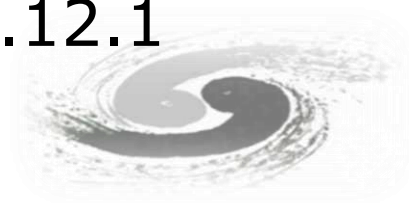


TID study of the IHEP-IME LGAD Sensor with shallow carbon

The 41st RD50 Workshop

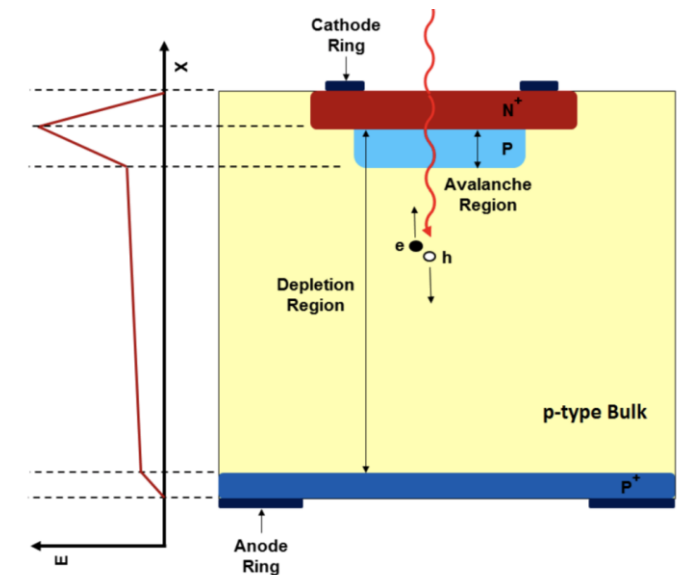
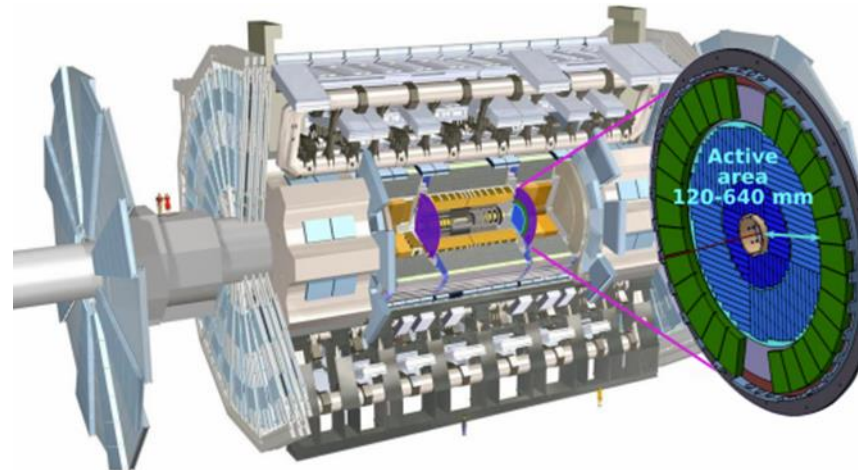
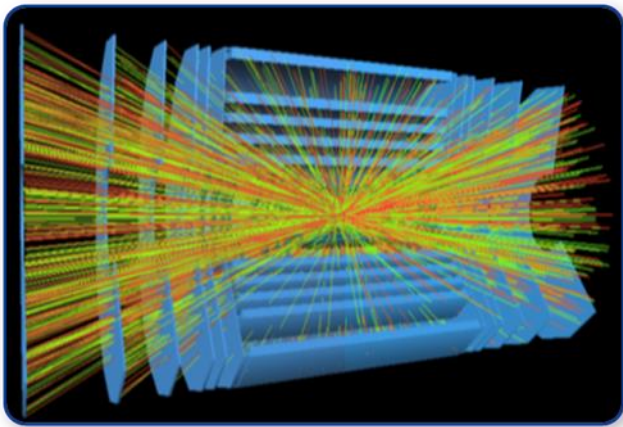
Yunyun Fan, weiyi Sun, zhijun Liang, yuan
Feng, Mei Zhao, Mengzhao Li

2022.12.1



High Granularity Timing Detector (HGTD)

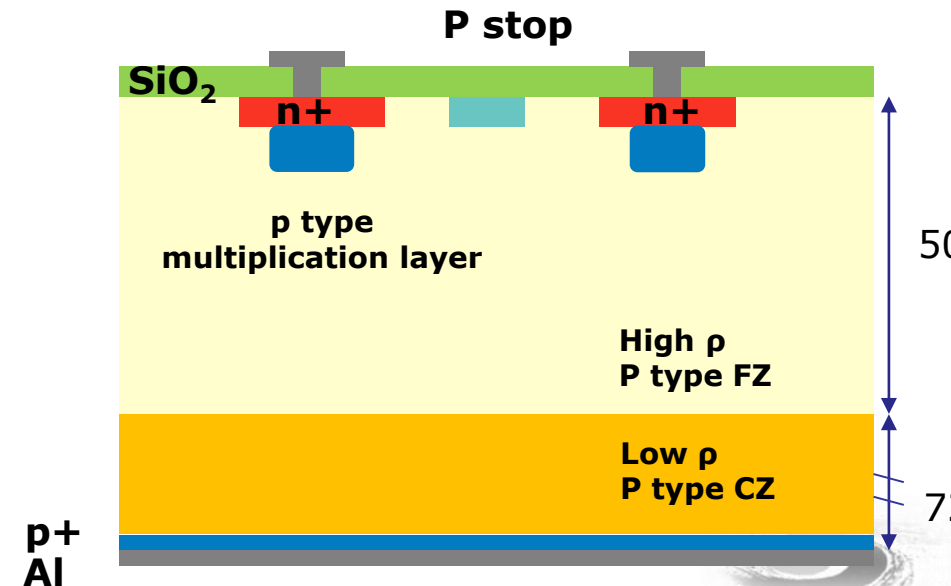
- Time resolution for particle 2 orders of magnitude up (**ns**→**30ps**)
- Low gain avalanche diodes (LGAD): 30 ps
- HGTD Reduce the pile-up in HL-LHC
 - Detector area: **6.4 m²**, time resolution: **30ps**
 - Radiation hardness for TID: **2MGy**





