Extending wide FoV gamma-ray observations with an array of compact Cherenkov telescope

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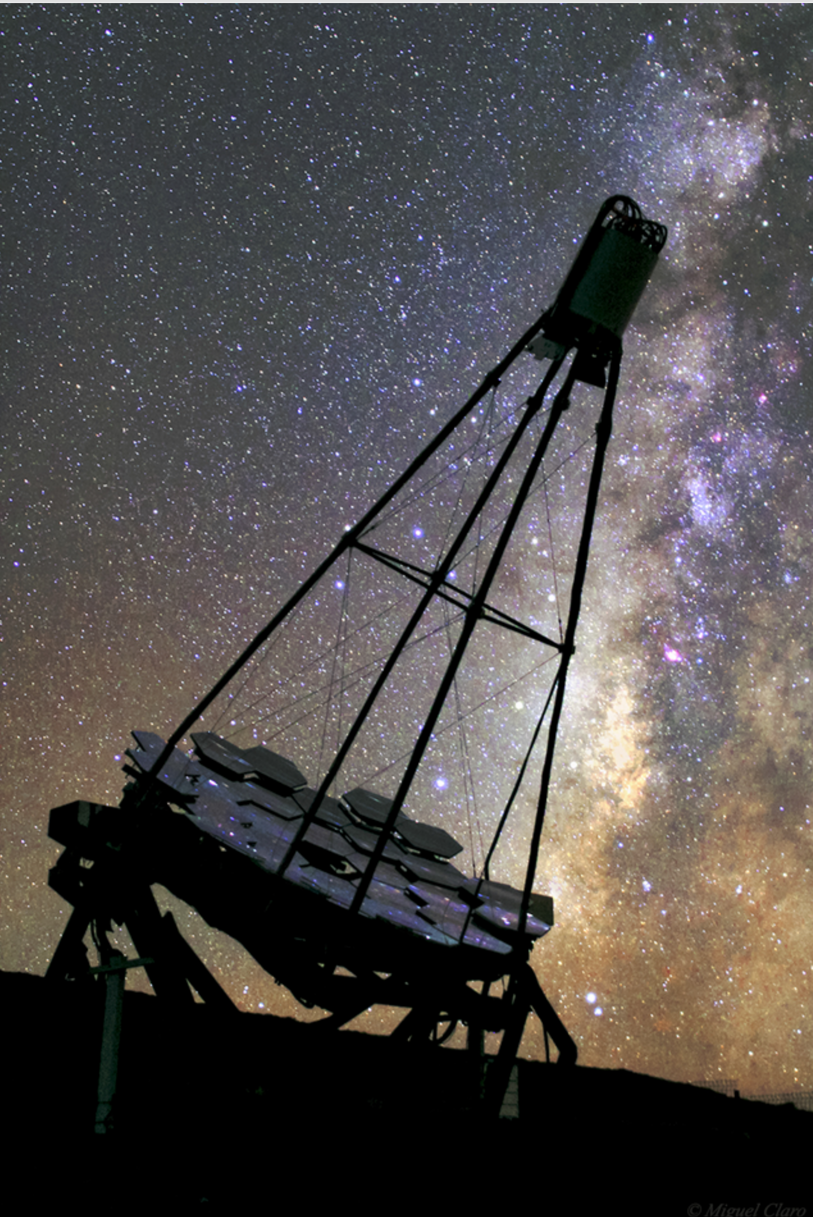
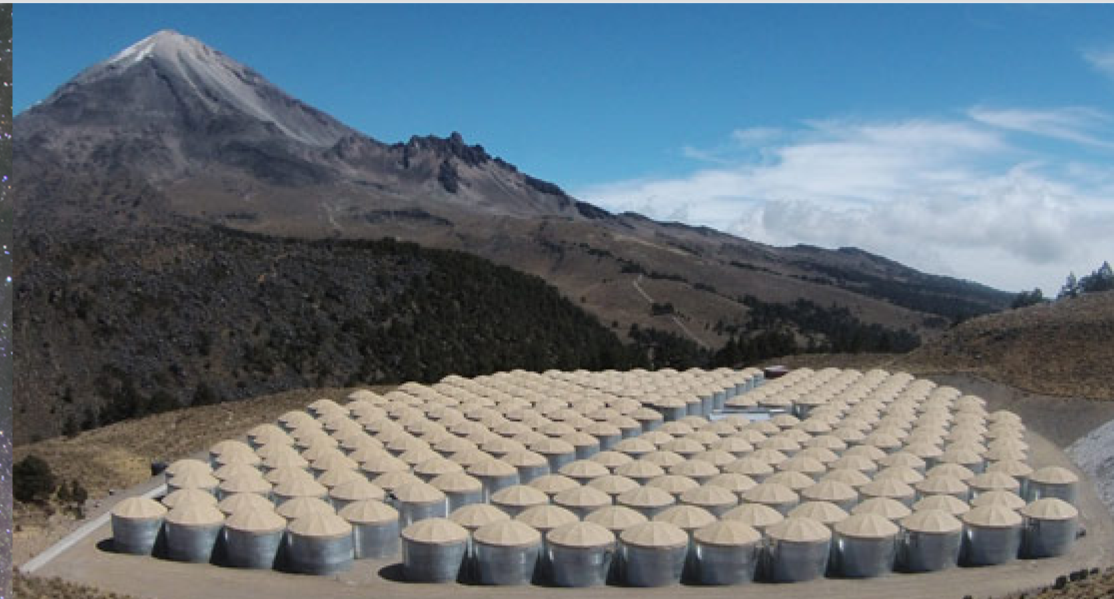
on behalf of several people from
INAOE, RWTH, UNAM and others

Hybrid detection



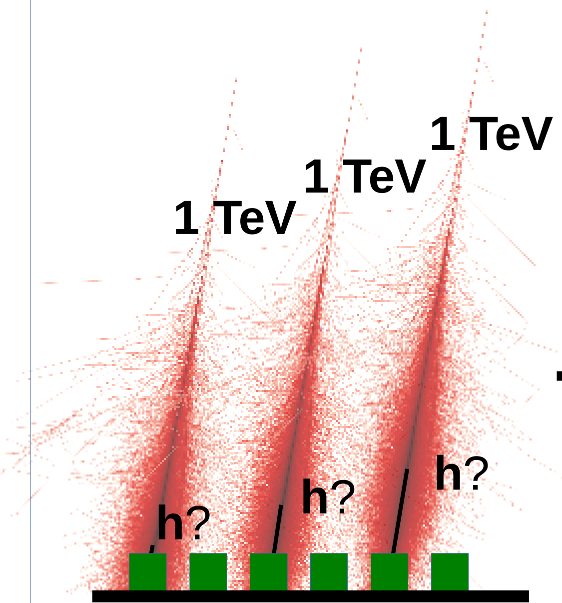


Hybrid detection:

- \+ HAWC's Eye
  Status and Performance
- \+ On-going
  Improvements

The (over-simplified) concept

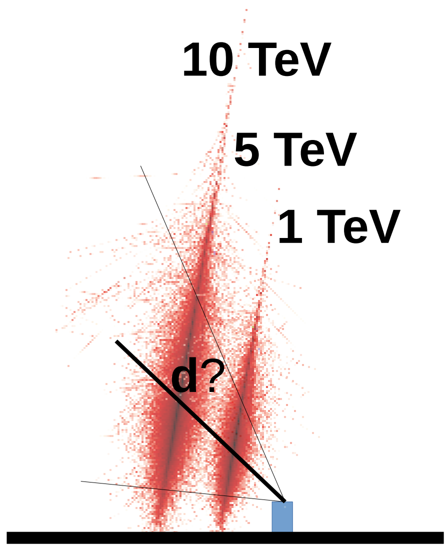
Extensive air-shower array



identical showers
at different heights
→ different signal

+

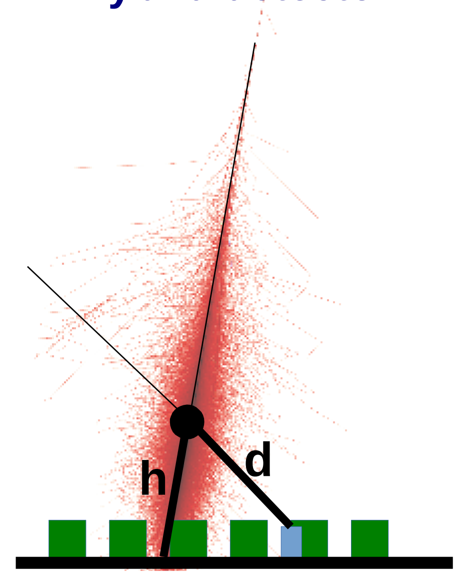
Imaging air-Cherenkov telescope



different showers
at different distance
→ similar signal

=

AllSkEye
hybrid detector



resolved ambiguities
→ better energy resolution
→ better angular resolution
→ better particle identification

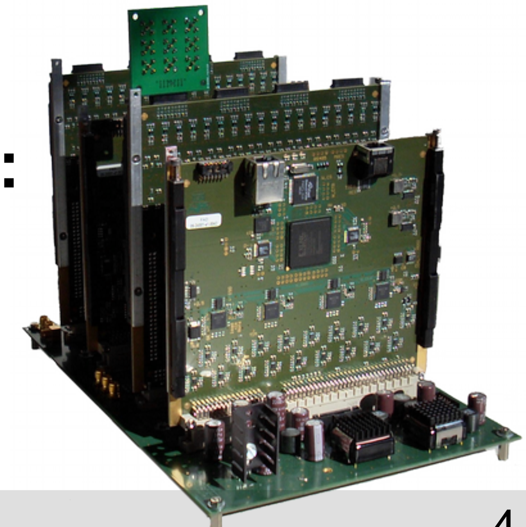
improved sensitivity

HAWC's Eye

FACTs:

- Fresnel lens, f ≈ D ≈ 0.5 m
- 61(+3) SiPM based pixel
- Al Winston cones
- 1.5°/px ~ 12° total FOV
- 72 ch. DRS4 DAQ, 2 GS/s

FACT Boards:



The *compact* IACT (shipment 2017)

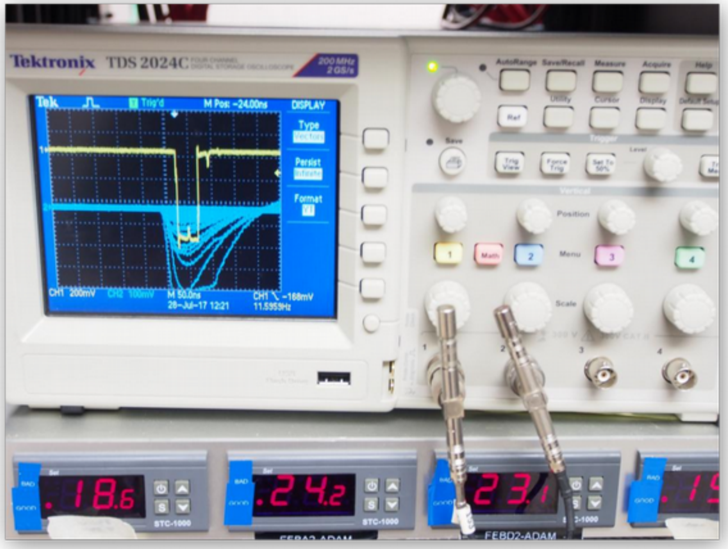
A compact and light-weight refractive telescope for the observation of extensive air showers

JINST 13 (2018) P07024

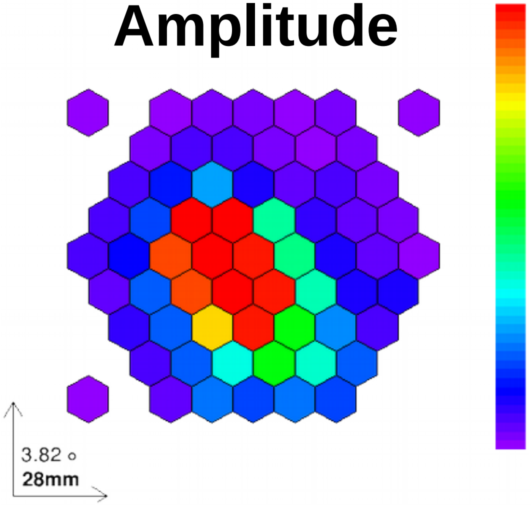
~ 10.000 €

First light 27.07.2017

Coincidences !



