# Some results from the FRICH prototype test beam at BINP

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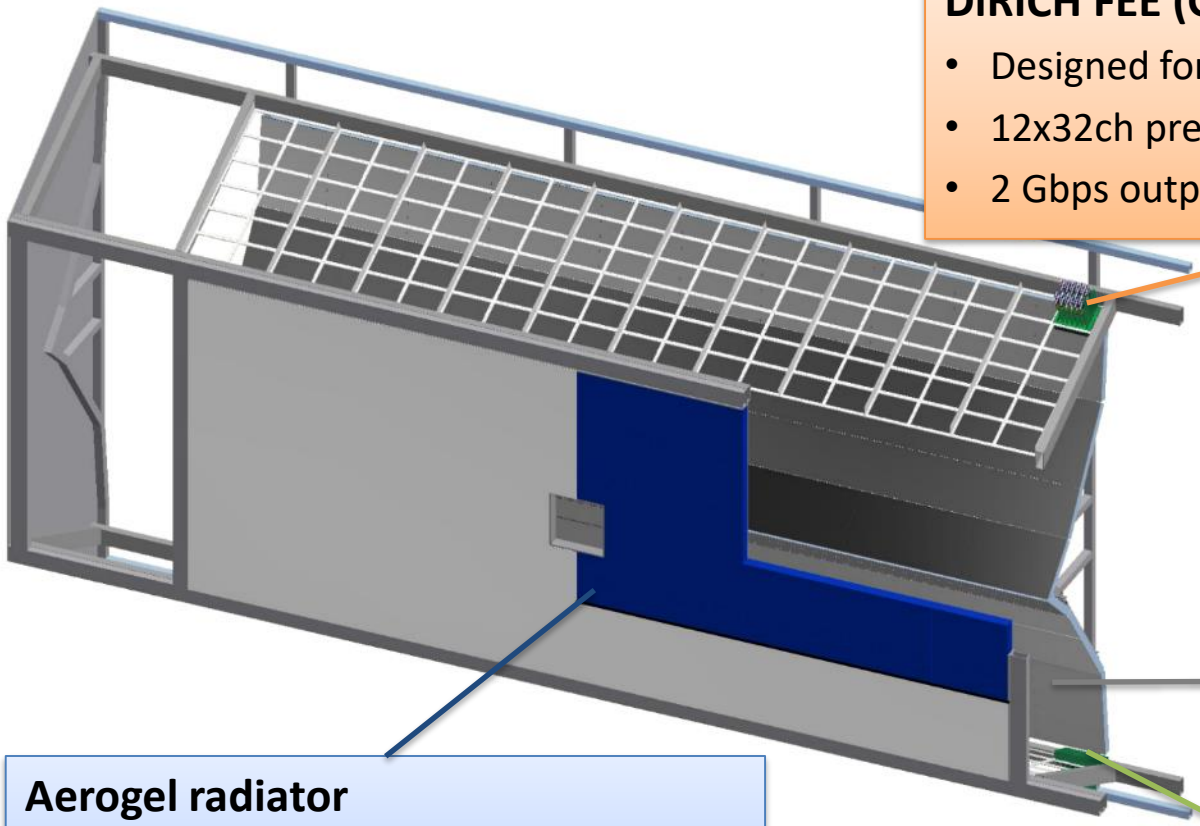
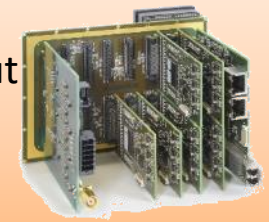
# PANDA FRICH baseline design



**DiRICH FEE (GSI)**

- Designed for H12700 readout
- 12x32ch preamp+disc+TDC
- 2 Gbps output link



**Mirrors**

- 2 mm float glass
- Al+$SiO_2$ coating

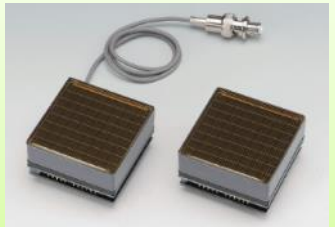
**Aerogel radiator**

- Focusing 2- or 3-layer aerogel
- n≈1.05
- Total thickness – 40 mm

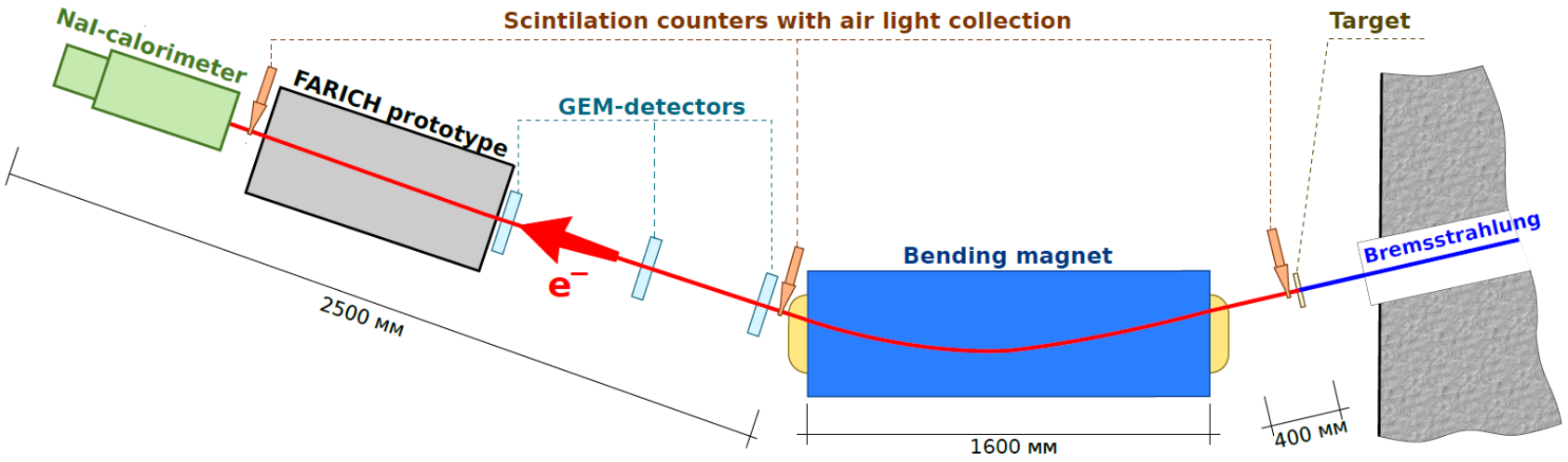
**Photon Detector**

H12700 MaPMTs (Hamamatsu)

