IHEP-IME LGAD传感器抗辐照特性研究

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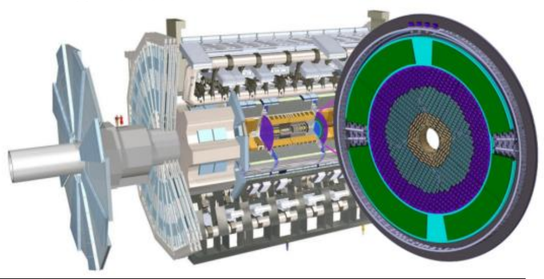
Abstracts

ATLAS 高粒度高时间分辨探测器 (HGTD) 项目拟通过采用时间分辨特性优于35ps的低增益雪崩探测器作为核心探测器件，以提供轨道的精确时间测量，进而减少HL-LHC探测器中的粒子堆积效应。中国科学院高能物理研究所（IHEP）一直在与中国科学院微电子研究所（IME）合作开发LGAD传感器（IHEP-IME）。到目前为止，已经生产了三个版本的 IHEP-IME LGAD 传感器。第一版IHEP-IMEv1器件很好地实现了满足项目时间分辨性能的器件的制备。第二版IHEP-IMEv2器件，在第一版基础上优化了器件制备工艺与并通过掺碳提高了器件辐照特性。具有不同碳剂量的 IHEP-IMEv2 传感器，具有优良的抗辐照特性，显著改善了器件辐照后硼失效的问题。15x15像素阵列器件在辐照前后展示了良好的一致性。本次报告将具体展示具有不同碳注入条件的器件在辐照前后的性能测试结果，分析碳注入工艺对器件辐照特性的影响。低温beta测试结果表明，经过2.5e15 neq/cm^{2}辐照后IHEP-IMEv2器件在400 V以下可采集4 fC电荷，时间分辨率优于50 ps，满足HGTD项目要求。也将对IHEP-IMEv3器件的设计情况与测试结果进行报告。

HGTD LGAD sensor requirement

ATLAS LHC upgrade HGTD project：High Granularity Timing Detector
LGAD sensor：Low Gain Avalanche Diode
Total area: 6.4m2，~21000个LGAD sensor
Requirement：
Size：1.3 x 1.3 mm2
array：15x15
voltage：<800V
Time resolution：<40ps
Radiation hardness：2.5e15 neq/cm^2

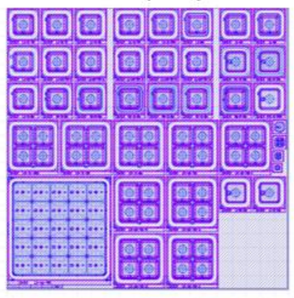


Hit efficiency at normal incidence with discrete/testing electronics and ALTIROC (central part of pad ~1x1 mm^2)	> 97% (>95%) before (after) irradiation
Time resolution (discreate/testing electronics) Time resolution (ALTIROC)	<40 ps (<50 ps) before (after) irradiation <50 ps (<70 ps) before (after) irradiation
Power consumption at V_{op}	< 100 mW/cm^2
Total leakage current	<160 μA/cm^2
Collected charge	>10 fC (>4 fC) before (after) irradiation
pad leakage current	<5 μA
Maximum V_{op} Power supply limit at the sensors	11 V/μm ·D 800 V

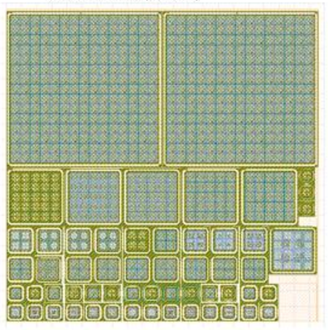
IHEP-IME 3版芯片制备

三版芯片设计制备工作
IHEP-IMEv1(2020.9)，性能满足HGTD项目要求
IHEP-IMEv2(2021.6)，掺碳工艺，具有最优的抗辐照性能，大阵列器件
IHEP-IMEv3(2022.5)， 工艺重复性验证，优化大阵列器件设计

