CF2 Instrumentation

Jim Buckley
for the CF2 working group

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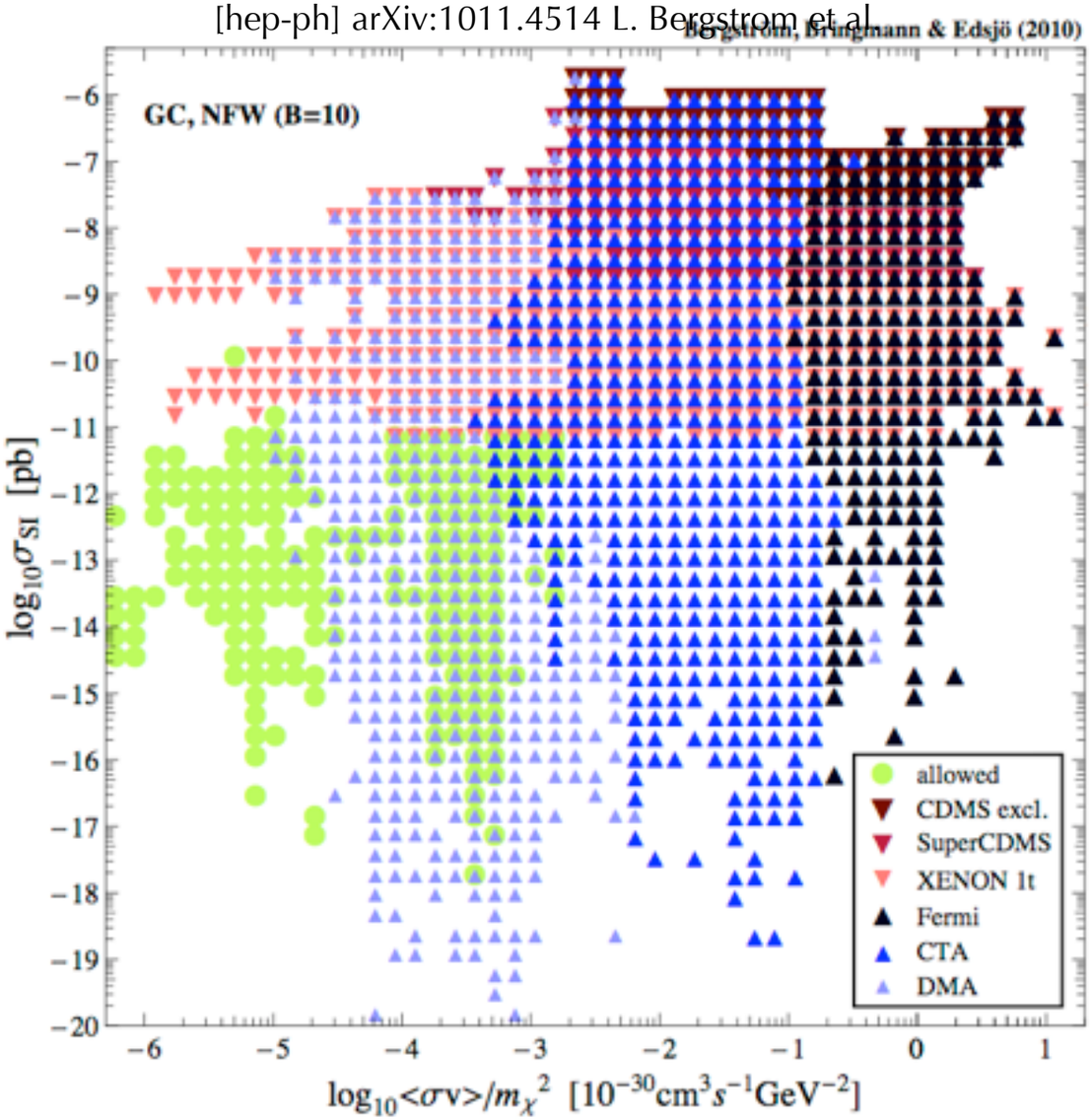
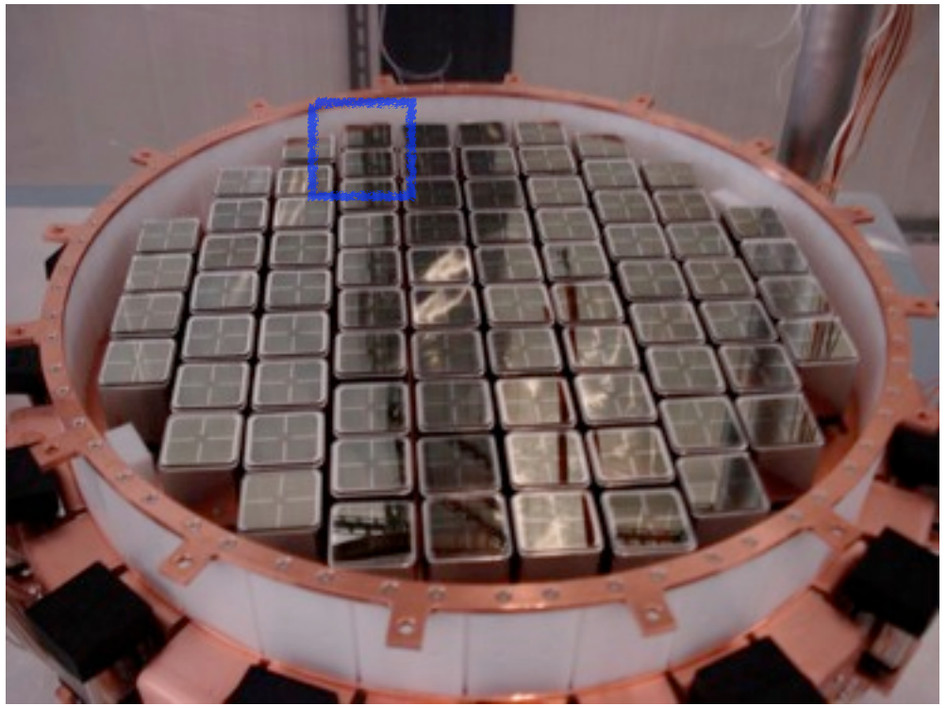
Direct and Indirect Detection

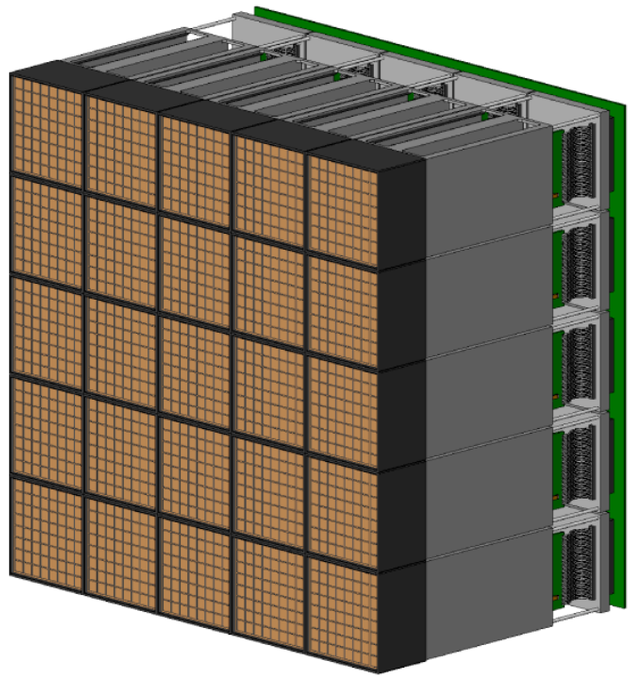
[hep-ph] arXiv:1011.4514 L. Bergstrom et al



- Scientific complementarity
- Technical complementarity



Xenon100 Detector



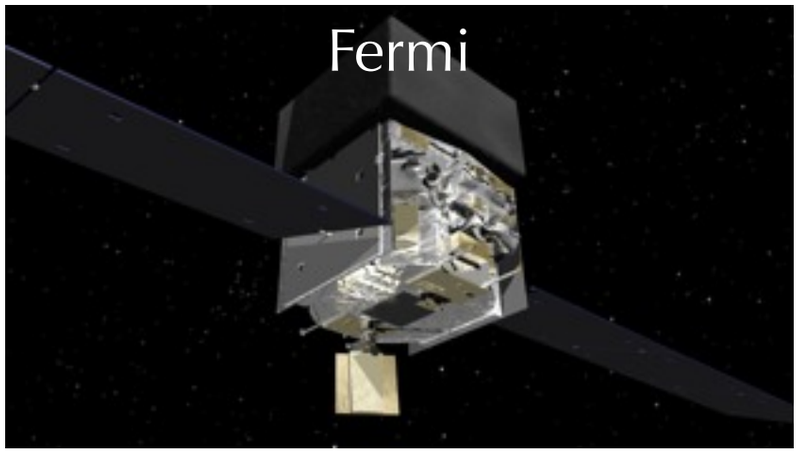
Proposed CTA SC camera module with 25 2″ MAPMTs

CF2 Experiments

Table 1-1. *Current and planned indirect detection experiments.*

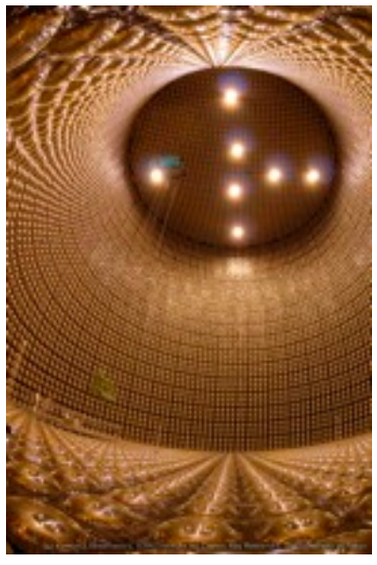
Status	Experiment	Target	Location	Major Support	Comments
Current	AMS	e^+/e^-, anti-nuclei	ISS	NASA	Magnet Spectrometer, Running
	Fermi	Photons, e^+/e^-	Satellite	NASA, DOE	Pair Telescope and Calorimeter, Running
	HESS	Photons, e^-	Namibia	German BMBF, Max Planck Society, French Ministry for Research, CNRS-IN2P3, UK PPARC, South Africa	Atmospheric Cherenkov Telescope (ACT), Running
	IceCube/ DeepCore	Neutrinos	Antarctica	NSF, DOE, International *Belgium, Germany, Japan, Sweden)	Ice Cherenkov, Running
	MAGIC	Photons, e^+/e^-	La Palma	German BMBF and MPG, INFN, WSwiss SNF, Spanish MICINN, CPAN, Bulgarian NSF, Academy of Finland, DFG, Polish MNiSzW	ACT, Running
	PAMELA	e^+/e^-	Satellite		
	VERITAS	Photons, e^+/e^-	Arizona, USA	DOE, NSF, SAO	ACT, Running
Planned	CALET	e^+/e^-	ISS	Japan JAXA, Italy ASI, NASA	Calorimeter
	CTA	Photons	ground-based (TBD)	International (MinCyT, CNEA, CONICET, CNRS-INSU, CNRS-IN2P3, Irfu-CEA, ANR, MPI, BMBF, DESY, Helmholtz Association, MIUR, NOVA, NWO, Poland, MICINN, CDTI, CPAN, Swedish Research Council, Royal Swedish Academy of Sciences, SNSF, Durham UK, NSF, DOE	ACT
	GAMMA-400	Photons	Satellite	Russian Space Agency, Russian Academy of Sciences, INFN	Pair Telescope
	GAPS	Anti-deuterons	Balloon (LDB)	NASA, JAXA	TOF, X-ray and Pion detection
	HAWC	Photons, e^+/e^-	Sierra Negra	NSF/DOE	Water Cherenkov, Air Shower Surface Array
	PINGU	Neutrinos	Antarctica	NSF	Ice Cherenkov

Indirect Detection

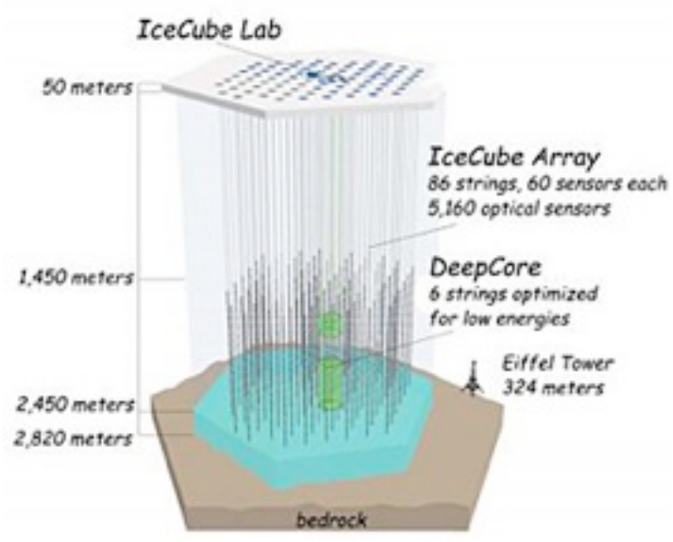


γ

Super-K



ν



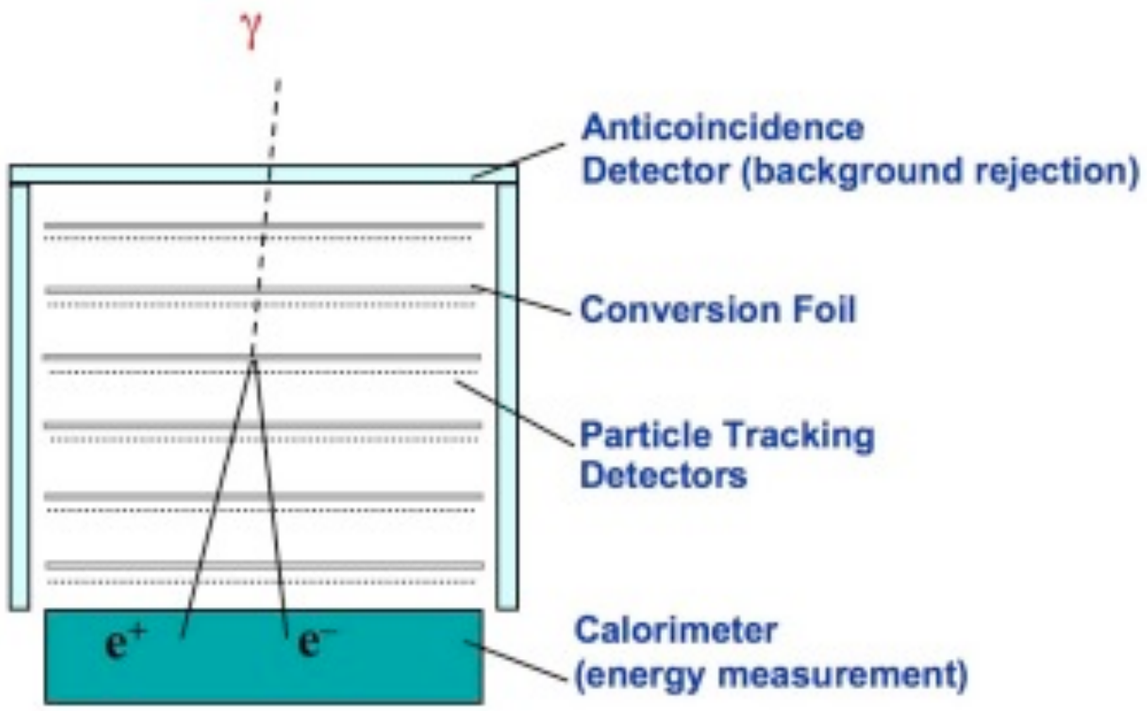
ICECUBE

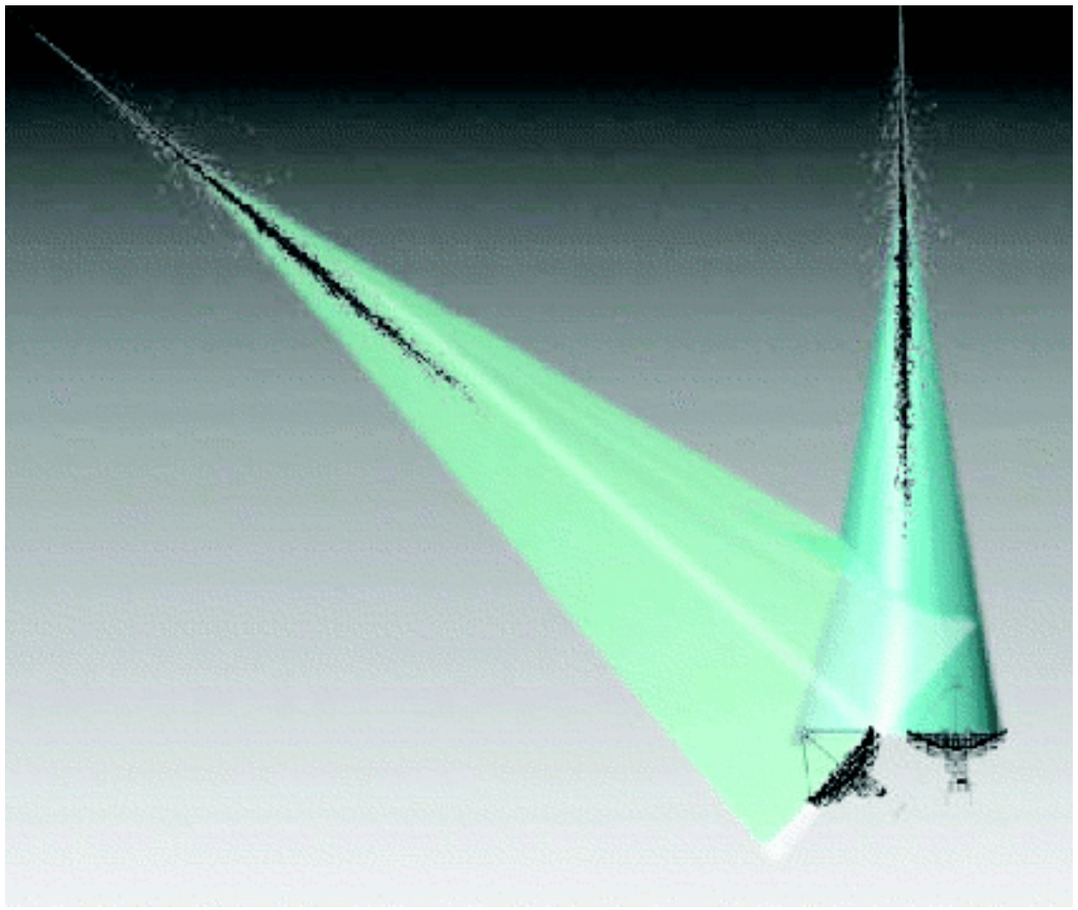
PAMELA

$e^-, e^+, p, \bar{p}$

AMS

Gamma-Ray Detection





- Both space-based and ground-based instruments use electromagnetic calorimeters, but for ground-based instruments the earth's atmosphere is basically a continuous 27 rad. length total absorption calorimeter, viewed with an array of telescopes.

