R&D on BASHIPH system for the STCF

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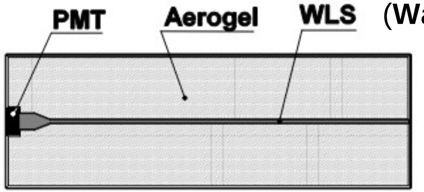
BINP

ASHIPH method for particle identification



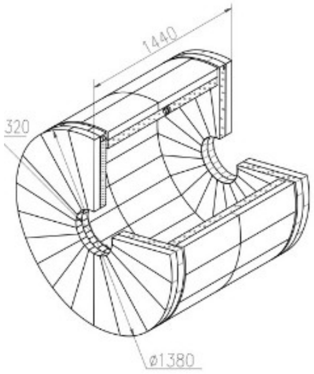
(**W**ave**L**ength **S**hifter)

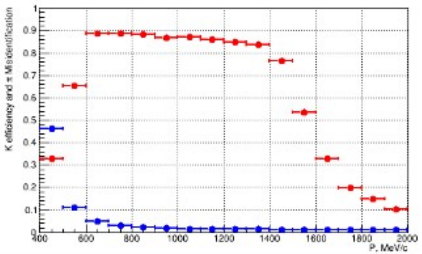
ASHIPH (Aerogel, SHifter, PHotomultiplier) method of light collection was suggested in 1992 (A. Onuchin et al. NIM A315, 1992, 517-520)

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

ASHIPH systems at the BINP (Novosibirsk):

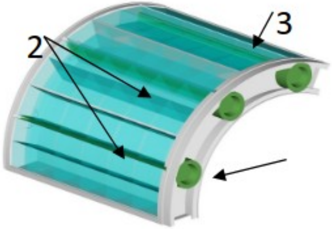
KEDR detector at VEPP-4M



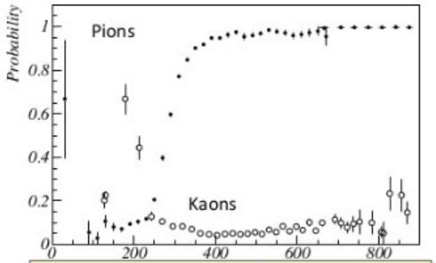


- 160 counters (2 layers)
- N=1.05 (1000 l.)
- MCP PMT ØPC=18 mm
- 0.97×4π

SND detector at VEPP-2000

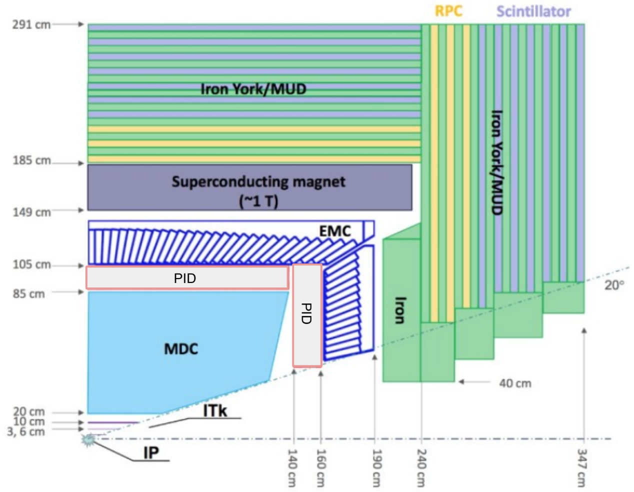


1 - PMT, 2 – aerogel, 3 - WLS



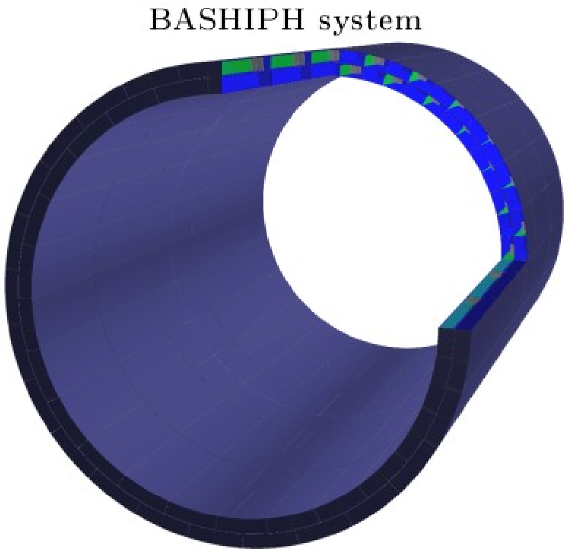
- 9 counters (1 layer)
- n=1.13 (π/K -separation)
  n=1.05 (e/π -separation)
- MCP PMT ØPC=18 mm
- 0.6×4π

BASHIPH geometry description



Solid Angle Coverage : 94%•4π (θ~20⁰)

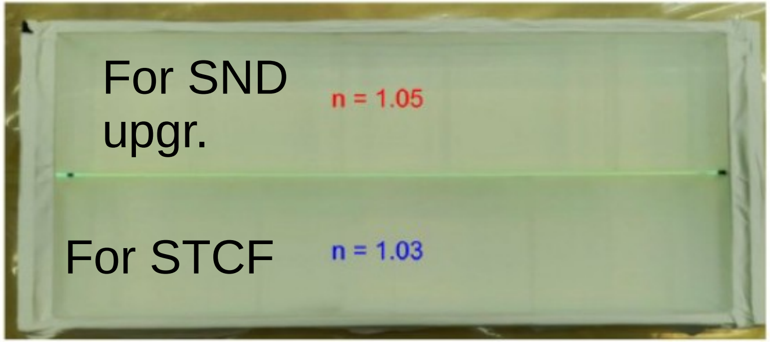
- Inner tracker (ITK, two options)
  - MPGD: cylindrical MPGD
  - Silicon: CMOS MAPS
- Central tracker (MDC)
  - Main drift chamber
- PID
  - Barrel:
    - RICH with CsI-MPGD
    - DIRC-like TOF
    - ASHIPH
  - Endcaps:
    - DIRC-like TOF (DTOF)
    - RICH with CsI-MPGD
- EMC
  - pure CsI + APD
- Muon detector (MUD)
  - RPC + scintillator strips
- Magnet
  - Super-conducting solenoid, 1 T

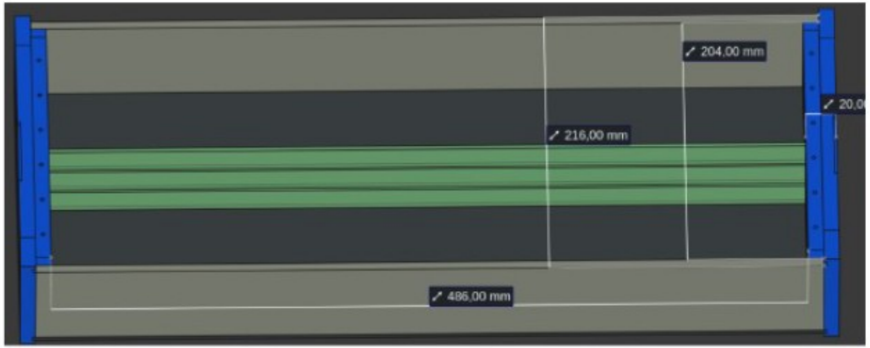


- Total number of counters: 250 (~ 1740 L of aerogel)
- 2 layers (125 counters on layer): are shifted relative to each other by half a period
- Thickness the system: 12.5 cm ($0.11X_0$, aluminium walls)
- 5 segments: 1 segments content of 25 counters
- Length of the system: 280 cm (counter length: 56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

