



Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

# Small pitch pixel detector for the CMS phase II upgrade

## Intern: Irene Zoi Supervisor: Gino Bolla, Lorenzo Uplegger Final Reports

22 September 2015

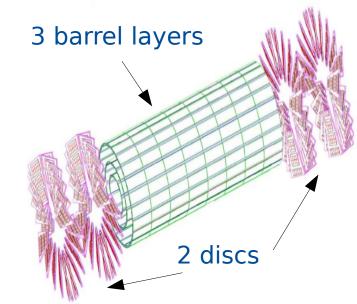


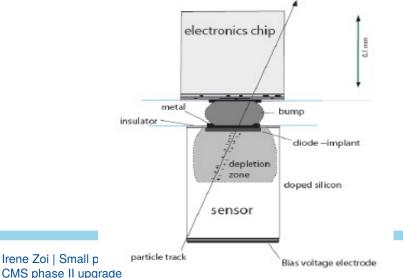
## **CMS Silicon Pixel Detector**

- It is the innermost and most precise part of the CMS tracking system.
- 1 barrel detector module is composed of 16 Read Out Chips (ROCs).
- 1 ROC has 4160 pixels.

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 Pixels of standard dimension (100x150 µm<sup>2)</sup> are arranged in 52 columns and 80 rows



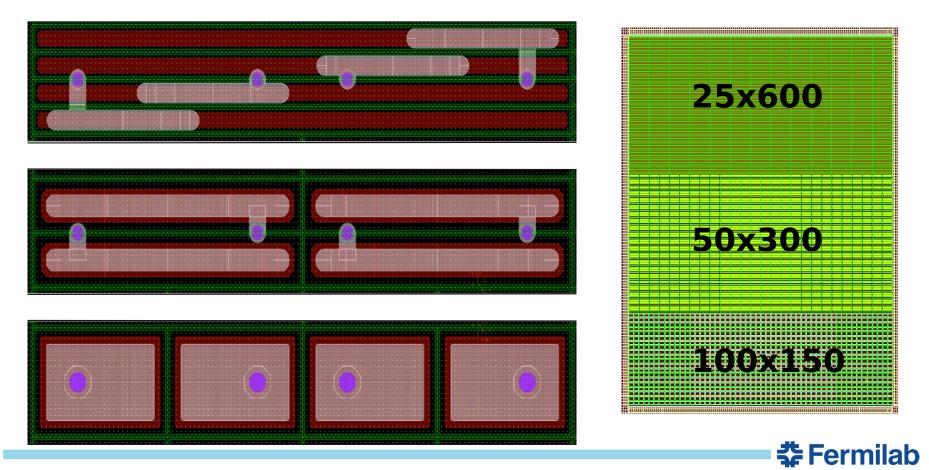


• Each pixel is bump bonded to the ROC



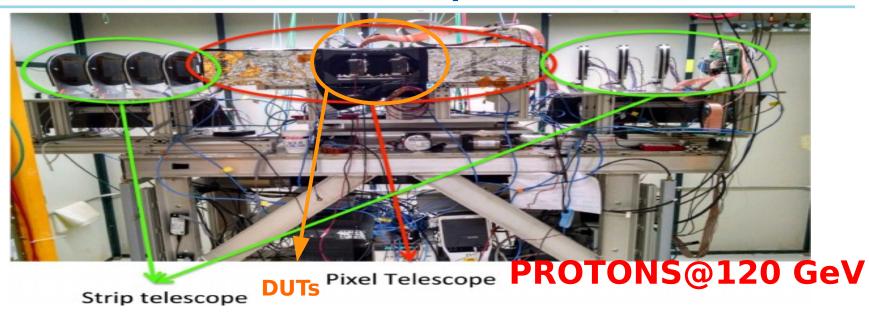
## **Small Pitch Prototype Design**

- Maintained the same pixel area  $100 \times 150 \mu m^2$  that is implemented in the Phase-I design
- Single ROC sensors split in 3 regions with 3 different pitches



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## June Test beam and data acquisition



- Hits in the pixel detectors are grouped together according to the trigger number.
- The data acquired are first analyzed by a tracking program (Monicelli) that aligns the detectors and reconstructs tracks.

