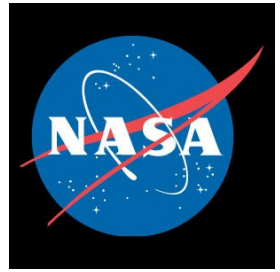
Extreme Universe Space Observatory on a Super Pressure Balloon II (EUSO-SPB2)



Lawrence Wiencke for the EUSO Collaboration

Cosmic Ray SIG Minisymposium

Lawrence Wiencke

Colorado School of Mines

(Virtual, w/ April APS meeting)

April 17 2021

NASA grant 80NSSC18K0477

COLORADOSCHOOLOFMINES

EARTH • ENERGY • ENVIRONMENT

Fluorescence: UHECRs EeV

First observation of UHECRs from near-orbit altitude with the fluorescence technique

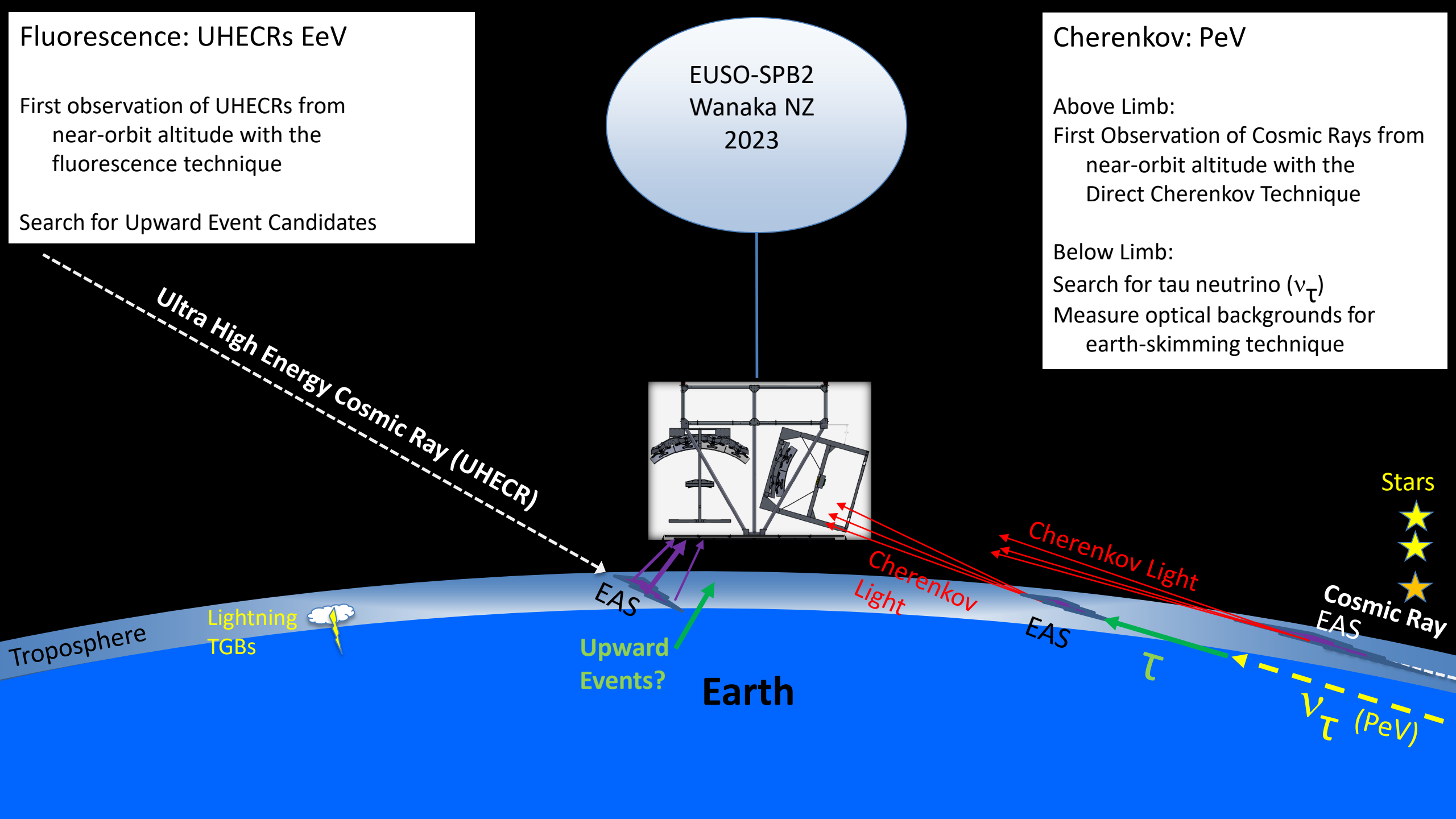
Search for Upward Event Candidates

EUSO-SPB2
Wanaka NZ
2023

Cherenkov: PeV

Above Limb:
First Observation of Cosmic Rays from near-orbit altitude with the Direct Cherenkov Technique

Below Limb:
Search for tau neutrino (ν_τ)
Measure optical backgrounds for earth-skimming technique



Country	Institution	EUSO-SPB2 Science Team	Work Packages
US	U. Chicago	A. Olinto (PI), R. Diesing, S. Meyer, J. Eser	IR Camera (UCIRC)
US	Mines	L. Wiencke (Dep. PI), F. Sarazin, G. Filippatos, V. Kungel	Telescopes:(Mech, Testing, Integ, Calib, Field Testing) Optical Test Stand, Simulations
US	Iowa	Y. Onel, M. Reno	CT, FT LED systems, simulations
US	MSFC	M. Christl, R. Young	Gondola, SIP Interfacing
US	UAH	P. Reardon, J.Adams, E. Kuznetsov,	Optics Design, Solar Power, CT systems
US	Lehman U.	L. Anchordoqui	MAPMTs, Simulations
US	Ga Tech	N. Otte, E. Gazda, M. Bagheri, O. Romero	CT SiPM camera development
AL	CDTA, CRAAG	M. Traiche (CDTA), M. FOUKA (CRAAG)	Simulations
CZ		C Kerny, M. Pech, P. Schovanek	Mirror Segments for CT and FT
FR	APC	G. Prévôt, S. E. Parizot	FT camera Elementary Cells,
FR	OMEGA	S. Blin	Electronics -ASICS
IT	INFN & U. Napoli	G. Osteria, V. Scotti, L. Valore, F. Guarino	CPU, Fluorescence Detector – DAQ, ….
IT	INFN & U. Torino	M. Battisti, M. Bertaina F. Bisconti, F Fenu H. Miamoto K. Shinozaki	Simulations, lab testing, trigger algorithms
IT	INFN & Univ. Bari	F. Cafagna	Flight (telescope) Software, FT Camera Housing
IT	UTIU	C. Fornaro	Fluorescence Telescope DAQ Software
IT	LNF-INFN, Frascati	M.Ricci	Italian coordinator
JA	RIKEN	M. Cassolino, T. Ebisuzaki, Y. Takizawa	Optics(ACP), PMT testing
Mx	U. Mexico	G. Medina-Tanco	Thermal Modeling
POL	NCBJ	J. Szabelski, L. Petrowski	FT HV system
RU	MSU	P. Klimov, A. Belov	FT Camera zynq boards
SE	KTH	C. Fuglesang.	FT Camera structure (prototype)
SK	SAS	S. Mackovjak	UV/Vis Monitors

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FR	OMEGA	S. Blin	
IT	INFN & U. Napoli	G. Osteria, V… …re, F. Guarino	…tor – DAQ, ….
IT	INFN & U. Torino	M. Batt… …a F. Bisconti, F Fenu H. Miamoto K. Sh…	…sting, trigger algorithms
IT	INFN & Univ. Bari	…	…cope) Software, FT Camera Housing
IT	UTIU	…ro	…scence Telescope DAQ Software
IT	LNF-INFN, Frascat…	…Ricci	Italian coordinator
JA	RIKEN	M. Cassolino, T. Ebisuzaki, Y. Taki…	Optics(ACP), PMT testing
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SK	SAS	S. Mackovjak	UV/Vis Monitors

11 Countries participating in EUSO-SPB2

nuSpaceSim Group (Krizmanic et al)

John F. Krizmanic[*1,2,3†], Yosui Akaike[1,2,3], Douglas R. Bergman[4], Johannes Eser[5], Sameer Patel[6], Mary Hall Reno[6], Andrés Romero-Wolf[7], Fred Sarazin[5], Tonia M. Venters[2], Luis Anchordoqui[8], Simon Mackovjak[9], Angela V. Olinto[10], Lawrence Wiencke[5], Stephanie Wissel[11], Alexander Reustle[2,12]

