

Detector for the ultrahigh energy cosmic rays composition study in Antarctica

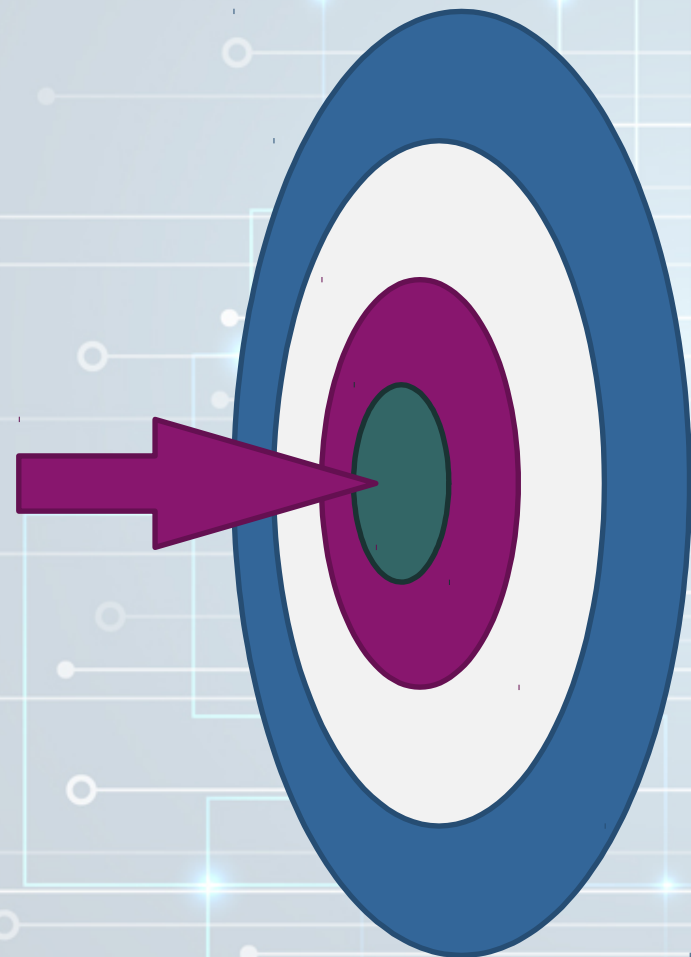
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*11 October 2016. Moscow.
2nd ICPPA*

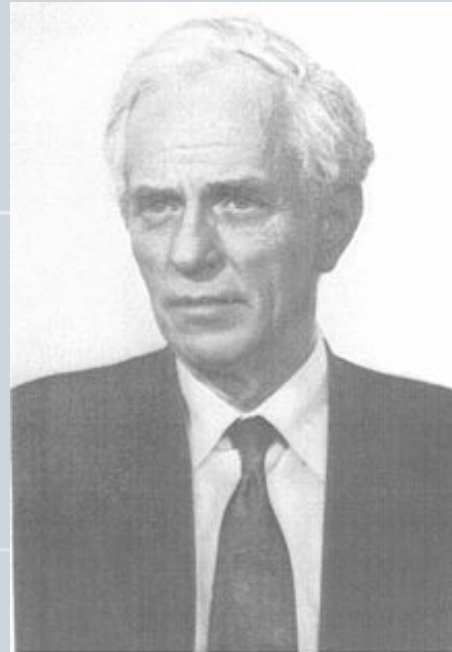
The purpose of Sphere Antarctica project

The study of the energy spectrum and mass composition of cosmic rays in the region of 10^{18} - 10^{20} eV by detecting reflected Cherenkov light and fluorescent light of EAS



History

The Sphere Antarctica experiment is based on the method proposed by A.E. Chudakov. The Vavilov-Cherenkov radiation generated by the extensive air shower is reflected from the snow surface and registered by a detector lifted above ground.



A. E. Chudakov

**Proc. Yakutsk office of
Siberian Branch of
AS USSR Press (in
Russian) (1974) 69-74**

In article «POSSIBLE METHOD OF REGISTRATION OF EAS BY CHERENKOV LIGHT, REFLECTED FROM THE SNOW-COVERED SURFACE OF EARTH» it was offered to install on an aircraft two photo multipliers and two electron-optical converter with identical fields of view of 45 degrees. All four devices had to observe a snow-covered surface of Earth from height about 10 km.

