Reconstruction of short lived particle spectra with KF Particle Finder

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(for the CBM collaboration)

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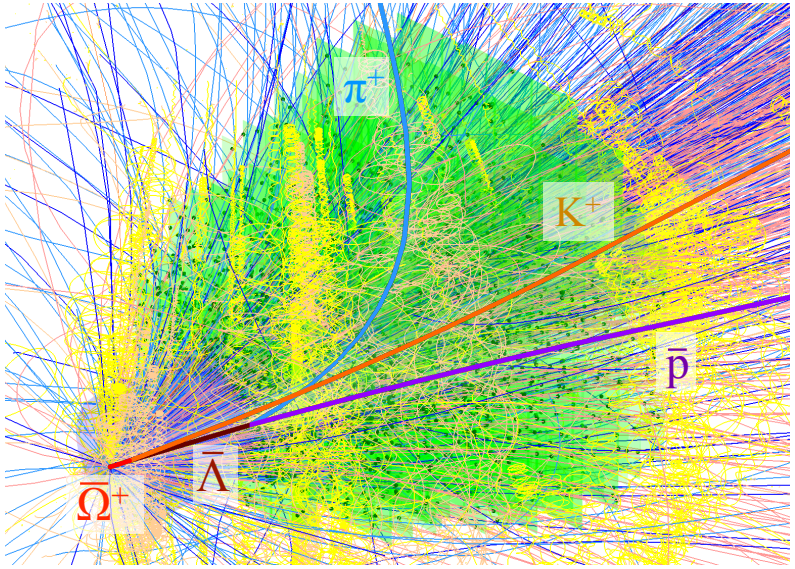
Concept of KF Particle



$$\bar{\Omega}^+ \rightarrow \bar{\Lambda}\, K^+$$
$$\hookrightarrow \bar{p}\, \pi^+$$

```
KFParticle Lambda(P, Pi);                  // construct anti Lambda
Lambda.SetMassConstraint(1.1157);          // improve momentum and mass
KFParticle Omega(K, Lambda);               // construct anti Omega
PV -= (P; Pi; K);                          // clean the primary vertex
PV += Omega;                               // add Omega to the primary vertex
Omega.SetProductionVertex(PV);             // Omega is fully fitted
(K; Lambda).SetProductionVertex(Omega);    // K, Lambda are fully fitted
(P; Pi).SetProductionVertex(Lambda);       // p, pi are fully fitted
```

