First measurements of strange baryons and anti-baryons with the ALICE experiment in pp collisions at LHC

\[ \Xi^{-} \rightarrow \Lambda^{0} + \pi^{-} \rightarrow p^{+} + \pi^{+} + \pi \]

- Effective mass: \( M_{\text{eff}} = 1.322 \text{ GeV}/c^{2} \)
- P_{t}^{\Lambda} = 0.987 \text{ GeV}/c
- \( R_{2d} = 9.75 \text{ cm} \)

[ ... and a few words on mesons ]

The IX International Conference on Hyperons, Charm and Beauty Hadrons

- Perugia, 21\textsuperscript{st} - 26\textsuperscript{th} June 2010 -

Renaud Vernet (CC-IN2P3 Lyon) for the ALICE collaboration
Outline

- Why study strange particle production?
- The tools ALICE offers to search for strange particles
- The data
- Secondary vertex reconstruction techniques
- Strange and multi-strange particle measurements in pp at $\sqrt{s}=900$ GeV and 7 TeV
- Summary
Why study strangeness production?

- Very powerful probe in heavy-ion physics
  - Degree of equilibration of the system
  - Quark recombination phenomena
- Why pp?
  - Essential reference system for HI studies
  - Genuine pp physics!

\[ \sqrt{s_{pp}} = 200 \text{GeV} \]

\[ \sqrt{s_{pp}} = 1.96 \text{TeV} \]


Varelas, Physics at LHC 2010
ALICE tools for strangeness

Time Projection Chamber

ITS (close to the beam)
- Silicon Pixel Detector
- Silicon Drift Detector
- Silicon Strip Detector

PID = ITS + TPC + TOF + TRD + RICH

Low material budget at central rapidity

arXiv:0901.3176v1 [hep-ex]
The data

- ALICE took pp data at $\sqrt{s}=900$ GeV in November-December 2009, the first LHC runs
  - ~300k Minimum Bias events kept for analysis
    - more 900 GeV taken later on in 2010
  - Selection on primary vertex
    - Vertex quality (SPD + tracks)
    - Vertex is kept within +/- 10 cm along the beam axis
- Since March 2010, $\sqrt{s}=7$ TeV
  - > 100M Min. Bias events !!
- Simulation
  - 1.8M events, pp 900 GeV, Pythia tune D6T
  - Particle transport with GEANT3
Secondary vertex reconstruction

- $K_S^0$ and hyperons ($\Lambda, \Xi, \Omega$) have a $c\tau \sim \text{few cm}$
  - Charged decay modes
  - Can be identified via topological methods
    - $\rightarrow$ momentum range limited by statistics only
  - PID not mandatory

<table>
<thead>
<tr>
<th></th>
<th>$K_S^0$</th>
<th>$\Lambda$</th>
<th>$\Xi$</th>
<th>$\Omega$</th>
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<tr>
<td>$c\tau$ (cm)</td>
<td>$d\bar{s}$</td>
<td>$uds$</td>
<td>$dss$</td>
<td>$sss$</td>
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<td>2.68</td>
<td>7.89</td>
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<td>decay</td>
<td>$\pi\pi$</td>
<td>$\rho\pi$</td>
<td>$\Lambda\pi$</td>
<td>$\Lambda K$</td>
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<tr>
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<td>69.2</td>
<td>63.9</td>
<td>99.9</td>
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</table>
\( K_0^S \) and (anti-)\( \Lambda \) performance

- Efficiency at low \( p_T \) limited due to
  - Acceptance and tracking efficiency
  - Branching ratios: \( \sim 69\% \) (K) and 64\% (\( \Lambda \))
- Anti-\( \Lambda \) below \( \Lambda \) because of anti-p absorption
  - \( \text{eff}(\text{anti-}\Lambda)/\text{eff}(\Lambda) \sim 0.85 \pm 0.03 \) in average

- Raw yields extracted from invariant mass spectrum
  - \(|y|<0.75\)
  - Fit \( \rightarrow \) mass \( m_0,\sigma^0 \)
  - Signal obtained by bin counting around \( m_0 \pm 4\sigma^0 \)
  - Background estimated with polynomial fit (gray area)

- PID used for (anti-) protons
  - \( \text{dE/dX} \) in TPC:
    - Cut at 5\( \sigma \) if \( p<0.7 \) GeV/c, 3\( \sigma \) otherwise
Data quality

- Measured $c_T$ in agreement with PDG
- Cut distribution of signal particles in real data are described by simulations reasonably well

![Graph showing $c_T$ distributions and ALICE Preliminary slope $-1$ (cm)]
Feed-down correction for $\Lambda$

What we measure

$$\Lambda = \Lambda_{\text{primary}} + \Lambda_{\text{from } \Xi \text{'s decay}} + \Lambda_{\text{others}}$$

What we want!

