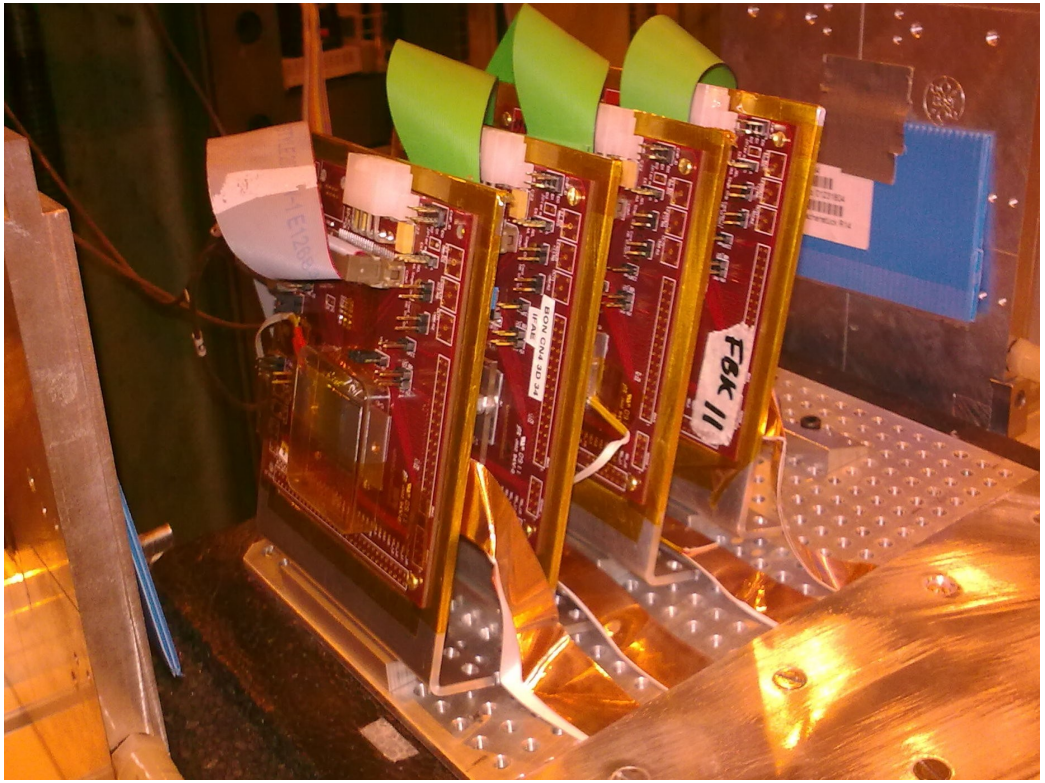
Test-beam results of CNM 3D FE-I4 devices



Sh. Tsiskaridze, S.Grinstein

19th RD50 Workshop-CERN

IFAE - Barcelona

23 November 2011

Outline

- Overview of the Devices Under Test (DUT) used at June and September IBL test-beams at CERN.

- Results from June IBL Test-beam:
  - Overall Efficiency.
  - Pixel Map Efficiency.
  - Edge Efficiency.
- Threshold and HV studies from September IBL Test-beam:
  - Impact of the Threshold on the Efficiency.
  - Impact of the HV on the Efficiency.
  - Impact of the HV on the charge collection (ToT Spectrum).
- Results from September IBL test-beam:
  - Pixel Map Efficiency.
  - Position resolution.

- Conclusions

All results presented here are still preliminary!

Devices overview

- All CNM 3D sensors used in the test-beams were:
  - Double sided process
  - P-bulk 230um thick , “2E-250” configuration ~210um columns
  - 3D guard ring + fence (200um inactive edge)

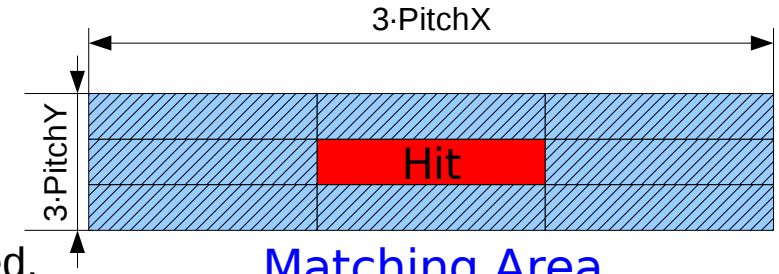
- Data were taken under 0 and 15 degrees to the beam.

