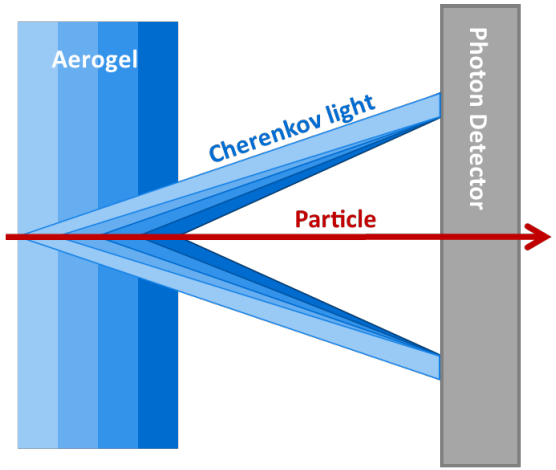
WP5.6 (option FARICH)

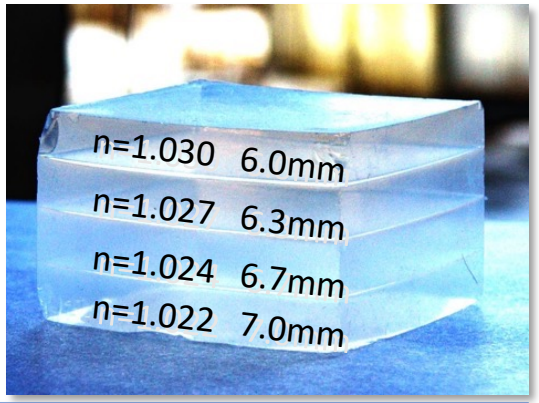
Status report on July of 2021

- **FARICH prototype development**
  - Focusing aerogel R&D
  - Photo Senseors+FEE R&D
- **FARICH simulation development**
  - Software for stand-allone sim. & reco.
  - Implementation in common framework (AURORA)

PID system – FARICH option (BINP)

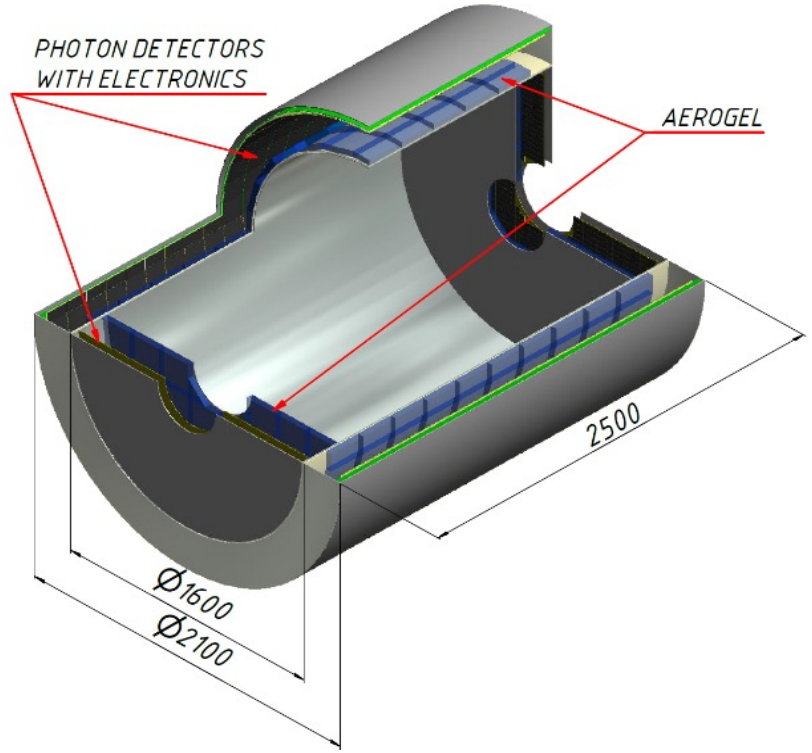


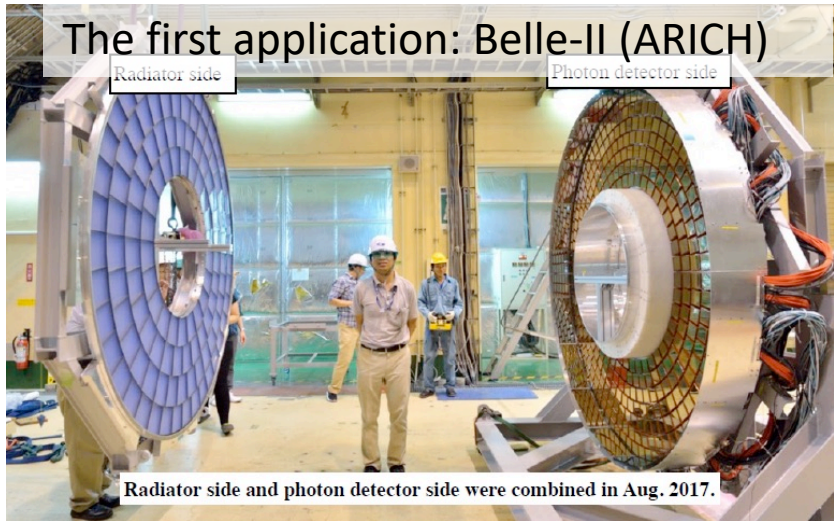
Первый 4-слойный аэрогель



Increase N_{pe} due to thickness of aerogel without degradation of $\sigma_{\Theta c}$

T.Iijima et al., NIM A548 (2005) 383
A.Yu.Barnyakov et al., NIM A553 (2005) 70





Capability to separate μ/π at the level ≥3σ at P=1 GeV/c was demonstrated in 2012.

