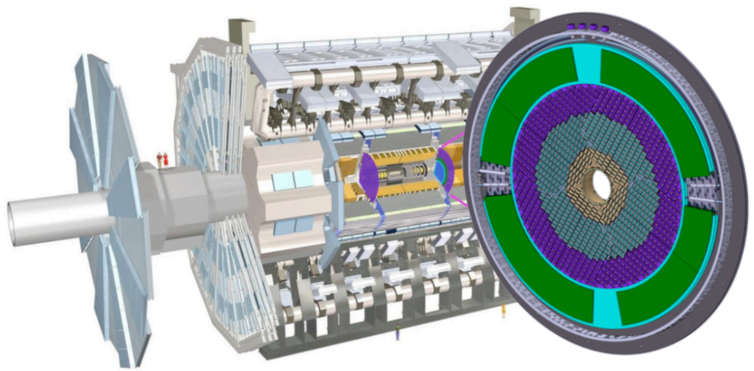
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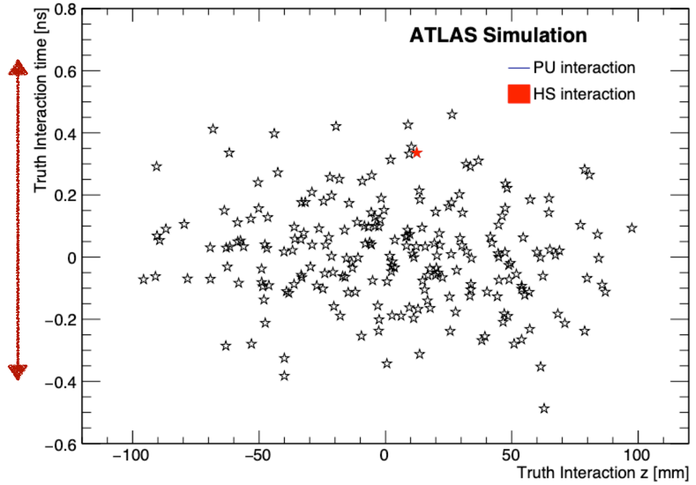
Performance of 15x15 full-size IHEP-IME LGAD sensor

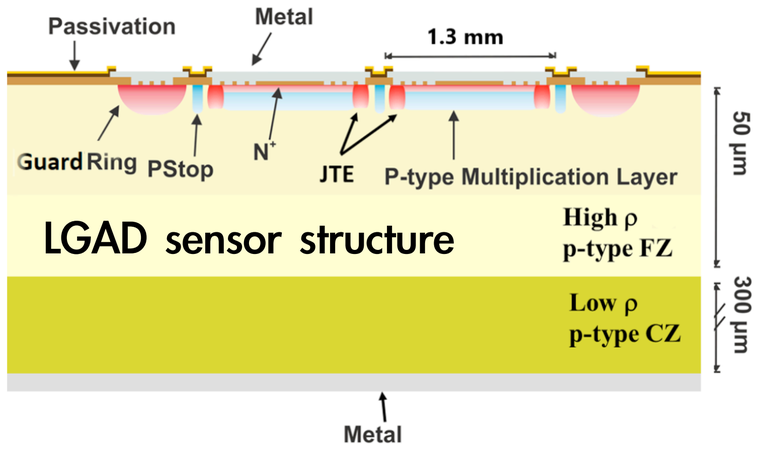
Jia Xuewei
2021/11/25

HGTD project and IHEP-IME LGAD sensor

- High-Granularity Timing Detector (HGTD): proposed for ATLAS phase II upgrade, to reduce the pile-up effect. To resolve primary vertex in time scale. Aiming at 30~50 ps per track.
- Low Gain Avalanche Detectors (LGAD) will be used as its sensing technology to provide a time resolution per hit of about 35 (70) ps at the start (end) of life time. Segmented into 1.3 × 1.3 mm^2 pads, with a total of 15x15 pads per sensor. Produced by many vendors eg. HPK, FBK, CNM.
- IHEP-IME: Designed by IHEP, fabricated by the Institute of Microelectronics of Chinese Academy of Sciences(IME) for the HGTD project

