第九届中国LHC物理年会
The 9th China LHC Physics Workshop

Computing vision QC in HGCal production

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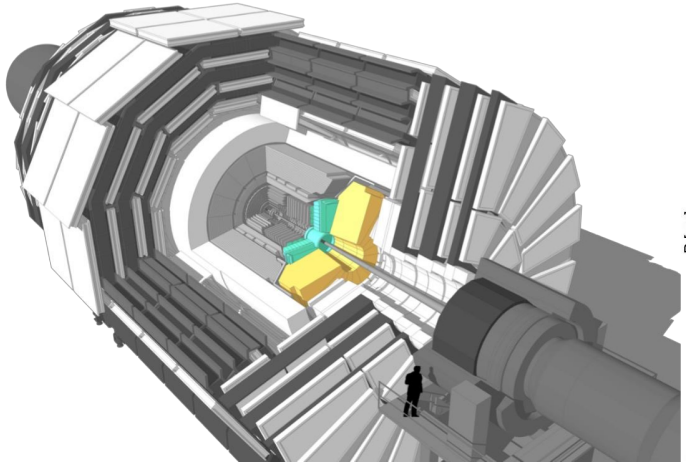
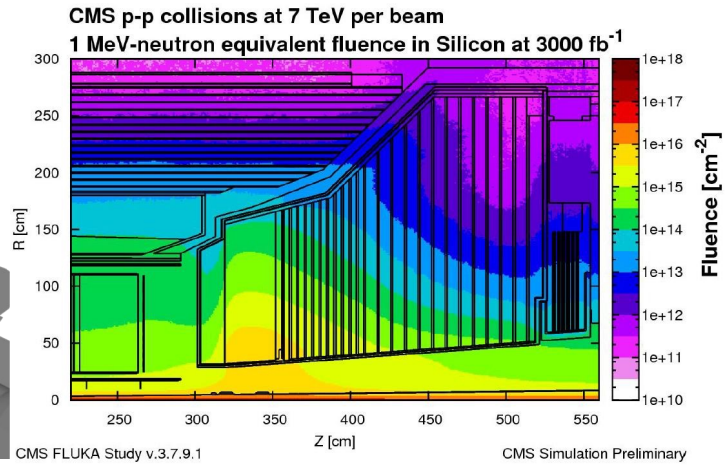
On behalf of CMS-HGCal IHEP group
2023-11-17

CMS HGCal project

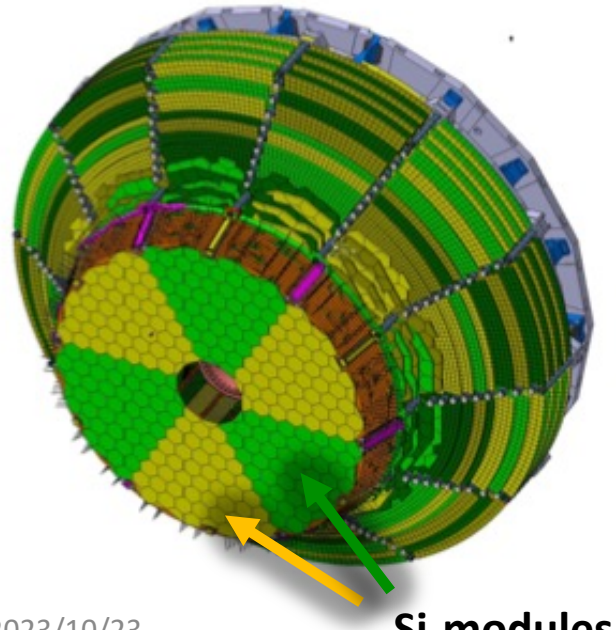
More details in Feng, Taozhe & Xiao's talks



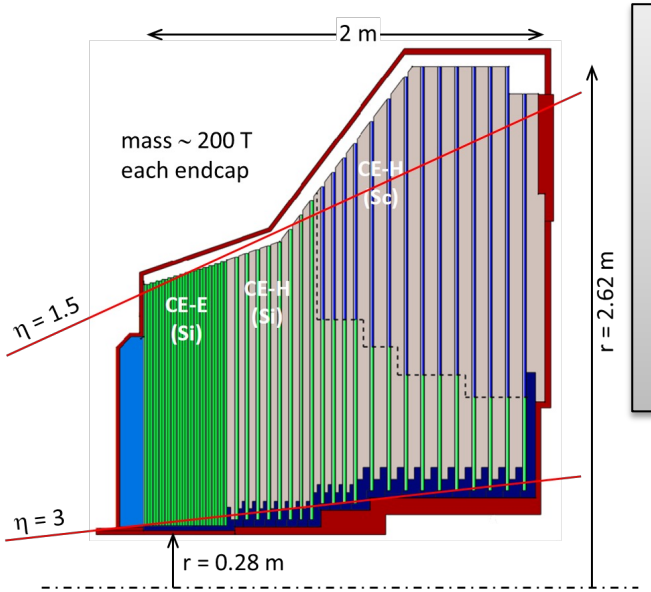


CMS endcap calorimeters: Phase-2 upgrade

- Harsh environment @ HL-LHC:
  pile-up ↑, radiation level ↑
- A new endcap calorimeters to be constructed
  - High Granularity Calorimeter: HGCal