State vector — Position, momentum and energy

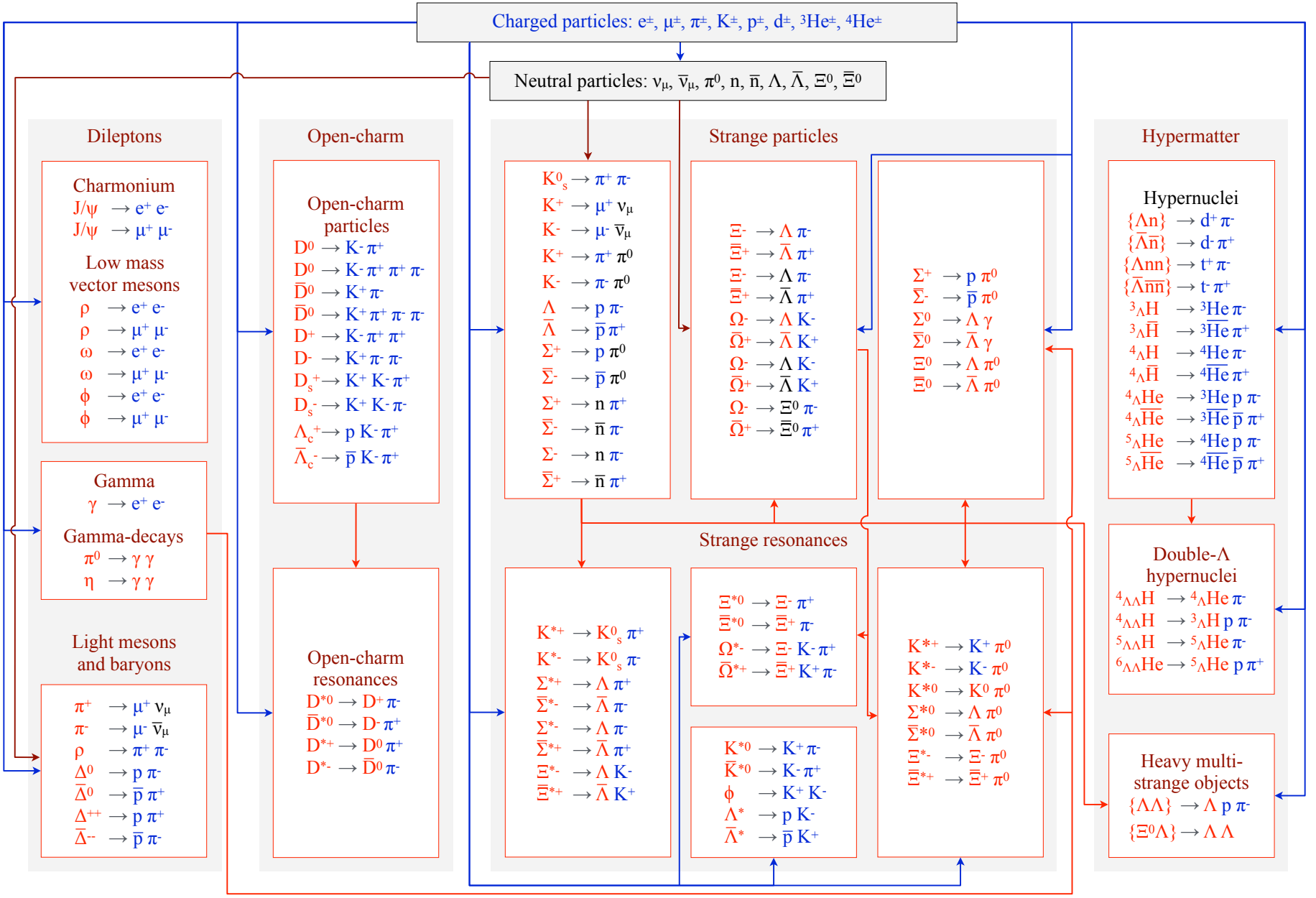
$$r = \{ x, y, z, p_x, p_y, p_z, E \}$$
$$C = \langle r r^T \rangle$$

