GEM Front-end Electronics Quality Control and Production Test Bench for CMS Muon Endcap

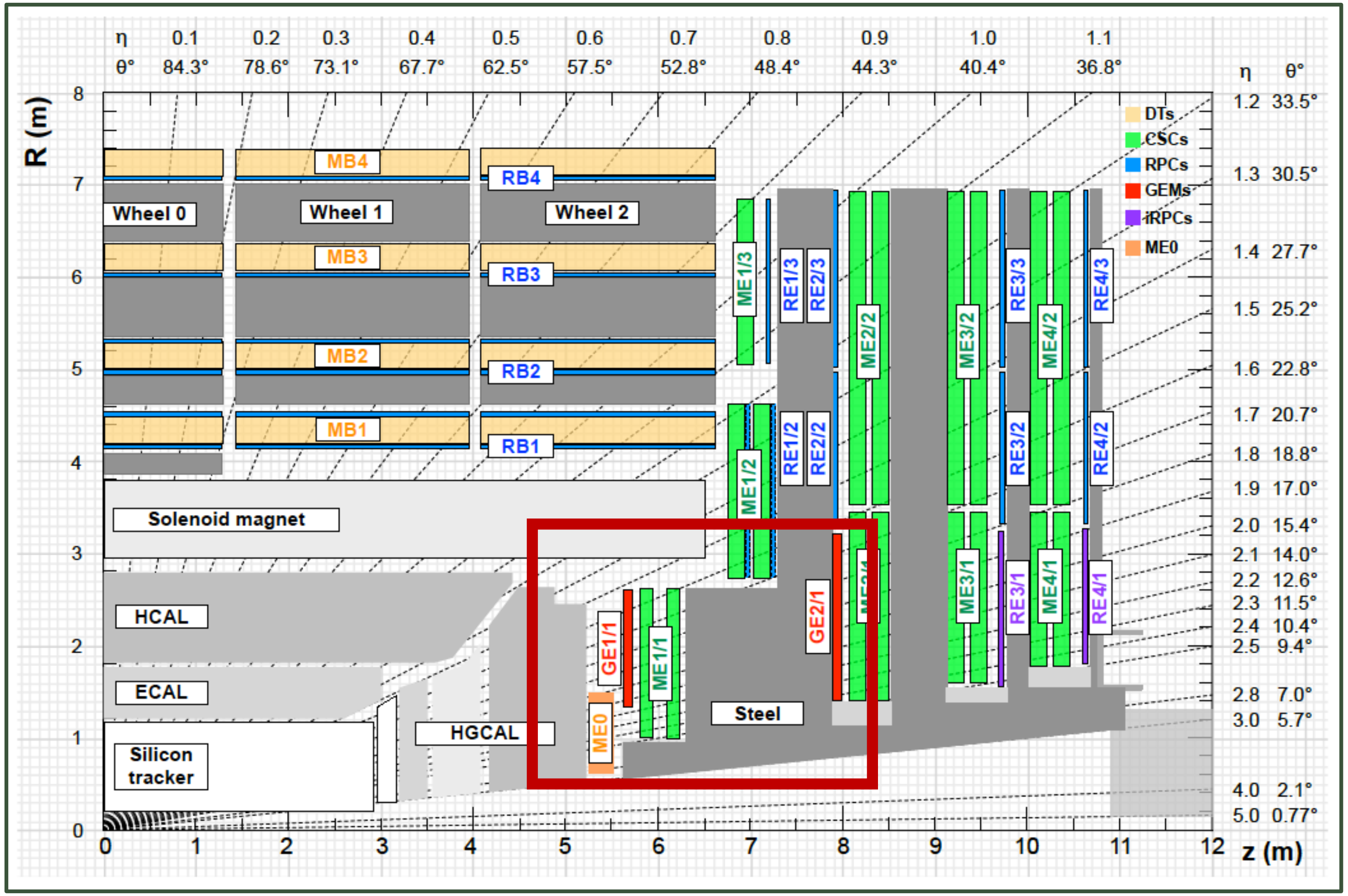
15 August 2019

Student : Kang Ying Chew

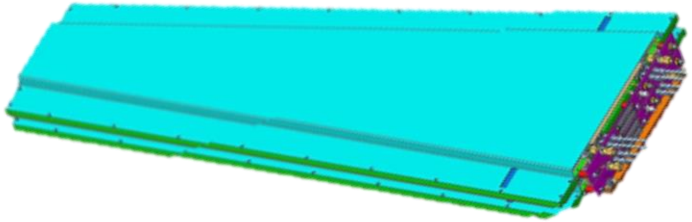
Supervisor : Aamir Irshad

On behalf of VFAT3 hybrid test team

The CMS Muon Upgrade

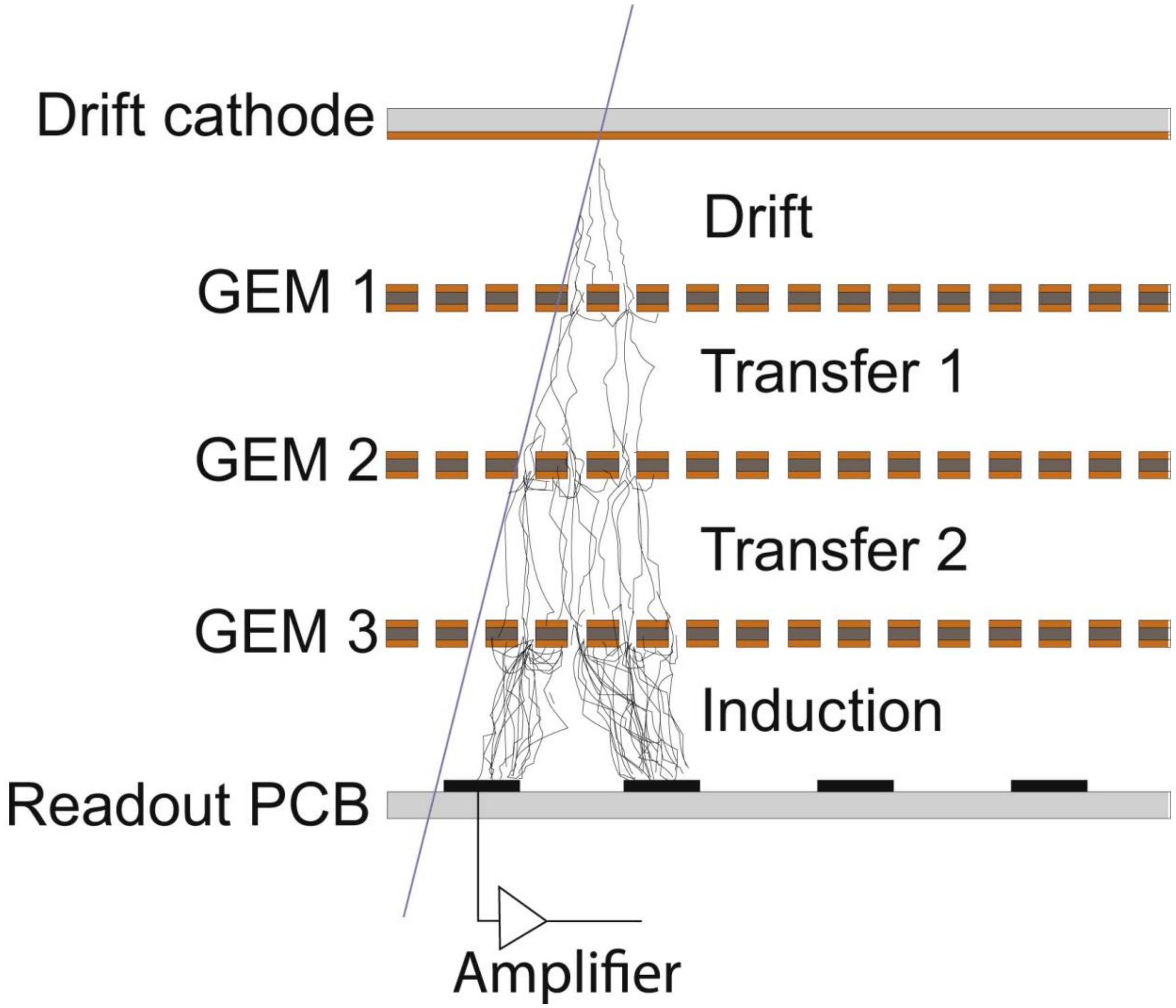


- GEM detectors in the Muon station of CMS endcaps:
  - ➢ LS2: GE1/1
  - ➢ LS3:GE2/1, ME0
- Improving muon trigger and tracking performance at high luminosity

