**Upgrade of ALICE**

The upgrade of ALICE is planned for the 2nd Long Shutdown of the LHC in 2019–2020.

**Motivations for the upgrade:**
- High precision measurements of heavy flavor and charmonia at low $p_T$ and low-mass dileptons
- Record large minimum bias samples → read out all Pb–Pb collisions at an interaction rate of 50 kHz
- Record integrated luminosity of $10^{34}$ nb$^{-1}$ in Pb–Pb (plus pp and p–A data)

**Upgrade of the Inner Tracking System**

**Design objectives:**
- Improve impact parameter resolution by a factor of 3(5) in $\pi$–$\phi(z)$ at $p_T = 500$ MeV/$c$
- Improve tracking efficiency and $p_T$ resolution at low $p_T$
- Fast readout (the present ITS is limited to 1 kHz)
- Fast insertion/removal for yearly maintenance

**Upgrade strategy:**
- First layer will be moved closer to interaction point: 39 mm → 23 mm
- Material budget will be reduced from $\sim 1.14% X_0$ to $0.3% X_0$ for the three innermost layers
- Pixel size will be reduced from $50 \mu m \times 425 \mu m$ to $29 \mu m \times 27 \mu m$
- 7 layers instead of current 6 layers
- All layers pixel chips

**Requirements**

<table>
<thead>
<tr>
<th>Inner barrel</th>
<th>Outer barrel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution</td>
<td>5 $\mu m$</td>
</tr>
<tr>
<td>Detection efficiency</td>
<td>$&gt; 99%$</td>
</tr>
<tr>
<td>Fake hit rate</td>
<td>$&lt; 10^{-5}$ per event per pixel</td>
</tr>
<tr>
<td>TID radiation *</td>
<td>2700 krad</td>
</tr>
<tr>
<td>NIEL radiation *</td>
<td>100 krad</td>
</tr>
</tbody>
</table>

* Including a safety factor of 10

**Technology Choice**

Monolithic Active Pixel Sensors (MAPS) using the TowerJazz 0.18 $\mu m$ CMOS imaging process

**Advantages:**
- High-resistivity ($> 1k\Omega$ cm) epitaxial layer on p-type substrate
- Deep p-well shields n-well of PMOS transistors → full CMOS circuitry within active area
- Moderate reverse substrate biasing is possible

**First Final-Size ALPIDE Prototype**

- pALPIDE-1 is first prototype with final size of 15 mm x 30 mm
- Produced in May 2014
- 512 $\times$ 1024 pixels of $28 \mu m \times 28 \mu m$
- Digital readout with a priority encoder
- Divided into four sectors with different pixel layouts

**Characterization Results**

- Efficiency is well above 99% before and after irradiation with a large operational margin
- Noise occupancy is slightly higher after irradiation, but stays below $10^{-5}$ hits/event/pixel
- Resolution is below 5 $\mu m$ with a large operational margin
- Average cluster size gets slightly smaller after irradiation

**Test Beam Setup**

- Seven layers of pALPIDE-1
- Six outer layers are kept at same settings for tracking
- Chip in the center is used as DUT (Device Under Test)
- Tests at various test beam facilities ranging in momentum from 60 MeV/$c$ to 120 GeV/$c$ (PS, SPS, DESY, BTF, PAL)
- Readout and analysis is done using the EUDAQ/EU Telescope framework [1]

**Status and Conclusions**

- Since the first full-size prototype, two new prototypes have been produced and tested which include the features missing from the pALPIDE-1
- Improved performance with the new prototypes (e.g. orders of magnitude lower noise occupancy) → all prototypes fulfill the upgrade requirements
- Prototypes stay fully functional after irradiation of $1.7 \times 10^{13}$ 1 MeV n$_{eq}$/cm$^2$
- Submission of the final ALPIDE chip is planned within a few weeks

**References**