Optimization of the cell configuration for a system of ideal IACTs

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ROADMAP

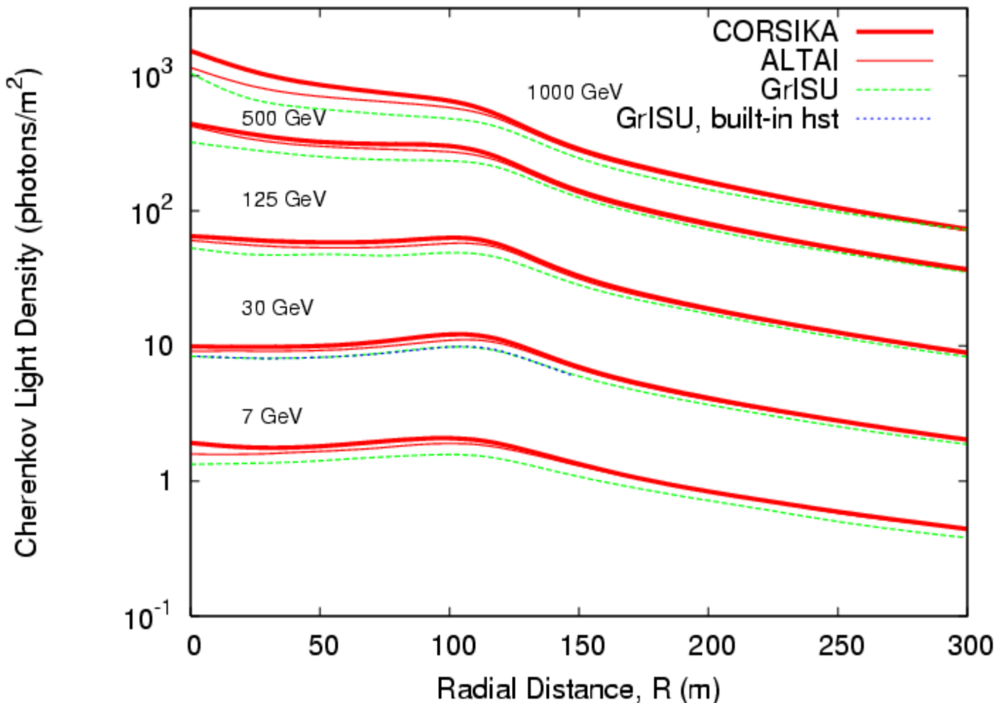
- Comparison of simulation codes
- Optimization of a telescope cell based on the lateral distributions for γ showers
- Optimization of an idealized cell of Cherenkov telescopes based on detailed MC

Lateral distributions of Cherenkov light, γ-showers

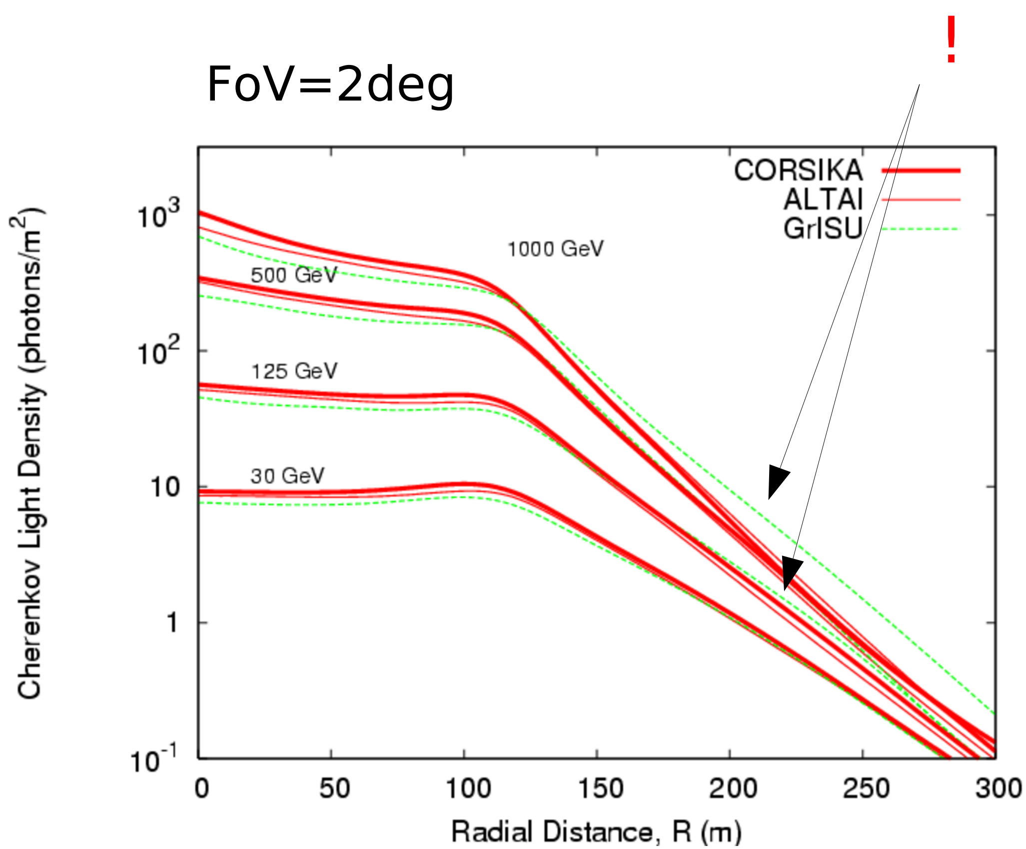
* GrISU: long tails for smaller FoV

"CORSIKA > ALTAI > GrISU", splitting becomes larger with the energy.