Si-modules



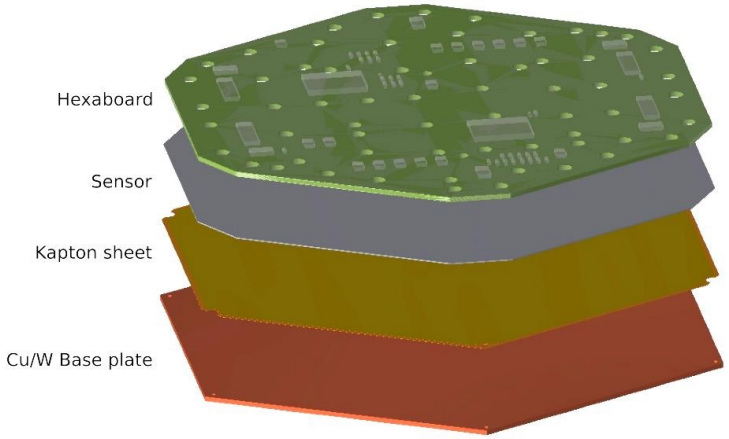
Key parameters

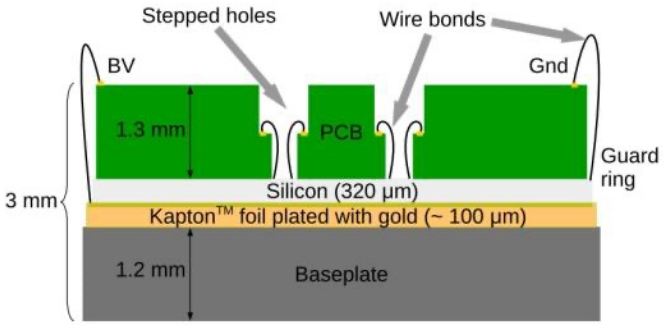
- Coverage 1.5<η<3.0
- Operation @ -30°C
- ~640 m^2 silicon sensors + ~370 m^2 scintillator tiles
  ⇒ 31k Si-modules including spares
- 6.1M silicon channels: 0.5 or 1.1 cm^2 cell size
  + 240K scintillator-tile-SiPM channels

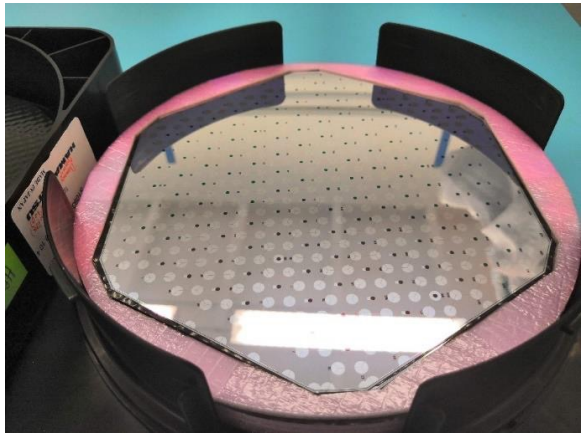
IHEP: focus on silicon modules

- One of Module Assembly Center (MAC), total 6 MACs world wide

Silicon modules







HGCal: ~31K silicon modules

- Module assembly chain established

Vision QC in module assembly

- Sensor: scratches lead to potential damage
- Wire-bonding: multiple wires at the same pad ↔ cell, single bad wire barely detected by electronic tests
- Encapsulation: glue on wire-bonds for better mechanical stability, QC needed for the glue dispensing

