Simulation of imaging air shower Cherenkov telescopes as part of the TAIGA Project

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Magellan Workshop 2016

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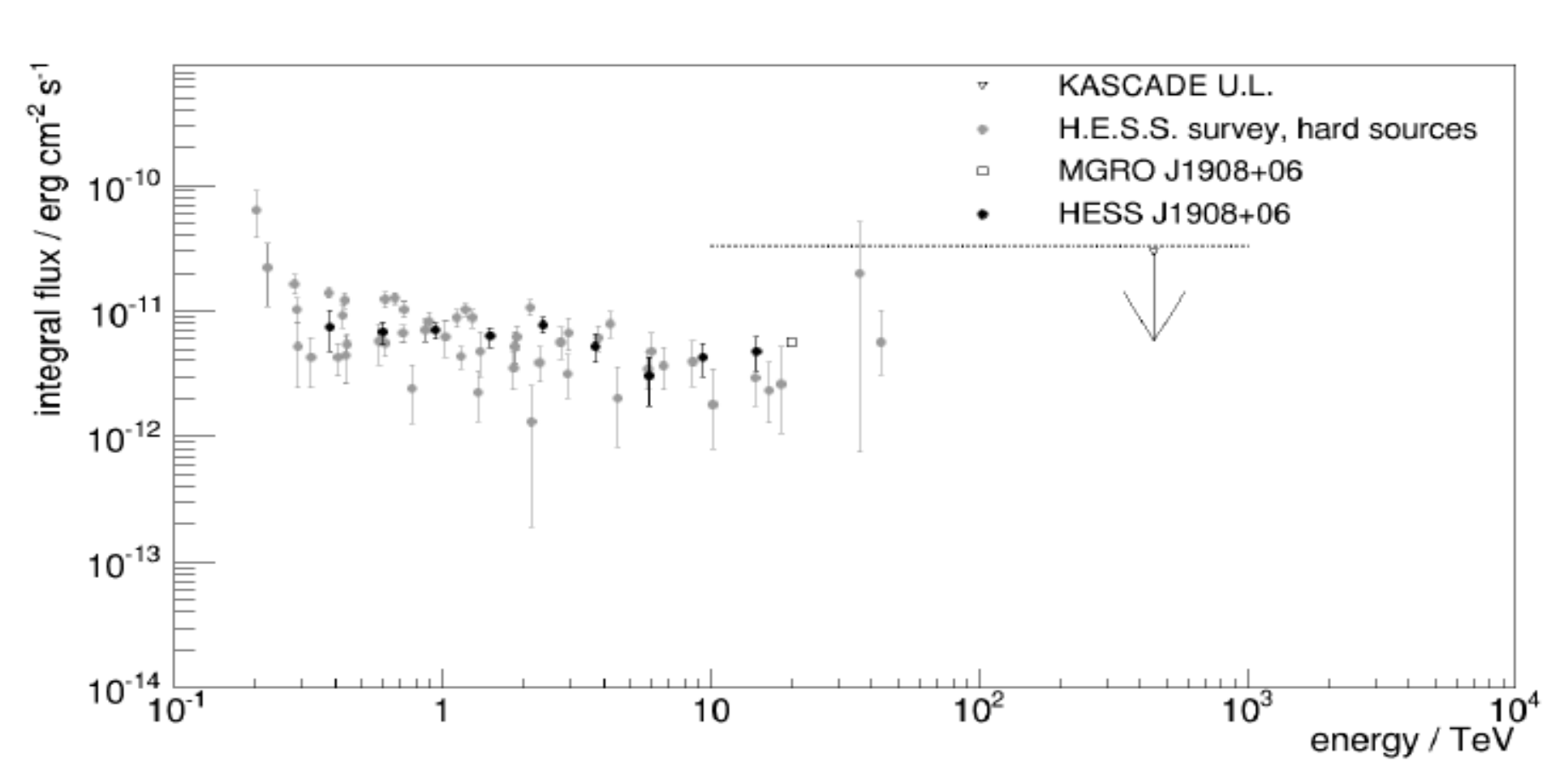
HELMHOLTZ ASSOCIATION

