3D ACTIVE EDGE SILICON SENSORS - RESULTS and PLANS

3Dc

Cinzia Da Via', Steve Watts
Brunel University UK
University of Manchester from January 2007

Collaboration

OUTLINE

- Modelling
- Test Beam Results
- Conclusions and Future plans

C. Kenney (MBC), L. Reuen, R. Kohrs, M. Mathes, J Velthuis, N. Wermes (Bonn Univ.) J. Hasi, A. Kok, (Brunel U.K.) S. Parker (U. of Hawaii) G. Anelli, M. Deile, P. Jarron, J. Kaplon, J. Lozano and the TOTEM Collaboration (CERN), V. Bassetti (Genova), M. Garcia-Scievert, K. Einsweiler (LBL), V. Linhart, T. Slavicheck, T Horadzof, S. Pospisil (Technical University, Praha), M. Ruspa (Torino).

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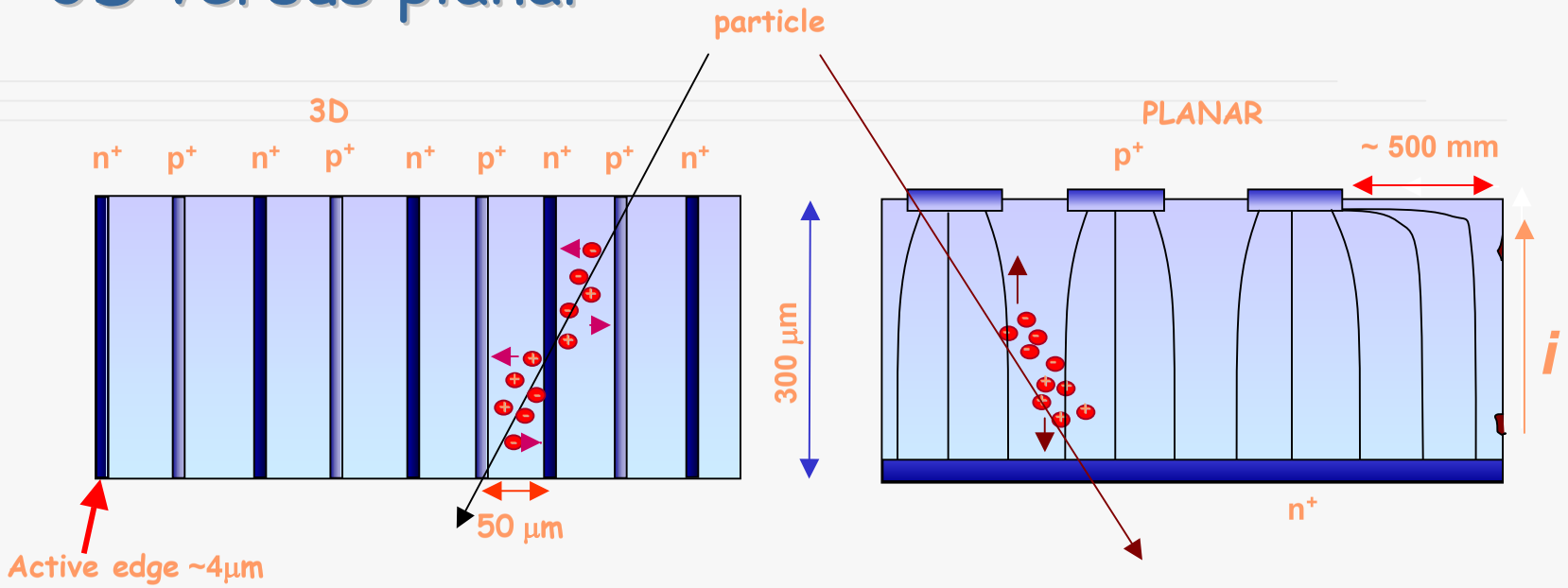
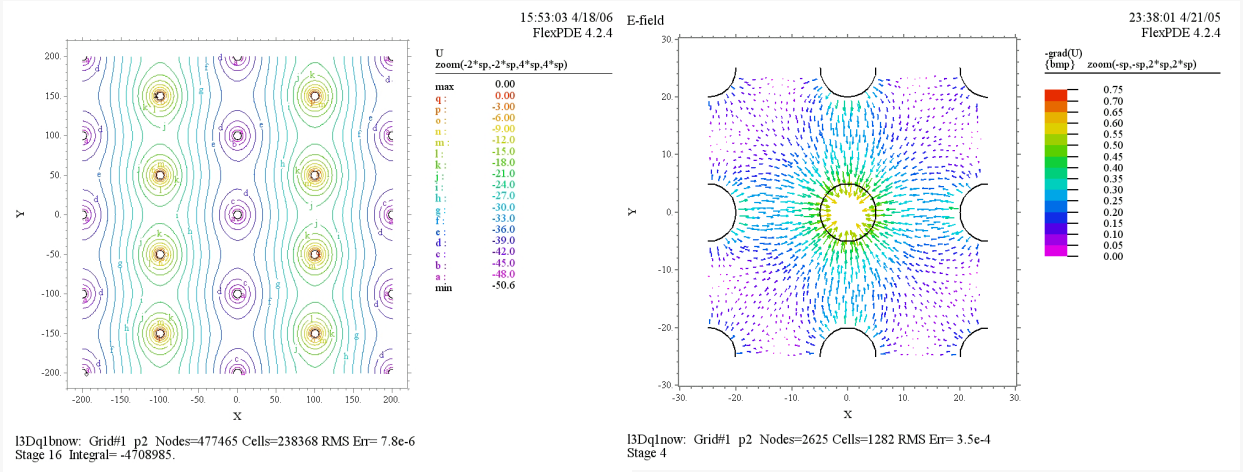
3D versus planar

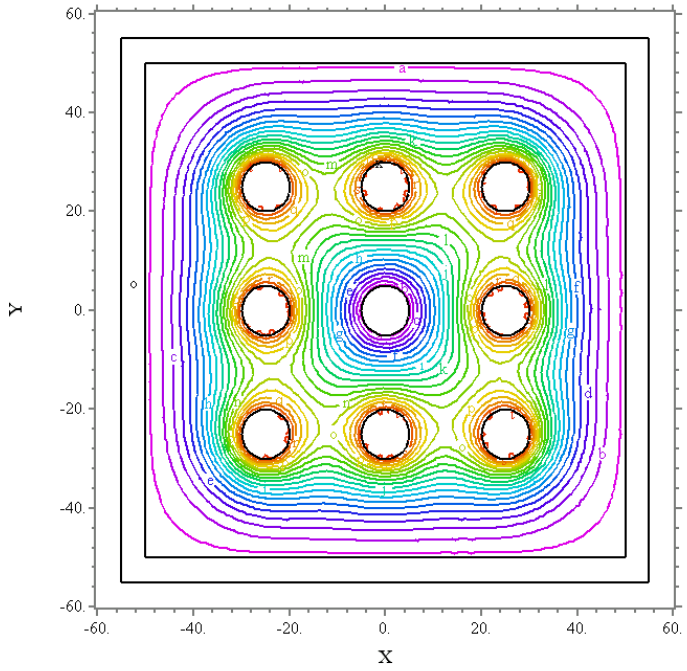


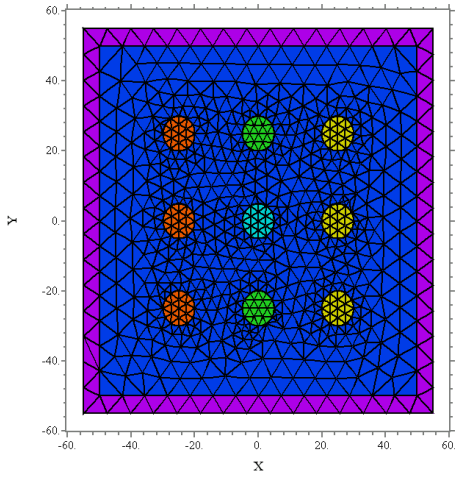


	3D	planar
V_{dep}	< 5-10 V	50-70 V
Q_{1mip}	24000e⁻	24000e⁻
C	40-80fF	50-200fF

Simulations using FlexPDE by S. Watts

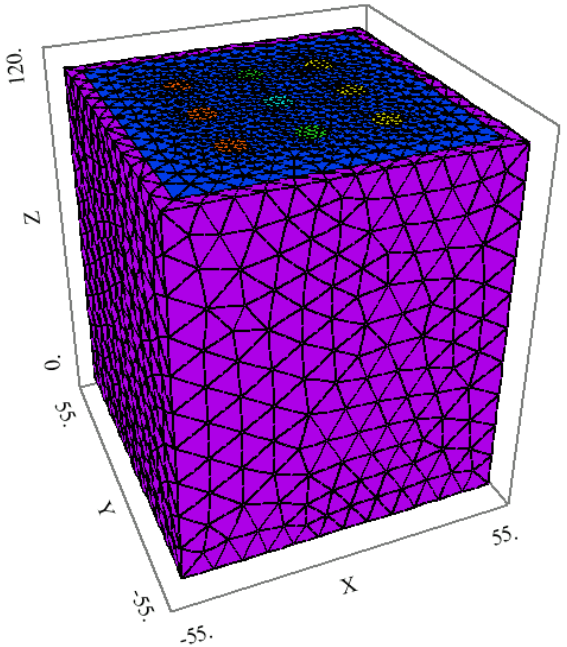
Device Modelling – e-field, weighting potential, and signals

