TAIGA status
and other experiments in the Tunka Valley

V.V. Prosin on behalf of TAIGA Collaboration

Torino, Nov. 30 – Dec. 2, 2016

TAIGA = Tunka Advanced Instrument for cosmic rays and Gamma-ray Astronomy

TAIGA - collaboration

Germany

Hamburg University (Hamburg)
DESY (Zeuthen)
MPI (Munich)

Italy

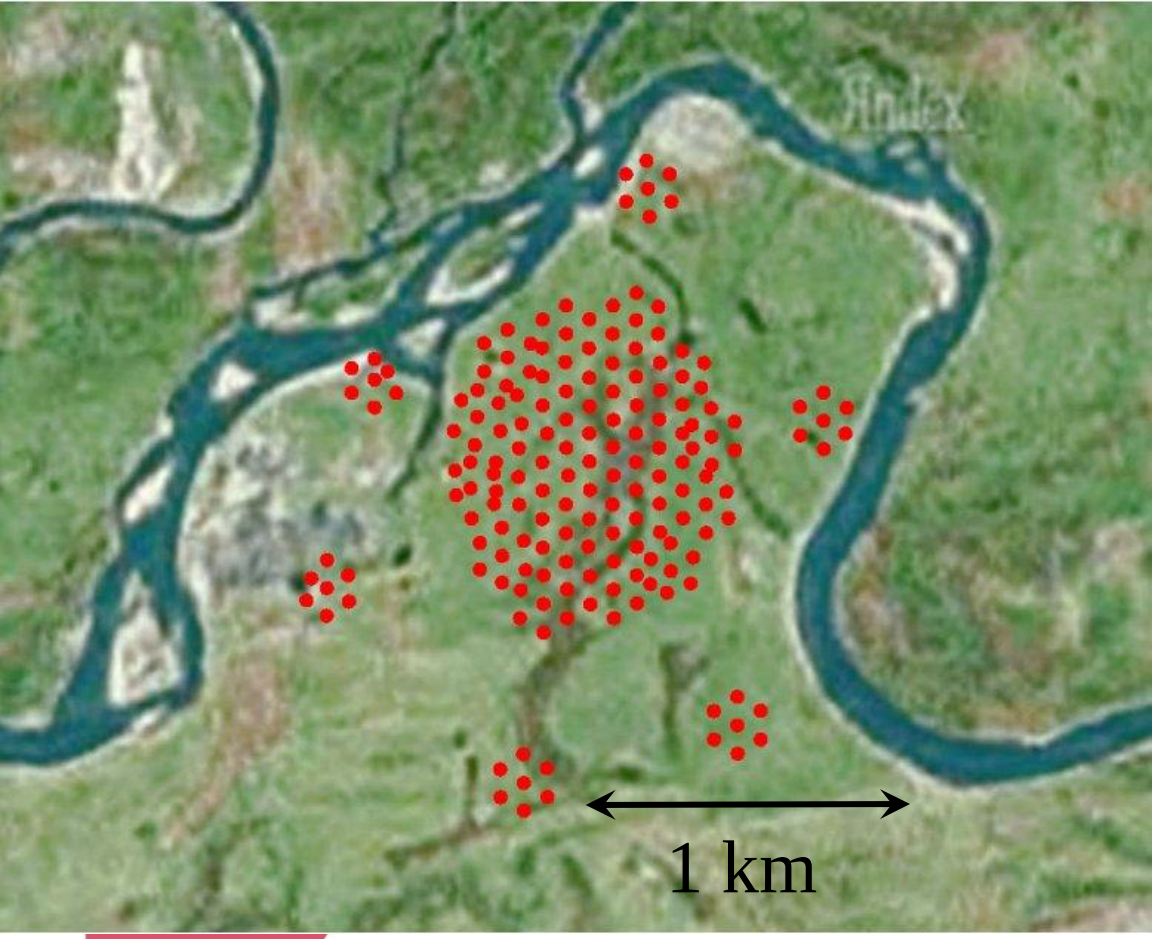
Torino University (Torino)

Romania

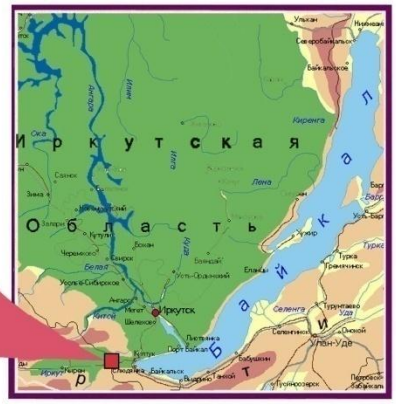
ISS (Bucharest)

Russia

SINP MSU (Moscow)
API ISU (Irkutsk)
INR RAS (Moscow)
JINR (Dubna)
MEPHI (Moscow)
IZMIRAN (Moscow)
NSU (Novosibirsk)
BINR SB RAS (Novosibirsk)



51° 48' 35" N
103° 04' 02" E
675 m a.s.l.

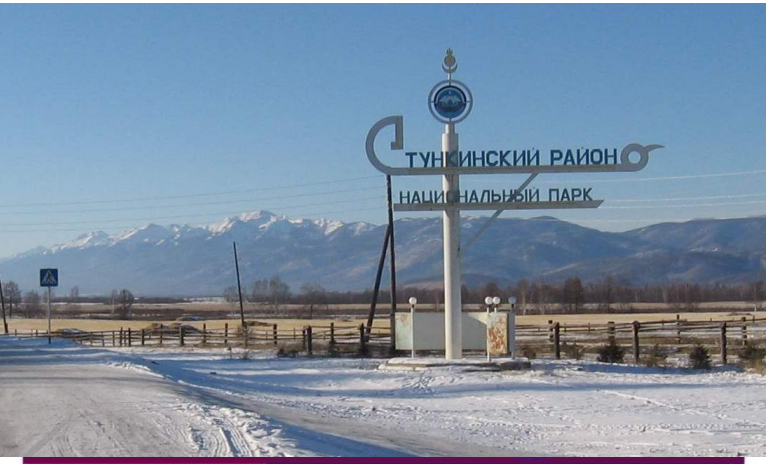


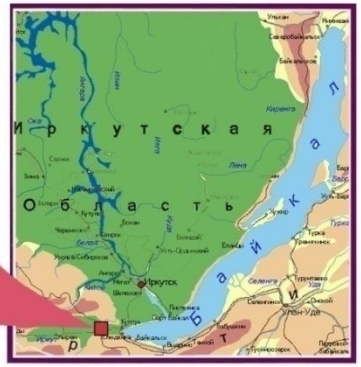
Tunka Valley

Republic Buryatia
150 km from Irkutsk
50 km from the shore of lake Baikal

EXPERIMENTS
in the Tunka Valley

Complex of Arrays in the Tunka Valley (50 km from the lake Baikal)





51° 48' 35" N
103° 04' 02" E
675 m a.s.l.

Tunka-133

Tunka-Grande

Tunka- REX

TAIGA – HiSCORE

TAIGA -IACT

Cosmic rays

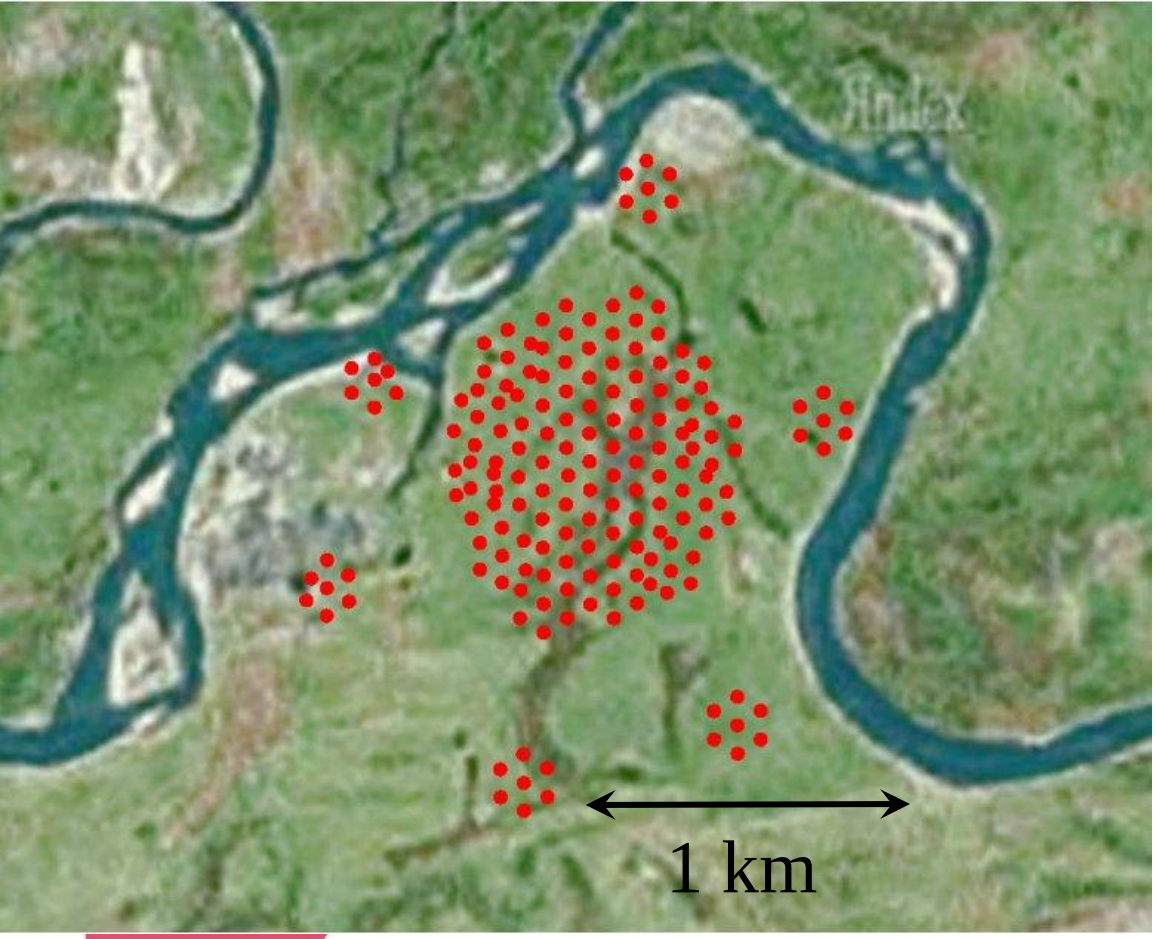
Gamma-ray astronomy

10^{18} eV

10^{15} eV

10^{13} eV

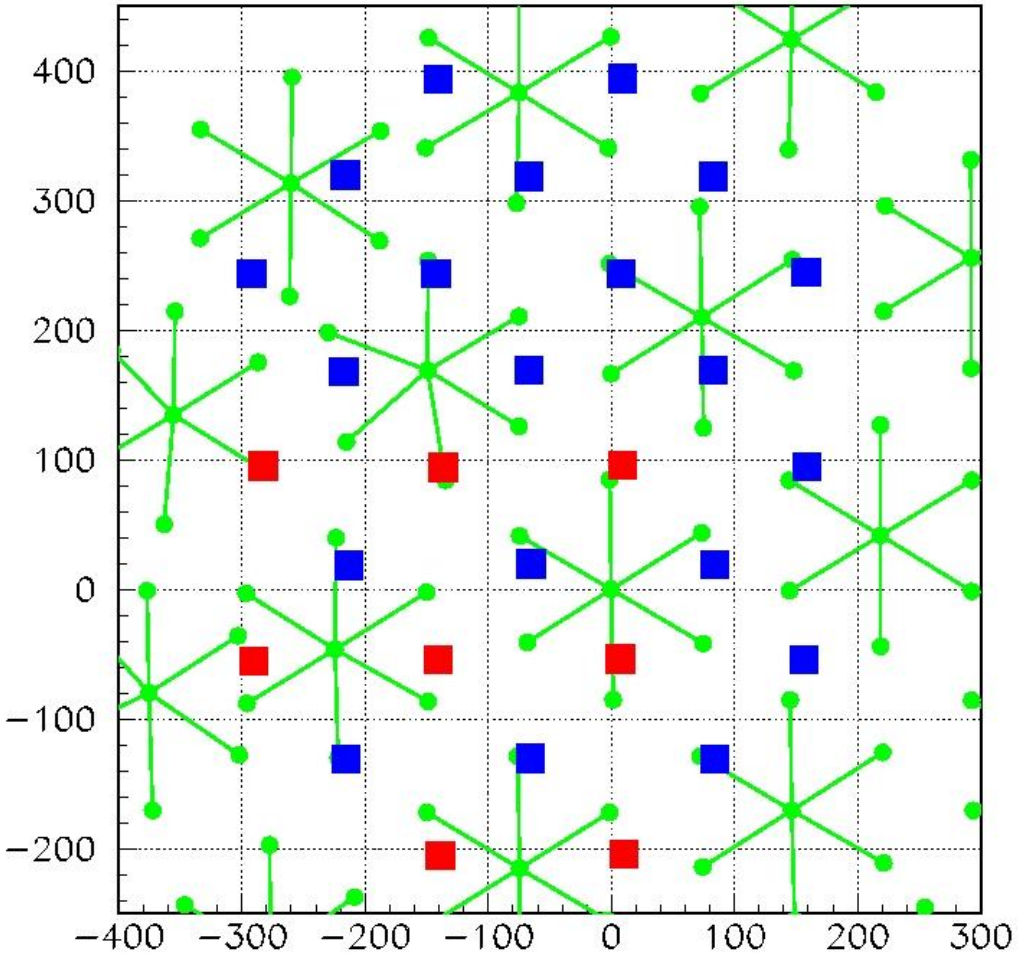
Tunka-133

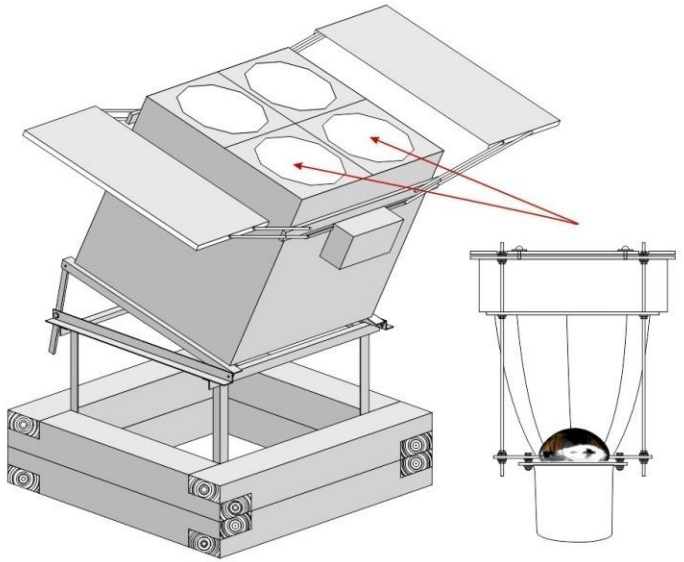


175 optical detectors
EMI 9350 and
HAMAMATSU Ø 20 cm

TAIGA-HiSCORE (2015-2016) – 28 stations

HiSCORE =
High Sensitivity Cosmic Ray Explorer





All the stations are tilted for 25° to the South for observation of Crab Nebulae

About 10 γ-events from Crab are expected during 100 h of observation.

Tunka-REX

Connection of 2 antennas to 2 free channels of FADC

63 antennas are installed.

57 antennas are situated at the area of 1 km^2 now.

