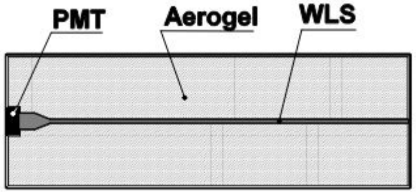
ASIPH-SiPM для детектора ВЭПП-6

Петрухин К. Г.

ASHIPH method for particle identification

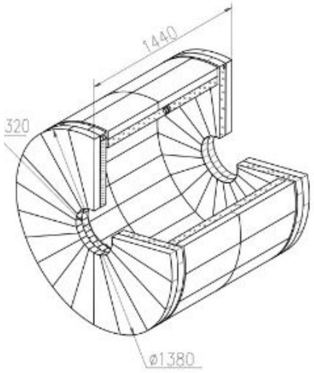


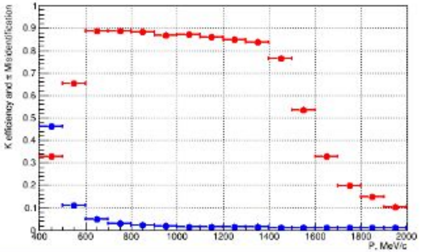
ASHIPH (Aerogel, SHifter, PHotomultiplier) method of light collection was suggested in 1992 (A. Onuchin et al. NIM A315, 1992, 517-520)

PMMA based light guide doped with BBQ dye is used as WLS

ASHIPH systems at the BINP (Novosibirsk):

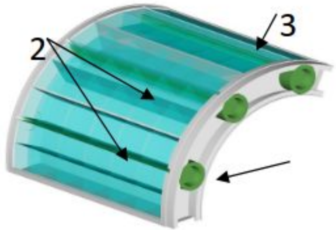
KEDR detector at VEPP-4M



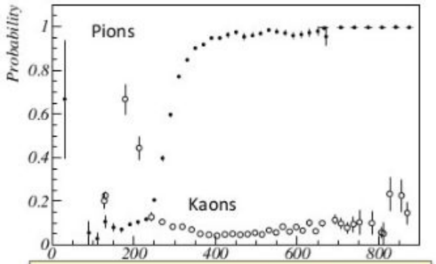


- 160 counters (2 layers)
- N=1.05 (1000 l.)
- MCP PMT ØPC=18 mm
- 0.97×4π

SND detector at VEPP-2000

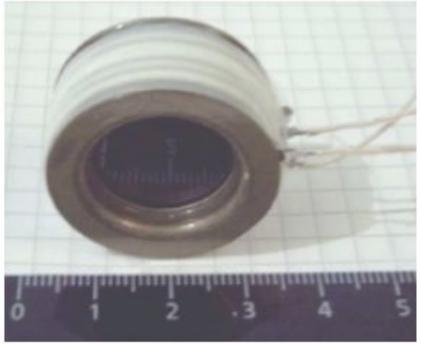


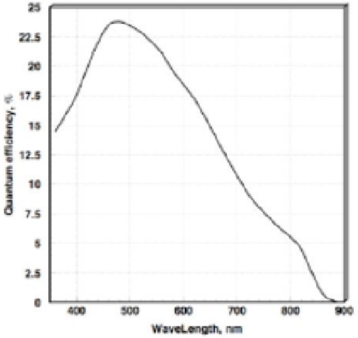
1 - PMT, 2 – aerogel, 3 - WLS

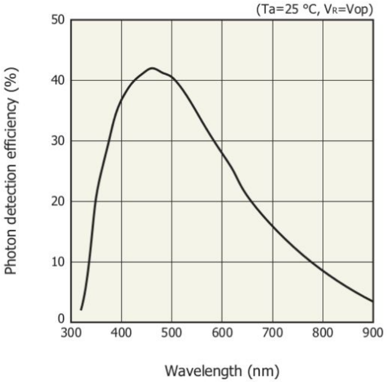


- 9 counters (1 layer)
- n=1.13 (π/K -separation)
  n=1.05 (e/π -separation)
- MCP PMT ØPC=18 mm
- 0.6×4π

The PMT choice







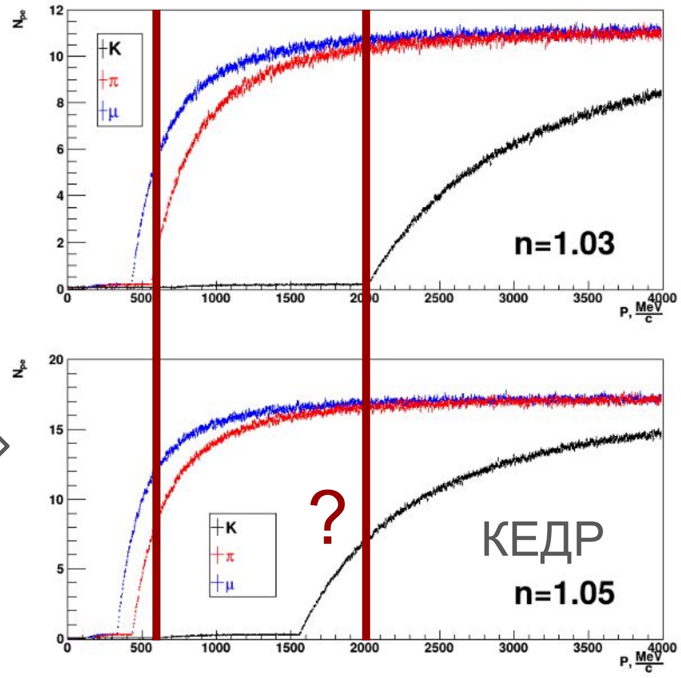
PDE=QE*CE = 23%*0.6 = 14%(500nm)

PDE = 40%(500nm)

Move to SiPMs must increase detected number of photoelectrons in 2.5 times!

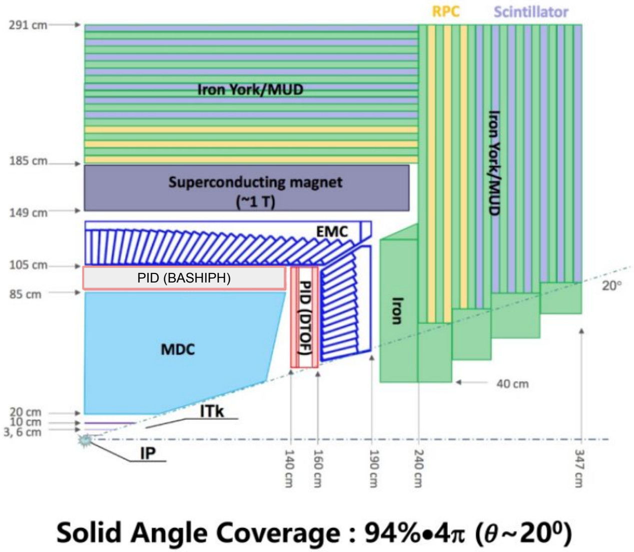
Для ВЭПП-6

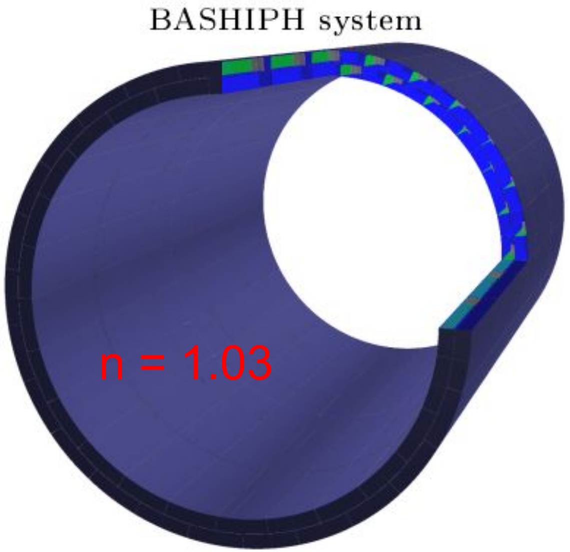
- π/K: 600 - 2000 МэВ/с
- Полное число счетчиков: 350
  - 2 слоя
  - 5 сегментов баррели
    - 25 счетчиков в сегменте на слой
  - 25 счетчиков на слой торца
- Длина системы: 230 см (длина счетчика: 46 см)
- Аэрогель n = 1.03
- Аэрогель n = 1.05
  - На сколько нам интересны двухчастичные процессы?
  - Возможность использовать аэрогель из КЕДРа?