- List of devices used at June test-beam:
  (SCC-55) CNM_3D_08 un-irradiated
  (SCC-34) CNM_3D_34 p-irradiated up to $5 \cdot 10^{15}$ neq/cm^2
  (SCC-82) CNM_3D_35 n-irradiated up to $5 \cdot 10^{15}$ neq/cm^2

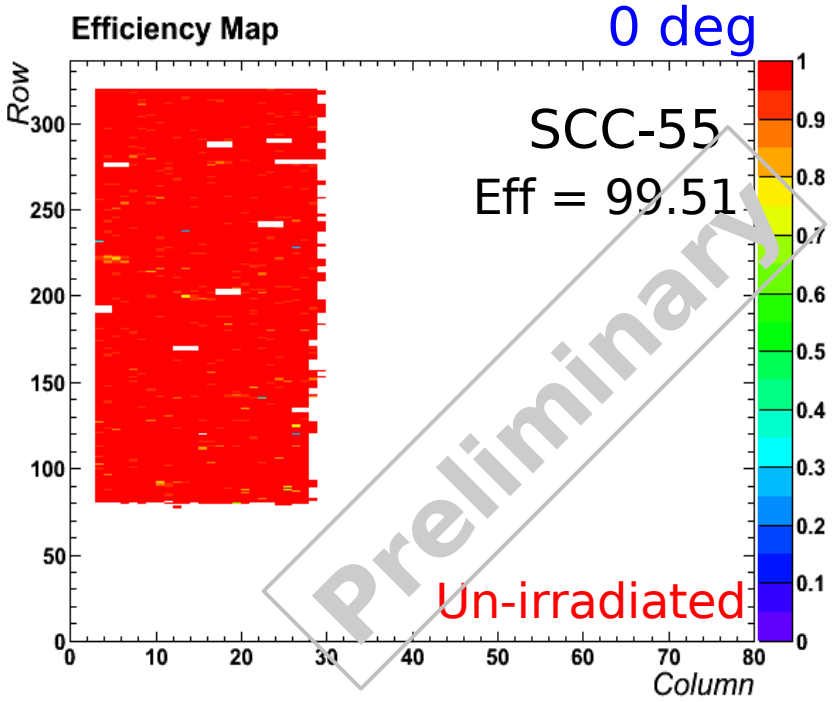
- List of devices used at September test-beam:
  (SCC-55) CNM_3D_08 un-irradiated
  (SCC-34) CNM_3D_34 p-irradiated up to $5 \cdot 10^{15}$ neq/cm^2
  (SCC-81) CNM_3D_37 n-irradiated up to $5 \cdot 10^{15}$ neq/cm^2

Hit Efficiency for CNM 3D FE-I4 devices (June TB)

$$Efficiency = \frac{Number\ of\ Matched\ Tracks}{Number\ of\ Total\ Tracks}$$



- requires at least one matched hit on any other DUT.
- hits nearby masked (noisy and dead) pixels are removed.



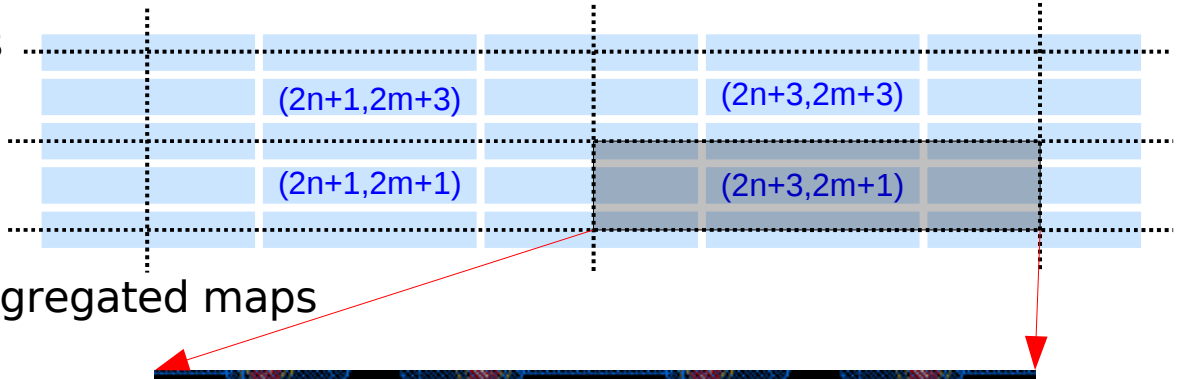
- SCC-55, 0deg, HV = 20V, Threshold = 1600e: Eff = 99.51%;
- SCC-34, 0deg, HV = 140V, Threshold = 3200e: Eff = 95.87%;

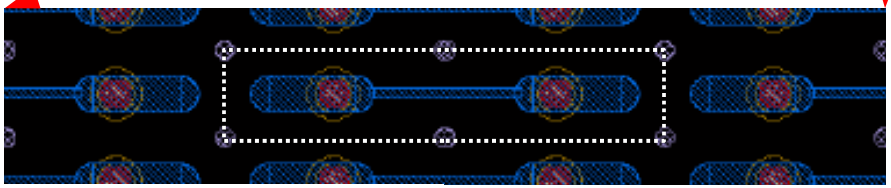
- CNM recommended 140V operation for irradiated sensors--> Low efficiency obtained
- Suggested that sensors were under biased.

