R&D for SCT detector PID

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[4]GSI, Darmstadt, Germany

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PID options for SCTF

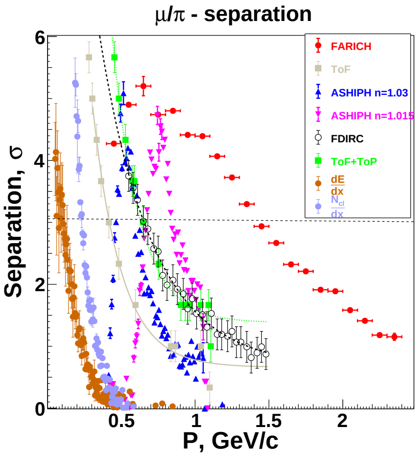
Several PID techniques were considered for SCTF detector:

- FARICH (Focusing Aerogel RICH)
- ASHIPH (Aerogel SHifter PHotomultiplier)
  aerogel threshold Cherenkov counters
- ToF+ToP
- FDIRC (Focusing DIRC)

Comparison of these options based on prototype tests and simulation results of 2018 were performed[a] .

R&D on **FARICH** and **FDIRC** options are carried out at BINP and Giessen Univ.

[a] JINST 15 (2020) C 04032
EPJ WoC 212 (2019) 01012

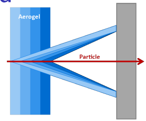


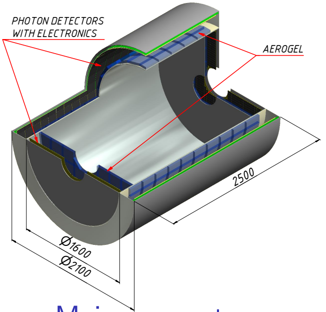
$\frac{dE}{dX}$ provide μ/π-separation up to 150 MeV/c
cluster counting — up to 220 MeV/c.
For P⩾220 MeV/c a dedicated PID system is need

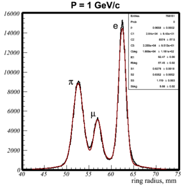
FARICH option

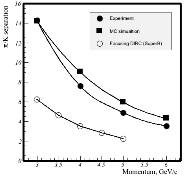
FARICH method

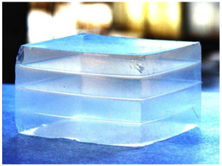
- Increase N_{pe} without σ_{Θ_c} degradation;
- μ/π-separation$\sim 5\sigma$ (1 GeV/c) demonstrated in beam tests;











Main parameters:

- Focusing aerogel n_{max}=1.05(1.07?), 4 layers, thickness 35 mm, $S_{aer.} \approx 14$ m^2
- Photon detectors (3×3 mm^2):
  - Barrel – SiPMs (16 m^2)
  - Endcap – MCP-PMT (5 m^2)
- 1÷2·10^6 readout channels
- DAQ rate 0.5÷1.0 MHz/ch
- Cooling system ($\leqslant$-30°C)
- FPGA or ASIC based FEE

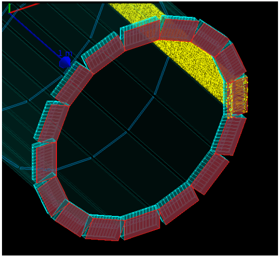
FDIRC option

- Inspired by design from BaBar, SuperB, Belle II, and PANDA
- For PANDA $\sigma_{\Theta_c} \approx 2.1$ mrad/track is achieved for π/K with 3σ@4 GeV/c
- For SCTF $\sigma_{\Theta_c} \approx 0.7$ mrad/track is required for μ/π with 3σ@1.5 GeV/c

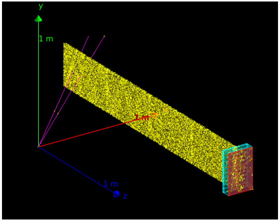
Main parameters:

- Synthetic fused silica:
  Barrel: 2×16 plates $110\times32\times1.5$ cm
  Endcap: 2×4 sectors $1\div2$ cm thick
- Focusing optics: innovative rad-hard 3-layer spherical lens
- MCP-PMT or SiPM with $\sigma_t \leqslant$100 ps
  Barrel:
  - $\square 2\div3$ mm pixel
  - $2.56\div1.14\cdot10^5$ readout channels