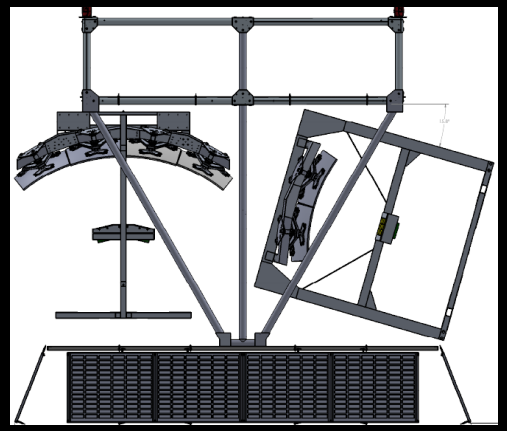
EUSO-Balloon

2014 Timmins

EUSO-SPB1

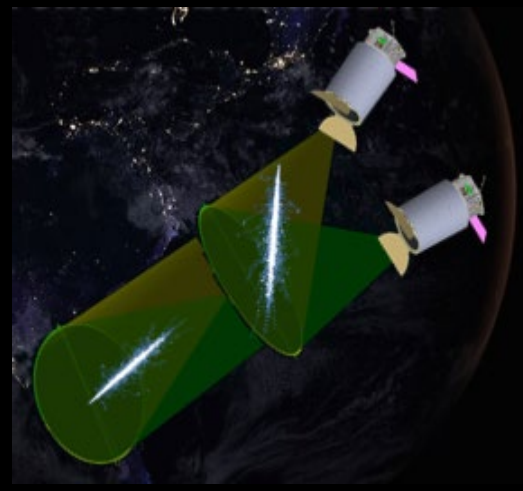
2017 Wanaka

EUSO-SPB2

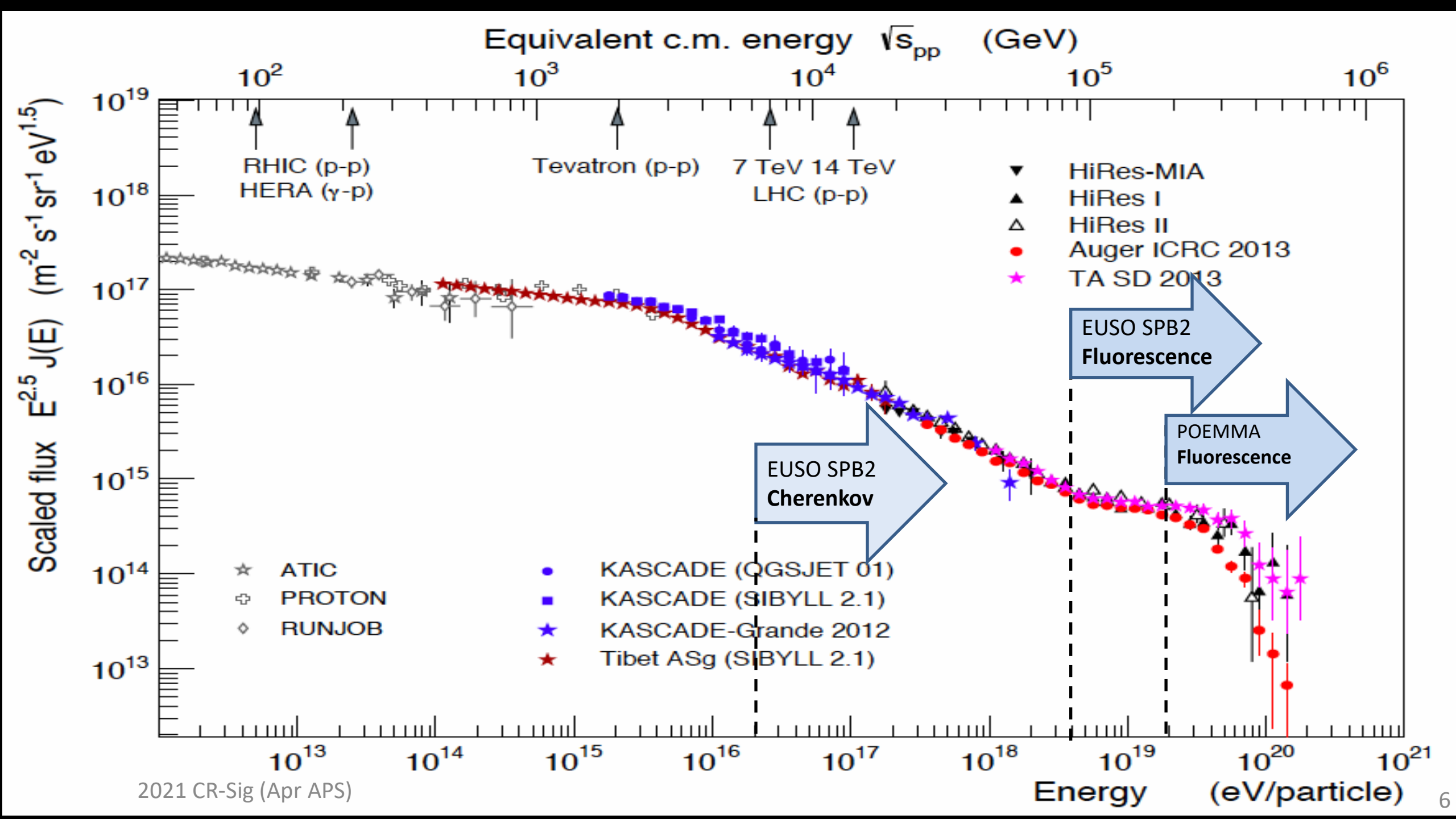


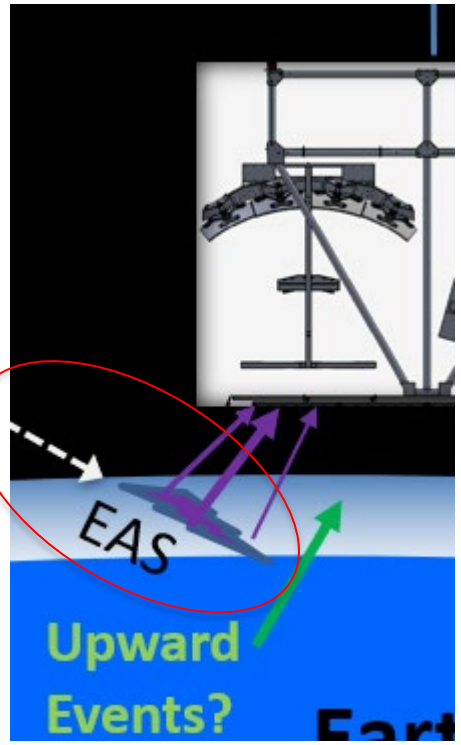
(2023) Wanaka

POEMMA



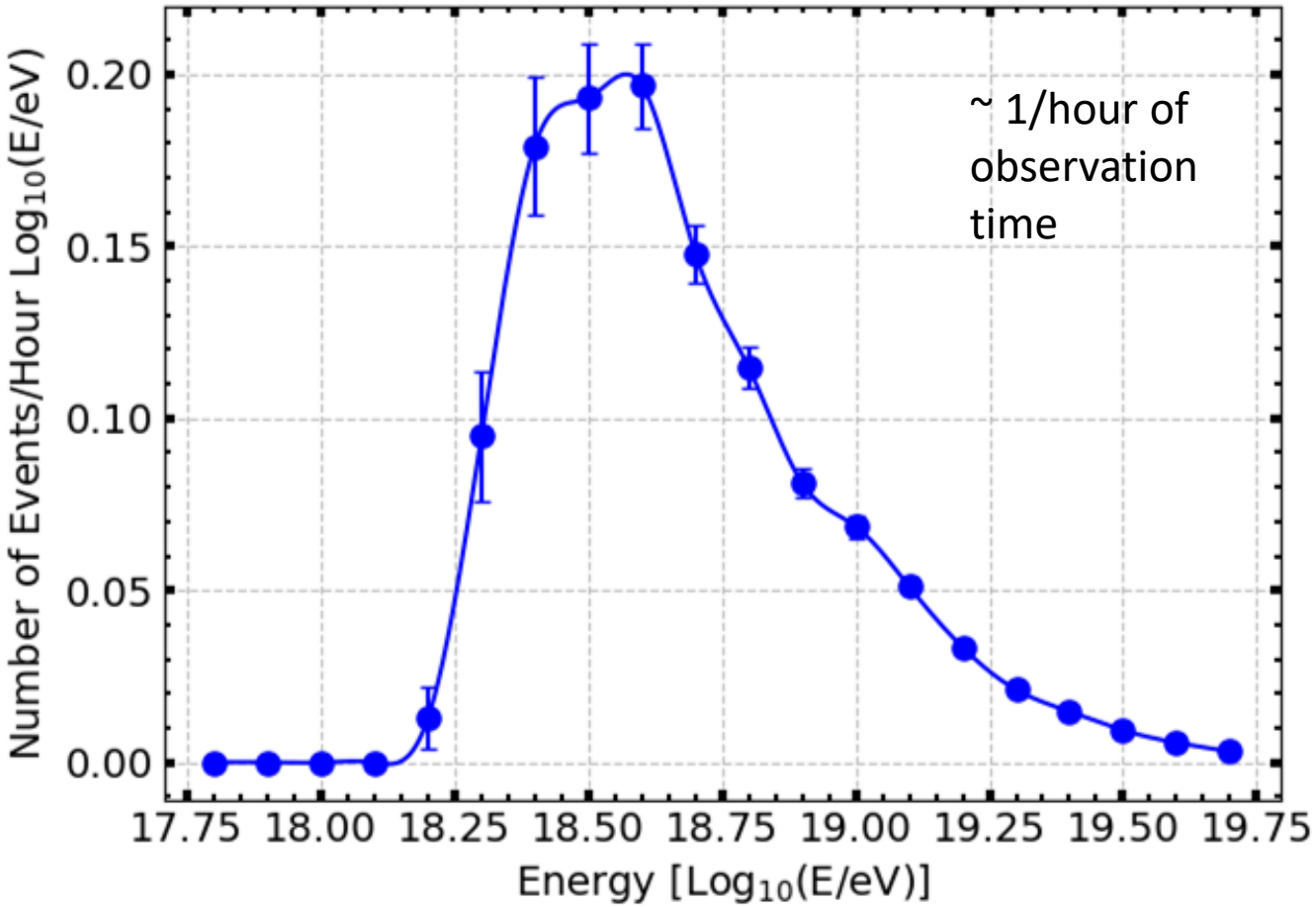
Earth Orbit


Equivalent c.m. energy √s_pp (GeV)
10^2
10^3
10^4
10^5
10^6
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
EUSO SPB2
Fluorescence
POEMMA
Fluorescence
EUSO SPB2
Cherenkov
Scaled flux E^2.5 J(E) (m^-2 s^-1 sr^-1 eV^1.5)
10^19
10^18
10^17
10^16
10^15
10^14
10^13
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
Energy (eV/particle)



EUSO-SPB2 Fluorescence Telescope
UHECR Simulation Event Rate

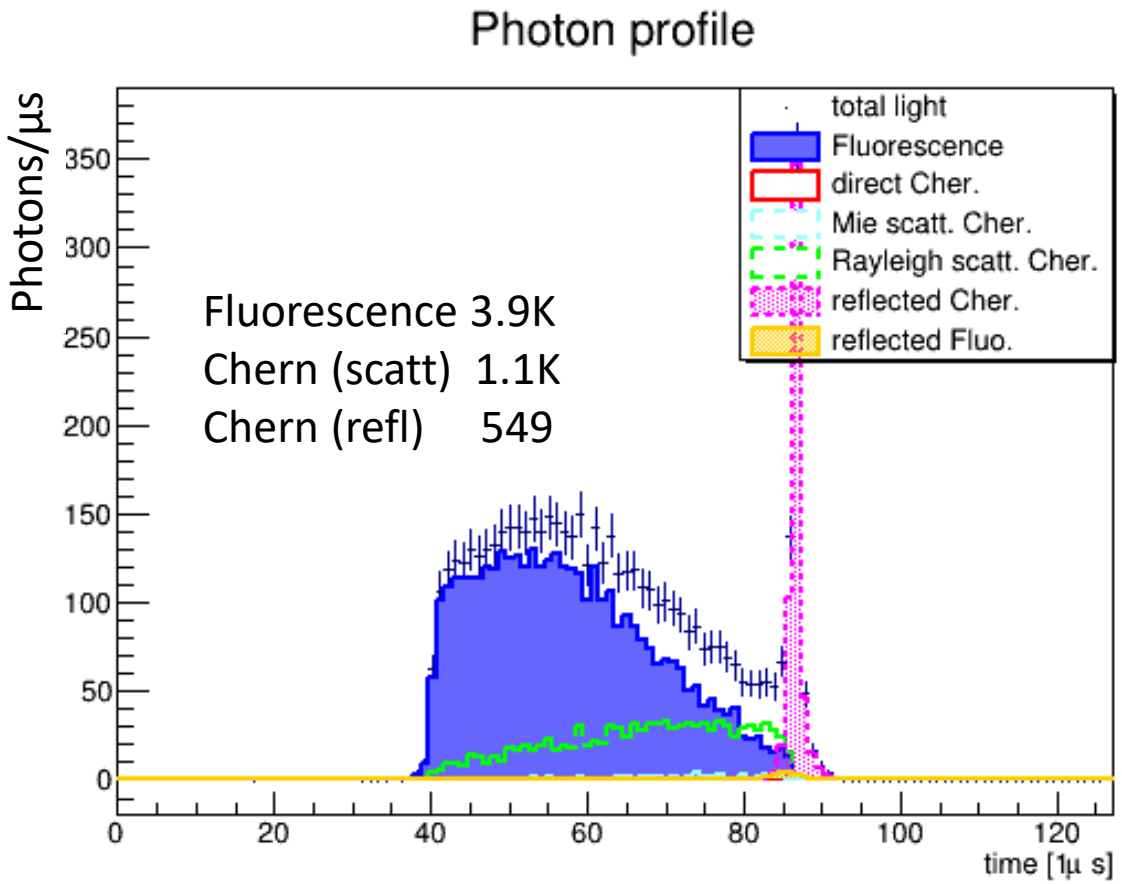
See George Filipatos, D10.00004
Status of the EUSO-SPB2 Fluorescence Detector

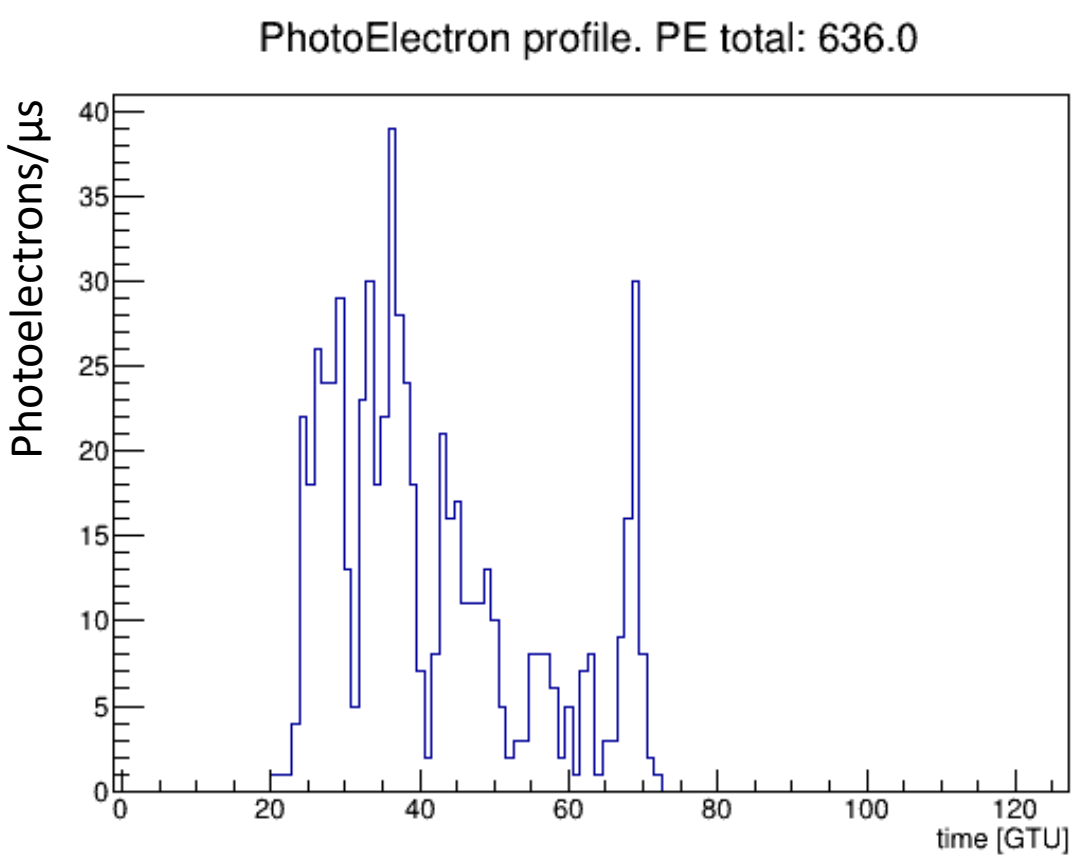


10% partially reconstructable

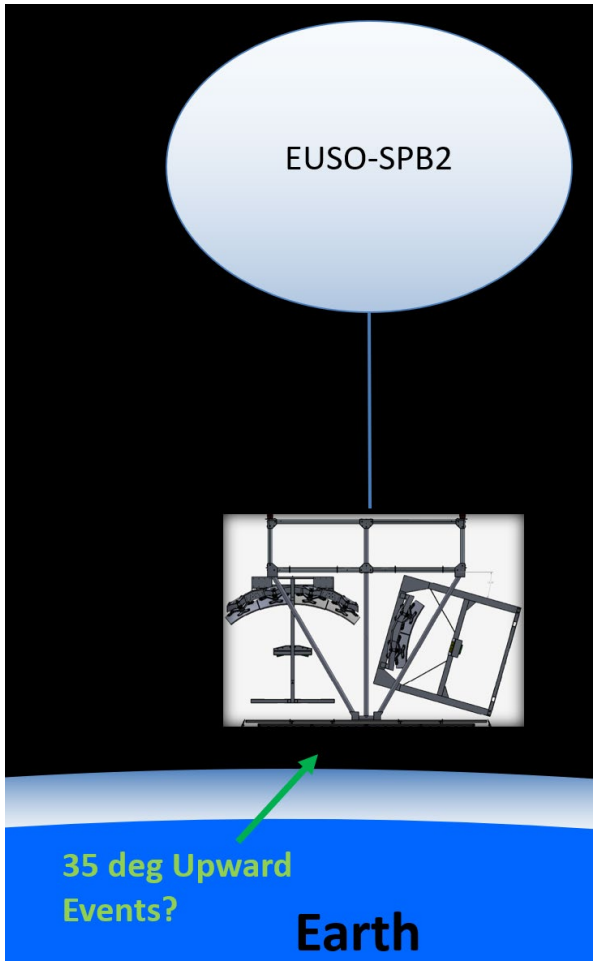
Few % with Xmax bracketed

EUSO-SPB2 Fluorescence Telescope UHECR Simulation
Example Air Shower 5 EeV, Zenith 34 deg