FoV=180deg



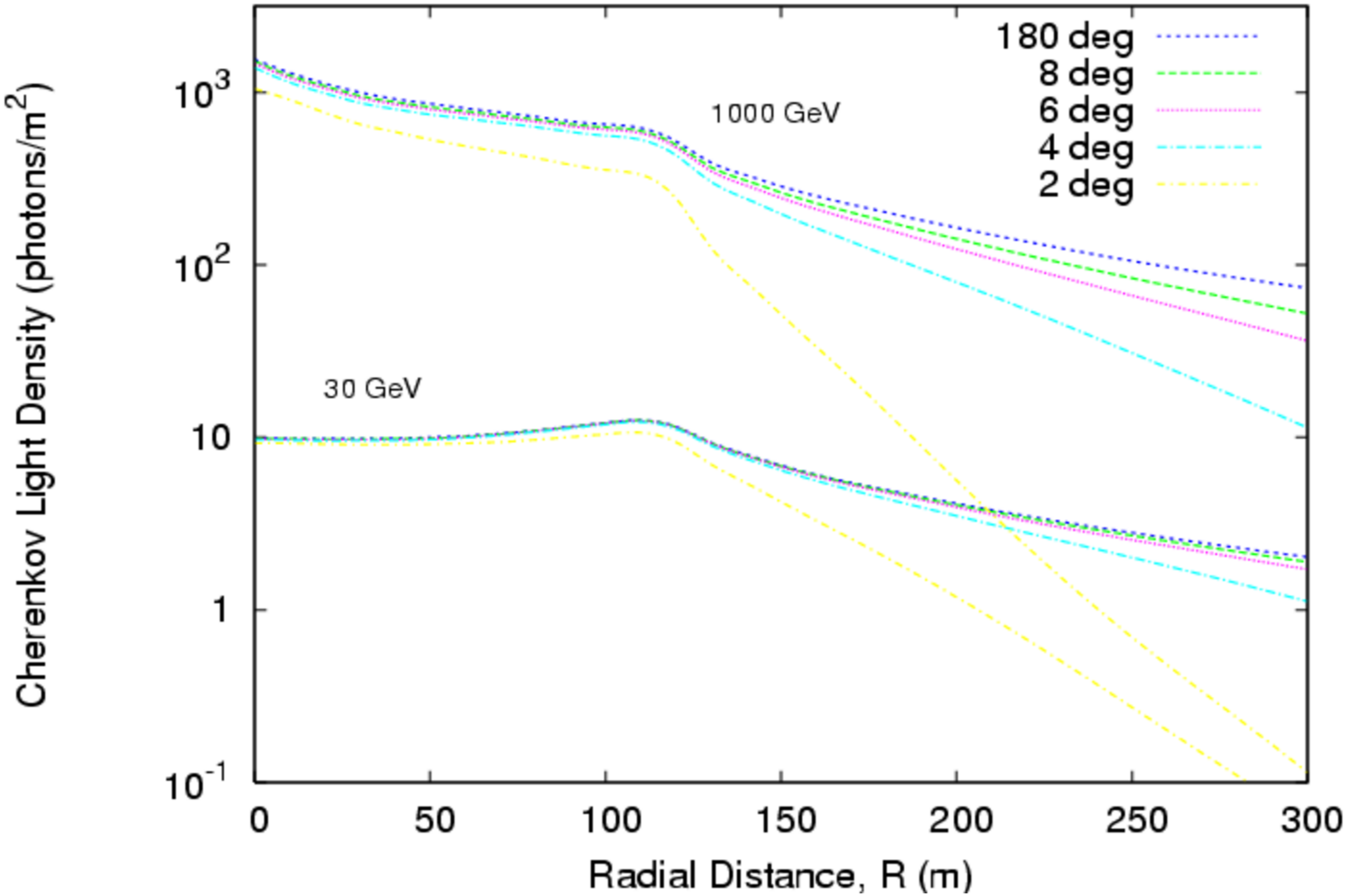
FoV=2deg



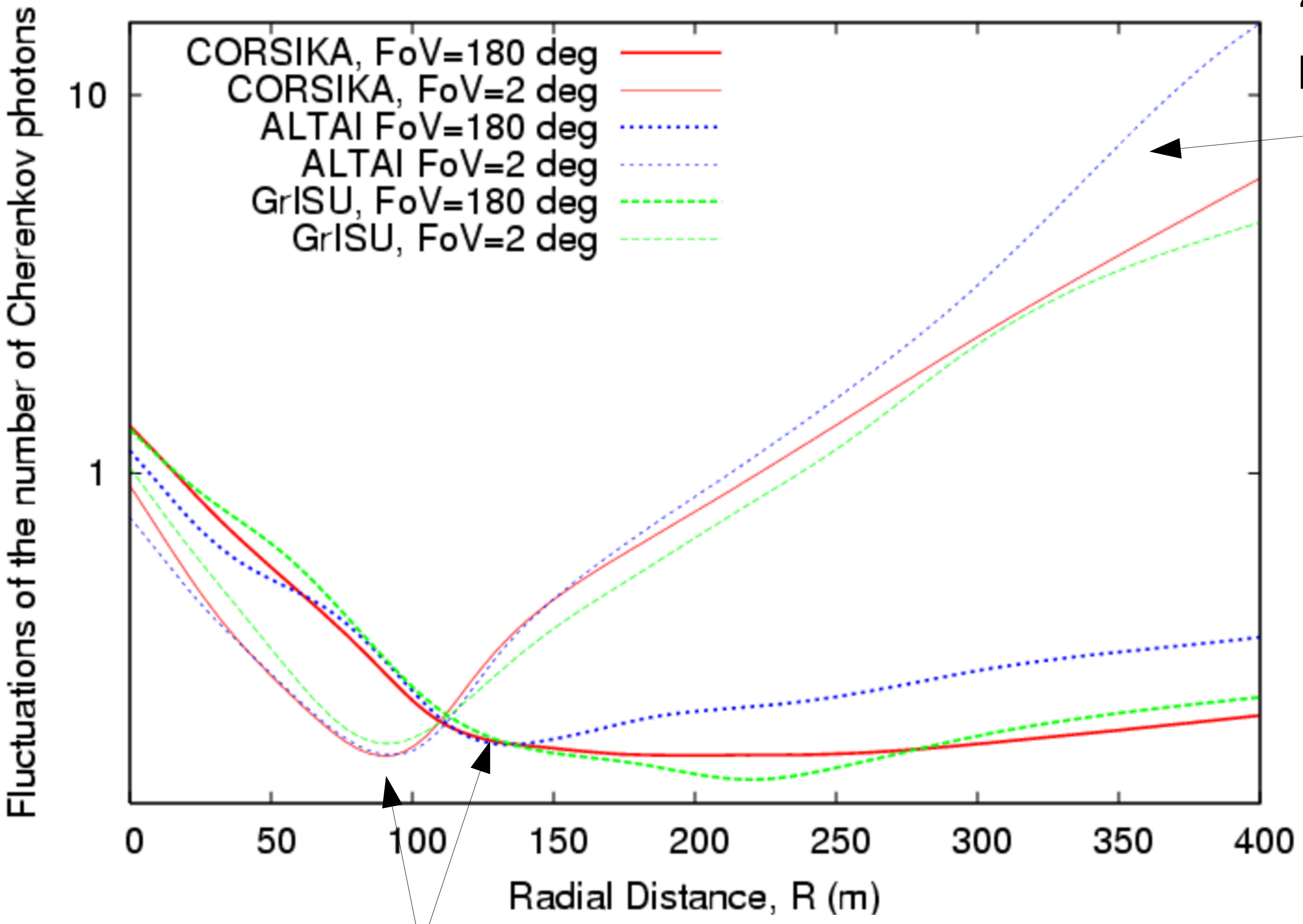
Lateral distributions for different fields-of-view

