Novosibirsk State University
*THE REAL SCIENCE

SiPMs for registration of scintillation and Cherenkov radiation

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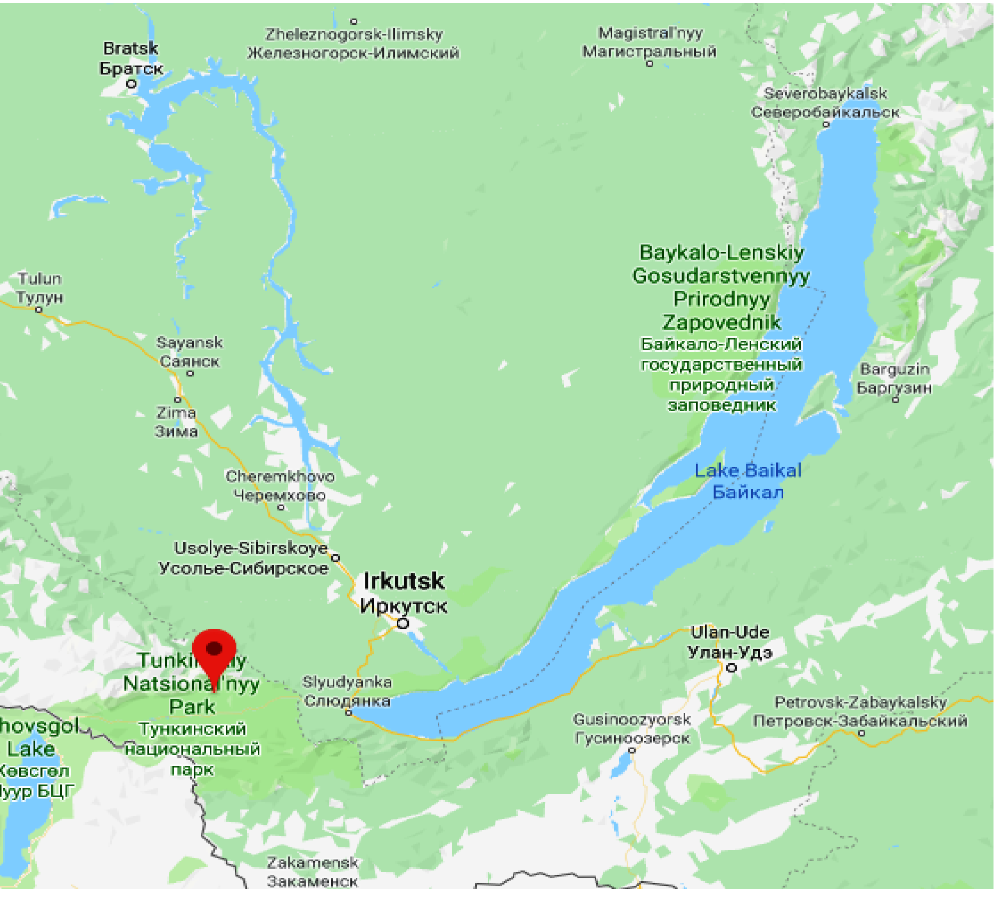
Outline

1. PMT vs SiPM
2. TAIGA project
3. Muon scintillation detector
4. Experiment
5. Conclusion and outlook
6. Super Charm–Tau Factory
7. Alternative PID system for SCTF
8. Experiment
9. Conclusion

TAIGA

Tunka Advanced Instrument for cosmic rays and Gamma Astronomy observatory

Tunka valley, the Republic of Buryatiya



Research area:

- **Primary cosmic rays**
  PeV–EeV
- **Primary gamma rays**
  TeV–PeV

+ their sources

TAIGA

Setups for registration of

- Secondary cosmic particles
- Cherenkov light
- Radio emission

from air showers

Tunka-133

Tunka-Rex antennas

Tunka-Grande scintillators

TAIGA

TAIGA-IACT
(Imaging Atmospheric Cherencov Telescope)

TAIGA-HiSCORE
(High-Sensitivity Cosmic ORigin Explorer)