EUSO-SPB2 Fluorescence telescope will also look for upward-going events



Anita event-like candidates

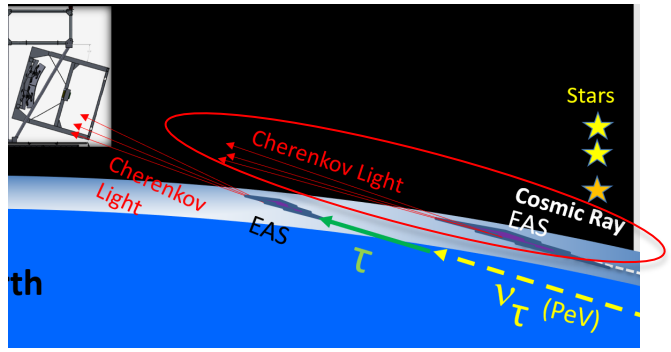
And

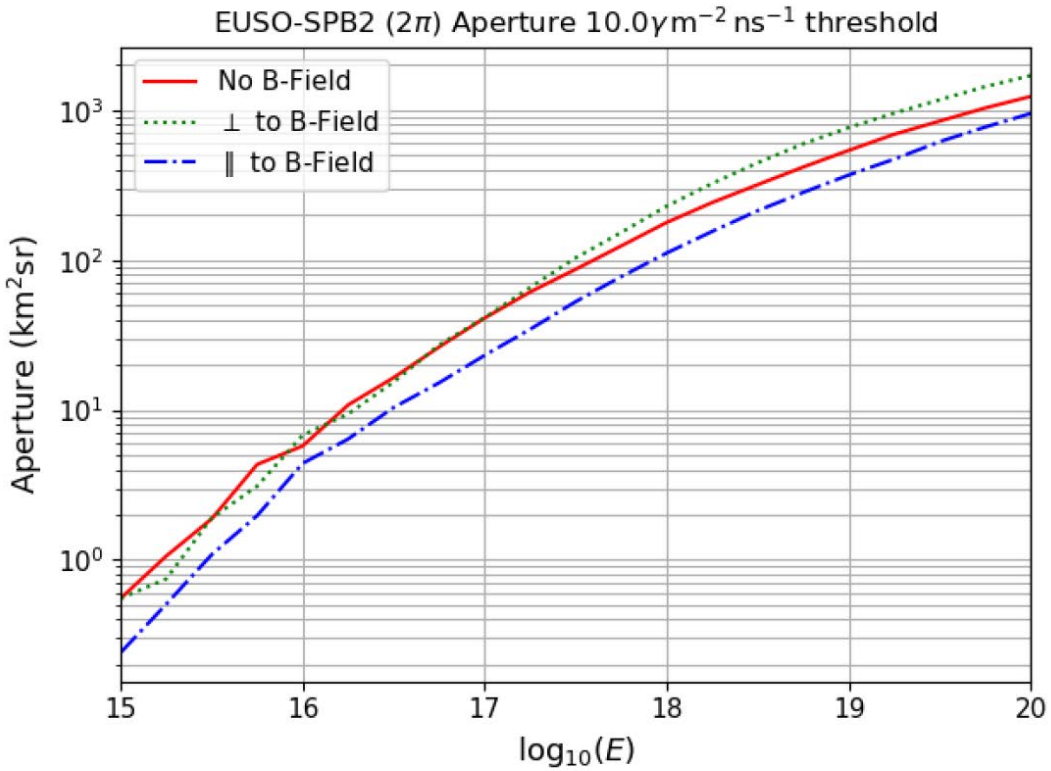
Macroscopic dark matter signatures
Fractionally Charged Particles
(5 MeV/c^2 – 100 TeV/c^2) and velocities ($\beta\gamma$=0.1 – 10^6)

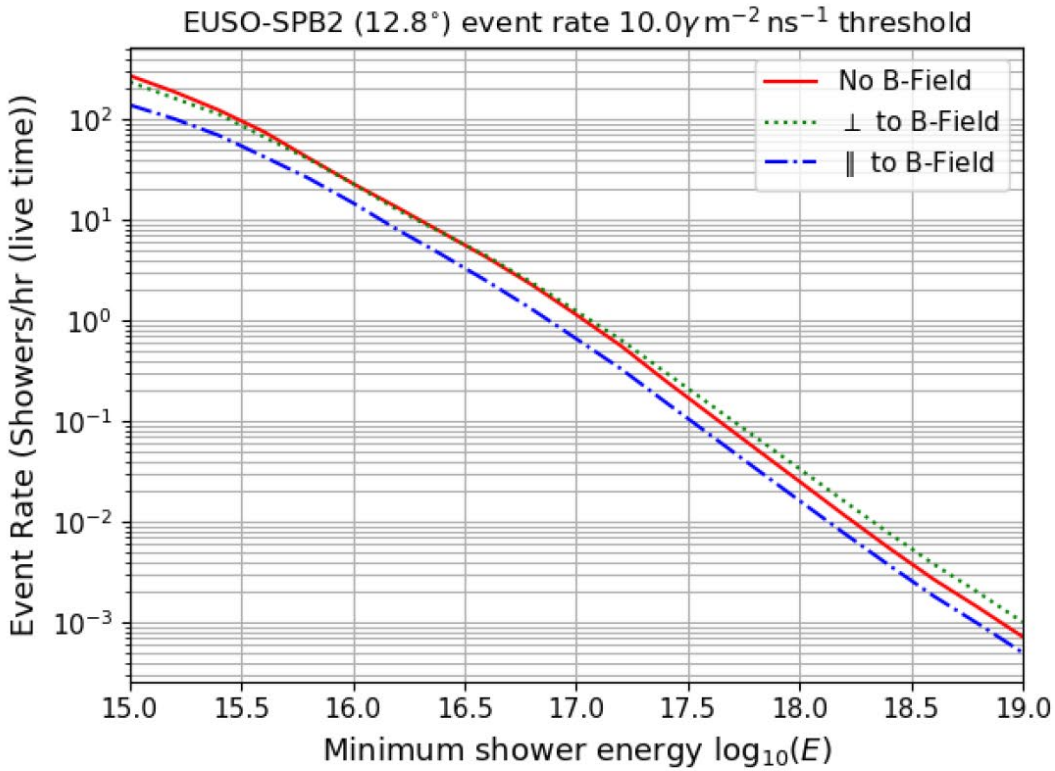
see T. Paul, L. Anchordoqui, A. Olinto
Q10.00009
Model independent probes of macroscopic dark matter with EUSO-SPB2

Astroparticle Physics with the EUSO-SPB2 Cherenkov Telescope

First Observation of Cosmic Rays from near-orbit altitude with the Direct Cherenkov Technique



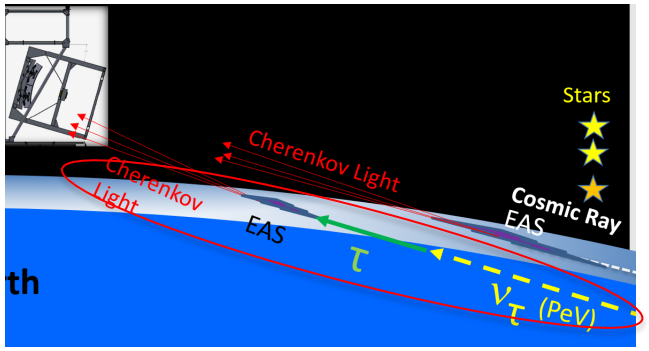




Predicted Event Rate above 10^{15} eV (1 PeV)
100/hr observing time
→In-situ test of the instrument

A. Cummings, PhD Thesis (GSI)

Astroparticle Physics with the EUSO-SPB2 Cherenkov Telescope



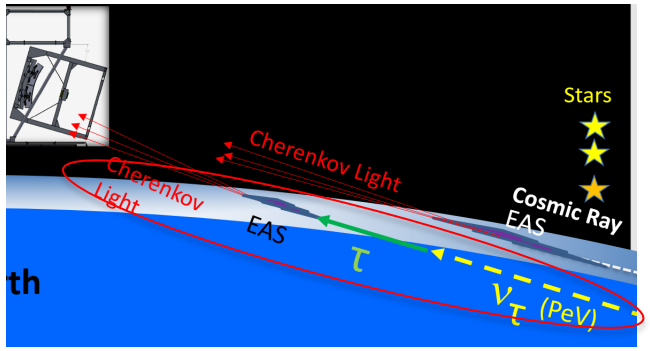
Earth Skimming Neutrinos

1. Optical Backgrounds: Fast flashes that mimic neutrino signatures?
2. Diffuse Neutrino Flux: Well below EUSO-SPB2 sensitivity
3. Target of Opportunity: Point the CT at a transient astrophysical object as it crosses the limb
   Tantalizing!

Reno et al., Phys. Rev. D 100 (2019) 963010
background discussion for ToO in Venters et al., Phys. Rev. D 102 (2020) 123013

Also see
nuSpaceSim (J. Krizmanic et al) https://pos.sissa.it/358/936/pdf

Astroparticle Physics with the EUSO-SPB2 Cherenkov Telescope



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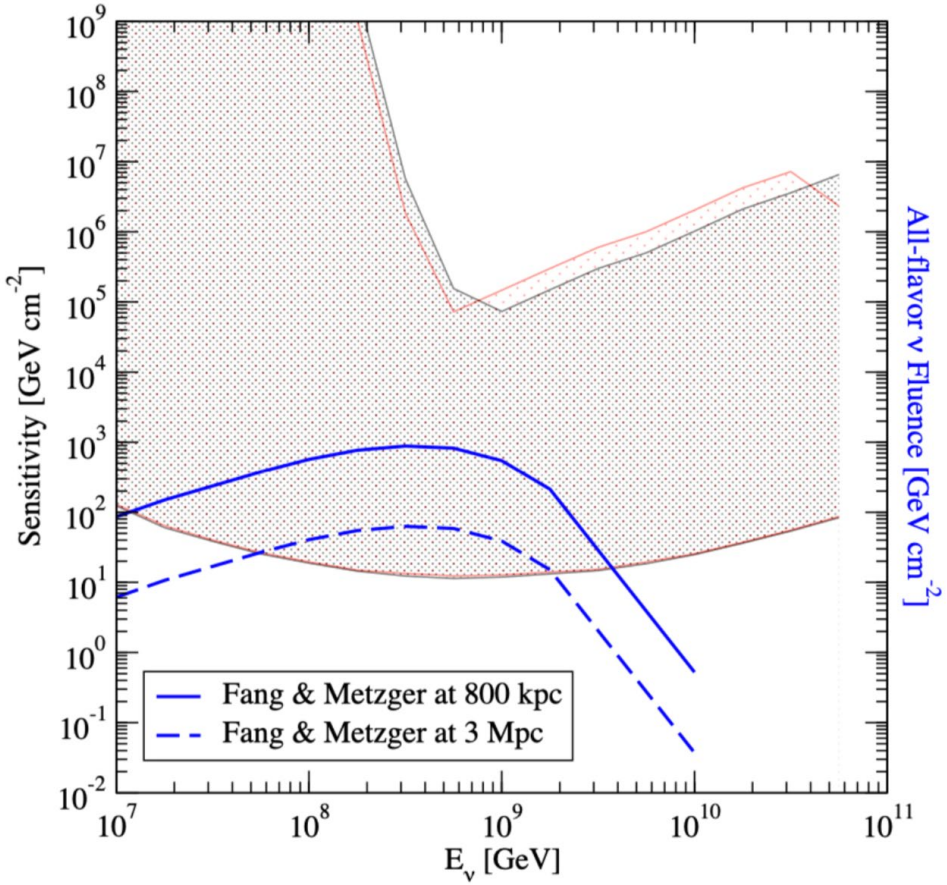


Sensitivity of EUSO-SPB2 to
"Long Burst Transient" ie 30 Days
(case that the transient is active during the SPB2 mission)

