Preliminary results from UFSD beam test @ FNAL

Large collaboration, CMS – ATLAS groups involved

A. Mangu, C. Peña, M. Spiropulu, S. Xie	California Institute of Technology
N. Minafra, H. Al Ghoul, C. Royon	The University of Kansas
A. Apresyan, G. Derylo, L. Gray, S. Los, A. Prosser, R. Rivera, L. Uplegger	FNAL
P. Freeman, H. Sadrozinski, E. Spencer, M. Wilder, F. Martinez-Mckinney, Z. Galloway, A. Seiden, Y. Ghao, C. Labitan, Z. Luce	University of California Santa Cruz
R. Arcidiacono, N. Cartiglia, M. Ferrero, V. Sola, M. Mandurrino, A. Staiano	Torino

Key improvements of FNAL Beam test

Many groups involved ➔ strong analyses community

Temperature control

Three read-out boards

Accurate tracking

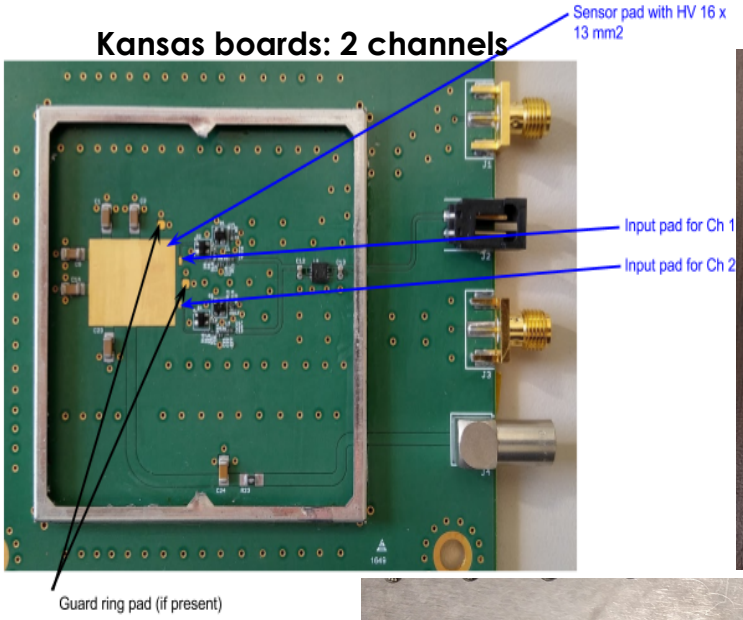
Results in this talk:

- Time resolution
- Effect of temperature
- Efficiency scans vs x- and y-position
- Fill factor
- Effect of Al. metal cover on the UFSD response

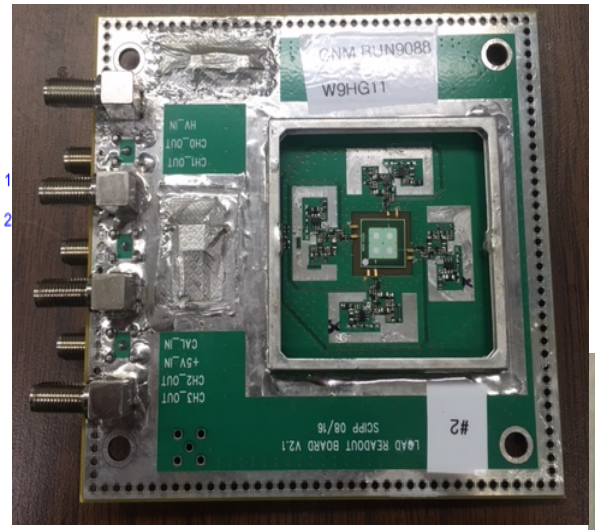
The electronics: KU, UCSC, FNAL boards

Several boards with 2, 4 or 8 channels were used for the characterization of the UFSDs.

