Development of a defect detection tool for visual inspection in the HL-LHC ATLAS pixel detectors production

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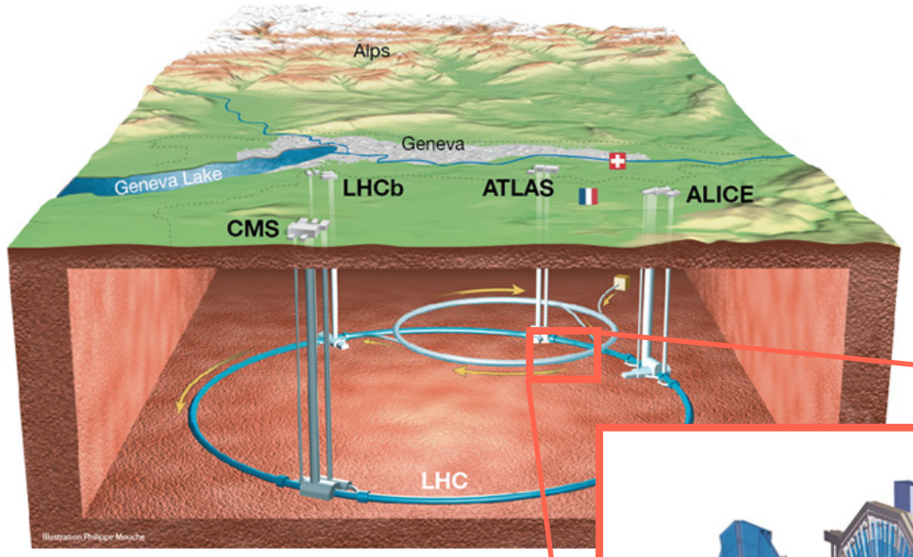
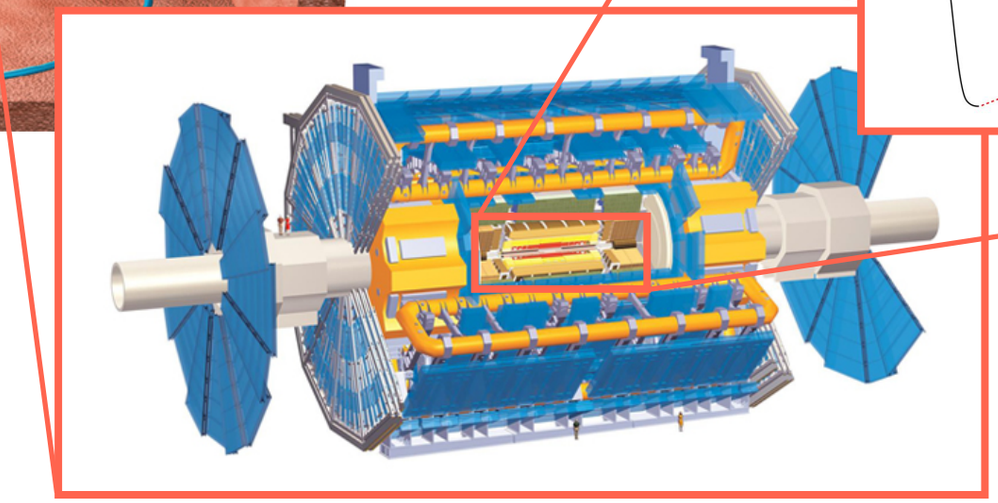
ATLAS Experiment

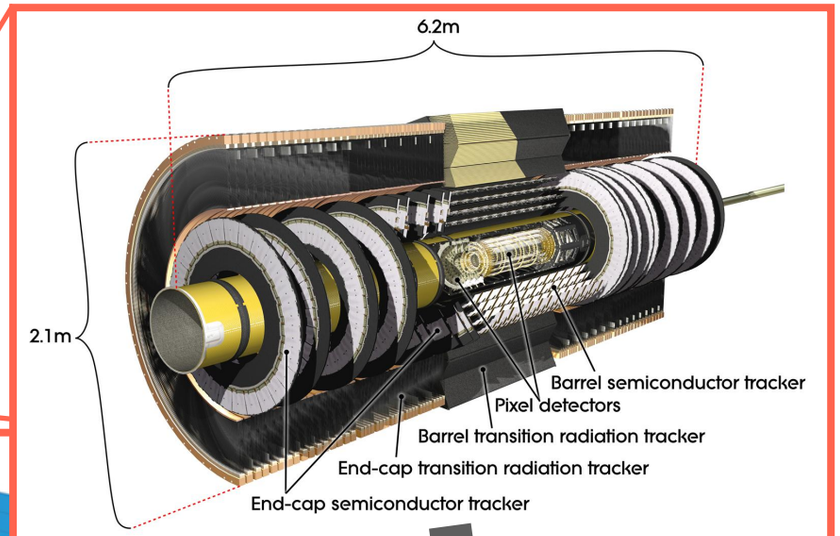


CERN

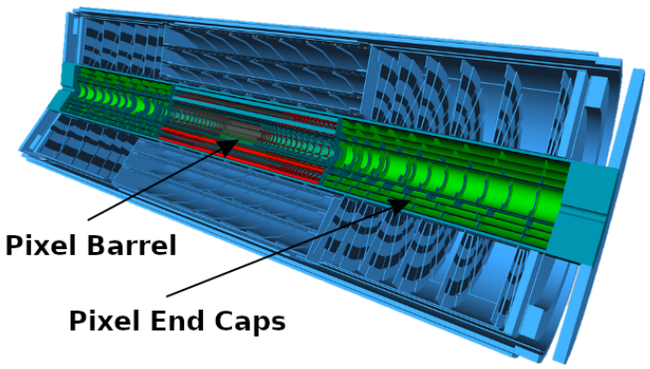


ATLAS detector

Inner tracker



Upgrade



New **I**nner **T**rac**k**er(ITk)

High Luminosity LHC(HL-LHC)

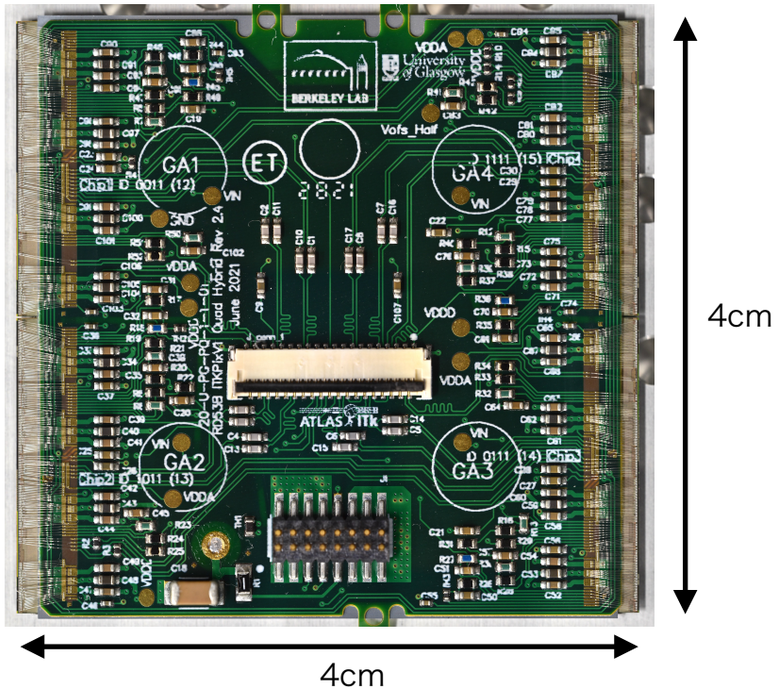
luminosity : $2\times10^{34}\,cm^{-2}sec^{-1} \rightarrow 5\sim7\times10^{34}\,cm^{-2}sec^{-1}$

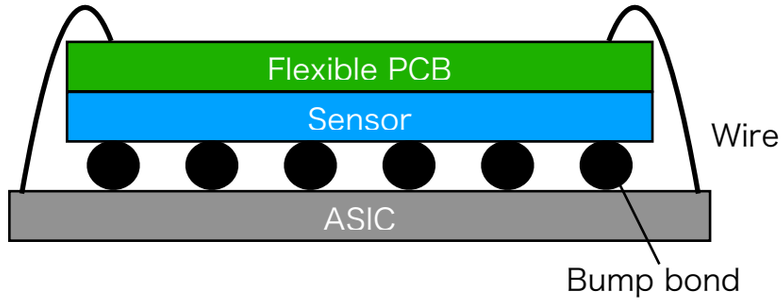
→ Will upgrade ATLAS detector too

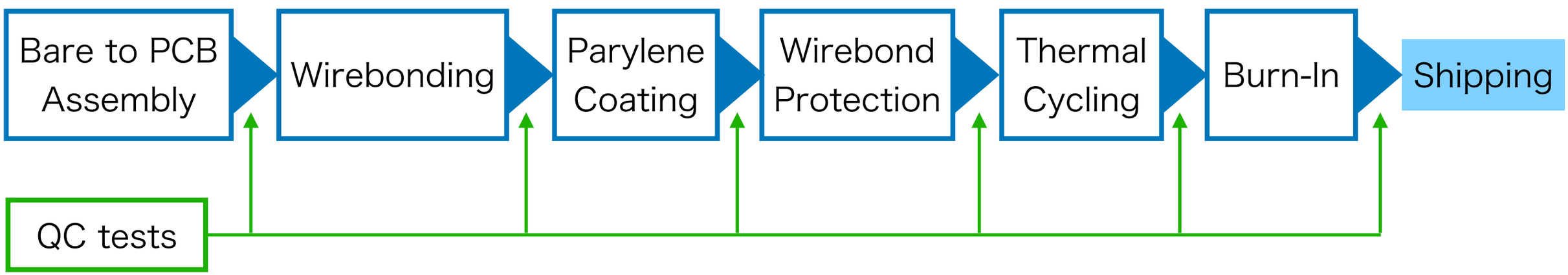
improve readout speed, radiation tolerance, etc.

Pixel Detector Production

- Silicon pixel detectors for new inner tracker
- Will produce10000 pixel detectors in the world, include 2000 in Japan
- Perform quality control(QC) tests at each stages of production
- Now preparing for mass production



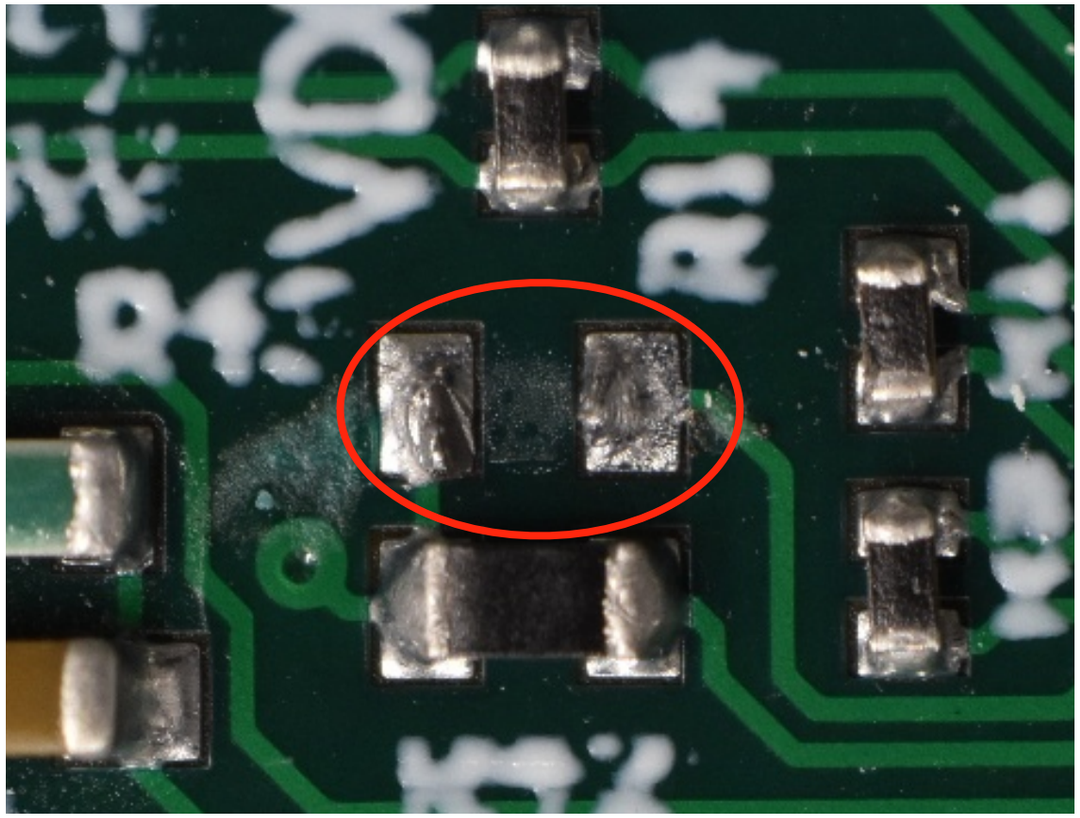




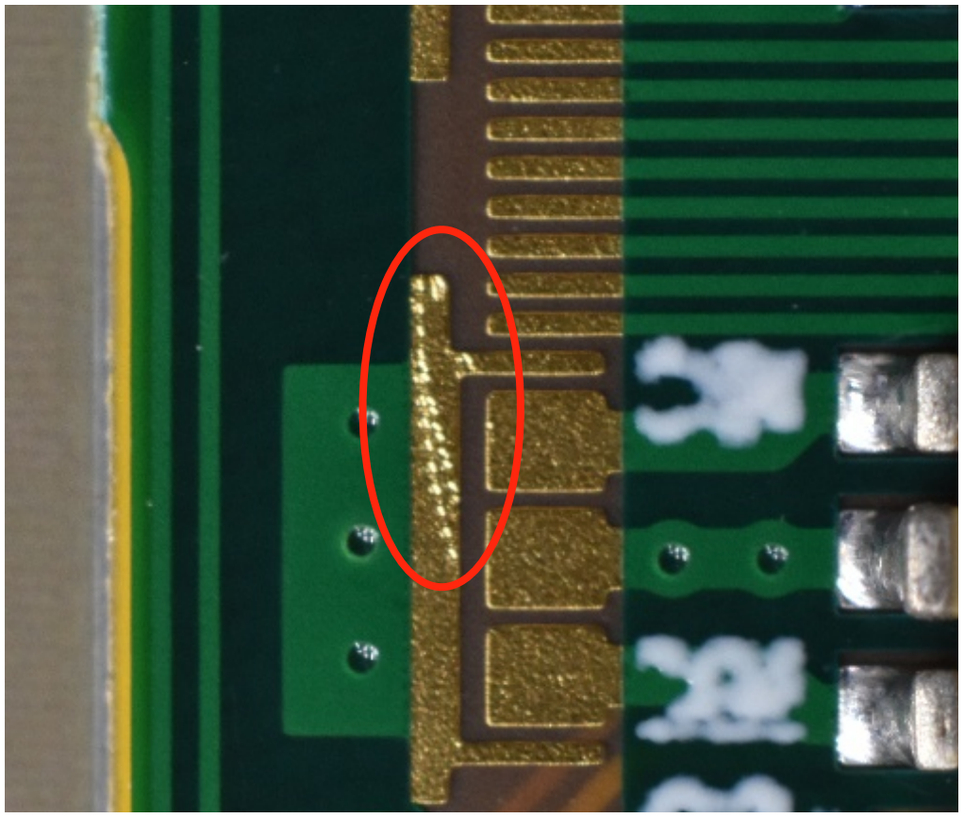
Visual Inspection

- Take pictures and perform visual inspections on each stage of mass production
- Check them with human eyes for anomalies

