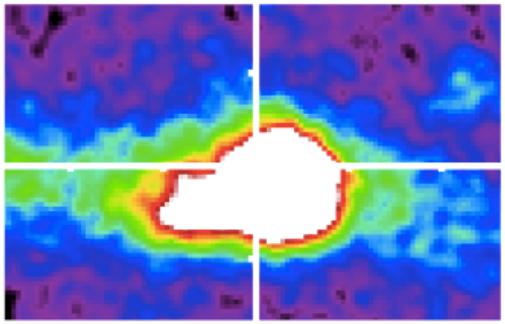
Main areas of the activities of DESY for

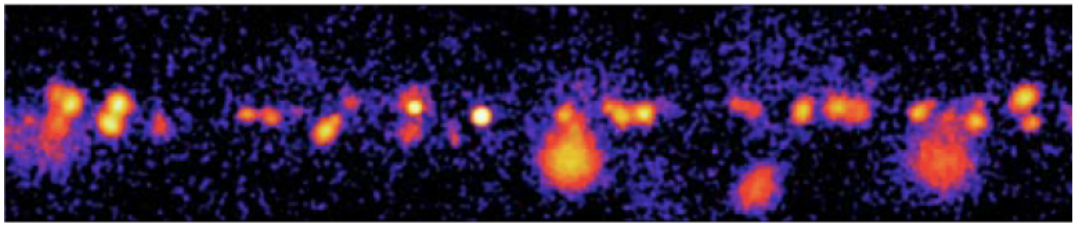
INSTRUMENTS UNDER DEVELOPMENT: CTA

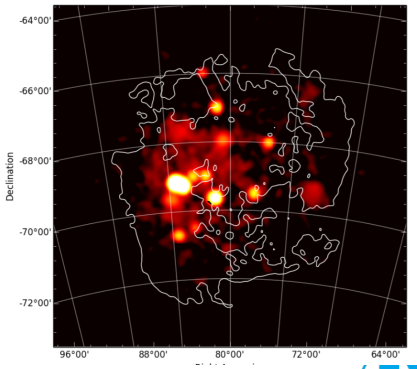
CTA: Key Science Projects (KSPs)

(S. Ohm, G. Pedaletti, G. Maier, M. Füßling, E. Bernardini, K. Satalecka, THAT group, …)

- KSPs ensure that important science questions for CTA are addressed
  - Use the proprietary time of the CTA consortium
  - In a coherent fashion and with a well-defined strategy
- Produce legacy data sets, address major science questions
- DESY involved in several KSPs
  - Leading the star-forming systems KSP
  - Significant contribution to Galactic and extragalactic surveys
  - Transient KSP
  - CTA cosmic ray science working group
- Review science topics according to threshold implementation scenarios





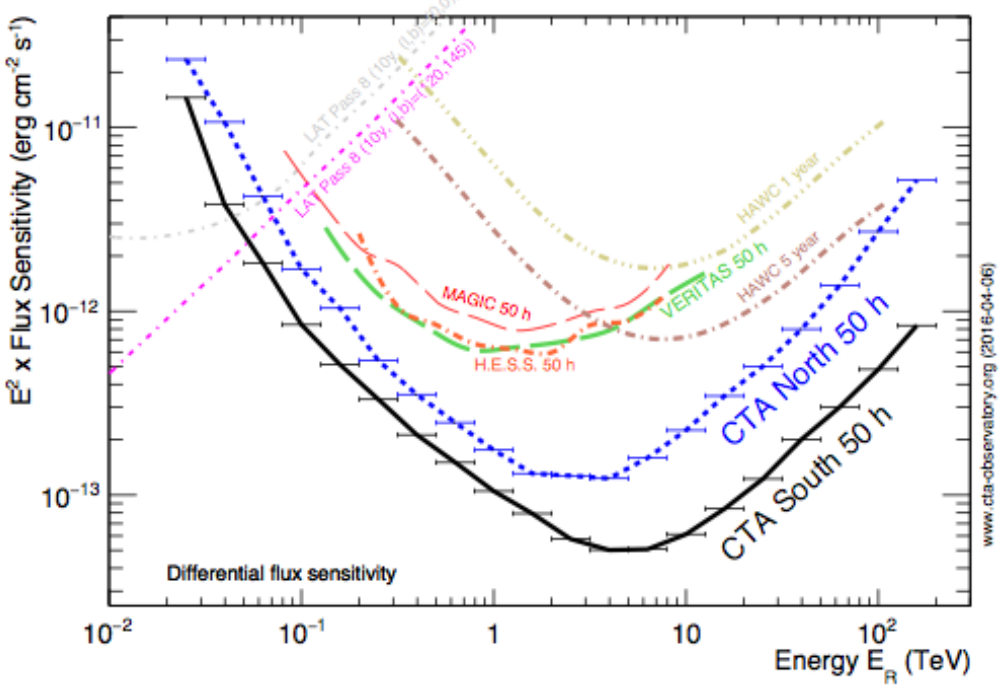


CTA Performance
(G. Maier)

- Performance characterisation of CTA is a central part of the DESY activities
  - Joint activity with groups at MPIK (Heidelberg) and IFAE (Barcelona)