The same detection efficiency as for FoV=180 deg is achieved for FoV:

* 4	deg for	30 GeV
6 – 8	deg for	1 TeV



Fluctuations in Cherenkov light, γ-showers

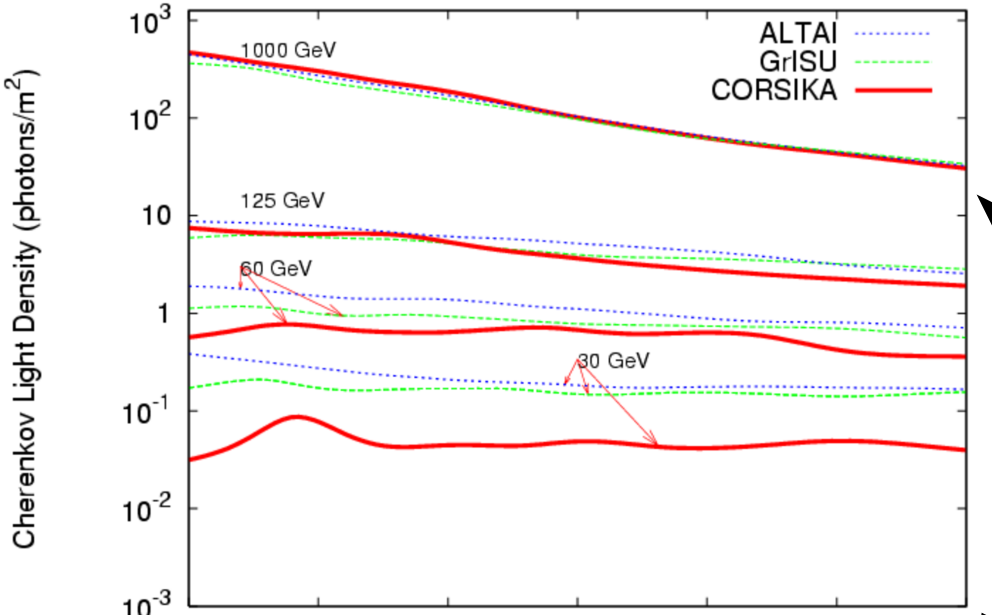


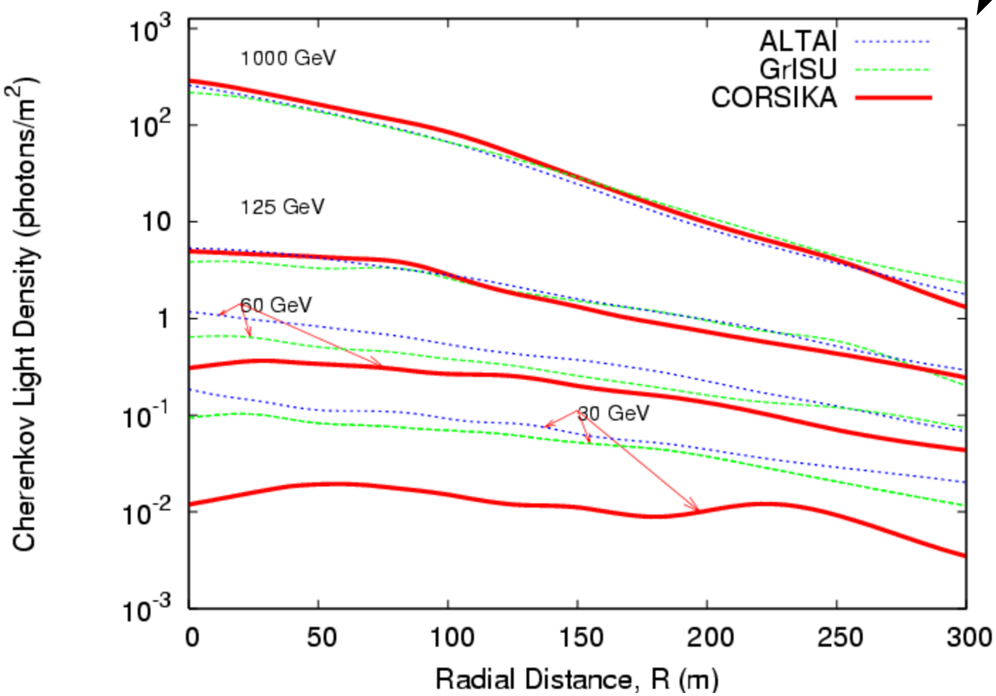
"ALTAI > CORSIKA": photons vs. bunches?

The most probable impact parameter should be in the range (80-130) m.

