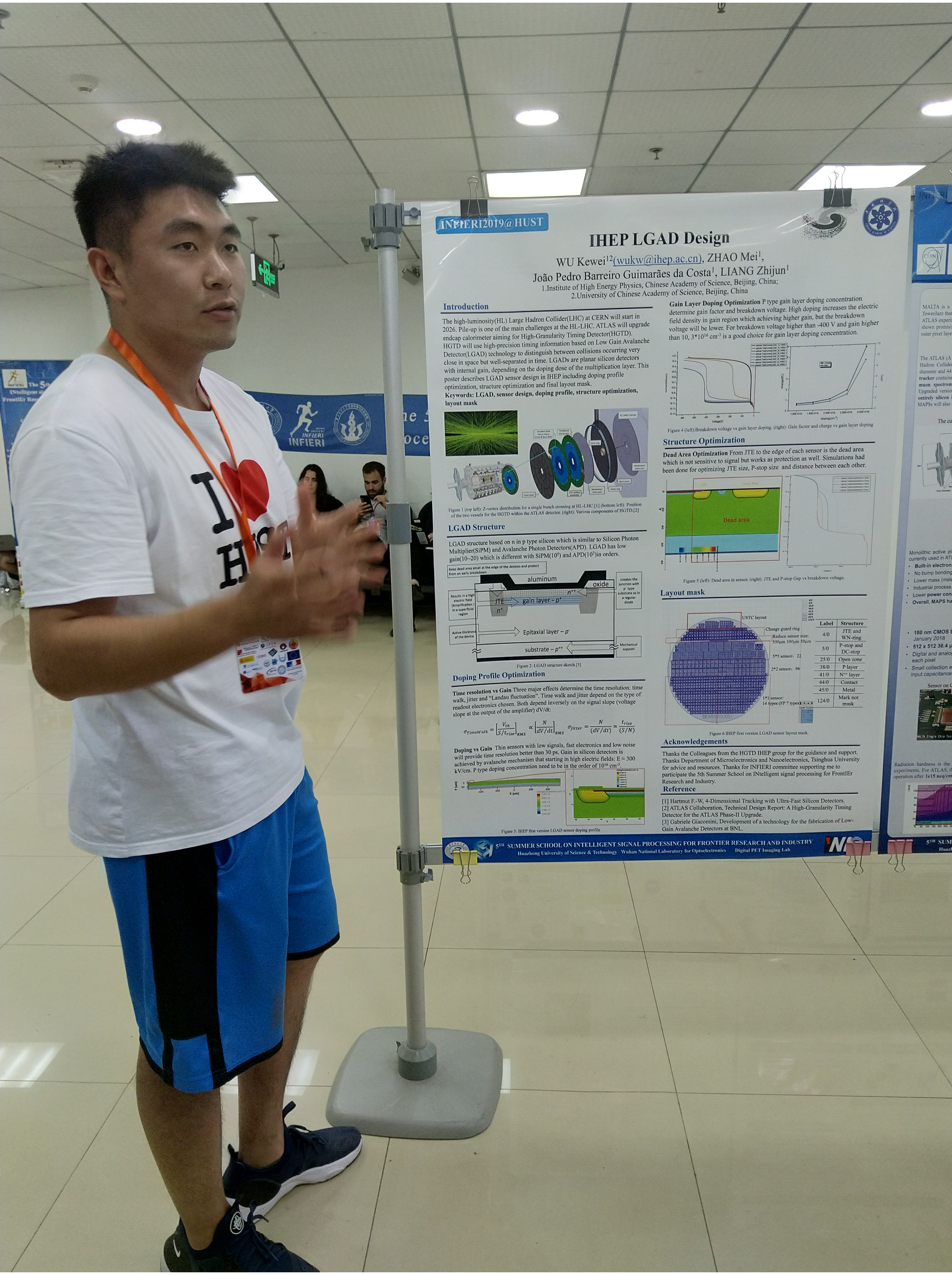

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IHEP LGAD Design
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Introduction
The high-luminosity(HL) Large Hadron Collider(LHC) at CERN will start in 2026. Pile-up is one of the main challenges at the HL-LHC. ATLAS will upgrade endcap calorimeter aiming for High-Granularity Timing Detector(HGTD). HGTD will use high-precision timing information based on Low Gain Avalanche Detector(LGAD) technology to distinguish between collisions occurring very close in space but well-separated in time. LGADs are planar silicon detectors with internal gain, depending on the doping dose of the multiplication layer. This poster describes LGAD sensor design in IHEP including doping profile optimization, structure optimization and final layout mask.
Keywords: LGAD, sensor design, doping profile, structure optimization, layout mask
Figure 1 (top left): Z-vertex distribution for a single bunch crossing at HL-LHC.[1] (bottom left): Position of the two vessels for the HGTD within the ATLAS detector. (right): Various components of HGTD.[2]
LGAD Structure
LGAD structure based on n in p type silicon which is similar to Silicon Photon Multiplier(SiPM) and Avalanche Photon Detectors(APD). LGAD has low gain(10~20) which is different with SiPM(10^5) and APD(10^2)in orders.
aluminum
oxide
JTE
gain layer – p+
Epitaxial layer – p-
substrate – p++
Figure 2: LGAD structure sketch.[3]
Doping Profile Optimization
Time resolution vs Gain Three major effects determine the time resolution: time walk, jitter and "Landau fluctuation". Time walk and jitter depend on the type of readout electronics chosen. Both depend inversely on the signal slope (voltage slope at the output of the amplifier) dV/dt:
Doping vs Gain Thin sensors with low signals, fast electronics and low noise will provide time resolution better than 30 ps. Gain in silicon detectors is achieved by avalanche mechanism that starting in high electric fields: E ≈ 300 kV/cm. P type doping concentration need to be in the order of 10^16 cm^-3.
Figure 3: IHEP first version LGAD sensor doping profile
Gain Layer Doping Optimization P type gain layer doping concentration determine gain factor and breakdown voltage. High doping increases the electric field density in gain region which achieving higher gain, but the breakdown voltage will be lower. For breakdown voltage higher than -400 V and gain higher than 10, 3*10^16 cm^-3 is a good choice for gain layer doping concentration.
Figure 4 (left):Breakdown voltage vs gain layer doping. (right): Gain factor and charge vs gain layer doping
Structure Optimization
Dead Area Optimization From JTE to the edge of each sensor is the dead area which is not sensitive to signal but works as protection as well. Simulations had been done for optimizing JTE size, P-stop size and distance between each other.
Dead area
Figure 5 (left): Dead area in sensor. (right): JTE and P-stop Gap vs breakdown voltage.
Layout mask
USTC layout
Label
Structure
4/0
JTE and WN-ring
5/0
P-stop and DC-stop
25/0
Open zone
38/0
P layer
41/0
N++ layer
44/0
Contact
45/0
Metal
124/0
Mark not mask
Figure 6 IHEP first version LGAD sensor layout mask.
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Reference
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