Energy Audit of MC-1

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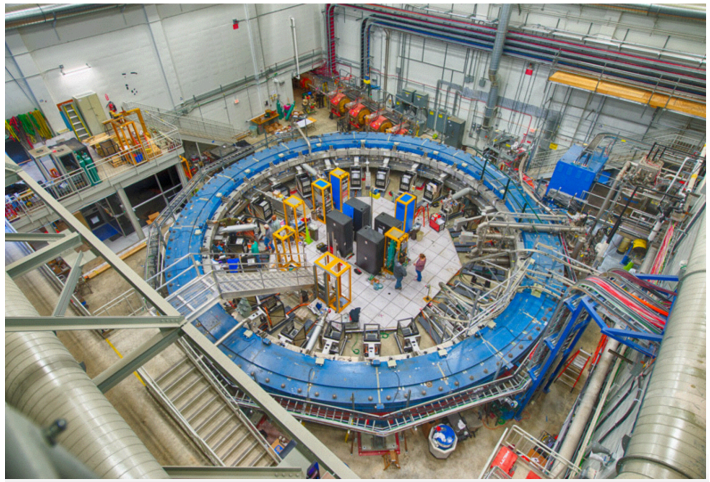
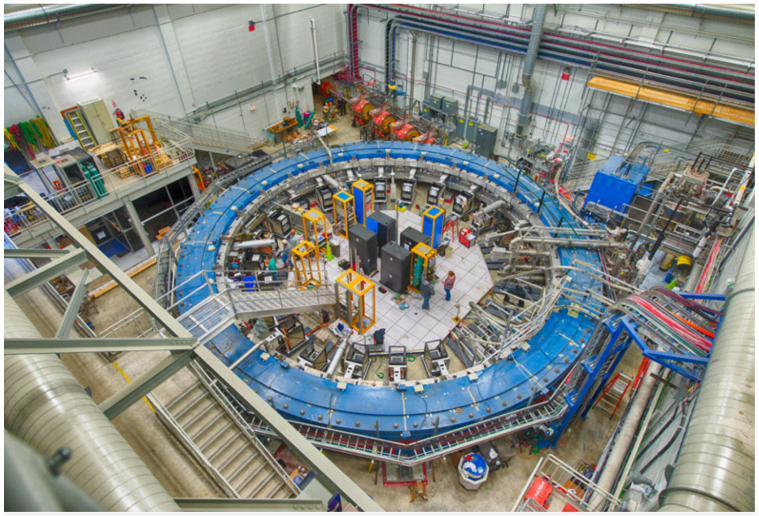
Outline

- Muon g-2 Experiment Overview
- Energy Audit Description
- MC-1 Building Description
- Methods and Tools Used
- MC-1 Energy Consumption
- Lighting Subsystem Analysis
- Conclusions



Muon g-2 Experiment

- Goal is to measure the muon magnetic anomaly "a_μ" to a precision of 140 ppb
- Compare the experimental a_μ to the theoretically calculated a_μ to see if the difference is statistically significant
- If so, this could be an indication of physics beyond the standard model



What is an Energy Audit?

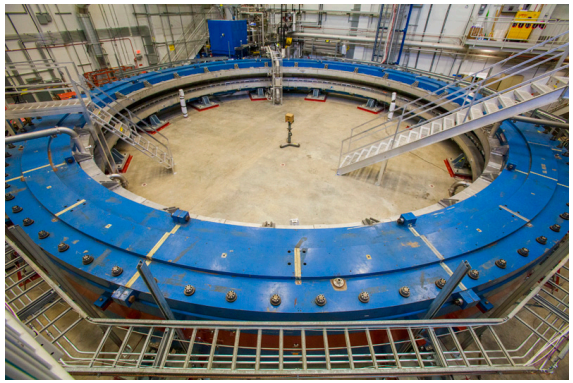
- An energy audit is an assessment of a building's energy consumption
- They are performed to identify measures that can be implemented to improve the energy efficiency of a building
- Energy audits provide numerous benefits:
  - Reduce energy costs
  - Reduce carbon footprint
  - Increase equipment lifespan
  - Improve comfort for building occupants

Typical Steps in an Energy Audit

- Data collection
  - Collect historical energy consumption data
  - Collect information on equipment inventory
- On-site visit
  - Collect building information and visit site for an inspection
- Analysis
  - Analyze data and determine a breakdown of the energy consumed by each subsystem
- Propose recommendations
  - Prepare a list of recommend energy cost reduction measures (ECRMs)
- Report results

MC-1 Building Description

- Completed construction in 2014
- Building area: 13,461 sq. ft
- Two floors and a basement
- Rooms with high power consumption:
  - DAQ
  - Cryogenic
  - Main ring area
  - HVAC