- First publication of official CTA performance curves.
  - Used in almost all studies of science prospects of CTA, threshold scenarios, KSPs; available through public web page

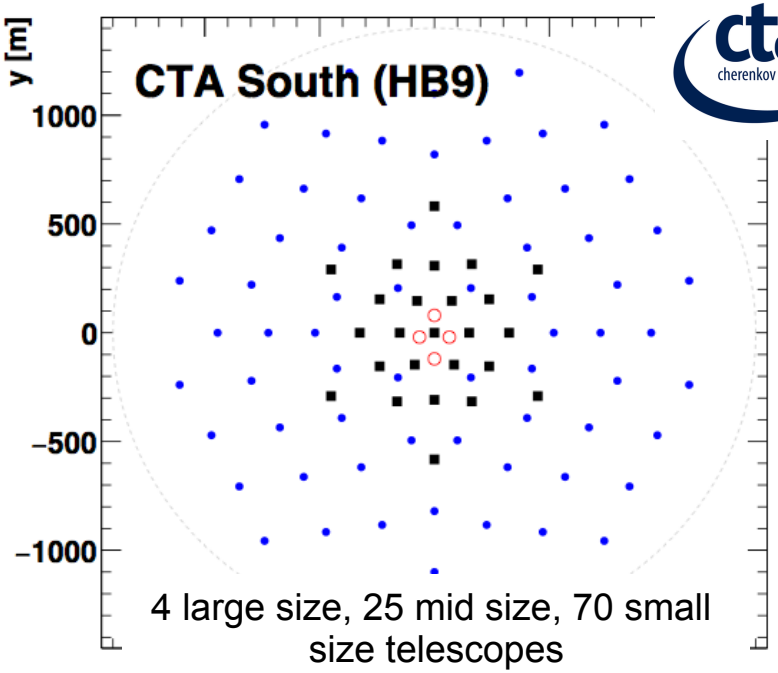
https://portal.cta-observatory.org/CTA_Observatory/performance/SitePages/Home.aspx

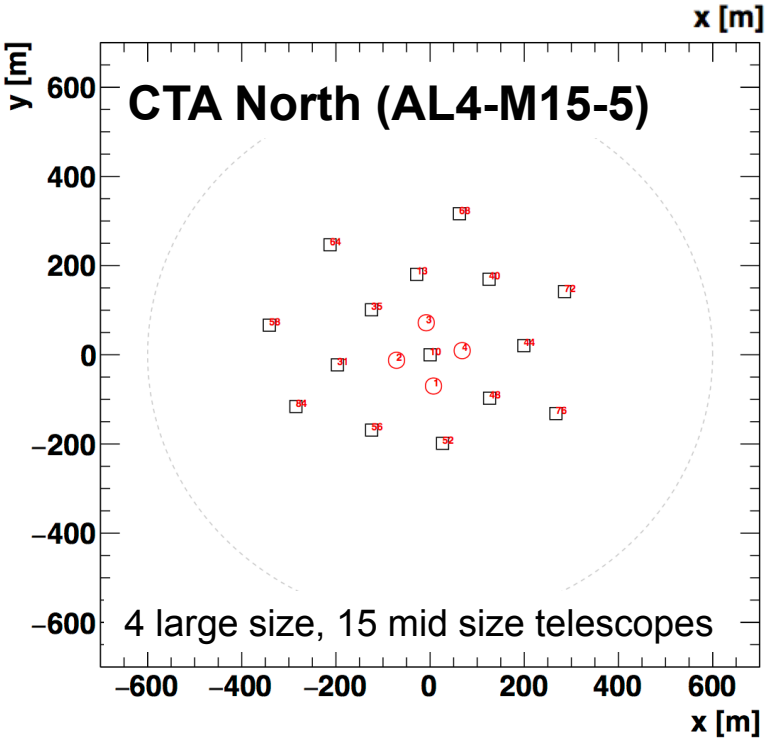


The Layouts of the CTA array
(G. Maier)