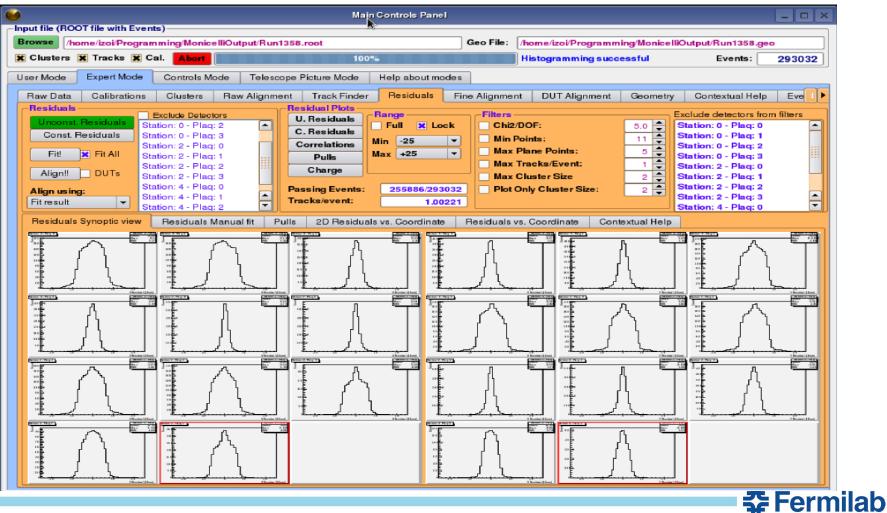
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 Then another program (Chewie) is used to analyze the reconstructed tracks.

## Monicelli

My first task was to complete the alignement of the DUTs in order to reconstruct the tracks.



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## Chewie

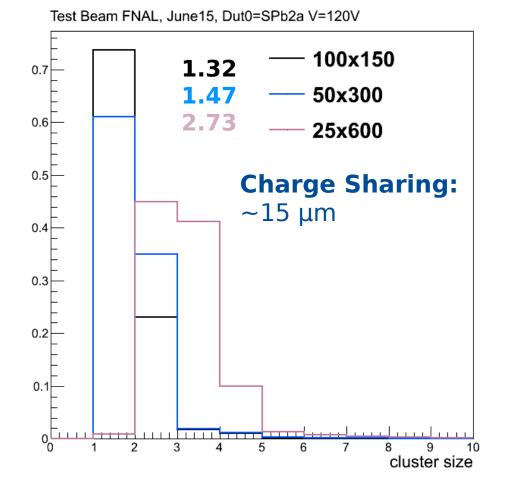
My second task is to modify the Chewie code in order to analyze the data obtained from the three different zones of the DUTs. I worked on the measurement of the collected charge and the resolution.

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## **Cluster size**

## **Cluster:** collection of adjacent pixels with signal.

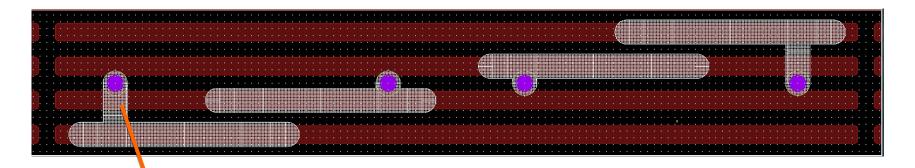


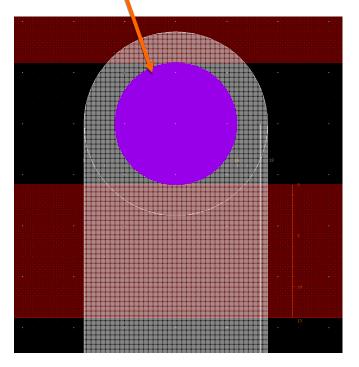
#### Cluster size increases as pixel pitch decreases.

- 100 and 50 µm pitch pixel behave according to expectations.
- For the **25 μm** pitch:
- No more single pixel clusters.
- Several (10%) clusters of size4
- maybe it is a consequence of the capacitors.



## 25x600, closer look at the bonding





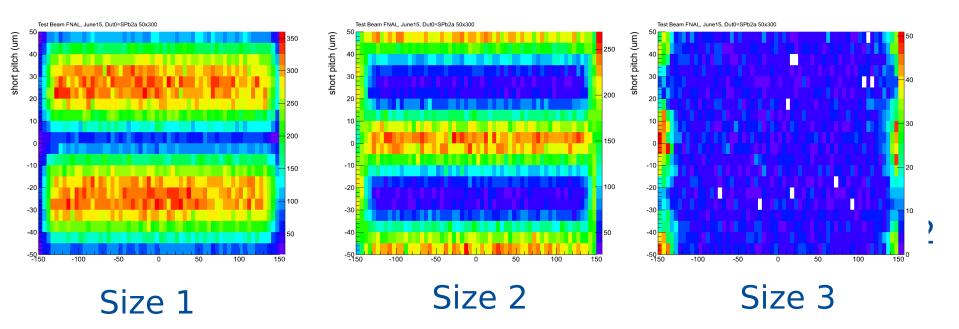
18  $\mu$ m x 13  $\mu$ m capacitance with a SiO<sub>2</sub> thickness of 900 Å results on ~85 fF.

