The dual-radiator Ring Imaging Cherenkov Interaction Tagger

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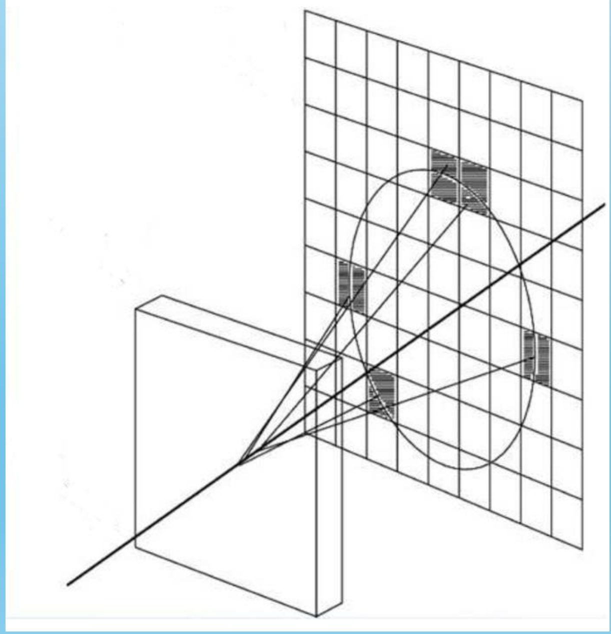
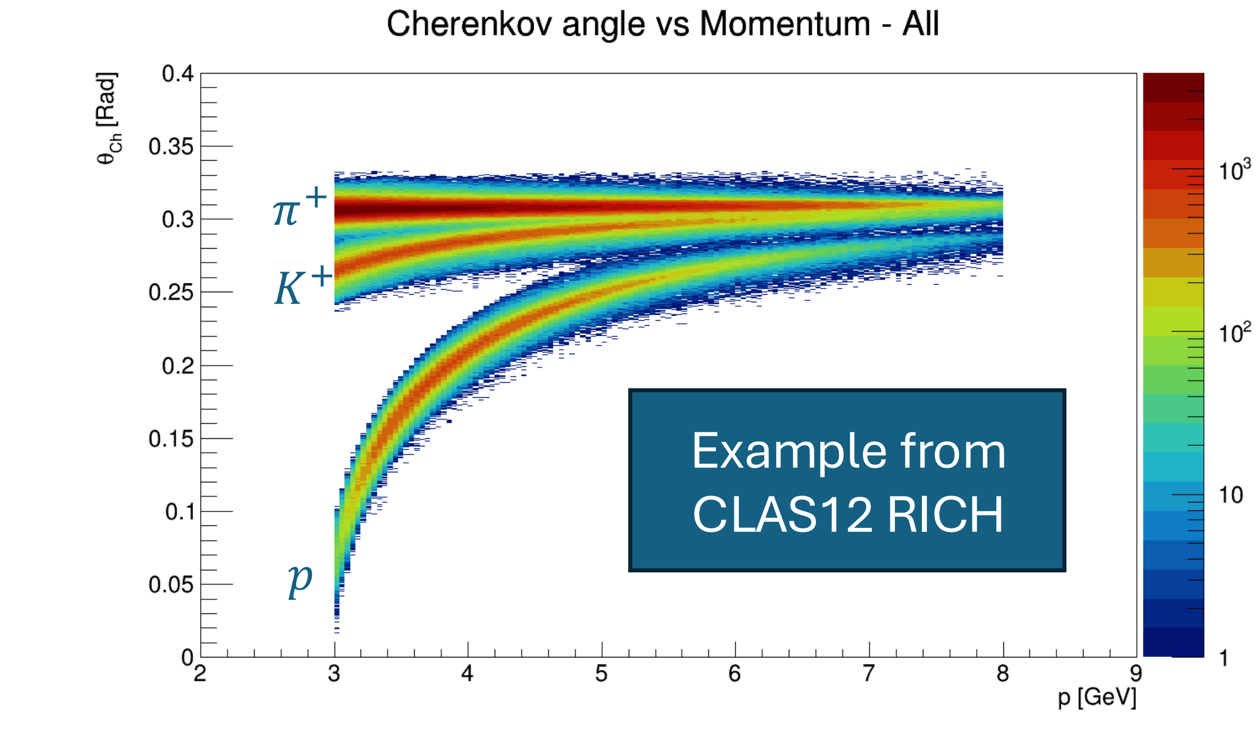
Ring Imaging Cherenkov detector

A charged particle moving faster than light in a medium emits photons forming a cone with angle:

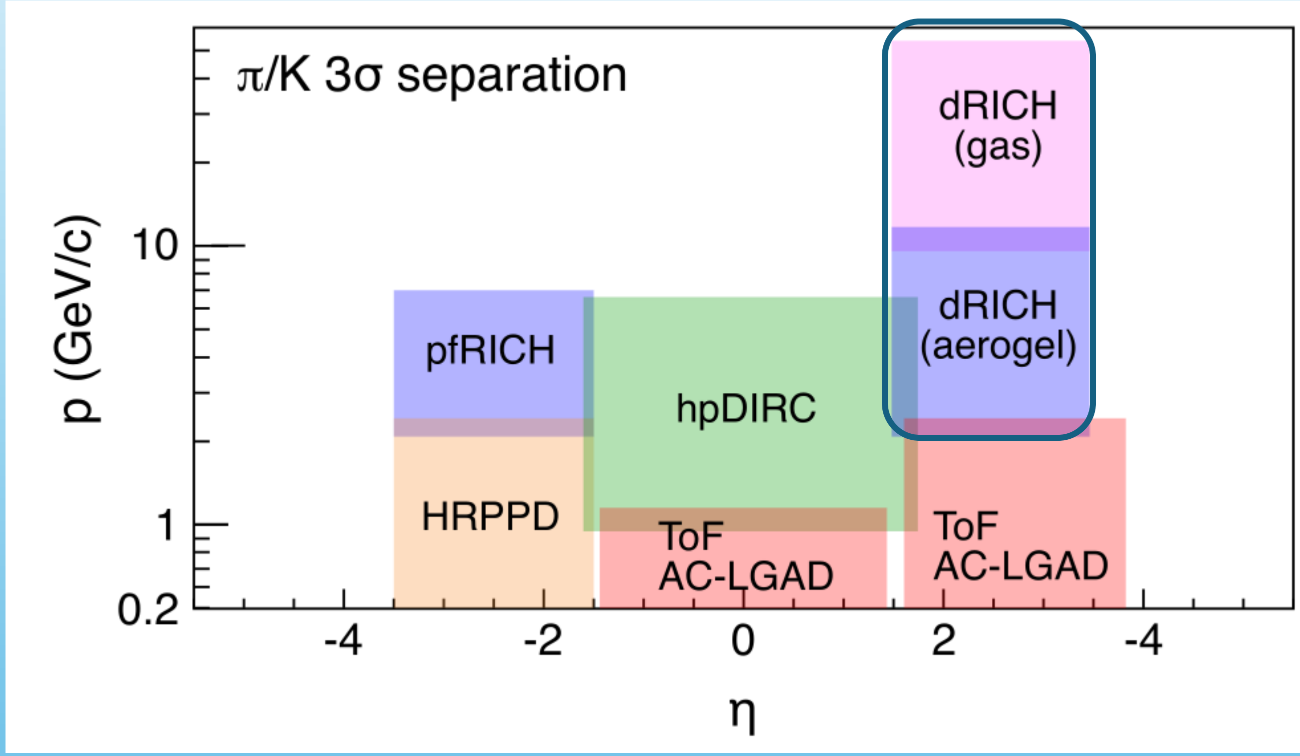
$$\cos\theta = \frac{1}{n\beta}$$



- By detecting the ring projection of the Cherenkov cone, the Cherenkov angle can be identified.
- Combining the Cherenkov angle with the particle momentum allows the determination of the particle mass → hadron identification.



The ePIC PID in hadronic endcap

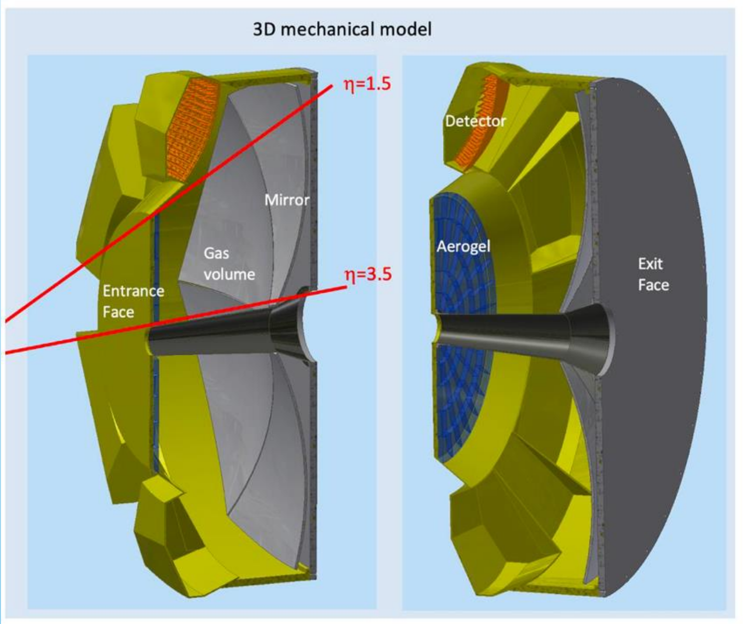


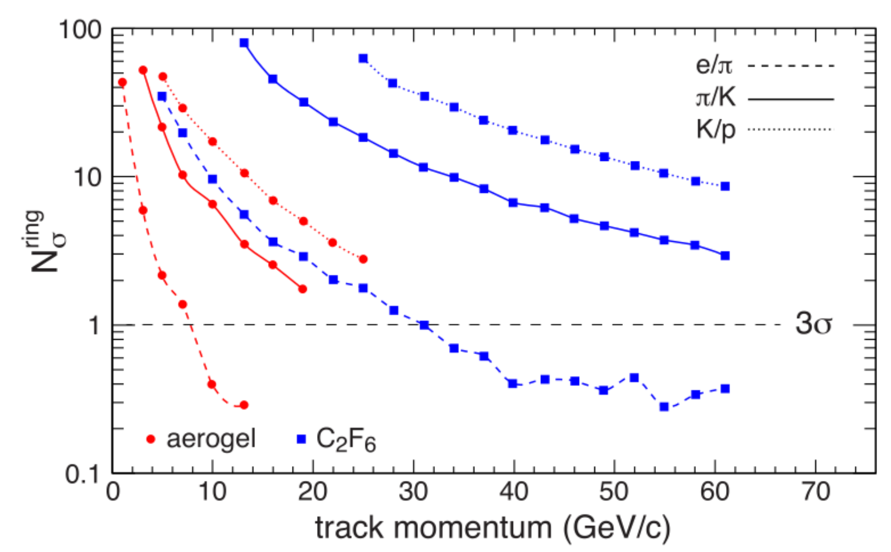
The dual-radiator Ring-Imaging Cherenkov Detector (dRICH) is essential to access flavor information.

Goals:

- Hadron 3σ separation between 3 - 50 GeV/c;
- Complement electron ID below 15 GeV/c;
- Cover forward pseudorapidity 1.5 (barrel) - 3.5 (b. pipe).

The ePIC dual-radiator RICH



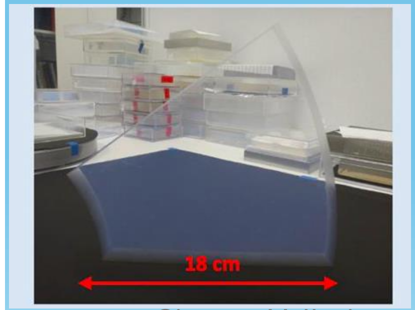


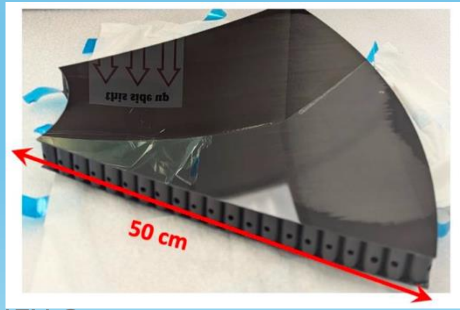
The identification of charged particles with momenta larger than 3 GeV/c in the hadronic endcap will face two major challenges:

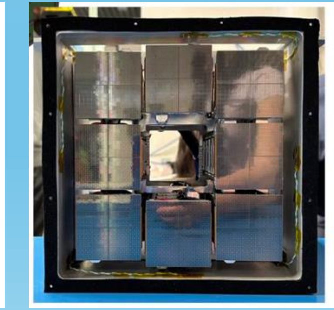
- to cover a wide momentum range (up to 50 GeV/c);
- to operate in a high (~1T) magnetic field.