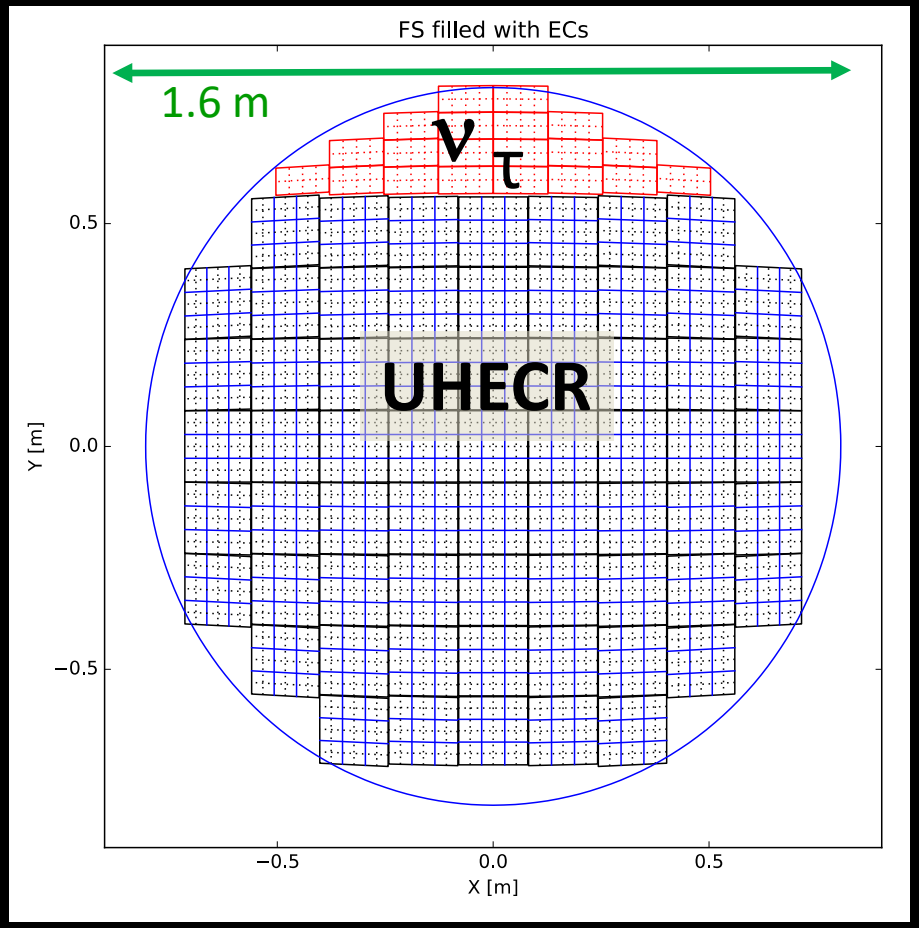
Blue curves are the prediction of
Fang & Metzger, Ap J 849 (2017) 153

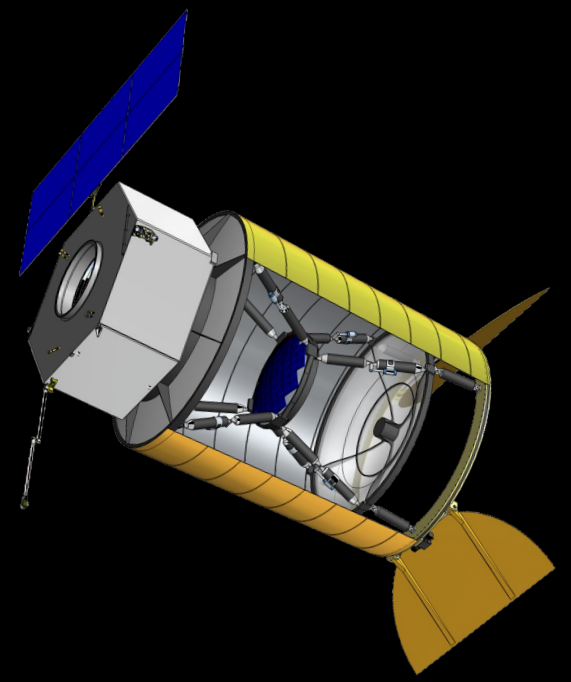
Shaded region is EUSO-SPB2 sensitivity

Also, sensitivity to "Short Burst Transients"

Reno, Mary Hall	S10.00005 Prospects for EUSO-SPB2 detection of transient astrophysical sources of neutrinos
Venters, Tonia	S10.00007 Targets of Opportunity with POEMMA

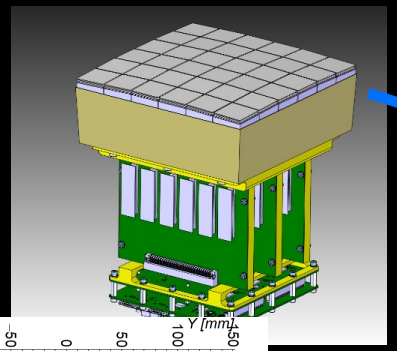
POEMMA
Hybrid Focal Surface

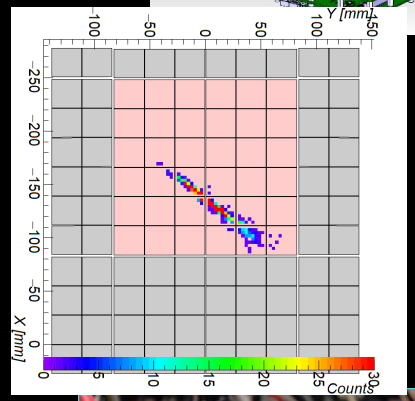


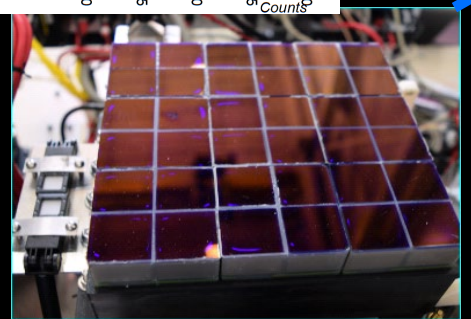


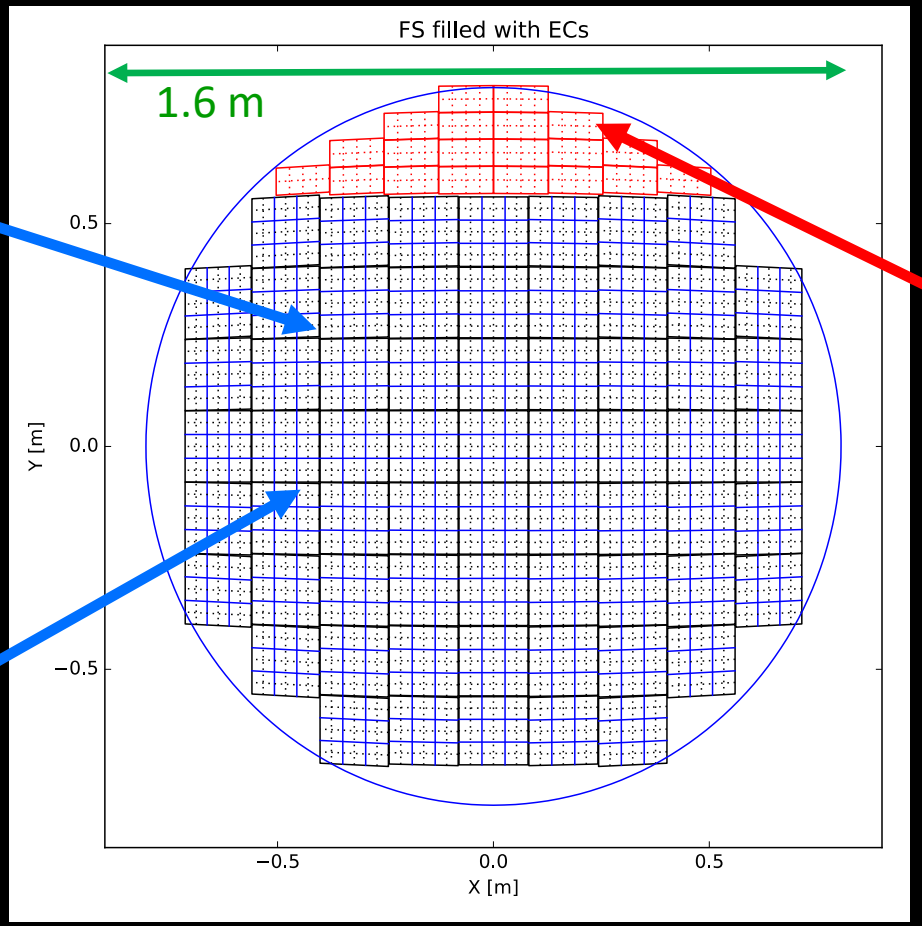
POEMMA
Hybrid Focal Surface

UV Fluorescence Detection with MAPMTs (1μs)

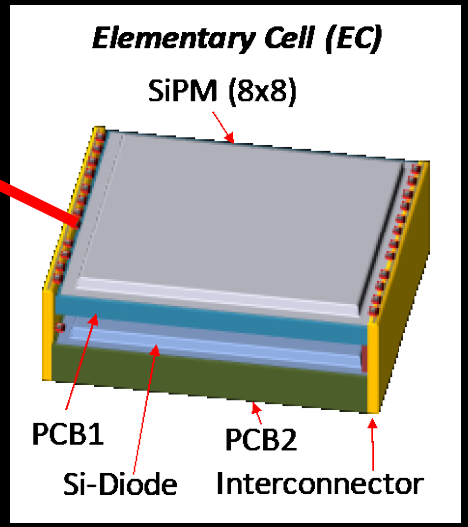








Cherenkov Detection with SiPMs (10 ns)



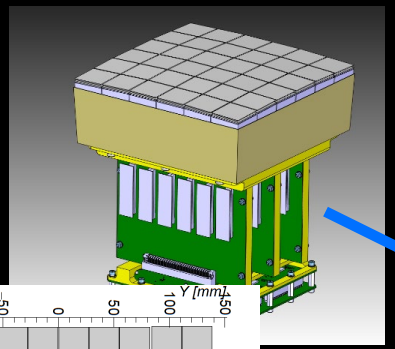
20 SiPM
focal surface units

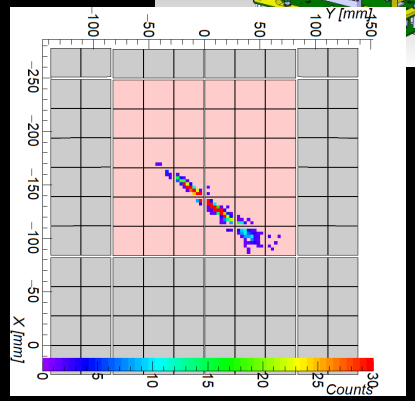
64 Photo Detector Modules (PDMs)= 147k pixels

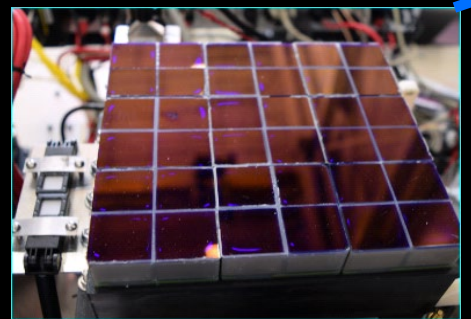
1 PDM = 36 MAPMTs = 2,304 pixels

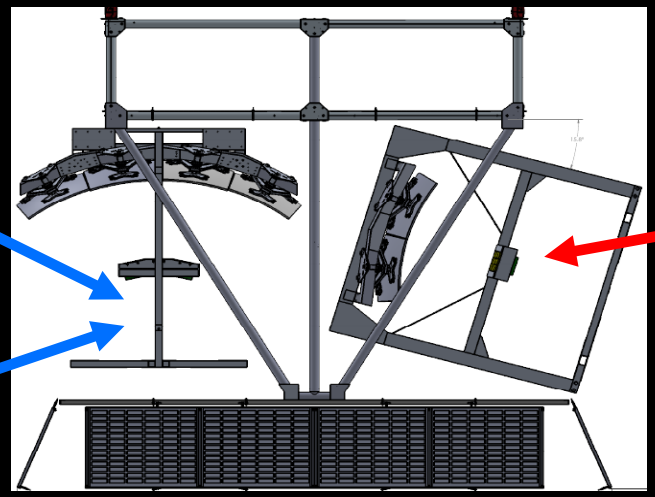
EUSO-SPB2
Two Telescopes

UV Fluorescence Detection with MAPMTs (1μs)

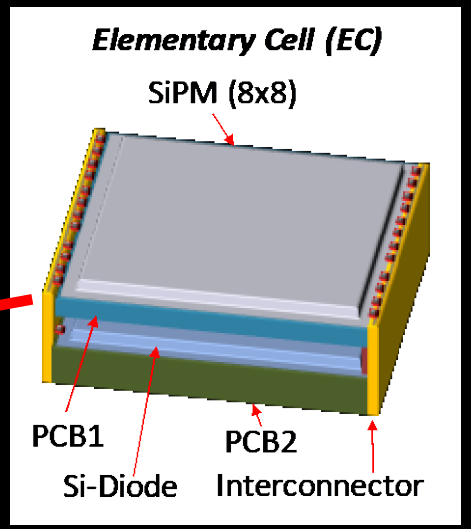








Cherenkov Detection with SiPMs (50 ns)



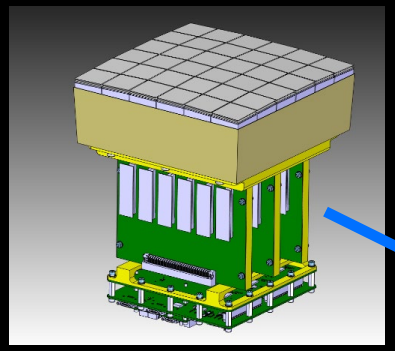
SiPM
focal surface units

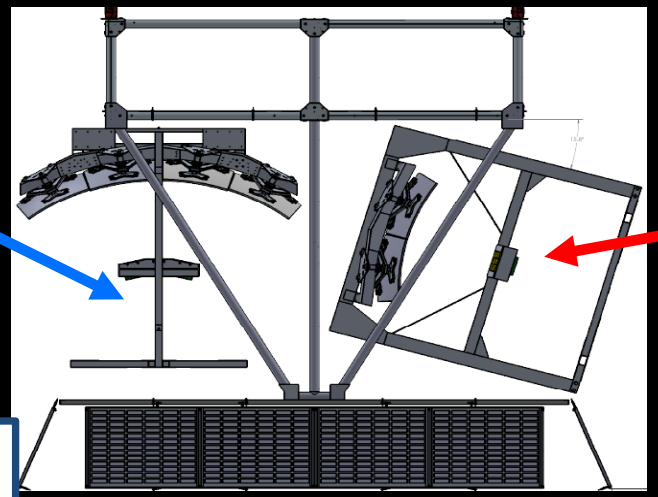
3 Photo Detector Modules (PDMs)= 6.9k pixels
3 x 11 deg x 11 deg FOV
0.2 deg/pixel w/ UV filter

