Najenergetickejšie objekty vo vesmíre

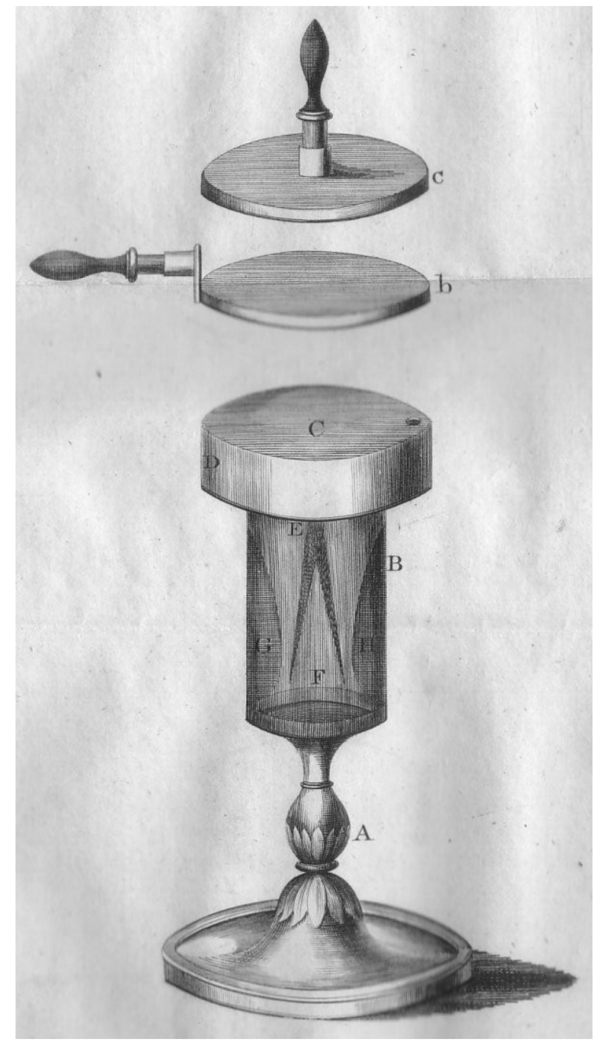
Čo môžu urobiť informatici pre ich odhalenie?

P. Bobik
bobik@saske.sk
Web: http://space.saske.sk

Ústav experimentálnej fyziky SAV, Oddelenie kozmickej fyziky

Kozmické žiarenie – začiatok príbehu

1785 *Charles Coulomb* - nabité teleso (vo vzduchu) sa po čase stane elektricky neutrálnym



1787 *Abraham Bennet* – elektroskop (dve tenké pásky zlata na bavlnených vláknach) sa postupne bez akéhokoľvek vonkajšieho zásahu vybíja

1900 Charles Thomson Rees Wilson – ionizácia vzduchu vonkajším žiarením spôsobuje vybíjanie elektroskopu

Záver: žiarenie spôsobujúce vybíjanie elektroskopu pochádza zo zeme – problém vyriešený.

Naozaj?

Kozmické žiarenie – objav

1912 *Victor Hess*

Dokonalejší elektroskop s ktorým meral ionizáciu na rôznych výškach.

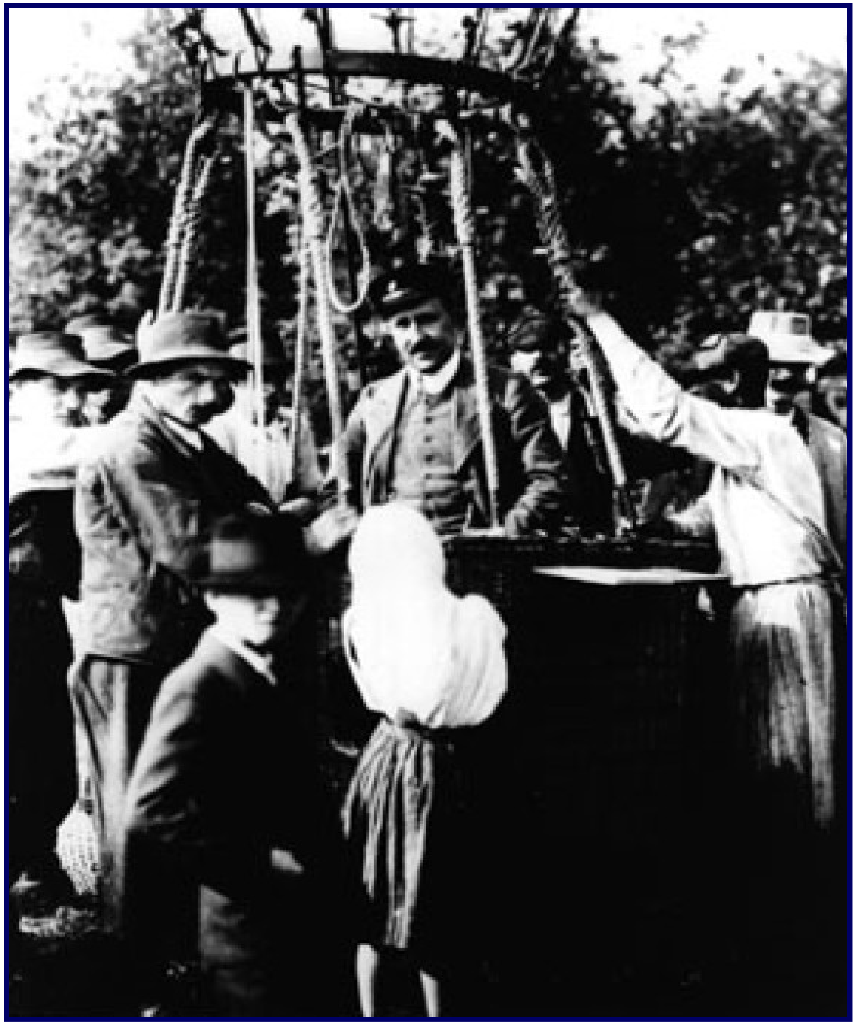
10 letov, z nich 5 v noci

Rovnaké výsledky – **ionizácia vo výškach od 2000 m.n.m rastie**

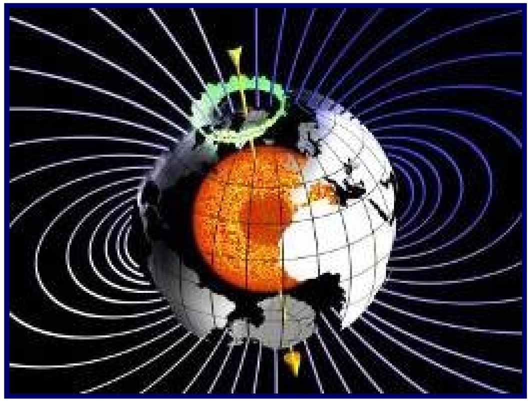
17. apríla 1912 počas zatmenia Slnka – rovnaký záver. Slnko tiež nie je zdrojom ionizujúceho žiarenia.

Žiarenie prichádza z vesmíru – termín Kozmické žiarenie zaviedol Robert Millikan

Nobelova cena v roku 1936.



Kozmické žiarenie



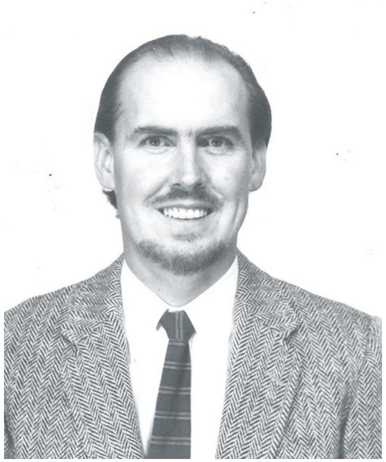
1933 Sir Arthur Compton - intenzita radiácie závisí na geomagnetickej šírke

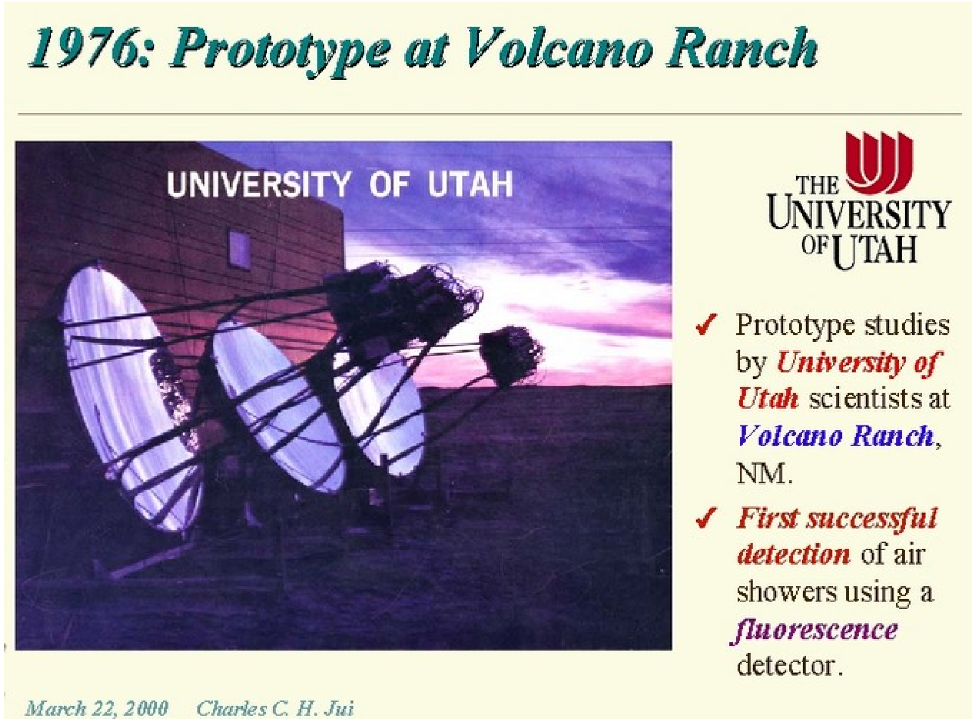
1937 Street a Stevenson - objav miónu v kozmickom žiarení, 207 krát ťažší než elektrón

1938 Pierre Auger a Roland Maze - žiarenie v detektoroch vzdialených od seba 20m (neskôr 200m) prichádza v rovnaký moment

Objav UHECR

- John D. Linsley
- Pole 19 scintilačných detektorov, Volcano Ranch, Albuquerque, New Mexico
- Začiatok pozorovaní v lete 1959
- 22. februára 1962, Linsley pozoroval atmosférickú spŕšku vytvorenú primárnou časticou s energiou viac než 16 Joulov





Oh-My-God particle

- Oh-My-God particle - 15 október 1991 – HiRes Fly's eye II, Dugway Proving Ground, Utah. Energia 3×10^{20} eV (51 J)
  - častica s kinetickou energiou rovnou basebalovej (142 gr) loptičke letiacej rýchlosťou 100 km/h či protón letiaci rýchlosťou 0.9999999999999999999999951c = pri ročnej ceste zaostane za fotónom len 46 nanometrov alebo 0.15 femtosekundy.

- z pohľadu častice - čas

Object	Distance[3] (light years)	Perceived Travel Time
Alpha Centauri	4.36	0.43 milliseconds
Galactic nucleus	32,000	3.2 seconds
Andromeda galaxy	2,180,000	3.5 minutes
Virgo cluster	42,000,000	1.15 hours
Quasar 3C273	2,500,000,000	3 days
Edge of universe	17,000,000,000	19 days

- z pohľadu častice – dĺžka „objektov"

Object	Rest Frame Thickness	Particle Frame Thickness
Earth's diameter	12,756 km	0.0399 mm
Solar system	80 AU	37 metres
Sun/Alpha Centauri	4.3 light years	127 km (79 miles)
Milky Way galaxy	30 kiloparsecs	2,895,000 km, about ten times the distance from the Earth to the Moon

http://www.fourmilab.ch/documents/OhMyGodParticle

Pohybová energia, čo to je?

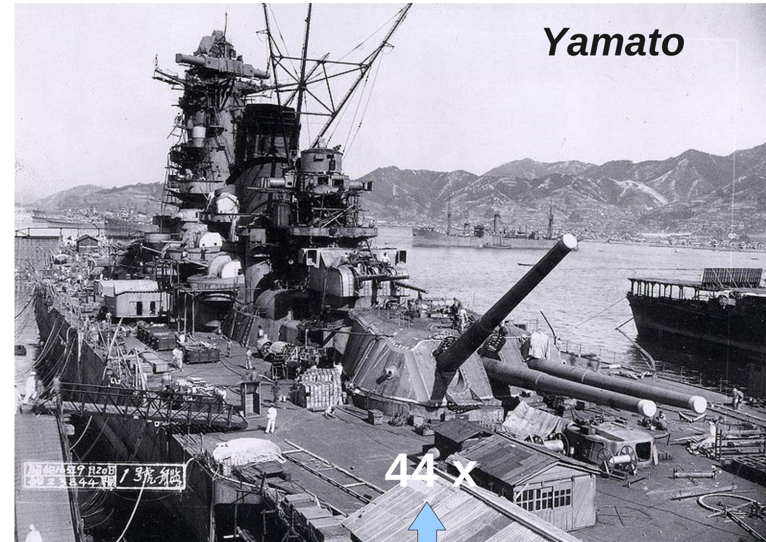
Bentley Continental GT

2320 kg, max. rýchlosť 318 km/h

110000 x

0,4 kg, 100 km/h

1064 x



Batillus supertanker

555 000 ton, dĺžka 414 metrov, bežná cestovná rýchlosť 30 km/h

≈

Airbus A380

575 ton, 945 km/h

Majme miniatúrnu guličku zo železa s váhou 1 gram

Nech sa pohybuje rovnakou rýchlosťou ako častice s ultravysokými energiami.

Je jej pohybová energia väčšia alebo menšia ako pohybová energia Airbusu A380?

Odpoveď : omnoho omnoho väčšia

- Cheopsova pyramída je približne 10 krát ťažšia ako supertanker Bautillus
- Ak by sa pohybovala **10 tisíc krát** rýchlejšie ako sa pohybuje Airbus A380 (za 15 sekúnd okolo Zeme)
- Potom bude mať pohybovú energiu rovnú jednogramovej železnej guľôčke pohybujúcej sa rýchlosťou častíc s ultravysokou energiou !!!

Kozmické žiarenie ultravysokých energií ma najviac energie vo vesmíre na jednotku hmotnosti

Zaujímavosť – UHECR a stabilita vesmíru

en.wikipedia.org/wiki/Large_Hadron_Collider#Safety_of_particle_collisions

Safety of particle collisions [edit source | edit beta]

Main article: Safety of high energy particle collision experiments

The experiments at the Large Hadron Collider sparked fears among the public that the particle collisions might produce doomsday phenomena, involving the production of stable microscopic black holes or the creation of hypothetical particles called strangelets.[99] Two CERN-commissioned safety reviews examined these concerns and concluded that the experiments at the LHC present no danger and that there is no reason for concern,[100][101][102] a conclusion expressly endorsed by the American Physical Society.[103]

The reports also noted that the physical conditions and collision events which exist in the LHC and similar experiments occur naturally and routinely in the universe without hazardous consequences,[101] including ultra-high-energy cosmic rays observed to impact Earth with energies far higher than those in any man-made collider.

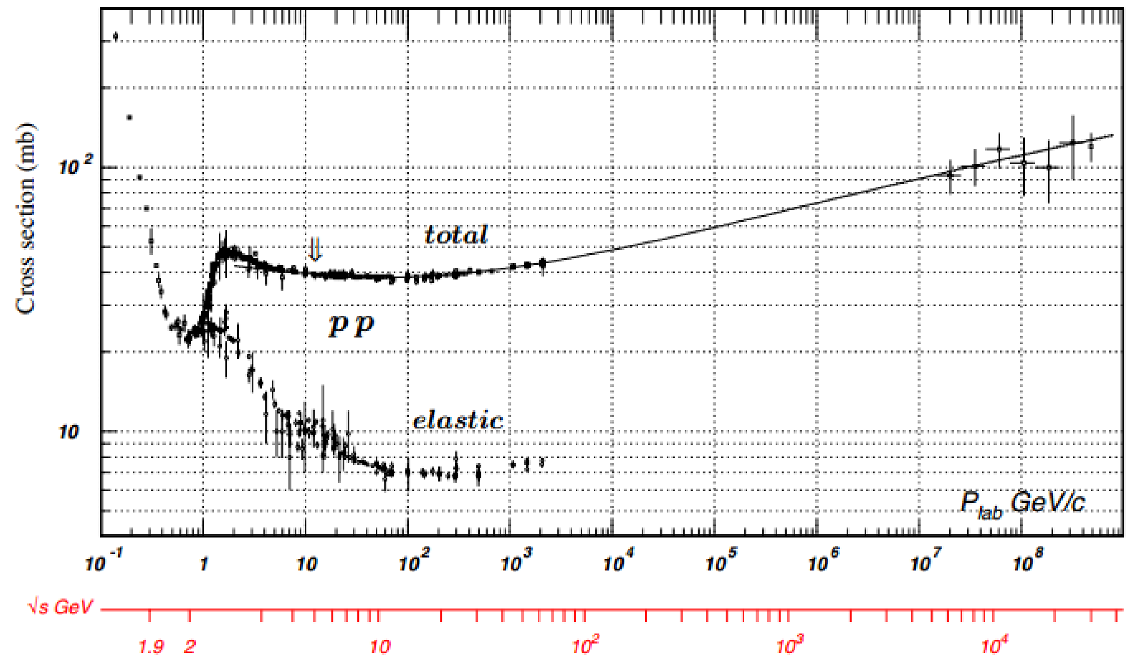
Zaujímavosť – UHECR a stabilita vesmíru

- Pri intenzite 1 častica / (m^2 s) sa mi na ploche 2x10^{28} m^2 zrazia 2 protóny s energiami 10^{20} eV každú sekundu
- Nad 10^{20} eV máme

  5x10^{-3} protónov / (km^2 sr rok)

  1.8x10^{-16} protónov / (m^2 sr s)

  resp. na 10^{16} m^2 sr za sekundu padnú 2 častice s energiou 10^{20} eV
- rádovo na 10^{16}x10^{28} m^2 prebehne jedna zrážka za jednu sekundu
  - 10^{44} m^2 je štvorec s hranou 10^{22} m čo je približne 10^6 sv. roku
- v celom vesmíre každú sekundu nastanú minimálne milióny takýchto zrážok



p-p cross section

http://pdg.lbl.gov/2009/reviews/rpp2009-rev-cross-section-plots.pdf

Pre 10^{20} eV menej ako 1 barn = 10^{-28} m^2

Poznámka : steradiány sme pre jednoduchosť zanedbali

Kozmické žiarenie ultravysokých energií

Kozmického žiarenia s ultravysokou energiou je extrémne málo.

Na ploche celého Slovenska približne jedna častica s ultravysokou energiou za deň !

Detektor s plochou ako územie Slovenska ?

Integrálne spektrum KŽ

1e10 eV	9.7e1	častíc / (m^2 sr s)
1e11 eV	1.9	častíc / (m^2 sr s)
1e12 eV	3.1e-2	častíc / (m^2 sr s)
1e13 eV	5.2e-4	častíc / (m^2 sr s)
1e14 eV	8.6e-6	častíc / (m^2 sr s)
1e15 eV	4.5	častíc / (m^2 sr rok)
1e16 eV	7.5e-2	častíc / (m^2 sr rok)
1e17 eV	1.2e-3	častíc / (m^2 sr rok)
1e18 eV	2.1e-5	častíc / (m^2 sr rok)
1e19 eV	3.4e-7	častíc / (m^2 sr rok)
1e20 eV	5.6e-3	častíc / (km^2 sr rok)

- nad kolenom približné hodnoty

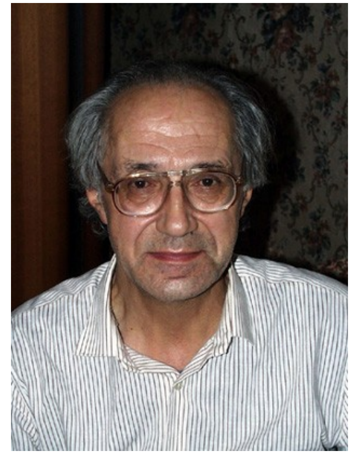
Koleno – nad kolenom sa sklon spektra zvačší

Členok – sklon spektra sa opäť zmenší

Záhada GZK efekt

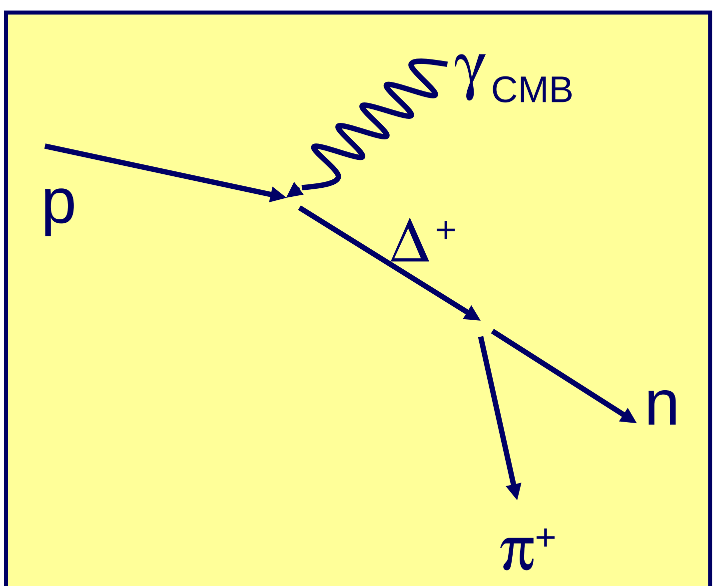
Kenneth Greisen

George Zatsepin



Vadim Kuzmin

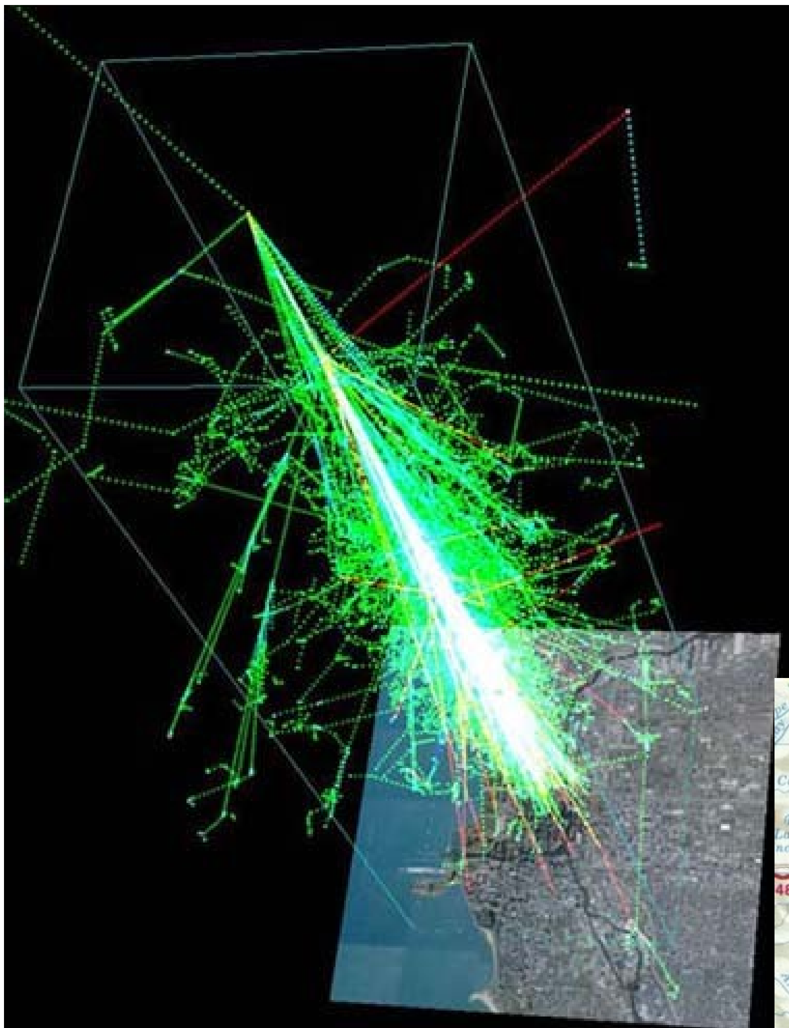
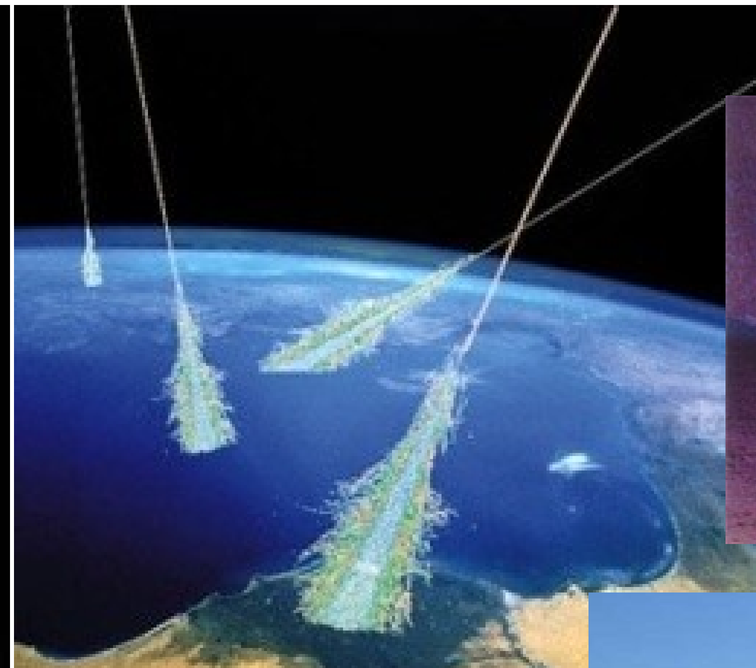
Greisen (1966) a, nezávisle Zatsepin & Kužmin (1966)