Motivation

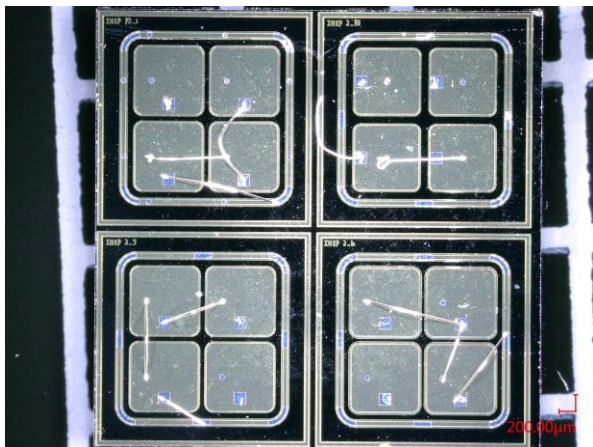
- **Study the TID damage of LGAD :**
 - optimize the design of LGAD surface properties such as the inter-pad distance and the gap between the active edge and the edge
 - Maximum the fill factor
- **Total ionizing dose experiment to study the TID: 2MGy**
 - surface damage at the SiO₂ and the Si - SiO₂ interface by inducing oxide charges and interface traps
 - Points defects in silicon sensors by Compton electrons and photoelectrons



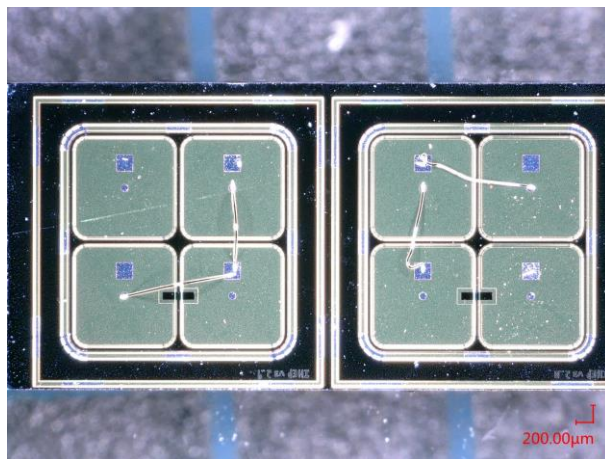
TID study of IHEP-IME version3/2 sensors

- Quad LGADS with Shallow carbon were produced with six different inter-pad spacings (50 μm – 100 μm)
- IME version 3 and the Version2 W7Q2
- 2x2 sensors with different IP (50-100 μm) :
 - IMEV3_2-5 < IMEV3_2-6 < IMEV3_2-7 < IMEV3_2-8 < IMEV3_2-9 < IMEV3_2-10

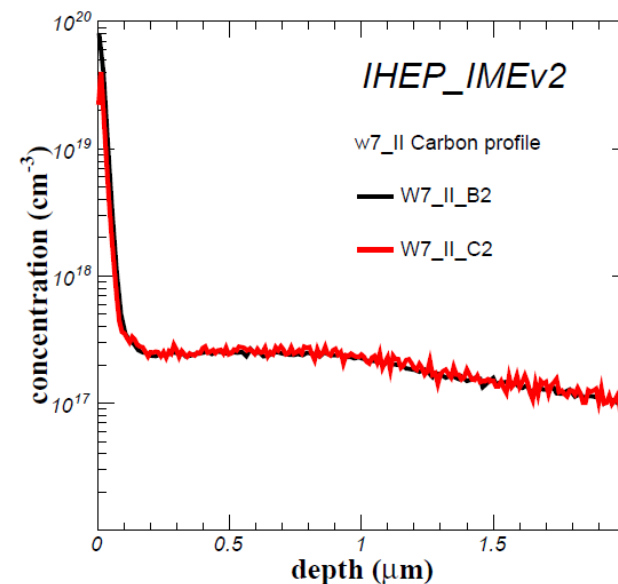
IMEv2 W7 Q2
(most radiation
hardness)