*POSSIBLE DOWNSIDE OF CLOSE PACKED ARRAY FOR THRESHOLD REDUCTION

Proton showers





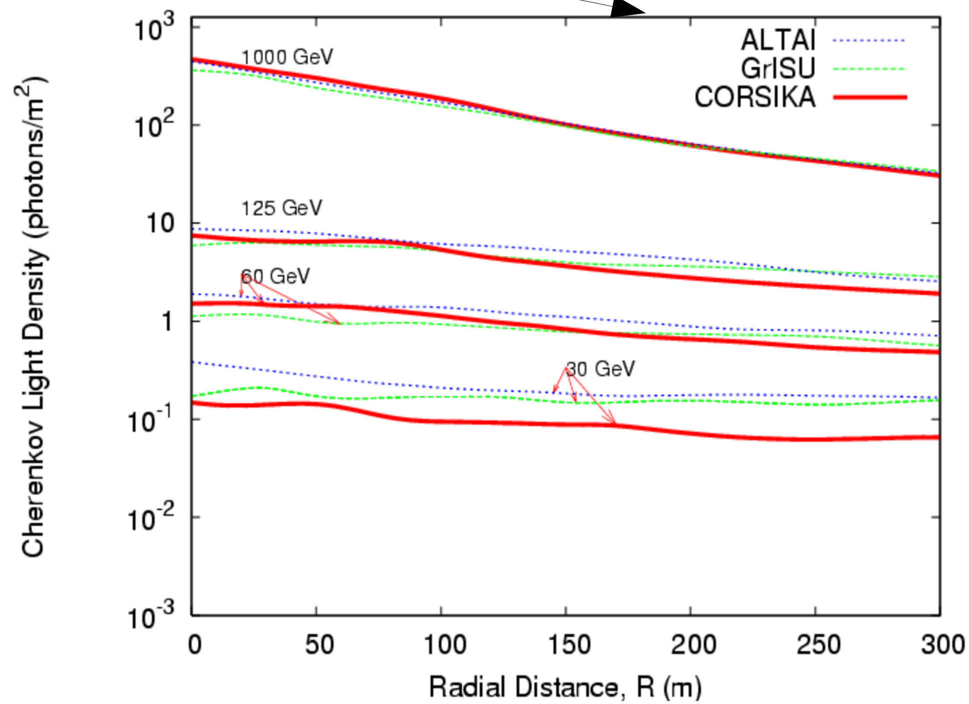
180deg

2deg

*SIGNIFICANT DIFFERENCES IN LOW ENERGY HADRONIC MODELS

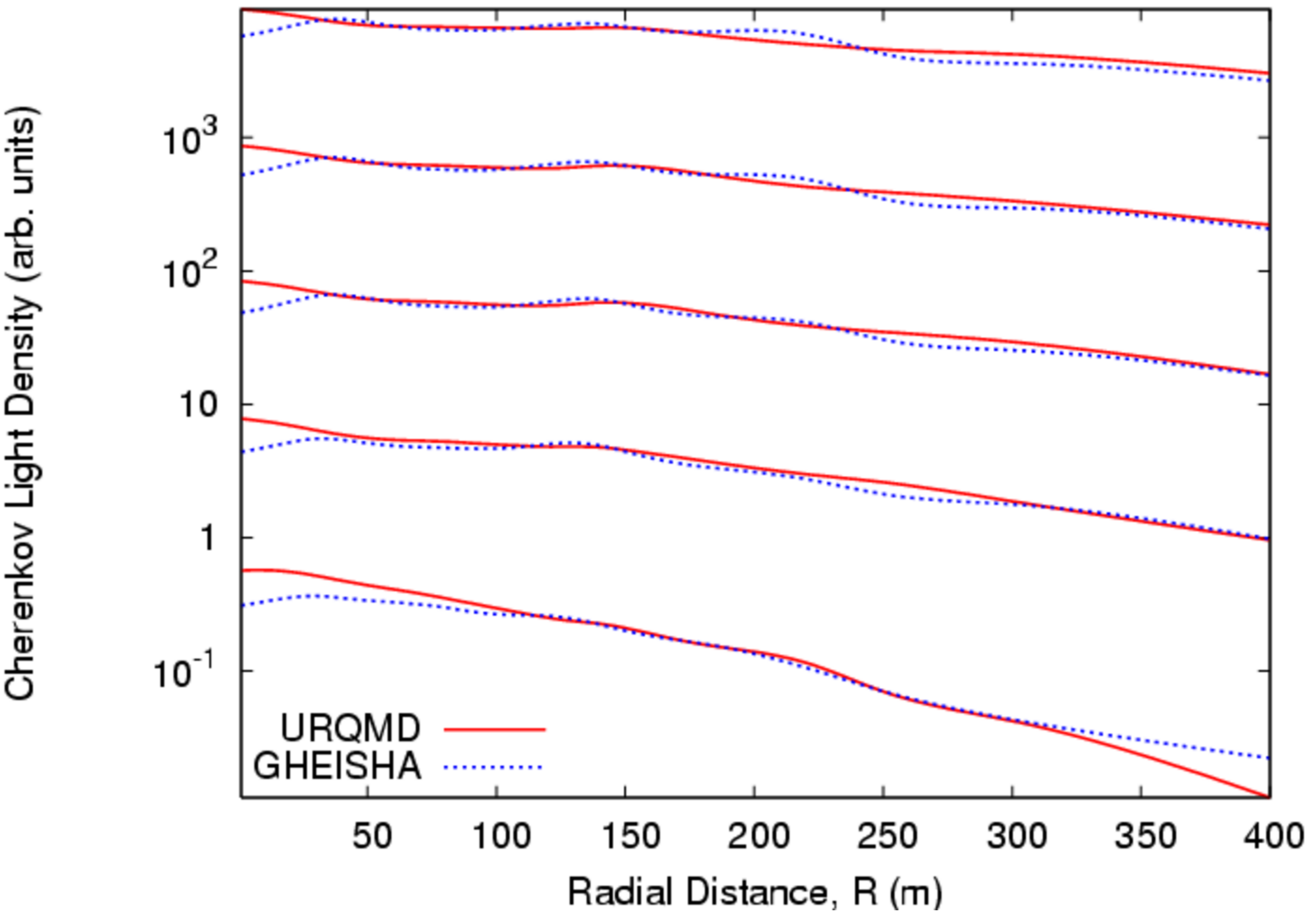
GrISU and ALTAI diverge from CORSIKA for lower E starting from **~60 GeV**

180deg, extrapolation of the high-energy hadronic model to lower energies

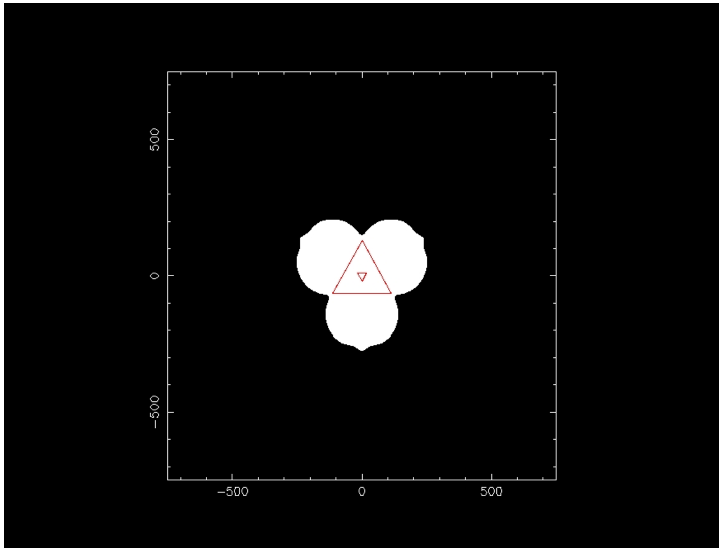


Lateral distributions of Cherenkov light, proton showers

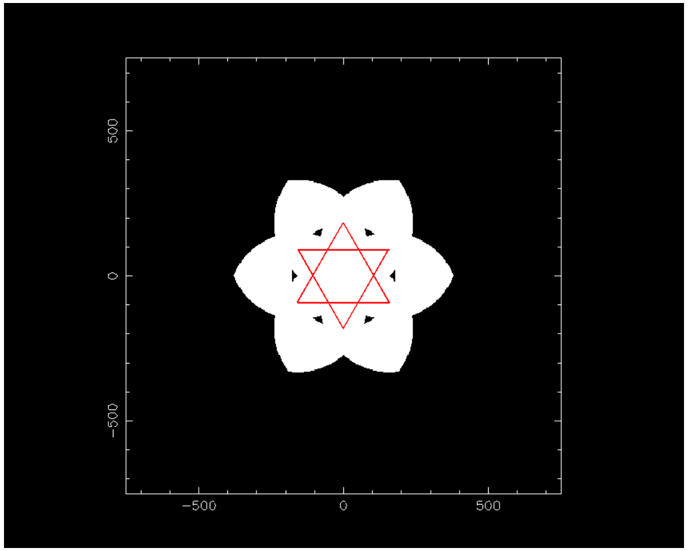
Low – energy hadronic models used in CORSIKA are compared for 60 GeV