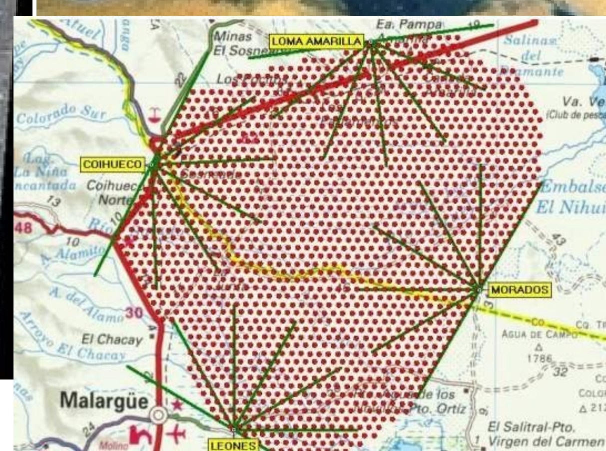


$$E_{th} = \frac{2m_N m_p + m_p^2}{4e} \rightarrow 5 \cdot 10^{19}\,\mathrm{eV}$$

Rozpty kozmického žiarenia ultravysokých energií na mikrovlnom pozadí vesmíru

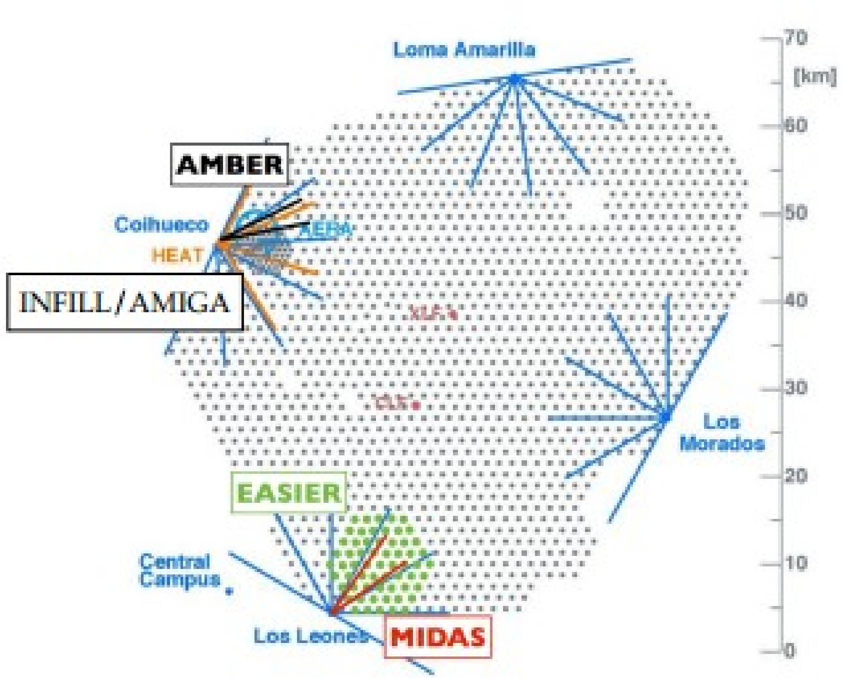
Kozmické žiarenie – registrácia UHECR
Pierre Auger Observatory

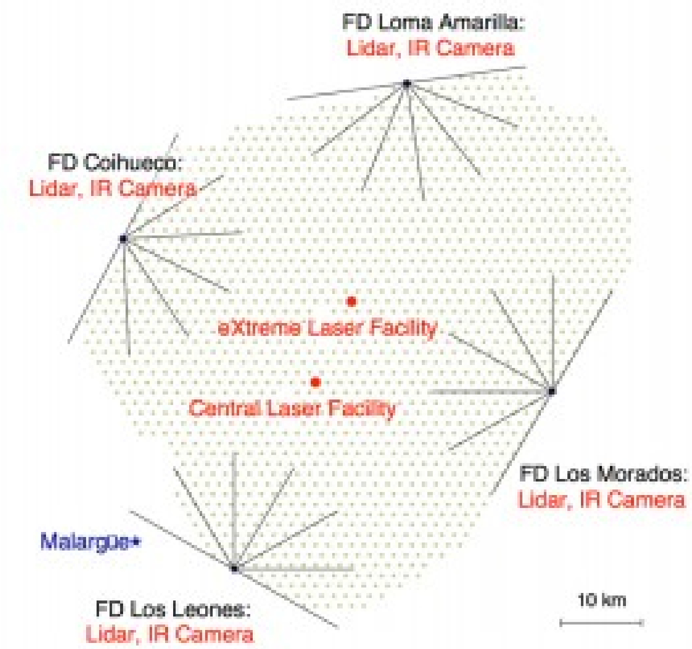





Pierre Auger Observatory

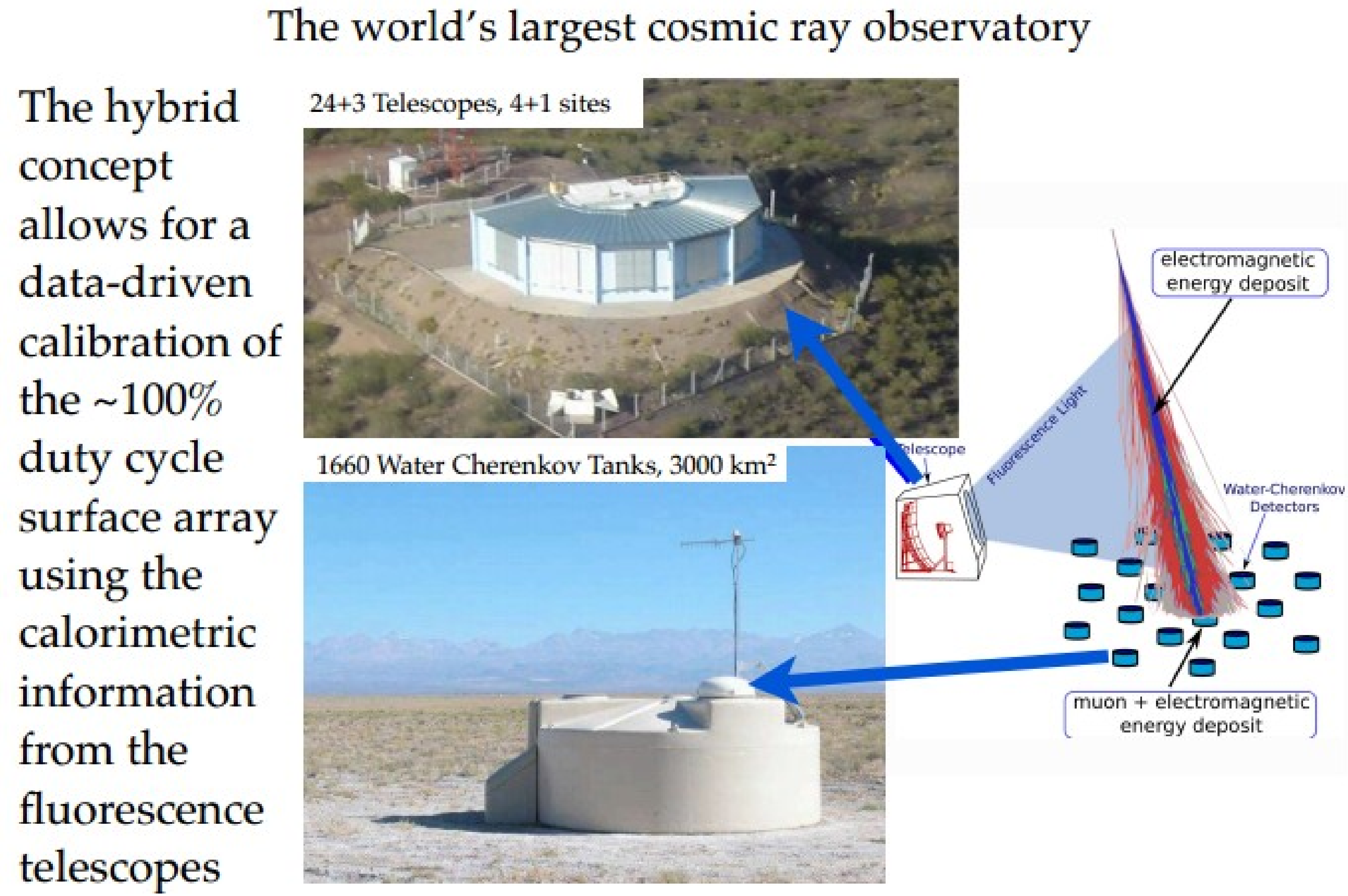
The world's largest cosmic ray observatory
In operation since 2004



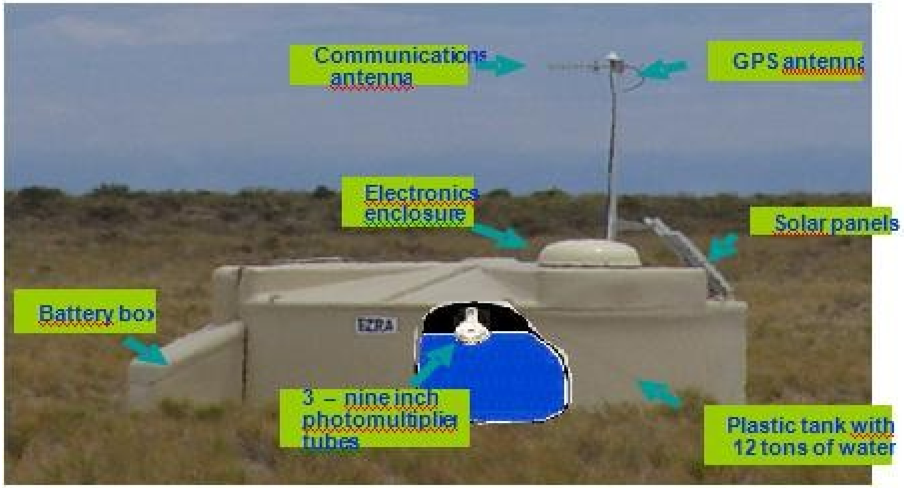


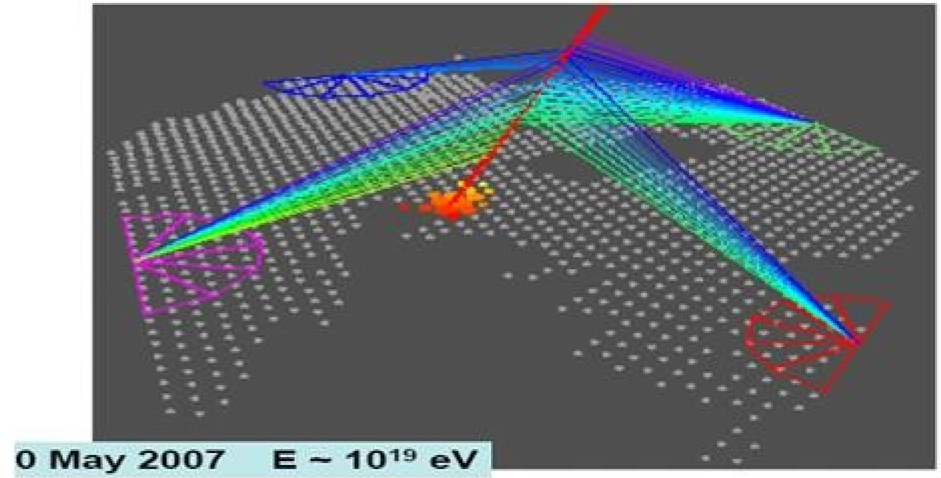
- Antoine LETESSIER-SELVON, Recent Highlights from the Pierre Auger Observatory, ICRC 2013

Pierre Auger Observatory

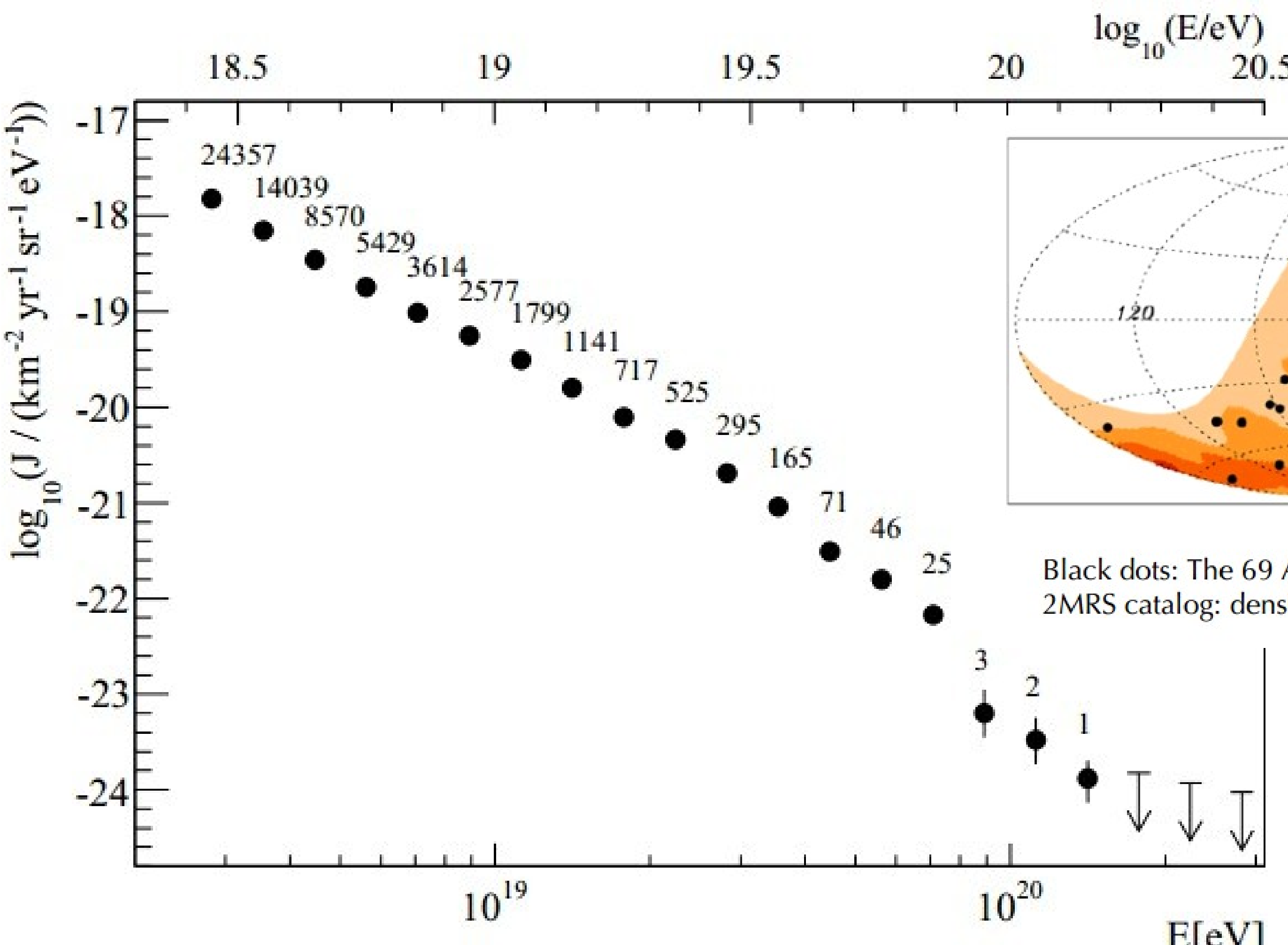


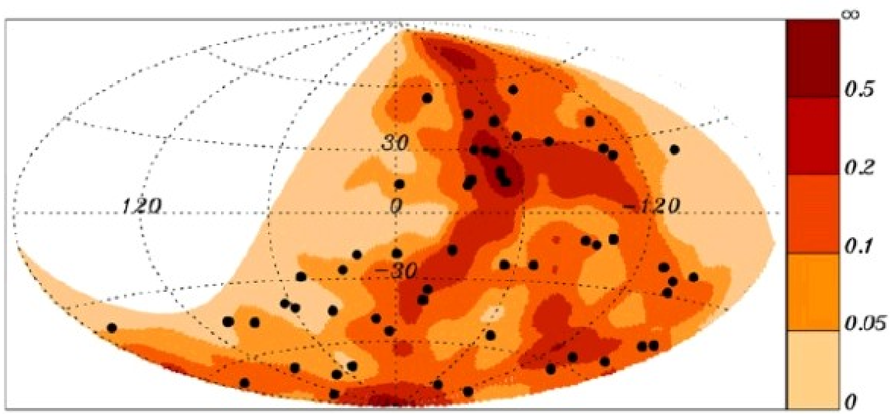
- Antoine LETESSIER-SELVON, Recent Highlights from the Pierre Auger Observatory, ICRC 2013





Približne 15 častíc / rok



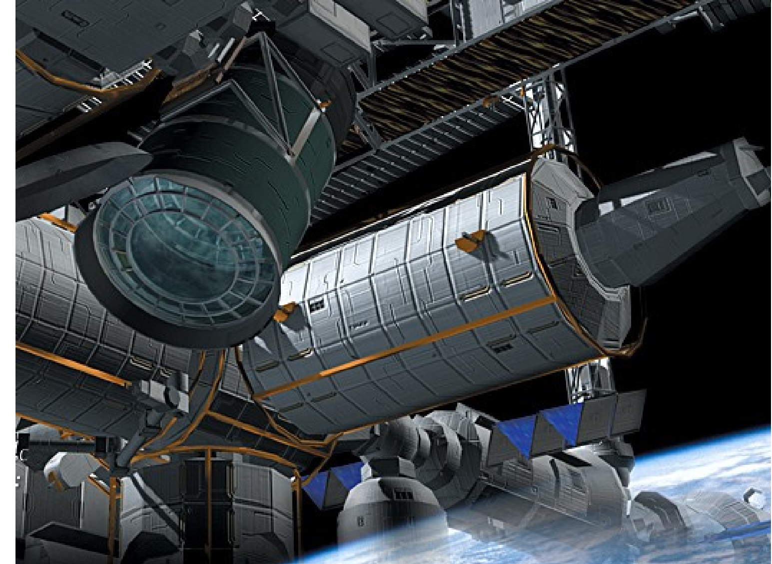


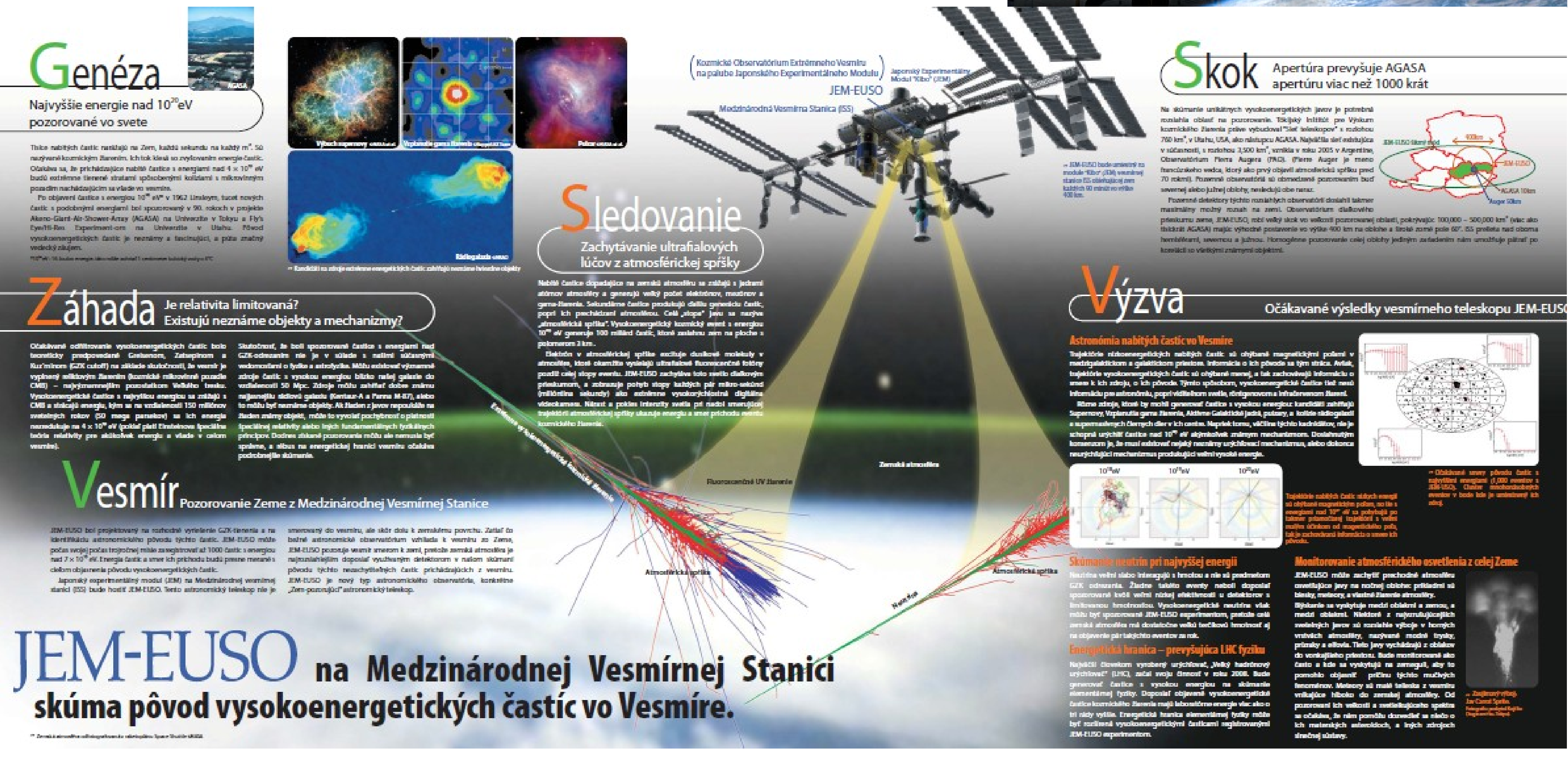
Black dots: The 69 Auger events with E>55EeV
2MRS catalog: density map with a 5° smoothing.

- Málo ?
- Riešenie ?