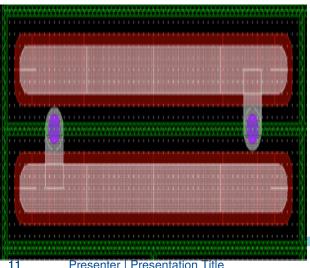
This capacitor can contribute to:
capacitive load for the preamplifier
spurious charge sharing between adjacent pixels



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## 50x300 – Number of Clusters





•Size 1: track is pointing at the center of the pixel.

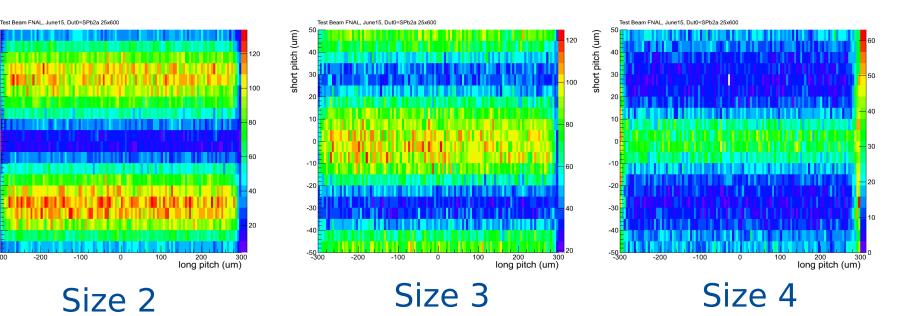
•Size 2: edge between two adjacent pixels.

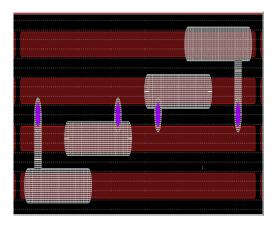
Pixels behave in the same way.



Presenter | Presentation Title

## 25x600 – Number of Clusters





Size 2: track is pointing to the top and bottom regions of the 4 cells.
Size 3: center of the region of the 4 cells structure.
Size 4: edge between the second and this

•Size 4: edge between the second and third row.

Pixels behave in different ways.

short pitch (um)

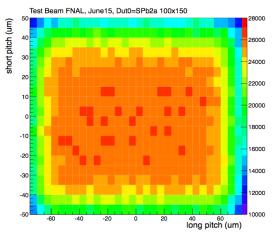
40 30

-30

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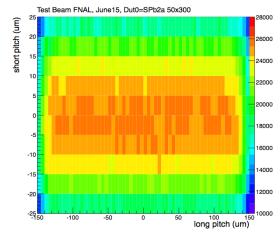
## **Pixel and Cluster Charge Map**

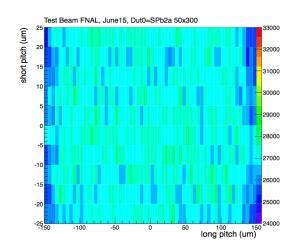
## **100x150**



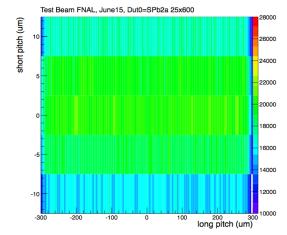
Test Beam FNAL, June15, Dut0=SPb2a 100x150 33000 short pitch (um) 40 32000 30 31000 20 30000 29000 28000 -10 27000 -20 26000 -30 25000 24000 -60 -40 -20 0 20 long pitch (um)

50x300

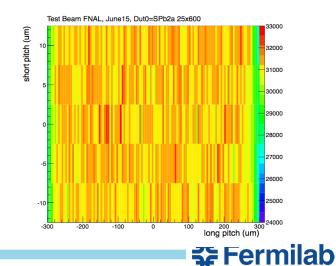




#### **25x600**

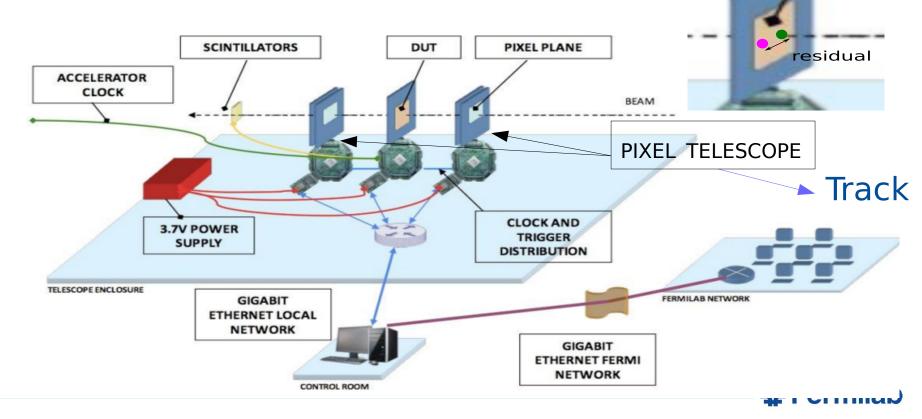


#### Always Charge Sharing



## **Spatial Resolution**

Spatial resolution is calculated using the **residuals**.
A residual is the difference between the measured impact point and the predicted impact point from the track reconstruction.



