PHOTON IMAGING WITH THE MODULAR AND MULTIPURPOSE READOUT ELECTRONICS OF THE LARGE-AREA CLAS12 RICH

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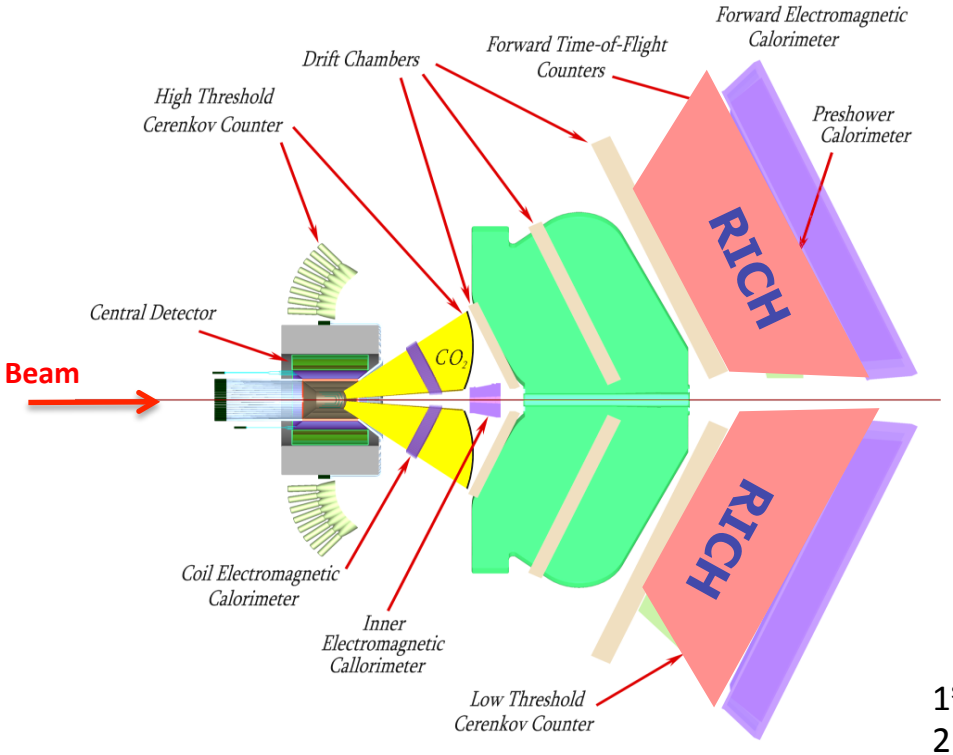
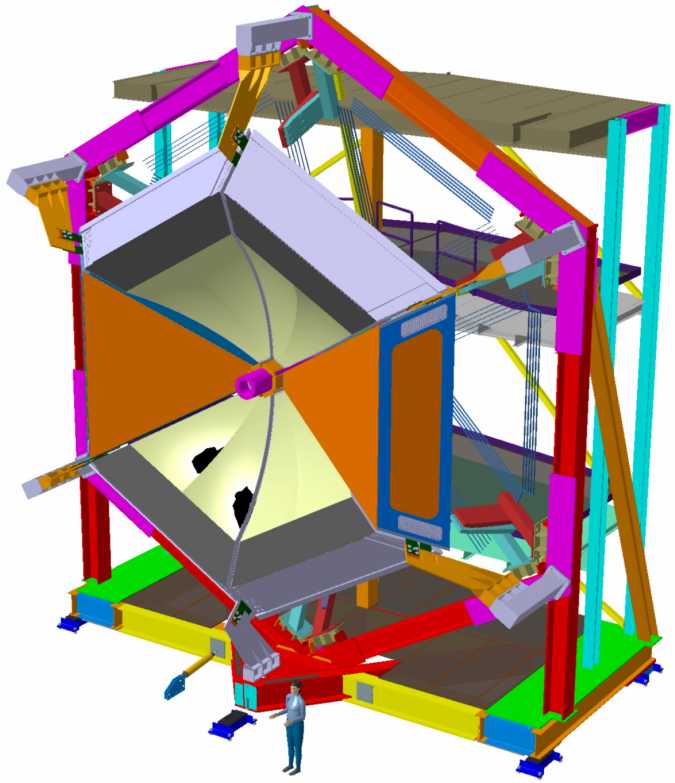
INFN Ferrara
On behalf of the CLAS12 RICH Group

8th NDIP Conference, 7th July 2017, Tours - France

The CLAS12 Spectrometer

Upgrade of the CLAS detector at Jefferson Lab almost complete.
First beam expected in fall 2017.





1st sector by October 2017
2 sectors to accomplish physics program

Highly polarized 12 GeV electron beam

Luminosity up to 10^{35} cm^{-2} s^{-1}

H and D polarized targets

Broad kinematic range coverage

3D structure of the nucleon by polarized deep-inelastic scattering

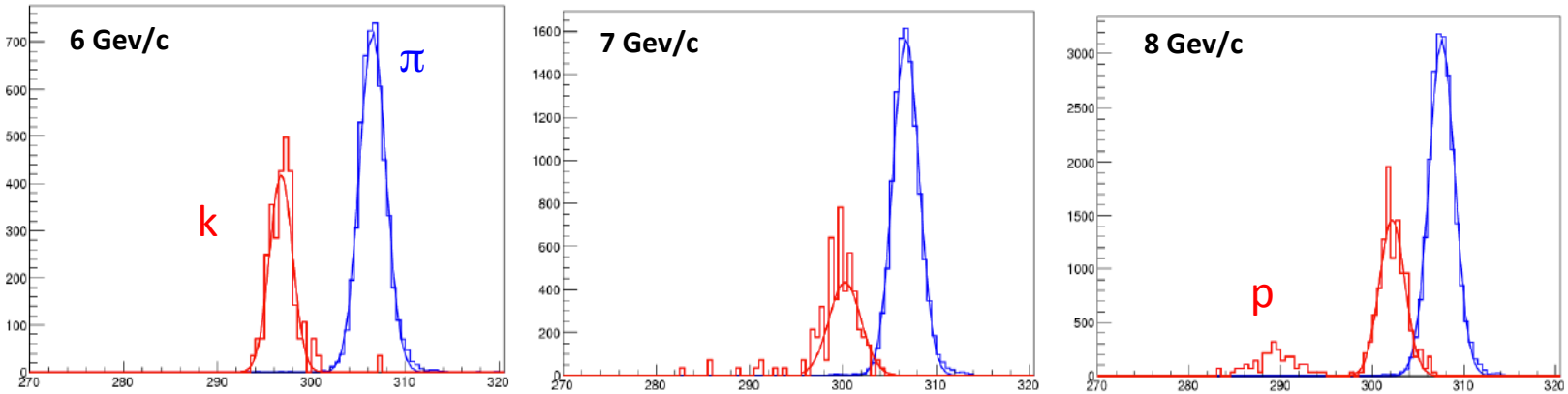
Hadron ID wanted for flavor separation

Crucial for the study of parton dynamics related to angular momentum and spin-orbit effects with flavor sensitivity.

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)
J. Gutenberg Universitat Mainz (Mainz, Germany)
Kyungpook National University, (Daegu, Korea)
University of Connecticut (Storrs, USA)
UTFSM (Valparaiso, Chile)

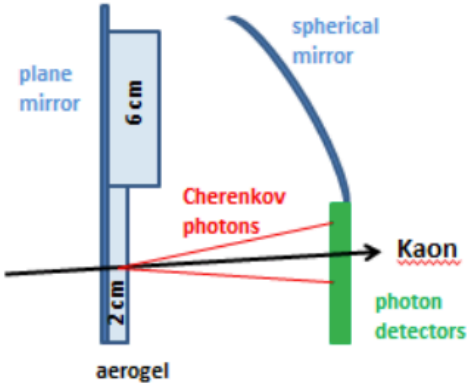
Prototype results:

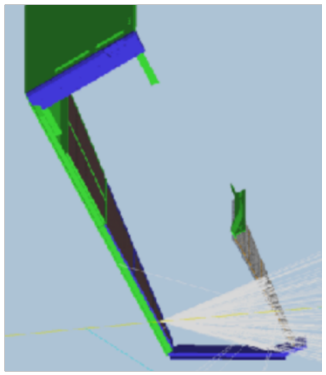


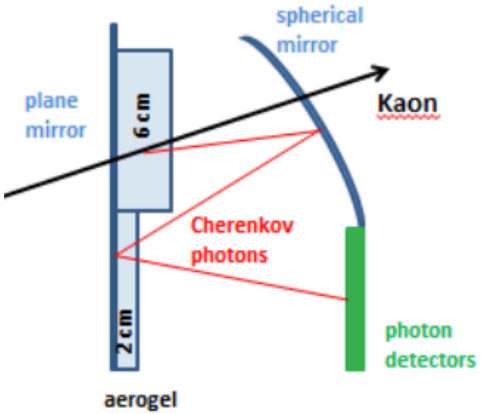
RICH Design

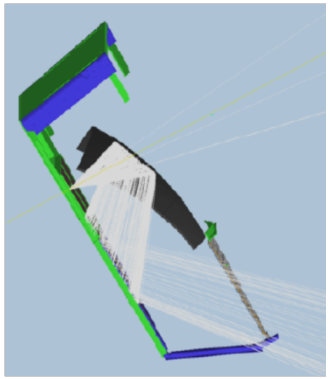
Goal: separate kaons from pions and protons in the momentum range 3-8 GeV/c

