

Test-beam analysis for ATLAS modules at different beam incident angles

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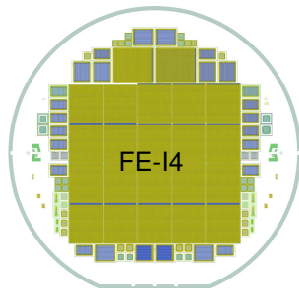
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München

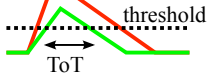
EUTelescope Workshop
26th March 2013

The Detector Under Test (DUT)

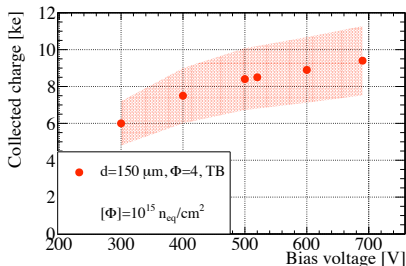
- ▶ N-in-p planar pixel sensor 150 μm thick
- ▶ designed and produced by MPP/HLL
 - ▶ 6 inches wafers with ATLAS FE-I4 chips ($250 \times 50 \mu\text{m}^2$ cells)
 - ▶ interconnected with bump-bonding at IZM
- ▶ irradiated in Los Alamos to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$



- ▶ Data reconstruction performed with the EUTelescope software
- ▶ TBmon analysis
- ▶ Threshold 1.6 ke

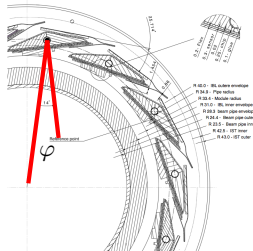
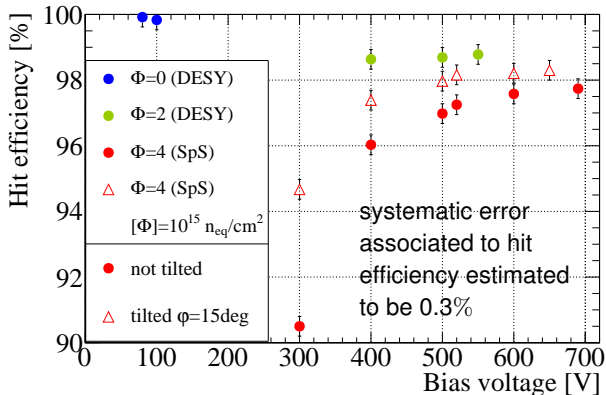
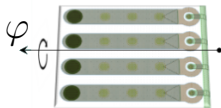


— high charge
— low charge



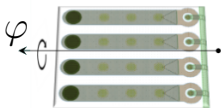
Hit efficiency

- ▶ Test-beam measurement with the EUDET telescope
 - ▶ at SpS, CERN with 120 GeV pions
 - ▶ at DESY, Hamburg with 4-6 GeV electrons

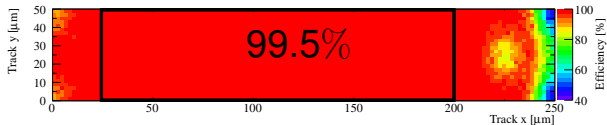


Pixel cell efficiency

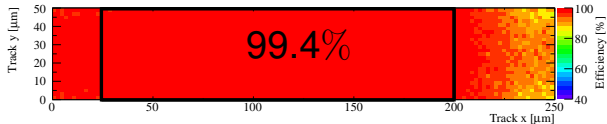
- ▶ **FE-I4 150 μm thick, irradiated at $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
 - ▶ test-beam at SpS, CERN with 120 GeV pions
 - ▶ threshold 1.6 ke (MPV ~ 9.5 ke)