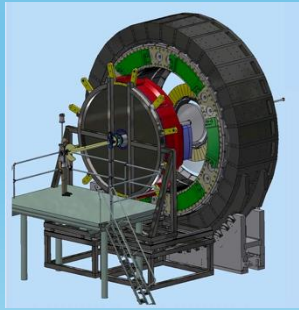
The two radiators, aerogel (n≃1.020) and gas (n≃1.0085) will allow for combining their information to identify hadrons over the full momentum range.

The **Silicon Photomultiplier (SiPM)** will be used as magnetic-insensitive photosensor.

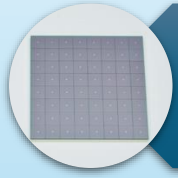






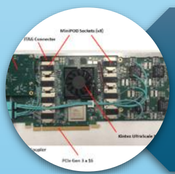


The dRICH data throughput challenge

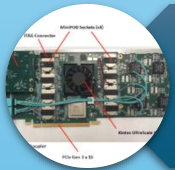


320k SiPM

1248 RDO



30 I-Level DAM



1 II-Level DAM

ePIC data storage

dRICH DAQ parameters	
RDO boards	1248
ALCOR64 x RDO	4
dRICH channels (total)	319488
Number of DAM L1	27
Input link in DAM L1	47
Output links in DAM L1	1
Number of DAM L2	1
Input link to DAM L2	27
Link bandwidth [Gb/s] (assumes VTRX+)	10
Interaction tagger reduction factor	1
Interaction tagger latency [s]	2,00E-03
EIC parameters	
EIC Clock [MHz]	98,522
Orbit efficiency (takes into account gap)	0,92

Bandwidth analysis		Limit
Sensor rate per channel [kHz]	300,00	4.000,00
Rate post-shutter [kHz]	55,20	800,00
Throughput to serializer [Mb/s]	34,50	788,16
Throughput from ALCOR64 [Mb/s]	276,00	
Throughput from RDO [Gb/s]	1,08	10,00
Input at each DAM I [Gbps]	50,67	470,00
Buffering capacity at DAM I [MB]	12,97	
Throughput from DAM I to DAM II [Gbps]	50,67	10,00
Output to each DAM II [Gbps]	1.368,14	270,00

Sensors Dark Count Rate: 3 - 300 kHz (increasing with radiation damage → with experiment lifetime).

Detector throughput: 14 - 1400 Gbps.

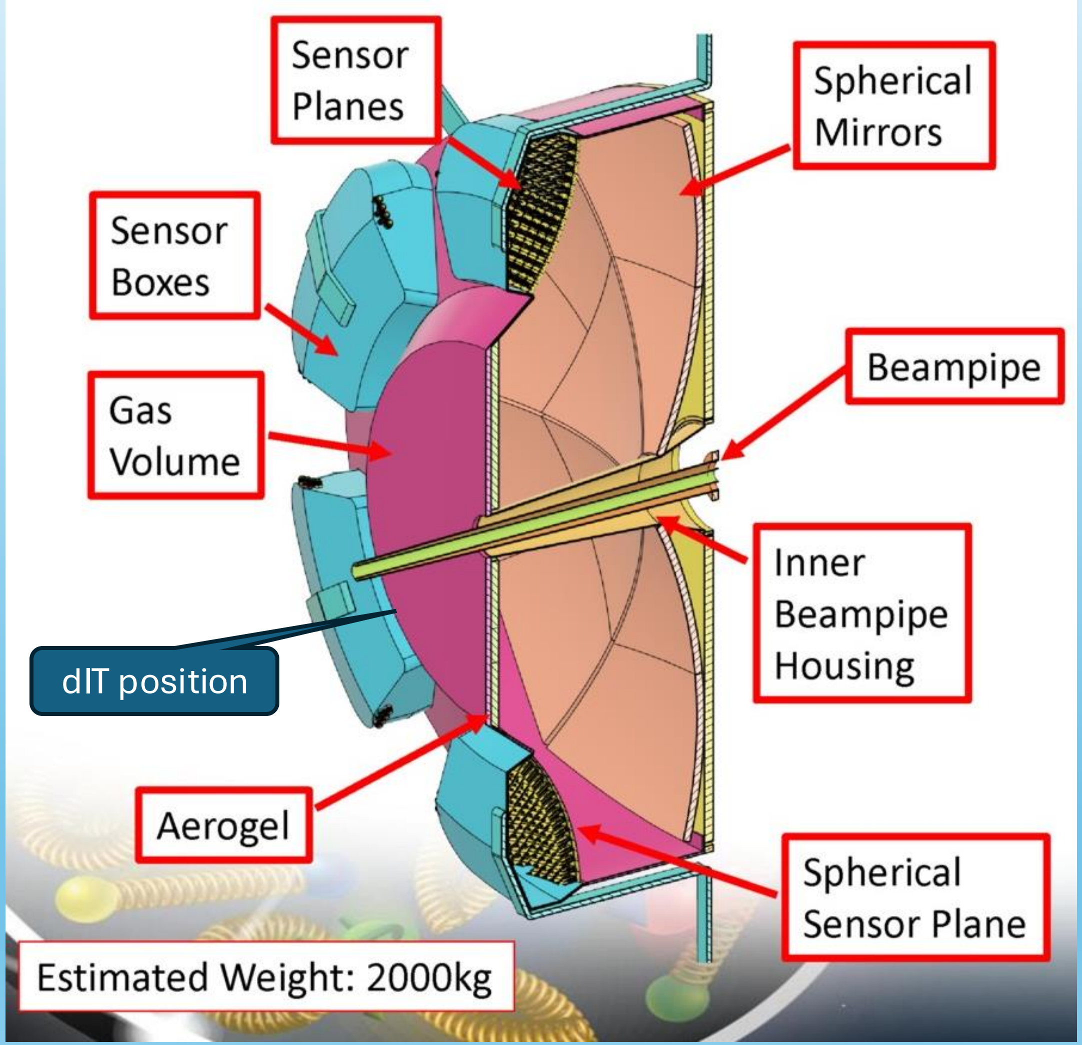
EIC bunch crossing: bunch crossing rate of 100 MHz.

Physical relevant interaction: one every ~ 200 bunch crossing → interaction rate of 500 kHz.