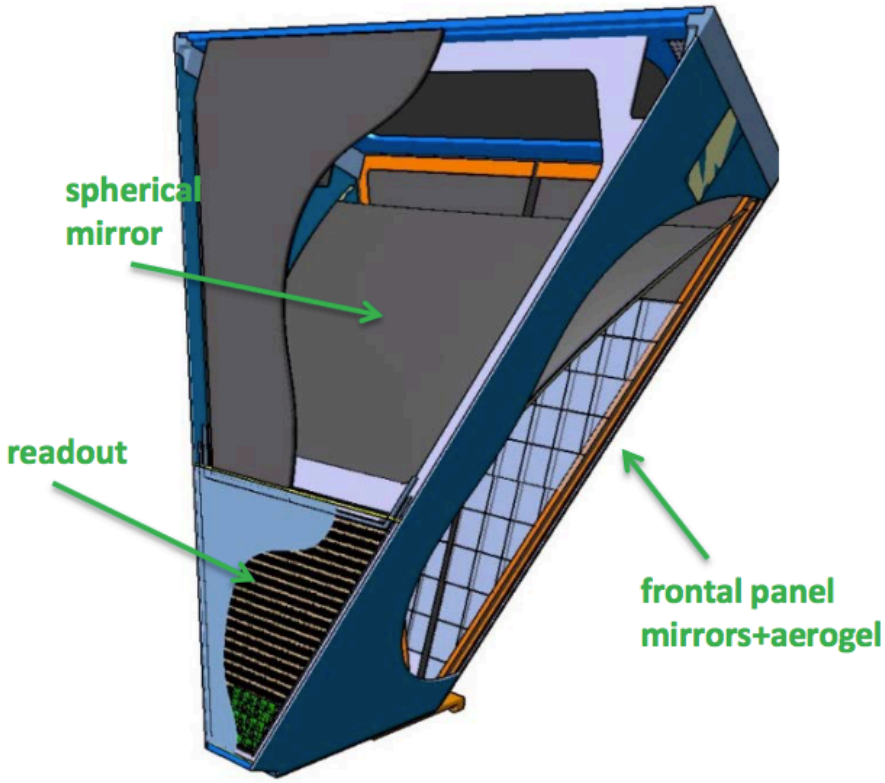
Aerogel radiator to match the momentum
Hybrid-optic to minimize the instrumented area
Working with VIS and near-UV photons (MAPMTs or SiPMs)









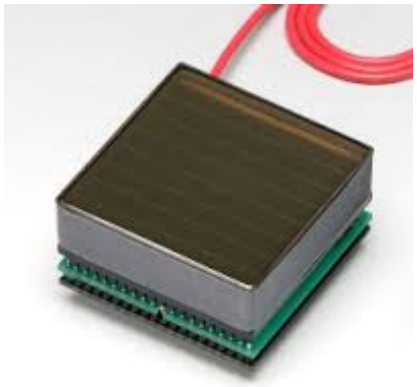


Photon Sensor: MA-PMT

MA-PMT

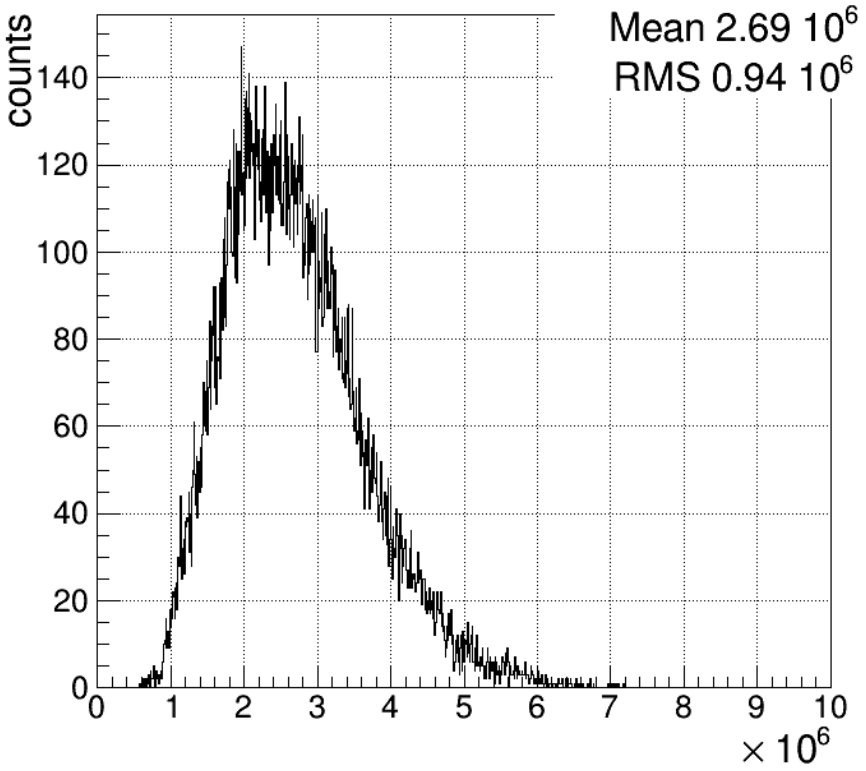
< 1 cm spatial resolution
< 1 ns time resolution
Compatible with the low torus fringe field

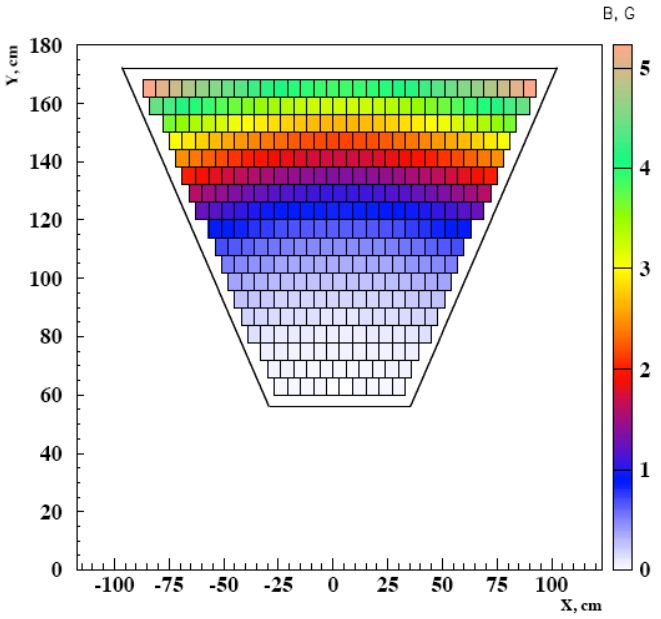
Average MA-PMT gain ~ 2.7 10^6
Corresponds to SPE ~ 400 fC



