Physics Results with the ALICE TOF detector

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QGP Studies $\rightarrow$ Particle Identification

**TOF**: hadrons PID thanks to the definition of the time taken by a particle to reach TOF

$$m = p \sqrt{\frac{t^2}{l^2} - \frac{1}{c^2}}$$
ALICE Experiment

See A. Agostinelli poster for TOF details
Time resolution in PbPb @ 2.76 TeV

Matching efficiency in pp @ 900 GeV

\[ \sigma_{\text{tot}} \approx 88 \text{ ps} \]

See A. Agostinelli poster for more details on time resolution.
TOF PID performance

Distribution of the particle masses calculated as:

\[ m = p \sqrt{\frac{t^2}{L^2} - \frac{1}{c^2}} \]
Some Physics Results
Particle species separation using the Time-of-Flight measured by the TOF detector ($t_{TOF}$) and calculated during the tracking procedure ($t_{calc}$) assuming different mass hypothesis.
**P_t Spectra for pp collisions @ $\sqrt{s} = 900$ GeV**

Production of pions, kaons, and protons in $pp$ collisions at $\sqrt{s} = 900$ GeV with ALICE at the LHC.

By ALICE Collaboration
Submitted to Eur. Phys. J. C.

Fit = Levi function

$$\frac{d^2N}{dp_t dy} = p_t \frac{dN}{dy} \frac{(n-1)(n-2)}{nC(nC + m_0(n-2))} \left(1 + \frac{m_t - m_0}{nC}\right)^{-n}$$
Production of pions, kaons and protons in pp collisions at $\sqrt{s}=900$ GeV with ALICE at the LHC. By ALICE Collaboration. Submitted to Eur. Phys J. C.
Resonances

\[ \phi \rightarrow K^+K^- \text{ in } pp \at \sqrt{s}=7 \text{ TeV} \]

TOF PID

\[ K^*(892)^0 \rightarrow K\pi \]

in pp \at \sqrt{s}=7 \text{ TeV}

TOF PID

Kaon-Pion invariant-mass spectrum (like-sign background subtracted)

\[ K^0 \rightarrow K^+\pi^-; \]
\[ \bar{K}^0 \rightarrow K^-\pi^+ \]

Fit parameters:

- \( m = 895.6 \pm 3.8 \text{ MeV}/c^2 \)
- \( \Gamma = 66 \pm 13 \text{ MeV}/c^2 \)

PDG parameters:

- \( m = 896.00 \pm 0.25 \text{ MeV}/c^2 \)
- \( \Gamma = 50.3 \pm 0.6 \text{ MeV}/c^2 \)

Breit-Wigner fit parameters:

- mass = 1019.48 \pm 0.03 \text{ MeV}
- width = 5.94 \pm 0.04 \text{ MeV}

PDG values:

- mass = 1019.455 \pm 0.020 \text{ MeV}
- width = 4.26 \pm 0.04 \text{ MeV}
Heavy flavours: $D^0 \rightarrow K^-\pi^+$ in PbPb

Invariant mass spectrum of 2.76 TeV Pb-Pb data. TOF and TPC PID are applied. The fit function corresponds to the sum of a gaussian (signal) and an exponential (background).

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Heavy flavours: $D^0 \rightarrow K^- \pi^+$ in pp

Invariant mass difference spectrum of 7 TeV data collected in April-May 2010. TOF and TPC PID is applied. The background is estimated using D0 candidates with invariant mass falling in the side-bands (4-8 sigma range) of the D0 mass region.
Heavy flavours: $D^0 \to K^-\pi^+$ in pp preliminary cross-section

Production cross section for $D^0$ mesons in pp at 7 TeV. The cross section is given for $D^0$ (obtained as 0.5*(D0+D0bar)) scaled to $|y|<0.5$ and compared to predictions from FONLL (Cacciari et al.) and GM-VFNS (Kramer et al.).
Invariant mass spectrum corresponding to 7 TeV data collected in April-May 2010. TPC, TOF and ITS PID are applied. The fit function corresponds to the sum of a gaussian (signal) and an exponential (background).
Electrons from HF decay in pp

Electron inclusive spectrum

Electron identification with TPC+TOF
Electrons from HF decay in pp

Ratio between the inclusive electron spectrum and the electron cocktail. Increasing significance of the heavy flavor electron signal over the inclusive background description.

When we subtract the cocktail from the inclusive electron spectrum, we are left with the transverse momentum distribution of electrons coming from the semileptonic decays of hadrons with charm and beauty.
Electrons from HF decay in pp

The Heavy Flavor Electron spectrum (inclusive-cocktail) is compared to the FONLL prediction for both charm and beauty semileptonic decays summed.