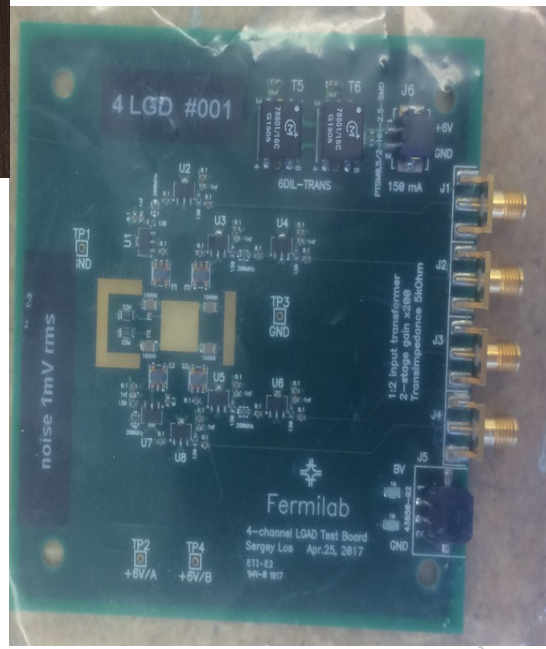
Kansas boards: 2 channels



UCSC boards: 4 channels

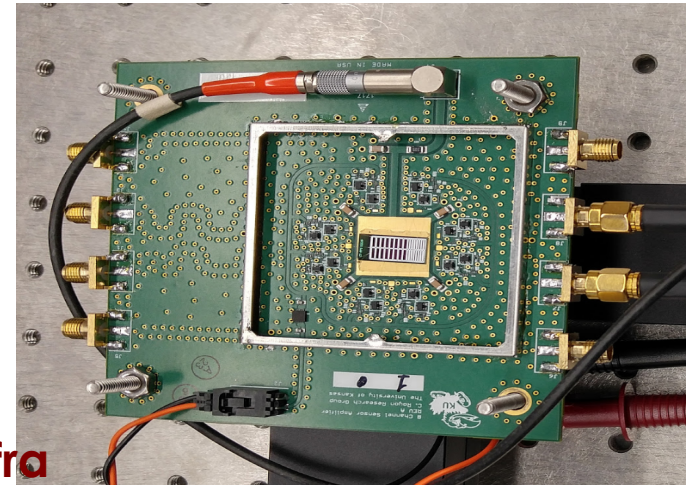


FNAL boards: 4 channels



Kansas boards:

8 channels



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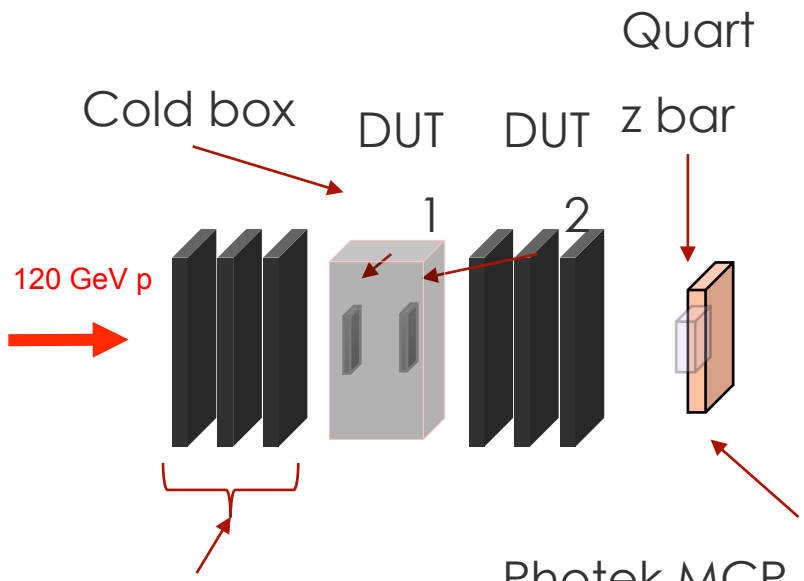
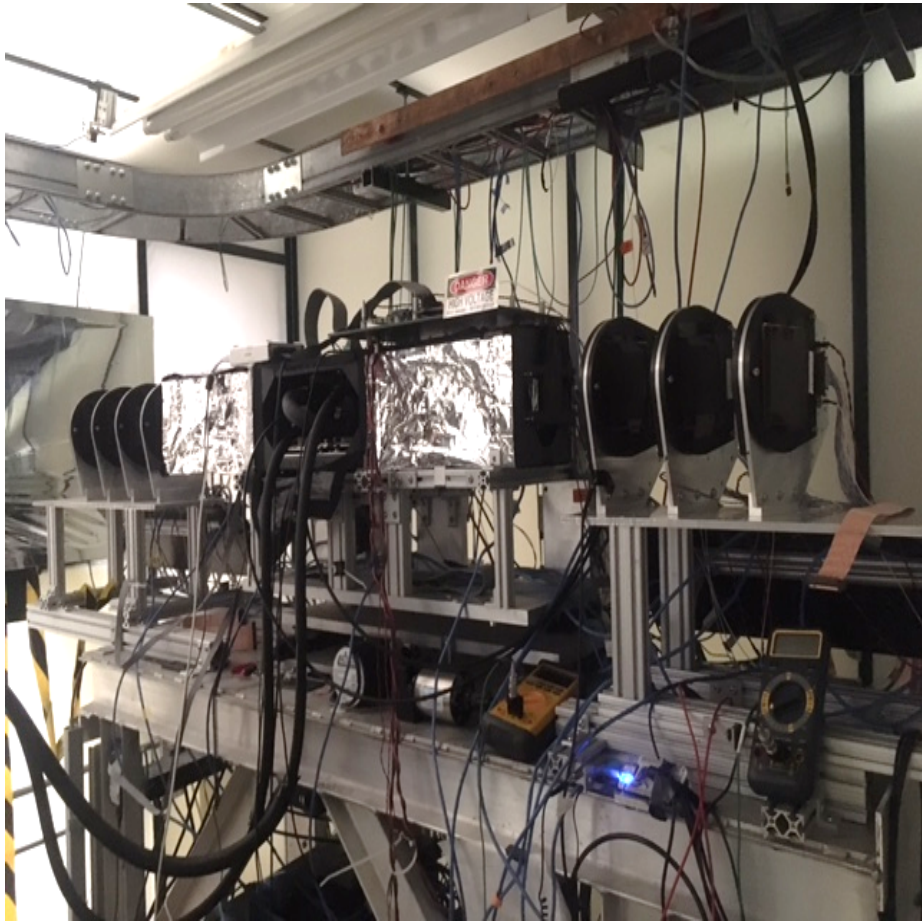
Fermilab Testbeam Facility