+ TAIGA-Muon

TAIGA-Muon

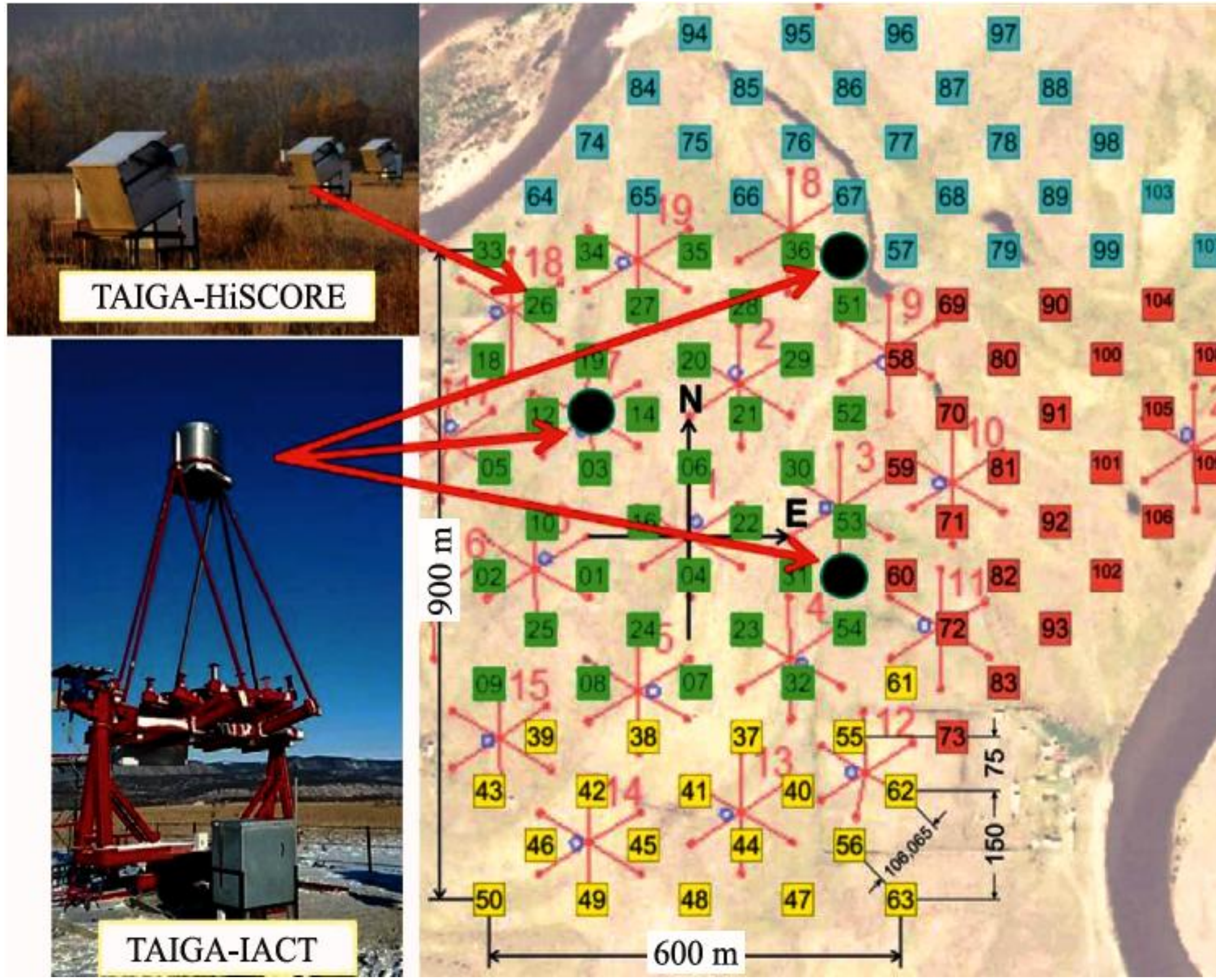
Setup area – 1 km²

Total scintillator area–2000 m²

Improving of gamma-hadron separation

Continuous collection of statistics

PLAN



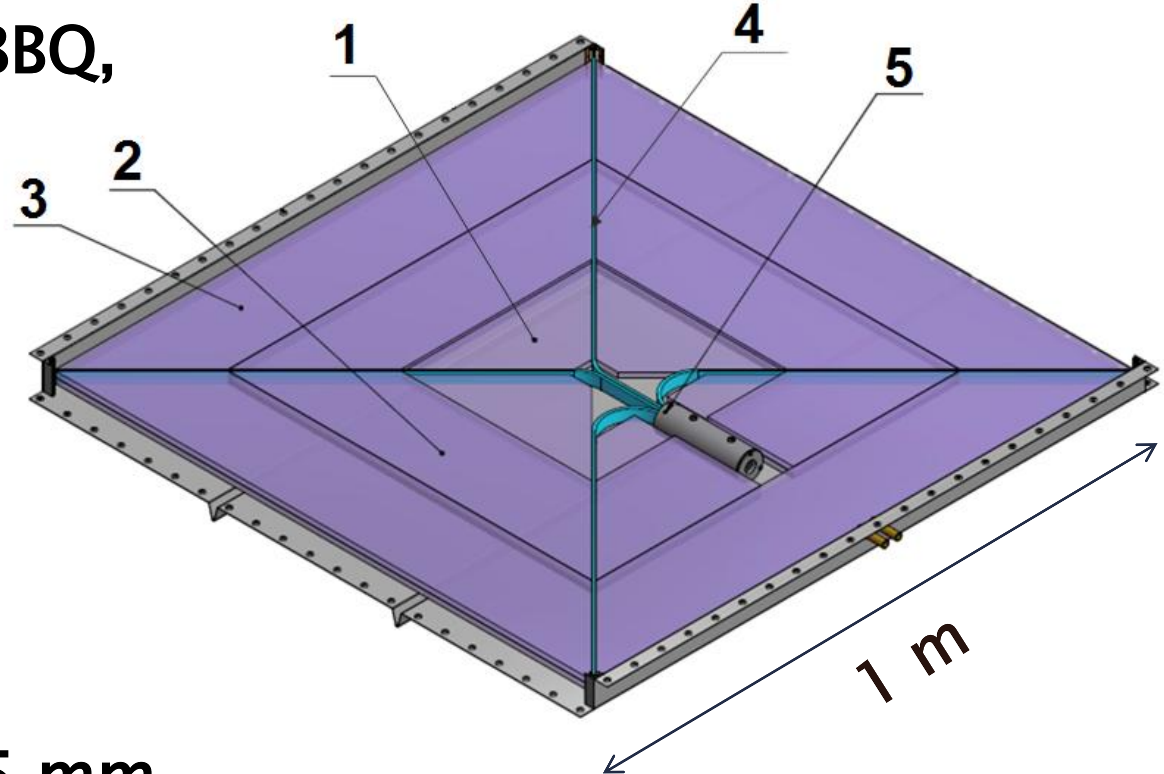
Muon scintillation detector

Cross section of the shifters – 5x20 mm²

Reemitting addition – BBQ,
n = 0.1 g/kg

Thickness of
scintillation plates
1,2 – 10 mm
3 – 2x10=20 mm

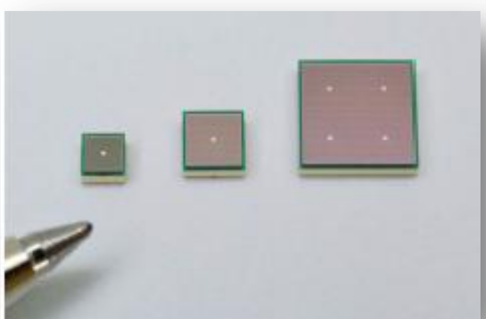
PMT entry window – 25 mm



1, 2, 3 – scintillator based on polystyrene,
4 – reradiating light guide plates (shifters),
5 – PMT

PMT vs SiPM

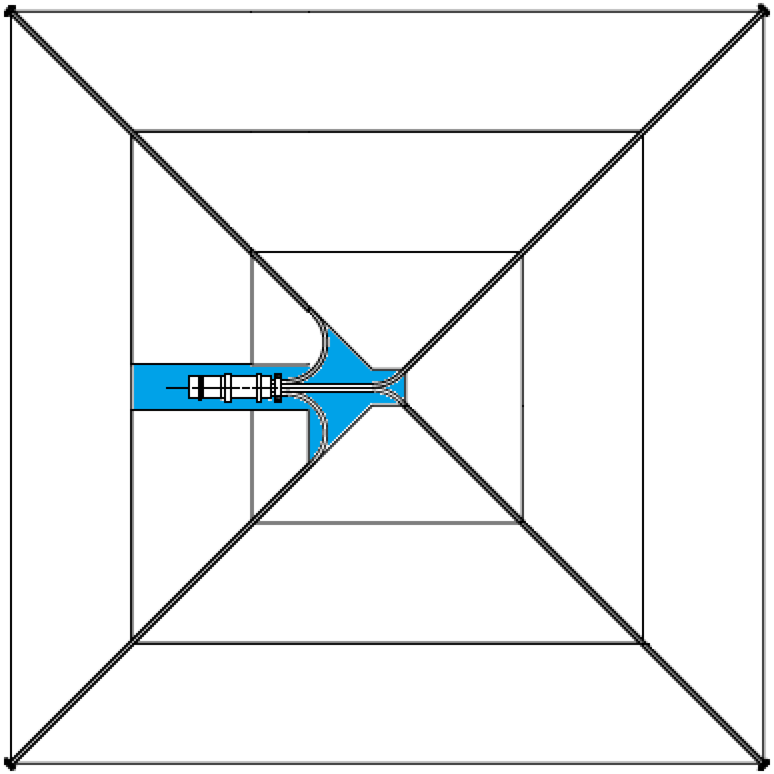
	PMT	SiPM
Size	10 cm	6 mm
Sensitivity to magnetic fields	yes	no
Operating Voltage	~ 1 kV	~ 50 V
Quantum efficiency	~ 20% (420 nm)	~ 40 %

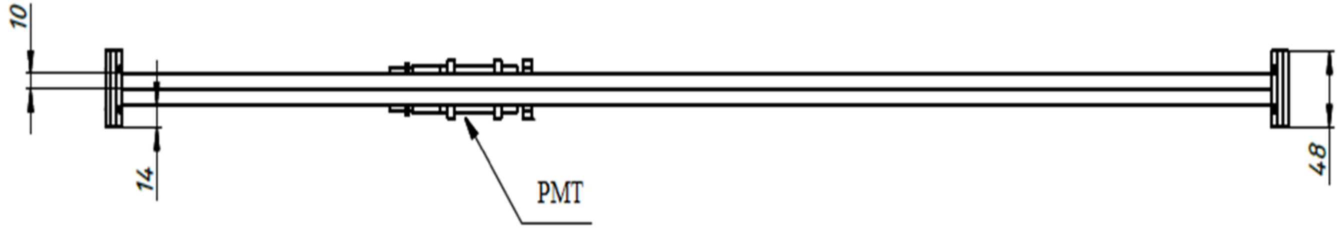


- **SiPM has a long service life, high operation speed and a wide spectral range**

SiPM instead PMT

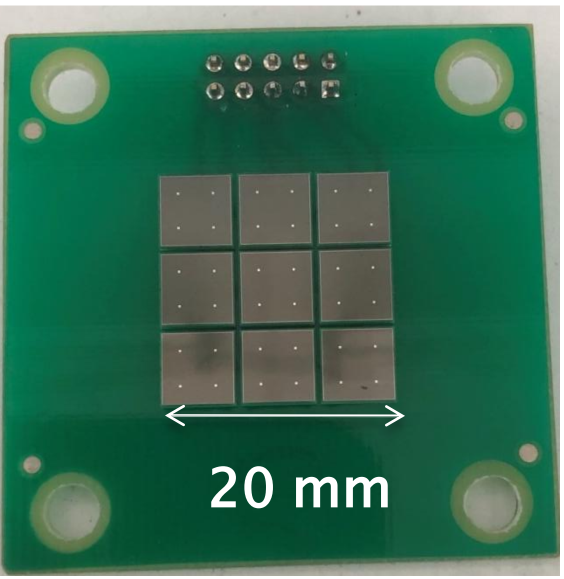
- Higher photon registration efficiency
- Increase the sensitive area
- Decrease the transverse size of the detector
- Simplification of its design



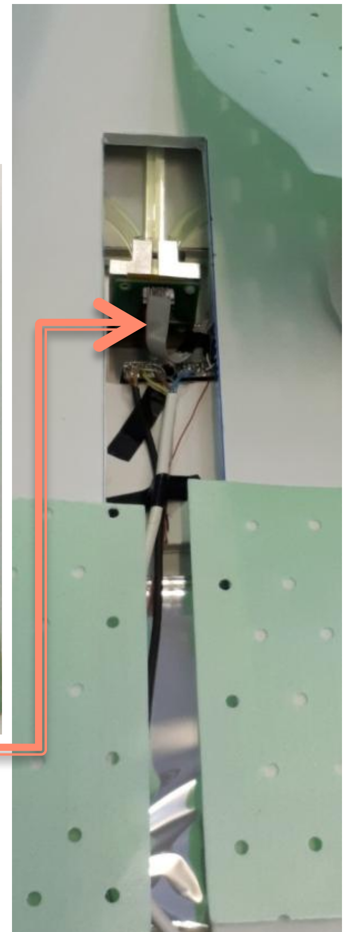


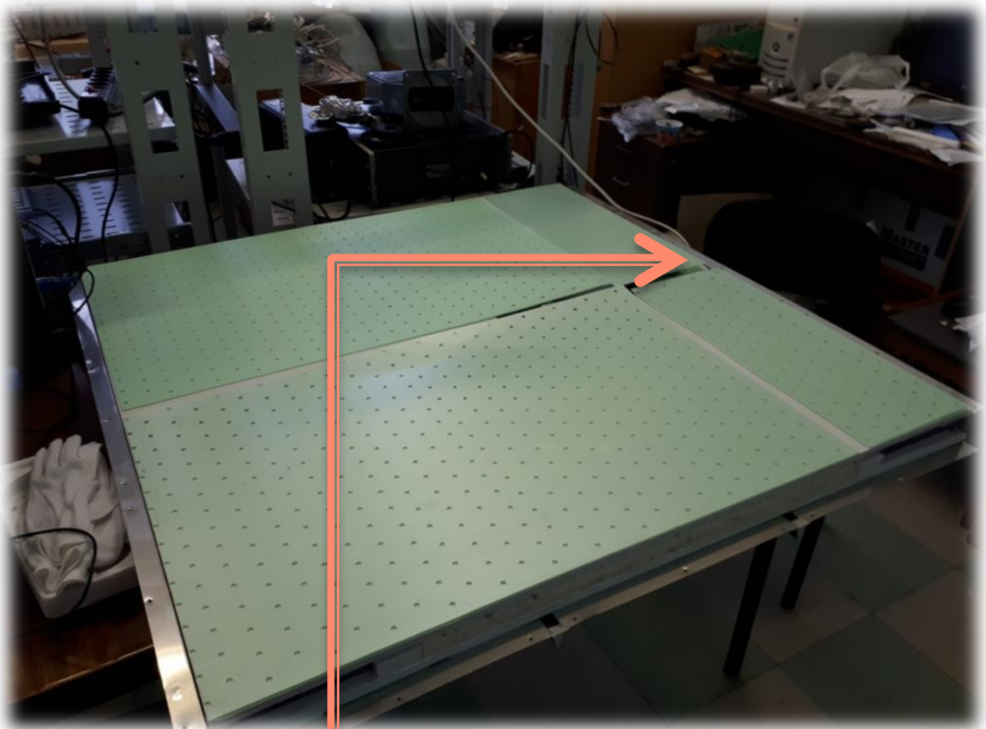
Evaluation of the possibility of replacement the vacuum PMT with the SiPMs

