Amplitude calibration with the HiSCORE-9 array

Sergey Epimakhov for the HiSCORE collaboration

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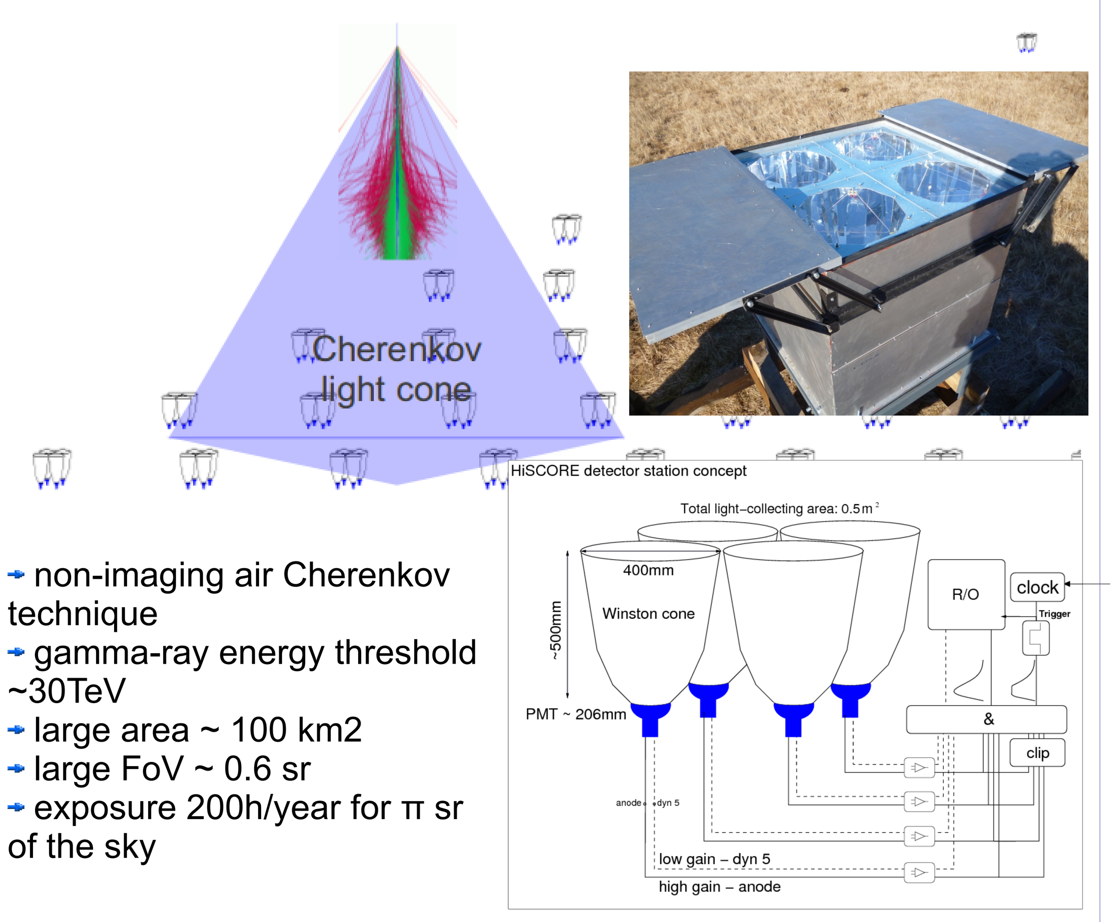
Abstract