VERITAS Array

- First Light in April 2007

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- *10 mCrab sensitivity* - 5σ detection at 1% Crab (2x10^{-13} erg cm^{-2} s^{-1} @ 1 TeV) in 28 hrs.
- *Effective area 10^5 m^2* above 500 GeV
- *Angular resolution <0.1 deg*
- *Energy range 150 GeV - 30 TeV, 15% resolution* (for spectral measurements)

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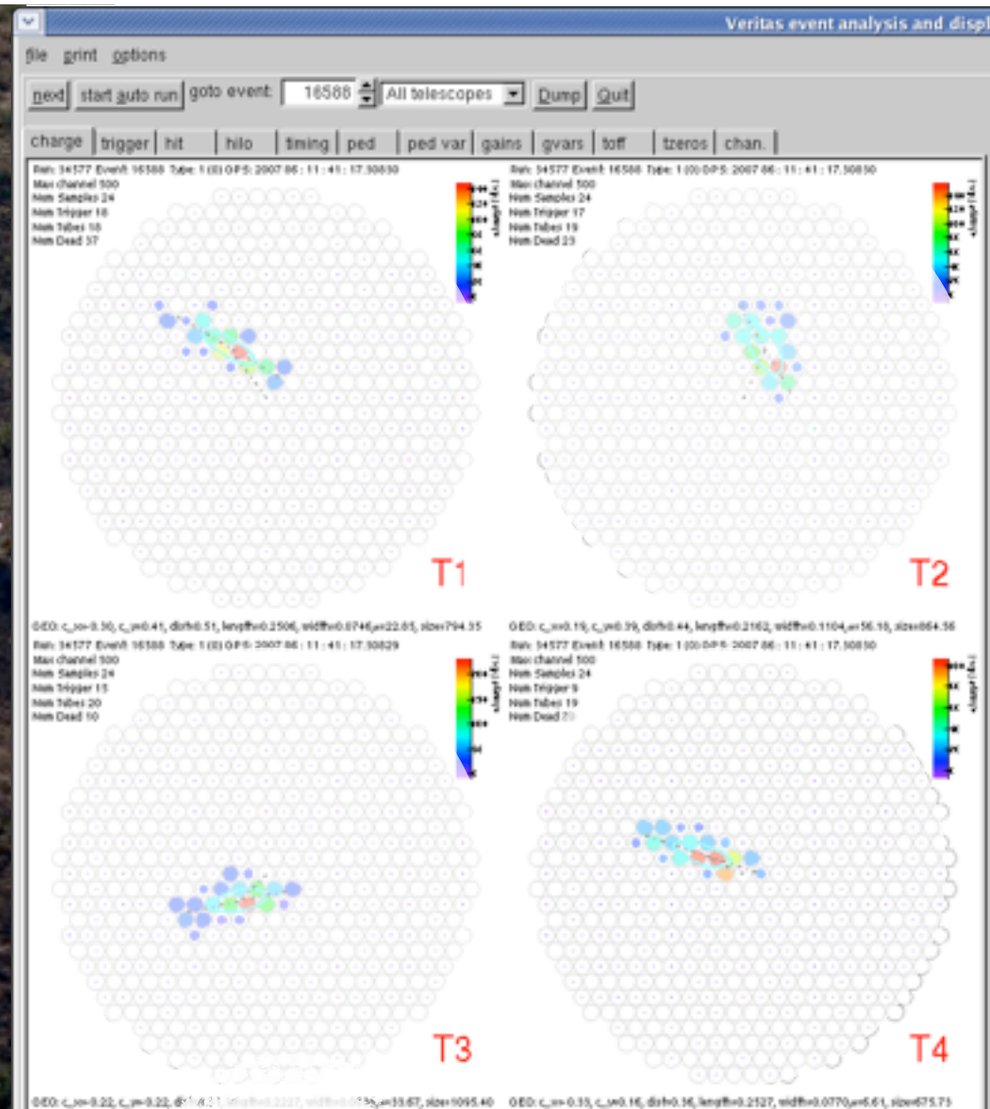

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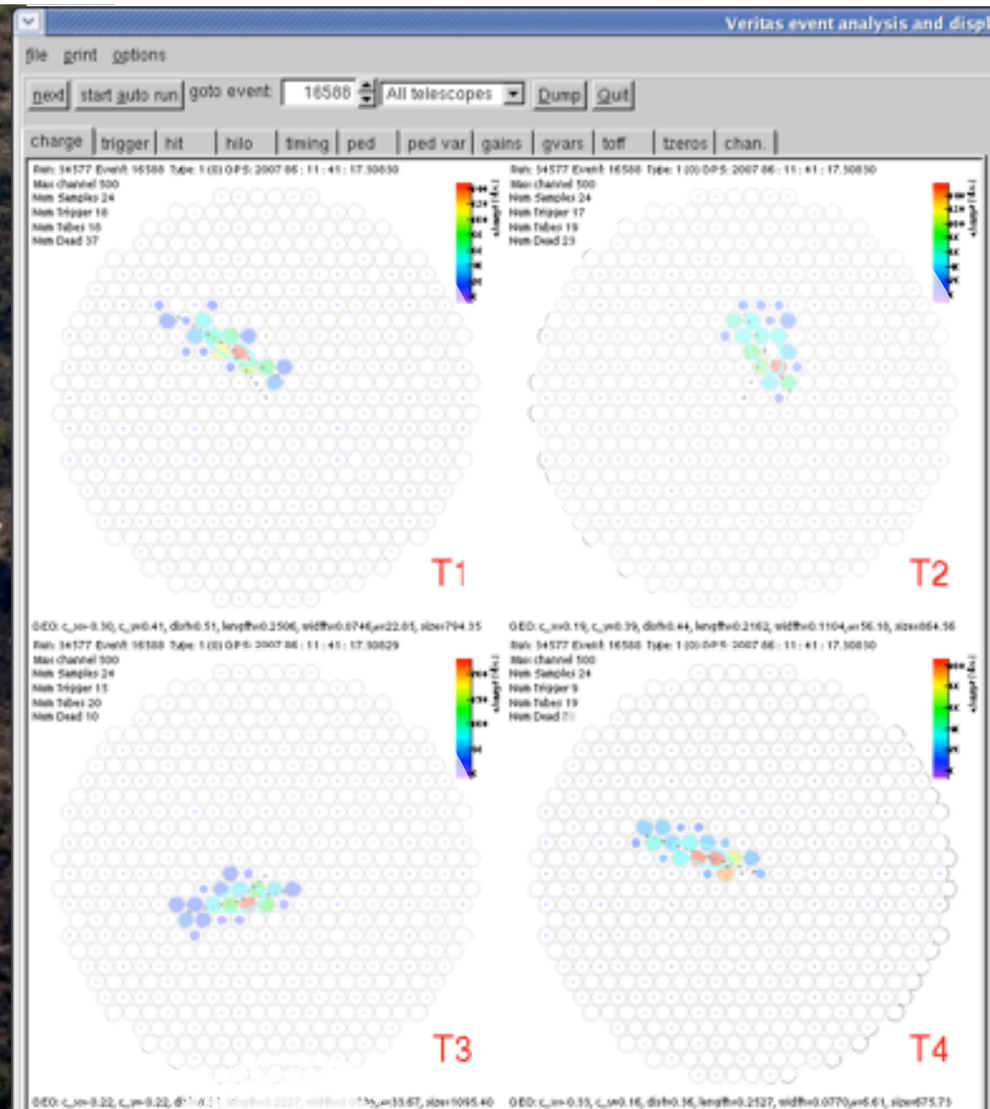

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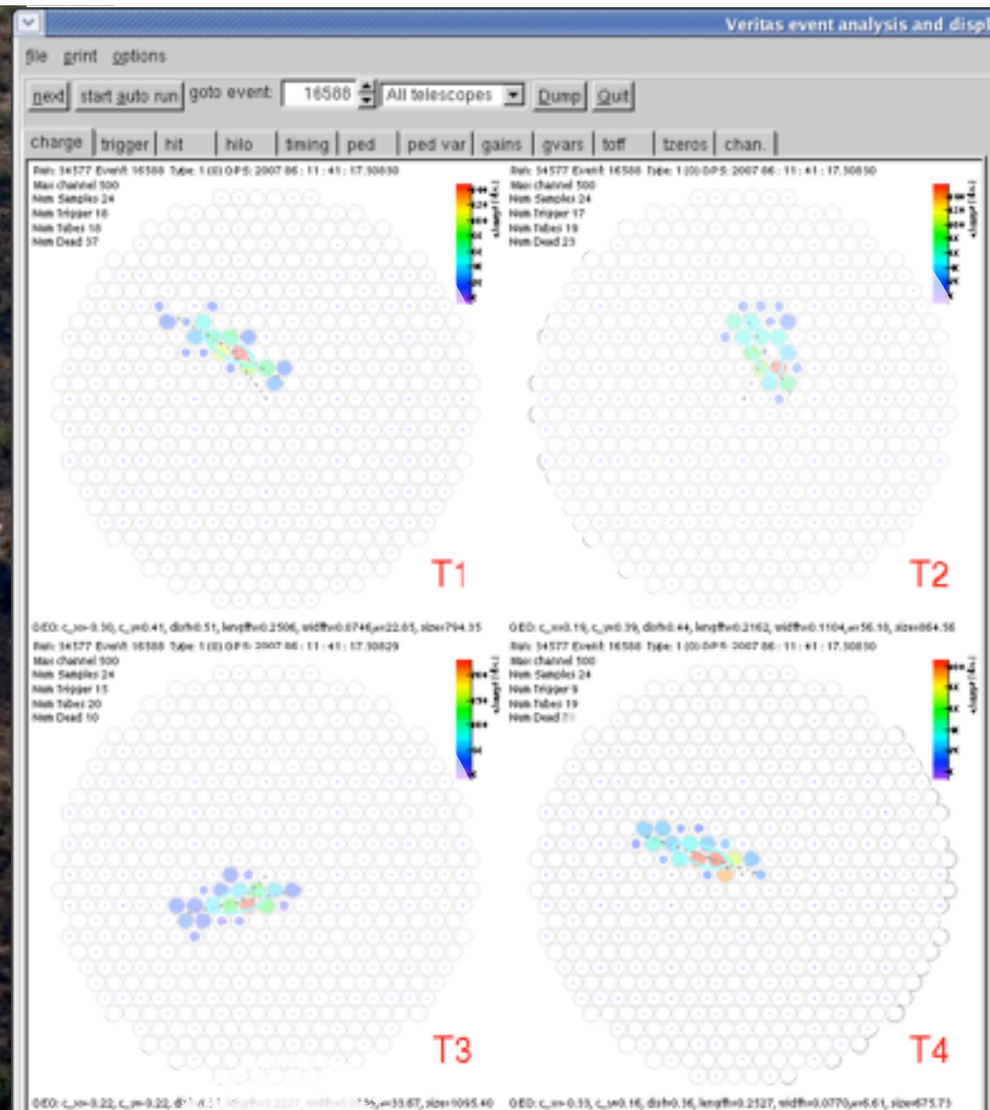

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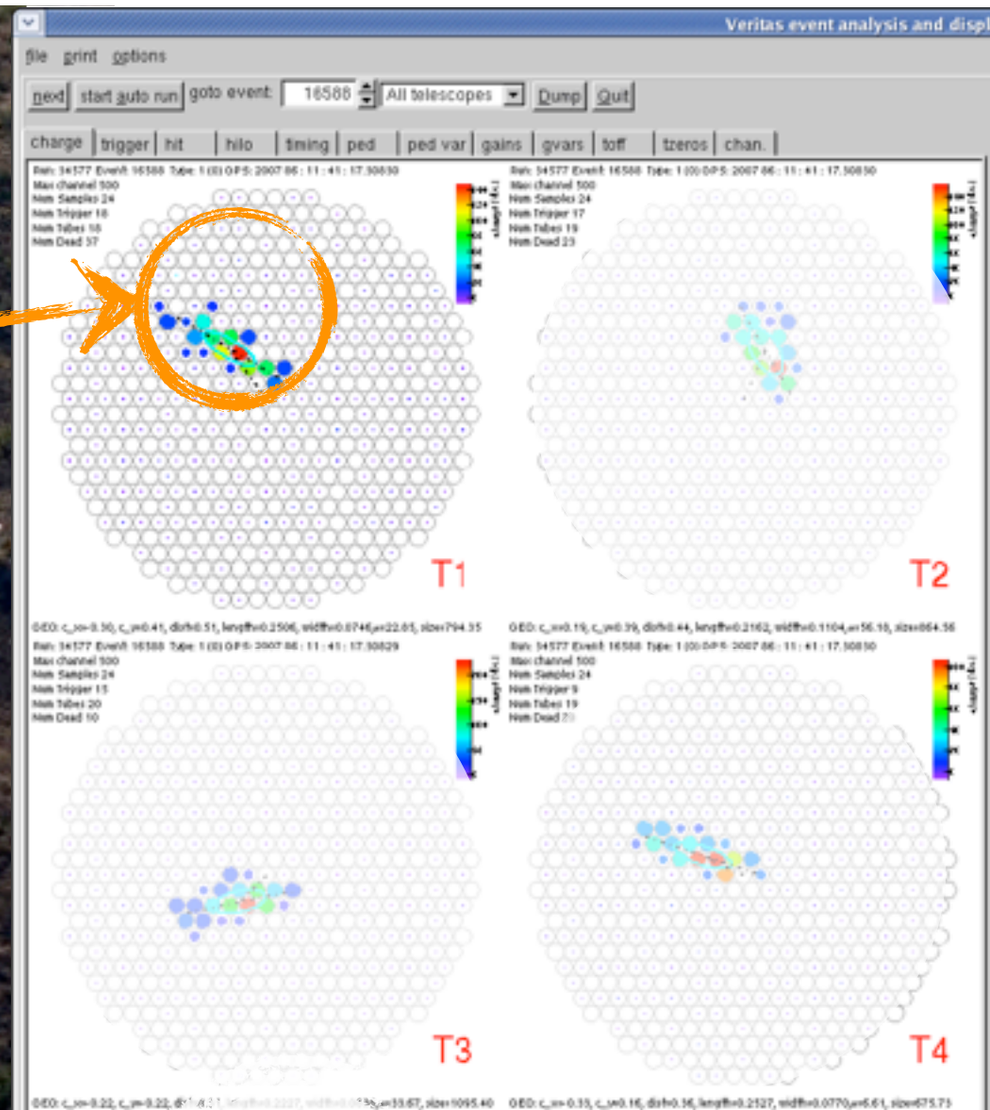

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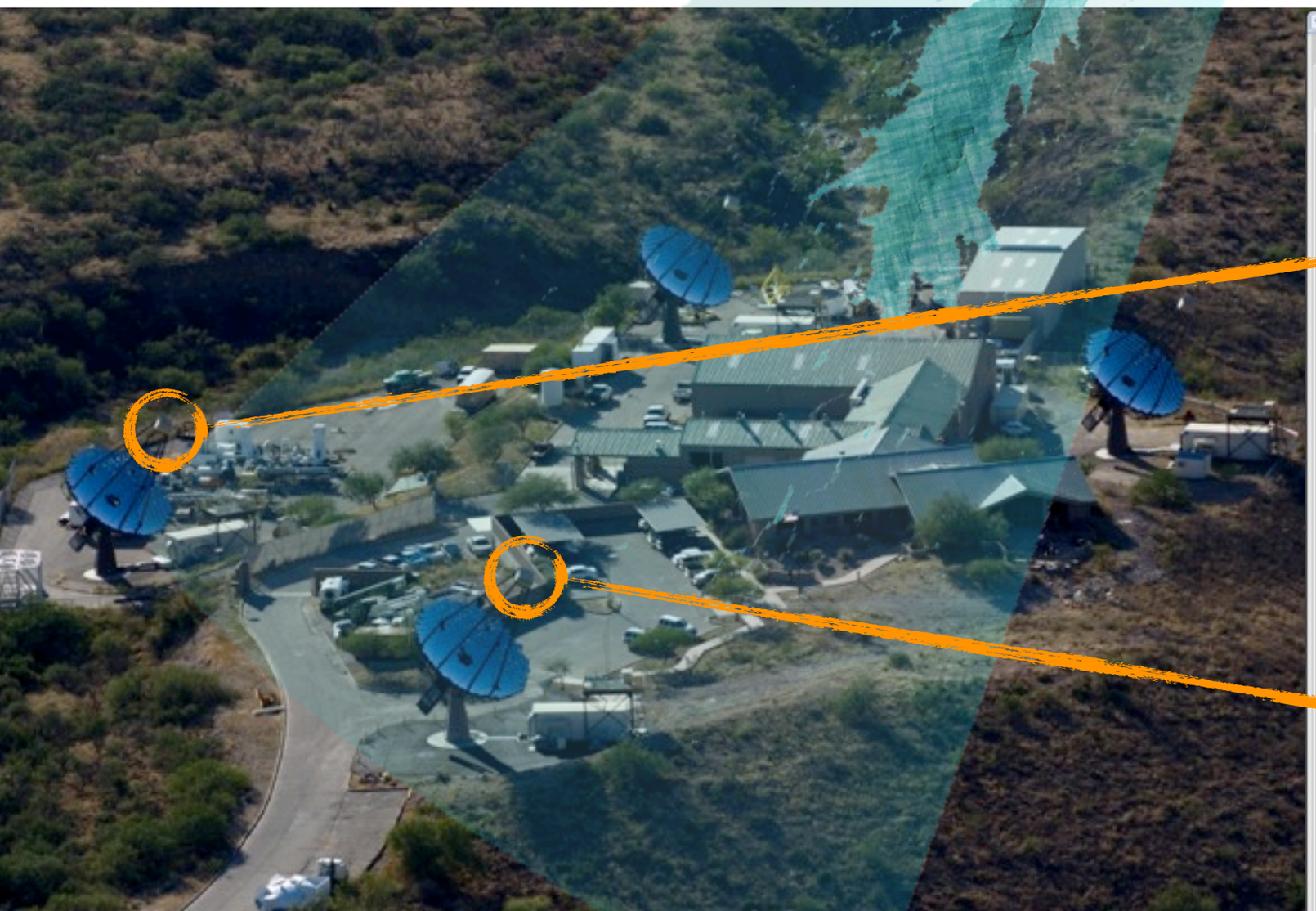