Amplitude

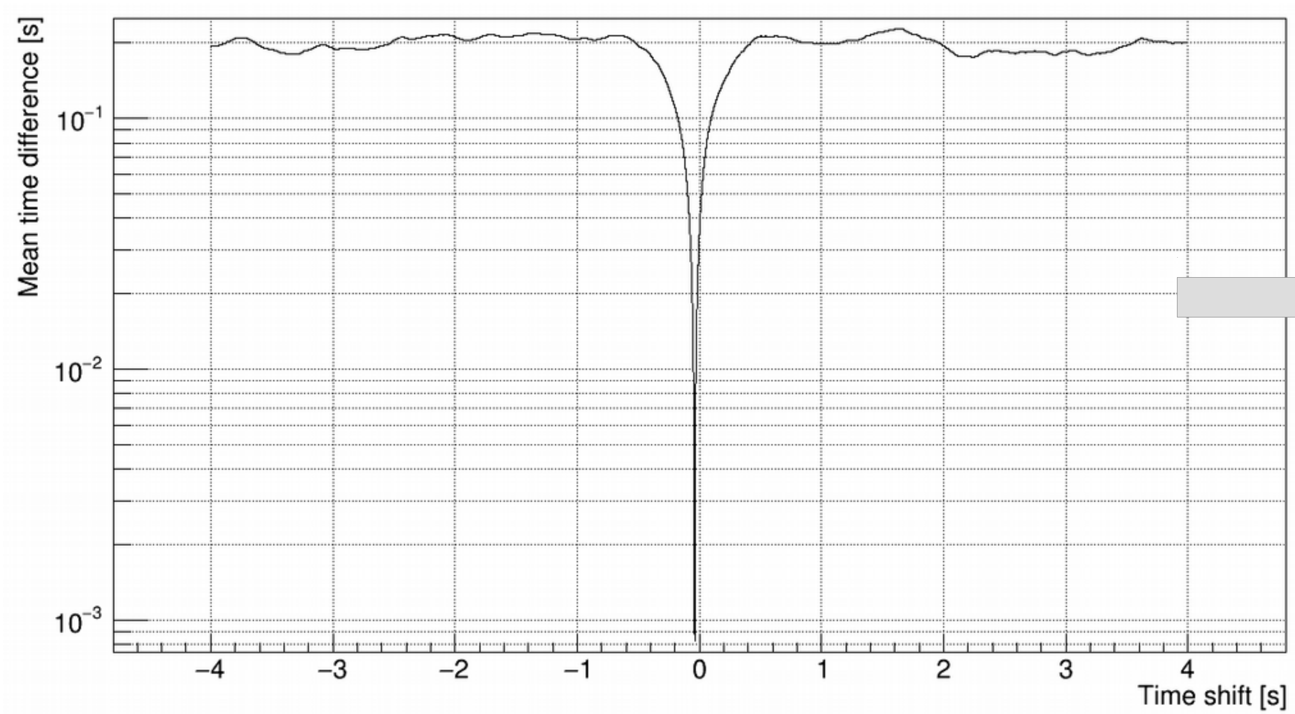


Previous Measurements

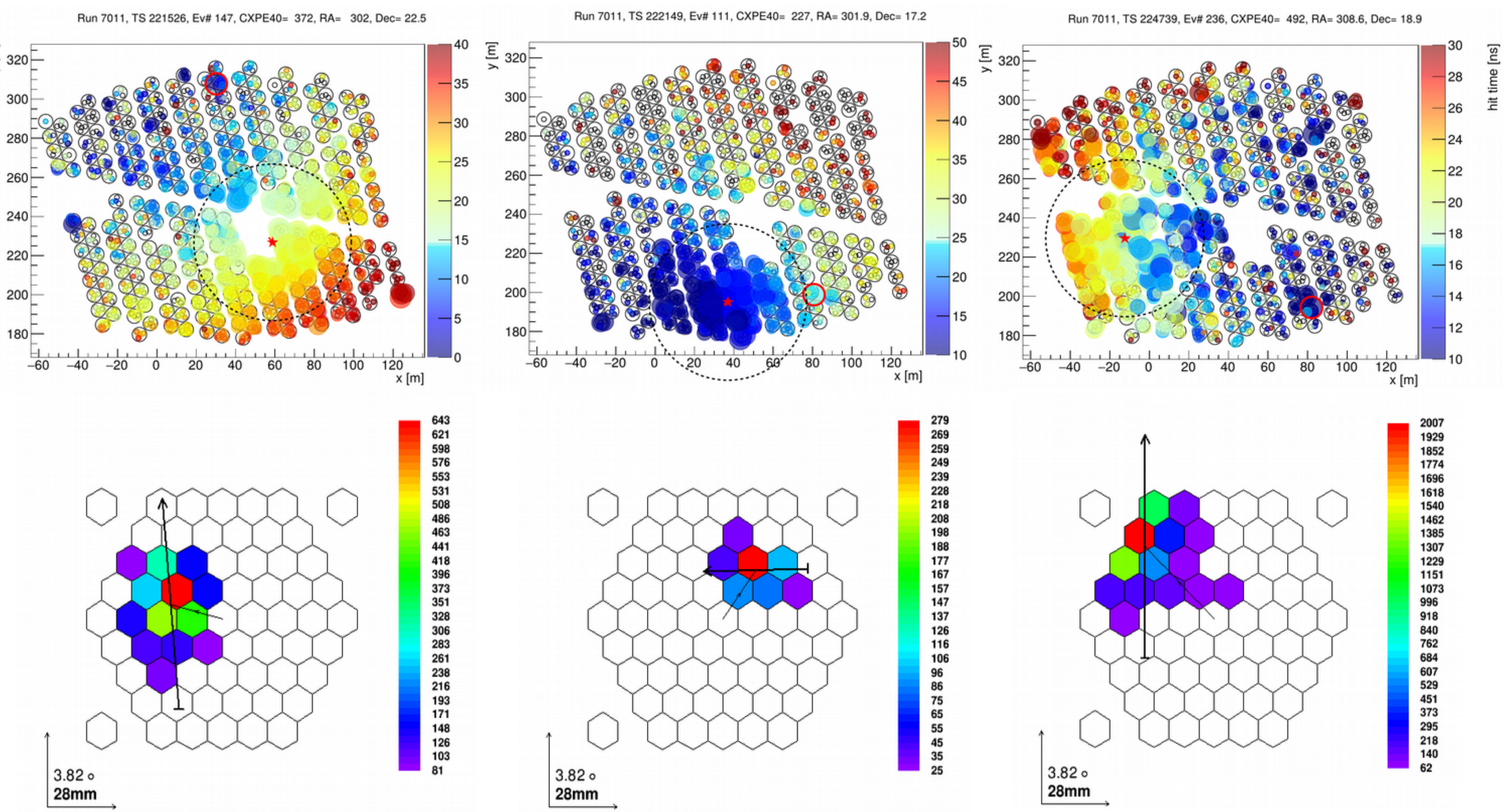
High threshold!

27.07.17:

- **Perfect weather** conditions, clear sky, milky way visible, no moon
- 10x “low” threshold runs (550 DAC) (**~ 50 min**)
- 20x “high“ threshold runs (600 DAC) (**~ 100 min**)

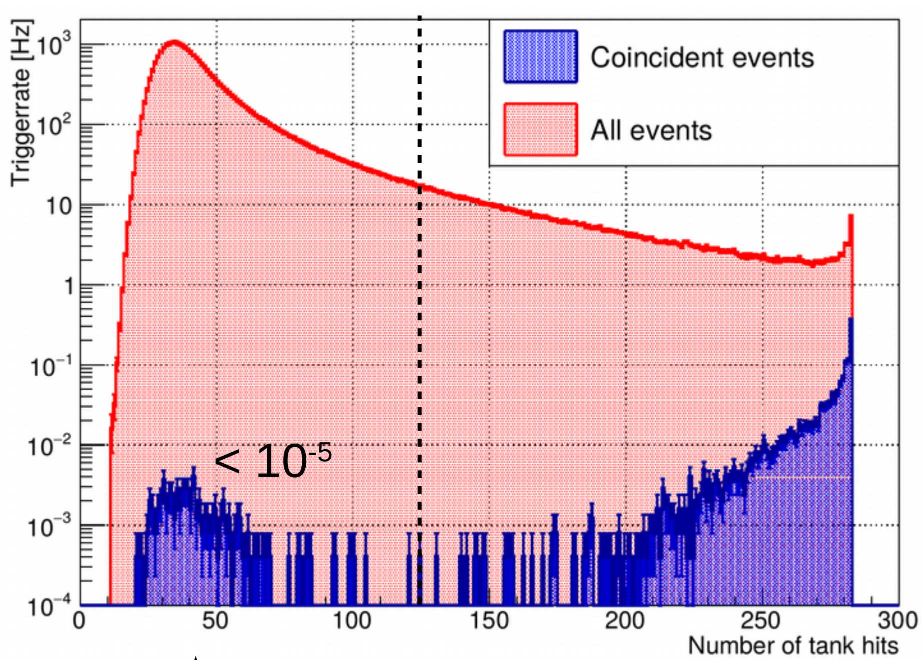


Synchronization better than 1 ms



Run 7011, TS 221526, Ev# 147, CXPE40= 372, RA= 302, Dec= 22.5
Run 7011, TS 222149, Ev# 111, CXPE40= 227, RA= 301.9, Dec= 17.2
Run 7011, TS 224739, Ev# 236, CXPE40= 492, RA= 308.6, Dec= 18.9
y [m]
x [m]
hit time [ns]
3.82 ∘
28mm