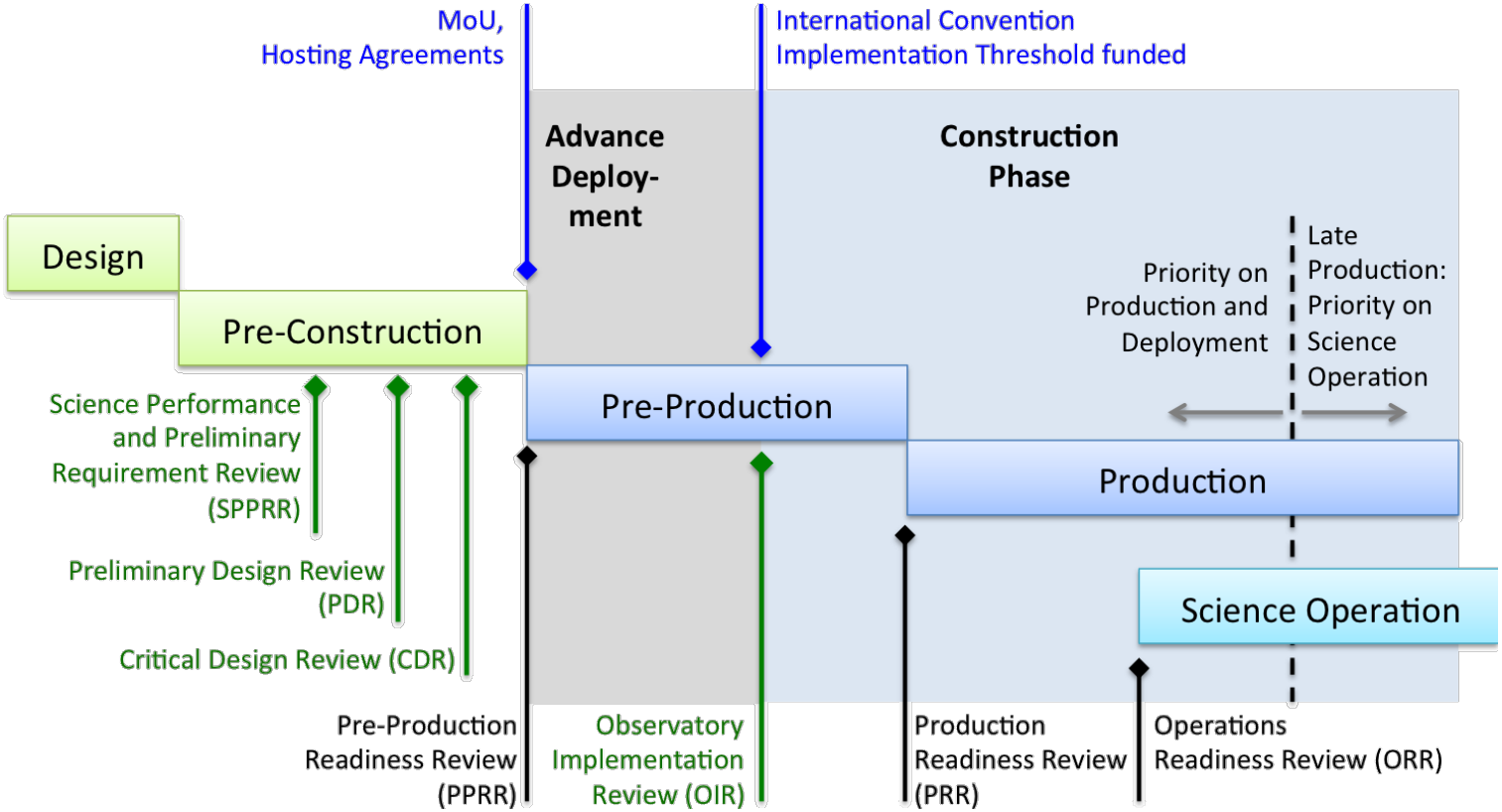
- Fixed the position of telescopes for both sites of CTA
  - CTA is ready to begin construction after 10 years of planning and designing
  - Significant computing effort (last MC production was ~120 million HS06 CPU hours and ~1.4 PByte of disk storage) using GRID, DESY resources and MPIK

- Final layouts provide significant improvements in comparison with initial suggestions
  - Results are the base for the upcoming infrastructure work in Chile and La Palma





Schedule for the implementation of CTA



Important dates:

- 1st telescope PPRR expected: Q2, 2017
- 1st telescope expected on site: Q2, 2018
- 1st release of control software: Q2, 2018

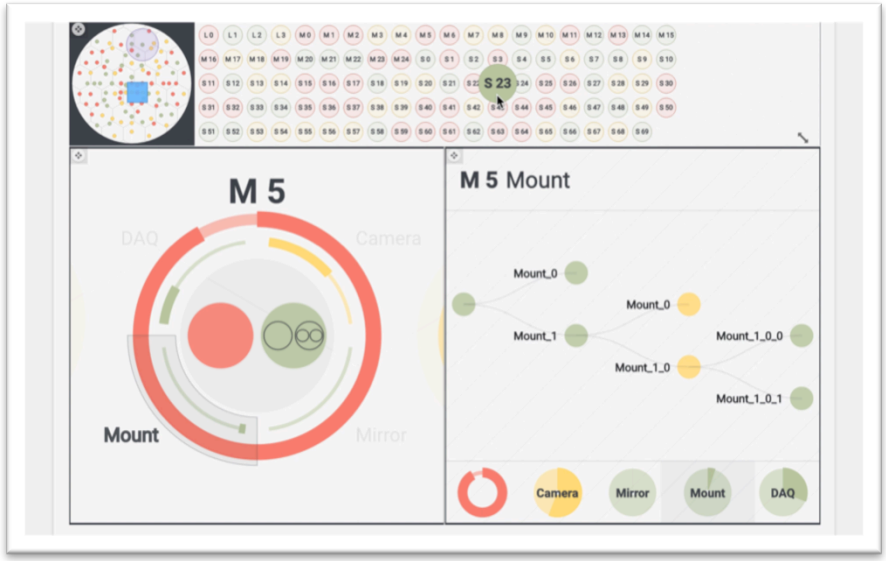
CTA site agreements

- CTA North: hosting agreement between CTAO Council and Instituto de Astrofisica de Canarias on September 19
  - Location on the existing site of the IAC's Observatorio del Roque de los Muchachos at an altitude of 2,200 m
  - Allows CTA to proceed with the construction of the CTA-N array
    - Ensures access to the infrastructure
    - Ensures access to common services needed for the operation of the Observatory

- CTA South: Negotiations with ESO for a site near the Paranal Observatory are expected to conclude before the end of 2016

Controlling the CTA arrays: Array Control and Data Acquisition (M. Fuessling, D. Melkumyan, I. Oya, I. Sadeh, P. Wegner, et al.)