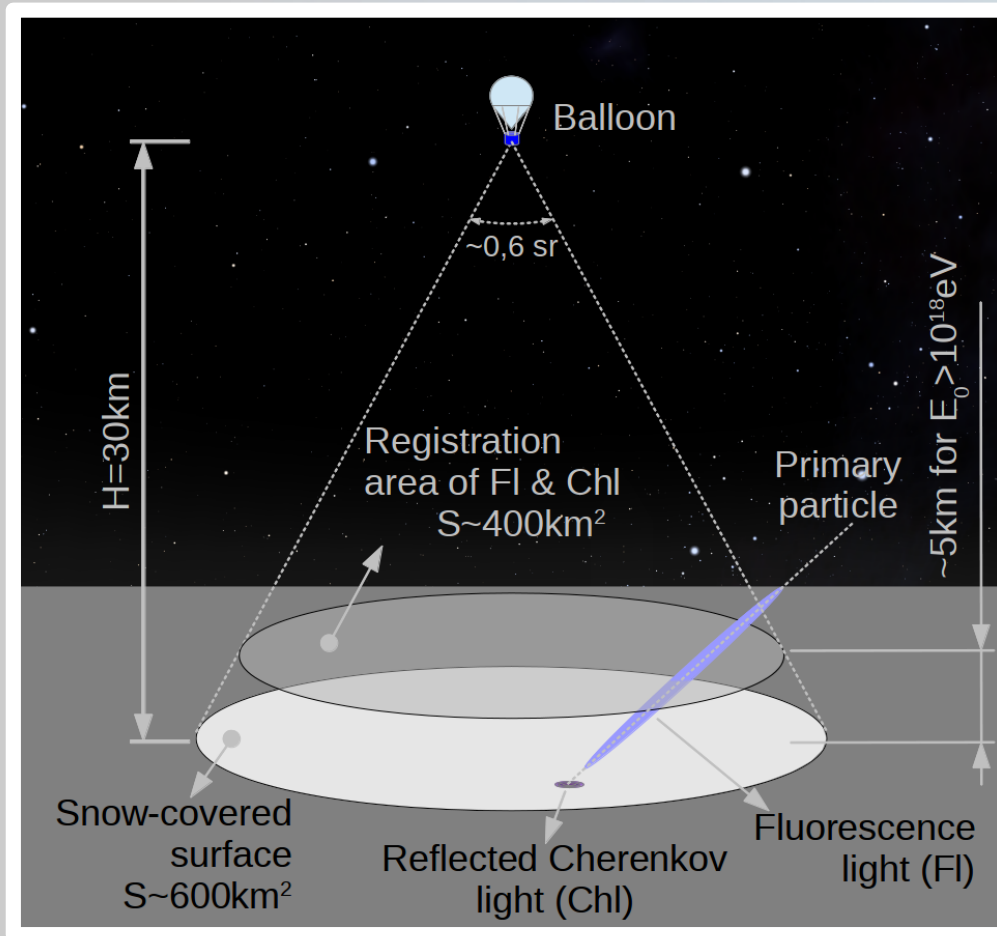
УДК 537.591
А.Е.Чудаков

**ВОЗМОЖНЫЙ МЕТОД РЕГИСТРАЦИИ ШАЛ
ПО ЧЕРЕНКОВСКОМУ ИЗЛУЧЕНИЮ,
ОТРАЖЕННОМУ ОТ ЗАСНЕЖЕННОЙ ПОВЕРХНОСТИ ЗЕМЛИ**

Экспериментальное изучение энергетического спектра первичных частиц космических лучей в области энергий $10^{18}-10^{20}$ эв, впервые начатое на установке Воллано-Ренч (США) около 10 лет тому назад, к настоящему времени ведется все более широким фронтом. Методика при этом в основном остается прежней и опирается на процедуру восстановления перпендикулярной энергии из данных о плотности потока частиц широкого атмосферного ливня на уровне наблюдения (обычно уровень моря). Площадь установок, регистрирующей ШАЛ с энергией 10^{19} эв из условия приемлемой статистики должна быть ~ 10 км² и более. Такими установками в Хаверал-Парк (Англия), Нораборей (Австралия), Якутск (СССР). Особый интерес эти исследования вызывают в связи с ожидаемым образованием энергетического спектра при энергии выше 10^{19} эв за счет взаимодействия с фотонами реликтового излучения. Однако, несмотря на большое внимание, уделяемое данной проблеме, и на то, что прошло уже несколько лет эксплуатации установок большой площади, ответа на поставленный вопрос об



The scheme of the experiment in Antarctica



- $A_{\text{Chl}} \sim 1300 \text{ km}^2 \text{ sr}$
- $A_{\text{"Chl+FI"}} \sim 15\text{-}30\% A_{\text{Chl.}}$
(depends on E_0)
Chl + FI (>50% EAS track)



Why Antarctica?

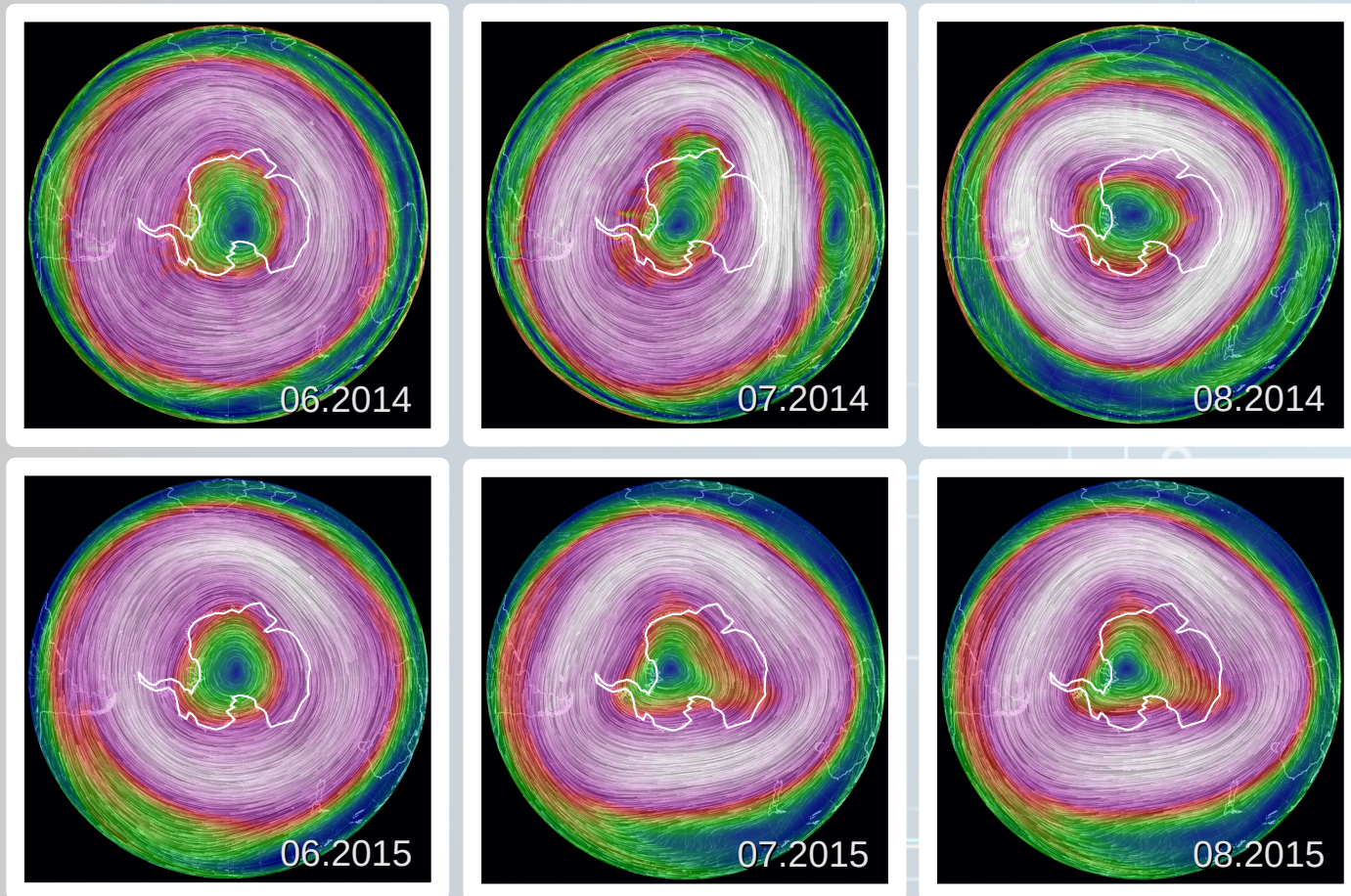
- Long polar night
- Pure atmosphere
- Stable circumpolar air flow
- Infrastructure polar stations of RF