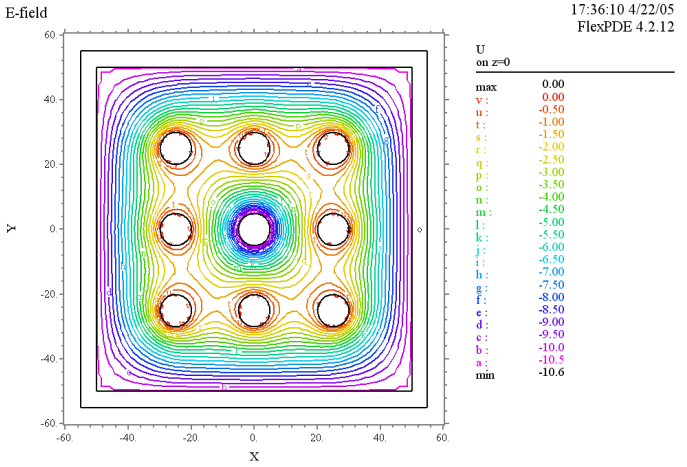


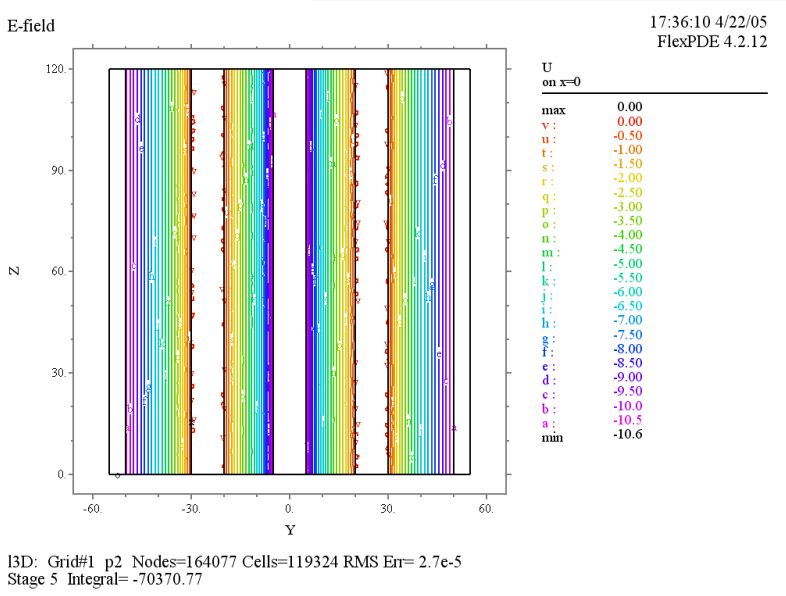


25 micron inter-electrode distance
p surrounded by n electrodes

Use general PDE solver (FlexPDE) with modified Poisson equn. to calculate e-field in silicon (depleted/non-depleted).



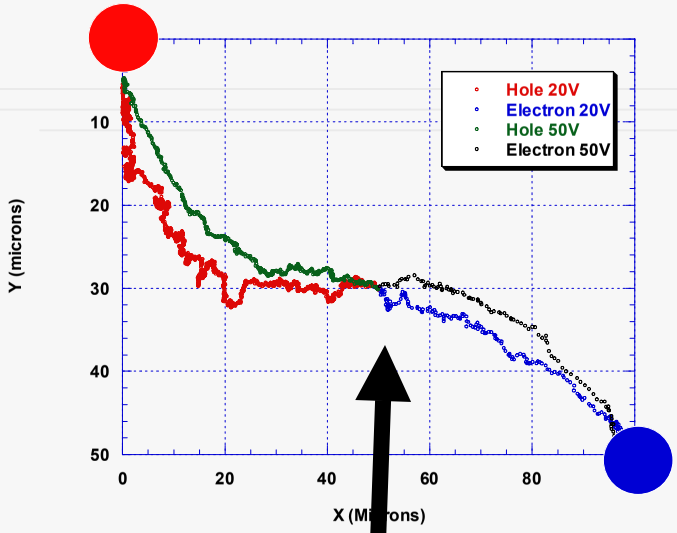


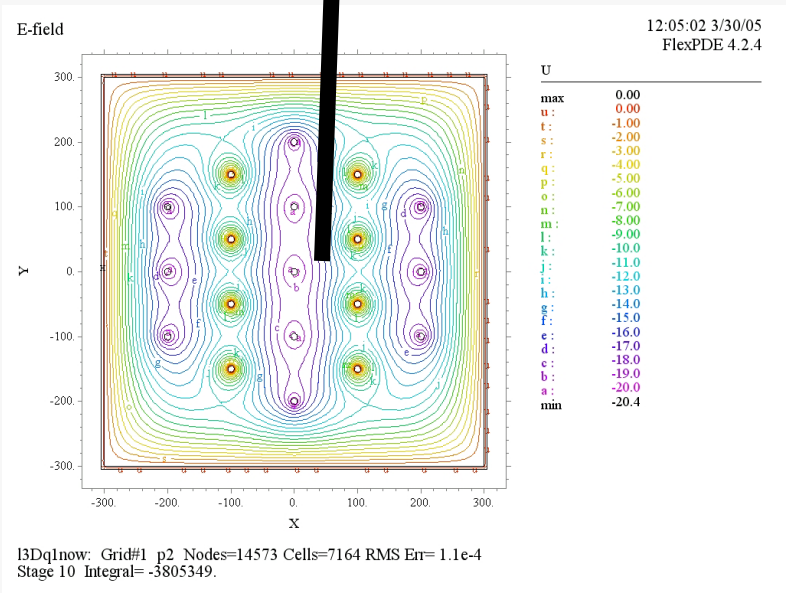


Can solve in 3D if necessary

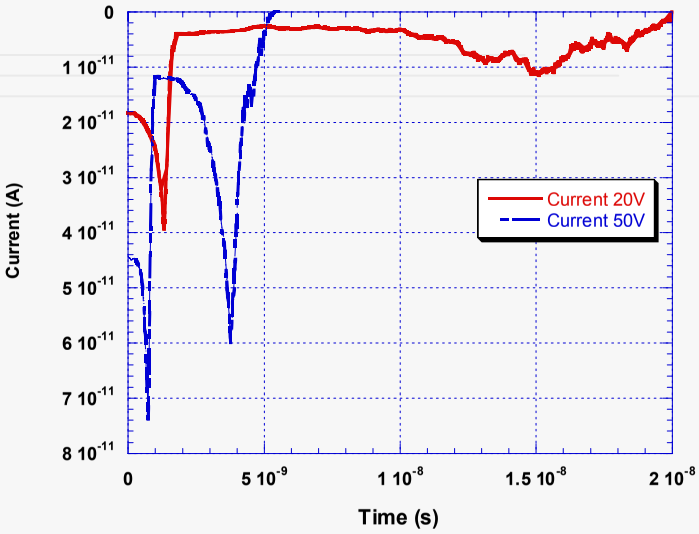
Stanford 3D detector has same field whatever the depth.

e/h paths in device - includes diffusion





Current signal at p+



100 micron inter-electrode strip connection

Mainly affects fall time

3D modelling and data fit

A. Kok PhD Thesis

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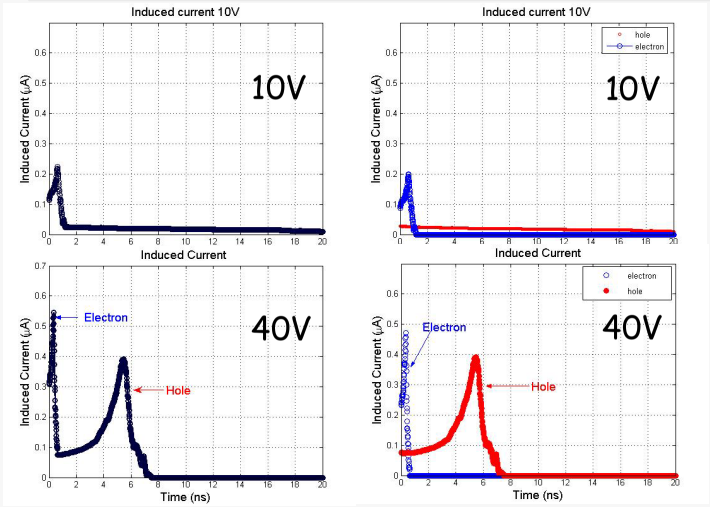
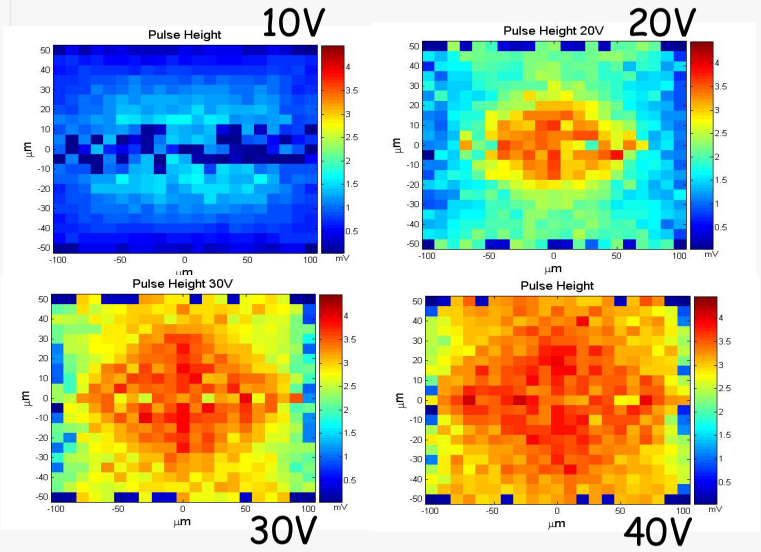
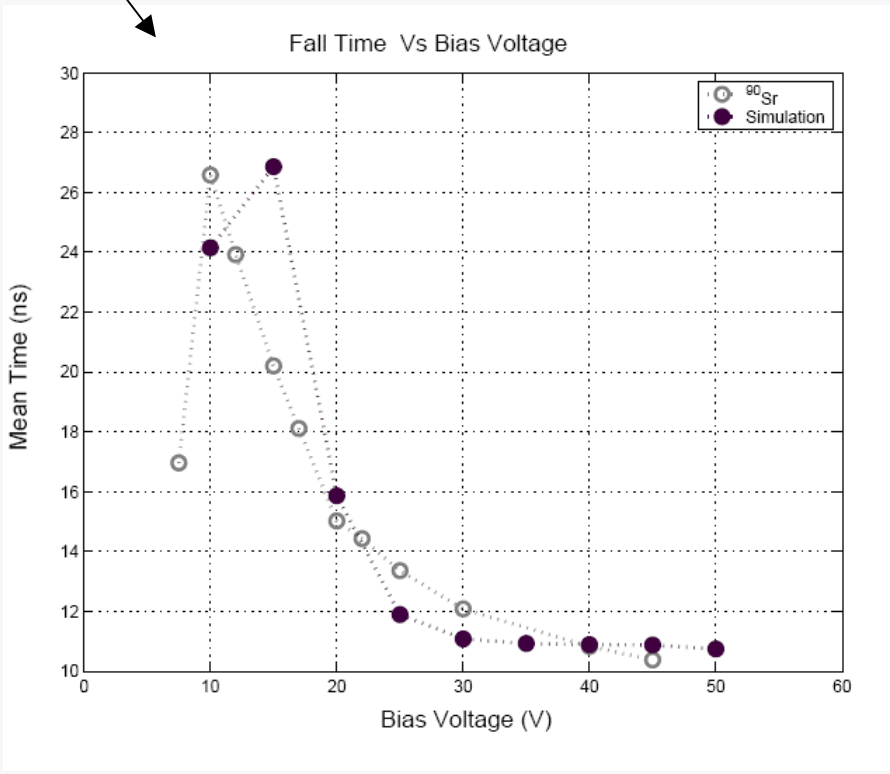
100 micron p/n electrode spacing. 3D Strip

