Heavy Flavour measurements in Pb–Pb collisions with the upgraded ALICE Inner Tracking System

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Introduction

Physics motivation for **Inner Tracking System 3 (ITS3)**
High-density QCD future opportunities after LS2

Current status
Talk by L. van Doremalen
Physics motivation

- Physics motivation for Inner Tracking System 3 (ITS3) [arXiv:1812.06772]
- High-density QCD future opportunities after LS2

- Characterisation of the macroscopic long wavelength Quark-Gluon Plasma (QGP) properties
  - Temperature
    - Thermal radiation at all collision stages
      - Real $\gamma$
      - Virtual $\gamma$ (dileptons)
Physics motivation

- Physics motivation for Inner Tracking System 3 (ITS3) [arXiv:1812.06772]
- High-density QCD future opportunities after LS2

- Characterisation of the macroscopic long wavelength Quark-Gluon Plasma (QGP)
  properties
  - Temperature
  - Transport coefficients

Heavy quark (c, b) diffusion coefficient $D_s$

Thermalization of heavy quarks in medium $\tau_q = \frac{m_q}{T} D_s$
Physics motivation

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  • High-density QCD future opportunities after LS2

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Hadronization through recombination with QGP quarks

Enhanced production of HF baryons ($\Lambda_c, \Lambda_b$)  
HF strange mesons ($D_s, B_s$)

• Investigation of the microscopic parton dynamics underlying QGP properties
  • Heavy Flavour recombination
Physics motivation

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  • Heavy Flavour recombination

• Development of a unified picture of particle production and QCD dynamics from small to large systems

• Exploration of parton densities in nuclei in a broad kinematic range and search for saturation
Physics motivation

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*Heavy Flavour measurements*
**ITS3 Upgrade concept**

### ITS1
- **Inner Radius**: 33mm
- **Layers**: 6
- **Materials**: SPD, SDD, SSD
- **Material Budget**:
  - Inner layers: $\frac{X}{X_0} = 1.14\%$
- **Pixel Size (SPD)**: $50 \times 425 \mu m^2$
- **Readout Rate**: 1kHz (Pb-Pb)

### ITS2
- **Inner Radius**: 22mm
- **Layers**: 7
- **Material Budget**:
  - Inner layers: $\frac{X}{X_0} = 0.35\%$
- **Readout Rate**: 100kHz (Pb-Pb)
- **Pixel Size**: $27 \times 29 \mu m^2$

**Higher Tracking Resolution & Efficiency**

<table>
<thead>
<tr>
<th>ITS1</th>
<th>ITS2</th>
</tr>
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<tbody>
<tr>
<td>6 Layers&lt;br&gt;SPD, SDD, SSD&lt;br&gt;Material Budget $\frac{X}{X_0} = 1.14%$ (inner layers)&lt;br&gt;Readout rate 1kHz (Pb-Pb)&lt;br&gt;Pixel size (SPD) $50 \times 425 \mu m^2$&lt;br&gt;Inner Radius 33mm</td>
<td>7 Layers of MAPS&lt;br&gt;Material Budget $\frac{X}{X_0} = 0.35%$ (inner layers)&lt;br&gt;Readout rate 100kHz (Pb-Pb)&lt;br&gt;Pixel size $27 \times 29 \mu m^2$&lt;br&gt;Inner Radius 22mm</td>
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ITS3 Upgrade concept

**ITS1**

**ITS2**

Impact Parameter Resolution

- ALICE
- Current ITS (data)
- Upgraded ITS

Tracking Efficiency

- ALICE
- Current ITS
- Upgraded ITS
ITS3 Upgrade concept

Can we get lighter? Can we get closer?
ITS3 Upgrade concept

Improvements for ITS3

- 3 Cylindrical layers of “massless” wafer-scale sensors
- Thinning to 20 - 40 um and bending of the silicon
- Air Cooling, 20 mW/cm²
- Removal of support structures
- Reduction of material budget 0.35% → 0.05%
- Beam pipe radius 22mm → 18mm
- Approach the interaction point
ITS3 expected performance

Impact Parameter Resolution

- Improvement x2 at all $p_T$

Tracking Efficiency

- Improvement x2 at low $p_T$
Heavy Flavour measurements

\[ \Lambda_c^+ \rightarrow \pi^+ + p + K^- \]

- PID for rejection of the large combinatorial background (p final state)
- Mean proper decay length \( \Lambda_c^+ : 59 \mu m \)
- High tracking precision for the primary to secondary vertex separation
- Large improvement in \( \Lambda_c^+ \) signal: improved precision
Heavy Flavour measurements

\[ \Lambda_b \to \Lambda_c^{+} + \pi^{-}, \quad \Lambda_c^{+} \to \pi^{+} + p + K^{-} \]

- Mean proper decay length \( \Lambda_b \): 417\,\mu m
- Large combinatorial background
- 4 prong final state
- Small B.R.
- Tight topological selection
- Improved vertex resolution important for \( \Lambda_b \) signal selection

\[ \theta : \text{pointing angle} \]

\( \text{ALICE Simulation} \)  
\( \text{Pb-Pb, } \sqrt{s_{NN}} = 5.5 \, \text{TeV} \)  
\( L_{\text{int}} = 10 \, \text{nb} \), 0-20\%  
\( 6 \leq p_T < 9 \, \text{GeV/c} \)
Heavy Flavour measurements

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Heavy Flavour measurements

$D_s \rightarrow \Phi + \pi \rightarrow K + K + \pi$ (non-prompt)

- Small $c\tau \sim 150\mu m$
- Improvement of significance by a factor of 2 at low $p_T$
- S/B improvement up to 20 GeV/c
Heavy Flavour measurements

c-deuteron

- $\Lambda_c n$ bound state
- Decay $d + K^- + \pi^+ (\Lambda_c \rightarrow p + K^- + \pi^+)$
- c-deuteron B.R. = B.R. $\Lambda_c \times P(p$ combines with $n)$
- Significance of ITS3 improved by a factor of 2.5
- Signal / Background of ITS3 improved by a factor of 3.3

![Graphs showing signal-to-background ratio for ITS2 and ITS3](image-url)
Conclusions

• Improvement on measurements of small $c\tau$ hadrons
• Improvement on multi-prong final states
• Heavy Flavour Baryon / Meson
  • $\Lambda_b / B$ enhanced if $b$ recombines
  • $\Lambda_c / D$
  • $D_s / D$
• New prospects
  • $B_s$ through the (non-prompt $D_s$)
  • $\Xi^+_c , \Xi^0_c , \Omega^0_c$ with $ct$ 130, 30, 20μm ($c, s$ quarks)
Conclusions

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ITS3 - Heavy Flavour
Improvements on challenging channels
Exploration of new channels in Pb-Pb
Thank you!