Lighting Subsystem

LIGHTING FIXTURE SCHEDULE

TYPE	DESCRIPTION	LAMP	BALLAST	MANUFACTURER	CATALOG NUMBER	REMARKS
A	FLUORESCENT HIGH-BAY FIXTURE WITH (6) T5 HO FLUORESCENT LAMP WITH WIREGUARD	PHILIPS 54T5 HO	277V, SYLVANIA QUICKTRONIC UNIVERSAL BALLAST	ENERGY SOLUTIONS INTERNATIONAL, INC.	F24HG-EA-654-UNV-WG-CL	FOR HIGH BAY AREA, EXPERIMENTAL HALL
B	48" FLUORESCENT FIXTURE, 32W, 277V, 2 LAMPS, RAPID START, 10% UP LIGHT, OPEN TYPE	SYLVANIA F032/741	120V, MVOLT ELECTRONIC BALLAST	LITHONIA	LA232MVOLT-GEB10RS	FOR SERVICE AND TECH. AREA, ETC.
C	42W COMPACT FLUORESCENT WALL - MOUNT UTILITY VAPOR TIGHT LIGHT FIXTURE WITH GLASS GLOBE, WIRE GUARD AND JUNCTION BOX	42 WATT CFL	120V	LITHONIA	VW42L M6	FOR ELEVATOR SERVICE PIT AREA
D	EXIT SIGN WITH RED LETTERS, WHITE HOUSING, UNIVERSAL MOUNTING, WITH BATTERY, SINGLE OR DOUBLE FACE AS REQD	L.E.D.	N/A	DUAL LITE	LX-U-R-W-E	EXIT SIGN. (TYP. MOUNTING HEIGHT 8' ABOVE FINISHED FLOOR)
E	48" SURFACE/PENDANT MOUNTED WRA SQUARE-BASKET FLUORESCENT LIGH					
F	9" DEEP x 16" WIDE EXTERIOR WALL MO METAL HALIDE LIGHT FIXTURE					RMI LAB
G	6" DIAMETER CLASSIC ROUND PENDAN FLUORESCENT LIGHT FIXTURE UP/DO UP/DOWN REFLECTOR, LIGHT DISTRIB					& 1-DN, FOR BUILDING ENTRANCE
EM1	SURFACE MOUNTED, BATTERY PACK W EMERGENCY LIIGHTING UNIT					SHED FLOOR
H	6"x48" SURFACE/PENDANT MOUNTED F AND WET LOCATION FLUORESCENT LI					
I	9"Dx18"W EXTERIOR WALL MOUNTED METAL HALIDE LIGHT FIXTURE	150MH	120V, TB SCWA	LITHONIA	MRW 150M MD 120 SCWA SF QRS PE	EXTERIOR, COLOR SELECTED BY FERMI LAB
J	400W METAL HALIDE ROADWAY FIXTURE DOWN LIGHT, TENON - MOUNTED ON A 30-FOOT LONG, 6-INCH DIA. SQUARE ALUMINUM POLE (SEE REMARKS)	400MH	277V, HPF	QUALITY LIGHTING	125-23-3-MH-400-277-BKA-PCT-FD	PROVIDE FIXTURE WITH A 30 - FOOT SQUARE ALUMINUM POLE, QUALITY LIGHTING TYPE SQSA - 30 - 6 - DBA - BKA - D1 OR APPROVED EQUAL
K	24" x 48" FLUORESCENT FIXTURE, 32W, 2 LAMPS, RECESSED MOUNT, ACRYLIC LENS, HINGE DOOR, RAPID START	SYLVANIA FO32/41K	120V, MVOLT ELECTRONIC BALLAST	LITHONIA	2GT8-232A12MVOLT-GEB10RS	

TYPE	DESCRIPTION	LAMP	BALLAST
A	FLUORESCENT HIGH-BAY FIXTURE WITH (6) T5 HO FLUORESCENT LAMP WITH WIREGUARD	PHILIPS 54T5 HO	277V, SYLVANIA QUICKTRONIC UNIVERSAL BALLAST
B	48" FLUORESCENT FIXTURE, 32W, 277V, 2 LAMPS, RAPID START, 10% UP LIGHT, OPEN TYPE	SYLVANIA F032/741	120V, MVOLT ELECTRONIC BALLAST
C	42W COMPACT FLUORESCENT WALL - MOUNT UTILITY VAPOR TIGHT LIGHT FIXTURE WITH GLASS GLOBE, WIRE GUARD AND JUNCTION BOX	42 WATT CFL	120V

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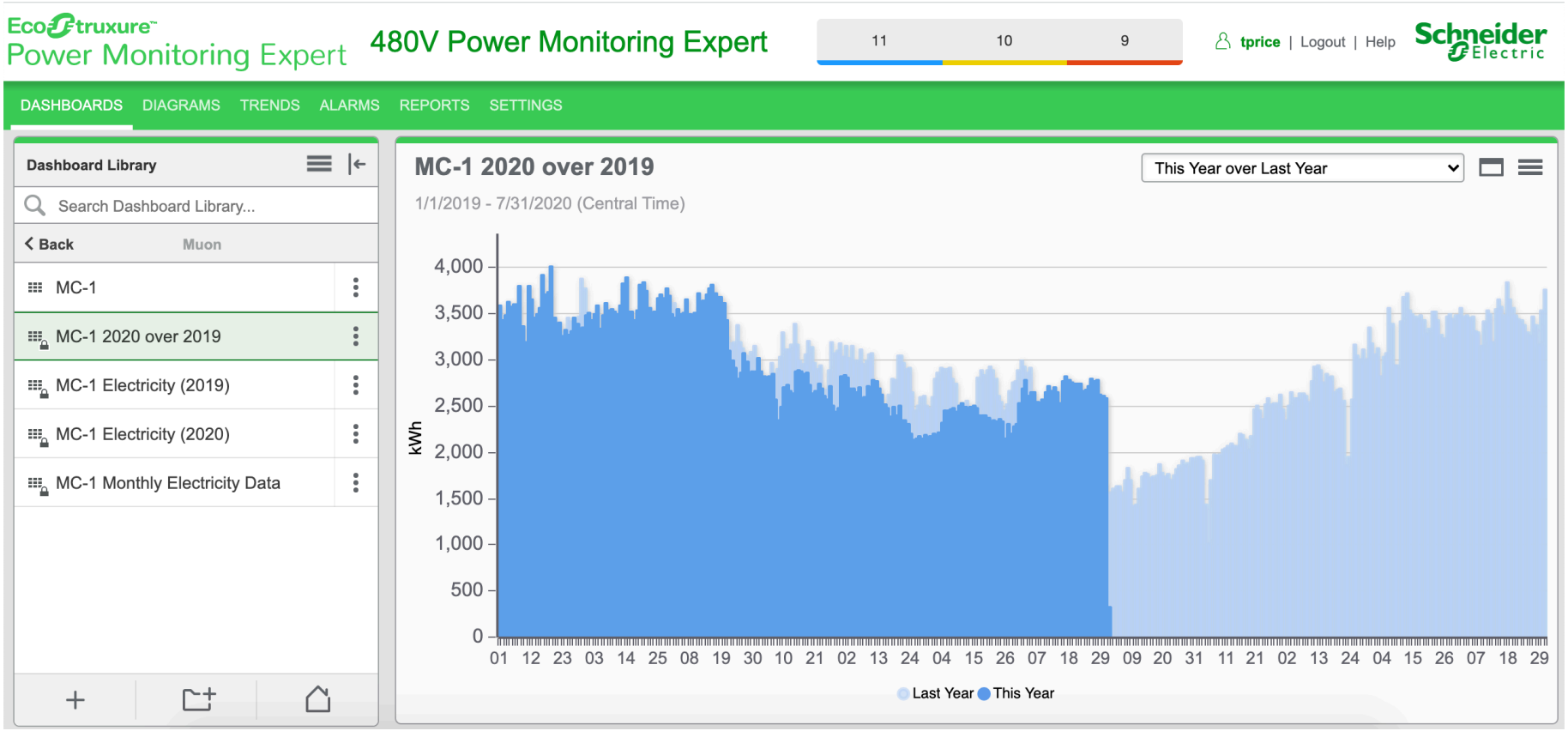
Methods