A system tagging the interacting bunches can address the throughput challenge.

A ML-guided data reduction system is being developed by INFN RM1 as a complementary approach.

The dRICH Interaction Tagger



The dRICH Interaction Tagger (dIT) will be a scintillating detector-based component of the dRICH, designed to tag events in which at least one charged particle with sufficient energy passes through.

Requirements:

- High efficiency (no false negative);
- Good timing ~1 ns;
- Reduction factor > 10;
- Thin due to strict geometrical constraints.

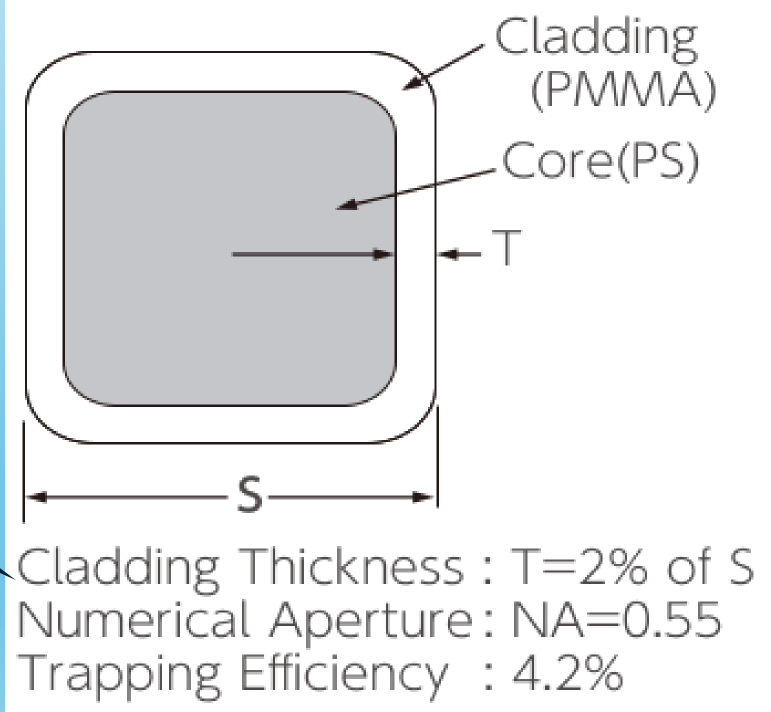
We are developing a hodoscope based on Scintillating Fibers (SciFi) to meet these requirements. It consists of two layers of square-shaped SciFi, rotated by 90°.

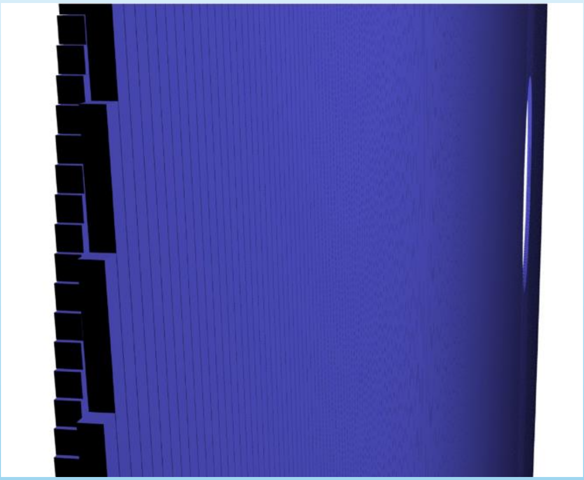
The dIT simulation

The SciFi simulation

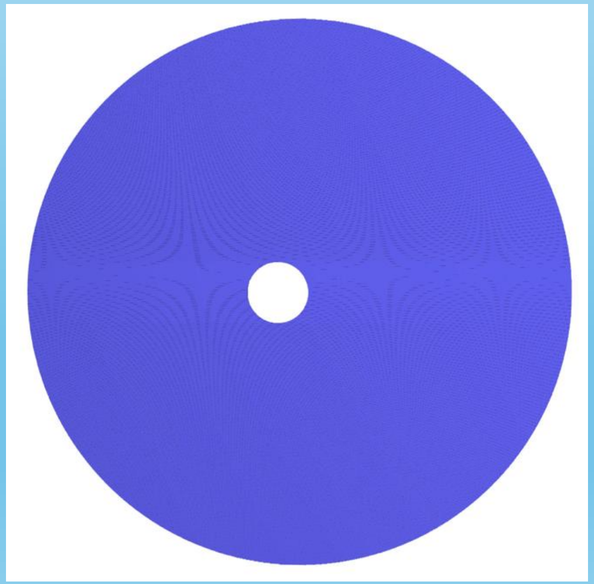
- Two layers of 2 mm wide SciFi, 2% cladding thickness
- XY-directions, 956 fibers/layer, 1.23 km of fiber length/layer;

From Kuraray datasheet





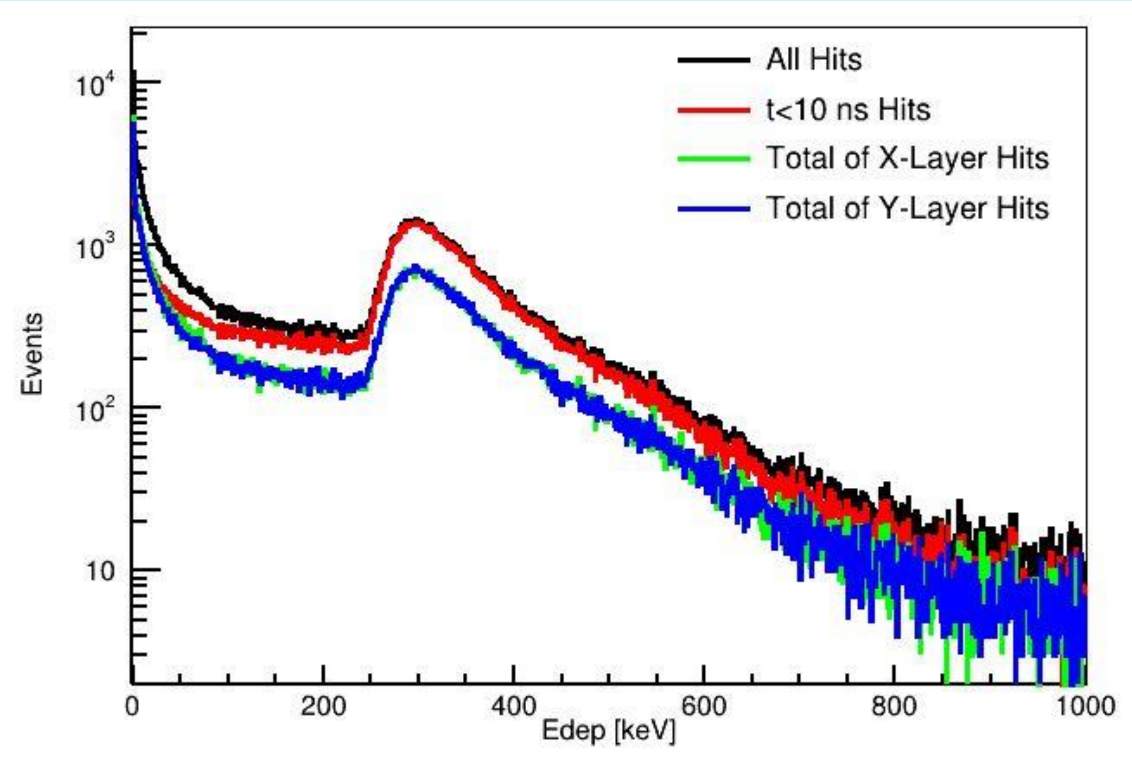
The 2mm squared-shape SciFi implementation on ePIC simulation framework