Automatic vision QC on silicon sensor

Visual inspection via microscope

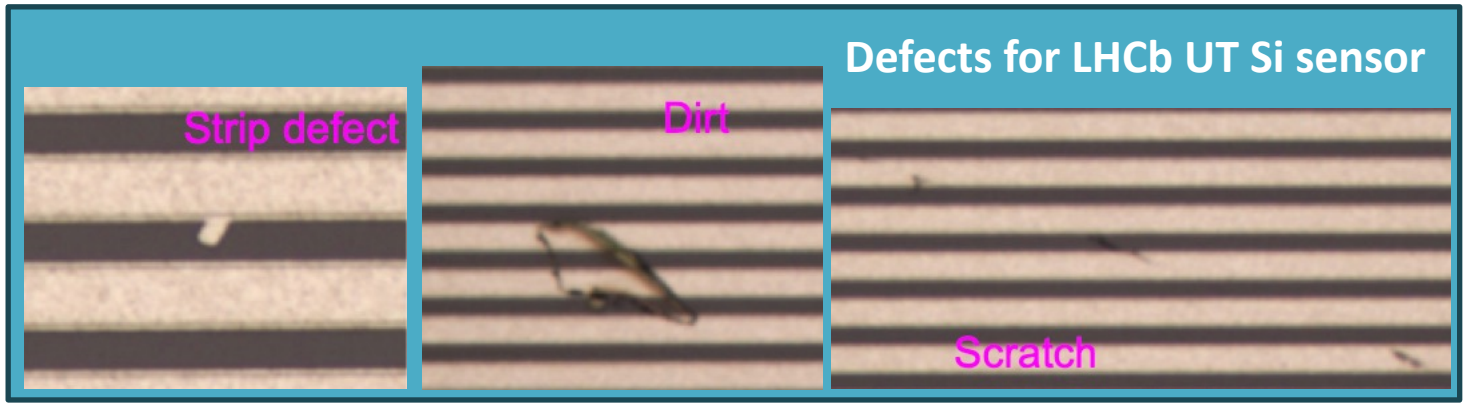
- Traditional manual inspection: huge manpower + low efficiency

An automatic visual inspection method needed

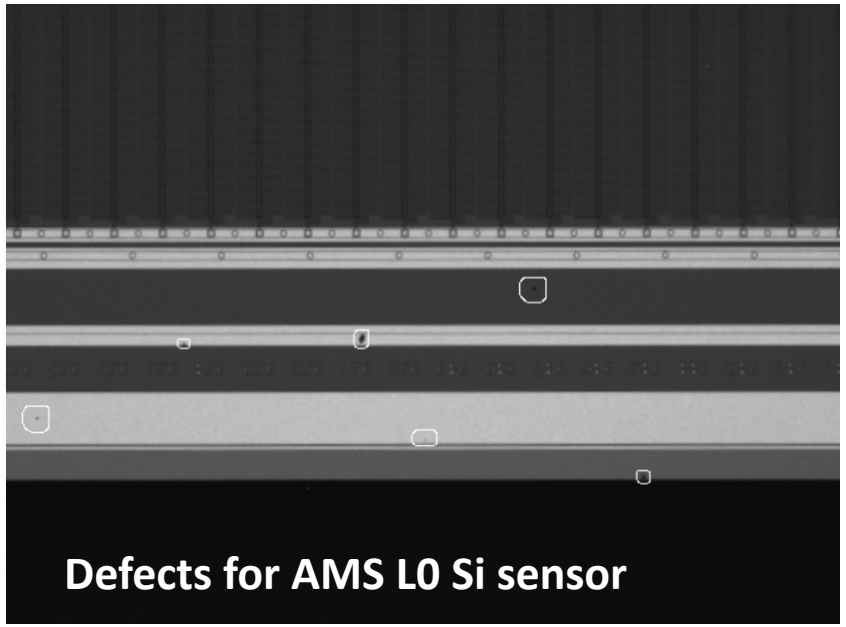
- Firstly developed for LHCb UT silicon strip sensor QC (2016-2018)
- Based on OpenCV package

See the presentation in *Forum on Tracking Detector Mechanics 2019*, https://indico.cern.ch/event/775863/contributions/3416994/

- Updated algorithms for AMS L0 detector. More pixels, more complicated feature, thinner strip line… => but better performance



Can we port this method onto HGCal?



