Cherenkov Telescope Array: Reflector Design Study

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Short CV

EDUCATION:

- Receiving Bachelor's degree in Theoretical Physics (June 2010)
- Deutsches Electronen Synchrotron (DESY) Summer Student Program 2009

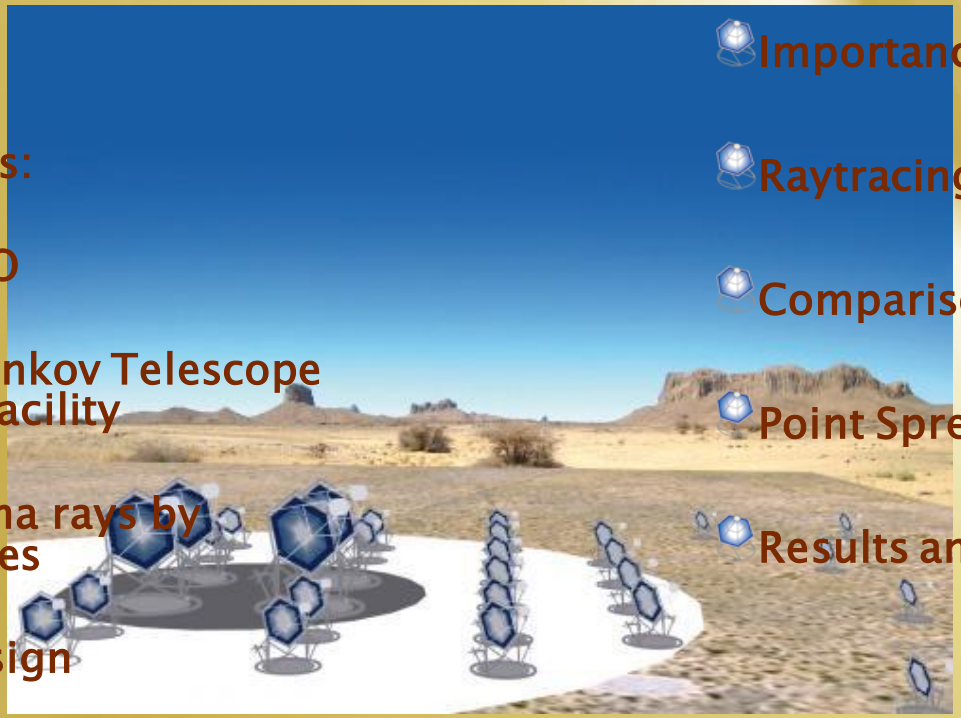
SCHOLARSHIPS:

- Presidential scholarship
- WORLD FEDERATION OF SCIENTISTS' SCHOLARSHIP

Outline

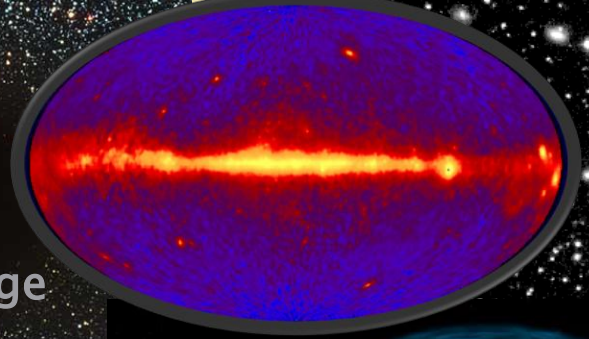
Cherenkov Telescope Array: the next generation facility for gamma-ray astronomy

- Physics's goal
- Current Telescopes: MAGIC, HESS, VERITAS, CANGAROO
- Future: CTA Cherenkov Telescope Array – an advance facility
- Detection of gamma rays by Cherenkov Telescopes
- Davies-Cotton design



- Importance of Raytracing
- Raytracing of Parabolic Mirror
- Comparison of arrival Time spread
- Point Spread Function
- Results and conclusion