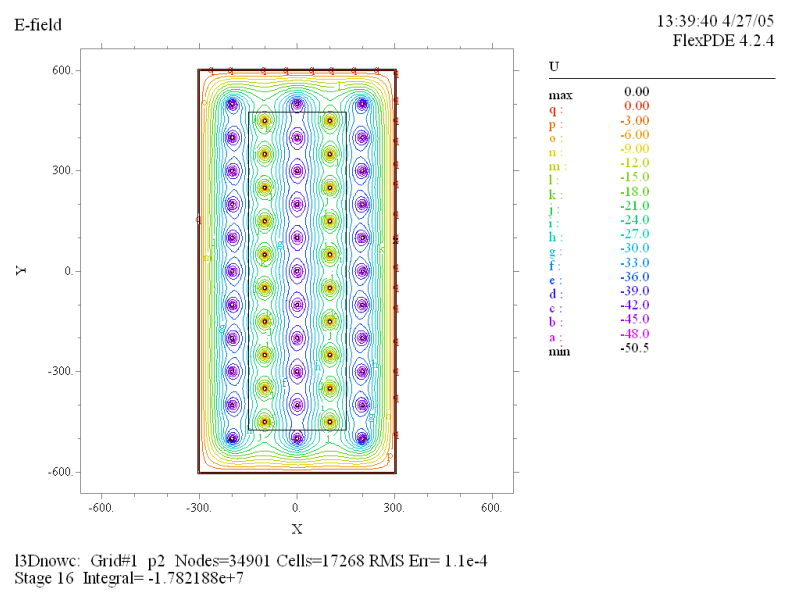






Simulation of signals fall time distribution over a cell (full dot) and ^{90}Sr data (open dot)

Capacitance Calculation



Equipotentials – 50V

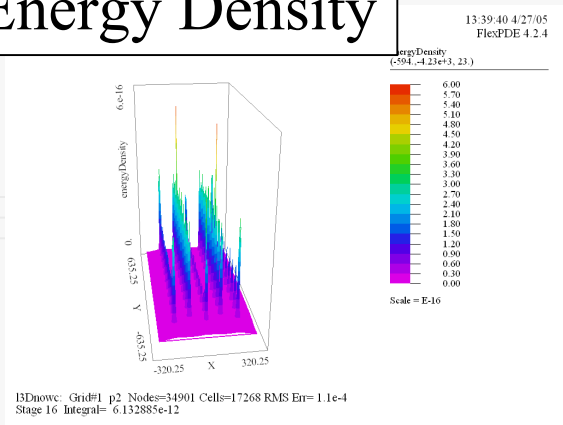
Energy Density = (1/2) * $\underline{E}$. $\underline{D}$ = (1/2) * ε $\underline{E}$.$\underline{E}$