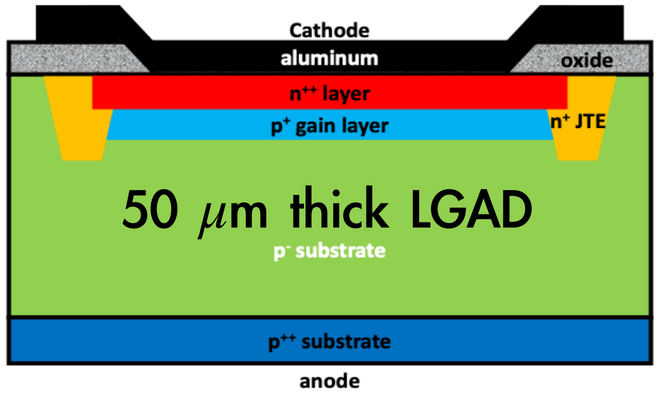


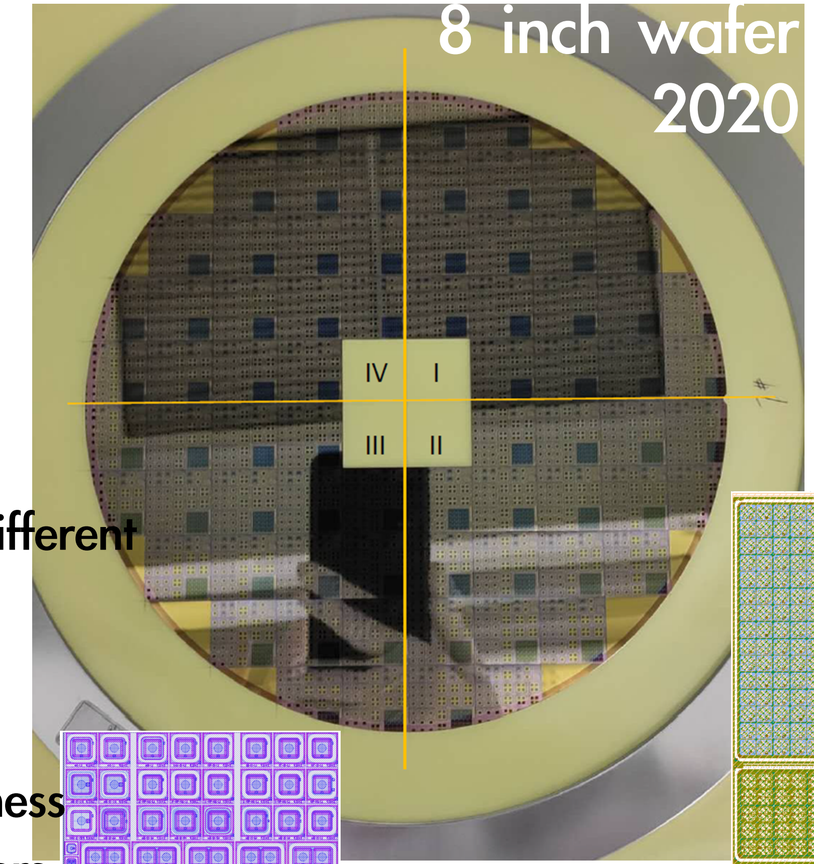


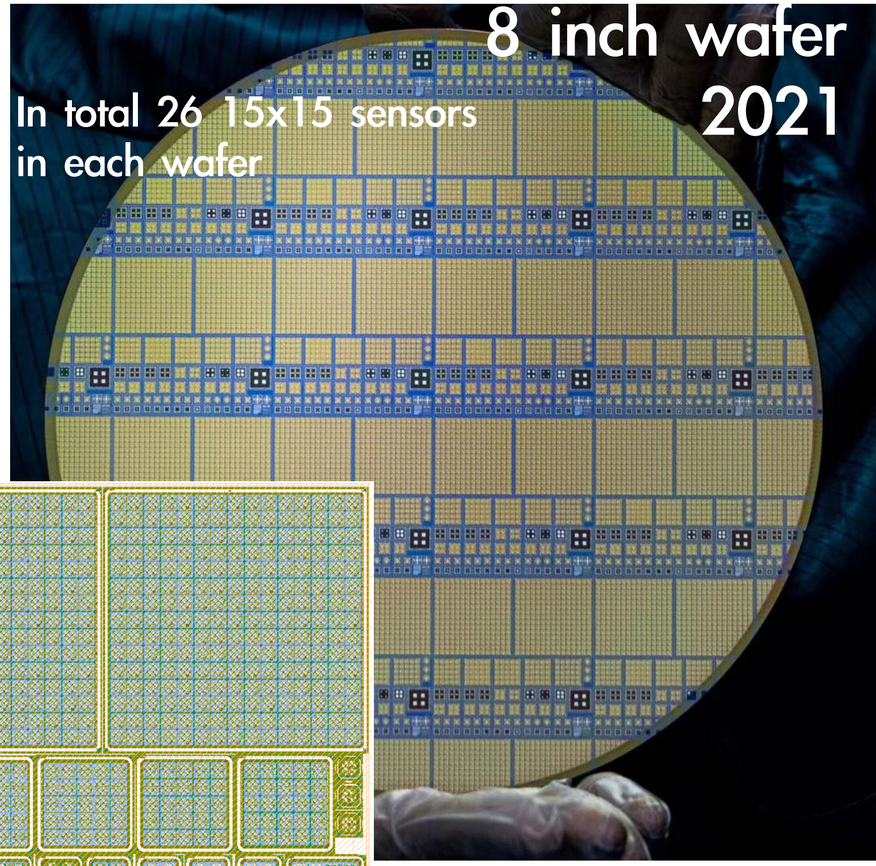


(a) Cross section of a 2 × 2 array.

Introduction of IHEP-IME LGAD

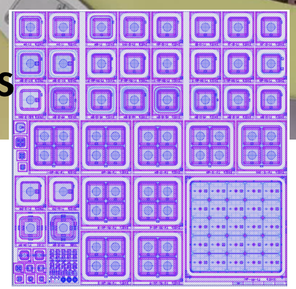




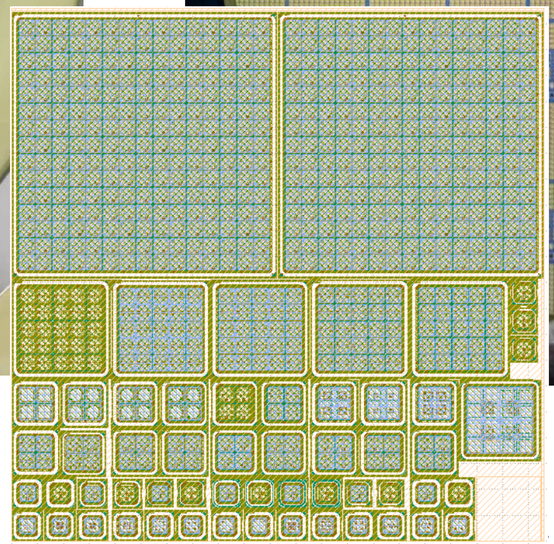


For each wafer, 4 quadrant tried different parameters.

