

Horizon-T experiment and detection of Extensive air showers with unusual structures

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for Horizon-T collaboration

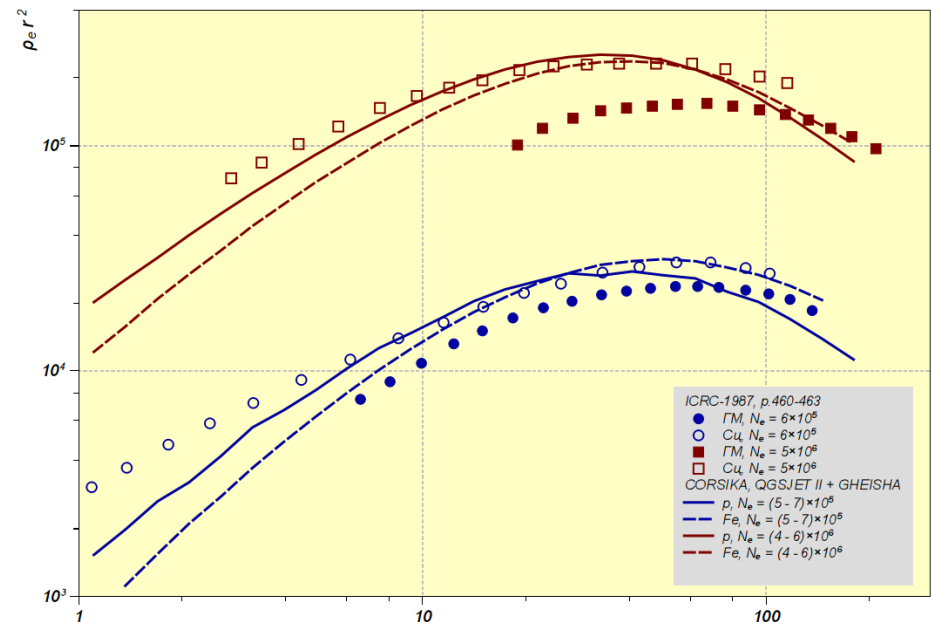
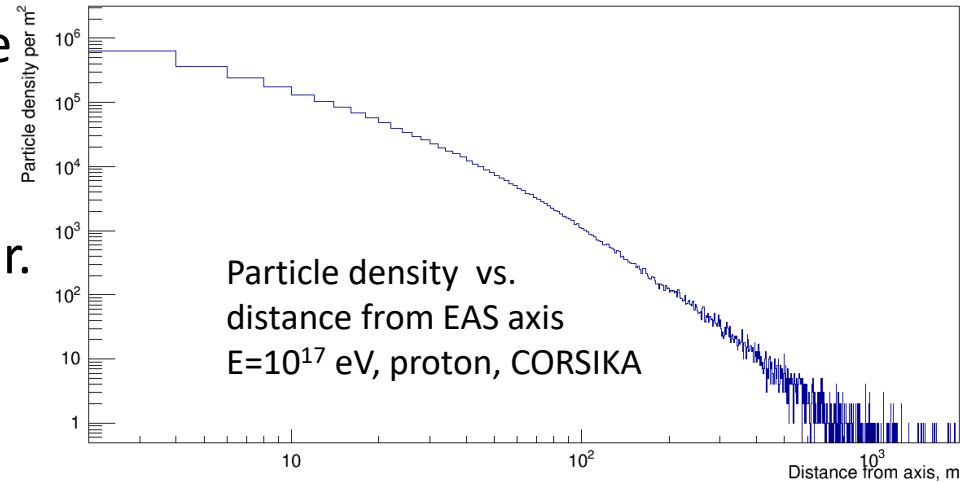
TAUP-2017

Horizon-T Collaboration

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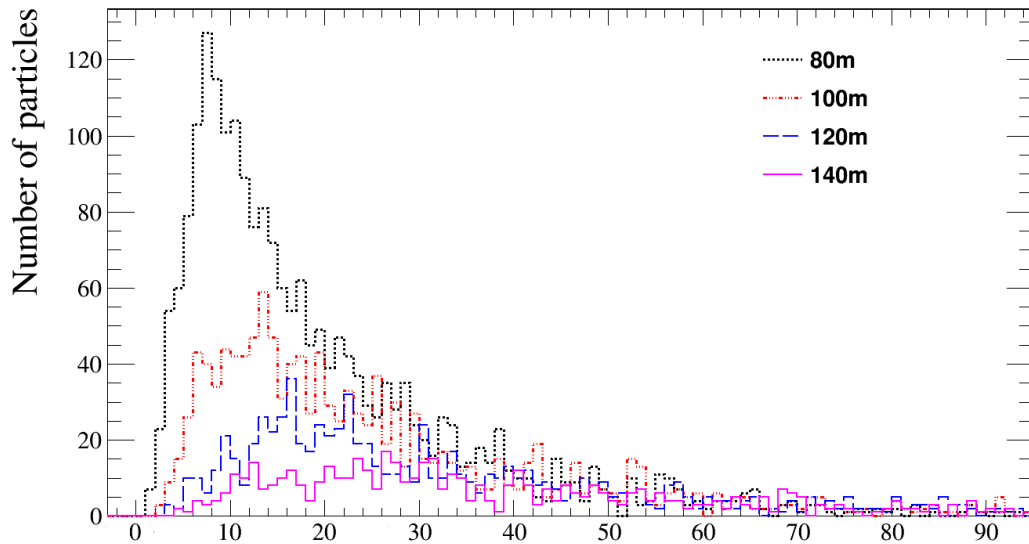
Standard EAS Definition [1]

- CORSIKA* simulation software is based on our current understanding of HEP, thus simulating a ‘**standard**’ shower.
- At observation level, such EAS has a single disk with particle density $\sim 1/r^2$ from the axis
- Experimental data from experiment Hadron
 - Adamov D.S. et al. ‘Phenomenological Characteristics of EAS with $N(E)=2 \cdot 10^{5-2} \cdot 10^{7}$ obtained by the Modern Tien-Shan Installation “Hadron”’, Proceedings of the 20th International Cosmic Ray Conference Moscow, Volume 5, p.460, 1987. Code: 1987ICRC....5..460A