Efficiency Pixel Maps for 3D devices (June TB)

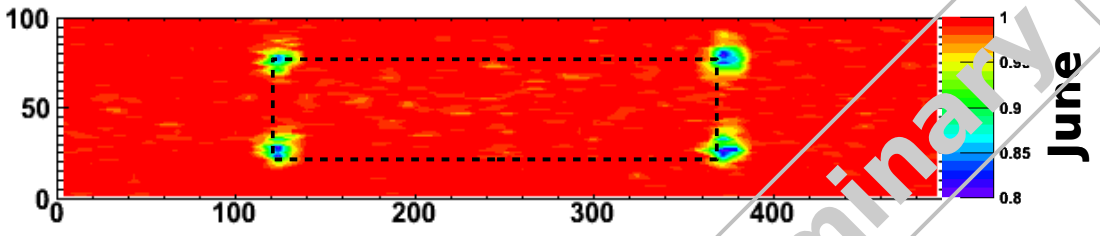
Obtaining Efficiency Pixel map:

- Divide sensor on doubled blocks
- For each block construct:
  - Matched Tracks Map
  - Total Tracks Map.
- Sum up the maps of all blocks
- Calculate the ratio of the two aggregated maps

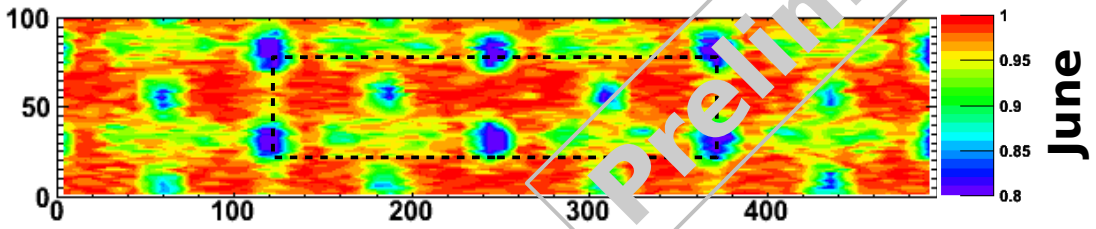




SCC55 (CNM-3D), HV=20V
Unirradiated, 0 degree
Threshold = 1600e, Eff=99.51



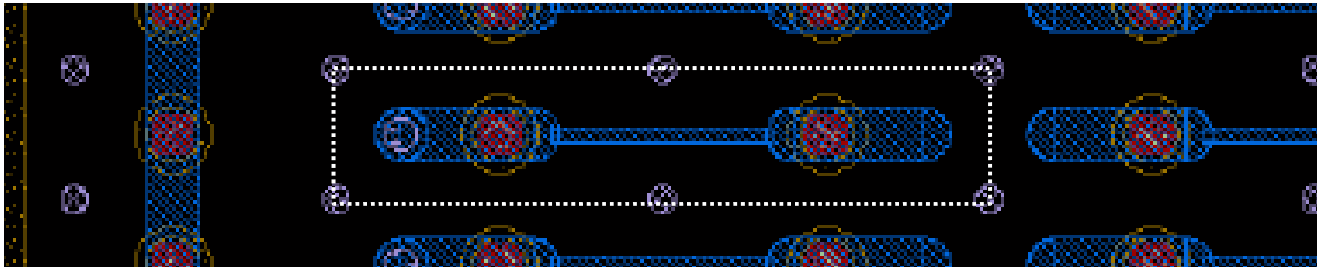
SCC34 (CNM-3D), HV=140V
p-irrad $5*10^{15}$, 0 degree
Threshold = 3200e, Eff=95.87