- Power Monitoring Expert (PME) tool used to gather historical electricity consumption data for 2019



Methods

- Natural gas consumption was obtained from on-site gas meters that are manually read monthly
  - Thank you FESS for doing this!

- The g-2 experiment's electronic logbook (eLog) was used to determine the building's daily operation conditions
  - Necessary for creating energy consumption breakdown chart
  - Expertise in running conditions were developed throughout this project

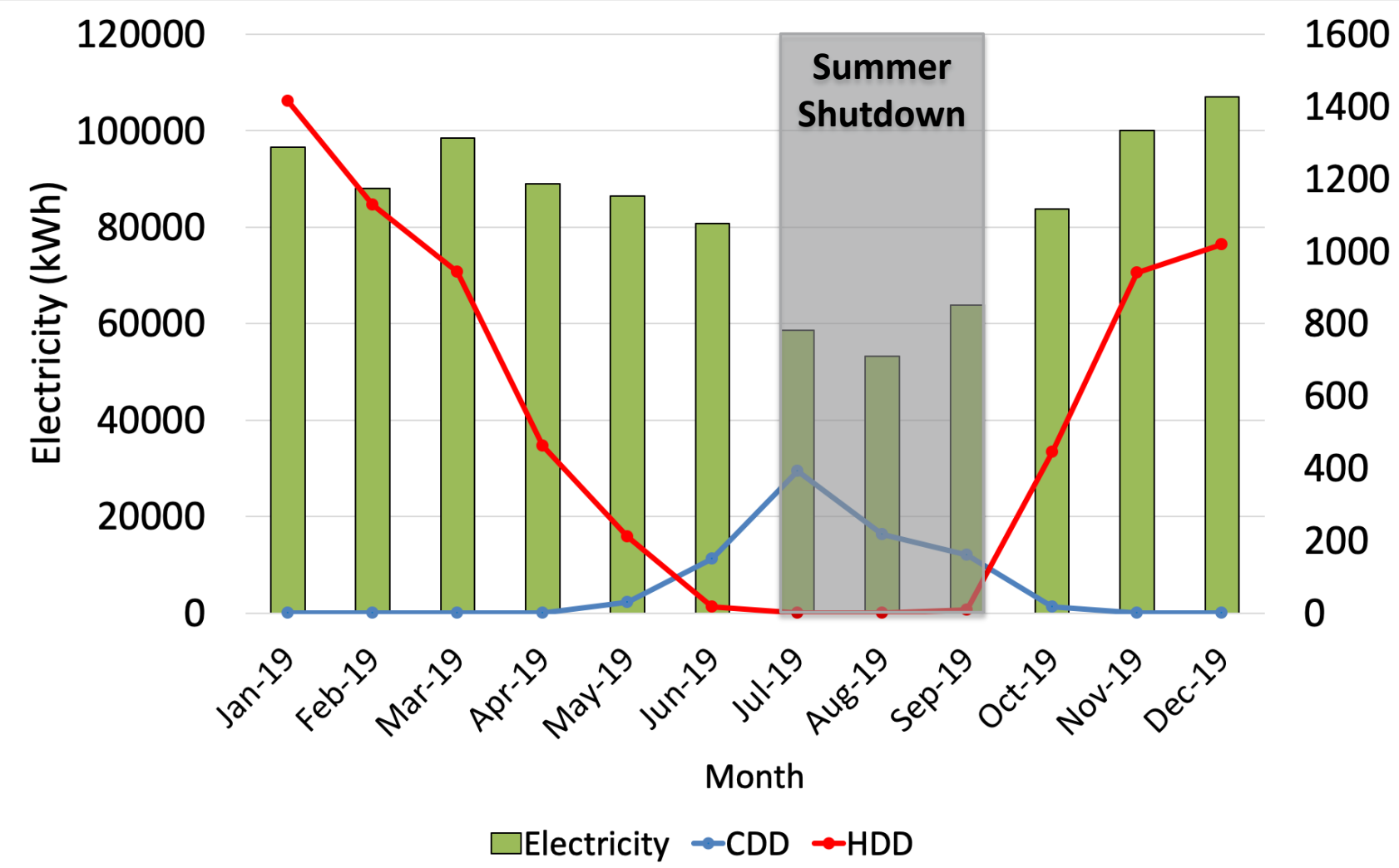
Methods

- Accessed local weather data using the National Oceanic and Atmospheric Administration (NOAA) climate and weather search tool

