Particle identification in the ALICE central barrel

Alexander Kalweit, for the ALICE collaboration
The ALICE particle identification capabilities are unique among the four major LHC experiments.

Almost all known techniques are exploited:
- $dE/dx$ measurements
- Time-Of-Flight measurements
- Transition Radiation
- Cherenkov Radiation

PID is used directly, e.g.:
- $p_t$-spectra of $\pi^\pm$, $K^\pm$, $p$, $\bar{p}$
- identification of anti- and hyper-nuclei

PID is used indirectly to improve signal-to-backgr. ratios.
Detectors and Performance
Drift and strip detectors have analog read-out for up to 4 samples of specific energy loss with $\sigma \approx 10$-15%.

Particle identification to very low $p_t$, e.g. $\pi$ down to 100 MeV with stand-alone tracking.

=> reduces systematics for yield extraction.
$dE/dx$ measurement in TPC

- Up to 159 samples in Ne-CO$_2$ gas mixture: $\sigma_{dE/dx} \approx 5\%$.

- Very large dynamic range (up to 26x min. ionizing) allows to identify light nuclei and separate their charge.

- PID can be extended to higher momenta on the relativistic rise using statistical unfolding.

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Transition Radiation Detector

- Transition radiation is absorbed in a high Z gas mixture (Xe-CO2).
- Hadron rejection above $p > 1$ GeV/c.
Time of Flight (TOF)

- Excellent particle identification over a large momentum range.
- Time-Of-Flight resolution close to design value (86ps in PbPb) allowing a $2\sigma$ $p/K$-separation up to 5 GeV/c.

\[
\sigma^{(i)}_{PID} = \sqrt{\sigma_{TOF}^2 + \sigma_{time-zero}^2 + \sigma_{tracking}^2}
\]
Cherenkov radiation -- HMPID

- The ALICE HMPID is a proximity focusing Ring Imaging Cherenkov.

- Cherenkov photons are emitted when a fast charged particle crosses the liquid C$_6$F$_{14}$ radiator.

- Physics analysis in progress:
Statistical vs. track-by-track PID

- In general for all detectors:
  - In regions of clean separation: a \textbf{track-by-track PID} is possible, e.g. based on \( n\sigma \)-bands.
  - For the direct extraction of spectra in region of limited separation, \textbf{statistical unfolding} has to be used, e.g. on the \textbf{relativistic rise} in the TPC or higher momenta in TOF.

\textbf{rel. rise poster}

P. Christiansen
Statistical vs. track-by-track PID

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rel. rise poster
P. Christiansen
Topological particle identification
Topological identification

- E.g. Kaons are identified by three different methods:
  - direct PID: $K^\pm$
  - $V^0$s: $K^0 \rightarrow \pi^+\pi^-$
  - Kinks: $K^\pm \rightarrow \mu^\pm \nu$

- PID helps to improve sig.-to-backgr. ratio:

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![Graph showing dN/dyp vs. p_T (GeV/c) with different categories for kaon identification.](image)
Physics example 1:
$\pi, K, p$ spectra in pp and Pb–Pb
Spectra extraction

• Measurement with the different overlapping techniques which are combined to a common spectrum afterwards.

\[ \pi^+ \text{ (5-10%)} \]

\[ \frac{d^2N}{dy dp_T} \text{ (c/GeV)} \]

\[ T_p \]

\[ N \]

\[ d \]

\[ 200 \]

\[ 400 \]

\[ 600 \]

\[ 800 \]

\[ 1000 \]

\[ \text{ITSsa} \]

\[ \text{ITSTPC} \]

\[ \text{TPCTOF} \]

\[ \text{TOF} \]

ALICE Performance

\[ \sqrt{s_{NN}} = 2.76 \text{ TeV} \]

20/05/2011

statistical errors only

pp results: next talk
M. Chojnacki
**Spectra extraction**

- Measurement with the different overlapping techniques which are combined to a common spectrum afterwards.

**Definition:** primary particle

Particles produced in the collision including products of strong and electromagnetic decay, but excluding feed-down from weak decays of strange particles.

=> That means

\[ \Lambda \to p\pi^- \]

\[ \Sigma^+ \to p\pi^0 \]

have to be subtracted from the proton spectrum.

ALICE Performance

\( \text{Pb-Pb } \sqrt{s_{\text{NN}}} = 2.76 \text{ TeV} \)

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\[ \frac{d^2N}{dydp_T} (\text{c/GeV}) \]

\[ T_p \]

\[ 0 \quad 0.2 \quad 0.4 \quad 0.6 \quad 0.8 \quad 1 \quad 1.2 \quad 1.4 \quad 1.6 \quad 1.8 \quad 2 \]

\[ \pi^+ \text{ (5-10\%)} \]
Spectra extraction

- Measurement with the different overlapping techniques which are combined to a common spectrum afterwards.

\[ \pi^+ \text{ (5-10\%)} \]

\[
\frac{d^2N}{dy dp_T} (c/GeV) = \begin{cases} 
1000 & \text{ITSsa} \\
800 & \text{ITSTPC} \\
600 & \text{TPCTOF} \\
200 & \text{TOF}
\end{cases}
\]

\[
\text{statistical errors only}
\]

Feed-down correction

\[ \text{pp results: next talk} \]
M. Chojnacki
Results

- Blast-wave fits to individual particles to extract yields, particle ratios and $<p_t>$. 

PLENARY TALK
M. Floris
Physics example 2: Anti- and Hyper-nuclei
Anti-alpha observation

\[ \frac{dE}{dx} \text{ in TPC (a.u.)} \]

\[ \text{He}_4^4, \text{He}_3^3 \]

Bethe-Bloch parameterisation

\[ \text{counts} \]

\[ 0, 5, 10, 15, 20, 25, 30, 35, 40 \]

\[ 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 \]

raw ratio

uncorrected

\[ \text{ALICE Performance 2011-05-18} \]
Antihypertriton reconstruction

- Identification of light nuclei which are daughter tracks and origin from displaced vertices.

$$\bar{\Lambda} \rightarrow ^3\text{He} + \pi^+$$

Graph:
- Invariant mass distribution of $^3\text{He} \pi^+$
- Counts vs. Invariant mass
- Performance
- Pb-Pb @ 2.76 TeV

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anti-matter poster
N. Sharma
Summary

• ALICE particle identification shows an excellent performance.

• Particle spectra of various identified spectra have been extracted, e.g. charged pions, kaons, and protons in pp (900 GeV and 7 TeV) and Pb-Pb collisions.

• Various internal cross-checks between different detectors and identification techniques show consistent results.

• ALICE is also very well set up for the detection of rare stable particles, e.g. light anti- or hyper-nuclei.
BACKUP