Status of upgrade the ASHIPH counter for the SND detector

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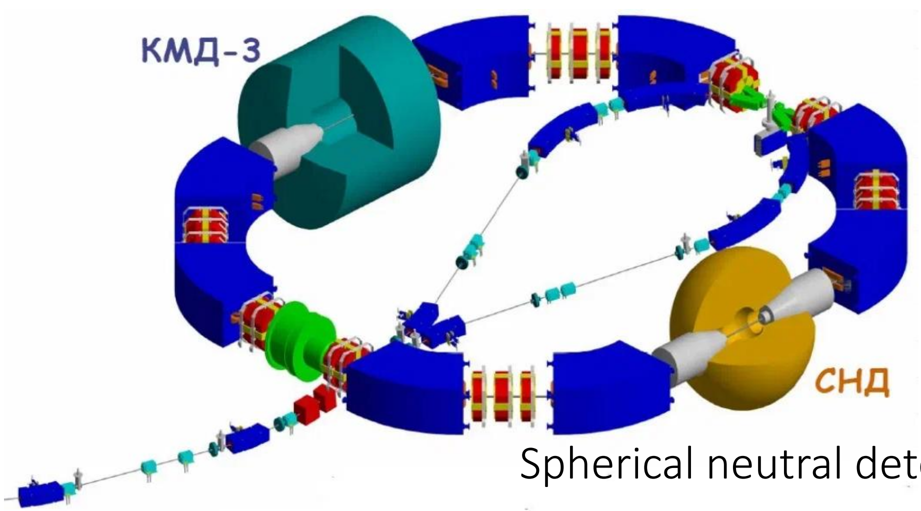
Contetns

- SND Detector at VEPP-2000
- ASHIPH method for particle identification
- ASHIPH upgrade
- ASHIPH-SiPM prototype
- Thermal stabilization system
- ASHIPH-SiPM prototype at electron beam
- Results

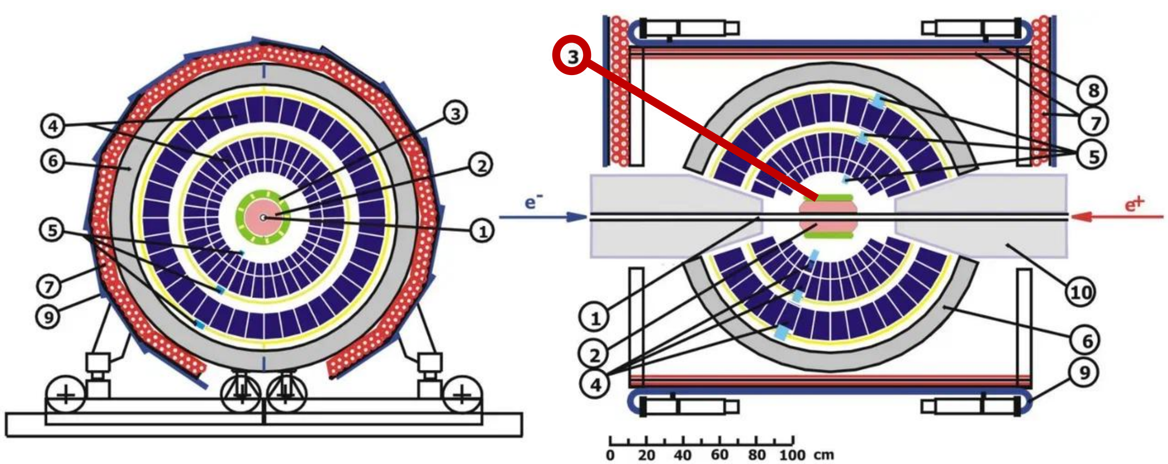
SND Detector at VEPP-2000

VEPP-2M collider



e^+e^- collider
Energy 320–2000 MeV
Luminosity $4{\cdot}10^{31}$ cm^{-2}s^{-1}
Detectors: SND and CMD-3

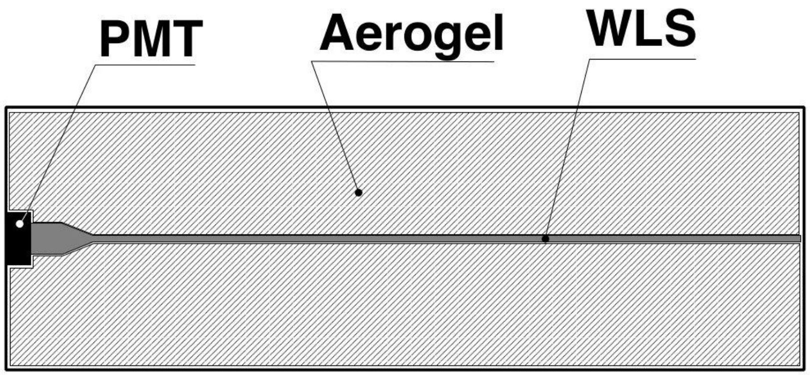
Spherical neutral detector (SND)



