Testbeam results of n+-in-p planar pixel sensor of quad ASIC pixels and high momentum resolution pixel detectors

K. Nakamura, H.Sawai, K.Sato, J. Suzuki, S. Kamada, K. Yamamura, Y. Ikegami, Y. Takubo, Y. Unno, K.Hanagaki, R. Takashima, J.Tojo, T.Kono, O.Jinnouchi, K.Motohashi, D.Yamaguchi, K.Hara, and M.Hagihara

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Introduction

High Luminosity LHC (HL-LHC)

Start around 2026- with new crab cavity in the interaction region. Target : $\sqrt{s}$=14TeV **L=5x10^{34} $\int Ldt$=3000fb^{-1}.** Physics program focus the precise measurement of the Higgs coupling (e.g. Y_τ, Y_b and λ_{HHH}) and BSM searches. To keep B/τ-tagging performance up to 200 pileup in an event. Mitigation for the pileup effect for MET calculation can be done by tracking from primary vertex.

Planer pixel module (Outer Pixel layer(s))

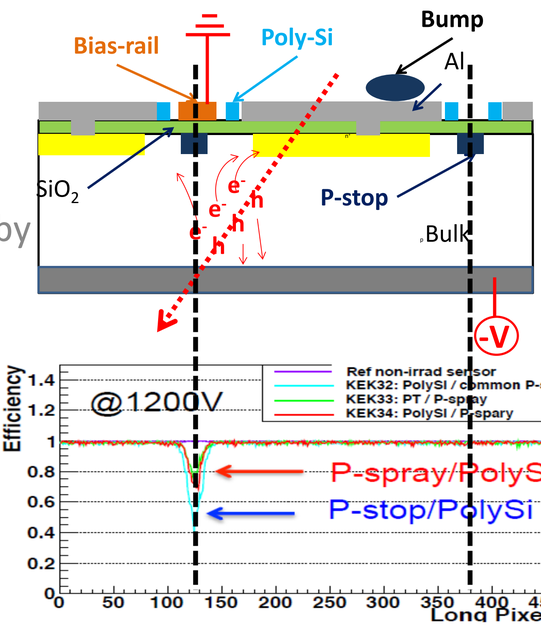
FE-I4 read out chip on the **n$^+$-in-p$^+$ type** sensor. Pixel size : **50x250µm**, thickness : **150µm.** Time-over-threshold (ToT) readout using 15x25ns clock.

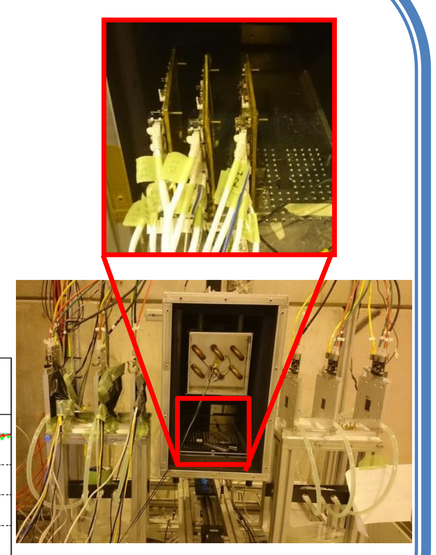
Expected radiation fluence in 3000fb^{-1} is ~1x10^{15} 1MeV n_{eq} /cm^2

test 3x10^{15} fluence of proton and 2.4MGy gamma to confirm radiation-tolerance.

Testbeam at CERN in Jun/Sep 2015 and June 2016

To figure out the efficiency drop at under the biasing structure, performed testbeam at CERN which can realize 3-4µm pointing resolution at detector under test by telescope