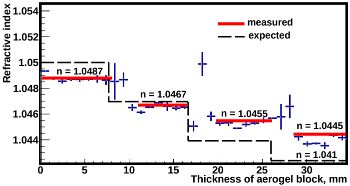
  Endcap:
  - 16×0.5 mm pixel
  - $2.88\cdot10^4$ readout channels



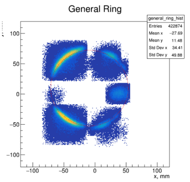
2×16 plates $110\times32\times1.5$ cm^3 and 2×16 expansion volumes $32\times20\times10$ cm^3



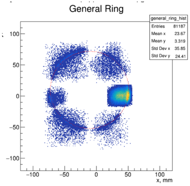
FARICH R&D: 4-layer aerogel production



op430f61 5×5×3.5 cm (2018)



6×6 mm^2

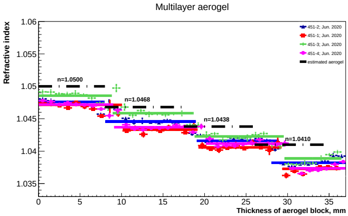


ø1 mm

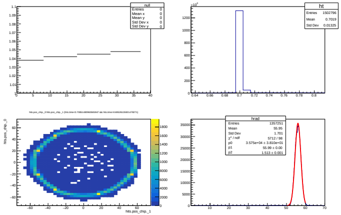
	Aerogel	PD	σ_R^{MC} mm	σ_R^{TB} mm
2018[a]	op430f61 5×5×3.5 cm	H12700 6×6 mm	3.2	3.4±0.15
		ø1 mm	1.96	2.01±0.18
2019[b]		SiPM 3×3 mm	2.18	2.25±0.09

[a] NIMA 952 (2020) 162247
[b] JINST 15 (2020) 10, C10014

FARICH R&D: 4-layer aerogel production



op451 10×10×3.5 cm (2020)



MC simulation results for SiPM (SensL,3×3 mm)

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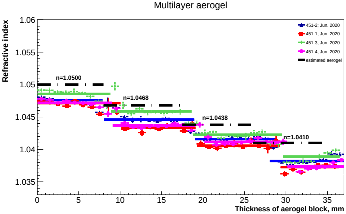

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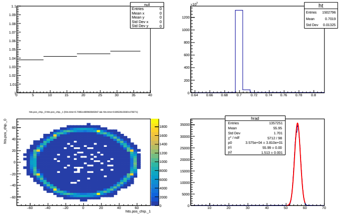

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Goal	$n_{max}=1.05$ 20×20×3.5 cm	SiPM 3×3 mm	1.45	

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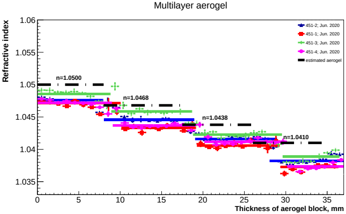
FARICH R&D: 4-layer aerogel production



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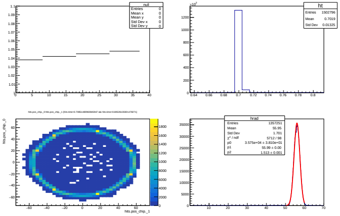

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It seems today we are very close to desirable σ_R!

Aerogel with increased n

- Proposed FARICH system has rather high threshold ($P_\pi \sim$450MeV/c)
- The higher n, the lower transparency of aerogel samples.
- Two approaches to increase n are developed in Novosibirsk.

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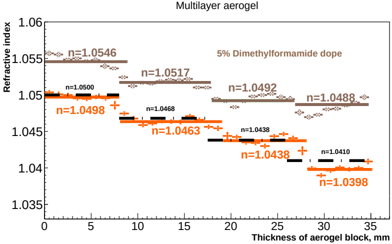
Dimethylformamide $(CH_3)_2NC(O)H$



	n_{max}	L_{sc}(400nm)
Ordinary	1.0498	32±0.5 mm
+5% DMF	1.0546	40±0.5 mm

5% of DMF increase n and L_{sc} significantly.