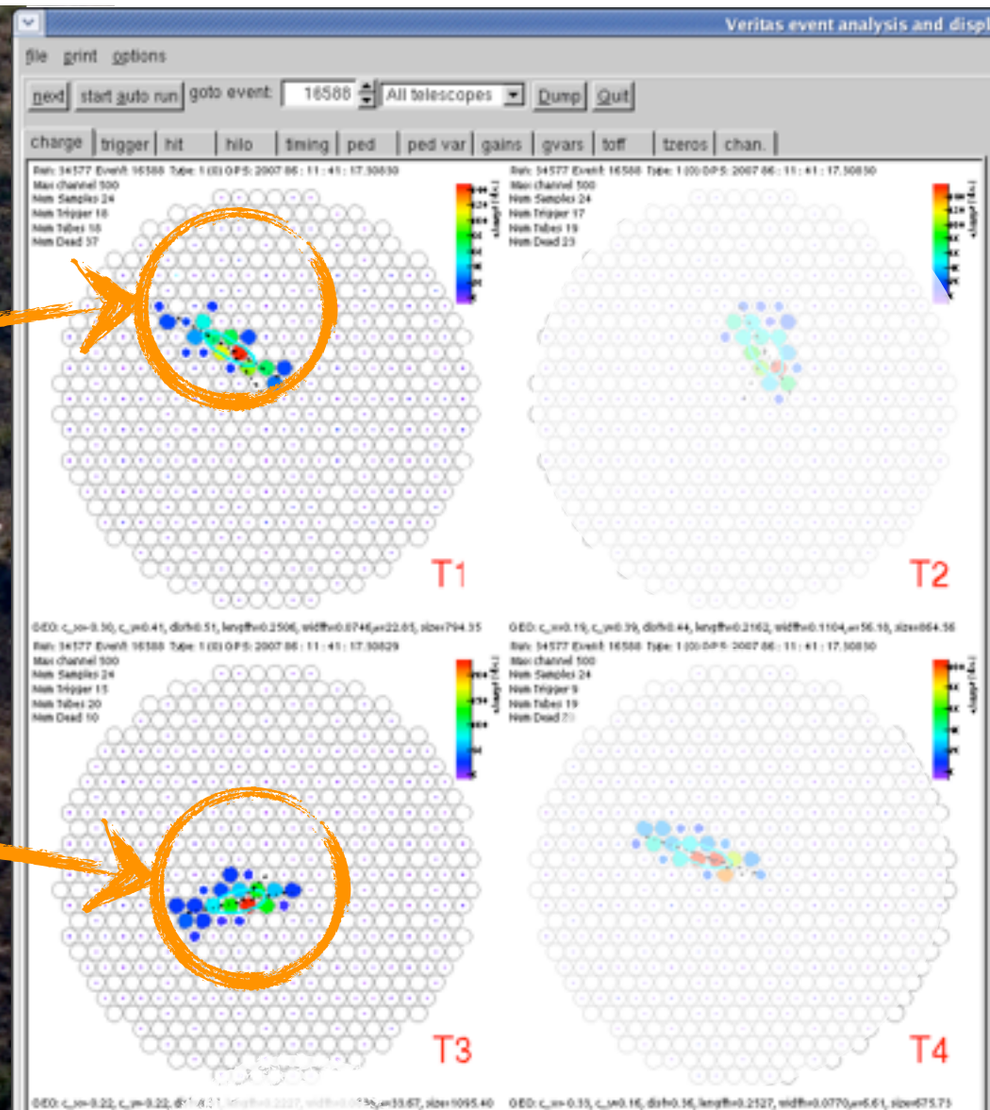

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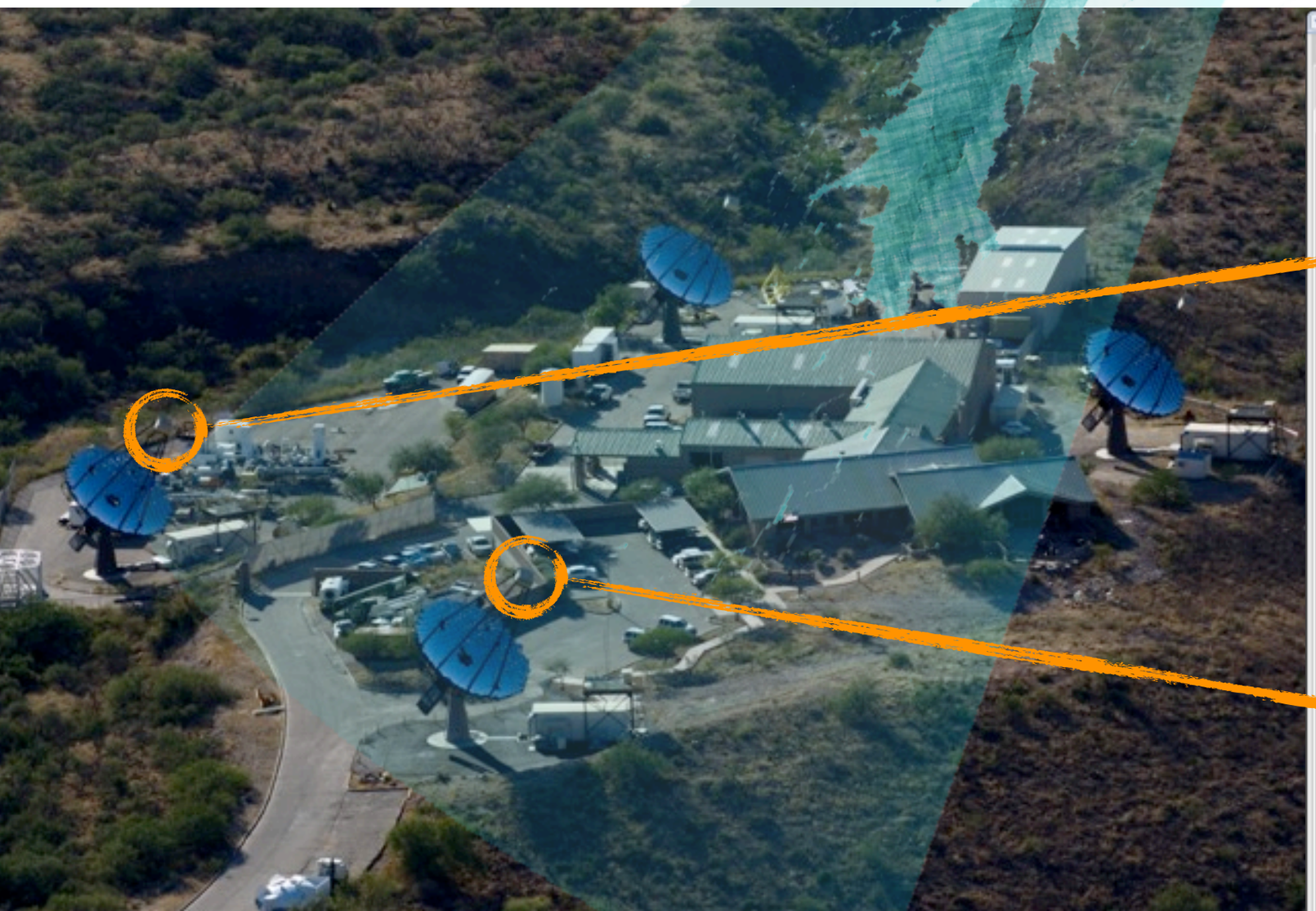

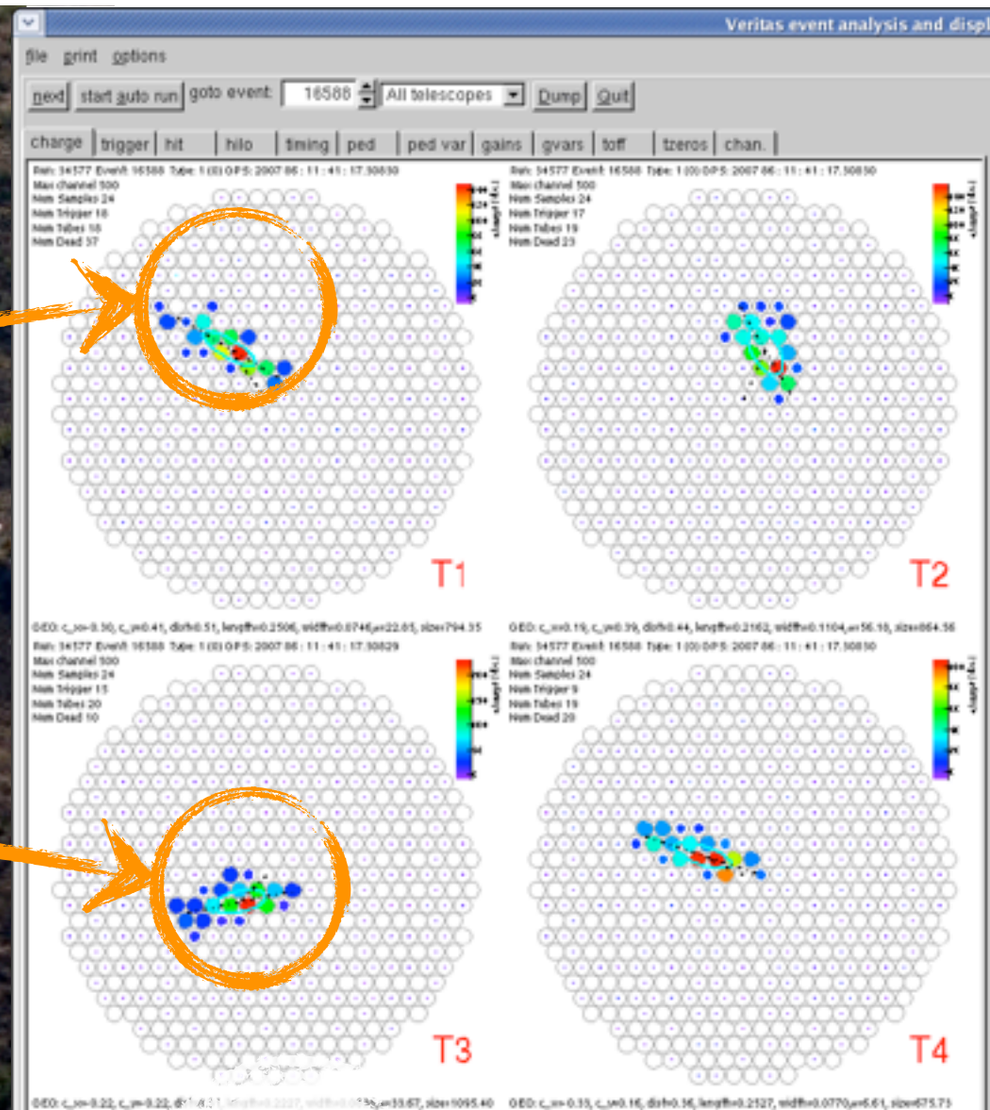

Technical Details

Telescope (x 4)

12-m diameter Davies-Cotton
f 1.0, 110 m2 area

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499 PMTs, 3.5º FOV

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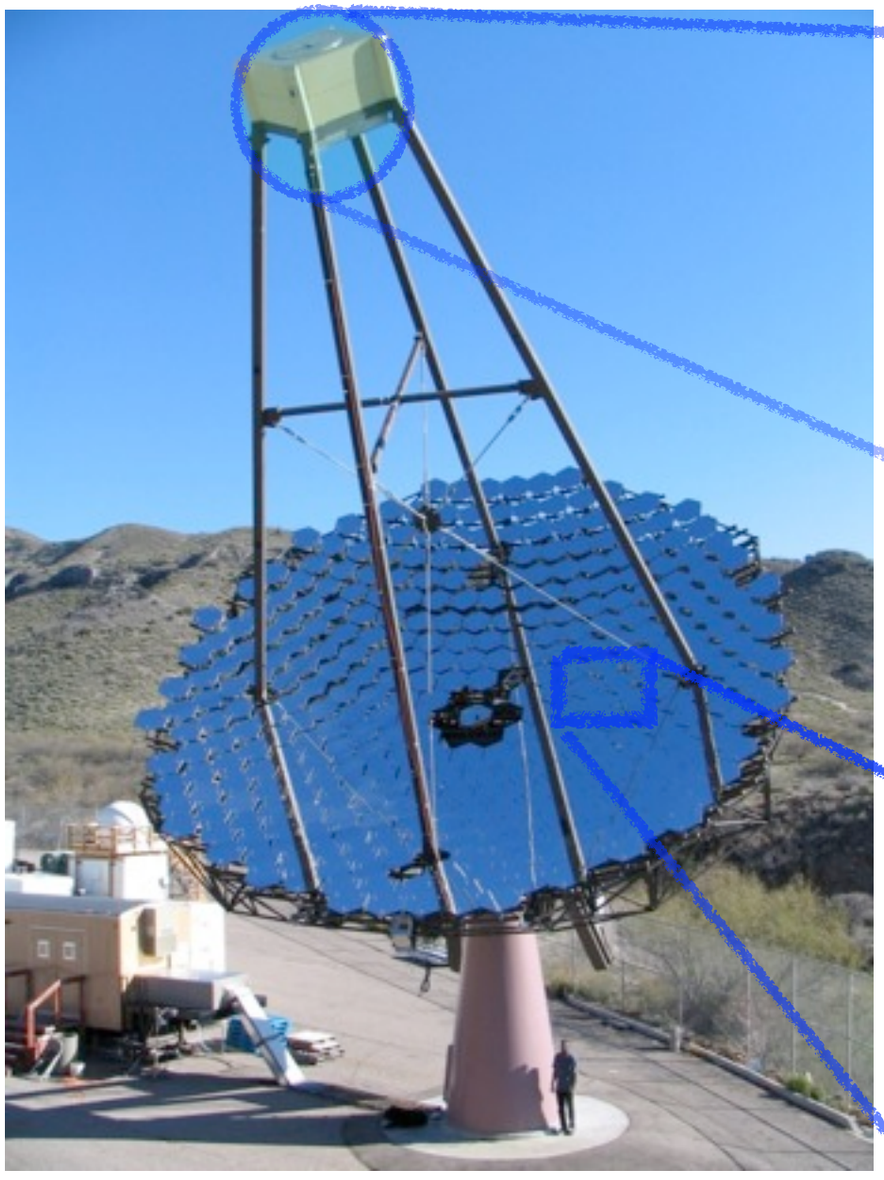

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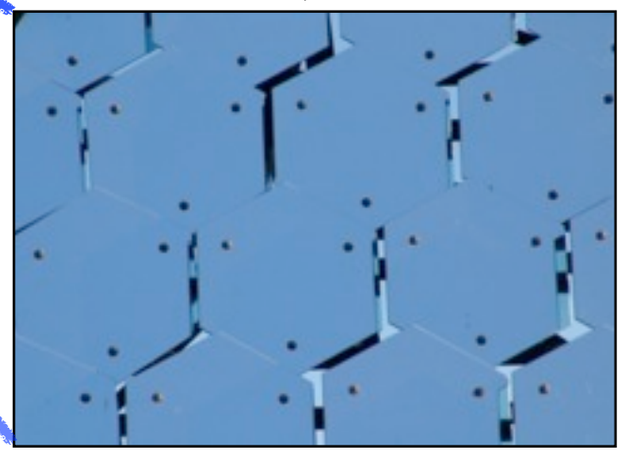

Mirror Facets (x 350)

Reflectivity ~ 88%
(Recoated every 2 years)

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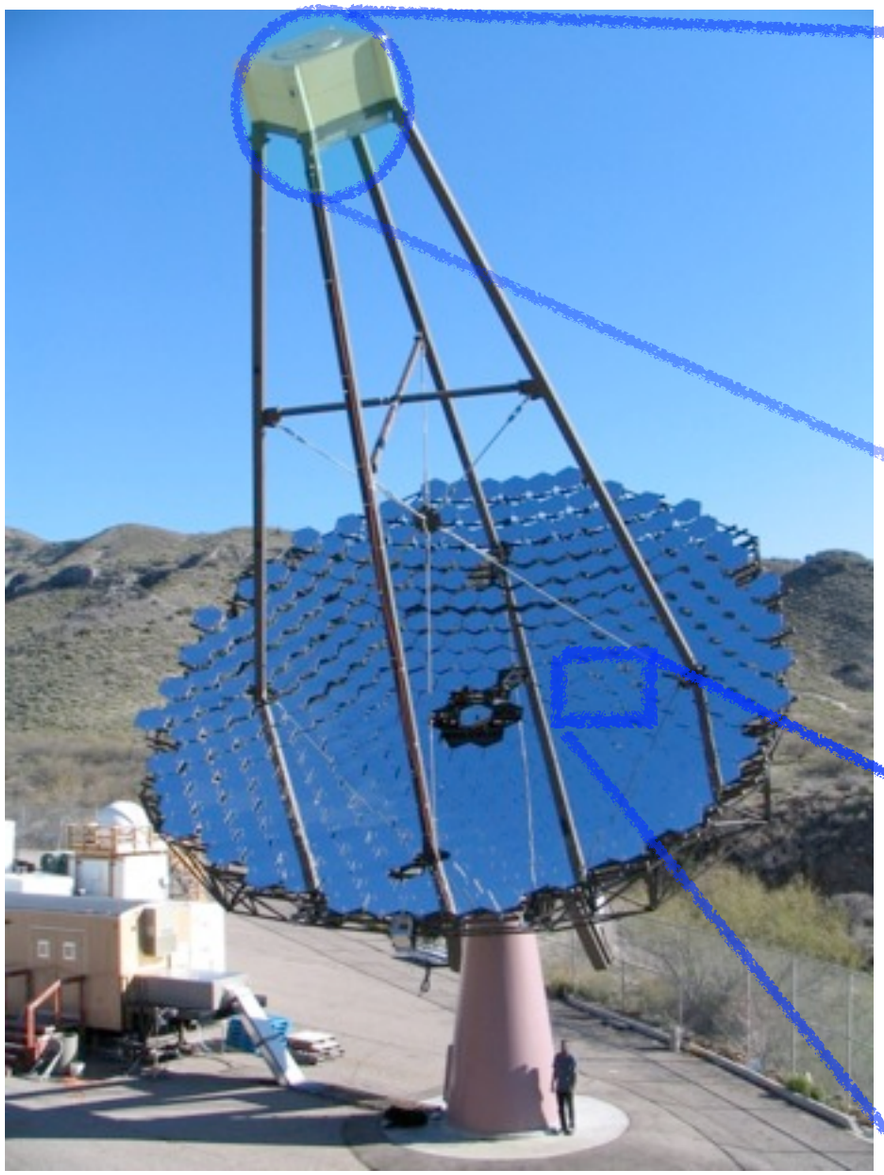

