

# Preliminary test results of 3D CMS pixel sensors for SLHC

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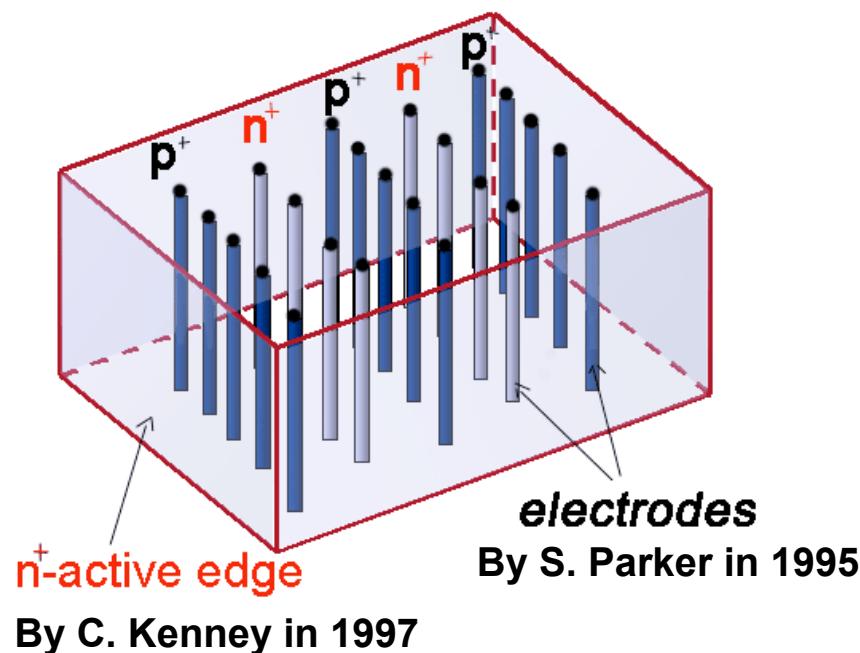
<sup>3</sup>*Fermilab, Batavia, IL 60510-5011 USA*

Pixel 2010, 8 September 2010

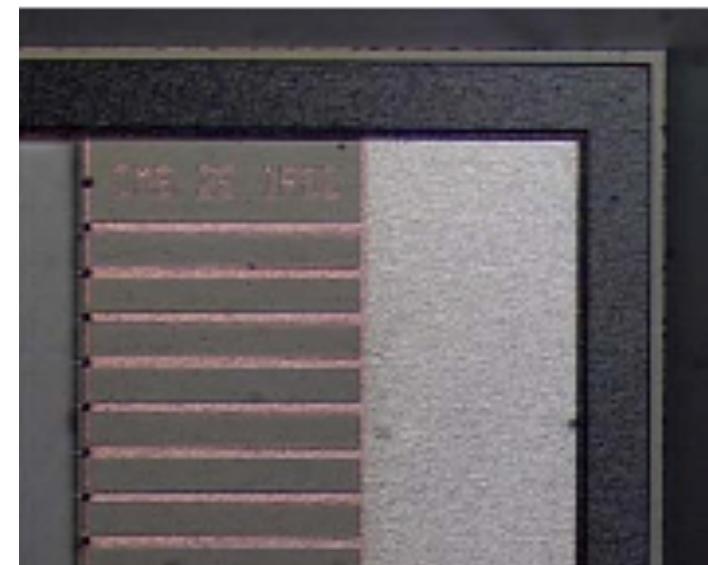
## Outline

- Introduction
- CMS 3D pixel sensors
- Wire bonding and assembly
- Readout characterization
- 3D testbeam at FNAL
- Source test
- Summary and outlook

# Introduction



- The edge is an electrode!
- Dead volume at the Edge < 2 microns!



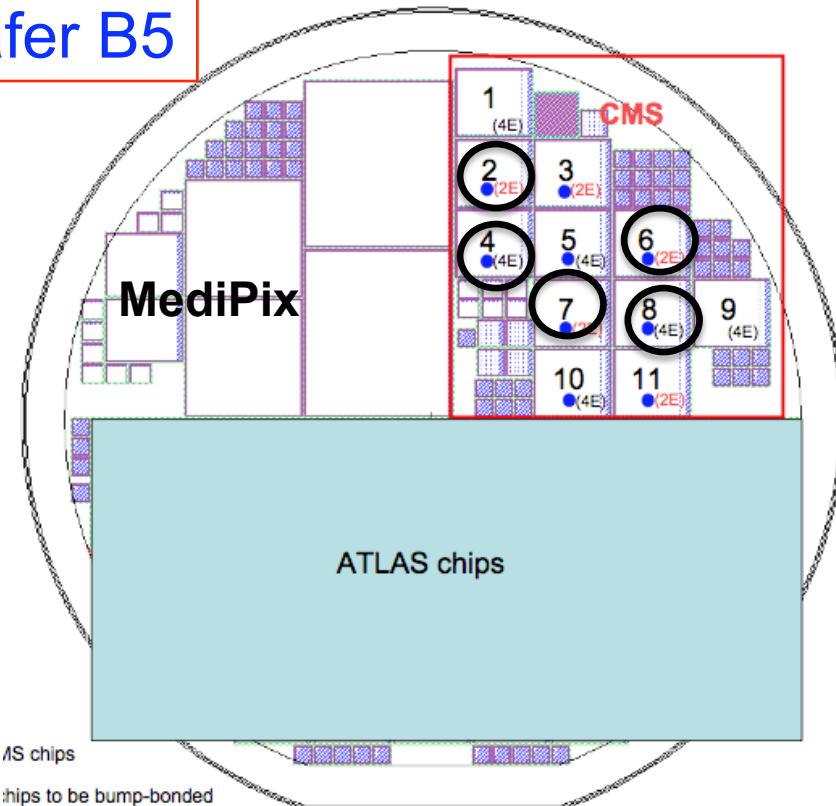
1. NIMA 395 (1997) 328
2. IEEE Trans Nud Sci 464 (1999) 1224
3. IEEE Trans Nud Sci 482 (2001) 189
4. IEEE Trans Nud Sci 485 (2001) 1629
5. IEEE Trans Nud Sci 48 6 (2001) 2405
6. CERN Courier, Vol 43, Jan 2003, pp 23-26
7. NIM A 509 (2003) 86-91
8. NIM A 524 (2004) 236-244
9. NIM A 549 (2006) 127
10. NIM A 560 (2006) 272
11. IEEE TNS 53 (2006) 1676
12. NIM A 587 (2008) 243-249

## Advantages:

- Low noise
- Lower depletion voltage
- Large area coverage
- Fast response
- Short drift length
- Less trapping