Integrate this over the volume…

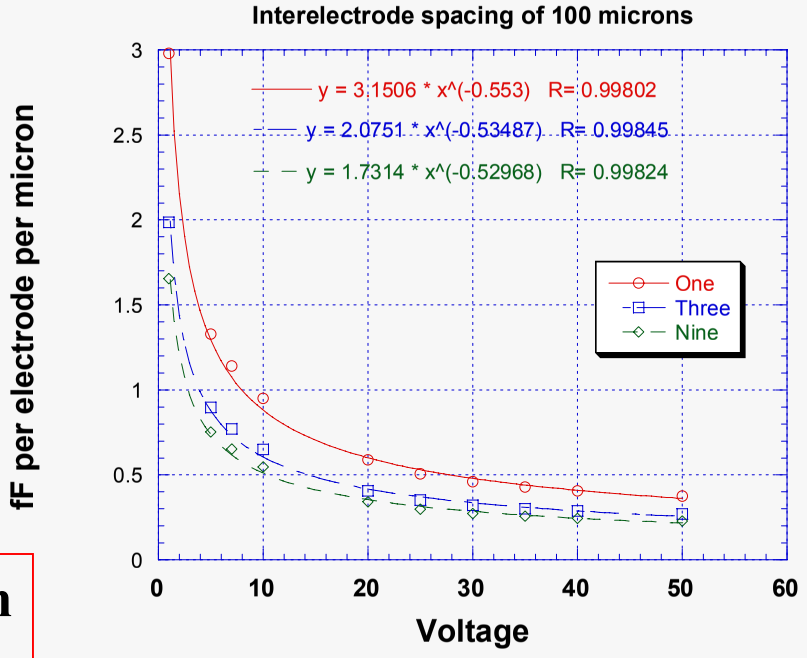
C = 2 * (Total Energy Density)/ V^2

Full depletion – 0.25 fF/electrode/micron
125 micron gives 31 fF

Energy Density

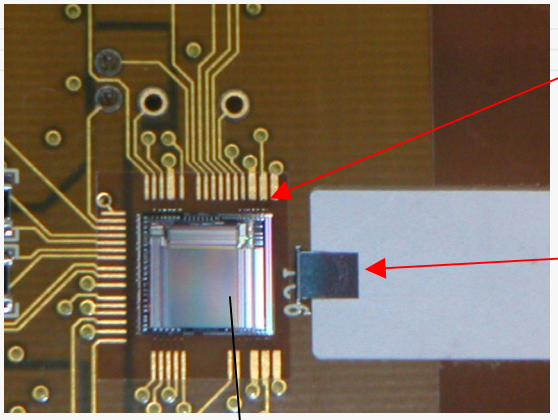


Results for 1, 3 and 9 electrodes



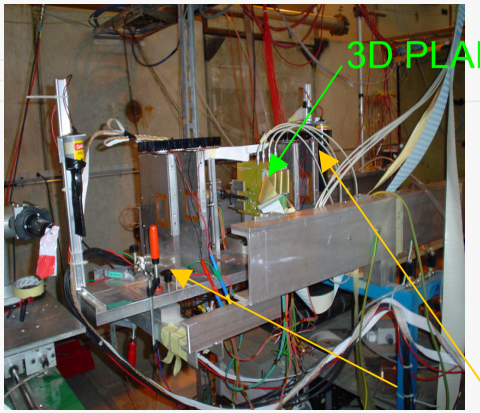
Ratio one to nine ~ 0.6

Efficiency (TOTEM X5-beam area) - 2003

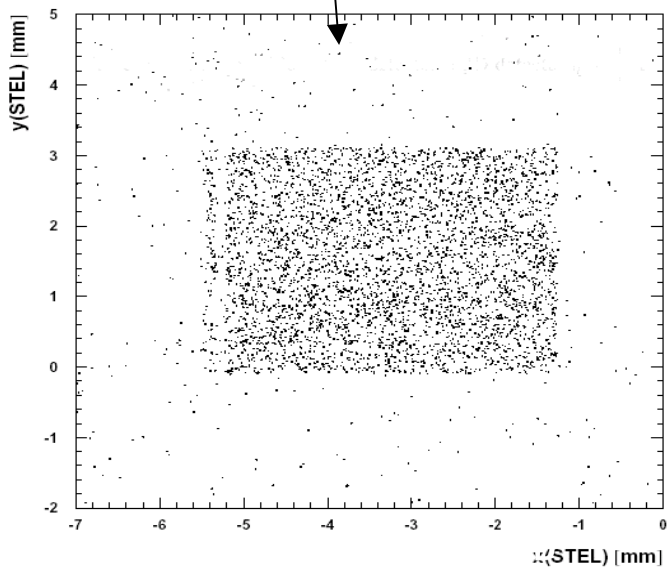


SCTA READOUT CHIP*

3.195 x 3.9 mm^2
3D SENSOR
Thickness=180 μm
n-type Si 4kΩ-cm

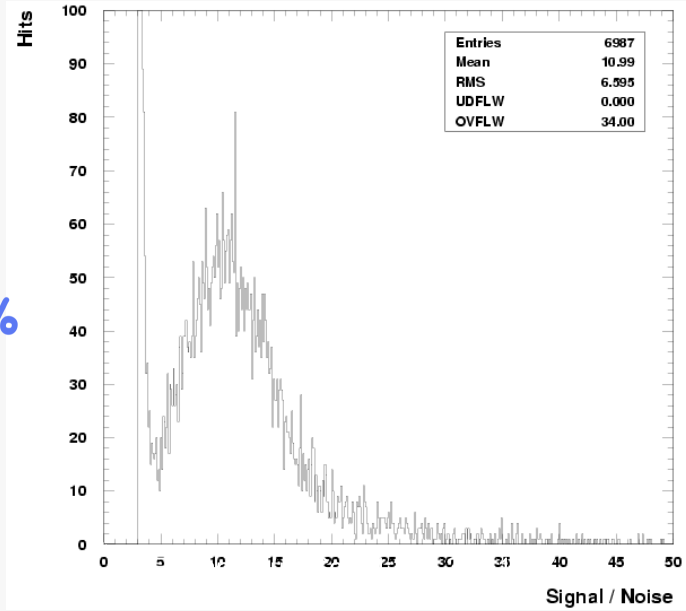


REFERENCE TELESCOPE



S:N=14:1

Efficiency= 98%



Efficiency: p and n electrodes response

Electrodes area ~1.8% of total area

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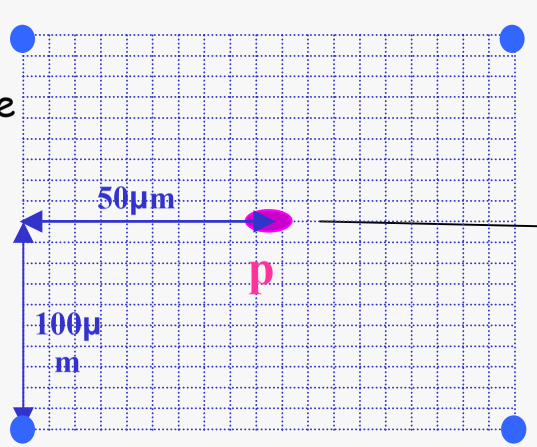
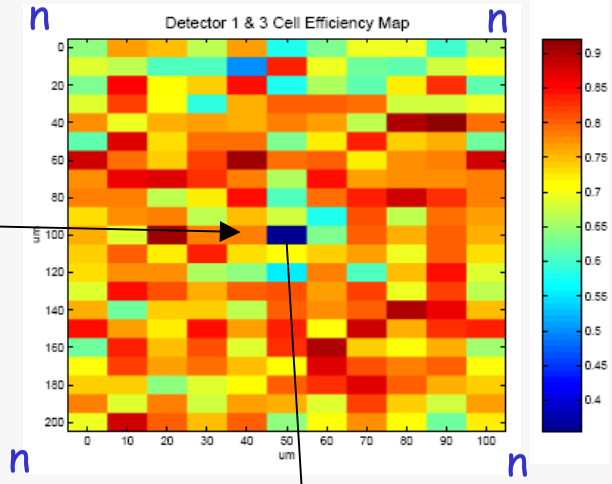
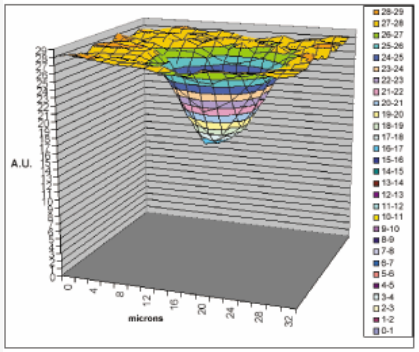
A. Kok PhD thesis

Cell study using 120GeV muons (Cern X5), Telescope Precision ~4μm.

Electrode response using 12KeV X-ray beam (ALS), beam size ~ 2μm

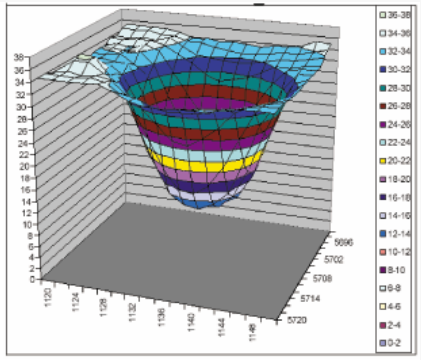






N – Electrode

Signal Reduction 43%

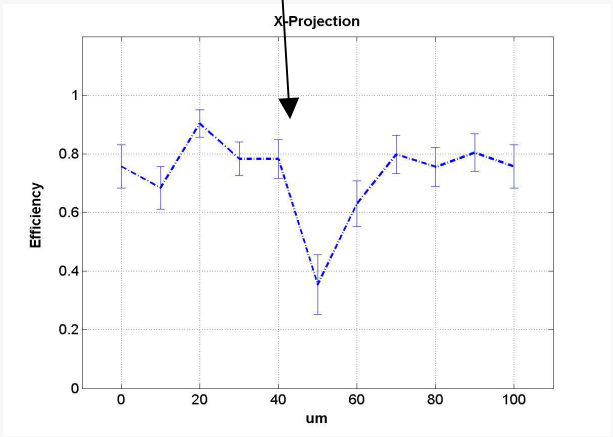


P – Electrode

Signal Reduction 66%

Differences between N and P:

Grain size of poly, Diameter, Diffusion rate, Trapping, Doping



40% reduction in count efficiency at p-electrode

Yield + Large area : FP420/Atlas pixel

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Atlas chip picture from Bekerle Vertex03

DIMENSIONS	RO SIGNAL	Technology	BUFFER/speed
50x400 μm^2 7.2x8mm^2	binary and time over threshold	0.25 μm IBM CMOS6SF	2 - 6.4μs 40 MHz

-32 3E ATLAS Single Chips

-6 4E ATLAS Single Chips

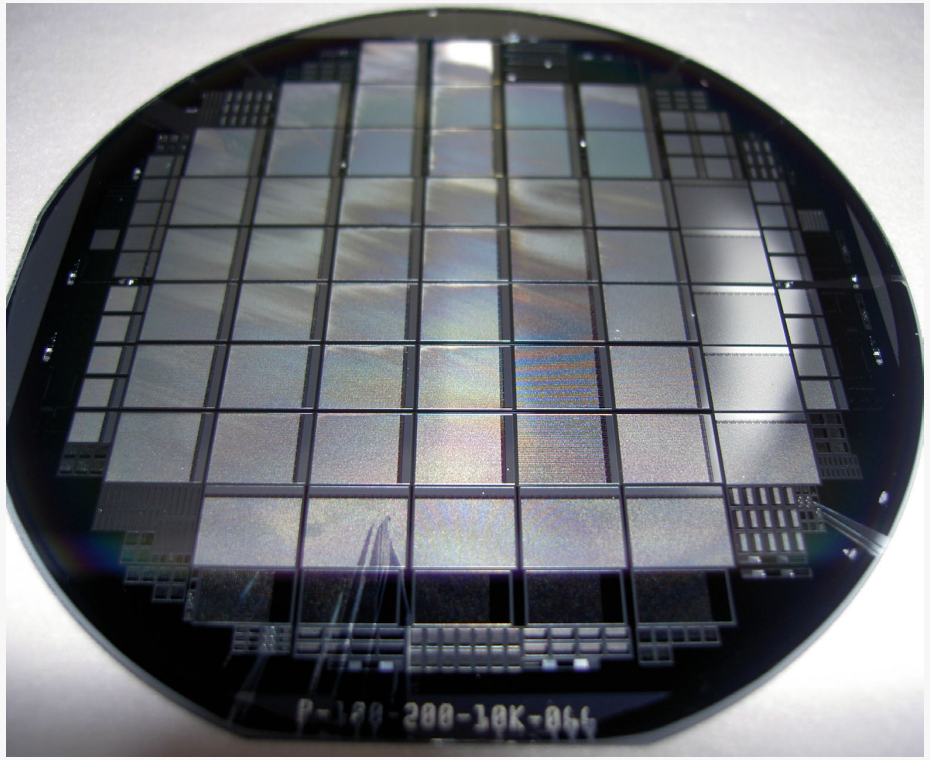
-6 2E ATLAS Single Chips

-Quarter Size ATLAS Chips

-ATLAS Test Structures

-Other structures

Thickness <250 μm>
p-type substrate 12kΩcm



10 wafers completed : Yield on one wafer ~80%

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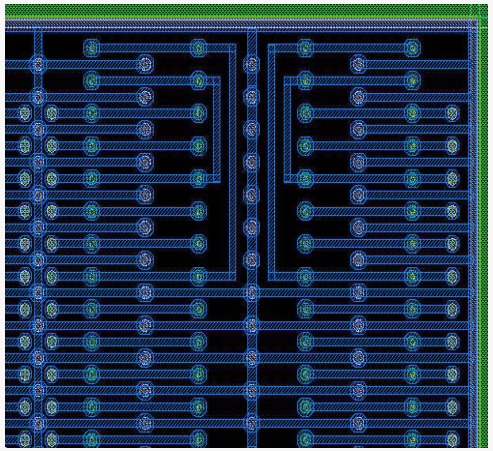
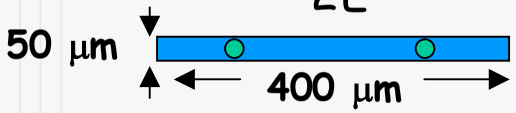
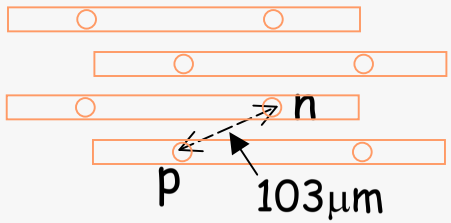
3D FP420/Atlaspix electrode configurations