- ▶ **97.7% hit efficiency at \perp incidence (690 V)**

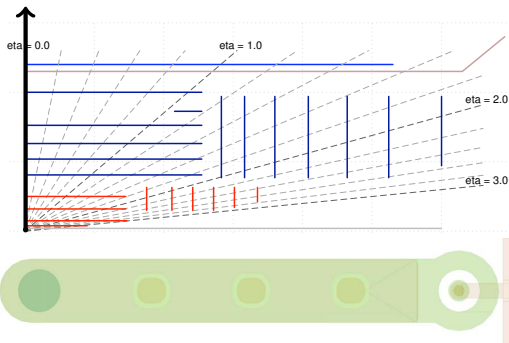
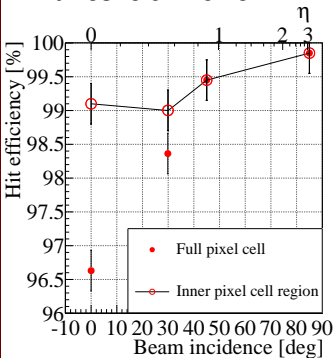


- ▶ **98.2% hit efficiency at $\varphi=15^\circ$ (650 V)**

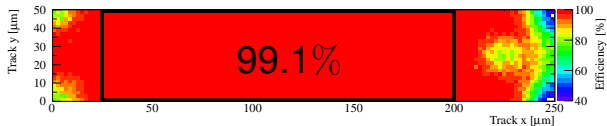


Hit efficiency at different η incidence

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ **threshold: 1.6 ke**

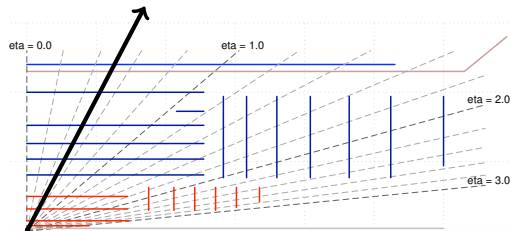
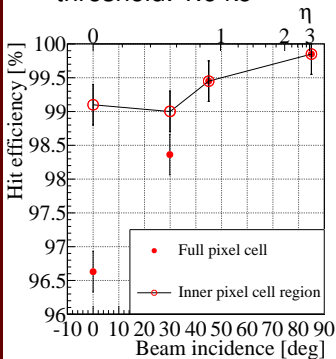


- ▶ **96.6% hit efficiency at \perp incidence (500 V)**

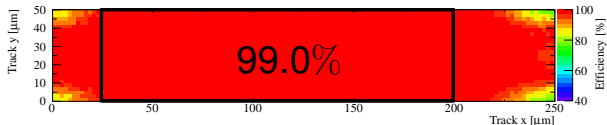


Hit efficiency at different η incidence

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} n_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ **threshold: 1.6 ke**

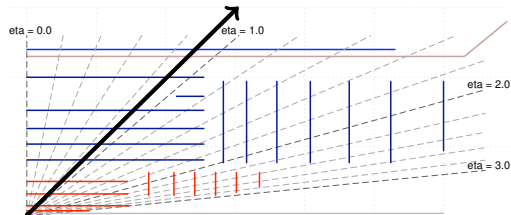
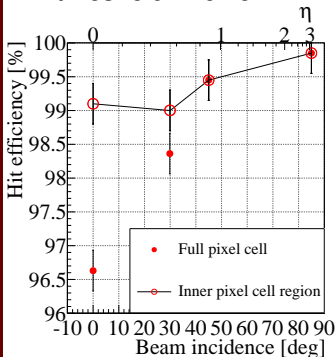


- ▶ **98.4% hit efficiency at $\vartheta=30^\circ$ ($\eta \sim 0.55$) (500 V)**

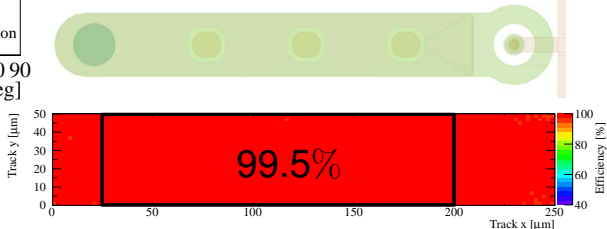


Hit efficiency at different η incidence

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ **threshold: 1.6 ke**

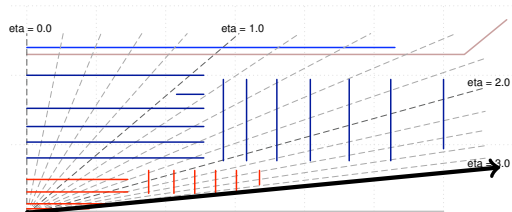
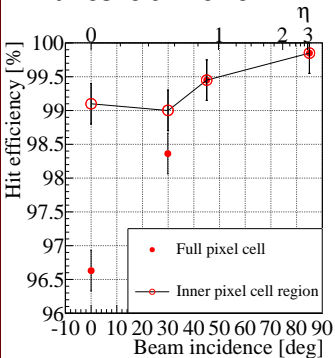


