PID system for Super C-τ Factory at Novosibirsk

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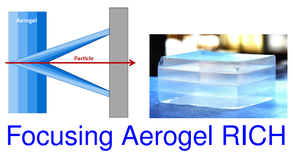
Super C-τ Factory project

Electron-Positron collider Super C-τ factory at Budker Institute of Nuclear Physics (BINP) will operate at total energies 2E = 2÷5 GeV with unprecedented high luminosity of 10^{35} cm^{-2}s^{-1} and the longitudinal polarization of the electrons at the interaction area. The main purpose of the experiments at the collider is search for effects of CP-violation in the decays of charmed particles, tests of the Standard Model in the decay of the τ-lepton, the search and study of an entirely new form of matter: glueballs, hybrids, etc. The data, which are planned to record, by 3÷4 orders exceed everything that has been recorded so far in any other experiment. The proposed program requires construction of a universal magnetic detector with a field of about 1÷1.5 T [1].
The excellent PID system is needed for successful execution of the broad experimental program especially for search of "new physics" and study of rare processes. For instance perfect μ/π - separation is required for search of $\tau \to \mu\gamma$ decay.

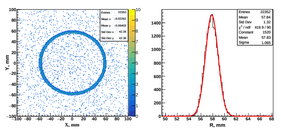
Operation conditions of the PID system:

- Event rate ~ 50÷300 kHz
- Neutron dose per year $\geqslant 2{\cdot}10^{9} n_{eq}/cm^2$ for barrel part and $\geqslant 10^{10} n_{eq}/cm^2$ for endcap part
- Gap between EMC and DC ~ 25 cm

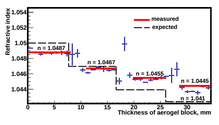
FARICH



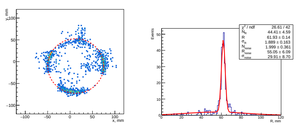
Focusing Aerogel RICH



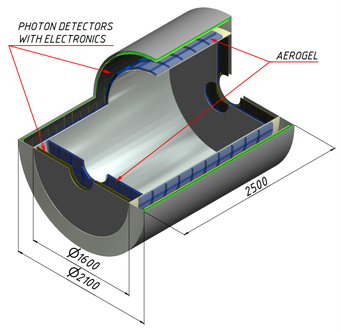
GEANT4 simulation results for ideal 4-layer focusing aerogel



Refractive index profile



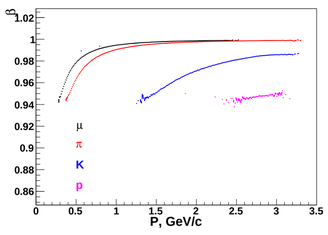
Beam tests results: pixel size ø1 mm, $\sigma_{track} \leqslant 0.3$ mm.



FARICH system for SCTF

- Photon detectors (3×3 mm^2):
  Barrel – SiPMs (16 m^2)
  Endcap – SiPMs or MCP PMTs (5 m^2)
- ~$1.8{\cdot}10^6$ channels
- Operation load 0.5÷1.0 MHz/ch.
- Power consumption ~40 kW
- -30°C or 77°K?!
- Amount of material ~13÷30%X_0

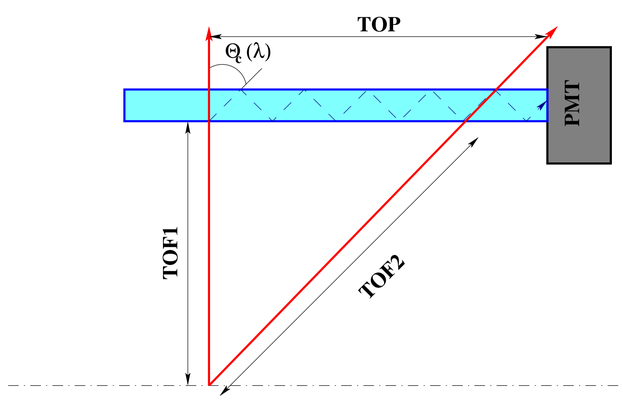
The excellent particle separation with FARICH prototype based on 4-layer aerogel and DPC sensors (Philips) as photon detector was demonstrated at hadron beams line T10 at CERN in 2012 [2]