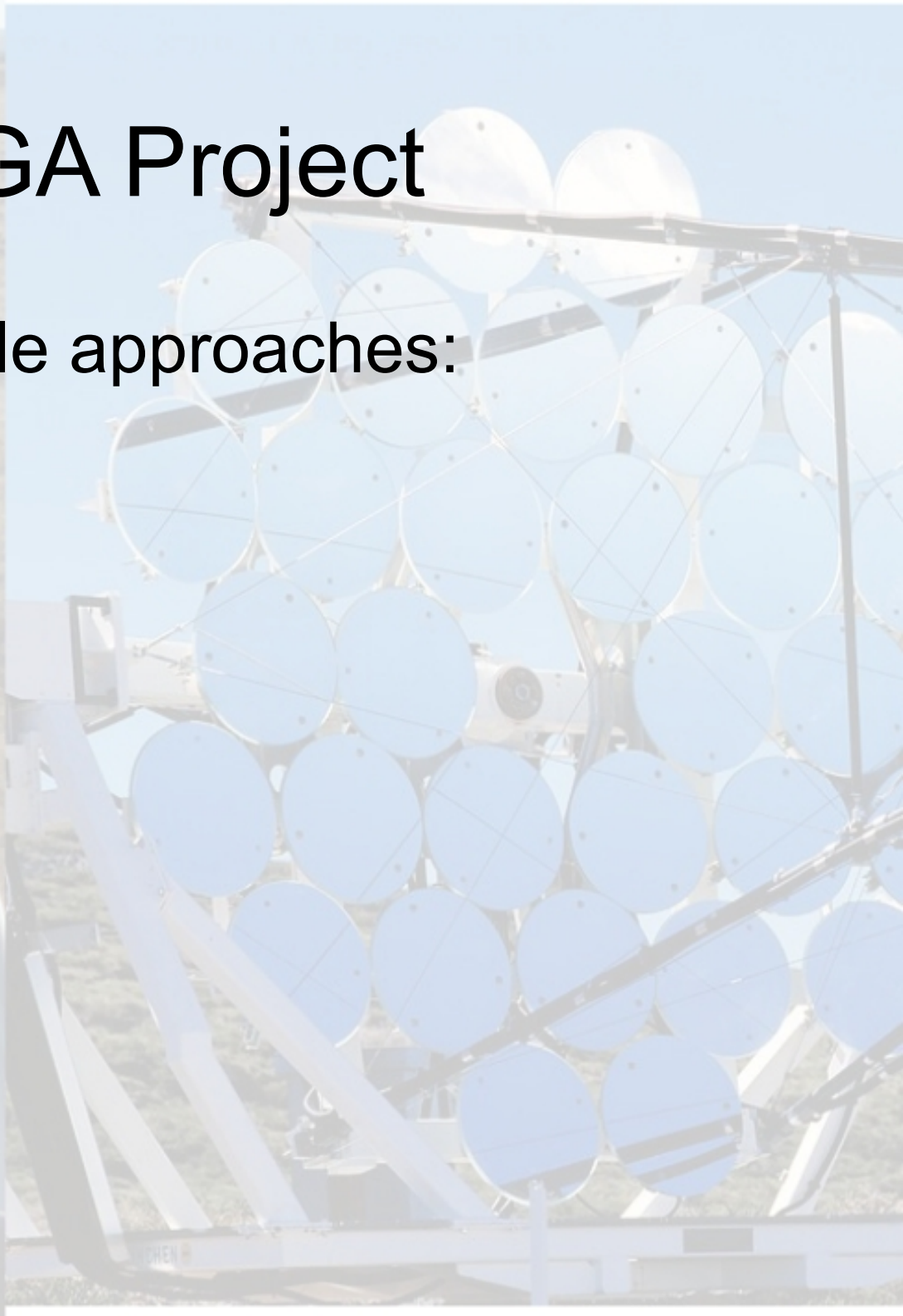
Motivation



- High energies → Low fluxes → Low rate requires large detection areas for proper sensitivity
- Sources at 10 - 100 TeV exist

The TAIGA Project

Combination of multiple approaches:



The TAIGA Project

Combination of multiple approaches:

HiSCORE:

- Shower-front sampling array
- Large area, good core position and directional reconstruction
- Poor Gamma-Hadron-separation at lower energies

For details, see talk by Martin Tluczykont, earlier today.

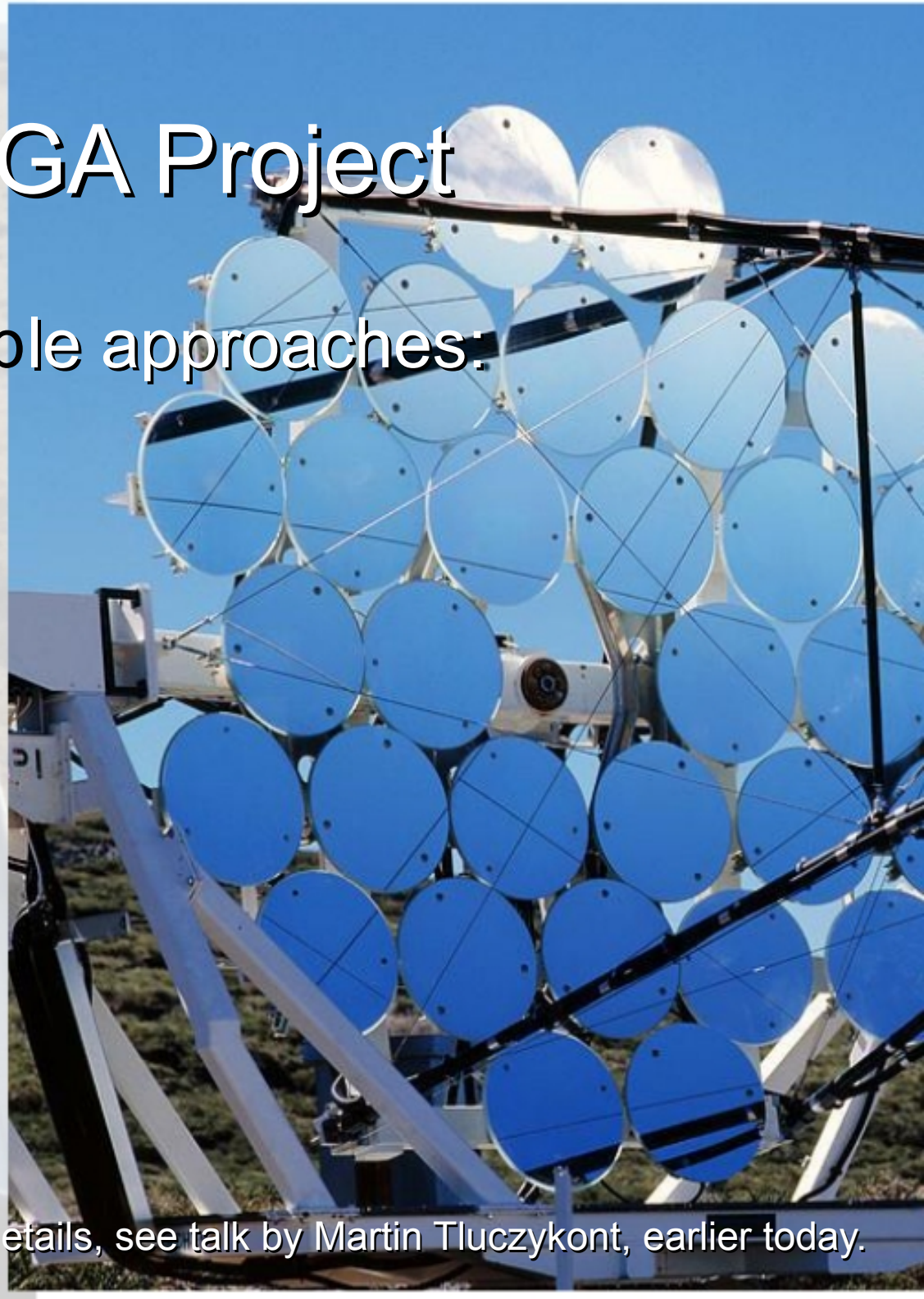
The TAIGA Project

Combination of multiple approaches:

Imaging air Cherenkov telescopes (IACT):

- HEGRA-like imaging telescopes
- Good gamma-hadron-separation, esp. for point sources
- Stereoscopy needed for excellent reconstruction

  → expensive to cover large areas



For details, see talk by Martin Tluczykont, earlier today.