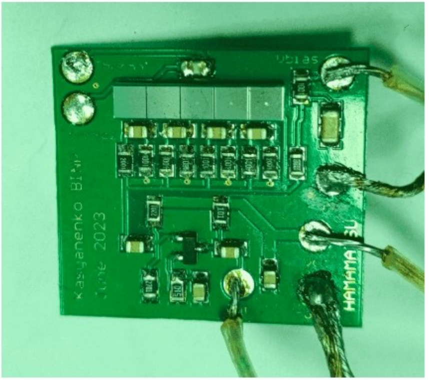
The ASHIPH - SiPM test prototype

ASHIPH-SiPM: the test prototype



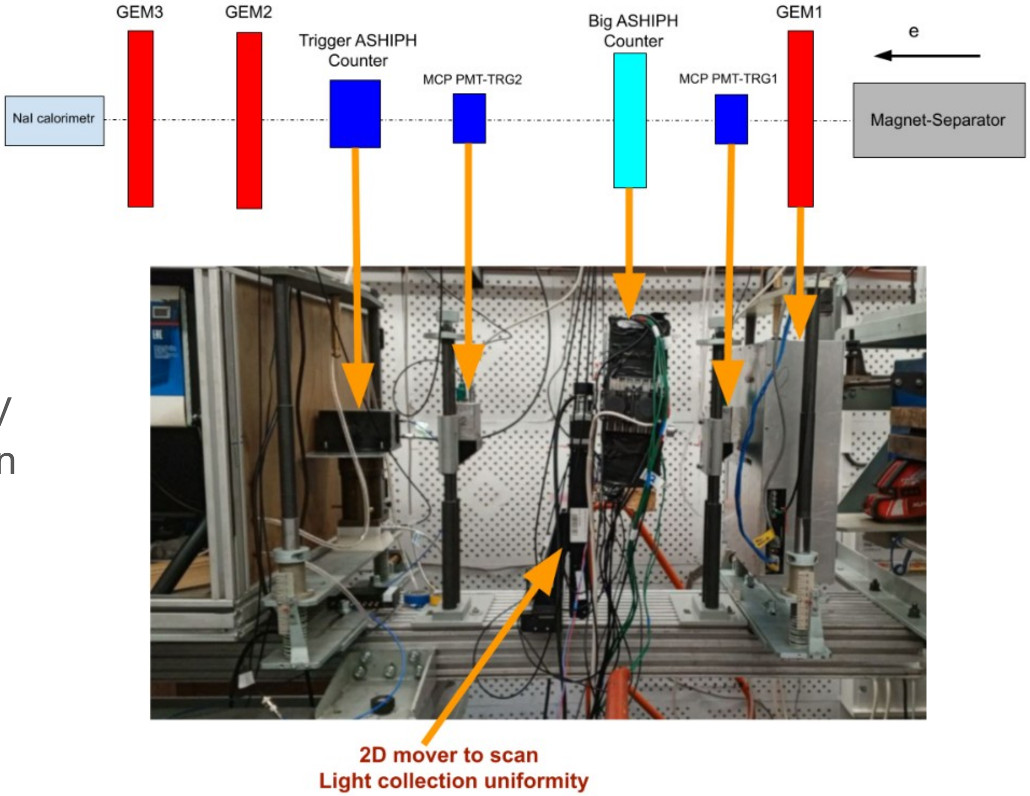


- Rectangular shape 50×22×6.4 cm
- Two types of aerogels with n=1.03 and n=1.05 for different halfs of the volume
- Aerogel blocks 100×100×60 mm with teflon wrapping
- 3 WLS plates based on Plex. with BBQ dope, crossection size is 17×3 mm
- 3 arrays of 5 SiPMs each were made from MPPC S13365-3050NE-16 (Hamamatsu)

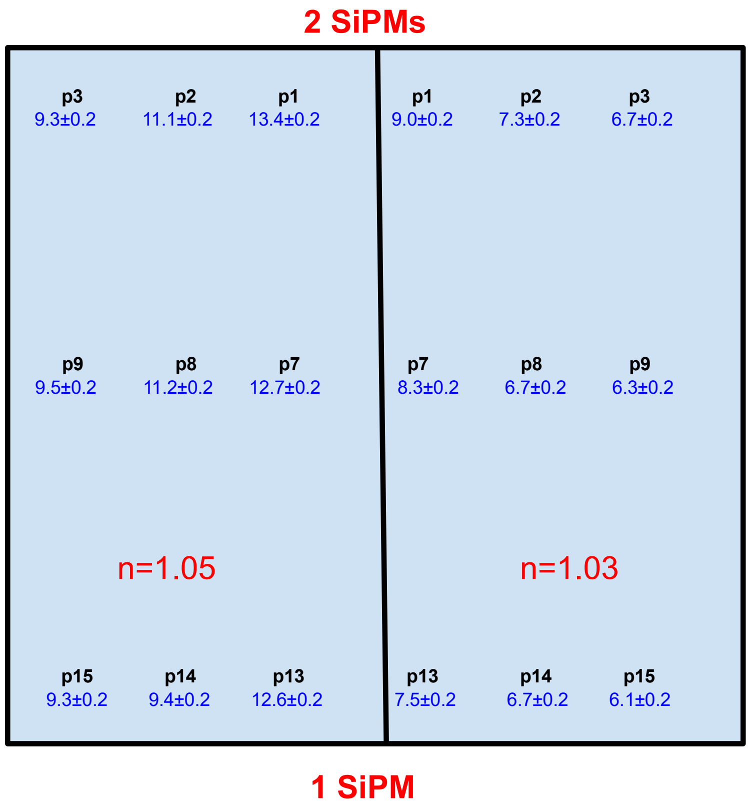


Electron beam at VEPP-4M (BINP, Novosibirsk)

- Beam energy:
  - 580 MeV
  - 2240 MeV
- 50000 events in each of the 30 different geom. areas
- t ≈ $24.5^{0}C$



Test beam (e+e-): results



- Beam energy: 580 MeV
- Average number of photoelectrons per counter:
  - Aerogel (n=1.03): 7.2 ph.e.
  - Aerogel (n=1.05): 10.9 ph.e.

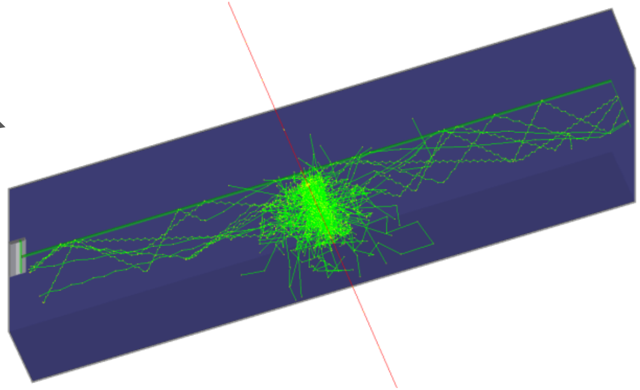
- Inhomogeneity of light collection from average value is:
  - Aerogel (n=1.03): ±20%
  - Aerogel (n=1.05): ±18%
- Inhomogeneity of light collection along(z-axis) the counter:
  - Aerogel (n=1.03): ±7%
  - Aerogel (n=1.05): ±5%
- On the electron test-beam we can’t observe the subthreshold efficiency or the beam background !