El. 4%



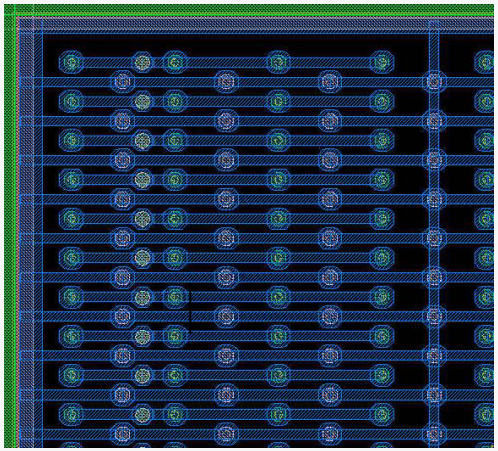
2E



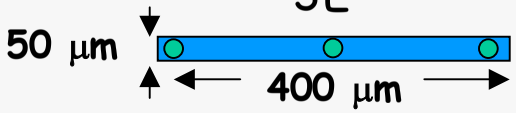


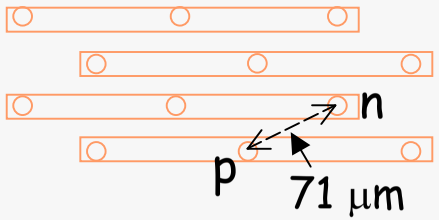
V_{fd} ~20V

El. 6%



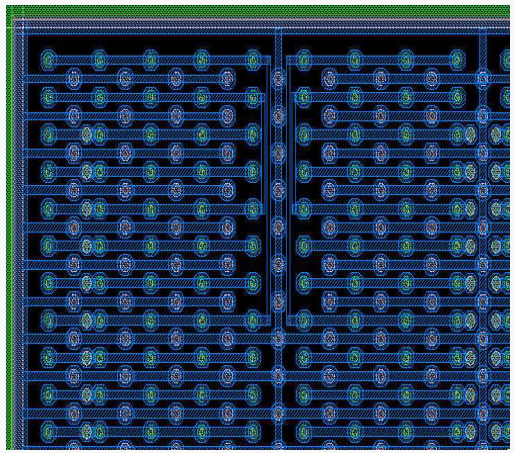
3E



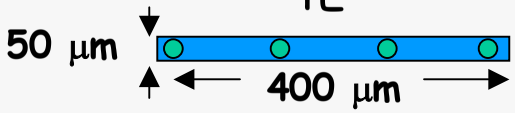


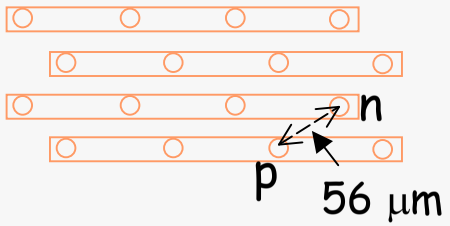
V_{fd} ~8V

El. 8%



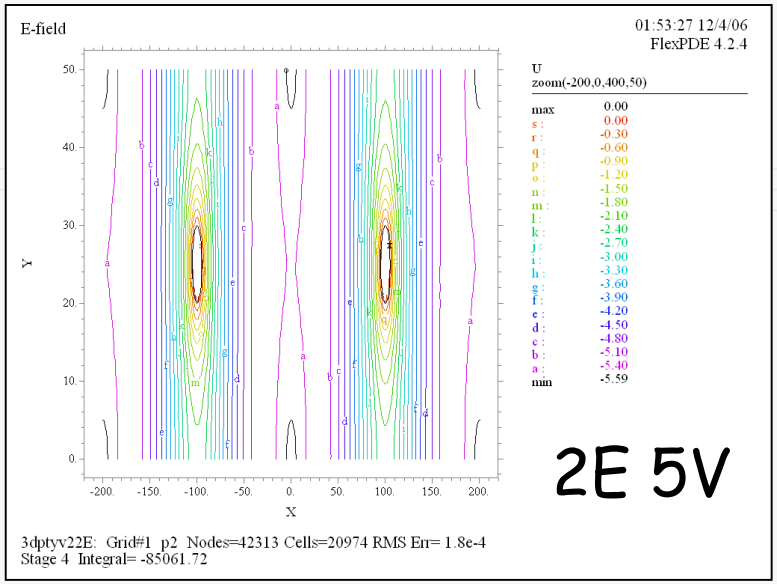
4E

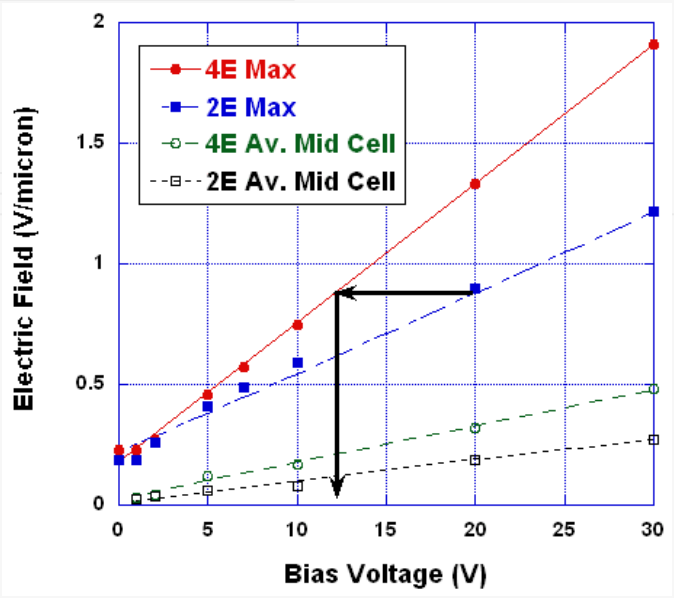


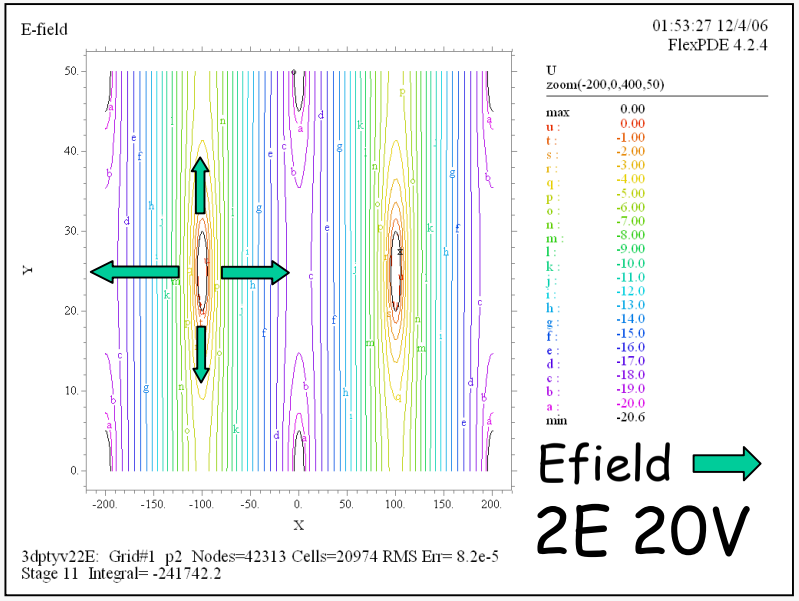


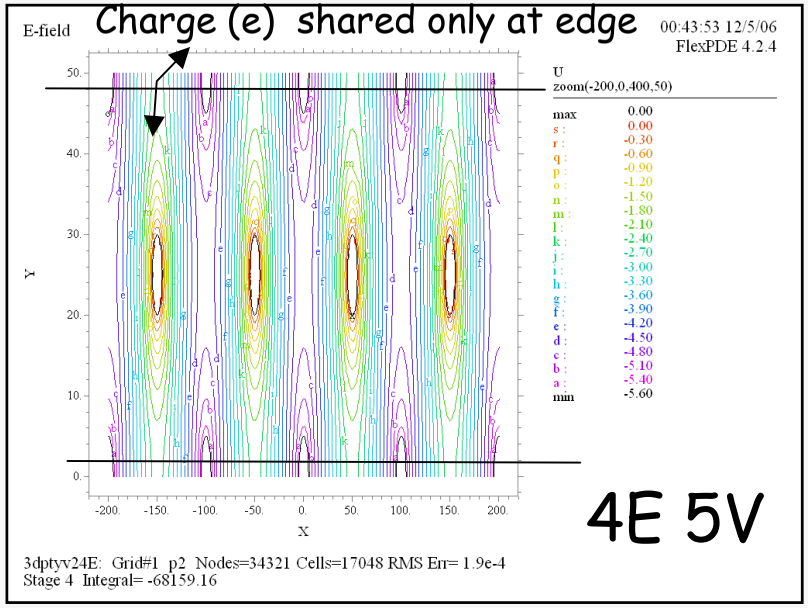
V_{fd} ~5V

Equipotentials in 2E and 4E detectors









Aug. 17 Sept. 3, 2006
H8 Cern beam line

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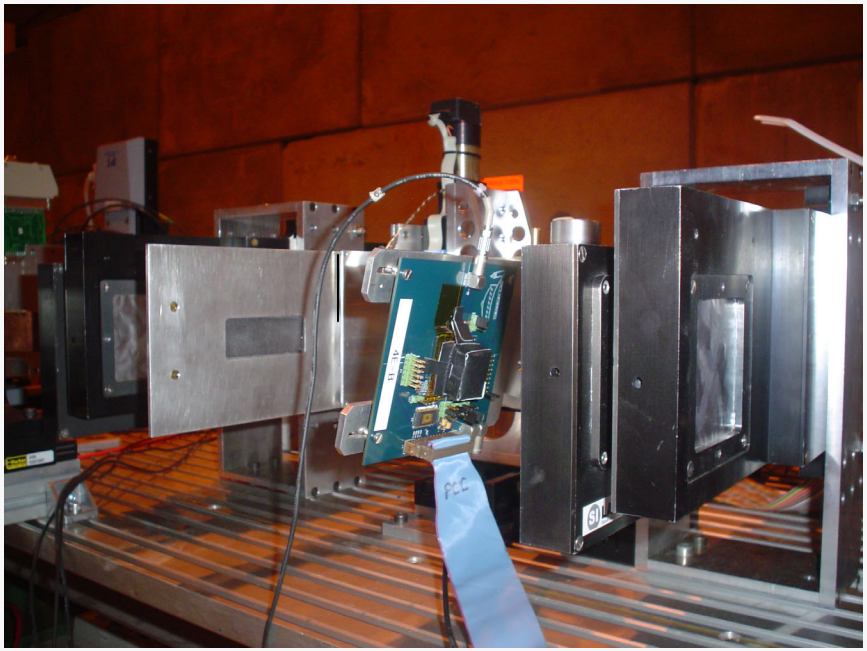

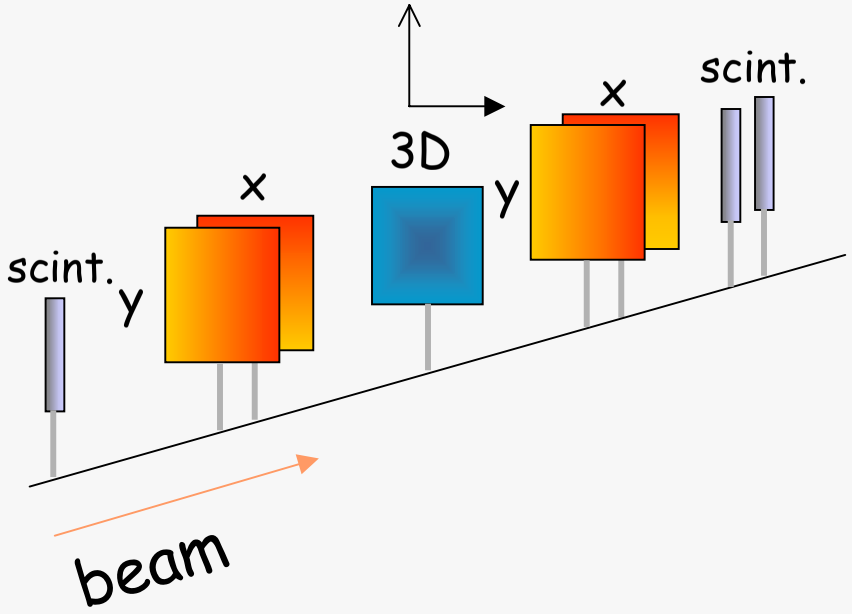

Telescope, daq and on-line monitor by Lars Reuen, Atlas pixel setup and data conversion Markus Mathes (Bonn group)

