## The EUSO-TA telescope for observing UHECR

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RIKEN

TeVPA, 29.X.2015

A small single-photon UV telescope – an on-ground prototype of JEM-EUSO space mission

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# A small single-photon UV telescope – an on-ground prototype of JEM-EUSO space mission



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TeVPA, 29.X.2015

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- Focal surface: 36 MAPMTs, 2304 channels
- Optics: Two 1 m<sup>2</sup> Fresnel lenses
- Field of view:  $\sim 10.5^{\circ} \times 10.5^{\circ}$



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- Location: in front of Black Rock Mesa TA FD detector, Utah, USA



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#### Work modes:

- Internal trigger (undergoing testing) (not optimized for ground observations)
- External (eg. TA) trigger
- Untriggered data taking

Main aims:

- Tests/modifications of electronics for other EUSO experiments
- Calibration with TA's facilities (CLF & ELS) and EUSO lasers/LEDs
- Gathering data (CR and artificial) for testing algorithms/software
- Comparison with TA results for CR and artificial sources
- Measurement of the UV night background

## EUSO-TA campaigns

#### So far EUSO-TA had 4 observation campaigns:

February/March 2015

May 2015

September 2015

October 2015

- Detector installation
- Focusing, initial calibration
- Initial CLF and CSOM laser observations
- Cosmic ray observations one UHECR detected
- CLF and CSOM laser observations
- Flat screen and LED calibration
- Cosmic ray observations analysis ongoing
- CLF and CSOM laser observations
- Cosmic ray observations analysis ongoing
- Internal trigger tests successful triggering on laser
- CLF and CSOM laser observations

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Found in some TA UHECR candidate data (preliminary analysis) by Shin Hengsu Preliminary data from TA:

- $E\simeq 10^{18}~{\rm eV}$
- Distance: 2.5 km



## Cosmic rays, diffuse

Background for TA, probably muon Cherenkov light



## Central Laser Facility

- Distance from EUSO-TA: 21 km
- Energy:  $\sim$ 3-7 mJ (4 mJ  $\simeq 10^{19.2}$  eV)



Empirical flat fielding applied – Z scale arbitrary

## Shape comparison



- A similar structure in light-curves in 07:00 run
- Disagrees exist in 07:30 run

EUSO-TA lightcurves are directly drawn from raw data Field-flatting, absolute calibration for EUSO-TA is yet to be done

#### Laser tests

Many tests using mobile Colorado School of Mines laser (up to 90 mJ, adjustable pointing) has been performed.

- Testing of EUSO sensitivity and triggers
- Allows for examining the whole focal surface
- $\bullet\,$  Can shoot at large distance like 100 km similar conditions to observations from ISS



#### Laser tests

Preliminary results of three campaings:

- $\bullet\,$  We can detect on some frames vertical laser with 1 mJ energy,  $\sim$  33 km from EUSO-TA
- We could see some shots from 100 km, but we need to check what was the pointing of the laser (if towards us, than the beam was closer when seen)
- We could swipe the whole focal surface additional detector sensitivity tests



#### Stars

#### Stars in EUSO-TA with Hipparchos catalogue superimposed



The superimposing will be improved.

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#### A scheme of triggers caused by a plane during a half hour run of EUSO-TA.



Lightcurve of observations performed during thunderstorm (judged by eye) not in our FoV – average number of counts on the whole PDM vs GTU.



The counts above signal are packets with lightning candidates (the label on X axis is wrong - these are GTUs).

### Flat frame

#### Jim Adams' team built a screen for flat fielding of EUSO-TA



#### Data should be properly analyzed, but initially spread of $\sim 5\%$ after FLAT fielding



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#### Star (Capella) close to the border of the frame:



2672-12800, pkt: 99-100, GTU in pkt: 0-0, UTC time: 2015-03-10 05:12:36-2015-03-10 05 Utab time: 2015-03-09 23:12:36-2015-03-09 23:12:36

- Coma/astigmatism/spherical aberration clearly visible
- $\sim 2.35$  pixel/ $\sim 0.42^{\circ}$  FWHM,  $\sim 0.6\sigma$  pixel/ $\sim 0.11^{\circ}$  of gaussian
- More detailed measurements for whole PDM needed

Imperfections:

- Flat field far from perfect
- Photometry extremely simple
- Background calculation very arbitrary
- No PSF assumption
- No proper spectral calculation (need to take star spectrum and our spectral acceptance)
- No weather conditions (aerosols, etc.) estimation

#### Preliminary EUSO-TA absolute efficiency



## Clouds

#### Sometimes well visible when flat frame used



TU: 0-1280, pkt: 0-10, GTU in pkt: 0-0, UTC time: 2015-05-17 05:55:45.5967126-05:55:54.45424

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- Balloon and Mini-EUSO payload tests in 2017
- Traversal profile of the laser/cosmic rays analysis
- Slow external trigger development (meteors, lightning)

Big thanks to all the Telescope Array people for help and patience!

EUSO-TA:

- Detector working, and collecting valuable data
- Calibration endless task, but progressing
- Lasers (CLF, CSOM), LEDs ("Balloon" flasher, calibration) lot's of data, undergoing analysis
- Stars, thunderstorms, clouds observed
- CR & UHECR seen, but waiting for more events
- Self trigger tested and detecting laser