Chiller runs to -25C, a Peltier cell keeps stable the temperature of the boards at **-20C**
Nitrogen gas keeps humidity low and prevent condensation

* Study of the timing performance of micro-channel plate photomultiplier for use as an active layer in a shower maximum detector, NIMA

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Sensor and amplifier tested

The different sensors were tested using the different boards in various conditions: bias, temperature and irradiation

Sensor	KU board 2 ch	UCSC board 4 ch	FNAL board 4 ch
HPK 50A	-630V		
HPK 50B	-450V -550V -600V -510V -510V -570V		
HPK 50C	-400V	-410V -470V	
HPK 50D	-100V -200V -250V -300V -325V		-250V -300V -210V -250V -250V -280V
CNM W9HG11		-140V -160V	
HPK 50D 6e14 neq/cm^2		-600V -635V	
CNM W11LGA35 6e14 neq/cm^2			-400V -420V

Temperature:

20C

-10C

-20C

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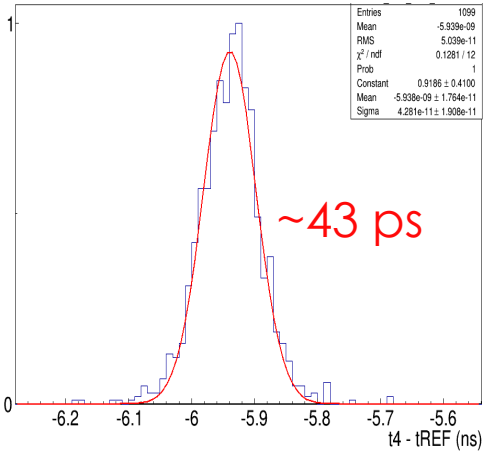
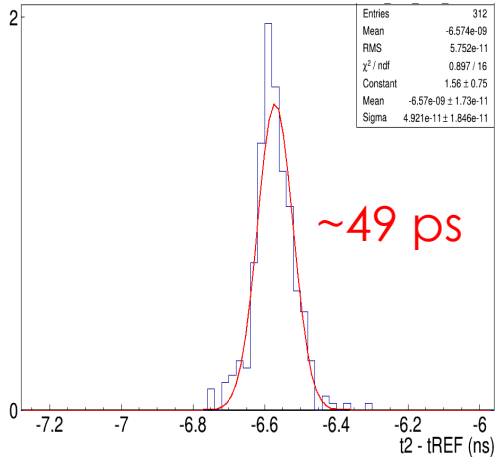
Boards performance

All the tested amplifiers able to exploit the performance of the sensors

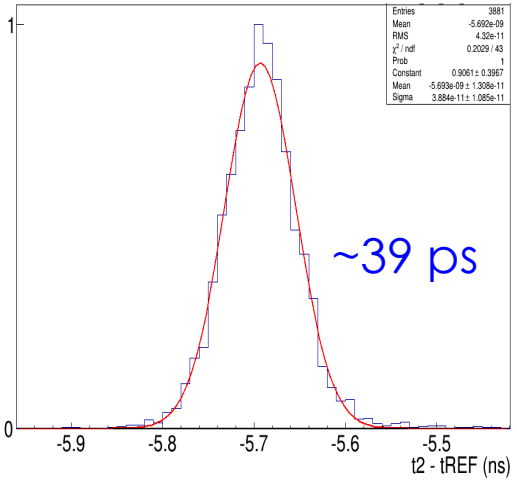
50C @ -400V on KU



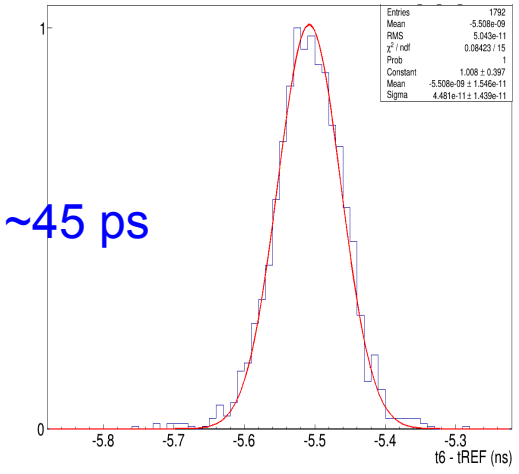
50C @ -410V on UCSC



50D @ -300V on KU



50D @ -300V on FNAL



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Temperature dependence

The gain of the sensor increases at lower temperatures while the effect on the noise is negligible: performances improve at low temperature