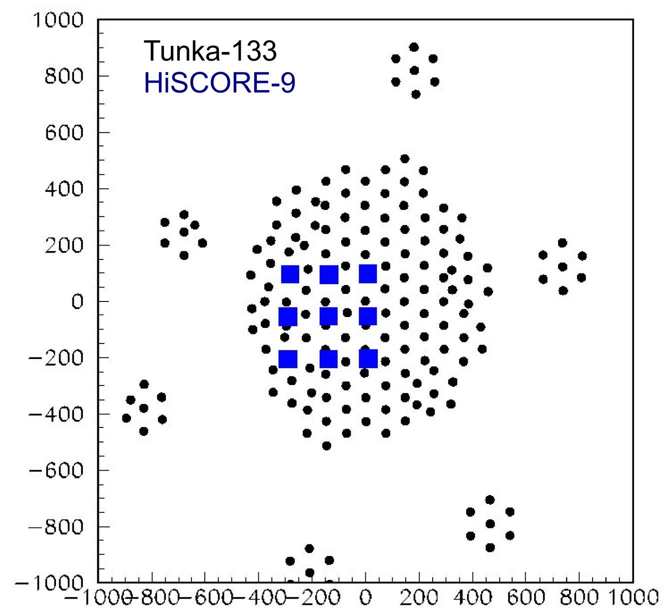
HiSCORE is a non-imaging wide-angle Cherenkov array for the detection of extensive air showers induced by ultrahigh energy gamma-rays above 10 TeV and cosmic ray studies above 100 TeV. Last autumn a 9-station engineering array has been deployed in Tunka valley. We present the first results on the amplitude calibration from the data of second DAQ system and discuss some results of the data analysis.

The HiSCORE concept



- non-imaging air Cherenkov technique
- gamma-ray energy threshold ~30TeV
- large area ~ 100 km2
- large FoV ~ 0.6 sr
- exposure 200h/year for π sr of the sky