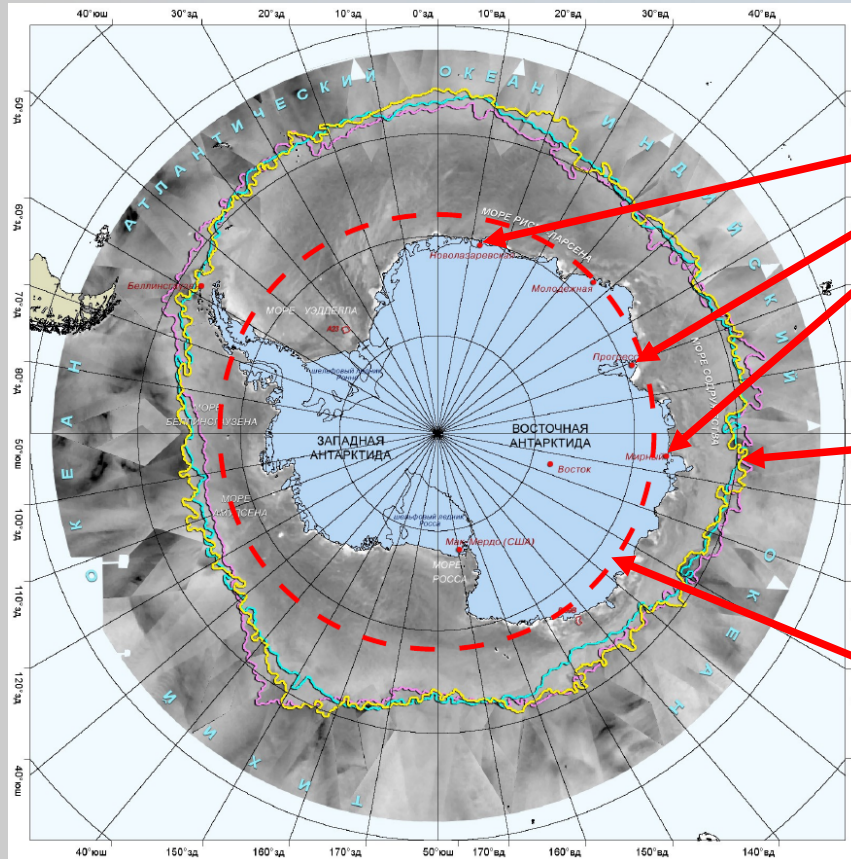
Climatic premise and the conditions of the experiment.



The movement of air masses over Antarctica at an altitude of ~ 27 km



The ice edge of Antarctica in 2013 and 2014



Russian
polar station

Ice edge

Possible initial
trajectory

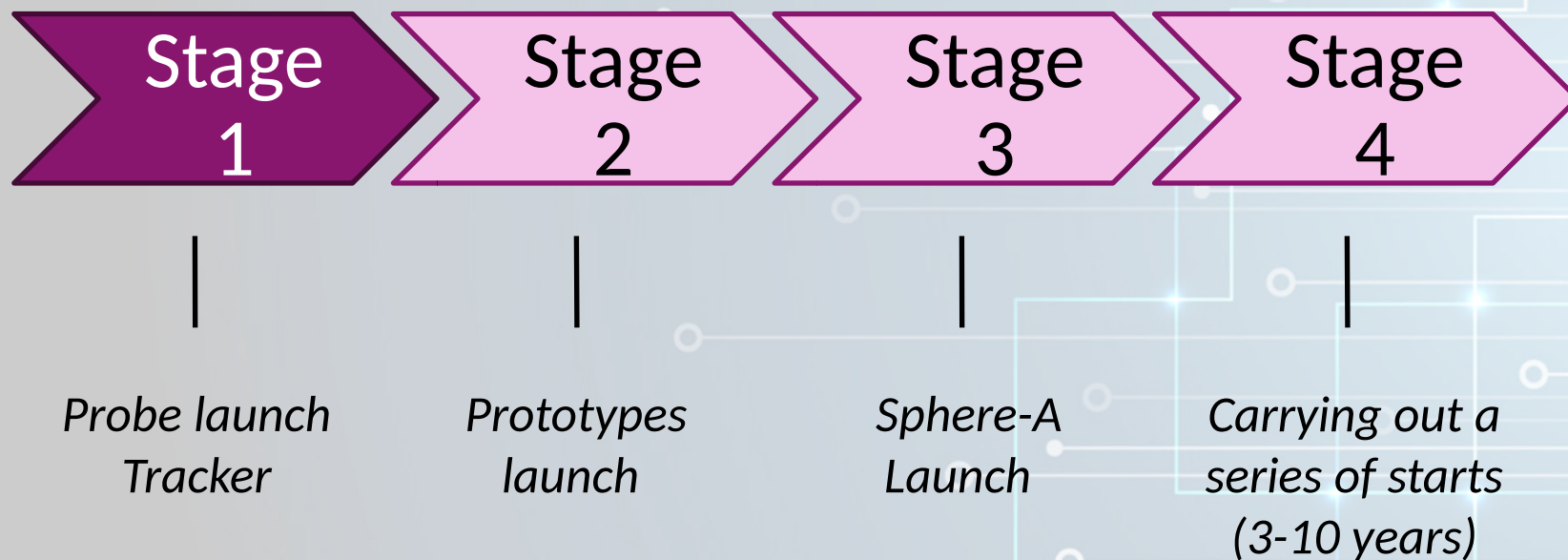
In the period from June to August edge of the ice cover is moved away from the mainland of Antarctica boundaries and the area of the snow-covered ice is increased many times over.