Covariance matrix

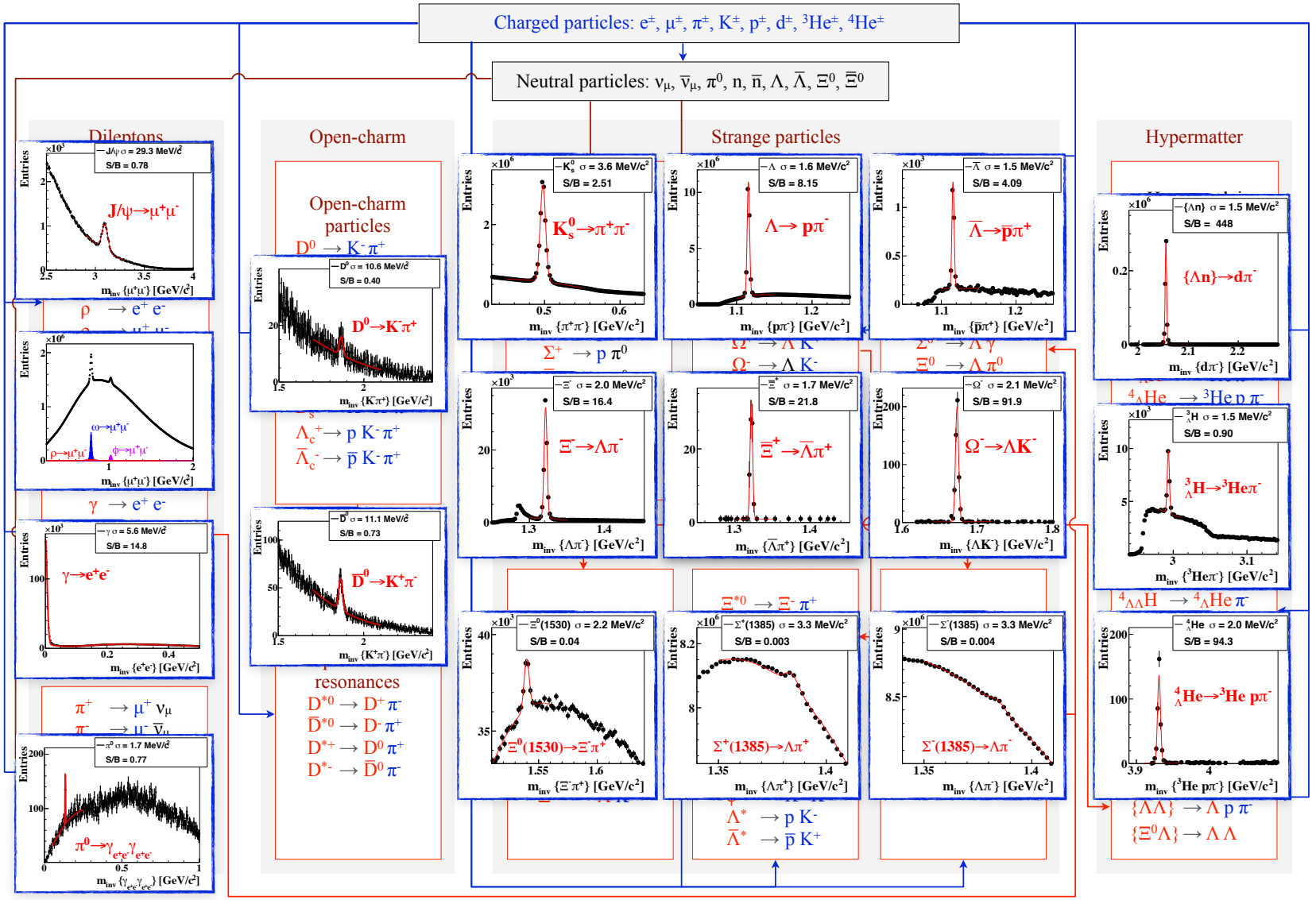
Concept:

- Mother and daughter particles have the same state vector and are treated in the same way
- Geometry independent
- Reconstruction of all physics parameters together with their errors
- Kalman filter based
- Easy reconstruction of decay trees
- Fast and fully vectorised