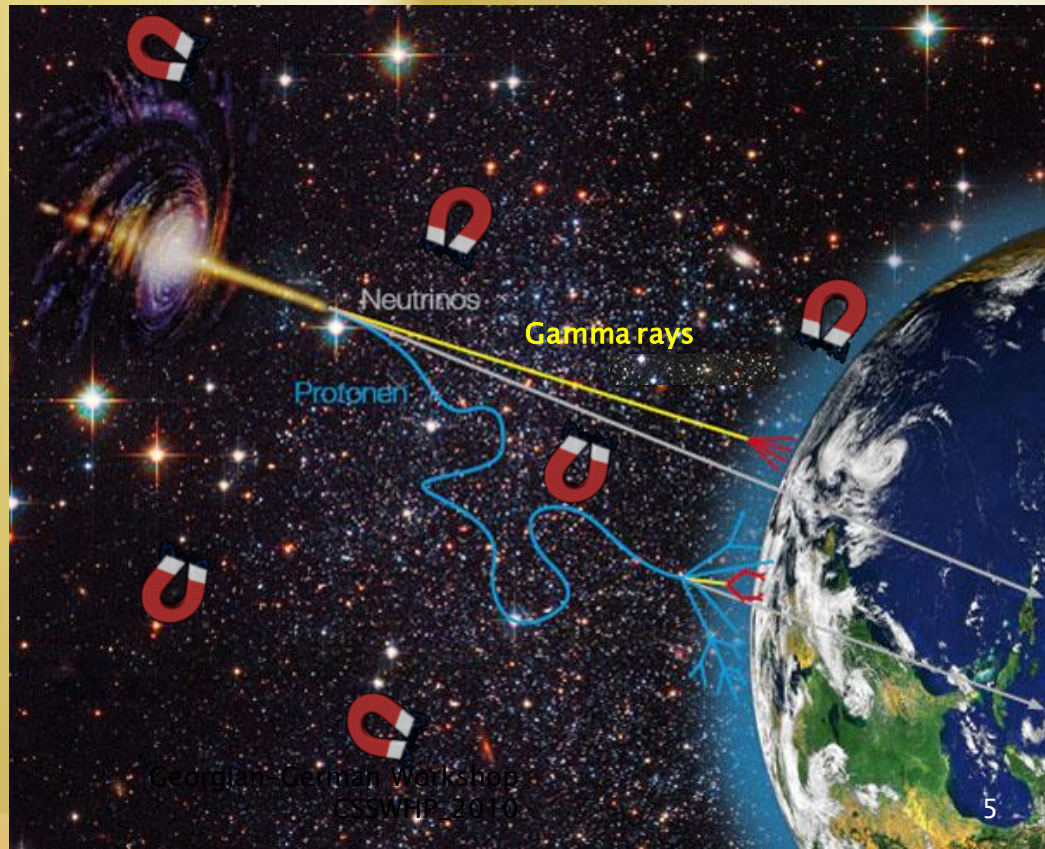
Physics's Goal



- Thermal radiation: keV energy range
- Exploring the Non-Thermal Universe: up to 10^{20} eV
- Sources of high energy particles in Cosmos: Supernovae, Pulsars and pulsar nebulae, Binary stars, Black holes, Relics of the Big Bang.
- Classification of the acceleration mechanisms

Gamma Ray Astronomy?

