Detector Health Report

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Detector Support Group

April 4, 2018

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- Gas system monitoring
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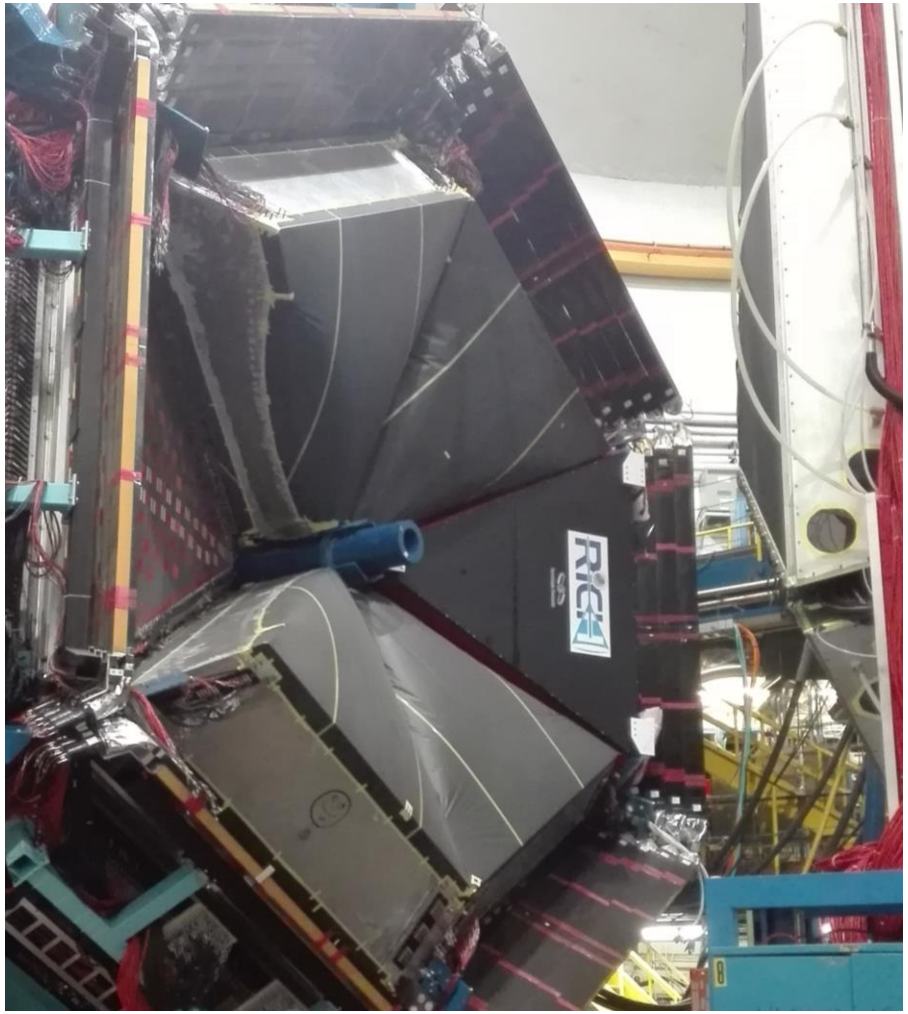
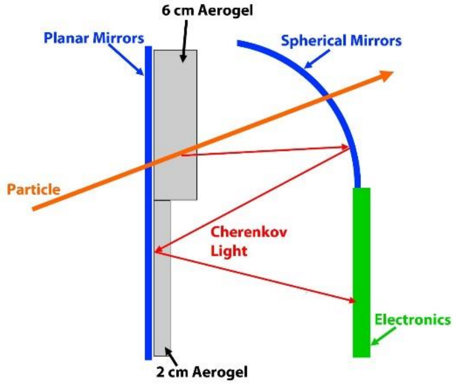
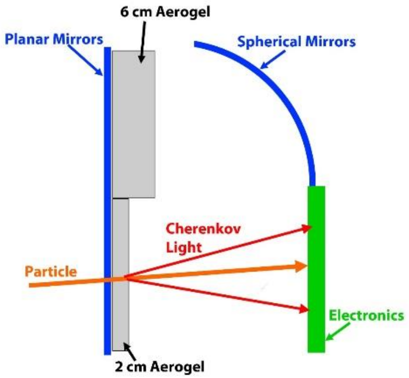


Ring-Imaging Cherenkov Detector Overview

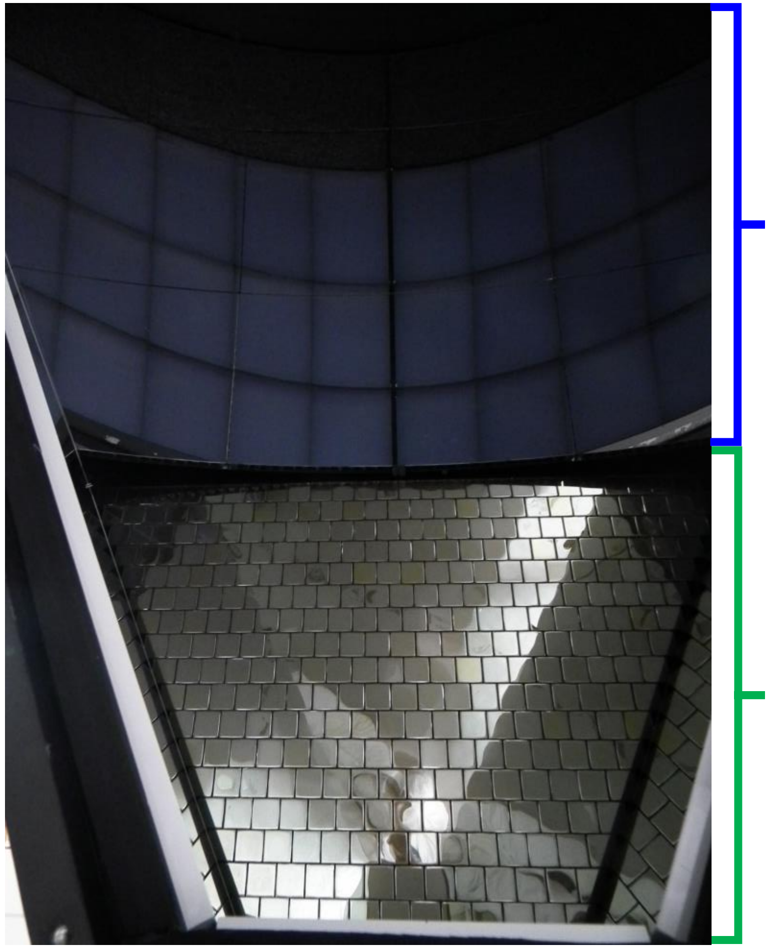
- Installed on Forward Carriage in Sector 4.
- Uses PMTs to detect Cherenkov light generated by charged particles passing through aerogel.
- Number of PMTs required reduced by using spherical mirrors.
  - Mirrors reflect light generated by particles with larger incident angles into PMTs.



Cherenkov Light Path for Large Incident Angle Particle



Cherenkov Light Path for Small Incident Angle Particle

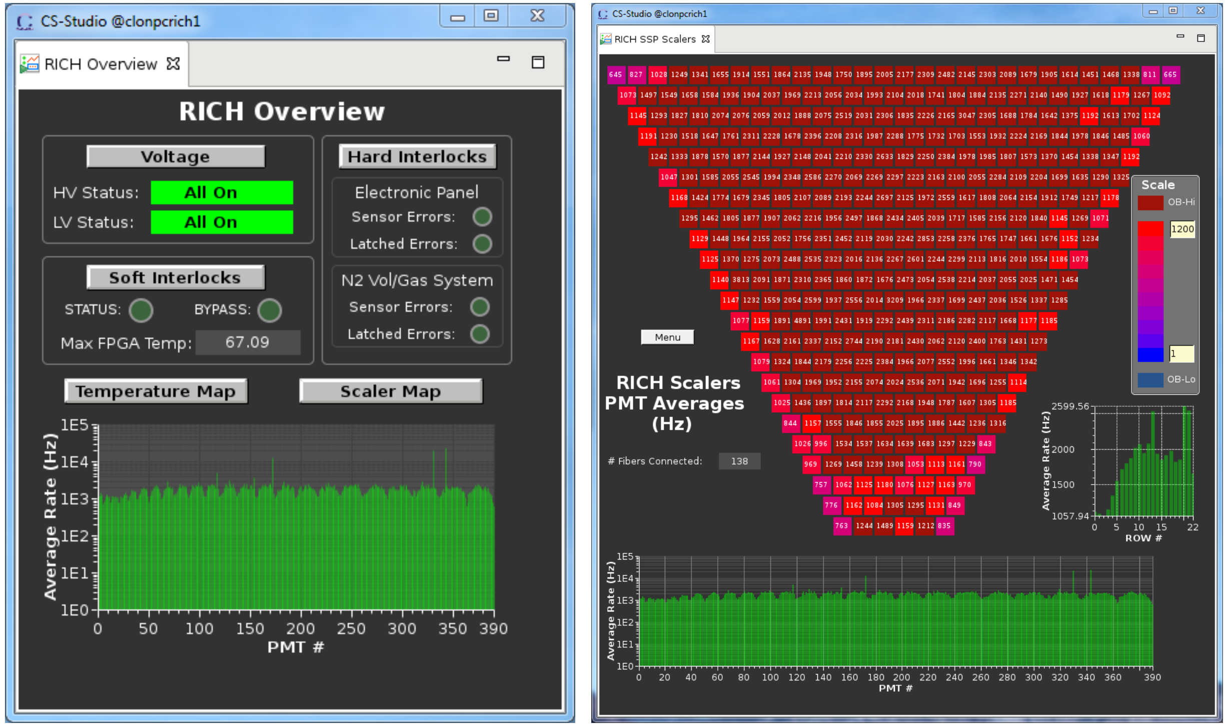


Spherical Mirrors with reflection of Aerogel tiles.

PMTs on Electronic Panel

RICH Monitoring Systems - EPICS

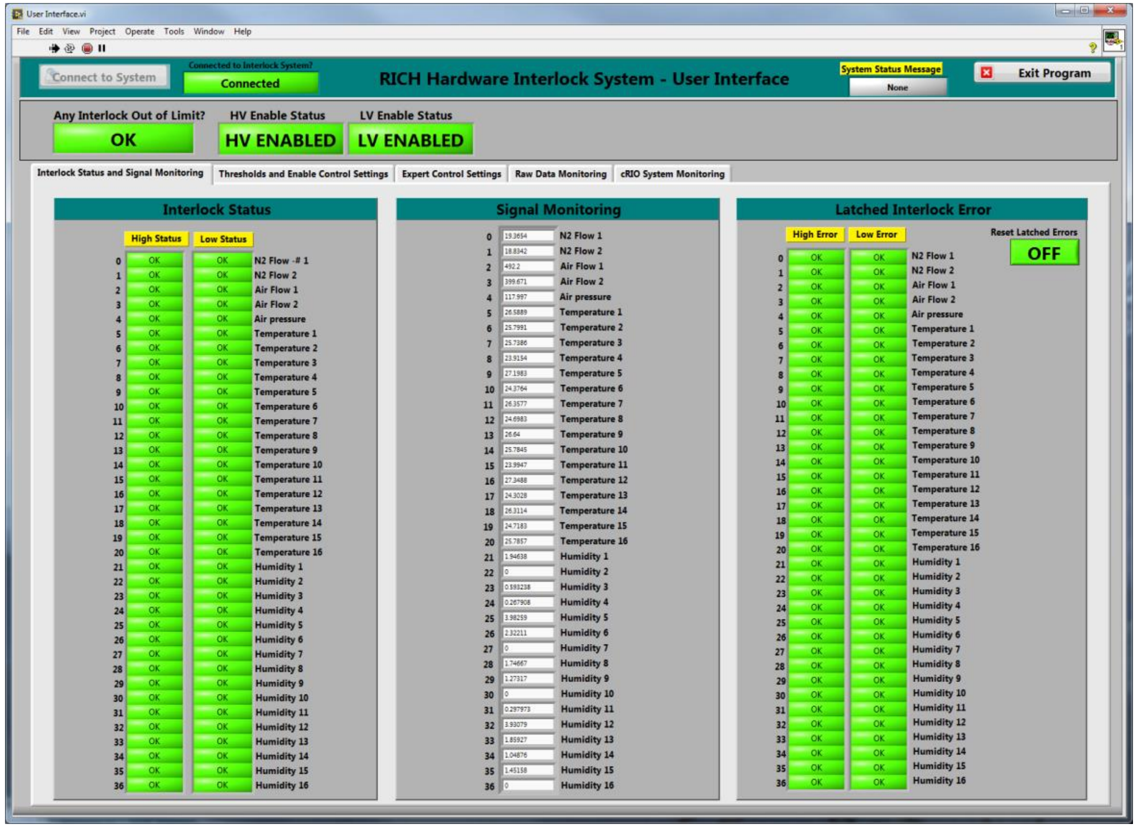
- Data read by IOC from electronics readout.
- Monitors voltages, currents, FPGA temperatures, and scaler counts.
- Information displayed in *clascss.*
- Uses software to send inhibit signal to CAEN to disable HV/LV.



RICH Overview and Scalers Map EPICS screens

RICH Monitoring Systems – Hardware Interlock System

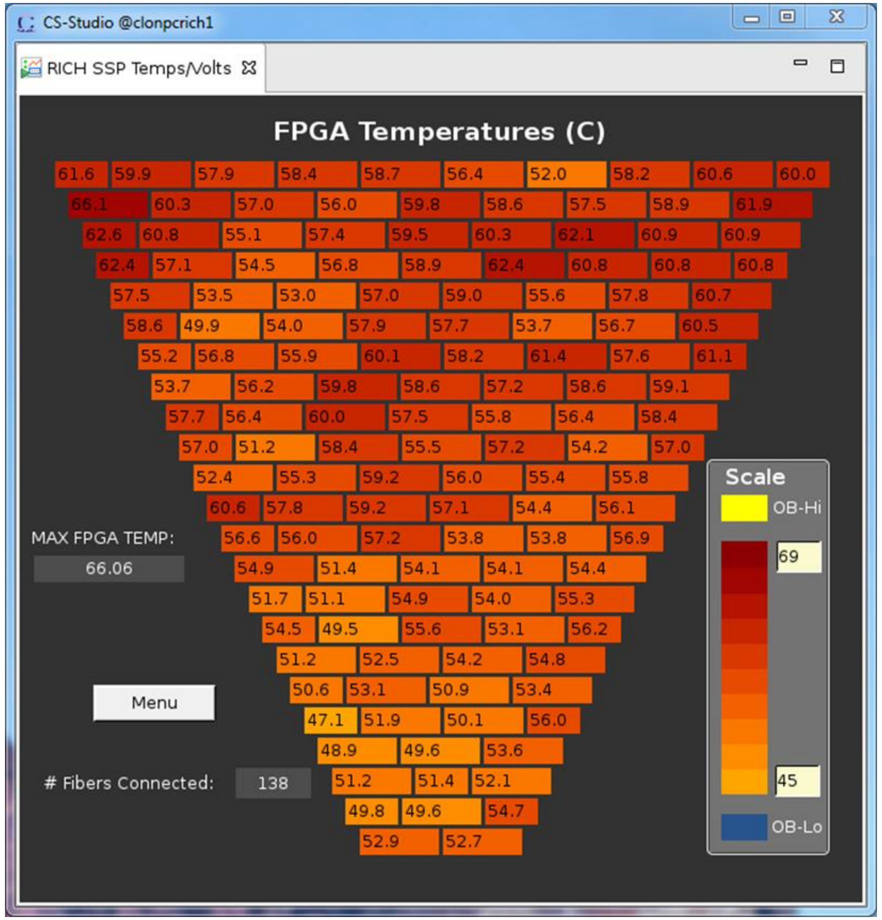
- *Network-independent* cRIO-based system that monitors detector conditions using independent sensors.
  - 32 RTDs
  - 32 humidity sensors
  - two nitrogen flow meters
  - two cooling air flow meters
  - two differential pressure transducers
  - one pressure transducer for cooling buffer tank pressure
- LabVIEW code for interlock system developed by DSG.
- Uses a relay connection to disable HV/LV using CAEN's front panel interlock connection.