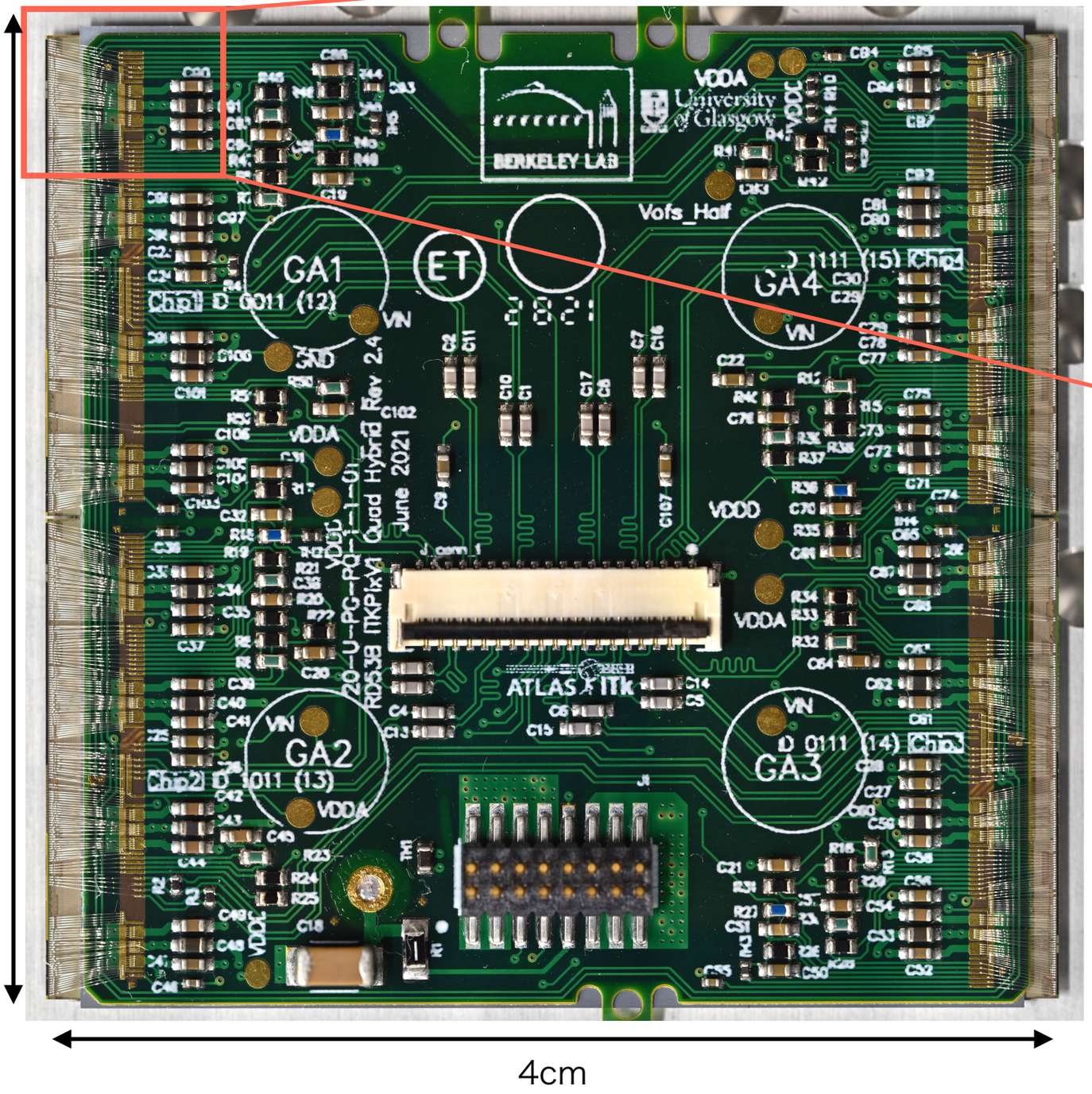
Defect of SMD(Surface Mount Device)

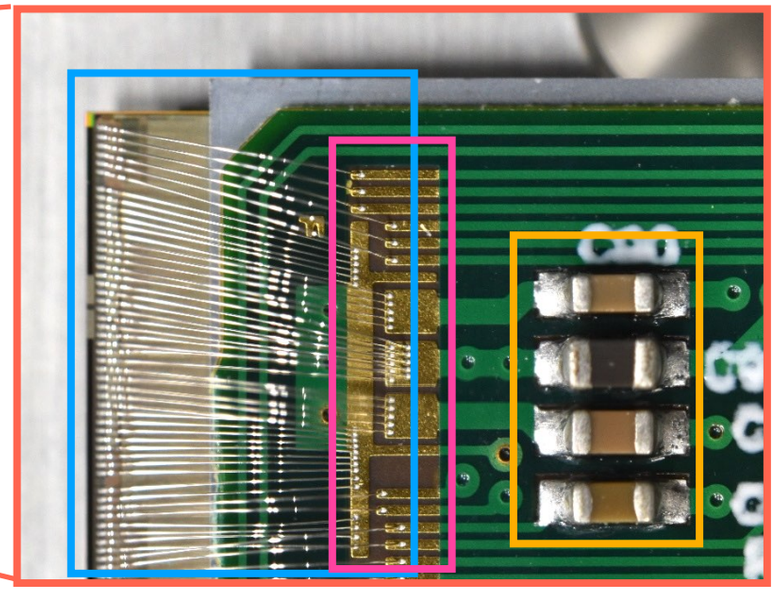


Scratch on pads



Appearance of Pixel Detector

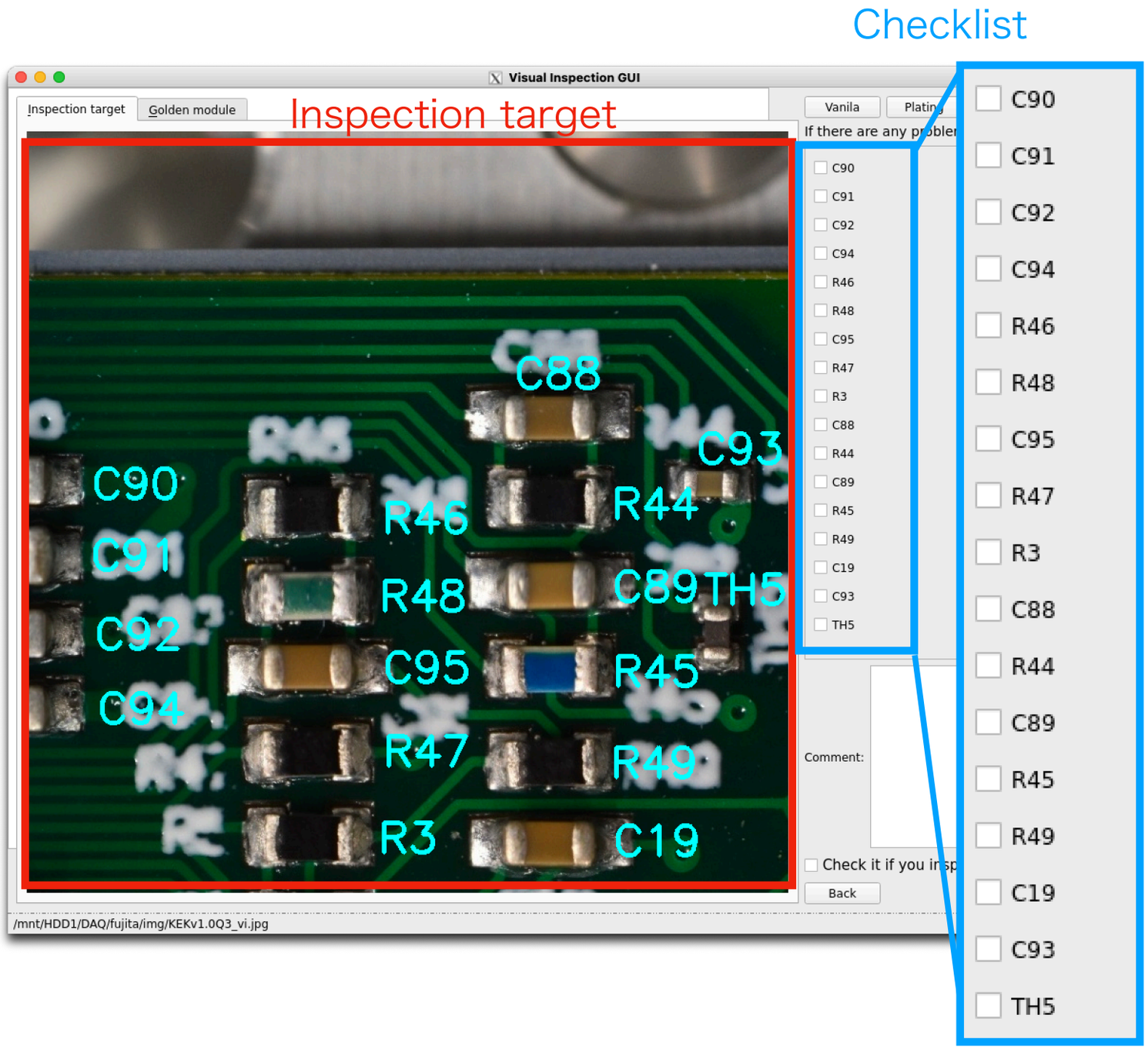




Many components on module

→ need to check them one by one

Current Visual Inspection Window



Users check each component using checklist

- Takes time
- Might overlook SMD defects

a tool to support users and improve inspection efficiency and accuracy

SMD Defect Detect

- Developing a tool that alerts users by highlighting areas where SMD may be missing

- Don’t want to overlook any SMD defects
(even if it highlights areas with SMDs)

Detection procedure

① Trim the image within a certain range

② Get color information(RGB) of each SMD and PCB location

③ Compare SMD and PCB color, and highlight the area that are the same color as PCB(not have SMD)

Classification to PCB or SMD

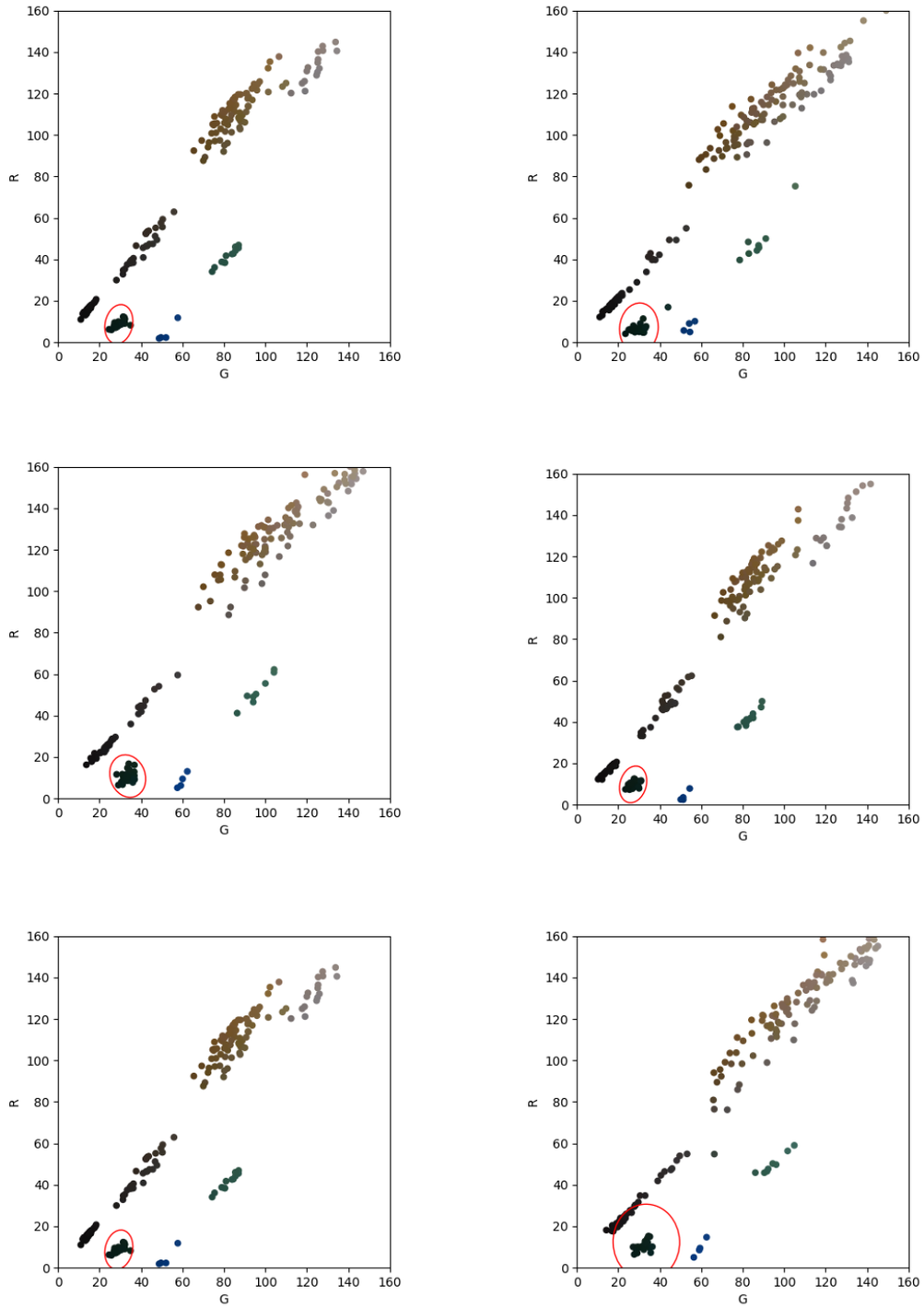
- For simplicity, distinguished the PCB color using 2 values, R and G

