“Simulation Studies of the MACE gamma ray Telescope : Sensitivity,Angular resolution and energy resolution

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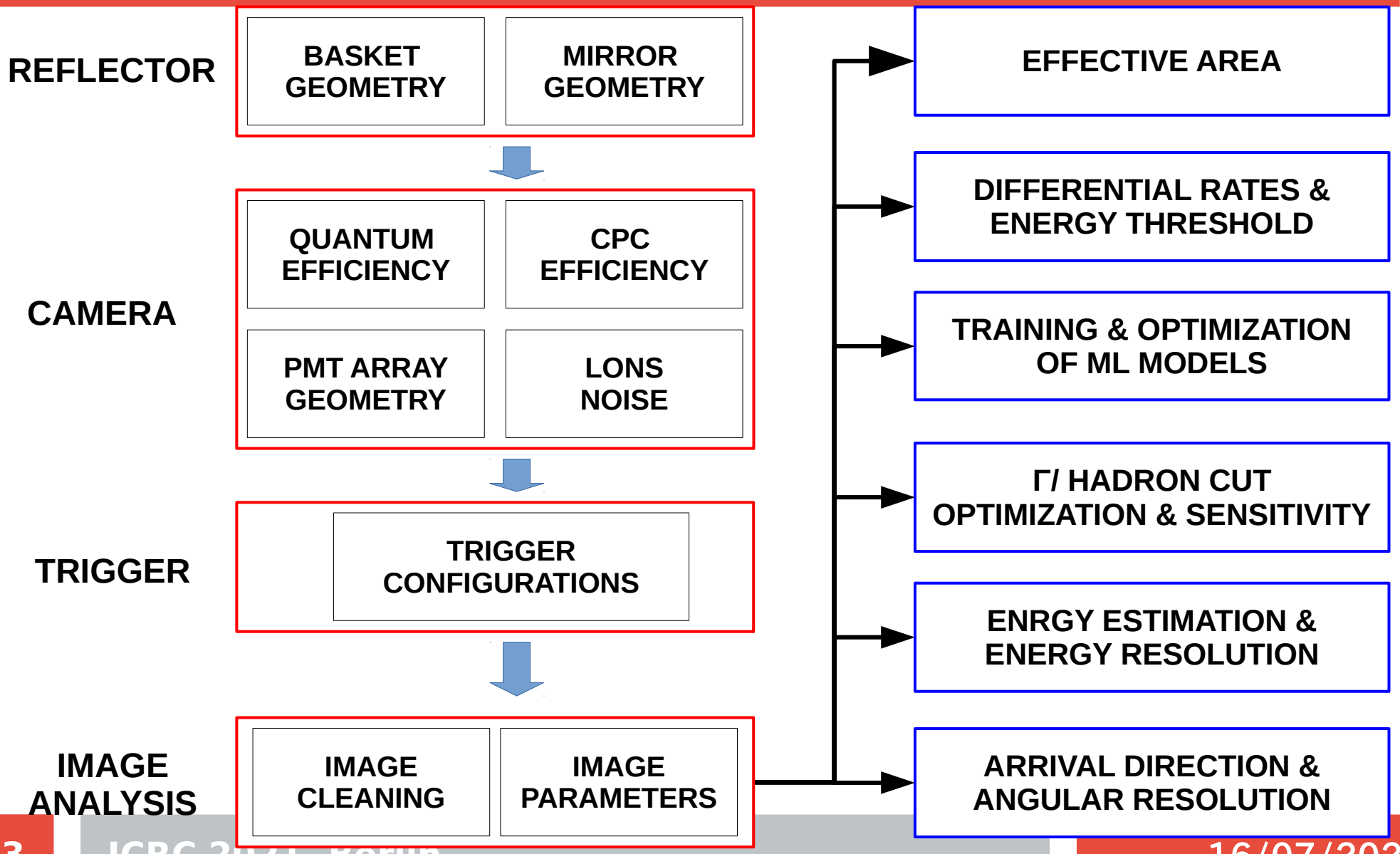
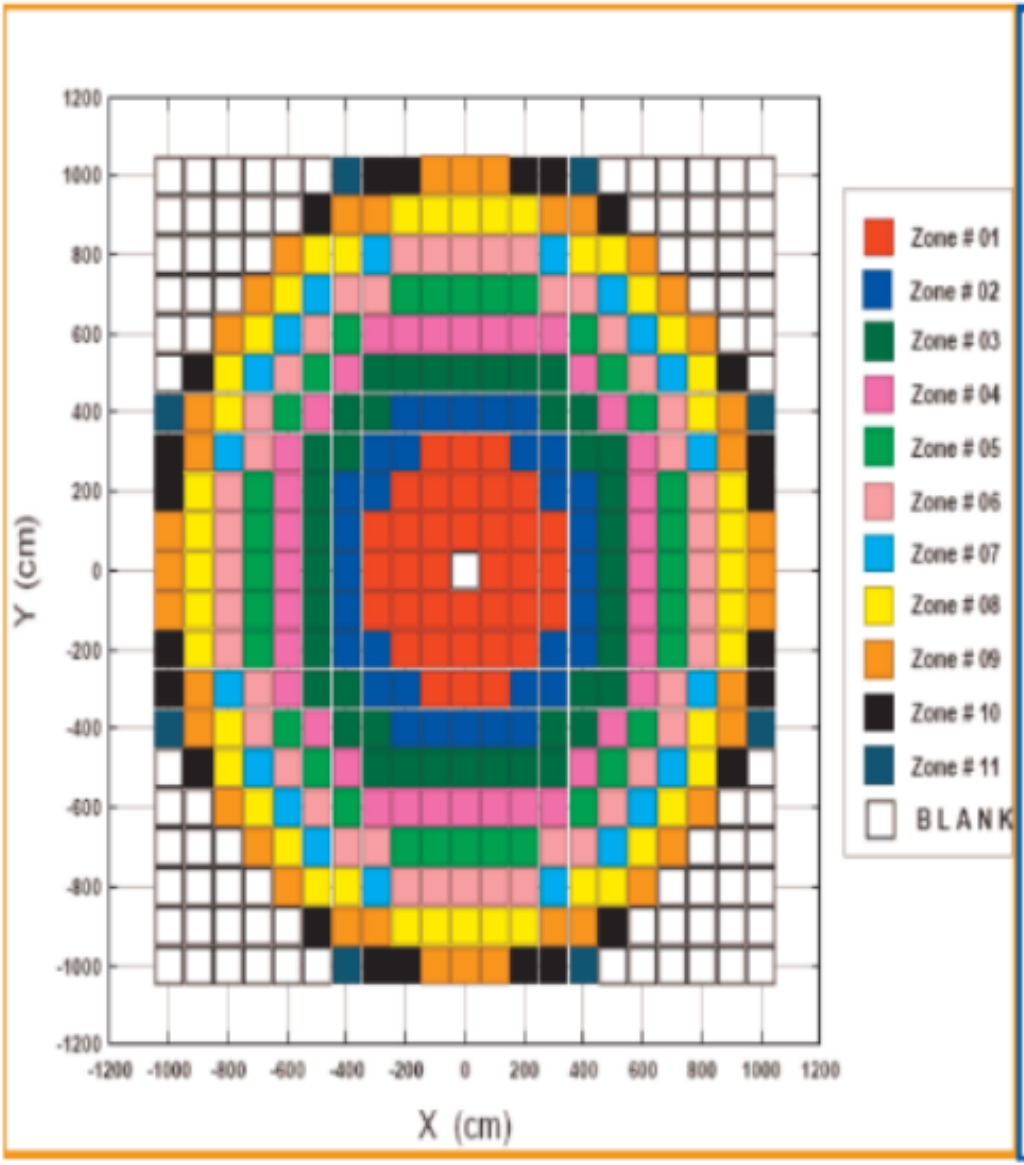
Extensive Air Shower Simulation

