

# RICH Detector Status

M. Contalbrigo  
INFN Ferrara

Hall-B Meeting  
11 September 2017

# 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)

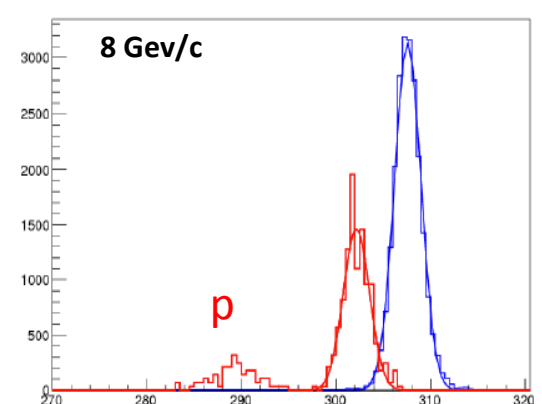
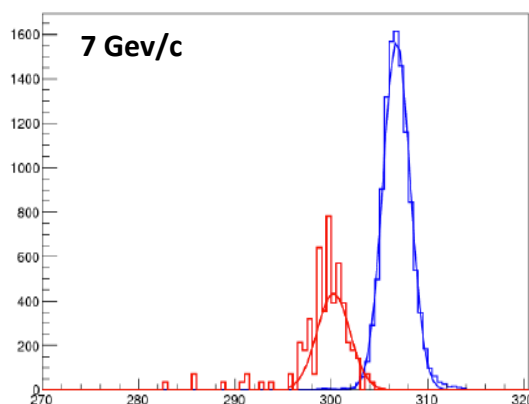
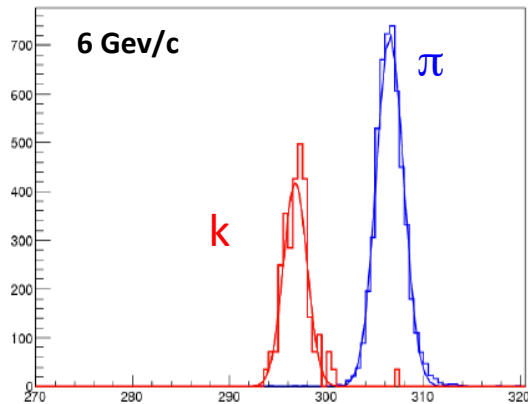
Glasgow University (Glasgow, UK)

Kyungpook National University, (Daegu, Korea)

University of Connecticut (Storrs, USA)

UTFSM (Valparaiso, Chile)

## Prototype results:



Cherenkov angle (mrad)

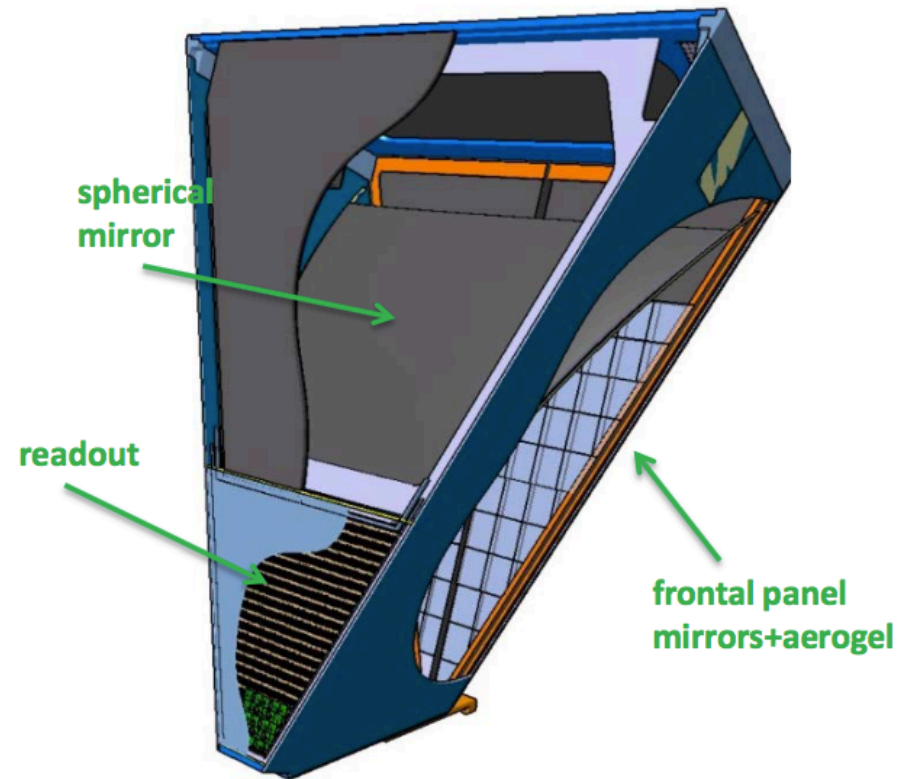
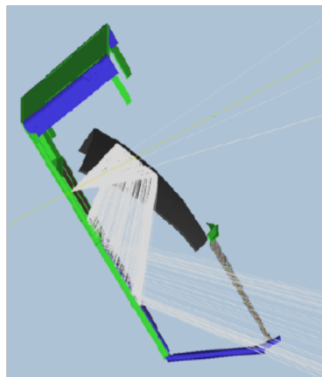
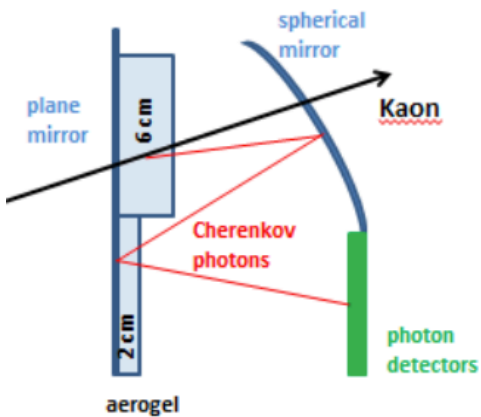
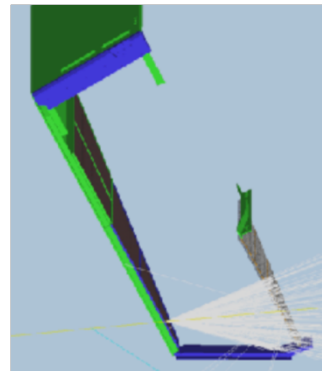
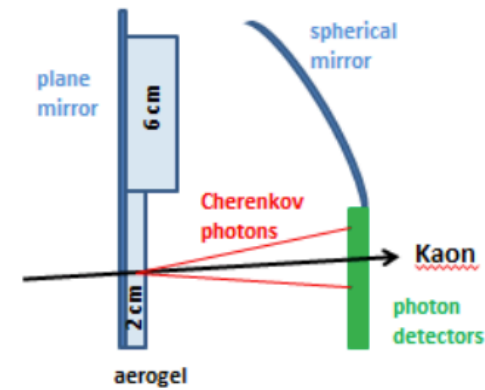
# RICH Design

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)



# Mechanic Assembling

- ✓ External RICH vessel assembled in EEL-124
- ✓ Entrance, exit and electronic panels ready
- ✓ Assembling tools ready

Thanks to DSG group!

Entrance bottom



Entrance top

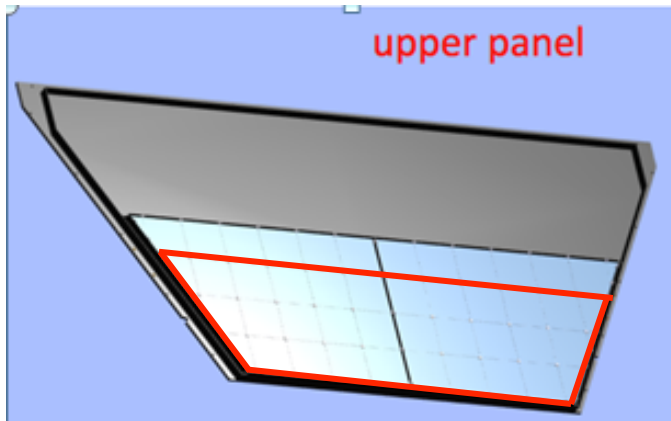


Electronic Panel

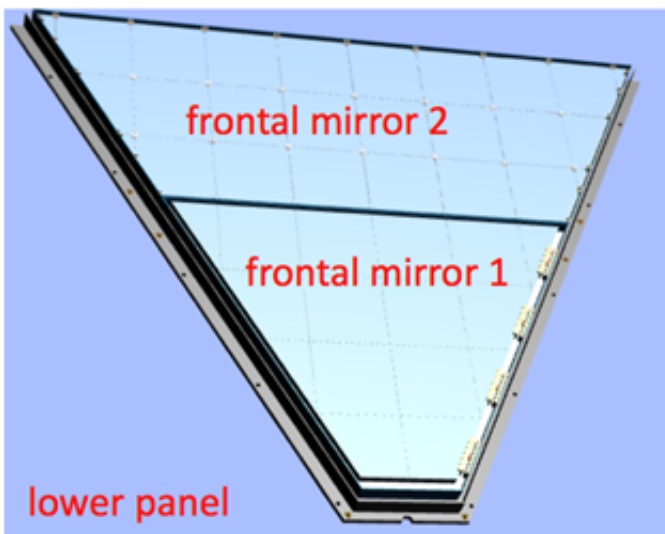


# Aerogel

✓ 3 cm: minimal quantity @ JLab

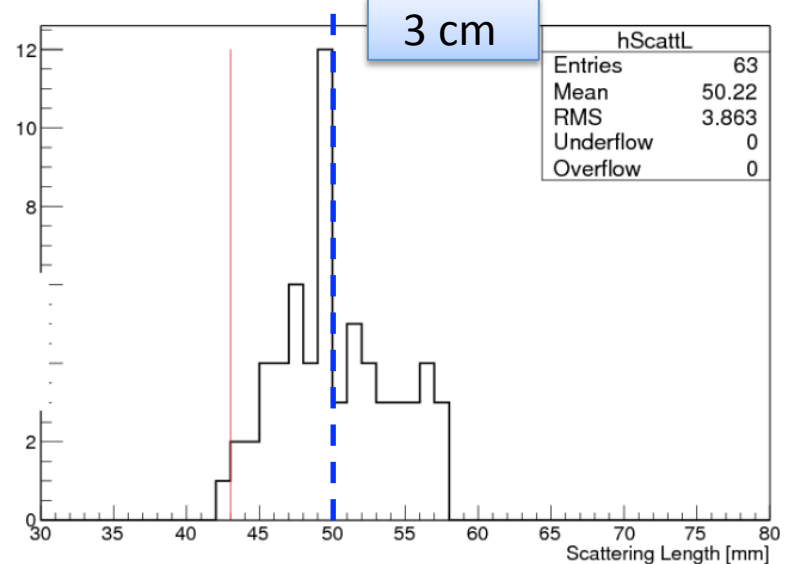
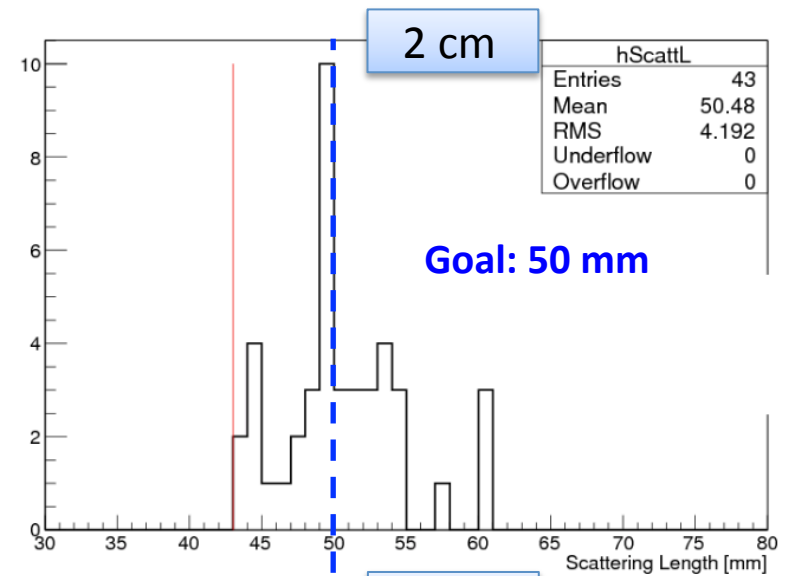