# SINTEF 3D Wafers

**Wafer B5**

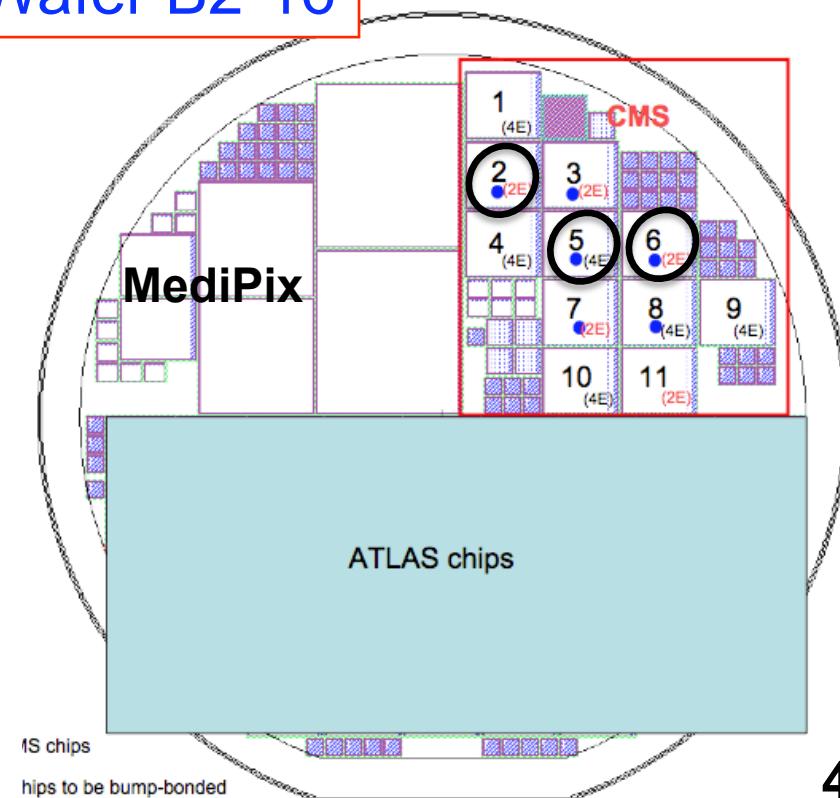


B5 : 280 $\mu$ m substrate thickness  
B2-16 : 200 $\mu$ m substrate thickness

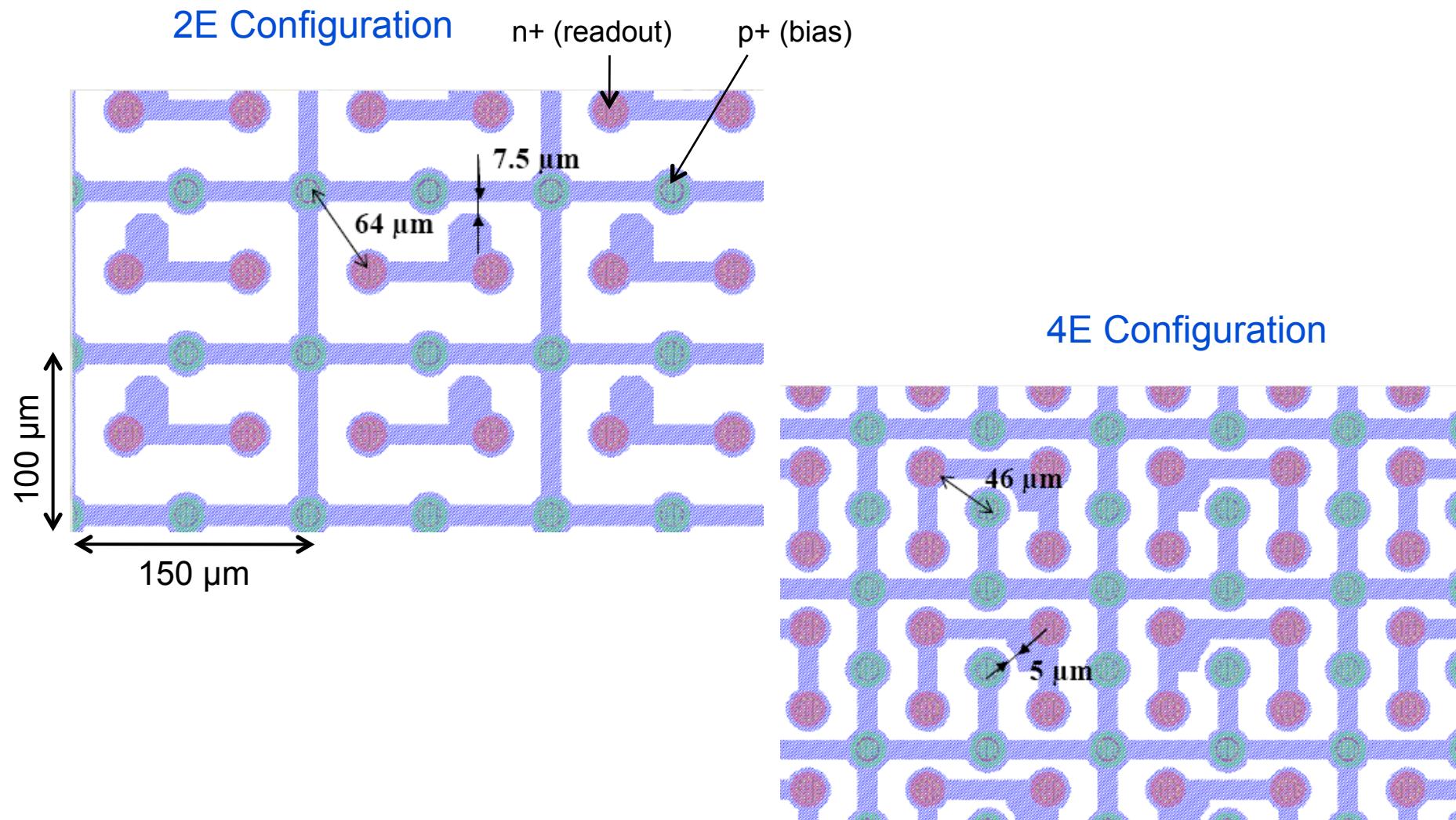
**P-type wafers include sensors for:**

- CMS
- ATLAS
- MediPix

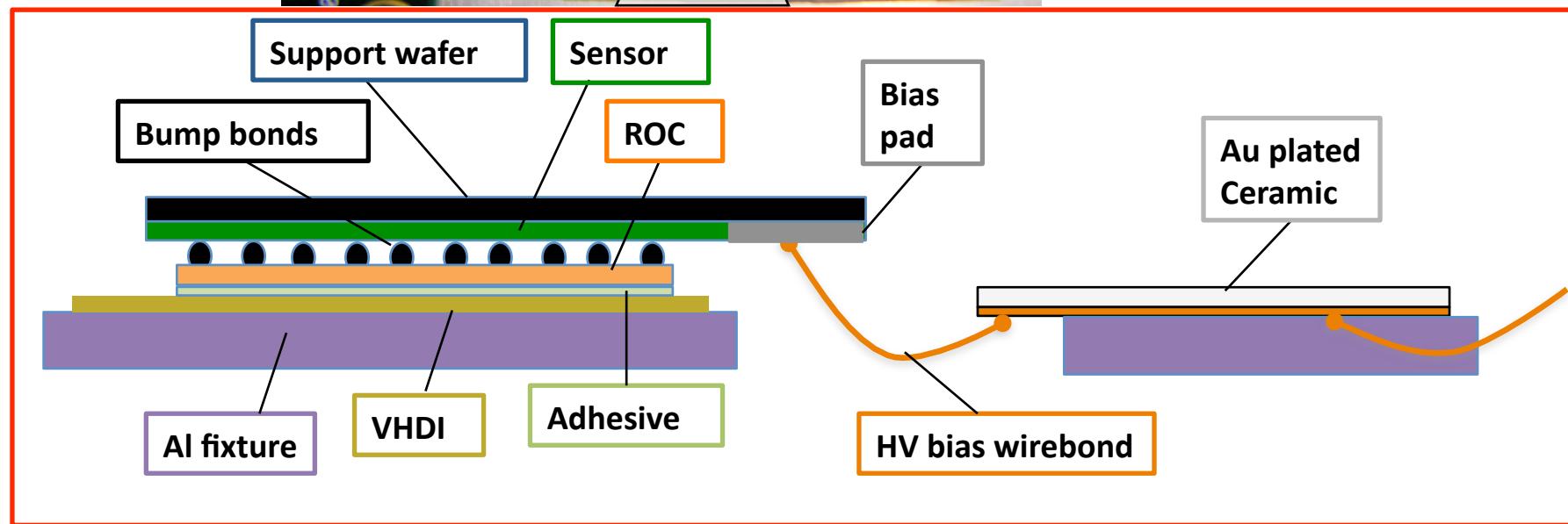
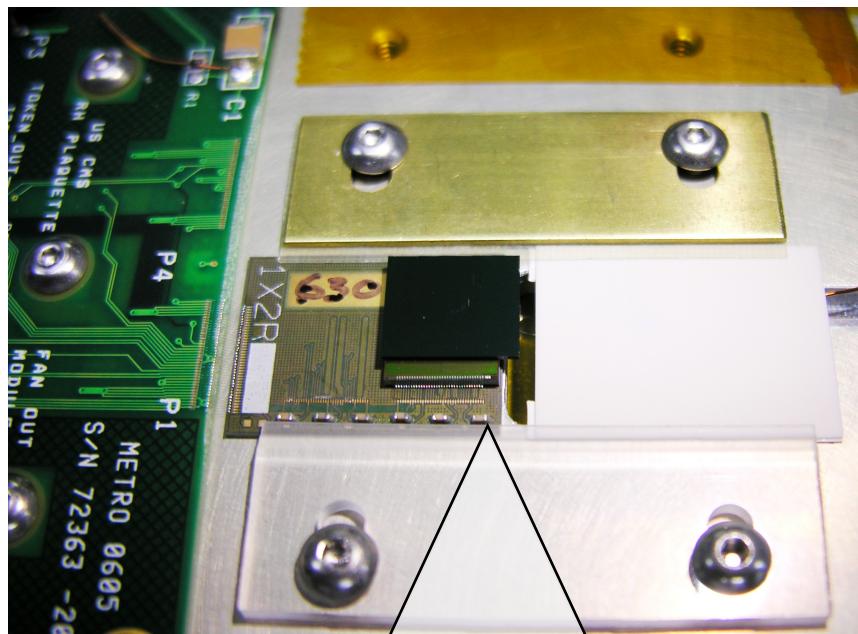
**Wafer B2-16**