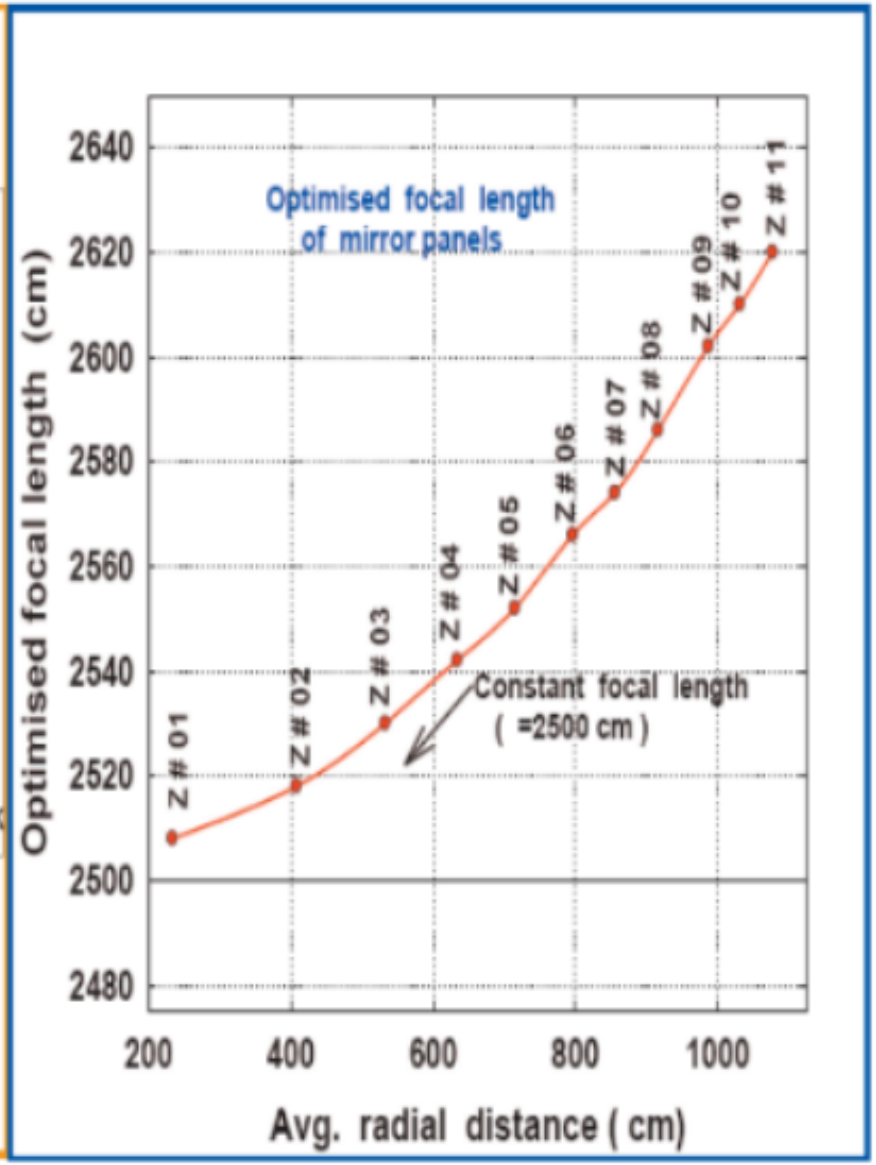
- CORSIKA (**CO**smic **R**ay **SI**mulation for **Ka**scade) (https://www.ikp.kit.edu/corsika/79.php)
- High Energy Model : QGSJET-I (Energy >= 80 GeV)
- Low Energy Interaction Model : GHEISHA (Energy <= 80 GeV)
- Electromagnetic Interactions : EGS4 / NKG
- Hanle Altitude : 4270 m asl
- Geomagnetic Field : IGRF12 => Vertical : 38.75 µG, Horizontal Component : 32.47 µG
- IACT/ATMO extension (Konrad Bernlohr, Astroparticle Physics, 2008 (30), 149)