✓ 2 cm: all squared tiles @ JLab  
2 cm corner tiles ready for shipment



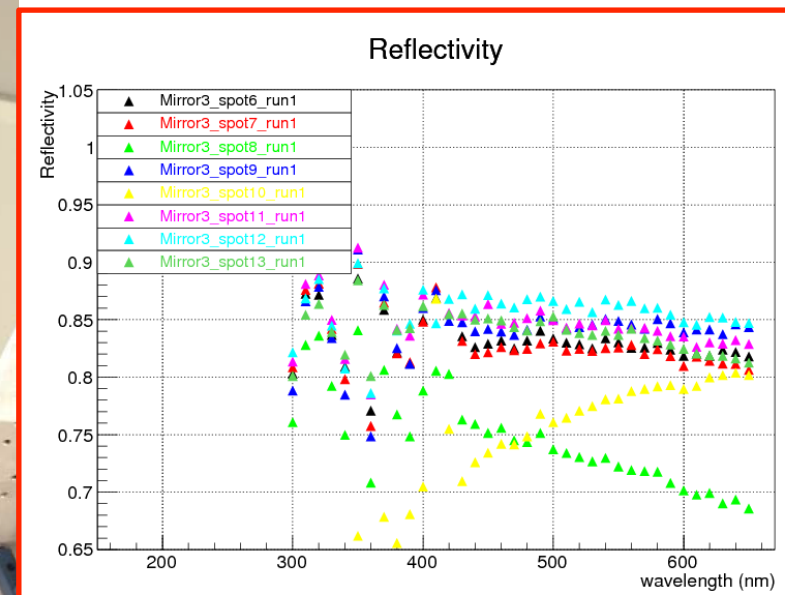
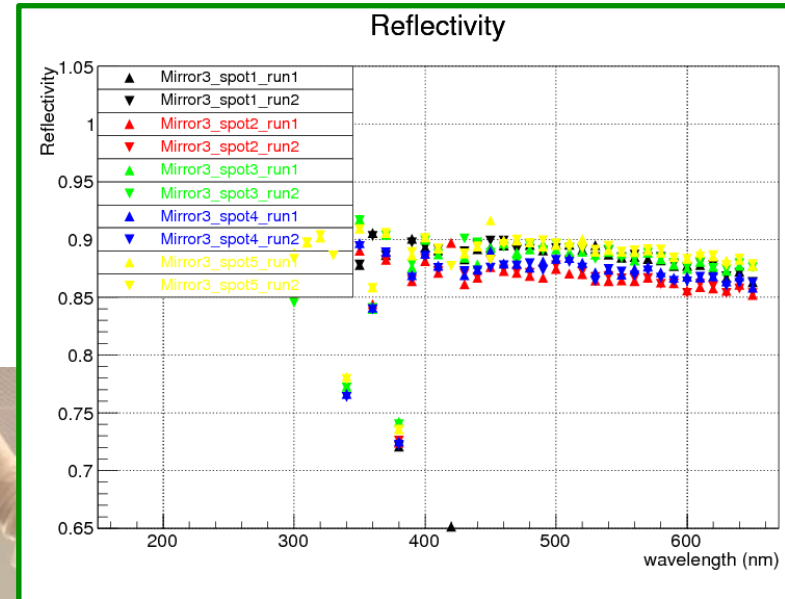
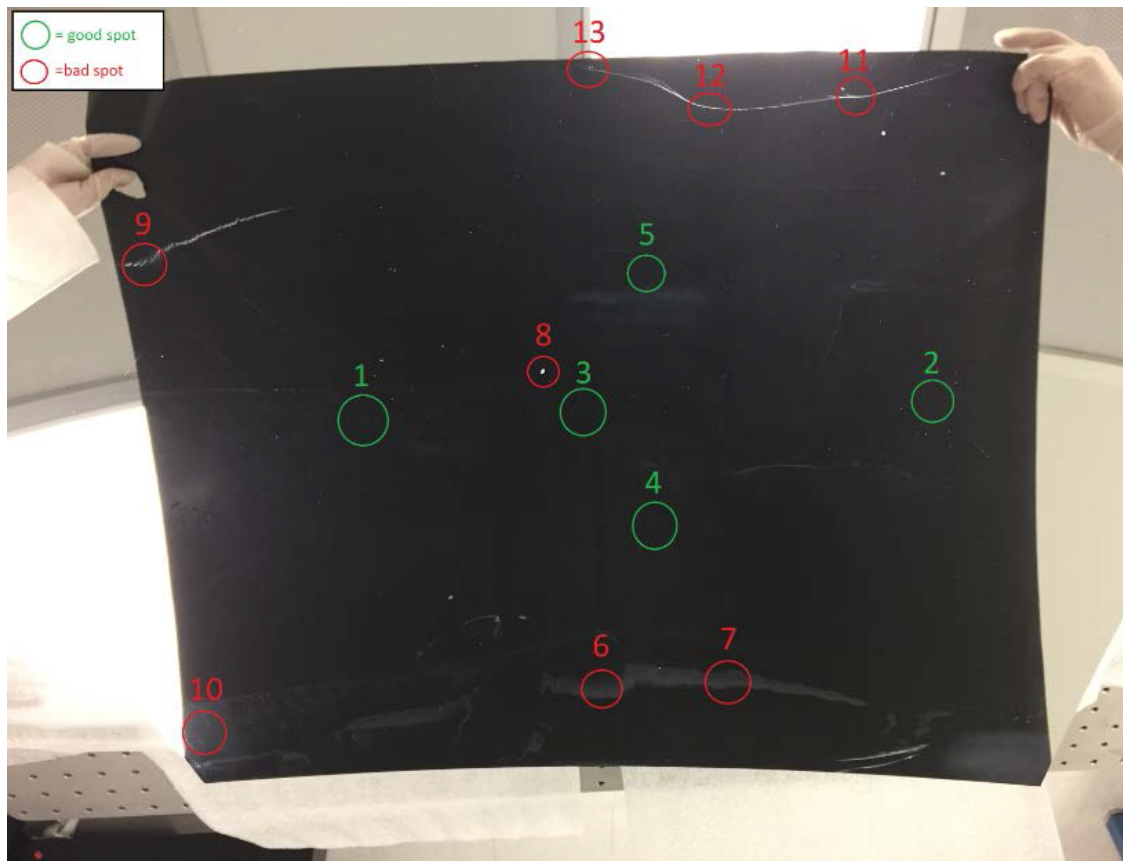
✓ additional spares being produced

Most critical parameter: scattering length



# Spherical Mirrors

- ✓ All 10 mirror produced  
30% less areal density vs LHCb  
Shape accuracy better than specifications
- ✓ Coating highlighted defects (chemical residuals)
- ✓ Resurfacing ongoing @ CMA (done this week)



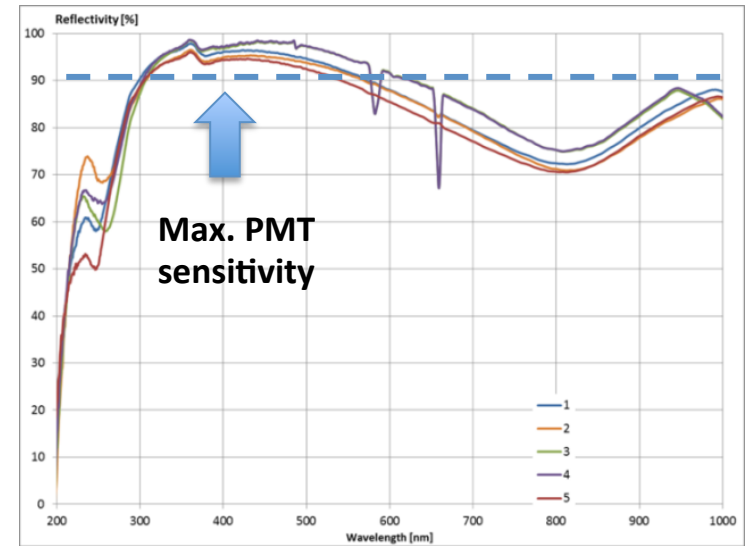
# Planar Mirrors

- ✓ Lateral mirror @ JLab  
Material budget comparable to CFRP @ 1/10 cost
- ✓ Assembling validated
- ✓ Surface defects mitigated
- ✓ Front mirror production ongoing (done next week)

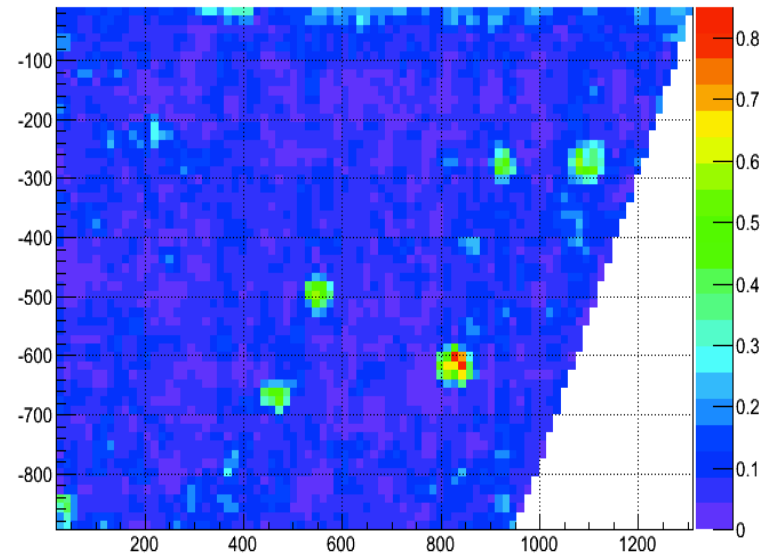
## Front panel and mirror assembling test



## Reflectivity specs: > 90% at 400 nm



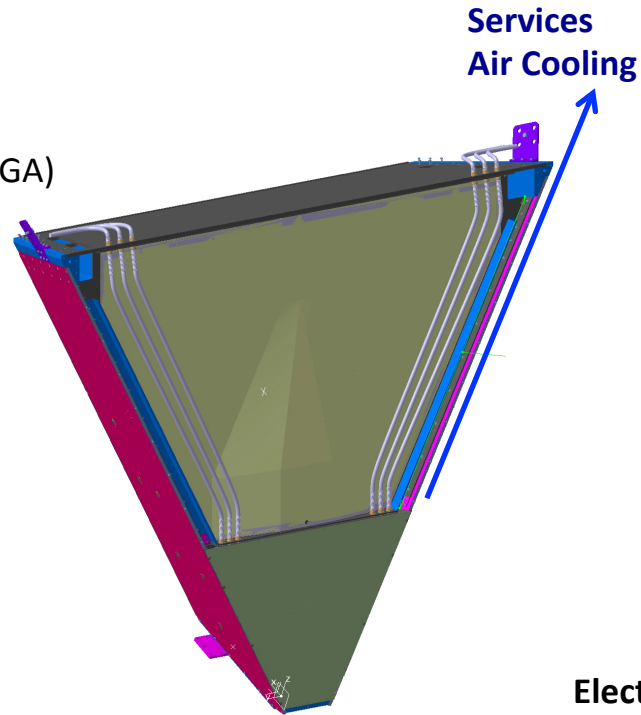
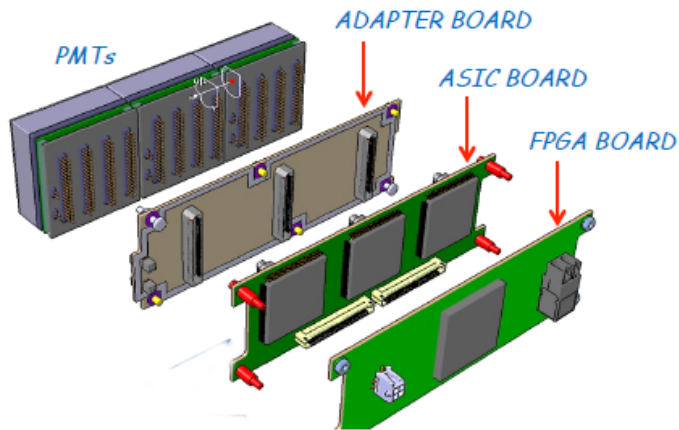
## Slope of surface from CMM machine