Tunka-Grande

19 stations

228 detectors (0.64 m^2)
on the surface

152 detectors undeground
(muons detectors),
total area = 100 m^2

TAIGA gamma-observatory

+

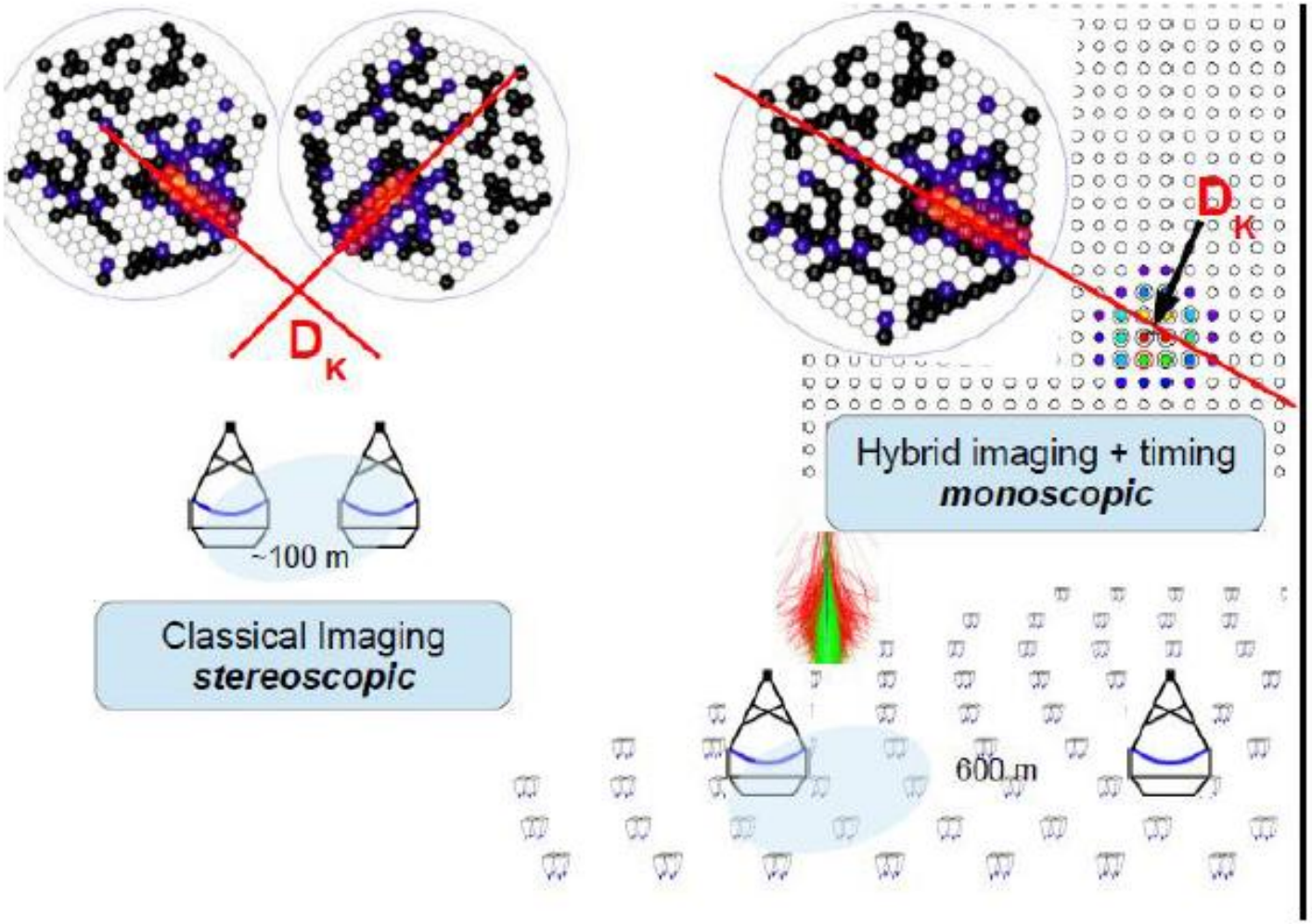
+

- 500 wide angle optical station on the 5 km^2 area, energy threshold 30 TeV

- up to 16 IACT (10 m^2 mirrors).

- Muon detectors with total area 2.0 10^3 m^2.

Hybrid approach to hadron rejection

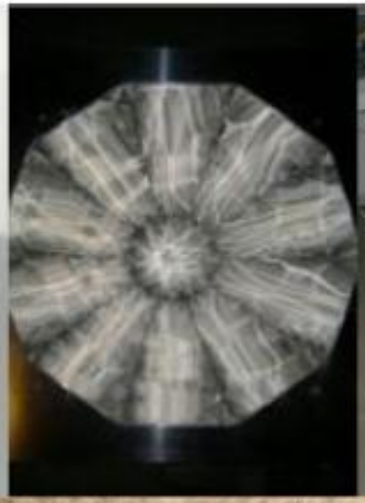


TAIGA- prototype

2015 – 2016 – 28 stations

2017 – 58 station will be inside the area of 0.6 km^2 and one IACT

All station are tilting to the South on 25 deg

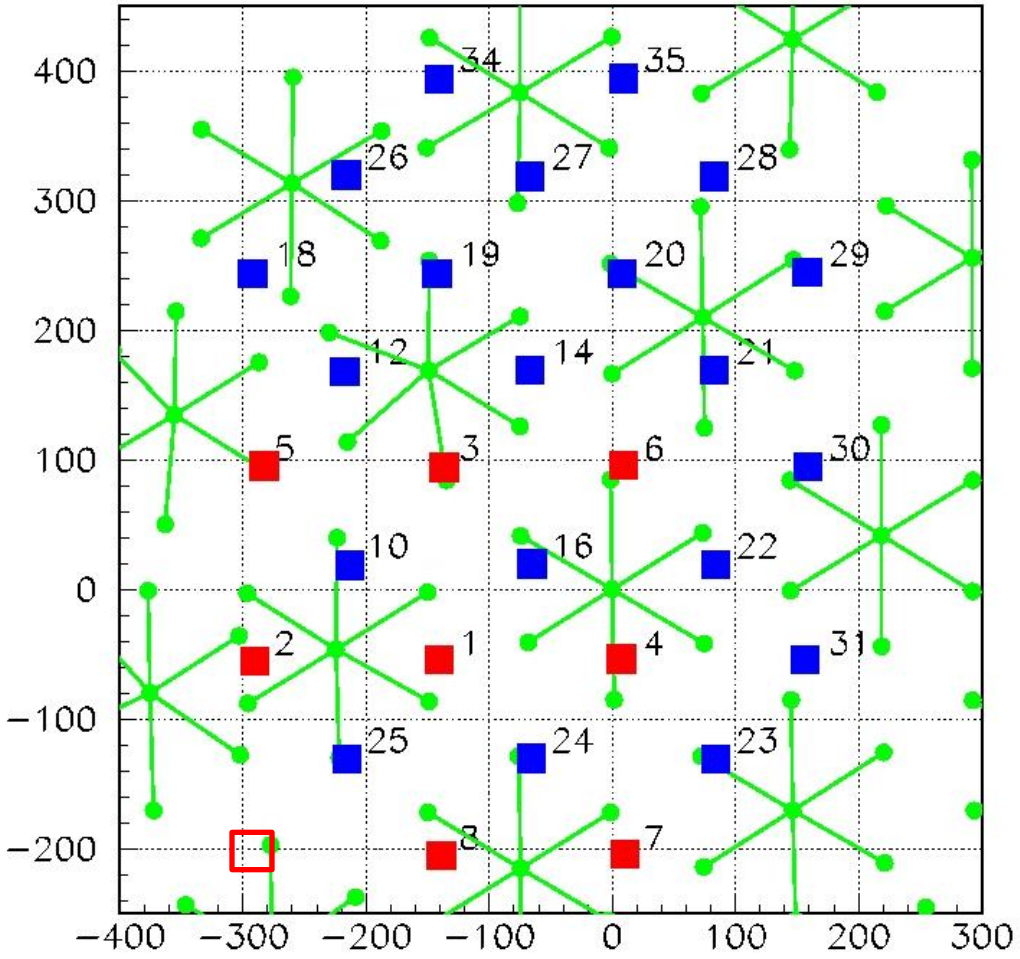


September 21, 2016

HiSCORE-28 stations layout.

HiSCORE = High Sensitivity COsmic Ray Explorer

- HiSCORE-9 – 2013-2014



One of TAIGA high-priority goals: operate 58 HiSCORE stations with the 1st IACT

13 new stations (2017)

N

17 new stations (2016)

A = 0.6 km²

58 stations

IACTs

October 2015 – February 2016 experimental data:

35 clear moonless nights – 210 h of the array operation
About $2 \cdot 10^8$ separate station triggers

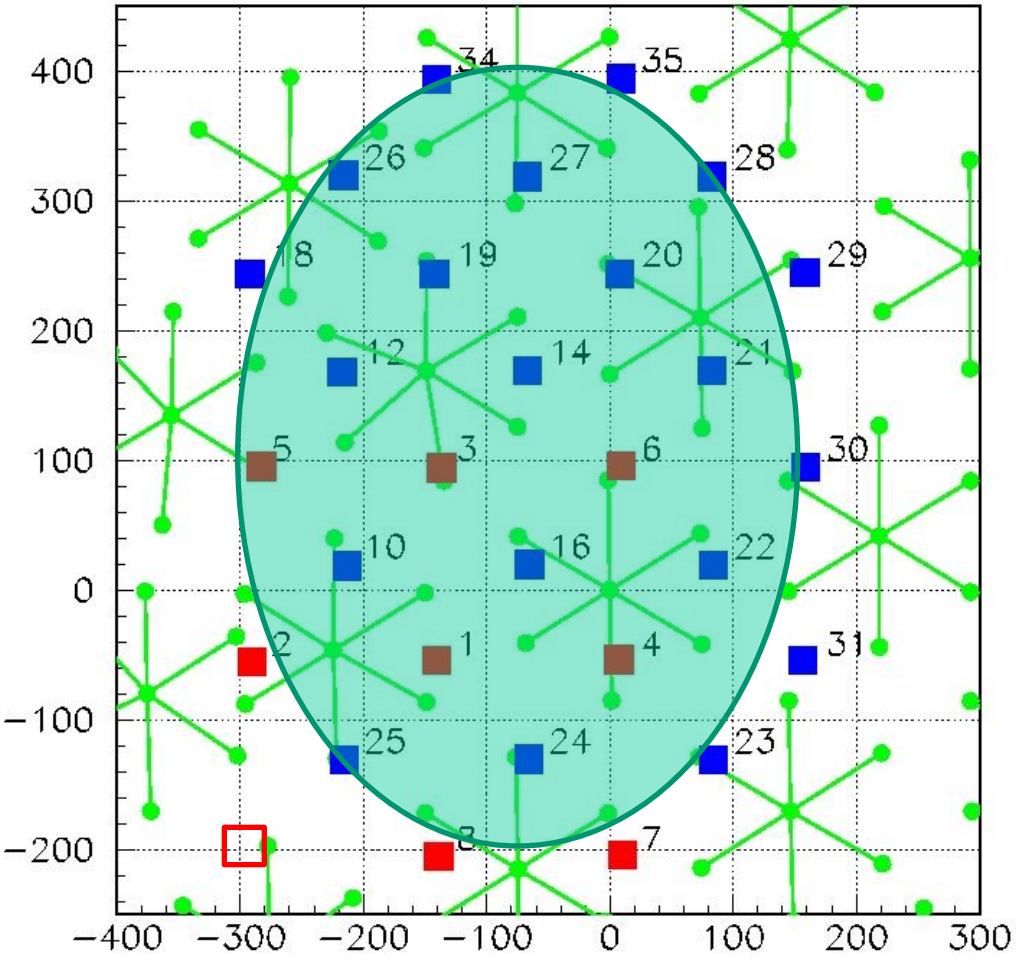
Off-line "merging" of shower events:

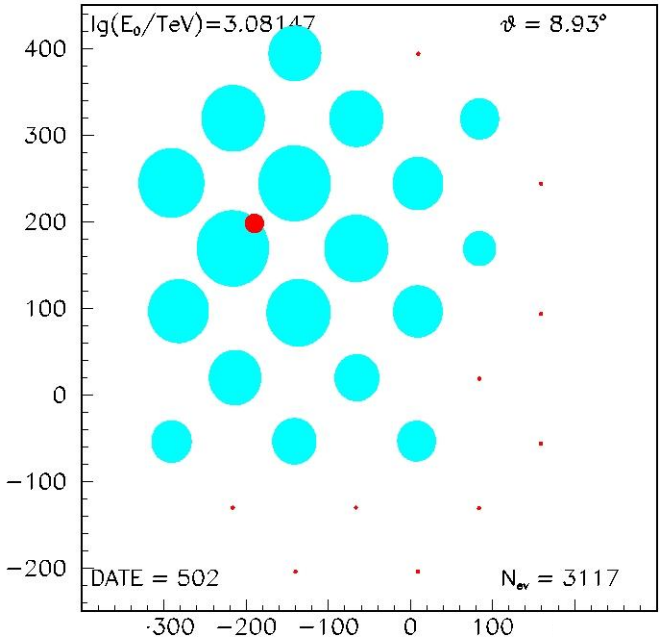
$\sim 1 \cdot 10^7$ pulse coincidences from 4 and more stations inside the time gate of 2 mcs.

The main EAS parameters reconstruction:

7845780 showers inside the ellipse with the axis 600 and 450 m and effective angle $\theta < 30^o$.

Effective Area

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ϑ = 8.93°
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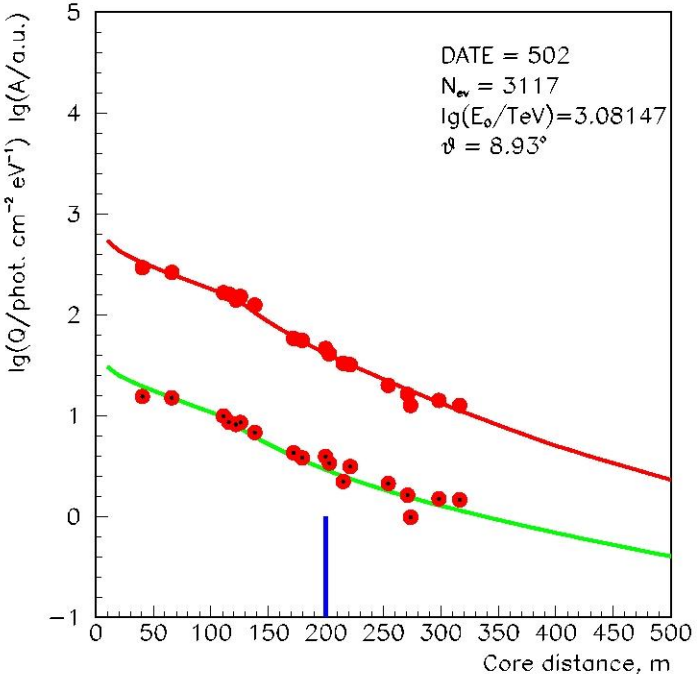
Nev = 3117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Nev = 3117
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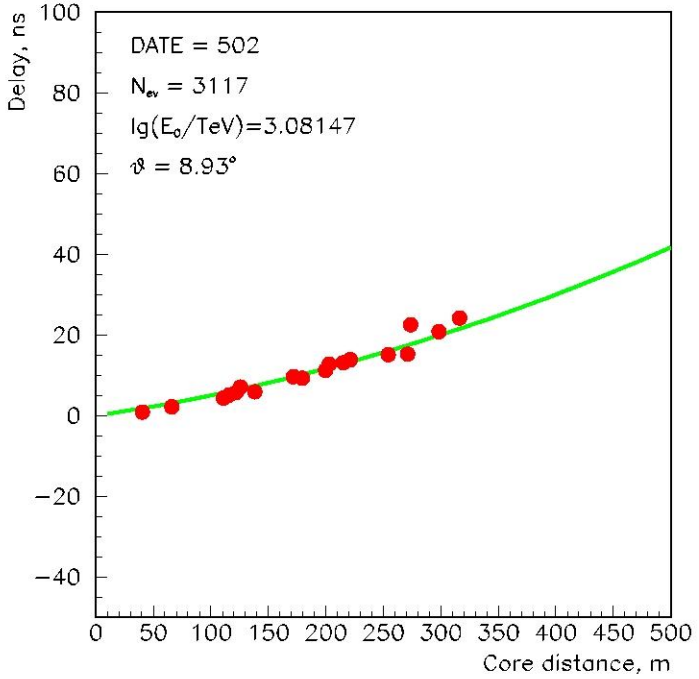
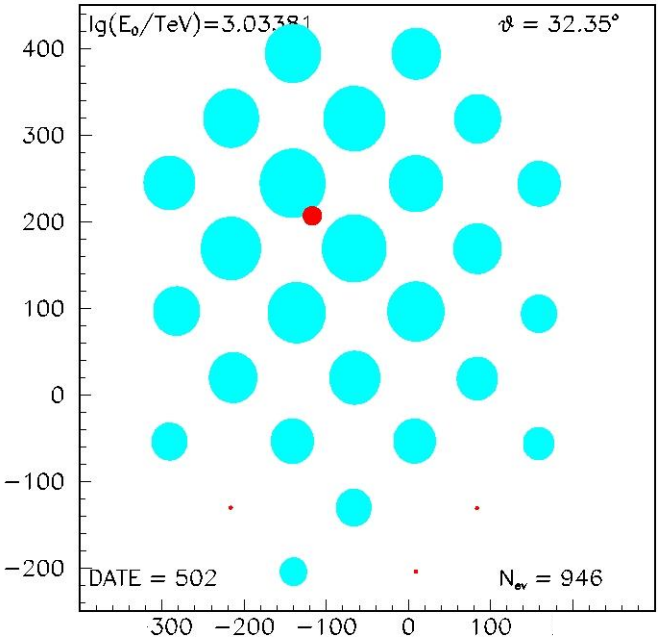
ϑ = 8.93°
lg(Q/phot. cm-2 eV-1) lg(A/a.u.)
Core distance, m