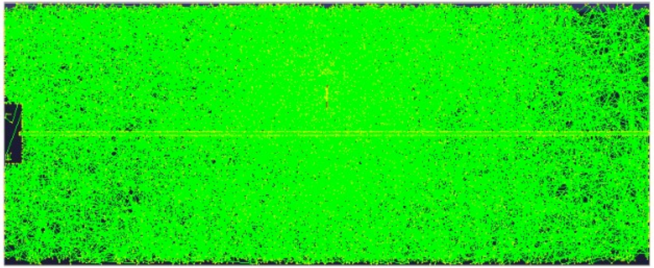
BASHIPH simulation with OSCAR framework:

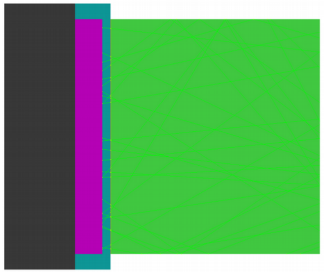
- Subthreshold effects
- Beam background
- Intrinsic SiPM noise
- Physical background

Simulated physical processes

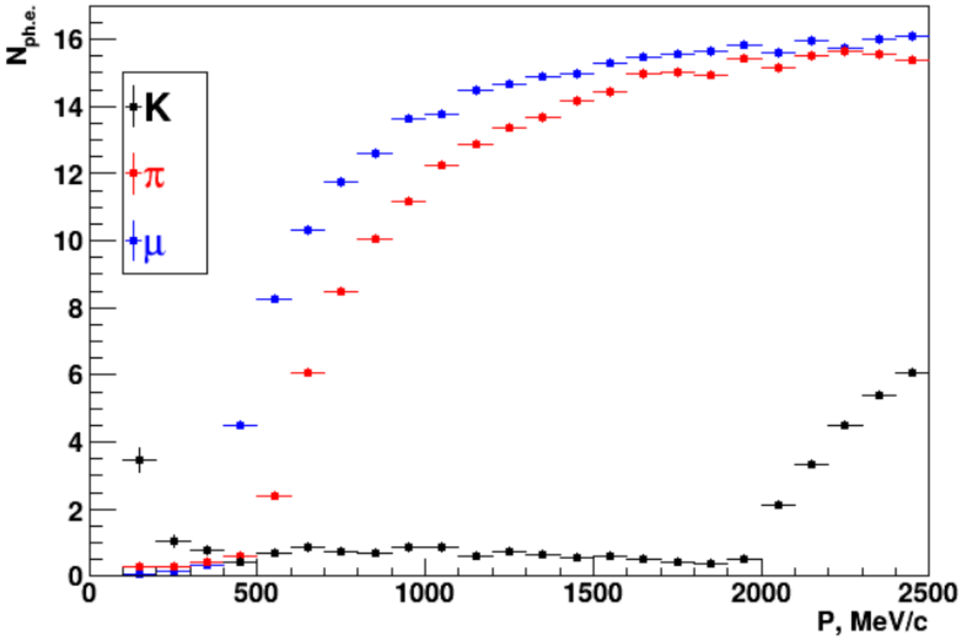
- Aerogel optics
  - Refractive index
  - Absorption length
  - Scattering length
- WLS optics
  - Refractive index of the Plex.
  - Absorption length of the Plex.
  - Emission of the BBQ
- Teflon reflection
  - Reflectivity
- SiPm simulation
  - Photon detection

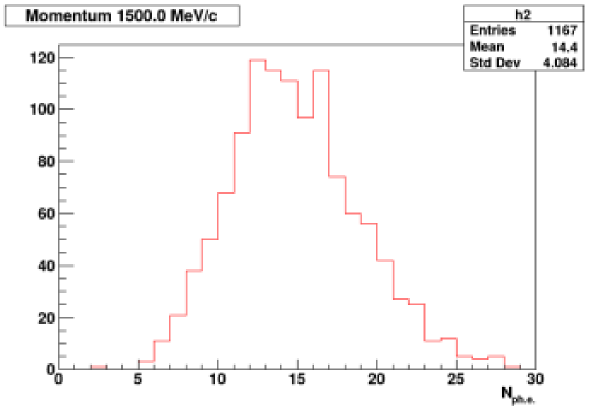






BASHIPH: simulation results





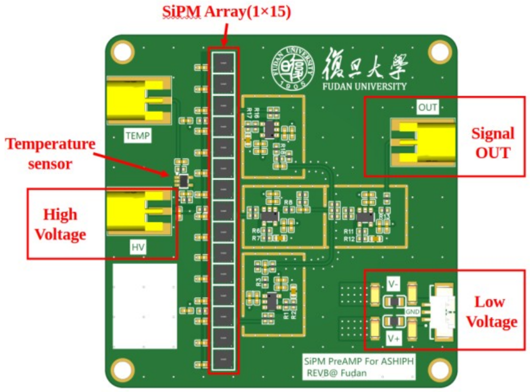
- $\Theta = 90^0$; $\varphi = 182^0$;
- Signal output from two layers ~ 14.4 ph.e. (at 1.5GeV/c);
- Need to simulate the SiPM noises!

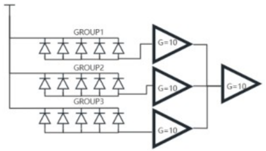
BASHIPH digitization

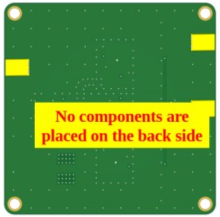
Digitization: PMT type

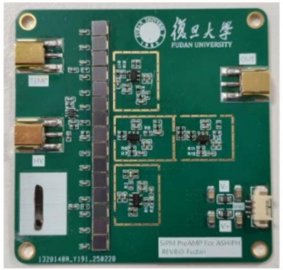
The following NDL SiPM parameters (20^0C) are used to simulate digitization:

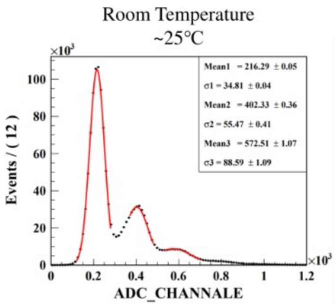
Type	EQR20 11-3030D-S	EQR20 11-6060D-S
Effective Pitch	20 µm	
Element Number	1×1	
Active Area	$3.00\times3.00\ mm^2$	$6.24\times6.24\ mm^2$
Micro-cell Number	$2500\ /mm^2$	
Typical Breakdown Voltage (V_B)	27.5 V	
Temperature Coefficient for V_B	24 mV / °C	
Recommended Operation Voltage	$V_B + 5$ V	
Peak PDE @ 420nm	46 %	
Gain	8.2×10^5	
Dark Count Rate (DCR)	$150\ kHz\ /\ mm^2$	