IMEv3 W12



The Carbon distribution of IME v2 W7Q2





Co60 at CIAE

- **Co60 source,**
 - damage in silicon sensors by Compton electrons and photoelectrons
- **Dose rate:**
 - Offline 10000 Gy/h (~ 2.77 Gy/s)
- **Dose rate uncertainty: $\pm 15\%$**
- **Offline test: 2MGy (200 hr)**
- **Three TID points**
 - 10KGy, 100kGy, 2MGy

KAPTON cape
fixed the sensor



Cylinder Co60
source





Performance test before and after irradiation

6

- **Performance test of IHEP-IME LGAD with shallow carbon before and after irradiation**
 - **The performance change of LGAD**
 - **Decrease the resistance between pads and guard rings, input resistance of ASIC > 10 k Ω)**
 - **The leakage current and the breakdown voltage**

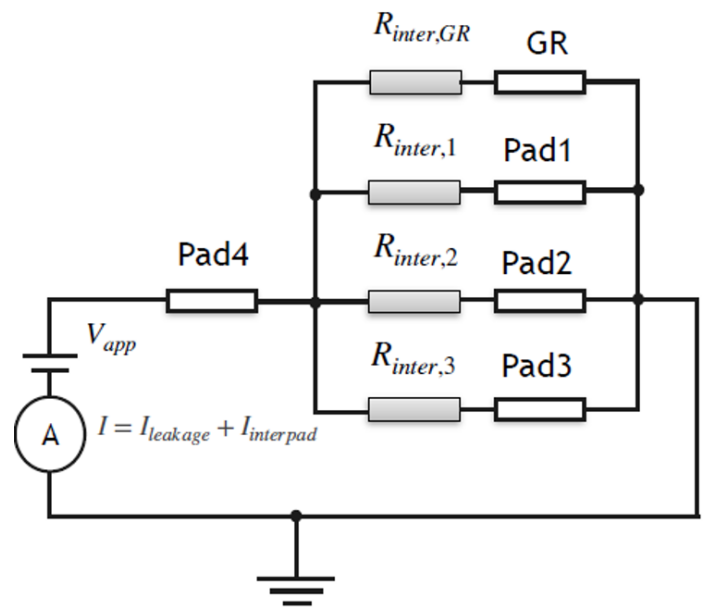
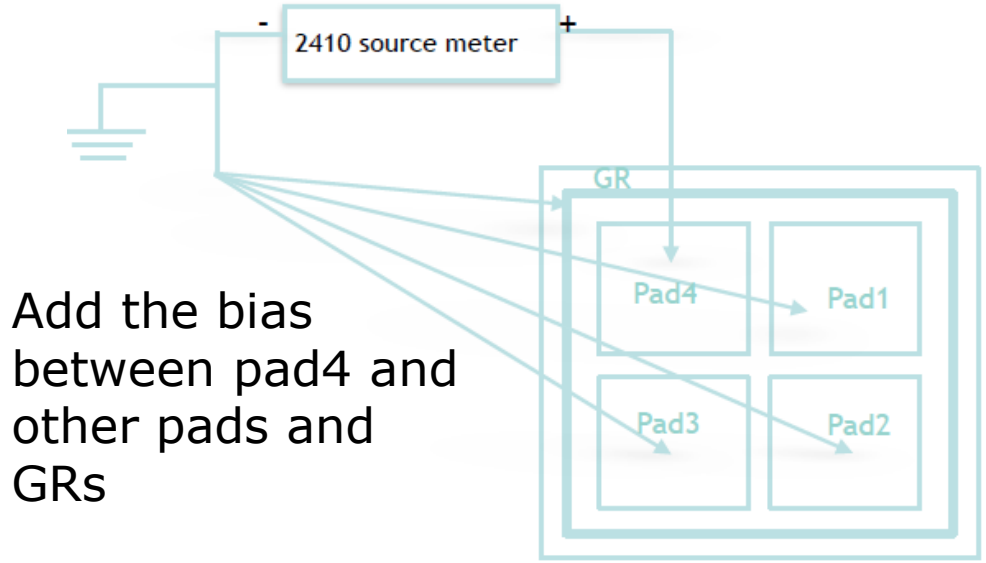


Inter-pad R Measurement

Apply the extra bias voltage (ΔU_i) between the tested pads (pad4) and the other pads and GR while the sensor is biased on the backside with a bias voltage (U).