512 pixels
6.4 deg x 12.8 deg FOV
0.6 deg/pixel

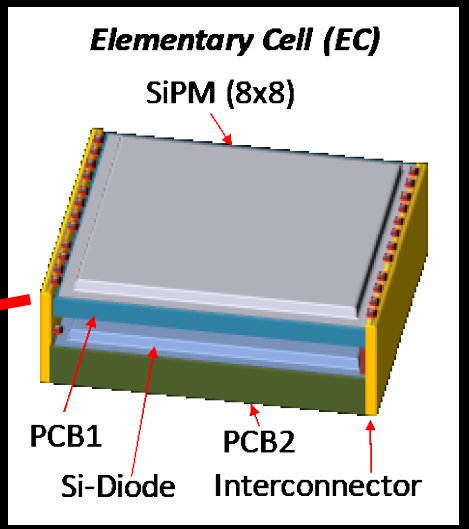
EUSO-SPB2
Two Telescopes

UV Fluorescence Detection with MAPMTs (1μs)





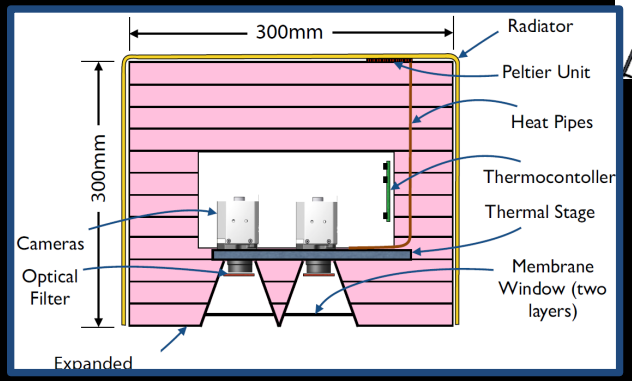
Cherenkov Detection with SiPMs (50 ns)



SiPM
focal surface units

512 pixels
6.4 deg x 12.8 deg FOV
0.6 deg/pixel

Also IR Camera System
For clouds UCIRC

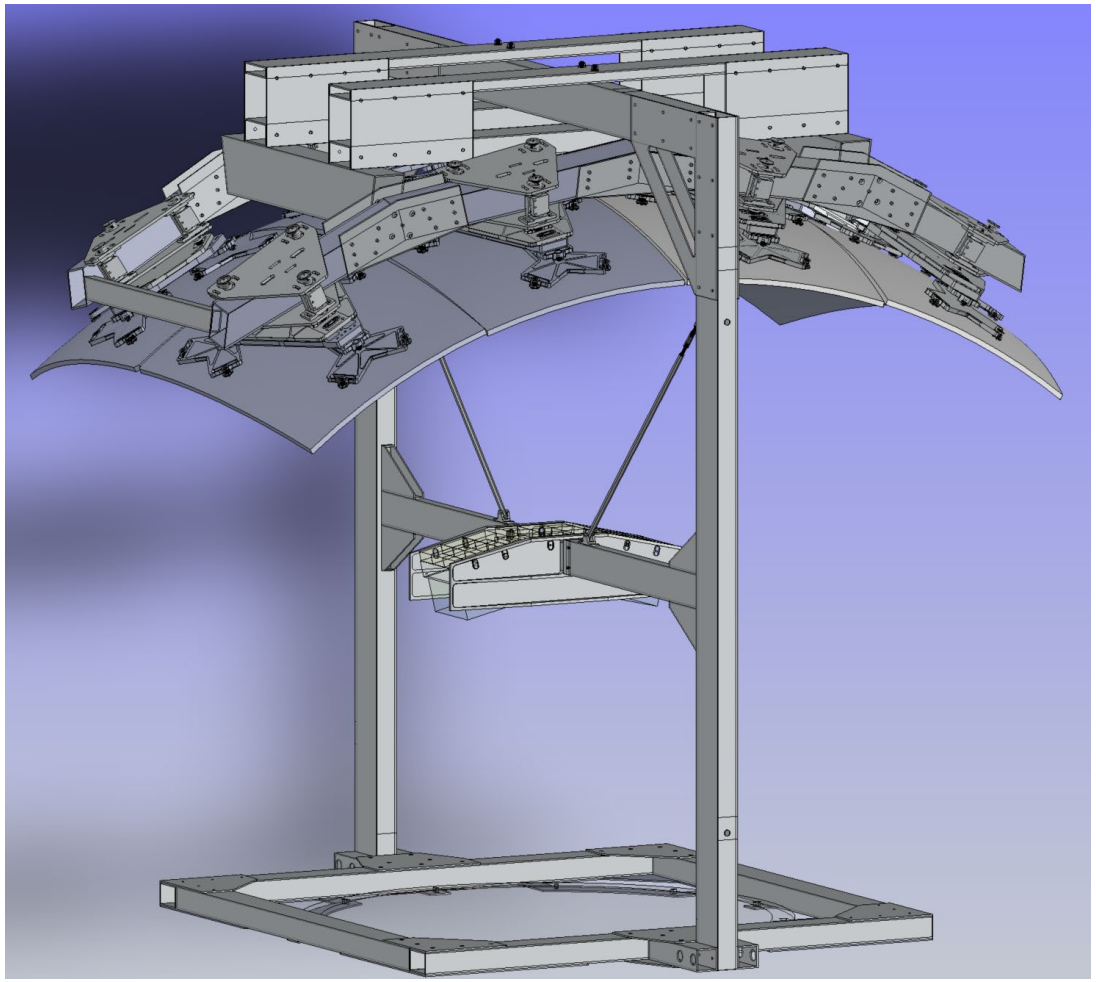


EUSO-SPB2 Specifications (update Oct 23 2020)

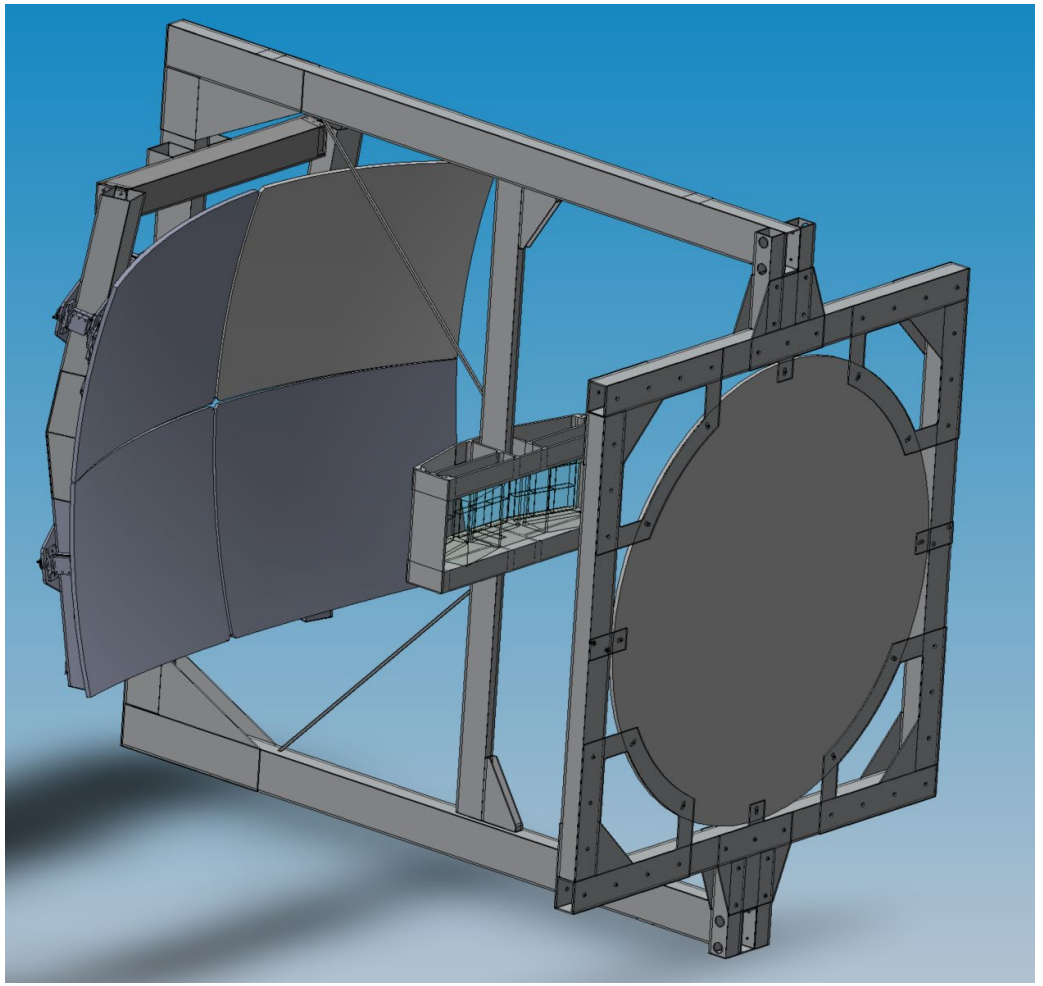
Telescopes	2	1 Fluorescence (FT)	1 Cherenkov (CT)
Energy Threshold		*~5 EeV*	*tbd (10's of PeV)*
Sensor Type		MAPMT (Hamamatsu)	SiPM Hamamatsu (S14521-6050CN)
Wavelength Sensitivity		UV 300-420 nm (BG3 filter x QE)	no filter (~300-~900 nm)
Time Bin		1000 ns/bin	10 ns x 512 bins 12 bit
Pointing (zenith angle)		nadir	Limb +/- 10
FOV (instrumented)		3x(11x11) deg	6.4x12.8 deg
Number of Pixels		3x2304=6912 (3 48x48 PDMs)	16x32=512 (16 Vert x 32 Horz)
Pixel FOV (& size)		0.2x0.2 deg (2.8x2.8 mm)	0.4x0.4 deg (6.25 x 6.25mm)
Optics (modified Schmidt)	Spherical Mirror Glass, ROC 1659.8 mm	8 segments common focus + camera corrector/filter	4 segments bifocal separation 2 pixels horizontal
Entrance Pupil	1 m diameter	PPMA corrector plate	PPMA corrector plate
Payload Mass (lbs)	3128/3533 (3000 max)	876 base 1050 w/ contingency	719 base 871 w/ contingency
Payload Power (24 V)	457/218/575 night day peak	142/49/181	197/53/241
Float Height	110,000 ft (33 km, 7 mbar)		Earth limb 5.8 deg below horz.
Launch Location	Wanaka NZ	2023 requested	
Duration Target	100 days		

Telescope Opto-Mechanics

UAH (Huntsville), Olomouc(CZ), Mines (US)