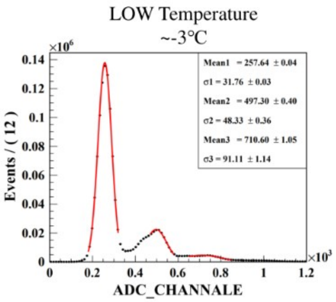












SPA(Single photon amplitude) = 178.1

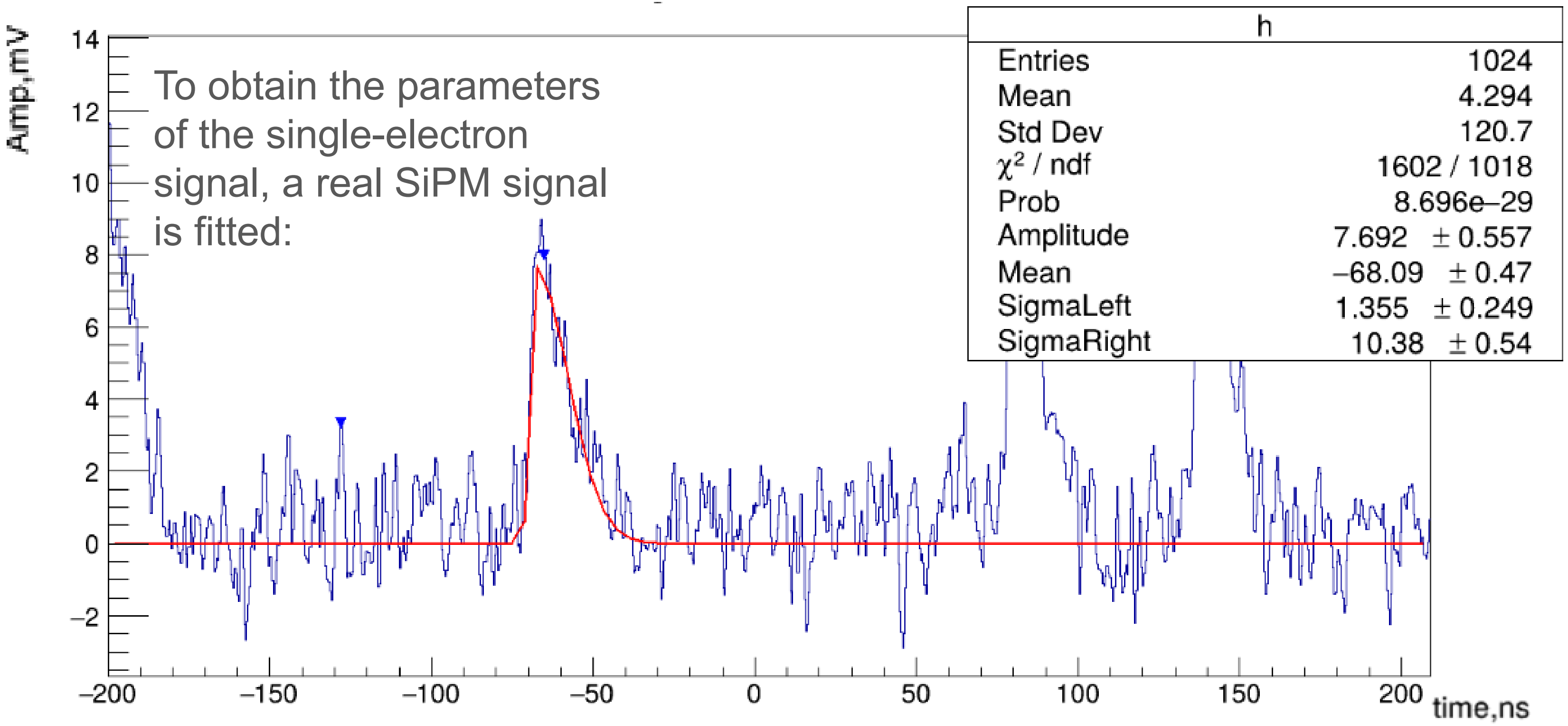
SNR(Signal to Noise Ratio) = SPA/σ1=5.2

SPA(Single photon amplitude) = 226.5

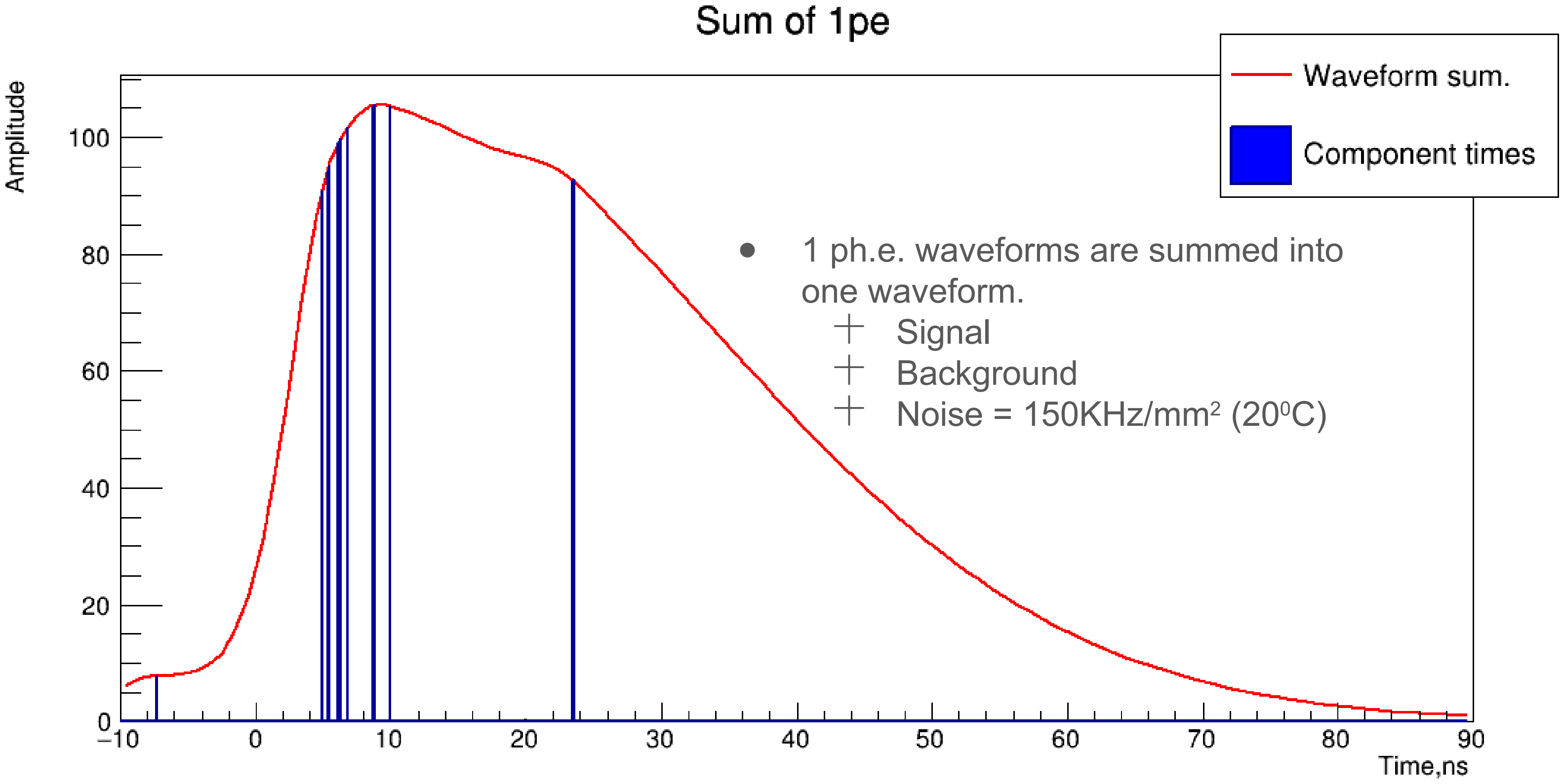
SNR(Signal to Noise Ratio) = 7.1

Digitization: 1 ph.e. signal waveform

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

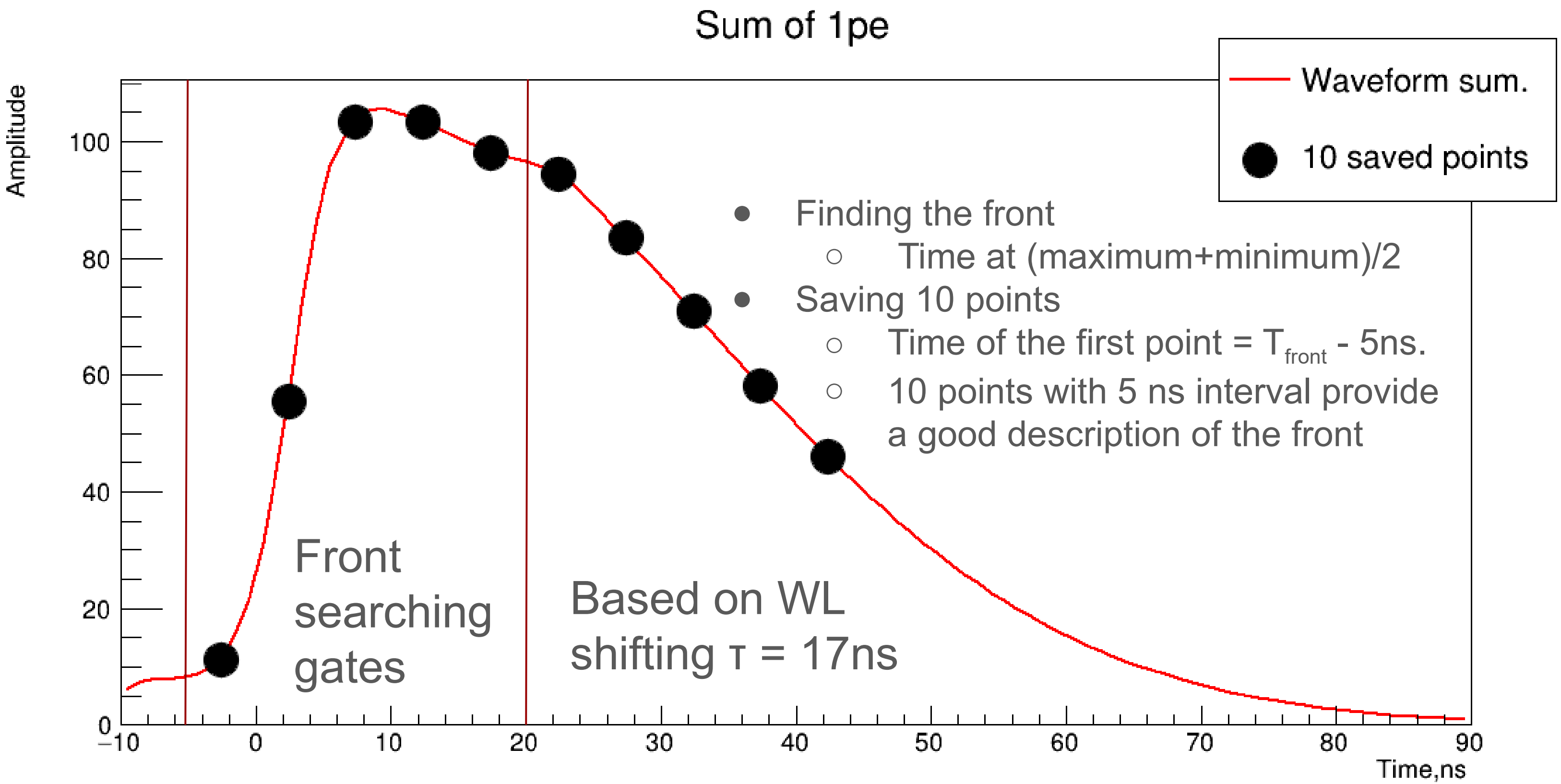