RICH Hardware Interlock's LabVIEW User Interface

Temperature Monitoring

- Temperature of electronics and detector volumes measured by built-in temperature sensors in FPGAs and interlock system RTDs.
- Typical FPGA temperature:
  - Only LV on: max ~65 °C
  - LV/HV on: max ~69 °C.

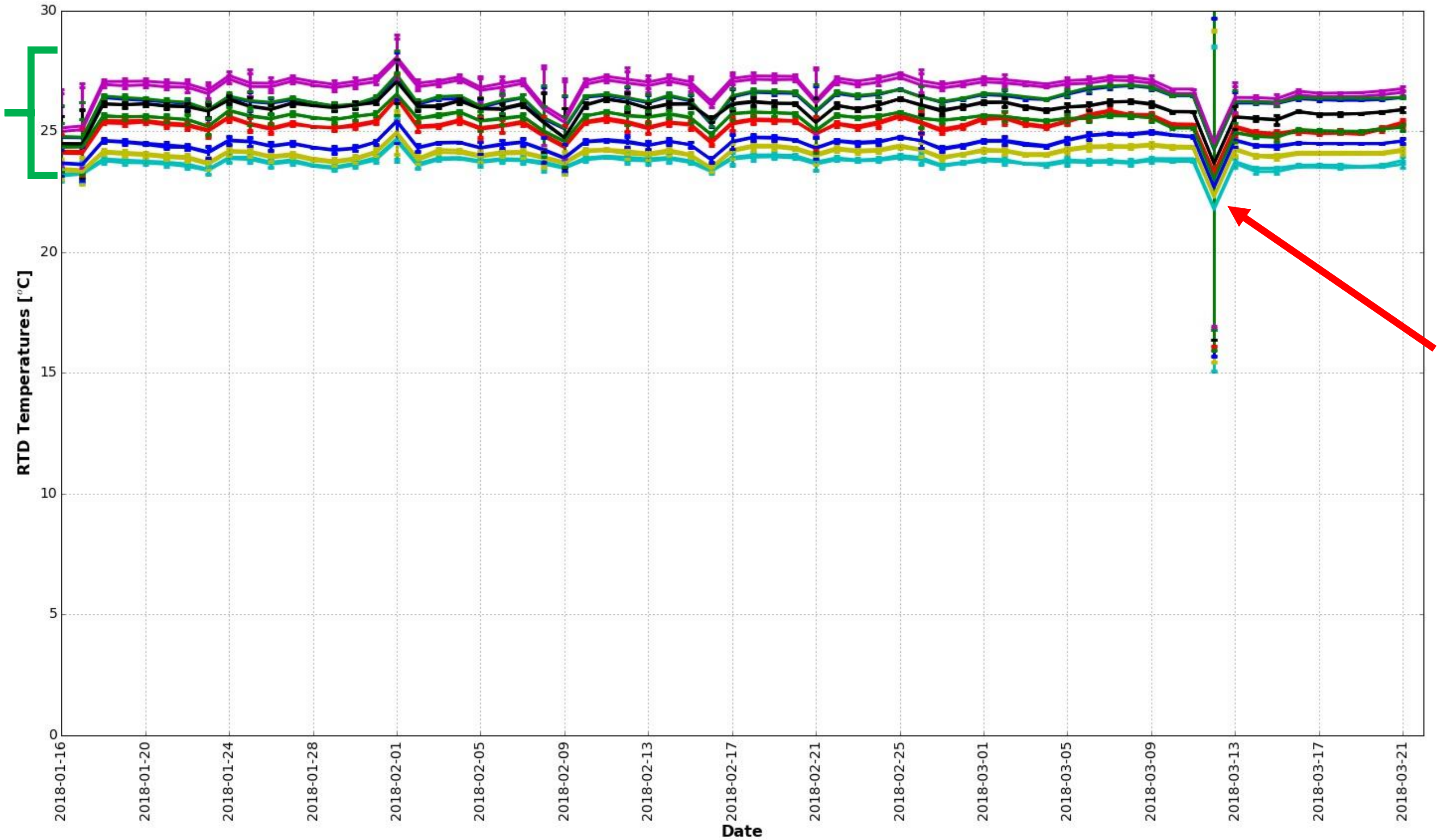


LV on, HV off

Hardware Interlock N_2 Volume Temperature History

From January 16, 2018 Through March 21, 2018

~ 3 °C spread



For each interlock sensor, MYA archived data was retrieved at one hour intervals.
For plot, data points are average measurement for every point that day. Error bars are calculated standard deviation for that day.

NOTE:
Large error bars on 3/12/2018 caused by an issue with EPICS readout.
For ~2 hours, all readouts from RICHCRIO were published to EPICS as zero while issue was resolved.
The large error bars are seen on all plots generated for report.

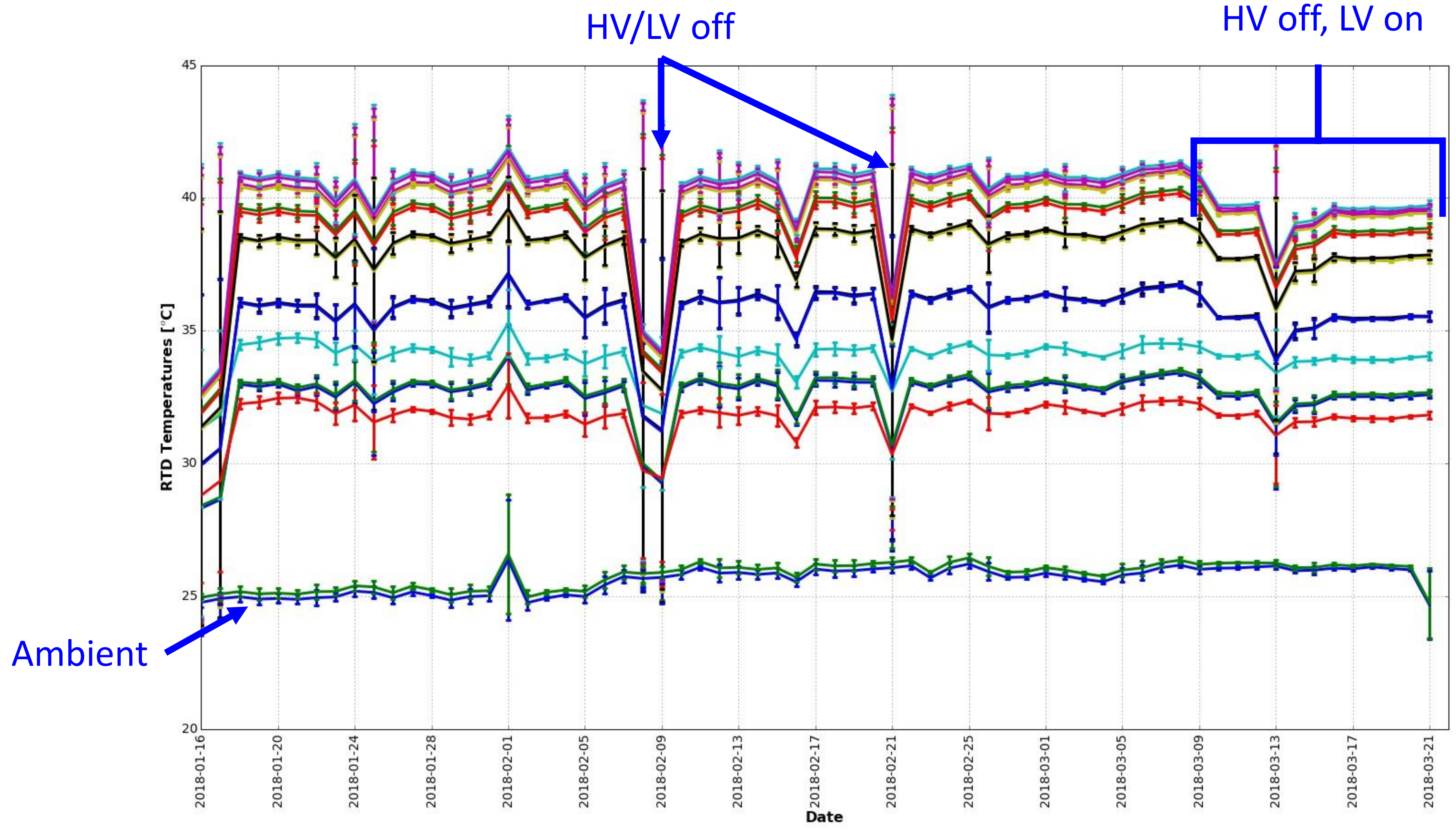
Hardware Interlock N_2 Volume Temperature Statistics

From January 16, 2018 Through March 21, 2018

Sensor Board	RTD	Mean [°C]	Standard Deviation [°C]
1	1	26.23	1.11
	9	25.40	1.04
2	3	25.17	1.01
	10	23.65	0.89
3	4	26.71	1.18
	11	24.10	0.92
4	5	25.91	1.08
	12	24.44	0.84
5	6	26.28	1.11
	13	25.23	1.01
6	7	23.73	0.89
	14	26.86	1.18
7	8	24.02	0.92
	15	25.89	1.08
8	2	24.47	0.95
	16	25.38	1.04
OVERALL		**25.22**	**4.11**

Hardware Interlock EP Temperature History

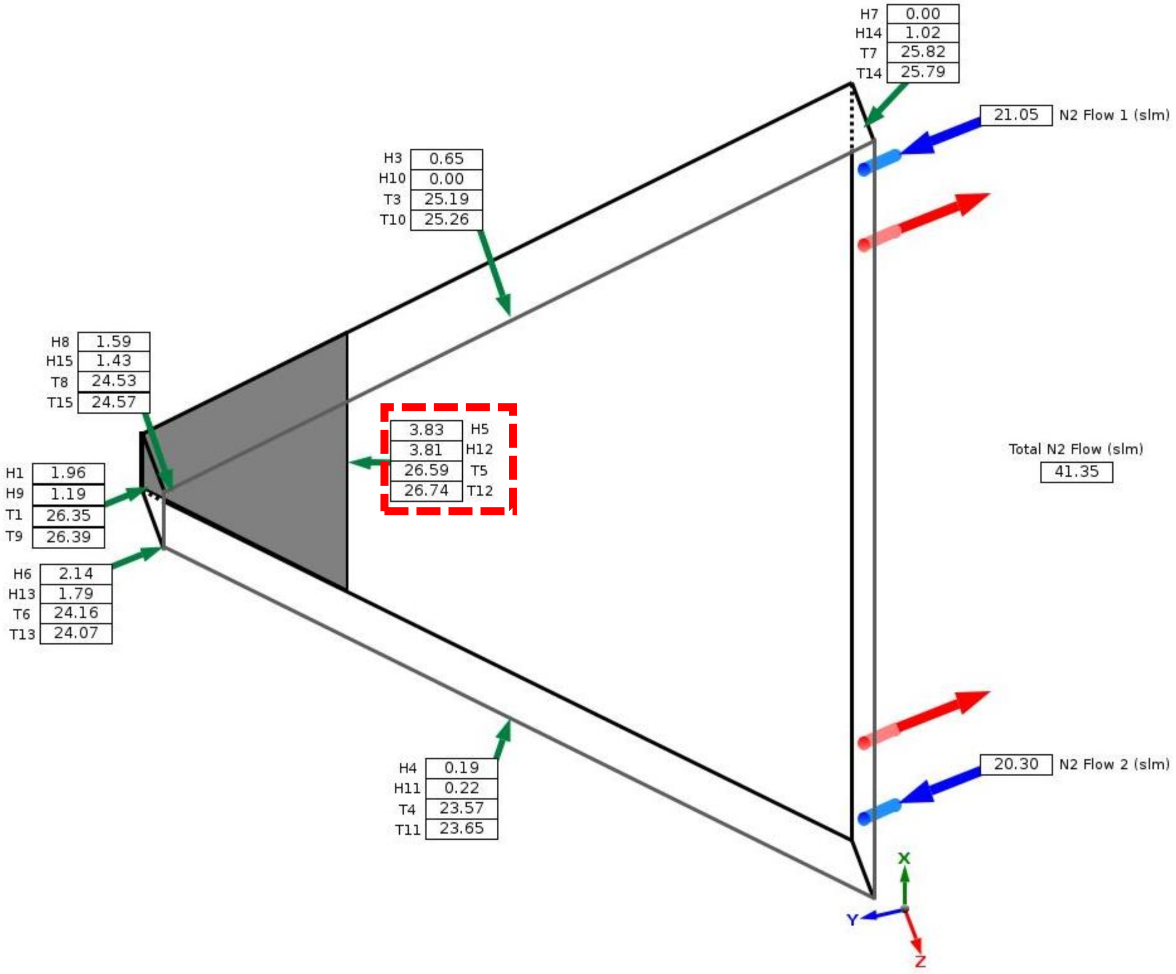
From January 16, 2018 Through March 21, 2018



Humidity Monitoring

- Humidity monitored by interlock system sensors.
  - Honeywell HIH-4030 series humidity sensors
  - Manufacturer Accuracy Spec: ± 3.5% RH
  - JLab Measured Accuracy: ± 1.5% RH
- Low humidity achieved by purging detector with nitrogen.
  - Goal is to keep humidity under 3% RH.
- Typical humidity:
  - ~1 % RH in EP
  - ~2 % RH in N2 volume.
    - Only H5/H12 (located behind spherical mirrors) ~4% RH; reason unknown.