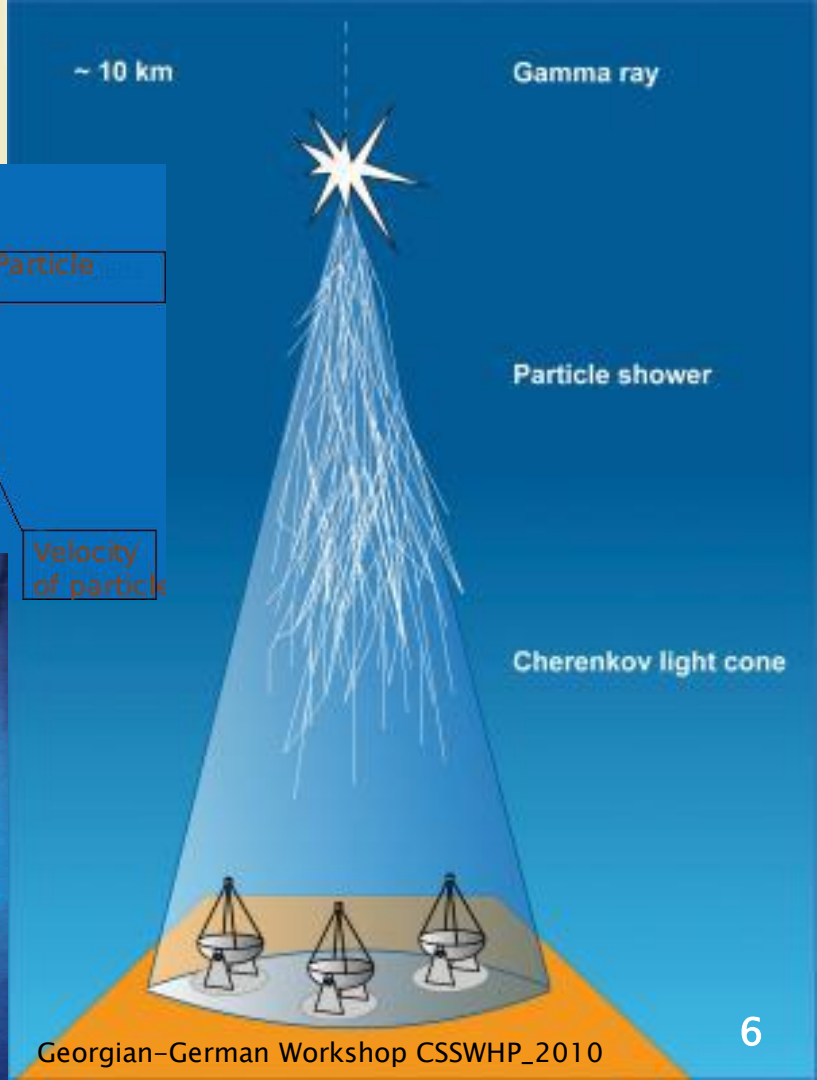
- Gamma rays point back directly to the sources
- Flux of gamma rays decreases rapidly with increasing energy
- Large effective detection area: ground-based telescopes
- Satellite telescopes: primary rays (only GeV)



Extensive Air Shower

- Birth of secondary particles
- If v>c/n, emission of Cherenkov light

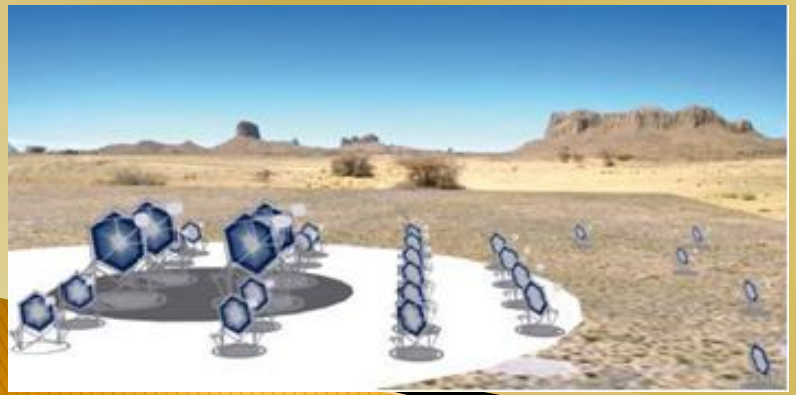
- Detection of Cherenkov light by telescope: Imaging Atmospheric Cherenkov Technique
- 0.05∘ resolution marks the upper limit for achieving gamma ray-hadron showers discrimination