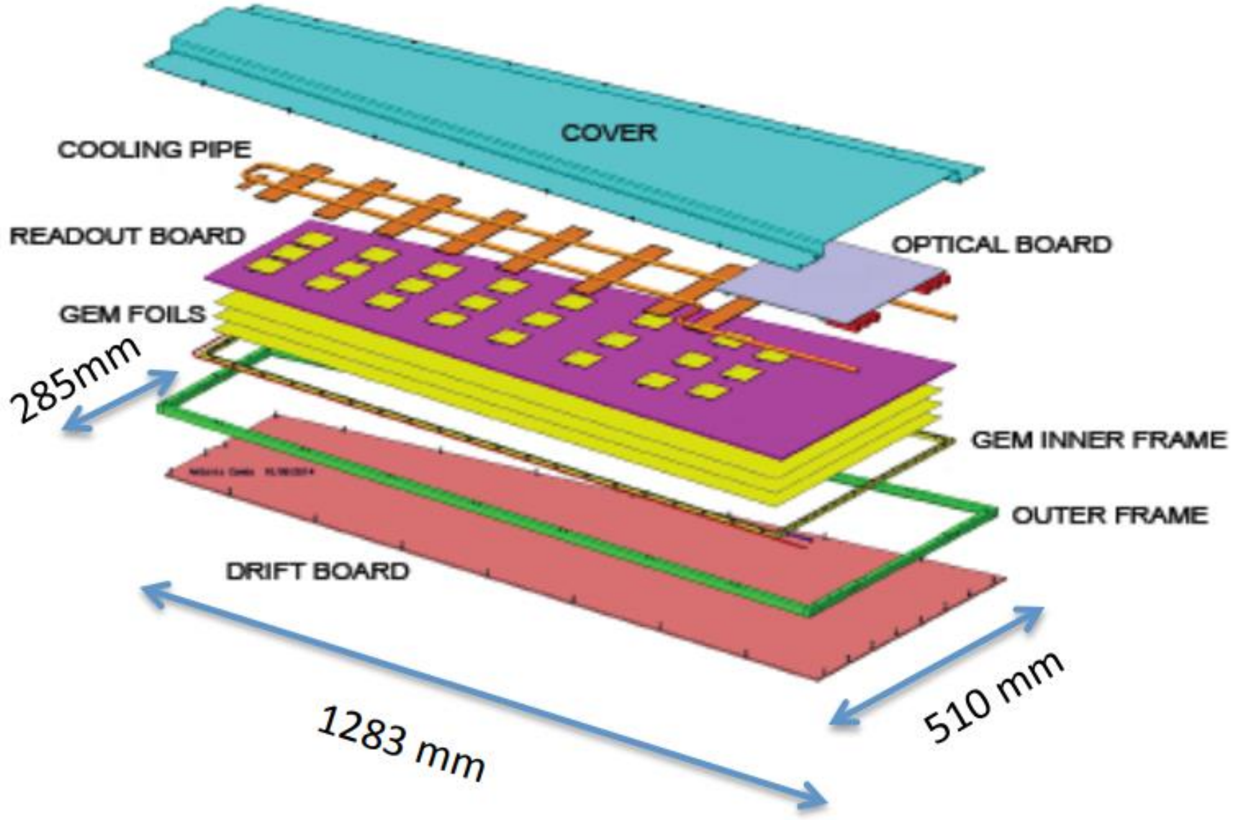


GEM and GE1/1 Chamber

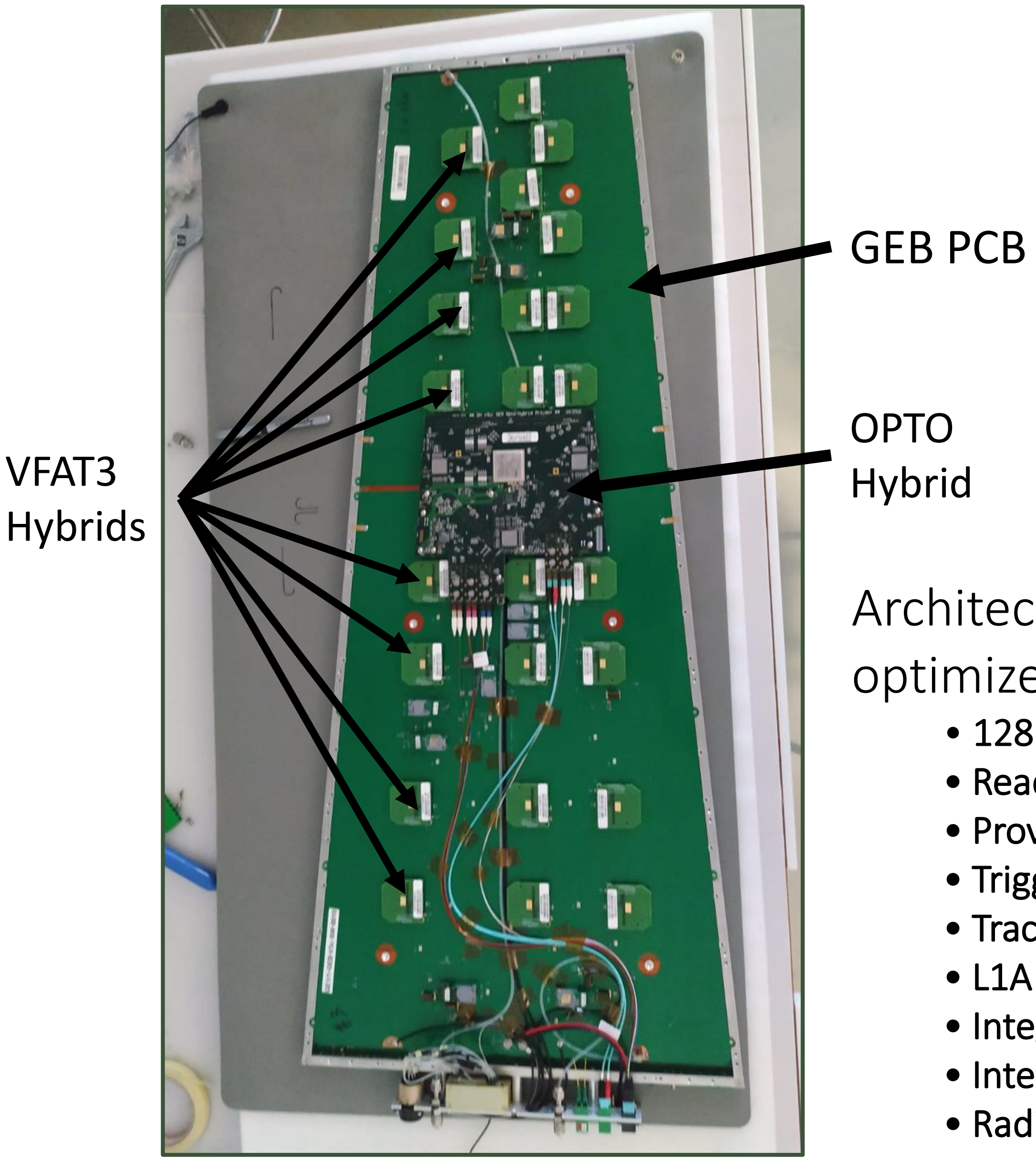
Gas Electron Multiplier concept

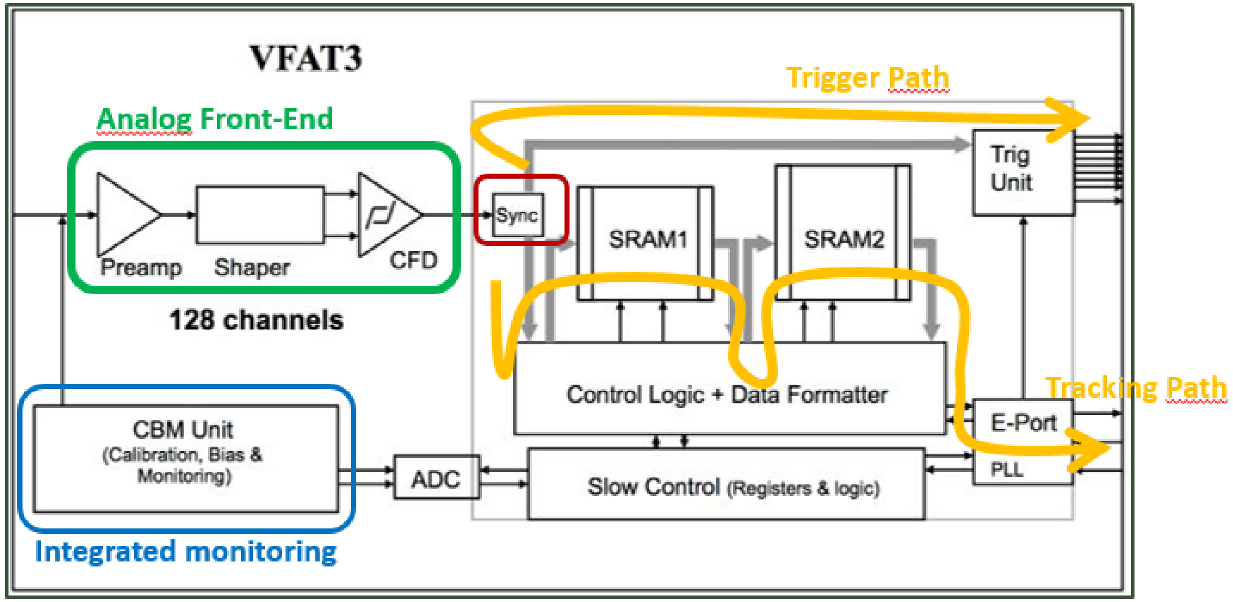


Section in GE1/1 Chamber



The VFAT3: A front-end ASIC for GEMs

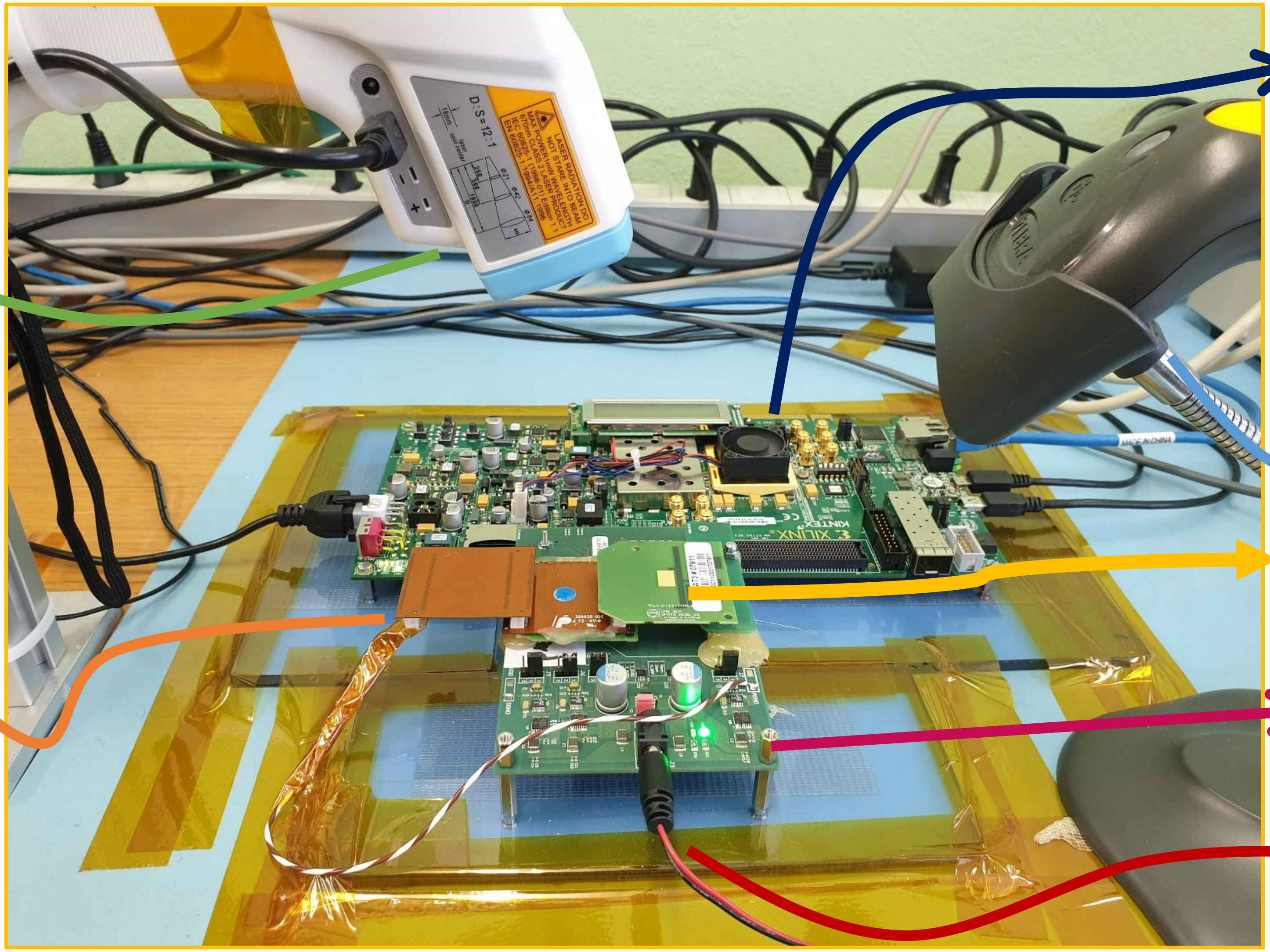




Architecture designed to satisfy CMS Phase II requirements and optimized for GEM signal charge characteristics

- 128 channel chip
- Read positive or negative charges from the sensor
- Provide tracking and trigger information
- Trigger information: Minimum fixed latency with granularity of 2 channels
- Tracking information: Full granularity after L1A.
- L1A capability: L1A latency beyond 12.5 µs
- Integrated calibration and monitoring functions
- Interface to and from the GBT at 320 Mbps
- Radiation resistant up to 35 MRads

VFAT3 Hybrids Test System



Temperature Gun

Detector Emulator Cables

Kc-705 Kintex-7 FPGA

Barcode Scanner

VFAT3 Hybrid

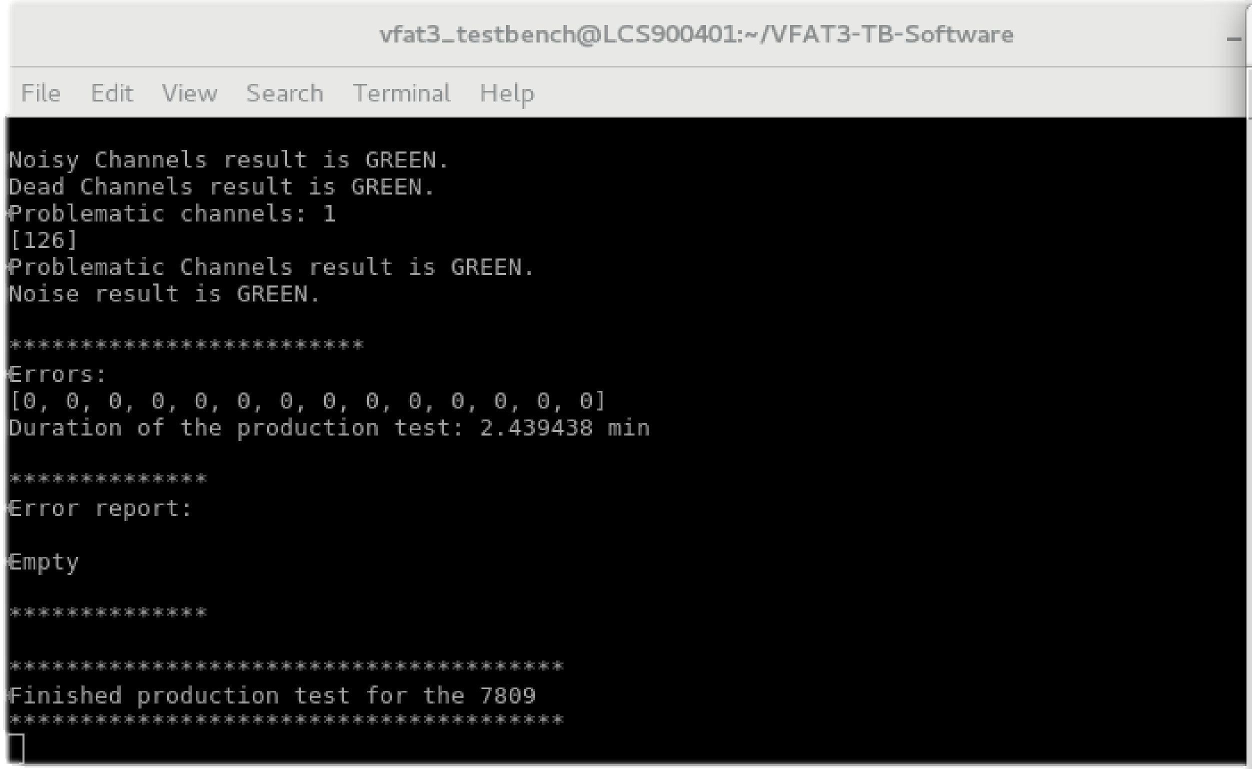
Verification Board

Connection to Power Supply

Classification of VFAT3 Hybrids

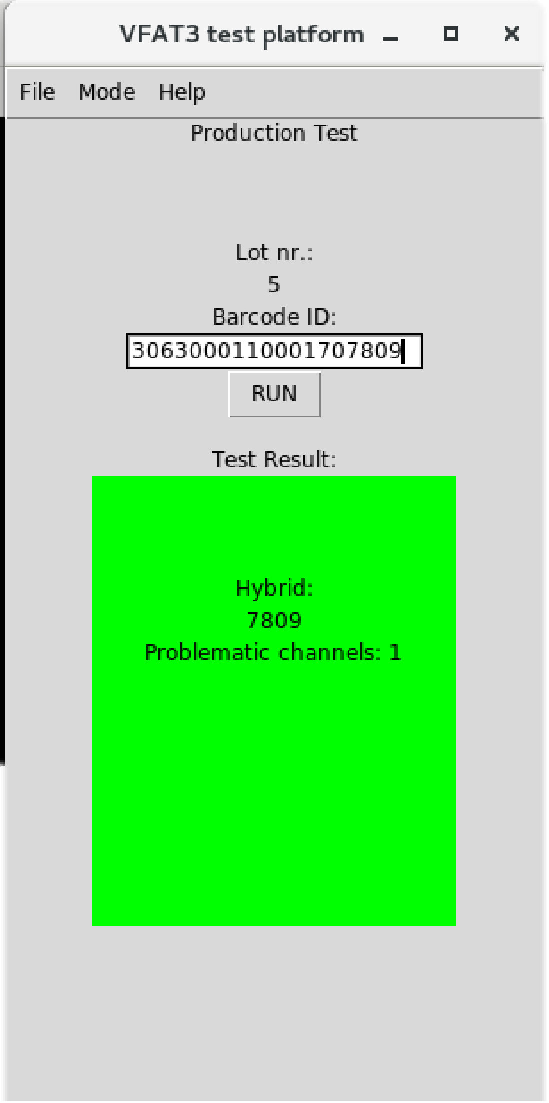
- GREEN – everything was fine. These chips were sent to 904 for GEM assembly.
- YELLOW – certain functions of chips was not functioning or very noisy VFATs. These chips were kept in 14 for further detailed testing. Sent to partner institute for GE2/1 R&D.
- RED – major problems of chips, usually unusable.

VFAT3 Hybrids Test Software



vfat3_testbench@LCS900401:~/VFAT3-TB-Software
File Edit View Search Terminal Help

```
Noisy Channels result is GREEN.
Dead Channels result is GREEN.
Problematic channels: 1
[126]
Problematic Channels result is GREEN.
Noise result is GREEN.

*************************
Errors:
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
Duration of the production test: 2.439438 min

**************
Error report:

Empty

**************

***************************************
Finished production test for the 7809
***************************************
```



Production Test

Lot nr.:
5

Barcode ID:
3063000110001707809

Test Result:

Hybrid:
7809
Problematic channels: 1

- Production test is automated
- 2 minutes per hybrid testing

credited to Henri Petrow

Test Bench Characterization

By sequence

1. Short circuit test
2. BIST (Built in self-test)
3. Read/Write register
4. Sync test
5. Chip ID burning
6. On-board Power monitoring
7. Global Reference Current Adjustment
8. Internal monitoring ADC Calibration
9. Temperature Calibration
10. CAL_DAC Calibration
11. Data Packet test
12. Trigger bit test (Sbit)
13. DAC Scan
14. S-curve test