- Determined the PCB range from RG values of the points known to be PCB

Verified with 7 normal modules

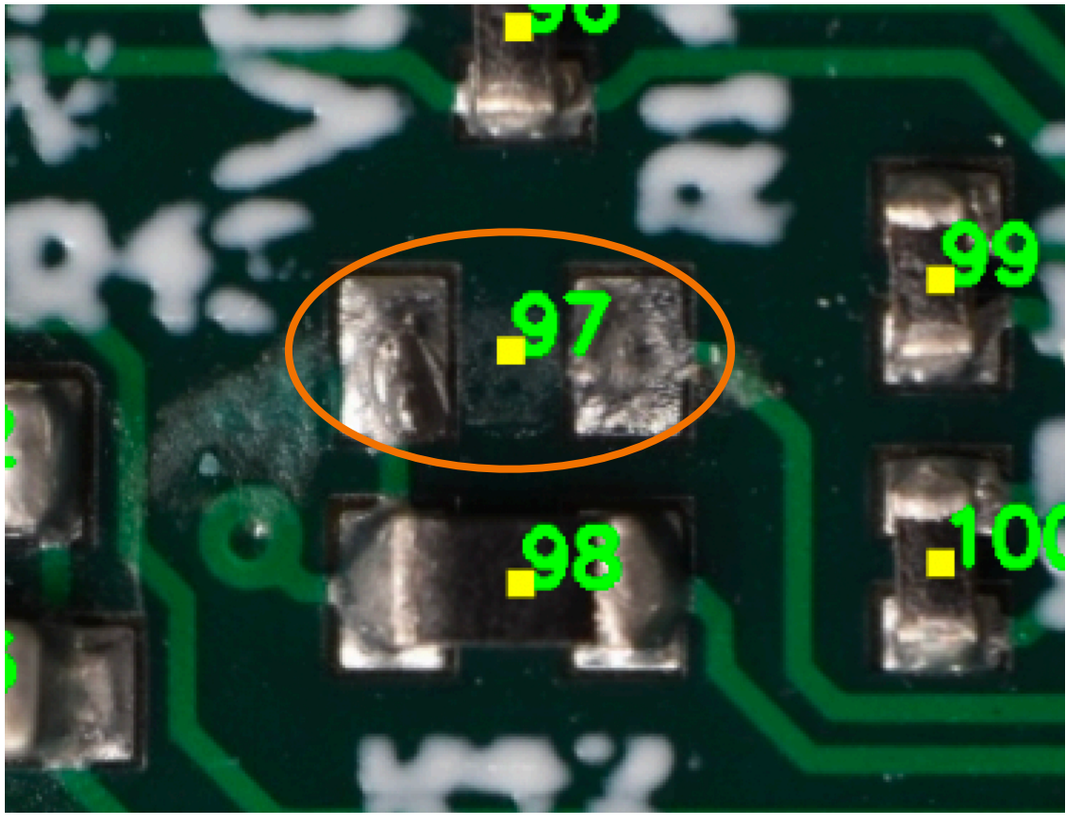
- Failure to classify to PCB
  3/(25×7) = 1.7±1.0 %

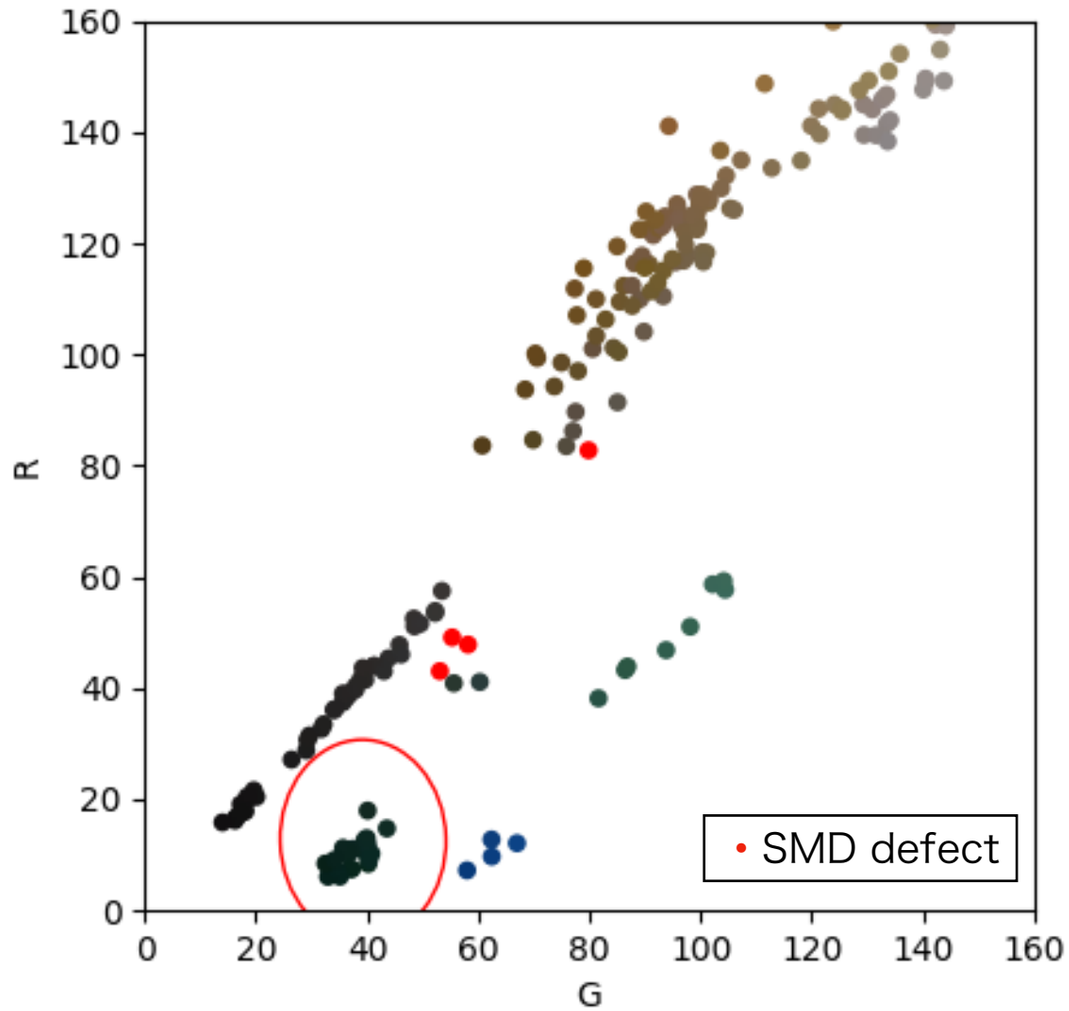
- Failure to classify to SMD
  20/(164×7) = 1.74±0.15 %



Verification with Defects

Missing SMDs cannot be detected if the surface is dirty





Solutions

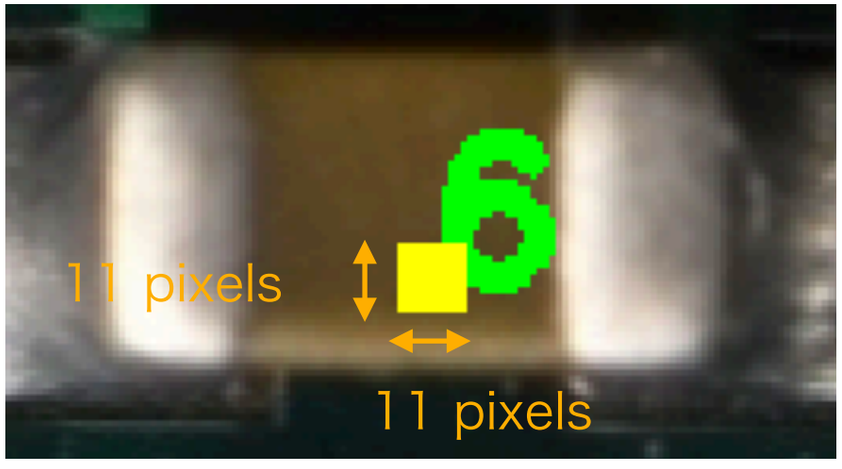
- Check for uneven color distribution in the acquisition area
- Check for deviations from the known SMD color distribution

Color Deviation

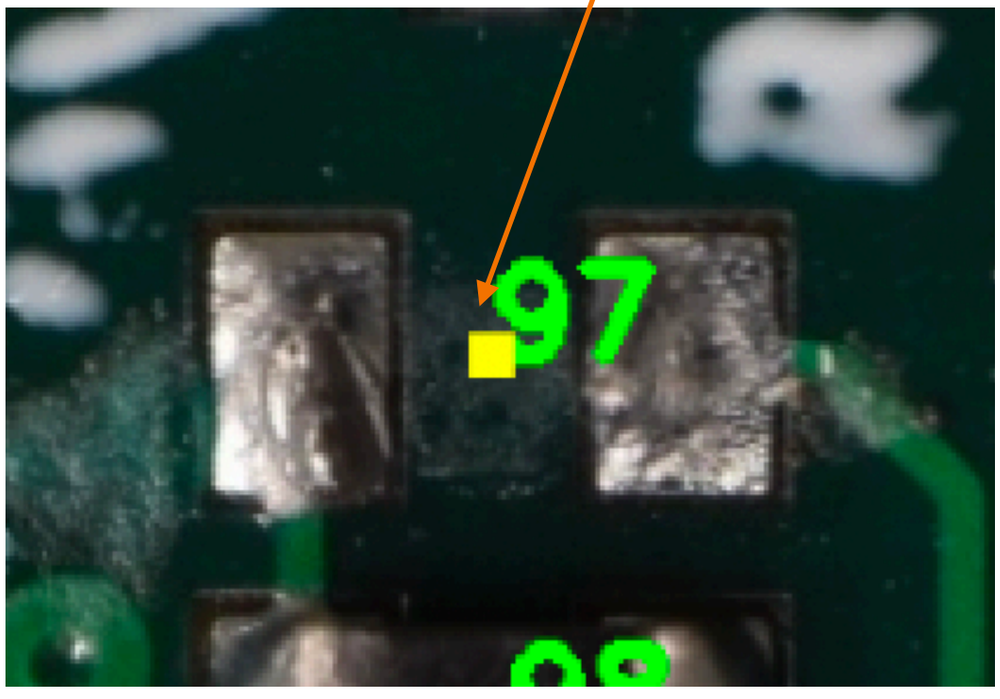
- Get RGB values in range 11x11 pixels and compare with PCB color

- Used only mean RG values

→ Try to use color distribution in the acquisition area



Color unevenness?