HPK 50D on FNAL board -250V	MIP 20C (mV)	MIP -20C (mV)	noise 20C (mV)	noise -20C (mV)	SNR 20C	SNR -20C
Ch 1	20	45	1.2	1.2	17	38
Ch 2	20	44	1.2	1.2	17	37
Ch 3	20	44	1.2	1.2	17	37
Ch 4	19	44	1.2	1.2	16	37

HPK 50D on FNAL board @ -250V	Time precision (ps)	Time precision (ps)
Ch 1	64	44
Ch 2	62	44
Ch 3	65	43
Ch 4	67	42

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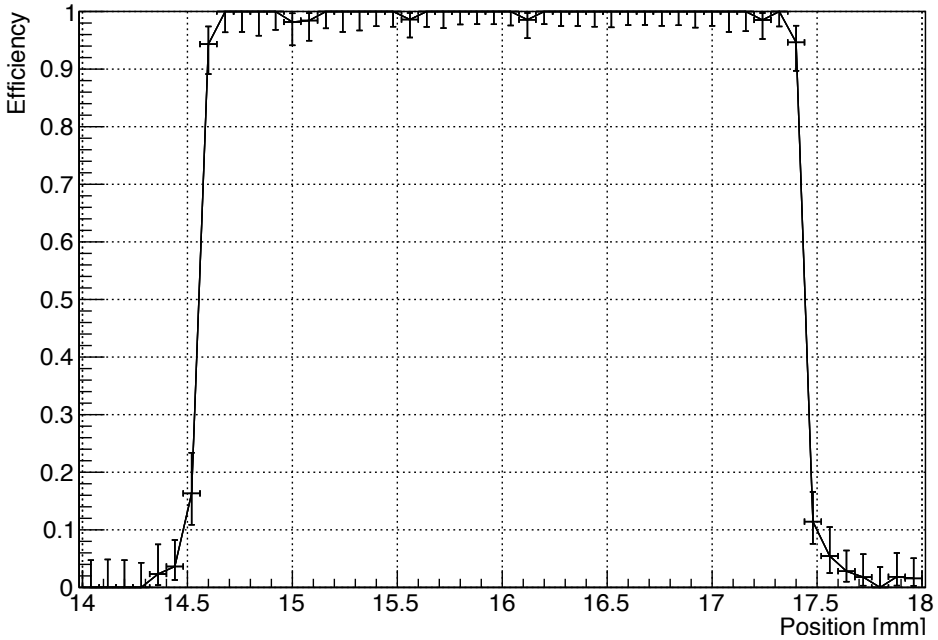
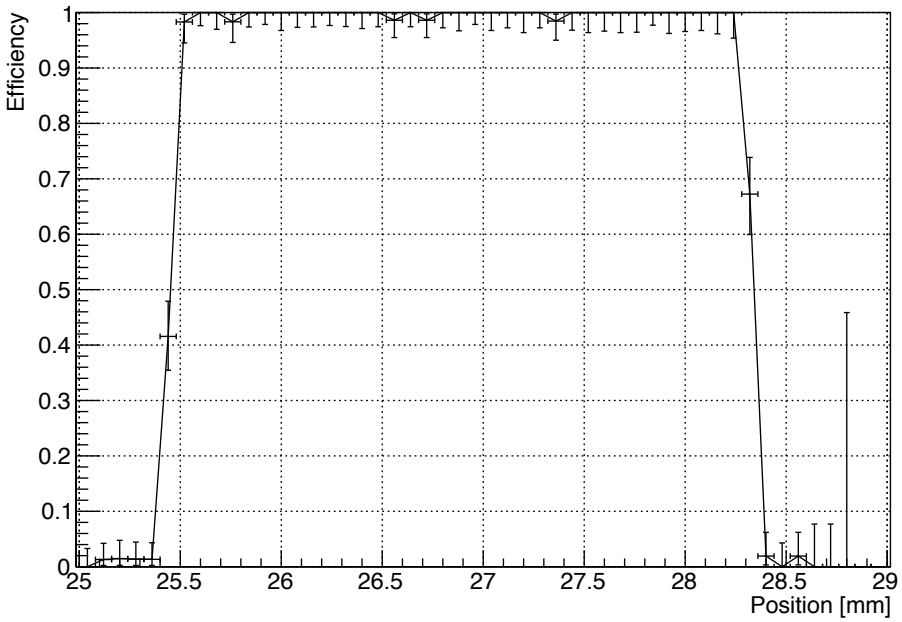
HPK 50D Efficiency vs position