VFAT Test Bench Upgrade

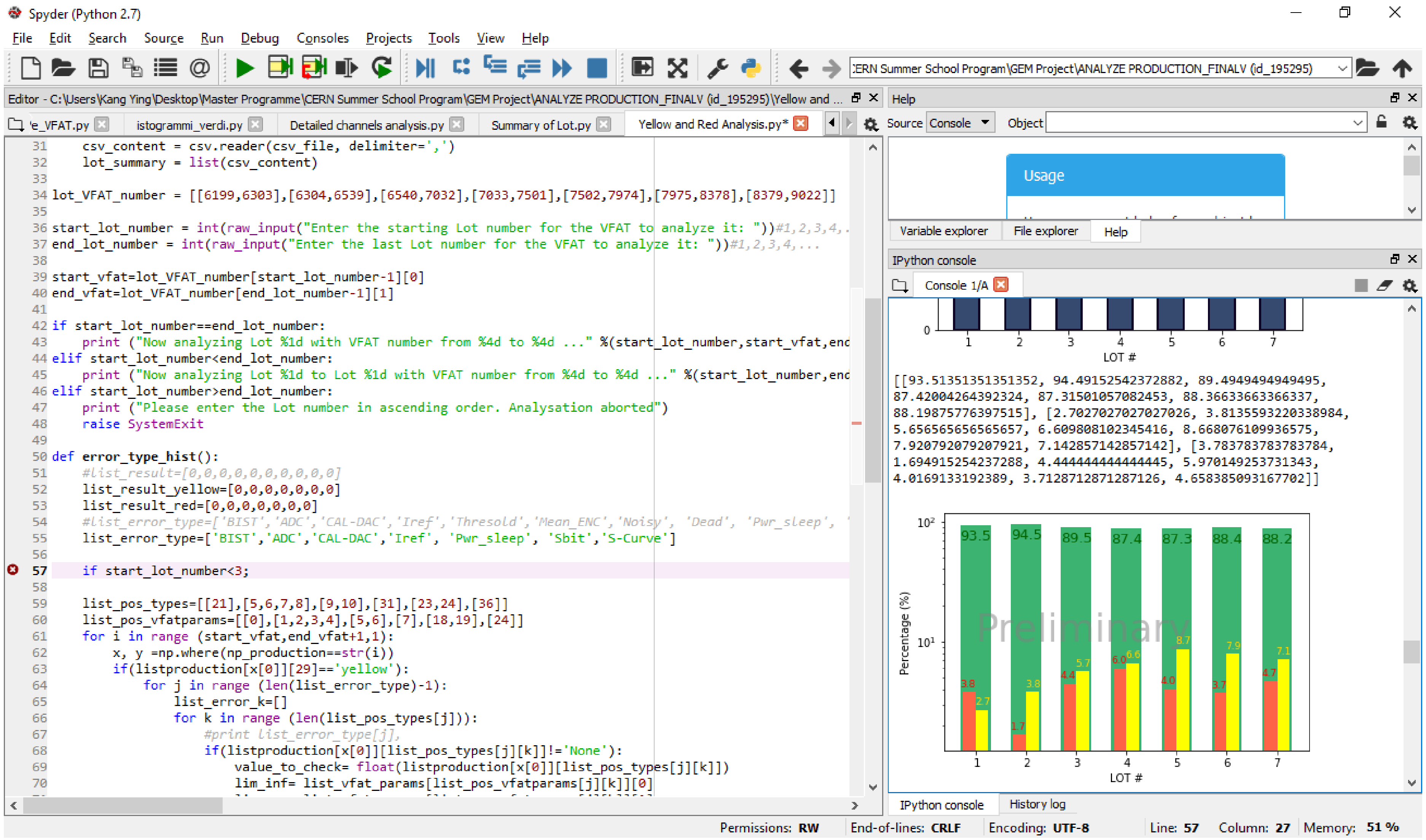
1. IOVDD is now measured, checked for limits and saved to the database
2. Short circuit and Sync error columns added to the database.
3. Tighten of ENC limits for noisy channel from 5σ to 3σ range.
4. Rerun of S-curves test is aborted if more than 100 are all zero channels.
5. Fixed bug regarding cancelation of rerun for production test when prompted.

Credited to : Henri Petrow

Ongoing ideas for upgrading

- Implementation of beep signal when the test is completed.
- Find out problems that causes VFAT test bench production test freezes on certain VFAT chips.
- Automatic execution of program when the entry of barcode came in.

Database Visualization Program – by Lot



```python
    csv_content = csv.reader(csv_file, delimiter=',')
    lot_summary = list(csv_content)

lot_VFAT_number = [[6199,6303],[6304,6539],[6540,7032],[7033,7501],[7502,7974],[7975,8378],[8379,9022]]

start_lot_number = int(raw_input("Enter the starting Lot number for the VFAT to analyze it: "))#1,2,3,4,.
end_lot_number = int(raw_input("Enter the last Lot number for the VFAT to analyze it: "))#1,2,3,4,...

start_vfat=lot_VFAT_number[start_lot_number-1][0]
end_vfat=lot_VFAT_number[end_lot_number-1][1]

if start_lot_number==end_lot_number:
    print ("Now analyzing Lot %1d with VFAT number from %4d to %4d ..." %(start_lot_number,start_vfat,enc
elif start_lot_number<end_lot_number:
    print ("Now analyzing Lot %1d to Lot %1d with VFAT number from %4d to %4d ..." %(start_lot_number,enc
elif start_lot_number>end_lot_number:
    print ("Please enter the Lot number in ascending order. Analysation aborted")
    raise SystemExit

def error_type_hist():
    #list_result=[0,0,0,0,0,0,0,0,0,0]
    list_result_yellow=[0,0,0,0,0,0,0]
    list_result_red=[0,0,0,0,0,0,0]
    #list_error_type=['BIST','ADC','CAL-DAC','Iref','Thresold','Mean_ENC','Noisy', 'Dead', 'Pwr_sleep', '
    list_error_type=['BIST','ADC','CAL-DAC','Iref', 'Pwr_sleep', 'Sbit','S-Curve']

    if start_lot_number<3;

    list_pos_types=[[21],[5,6,7,8],[9,10],[31],[23,24],[36]]
    list_pos_vfatparams=[[0],[1,2,3,4],[5,6],[7],[18,19],[24]]
    for i in range (start_vfat,end_vfat+1,1):
        x, y =np.where(np_production==str(i))
        if(listproduction[x[0]][29]=='yellow'):
            for j in range (len(list_error_type)-1):
                list_error_k=[]
                for k in range (len(list_pos_types[j])):
                    #print list_error_type[j],
                    if(listproduction[x[0]][list_pos_types[j][k]]!='None'):
                        value_to_check= float(listproduction[x[0]][list_pos_types[j][k]])
                        lim_inf= list_vfat_params[list_pos_vfatparams[j][k]][0]
```

```
[[93.51351351351352, 94.49152542372882, 89.4949494949495,
87.42004264392324, 87.31501057082453, 88.36633663366337,
88.19875776397515], [2.7027027027027026, 3.8135593220338984,
5.656565656565657, 6.609808102345416, 8.668076109936575,
7.920792079207921, 7.142857142857142], [3.783783783783784,
1.694915254237288, 4.444444444444445, 5.970149253731343,
4.0169133192389, 3.7128712871287126, 4.658385093167702]]
```

- Written in Python 2.7, using Anaconda Navigator and Sypder IDE.

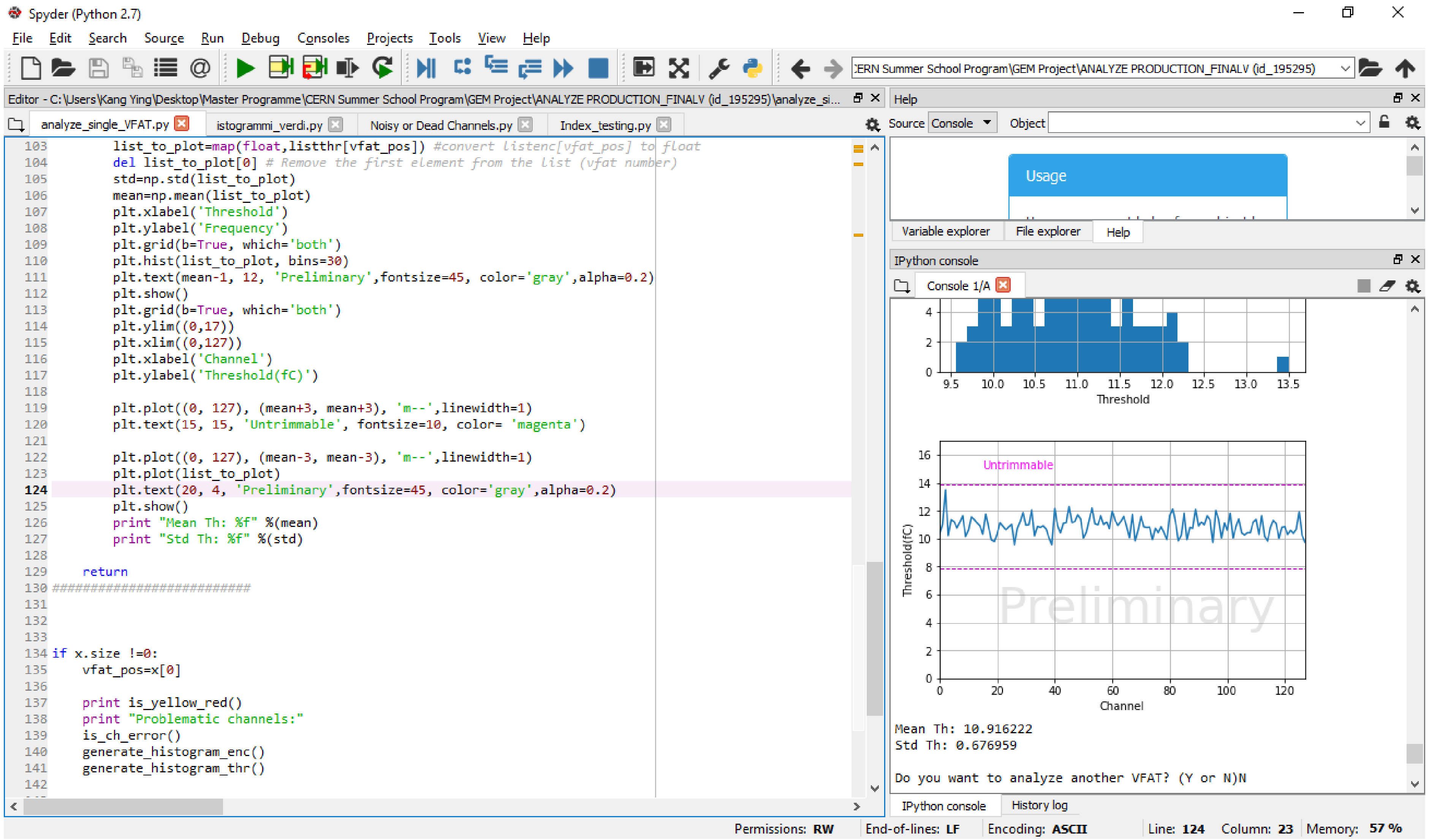
- Analysation type:

1. Summary of Lot
2. Noisy or Dead channels
3. Detailed channels
4. Yellow and Red

Just key in the Lot number to be analyzed, and done.

credited to Luis Felipe

Database Visualization Program – by VFAT3



```
        list_to_plot=map(float,listthr[vfat_pos]) #convert listenc[vfat_pos] to float
        del list_to_plot[0] # Remove the first element from the list (vfat number)
        std=np.std(list_to_plot)
        mean=np.mean(list_to_plot)
        plt.xlabel('Threshold')
        plt.ylabel('Frequency')
        plt.grid(b=True, which='both')
        plt.hist(list_to_plot, bins=30)
        plt.text(mean-1, 12, 'Preliminary',fontsize=45, color='gray',alpha=0.2)
        plt.show()
        plt.grid(b=True, which='both')
        plt.ylim((0,17))
        plt.xlim((0,127))
        plt.xlabel('Channel')
        plt.ylabel('Threshold(fC)')

        plt.plot((0, 127), (mean+3, mean+3), 'm--',linewidth=1)
        plt.text(15, 15, 'Untrimmable', fontsize=10, color= 'magenta')

        plt.plot((0, 127), (mean-3, mean-3), 'm--',linewidth=1)
        plt.plot(list_to_plot)
        plt.text(20, 4, 'Preliminary',fontsize=45, color='gray',alpha=0.2)
        plt.show()
        print "Mean Th: %f" %(mean)
        print "Std Th: %f" %(std)

    return
##########################



if x.size !=0:
    vfat_pos=x[0]

    print is_yellow_red()
    print "Problematic channels:"
    is_ch_error()
    generate_histogram_enc()
    generate_histogram_thr()

```

```
Mean Th: 10.916222
Std Th: 0.676959

Do you want to analyze another VFAT? (Y or N)N
```

- Written in Python 2.7, using Anaconda Navigator and Sypder IDE.

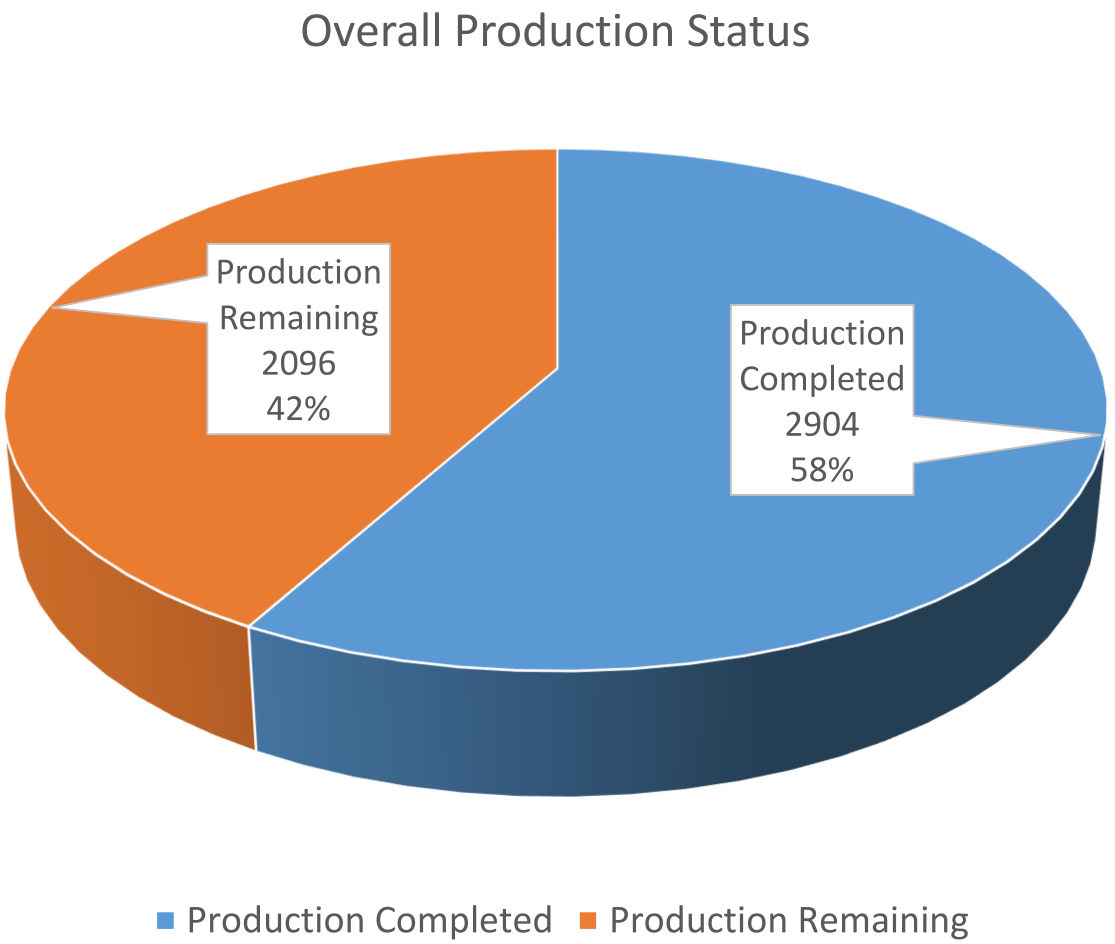
- Analysation type:

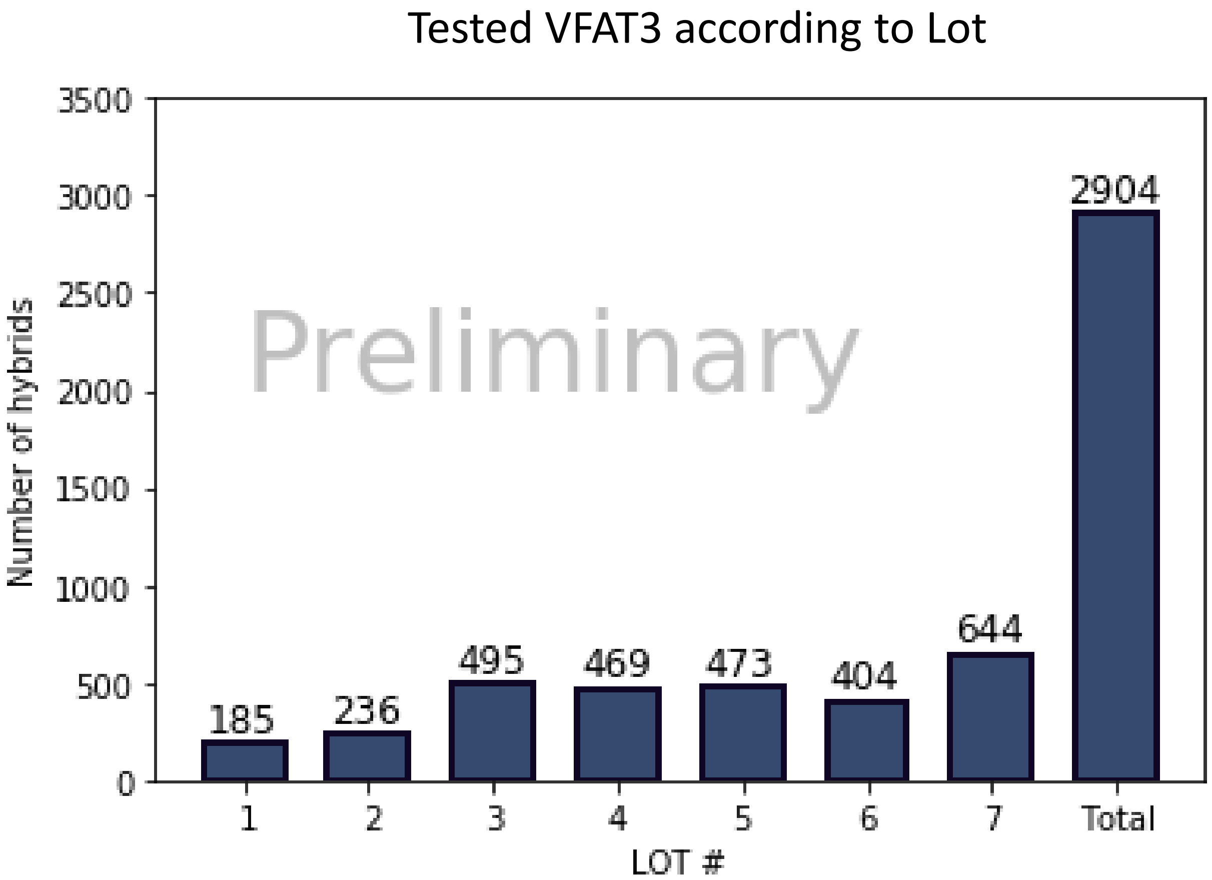
1. Distribution of ENC value
2. ENC plot for individual channel
3. Distribution of Threshold value
4. Threshold plot for individual channel

Just key in the VFAT3 number to be analyzed, and done.

