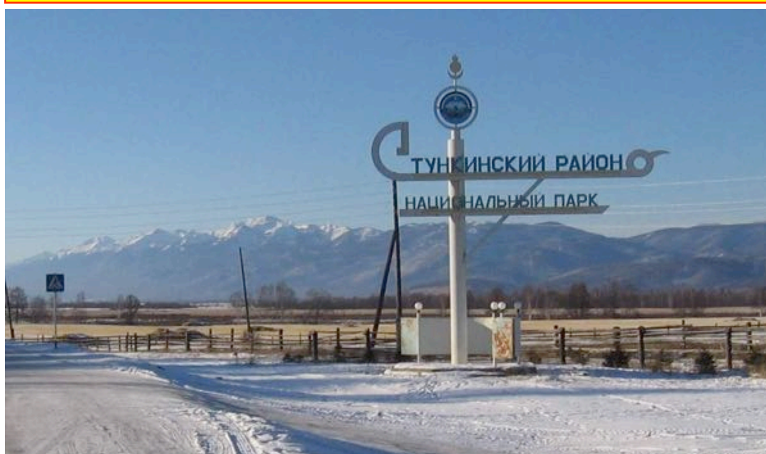
The gamma-ray observatory TAIGA: status and perspective

L.Kuzmichev (SINP MSU)
on behalf of TAIGA collaboration

RICAP -2016

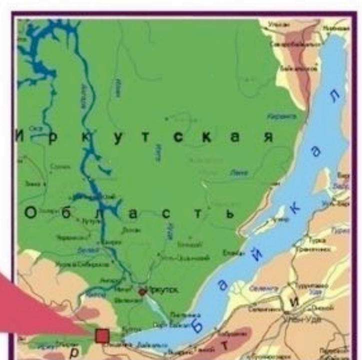
TAIGA (Tunka Advanced Instrument for cosmic rays and Gamma - Astronomy)



Tunka Valley, Republic Buryatia
- 50 km to west
from Lake Baikal.

150 km from Irkutsk

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



TAIGA - collaboration

Germany

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

Italy

Torino University (Torino)

Rumania

ISS (Bucharest)

Russia

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

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L.Kuzmichev (MSU)

Content of report

1. Motivation or Multi-TeV gamma-ray astronomy

2 . CR experiments in Tunka valley

3. Gamma-ray observatory TAIGA

4. TAIGA-prototype

5. First season of TAIGA-HiSCORE prototype operation

Motivation for Multi-TeV gamma-ray astronomy

For the energy range of gamma-quanta of higher than 30 TeV (high energy gamma-astronomy) there are a number of fundamental questions which have presently no answers, and first of all this is a question of sources of Galactic cosmic rays with energies around 1 PeV

(much more was in M.Tluczykont report)

CR (>10^{15} eV) experiments in Tunka Valley

1. Tunka-133 - 175 detectors, single PMT of Ø20 cm.

2. Tunka-Rex - 45 radio antennas.

3. Tunka-Grande - 380 scintillation detectors of electrons and muons (former EAS-TOP and KASCADE-Grande detectors).
19 stations (in each station 12 detector for electron-photon component and 8 for muons
(total area for muons 100 m^2)

CR and gamma-rays with energy $>10^{15}$ eV

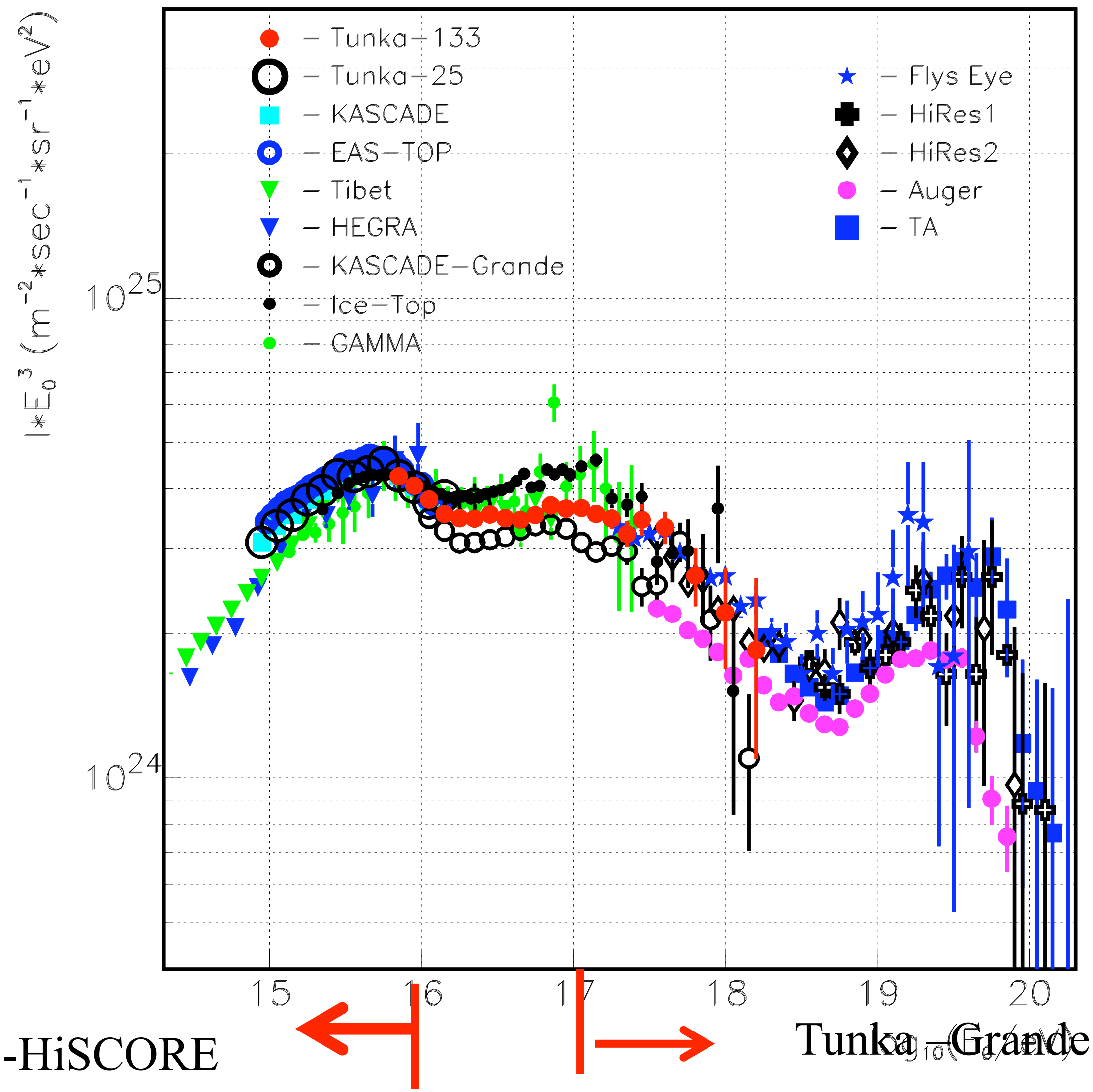
Tunka-133 - 175 optical detectors on the area 3 km^2

Tunka-Grande – 380 scintillation counters for registration of charged particles

Тунка-REX – 45 antennas for registrations of radio signals From EAS

Entrance to muons conters

All particle energy spectrum



TAIGA -HiSCORE

Tunka –Grande + Tunka-REX

TAIGA gamma-observatory

• 500 wide angle optical stations 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.

TAIGA - HiSCORE

(High Sensitivity Cosmic Origin Explorer).

Non-imaging air Cherenkov array
Angular resolution : ~ 0.4 - 0.1 degree
Large Field of view (FOV): ~ 0.6 sr
Area: from 0.25 km² → 5 km²

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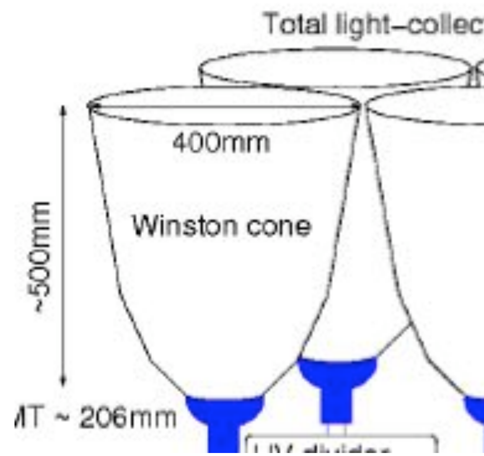
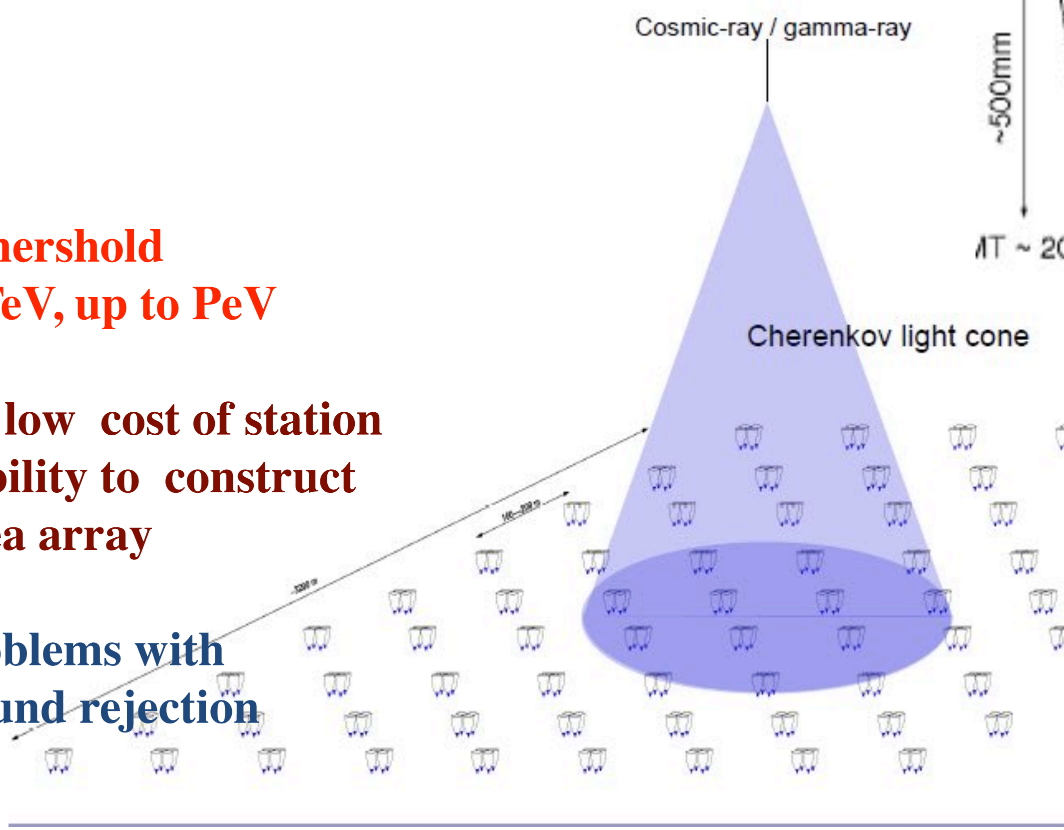