Very good tracking

100% efficiency



x-scan

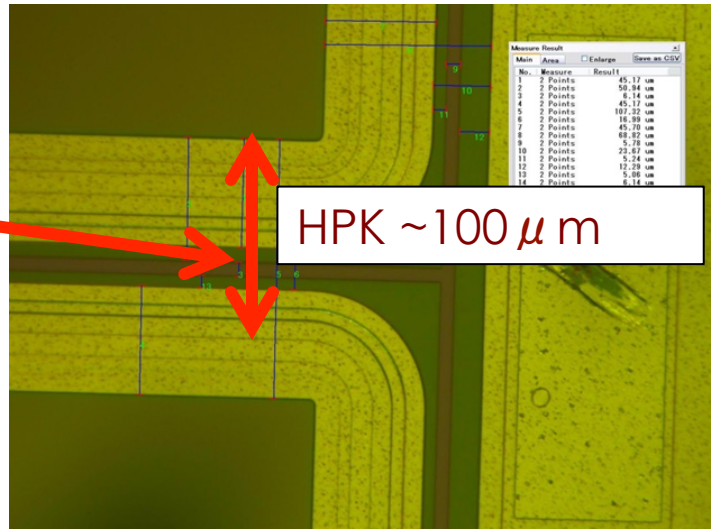


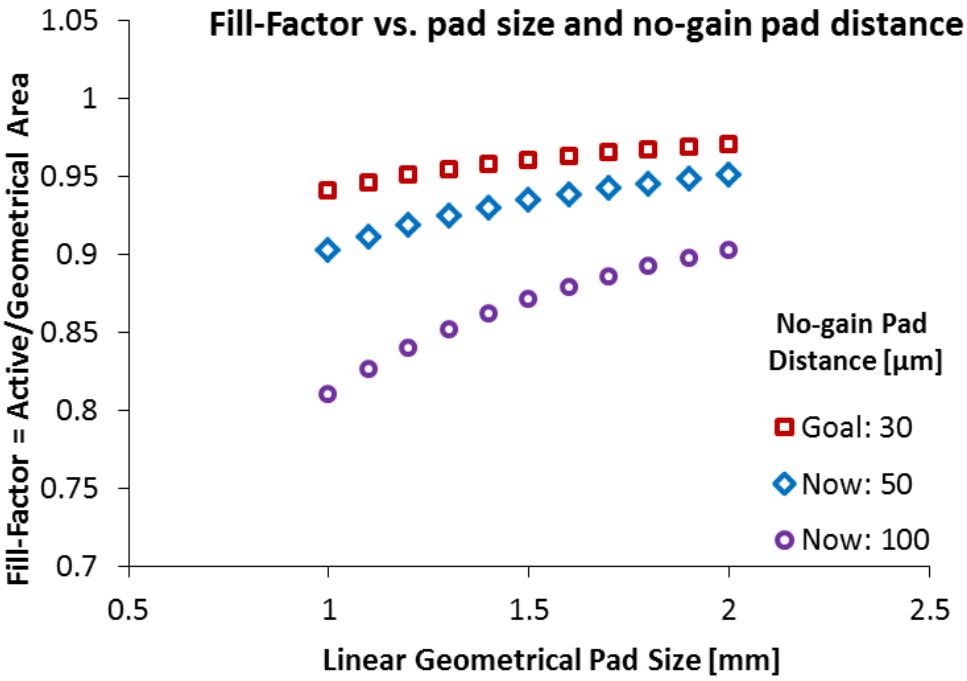
y-scan

Fill-Factor vs. "no-gain" Pad Distance & Pad Size

Fill factor = Active Area / Geometrical Area

"no-gain "region between pads





Improvement of fill factor with reduction of no-gain distance from 100 to 50 to 30 μ m :
Pad size 1mm: FF = 81% -> 90% -> 94%
Pad size 1.4mm: FF = 86% -> 93% -> 96%

Is there a difference between CNM and HPK LGAD arrays?

At first look: no.
Both have 100 μ m no-gain zone.
Need to improve!