Моделирование проводится в среде AURORA 3.0.0 схожей с OSCAR (STCF)

BASHIPH geometry description





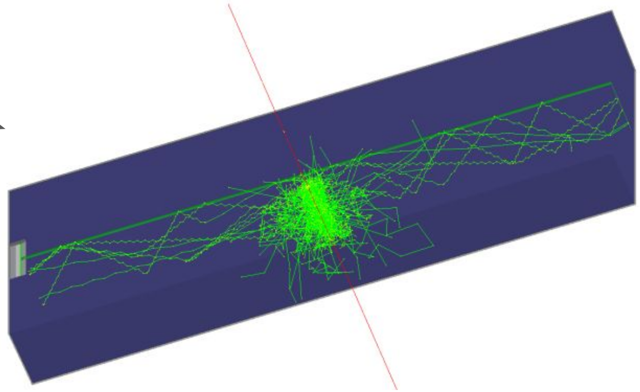
- Total number of counters: 250 (~ 1740 L of aerogel with n=1.03)
- 2 layers (125 counters on layer): are shifted relative to each other by half a period
- Thickness the system: 12.5 cm (0.11X_0)
- 5 segments: 1 segments content of 25 counters
- Length of the system: 280 cm (counter length: 56 cm)

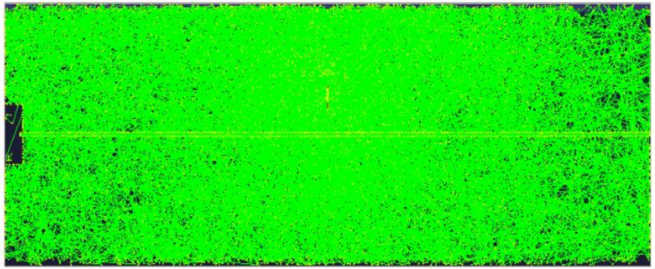
BASHIPH simulation with OSCAR framework:

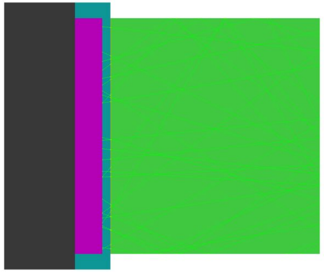
- Subthreshold effects
- Beam background
- Intrinsic SiPm noise
- Physical background

Simulated physical processes

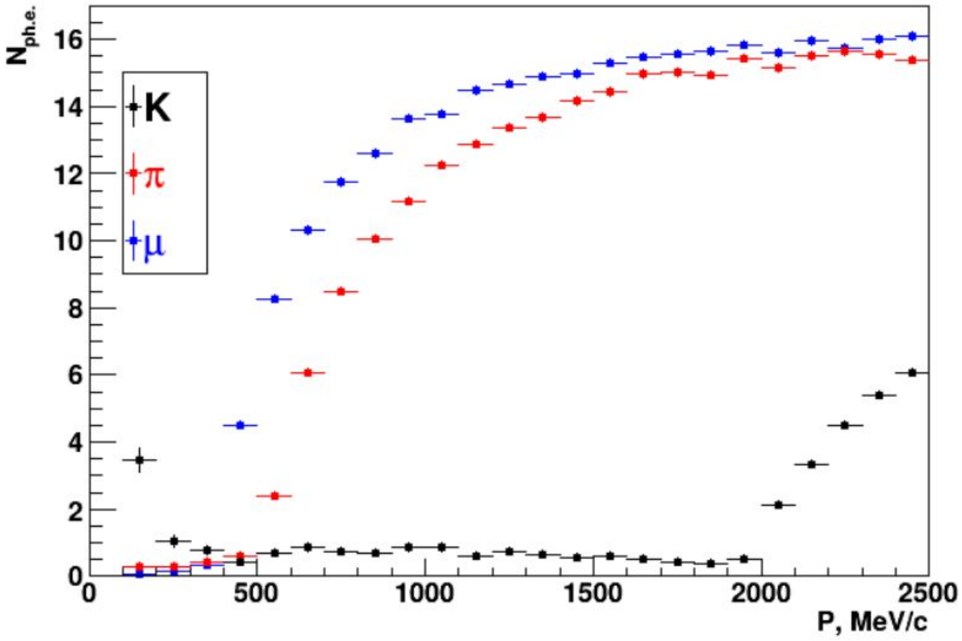
- Aerogel optics
  - Refractive index
  - Absorption length
  - Scattering length
- WLS optics
  - Refractive index of the Plex.
  - Absorption length of the Plex.
  - Emission of the BBQ
- Teflon reflection
  - Reflectivity
- SiPm simulation
  - Photon detection

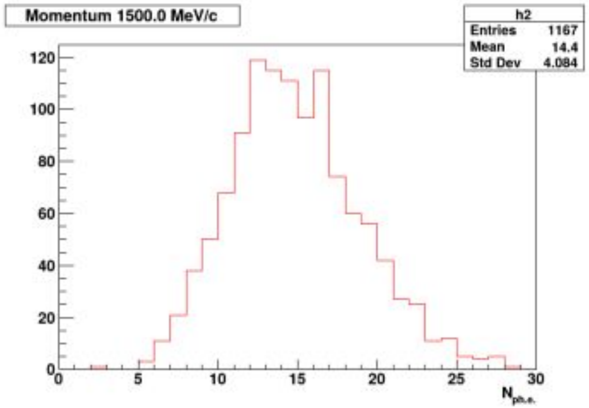






BASHIPH: simulation results

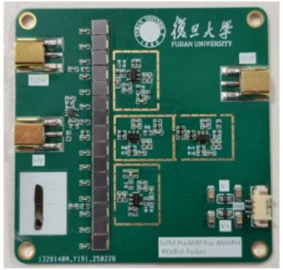




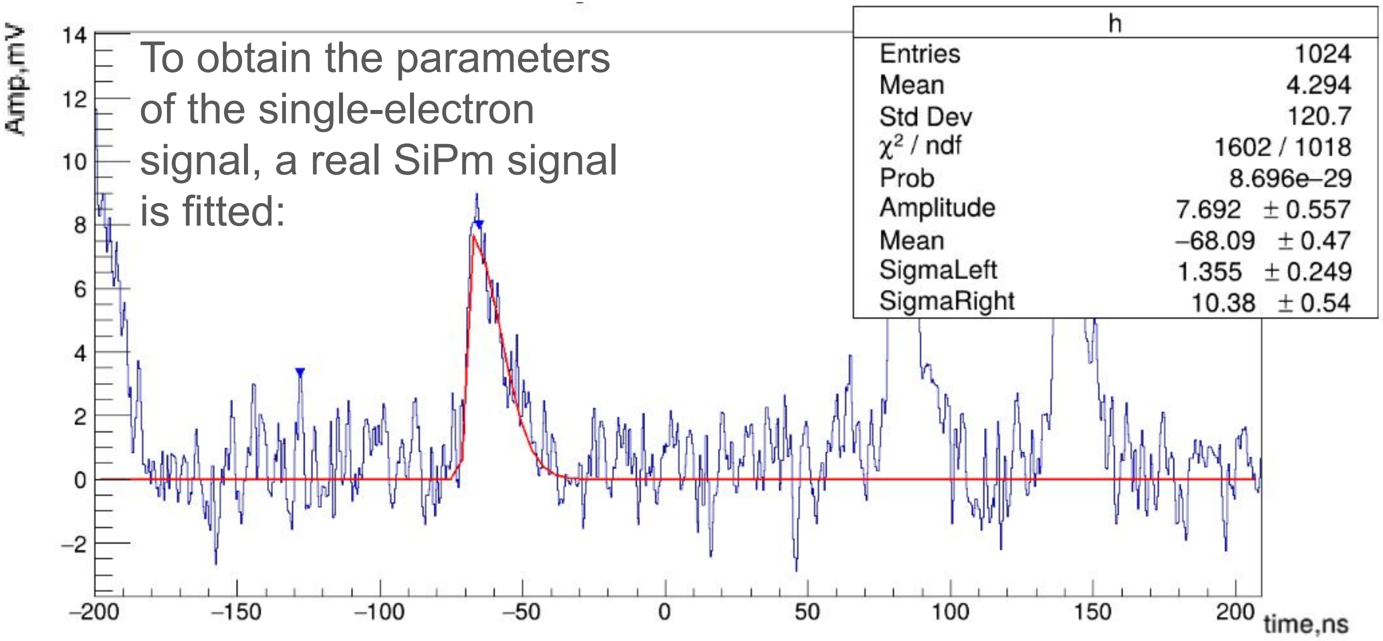
- $\Theta = 90^0$
- $\varphi = 182^0$
- Signal output from two layers ~ 14.4 ph.e.
- Need to simulate digitization!