Experiment

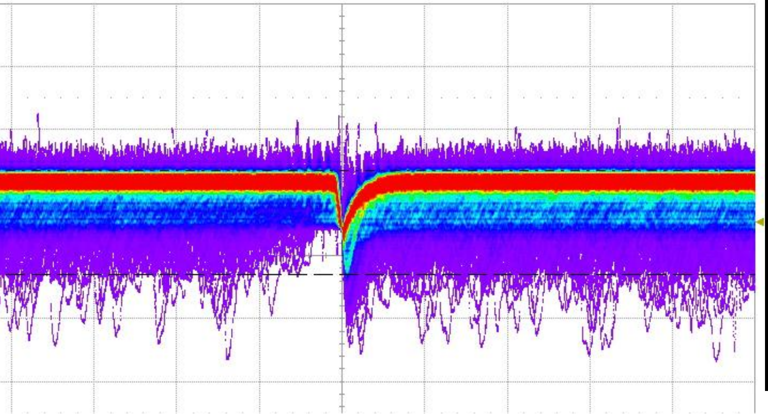


Hamamatsu
s21360-6050 ve



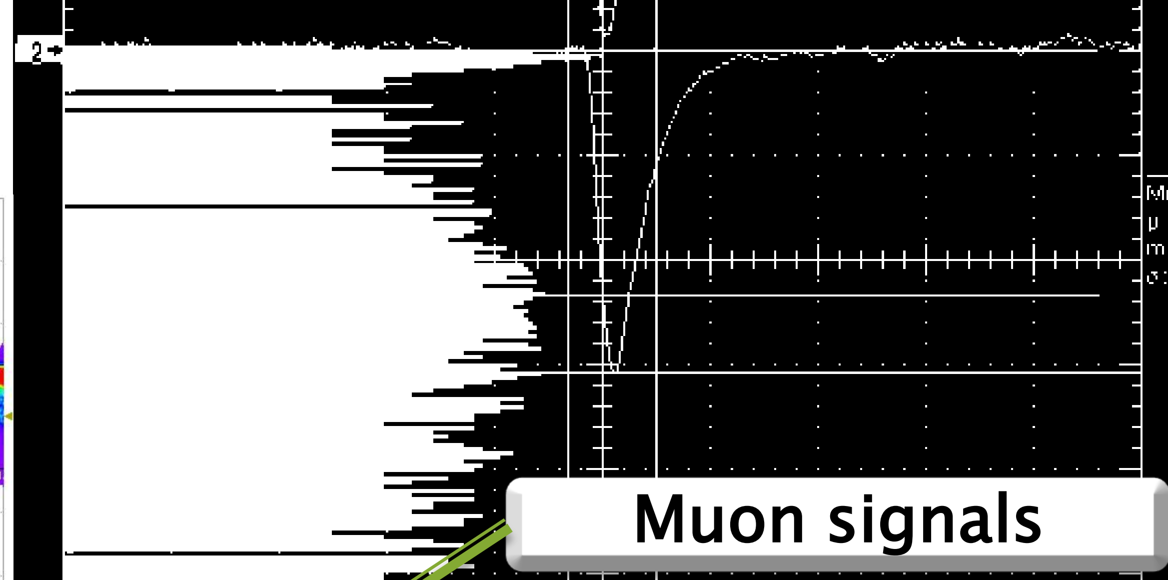


Experiment

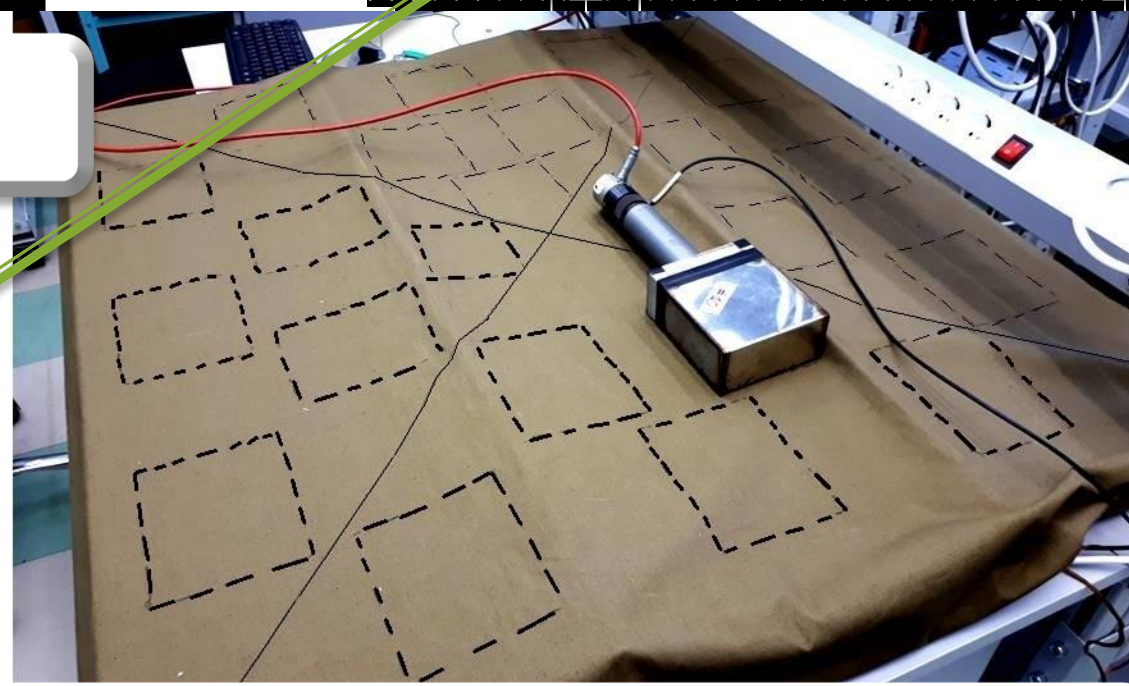


Oscillogram of SiPM noise signals

Calibration



Muon signals



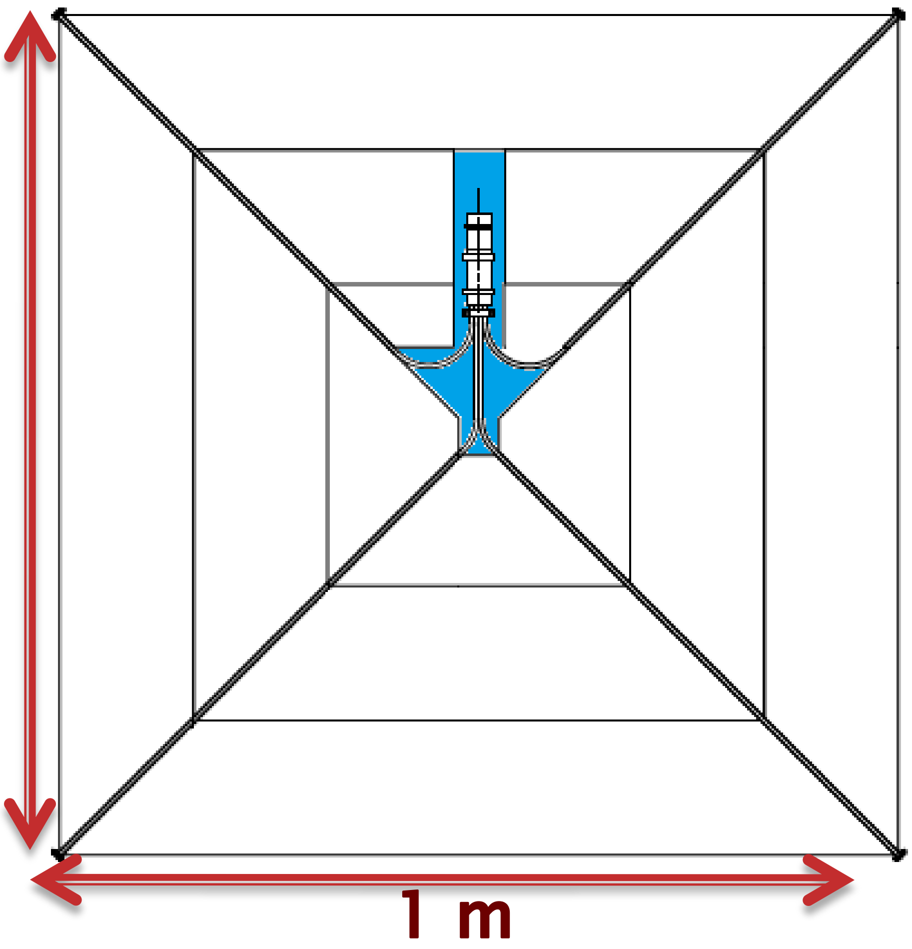
Coincidence Muon detector 1x1 m² and scintillation counter 10x10 cm²

