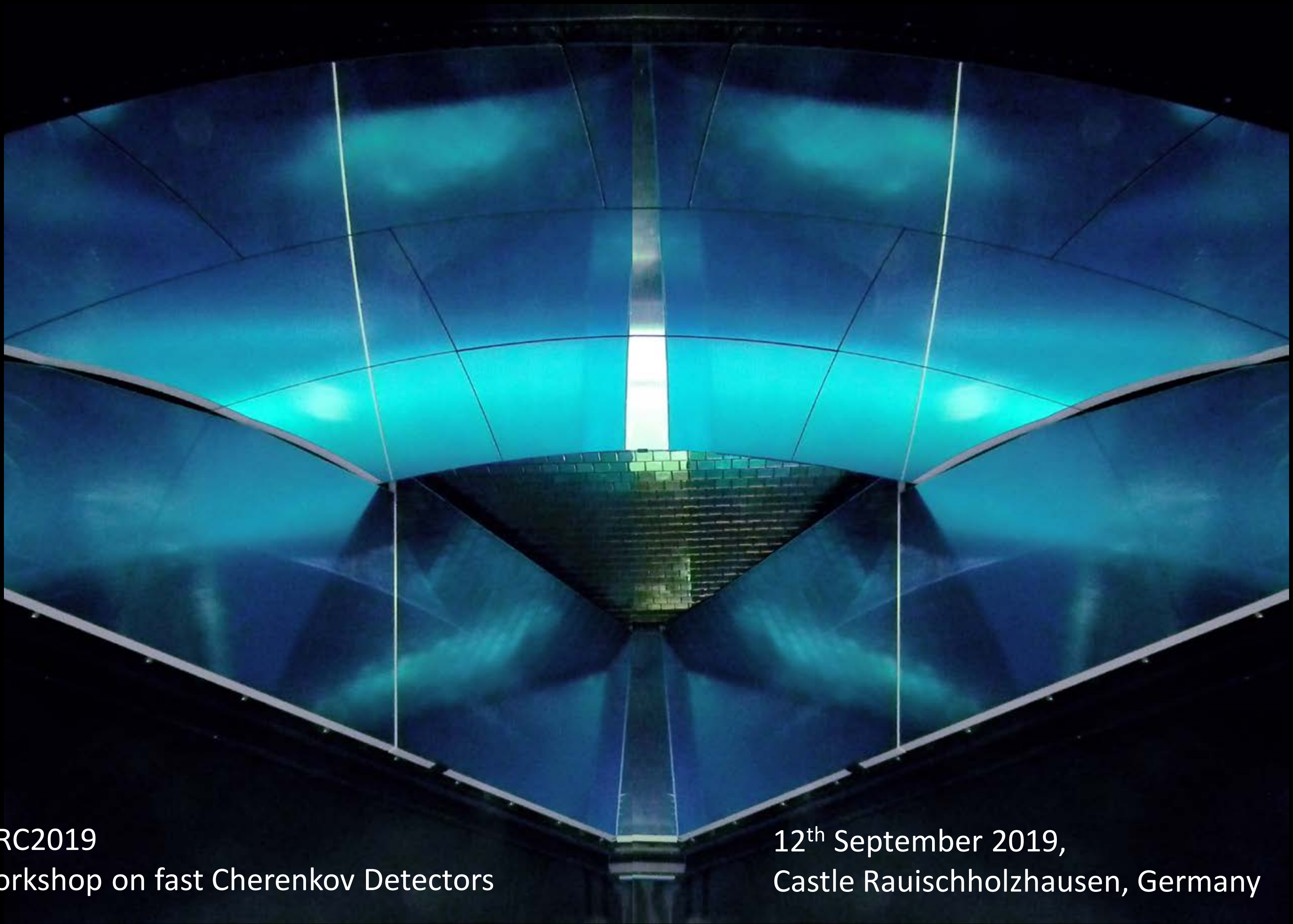
Single Photon Imaging with the CLAS12 RICH Detector

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

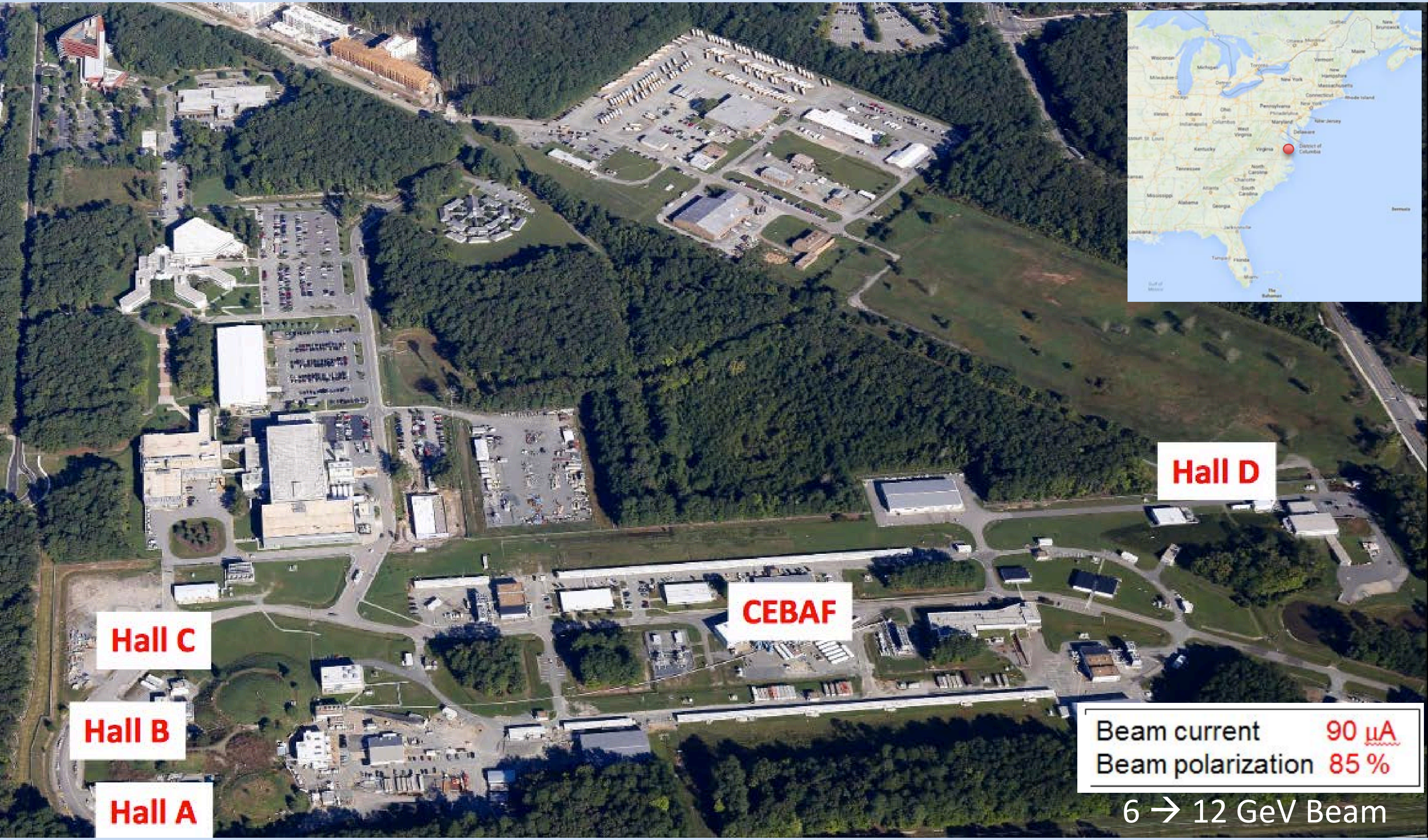


DIRC2019
Workshop on fast Cherenkov Detectors

12th September 2019,
Castle Rauischholzhausen, Germany

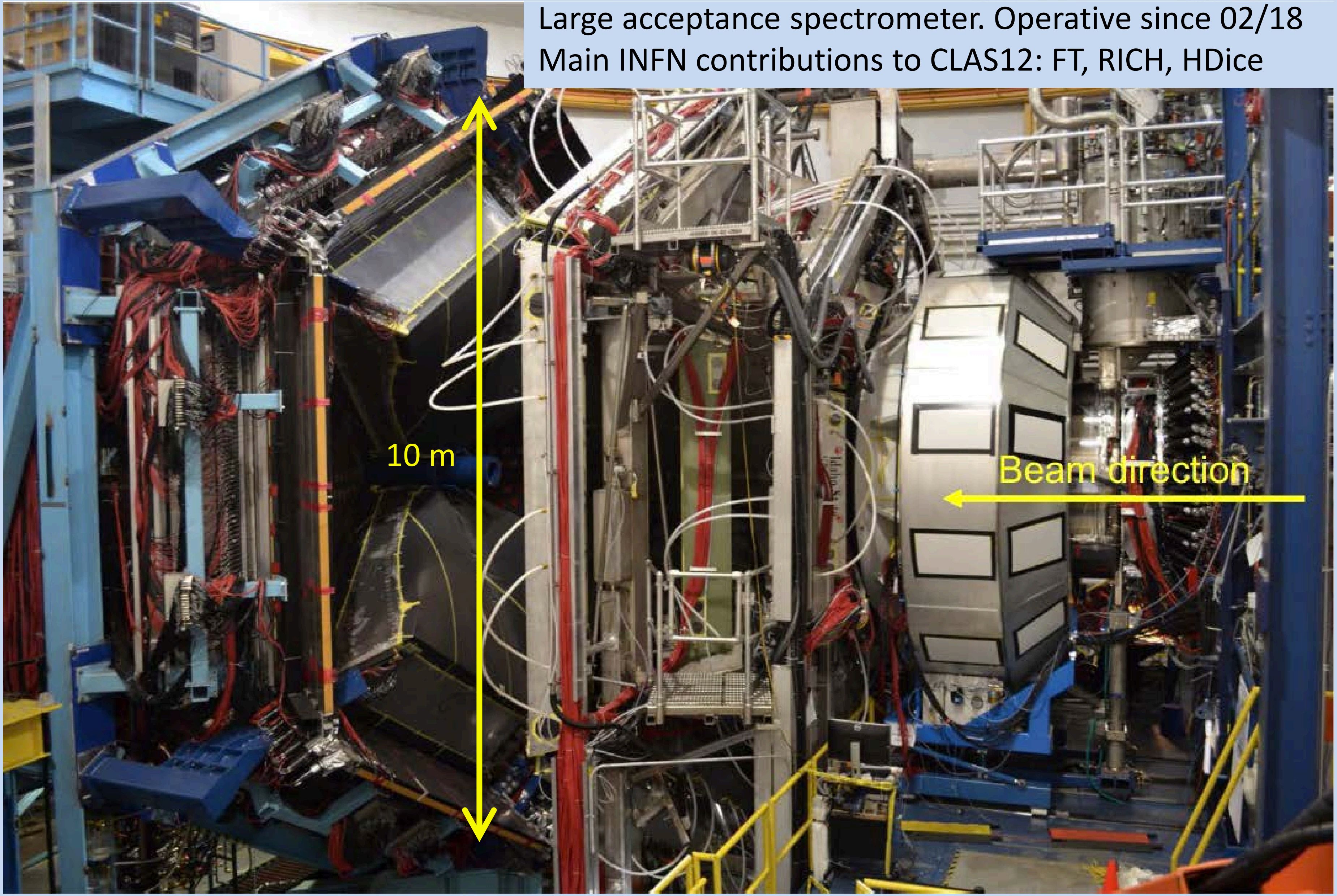
Jefferson Lab

Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

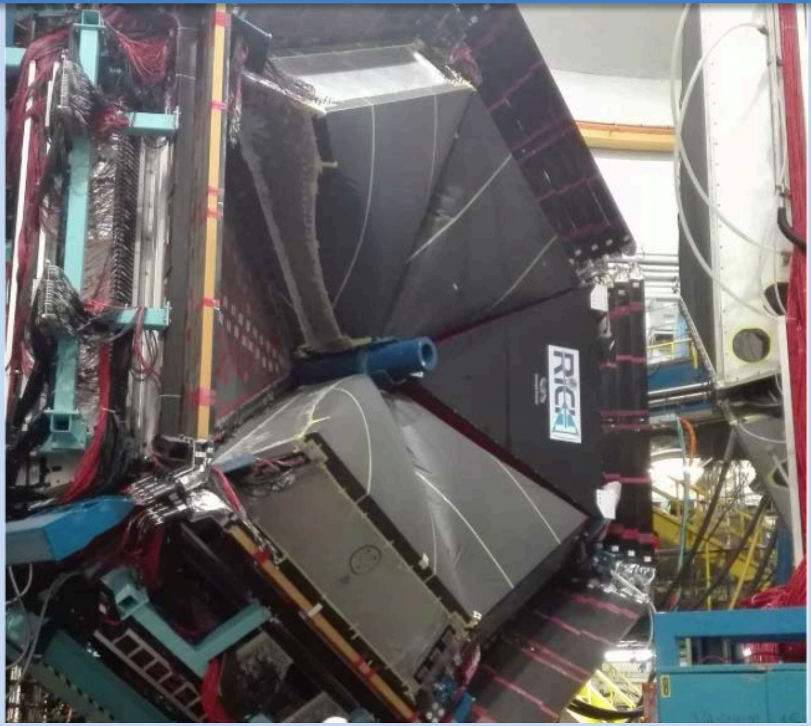


CLAS12 in Hall-B

Large acceptance spectrometer. Operative since 02/18
Main INFN contributions to CLAS12: FT, RICH, HDice