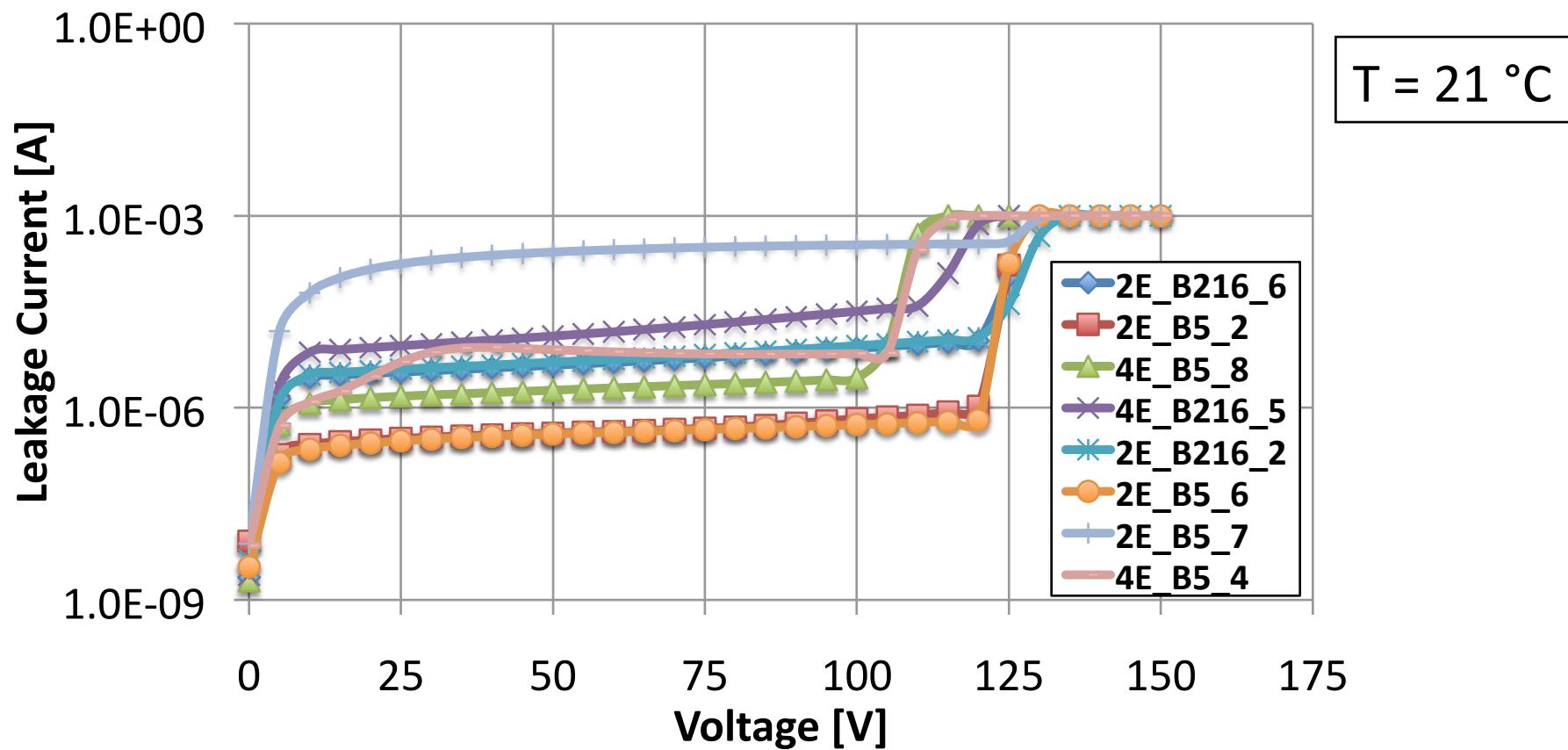
# 3D CMS pixel layouts



## 3D Plaquette – HV bias connection

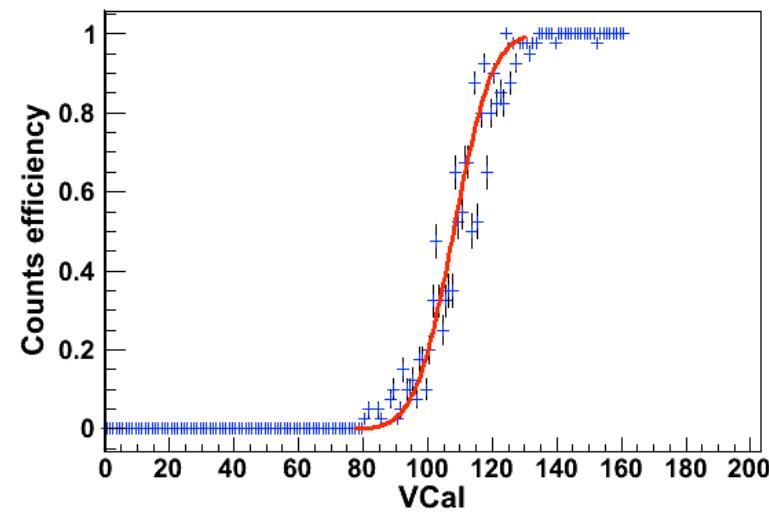
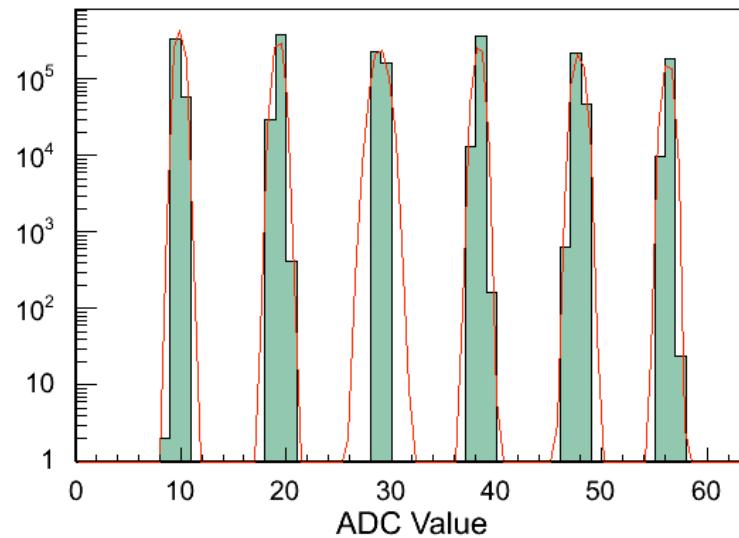
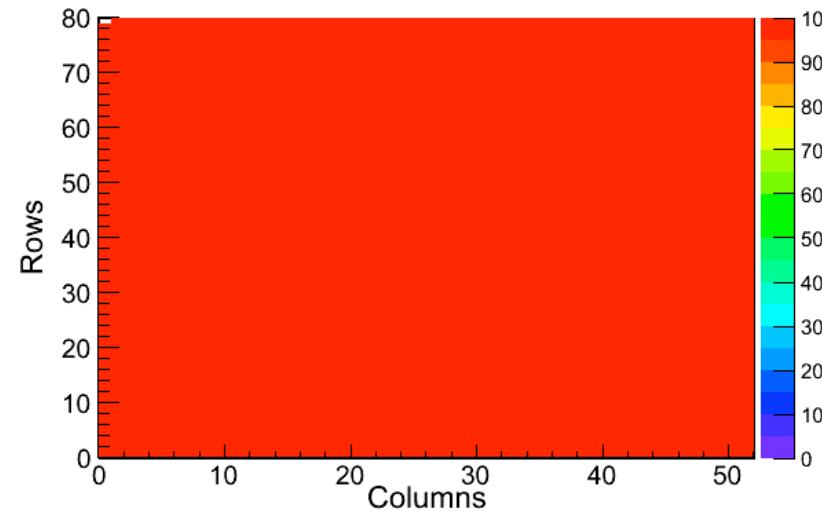
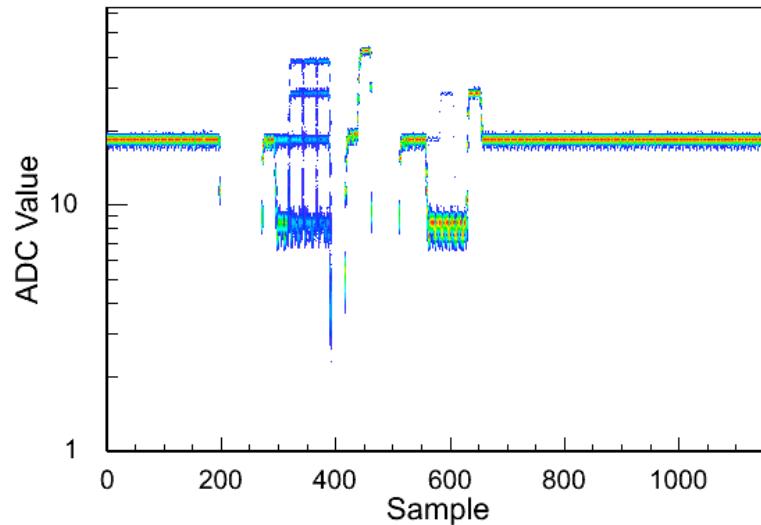


## 3D IV measurements



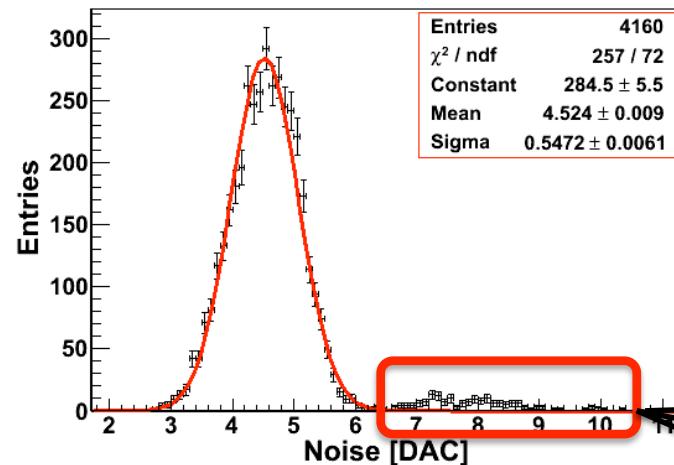
| Detector    | Voltage [V] | Purdue IV [ $\mu\text{A}$ ] | SINTEF IV [ $\mu\text{A}$ ] | Breakdown |
|-------------|-------------|-----------------------------|-----------------------------|-----------|
| 2E-WB5-2    | 40          | 0.7                         | 1                           | 120       |
| 2E-WB2-16-6 | 40          | 5                           | 5                           | 120       |
| 4E-WB5-8    | 40          | 2                           | 5                           | 100       |
| 4E-WB2-16-5 | 40          | 10                          | 15                          | 100       |

