

# Study on silicon sensors with high timing/position resolution

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## **Particle ID by ToF**

- K/π/p separation is difficult by shower shape
- Possible by dE/dx at TPC and ToF at calorimeters
   – 50 psec → 3-4 GeV
- Requirements
  - Fast detector  $\rightarrow$  LGAD
  - Electronics
  - Calibration



### **Position resolution of hits**

- Position resolution of hits is only important at innermost layers
- Both position and angular resolution matters
  - For angular: should have similar resolution to shower-max

Inner layers position reso of hits more important

Shower-max Moriere radius divided by sqrt(N hits) 9 mm / sqrt(1000) ~ 0.3 mm



### "5-D calorimeter"



#### LGAD (tracker / preshower)

### Inverse APD as LGAD

- APD and LGAD are based on the same technology
  - \* APD can be a reference for the LGAD development
- Reach-through vs inverse LGAD/APD
  - Reach-through: multiplication just below electrode
  - Inverse: multiplication on the other side
- Advantage of inverse LGAD/APD
  - Better gain flatness can be obtained because of avalanche region deeper in silicon.
    - Especially critical in LGAD strip detector

#### Disadvantages of inverse LGAD/APD

- Radiation tolerance
  - Should be acceptable in ILC application
- Timing resolution can be worse due to longer travel length after multiplication
  - Should be checked
- We are investigating the inverse APD as a reference of LGAD for ILC



### Inverse APD sample

#### • APD : S8664-20K manufactured by Hamamatsu photonics

- > Inverse APD ("for short wavelength")
- ≻active area : 2 mm φ
- ≻break down V : ~430 V
- ≻Max gain: ~50
- ≻Capacitance: ~20 pF
- > Used for measurements with radiation

#### • Bare-chip APD

- $\triangleright$  Similar process to S8664-20K
- $\succ$  Need a probe to access the electrode
- Currently only used for measurements of DC characteristics







Bare-chip APD geometry 5 x 5 mm active area

Probe station in Kyushu

### Radiation detection with APD

#### • Target

- Confirmation of signal with radiation.
- Obtain active thickness
- Radiation sources
  - - $\gamma$  source (<sup>57</sup>Co, <sup>133</sup>Ba) for signal of fixed energy deposit.



• Calculate active thickness by comparing these.





#### • HV filter circuit

To reduce noise caused by HV fluctuation.

- Setup
- We use SKIROC2A to measure the signal.
- SKIROC is implemented on the evaluation board
- Daughter board was made and it can be connected to testboard directly.
- If testboard is not connected to sensor, S/N>20 is obtained.



1 mm collimator

### Results with $\gamma$ and $\beta$ rays



Gain curve with laser

410V h1 entry 0025 C 297618 Entries Mean 433.8 2000 RMS 153.1 1800 1600 1400 1200 1000 800 600 400 200 300 400 500 600 700 ADC <sup>90</sup>Sr MIP-like signal

- Confirmed to see MIP signal with the APD
- Suffered from non-flatness of the APD (with small φ)
- Active thickness: O(10 μm) to be confirmed

# **PSD: principles**





Meshed p+

- Multiple electrodes in one cell to obtain hit position by charge sharing
- Surface resistivity is a key for the dynamic range of ratio at 4 pads
- S/N ratio determines position resolution
  → thicker sensor preferred
- Multiple hits → gravity center
  → Hit density should not be high



Position distortion

### **Sensor configuration**

4 x 4 cells two surface R (meshed P+, additional R layer) Electrodes not at the corner to check the response at the corner by laser injection

Ideas for smaller position distortion





Productions with various ideas implemented at production in March 2018



Connected electrodes

### Results



Laser injection at center region

- Good DR with higher R
  - Timing response should be checked
- Issue on vertical reco with striped R structure
- Other structures: to be checked





#### Normal structure

#### Strip structure



Strip structure: horizontal is OK Reconstruction of vertical position has an issue

### **Summary and plans**

- Study on APD/LGAD and PSD ongoing for precise 5D calorimetry
- APD: success to see MIP and gamma active thickness to be confirmed
  - We obtained various structure: to be examined
- PSD: Various test structure produced and being tested
  - Good dynamic range obtained
  - Striped R is not good in vertical reconstruction