1. Vacuum chamber
2. Tracking system
3. Cherenkov counters
4. NaI(Tl) crystals
5. Vacuum phototriodes
6. Iron absorber
7. Proportional tubes
9. Scintillation counters
10. VEPP-2000 solenoids

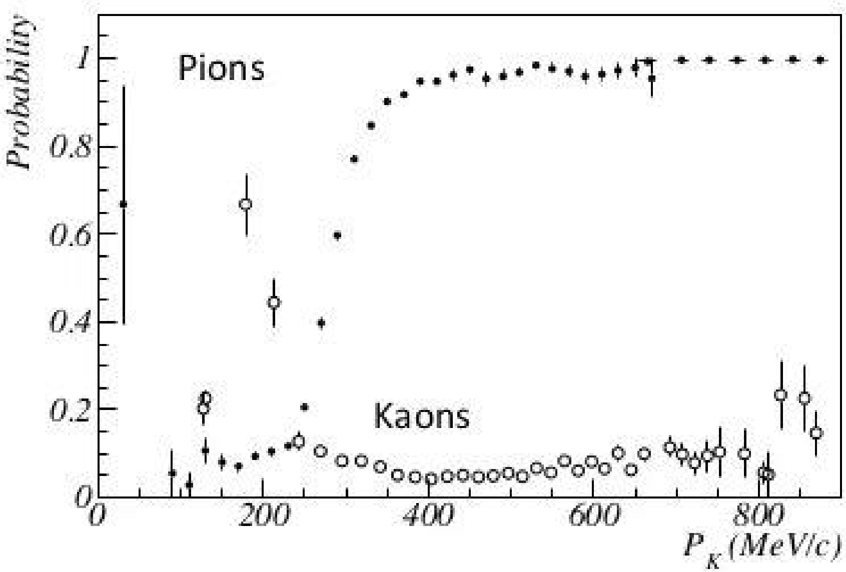
ASHIPH method for particle identification

ASHIPH (Aerogel, SHifter, PHotomultiplier) method of light collection was suggested in 1992 (A. Onuchin et al. NIM A315, 1992, 517-520).



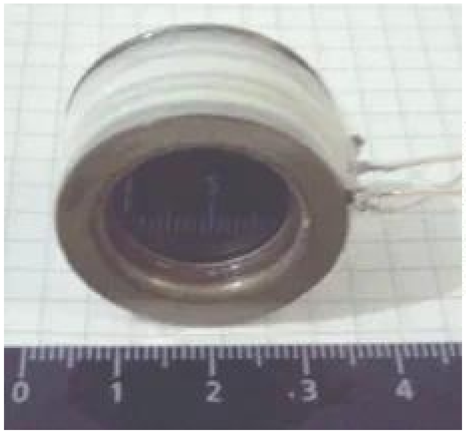
Cherenkov light from particle in aerogel is collected by the wavelength shifter (WLS) placed in the middle of the counter and transported by WLS like a lightguide to photomultiplier (PMT):

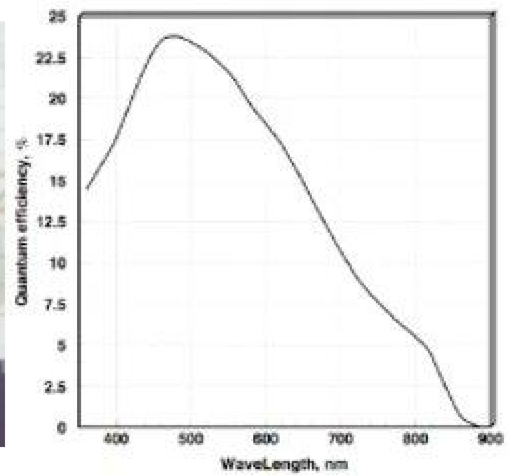
- PMMA based light guide doped with BBQ dye is used as WLS
- This method helps us significantly to decrease the PMT photocathode area and material budget before a calorimeter

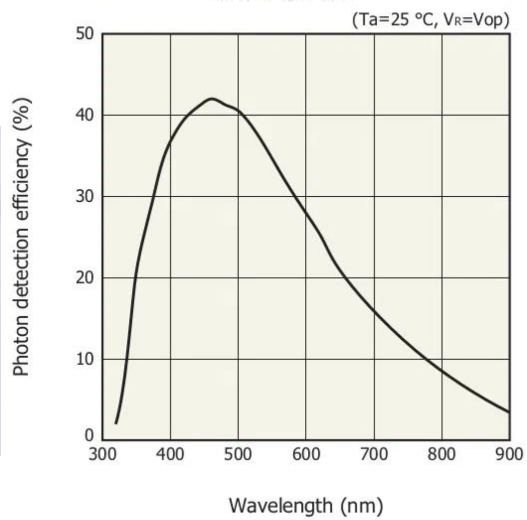


ASHIPH upgrade

As part of the modernization of the ASHIPH SND system, it has been proposed to use silicon photomultipliers (SiPMs) as photodetectors instead of microchannel plate-based photomultiplier tubes (MCP-PMTs).