Simulations for the IACT

- Point spread function

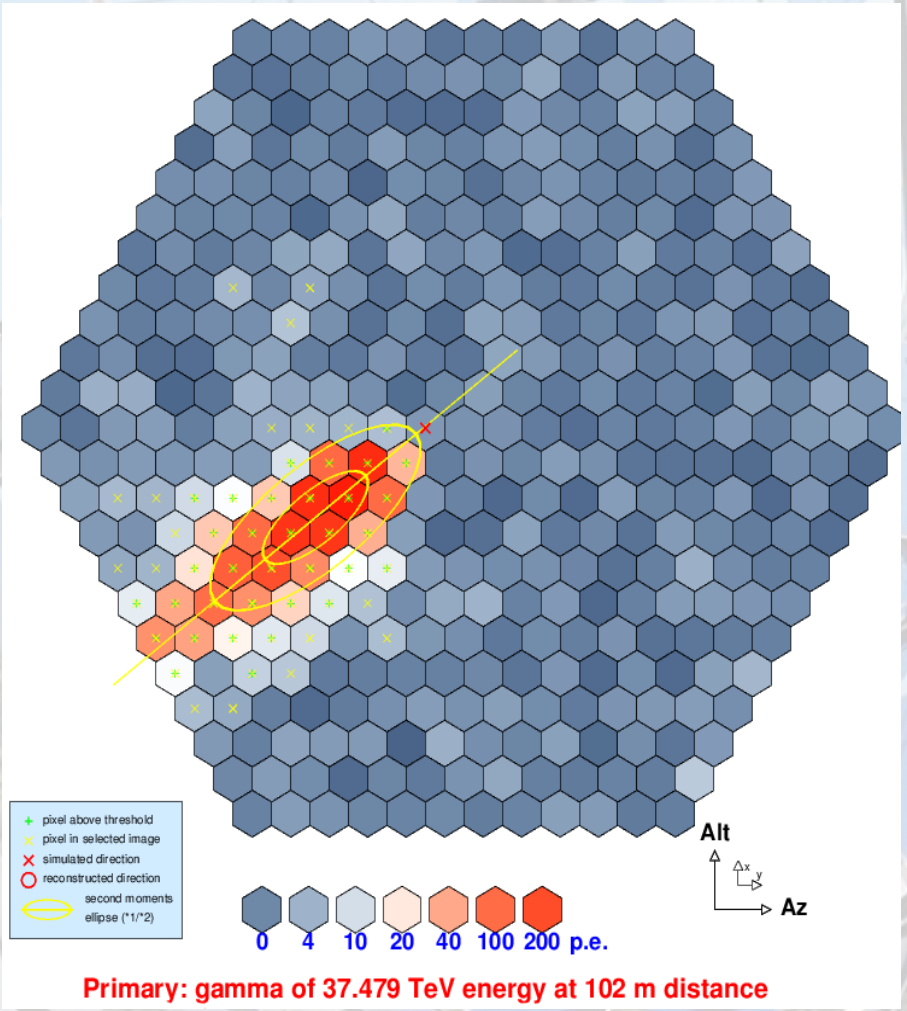
  → Determine quality of telescope design

- Gamma-Hadron-Separation

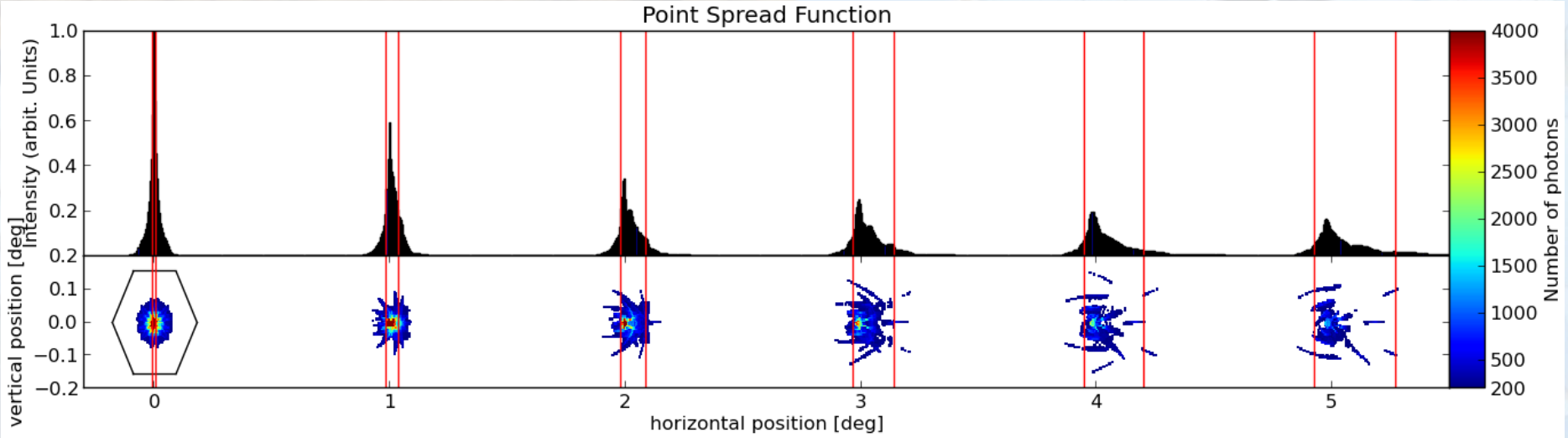
  → Do we get the desired effect?

All done with CORSIKA [D. Heck et al., 1998] and the sim_telarray code [K. Bernlöhr, 2008]

Simulated TAIGA IACT image



Point Spread Function Simulation

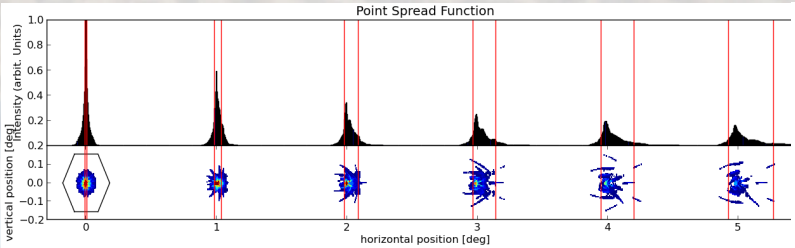


Whole dish, ideal Davies-Cotton telescope:

No night sky background, ideally spherical mirrors, no mirror misalignment

Dish diameter: 4.3 m, Focal length 4.75 m, 32 mirror segments with 0.6 m diameter each