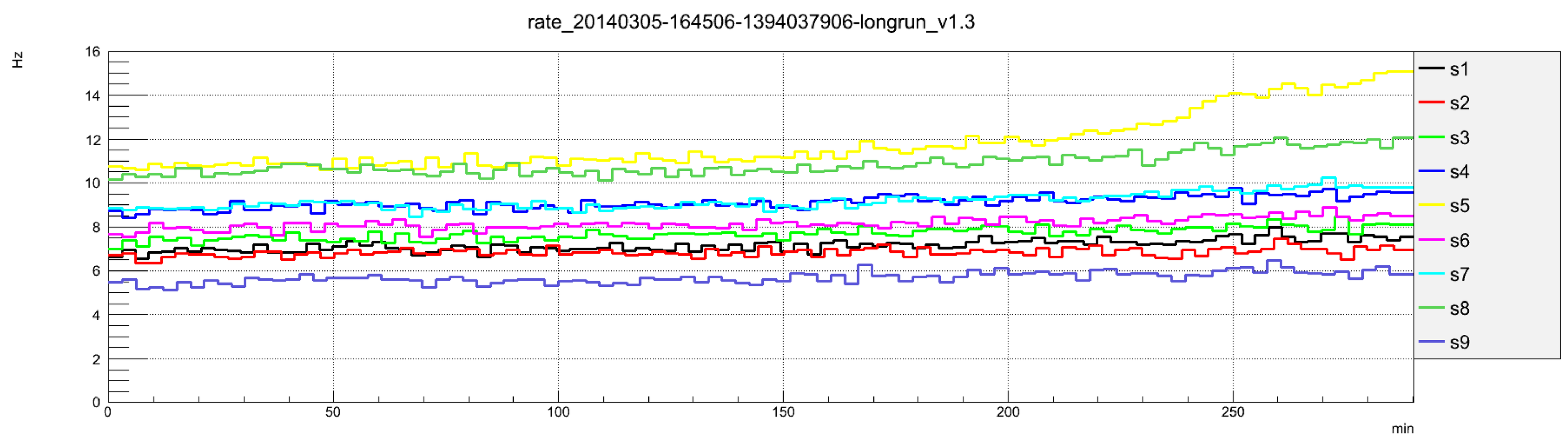
Prototype-array



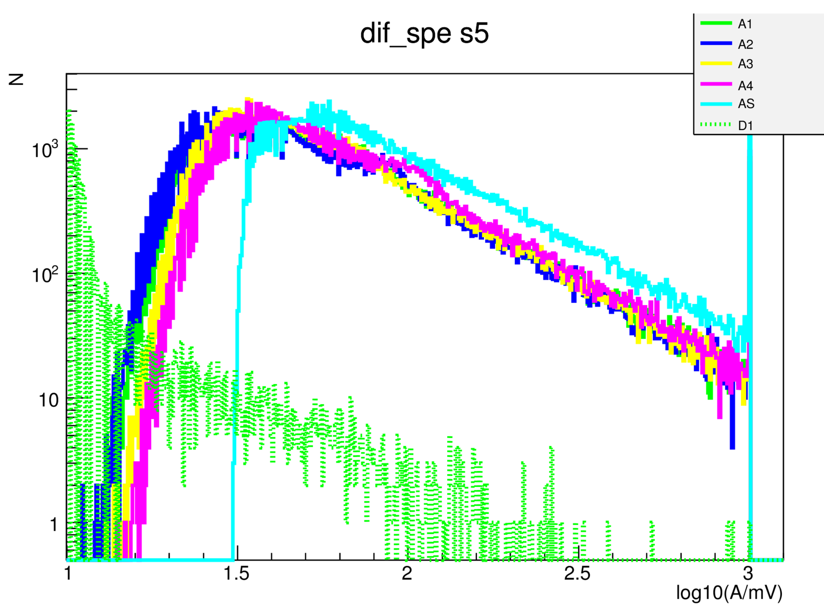
- 9 stations, 300m X 300m
- 150m inter-station distance
- 4 channels (PMT+Winstone cone)
- w/o clipping (analog clipping trigger is planned)
- 2 parallel DAQ systems
- Gamma-ray energy threshold: <100TeV

Daily analysis

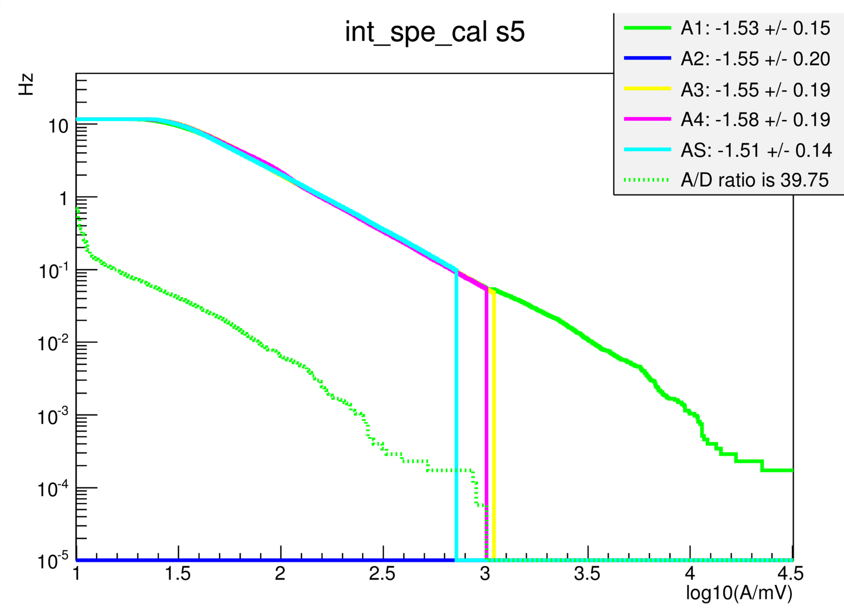
The analysis program is used for daily data checks and amplitude calibration with detailed run summary. Daily script produces different plots and performs necessary analysis for: differential/integral spectra plot, counting rate plot, anode/dynode ratio, event-by-event PC-time difference plot, time distribution plot of a signal relatively to WhiteRabbit pulse in the DRS board.



Rate plot stability



Differential spectra plot of one station



Integral spectra after adjusting amplitude calibration. The legend includes integral slope of the fit in the range 2.5-3 and anode-dynode ratio. Also, dynode extension can be seen for channel 1.

