The Cherenkov Telescope Array

8th Terascale Detector Workshop, Berlin March 2015

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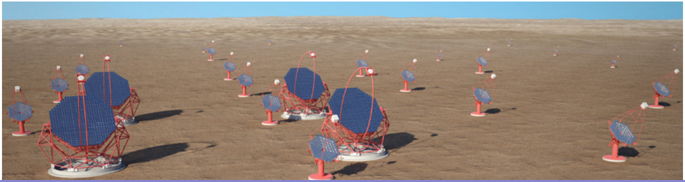
Overview

Prototype telescope in Adlershof, Berlin

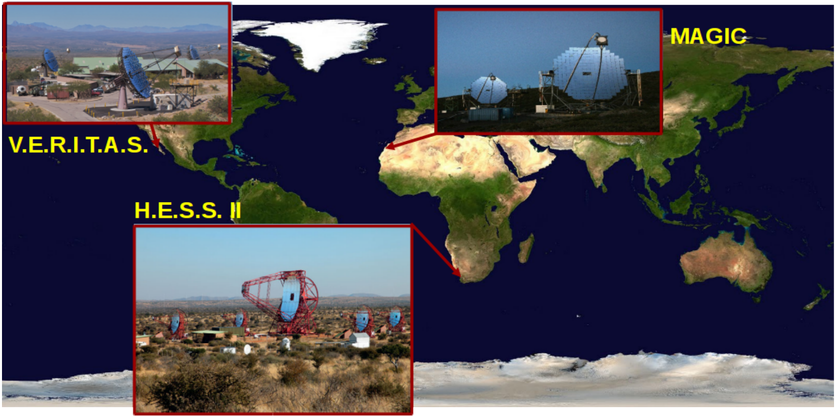
Introduction

- The Cherenkov Telescope Array (CTA) is a planned next generation ground based gamma-ray observatory
- Sites planned in Northern and Southern hemisphere
- CTA consortium currently has over 1000 members in 28 countries
- Under physics operation CTA will be an open observatory, taking external observation proposals
- Sensitivity improvement of order of magnitude over current experiments
- Broad science programme - astronomy to fundamental physics



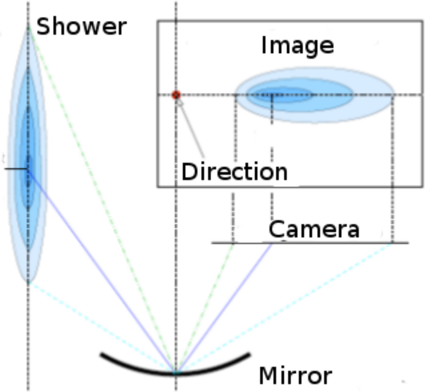
Current Gamma-Ray Experiments

Fermi-LAT→



Cherenkov Technique

- VHE gammas produced in non-thermal processes, interact in upper atmospere - emit secondary shower
- Cherenkov light emitted by high energy particles **in direction of incident particle**
- Atmosphere acts as **calorimeter**

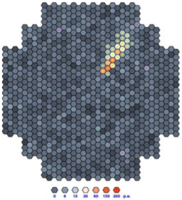


Telescope mirrors focus incoming light on camera PMTs

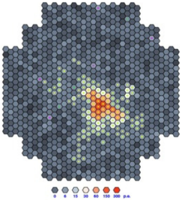
Cherenkov Telescope Array Principle

Background suppression

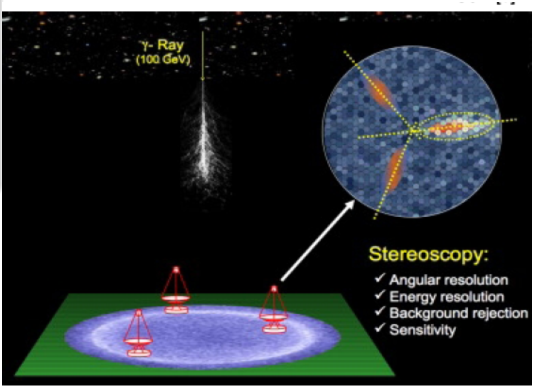
- Gamma shower: compact ellipse.
- Cosmic Ray hadron showers: broader angular distribution.



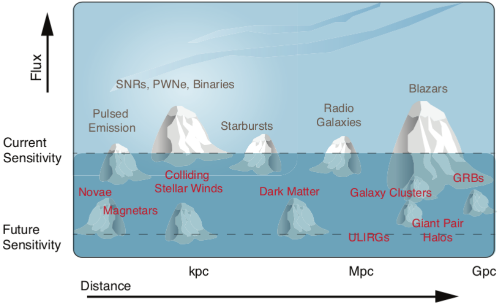
1.0 TeV gamma shower



2.6 TeV proton shower



Core CTA Science Questions and Goals



Great discovery potential for new sources and deeper study of known sources.