# 3D lab tests @ $V = -40\text{ V}$ : $T=21\text{ }^{\circ}\text{C}$

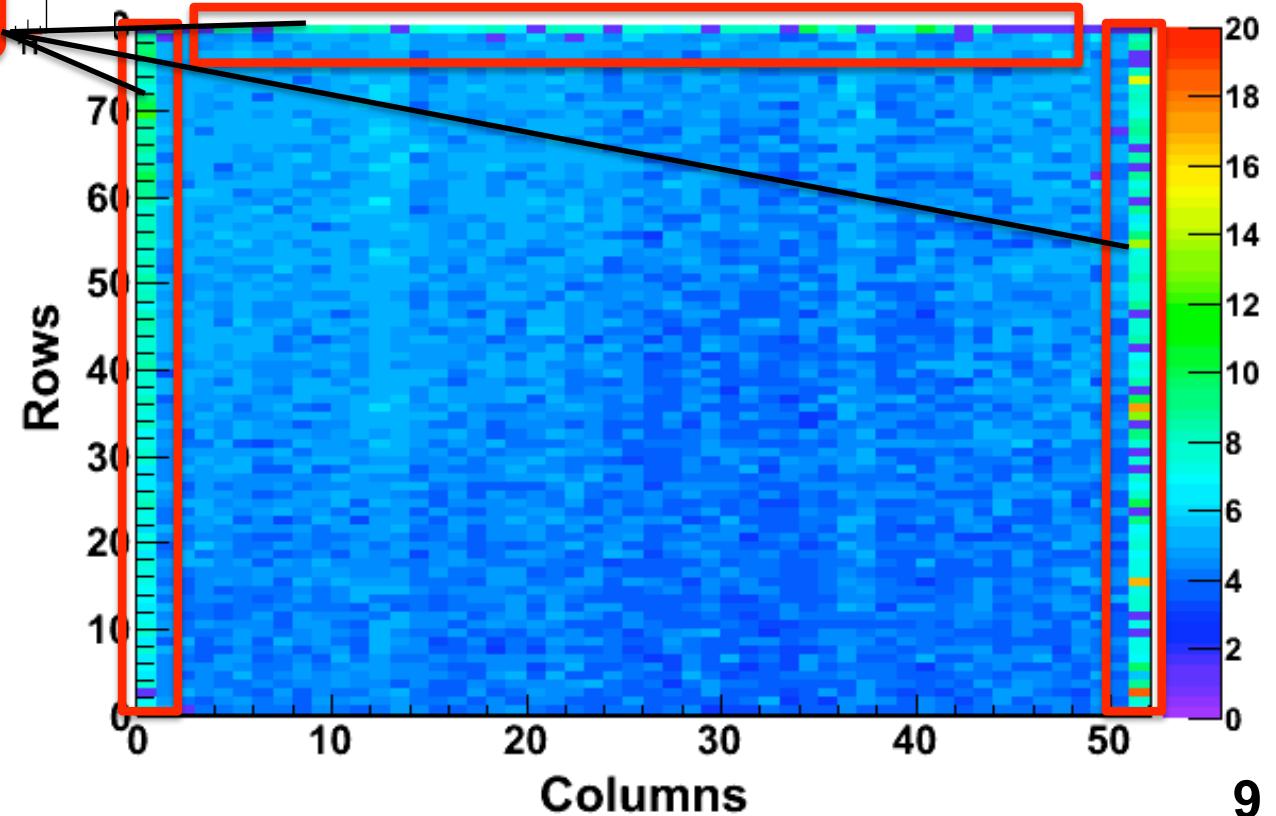


## 3D noise tests @ V = -40 V : T=21 °C

2E Wafer B5 #2

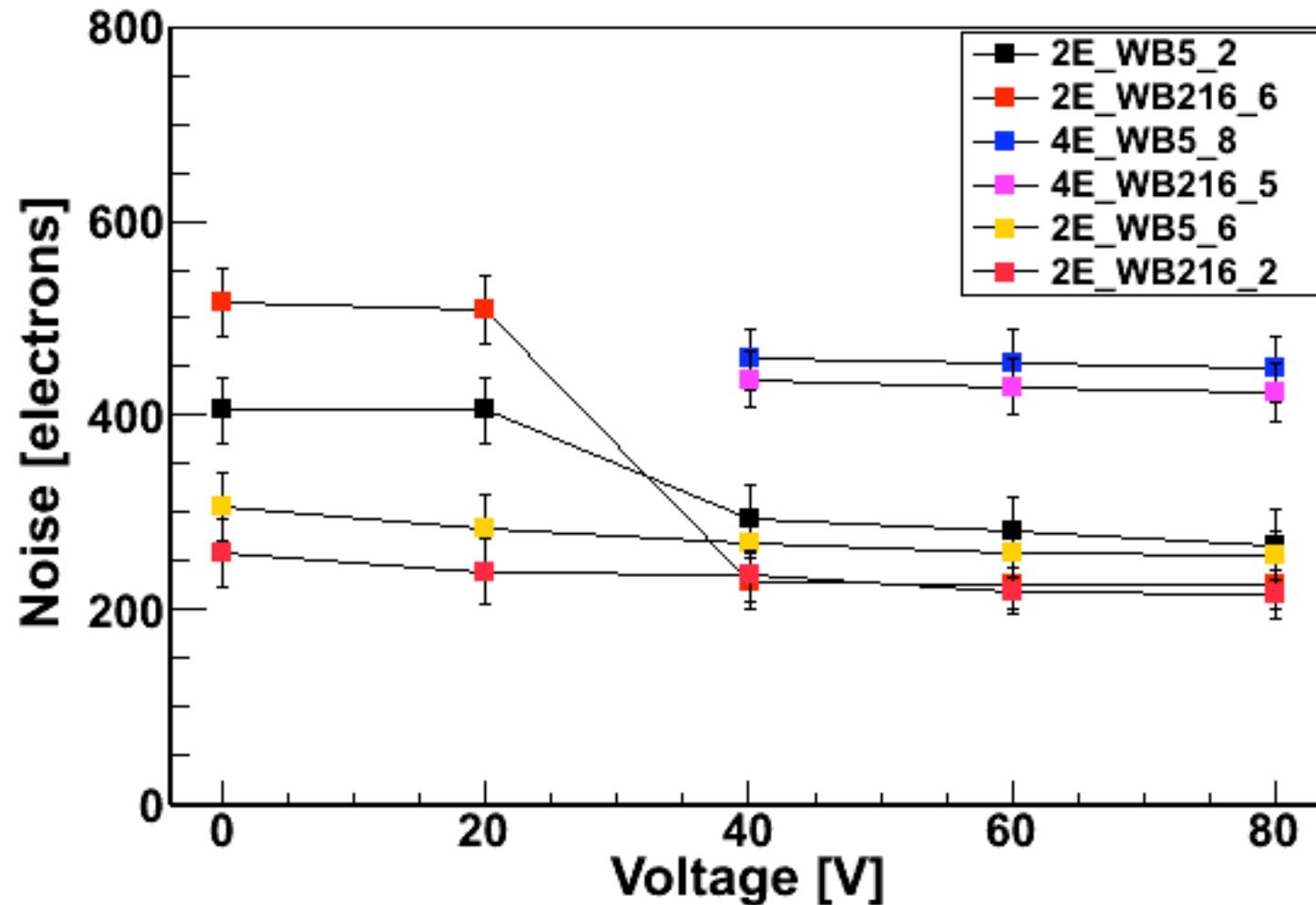


Noisy edges

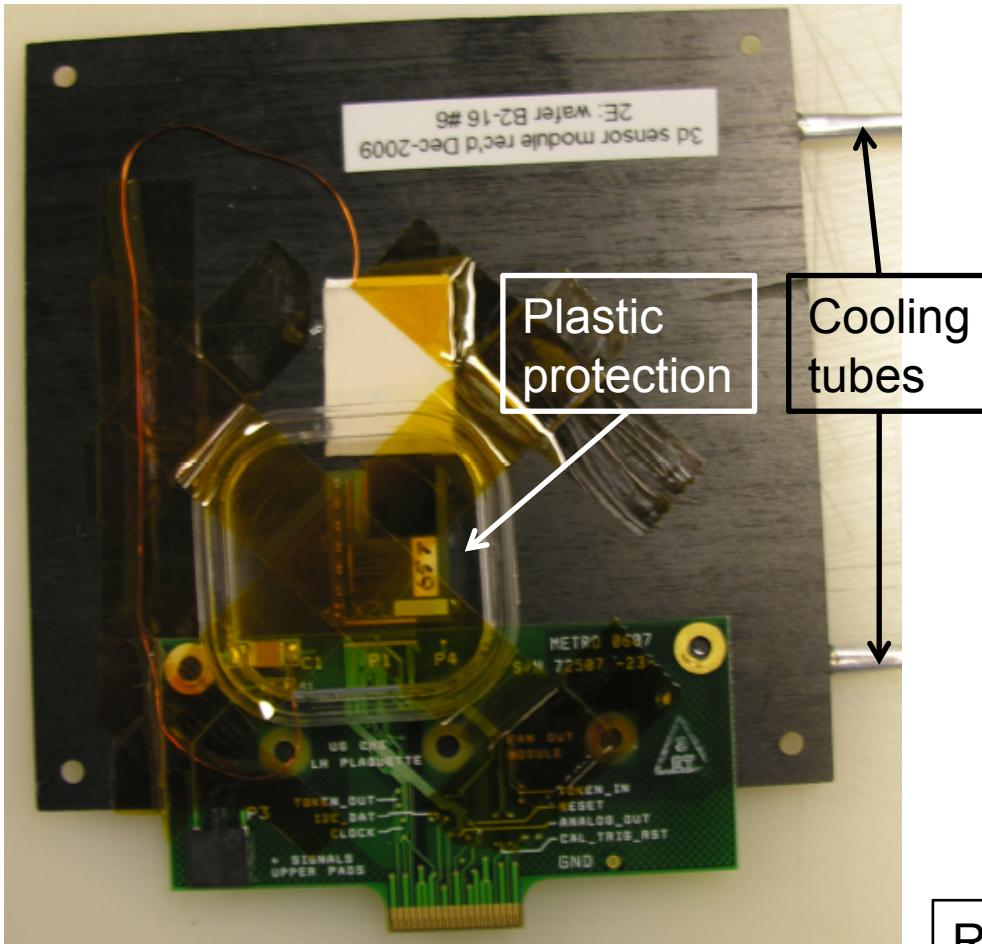


## 3D noise tests @ T=21 °C

- Unable to measure noise at  $V_{bias} < 40V$  for 4E sensors
- 2E\_WB5\_7 and 4E\_B5\_4 could not be characterized