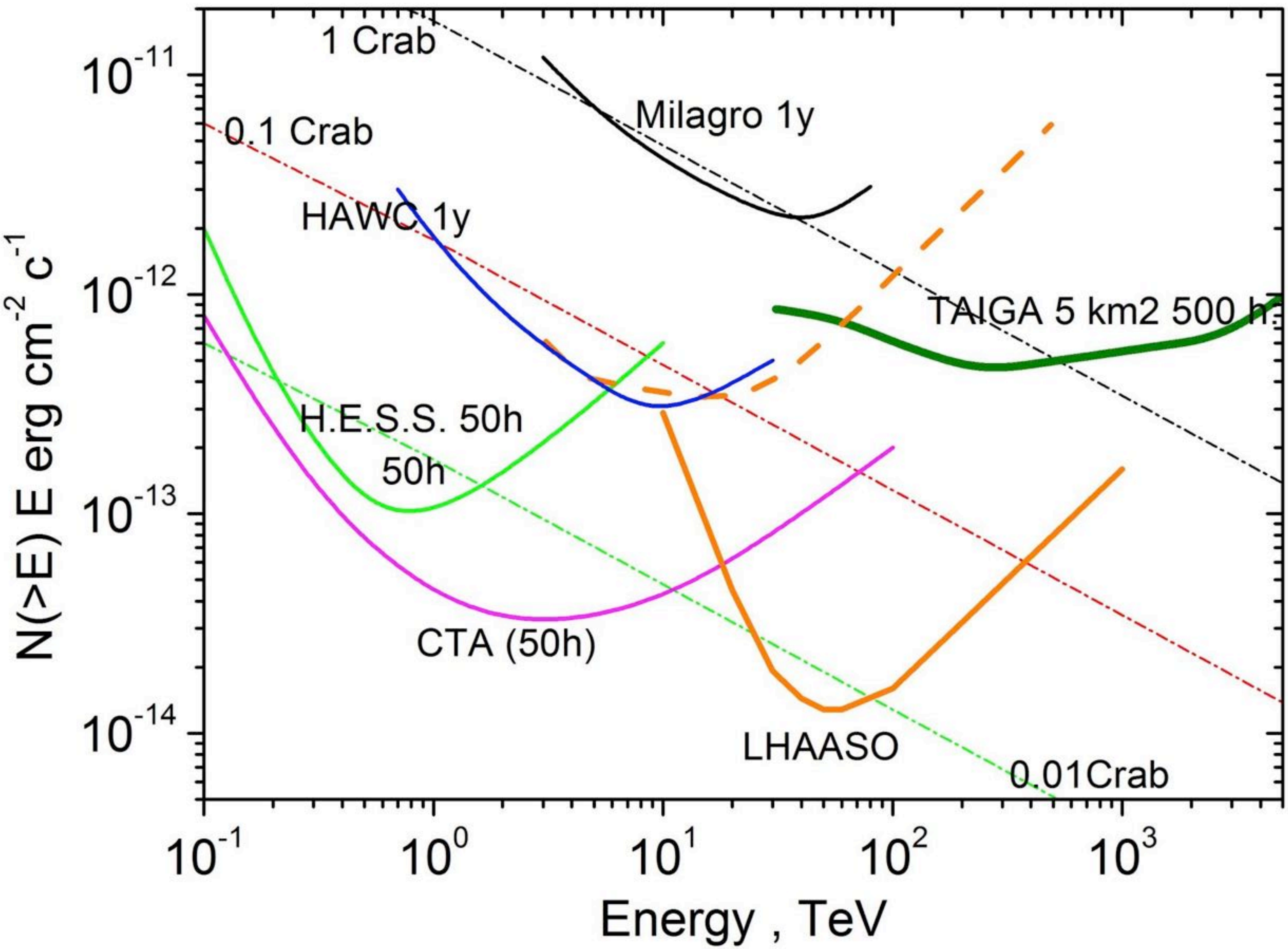
Energy thershold
Eγ > 30 TeV, up to PeV



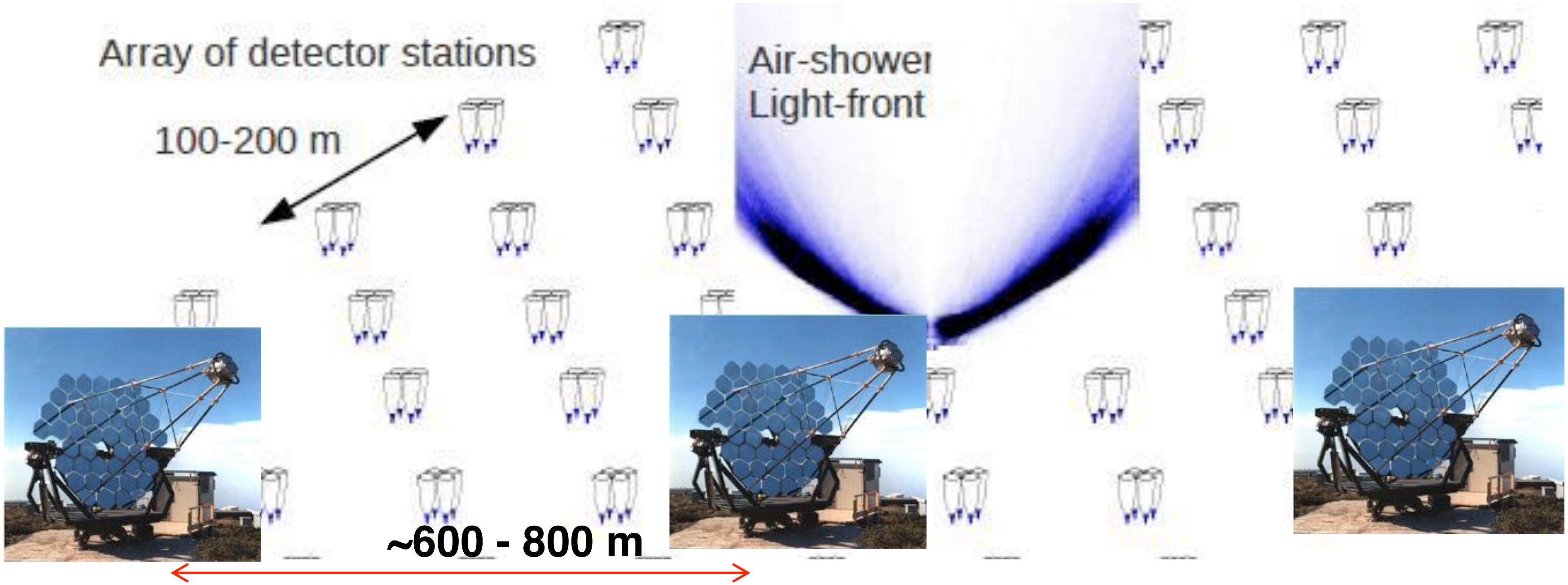
Relativly low cost of station – possibility to construct large area array

But – problems with background rejection

Integral sensitivity to local sources

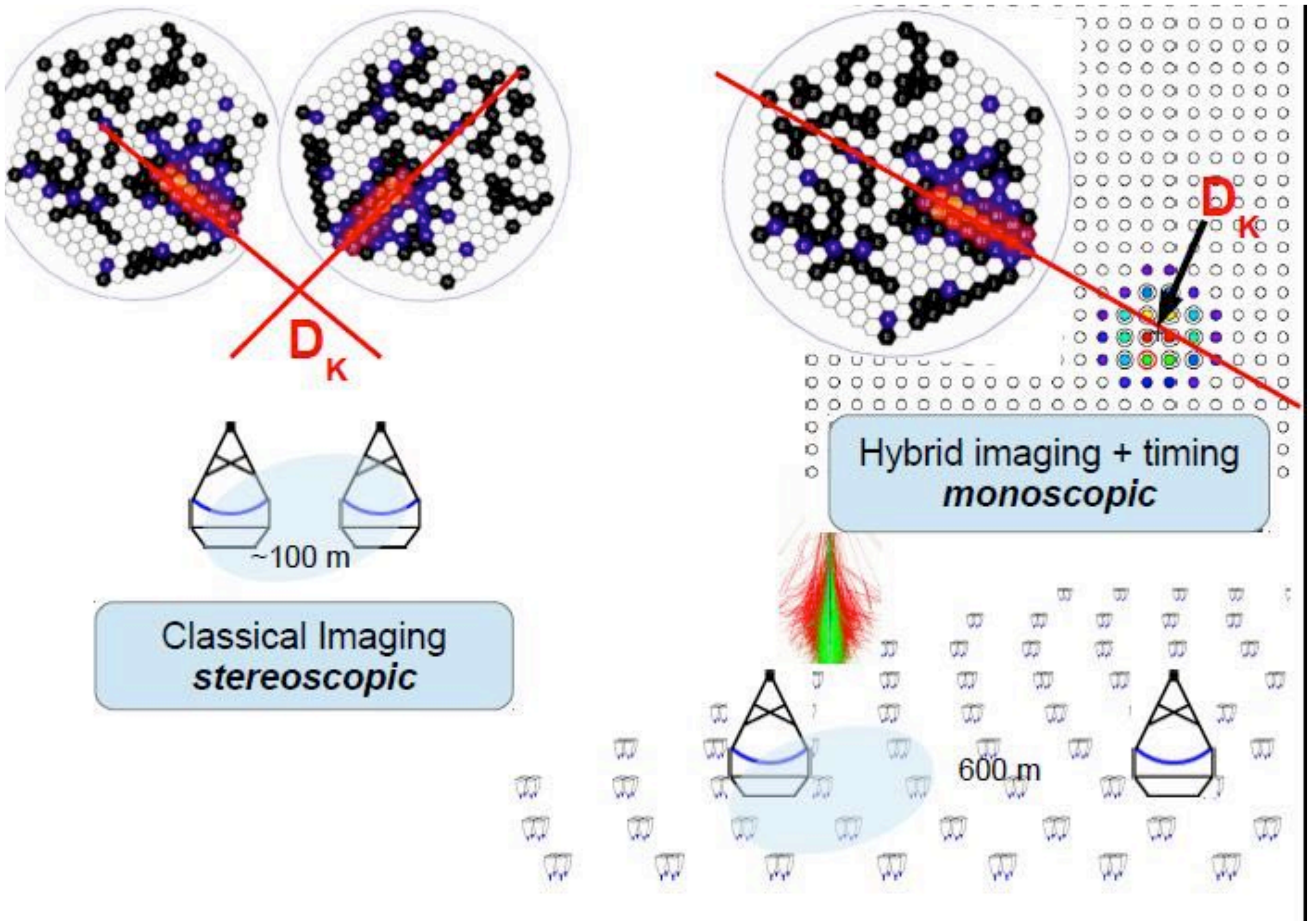


TAIGA : Imaging + non-imaging techniques



TAIGA - HiSCORE: core position, direction and energy Gamma/ hadron separation - TAIGA-IACT (image form, monoscopic operation)

Hybrid approach to hadron rejection

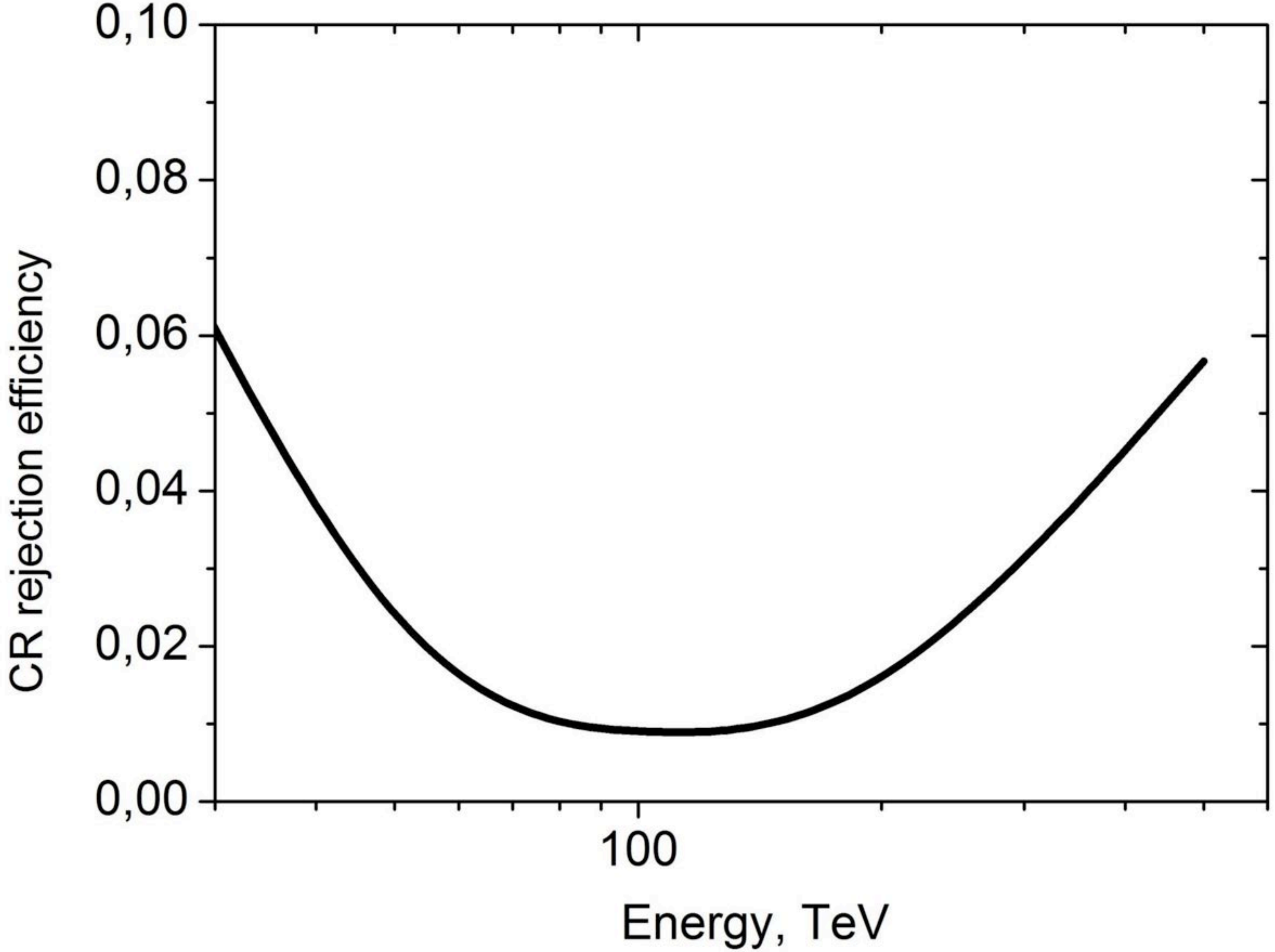


The differences between an isolated operation of the IACT and a joint operation together with HiSCORE