- ✓ 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

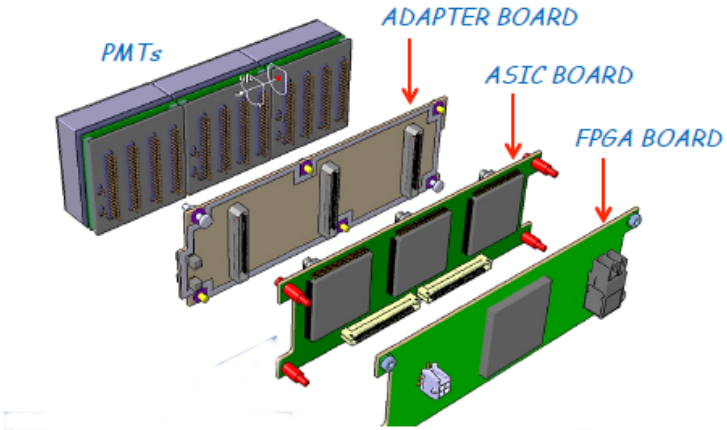


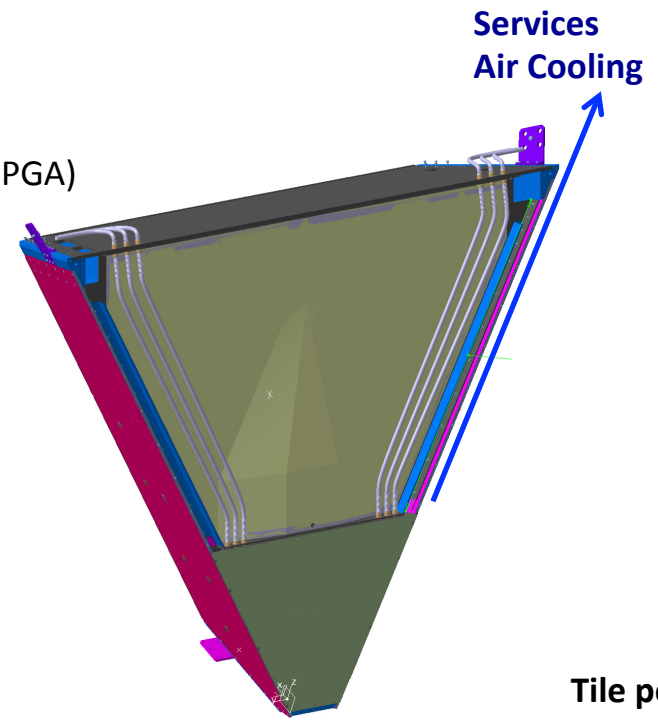


RICH Readout Electronics

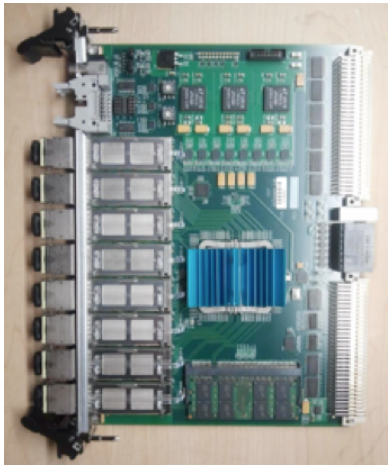
Readout Electronics

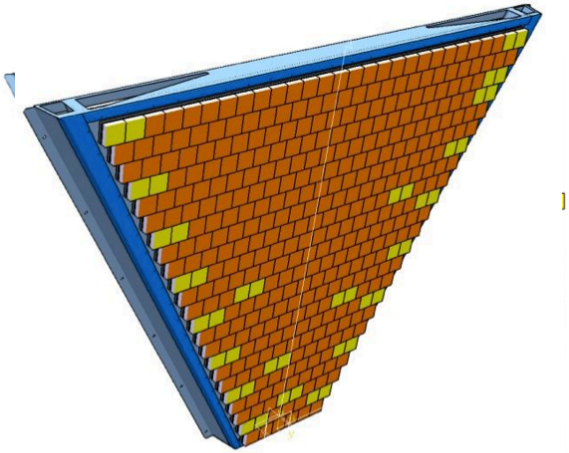
Compact (matches sensor area)
Modular Front-End (Mechanical adapter, ASIC, FPGA)
Scalable fiber optic DAQ (TCP/IP or SSP)
Tessellated (common HV, LV and optical fiber)



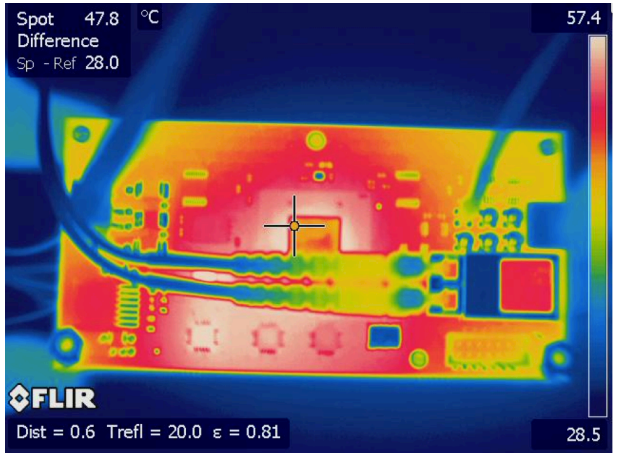


SSP Fiber-Optic DAQ

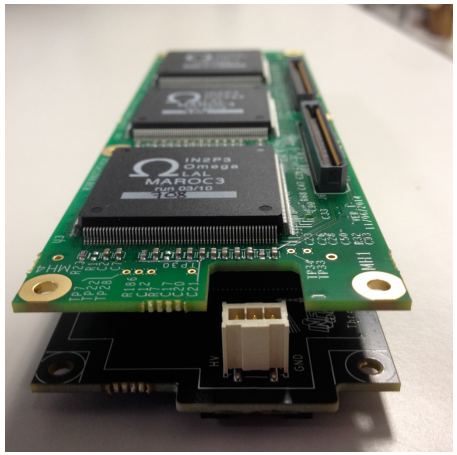


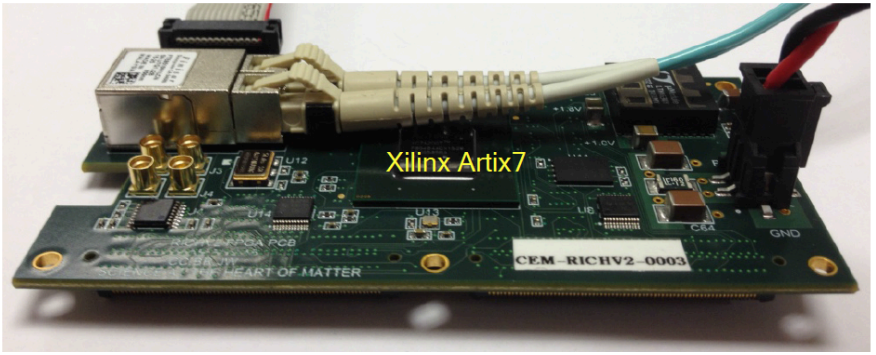


Tile power dissipation ~ 3.5 W



RICH Front-End Electronics





example of MAROC signal processing

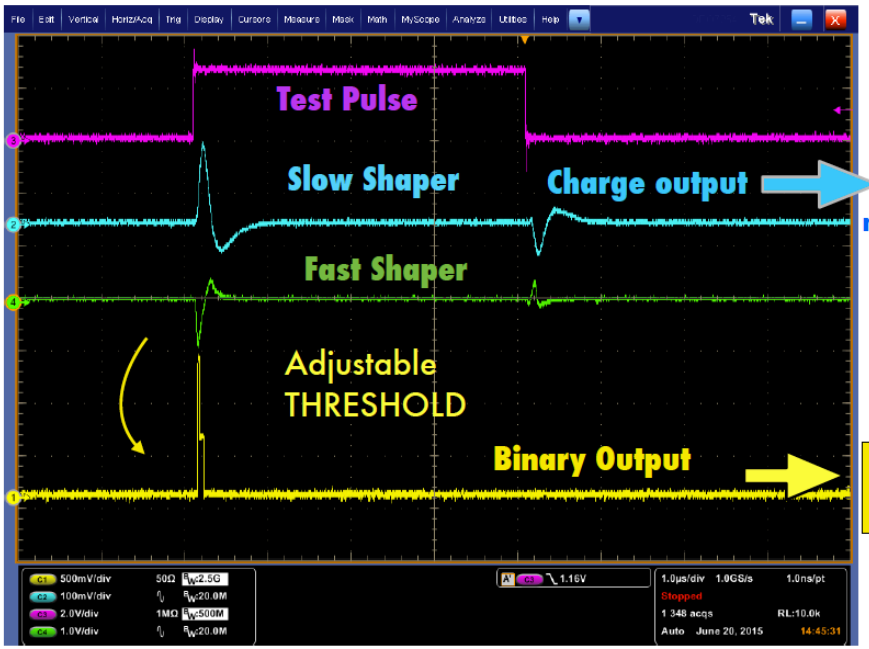
Analog: Charge (1 fC)
Digital: Time (1 ns)

Trigger latency (8 μs)

Optical ethernet (2.5 Gbps)

Trigger: external
internal
self

On-board pulser



ADC
(MAROC)
calibration only
more on backup slide

SCALER/TDC
(FPGA)

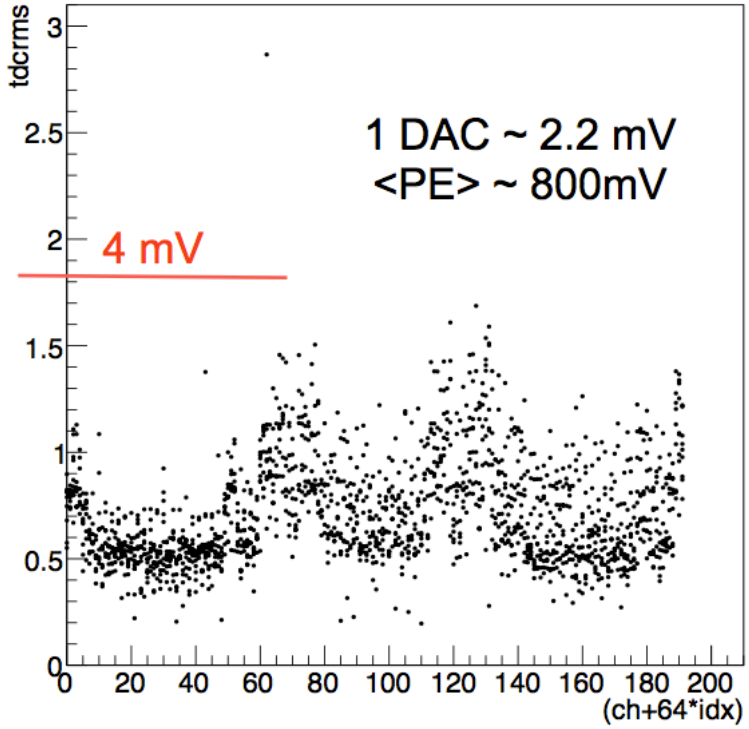
TDC used for physics runs!