KF Particle Finder block-diagram

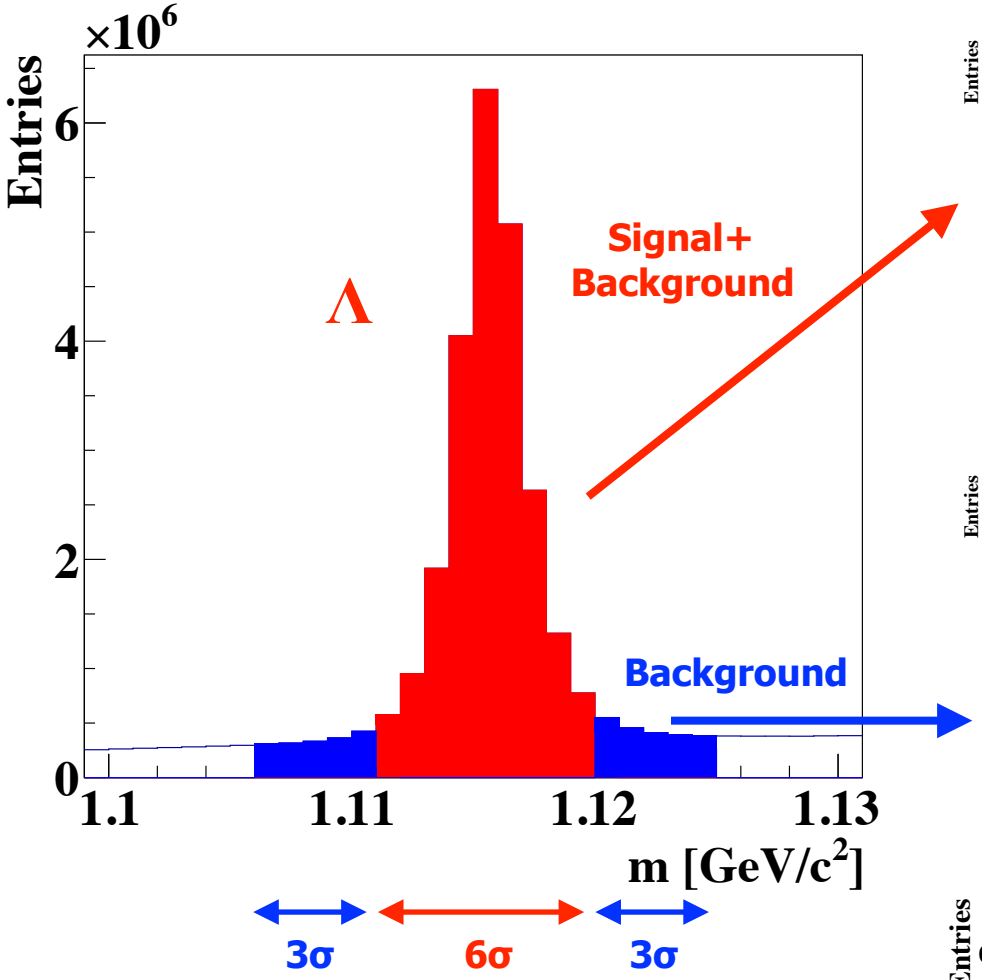


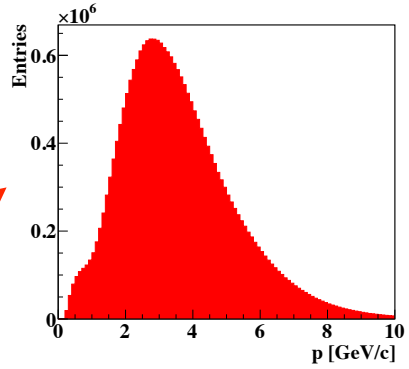
Physics coverage



All main CBM decays are covered

Extraction of the signal: side bands method





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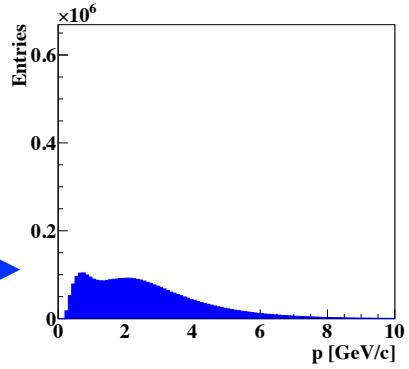