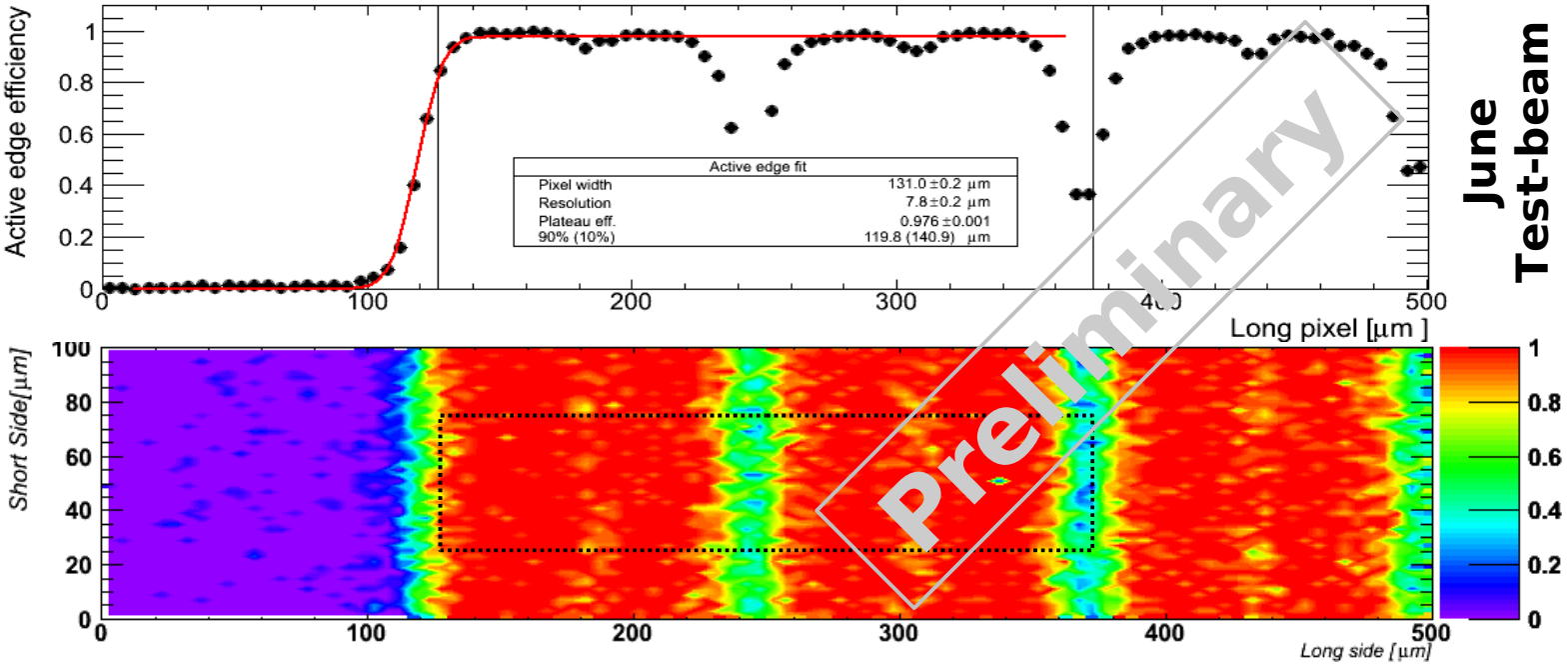


- Low efficient areas associated to n+column were observed.

Edge Pixel studies for CNM 82 device (June TB)

Very low efficiency for SCC82 (n-irradiated up to 5E15neq/cm2)