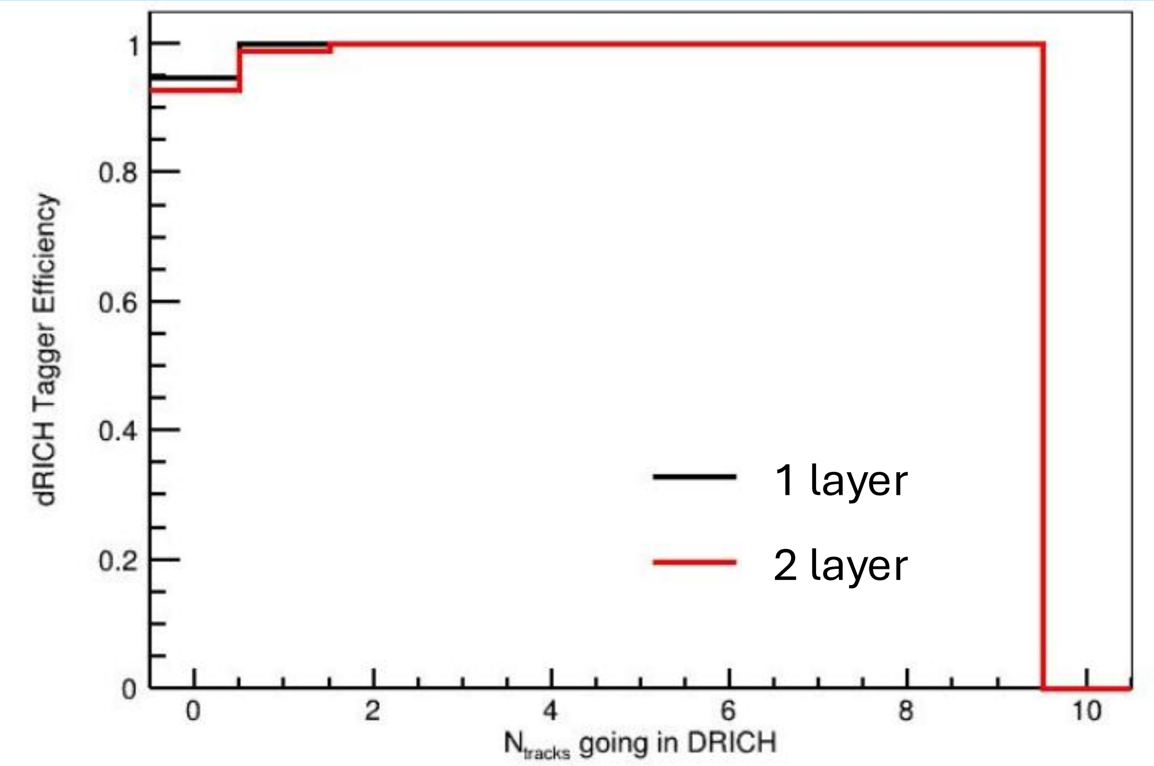


The dIT simulation. The beam pipe hole has an offset of ~25 mRad

The dIT efficiency

- E_{MPV} = 300 keV/layer = 2400 photons ≊ 20 p.e./SiPM;
- The threshold could be set at 100 keV ≊ 7 p.e./SiPM → expected Poisson inefficiency < 0.1 %;
- Efficiency is estimated as the ratio of events with charged tracks having dIT over the number of events with dRICH hits.
- Overall expected efficiency 99.97%, if there is at least one track from the interaction point in the dRICH.