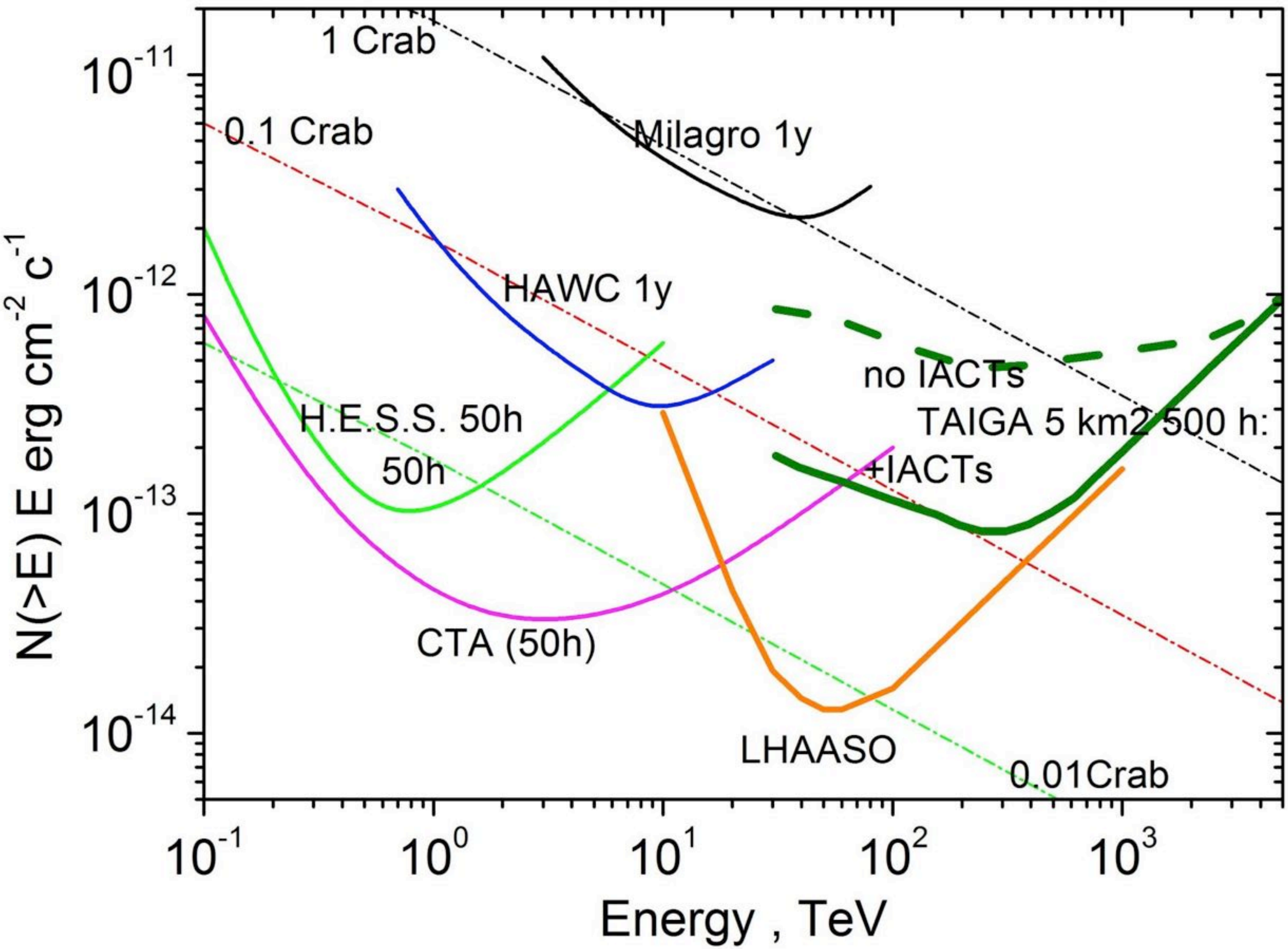
Shower source direction and shower core position may come from HiSCORE, not from the IACT image analysis

Shower core may be located on a greater distances from the IACT, so images can partly spread outside of the camera and be truncated

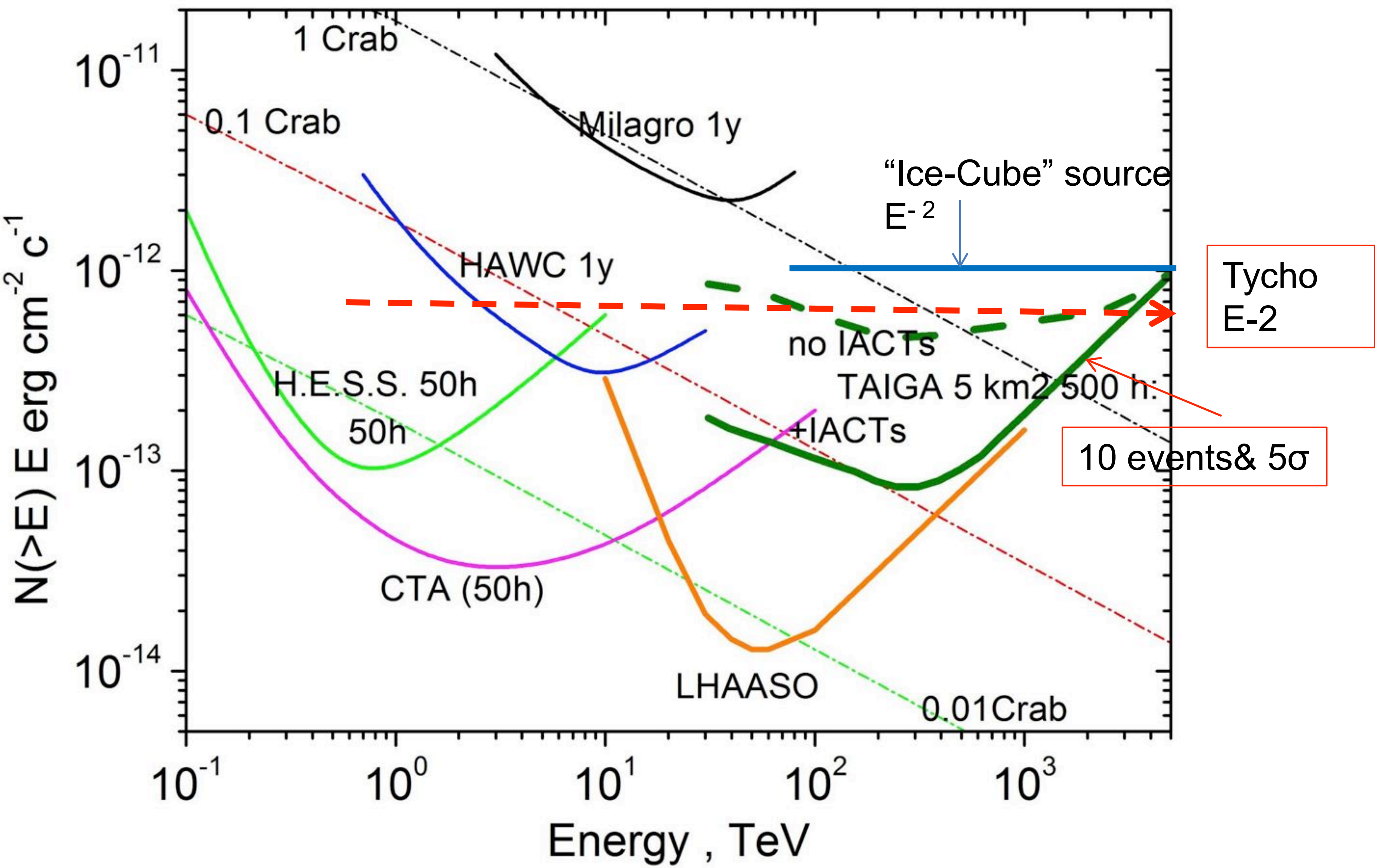
CR rejection efficiency



Integral sensitivity to local sources



Integral sensitivity to local sources

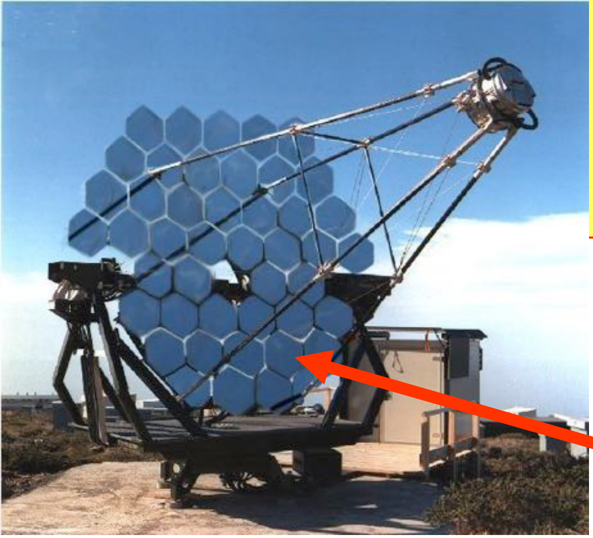


What we can see with 5 km^2 array (short list)

Name	RA degrees	Decl	Flux at 1 TeV, $10^{-12}cm^{-2}s^{-1}TeV^{-1}$ slope Γ	Flux at 35 TeV, $10^{-17}cm^{-2}s^{-1}TeV^{-1}$ (from Milagro)	Time of observation per one year (x 0.5- weater factor)	Number of events per one season E> 30 TeV
Tycho SNR (J0025+641)	6.359	64.13	0.17 ±0.05 Γ=1.95 ±0.5		**236h**	**~150 2.5 σ – for HiSCORE, for 12 σ - TAIGA**
Crab	83.6329	22.0145	32.6 ±.9.0 Γ=2.6 ±0.3	162.6 ±9.4	**110h**	**~ 500**
SNR IC443 (MAGIC J0616+225)	94.1792	22.5300	0.58 ±0.12 Γ=3.1 ±0.30	28.8 ±9.5	**112h**	**10**–(from MAGIC) **200** (from Milagro)
Geminga MGRO C3 PSR	98.50	17.76		37.7 ±10.7	**102h**	**400**
M82 (Starburst Galaxy)	148.7	69.7	0.25 ±0.12 Γ=2.5 ±0.6±0.2		**325h**	**50**
Mkn 421 (BL, z=0.031 Variable)	166.114	38.2088	50-200 Γ=2.0-2.6		**140h**	**20 – 1000 ??**
SNR 106.6+2.7 (J2229.0+6114)	337.26	61.34	1.42 ±0.33 ±0.41 Γ=2.29 ±0.33 ±0.30	70.9 ±10.8	**167h**	**400** (from VERITAS **700** (from Milagro)
Cas A (SNR)	350.853	58.8154	1.26 ±0.18 Γ=2.61 ±0.24±0.2		**177h**	**100**
CTA_1(SNR,PWN)	1.5	72.8	1.3 Γ=2.3		**266 h**	**500**

TAIGA- prototype

58 wide angle station on the area 0.6 km^2 and one IACT



TAIGA-IACT

D = 4.32m F = 4.75m

34 mirrors of 60 cm diameters

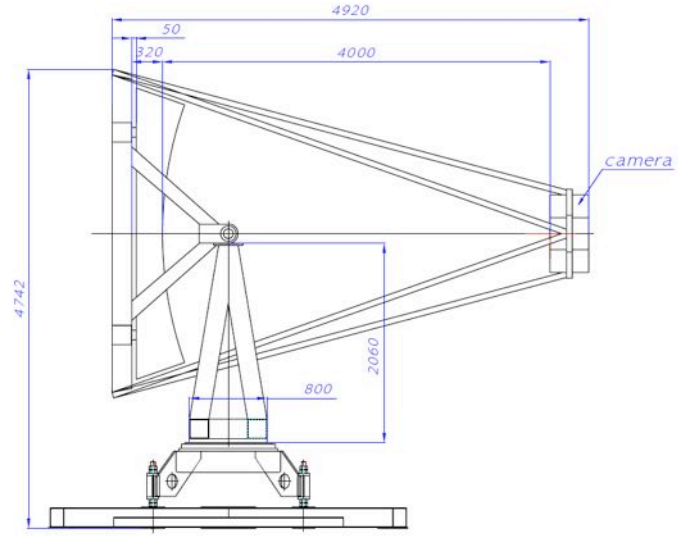
Camera : 547 PMTs (XP 1911) with 15 mm useful diameter of photocathode
Winston cone: 30 mm input size, 15 output size
1 single pixel = 0.36 deg
full angular size 9.6x9.6 deg