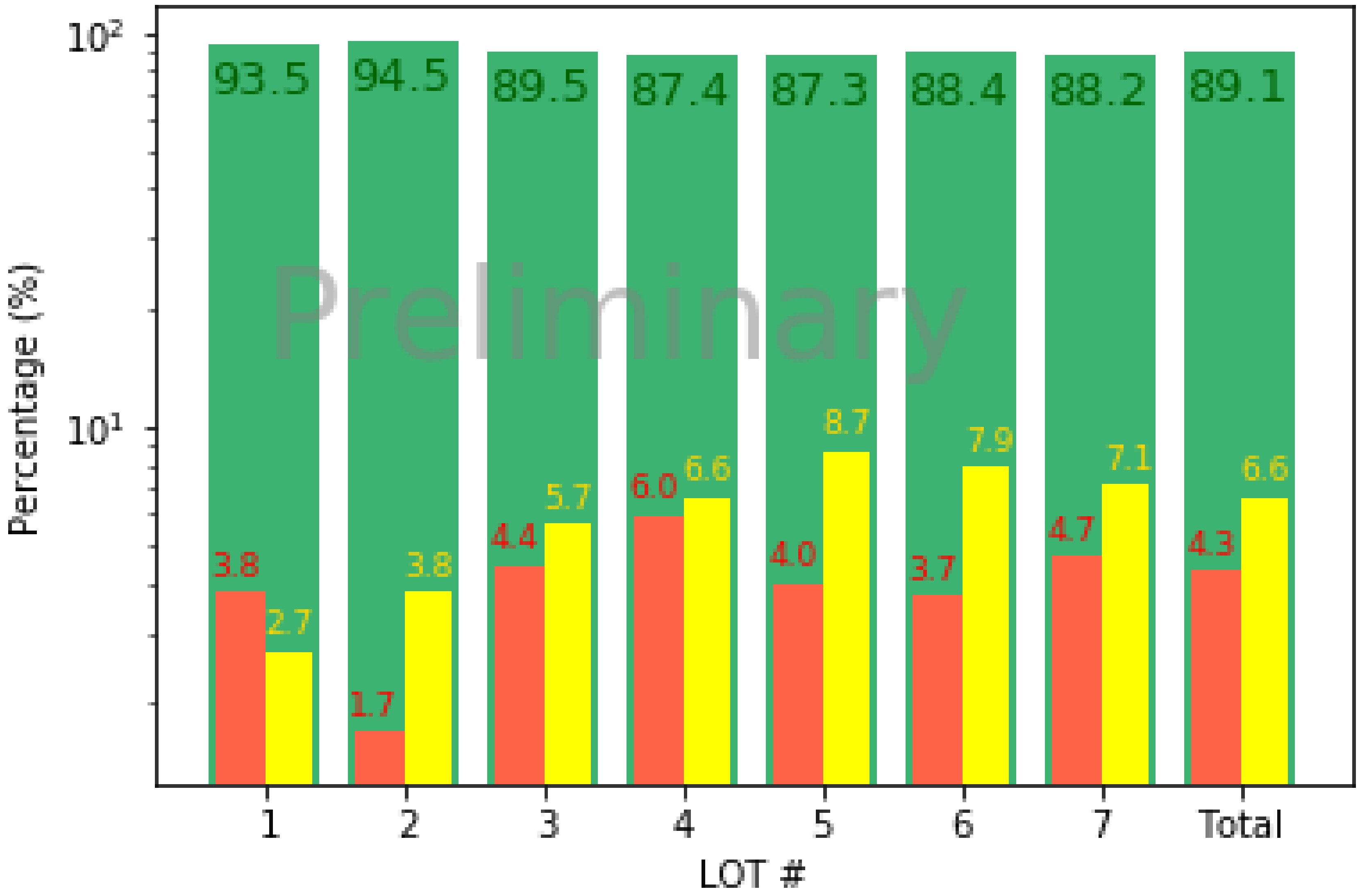
credited to Luis Felipe

Number of tested VFAT3 hybrids





Yield of production



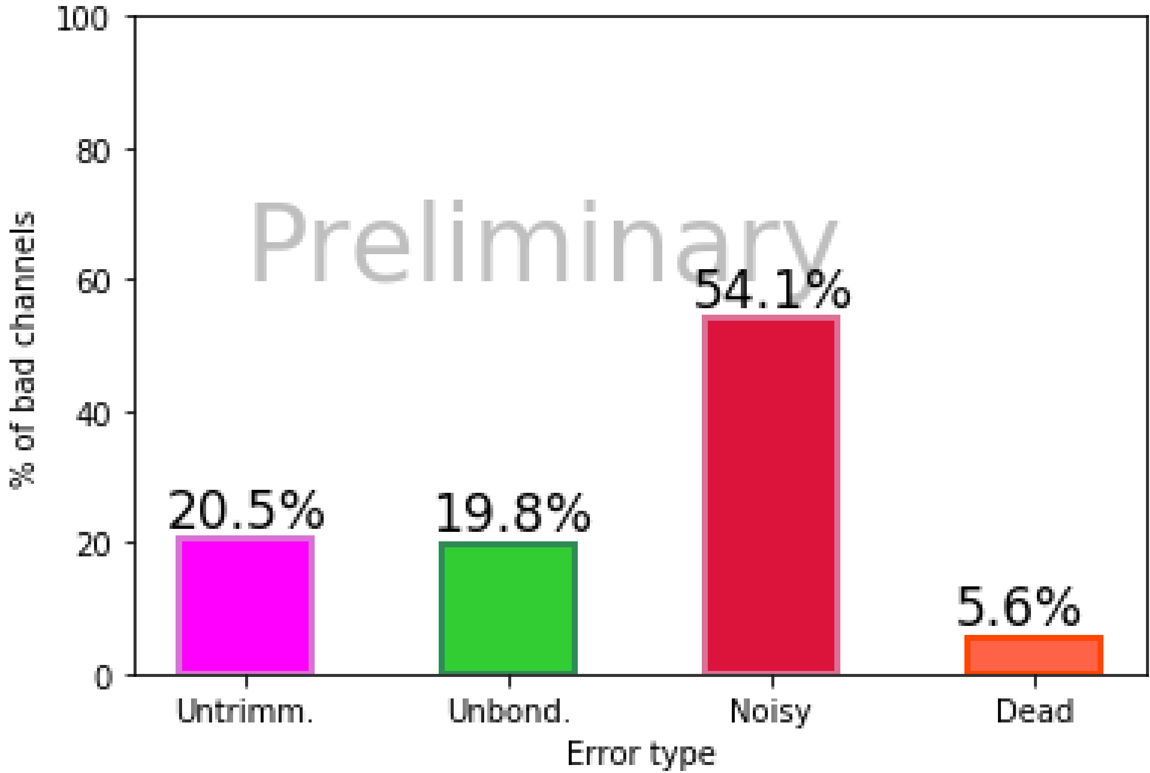
- Percentage of GREEN dropped since Lot 3 due to upgrade of test bench managed to identified more potential errors for VFAT3

- Percentage of YELLOW increases due to fixing of noisy channels bound from a constant value to 5σ and later to 3σ range.

- Percentage of RED remains quite consistent.

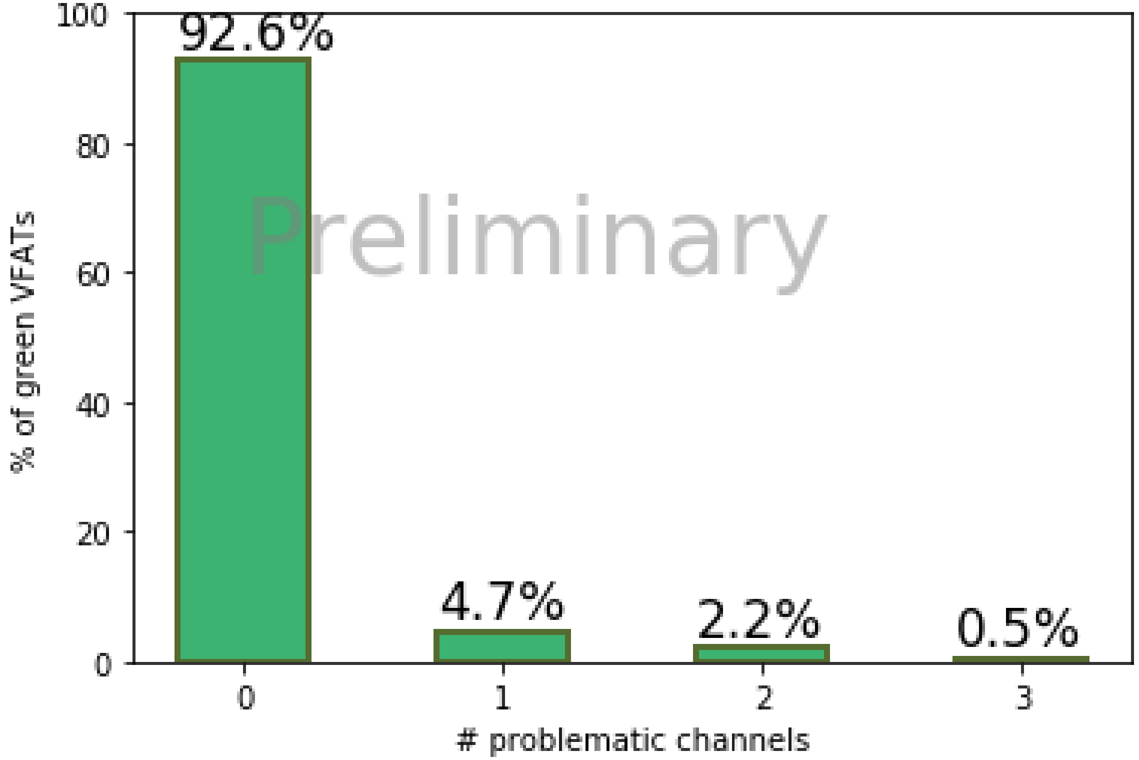
Detailed Channels Analysis for Green VFAT3