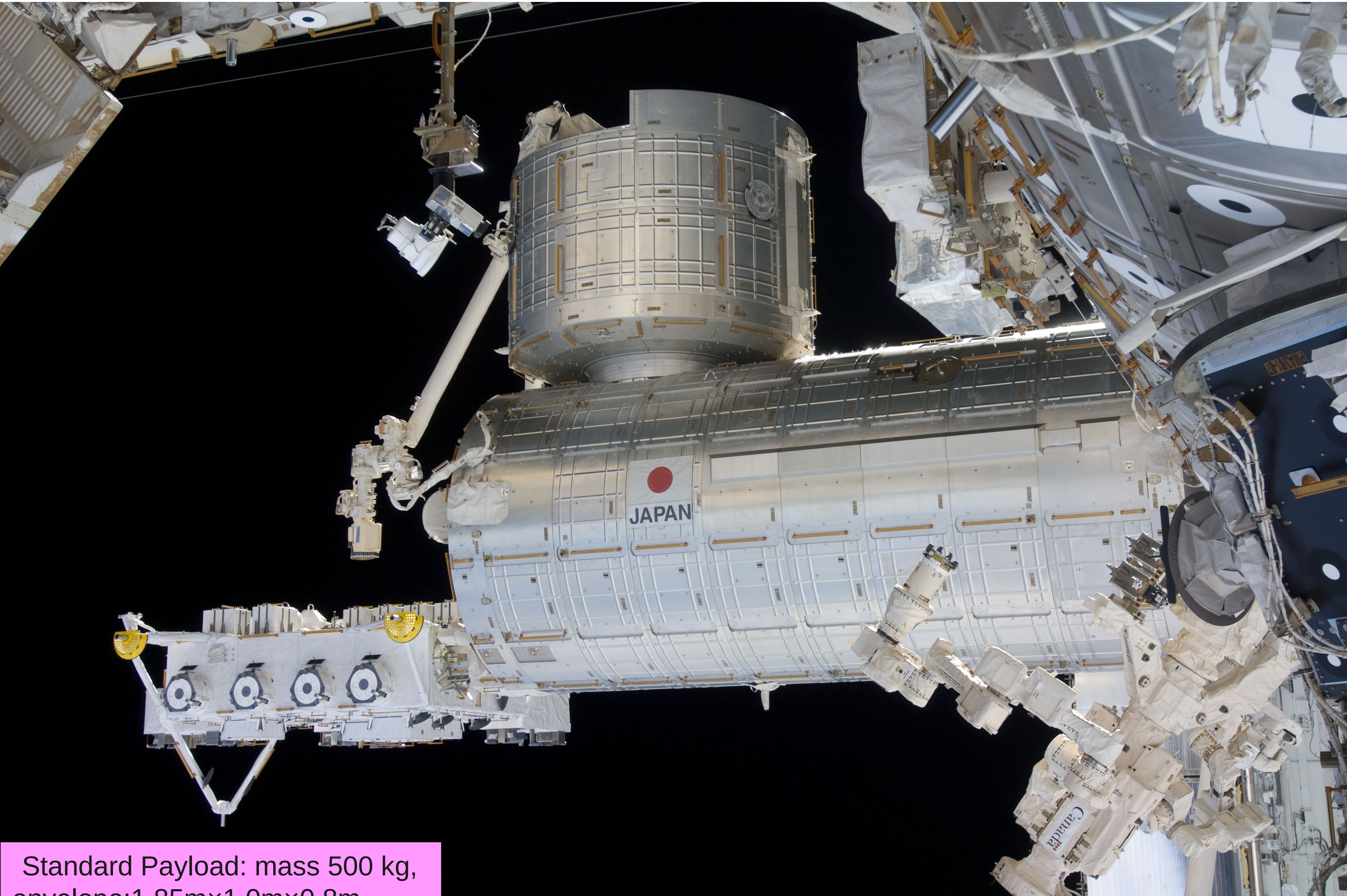
JEM-EUSO

- Kozmické Observatórium Extrémneho Vesmíru na palube Japonského Experimentálneho Modulu
- Projekt JAXA & ESA & NASA & Roskosmos,
- 16 členských krajín
  93 vedeckých inštitúcií



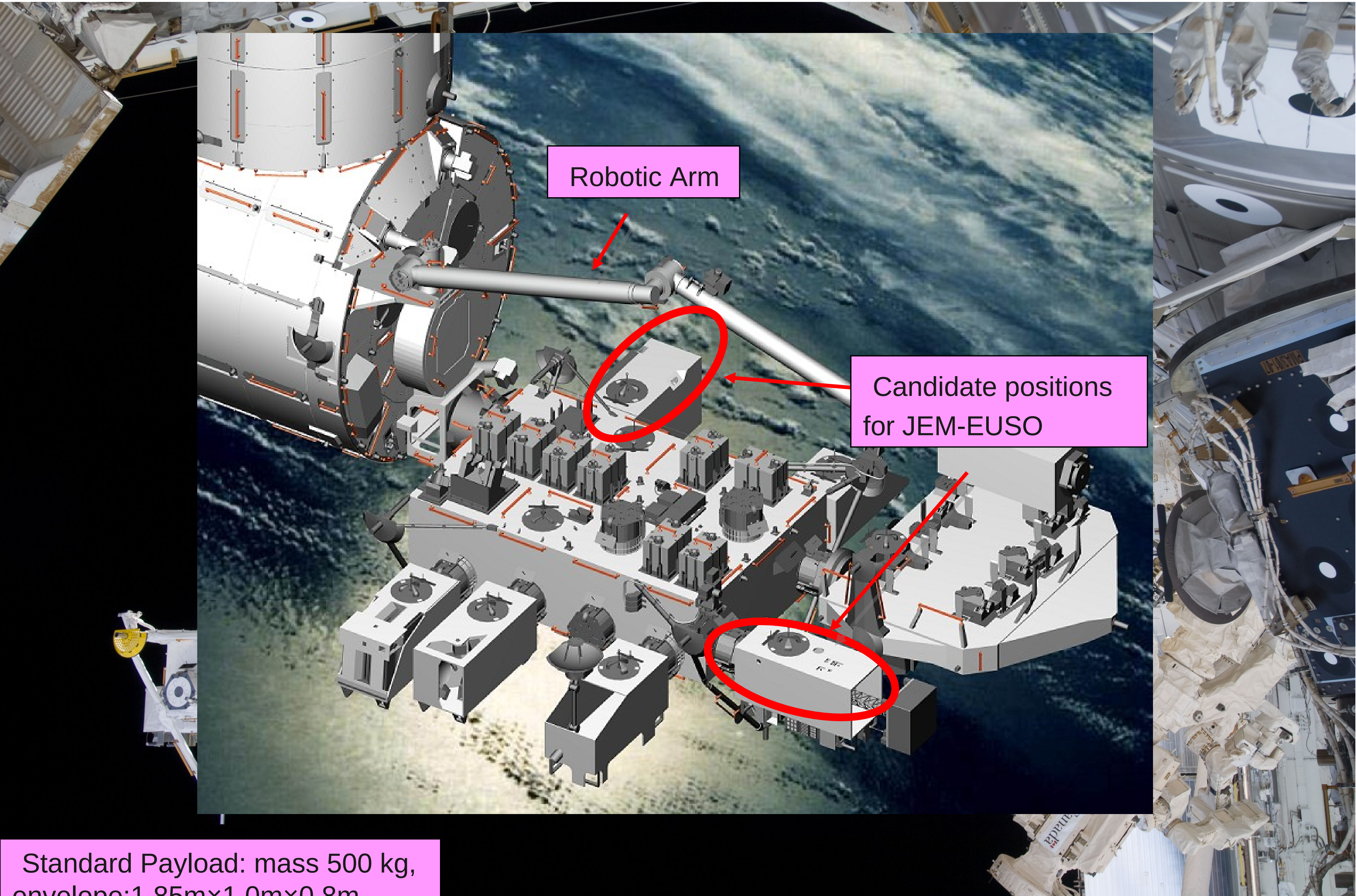


Medzinárodná vesmírna stanica ISS

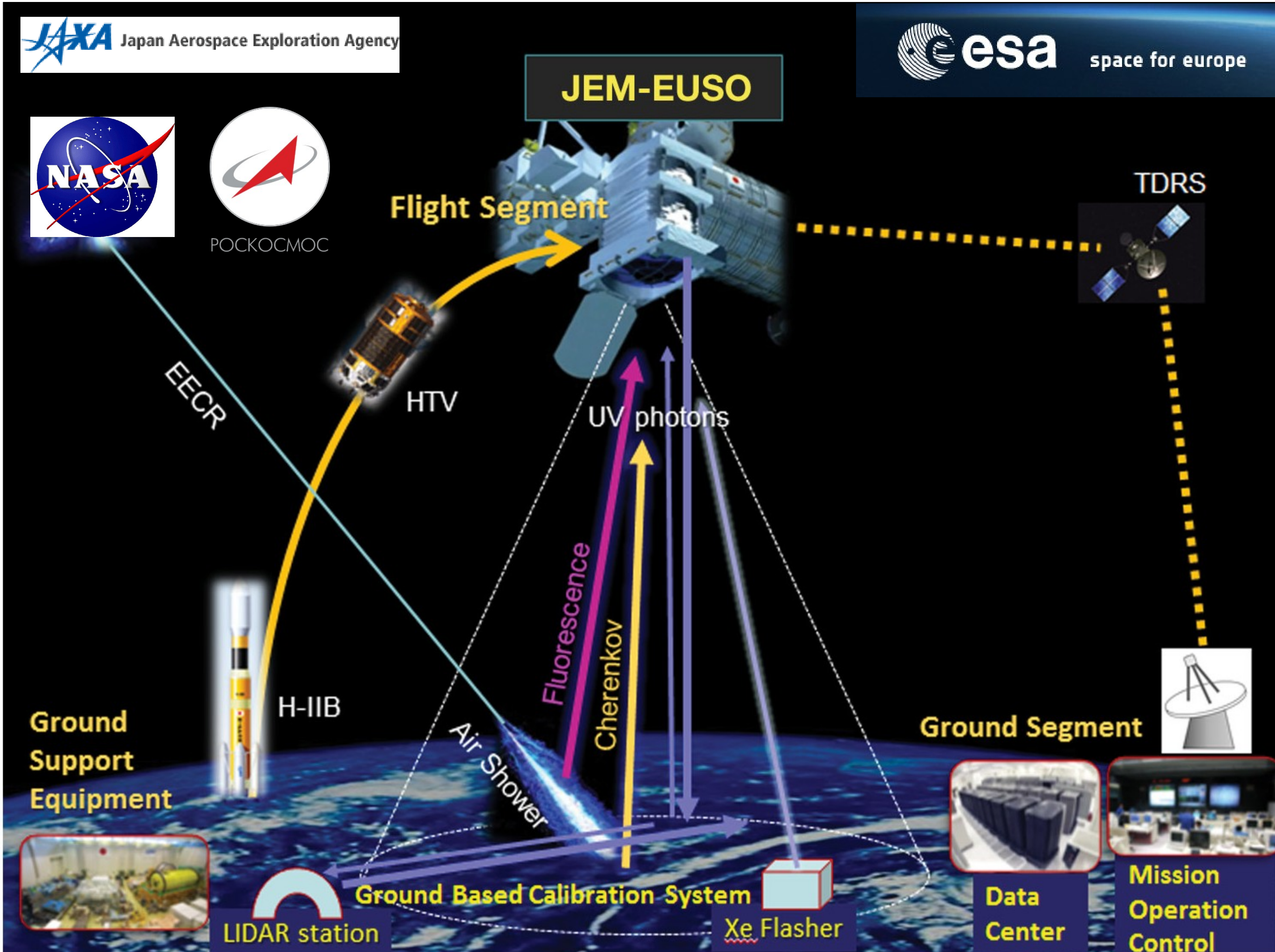


Standard Payload: mass 500 kg, envelope:1.85m×1.0m×0.8m

ISS020E025022



Standard Payload: mass 500 kg, envelope:1.85m×1.0m×0.8m



Japan Aerospace Exploration Agency
esa
space for europe
JEM-EUSO
NASA
РОСКОСМОС
Flight Segment
TDRS
EECR
HTV
UV photons
Fluorescence
Cherenkov
H-IIB
Air Shower
Ground Support Equipment
Ground Segment
Ground Based Calibration System
LIDAR station
Xe Flasher
Data Center
Mission Operation Control

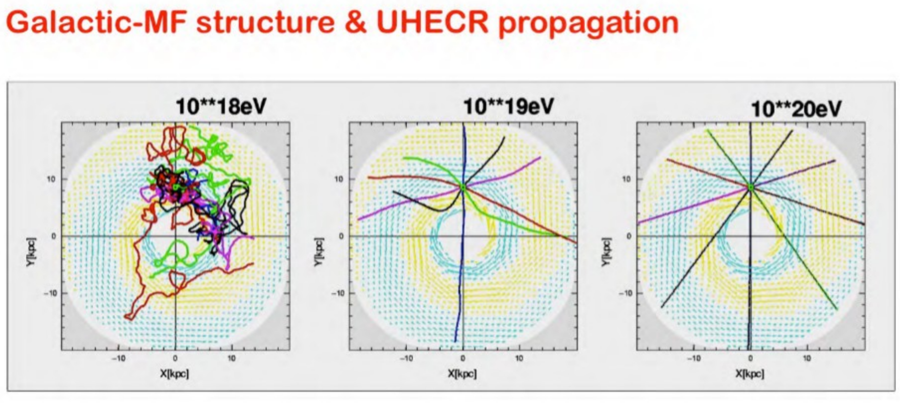
Základné parametre JEM-EUSO misie

Parameter	Value
Launch date	JFY 2016
Mission Lifetime	3+2 years
Rocket	H2B
Transport Vehicle	HTV
Accommodation on JEM	EF#2
Mass	1938 kg
Power	926 W (op.) 352 W (non op.)
Data rate	285 kbps (+ on board storage)
Orbit	400 km
Inclination of the Orbit	51.6°
Operation Temperature	-10° to 50°

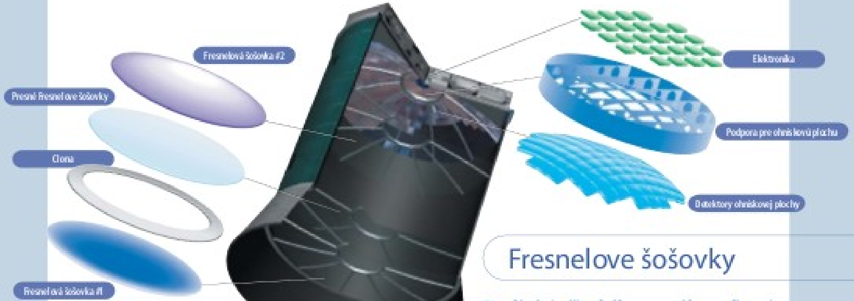
Čo JEM-EUSO hľadá

- *Zdroje kozmického žiarenia ultravysokých energií*
- *Neutrína ultravysokých energií*
- *Gamma žiarenie ultravysokých energií*
- *Galaktické a mimogalaktické magnetické polia*

Fyzika a Astrofyzika pre Energie > $5.\times10^{19}$ eV



Najnovšie Technológie v službách JEM-EUSO

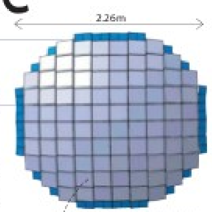


Zloženie

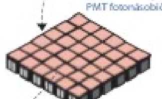
Detektory ohniskovej plochy

6,000 fotonásobičov

Ohnisková plocha je zakrivená s priemerom 2.26 m. 6000 1-palcových štvorcových multianódových rúriek fotonásobičov (PMTs) detektuje svetlo z rôznych miest v zemskej atmosfére. Predchádzajúce fotonásobiče (PMTs) mali obmedzenú fotosenzitívnu plochu približne 45%. JEM-EUSO a Hamamatsu Photonics spoločne vyvinuli fotonásobiče (PMTs), ktoré majú účinnú plochu 85%.



→ **Ohnisková plocha**
Pozostáva zo 164 modulov a celkového počtu 5,904 PMT fotonásobičov.



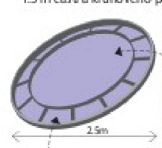
→ **Svetlocitlivý modul**
Pokrýva ohniskovú plochu s priemerom 2.26m s 5,904 PMT fotonásobičmi, z ktorých má každý 6 x 6 = 36 svetlocitlivých jednotiek.

→ **Fotonásobiče**
85% povrchu PMT fotonásobičov tvorí aktívna plocha, majúca 6 x 6 pixelov s celkovou plochou 26.2 mm štvorcových.

Fresnelove šošovky

Realizácia širokého zorného poľa pri nízkej hmotnosti

JEM-EUSO teleskop používa Fresnelove šošovky. Fresnelova šošovka je poloplochá šošovka, ktorá má kruhové drážky, ktoré eliminujú veľkú hmotnosť štandardných konvektívnych a konkávnych šošoviek. Tenkosť a ľahkosť Fresnelovej šošovky je nevyhnutnou podmienkou jej využitia vo vesmíre, pričom ponúka rovnaké optické funkcie ako hrubé a ťažké šošovky. JEM-EUSO používa dve zakrivené obojstranné Fresnelove šošovky z UV priepustného plastu a jednu mikromriežkovú Fresnelovu šošovku. Tento dizajn umožňuje najvyššiu účinnosť širokého zorného poľa. Veľkosť trojitej šošovky je 2.5 m v priemere, zložený zo stredovej 1.5 m časti a kruhového povrchu prstencových šošoviek.



→ Konfigurácia stredovej šošovky a prstencových šošoviek umožňuje vytvoriť väčšiu šošovku než aká môže byť vytvorená na jednom stroji.

Vypustenie

Transportný dopravník agentúry JAXA pre kozmickú stanicu (HTV) nesie JEM-EUSO

HTV bude vypustený H-IIB raketou (JAXA) ktorá prenesie JEM-EUSO k ISS. Robotické ramená na ISS umiestnia JEM-EUSO na JEM modul "Kibo."

→ Transportný dopravník kozmickej stanice (HTV) prilieta k ISS. JAXA

Porovnanie JEM-EUSO s najväčšími pozemnými observatóriami

	AGASA	HiRes	Auger	Telescope Array	JEM-EUSO
Organizácia	Tókijská Univerzita	Univerzita v Utahu	Medzinárodné konzorcium	Tókijská Univerzita a Univerzita v Utahu	Medzinárodné konzorcium
Miesto	Yamanashi, Japonsko	Utah, USA	Argentína	Utah, USA	Medzinárodná vesmírna stanica
Typ detektorov	Pozemná sieť	Fluorescenčný pozemný teleskop	Pozemná sieť + Fluorescenčný pozemný teleskop	Pozemná sieť + Fluorescenčný pozemný teleskop	Fluorescenčný vesmírny teleskop
Doba prevádzky	1990～2004	1997～2006	2005～	2007～	Vypustenie očakávané v 2013
Efektívna apertúra (km²sr)	150	500	～7,000	760	125,000
Výskyt EHE udalostí (počet/rok)	1, experimenty ukončené	Menej ako 1 experimenty ukončené	50 (očakávané), 3 (pozorované)	10 (očakávané)	350 – 1,700 (očakávané)

JEM-EUSO misia

Výška	okolo 400km	Počet pixelov ohniskového povrchu	okolo 0.2 miliónov
Pozorovacia dĺžka a šírka	N51°- S51° × všetky dĺžky	Rozlíšenie na zemi	okolo 0.8 km
Zorné pole	60°	Strieda	12～25%
Apertúra (pozemná plocha)	0.2 miliónov km²	Trvanie misie	3 (+2) rokov
Priemer teleskopu	2.5 m	Celková hmotnosť	～1.9 ton
Optický Systém	Dve zakrivené obojstranné Fresnelove šošovky a vysoko-presné Fresnelove šošovky	Príkon	< 1kW

Medzinárodní Partneri

Japonsko	RIKEN Konan Univ. Fukui Tech. Univ. Aoyama Gakuin Univ. Saitama Univ. NIRS Univ. Tokyo Tohoku Univ. ICRR, Univ. Tokyo KEK Chiba Univ. NAOJ ISAS/JAXA Kanazawa Univ. Nagoya Univ. STE Lab., Nagoya Univ. Yukawa Inst., Kyoto Univ. Kyoto Univ. Kobe Univ. Kinki Univ. Hiroshima Univ. Hokkaido Univ Tokyo Inst. Tech.
USA	NASA/MSFC UAH LBL, UCB UCLA Vanderbilt Univ. Univ. Arizona.
Francúzsko	APC-Paris 7 LAL, IN2P3-CNRS
Nemecko	MPI Munich Univ. Tuebingen MPI Bonn Univ. Erlangen LMU&MPQ
Taliansko	Univ. Florence Univ. Naples Univ. Palermo Univ. Rome "Tor Vergata" Univ. Turin INOA/CNR IASF-PA/INAF IFSI-TO/INAF INFN
Mexiko	ICN-UNAM BUAP UMSNH
Kórejska republika	Ehwa W. Univ. Yonsei Univ.
Rusko	SINP MSU Dubna JINR
Švajčiarsko	Neuchatel, CSEM IACETH
Španielsko	Univ. Alcalá
Poľsko	IPJ Podlasie Univ. Kielce Univ. Jagiellonian Univ.
Slovensko	Inst. Experimental Physics, Košice

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E-mail : jem-euso-staff@riken.jp URL : http://jemeuso.riken.jp/

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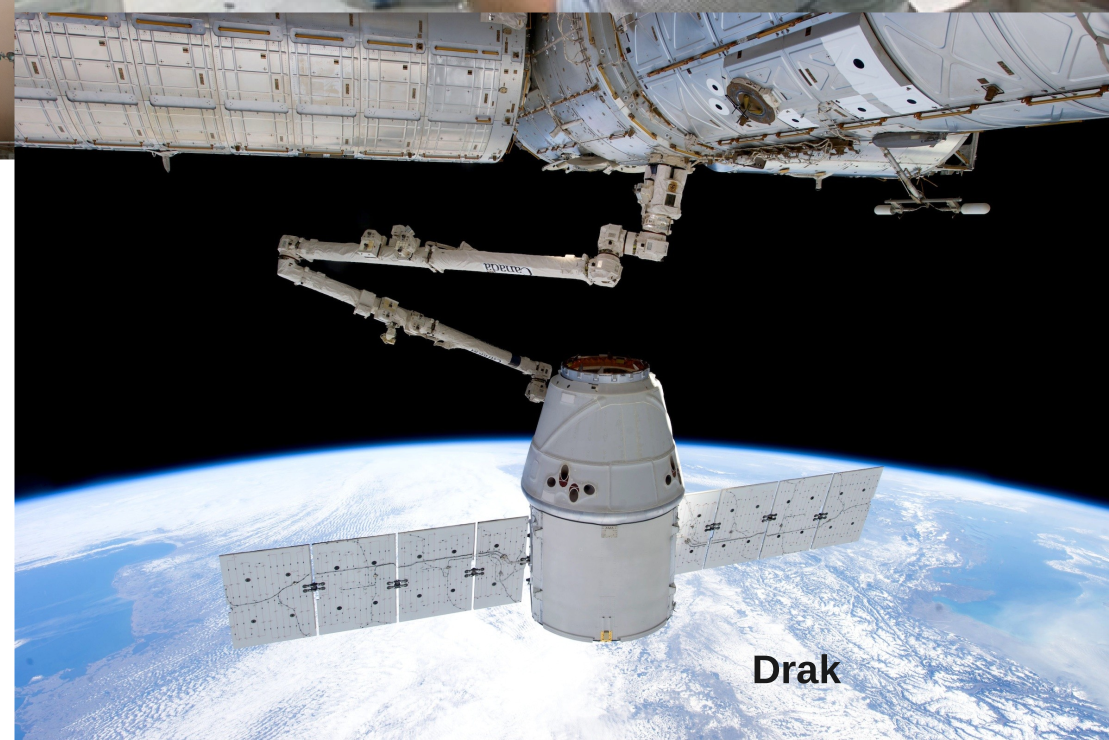
E-mail : jem-euso@saske.sk URL : http://space.saske.sk/