Simulation of Telescope Response



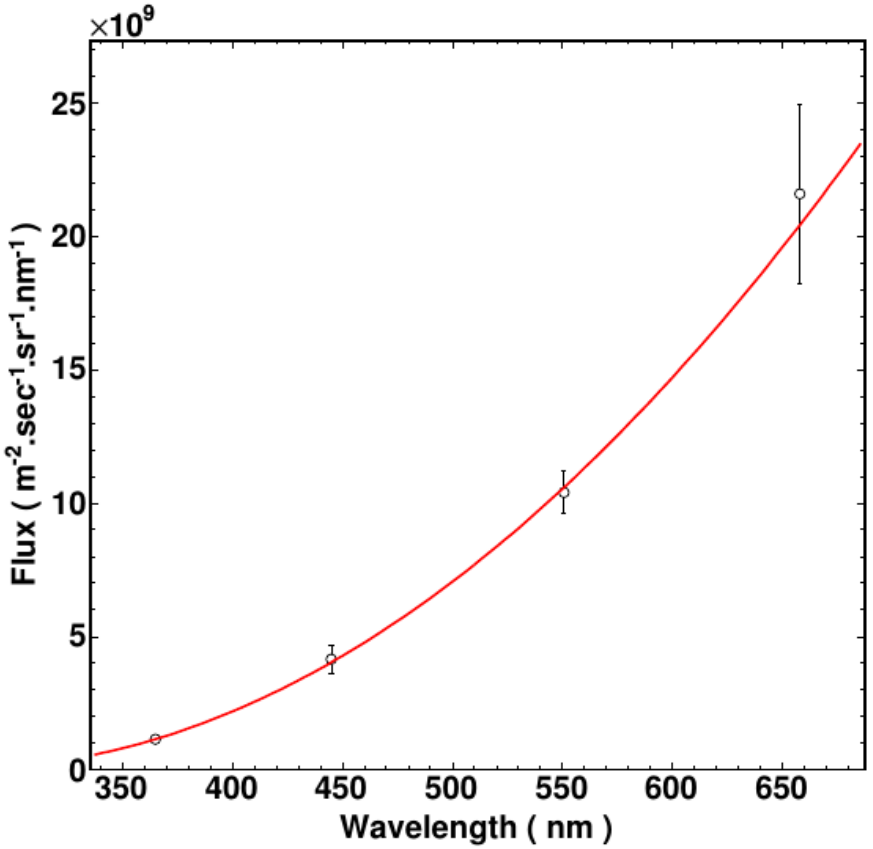
Simulation Of Telescope Response : Reflector