- flat panel
- 8x8 anode pixels of 6mm size



# Test beam of F(A)RICH prototype at BINP VEPP-4 (2018)



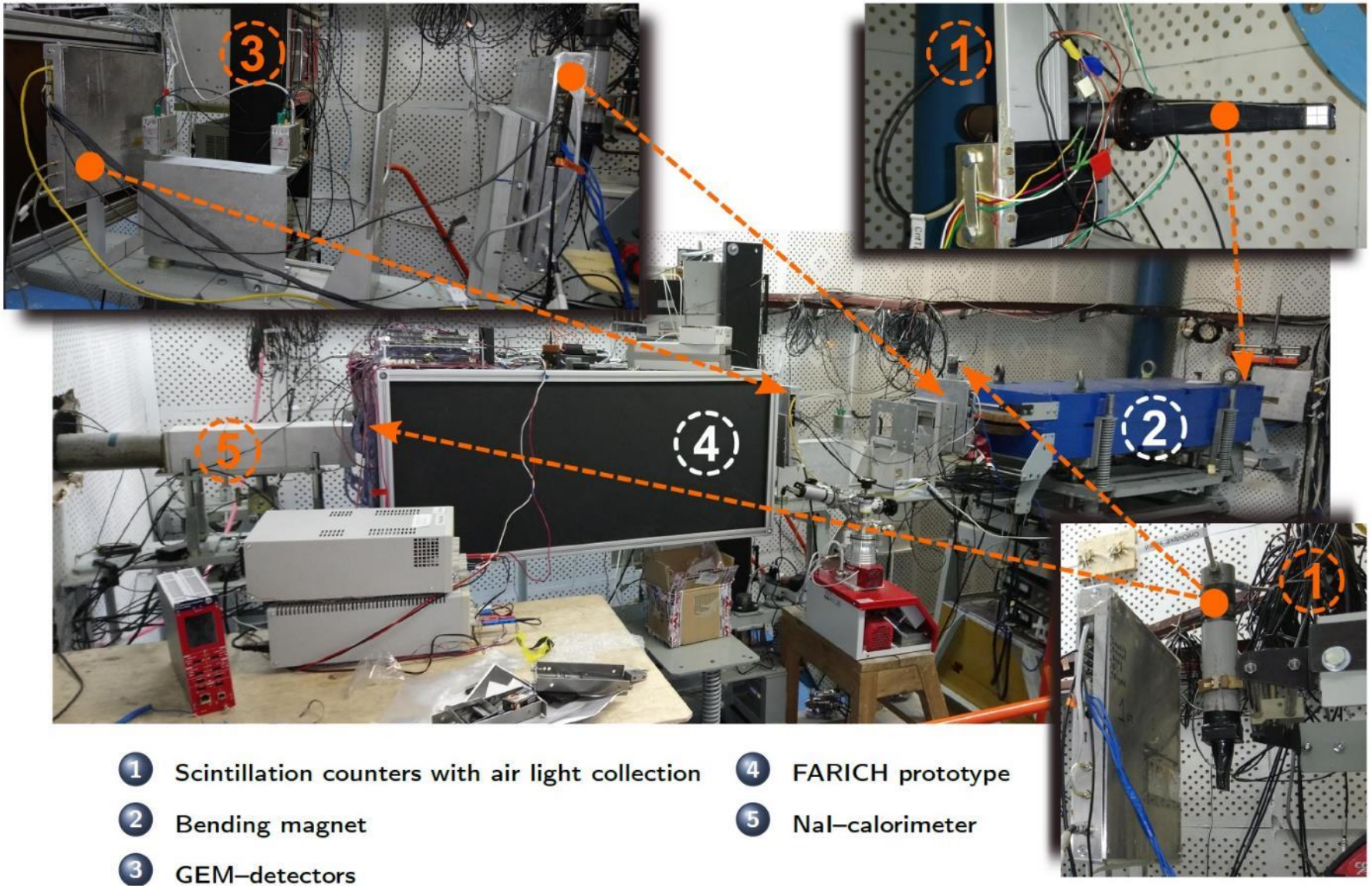

| Electron beam parameters in 2018 | |
|---|---|
| Energy range | 3 GeV |
| Averaged intensity | up to 100 $e^-$ / s |
| Energy spread | 2.6% |

Purpose of the tests beam:

- Test H12700 MaPMTs and PADIWA&TRB3 readout
- Obtain single photon resolution for several aerogel configurations and compare with expected ones

# Test beam of electrons: Infrastructure

## Example disposition of equipment in experimental hall (15/03/2018)

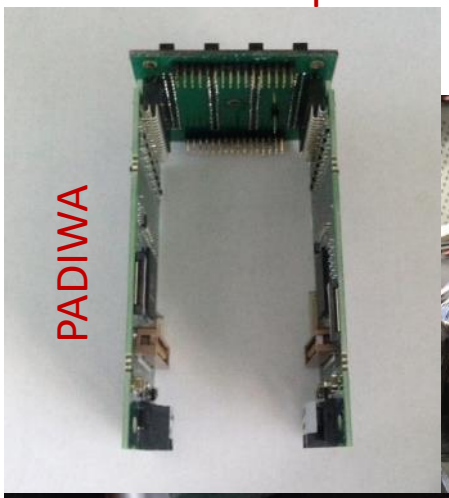



1. Scintillation counters with air light collection
2. Bending magnet
3. GEM–detectors
4. FARICH prototype
5. NaI–calorimeter

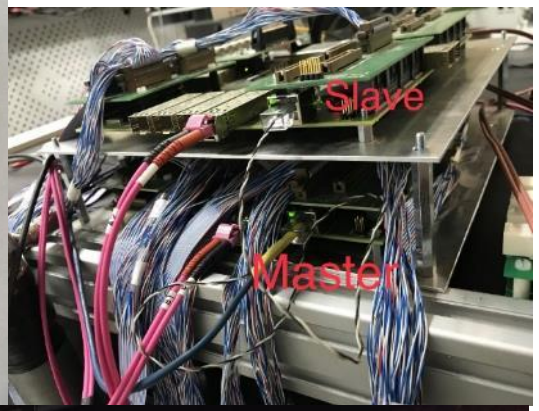
# F(A)RICH prototype readout

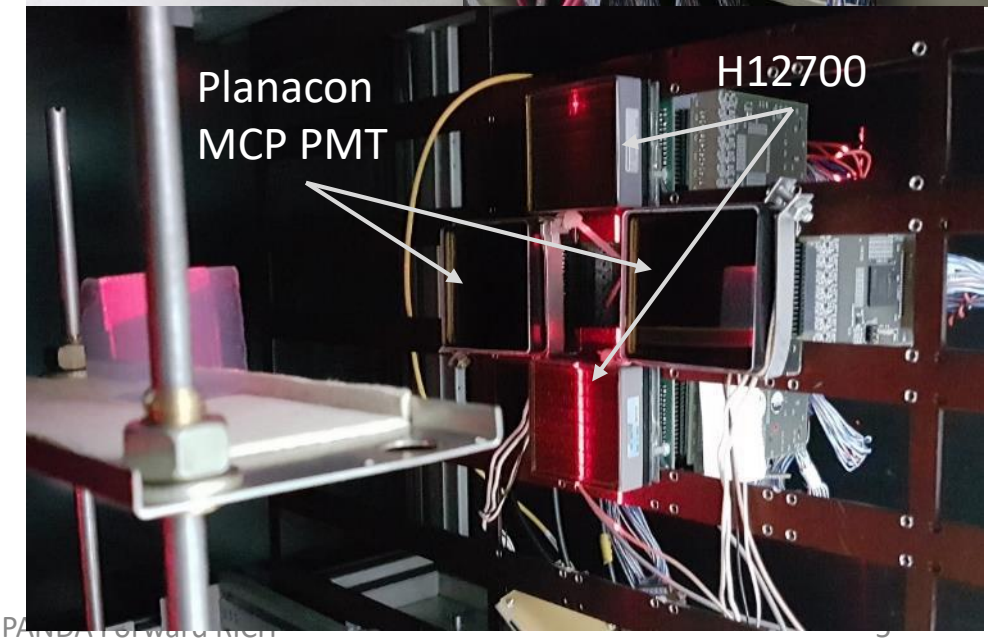
- Custom adapter board to couple 4 PADIWAs to a H12700 MaPMT (PADIWA couple with Planacon MCP PMT without adapter)
- 2 TRB3 boards and 14 PADIWA3 boards – 224 channels (cover 3.5 64-anode PMTs)
- Each TRB board transmits data via Gbit-ethernet switch to a PC
- GSI DABC software used for DAQ from TRB
- Triggered by coincidence of signals from the sc. counter before F(A)RICH and the NaI calorimeter
- Trigger signal is blocked by PC for readout period. Sync between subsystems is assured by the same event number observed

