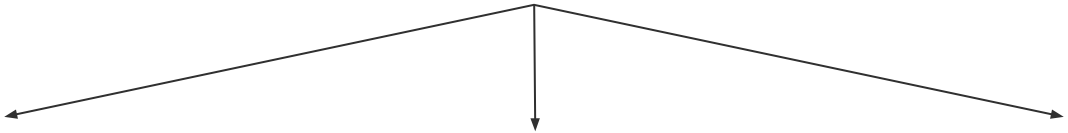




# SUMMER RESEARCH

Joshua Doucette (University of Iowa)
Funded by US ATLAS SUPER PROGRAM

# OUTLINE: Research



## ITk-Strips, Modules, Staves

- Testing:
  - 3-Point Gain
  - Noise Occupancy
  - Threshold Scans
  - Thermal Cycling
- Helped with Communication between ITSDAQ and Coldbox
- Created Library for HV supply

## Environmental Monitors

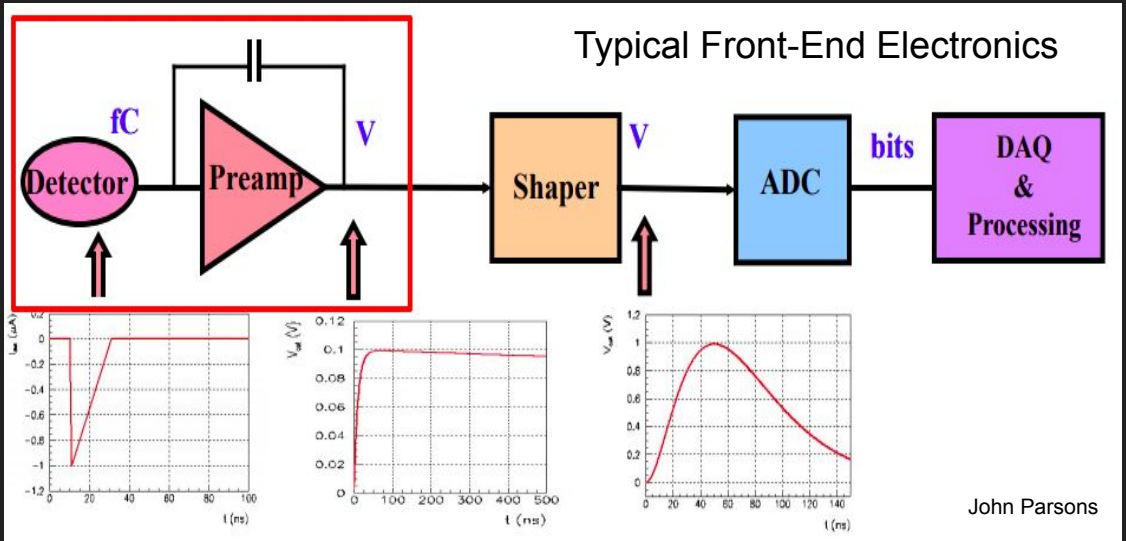
- Maintenance
- Programming
- Plotting
- Debugging
- Some Construction
- Error Handling

## ATLAS Analysis

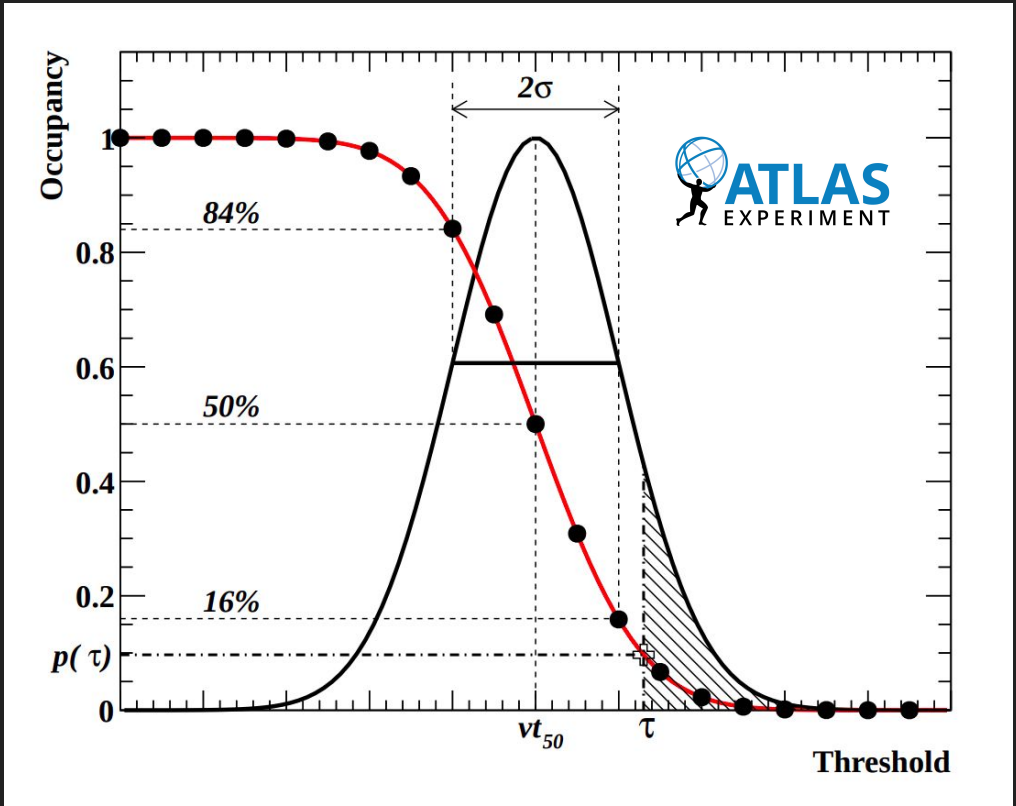
- Beyond Standard Model
- Based on Two Higgs Doublet Model which predicts DM production in association w/ SM Higgs (monoHiggs)
- 3D Plots of Significance for variations in mass parameters
- Learning monoHiggs framework

# ITk-Strip Modules and Staves (with Punit Sharma's Tutelage)

- A completely new inner tracker will be developed for high luminosity LHC
- Several tests must be done to modules to ensure their quality
- Modules that meet the tests are mounted to staves and shipped to CERN
- Tests of modules are done by the ITSDAQ Software




# Threshold Scan of ABCstar Chips in Module




Use charge injection for tests:

$$\text{Occupancy} = \frac{\text{Number of Signals}}{\text{Number of Test Charges}}$$

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The occupancy would be a step function if there was no noise.

However assuming the electronic noise is a gaussian, the occupancy follows an s-curve.

The threshold of the detector is a parameter we can control to change occupancy.

- Using the TrimDAC, we can apply a threshold correction to each channel.
- If S-Curves do not align after TrimDAC scan, something may be wrong with a channel, or the chip.

## Using TrimDAC to Align S-Curves

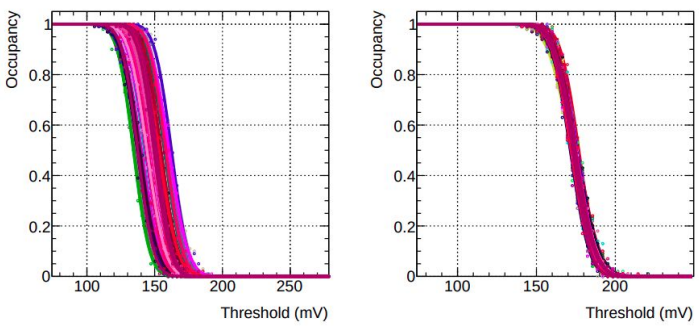



Figure 20. S-curves for all 128 channels of a chip before (left) and after (right) applying the individual channel threshold correction. The measurements correspond to a threshold scan for a 1 fC input charge. The data-points are fit to a complementary error function.

Without TrimDAC ↑ With TrimDAC ↑

## Threshold scan of ten ABCstar chips from module

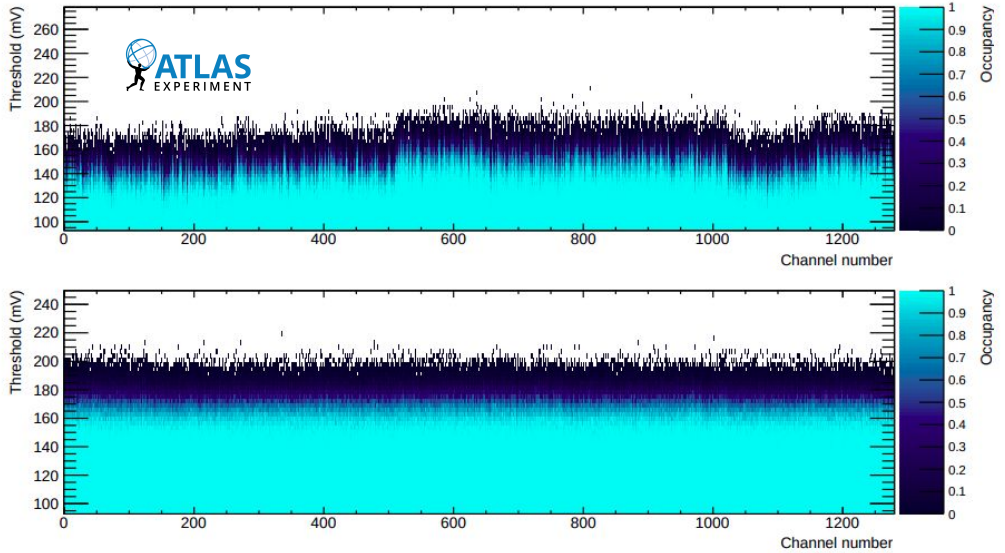



Figure 19. Threshold scan for all 1280 channels of one column of ten chips, before (top) and after (bottom) trimming. The horizontal axis is the channel number, the left-vertical axis is the threshold [mV] and the right-vertical color-scale is the channel occupancy.