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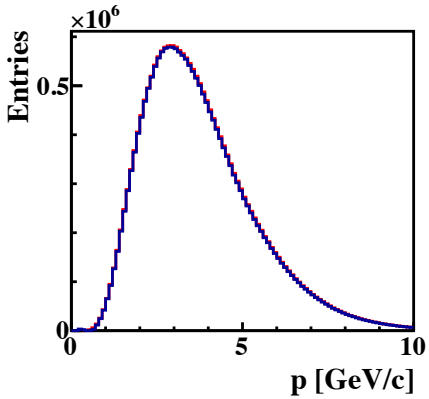
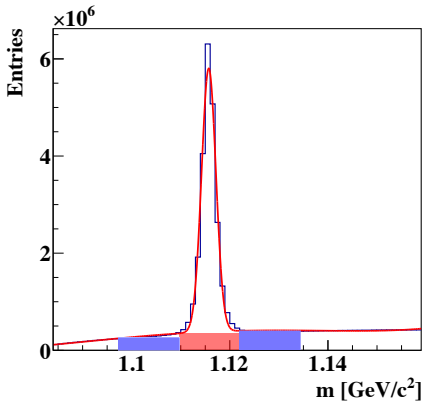
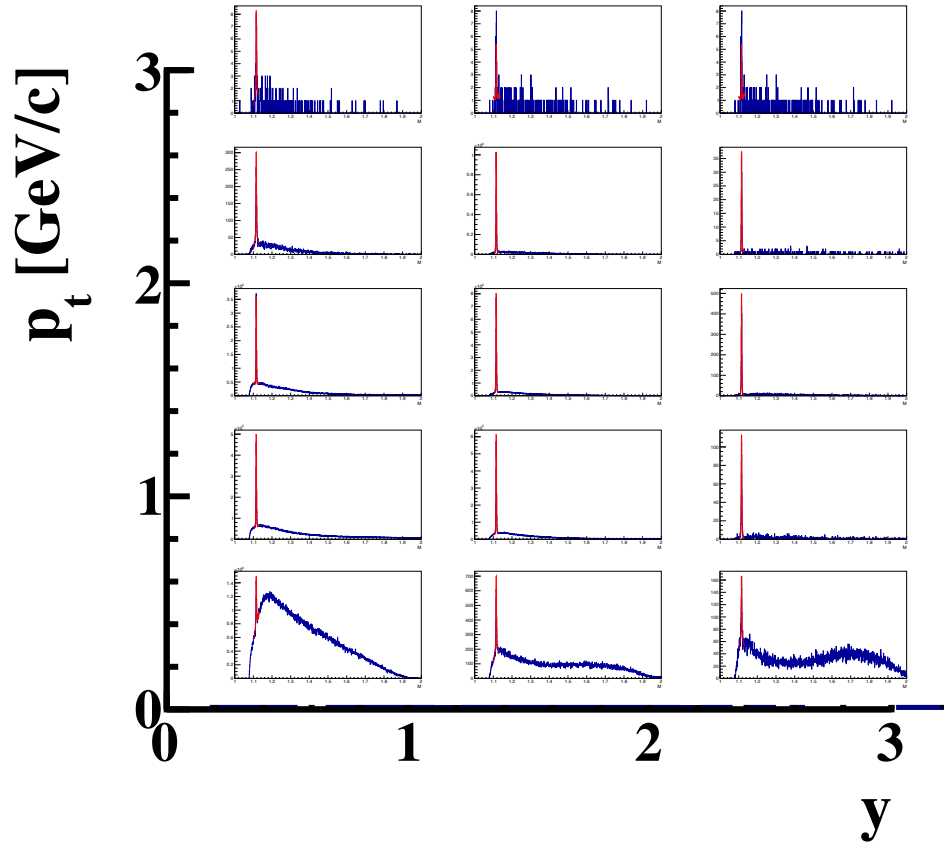


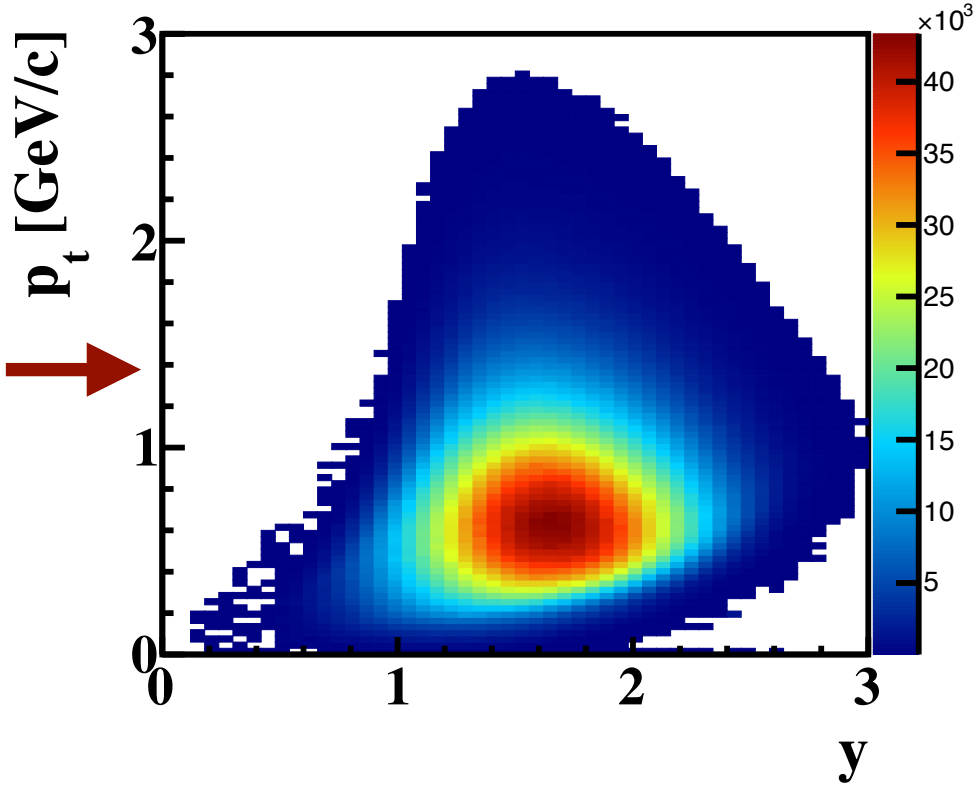


$$\times \frac{BG_{\pm 3\sigma}}{BG_{\{-6\sigma,-3\sigma\}} + BG_{\{3\sigma,6\sigma\}}}$$