# RICH Readout Electronics

## Readout Electronics

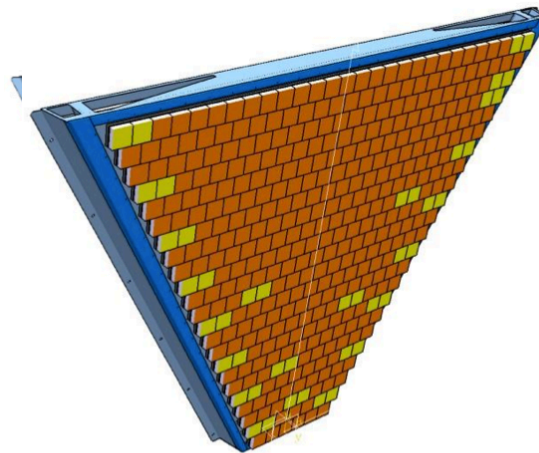
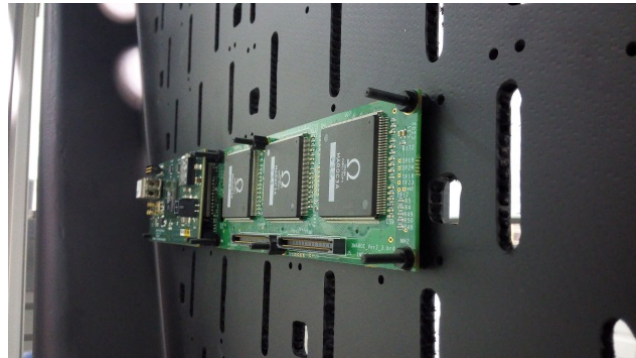
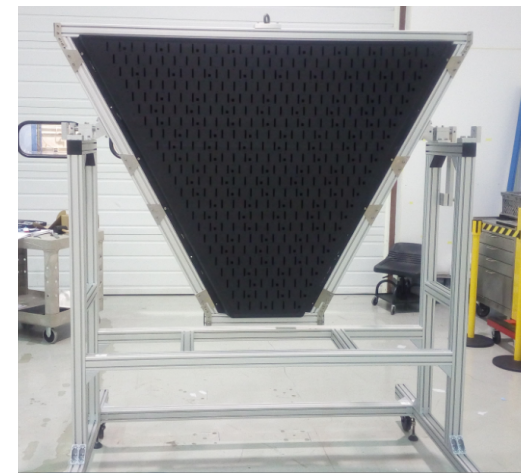
- Compact (matches sensor area)
- Modular Front-End (Mechanical adapter, ASIC, FPGA)
- Scalable fiber optic DAQ (TCP/IP or SSP)
- Tessellated (common HV, LV and optical fiber)



## SSP Fiber-Optic DAQ

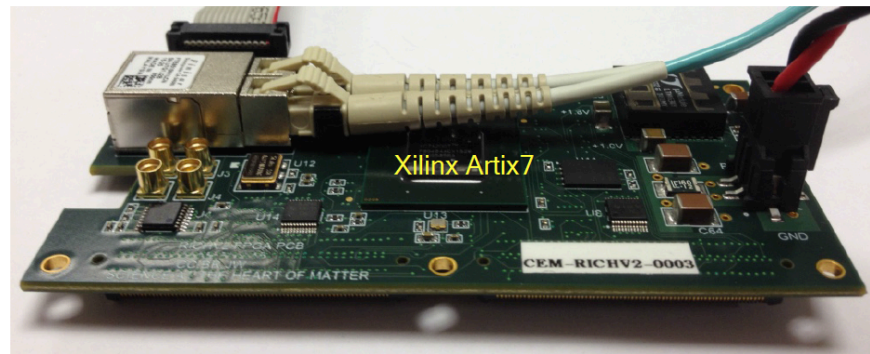
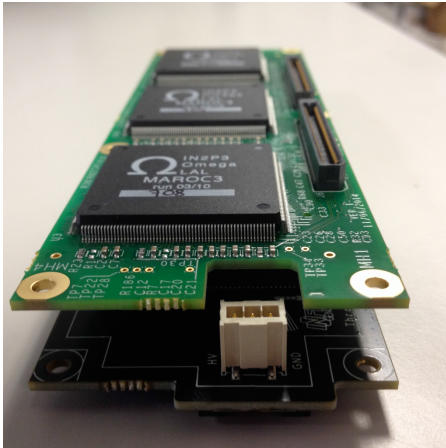


## Electronic Panel





# RICH Front-End Electronics



example of MAROC signal processing

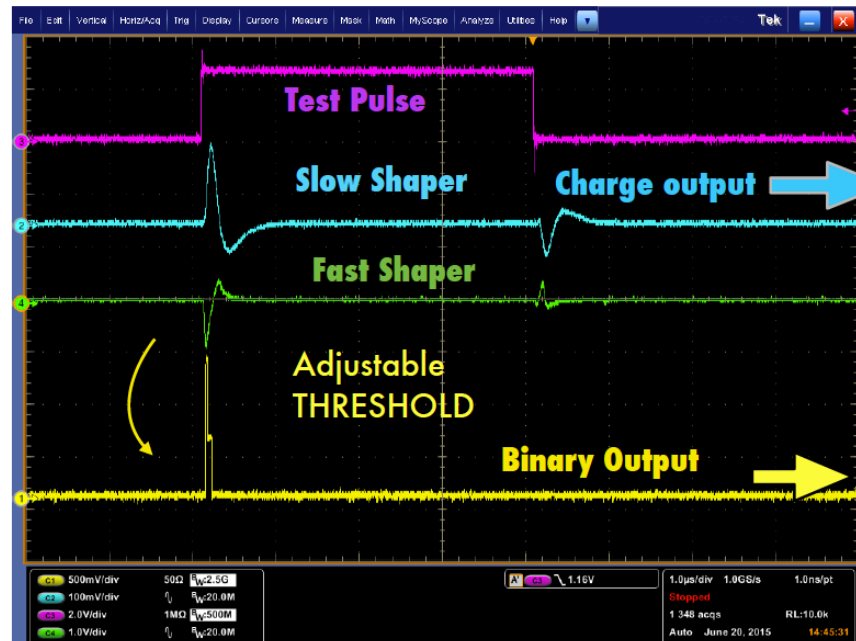
Analog: Charge (1 fC)  
Digital: Time (1 ns)

Trigger latency (8  $\mu$ s)

Optical ethernet (2.5 Gbps)

Trigger: external  
internal  
self

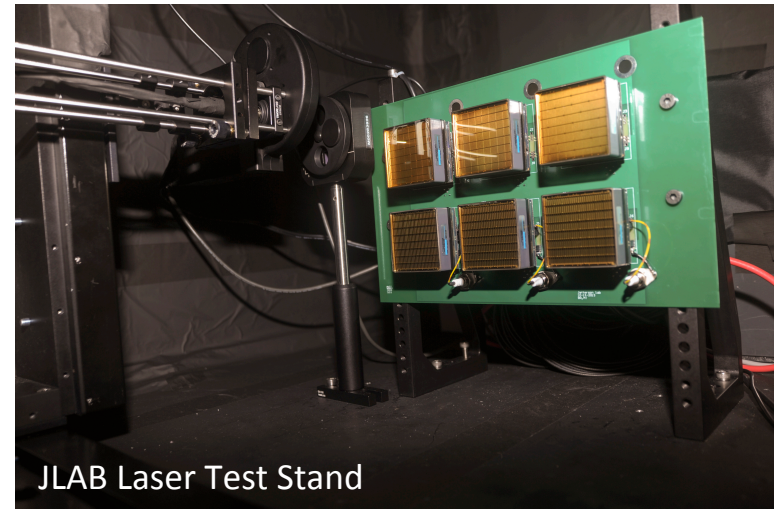
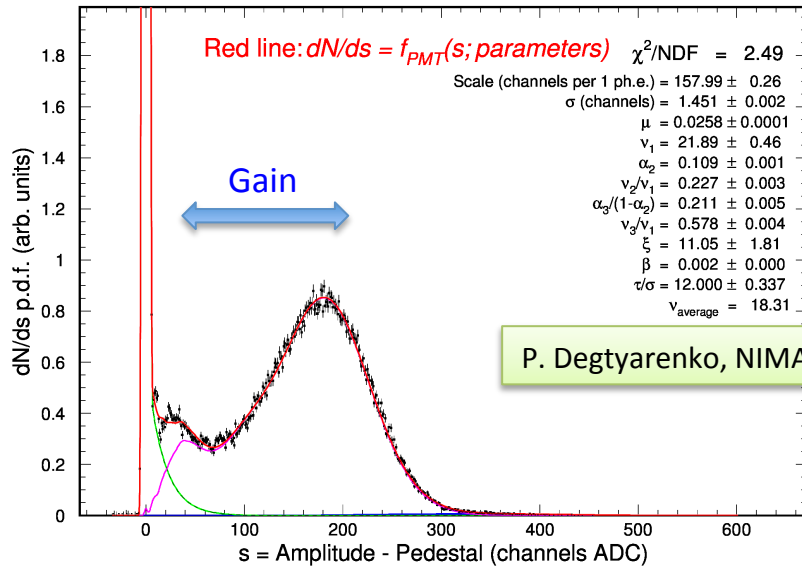
On-board pulser



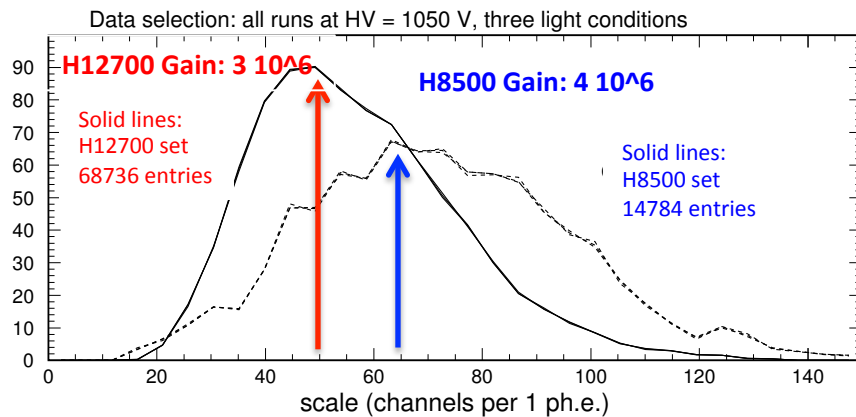
Single channel response, 1 microsecond/div

# ADC: Collected Charge

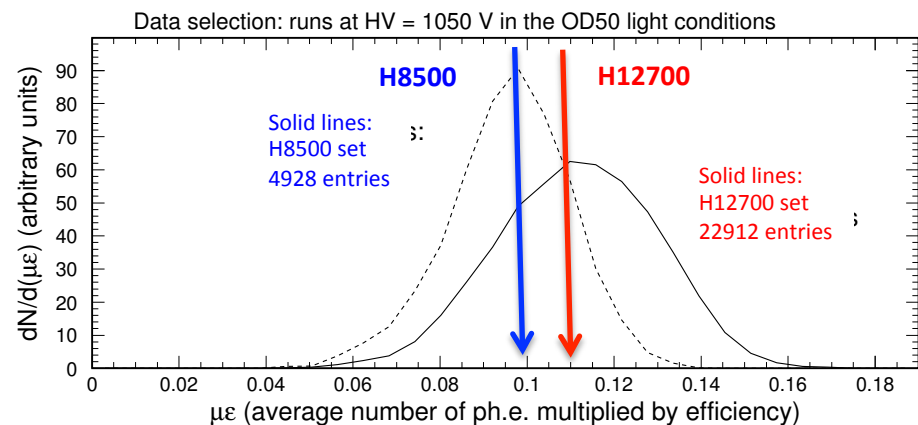
## MAPMT model for gain, resolution, SPE efficiency accounting for cross-talk