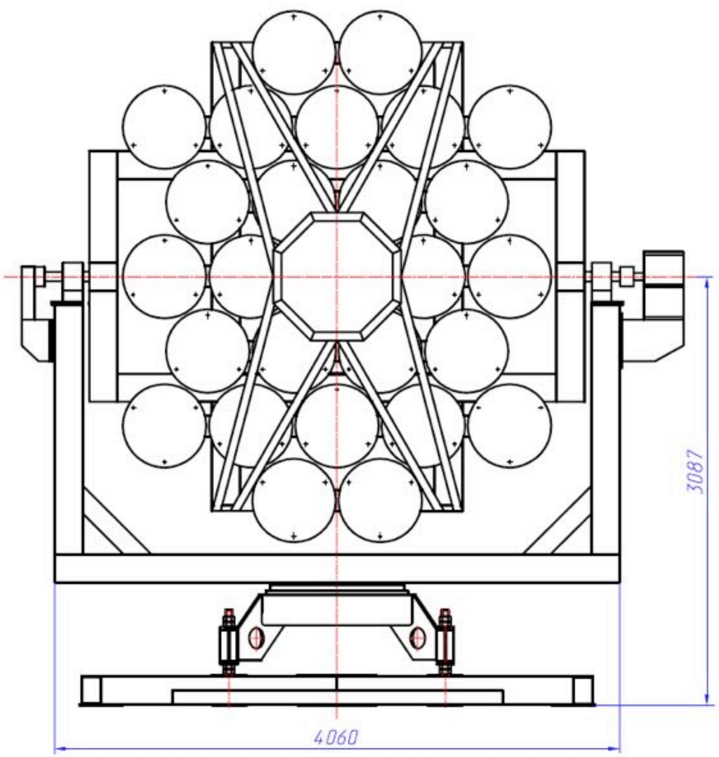
Energy threshold ~1.5 TeV

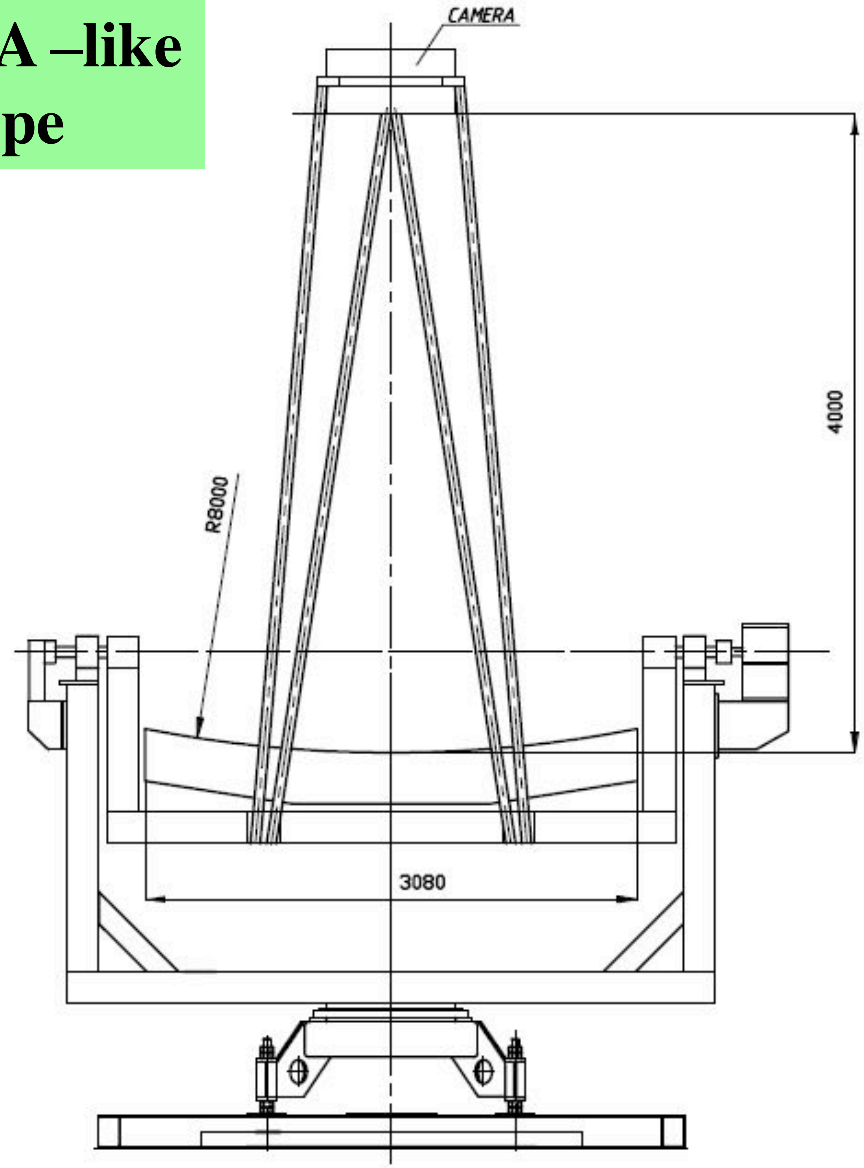
Cost : 300 Keur

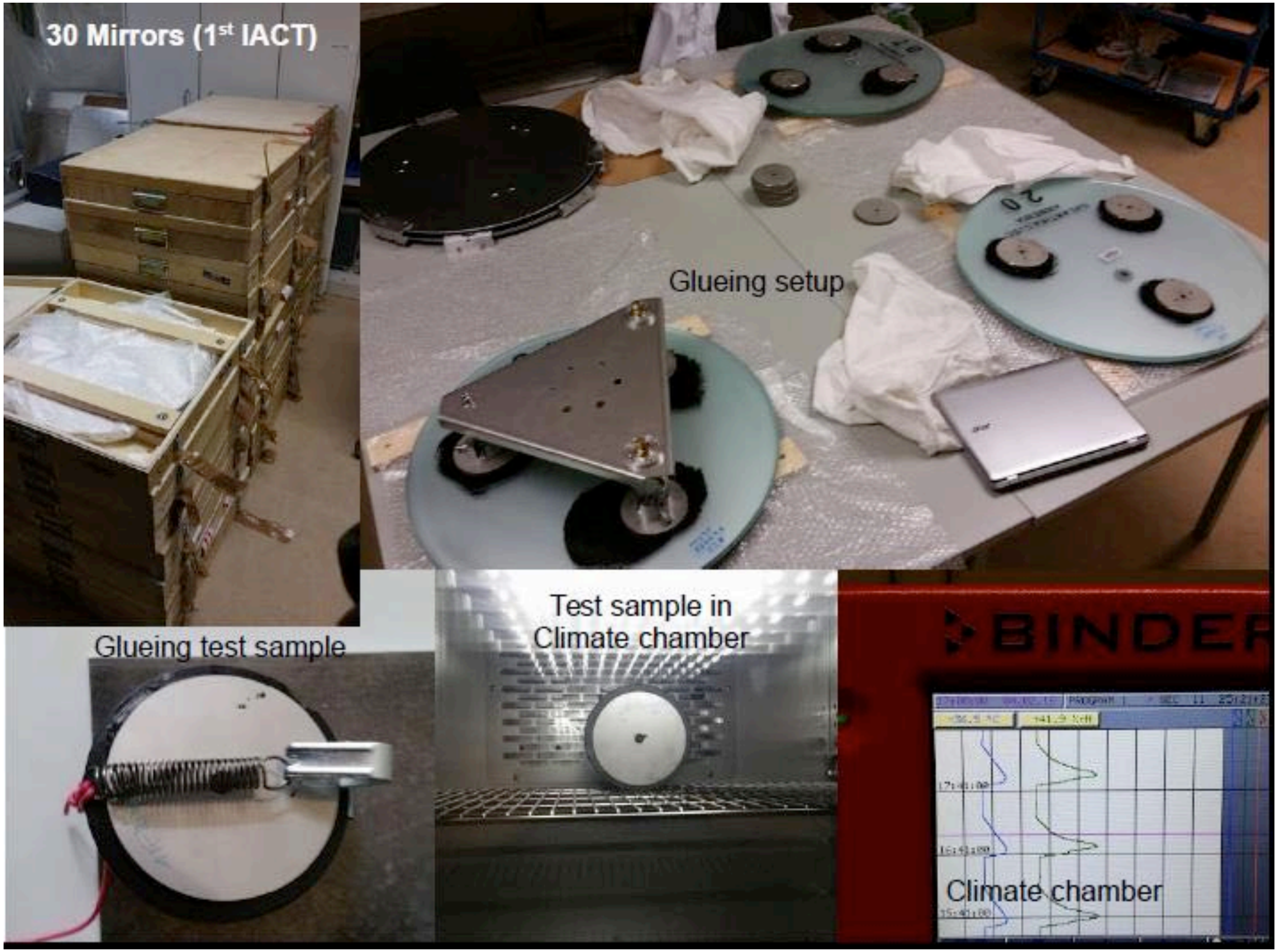
Commission of the first telescope – October 2016