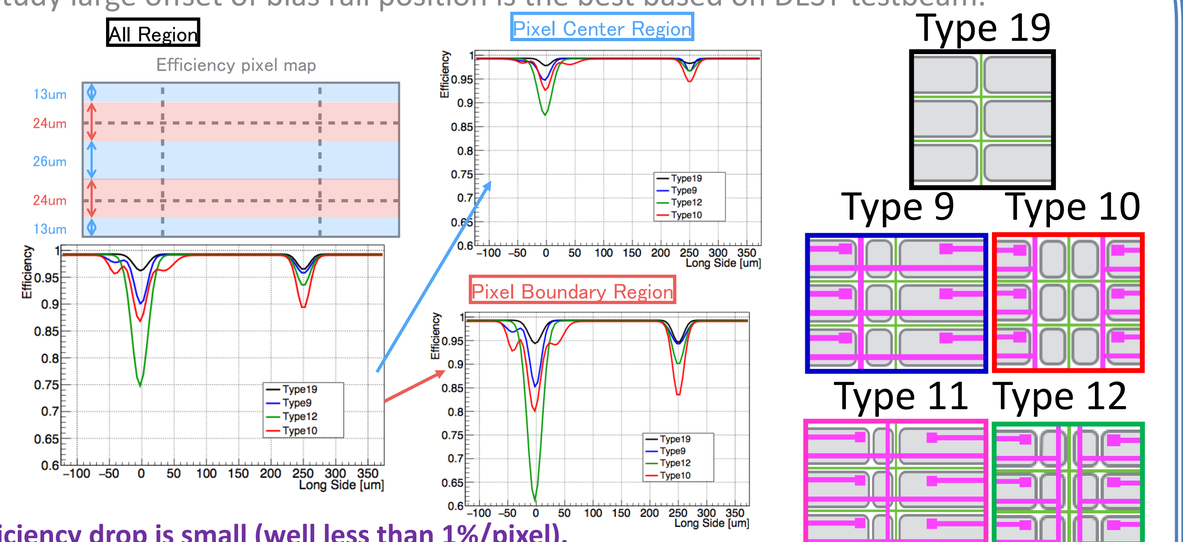




Biasing structure

Biasing structure optimization

Compare efficiency drop at under the various biasing structure. In the previous study large offset of bias rail position is the best based on DESY testbeam.



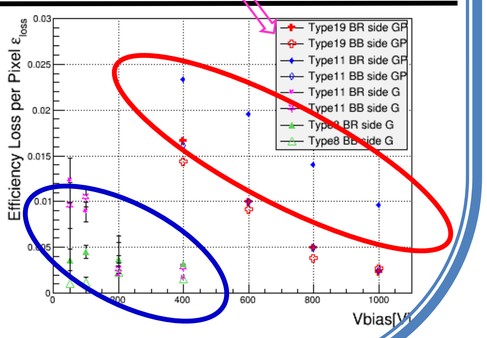
Efficiency drop is small (well less than 1%/pixel).

Thanks to the better pointing resolution of CERN testbeam, clearly see the efficiency drop at bias rail across the pixel boundary.

Source of efficiency drop issue

To identify the issue if it's caused by surface damage or bulk damage, **Gamma irradiated (2.4MGy)** and **Gamma(2.4MGy)+Proton irradiated(3x10^{15}n$_{eq}$/cm^2)** samples are tested.

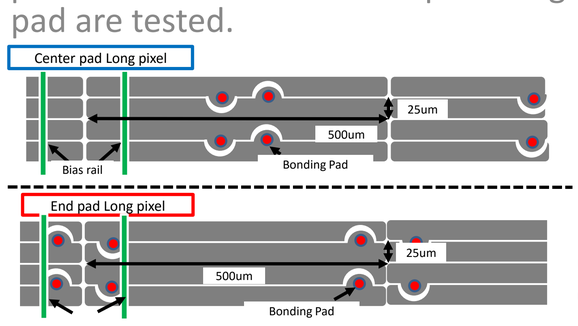
Clearly efficiency loss at the pixel boundary region does not appear after Gamma only irradiated sample but see in Gamma+Proton Irradiated sample.

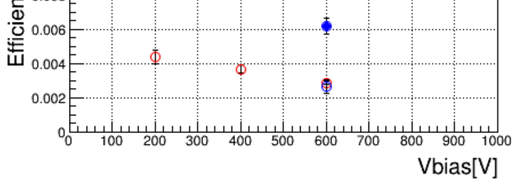


High Momentum resolution pixel

High Momentum resolution pixel

Default pixel size : 250um x 50um. 500um x 25um pixel size can be also produced by using the same ASIC and bumpbonding pad. Two types of pixel position relative to the bumpbonding pad are tested.