- DESY leading the effort in CTA: Leadership, systems engineering, project management
- Creating a precise description of the system: The Software Architecture
- Central Control Prototype: joining in-house programmers and physicists with external company programmers
- Operator GUI: Novel technologies and visualization procedures

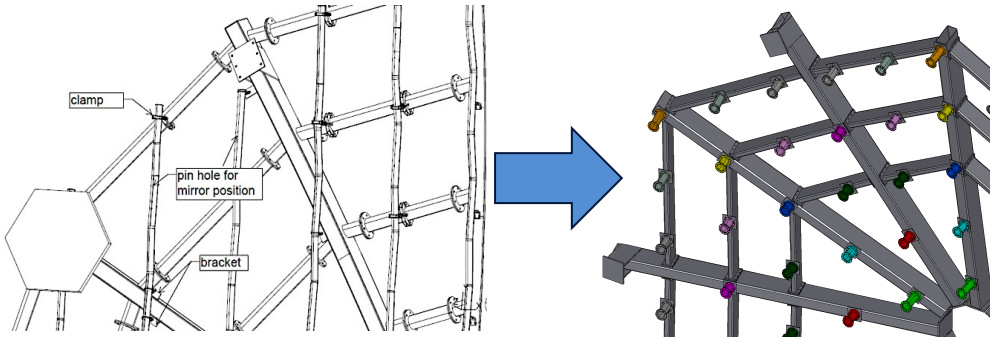


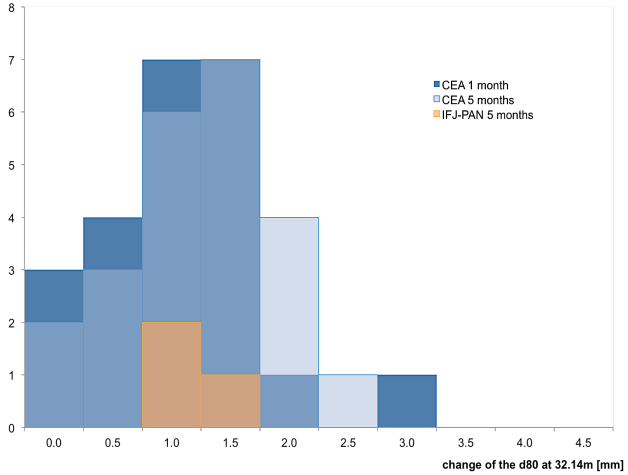
- Collaboration of DESY and external companies (Fraunhofer, INRIA, Cosylab), applying the best practices to CTA
- CTA on-site computer clusters: Main advisors for CTAO

MST Update: Working on the Prototype

(M. Garczarczyk, S. Schlenstedt, A. Schulz, et al.)

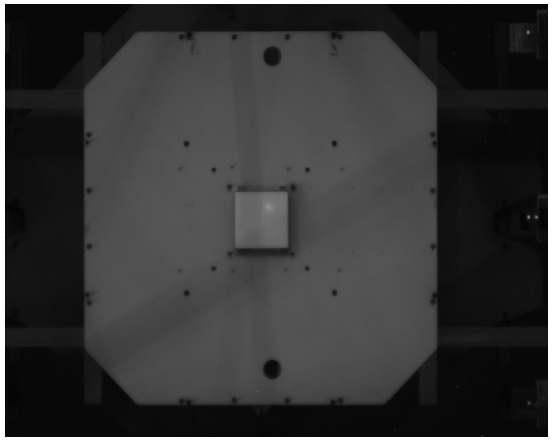
- Medium Size Telescope
- Dish optimization
  - No intermediate structure needed
  - Structure behind each mirror
  - Unified mirror interface, straight profiles
  - 3 tons lighter
  - New dish: will be delivered in November 2016
- Measurement of mirror facets
  - Point spread function and reflectivity of individual facets
  - > 300 temperature cycles -20°… 30°C
  - No continuous worsening seen
  - New prototypes from CEA, IFJ, INAF

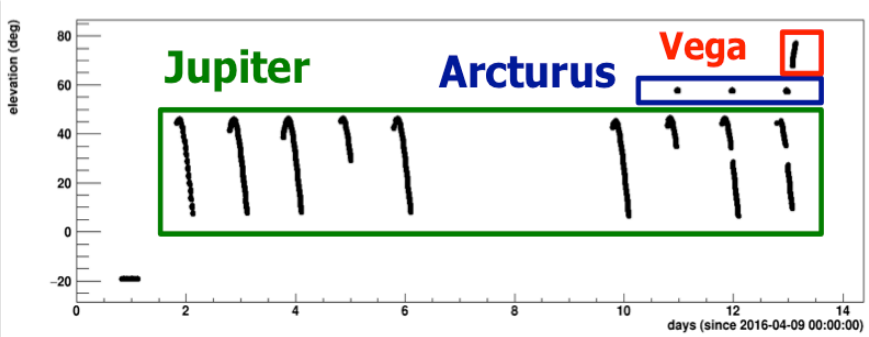




MST Update: from the Prototype towards Preproduction (M. Garczarczyk, S. Schlenstedt, A. Schulz, et al.)