BASHIPH digitization

Digitization: 1 ph.e. signal waveform

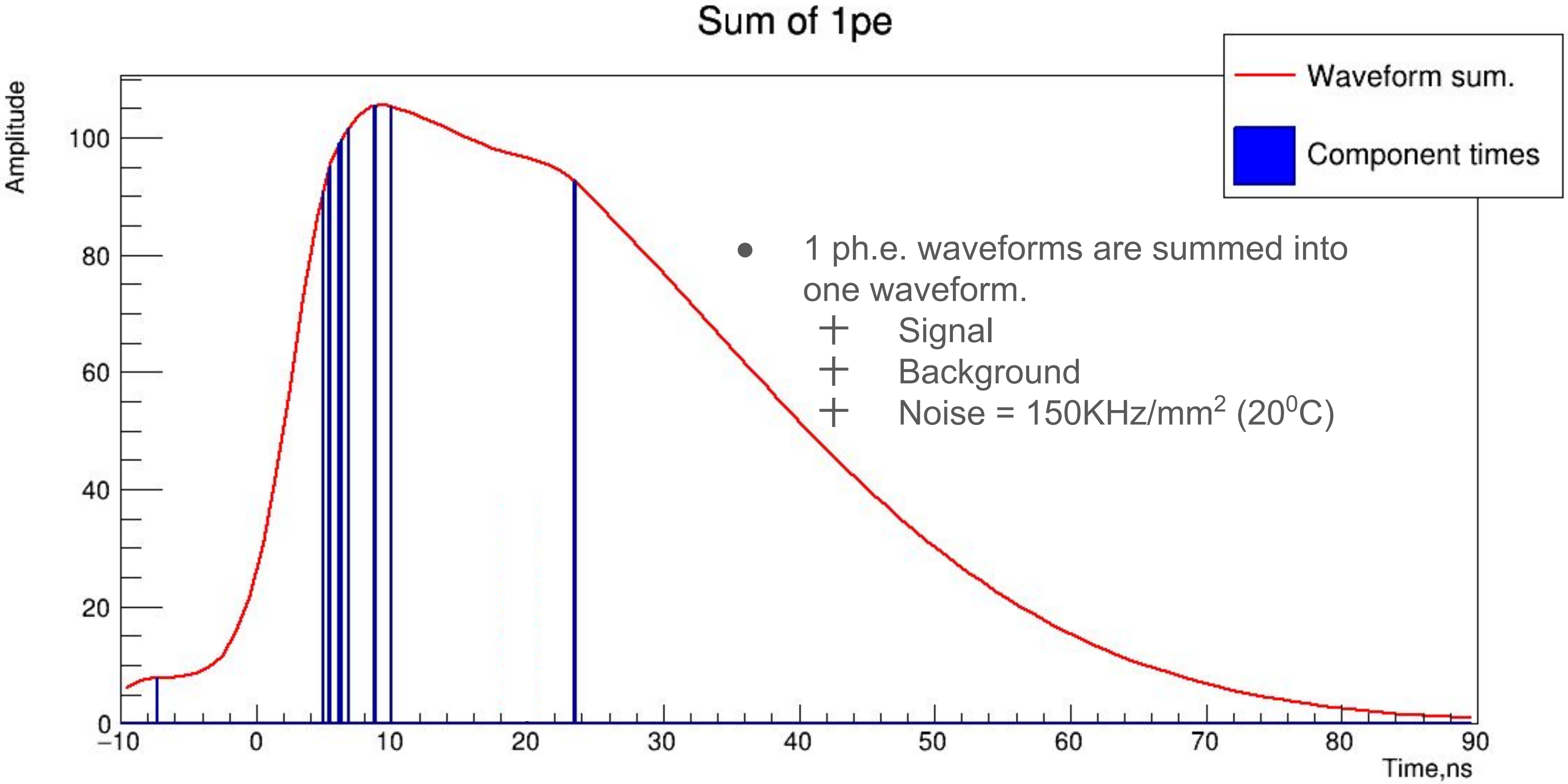


To obtain the parameters of the single-electron signal, a real SiPm signal is fitted:



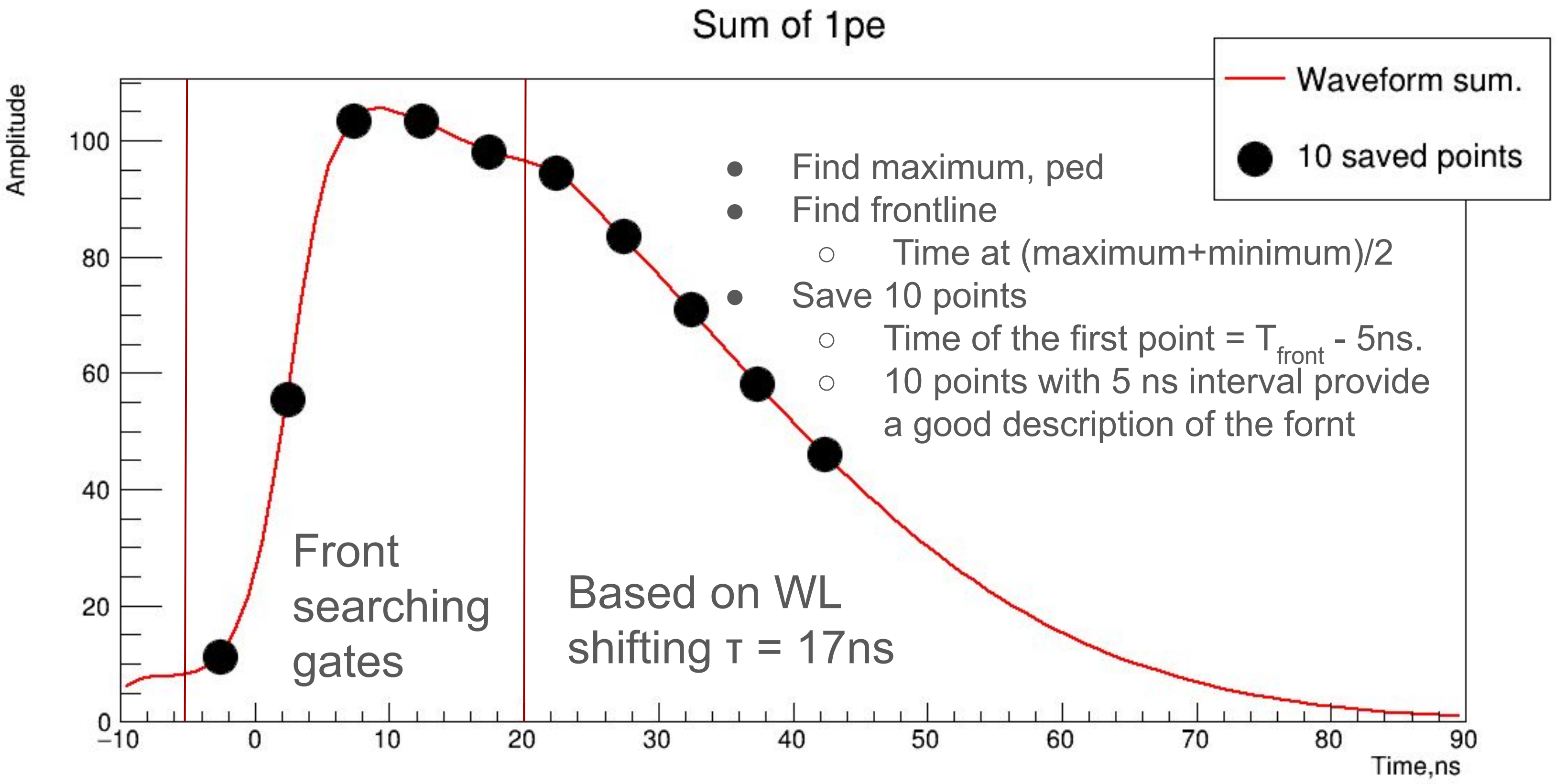
- NDL SiPM array:
  - 15 PMT
  - 3x3 mm
  - 150KHz/mm^2
    - at 20^{0}C

Digitization: summation of waveforms



- 1 ph.e. waveforms are summed into one waveform.
  - Signal
  - Background
  - Noise = 150KHz/mm^2 (20^{0}C)

