The CMS Pixel Detector

Study of the CMS pixel detector in the DESY Testbeam using a beam telescope

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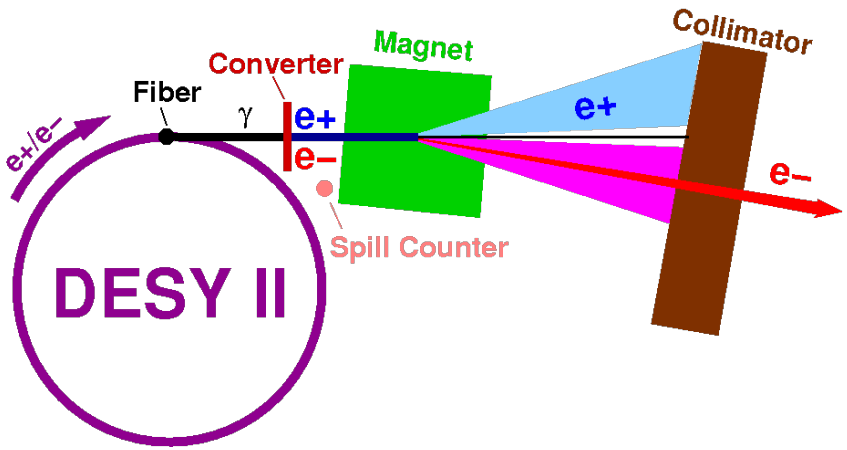
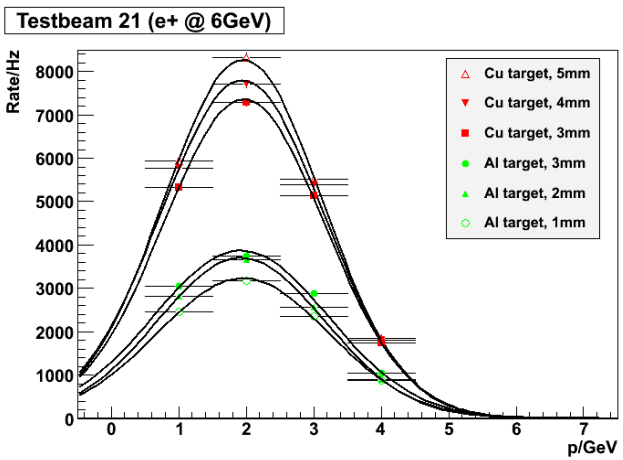
Outline

The DESY-II Testbeam

$e^{\pm} \rightarrow$ bremsstrahlung $\gamma \rightarrow e^{+}e^{-}$ pairs $\rightarrow$ magnet $\rightarrow$ collimator $\rightarrow$ the Testbeam.