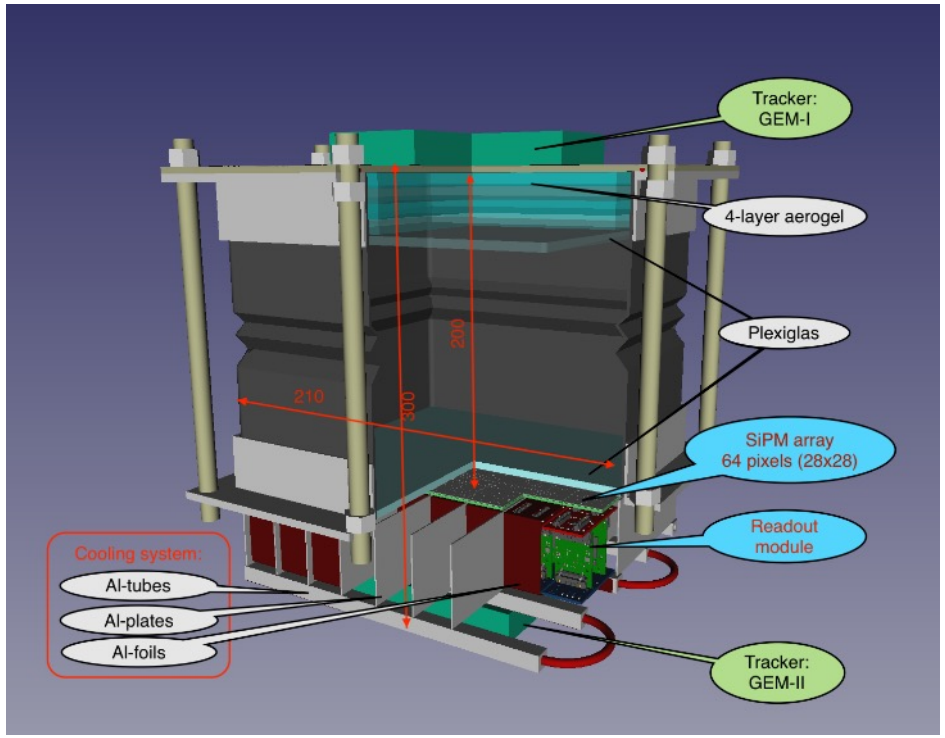
A.Yu. Barnyakov, et al., NIM A 732 (2013) 352

- Proximity focusing RICH
- 4-layer or gradient aerogel radiator n_{max} = 1.05 (1.07?), thickness 35 mm
- 21 m^2 total photon detector area
  - SiPMs in barrel (16 m^2)
  - MCP PMTs in endcaps (5 m^2)
- ~10^6 pixels with 4 mm pitch

Full-scale FARICH prototype

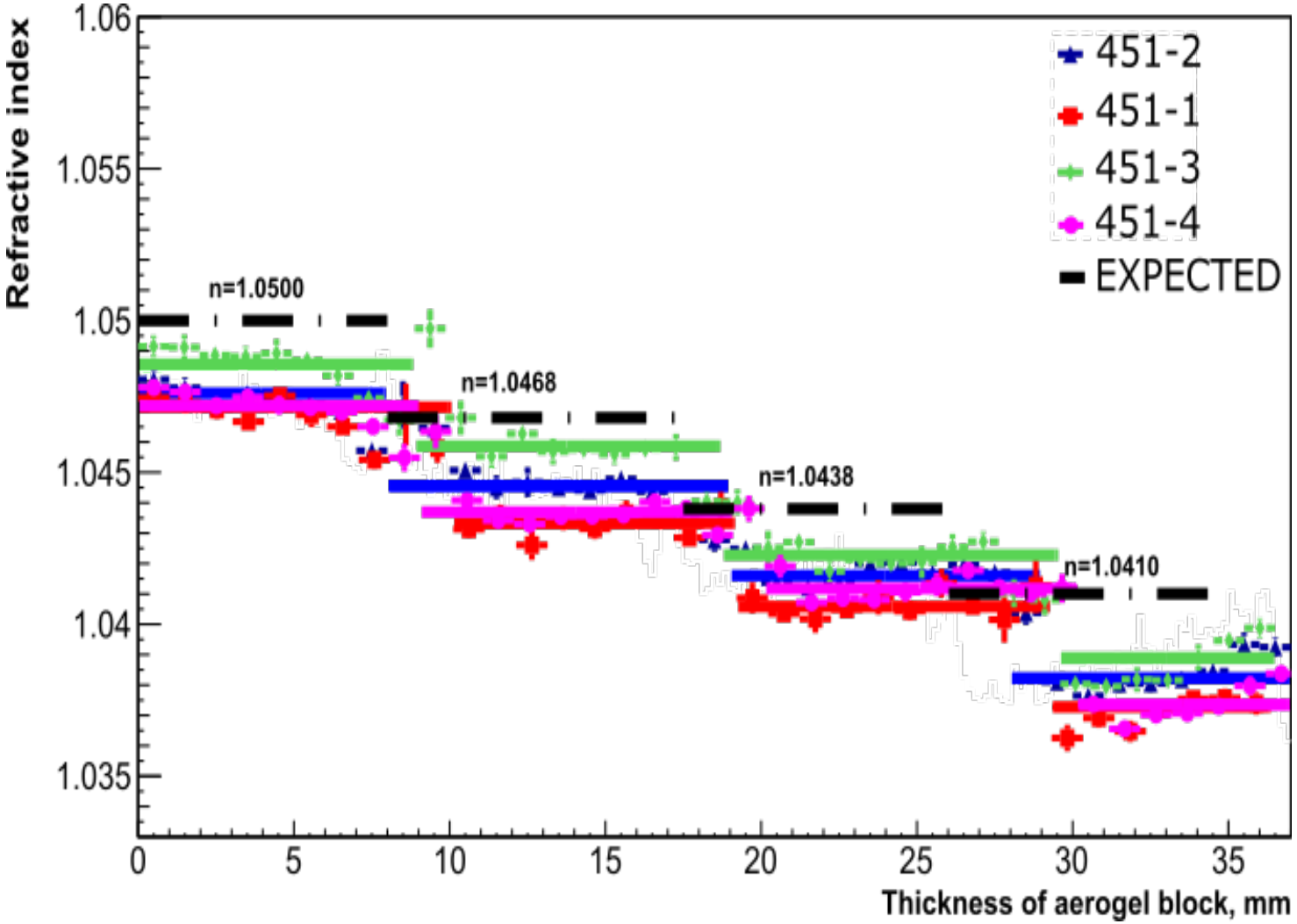
Full-scale prototype will detect full Cherenkov rings with SiPM arrays & compact readout FEE.