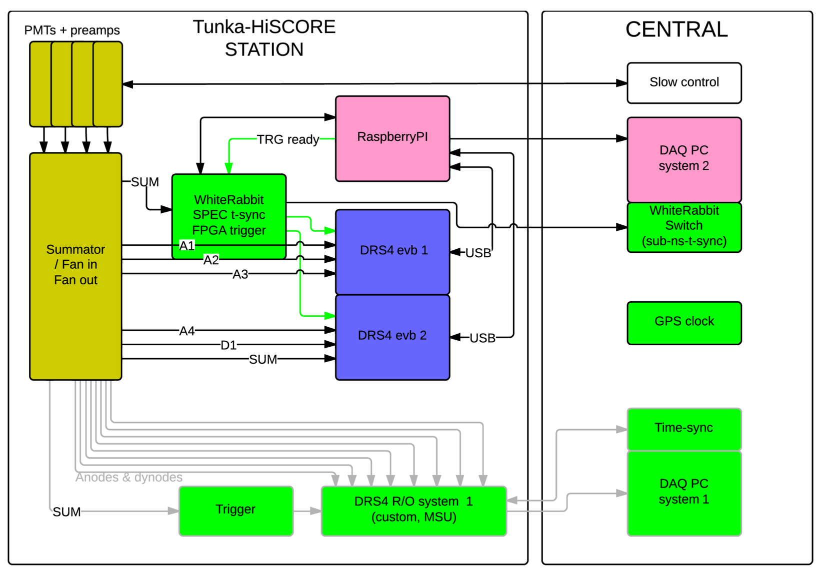
DAQ 2

DRS4 based acquisition system with WhiteRabbit integrated time synchronization[1]. The system is used for data quality cross checks and all necessary tests.

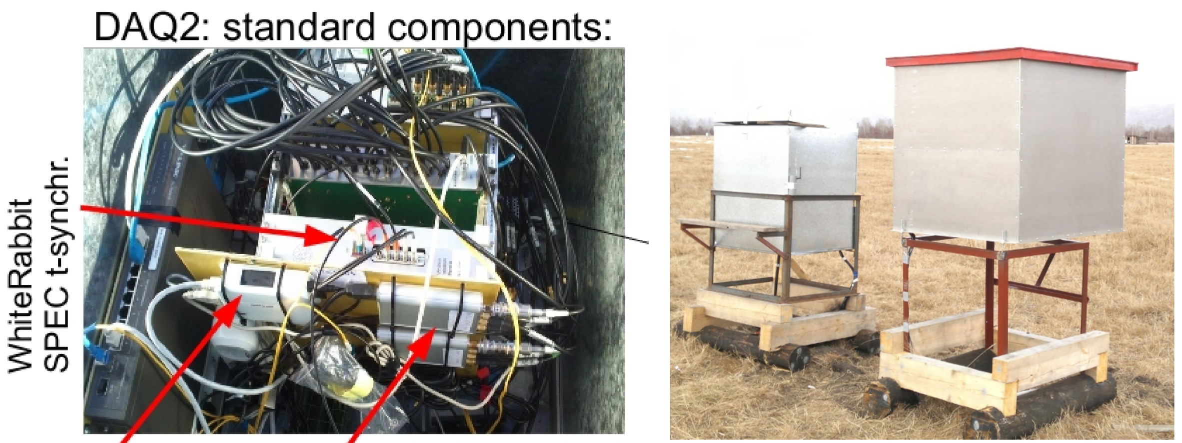
Anode and dynode signals from every PMT go to the summator. Anode signals are summed up. The sum is used for the trigger. The trigger is built with the FPGA on-board the WhiteRabbit card.

We store three anode signals to one DRS4 evaluation board and fourth anode signal, dynode signal and sum to another DRS4 board. Additionally, every board samples the WhiteRabbit trigger.

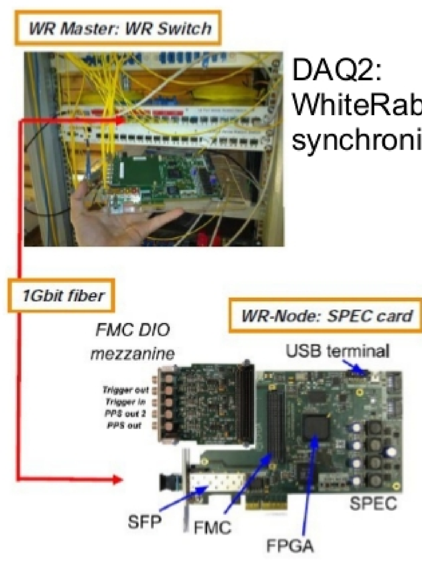
Data is transferred from RaspberryPi PC directly to the central DAQ PC via ssh connection.