DATE = 502
Nev = 3117
lg(E0/TeV)=3.08147
ϑ = 8.93°
Delay, ns
Core distance, m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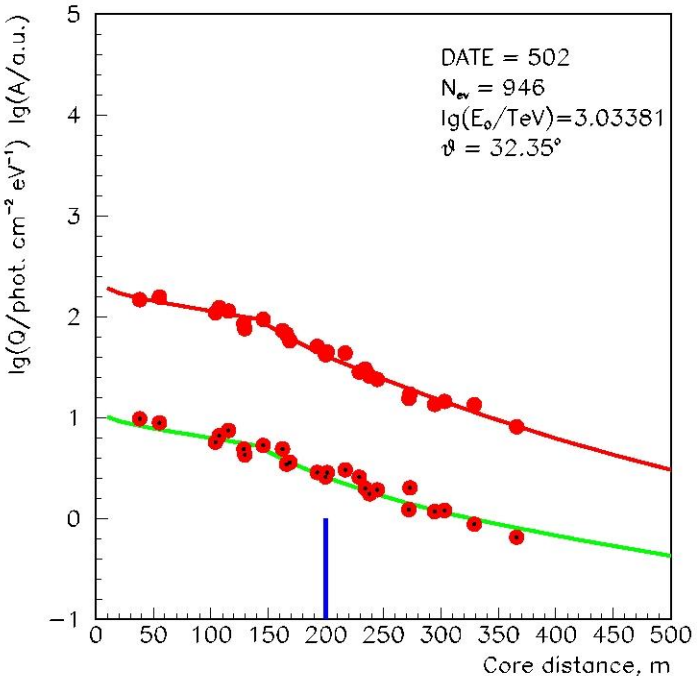
ϑ = 32.35°
DATE = 502
N_ev = 946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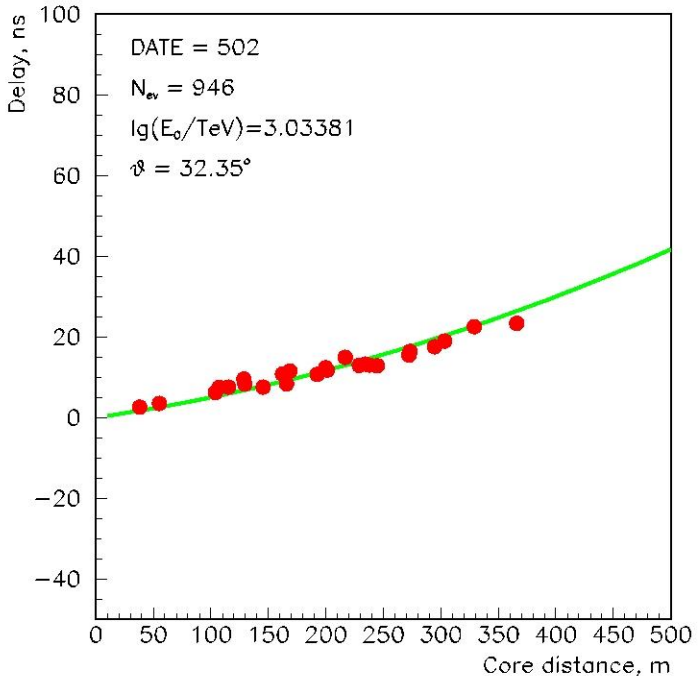
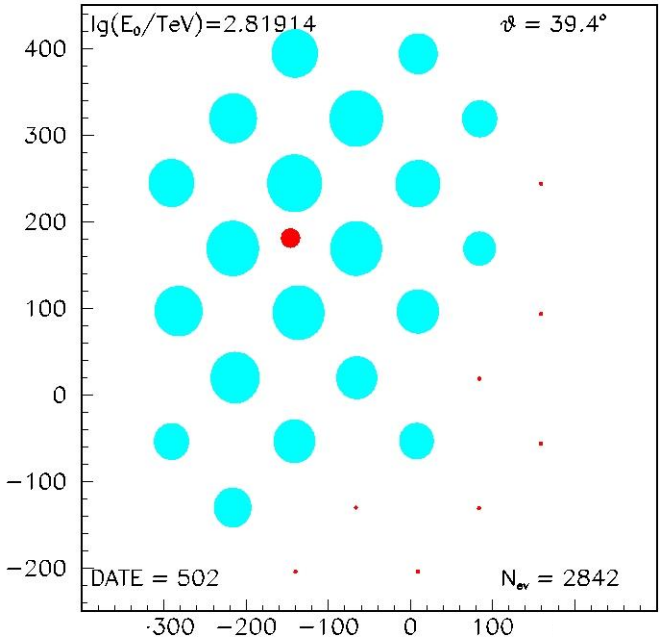
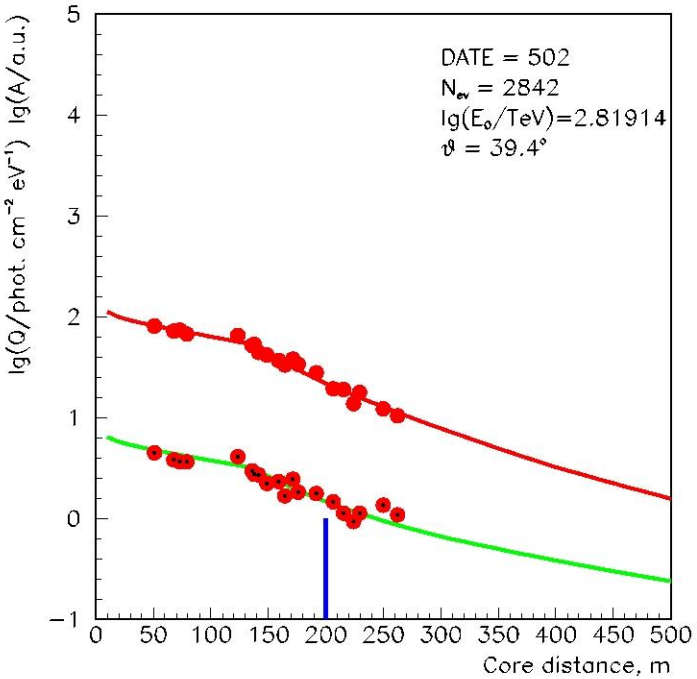
N_ev = 946
lg(E₀/TeV)=3.03381
ϑ = 32.35°
lg(Q/phot. cm⁻² eV⁻¹) lg(A/a.u.)
Core distance, m


DATE = 502
N_ev = 946
lg(E₀/TeV)=3.03381
ϑ = 32.35°
Delay, ns
Core distance, m


lg(E0/TeV)=2.81914
ϑ = 39.4°
DATE = 502
Nev = 2842
400
300
200
100
0
−100
−200
·300
−200
−100
0
100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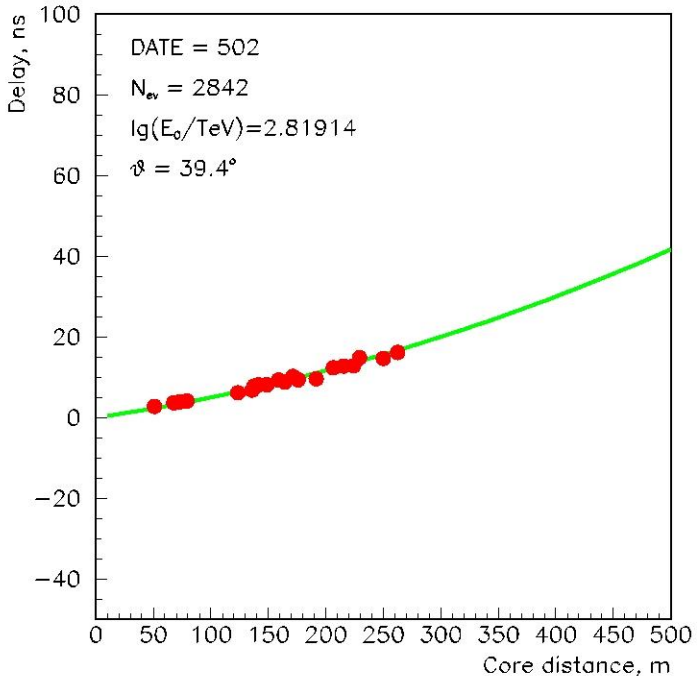
ϑ = 39.4°
lg(Q/phot. cm−2 eV−1) lg(A/a.u.)
Core distance, m
5
4
3
2
1
0
−1
0
50
100
150
200
250
300
350
400
450
500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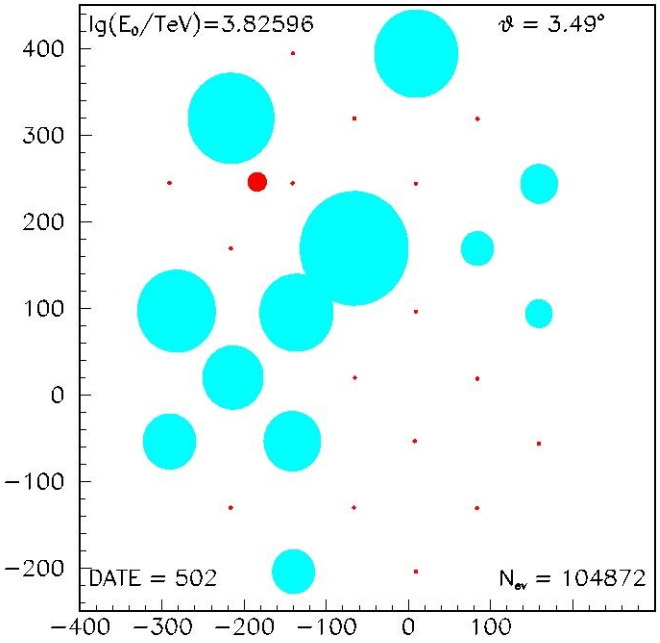
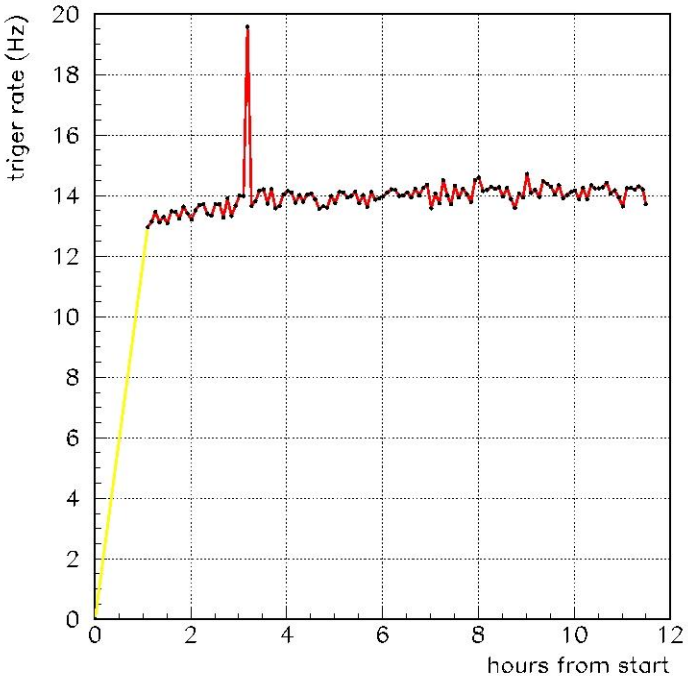
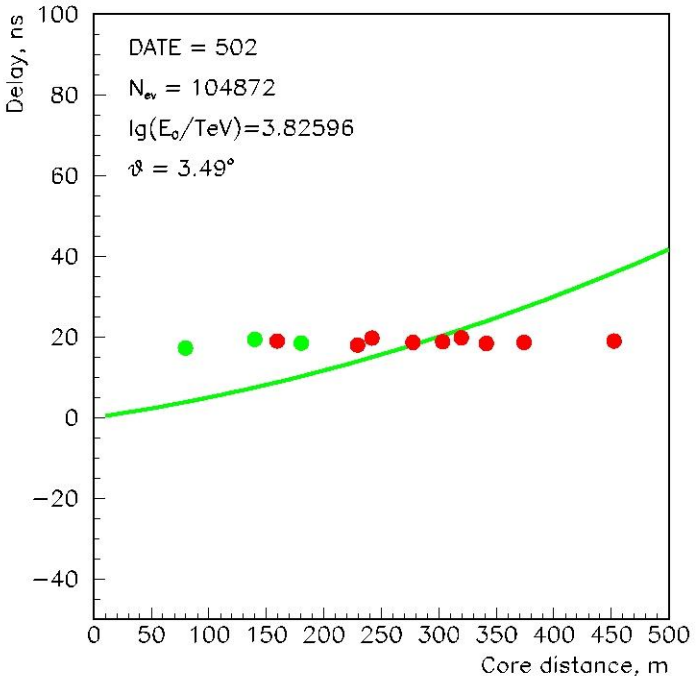
Nev = 2842
lg(E0/TeV)=2.81914
ϑ = 39.4°
Delay, ns
Core distance, m
100
80
60
40
20
0
−20
−40
0
50
100
150
200
250
300
350
400
450
500

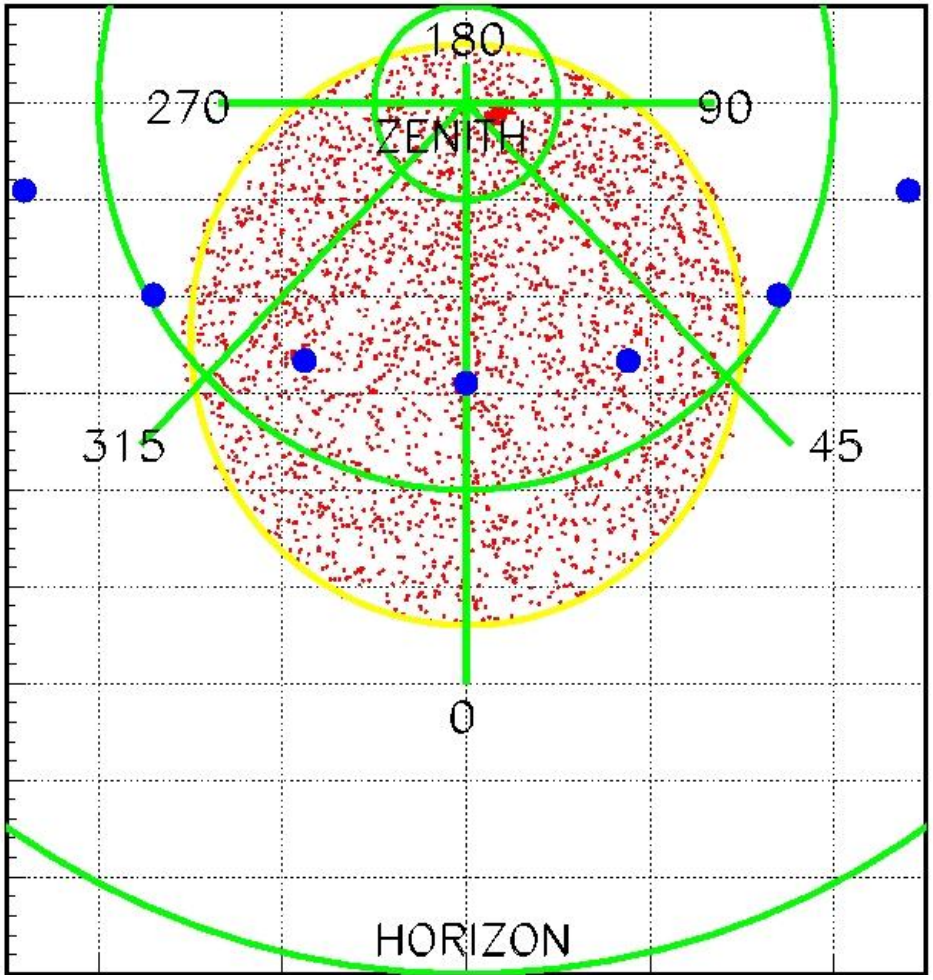
Unusual events – **International Space Station**







Array field of view with stations tilted to 25º to the South.

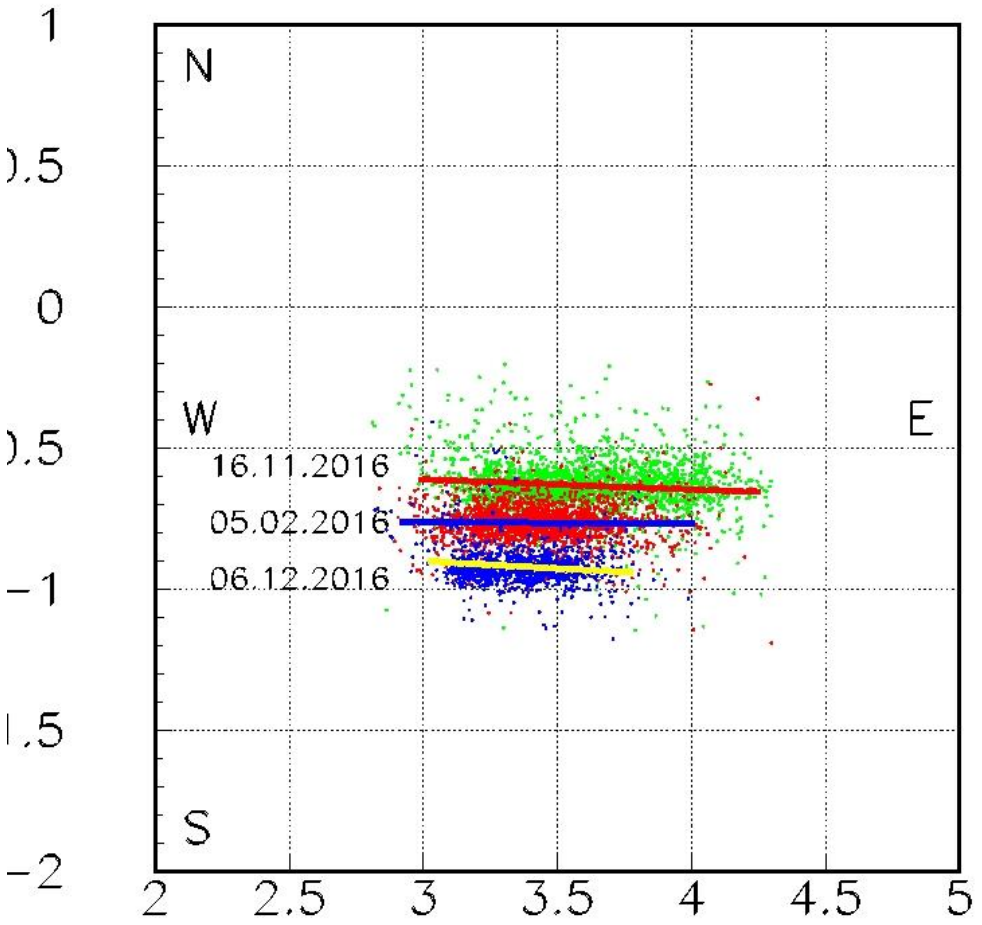


- - Crab trace in the Array aperture (interval– 1 hr).