Number of photoelectrons measurements

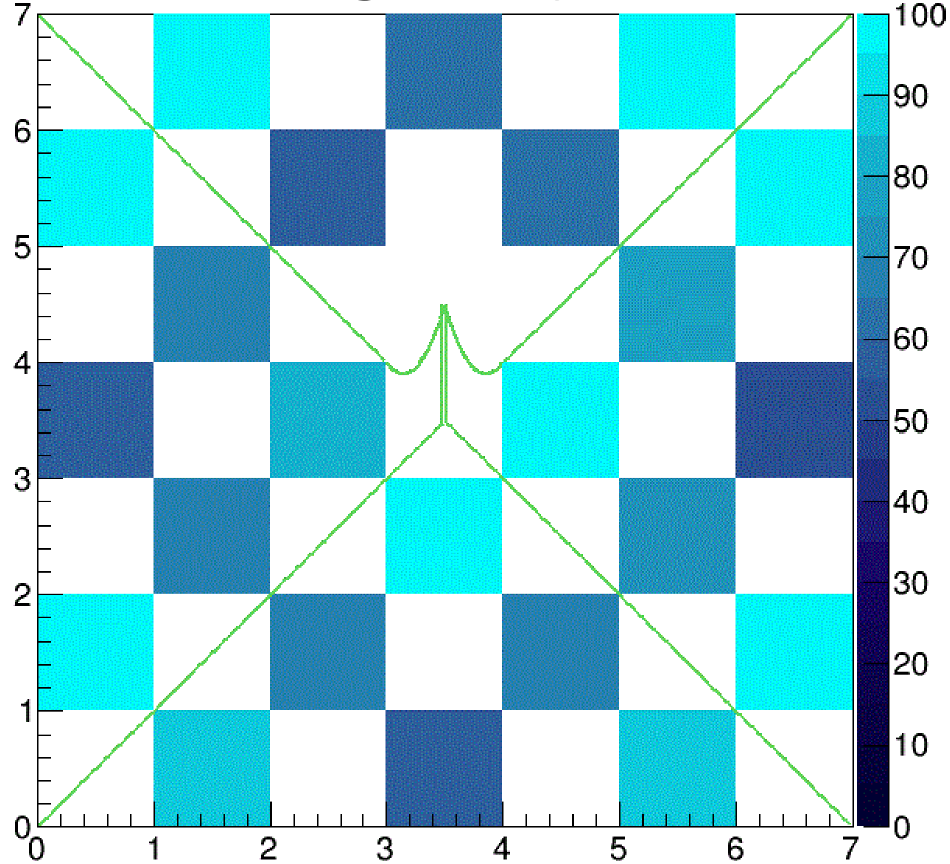
Experiment

$N_{pe} = Ampl\_muon \ / \ Ampl\_calibration$

Number of photoelectrons (2D histogram)



SiPMs

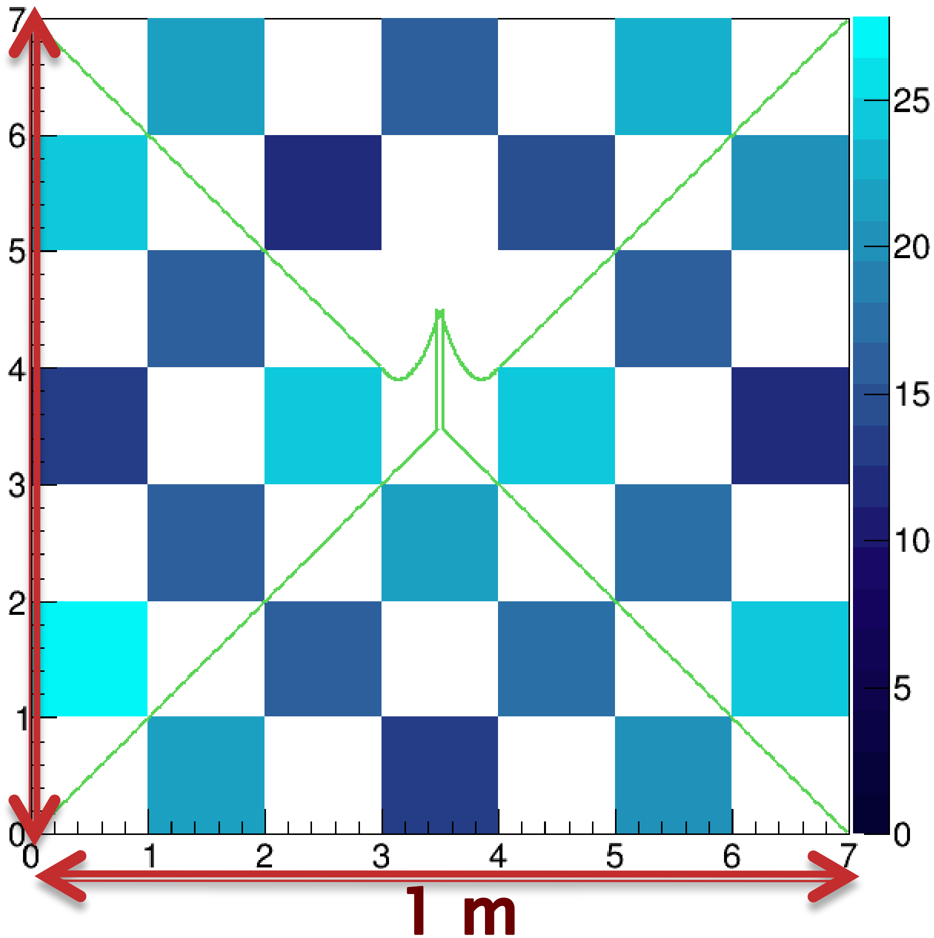


Experiment

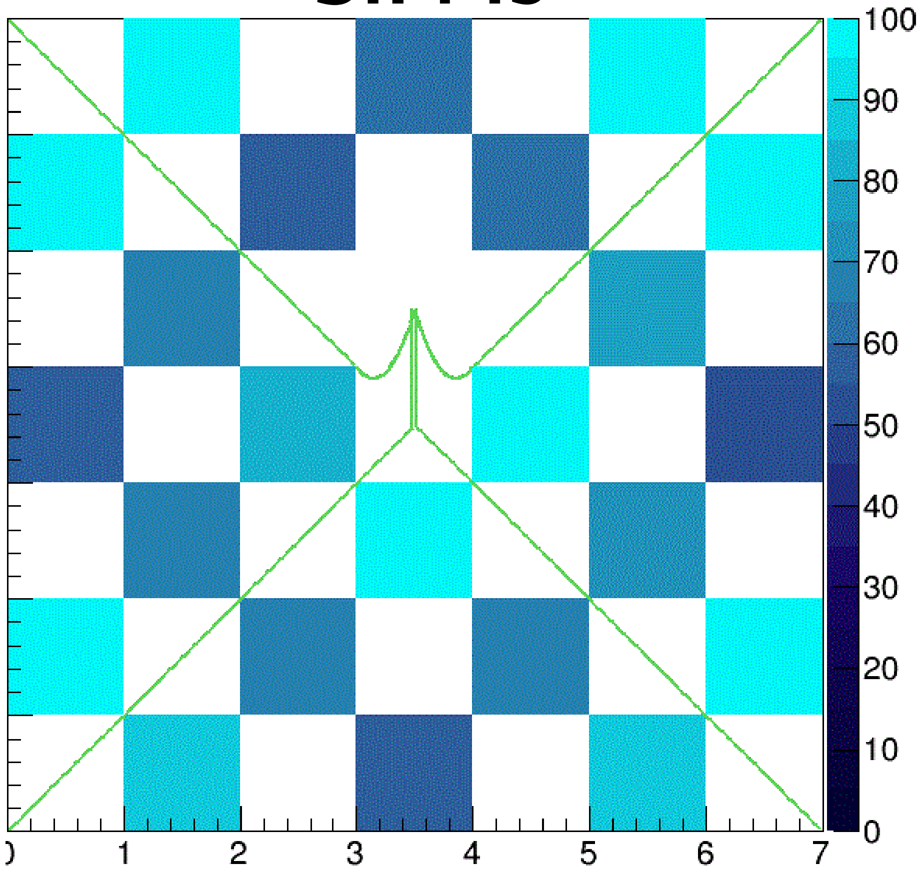
$N_{pe} = Ampl\_{muon} \; / \; Ampl\_{calibration}$

Number of photoelectrons (2D histogram)