# Noisy and Dead Chips in a Module

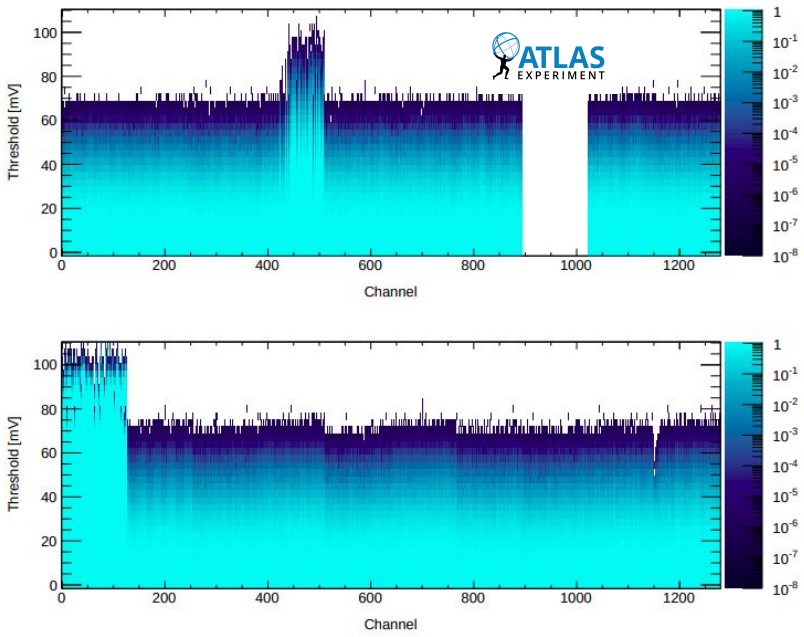



Figure 32. Threshold scan of a NO test for module KMX-2003. Results for column 1 of hybrid 0 and 1 are shown on top and bottom respectively. Two noisy chips are clearly visible, plus a dead chip in hybrid 1 seen as empty entries in the distribution (zero-occupancy) for channels ranging between 896 and 1023.

Noise occupancy is the probability that a Signal Hit is caused by noise.

Noise occupancy is determined by doing a threshold scan without any input charge being injected into the analog stage.

The noise occupancy decreases with increasing threshold values.

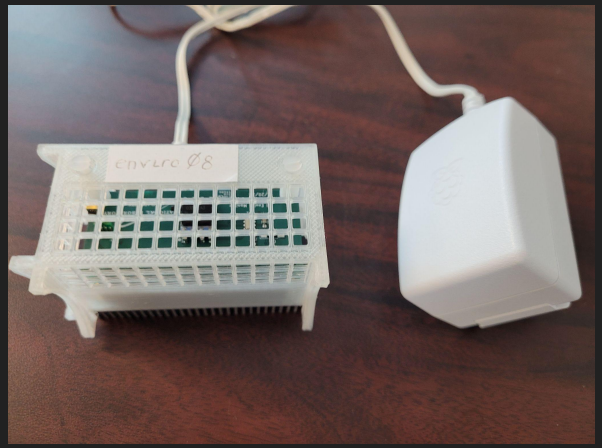
Preferably the noise occupancy should be as low as possible.

Ideally:

$$\text{Noise Occupancy} \leq 10^{-8}$$

# Environmental Monitors at BNL

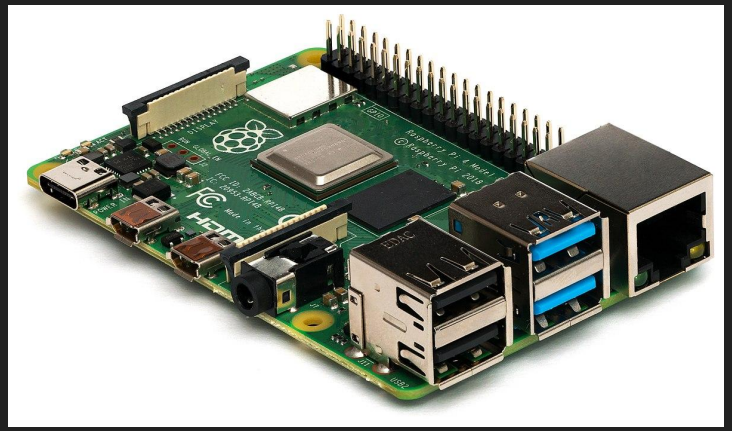
- Built to monitor important physical parameters
- Ensure proper environment for staves and modules
- Used in construction, testing, and shipping
- Around 30 units are built and maintained at BNL

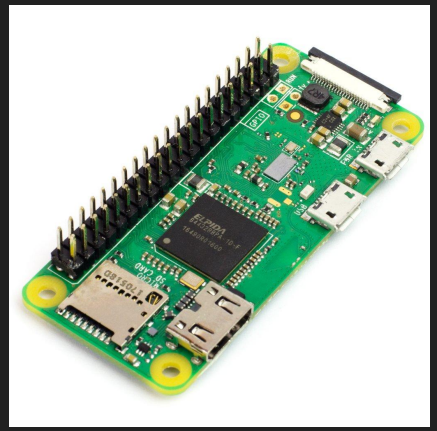




# What is a Raspberry Pi?

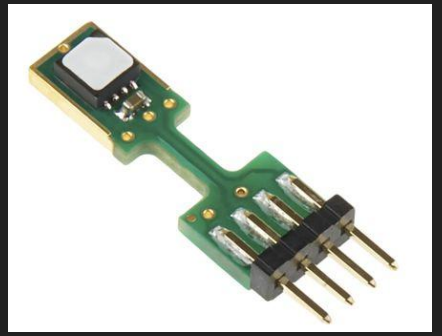
- Computer small enough to be held in your hand
- Has limited computation resources
- Great for small tasks with a low budget
- Many can be combined to perform big tasks
- Foundational device for environmental monitors





# Sensors and Parameters Measured

- Each Environmental Monitor has three I2C sensors:
  - **SHT85** (Measures Temperature and Relative Humidity)
  - **MPL3115A2** (Pressure and Temperature sensor)
  - **HSCSMRNxx** (Pressure sensor)



- Some have an additional serial USB sensor:
  - **Dylos DC1100 PRO** (Particulate Matter / Particle Count Sensor)
  - Used to ensure clean room specifications are met


- Hardware is read using Python Programming Language:
  - Easy to implement and fast to debug
  - Fast enough for data collection with minimal processing
  - Many libraries to use for different purposes

# influxdb

## Why InfluxDB?

Time-series databases are great for physics

Fast to query if queried over time and tags

Authentication and Authorization features

Curl commands exist for UNIX command line and C++

Client libraries exist for Python

Data from Python can be inserted as a String, Dictionary or in a JSON format.

## Where was InfluxDB used?

Database for over 30 environmental monitors:

-Able to process data from all the environmental monitors at once

Communication between ITSDAQ and Coldbox:

-Acts as intermediary between ROOT software and Python software

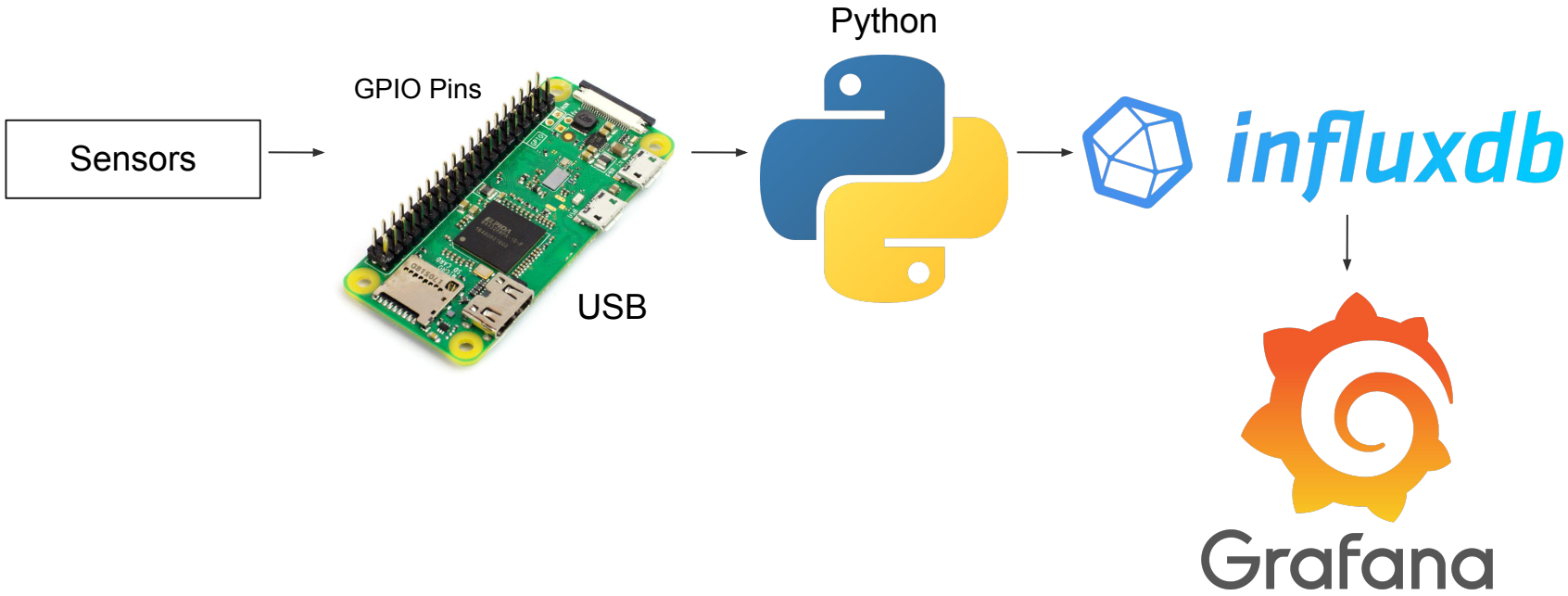
I-V plots for BNL's new HV supplies:

-Two fields for each channel: one field for channel current, another field for channel voltage

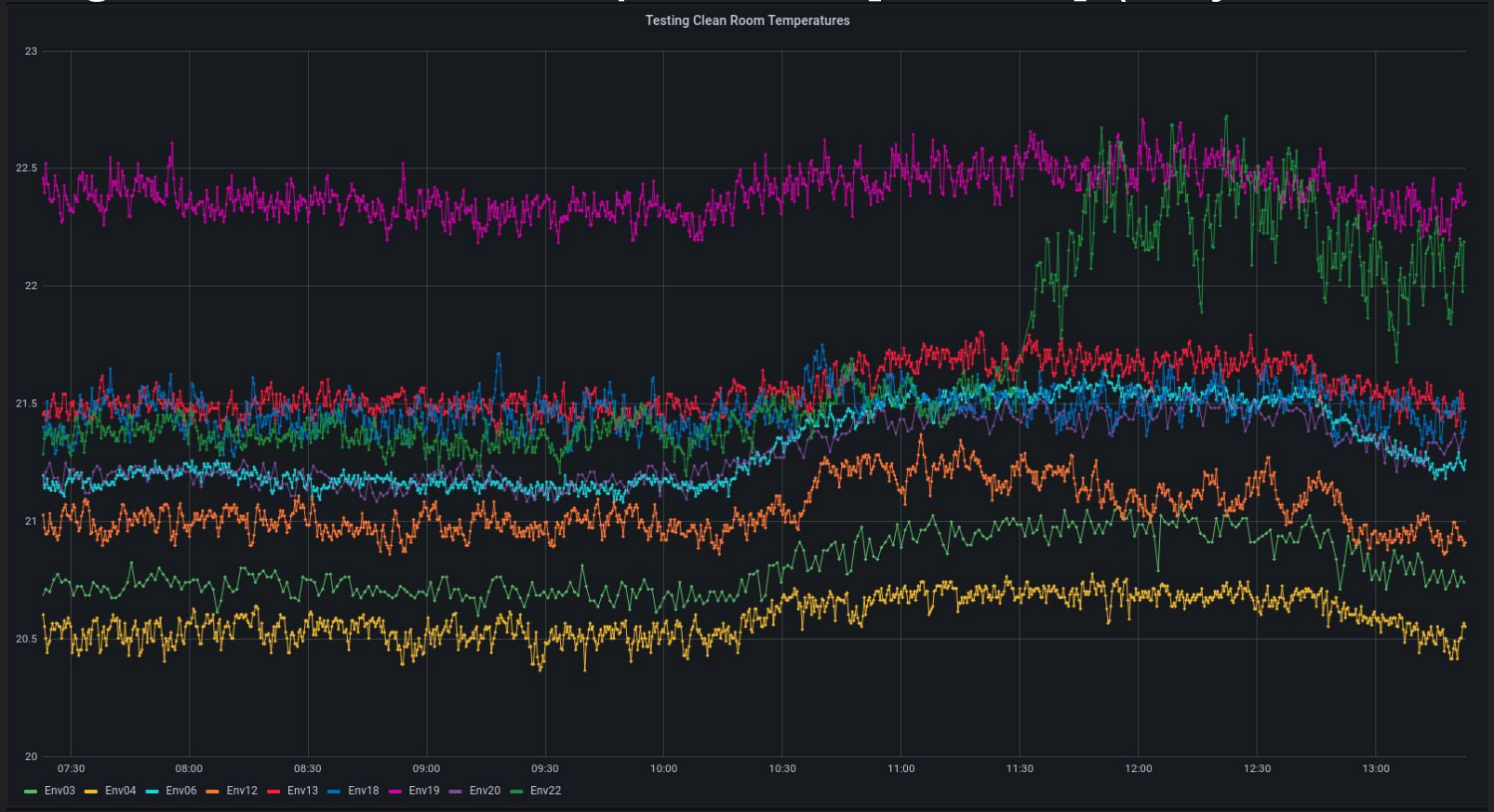
# Grafana

- Used to plot data from InfluxDB in real time
- Great when used with time-series data
- Plugins can be used to make scatter plots
    - In the event that the x-axis is not time

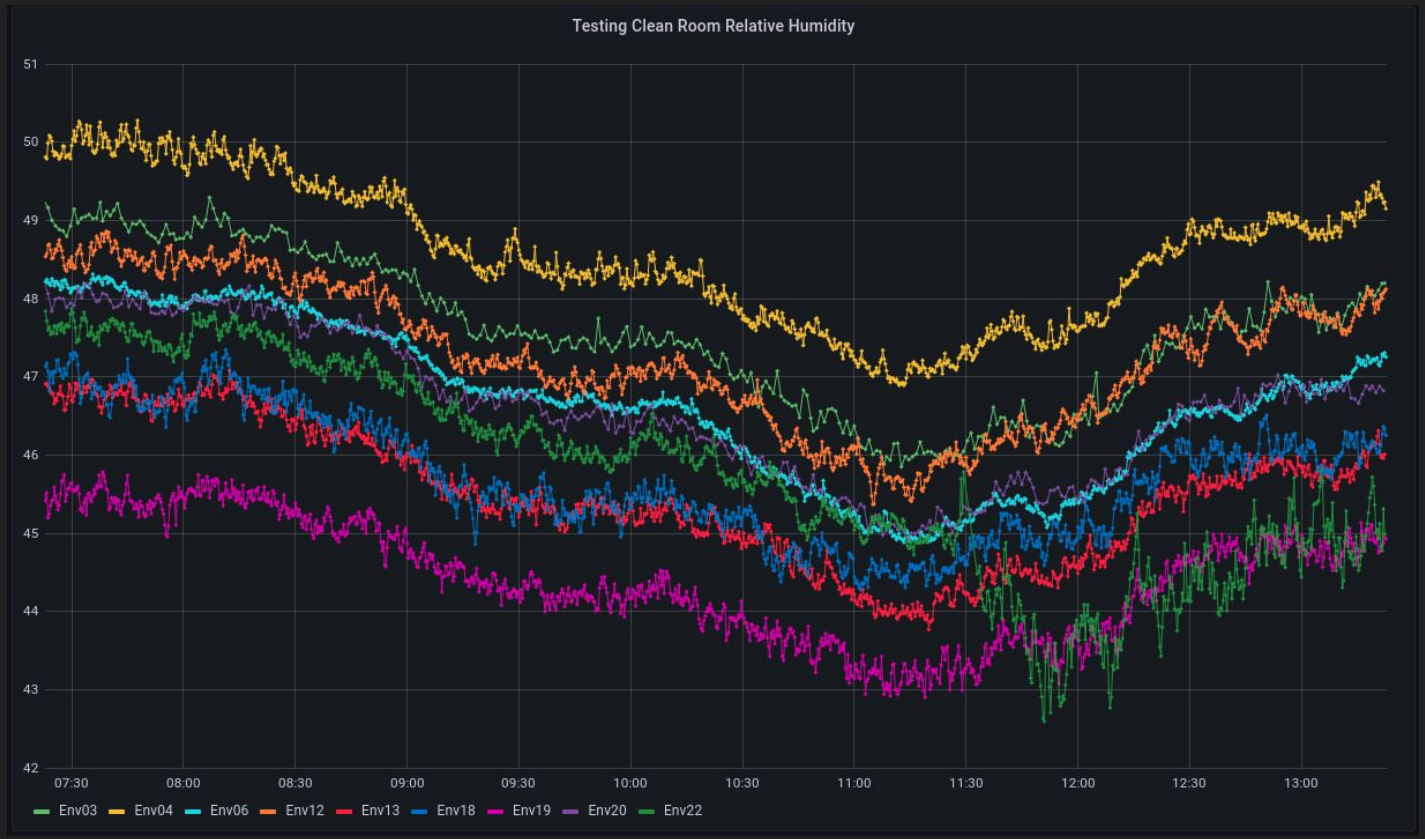
# Environmental Monitors cont.