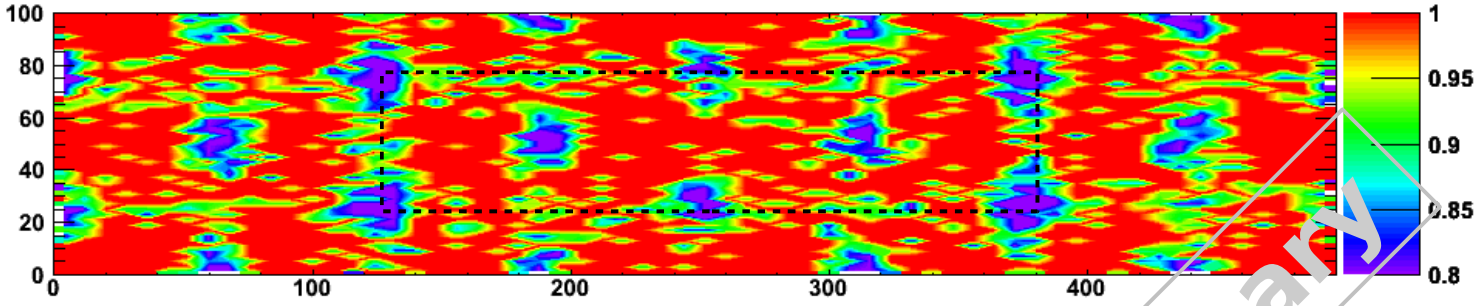




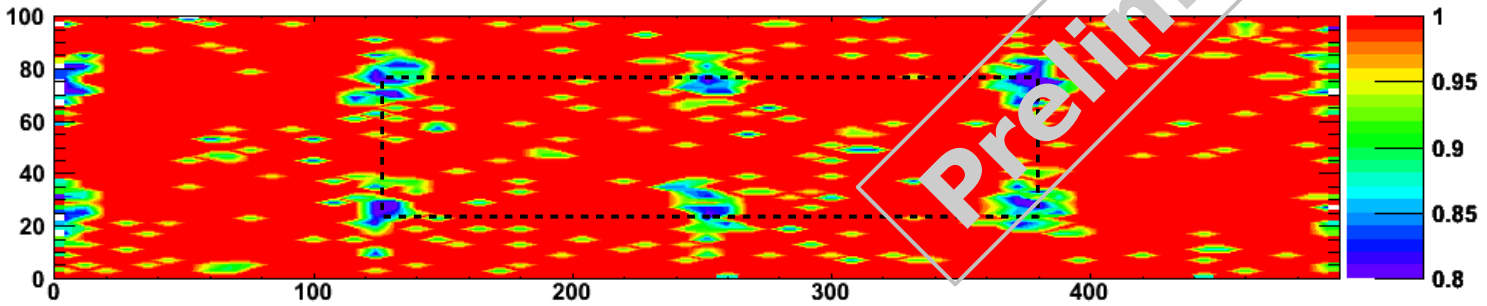
- Overall efficiency was about 90%
- device was under-biased (140V)
- inactive edge area of about 200um.

Efficiency studies for various Thresholds

SCC-34, 0deg, HV = 160V, Threshold = 3200e: Efficiency = 94.53



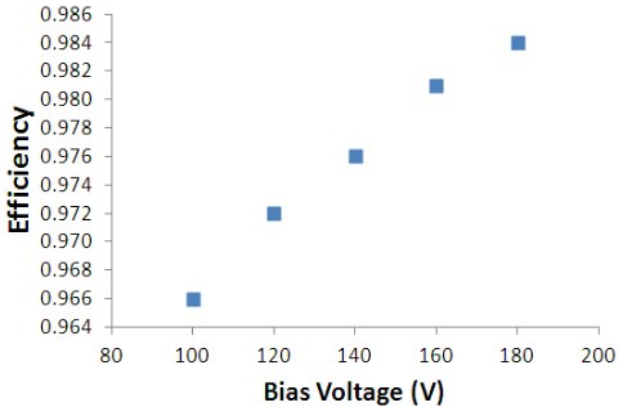
SCC-34, 0deg, HV = 160V, Threshold = 1500e: Efficiency = 98.10



- Inefficiency area associated to n+column disappears.
- Thresholds were NOT verified at the test-beam:
  - Can not fully trust the results above.
  - Temperature and geometry are the same.
- However, very likely lower threshold makes significant improvement on efficiency.

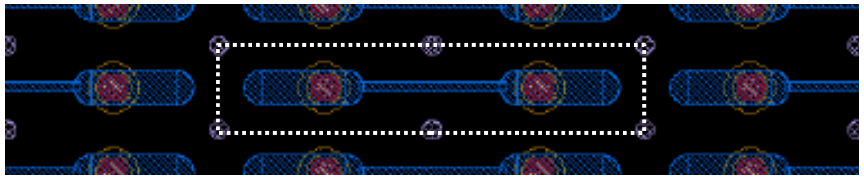
Efficiency Pixel Maps for SCC34 for different HV

0 deg

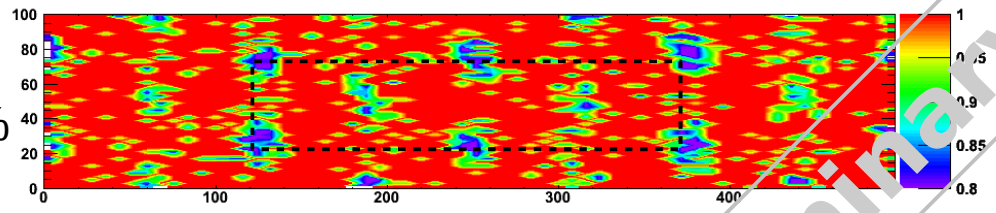


- At ~160V inefficiency area associated to n+column disappears

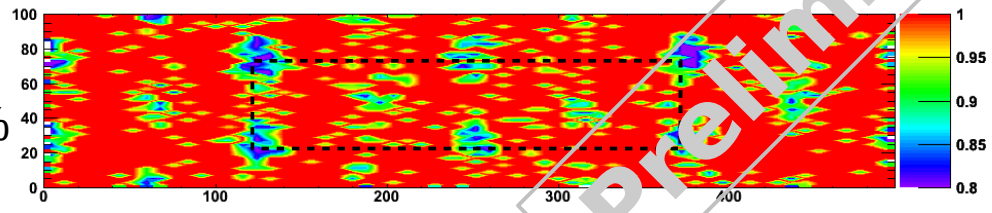
- Efficiency and charge collection increase beyond 160V (but no charge multiplication expected)