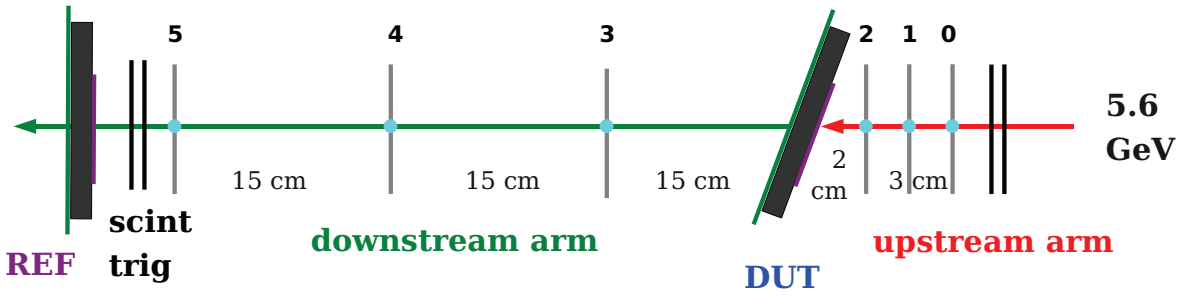


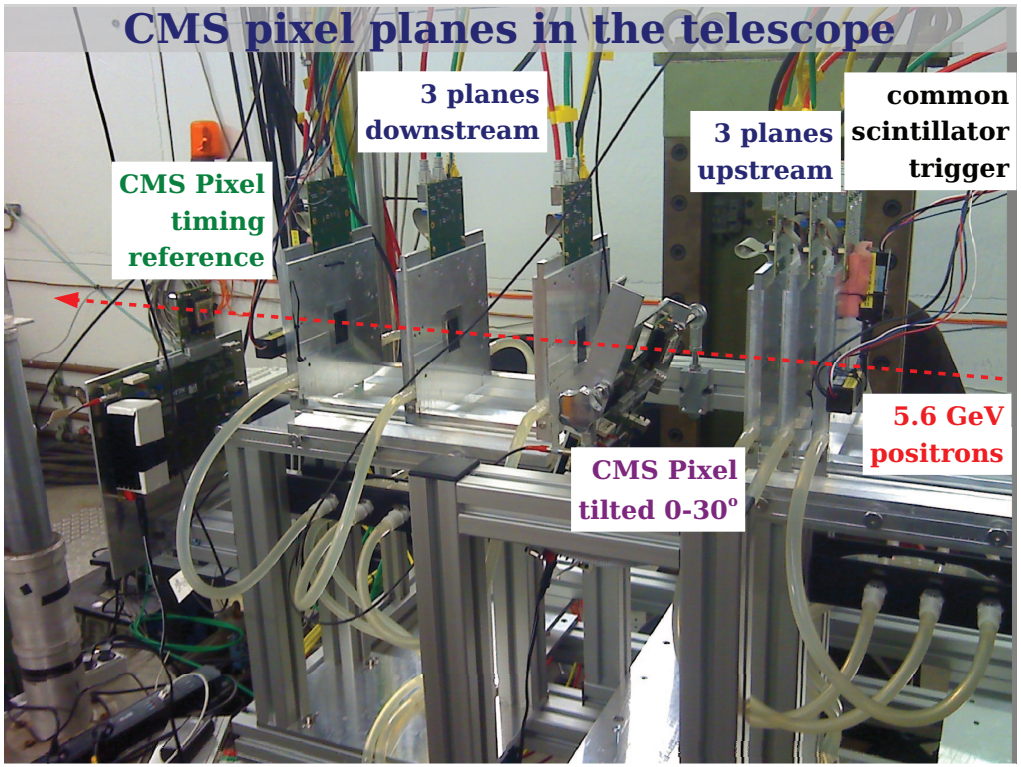


- electrons and positrons with 1-6 GeV
- rate in range of kHz

← The rate of particles as function of the energy at testbeam 21 for different converter target.

The experimental setup





Testbeam + telescope → particle tracks + timing information

Pixel Modules

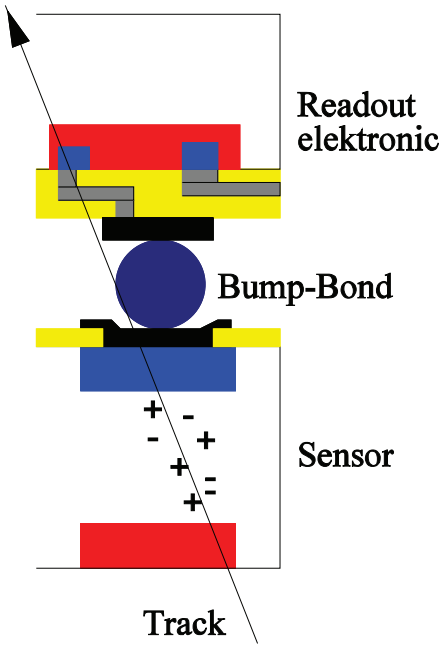
Motivation:

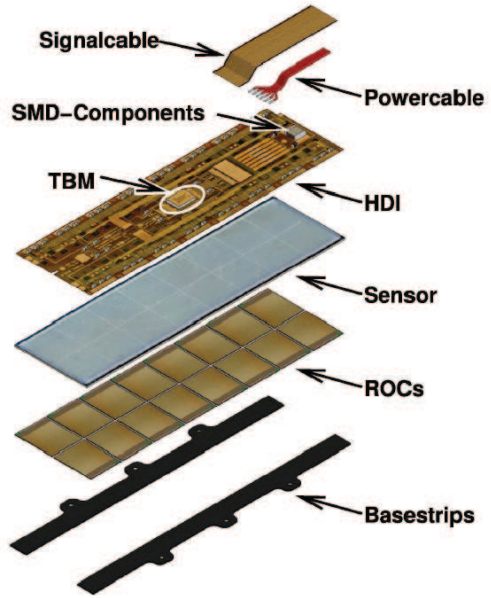
1. innermost tracker in CMS will be upgraded
2. intermediate development prototypes need testing

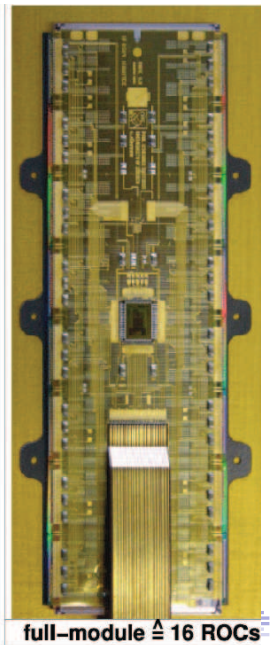
A single Si-CMS pixel detector consists of:

1. sensors layer ($52 \cdot 80 = 4\,160$ pixels, each $150 \times 100\,\mu\text{m}^2$)
2. read-out chip, bump bonded to sensor.
3. infrastructure

total thickness: $(285\,\mu\text{m} + 175\,\mu\text{m})$

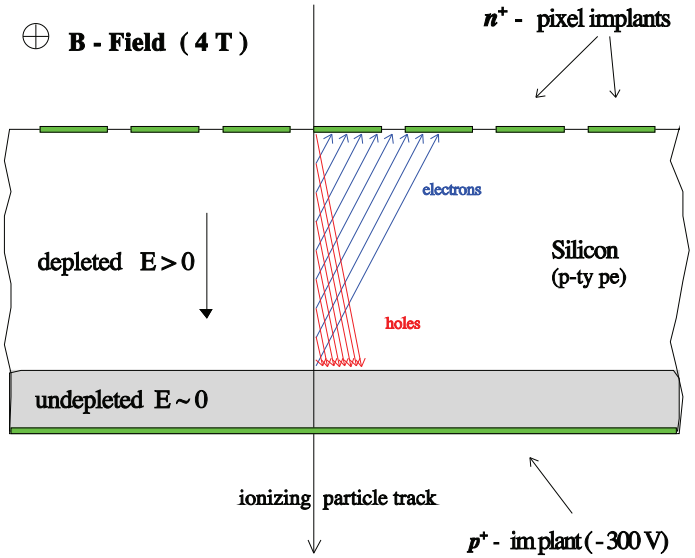






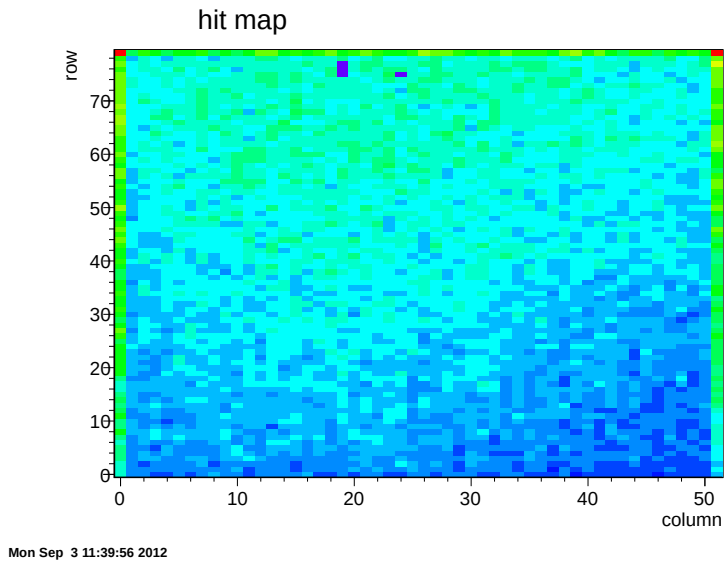
How does a pixel sensor work. Underlying physics