- photon detector size ≈21×21 cm^2
- 64 × (8×8) = 4096 pixels of 3×3 mm^2
- aerogels up to 20×20 cm^2 size
- aerogel isolated from environment
- folding envelope enabling focal distance adjustments
- liquid cooling system to operate at −30°C (≤ 5%X_0)



Full-scale prototype should be ready for test beam in 2022 well ahead of MS5.6 due date (M42)

Aerogel 2020-2021



2019 beam test results and comparison with MC

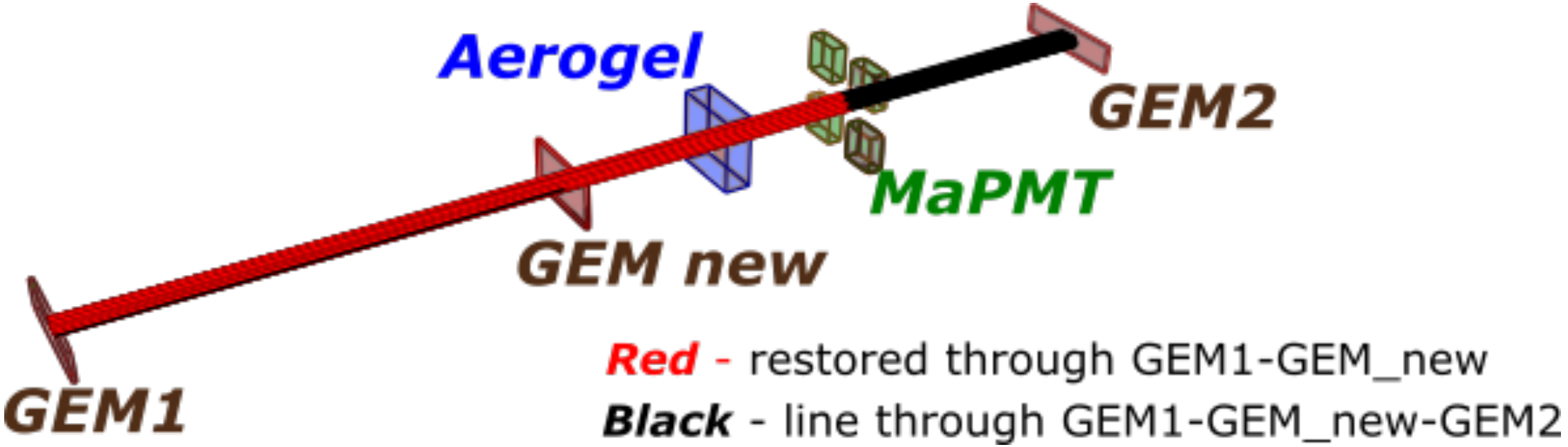
PD pixel size	σ_R(MC) [mm]	σ_R(EXP) [mm]
H12700 Ø1 mm	1.98	1.97±0.04
SiPM 3×3 mm^2	2.18	2.16±0.04