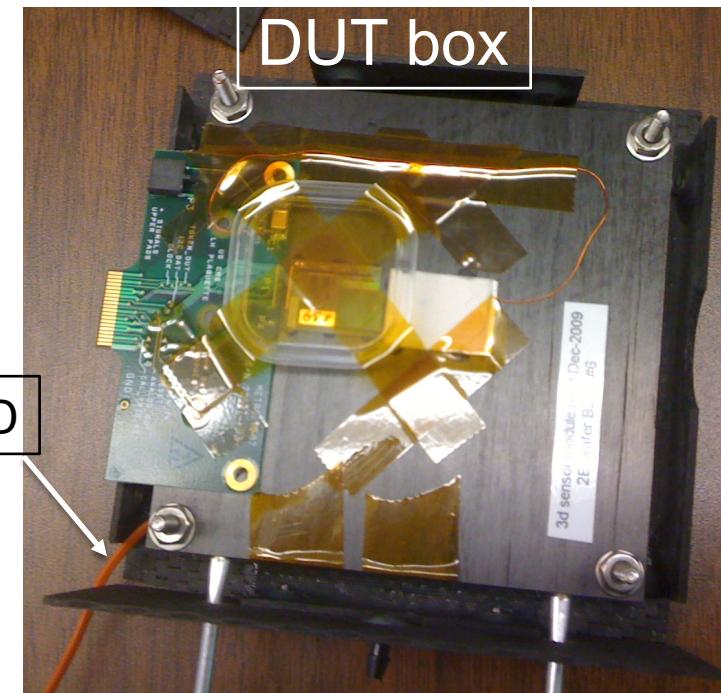


# 3D testbeam preparation

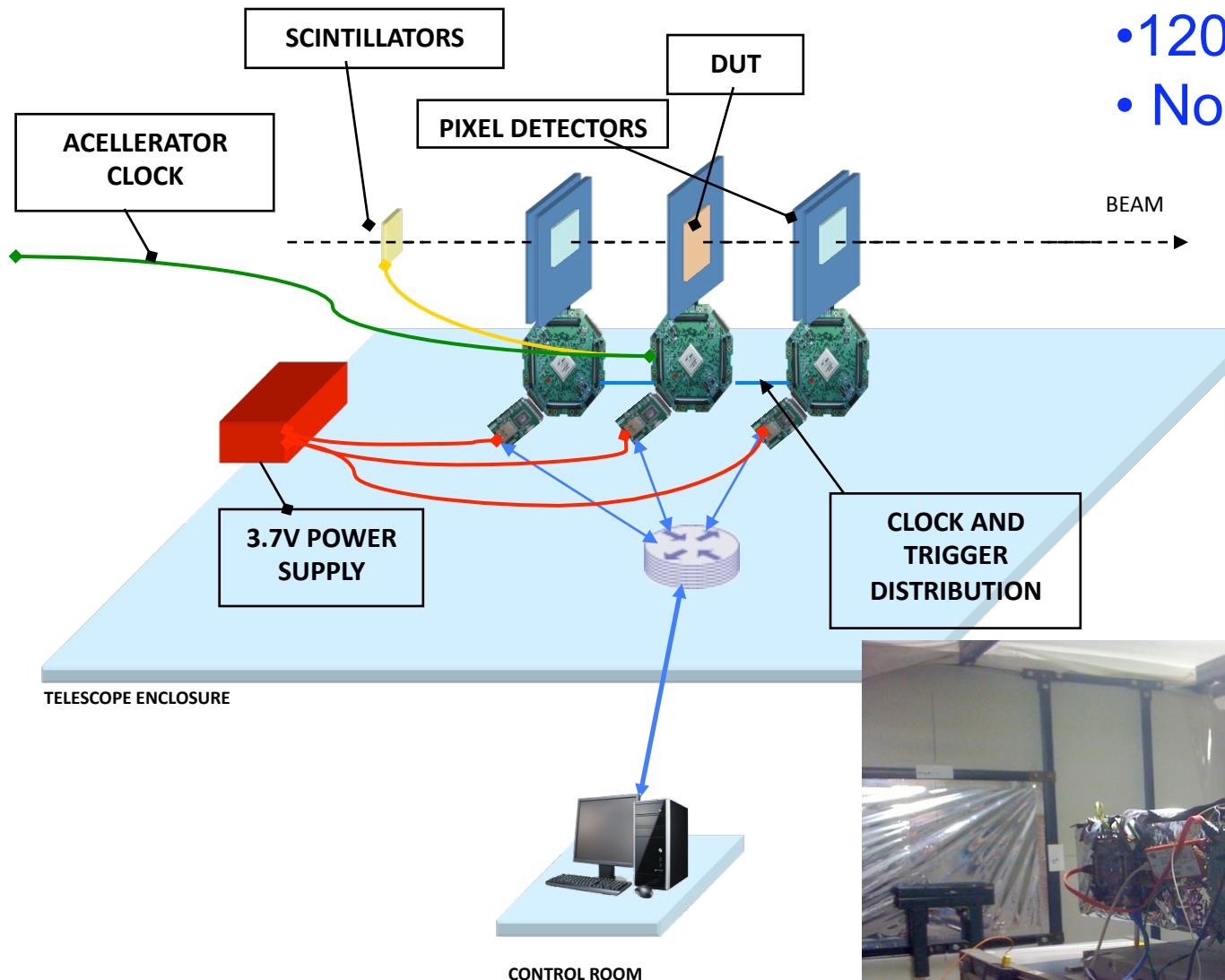


Prepared: 2E\_B5\_2, 2E\_B216\_6  
4E\_B5\_8, 4E\_B216\_5

- Sensors mounted on carbon fiber plates placed in DUT box
- Cooling was done by a chiller
- RTD placed on the carbon fiber
- Dry air