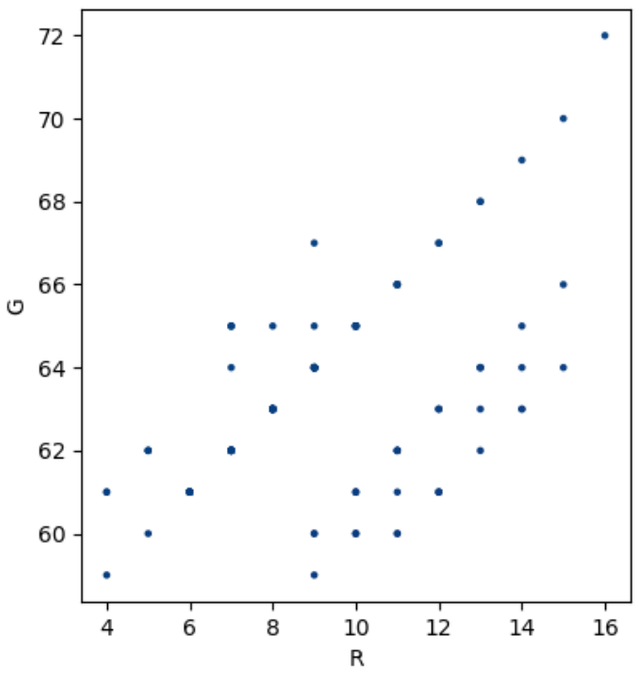


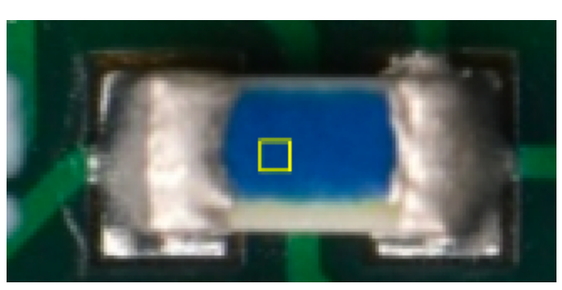
Color Distribution

No.43

dev 2

Clean

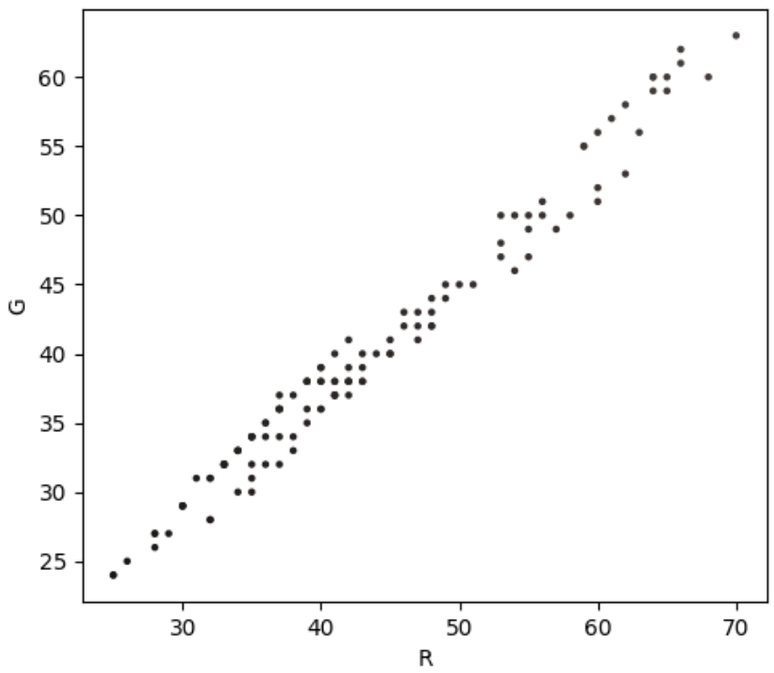


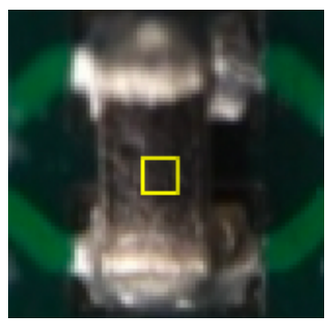


No.96

dev 10

Bumpy

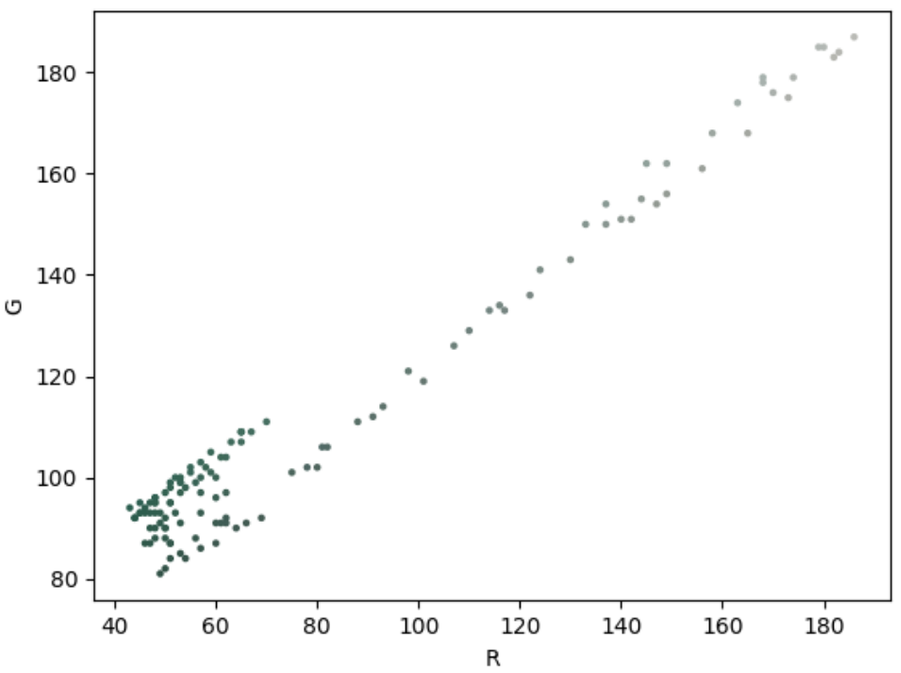


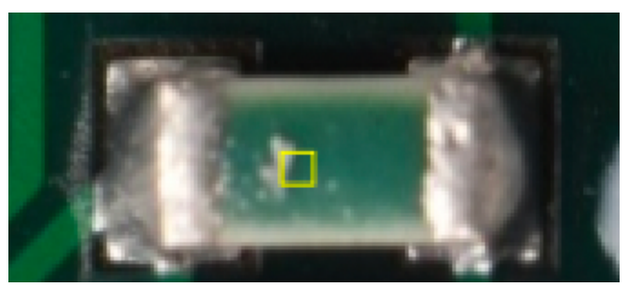


No.45

dev 30~40

Dreg

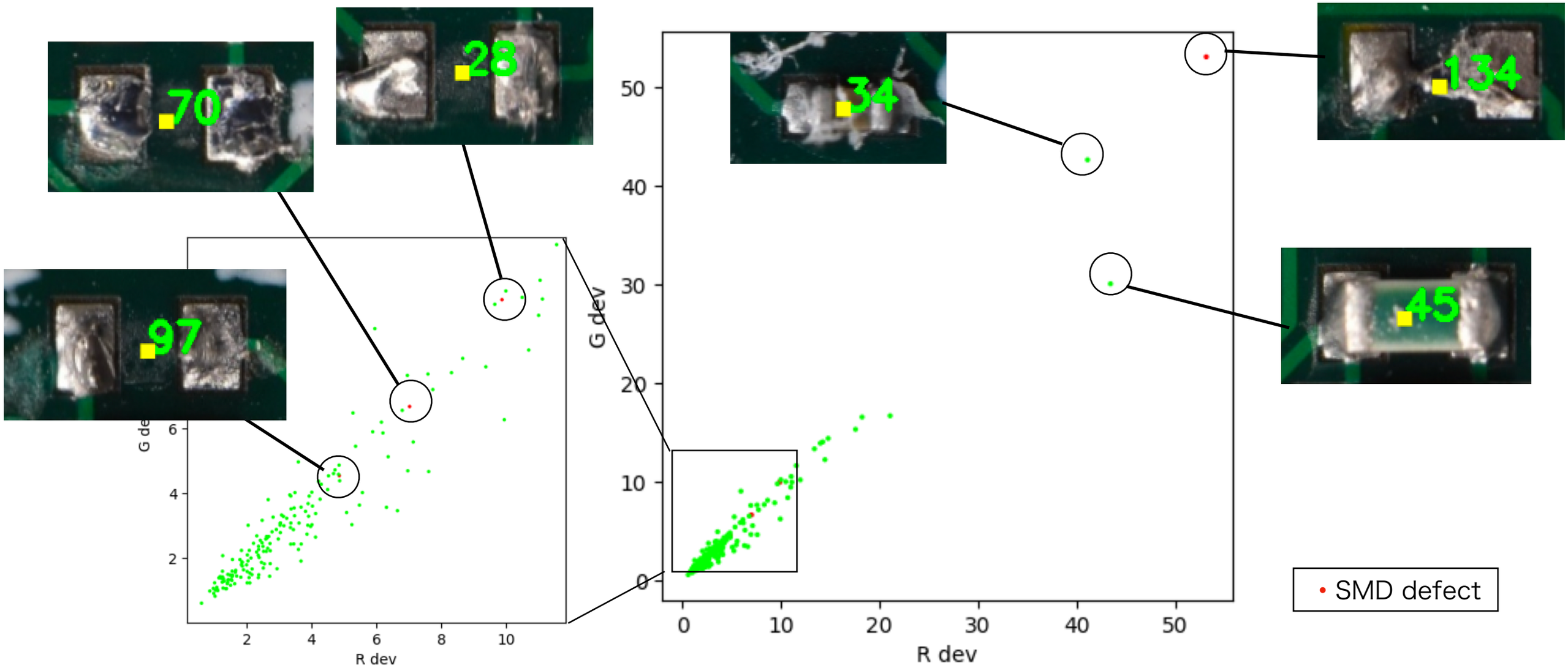




Color Deviation

Tried with the module 4 SMDs missing

→ Couldn't distinguish SMDs and missing points,
but could find dregs on modules



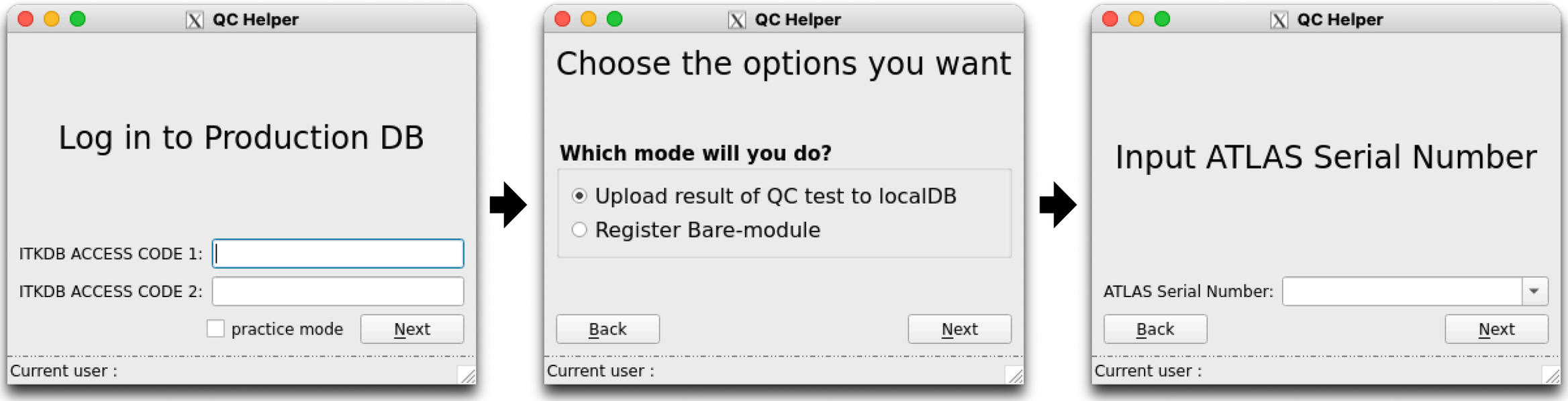
Conclusion

- Will upgrade ATLAS detector for HL-LHC and produce 10000 pixel detectors
- Visual inspection will be performed in each production stage
- To support visual inspection, developing a tool to detect SMD defects

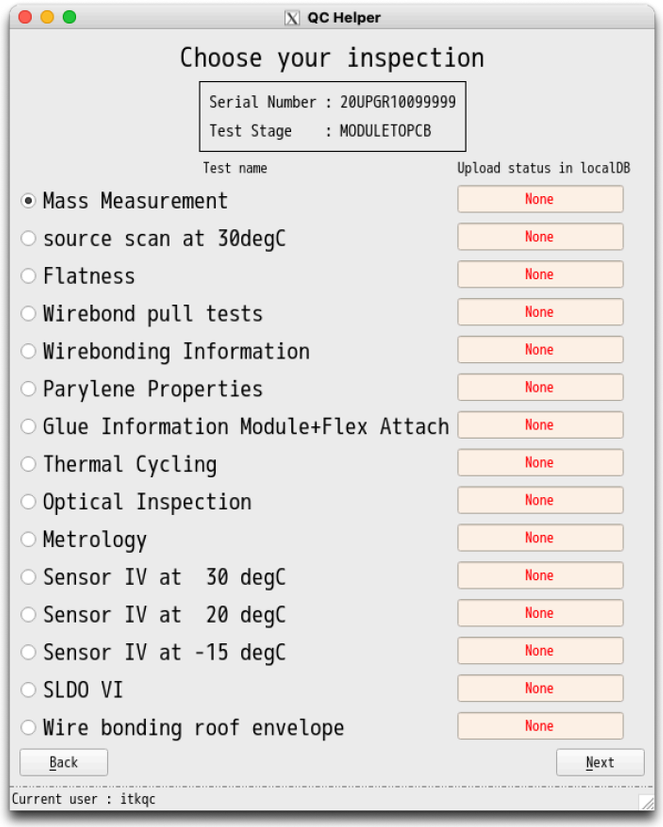
  Surface is clean : can distinguish the PCB color
  Surface is dirty : can't detect SMD defects
  → Now improving