- Continuous studies:
  - Software development including remote operation
  - Mirror alignment
  - Tracking and pointing tests
- Preproduction:
  - Preparation of the preproduction readiness review
  - Plan to install 2 MSTs on site in 2018
  - Followed by extensive testing and the production readiness review





CTA Science 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 contract with CTAO and negotiations for construction started

Conclusions

- DESY is a unique center for gamma-ray astrophysics
- Important contribution to the four most important gamma-ray instruments in the world, and in projects under construction
- The accumulated knowledge provides invaluable input for CTA
  - Leading WP Medium Size Telescope
  - Leading the WP Array Control and Data Acquisition
  - Important contribution to preparation for science exploitation
  - Decisive contribution to performance characterization and telescope layout characterization
- A bright future for DESY as a key player of CTA: DESY will host the CTA Science Management Center

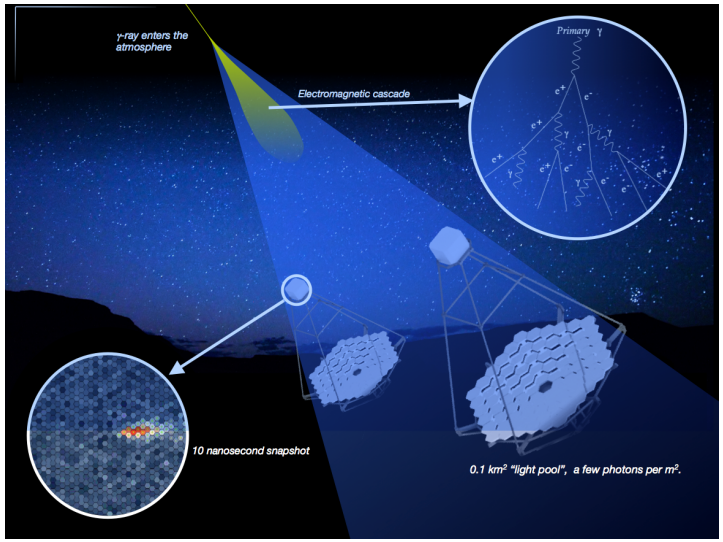
Backup

Gamma-ray instruments

Imaging atmospheric Cherenkov Telescopes (IACTs)

Typical characteristics:

- ~20 GeV to 100 TeV
- 10^5 m^2 collection area
- 3-5 deg field of View
- 0.1 deg angular resolution
- 10% energy resolution