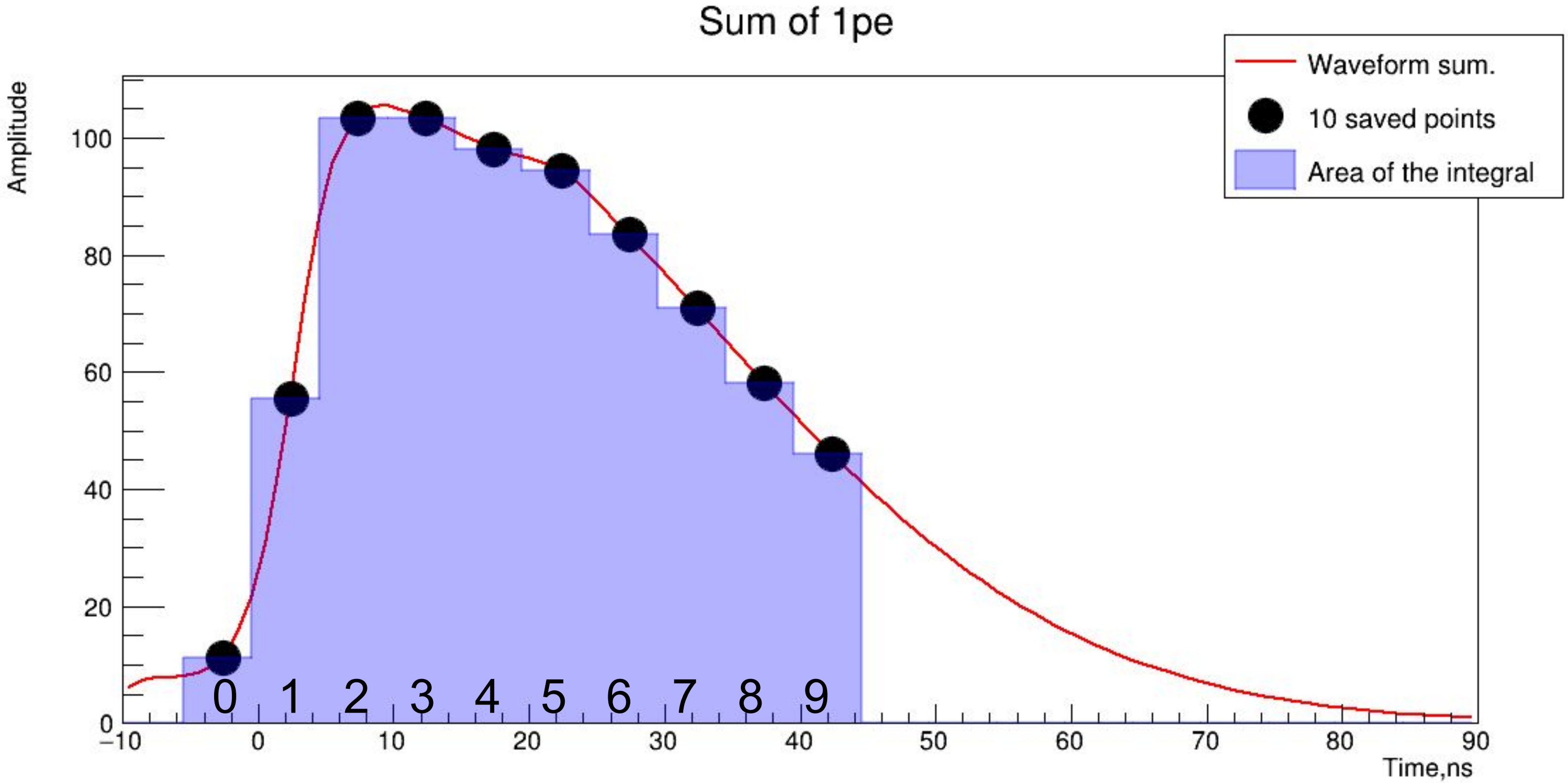
Digitization: getting 10 points



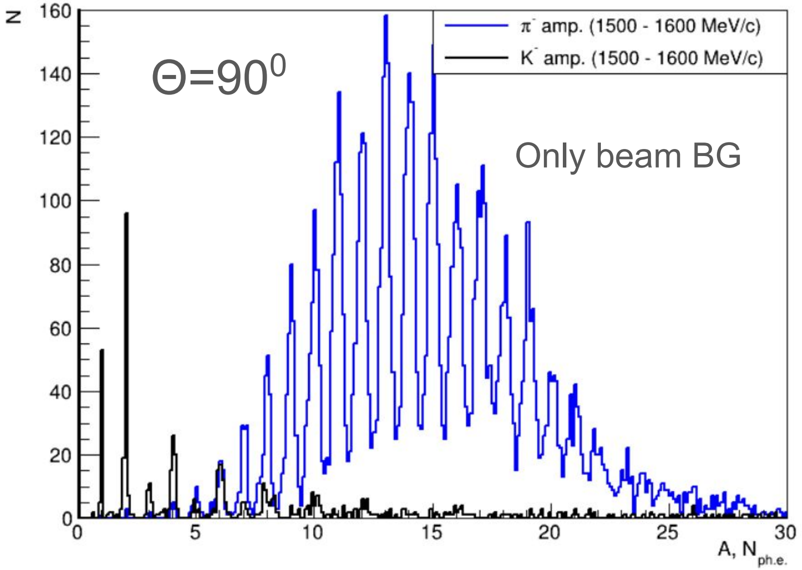
- Find maximum, ped
- Find frontline
  - Time at (maximum+minimum)/2
- Save 10 points
  - Time of the first point = T_{front} - 5ns.
  - 10 points with 5 ns interval provide a good description of the fornt