Type of Problematic Channels



55 53 145 15

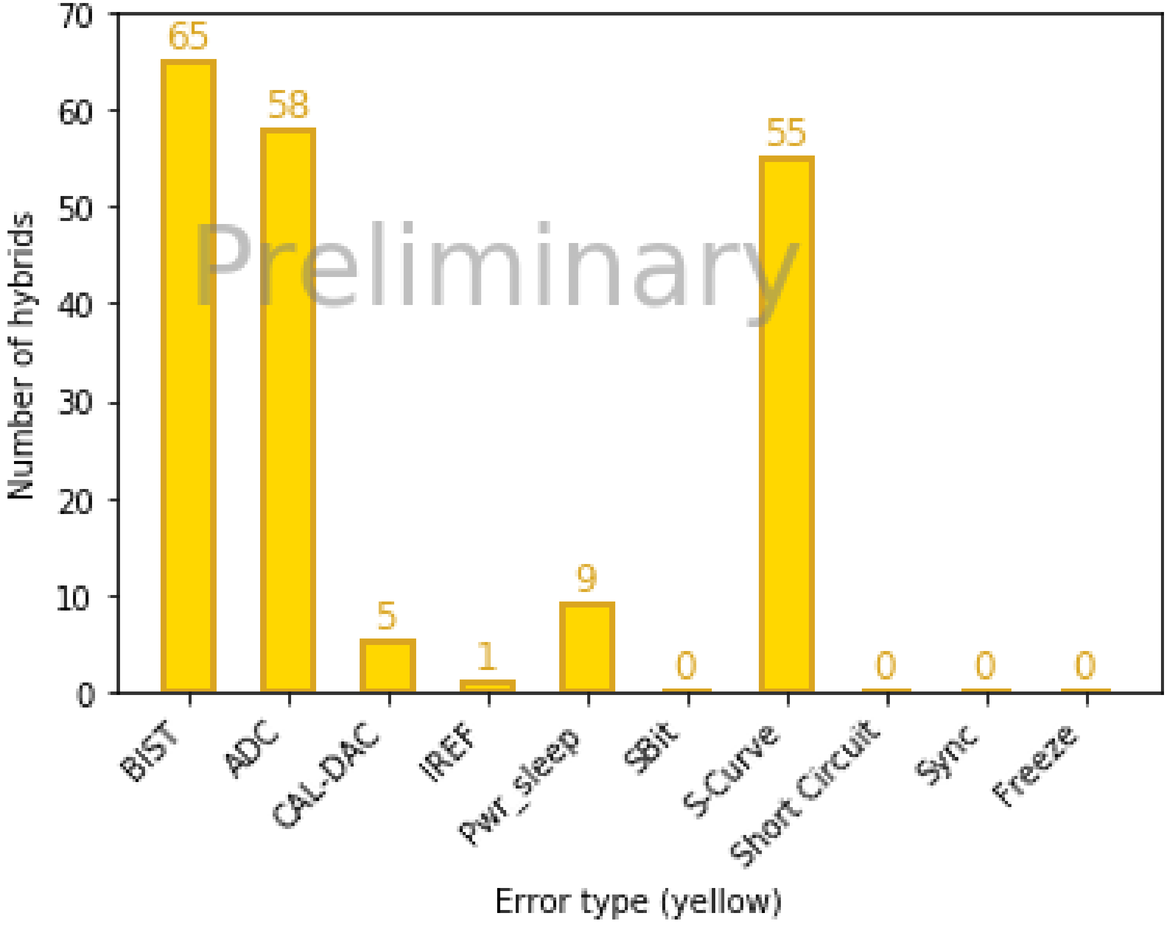
Number of Problematic Channels

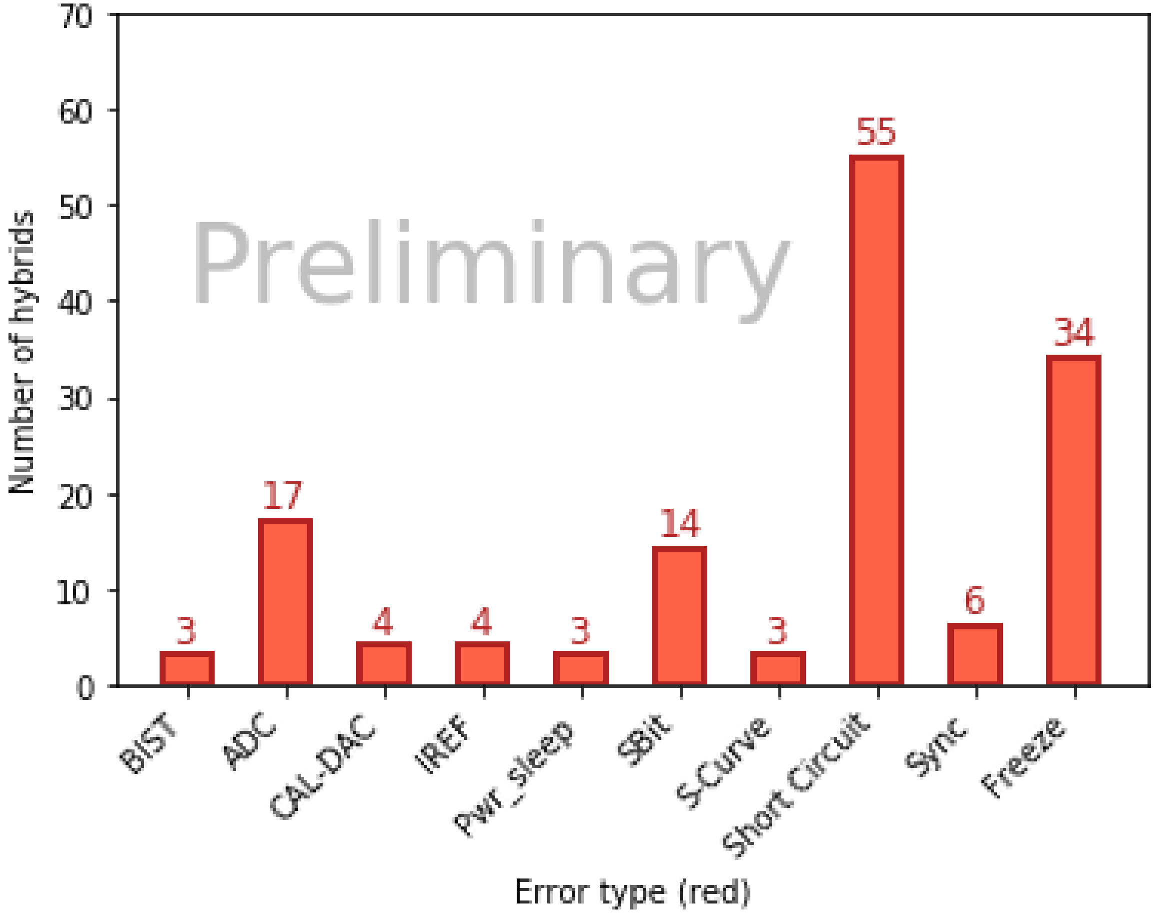


Number of VFAT3

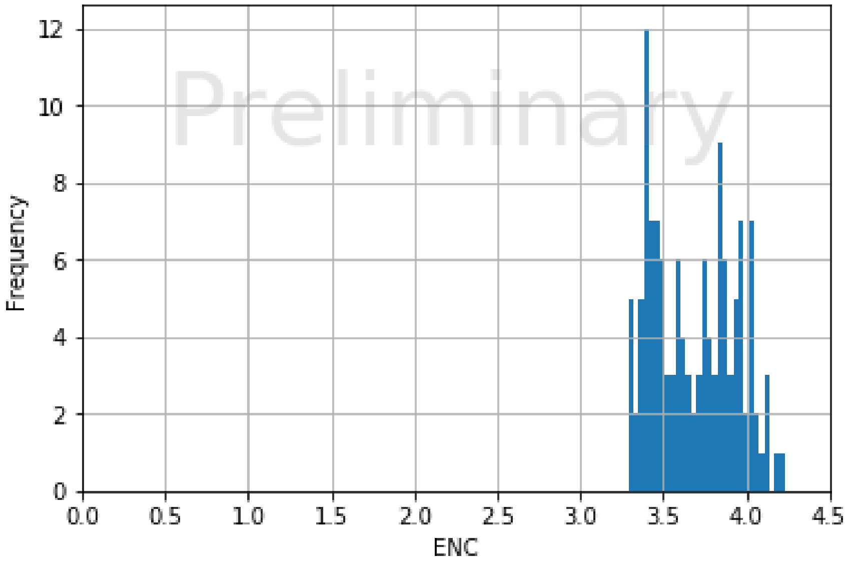
2031 103 48 11

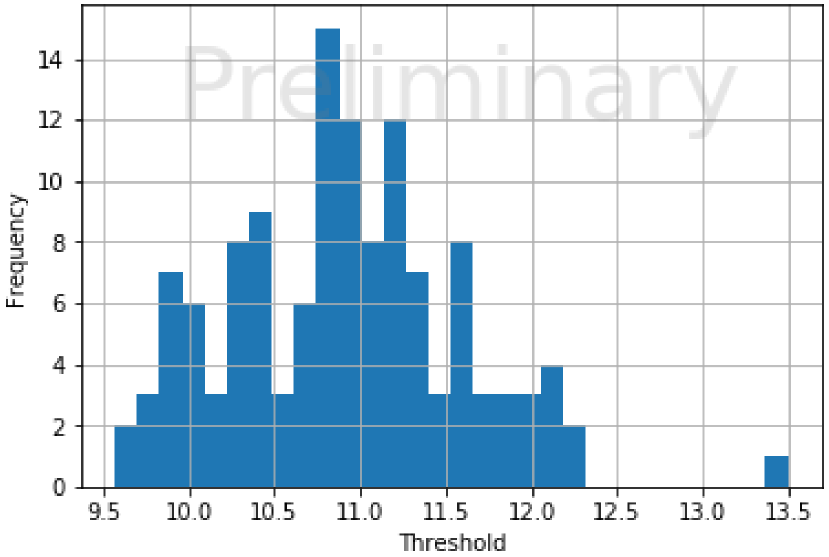
Yellow and Red Analysis for VFAT3

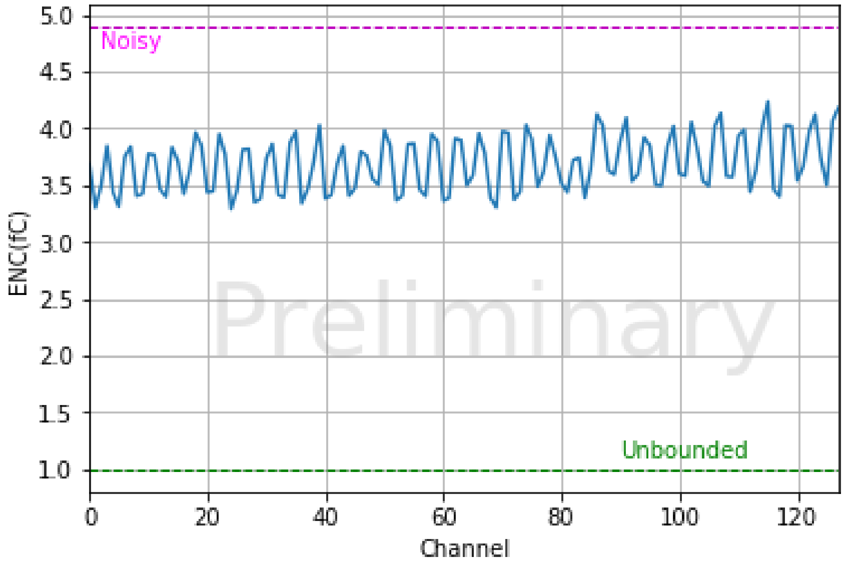


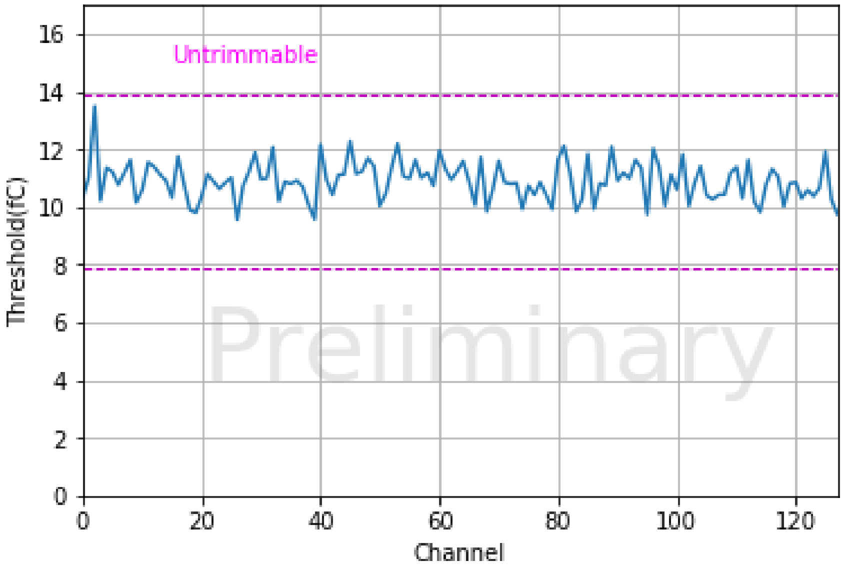


ENC and Threshold Analysis for VFAT3 Hybrid









This is one of the 2904 VFAT3 chips that are tested.

ENC are very stable

Threshold are very stable.

Conclusion

- 2904/5000 tested succesfully (58% completed)
- Improved test bench gradually with the feedback of experiment.
