Aerogel Cherenkov counters for experiments at VEPP-2000 e^+e^- collider with SND detector

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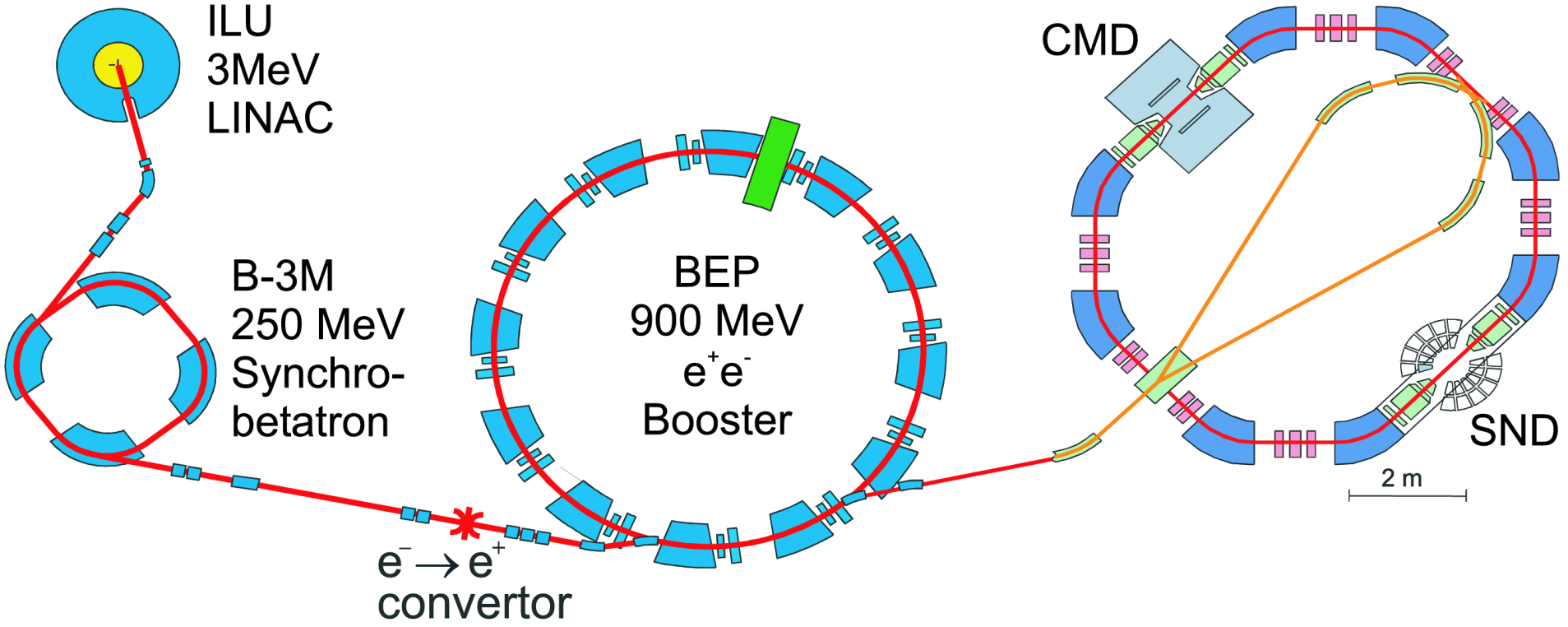
Outline

- VEPP-2000 collider, SND detector
- Physics program for SND at VEPP-2000
- Aerogel Cherenkov counter (ACC) system design
- ACC with n=1.13:
  - calibration on e, μ, π, K;
  - π/K-separation
- ACC with n=1.05: test using e and μ
- Summary