## **Spatial Resolution**

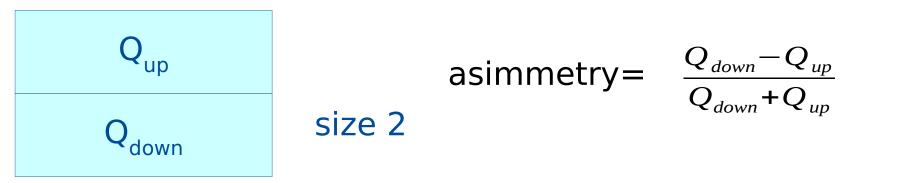
•We calculate the measured impact point with two different algorithm:

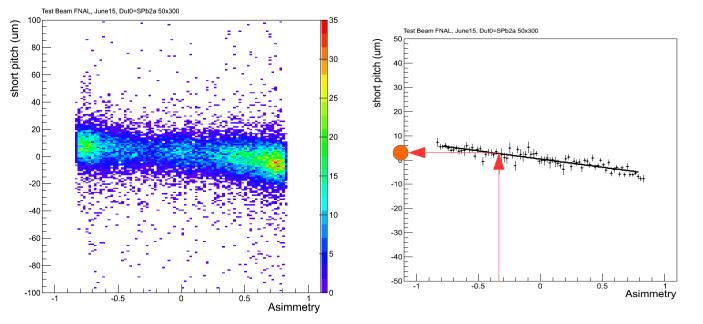
## Center of mass Asimmetry fit

•The resolution is quantified using the sigma of a gaussian fit on the residuals distribution. In both cases we applied cuts on the collected charge and on the quality of the tracks.



## Asimmetry

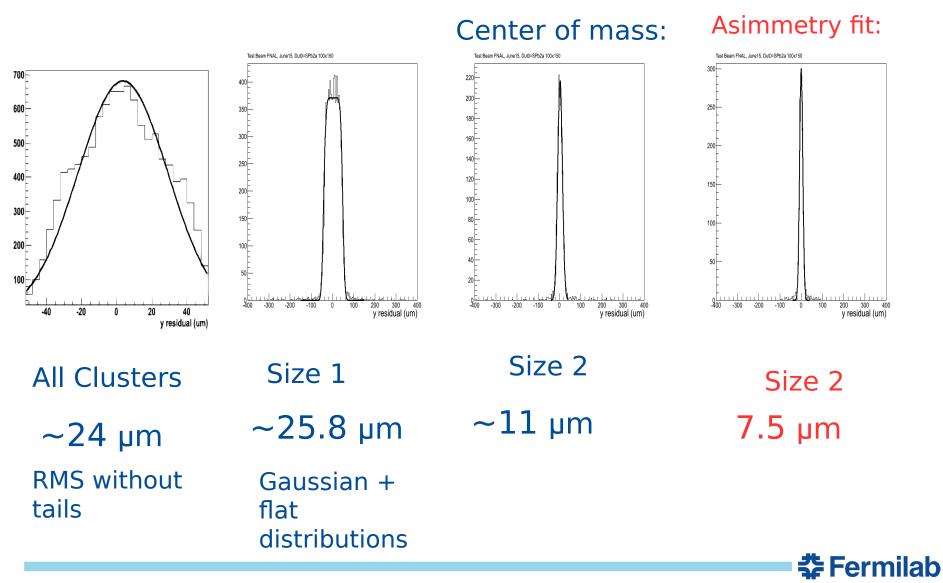




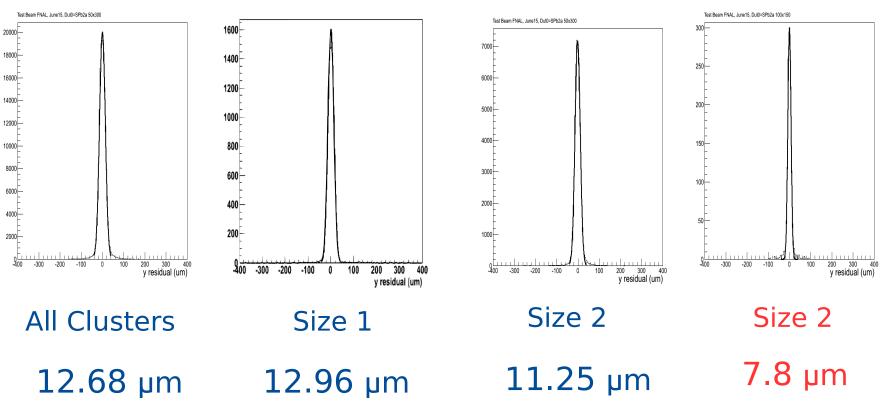
Linear fit on asimmetry to evaluate the measured impact point.