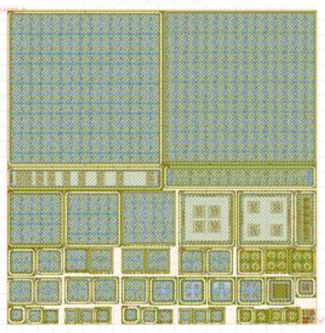
IHEP-IMEv1(2020.9)



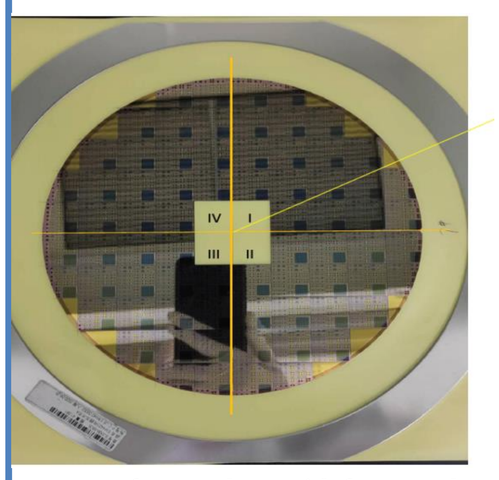
IHEP-IMEv2(2021.6)



IHEP-IMEv3(2022.5)



IHEP-IMEv2 掺碳LGAD器件



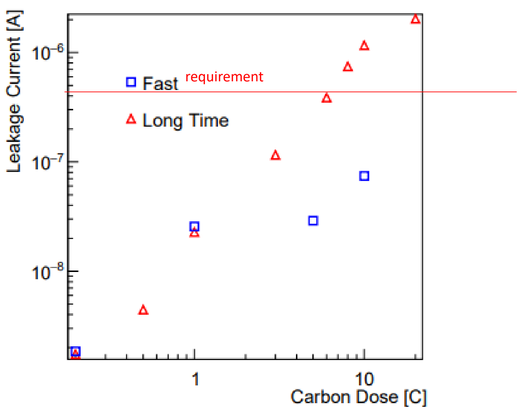
one wafer taped out with four quadrants

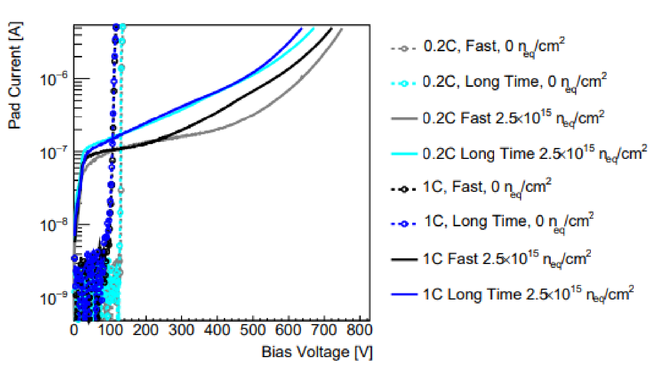
◆3 wafers with different carbon dose and thermal treatment were taped out. （W4,W7,W8）

Wafer	Quadrant	Carbon Dose	Carbon Thermal Process
4	I	0.2 a.u.	fast
4	II	1 a.u.	fast
4	III	5 a.u.	fast
4	IV	10 a.u.	fast
7	I	0.2 a.u.	long-time
7	II	0.5 a.u.	long-time
7	III	1 a.u.	long-time
7	IV	3 a.u.	long-time
8	I	6 a.u.	long-time
8	II	8 a.u.	long-time
8	III	10 a.u.	long-time
8	IV	20 a.u.	long-time