Watching of International Space Station

ISS traces in the sky during ~ 1 s

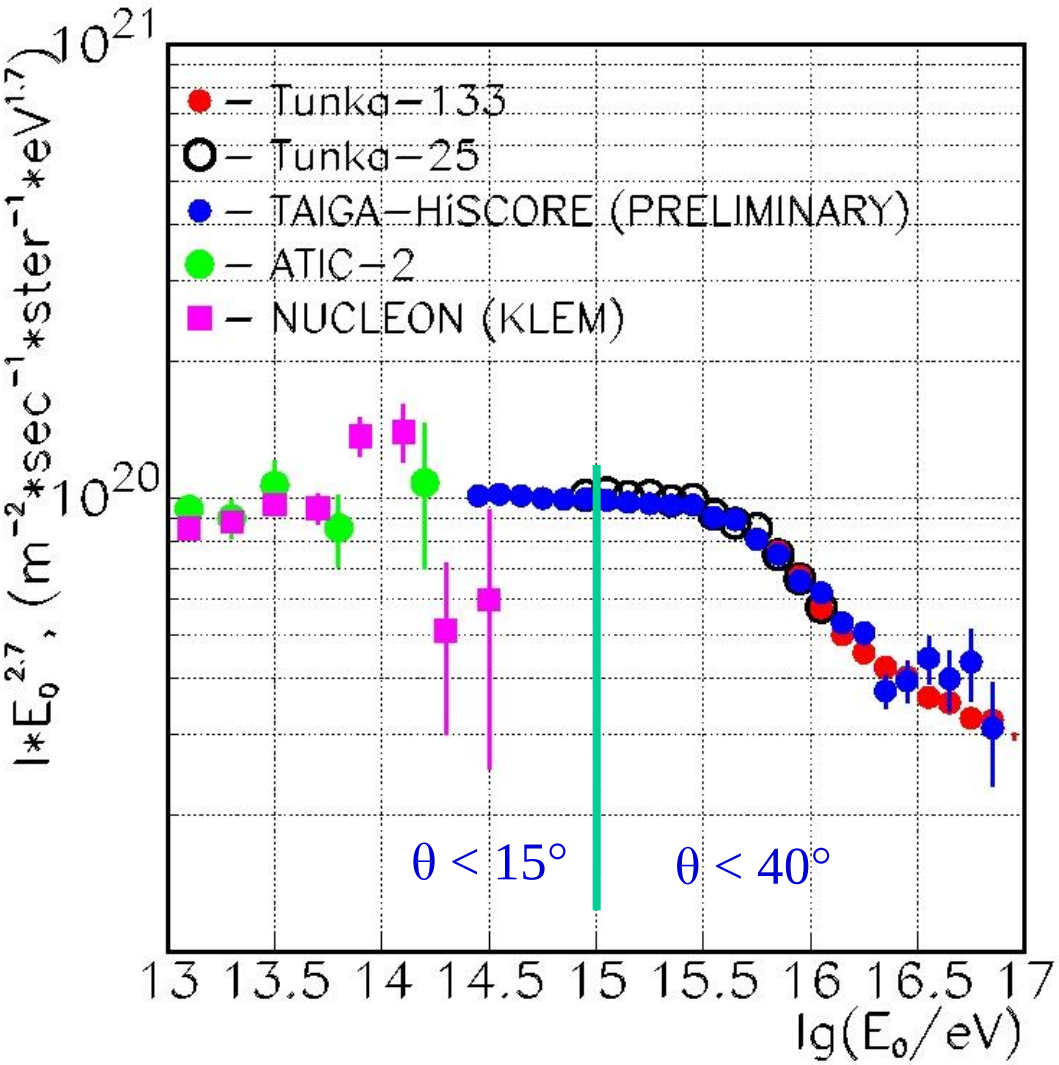
3º x 3º sky view:



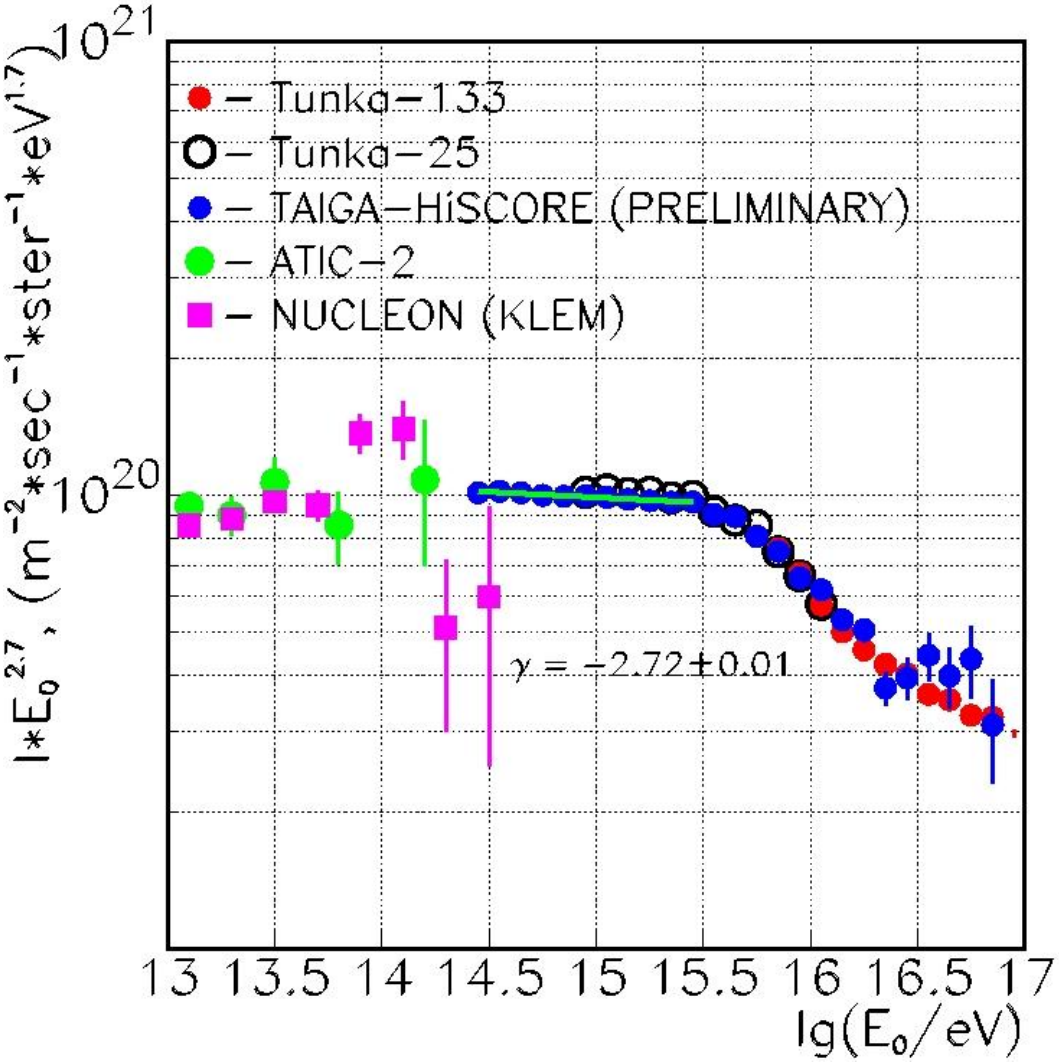
Energy spectrum
PRELIMINARY

1. $\theta < 15°$
$E_0 \leq 10^{15}$ eV – 1300000 EAS
Among them 450000 with $E_0 > 2.5 \cdot 10^{14}$ eV

2. $\theta < 40°$
162500 EAS with $E_0 \geq 10^{15}$ eV

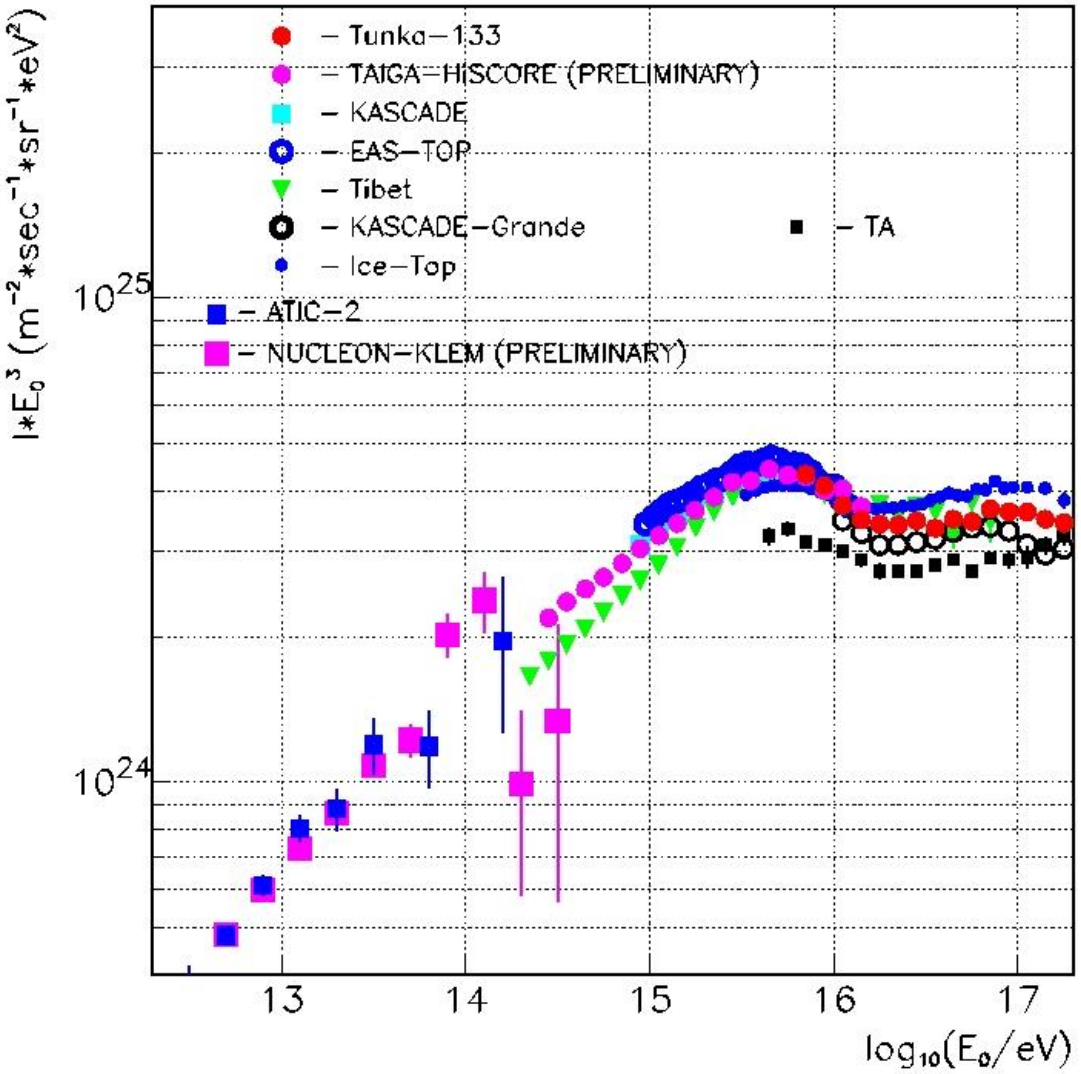


Energy spectrum power law fitting



Energy spectra comparison

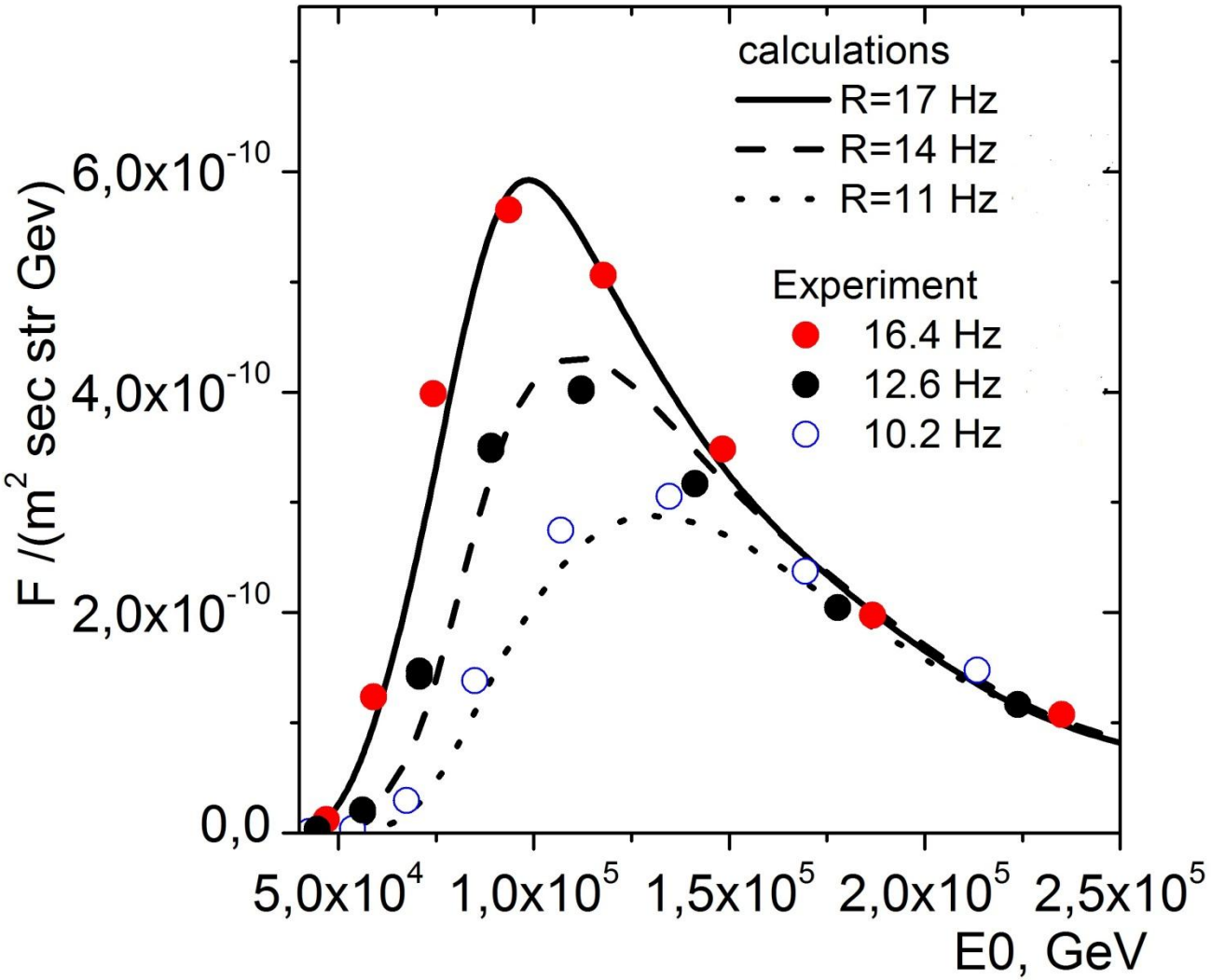
PRELIMINARY



Attempt of Crab observation

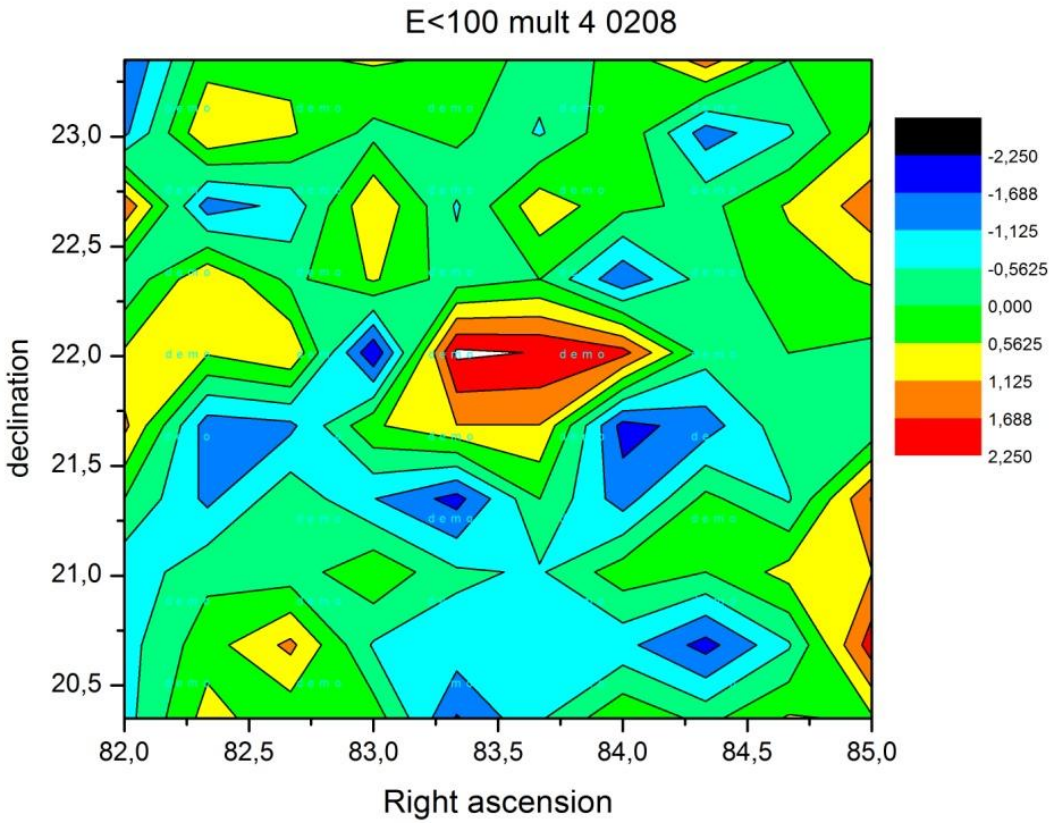
Energy distribution at the threshold range.