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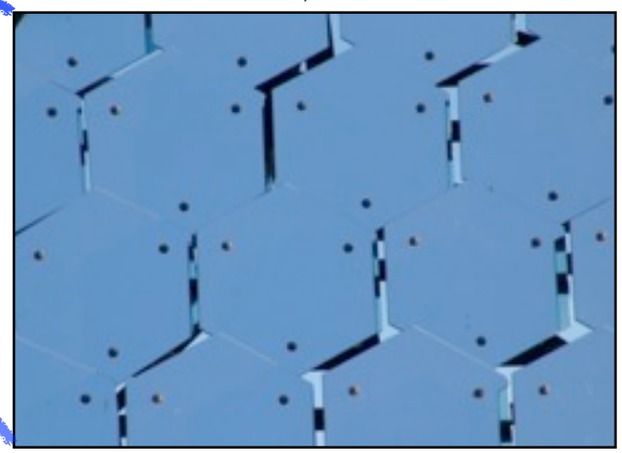

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Electronics

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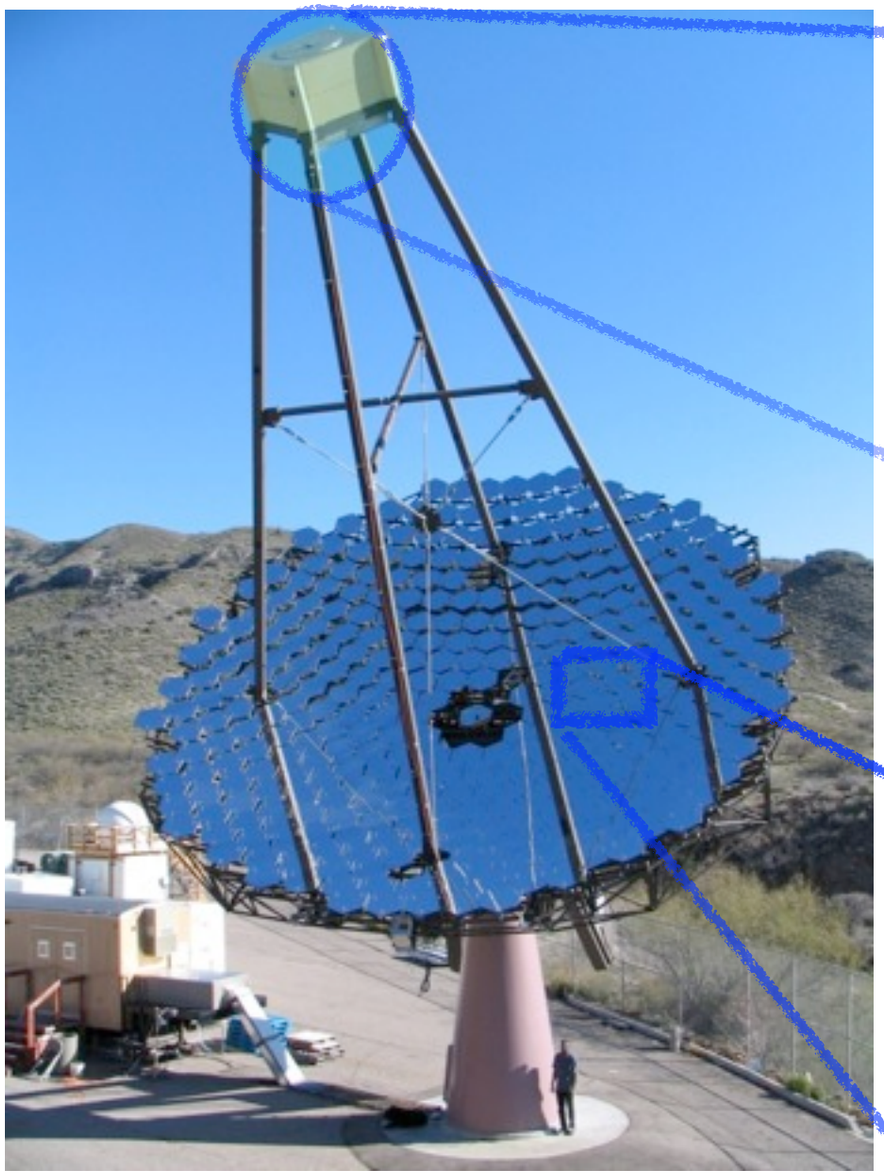

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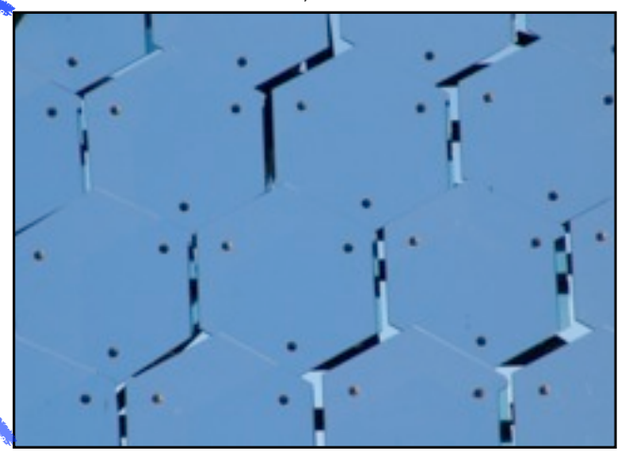

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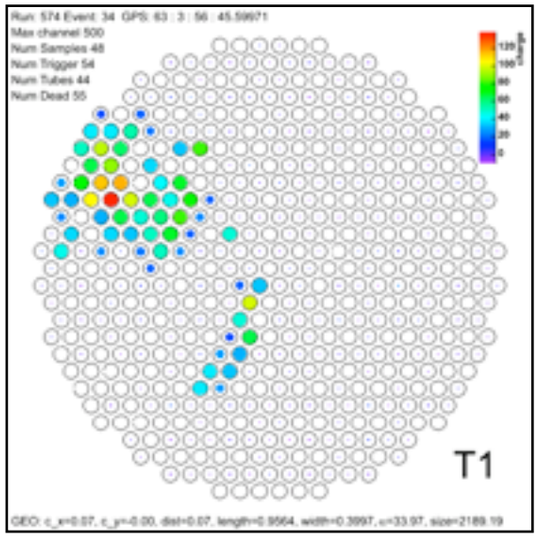

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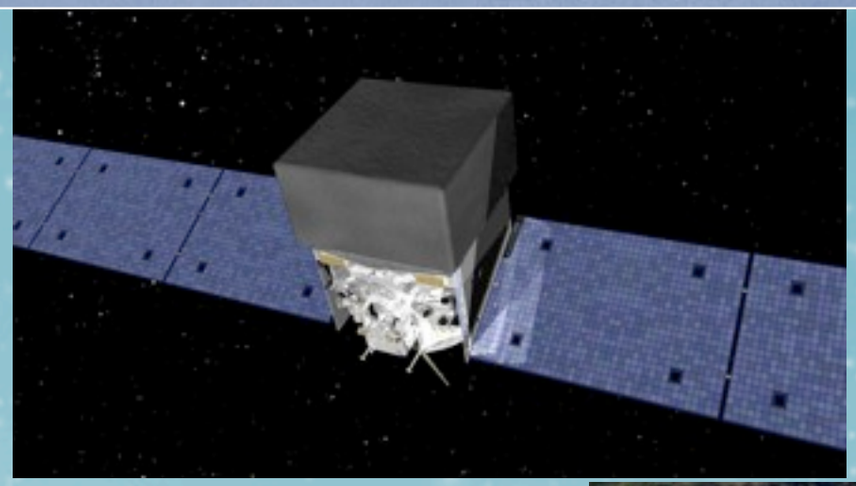
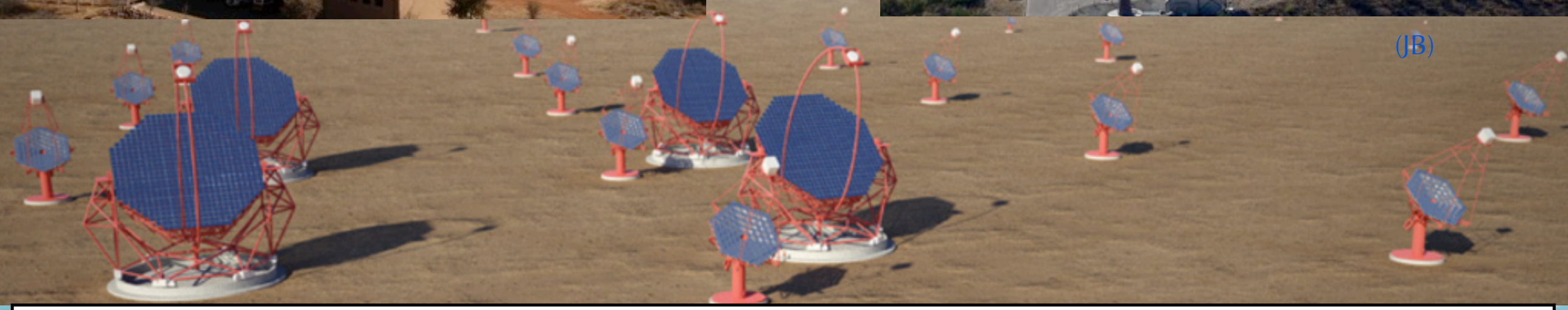
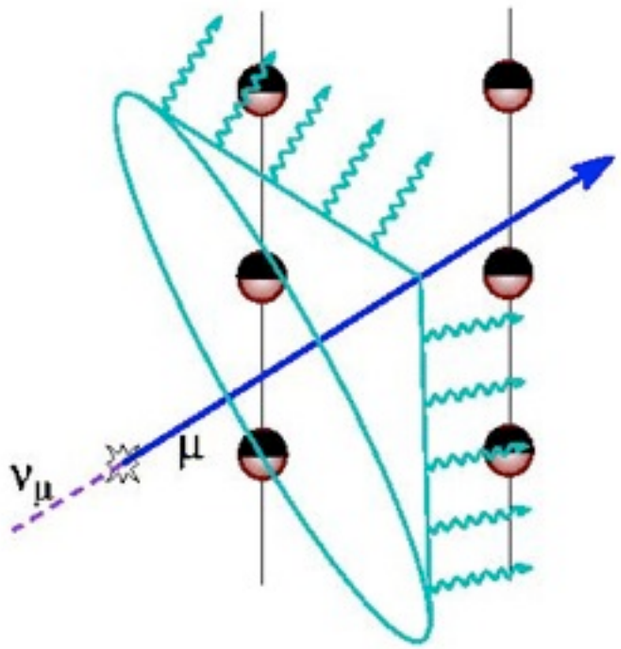
Gamma-Ray Instruments

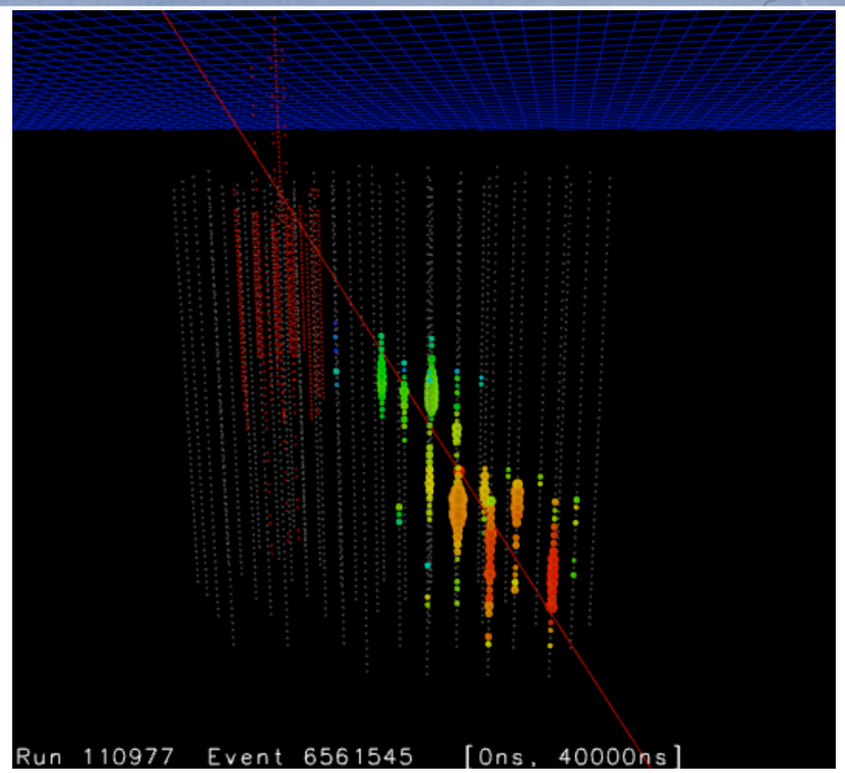




(JB)

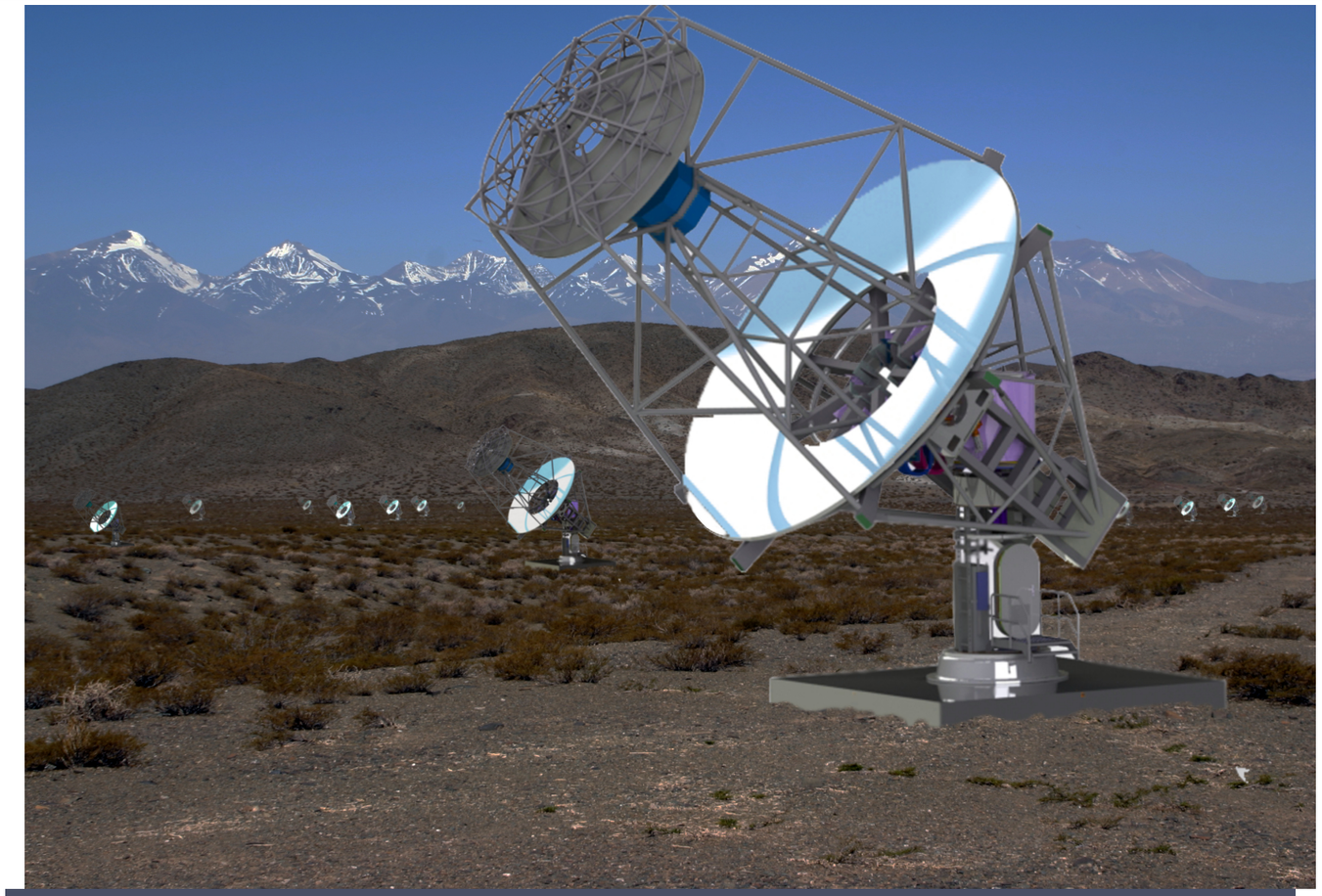
Neutrino Detection

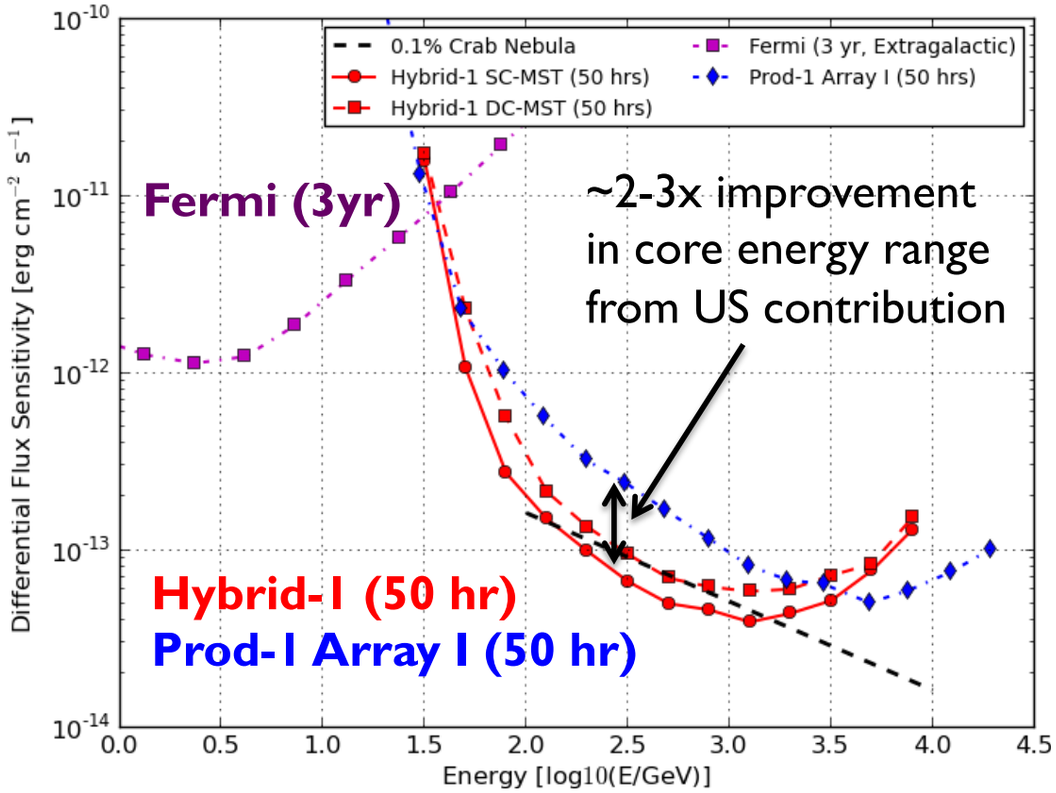




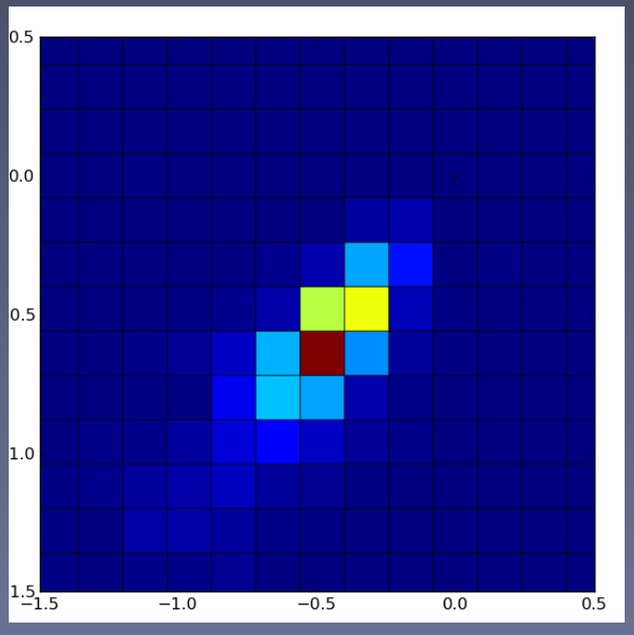
(simulated neutrino event in ICECUBE)