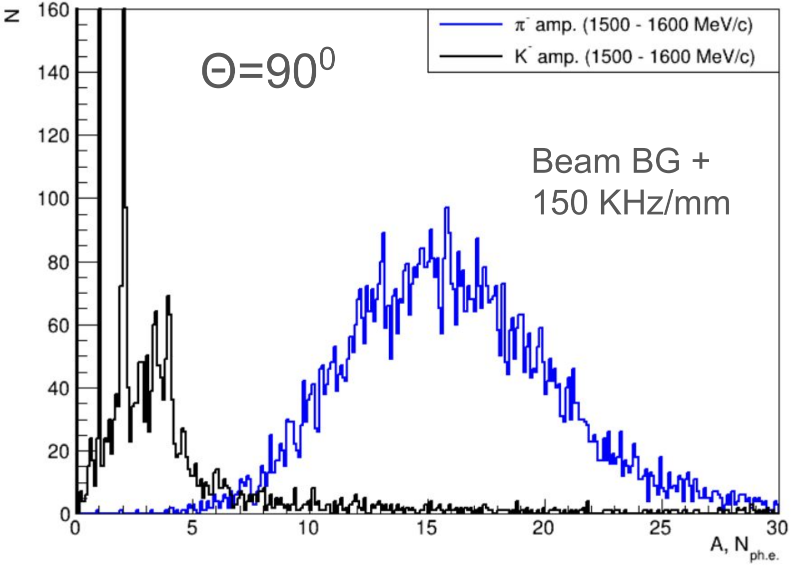
BASHIPH reconstruction

Reconstruction: amplitude reconstruction



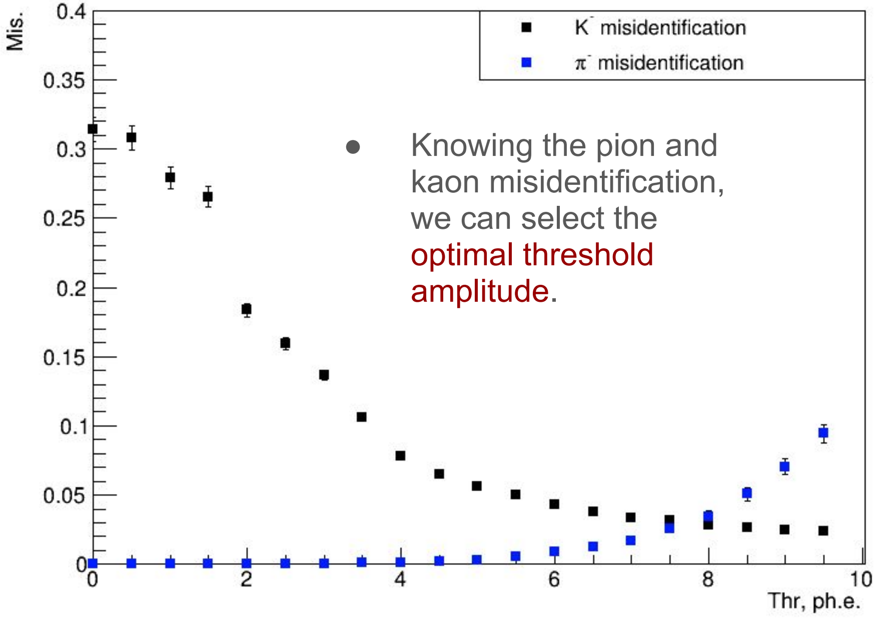
Reconstruction: amplitude spectrum



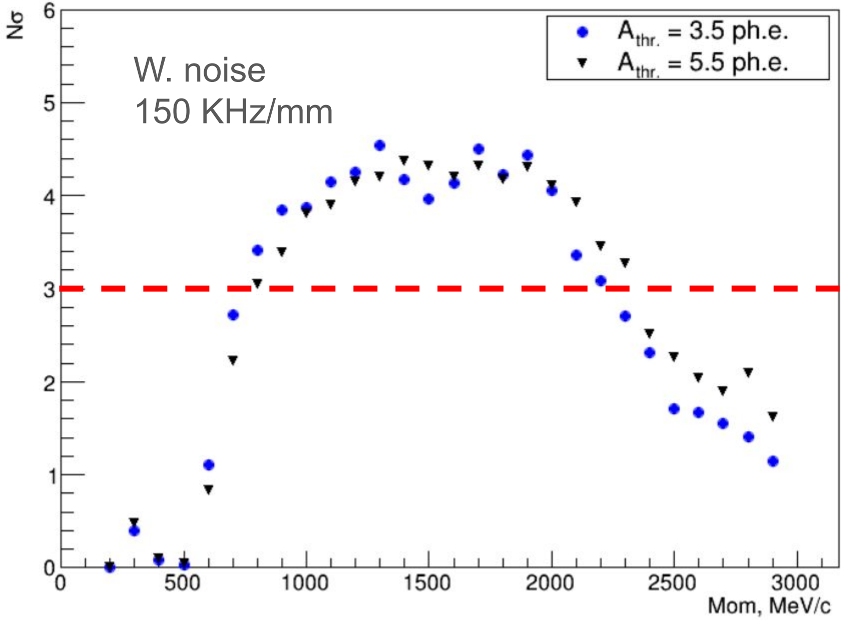


- Per each track, the amplitudes from the two layers of the system are summed. This allows for better geometric homogeneity to be achieved.
- Here are presented variants of the amplitude spectra of pions and kaons for different cases of noise frequencies.
- Knowing the amplitude distribution, the threshold amplitude can be chosen.

Reconstruction: quality of π/K separation with const. thr.



- Knowing the pion and kaon misidentification, we can select the optimal threshold amplitude.

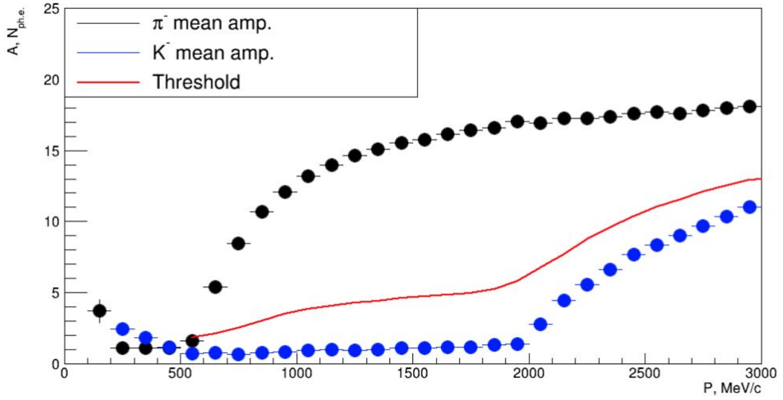


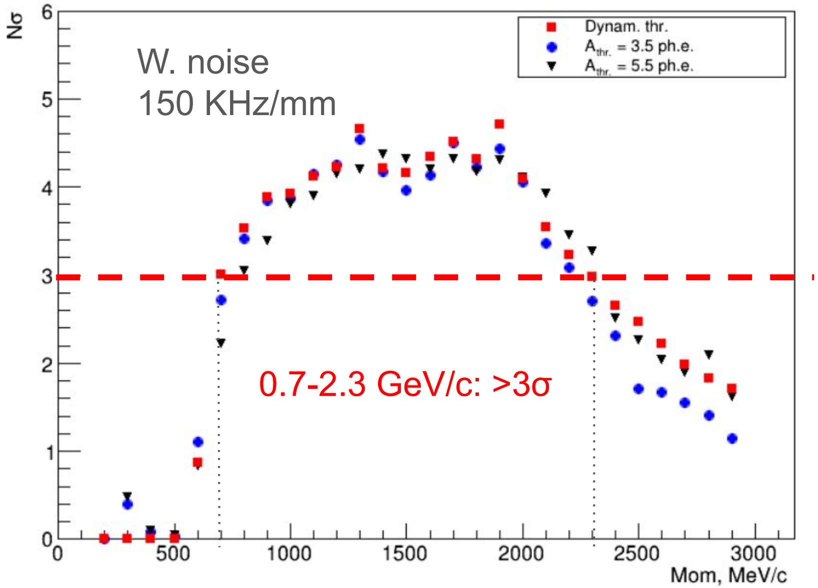
- The separation can be estimated in terms of standard deviations:

$$N\sigma = \sqrt{2} \times \left(\frac{1}{erf\,(1 - 2 \times (1 - Mis.Id._K\,))} + \frac{1}{erf\,(1 - 2 \times (1 - Mis.Id._\pi\,))} \right)$$

- A constant threshold is not an optimal solution for all momentum ranges
- Operating the system at room temperature will reduce separation quality by ≈0.5σ.

Reconstruction: quality of π/K separation with dynam. thr.

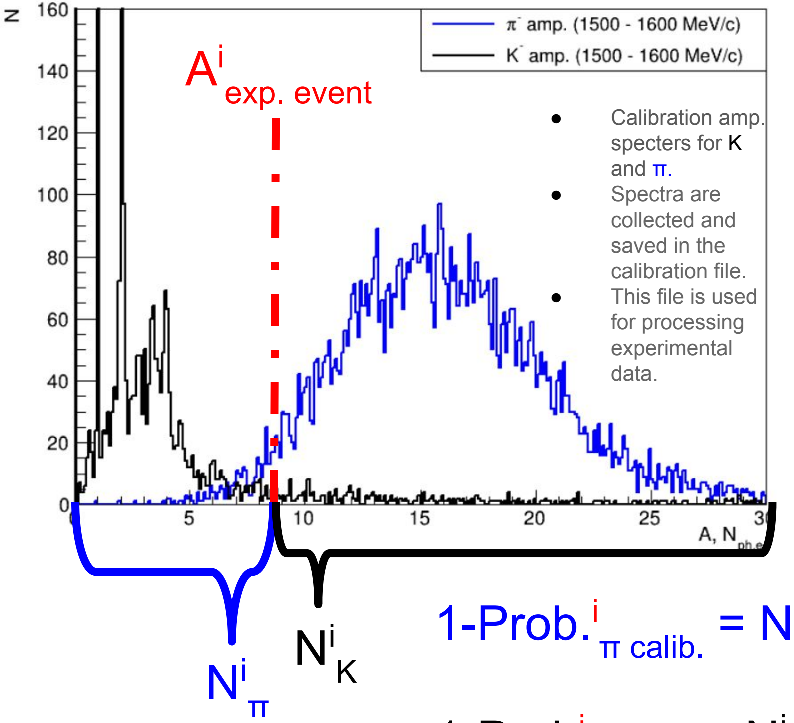




- The introduction of a dynamic threshold helped to select optimal values for each point of the momentum range.

- Also is possible to obtain separation of about ≈3σ in the momentum range of 2-2.3 GeV/c.