Coincident showers

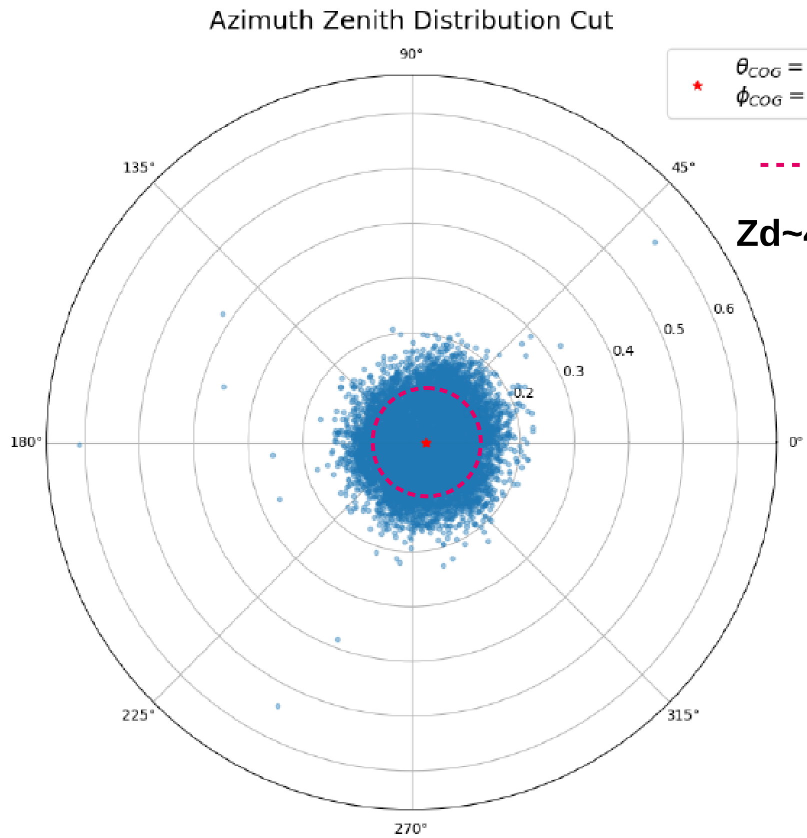


random coincidences

showers seen by HAWC and HAWC's Eye

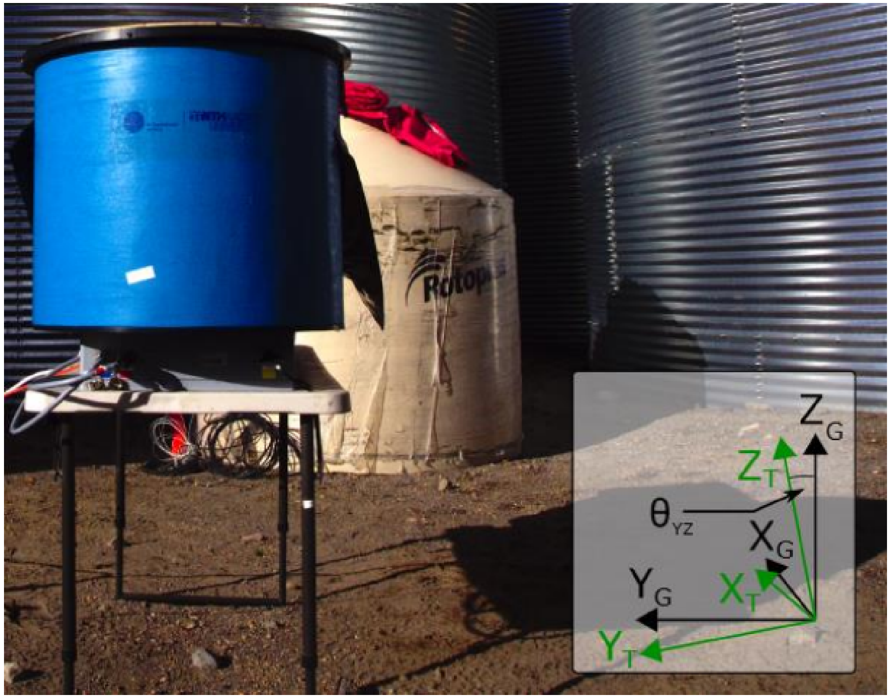
cut at 120

Field of view



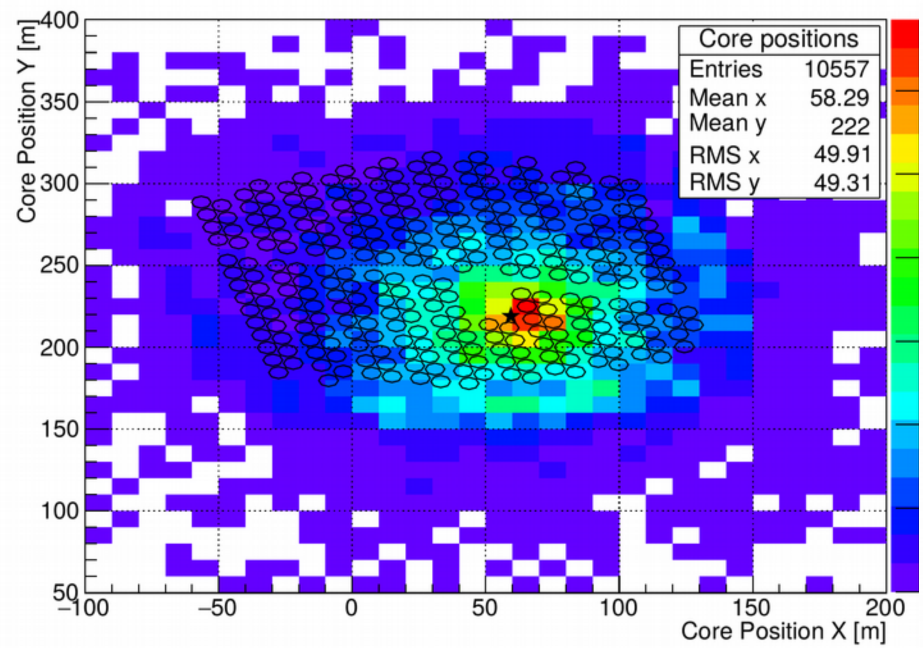
----- Field-of-view

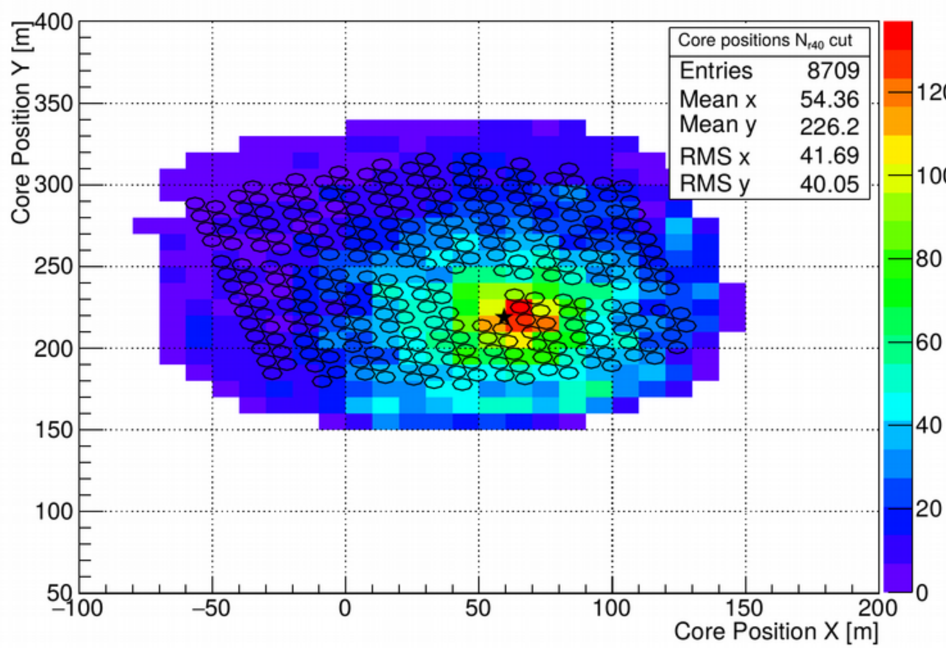
Zd~45°



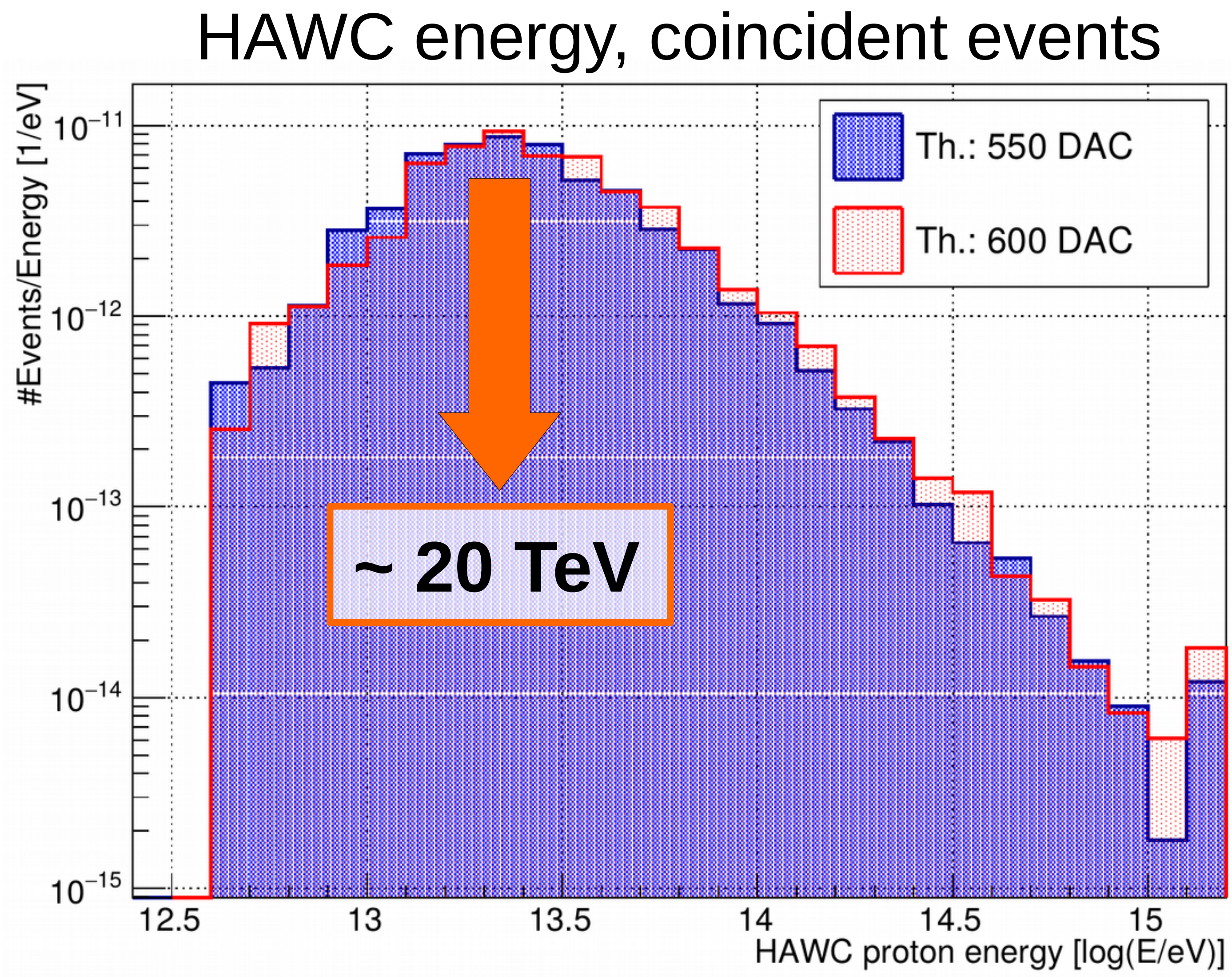
HAWC core pos. of coincident events

triggered PMTs > 40 within 40m around the shower core position

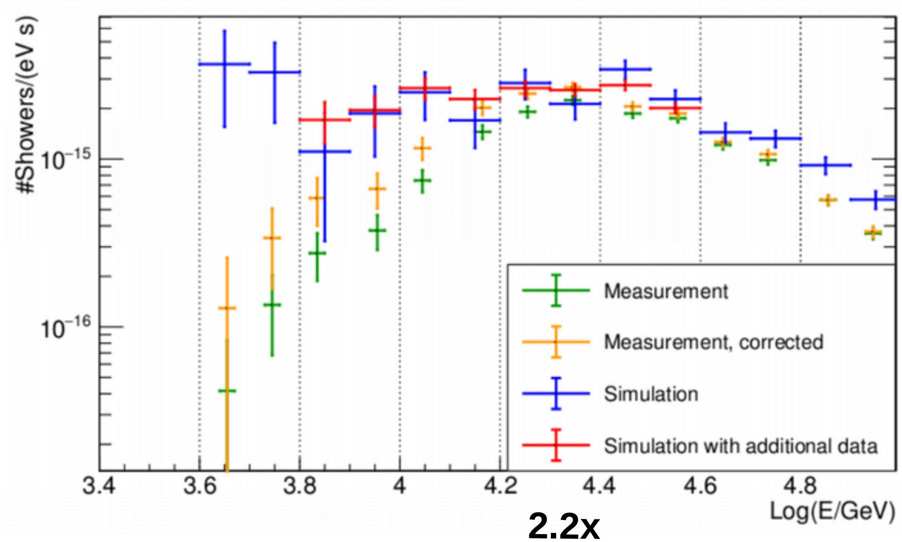