Digitization: summation of waveforms



- 1 ph.e. waveforms are summed into one waveform.
  - Signal
  - Background
  - Noise = 150KHz/mm² (20⁰C)

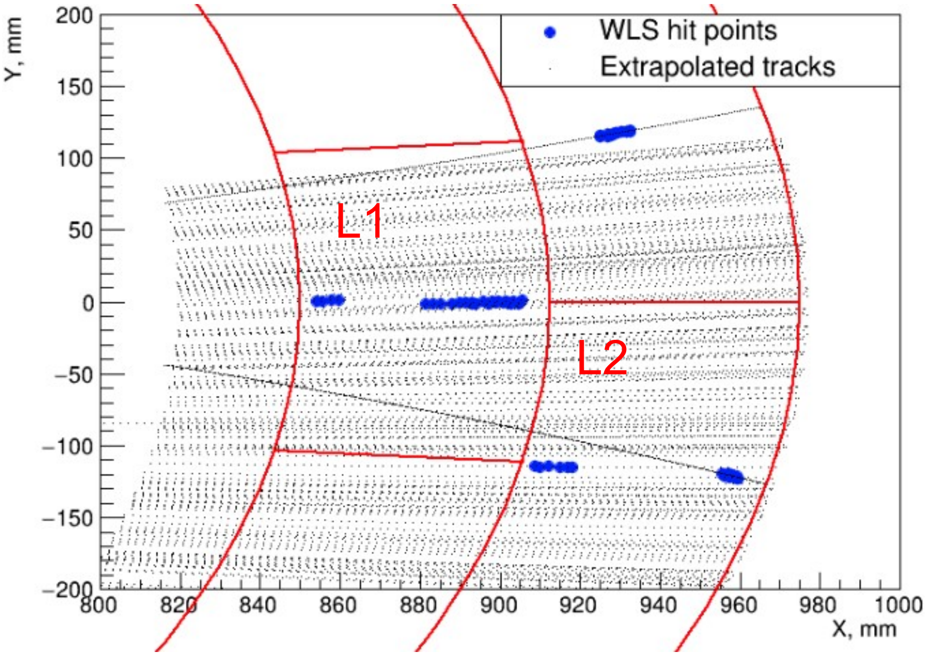
Digitization: getting 10 points



- Finding the front
  - Time at (maximum+minimum)/2
- Saving 10 points
  - Time of the first point = T_{front} - 5ns.
  - 10 points with 5 ns interval provide a good description of the front