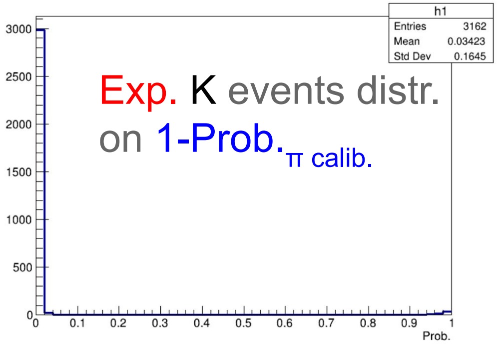
Reconstruction: likelihood

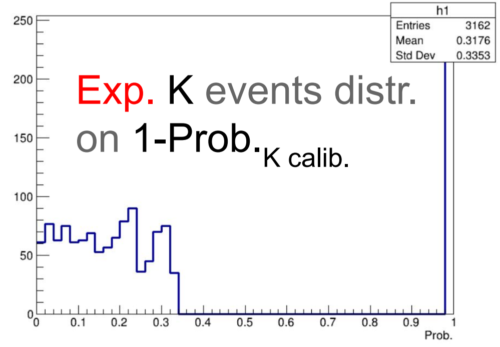


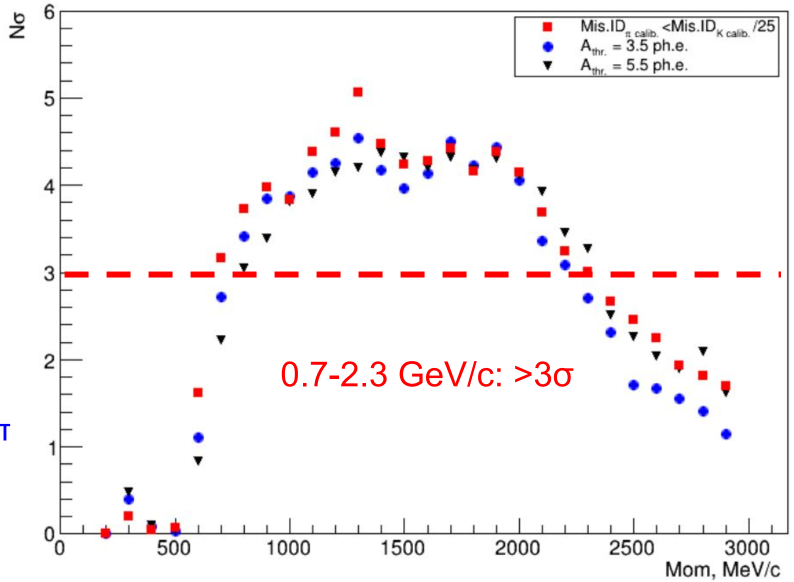
- Calibration amp. specters for K and π.
- Spectra are collected and saved in the calibration file.
- This file is used for processing experimental data.