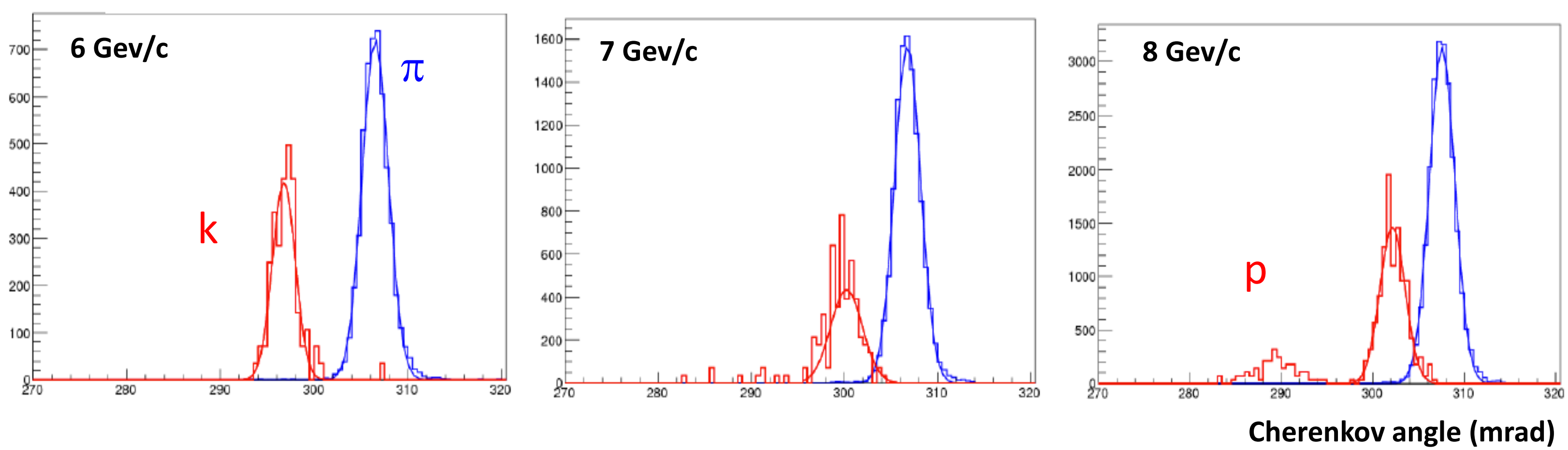


CLAS12 RICH



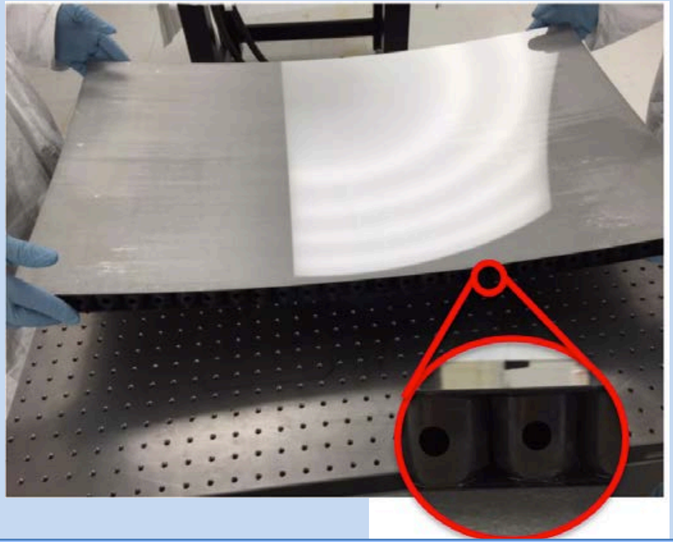
INSTITUTIONS
INFN (Italy) Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Jefferson Lab (Newport News, USA)
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
George Washington University (USA)
Glasgow University (Glasgow, UK)
Kyungpook National University, (Daegu, Korea)
University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

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



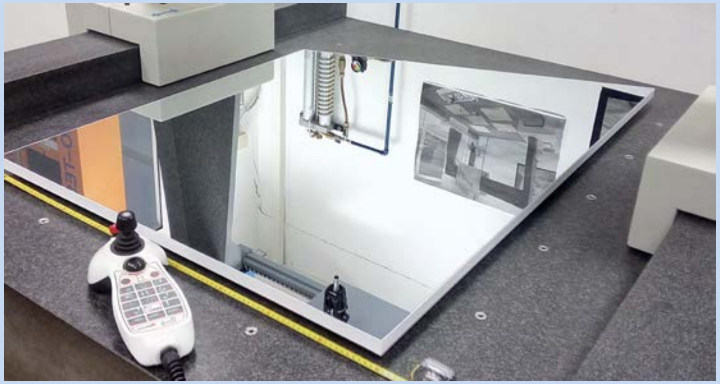
RICH Components

Aeronautic technology for structure
to maximize lightness and stiffness. Trapezoid of composite materials: CFRP inside acceptance, Aluminum outside



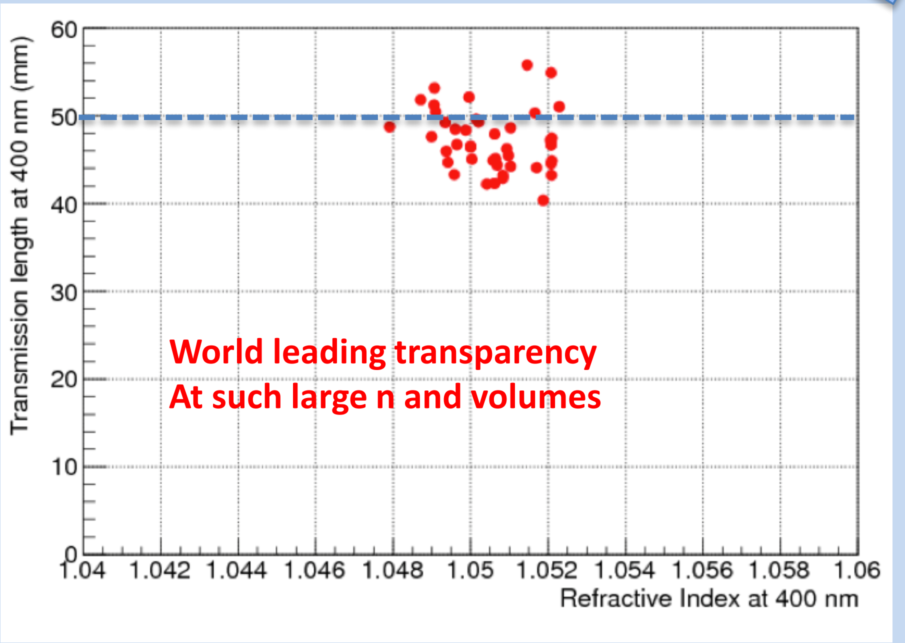
Carbon Fiber Mirrors (spherical)
to maximize lightness and stiffness. Consolidate technology (HERMES, AMS, LHCb) but ~ 30 % material budget reduction

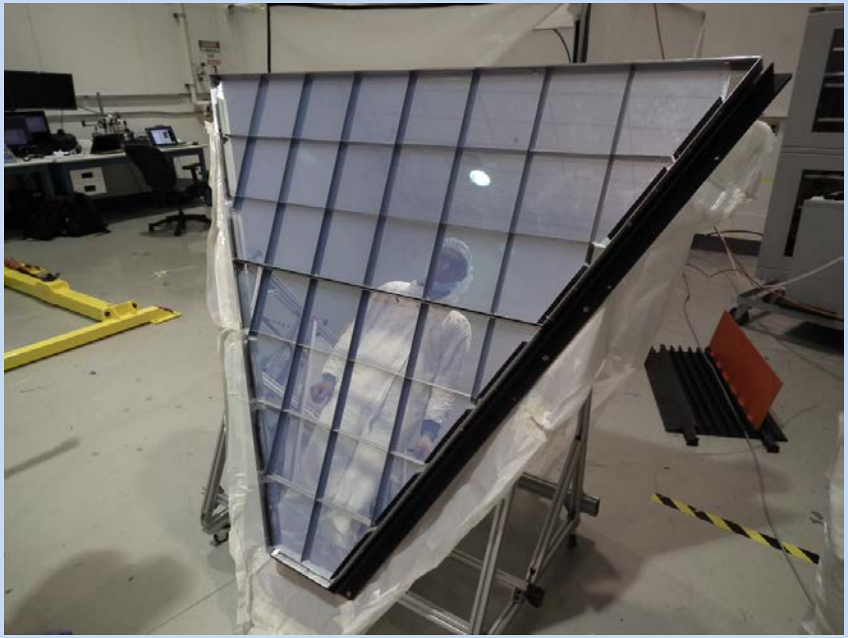
RICH Components



Glass-Skin Mirrors (planar)
Innovative technology never used in nuclear experiments.
1.5 mm outside, 0.7 mm inside acceptance
~ 1/5 cost for squared meter vs CFRP

Large refractive index aerogel radiator
Tiles up to 20x20x3 cm^2 at n=1.05.



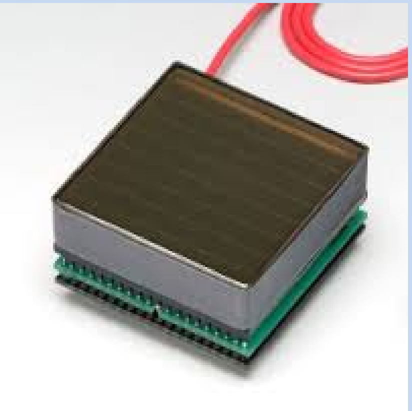


Photon Sensor: MA-PMT

80 H8500 + 350 H12700

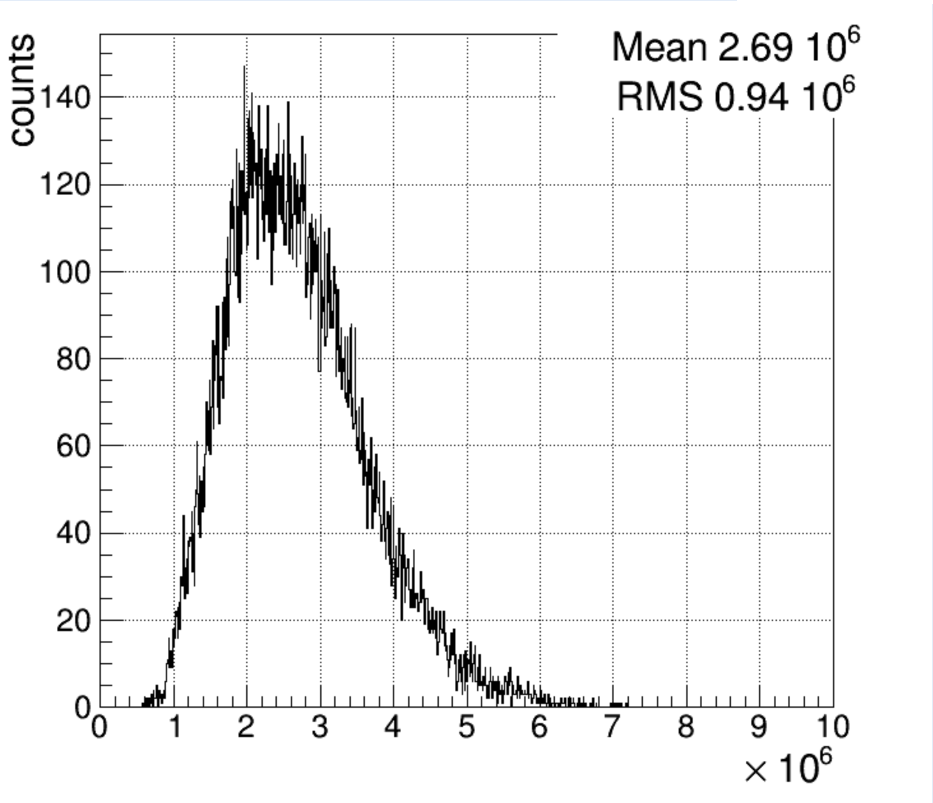
< 1 cm spatial resolution
< 1 ns time resolution
Compatible with the low torus fringe field

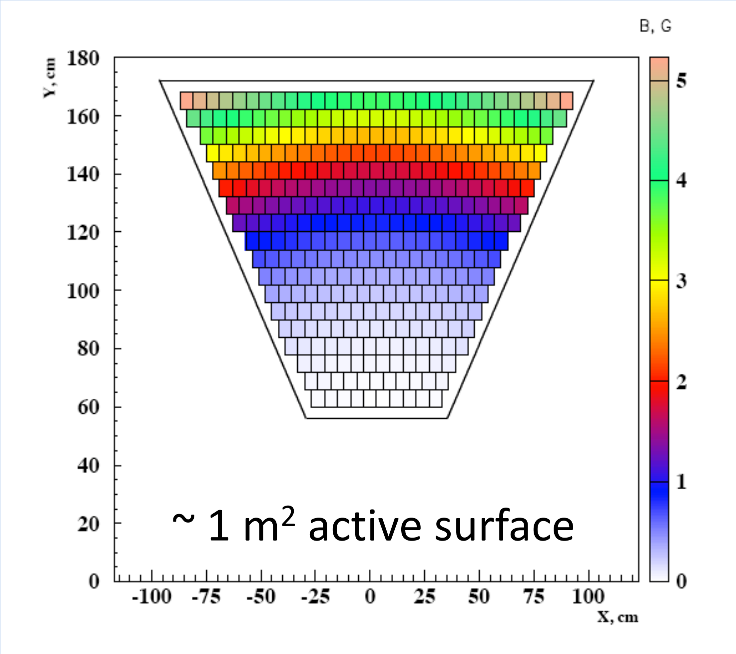
Average MA-PMT gain ~ 2.7 10^6
Corresponds to SPE ~ 400 fC