PMT

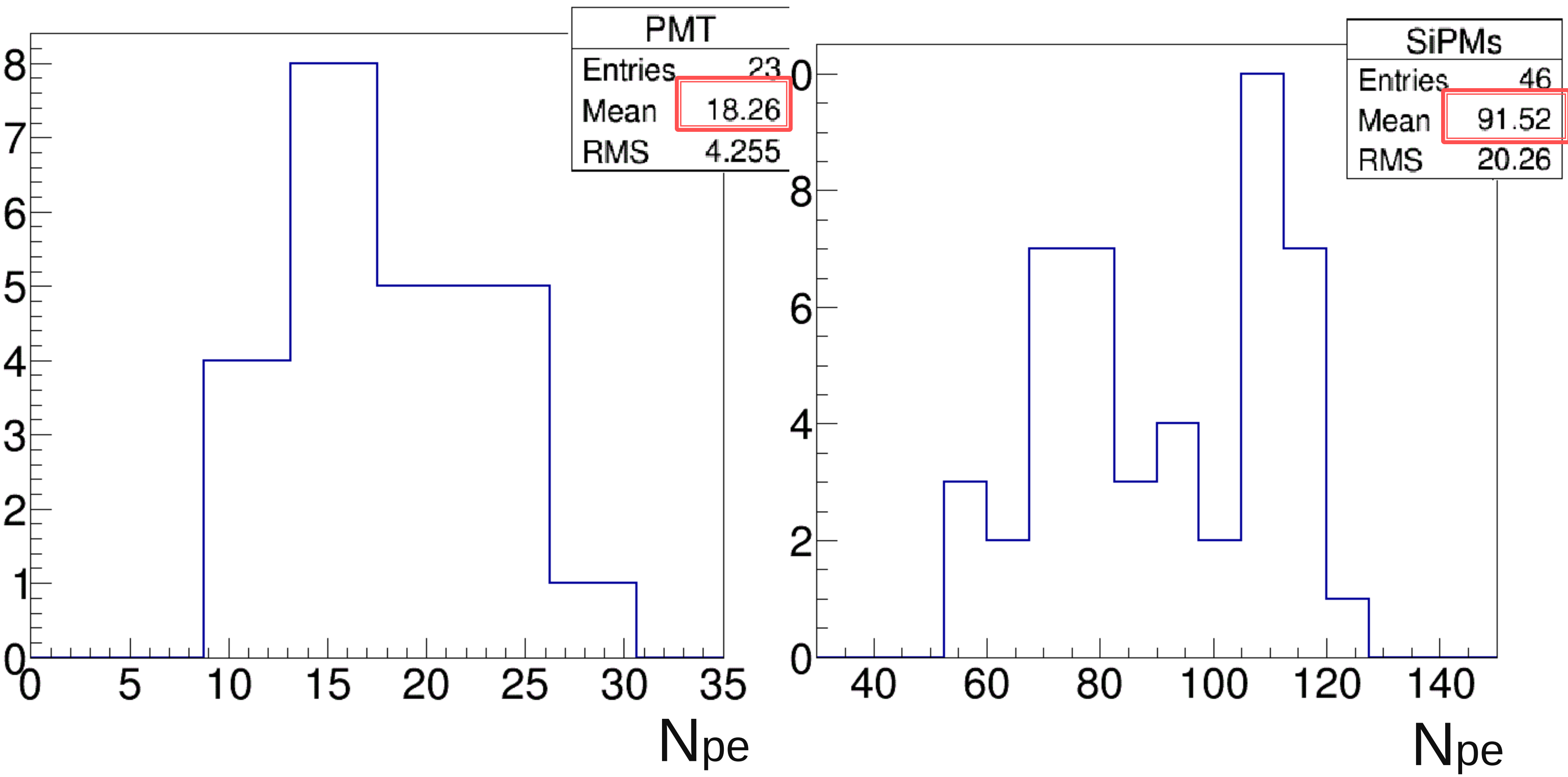


SiPMs



Experiment

Average number of photoelectrons



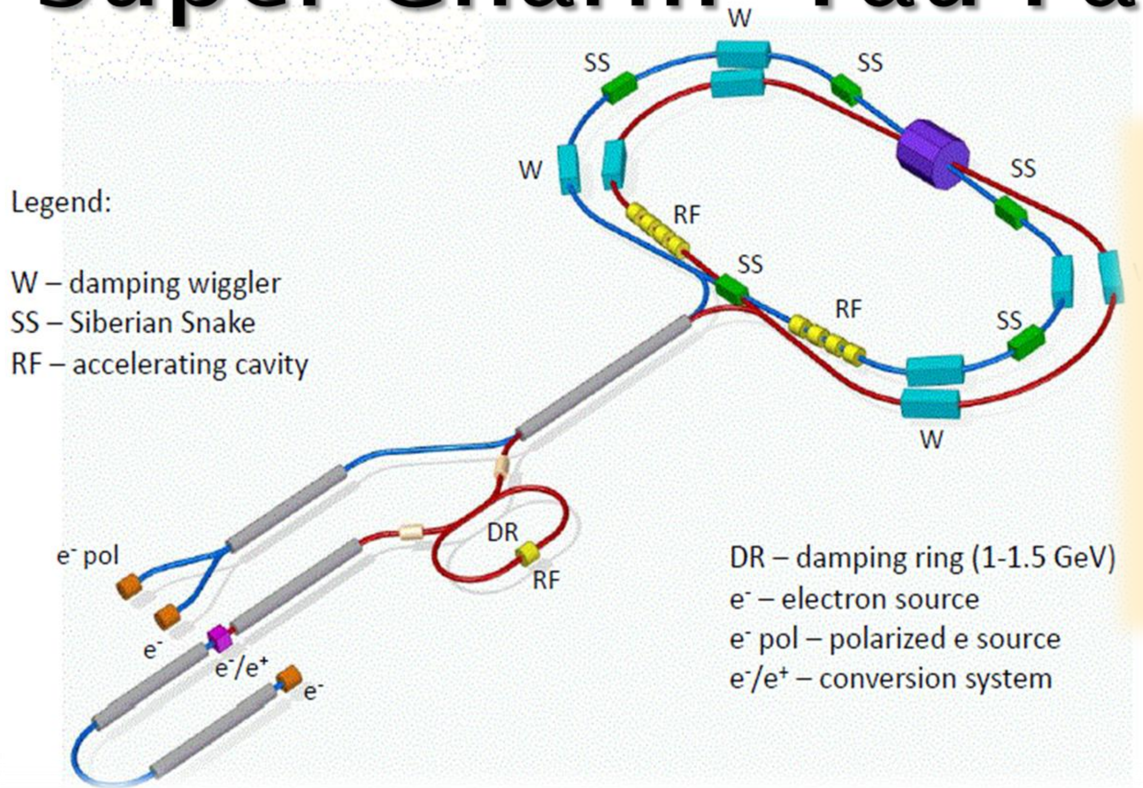
Conclusion

- Possibility of muon signal registration via matrix of SiPMs have been demonstrated
- More photoelectrons

Outlook

- **Simplification of the design**
- **Mass production of improved detectors for TAIGA-Muon**

Super Charm–Tau Factory



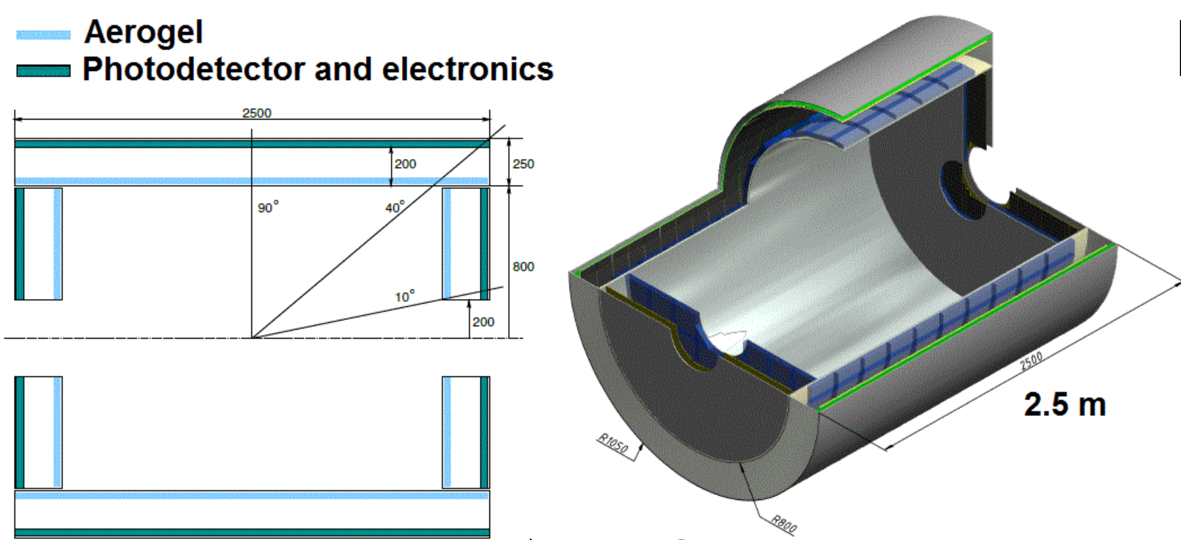
2E = 3–4.5 GeV

Crab Waist collision

Peak luminosity 10^{35} $cm^{-2}s^{-1}$

- Processes with c–quarks and τ–leptons,
- Exotic states
- CP–violation in systems of charmed hadrons and τ–leptons
- Lepton number violation

Identification system for SCTF



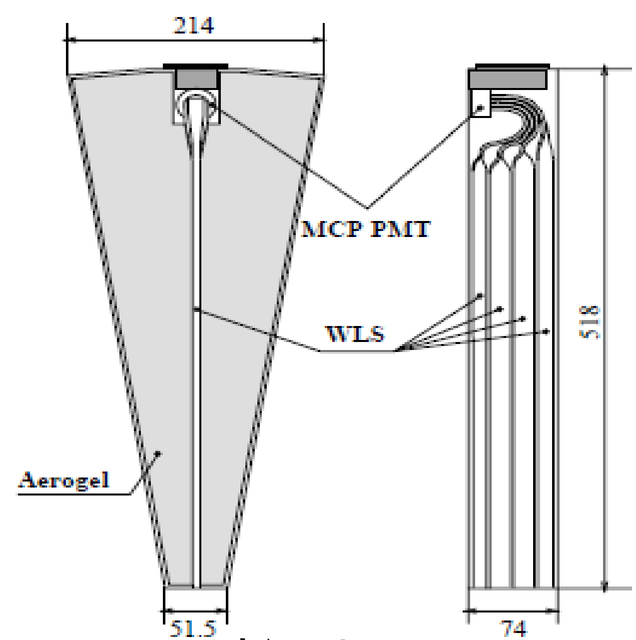
a) FARICH

project -> FARICH
B ~ 1 T

~1 million SiPMs

Alternative: PID based on ASHIPH (Aerogel, wavelengt SHIfter and Photomultipliers) detectors with SiPMs as a photodetector