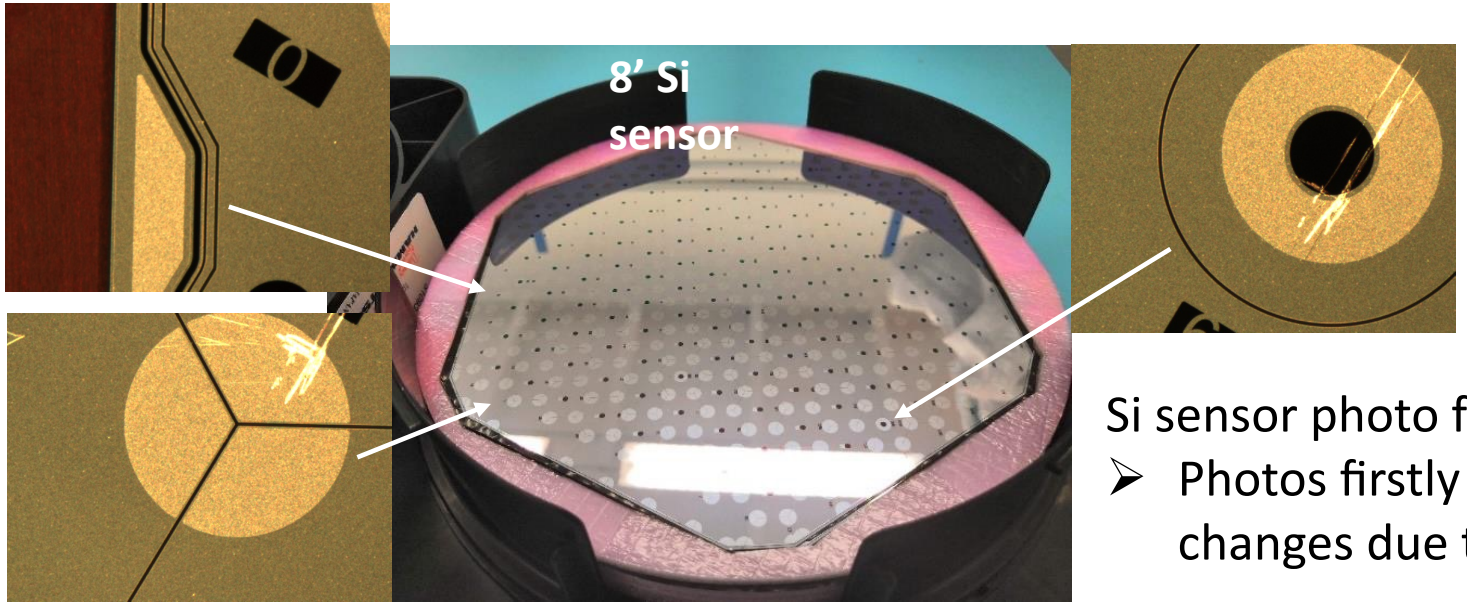
Automatic vision QC on HGCal Si sensor

Currently we focus on defects searching on 8” silicon sensor

- Vision QC for wire-bonding & encapsulation to be done soon later

OGP ZIP 635 shooting for micro photos

- $\mathcal{O}(10^2)$ micro photos in ~0.5h, only for bonding pad areas



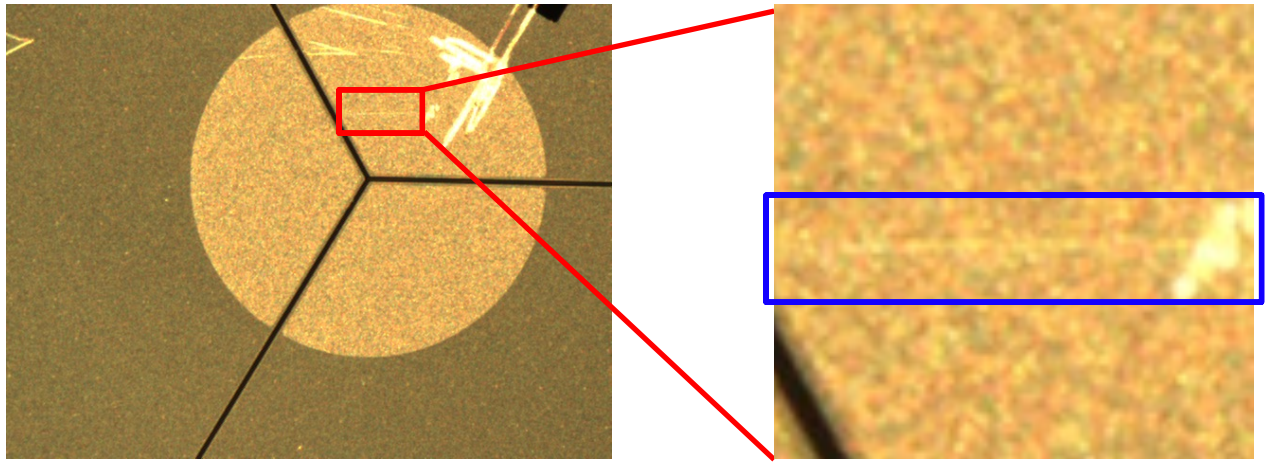
Si sensor photo features very different along the position