IHEP-IMEv2 sensor characteristics

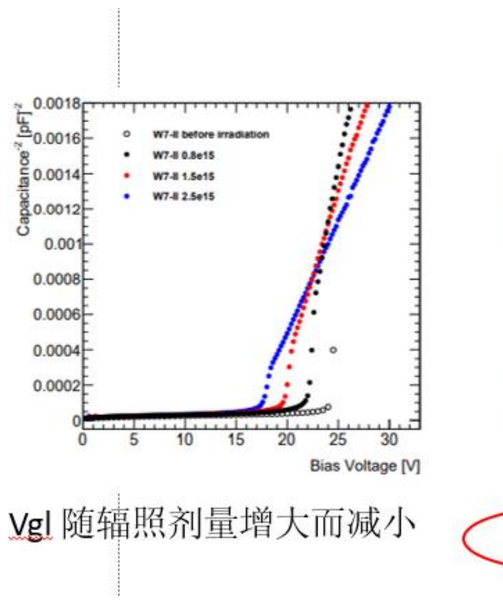
辐照前漏电流情况

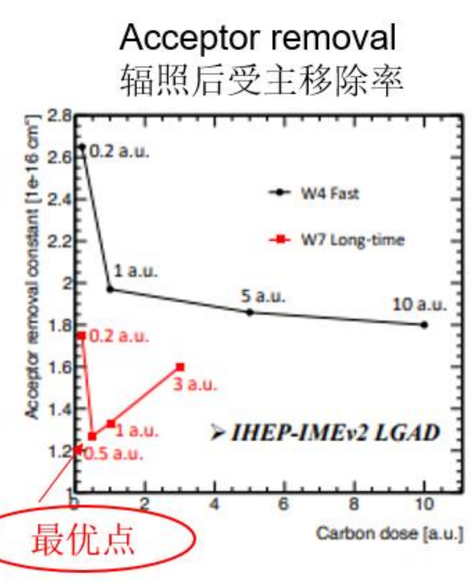




Leakage current increase as increasing carbon dose

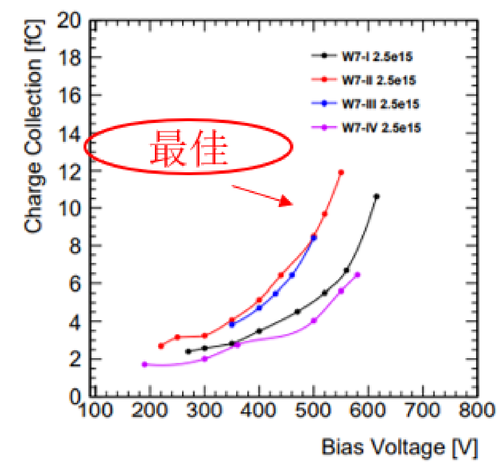
IHEP-IMEv2 sensor characteristics

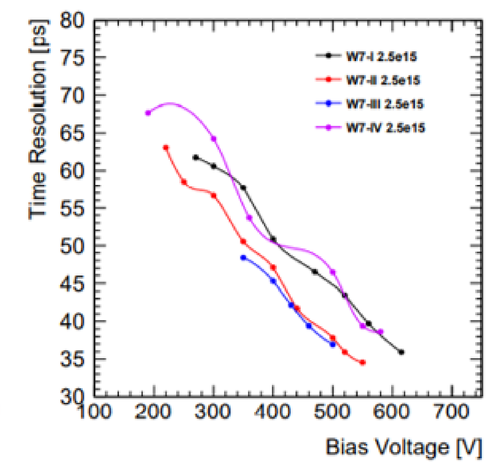




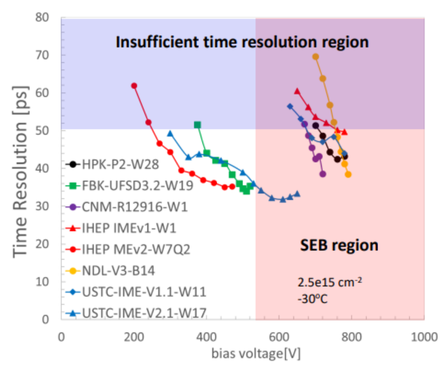
Vgl 随辐照剂量增大而减小

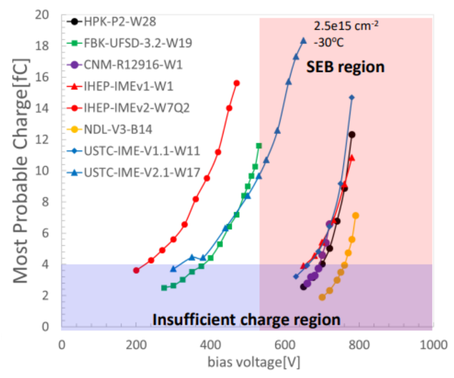
不同碳注入剂量时的收集电荷与时间分辨情况（0.2C-3C）

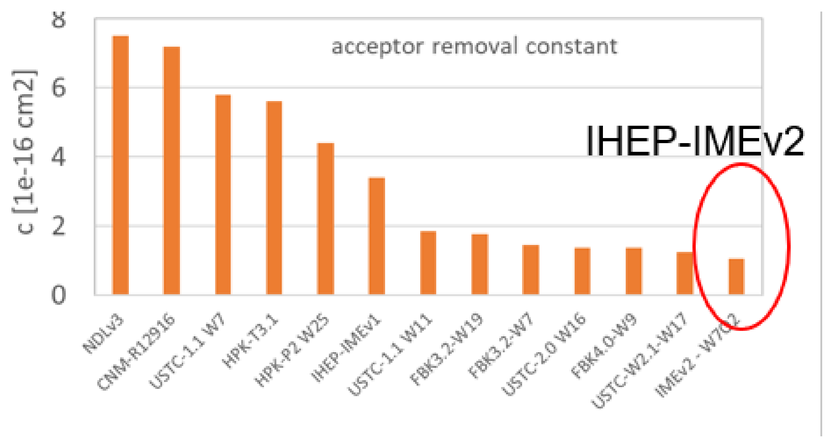




Charge collection and time resolution



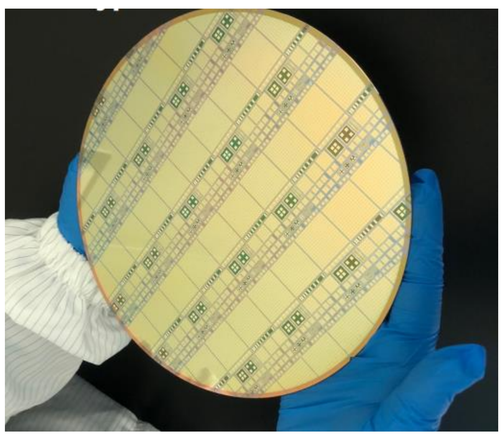




◆After 2.5e15neq/cm^2 irradiation, sensors have a collected charge larger than 4fC at about 450V, which satisfy the requirement of the ATLAS HGTD project (>4fC after irradiation).

IHEP-IMEv3 design and fabrication

➢工艺重复性验证
➢优化设计大阵列器件外围GR结构
➢优化设计pixel间距
➢掺碳工艺进一步优化
（掺碳剂量和退火条件）



	number	Type
最优工艺条件重复	12	repeat v2 w7_II
	13	repeat v2 w7_II
	14	repeat v2 w4_II
掺碳工艺进一步优化	15	change B dose, 0.5 unit C(low thermal load)
	16 ,17	change C dose (high thermal load)
	18	C with median thermal load
高能碳注入	19	repeat v2 w1_I
	20,21,22	high energy C implantation
厚EPI器件	23	thick EPI(65um) without C implantation
	24	thick EPI(65um) , 0.5 unit C(high thermal load)
	25	thick EPI(80um) without C implantation
	26	thick EPI(80um), 0.5 unit C(high thermal load)

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