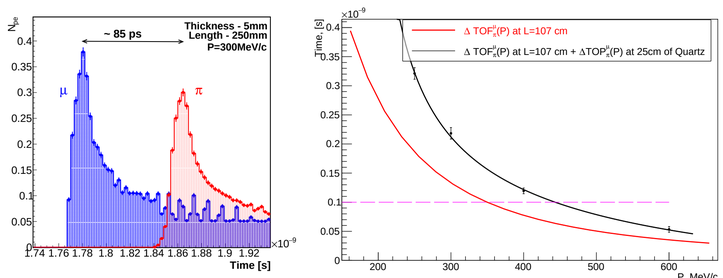


β from parametric simulation

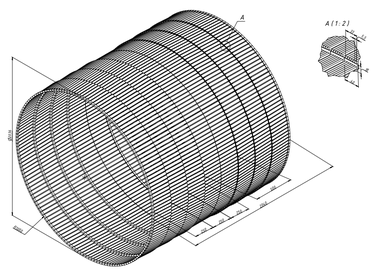
The σ_R obtained in beam tests in two times worse than expected for aerogel with ideal refractive index profile.

TOF+TOP

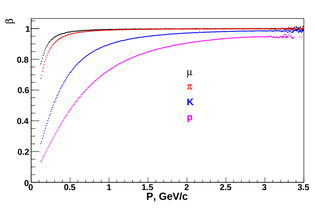




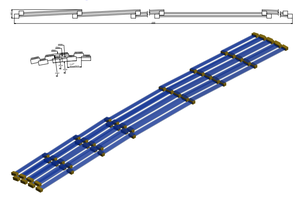
Idea illustration



- Quartz 5×5×250÷500 mm 10000 bars
- 1648 – MCP PMTs ~40×20 mm
- Material budget~ 7%X_0



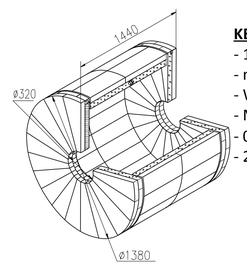
β from parametric simulation



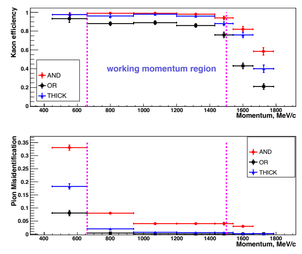
For endcap part could be used such approaches as DIRC-like-TOF, FTOF(Orsay), EndcapDIRC(PANDA), TORCH(LHCb) and . . .

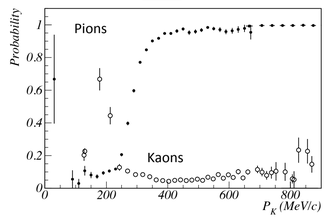
ASHIPH

Aerogel Cherenkov ASHIPH counters

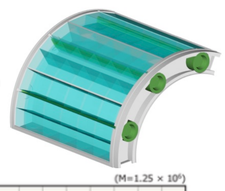


KEDR:
- 160 counters (2 layers)
- n=1.05 (1000l)
- WLS (BBQ)
- MCP PMT øPC=18 mm
- 0.97x4π
- 24% X_0



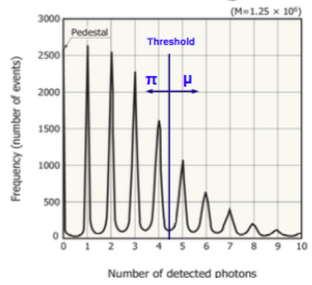


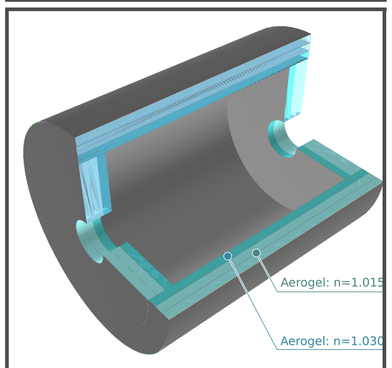
SND:
- 9 counters (1 layer)
- n=1.13 (9l)
- WLS (BBQ)
- Thickness ~ 30 mm
- MCP PMT øPC=18 mm
- 0.6x4π



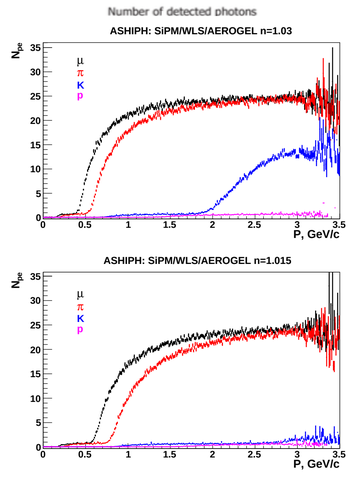
Basic ideas

- Threshold aerogel counters with two refractive indices: n_1=1.030, n_2=1.015.
- Large number of photoelectrons in the signal ($N_{pe}(\beta=1)\geqslant 20$) to extend PID momentum range
- In the region above $P_{thr}(\pi)$ separate particles using variable threshold depending on particle momentum