## SPE signal proportional to the MAPMT gain

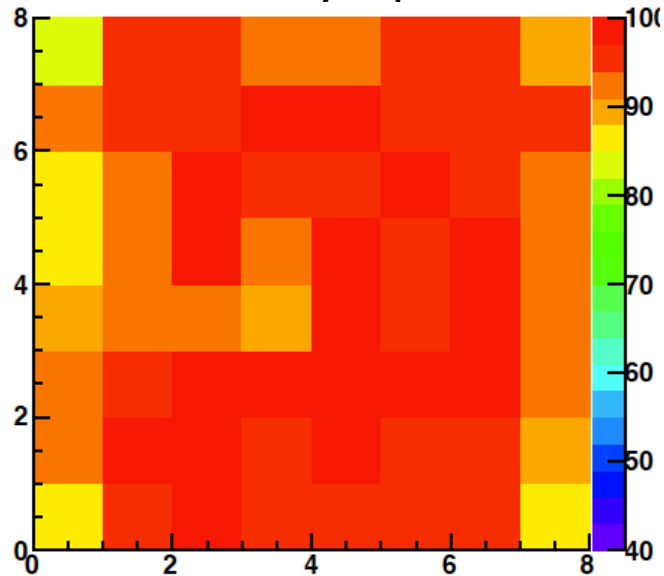


## SPE relative efficiency: +20% for H12700

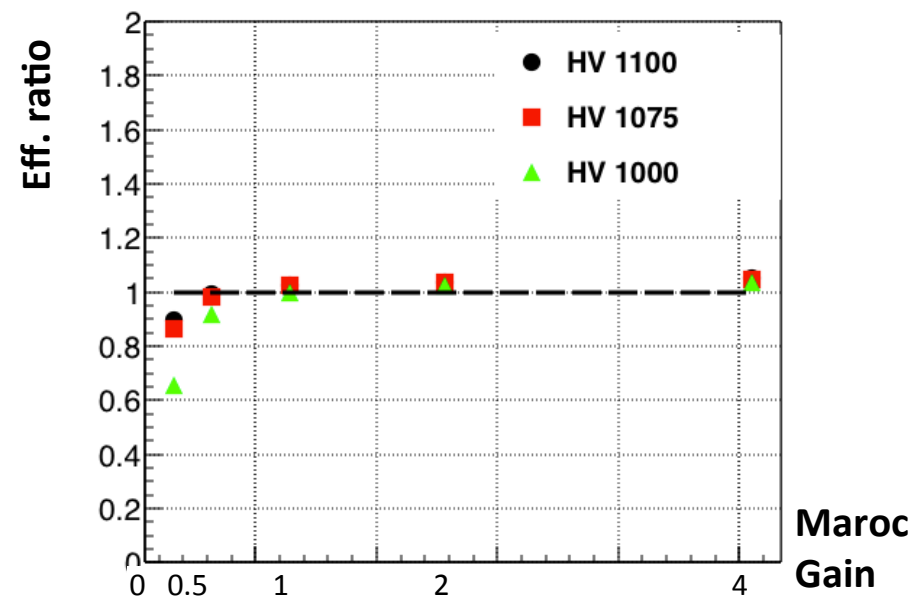
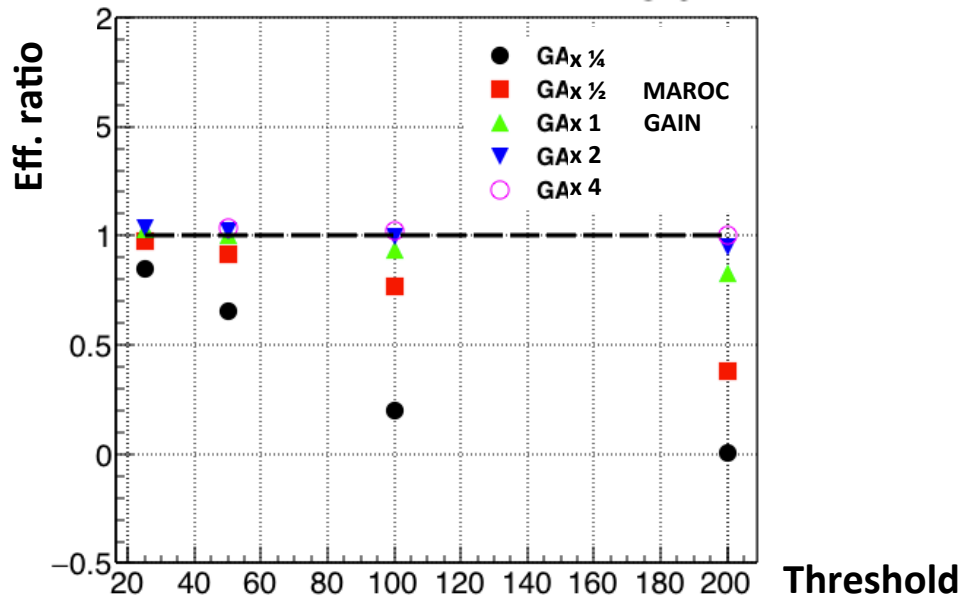
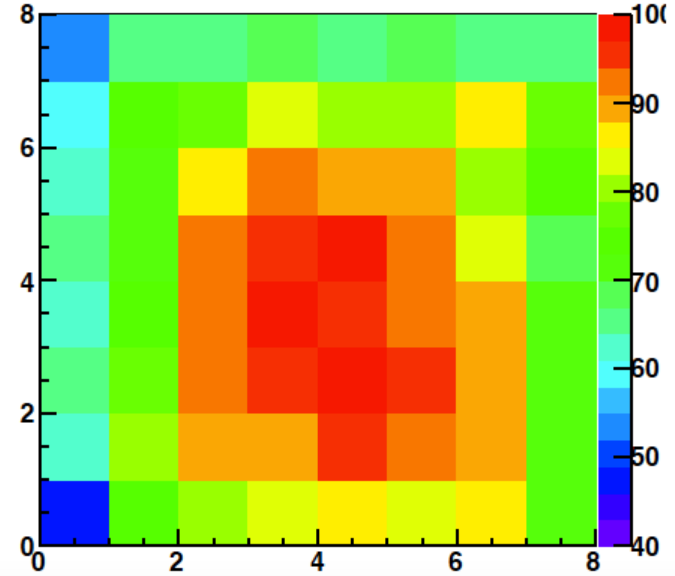


# TDC: SPE Discrimination Calibration

Relative efficiency map

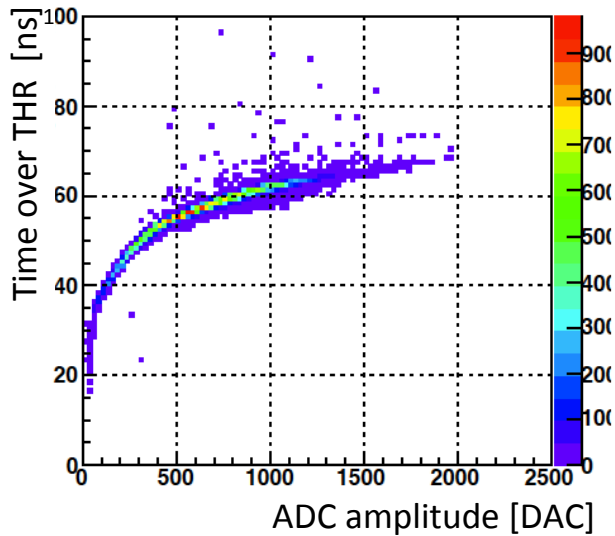


Relative gain map

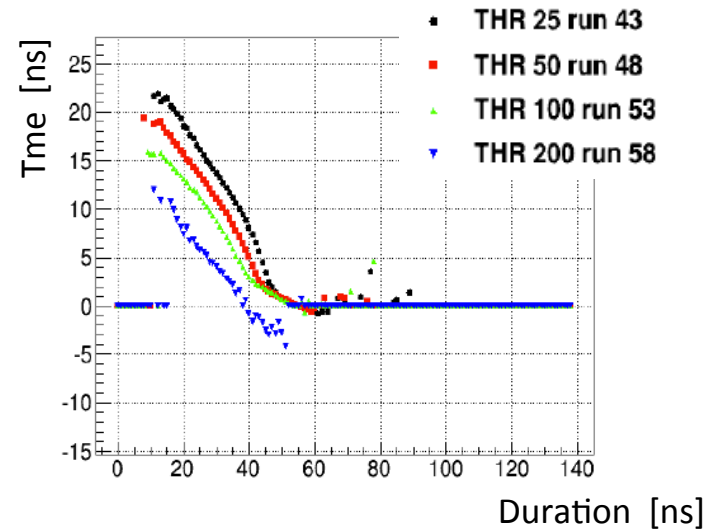


# TDC: SPE Timing Calibration

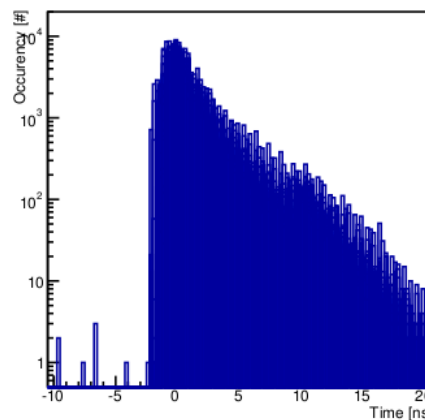
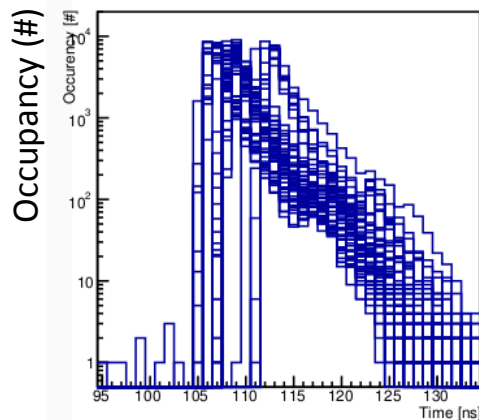
Time over threshold relates to charge



