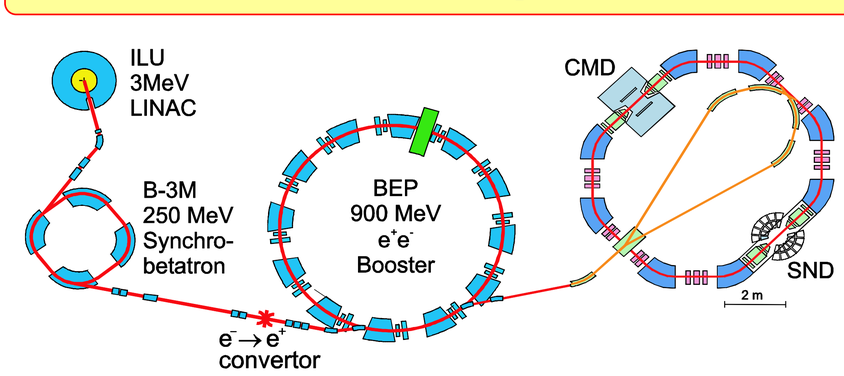
Particle identification system based on dense aerogel

A. Yu. Barnyakov [a], M. Yu. Barnyakov [a,d], **K. I. Beloborodov** [a,c], V. S. Bobrovnikov [a], A. R. Buzykaev [a], A. F. Danilyuk [b], V. B. Golubev [a,c], V.V. Gulevich[a], S. A. Kononov [a,c], E. A. Kravchenko [a,c], A. P. Onuchin [a,d], K. A. Martin [a,d], S. I. Serednyakov [a,c], V. M. Vesenev [a]

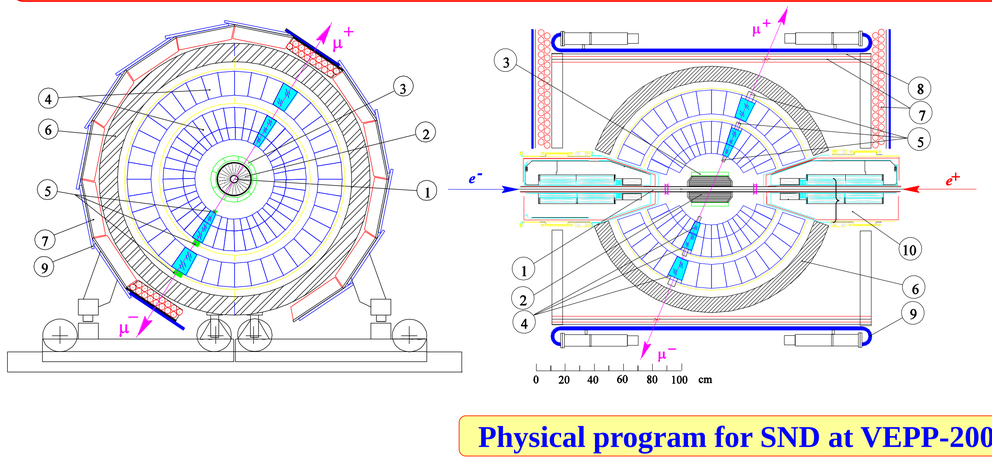
[a] Budker Institute of Nuclear Physics, Novosobirsk, Russia
[b] Boreskov Institute of Catalysis, Novosibirsk, Russia
[c] Novosibirsk State University, Novosibirsk, Russia
[d] Novosibirsk State Technical University, Novosibirsk, Russia

For experiments with the SND detector at the electron-positron collider VEPP-2000 a new particle identification system is designed, constructed, and put into operation. The system is designed for the separation of π and *K* mesons up to particle energy of 1 GeV. Cherenkov radiator is dense aerogel with a refractive index n = 1.13. Structurally, the system has the shape of a barrel, divided into 9 sections in the angle φ. Light collection is realized through green wave length shifter on the flat PMT with micro channel plate. Mimimal ionization particle creates a 6—10 photoelectrons signal. In the period 2011-2012, experiments with SND detector at VEPP-2000 were carried out, which allowed to calibrate the identification system on the e, μ, π and *K* particles produced in e^+e^- —collisions.