- Boron concentration
- N implantation energy
- Carbon doses for radiation harness
- Different layout design parameters



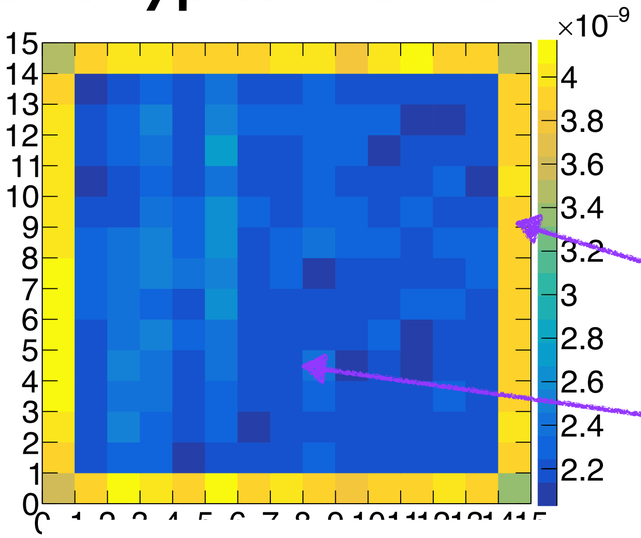
IHEP-IMEv1 layout

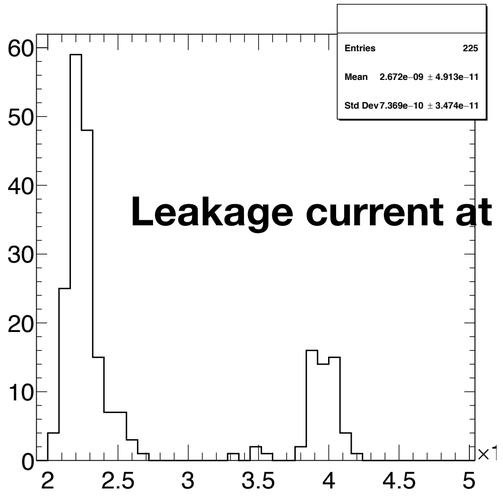


IHEP-IMEv2 layout

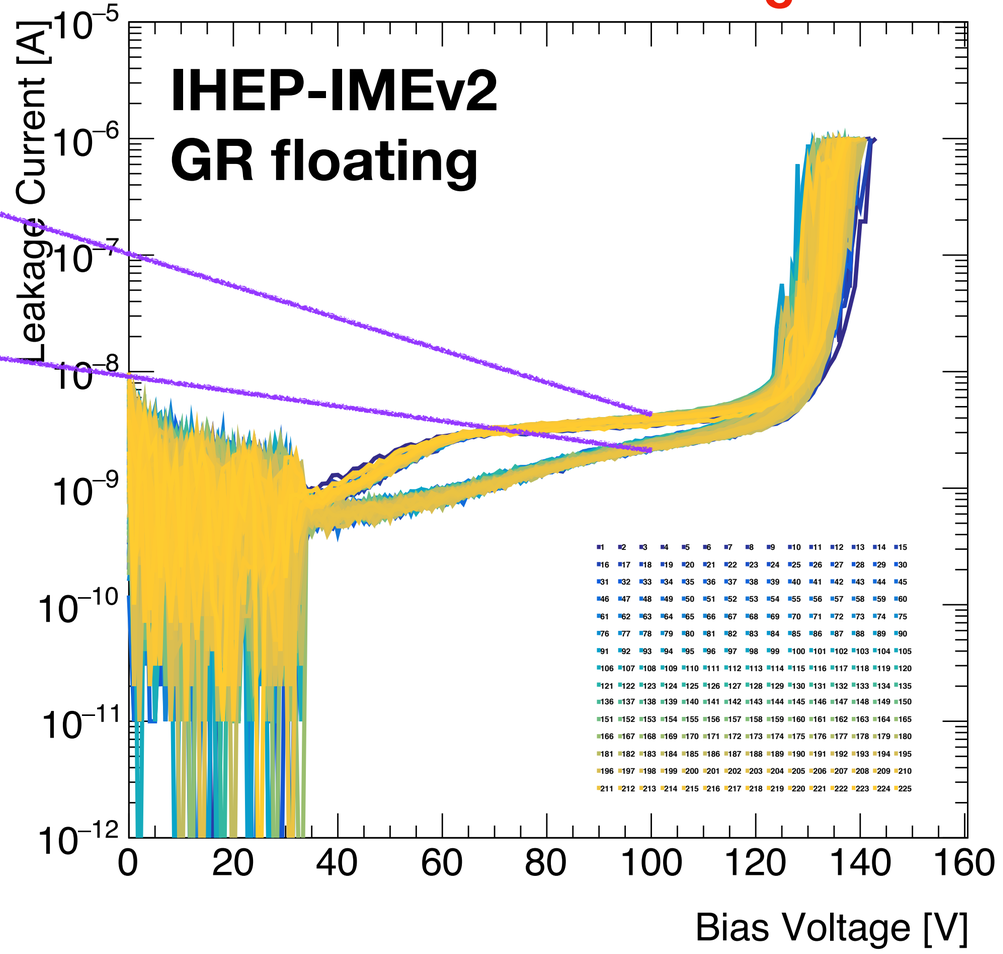
Performance of IHEP-IME full size sensor