Single channel response, 1 microsecond/div

FE Electronics: Digital Readout

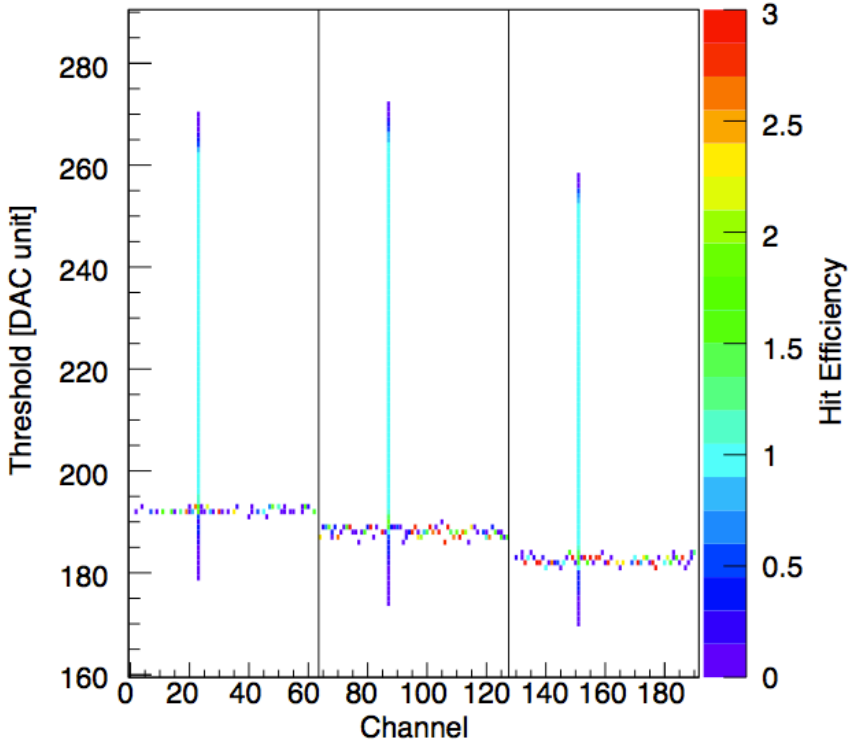
During Acceptance tests

Pedestal level 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

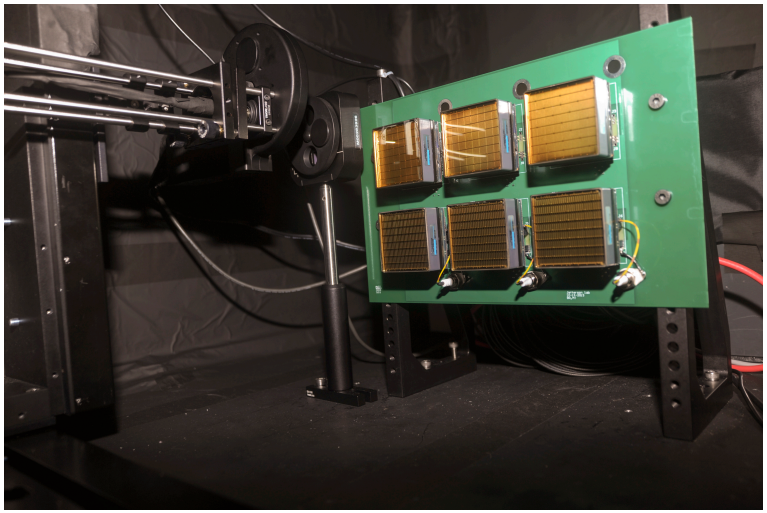
FE Electronics: Charge

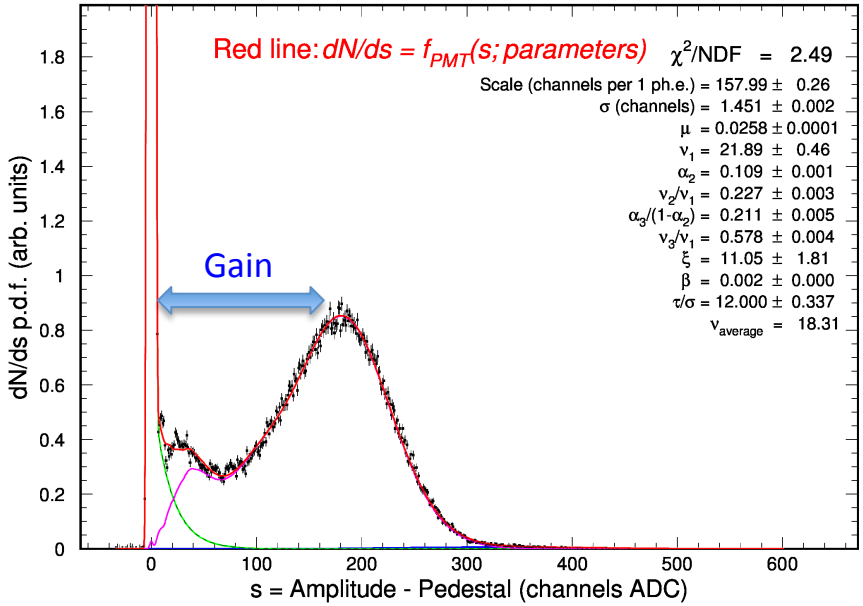
Multiplexed readout up to 50 kHz

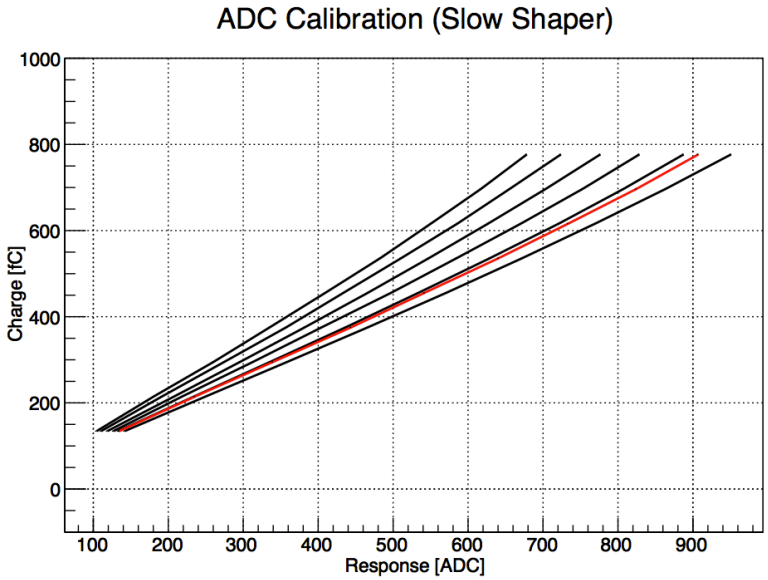
High resolution SPE spectrum

Viable for efficiency and gain monitors

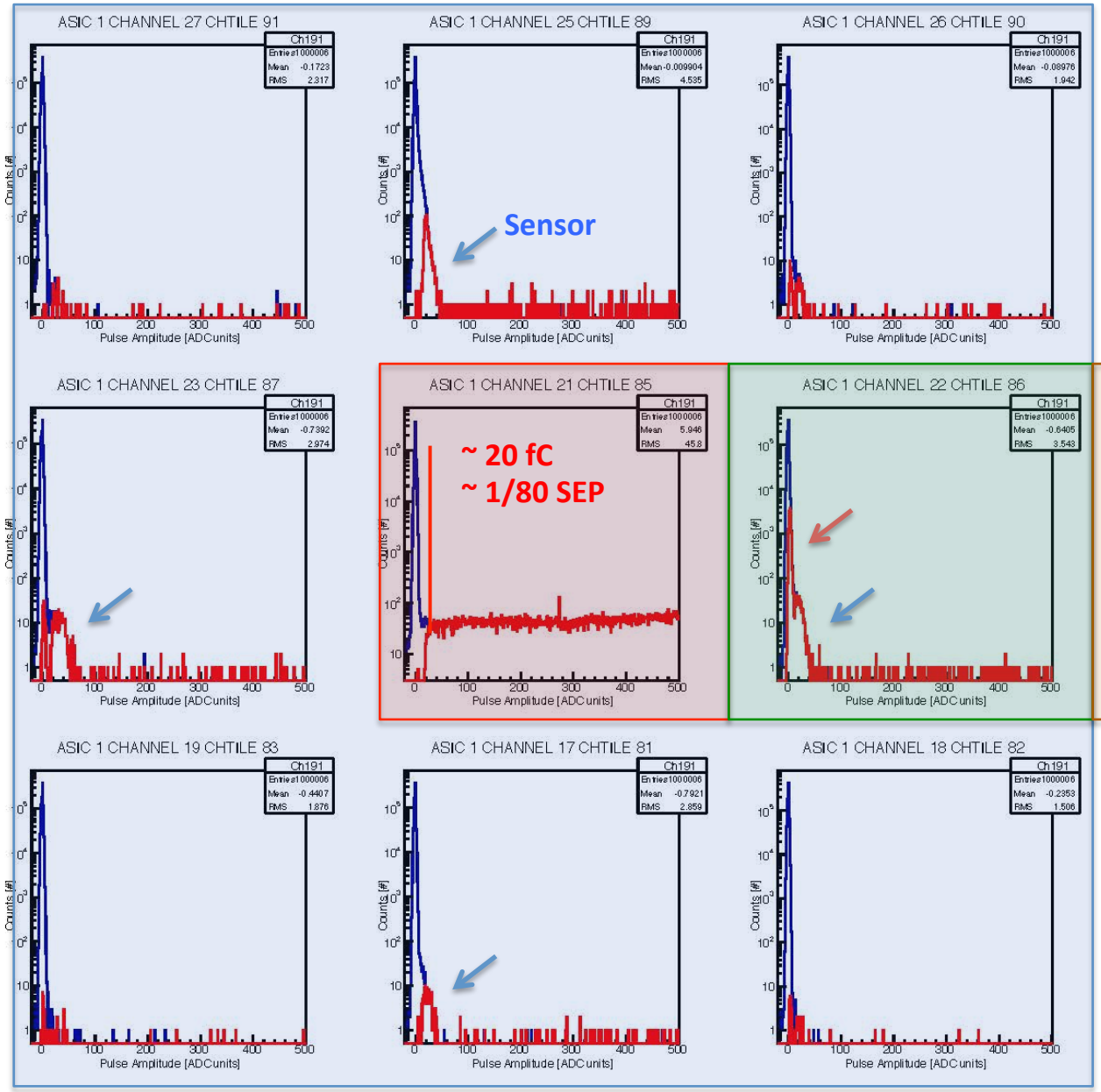
In conjunction with timing, allows the study of PMT discharge and cross-talk