VEPP-2000 complex



Spherical Neutral Detector (Nucl. Instr. and Meth. A **449** (2000) 125-139)



SND detector

1. VEPP-2000 beam pipe
2. Tracking system
3. Aerogel Čerenkov counter
4. NaI(Tl) counters
5. Vacuum phototriodes
6. Fe absorber
7.
8. Muon system
9.
10. VEPP-2000 s.c. focusing solenoids

Physical program for SND at VEPP-2000

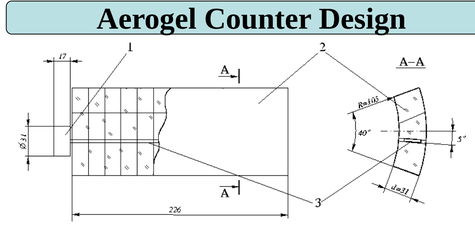
- Precise measurement of the quantity of R = σ(e+e- → hadrons) / σ(e+e- → μ+μ-)
- Study of hadronic channel: e+e- → 2h, 3h, 4h …, h = π, K, η
- Study of 'excited' vector mesons: ρ', ρ'', ω', ω'', φ',..
- CVC tests: comparison of e+e- → hadrons (I=1) cross section with τ-decay spectra
- Study of nucleon-antinucleon pair production, nucleon electromagnetic form factors, …
- Hadron production in 'radiative return' (ISR) 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

Aerogel Čerenkov Counter

Aerogel System Design

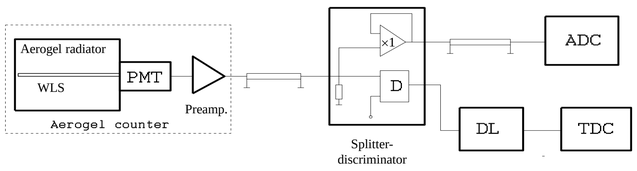
1. Cylindrical shape: R=105÷141 mm
2. Walls material: Al, 1 mm thickness
3. Consists of 3 segments with 3 separate counters in each
4. Solid angle: ~60% of 4π
5. Thickness: ~0.09 X_0

Aerogel Counter Design



1. Scheme: Aerogel + Wavelength shifter (WLS) + PMT
2. WLS position: displaced by ~5° from counter center
3. Aerogel cover: teflon with a reflectivity of R~98%
4. Aerogel thickness: ~31 mm