## **Resolution 100x150**



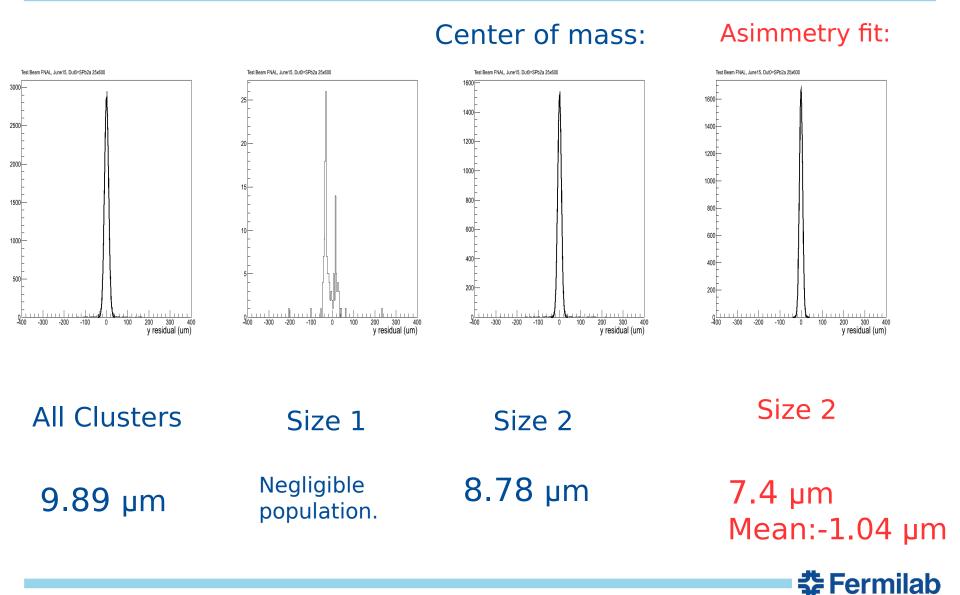
## **Resolution 50x300**



#### Center of mass: Asimmetry fit:

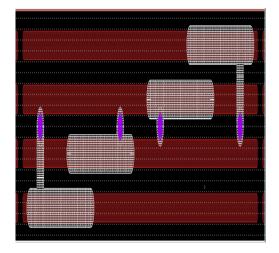


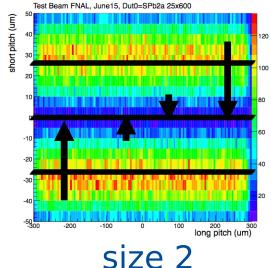
## **Resolution 25x600**

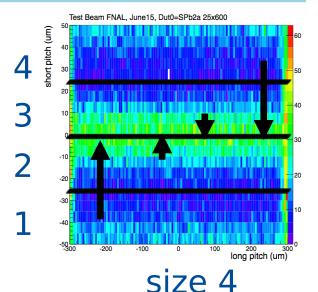


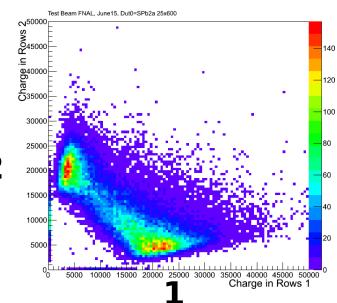
#### 20

## 25x600







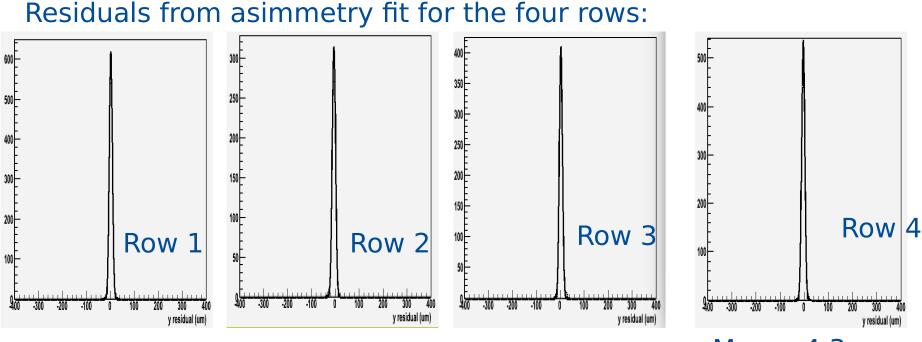


Missing highest charge in row 2: Cluster of size 4

We are trying to estimate in a quantitative way the correlation between the charge in this two rows.