JINST **15** (2020) C10014

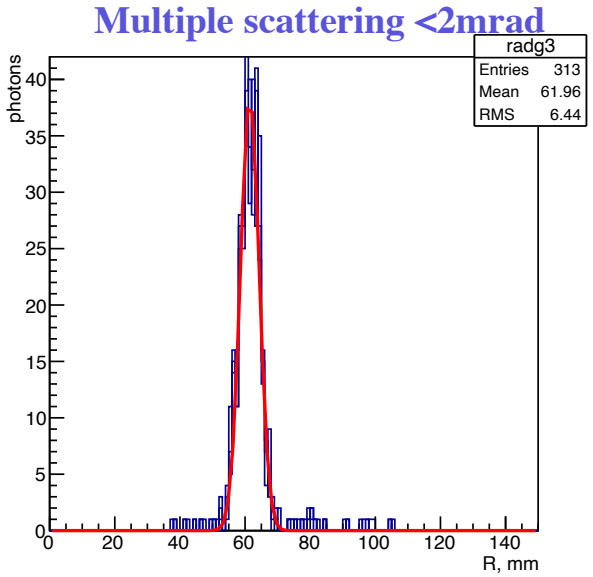
Aerogel	PD pixel size	σ_R(MC) [mm]
op451	SiPM 3×3 mm^2	1.55
Ideal 4-layer		1.45

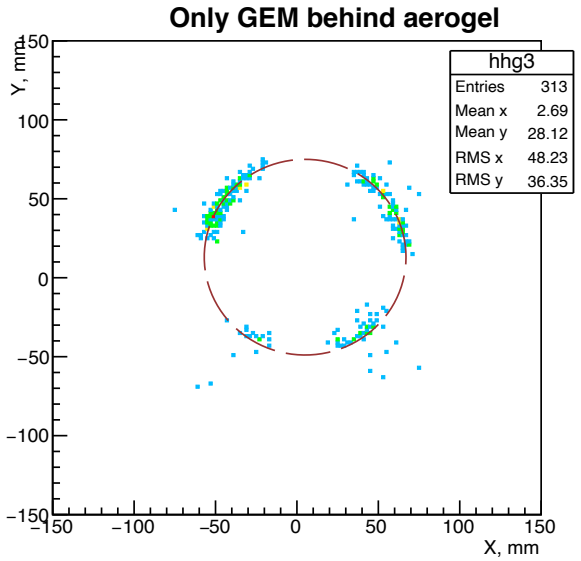
Beam tests with FARICH in 2021 at BINP

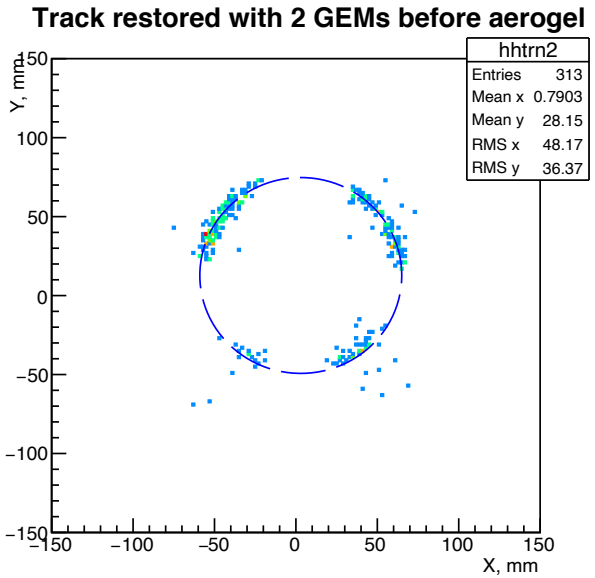
- We had two runs in April-May 2021 with electrons E=1.5 GeV.
- Masks with Ø1 mm in the center of each MaPMT pixel were used to minimize impact from pixel size to Cherenkov angle resolution.
- Three GEMs were used at beamline (+ new one).
  - ✓ Two befor aerogel sample and one behind
  - ✓ It alows us to metigate multiple scattering affects.

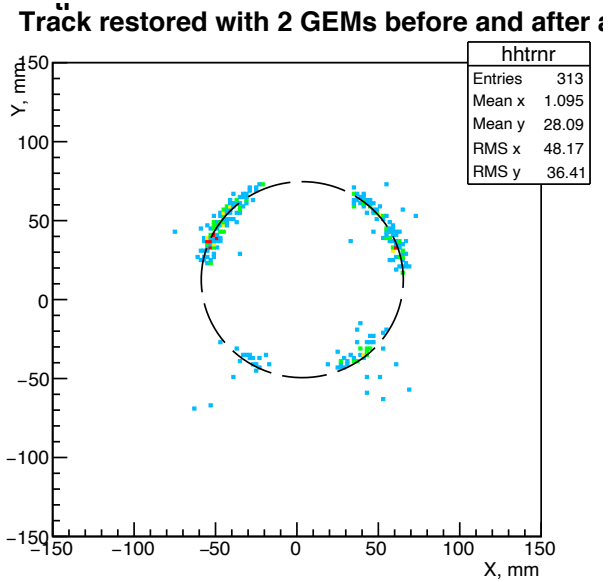


Very preliminary TB results







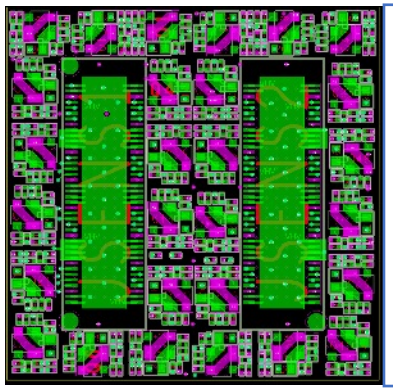


Five 4-layer focusing aerogel blocks with size 10x10x35cm were tested.