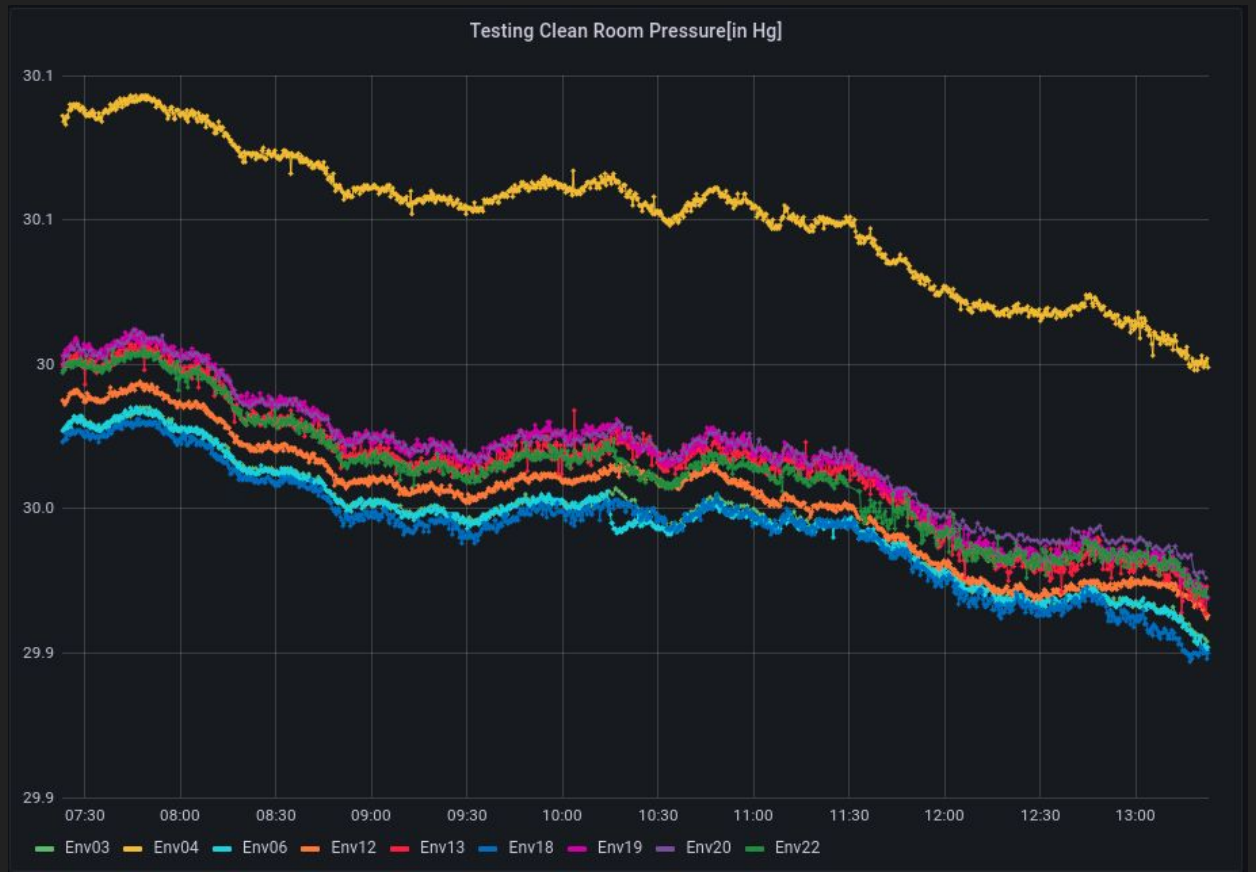
# Testing Clean Room Temperature [Cesius] (July 29, 2021)



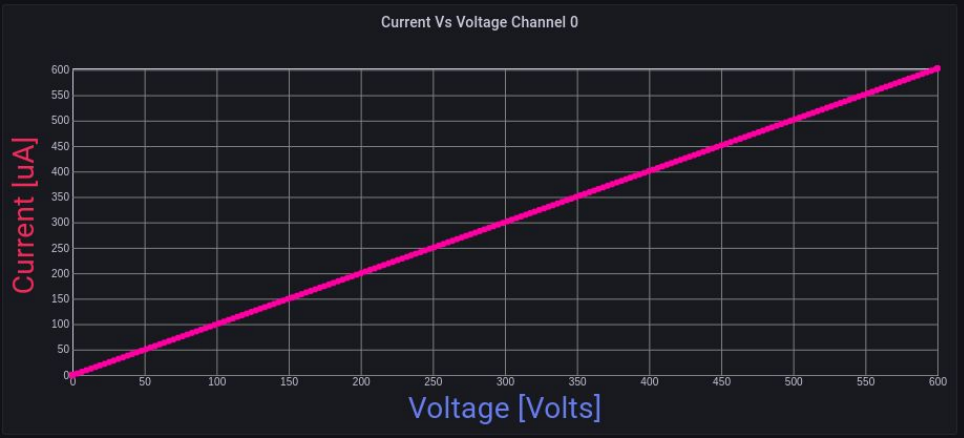
# Testing Clean Room Relative Humidity [%] (July 29, 2021)

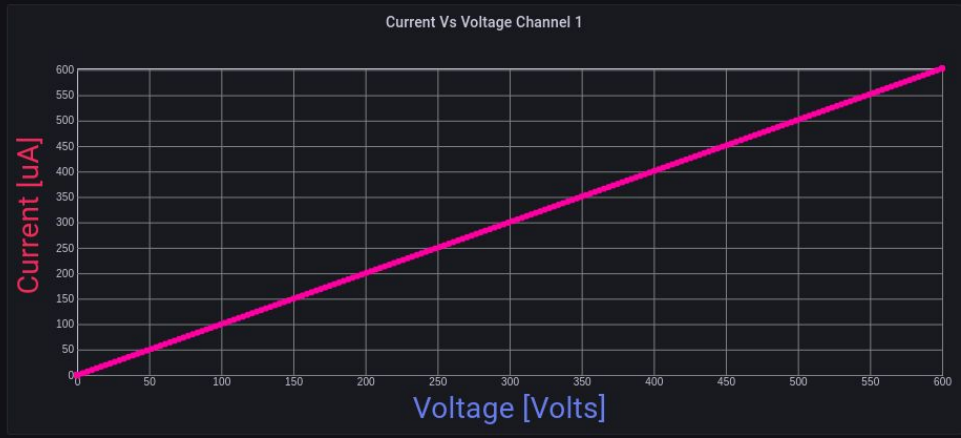


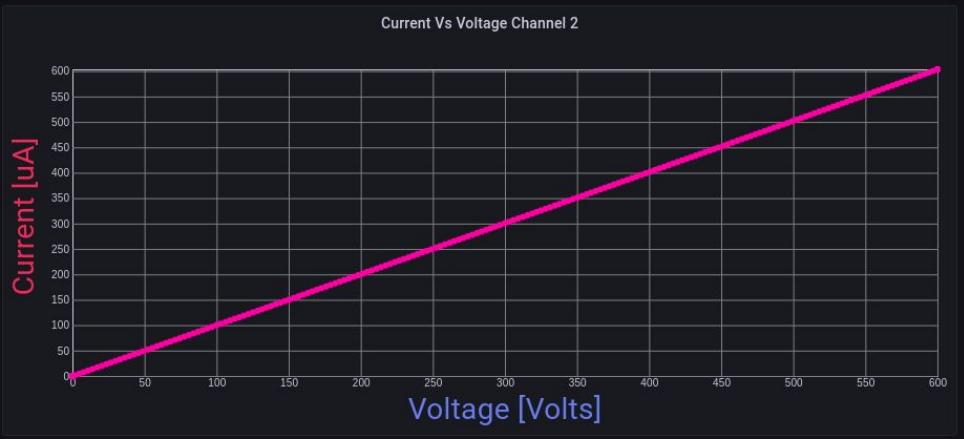
# Testing Clean Room Pressure [in Hg] (July 29, 2021)

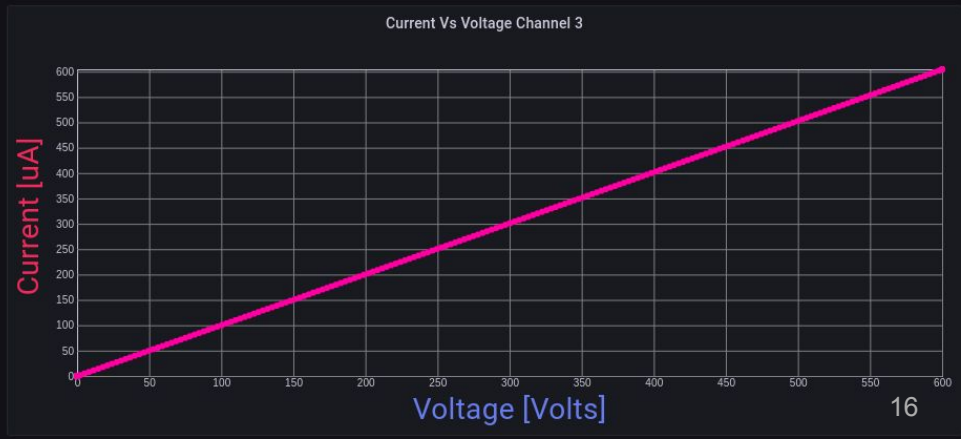


# I-V Plots for iseg SHR 4 channel power supplies:



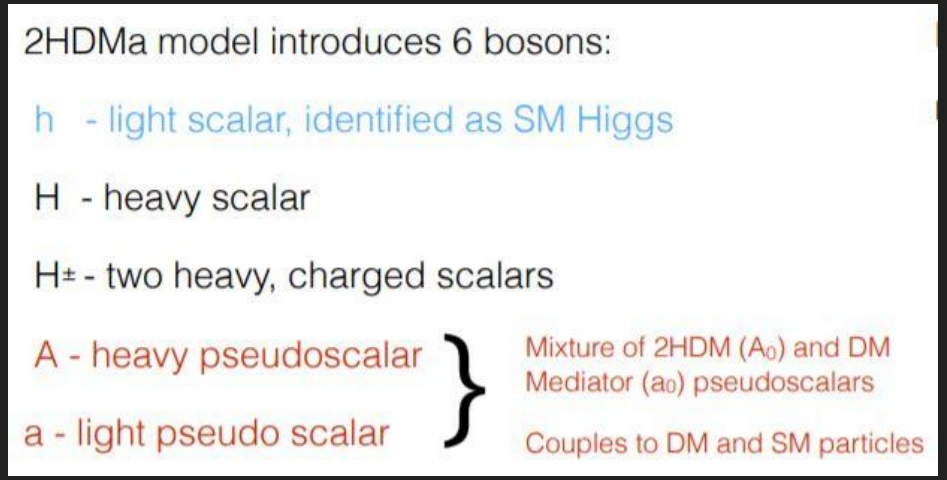



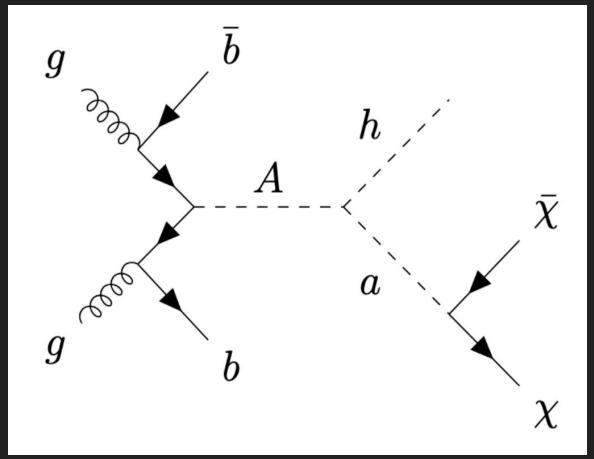
# ATLAS Analysis Work

- Advised by Professor Usha Mallik and Dr. Anindya Ghosh
- Research based on the Two Higgs Doublet Model (2HDM)
- 2HDM is a Beyond Standard Model (BSM) theory, apart of Higgs Portal Models
- 2HDM predicts Dark Matter (DM) production in association with a SM Higgs