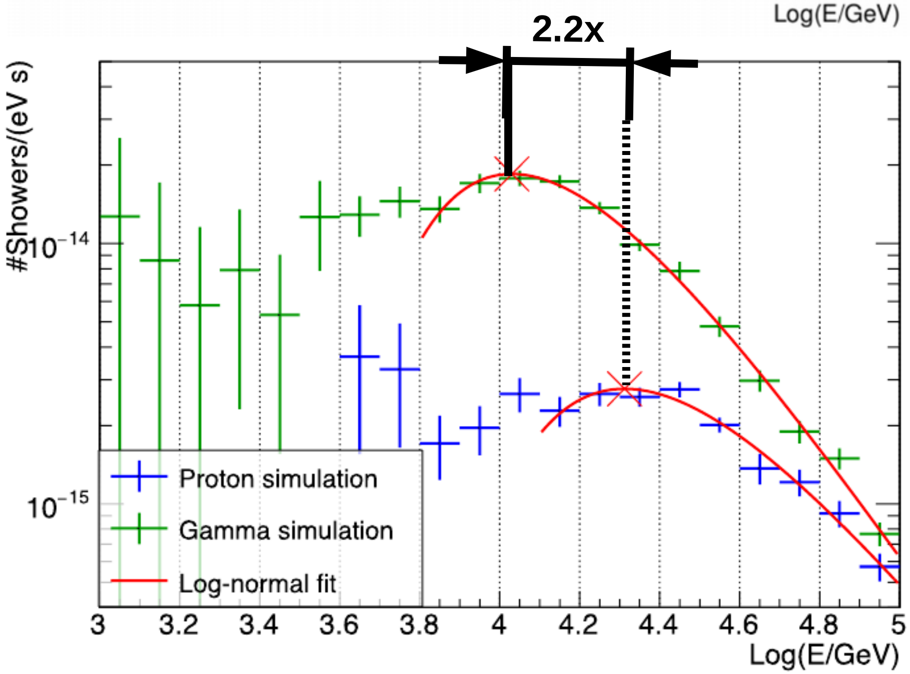
Energy threshold for protons



Gamma Energy Threshold



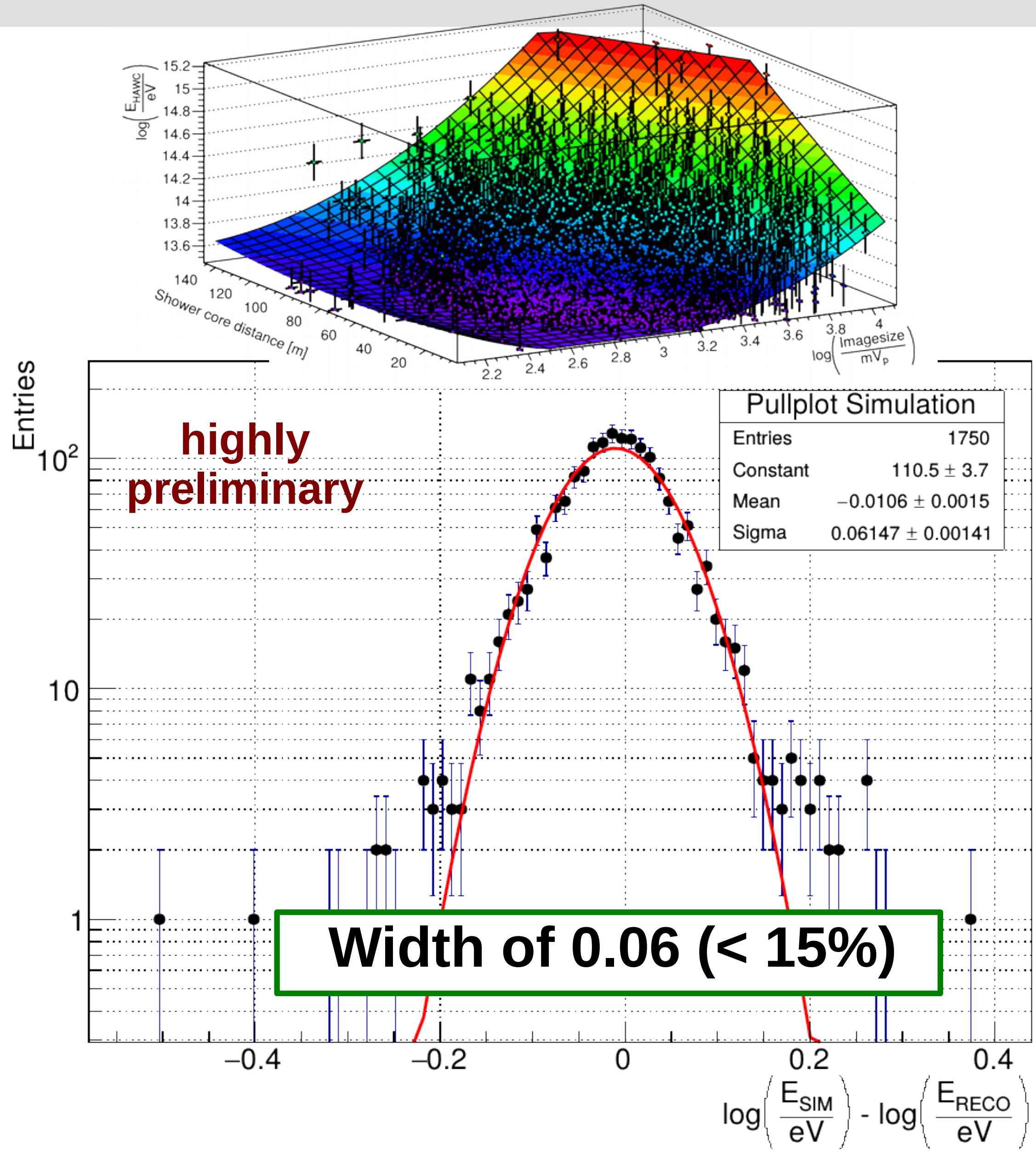
Reproduced distribution of measured energies with proton Monte Carlos



Expectation: x3

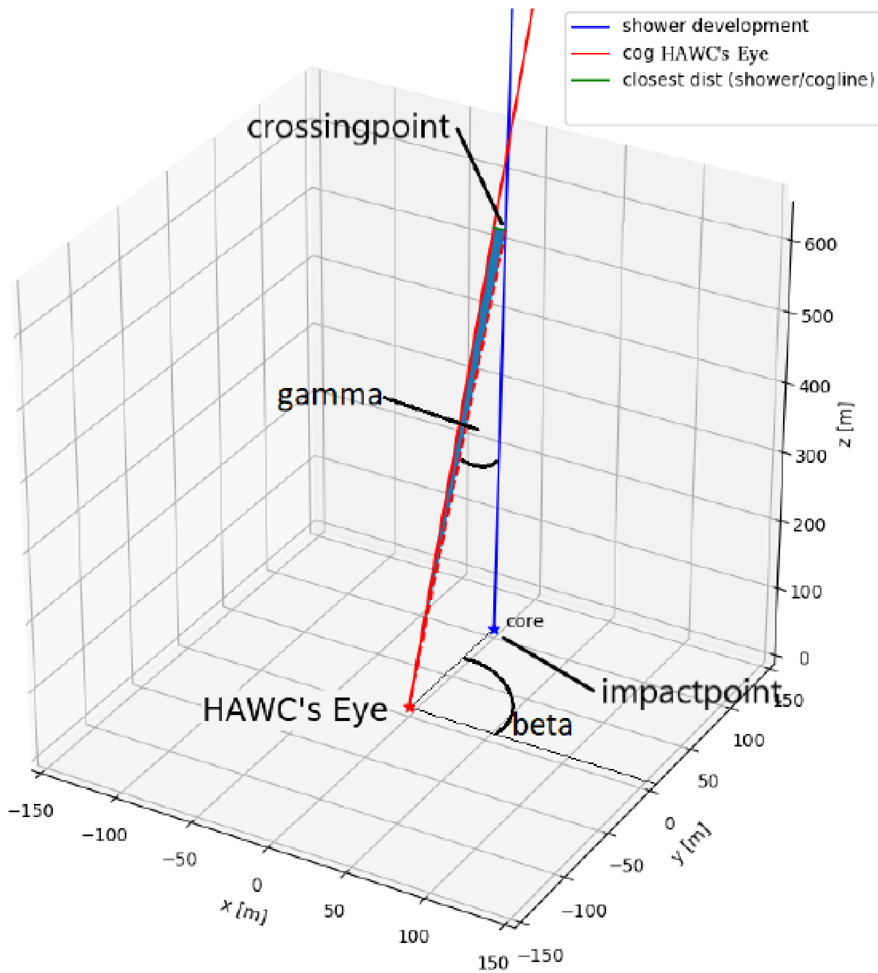
Applied simulation to gamma-MC
→ Energy threshold 10 TeV

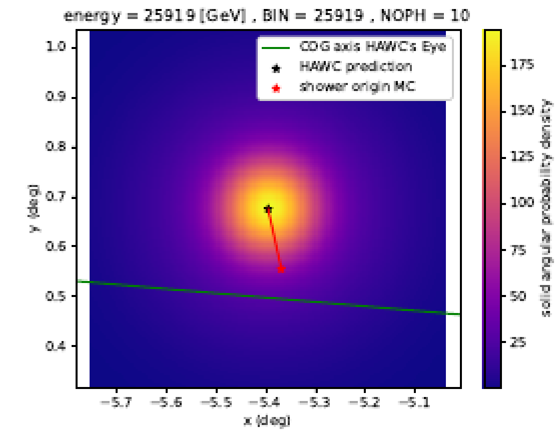
Proton energy from hybrid reconstr.



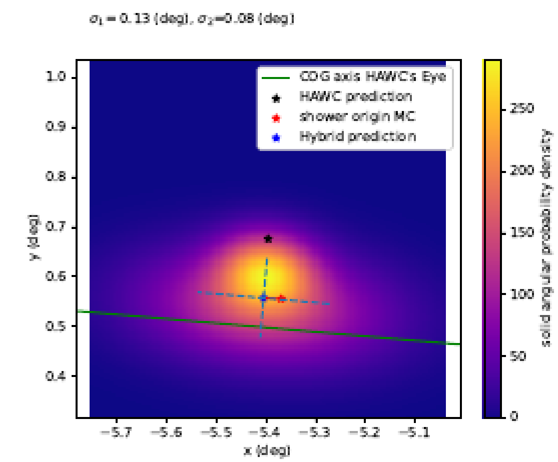
Arrival direction (MC)