Point Spread Function Simulation



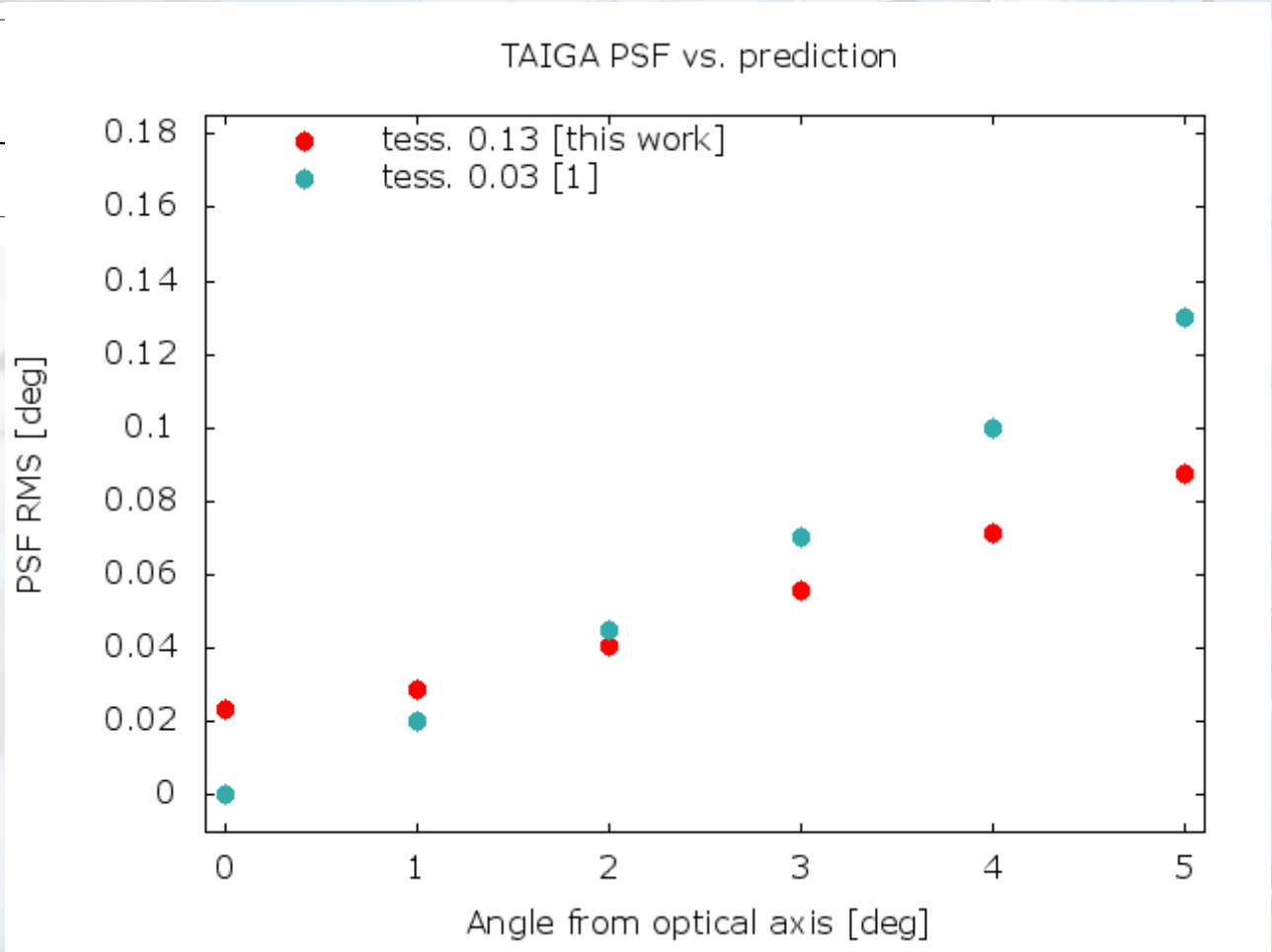
Tesselation ratio:

$$T = r_{segment} / R_{dish}$$

Bigger tiles → bigger spherical abberations

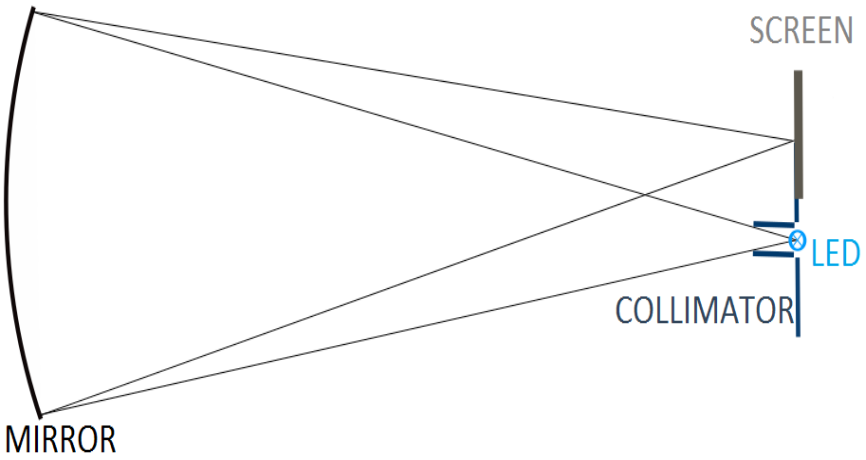
→ Slant to semi-analytical prediction was expected

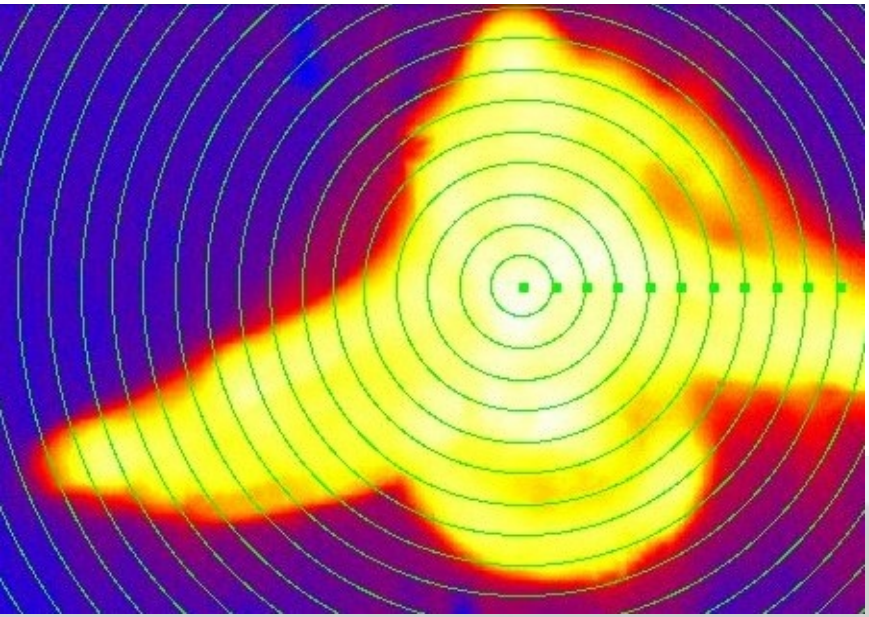
TAIGA IACT pixel diameter:
3 cm, 0.38°
→ PSF significantly smaller than pixel size