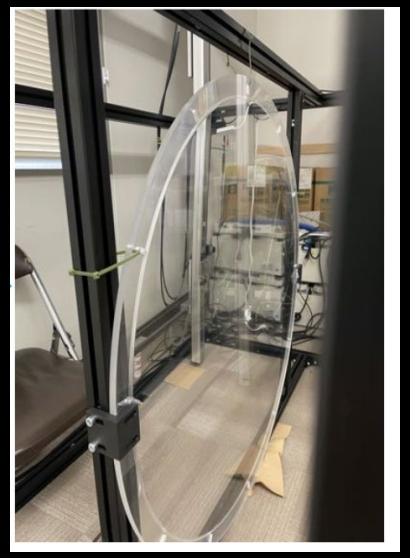
Fluorescence Telescope



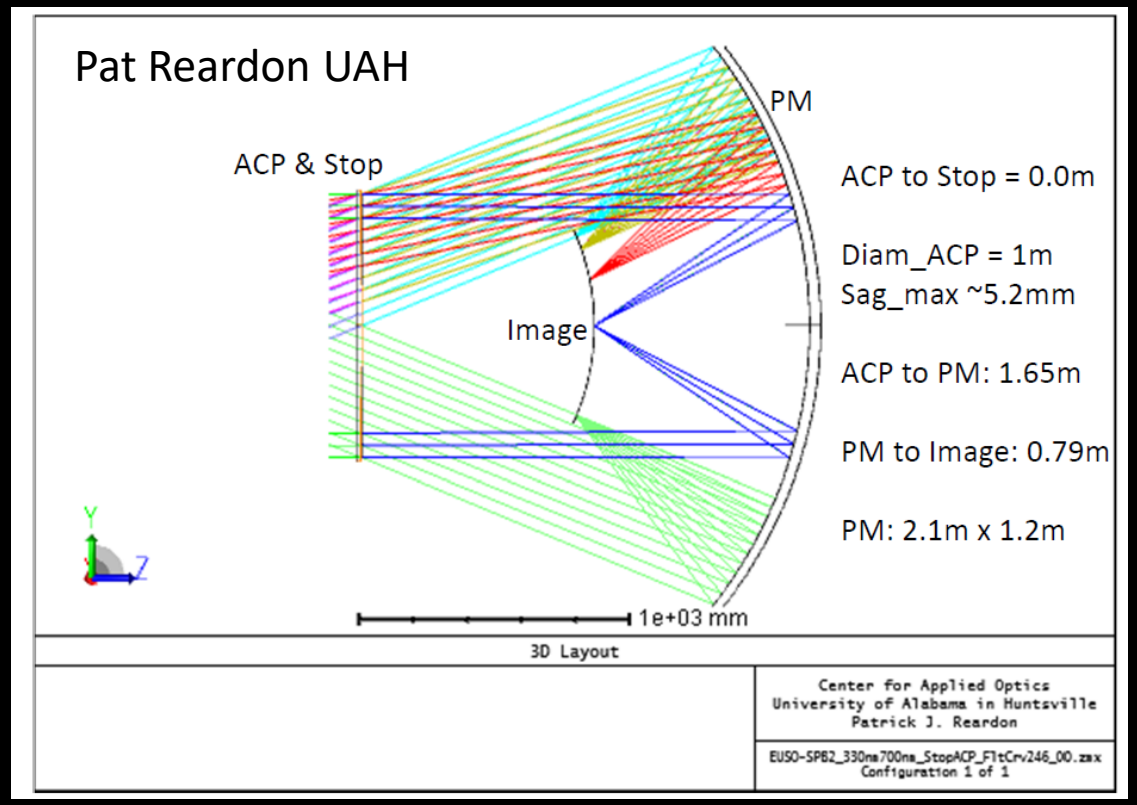
Cherenkov Telescope

Not Shown: light shrouds, aperture doors

EUSO-SPB2 Opto-Mechanical

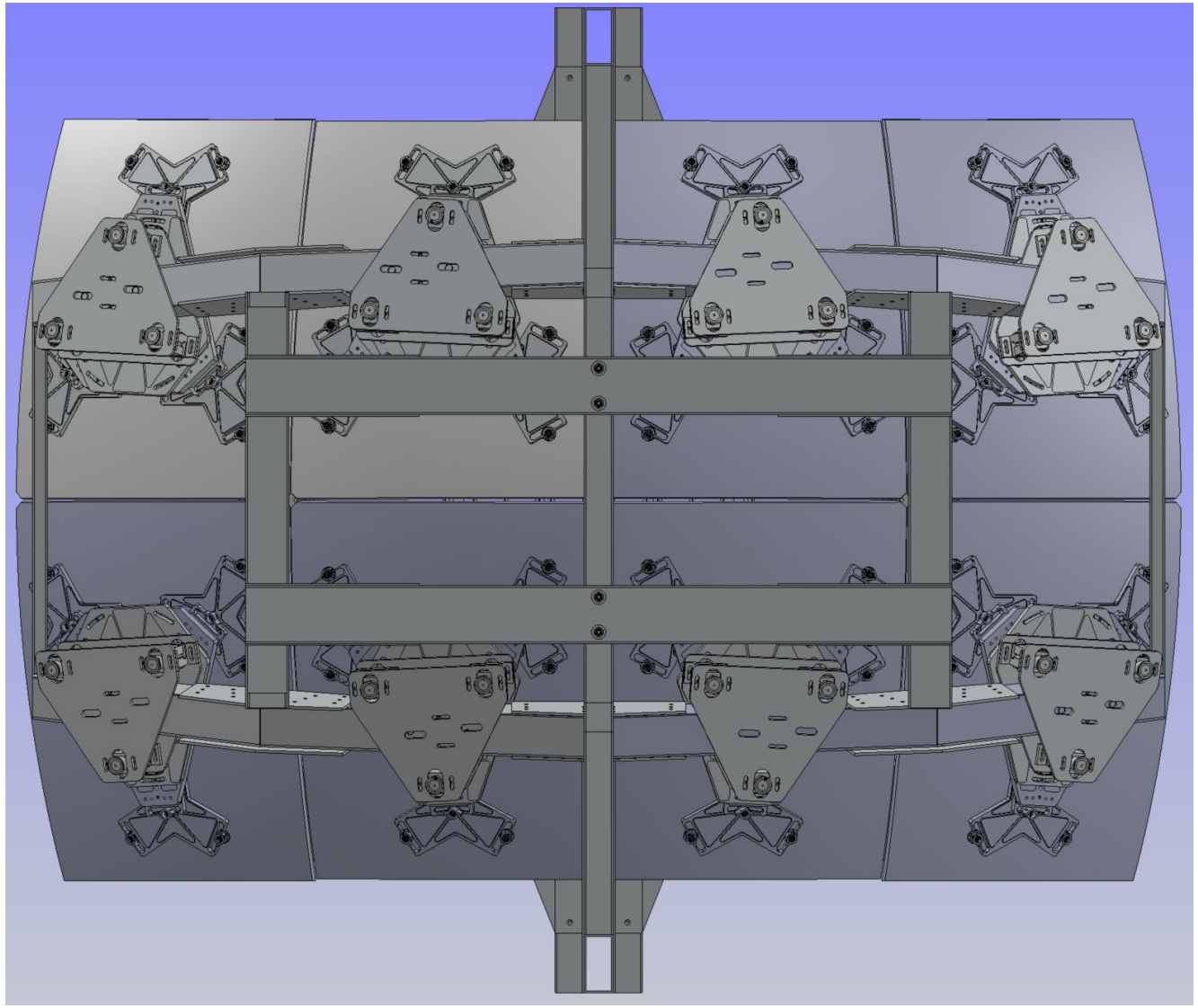


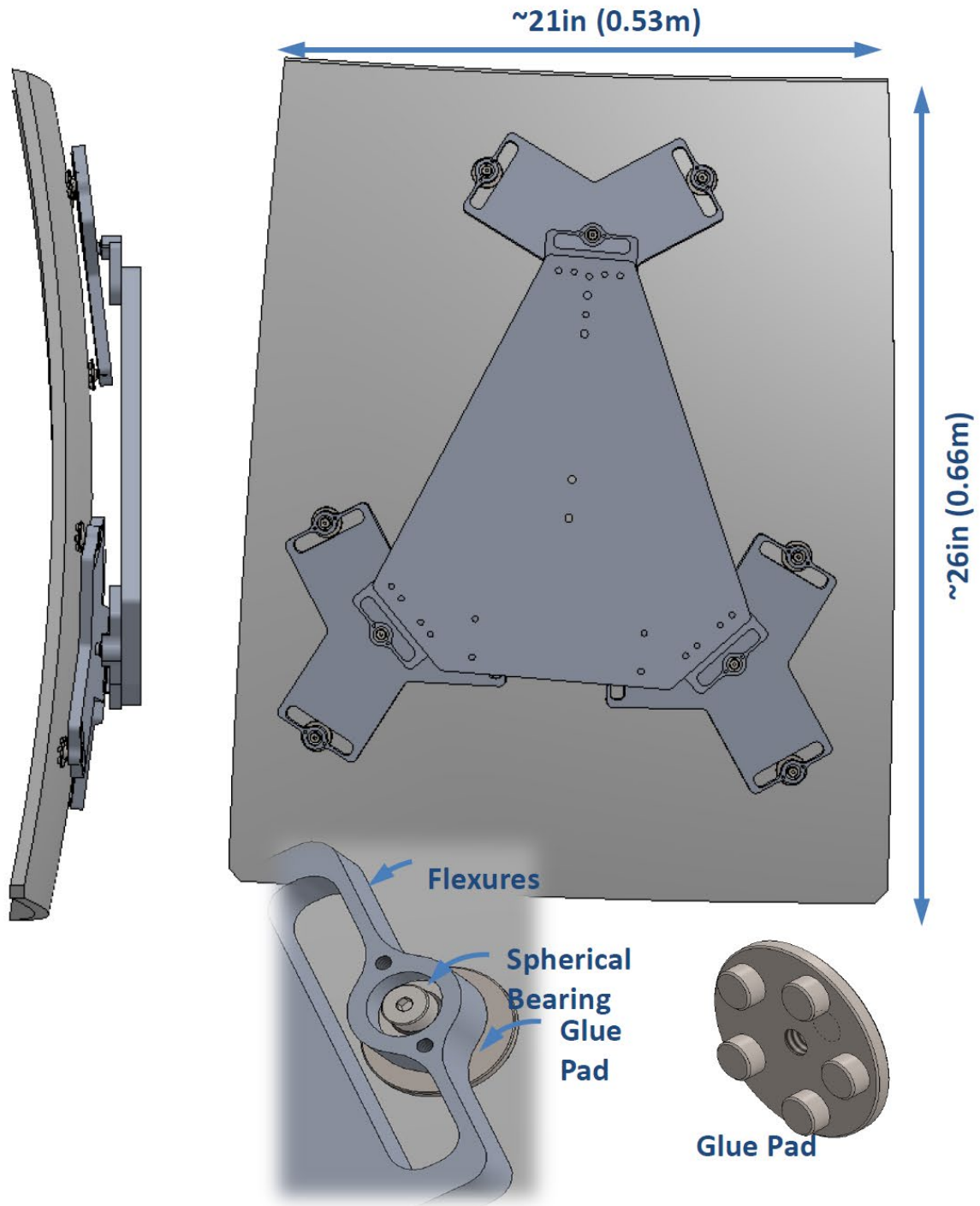
Y. Takizawa,
RIKEN (Japan)



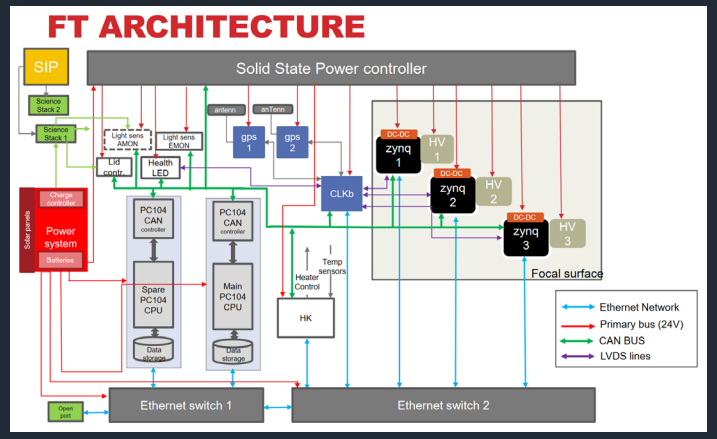
Petr Schovanek , Miroslav Pech (Olomouc Group (CZ)

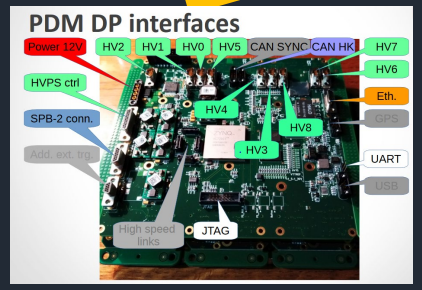
Kungel, Viktoria — D10.00009 EUSO-SPB2 Telescope Optics and Testing

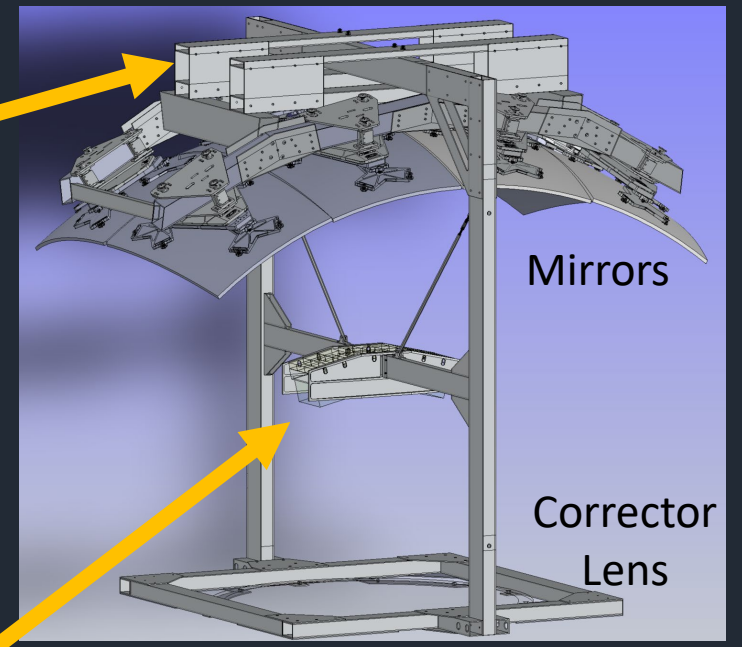


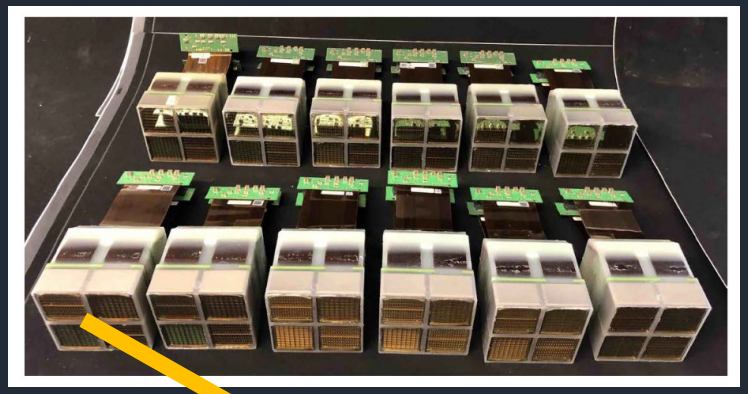

~21in (0.53m)
~26in (0.66m)
Flexures
Spherical
Bearing
Glue
Pad
Glue Pad

The Fluorescence Camera

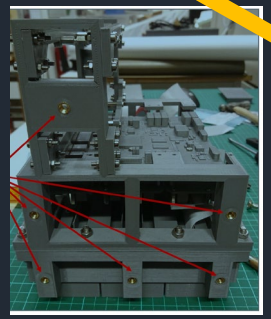


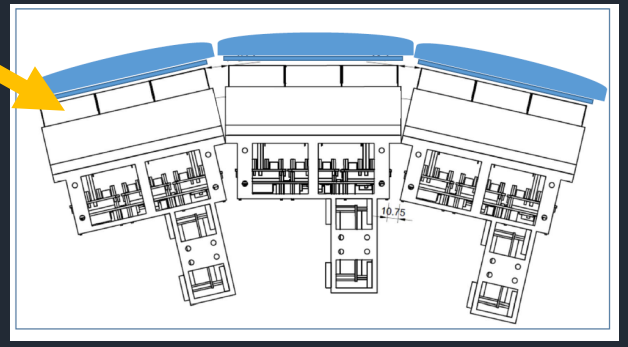






Cherenkov Telescope





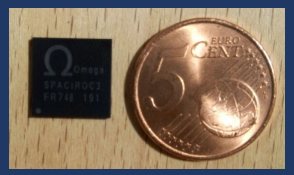
EUSO-SPB2 Fluorescence Telescope Camera Components