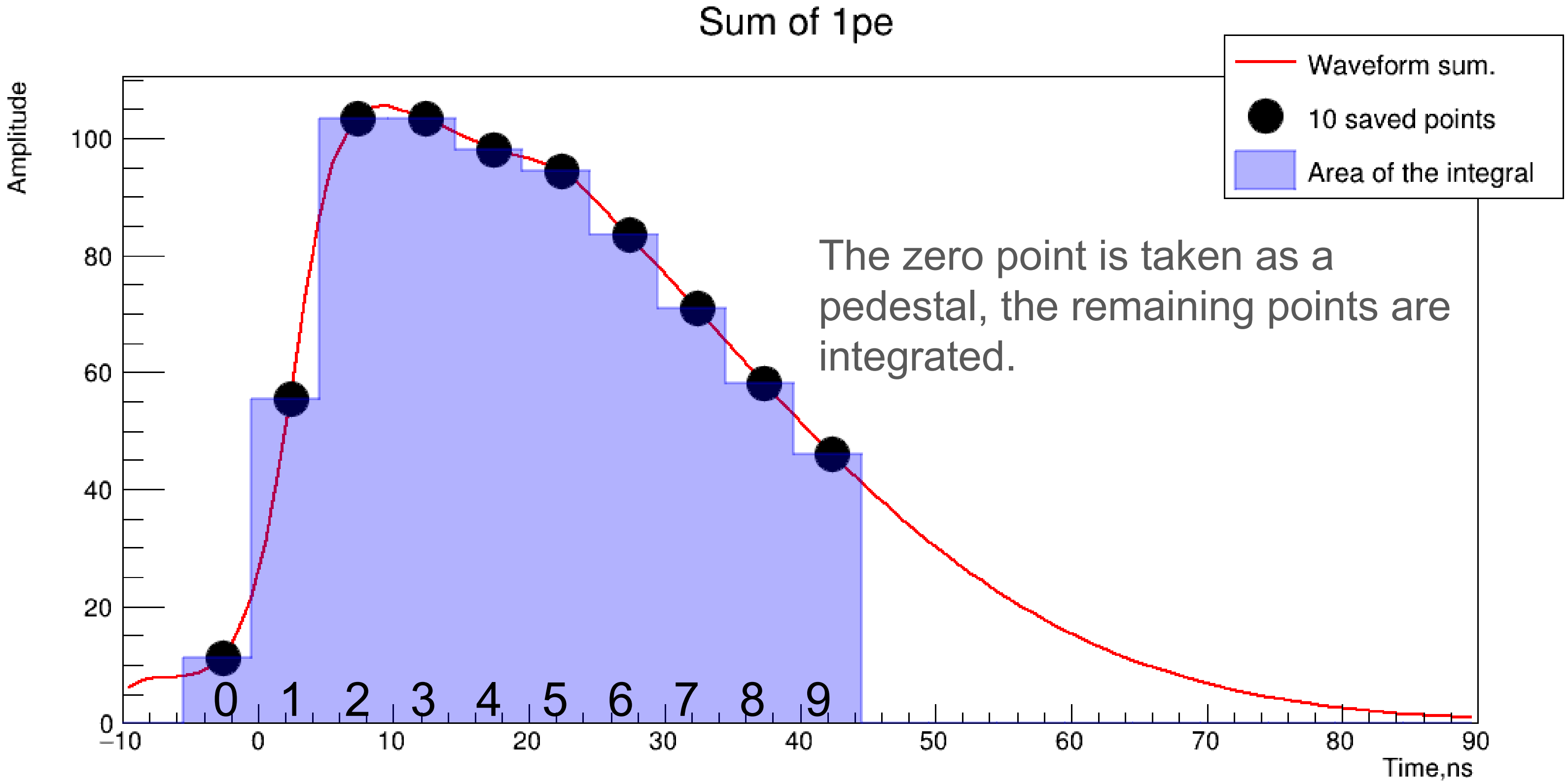
BASHIPH reconstruction

Reconstruction: track extrapolation



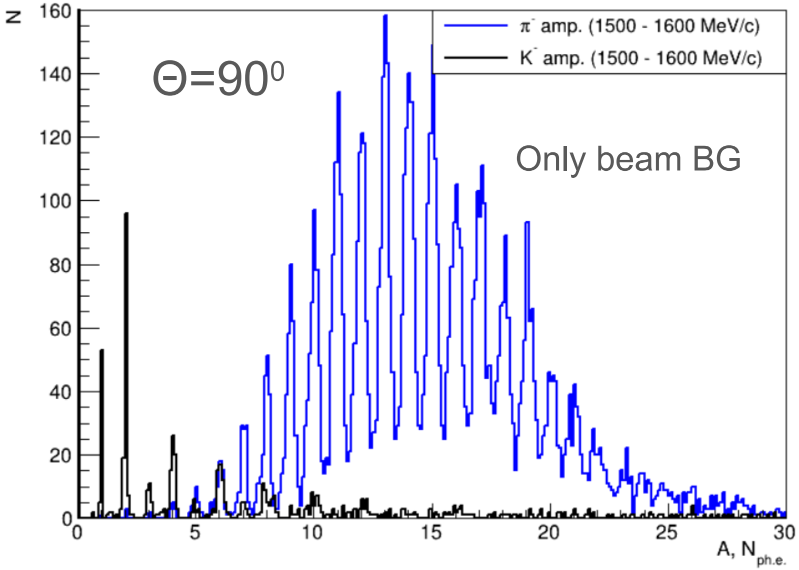
- The Cherenkov thr. in WLS lower then that in aerogel. Counters data with WLS crossing must be excluded.
- Based on the drift chamber data (momentum, last track coordinate, trajectory curvature radius), the track is extrapolated to the BASHIPH region.
- The extrapolated track points are checked for crossing of BASHIPH geometry elements (for example, the WLS).

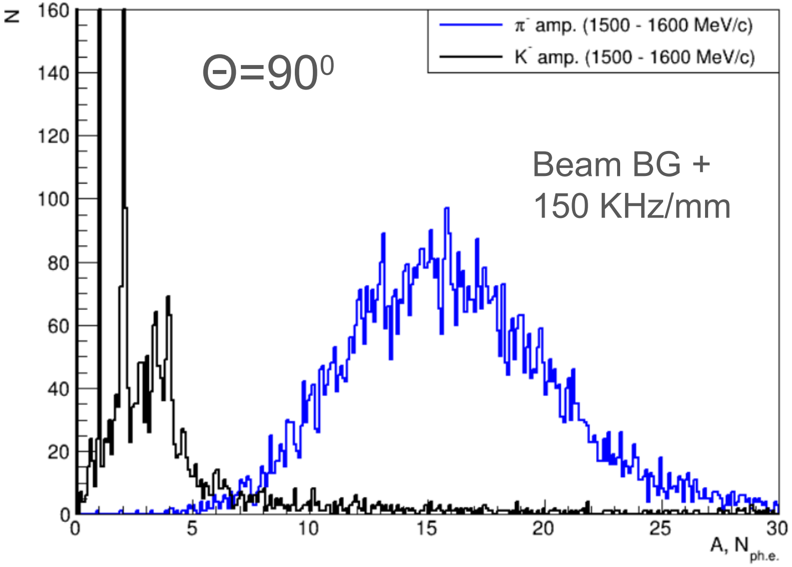
Reconstruction: amplitude reconstruction



The zero point is taken as a pedestal, the remaining points are integrated.