$$R_I \approx \frac{\Delta U_i}{\Delta I}$$

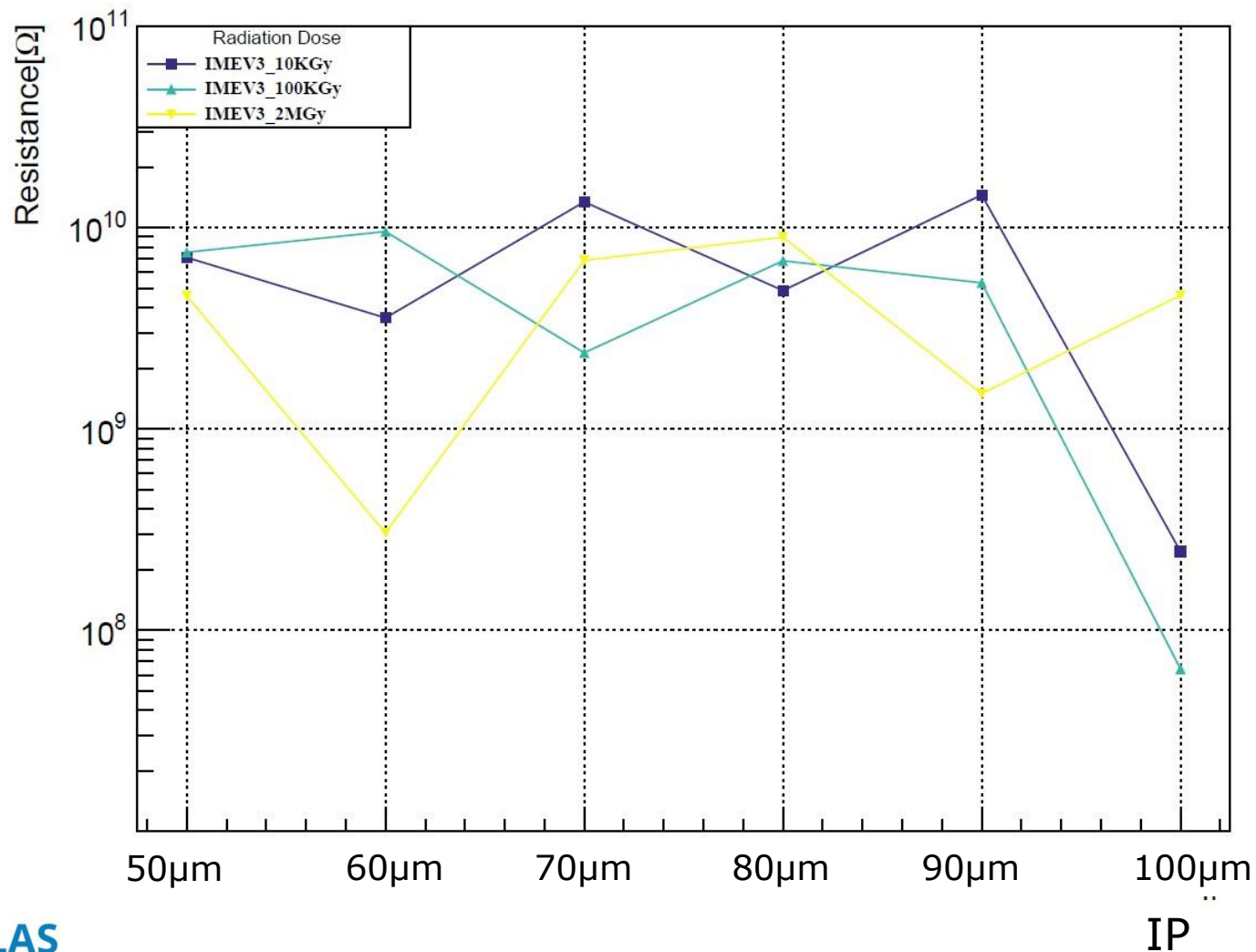
ΔI : $I_{Ui} - I_{Ui=0}$ the increase of the leakage current on pad4 while the bias voltage increase ,
 ΔU_i : the change of biased voltage on pad4.
The pad1-3 and GR are grounded.