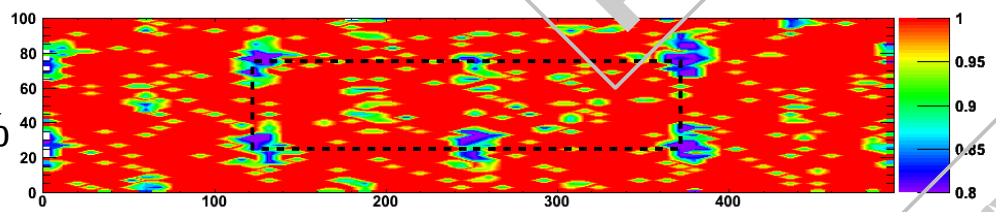
HV=100
Eff=96.6%



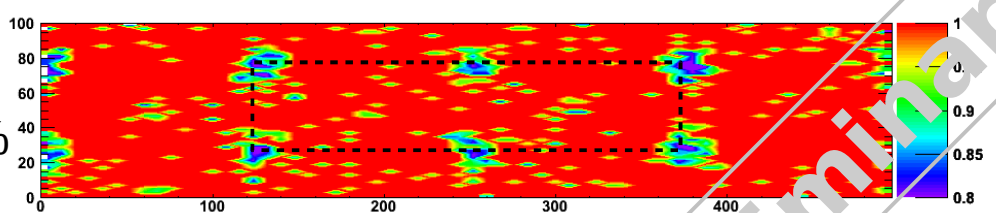
HV=120
Eff=97.2%



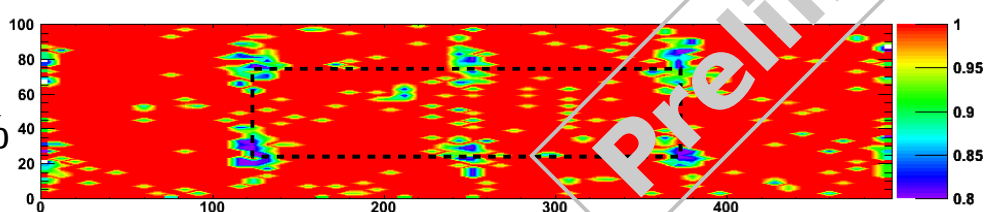
HV=140
Eff=97.6%