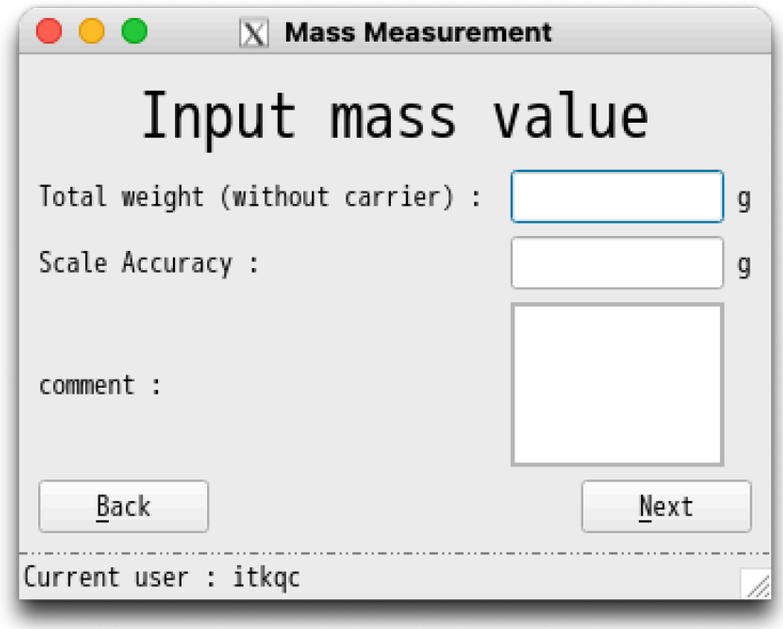
Back up

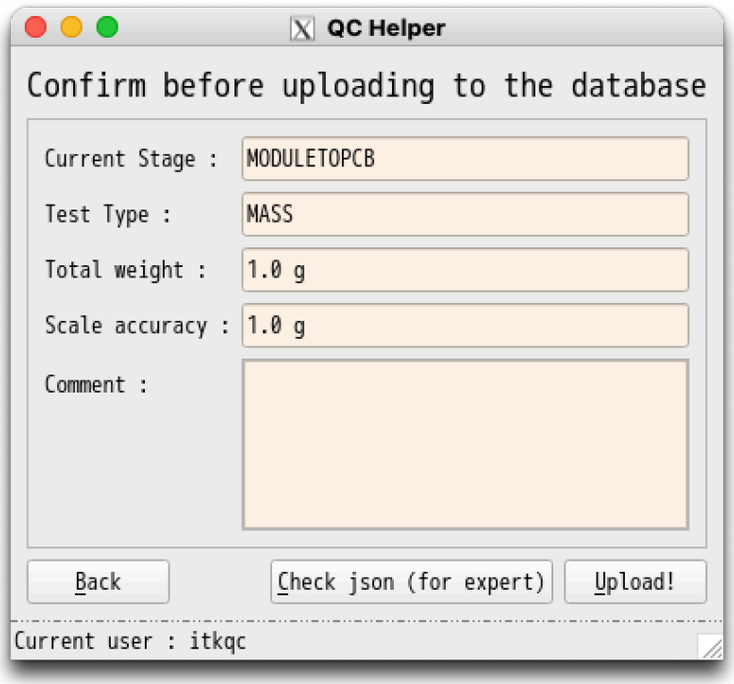
Flow of QC Helper

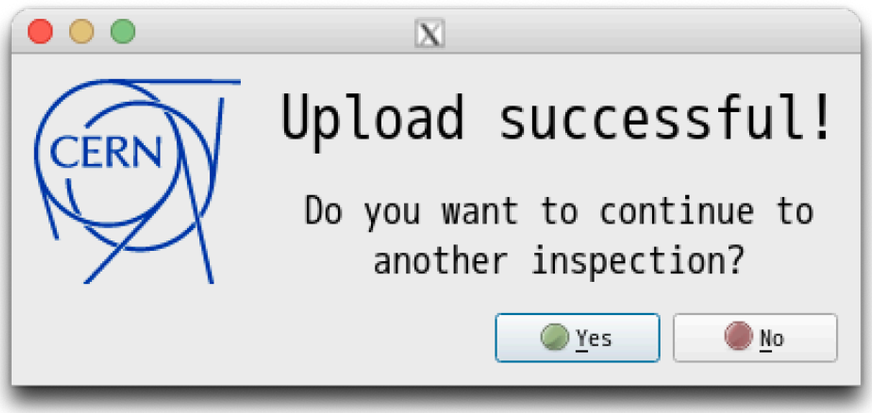


Flow of QC Helper





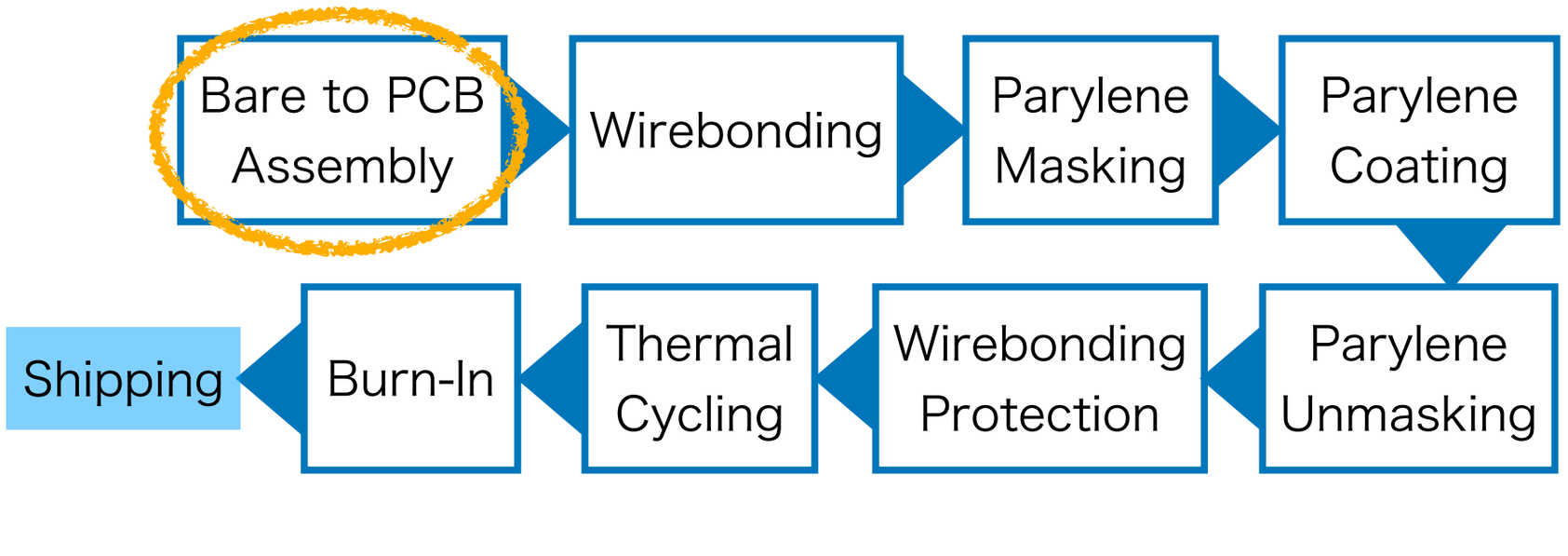


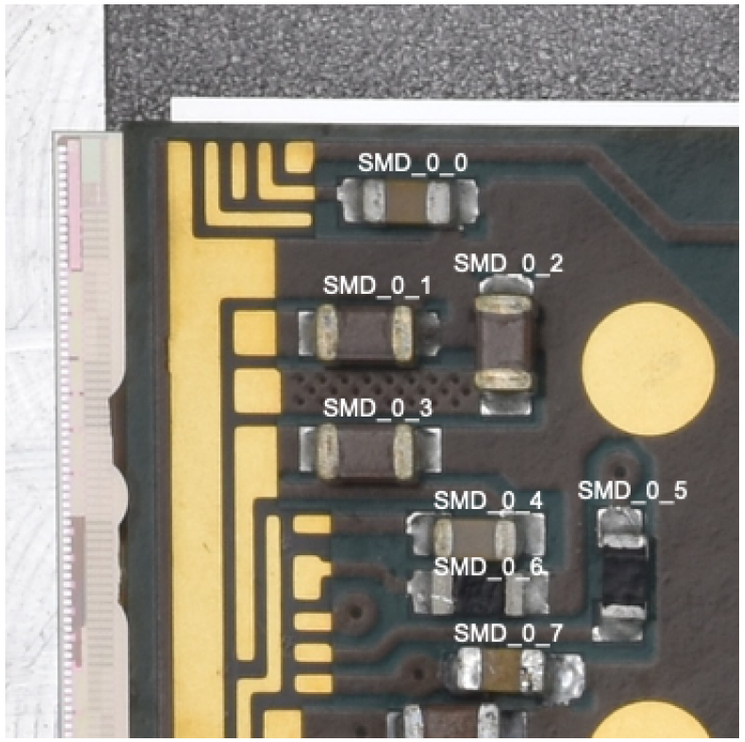


Upgrade of QC Helper

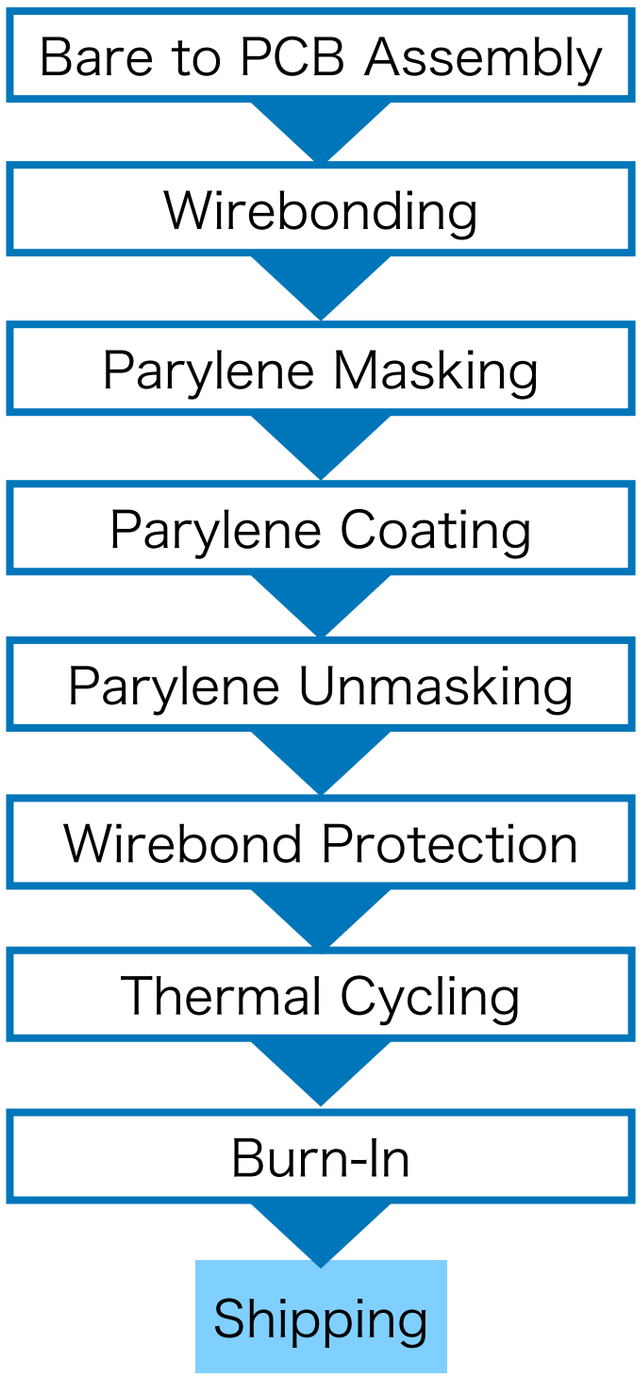
- Only the first stage was supported
  → supported all stages

- SMDs or other components names are written only on ideal images
  → wrote the names also on inspection target images





Support All Stages

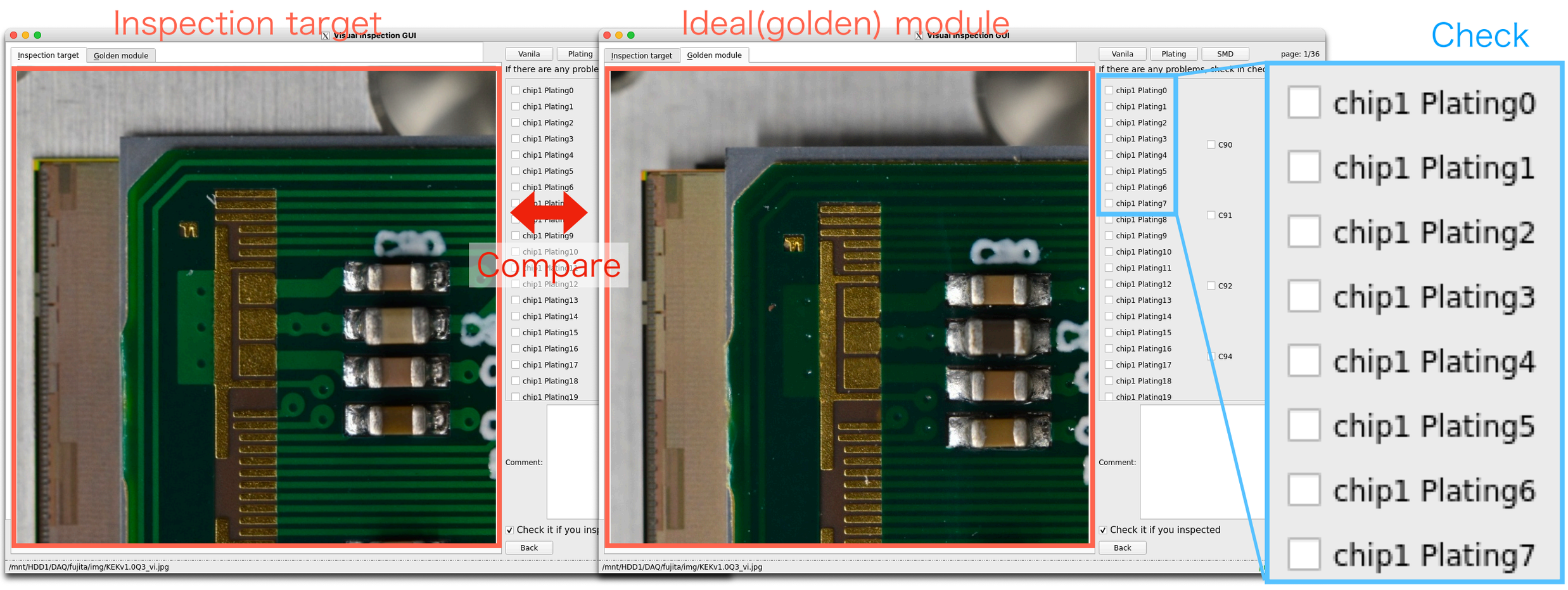


Ideal module image	Checklist
○	○
○	○
Wirebonding	Pass/Fail
Wirebonding	Pass/Fail
○	Pass/Fail
Parylene Unmasking	Pass/Fail
Parylene Unmasking	Pass/Fail
Parylene Unmasking	Pass/Fail

Can inspect in all stages

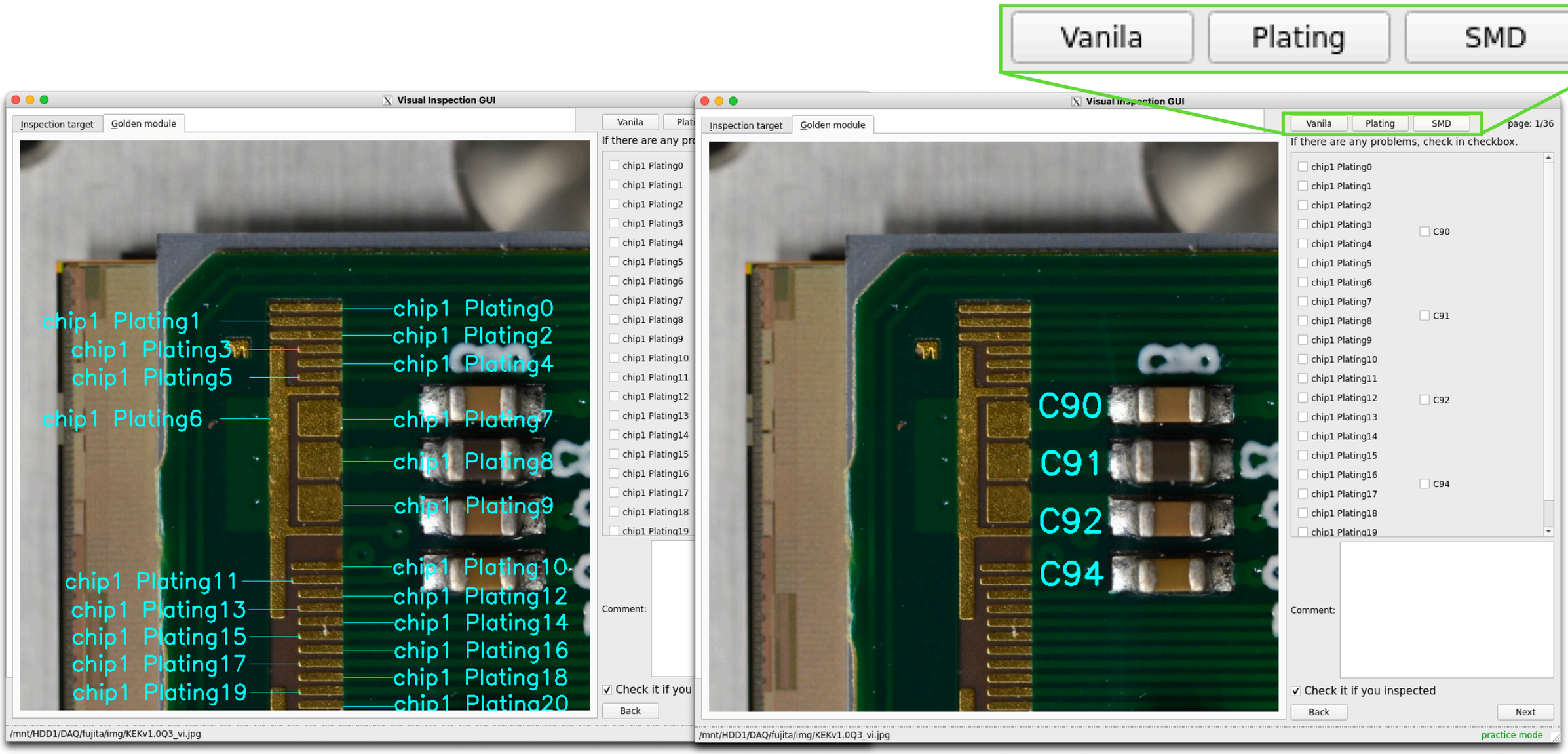
Visual Inspection Tool

- Trim inspection image and split it to 36 tiles
- Compare them with the ideal module image
- Check the checklist if there are any anomalies