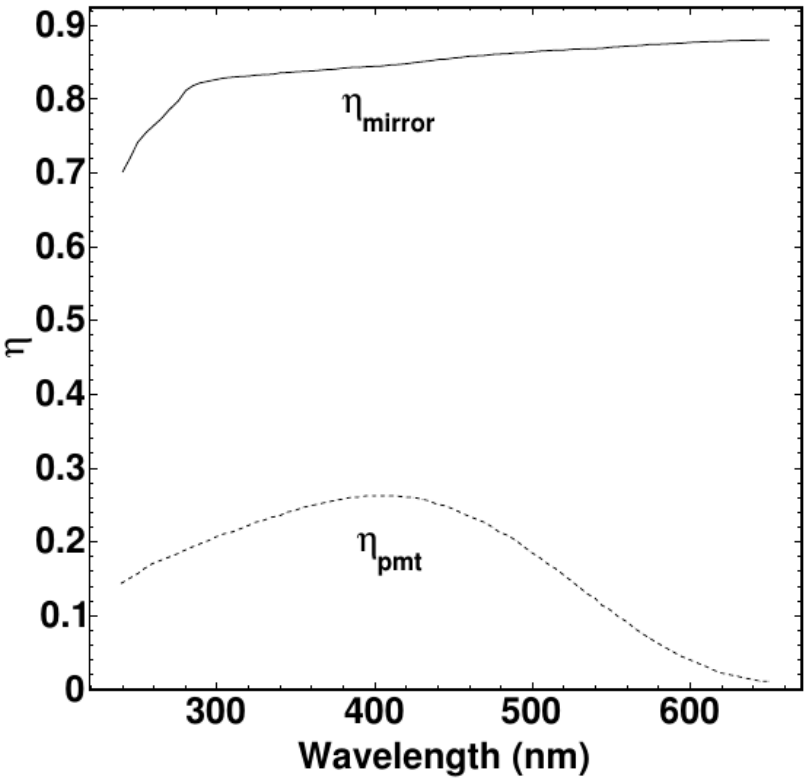
Simulation Of Telescope Response : LONS

Light Of Night Sky at Hanle Stanley et al. 2008	
Band	**Flux (mag/arcsec^2)**
U	22.14 ± 0.32
B	22.42 ± 0.30
V	21.28 ± 0.20
R	20.54 ± 0.37



A Parabolic fit to the observed flux of LONS at HCT site

Simulation Of Telescope Response : LONS



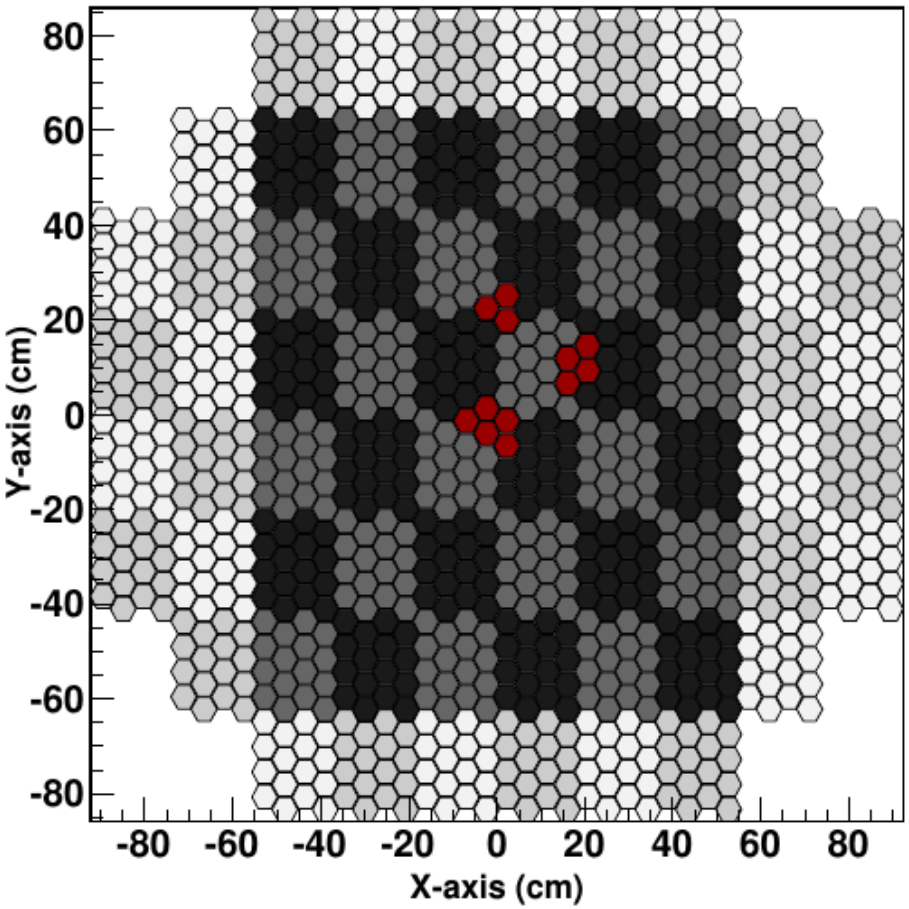
Reflectivity and Quantum Efficiency for the MACE

- Photo electrons due to Light of Night Sky given by,

$$N_{phe} = \Omega_{CPC} A_{mirror} \int \Phi(\lambda) \eta_{mirror}(\lambda) \eta_{PMT}(\lambda) d\lambda \, sec^{-1}$$

