The ALICE ITS Upgrade

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for ALICE collaboration
A New ALICE Inner Tracking System (ITS) with NEW CMOS MAPS

New Inner Tracking System (ITS)

- Novel **Monolithic Active Pixel Sensors (MAPS) Technology**
- **CMOS Pixels**
  - improved resolution, less material, faster readout

**Current Detector**

6 layers:
- 2 hybrid silicon pixel
- 2 silicon drift
- 2 silicon strip

**Inner-most layer:**
- radial distance: 39 mm
- material: $X/X_0 = 1.14\%$
- pitch: $50 \times 425 \, \mu m^2$
- rate capability: 1 kHz

**Upgraded Detector**

LHC LS2 2019/20

7 layers:
- all Monolithic Active Pixel Sensors

**Inner-most layer:**
- radial distance: 23 mm
- material: $X/X_0 = 0.3\%$
- pitch $O(27 \times 29 \, \mu m^2)$
- rate capability: 100 kHz (Pb-Pb)

$|B| = 0.5 \, T$
Closer to IP, Thinner, Higher Granularity & Faster RO

- Closer to IP: 39 - 430mm ➤ 22 - 400mm
- Thinner (X/X0): ~1.14% ➤ ~0.3% (inner)
- Smaller pixel: 50µm x 425µm ➤ 27µm x 29µm
- Higher Granularity (×10³): 20 Ch/cm³ ➤ 2k Pxl/cm³
- 10 m² active area of 12.5 GPxl with σ ~ 5 µm
- Fast readout: 1 kHz (1kHz) in PbPb (pp) ➤ 100 kHz (400kHz) in PbPb (pp)
- ALice Plixel DEtector (ALPIDE) for other projects as well: MPD@NICA.JINR, sPHENIX@RHIC.BNL and Proton Therapy Tracking etc.

L. Musa (CERN) – ALICE Upgrade Asian Workshop, Hiroshima, June 2018
ALPIIDE (ALIce PIxel DEtector)

- CMOS Pixel Sensor using 0.18µm CMOS Imaging Process
  - High-resistivity (>1kΩ·cm) p-type epitaxial layer (25µm) on p-type substrate
  - Small n-well diode (2µm φ) ~ low capacitance (fF)
  - -6V < V_BB < 0V to increase depletion zone around n-well diode
  - Deep p-well shields n-well of PMOS transistors
- Full CMOS circuitry within active area

- Pixel: 27 x 29 x 25 µm³
- 130 000 pixels/cm² ~ Total 10m², 12.5 G-pixels
- Spatial resolution ~ 5µm in 3D
- Max. particle rate: 100MHz/cm²
- fake-hit rate ~ 10⁻¹⁰ pixel/event
- Power ~ 300 nW/pixel

2 x 2 pixel volume

C_{in} ≈ 5 fF

Q_{in} (MIP) ≈ 1300 e⁻ \Rightarrow V = 40mV

IB: 50µm thick
OB: 100µm thick

0.3 pJ / bit

L. Musa (CERN) – ALICE Upgrade Asian Workshop, Hiroshima, June 2018
ALPIDE Production and Test Flow

1500 raw wafers

Raw Wafer Production

CMOS Manufacturing
TowerJazz (Israel)

Thinning & Dicing
FUREX (South Korea)

Pick & Place
FUREX (South Korea)

1200 CMOS wafers

1% 8% (2/25) 75%

1% 8% (2/25) 75%

Raw Wafer QA
TMEC (Thailand)

Wafer Probe Testing
CERN

Chip Series Testing
Yonsei, Pusan/Inha
(South Korea)

Module Assembly

CERN

• 50-μm chip testing: running
• wafer testing: done

Pusan/Inha

• 100-μm chip testing: done (end-Apr. ’18)
• (switchover to HIC construction)
• Backup site

Yonsei

• 100-μm chip testing: running
• Working schedule: 24/7
• Test rate: 26 wafers/week
• Smooth operation
Detector Barrel Staves (IB)

- 7 layers: 3(IB with 50µm-chips), 4(OB with 100µm-chips)
- 192 staves: 48(IL), 54(ML), 90(OL)

Q.ty to build: 48 (one full IB) + 48 (spare IB) + 12 (spares)