VEPP-2000



C.m. energy range: 0.4 — 2.0 GeV

Design luminosity: 10^{31}cm^{-2}s^{-1} at 2E=1 GeV

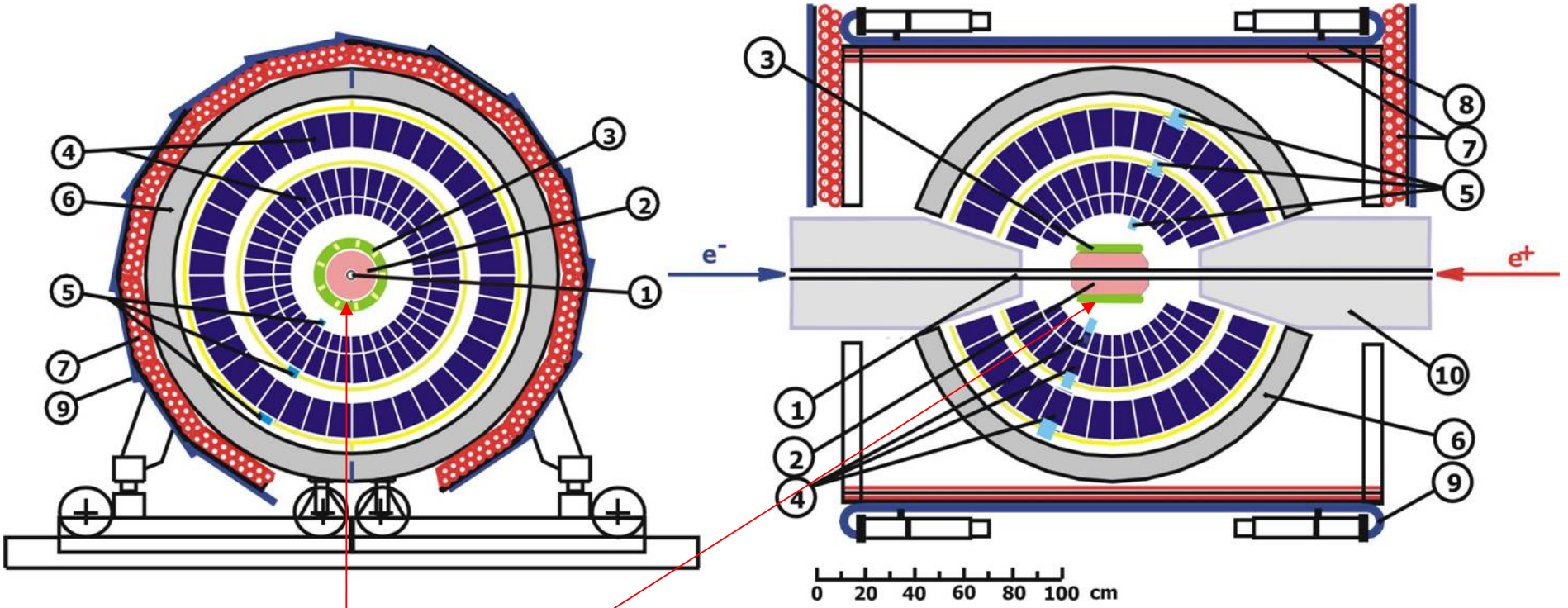
10^{32}cm^{-2}s^{-1} at 2E=2 GeV

Achieved luminosity: 10^{31}cm^{-2}s^{-1}

Detectors: **Spherical Neutral Detector**

Cryogenic Magnetic Detector

Spherical Neutral Detector (SND)



1 – VEPP-2000 beam pipe, 2 – tracking system,
3 – aerogel Cherenkov counters , 4-5 – electromagnetic calorimeter, 6 – spherical iron absorber, 7-9 - muon system,
10 – VEPP-2000 focusing solenoids

Physics program for SND at VEPP-2000

- Precise measurement of the ratio

  $R = \sigma(e^+e^- \to \text{hadrons}) / \sigma(e^+e^- \to \mu^+\mu^-)$
- Study of the hadronic channels:

  $e^+e^- \to 2h, 3h, 4h \ldots, h = \pi, K, \eta$
- Study of the excited vector mesons: ρ', ρ'', ω', ω'', φ',..
- CVC tests: comparison of the $e^+e^- \to$ hadrons (I=1)

  cross sections with the τ-decay spectral functions
- Study of the nucleon-antinucleon pair production,

  nucleon electromagnetic form factors, …
- Hadron production in radiative return

  processes: e+e- → γ γ* , γ* → hadrons
- Two photon physics: e+e- → e+e- + X
- Test of the QED high order processes 2 → 4,5

Particle identification system

For the PID in different c.m. energy ranges of VEPP-2000 collider two systems of aerogel Cherenkov counters (ACC) with the identical design, but with different refractive indexes of aerogel were developed.

1) ACC system with refractive index n=1.13

Main goal: π/K separation

C.m. energy range : 1-2 GeV

Used in experiment from 2010 to 2012

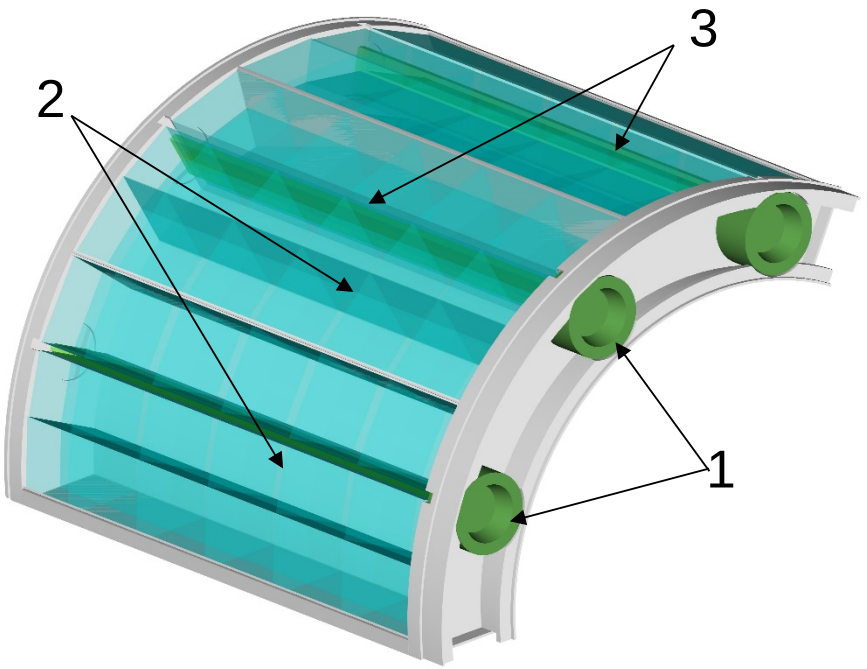
2)ACC system with refractive index n=1.05

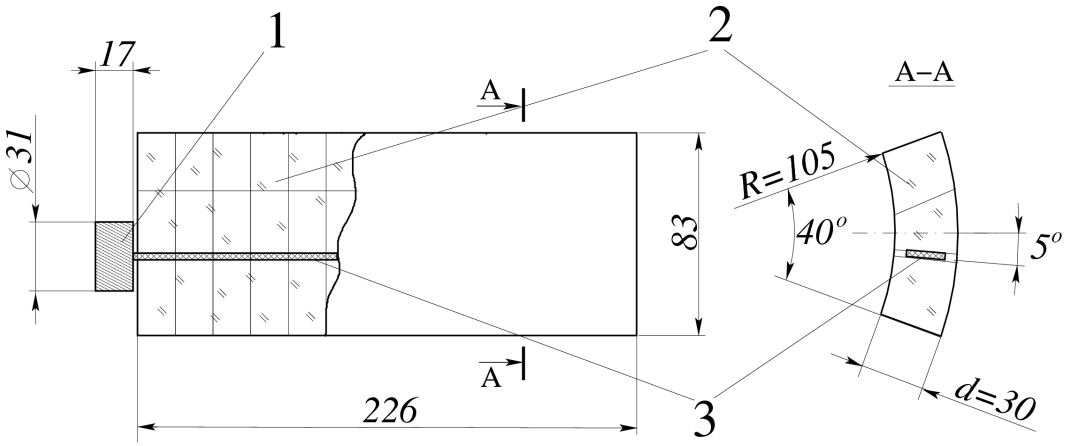
Main goal: e/π separation

C.m. energy range : <0.9 GeV

Used in experiment from the end of 2012 to 2013

Particle identification system (design)