Inter-pad R

The inter-pad resistance of IHEP-IME v3 sensors when Bias = 85 V



IMEV3_2-5, IMEV3_2-6,
IMEV3_2-7, IMEV3_2-8 ,
IMEV3_2-9, IMEV3_2-10

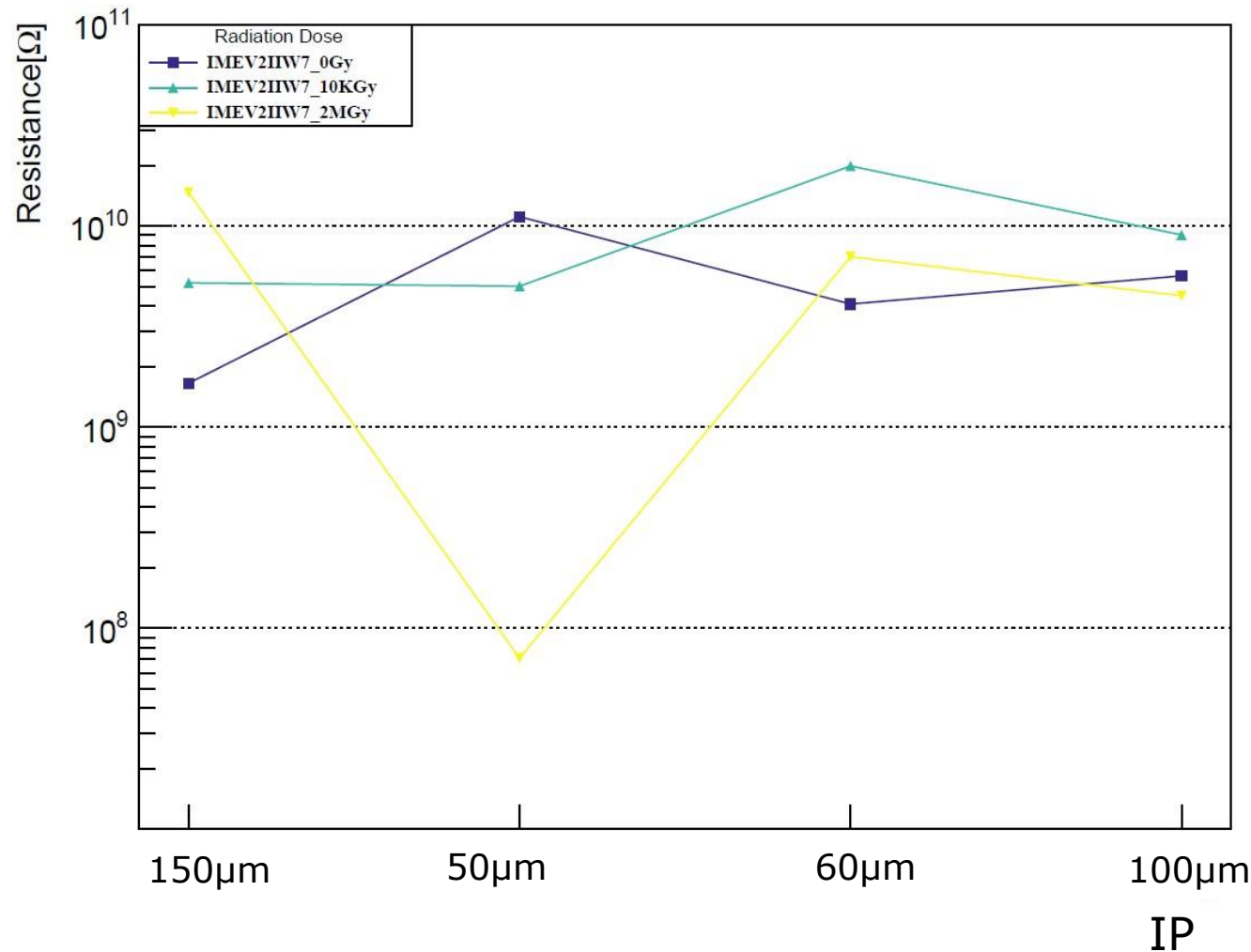
10 MΩ < R after 2 MGy irradiation

No regular pattern was observed. Will study the reason further.



Inter-pad R