- 54 HICs (10 NOK) ~ yield 80%
- 39 Staves (3 NOK) ~ yield 7%

Fraction of dead pixels < 10^{-4}
( number of dead pixels / chip <50)
Detector Barrel Staves (IB)

First Half-Layer-0

First Inner Half-Barrels

Half-Layer 2 (A-side)

Half-Layer 2 (C-side)
OB-HIC

- 2115 to be produced → 1692 (assuming 80% yield)
- Where: Bari, Liverpool, Pusan/Inha, Strasbourg, Wuhan
- Prod. rate: 2 HICs/day

OB-Stave

- Where: Torino, Frascati, Daresbury, Nikhef (OL) and Berkley (ML)

<table>
<thead>
<tr>
<th>Year</th>
<th>Working Weeks</th>
<th>Nominal Rate per Week OL</th>
<th>Nominal Rate per Week ML</th>
<th>Stave Produced per OL</th>
<th>Stave Produced per ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>52</td>
<td>1.4</td>
<td>0.7</td>
<td>72.8</td>
<td>36.4</td>
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<tr>
<td>2019</td>
<td>30</td>
<td>1.4</td>
<td>0.7</td>
<td>42</td>
<td>21</td>
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</tbody>
</table>

Total (90% yield)  
OL: 114.8 (109)  
ML: 57.4 (54.5)
Detector Barrel Staves (OB)

OB-HIC

Torino - Stave 3

OB-Assembly

OB Stave

Pusan/Inha

A-side

C-side

Padova
Service Barrel and Cage: Dry Assembly and Insertion
Tests: IB and OB

Cage

Service Barrels and Cage

OB Service Half Barrel
Electronics - Readout Unit Production

- Development Completed
- Production of RUv2 (222 boards + 88 for MFT) will take 3-4 months (batched)
Overall ITS Planning

2016 - 2020

- Development
- Sensor Series Production
- Dicing + Test
- Stave Mechanics
- HIC Production
- Stave Production
- Hic and Stave
- Mechanical Support Structures
- Readout Electronics
- Design & Prototyping
- Global Assembly
- Dry Assembly Test
- Assembly and Commissioning Area
- Insertion test
- Commissioning @ Surface
- Installation
- Commissioning in ALICE
- Where we are!
- 7 months

Timeline:
- 2016: Development
- 2018: Dicing + Test, HIC Production, Jan 2018, Dry Assembly Test, Global Assembly, Mar 2018
- 2019: Commissioning
- 2020: May 2020, Installation, Commissioning in ALICE
Overall ITS Planning

**2016**
- Development
- Sensor Series Production
- Mechanical Support Structures
- Readout Electronics

**2017**
- Stave Development
- Stave Mechanics
- HIC Production
- Stave Production

**2018**
- Dicing + Test
- Dry Assembly Test

**2019**
- PRR
- Global Assembly

**2020**
- PRR

**Assembly and Commissioning Area**
- Assembly and test
- Commiss.
- Chiller
- Control room
- Cooling Plant
- El crates (1)
- May 2020
- 7 months
- Oct 2017
- Jan 2018
- Mar 2018
- 6 months commissioning
- March 2020
- 7 months

**Activity in ALICE PIT**
- Install ITS
- 10 Aug
- 22 Feb '21
- Install MFT and FIT-C
- 27 May
- Install cage and central beampipe
- 7 Apr
- Install TPC to UKE5
- 26 Feb
- 10 Apr
- Insertion test
- Storage

**Where we are!**
Physics Performance expected in RUN3&4

- **ITS - TPC Upgrades** ➔ Enhanced tracking

- **Heavy-Flavor Production**
  - Open Charm (D, \( \Lambda_c \)) / Beauty (B, \( \Lambda_b \))
  - Strange/non-strange Charm
  - Flavor dependent \( R_{AA} \) in low \( \rho_T \)

- **Low Mass di-electrons**
  - Reduced uncertainty (Photon-Conversion BG)
  - Initial Temperature from EM radiation

- **Hypernuclei**
  \( \frac{3}{4}H \) \( \frac{4}{3}H \) \( \frac{3}{4}He \)
감사합니다.