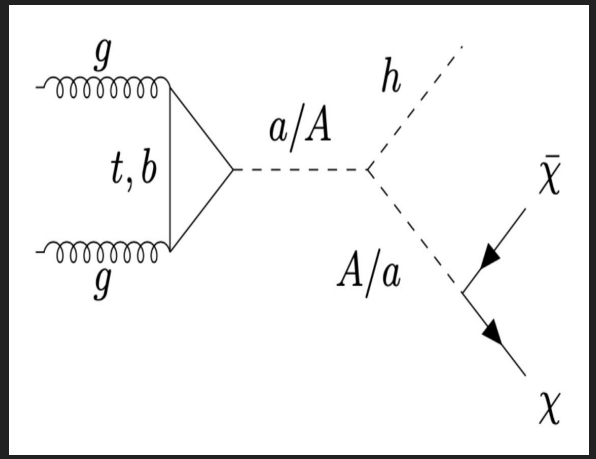


# 2HDM Signals

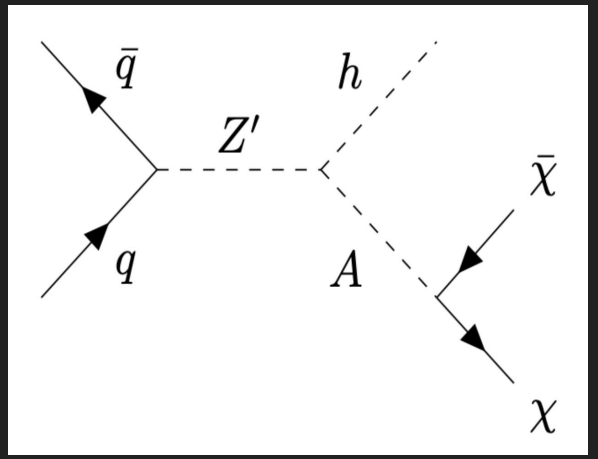
2HDM+a Hbb




2HDM+a ggF




Z'-2HDM



# MET Binning

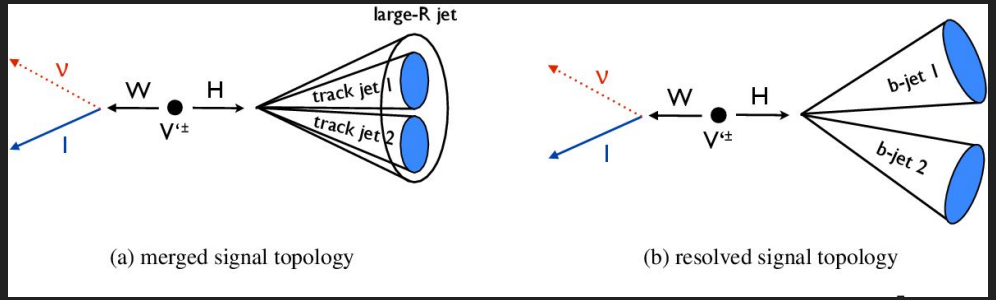
- Currently 5 MET Regions:

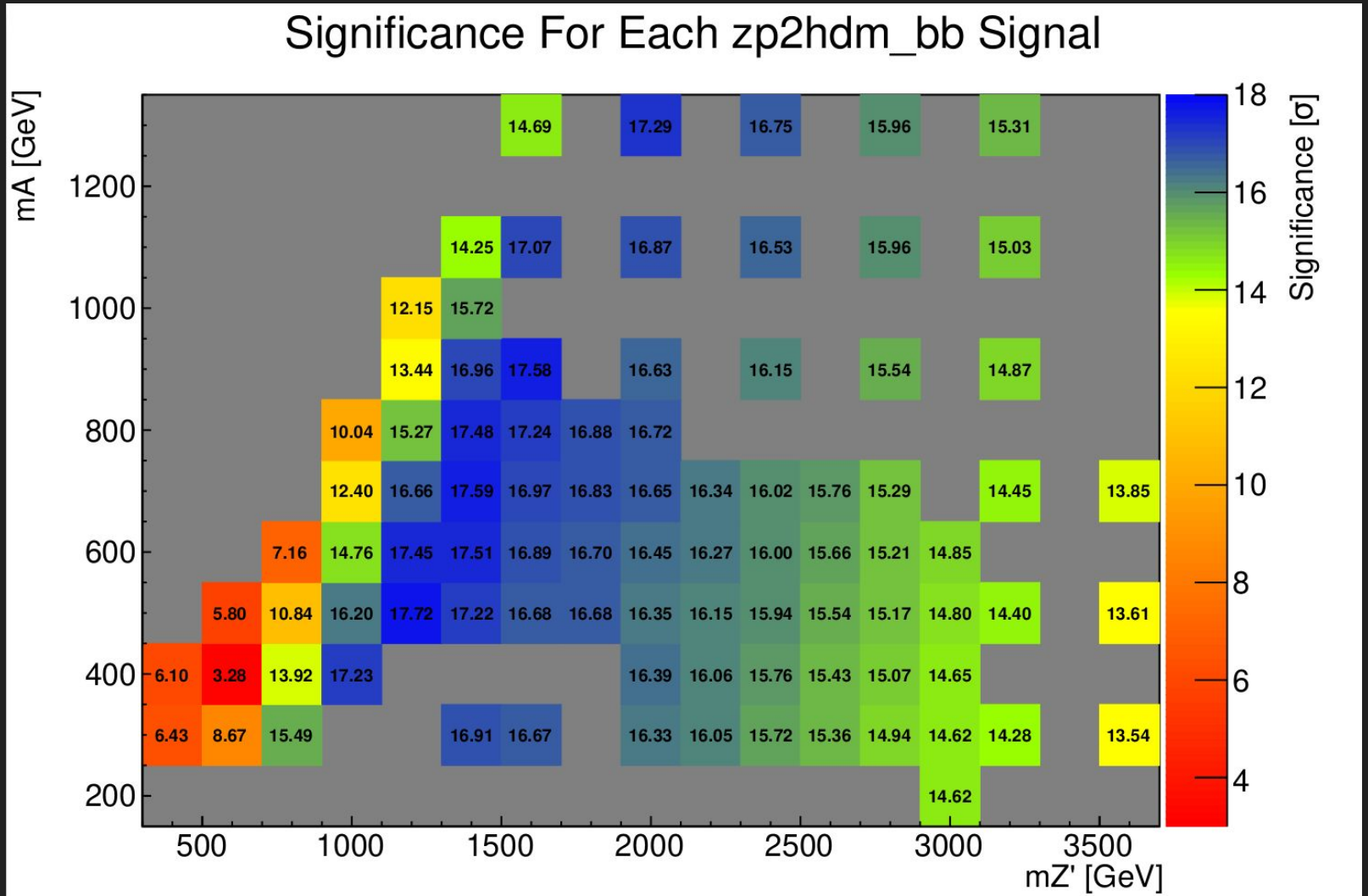
  Resolved Regions:

  - 150 GeV < **MET** < 200 GeV
  - 200 GeV < **MET** < 350 GeV
  - 350 GeV < **MET** < 500 GeV

  Merged Regions:

  - 500 GeV < **MET** < 750 GeV
  - 750 GeV < **MET**



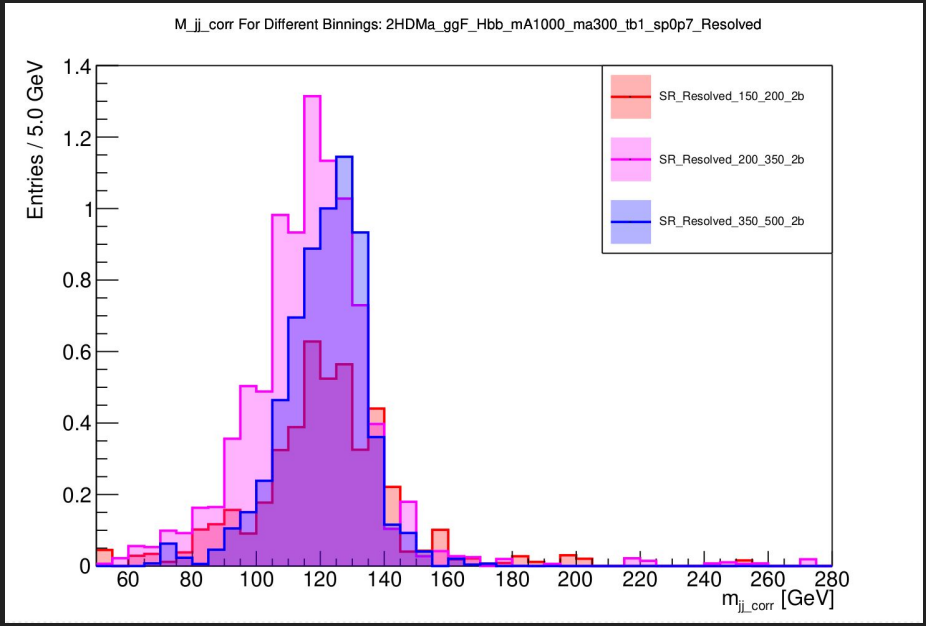

Significance For Each zp2hdm_bb Signal
mA [GeV]
mZ' [GeV]
Significance [σ]
200
400
600
800
1000
1200
500
1000
1500
2000
2500
3000
3500
4
6
8
10
12
14
16
18
14.69 17.29 16.75 15.96 15.31
14.25 17.07 16.87 16.53 15.96 15.03
12.15 15.72
13.44 16.96 17.58 16.63 16.15 15.54 14.87
10.04 15.27 17.48 17.24 16.88 16.72
12.40 16.66 17.59 16.97 16.83 16.65 16.34 16.02 15.76 15.29 14.45 13.85
7.16 14.76 17.45 17.51 16.89 16.70 16.45 16.27 16.00 15.66 15.21 14.85
5.80 10.84 16.20 17.72 17.22 16.68 16.68 16.35 16.15 15.94 15.54 15.17 14.80 14.40 13.61
6.10 3.28 13.92 17.23 16.39 16.06 15.76 15.43 15.07 14.65
6.43 8.67 15.49 16.91 16.67 16.33 16.05 15.72 15.36 14.94 14.62 14.28 13.54
14.62