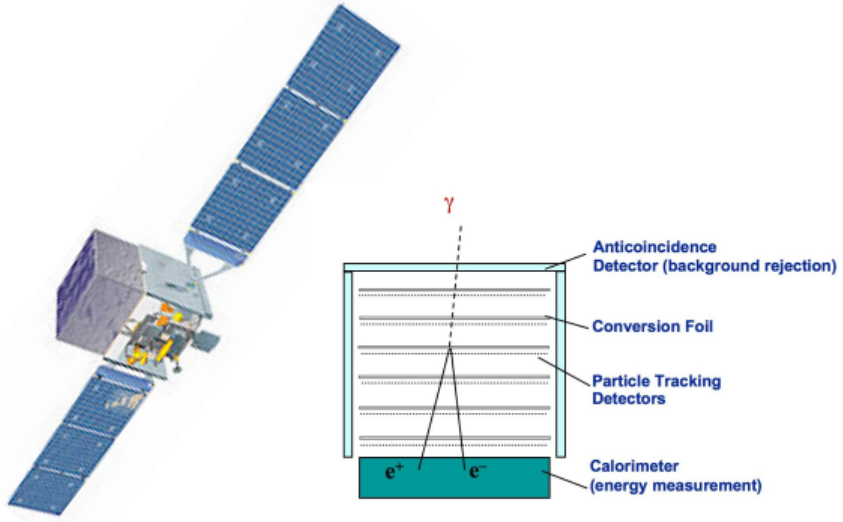


+ non-imaging arrays Cherenkov detectors

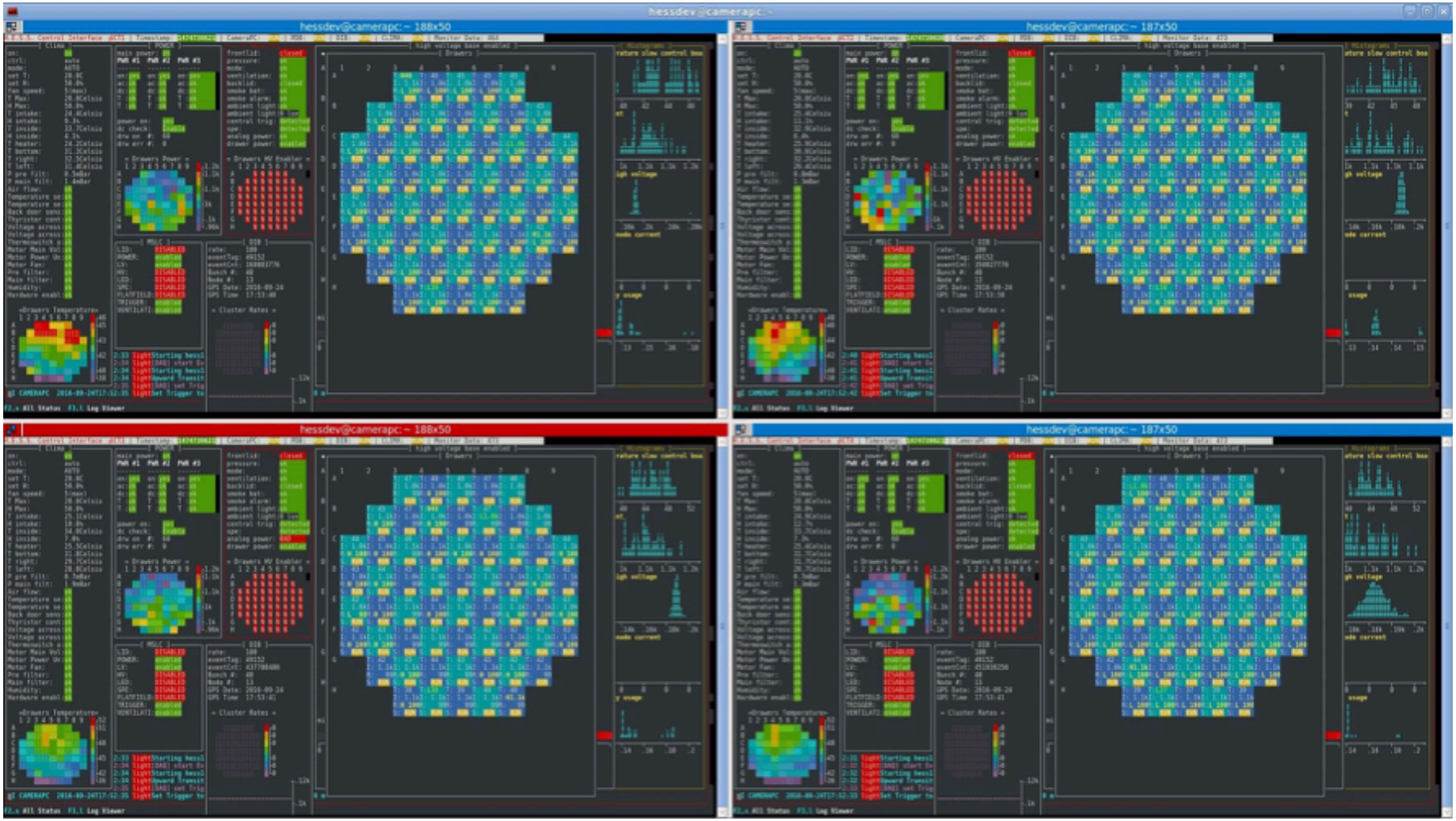
Gamma-ray satellites

Typical characteristics:

- ~20 MeV – 300 GeV
- 1 m^2 collection area
- 20% of the sky field of view, whole sky scanned every 3 hours
- 6 to 0.3 deg angular resolution
- 10% Energy resolution



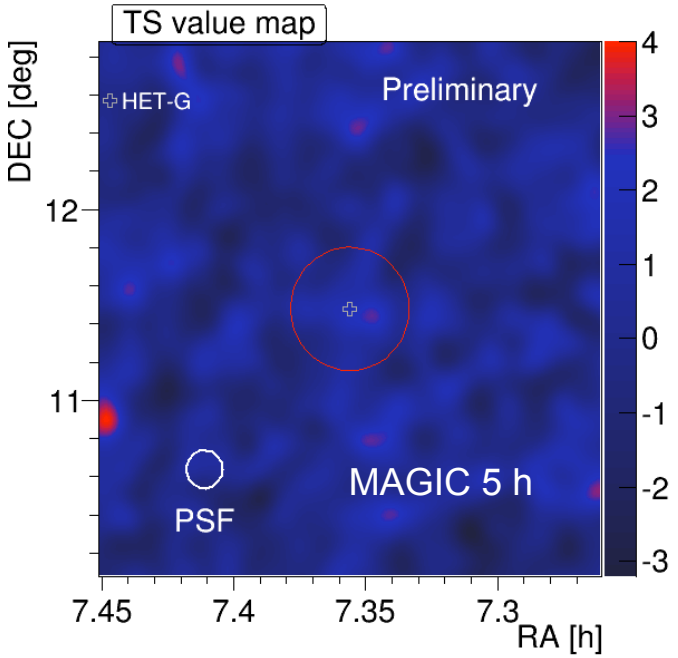
New soft-trigger runs for the H.E.S.S. Telescopes