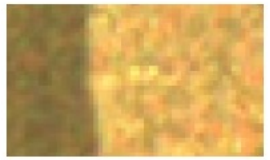
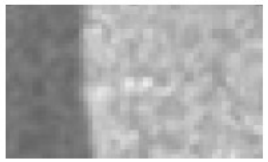
- Photos firstly categorized, processing software with minimal changes due to their features

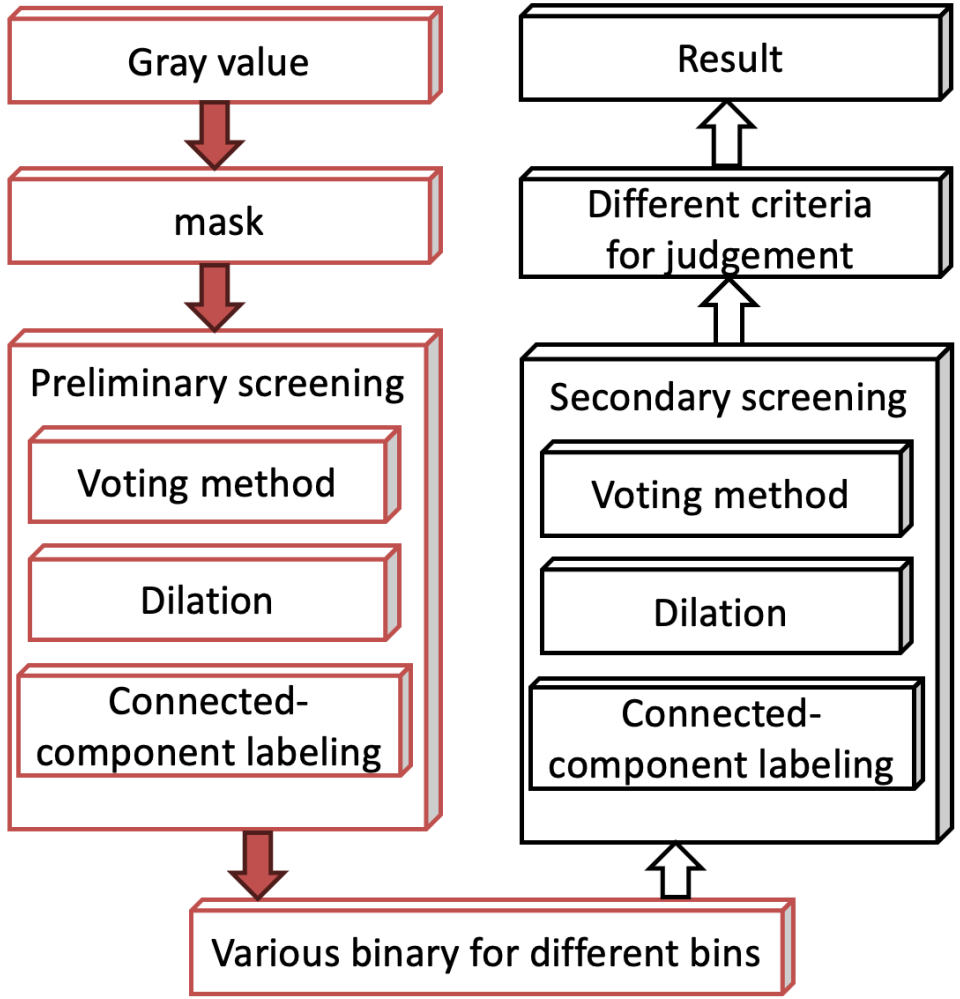
Two-step screening

Taking the “Y” shape photo as an example

Challenge from the high-level noise



	color	gray	binary
scratches			
noise points			



Screening performed on photo twice for further noise suppression

Noise suppression @ 1st screening

Gray value

mask

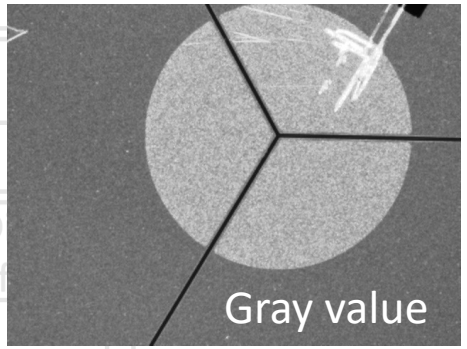
Preliminary screening

Voting method

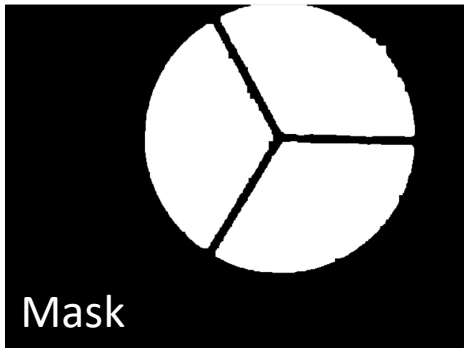