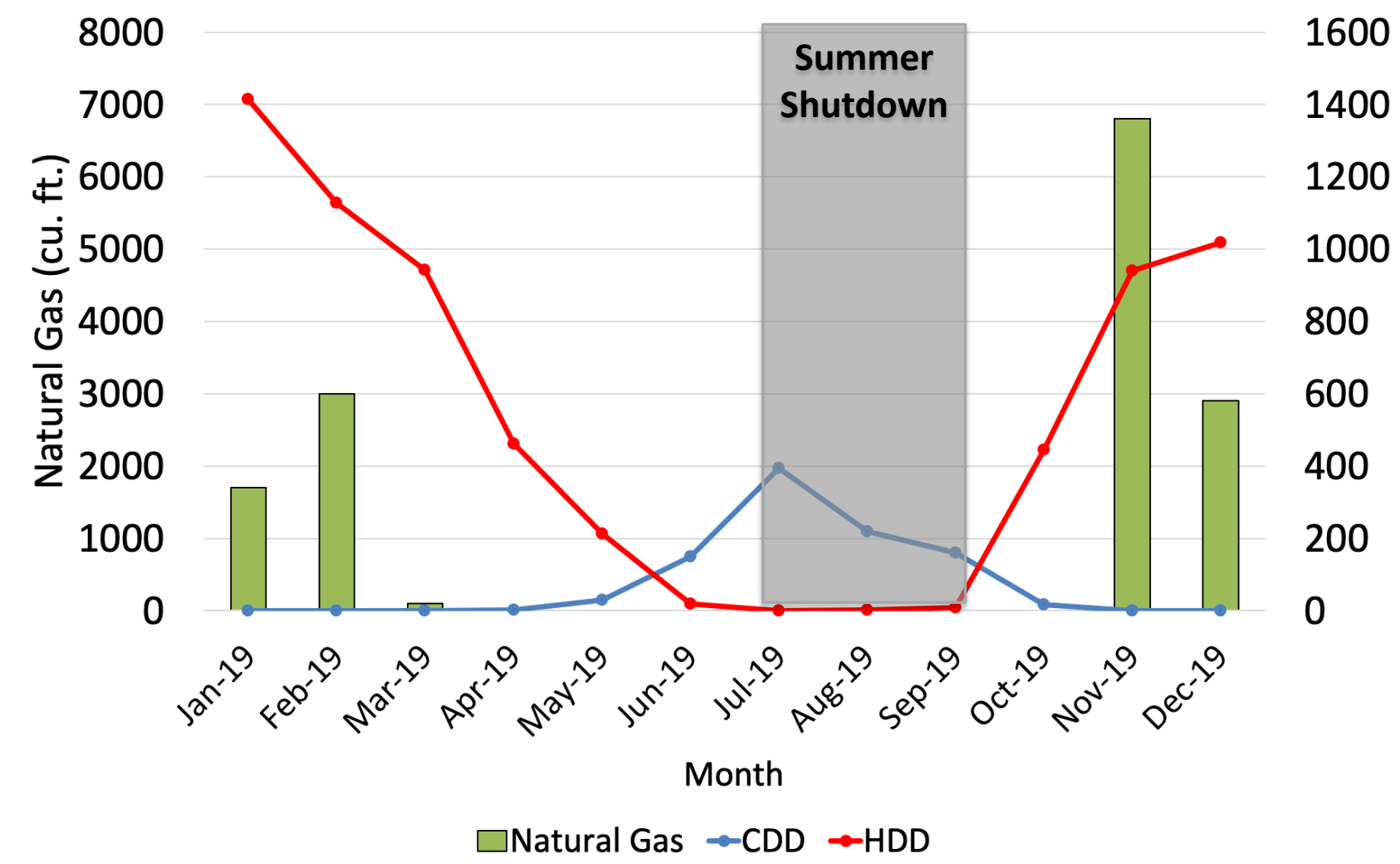
- Weather data used to compare energy consumption against weather conditions at that time using degree days

- Degree days measure how hot or cold a location is by comparing the average outdoor temperature to a standard temperature of 65 °F
  - Heating degree day (HDD): $65\ °F - T_{Outside}$
  - Cooling degree day (CDD): $T_{Outside} - 65\ °F$

MC-1 Electricity Consumption vs CDD and HDD



MC-1 Natural Gas Consumption vs CDD and HDD



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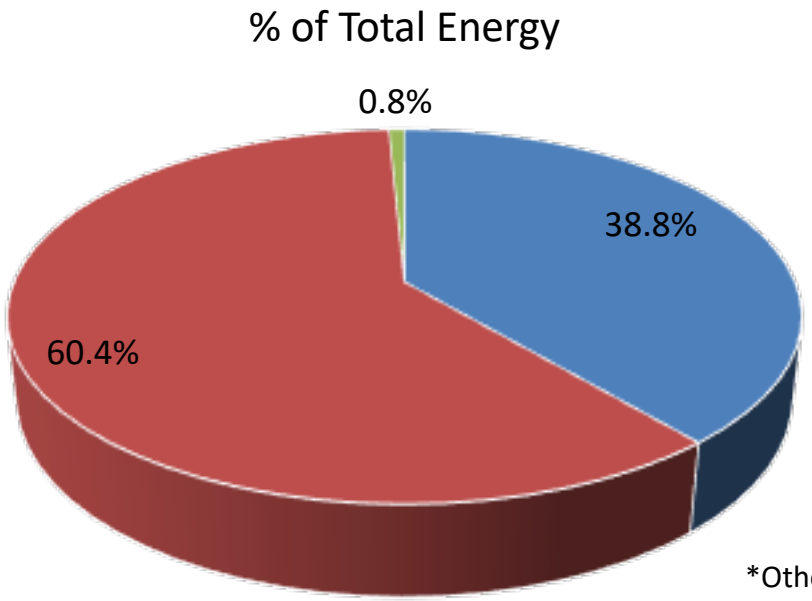
Utility Costs