Alternatíva k HII-B / HTV :: SpaceX / Falcon 9 / Dragon

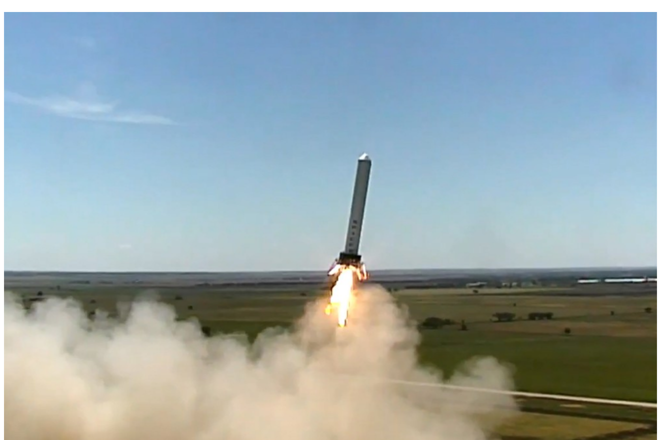
Sokol 9

Elon Musk

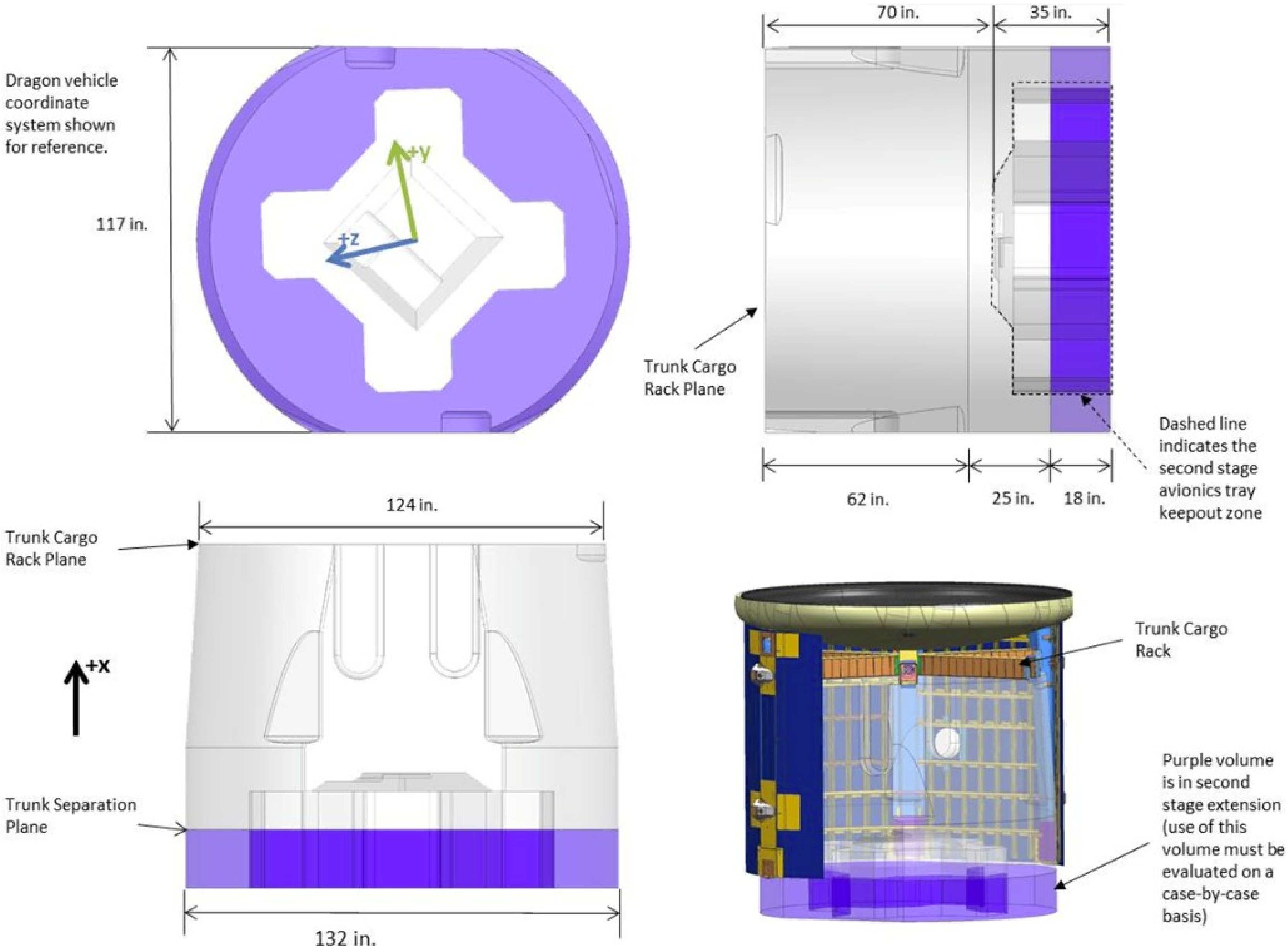


Drak

Lúčný koník

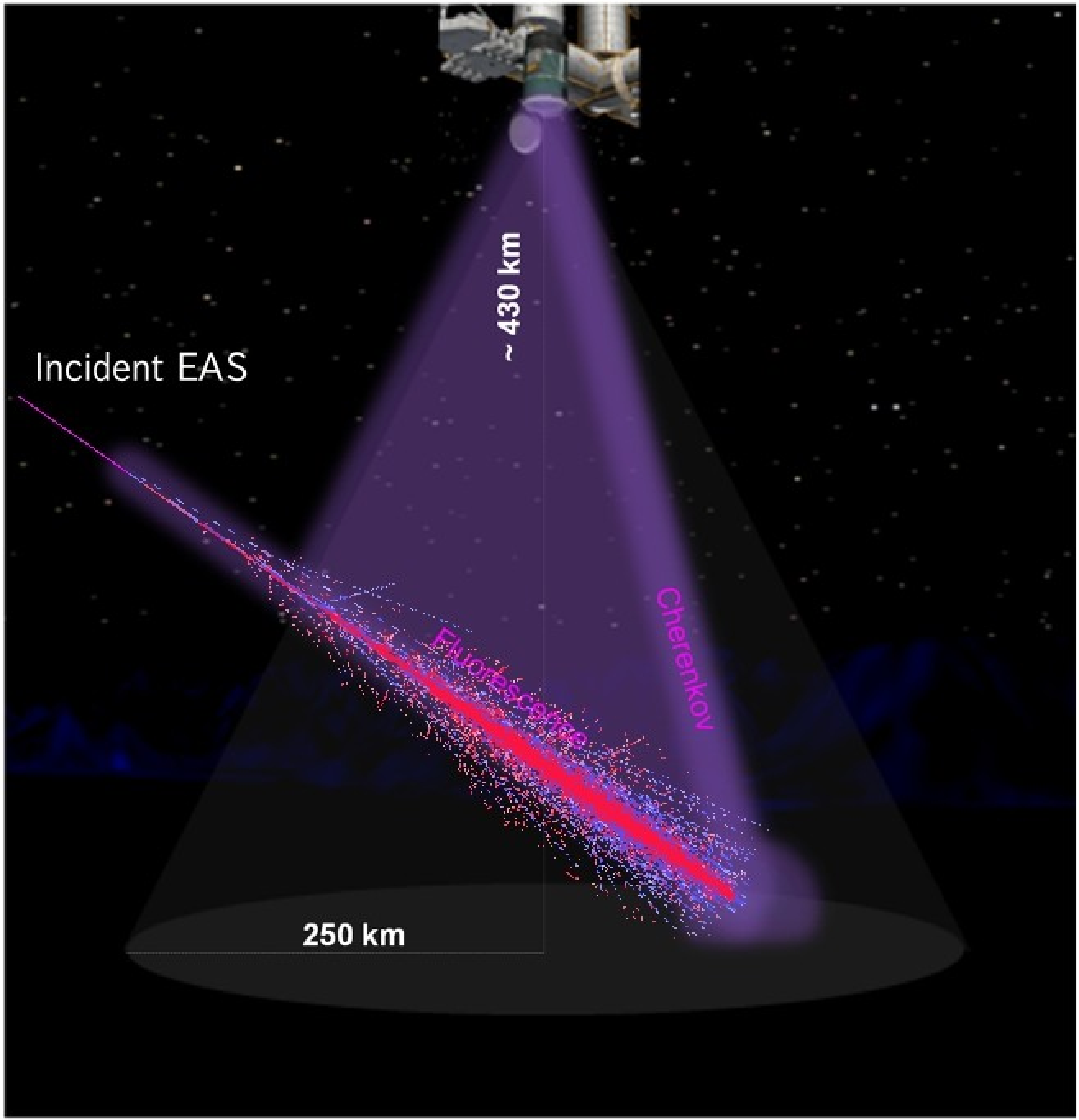


Kufor Draka



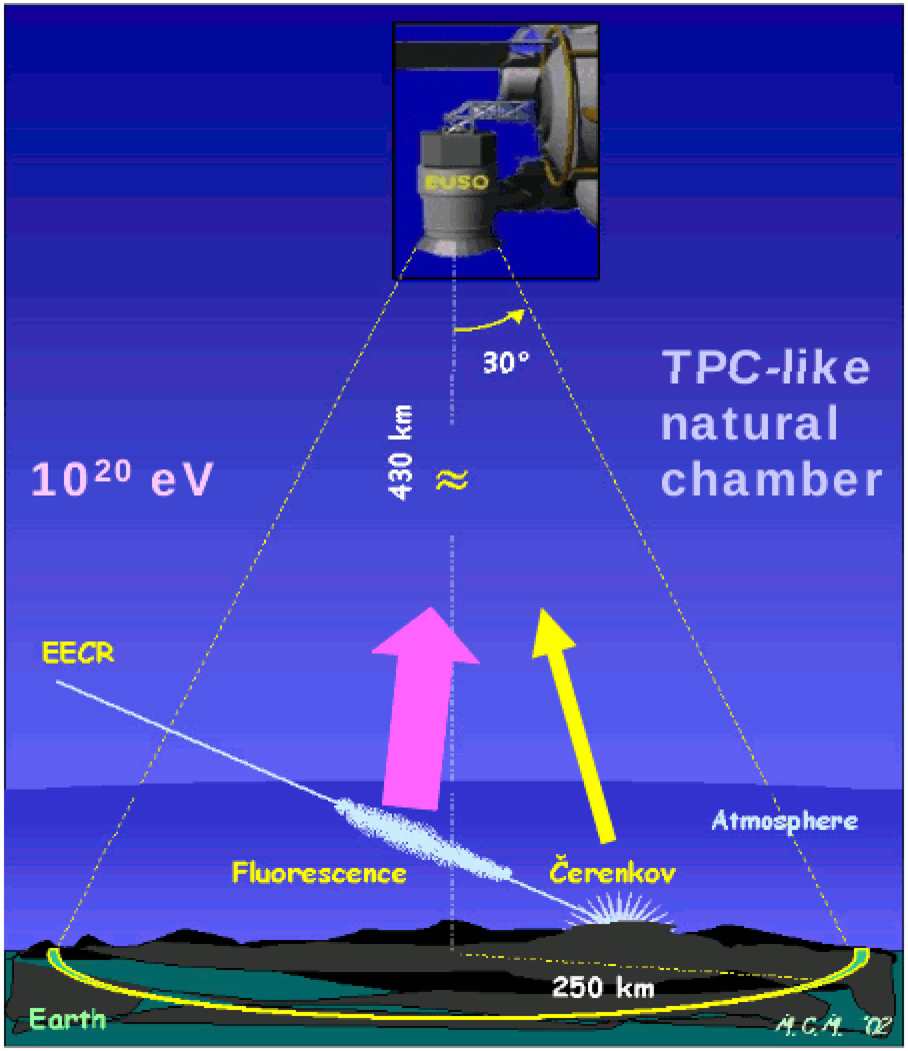
Dragon vehicle coordinate system shown for reference.
+y
+z
117 in.
70 in.
35 in.
Trunk Cargo Rack Plane
62 in.
25 in.
18 in.
Dashed line indicates the second stage avionics tray keepout zone
124 in.
Trunk Cargo Rack Plane
+x
Trunk Separation Plane
132 in.
Trunk Cargo Rack
Purple volume is in second stage extension (use of this volume must be evaluated on a case-by-case basis)

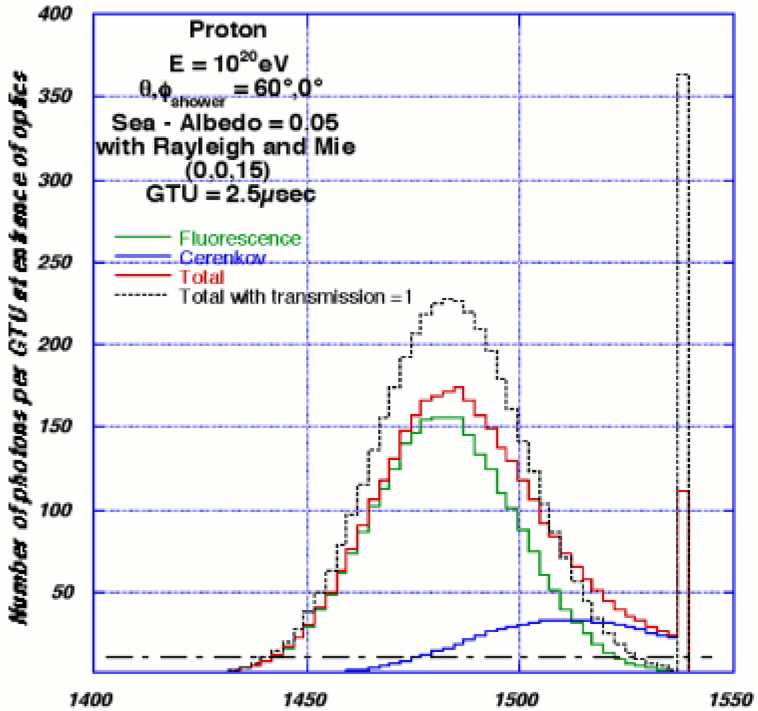
JEM-EUSO Observational Approach



Principle of EUSO

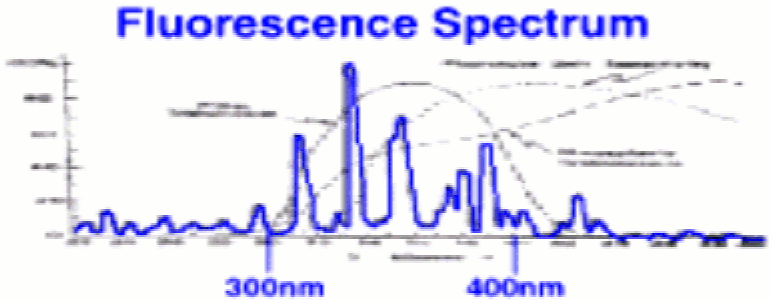
- first *remote-sensing* from space, opening a new window for the highest energy regime