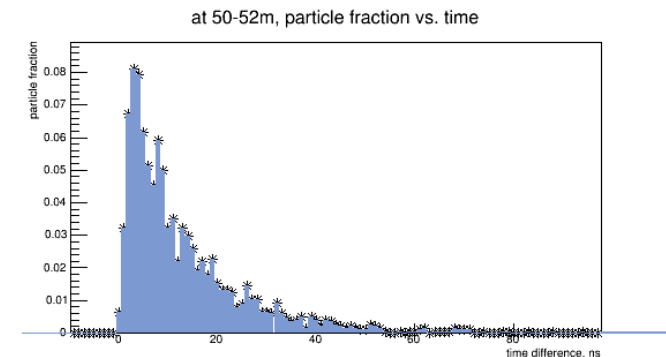
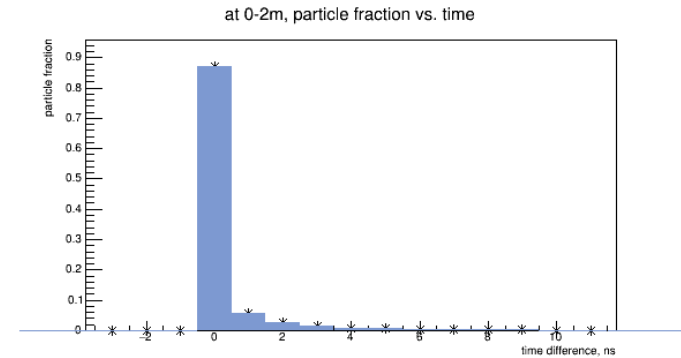


* D. Heck, J. Knapp, J.N. Capdevielle, G. Schatz, T. Thouw. CORSIKA: A Monte Carlo Code to Simulate Extensive Air Showers, Forschungszentrum Karlsruhe Report FZKA (6019)

Standard EAS Definition - TIME



Histograms of particles arriving at observation level at 80 m, 100 m, 120 m and 140 m from EAS axis, $E=10^{17}$ eV, proton, CORSIKA

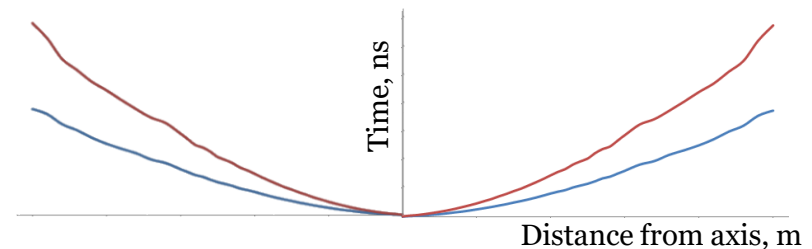


Time distribution of particles passage in simulated EAS vs distance from axis

Disk passage time is growing with r
Plots are for $E=10^{17}$ eV proton.

Can use both particle density and pulse shape information with timing from each detection point

Need time resolution <10ns



Standard EAS Definition - TIME

Hadrons
Muons
Electrons

Proton, $\lg E/eV = 16$
 $t = 0 \mu s$

.

At the observation level:

- 'Classical' methods:
 - Use chronotron to get angles/direction
 - Use density distribution function to get axis position, E_0
- Additions:
 - Use additional pulse width information to get axis position, E_0
 - Individual EAS information

Charged particles arrival widths.
(10% to 50% of pulse area)

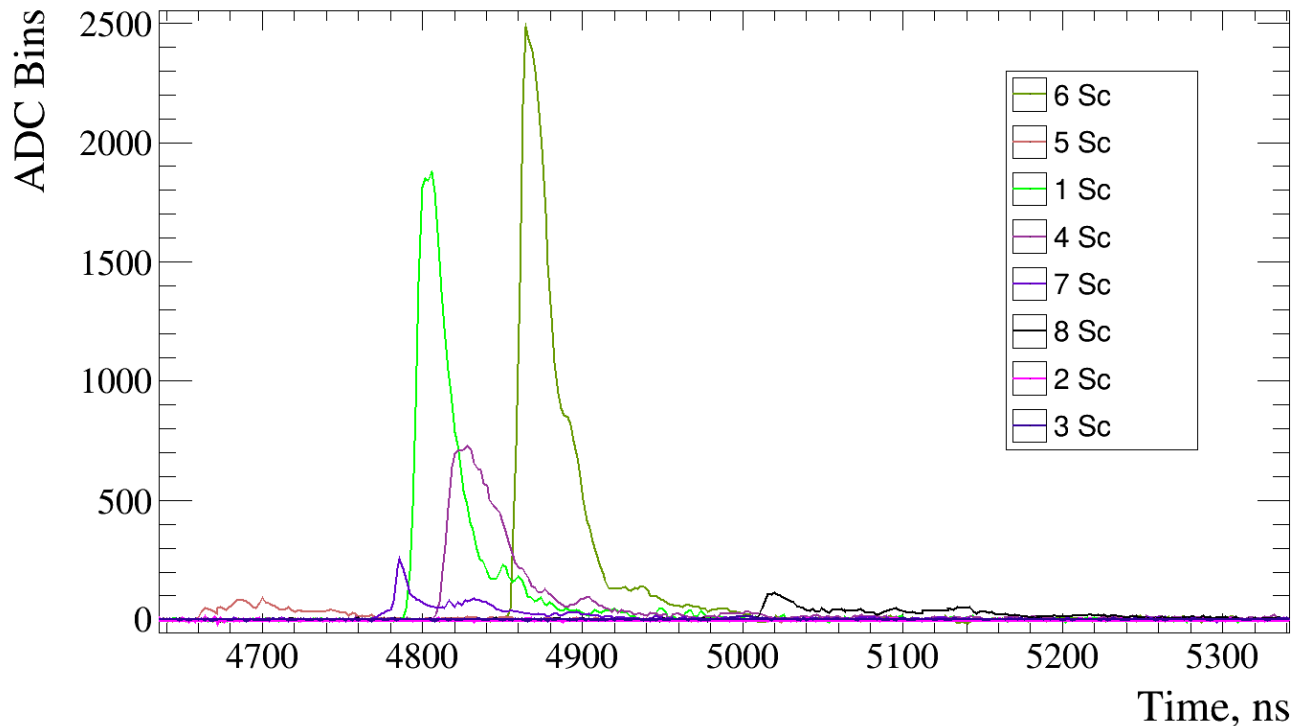
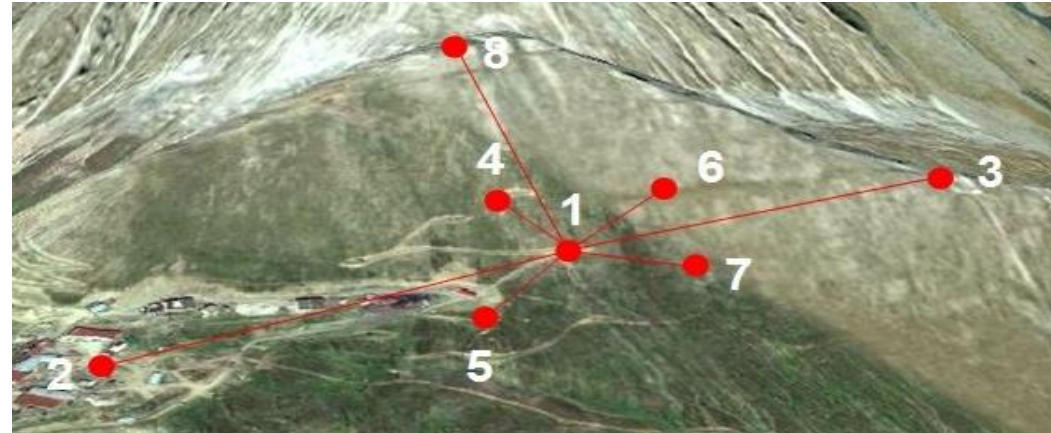
Observation level with detectors