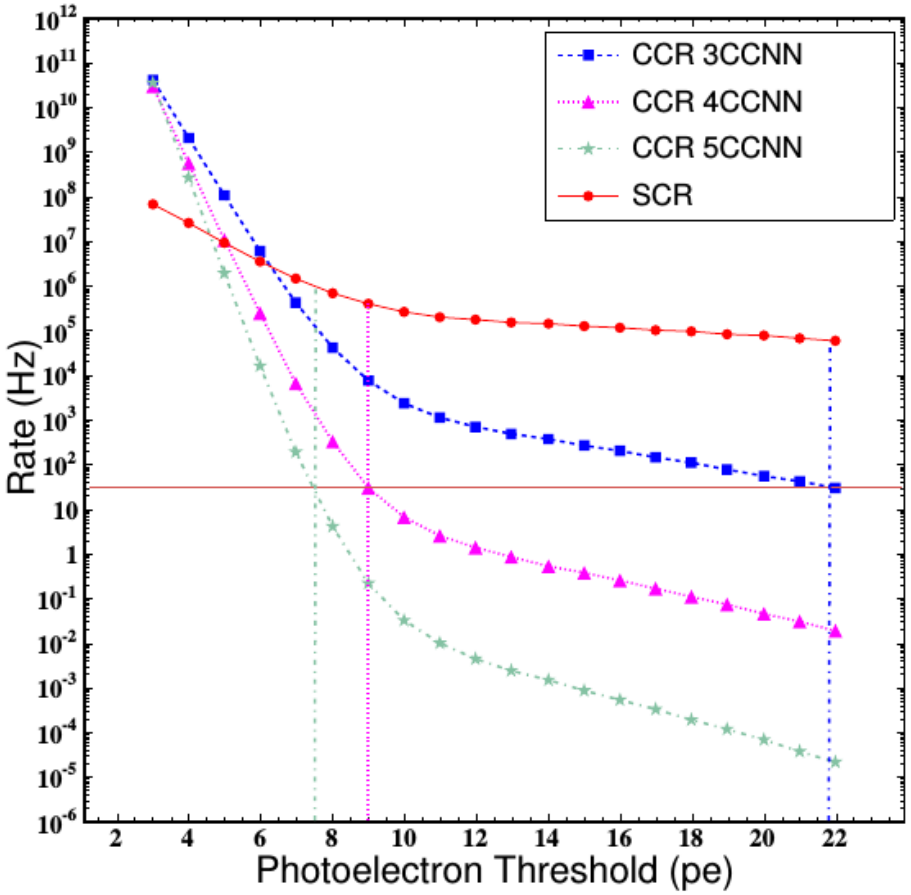
- For coincidence gate width of 5 ns, contribution due to LONS ~ 1.46 photo-electrons per pixel
- Poissonian distribution

Simulation Of Telescope Response : Camera



- 1088 PMTs with hexagonal CPC
- 16 PMT x 68 Modules
- 24 x 24 trigger
- Angular size ~ 0.125^{o}
- Total FOV ~ 4.3^{o} x 4.0^{o}
- Trigger FOV ~ 3.02^{o} x 2.62^{o}

Trigger Performance : Trigger Configuration



- Afterpulsing rate of PMTs primary factor
- Average SCR of 3 gain calibrated PMTs with gains ~42000, ~54000 and ~60000

$$R_{Chance}(m) = m C_m^n R_{pixel}(q_o)^m \tau^{m-1}$$

$$FLT(l, q_o) = l C_l^M R_{pixel}(q_o)^l \tau^{l-1}$$

$$SLT(m, q_o : l_1, l_2) = C \cdot FLT(l_1, q_o) FLT(l_2, q_o) \tau$$

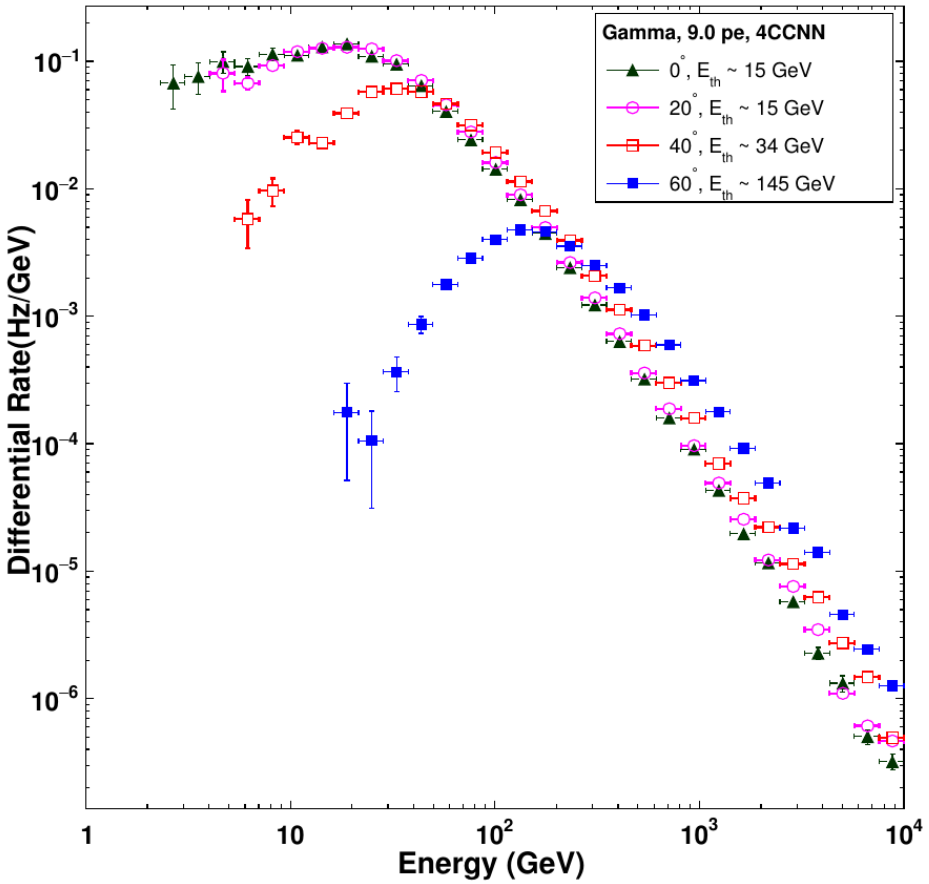
Estimated Optimum Trigger Configuration
4 CCNN Trigger Configuration
Single Channel Discrimination Threshold of 9.0 photo electrons