most simple analysis



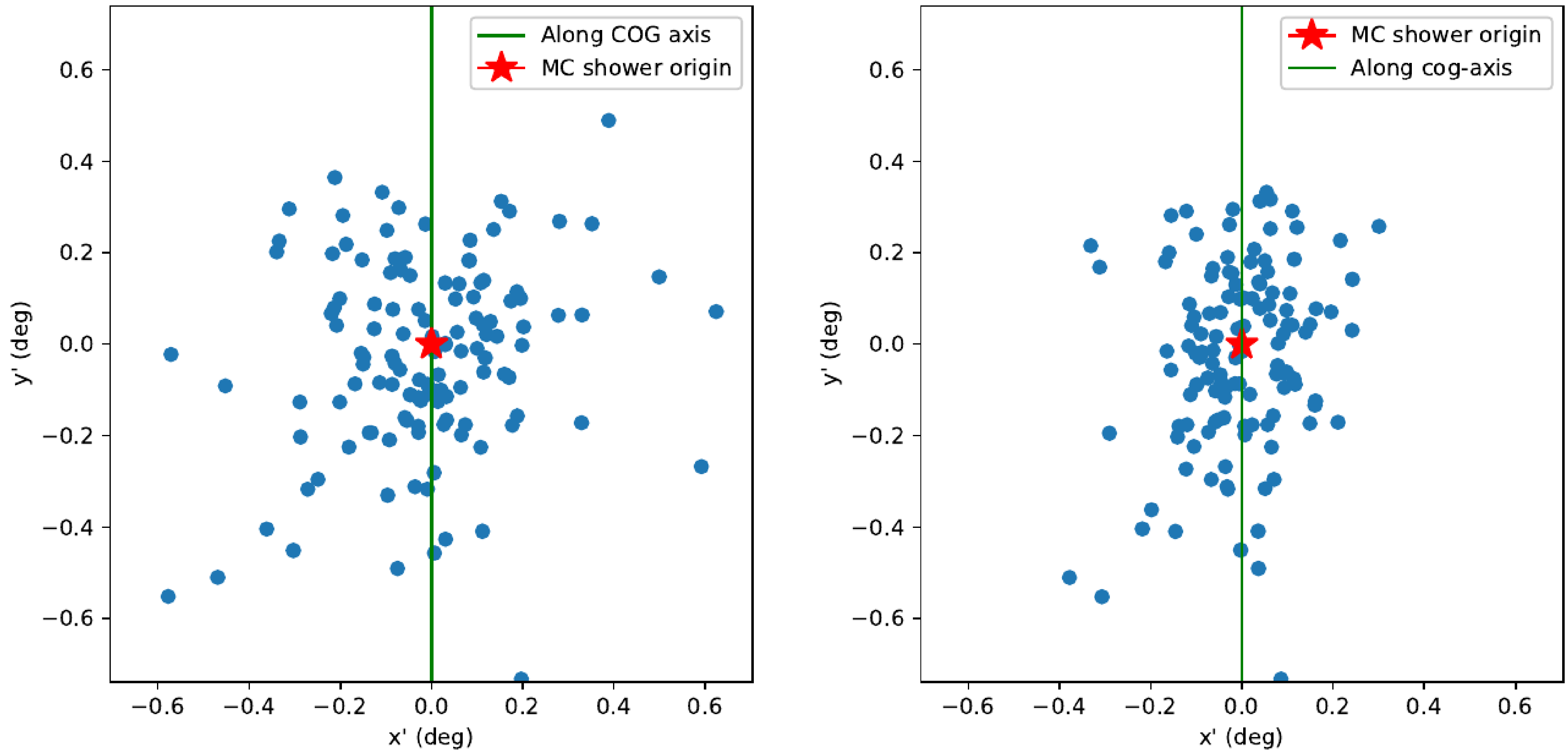


(c) HAWC's prediction and its uncertainty outlined in a not normed solid angular probability density function. 'Shower MC' labels the true origin of the primary particle.



(d) The hybrid predicion and its calculated solid angular probability density function projected into the impactpoint on ground. The blue lines show its estimated standard deviations.

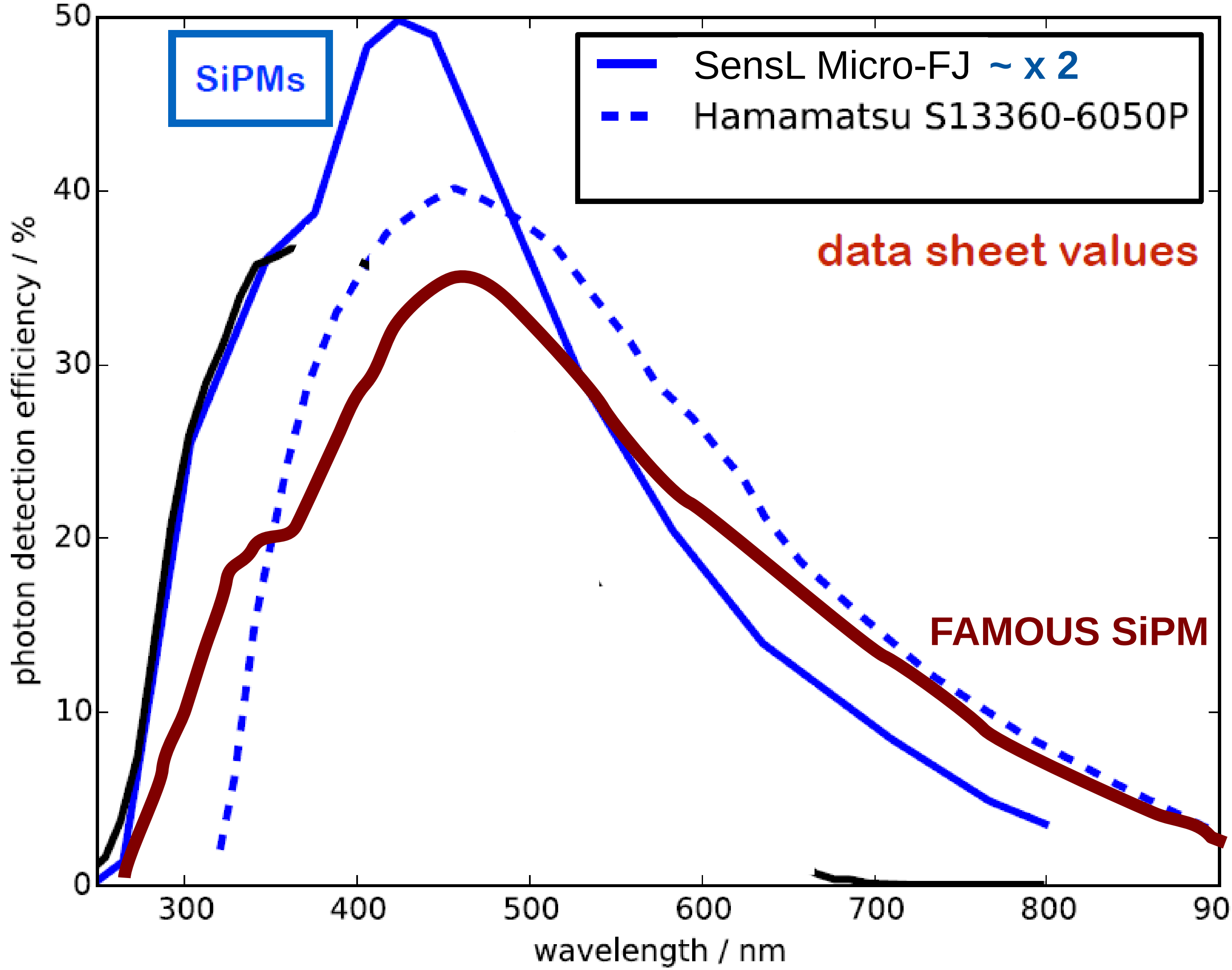
Improvement (MC)



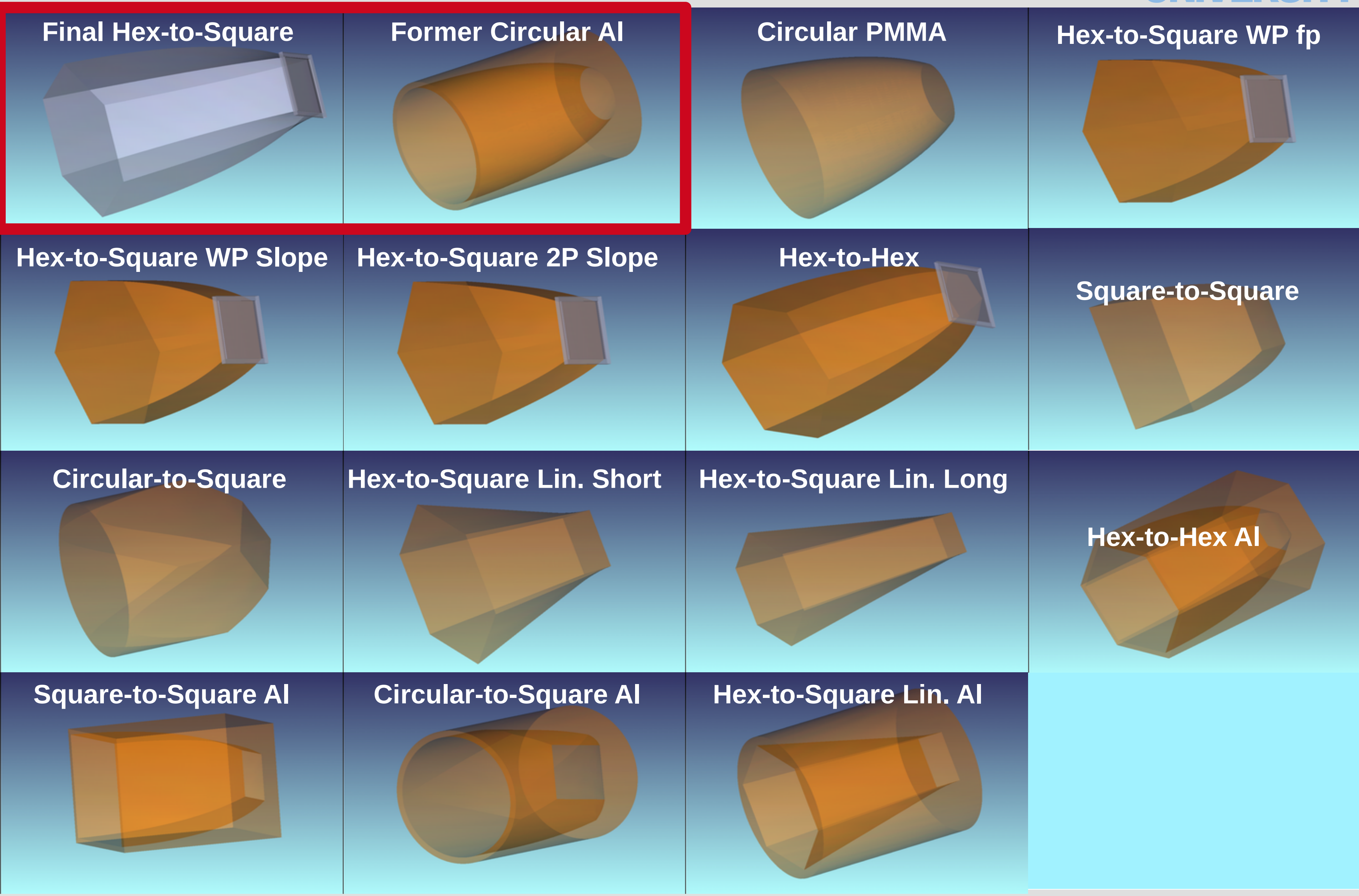
(a) HAWC prediction. (b) Hybrid prediction.

