

# Welcome & Introduction

Workshop for development  
and applications of fast-timing  
semiconductor devices

8<sup>th</sup> Dec 2018  
@ University of Tsukuba,  
Tokyo Campus (Otsuka) Room 117/119

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Workshop organized by:

KH

Koji Nakamura (KEK)

Yoshinobu Unno (KEK)

Workshop sponsored by:

Japan-US Science & Technology  
Cooperation Program  
-in the field of high energy physics-



# An History - beginning

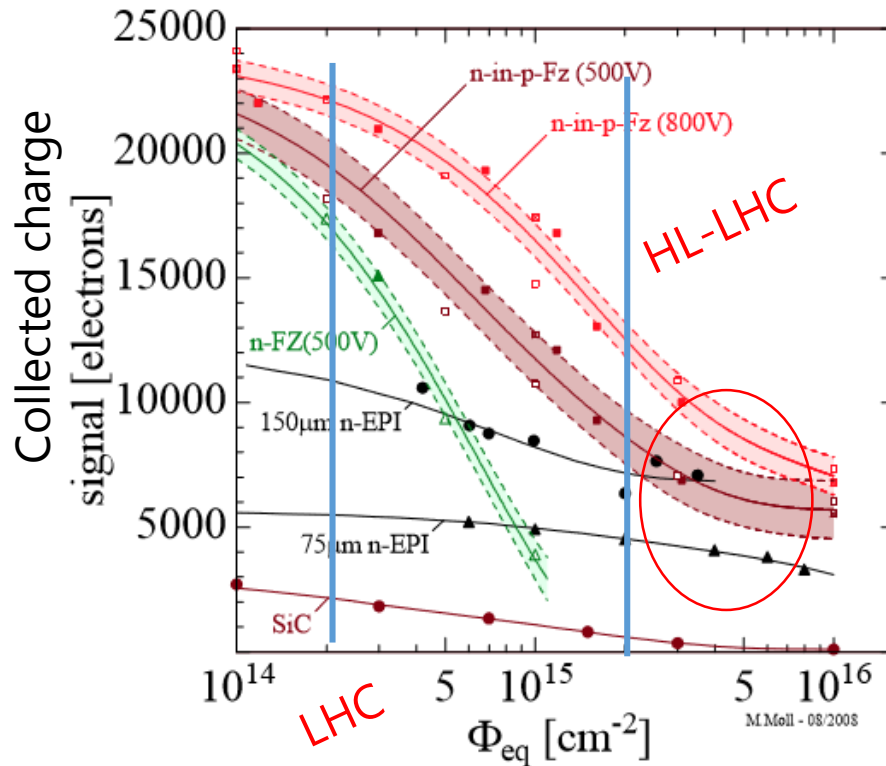
~2005 : Silicon sensor fabrication completed for LHC (p-in-n)  
Started investigation on application for higher fluence (HL-LHC and beyond)

## RD50 Silicon materials for Tracking Sensors



### • Signal comparison for various Silicon sensors

**Note:** Measured partly under different conditions!  
Lines to guide the eye (no modeling)!



### Silicon Sensors

- p-in-n (EPI), 150  $\mu m$  [7,8]
- ▲ p-in-n (EPI), 75  $\mu m$  [6]
- n-in-p (FZ), 300  $\mu m$ , 500V, 23GeV p [1]
- n-in-p (FZ), 300  $\mu m$ , 500V, neutrons [1]
- n-in-p (FZ), 300  $\mu m$ , 500V, 26MeV p [1]
- n-in-p (FZ), 300  $\mu m$ , 800V, 23GeV p [1]
- n-in-p (FZ), 300  $\mu m$ , 800V, neutrons [1]
- n-in-p (FZ), 300  $\mu m$ , 800V, 26MeV p [1]
- ▲ p-in-n (FZ), 300  $\mu m$ , 500V, 23GeV p [1]
- △ p-in-n (FZ), 300  $\mu m$ , 500V, neutrons [1]