Trigger Performance : Database

Primary Particle	Gamma				Electron			
Zenith Angle (deg)	0^o	20^o	40^o	60^o	0^o	20^o	40^o	60^o
Energy Range (GeV)	$5 – 10^4$				$5 - 10^4$			
Impact Distance (m)	400	450	500	550	400	450	500	550
View cone angle (deg)	-	-	-	-	4	4.5	5	5.5

Primary Particle	Proton				Alpha			
Zenith Angle (deg)	0^o	20^o	40^o	60^o	0^o	20^o	40^o	60^o
Energy Range (GeV)	$10 – 10^4$				$10 - 10^4$			
Impact Distance (m)	500	550	600	650	500	550	600	650
View cone angle (deg)	5	5.5	6	6.5	5	5.5	6	6.5

Trigger Performance : Results

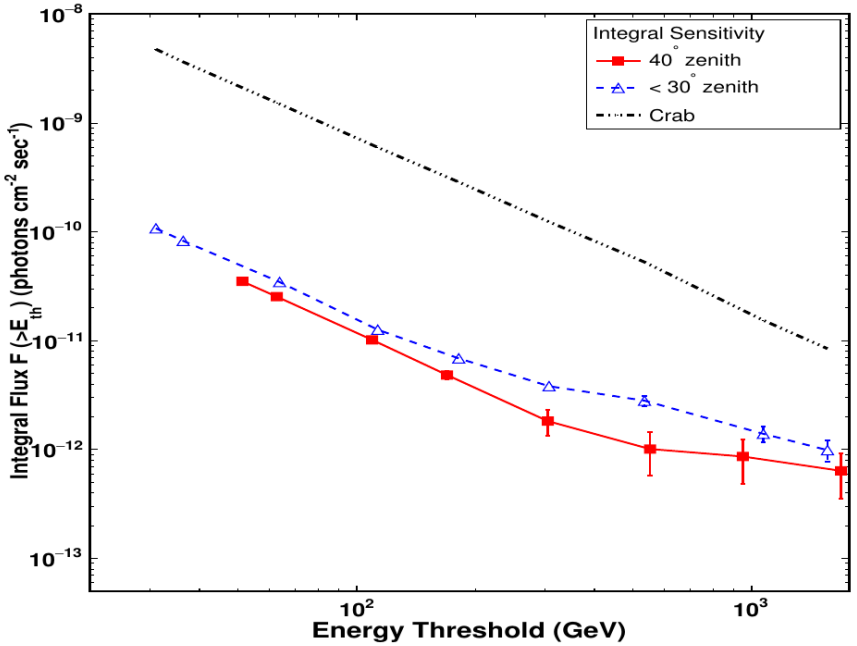


- Increasing trigger energy threshold with increasing zenith angle
- Enrgy threshold ~15 GeV at zenith angle of 0^o – 20^o

Integral Flux Sensitivity : Database

		Gamma	Proton	Alpha	Electron
5°	**Total (x 10^6)**	16.8	164	38.4	128
	Triggered	545368	269503	223674	167285
25°	**Total (x 10^6)**	16.8	164	38.4	128
	Triggered	460274	192466	165274	163912
40°	**Total (x 10^6)**	12.8	192	38.4	128
	Triggered	429617	432351	203715	324992

Integral Flux Sensitivity : Results



- **Sensitivity of 1.7 % Crab units at Energy Threshold ~ 52 GeV**
- **Crab detection time of ~80 sec**

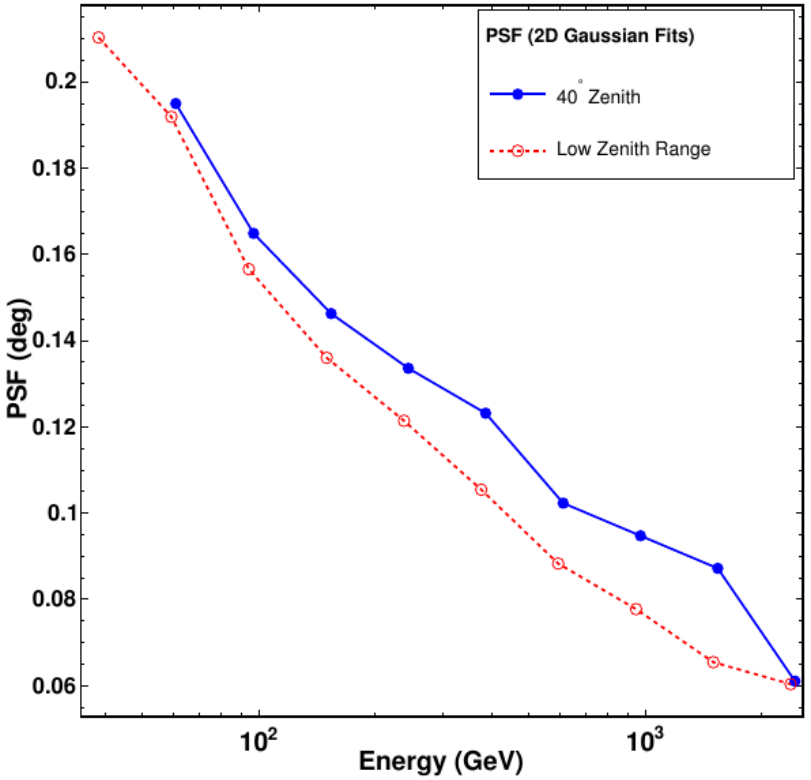
Sensitivity based on α – analysis at 40° zenith angle