~28 000 SiPMs



b) ASHIPH

PID system with extended range

Threshold Cherenkov counter with two refractive indexes

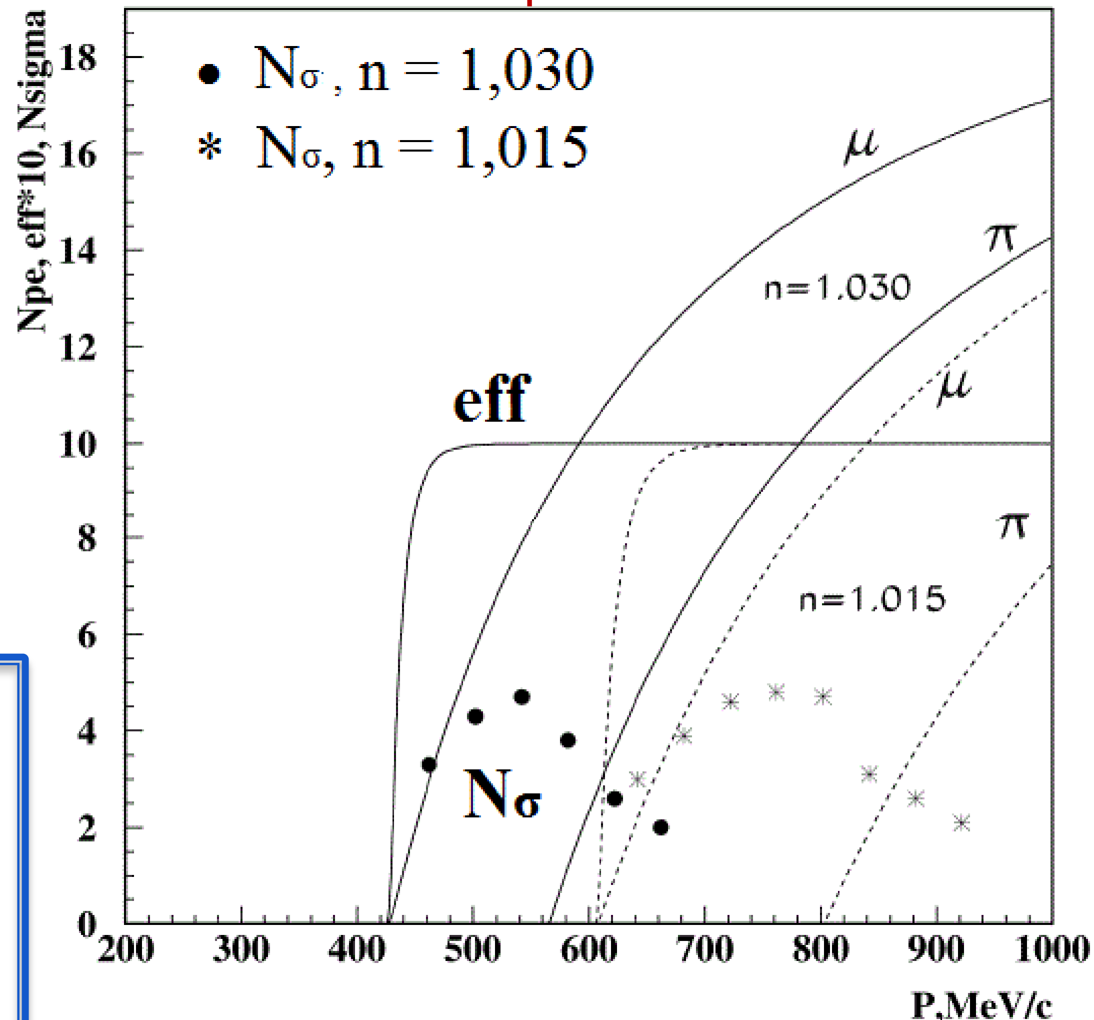
SiPM:

ability to set exact threshold on N_{pe}

Noise

ability to separate particles with momentum above $P_{thr}(\pi)$

from report of E. Kravchenko



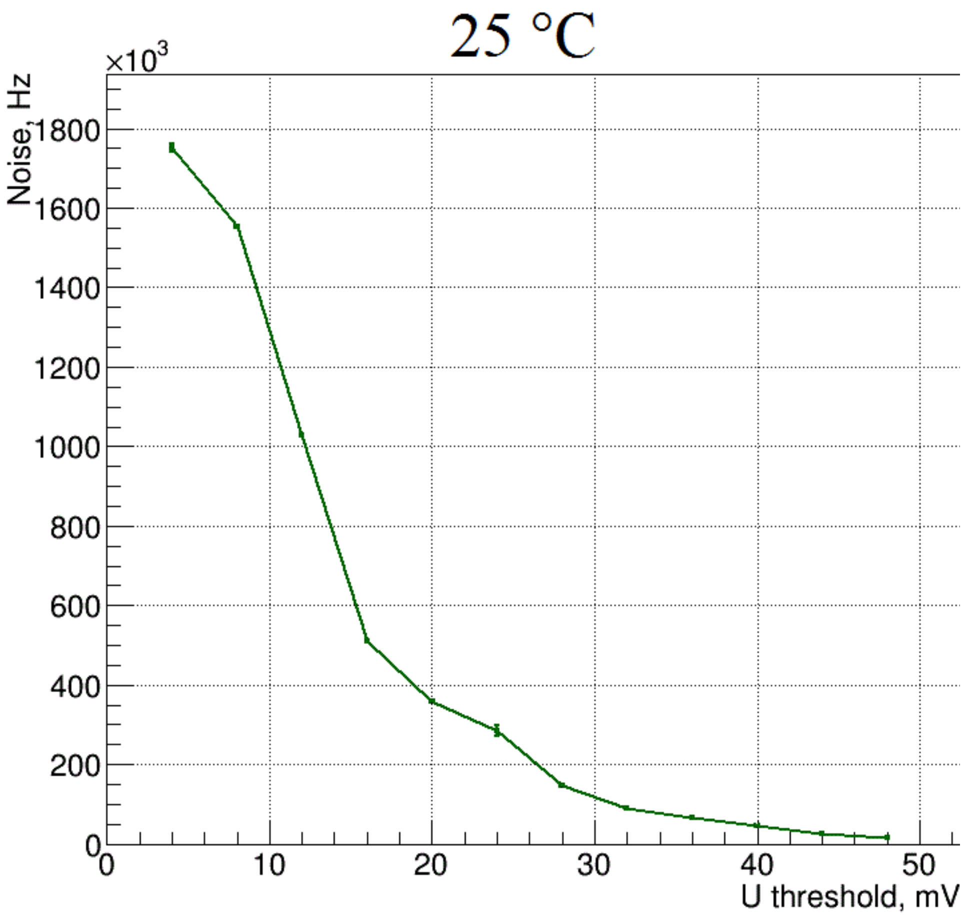
Necessity of cooling

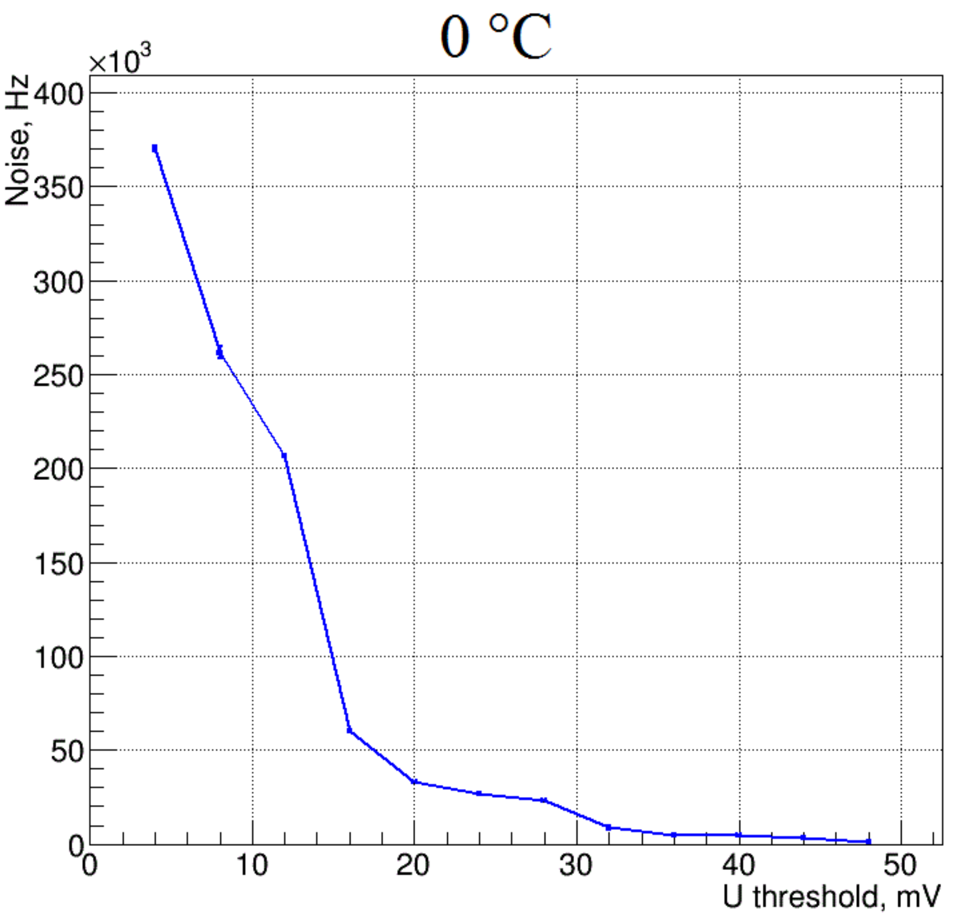
Experiment

Assessment of ability of SiPM to work in photon counting mode at lower temperature