CTA-US

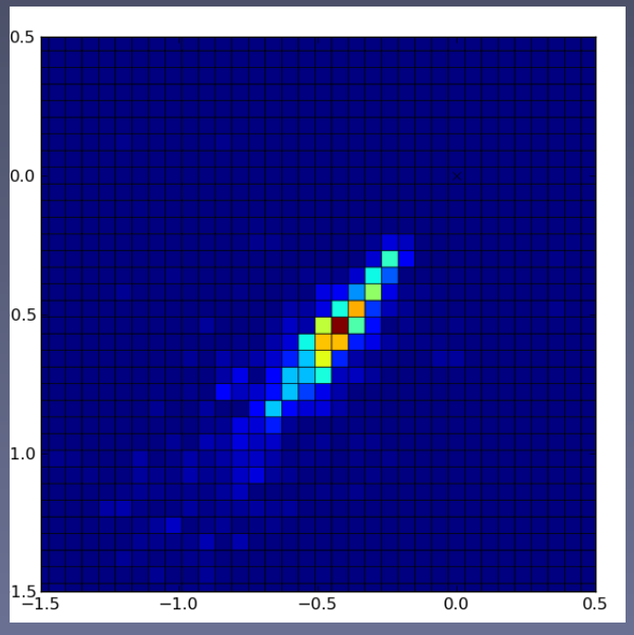


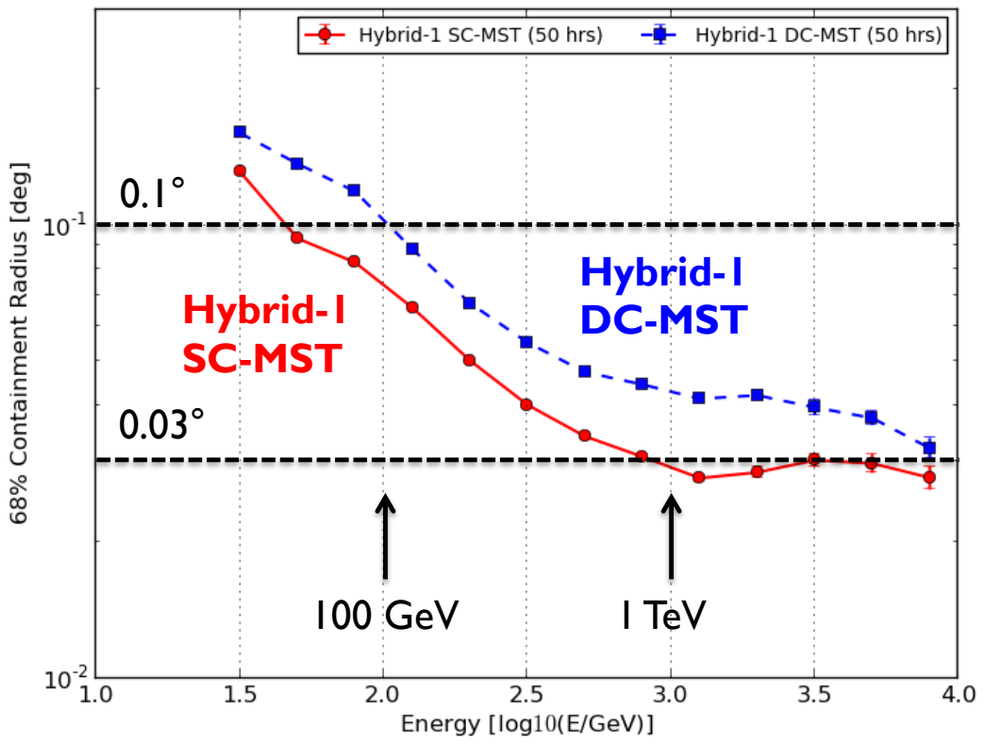


DC-MST (Single Mirror)

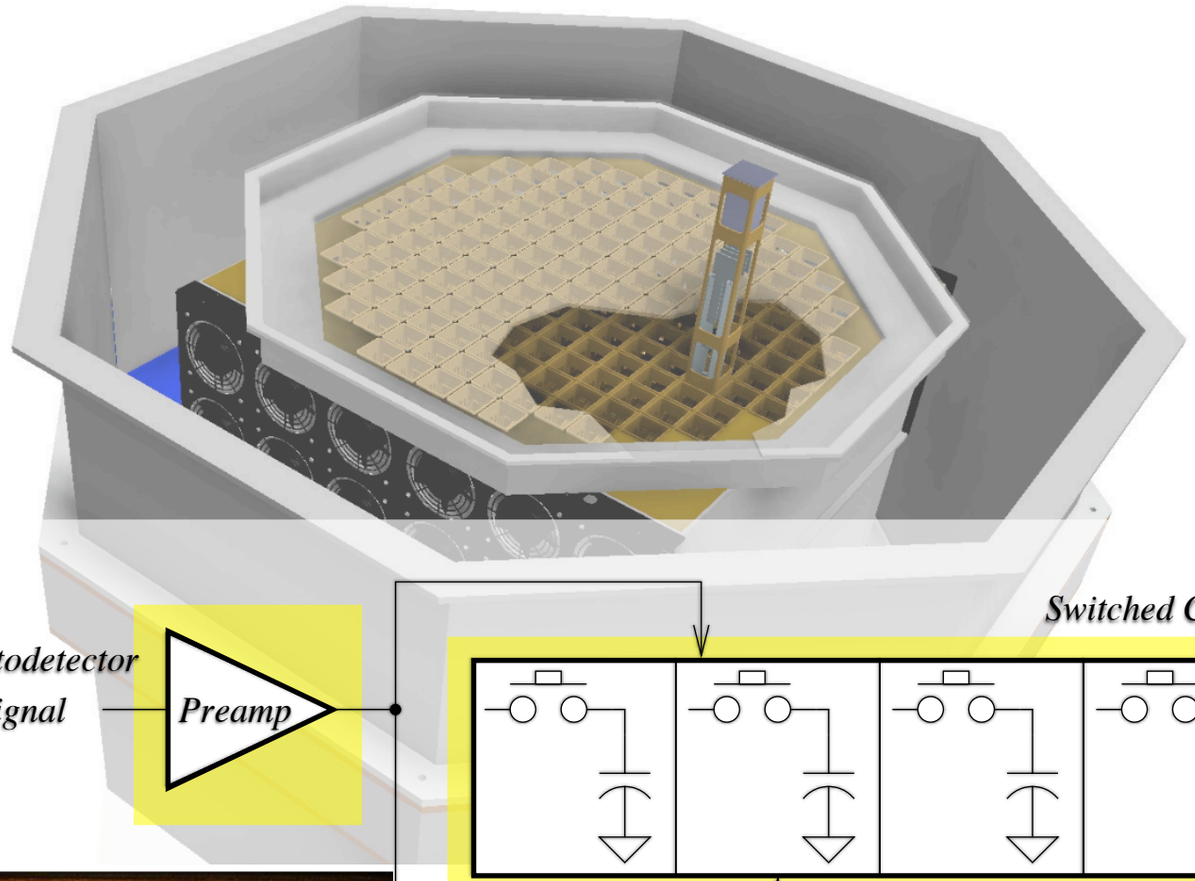


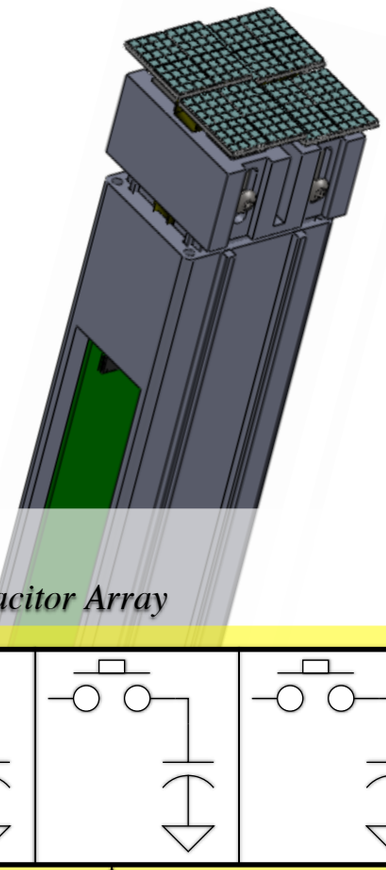
SC-MST (Dual Mirror)

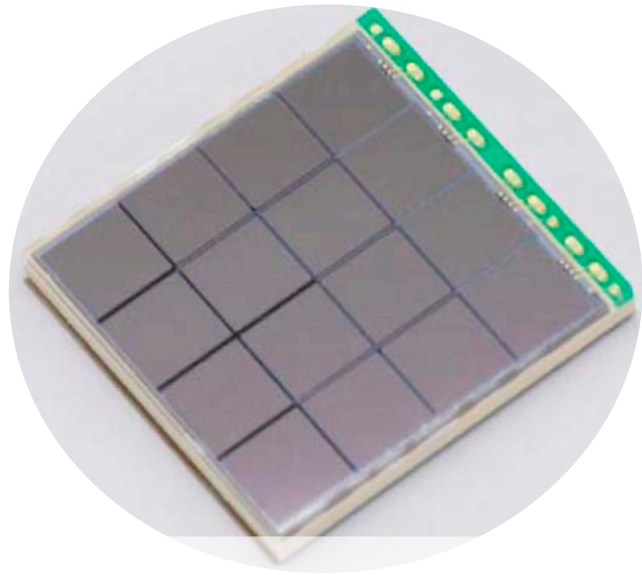


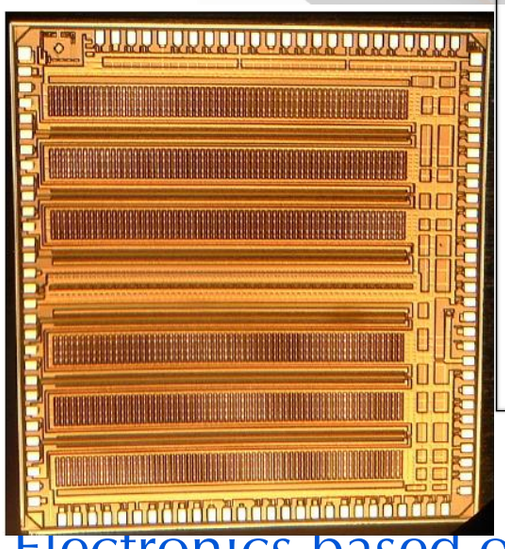


CTA Camera





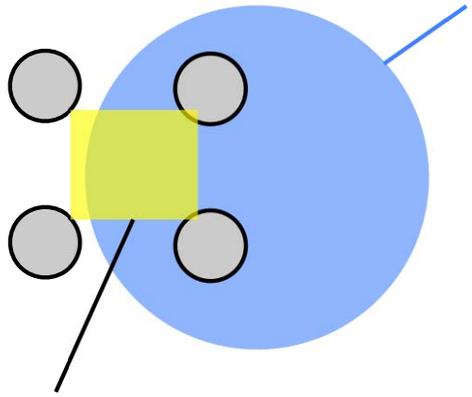




Electronics based on TARGET were developed by SLAC and U. Hawaii

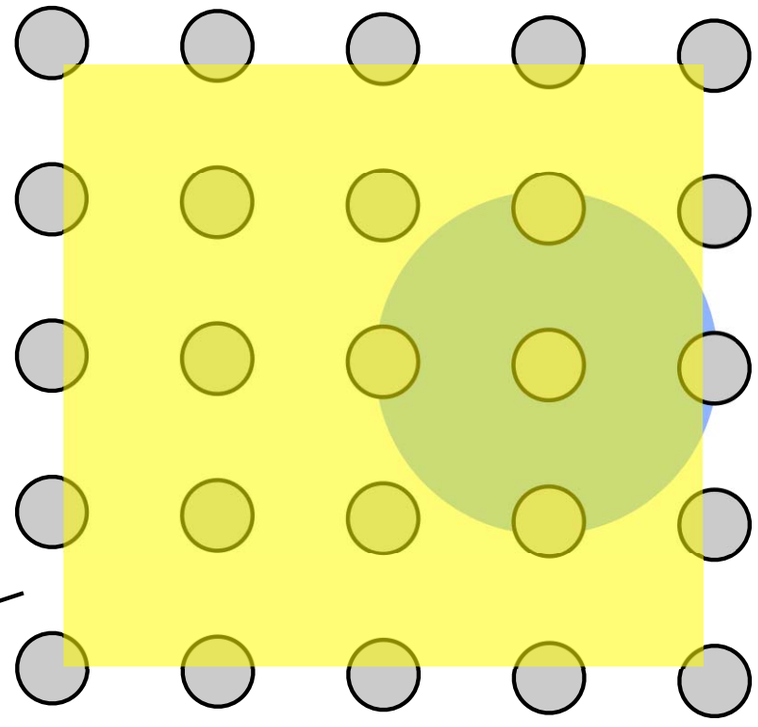
Contained Events

From current arrays to CTA



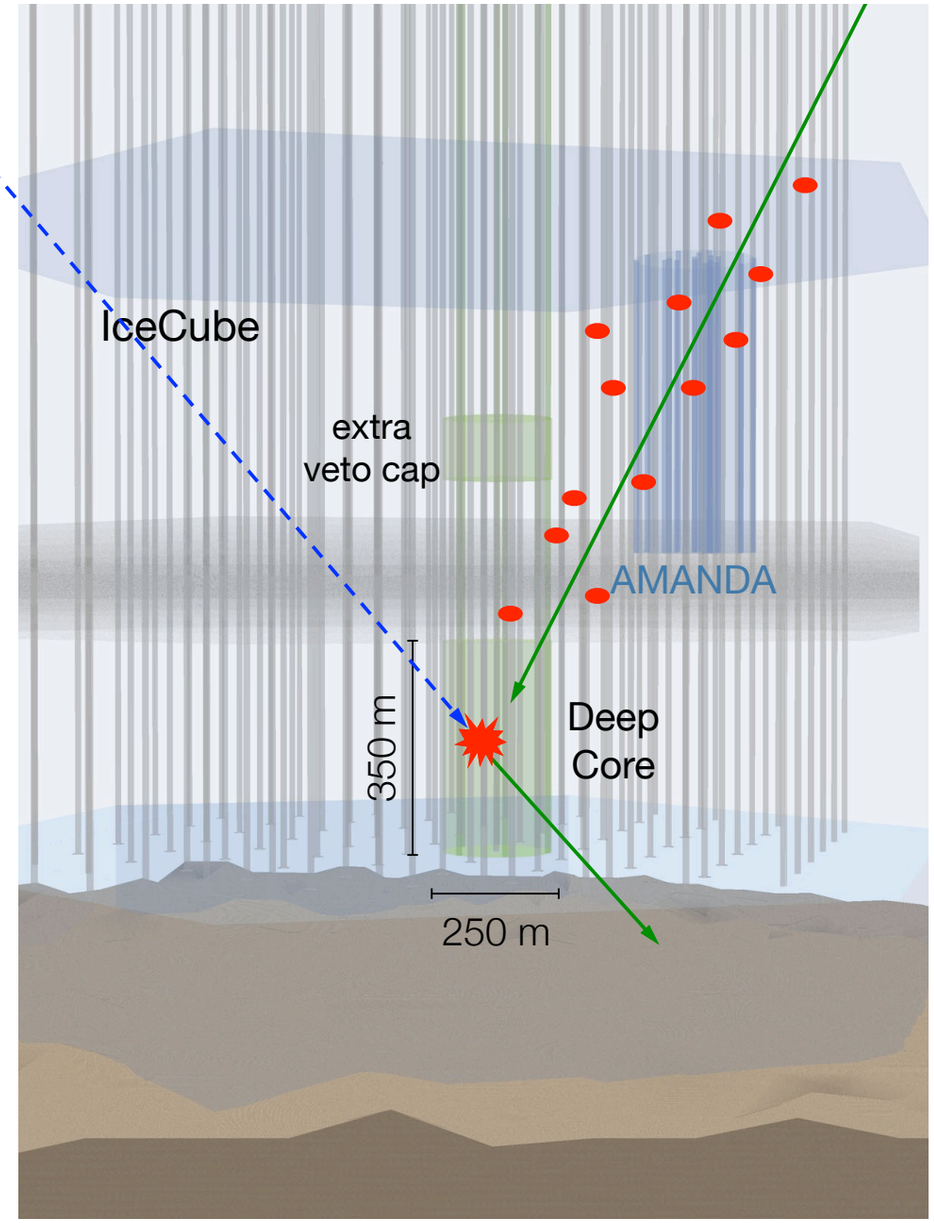
Light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
Most shower cores miss it!