Differences between SiPMs and MCP-PMTs:

+ Increase in the number of detected photoelectrons by a factor of 2.5 → improved particle separation quality

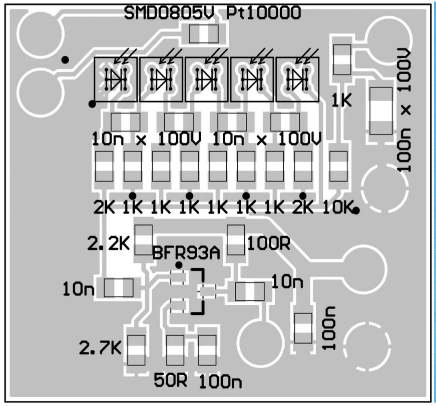
+ Operating voltage <100 V, while MCP-PMTs require ~2–4 kV

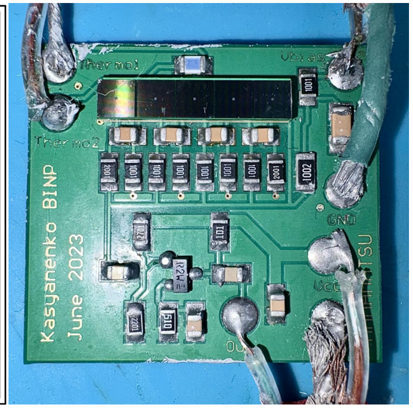
+ Immunity to magetic fields

+ Smaller size (3*3mm)

− High level of dark count rate (DCR) (55.6 kHz/mm^2)

ASHIPH-SiPM prototype





The segment of the SND detector ASHIPH system are used

Two counters from the segment were used:

- 1st counter: Aerogel with n=1.05, thickness 30 mm
- 2nd counter: Aerogel with n=1.12, thickness 25 mm (counter not fully filled up to 30 mm)

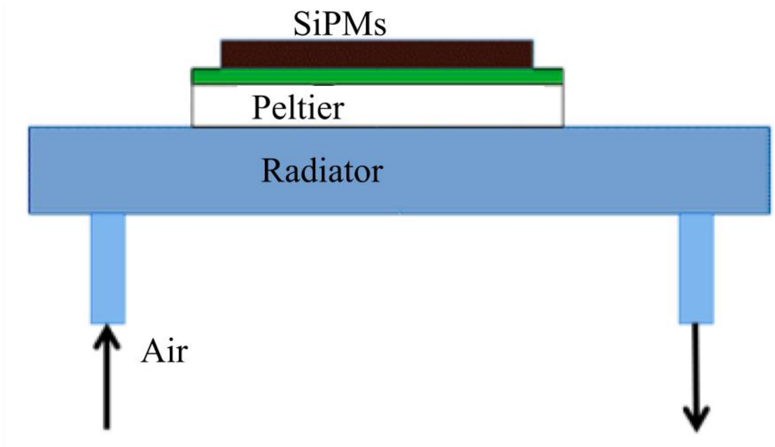
Counter dimensions: R=105÷141 mm, length 260 mm, width 80 mm

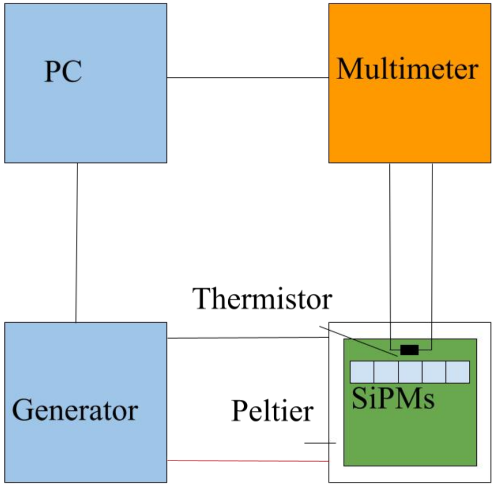
Aerogel cover: teflon with a refractivity of R~ 98%