- ▶ **99.5% hit efficiency at $\vartheta=45^\circ$ ($\eta \sim 0.88$) (500 V)**

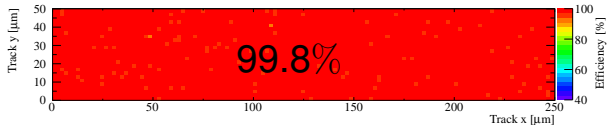


Hit efficiency at different η incidence

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ **threshold: 1.6 ke**



- ▶ **99.8% hit efficiency at $\vartheta=85^\circ$ ($\eta \sim 3.1$) (500 V)**

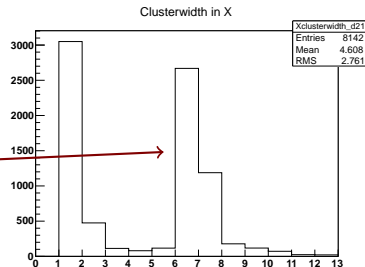


EUTelescope settings for high-eta analysis

► EUTelescope alignment:

- run by run: 50'000 triggers (2/4 minutes per run)
- long cluster selection on the high-eta DUT (software change non yet in svn)
- only tracks with hits on all planes (6 telescope planes and 2 DUTs)

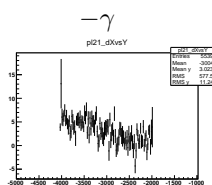
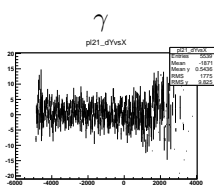
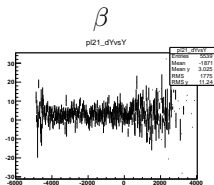
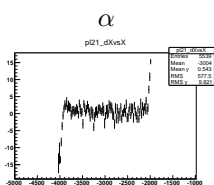
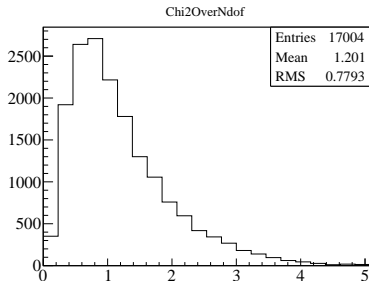
more than 1000 tracks selected for the alignment for each run



Cluster distribution along the tilted direction before tracking

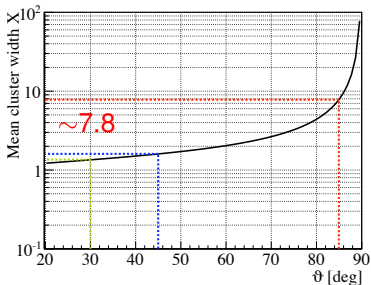
EUTelescope results

- ▶ **Final tracking:**
 - ▶ no additional cluster pre-selection
 - ▶ $\sim 36\%$ of the reconstructed tracks have a matched cluster on the DUT after the alignment

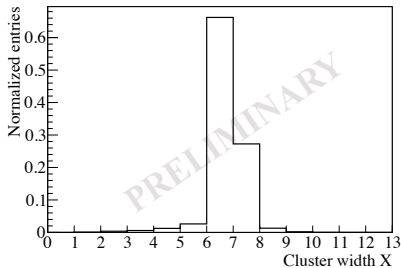


Cluster analysis after tracking

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ $\varphi=0^\circ$, $\vartheta=85^\circ$ track incidence ($\eta \sim 3.1$)
- ▶ bias voltage: 500 V
- ▶ threshold: 1.6 ke



Mean cluster width expected along the tilted direction for different incident angles

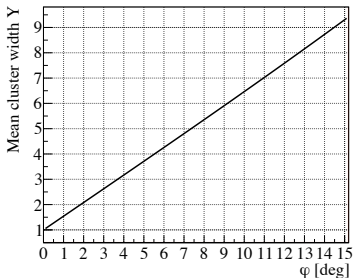


Cluster distribution along the tilted direction.