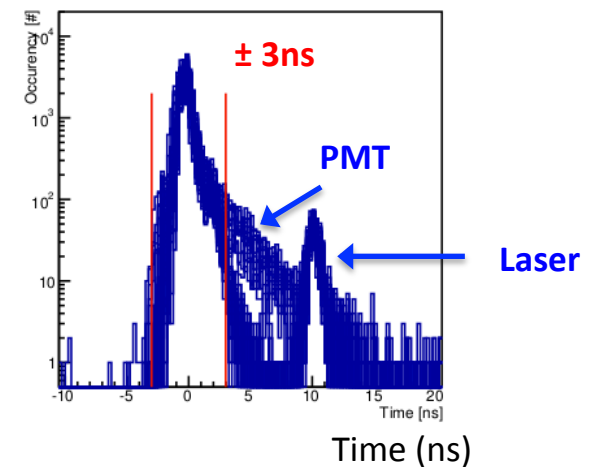
Typical time-walk with charge



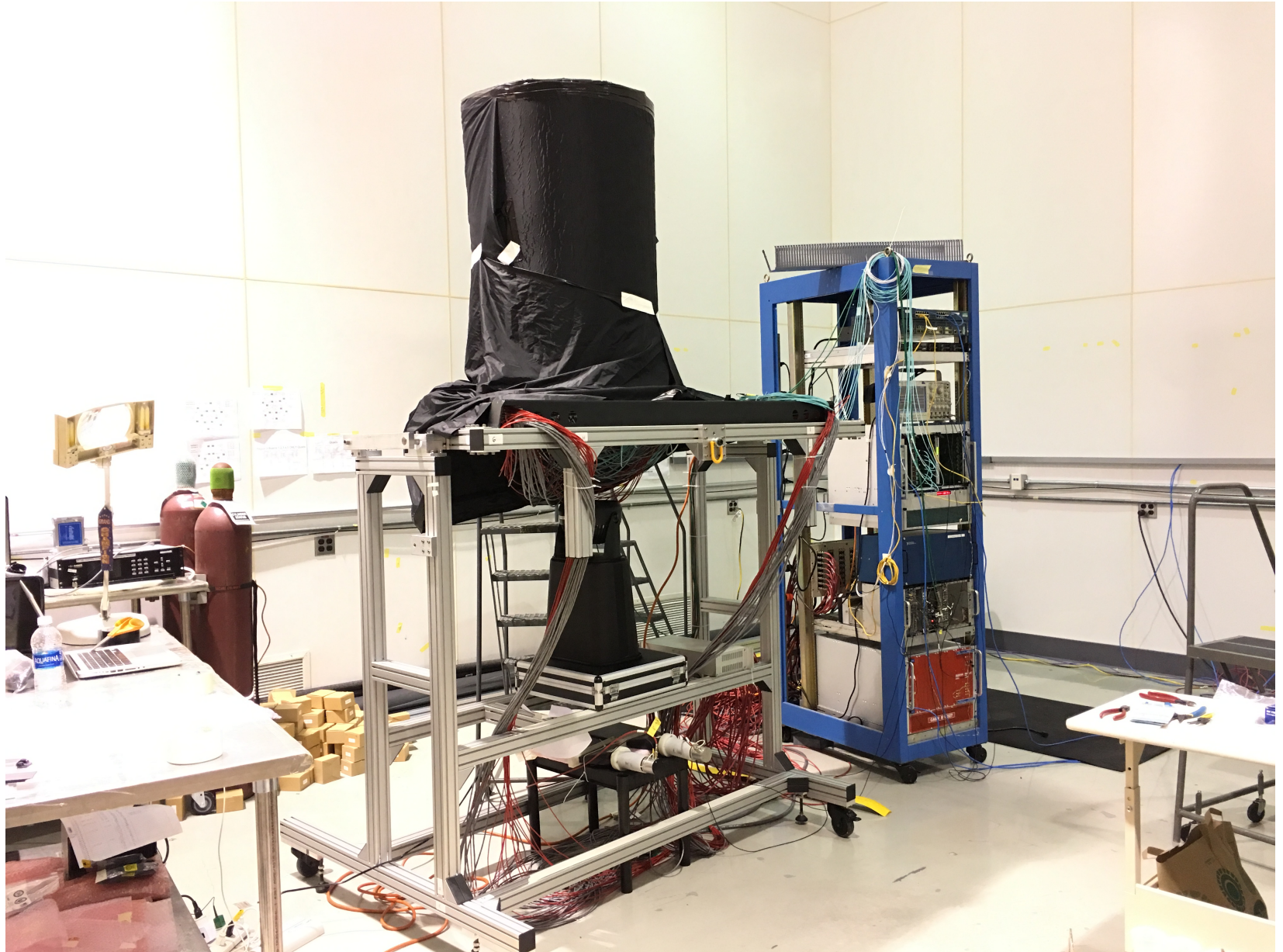
Channel by channel time calibration: -offsets



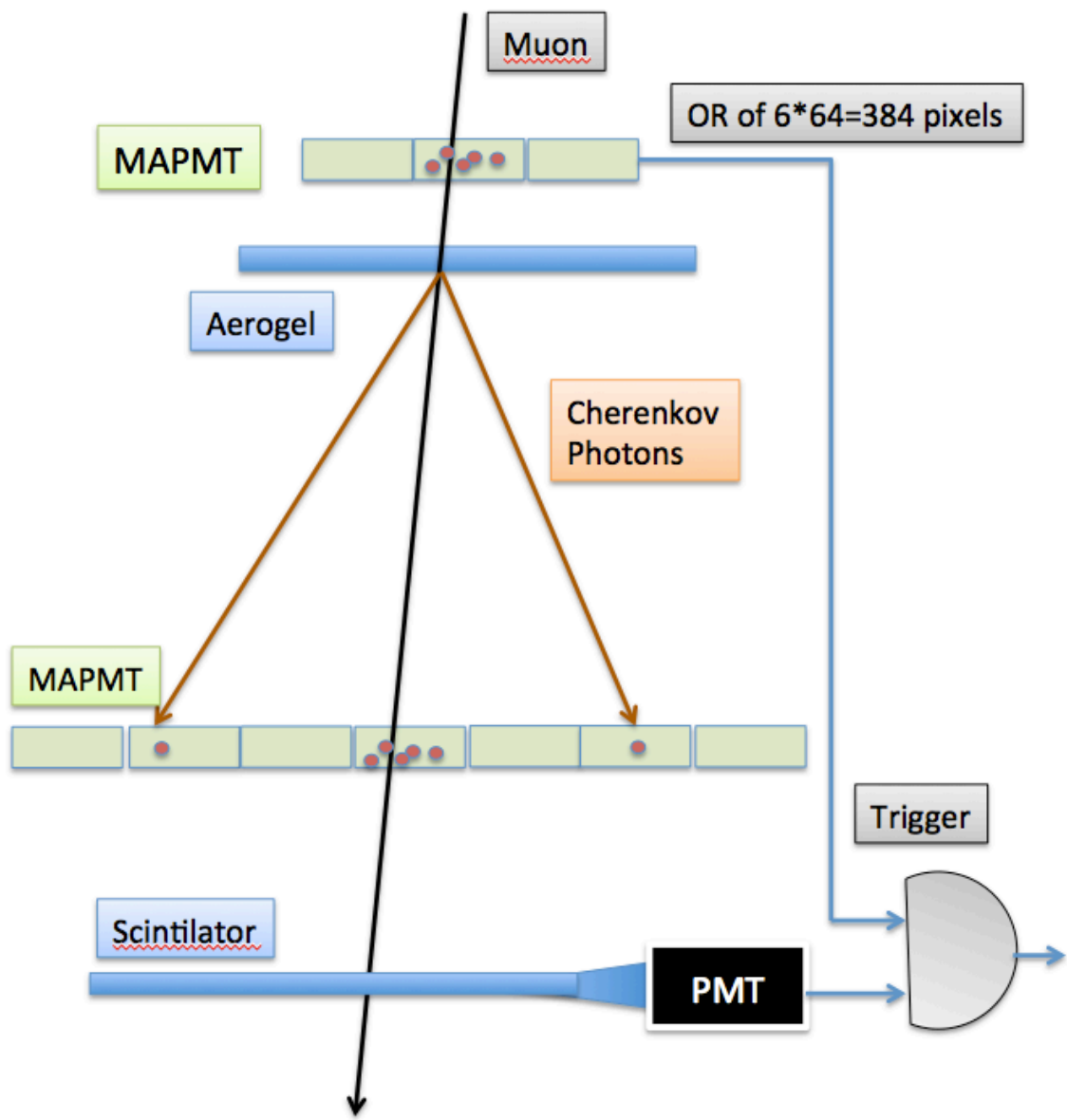
-walk



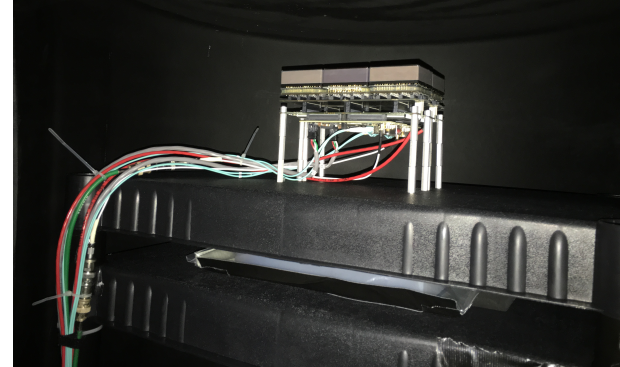
# Cosmic Stand



# Cosmic Run



Trigger and tracking station



PMT plane



Scintillator pads



# Power Supply Control

## LV voltages

HVRICH1 - Board #00

Controls **HVRICH1 Board #00**

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)
00	HVRICH1_LV_SPARE_Sl00_Ch00	ON	5.19 V	3.07 A	ON	5.200 V	4.0 A
01	HVRICH1_LV_SPARE_Sl00_Ch01	ON	5.20 V	3.10 A	ON	5.200 V	4.0 A
02	HVRICH1_LV_SPARE_Sl00_Ch02	ON	5.20 V	3.12 A	ON	5.200 V	4.0 A
03	HVRICH1_LV_SPARE_Sl00_Ch03	ON	5.20 V	3.13 A	ON	5.200 V	4.0 A
04	HVRICH1_LV_SPARE_Sl00_Ch04	ON	5.20 V	3.11 A	ON	5.200 V	4.0 A
05	HVRICH1_LV_SPARE_Sl00_Ch05	ON	5.20 V	3.10 A	ON	5.200 V	4.0 A
06	HVRICH1_LV_SPARE_Sl00_Ch06	ON	5.20 V	3.12 A	ON	5.200 V	4.0 A
07	HVRICH1_LV_SPARE_Sl00_Ch07	ON	5.20 V	3.10 A	ON	5.200 V	4.0 A



## HV Voltages

HVRICH1 - Board #11

Controls **HVRICH1 Board #11**

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)
00	HVRICH1_HV_SPARE_Sl11_Ch00	OFF	0.00 V	0.00 uA	OFF	0.000 V	100.0 uA
01	HVRICH1_HV_SPARE_Sl11_Ch01	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
02	HVRICH1_HV_SPARE_Sl11_Ch02	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
03	HVRICH1_HV_SPARE_Sl11_Ch03	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
04	HVRICH1_HV_SPARE_Sl11_Ch04	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
05	HVRICH1_HV_SPARE_Sl11_Ch05	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
06	HVRICH1_HV_SPARE_Sl11_Ch06	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
07	HVRICH1_HV_SPARE_Sl11_Ch07	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
08	HVRICH1_HV_SPARE_Sl11_Ch08	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
09	HVRICH1_HV_SPARE_Sl11_Ch09	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
10	HVRICH1_HV_SPARE_Sl11_Ch10	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
11	HVRICH1_HV_SPARE_Sl11_Ch11	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
12	HVRICH1_HV_SPARE_Sl11_Ch12	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
13	HVRICH1_HV_SPARE_Sl11_Ch13	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
14	HVRICH1_HV_SPARE_Sl11_Ch14	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
15	HVRICH1_HV_SPARE_Sl11_Ch15	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
16	HVRICH1_HV_SPARE_Sl11_Ch16	ON	1300.02 V	698.49 uA	ON	1300.000 V	1550.0 uA
17	HVRICH1_HV_SPARE_Sl11_Ch17	ON	1299.98 V	698.47 uA	ON	1300.000 V	1550.0 uA
18	HVRICH1_HV_SPARE_Sl11_Ch18	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
19	HVRICH1_HV_SPARE_Sl11_Ch19	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
20	HVRICH1_HV_SPARE_Sl11_Ch20	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
21	HVRICH1_HV_SPARE_Sl11_Ch21	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
22	HVRICH1_HV_SPARE_Sl11_Ch22	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
23	HVRICH1_HV_SPARE_Sl11_Ch23	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
24	HVRICH1_HV_SPARE_Sl11_Ch24	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
25	HVRICH1_HV_SPARE_Sl11_Ch25	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
26	HVRICH1_HV_SPARE_Sl11_Ch26	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
27	HVRICH1_HV_SPARE_Sl11_Ch27	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
28	HVRICH1_HV_SPARE_Sl11_Ch28	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
29	HVRICH1_HV_SPARE_Sl11_Ch29	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
30	HVRICH1_HV_SPARE_Sl11_Ch30	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA
31	HVRICH1_HV_SPARE_Sl11_Ch31	OFF	0.00 V	0.00 uA	OFF	0.000 V	155.0 uA