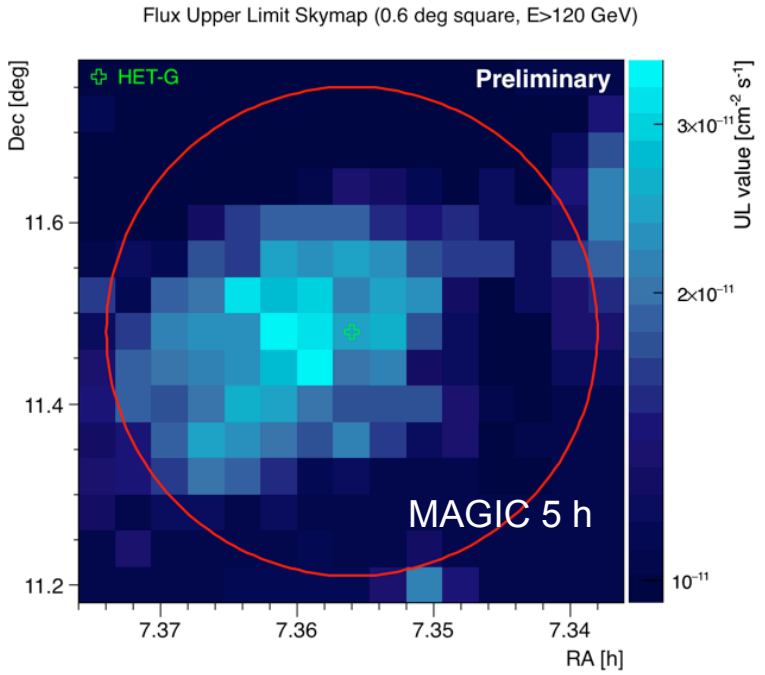


MAGIC neutrino hunt – IceCube events follow-up

(K. Satalecka)

- Strongly involved in the IceCube multi-messenger program since 2009
- Goal: identify γ-ray counterparts of IC events, find cosmic ray sources
- In 2016 MAGIC invested 20 h in 3 archival IC events and 3.3 h in 2 real-time IC alert observations
- Novel method of calculating UL sky maps developed
- Integral flux ULs > 120 GeV ~ few % Crab Nebula flux





Example: Highest Energy Track ~ 2.6 PeV deposited in IceCube

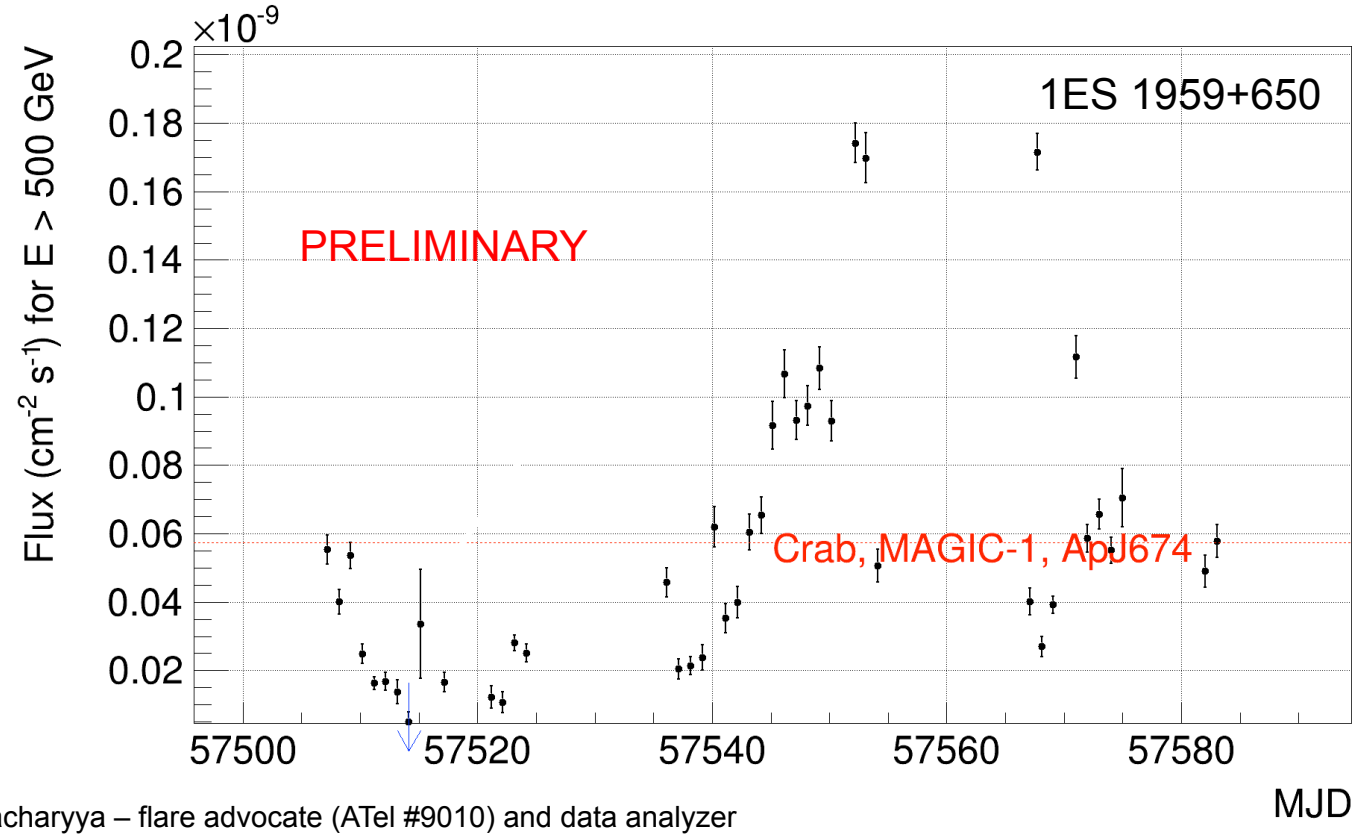
D. Góra et al, for MAGIC Collaboration, Proceed. of NEUTRINO 2016
K. Satalecka et al., for MAGIC Collaboration, Proceed. of GAMMA 2016
K. Noda et al., for MAGIC Collaboration, TeVPA 2016