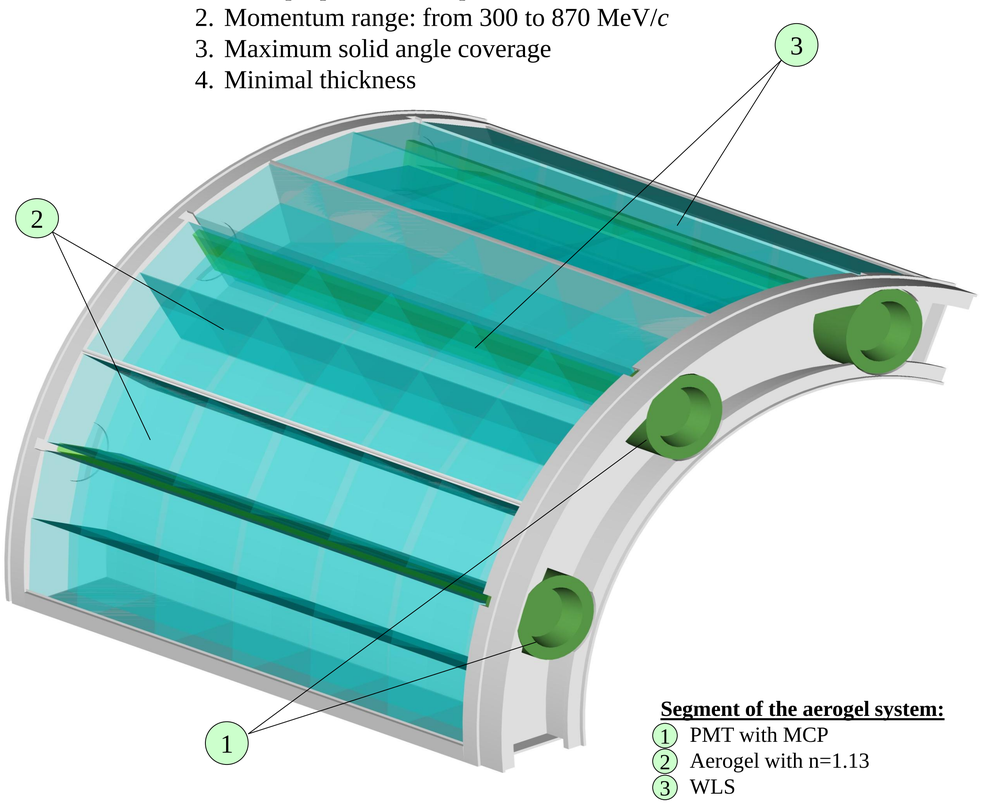
Electronics



1. 9 independent channels
2. Measurements: charge and time
3. Charge measurement:
   - Sensitivity: 0.25 pC/ch.
   - 12-bit ADC
4. Time measurement:
   - Sensitivity: 50 ps/ch.
   - 12-bit TDC

Aerogel Čerenkov Counter requirements

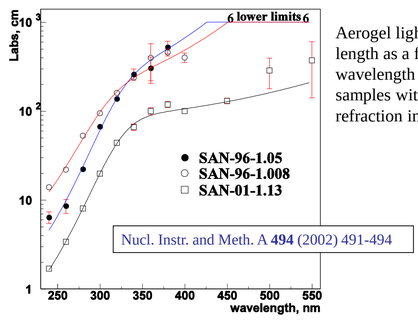
1. Main purpose – π/*K*-separation
2. Momentum range: from 300 to 870 MeV/*c*
3. Maximum solid angle coverage
4. Minimal thickness



Segment of the aerogel system:
1. PMT with MCP
2. Aerogel with n=1.13
3. WLS

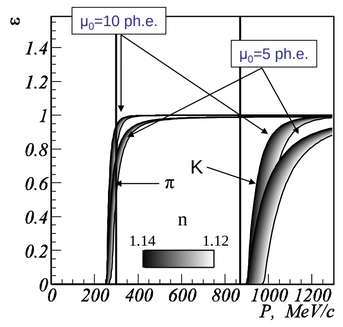
Aerogel parameters

1. Refraction 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



Aerogel light absorbtion length as a function of wavelength for aerogel samples with different refraction indexes

Detection efficiency



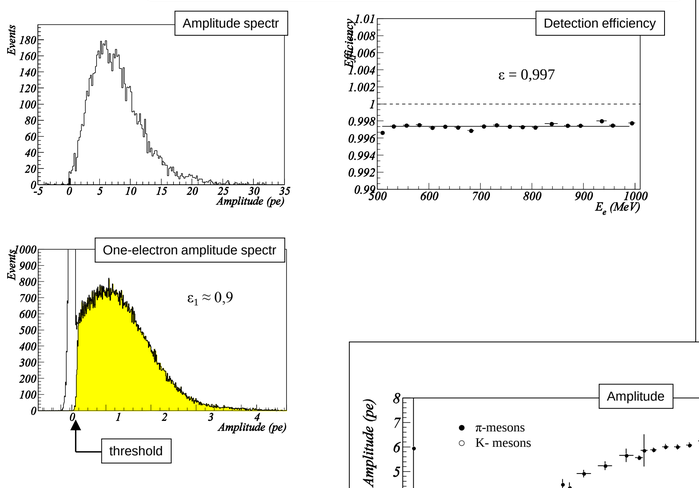
Dependence of the detection efficiency on particle momentum:

$$\begin{cases} \varepsilon(p) = 1 - e^{-\mu(p)} \\ \mu(p) = \mu_0 \cdot (1 - (p_{thr}/p)^2) \end{cases}$$