100 GeV π^-
Triggers: 3x3 mm^2 , 12x12 mm^2

3D-2E-A preliminary

V_{bias}=30V Threshold=4000e$^-$

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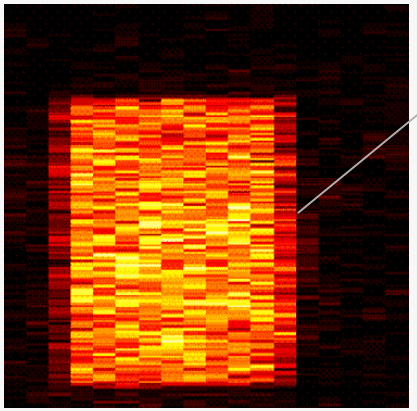
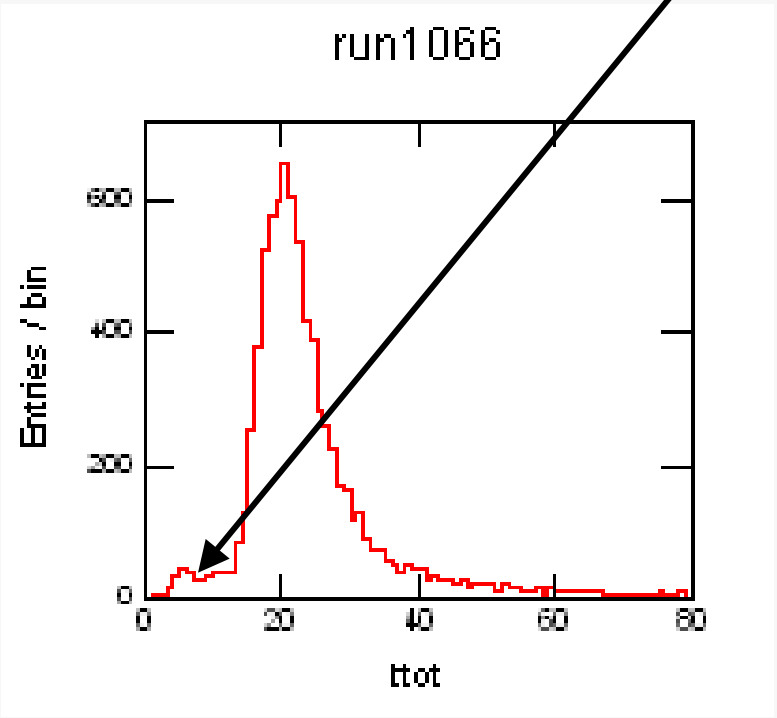
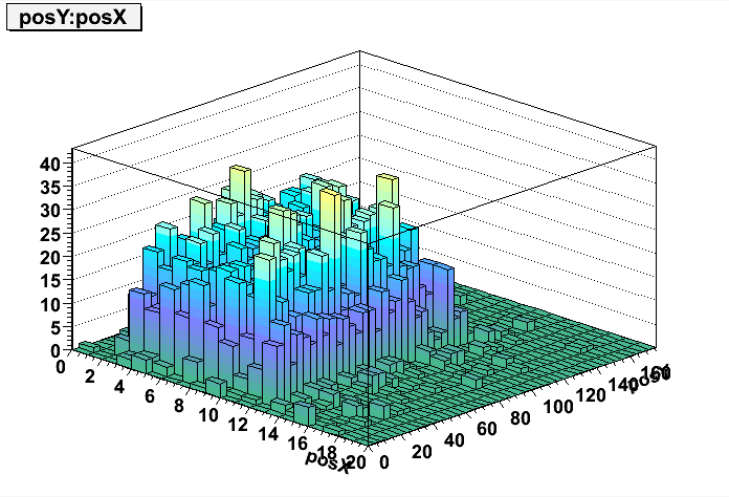
Track through electrode ?

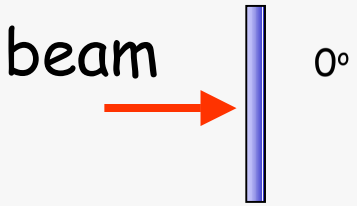


hitmap with the 12x12 mm^2 trigger





hitmap with the
3x3 mm^2 trigger



3E-G correlation plots and hit maps

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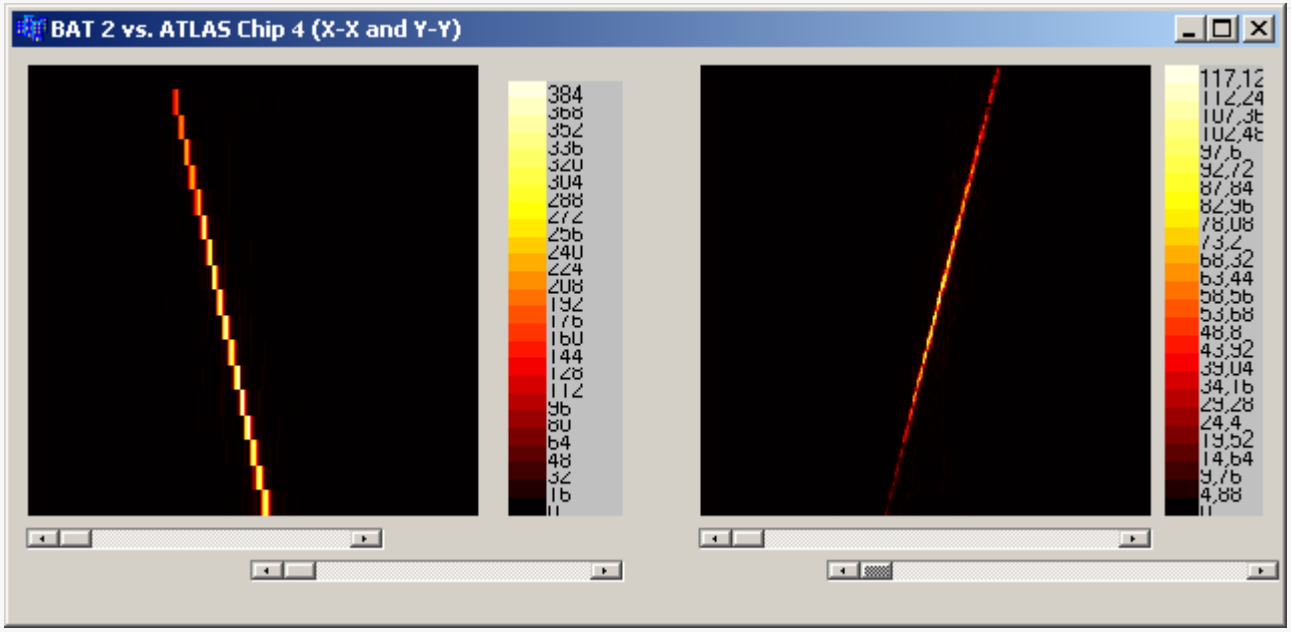
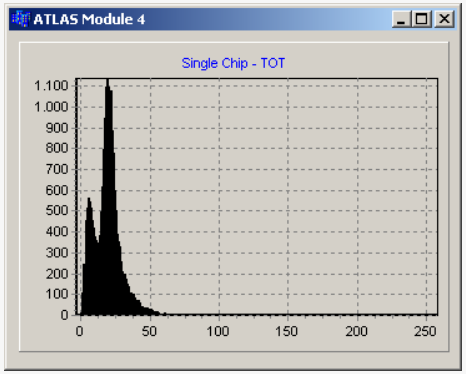
x-x y-y

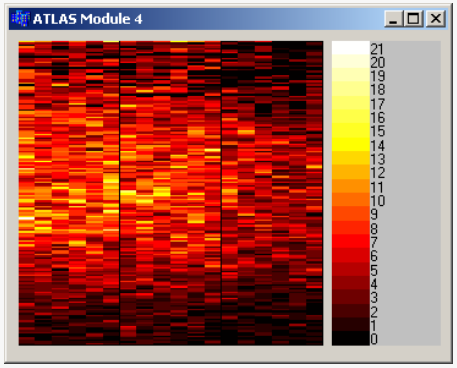


V_{bias} =15V

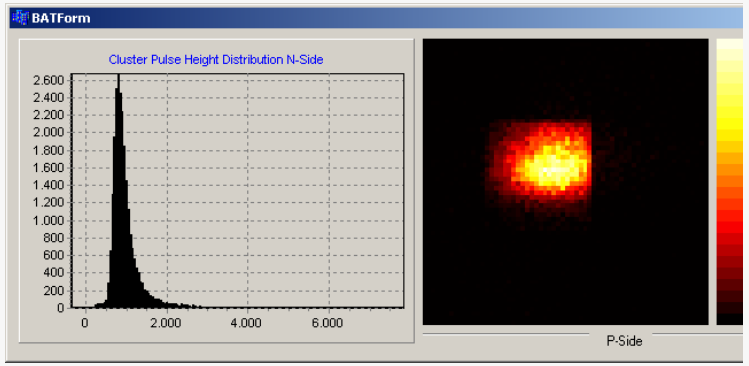
Th. = 4000e$^-$

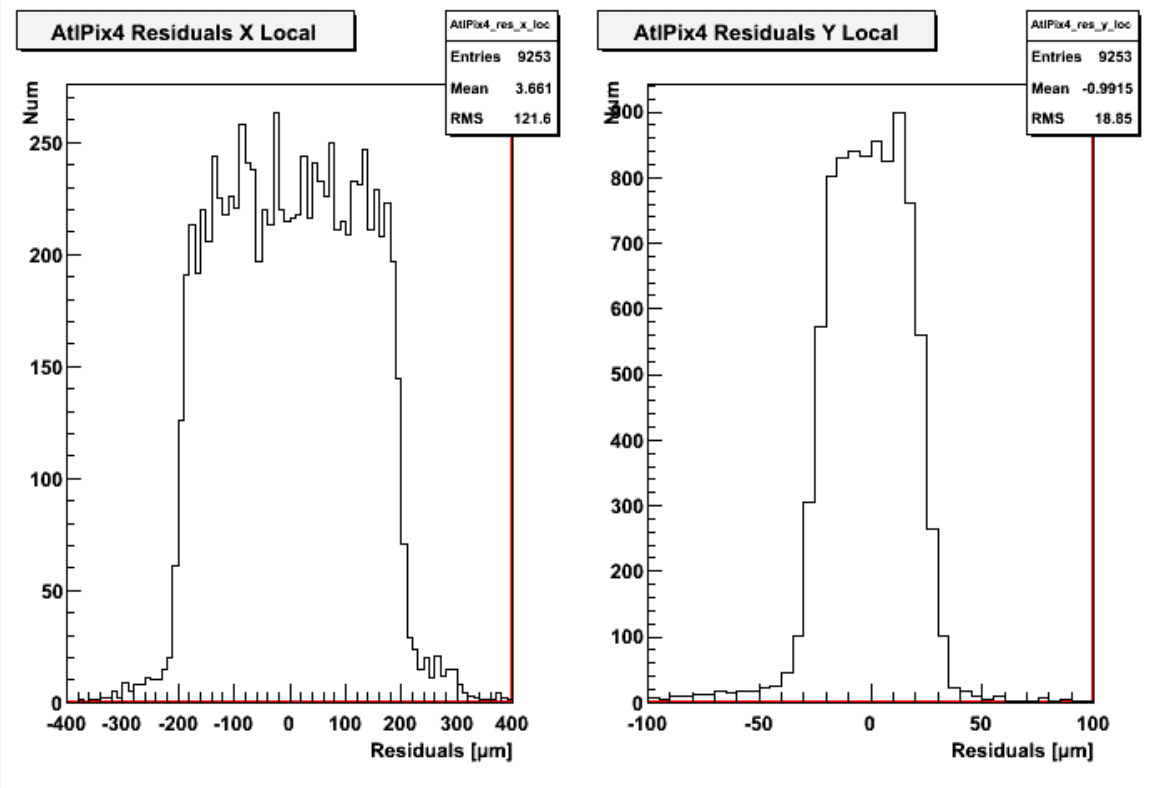
Tot 3D





Telescope





Thanks to M. Mathes, Bonn

Tracking to check resolution, efficiency started. Much to do.