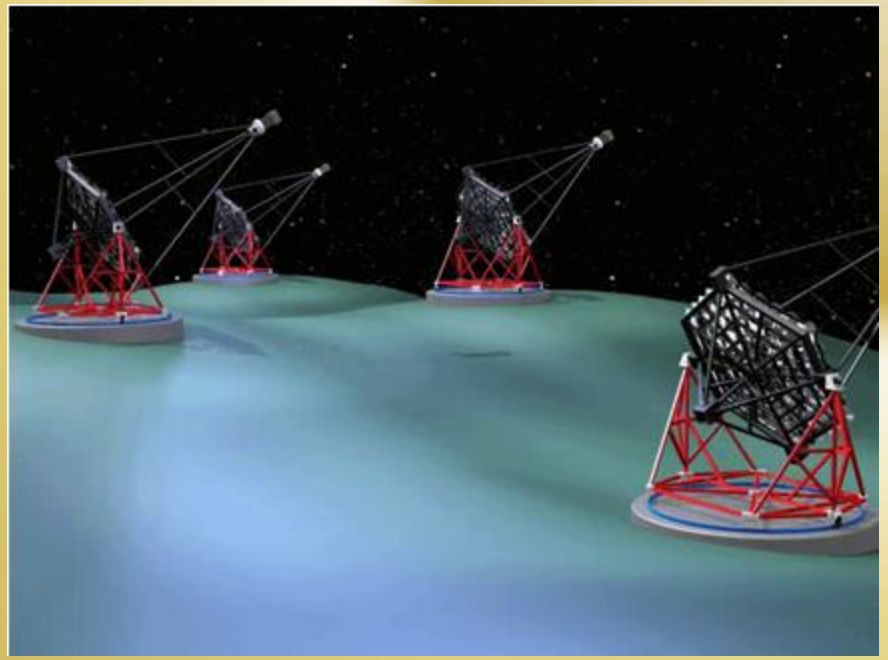
Ground-based γ-ray astronomy in the World: exploring several TeV

Cherenkov Telescope Array: above 100 TeV

- Two arrays: Northern and Southern Hemispheres': full sky coverage
- Southern(10GeV-100TeV): mixed array of 50-100 telescopes with 23m, 12m, 6m diameters

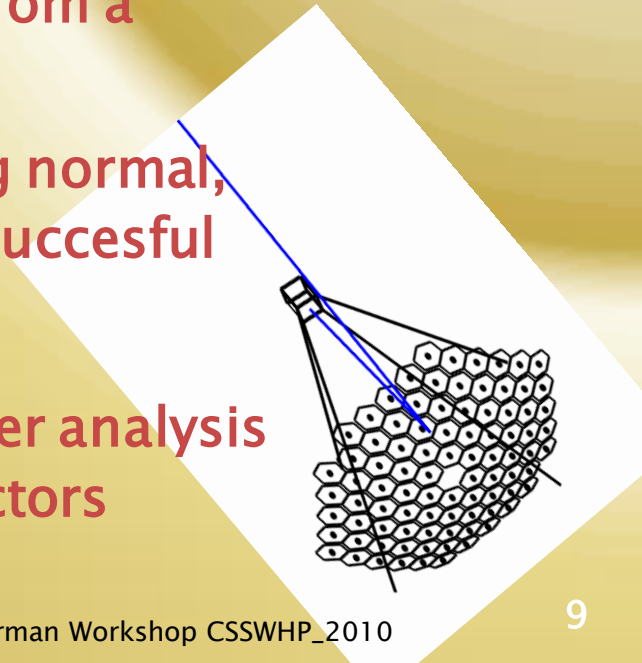


- DESY Zeuthen: designing and simulating performance of 12m telescope



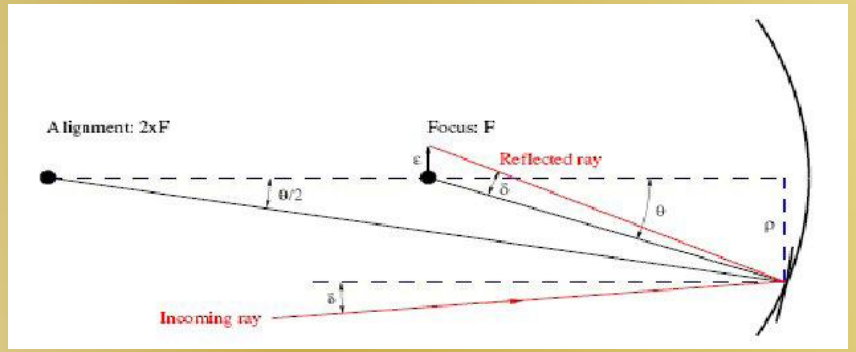
Reflector Geometry: Raytracing

- Accurate prediction of optical performance for imaging system, including tessellated reflector geometries.
- Light randomly distributed across the mirror from a source point in infinity
- Hit point on the mirror is found:corresponding normal, and therefore reflection vector (untill 1000000 succesful rays are traced onto the camera face
- Before the advent of fast computers Third Order analysis was used, not applicable to the tessellated reflectors