Comparison of registration methods for some modern experiments

Method Experiment	Particles of EAS	Cherenkov light	Fluorescent light	Location
AUGER (PAO)	✓		✓	Southern hemisphere
Telescope Array (TA)	✓		✓	North hemisphere
Yakutsk Array	✓	✓		North hemisphere
Sphere-A		✓	✓	Southern hemisphere
JEM-EUSO (K-EUSO)		?	✓	North and south hemisphere

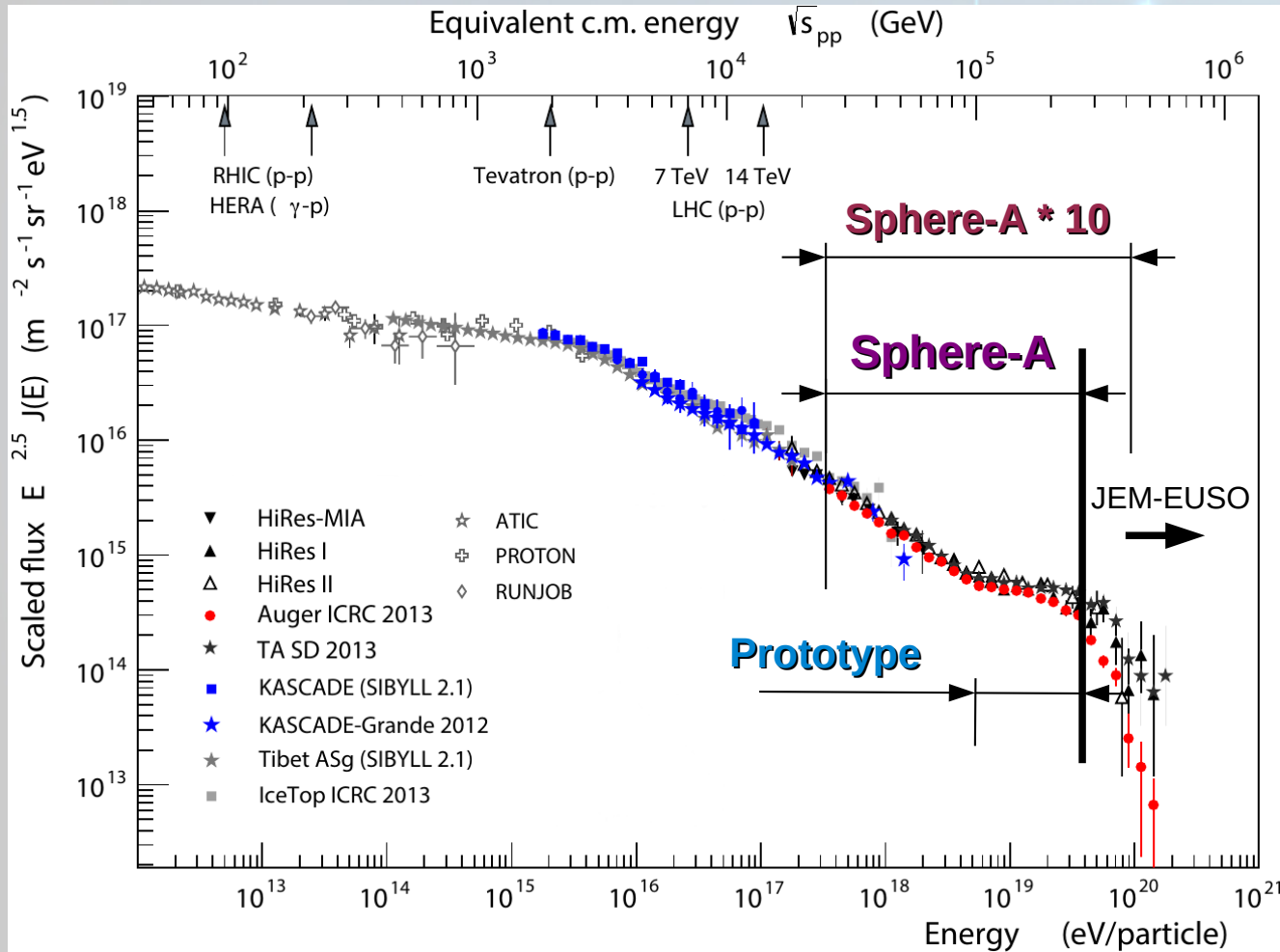


Stages of the Project



The energy range of the experiment

Sphere-Antarctic



Scheme of the Sphere-A optical system (preliminary)

Characteristics:

Diameter of the aperture (D) - 480mm

Input window area- 0.18 m²

Photodetector diameter – 440 mm

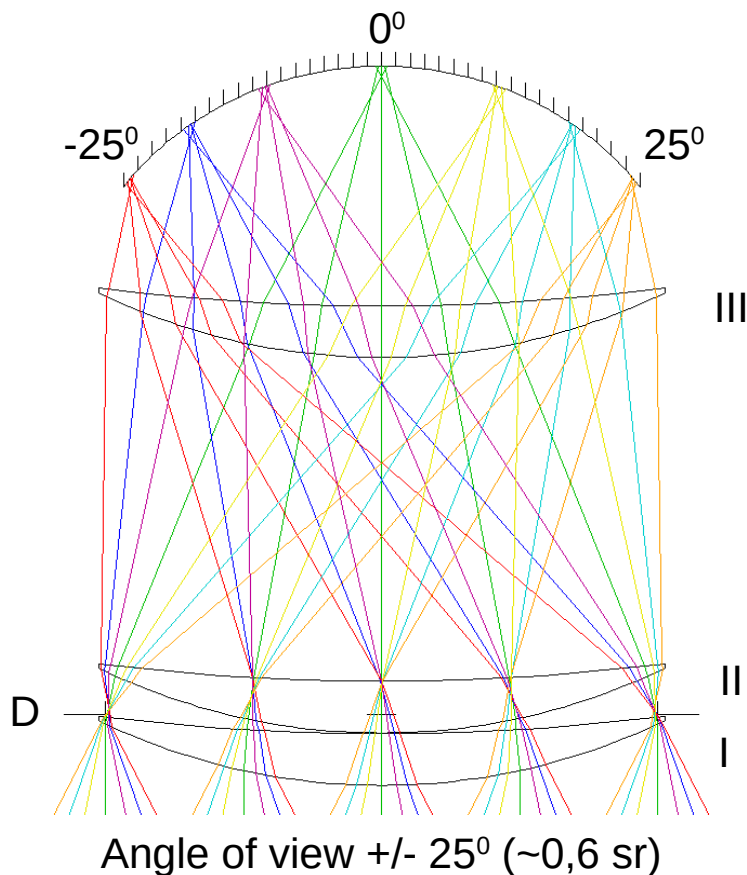
SiPM channels in a mosaic - 3328 pcs.