- ✓ 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

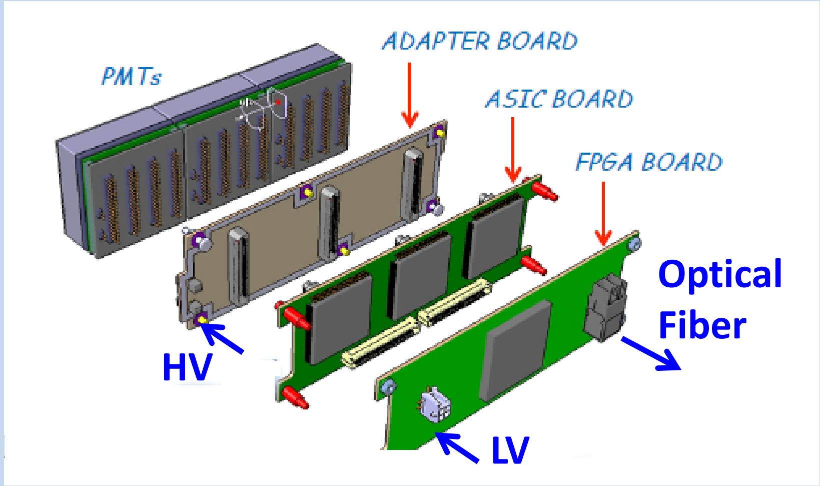
- ✓ Expensive technology





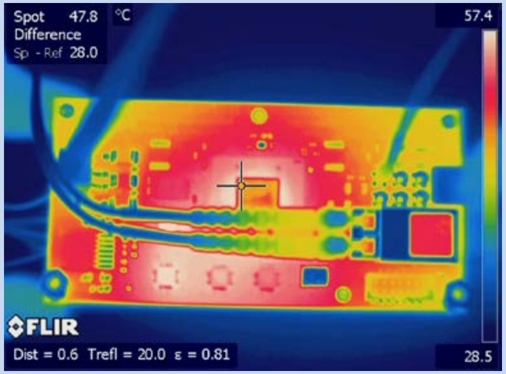
Readout Electronics

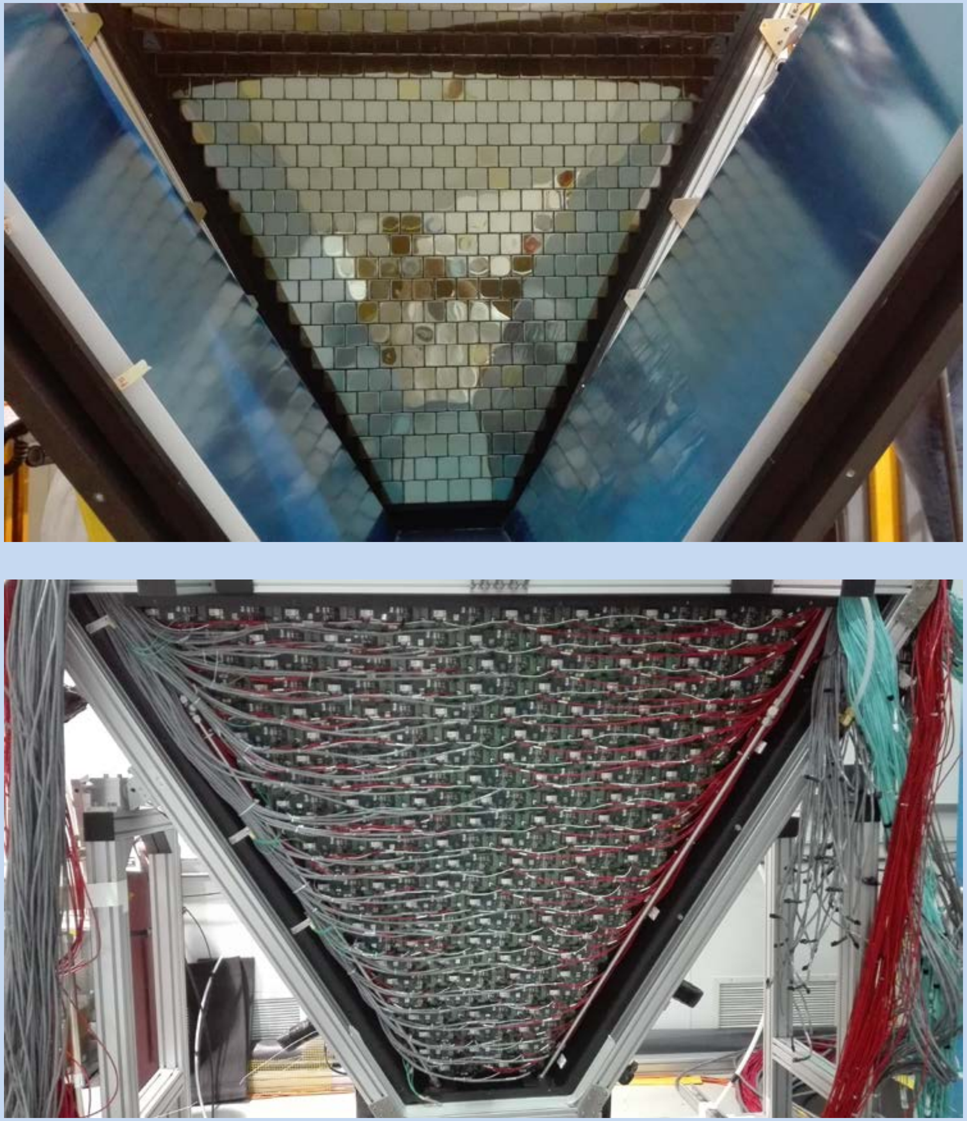
Compact (matches sensor area)
Modular Front-End (Mechanical adapter, ASIC, FPGA)
Scalable fiber optic DAQ (TCP/IP or SSP)
Tessellated (common HV, LV and optical fiber)



SSP Fiber-Optic DAQ

Tile power dissipation ~ 3.5 W





RICH Front-End Electronics

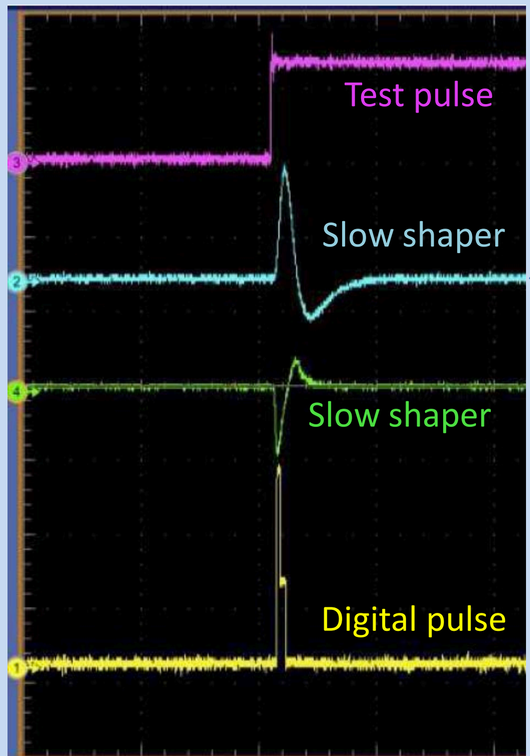
Analog: Charge (1 fC)
Digital: Time (1 ns)

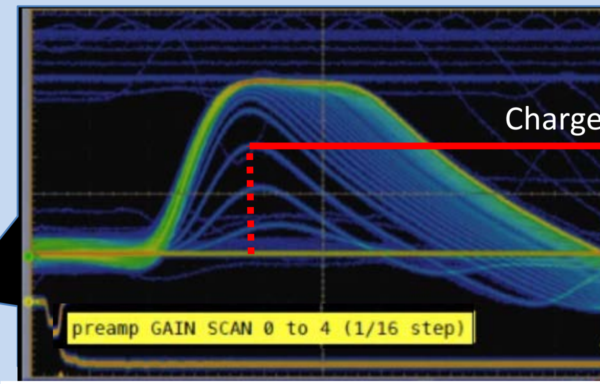
Trigger latency (8 μs)

Optical ethernet (2.5 Gbps)

Trigger: external
internal
self

On-board pulser





Linear response

Multiplexed readout
Limited holding time delays

Used for calibrations

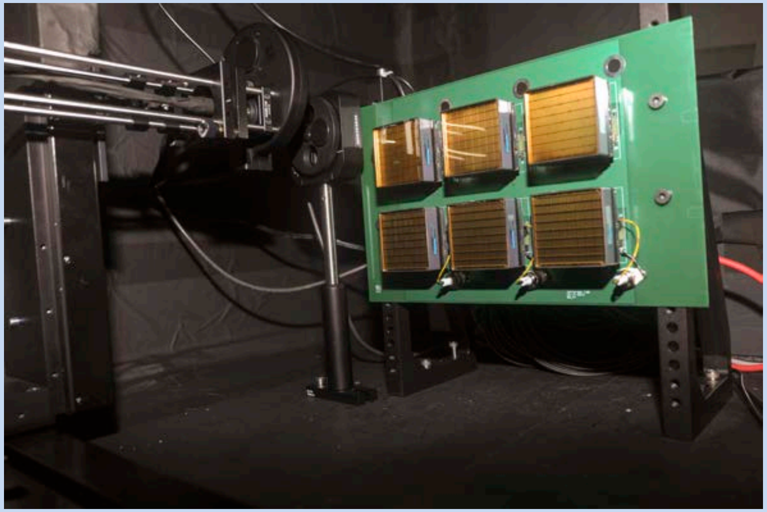
ADC Charge Measurement

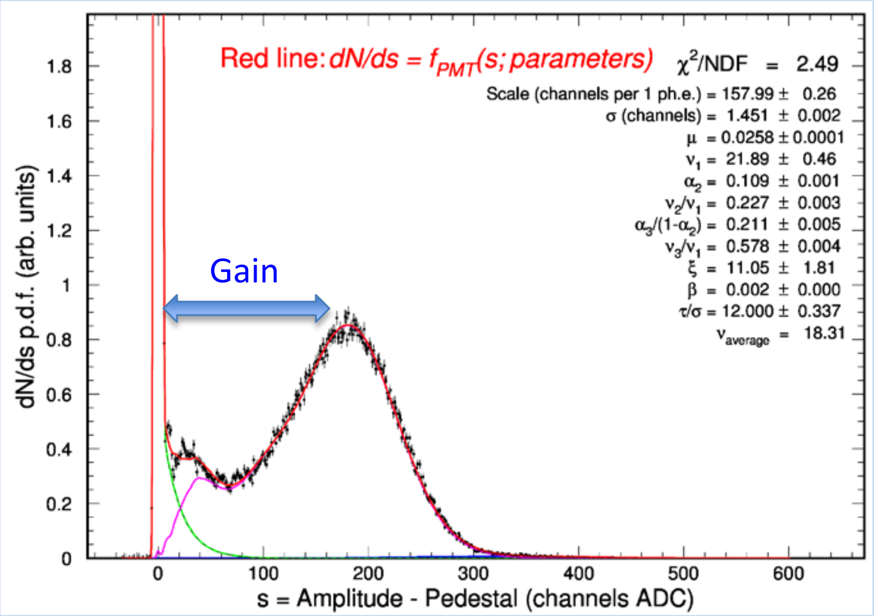
Multiplexed readout up to 50 kHz

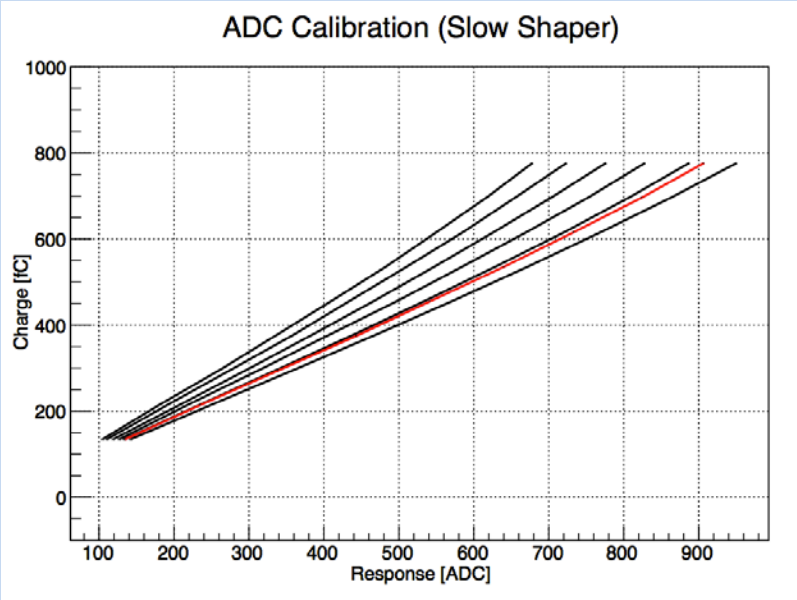
High resolution SPE spectrum

Viable for efficiency and gain monitors

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







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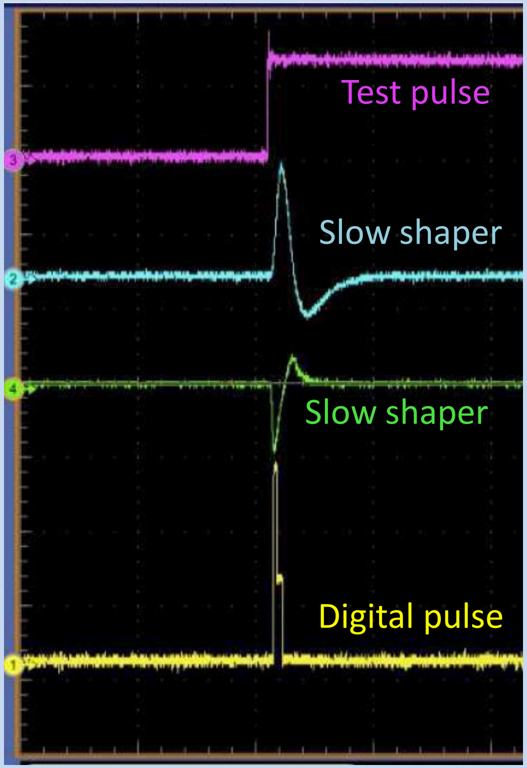
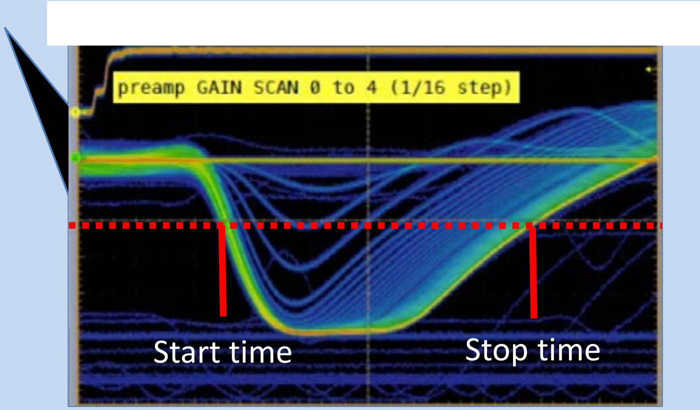