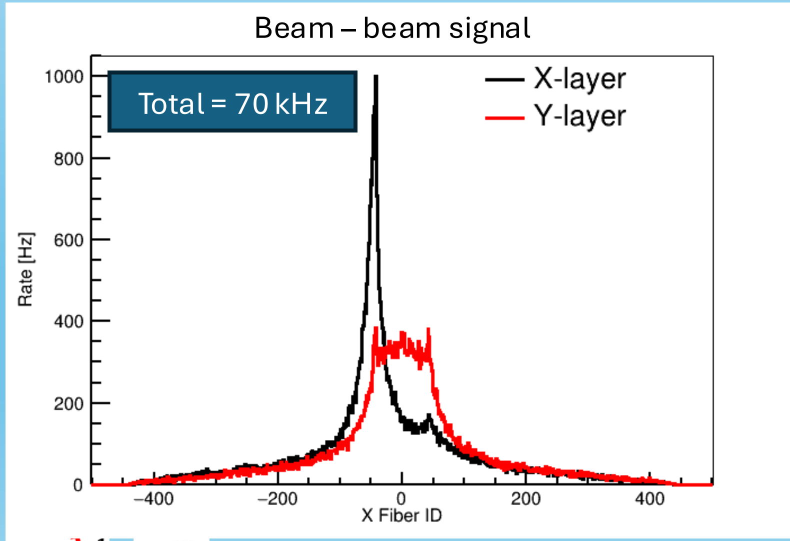
The dIT reduction factor

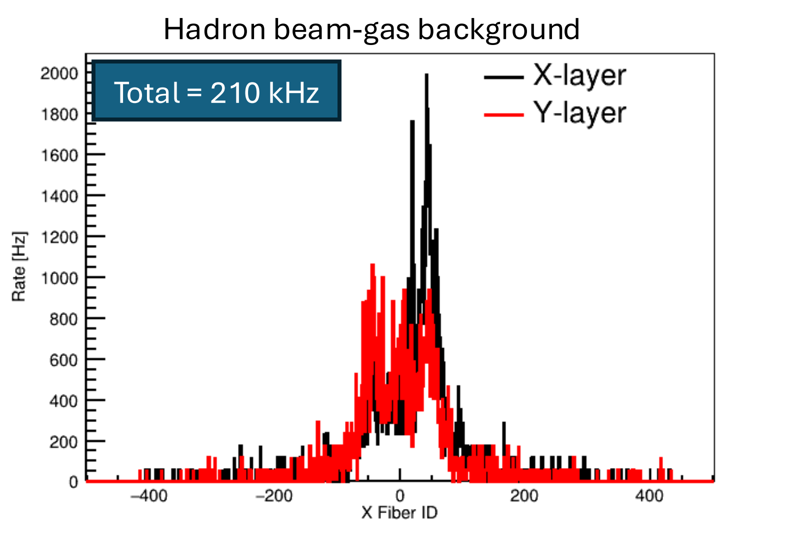
- ePIC maximum nominal luminosity: $10^{34}\ cm^{-2}s^{-1}$.
- ePIC cross section for $Q^2 > 1\ GeV^2$: $0.556\ \mu b$
- Beam gas luminosity: $4.2\ \times 10^{29} cm^{-2}s^{-1}$.
- Hadron beam and electron beam gas cross sections: $78.54\ mb$ and $699.4\ mb$.

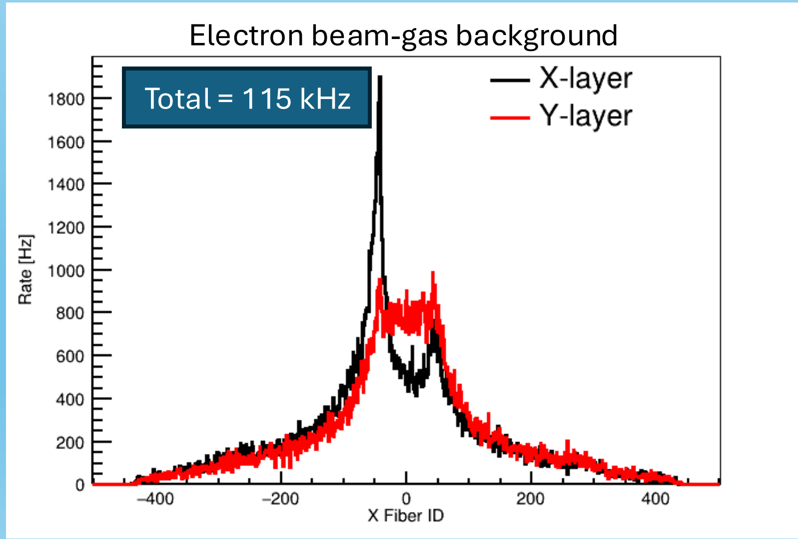
The total dIT rate became $R_{dIT} = 395\ kHz$.

The reduction factor is then $^{R_{Bunch-crossing}}/_{R_{dIT}} = {}^{500\ MHz}/_{395\ kHz} \cong 1.3 \times 10^3 \gg 10$