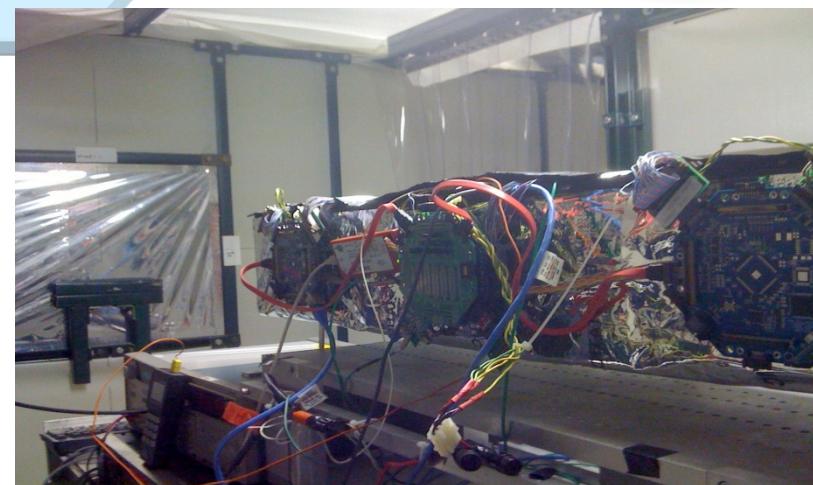


# FNAL testbeam setup



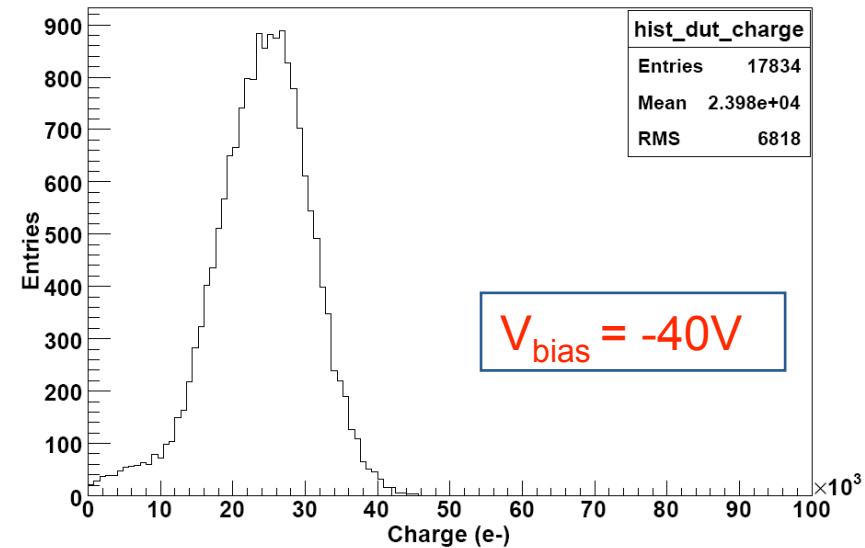
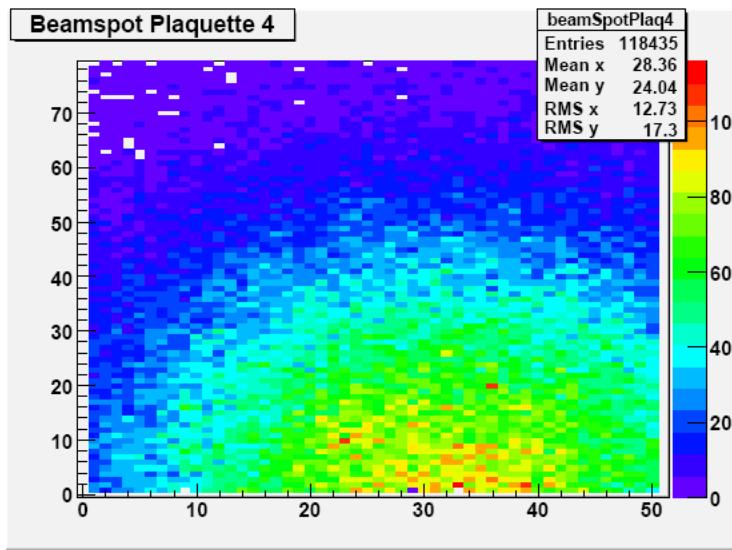
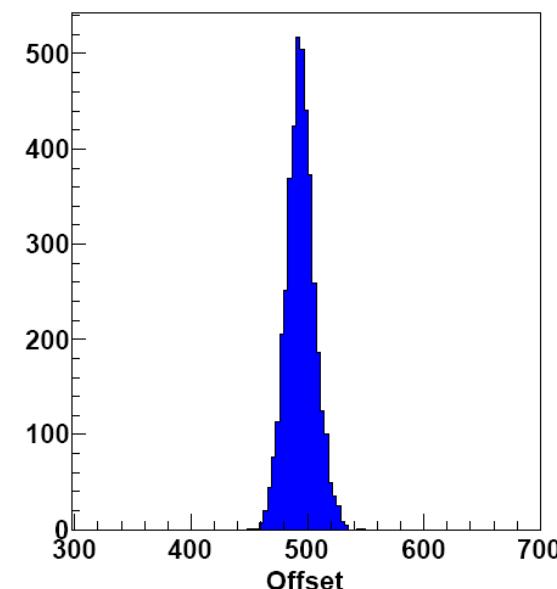
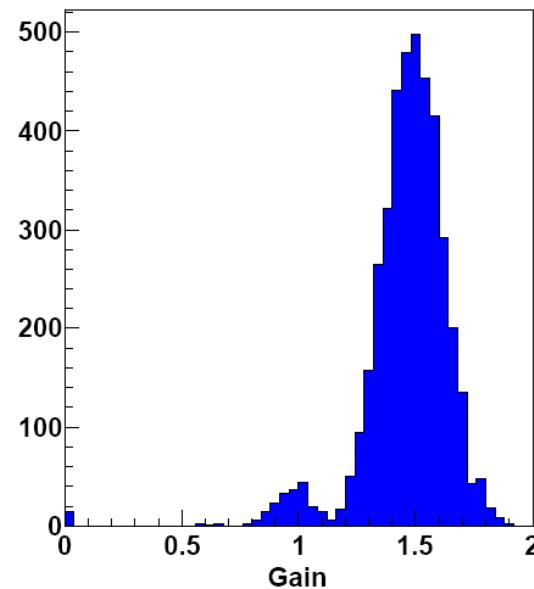
- 120 GeV protons
- No B field

