Performance of the upgraded CMS pixel detector

Giorgia Rauco on behalf of the CMS Collaboration

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The CMS detector

- one of the two multipurpose experiments located at the Large Hadron Collider
- symmetric cylindrical shape and its central feature is a superconducting solenoid generating a magnetic field of 3.8 T
- inside the solenoid several sub-detectors are installed
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The Pixel detector

- It is the **innermost sub-detector**, closest to the interaction region
- Crucial role in track reconstruction and vertexing, and its high-quality performance is **fundamental for many physics analysis** (e.g. b-tagging)
- Split in Barrel and Forward Pixel
  - 4 layers located at $r = 3, 7, 11, 16$ cm
  - 3 disks local at $z = 29, 40, 52$ cm
- Pixel size of $100 \times 150 \, \mu m^2$
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**Newly installed in during the 2016/17 Technical Stop**
Performances of the upgraded CMS pixel detector

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<table>
<thead>
<tr>
<th>Phase 0</th>
<th>Phase 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-18</td>
<td>2021-23</td>
</tr>
<tr>
<td>$E_{\text{CM}}$ [TeV]</td>
<td>8</td>
</tr>
<tr>
<td>Luminosity [cm$^2$ s$^{-1}$]</td>
<td>$7 \times 10^{33}$</td>
</tr>
<tr>
<td>pile up</td>
<td>~21</td>
</tr>
<tr>
<td>Integrated Luminosity [fb$^{-1}$]</td>
<td>30</td>
</tr>
</tbody>
</table>
From Phase0 to Phase1

- One more barrel layer, one more forward disk
- Innermost barrel layer closer to the interaction point
- Improved readout electronics
- Lower material budget

Sustain huge amount of data taking and improve tracking

Phase 1 (new) detector

Phase 0 (old) detector
Hit Efficiency is the probability to find any clusters within a 1 mm area around an expected hit

- It gives a measure of the pure detector efficiency

- Pixel hit efficiency stays above 99% for all layers and disks except for the first layer of the BPix, where temporary losses are observed

- Big improvement with respect to 2016 data taking!

- Dynamic inefficiency at high instantaneous luminosity reduced
Pixel Charge Profiles

- non-irradiated, fully depleted detector → profile expected to be flat
- irradiated detector → losses expected due to the trapping

During the 2017 Technical Stop an annealing was performed, resulting in the flattening of the pixel charge profile.

At the beginning of 2018, the charge collection was further increased in Layer 1 by raising the bias voltage.

Similar results are expected for the other three layers.
The measurement of the Lorentz angle for the BPix is performed using the **Grazing Angle** technique:

- Uses well measured tracks to determine the drift of the electrons in pixel sensors
- The curve in the range \([80,205] \, \mu m\) is then fitted

Because of the **irradiation of the detector** both at the end of 2017 year and with more integrated luminosity in 2018 the shape of the drift vs depth curve changes and a larger Lorentz angle is obtained

- Much smaller LA compared to 2015 data taking!
The resolution measurement is performed using the **Triplet method**:  
- Tracks with hits in 3 layers are selected and refitted using hits in two out of three layers  
- Trajectory extrapolated to remaining layer, residuals with the actual hit are calculated  
- Residual distribution fitted with a Student-t function  
- **Good agreement between data and simulation** along both direction  
  - Very good results achieved: 12 \( \mu \text{m} \) along \( r-\phi \) and 22 \( \mu \text{m} \) along \( z \)
The same approach used for the BPix resolutions is deployed in the forward region.

- For Disk 2, only hits on the disks are used, reducing the smearing and the inference due to extrapolating the tracks or using the barrel layers.

- Good agreement between simulation and data is obtained.
  - 8 \( \mu \)m along the local-x direction and 16 \( \mu \)m along the local-y.

For both BPix and FPix updated results with 2018 data are work-in-progress.
Conclusions

- **New Pixel Detector successfully installed** during the Technical Stop in 2016/2017
  - Huge effort, allowing high-quality standard for the data-taking in harsher conditions

- Despite challenges, **very good performance** obtained
  - High hit efficiencies in all layers and disks
  - Smaller impact of the irradiation on charge profile and on the Lorentz angle
  - Small residuals and excellent hit resolution
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*Thank you for the attention!*