Digital response
Working in saturated regime

64 parallel channel readout

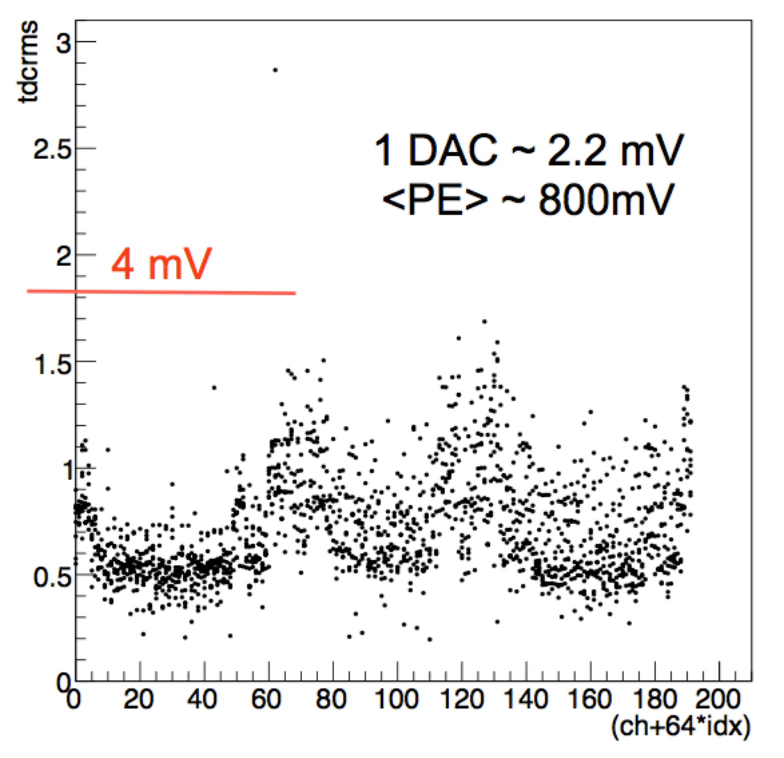
8 μs FIFO and delays
1 ns time resolution



TDC Digital Readout

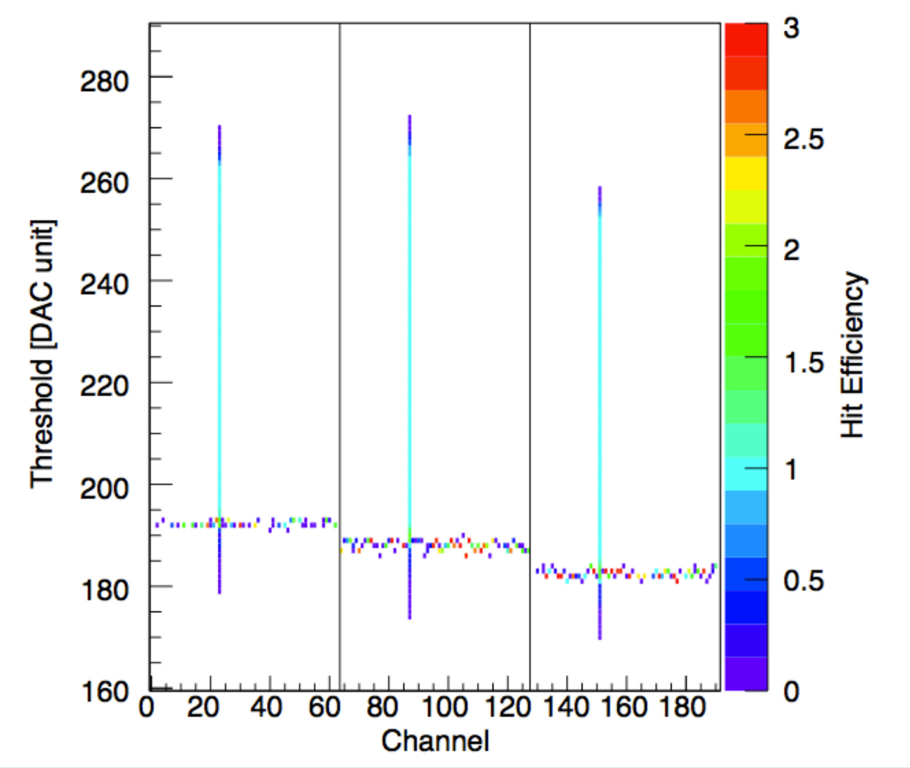
During Acceptance tests

Pedestal rms as seen by a test-point



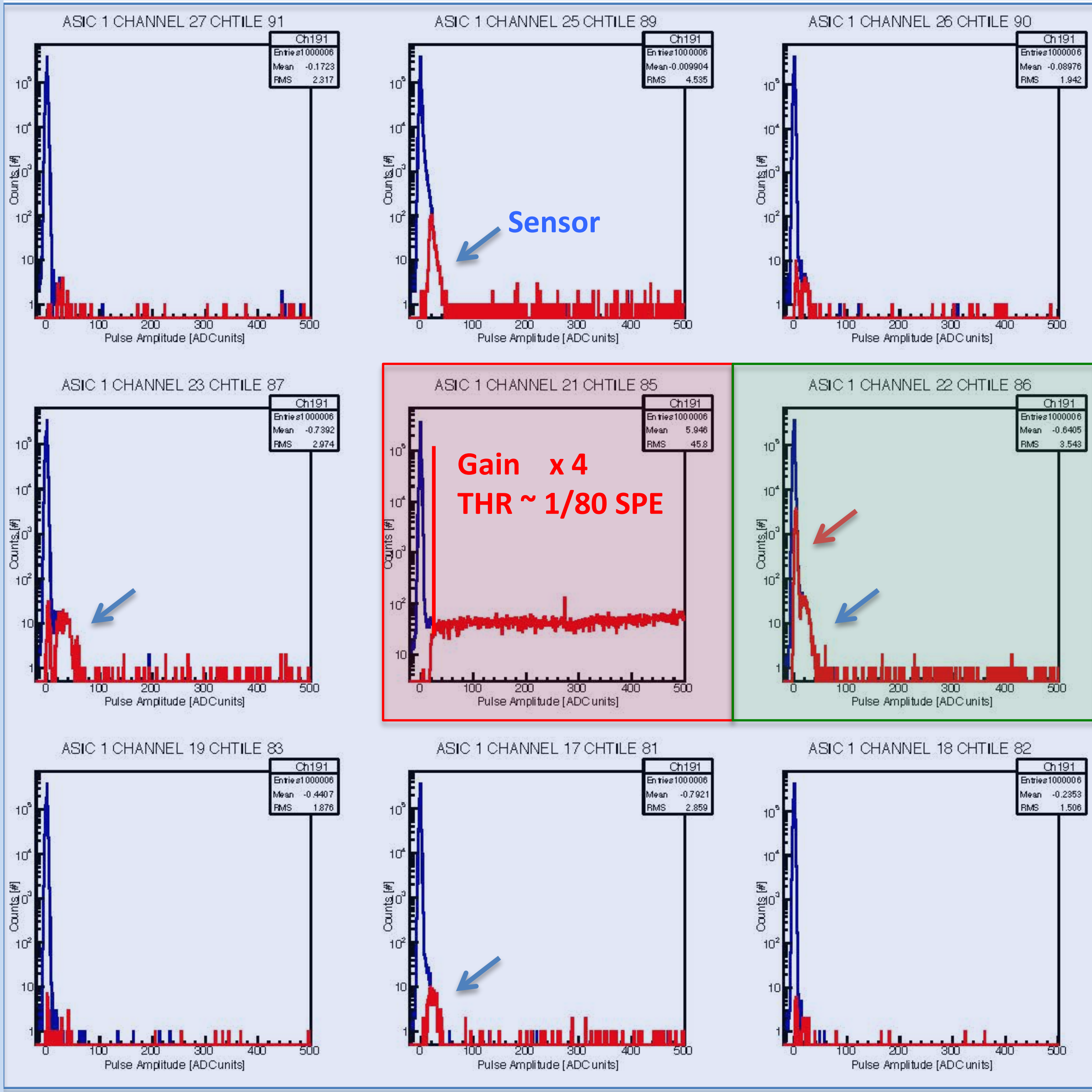
During Internal Pulser Calibration

As seen by RICH readout



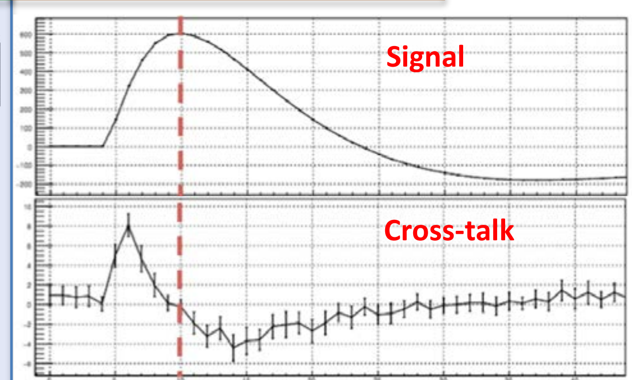
Discrimination down to 20 fC, i.e. few % of SPE, allows sensor characterization