Custom adapter

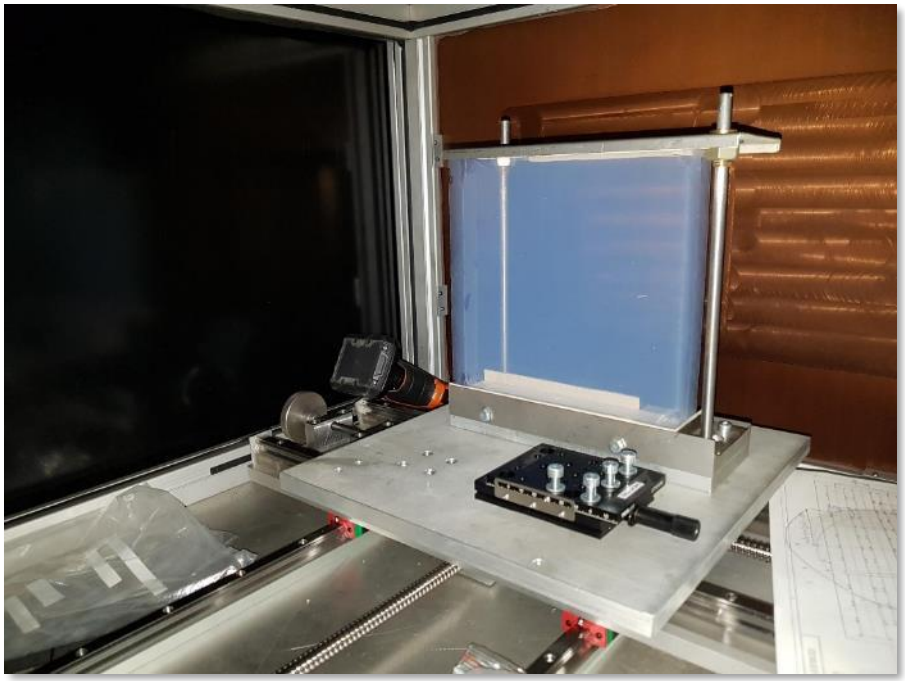


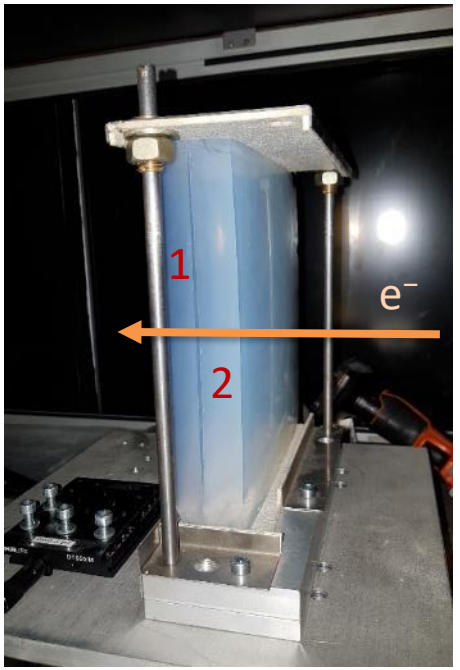

TRB3 boards



# Tested aerogel radiator samples (test beam run on 3-4 June 2018)






Configuration 1
$n_1$ = 1.0514, $t_1$ = 2 cm
$n_2$ = 1.0503, $t_2$ = 2 cm

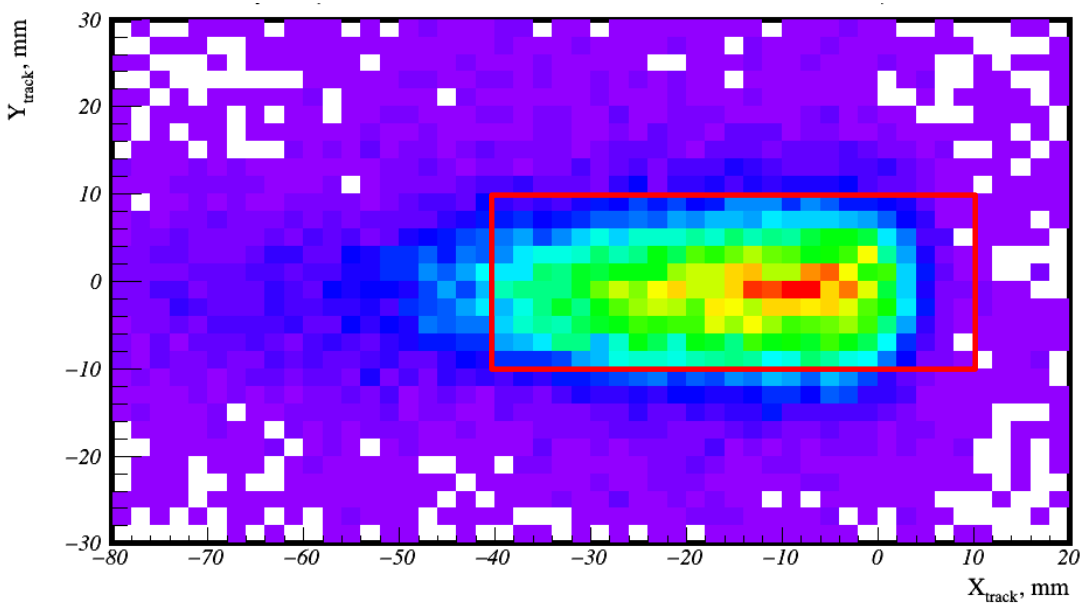
Configuration 2
$n_1$ = 1.0514, $t_1$ = 2 cm
$n_2$ = 1.0514, $t_2$ = 2 cm

Monolithic aerogels:
3 three-layer samples of
30-40 mm thickness

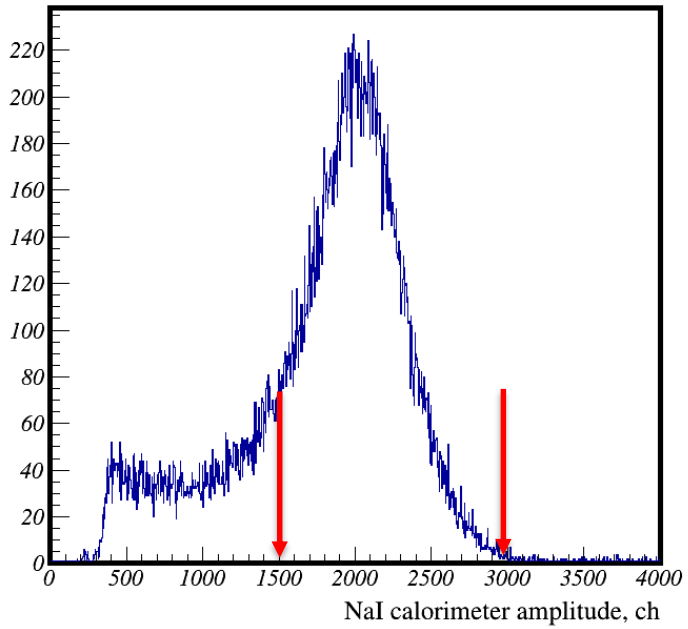
About 300k event per setup configuration were collected

# Event selection

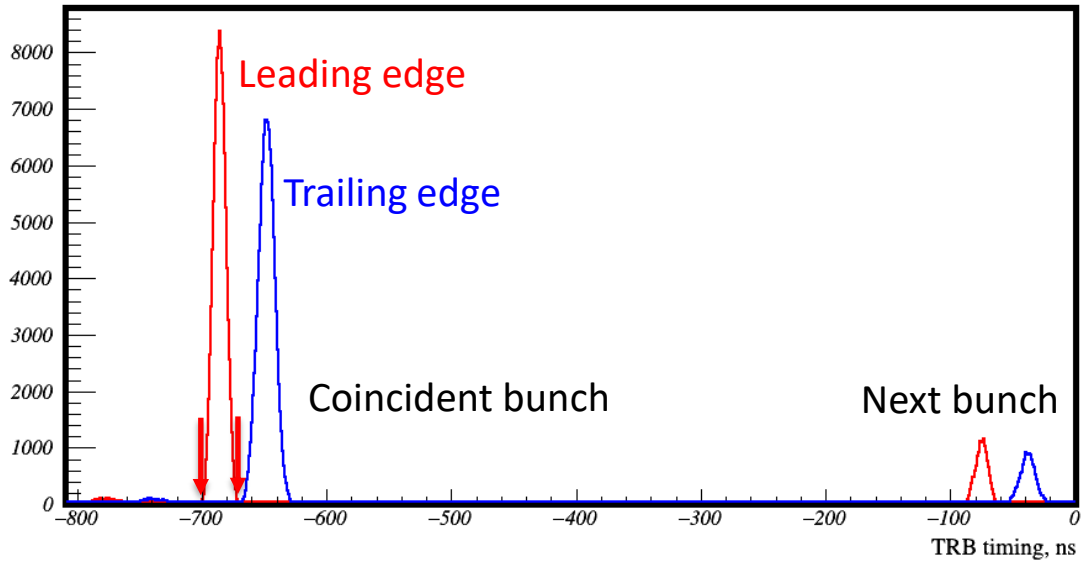
Reconstructed track position XY-map at PMT and cut region

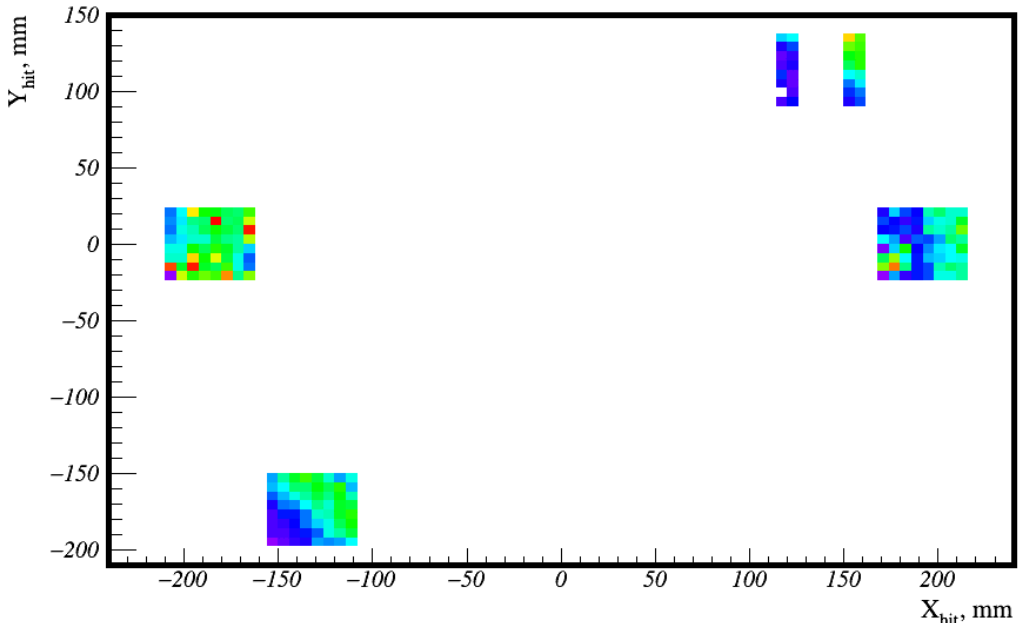



NaI calorimeter amplitude distribution and cut interval



# Hit plots




**Hit timing distribution**

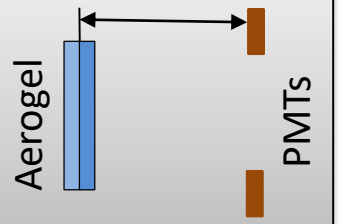
- VEPP-4M bunch structure can be seen with 600 ns separation.
- Timing resolution here is determined by the rough measurement of reference timing in TRB3
- Hits are selected by leading edge timing in 30ns interval