Dilation

Connected-component labeling

Various binary for different bins



Threshold used for inner area



High level noise

If do nothing, light scratches missed

Voting: any pixel with weight less than global average removed

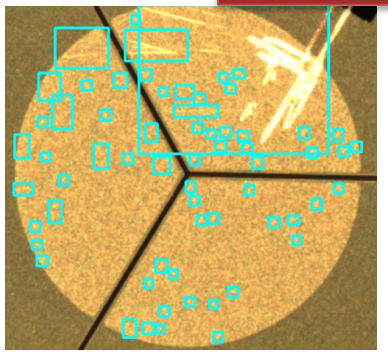
- Weight: 1 for white pixel, 0 for black one

Dilation: single pixel expanded into 3x3 pixel

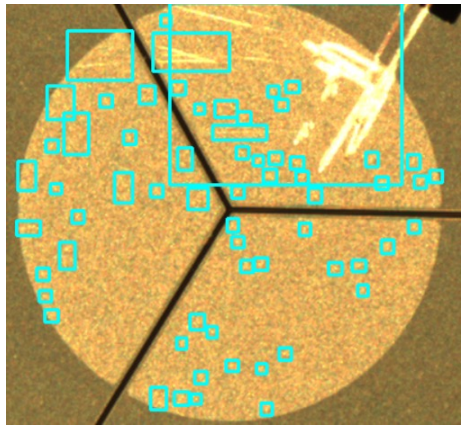
- Removed if no connection with others

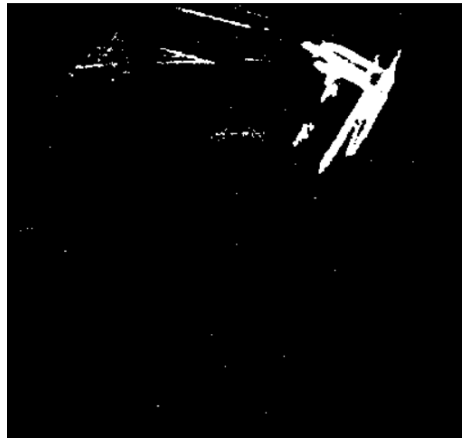
Noise suppressed

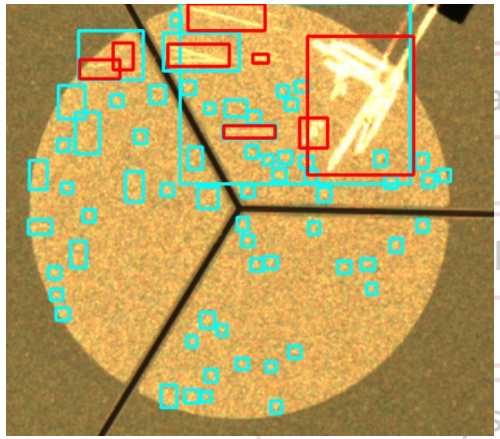
Connected-component labeling and re-do the binary in different boxes