Optical resolution of ~ 1 degree

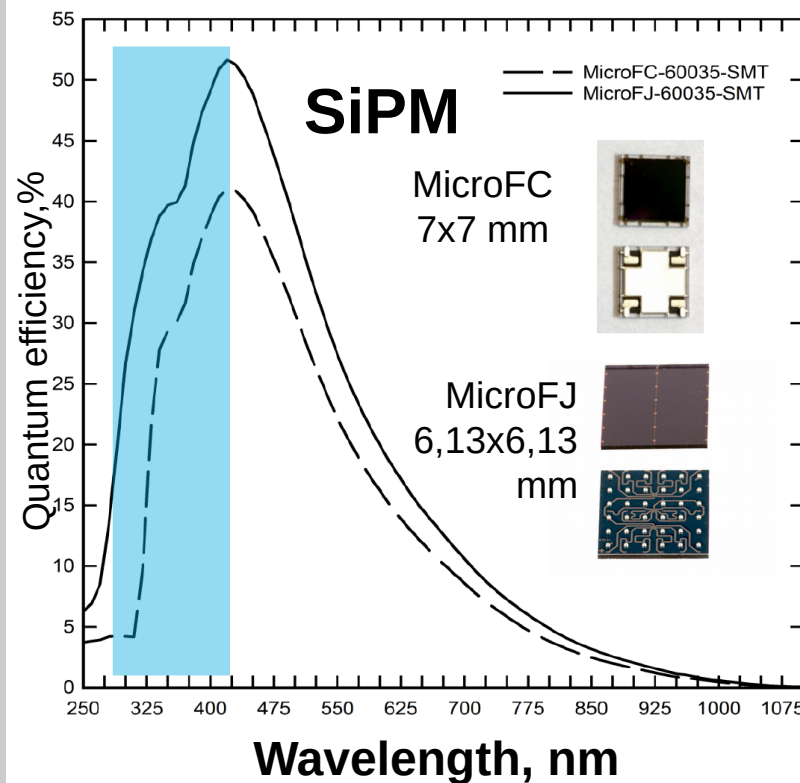
Lens I, II, III (or a Fresnel lens):

Diameter - 500mm

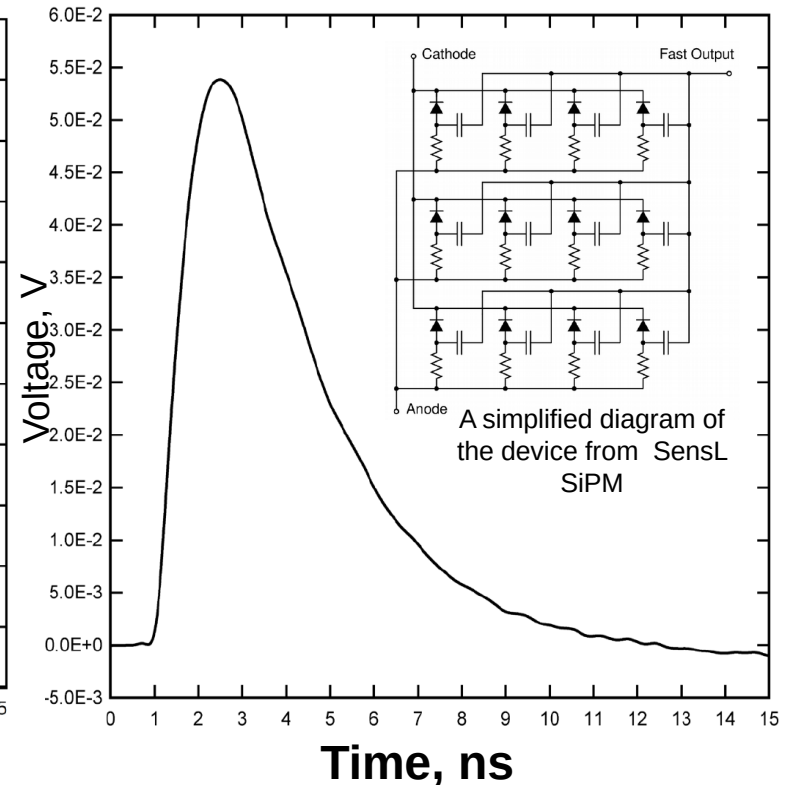
Lens material - PMMA (acrylic)