DAQ2: standard components:



RaspberryPI, DRS4ev.boards
Inside electronic box of each station



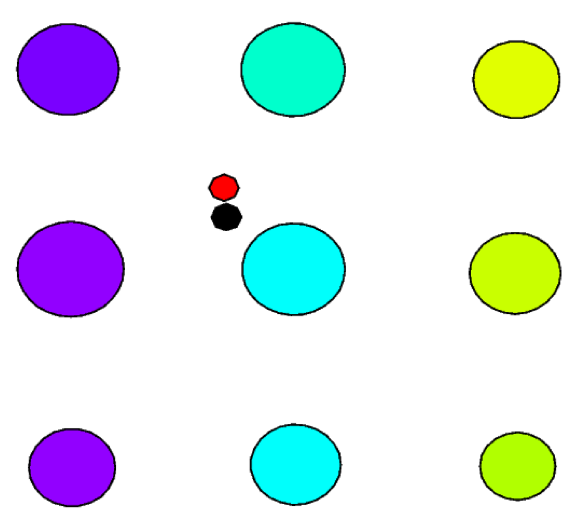
DAQ2: WhiteRabbit time-synchronization

Data reconstruction

The signal amplitude and the signal timing are used for the reconstruction of the core position and the shower direction. The reconstruction is mainly based on the standard tool reco_score [2].

The zenith and azimuth angles are reconstructed using a non-linear shower front model. The energy is estimated from the value of the amplitude-distance function (ADF) at 200 m.

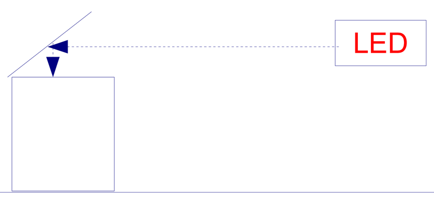
Data event display. Circles size is proportional to log10(A). The color scale indicates arrival time (from blue to yellow). Small circles mark reconstructed core position by Center of Gravity and ADF fit methods.



Data event display.

LED calibration

For calibration, a fast and powerful distant LED source was used in February-March 2014 (22.02, 25.02, 07.03). The horizontal light source Illuminated 45° reflectors at each station.