Elementary Cell

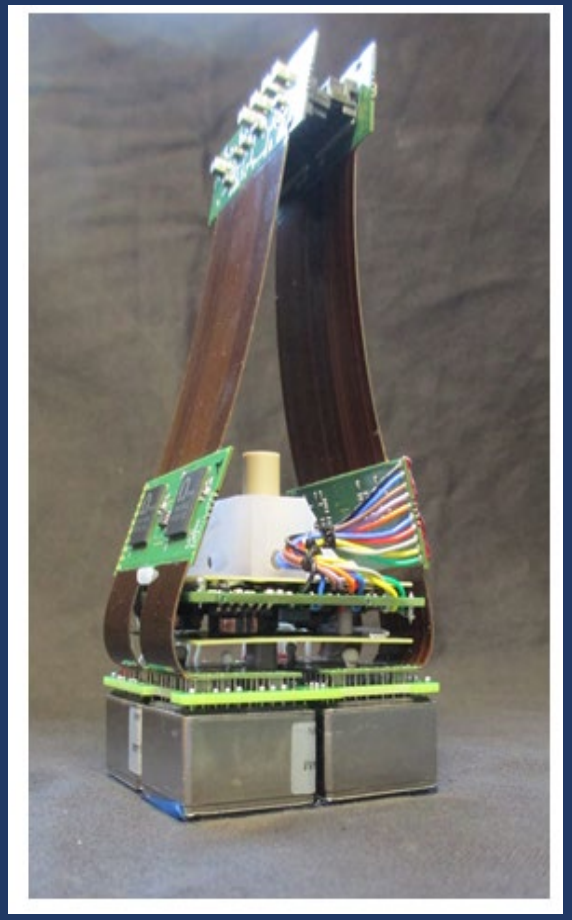
4 Multi-Anode PMTs
256 channels total

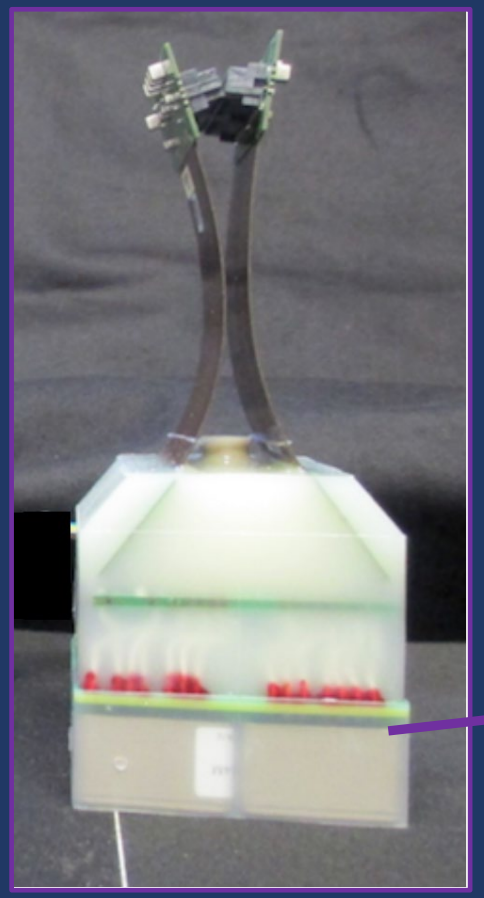
Cockcroft-Walton High Voltage Circuit

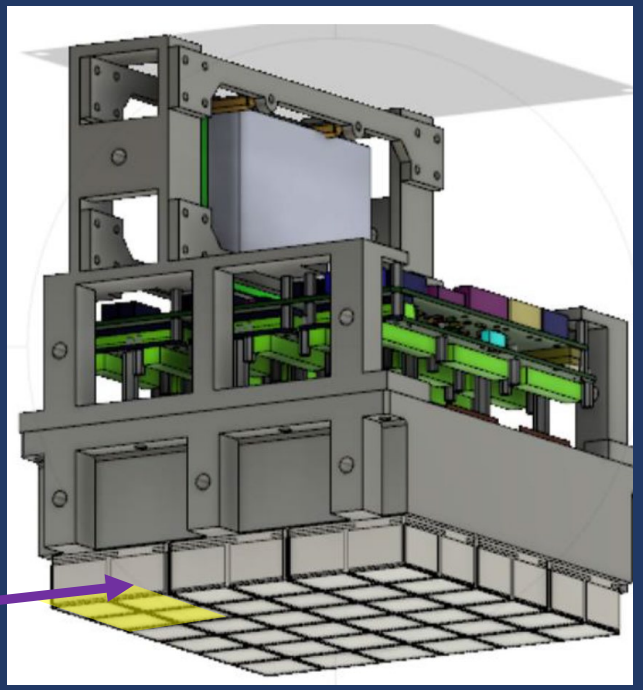
Digitization
count single photoelectron pulses



Data Out:
# of PE / microsecond







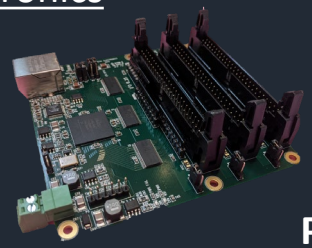
Sylvie Blin (OMEGA, IN2P3), (France)
Guillaume Prévôt (APC, IN2P3) (France)

The Cherenkov Camera

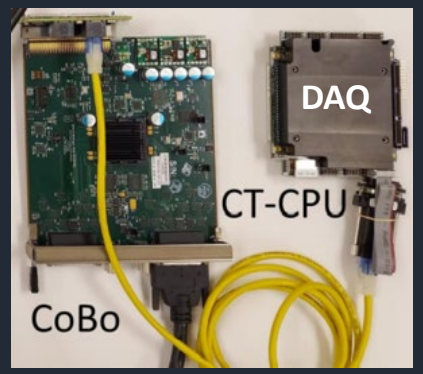
Read-out Electronics

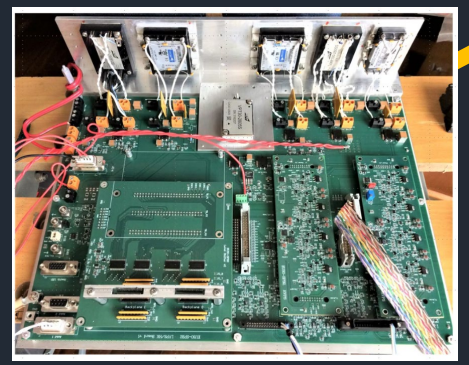
Digitizer Board

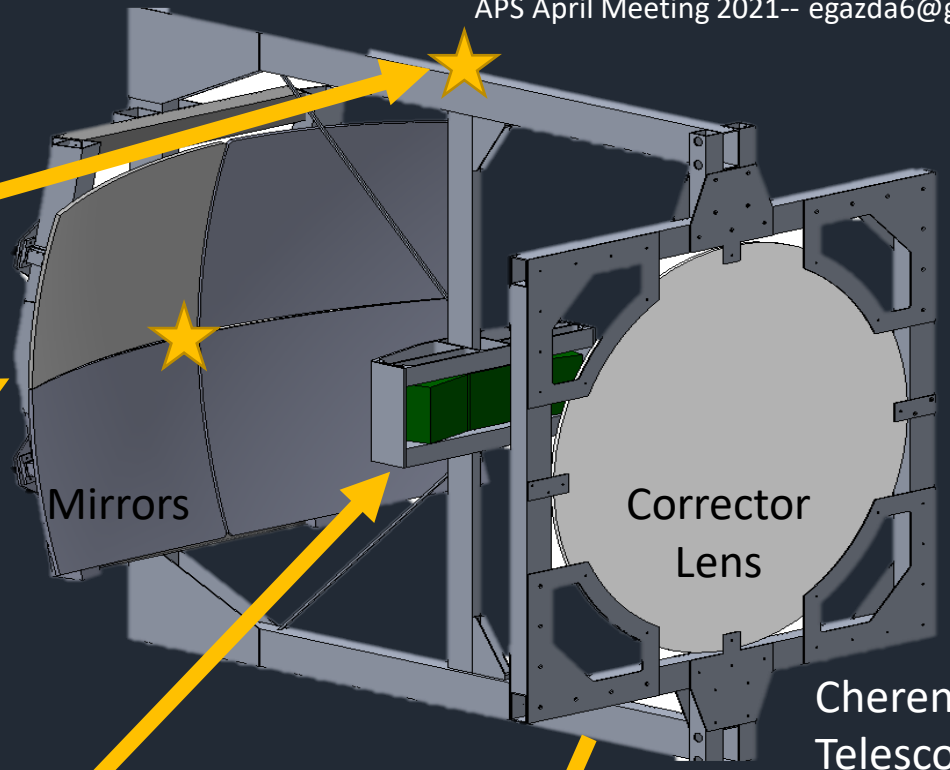
Trigger Board



Power Module







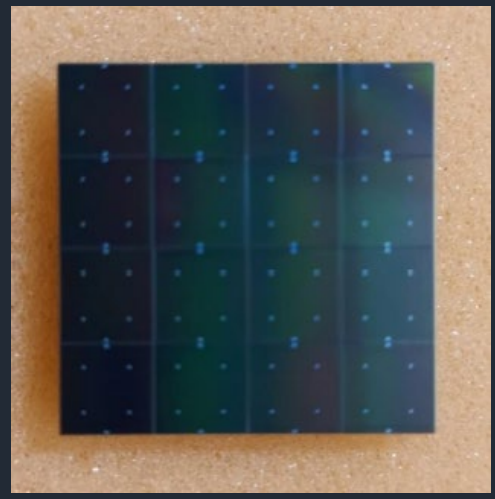
Cherenkov Telescope

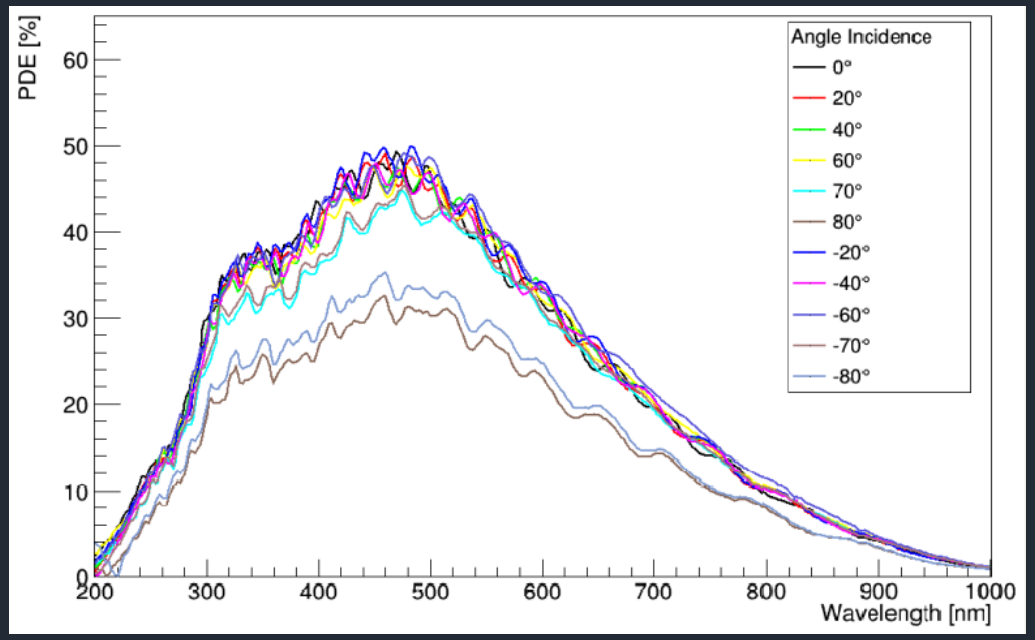
SiPM characterization

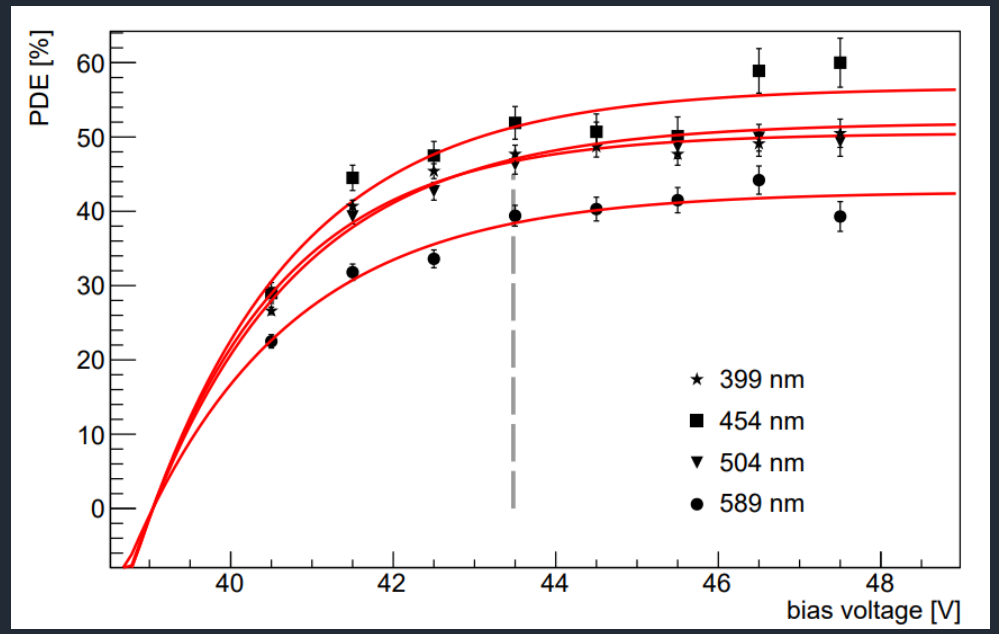
We have 35 SiPM arrays from Hamamatsu in the lab