The inter-pad resistance of IHEP-IME v2 W7 sensors when Bias = 85 V



IMEV2_2-1, IMEV2_2-5
IMEV2_2-6, IMEV2_2-10

10 MΩ < R after 2 MGy irradiation

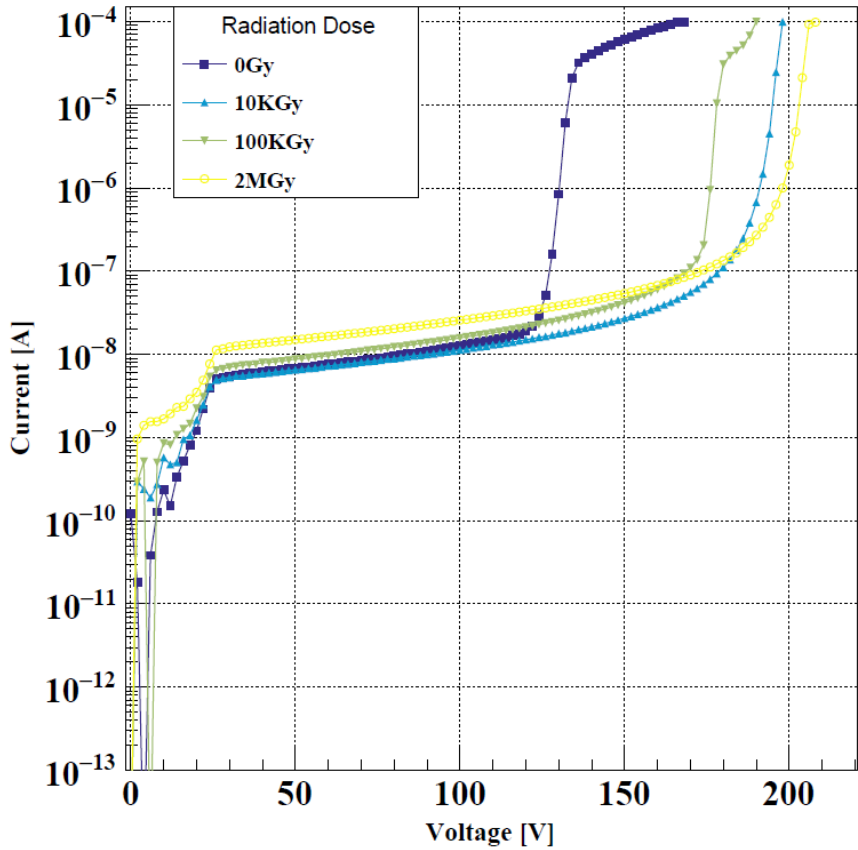
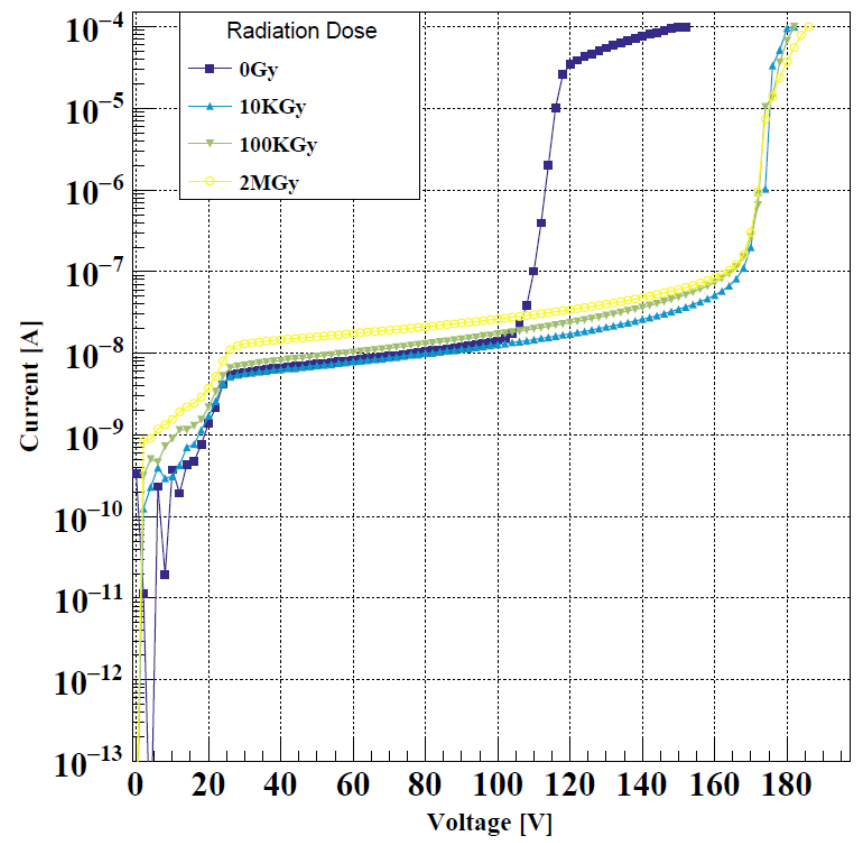
No regular pattern was observed. Will study the reason further.