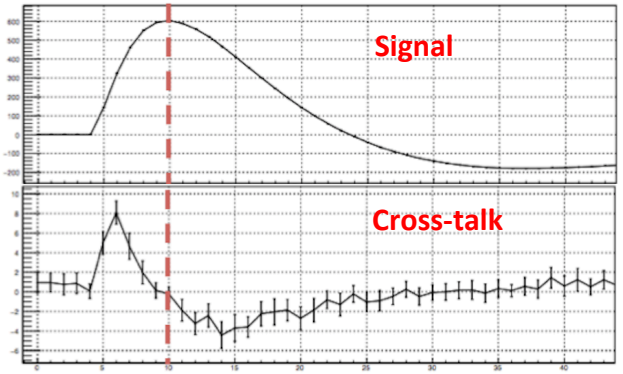


RICH Electronic: Cross-talk

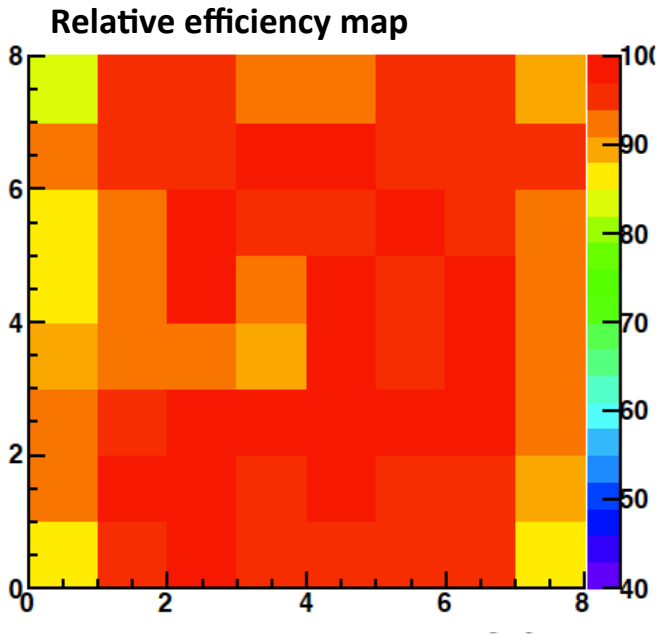


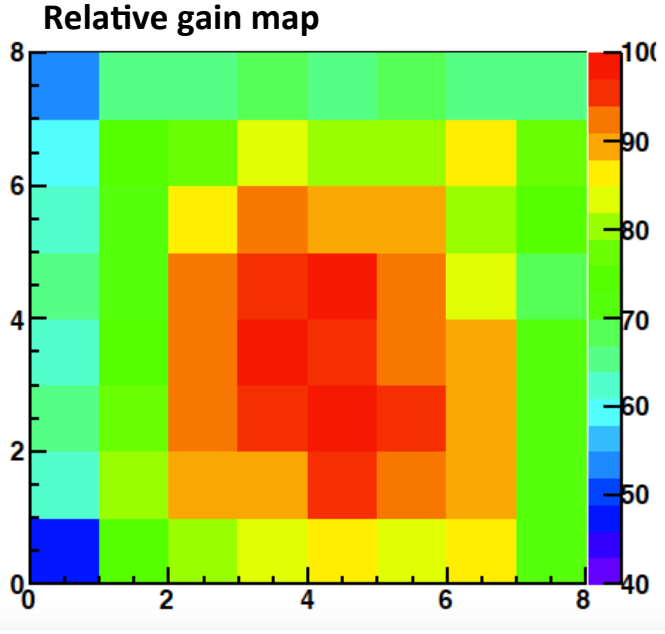
GA0501

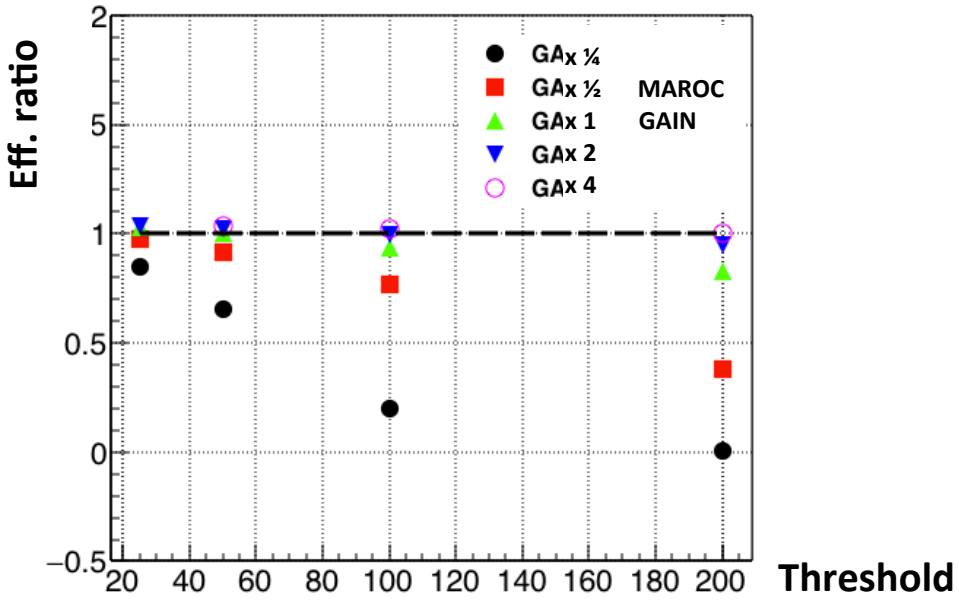
95	93	94	92	96	98	97	99
91	89	90	88	100	102	101	103
87	85	86	84	104	106	105	107
83	81	82	80	108	110	109	111
79	77	78	76	112	114	113	115
75	73	74	72	116	118	117	119
71	69	70	68	120	122	121	123
67	65	66	64	124	126	125	127