Angular Resolution : Database

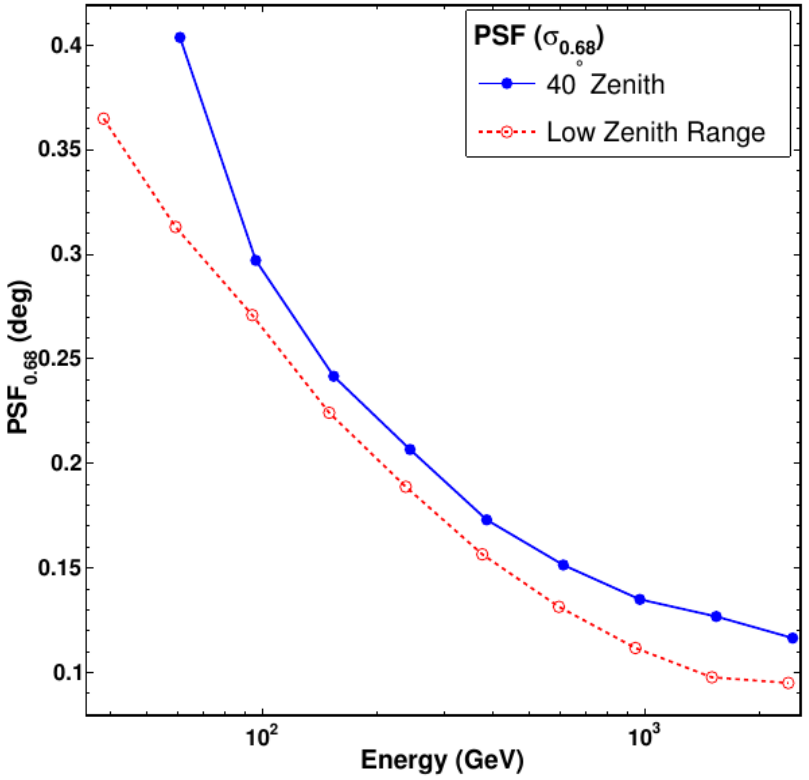
Zenith	Total	Triggered
5^{o}	1.92 x 10^{6}	472325
25^{o}	1.92 x 10^{6}	457120
40^{o}	1.92 x 10^{6}	563121

- **Leakage > 0.1 and size < 50.0 rejected**
- **From the rest ~80000 used for RFM training at each zenith**
- **Same database for the estimation of energy resolution**