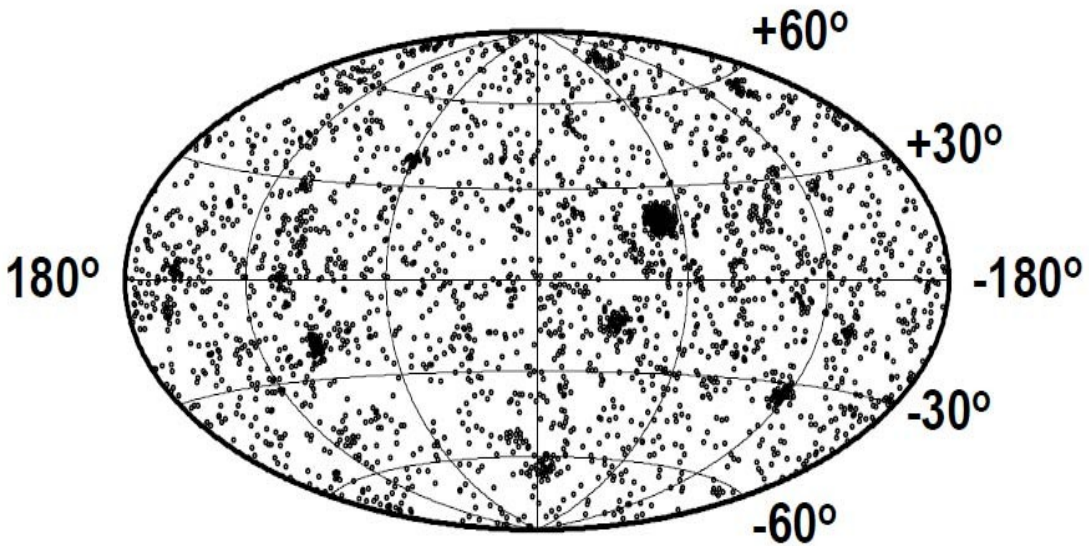
Cf: Ground-based arrays < 0.01 EUSO

(1) Scintillator array,(2)Fluorescence telescope array

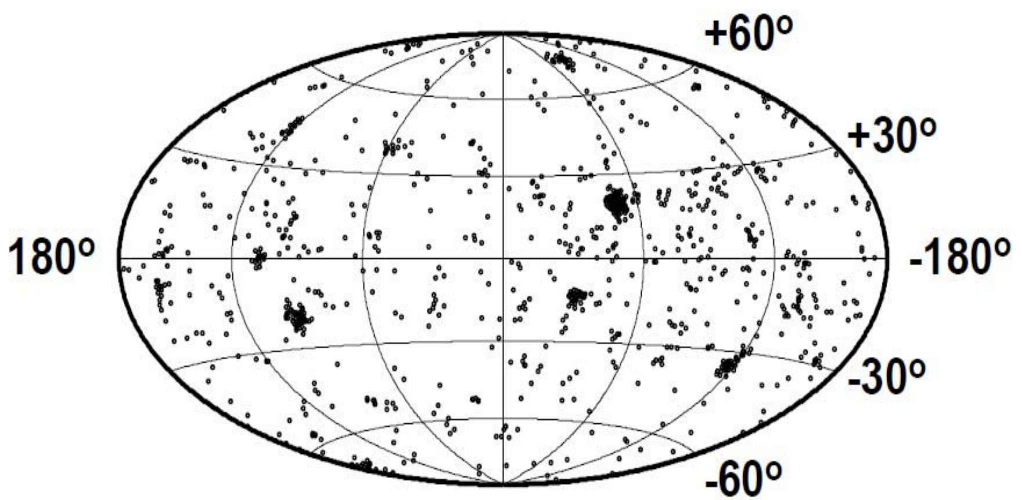


From College de France: better data now

Simulácia predokladajúca že zdrojmi sú Aktívne Jadrá Galaxií



3000 eventov
E > 5 10^{19}eV



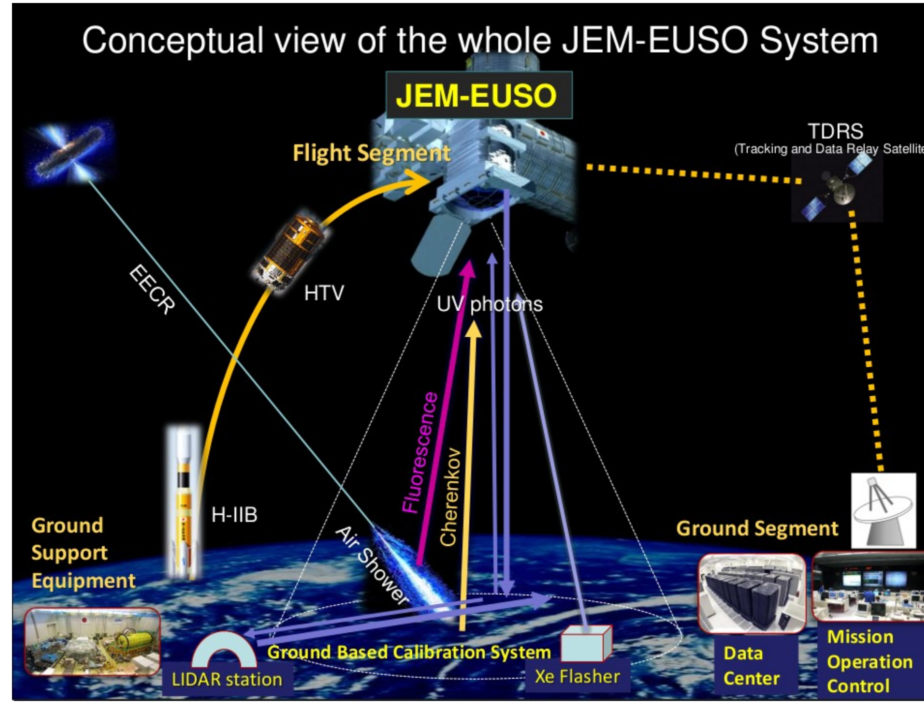
1000 eventov
E > 7 10^{19}eV

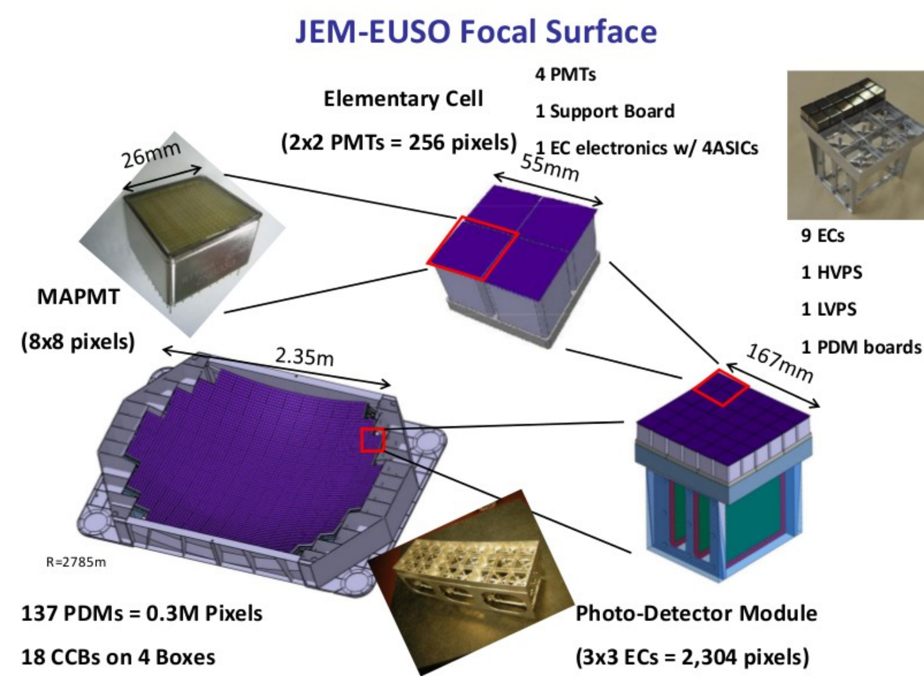
JEM-EUSO

- JEM-EUSO balón - stratosférický balón – 1 PDM, 2014

- JEM-EUSO TA, jar/2015

- JEM EUSO ISS - let po 2020



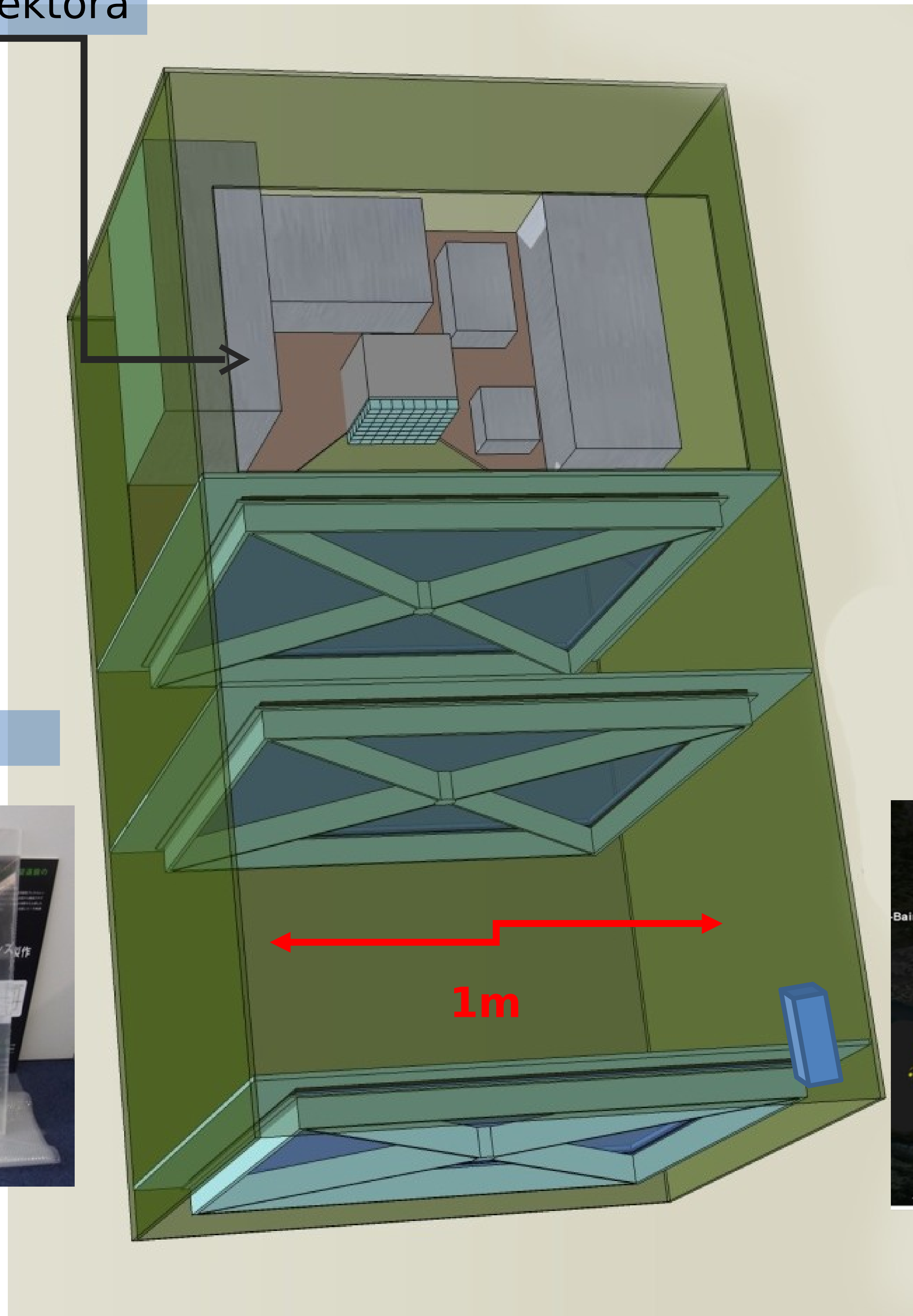


Elektronika detektora

EUSO balón

august 2014

Šošovky

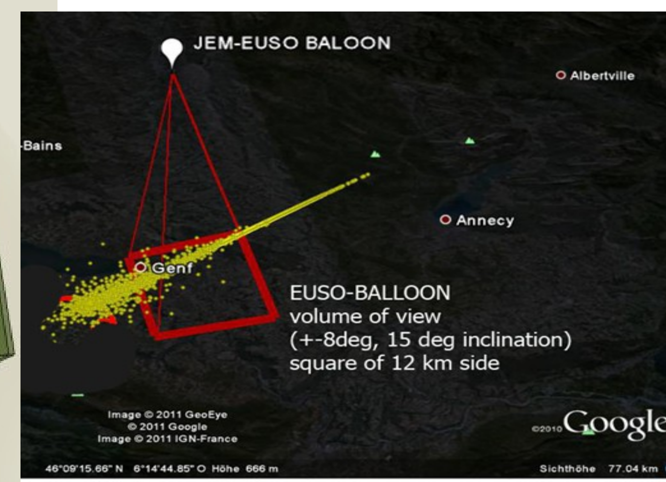


Prvý JEM-EUSO prekurzor experiment

- šošovky 1 m^2
- 1 PMD
~300 kg
- vodotesná gondola
- letová hladina ~38 km

Výber z hlavných cieľov prekurzor experimentu

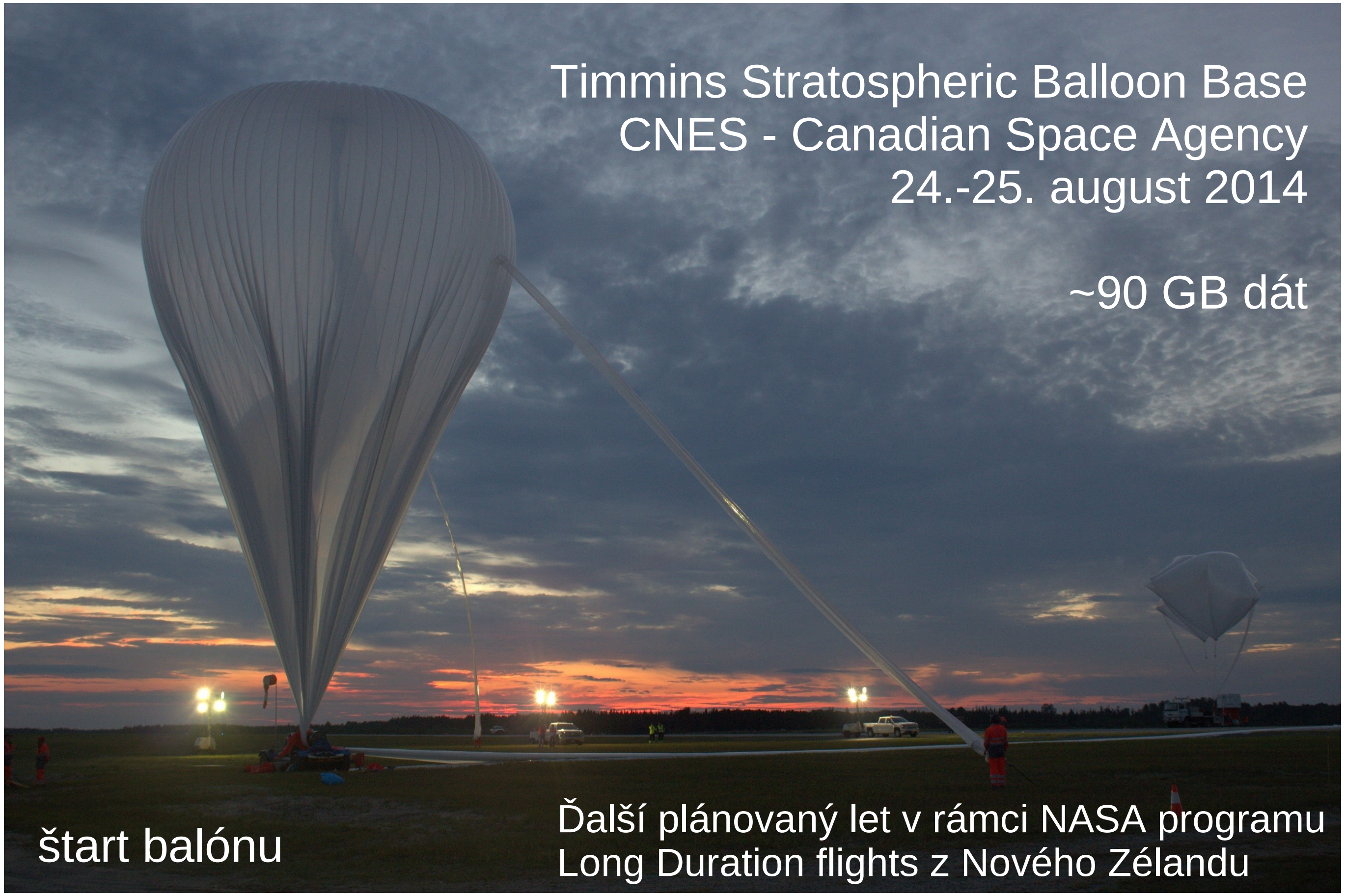
- overenie hw v podmienkach blízkych vesmírnym podmienkam
- meranie UV pozadia za rôznych pomienok
- verifikácia trigerovacej schémy experimentu

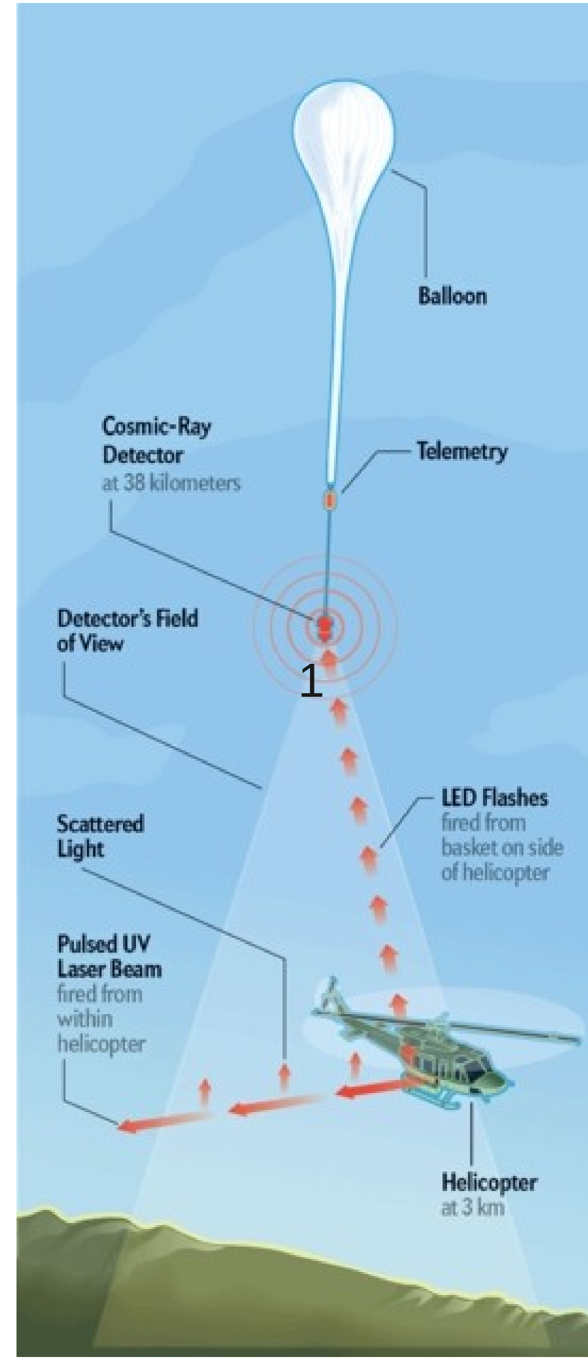


Simulácie


moving into the CU hall at Timmins 12.8.2014!

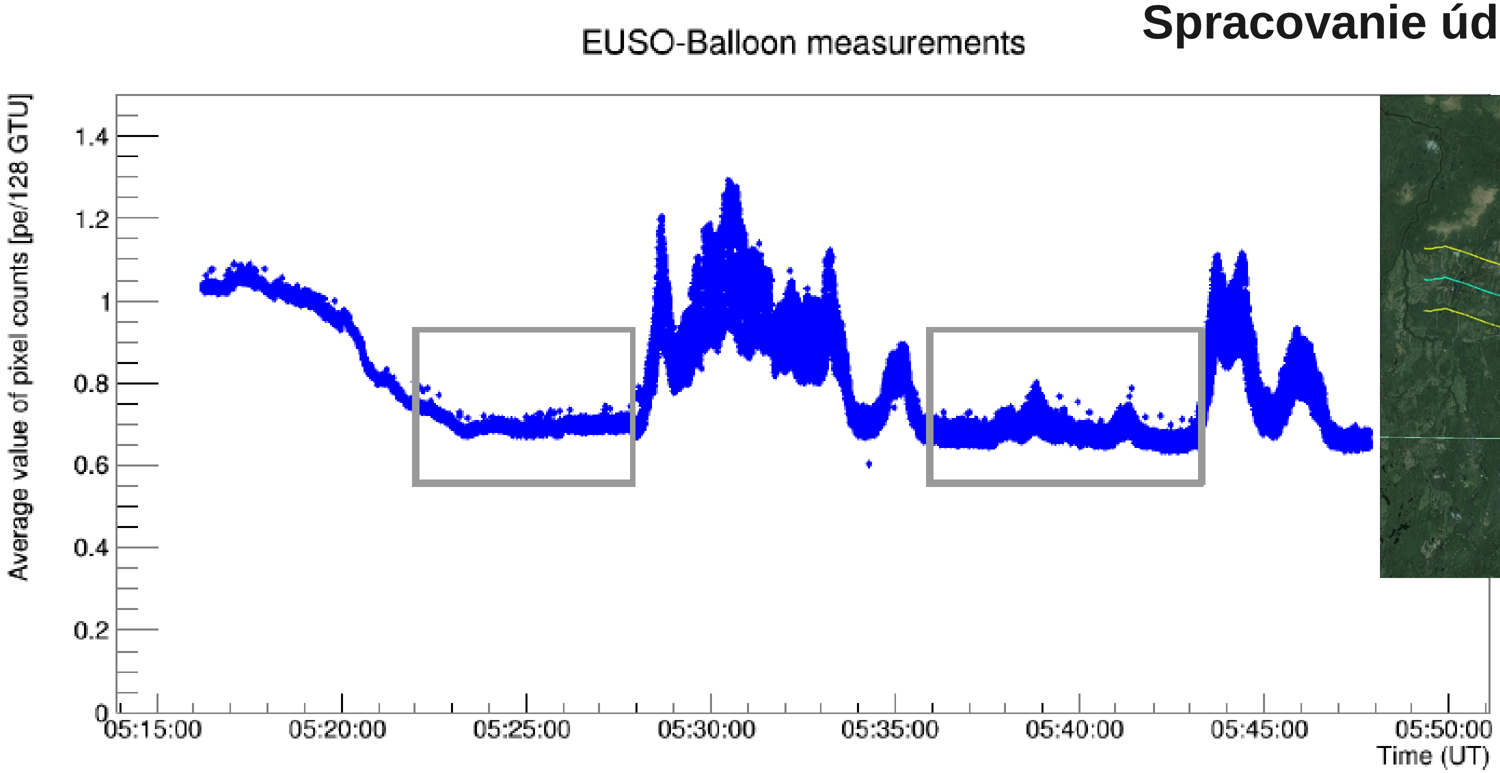
flight configuration : 18.8.2014

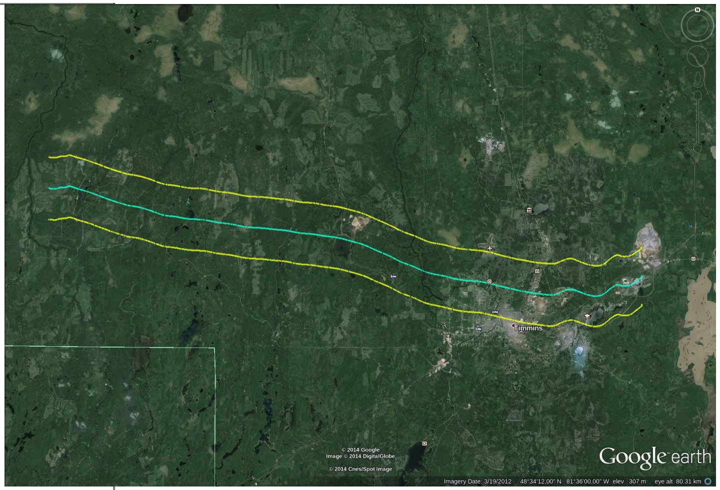




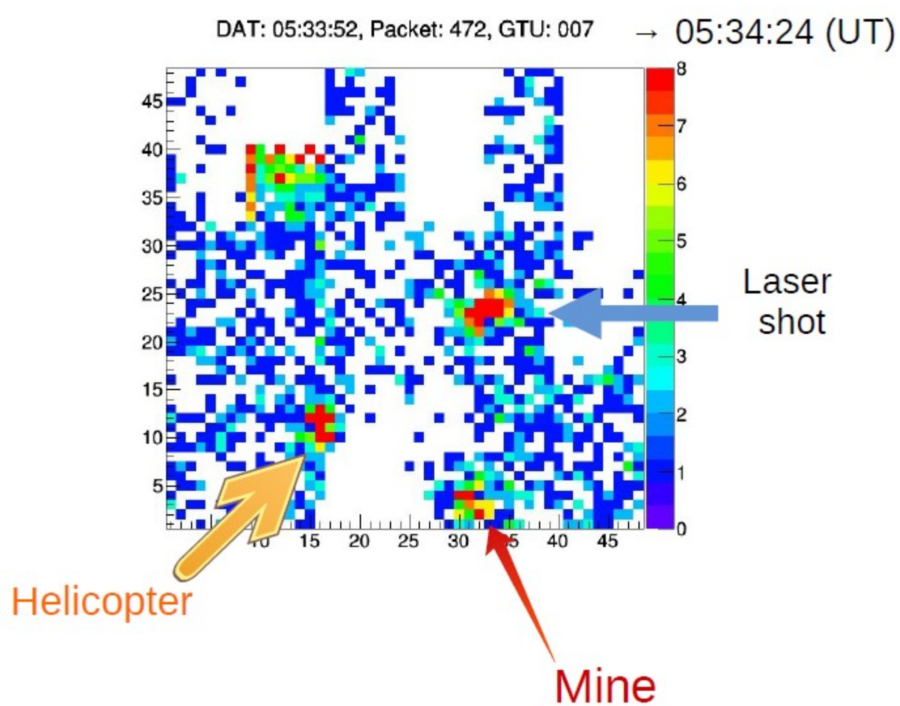
Článok v Scientific American:
Cosmic-RayTelescope Flies High

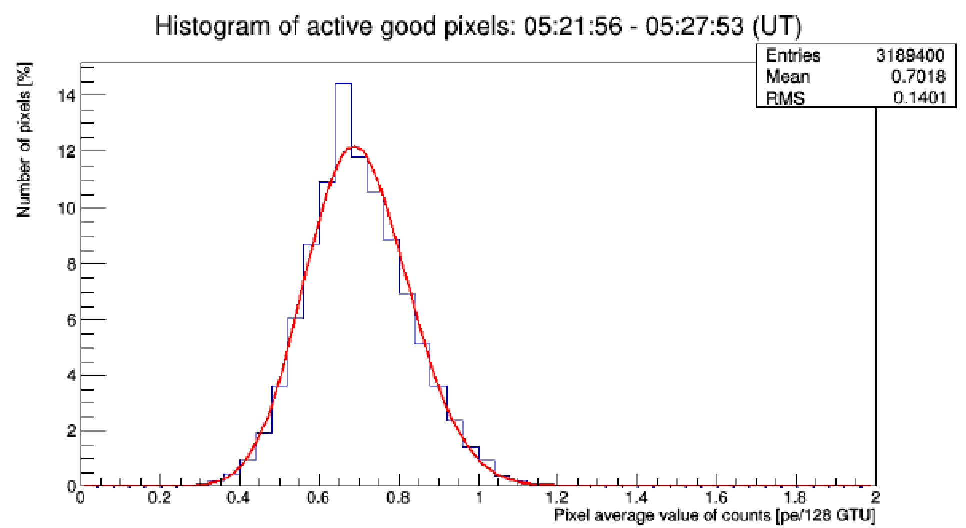
Spracovanie údajov z JEM-EUSO balónu





Prvé publikované výsledky ~jar/leto 2015





Fitted by Poisson distribution with $\lambda = 0.699$

Duty cycle estimation

UV light sources

If background 1500 ph/(m^2 ns sr) is allowed [in % of total time on orbit]

- sun
- moon

  } ~ 21-22 %

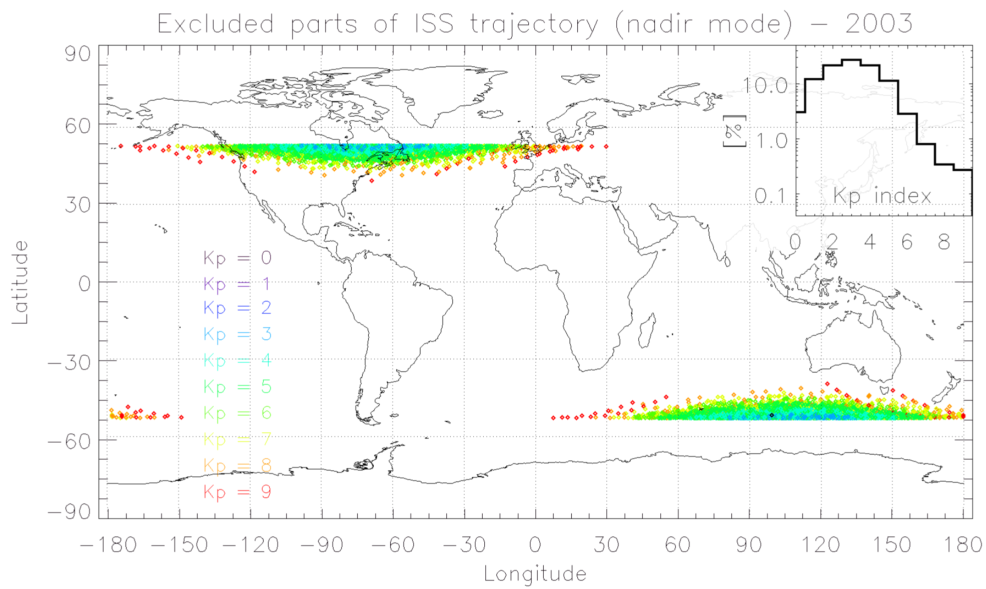
- airglow/nightglow
- zodiacal light
- integrated faint star light

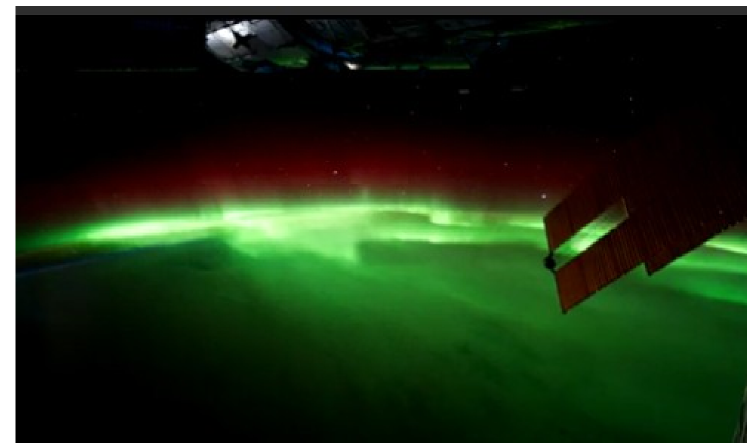
  } ~ 20-21%

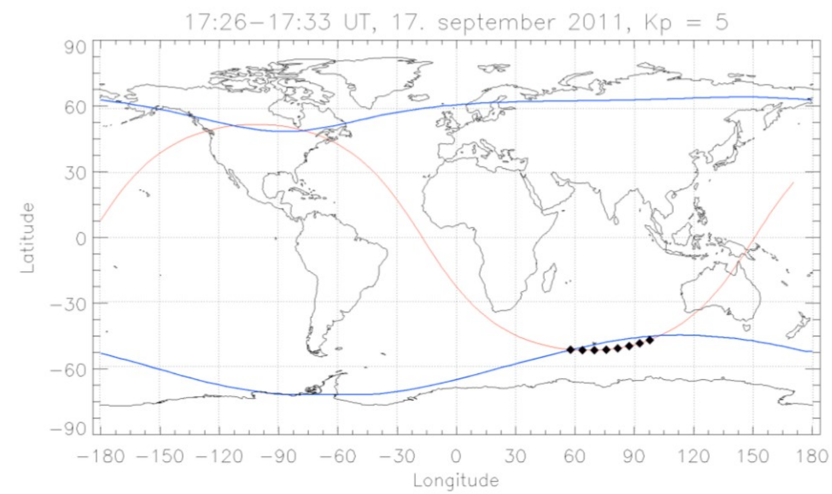
- Boreal/austral auroras **~ 1%**
- South Atlantic anomaly **small**
- Lightning and TLEs **~ 2%**
- artificial sources (Anthropogenic / city light) **~ 9%**