→ Significant improvement in one direction
→ Needs stereo measurements

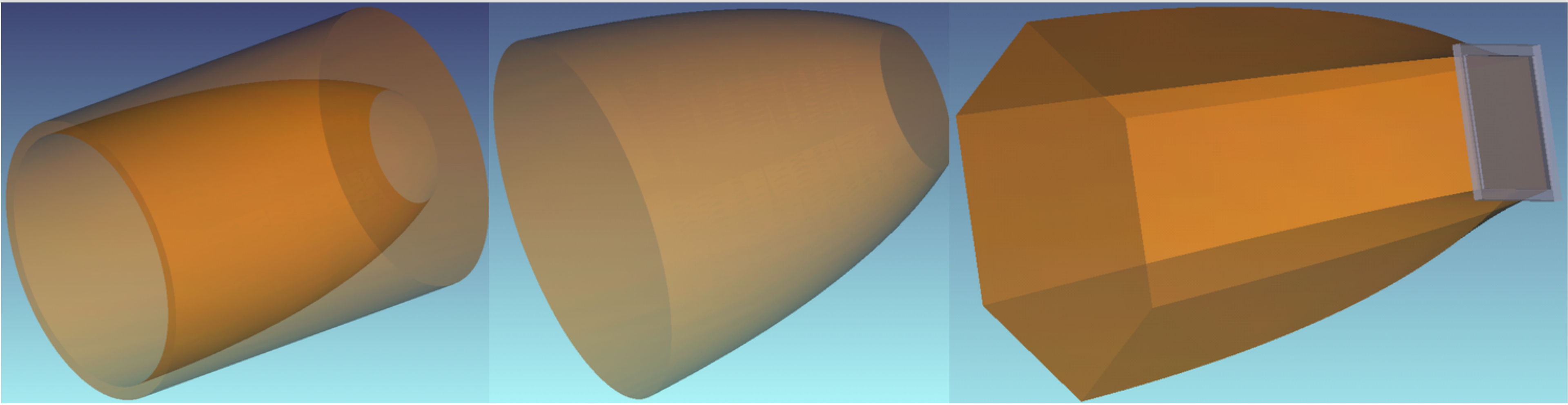
Replacing Hamamatsu with SensL



Investigated Cones



Light-collector efficiencies

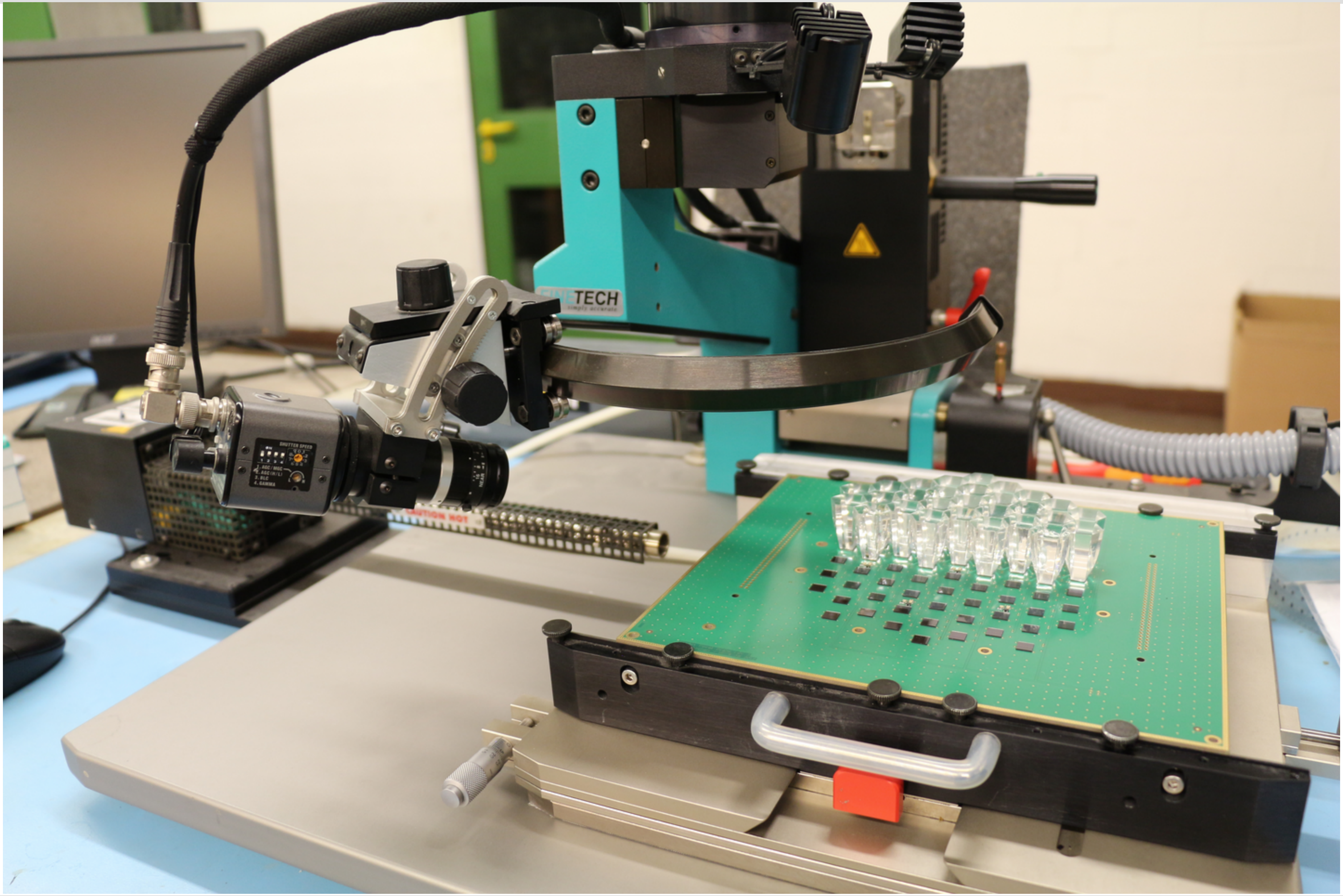


Currently installed: Former Circular Al Winston surface	Circular PMMA Cut Winston surface	Final Hex-to-Square PMMA

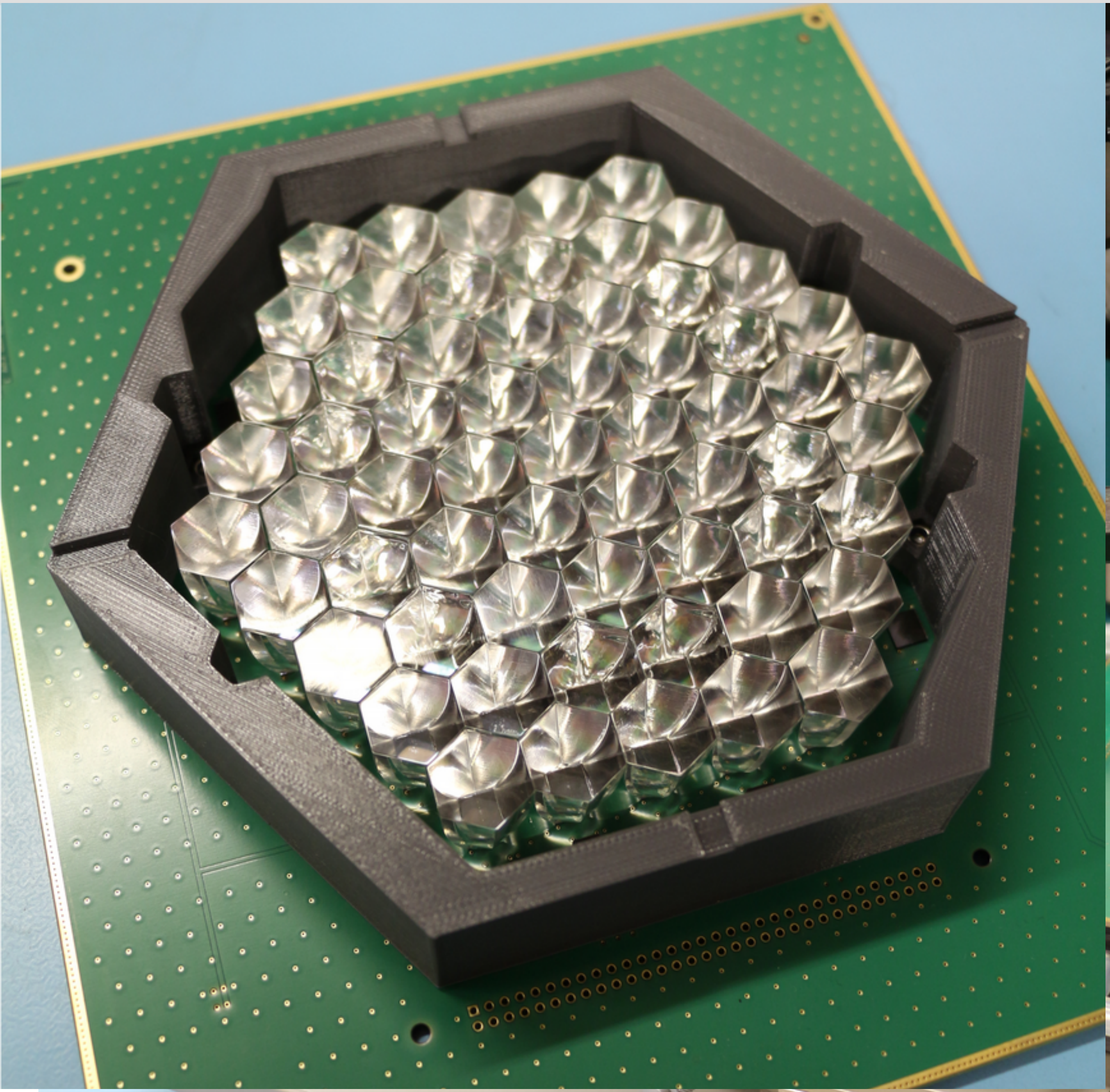
Cone type	Central cone position $a_\gamma \pm$ RMS	Edge cone position $a_\delta \pm$ RMS
Former Circular Al	$0.1889 \pm 2.6\%$	$0.1375 \pm 2.5\%$
Circular PMMA	$0.3060 \pm 0.5\%$	$0.3039 \pm 2.1\%$
Final Hex-to-Square	$0.3323 \pm 1.5\%$	$0.3232 \pm 2.4\%$

