



Quality assurance of Macro-Pixel Sub-Assemblies (MaPSA) before installation in CMS

Mentee: I-see Warisa Jaidee (Wellesley College)

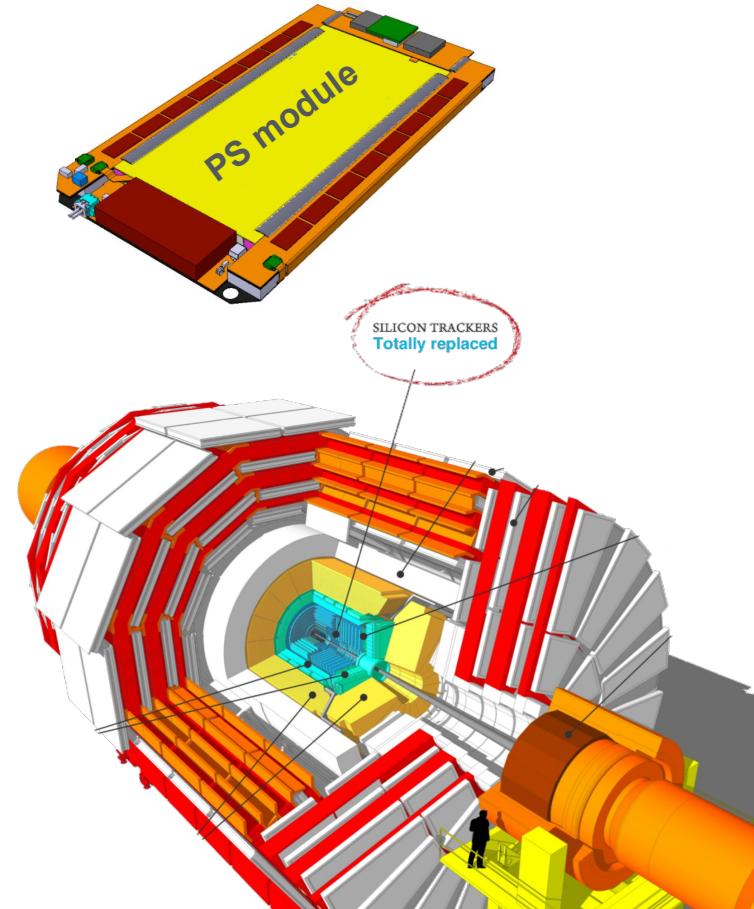
Mentor: Jennet Dickinson (Fermilab)





Abstract

The High Luminosity upgrade for CERN's LHC will replace CMS silicon tracking detectors with PS modules, consisting of one strip sensor and one macro-pixel sensor. The Macro-Pixel Sub-Assembly (MaPSA) requires thorough testing of each pixel for optimal performance. This project aims to develop an efficient data handling system for MaPSA quality assurance, enabling performance tracking of each MaPSA's pixel through an accessible database before installation into the CMS outer tracker.



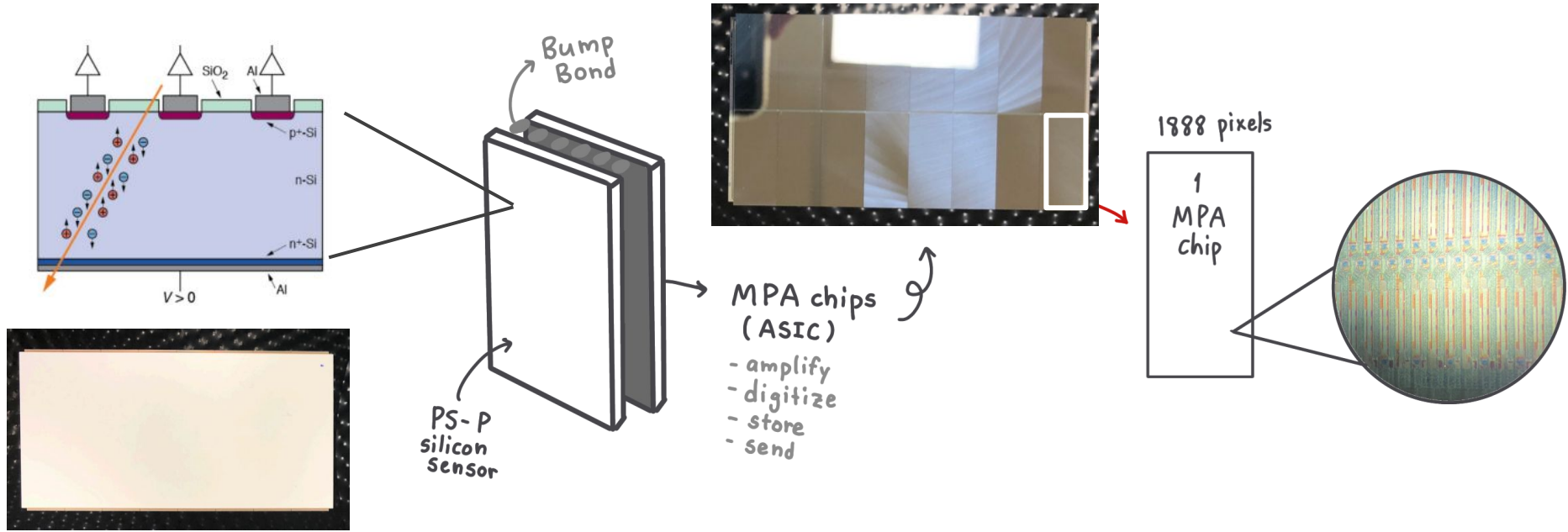


Overview

1. Introduction
2. Database
3. Probe Testing
4. Grading and Analysis
5. Conclusion

MaPSA

MaPSA = 1 Silicon sensor + 16 MPAs readout chip

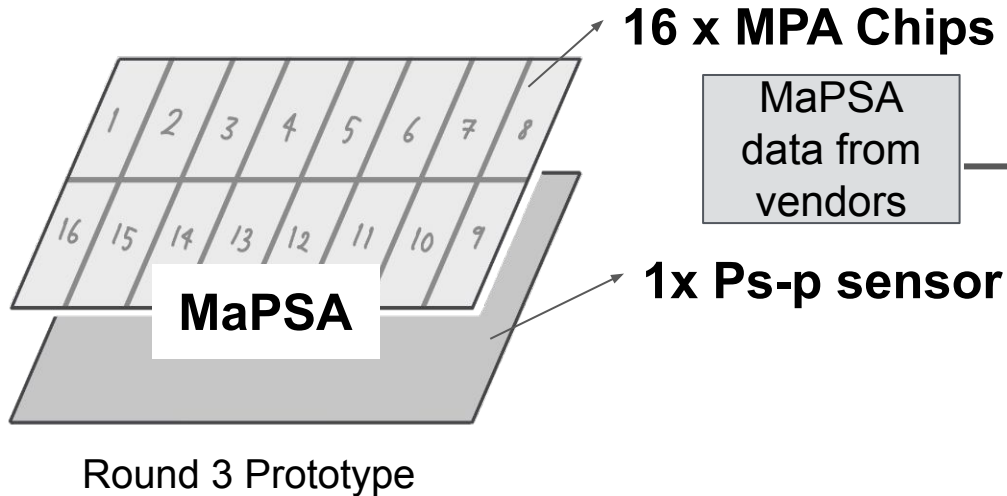




Methods

Tools

- Python: ElementTree, pandas
- MaPSA Probe Testing
- Round 3 Prototype data
- Linux, Github