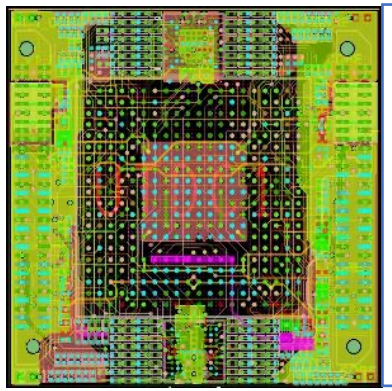
After strong cuts for multiple scattering we have only few handreds photons per each aerogel sample. We need more statistics in such schem of experiment!

For best sample σ_R=1.75mm was observed (very preliminary).

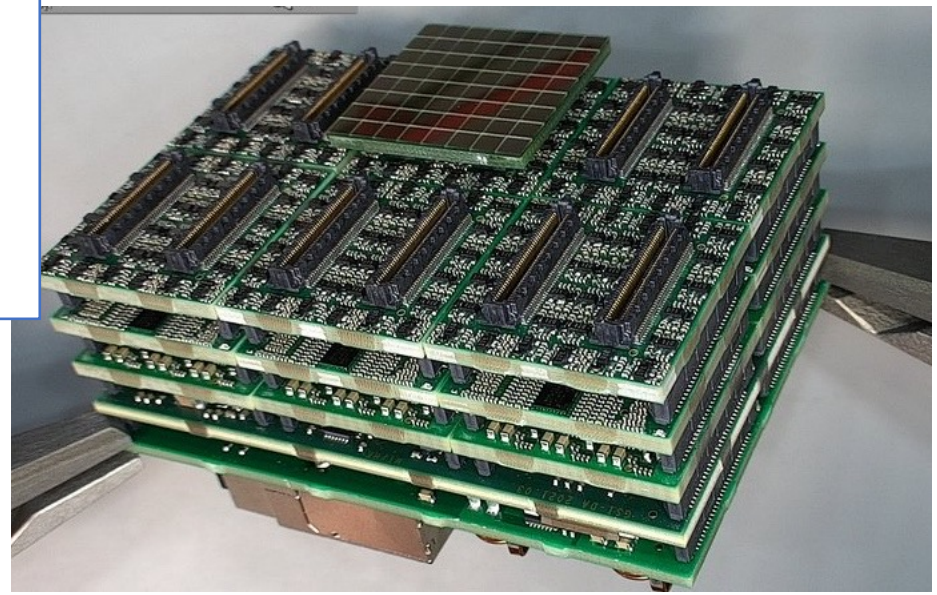
Compact FPGA based Front-End electronics (GSI)

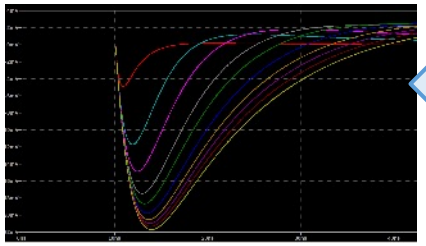


Amplifier board
- 27×27 mm^2 size
- 14-layer PCB
- 30x gain, 64 channels
- couples to KETEK 8×8 SiPM array

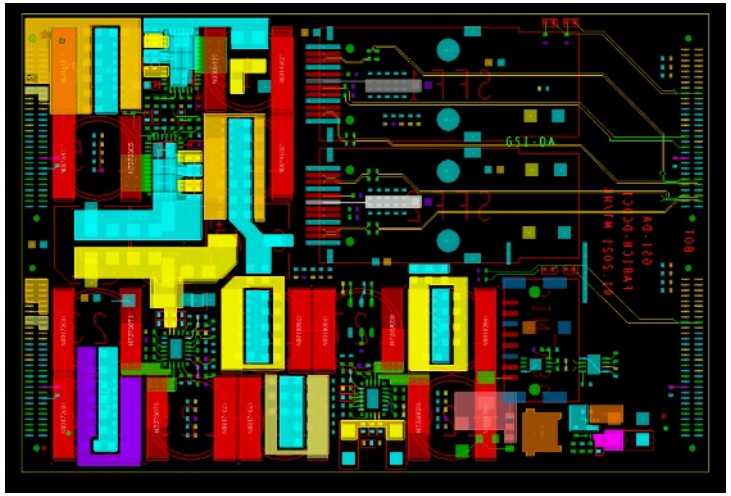


TDC board
- 64 channels
- 2 TDC + 4 threshold FPGAs
- 10ps precision



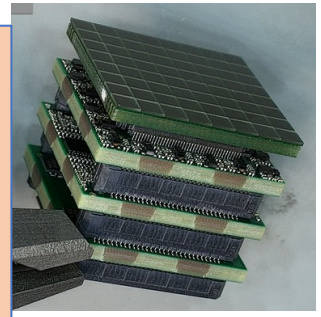


Simulated single photon pulse shapes from amplifier for different input resistance. ~ 22mV amplitude can be achieved.