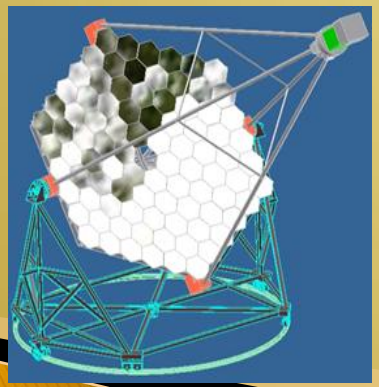


Choice of Reflector Geometry:

Davies-Cotton



- Intiially designed as solar concentrator
- Spherical support
- Spherical facets with 2x radius of curvature



Parabolic

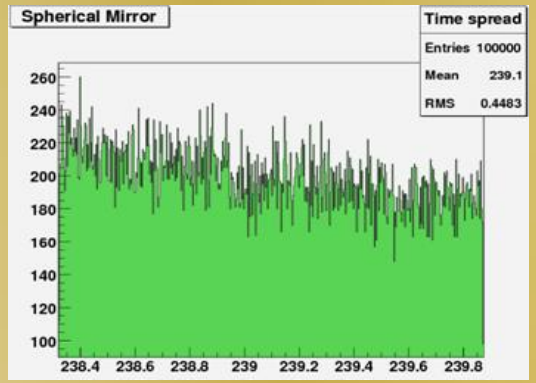
- Paraboloid of revolution a =b $z = \frac{x^2 + y^2}{a^2}$
- Rotational symmetry $z(r) = \frac{r^2}{4f}$
- Obtained the equation of normal for any point on the mirror in terms of focus $z'(r) = -\frac{2f}{R} r + z(R) + 2f$

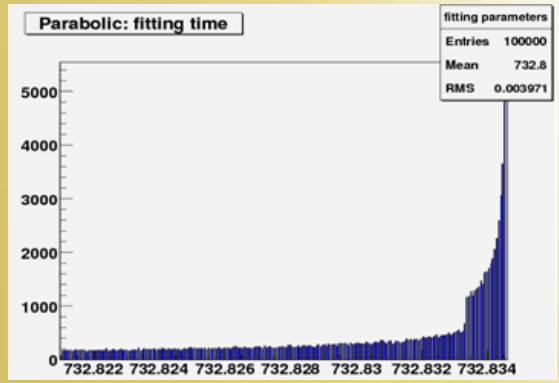
where $(R, z(R))$ is the point on the mirror

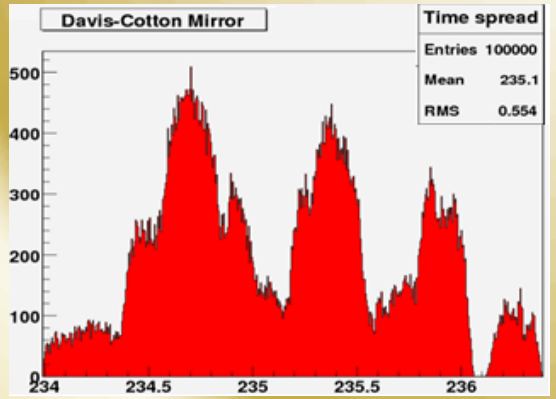
Timing(f/d=1.5)

I edited Ray Tracing codes to obtain photons' arrival time at the camera

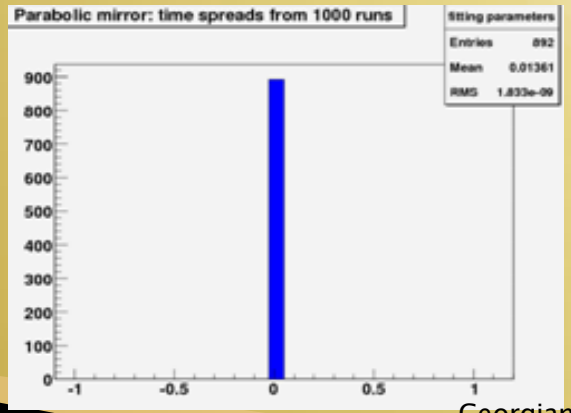
Histograms of arrival time of 1, 000, 000 successful photons