MaPSA data from vendors

```

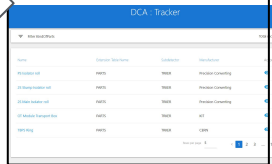
<ROOT>
  <PARTS>
    <PART mode="auto">
      <KIND_OF_PART>MaPSA</KIND_OF_PART>
      <NAME_LABEL>AEM_35494_010L</NAME_LABEL>
      <MANUFACTURER>AEMtec</MANUFACTURER>
      <LOCATION>AEMtec</LOCATION>
      <VERSION>2.0</VERSION>
      <PREDEFINED_ATTRIBUTES>
        <ATTRIBUTE>
          <NAME>Has Kapton isolation</NAME>
          <VALUE>Yes</VALUE>
        </ATTRIBUTE>
        <ATTRIBUTE>
          <NAME>Grade</NAME>
          <VALUE>A</VALUE>
        </ATTRIBUTE>
        <ATTRIBUTE>
          <NAME>Status</NAME>
          <VALUE>Good</VALUE>
        </ATTRIBUTE>
      </PREDEFINED_ATTRIBUTES>
      <CHILDREN>
        <PART mode="auto">
          <KIND_OF_PART>MPA Chip</KIND_OF_PART>
          <NAME_LABEL>N6Y215_04_400</NAME_LABEL>
          <PREDEFINED_ATTRIBUTES>
            <ATTRIBUTE>
  
```

xml file

Upload

Probe Testing data

MaPSA database





MaPSA Database

week 1 - 3: Generate xml

week 6 - 8: Upload





MaPSA Database

cmsdca.cern.ch/

DCA : Tracker Detector Construction Application

- Management
- Construction
- Kind of Parts**
- Parts
- Module assembly
- Tracking
- Condition

Filter KindOfParts Total records: 72

Name	Extension Table Name	Sub-detector	Manufacturer	Action
PS Isolator roll	PARTS	TR		
2S Stump Isolator roll	PARTS	TR		
2S Main Isolator roll	PARTS	TR		
OT Module Transport Box	PARTS	TR		
TBPS Ring	PARTS	TR		

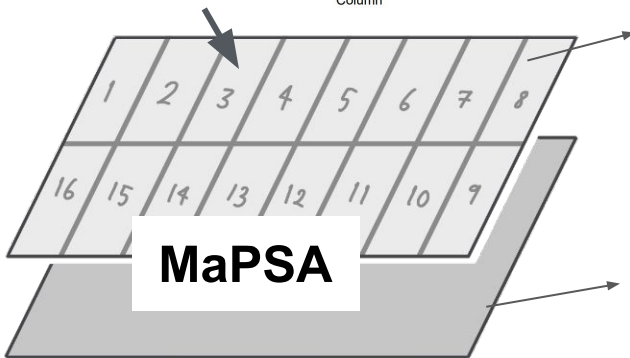
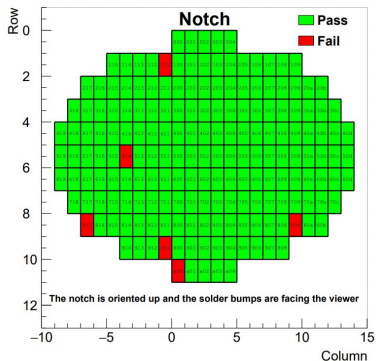
KindOfPart	Name	Serial number	Barcode	Location	Manufacturer	Latest status	Parent	Children	Action
MaPSA	AEM_35494_003L			DE - AEMtec [AEMtec]	AEMtec	Good	ROOT	17	👁

Rows per page: < 1 >

Latest status	Good
Extension table name	PARTS
Record insertion time	June 21, 2023, 5:52 p.m.
Record Insertion user	CMS_TRK_PRTTYPE_TRKER_WRITER
Record last update time	June 21, 2023, 6:08 p.m. History
Record last update user	CMS_TRK_PRTTYPE_TRKER_WRITER
Comment	Round 3 prototype

AEM_35494_003L part children

KindOfPart	Name	Location	Manufacturer	Latest status	Parent	Children
PS-p Sensor	35494_003_PSP_MAINL	DE - AEMtec [AEMtec]	Hamamatsu	Good	AEM_35494_003L	0
MPA Chip	N6Y215_03_711	DE - AEMtec [AEMtec]	TSMC	Good	AEM_35494_003L	0
MPA Chip	N6Y215_03_712	DE - AEMtec [AEMtec]	TSMC	Good	AEM_35494_003L	0
MPA Chip	N6Y215_03_713	DE - AEMtec [AEMtec]	TSMC	Good	AEM_35494_003L	0
MPA Chip	N6Y215_03_714	DE - AEMtec [AEMtec]	TSMC	Good	AEM_35494_003L	0
MPA Chip	N6Y215_03_715	DE - AEMtec [AEMtec]	TSMC	Good	AEM_35494_003L	0



- Name
- Grade
- Location
- Status

```

</PART>
<PART mode="auto">
  <KIND_OF_PART>MPA Chip</KIND_OF_PART>
  <NAME_LABEL>NGY215_04_40B</NAME_LABEL>
  <PREDEFINED_ATTRIBUTES>
    <ATTRIBUTE>
      <NAME>Chip Posn on Sensor</NAME>
      <VALUE>11</VALUE>
    </ATTRIBUTE>
  </PREDEFINED_ATTRIBUTES>
</PART>

```

16 x MPA Chips

- Name
- Position on Wafer
- Position on Sensor

1 x Ps-p sensor

- Name

```

</PART>
<PART mode="auto">
  <KIND_OF_PART>PS-p Sensor</KIND_OF_PART>
  <NAME_LABEL>35494_010_PSP_MAINL</NAME_LABEL>
</PART>

```



MaPSAname.xml

```

<ROOT>
  <PARTS>
    <PART mode="auto">
      <KIND_OF_PART>MaPSA</KIND_OF_PART>
      <NAME_LABEL>AEM_35494_010L</NAME_LABEL>
      <MANUFACTURER>AEMtec</MANUFACTURER>
      <LOCATION>AEMtec</LOCATION>
      <VERSION>2.0</VERSION>
      <PREDEFINED_ATTRIBUTES>
        <ATTRIBUTE>
          <NAME>Has Kapton isolation</NAME>
          <VALUE>Yes</VALUE>
        </ATTRIBUTE>
        <ATTRIBUTE>
          <NAME>Grade</NAME>
          <VALUE>A</VALUE>
        </ATTRIBUTE>
        <ATTRIBUTE>
          <NAME>Status</NAME>
          <VALUE>Good</VALUE>
        </ATTRIBUTE>
      </PREDEFINED_ATTRIBUTES>
    </PART>
  </PARTS>
  <CHILDREN>
    <PART mode="auto">
      <KIND_OF_PART>MPA Chip</KIND_OF_PART>
      <NAME_LABEL>NGY215_04_400</NAME_LABEL>
      <PREDEFINED_ATTRIBUTES>
        <ATTRIBUTE>