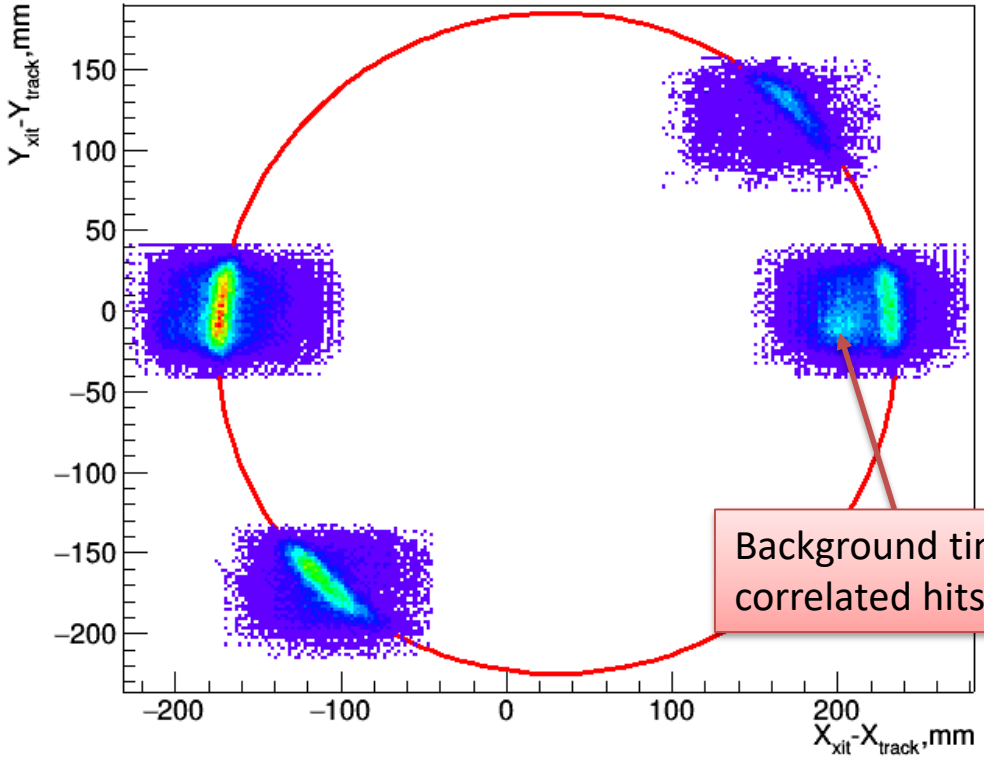
**Hit XY map**

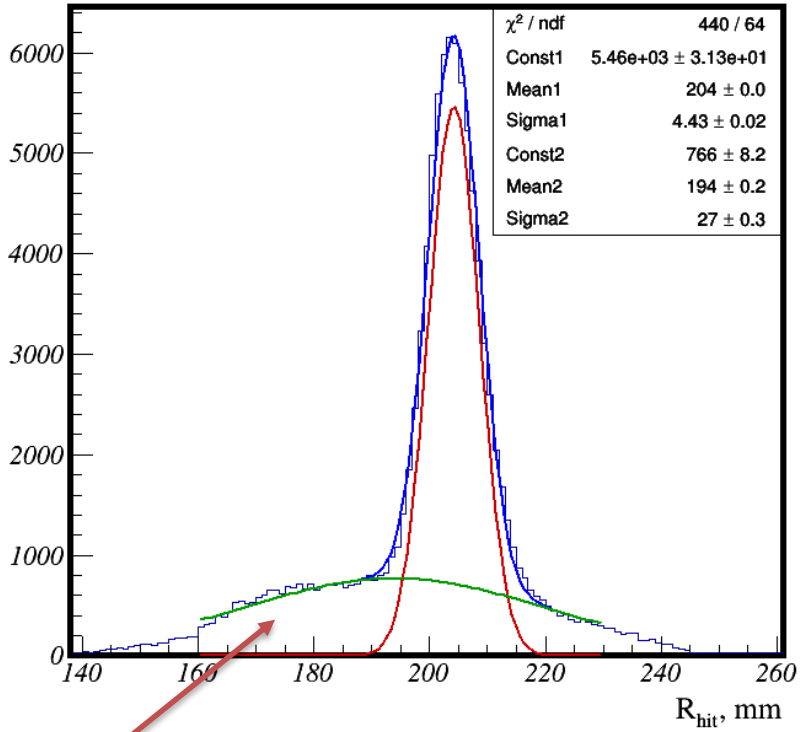
The ring is not seen here because the $e^-$ beam is too wide

# Cherenkov rings

**Run: 03 June 2018**
PD: 4 MaPMTs
Aerogel: Configuration 1
Aerogel-PMT distance: 600 mm



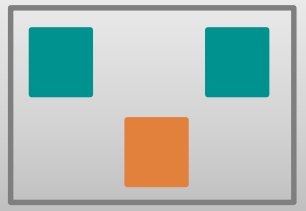

Background time-correlated hits

**Preliminary results:**
R = 204 mm
$\sigma_{R1}$ = 4.4 mm (6.6 mrad)

# Cherenkov rings with Planacon MCP PMTs

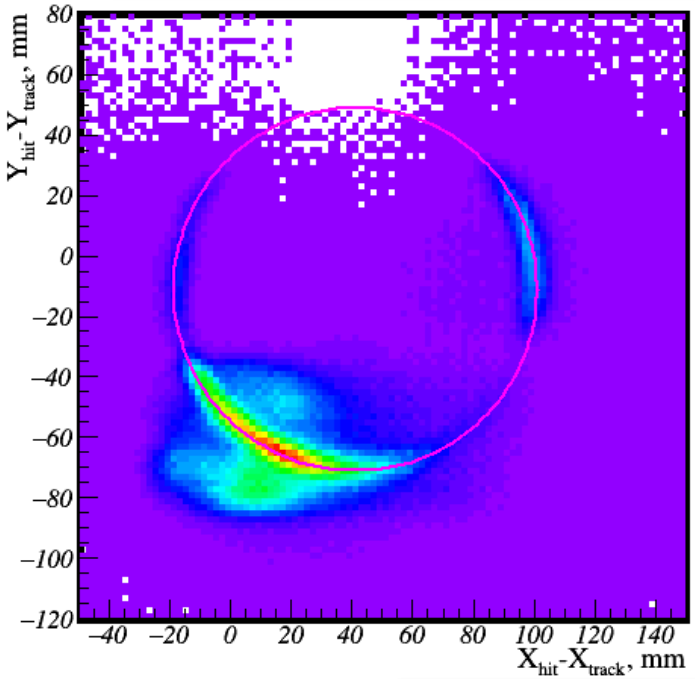
## short focusing distance of FARICH for SCTF

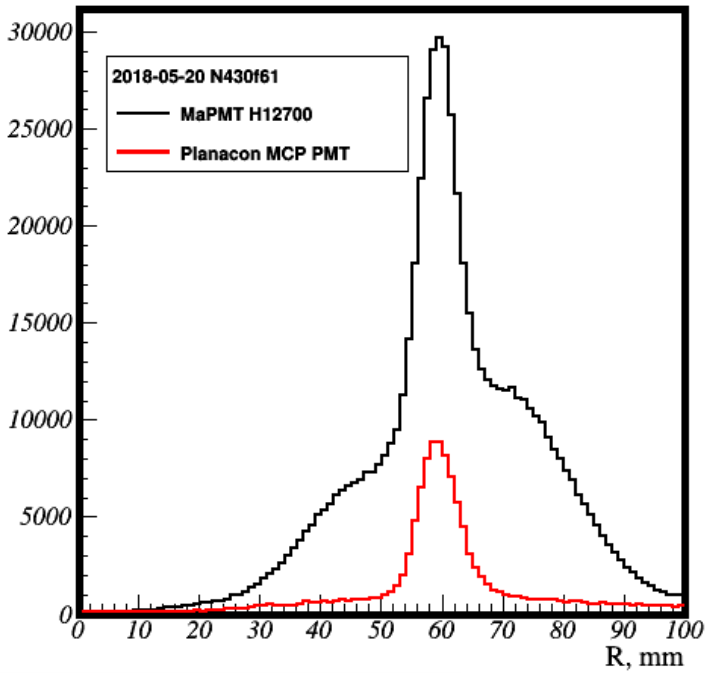
**Run: 20 May 2018**
PD: 2 Planacons, 1 MaPMT
4-layer aerogel
Aerogel-PMT distance: 200 mm