Angular Resolution : Results



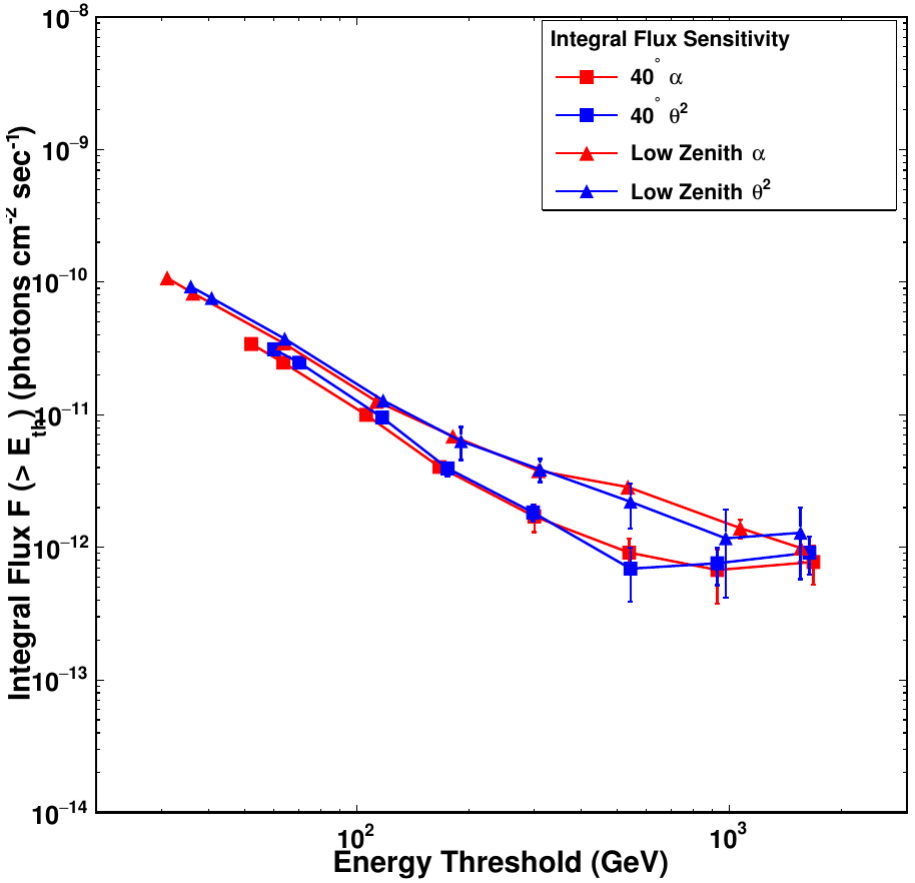
MACE angular PSF as function of energy



MACE 68% containment radius as function of energy

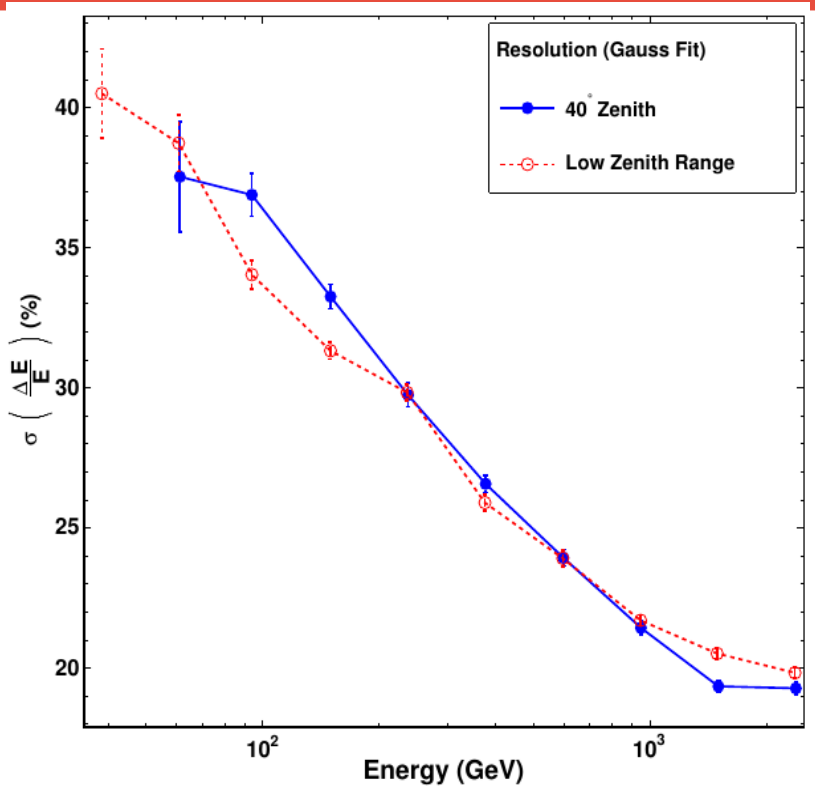
- Comparable angular PSF with MAGIC-I

Integral Sensitivity using θ^2

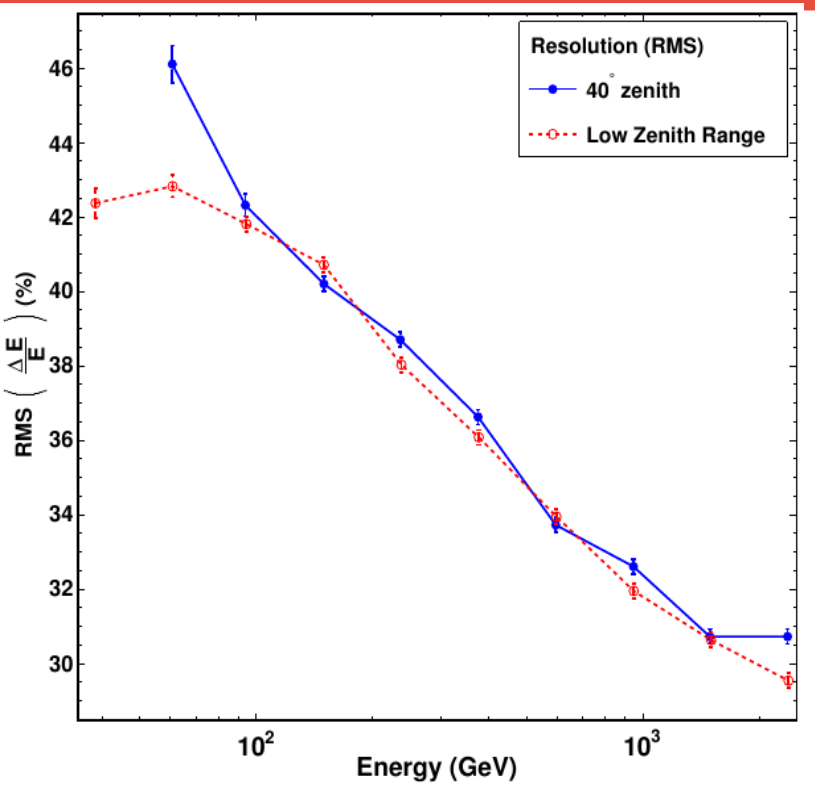


No significant difference compared to alpha analysis

Energy Resolution : Results



MACE energy resolution (Gaussian Fit) as function of energy



MACE energy resolution (RMS) as function of energy

Conclusions

- *MACE Achieves the target of wide energy range which it set out for*
- *Low energy threshold, good sensitivity over wide zenith angle range of 0^0- 40^0*
- *Very good instrument for detailed spectral and temporal study of variety of VHE sources detected by Fermi/LAT and other IACTs*

Thank You