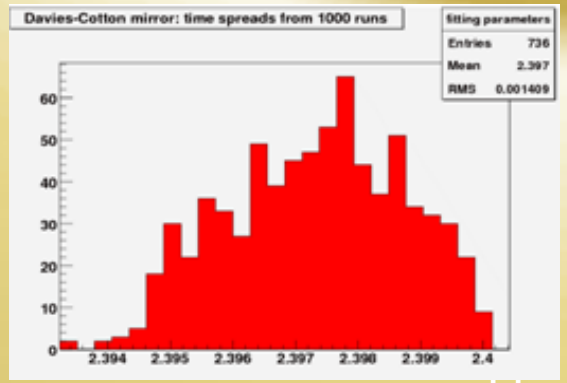






After many iterations of simulations, I made histograms of distribution of arrival Time spreads





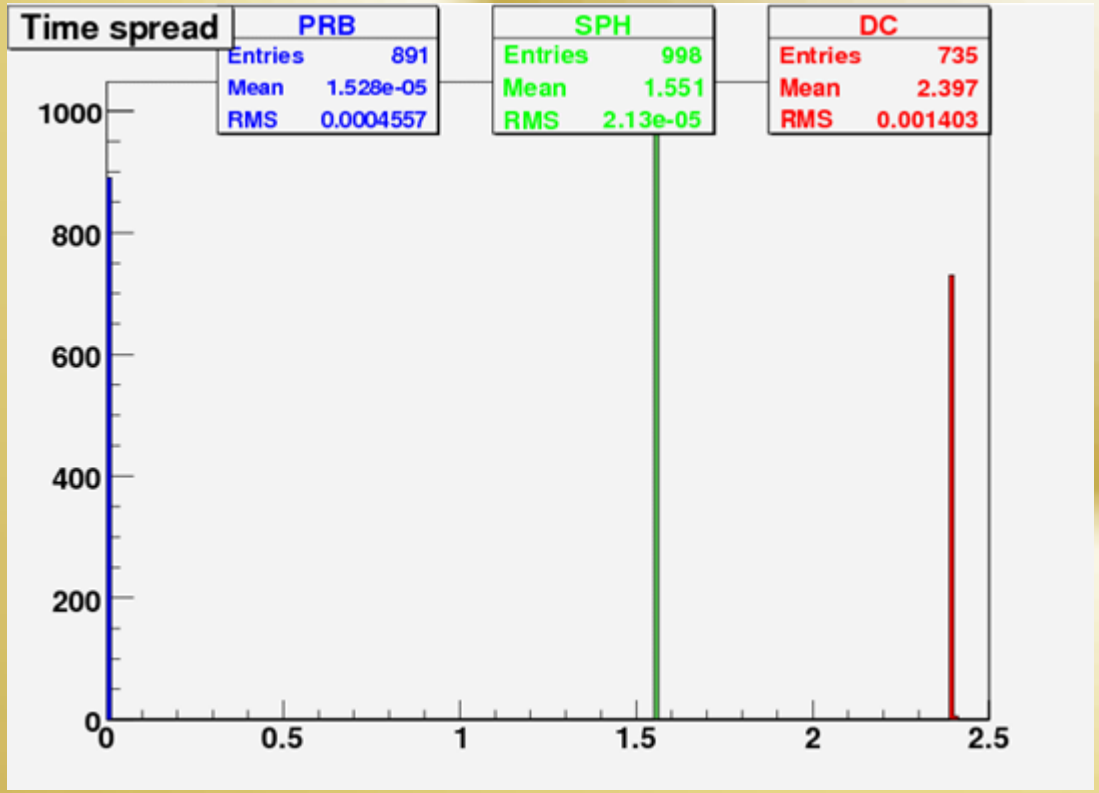
Comparison

Putting all three histograms on one scale:

Mean values of arrival time:

Parabolic mirror:	0.015
Spherical mirror:	1.55
Davies-Cotton mirror:	2.397

As far as flashes of Cherenkov lights last only for few nanosecs, isochronous arrival at camera is very important

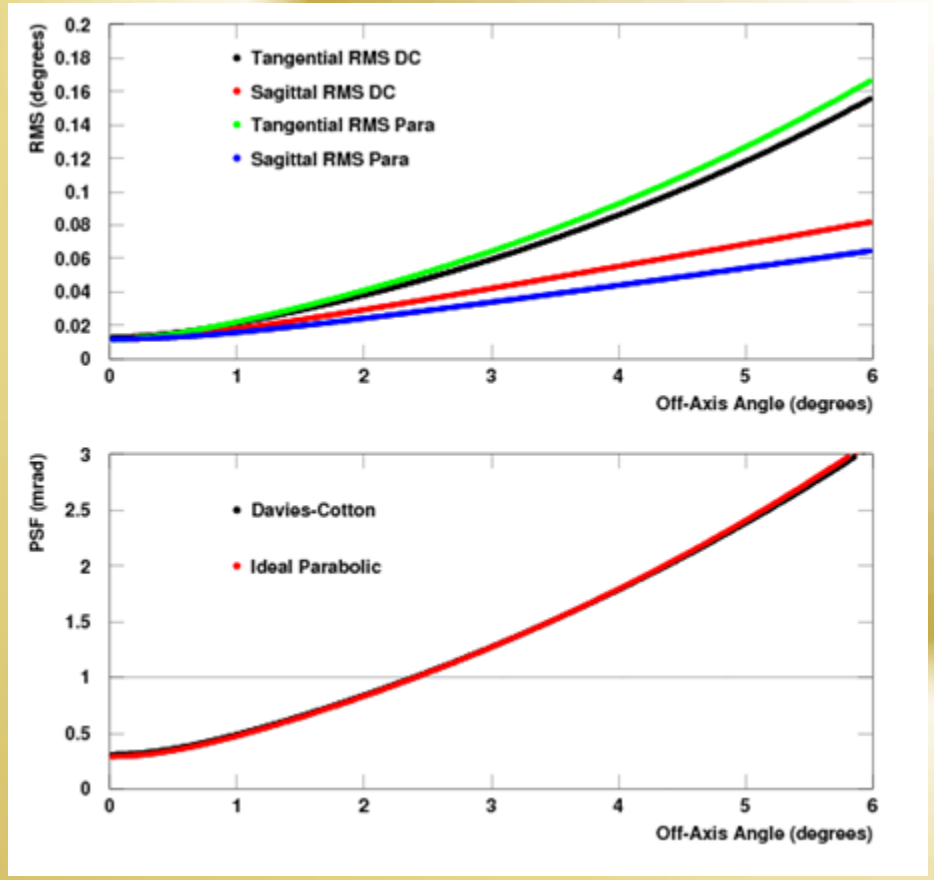


Point Spread Functions:

Response of an imaging system to a point source.

RMS root-mean square deviations of the ray's actual image coordinates from centroid position are reasonable measure of optical spot size

Real Davies-Cotton ~ Ideal Single parabolic



Point Spread Function, as the function of Off-Axis Angle

Conclusions:

- Simulation of performance for Spherical, Davies-Cotton, Single parabolic mirror was performed in C and analyzed in ROOT
- Parabolic mirror showed good timing and PSF. Results of this work were put in DESY Design Report
- Current status of CTA: proposed design's costs are checked. In 2010-2011 prototype telescopes will be built
- Deep investigation of galactic sources, the central part of our Galaxy, and also the observation of extragalactic objects.

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- 2. F.A. Aharonian Very High Energy Cosmic Gamma Radiation.
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- 4. Albert Schliesser, Razmik Mirzoyan: Wide field prime focus Imaging Atmospheric Cherenkov Telescopes: A systematic study.
- 5. Astrophysics with H.E.S.S: www.mpihd.mpg.de/hfm/HESS/pages/about/physics
- 6.Pratik Majumdar: Lectures for Summer Students: Astroparticle Physics