Minimum requirement

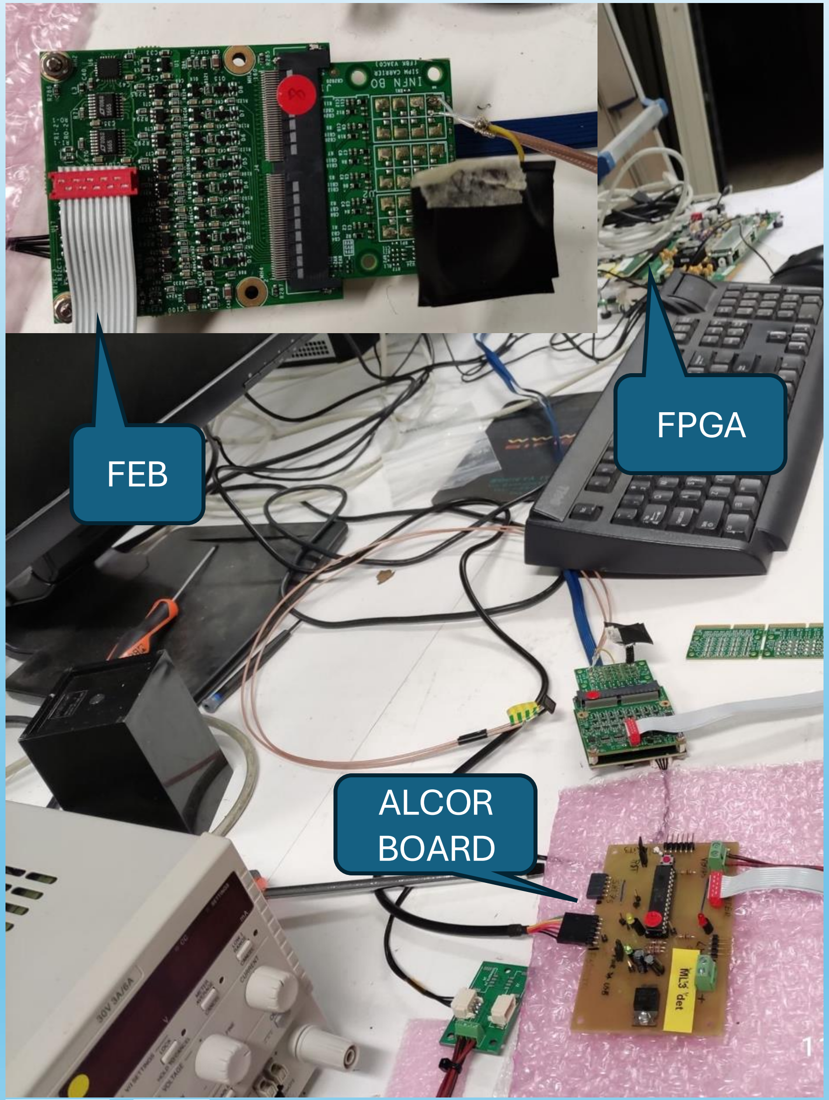




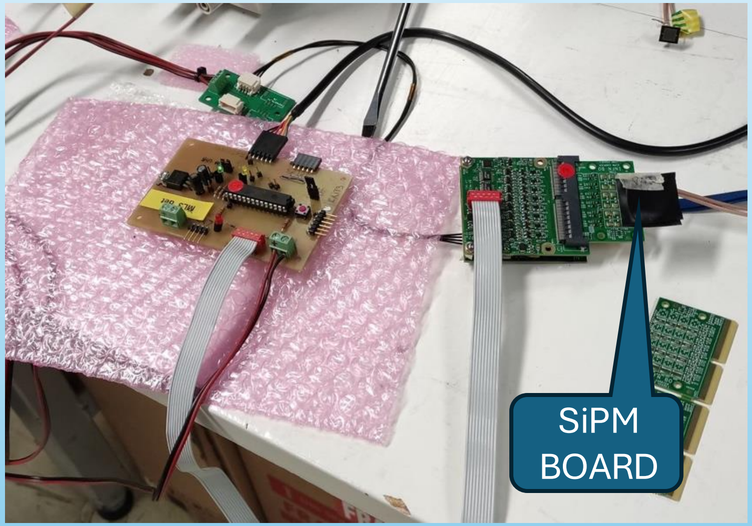


Ongoing R&D in Genova

The ALCOR readout

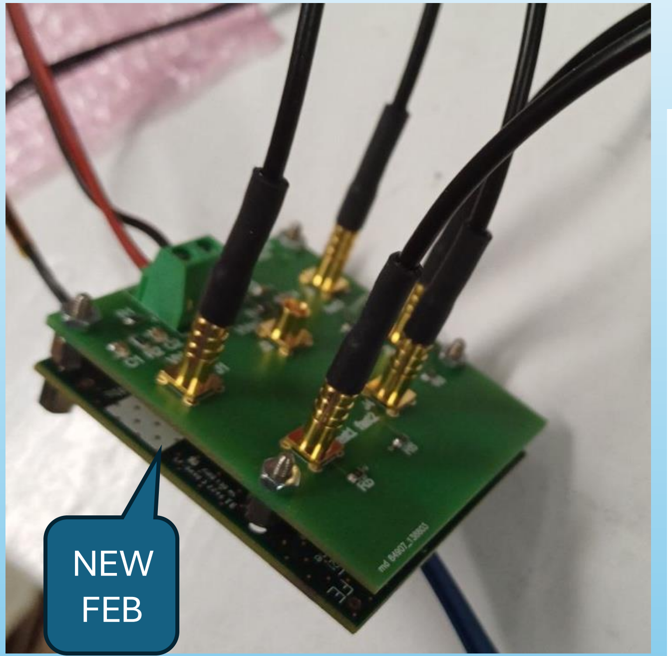


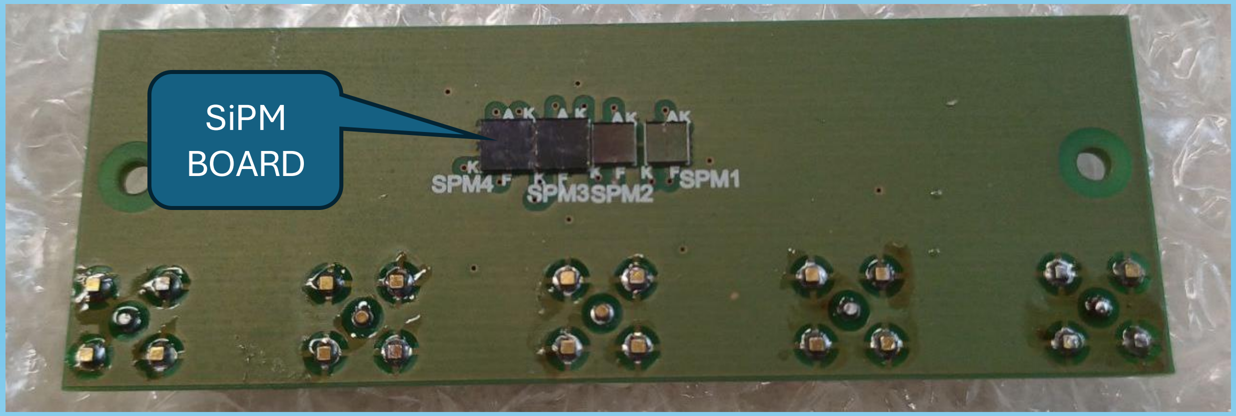
- ALCOR is the ASIC selected for the dRICH readout – it is designed to perform Time-over-Threshold (ToT) measurements.
- A readout chain based on ALCOR has been implemented in Genova.