```

MaPSA block

Children block



Parent block (MaPSA) loop over filenames

```
#for HPK sheet
def HPK_getXML1(sheetname):
    filename_list = HPK_split1(sheetname) #split, save csv files
    for filename in filename_list:
        chip_data = HPK_getdata(filename)
        print(chip_data)
        root = ET.Element("ROOT")
        parts = ET.SubElement(root, "PARTS")

        # MaPSA block
        MAPSA = ET.SubElement(parts, "PART", mode="auto") #use ElementTree to add m
ode='auto'
        ET.SubElement(MAPSA, "KIND_OF_PART").text = "MaPSA"
        ET.SubElement(MAPSA, "NAME_LABEL").text = HPK_MapasaName(filename)
        ET.SubElement(MAPSA, "MANUFACTURER").text = Loc
        ET.SubElement(MAPSA, "LOCATION").text = Loc
        ET.SubElement(MAPSA, "VERSION").text = "2.0"

        # MaPSA attributes
        predefMapsa1 = ET.SubElement(MAPSA, "PREDEFINED_ATTRIBUTES")
        attr1 = ET.SubElement(predefMapsa1, "ATTRIBUTE")
        ET.SubElement(attr1, "NAME").text = "Has Kapton isolation"
        ET.SubElement(attr1, "VALUE").text = HPK_Kapval(HPK_MapasaName(filename))

        attr2 = ET.SubElement(predefMapsa1, "ATTRIBUTE")
        ET.SubElement(attr2, "NAME").text = "Grade"
        if HPK_MapasaName(filename) in GradeB:
            Grade = 'B'
        elif HPK_MapasaName(filename) in GradeC:
            Grade = 'C'
        elif HPK_MapasaName(filename) in GradeF:
            Grade = 'F'
        else:
            Grade = 'A'
```

⋮

Children block (MPA chips, sensor) loop over rows of dataframe

```
child = ET.SubElement(MAPSA, "CHILDREN")

df = HPK_getdata(filename)
for index, row in df.iterrows():
    child_sub = ET.SubElement(child, "PART", mode="auto")
    ET.SubElement(child_sub, "KIND_OF_PART").text = "MPA Chip"
    ET.SubElement(child_sub, "NAME_LABEL").text = str(HPK_getNameLabel1(chi
p_data, index))

    #Predefined attributes of child
    child_predef = ET.SubElement(child_sub, "PREDEFINED_ATTRIBUTES")
    child_predef_attr = ET.SubElement(child_predef, "ATTRIBUTE")
    ET.SubElement(child_predef_attr, "NAME").text = "Chip Posn on Sensor"
    ET.SubElement(child_predef_attr, "VALUE").text = str(HPK_getPosn(row['\
ocation']))

    sensor_sub = ET.SubElement(child, "PART", mode="auto")
    ET.SubElement(sensor_sub, "KIND_OF_PART").text = "PS-p Sensor"
    ET.SubElement(sensor_sub, "NAME_LABEL").text = chip_data['number'][0]
    xmlstr = ET.tostring(root)
    dom = xml.dom.minidom.parseString(xmlstr)
    xmlfinal = dom.toprettyxml(indent="  ")

    print(xmlfinal)

    ET.indent(ET.ElementTree(root), '  ')
    f = open('/uscms/home/wjaidee/nobackup/MaPSA_database/XMLgenerator/XMLnew/'\
+HPK_MapasaName(filename)+'.xml', "wb")
    ET.ElementTree(root).write(f)
```

⋮



Input

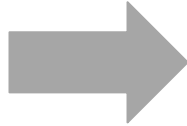
- Manufacturer
- File name
- Data format

```
[wjaidee@cmslpc122 MaPSA_database]$ cat 35494_040_
number,Location,WaffelPackno,WaffelPackrow,WaffelP
35494_040_PSP_MAINL,1,9,2,5,N6Y21501D6,-8,16,49
,2,9,2,4,N6Y21501D6,-8,17,49
,3,9,2,3,N6Y21501D6,-8,18,49
,4,9,2,2,N6Y21501D6,-8,19,49
,5,9,2,1,N6Y21501D6,-8,20,49
,6,9,1,6,N6Y21501D6,-8,14,49
,7,9,1,5,N6Y21501D6,-8,13,49
,8,9,1,4,N6Y21501D6,-8,12,49
,9,9,1,3,N6Y21501D6,-8,11,49
,10,9,1,2,N6Y21501D6,-8,10,49
,11,9,1,1,N6Y21501D6,-8,9,49
,12,10,3,6,N6Y21502D1,-1,10,49
,13,10,3,5,N6Y21502D1,-1,11,49
,14,10,3,4,N6Y21502D1,-1,12,49
,15,10,3,3,N6Y21502D1,-1,13,49
,16,10,3,2,N6Y21502D1,-1,14,49
```

Output

Raw data parsed and saved
XMLs saved to folder

```
[wjaidee@cmslpc176 XMLgenerator]$ python Generator.py
Enter LOCATION:A
AEMtec
{'A': 'AEMnamelists.txt', 'B': 'MissingAEM.csv', 'C': 'H
'D': 'hpk2.csv'}
Which file:A
Is the input file in txt? [y/n]y
```



```
[wjaidee@cmslpc176 XMLgenerator]$ cd XMLnew/
[wjaidee@cmslpc176 XMLnew]$ ls
AEM_35494_002L.xml AEM_35494_016L.xml HPK_35494_037L.xml
AEM_35494_003L.xml AEM_35494_026L.xml HPK_35494_038L.xml
AEM_35494_004L.xml AEM_35494_027L.xml HPK_35494_039L.xml
AEM_35494_005L.xml AEM_35494_028L.xml HPK_35494_040L.xml
AEM_35494_006L.xml AEM_35494_029L.xml HPK_35494_041L.xml
AEM_35494_007L.xml AEM_35494_030L.xml HPK_35494_042L.xml
AEM_35494_008L.xml HPK_35494_001R.xml HPK_35494_043L.xml
AEM_35494_009L.xml HPK_35494_002R.xml HPK_35494_044L.xml
AEM_35494_010L.xml HPK_35494_003R.xml HPK_35494_046L.xml
AEM_35494_011L.xml HPK_35494_004R.xml HPK_35494_047L.xml
AEM_35494_012L.xml HPK_35494_005R.xml HPK_35494_048L.xml
AEM_35494_013L.xml HPK_35494_032L.xml HPK_35494_049L.xml
AEM_35494_014L.xml HPK_35494_033L.xml
AEM_35494_015L.xml HPK_35494_036L.xml
```

```
['35494_003_PSP_MAINL.txt', '35494_004_PSP_MAINL.txt', '35494_005_PSP_
MAINL.txt', '35494_006_PSP_MAINL.txt', '35494_007_PSP_MAINL.txt', '354
94_008_PSP_MAINL.txt', '35494_009_PSP_MAINL.txt', '35494_010_PSP_MAINL
.txt', '35494_011_PSP_MAINL.txt', '35494_012_PSP_MAINL.txt', '35494_01
3_PSP_MAINL.txt', '35494_014_PSP_MAINL.txt', '35494_015_PSP_MAINL.txt'
, '35494_016_PSP_MAINL.txt', '35494_026_PSP_MAINL.txt', '35494_027_PSP_
_MAINL.txt', '']
<?xml version="1.0" ?>
<ROOT>
<PARTS>
<PART mode="auto">
<KIND_OF_PART>MaPSA</KIND_OF_PART>
<NAME_LABEL>AEM_35494_003L</NAME_LABEL>
<MANUFACTURER>AEMtec</MANUFACTURER>
<LOCATION>AEMtec</LOCATION>
<VERSION>2.0</VERSION>
<PREDEFINED_ATTRIBUTES>
<ATTRIBUTE>
<NAME>Has Kapton isolation</NAME>
<VALUE>Yes</VALUE>
</ATTRIBUTE>
<ATTRIBUTE>
<NAME>Grade</NAME>
<VALUE>A</VALUE>
</ATTRIBUTE>
<ATTRIBUTE>
<NAME>Status</NAME>
<VALUE>Good</VALUE>
</ATTRIBUTE>
</PREDEFINED_ATTRIBUTES>
<CHILDREN>
<PART mode="auto">
<KIND_OF_PART>MPA Chip</KIND_OF_PART>
<NAME_LABEL>N6Y215_03_711</NAME_LABEL>
<PREDEFINED_ATTRIBUTES>
<ATTRIBUTE>
<NAME>Chip Posn on Sensor</NAME>
<VALUE>1</VALUE>
</ATTRIBUTE>
```



py4DBupload

gitlab.cern.ch/cms-ph2-database/py4dbupload

Uploading xml to the database

- Get CERN Standard account
- Install required packages: lxml, openpyxl, xlrd, progressbar2, pandas
- Get py4DBupload
- Run