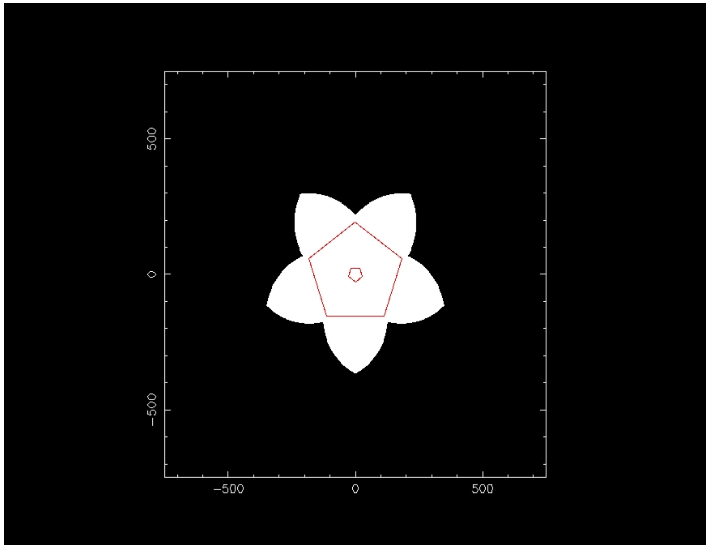


Optimization of the detection area based on the lateral distributions for γ-showers

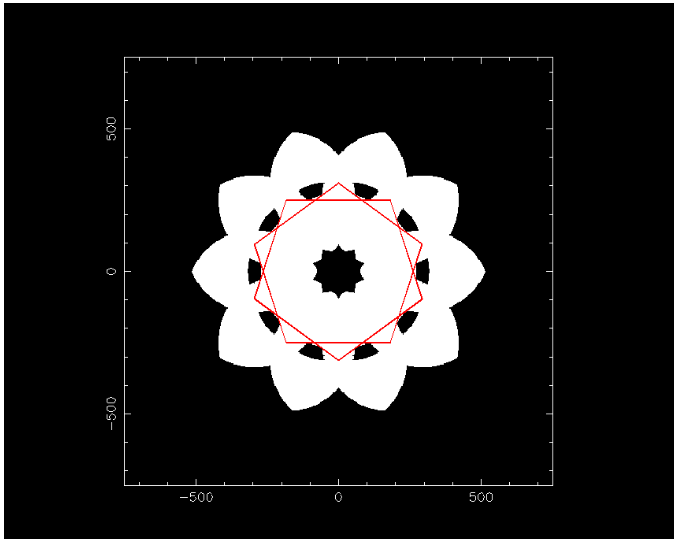


optimization





optimization



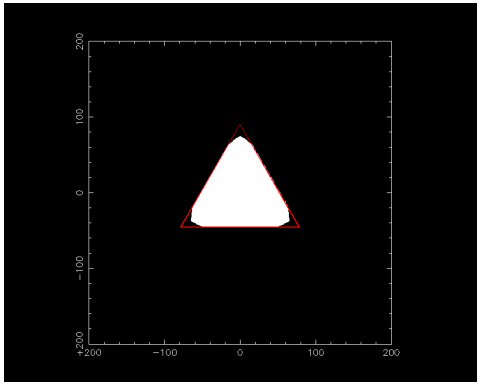
*Concentric cells should have the same cell length to reach the maximal A_{eff}

Maximal effective detection area per telescope for different cell configurations

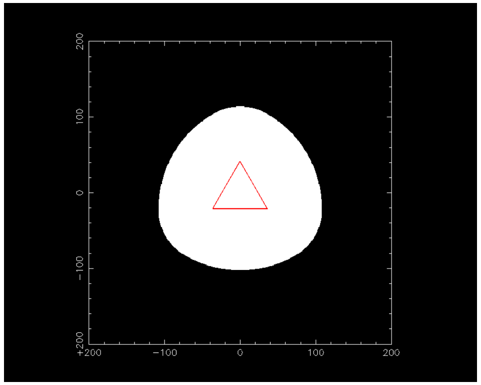
*Array of closely packed triangular cells is almost twice as good as an array of cells with non-overlapping detection areas!

	cell type	multiplicity	# tel. in cell	detection area, m^2
1	packed	2	3	19908
2	packed, l=160m	3	3	19836
3	single	2	5	19634
4	single	2	4	19052
5	single	2	3	19003
6	single, l=70m	3	3	11983

1



6



Detailed simulations of an idealized triangular cell

The basic properties of an IACT array can be derived partially from the studies of a single cell of 3 telescopes. We determine the best performance of a system of 3 telescopes with the aperture of 250 m^2.

The idealizations used here include:

- **a perfect optical system**
- **ability to measure the exact coordinates of individual photoelectrons in the focal plane of the camera**
- **zero level of night sky background (NSB)**
- **field of view of a telescope that can be as large as 180 deg.**

These idealizations allow us to study the limitations of the IACT technique imposed by the nature of the atmospheric shower itself and geometry of the telescopes rather than by the specific details of the telescope hardware. We determine the optimal spacing between the telescopes for each target energy.

FIGURE OF MERIT

For the optimization we chose the figure of merit to be the highest *signal-to-noise ratio* achieved for a point-like γ-source, or

$$S(E,l)=\frac{dN_g(E,l)/dE}{\sqrt{R_{CR}(l)}}$$

R_{CR} - integral detection rate for the cosmic-ray background,

dN_g/dE - the differential detection rate of photons from Crab.