# Slow Control

RICH SSP Boards

RICH SSP Boards													
# Fibers Connected: 32 32													
Menu													
Slot 3 Slot 4 Slot 5 Slot 6 Slot 7													
		Scaler Average (Hz)			Temperatures (C)			Voltages (V)					
Slot	Fiber	Pmt 0	Pmt 1	Pmt 2	FPGA	Reg 0	Reg 1	Pcb5	Pcb3_3	Int1	Aux1_8	Mgt1	Mgt1_2
04	00	44	17	11	43.97	40.97	38.13	5.013	3.321	0.993	1.782	0.998	1.198
04	01	26	27	7	44.53	42.07	42.93	5.012	3.329	0.991	1.779	0.996	1.196
04	02	2050549	0	0	2147483.65	128.73	326.00	0.000	0.000	1.945	2.589	0.161	0.000
04	03	9	26	46	43.91	41.96	41.99	5.024	3.317	0.988	1.780	0.994	1.194
04	04	24	15	22	43.61	36.43	37.70	5.037	3.345	0.997	1.793	1.000	1.200
04	05	25	52	40	43.20	37.84	36.49	5.056	3.334	0.993	1.784	0.997	1.202
04	06	28	10	38	41.57	33.52	36.49	5.051	3.335	0.995	1.790	0.996	1.196
04	07	45	14	33	38.60	34.73	34.05	5.031	3.323	0.992	1.785	0.998	1.199
04	08	25	26	11	43.56	37.17	35.14	5.055	3.344	0.994	1.785	0.999	1.199
04	09	12	122	5	41.55	40.17	40.21	5.019	3.320	0.991	1.780	0.993	1.195
04	10	5	6	12	38.45	33.34	35.73	5.032	3.329	0.995	1.787	0.996	1.195
04	11	Scaler Average for each PMT (Hz)			Temperatures for each FE unit (C)			Bias voltages for each FE unit (V)					
04	12												
04	13												
04	14												
04	15												
04	16	28	22	17	42.49	37.34	37.36	5.004	3.336	0.992	1.786	0.996	1.199
04	17	19	12	12	40.03	33.05	35.72	5.029	3.343	0.996	1.789	1.000	1.198
04	18	13	7	6	41.23	35.62	37.78	5.033	3.327	0.991	1.782	0.997	1.194
04	19	25	23	414	40.03	35.99	36.40	5.026	3.327	0.992	1.786	0.996	1.195
04	20	10	20	49	43.92	39.19	39.48	5.029	3.346	0.993	1.783	0.996	1.197
04	21	24	29	10	40.65	37.21	33.28	5.027	3.339	0.994	1.787	0.999	1.196
04	22	10	7	49	40.60	35.60	36.03	5.022	3.339	0.991	1.780	0.998	1.192
04	23	10	5	41	42.44	36.08	33.35	5.045	3.327	0.993	1.786	1.000	1.200
04	24	12	10	6	39.61	35.54	36.81	5.036	3.343	0.995	1.787	0.994	1.195

Option: add some of these values to the interlock of the system





# Hardware Interlock

RICH-hwintlk.opi

## RICH Hardware Interlock System User Interface

### Detector Interlock Status

Any Internal Interlock Over Limit?

OK

RICH CAEN HV Enable Status

HV ENABLED

RICH CAEN LV Enable Status

LV ENABLED

### Air Compressor Status

COMPRESSOR ON

### EPICS Control

ENABLED

Interlock Status and Signal Monitoring    Threshold and Enable Control Settings    Summary of Interlocks    RICH cRIO Heartbeats: 45.7    cRIO CPU Usage: 64.33%    cRIO Uptime [hr]

### Interlock Enable Status

0	DISABLED	N2 Flow 1
1	DISABLED	N2 Flow 2
2	DISABLED	Airflow 1
3	DISABLED	Airflow 2
4	DISABLED	Air Pressure
5	ENABLED	Temperature 1
6	ENABLED	Temperature 2
7	DISABLED	Temperature 3
8	DISABLED	Temperature 4
9	DISABLED	Temperature 5
10	DISABLED	Temperature 6
11	DISABLED	Temperature 7
12	DISABLED	Temperature 8
13	DISABLED	Temperature 9
14	DISABLED	Temperature 10
15	DISABLED	Temperature 11
16	DISABLED	Temperature 12
17	DISABLED	Temperature 13
18	DISABLED	Temperature 14
19	DISABLED	Temperature 15
20	DISABLED	Temperature 16
21	DISABLED	Humidity 1
22	DISABLED	Humidity 2
23	DISABLED	Humidity 3
24	DISABLED	Humidity 4
25	DISABLED	Humidity 5
26	DISABLED	Humidity 6
27	DISABLED	Humidity 7
28	DISABLED	Humidity 8
29	DISABLED	Humidity 9
30	DISABLED	Humidity 10
31	DISABLED	Humidity 11

### Temperature Interlock Trip Limits

	High Limit	Low Limit	
0	40	10	Temperature 1
1	40	10	Temperature 2
2	30	10	Temperature 3
3	30	10	Temperature 4
4	30	10	Temperature 5
5	30	10	Temperature 6
6	30	10	Temperature 7
7	30	10	Temperature 8
8	30	10	Temperature 9
9	30	10	Temperature 10
10	30	10	Temperature 11
11	30	10	Temperature 12
12	30	10	Temperature 13
13	30	10	Temperature 14
14	30	10	Temperature 15
15	30	10	Temperature 16

### Humidity Interlock Trip Limits

	High Limit	Low Limit	
0	50	0	Humidity 1
1	50	0	Humidity 2
2	50	0	Humidity 3
3	50	0	Humidity 4
4	50	0	Humidity 5
5	50	0	Humidity 6
6	50	0	Humidity 7
7	50	0	Humidity 8
8	50	0	Humidity 9
9	50	0	Humidity 10
10	50	0	Humidity 11
11	50	0	Humidity 12
12	50	0	Humidity 13
13	50	0	Humidity 14
14	50	0	Humidity 15
15	50	0	Humidity 16

### Nitrogen Interlock Trip Limits

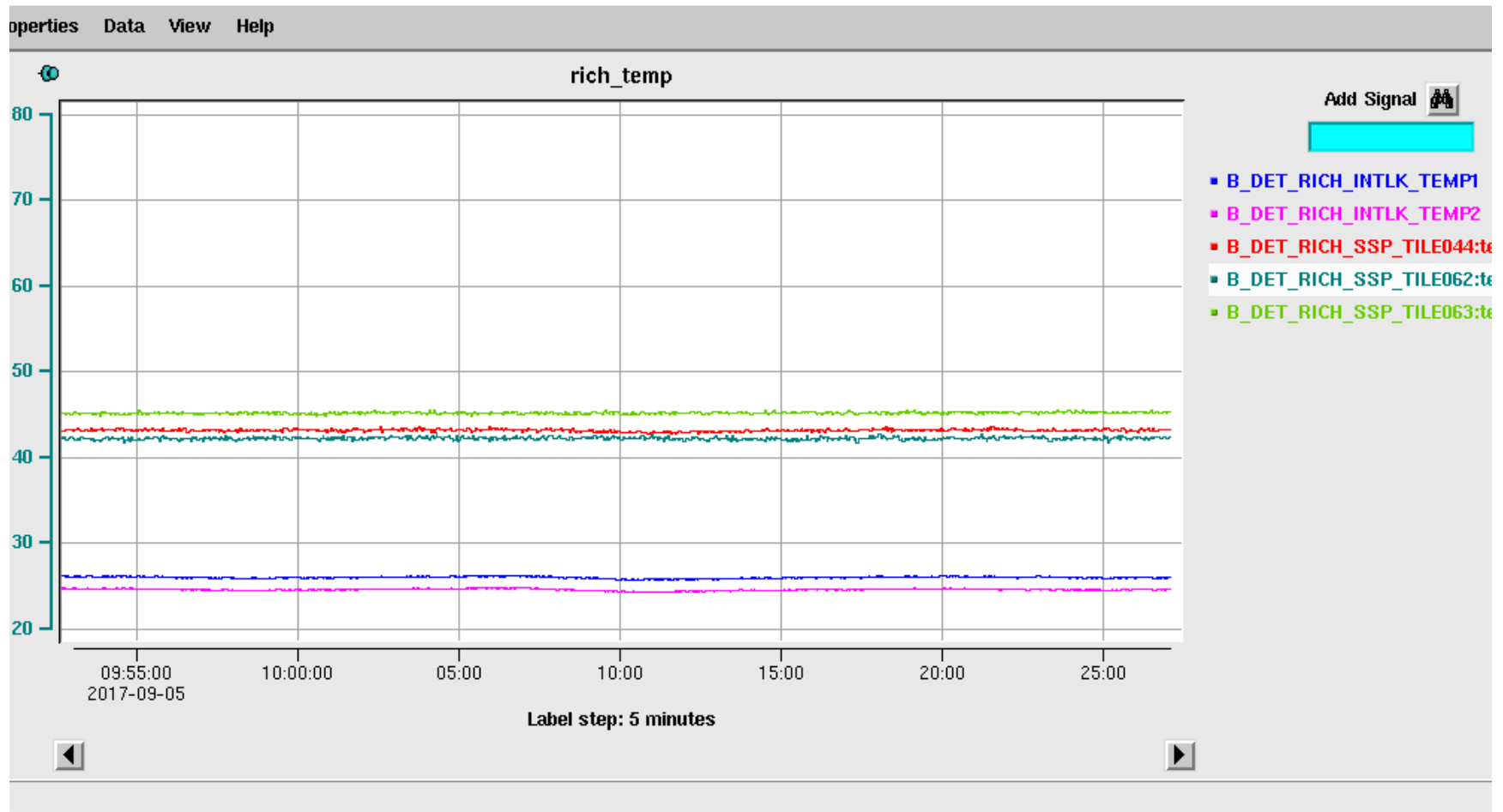
	High Limit	Low Limit	
0	6	2	N2 Flow 1
1	6	2	N2 Flow 2

