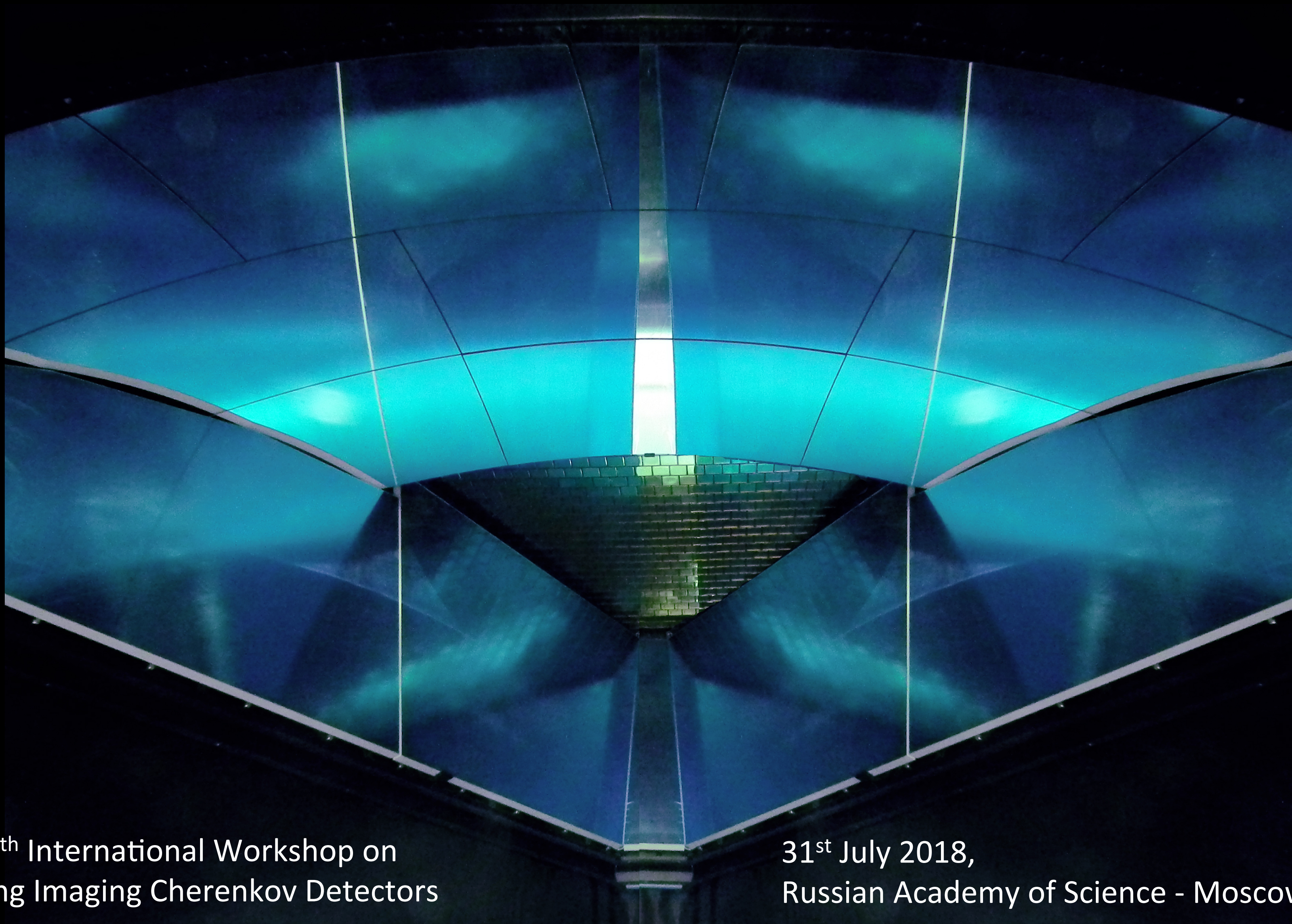
Single Photon Detection with the Multi-anode CLAS12 RICH Detector

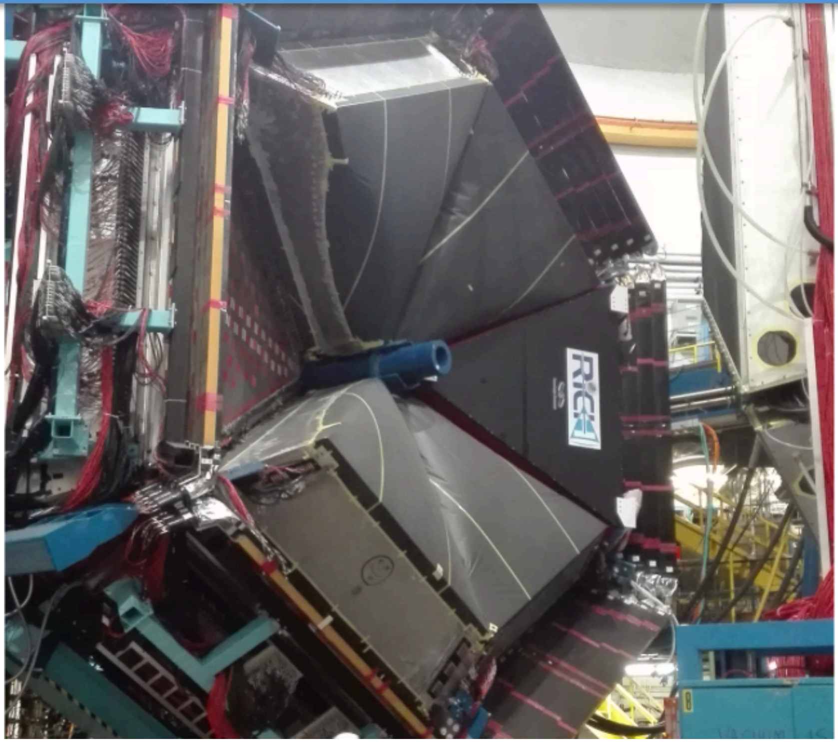
M. Contalbrigo – INFN Ferrara – on behalf of the CLAS12 RICH group



10th International Workshop on
Ring Imaging Cherenkov Detectors

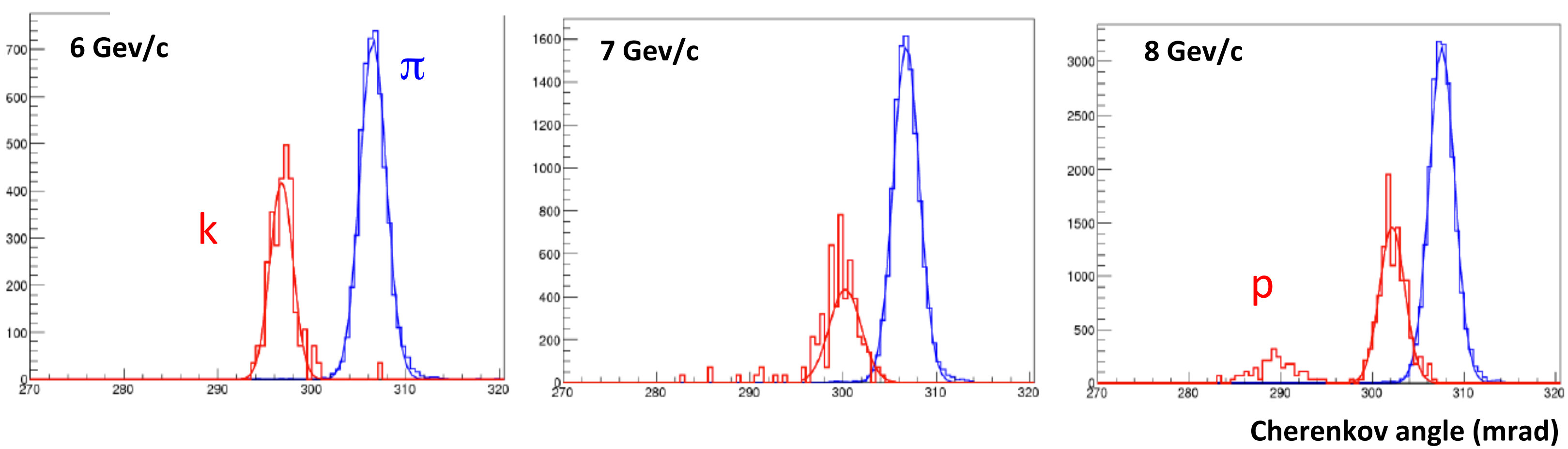
31st July 2018,
Russian Academy of Science - Moscow

CLAS12 RICH



INSTITUTIONS
INFN (Italy)   Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Jefferson Lab (Newport News, USA)
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
George Washington University (USA)
Glasgow University (Glasgow, UK)
Kyungpook National University, (Daegu, Korea)
University of Connecticut (Storrs, USA)
UTFSM (Valparaiso, Chile)

Goal kaon-pion separation up to 8 GeV/c (prototype results):

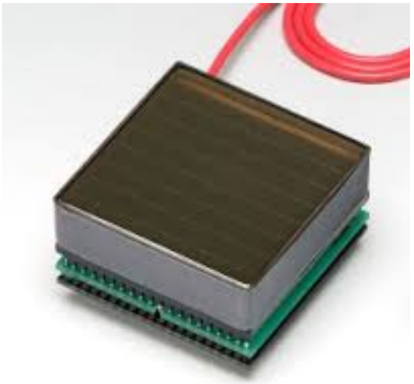


Photon Sensor: MA-PMT

MA-PMT

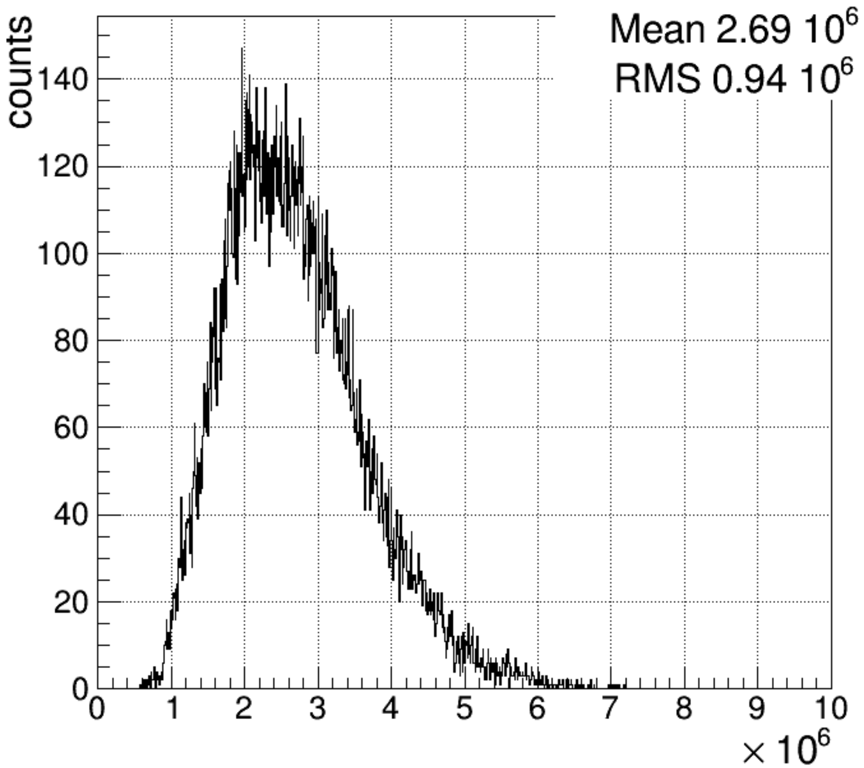
< 1 cm spatial resolution
< 1 ns time resolution
Compatible with the low torus fringe field

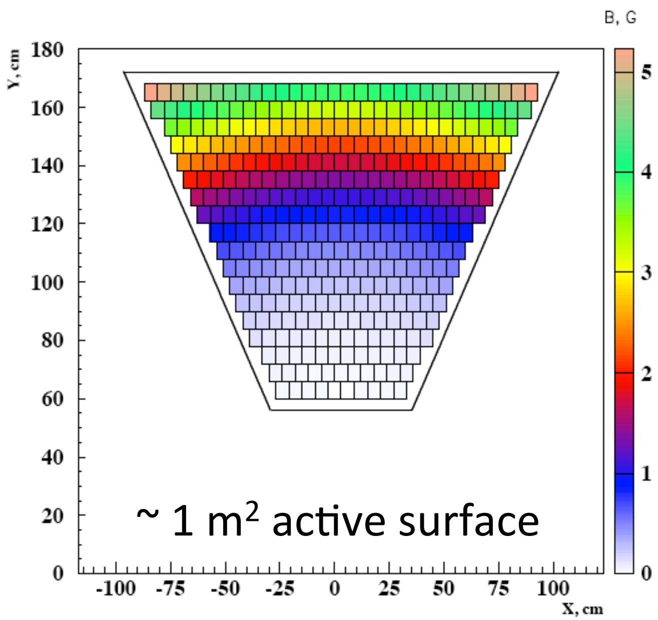
Average MA-PMT gain ~ 2.7 10^6
Corresponds to SPE ~ 400 fC