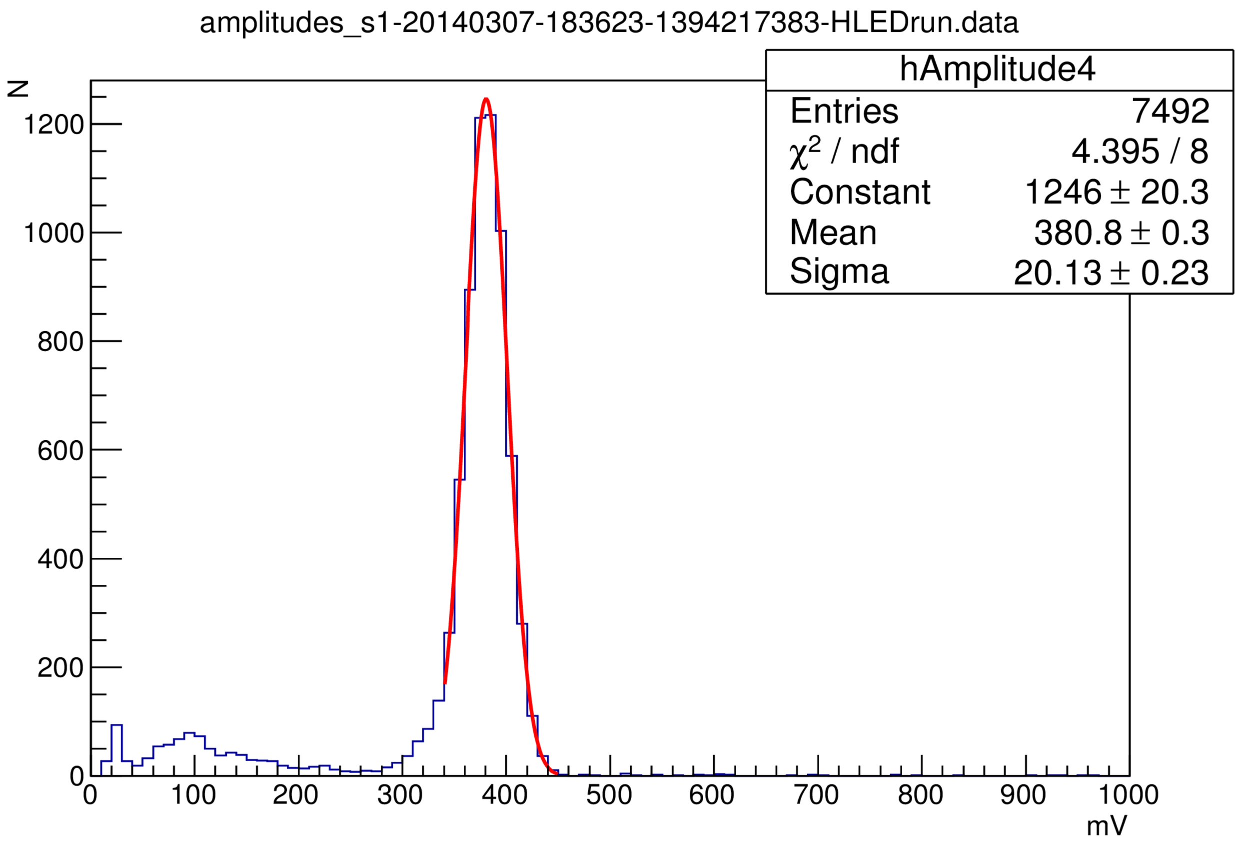
So-called excess noise factor method (F-factor method) can be used here. If the mean value and the signal peak are known, it is possible to extract the number of photoelectrons N. Assuming that the number of photons falling on the photo-cathode has a Poisson variance and noise variance is negligible one can derive the conversion factor:

$C = F^2 * \sigma^2/\mu$ [p.e./mV],

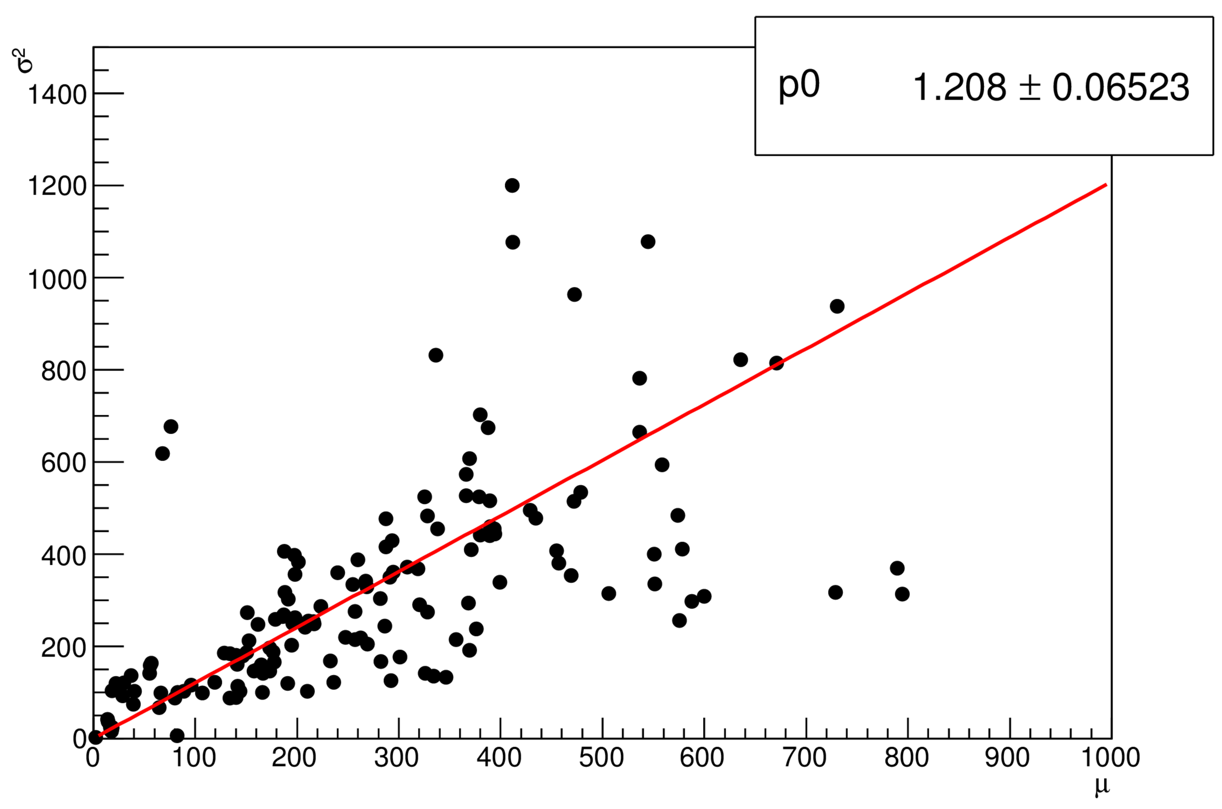
where F is excess noise factor. F squared is equal to 1.5 in our case (Hamamatsu 8''-PMT). Sigma is measured variance of the peak and mu is mean value.