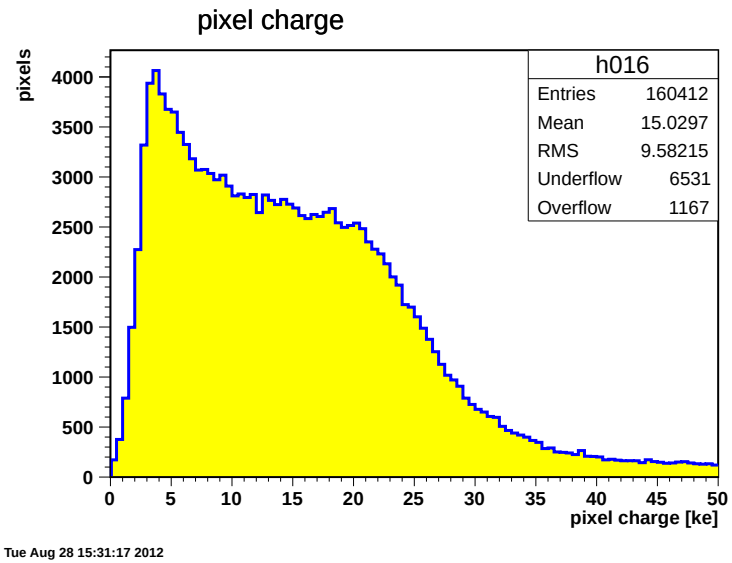
1. Electrons and holes are generated by an ionizing particle passing through the pixel sensor.
2. Electric field $\rightarrow$ drift in silicon.
3. Diffusion area $\sim 100\,\mu\mathrm{m}^2$
4. The charge can be split between pixels.
5. In CMS: Lorentz angle is 19° in 3.8 T B-field.



Pixels

- One run is $\approx 10^5$ events.
- 52 columns $\times$80 rows $=$ 4160 pixels.