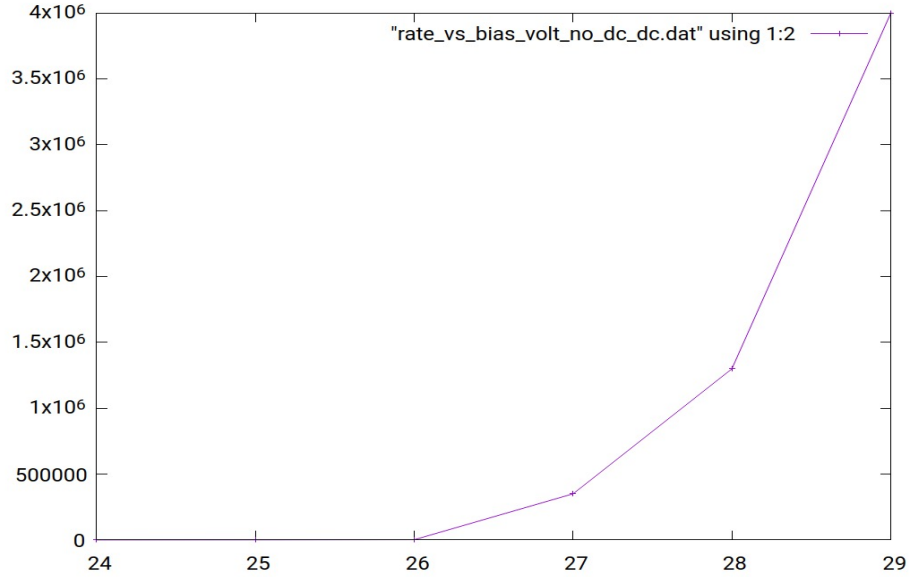


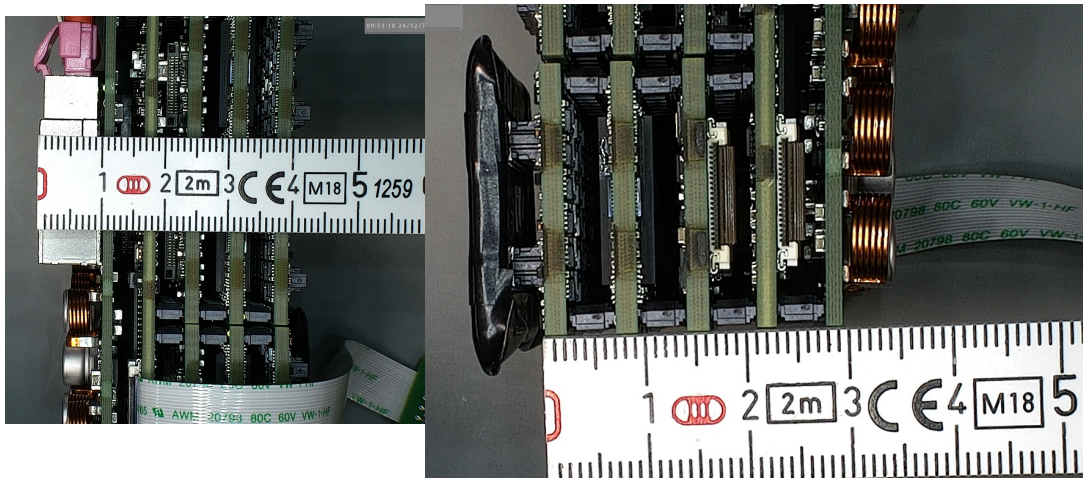
DC-DC convertor board
- goes behind the backplane
- 51×84 mm^2 size
- provides power to SiPMs, amplifiers, FPGA
- uses air inductive coils to operate in the detector magnetic field
- power, trigger & clock connectors

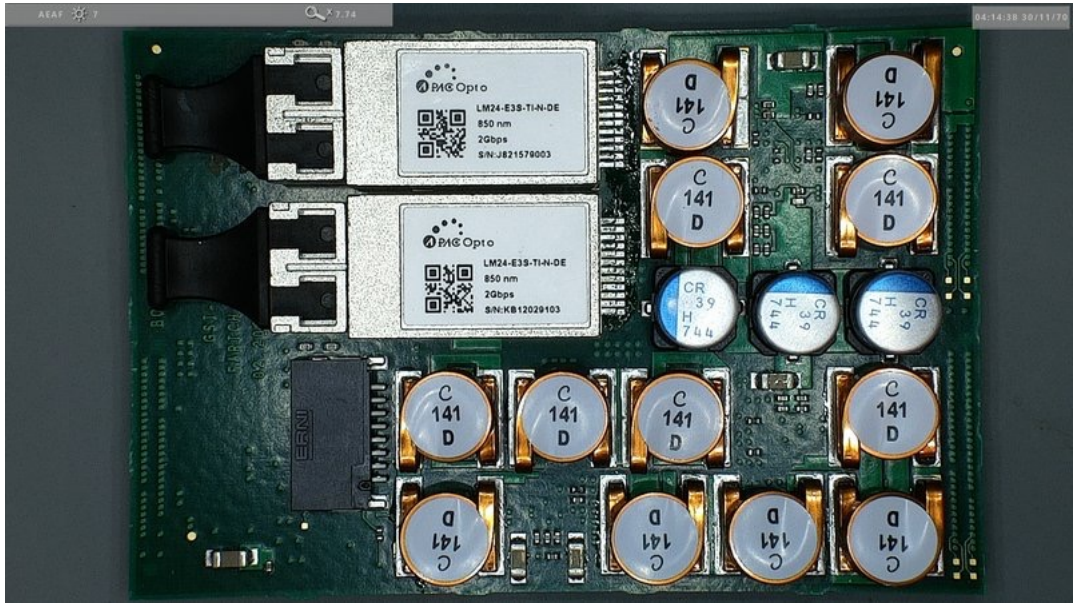
- Design of FEE with 5 layers was developed
- One module (81x54x50mm^3) readout 384 pixels (3x2x64) and transfer data through optic-link.
- The first version was produced ~01/06/2021r. The first simple test in lab at GSI have been performed.