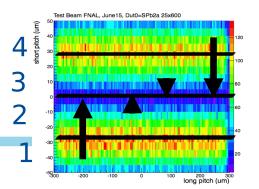
## **Resolution 25x600, Size 2**



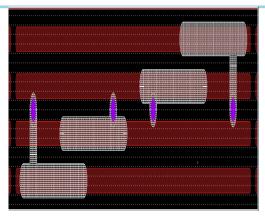
Mean:1.9µm Sigma:6.4µm Mean:-5.9µm Sigma:6.9µm Mean:2.8µm Sigma:6.4µm Mean:-4.3µm Sigma:6.6µm

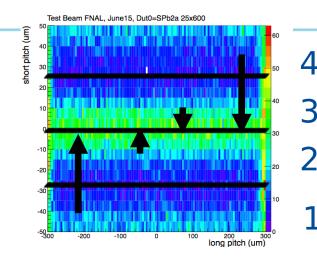
•The gaussian distribution for the residuals of size 2, calculated from the asimmetry fit, is the sum of these 4 gaussians.

•Gaussians are not centered in zero because of the asimmetric behavior of the pixel 1(4) and 2(3).



### **25x600**





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€4000

Charge 0028200

30000

25000

20000

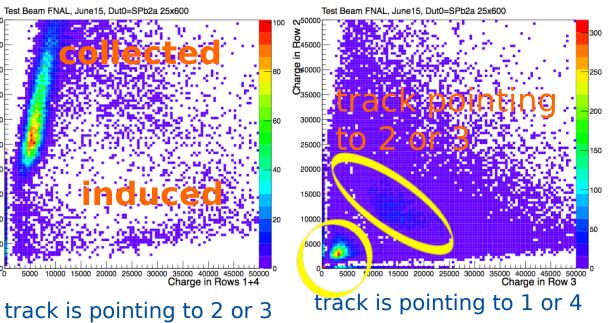
15000

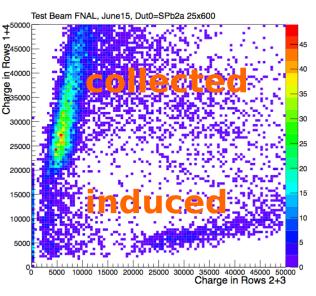
10000 5000

10000

## **Clusters** of size 4

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track is pointing to 1 or 4

## **Conclusions and plans**

- •The devices are fully efficient independently of the pitch.
- •Cluster size varies with the pitch as expected, except for 25x600.
- •We are working to understand the impact of the extra capacitance.
- •We are working on the corrections to be applied.
- •Calculate the telescope resolutions.
- •Calculate the errors on the resolution.

After this experience I've learned more about the use of ROOT.
I studied pixel detector and I have a better understanding on the track reconstruction.

I learned how to analyze data on a prototype.



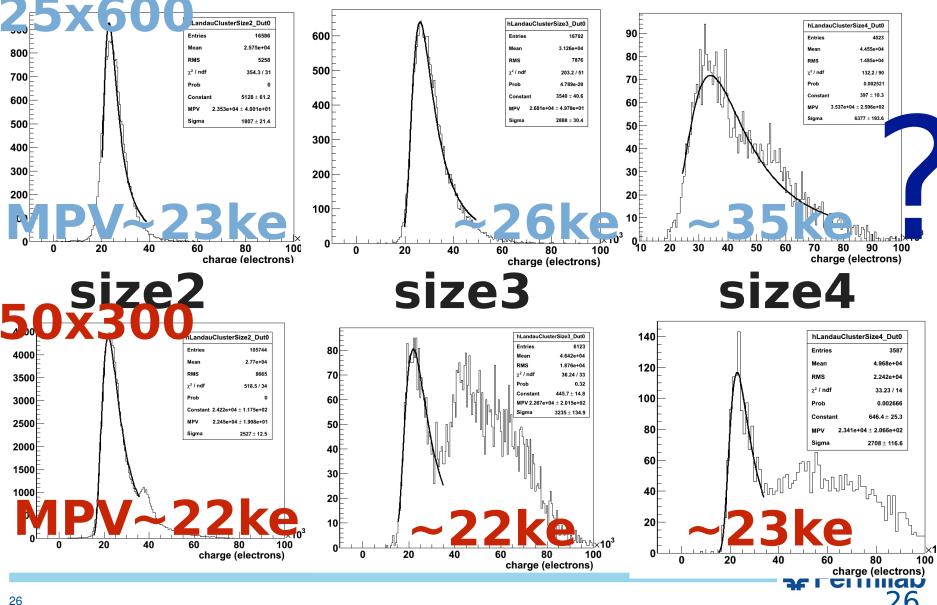


## Thank you



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## **Cluster charge distributions**