Optical and Electronic Cross-talk



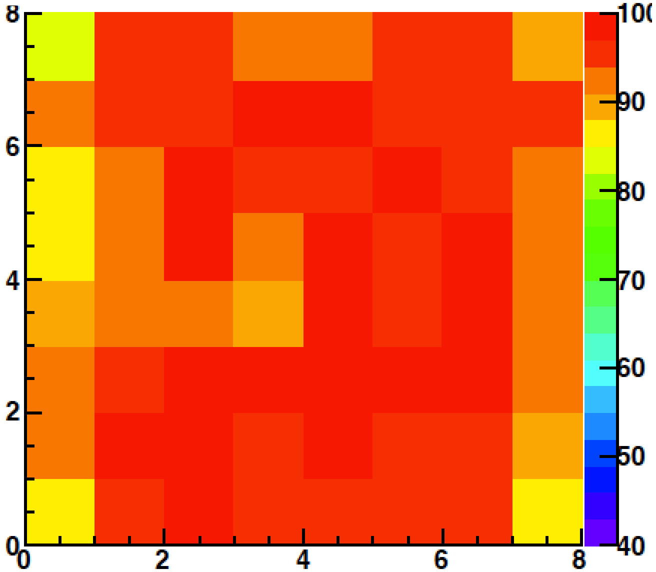
GA0501

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

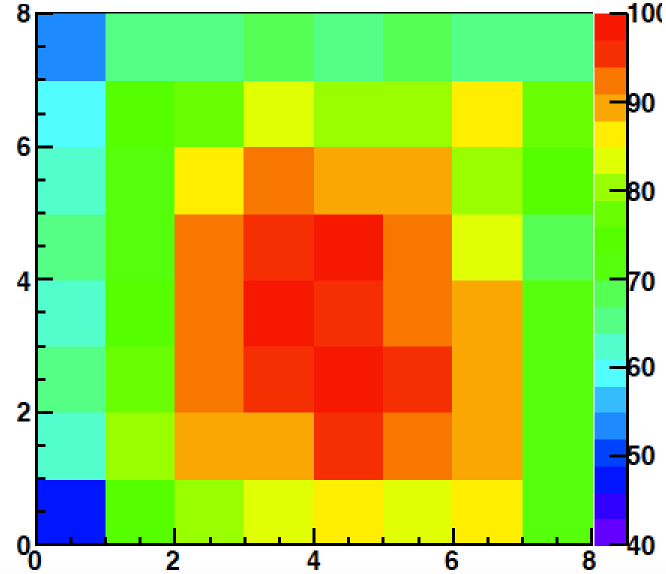


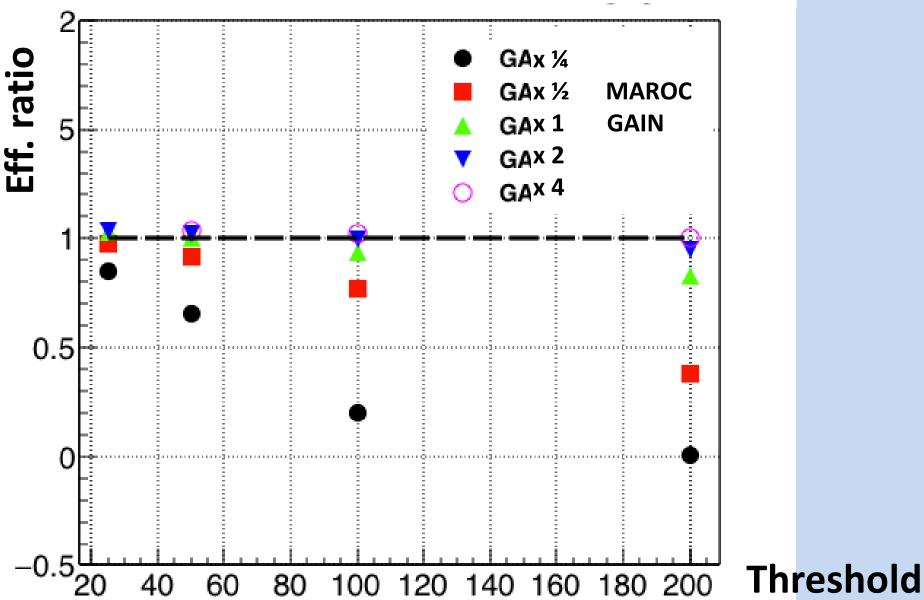
Single-photon Discrimination

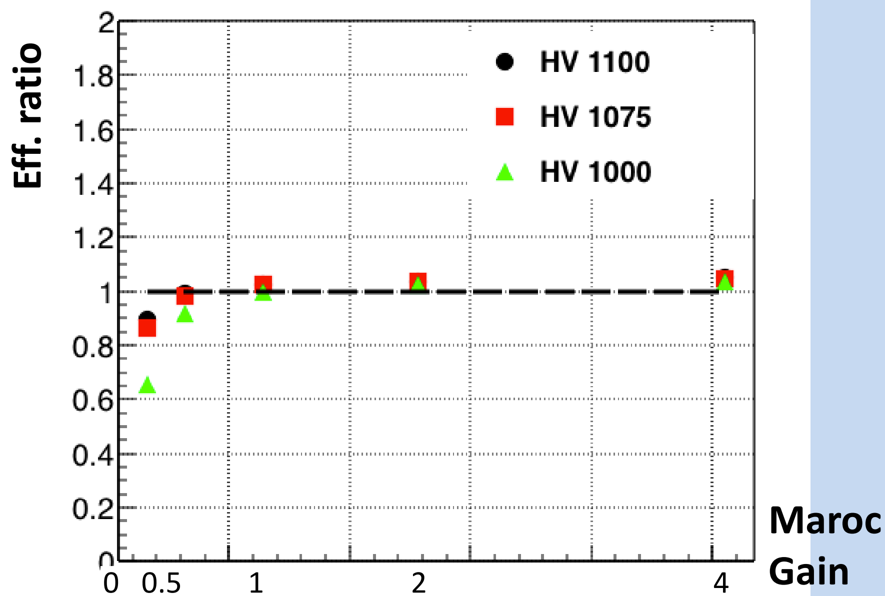
Relative efficiency map



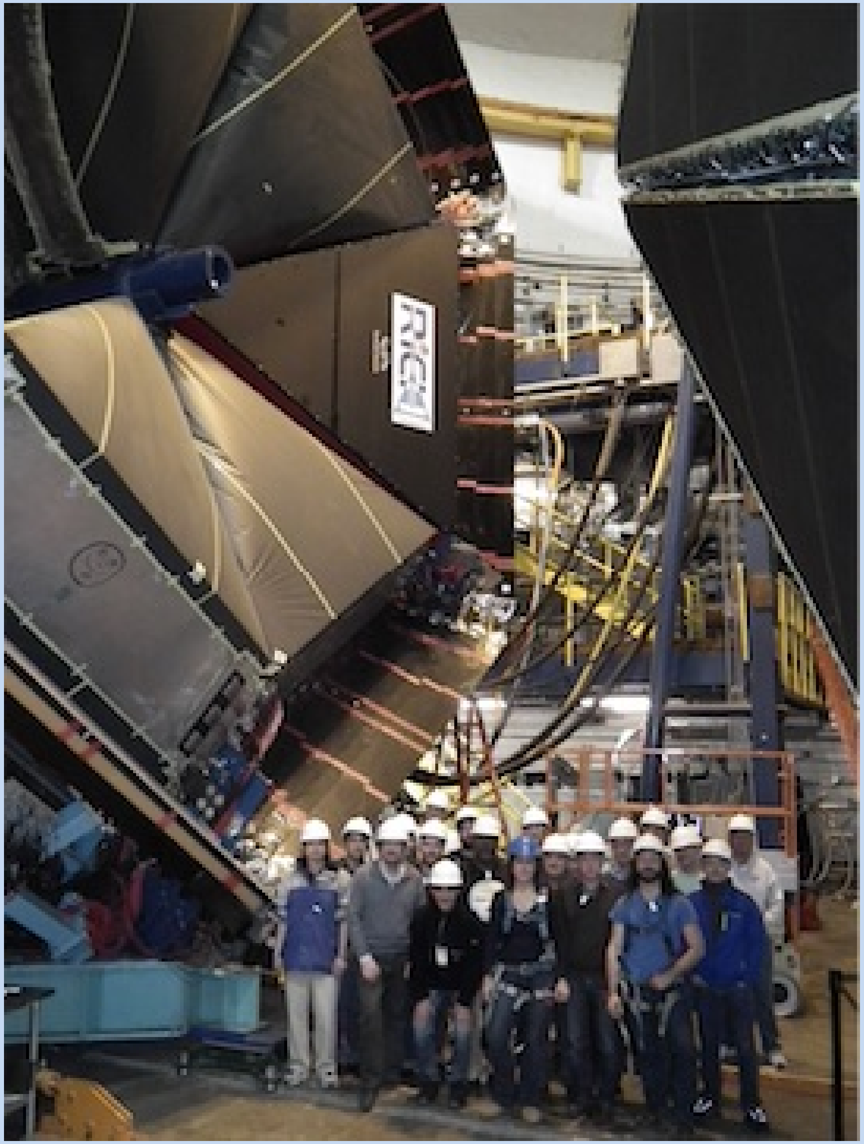
Relative gain map



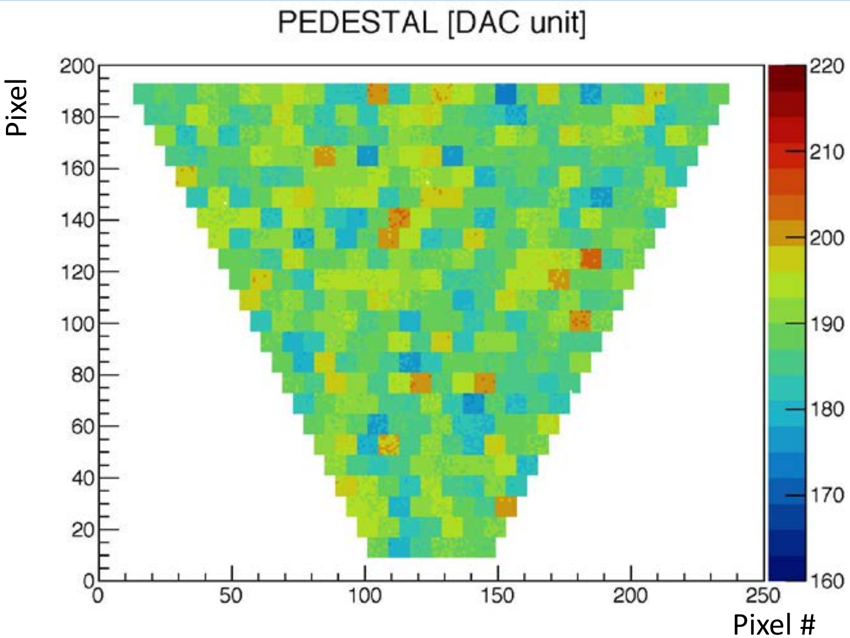


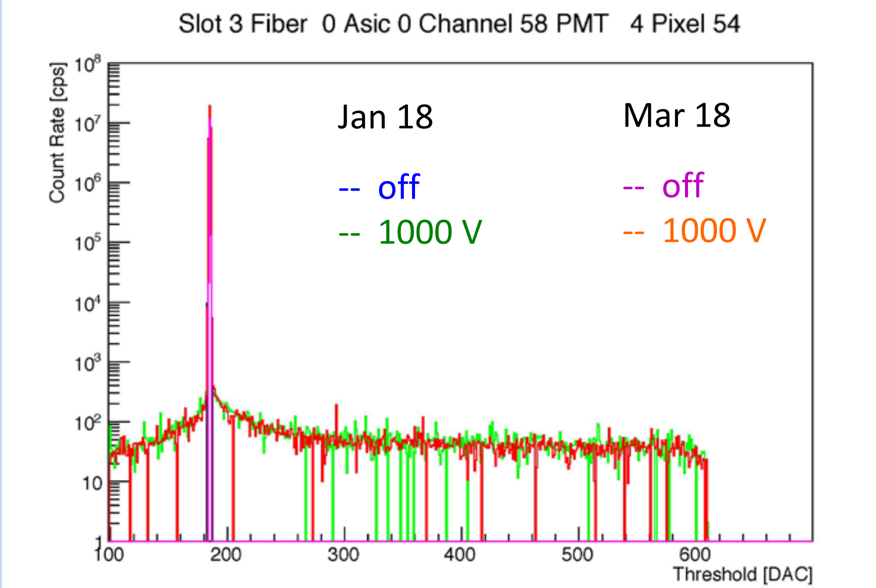


RICH Installation

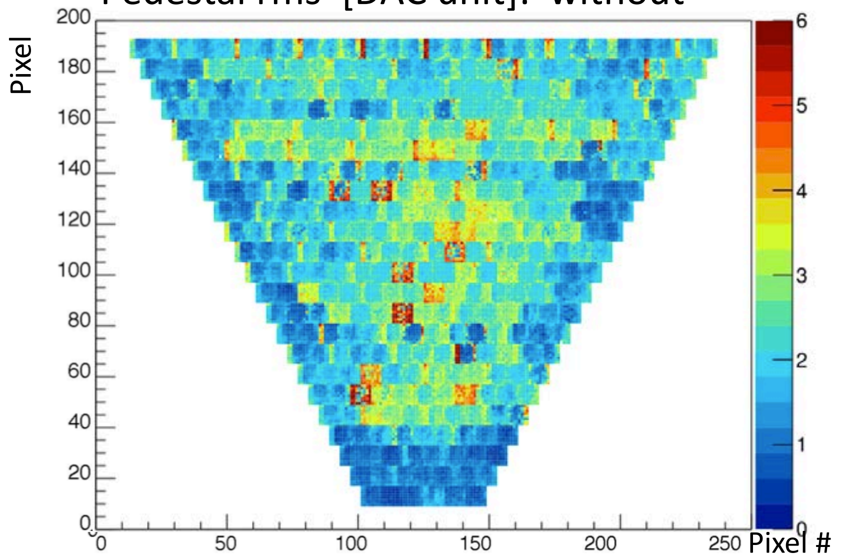


Electronic Pedestals

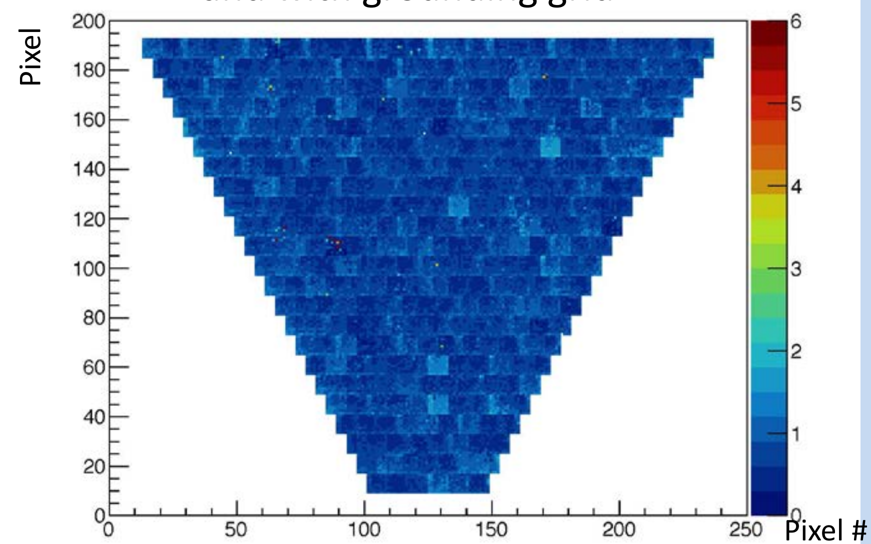




Pedestal rms [DAC unit]: without