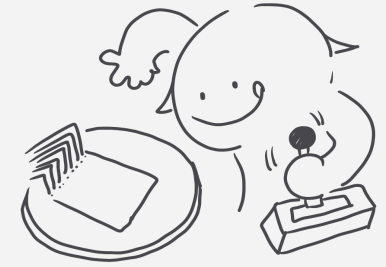
```
$python cmsdbldr_client.py --login  
--url=https://cmsdca.cern.ch/trk_loader/trker/int2r HPK_35494_002R.xml
```

The screenshot shows the GitLab interface for the project 'py4DBupload' under the namespace 'cms-ph2-database'. The project name is 'py4DBupload' with a Project ID of 90963. It has 95 commits, 1 branch, 0 tags, and 12.7 MB of project storage. The description states it is a 'Collection of python classes to facilitate the production of the XML file for the data upload...'. A recent commit is shown as a merge of the 'master' branch, authored by Sandro Di Mattia 21 hours ago. The interface includes navigation icons on the left, a search bar at the top, and buttons for 'Find file', 'Clone', and 'README'. A table at the bottom shows the file structure with columns for Name, Last commit, and Last update.

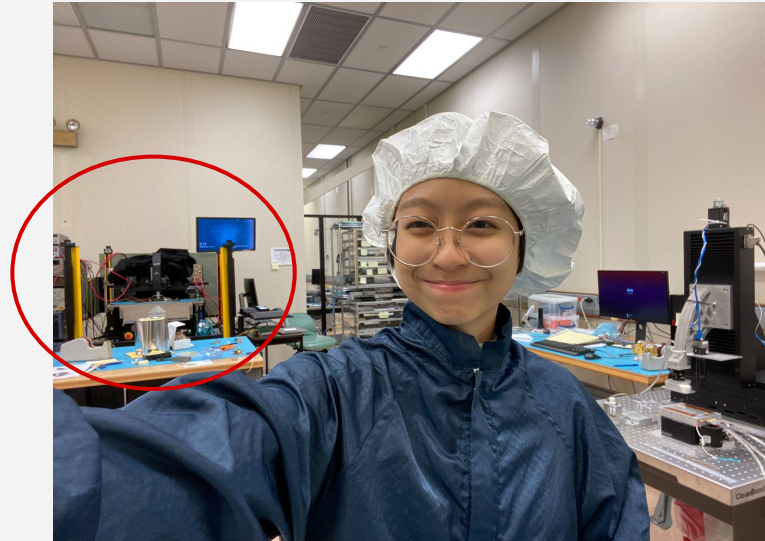
Name	Last commit	Last update
bin	Check Hybrids test	7 months ago



MaPSA Testing



week 1, week 7





MaPSA probe testing: setup

HV Supply
LV Supply

Interface Board

Probe Station Control

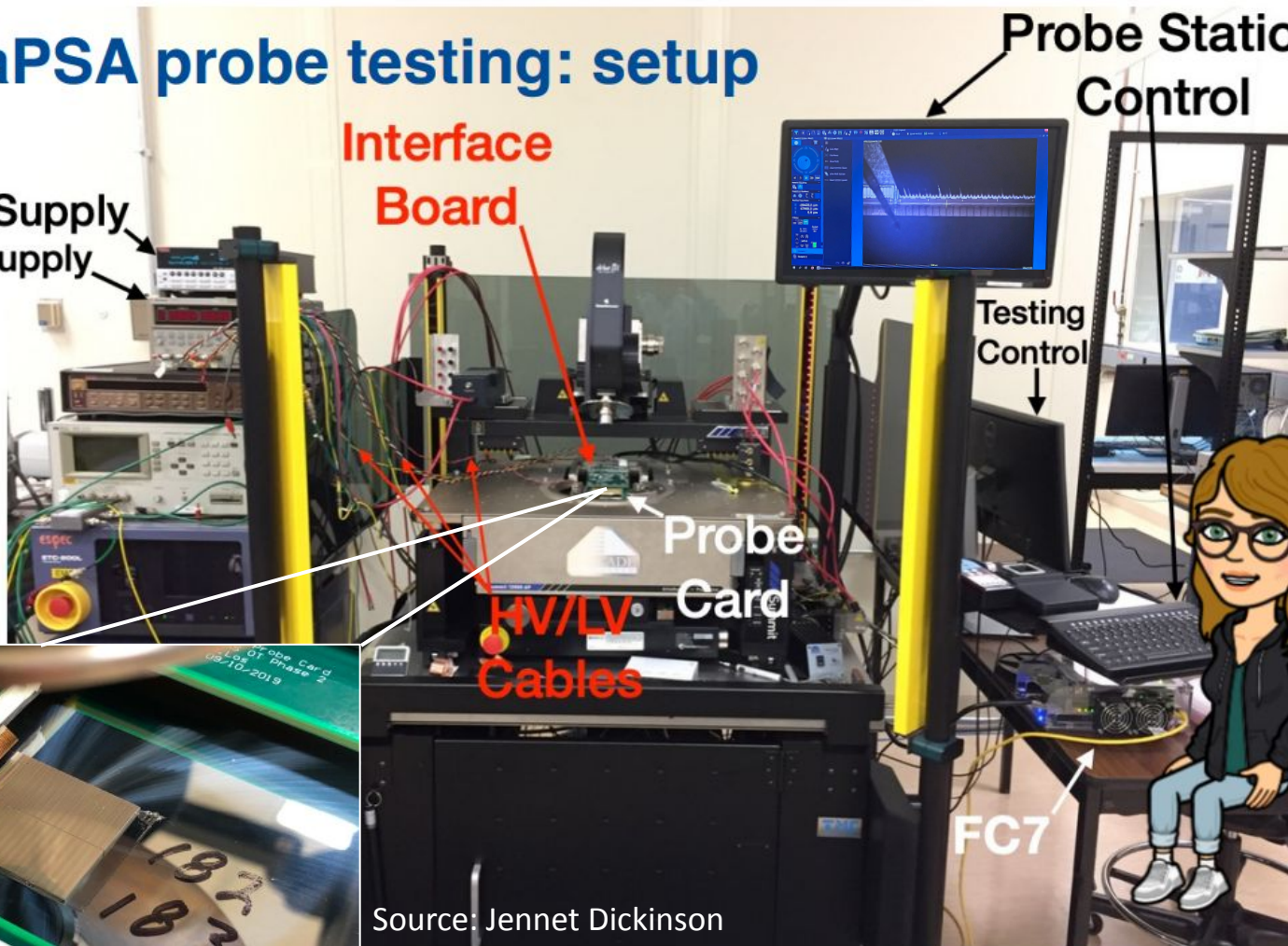
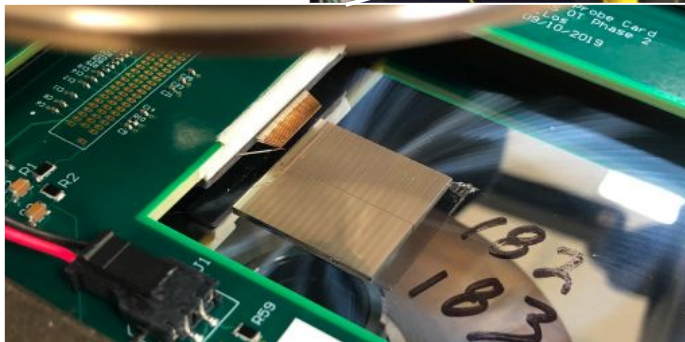
Testing Control