—Planacon MCP PMT

—H12700 MaPMT



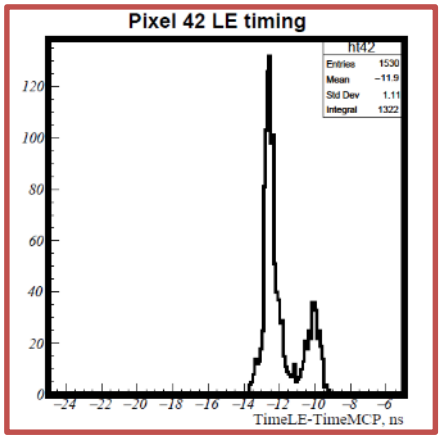



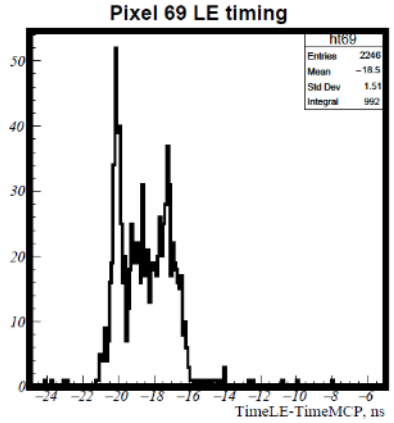

NB: Low background & lower PDE with Planacons

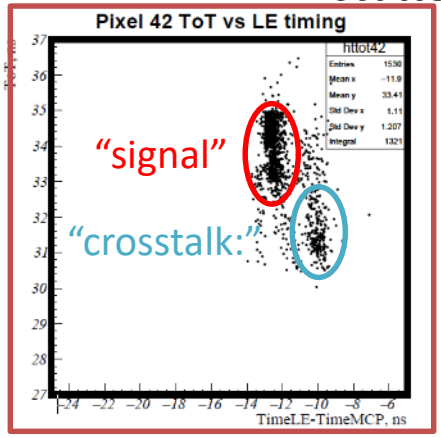
# Time + ToT plots for MaPMTs
# 3 June 2018

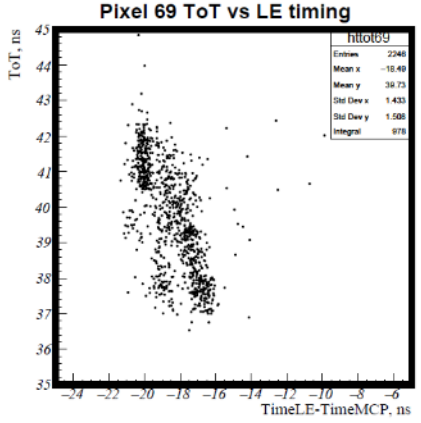
Leading edge timing distributions for 4 random anodes of different MaPMTs

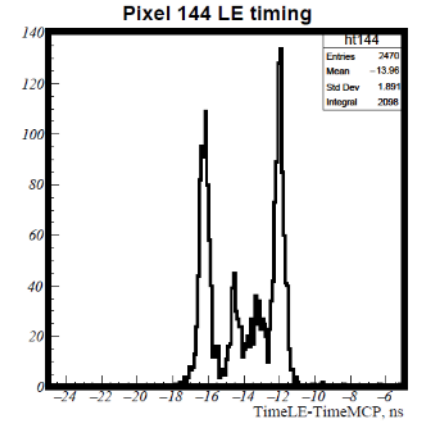
Corresponding timing vs ToT scatter plots