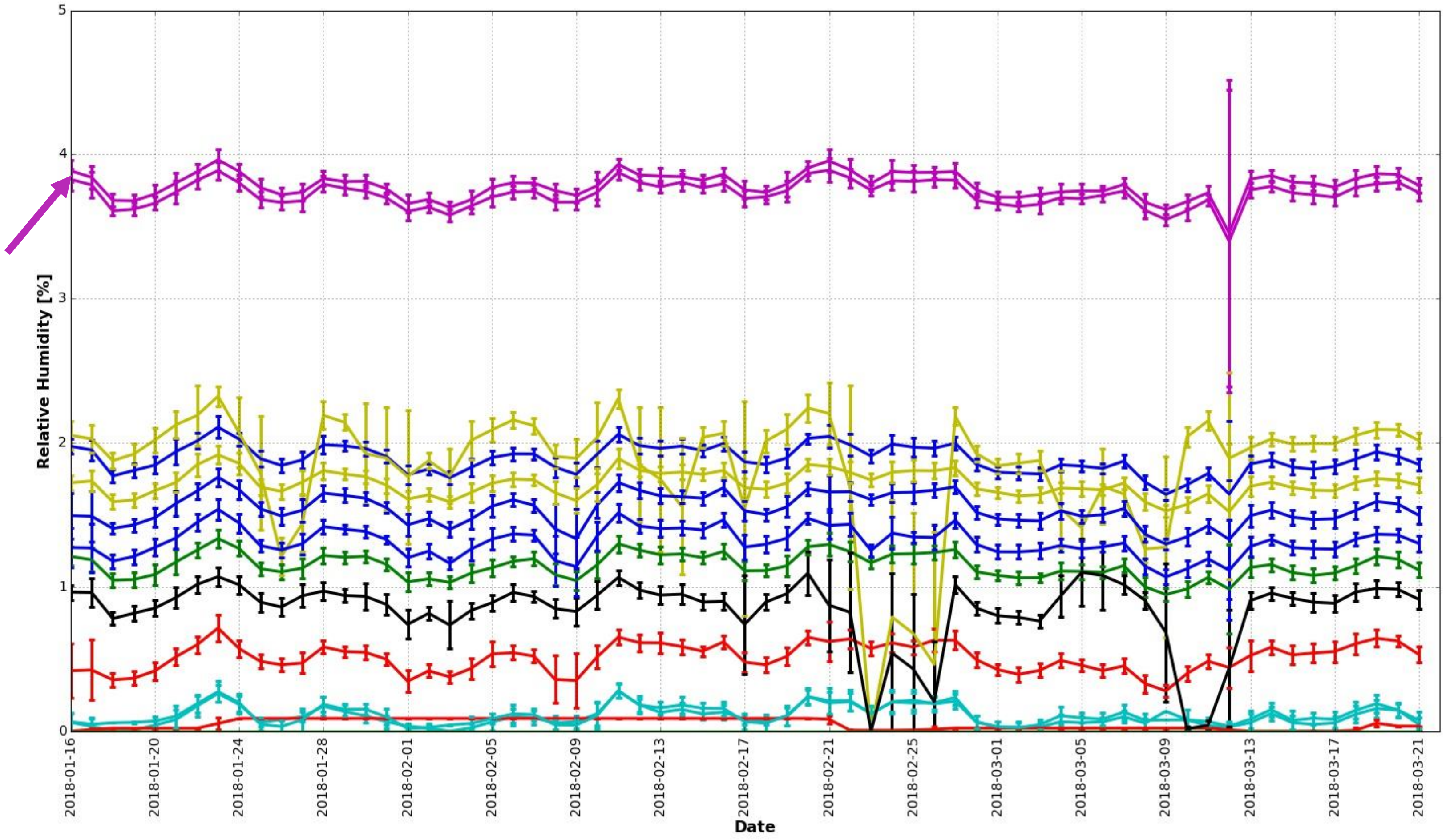
Humidity Monitoring – N2 Volume



N_2 Volume Humidity History

From January 16, 2018 Through March 21, 2018

Humidity 5 and 12 (behind spherical mirrors) are only sensors above 3 % RH.



All other humidity sensors below 3 % RH

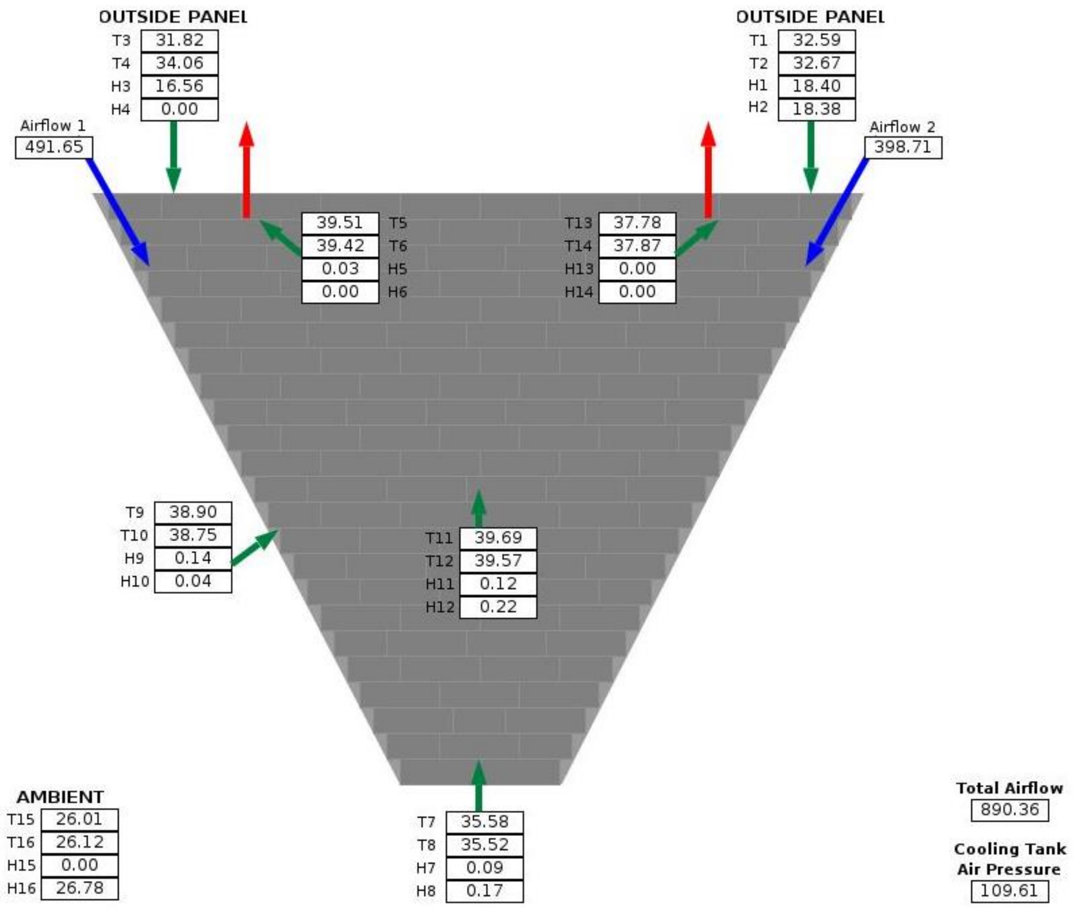
N_2 Volume Humidity Statistics

From January 16, 2018 Through March 21, 2018

Sensor Board	Humidity Sensor	Mean [% RH]	Standard Deviation [% RH]
1	1	1.89	0.13
	9	1.15	0.11
2	3	0.51	0.12
	10	0.05	0.04
3	4	0.10	0.08
	11	0.11	0.08
4	5	3.79	0.17
	12	3.73	0.16
5	6	1.83	0.52
	13	1.72	0.12
6	7	0.00	0.00 Bad Sensor
	14	0.84	0.29
7	8	1.54	0.13
	15	1.31	0.13
8	2	0.00	0.00
	16	0.00	0.00
OVERALL Without H2,5,7,12,16		**1.00**	**0.68**

Humidity 5 and 12 thought to be higher due to placement in RICH behind mirrors.

Humidity Monitoring – EP



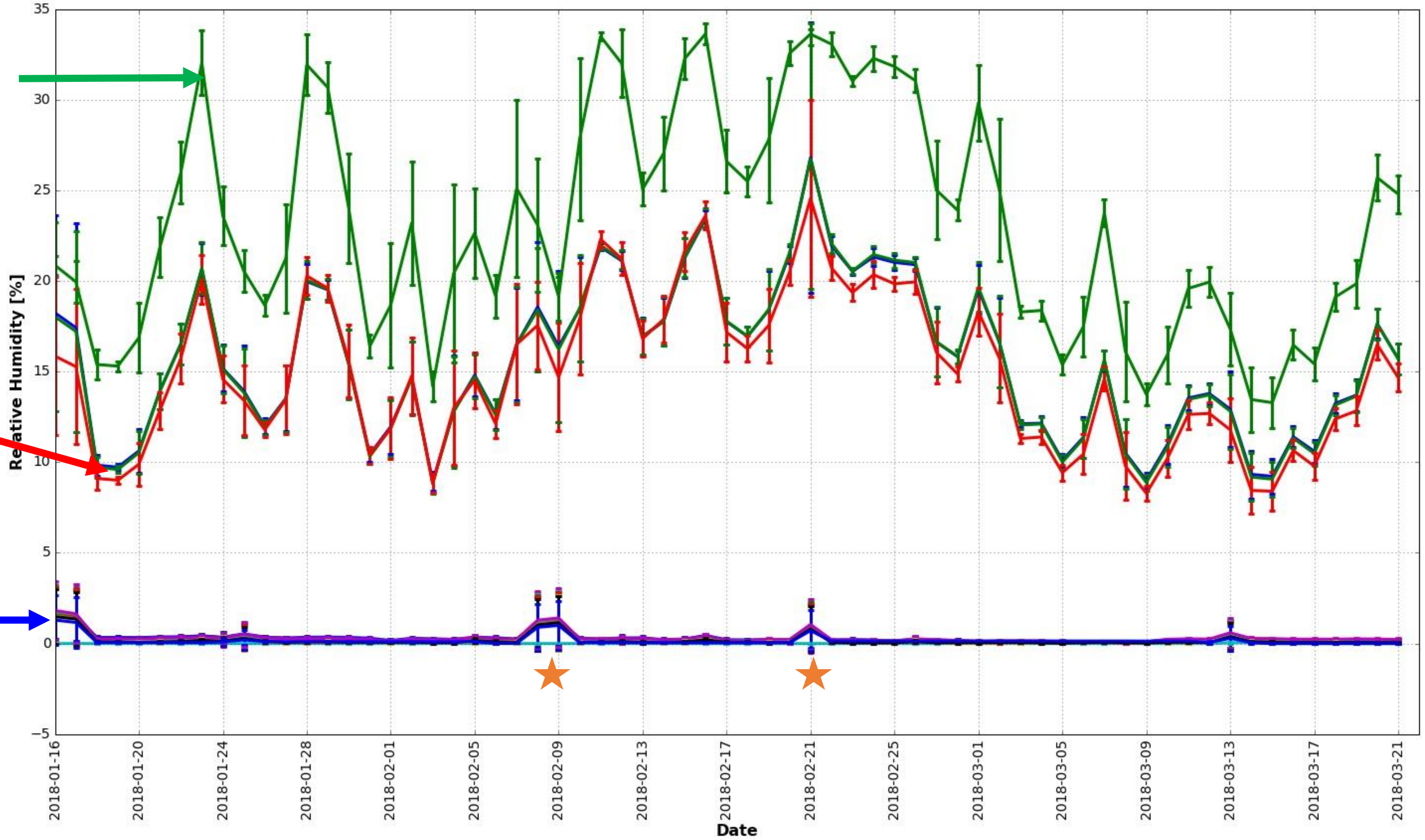
EP Humidity History

From January 16, 2018 Through March 21, 2018

Ambient in rack near cRIO

Outside EP/N_2 Volume behind RICH

Inside EP



★ Slightly higher humidity because both HV/LV were off, causing a lower temperature in the EP. Relative humidity is dependent on both temperature and water concentration.

Example:

At, 2% RH at 25 °C the true water concentration in air is ~0.46 mg/m³. With the same water concentration, but at a temperature of 35 °C, the relative humidity is 1.2%.

EP Humidity Statistics

From January 16, 2018 Through March 21, 2018

Sensor Board	Humidity Sensor	Mean [% RH]	Standard Deviation [% RH]	
1	1	15.60	4.60	
	2	15.56	4.64	
2	3	14.92	4.49	
	4	0.00	0.01	Bad Sensor
3	5	0.19	0.56	
	6	0.16	0.52	
4	7	0.30	0.50	
	8	0.33	0.50	
5	9	0.25	0.54	
	10	0.19	0.54	
6	11	0.27	0.57	
	12	0.33	0.57	
7	13	0.18	0.51	
	14	0.17	0.51	
8	15	0.15	0.46	Bad Sensor
	16	23.16	6.40	Ambient

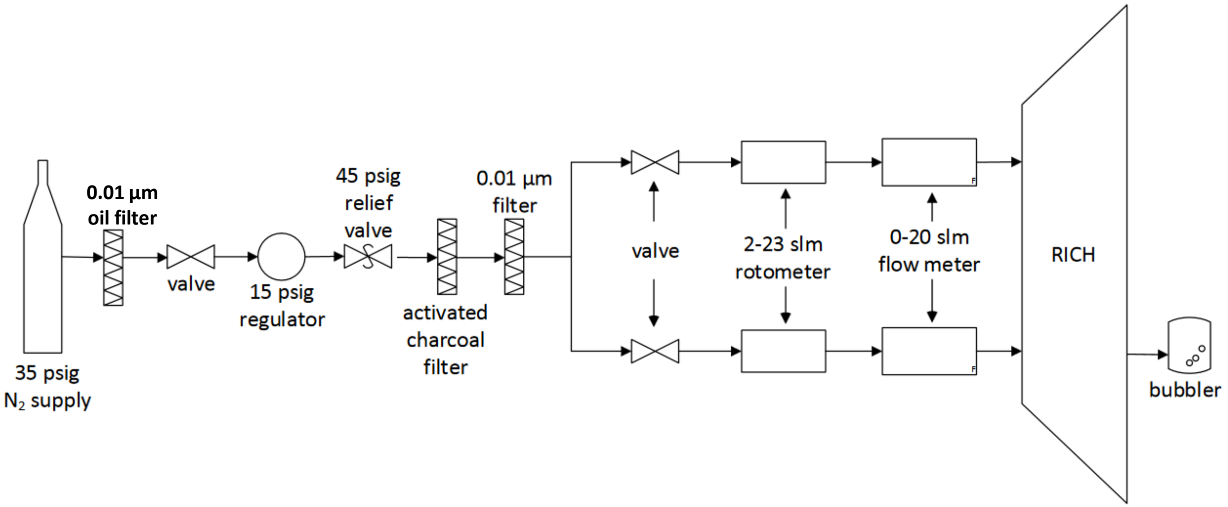
Sensors 1–4: Outside EP/N_2 Volume behind RICH

Gas System

- All components located on top deck of Forward Carriage
- Nitrogen System
  - Provides ~40 slm of nitrogen to RICH to maintain a low internal humidity
  - Upgraded valve panel assembled to allow ~120 slm total flow.
    - *Upgraded panel yet to be reviewed by System Owner, Bob Miller.*
- Air-Cooling System
  - Provides ~900 slm of airflow to RICH's Electronic Panel for cooling.
  - Airflow supplied by Atlas Copco compressors.