Duty cycle estimation

Auroras effect on JEM-EUSO operational efficiency







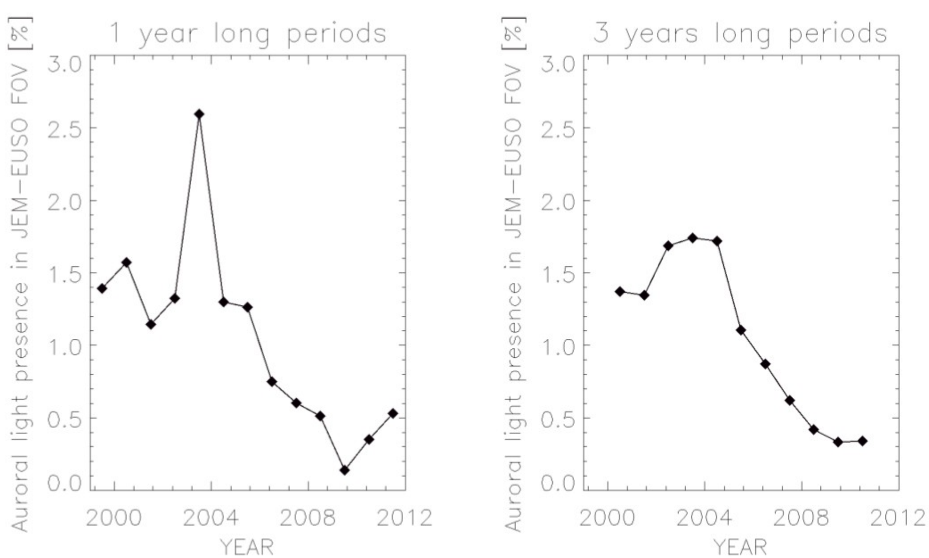


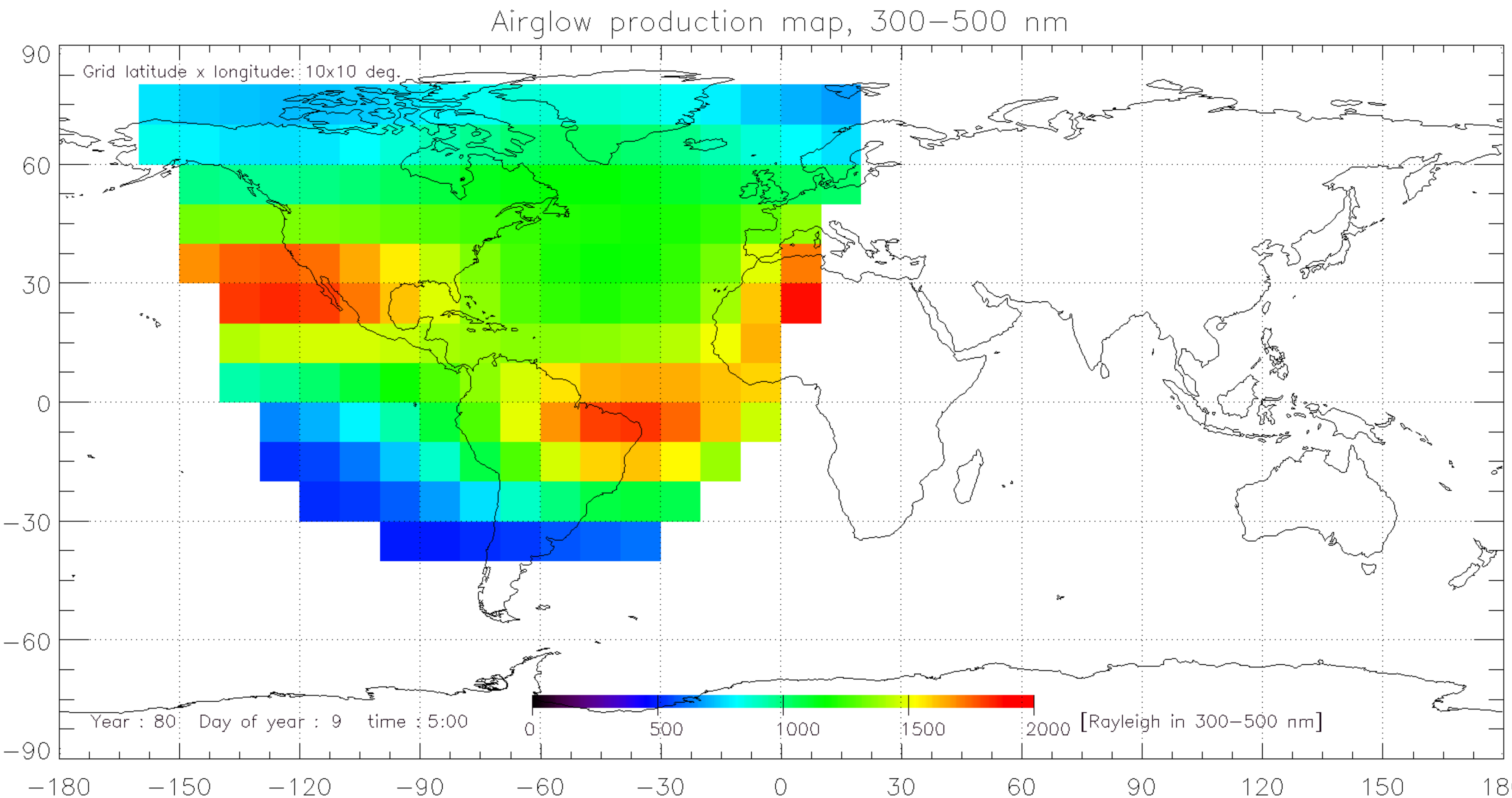
Figure 3: Left panel: Fraction of time f_{AL} in which auroral light restrain EAS measurements for one year long periods from 2000 to 2011. Right panel: Same as in the left panel, but integrating for 3-year periods.

V rokoch 2017–2019 pravdepodobne ďalšie hlboké solárne minimum- **efekt aurorornálneho svetla na meranie EAS ~ 1%** .

Advances in Space Research článok

Vývoj modelu UV pozadia

- skladá sa z modelov zdrojov svetla na nočnej strane Zeme a modelu radiačného transferu



AURIC model, D. J. Strickland et al. Journal of Quantitative Spectroscopy and Radiative Transfer 62 (1999) 689-742, doi:10.1016/S0022-4073(98)00098-3

Príklady výsledkov

Night time measurement of the UV background by EUSO-Balloon

Author(s): MACKOVJAK, Simon[1]
Co-author(s): NERONOV, Andrii [1] ; MORETTO, Camille [2] ; BACHOLLE, Simon [3] ; BOBÍK, Pavol [4] ; PUTIŠ, Marian [4] ; DEL PERAL, Luis [5] ; RODRIGUEZ FRIAS, Maria [5] ; SHINOZAKI, Kenji [6] ; CATALANO, Camille [7] ; SORIANO, Jorge Fernández [5] ; SÁEZ CANO, Guadalupe [5]

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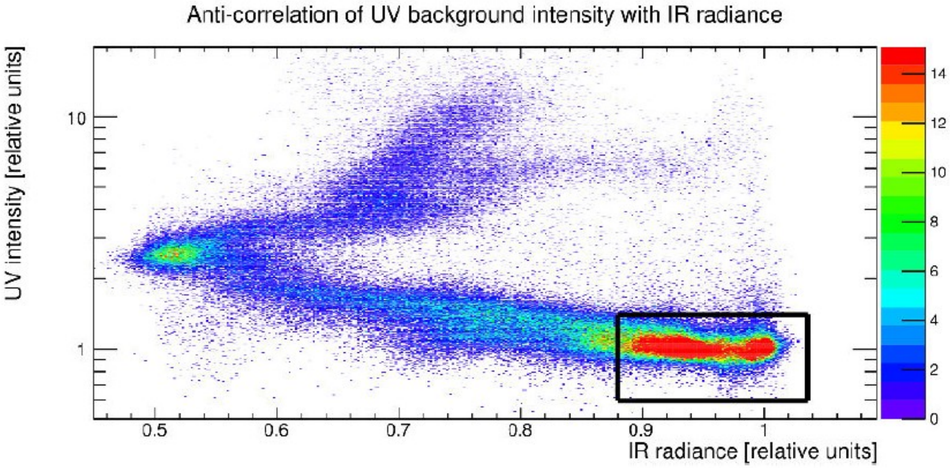
Corresponding Author(s): simon.mackovjak@gmail.com

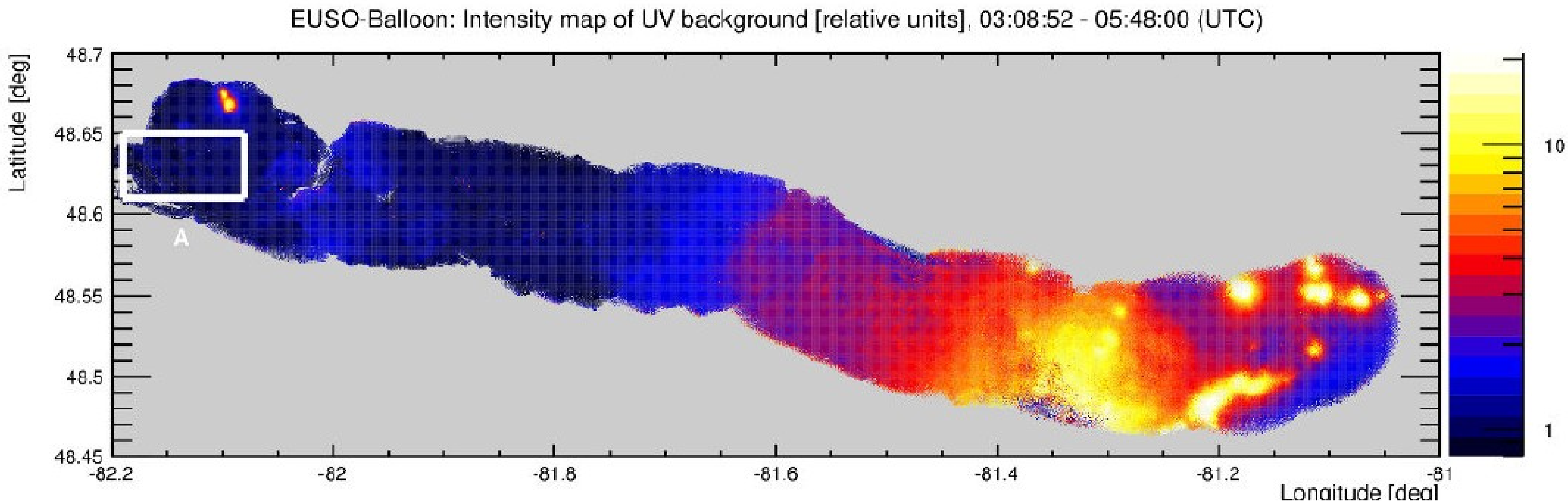
Precise characterization of the Earth night side UV background is essential for observation of the ultra-high-energy cosmic ray induced extensive air showers (EAS) from the space. We have analyzed data from the flight of EUSO-Balloon pathfinder mission that took place near Timmins (Canada) in the moonless night from 24^{th} to 25^{th} August 2014. The EUSO-balloon telescope imaged the UV background in the wavelength range 290–430 nm from the altitude ~38 km with a 1 m^2 refractor telescope with 11.5° field-of-view pointed in nadir direction. The UV data were complemented by the data of the Infrared (IR) camera onboard EUSO-balloon, which operated in the wavelength ranges 10.37–11.22 μm and 11.57–12.42 μm. We have combined the UV and IR images to study the upward UV radiance from the Earth surface and Earth atmosphere. This allowed us to estimate UV background in clear atmosphere conditions without man-made lights and also to investigate influence of clouds on the UV background values. The obtained UV intensity for clear atmosphere conditions is in a good agreement with previous BaBy and NIGHTGLOW balloon measurements. Comparison of the UV and IR images reveals a strong dependence of the upward UV radiance on the atmospheric conditions, so we discuss the possibility to use the UV albedo effect for characterization of the clouds. For estimating the observation efficiency of EAS from space by EUSO like detectors, it is important to determine the time variation of average UV background intensity, cloud distribution and local man-made light. Using available data, we also discuss these key factors that determine the observable time and area for EAS observation.

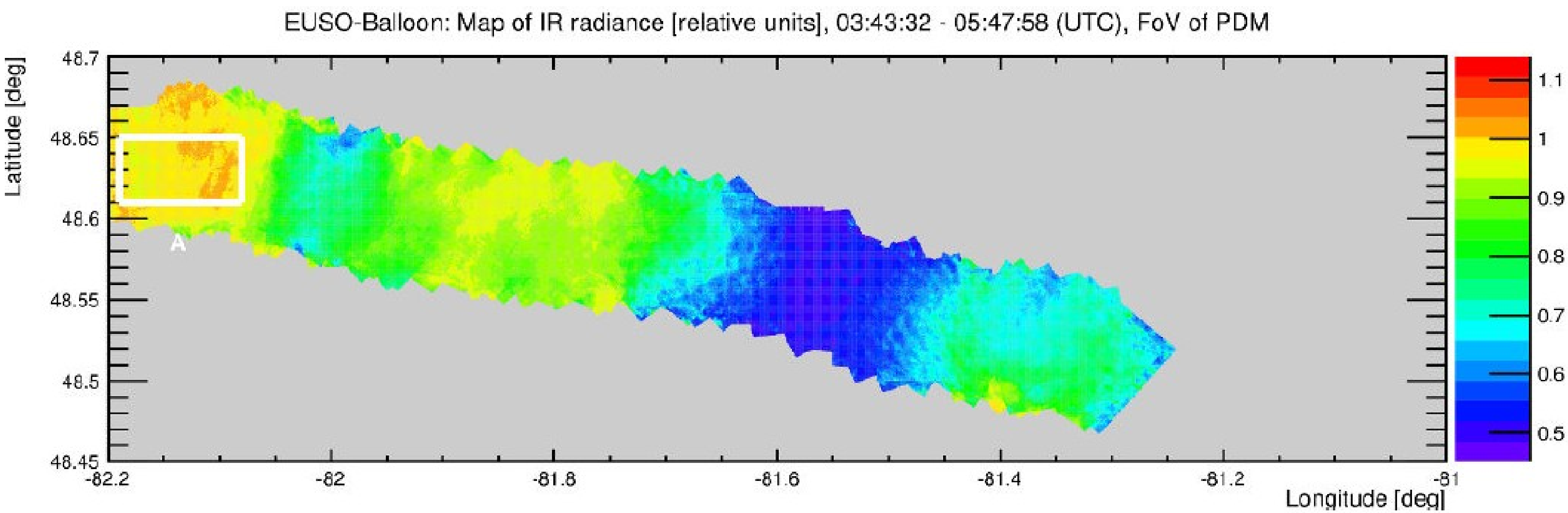
Main results

- EUSO-Balloon is the first mission that imaged the UV background in different atmospheric conditions, well monitored by dedicated Infrared Camera
- An anti-correlation between UV and IR up-going radiation was found and an evident dependence of the UV background on atmospheric conditions was revealed
- The tool for masking the regions affected by clouds and manmade light in the FoV is prepared to fulfill the requirements for a high quality detection of UHECR



34th International Cosmic Ray Conference (ICRC), July 30 to August 6, 2015, Hague, Netherlands





- The displayed values are relative to the mean value of *I* BG over reference area “A” (white box)
- Pixels with the lowest IBG and the highest IR radiance correspond to clear atmosphere
- The clouds have higher albedo than ground and increased IBG values
- The pixels affected by man-made lights (the city Timmins with

Príklady výsledkov

Pattern recognition study for different levels of UV background in JEM-EUSO experiment

Author(s): PASTIRČÁK, Blahoslav[1]
Co-author(s): BOBÍK, Pavol [1] ; PUTIŠ, Marián [1] ; VRÁBEĽ, Michal [2] ; VASIĽKO, Ján [3] ; BERTAINA, Mario [4] ; SHINOZAKI, Kenji [5] ; FENU, Francesco [6]

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[3] *Technical University Košice Slovakia*

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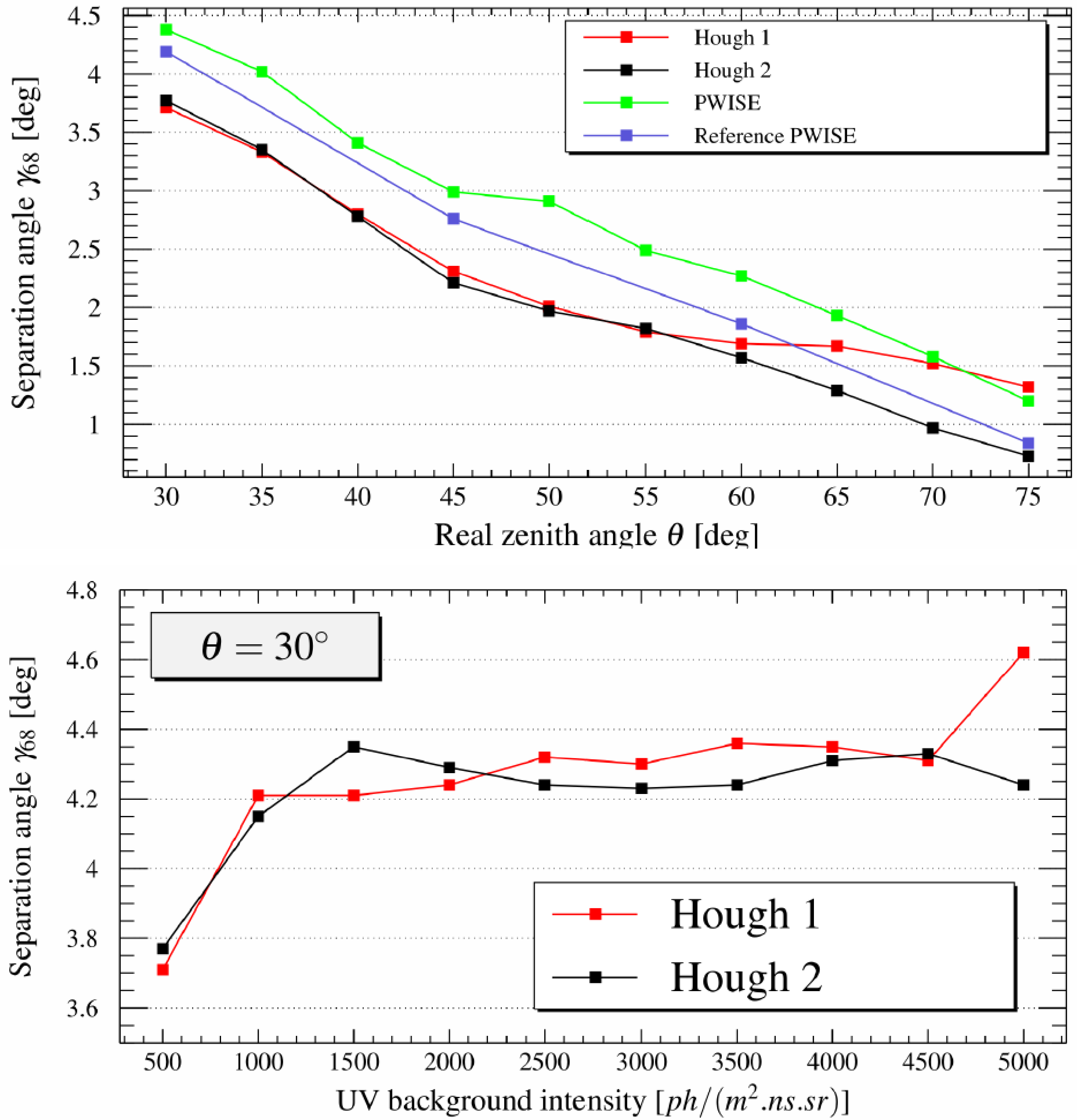
Corresponding Author(s): slavo@saske.sk

JEM-EUSO experiment will observe UV light created by extensive air showers initiated by ultra high energy cosmic rays (UHECR). Reconstruction of UHECR particle direction from detected signal depends also on the level of signal background, which can vary in time and with location.
We developed an alternative pattern recognition (PR) method based on Hough transformation besides to existing PR methods in JEM-EUSO software framework. The results of them, namely of PWISE method and Hough method were compared for the nominal UV background 500 ph/(m2 ns sr). Hough method was used to evaluate UHECR direction reconstruction ability for higher level of the UV backgrounds on the Earth's night side. The study what impact on fake trigger events rate come from varying background levels was performed, too.

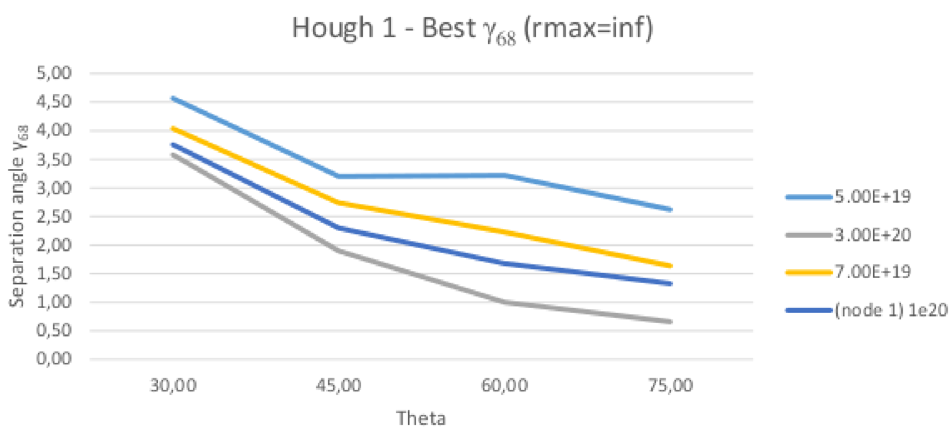


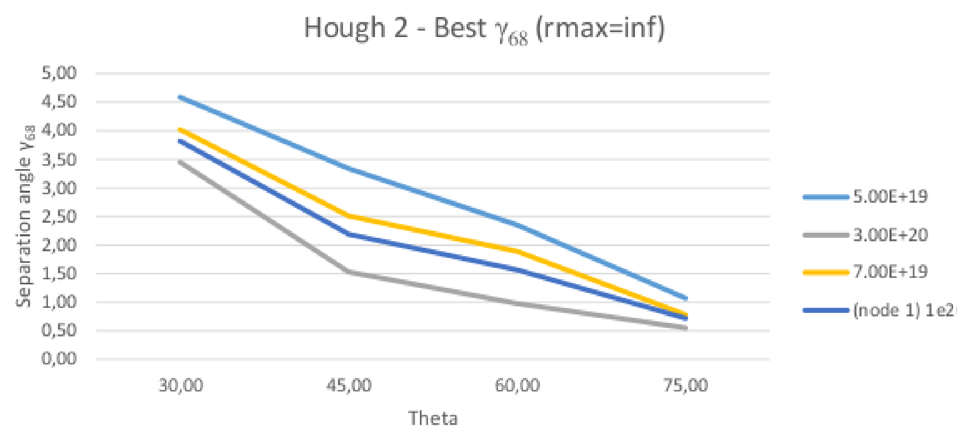
Hough 1
Hough 2
PWISE
Reference PWISE
Separation angle γ_{68} [deg]
Real zenith angle θ [deg]
$\theta = 30°$
Hough 1
Hough 2
Separation angle γ_{68} [deg]
UV background intensity $[ph/(m^2.ns.sr)]$

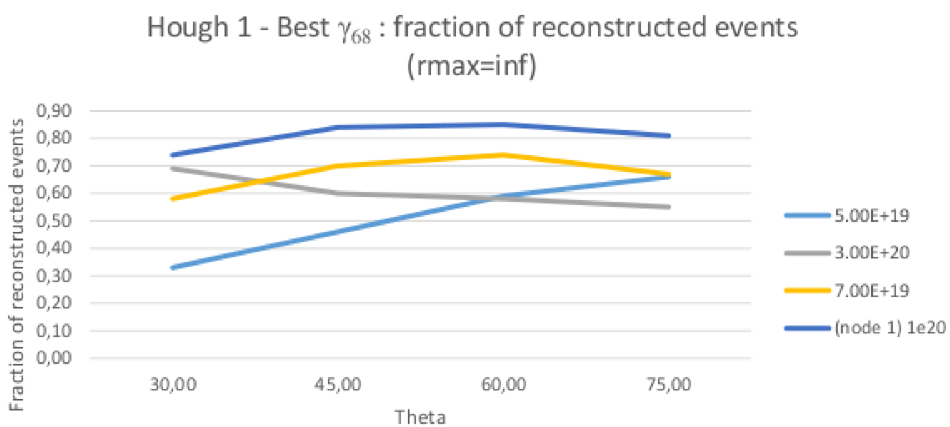
Príklady výsledkov

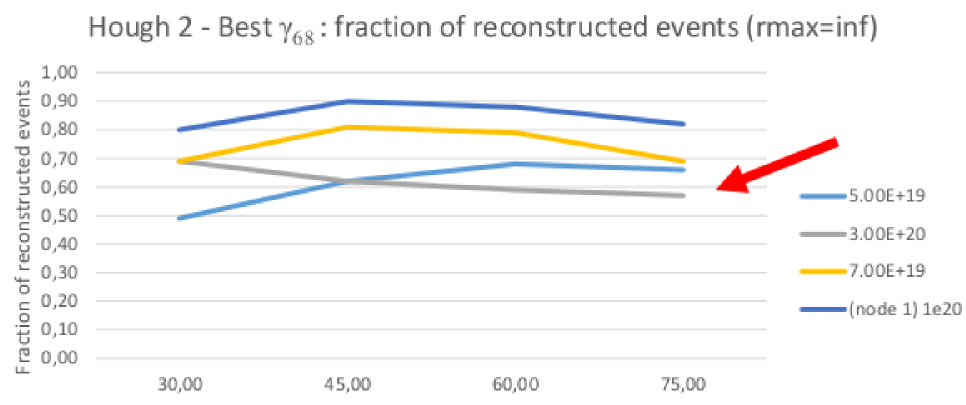
Precision of angular reconstruction (1)

energy of primary particle ... eV ; background **500** ph/(m^2 ns sr)