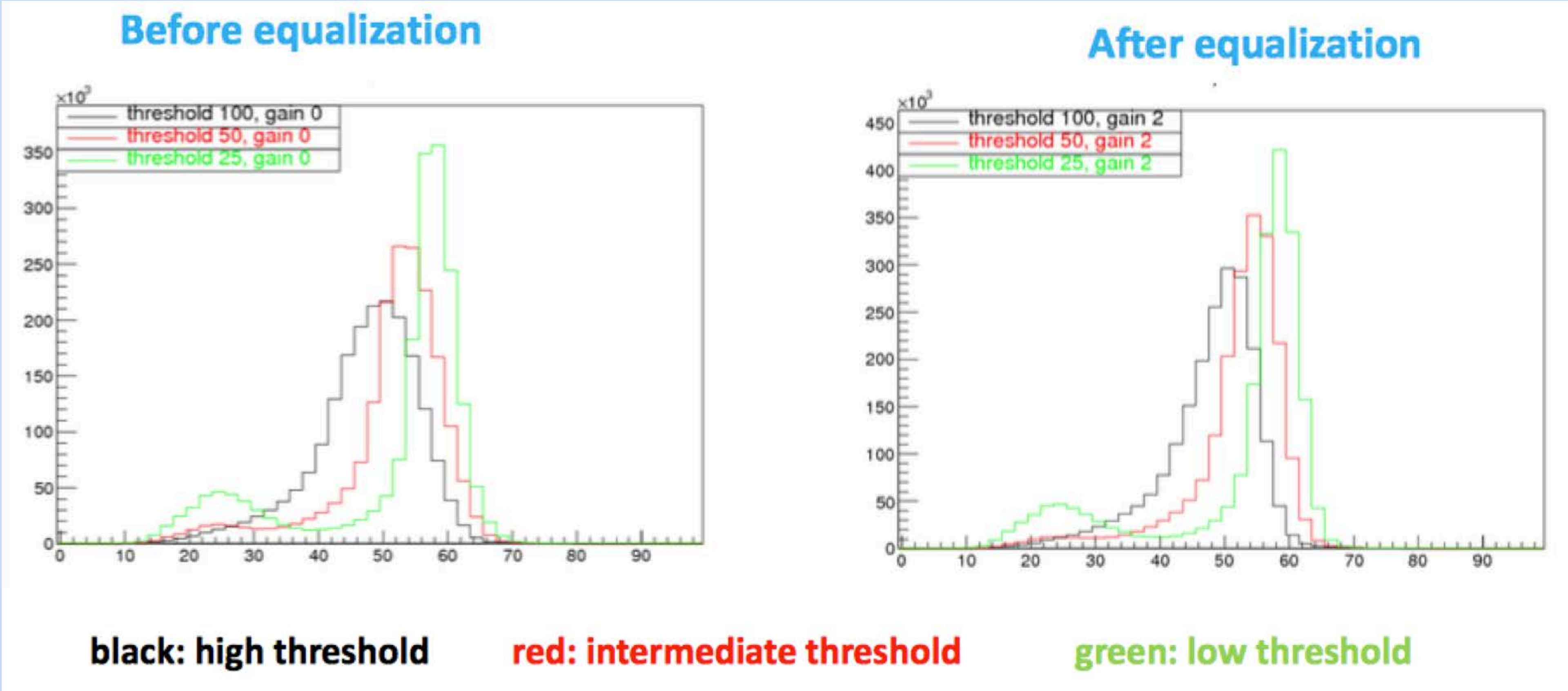


and with grounding grid

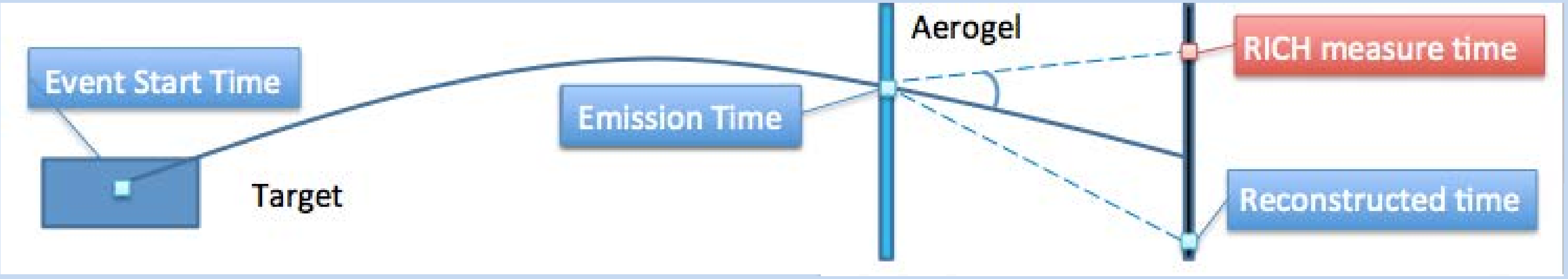


Online Equalization

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



Single Photon Time Analysis

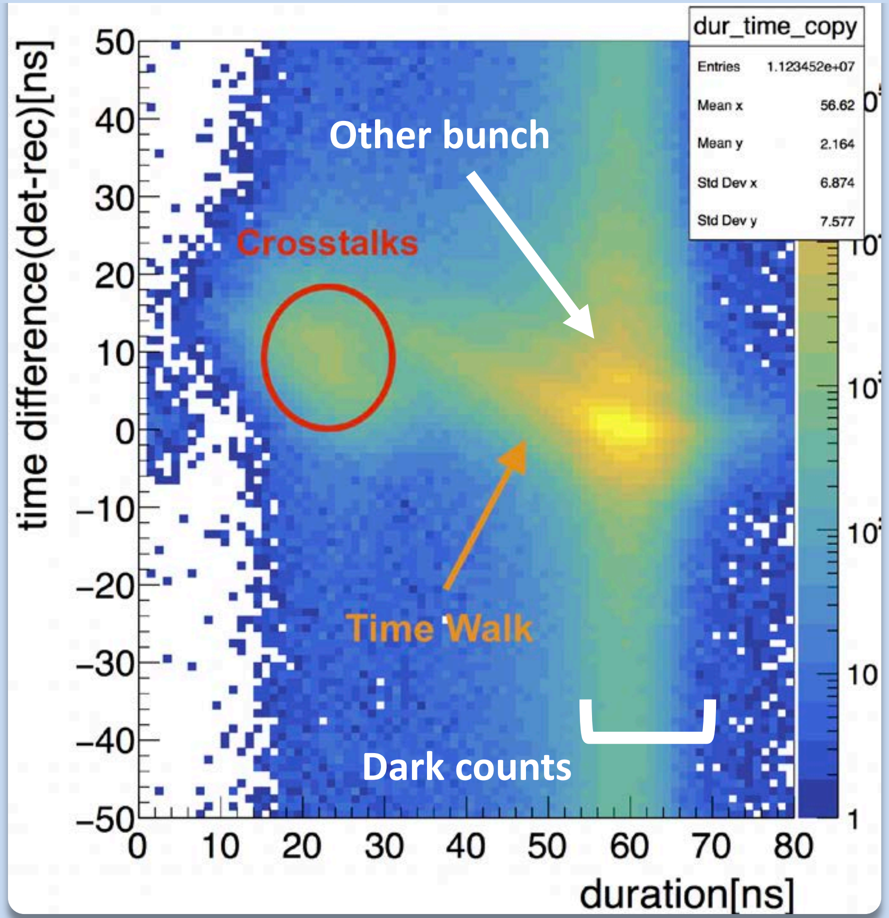


CLAS12 Reconstructed Time and Position:
Photons are traced using information from other CLAS12 detectors

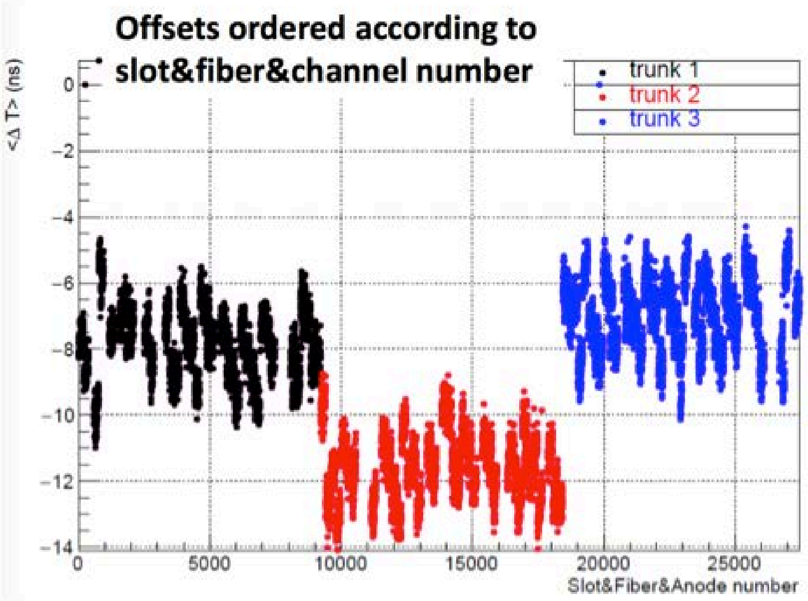
RICH Measured Time and Position:
Defined by the RICH DAQ

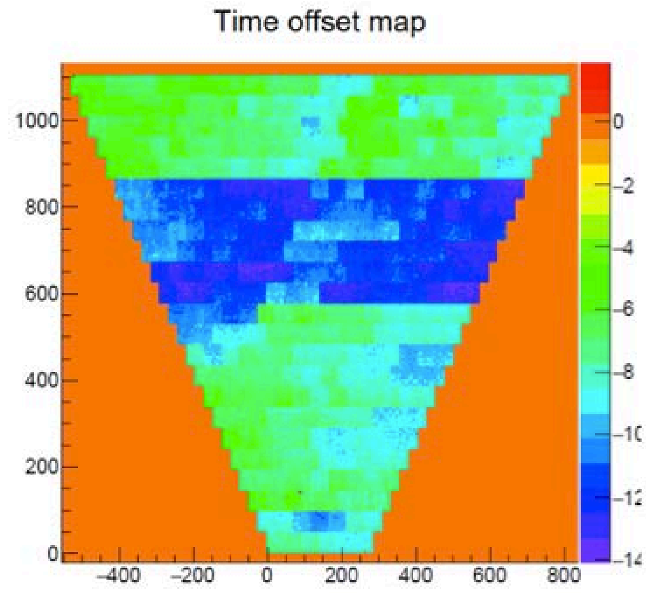
Good photons should match in time and space

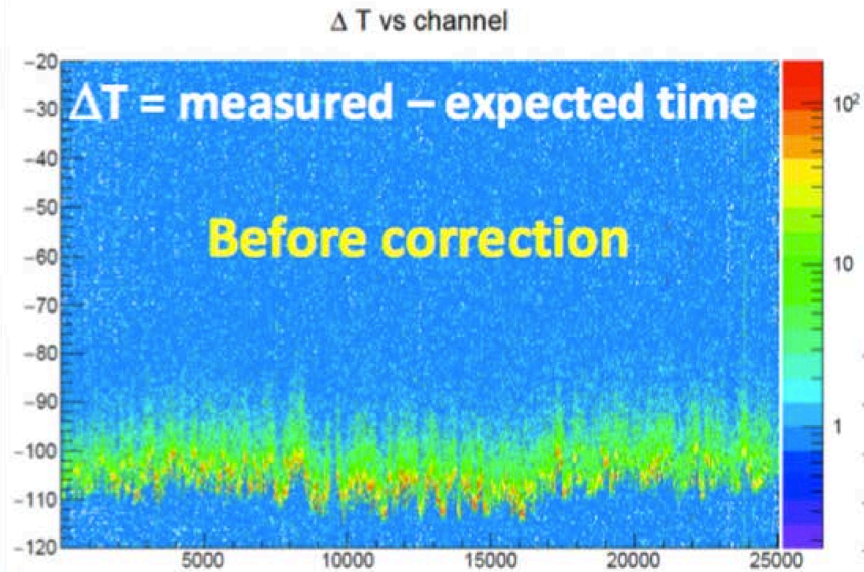
Time analysis allows to separate spurious signals