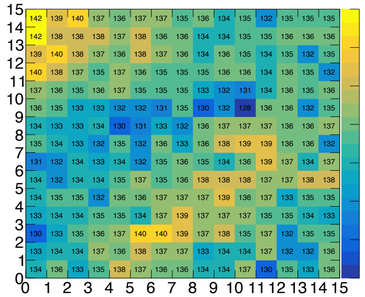
One typical 15x15

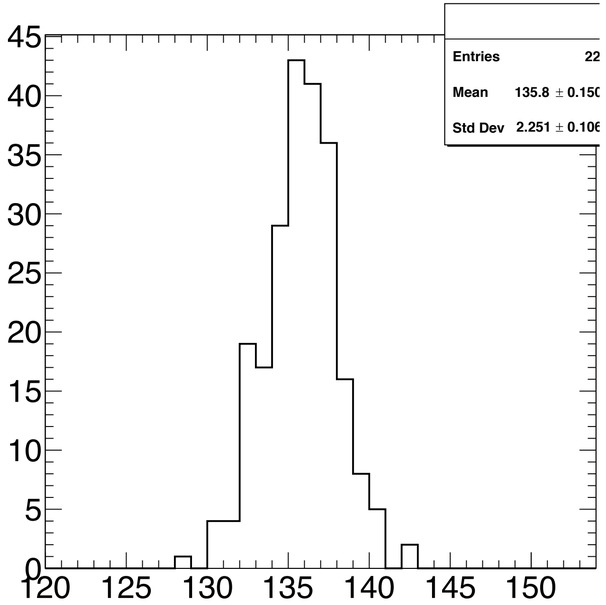




Breakdown voltage and leakage current of full size sensor showed good uniformity







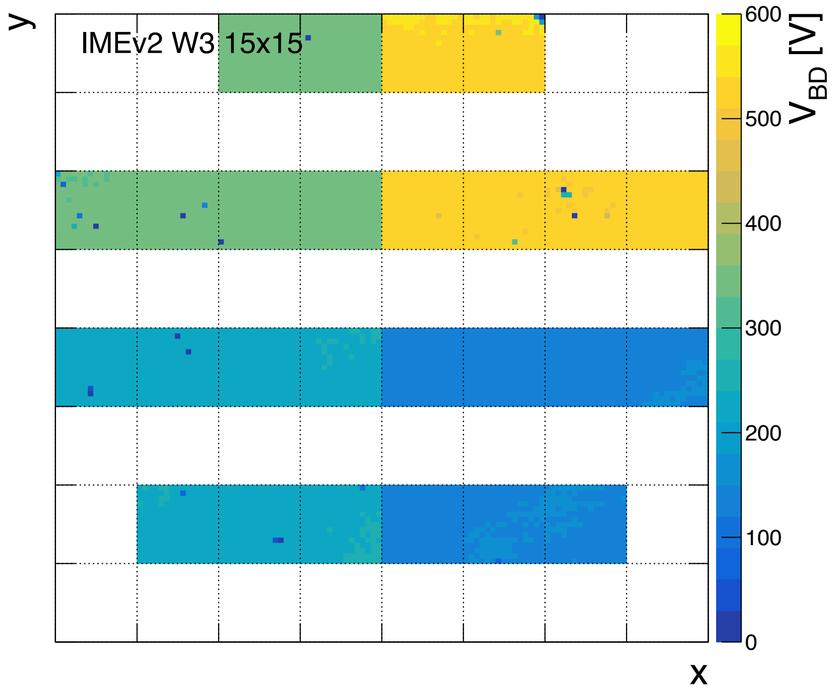
Performance of IHEP-IME full size sensor