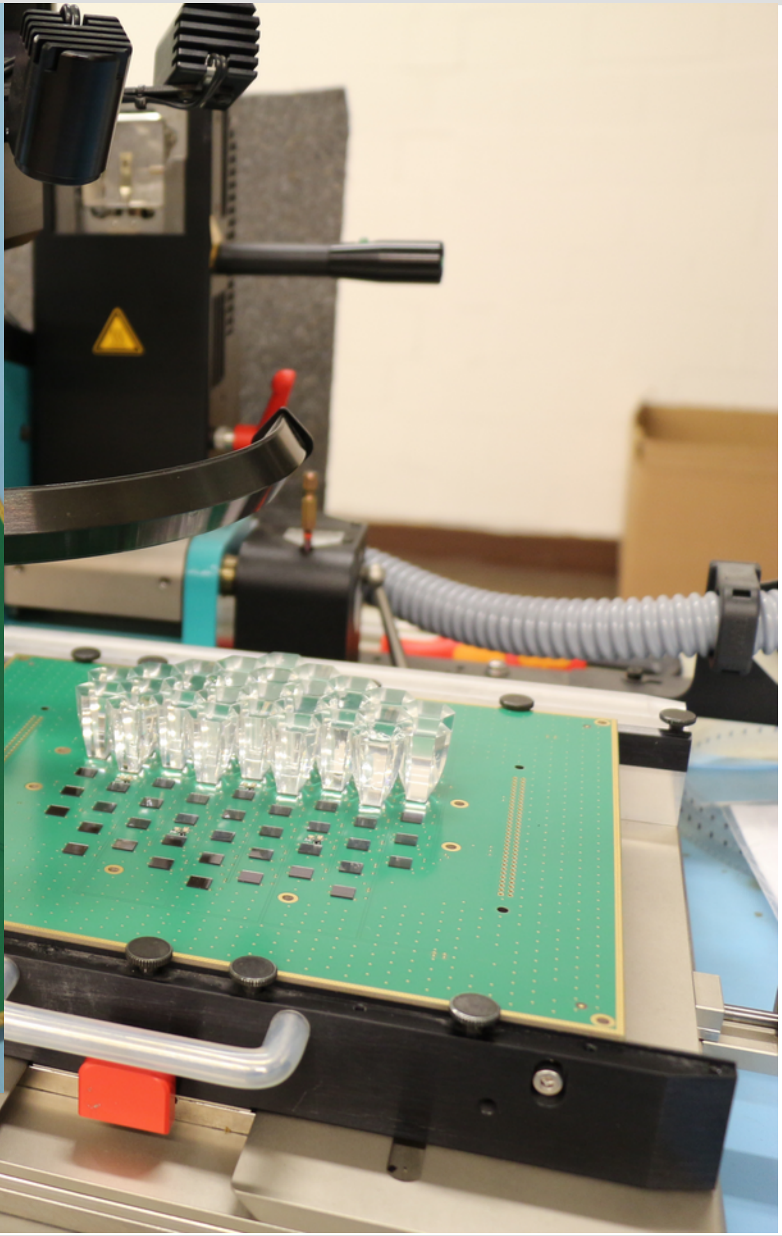
x 2

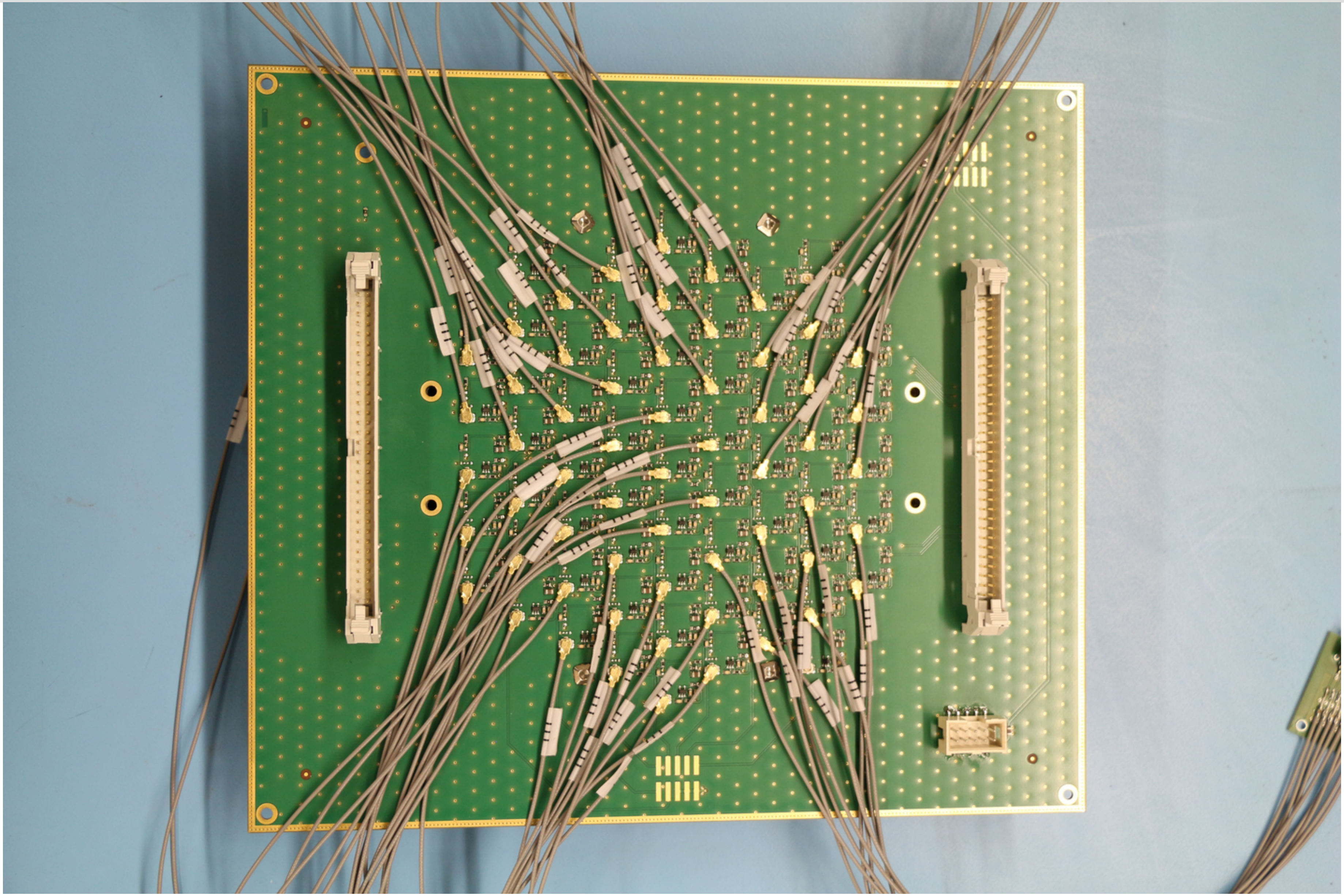
Glueing light concentrators



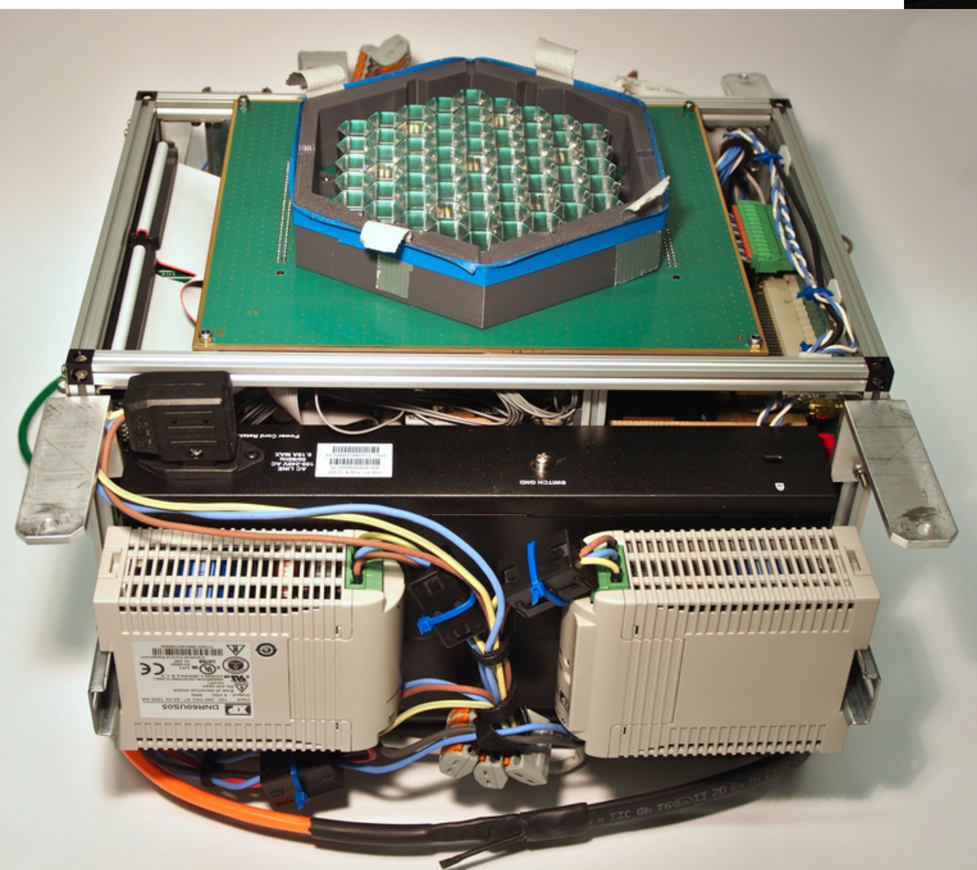
Glueing light concentrators

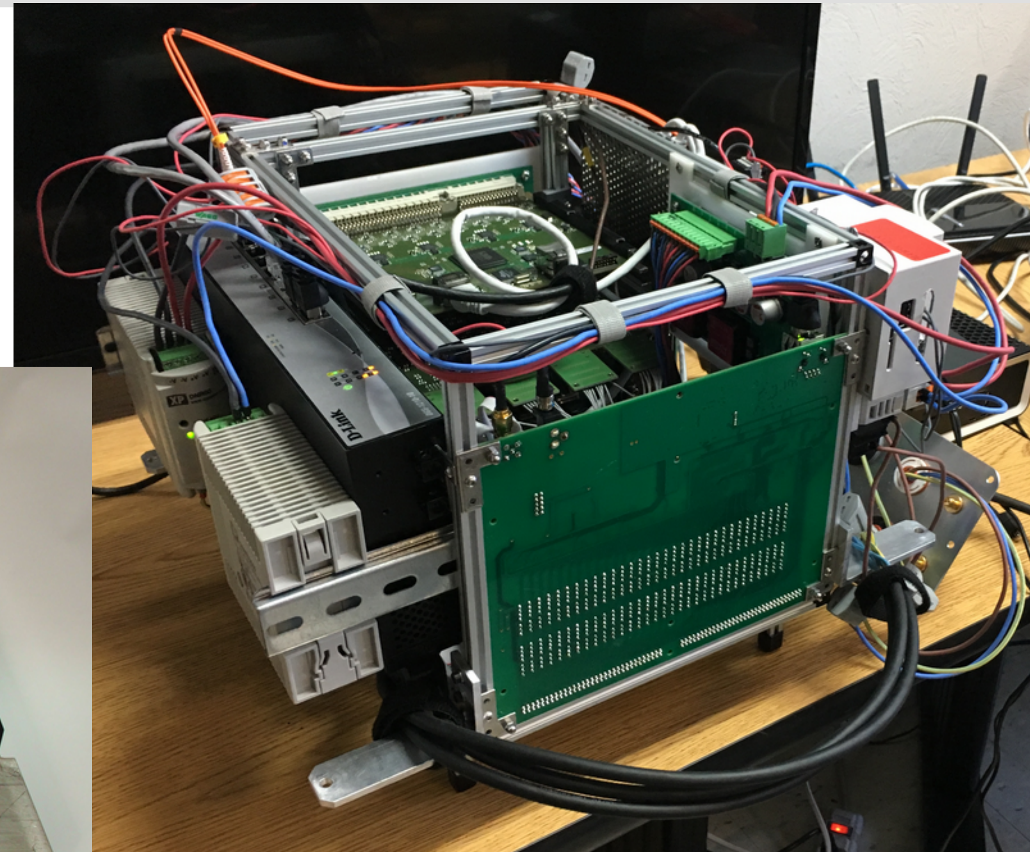




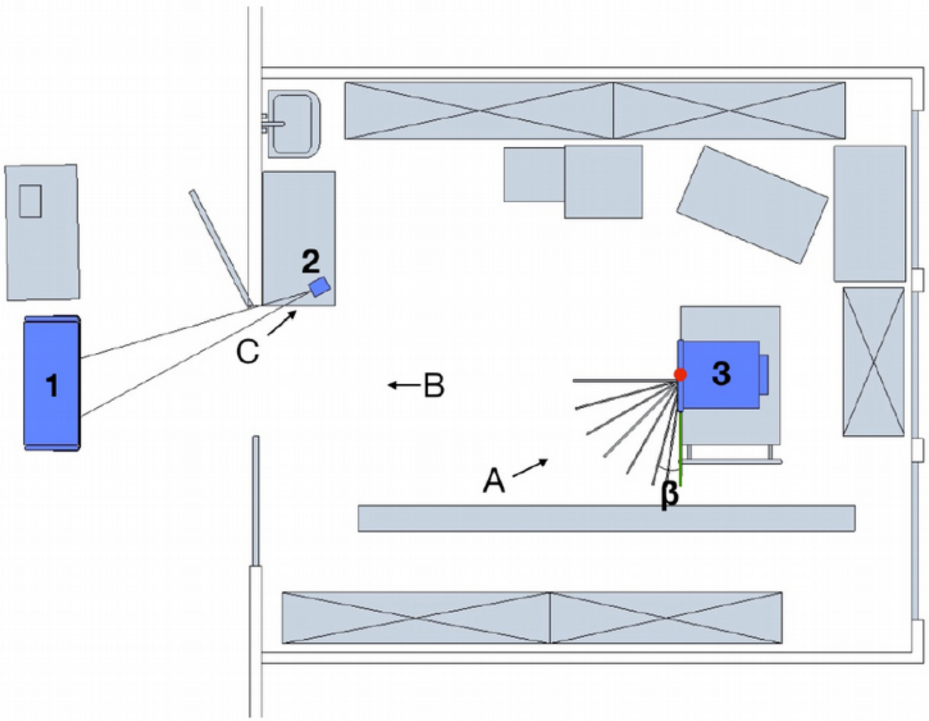


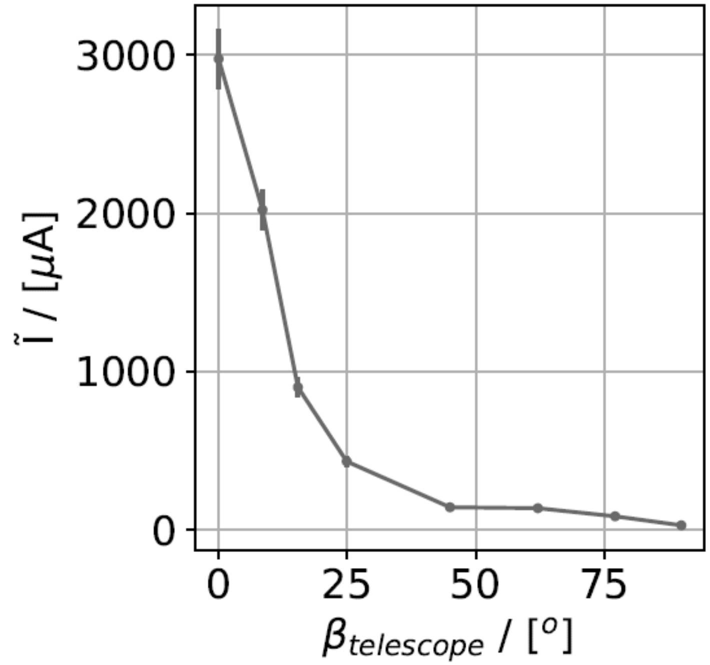
The new camera frame

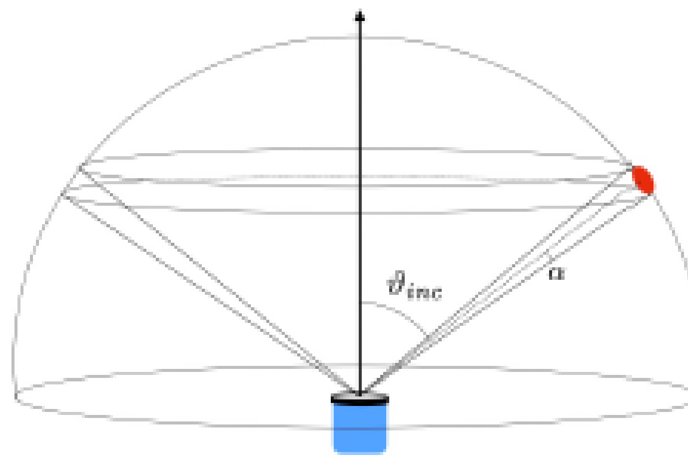




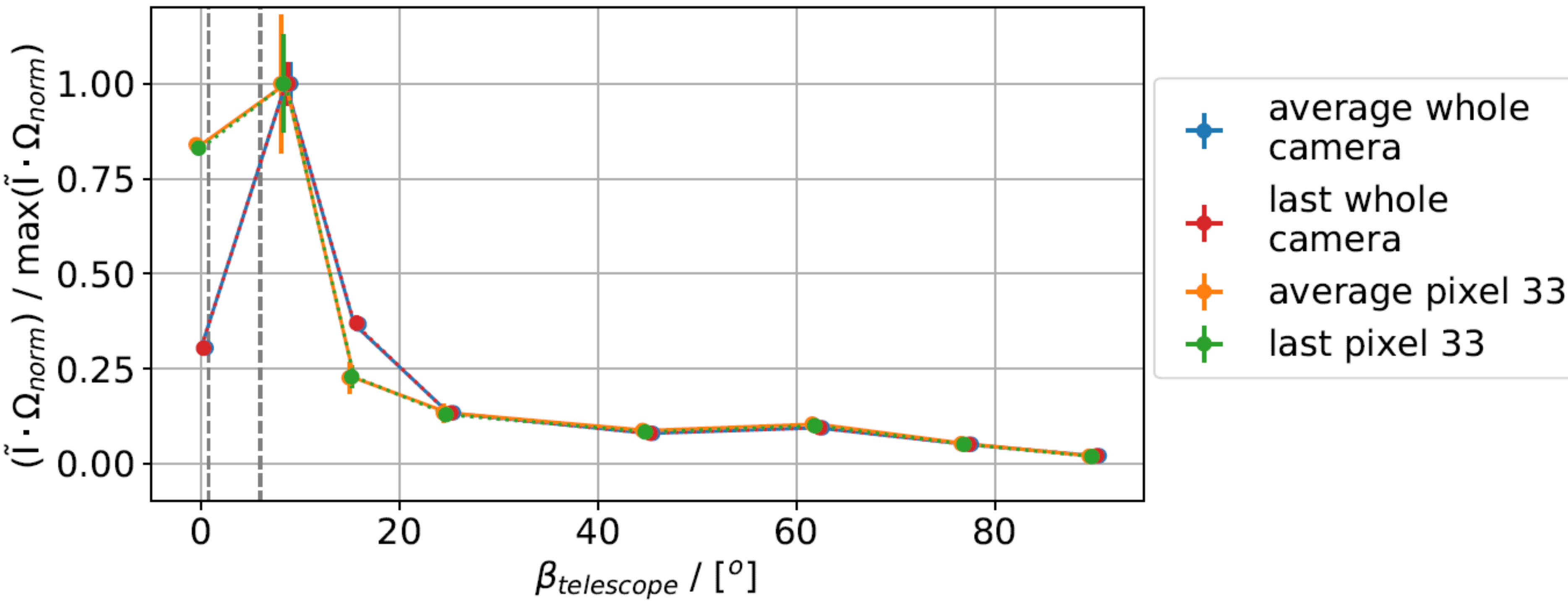
Off axis measurement







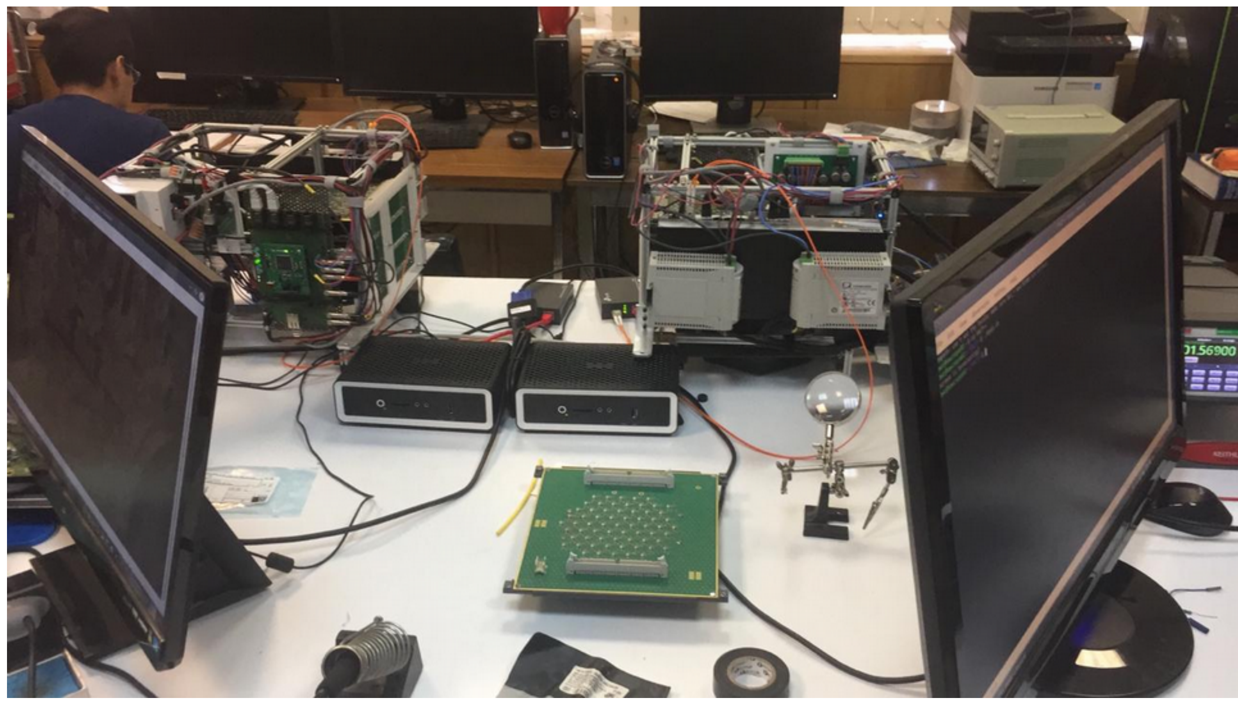