1 - PMT, 2 – aerogel, 3 - WLS

ACC system design

- 9 aerogel Cherenkov counters which form the cylinder
- Solid angle: ~60% of 4π
- Thickness: 0.09 X_o

ACC design

- **ASHIPH** technique:
Aerogel, Wavelength **SHI**fter (WLS), **Ph**otomultiplier
- Aerogel thickness: ~30 mm
- Aerogel cover: teflon with reflectivity ~98%
- PMMA WLS doped with BBQ
- PMT based on microchannel plates (MCP PMT)

ACC system installed into the SND detector

ACC system with n=1.13

Test on $e^+e^- \rightarrow e^+e^-$ events

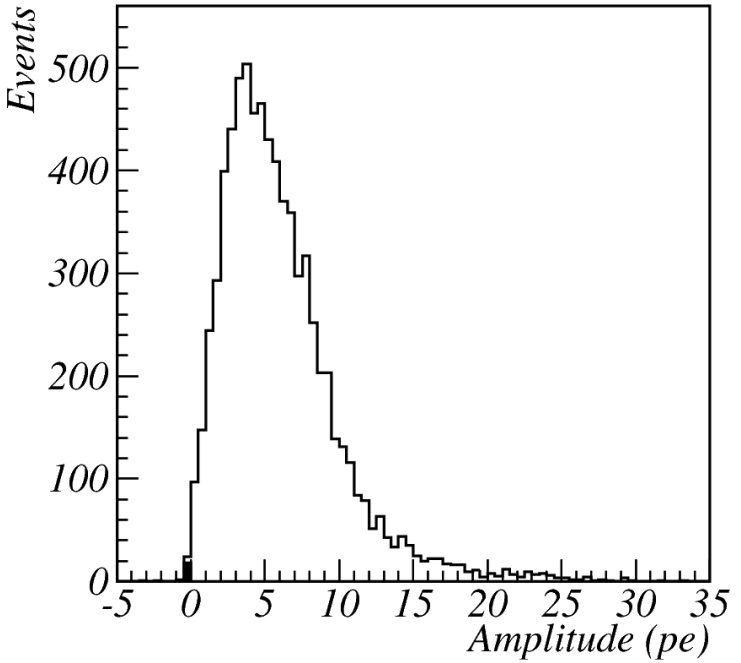
Properties of the aerogel

1. Refractive index: n=1.13±0.01
2. Density: ρ=0.65 g/cm^3
3. Light scattering length: L_{sc}=19 mm at λ=400 nm
4. Light absorbtion length: L_{abs}=100 cm at λ=400 nm

Main goal : π/K separation in the momentum range **from 300 to 870 MeV/c**

The system was used in the experiments at the VEPP-2000 collider with the SND detector from 2010 to 2012.