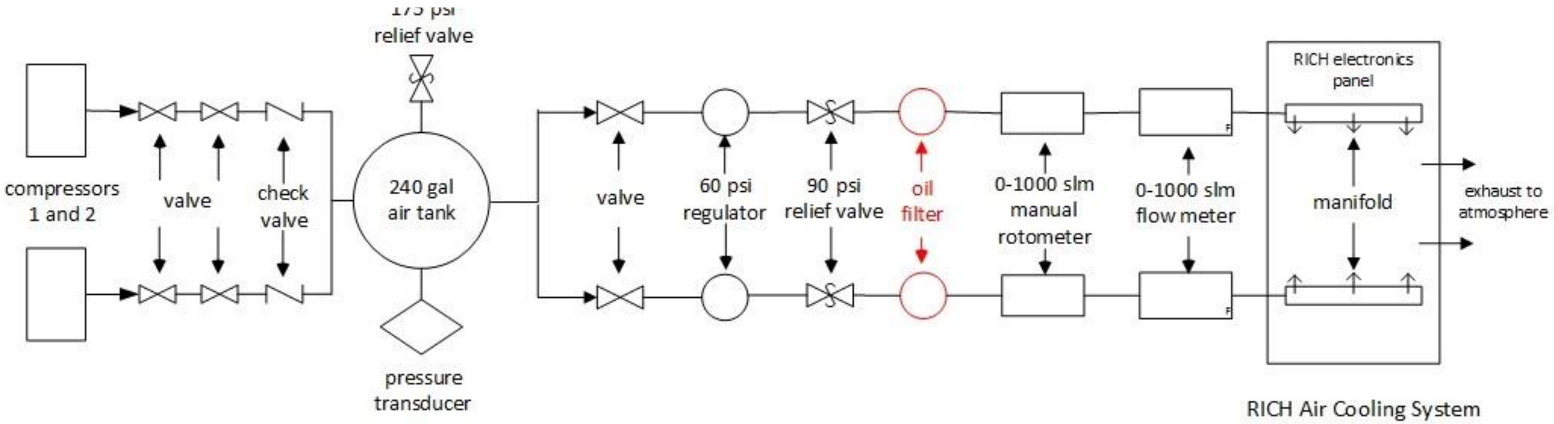
Gas System Currently In Use

Nitrogen System



RICH N_2 System
M.A. Antonioli
11/3/17
rev. 4/10/18

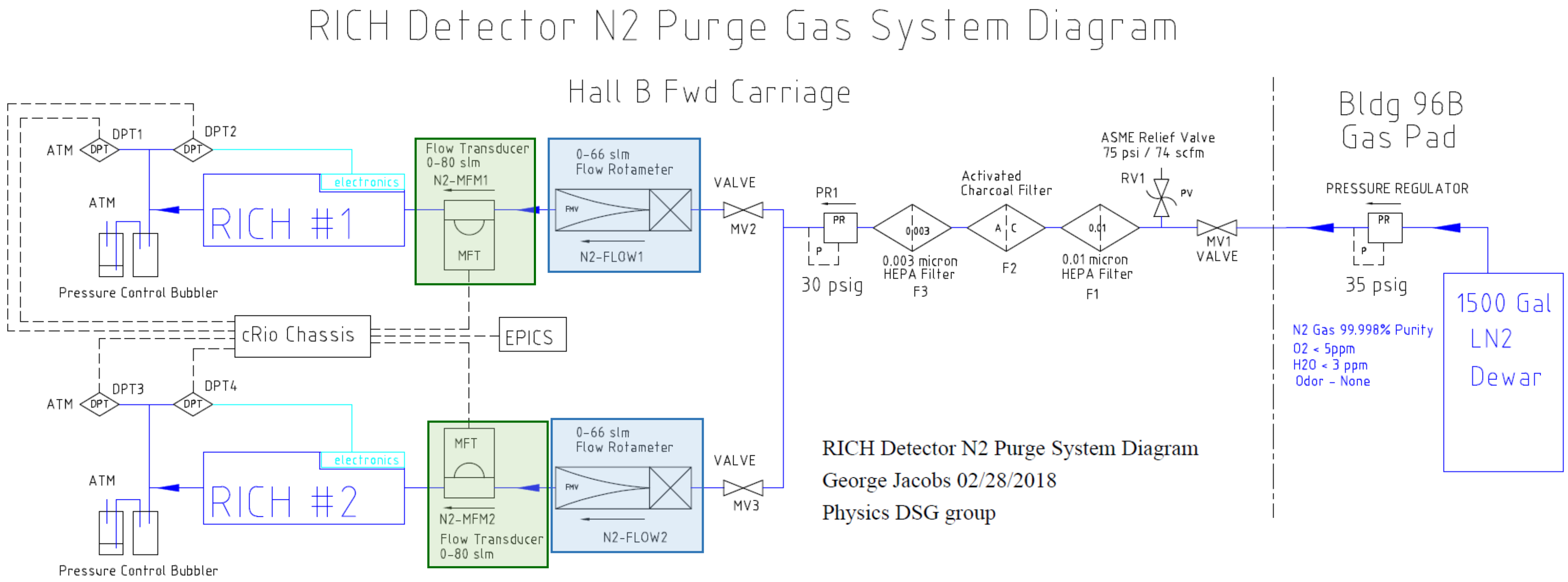
Air-Cooling System



RICH Air Cooling System
Proposed Upgrade
M.A. Antonioli
11/16/17

Upgraded Nitrogen System Panel

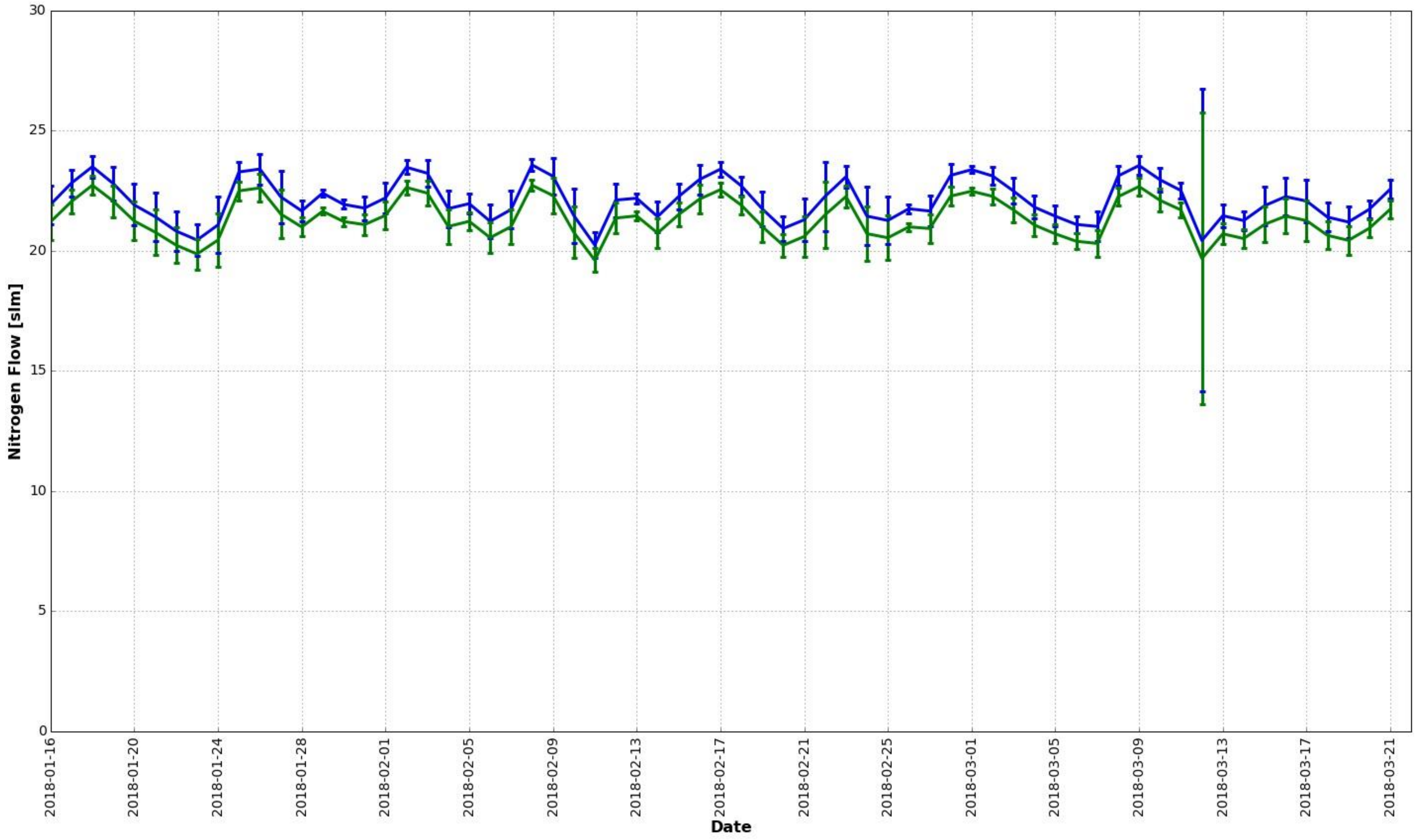
- Increased flow capability
  - 2 – 22 slm rotameter upgraded to **0 – 66 slm rotameter**
  - 0 – 20 slm flow meter upgraded to **0 – 80 slm flow meter**



Nitrogen Flow History

From January 16, 2018 Through March 21, 2018

Flow is not steady because of changes in supply pressure.

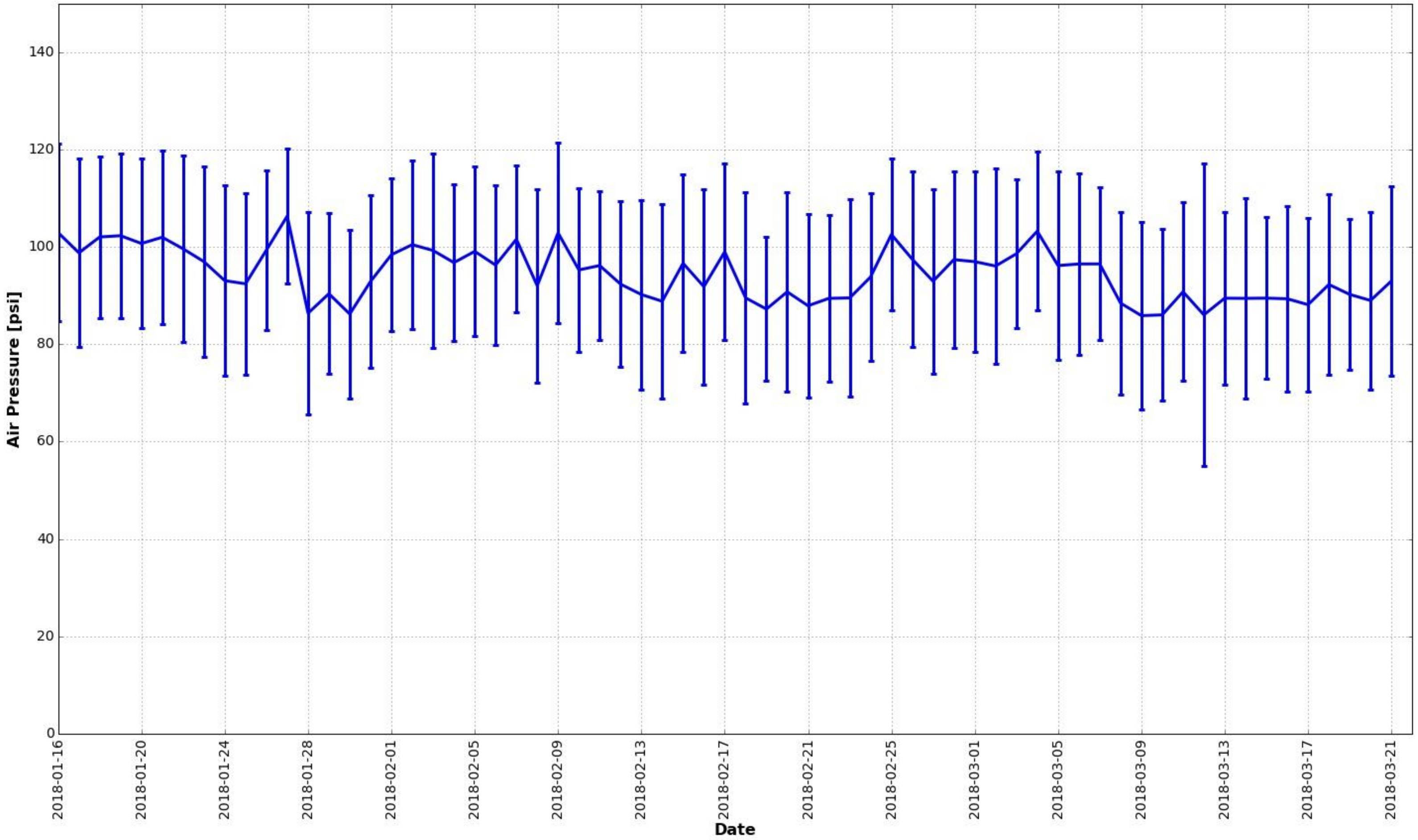


N_2 Flow 1

N_2 Flow 2

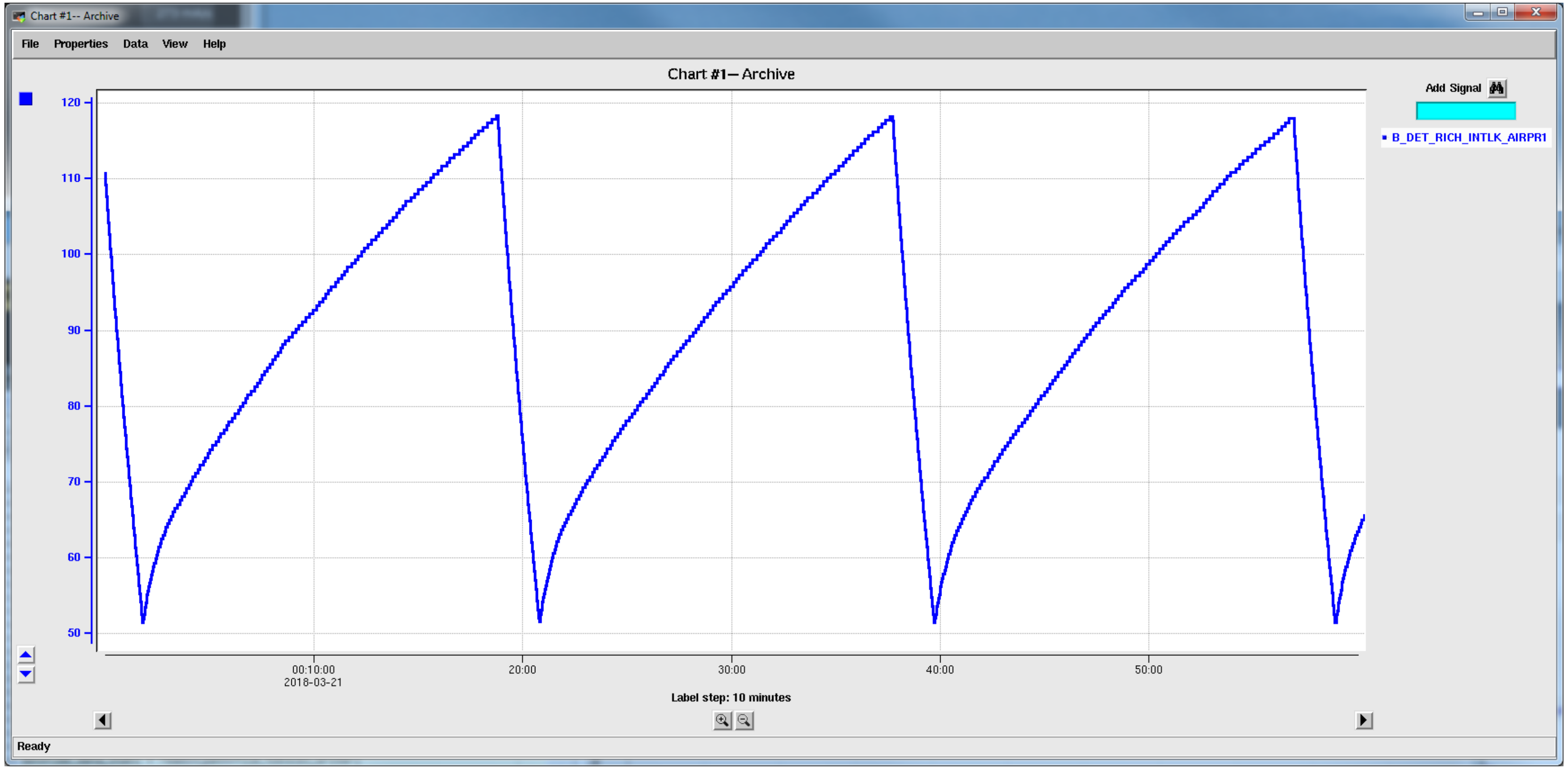
Air-Cooling Buffer Tank Pressure History

From January 16, 2018 Through March 21, 2018



Instability of pressure reading caused by oscillations in buffer tank pressure due to compressor's on-off cycle.