These events are used for Crab events search.



Example of the map Ra-Dec 3×3 degrees with the sell 0.3 × 0.3 degrees for events with E<100 TeV. (Crab: Ra =83.65, Dec=22.01)

E<100 TeV
Excess ~28 events (2.6 σ)



TAIGA-IACT

D = 4.32m F = 4.75m

34 mirrors of 60 cm diameters

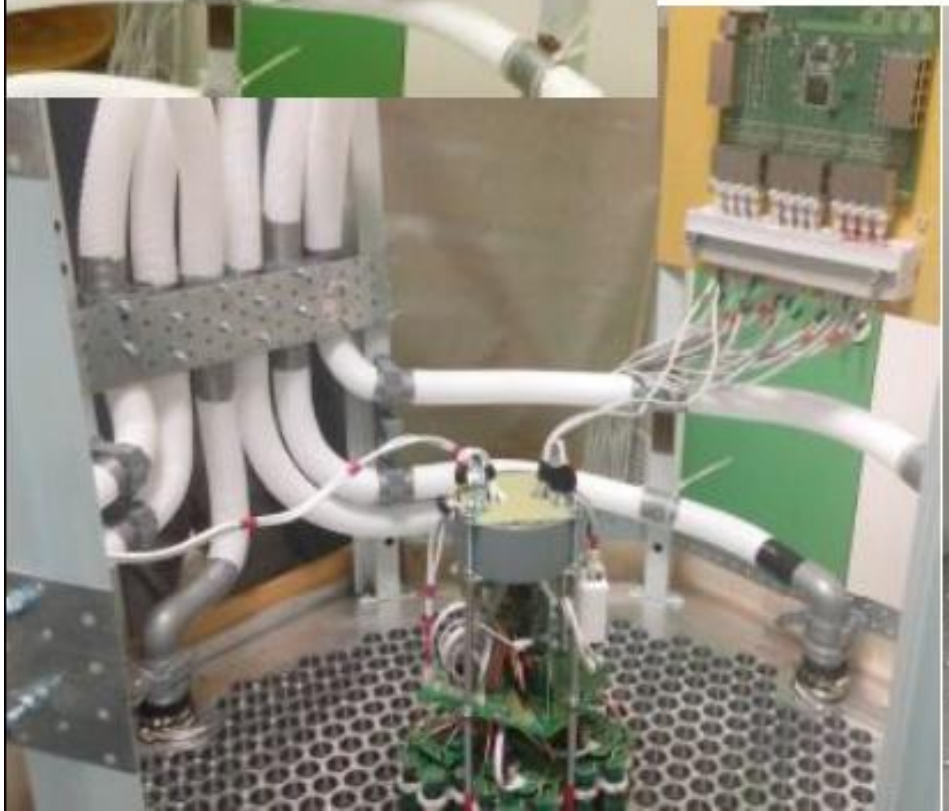
Camera : 547 PMTs (XP 1911) with 15 mm useful diameter of photocathode
Winston cone: 30 mm input size, 15 output size
1 single pixel = 0.36 deg
full angular size 9.6x9.6 deg

Energy threshold ~1.5 TeV

Cost : 300 Keur

Commission of the first telescope – October 2016

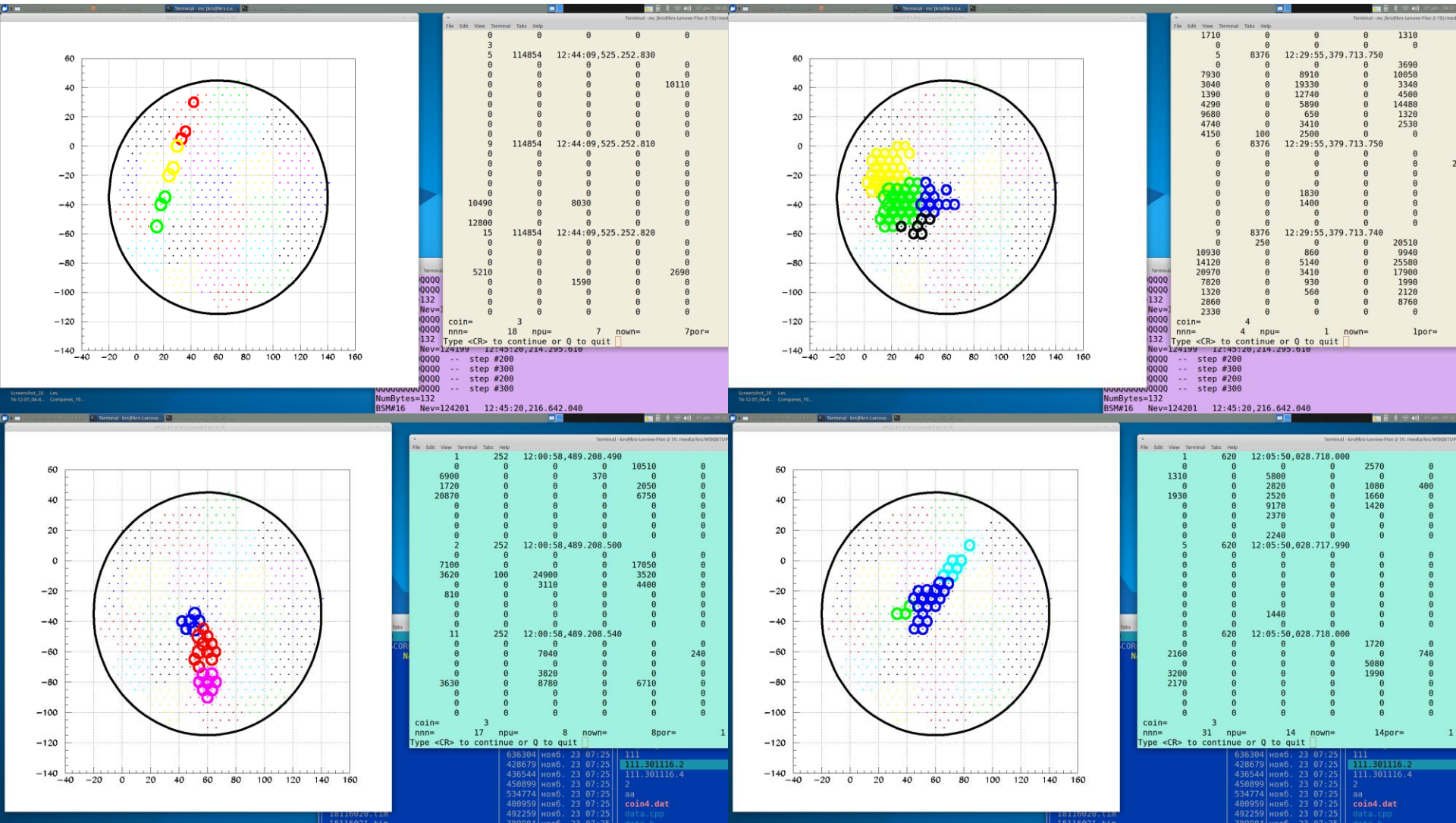
07.09.2016
IACT camera assembling



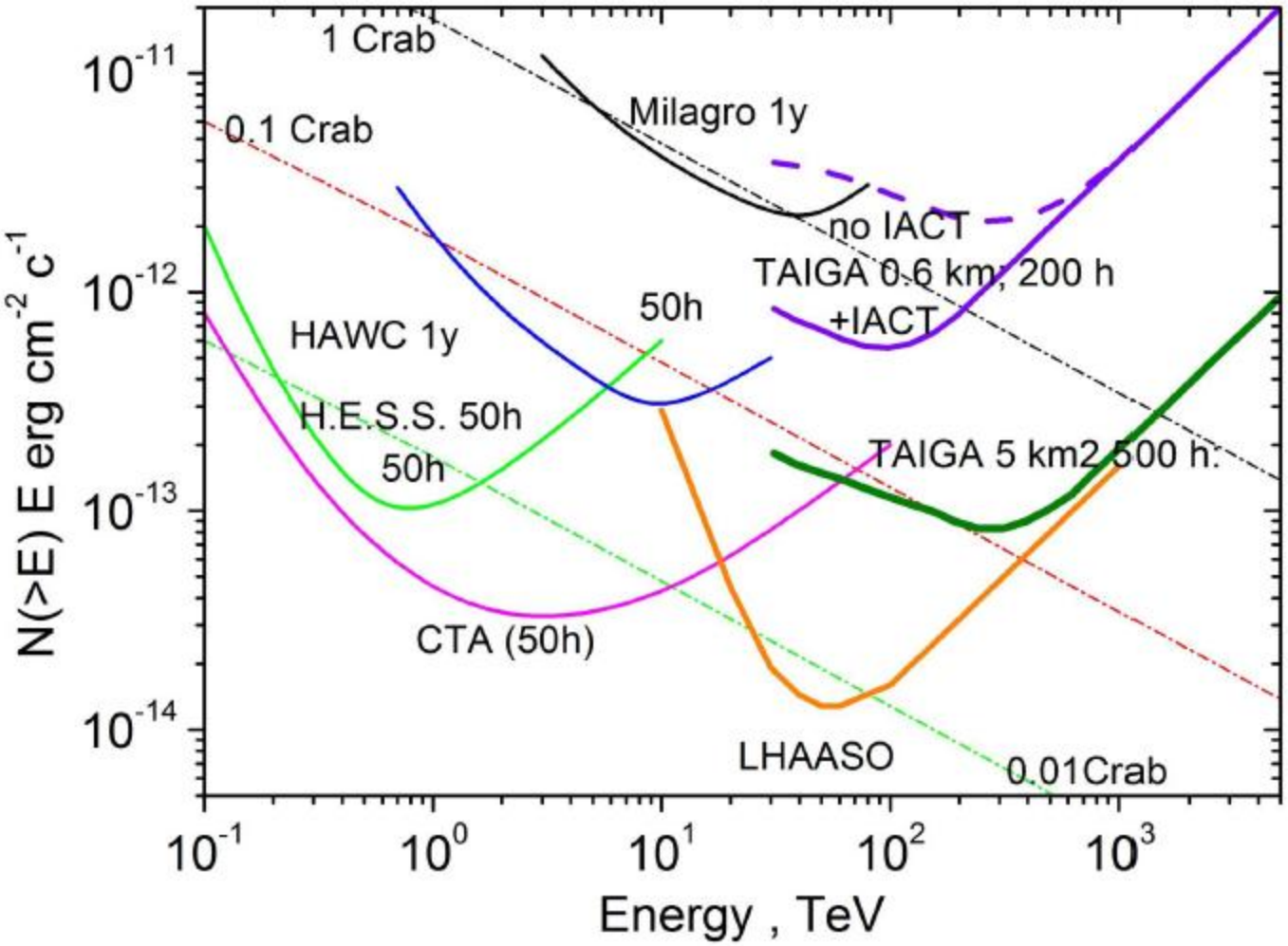
TAIGA- prototype


2016 11 25 13 34

TAIGA-IACT the very first events during the night of 30.11- 01.12 (2016):

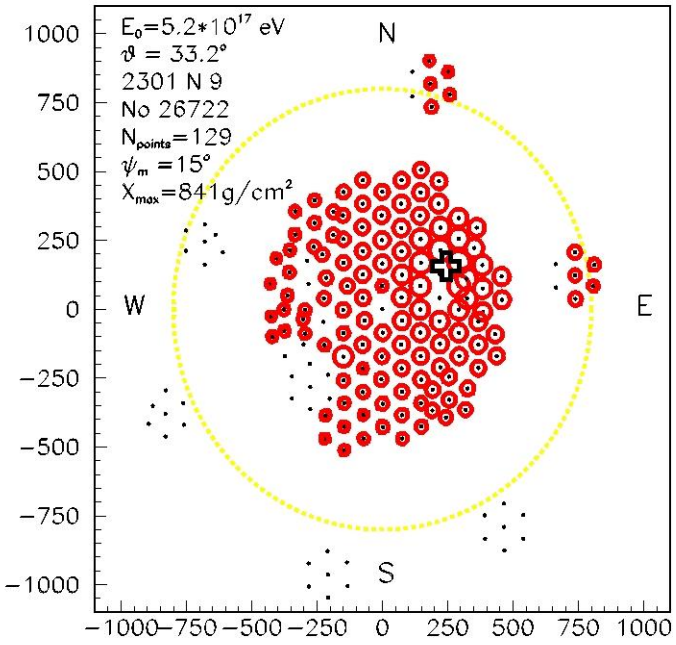


TAIGA sensitivity (without muon detectors)



