Strange Particles Reconstruction
by the Missing Mass Method

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CBM Experiment

- **CBM** — future fixed-target heavy-ion experiment at FAIR, Darmstadt, Germany.
- \(10^5-10^7\) collisions per second.
- Up to 1000 charged particles/collision.
- Free streaming data.
- No hardware triggers.
- On-line time-based event reconstruction and selection is required in the first trigger level.

- On-line reconstruction at the on-line farm with 60000 CPU equivalent cores.
- High speed and efficiency of the reconstruction algorithms are required.
- The algorithms have to be highly parallelised and scalable.
- CBM event reconstruction: Kalman Filter and Cellular Automaton.
**Missing Mass Method**

### Σ⁺ and Σ⁻ physics:
- completes the picture of strangeness production: abundant particles, carry out large fraction of strange quarks.

### Main decay modes:
- Σ⁺ → pπ⁺
- Σ⁺ → π⁺π⁺
- Σ⁺ → nπ⁺
- Σ⁺ → π⁺π⁻
- Σ⁻ → nπ⁻
- Σ⁻ → π⁻π⁻
- BR = 51.6%
- BR = 48.3%
- BR = 99.8%

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

Find tracks of Σ and its charged daughter in STS and MVD

Reconstruct a neutral daughter from the mother and the charged daughter

Reconstruct Σ mass spectrum from the charged and obtained neutral daughters
KF Particle Finder Algorithm

Selection criteria:
- $\chi^2_{\text{fit}} - \chi^2$ given by a track fit
- $\chi^2_{\text{prim}} - \chi^2$ distance to a primary vertex (PV)
- $\chi^2_{\text{geo}} - \chi^2$ given by a particle fit
- $\chi^2_{\text{topo}} - \chi^2$ of a particle fitted to PV

1. $\Sigma^+ \rightarrow n\pi^+$
2. $\Sigma^0 \rightarrow n\pi^0$
3. $\Sigma^+ \rightarrow \pi^0\nu$
4. $\Sigma^0 \rightarrow \pi^0\nu$
5. $\Xi^+ \rightarrow \Lambda\pi^+$
6. $\Xi^0 \rightarrow \Lambda\pi^0$
7. $\Omega^+ \rightarrow \Lambda K^+$
8. $\Omega^0 \rightarrow \Lambda K^0$
9. $\Omega^+ \rightarrow \Xi^+ K^+$
10. $\Omega^0 \rightarrow \Xi^0 K^0$
11. $\Xi^+ \rightarrow \mu^+\nu
12. $\Xi^0 \rightarrow \mu^0\nu
13. $\pi^+ \rightarrow \mu^+\nu
14. $\pi^0 \rightarrow \mu^0\nu
15. $K^+ \rightarrow \mu^+\nu
16. $K^0 \rightarrow \mu^0\nu
17. $K^+ \rightarrow \pi^+\pi^0$
18. $K^0 \rightarrow \pi^0\pi^0$

Secondary neutals $n, \pi^0, \Lambda, \Xi^0, \nu\mu$

Secondary tracks $\Sigma^{+/-}, \Xi^{+/-}, \Omega^{+/-}, K^{+/-}, \pi^{+/-}$

Primary tracks $K^0_s, \Lambda$ and $\bar{\Lambda}$ candidates

Secondary $\Xi^-, \Xi^+, \Omega^-$ and $\Omega^+$ candidates

H-dibaryon candidates

Selected $K^0_s, \Lambda$ and $\bar{\Lambda}$

Selected $K^0_s, \Lambda$ and $\bar{\Lambda}$

Selected $K^0_s, \Lambda$ and $\bar{\Lambda}$

Secondary $\Lambda$ and $\bar{\Lambda}$

Primary $K^0_s, \Lambda$ and $\bar{\Lambda}$

Checking mass

$\chi^2_{\text{geo}}, \chi^2_{\text{topo}}, z_{\text{vertex}}$

$\chi^2_{\text{fit}}$

Selected tracks

Store

Selected $\Xi^-, \Xi^+, \Omega^-$ and $\Omega^+$

Selected $H$

Selected $\Sigma^{*+}, \Sigma^{*+}, \Sigma^{*-}$ and $\Sigma^{*-}$, $K^*0$, $K^*0$, $K^*$ and $K^{*+}$

Store

Selected $\Sigma^{*+}, \Sigma^{*+}, \Sigma^{*-}$ and $\Sigma^{*-}$, $K^*0$, $K^*0$, $K^*$ and $K^{*+}$

$\chi^2_{\text{geo}}$

$\chi^2_{\text{fit}}$
Reconstruction Procedure & Selection Cuts

**Primary** and **secondary** reconstructed tracks

- **Z** daughter’s first hit > **Z** mother’s last hit
- **E** mother > **E** daughter
- Subtract charged daughter
- **Z** decay is between tracks
- Fit quality of neutral
- Momenta and rapidity cuts on clones for a neutral candidate
- Set mass constraint for neutral
- Construct mother
- **Z** decay is between tracks
- Fit quality of constructed mother
- Is particle from vertex?
- Collect histograms

NeutralDaughterDecay(...);

PDG from TOF

no PDG

Kisel Pavel, GSI, Uni-Frankfurt, JINR
Extraction of the Signal: Side Bands Method

- Collect spectra ($M$, $p$, $p_t$, $y$, $Z$...) for the signal+BG (particles within the mass peak) and BG (particles near the peak).
- Calculate the correction factor using the fitted BG.
- Subtract the corrected BG.

Signal + Background

Background

$BG_{±3σ}$

$BG_{(-6σ,-3σ)} + BG_{(3σ,6σ)}$
Extraction of the Signal: Multi-differential Analysis

- Is illustrated at the example of Λ hyperon.
- Collect mass spectra in different y-p_t bins.
- Fit the spectra with a signal+background function — calculate an integral of the signal function.
- Fill bins of the y-p_t histogram with the integral values — obtain the y-p_t distribution for the signal particles.
- Integral y and p_t distributions are obtained by projecting the multi-differential distribution to the corresponding axes.
Particles found with MMM

The goal is to have a clean sample of short-lived particles for further physics analysis

5M Au+Au central events, 10 AGeV, TOF PID
The signal distributions are nicely described by the extracted signal.
Both methods show similar results.
Due to the limited statistics in the outer regions, multi-differential analysis cannot be applied there, the integral distributions are describing the central region.
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2D y-p_t plots for reconstruction efficiency have been added.
Efficiency Corrected Spectra for $\Sigma^- n n^-$ in 4\pi

1.8M Au+Au central events, 10 AGeV, TOF PID

- Reconstructed spectra in 4\pi have few artefacts and requires further analysis
Summary and Plans

✓ The missing mass method for reconstruction of $\Sigma$ and other particles has been further developed.
✓ With TOF PID the missing mass method reconstructs particles with high efficiency and S/B ratios.
✓ The side bands and multi-differential methods have been implemented.
✓ Results from both methods are in a good agreement with the simulated signal.
✓ Efficiency corrected spectra in $4\pi$ range are now available.

Investigate a drop of efficiency at the station positions.
Implement search for double reconstructed $\Xi$ and $\Omega$ by the direct search and the missing mass method.
Port the algorithms to the STAR High-Level Trigger for future BES-II.
Apply the algorithms to STAR real data (with the Heavy Flavour Tracker).