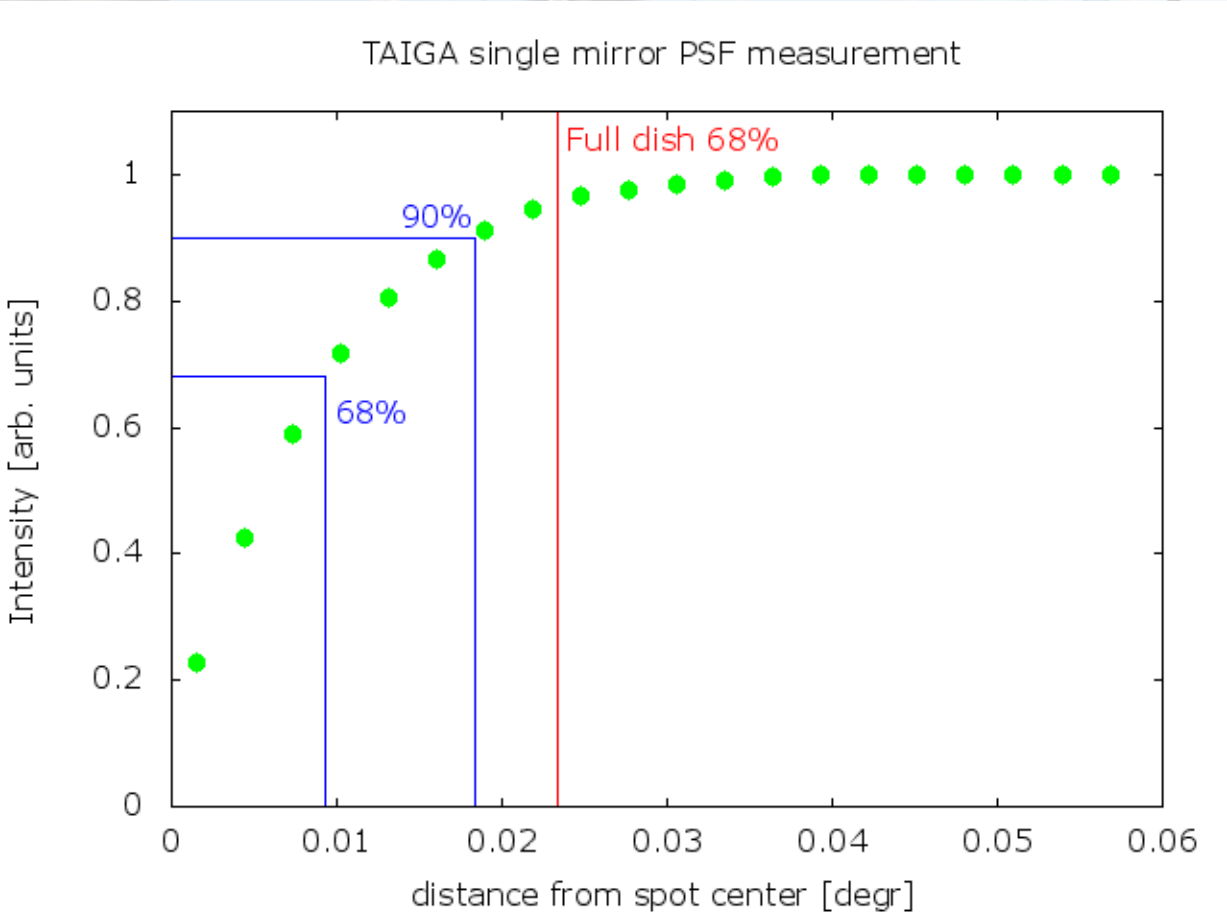


[1] Schliesser, Mirzoyan 2005

Point Spread Function Measurement

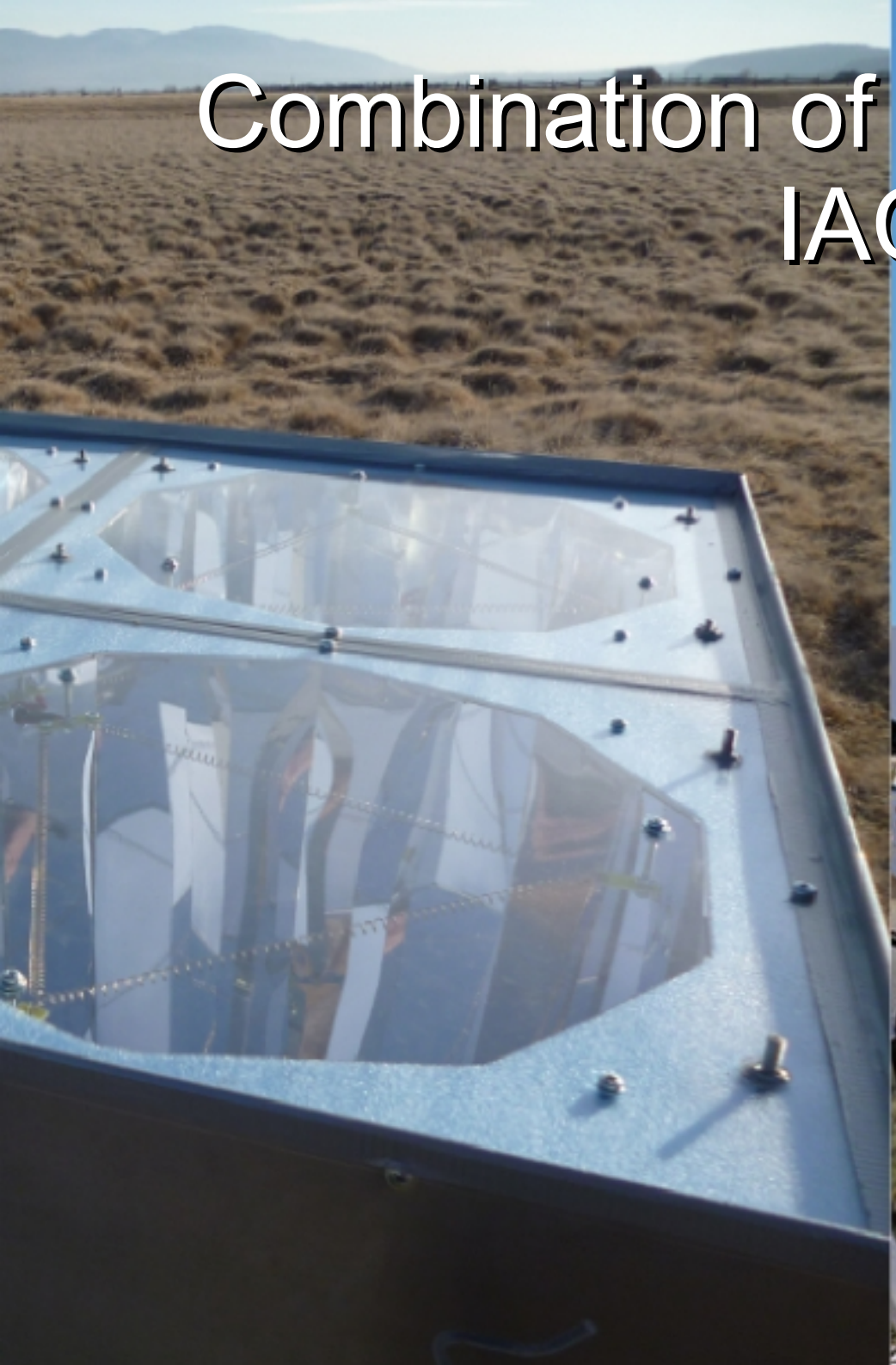


