Σ hyperons reconstruction by the missing mass method

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**Σ⁺ and Σ⁻ physics:**

- completes the picture of strangeness production: abundant particles, carry out large fraction of strange quarks;
- possible to compare yields of Σ and Σ⁺ production, that can be used in study of the QCD phase diagram;
- reconstruction of resonances decaying into Σ;
- reconstruction of hypothetic particles, like H-dibaryon.

**Main decay modes:**

- \( \Sigma^+ \rightarrow p\pi^0 \) \( \Sigma^+ \rightarrow \bar{p}\pi^0 \) \( \text{BR} = 51.6\% \)
- \( \Sigma^+ \rightarrow n\pi^+ \) \( \Sigma^+ \rightarrow \bar{n}\pi^- \) \( \text{BR} = 48.3\% \)
- \( \Sigma^- \rightarrow n\pi^- \) \( \Sigma^- \rightarrow \bar{n}\pi^- \) \( \text{BR} = 99.8\% \)

The main challenge: at least one neutral daughter in a decay channel
Missing Mass Method

- $\Sigma^+$ and $\Sigma^-$ have only channels with at least one neutral daughter.
- A lifetime is sufficient to be registered by the tracking system: $c\tau = 2.4$ cm for $\Sigma^+$ and $c\tau = 4.4$ cm for $\Sigma^-$. 
- Can not to be identified by the PID detectors.
- Identification is possible by the decay topology:

  Find tracks of $\Sigma$ and its charged daughter in STS and MVD

  Reconstruct a neutral daughter from the mother and the charged daughter

  Reconstruct $\Sigma$ mass spectrum from the charged and obtained neutral daughters

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- Identification is possible by the decay topology:
The acceptance of STS for $\Sigma^+$ and $\Sigma^-$ is limited by $50 < Z < 70$ cm:
- the primary $\Sigma$ track can have 3 or 4 hits;
- the $\pi^-$ daughter track should have at least 4 hits.

MVD allows to increase the acceptance significantly to $15 < Z < 70$ cm.
\( \Sigma^+ \) and \( \Sigma^- \) reconstruction with STS and MVD

**MVD+STS**

\[ \Sigma^- \rightarrow n\pi^- \]

Entries \( \times 10^3 \)

- \( m_{\text{inv}} \) [GeV/c²]

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\( \Sigma^- \rightarrow n\pi^- \)

\( \Sigma^+ \rightarrow n\pi^+ \)

Entries \( \times 10^3 \)

- \( m_{\text{inv}} \) [GeV/c²]

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\( \Sigma^+ \rightarrow n\pi^+ \)

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

Entries \( \times 10^3 \)

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\( \Sigma^+ \rightarrow p\pi^0 \)

5M central UrQMD AuAu events at 10 AGeV, no PID
The background has a complicated structure and will be further studied.
The proposed method can be applied for reconstruction of multi-strange hyperons:

\[ \Xi^- \rightarrow \Lambda \pi^- \quad \text{with} \quad \Lambda \rightarrow n\pi^0 \quad \text{BR} = 35.6\% \]
\[ \Xi^+ \rightarrow \bar{\Lambda} \pi^+ \quad \text{with} \quad \bar{\Lambda} \rightarrow \bar{n}\pi^0 \quad \text{BR} = 35.6\% \]
\[ \Omega^- \rightarrow \Lambda K^- \quad \text{with} \quad \Lambda \rightarrow n\pi^0 \quad \text{BR} = 24.3\% \]
\[ \Omega^+ \rightarrow \bar{\Lambda} K^+ \quad \text{with} \quad \bar{\Lambda} \rightarrow \bar{n}\pi^0 \quad \text{BR} = 24.3\% \]
\[ \Omega^- \rightarrow \Xi^0 \pi^- \quad \text{BR} = 23.6\% \]
\[ \Omega^+ \rightarrow \Xi^0 \pi^+ \quad \text{BR} = 23.6\% \]

Kaons and Pions:

\[ \pi^+ \rightarrow \mu^+ \nu_\mu \quad \text{BR} = 99.99\% \]
\[ \pi^- \rightarrow \mu^- \bar{\nu}_\mu \quad \text{BR} = 99.99\% \]
\[ K^+ \rightarrow \mu^+ \nu_\mu \quad \text{BR} = 63.6\% \]
\[ K^- \rightarrow \mu^- \bar{\nu}_\mu \quad \text{BR} = 63.6\% \]
\[ K^+ \rightarrow \pi^+ \pi^0 \quad \text{BR} = 20.7\% \]
\[ K^- \rightarrow \pi^- \pi^0 \quad \text{BR} = 20.7\% \]

These decays are being added to the KF Particle Finder (HK 25.5)

Reconstruction of these decays allows to:
- increase reconstruction efficiency for multi-strange hyperons;
- investigate systematic errors;
- study the background.
Summary

• The method for reconstruction of $\Sigma^+$ and $\Sigma^-$ has been developed, that allows to complete the picture of strangeness production.

• The missing mass method provides a capability to reconstruct $\Sigma^+$ and $\Sigma^-$ with high efficiencies and S/B ratios.

• The method can be applied for reconstruction of other decays including multi-strange hyperons and hypernuclei.

Plans

• Implement all decays in KF Particle Finder.

• Add PID information.