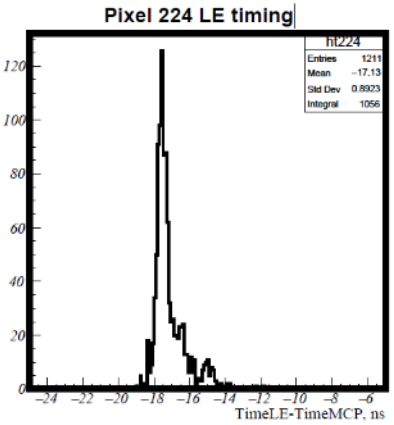


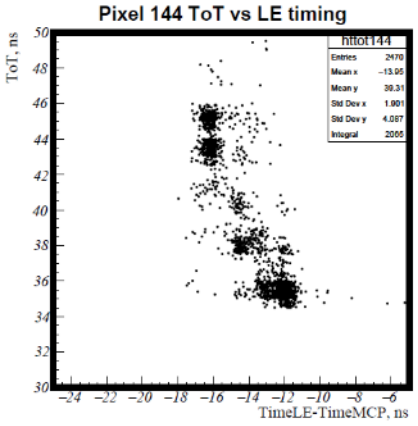



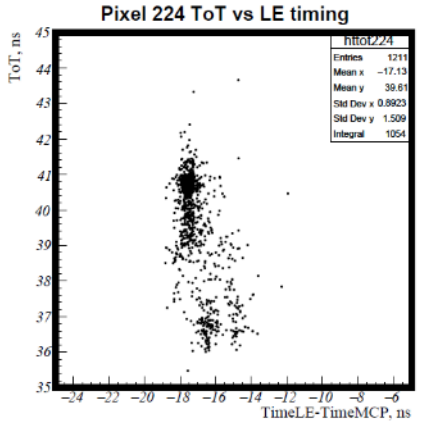



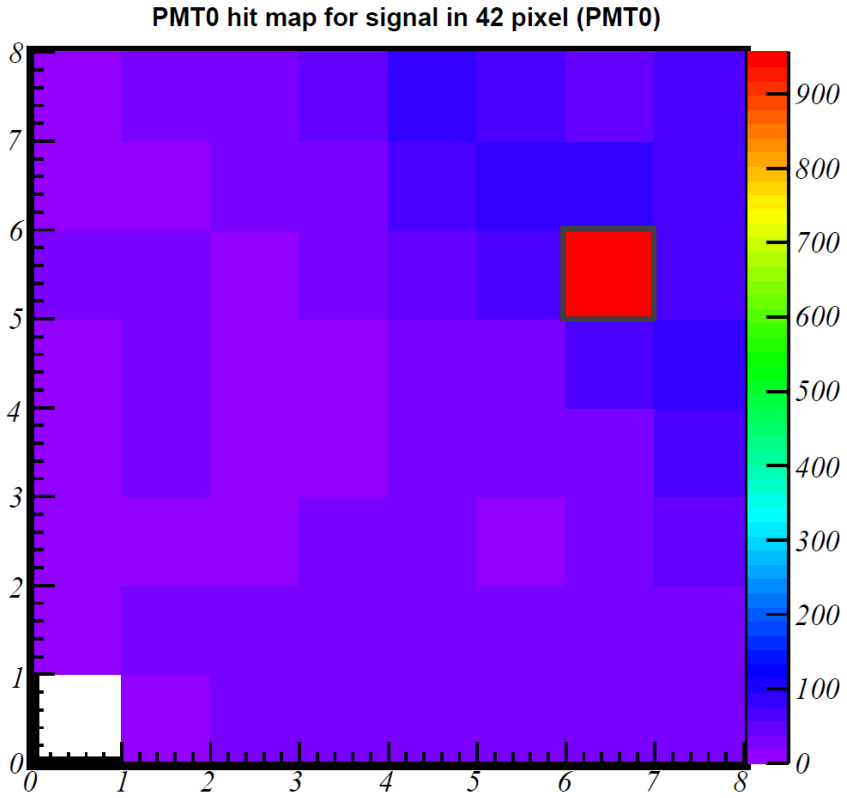



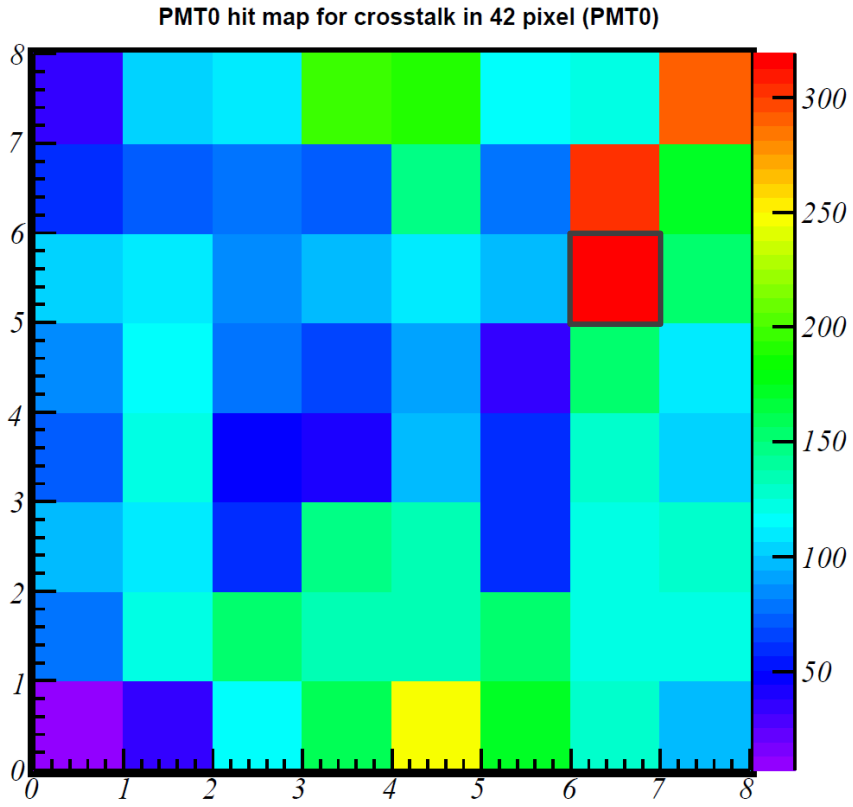

NB: 2-4 ns separation between peaks. Earlier one has largest ToT (amplitude). Looks like crosstalks between anodes or common crosstalk.

# Signal and crosstalks hit patterns

Events with signal hits in anode 42

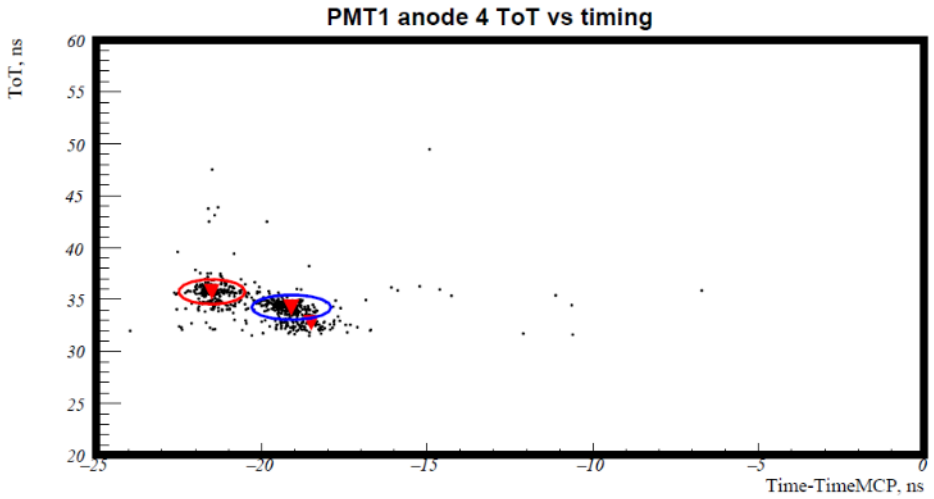


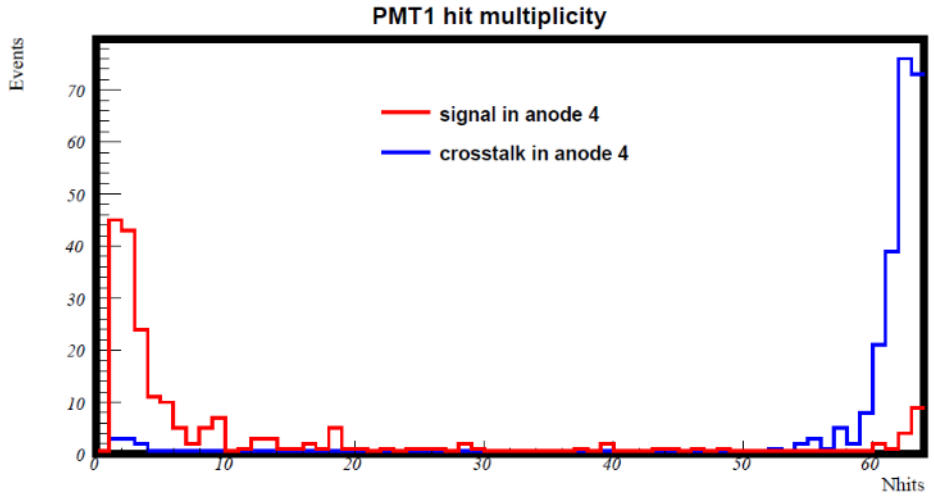

Events with crosstalk hits in anode 42




NB: No typical pattern of neighboring anodes

# Hit multiplicity for signal and CT

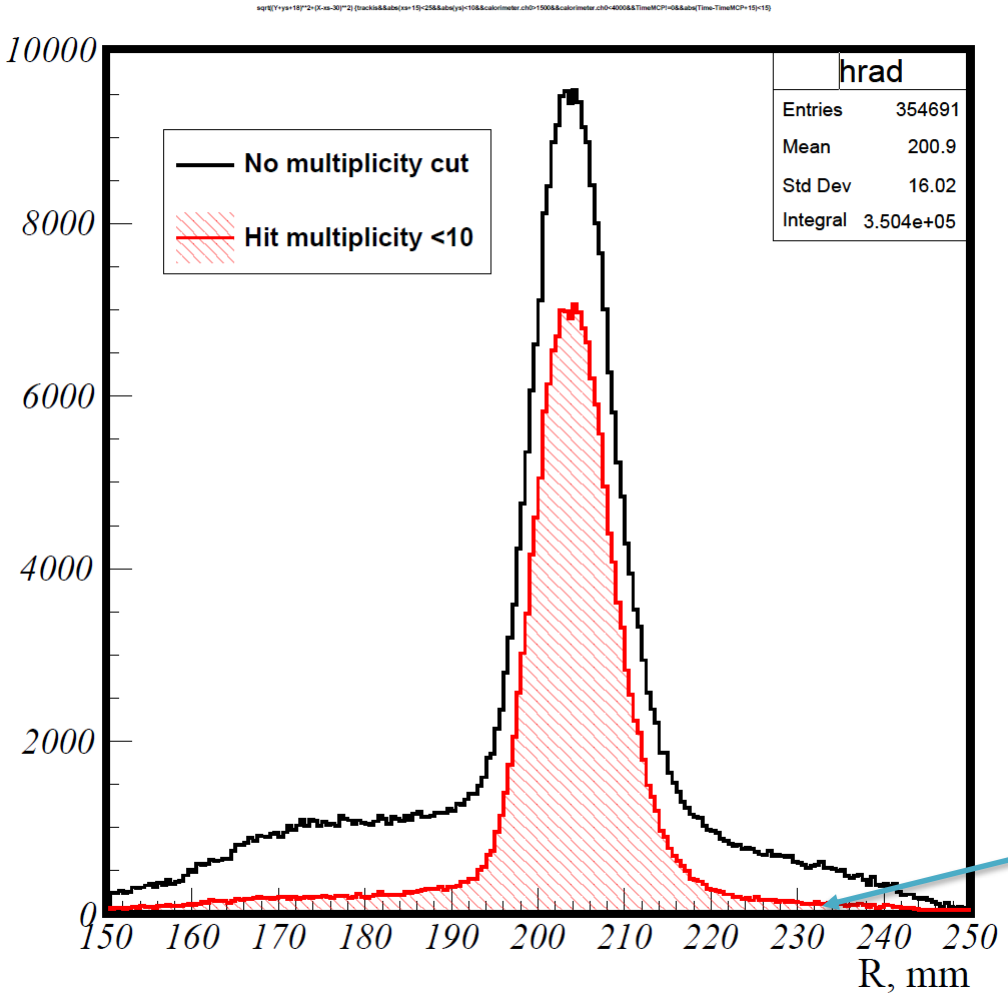



- Signal and CT hits are determined by ROOT::TSpectrum2 class.
- Cut regions – ellipses.

NB: Almost all nodes of the MaPMT fire when we observe crosstalk in one anode.