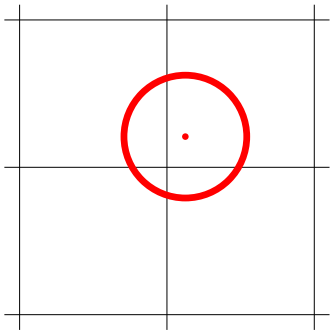


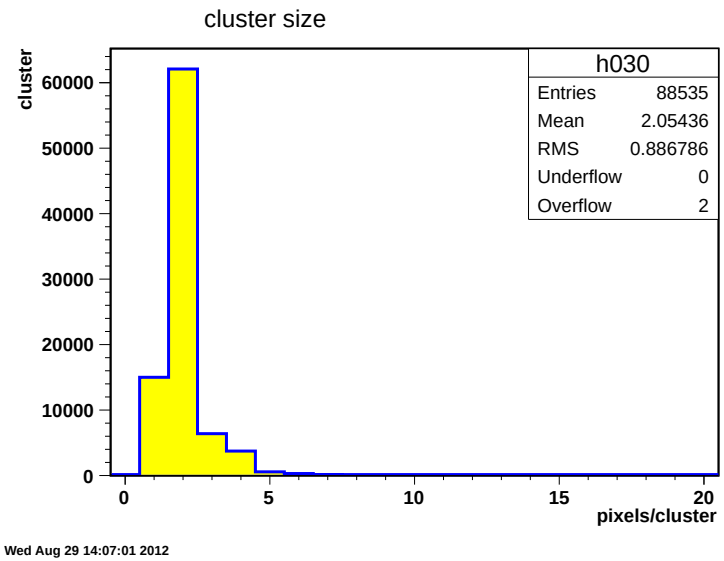


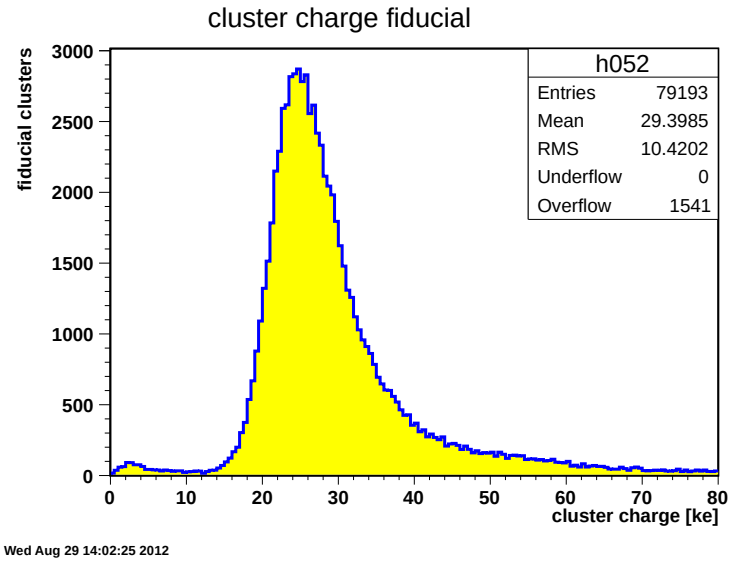
- The beam profile can be seen in the hit map.
- The pixel charge histogram shape shows:
  - Threshold $\approx$ 4 keV.
  - The bump is result of direct hit.
  - The long tail of the Landau distribution.

Clusters

- A cluster is a group of neighboring pixels which have non-zero charge.
- The cluster charge distribution has a Landau shape. $\leftarrow$ Our $e^{\pm}$ are Minimal Ionizing Particles.