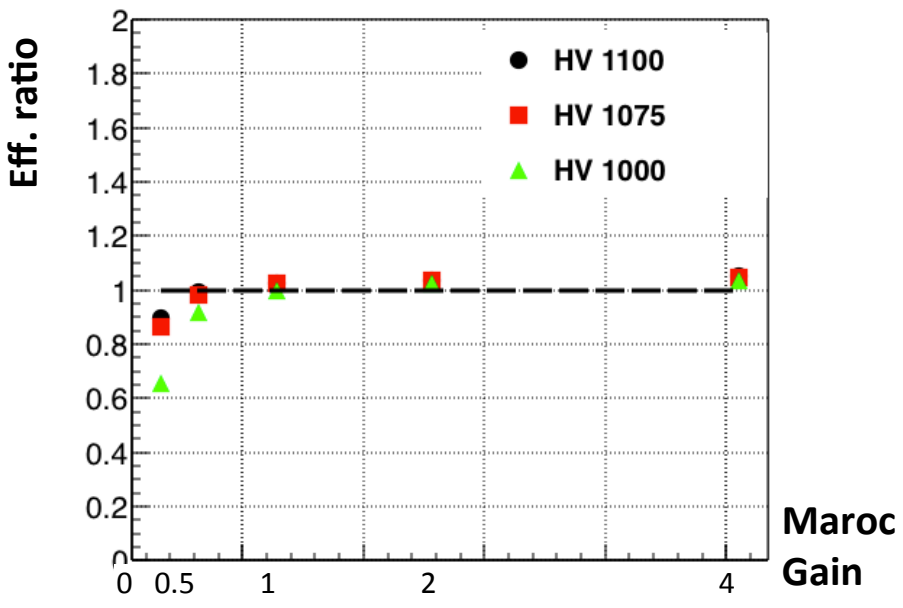


FE Electronics: SPE Discrimination



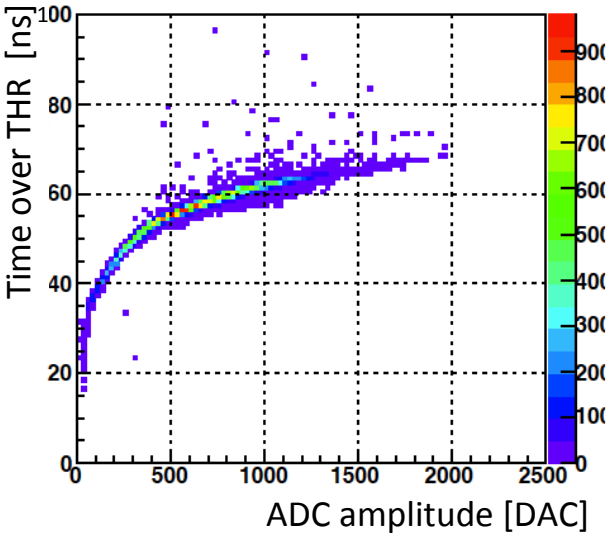




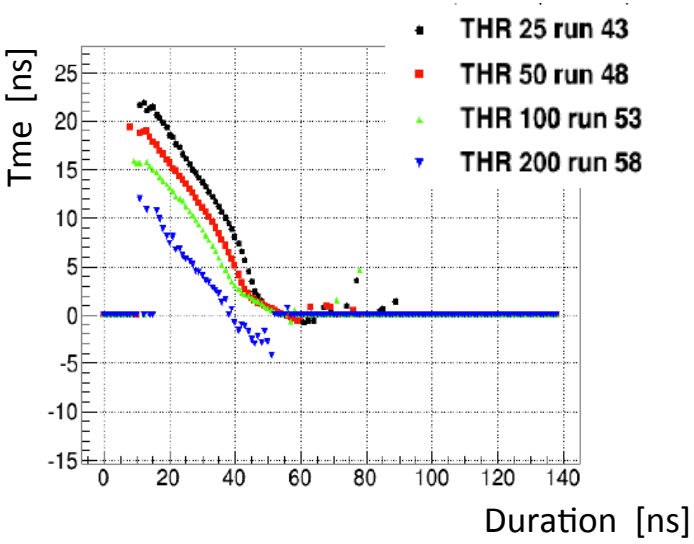


FE Electronics: SPE Timing

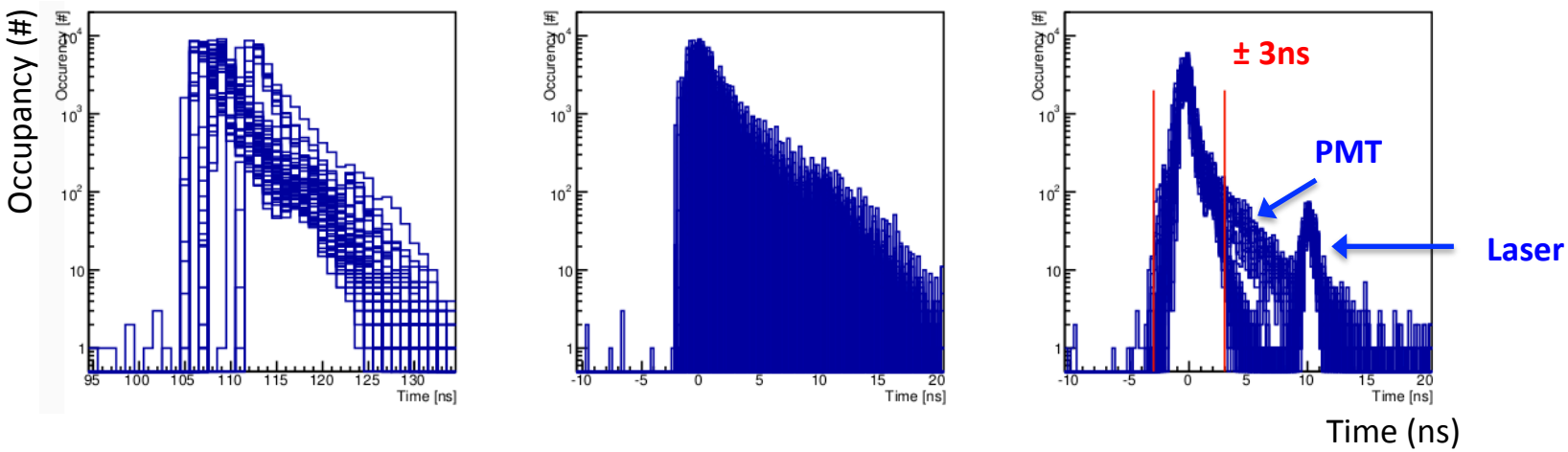
Time over threshold relates to charge



Typical time-walk with charge

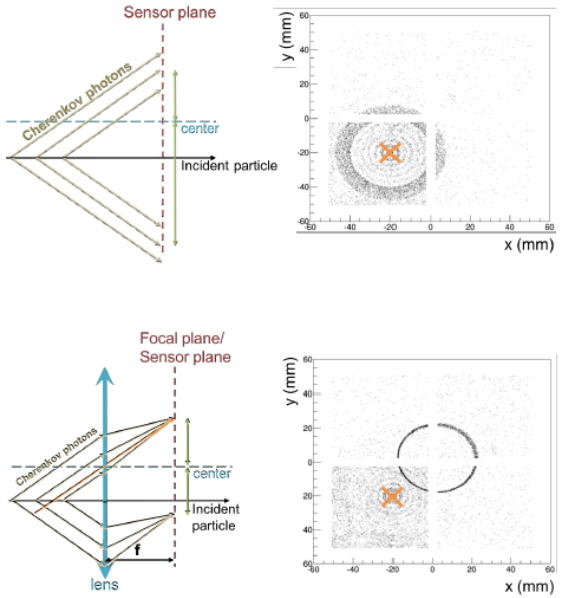


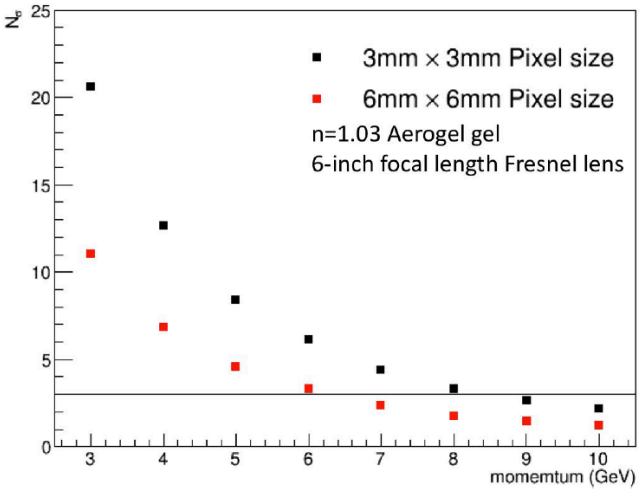
Channel by channel time calibration: **-offsets** **-walk**