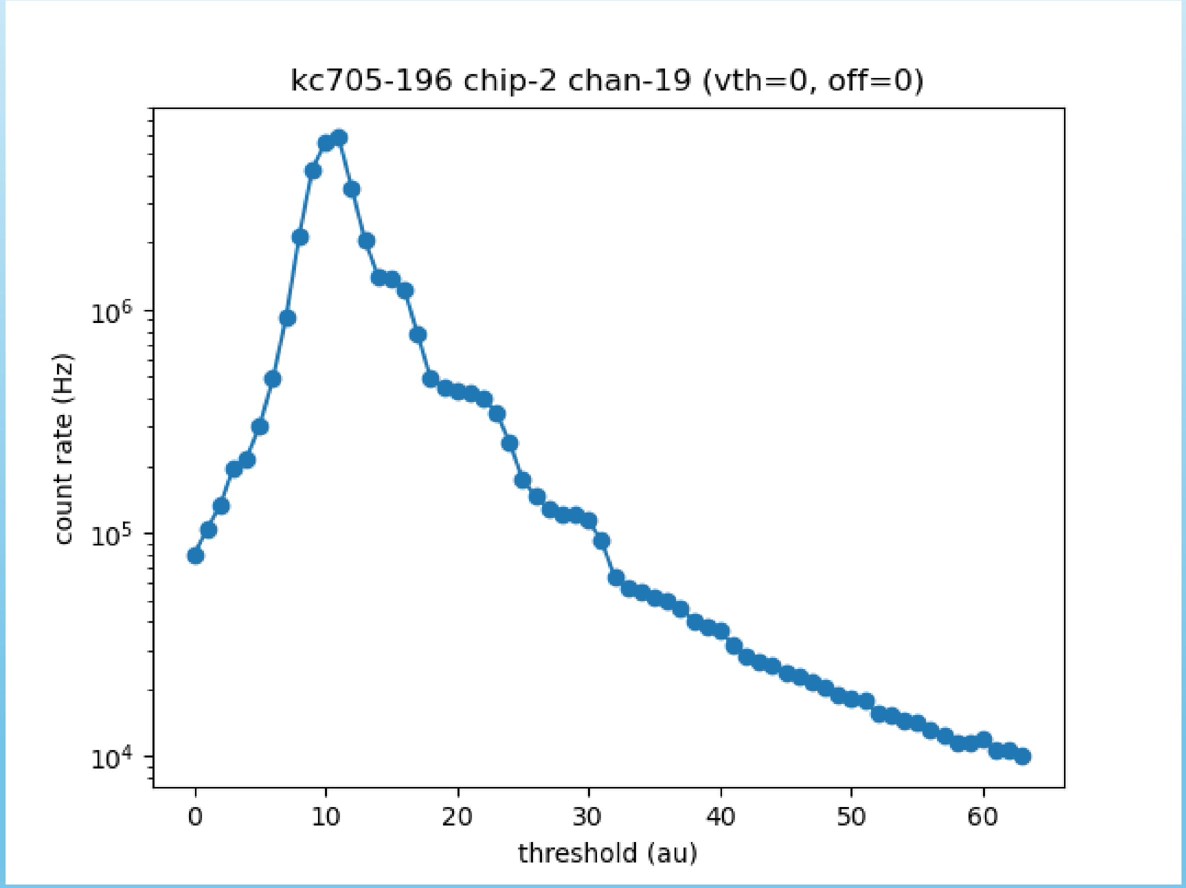


- ALCOR will also be used for reading out the dIT fibers.
- This readout chain enables testing of the SiPMs and scintillating fibers we are procuring.

The ALCOR readout – new Front End Board







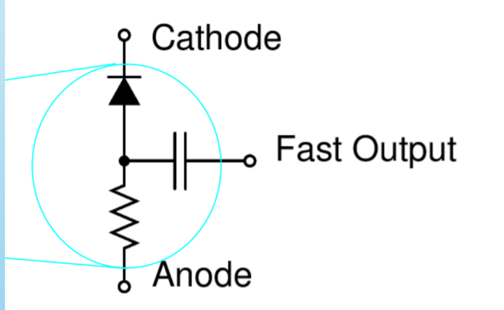
ONSEMI Fast output SiPM

We performed some preliminary test with the Onsemi fast output SiPM:

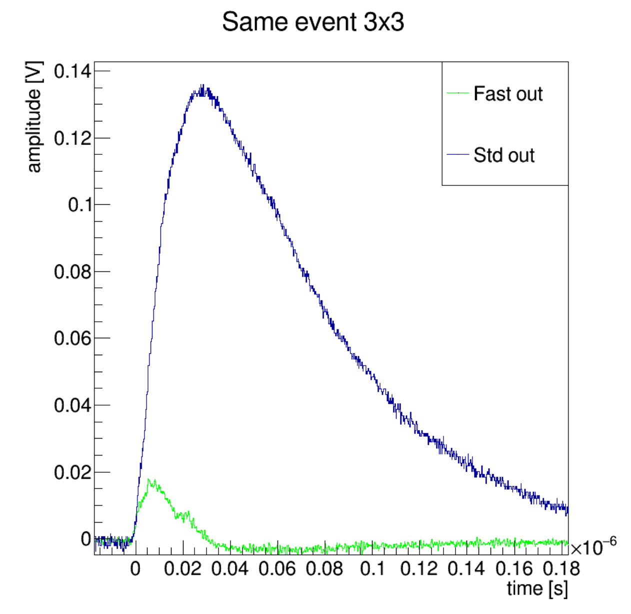
- The test setup included a plastic scintillator tile with VM2000 reflective layer and the SiPM readout;
- Sensors with 3x3 and 4x4 mm^2 active area were tested;
- Both fast and standard output were evaluated.

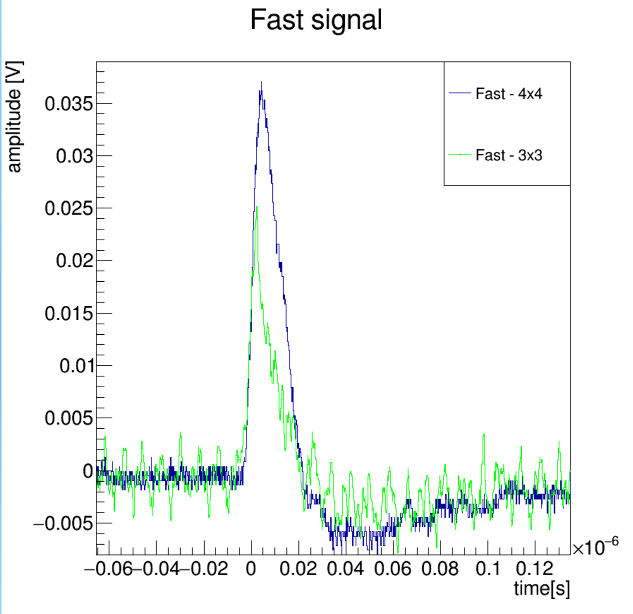
Expected performance from datasheet:

- Fast output rise time ~ 100 ps;
- Fast output pulse width (FWHM) 1.5 ns →limited by the plastic scintillator response time (~10 ns).



ON Semiconductor®





The Onsemi fast-output SiPM appears to be a promising option for improving the timing performance of our detector.

Further tests will be carried out to evaluate the Time-over-Threshold (ToT) measurement compared to the standard output signal.

Conclusions

- Simulations show that the dRICH Interaction Tagger (dIT), based on a two-layer SciFi design, is a highly efficient hodoscope.
- According to current simulations of collisions and background, the dIT provides a suppression factor sufficient to meet the minimum requirement.
- The ALCOR-based DAQ chain, together with our custom FEB, enables testing of the SciFi.
- Fast-output SiPMs from Onsemi are promising candidates for improving timing resolution, potentially down to ~100 ps.
- The dIT appears to effectively address the dRICH data throughput challenge, and its implementation is supported by the dRICH working group.
- Once SciFi tests are completed and the design is finalized, a proposal will be submitted to the ePIC Technical Coordination Office.

Thank you for you attention