### Other materials

- SiC, n-type, 55  $\mu m$ , 900V, neutrons [3]

### References:

- [1] p/n-FZ, 300  $\mu m$ , (-30°C, 25ns), strip [Casse 2008]
- [2] p-FZ, 300  $\mu m$ , (-40°C, 25ns), strip [Mandic 2008]
- [3] n-SiC, 55  $\mu m$ , (2  $\mu m$ ), pad [Moscato 2006]
- [4] pCVD Diamond, scaled to 500  $\mu m$ , 23 GeV p, strip [Adam et al. 2006, RD42]  
Note: Fluences normalized with damage factor for Silicon (0.62)
- [5] 3D, double sided, 250  $\mu m$  columns, 300  $\mu m$  substrate [Panicard 2007]
- [6] n-EPI, 75  $\mu m$ , (-30°C, 25ns), pad [Kramberger 2006]
- [7] n-EPI, 150  $\mu m$ , (-30°C, 25ns), pad [Kramberger 2006]
- [8] n-EPI, 150  $\mu m$ , (-30°C, 25ns), strip [Mazzocco 2007]

- n-in-p is just OK for HL-LHC (3D for shorter collection path)
- signal multiplication preferred for higher fluence

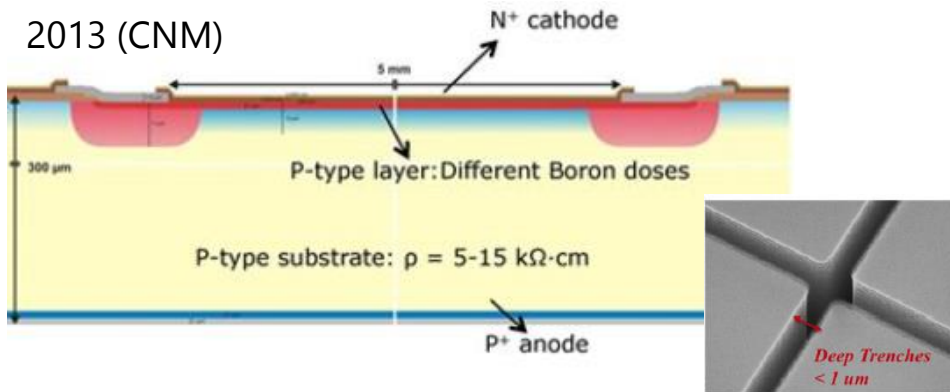
# An History

2010~ possibility of detector with multiplication discussed in RD50 (CNM/UCSC/...)

operate avalanche diode (APD) in linear mode: fine segmentation for tracking

LGAD (low gain avalanche diode)

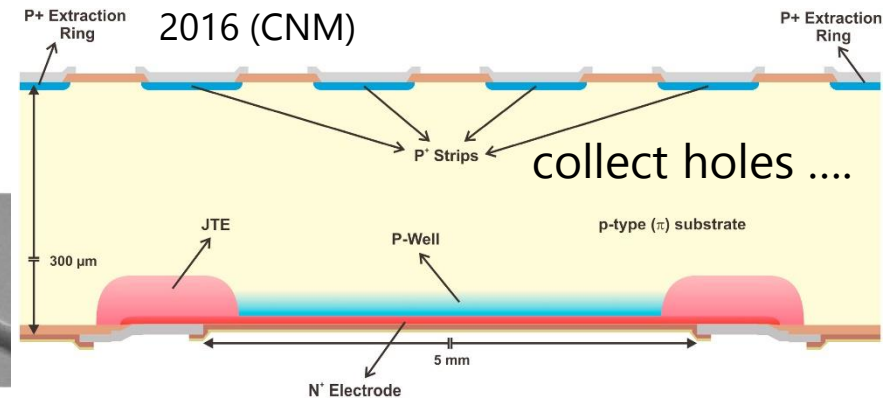
2013 (CNM)