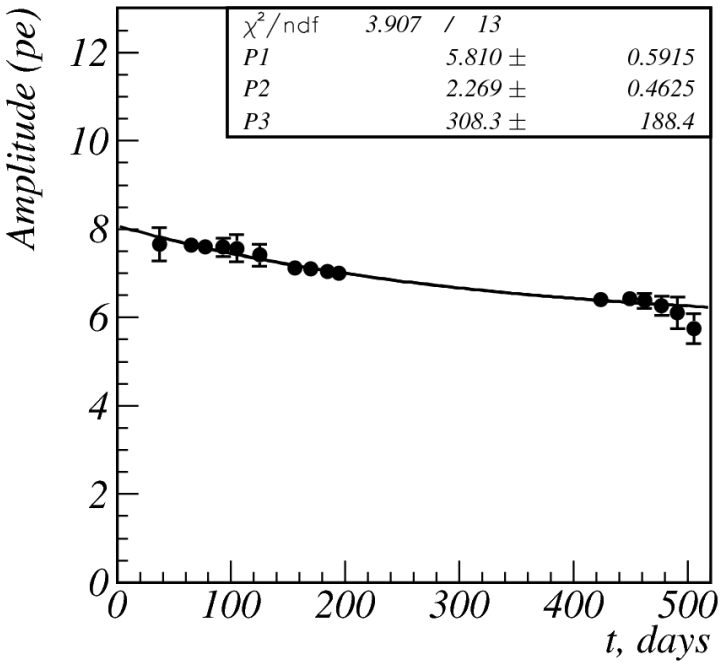
Amplitude spectrum for electrons



ACC system with n=1.13

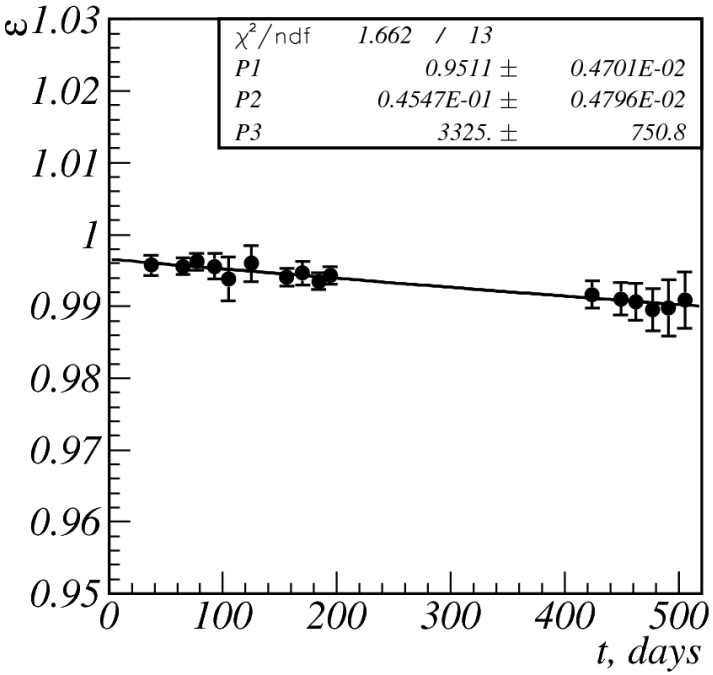
Test on $e^+e^- \rightarrow e^+e^-$ events

The time dependence of the ACC amplitude for electrons



0 — 06.12.2010
505 - 24.04.2012

The time dependence of the ACC detection efficiency for electrons



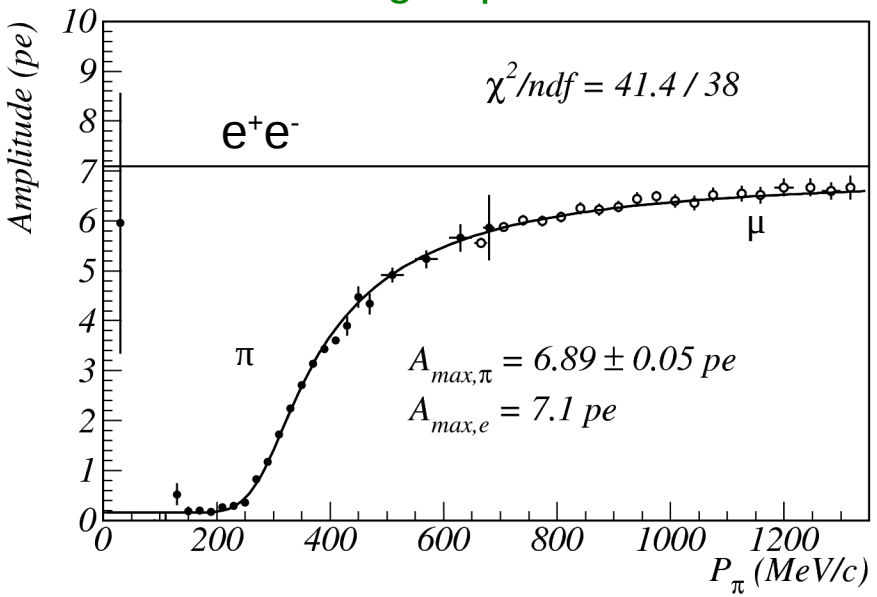
The average signal from electrons obtained just after installation of ACC system into the detector was about **8 photoelectrons**, the detection efficiency was **≈99.6%**. At the end of the measurement period the average signal was about **6 photoelectrons**, the detection efficiency was **≈99%**.

Observed decrease of the ACC performance is explained by changing of the light absorbtion length due to oxidation of metal impurities in the aerogel.

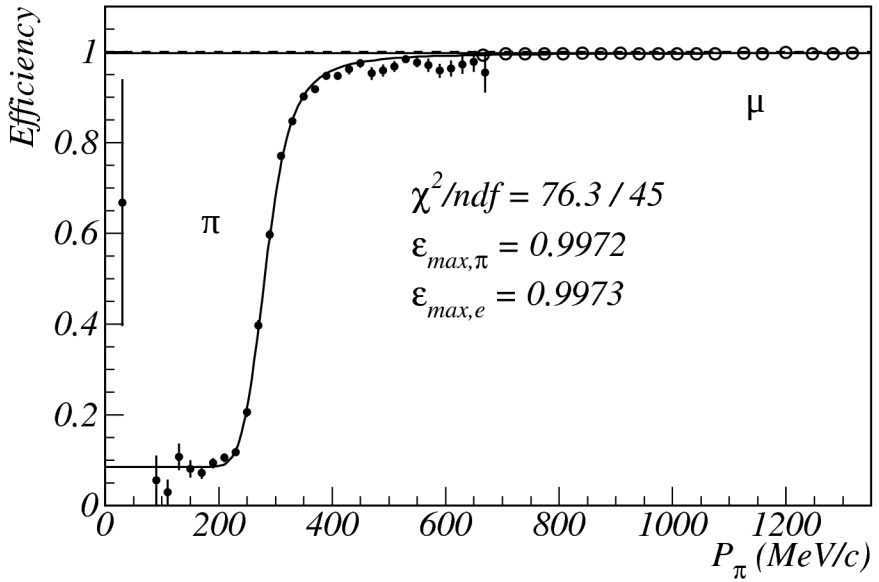
ACC system with n=1.13

Test on $e^+e^-\to\pi^+\pi^-\pi^0$ and $e^+e^-\to\mu^+\mu^-$ events

The dependence of the ACC amplitude on charged pion momentum



The dependence of the ACC detection efficiency on charged pion momentum



The charged pion momenta from $e^+e^-\to\pi^+\pi^-\pi^0$ reaction are determined using a kinematic fit .