One Hour of MYA Pressure Data



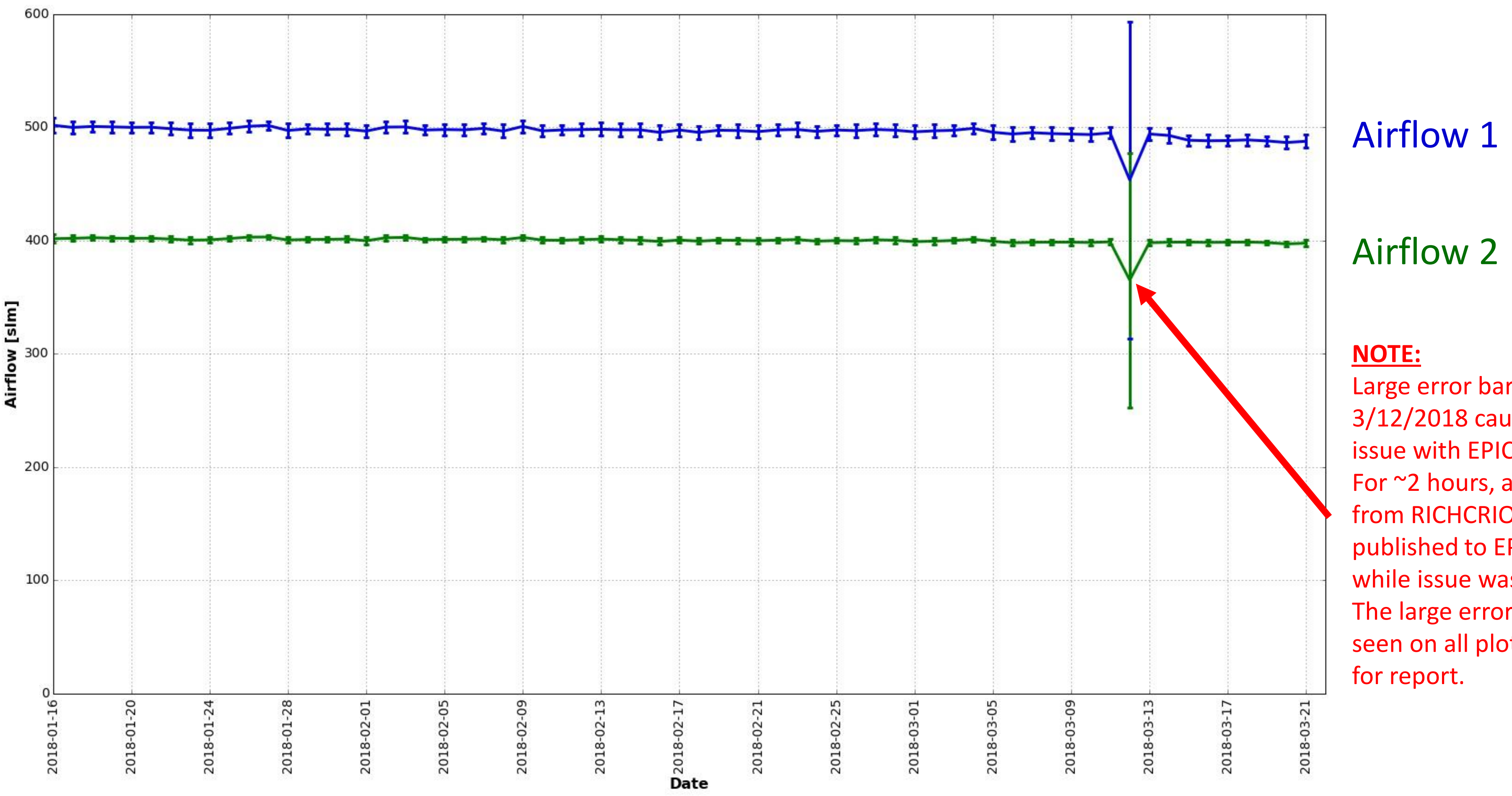
Pressure oscillates between ~120 psi and ~65 psi because of operation deadband set on compressor.

Compressor turns on when its output pressure drops below 104 psi and turns off when pressure increases to 113 psi.

Air Flow History

From January 16, 2018 Through March 21, 2018

Airflow 1 is set to 500 slm and Airflow 2 is purposely set lower to 400 slm. This it to flow more air to the portion of the EP that tends to be the highest temperature.



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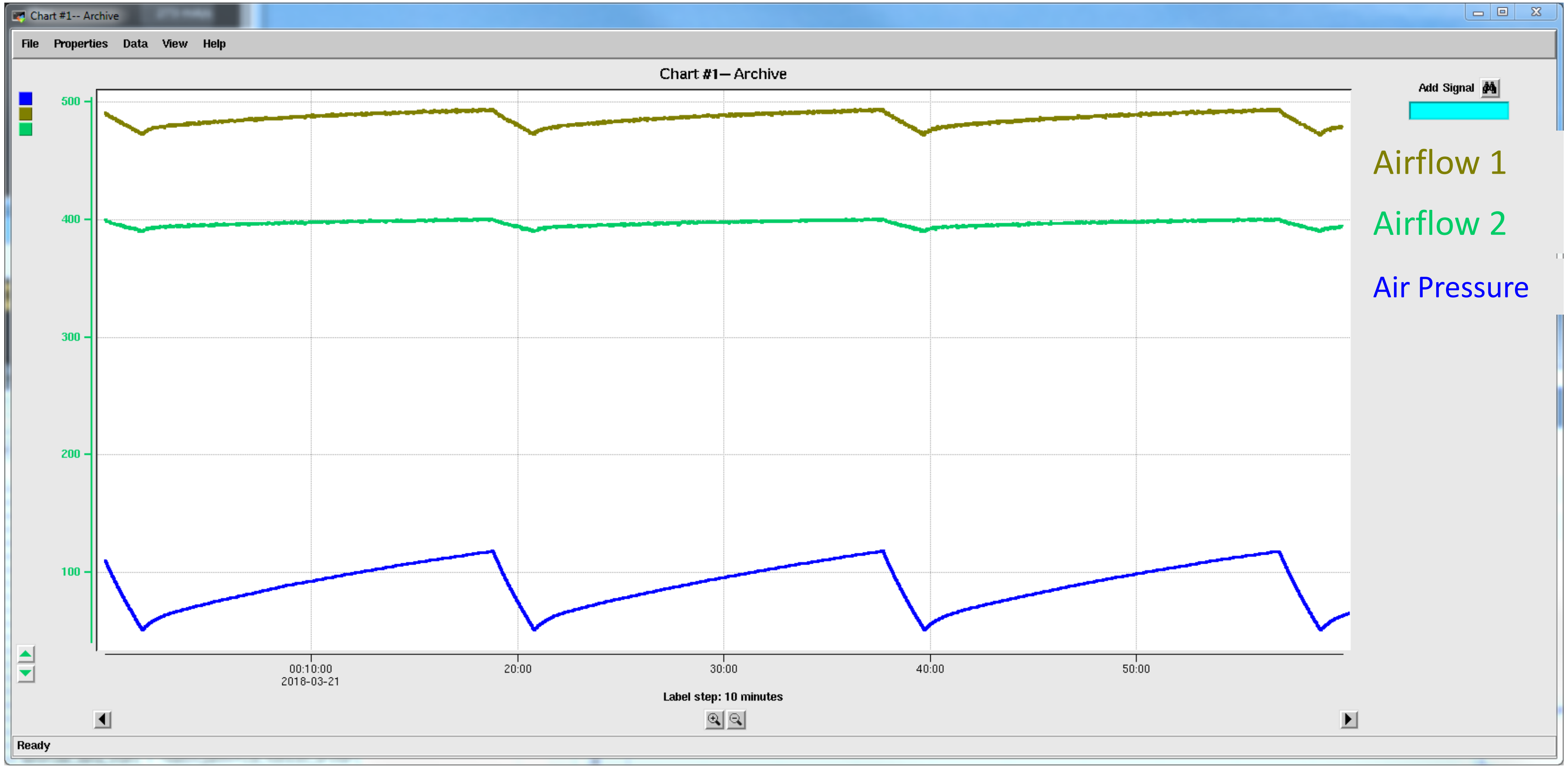
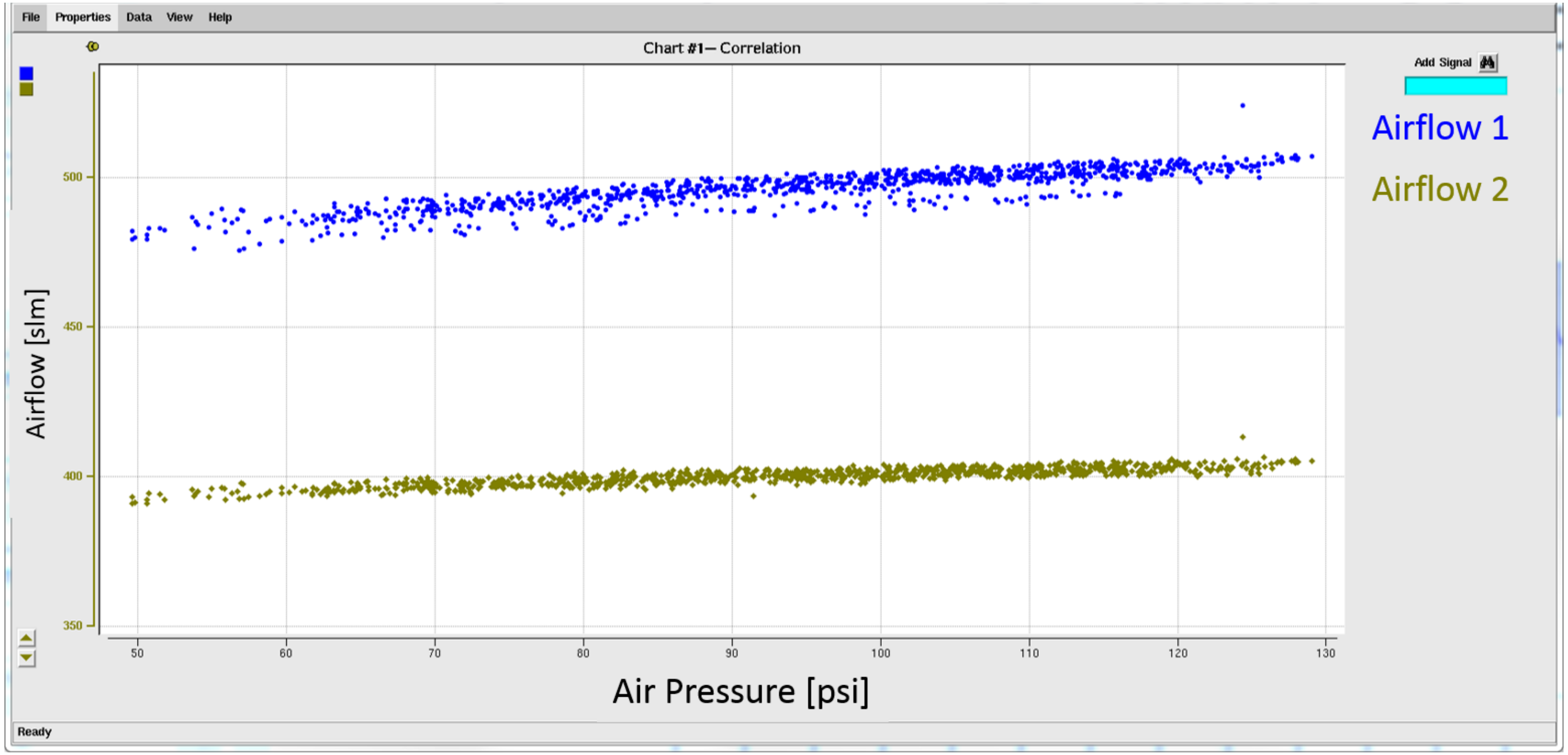
One Hour of MYA Airflow Data Plotted With Air Pressure

Airflow 1 is more sensitive to changes in air pressure because of higher flow rate.



Air Pressure – Airflow Correlation Plot

Airflow 1 is more sensitive to changes in air pressure because of higher flow rate.

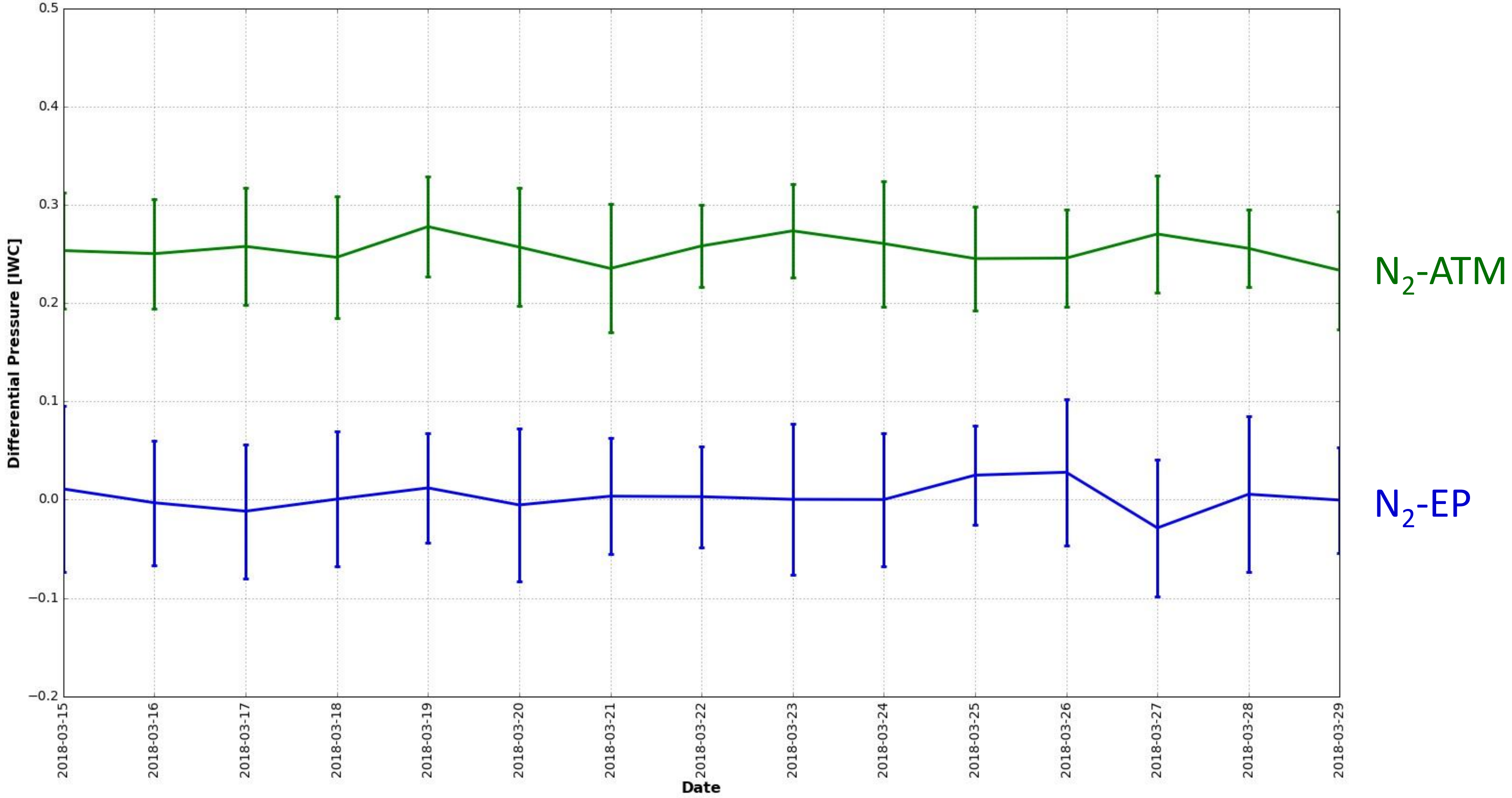


Differential Pressure Transducers

- Two pressure transducers installed to measure:
  - Pressure differential between nitrogen volume and atmosphere
  - Pressure differential between nitrogen volume and EP.
- Goal is to have nitrogen volume over-pressured in relation to EP and atmosphere.
  - Prevents external air from leaking into nitrogen volume.
- Measurements indicate that EP and N2 Volume are at a similar pressures.
- No correlation observed between differential pressures and internal humidity readings.