EAS animation.

$E=10^{16}$ eV, proton, CORSIKA

Distance to axis, m	50	100	150	200	250	300
Width, ns	4.60	13.15	24.13	37.0	51.3±	66.5
	±0.08	±0.23	±0.45	±0.6	0.9	± 1.0

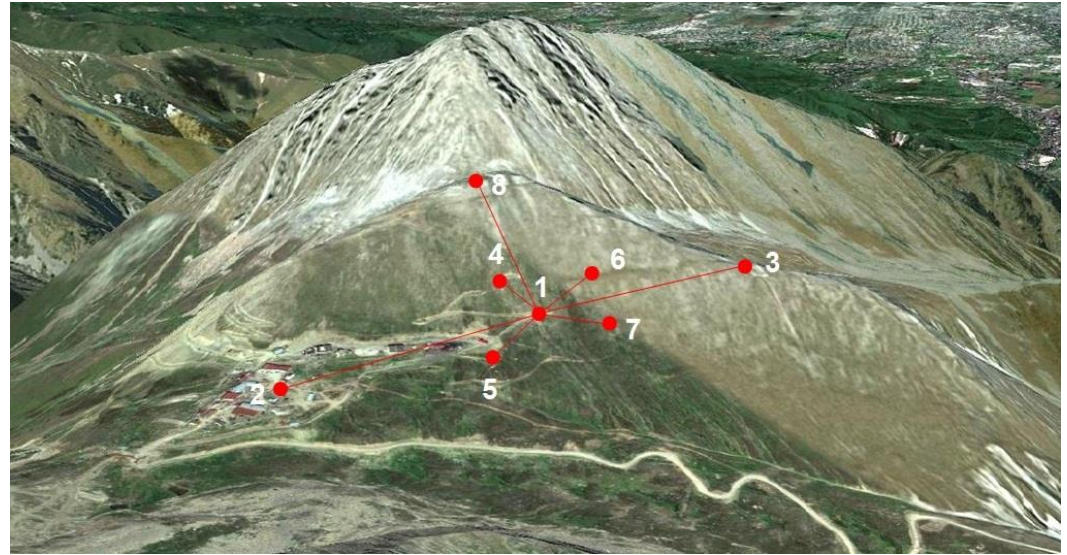
EAS data sample



- Axis between points 6, 1 and 4
- $E_0 \sim 3 \cdot 10^{16} \text{ eV}$

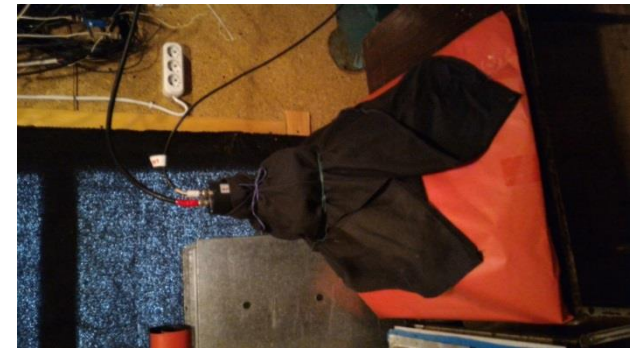
Horizon-T (HT) Detector System [1][2]

- An innovative detector system [1] [2]
 - pulse shape \rightarrow disk width information, 2ns resolution
- EAS $E > 2 \cdot 10^{15}$ eV
- Zenith angles ($0^\circ - 85^\circ$).
- At Tien Shan high-altitude Science Station at ~ 3340 meters above the sea level
- **Eight** charged particle detection points [3] [4]
 - separated by the distance up to one kilometer
- Optical detector subsystem
 - to view the Vavilov-Cherenkov light from the EAS