The use of SiPM in the project Sphere-Antarctica



Spectral sensitivity of SensL's SiPM



Temporal characteristics of fast output signal SiPM

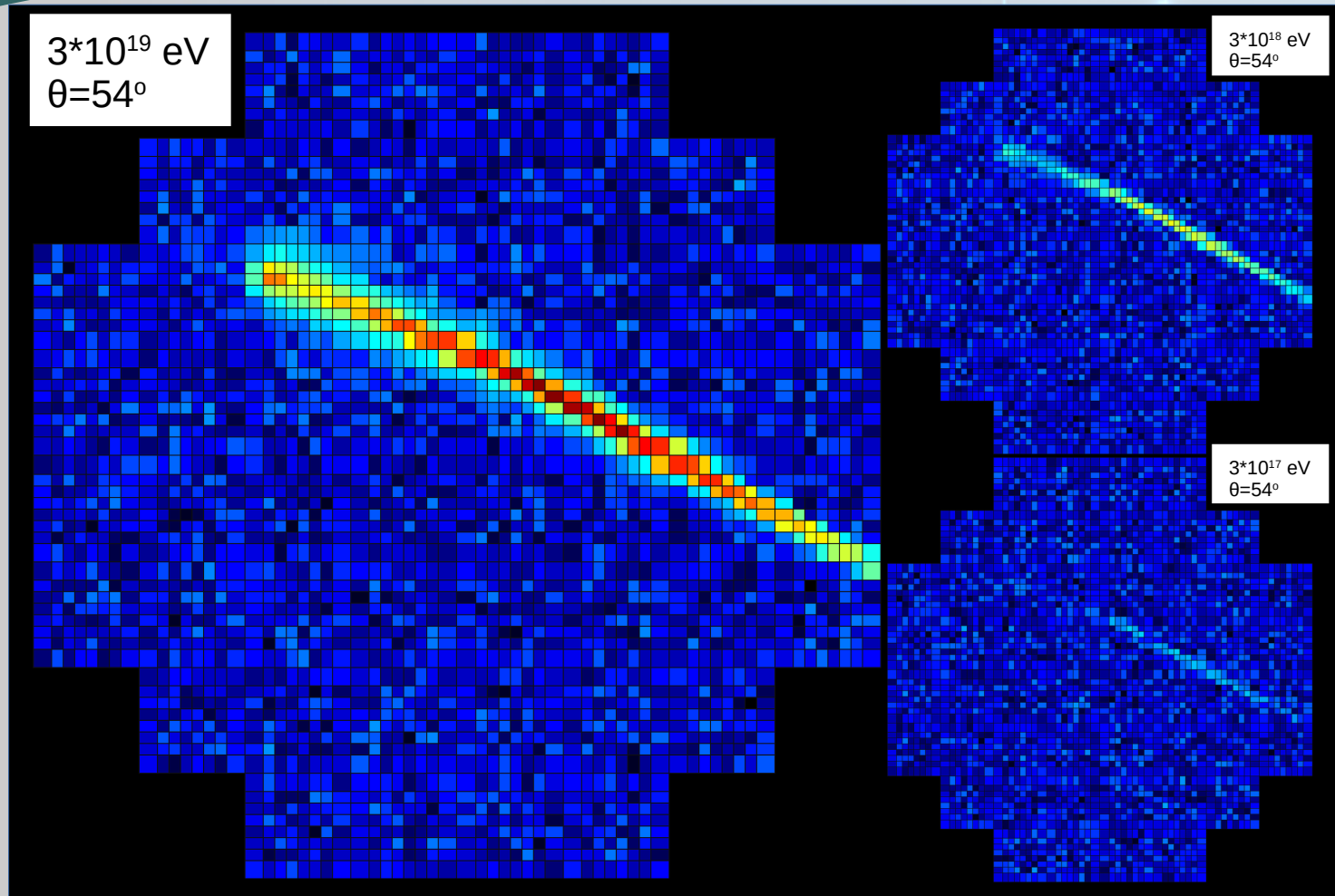
Apparatus characteristics

- Electronic channels - 3328
- Registration threshold - $3 * 10^{17}$ eV
- Laser lidar - 0.3 W, 405 nm
- Satellite Communication System
- Sensors stellar orientation
- Apparatus mass less than 80 kg

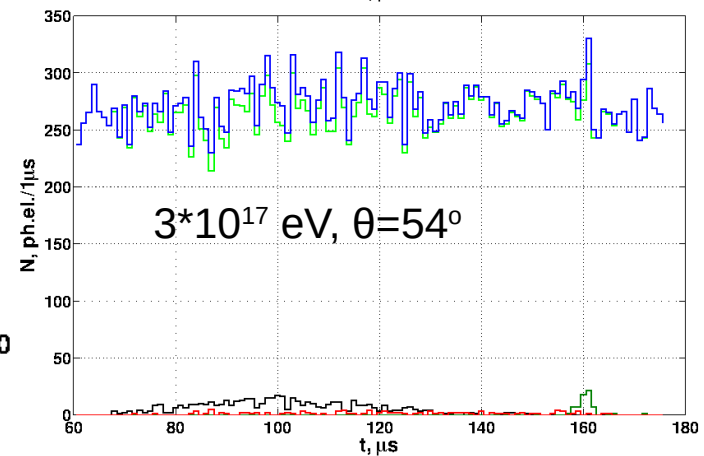
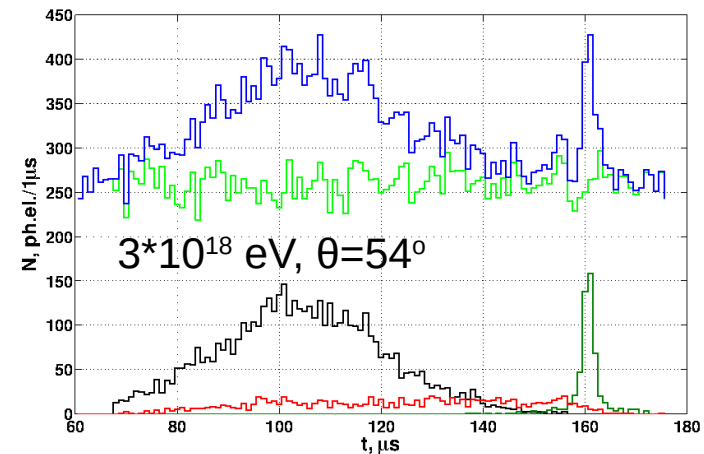
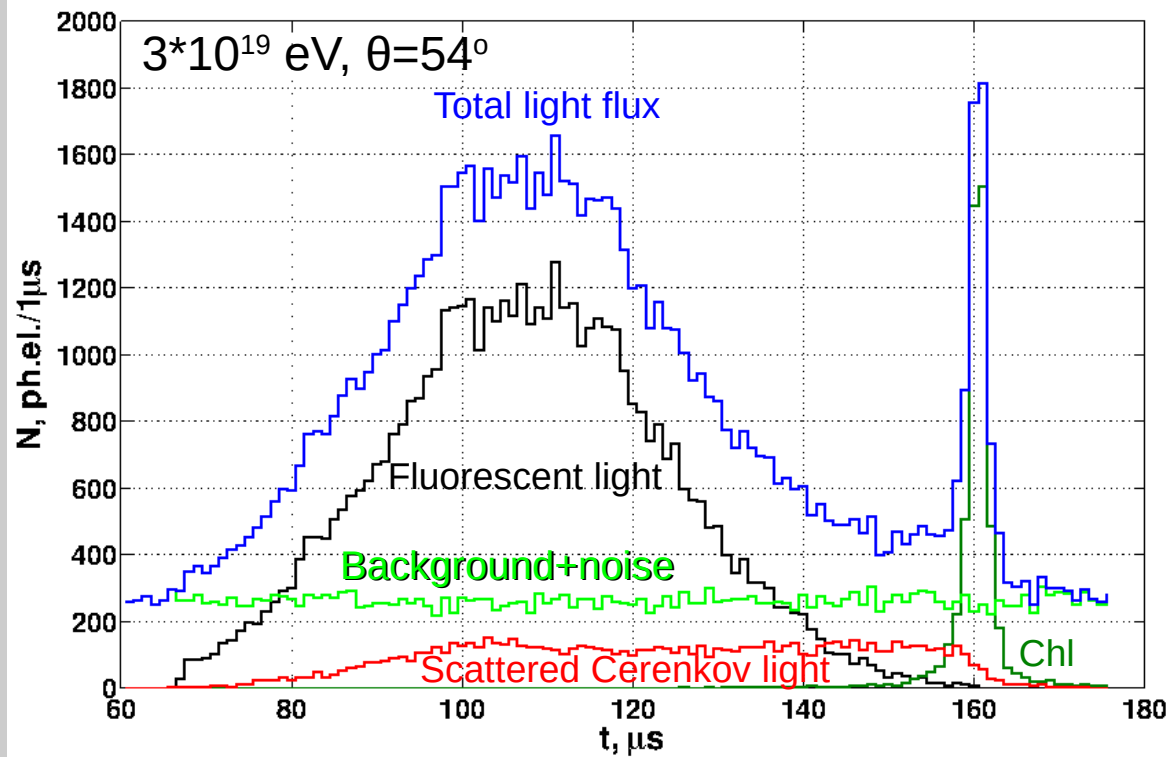