Off axis measurement



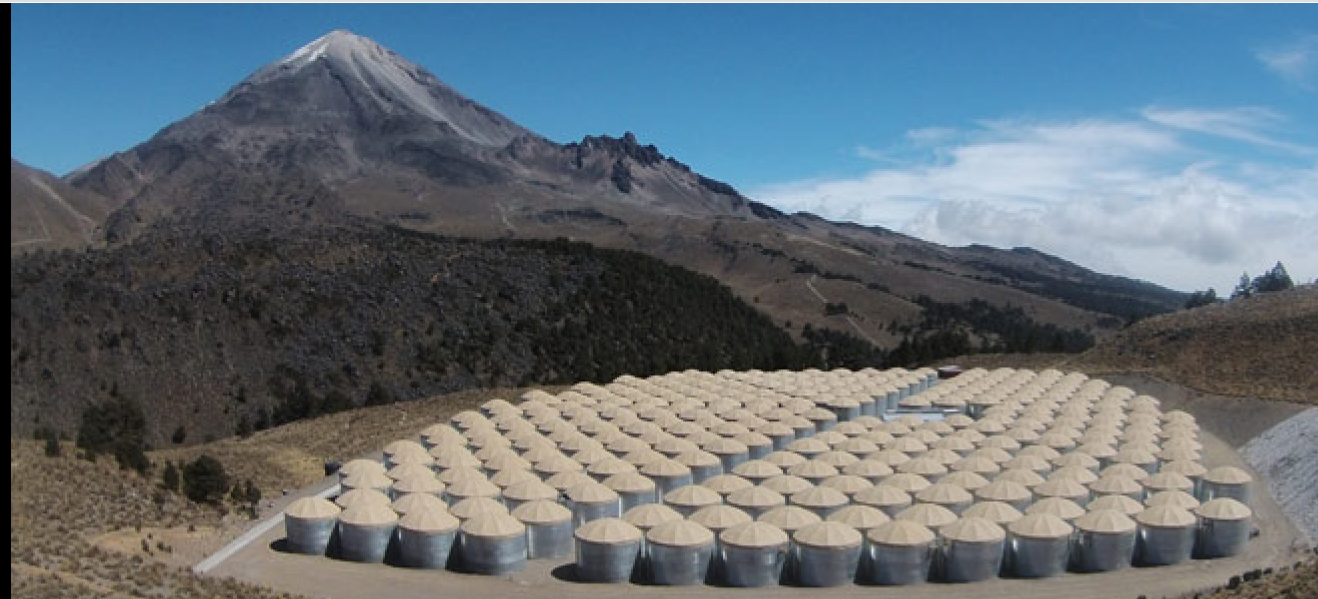
> 50% off-axis background light
We are working on reducing that!

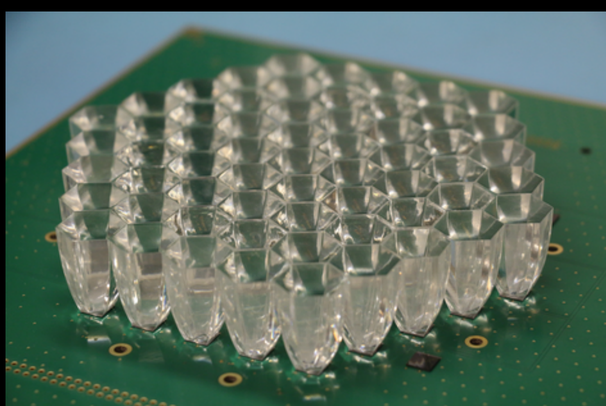
Status

- Two telescopes built end of 2018
- Currently at UNAM
- Hopefully measurements within the coming six weeks
- Expected improvement in energy threshold:
  - **factor ~4**
- MC production just started



Conclusion





Hybrid Detection should be considered for the new wide-FoV observatory