Meson Area



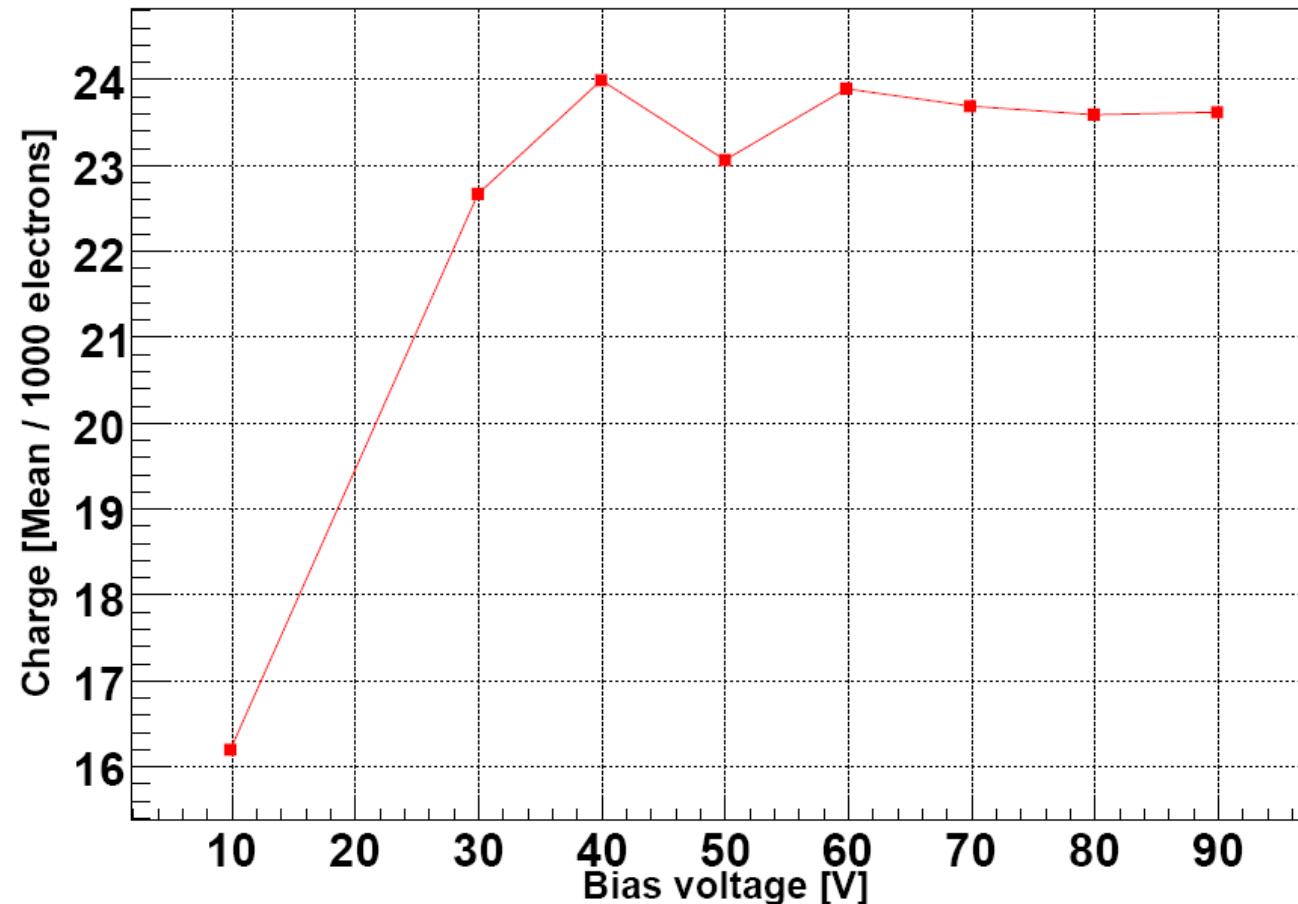
# Beam test results 2E WB5 2

$T_{\text{sensor}} \approx 16 \text{ }^{\circ}\text{C}$

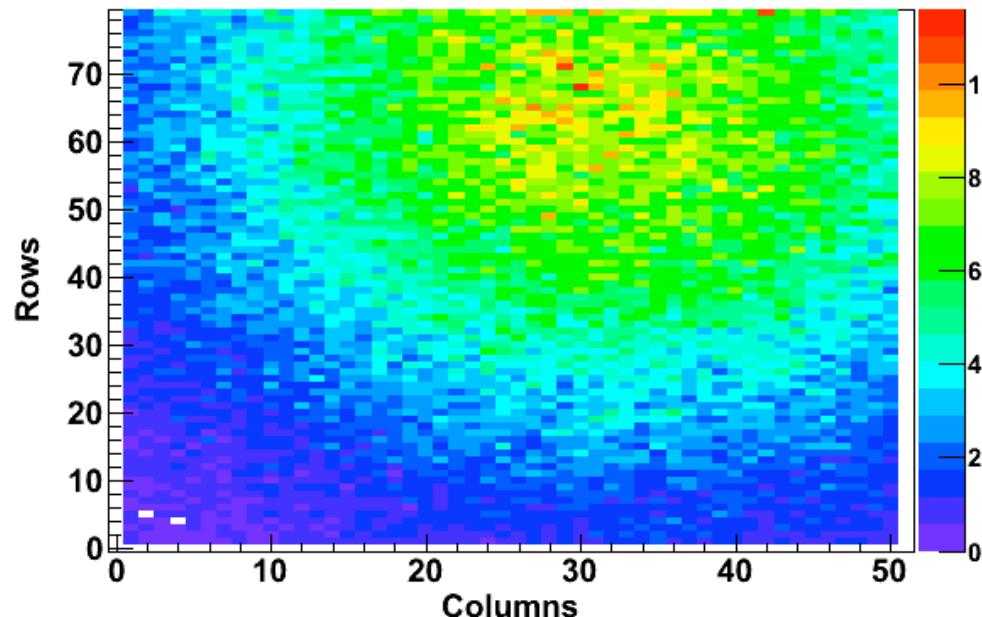


# Beam test results 2E WB5 2

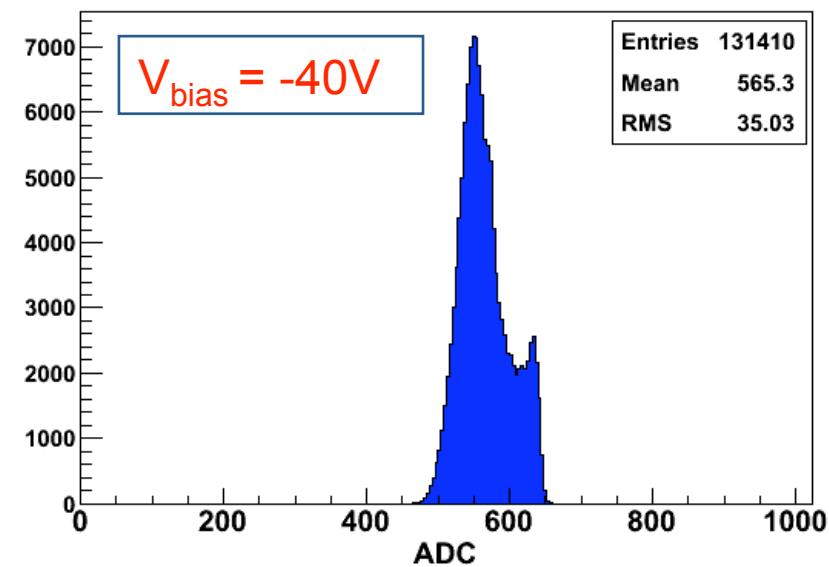
- Each point is total charge distribution mean



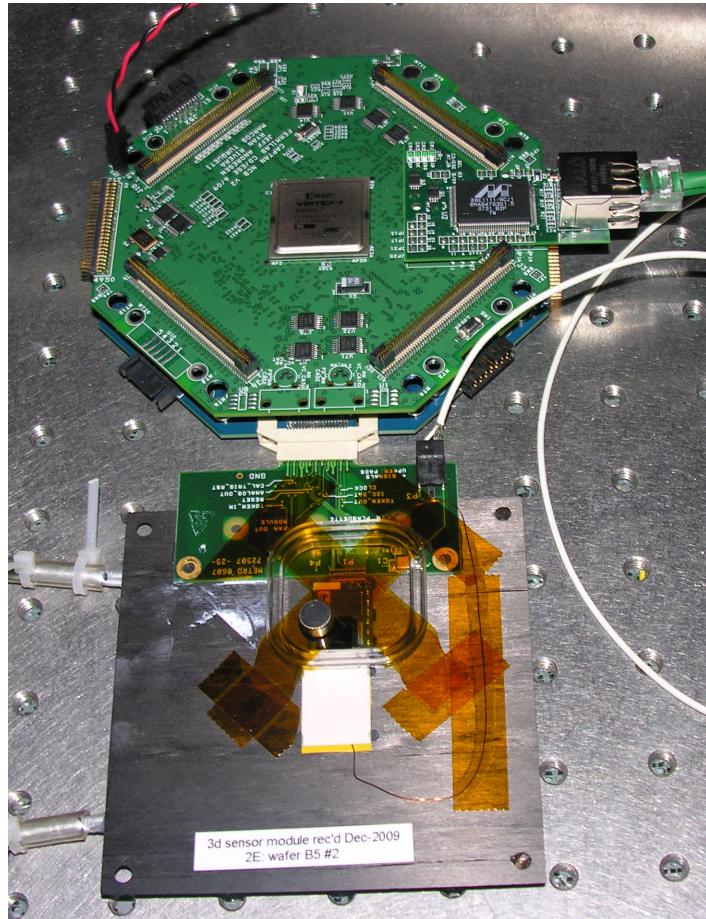
# Beam test results 2E WB2-16 6



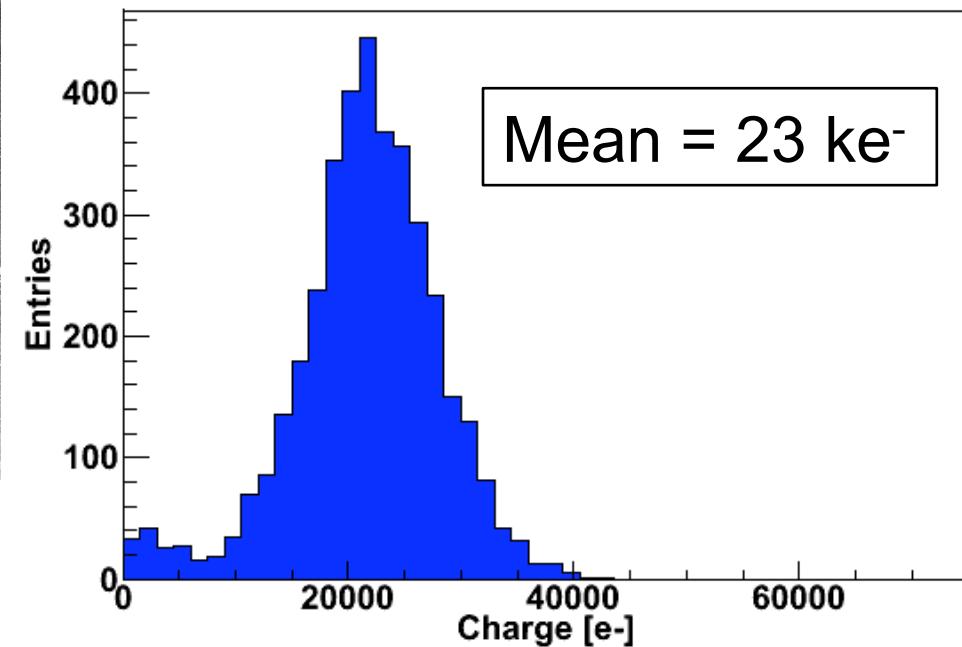
- Gain calibration is problematic



# Source test 2E WB5\_2



- $^{90}\text{Sr}$  (1 mCi)
- $T_{\text{sensor}} = 15 \text{ }^{\circ}\text{C}$
- $V_{\text{bias}} = -40 \text{ V}$



## Summary (1)

- Four 3D sensors were wire bonded and tested
- IV results were compatible with SINTEF results
  - all sensors deplete at  $\sim 10$  V, breakdown  $> 100$  V
- 2E sensors performed well but noise is larger than standard CMS pixel sensor (expected)
- 4E sensors test results
  - good IV curve
  - good bump bond quality
  - high noise
- All tests run at  $T = 21$  °C

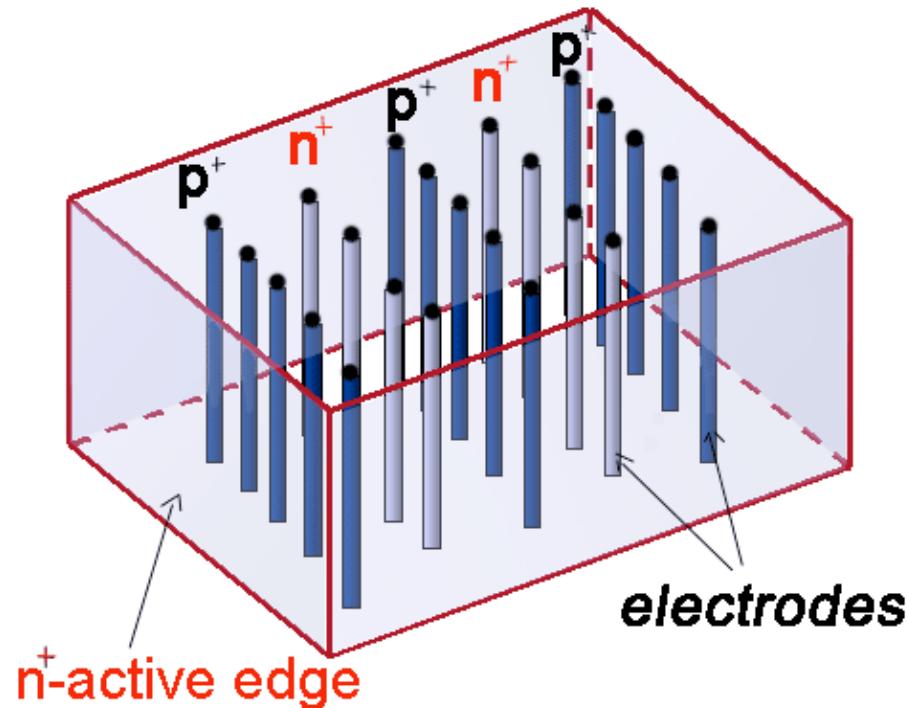
## Summary (2)

- Four 3D sensors were assembled for the testbeam
- Testbeam at FNAL with 120 GeV protons
- Sensors cooled down to  $T = 15\text{-}18\text{ }^{\circ}\text{C}$
- Bias scan performed for 2E sensors
  - $S/N \approx 100$  at  $V_{bias} = -40\text{ V}$  ( $S$  = Total charge mean)
- 4E sensors failed
- Charge collection with  $^{90}\text{Sr}$  (1 mCi) setup at Purdue with CAPTAN station

## Plans

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- More 3D sensors will be bump bonded (@IZM & SELEX)
- Test sensors cold ( $T = -10 \text{ }^{\circ}\text{C}$ )
- Lab characterization and charge collection with  $^{90}\text{Sr}$  (1 mCi) at Purdue with PSI testboard
- Irradiation
- Post irradiation lab and charge collection test
- Position resolution?