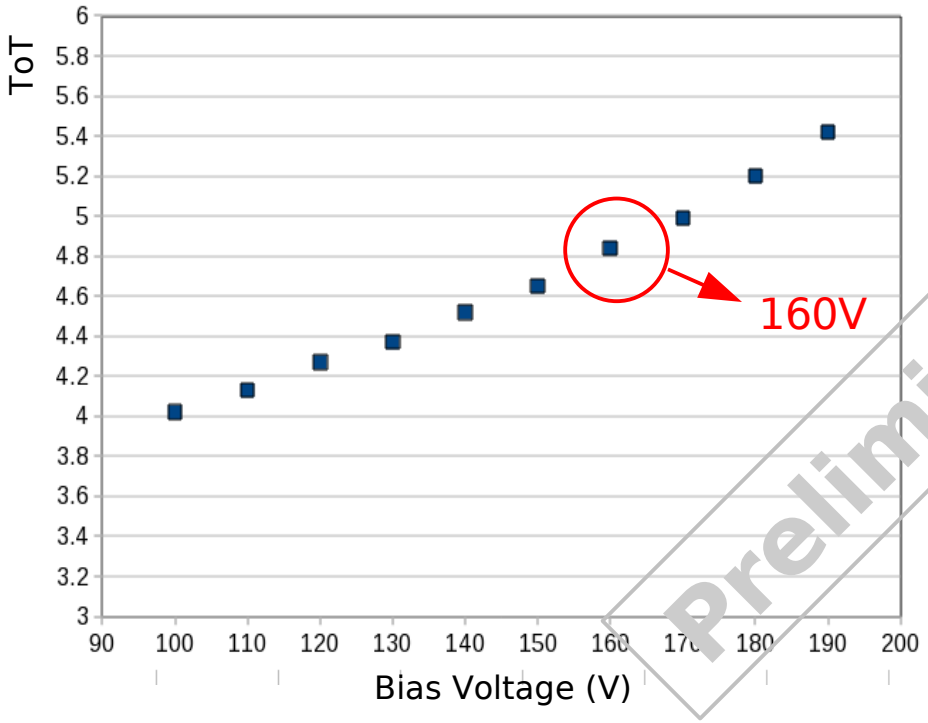
HV=160
Eff=98.1%

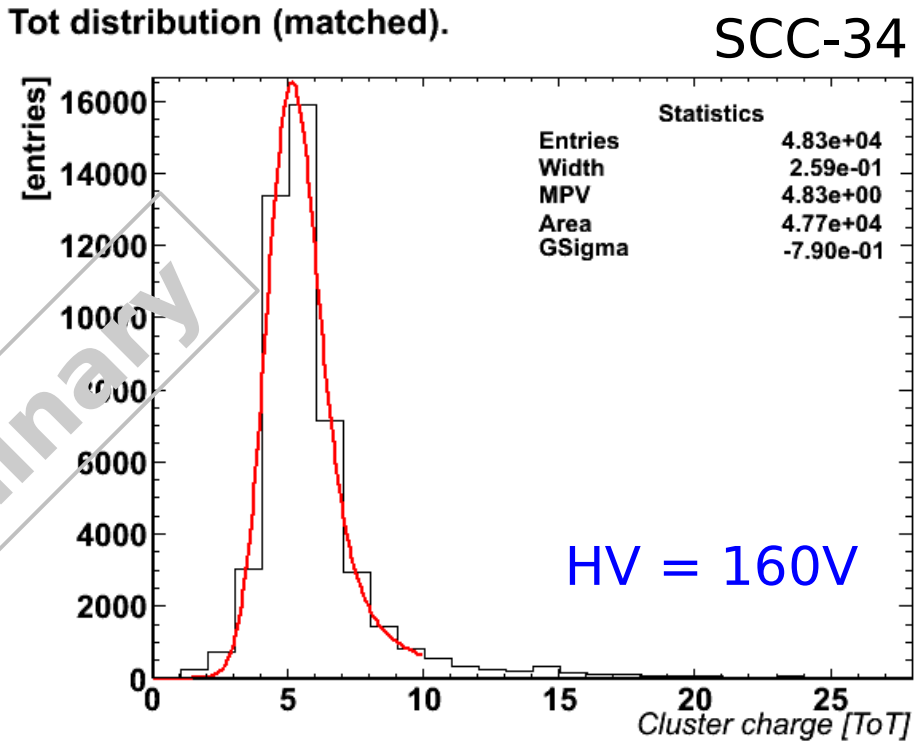


HV=180
Eff=98.4%



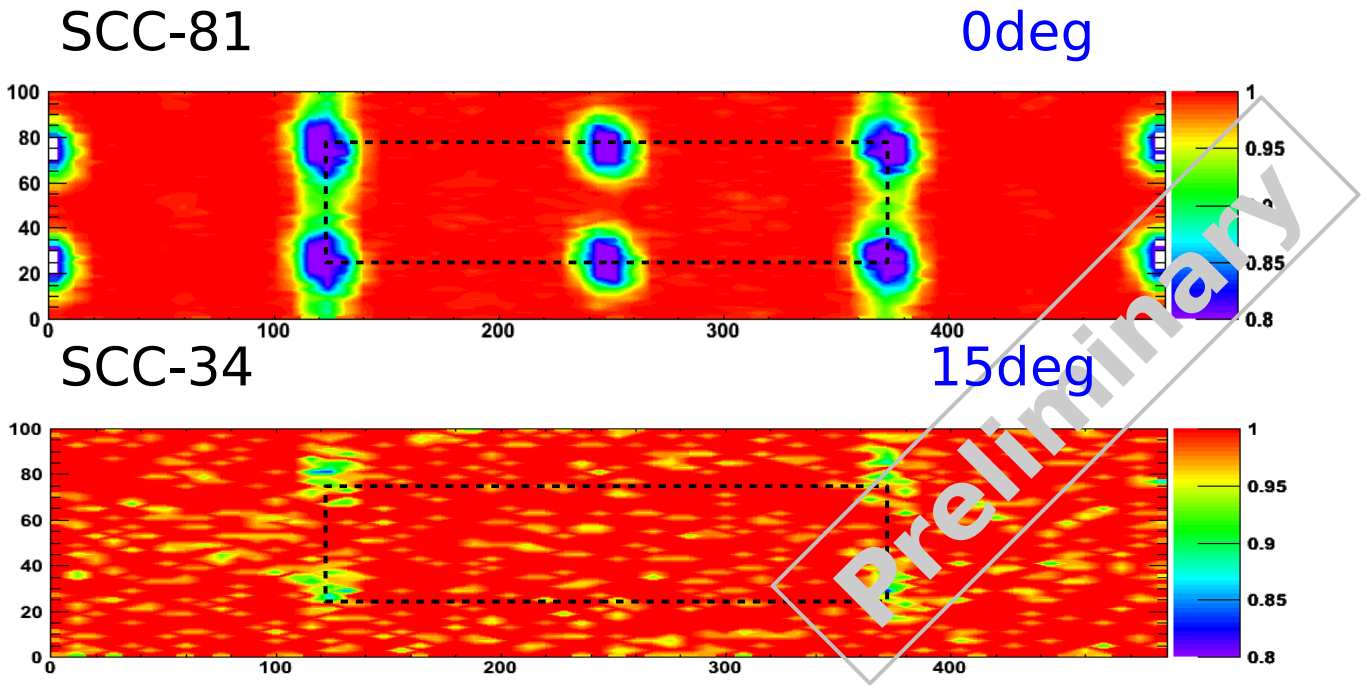
Matched Cluster ToT spectrum for different HV