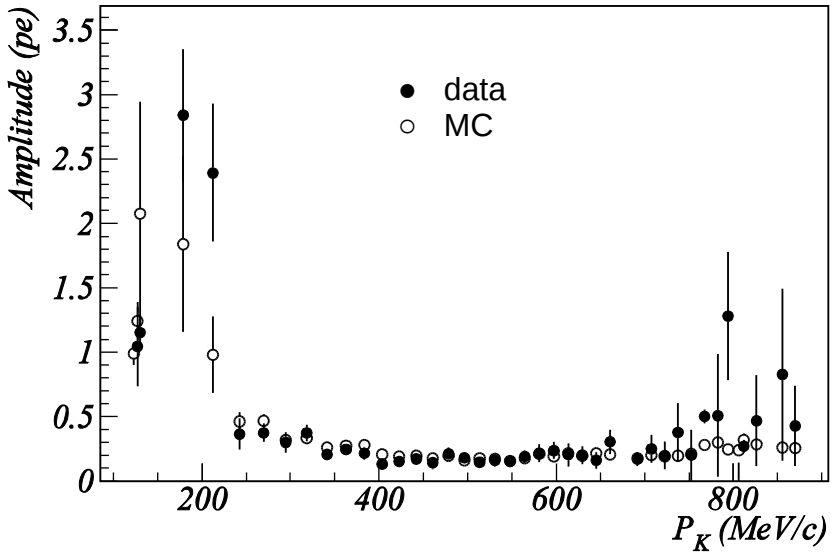
For momenta larger than 650 MeV/c, the ACC signal is measured using $e^+e^-\to\mu^+\mu^-$ events. For the muons, momentum was recalculated using the formula: $p_\pi=p_\mu\cdot M_\pi/M_\mu$

Data are approximated by the function $F(p)=A_0+A_{max}(1-(p_{thr}/p)^2)$, where p_{thr} is the threshold momentum for pions in the aerogel.

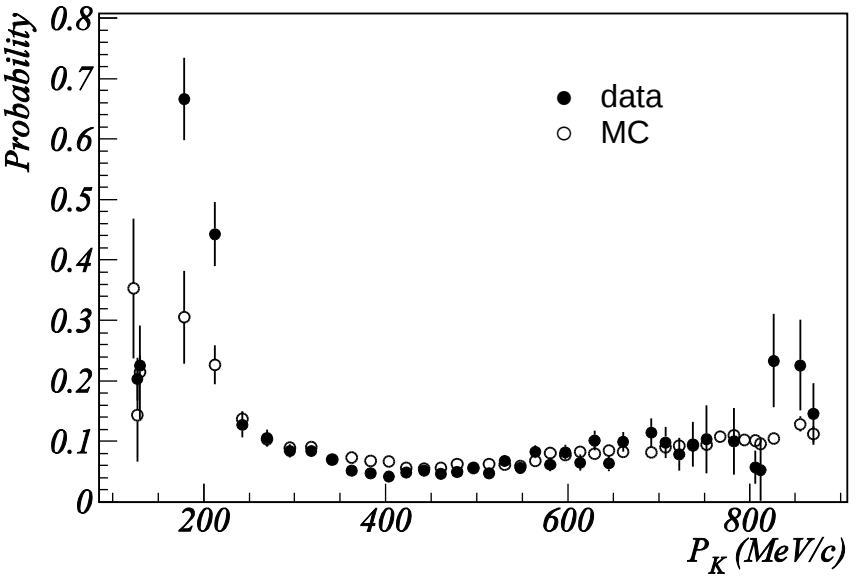
ACC system with n=1.13

Test on $e^+e^- \rightarrow K^+K^-$ events

The dependence of the ACC amplitude on charged kaon momentum



The dependence of the ACC detection efficiency on charged kaon momentum



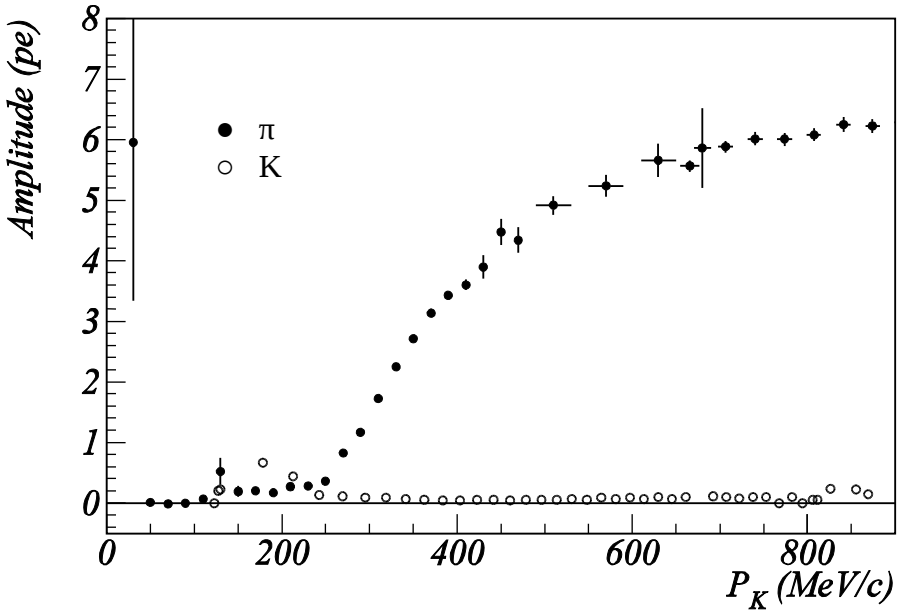
The subthreshold efficiency is explained by:

- Cherenkov radiation of δ-electrons;
- Cherenkov radiation and scintillations in the teflon film;
- nuclear interactions and decays of K mesons,