Examples of simulated events

(for Sphere-A, preliminary)



Examples of model events (preliminary)



Statistics for one flight and a series of 10 launches

(Height of 30km, 1,000 hours of exposure at 1 flight)

E_0 [eV]

$\sim N_{\text{chl}}$

x10

10^{18}

$15 \cdot 10^3$

$150 \cdot 10^3$

10^{19}

100

1000

E_0 [eV]

$\sim N_{\text{chl+fl}}$

x10

10^{18}

2500-5000

$25-50 \cdot 10^3$

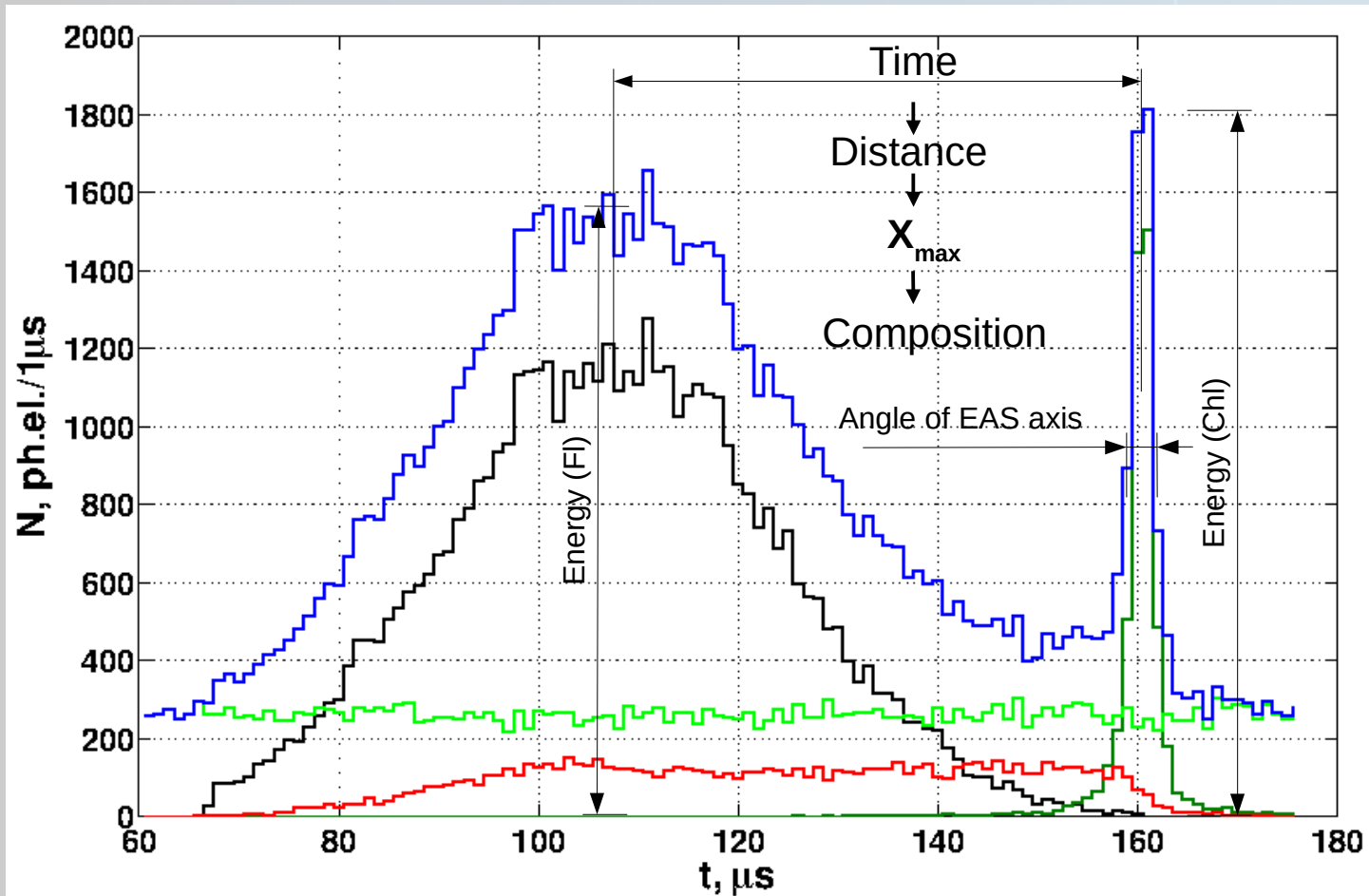
10^{19}

15-30

150-300



Evaluation of composition (very simplified scheme)



Advantages of the experiment

1. Measurements of the Cherenkov (reflected) and fluorescent light of EAS simultaneously.
2. The accuracy of energy estimation up to 15% in the individual event (Chl + FI).
3. Accuracy of X_{\max} estimation up to 5 g/cm² (Chl + FI, $E_0 > 10^{19}$ eV).
4. The southern celestial hemisphere observation.
5. Possibility of multiple launches.
6. Low Cost and easy to implementation (compared to ground or space-based detectors).