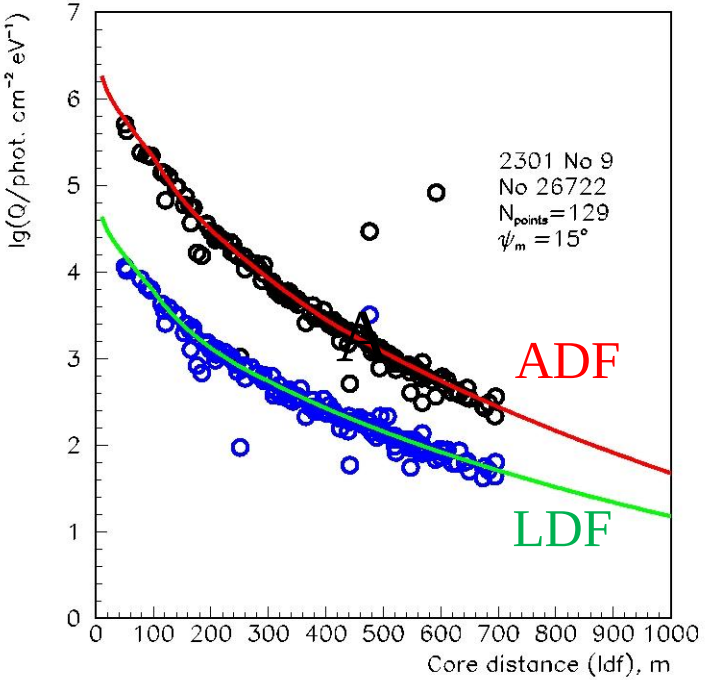
Tunka-133 results

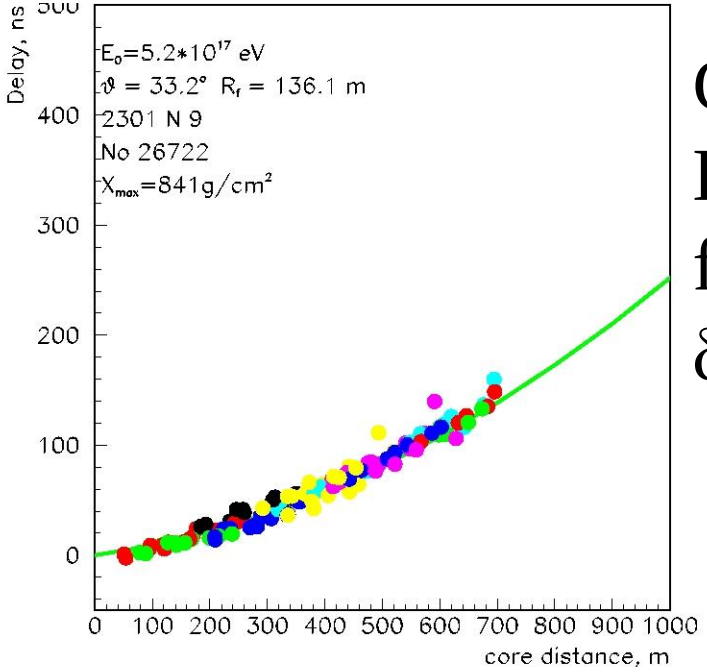
Single event example



Plan

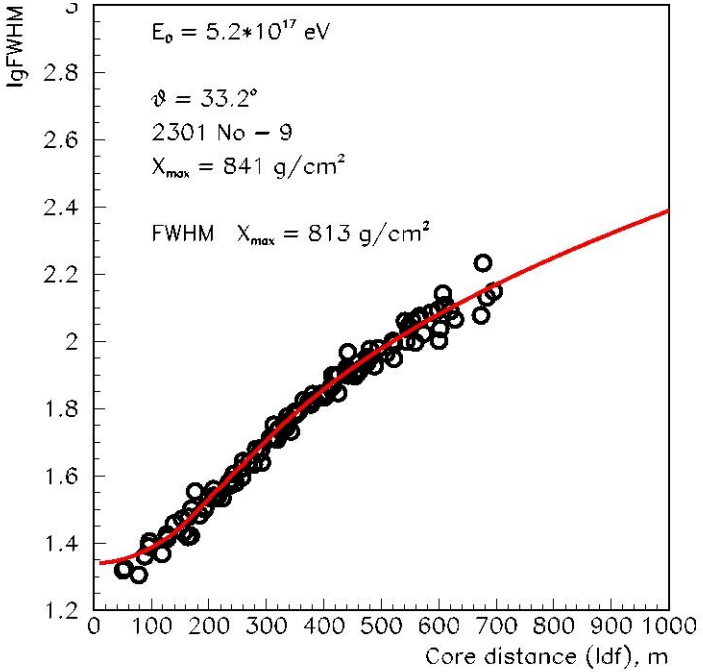
ADF and LDF



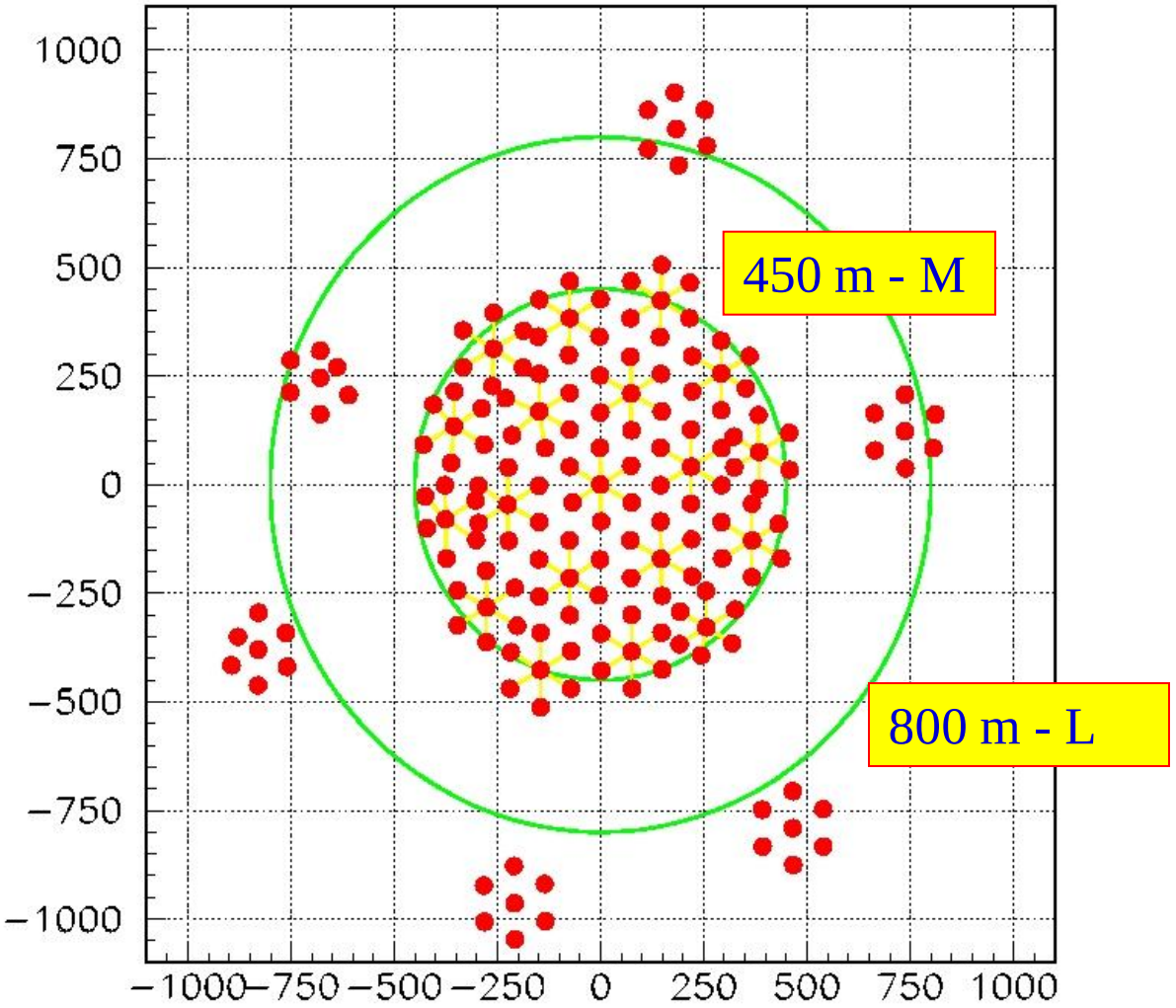


Curve EAS time front provides $\delta\theta<0.5°$

τ_{eff} vs. core distance



Effective areas



Tunka-133 Experimental Data

6 winter seasons: 2009-2010 , 2010-2011, 2011-2012, 2012-2013, 2013-2014, 2015-2016
303 clear moonless nights
~ 1850 h of observation with a trigger frequency ~ 2 Hz
~ 12 000 000 triggers
The cuts for the energy spectrum used:
$\theta \leq 45°$

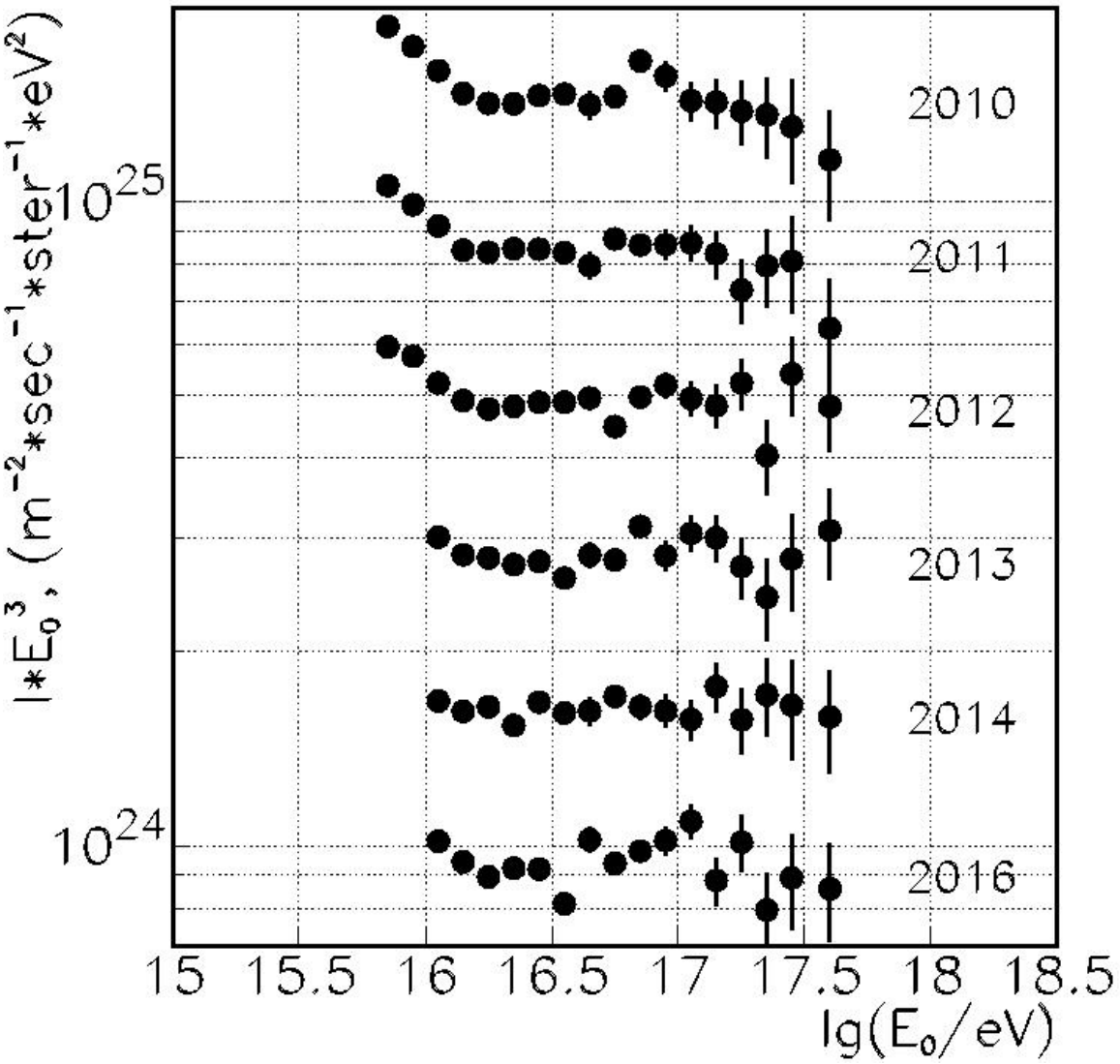
M: $R_{center} < 450$ m:

~ 320 000 events with $E_0 > 6 \cdot 10^{15}$ eV – 100% efficiency
~ 117 000 events $E_0 > 10^{16}$ eV
~ 4700 events $E_0 > 5 \cdot 10^{16}$ eV
~ 1150 events $E_0 > 10^{17}$ eV

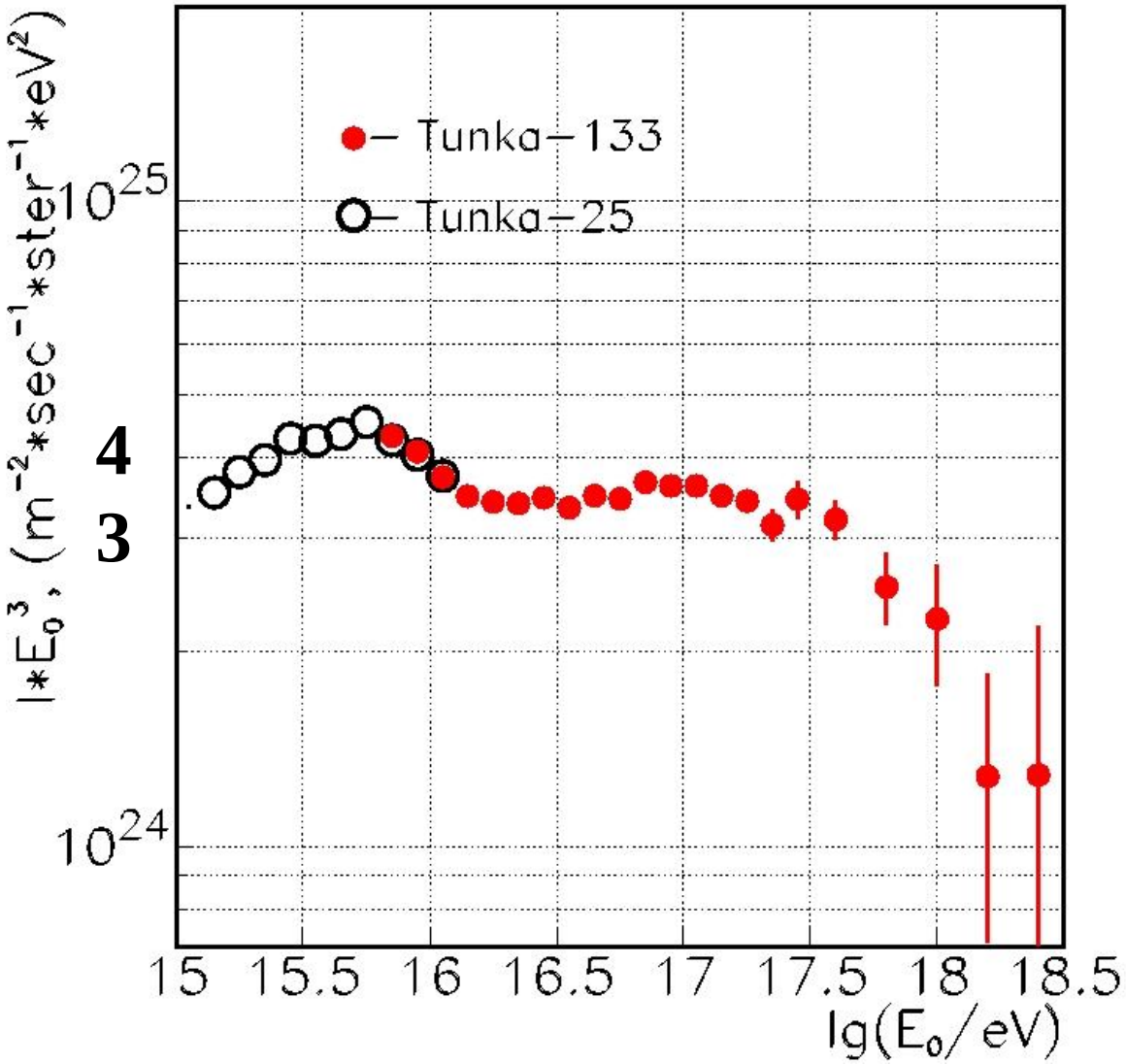
L: $R_{center} < 800$ m:

~ 14600 events $E_0 > 5 \cdot 10^{16}$ eV
~ 3581 events $E_0 > 10^{17}$ eV

Single year spectra



Six years summarized spectrum

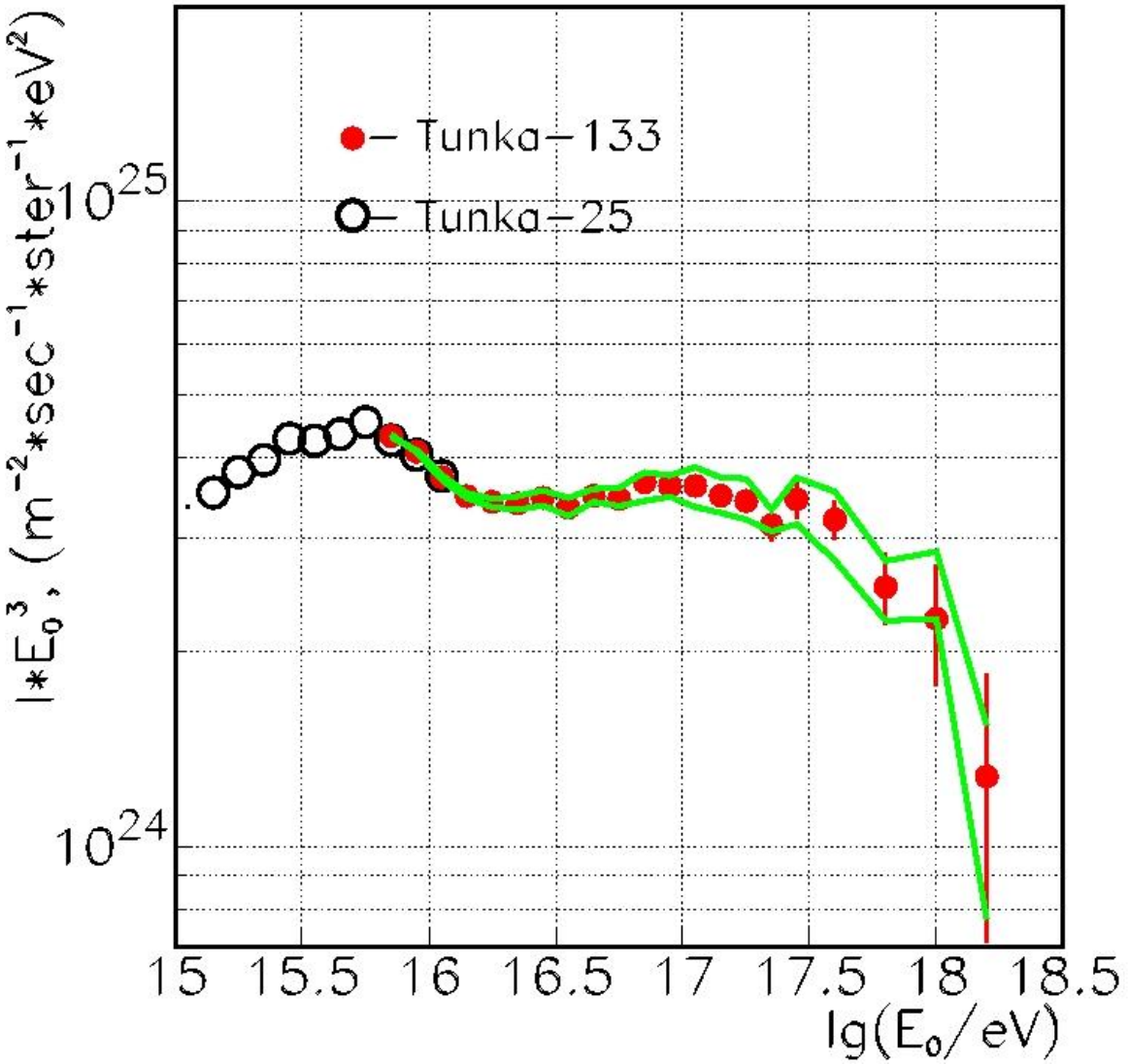


Spectrum systematic uncertainty

$$E_0 = C \cdot Q_{200}^{g}$$

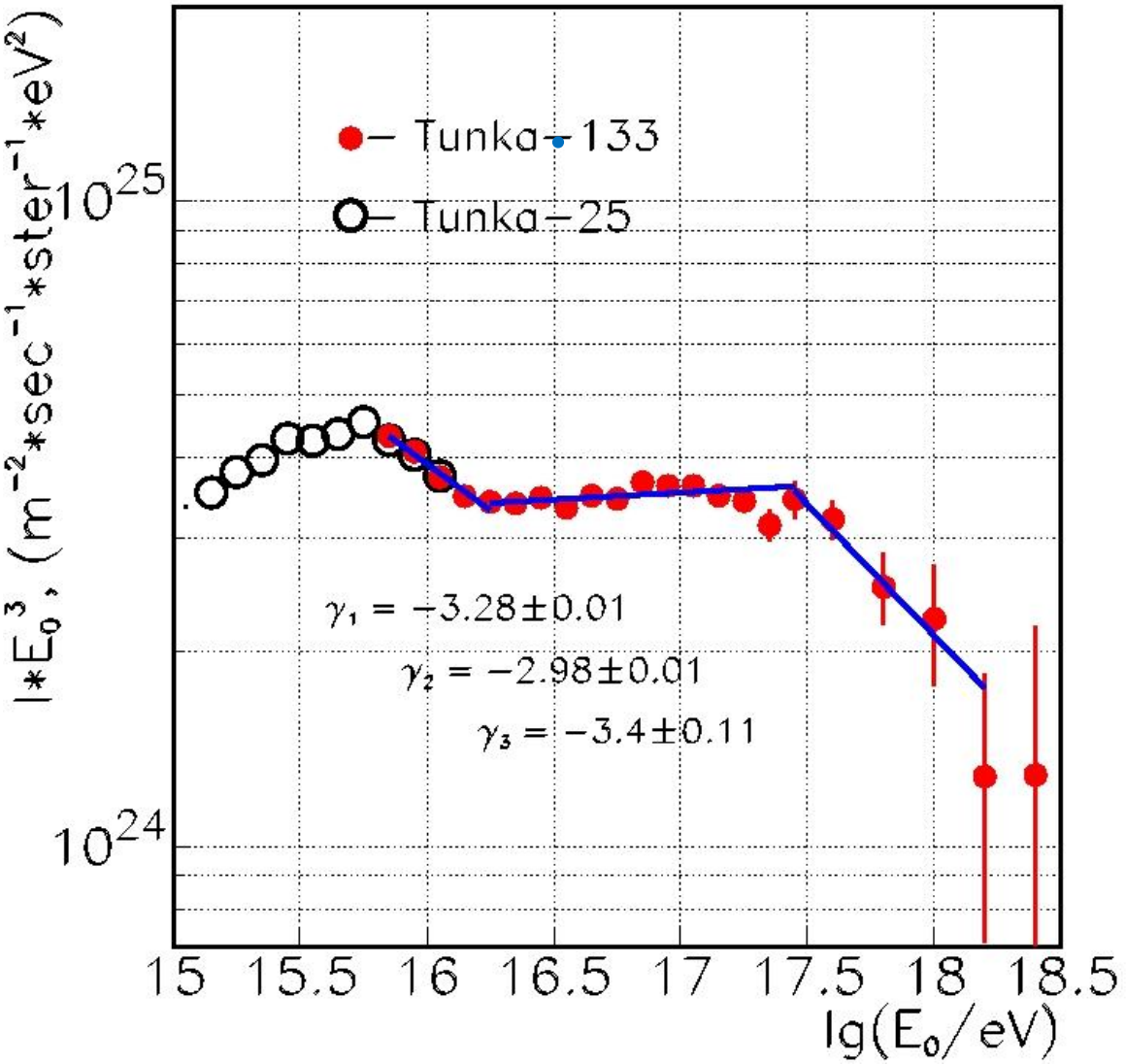
$$g = 0.94 \pm 0.01$$

Uncertainty of g is due to unknown exact mass composition.

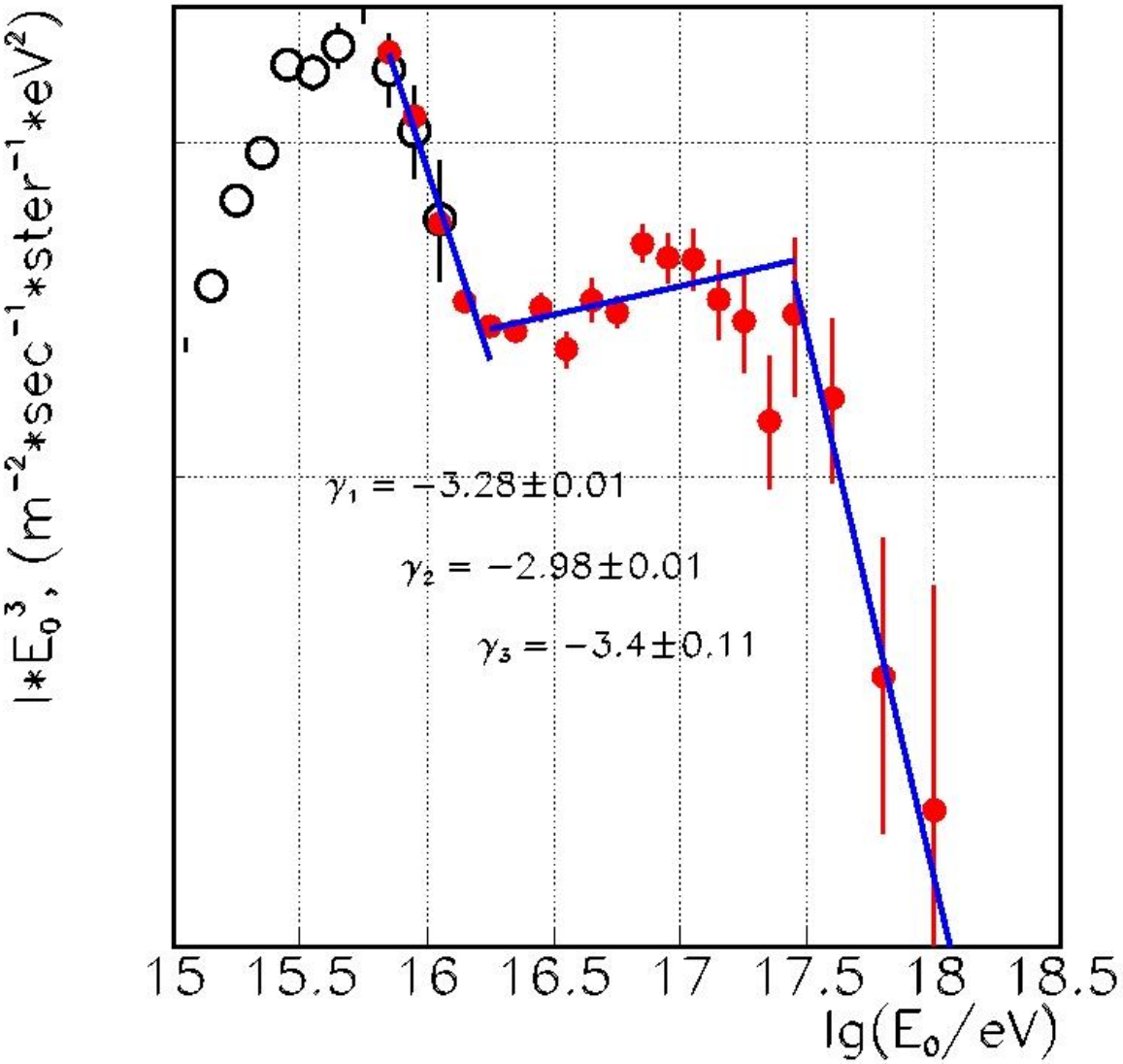


Energy spectrum: power law fitting

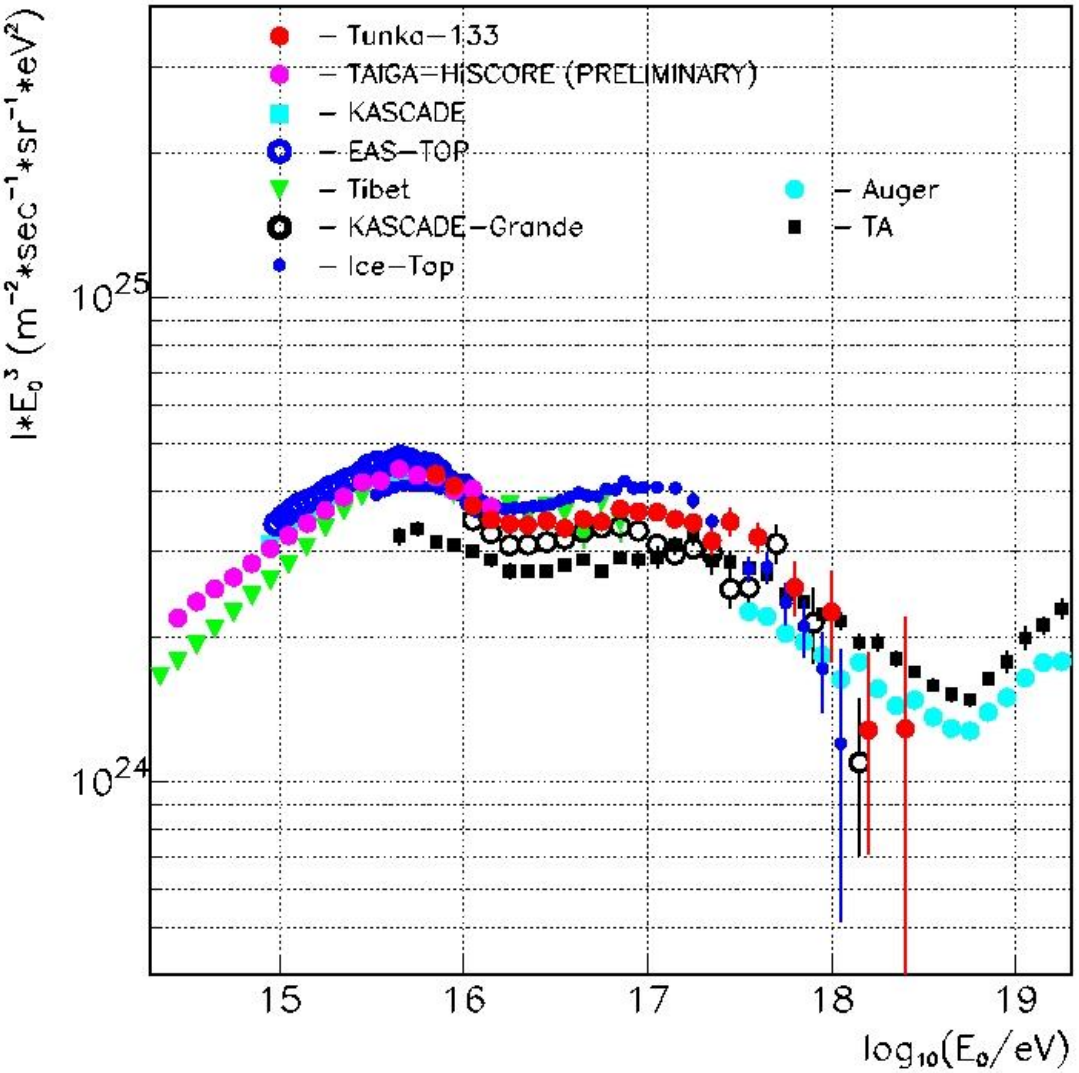
Probability of power law fitting is very small:
0.02 from χ^2 analysis.



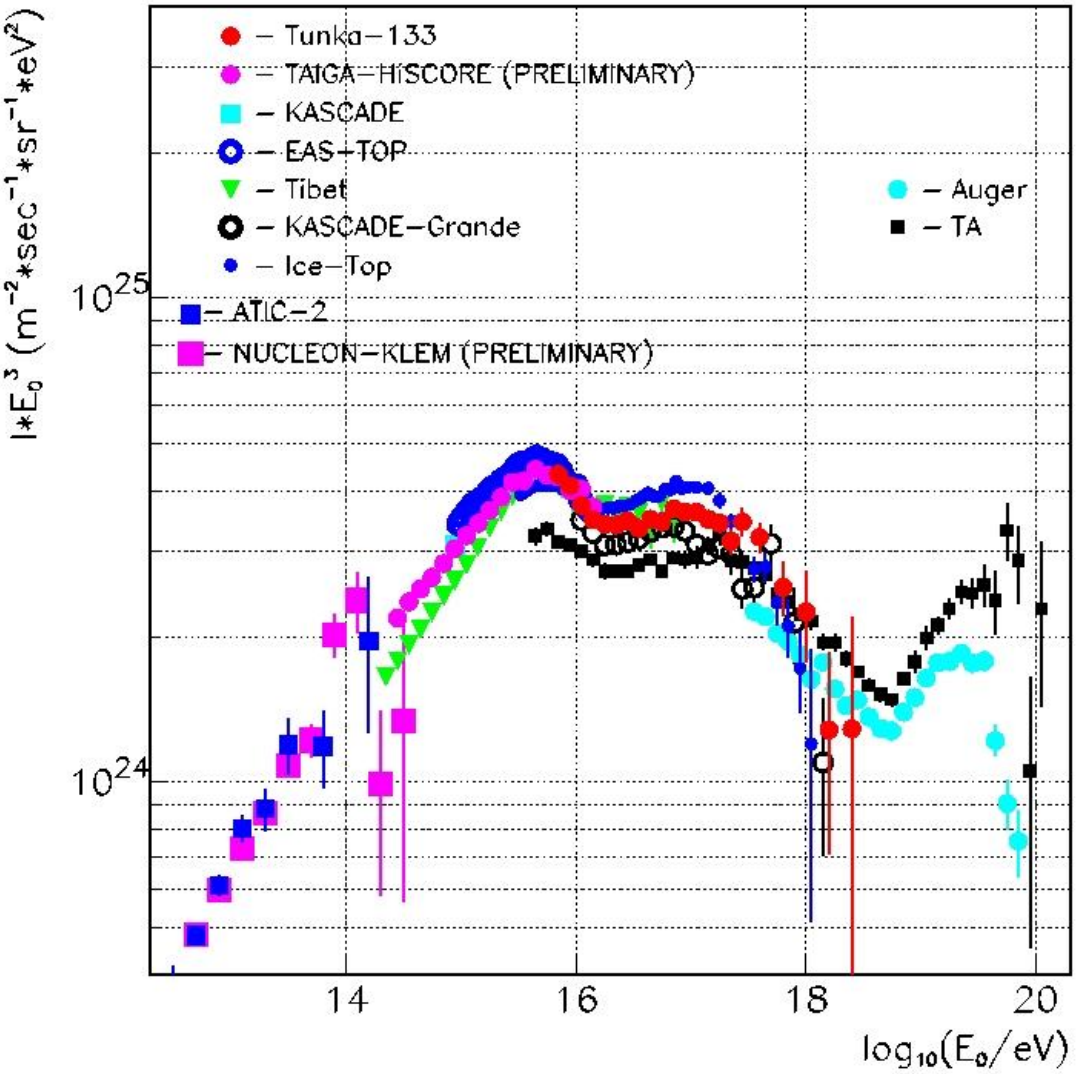
Structure of the “second” knee



Energy spectrum: comparison with some other experiments



Energy Spectrum: Comparison of Experiments in Wide Energy Range



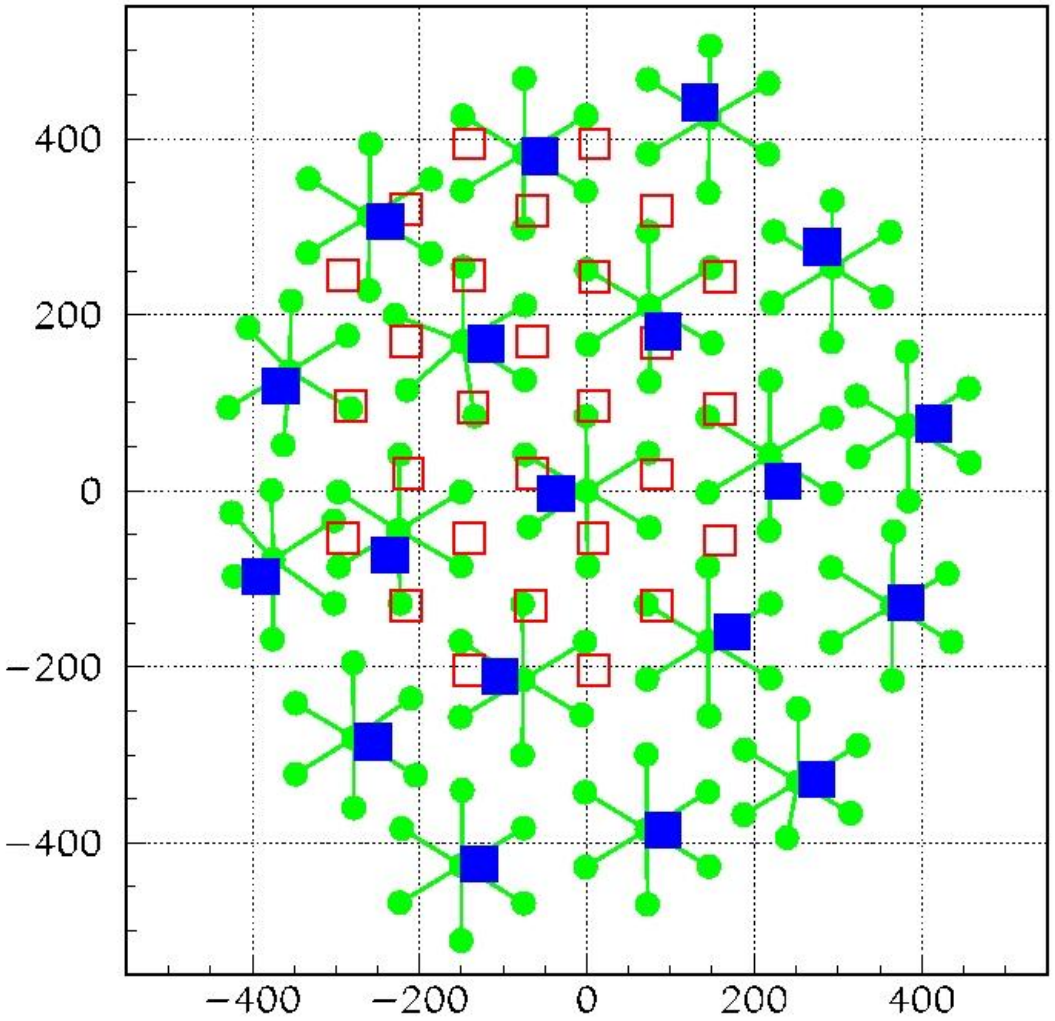
Tunka-Grande

Scintillation detectors for EAS
electron and muon measurements.