4E electrode angular response – preliminary

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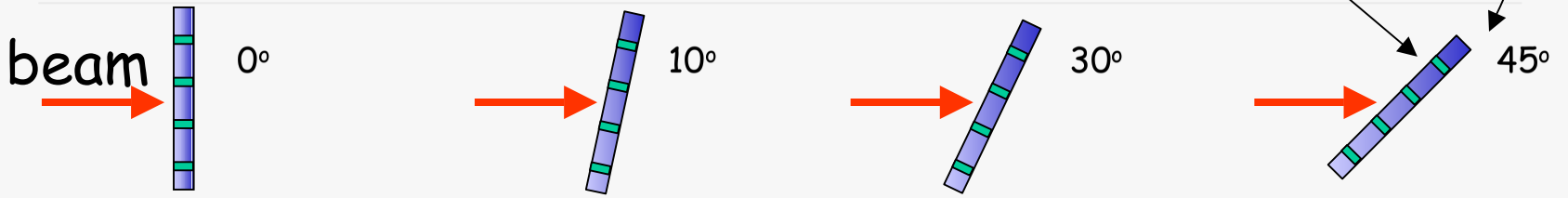
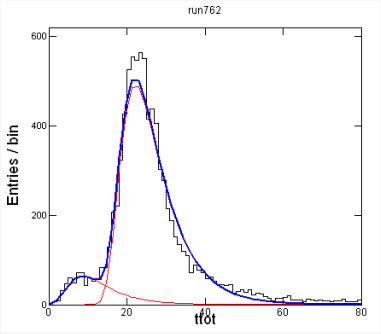
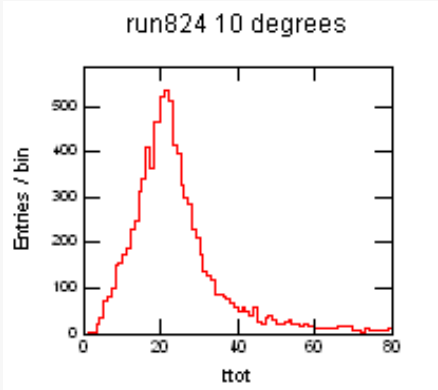
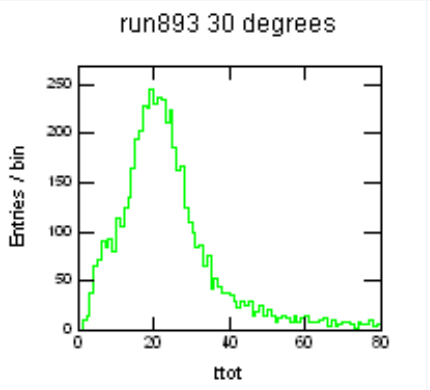
V_{bias}= 20V Th. = 4000e^-