The function is closely related to the definition of the *angular resolution* we use, which is the **radius around the source position in camera coordinates that provides the highest value for the signal-to-noise ratio.**

SIMULATIONS

EAS simulation code: ALTAI (A.K. Konopelko and A.V. Plyasheshnikov, 2000)
Altitude of the site: 2650 m a.s.l. (SPM Baja de Nord)

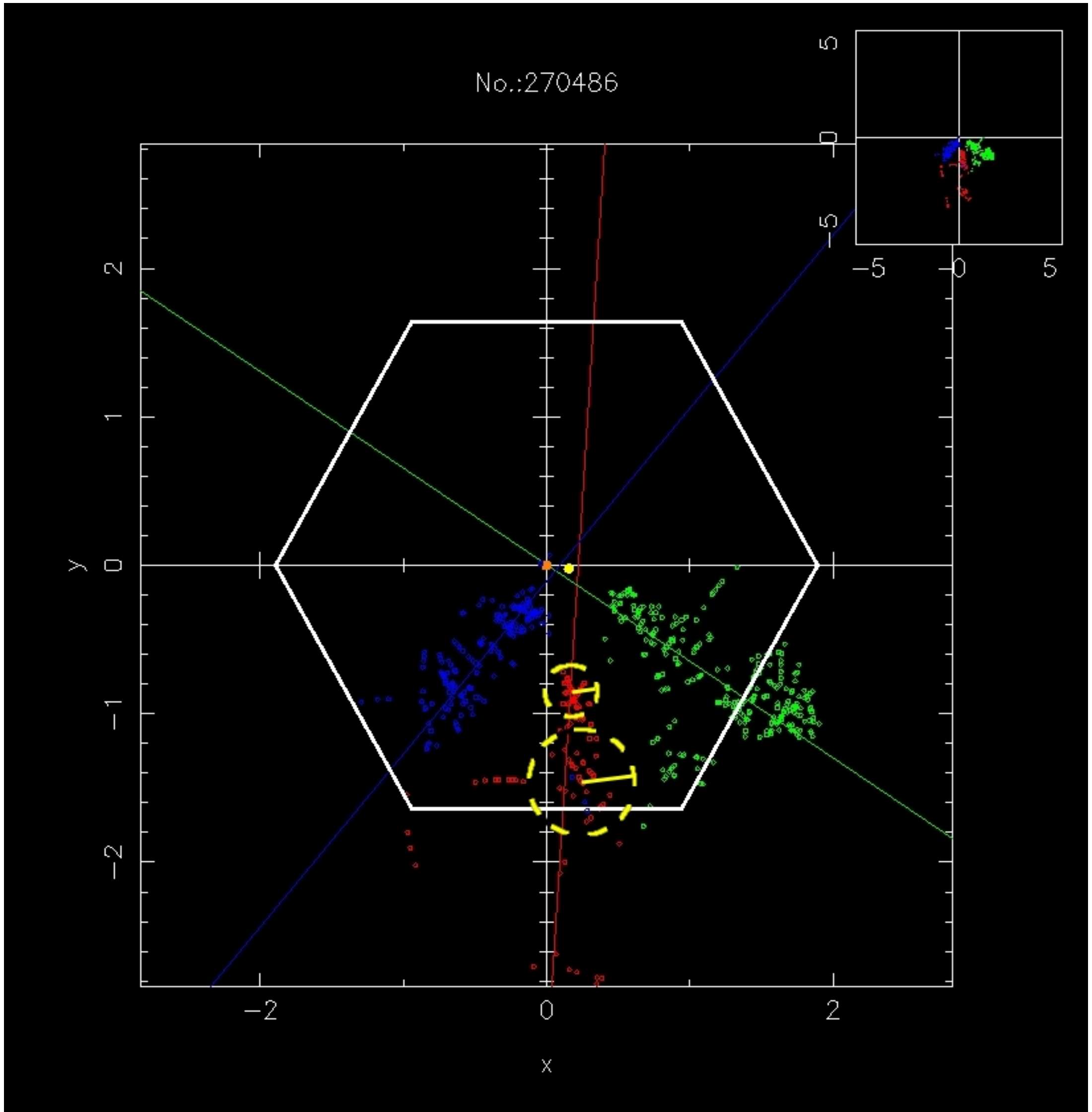
Cell shape: triangle
The range of cell lengths (l): 40 - 400 m

Telescope trigger: image contains at least 100 p.e.
Array trigger: at least two of the telescopes are triggered.

The photon-to-photoelectron conversion efficiency: as for the VERITAS
The overall photon-to-photoelectron conversion factor: 0.1
The mirror size: 250 m^2 (corresponds to an 18~m diameter dish)
Pixel geometry: closely packed, rectangular
Pixel size (PS): defined as the side length of a pixel

Impact parameter radii of the showers: up to 900 m
γ-rays: vertical and parallel, E = 3 - 2000 GeV
CR background: isotropically distributed protons (0 - 5 deg), with spectrum
~ E^-2.7 in the energy range 80 GeV - 10 TeV.

EVENT RECONSTRUCTION



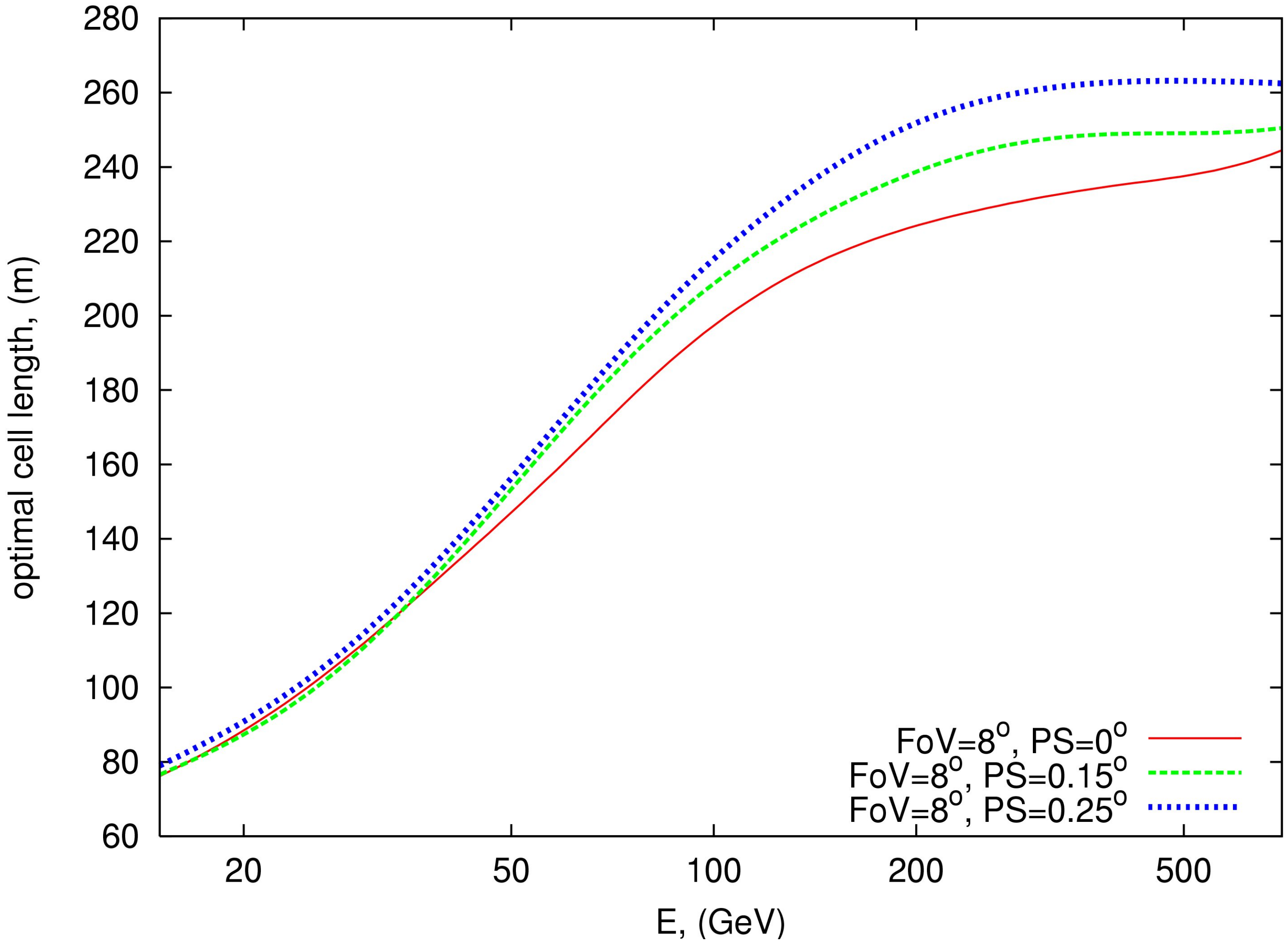
We are using:

Hillas moment analysis

Weighting for each pair of telescopes based on the angle between the major axes.

Weighting of each photoelectron depending on the proximity $R_{25\%}$ to the other photoelectrons in the image. $w=1/R_{25\%}{}^\wedge\alpha$, where $\alpha\sim 2$.

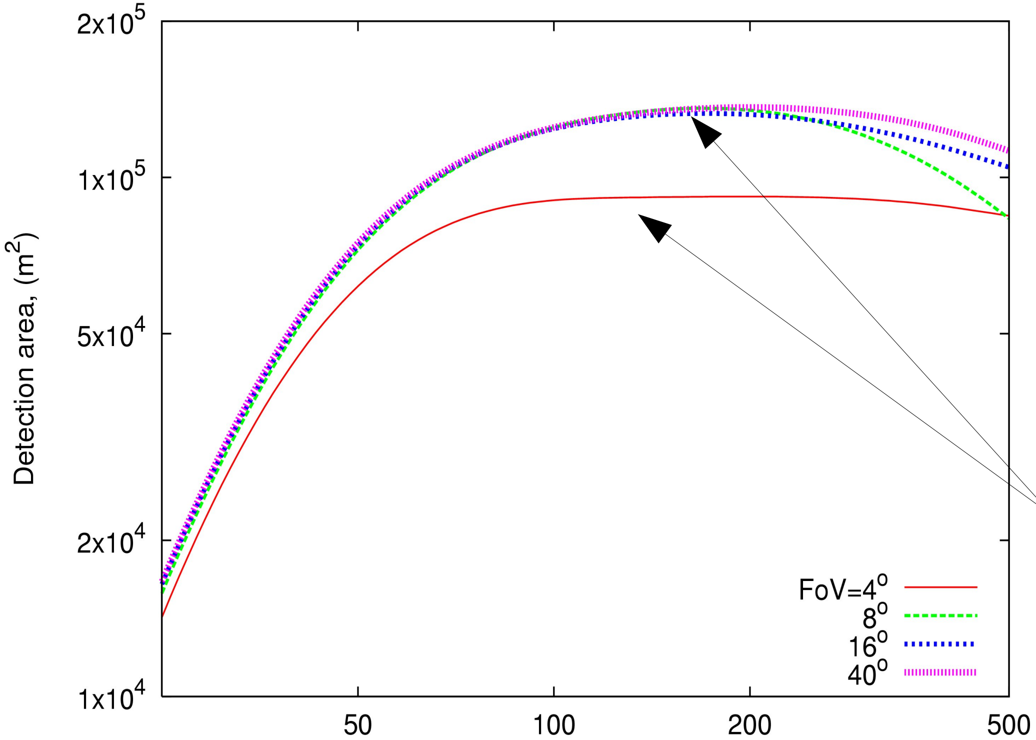
OPTIMAL CELL LENGTH



All the values on y-axes in the plots correspond to the optimal value of the cell length at that energy.

The dependence of the optimal cell length on energy for FoV=8 deg is shown for different pixel sizes.

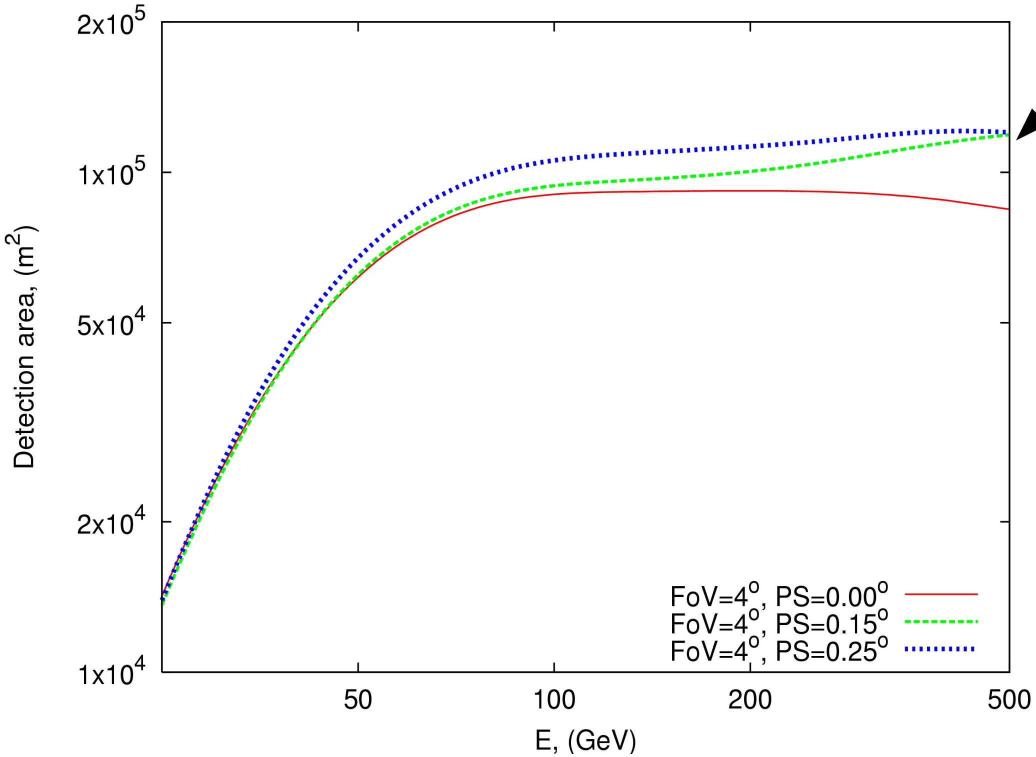
Detection areas after optimized angular cut