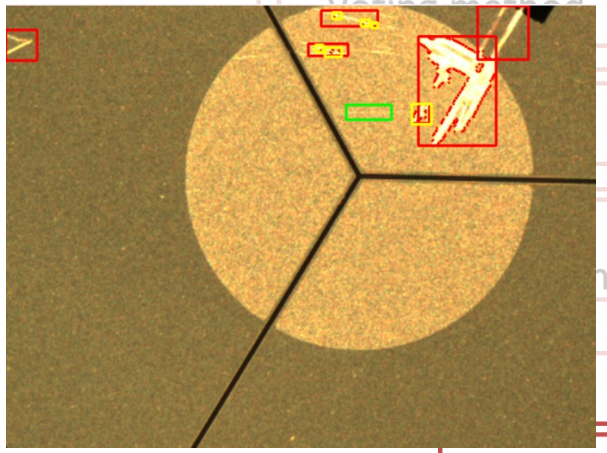


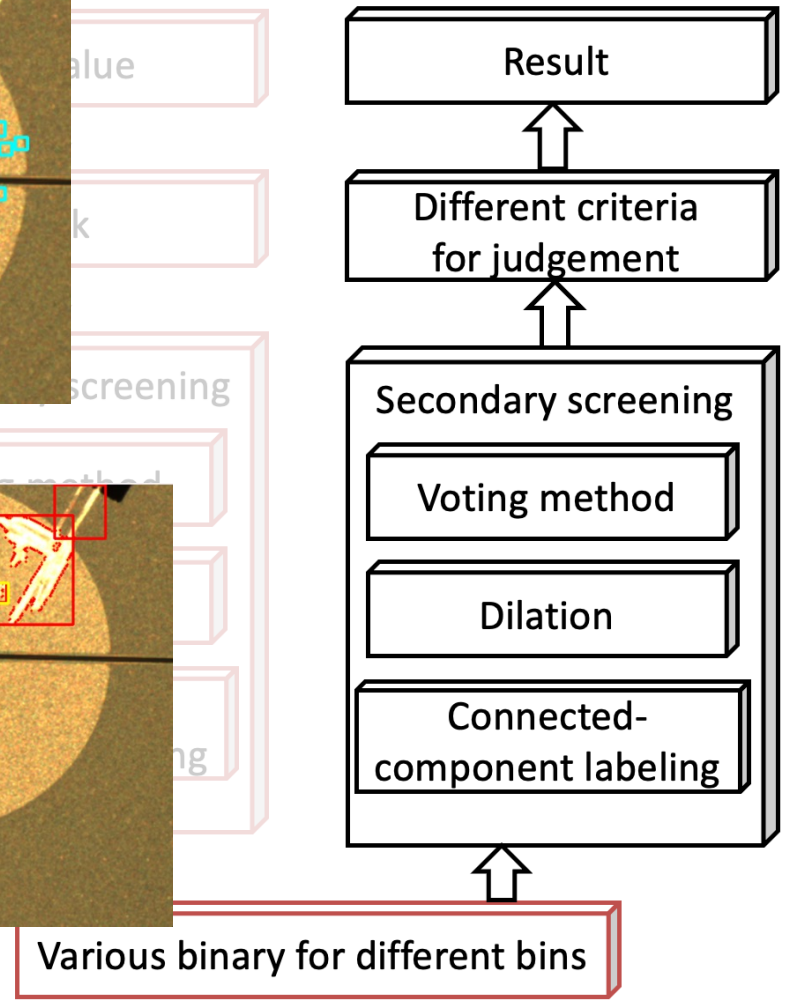
Defects found @ 2nd screening











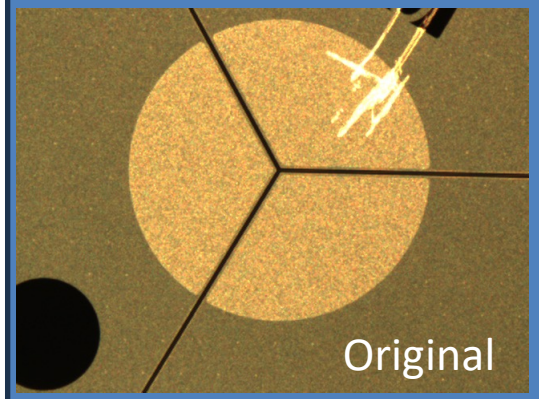
Secondary screening performed in each box

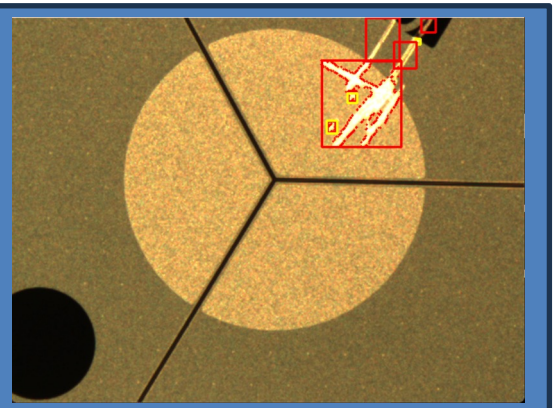
- Further noise suppression and clean feature image obtained

Criteria for defects judgement different

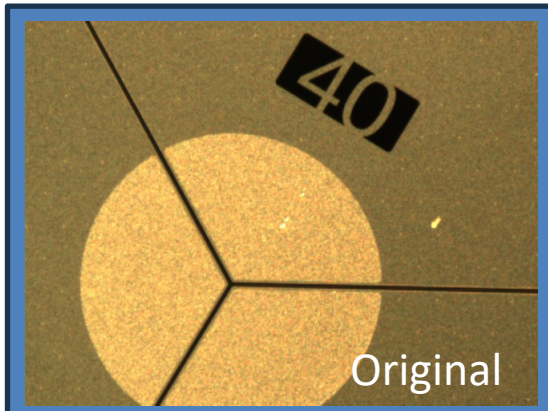
- "Big" component: threshold on area (in red)
- "small" component: "white" ratio in each box
  - Square-like defects: yellow
  - Line-like defects: green