- ✓ 64 6x6 mm^2 pixels cost effective device
- ✓ High sensitivity on VIS towards UV light
- ✓ Mature and reliable technology
- ✓ Large Area (5x5 cm^2)
- ✓ High packing density (89 %)
- ✓ Fast response

- ✓ Expensive technology

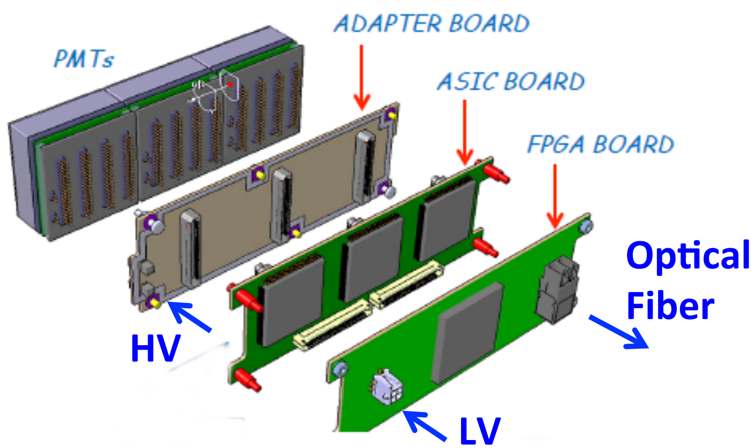


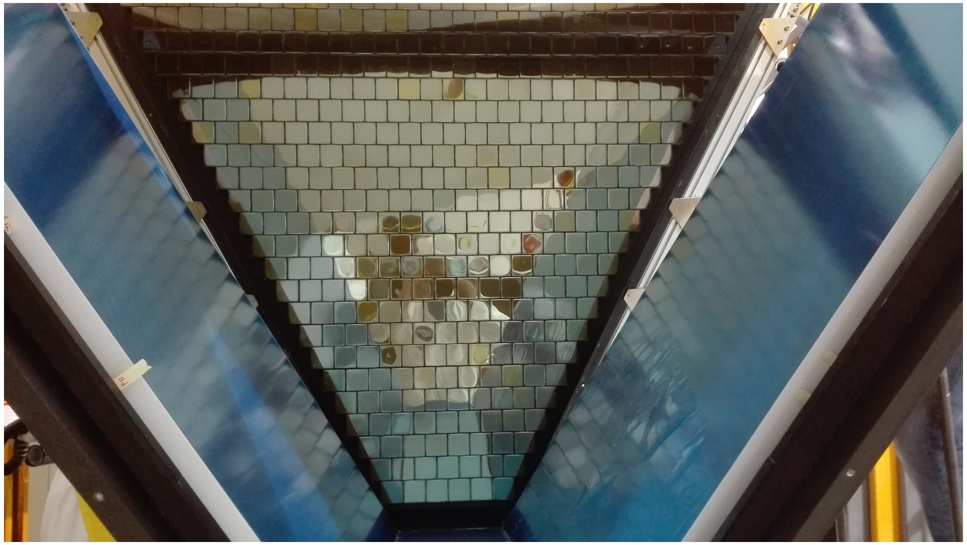


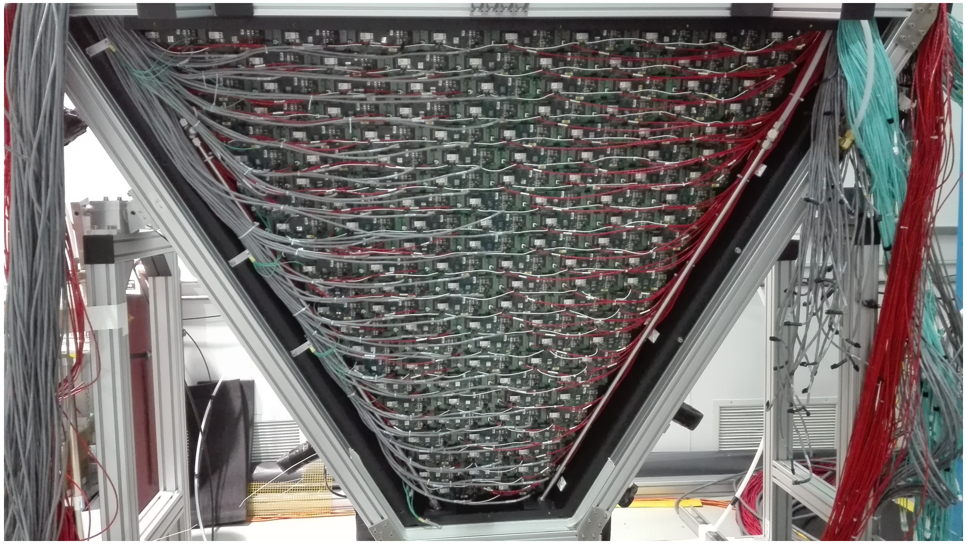
RICH Readout Electronics

Readout Electronics

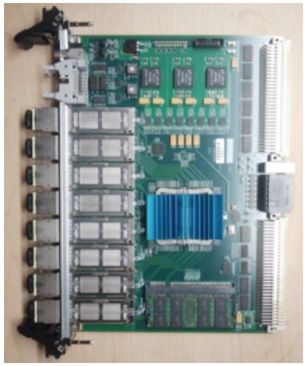
Compact (matches sensor area)
Modular Front-End (Mechanical adapter, ASIC, FPGA)
Scalable fiber optic DAQ (TCP/IP or SSP)
Tessellated (common HV, LV and optical fiber)



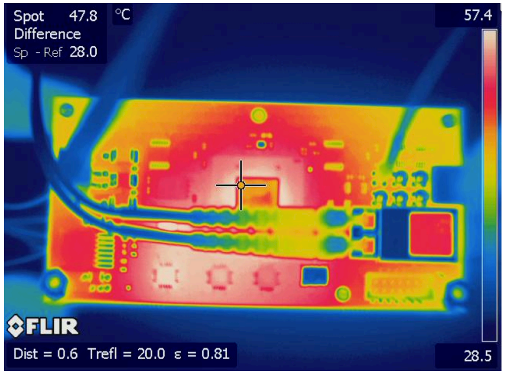




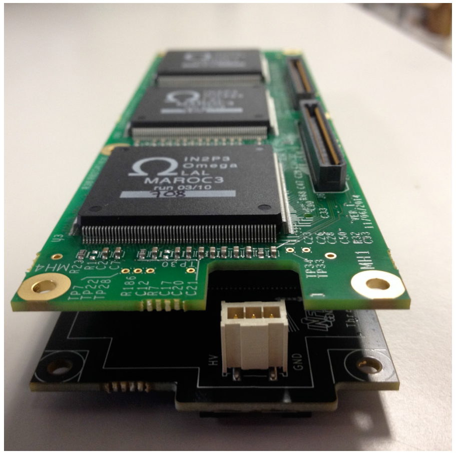
SSP Fiber-Optic DAQ

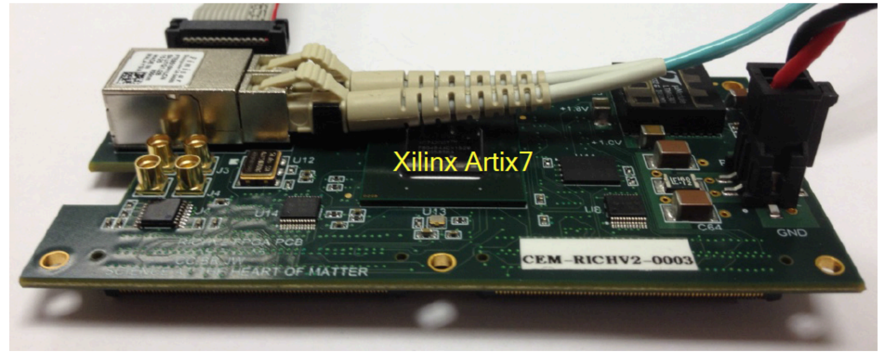


Tile power dissipation ~ 3.5 W



RICH Front-End Electronics





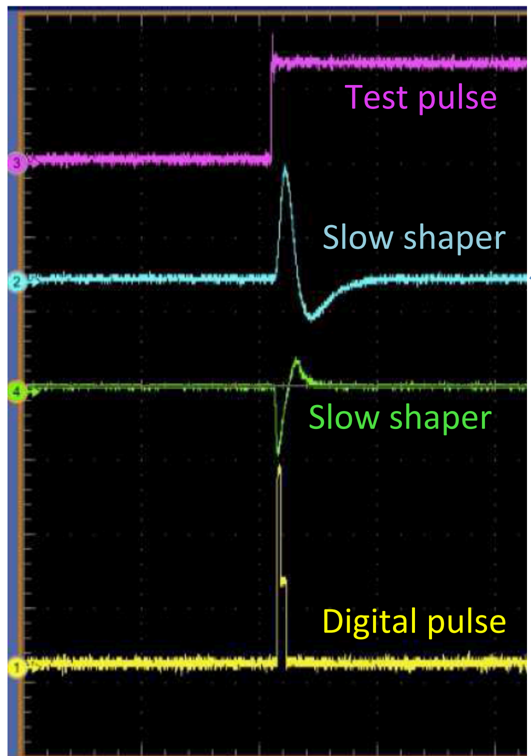
Analog: Charge (1 fC)
Digital: Time (1 ns)

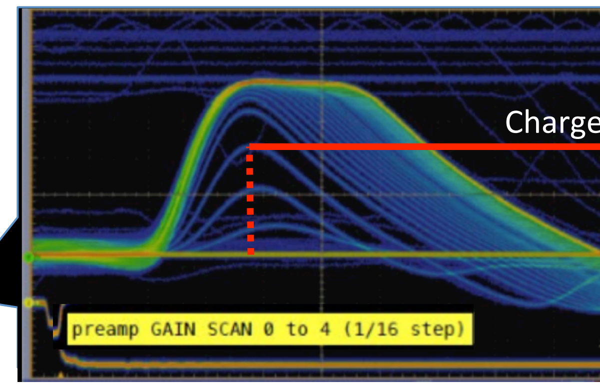
Trigger latency (8 μs)

Optical ethernet (2.5 Gbps)