The first impression from New FEE (GSI)







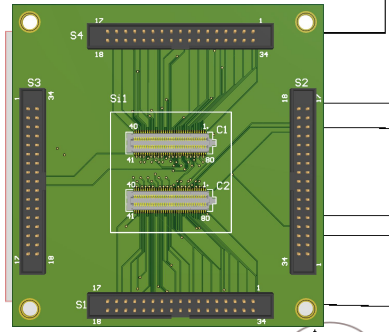
- New FEE thickness is less than 50 mm!!!
- IT WORKS! The dependence of noise rate on voltage is as expected. Count rate depends on illumination intensity of the sensor.

- DC-DC converter board is too hot to operate without liquid cooling system
- It is necessary to test FEE capability to with single photon signals

Stand for tests and comparison of SiPM Arrays

MOTIVATION:

- We have to compare SiPM arrays of different producers: Hamamtsu, KETEK, SensL
- We have to test about 64 arrays before Full-scale prototype assimbling (OV, DCR, PDE, TR etc.)



Software package for data taking and analysis is to be developed.

All PCBs to be produced untill the end of July 2021.

Existing readout electronics:

- FILIP is preamplifier and power distribution board from the CMD-3 experiment
- V1742 is digitizer based on DRS4 chip from CAEN

Event reconstruction in FARICH using Neural Networks

Motivation

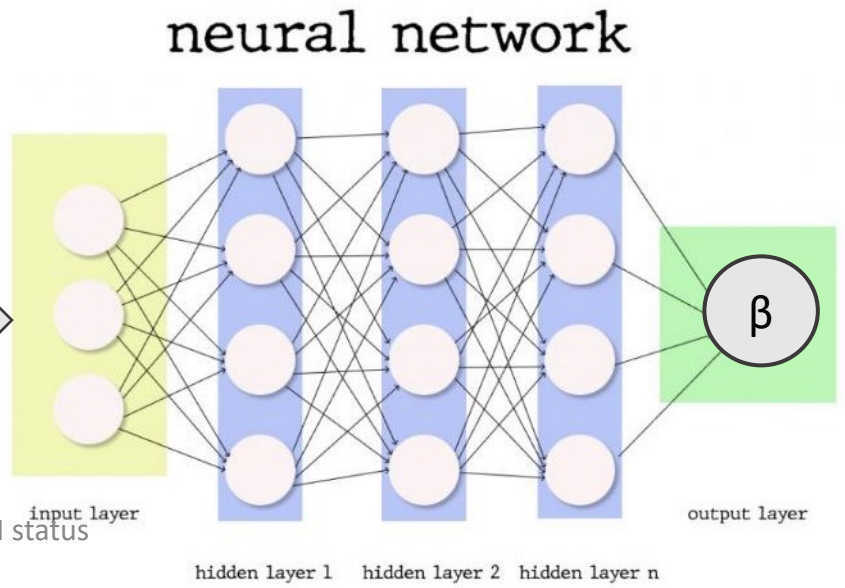
- Alternating approach to event reconstruction with a potential to include all observed data without knowing PDFs → flexibility
- More straightforward and attractive for developer

Implementation (started in Fall 2020)

- Python with Pandas, TensorFlow etc. packages
- Fully connected feedforward NN
- Feature extraction with analytical reconstruction of hit θ_c, φ_c,
- Obtain particle's β from a single NN output