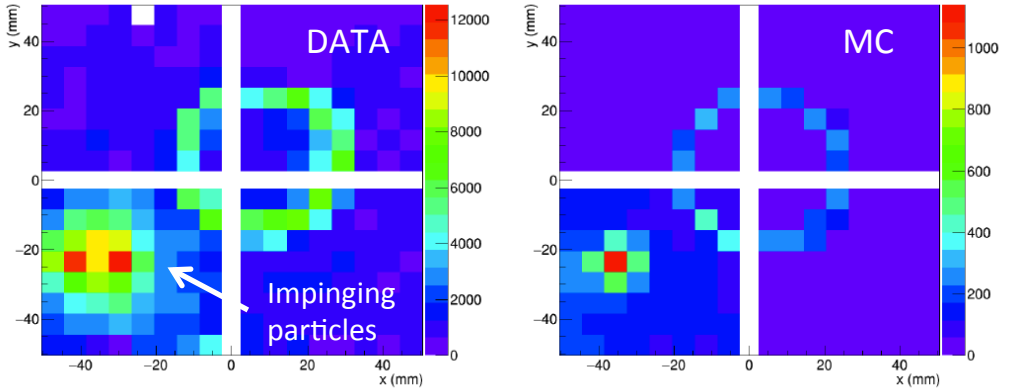
Application: Modular RICH @ EIC

Fresnel lens focalization concept for a compact (short gap) device

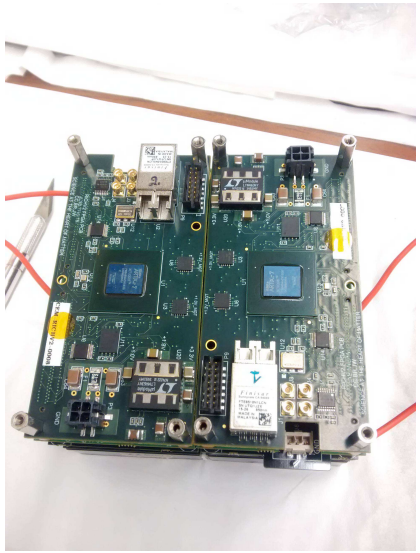


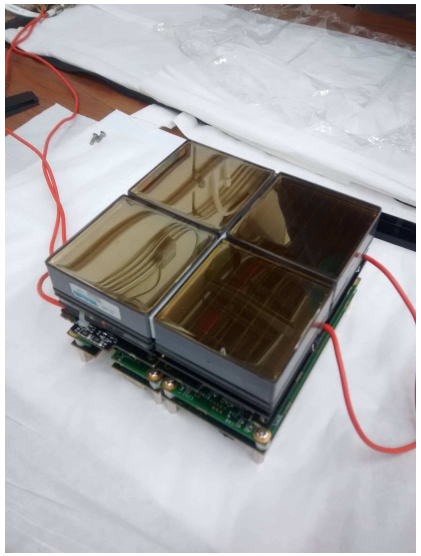


Test beam of small EIC mRICH prototype Fermilab – April 16

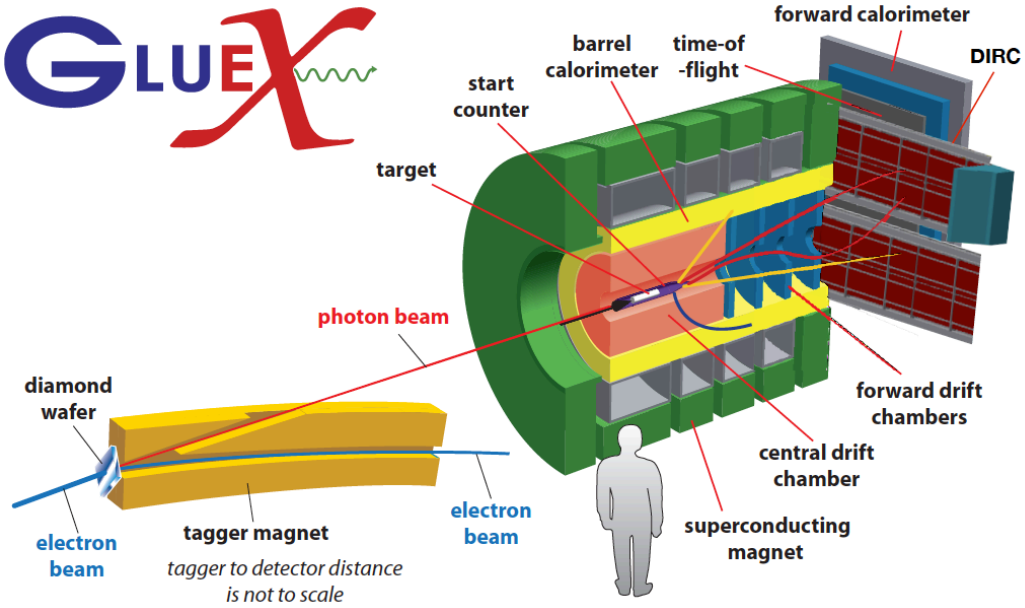


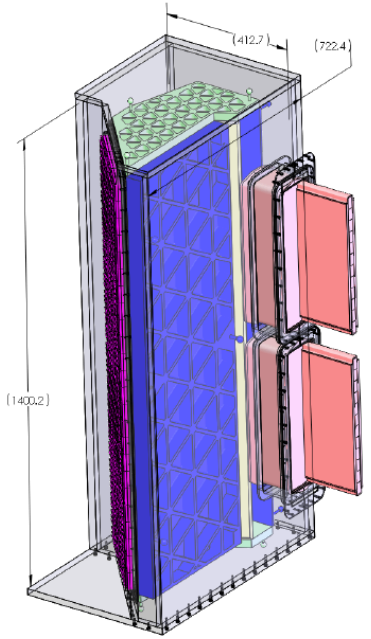
CLAS12 MAPMTs and readout electronics



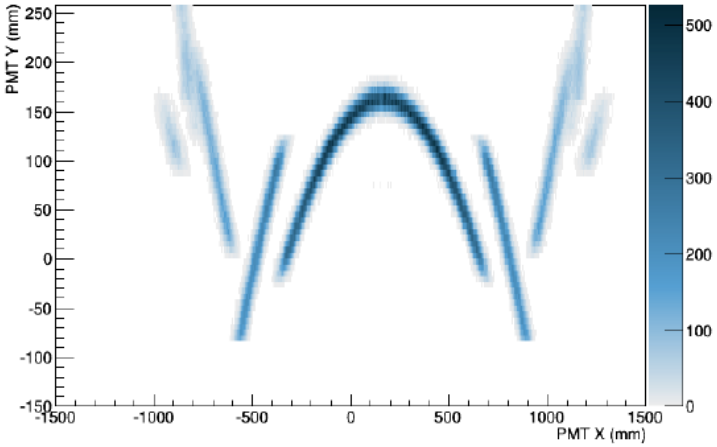


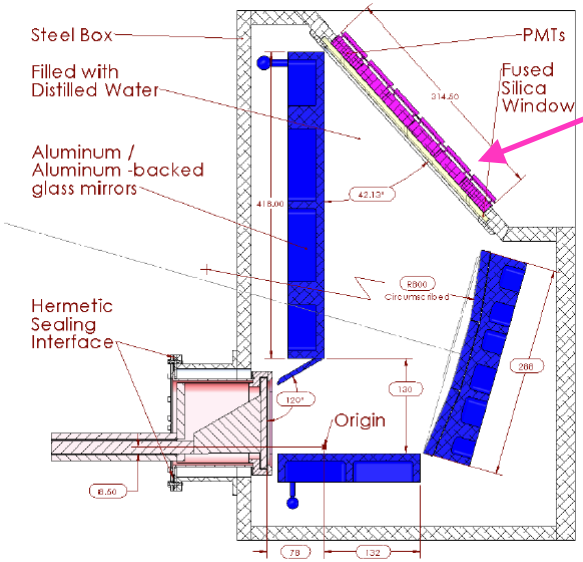
Application: DIRC @ GlueX





Hadron discrimination up to 4 GeV/c





H12700 + CLAS12 readout

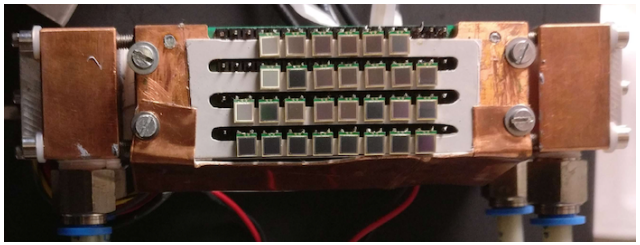
Photon Sensor: SiPM

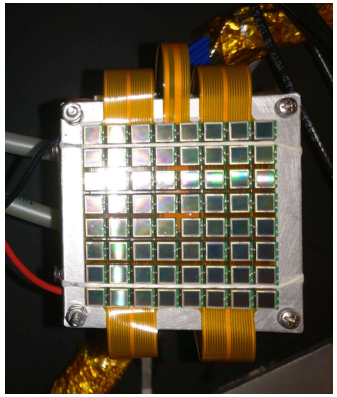
SiPMs

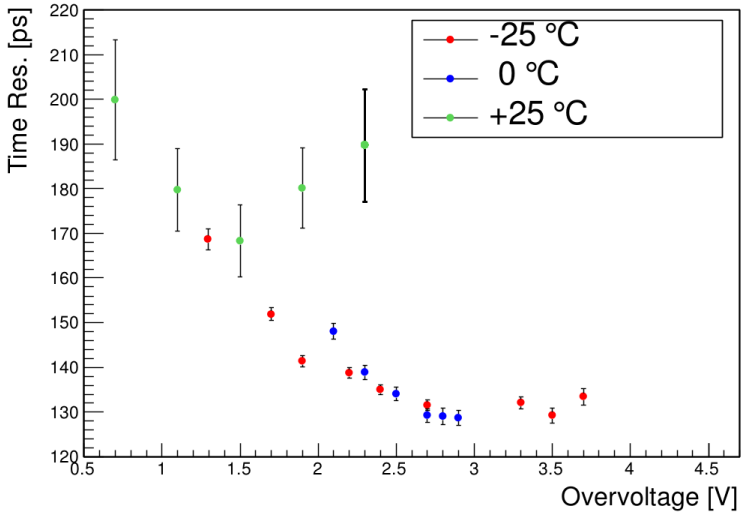
- ✓ Mass production technology
- ✓ Photon counting
- ✓ Excellent time resolution
- ✓ Compatible with magnetic field

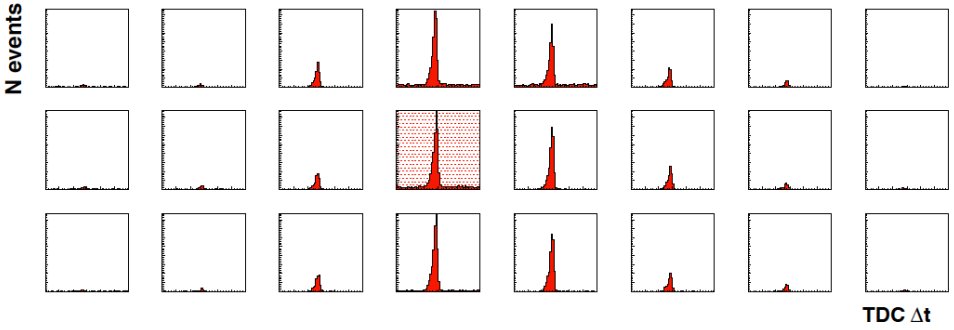
- ✓ High dark rate
- ✓ Low radiation tolerance