- Assumed an overall average sitewide electricity cost of $0.0467/kWh and natural gas cost of $0.32/therm

MC-1		
Electricity (kWh)	Gas (therms)	$ Energy
1,006,158.00	145	$47,033.98
kWh/sq.ft.	therms/sq.ft.	$/sq.ft
74.75	0.01	$3.49

Estimated Energy Consumption Breakdown

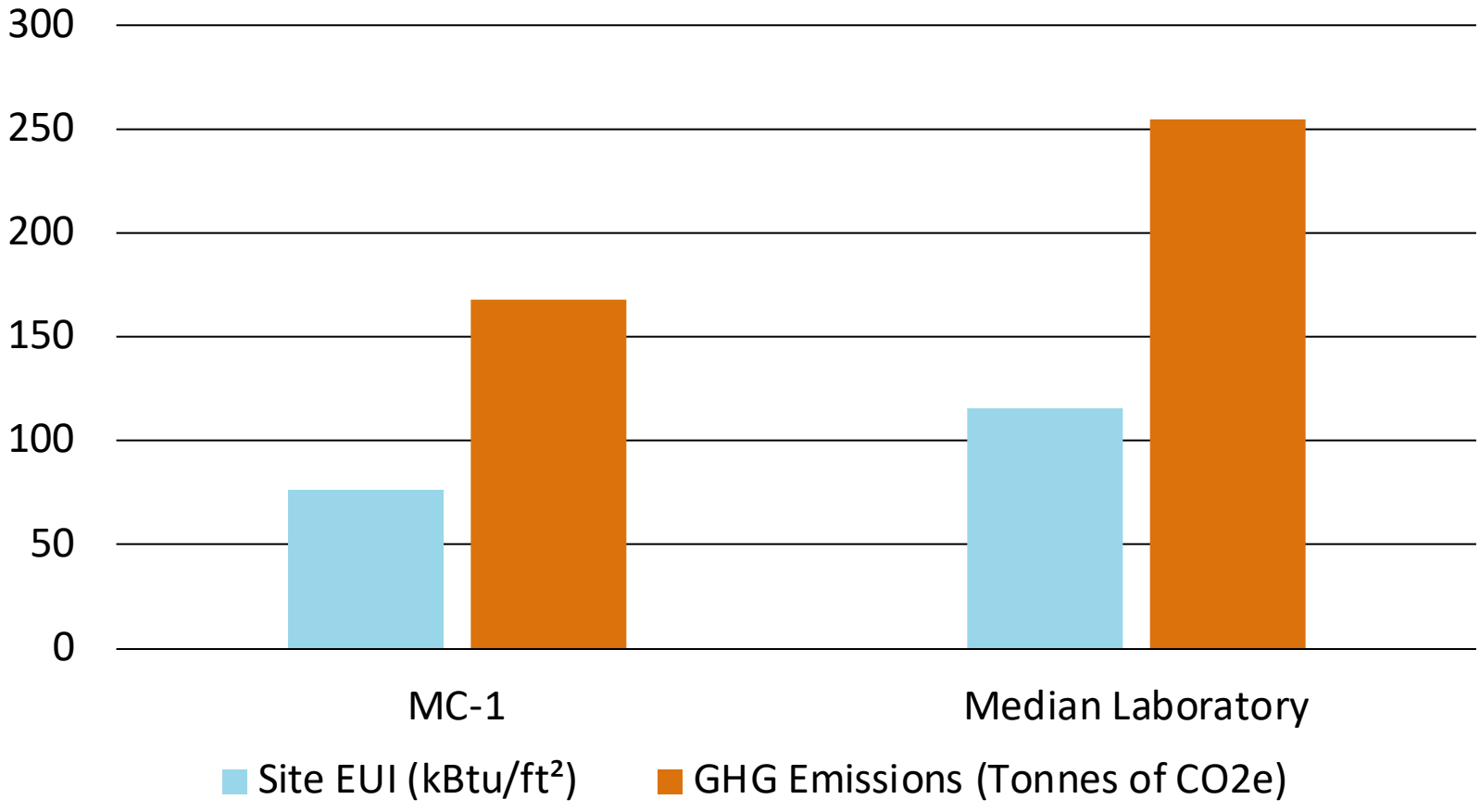


*Other process that could not be teased out between MR Open and MR Closed days

Process HVAC and Other* Lighting

- HVAC and lighting systems provide opportunities for energy efficiency improvements