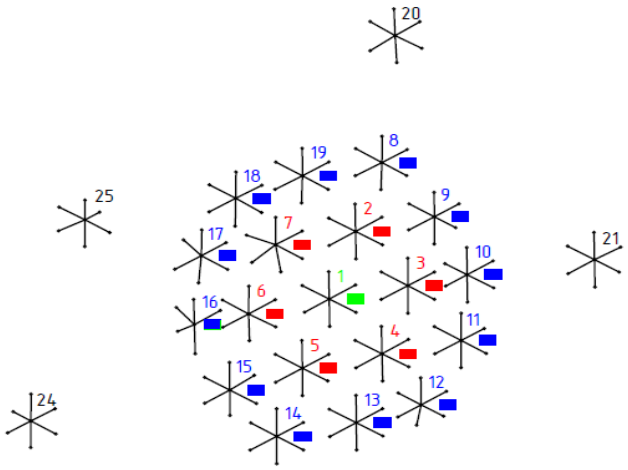
(Former EAS-TOP and KASCADE-Grande detectors)

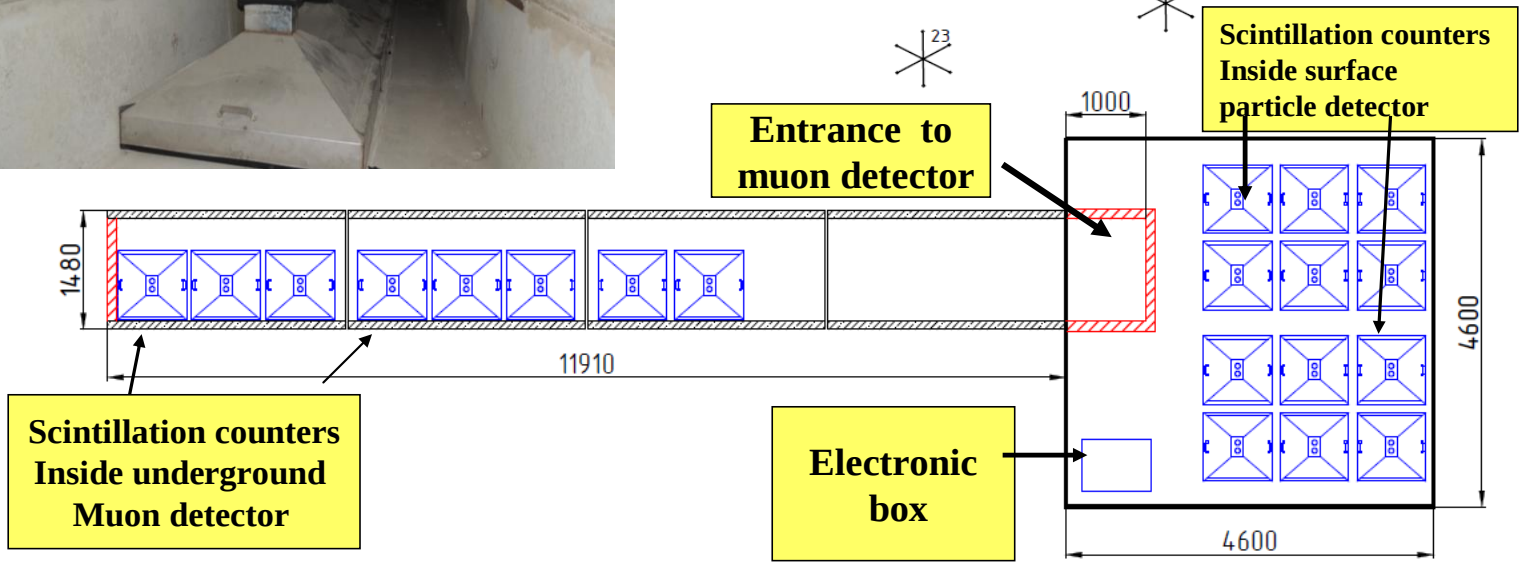
+ Tunka-REX = Complex Array for the Very High Energy CR spectrum and mass composition analysis

Tunka-Grande stations layout



Tunka-Grande: Surface and underground detectors of EAS electrons and muons



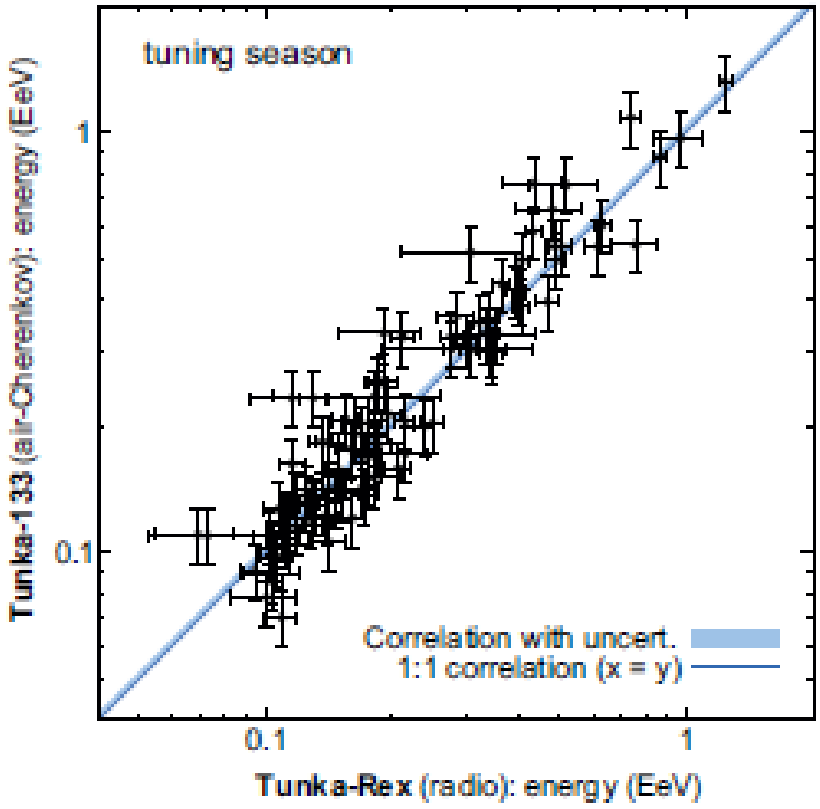


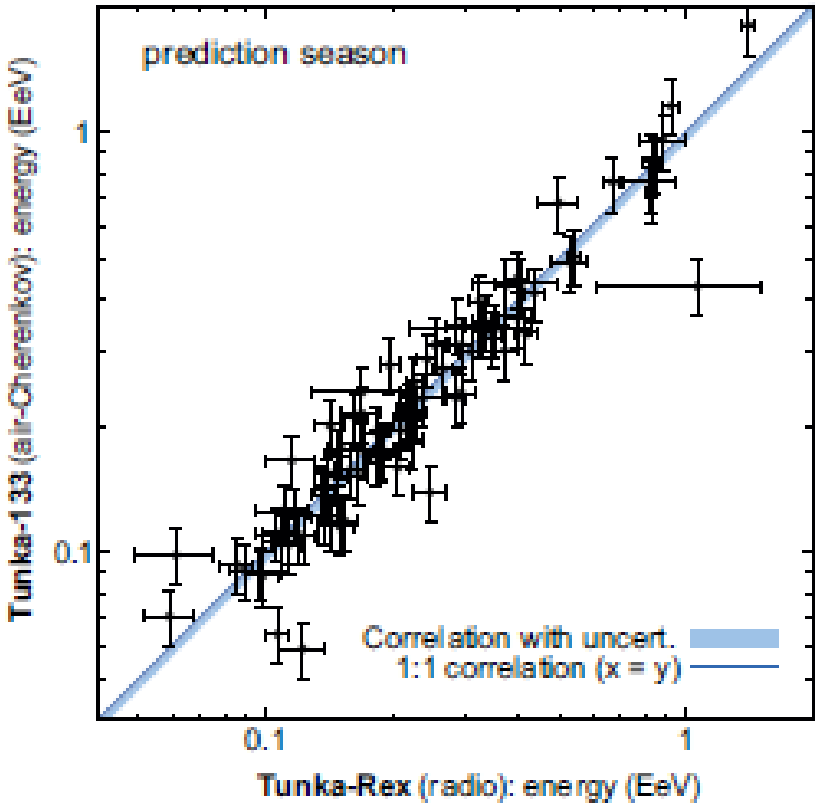
Tunka-REX

EAS energy measurement by the radio emission (63 antennas)

Tunka-REX

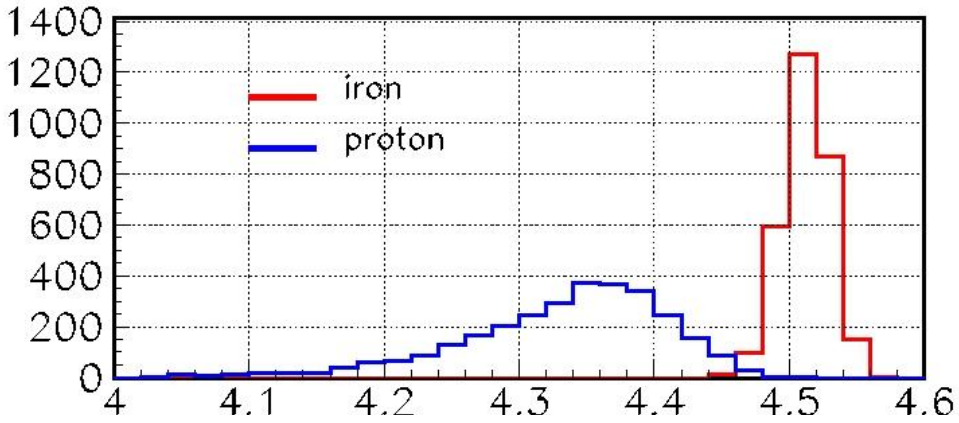
Correlation of the shower energy reconstructed with Tunka-Rex radio and Tunka-133 air Cherenkov measurements:





$$\frac{E_{CL} - E_{Radio}}{E_{CL}} = (17 \pm 2)\ \%$$

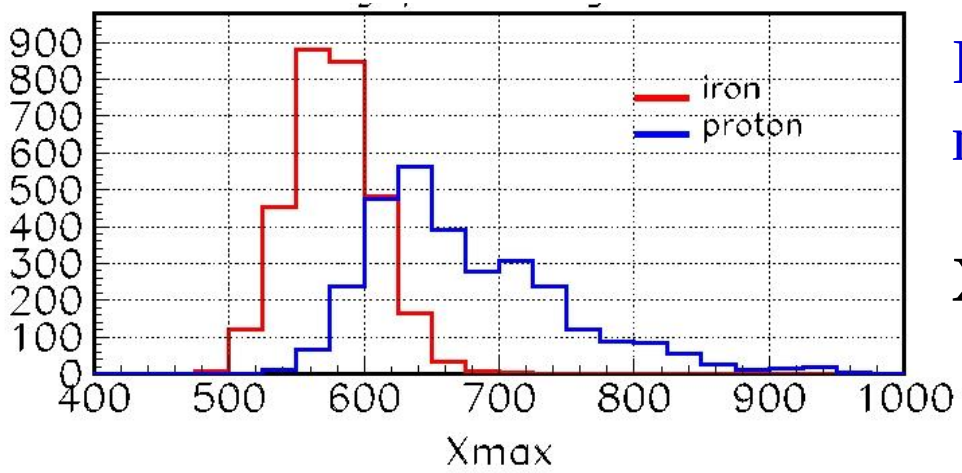
Study of mass composition in the energy $10^{17} – 10^{18}$ eV.



Energy by the data of Tunka-REX (17%)

$S = lgN\mu – 0.2xlgNe – 0.7xlgE_0$

(by Tunka-Grande) (by REX)

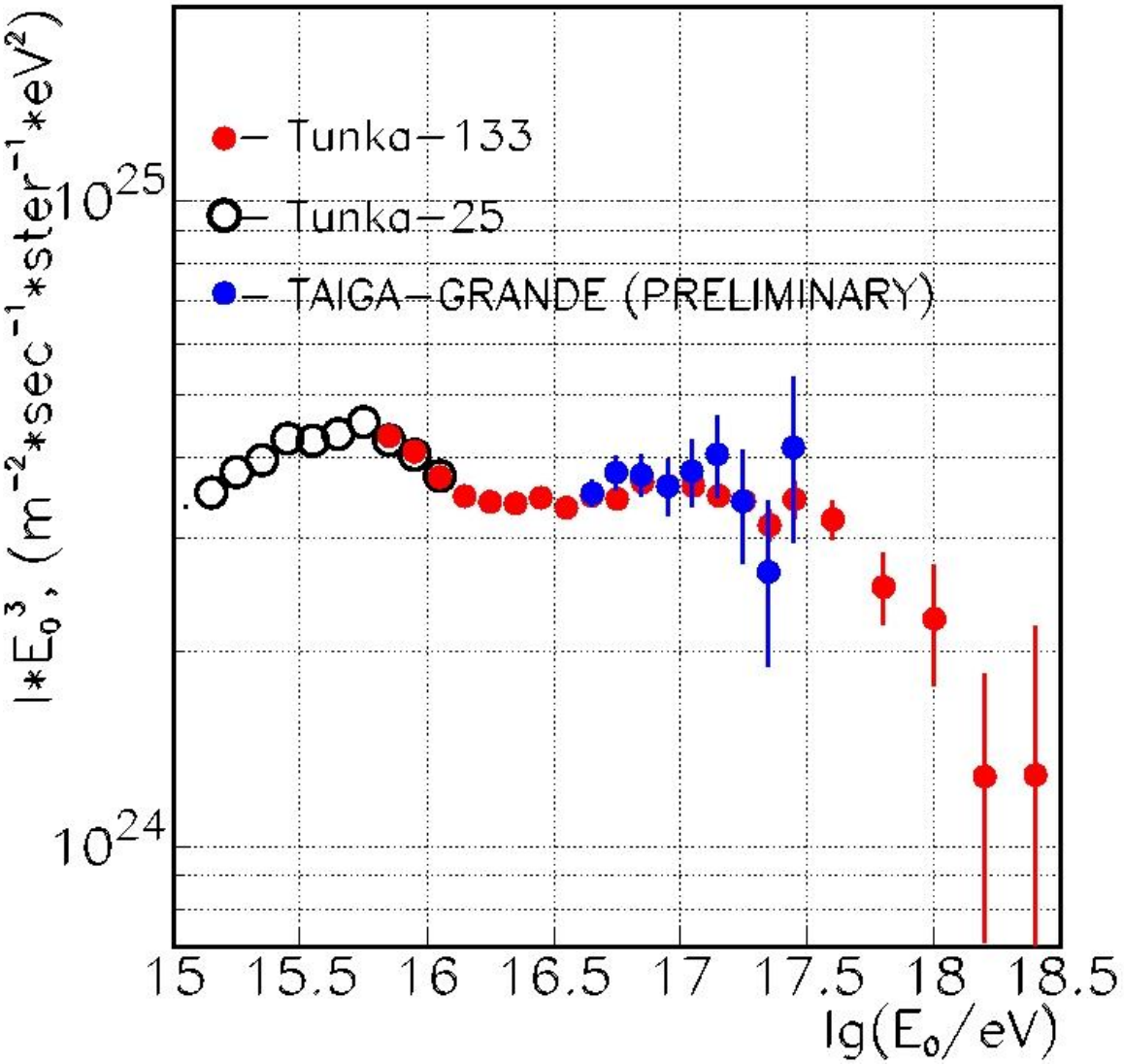


It is more sensitive to the particle mass than

X_{max}

Energy spectrum from TAIGA-Grande (very preliminary)

Test RUN: 92 days, 880 h,
$\theta < 40^{o}$, $R_c < 300$ m
$E_0 > 5 \cdot 10^{16}$ eV – 700 events
$E_0 > 10^{17}$ eV – 160 events



CONCLUSIONS

1. **TAIGA will be 5 km^2 hybrid detector (500 HiSCORE wide-angle stations and 16 IACTs). The sensitivity for local sources in the energy range 30 – 200 TeV is expected to be about 10^{-13} erg ·cm-2· s-1 (for 500 h of observation).**

2. **Deployment of a TAIGA prototype with 58 wide-angle HiSCORE stations and one IACT will be completed in 2017. The sensitivity of the prototype for local sources in the energy range 30 – 200 TeV is expected to be about 10^{-12} erg cm-2 s-1 (for 200 h of observation).**

3. **The first winter season of the TAIGA-HiSCORE operation has been successfully carried out. The analysis of the data is in progress. All particle energy spectrum is reconstructed. The peak energy in the threshold region is about 100 TeV (about 60 TeV for γ)**

4. **The first hint on the event excess from Crab is obtained with the data of TAIGA-HiSCORE alone.**

5. **The very high energy complex of EAS electrons, muons detectors and radio antennas has started data acquisition this year. The spectrum and composition in the energy range 10^{17} – 10^{19} is expected in 3 years.**

Thank you!