Differential Pressure History

From March 15, 2018 Through March 29, 2018

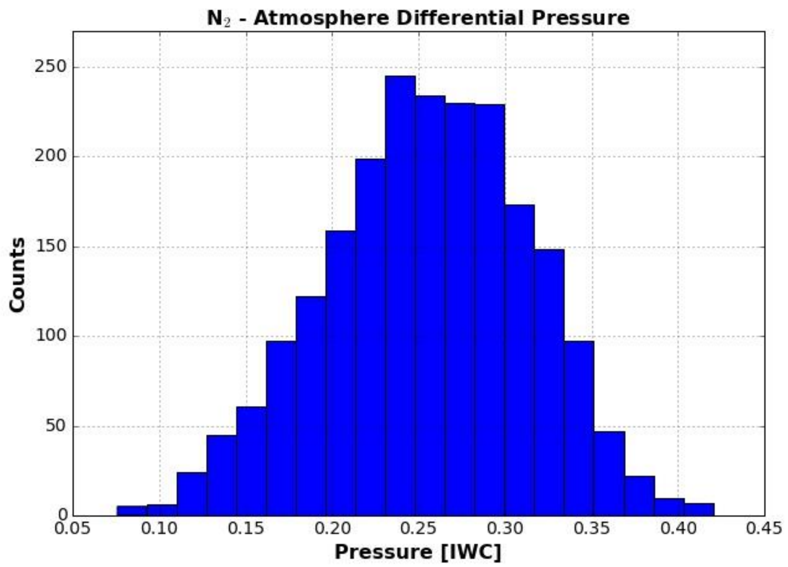


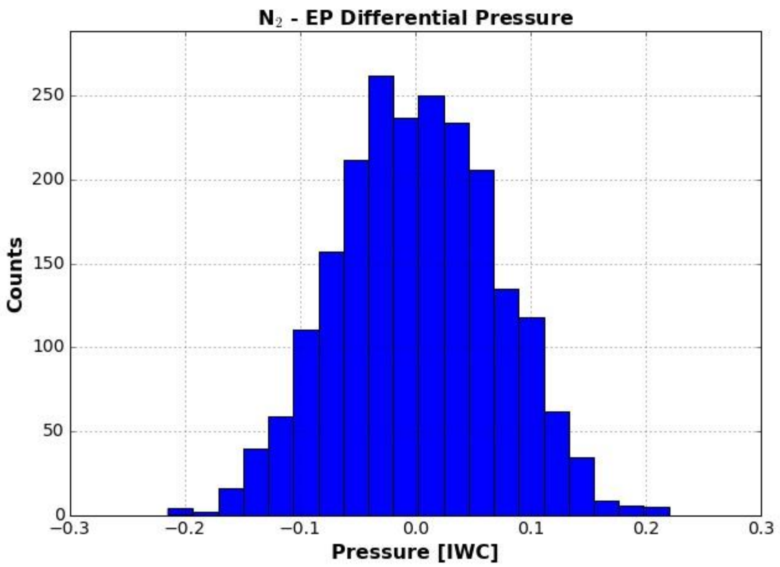
Differential Pressure History

From March 15, 2018 Through March 29, 2018

Pressure Differential Between	Mean [IWC]	Standard Deviation [IWC]
N_2 Volume – ATM	0.255	0.056
N_2 Volume – EP	0.002	0.068

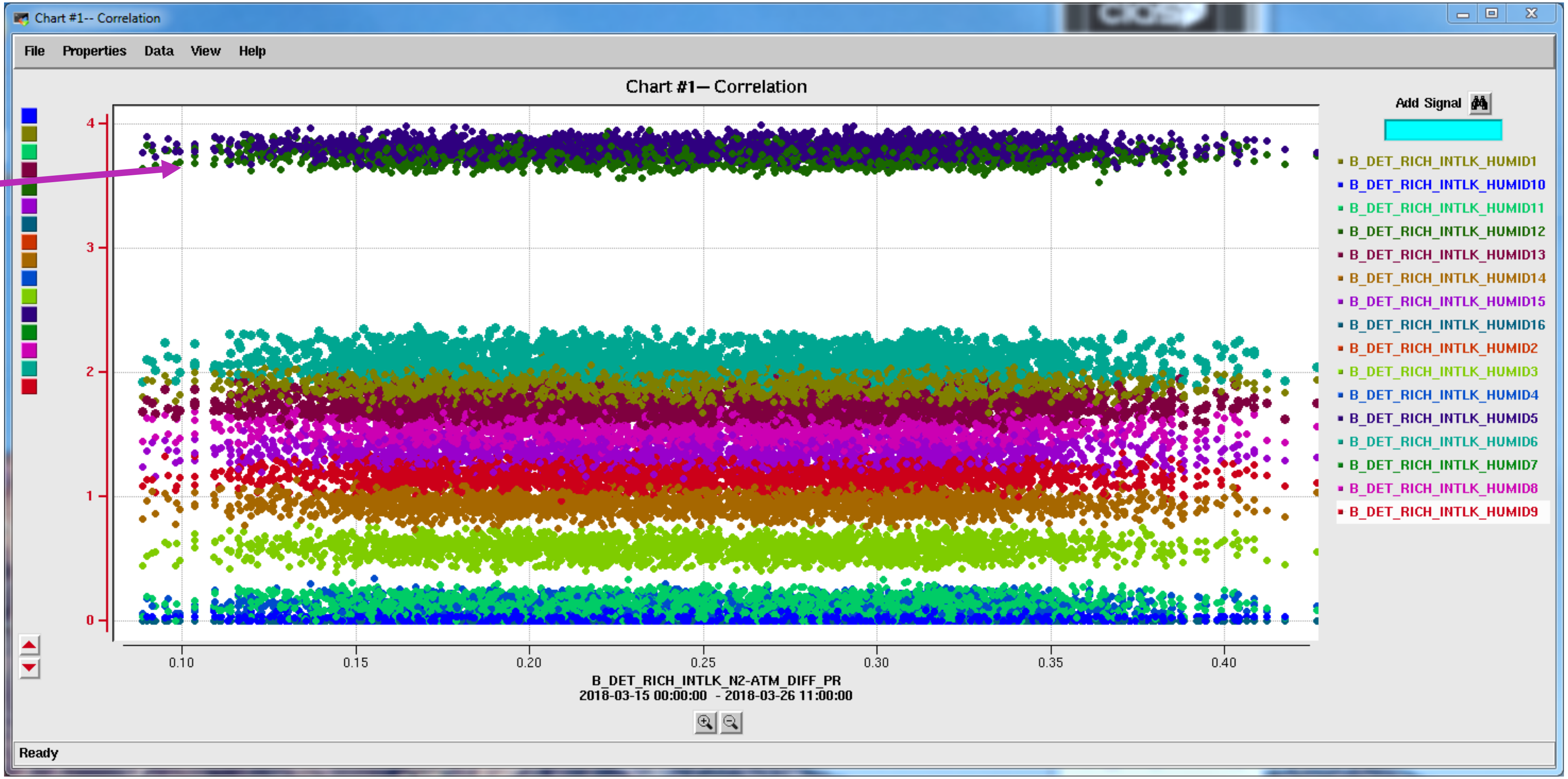
Mean and standard deviation in table calculated from raw data





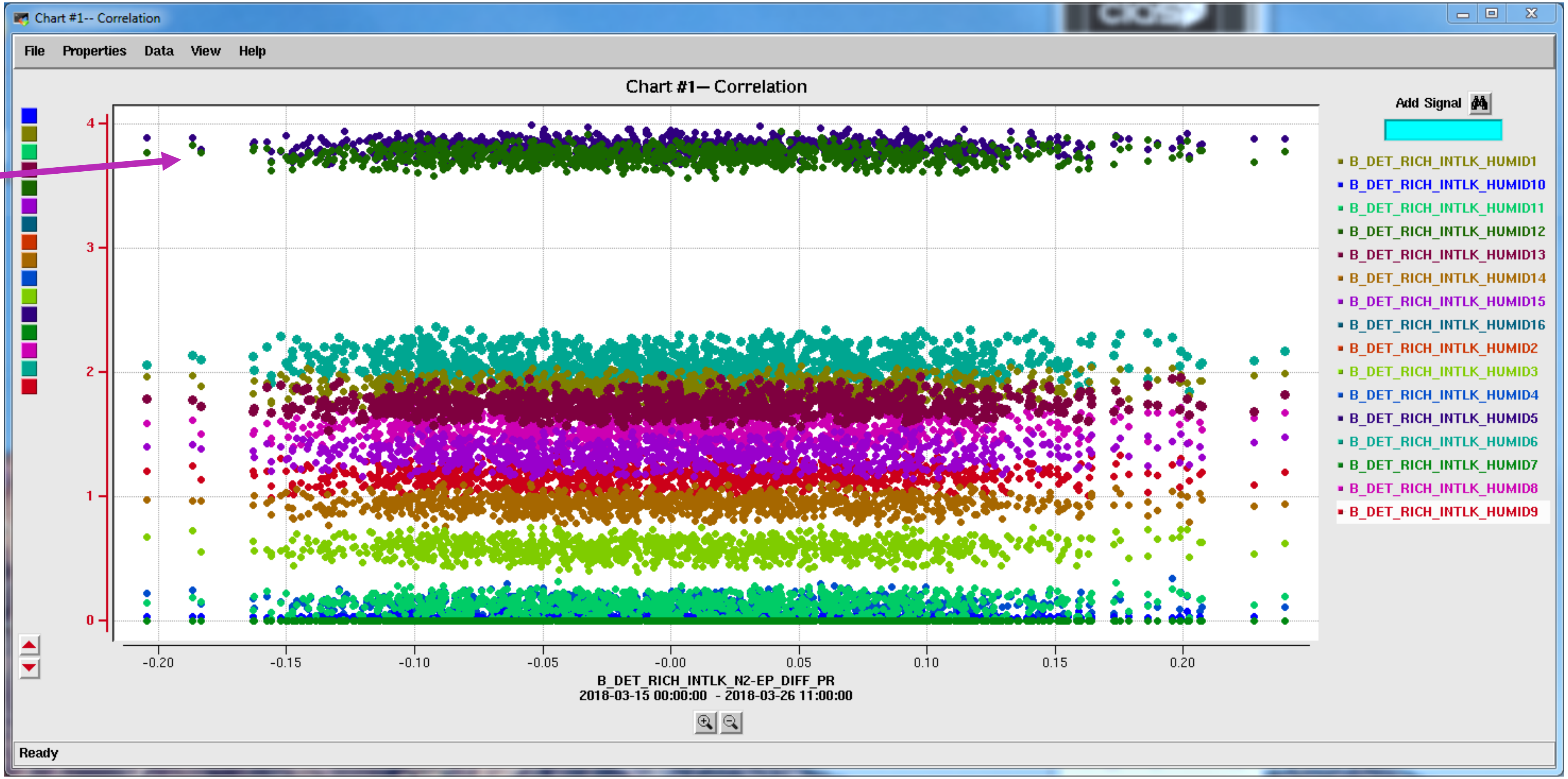
N2 Volume – Atmosphere Differential Pressure Correlation Plot for N_2 Volume Sensors

Only Humidity 5 and 12 are above 3 % RH.



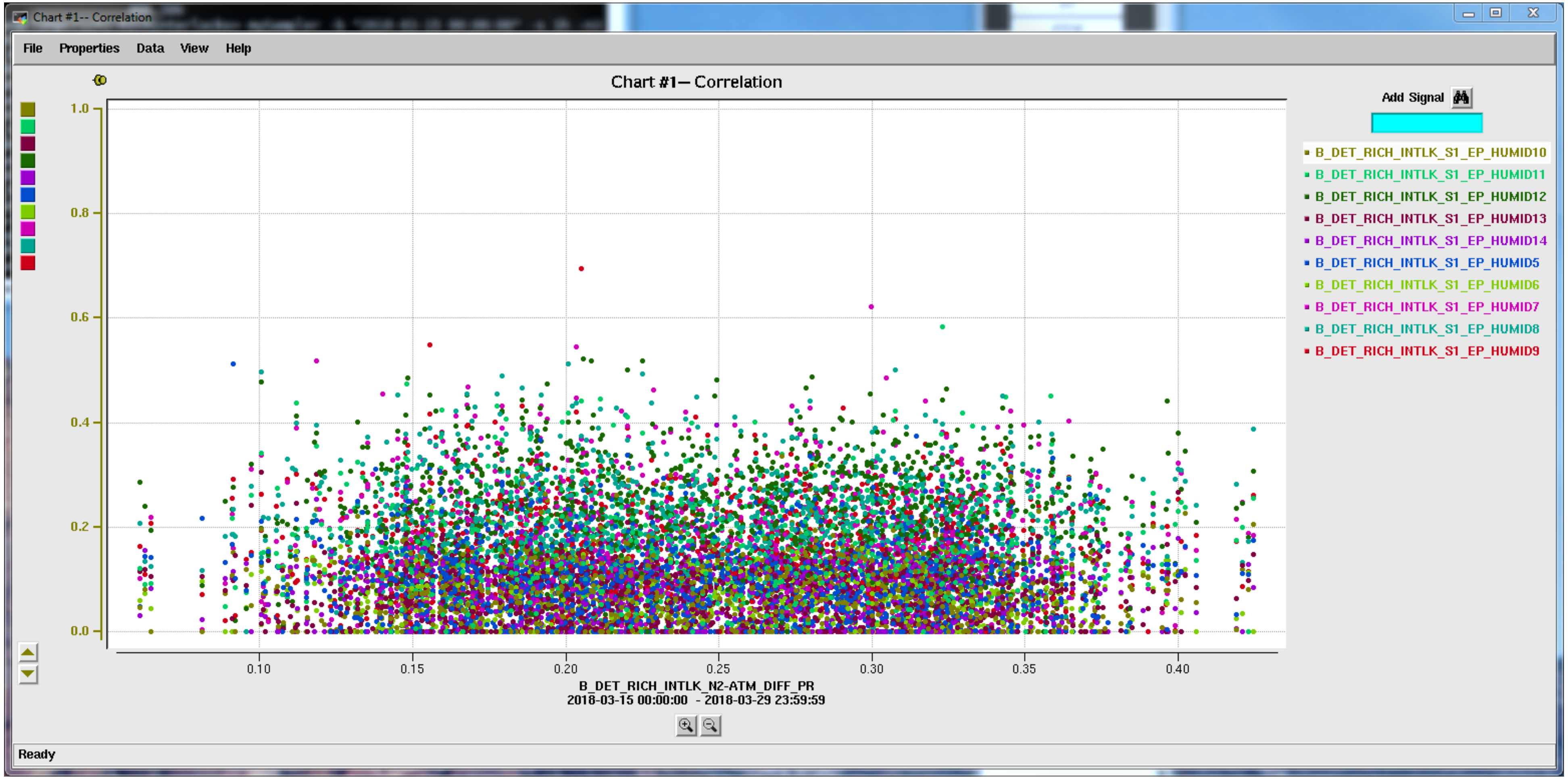
N2 Volume – EP Differential Pressure Correlation Plot for N_2 Volume Sensors

Only Humidity 5 and 12 are above 3 % RH.