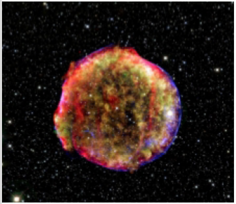
Key science themes

- Understanding the origin of cosmic rays and their role in the Universe
- Understanding the nature and variety of particle acceleration around black holes
- Searching for the ultimate nature of matter and physics beyond the Standard Model

CTA Science

Cosmic Rays

- Investigate Supernova Remnants (SNRs) as probable accelerators of cosmic rays
- Detect large population of VHE gamma-ray emitting SNRs.
- Search for young SNRs accelerating particles up to PeV energies.

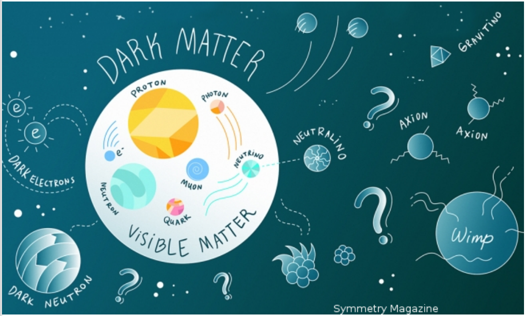


Black Holes, Jets and Star Formation

- Observe large sample of Active Galactic Nuclei (AGN).
- Study jet formation and its connection to central black hole properties.

CTA Science - Nature of Dark Matter

- Annihiliation of DM particles likely to result in gamma-rays, detectable with CTs → indirect search.
- Weakly Interacting Massive Particles (WIMPs) are popular candidates - expected mass in range 0.01-1 TeV.

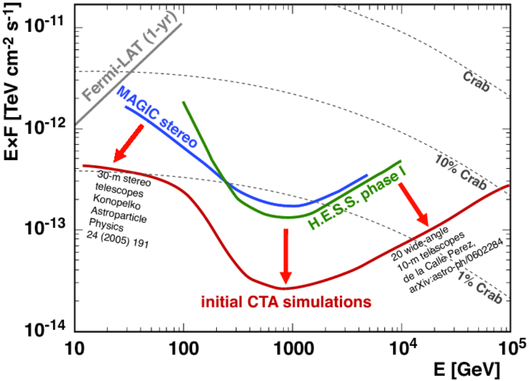


Large field of view and improved angular resolution → possible to study extended sources and spatial anisotropies.

Sensitivity: Expected performance

- 50 h data compared to 1 year of Fermi data (below).
- Array layout optimised for good performance across energy range.

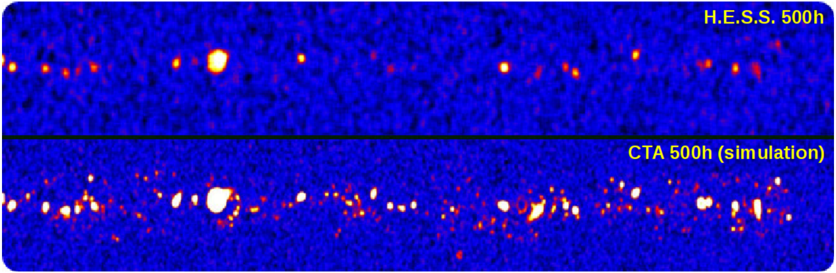
The Crab Nebula is a "standard candle" in VHE gamma-ray astrophysics, seen by HESS with about 20 gammas per minute



1 year of data taking is approx. 1500 h → 50 h data time is a reasonable estimate for a particular source in a year.

Performance goals driven by science goals

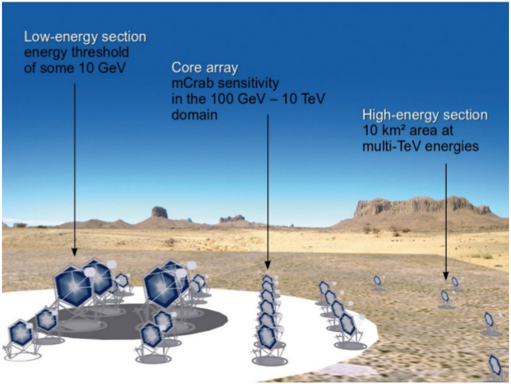
- Sensitivity: Order of magnitude greater sensitivity than current experiments, *milli-Crab* sensitivity at core energies.
- Energy Range: 4 decades in energy, from 0.01-100 TeV.
- Angular Resolution: resolutions of order arcmin
- Temporal Resolution: Large detection area $\rightarrow$ resolve flaring and time-variable emission at the sub-minute level.