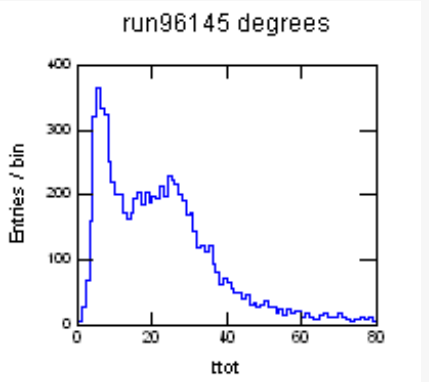
1 pixel cross section 50 x 250



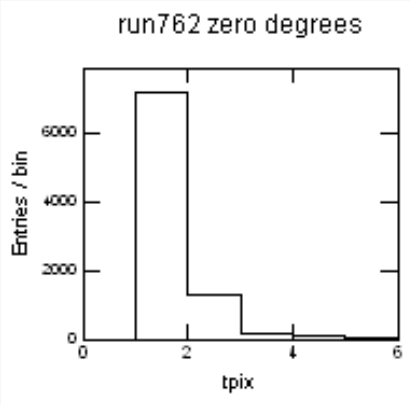


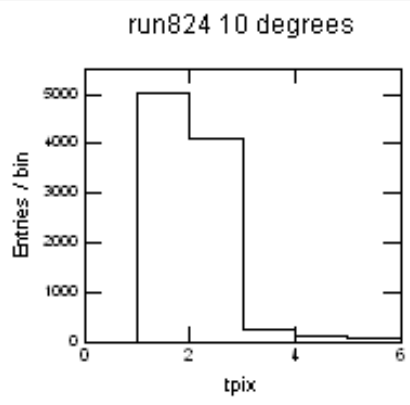


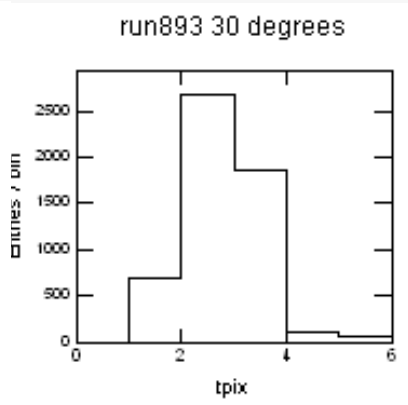


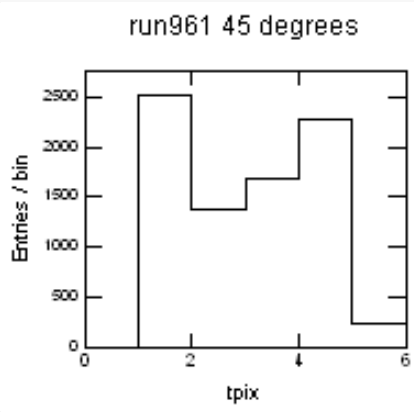


~82 % one pixel





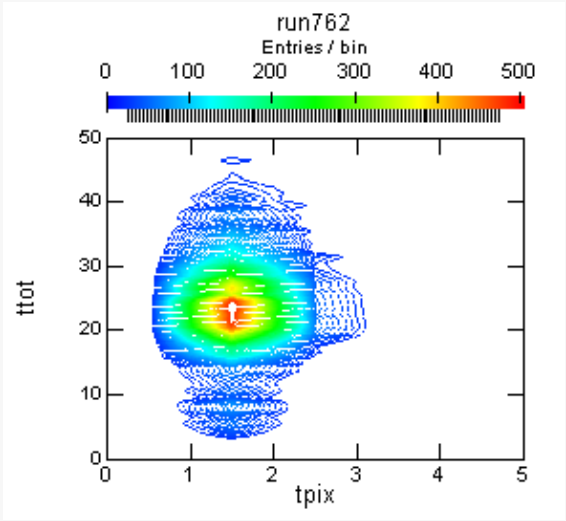




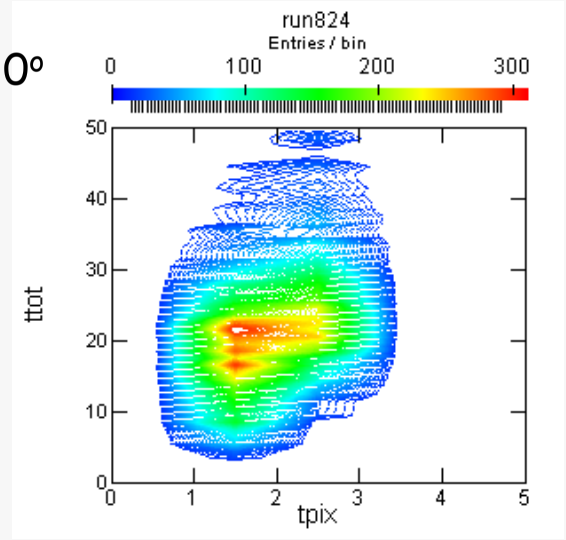
4E- Signal size versus cluster size

3Dc

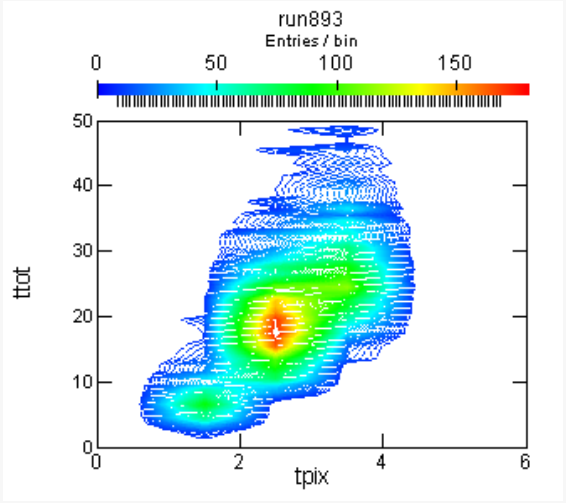
0°



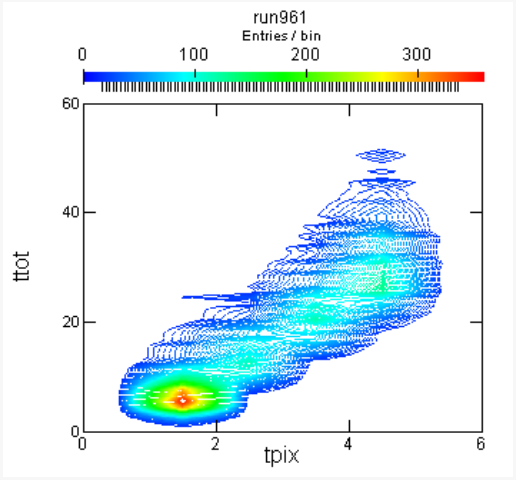
10°



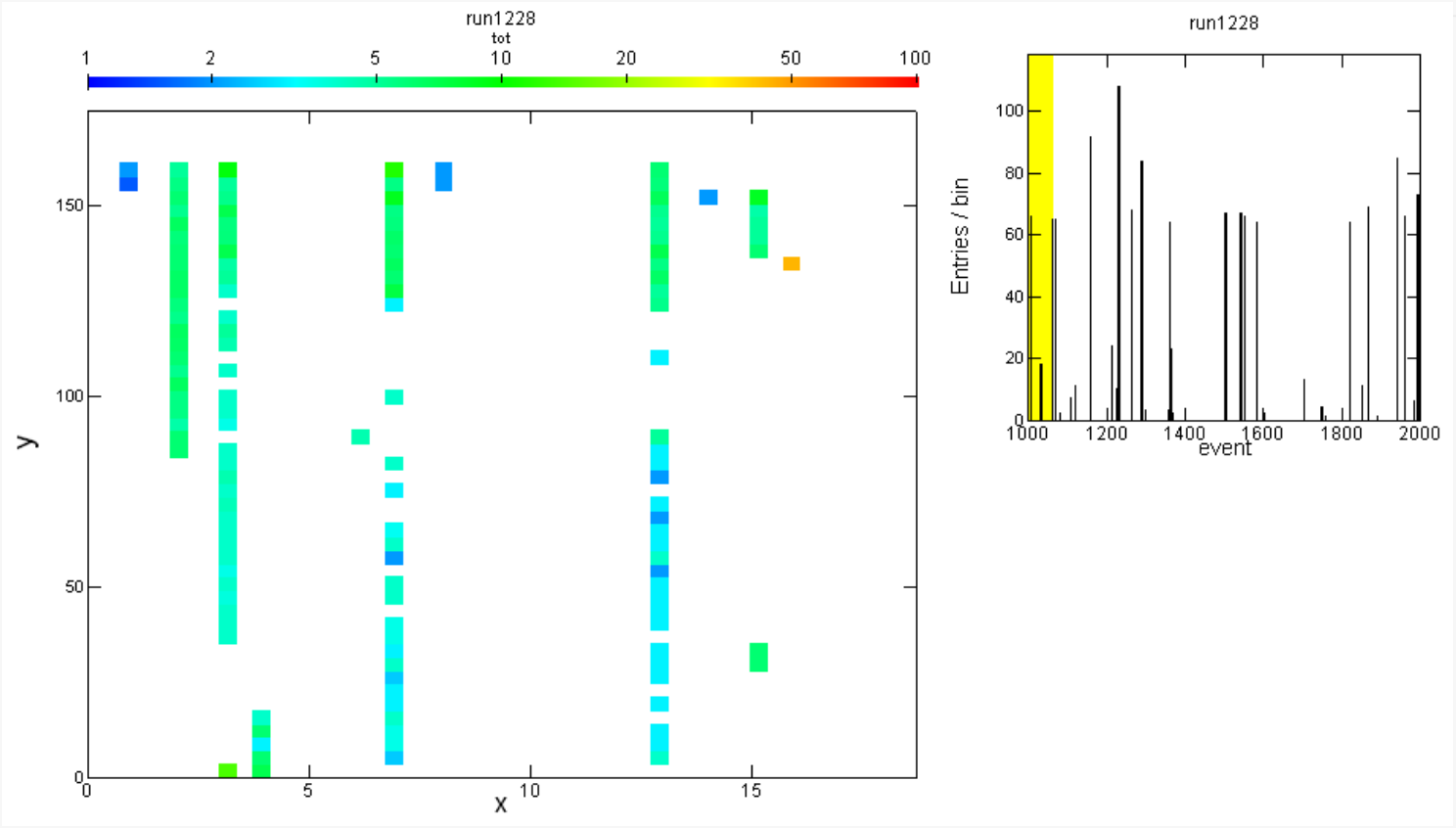
30°



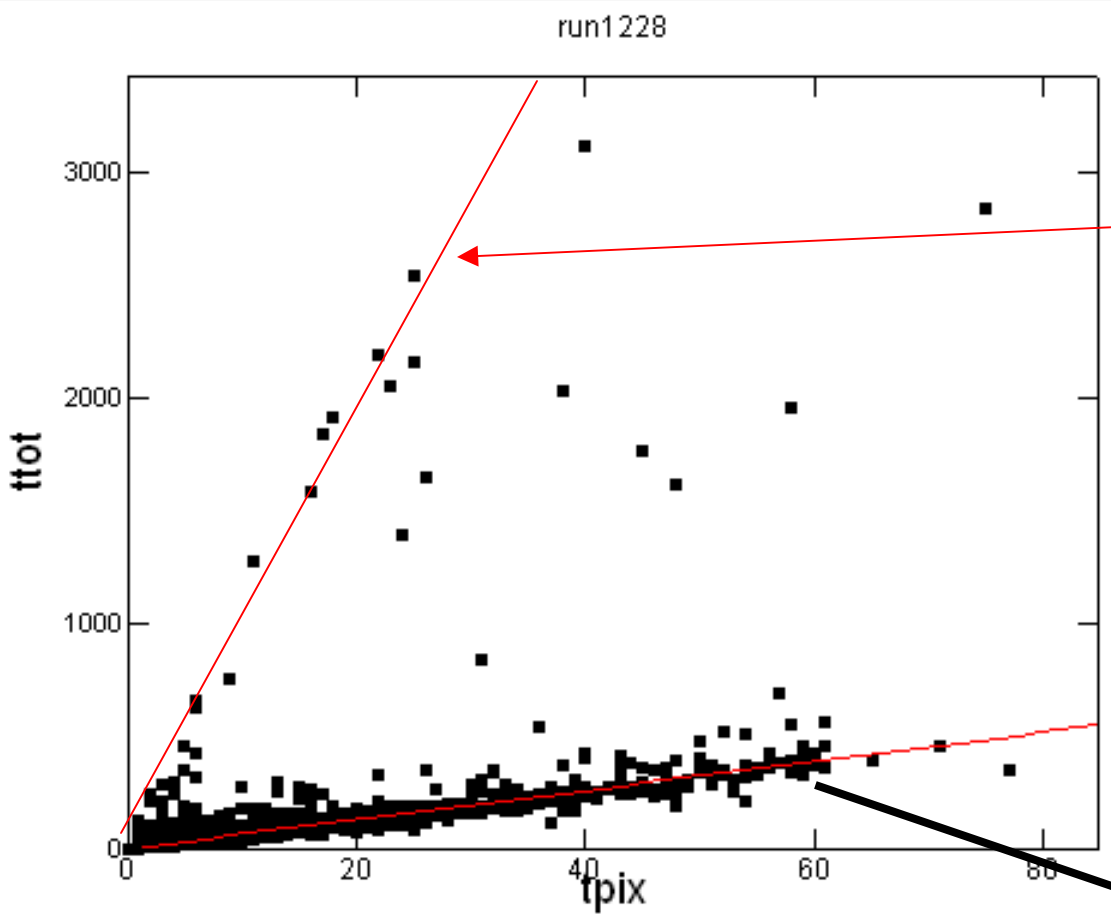
45°



90 Degree data – run 1228



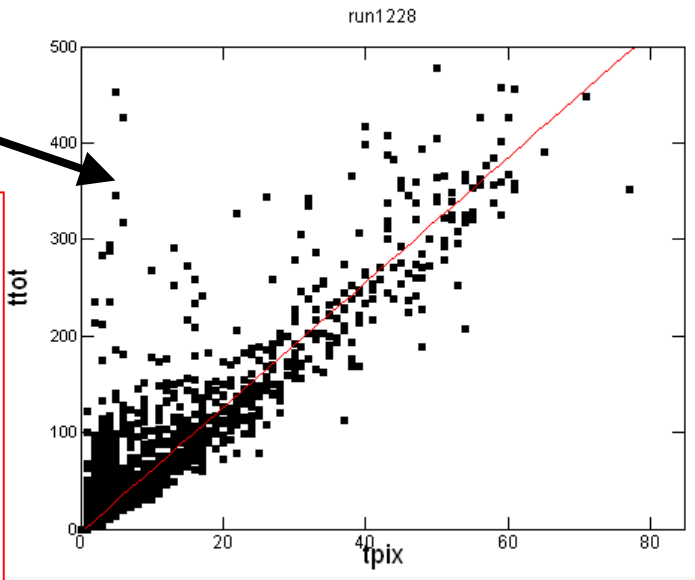
Several events on one plot



Nuclear Recoils???

V. Preliminary

90 degree data



For MIP's
~6 counts/pixel
Or 6 counts per 50 micron
Zero degree get 24 ADC counts
i.e. wafer thickness = 4*50 = 200 micron

Conclusions and future plans

The results so far:

- Speed of response – data and modelling
- Edge response, Data from tests as XLS, CERN
- Efficiency, Data from tests at CERN
- Rad. Hardness – data and modelling in progress.
- 3D strip, 3D/planar, 3D pixel detectors made and tested.

For 3D sensors fabricated at Stanford
Will need to further study the test beam data and backup with detector modelling

{ charge sharing – not like a planar silicon detector, check the efficiency versus cell position
check the electrode response,
check the spatial resolution – can one do better with cluster size > 1 ? }

We have millions of tracks for 2E, 3E, 4E detectors at several angles.

WORK driven by application in TOTEM, FP420 and ATLAS pixel upgrade.
Team has driven the R&D work to make these applications possible using PPARC funding.

Team: Cinzia DaVia (Tech. Coordinator,FP420), Angela Kok (now at SINTEF)
Jasmine Hasi (based at Stanford), Steve Watts
Now backed up by engineering support at Manchester – Scott Kolya, Ray Thompson.
Collaboration: Stanford/MBC, Hawaii, LBL, Prague, Bonn, CERN.
2006 – Collaboration with SINTEF,Univ. Oslo formed.

Keen to drive forward the ATLAS upgrade work and obtain further PPARC funding.