- Tighten some criteria to catch more bad channels.
- Improving current Database visualisation program to handle more complex queries and automatic generation of reports.

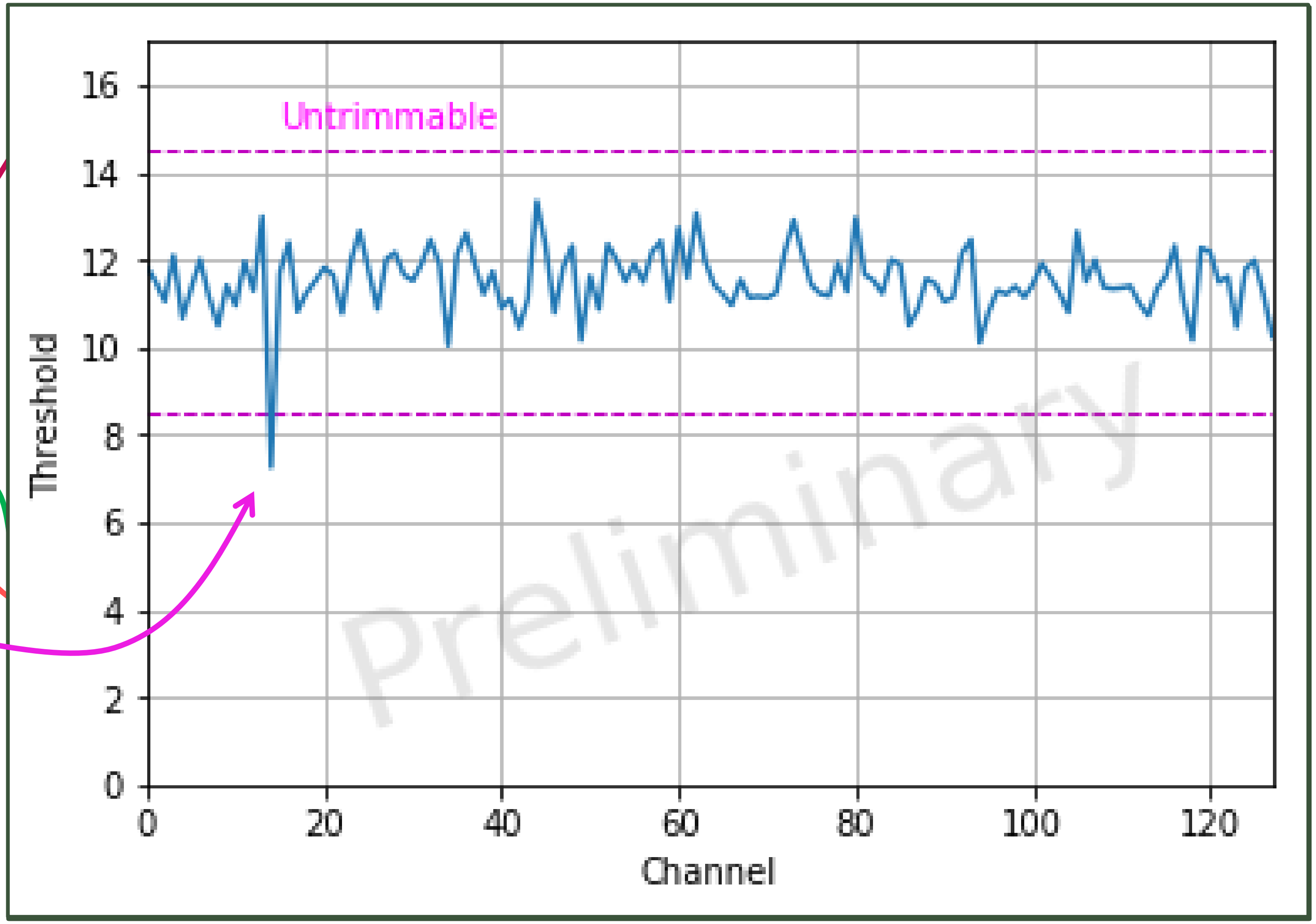
Thank you for your attention

Yield of production

Lot Number Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Green	173	223	443	410	413	357	568	2587
Yellow	5	9	28	31	41	32	46	192
Red	7	4	22	28	19	15	30	125
Total	185	236	493	469	473	404	644	2904

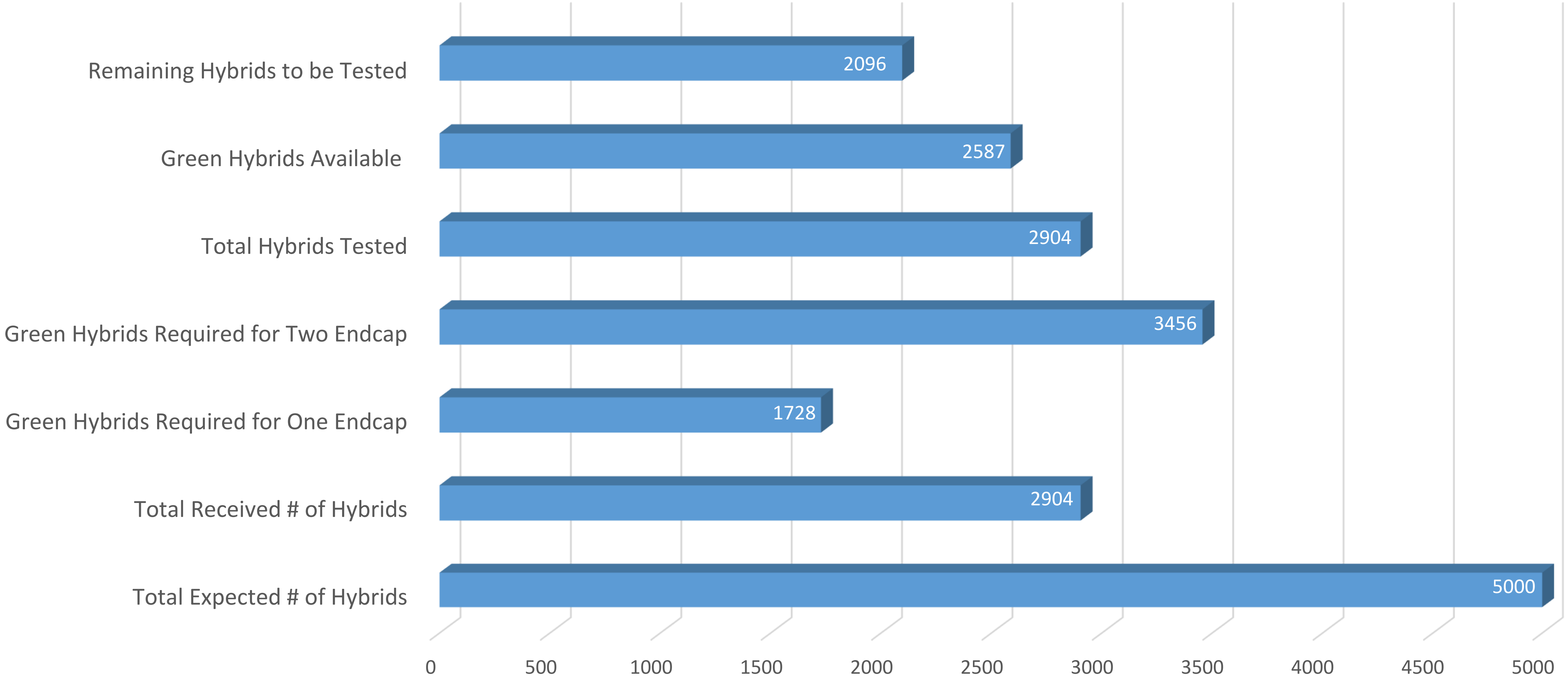
Classification of Bad Channels

- Dead Channels
- Noisy Channels
- Unbounded Channels
- Untrimmable



credited to Paola

Overall Production Statistic



Backup Slides