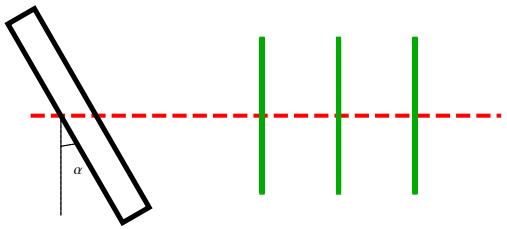




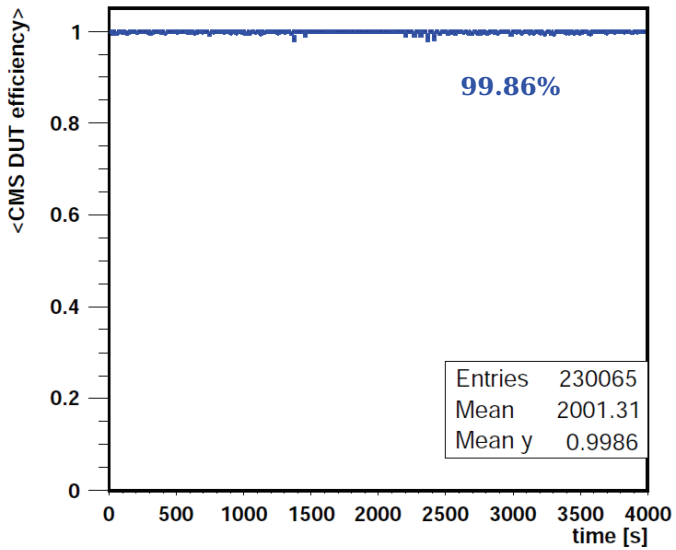
Resolution and efficiency

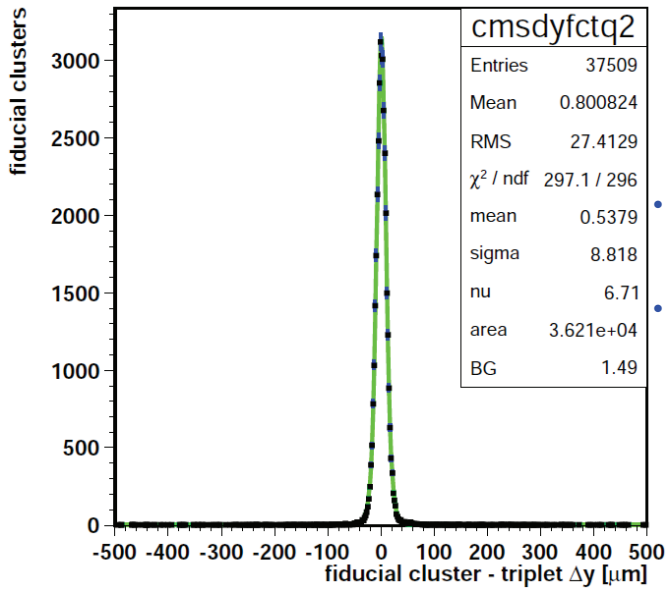
- Efficiency definition:

$$\varepsilon = \frac{N_{CMS}}{N_{telescope}},$$



- Resolution: distance between expected hit and measured one.





The pixel resolution is 7 μm. The pixel size is $100 \times 150\,\mu\text{m}^2$.

Angle dependency measurements

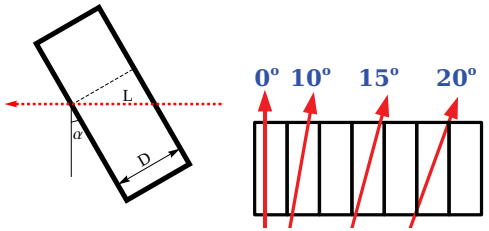
In CMS the Lorentz angle is decreasing with radiation damage. $\rightarrow$ test in setup.
Expected behavior of CC as function of angle:

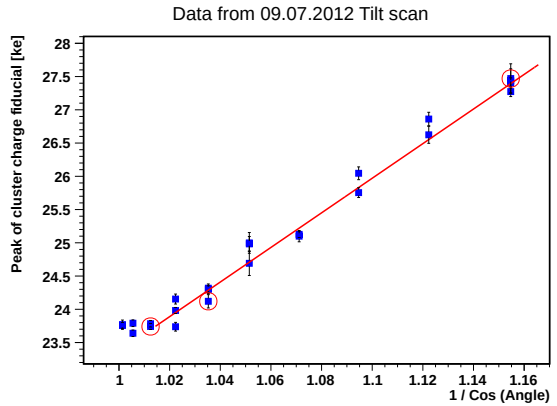
$$L(\alpha) = D \times \frac{1}{\cos\alpha}$$

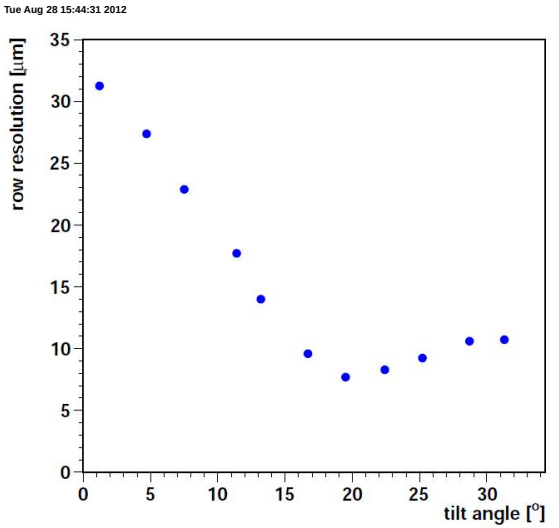
Optimal angle: highest resolution, because of best sharing of the diffusion area between pixels.

$$\alpha_{opt} = \arctan\frac{100\mu m}{285\mu m} = 19.3^{\circ}$$

The α_{opt} corresponds to an average cluster size equaled 2.







Conclusion

Testbeam enables studies of sensors with particle tracks
Extensive measurements performed:

- angle dependancy of sensor properties
- Also (not shown):
  - threshold dependency studies.
  - bias voltage scans (required voltage is approx. 100 V).
  - extensive timing studies to ensure synchronization between DESY-II accelerator and our setup.

Theoretical expectations were derived and confirmed.

For more details please read my report!

Acknowledgment

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THANK YOU