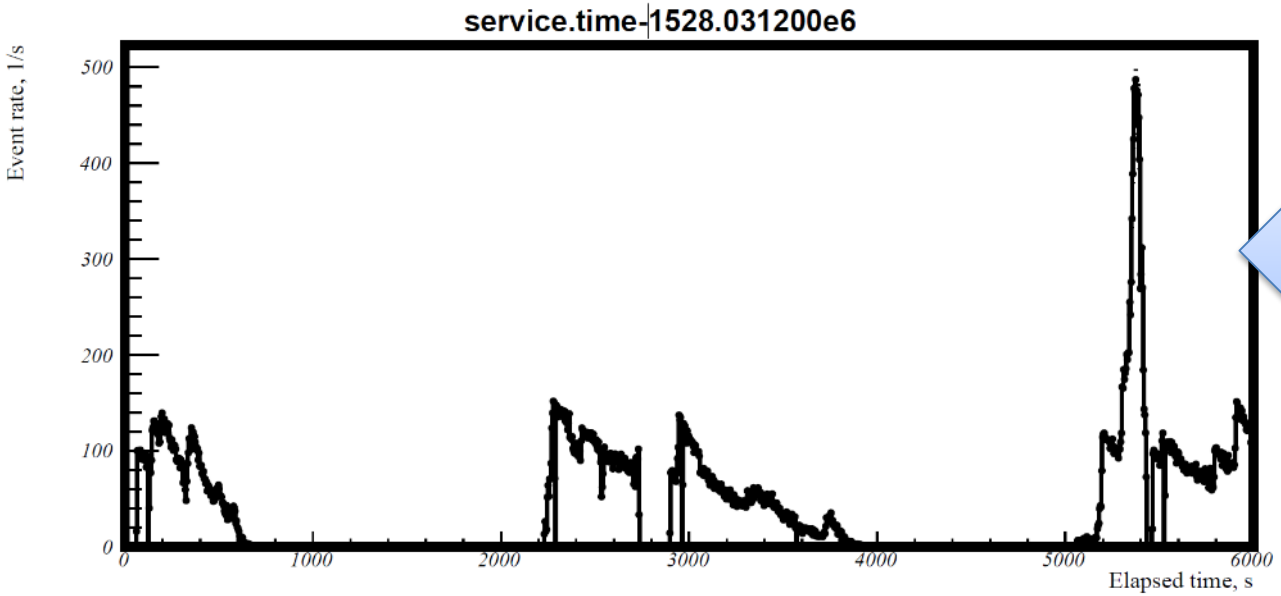
# Hit radius distribution with multiplicity cut



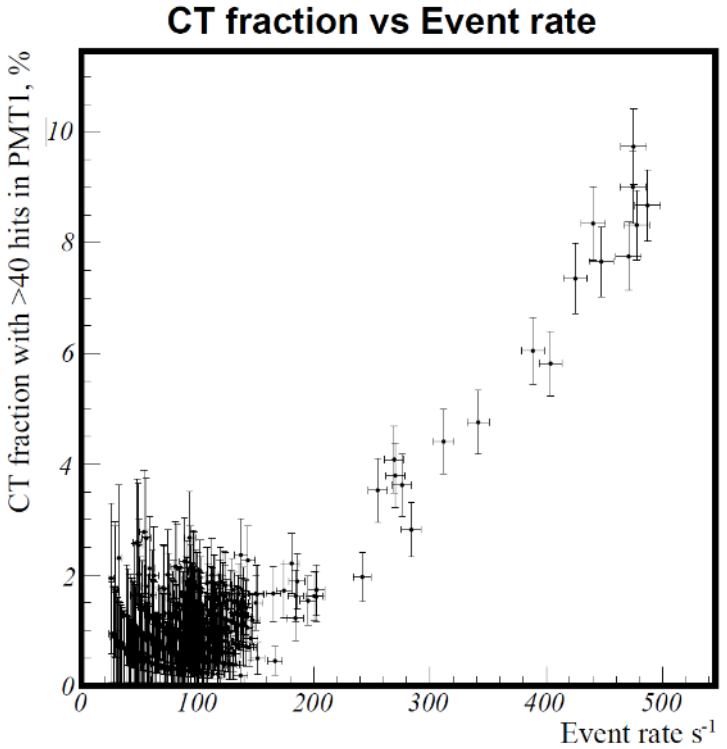

Apply per-event cut for number hits in 30-ns window

**5x S/B increase**

NB: still non-negligible background remains




Run 3 June 2018.
Event rate during 2 hours
measured in 4 sec intervals




Fraction of events with CT in PMT1
as function of event rate

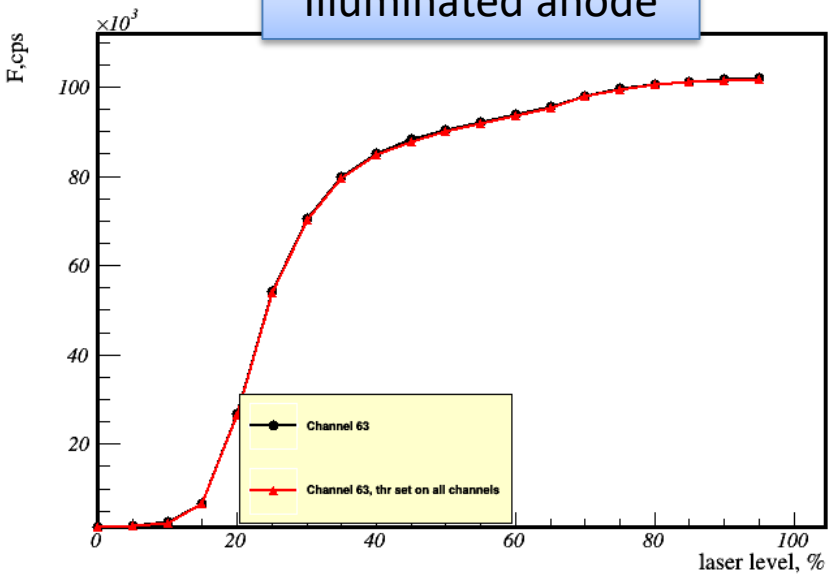
NB: For 20-cm ring radius setups we should avoid event rates higher than 200 $s^{-1}$.

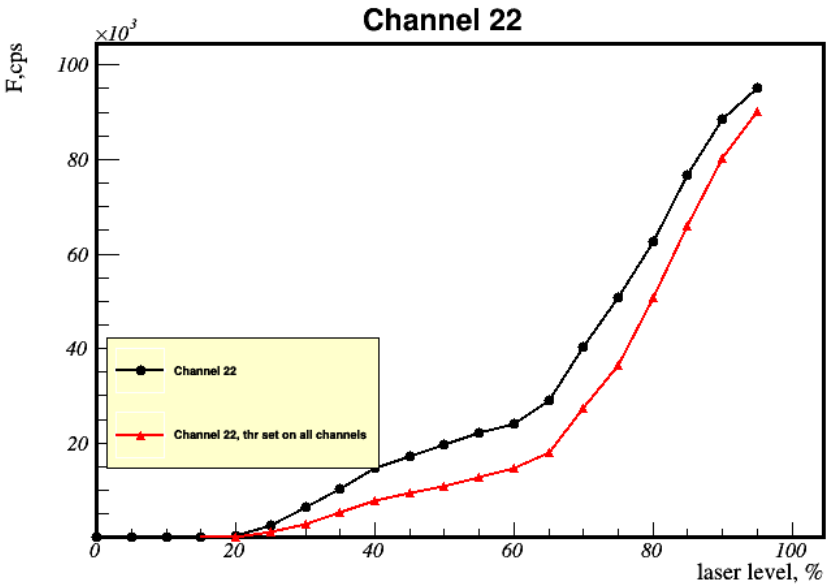
# Speculations on the nature of crosstalk

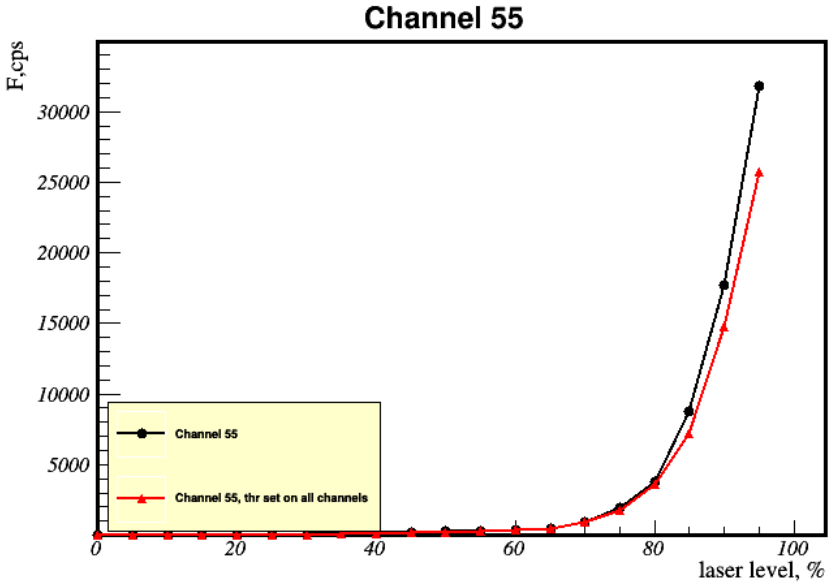
- Studies with pulsed laser illumination show that single photon signals can not cause CT to exceed standard calibrated PADIWA thresholds. It should be many photon signals.
- A relativistic particle produces about 20 Cherenkov photoelectrons in 1.5 mm window of MaPMT.
- BINP electron test beam is not essentially collimated and originates from 5-cm bunches in the VEPP-4M accelarator.
- Electrons and positrons scattered far from the beam may be a cause of the large signals in MaPMT and CT on all anodes.
- Probably origin: parasitic capacitive coupling between the last dynode and anodes.
- This effect should be event rate dependent for bunched beam.
- More studies with laser illumination and particle sources with aim to suppress the crosstalk w.r.t. signal. Options: RF-filters, HV divider redesign, even another PMT.
- May be an issue in PANDA. Study of effect with MC is needed.