Names on Images

- Can see names by pushing buttons



Trimming Images

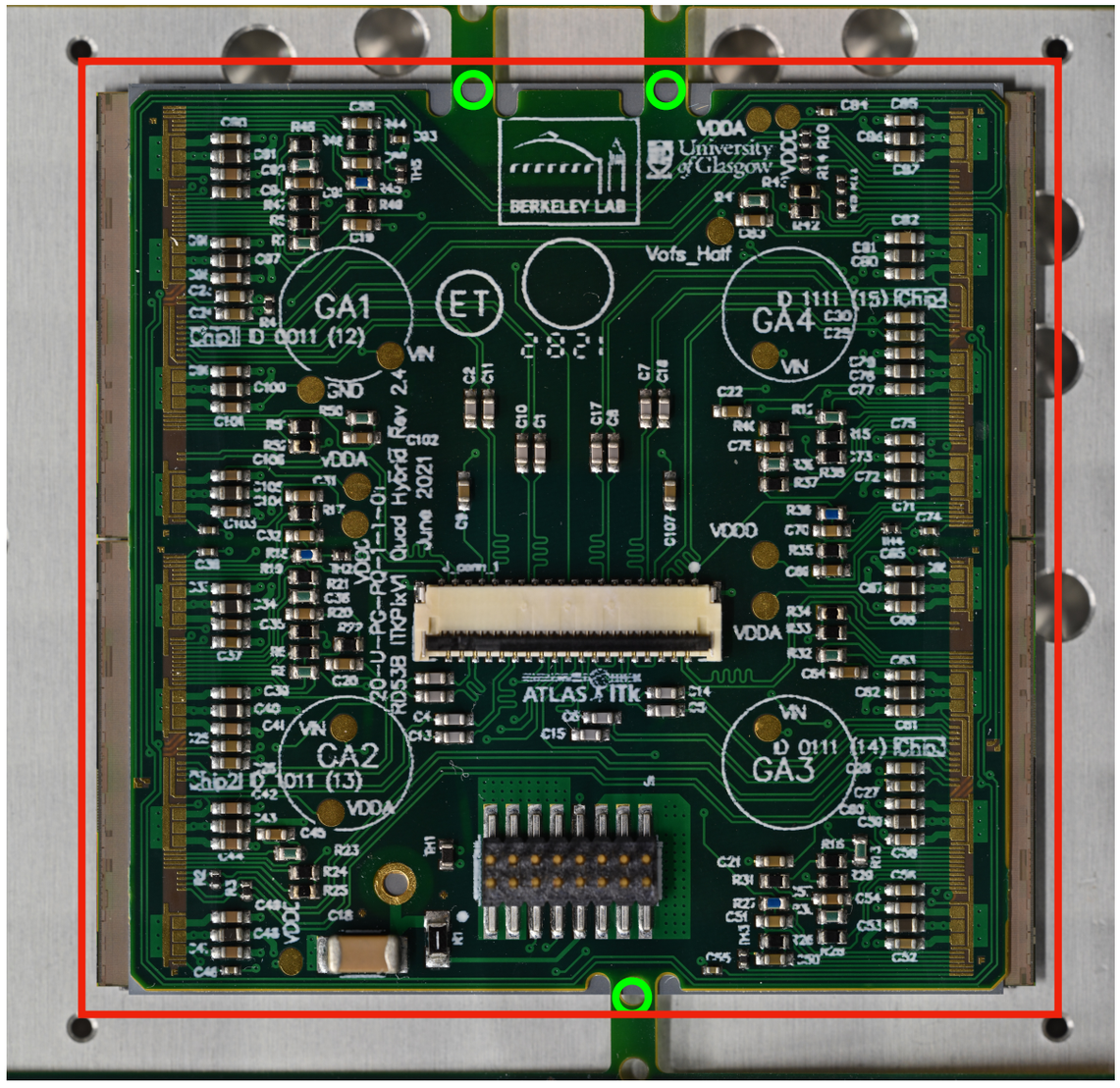
Method

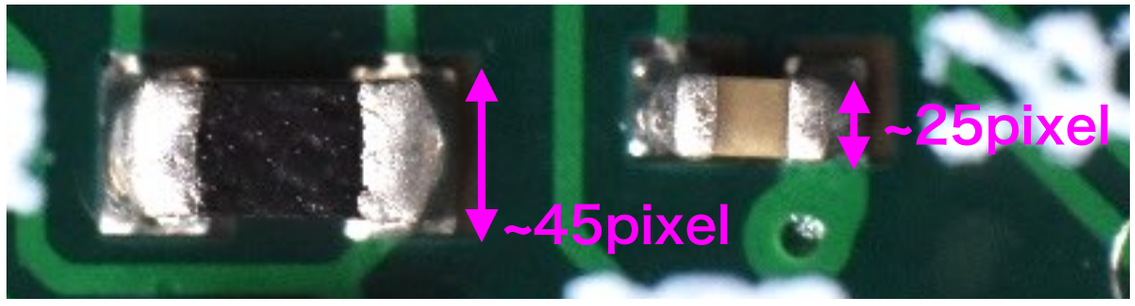
① Get position coordinates of 3 point on the image(○)

② From ① result, calculate the range to trim(□)

- Position accuracy～±5pixel
  ～trimming accuracy
- The size of minimum SMD
  ～25pixel

➡ The range of ±5pixels from the center position of the SMD is the range on the SMD

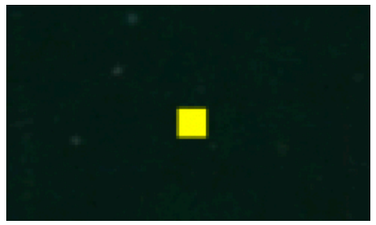




1pixel～10μm

Acquisition RBG Values

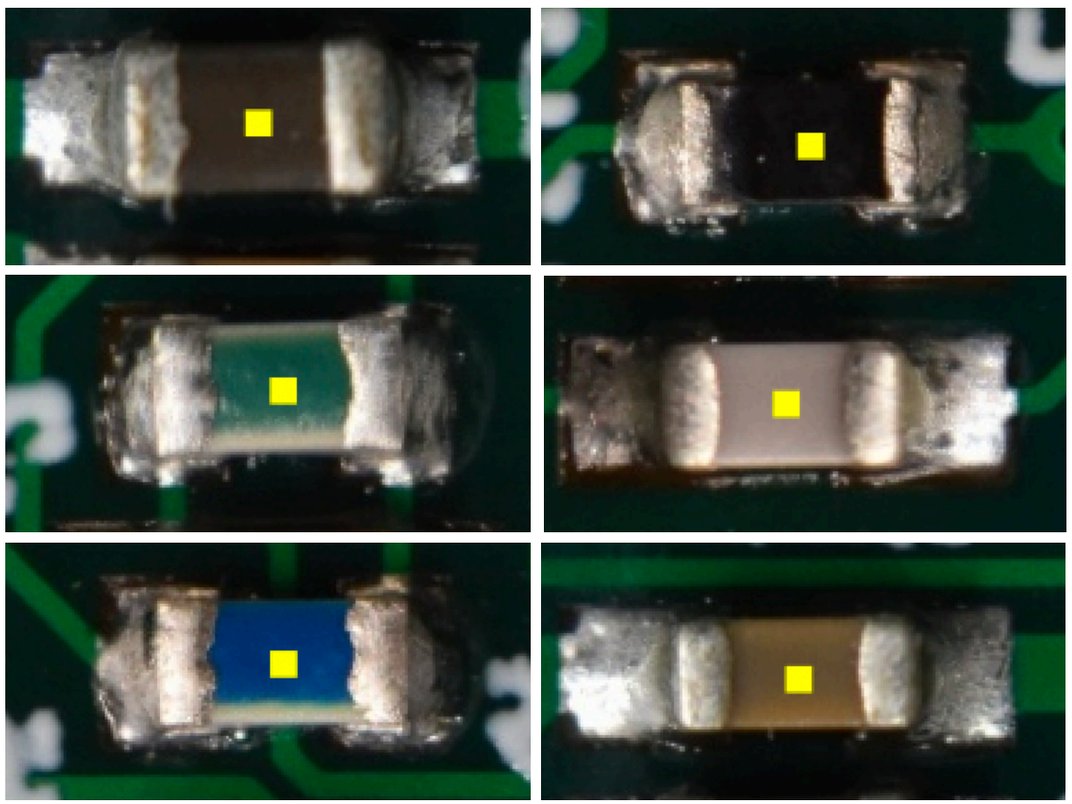
- Get the average of RGB values of SMD center 11×11pixels
- Get PCB color of 25 location as well

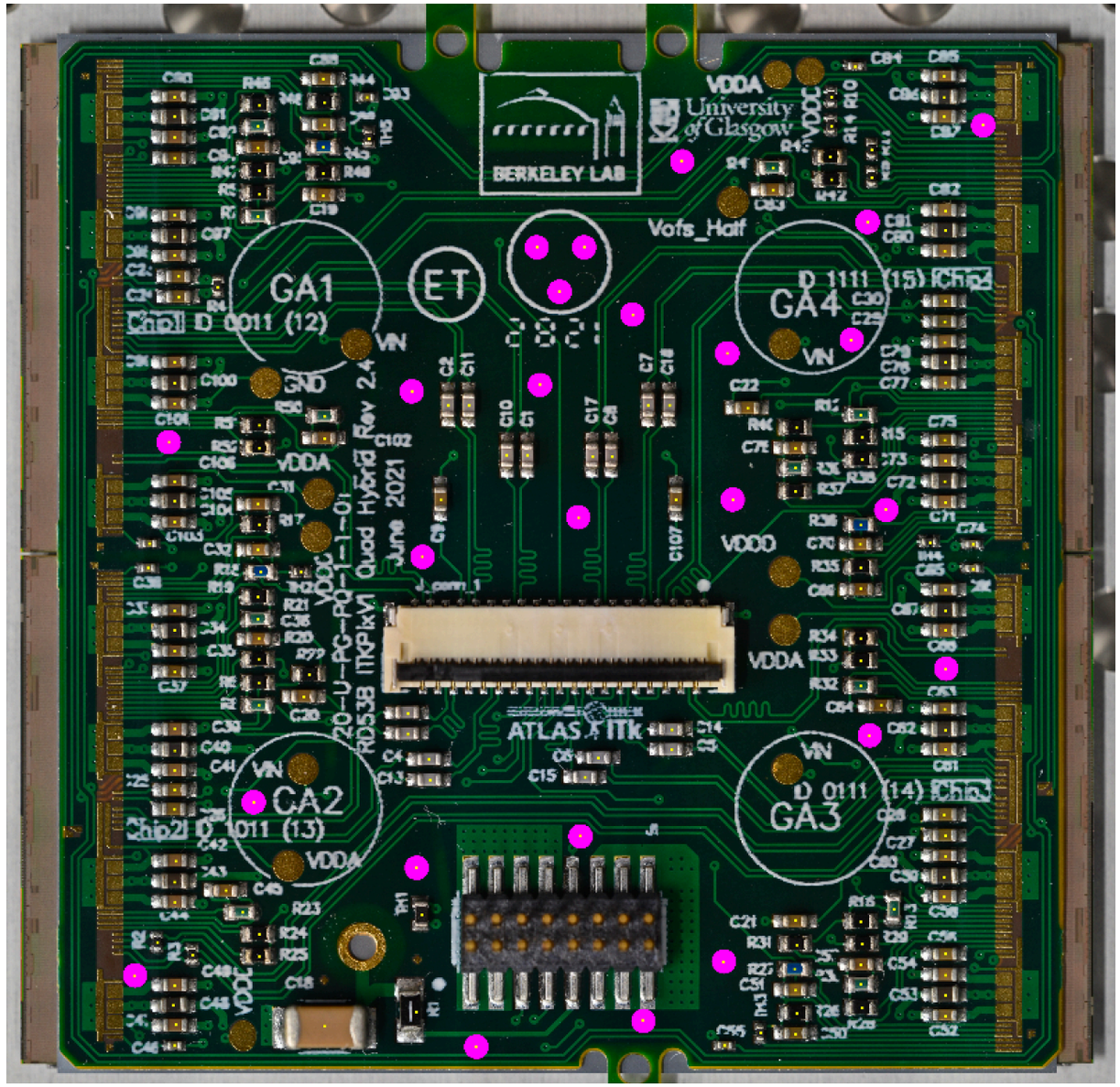


PCB

range of acquisition

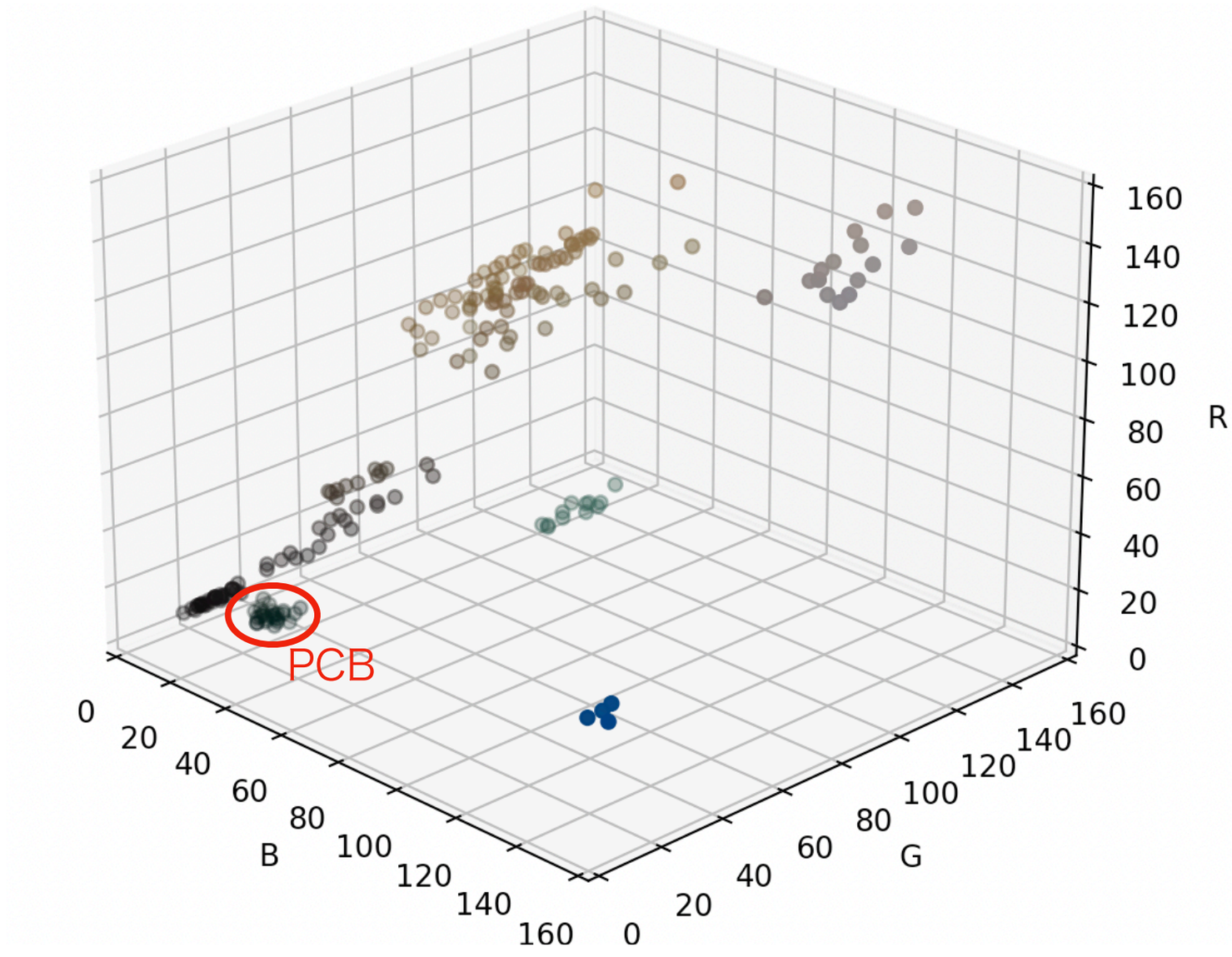
SMD





Acquisition RBG Values

- Got RBG values of each SMD and PCB(25 location)
- Distinguished the points that have the same color with PCB from this