Telescopes

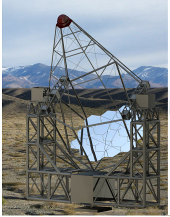
3 sizes of Telescope:

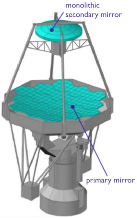
- Small Size Telescopes (SSTs) for E $>$ 10 TeV , 4-6m diameter
- Medium Size Telescopes (MSTs) for E $>$ 0.1 - 1 TeV, 10-12m diameter
- Large Size Telescopes (LSTs) for lowest energy, 23m diameter

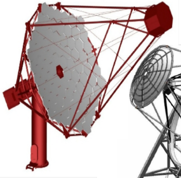


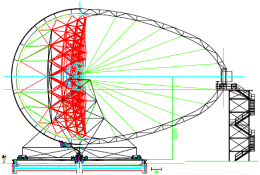
Optimal telescope array layout is being determined using MC simulations

Telescopes









LST

SSTs and SCTs

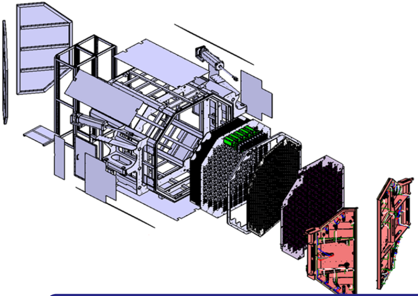
- Single and dual mirror designs in development
- 10° FoV
- Approx. 30 telescopes

MSTs

- Single and dual mirror designs
- 7-8° FoV
- Approx. 50 telescopes

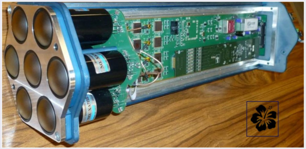
- Parabolic Mirror
- MAGIC design
- 5° FoV
- Approx. 4 telescopes

Cherenkov Cameras



Several competing camera options under development, prototyping and testing. One option is the standard drawer based approach.

Example: NectarCam

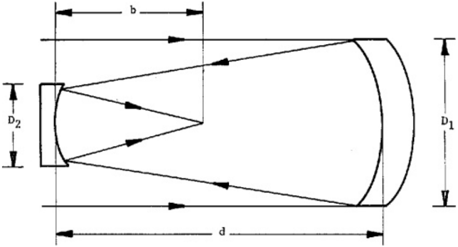


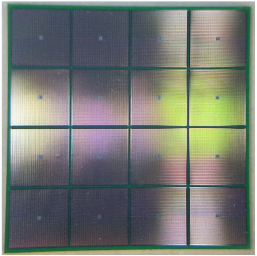
NectarCam module

- NectarCam: Modular approach
- HESS like camera design
- analogue or digital trigger
- standard PMTs, approx. 2K pixels

Cherenkov Cameras for dual mirror telescopes

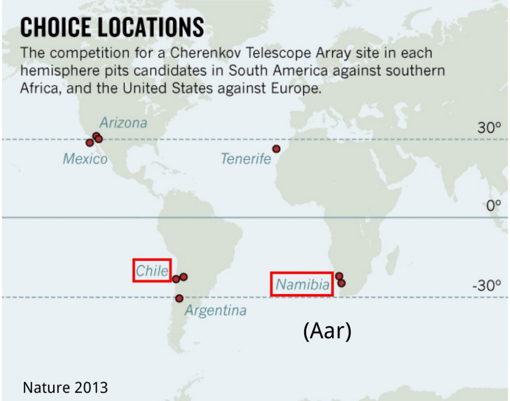
- Dual mirror design offers different advatages and challenges
- De-magnifying optical design $\rightarrow$ reduction of camera scale w.r.t. traditional design.
- Standard PMTs with light collectors become impractical
- SiPMs
- Approx. 12K Pixels





Site selection

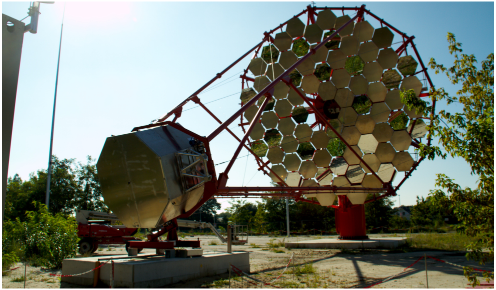
- Sites for Northern and Southern arrays under consideration
- Altitude, weather conditions and background light levels are important factors, as well as access for experimenters
- Decision from Resource Board expected in summer 2015



Current and planned prototype telecopes

- First CTA prototype telescope: Modified Davis Cotton MST, built in Adlershof in 2012
  - More details on this project in following slides.
- Dual mirror, Schwarzschild-Couder design SST in Sicily (Left)
  - Full working prototype
  - First of its kind to be built
- SST and SCT prototypes in US and Poland
- LST prototyping to take place on site.