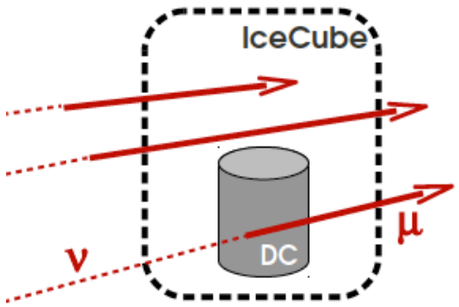


Large detection area
More images per shower
Lower trigger threshold

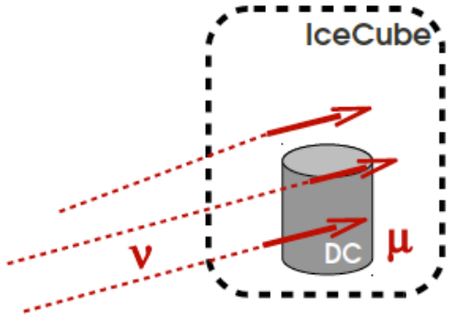
Contained Events



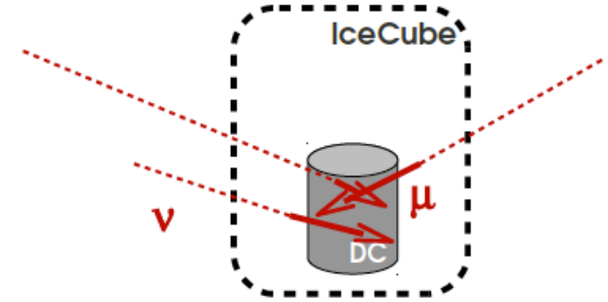
- Up-going ①
- No containment



- Up-going ②
- strong containment



- Down-going ③
- strong containment



Positron/Antiproton Detection

Schematic of HEAT

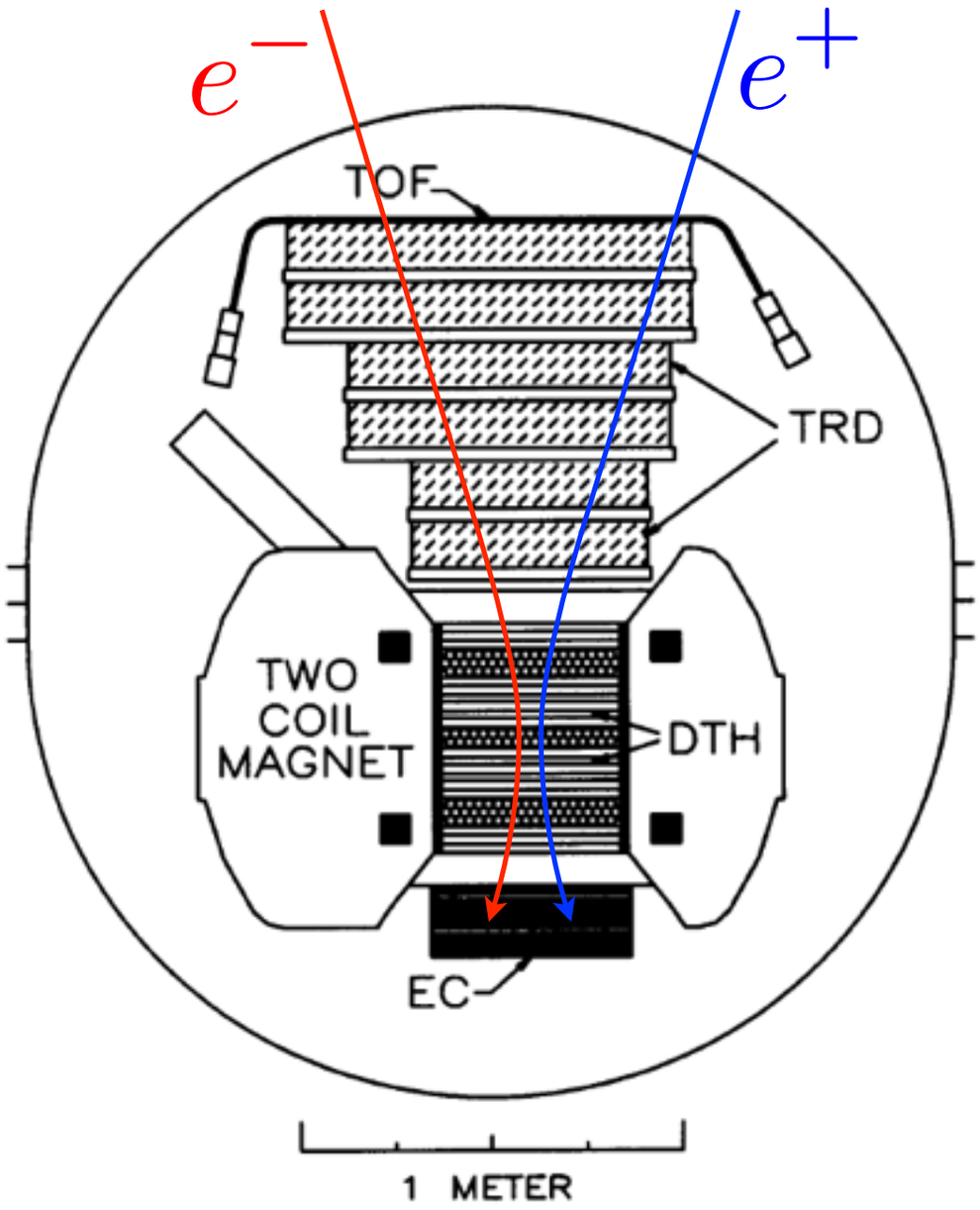


FIG. 2.—HEAT instrument schematic cross section

- Typical instruments include:
  - MS for measurement of momentum (rigidity)
  - EC for measurement of energy and for discrimination of hadronic showers
  - Redundant measurement of Lorentz factor (e.g., RICH or TRD) for particle discrimination against large background of protons.

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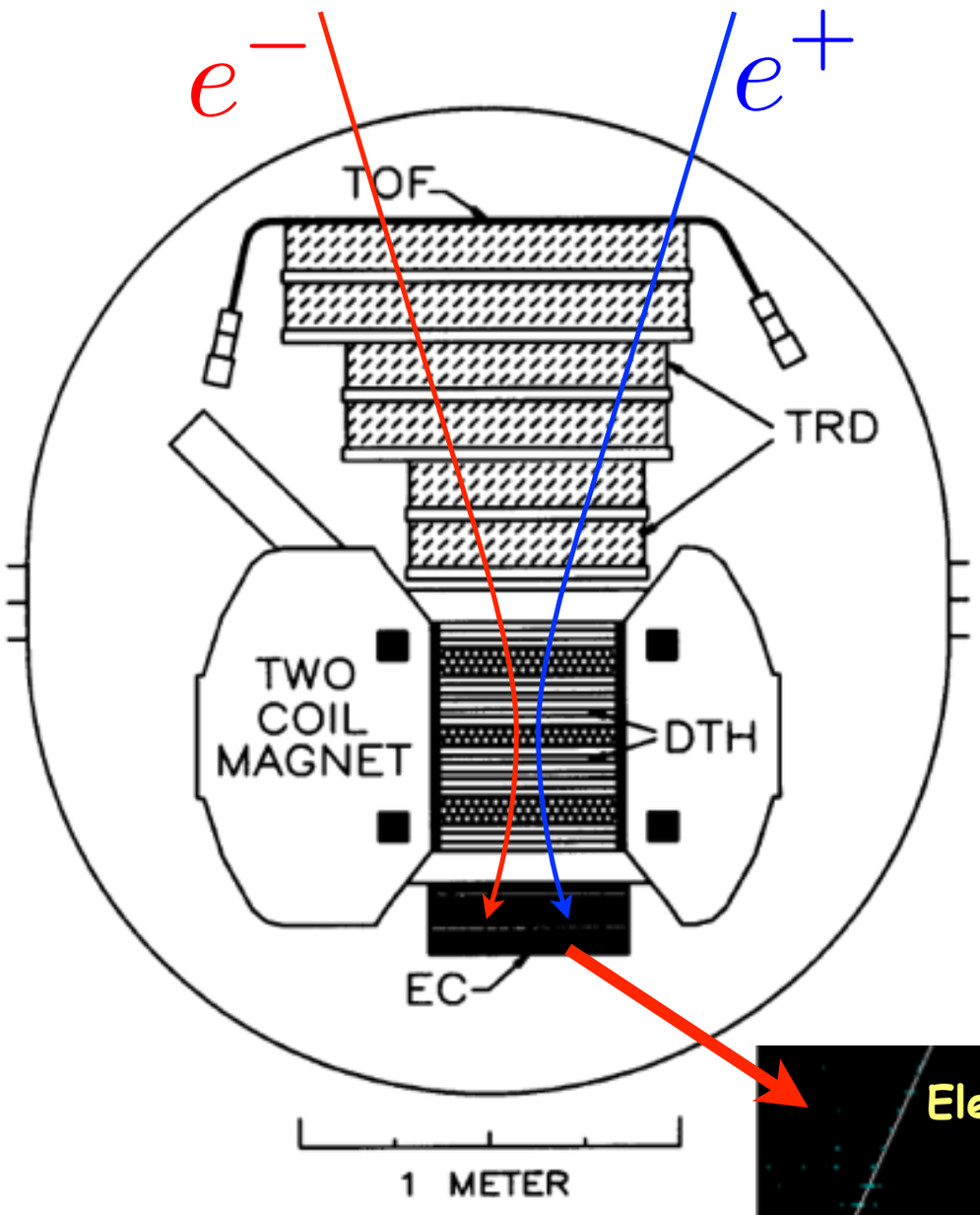

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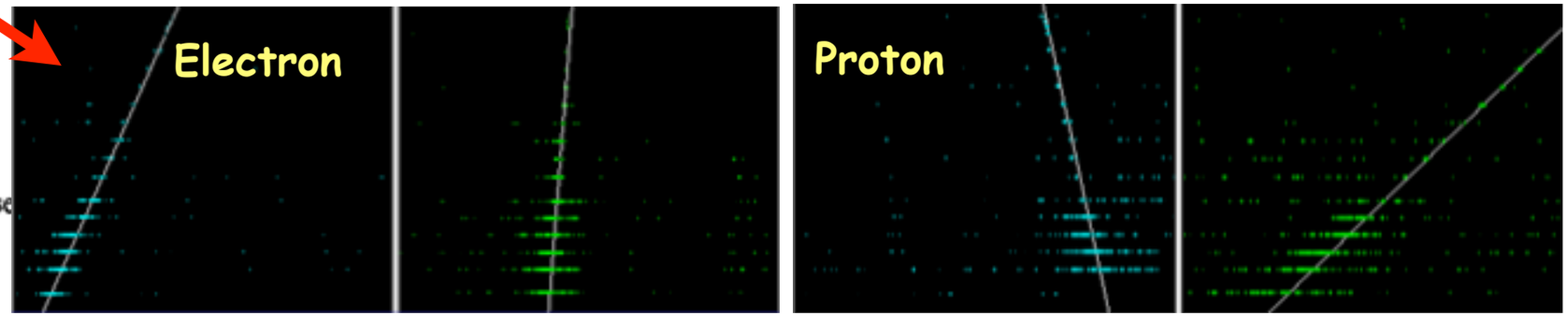
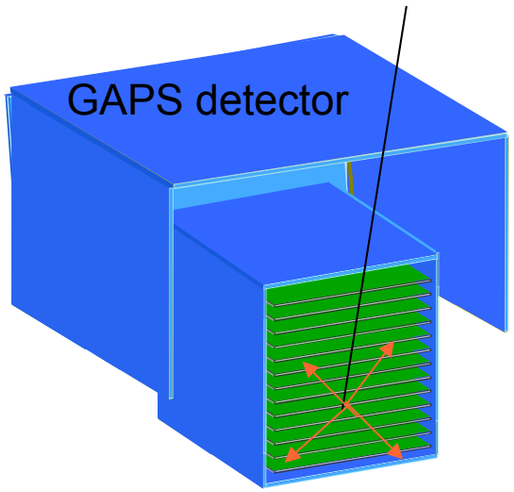
(BETS-Tori, et. al.)

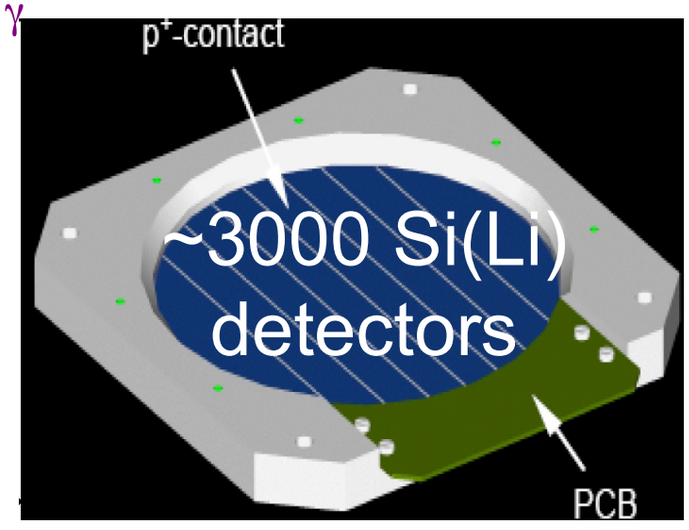


GAPS

Novel approach for antideuteron identification

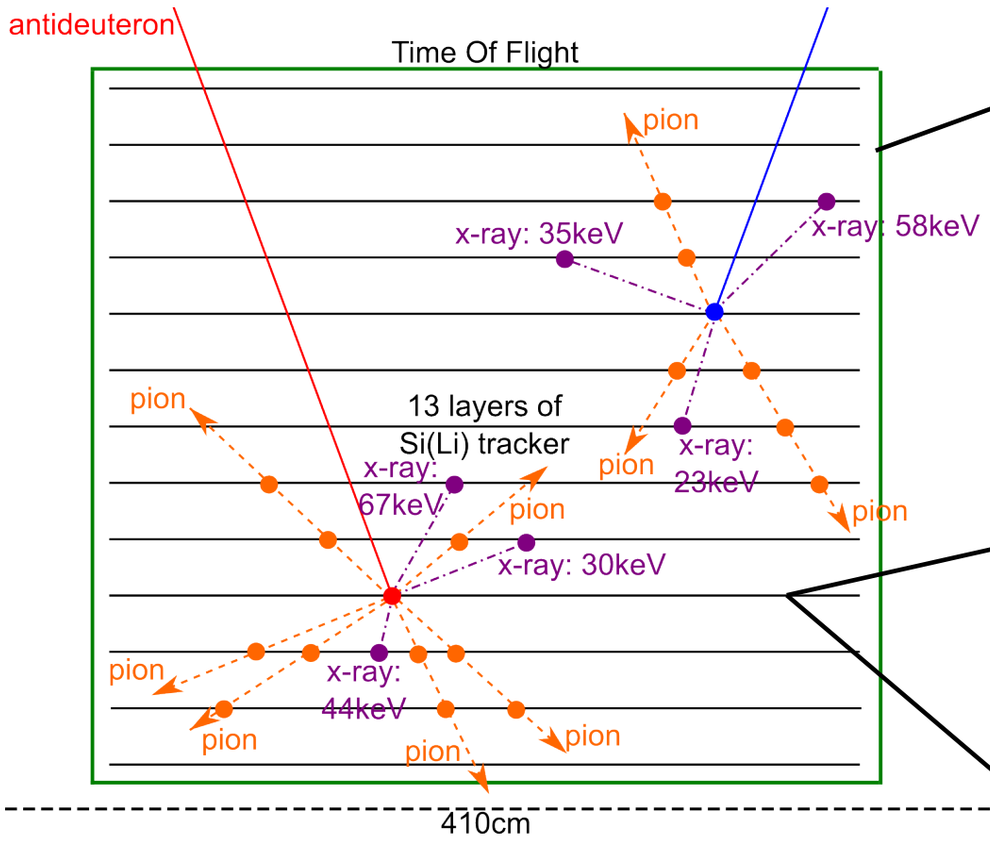
- antideuteron slows down and stops in material
- large chance for creation of an excited exotic atom (E_{kin}~E_I)
- deexcitation:
  - fast ionisation of bound electrons (Auger)
    → complete depletion of bound electrons
  - Hydrogen-like exotic atom (nucleus+antideuteron) deexcites via **characteristic X-ray transitions**
- nucleus-antideuteron annihilation: **pions and protons**
- exotic atomic physics understood (tested in KEK 2004/5 testbeam)

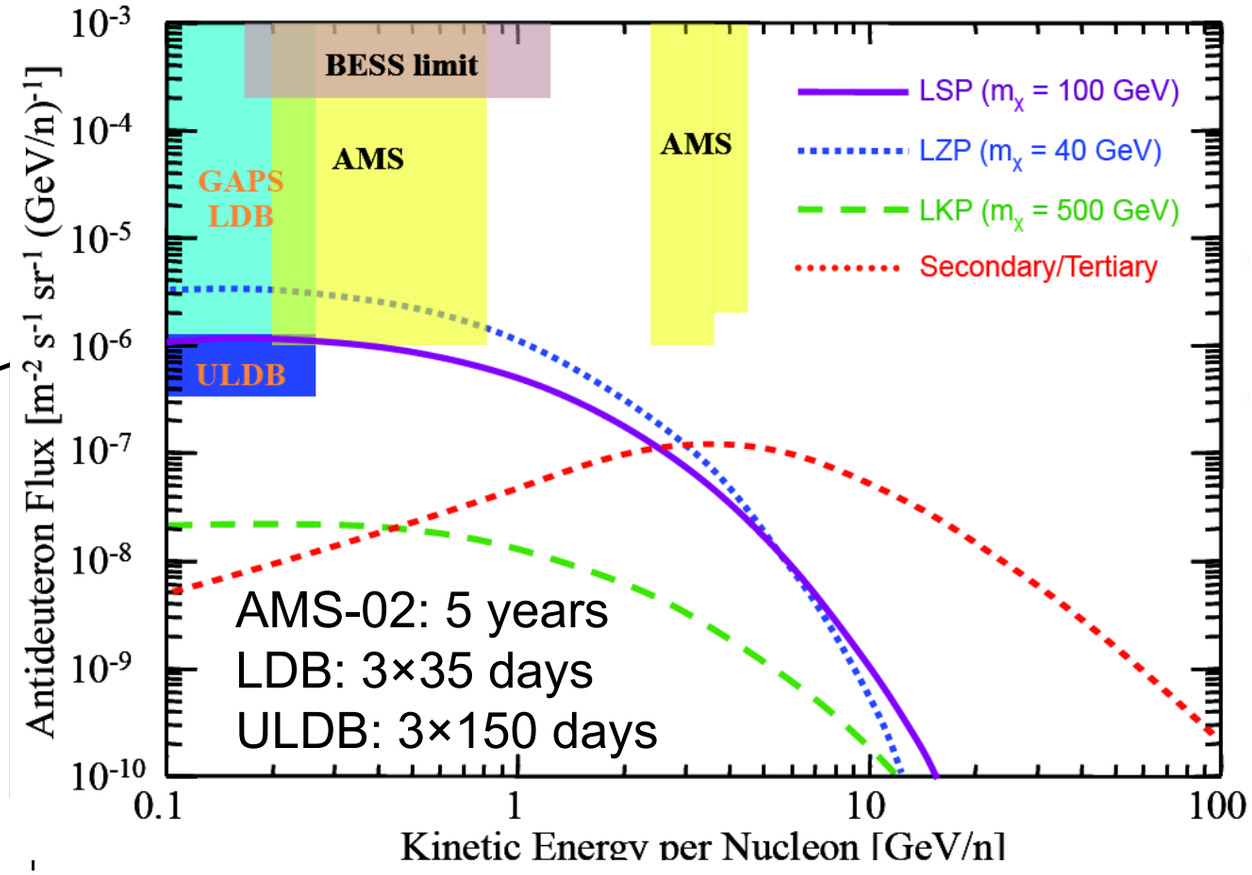


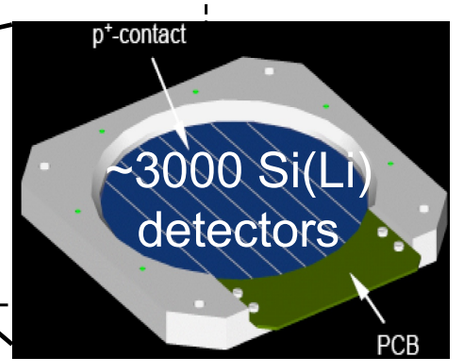


Antideuteron Measurements

(talk by P. von Doetinchem)