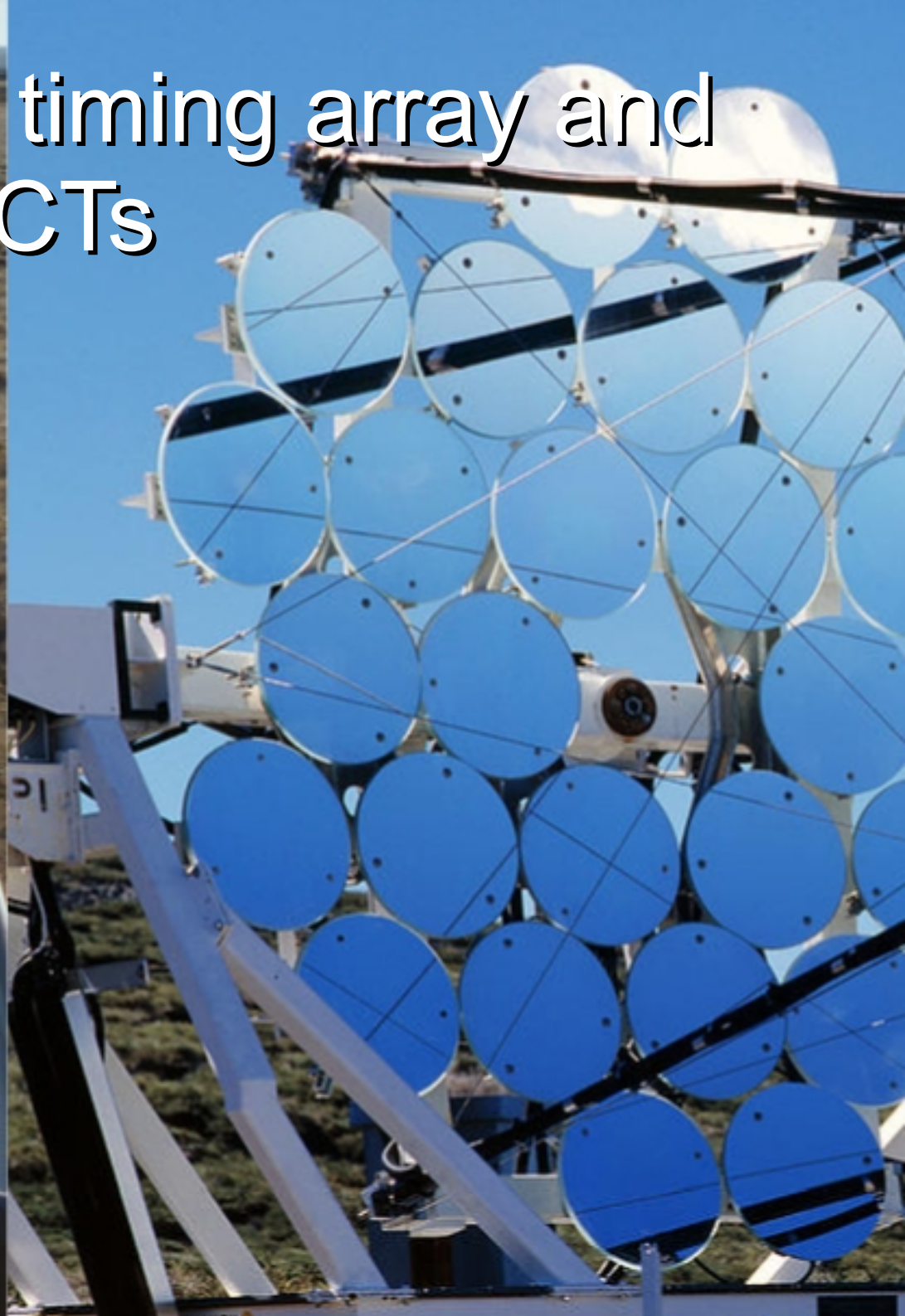




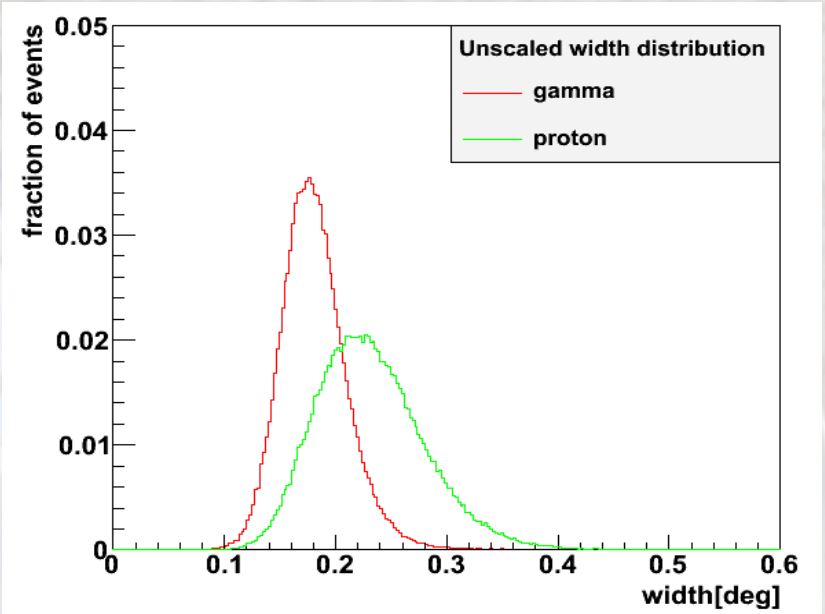
All mirrors received so far are well below the full dish's PSF