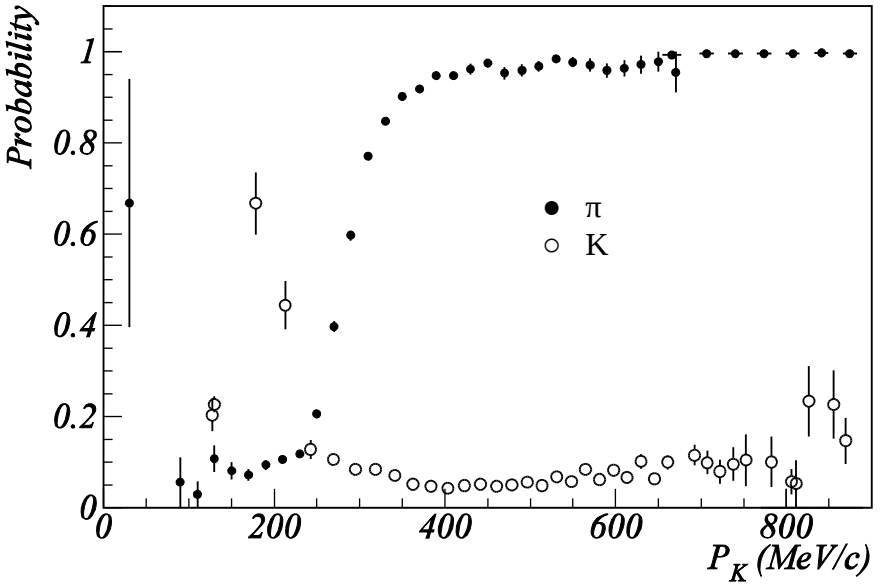
in particular at low momenta P_K<200 MeV/c.

ACC system with n=1.13
π/K separation

The dependence of the ACC amplitude on charged particle momentum



The dependence of the ACC detection efficiency on charged particle momentum



Detection efficiency:

P(MeV/c)	ε_K	ε_π	σ
300	~0,10	0,68	1,7
350	~0,07	0,90	2,8
400	~0,05	0,96	3,4

π/K-separation:

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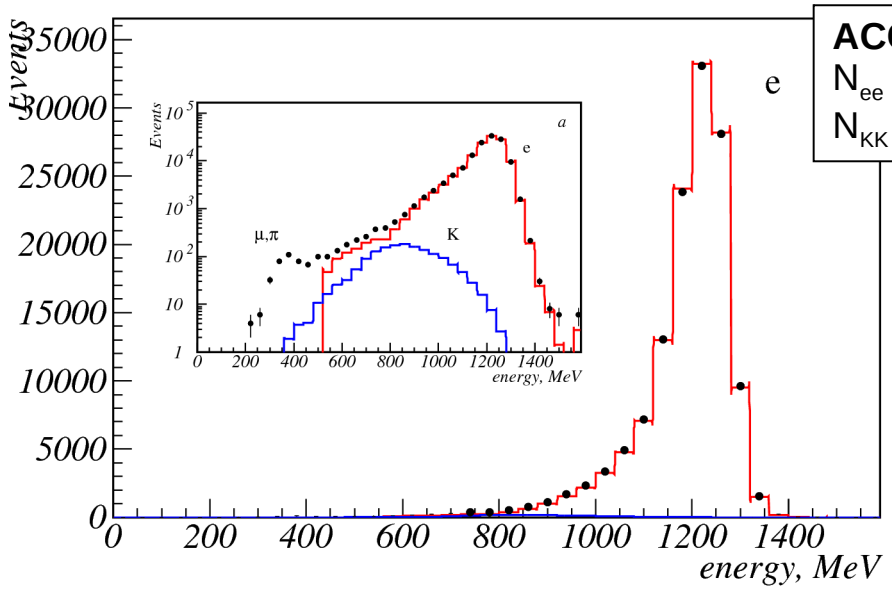
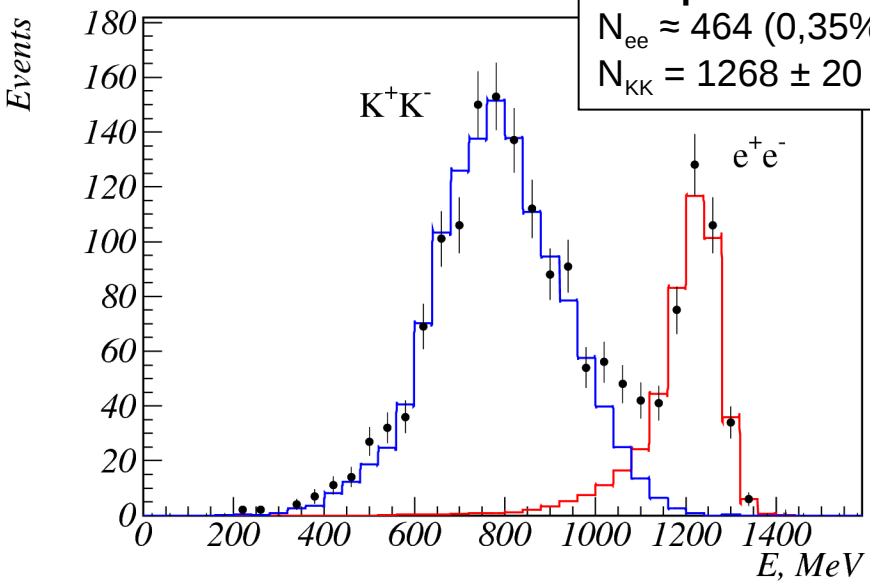
1. The sufficient degree of the particle separation is achieved at momenta above 350 MeV/c.
2. For the particle separation at momenta below 350 MeV/c, the additional information from other detector systems (in particular, from the drift chamber) should be used.