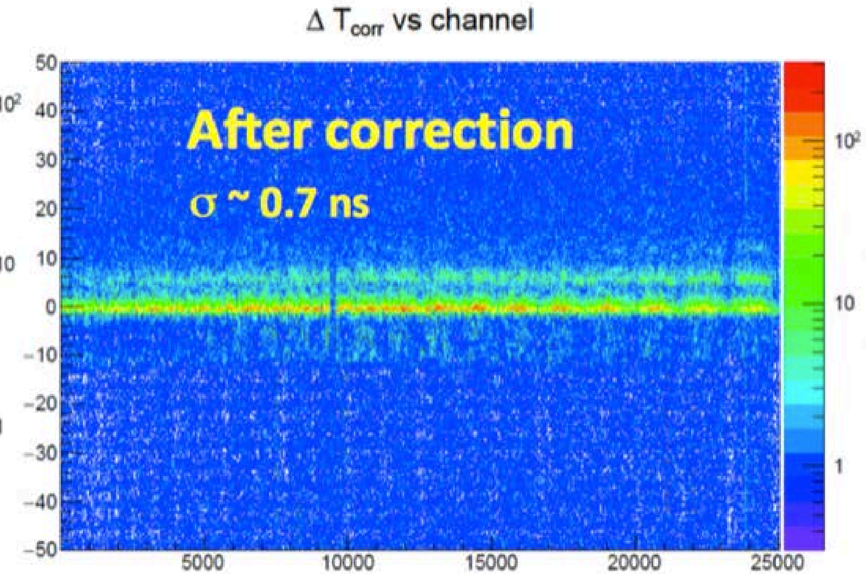


Time Offsets



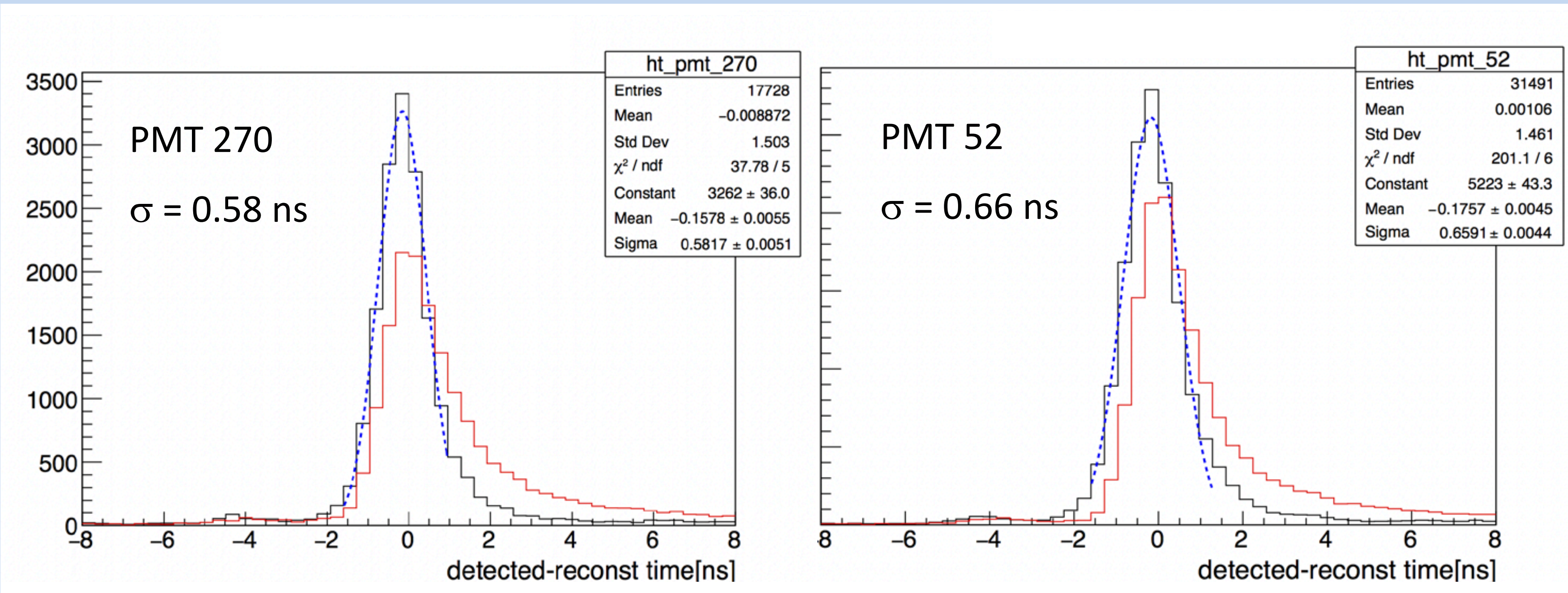






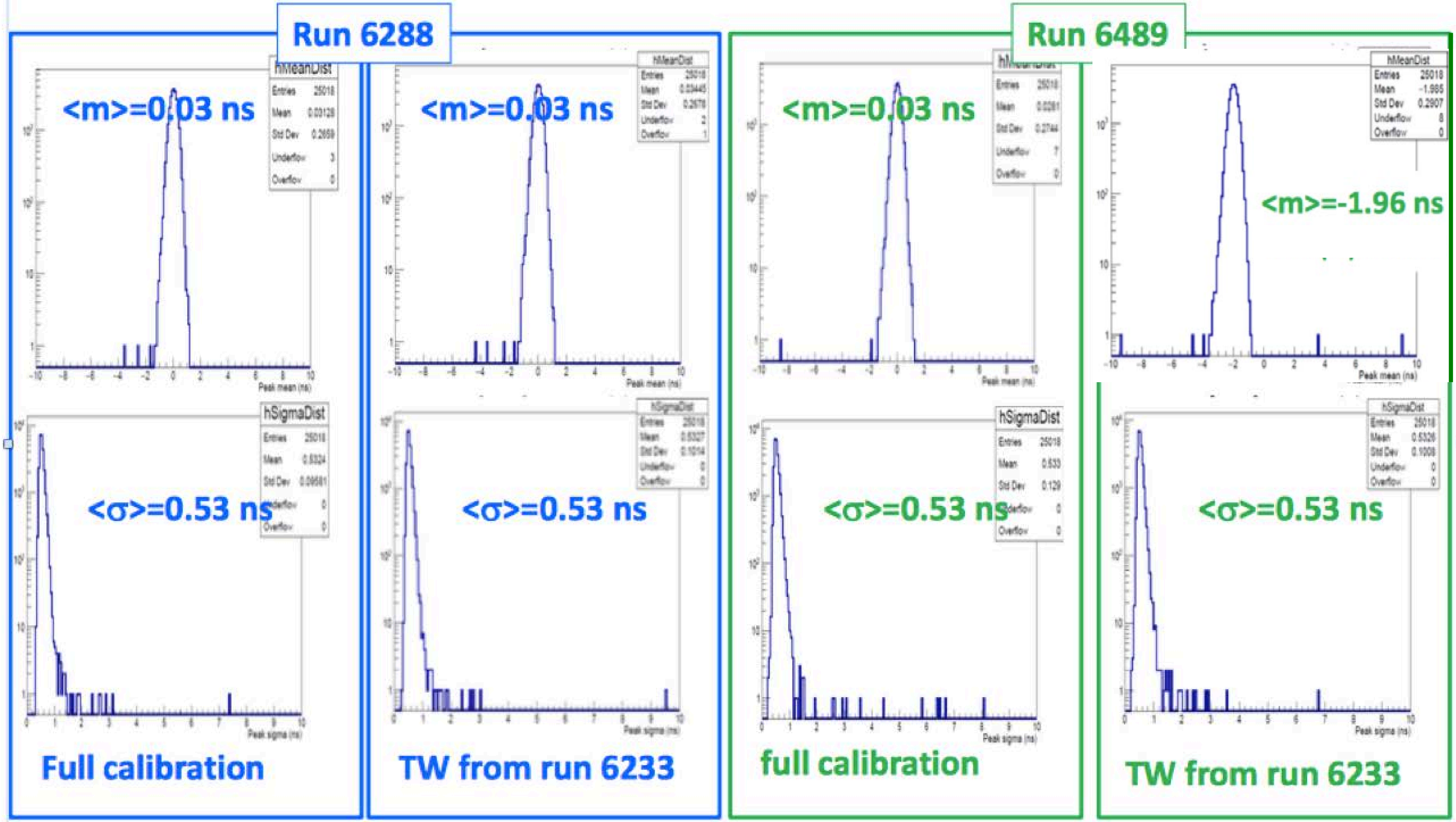
Single-photon Time Resolution

Single-photon time resolution better than the 1 ns specification



— before time-walk correction — after time-walk correction

Time Calibration



Cherenkov Angle Reconstruction

Analytic solution for direct photons

“Exact” solution for the Cherenkov Angle

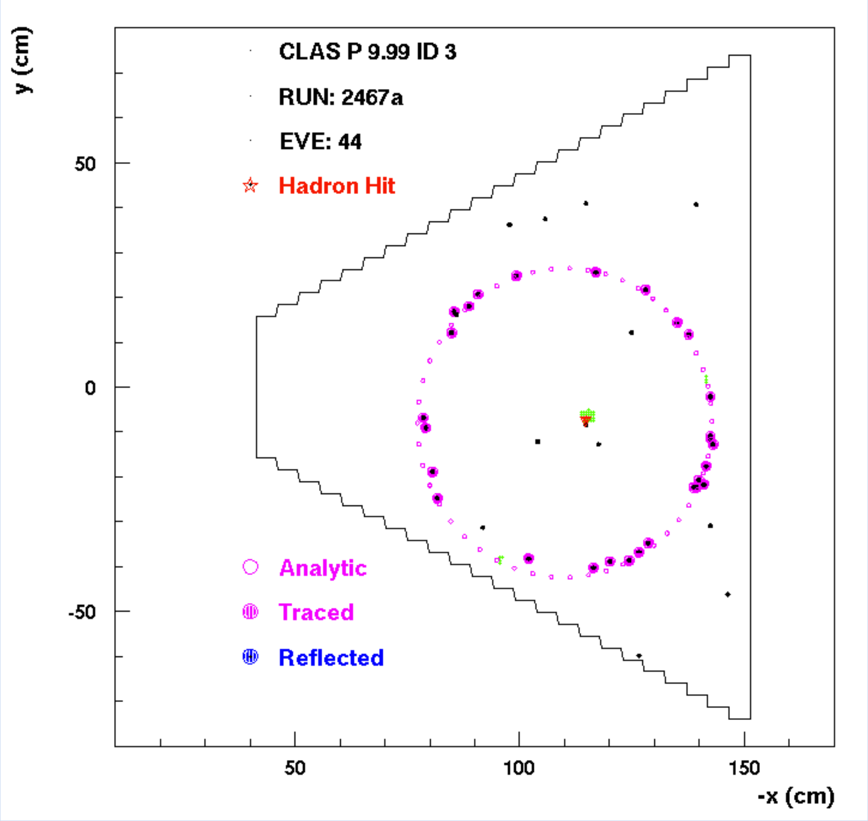
Only direct photons

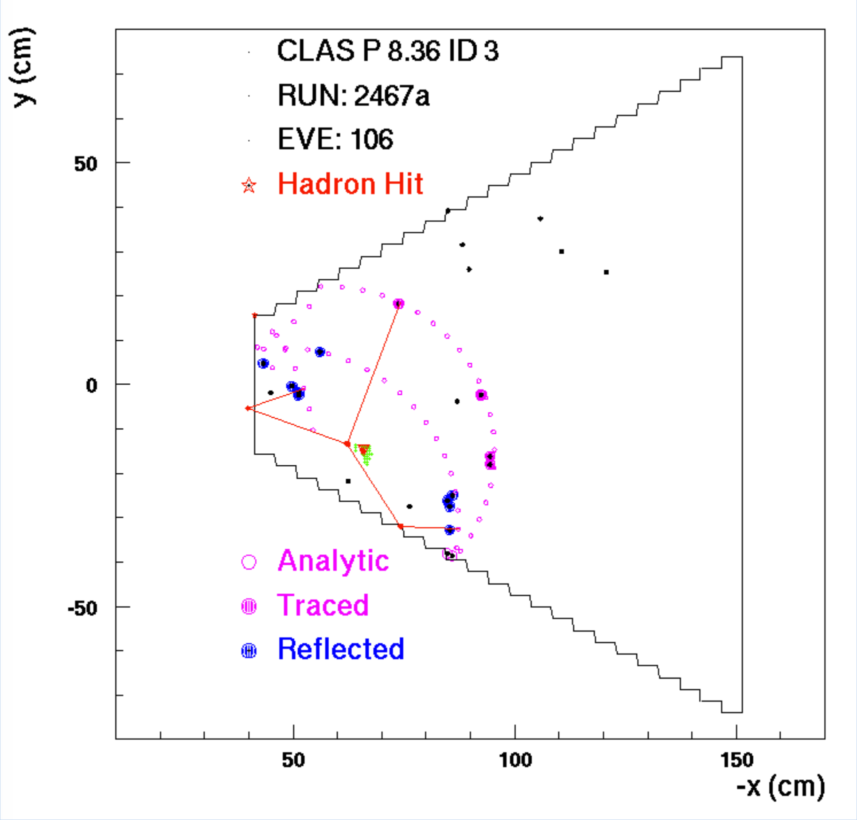
Ray traced solution for direct photons

Assume knowledge of aerogel ref index

Any photon

GOAL: get a Cherenkov angle estimate for each photon for detailed PID optimization

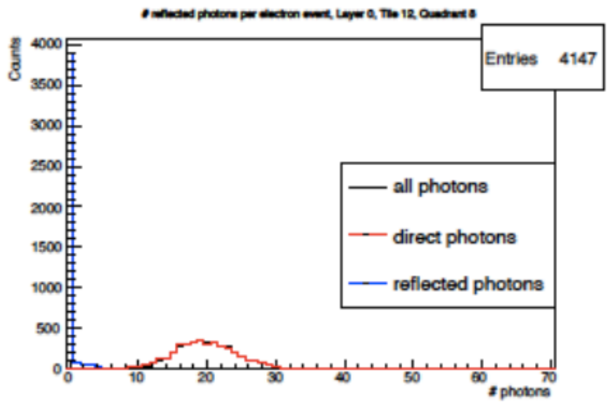


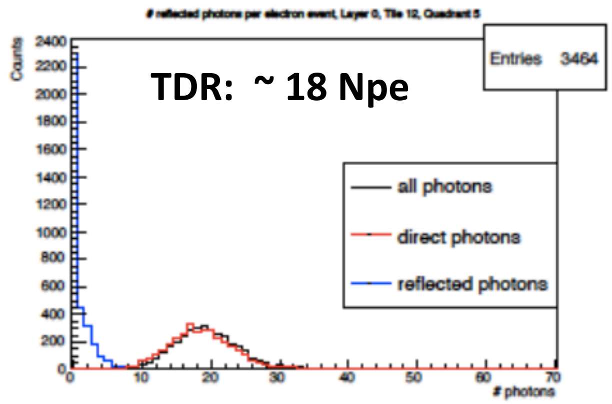


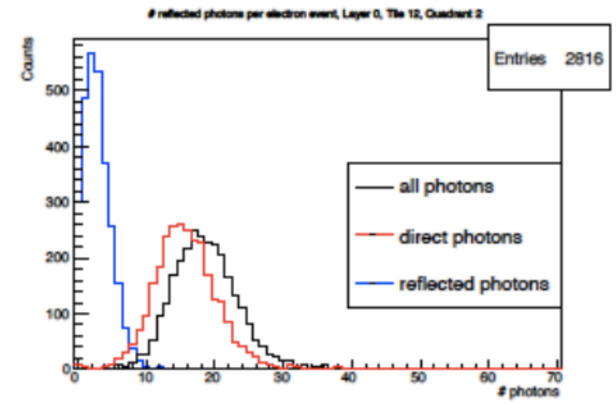
RICH Hadron Separation

RGA data, direct photons   No alignment of internal components

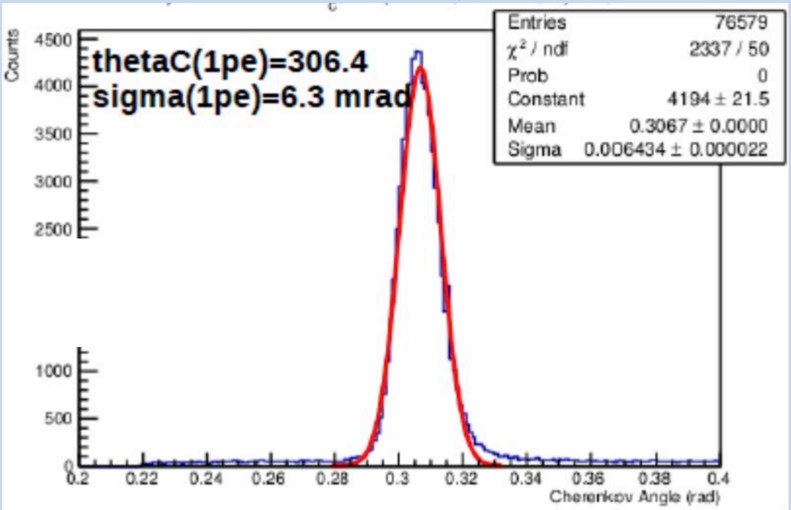
Number of photons and single photon resolution close to TDR

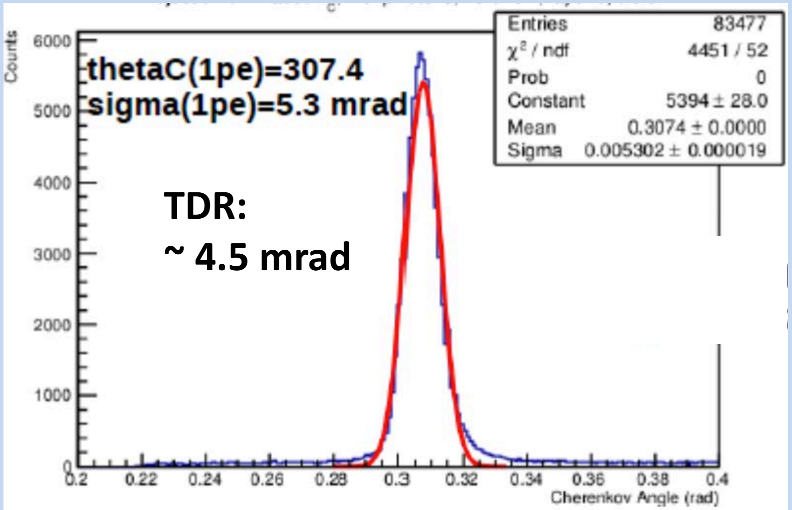




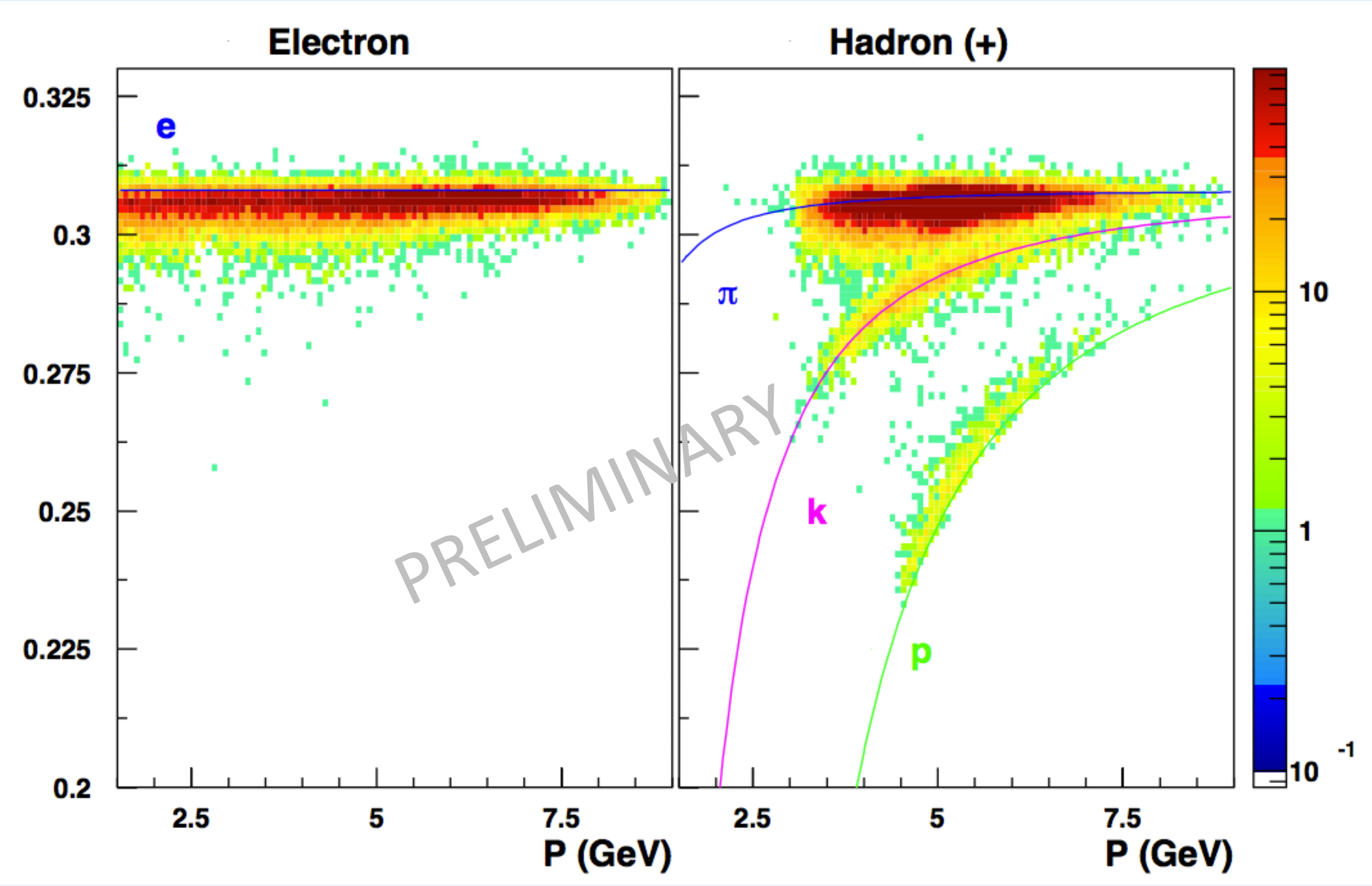


Raw RICH alignment (not for internal components)