MC-1 vs Other Laboratories



Proposal: Replace existing lighting with LEDs

		CURRENT EQUIPMENT				LED REPLACEMENT		
LIGHTING EQUIPMENT DESCRIPTION	NUMBER	LAMP TYPE	WATTS	kWh/yr	$/yr	WATTS	kWh/yr	$/yr
FLUORESCENT HIGH BAY FIXTURE WITH (6) H5 HO FLOURESCENT LAMP WITH WIRE GUARD	6	FLUORESCENT	54.1	1895.66	88.53	22	770.88	36.00
48" FLUORESCENT FIXTURE, 32W, 277V, 2 LAMPS, RAPIS START, 10% UP LIGHT, OPEN TYPE	2	FLUORESCENT	32	373.76	17.45	17	198.56	9.27
42W COMPACT FLOURESCENT WALL - MOUNT UTILITY VAPOR TIGHT LIGHT FIXTURE WITH GLASS GLOBE, WIRE GUARD AND JUNCTION BOX	1	CFL	42	245.28	11.45	16	93.44	4.36
EXIT SIGHT WITH RED LETTERS, WHITE HOUSING, UNIVERSAL MOUNTING, WITH BATTERY, SINGLE OR DOUBLE FACE REQ'D	1	LED	2.7	15.77	0.74	2.7	15.768	0.74
48" SURFACE/PENDANT MOUNTED FOR COLD TEMP. AND WET LOCATION FLUORESCENT LIGHT FIXTURE	1	FLUORESCENT	32	186.88	8.73	17	99.28	4.64
9" DEEP x 16" WIDE EXTERIOR WALL MOUNTED METAL								
Total:	**7634.63**	**$ 356.54**			**2918.25**		**$ 136.28**	
6" DIAMETER CLASSIC ROUND PENDANT MOUNTED FLUORESCENT LIGHT FIXTURE UP/DOWN LENS AND UP/DOWN REFLECTOR. LIGHT DISTRIBUTION MOSTLY UP	1	FLUORESCENT	32	186.88	8.73	17	99.28	4.64
6" x 48" SURFACE/PENDANT MOUNTED FOR COLD TEMP. AND WET LOCATION FLUORESCENT LIGHT FIXTURE	3	FLUORESCENT	32	560.64	26.18	17	297.84	13.91
9"D x 18"W EXTERIOR WALL MOUNTED METAL HALIDE LIGHT FIXTURE	1	METAL HALIDE	150	876.00	40.91	54	315.36	14.73
400W METAL HALIDE ROADWAY FIXTURE DOWN LIGHT, TENON - MOUNTED ON A 30-FOOT LONG, 6-INCH DIA. SQUARE ALUMINUM POLE	1	METAL HALIDE	400	2336.00	109.09	120	700.8	32.73
24" x 48" FLUORESCENT FIXTURE, 32W, 2 LAMPS, RECESSED MOUNT, ACRYLIC LENS, HINGE DOOR, RAPID START	2	FLUORESCENT	32	373.76	17.45	17	198.56	9.27
			Total:	**7634.63**	**$ 356.54**		**2918.25**	**$ 136.28**

Proposal: Replace existing lighting with LEDs

Estimated Cost and Savings Description	Value
Annual Electricity Savings (kWh/yr)	4716.38
Annual Material Cost Savings ($)	-1.83
Annual Energy Cost Savings ($)	220.26
Total Annual Savings ($)	218.42

- Further research shows that rad hard LEDs would be necessary for high rad areas

- Topic has been researched by CERN for accelerator tunnels
  http://cds.cern.ch/record/2215317

Conclusions and Next Steps

- Replacing the current lighting equipment with LEDs, electricity consumption for lighting could be reduced by 62%
- Further R&D on radiation hardening of LEDs would provide new exploration into green design
  - Would have broad impacts on society
- Future in-depth analysis into the energy consumption of other subsystems at MC-1 would provide more energy savings and reduce the buildings carbon footprint further

Acknowledgement

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- Dr. Jessica Esquivel for her guidance and for giving me the opportunity to contribute to the g-2 collaboration

- Andrew Martens and Cedric Madison from FESS for providing access to the energy analysis and monitoring tools

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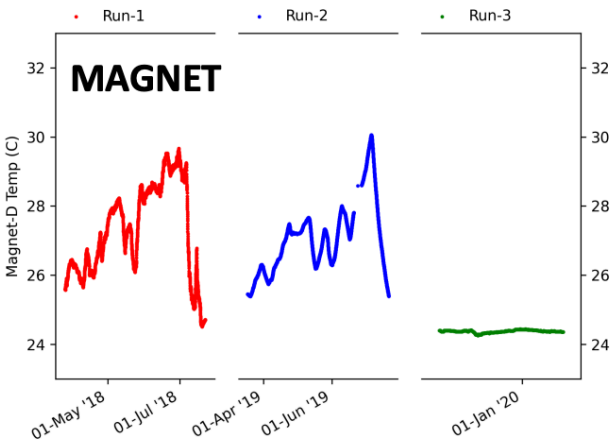
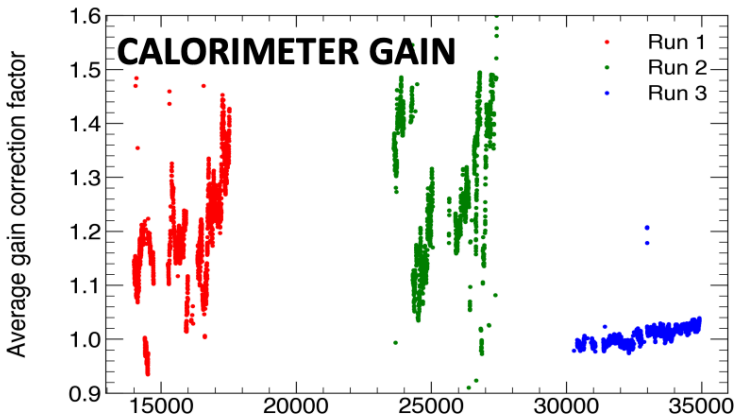
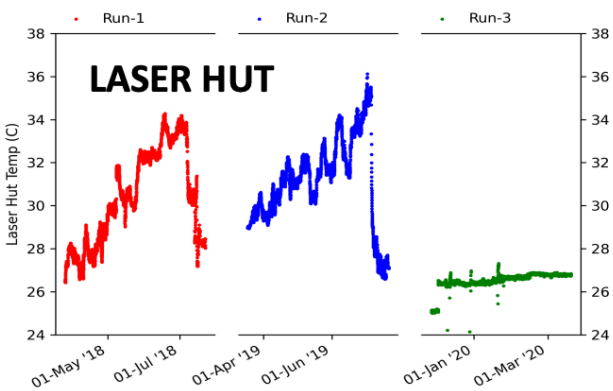
Questions?