Good agreement with pQCD FONLL
Anti-Alpha candidates in Pb-Pb

Time of flight (sensitive to m/z-ratio): \[ m = \frac{z \cdot R}{\sqrt{\gamma^2 - 1}} \]

\[ < \frac{dE}{dx} > = \frac{4\pi Ne^4}{mc^2} \frac{z^2}{\beta^2} \left( \frac{1}{2} \ln \frac{2mc^2E_{\text{max}}}{T^2} \beta^2 \gamma^2 - \frac{\beta^2}{2} - \frac{\delta(\beta)}{2} \right) \]

Three candidates confirmed by TOF analysis

From ALICE Status Report, LHCC Meeting, 23 March 2011
Conclusions

• Since the first LHC collisions the TOF detector has played a relevant role in the ALICE particle identification thanks to its good performance in terms of time resolution and efficiency.

• Thanks to this excellent PID performances TOF detector is used in many physical pp and PbPb analysis as:

  × Transverse momentum spectra of charge hadrons produced in p-p collisions
  × Reconstruction of invariant masses
  × Electrons from HF decay
  × Search for Anti-Alpha
Backup
TOF Detector: SuperModule

**Space frame**
- $R = 3.5 \text{ m}$
- 18 SM $0 < \phi < 360$
- $|\eta| < 0.9$

**SM active area:**
- Length: 7.50 m
- Width: 1.28 m

**SuperModule (91 MRPC)**
TOF Detector: strip

Cross section of a central module

Pad dimension: 3.7x2.5 cm²

TOF: ~ 153K redout channels
dE/dx Performance of the ALICE ITS

dE/dx of charged particles vs their momentum, both measured by the ITS alone, in PbPb collisions at 2.76 TeV.

dE/dx of charged particles vs their momentum, both measured by the ITS alone, in pp collisions at 7 TeV.
dE/dx Performance of the ALICE TPC

Measured energy-deposit of charged particles vs. their momentum in the TPC. Pions, kaon, electrons, protons, and deuterons are visible. Lines = ALEPH parameterization of the Bethe-Bloch curve.

Measured energy-deposit of charged particles vs. the rigidity of the track for positive and negative particles. Anti-Deuterons are visible in the data. Lines = ALEPH parameterization of the Bethe-Bloch curve.
dE/dx performance of the ALICE HMPID
Physical motivation for studying hadron spectra

In heavy ions collisions the transverse momentum ($p_t$) hadron spectra give informations about the system produced at the kinetic freeze-out. If a deconfined phase at thermal equilibrium is produced we expect:

- $m_t = \text{transverse mass}$
- $m = \text{rest mass}$
- $T = \text{function of the kinetic freeze-out temperature.}$

We expect that the slope of the spectra is different in $pp$ and heavy ions collisions so the importance of the knowledge of $pp$ spectra.
Heavy flavours: $D^+ \rightarrow K^- \pi^+ \pi^+$

Invariant mass spectrum of 2.76 TeV Pb-Pb data collected in November 2010.
TPC+TOF PID is applied.
Topological cuts are applied.
The fit function corresponds to the sum of a gaussian (signal) and an exponential (background).
Heavy flavours: $D^+ \rightarrow K^- \pi^+ \pi^+$

preliminary cross-section

Production cross section for $D^+$ mesons in pp at 7 TeV. The cross section is given for $D^+$ (obtained as $0.5\times(D^+ + D^-)$) and scaled to $|y|<0.5$, and compared to predictions from FONLL (Cacciari et al.) and GM-VFNS (Kramer et al.).

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Heavy flavours: $D^{*\pm} \rightarrow D^0 \pi^\pm$

Invariant mass difference of 2.76 TeV Pb-Pb data collected in November 2010. TPC+TOF PID is applied.

Invariant mass spectrum of 7 TeV data collected in April-May 2010. TOF and TPC PID are applied. The fit function corresponds to the sum of a gaussian (signal) and an exponential (background).
Heavy flavours: $D^{*+} \rightarrow D^0 \pi^+_s$

**Preliminary cross-section**

| $d\sigma / dp_t \mid |y|<0.5$ [µb/GeV/c] |
|-----------------|
| $10^3$ |
| $10^2$ |
| $10$ |
| $1$ |
| $10^{-1}$ |

Production cross section for $D^{*+}$ mesons in $pp$ at 7 TeV. The cross section is given for $D^{*+}$ (obtained as $0.5*(D^{*+} + D^{*-})$) and scaled to $|y|<0.5$, and compared to predictions from FONLL (Cacciari et al.) and GM-VFNS (Kramer et al.).
Resonances: $\Sigma^* \rightarrow \Lambda \pi$ @ $\sqrt{s}=7$TeV