Experiment

Dependence of noise frequency on threshold

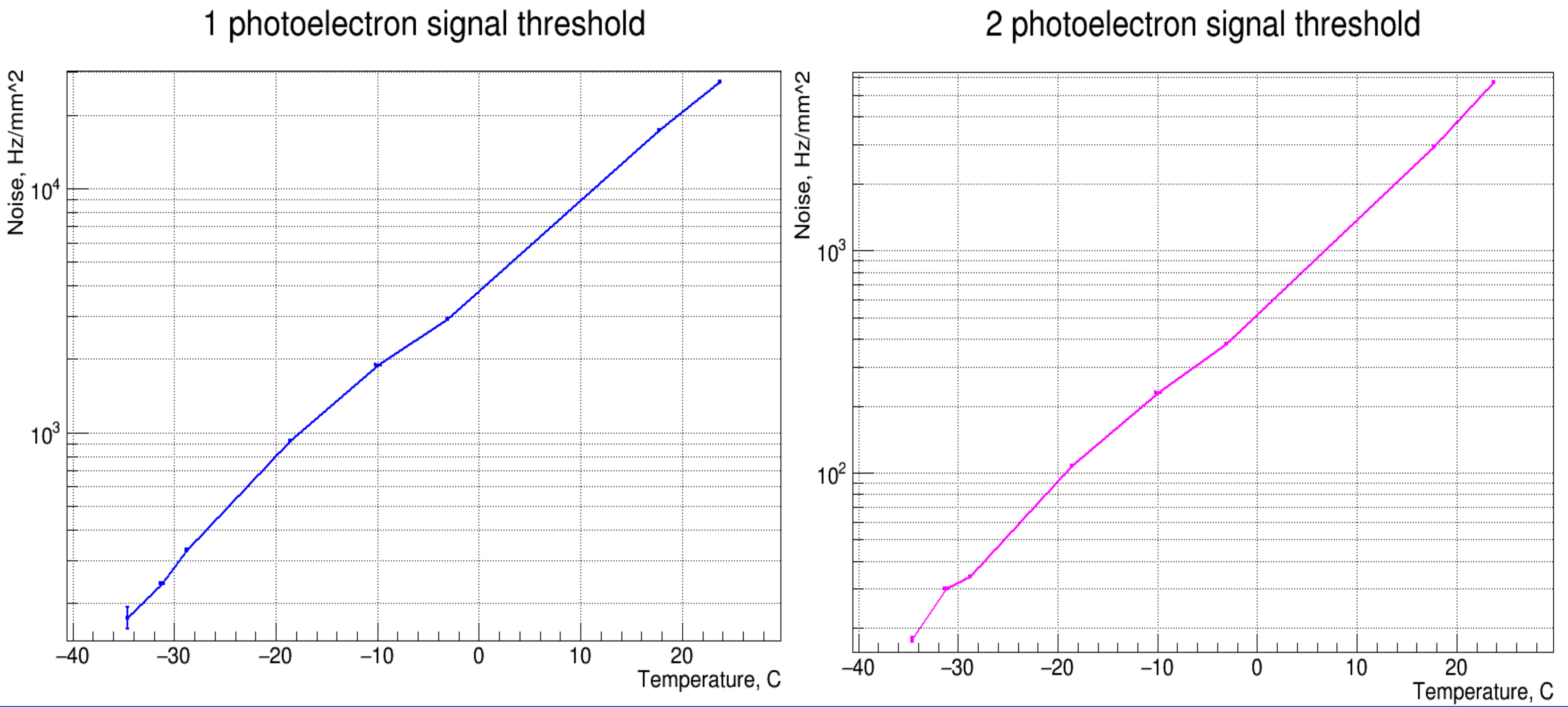




Conclusion: possibility of partial separation of useful data from noise by threshold

Experiment

Dependence of noise frequency on temperature



Probability of noise event during the time of registration in the projected Cherenkov counter is < 1 % when T ≈−30 °C (1 pe threshold)

Conclusion

- It is enough to cool the system to −30 °C for effective working of the identification system on the base of ASHIPH detectors with light registration by SiPMs

Outlook

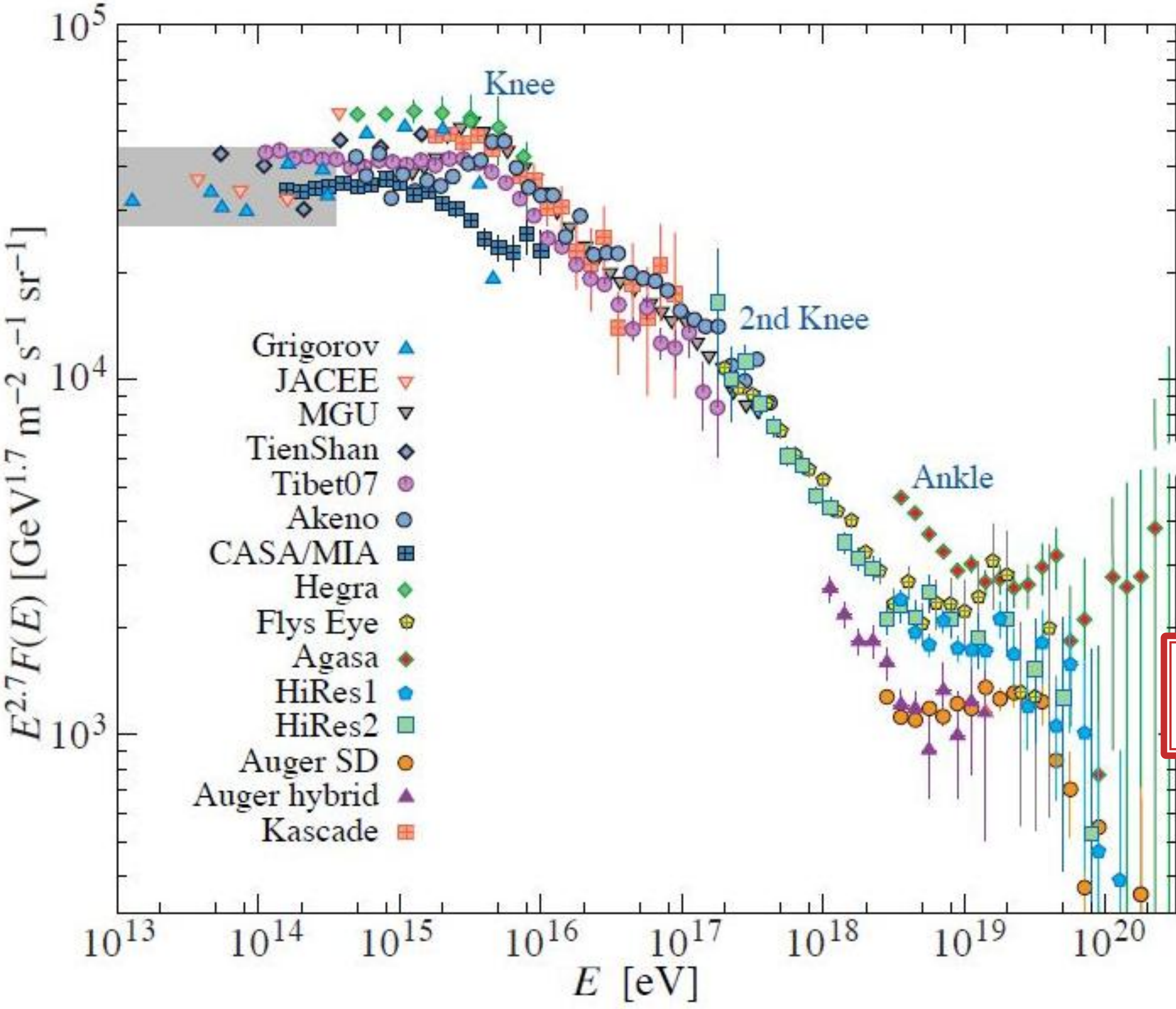
- **This level of cooling can (probably) be decreased by using a coincidence scheme**


Thank you!