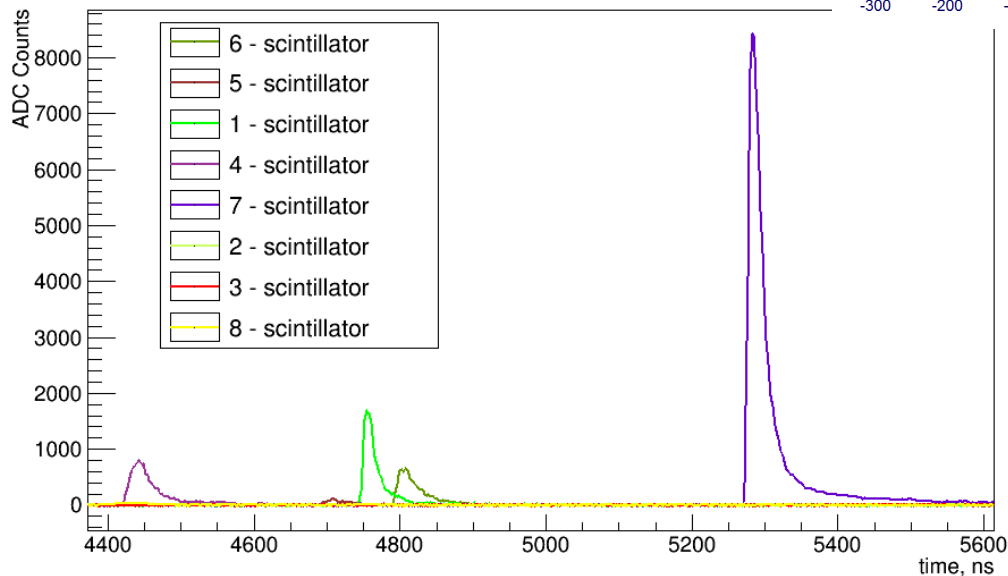
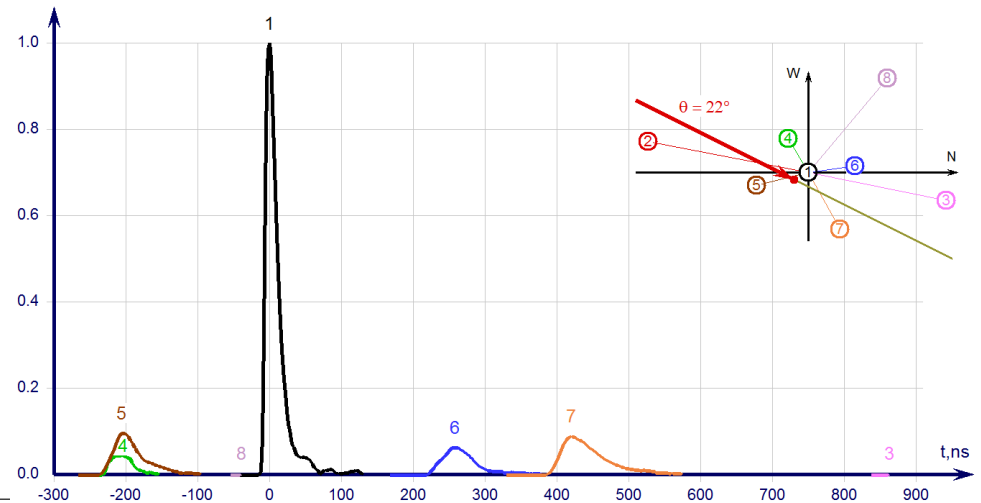
HT changed particle detectors

- Scintillator
 - ~ 7 ns pulse front resolution
- Glass
 - ~ 2.1 ns pulse front resolution



Data for Standard EAS

- Standard EAS signal from HT detector
- Corresponds to simulation data

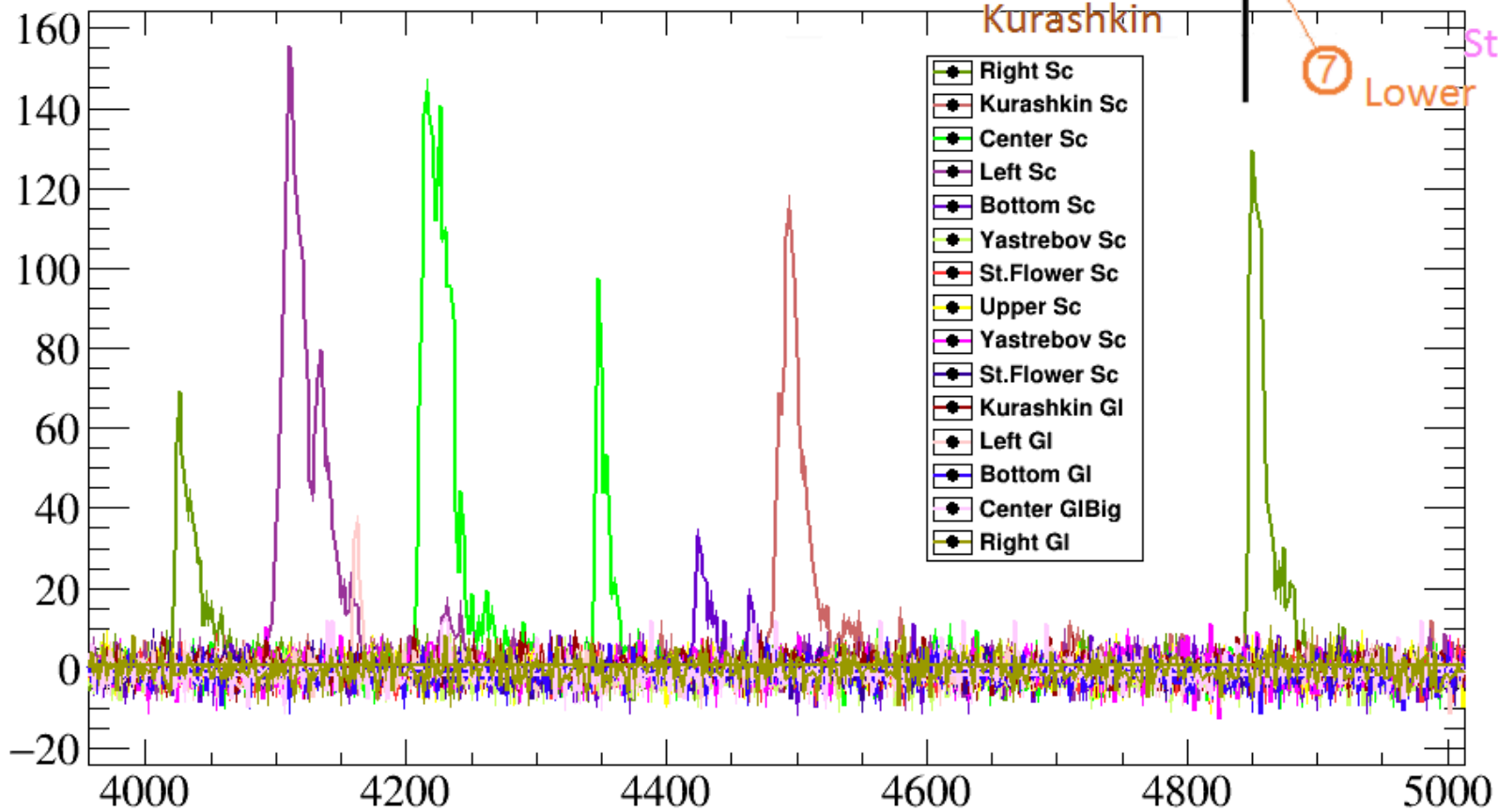
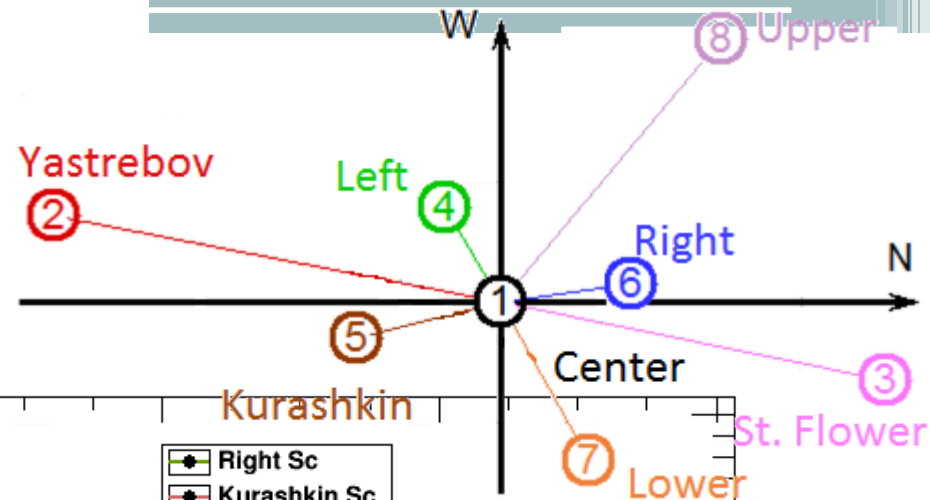