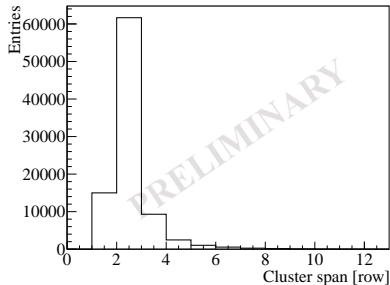
Arithmetic mean = 6.2

Cluster analysis after tracking

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ $\varphi \sim 1^\circ/2^\circ$ (alignment output), $\vartheta=85^\circ$ track incidence
- ▶ bias voltage: 500 V
- ▶ threshold: 1.6 ke



Mean cluster width expected along the not tilted direction for different incident angles

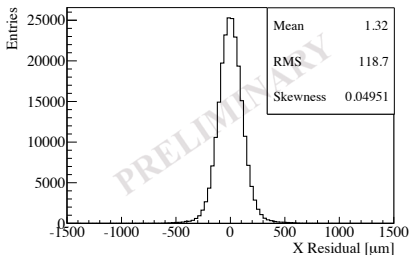


Cluster distribution along the not tilted direction.

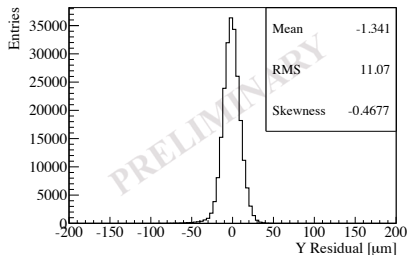
Arithmetic mean = 2.1

Residuals after tracking

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ $\varphi \sim 1^\circ/2^\circ$ (alignment output), $\vartheta=85^\circ$ track incidence ($\eta \sim 3.1$)
- ▶ bias voltage: 500 V
- ▶ threshold: 1.6 ke



Residual along the tilted
direction (pitch: 250 μm)



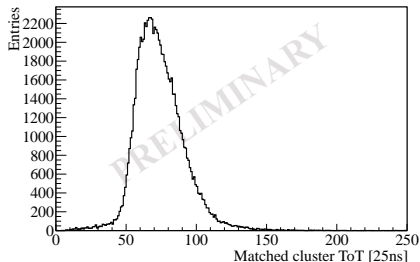
Residual along the not
tilted direction (pitch: 50 μm)

- ▶ cluster reconstructed with the charge weighting algorithm (TBmon)

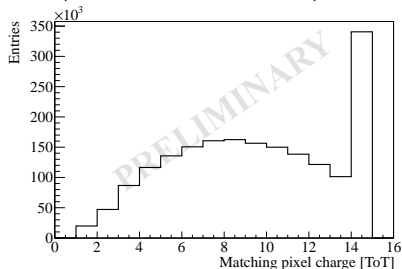
Collected charge

- ▶ **FE-I4 150 μm thick, irradiated to $4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ in Los Alamos**
- ▶ $\vartheta=85^\circ$ track incidence ($\eta \sim 3.1$)

ToT distribution of matched clusters (10 ToT@10 ke)



Single pixel ToT distribution (for all matched clusters)



- ▶ overflow peak in the single pixel ToT distribution due to the calibration (10ToT @10 ke) at the edge of the ToT range (1-14) for a particle crossing 250 μm (15 ke expected)

Conclusions and outlook

Conclusions:

- ▶ good results and smooth reconstruction up to 45° track incidence
- ▶ alignment at high incident angles requires:
 - ▶ a good starting parameters for millepede
 - ▶ selection of the good clusters on the DUT
- ▶ good preliminary results at high incidence considering that the sensor is irradiated and not fully depleted

Outlook:

- ▶ cluster reconstruction of more than 2 hit clusters can be improved considering only hits at the edge of the cluster
- ▶ further analysis and comparison with not irradiated devices for a better understanding of results