Probe Card

HV/LV Cables

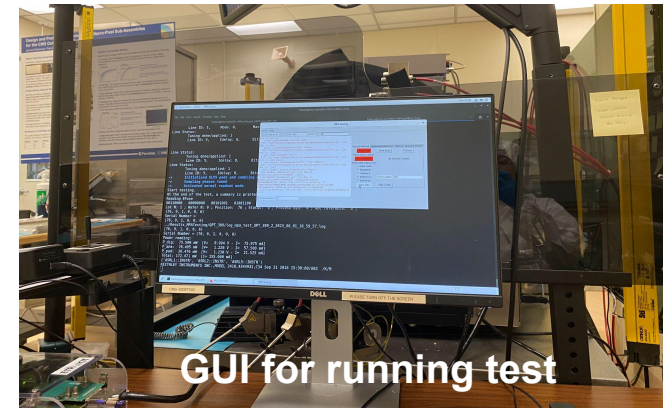
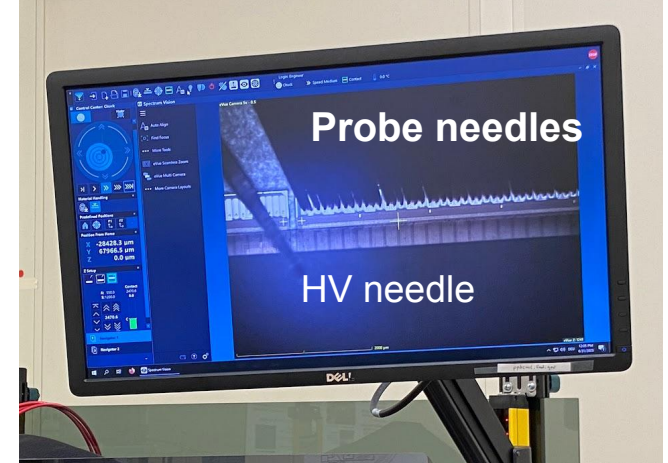
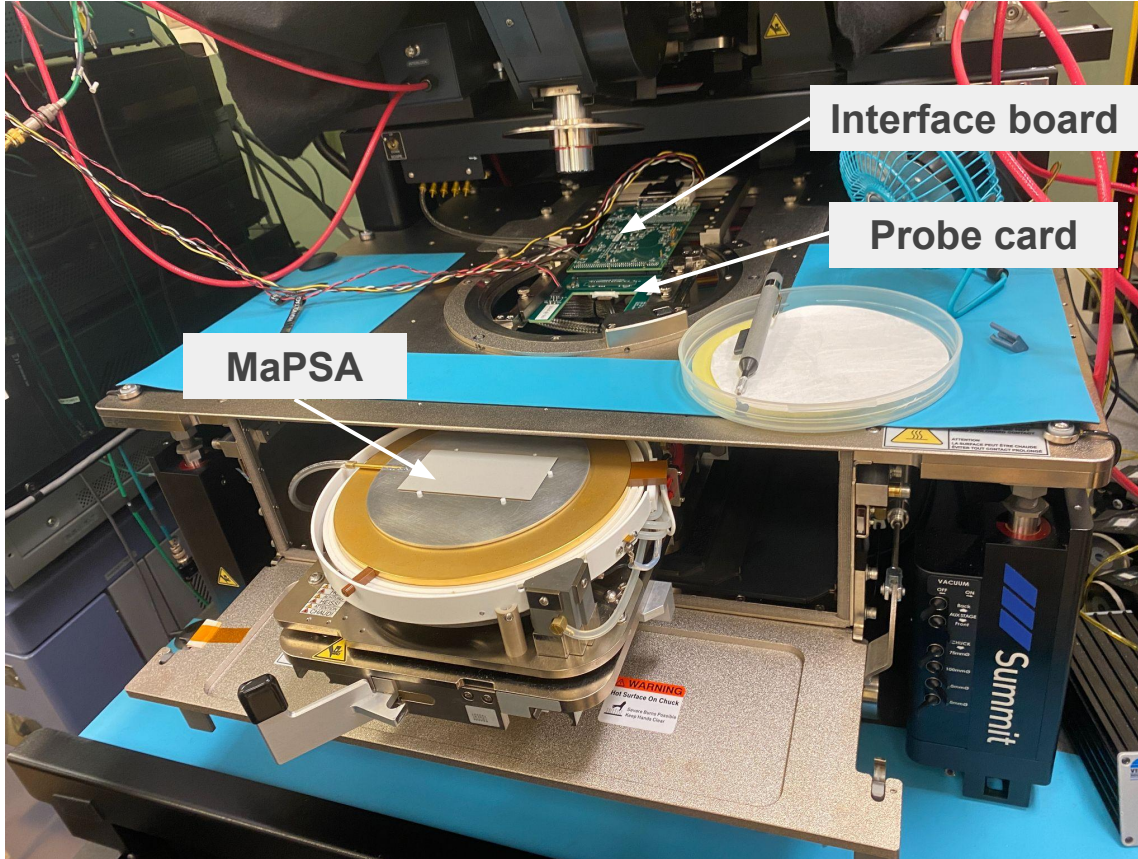
FC7

Source: Jennet Dickinson





Probe test station at SiDet





Pixel Tests

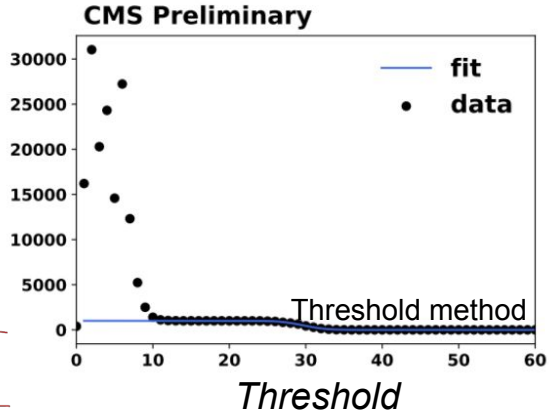
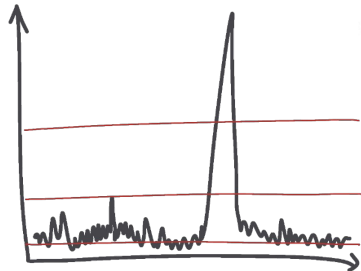
Alive