How to evaluate $\Lambda_{\text{from } \Xi \text{'s decay}}$ in the data?

In Monte-Carlo:

$$r = \Xi_{\text{MC reconstructed}} / \Lambda_{\text{MC from } \Xi}$$

In real data:

$$\Lambda_{\text{Data from } \Xi} = \Xi_{\text{Data reconstructed}} / r$$

which is $\sim 13 \pm 2\%$ of all $\Lambda$ candidates

Current estimate for this correction for $\Lambda$: $13 \pm 2\%$.

- neglecting the $\Lambda$'s re-generated in material ($\sim 2\%$, in MC).

The same for anti-$\Lambda$ is $12 \pm 2\%$.

- neglecting the anti-$\Lambda$'s re-generated in material ($\sim 0.3\%$, in MC).

Pt spectra: same shape for associated $\Lambda$ and for secondary $\Lambda$

This opens the possibility to apply just a global correction to the final spectra.

Does the $p_t$ spectra of $\Lambda_{\text{primary}}$ differ from the $\Lambda_{\text{from } \Xi \text{'s decay}}$'s spectra?

In Monte-Carlo simulation:

Use the dca to Primary Vertex distribution to distinguish between primary and secondary $\Lambda$

In real data

Table 1: $\Lambda$ candidates with $p > 0.7$ GeV/c

<table>
<thead>
<tr>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
<th>Underflow</th>
<th>Overflow</th>
<th>Integral</th>
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<tr>
<td>1975</td>
<td>1.404</td>
<td>0.622</td>
<td>0</td>
<td>1</td>
<td>1974</td>
</tr>
</tbody>
</table>

Graphs showing $p_t$ and DCA distributions for Monte Carlo and real data.
$K^0_S$ and (anti-)\$Lambda$ spectra
Systematics on corrected spectra

- Errors are partly due to the choice of the cut value for $V_0$s
  - How much? How does it compare to stat. error?

- Two contributions
  - 1/ discrepancies on the cut variable distributions between MC and real data
    - This error can be extracted from those distributions → <5%
  - 2/ different resolutions on cut variables between MC and real data
    - Estimated by making the cuts vary around their nominal values
    - → see if the corrected spectra change
      - <1%
$K^0_s$ and $\Lambda$ at 7 TeV

- 8.5 Mevents analysed
- No PID used
\[ \frac{1}{p_T} \frac{dN}{dp_T} \propto \frac{(n-1)(n-2)}{2\pi T[nT+m_0(n-2)]} \left[ 1 + \frac{m_T-m_0}{nT} \right]^{-n} \]
Multi-strange at 900 GeV

- low statistics, but $\Xi$ peak visible!
  - $|y| < 0.8$
- PID used on all 3 daughters
  - $\Xi \rightarrow \Lambda \pi \rightarrow p\pi\pi$
  - Selection from $dE/dX$ in TPC
    - Cut at 4\(\sigma\) from BB curve
- We have got three points to draw the $\Xi$ corrected $p_T$ spectra
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Multi-strange at 7 TeV

- The statistics at 7 TeV makes the $\Omega$ measurable
  - $|y|<0.8$
  - 24M Min Bias events
  - S/B $\sim 0.4$

- Four points in raw $p_t$ spectrum
- Analysis of 7 TeV data makes the full set of secondary vertex hyperons measurable
\[ \Sigma^* \text{ at 7 TeV} \]

- Strong decay \( \Sigma^* \rightarrow \Lambda \pi \)
- \( \rightarrow \) can probe fireball evolution in HI collisions
  - time-span between chemical and thermal freeze-outs
  - pp reference needed

Venaruzzo, INPC2010, poster
Measurement of hyperons ($\Lambda, \Xi, \Omega$) -and strange particles ($K^\pm, K_S^0, \phi$) in general- has been a success from the very first LHC pp data

- Small samples at 900 GeV already made us draw the first corrected $p_t$ spectra of identified particles
- Understand our detector
- Fine-tune our analysis cuts

- Very final correction of $p_t$ spectra has to be done
- 7 TeV data already very promising (lots of events!)
  - New physics at such energy
  - Statistics will help us understand better the systematics