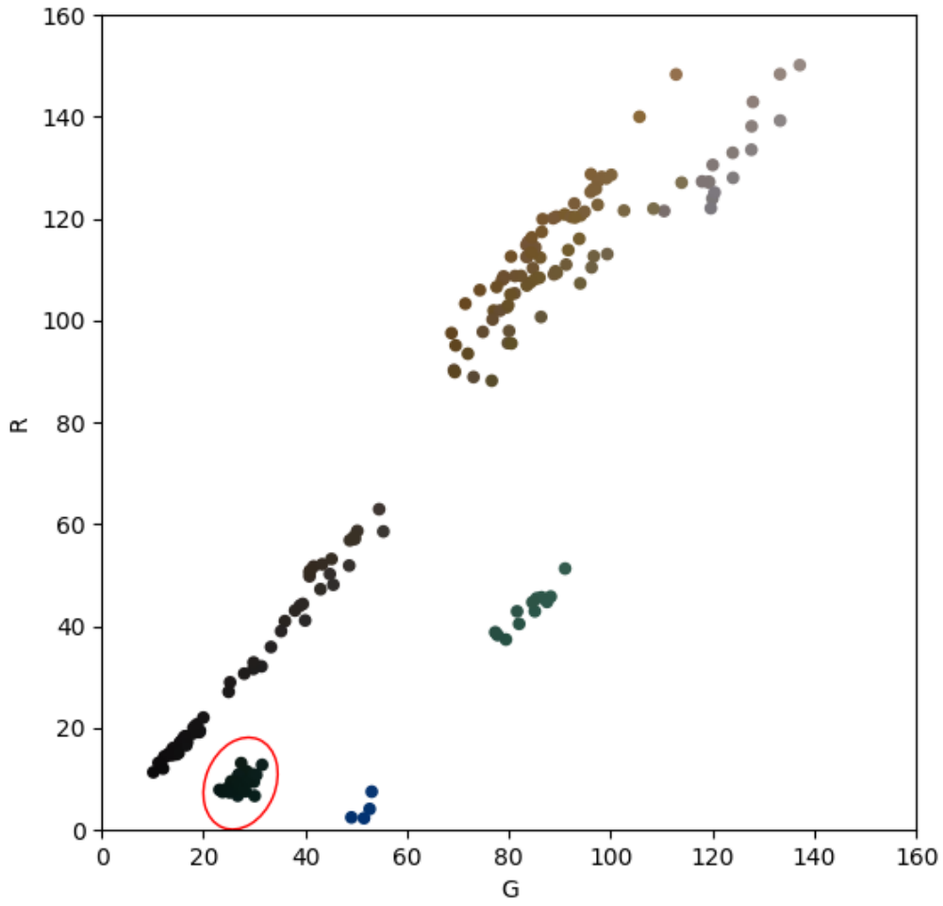
Distinction of PCB Color

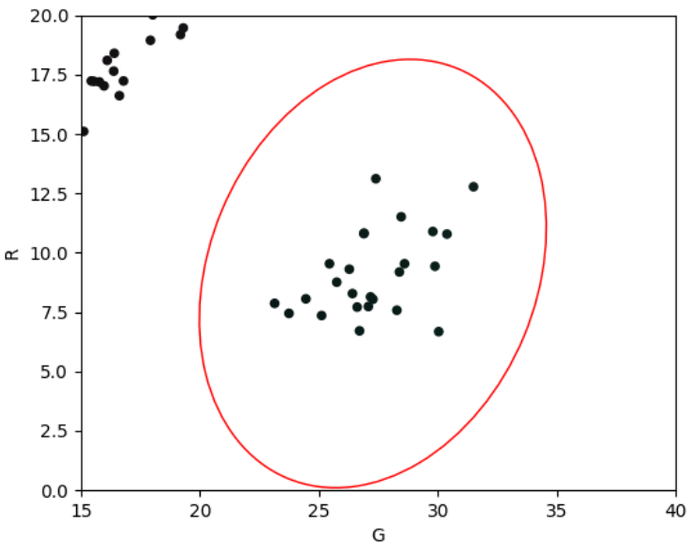
Distinguished the PCB color using 2 values, R and G

① Calculate average, deviation and correlation coefficient of R and G of PCB color

② Assume two-dimensional normal distribution, and calculate the ellipse that 99% of the time the point will fit inside

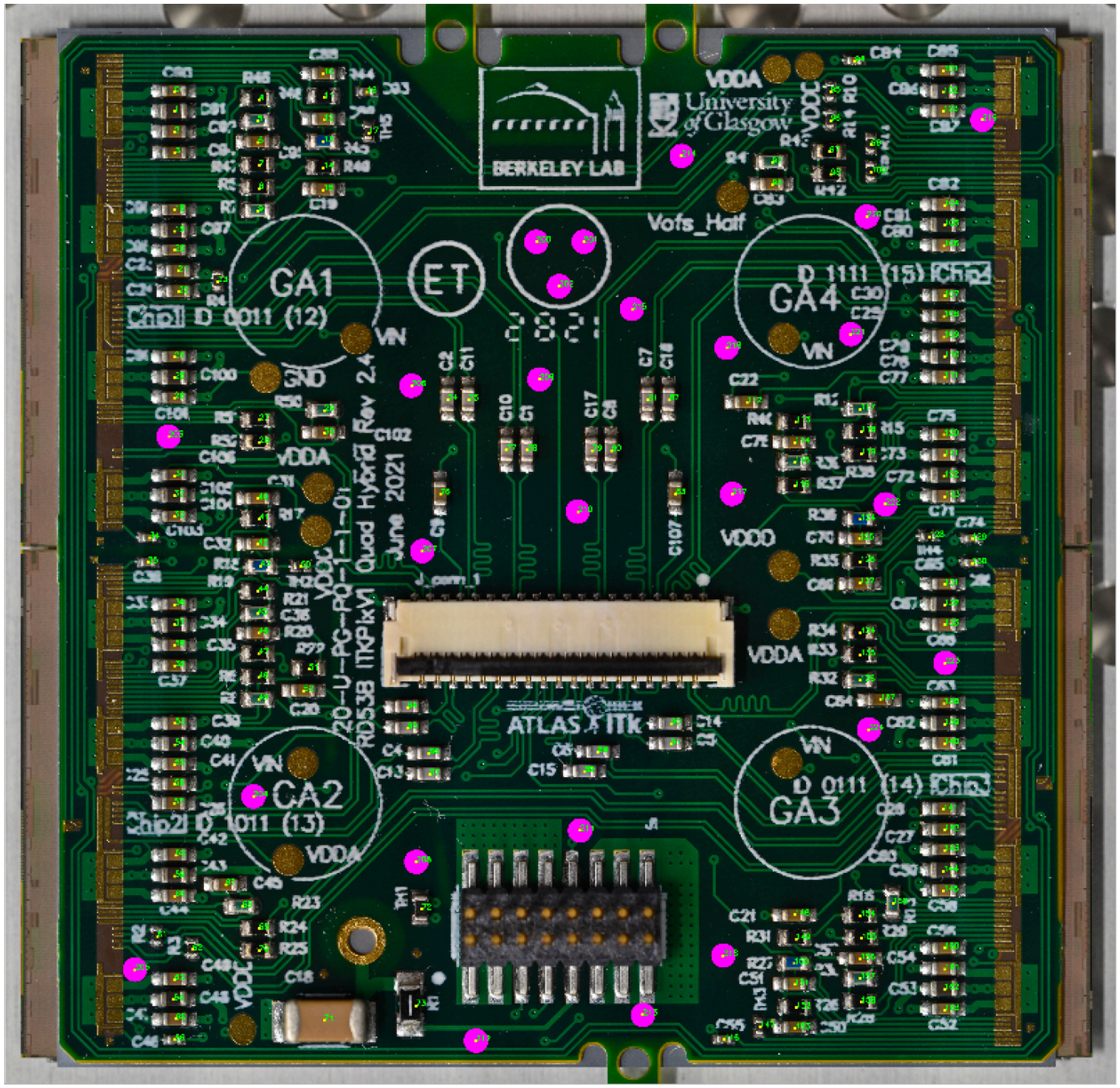
③ To prevent to overlook the same color as PCB(=defect), judge points that fit within an ellipse twice the size of ② to be the PCB color





Check in the Original Image

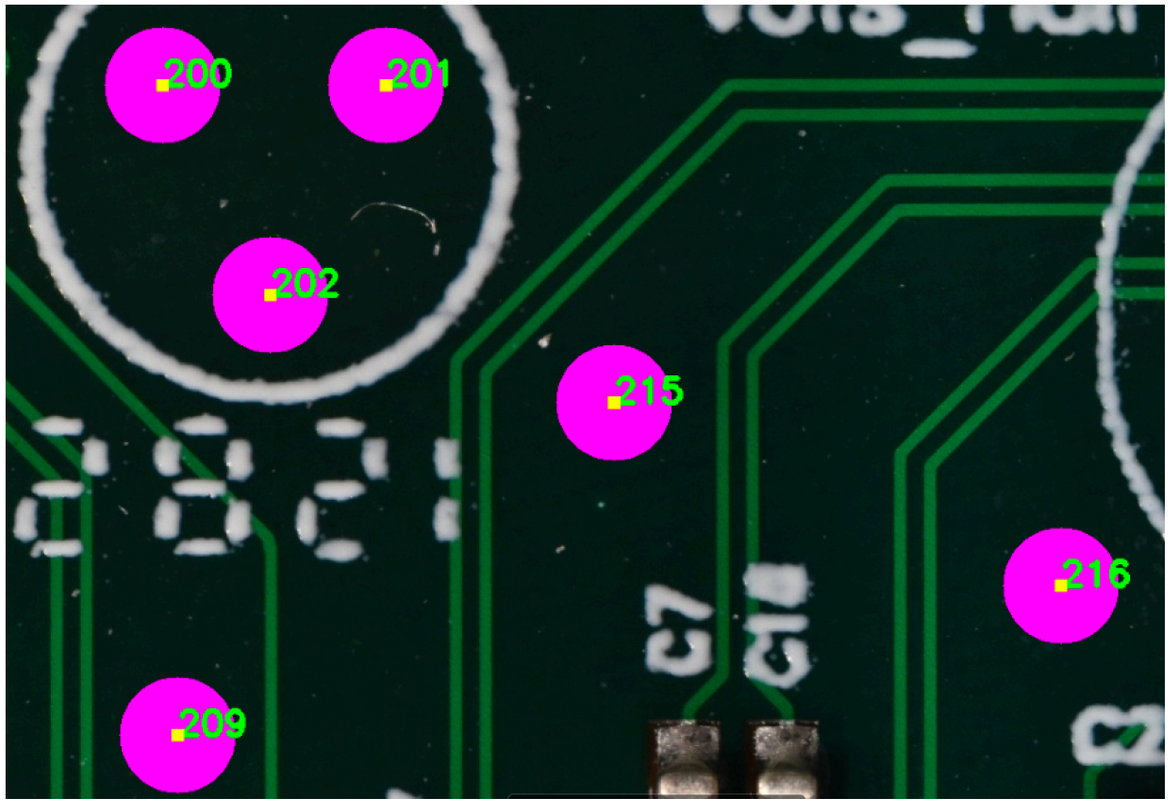
Could highlight the 25 points that were used for PCB color

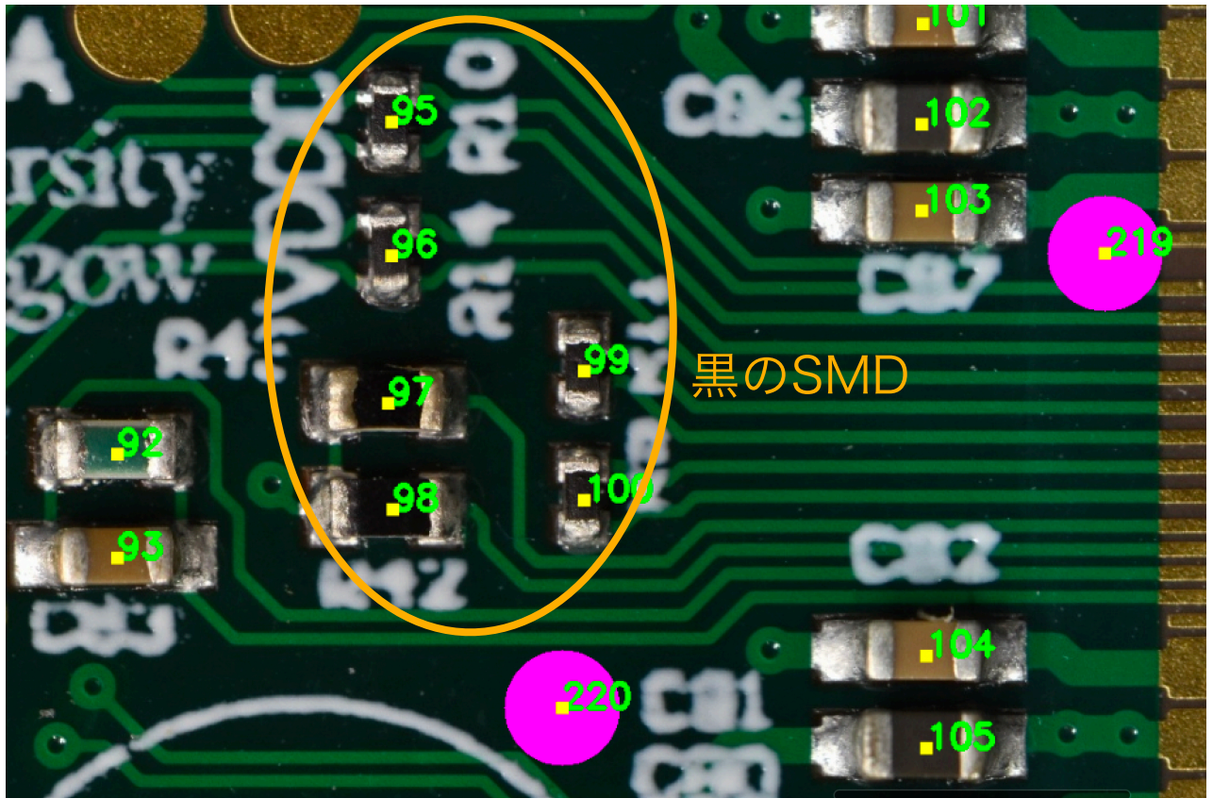


● highlight position

Check in the Original Image

The black(close to PCB color) SMDs are not highlighted
→ Can distinguish from PCB