IV of IHEP-IME v3

IMEV3_2-5 I-V

IMEV3_2-10 I-V



IV test setup:
1 pad gnd+3 pad float+GR gnd

- Breakdown voltage: increase **60V-70V ↑**
- The leakage currents of pad4 increase slightly with the increase of the TID dose



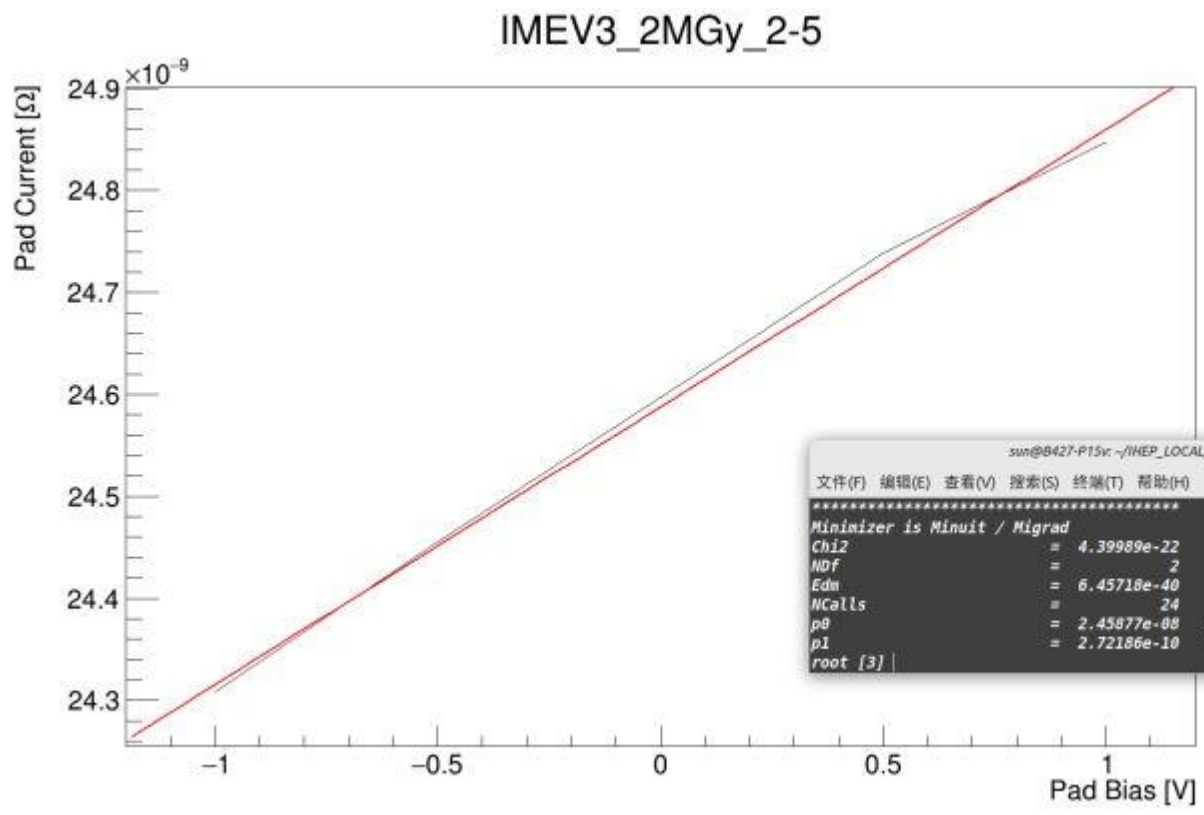
Summary

- **TID for IHEP IME version3**
 - The interpad-R of IHEP-IME v2 W7 II and IHEP-IME v3 after 2 MGy irradiation is **10 M Ω < R** .
 - No regular pattern was observed. Need to explore further
 - The breakdown voltage of the IHEP-IME LGAD after 2MGy increases 60-70 V
 - The leakage currents increase slightly with the increase of the TID dose, and **is smaller than 5 μ A/pad required by ATLAS HGTD** after 2MGy
- **Future plan**
 - Test IV of different setup(2 pad gnd+2 pad float+GR gnd / 4 pad gnd+GR gnd/et al.) of the IV after irradiation
 - Interpad-R will be test at with GR floating.
 - Test the Vgl and Vfd after irradiation

Thanks for your attention!



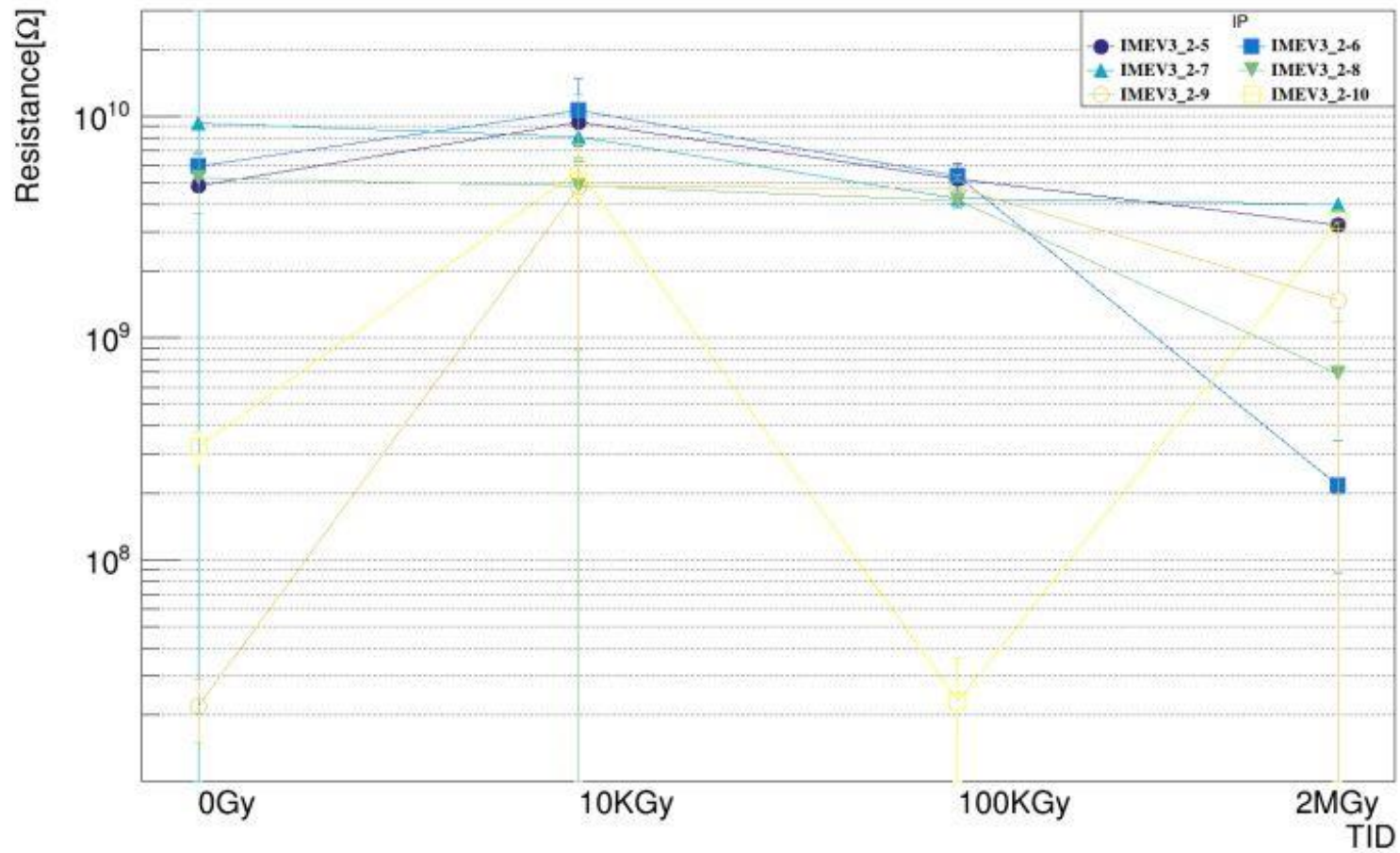
-
- **Back up**



```
sun@B427-P15v: ~/IHEP_LOCAL/LGAD/IME_LGAD/Analysis
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
*****
Minimizer is Minuit / Migrad
Chi2          = 4.39989e-22
NDF           = 2
Edm           = 6.45718e-40
Ncalls        = 24
p0            = 2.45877e-08 +/- 7.4161e-12
p1            = 2.72186e-10 +/- 9.38071e-12
root [3] |
```