### Air Cooling Interlock Trip Limits

	High Limit	Low Limit	
0	7	3	Airflow 1
1	7	3	Airflow 2
0	15	7	Air Pressure

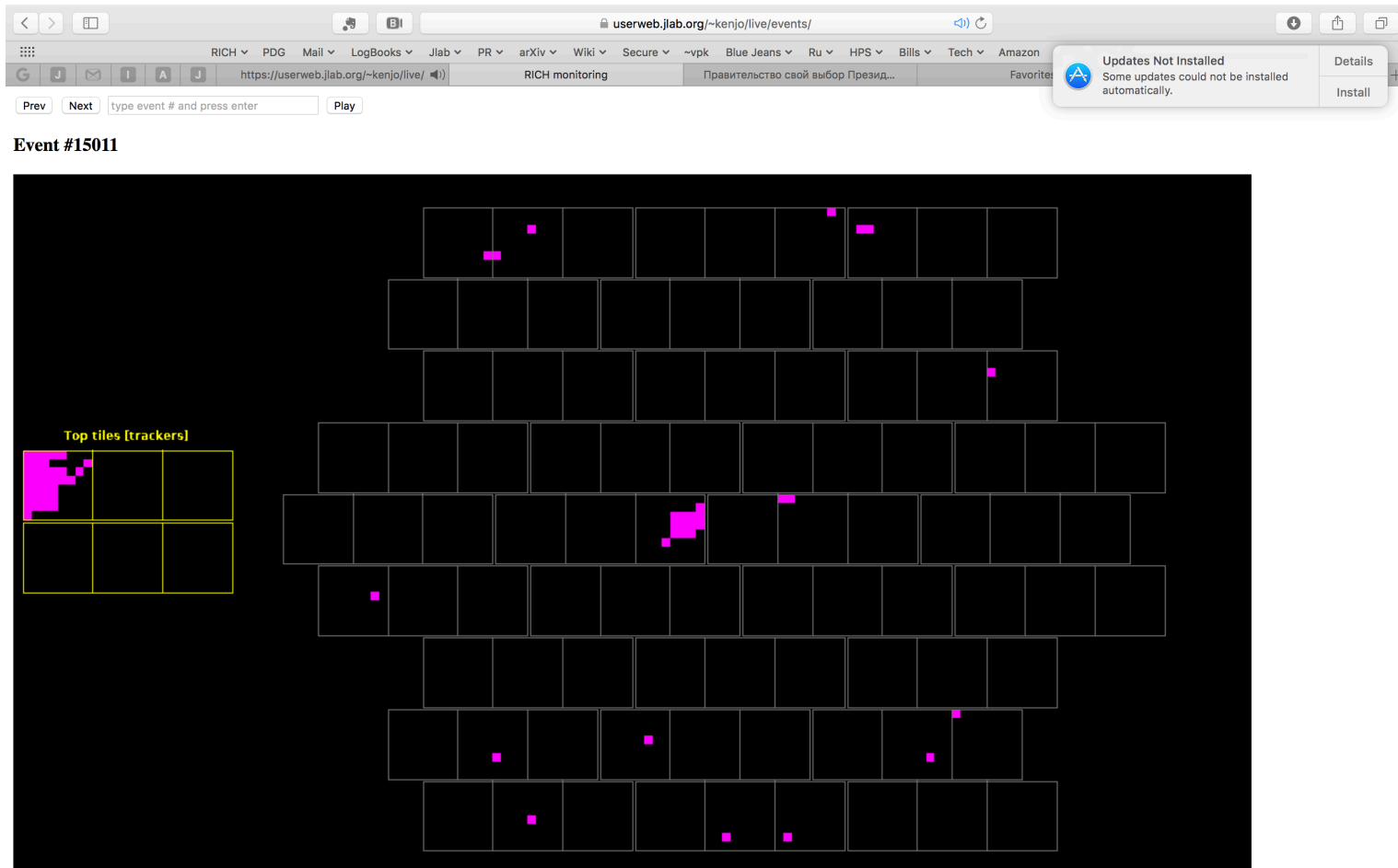
# Mya Strip Charts

Cosmic stand worked smoothly during first run (3 days)

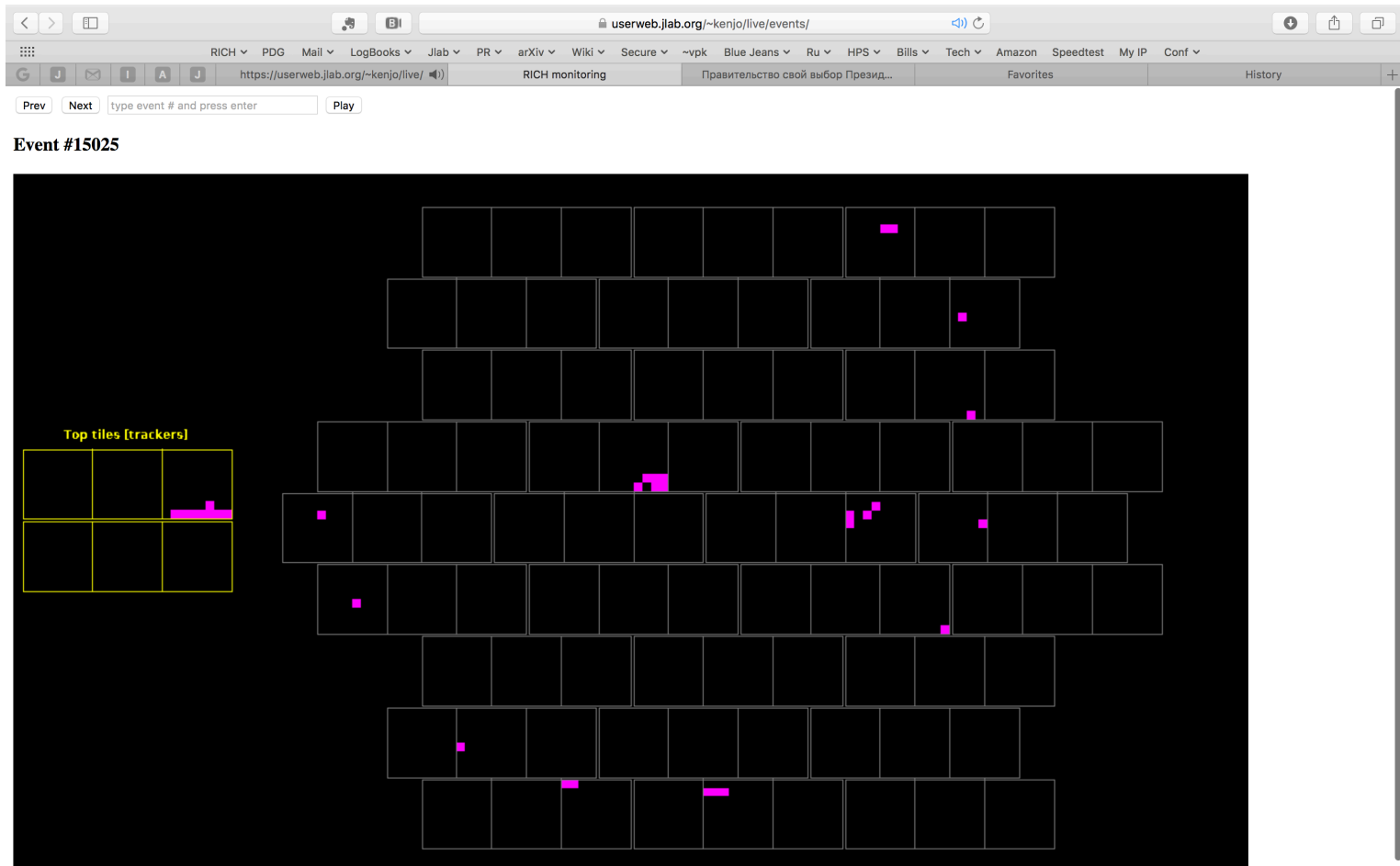


# Online Event Display

No background suppression: 1 microsec readout window



# Online Event Display



# Online Event Display

Browser tabs: G J [mail icon] I A J | <https://userweb.jlab.org/~kenjo/live/> | RICH monitoring | Правительство свой выбор Презид... | Favorites | History +

Prev Next  Play

### Event #15035

The event display shows a grid of 10 rows of tiles. The tiles are arranged in a roughly rectangular shape, with the top row having 10 tiles, the second row 9, the third 8, the fourth 7, the fifth 6, the sixth 5, the seventh 4, the eighth 3, the ninth 2, and the tenth 1. Pink tracks are visible on several tiles, indicating particle interactions. A legend on the left shows a 2x2 grid of tiles with a pink track on the top-right tile, labeled "Top tiles [trackers]".

Top tiles [trackers]

# Online Event Display

userweb.jlab.org/~kenjo/live/events/

RICH PDG Mail LogBooks Jlab PR arXiv Wiki Secure ~vpk Blue Jeans Ru HPS Bills Tech Amazon Speedtest My IP Conf

https://userweb.jlab.org/~kenjo/live/ RICH monitoring Правительство свой выбор Презид... Favorites History

Prev Next type event # and press enter Play

### Event #15207

Top tiles [trackers]

# Online Event Display

Browser tabs: G J [mail icon] I A J | <https://userweb.jlab.org/~kenjo/live/> | RICH monitoring | Правительство свой выбор Презид... | Favorites | History

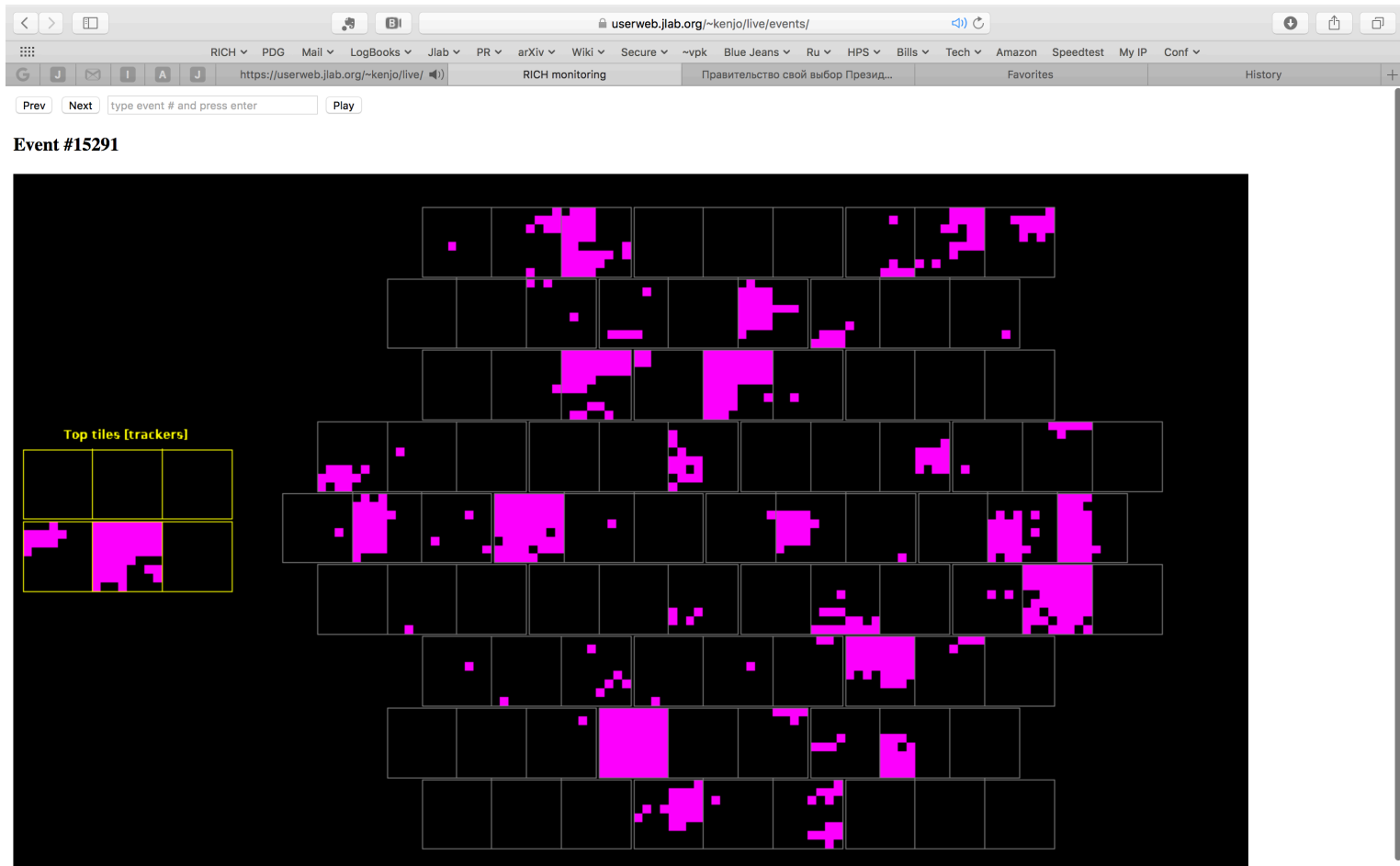
Prev Next  Play

### Event #15289

Top tiles [trackers]