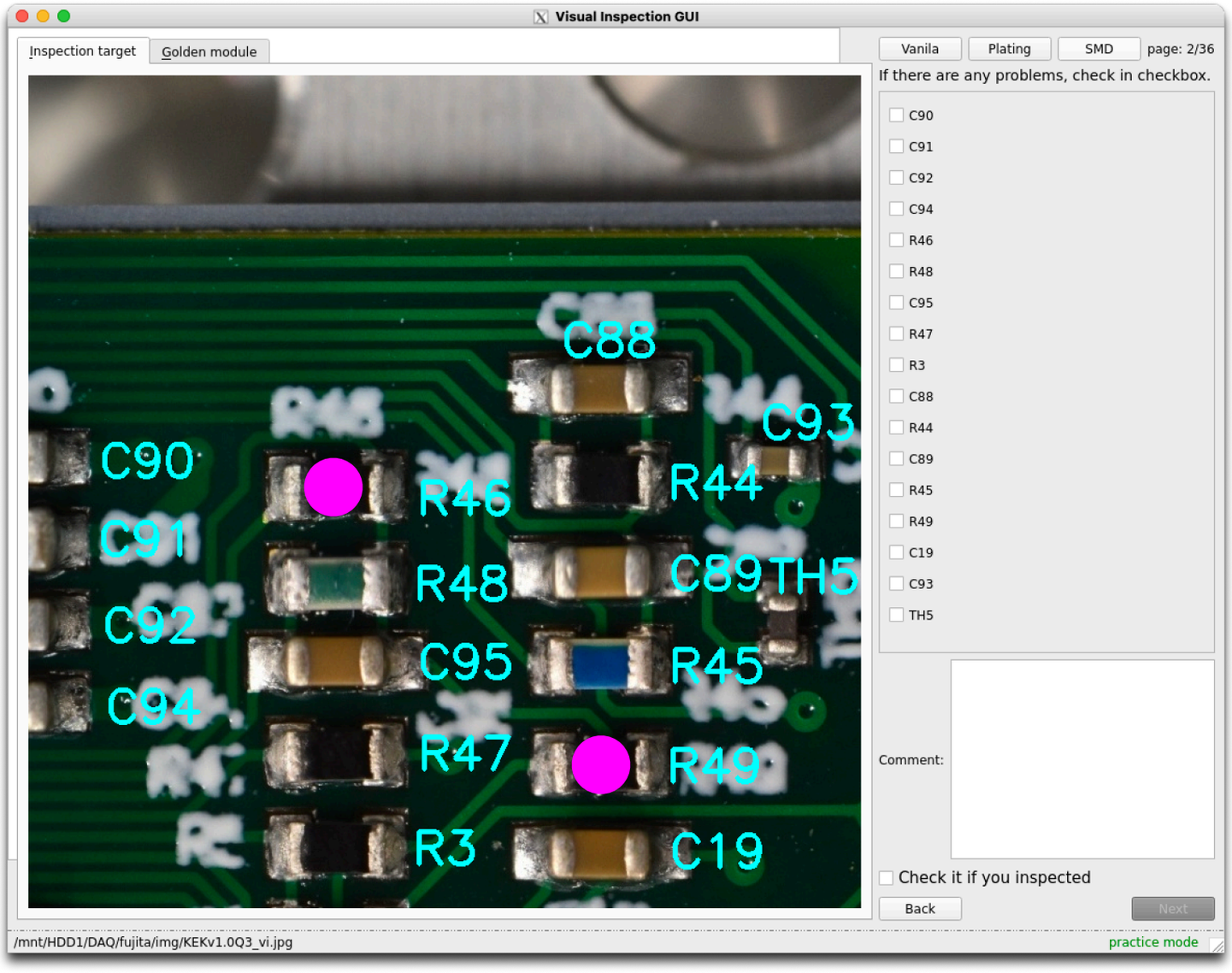




Implementation in QC Helper

Will implement SMD defect detection function in QC Helper

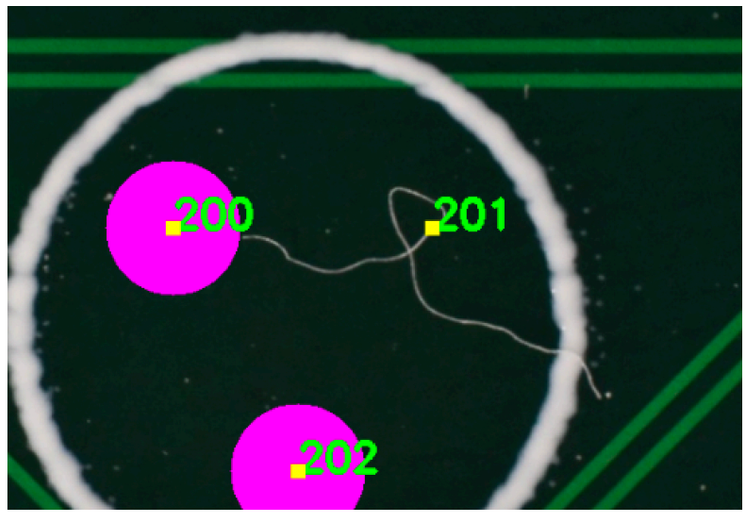
→ Will prevent user overlook and increases inspection accuracy and efficiency



Classification Failures

Failure to classify to PCB

- Got the color of dust on PCB

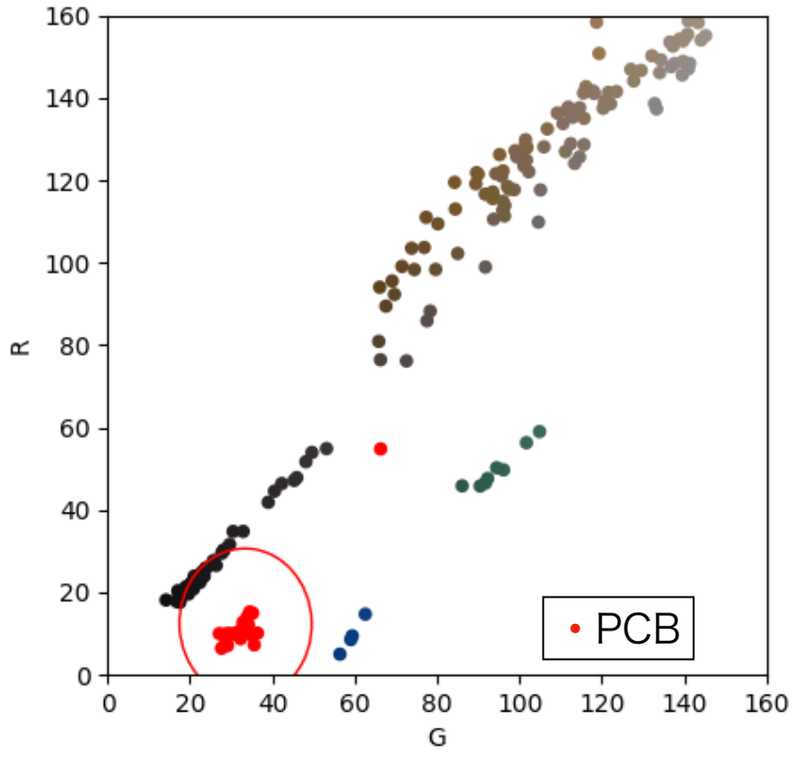


Solution

Check for abrupt change in RGB values within the acquisition range

Failure to classify to SMD

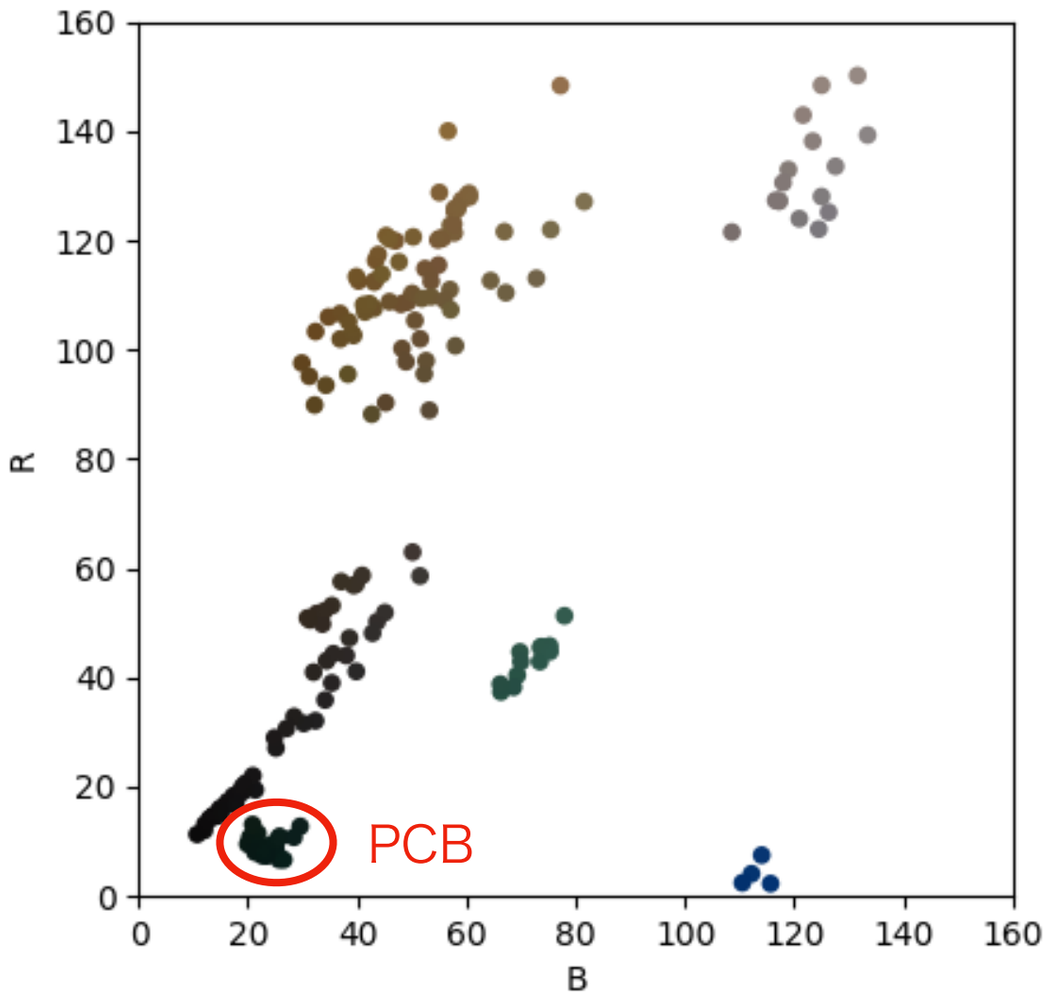
- The PCB point at large outliers makes the PCB range larger



Plot Using B Value

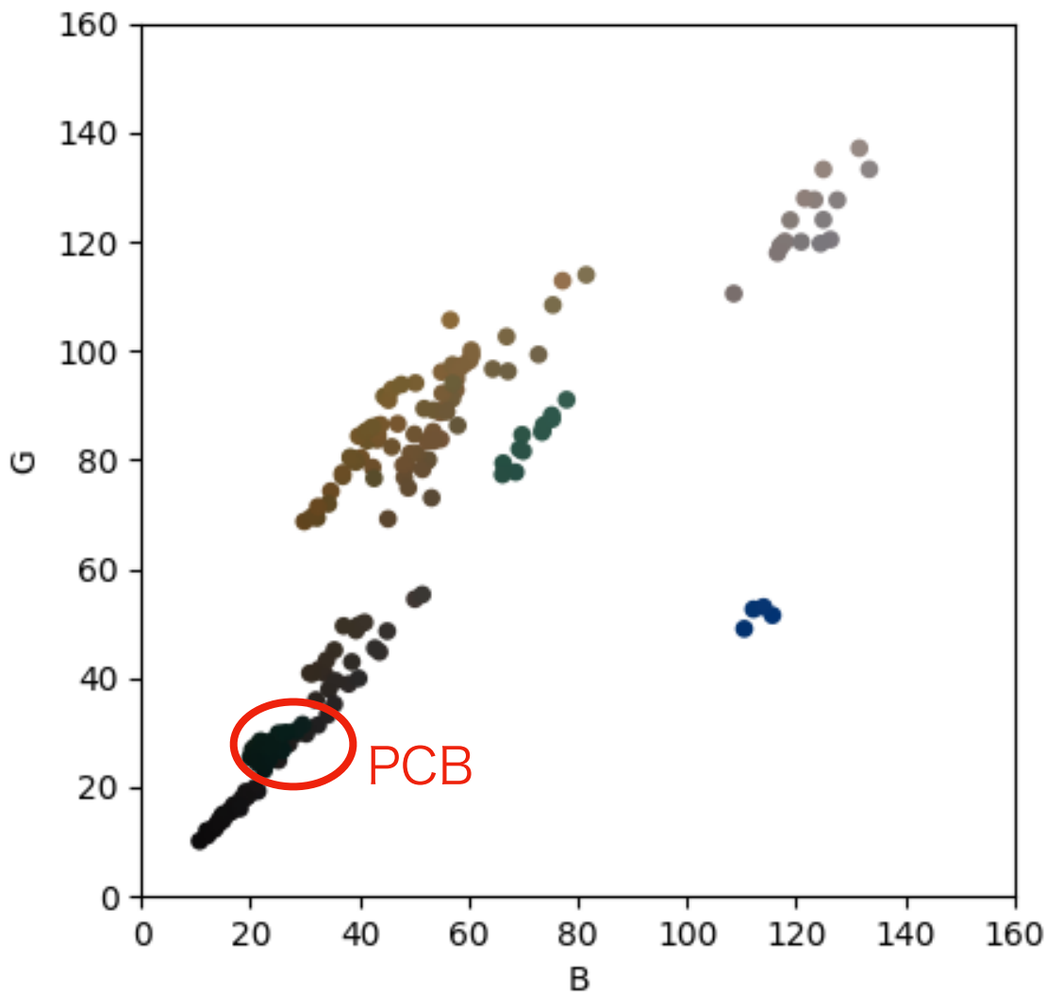
RB

- Should be able to distinguish the PCB color



GB

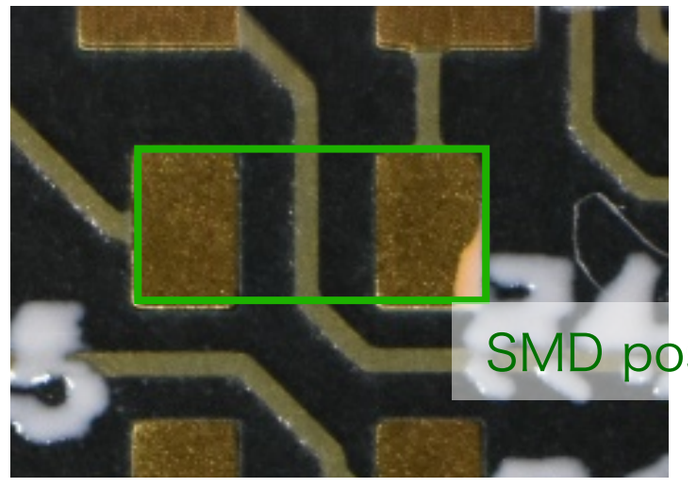
- Can’t distinguish the colors



Future Outlook

Another problem

- There are some lines under SMDs
  → will solve by registering the line color and checking color distribution



To do

- Verify with different colors PCBs and final version ones
- Implement SMD detection function in QC Helper