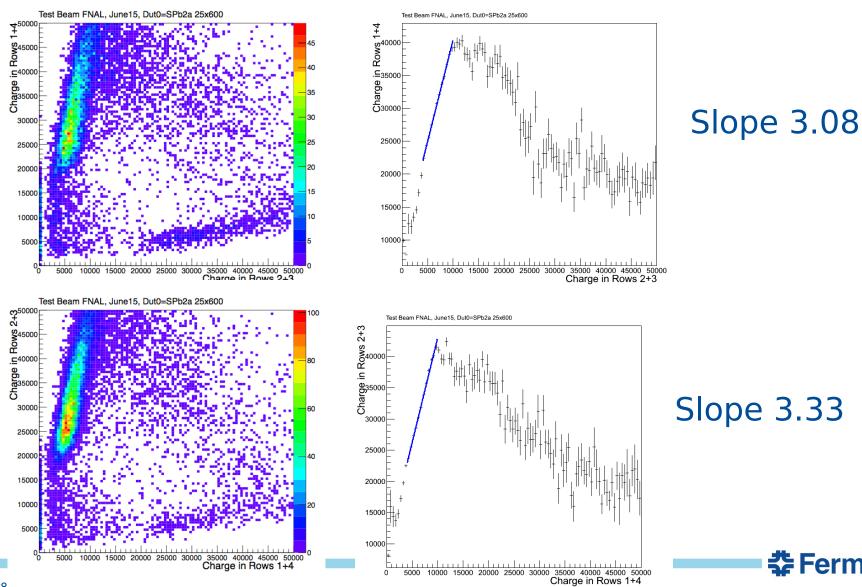


## Thank you



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### 25x600



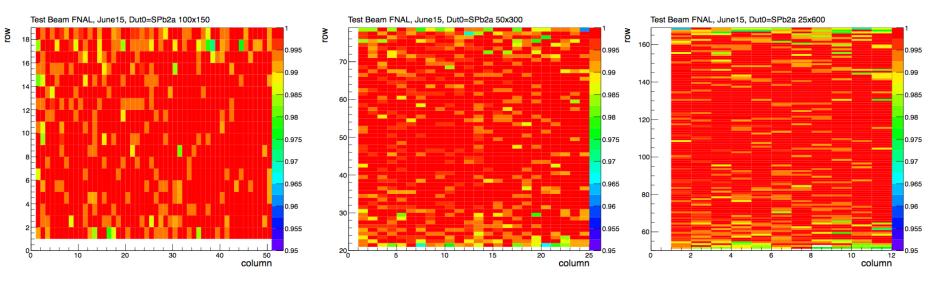
## Efficiency

•Efficiency is computed excluding first and last row/column.

## **100x150**

**50x300** 

## **25x600**



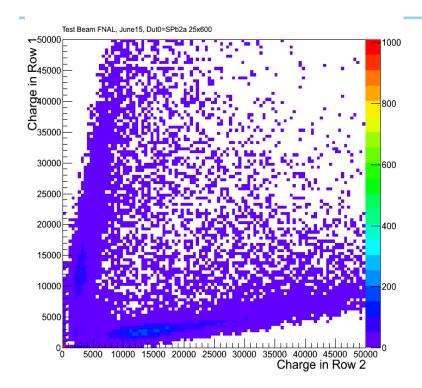
99.75 %

99.72 %

99.58 %

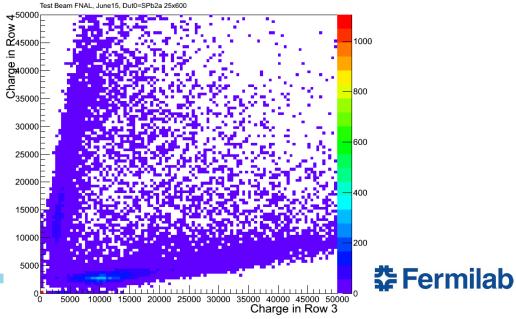




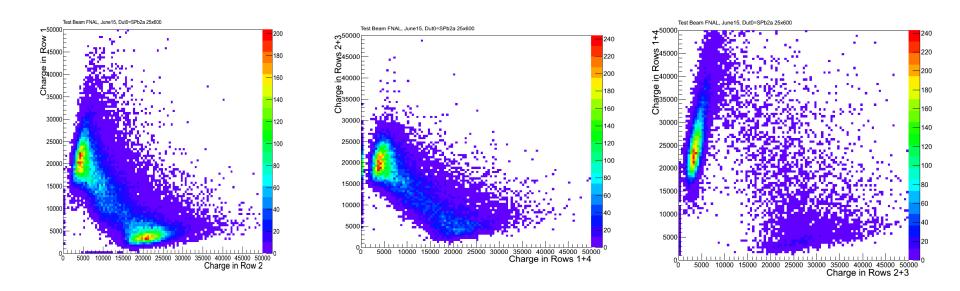


Size 4

Test Beam FNAL, June15, Dut0=SPb2a 25x600 ∼<sup>50000</sup> distant of the second 15000 20000 25000 30000 35000 40000 45000 50000 Charge in Row 3 