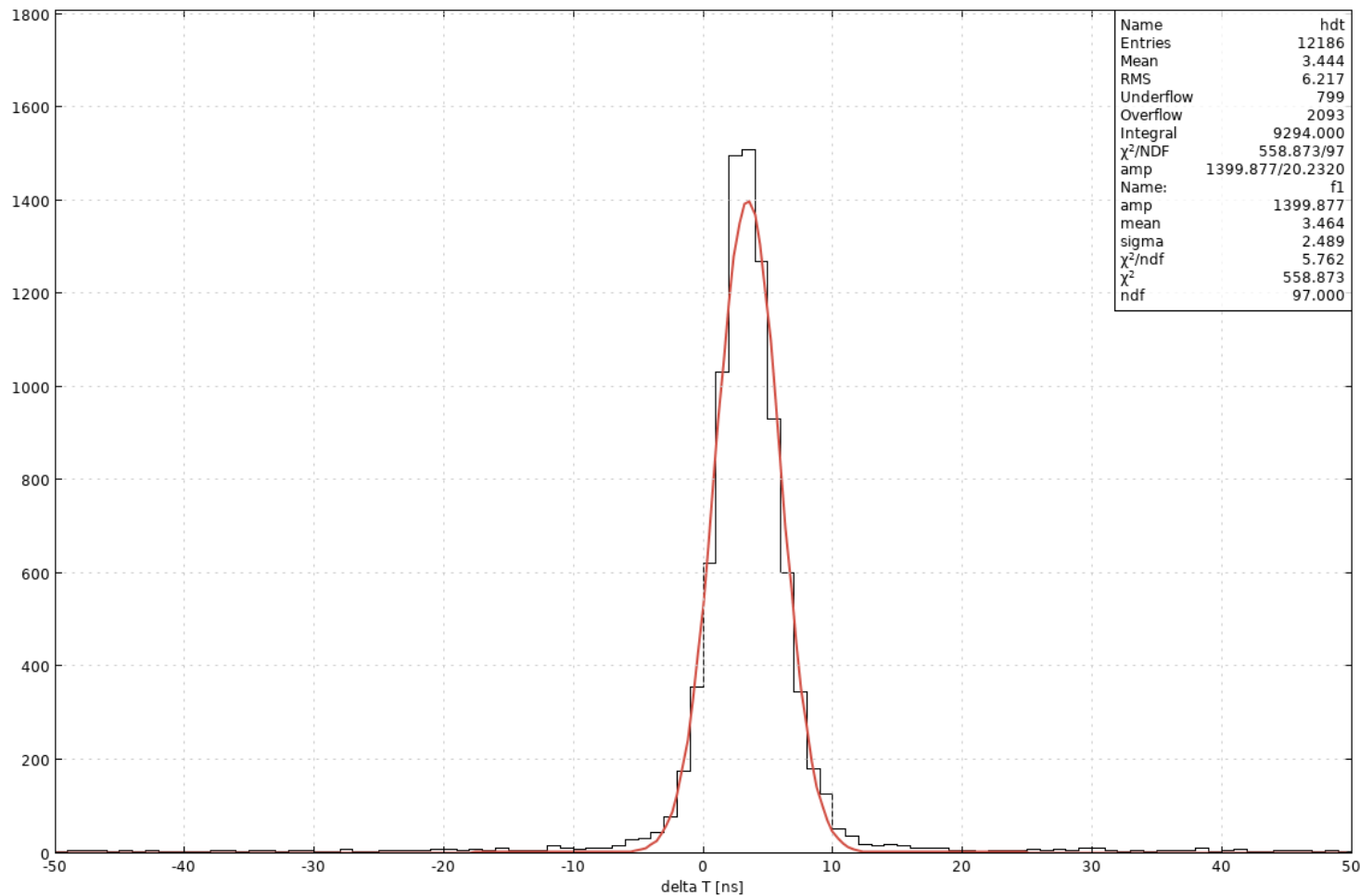

# Online Event Display



# Hit Time Distribution

$\Delta T$  (BOTTOM plane – TOP Tracking Unit) = 3.4 ns

$\sigma_T$  without any correction = 2.4 ns



# RICH Software

RICH geometry is implemented in the software mostly from CAD through mesh files

- a detailed, consistent and updated description of the detector can be obtained
- simulation and reconstruction shared the same database

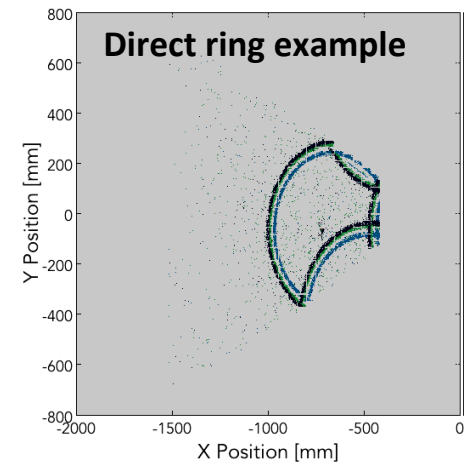
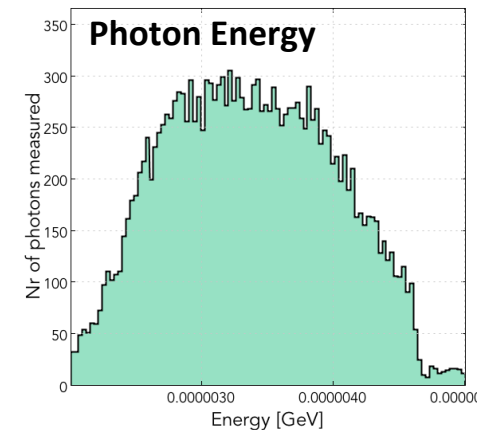
Digitization of the MAPMT response:

- calculate the pixel ID
- interface to CCDB
- apply efficiency
- simulated ADC and TDC spectra

Event reconstruction started

- match with DC information in coat-java
- photon tracing algorithm (tested with prototype and cosmic runs)
- event display

Strong crew: Matteo, Ilaria, Marco, Giovanni,  
Justin, Morgen, Elise, Aram, Andrey, ...

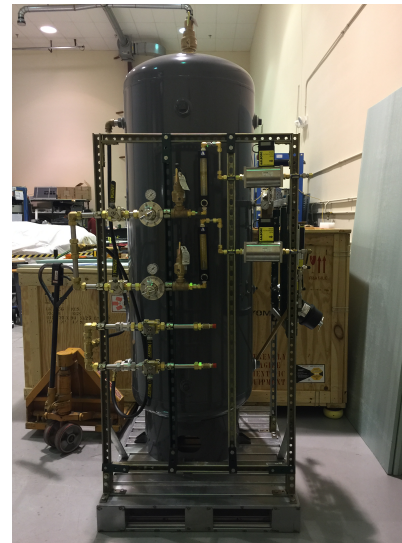
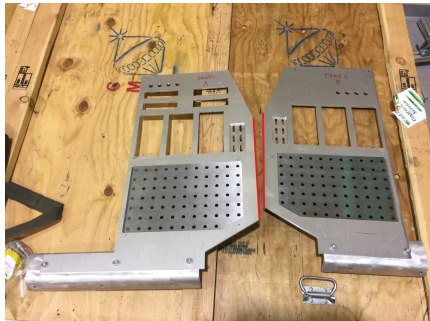
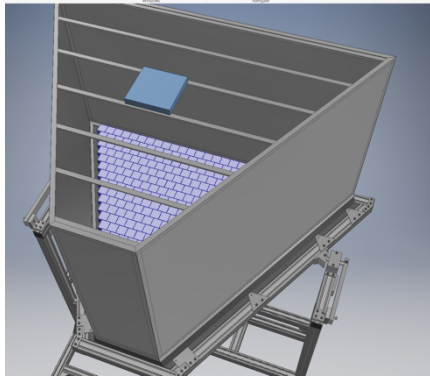
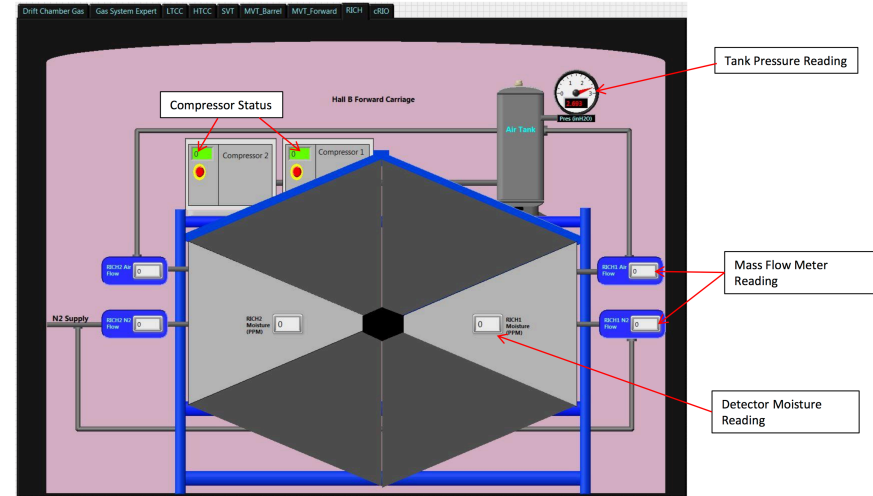


# Photon Detector

Scale the system up:

- ✓ Argonne cosmic box
  - ✓ Cabling with patch panels
  - ✓ Gas system being installed in EEL-124 (DSG)
- Operative test foreseen in October 17  
with fully instrumented electronic panel

## Gas System GUI



## Air Tank and Gas Line Controls Clean Air Compressor



# Assembling Schedule

activity	WEEK											
	aug 28	sep 4	sep 11	sep 18	sep 25	oct 2	oct 9	oct 16	oct 23	oct 30	nov 6	nov 13
EPanel tests with 32 boards												
Spherical mirror resurfacing and coating												
Aerogel production and delivery												
3D print of the pushers of the 2 cm layer												
Purchase of the wire and spacers												
Construction of the brackets for the load test												
Construction of the brackets for the strong-back												
Construction of the mounts for the trolley												
Setup of the gas slow control and interlocks												
3D print of the cooling distributor (left)												
Setup of the N2 dewar												
3D print of the N2 manifold												
Cosmics box at JLab												
Production of the patch panels												
Assembly of the frontal panel tools												
Test of the lateral mirror installation												
Test of the prototype mirror B1 installation												
Production of fake tiles												
Setup of the dry area with the Fe cabinet												
Assembly test of the frontal panels												
Preliminary test of the cooling distributor												

October:

RICH Component Assembling

Photon Detector Commissioning

Steady Cosmic Run

September:

Photon Detector Assembling

RICH Components Preparation

activity	WEEK											
	aug 28	sep 4	sep 11	sep 18	sep 25	oct 2	oct 9	oct 16	oct 23	oct 30	nov 6	nov 13
3D print of the cooling distributor (right)												
Drilling holes on the RICH for the N2 distributors												
Fix of the main leaks on the RICH												
Full EPanel assembly												
Test of the spherical mirrors (surface, reflectivity)												
Drilling wire holes on the top frontal panel												
Assembly test of the 3 cm aerogel layers												
Assembly test of the patch panels												
Assembly of the cosmics box on the EPanel												
Stiffening tool load test												
Full EPanel test with cosmics												
Cooling system on the full EPanel												
Assembly test of the brackets of the strong-back												
Cut of the frontal pillar from the trolley												
Assembly test of the mounts on the trolley												
Cleanup of the clean room												
Installation of the spherical mirrors												
Test of the nitrogen system on the cosmics box												
Setup of the N2 system for the RICH transportation												
Installation of the lateral mirrors												
Services in Hall B												

# Assembling Schedule

activity	WEEK											
	aug 28	sep 4	sep 11	sep 18	sep 25	oct 2	oct 9	oct 16	oct 23	oct 30	nov 6	nov 13
Installation of the exit panel												
Installation of the stiffening tool												
RICH in vertical position												
Alignment of the spherical mirrors												
Alignment of the lateral mirrors												
Installation of the bottom mirror												
Survey of the RICH												
Installation of the EPanel												
Installation of the patch panels on the RICH												
Installation of the frontal panels												
Test of the N2 system on the RICH												
Light-tightness test												
De-installation of the frontal panels												
Final assembly of the 3 cm aerogel layer												
Final assembly of the 2 cm aerogel layer												
Installation of the frontal panels with the aerogel												
Transportation of the RICH in Hall B												
Installation in CLAS12												

November:

Final Assembling

Validation

Installation

Week of 30 October: RICH Services in the Hall

Week of 13<sup>th</sup> November: RICH in the Hall