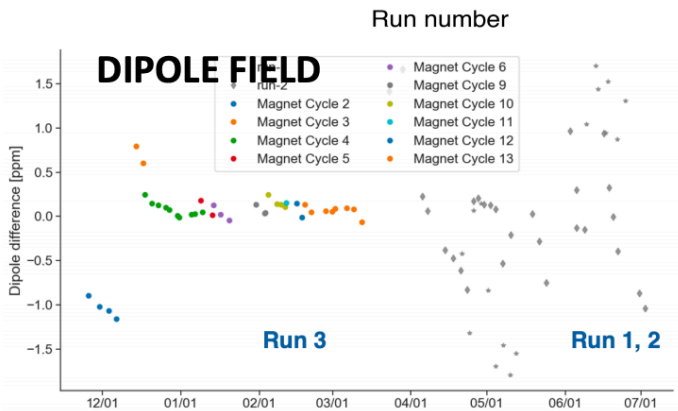
Appendix

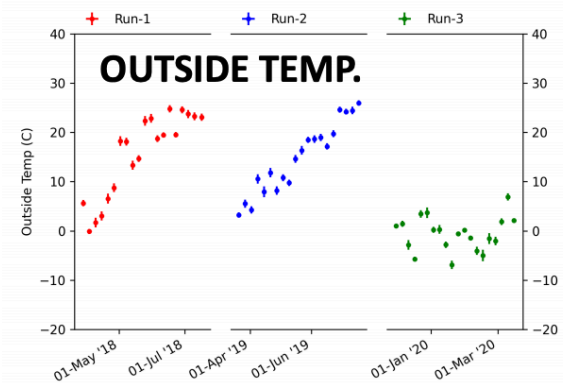
Temperature Variations on Run-3











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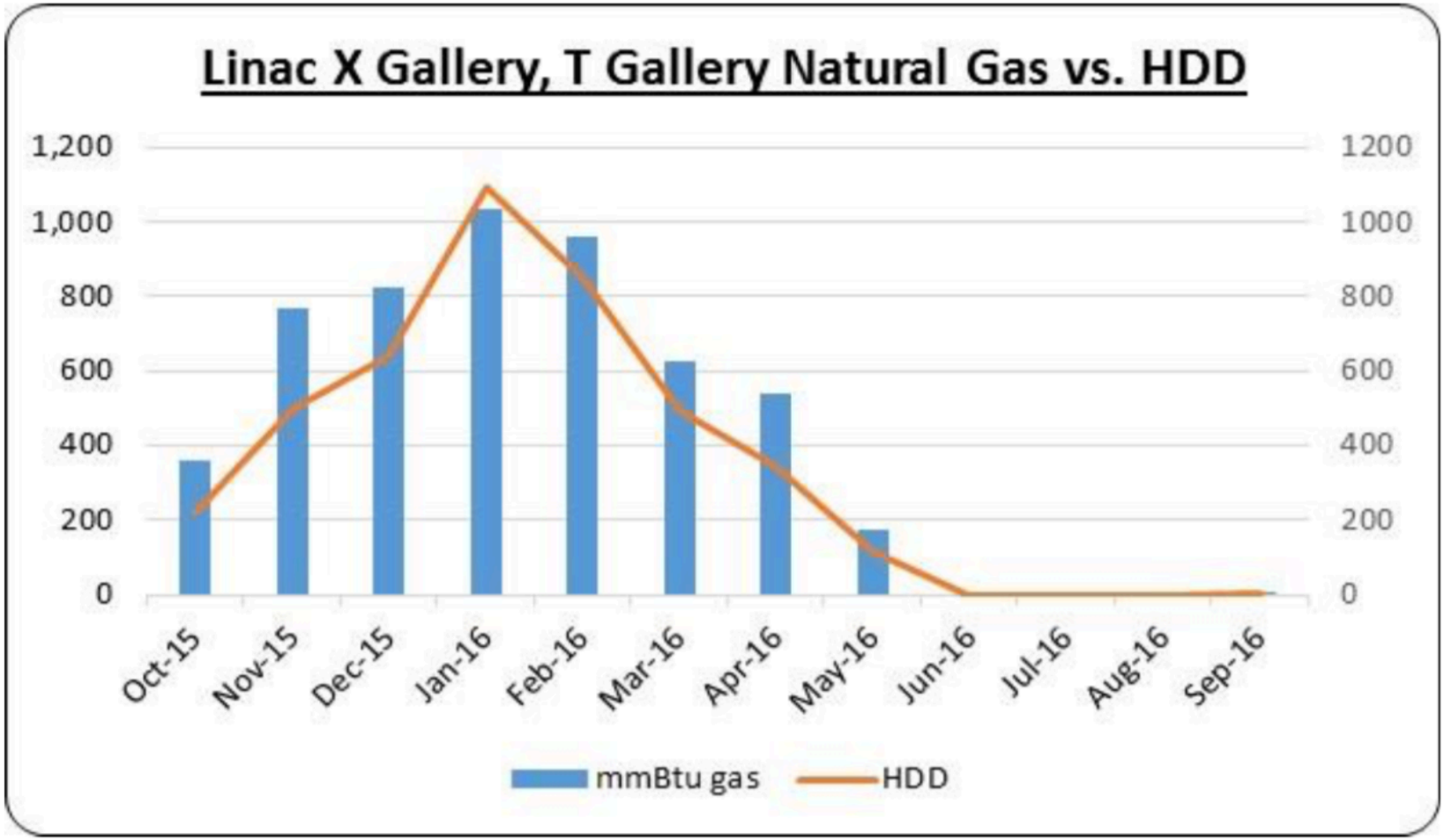
Linac Energy Audit (FY2015) – Natural Gas