HEGRA –like telescope

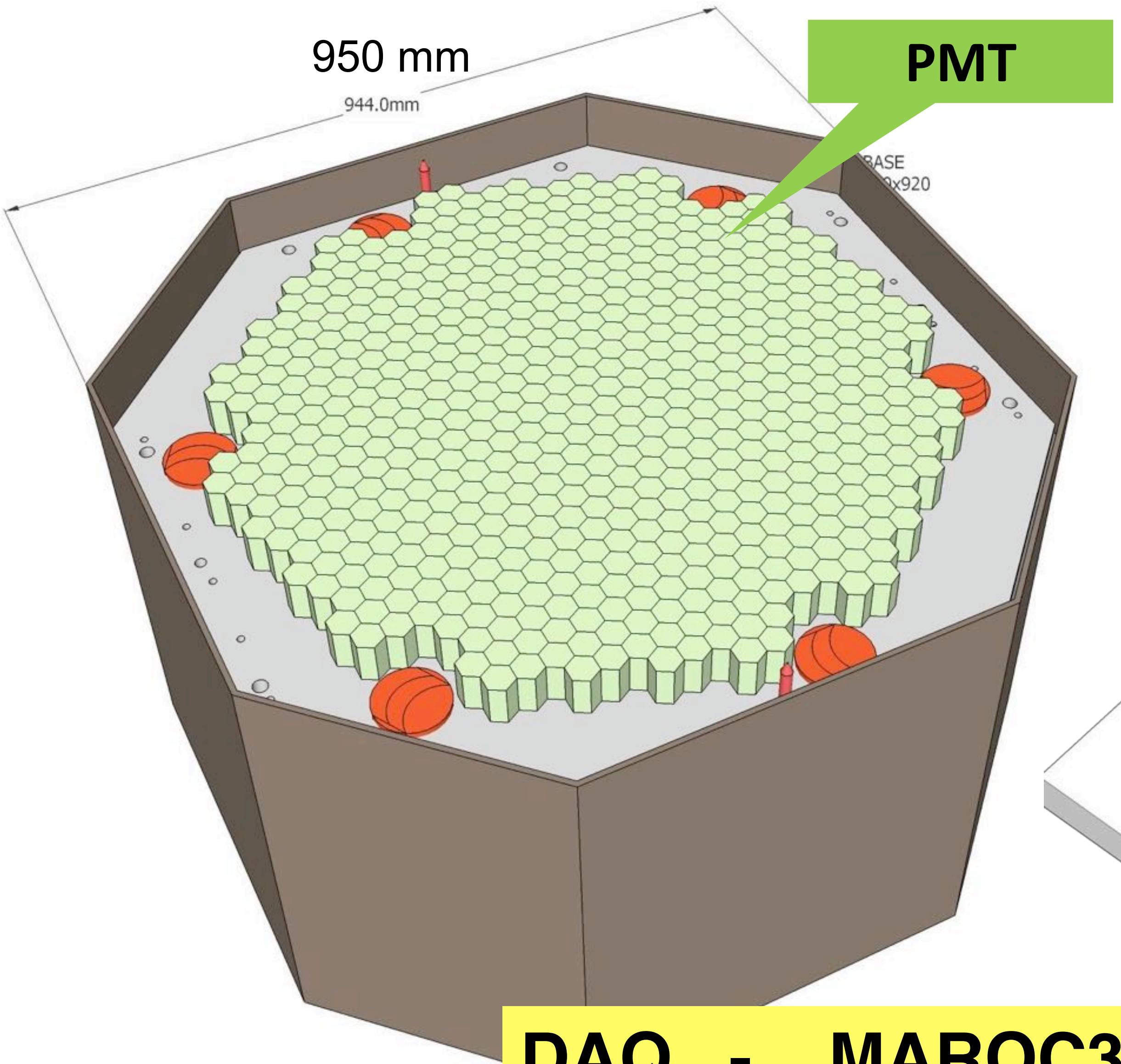


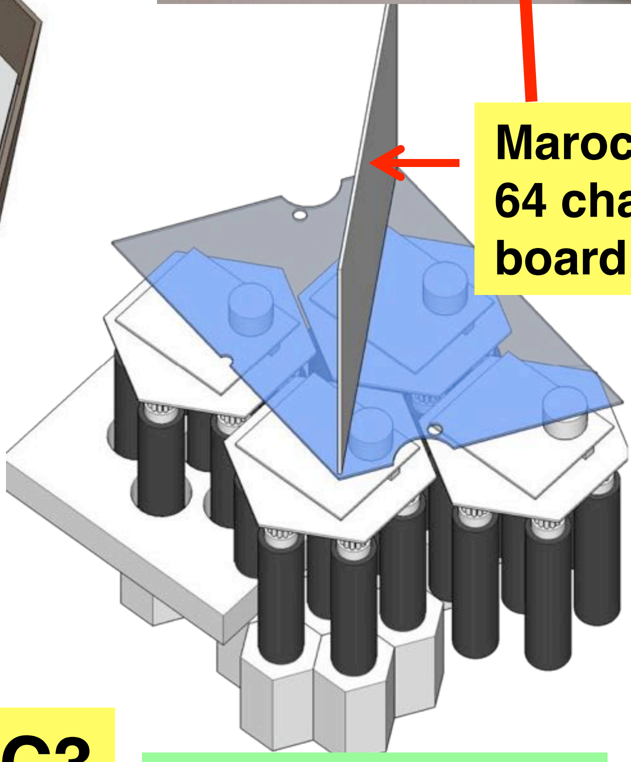





30 Mirrors (1st IACT)
Glueing setup
Glueing test sample
Test sample in
Climate chamber
BINDER
Climate chamber

Camera of the TAIGA-IACT

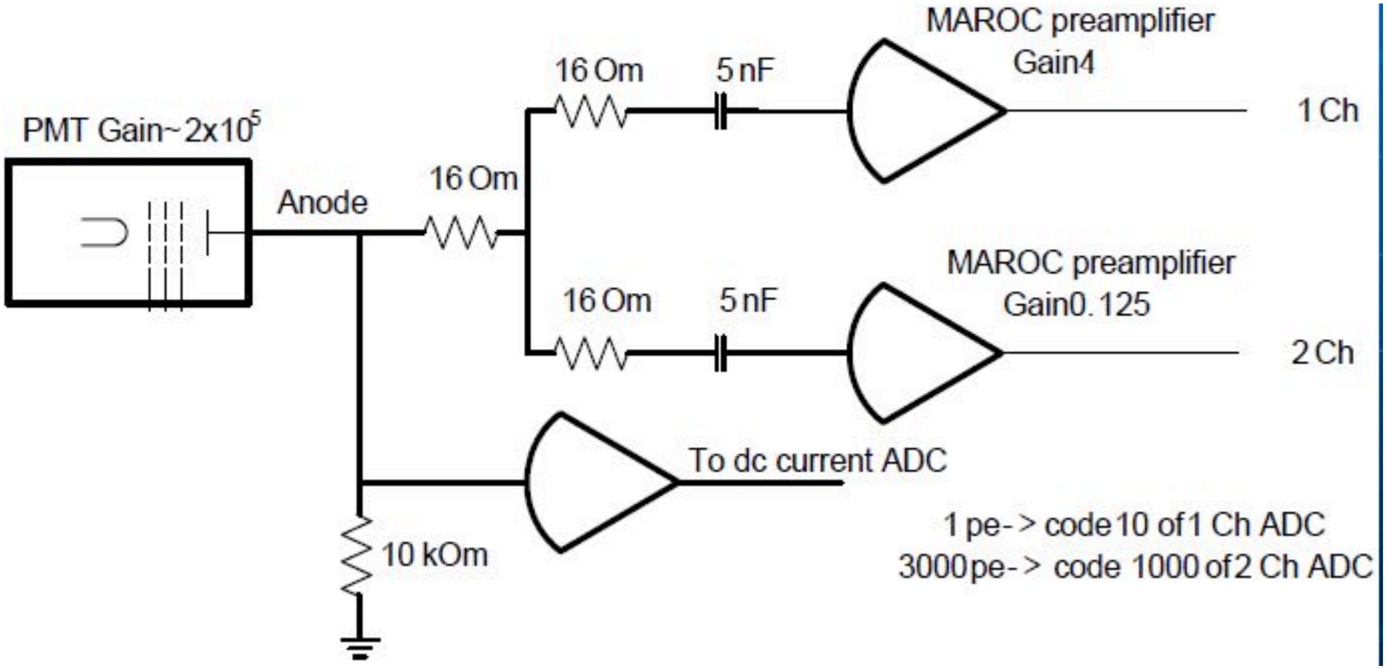




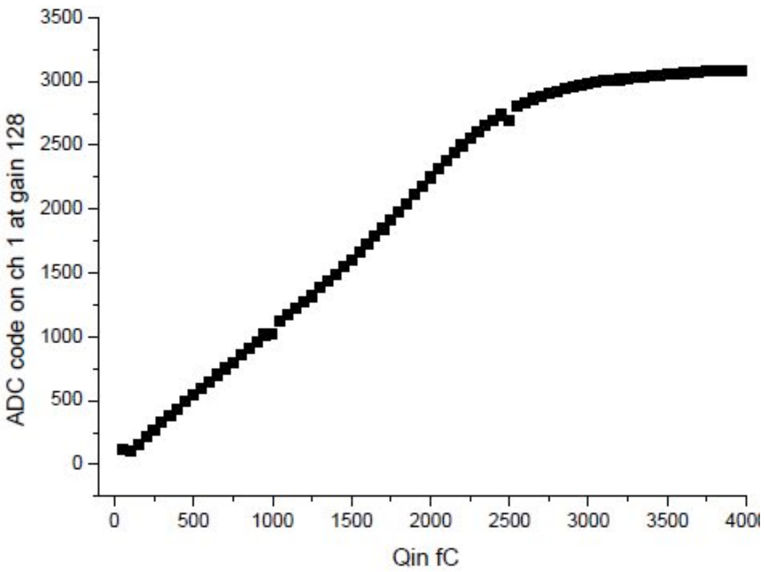
DAQ - MAROC3

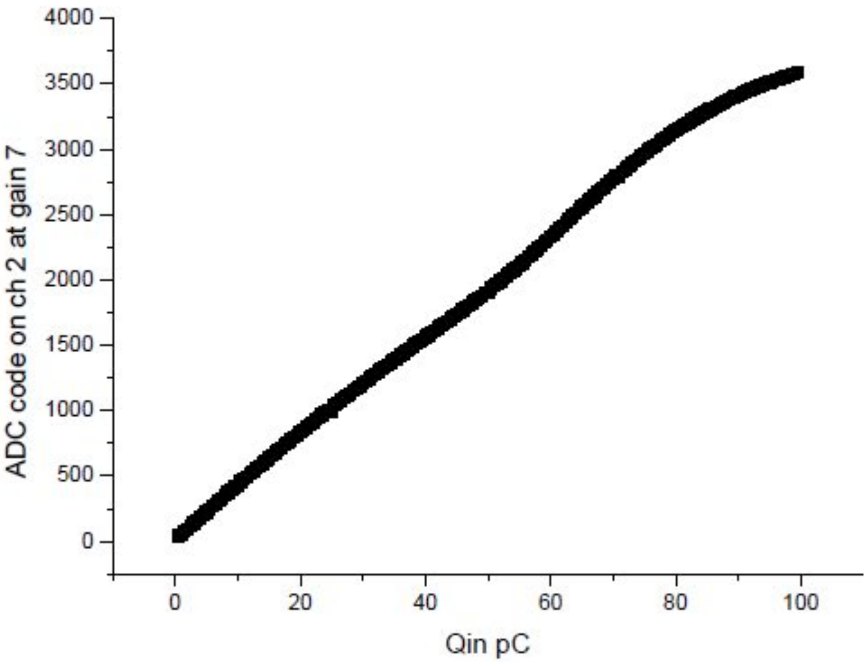
Cluster – 28 PMTs

Marching of the PMT anode signal output with MAROC-3



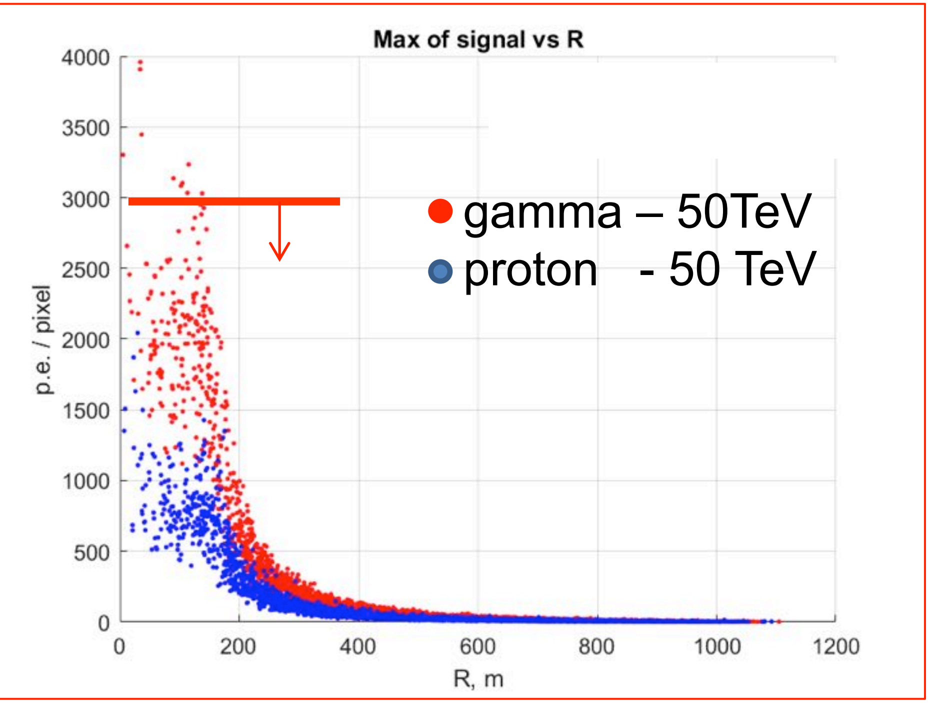
ADC code versus injection charge

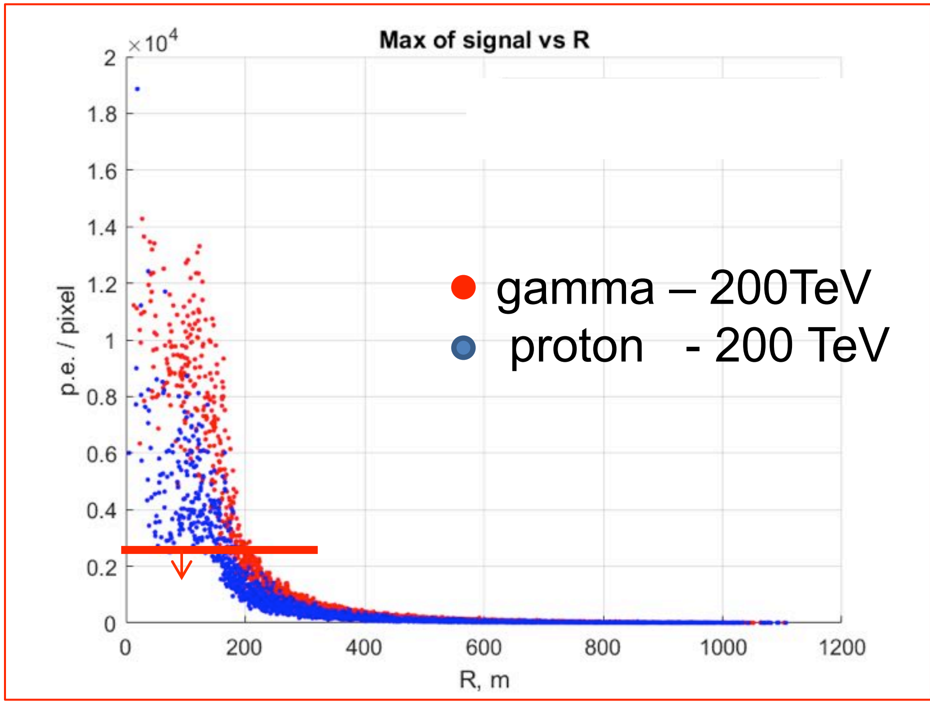


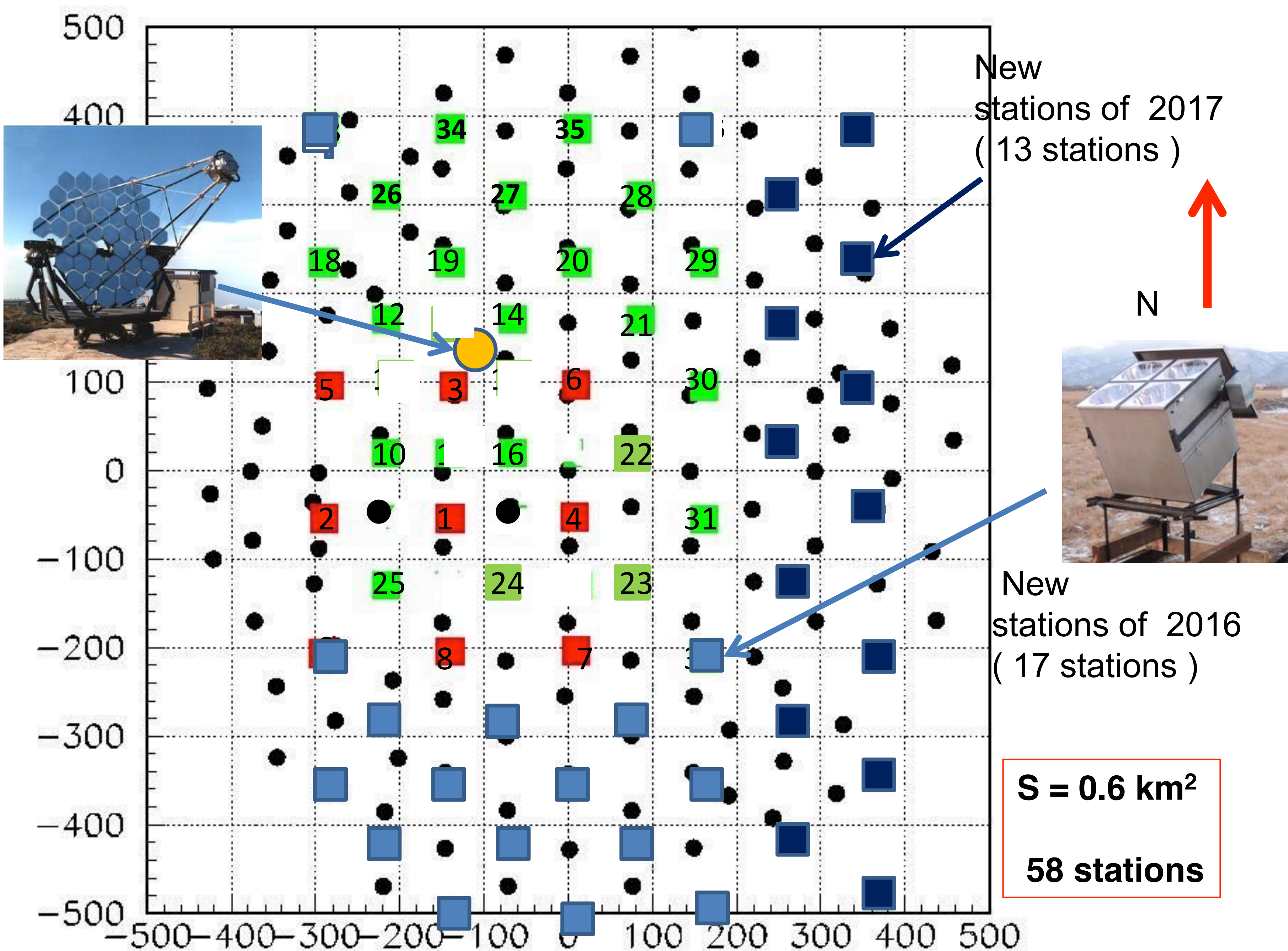