Deep trench  
(2018 CNM)

Inverse LGAD (iLGAD) for larger active area

2016 (CNM)



UFSD (ultra-fast silicon detector)

USCS ~2012

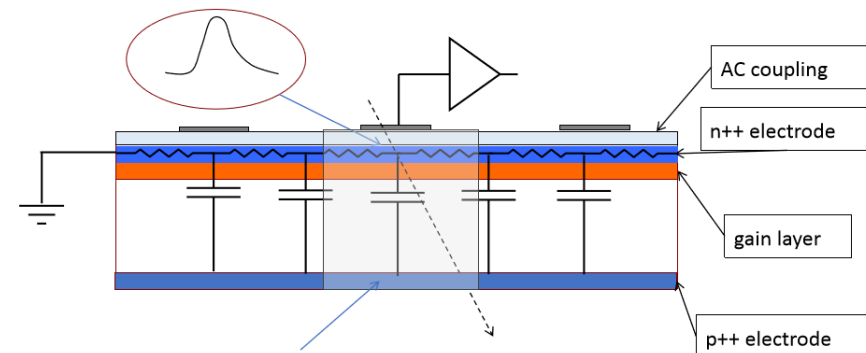
Timing measurements (thin detector) by

2016, 2017 (UCSC/INFN et al.) ... 27ps

2018 TB (Tsukuba/KEK)...30ps

4D tracking is being realized

AC LGAD 2018 (INFN/BNL)



The AC read-out sees only a small part of the sensor:

# At this Workshop

## evaluation

- ✓ Gain
- ✓ Fast signal
- ✓ Radiation resistance

## promising application

ToF-PET

## understanding detector

simulation

LGAD/  
Fast CMOS

we need to read out

future HEP application

on-going application

# At this Workshop

10min is allocated for discussion

## evaluation

HPK LGAD performance  
evaluation by Tsukuba/KEK

Onaru(Tsukuba/M1)  
Wada(Tsukuba/M2)

Inverse LGAD for ILC PID

Mori(Kyushu U)

## promising application

ToF-PET

Taiga (NIRS)\*  
Hayakawa (U Genève)\*\*

## understanding detector

TCAD simulation

Wada(Tsukuba/M2)

## we need to read out

Fast electronics

Lai (U di Cagliari)

## for future HEP

Tracking at FCC

Saito (U Tokyo)

## on-going application

ATLAS HGTD

Mezza (UCSC)

Summary& prospects

Nakamura (KEK)

\*Move to Rm119 at 12:00

\*\*Working lunch

Decide your preference by 10:00



オリジン弁当 茗荷谷店

03-3943-8593

# Working lunch menu

NEW

shrimp



hamburg

Dx和風オニオンチーズハンバーグ弁当

本体価格：741円/1個  
(税込：800円/1個)

shrimp



oyster

カキフライ生姜焼き弁当

本体価格：639円/1個  
(税込：690円/1個)  
1180kcal / 27.5g / 59.6g / 125.3g / 1221mg / 3.1g



pork

とんかつ弁当

本体価格：460円/1個  
(税込：496円/1個)  
968kcal / 28.7g / 36.1g / 125.2g / 963mg / 2.4g



chicken/pork

チキン竜田生姜焼き弁当

本体価格：602円/1個  
(税込：650円/1個)  
1268kcal / 37g / 63g / 129.8g / 1494mg / 3.8g

shrimp/vegetable



Dx塩野菜炒め弁当

本体価格：695円/1個  
(税込：750円/1個)  
1094kcal / 27.1g / 51.4g / 125g / 3228mg / 8.2g



salmon

幕の内 天然銀鮭

本体価格：649円/1個  
(税込：700円/1個)  
678kcal / 21.3g / 18.2g / 104g / 1730mg / 4.4g