Between 4 deg and 8 deg FoV, the effective detection area (of the optimized array configuration for PS=0deg) increases by a factor of ~1.6

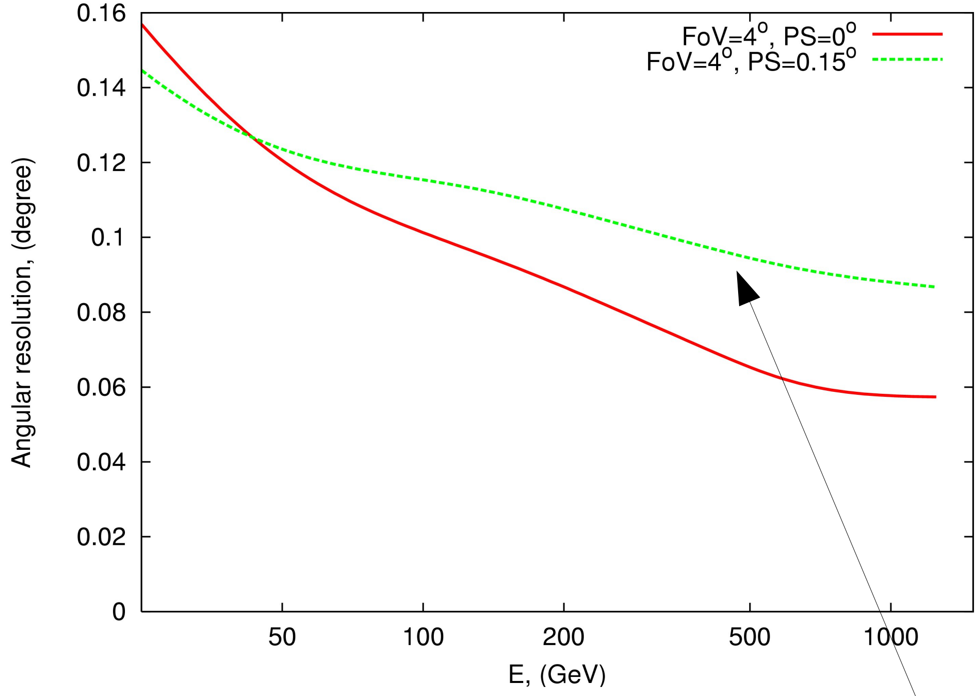
+

Splitting for different PS
For FoV > 4 it is even smaller

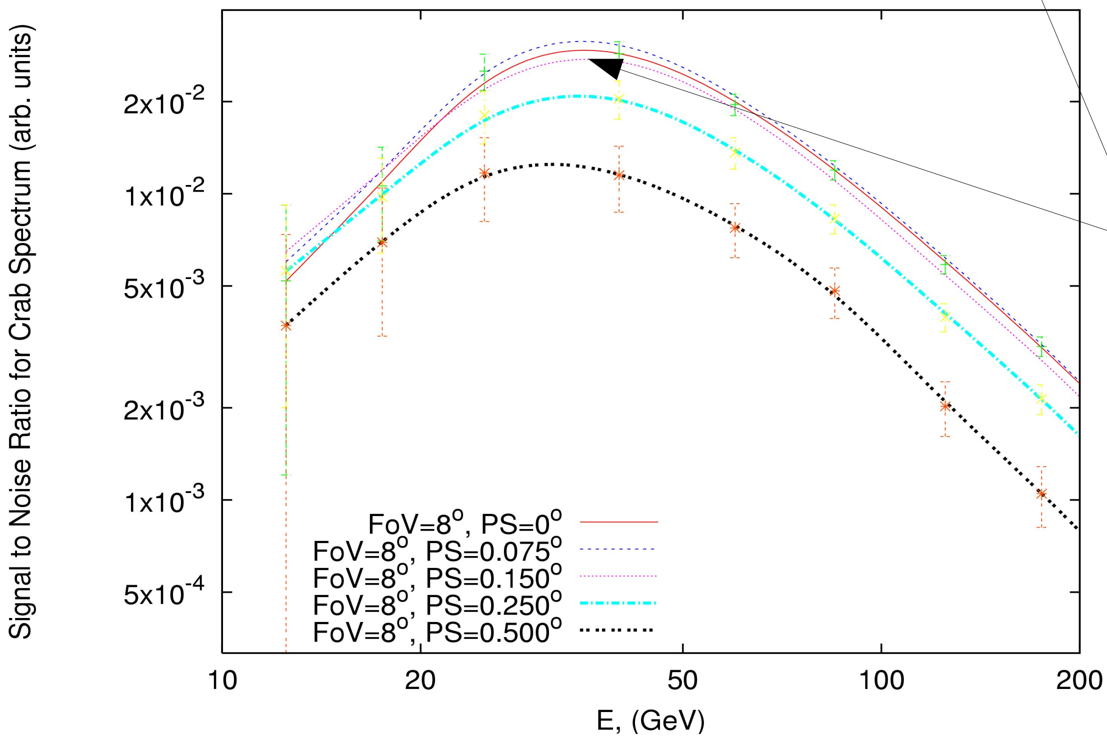


*For the assumed reconstruction algorithm, the optimum camera size lies somewhere between 4 deg and 8 deg regardless of the pixel size.

Optimal angular resolutions and signal-to-noise ratios



Below 50 GeV the cell spacing that optimizes the sensitivity results in an
angular resolution on the order of **0.15 deg**.



*PS=0.15 deg provides almost the same signal-to-noise ratio as the case with the infinitely small pixel size but angular resolution does improve for smaller pixels.

CONCLUSION

CORSIKA, GrISU and ALTAI give the same amount of Cherenkov light for γ and diverge for protons with energies below 60 GeV.

For a good reconstruction of events the cell length of an array of closely packed cells should be >~80 m.

Array of closely packed triangular cells is almost 2x as good as an array of cells with non-overlapping detection areas!

The main motivation for building telescopes with a large FoV (>8 deg) is to observe extended sources and to survey the TeV γ–ray sky more efficiently.

No significant differences in the signal-to-noise ratios are observed for pixel size up to 0.15 deg compared with the perfect detector.

Optimization of angular resolution at high energies, as well as the desire to reduce the NSB background in individual pixels may favor smaller pixels.

The values obtained here are optimal if night-sky noise is negligible. For a future array this may indeed be the case, if the signal integration windows are further shortened, and sites with lower night sky background noise are used.

Maximal effective detection area per telescope for different cell configurations

Array of closely packed triangular cells is almost twice as good as an array of cells with non-overlapping detection areas!