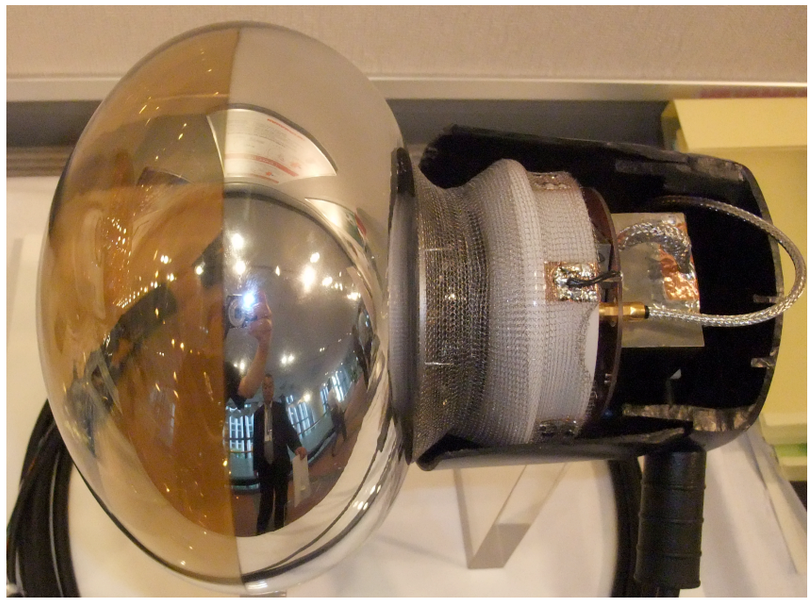




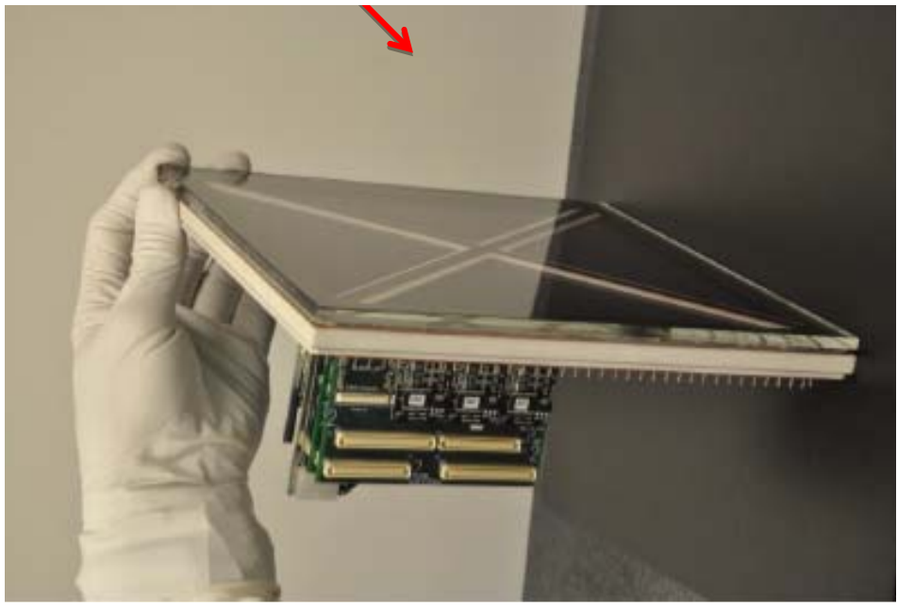


- GAPs looks for anti-deuterons (hard to produce as CR secondaries), uses TOF, X-rays from short-lived exotic atom, pion star from annihilation

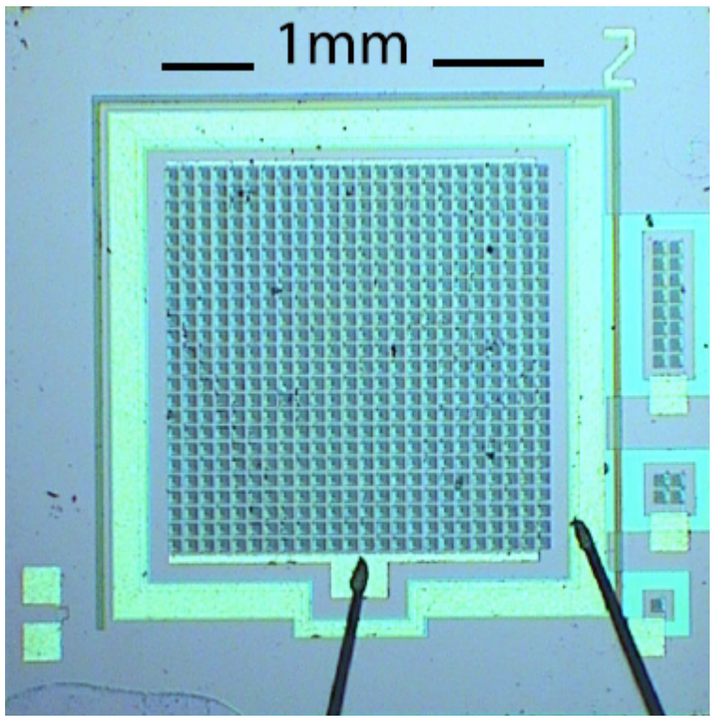
Technical Developments



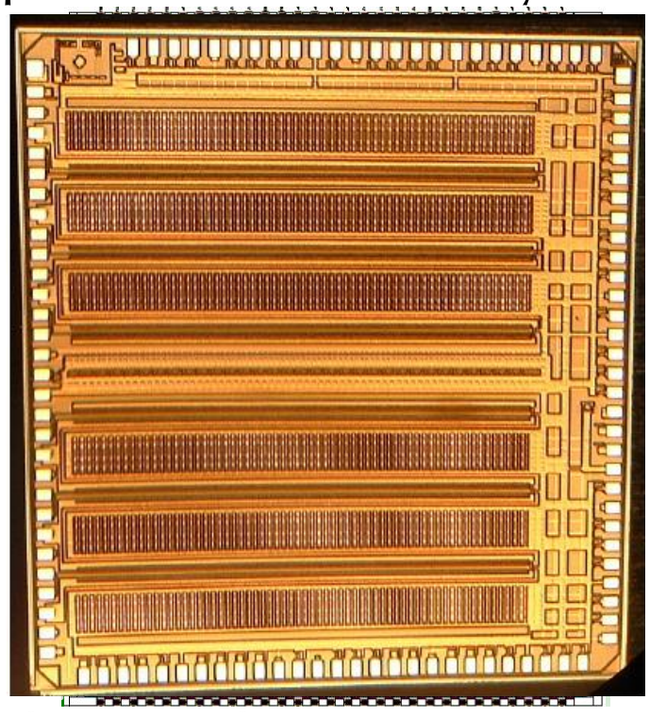
Large-Area HPMT (Masahi Yokoyama)



LAPPD psec timing, 8″ square photodetector, (K. Byrum)

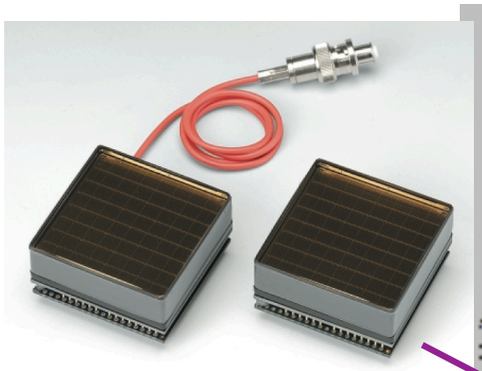


SiPMs, (N. Otte)



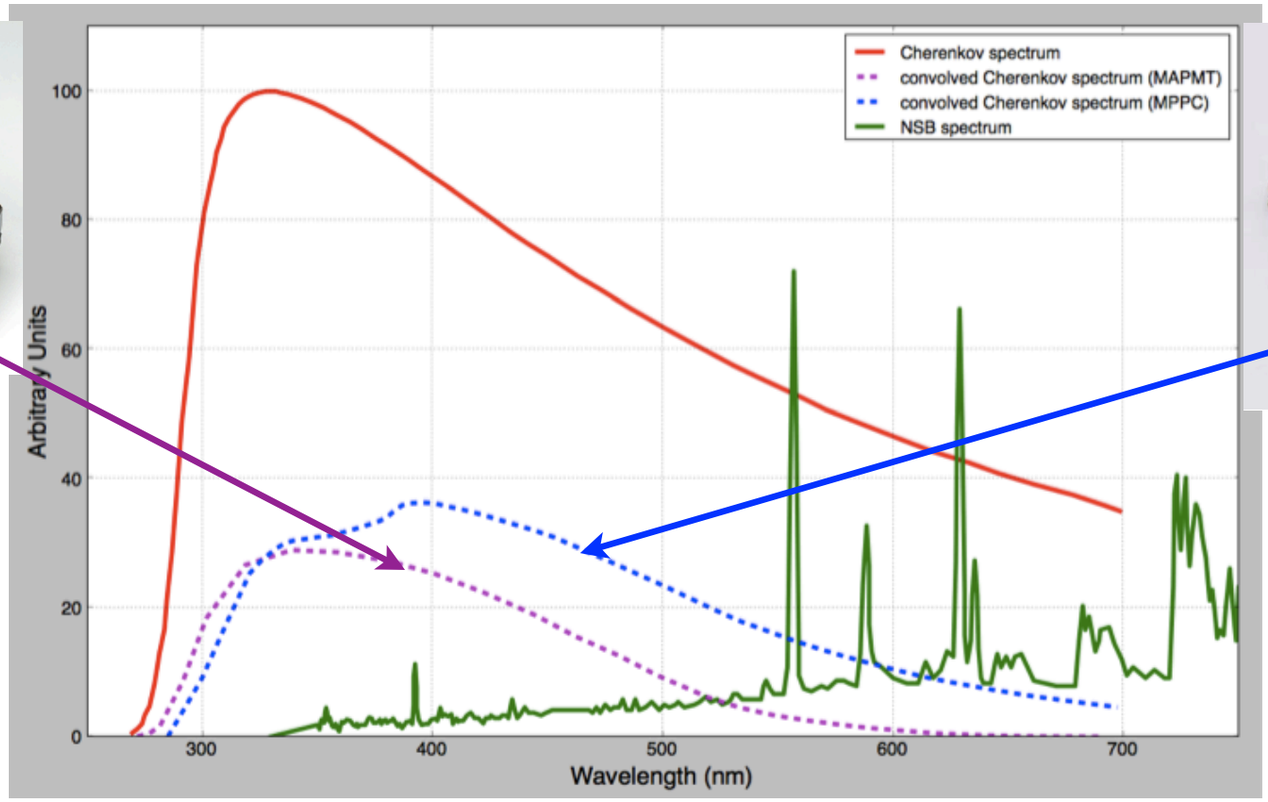
- Analog pipeline ASICs (K. Nishimura)

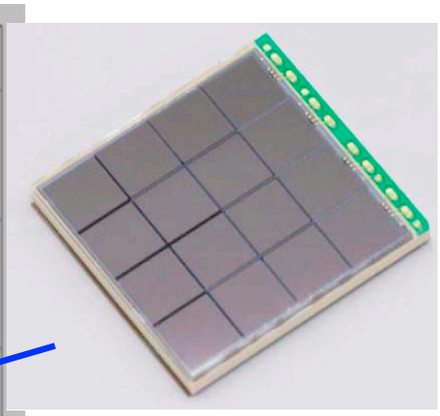
CTA Photosensors



MAPMTs

(H8500-10x MOD8)

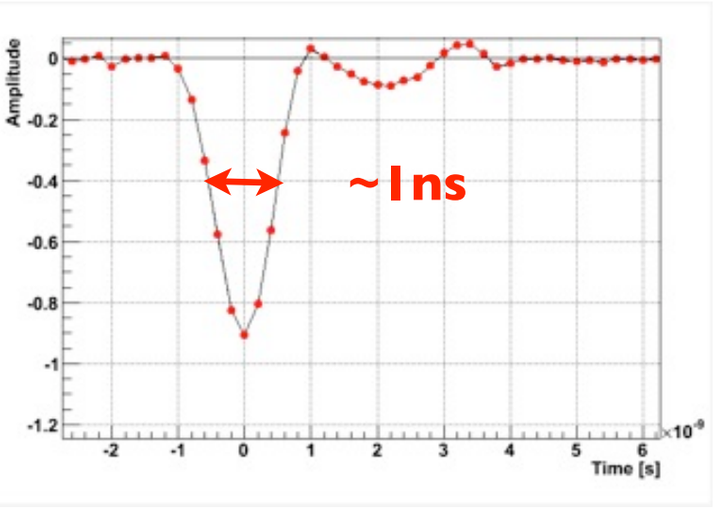




SiPMs

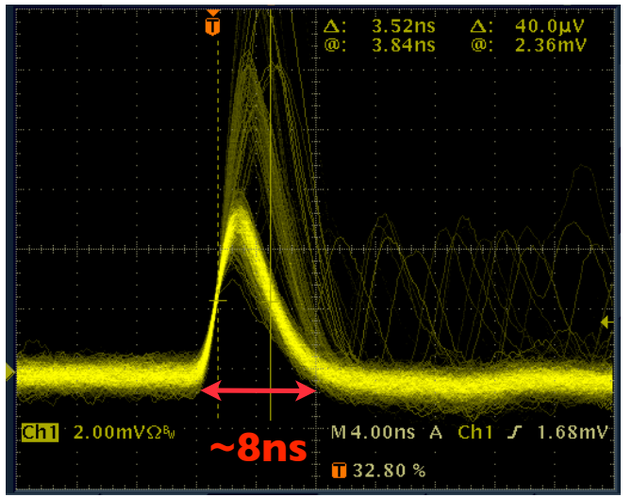
S11828-3344 MPPC

MAPMT Pulse

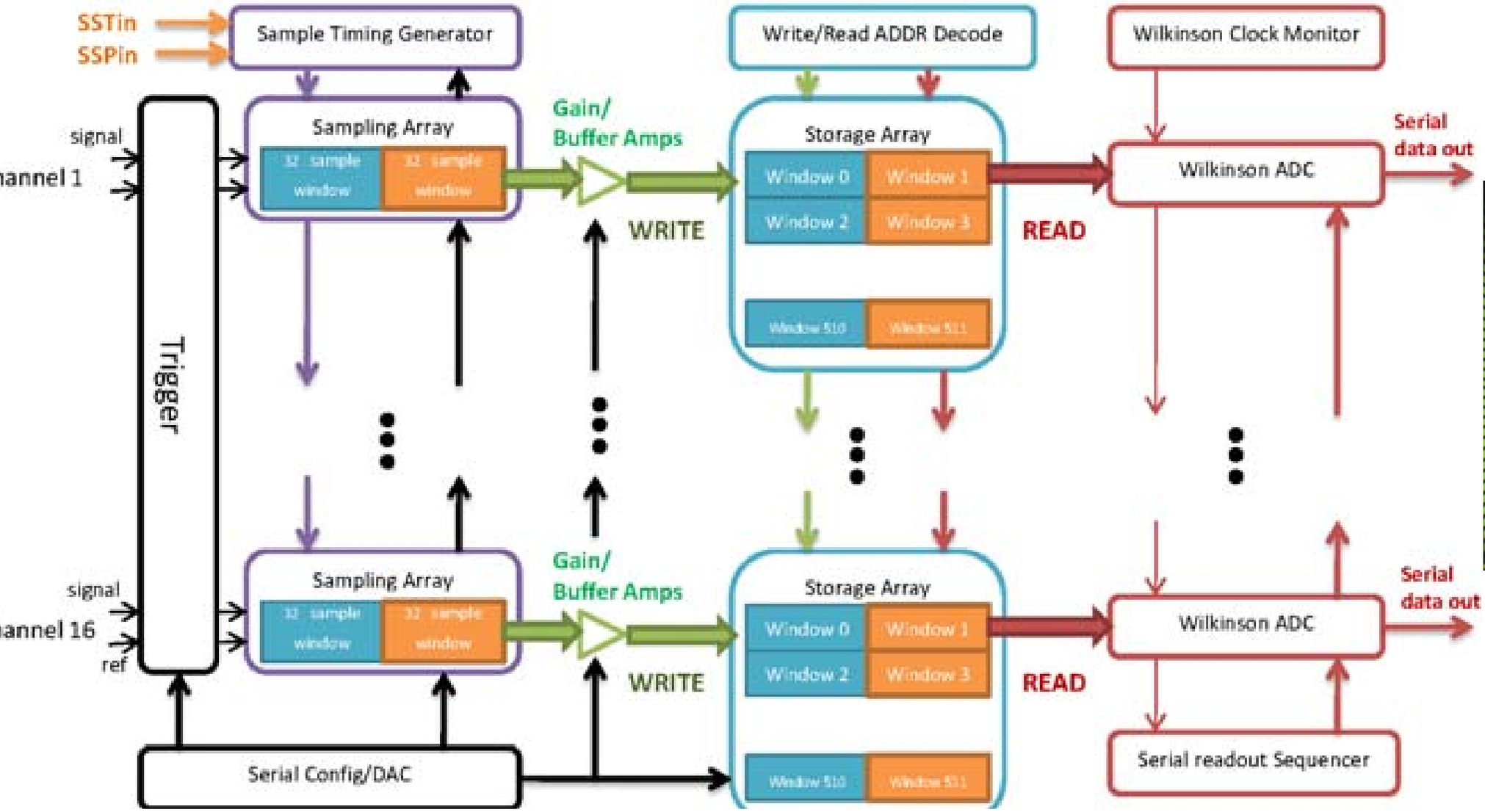


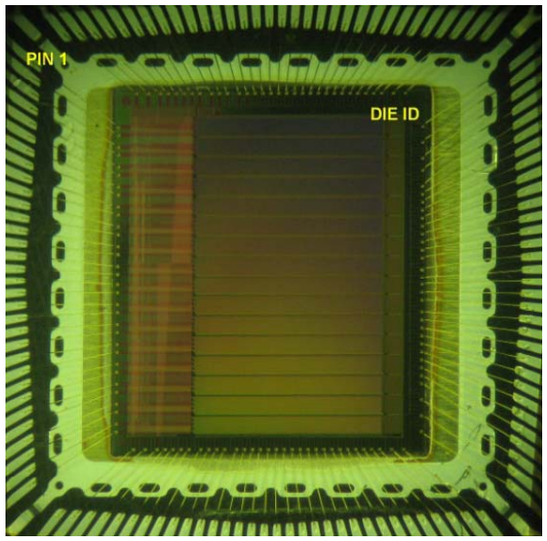
Currently, crosstalk (~10% and pixel pitch are key concerns)