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

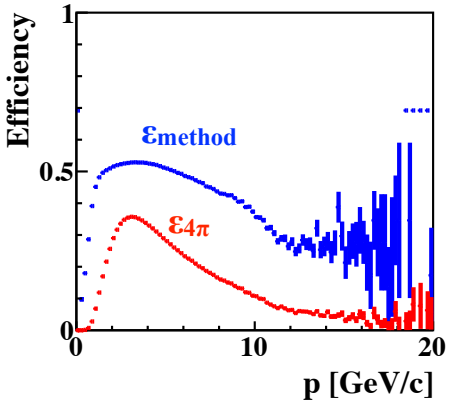
Extraction of the signal: polynomial background fit

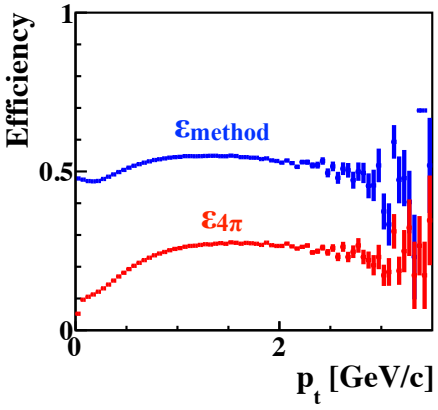


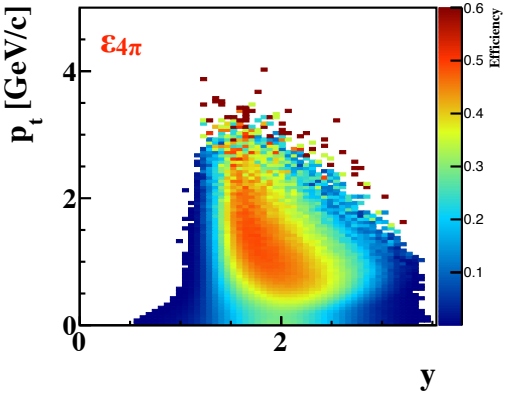


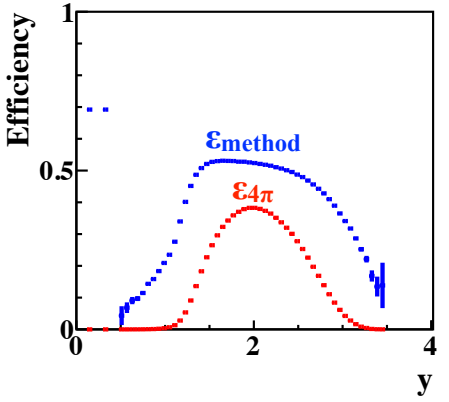
- Is illustrated at the example of Λ hyperon.
- Collect mass spectra in different y-p_t bins.
- Fit the spectra with a signal+background function — calculate an integral of the signal function.
- Fill bins of the y-p_t histogram with the integral values — obtain the y-p_t distribution for the signal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

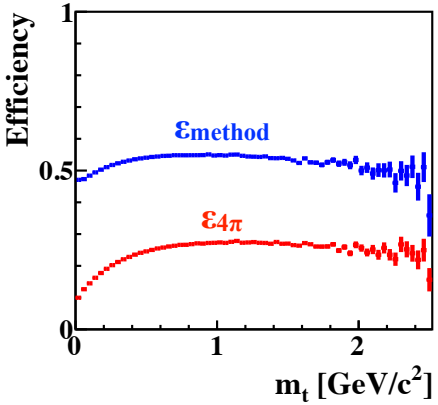
Reconstruction efficiency at the K^0_s example