- Estimated Energy:
 - $\sim 10^{16}$ eV (top) at low angle
 - $\sim 2 \cdot 10^{16}$ eV (left) high zenith angle

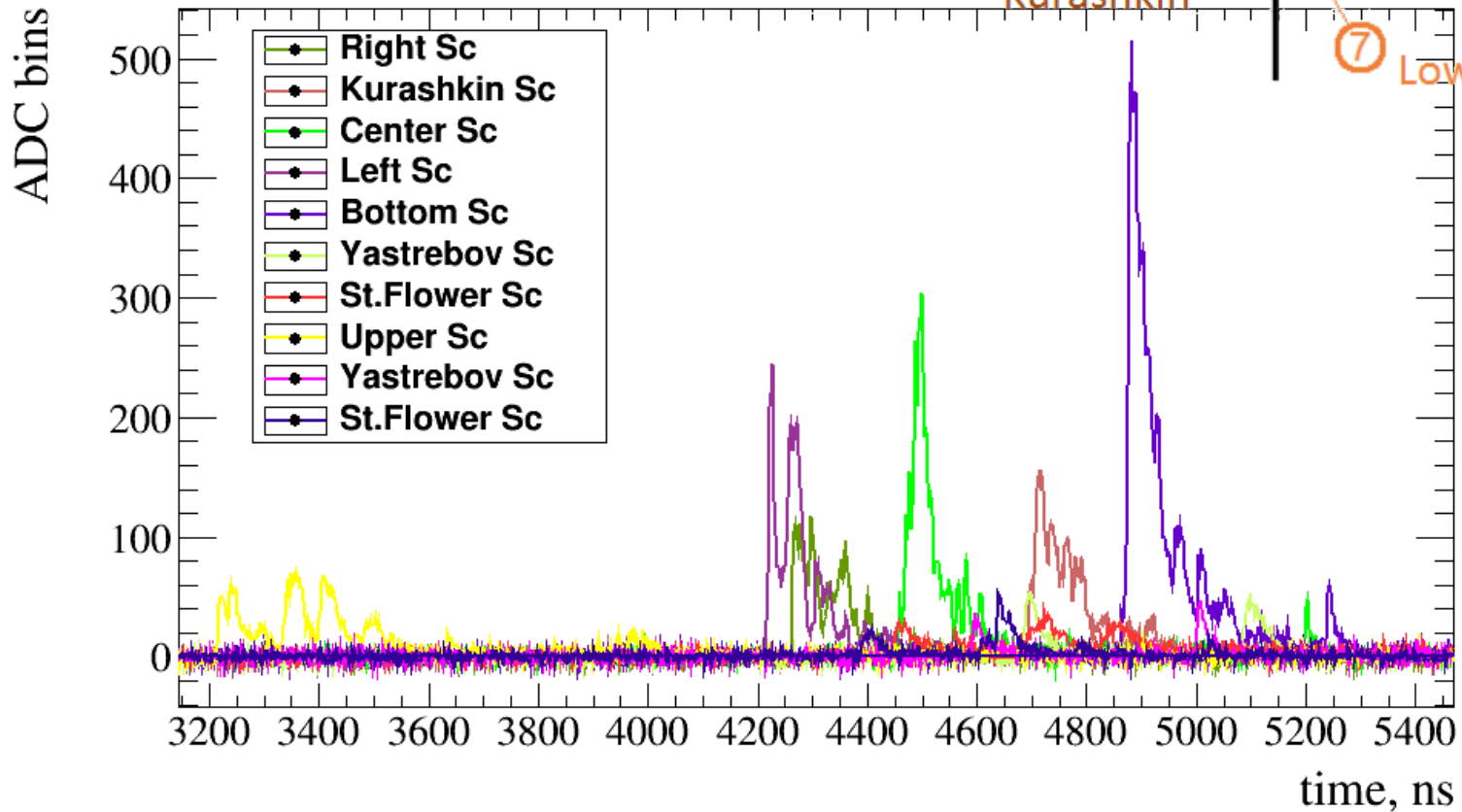
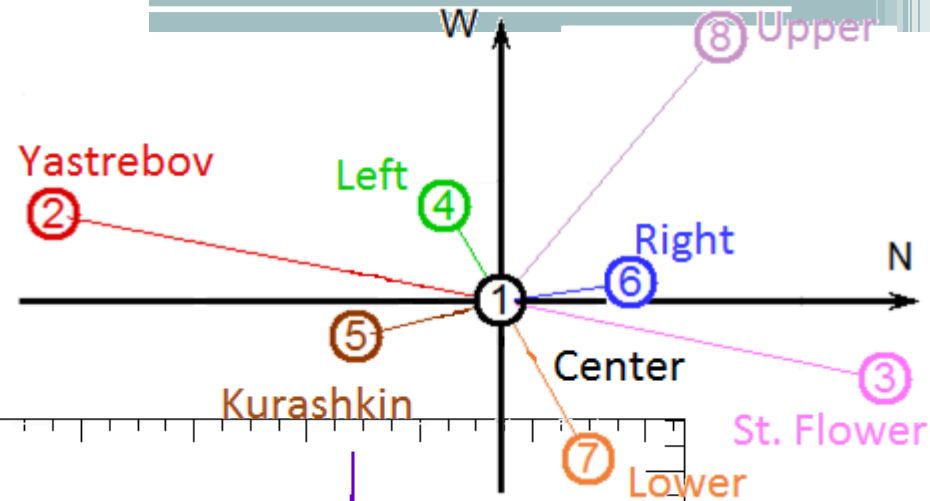
Types of events

- Multi-modal events
 - Multiple peaks in more than one detection point.
- Unusual
 - A specific type of multi-modal? Related to delayed-particle? One large peak, then at near to it points - a 'fence', then multi-modal peaks at far points – can be analyzed?