SiPM Pulses (after preamp)



TARGET ASIC





- Target-5 ASIC Designed by U. Hawaii (Garry Varner) for SLAC
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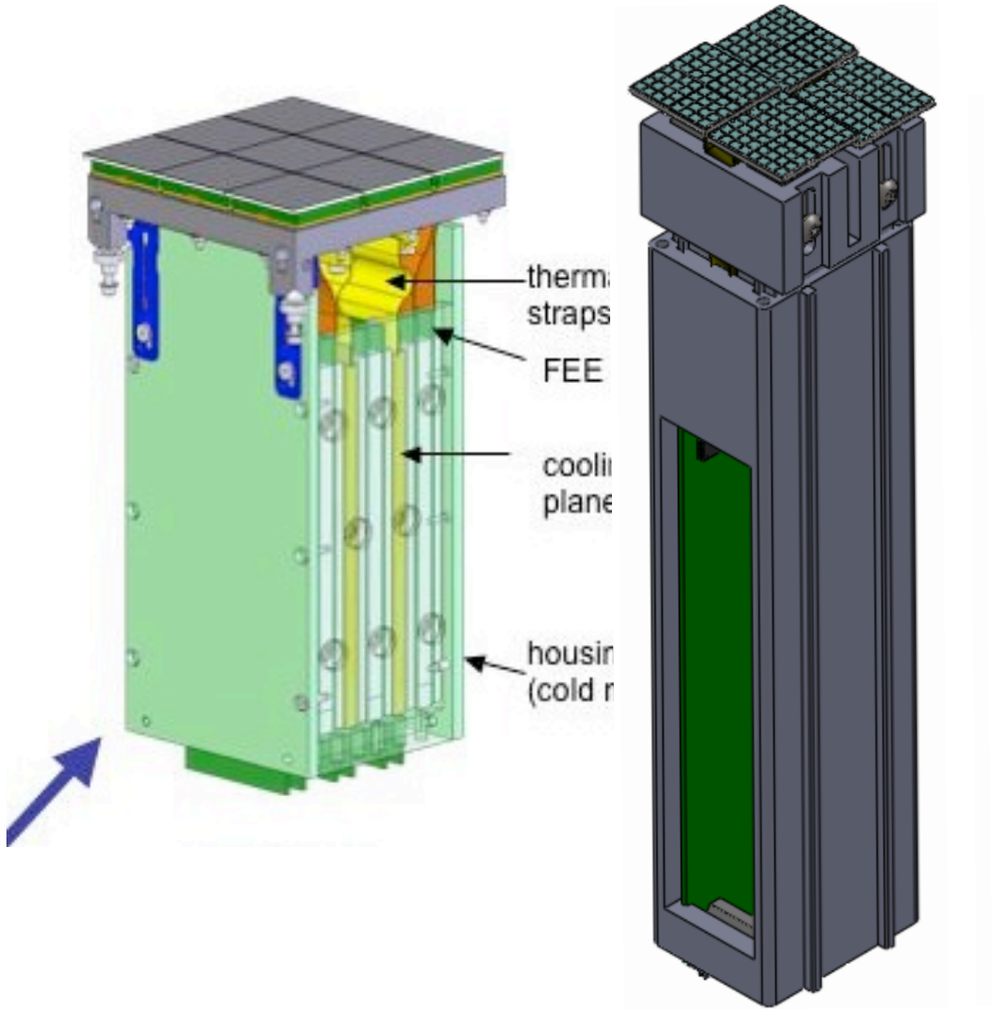
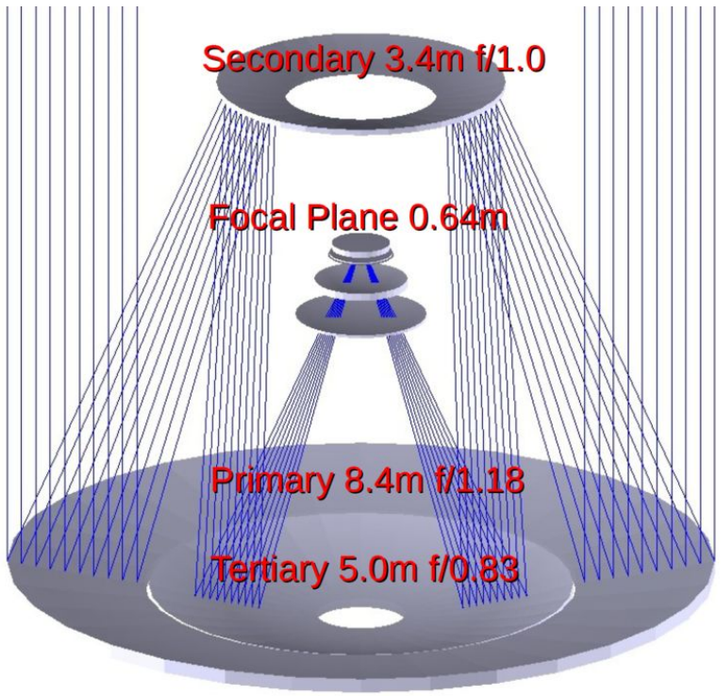
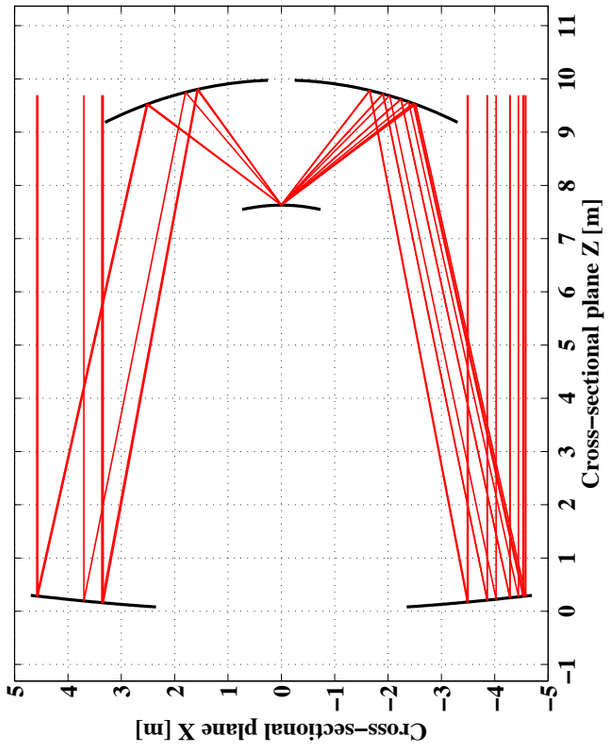
Quiz

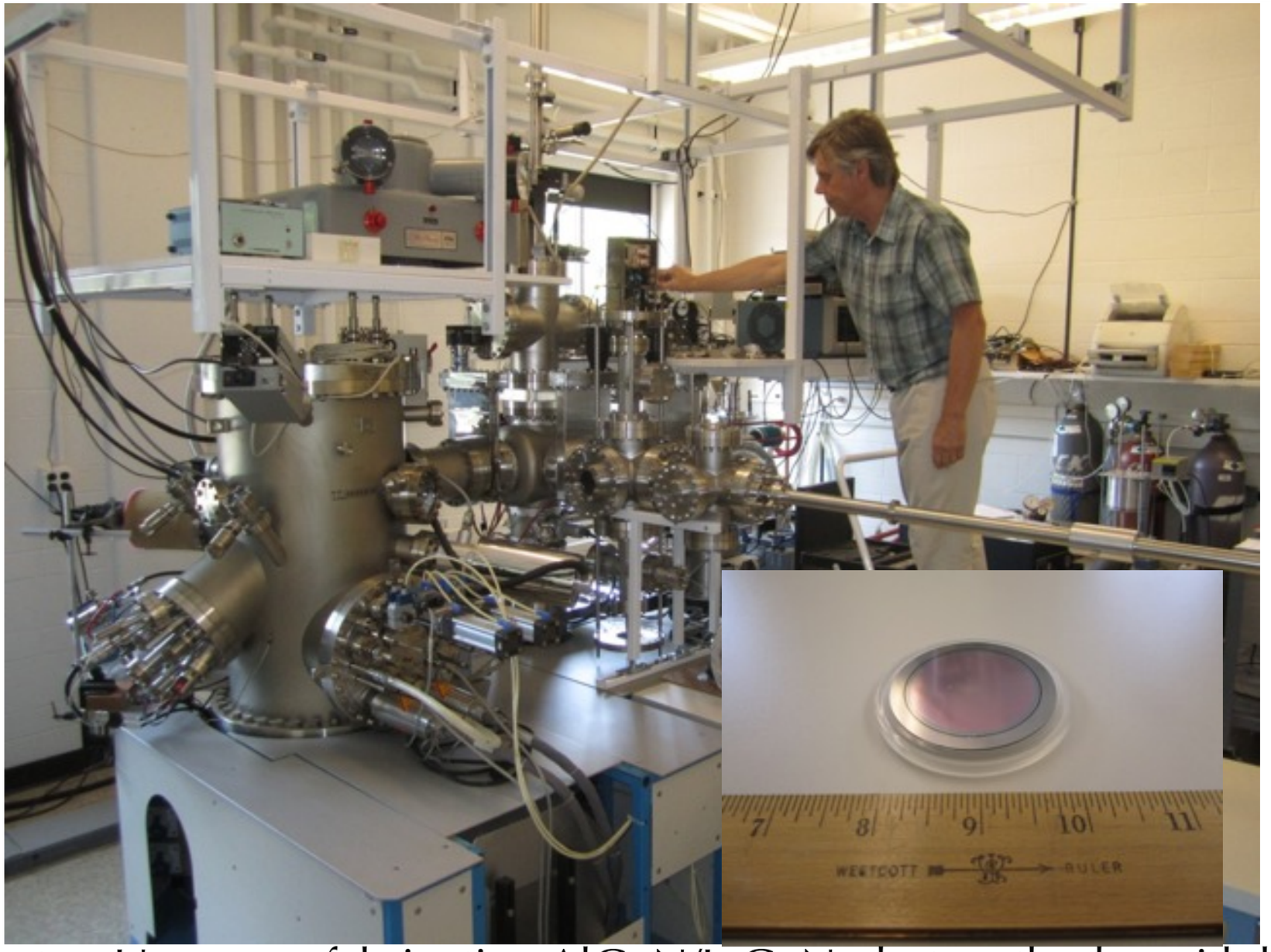






- Question: (a) Which is the camera module for the gamma-ray instrument and which is the module for the optical telescope? (b) Which is the optical system for the gamma-ray telescope and for the optical telescope?

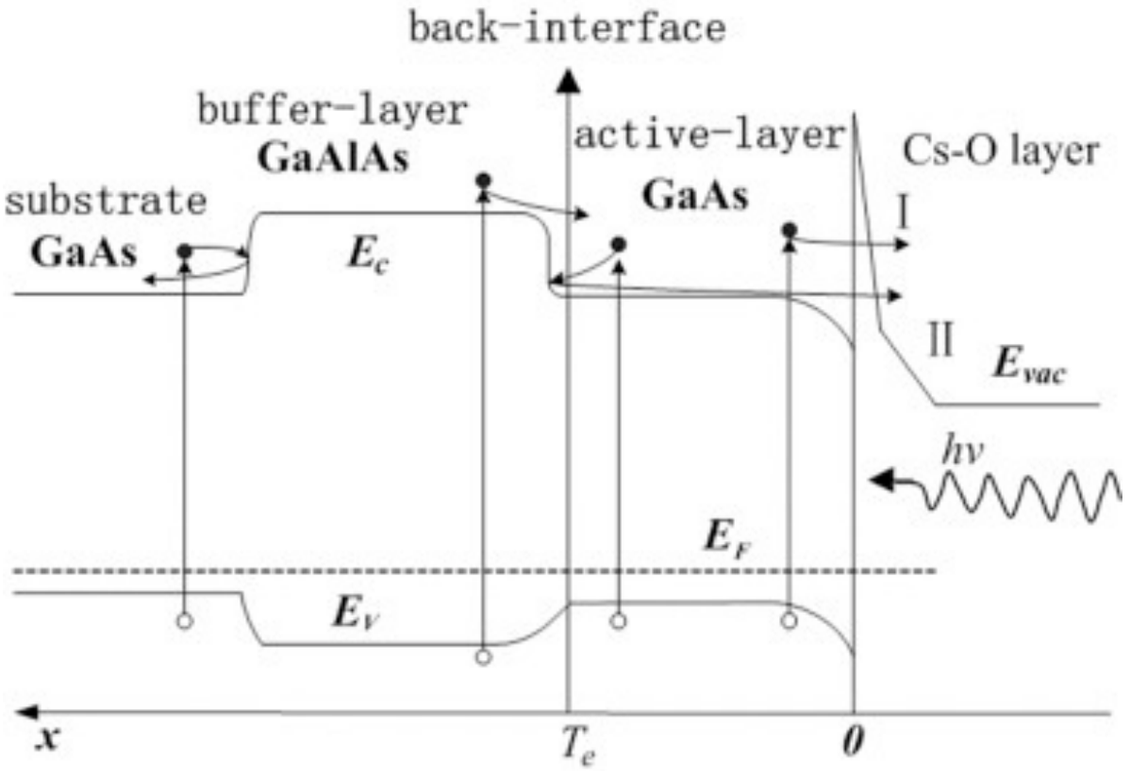
GaN MBE Lab

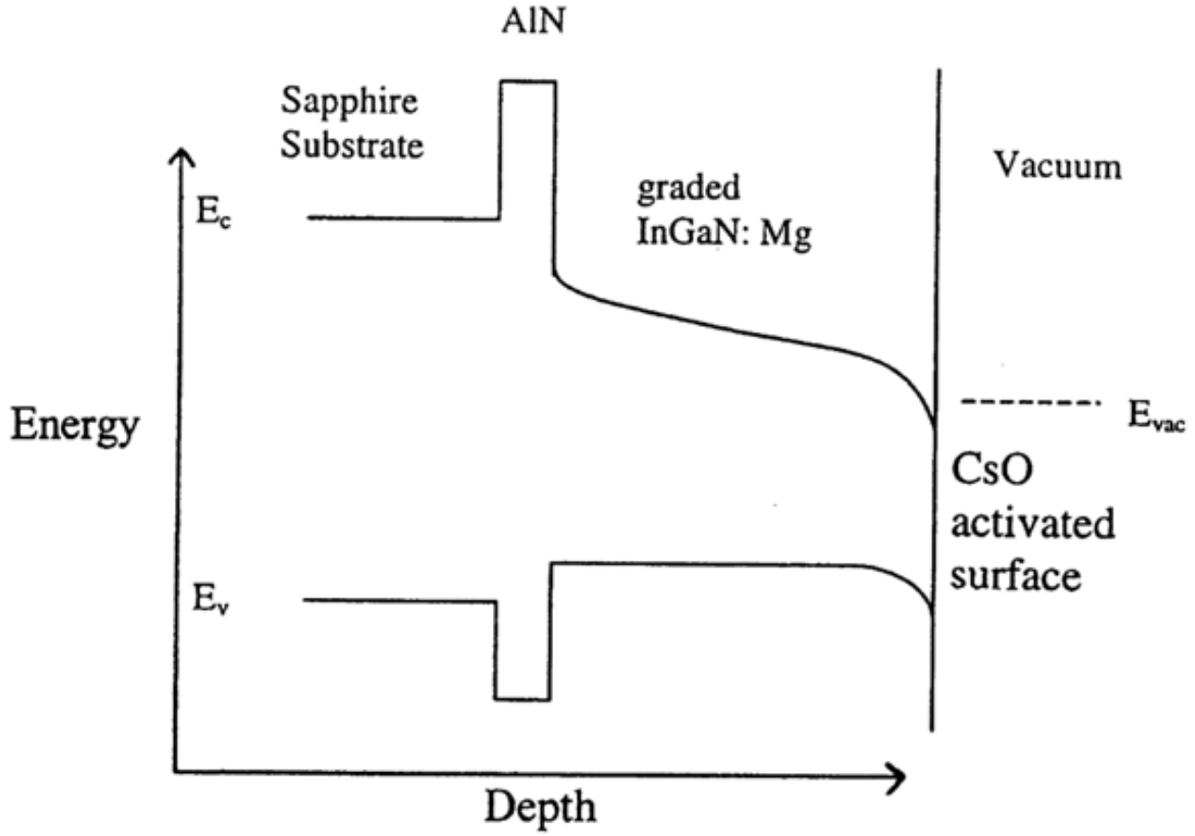


- At Washington U. we are fabricating AlGaN/InGaN photocathodes with both epitaxial and amorphous heterostructures using a Molecular Beam Epitaxy/ Transfer system. Beginning work on solid state detectors with intrinsic gain, hybrid Silicon/GaN devices.

- Potential for High QE detection at 175nm in a very low radiation background PMT housing

Photocathode Devices





- Semiconductor photocathodes hold promise for improvement in QE. Features include a reflection barrier, p-type doping profiles to bend the band, and a thin dipolar Cs-O layer to achieve negative electron affinity, and a barrier to tunneling.