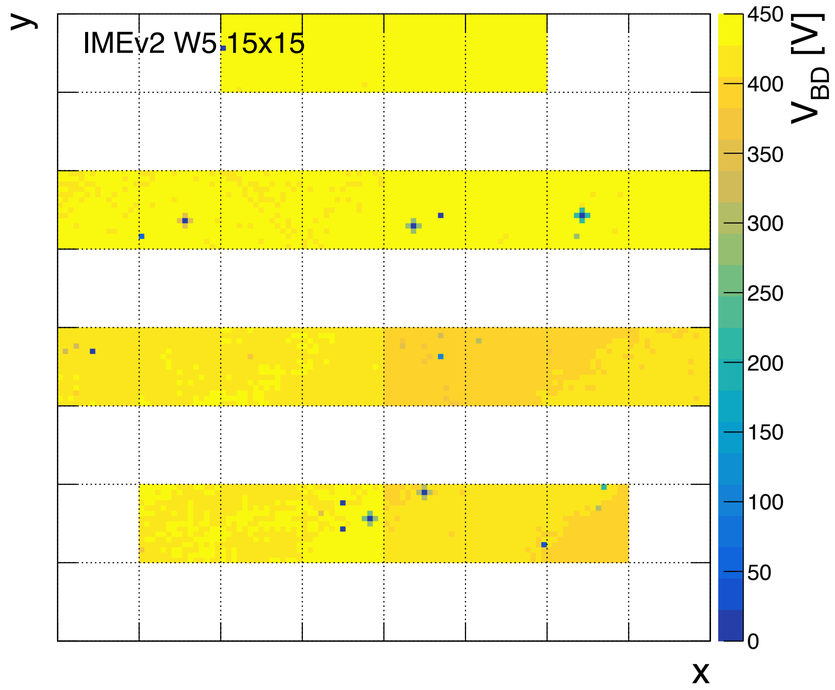
Satisfy the HGTD requirements

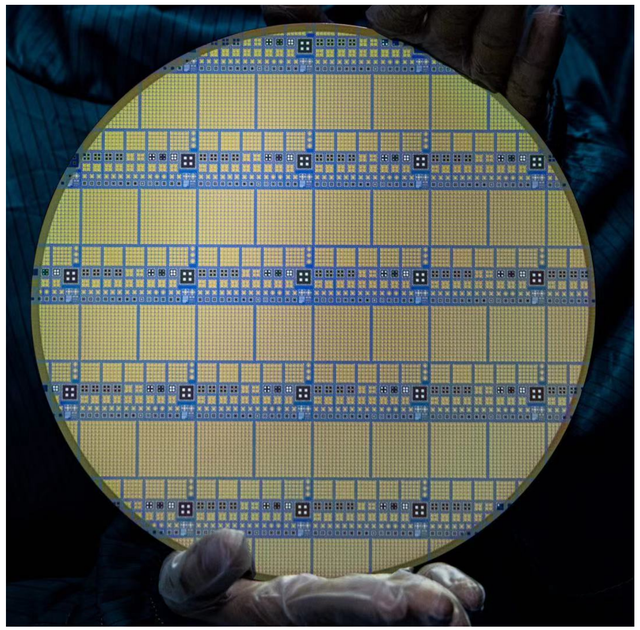
HGTD sensor specification		
Breakdown voltage requirement $(V_{bd} - V_{gl})/D > 1.7V/\mu m$	2.0	☑
Device leakage current $< 5\mu A/cm^2$		☑
$V_{bd,pad}$ spread over the sensor $\frac{RMS(V_{bd,pad})}{< V_{bd,pad} >}$	0.017	☑
Pad leakage current spread at $0.9V_{bd}$ *peak to peak within a factor of 3*	2.0	☑

Performance of IHEP-IME full size sensor

Breakdown voltage of all 15x15 sensor pads of a full wafer







- Most 15x15 sensor showed good uniformity and the pad yield > 99.3%

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Summary

- IHEP-IME 15x15 sensor showed good uniformity and can satisfy the HGTD requirements
  - Confident that yield can be further improved in future iterations
- IHEP-IME LGAD sensors showed very promising performance before and after irradiation.
  - More details in the upcoming talks of Zhaomei and Kewei

Thanks!

Introduction of IHEP-IME LGAD

- The first IHEP design LGAD was first produced by Zhonghuan in the middle of 2018
- IHEP-IME: Designed by IHEP, fabricated by the Institute of Microelectronics of Chinese Academy of Sciences(IME) for the HGTD project
- So far two versions of IHEP-IME has been produced.
  - IHEP-IMEv1 was submitted in May 2020, 4 wafers

    finished in September
  - IHEP-IMEv2 was produced in January 2021, 8 wafers

    finished April/June 2021
  - IHEP-IMEv3 production is ongoing.

Introduction of IHEP-IME LGAD

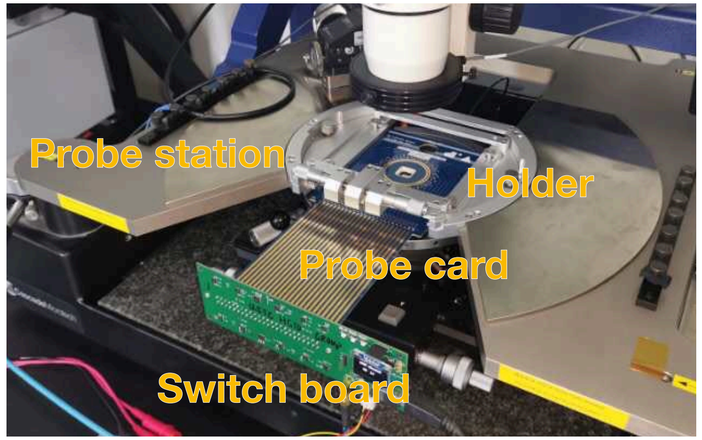
- 4 wafers in v1 production
  - W1: Carbon implantation
  - W7: Baseline
  - W8: High N implantation energy
- 8 wafers in v2 production
  - W1: fast annealing (close to v1 design).
  - W2: Long time annealing.
  - W3: High N energy, long time annealing.
  - W5: AC-LGAD
  - W6: Low P energy
  - W4: Carbon, fast annealing.
  - W7&8: Carbon, long time annealing.

15x15 full size sensor test

- 15x15 sensor can be tested with a probe card
  - with all the other pads grounded
- We tested I-V of large array sensors (5x5, 15x15) of a whole wafer using automatic probe station in a company. Then analyzed the data.
- Applied negative high voltage on the chuck
  - GR and other pads floating