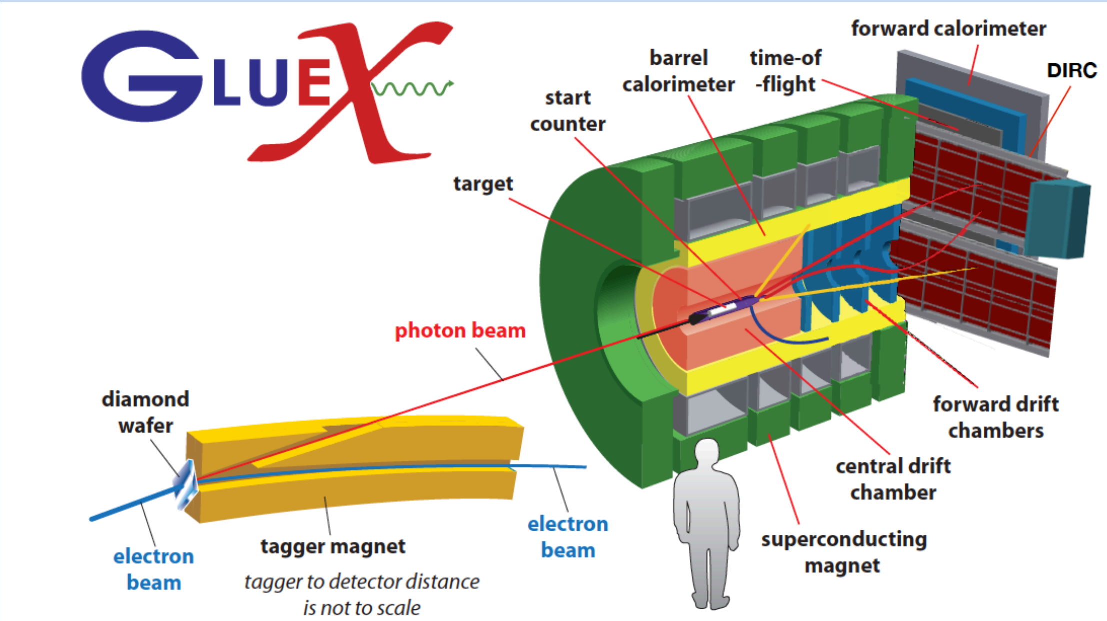


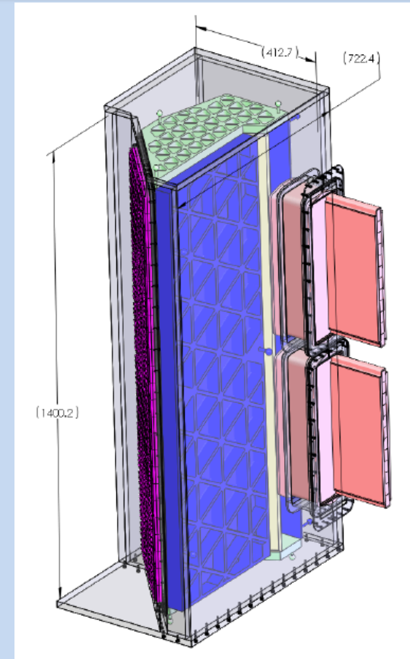


Hadron separation, direct photon, RGA data, raw alignment

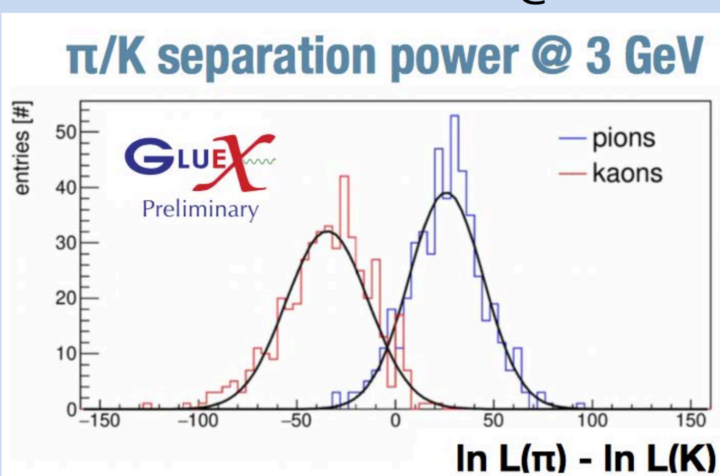


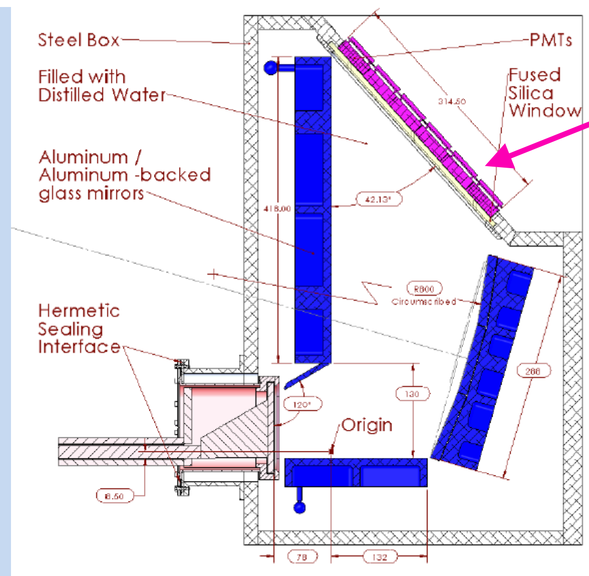
DIRC @ GlueX





J. Stevens @ DIRC19

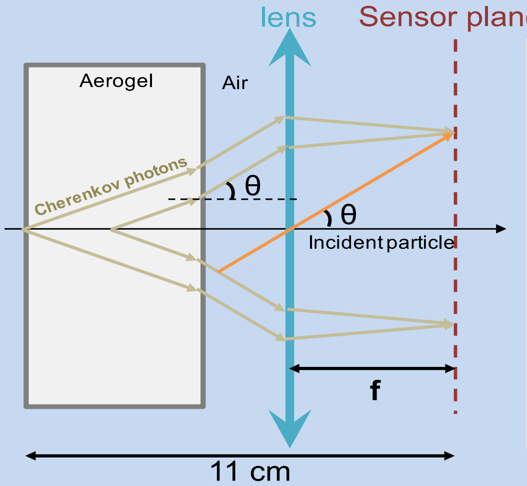


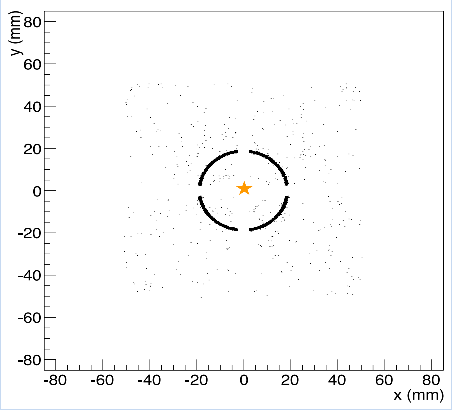


H12700 + CLAS12 readout

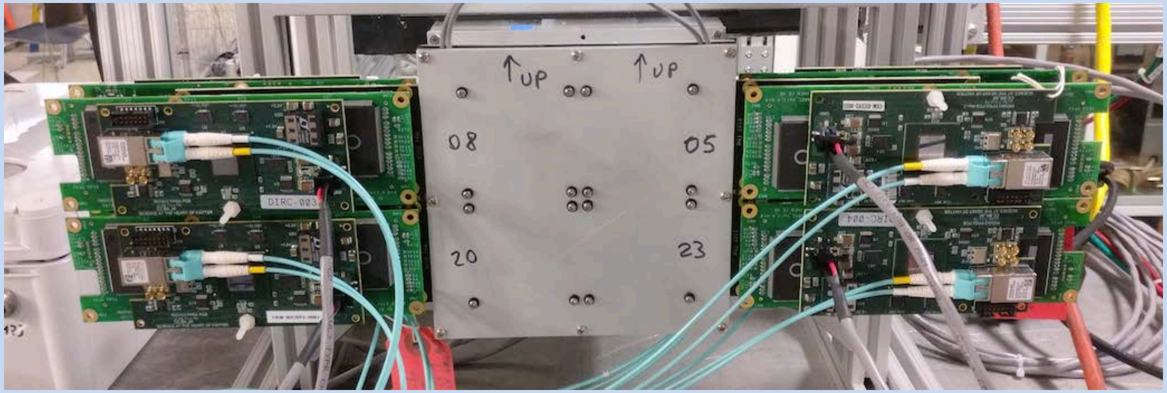
Application: Modular RICH @EIC

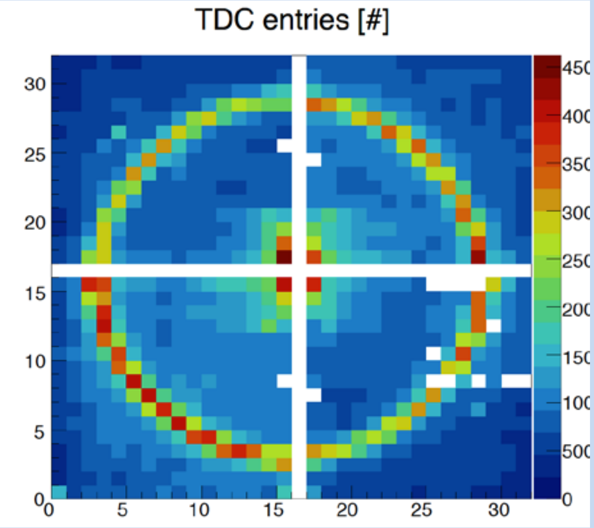
Compact and modular RICH indipendent elements



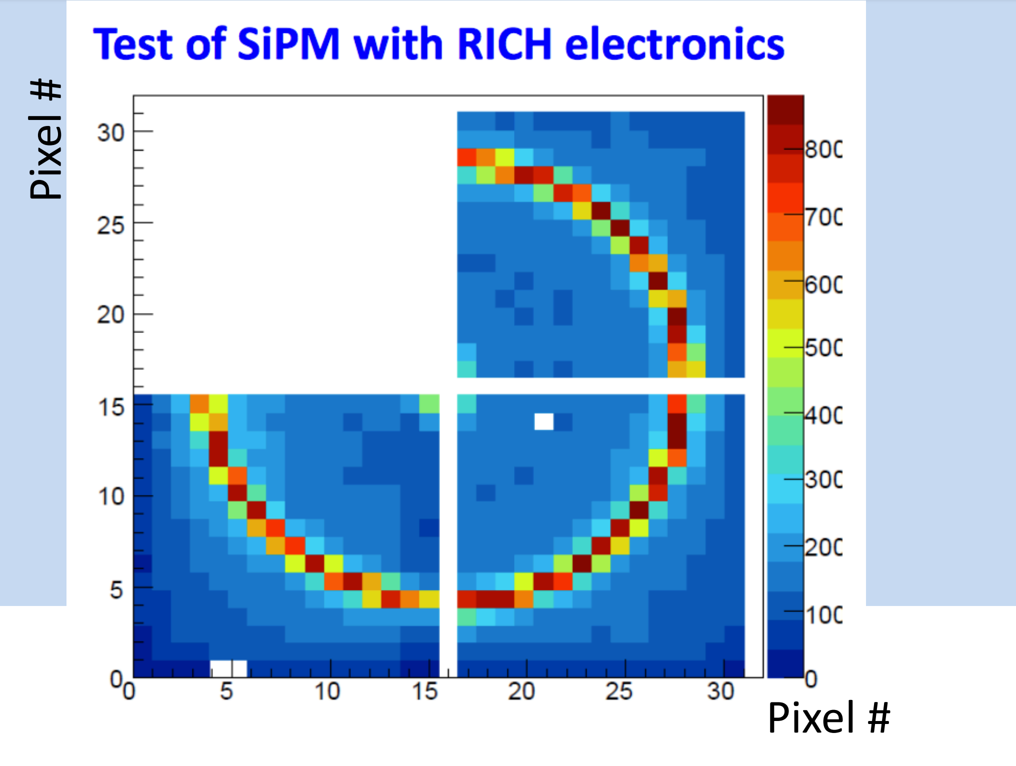


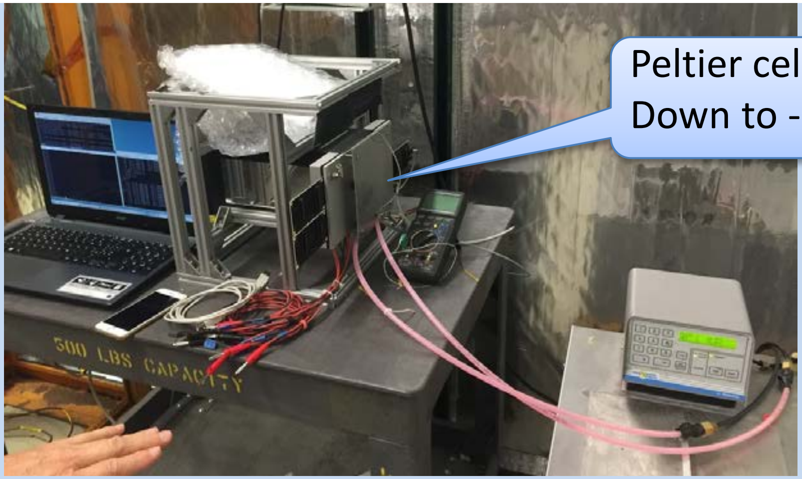
H13700 to reach the 3 mm spatial resolution





Application: SiPM Arrays





Peltier cell cooling
Down to -30^{o} in N_2

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

RICH has successfully taken data, performance moving towards specifications

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