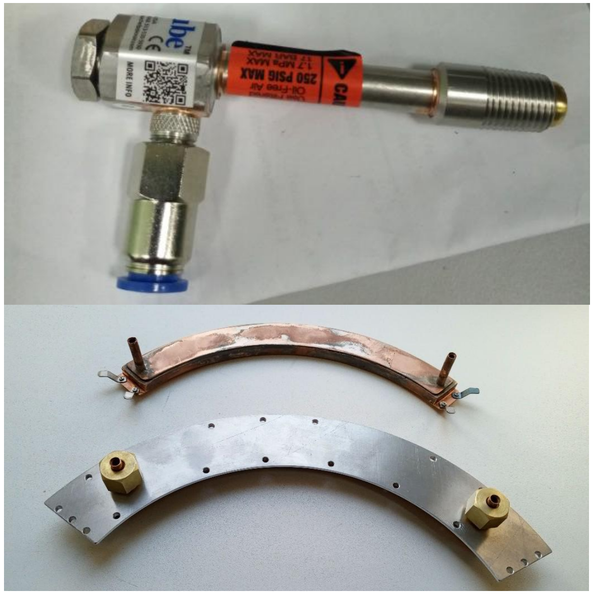
A line of 5 SiPMs allows cover a WLS with sizes 17x3 mm^2

Series connection of 5 SiPMs with parallel distribution of bias voltage

Thermal stabilization system

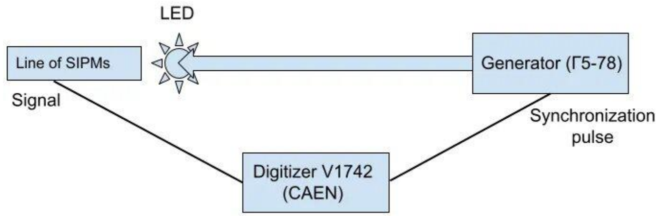


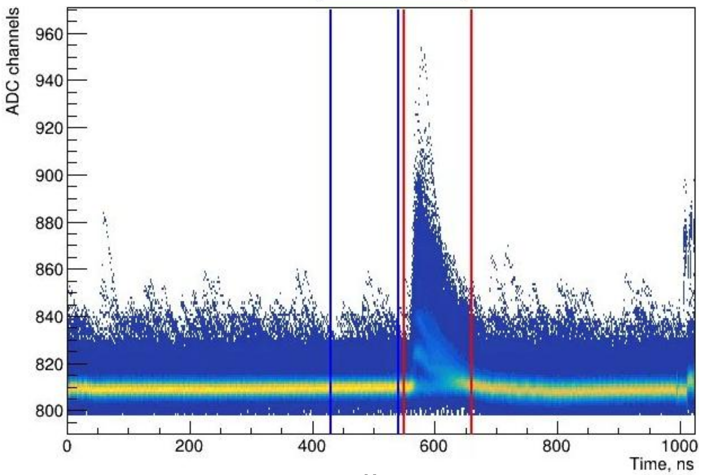


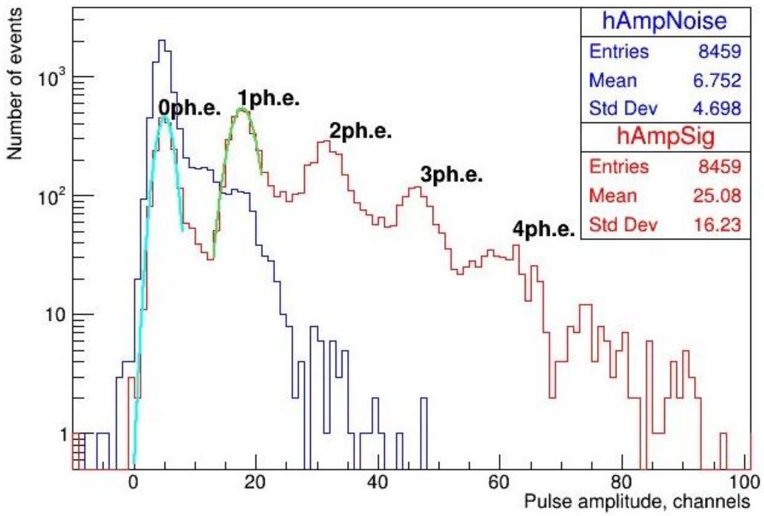


45°C inside the detector, 12°C dew point. Water cannot be used because the NaI calorimeter is highly sensitive to moisture. Cooling target is 15°C. The temperature stabilization system employs a Peltier element powered by a generator controlled via software. Heat is removed through a copper radiator, cooled by air supplied via a vortex tube.

SiPM calibration

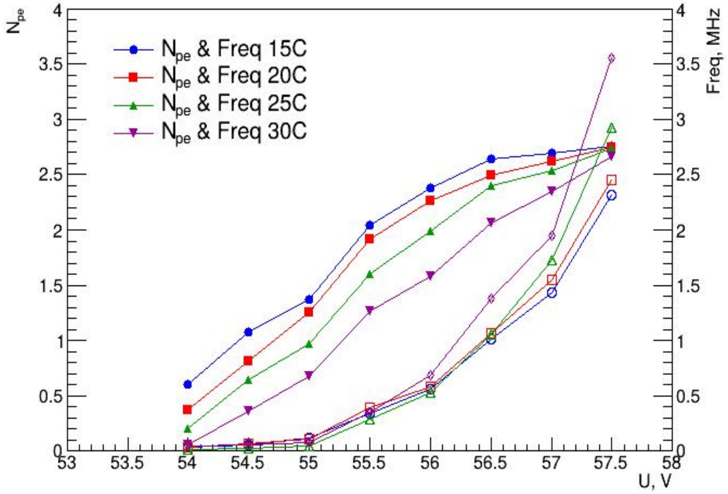






A1ph.e. from the distance between the peaks

Nph.e. = (Asig – Aped)/A1ph.e.