# 3DC

Czech Technical  
University, Fermilab,  
Purdue University,  
SINTEF, SLAC, University  
of Hawaii, University of  
Manchester



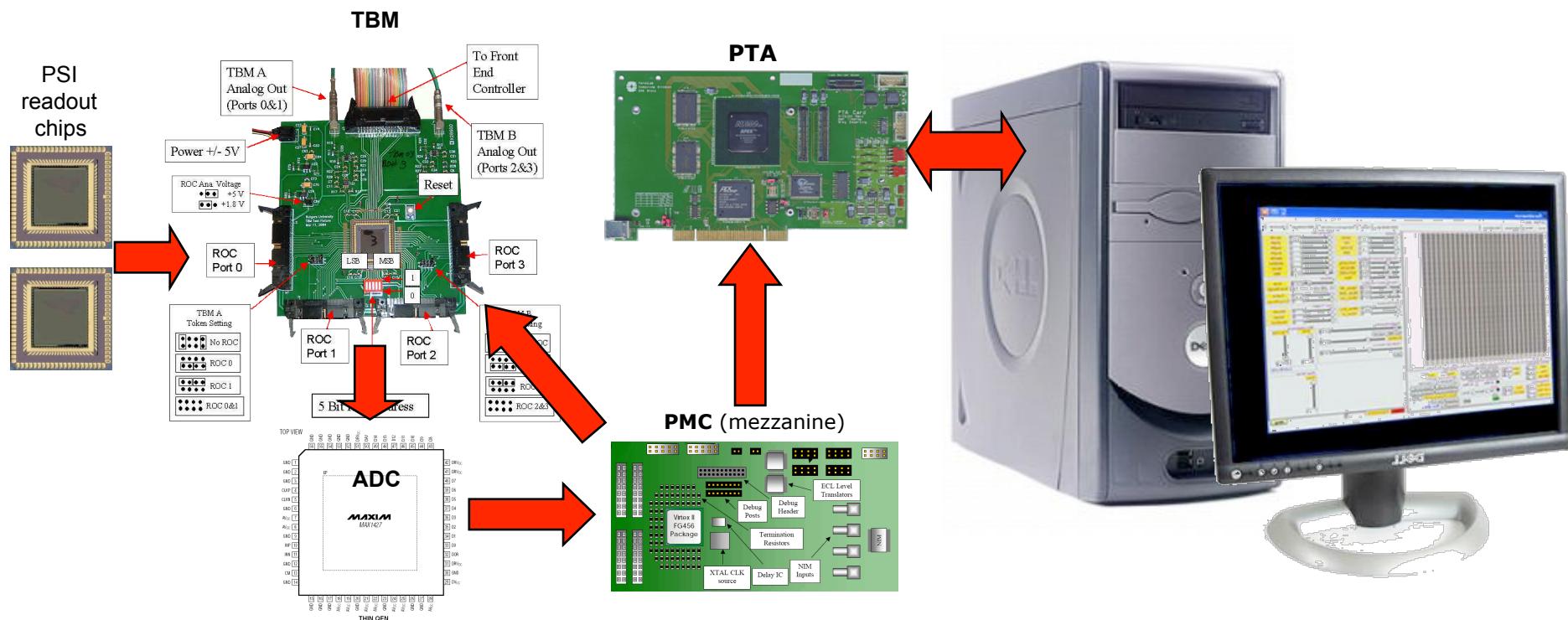
# **BACKUP SLIDES**

# Renaissance

The system is based on:

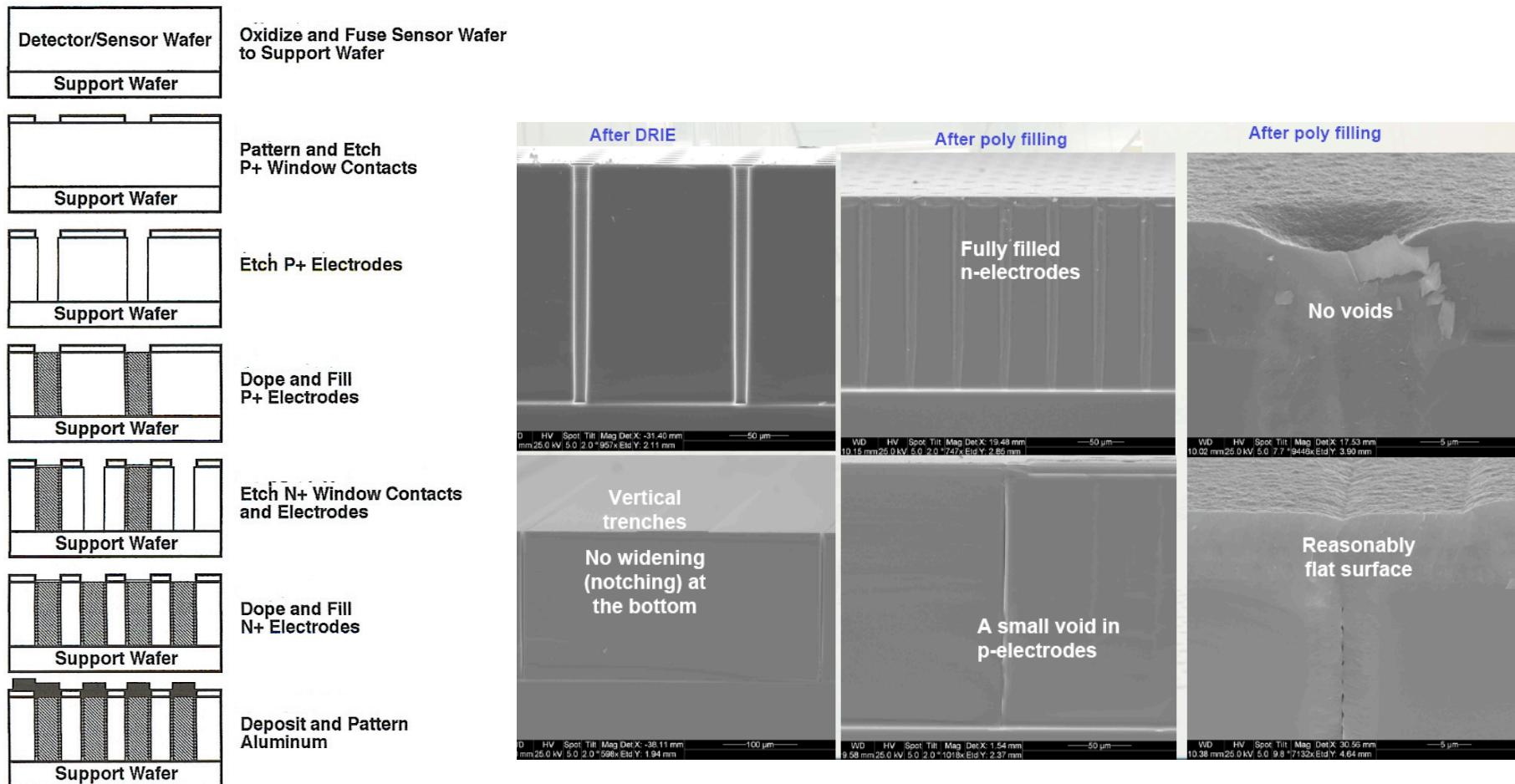
- custom made PCI cards with an on-board programmable FPGA and two memory banks (PTA cards). These cards communicate to the PC.
- A programmable mezzanine card (PMC, also featuring an FPGA): allows the system to talk to the PSI using the chip custom protocol.
- A Token Bit Manager and a custom ADC (Maxim)

A programming of the PTA/PMC FPGAs is all which is needed to read-out the PSI chip



# Fabrication at SINTEF

- p-spray isolation :  $6 \times 10^{12} \text{ cm}^{-2}$ , 60keV, through a 60nm oxide. Annealed at 900°C for 30 minutes
- Wafer bonding by direct fusion bonding
- Deep Reactive ion etching (DRIE) & polysilicon filling and doping of electrodes
  - n-type electrode etching & filling (diameter of 14  $\mu\text{m}$ )
  - 300nm thermal oxide barrier protection
  - p-type electrode and active edge etching & filling (5  $\mu\text{m}$  active edge)
- Metal layer deposition & patterning
- Passivation layer of 0.5 $\mu\text{m}$  oxide and 0.25 $\mu\text{m}$  nitride deposition by PECVD & patterning



# Compact And Programmable daTa Acquisition Node

- First design in 2008.
- It is a distributed system that uses vertical bus based hardware and a series of specially designed core boards to implement a flexible and expandable data acquisition, processing, control and communication platform.
- The CAPTAN platform is network based.
- Systems based on the CAPTAN architecture can vary from a single board to a farm containing hundreds of boards.
- The CAPTAN architecture is intended to be open with a few core boards, allowing users to make their own custom boards and systems.

# 3D gain calibration

## No trimming