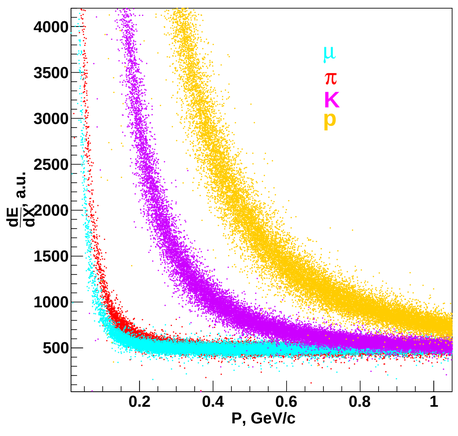


- 6000 l of aerogel in three layers: n=1.03 (8 cm) and n=1.015 (8+8 cm)
- 1400 counter with sizes ~ 18×30×8 cm
- Material budget~ 15%X_0
- Light collection – WLS(BBQ) and 28000 SiPMs 3×3 mm^2

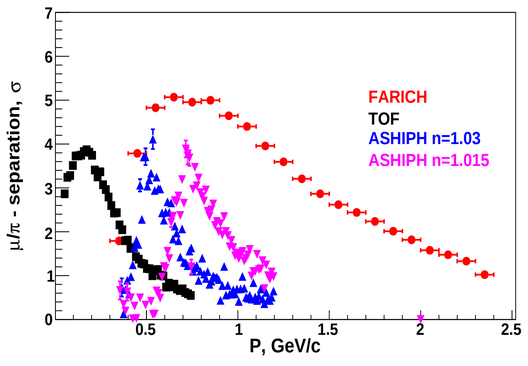


N_{pe} from parametric simulation

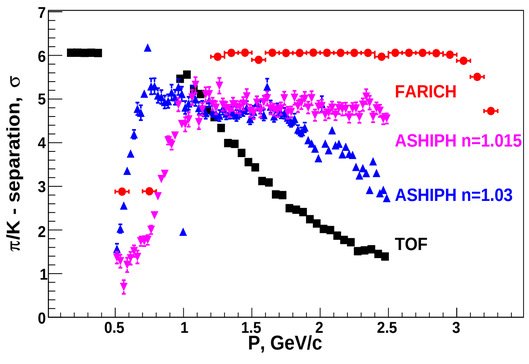
Particle separation: comparison of different approaches with help of parametric simulation



$\frac{dE}{dx}$:
- π/K-separation up to 600 MeV/c
- μ/π-separation up to 100 MeV/c
- Cluster counting mode improves dE/dx capabilities of DC



- π/K-separation in whole momentum range provided by all tested approaches
- μ/π-separation from 450 MeV/c up to 1500 MeV/c is provided by FARICH
- ASHIPH technique provides μ/π-separation from 450 MeV/c up to 900 MeV/c
- TOF technique is needed for μ/π-separation below 450 MeV/c



Summary

- To provide superior particle identification in whole energy range of the experiment it is necessary to use all detector systems.
- Special PID system is necessary to separate π/K mesons above 600 MeV/c and μ/π mesons from 220 to 1200 MeV/c.
- Parametric simulation to compare the three presented techniques was done. It was shown that all methods could provide the good π/K-separation above 600 MeV/c up to 2000 MeV/c while for μ/π-separation in momentum range 200÷1200 MeV/c it is possible to use combination of the methods.
- Full detector simulation and physics simulation currently are developing to optimize the parameters of the PID and other detectors' systems.
- For successful development of these and other PID options (simulation, prototyping, beam tests and so on) the wide international collaboration is needed.
- BINP beam test facility is available [3] for prototype tests.

References

[1] Super Charm Tau Factory, BINP SB RAS, Novosibirsk 2018, https://ctd.inp.nsk.su/wiki/images/4/47/CDR2_ScTau_en_vol1.pdf

[2] A.Yu. Barnyakov *et al.*, Beam test of FARICH prototype with digital photon counter, Nucl. Instr. and Meth. A 732 (2013) 352-356.
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[3] G.N. Abramov *et al.*, Extracted electron and gamma beams in BINP, 2014 **JINST 9** C08022.
G.N. Abramov *et al.*, Measurement of the energy of electrons extracted from the VEPP-4M accelerator, 2016 **JINST 11** P03004.