Trigger: external
internal
self

On-board pulser





Linear response

Multiplexed readout
Limited holding time delays

Used for calibrations

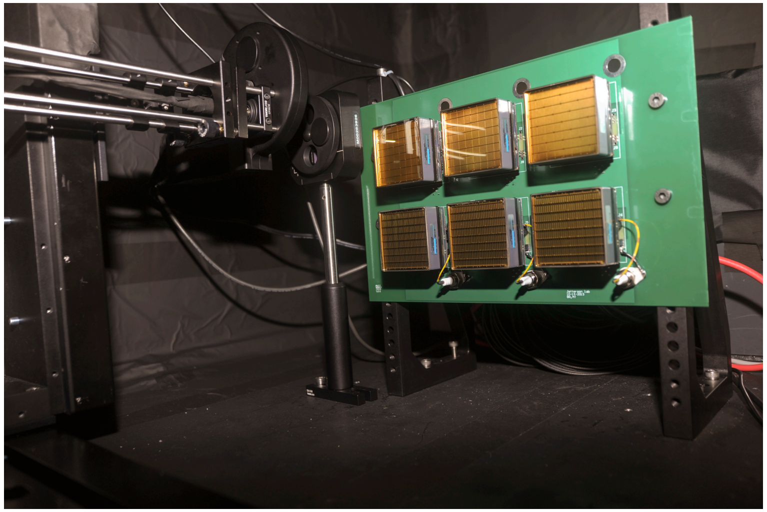
ADC Charge Measurement

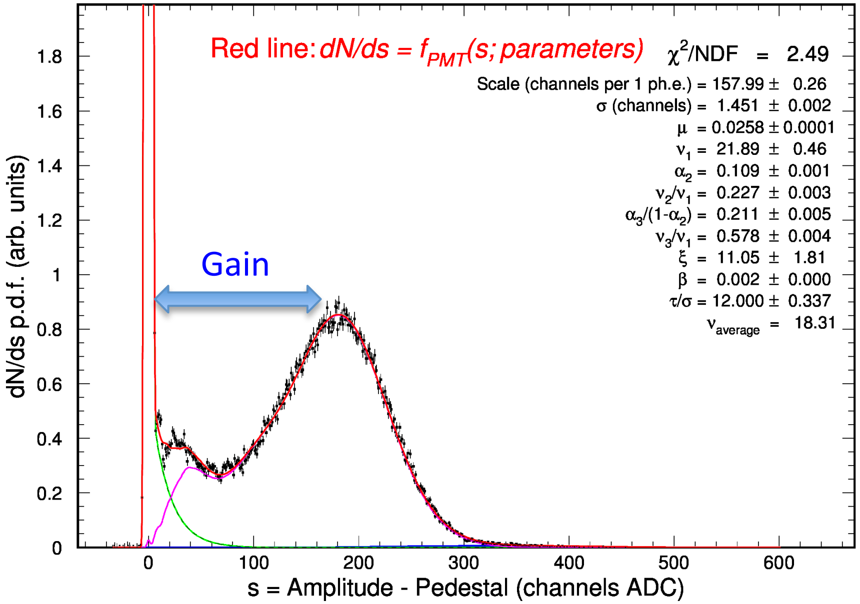
Multiplexed readout up to 50 kHz

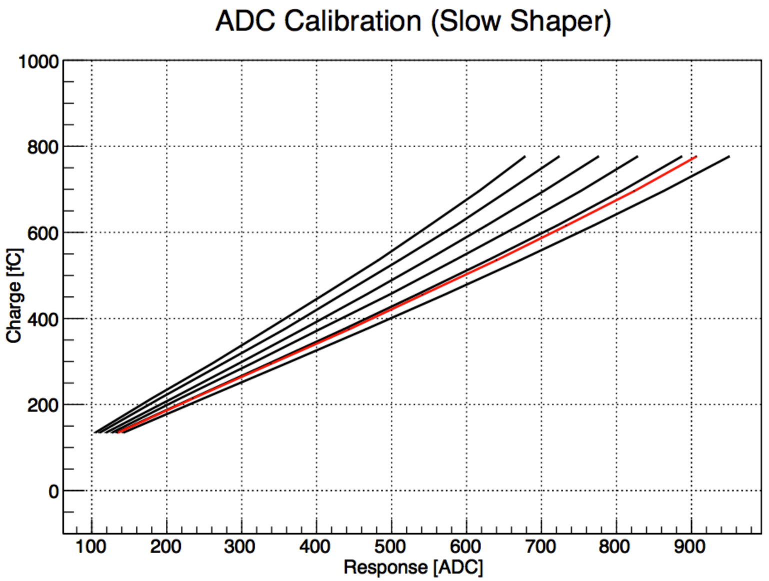
High resolution SPE spectrum

Viable for efficiency and gain monitors

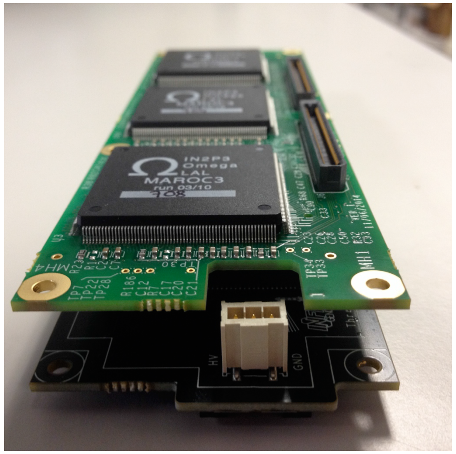
In conjunction with timing, allows the study of PMT discharge and cross-talk

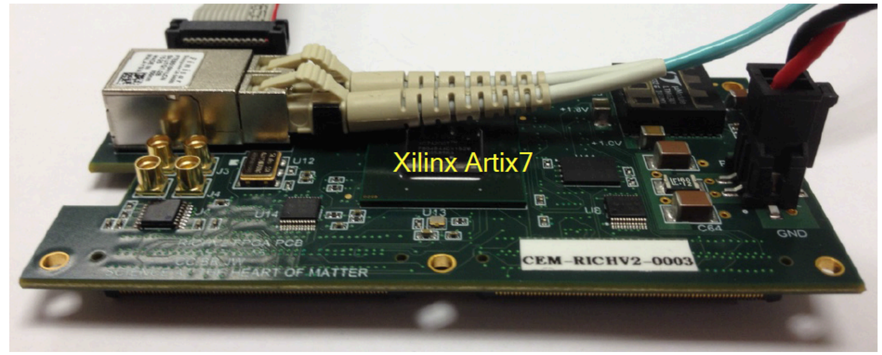






RICH Front-End Electronics





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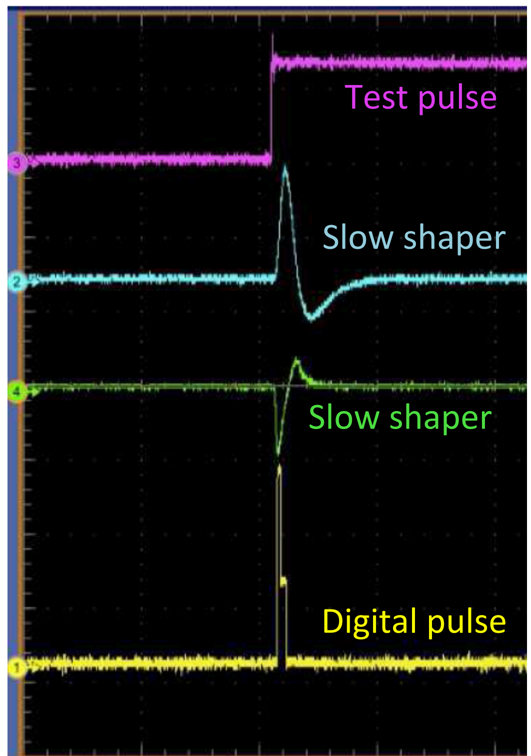
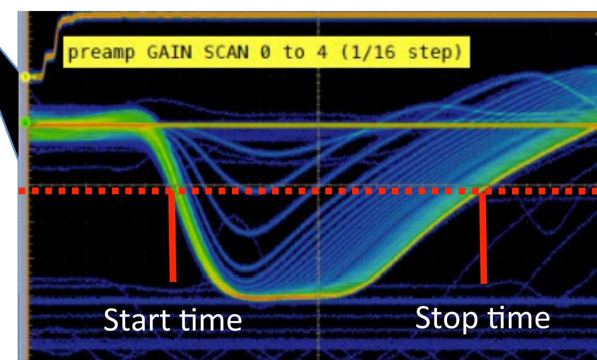
On-board pulser



Digital response
Working in saturated regime

64 parallel channel readout

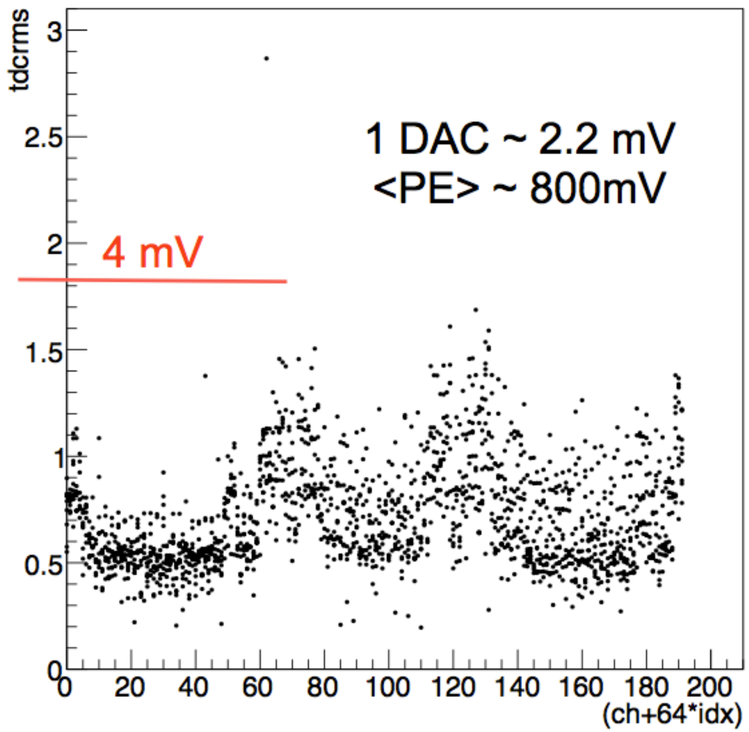
8 μs FIFO and delays
1 ns time resolution



TDC Digital Readout

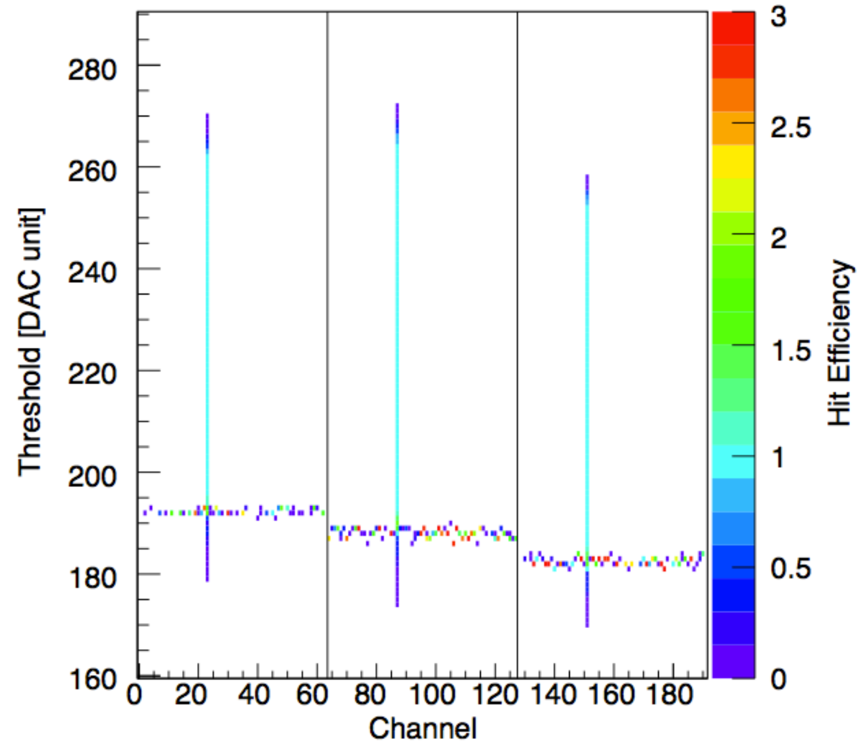
During Acceptance tests

Pedestal rms as seen by a test-point



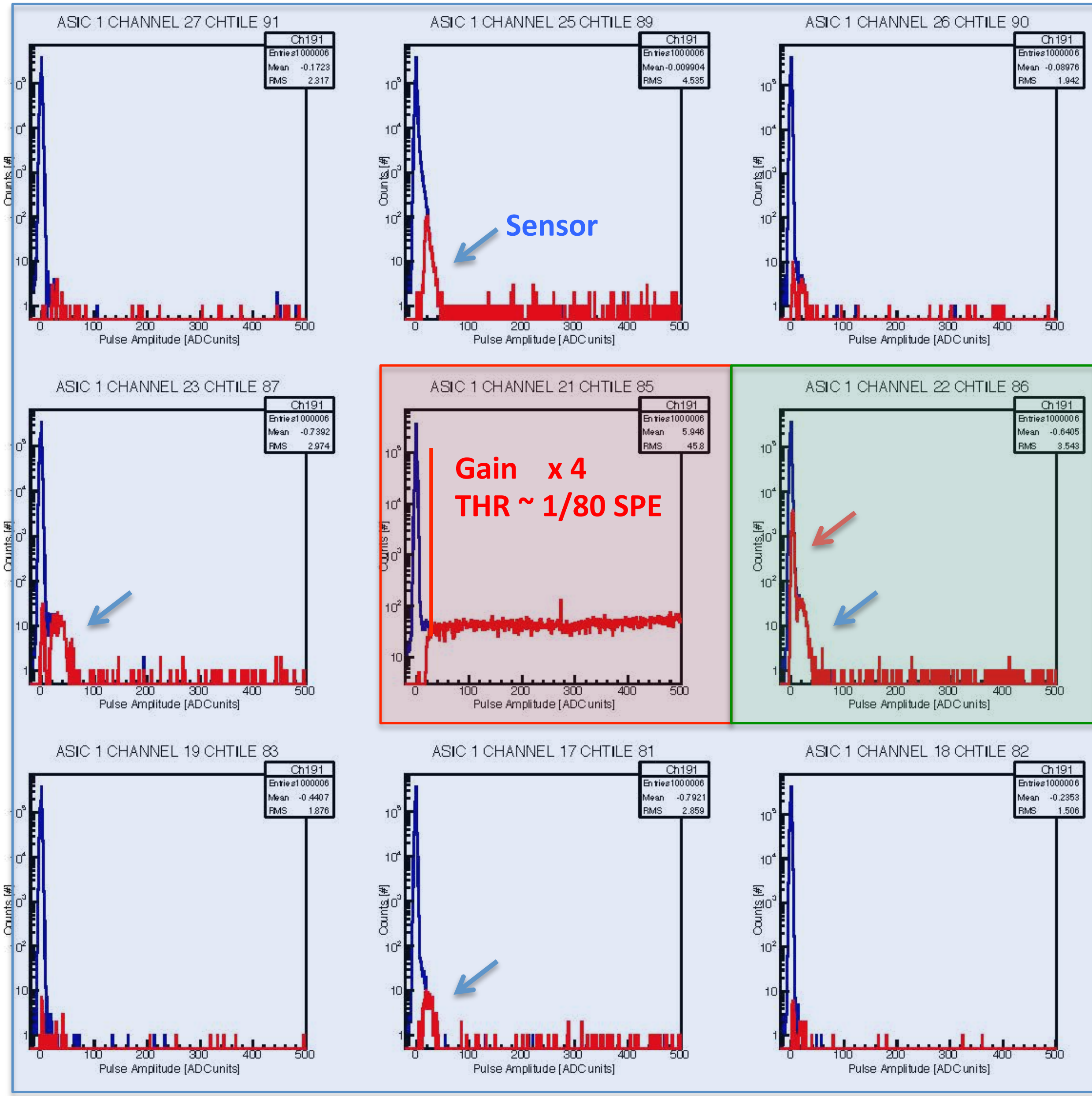
During Internal Pulser Calibration

As seen by RICH readout



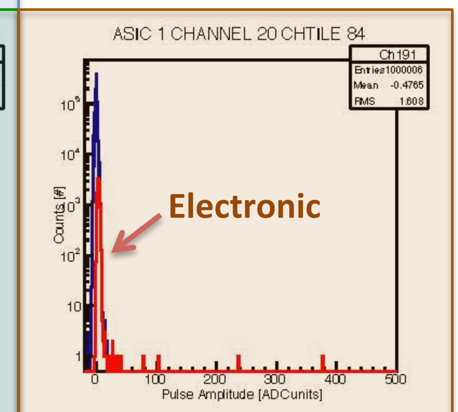
Discrimination down to 20 fC, i.e. few % of SPE, allows sensor characterization