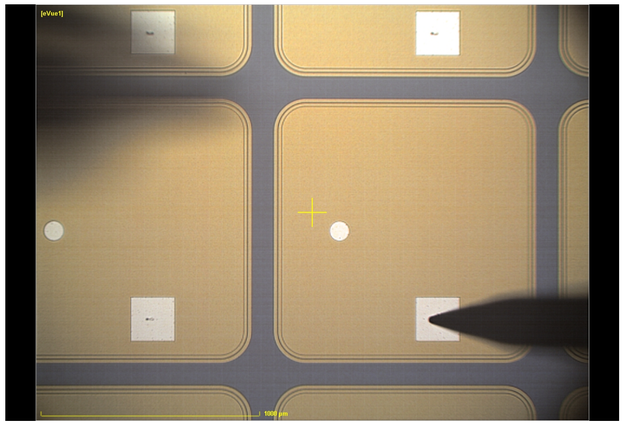
15x15 probe card



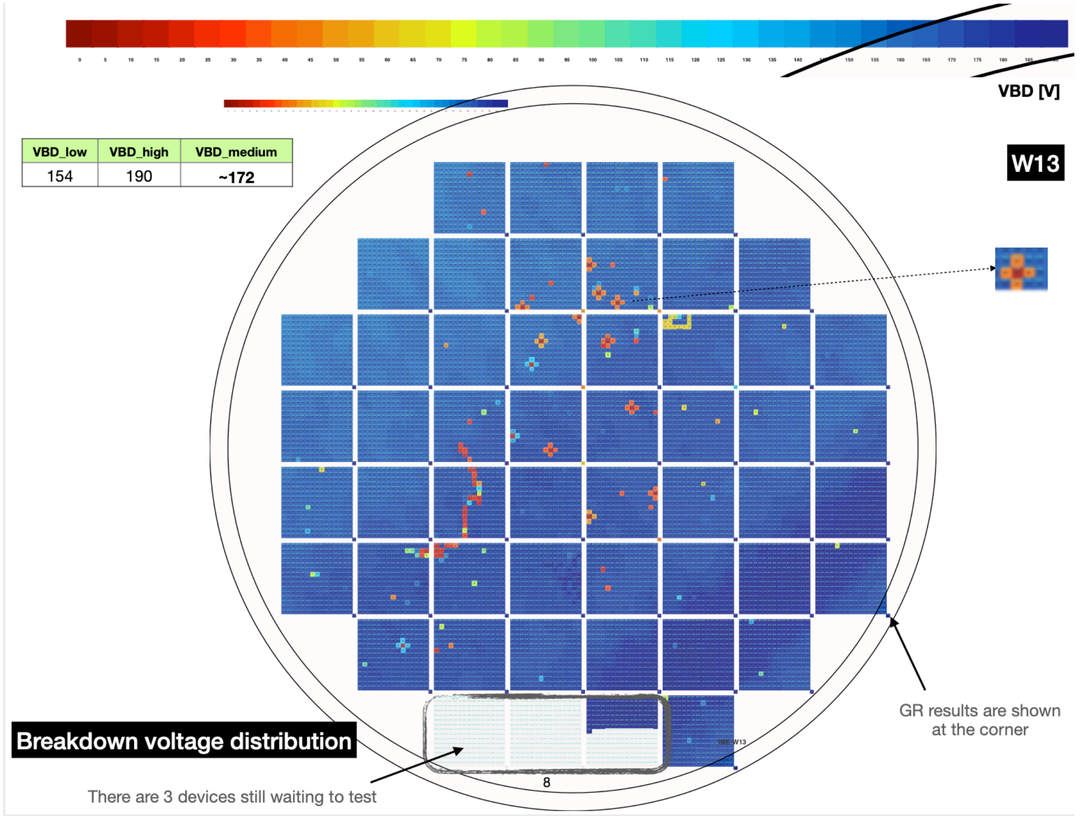
probe card test set up



automatic probe station

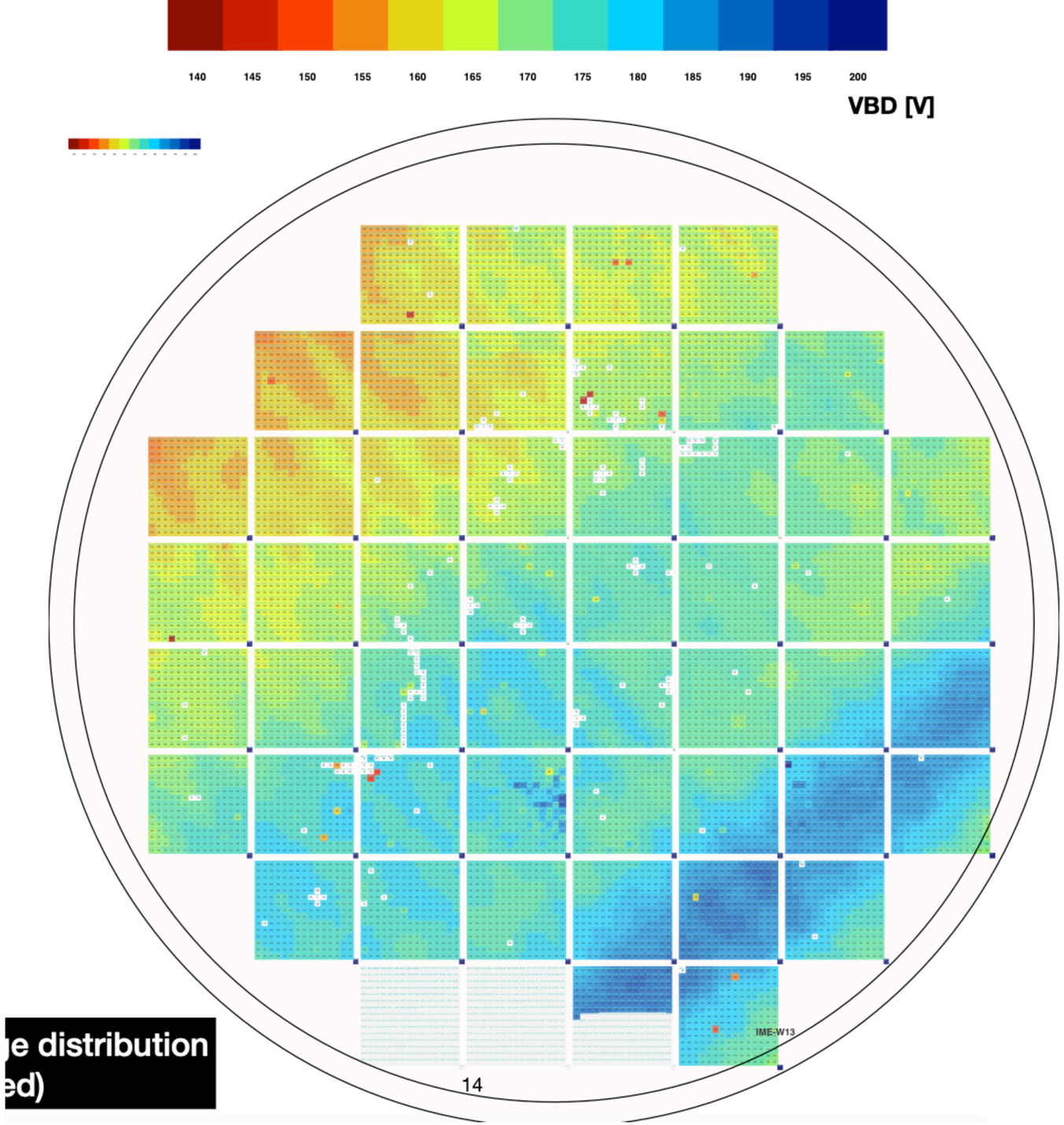


one pad of 15x15



VBD_low	VBD_high	VBD_medium
154	190	~172