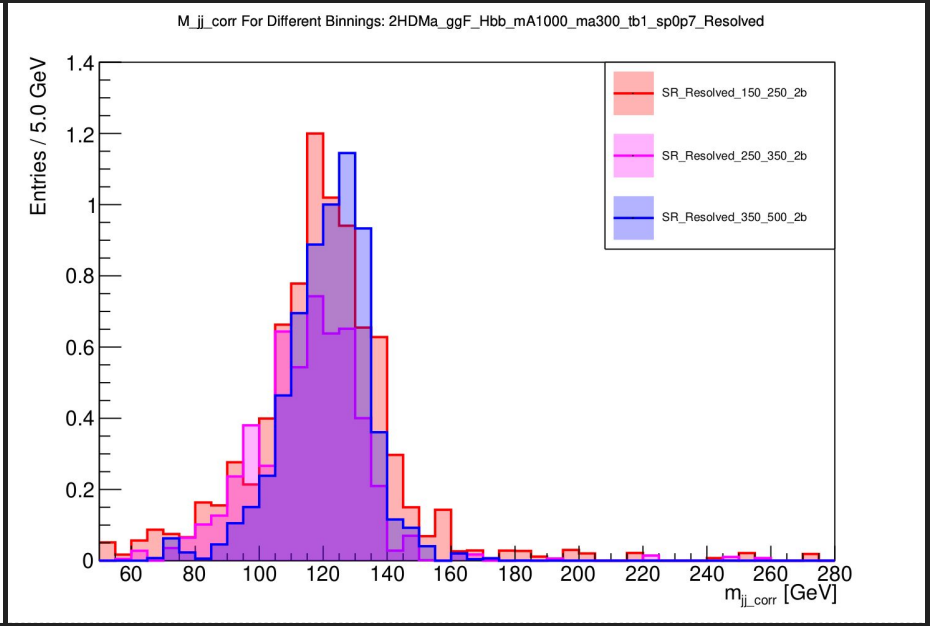
# Optimizing MET Bins

- To optimize the MET binning, significances will be recalculated for a different binning until an optimal binning is found using the monoHiggs framework

| Current Binning: | Changed Binning: |
| --- | --- |
| ● 150 GeV < **MET** < 200 GeV<br>● 200 GeV < **MET** < 350 GeV<br>● 350 GeV < **MET** < 500 GeV<br>● 500 GeV < **MET** < 750 GeV<br>● 750 GeV < **MET** | ● 150 GeV < **MET** < 250 GeV<br>● 250 GeV < **MET** < 350 GeV<br>● 350 GeV < **MET** < 500 GeV<br>● 500 GeV < **MET** < 750 GeV<br>● 750 GeV < **MET** |

# How mass histograms change with MET binning (Testing)



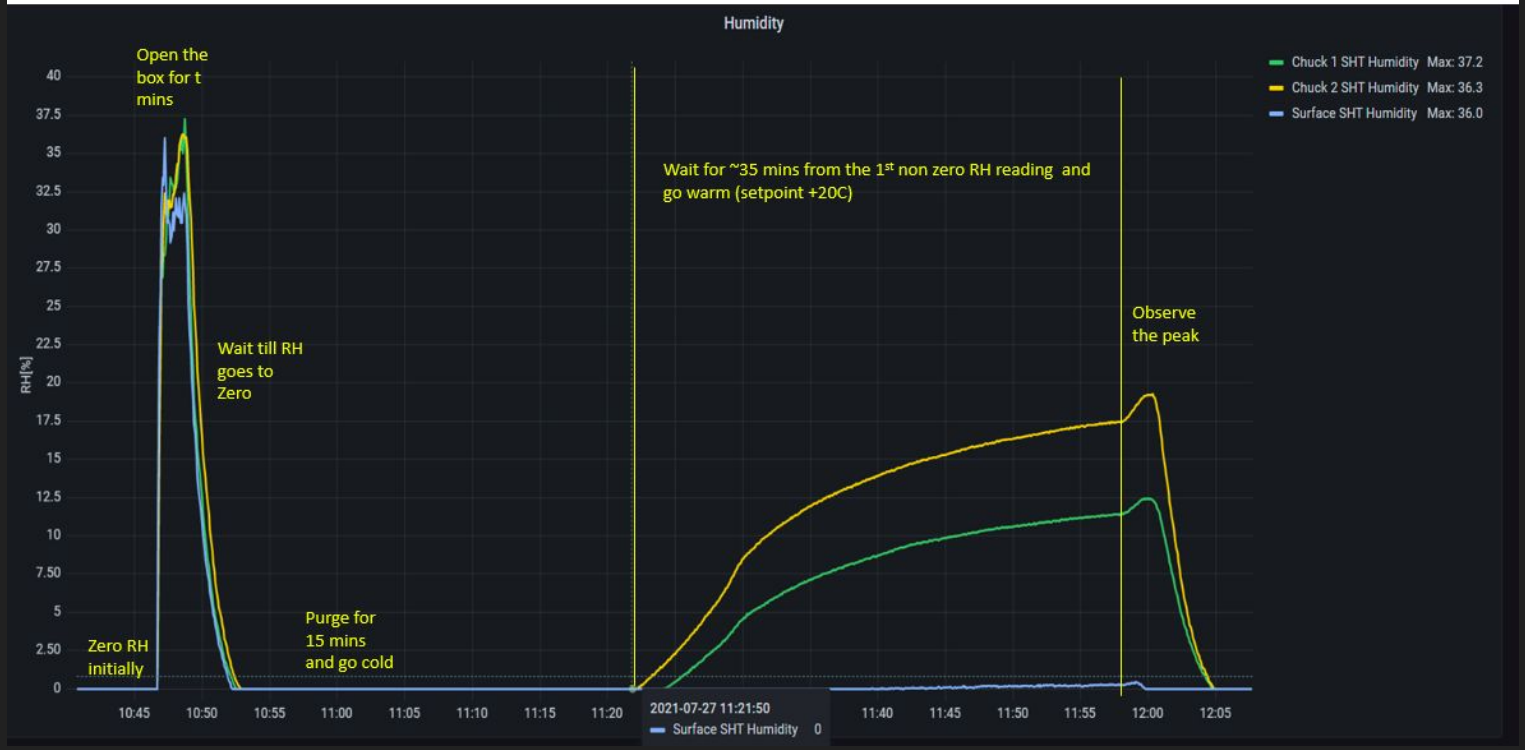
# Conclusion

- It has been a very fruitful summer at BNL
- I gained many skills that will be beneficial to me and for utility to ATLAS
- I also made significant progress on ATLAS analysis in parallel
- Special thanks to David Lynn (BNL), Stefania Stucci (BNL), Punit Sharma (UIowa), Anindya Ghosh (CERN), and Professor Usha Mallik (UIowa) for their guidance and support

# Backup Slides

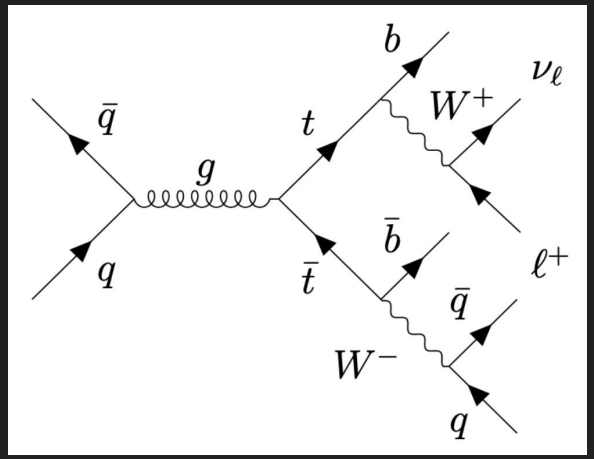
# Testing of environmental conditions of modules