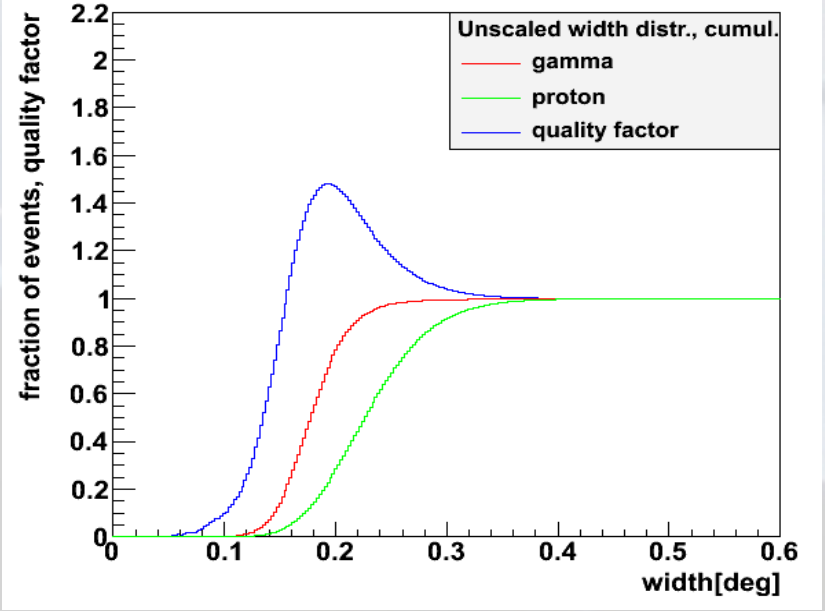
Combination of timing array and IACTs

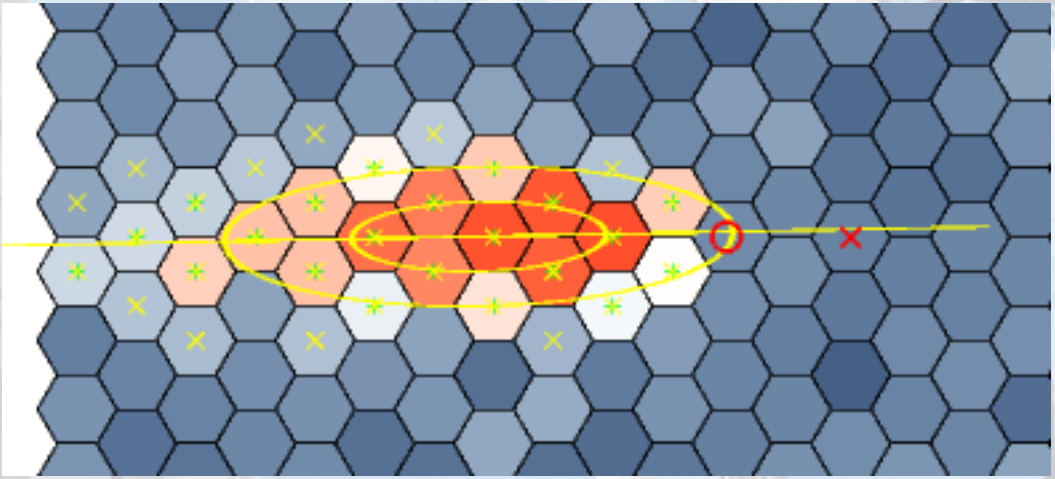




Gamma-Hadron-Separation using shower width







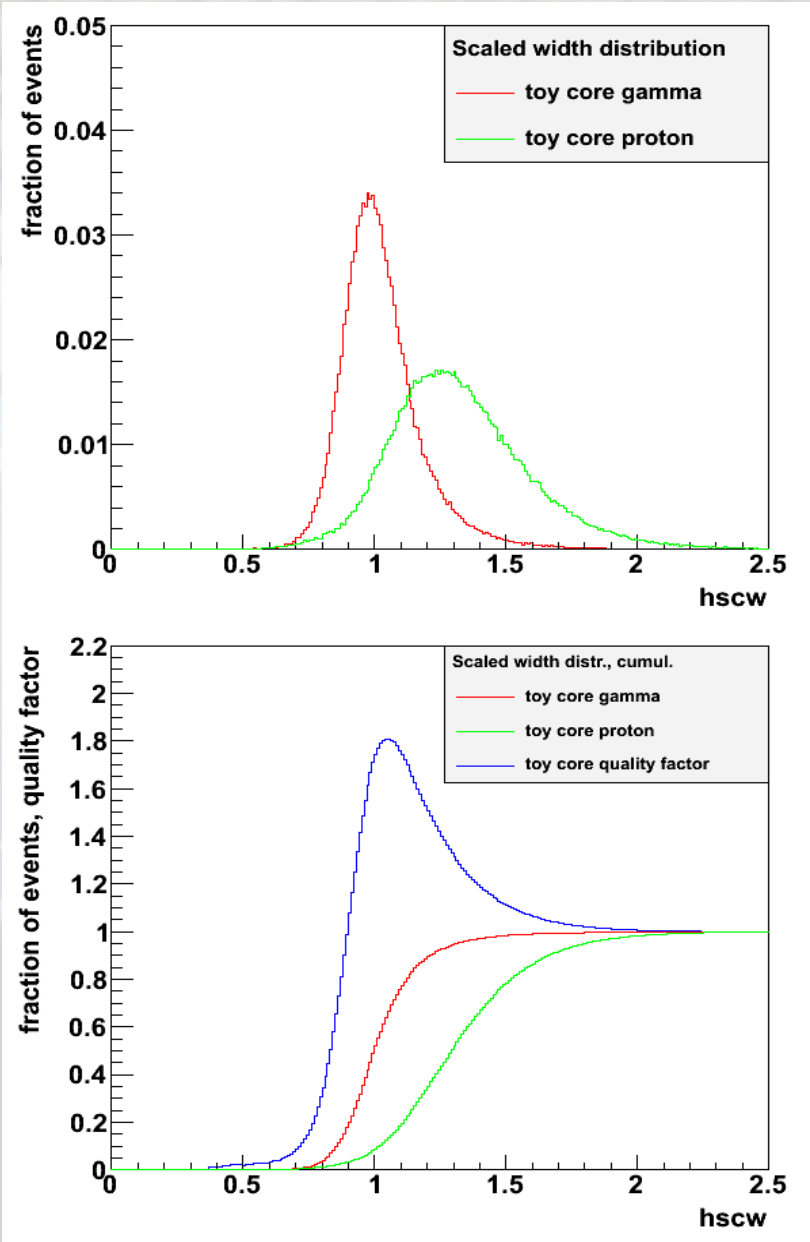
EAS with 0.5-50 TeV as seen by IACT

Hillas analysis parameter: shower width

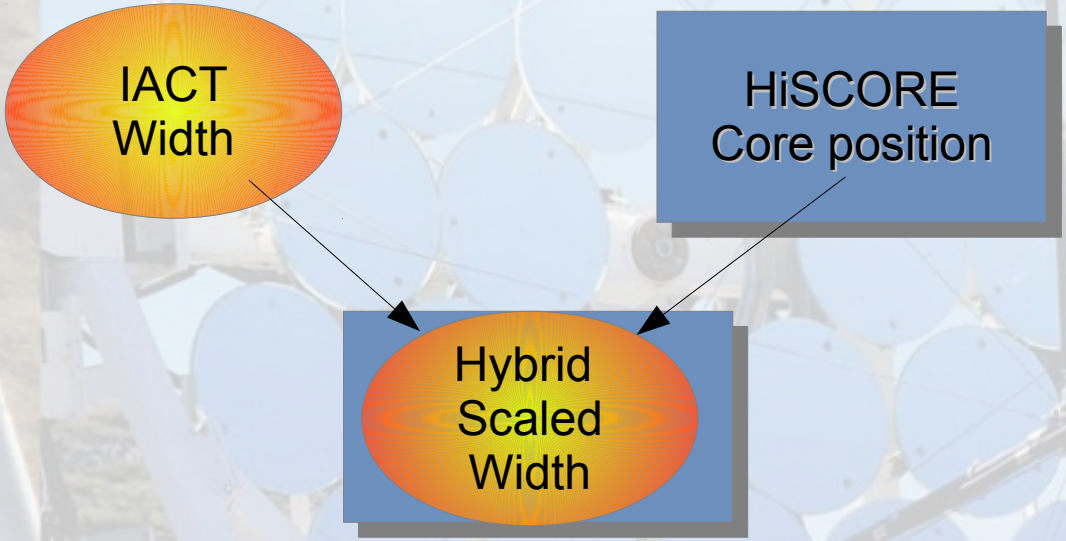
Hadronic showers are wider
→ Cut on width

Cut Quality $Q = \frac{\epsilon_\gamma}{\sqrt{\epsilon_p}}$ <1.5

Gamma-Hadron-Separation using shower width



Scale width to the Monte Carlo expectancy value for gamma showers



$\rightarrow Q_{TAIGA} \approx 1.8$

Compare: $Q_{H.E.S.S.} = 2.4$
(width cut only)

Conclusion and outlook

Conclusion:

- First combination between shower front sampling and IACT
- Our IACT design is feasible
- Core information from sampling array, gamma-hadron separation from IACT images

  → Improve the separation quality

Outlook:

- Full Hybrid simulation
- Improved geometrical reconstruction

  → Reconstruction of partly truncated IACT images
- Include separation information from shower front sampling

  → Improve separation quality even further

Thank you for your attention!

Acknowledgements

We acknowledge the support of the Russian Federation Ministry of Education and Science (agreements N 14.B25.31.0010, N2014/15, project 1366, zadanie N 3.889.2014/K), the Russian Foundation for Basic Research (grants 13-02-00214, 15-02-10005, 13-02-12095), The Helmholtz Association (grant HRJRG-303), and the Deutsche Forschungsgemeinschaft(grant TL 51-3).