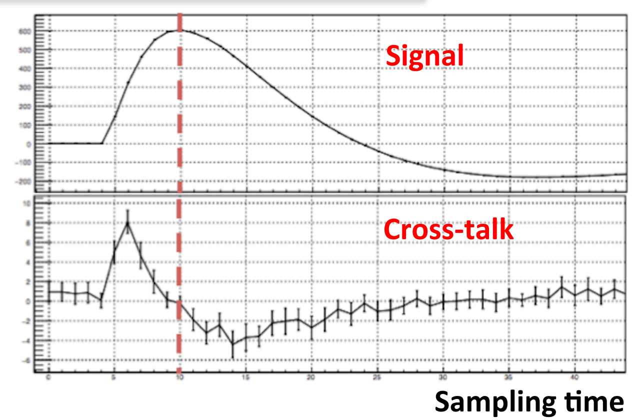
Optical and Electronic Cross-talk



GA0501

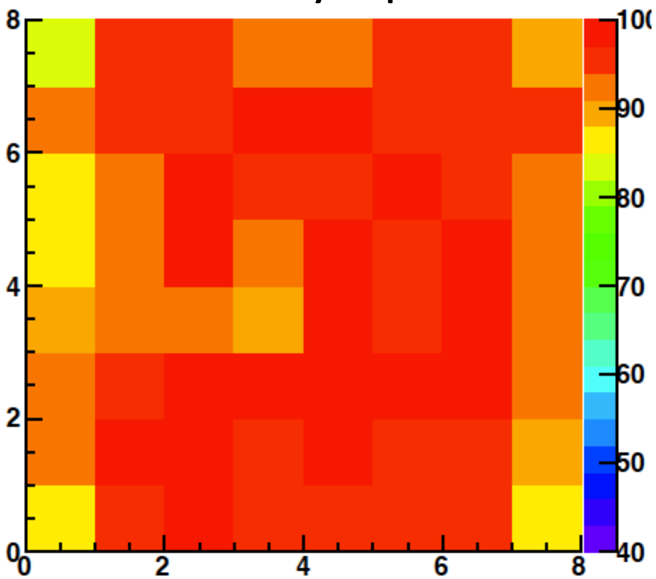
95	93	94	92	96	98	97	99
91	89	90	88	100	102	101	103
87	85	86	84	104	106	105	107
83	81	82	80	108	110	109	111
79	77	78	76	112	114	113	115
75	73	74	72	116	118	117	119
71	69	70	68	120	122	121	123
67	65	66	64	124	126	125	127