Backup

Installation of the first cluster of TAIGA-MUON

July 2019



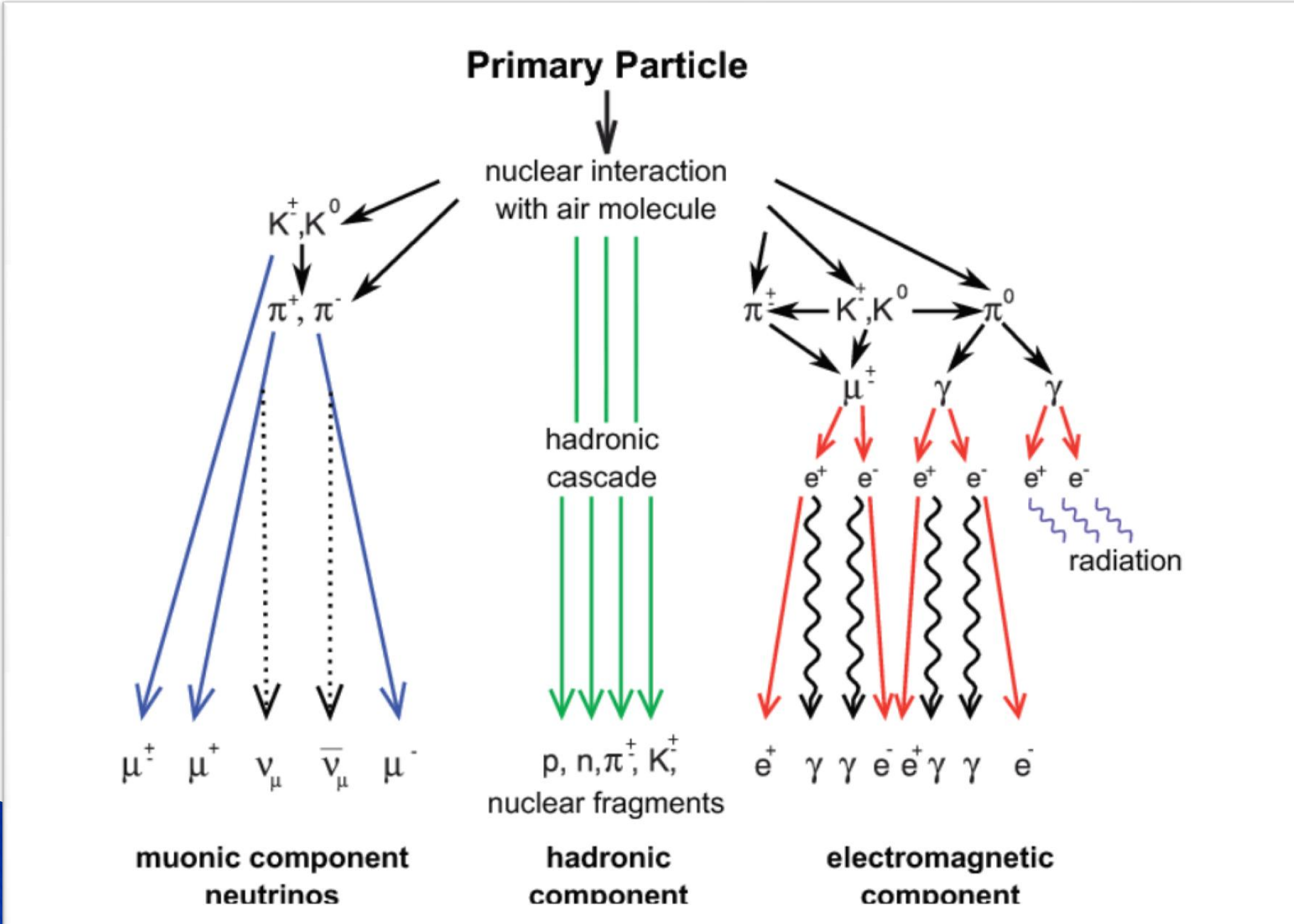
Before the knee:

Flux $\propto E^{-2.7}$

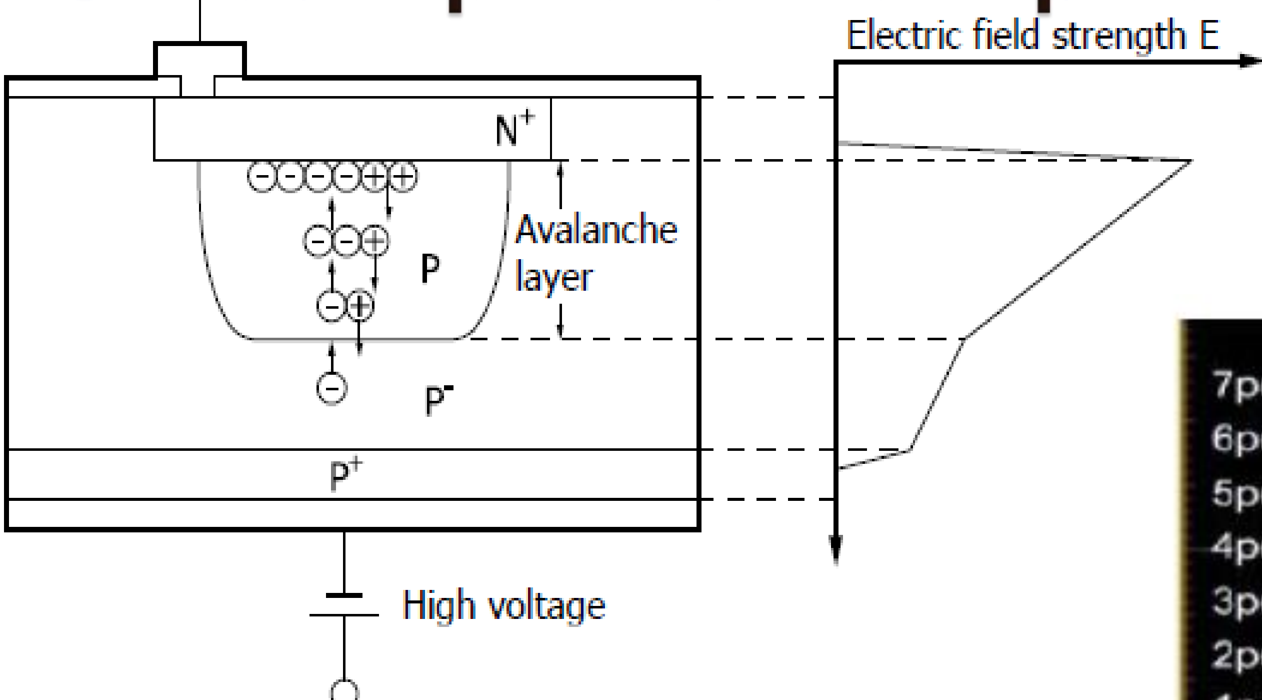
After:

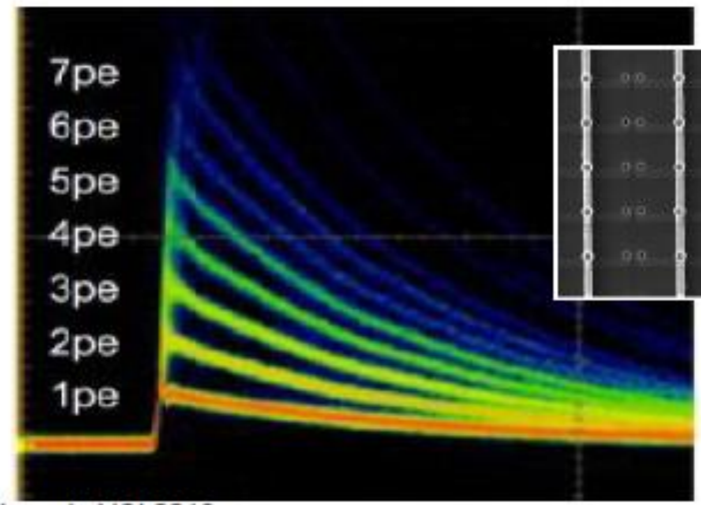
Flux $\propto E^{-3.2}$

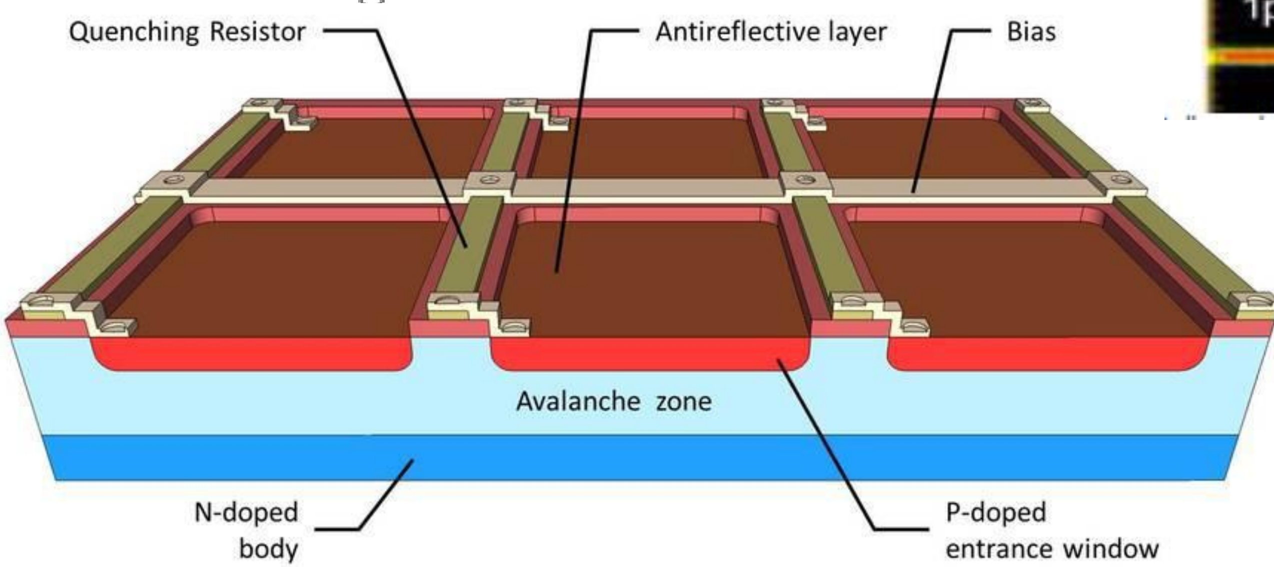
Extensive air shower



Silicon photomultiplier







Focusing Aerogel Ring Image Cherenkov (FARICH) counter