Multiple maxima Apr22002340-2017

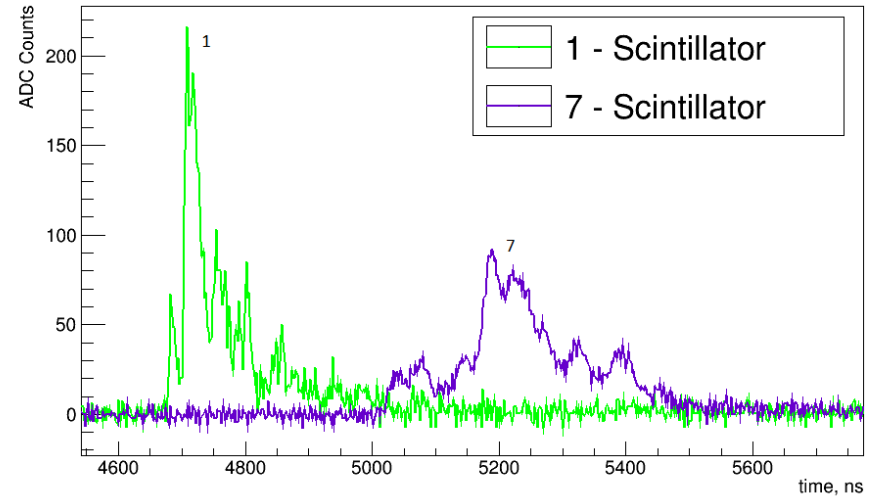
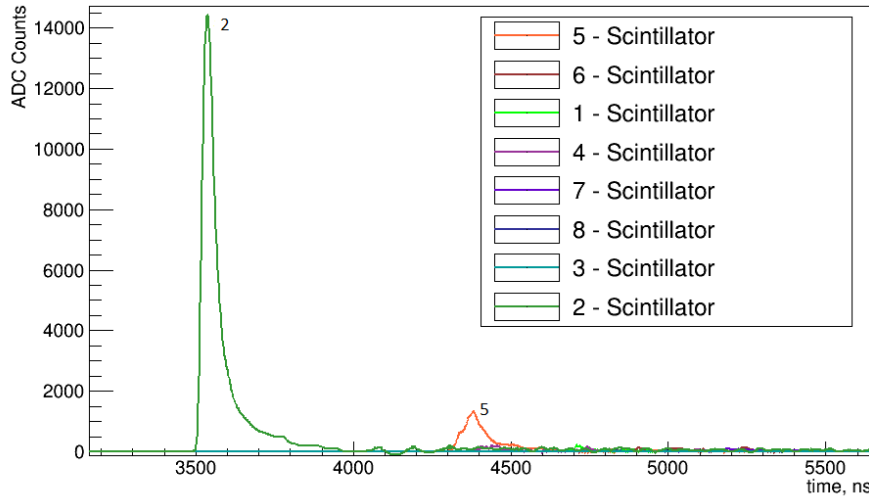


Multi-modal Apr21 145622'17

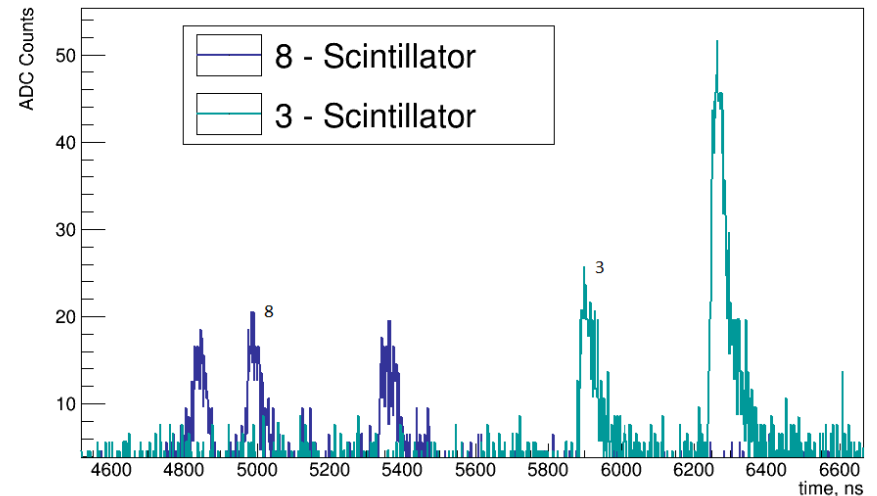
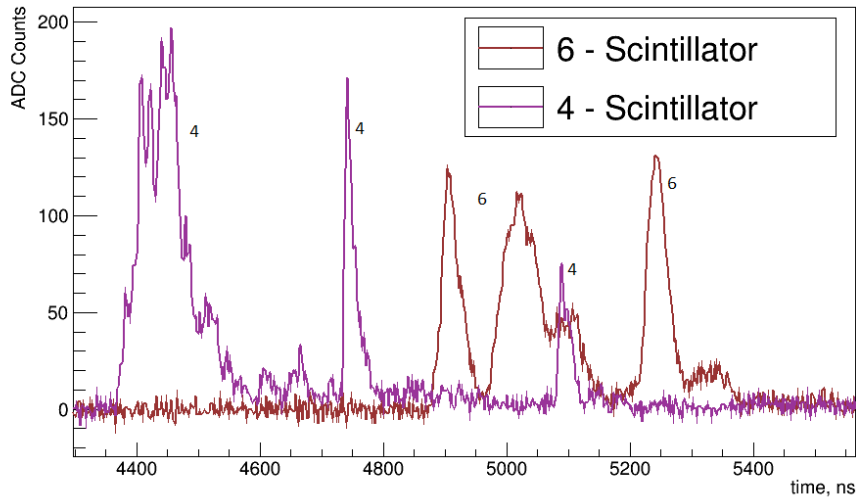