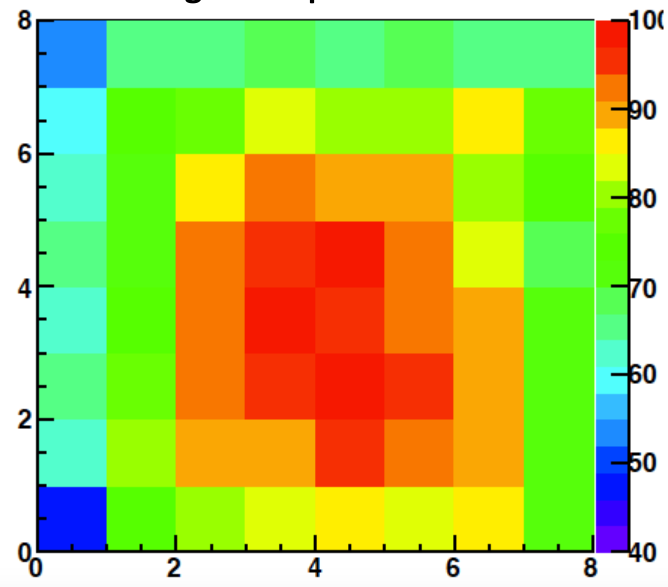


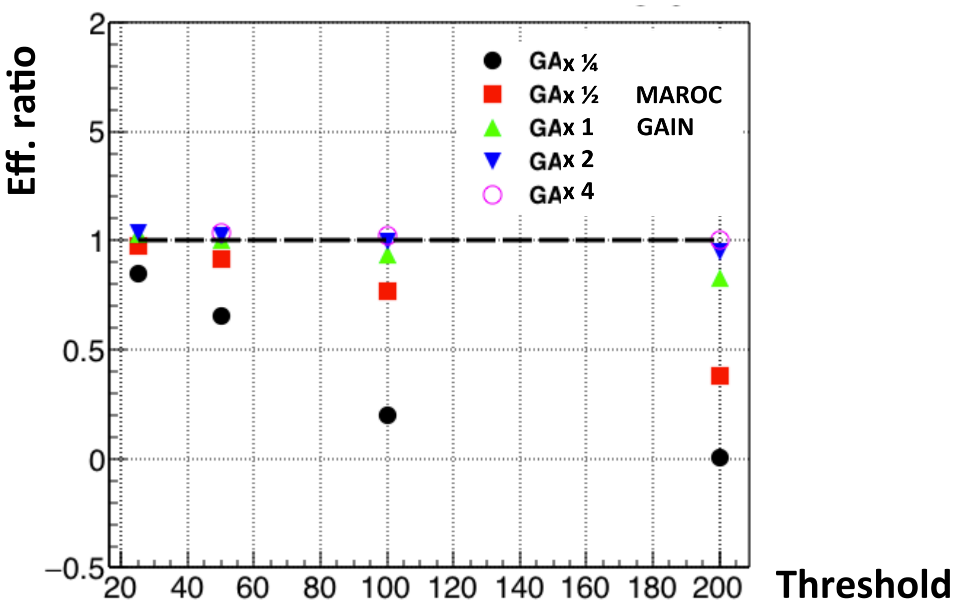
Single-photon Discrimination

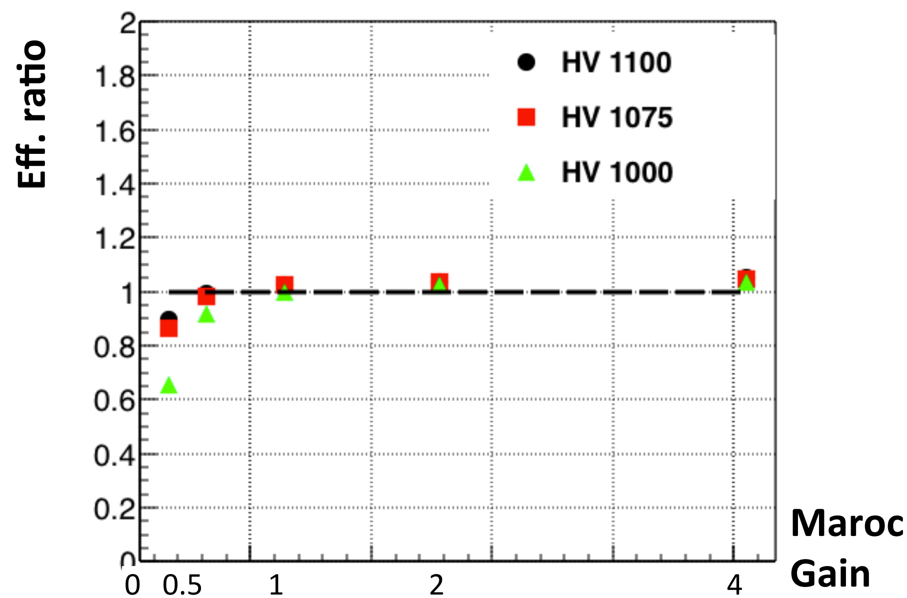
Relative efficiency map



Relative gain map

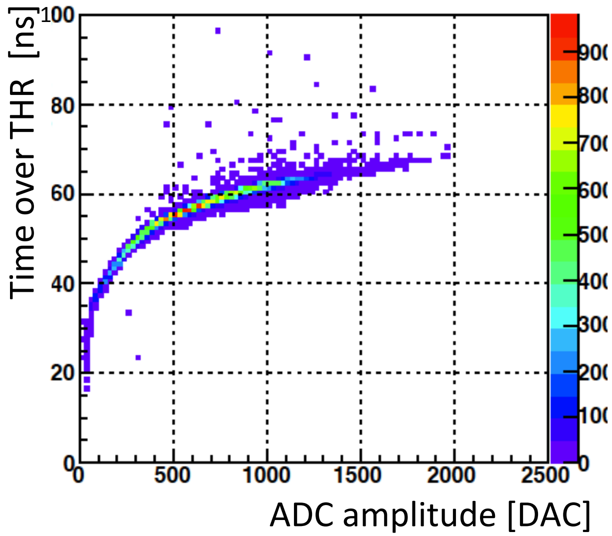




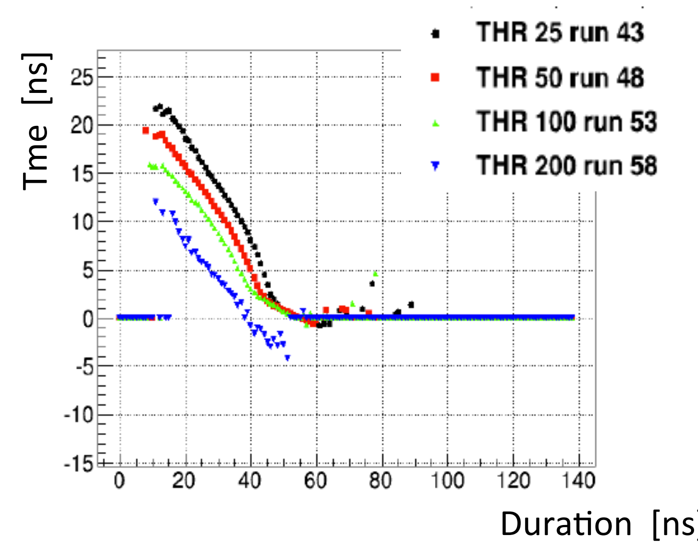


Single Photon Electron Timing

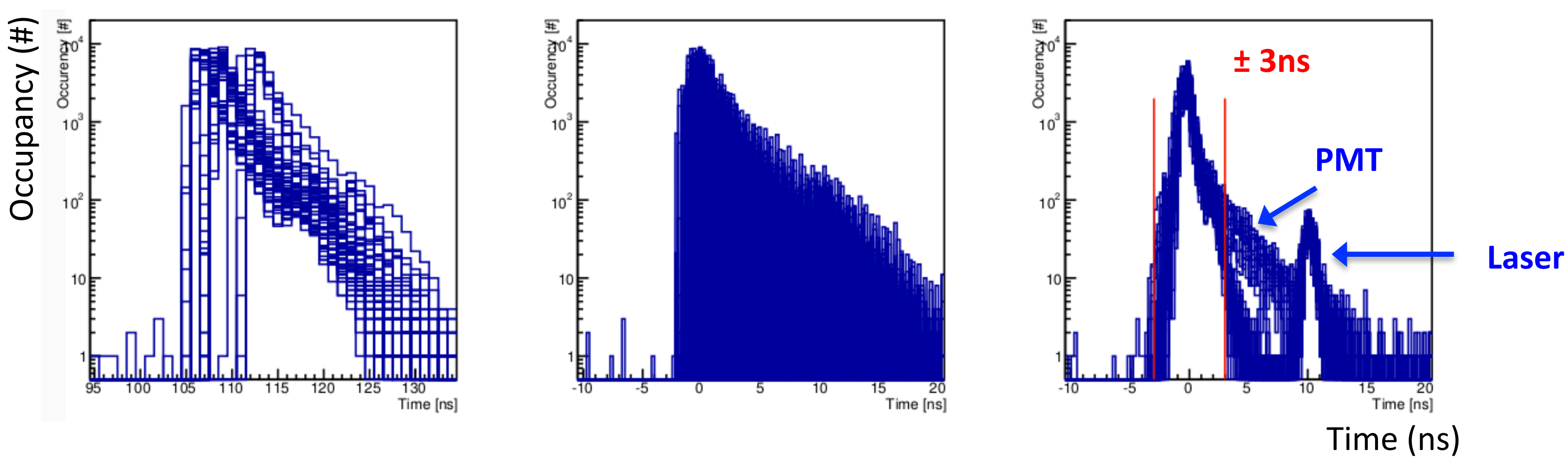
Time over threshold relates to charge



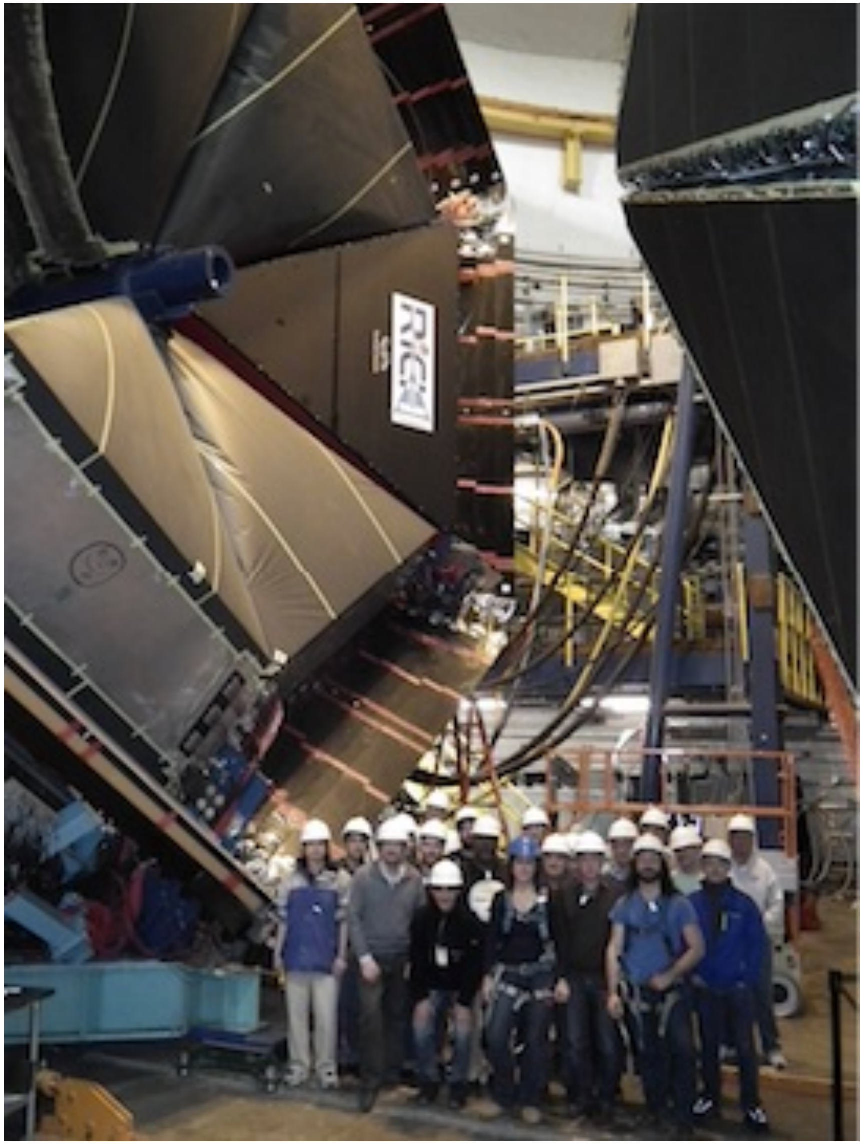
Typical time-walk with charge



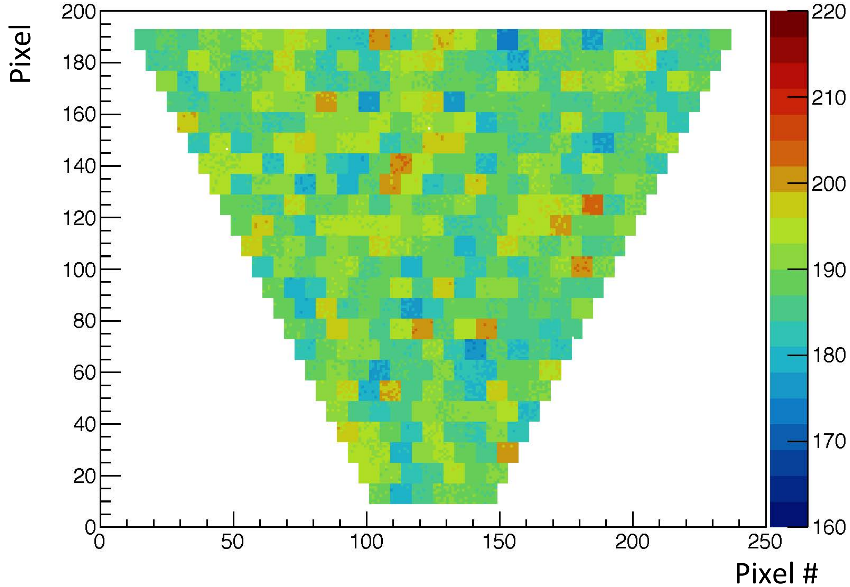
Channel by channel time calibration: **no offsets** **no walk**

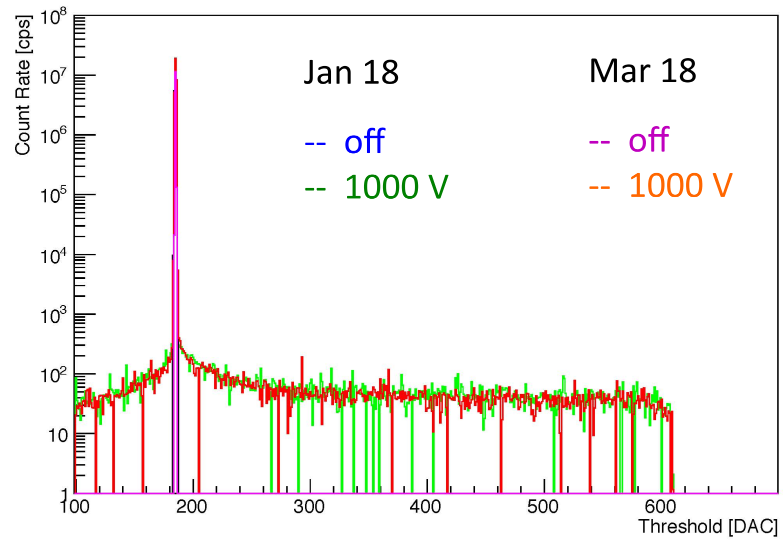


RICH Installation

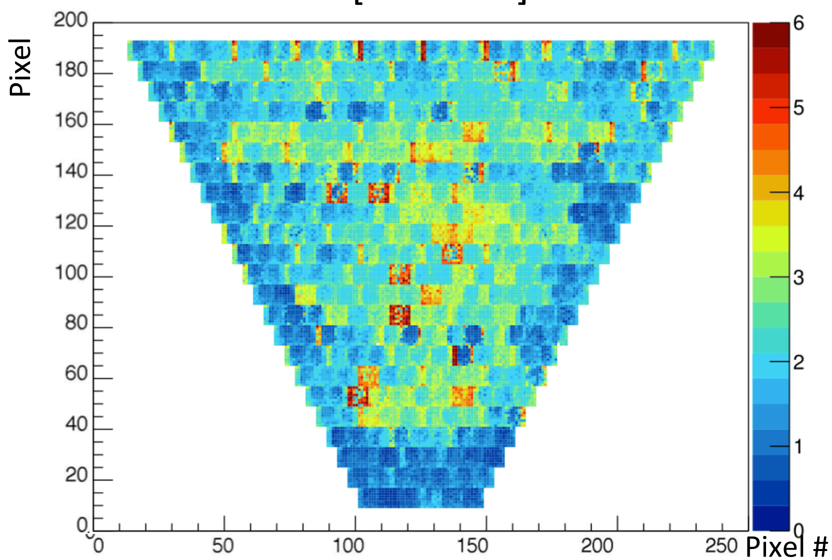


Electronic Pedestals

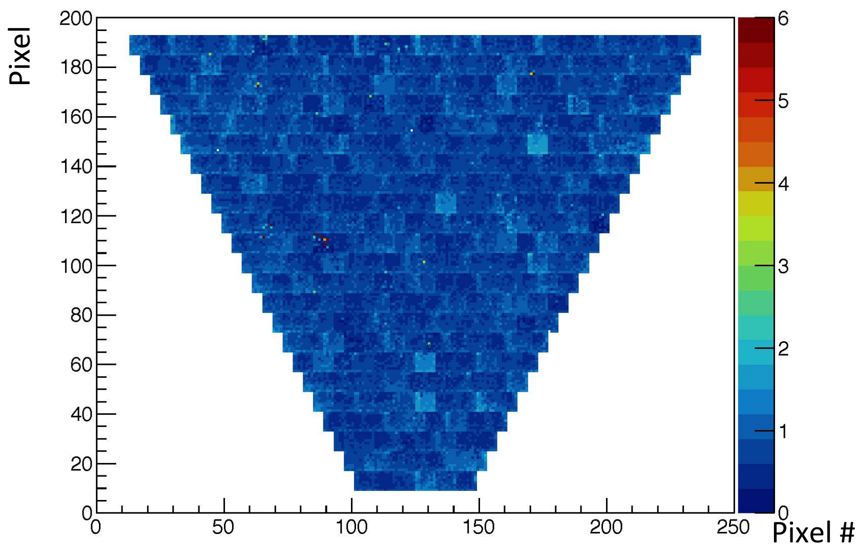




Pedestal rms [DAC unit]: without

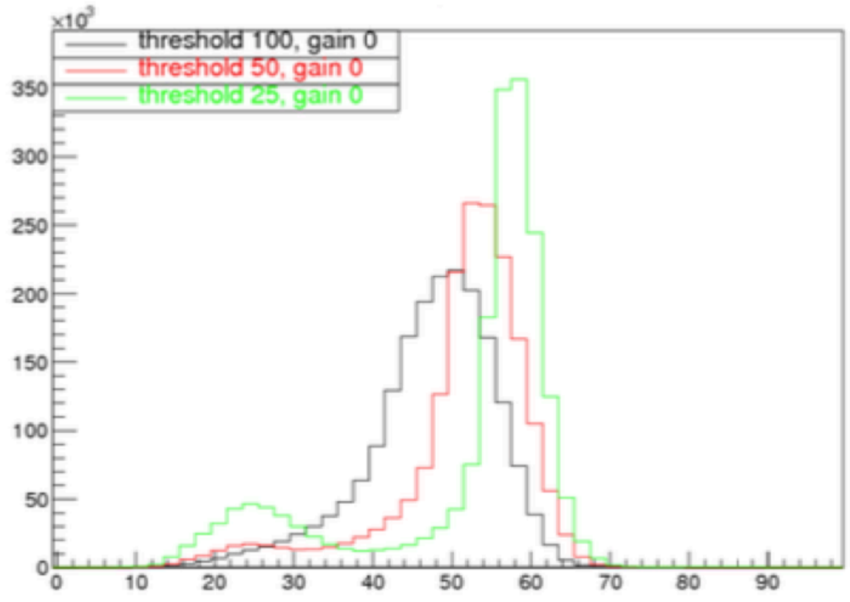


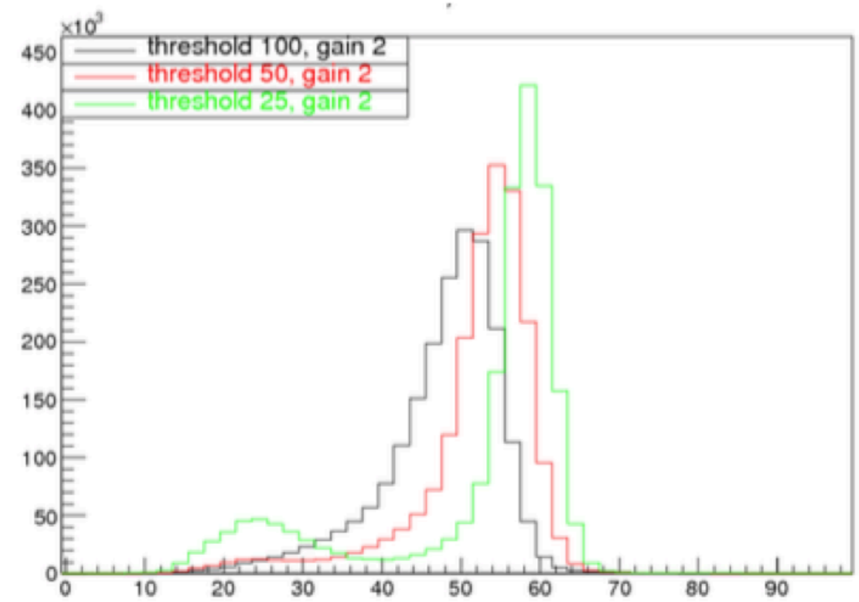
and with grounding grid



Online Equalization

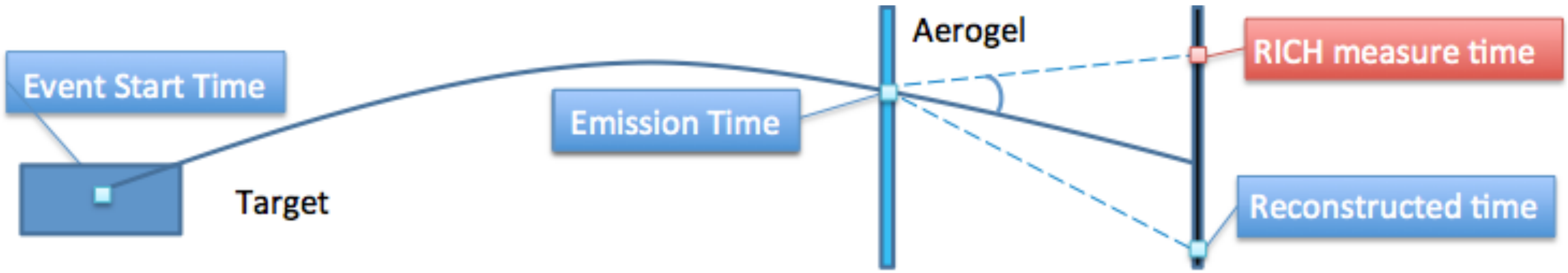
After equalization: distributions narrower and less sensitive to the common threshold
saturate signals and cross-talk well separate