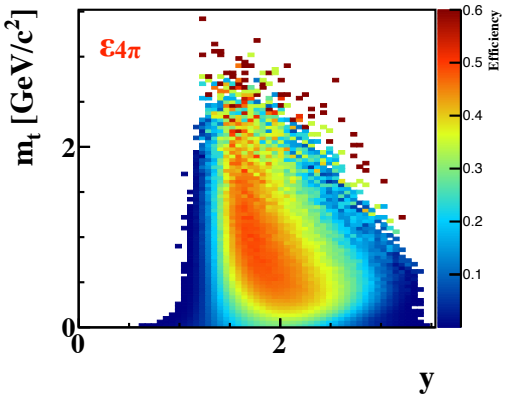










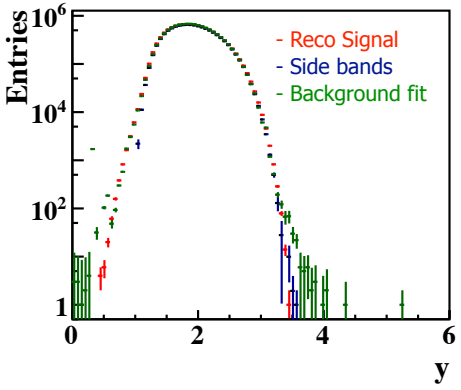


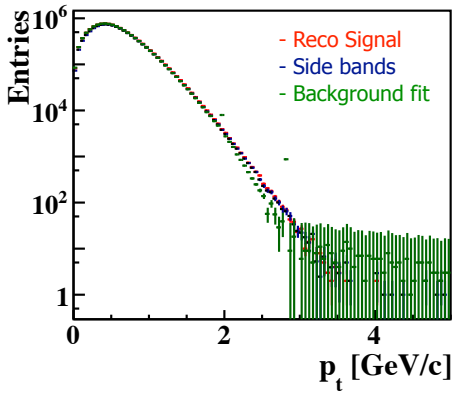
5M central AuAu UrQMD events at 10 AGeV

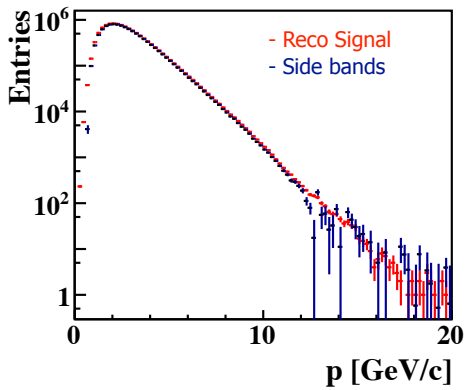
- A set of efficiency plots is collected for each particle decay.
- The efficiencies are shown at the example of $K^0_s \rightarrow \pi^+\pi^-$.
- Efficiencies are used for extraction of the signal spectra.