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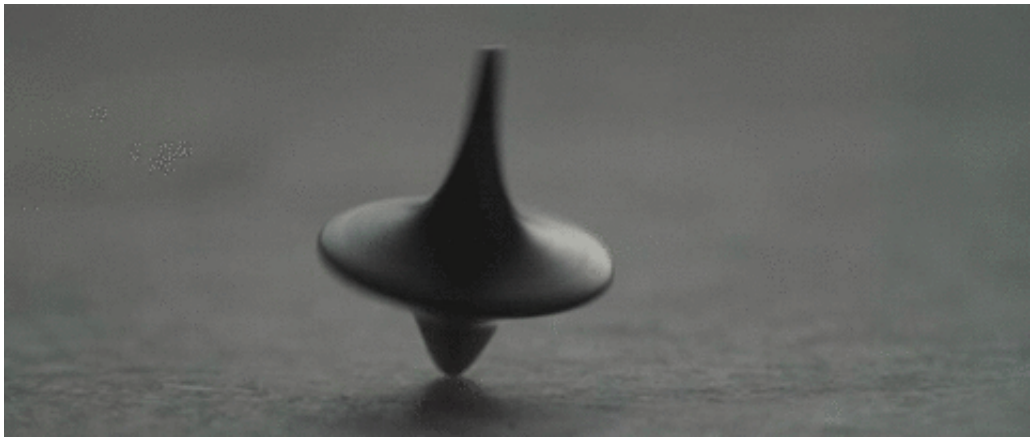
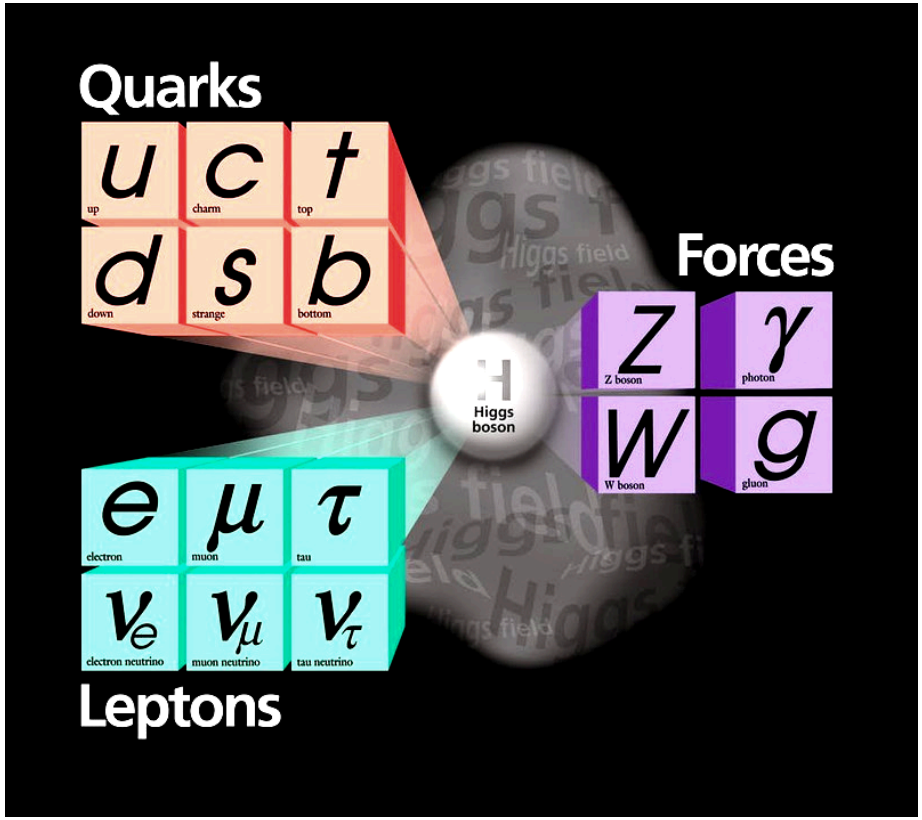
MR Open vs MR Closed Days

Month	MR Open Days	MR Closed days	% Difference	# MR Open Days	# MR Closed Days
January	3703.02	3044.83	-17.77%	3	27
February	3077.12	3265.58	6.12%	9	8
March	2952.10	3241.11	9.79%	4	20
April	2583.23	3060.80	18.49%	3	23
May	2459.01	2991.76	21.67%	10	18
June	2463.79	2799.85	13.64%	4	19
July	1588.36	2207.67	38.99%	13	15
August	1719.88	N/A	N/A	31	0
September	2128.78	N/A	N/A	27	0
October	2581.99	2908.78	12.66%	17	7
November	2979.79	3483.45	16.90%	6	18
December	N/A	3475.98	N/A	1	25
		Mean	13.39%		

Muons in Magnetic Fields

- When placed in a magnetic field, muon's will precess like a spinning top
- The gyromagnetic ratio or "g-factor" is a measure of this precession frequency
  - Differs from 2 by about 0.1 percent
- This anomaly is commonly called the anomalous magnetic moment, $a_\mu = \frac{g-2}{2}$



What are Muons?

- Similar to electrons:
  - Same charge and spin
- Different from electrons:
  - 200 times more massive
  - Unstable
- Great probes of the Standard Model (SM):
  - Not affected by strong force
  - Relatively long lifetime