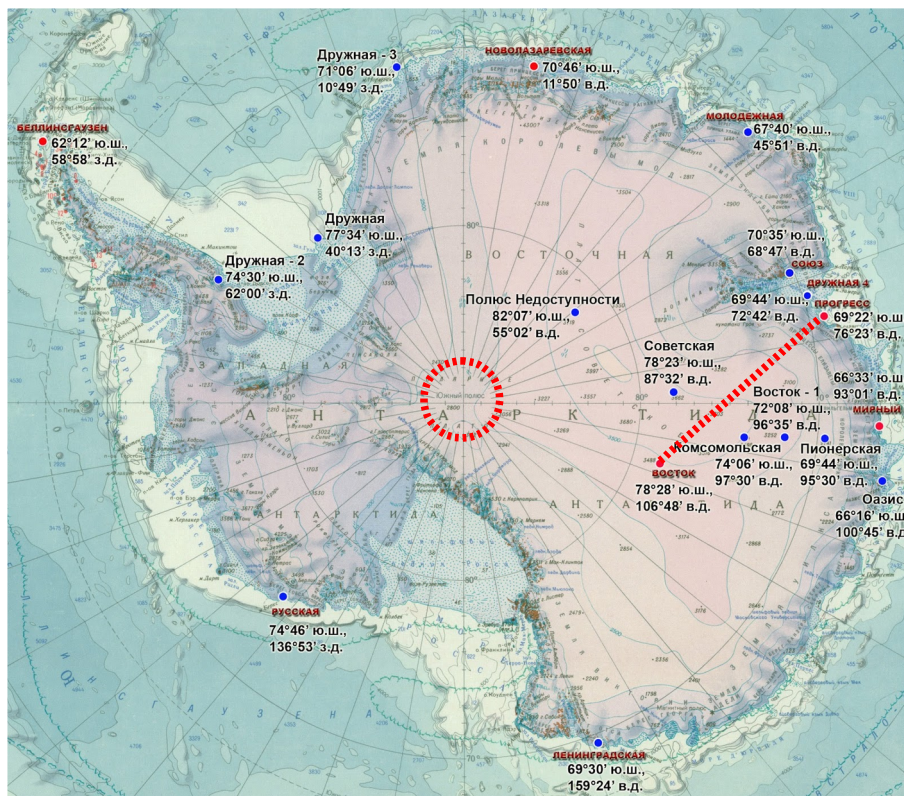


**Thank you for
attention!**

Questions



Evacuation equipment

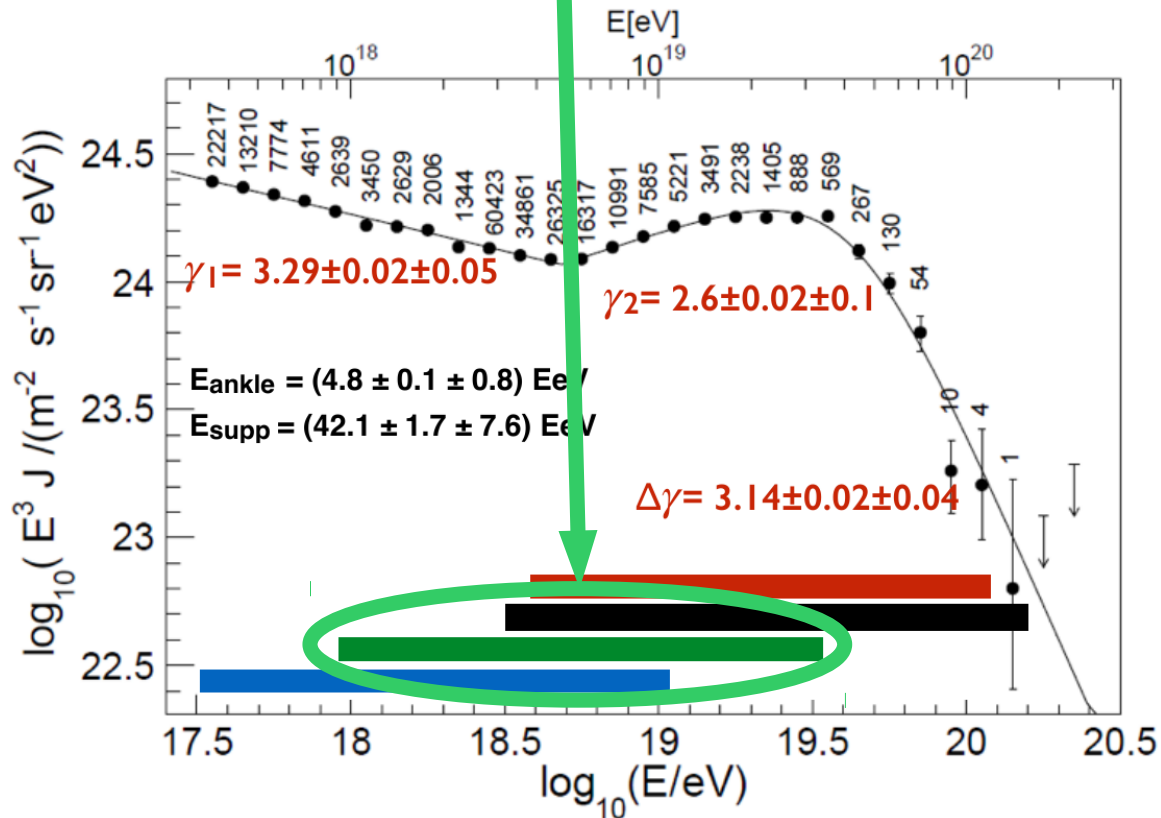


- Evacuation equipment is possible, but not guaranteed.
- One of the options - the implementation of flight termination when crossing the path of the balloon route the annual convoy from Progress station to Vostok station.
- The second option - the termination of the flight near the Amundsen-Scott station. Эвакуация оборудования возможна, но не гарантирована.

The Pierre Auger Project

4 data sets combined : SD 750 m, **FD (hybrid)**, SD 1500 m [0-60°], SD 1500 m (60-80°)

$\approx 200\,000$ events, $\approx 50\,000\text{ km}^2$ s yr exposure, FOV: -90° , $+25^\circ$ in δ



Starting balloon for BARREL experiment in Antarctica



Helium-filled envelope easily hold two people. To fill a balloon requires no more than 10 standard 40-liter cylinders with helium.



Project Loon



In November 2014
Project Loon balloon
worked for 130 days.
Launched in March
2015 - 187 days!

Some hope for us to fly the whole night!