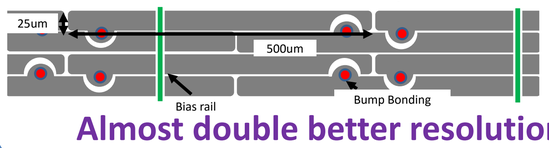


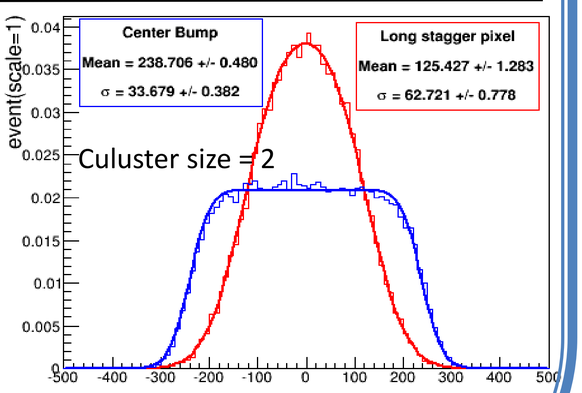


Both type have small efficiency drop (<1%/pixel). Center pad is better efficiency than end pad. High momentum resolution pixel is able to be used as an option of pixel detector.

Stagger geometory

500um x 25um pixel size indeed have better momentum resolution, but worse resolution for the pseud-rapidity direction. To improve pseud-rapidity direction resolution, rows with even row number are shifted half pitch (250um), so that the resolution improve in case have hits with two rows (cluster size=2).



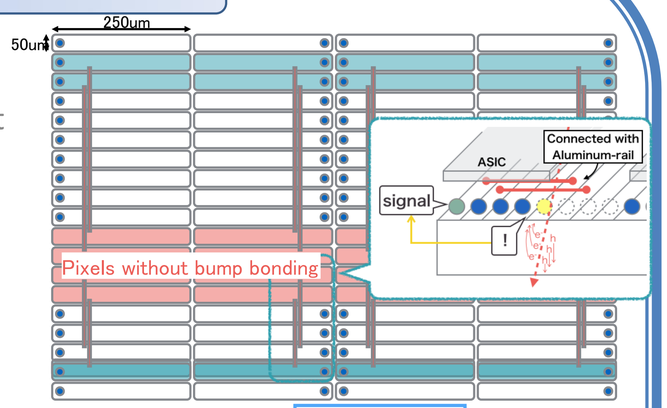


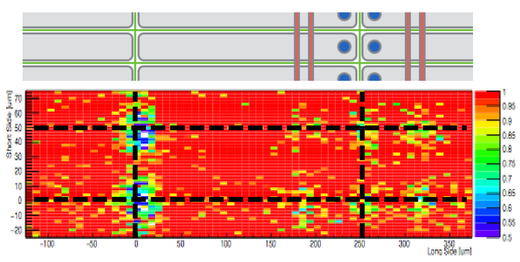
Almost double better resolution for cluster size = 2 events compared to the non-staggered geometry. Even vertical beam condition, about 10% of events have cluster size =2. (larger rate in actual ATLAS det.)

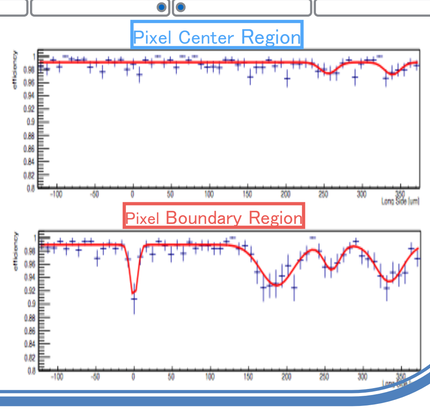
Quad ASIC pixels

Quad chip module

4 ASICs are bumpbonded to the single sensor. There are pixel rows which don't have bumpbonding to ASIC due to the ASIC boundary region. Ganging structures are constructed to read out such pixels. (Al lines are connected.)







Over all efficiency is around 99% even after 3x10^{15}n$_{eq}$/cm^2 irradiation.

We observed small efficiency drop (<1%/pixel) at the gang Al across the pixel boundary. (~ 0.1%/pixel at center of pixel but 1.2%/pixel at pixel boundary)

Magnetic field Test

Lorentz angle is measured by obtaining minimum point of cluster size as a function of incident angle. As the result, Lorentz angle for B=0.8T is 6.0±1.9 degree and this result is consistent to the weighting field simulation.

As further performance study

Magnetic field test has been done with Super conducting Solenoid magnet at KEK Cryogenic center.

Three layer of planner pixel sensors are installed and detected cosmic muon to obtain Lorentz angle in the magnetic field.