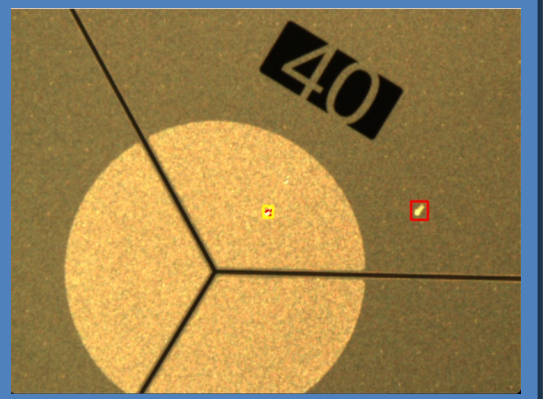
More examples



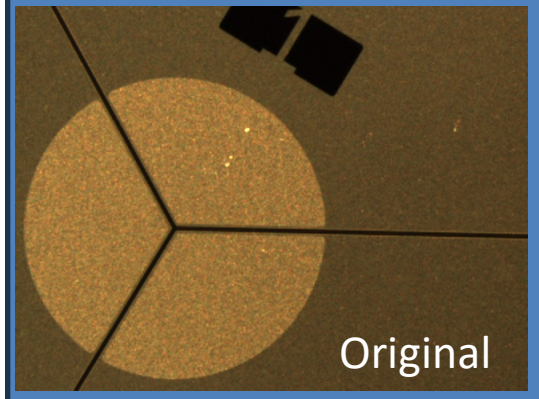


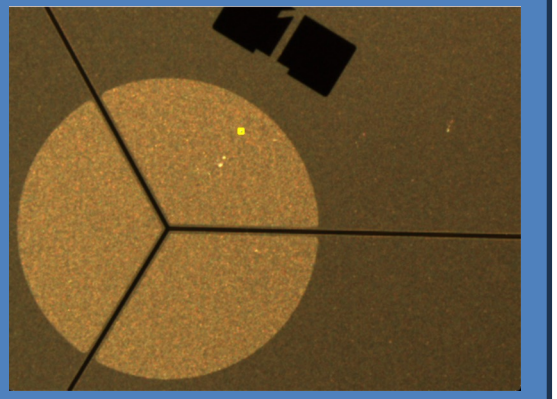
Printed labels doesn't effect



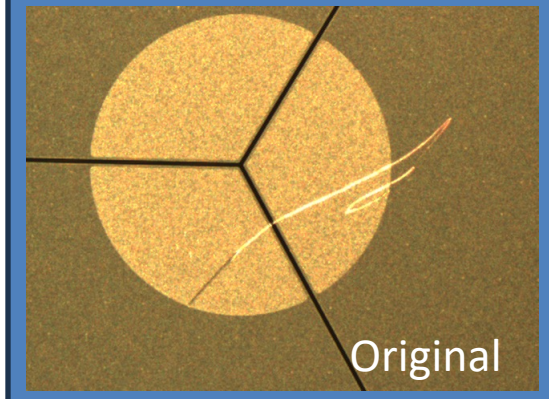


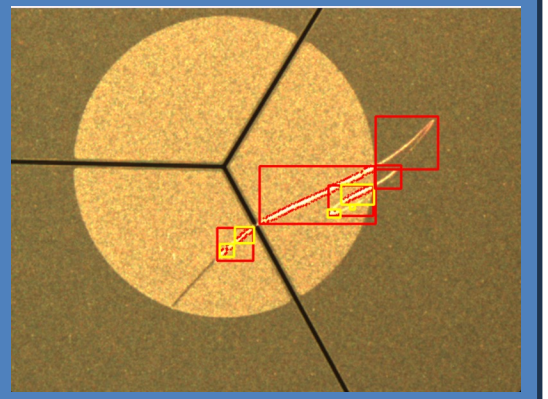
Small defects also can be detected





Works for dark-light region





Sensitive to "bright" scratch, not for "dark" marks

Summary

Automatic vision inspection for scratches on HGCal silicon sensor developed

- Based on OpenCV and widely used in some other silicon detectors constructions
- Save man power dramatically, with high defects searching efficiency

Done by Shengbo Cao (Shandong Univ.), Changcheng Liu (Jilin Univ.), Hanbing Liu (Jilin Univ.), Lusen Zhang (Hunan Univ.),

Machine learning method in next step

- Current method still miss some tiny potential scratches ⇒ new algorithm may improve
- Final goal: automatic vision check for wire bonding and encapsulation, in which more complicated structure expected

Thank you for your attentions