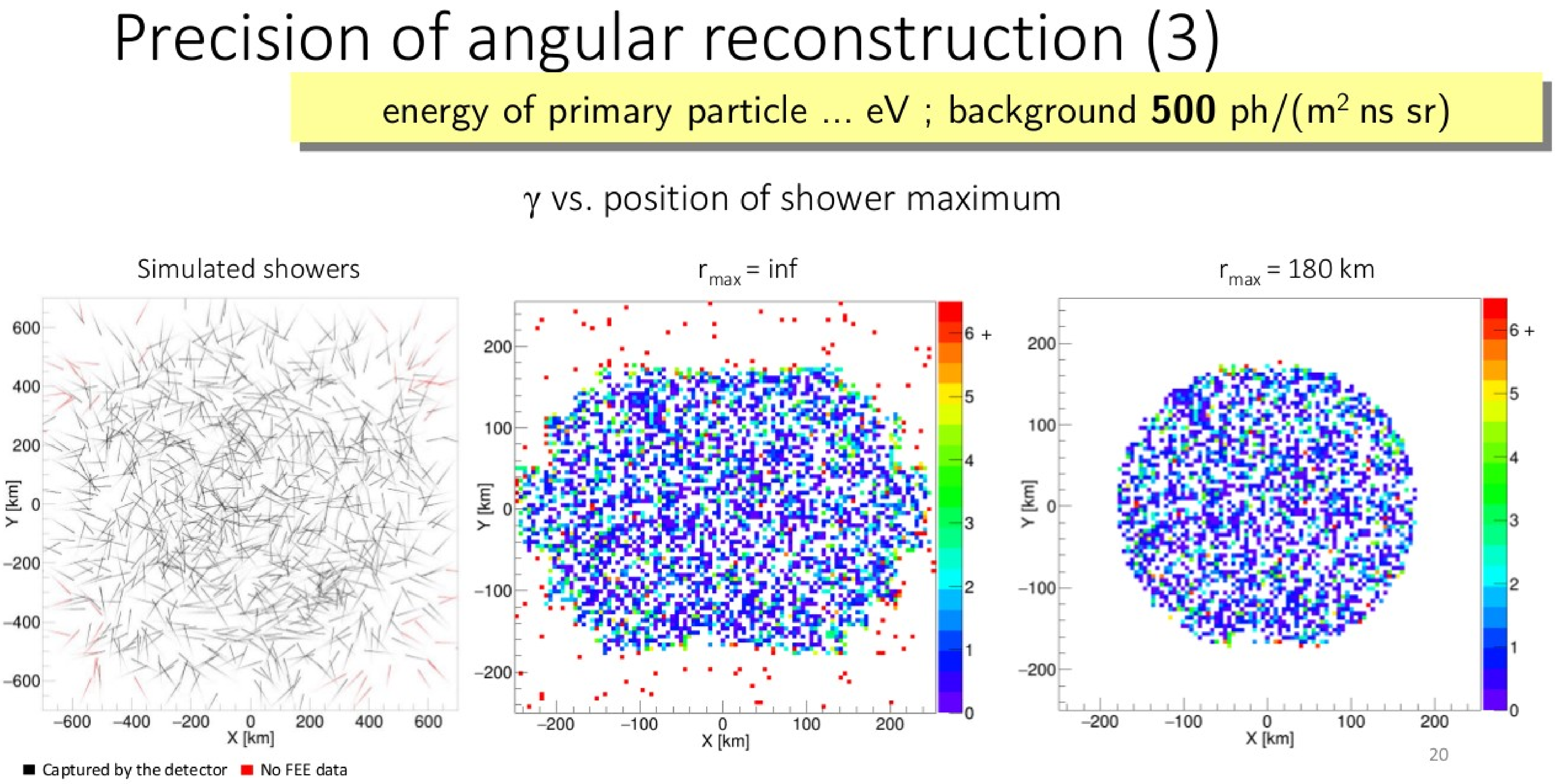






M. Vrábel, The 18th International JEM-EUSO collaboration meeting @Stockholm, Sweden

Príklady výsledkov



M. Vrábel, The 18th International JEM-EUSO collaboration meeting @Stockholm, Sweden

Evaluation of scientific performance of JEM-EUSO mission with Space-X Dragon option

Author(s): Dr. SHINOZAKI, Kenji[1] ; Prof. SANTANGELO, Andrea[1]
Co-author(s): Mr. BAYER, Jörg [1] ; Dr. BERTAINA, Mario [2] ; Dr. BOBIK, Pavol [3] ; Dr. FENU, Francesco [2] ; Dr. GORODETZKY, Philippe [4] ; Mr. GUZMAN, Alejandro [1] ; Dr. HAUNGS, Andreas [5] ; Mr. IWOTSCHKIN, Elias [6] ; Prof. MEDINA TANCO, Gustavo [7] ; Dr. MERNIK, Thomas [6] ; Prof. NERONOV, Andrii [8] ; Prof. OLINTO, Angela [9] ; Dr. PASTIRCAK, Blahoslav [10] ; Dr. PUTIS, Marian [11] ; Prof. WIENCKE, Lawrence [12]

[1] *University of Tübingen*
[2] *University of Torino*
[3] *Institute for Experimental Physics SAS Kosice*
[4] *APC, University of Paris Diderot, CNRS/Irfu*
[5] *Karlsruhe Institute of Technology*
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[7] *Instituto de Ciencias Nucleares - UNAM*
[8] *University of Geneva*
[9] *University of Chicago*
[10] *Institute of Experimental Physics, SAS Kosice*
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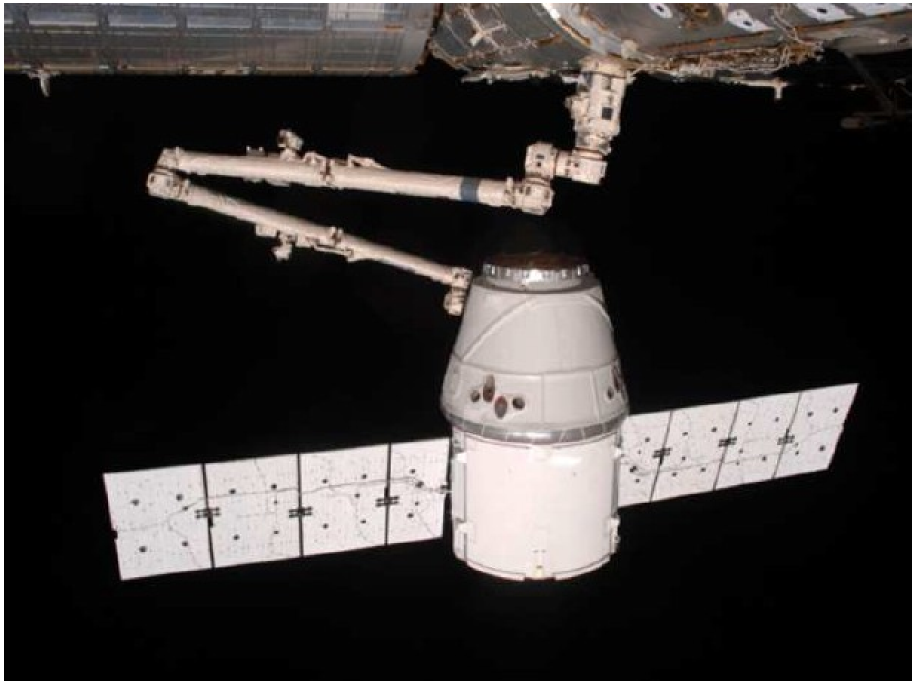
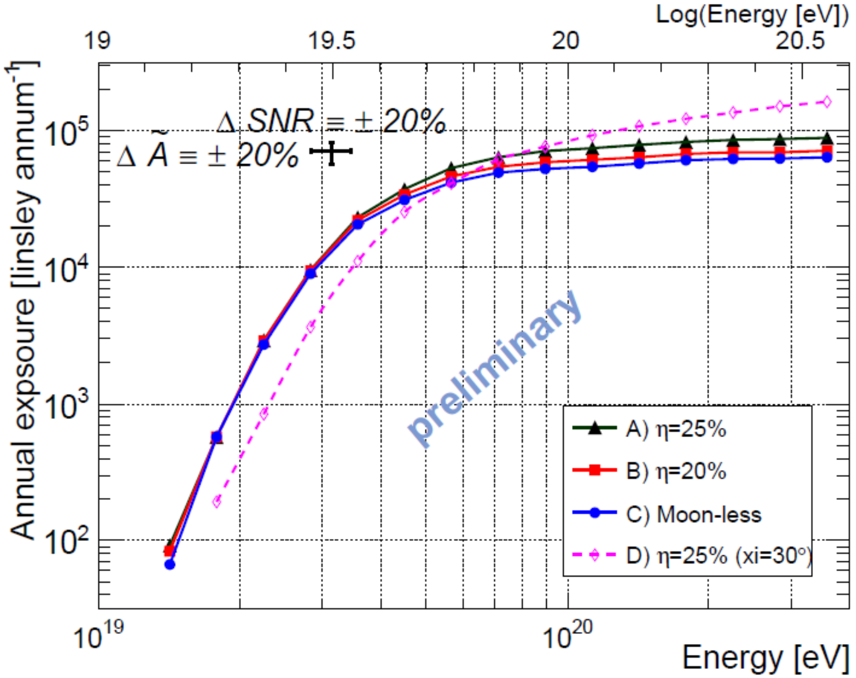
Corresponding Author(s): kenjikry@astro.uni-tuebingen.de

The Extreme Universe Space Observatory on-board the Japanese Experiment Module (JEM-EUSO) is a mission devoted to the observation of ultra-high energy cosmic rays (UHECRs) around and above the so-called Greisen-Zatseptin-Kuzimin energy at $\sim 5 \times 10^{19}$ eV. The origin of these enigmatically energetic cosmic rays remain an open question since their discovery more than 50 years ago. Very high statistics observations of UHECRs are essential to provide key information to answer this question. Very large exposure are indeed necessary to overcome their extremely low fluxes of an order of a few events per square kilometer per century. JEM-EUSO is designed to measure the extensive air showers induced by UHECRs using an super-wide field-of-view ultra-violet fluorescence telescope pointed downwards nighttime atmosphere. Orbiting onboard the International Space Station (ISS), JEM-EUSO rather uniformly covers the entire celestial sphere, allowing a thorough analysis of UHECR arrival direction distributions. In the present work, we introduce the current design of the JEM-EUSO telescope using the Space-X Falcon 9 as launcher and the Dragon as transport vehicle to the ISS. We then discuss the expected performances, and in particular the science of the search for the UHECR origin. Assuming the detector configuration based on the full-scale JEM-EUSO, the expected exposure and quality of arrival direction distribution analysis during the assumed mission lifetime are evaluated by simulation studies. We also preliminarily investigate an advanced scenario based on the use of silicon photomutiplers as focal surface detectors. Eventually we report the expected efficiency of UHECRs observation for these options including the expected sky map UHECRs.





EUSO-TA

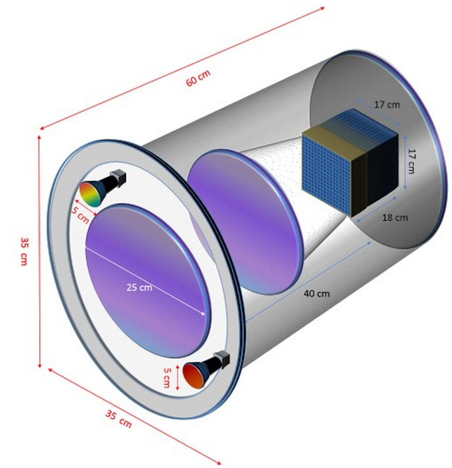
- Začiatok meraní: jar 2015
- Black Rock Mesa, Utah, pri Telescope Array experimente
- Vývoj a overenie funkčnosti hardvéru a softvéru, kalibrácia, pozorovanie pozadia pod vysokým zenitovým uhlom

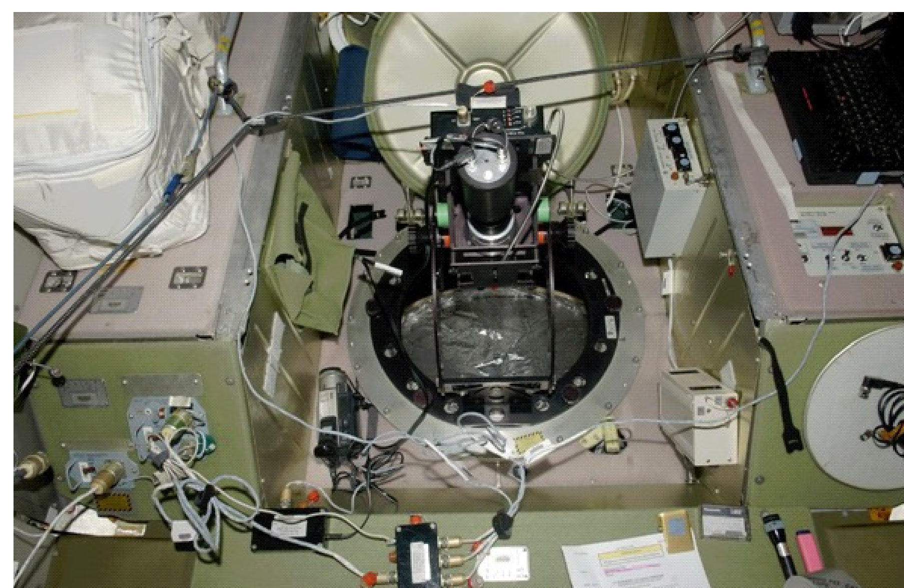
EUSO Super Pressure Balloon
EUSO-SPB

- Štart: apríl 2017
- Dĺžka letu: ~50 dní
- Letová výška: 36,6 km
- Hmotnosť vedeckého nákladu: ~600 kg
- Predpokladaný počet pozorovaných EAS: 100

Mini-EUSO

- Štart: koniec roka 2017
- Umiestnenie v UV priepustnom okne ISS
- Hmotnosť vedeckého nákladu: ~30 kg
- Pozorovanie
  - UV pozadia
  - TLE
  - bioluminiscencie

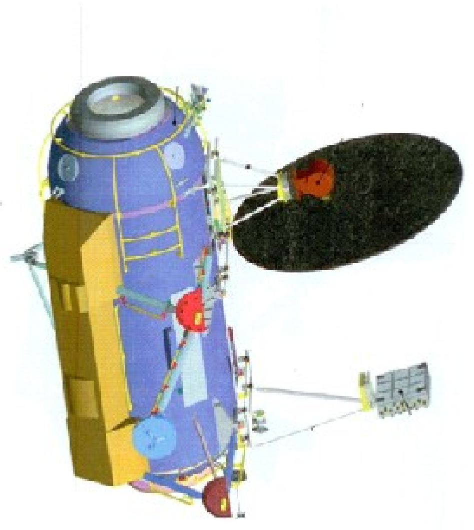


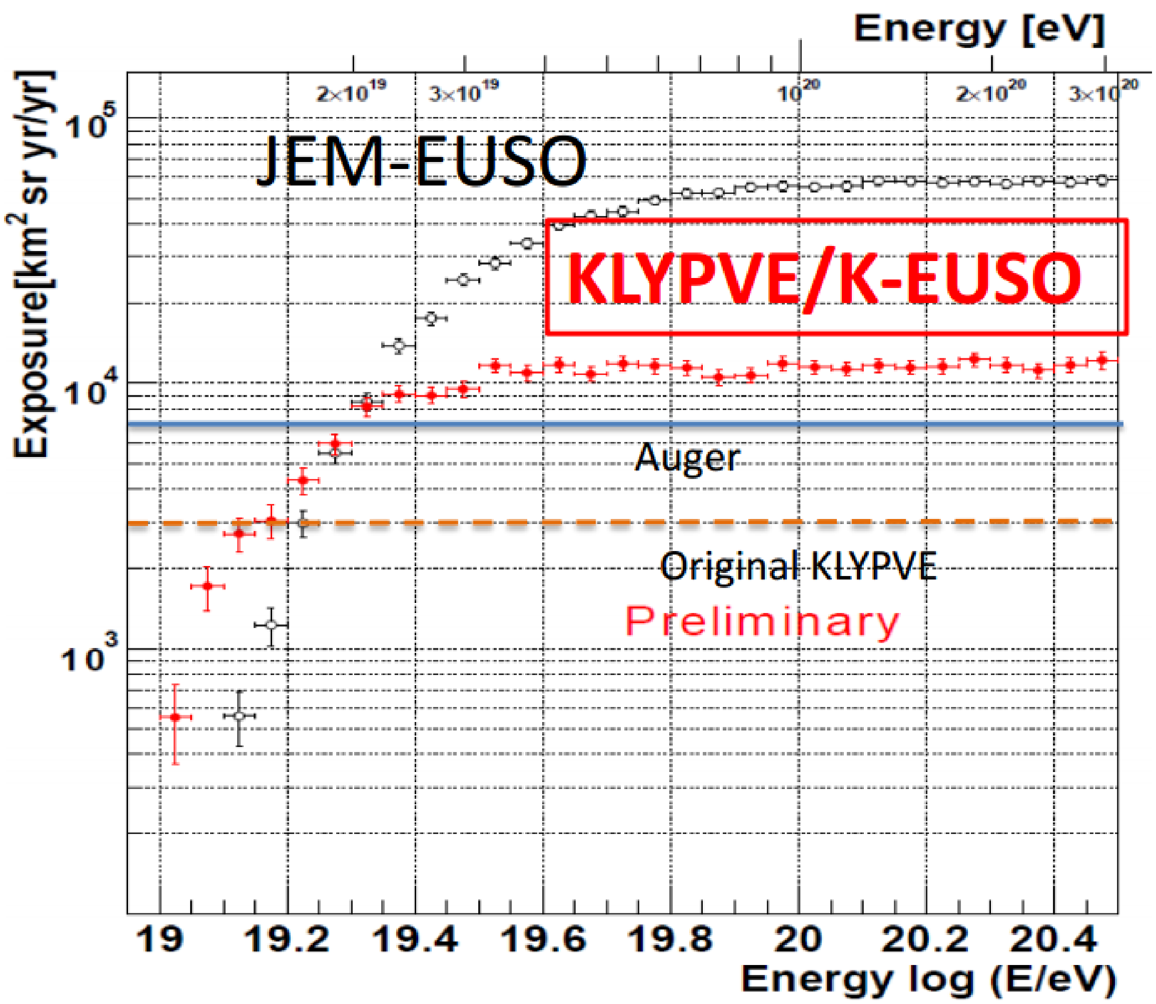


K-EUSO

- KLYPVE projekt
- Štart: 2020
- Meranie z ISS

  2020-2024 (2026)
- Koncept založený na zrkadle (10 m^2)
- Ročná triggerovacia expozícia
  ~1.2x10^4 km^2 sr yr/yr (~ 1.7x viac než Auger:
  A(zenith<60º)=7,000 km^2 sr yr/yr)





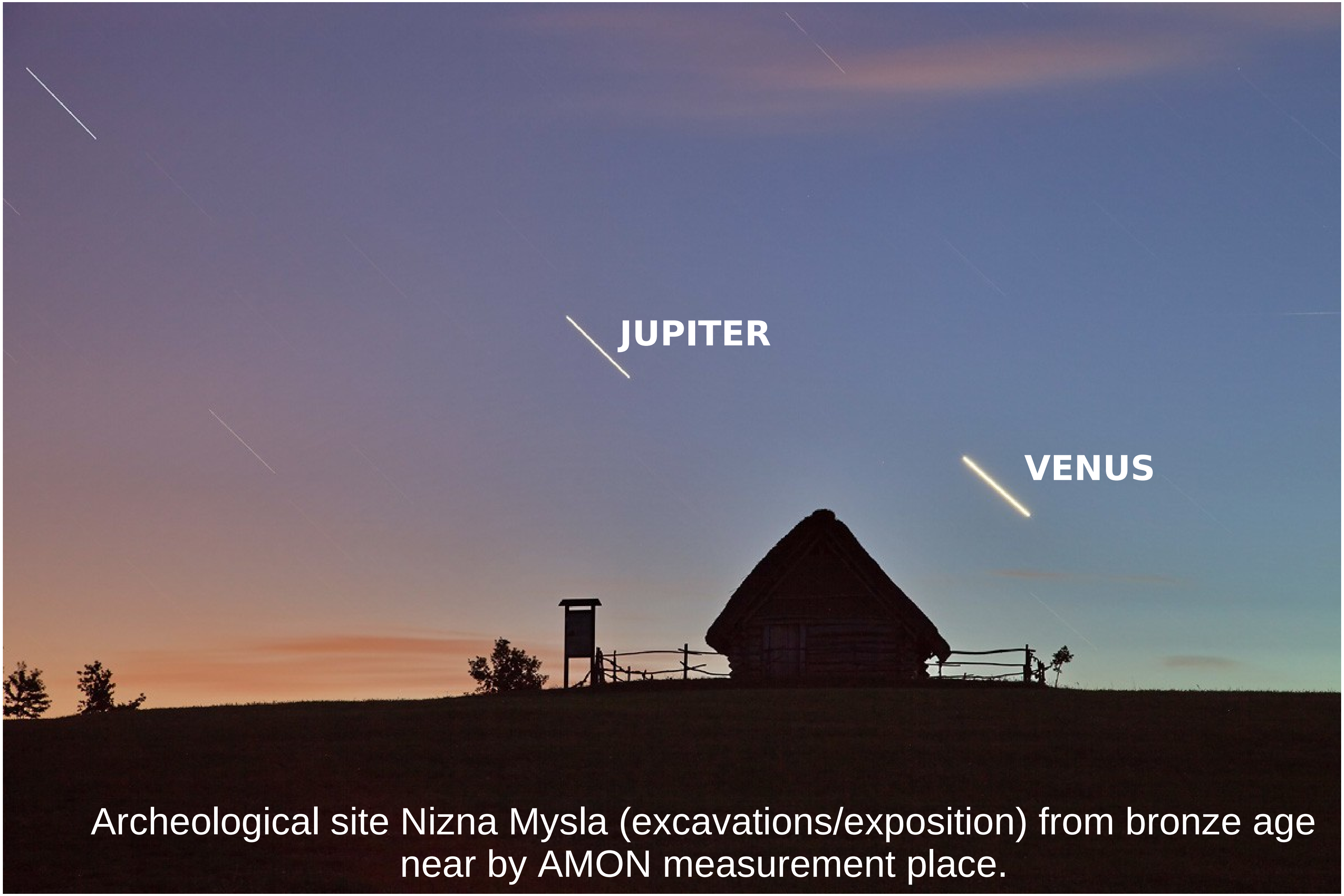
N.Sakaki, F. Fenu et al.
(ICRC2015 #647)

AMON, **A**irglow **MON**itor

- One pixe UV background detector
- DAQ 50 bits/second, 1 second integration
- Small & cheap, appropriate to measure BG
  - Optical sensor: actually Hamamatsu microPMT

    could be another one, for example M1
  - BG3 filter, easy to change another filters
  - Collimator: FoV, in order of 1 degree
  - No optics
  - Power consumption: < 0.5W (< 0.05W stand by)
  - Dimmensions: 110x75x60mm
  - Weight: 0.58 kg

First test measurements 17.-18. june 2015



Archeological site Nizna Mysla (excavations/exposition) from bronze age near by AMON measurement place.