Unusual EAS at HT

Jan26035100'16

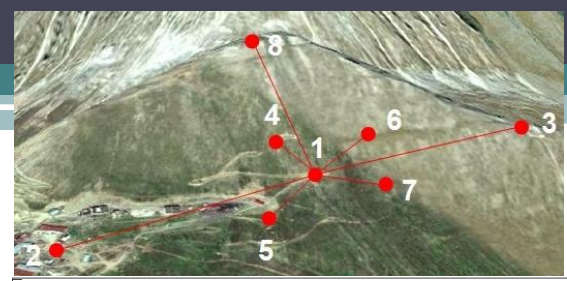


Event of Jan26 '16

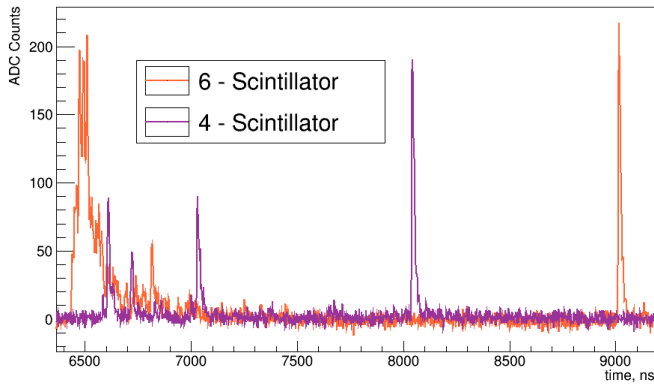
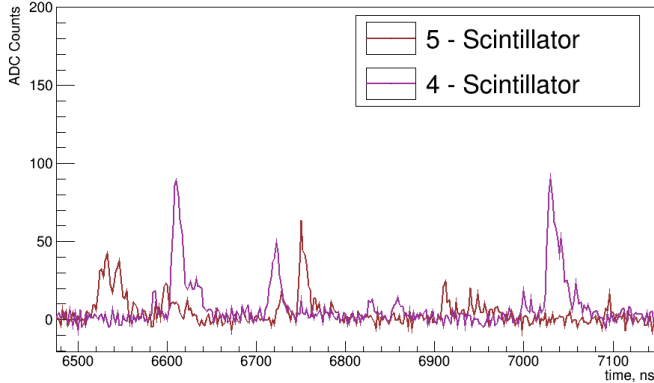


Unusual EAS at HT

Oct07131310'16

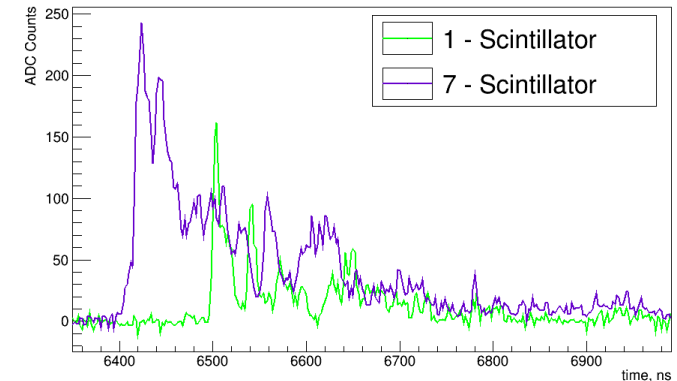
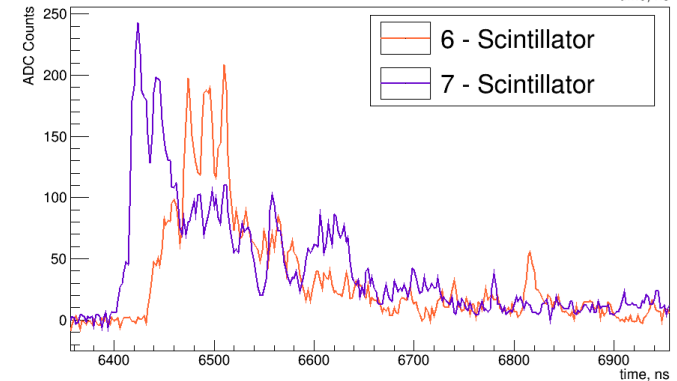
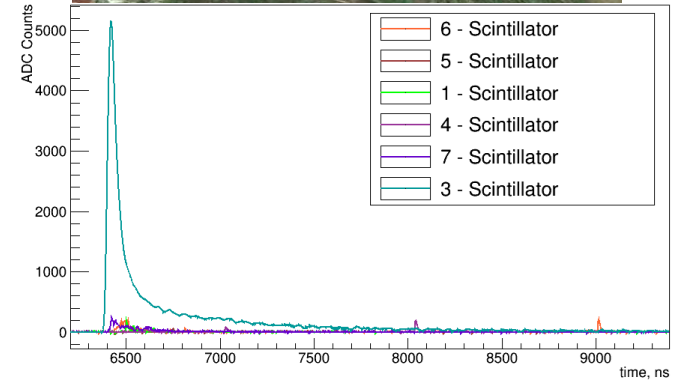


Event of
Oct 07 '16



New class of
events

- Observe similar features:
 - One large pulse near core
 - Multi-peaked mashed pulses at mid-range
 - Highly separated multi-modal pulses at large distances from core



New Physics?

- At $E >$ about 10^{17} eV
 - All events have this unusual structure
- Exhibit same features - pulse multimodality
 - Hypothesis rules out – multiple EAS overlapping
- If same parent – large transverse angles in EAS
 - Typ. Angles $\sim 10^{-4}$ rad
 - From pion decay at typ. $E \sim$ TeV or 100GeV
- Need ~ 0.1 rad
 - New particle? New interaction?
 - In SM, prob. for heavy particle to appear $\sim 1/\text{m}^2$

Future Plans

Artist's concept of HT-KZ detector module, by Tatiana Beznosko



- ❑ Increase scintillator area on HT far periphery points
 - ❑ (in progress)
- ❑ Future plan is to construct the HT-KZ (HorizonT-Kazakhstan) detector system
 - ✓ to study the newly discovered event class of multi-modal signals that may indicate the new physics discovery
 - ✓ to measure the directions to the origins of the UHECRs that are being currently studied at higher energy range.
- ❑ Construction will be done at NU, SST, by CRPg with a collaboration of Physics, Robotics and Mechatronics, Computer Science departments and ECL

Thank you for your attention.

- Any questions?