## Testing protocol

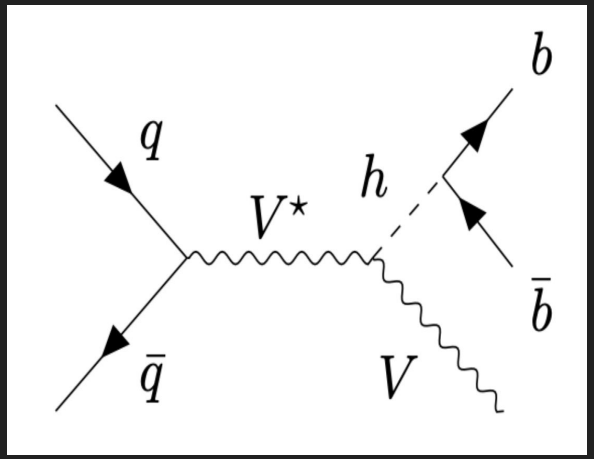


# 2HDM Backgrounds

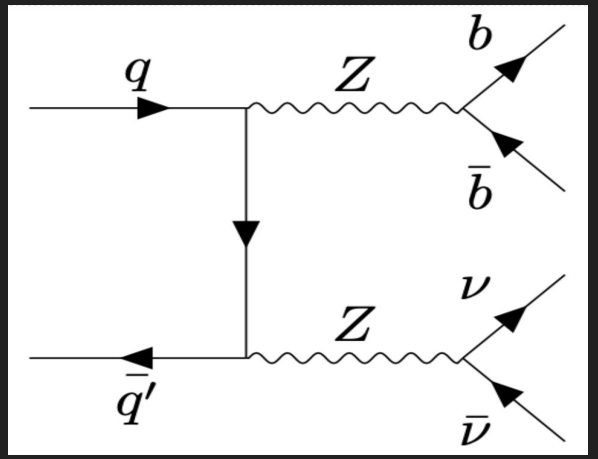
ttbar




VHbb

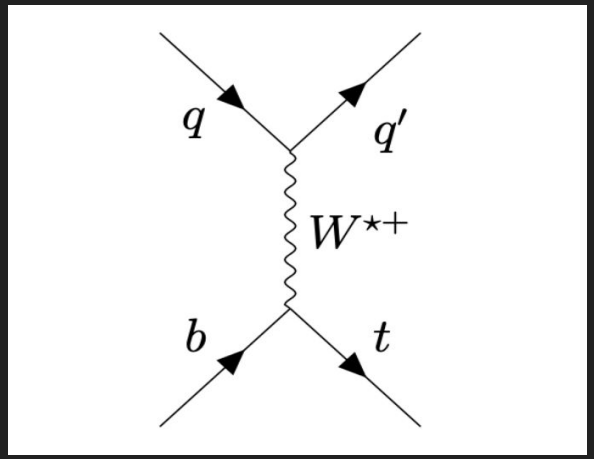



Diboson

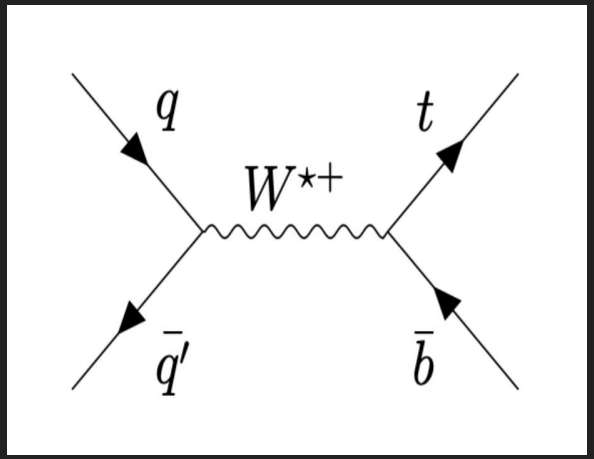


# 2HDM Backgrounds

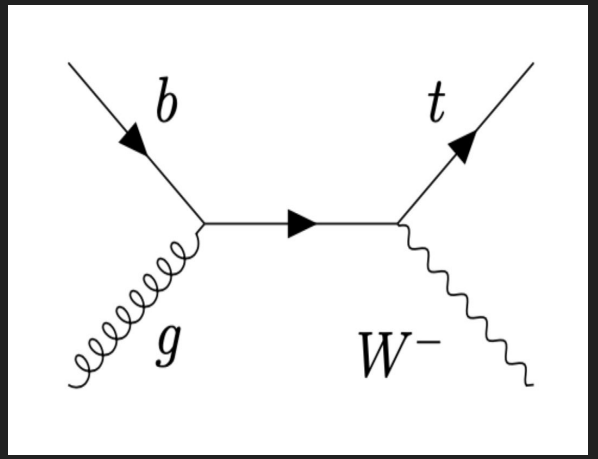
Single Top T-Channel




Single Top S-Channel

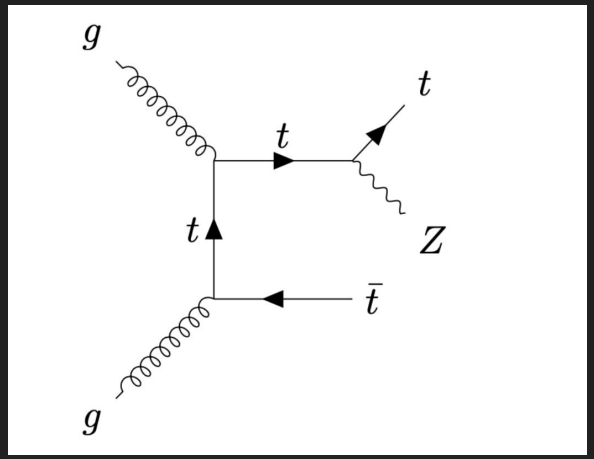



Single Top Wt-Channel

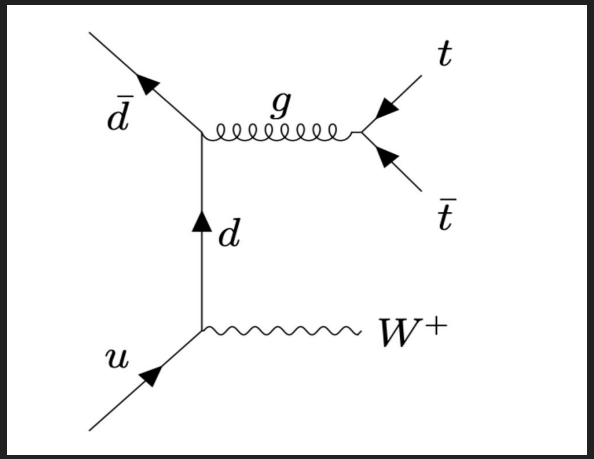


# 2HDM Backgrounds

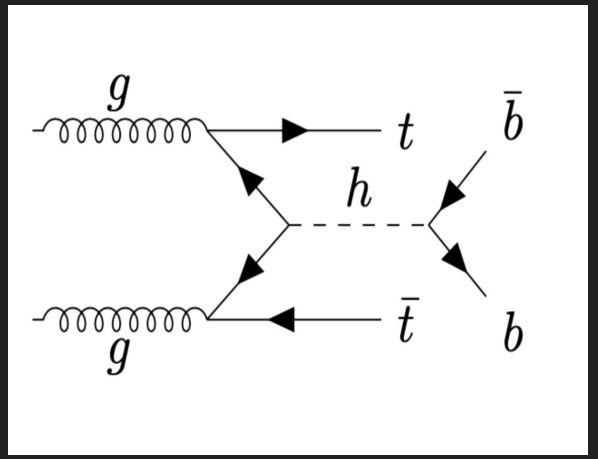
ttZ




ttW

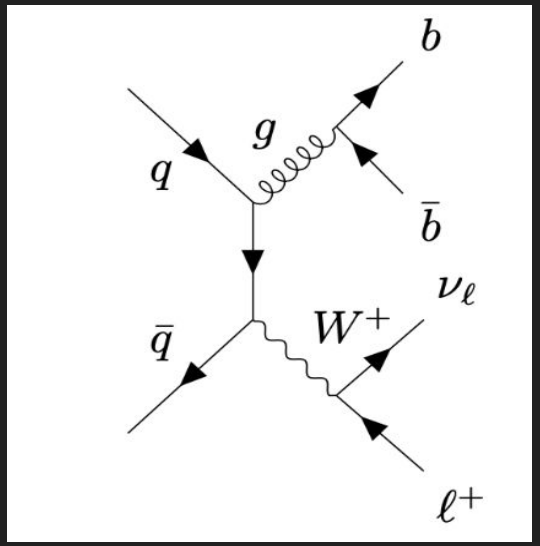



tth

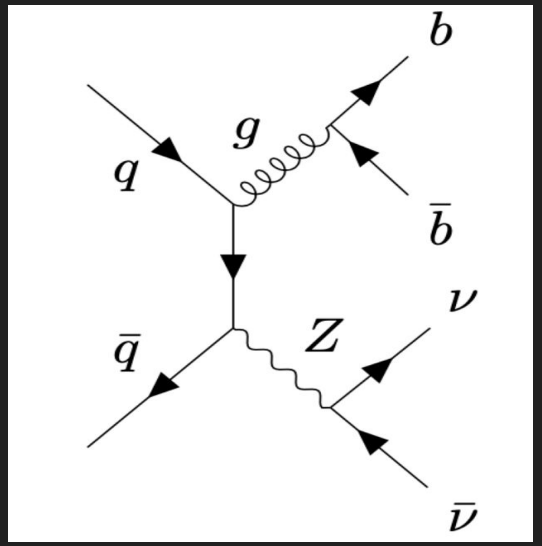


# 2HDM Backgrounds

W+Jets




Z+Jets



# Significance of Mass Histograms

- Significance calculated for each bin and region and then added in quadrature:

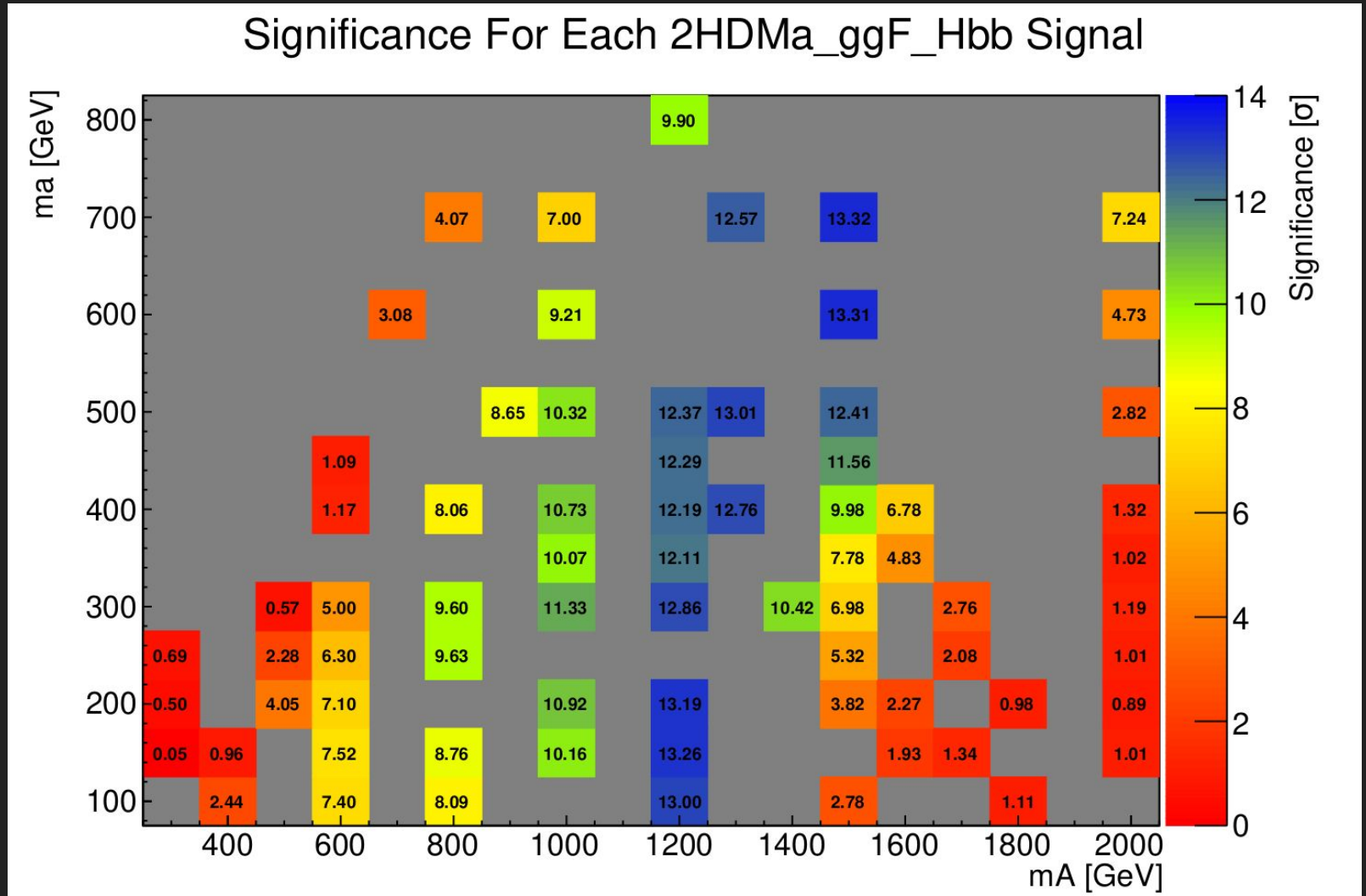
$$S = \sqrt{\sum_j \sum_i \frac{{S_{i,j}}^2}{S_{i,j} + B_{i,j}}}$$

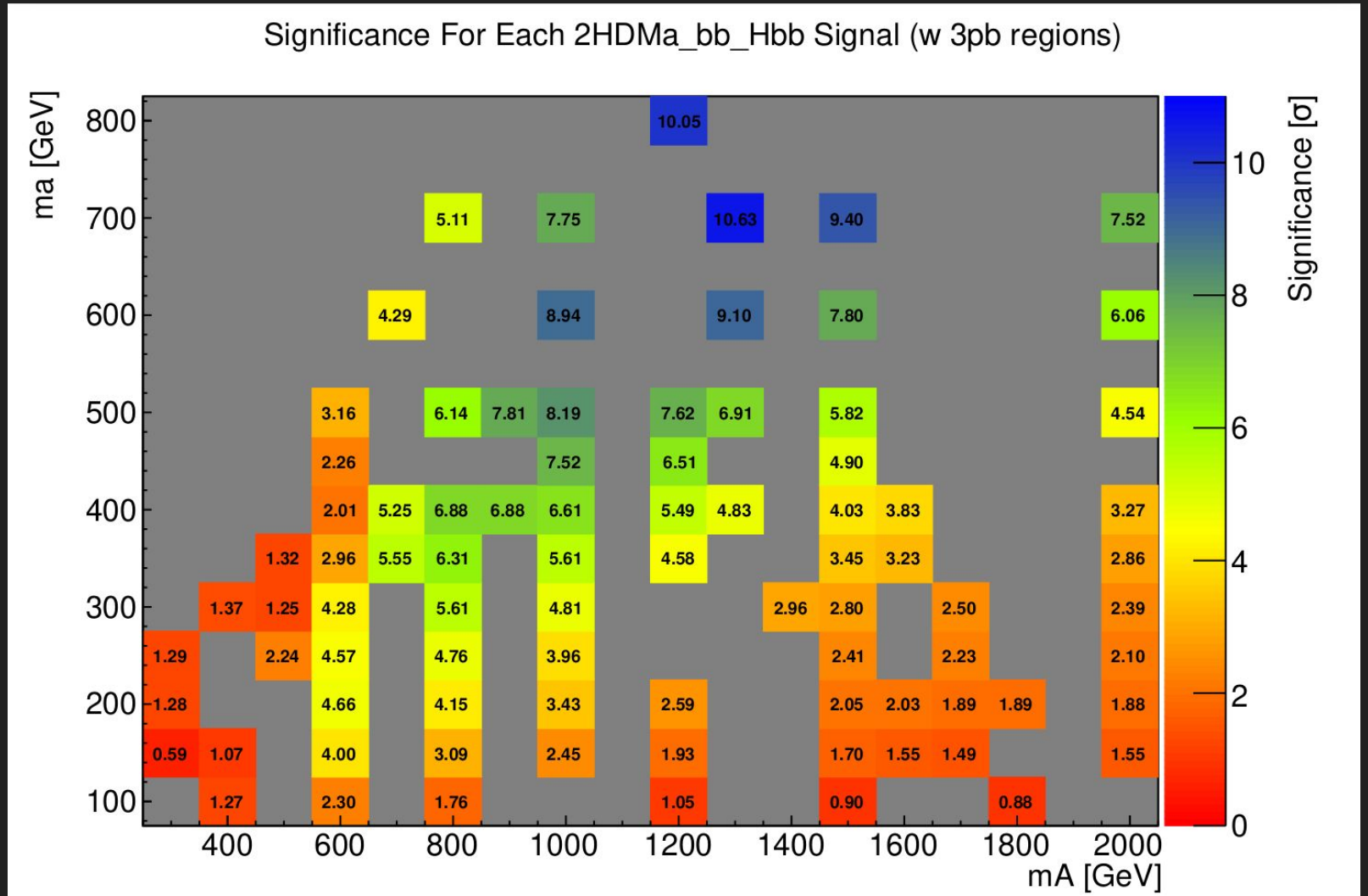
i - ith bin of Region j
j - jth Region of MET

- Backgrounds added before calculation:

$$B_{i,j} = \sum_k B_{i,j,k}$$

i - ith bin of Region j
j - jth Region of MET
k - kth Background File


Significance For Each 2HDMa_ggF_Hbb Signal
ma [GeV]
mA [GeV]
Significance [σ]
800
700
600
500
400
300
200
100
400
600
800
1000
1200
1400
1600
1800
2000
0
2
4
6
8
10
12
14
9.90
4.07
7.00
12.57
13.32
7.24
3.08
9.21
13.31
4.73
8.65
10.32
12.37
13.01
12.41
2.82
1.09
12.29
11.56
1.17
8.06
10.73
12.19
12.76
9.98
6.78
1.32
10.07
12.11
7.78
4.83
1.02
0.57
5.00
9.60
11.33
12.86
10.42
6.98
2.76
1.19
0.69
2.28
6.30
9.63
5.32
2.08
1.01
0.50
4.05
7.10
10.92
13.19
3.82
2.27
0.98
0.89
0.05
0.96
7.52
8.76
10.16
13.26
1.93
1.34
1.01
2.44
7.40
8.09
13.00
2.78
1.11


Significance For Each 2HDMa_bb_Hbb Signal (w 3pb regions)
ma [GeV]
mA [GeV]
Significance [σ]
800
700
600
500
400
300
200
100
400
600
800
1000
1200
1400
1600
1800
2000
0
2
4
6
8
10
10.05
5.11
7.75
10.63
9.40
7.52
4.29
8.94
9.10
7.80
6.06
3.16
6.14
7.81
8.19
7.62
6.91
5.82
4.54
2.26
7.52
6.51
4.90
2.01
5.25
6.88
6.88
6.61
5.49
4.83
4.03
3.83
3.27
1.32
2.96
5.55
6.31
5.61
4.58
3.45
3.23
2.86
1.37
1.25
4.28
5.61
4.81
2.96
2.80
2.50
2.39
1.29
2.24
4.57
4.76
3.96
2.41
2.23
2.10
1.28
4.66
4.15
3.43
2.59
2.05
2.03
1.89
1.89
1.88
0.59
1.07
4.00
3.09
2.45
1.93
1.70
1.55
1.49
1.55
1.27
2.30
1.76
1.05
0.90
0.88