Dynamic range $\sim 4 \cdot 10^4$ p.e.

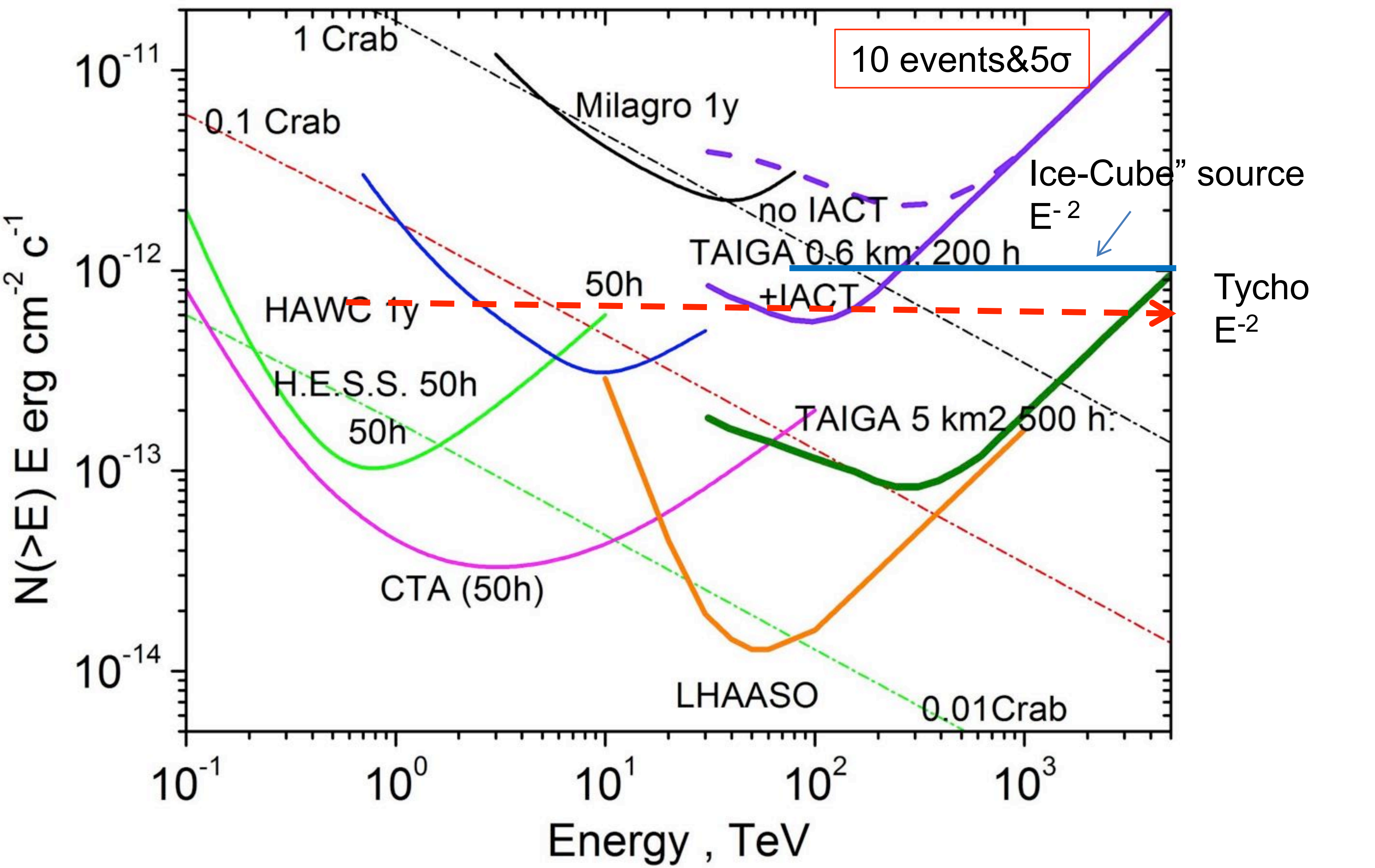
Maximum amplitude per pixel& distance from the EAS core





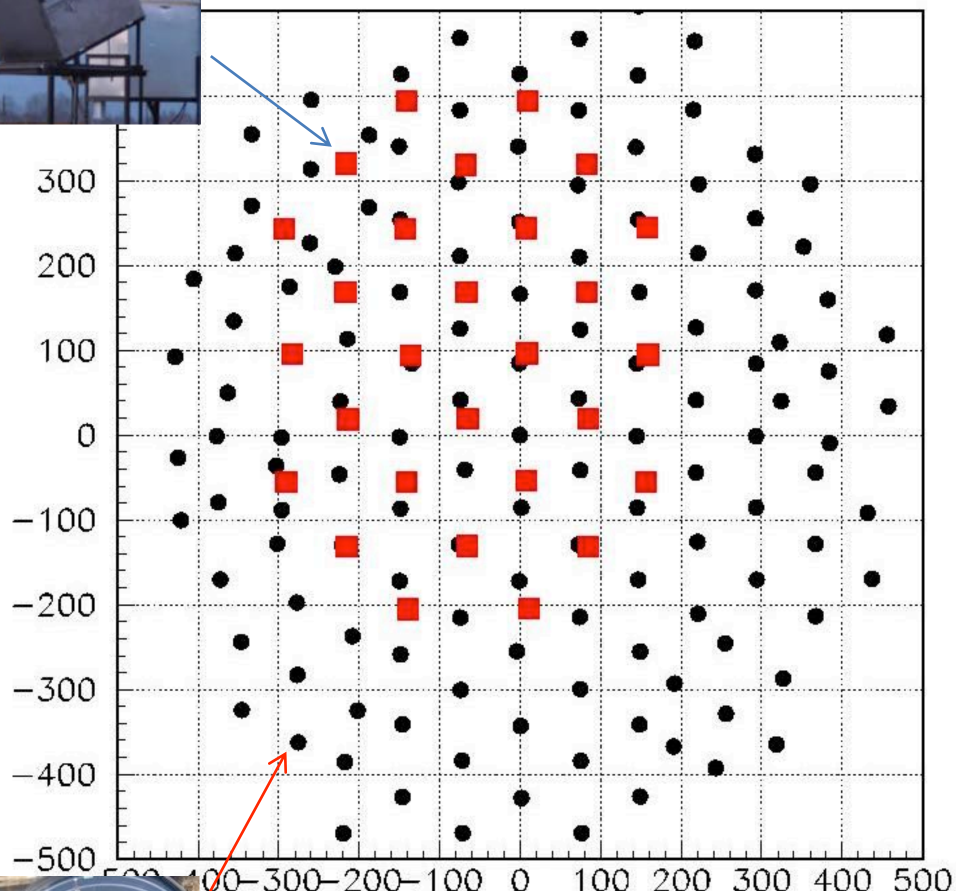

New
stations of 2017
(13 stations)
N
New
stations of 2016
(17 stations)
S = 0.6 km²
58 stations
500
400
100
0
−100
−200
−300
−400
−500
−500 −400 −300 −200 −100 0 100 200 300 400 500
34
35
26
27
28
18
19
20
29
12
14
21
5
3
6
30
10
16
22
2
1
4
31
25
24
23
8
7

Integral sensitivity to local sources



Results from last season of operation

28 stations, S = 0.25 km^2



35 nights of array operation

250 h of good weather operation.
(October-February)