Inject 100 pulses
expect 100 recorded

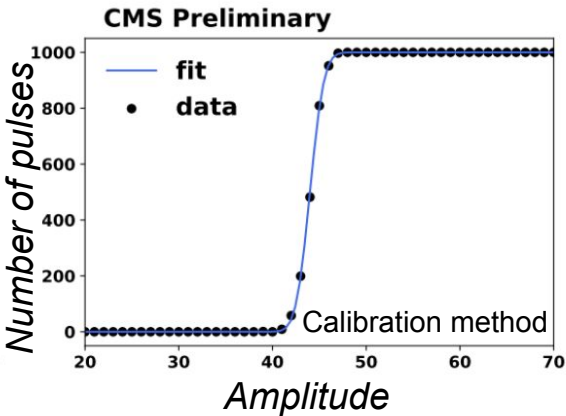
Masking

Set mask bit = 1
Inject 100 pulses
expect 0 recorded

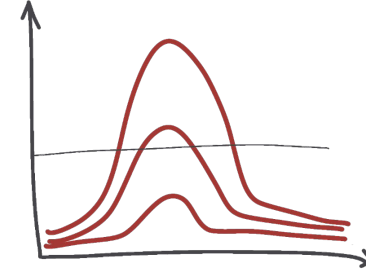
Noise, Threshold



fixed pulse amplitude,
vary threshold



fixed threshold, vary
pulse amplitude





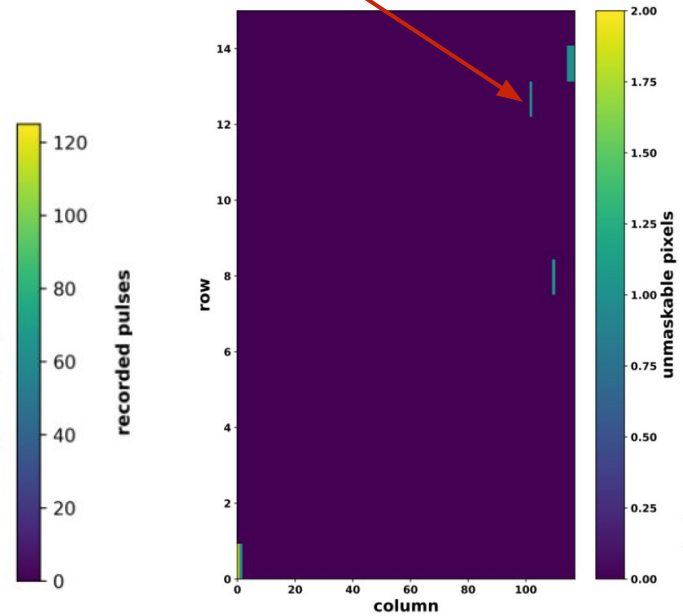
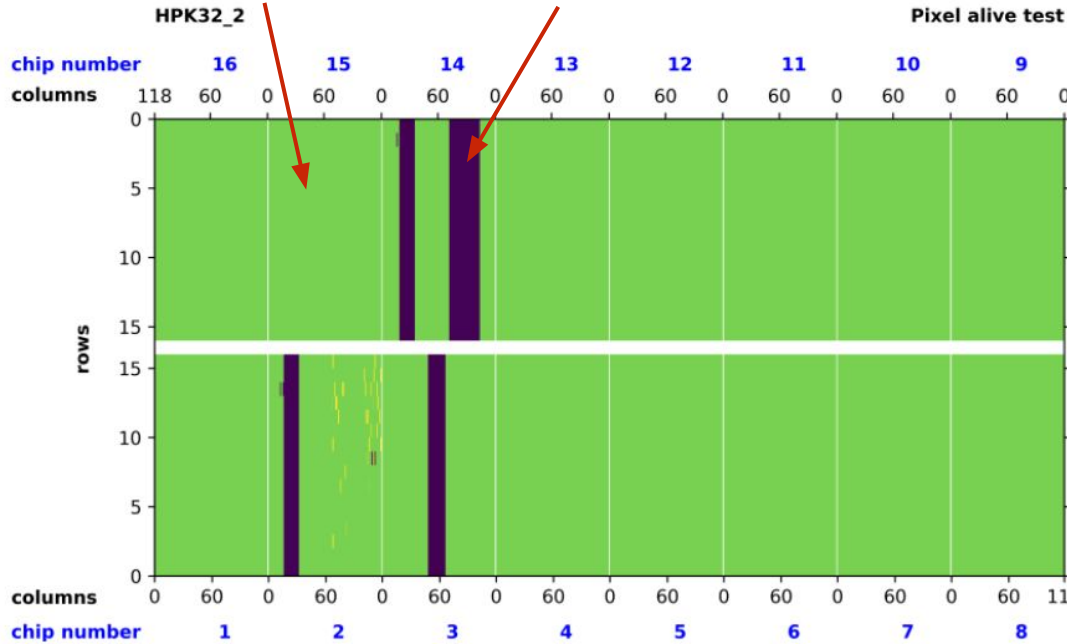
Pixel Map

Good Pixel

Dead Pixel

Noisy Pixel

Unmaskable Pixel



Source: CMS MaPSA_Round2 Note | Doug Berry, Jennet Dickinson, and Fermilab



MaPSA Grading and Analysis

week 4 - 6

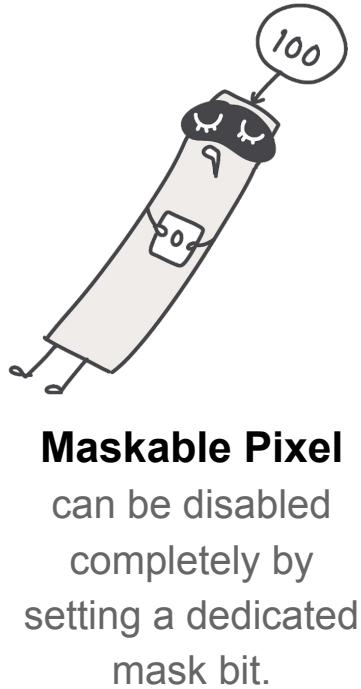




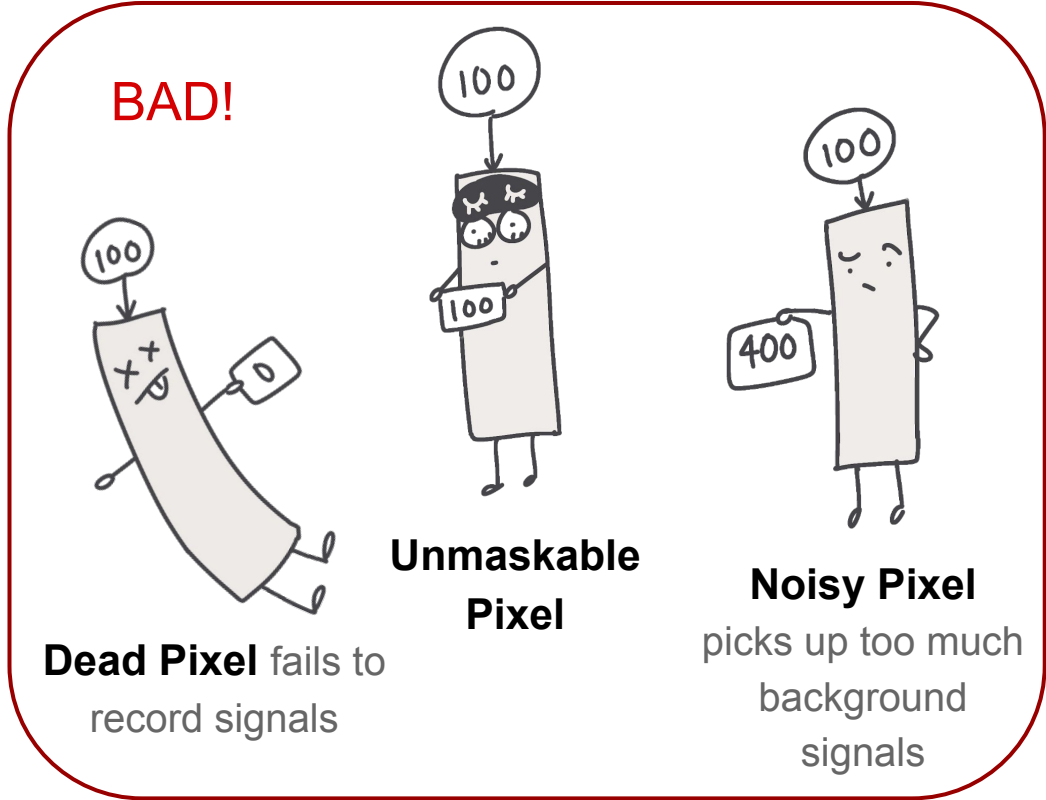
Pixel Status



GOOD!