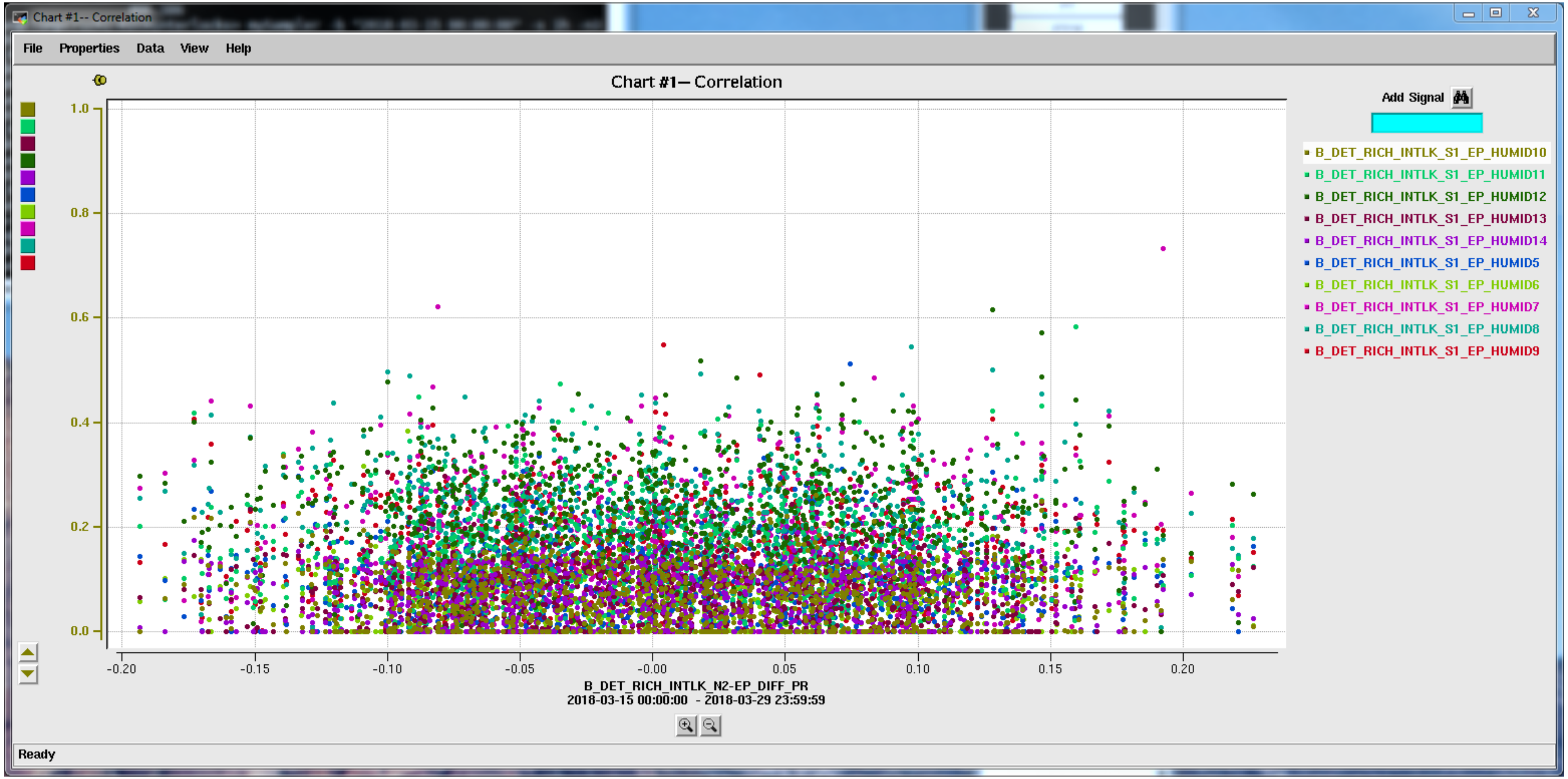
N2 Volume – Atmosphere Differential Pressure Correlation Plot for EP Sensors

Humidity Sensors not installed inside EP are not shown.



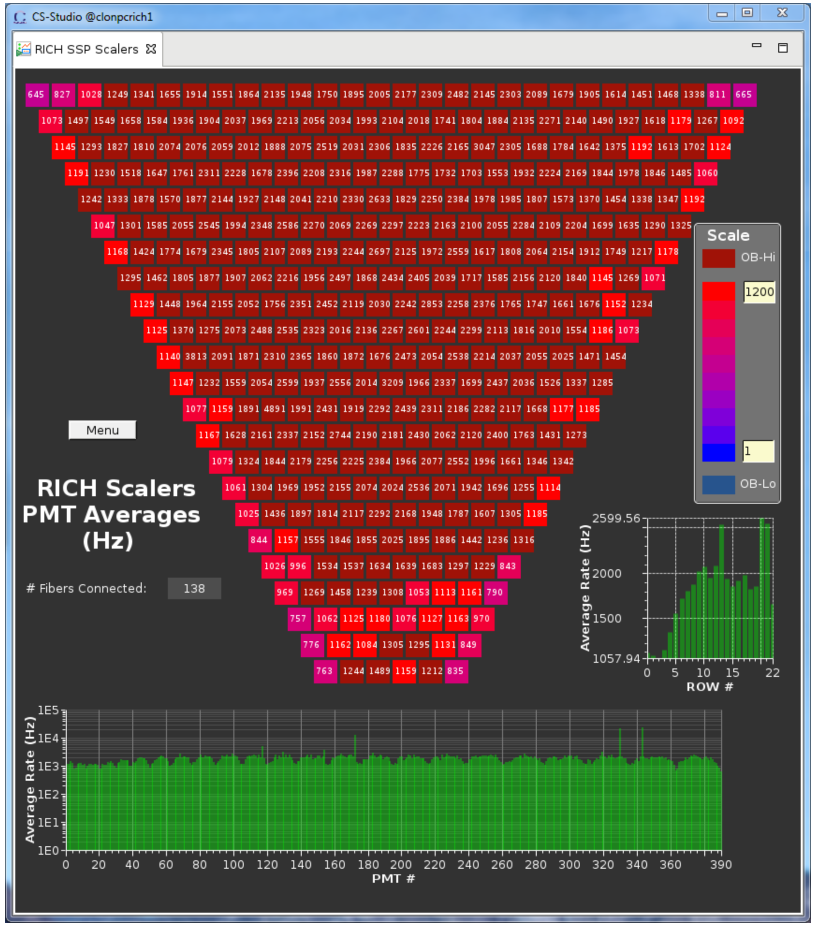
N2 Volume – EP Differential Pressure Correlation Plot for EP Sensors

Humidity Sensors not installed inside EP are not shown.

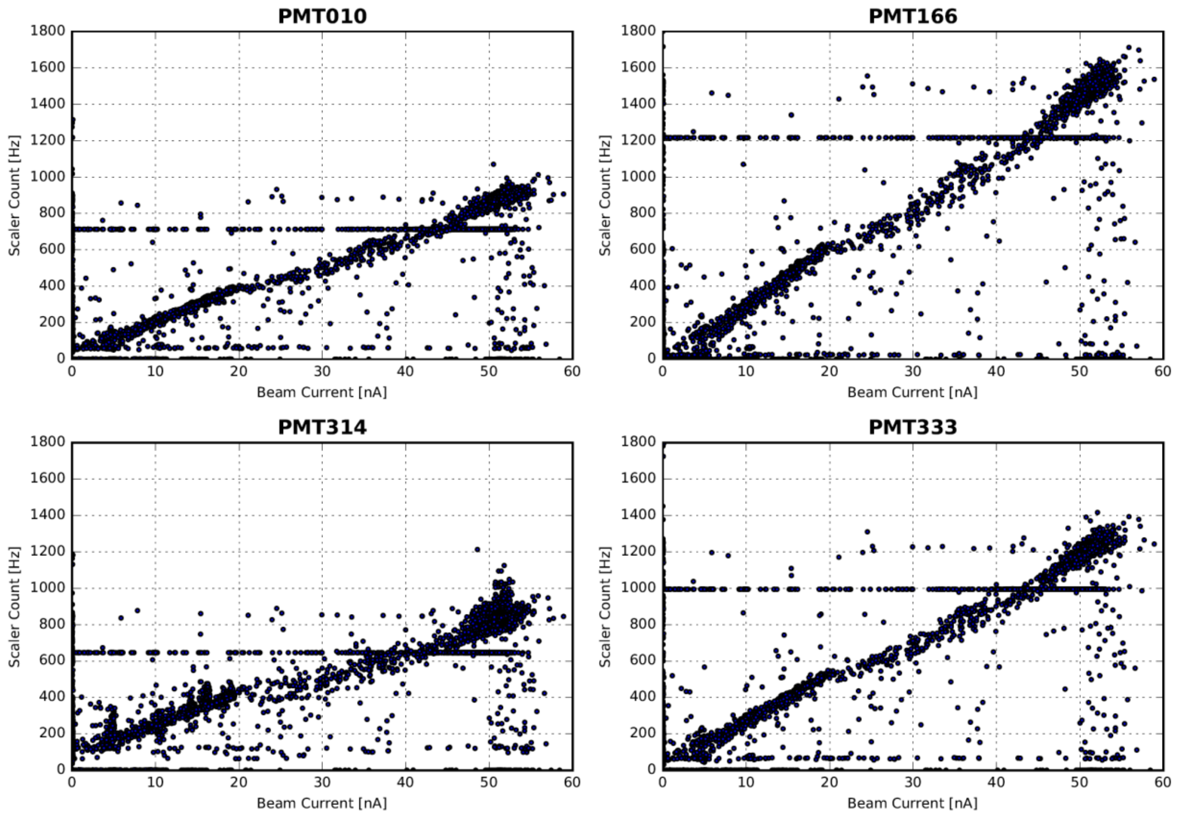


Scalers

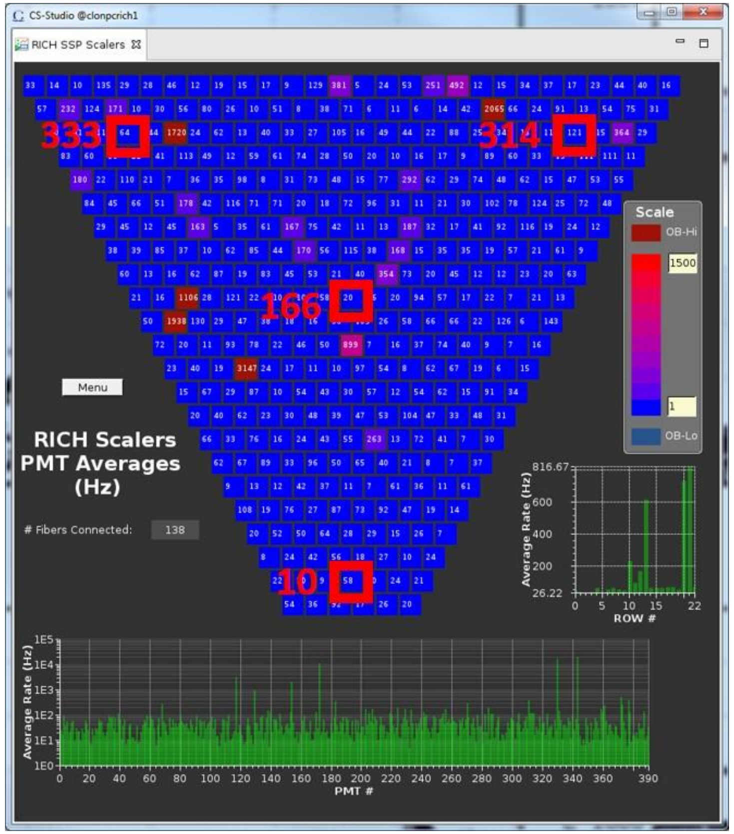
- Scalers help give a real-time indicator of health of electronics.
  - Scalers give count of events detected per seconds.
  - If counts increase, PMT may be starting to have issues.
- Scaler counts are correlated to beam current.
  - Higher beam current, higher scaler counts.



Scaler Averages vs. Beam Current

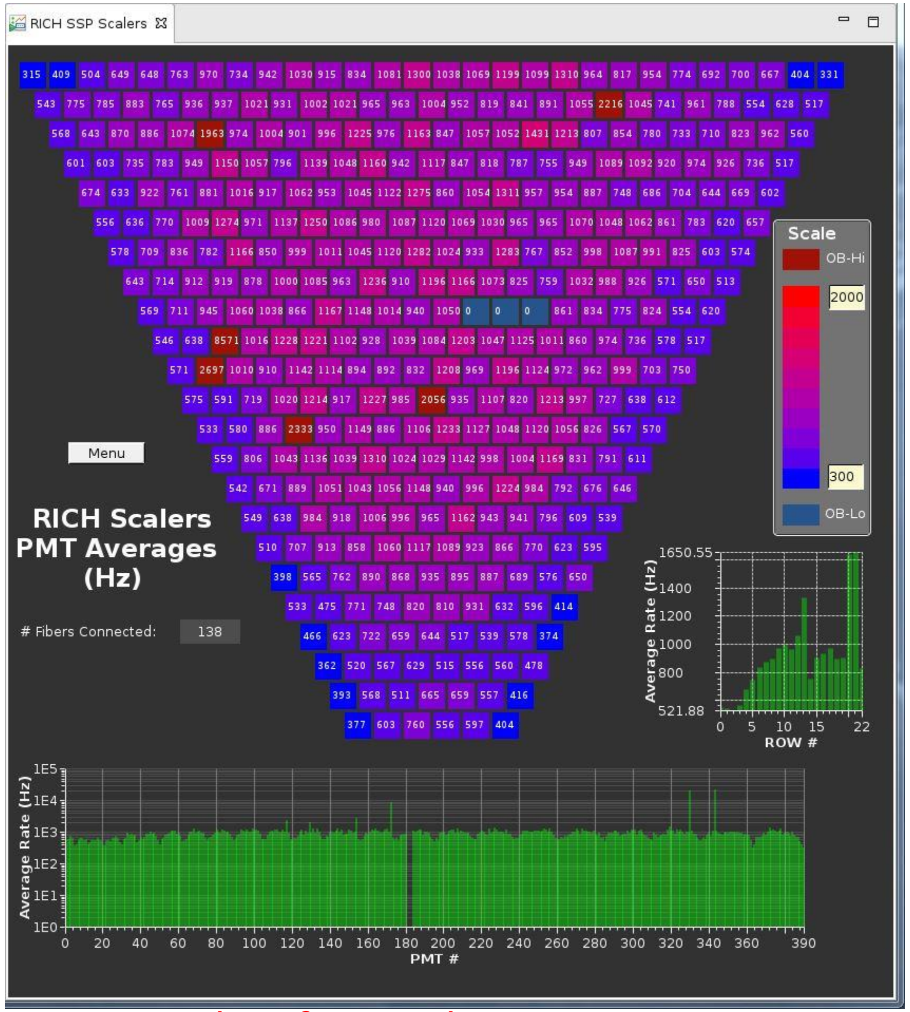


PMT 166 has higher scalers because more particles go through center of EP than at its edges.