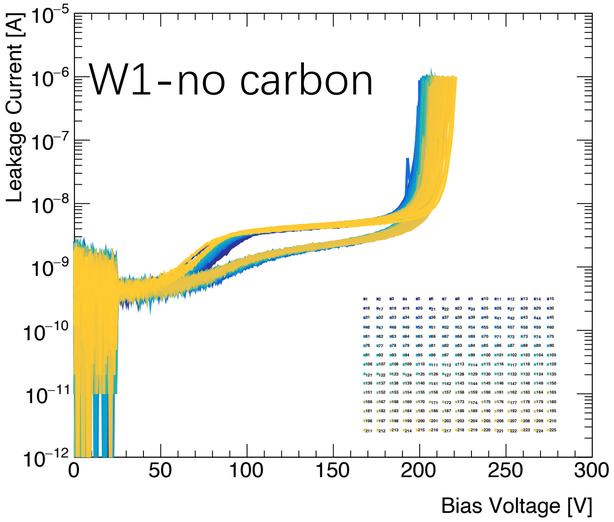
By Yang Xiao USTC

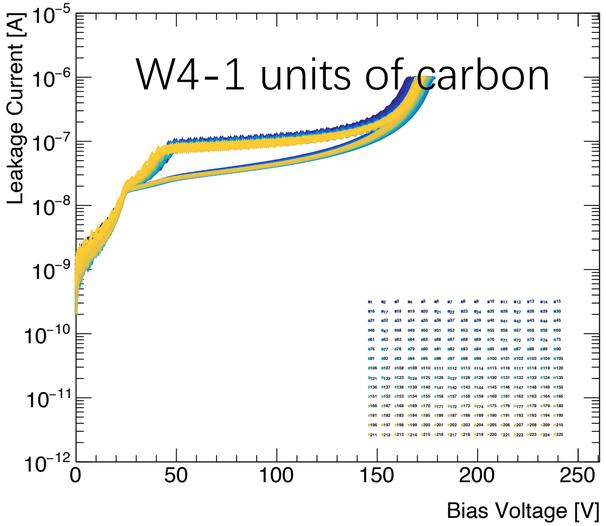


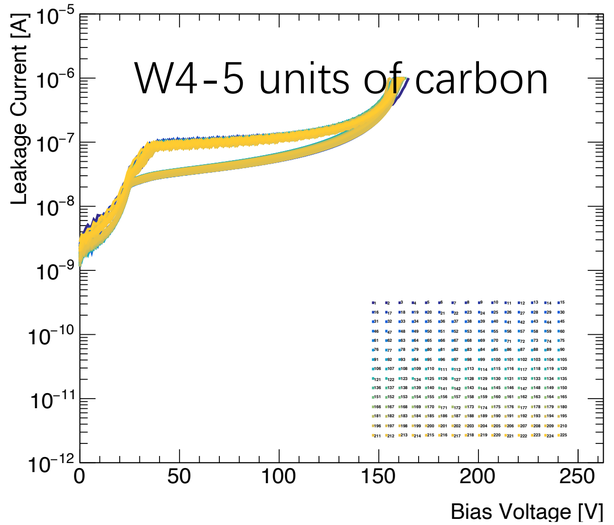
ge distribution
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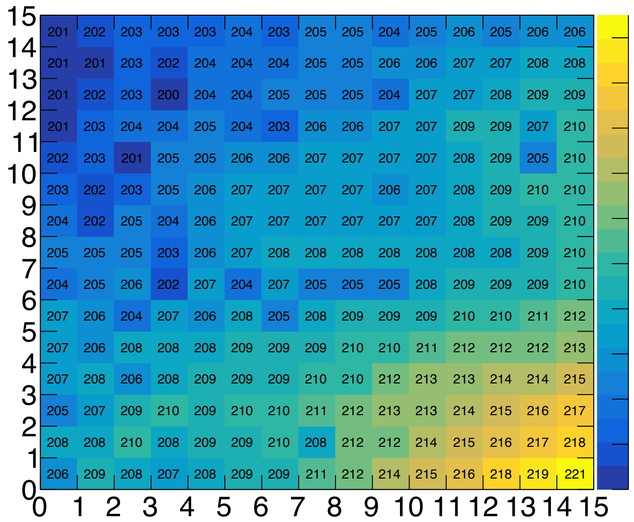
Carbon effect-large leakage curre