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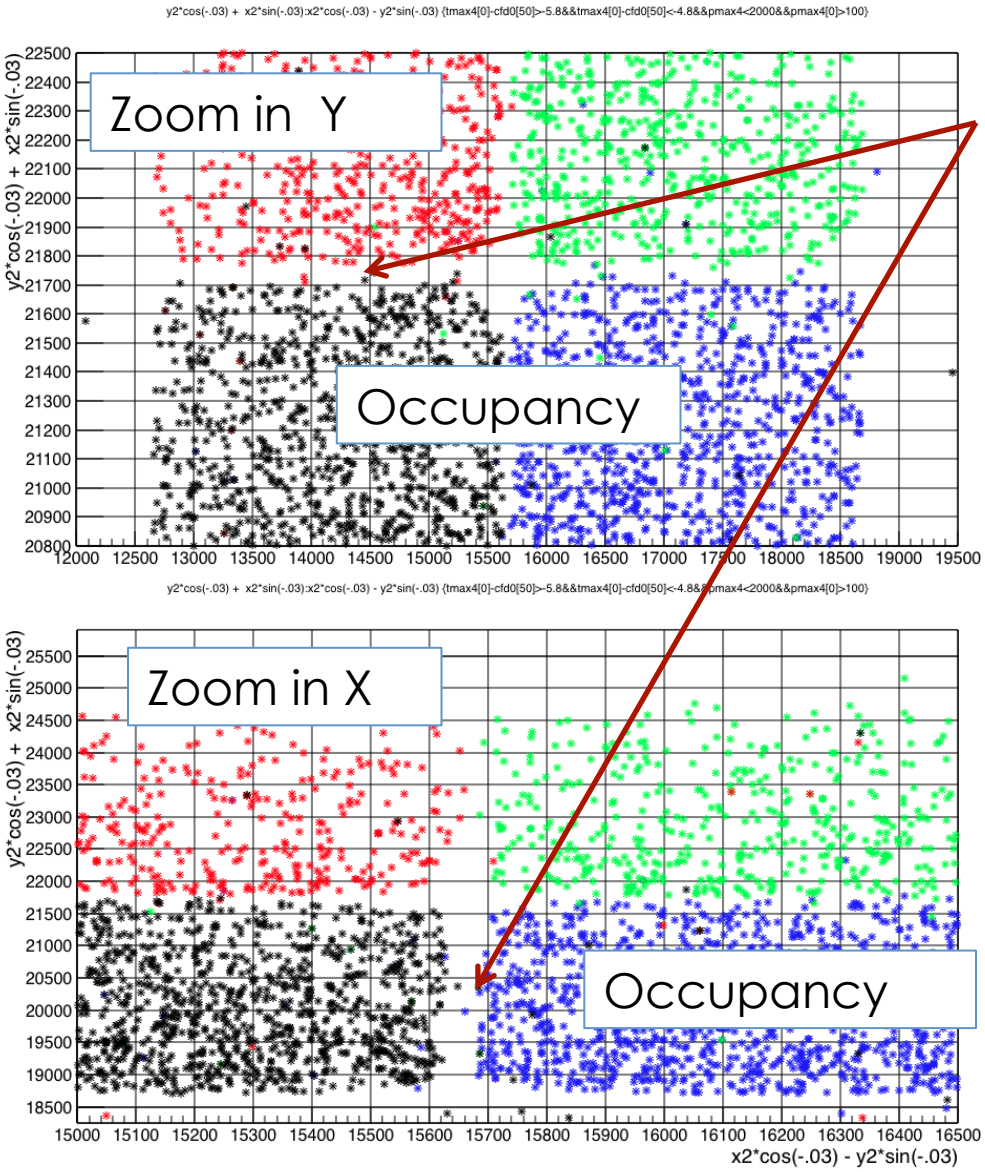
CNM W9HG11 – Dead Area between 3x3 mm^2 pads



- Dead area is approximately 100 μm
- Approximately equal in horizontal and vertical directions
- Statistics may be too low for study of edge effects, for example amplitude as function of position

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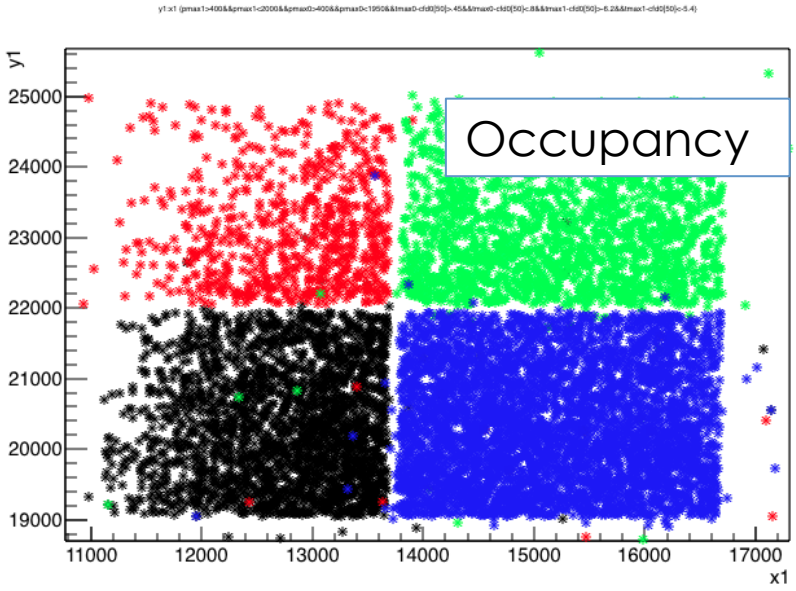
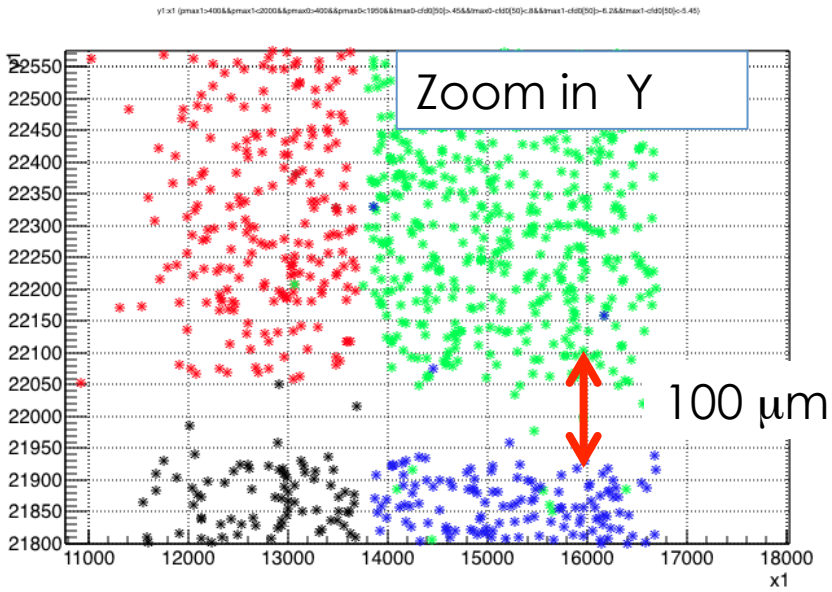
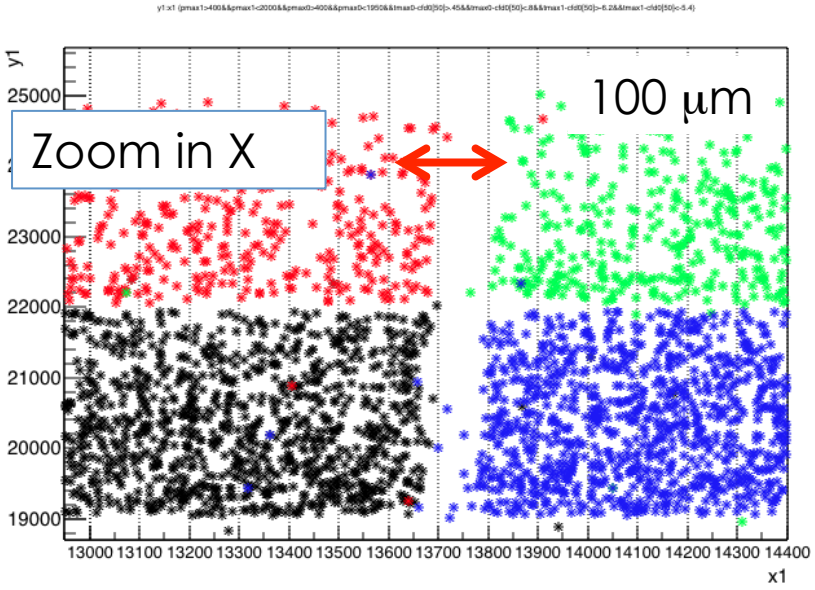
HPK 50C PIX – Dead Area between 3x3 mm^2 pads