Measurements preformed on SiPM array:

1. photon detection efficiency (PDE)
2. gain using a pulsed laser
3. breakdown voltage for each array and pixel

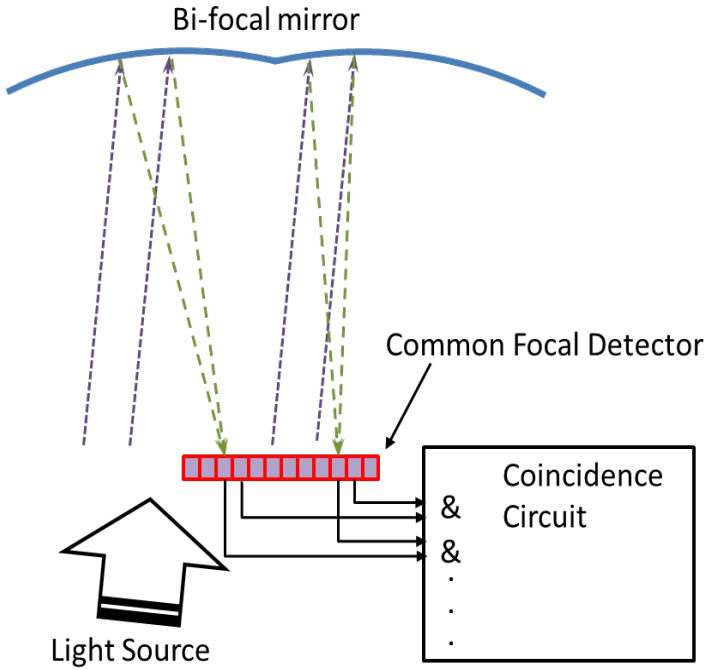


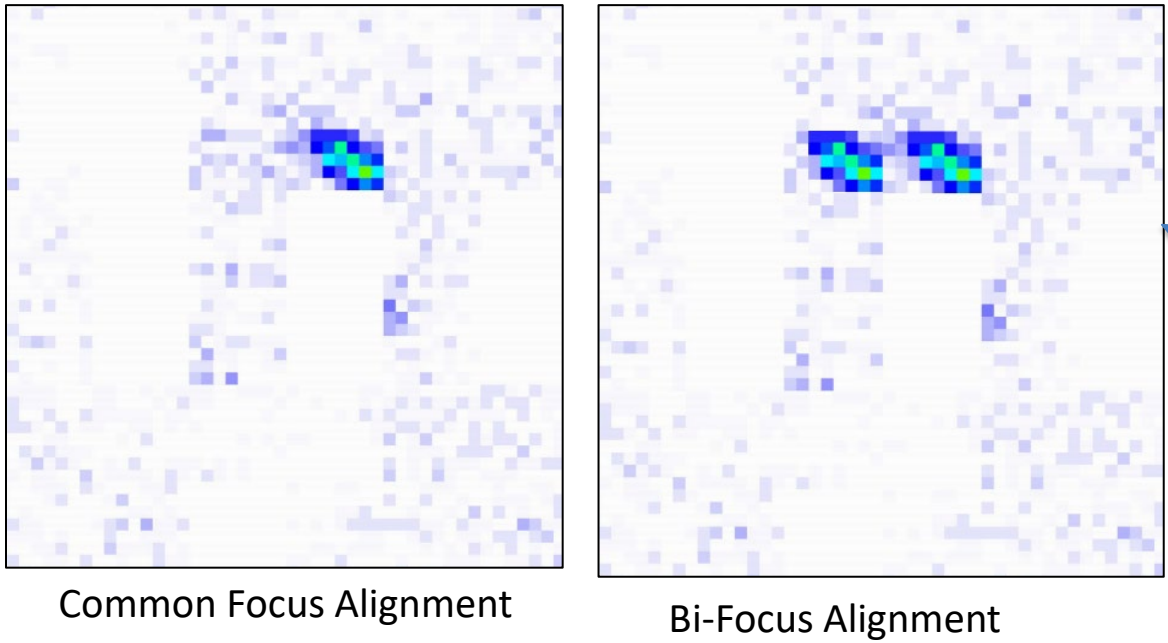




Bi-focus Mirror Segment Alignment: Cherenkov Telescope

(Background Reduction Technique)



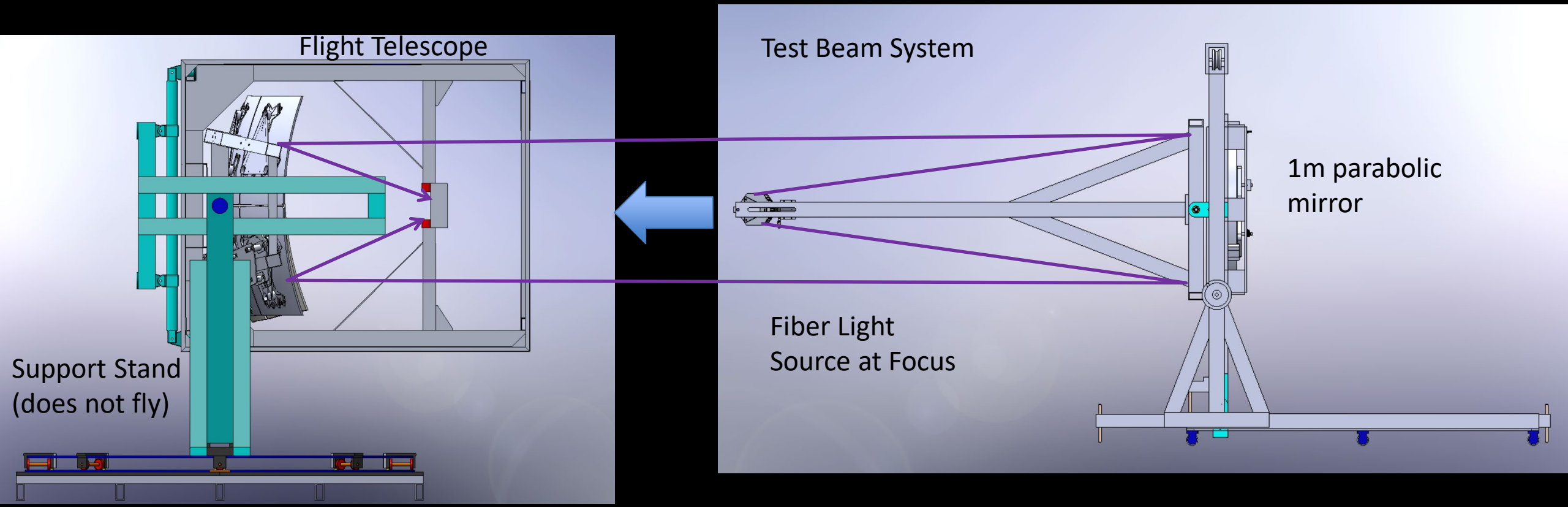


Common Focus Alignment

Bi-Focus Alignment

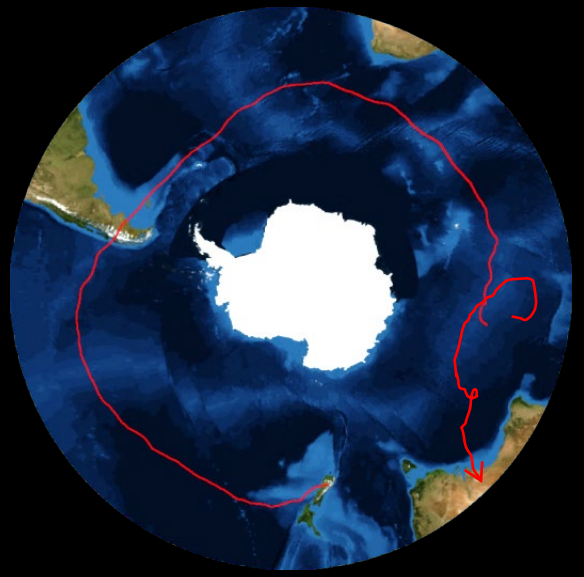
Charged Particle Hits Camera:	**1** spot	**1** spot
Light Pulse from far-field *outside* the telescope:	**1** spot	**2** spots

Planned Lab Test Configuration (CT, FT) using 1 meter diameter test beam system



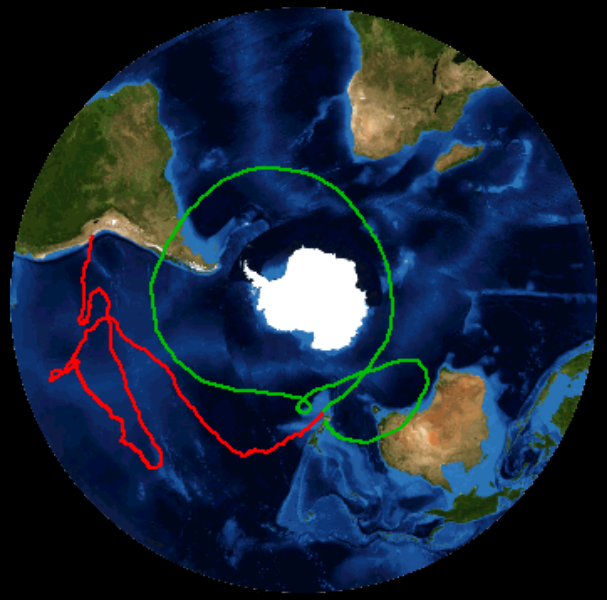
Also, field tests with a laser and point light sources

2015: 32 d 5 h



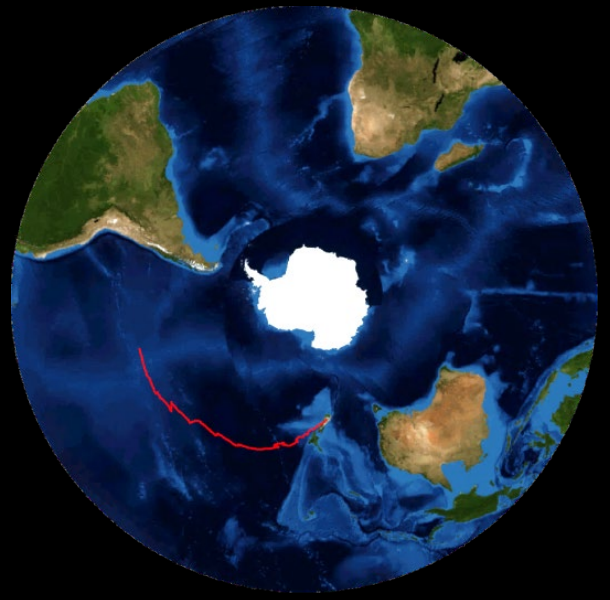
Engineering Flight

2016: 46 d 20 h



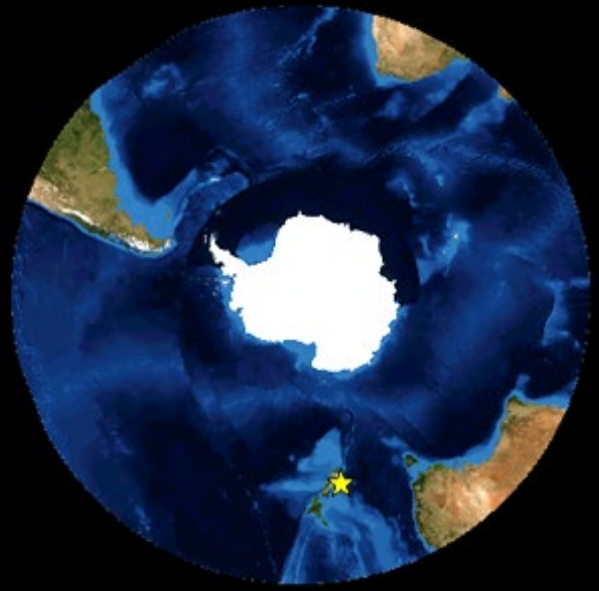
COSI

2017: 12 d 4 h



EUSO-SPB1

2023: 100 d ?



EUSO-SPB2

Summary

POEMMA will open two new Cosmic Windows:
neutrinos from transient astrophysical sources
extreme energy cosmic ray (> 20 EeV)

EUSO-SPB2 Improved 2-Telescope Instrument, builds on SPB1 experience
Add unexplored areas
EAS observations from suborbital altitude
Search for upward candidate-events (beyond standard model)
Direct Cherenkov above the limb from suborbital altitude
Optical backgrounds for Earth-Skimming neutrino technique
Target of Opportunity Neutrino Search

EUSO-SPB2 on track for 2023 launch from Wanaka NZ (also thinking about SPB3)
Scientific and Technical Pathway toward POEMMA or POEMMA-like instrument