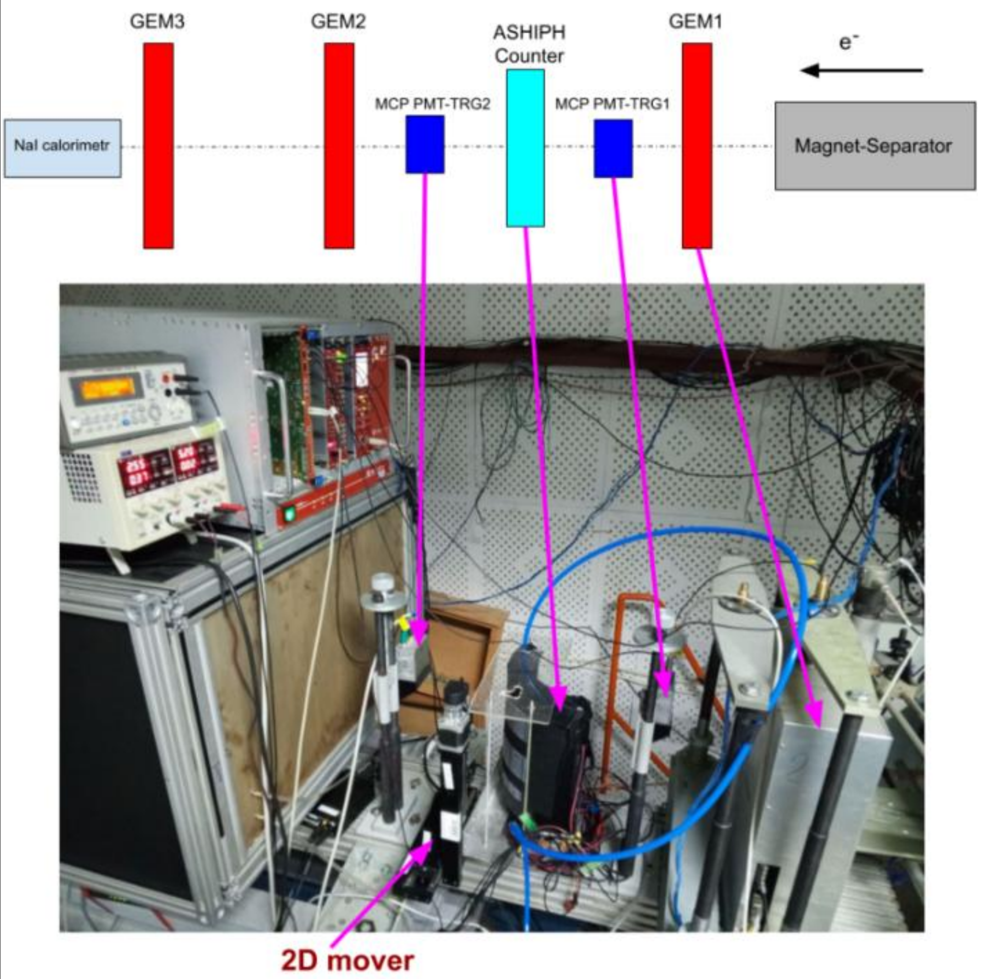


$$P(n,\mu) = \frac{e^{-\mu}}{n!}\mu^n, \ \mu = -\ln P(0,\mu)$$

where n - number of photoelectrons,
μ - average number of photoelectrons.

$$P(0,\mu) = \frac{N^{sig}_{ped}}{N^{sig}} \times \frac{N^{noise}}{N^{noise}_{ped}}$$