black: high threshold **red: intermediate threshold** **green: low threshold**

Single Photon Time Analysis

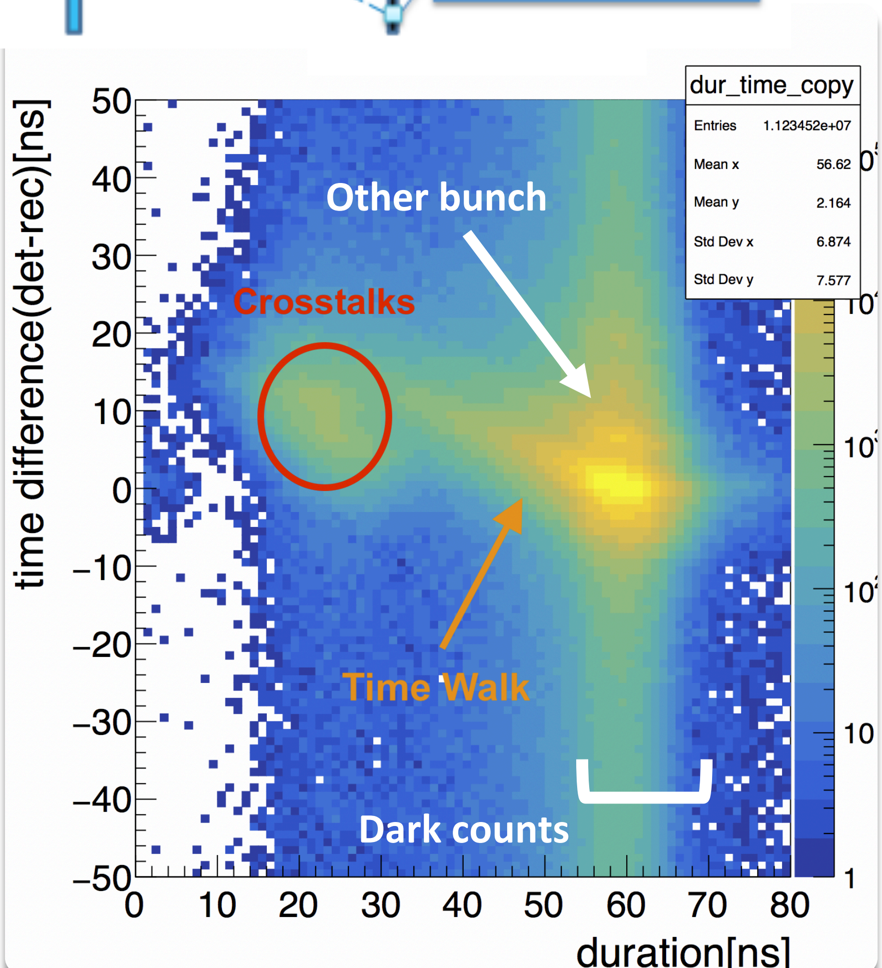


CLAS12 Reconstructed Time and Position:
Photons are traced using information from other CLAS12 detectors

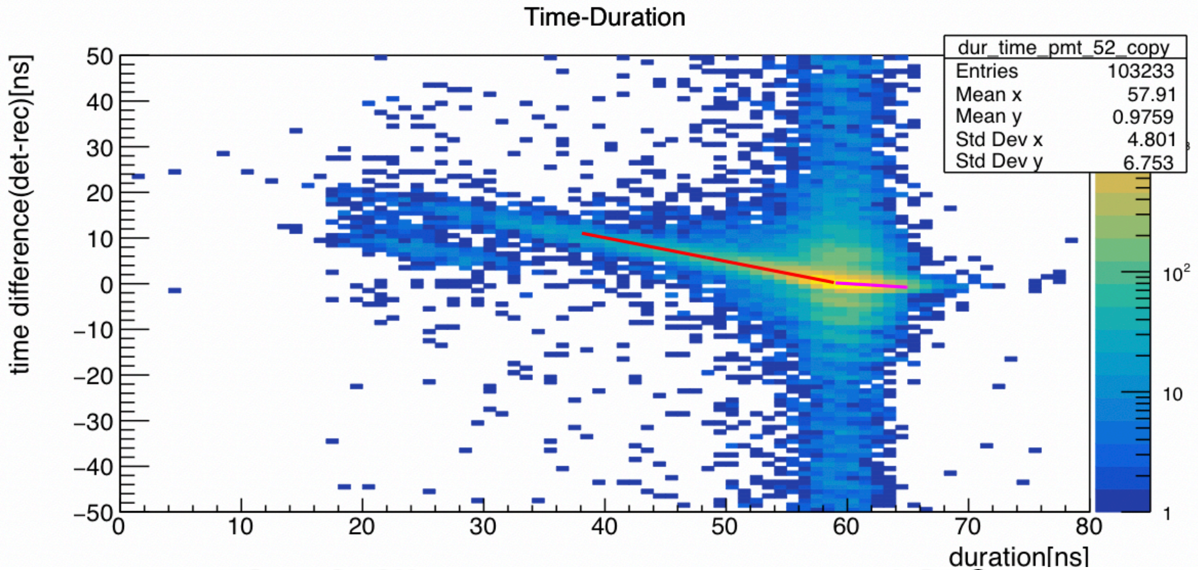
RICH Measured Time and Position:
Defined by the RICH DAQ

Good photons should match in time and space

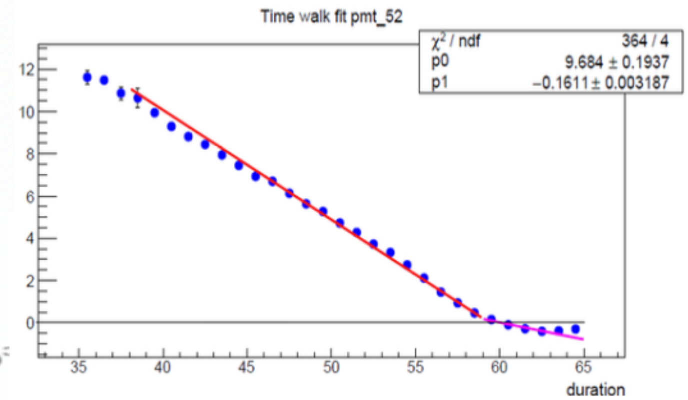
Time analysis allows to separate spurious signals