- Improving charge collection with increasing Bias Voltage.
- Noise increases after 160V significantly. (see Ali Harb talk)
- Optimal voltage for SCC-34 5E15neq/cm^2 irradiated devices ~ 160V

Efficiency Pixel Maps for CNM 3D FE-I4 devices (Sep. TB)

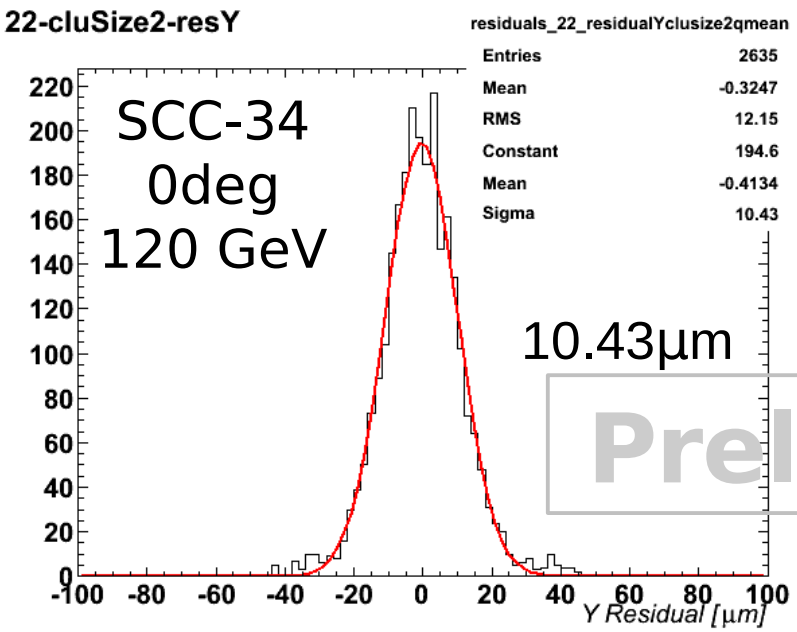


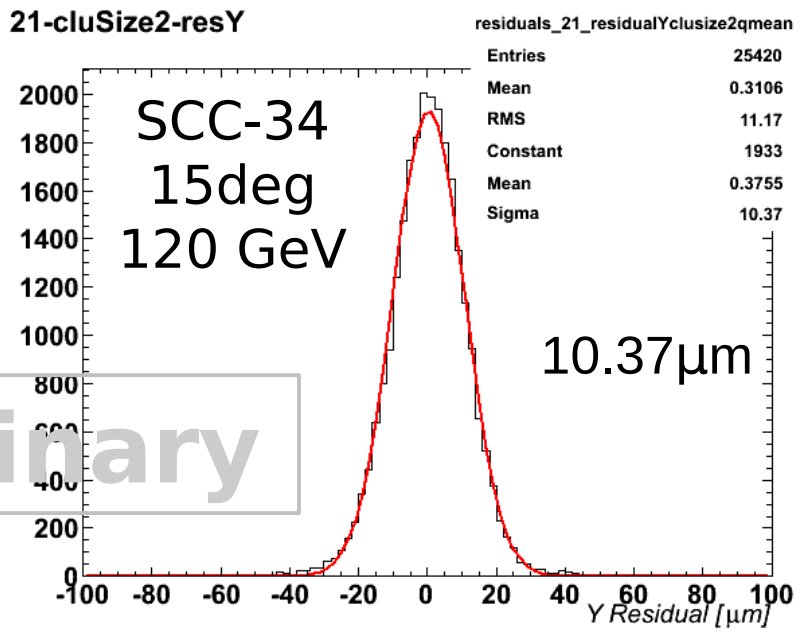
- SCC-81, 0deg, HV = 160V, Threshold = 1500e: Eff = 97.46%;
- SCC-34, 15deg, HV = 160V, Threshold = 1500e: Eff = 98.95%;

- Conclusions:
  - Electrode columns are “on/off” depending on angle, HV and Threshold.
  - CNM 3D FE-I4 devices perform according to IBL requirements in terms of efficiency: Efficiency > 97% for irradiated devices to $5 \cdot 10^{15}$neq/cm^2.

Position Residuals for CNM 3D FE-I4 devices

$$Residual.Y = Track.Y - ClusterCenter.Y$$





- Position resolution estimated from residual distribution in 2-cluster hits include ~4um telescope resolution.

- Position resolution for 0 and 15 degrees are the same

Conclusions

- With operative voltage = 160V and Threshold = 1500e CNM 3D FE-I4 devices satisfy IBL requirements in terms of efficiency:
  - Efficiency > 97% (for irradiated devices to 5E15neq/cm2)

- More studies underway

Thank you for your attention!