Further References

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- M. Tluczykont et al, *The HiSCORE concept for gamma-ray and cosmic-ray astrophysics beyond 10 TeV Astropart. Phys.* **56** 42-53 (2014) [1403.5688].
- D. Heck et al, Report *FZKA 6019* (1998), available from http://www-ik.fzk.de/corsika/physics_description/corsika_phys.html
- D. Hampf, M. Tluczykont and D. Horns, *Event reconstruction techniques for the wide-angle air Cherenkov detector HiSCORE Nucl. Inst. Meth. in Phys. Res. A* 137-146 (2012/13) [1302.3957]
- M. Tluczykont et al, *Towards gamma-ray astronomy with timing arrays* in proceedings of *ECRS* (2014)
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Backup Slides

IACT and HiSCORE parameters

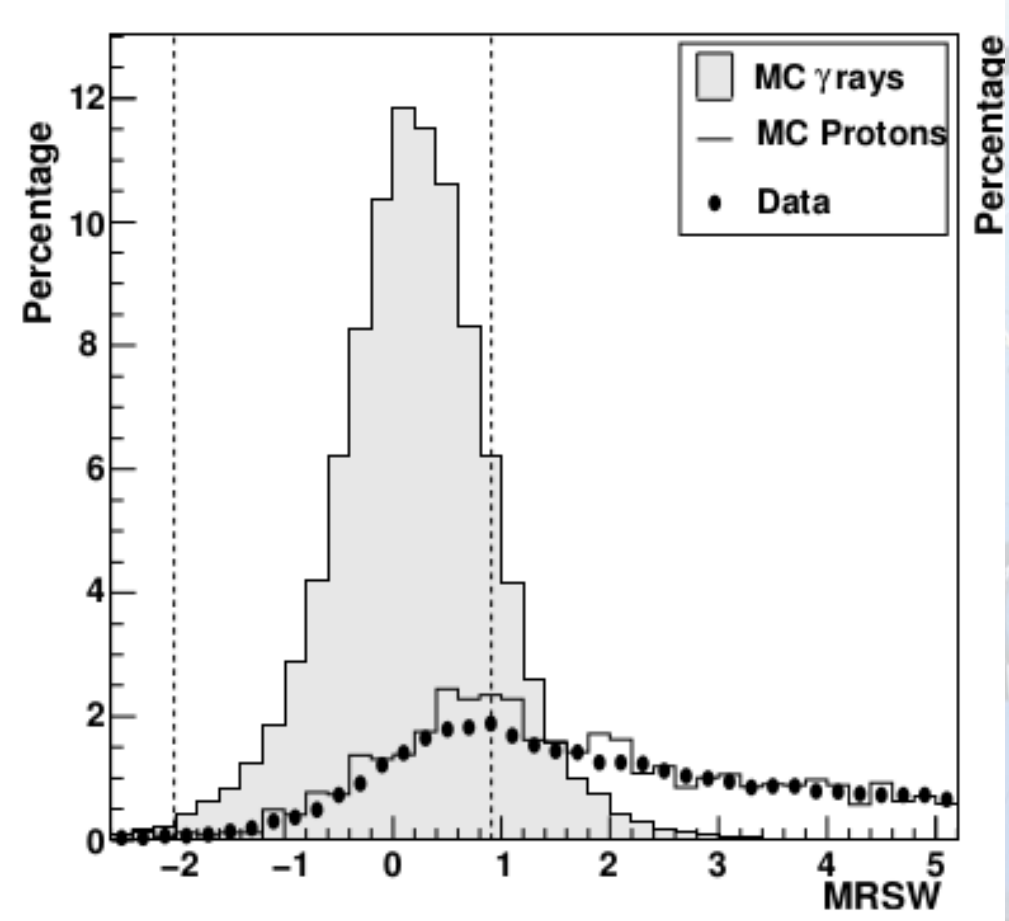
Hundred*i Square km Cosmic Origin Explorer (HiSCORE)

- 4 8" PMTs per station
- Winston cone light collectors
- 60 ° of view
- 28 stations deployed sofar
- 0.25 m^2 covered
- 120 m - 160 m spacing
- extendable to 3 km^2

TAIGA IACTs:

- Davies-Cotton design
- 4.30 m mirror diameter
- 4.75 m focal length
- 540 pixel camera
- 10° of view
- in development
- 600m spacing considered

HESS



Hess width distribution from [F. Aharonian et al, 2007]