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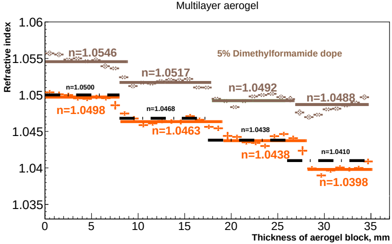

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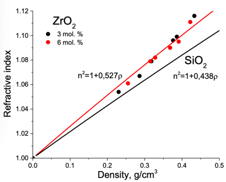
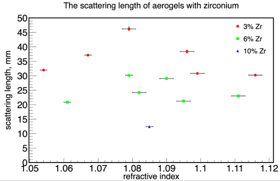
ZrO_2 dope





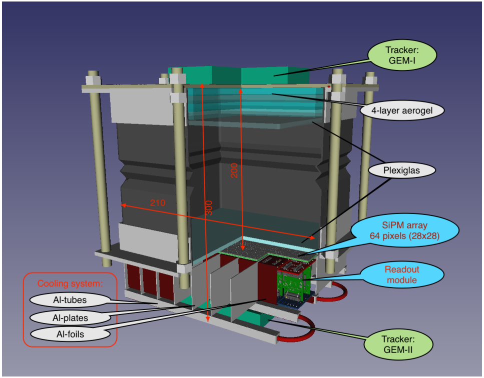
Aerogel with n=1.12 and $L_{sc}^{400nm} \geqslant 30$mm

produced by addition of 3÷6% of mol ZrO_2.

Full-scale prototype

Prototype for TBs & CRT:

- photon detector $\sim 21\times21$ cm^2
- $64\times(8\times8)=4096$ pixels 3×3 mm^2
- aerogels up to 20×20 cm^2
- aerogel isolated from environment
- squeezed shield for focal distance adjustment (around 20 cm)
- liquid cooling system to operate at -30°C ($\leqslant 5\% X_0$)

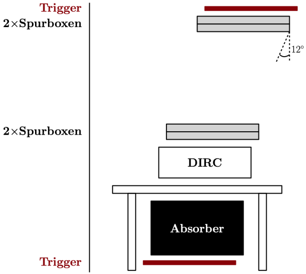


Conceptual design

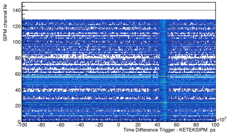
R&D of FDIRC option

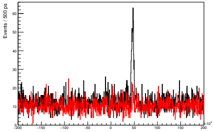
- Main activity today is aimed on optimization of FDIRC design with help of MC simulation
  (details are in next talk)
- Cosmic Ray Telescope was

  constructed in Giessen.
  - To investigate Cherenkov angle resolution of FDIRC prototypes.
  - To compare different photodetectors (MCP-PMTs, SiPMs) with different radiators (scintillator, plexiglas, aerogel, etc.).
  - Data taking is ongoing.



Run with EDD module is ongoing now





Accumulated plot of ΔT between trigger and SiPM signals with and without radiator (aerogel)

Front-End electronics

- For both options compact and fast readout electronics is needed
- Two approaches are considered for the moment:

- **ASIC**
- **FPGA**

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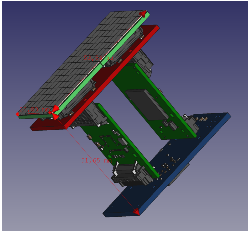
TOFPET-II (ASIC)


ROM with 2×TOFPET-II (PetSys) + 2×PA33xx-WB-08 arrays (KETEK)

Pros:

- Ready to use
- ∼15 mW/ch
- DAQ rate ∼480 kHz/channel

Cons:

- No external TRG
- Large cost of upgrade
- R&D of backplane based on FPGA is needed

TOFHiR2 should fit better for the project!

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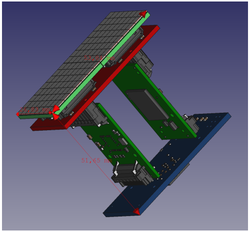

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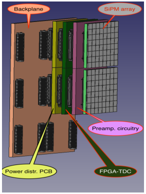
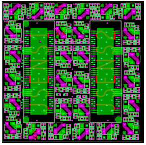
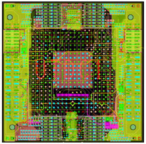
FPGA-based TDC

Four layer stack (GSI design):





Analog layer: 14-layer PCB Preamplifier circuitry



Digital level: FPGA-TDC + DAQ + Thresholds

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Design is coming soon !!!

Power distr. & backplane PCB

Summary

- The development of aerogel radiator production is going in Novosibirsk. In 2020 very promising 4-layer focusing aerogel samples were produced, which will be tested with electron beams in 2021.
- Cosmic Ray Telescope was constructed in Giessen to test FDIRC prototypes and investigate photon detectors. Data taking have just started and first results are coming soon.
- Design of a full-scale FARICH prototype has been started at BINP and is to be completed in 2021.
- A compact FPGA-based TDC is being designed at GSI. First version is expected in 2021.