$$1\text{-Prob.}^i_{\pi\ calib.} = N^i_\pi / N^{total}_\pi$$

$$1\text{-Prob}^i_{K\ calib.} = N^i_K / N^{total}_K$$

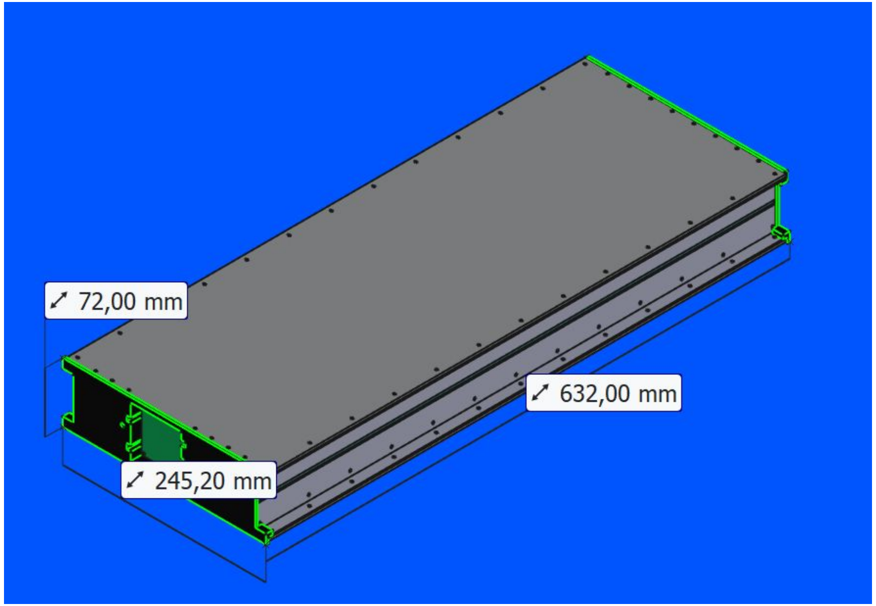


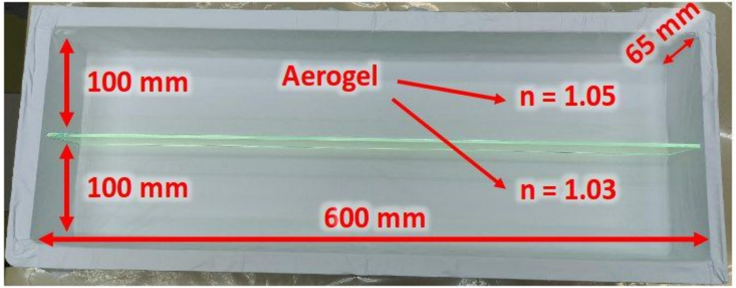




Исследование допороговой эффективности счетчика АШИФ-SiPM на адронных пучках

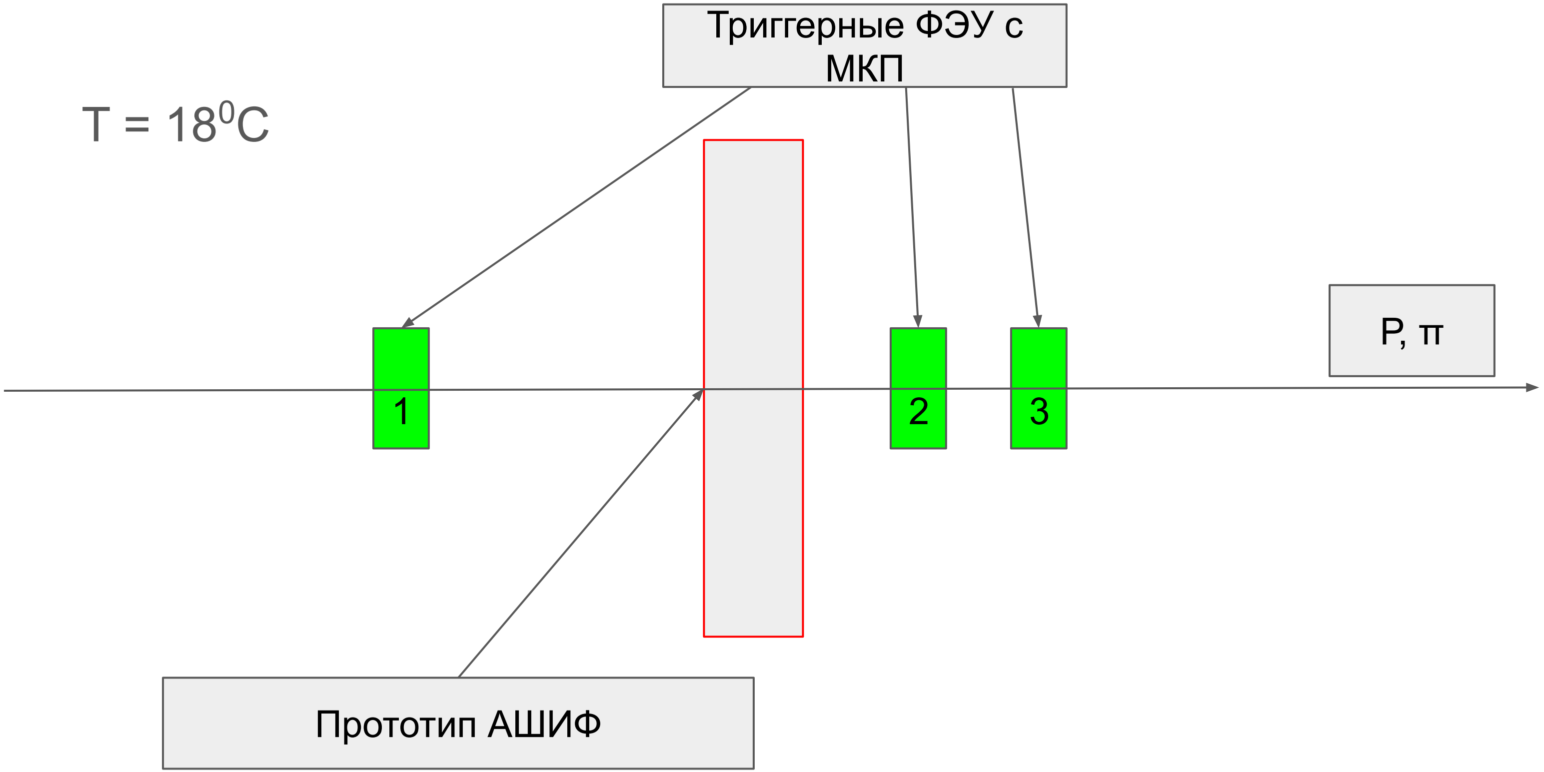
Прототип АШИФ SiPM(NDL) n=1.03/1.05





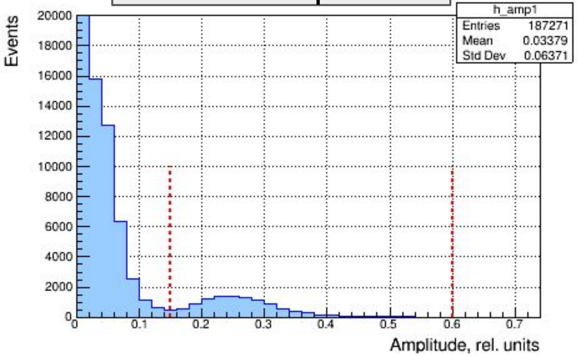
- Прототип содержит 2 вида аэрогеля:
  - n = 1.03
  - n = 1.05
- Переизлучатель:
  - Плексиглас + BBQ
- ФЭУ:
  - NDL SiPM
- Покрытие корпуса:
  - Тефлон

Тест прототипа на выведенном пучке адронов в ЦЕРН

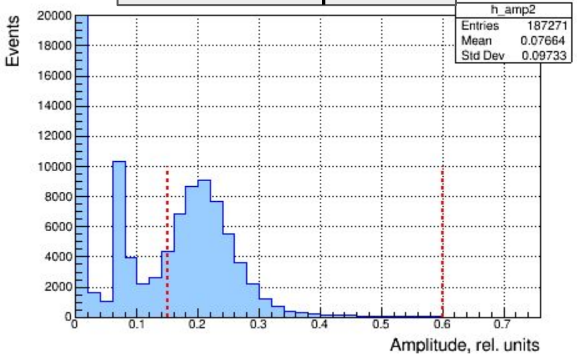


Условия отбора

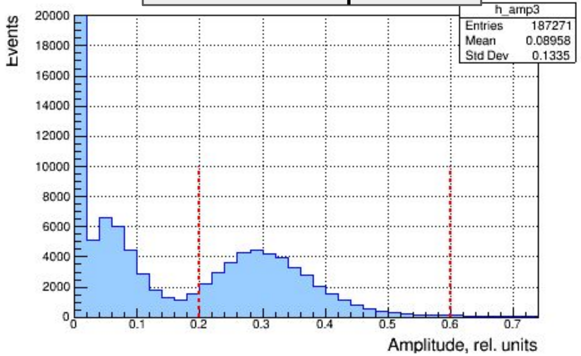
MCP 1 amplitude



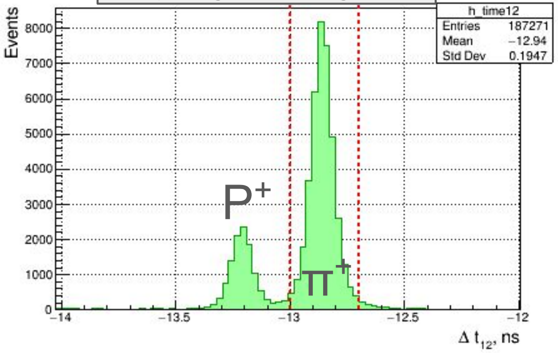
MCP 2 amplitude



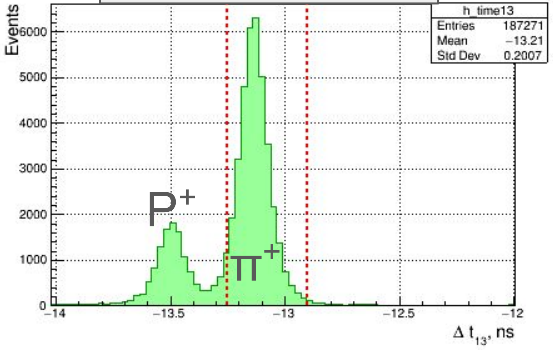
MCP 3 amplitude



Δt: MCP 1 - MCP 2

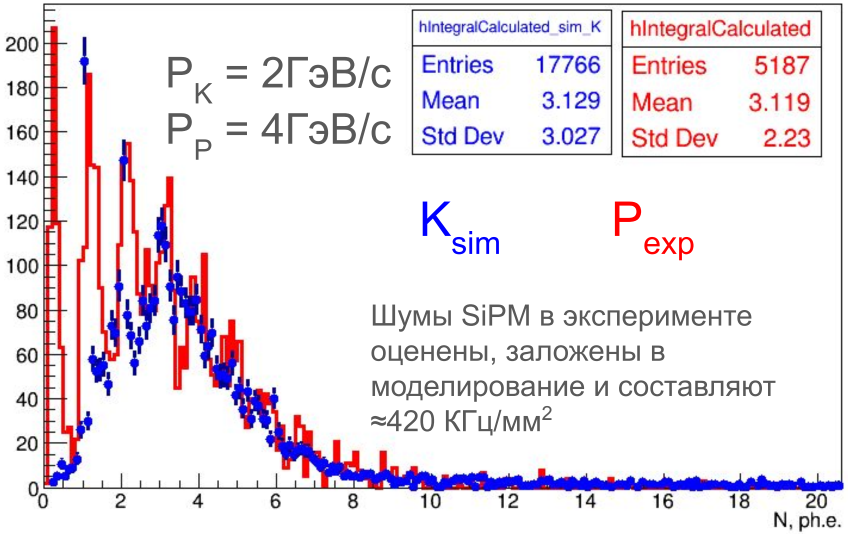


Δt: MCP 1 - MCP 3

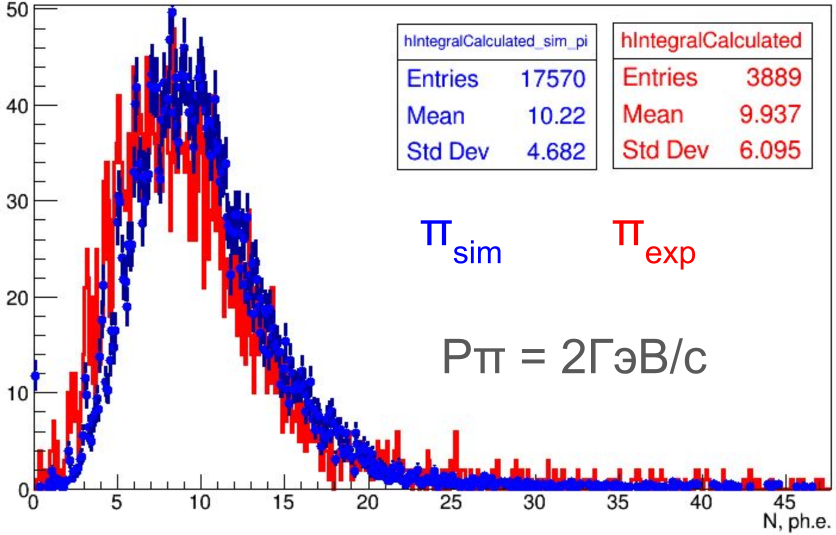


- События отобраны по амплитудам триггерных ФЭУ
- P/π разделение произведено по времени пролета между триггерными ФЭУ

Сравнение моделирования (1 слой, n=1.03) и эксперимента (предварительные результаты)



Шумы SiPM в эксперименте оценены, заложены в моделирование и составляют ≈420 КГц/мм^2



Допороговая эффективность (n=1.03)

Шумы SiPM

Шумы SiPM + допороговая эффективность P

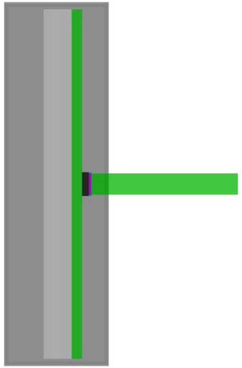
Спектр шумов SiPM построен путем анализа внесигнальной области

Заключение

- Система ASHIPH-SiPM для детектора ВЭПП-6 находится в разработке
  - Предлагаемые варианты аэрогеля: 1.03, 1.05
  - Проводится моделирование в среде AURORA
- Для ASHIPH-SiPM STCF проведены моделирование, дигитизация и реконструкция (с аэрогелем 1.03 и уровнем собственных шумов 150 КГц/мм^2) в среде OSCAR аналогичной AURORA:
  - Динамический порог позволяет получить π/K разделение около 3-5σ в диапазоне импульсов 0.7-2.3 ГэВ/с.
  - Продемонстрирована возможность расширения импульсного диапазона на 0.3 ГэВ/с.
- На выведенном пучке адронов в ЦЕРН был испытан прототип ASHIPH-SiPM с двумя видами аэрогеля (1.03, 1.05)
  - Предварительное сравнение с моделированием показывает хорошее соответствие: среднее число ф.э. от π составило ≈10, от K/P ≈3 (P = 2ГэВ/с, шумы ≈420 КГц/мм^2)
  - По результатам теста проводится оценка компонент допороговой эффективности.