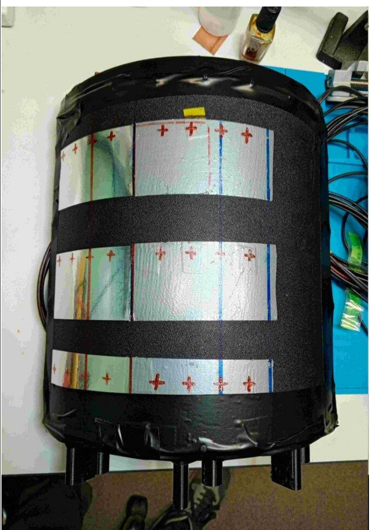
ASHIPH-SiPM prototype at electron beam

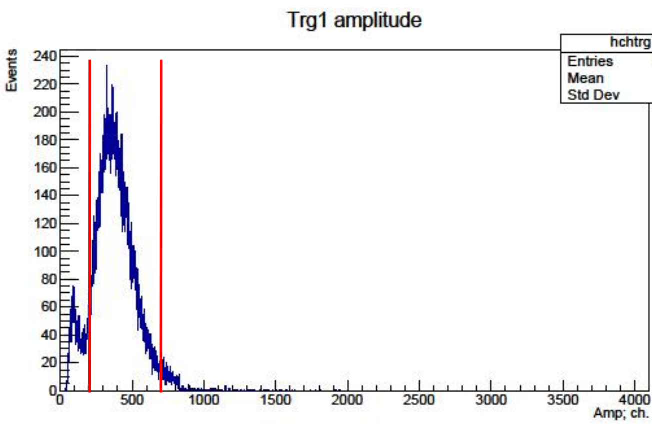


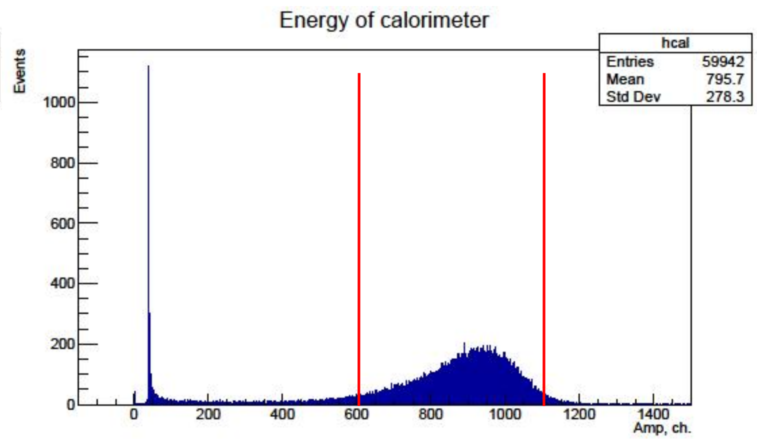
- Beam test facilities at the BINP, electron energy 2.5 GeV;
- Tracking based on 3 coordinate GEM detectors (σx=50 μm, σy=50 μm) and NaI calorimeter;
- The trigger is formed from the coincidence of two counters based on a MCP-PMT;
- The signals from the counters and the prototype are digitized by V1742 CAEN;
- ~ 50000 events were collected in each of 12 different geometric areas of the counter at temperatures 15∘C and 45∘C, and at different bias voltages on the SiPMs.

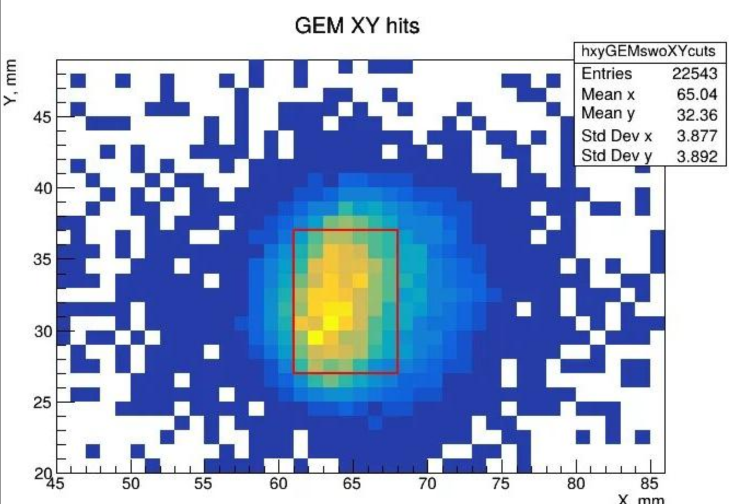
ASHIPH-SiPM prototype at electron beam

Selection electron beam









To evaluate the light collection inhomogeneity, data were collected at various geometrical positions of the detector. Events were then selected to be non-noise, single-particle, and localized within a specific detector region.

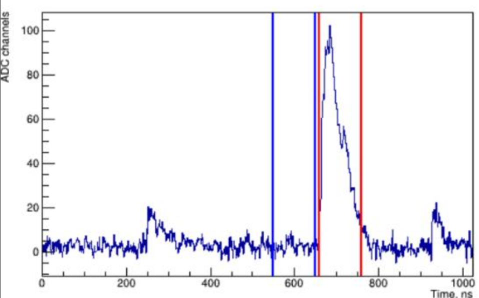
ASHIPH-SiPM prototype at electron beam

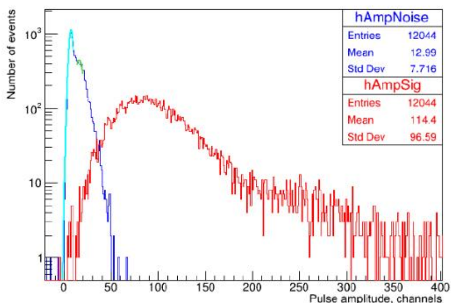
The subthreshold efficiency is primarily determined by the intrinsic DCR. Other sources:

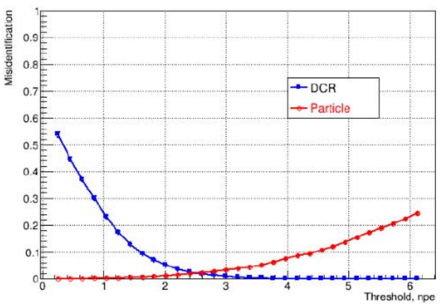
- Cherenkov light from δ-electrons in aerogel
- Scintillations in teflon
- Cherenkov light in teflon

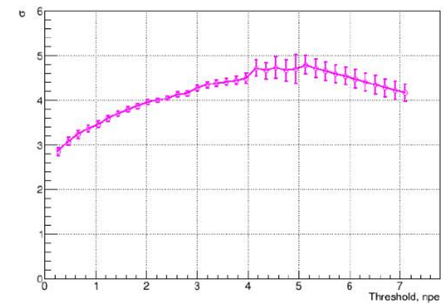
Prototype of the ASHIPH counter with n=1.05 aerogel, point 2:

T=15°C, U=53.5 V

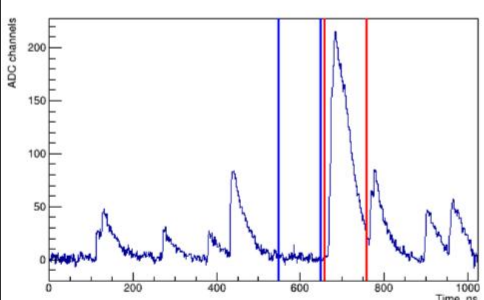


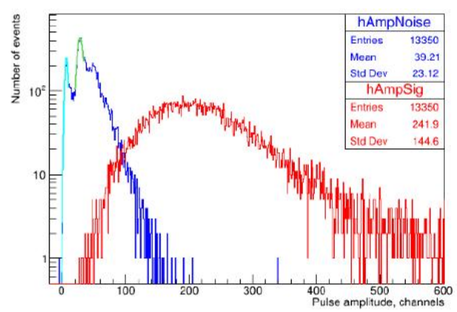


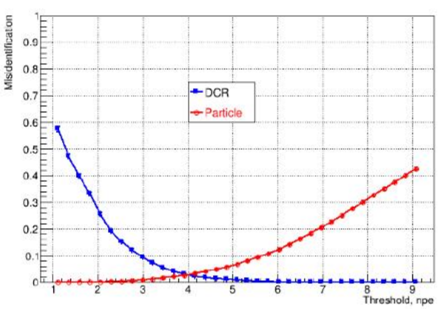


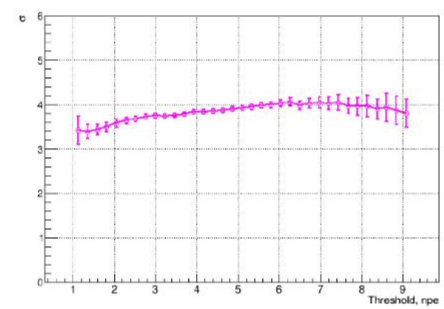


T=45°C, U=57 V





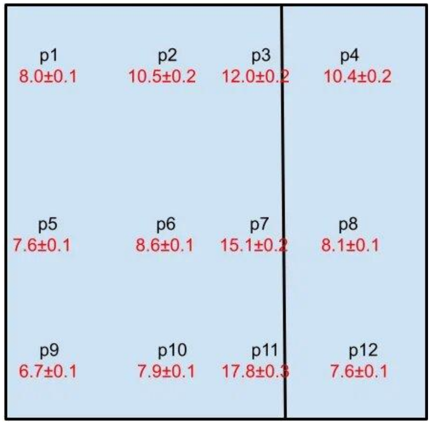


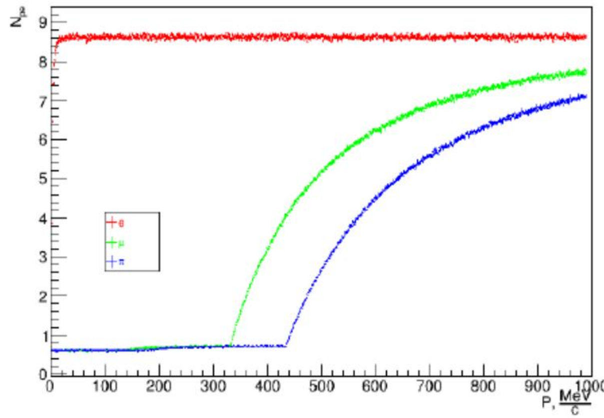


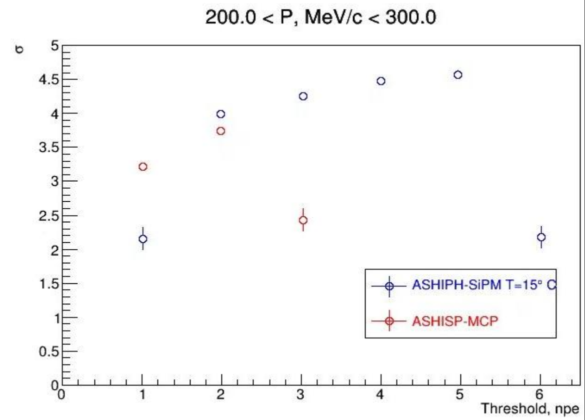
$$K[\sigma] = \sqrt{2}\left(\mathrm{erf}^{-1}(1-2\varepsilon_K) + \mathrm{erf}^{-1}(1-2(1-\varepsilon_\pi))\right)$$

ASHIPH-SiPM prototype at electron beam

Prototype of the ASHIPH counter with n=1.05 aerogel, T=15ºC

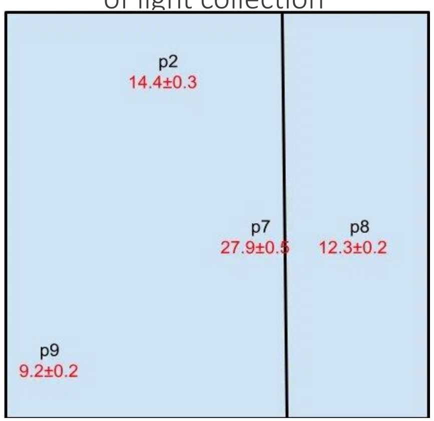


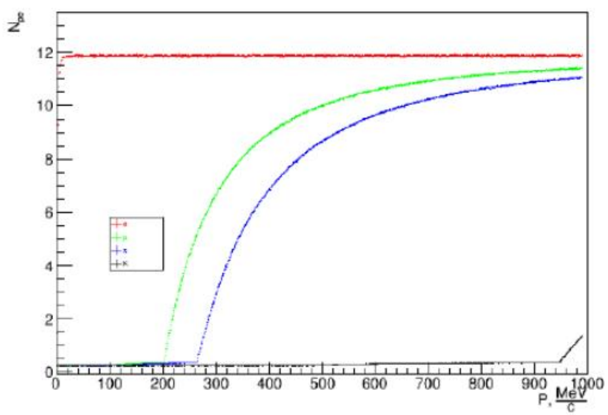


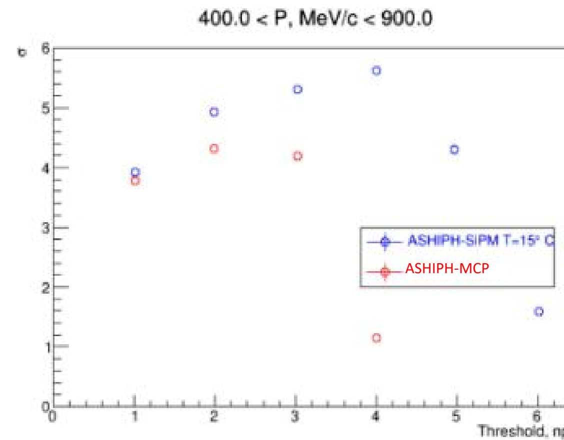


Maps with inhomogeneity of light collection

with n=1.12 aerogel







The central graph was obtained using parameterization via $\mu = \mu_0 \left(1 - (\frac{P_{\rm thr}}{P})^2\right)$

Summary

A prototype of the ASHIPH-SiPM has been constructed, containing two counters with aerogel refractive indices of n = 1.05 and n = 1.12, equipped with a thermal stabilization system based on Peltier modules and an air radiator. Tests on an electron beam:

Aerogel n = 1.05:

- Average number of photoelectrons per counter $N_{ph.e.} \simeq 8.6$ ((p2+p9)/2)
- Inhomogeneity of light collection is ~ ±22%

Aerogel n = 1.12:

- Average number of photoelectrons per counter $N_{ph.e.} \simeq 11.8$
  - For aerogel with n=1.13, 30 mm $N_{ph.e.} \simeq 11.8 \times 1.3 = 15.3$ is expected
- Inhomogeneity of light collection is ~ ±22%

Comparison with MCP-PTM:

Aerogel n = 1.05:

- $N_{ph.e.}$: 3.5 -> 8.6
- 3.7σ -> 4.6σ

Aerogel n = 1.13:

- $N_{ph.e.}$: 7 -> 15.3
- 4.3σ -> 5.6σ

The prototype counter has the geometry of the real counter and can be easily integrated into the SND detector. Successful calibrations of the counter were carried out in the electron channel of the ASHIPH-MCP PMT of the SND detector.

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