Operational pixels



Non-Operational pixels



Grading Criteria

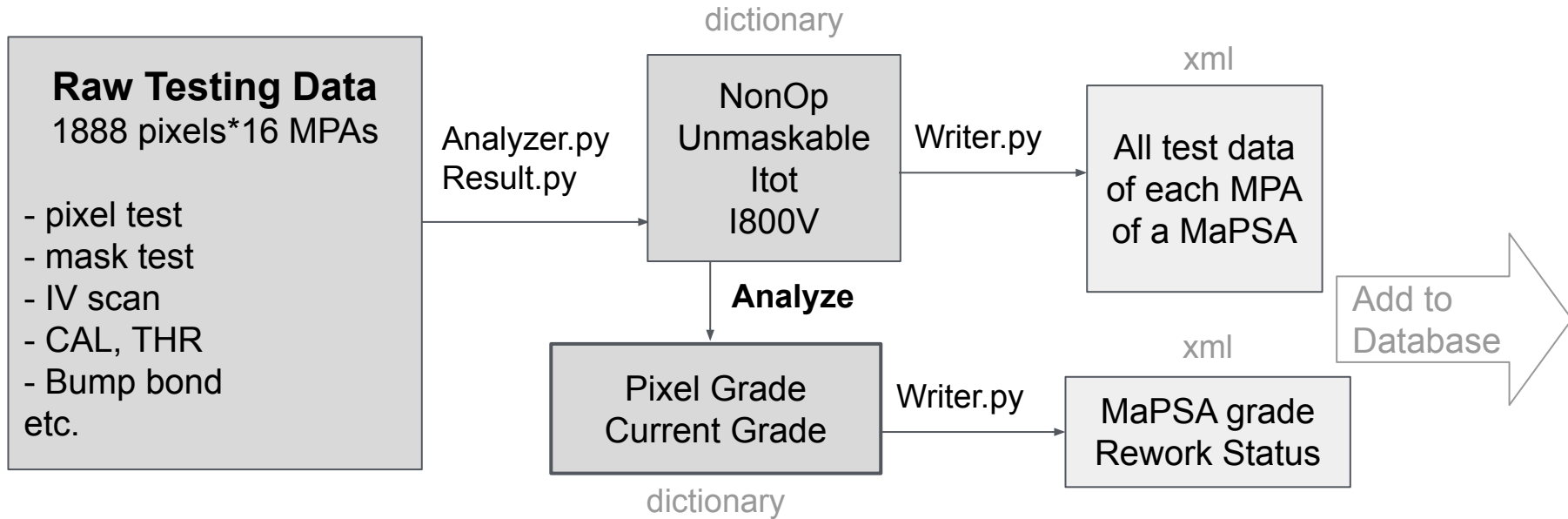
Good quality MaPSA is required to have minimal dead pixels, appropriate total current, and all pixels must be maskable.

1 MaPSA Grade: the worst grade of both			
16 MPA chips' grades			1 HV Current Grade current from IV scan at -800V
Pixel Grade % of operational pixel	LV Current Grade total current to power the chips		
A	NNonOp < 19	100 mA < Itot < 250 mA	
B	19 < NNonOp < 94	-	
C	NNonOp > 94 or NUnmakable > 0	Itot < 100 or Itot > 250 mA	



Analyze

github.com/IseeJ/OT



```
$source /cvmfs/sft.cern.ch/lcg/views/LCG_101/x86_64-centos7-gcc8-opt/setup.sh  
$python SummaryOneMaPSA.py HPK_35494_002R
```



Result

Raw testing data of each MaPSA saved as xml file

```
<ROOT>
  <HPK_35494_002R>
    <1>
      <Ianalog>58.75</Ianalog>
      <Idigital>77.25</Idigital>
      <Ipad>19.9</Ipad>
      <Itotal>155.9</Itotal>
      <NDeadPix>0</NDeadPix>
      <DeadPix />
      <NInefficientPix>0</NInefficientPix>
      <InefficientPix />
      <NNoisyPix>0</NNoisyPix>
      <NoisyPix />
      <NUnmaskablePix>0</NUnmaskablePix>
      <UnmaskablePix />
      <NoiseMean>1.62828985994543</NoiseMean>
      <NoiseStd>0.31485345156974914</NoiseStd>
      <NoiseNOutliersLow>1</NoiseNOutliersLow>
      <NoiseOutliersLow>942,</NoiseOutliersLow>
      <NoiseNOutliersHigh>3</NoiseNOutliersHigh>
      <NoiseOutliersHigh>592,630,1610,</NoiseOutliersHigh>
      <PedestalMean>13.759533898305085</PedestalMean>
      <PedestalStd>4.590360916319244</PedestalStd>
      <PedestalNOutliersLow>0</PedestalNOutliersLow>
      <PedestalOutliersLow />
      <PedestalNOutliersHigh>4</PedestalNOutliersHigh>
      <PedestalOutliersHigh>592,630,1027,1610,</PedestalOutliersHigh>
      <NNonOperational>0</NNonOperational>
    </1>
    <2>
      <Ianalog>58.4</Ianalog>
      <Idigital>77.0</Idigital>
```

Summary of result and Grade Dictionary including

- Pixel, Current grades
- MaPSA grade
- Rework status

Summary

```
ItotPerChip= [155.9, 156.825, 159.825, 160.725, 155.725, 157.775, 158.4, 165.925, 161.4  
 , 162.775, 166.05, 169.2, 168.75, 170.2, 171.825, 157.025]  
Itot Grade= ['A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A']  
NNonOperationalPerChip = 0,0,0,0,0,8,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,  
NUnmaskablePerChip= [0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]  
Pixel Grade = ['A' 'A' 'A' 'A' 'A' 'A' 'C' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A' 'A']  
Iat800= -0.182598  
IV Grade = A  
  
MPA Grade= ['A', 'A', 'A', 'A', 'A', 'A', 'C', 'A', 'A', 'A', 'A', 'A', 'A', 'A', 'A', 'A', 'A',  
'A']  
Number of grade 'C': 1  
Grade = {'HPK_35494_002R': {'MPA Grade': {1: 'A', 2: 'A', 3: 'A', 4: 'A', 5: 'A', 6: 'C'  
' , 7: 'A', 8: 'A', 9: 'A', 10: 'A', 11: 'A', 12: 'A', 13: 'A', 14: 'A', 15: 'A', 16: 'A'  
' }, 'Current Grade': 'A', 'IV Grade': 'A', 'Rework': 'Yes', 'MaPSA Grade': 'C'}}  
Creating XML file for MaPSA HPK_35494_002R
```