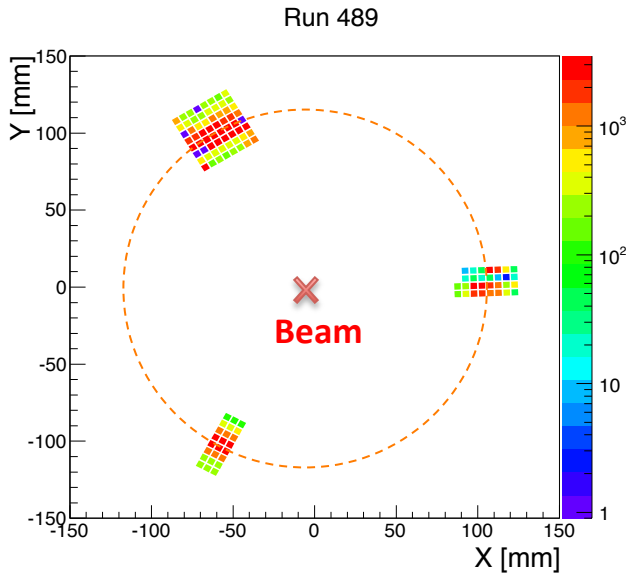
Work at low temperature











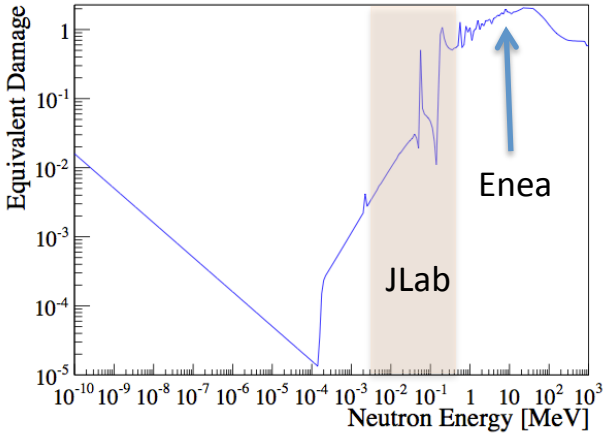
Photon Sensor: SiPM

Neutrons produced isotropically through

d(230keV) t → n α

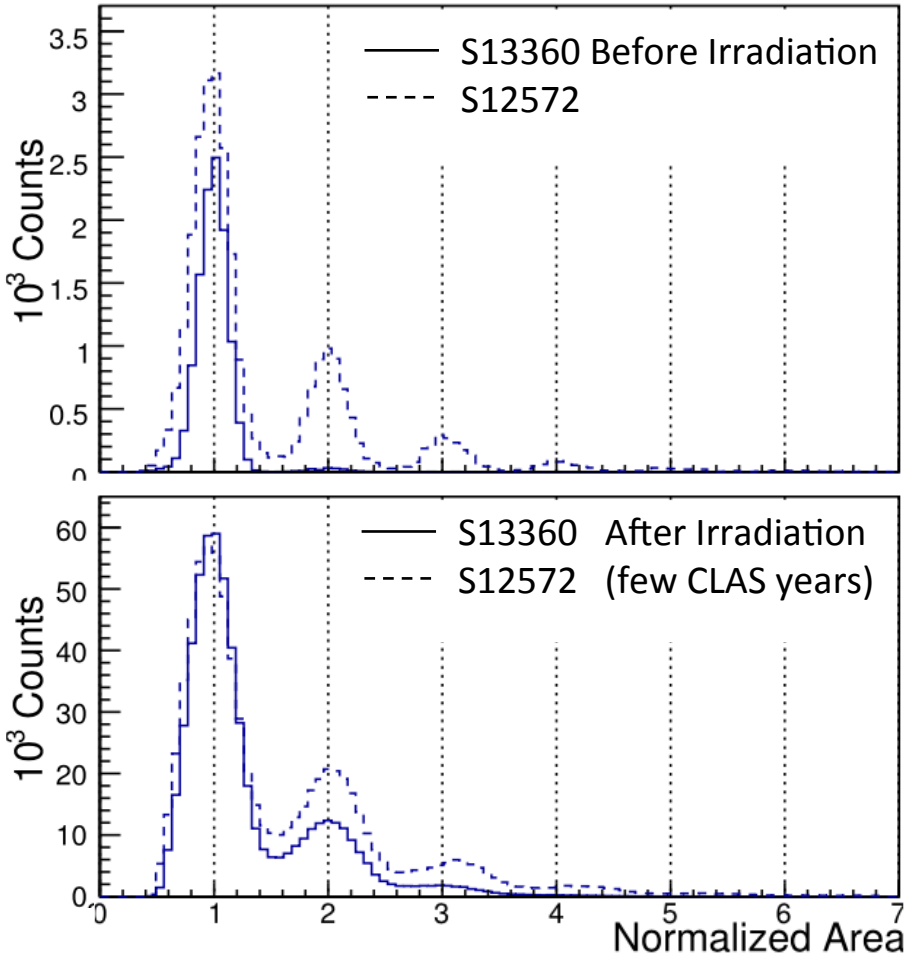
α particles measured to monitor the intensity

- max flux 10^{11} s^{-1} in 4π
- max neutron energy 14.6 MeV

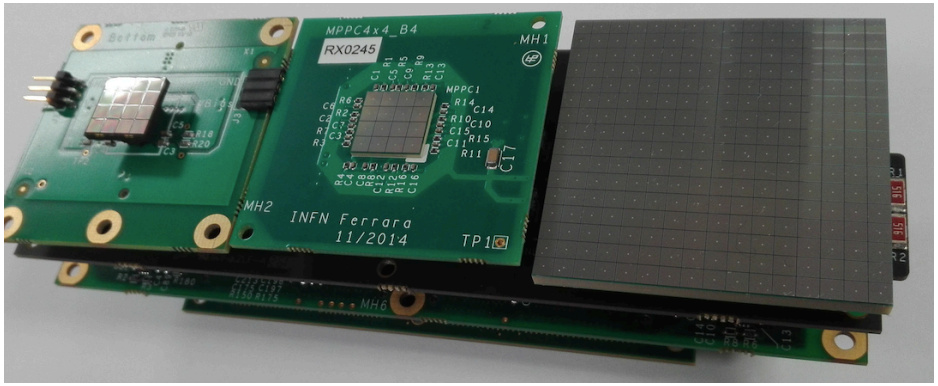


Single-photon capability after irradiation ?

S12572 standard technology
S13360 trench technology

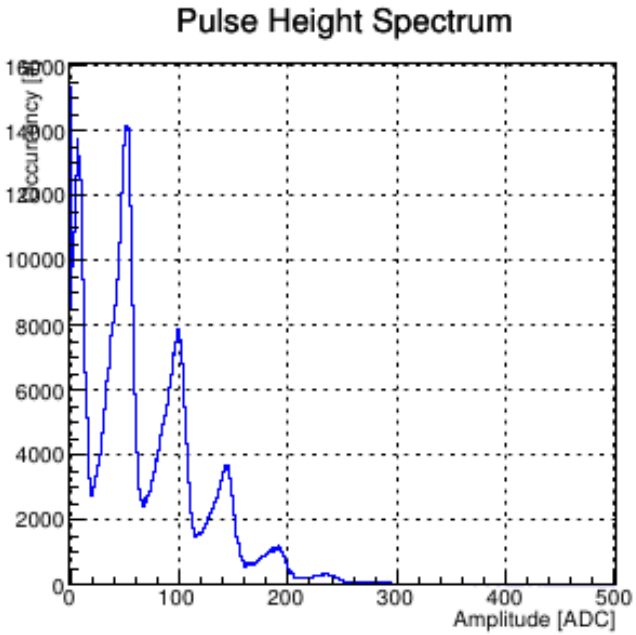


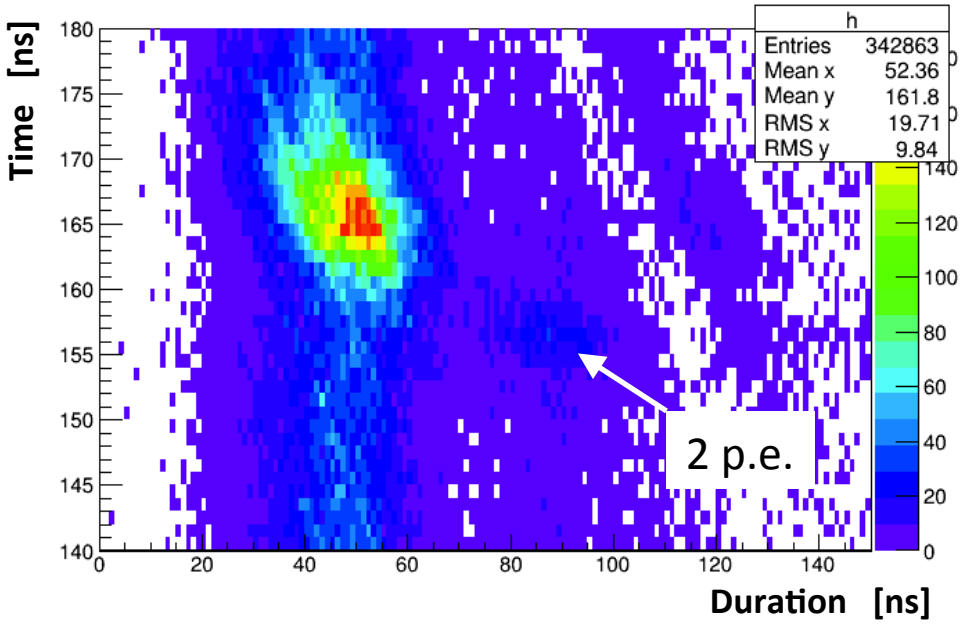
FE Electronics: SiPM



Photon counting with
ADC charge measurement

Single photon discrimination with
TDC time measurement





Conclusions

The CLAS12 RICH is 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

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

- 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)
- Discrimination down to few % of SPE
- Time resolution of 1 ns
- Charge measurement (multiplexed ADC or time-over-threshold)

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