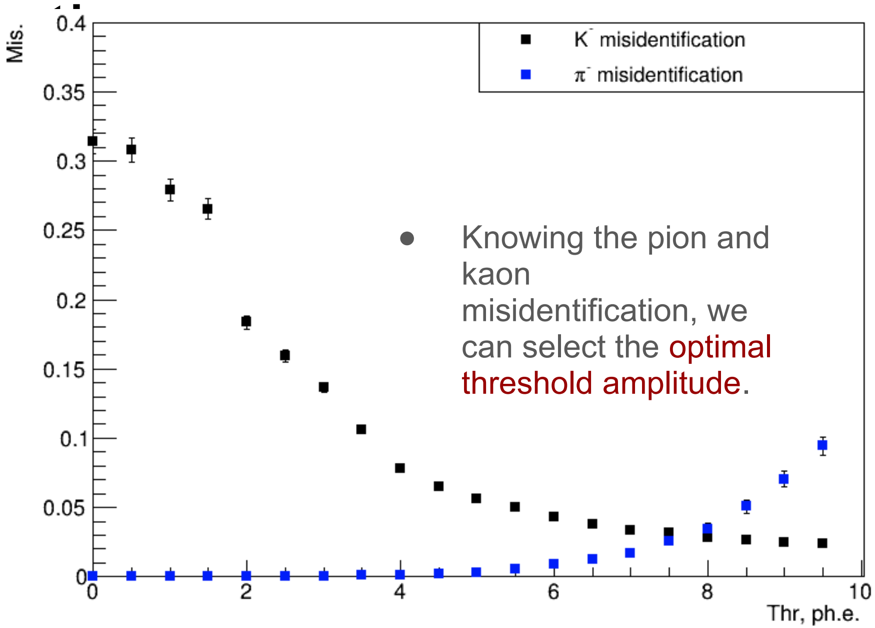
Reconstruction: amplitude spectrum



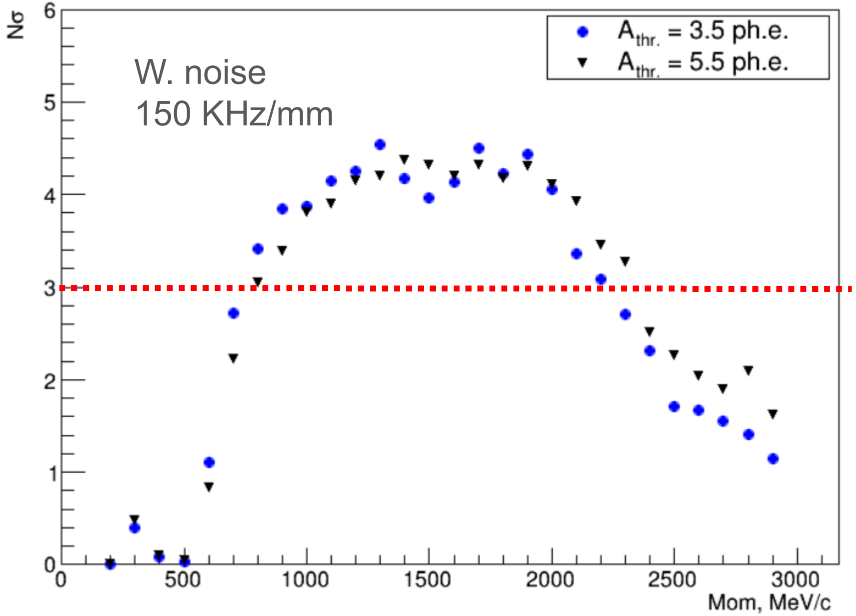


- Per each track, the amplitudes from the two layers of the system are summed to better geometric homogenity.
- Here are presented variants of the amplitude spectra of pions and kaons for different cases of noise frequencies.
- Knowing the amplitude distribution, the threshold amplitude can be chosen.

Reconstruction: quality of π/K separation with const.



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

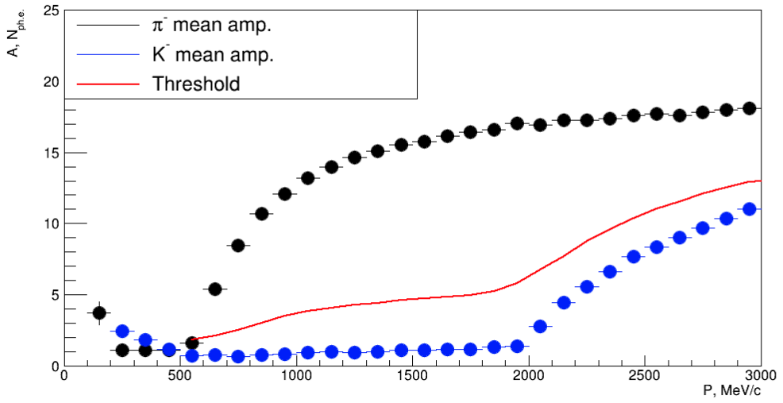


- The separation level can be estimated in terms of standard deviations:

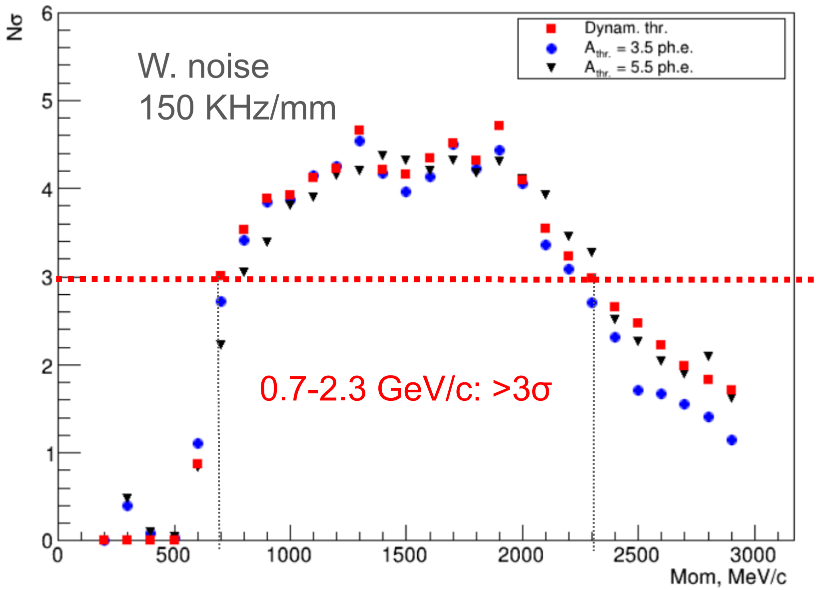
$$N\sigma = \sqrt{2}(erf^{-1}(1-2\times(1-MisID._K)) + erf^{-1}(1-2\times(1-MisID._\pi)))$$

- The constant threshold is not an optimal solution for all momentum ranges

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

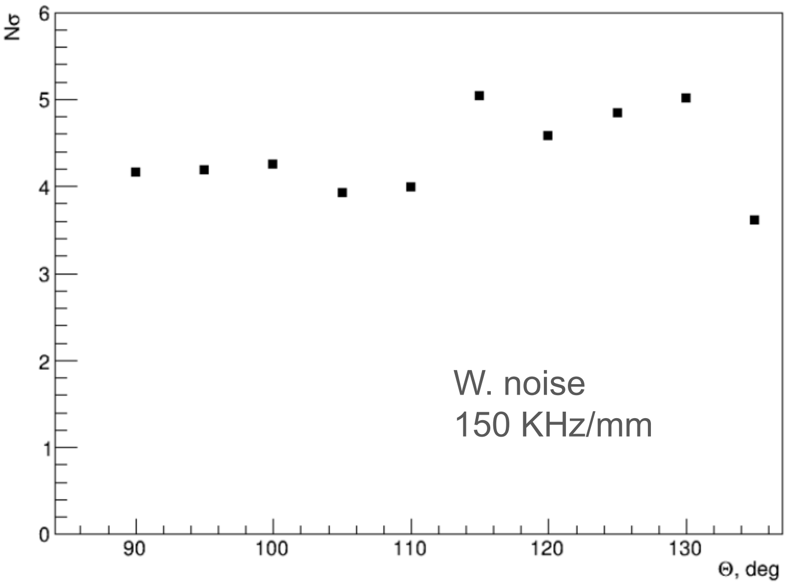


- Calibrated (on the pions and kaons data) dynamic threshold help to select optimal values for each point of the momentum range.