Measurement place
AMON position

AMON – summer-autumn campaigns

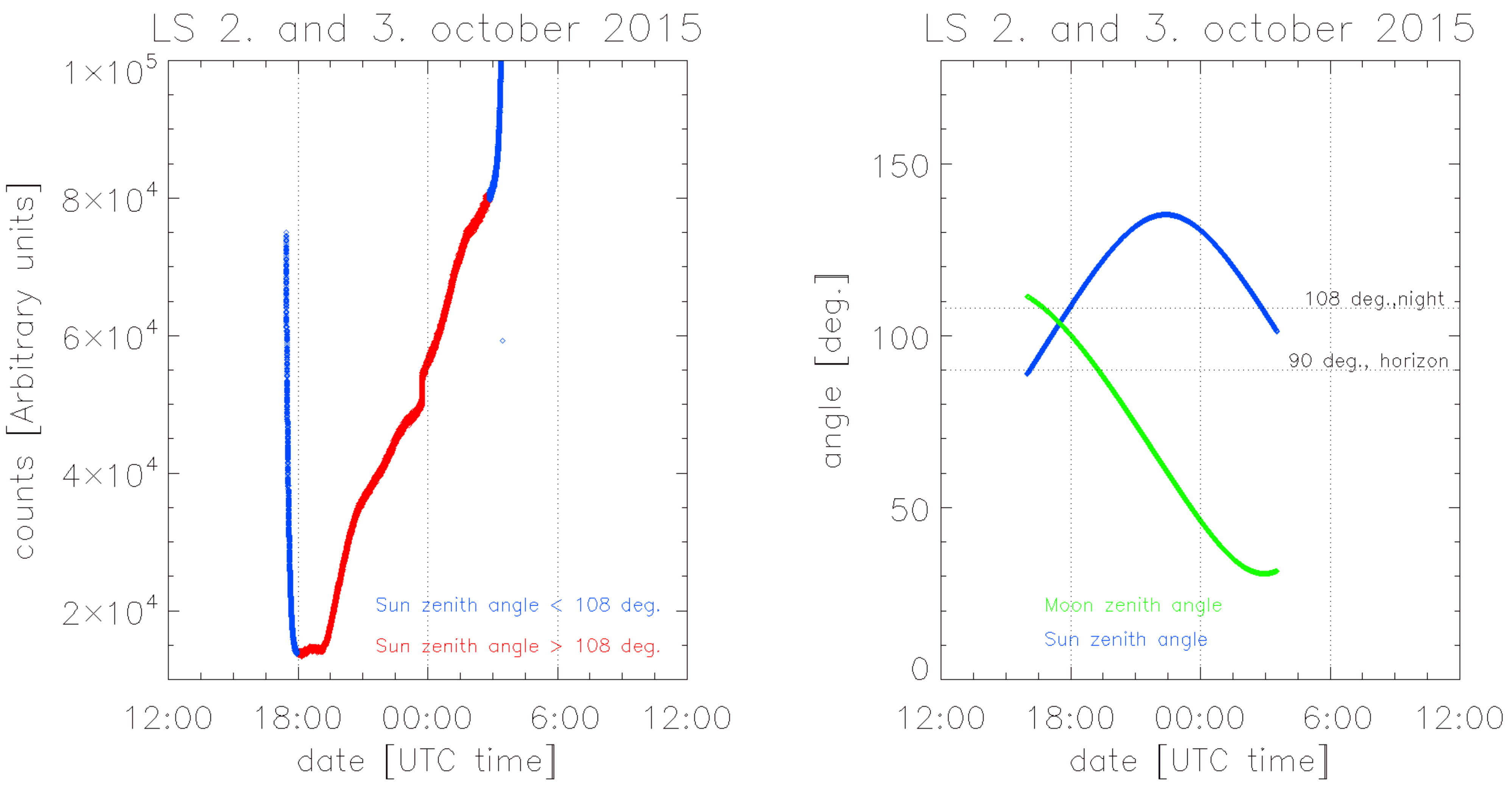
Measuement setup, Byšta

- July 2015 : Slanská Huta
- August 2015 : Byšta
- October 2015 : Lomnický štít – first one month test continuous measurement
- Start of continuous measurements at Lomnicky štit since december 2015

Test measurements on Lomnicky štít, octóber 2015

Lomnický štít november 2015 campaign

example



AMON (version 1.) for Utah

november 2015

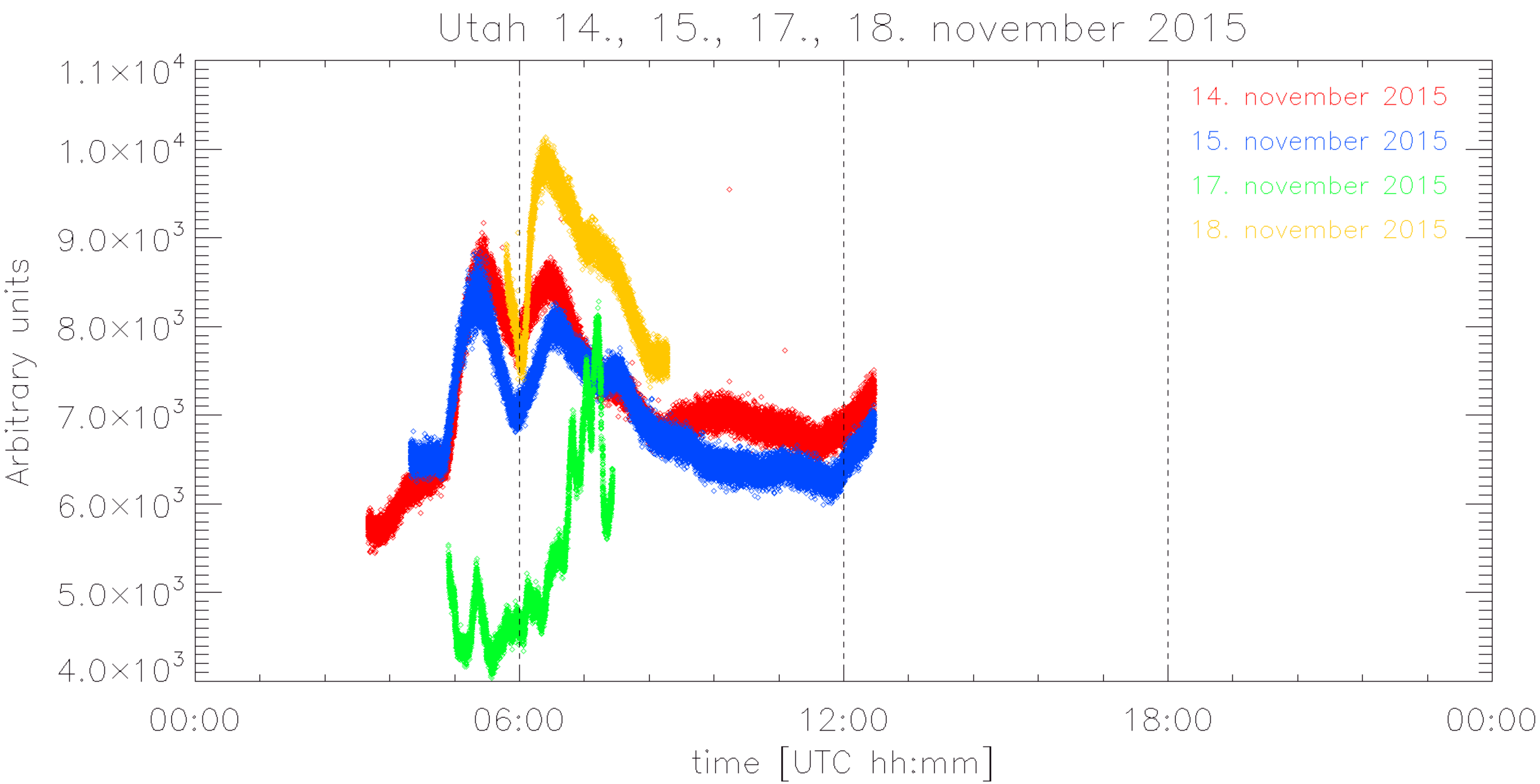
Measurements in paralelne with TA-EUSO

- intercalibration of AMON
- measurements on new (second) geographical position

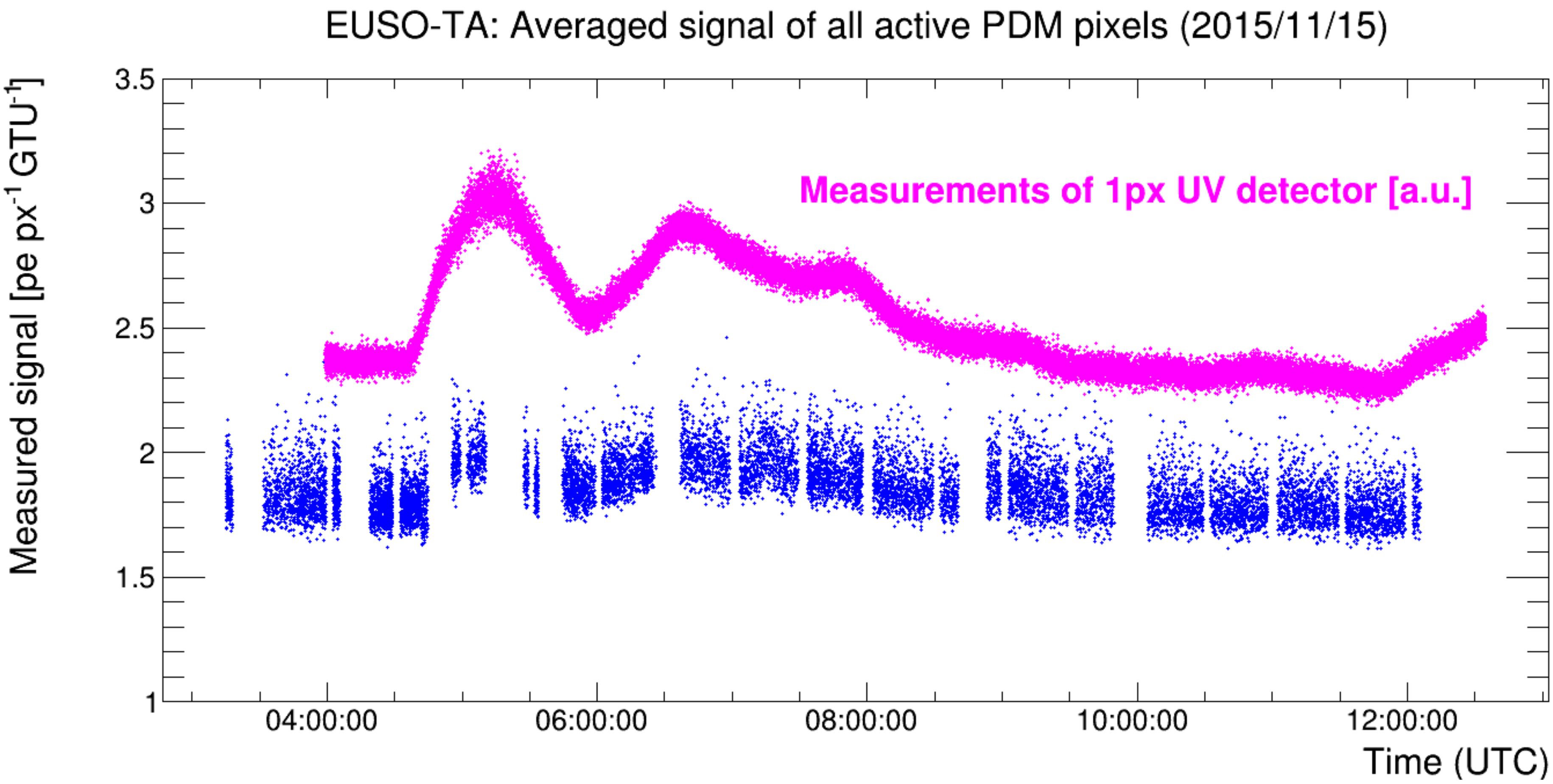
AMON in Utah

november 2015

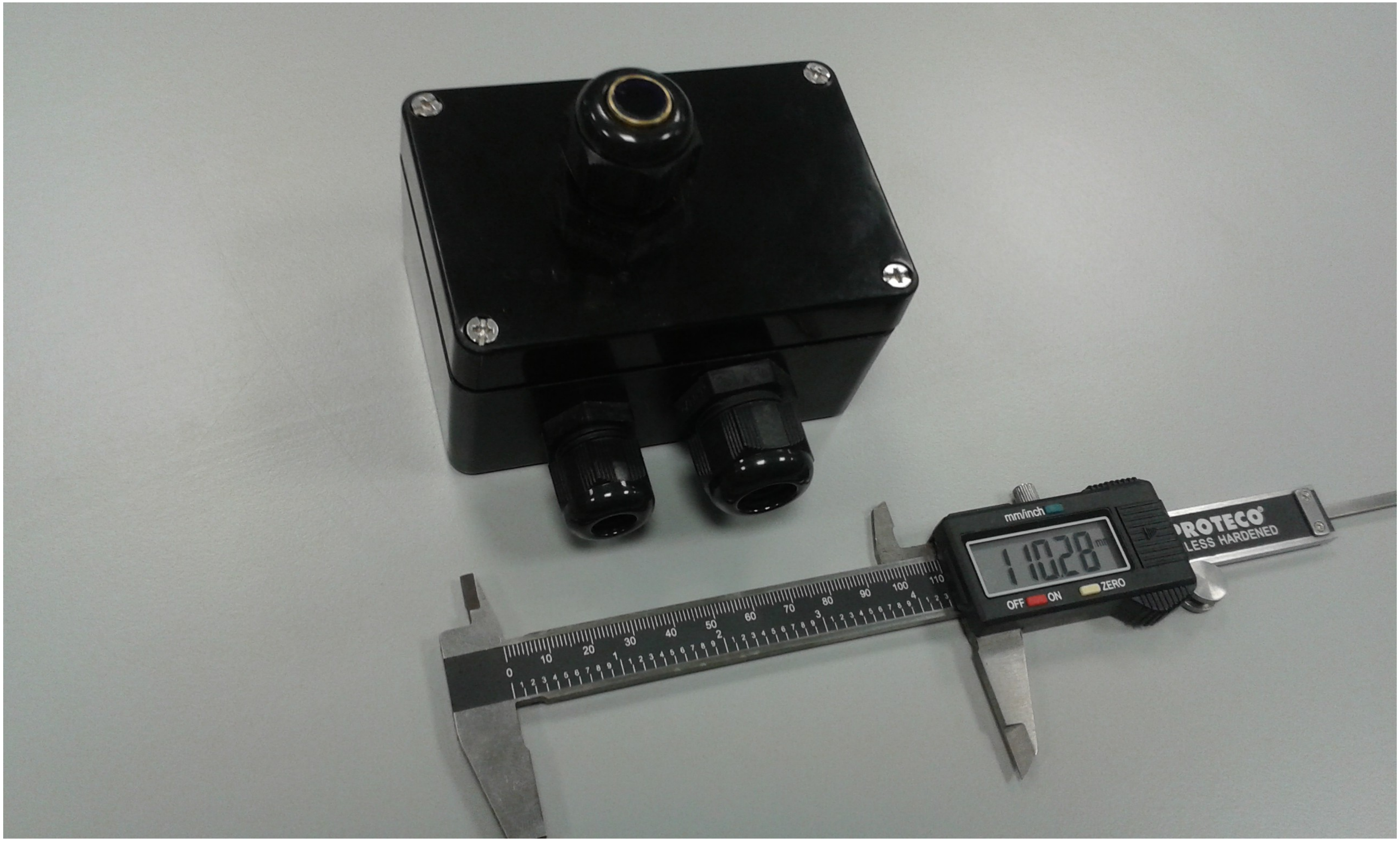
Utah : AMON measurements



Utah : TA-EUSO vs. AMON



AMON : Aktuálna fotografia



ESA PECS: SK1_05

AO/1-8224/15/NL/NDe - 1st Call under PECS in Slovakia

From 1.june 2016 to 31.10.2017

The objective of the proposed project is a study of night-time UV background models and data for the estimation of ionospheric disturbances visibility, especially during active years of the solar cycle, in night-time UV airglow light that is produced by upper atmosphere of the Earth. We will analyze if the available UV background models and data could be compared with the measurements of relatively simple and inexpensive ground-based one pixel UV detector. Feasibility study of ionospheric disturbances observation by one pixel detector is the main objective of this proposal.

ÚEF SAV

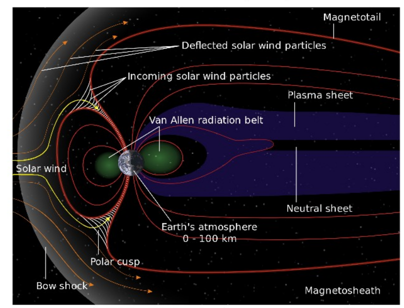
Feasibility study to observe ionospheric disturbances by one pixel UV detector

Institute of Experimental Physics, Slovak Academy of Sciences

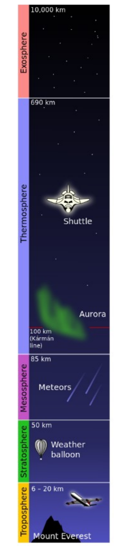
esa
European Space Agency

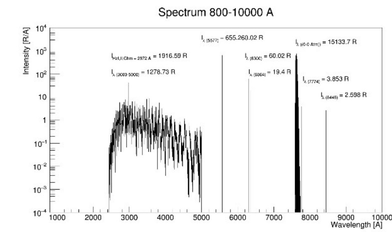
The objective of the proposed project is a study of night-time UV background models and data for the estimation of ionospheric disturbances visibility, especially during active years of the solar cycle, in night-time UV airglow light that is produced by upper atmosphere of the Earth. We will analyze if the available UV background models and data could be compared with the measurements of relatively simple and inexpensive ground-based one pixel UV detector. Feasibility study of ionospheric disturbances observation by one pixel detector is the main objective of this proposal.

Airglow layer. Credit: NASA

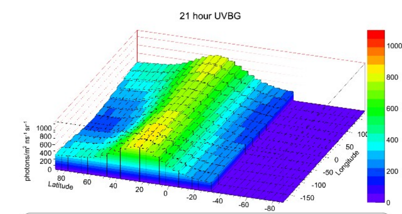


Interaction between Sun and Earth's atmosphere is responsible for airglow radiation of upper atmosphere.

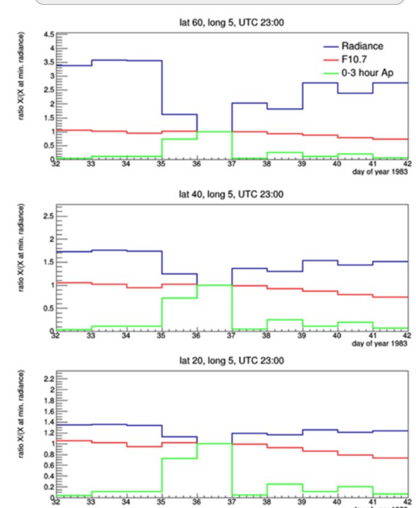




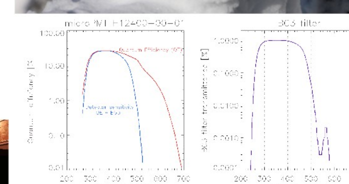
Nightglow radiation in range from 200 to 500 nm is produced by photodissociation of O_2 and consequent combination of atomic oxygen followed by photon emission.



Airglow production distribution over the Earth, example. Same local time, 21:00, december 1994.



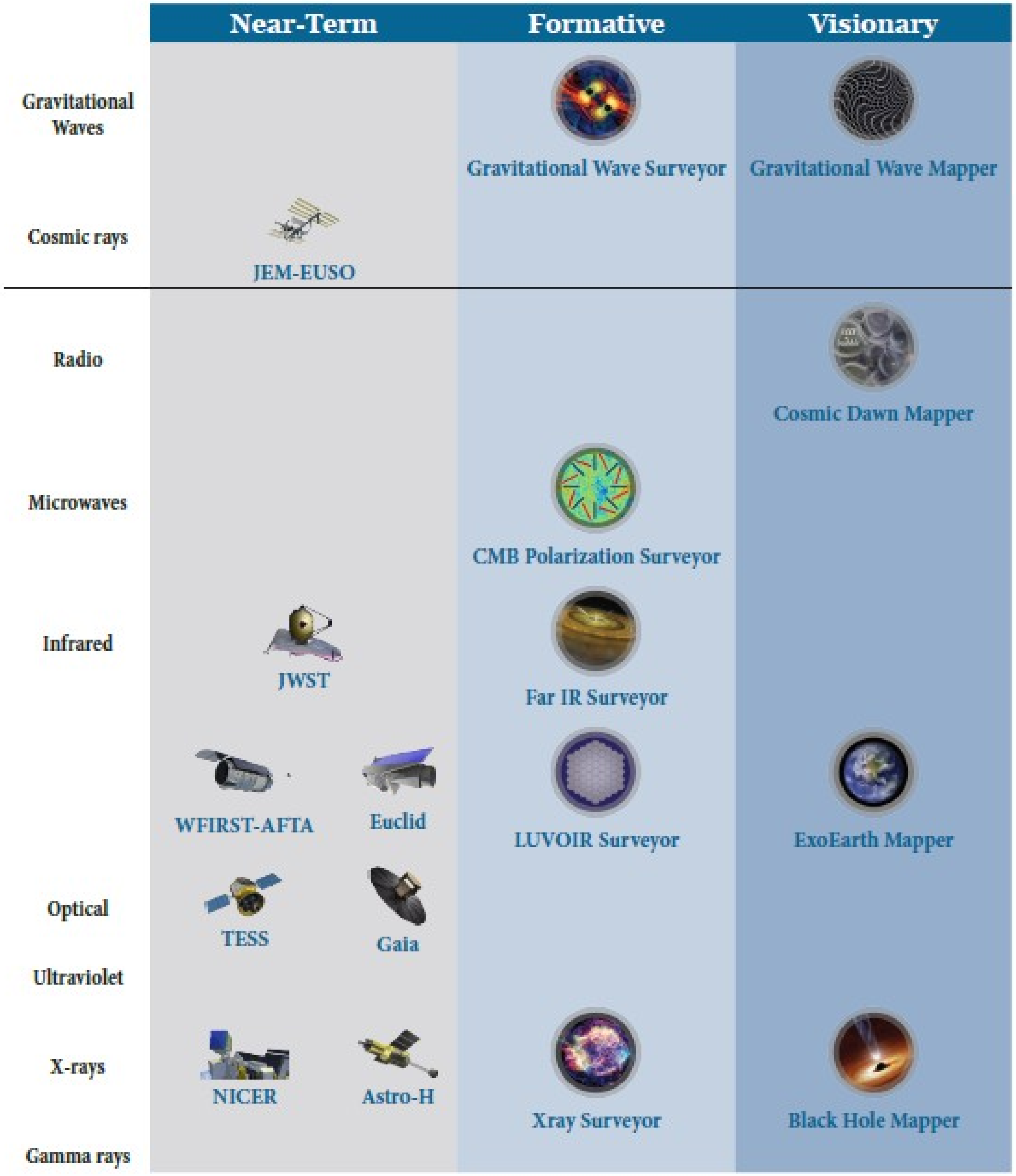
Upper atmosphere light production (blue line), Ap 3 hours index (green line) and F10.7 index (red line) evolution in 10 days time window starting 4 days before storm maximum (i.e. in undisturbed period). Storm with maximum at 4. - 5. february 1983.



One pixel UV detector, response, quantum efficiency and transmittance of optical filter.

Measurements of the variability of airglow light produced in lower ionosphere can provide additional information on ionospheric disturbances to existing and proposed experiments based on different physical principles. To our knowledge there is no complex study of this topic in UV spectral range. Furthermore such study could be important for detection of extensive air showers induced by ultra high energy cosmic rays with fluorescence telescopes from the Earth orbit.

2013 : NASA Astrophysics in the Next Three Decades



http://science.nasa.gov/media/medialibrary/2013/12/20/secure-Astrophysics_Roadmap_2013.pdf

2015 : štart v roku 2021?

Science, *Catching cosmic rays where they live,* 7. august 2015, vol. 349, 6248

„Another ISS detector, the Extreme Universe Space Observatory at the Japanese Experiment Module (JEM-EUSO) - now being considered for launch in 2021 - would look down on Earth with a wide-angle camera, watching for ultraviolet light produced by the showers of particles that ultrahigh-energy cosmic rays spawn when they hit the atmosphere.“

Ďakujem za pozornosť