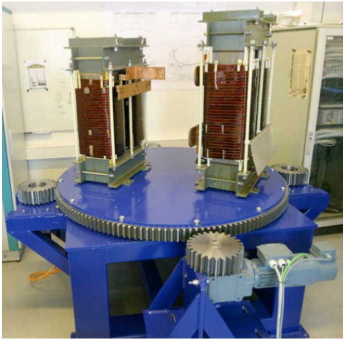
MST Prototype in Berlin: Concept and Aims

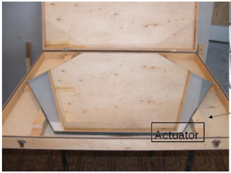


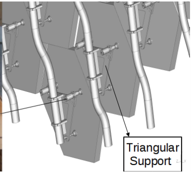
- Non-optical measurements (star visibility not optimal in Berlin)
- Pointing and pointing calibration (CCD cameras)
- Point Spread Function (PSF) measurement
- Test array control software
- Safety system tests
- Observation of weather conditions and related performance

MST Prototype: Mechanical Concept

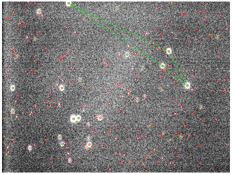
- Prototype consists of all mechanical systems:
  - Drive system (pointing and tracking)
  - Safety system
- Mirrors: mixture of dummies and prototypes
- Active mirror control (AMC) for mirror alignment
- No Cherenkov camera
  - Weighted dummy camera to simulate bending of telescope
- Steered by array control (ACTL) prototype software







MST Prototype: Instrumentation and measurements



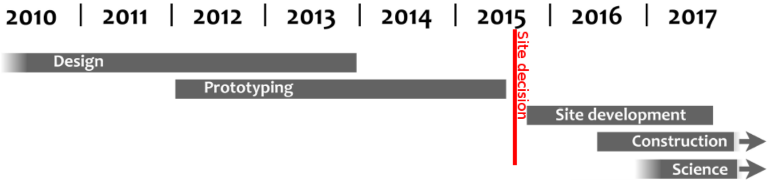
Pointing

- Telescope pointing direction measured using images from CCD cameras on telescope frame
- Sky direction identified using astrometry technique

- Weather station used to study performance dependence on conditions
- Temperature and humidity sensors mounted on most components

Status and plans

Timeline of CTA plans:

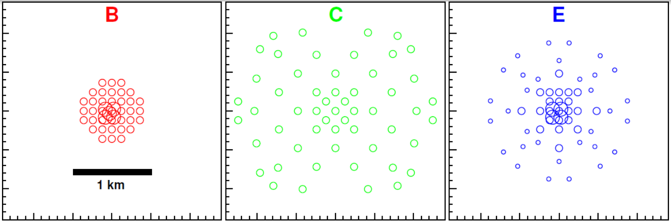


- Design and prototyping of telescopes and components at an advanced stage
- Significant improvements in sensitivity over current experiments
- Broad ranging science goals to answer fundamental questions in astronomy and astroparticle physics.


Thank you for your attention!

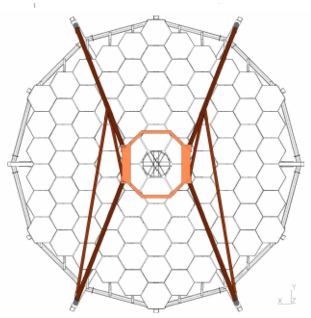
Array layout options

Several potential arrays are being considered for southern CTA site



Array B is optimised for low-energy gamma detection, with 5 LSTs at the centre, E is designed for good performance across the full energy range and C is tuned for high-energy gammas.

Optical design



- Optical Support Structure ("dish")
- Optical surface diameter of mirror: 12m
- 84 mirror facets mounted on dish
  - fully adjustable in 3D space (AMC)
  - hexagonal, spherical mirrors
  - 1.2 m flat-to-flat
  - 16.07m focal length
- Modified Davies-Cotton design
  - focal length of mirror facets and radius of curvature of dish adjusted to account for spread of photon arrival time across identical mirror facets