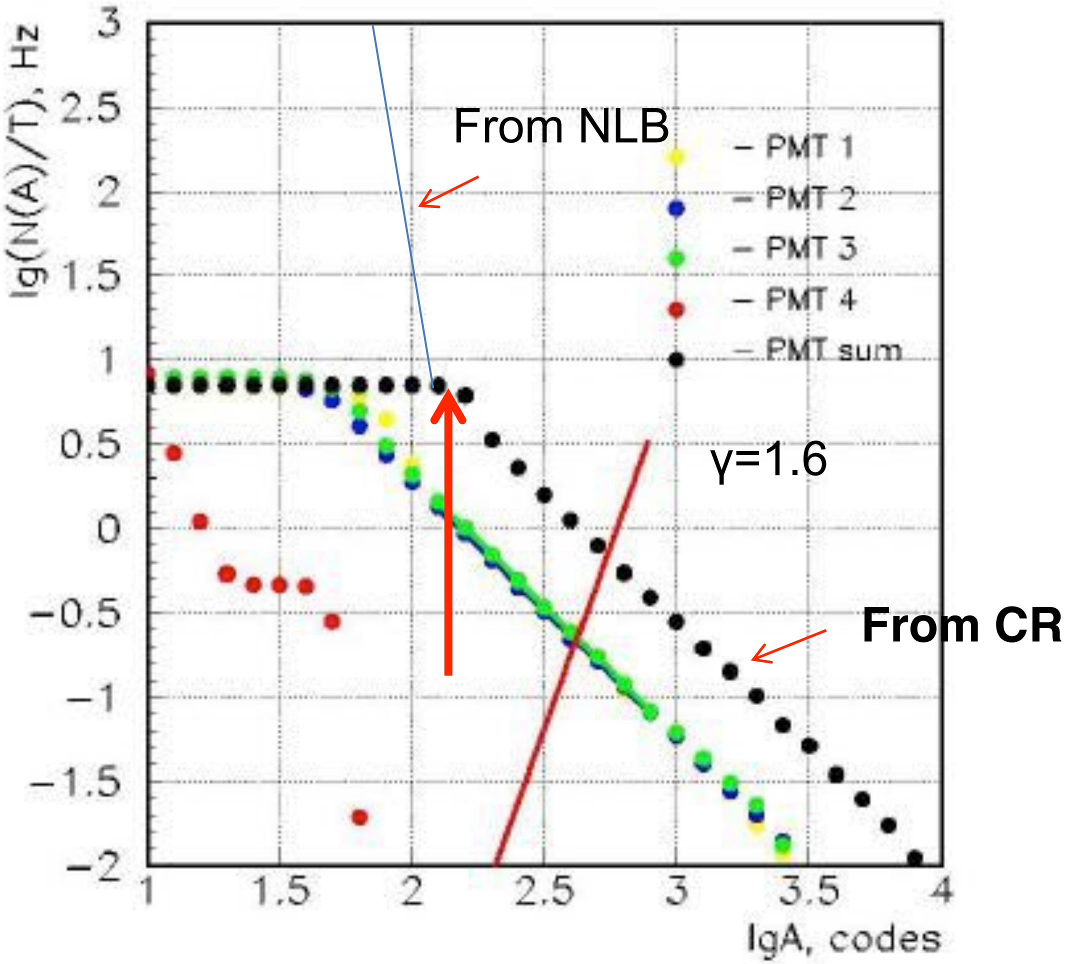
10 10^6 events (≥ 4 stations)

Crab in the array field of view – 60 h (good weather conditions)

3 $\cdot 10^4$ events in the 3 deg angle around direction to Crab

Tunka-133 detectors

Integral amplitude spectrum of single station



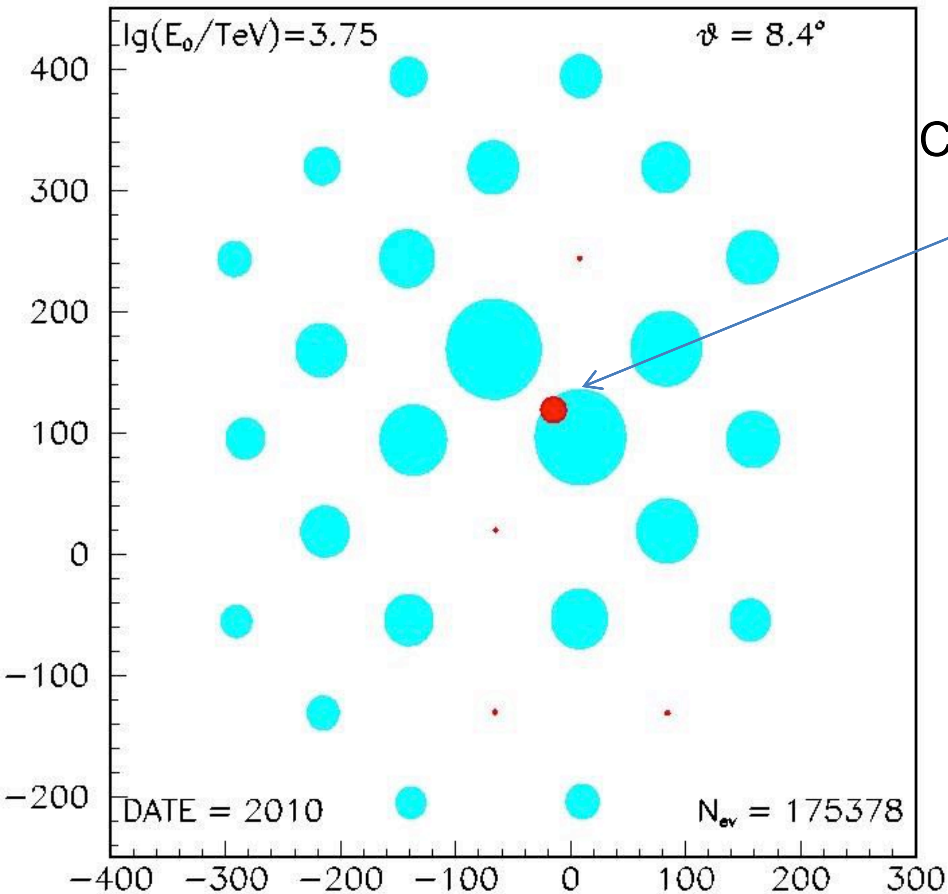
Counting rate of single station 8-12 Hz

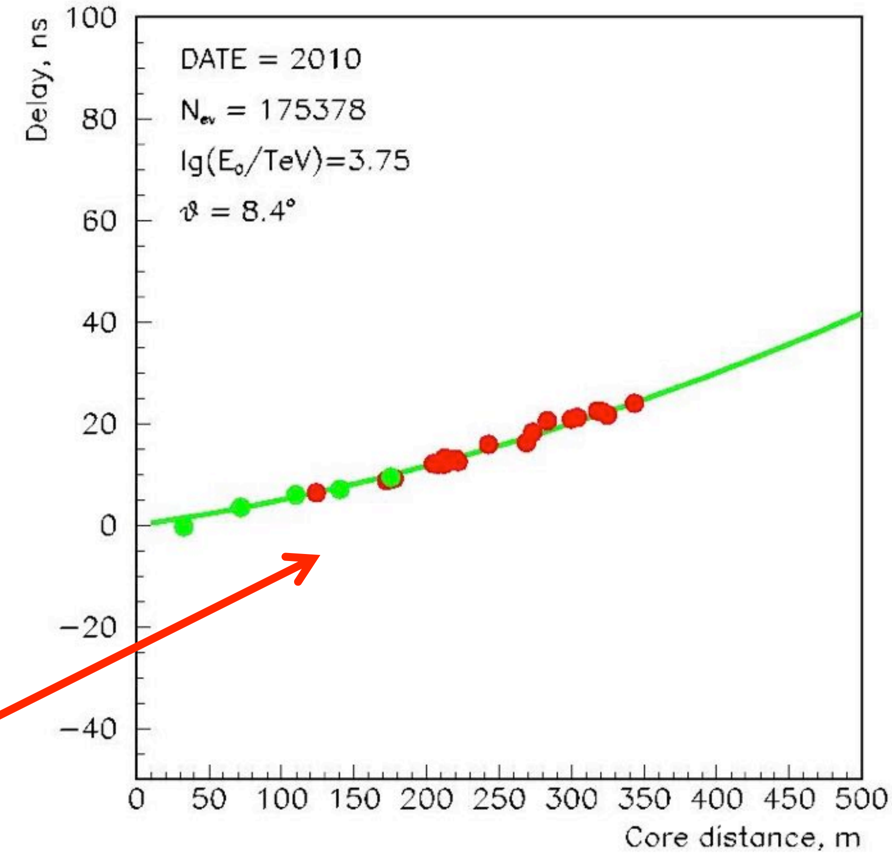
In the most of stations 3 PMTs

Event example

R ~ Lg (Photon flux)