$\Lambda \pi$ invariant mass spectrum with side-bands background

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ALICE Performance

28/05/2010

$\Lambda \pi$ invariant mass spectrum (side-bands background subtracted)

Yield = $(10 \pm 2) 10^3$

$\Gamma = (39 \pm 6)$ MeV/c$^2$

$\Gamma = (39.4 \pm 2.1)$ MeV/c$^2$

PDG values

$\Gamma = (39.4 \pm 2.1)$ MeV/c$^2$
Topological decay

ALICE data, p-p at 7 TeV (sel. runs / GRID pass1) - 8.53 Mevents

2010 data
p+p at \( \sqrt{s} = 7 \) TeV

\( \Lambda^0 \) candidates
\( (M_{\text{pdg}} = 1.11568 \text{ GeV/c}^2) \)

\( K^0 \)’s candidates
\( (M_{\text{pdg}} = 0.49761 \text{ GeV/c}^2) \)

ALICE Performance
April 2010

Counts per 1.0 MeV/c^2

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Topological decay

\[ \Omega \rightarrow \Lambda K \]

ALICE data, p-p at 7 TeV (sel. runs 114783 - 115401 / GRID pass1) - 5.71 Mevents

2010 data
p+p at \( \sqrt{s} = 7 \) TeV

**\( \Omega^- \) candidates**

\( (M_{\text{pdg}} = 1.6725 \text{ GeV}/c^2) \)

Gaussian+Pol1 Fit:
\( \chi^2/\text{ndf} = 43.71/45 \)
\( M_{\Omega} = 1.6722 \pm 0.0003 \text{ GeV}/c^2 \)
\( \sigma_M = 2.7 \pm 0.3 \text{ MeV}/c^2 \)

**ALICE Performance**
April 2010

\[ M(\Lambda, K) \text{ (GeV}/c^2) \]

2010 data
p+p at \( \sqrt{s} = 7 \) TeV

**\( \Omega^+ \) candidates**

\( (M_{\text{pdg}} = 1.6725 \text{ GeV}/c^2) \)

Gaussian+Pol1 Fit:
\( \chi^2/\text{ndf} = 53.42/44 \)
\( M_{\Omega} = 1.6726 \pm 0.0002 \text{ GeV}/c^2 \)
\( \sigma_M = 2.1 \pm 0.2 \text{ MeV}/c^2 \)

**ALICE Performance**
April 2010
Topological decay

\( \Xi \to \Lambda \pi \)

ALICE data, p-p at 7 TeV (sel. runs 114783 - 115401 / GRiD pass1) - 5.71 Mevents

2010 data
\( p+p \) at \( \sqrt{s} = 7 \text{ TeV} \)

- \( \Xi^+ \) candidates
  \[ (M_{\Xi^+} = 1.3217 \text{ GeV/c}^2) \]
  Gaussian+Pol1 Fit :
  \[ \chi^2/\text{ndf} = 56.89/40 \]
  \[ M_{\Xi} = 1.3219 \pm 0.0000 \text{ GeV/c}^2 \]
  \[ \sigma_M = 2.0 \pm 0.0 \text{ MeV/c}^2 \]

ALICE Performance
April 2010

- ALICE

2010 data
\( p+p \) at \( \sqrt{s} = 7 \text{ TeV} \)

- \( \Xi^- \) candidates
  \[ (M_{\Xi^-} = 1.3217 \text{ GeV/c}^2) \]
  Gaussian+Pol1 Fit :
  \[ \chi^2/\text{ndf} = 98.97/40 \]
  \[ M_{\Xi} = 1.3214 \pm 0.0000 \text{ GeV/c}^2 \]
  \[ \sigma_M = 2.0 \pm 0.0 \text{ MeV/c}^2 \]
Identification of gamma conversions with the ALICE TPC

Two-dimentional (XY) distribution of gamma conversions. Gamma conversion candidates are obtained via a V0 topology identification which is performed during the track reconstruction. The electron and positron daughters tracks are further selected by requiring a (-3,+10) number of sigmas with respect to the Bethe-Bloch parameterization describing the linear energy loss in the ALICE TPC. Potential contamination is suppressed with rejecting tracks compatible with the lowest half band of the pions. A vertex and mass constraint is applied as well.
Invariant mass distribution of 2 gamma

The peaks at the pi0 and eta masses are seen. The blue histogram is the combinatorial background calculated using mixed events.

Electron ID in TPC
Armenteros-Podolanski's plot

ALICE Performance
p+p at $\sqrt{s} = 900$ GeV (2009 data)

$\alpha = (p_L^+-p_L^-)/(p_L^++p_L^-)$

$\Lambda$, $\bar{\Lambda}$, $K_S^0$, $\gamma$