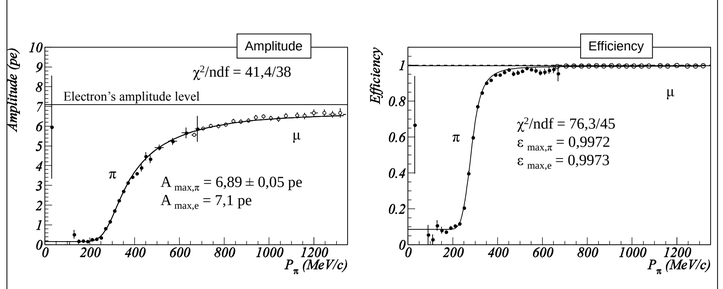
μ_0 – average number of photoelectrons for a relativistic particle
p_{thr} – Čerenkov threshold momentum for a particle

π/K – separation power: experimental results

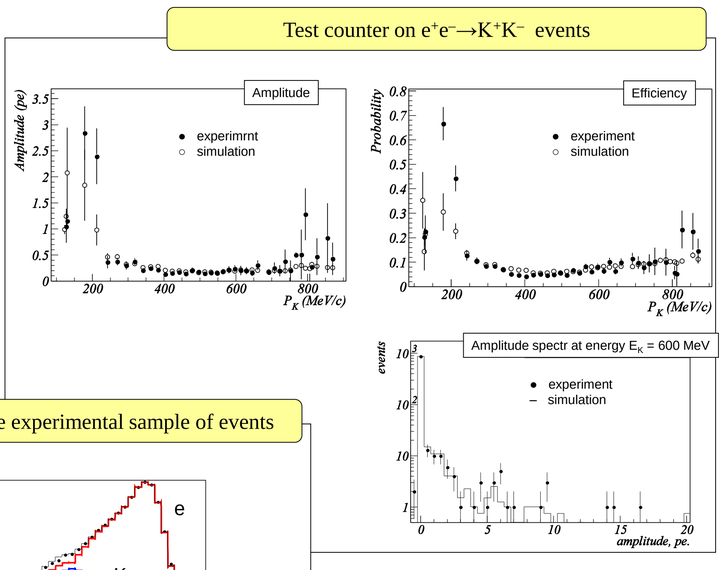
Test counter on $e^+e^-\to e^+e^-$ events



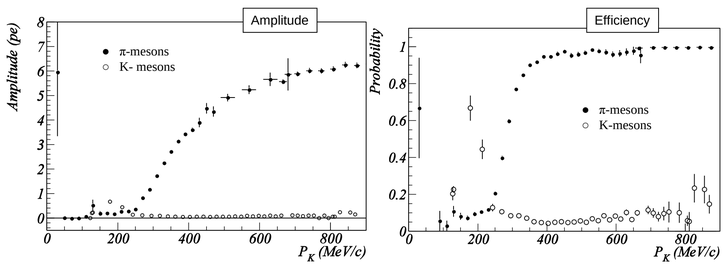
Test counter on $e^+e^-\to\pi^+\pi^-$ and $\mu^+\mu^-$ events



Test counter on $e^+e^-\to K^+K^-$ events



π/K – separation power



Efficiency of registration:

P, МэВ/с	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:

1. At momenta above 350 MeV/c achieved a sufficient degree of separation of particles
2. At momenta below 350 MeV/c separation to be completed by the identification of other systems, in particular the drift chamber

K-meson selection in the experimental sample of events