Thus, we can conclude that the average conversion factor C is about 1.8 p.e./mV.

We plan to improve the technique and then to use an amplitude dedicated system for calibration in future.



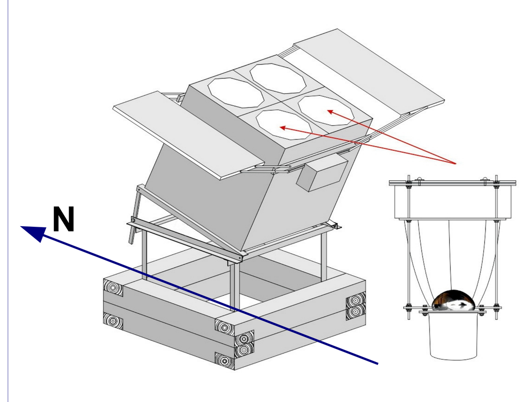
Fitting the DRS4 distribution for LED run with a gaussian.



Overall linear fit of anode channels.

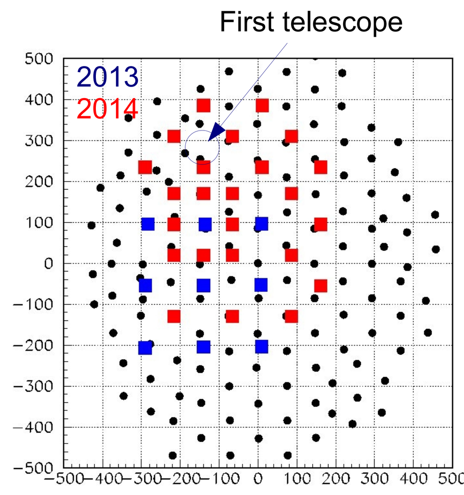
Outlook

- 2014/2015: 25 additional stations
- single DAQ
- planned observation mode: tilted south
- combination with IACT[3] and charge particles counters
- new collaboration TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy))[4]



Tilting mode

First telescope



Possible layout 2014/2015

Reference

[1] A. Porelli et al. Timing calibration and directional reconstruction for Tunka-HiSCORE, this conf.
[2] D. Hampf, Tluczykont, M., and Horns, D. Event reconstruction techniques for the wide-angle air Cherenkov detector HiSCORE. NIM 712, 137 (2013)
[3] M. Kunnas et al. Simulation of the Tunka Area International Gamma-ray Advanced experiment (TAIGA), this conf. S7-401
[4] N. Budnev et al. The Tunka experiment: from cosmic ray to gamma-ray astronomy, this conf.

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