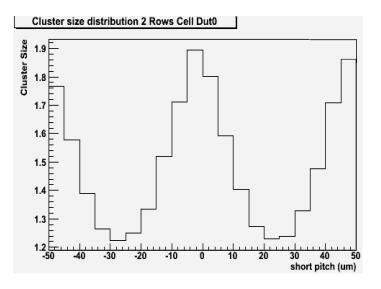


#### Size2

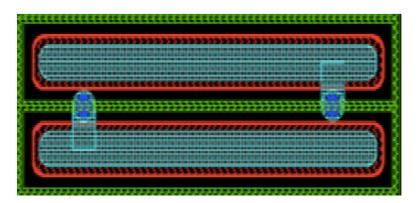


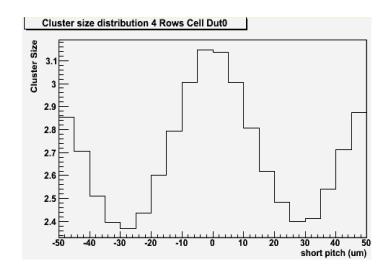


#### Summary

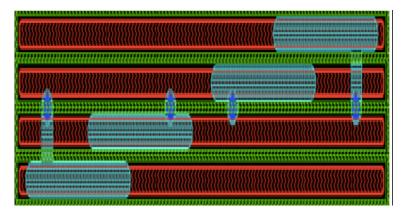


50x300





25x600





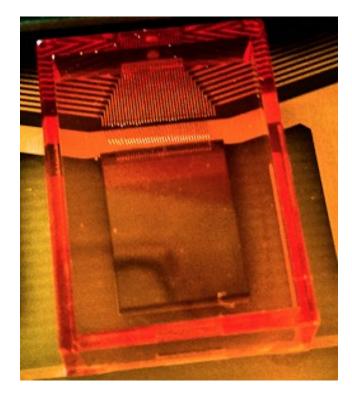
## **Future Plans**

- Keep working on the analysis of the Small Pitch Sensors to have a better understanding of their behavior.
- In particular, I'll focus my studies on the charge and the resolution.

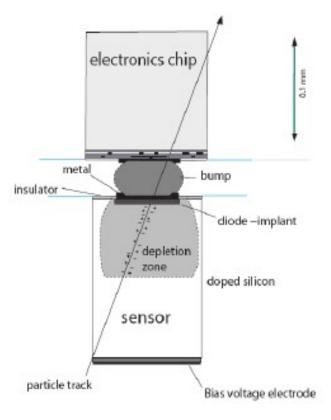


## **CMS Pixel Detector Design**

- 1 ROC has 4160 pixels
- Pixels of 100x150 µm<sup>2</sup> are disposed in 52 columns and 80 rows

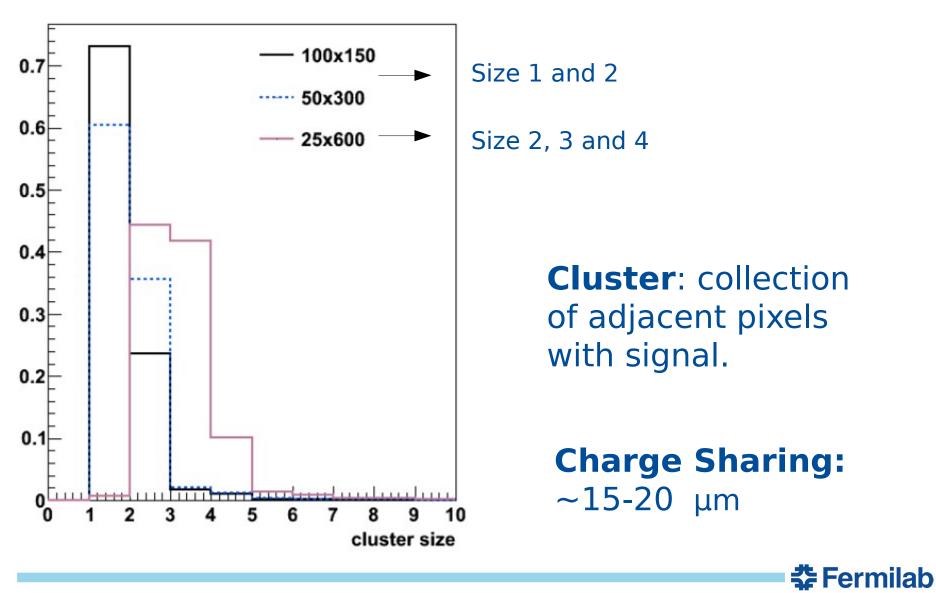


• Each pixel is bump bonded to the ROC





## **Cluster Size**



09/22/15