Core Position



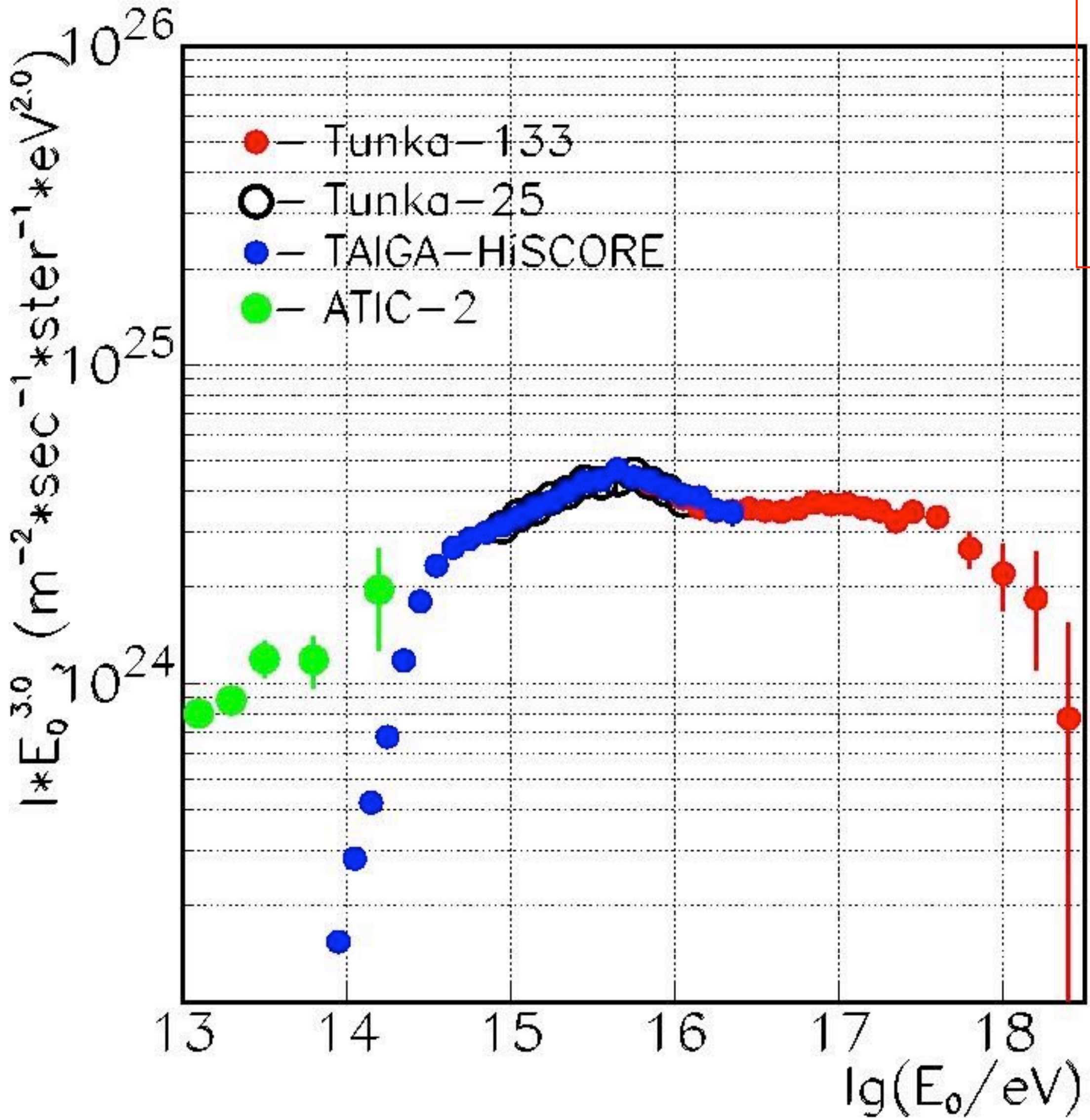


EAS time front

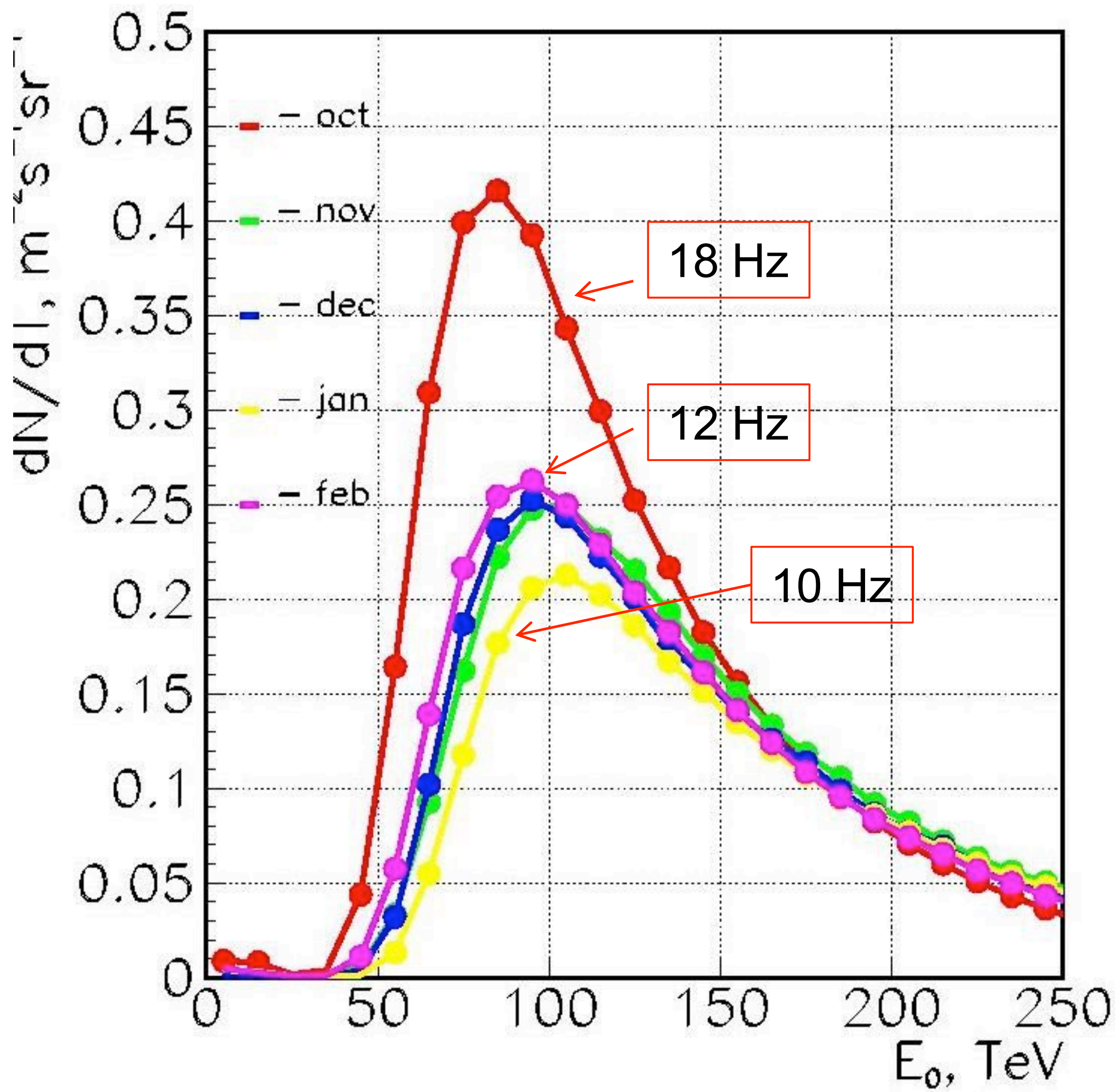
All particle energy spectra

E = A (Q200)^g g=0.94

Density of Cherenkov light at core distance of 200 m form the core



Energy distribution in the threshold region (per months)



MC-MSU & Experiment

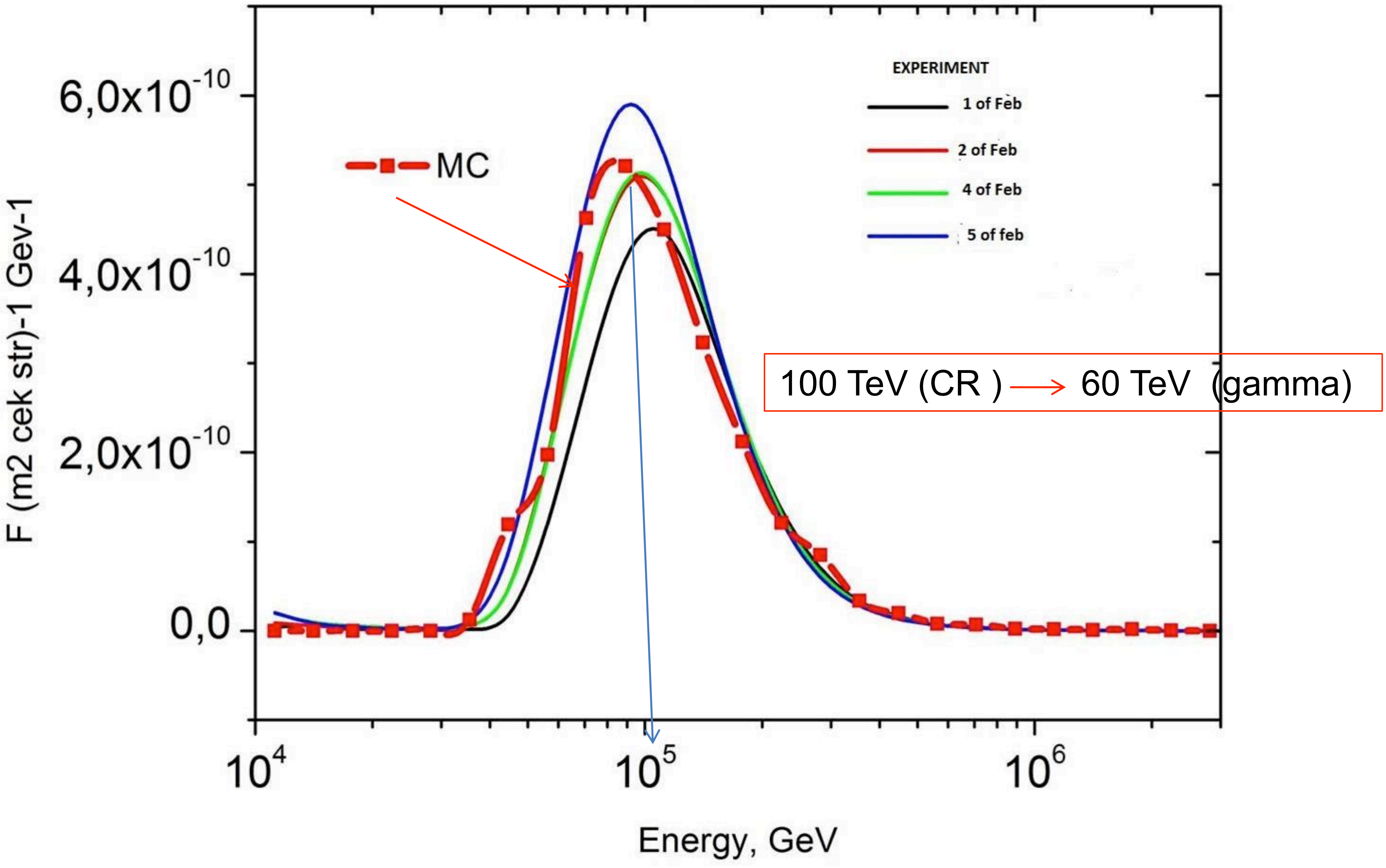
(P + He + CNO + Fe) E^2.6
= 10^4 m^{-2} sec^{-1} $ster^{-1}$ Gev^1.6

(ATIC-2, CREAM)

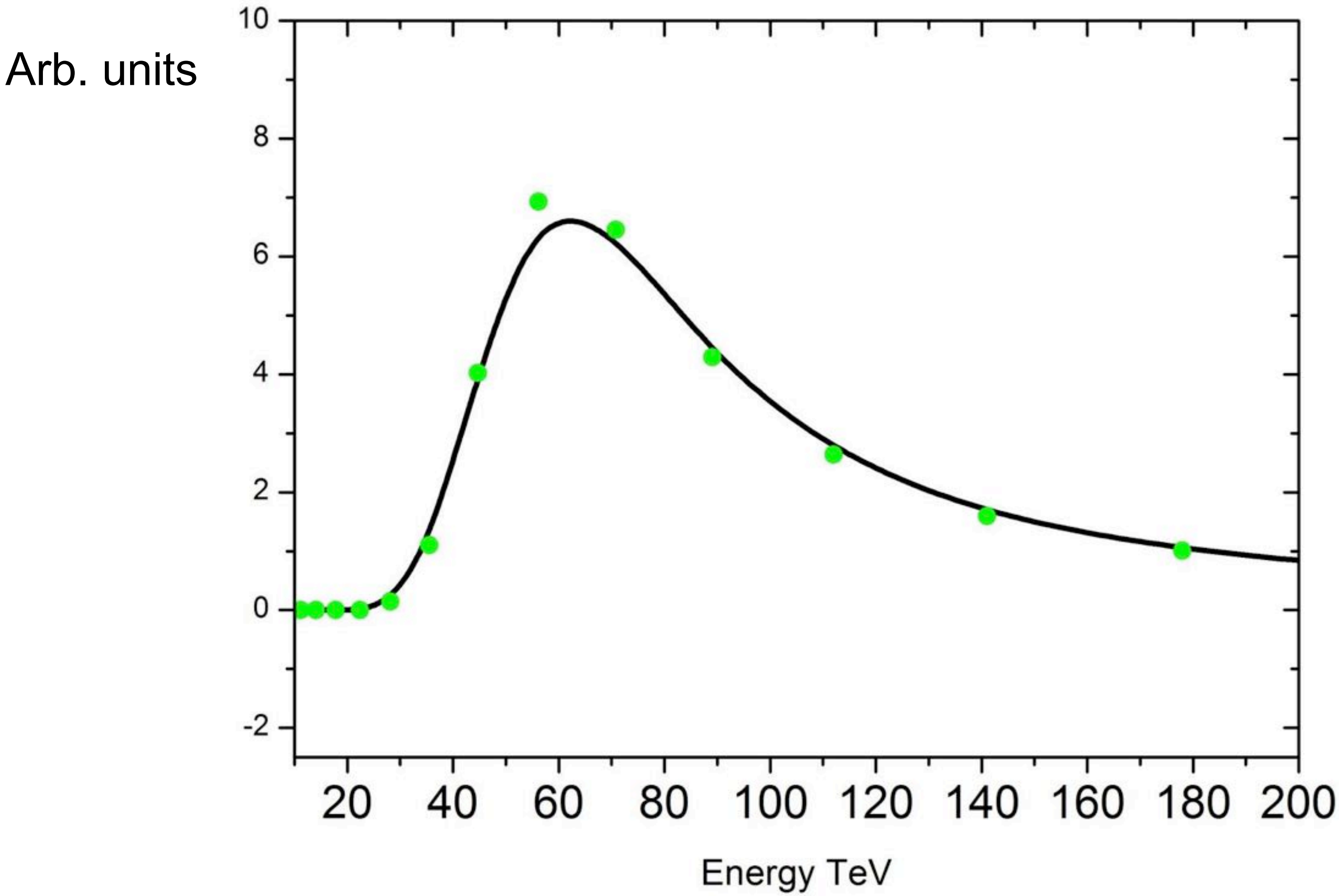
Threshold flux , ph/cm^2	**Array counting rate (≥4 stations), Hz**
0.25	21
0.3	16
0.35	14
0.40	12

Experimental counting rate
18-10 Hz

Energy distribution (MC & Experiment)



Expected energy distribution of events from Crab in TAIGA-HiSCORE



Number of events during 60 hours – 5-20

Excess of events from Crab in 0.4 deg (very preliminary)

Excess during 60 h observation: 10 - 25 depending on selection cuts

Work In progress:

Improvement of reconstruction method for low-E
(core position, direction, energy)

optimization of cut-selection procedure

For next season:

Add the 4-th PMTs in all stations
On-line checking the array counting rate and correction of trigger threshold

Conclusion

1 TAIGA - 5 km^2 hybrid array (500 wide-angle stations and 10-16 IACT).

The sensitivity for local sources in the energy range 30 -200 TeV is expected be **– 10^{-13} erg cm^{-2} sec^{-1} (for 500 h observation)**

2. Deployment of a TAIGA prototype -

58 wide-angle stations and one IACT will be finished in 2017. The sensitivity of the prototype in energy range 30 - 200 TeV is expected to be **– 10^{-12} erg cm^{-2} sec^{-1} (for 200h observation)**

3. The first season of prototype TAIGA-HiSCORE has been successfully carried out. The analysis of the experimental data is in progress. All particle energy spectrum has been reconstructed.

Peak energy in the threshold region is near to 100 TeV (60 TeV for gammas).

10 -25 excess above background in 0.4 deg/ around Crab.

Thank you