The dead area has a width of ~100um.

More refined analysis underway.

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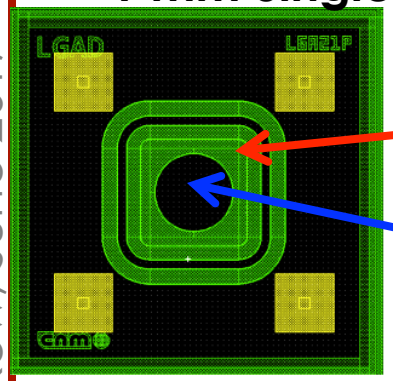
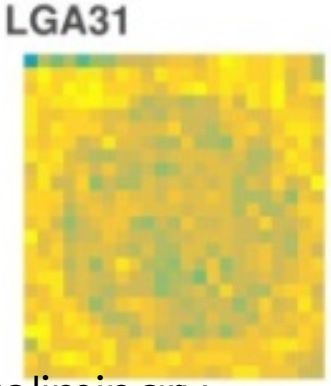
Effect of metal covering on the LGAD response

1 mm Single pad:



covered with Al

no Al



Preliminary

Pre-rad

HGTD Beam Test:

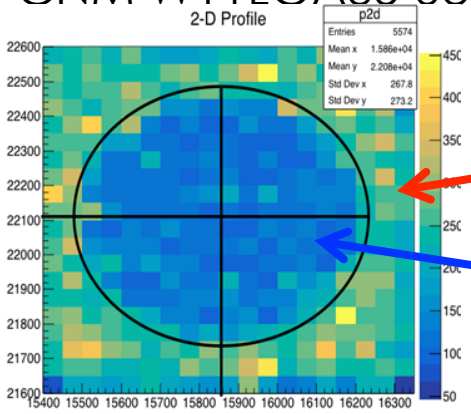
(I. Nikolic and S. Trincaz-Duvoid, LPNHE),

CNM W5LGA31, +20C gain map shows ~10% effect

Post-rad

UCSC β-source & LGAD R&D beam test @ FNAL:

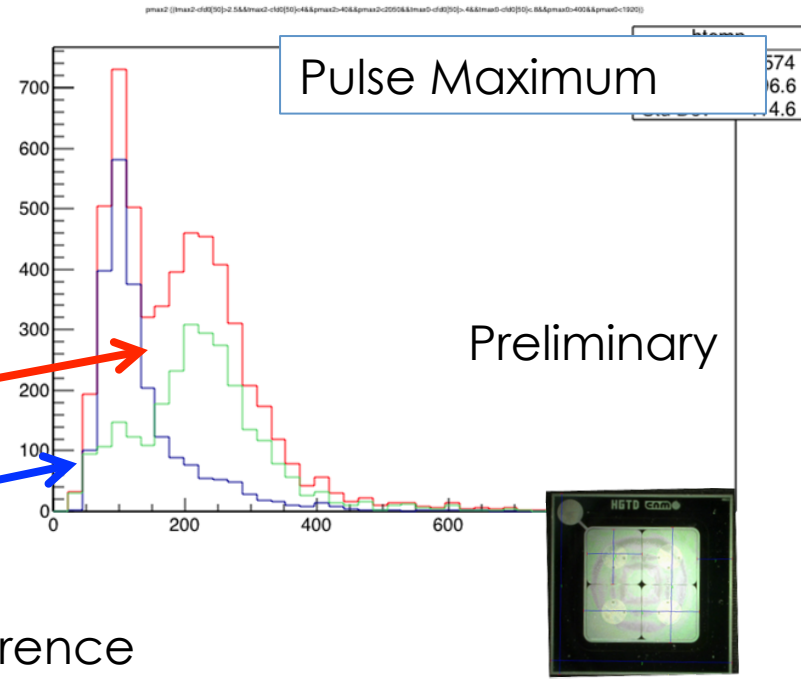
CNM W11LGA35 6e14 n/cm^2 -20C



covered with Al: 38ps

No Al: 44ps

Pulse maximum map shows a factor 2.5 difference



2x2 CNM Array (completely covered in metal) **no effect pre-rad**

Preliminary

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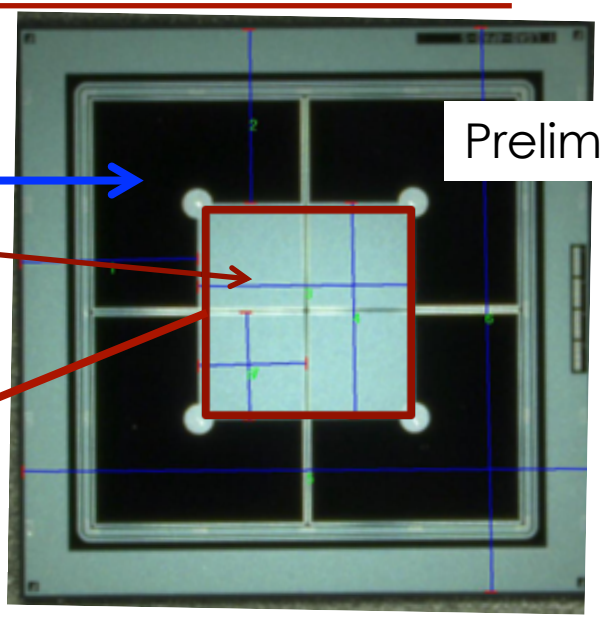
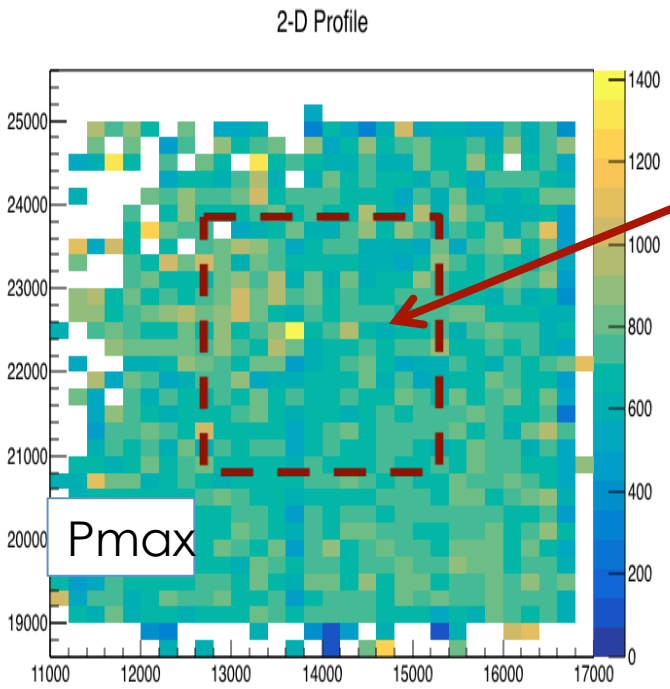
Al metallization in HPK LGAD

2x2 3mm Array: large areas
with / without metal covering





Pre-rad:
LGAD R&D beam test @ FNAL:
HPK 50C-PIX
no difference between
areas with and without metal covering.

Looking forward to a beam test campaign with irradiated HPK arrays and CNM single pads.

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Summary

Very good collaboration from different groups and experiments

- Accurate tracking allows extracting a wealth of new information
- Time resolution of ~ 35 – 40 ps confirmed by a lot of new results
- Strong effect of Temperature (for once an effect is actually helping)
- Good signal uniformity across pads
- Study of fill factor defines new R&D direction aimed at large area construction
- Need to understand Al-related difference in UFSD response. Is this a "universal effect" or it is a production effect?