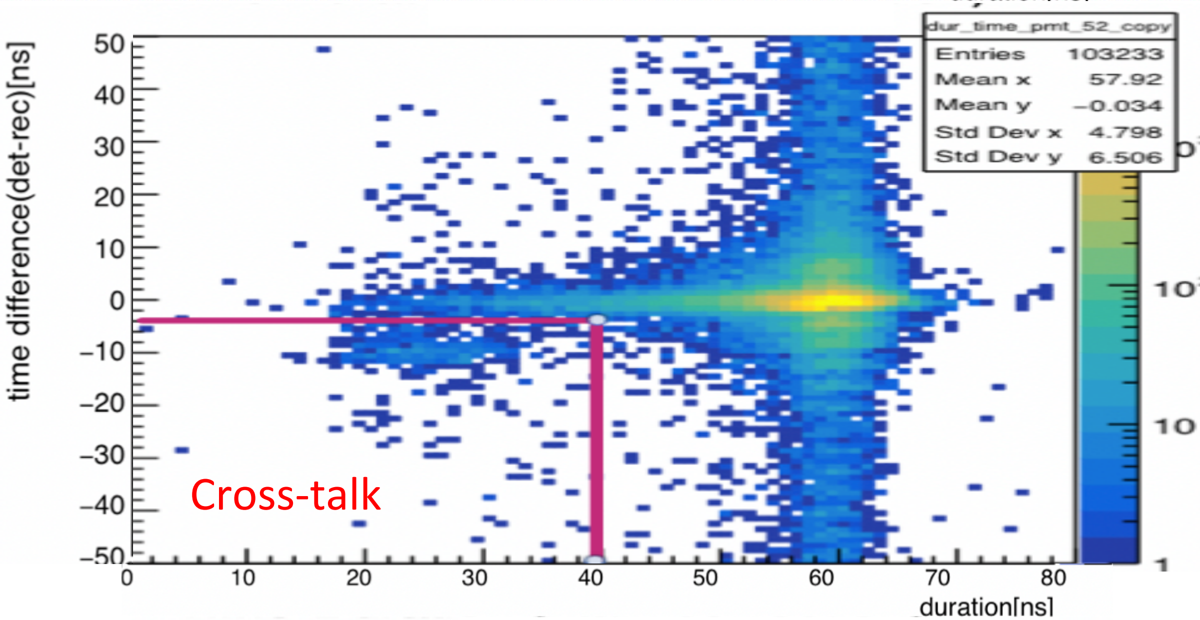


Time Calibration



Time vs Duration
after offset correction

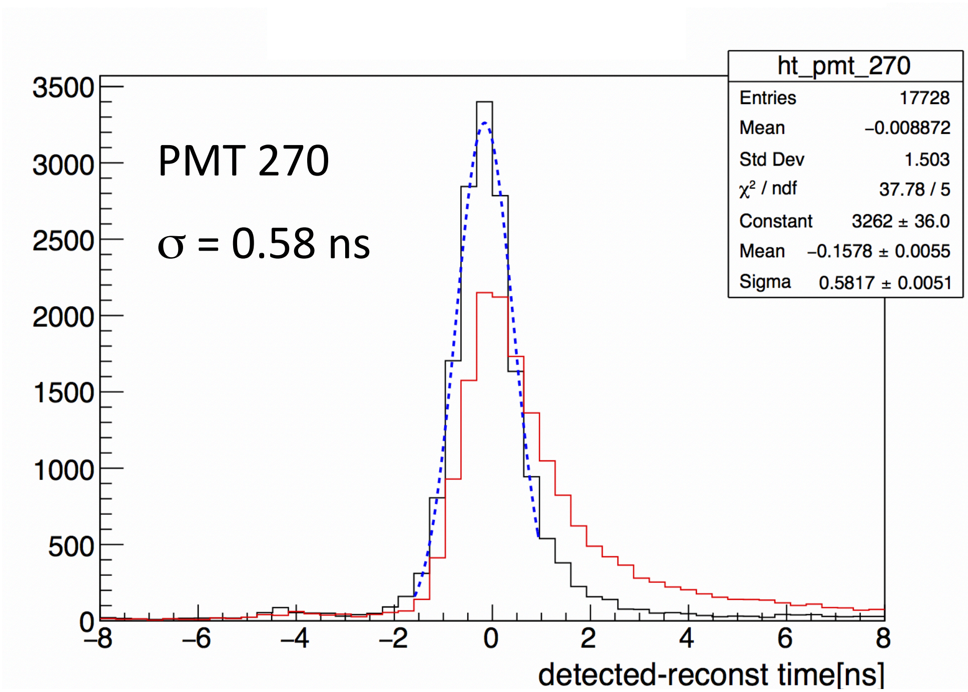


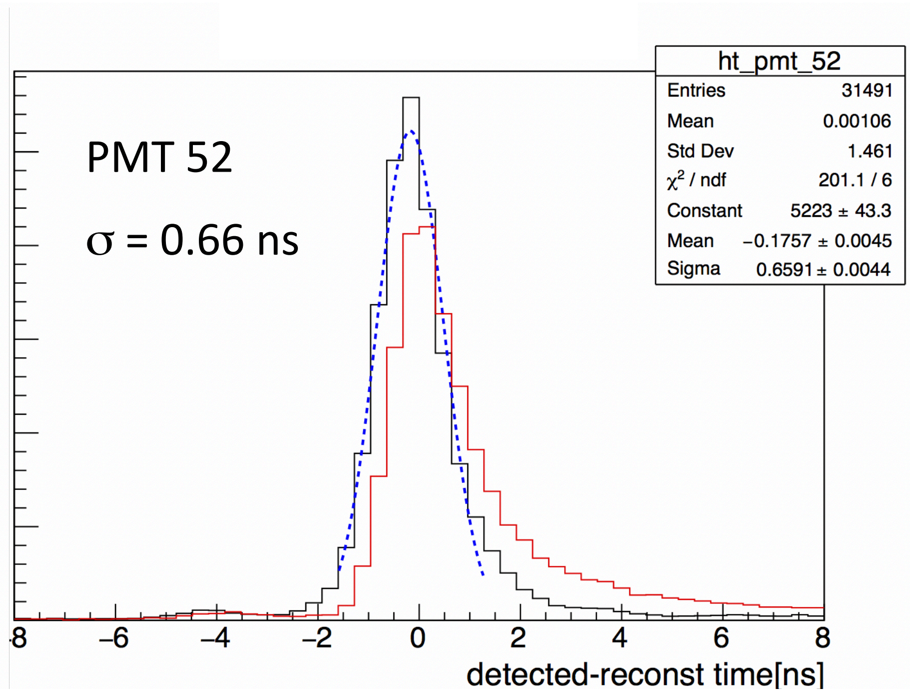


Time vs Duration
after walk correction

Single-photon Time Resolution

Single-photon time resolution better than the 1 ns specification



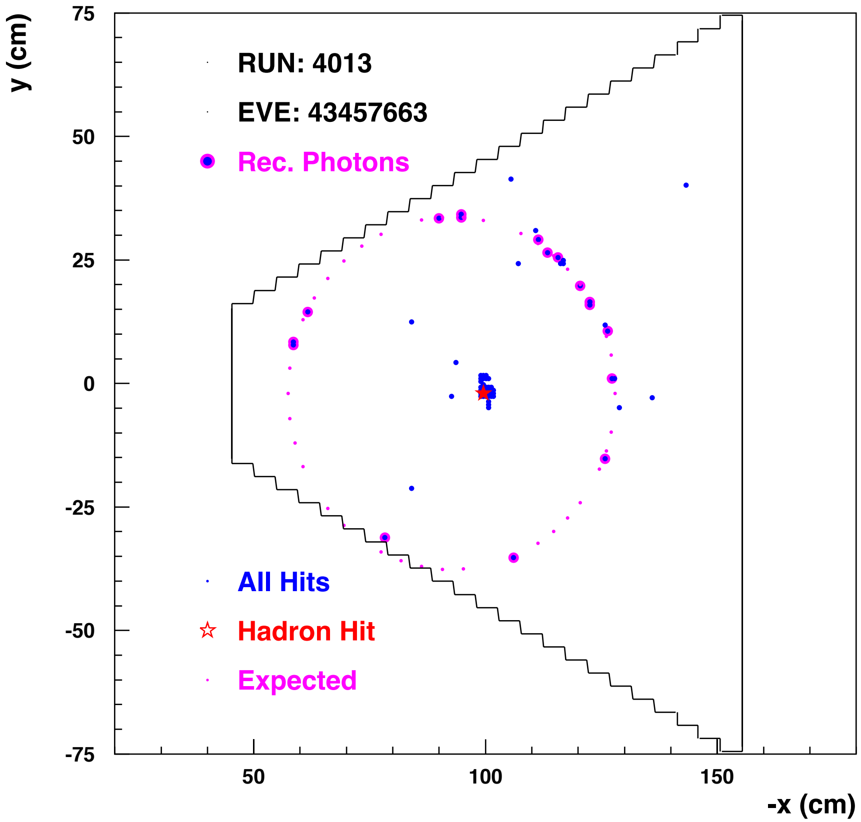


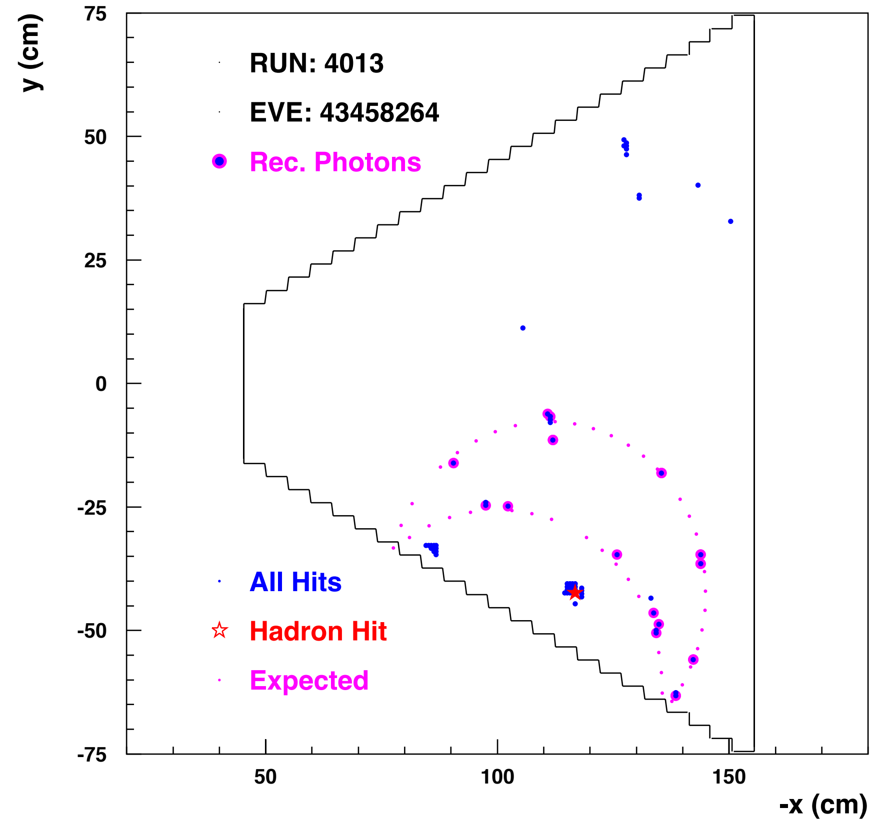
— before time-walk correction

— after time-walk correction

Cherenkov Photon Reconstruction

Example of signal hits identified by time consistent with CLAS12 reconstruction





Direct ring

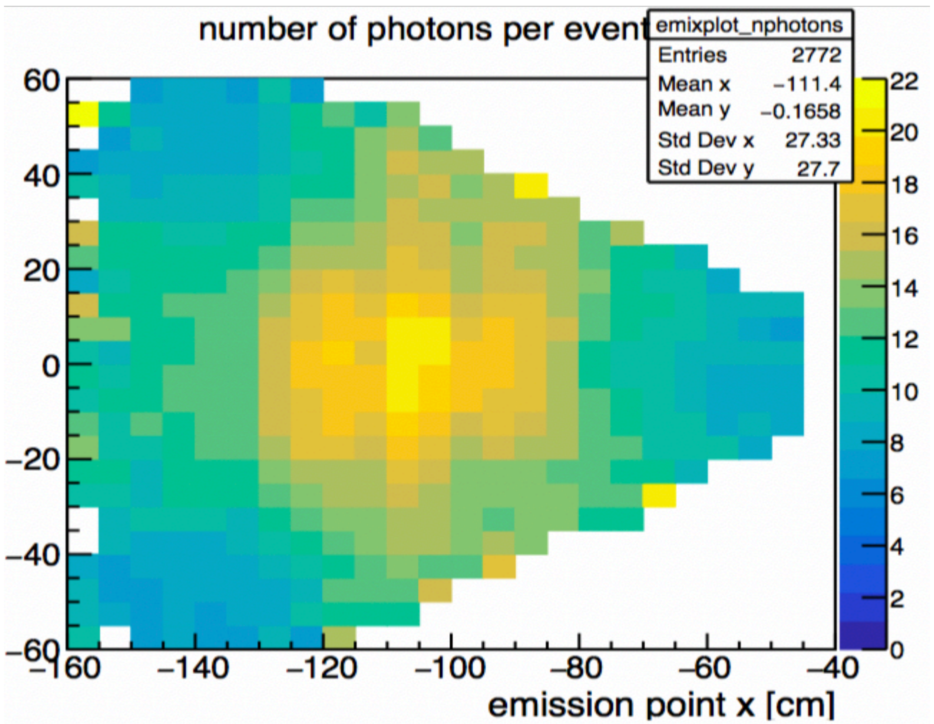
Next Page

Half recflected ring

Direct Cherenkov Photons

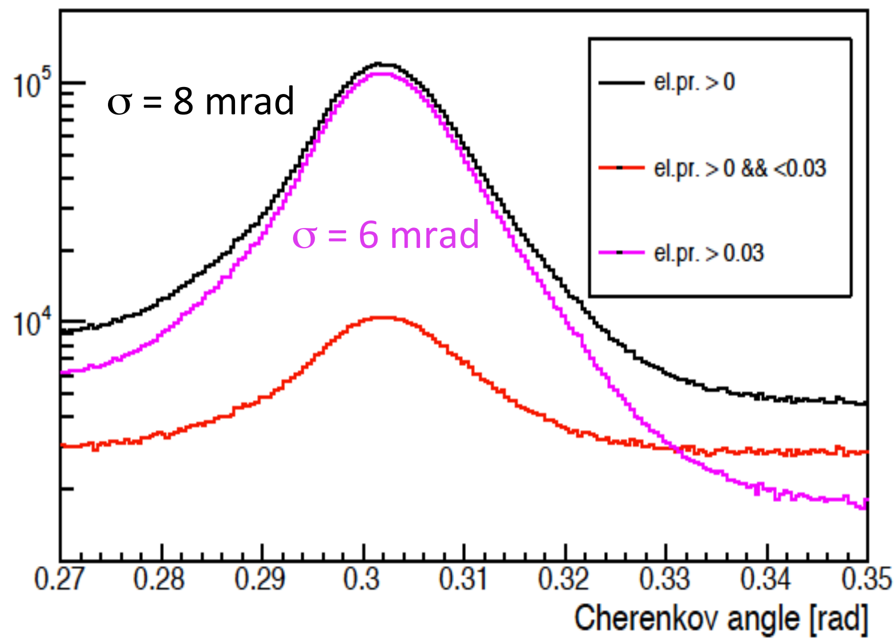
About 18 photons for a center ring (no reflection accounted for)

Consistent with the TDR projection



Preliminary single photon Cherenkov angle resolution = 6 mrad

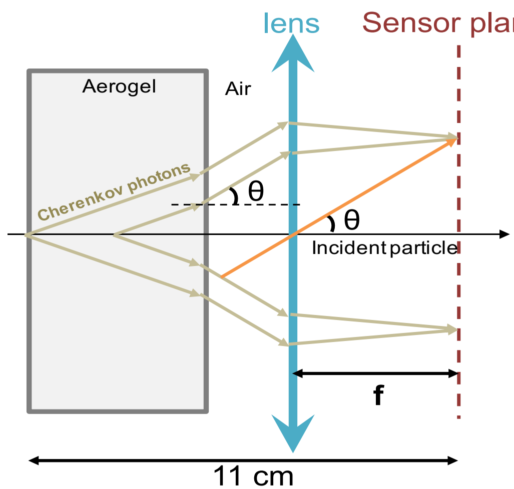
Close to the 4.5 mrad goal despite
- No alignment
- Nominal (no real) optical property

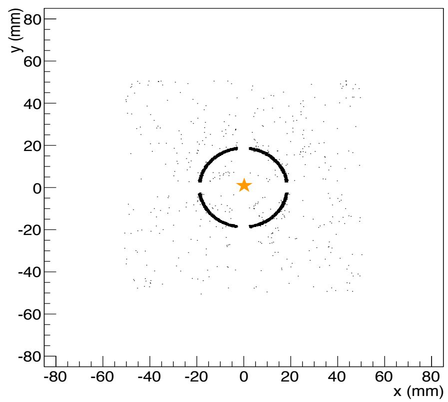


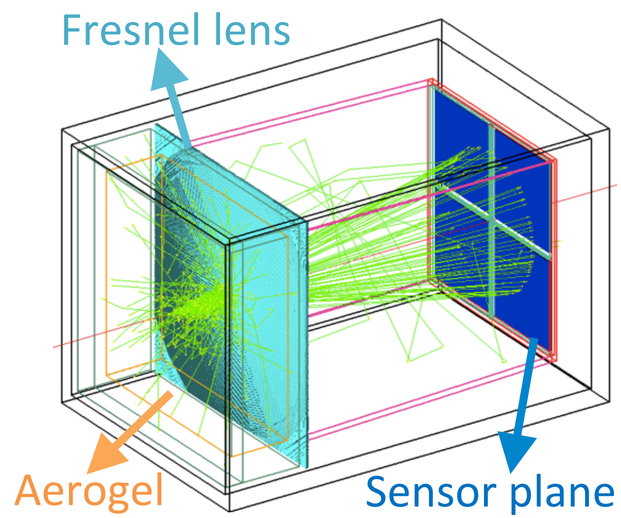
In principle enough for a Cherenkov resolution at track level of $\sigma = \sigma_1/\sqrt{N} \sim 1.5$ mrad