ACC system with n=1.13

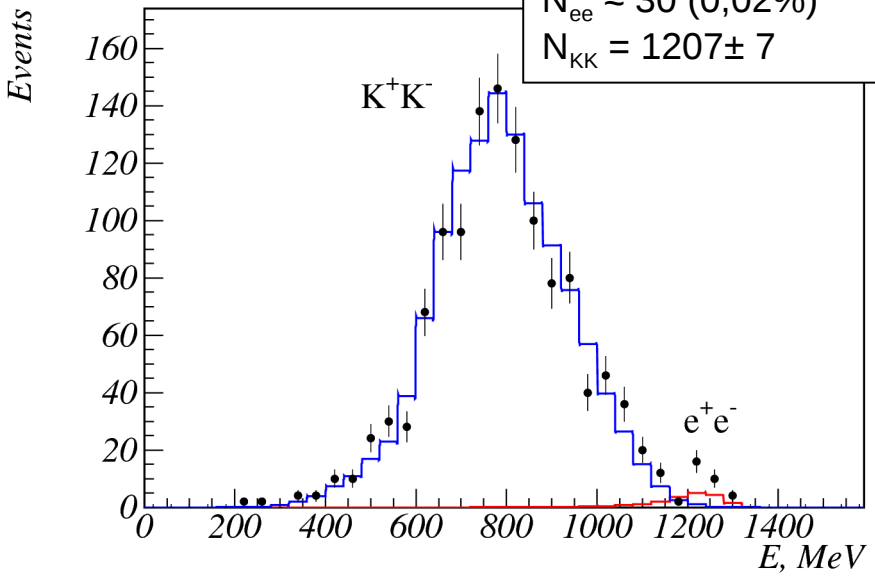
K-meson selection in the experimental sample of events



ACC system is not used:
N_{ee} ≈ 132000 (100%)
N_{KK} = 1251 ± 58



One particle is «kaon»:
N_{ee} ≈ 464 (0,35%)
N_{KK} = 1268 ± 20



Both particles are «kaons»:
N_{ee} ≈ 30 (0,02%)
N_{KK} = 1207± 7

ACC system with n=1.05

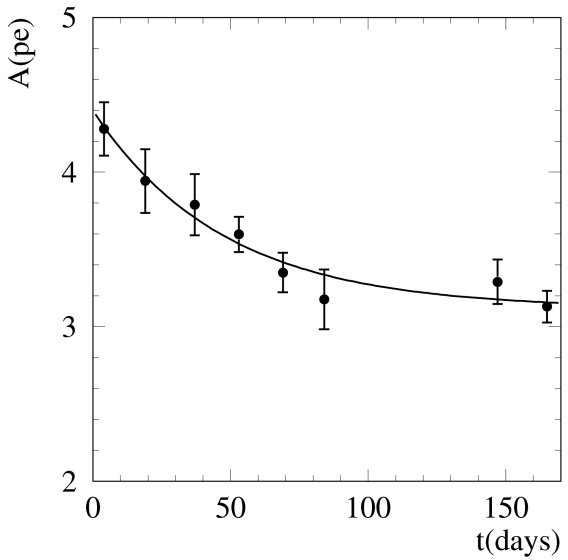
Test on $e^+e^- \rightarrow e^+e^-$ events

Properties of the aerogel

1. Refractive index: n=1.05±0.002
2. Density: ρ=0.24 g/cm^3

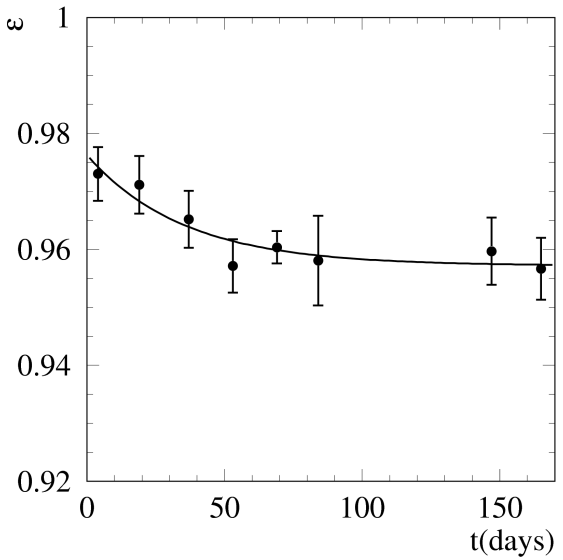
Main goal : e/π separation in the momentum range up to 450 MeV/c.
The system is used in the experiments at the VEPP-2000 collider with the SND detector from the end of 2012.

Time dependence of the ACC amplitude for electrons



The average signal from electrons was about 3.5 photoelectrons at the end of the measurement period.

Time dependence of the ACC detection efficiency for electrons

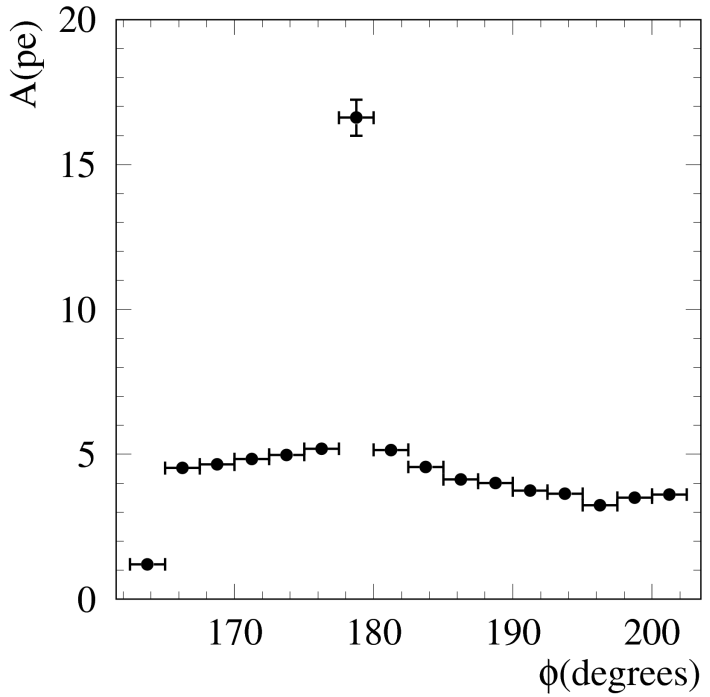


The ACC detection efficiency at the end of the measurement period was about 95.5%.