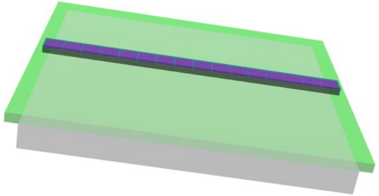
Backup

BASHIPH: counters geometry



Electronic box

Counter



SiPMs + PCB(5×5.4 cm)+
Peltier(5×5 cm)

SiPMs (HAMAMATSU
S13363-3050NE-16)

- Counters simulation is integrated in the detector volume by framework based on OSCAR
- Counter:
  - Each counter - cylindrical sector
  - Tefon covered from inside
  - Aerogel n=1.03 inside
  - WLS assembly at the middle of counter - BBQ doped plexiglass (PMMA)
  - SiPM optically coupled to WLS
  - Electronic box with SiPMs, PCB and Peltier module

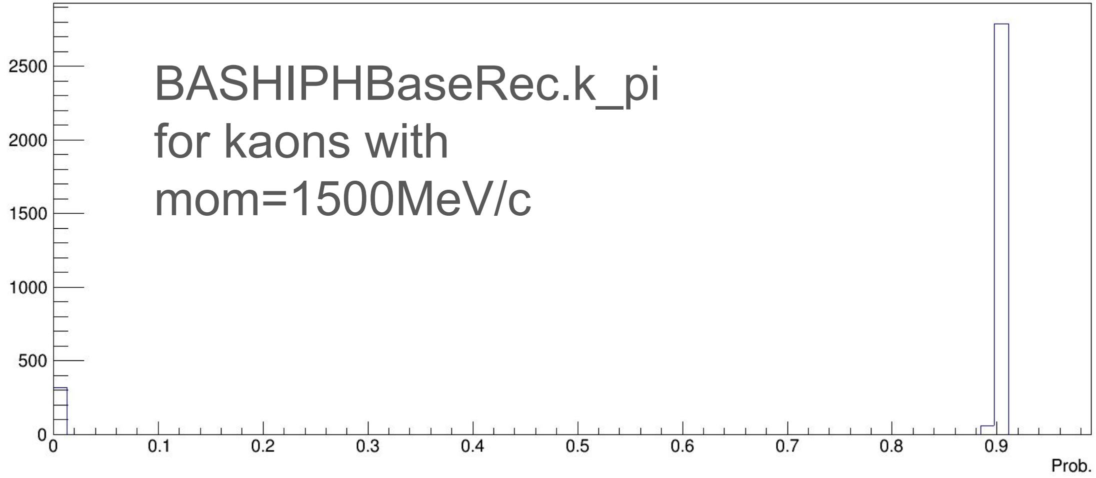
Reconstruction: dynamic threshold formulae

$$Thr = \overline{Amp_{K^-}} + \left(\overline{Amp_{K^-}} - \overline{Amp_{\pi^-}}\right) \times C$$

$$C = \frac{\sigma_{K^-}}{N \times \sigma_{\pi^-}}$$

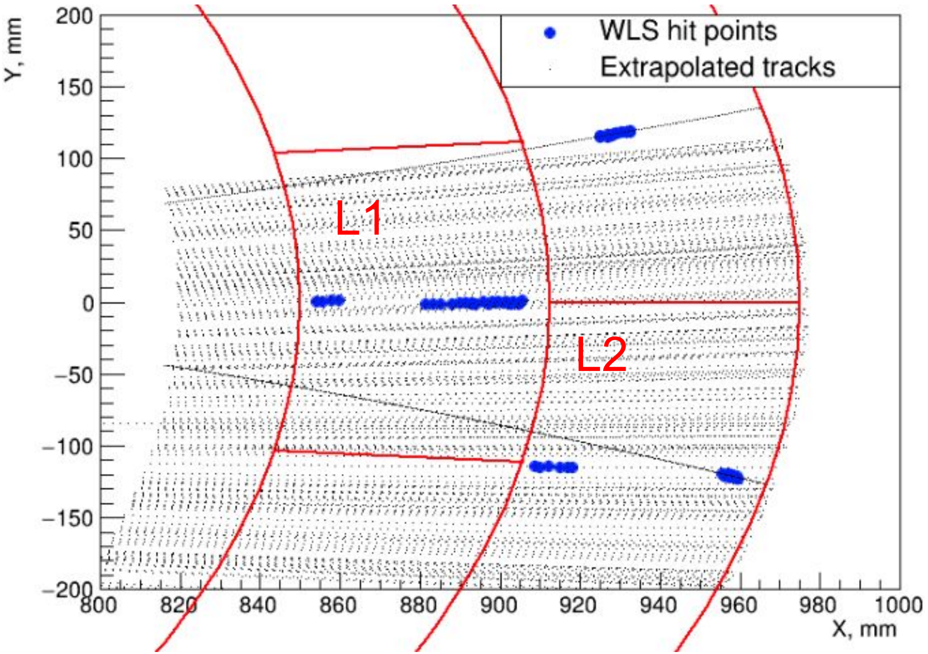
- The dynamic threshold is defined using the mean values of the kaon and pion amplitude distributions, as well as their standard deviations.
- At C = 0.5, the threshold is set between the mean pion and kaon amplitudes.
- Using the N parameter, the threshold can be tuned manually.

Reconstruction: to use



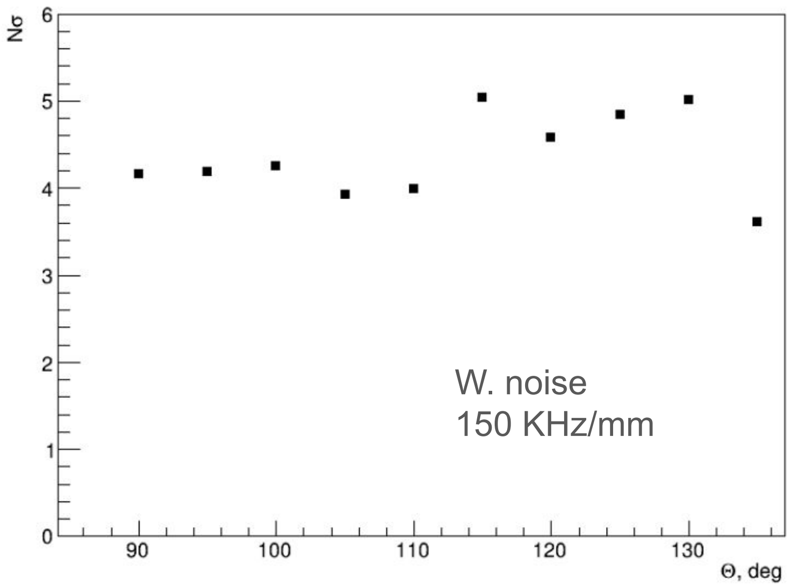

```
BASHIPHBaseRec:
  Description: "Data class for BASHIPHBaseRec"
  Author: "KP"
  Members:
    - int trk                          //track
    - double ampl                      //Reconstructrd sum. of amplitudes per track
    - double k_pi                      //kaons from pions prob.
```

Reconstruction: track extrapolation



- Based on the drift chamber data (momentum, last track coordinate, trajectory curvature radius), the track is extrapolated to the BASHIPH region.
- The extrapolated track points are checked for crossing of BASHIPH geometry elements (for example, the shifter).
- By excluding WLS, the amplitude distribution of signals from the aerogel can be obtained.

Reconstruction: dependence on θ



- The dependence of the degree of separation on the angle to the beam axis was also studied (at 1.5 GeV/c).

STCF final state particles