N_{hits} (i, j, k)
i – bin on ϕ_c
j – bin on θ_c
k – bin on time

particle inc. angle



SCTF FARICH simulated configuration

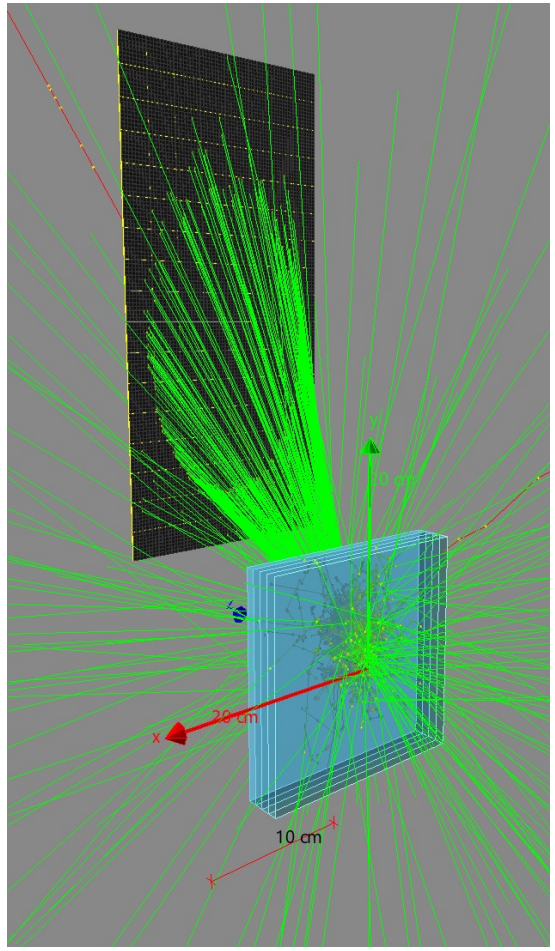
Photon detector

- ON Semiconductor (SensL) ArrayJ-30020-64P-PCB
- Pixel size 3.16×3.16 mm^2
- Pixel pitch 3.36 mm
- U_{bias} = 2.5V
- λ_{max}≈400 nm, PDE_{max}≈ 38%
- Sensor geom. fill factor ≈ 88%

Radiator

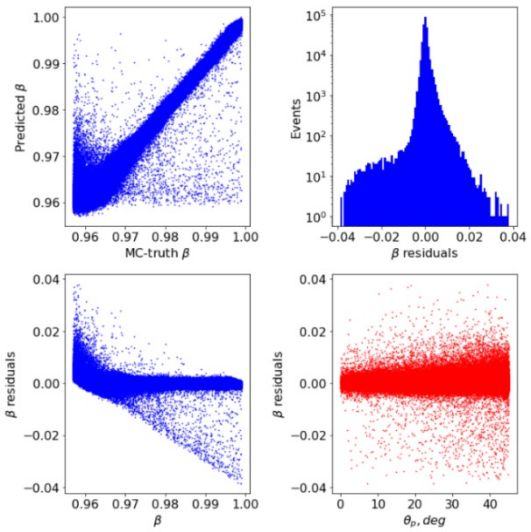
- 4-layer focusing aerogel
- n_{max} = 1.05
- 35 mm thickness

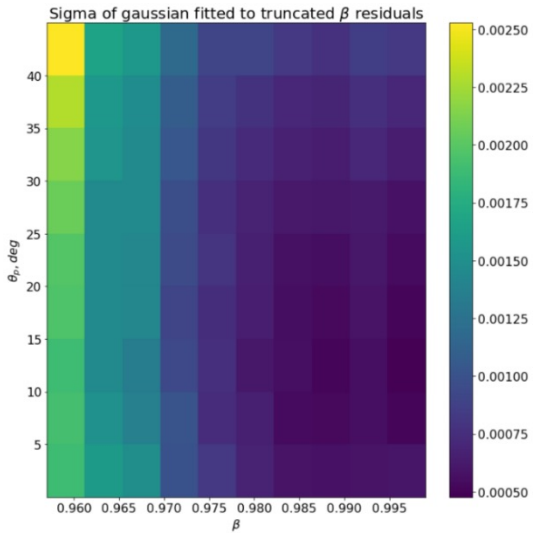
PD-Radiator distance: 200 mm

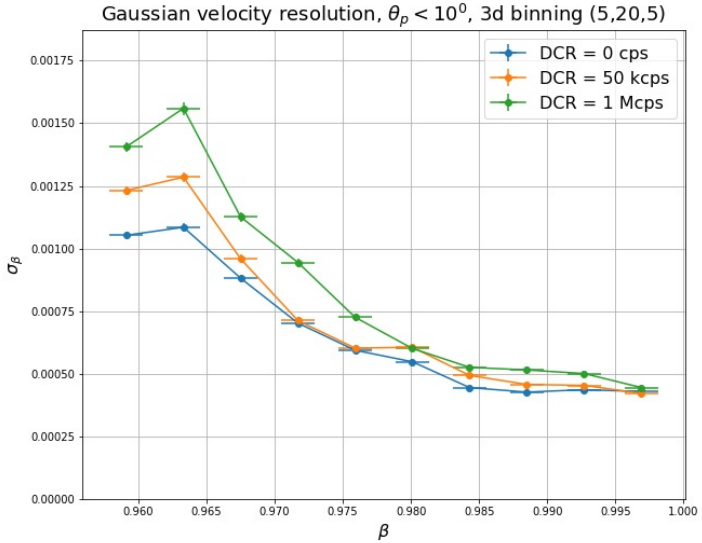


Results of NN event reconstruction

DCR = 1 Mcps/mm^2







Robust against DCR

- NN reconstruction gives the best β error $5 \cdot 10^{-4}$ for 1 Mcps/mm^2 dark count rate
- Minimum β error for geometrical reconstruction (w/o dark noise) ~ $4 \cdot 10^{-4}$
- Theoretical limit (w/o dark noise) ~ $3 \cdot 10^{-4}$

Plans for Q3-4 of 2021:

- compare NN reco vs “classical” reco with dark noise
- compare speed

Conclusion

- R&D on Full-scale FARICH prototype is go on and progress is visible.

- Software for FARICH simulation and reconstruction is developing.
  - ✓We have some delay with implementation of our soft in AURORA framework connected with tuning of the AURORA it self.

- We have all chance to be in time for MS5.6 (M42), but we have no room for additional iterations or mistakes!