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

(W. Bhattacharyya, K. Satalecka & T. Kintscher)

> 1ES 1959+650, one of the first VHE g-ray sources discovered, laid dormant since 2002…
> April – July 2016 long flaring period with VHE g-ray fluxes ~3.0 x Crab Nebula flux!
> Input to joint analysis with neutrino data from IceCube to test hadronic emission

> MAGIC & IC DESY groups involved in data analysis and interpretation



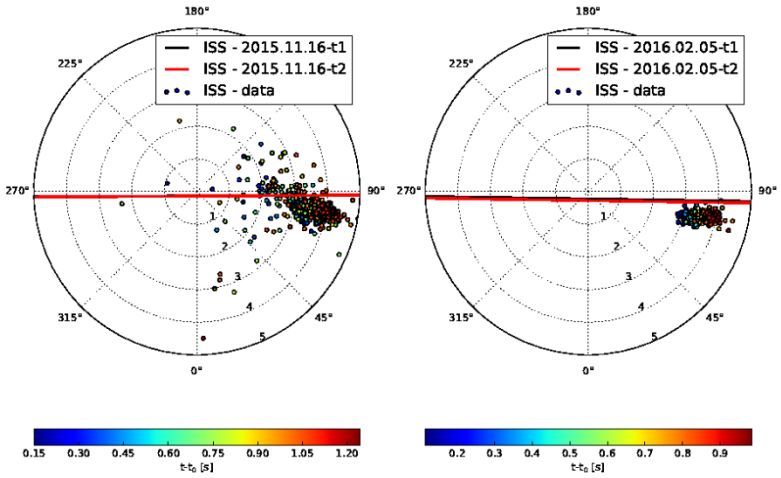
W. Bhattacharyya – flare advocate (ATel #9010) and data analyzer

HiSCORE sees the ISS - Laser: 10 nsec 1 mJ Flashes

(A. Porelli)

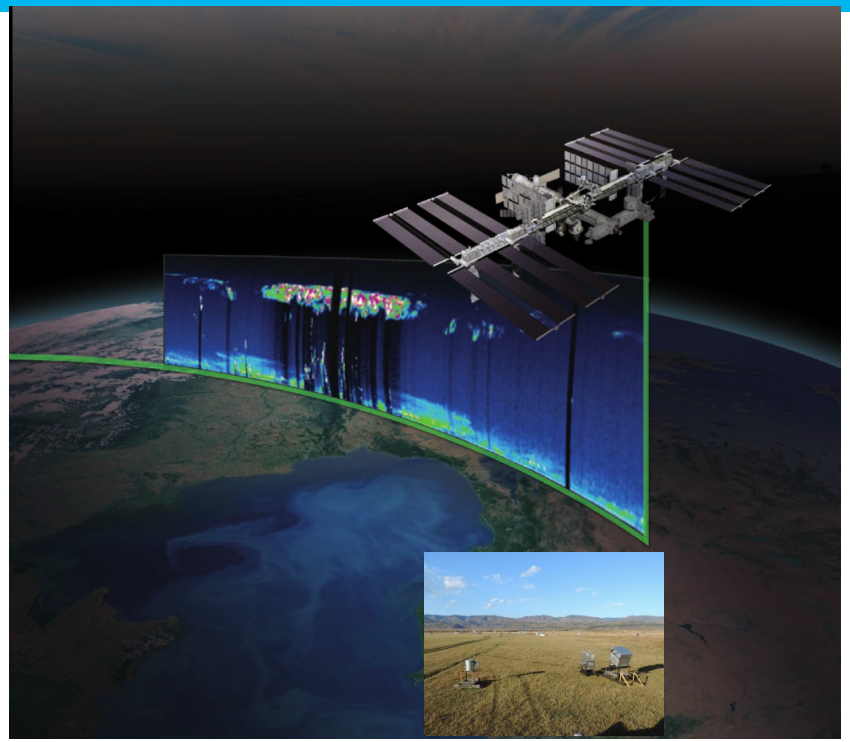
- The CATS Lidar on ISS at 410 km a.s.l.

- Serendipitous discovery. Next occurrence predicted and verified 2 weeks after.
  - Detected: 4 times in 2015/16



ISS track on local sky (line), and reconstructed HiSCORE events

https://www-zeuthen.desy.de/~wischnew/cta/trigsim/mc/iss/movies/vs1/



- Excellent HiSCORE calibration source:
  - flat timing profile
  - precision pointing
- Further Interest:
  - useful for IACTSs (H.E.S.S., MAGIC, CTA…)?
  - LIDAR physics: opens forward scattering