Application: Modular RICH @EIC

Compact and modular RICH indipendent elements



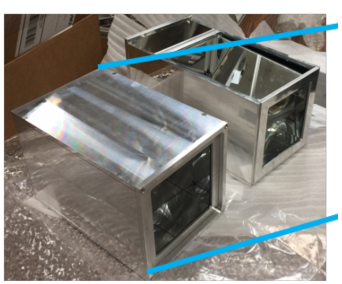


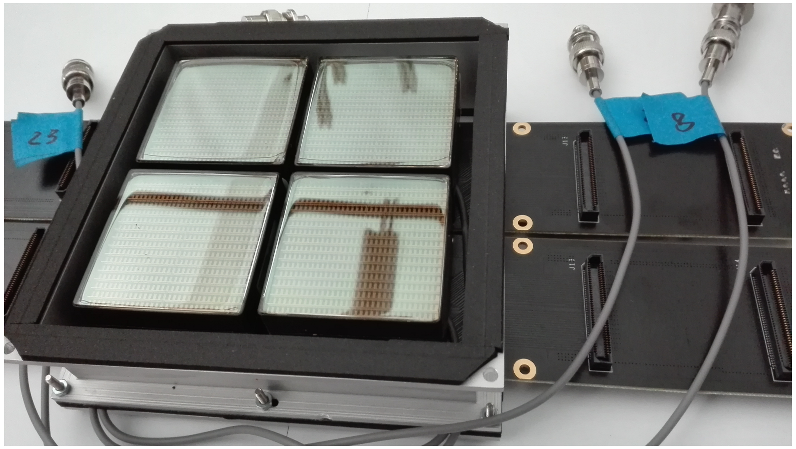


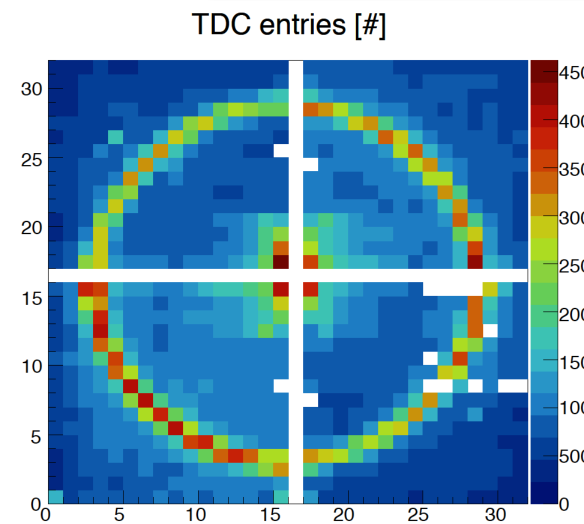
See Xiaochun He talk

H13700 to reach the 3 mm spatial resolution

Two completed mRICH prototypes

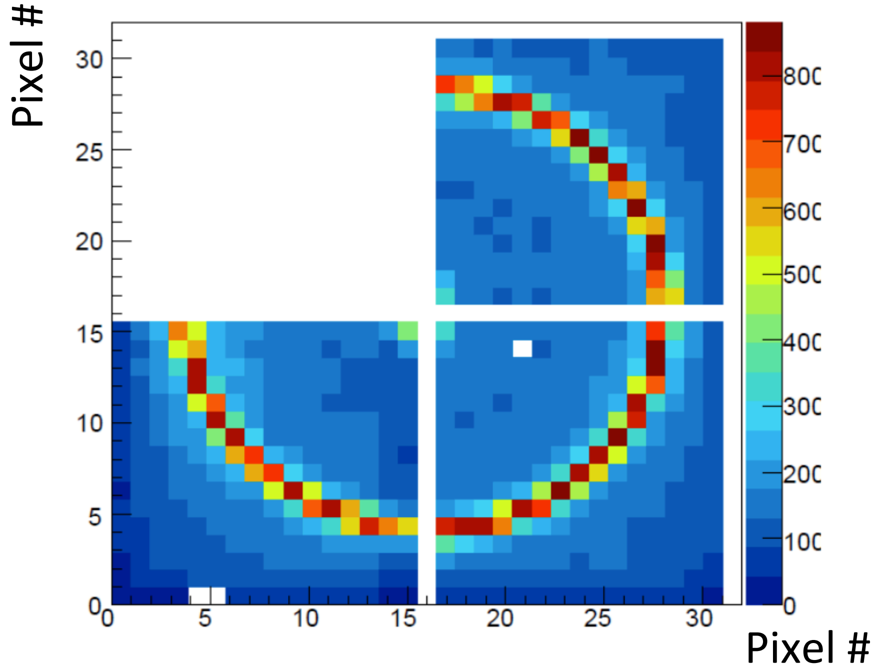


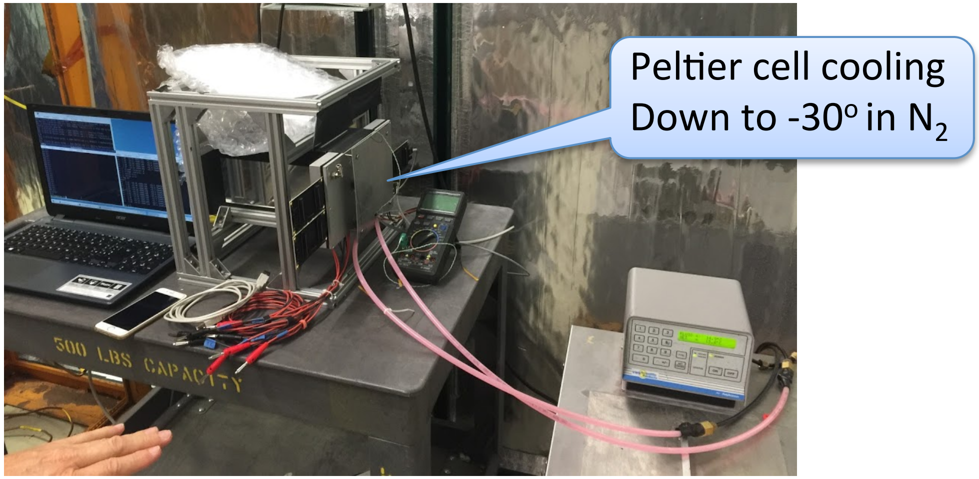




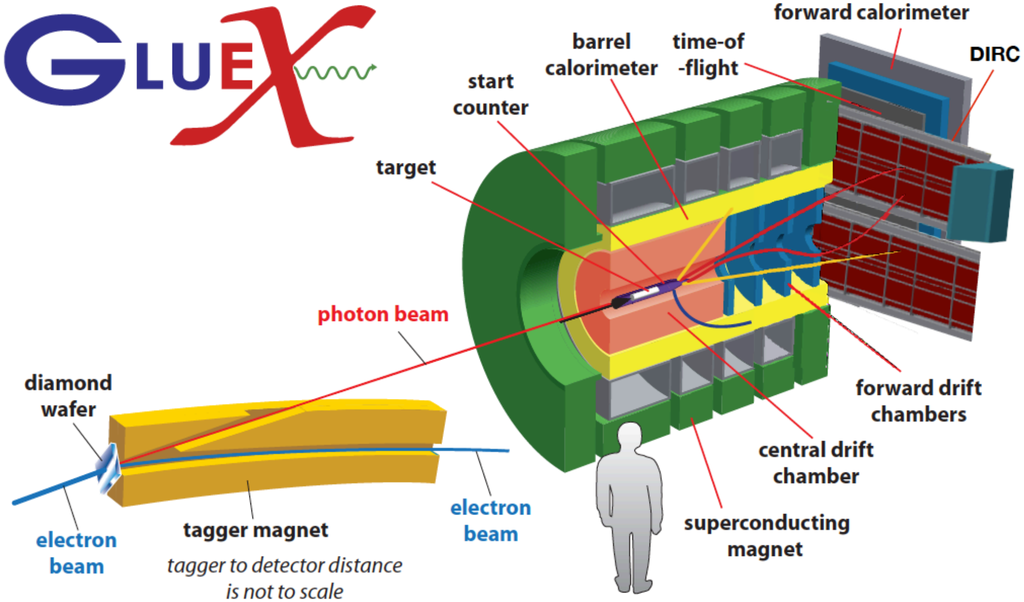
Application: SiPM Arrays

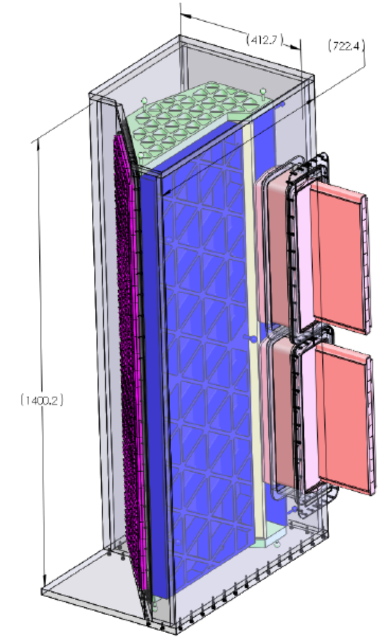
Test of SiPM with RICH electronics



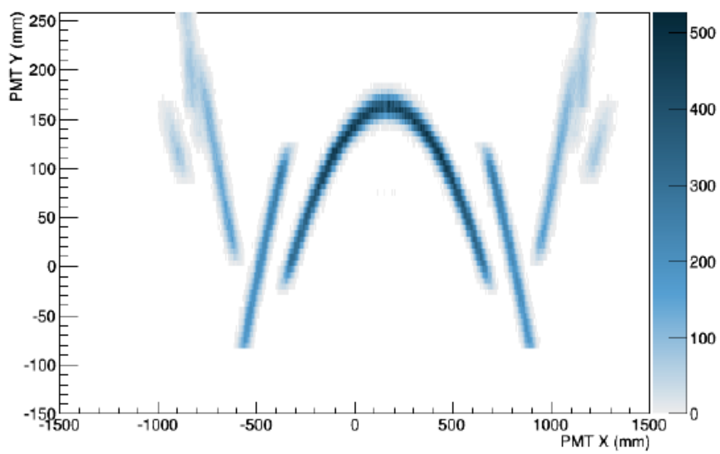


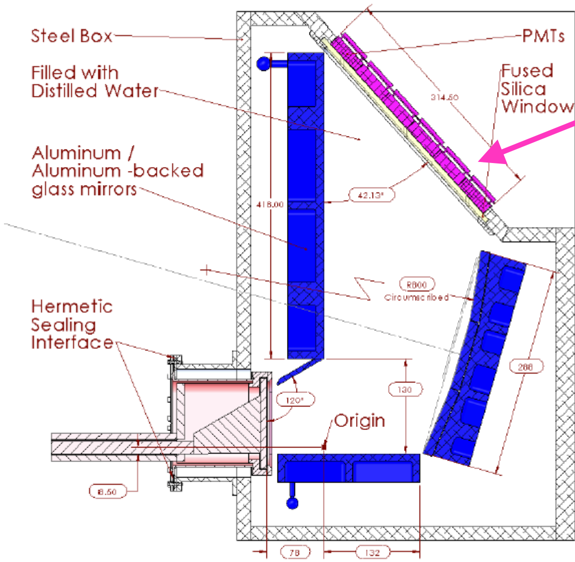
Application: DIRC @ GlueX





Hadron discrimination up to 4 GeV/c





H12700 + CLAS12 readout

Conclusions

CLAS12 RICH designed to provide hadron identification in the 3 to 8 GeV/c momentum range
A hybrid-optic design has been adopted to minimize the instrumented area to about 1 m^2

Flat-panel multi-anode PMTs are being used for the first module
SiPMs are being investigated for the second module

The readout electronics is designed to offer

- Discrimination down to few % of SPE
- Time resolution of 1 ns
- Negligible dead time at 30 KHz
- Trigger latency up to 8 μs

Featuring:

- Compatibility with various sensors and applications
- Modular Front-End (Mechanical adapter, ASIC, FPGA)
- Scalable fiber optic DAQ (TCP/IP or SSP)
- Compact and tessellated geometry (common HV, LV and optical fiber)
- Flexible trigger logic (external, auto, self)
- Charge measurement (multiplexed ADC or time-over-threshold)

Multi purpose electronics: in use also for GlueX DIRC and EIC R&D