# Pulsed laser illumination: intensity scan

Illuminated anode



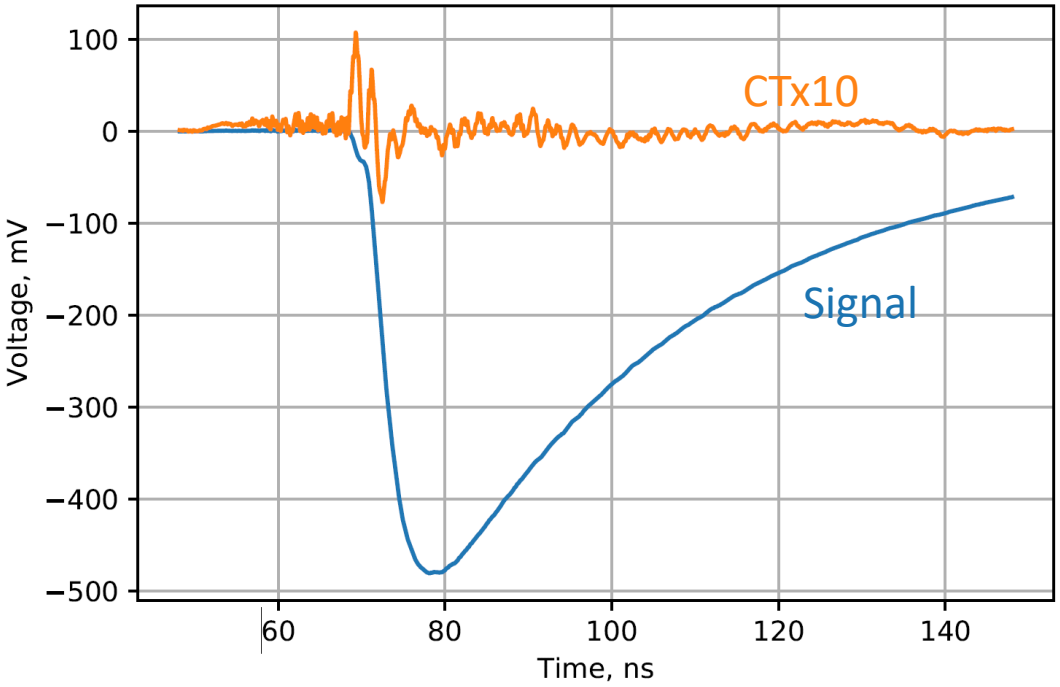




During illumination intensity scans there were problems with HV power source interference and external light leaks.

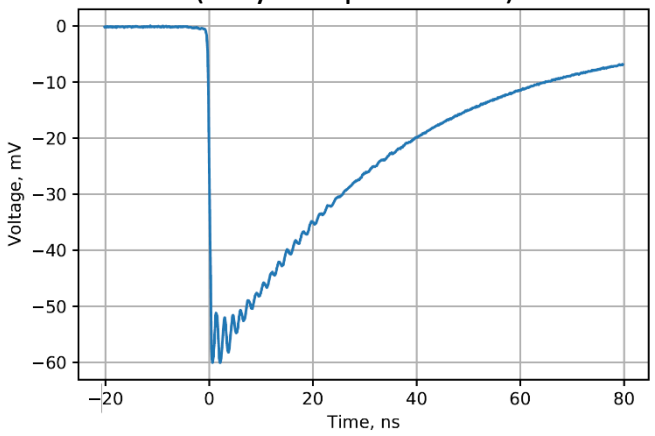
# Signal and crosstalk averaged waveforms

Pulsed illumination from a laser




- Light source: PiLas PiL051x, 510nm, Δt<140 ps
- Oscilloscope: Keysight MSOX6004A, 6 GHz BW with differential active probe N2752A, 6 GHz BW
- Signal viewed directly on illuminated anode, CT viewed on a distant anode
- All anodes connected to PADIWA

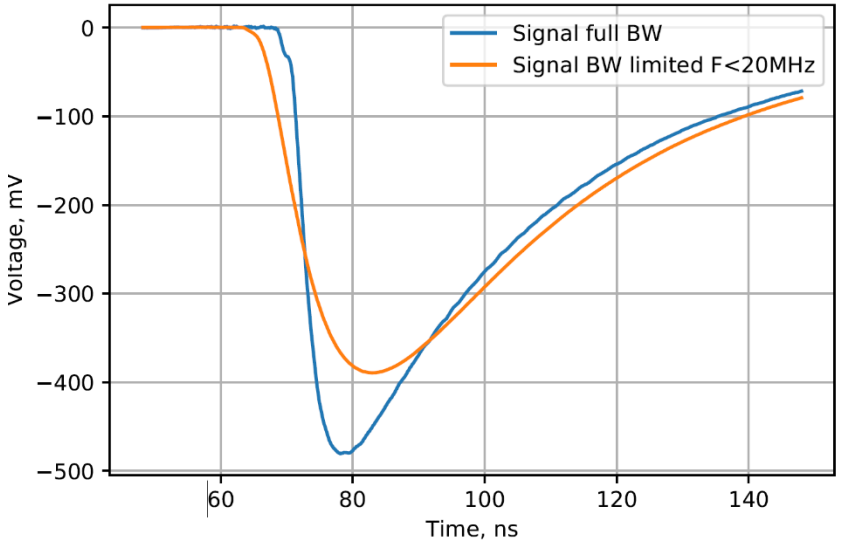
Single photon pulse
(very sharp rise time)



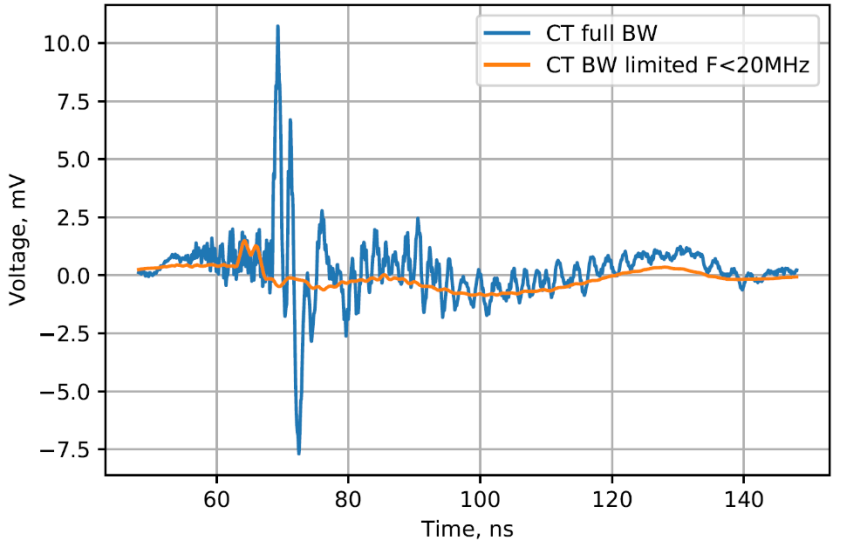

- Signal amplitude is ~9 p.e.
- CT amplitude is about 2% of signal
- CT negative swing is delayed by a few ns w.r.t. signal at the same voltage level.

# Bandwidth filtering by oscilloscope

**Signal**




**Crosstalk**




Filtering helps to suppress CT but at the cost of increasing signal rise time and worse timing resolution (not measured but should be at worst proportional to rise time). Still viable option to explore in case of a high intensity particle background in PANDA (should be simulated).

# Conclusion and outlook

- First test beam with a dedicated FRICH prototype was carried out on 3-4 June 2018. 5 different aerogel radiators are tested. Analysis is in progress.
- Gained experience with TRB3 & PADIWA electronics but more to learn with DiRICH FEE.
- High hit multiplicity events were observed that clutter the ring pattern. Origin is believed to be coincidences with beam particles hitting MaPMT directly. May be a problem for high intensity mode in the real experiment. Should be studied with MC.
- DiRICH is expected to be delivered in a week or so. Original plans were to buy it in May but better than nothing.