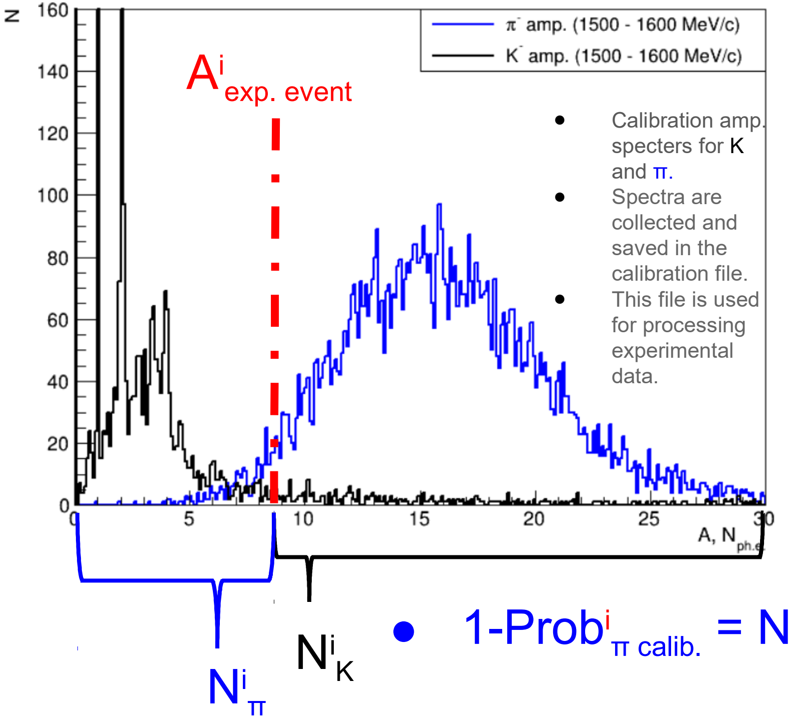
- Also is possible to obtain separation of about ≈3σ in the momentum range of 2-2.3 GeV/c.

Reconstruction: dependence on θ



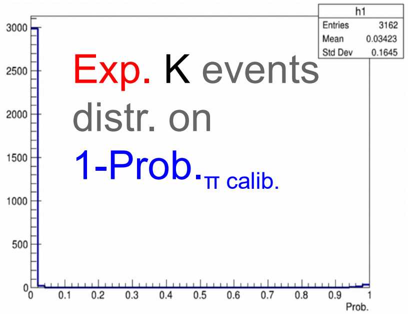
- The dependence of the degree of separation on the angle to the beam axis was also studied (at 1.5 GeV/c).

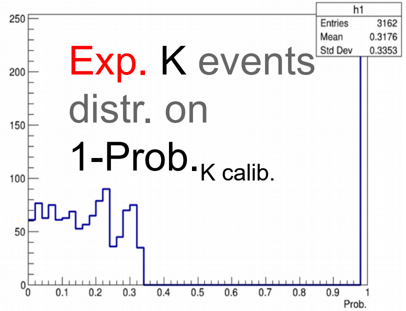
Reconstruction: likelihood

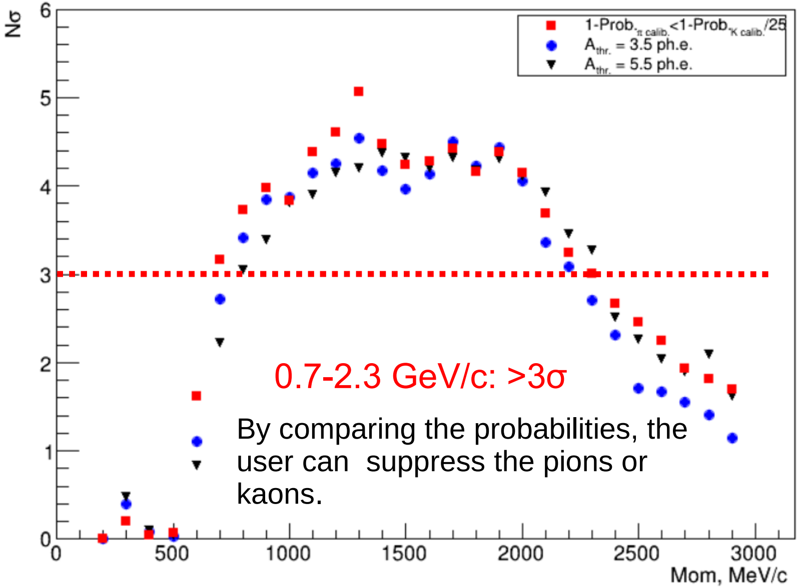


- Calibration amp. specters for K and π.
- Spectra are collected and saved in the calibration file.
- This file is used for processing experimental data.

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







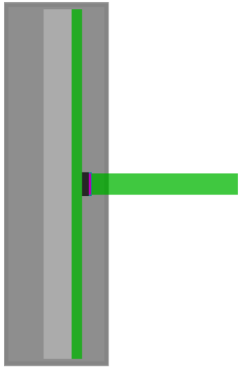
By comparing the probabilities, the user can suppress the pions or kaons.

Summary

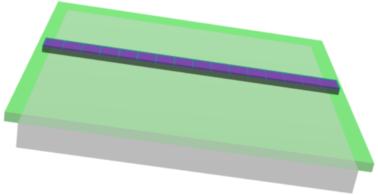
- ASHIPH-SiPm prototype with n=1.03 aerogel is tested on the electron test-beam
  - ≈7.2 ph.e. obtained from one counter (layer) on 0.58 GeV
- BASHIPH simulation, digitization and reconstruction integrated into the OSCAR framework
  - Subthreshold effects, SiPM intrinsic noises, beam background are simulated
  - ≈14.4 ph.e. obtained on 1.5 GeV/c from two layers
  - Dynamic threshold function allows to obtain π/K separation of 3-5σ in the range of 0.7-2.3 GeV/c.
  - 3-5σ separation in the Θ range of 90-135^0 (at 1.5 GeV/c).
  - Simple parameters for separation are obtained.
  - Ready to test with physical background.

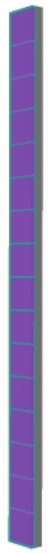
Backup

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

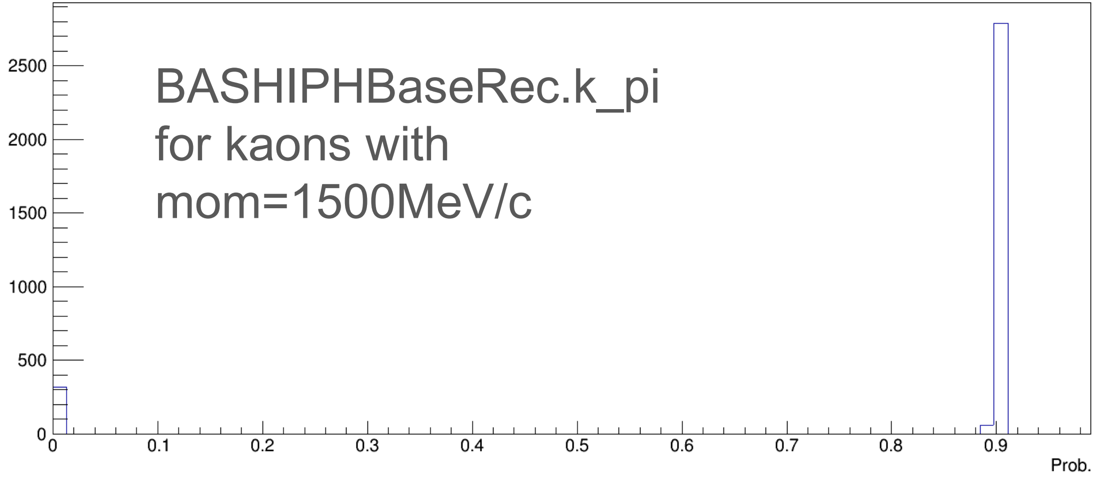
Reconstruction: dynamic threshold formulae

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

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

- 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.
```