Scalers Problem

- Scalers for some PMTs read zero and do not update.
- Bad scalers most likely caused by DAQ initialization error.
  - Readout electronics could not determine whether tile is a 2 or 3 ASIC tile.
  - Error causes PMT data not to be read by DAQ.



Scalers from February 22, 2018

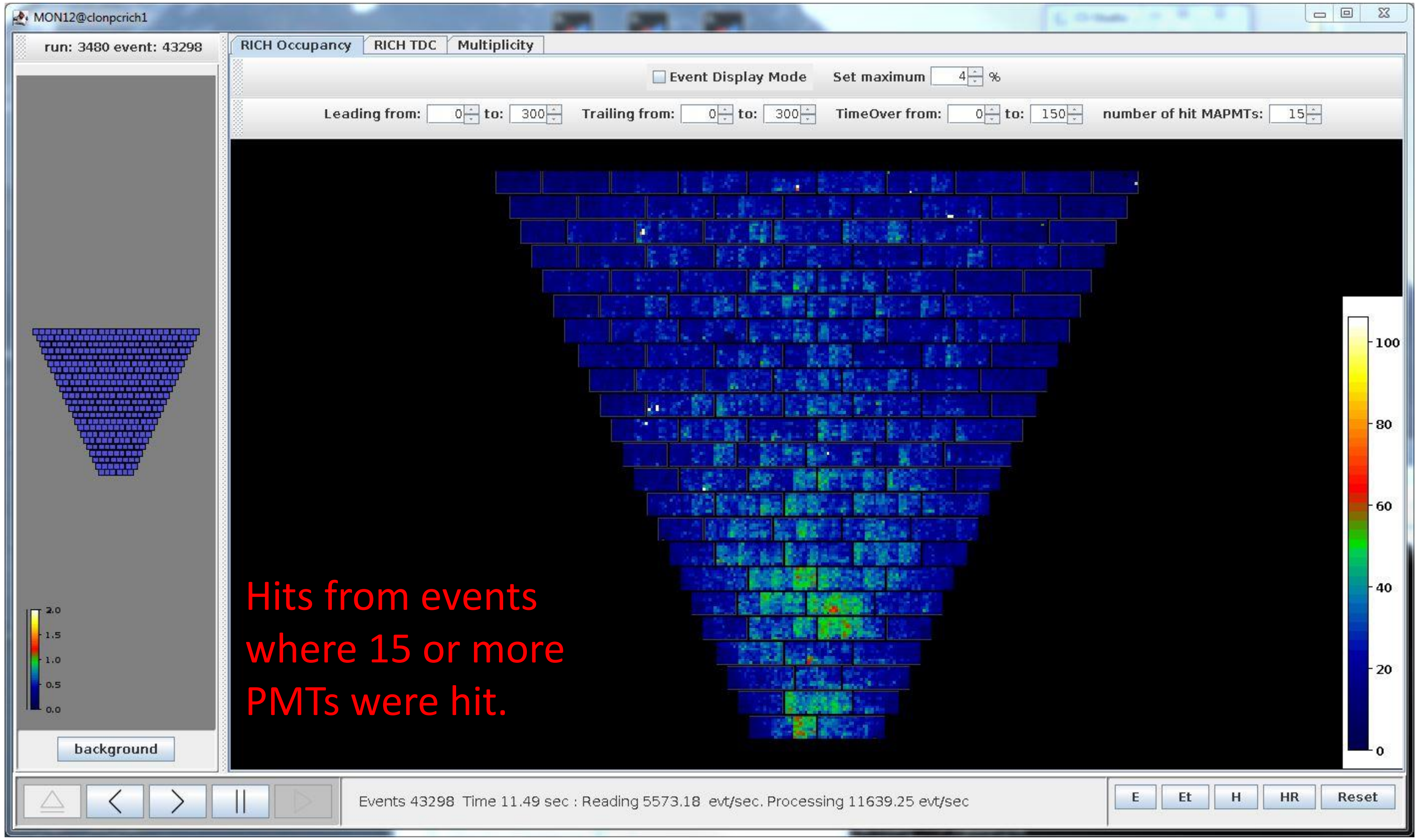
Scalers Problem Solution

- Cycle of LV to RICH and restart of DAQ to reinitialize RICH electronics.
  - Temporary solution; debugging will be done after Spring 2018 Physics Run.
- Present course of action:
  - Monitoring scalers to see if same tile continuously has issues.
    - Could indicate hardware problem with tile or its DAQ connections.
  - Monitoring logbook to note patterns in DAQ starts and PMT scaler issues.
    - If PMT scalers only freeze when DAQ is started, could indicate problem with RICH DAQ initialization.

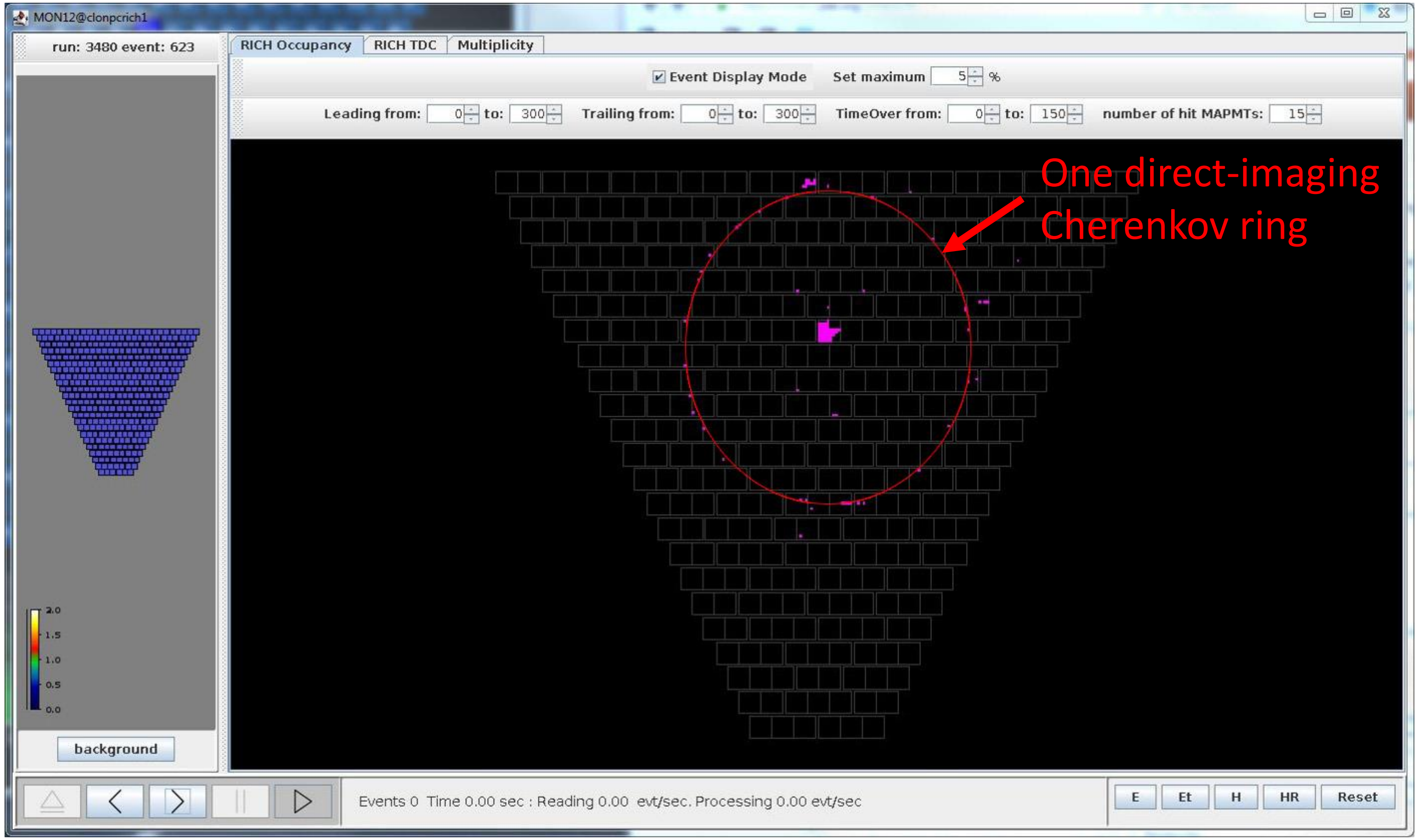
Occupancy Plots

- Plots generated by *richmon* program.
- Shows pixels hit during event.
  - 391 PMTs x 64 pixels each = 25024 total pixels.
- Two display modes:
  - Integrated counts per pixel from a set number of events.
  - Individual events.
- Can show preliminary images of Cherenkov rings.

Occupancy Plot - Integrated Count-per-Pixel

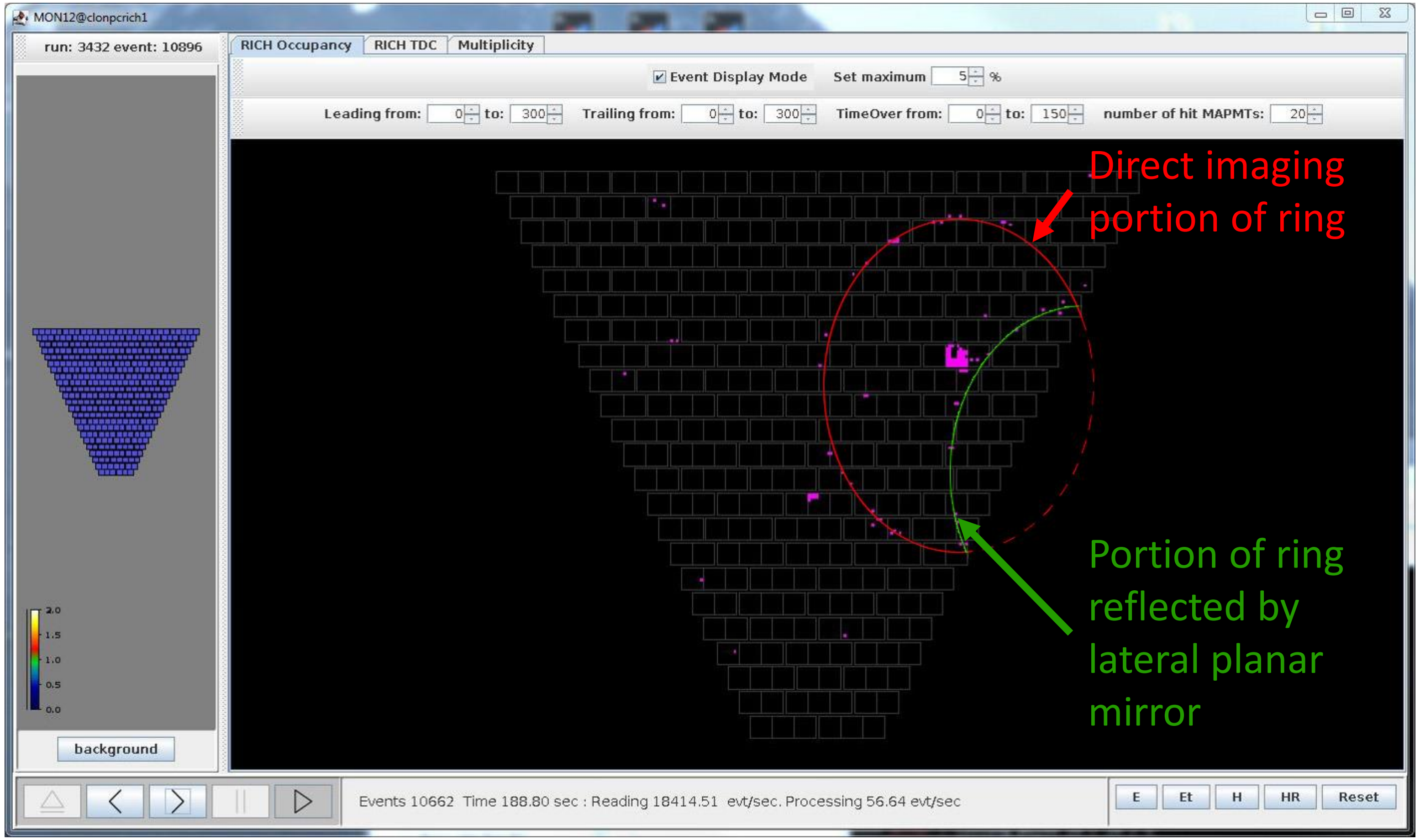


Occupancy Plot - Individual Events



Cherenkov ring drawn in by hand

Occupancy Plot - Individual Events



Cherenkov ring drawn in by hand

Interlock Sensors and Limits

Sensor Type	Typical Value	High Limit	Low Limit
FPGA Temperatures	50 – 68 °C	75 °C	N/A
Hardware Interlock EP RTD Temperatures	26 °C off 40 °C on	45 °C	10 °C
EP Humidity	0 – 4 % RH off <1 % RH on	30 % RH	0 % RH
N2 Volume RTD Temperature	26 °C	30 °C	10 °C
N2 Volume Humidity	< 2 % RH H5/H12: <4 % RH	5 – 7 % RH	-1 % RH
Airflow 1	500 slm	573 slm	400 slm
Airflow 2	400 slm	500 slm	300 slm
N2 Flow 1 and 2	20 slm	50 slm	15 slm
Buffer Tank Pressure	65 – 120 psi	160 psi	40 psi
N2-ATM Differential Pressure	0.25 IWC	N/A	N/A
N2-EP Differential Pressure	~0.002 IWC	N/A	N/A
Scaler Counts	Varies with beam current	N/A	N/A

On/Off refers to state of electronics.

Signals with no interlocks have limits noted as N/A.

Detector Specifications

Electronics Voltages		
High Voltage	Tiles	138
	Set Value	1000 V 800 µA
	Read-back Value	~1000 V 3-PMT Tiles: ~620 µA 2-PMT Tiles: ~325 µA
Low Voltage	Groups	40
	Set Value	5.2 V 4 A
	Read-back Value	~5.20 V ~3.15 A

Aerogel		
2-cm Tiles	Index of Refraction	~1.05
	Quantity	38 total (24 whole, 14 partial)
	Number of Layers	1
	Dimensions	10 cm x 10 cm x 2 cm
3-cm Tiles	Index of Refraction	~1.05
	Quantity	68 total (52 whole, 16 partial)
	Number of Layers	2
	Dimensions	10 cm x 10 cm x 3 cm

Mirrors		
Spherical	Quantity	10
	Radius of Curvature	~2.7 m
	Reflectivity	~90%
Planar	Quantity	5 lateral 4 front
	Reflectivity	~90%

Conclusion

- RICH detector is in **good health**
  - Humidity under 3%
  - FPGA temperatures under 70 °C
  - Over-pressured in relation to atmosphere

- Items to improve upon:
  - Increase pressure in N_2 Volume so it is more over-pressured in relation to EP.
  - Improve reliability of scaler readout.

Thank You