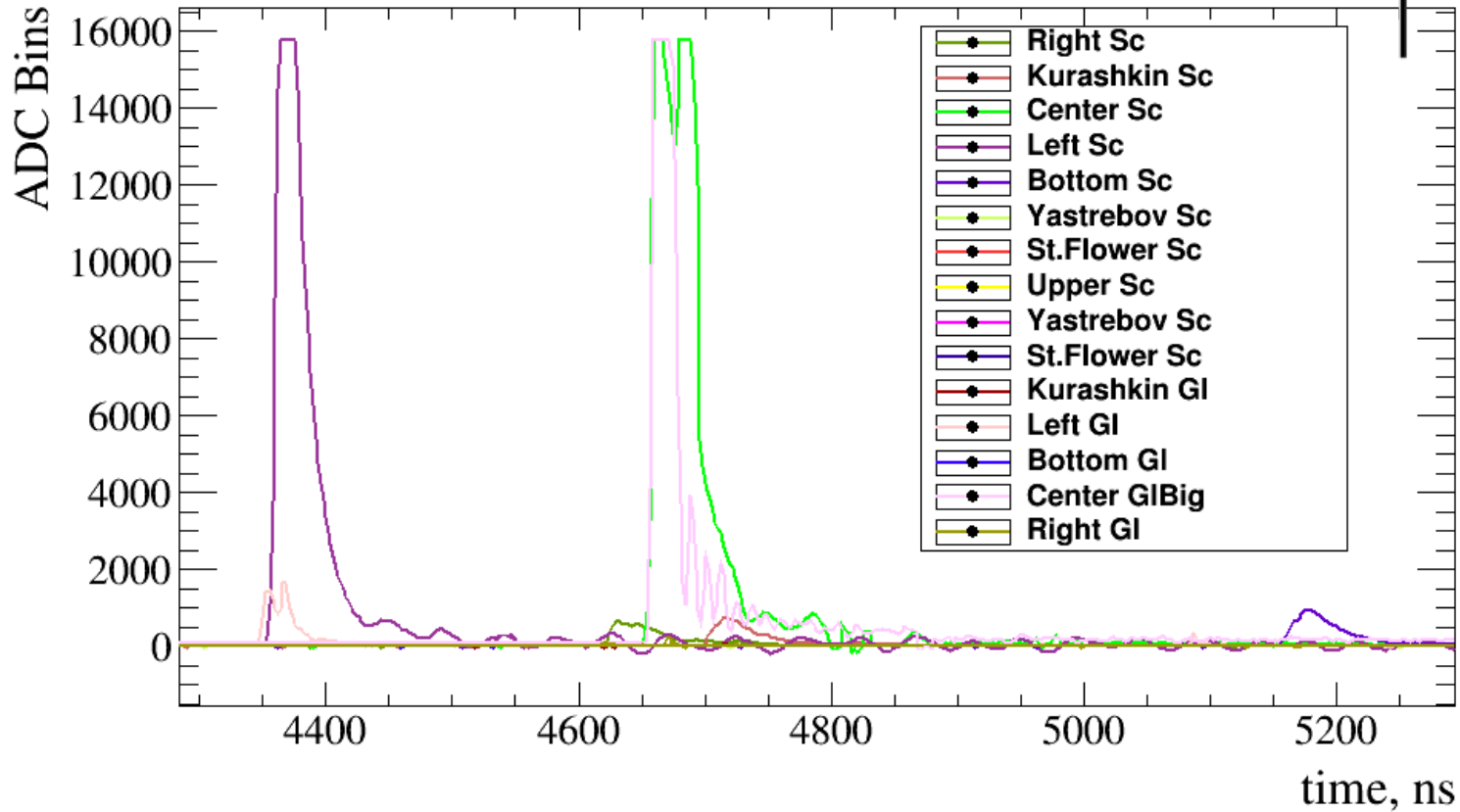
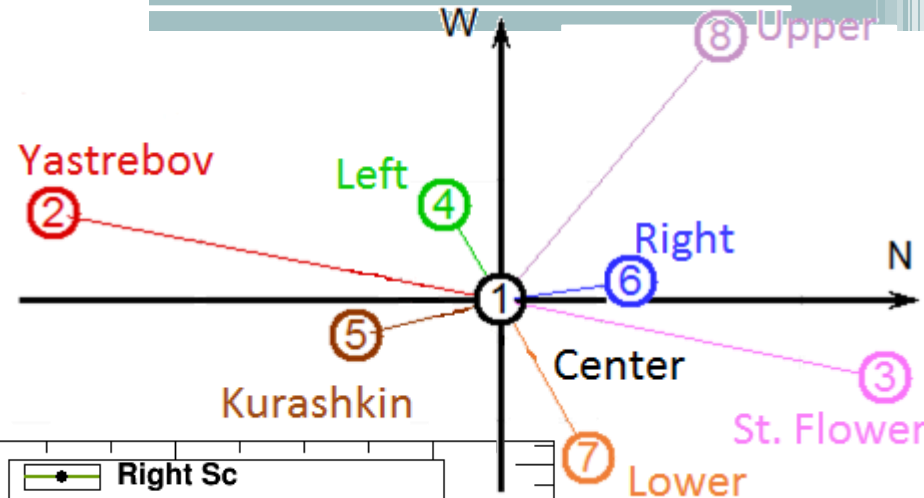
- **References:**

- [1] D. Beznosko et al., "Horizon-T Extensive Air Showers detector system operations and performance," in PoS(ICHEP2016)784, proceedings of ICHEP2016, Chicago, 2016.
- [2] RU Beisembaev, EA Beisembaeva, OD Dalkarov, VA Ryabov, AV Stepanov, NG Vildanov, MI Vildanova, VV Zhukov, KA Baigarin, D Beznosko, TX Sadykov, NS Suleymenov, "The 'Horizon-T' Experiment: Extensive Air Showers Detection," arXiv:1605.05179 [physics.ins-det], May 17 2016.
- [3] D Beznosko, T Beremkulov, A Iakovlev, Z Makhataeva, M I Vildanova, K Yelshibekov, V V Zhukov, "Horizon-T Experiment Calibrations-Cables," arXiv:1608.04312, 8/2016.
- [4] Adil Baitenov, Alexander Iakovlev, Dmitriy Beznosko, "Technical manual: a survey of scintillating medium for high-energy particle detection," arXiv:1601.00086, 2016/1/1.
- [5] Duspayev et al., "The distributed particle detectors and data acquisition modules for Extensive Air Shower measurements at "Horizon-T KZ" experiment," in PoS(PhotoDet2015)056, in proceedings to PhotoDet2015 conference, Moscow, 2015.

Other events

- Multi-peak
 - High peaks in two or more detection point. Small peaks at other points. Particles distribution at high angles? Analysis pending.

Multi-peak event Apr06'17, at 62°



Multi-peak Dec 29'16, at 63°