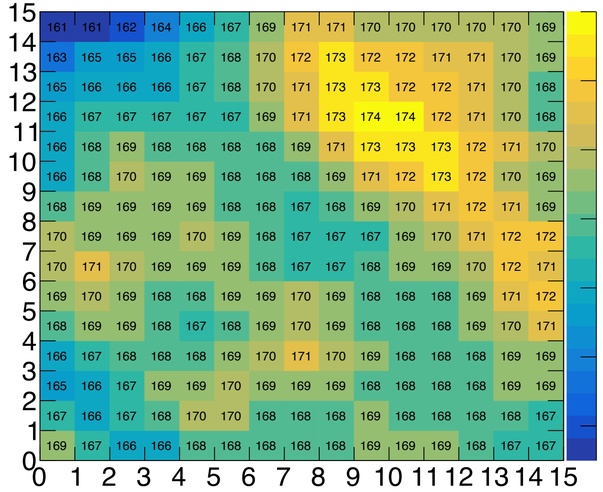
Carbon dose	0	1	5
Vbd [V]	207.6(3.7)	168.8(2.1)	155.0(0.6)
Leakage	1.65(8.50e-2)	57.2 (2.17)	80.6(7.76)

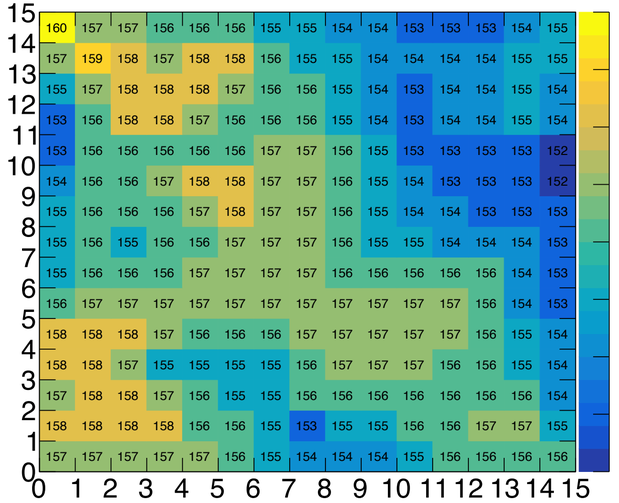




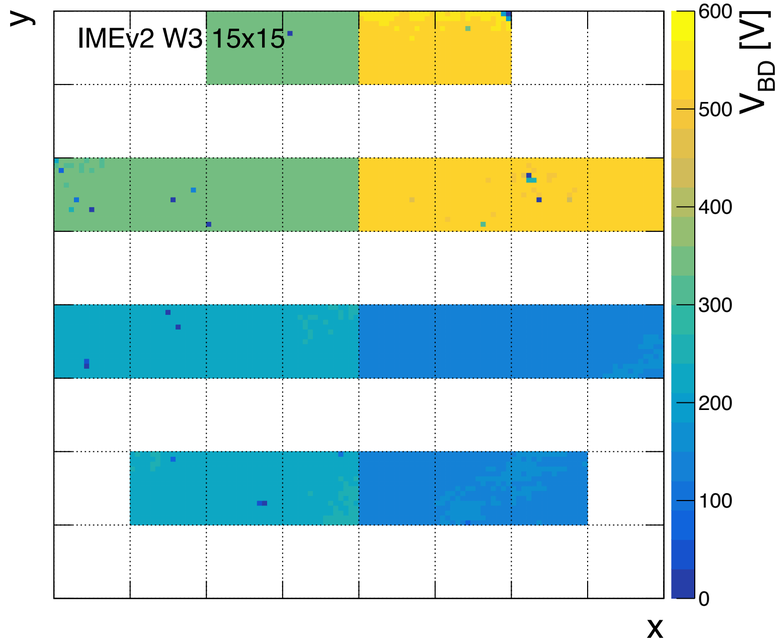








W3 (long annealing +high N&P energy)



Four quadrants have different P dose.

Quadrant	Entries	Mean	Std Dev (excluding bad pads)	Std Dev/Mean	Std Dev
1	1350	524.9	8.5	1.6%	31.2
2	1350	346.2	5.0	1.4%	22.0
3	1575	235.4	3.8	1.6%	14.5
4	1575	142.0	6.2	4.4%	6.4

Pad yield 99.50(0.09)%; Sensor yield 46.2(9.78)%

- We get the mean value and uniformity of different design from very large statistics.
- Estimate the yield of the sensor and check with sensor specifications.
- See the distribution of the bad pads.

IHEP-IMEv2 large array sensor I-V test

Early breakdown pads:

IME understanding:

- The bad pads may come from the dust between process steps. Will work on minimizing it.
- 4 quadrants have different parameters, increase the production steps.
- And also from the current distribution there could be some scratch during the test causing the bad pads.