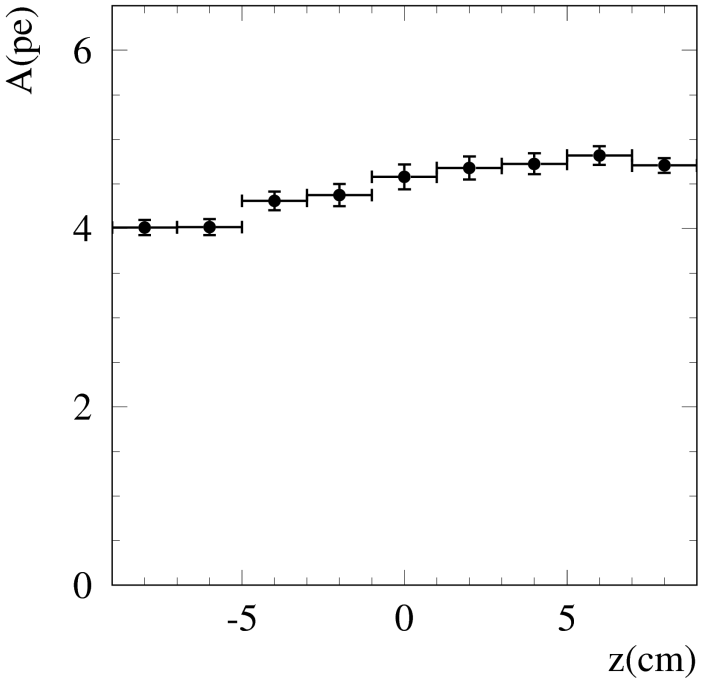
ACC system with n=1.05

Test on $e^+e^- \rightarrow e^+e^-$ events

The dependence of the ACC amplitude for electrons on azimutal angle φ



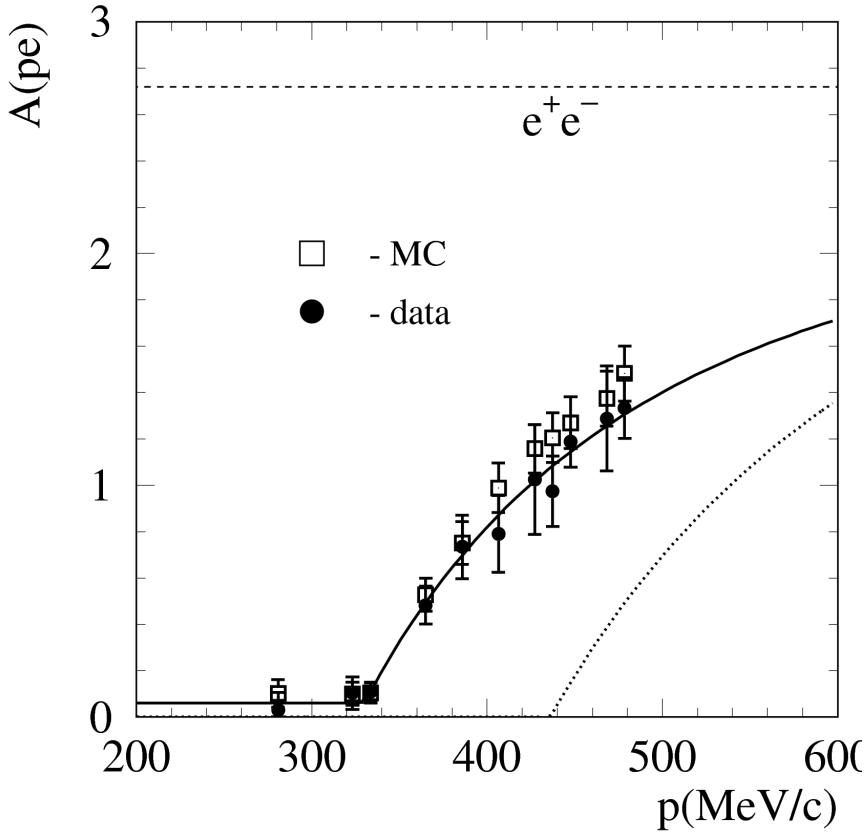
The dependence of the ACC amplitude for electrons on longitudinal coordinate z



ACC system with n=1.05

Test on $e^+e^- \rightarrow \mu^+\mu^-$ events

The momentum dependence of the ACC amplitude for the muons



Solid curve is the result of the approximation of experimental data with the function : $\mu(p)=\mu_0+\mu_{max}*(p^2-p_{thr}^2)/p^2$, where p_{trh}=330 MeV/c is the threshold momentum for muons in the aerogel

Dotted curve shows expected ACC signal for charged pions (without subthreshold efficiency).

Summary

- The ACC system with n=1.13 has been designed, produced and used in experiments at the VEPP-2000 collider with the SND detector from 2010 to 2012.
  - The system was calibrated with particles (e, μ, π, K) produced in e^+e^- collisions.
  - The signal magnitude from ultrarelativistic electrons is 6-8 photoelectrons.
  - This system provides pion suppression by more than two orders of magnitude in the momentum range from 0.35 to 1.00 GeV/c.
- The ACC system with n=1.05 has been produced and used in experiments at the VEPP-2000 collider with the SND detector from the end of 2012.
  - The system was tested using electrons and muons from $e^+e^- \rightarrow e^+e^-$ and $e^+e^- \rightarrow \mu^+\mu^-$ reactions at momenta less than 500 MeV/c.
  - The average signal from electrons is 3.5 photoelectrons.
  - Measured experimental threshold curve for muons is in a good agreement with the expected curve obtained from MC simulation.

Thank you for your attention!