Bias = 105V

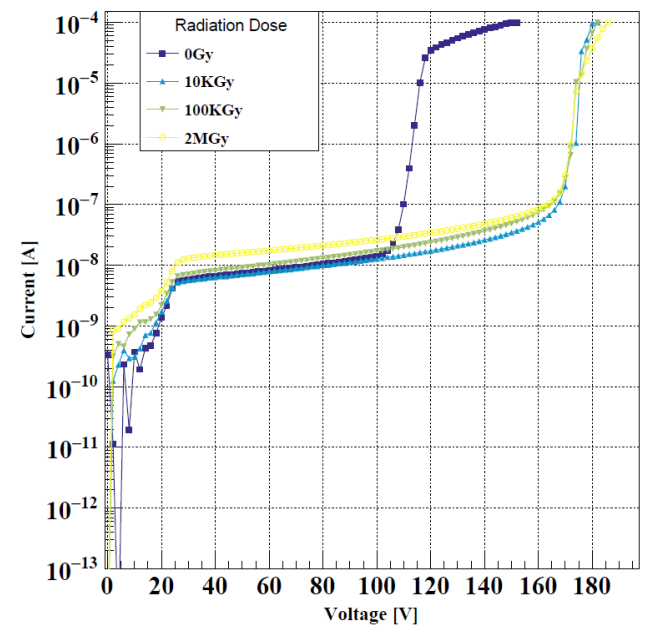
IMEV3 2X2 Resistance



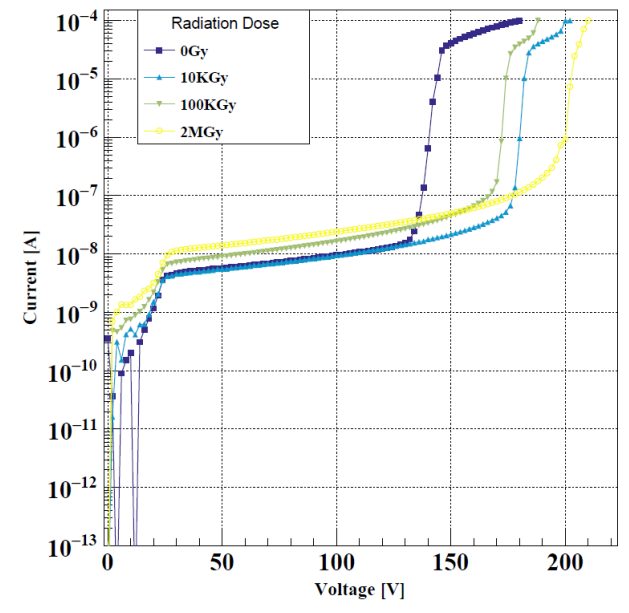


IV of IHEP-IME v3

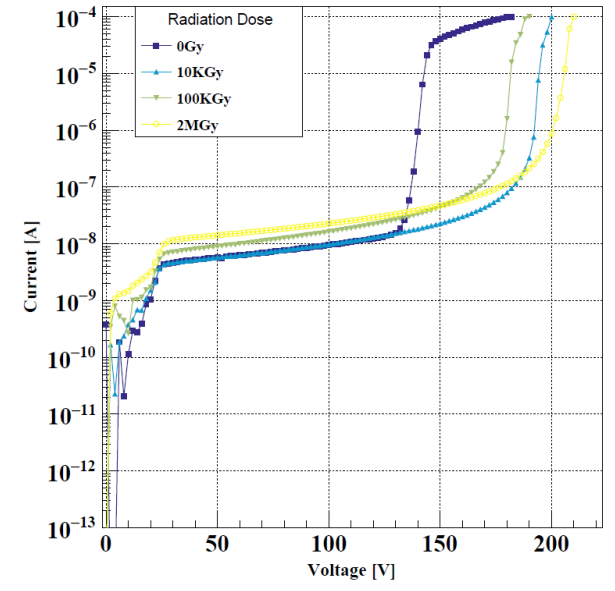
IMEV3_2-5 I-V



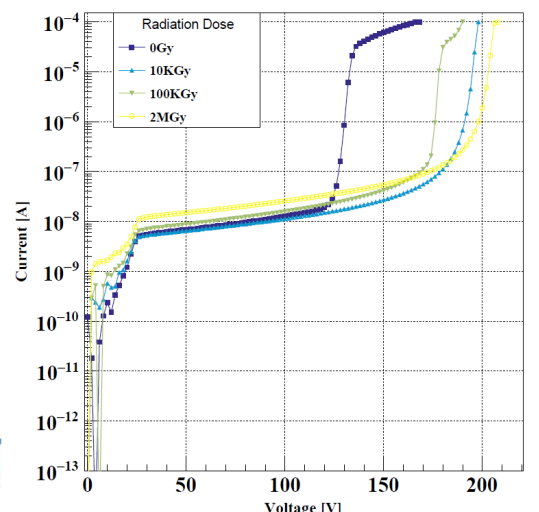
IMEV3_2-8 I-V



IMEV3_2-9 I-V



IMEV3_2-10 I-V



1 pad gnd+3 pad float+GR gnd