Conclusion



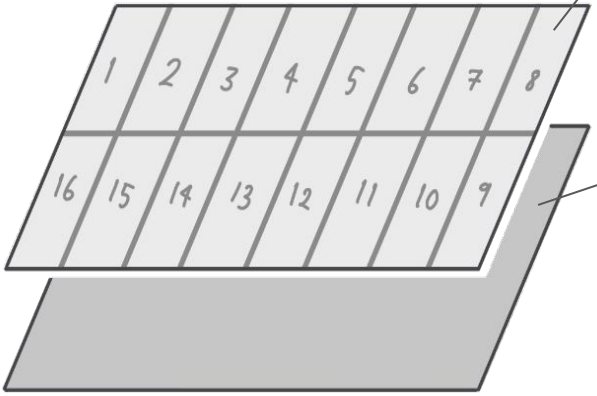
```

<ROOT>
  <PARTS>
    <PART mode="auto">
      <KIND_OF_PART>MaPSA</KIND_OF_PART>
      <NAME_LABEL>AEM_35494_010</NAME_LABEL>
      <MANUFACTURER>AEMtec</MANUFACTURER>
      <LOCATION>AEMtec</LOCATION>
      <VERSION>2.0</VERSION>
      <PREDEFINED_ATTRIBUTES>
        <ATTRIBUTE>
          <NAME>Has Kapton isolation</NAME>
          <VALUE>Yes</VALUE>
        </ATTRIBUTE>
      </PREDEFINED_ATTRIBUTES>
      <NAME>Grade</NAME>
    </PART>
  </PARTS>
</ROOT>

```

MaPSA

- Name
- Grade
- Location
- Status



16 x MPA Chips

- Name
- Position on Wafer
- Position on Sensor

1x Ps-p sensor

- Name

```

</PART>
<PART mode="auto">
  <KIND_OF_PART>PS-p Sensor</KIND_OF_PART>
  <NAME_LABEL>B5494_010_PSP_MAIN</NAME_LABEL>
</PART>

```

```

</PART>
<PART mode="auto">
  <KIND_OF_PART>MPA Chip</KIND_OF_PART>
  <NAME_LABEL>NGY215_04_40B</NAME_LABEL>
  <PREDEFINED_ATTRIBUTES>
    <ATTRIBUTE>
      <NAME>Chip Posn on Sensor</NAME>
      <VALUE>11</VALUE>
    </ATTRIBUTE>
  </PREDEFINED_ATTRIBUTES>
</PART>

```

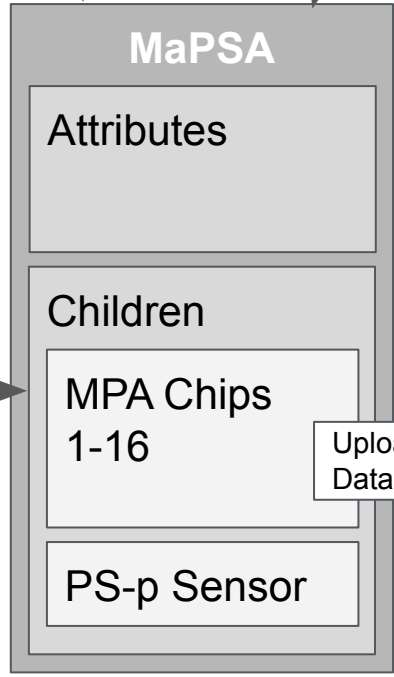
- Parse
- Map value
- Assign
- Convert

Generator.py

Analyzer.py , Result.py



Writer.py



MaPSA.xml



Reflection





Acknowledgements

Jennet Dickinson

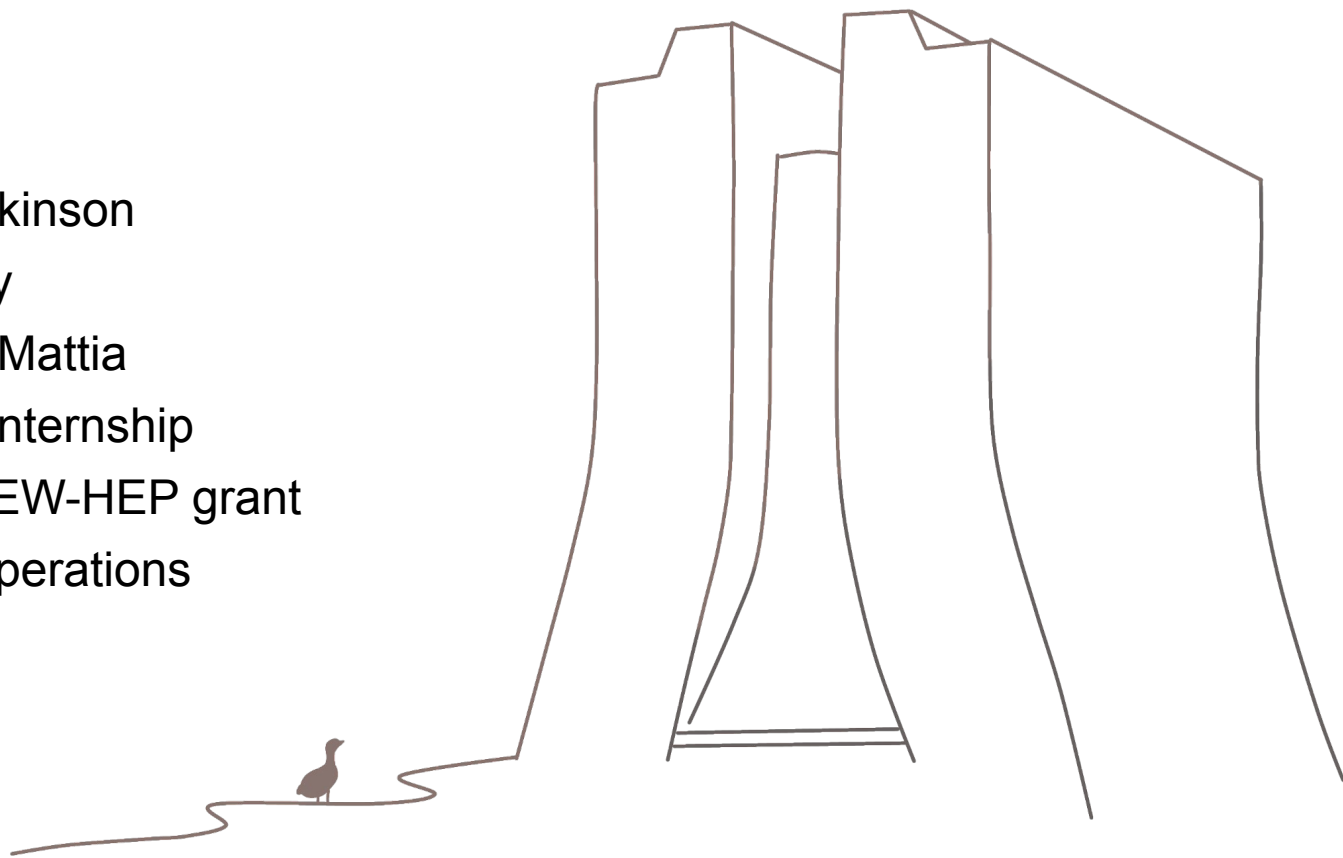
Doug Berry

Sandro Di Mattia

PURSUE Internship

DOE RENEW-HEP grant

USCMS Operations



Thank you!