Efficiency corrected spectra, K^0_s example

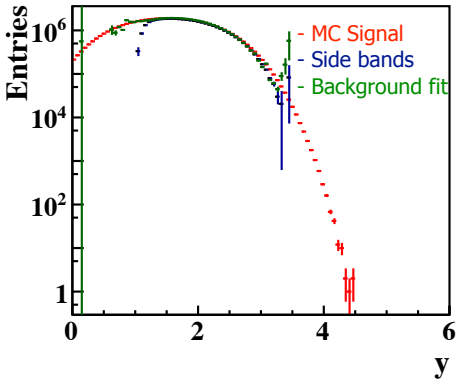
Raw

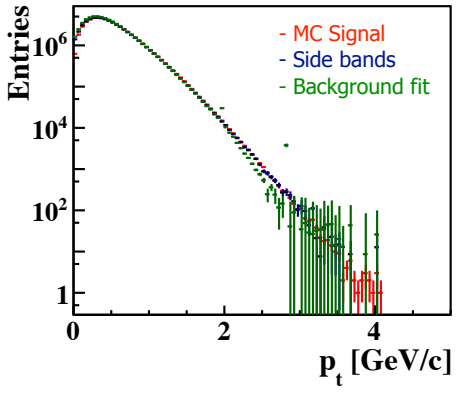


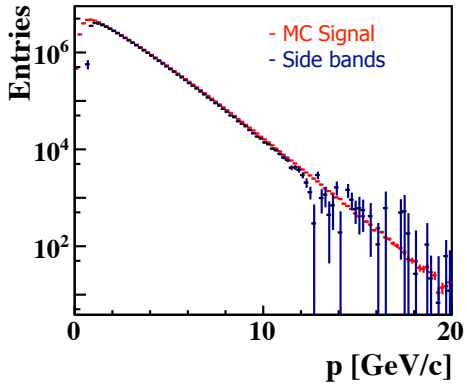




Efficiency corrected



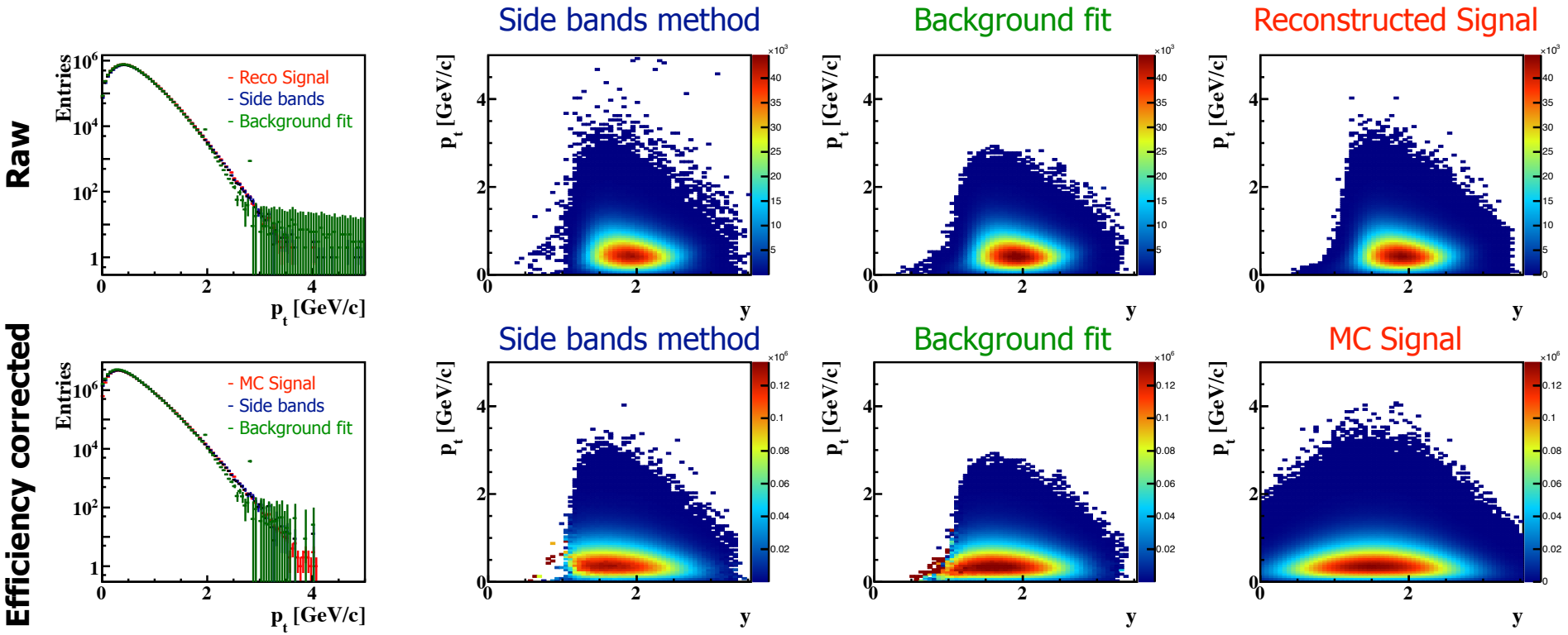




5M central AuAu UrQMD events at 10 AGeV

- Results are shown at the example of $K^0_s \rightarrow \pi^+\pi^-$.
- Implemented methods allow to reconstruct signal spectra (Side bands and Background fit) reproducing the shape of distributions obtained from the reconstructed signal particles (Reco Signal).
- Side band method and multi-differential analysis are in a good agreement.
- Efficiency corrected spectra reproduce the MC Signal distributions.

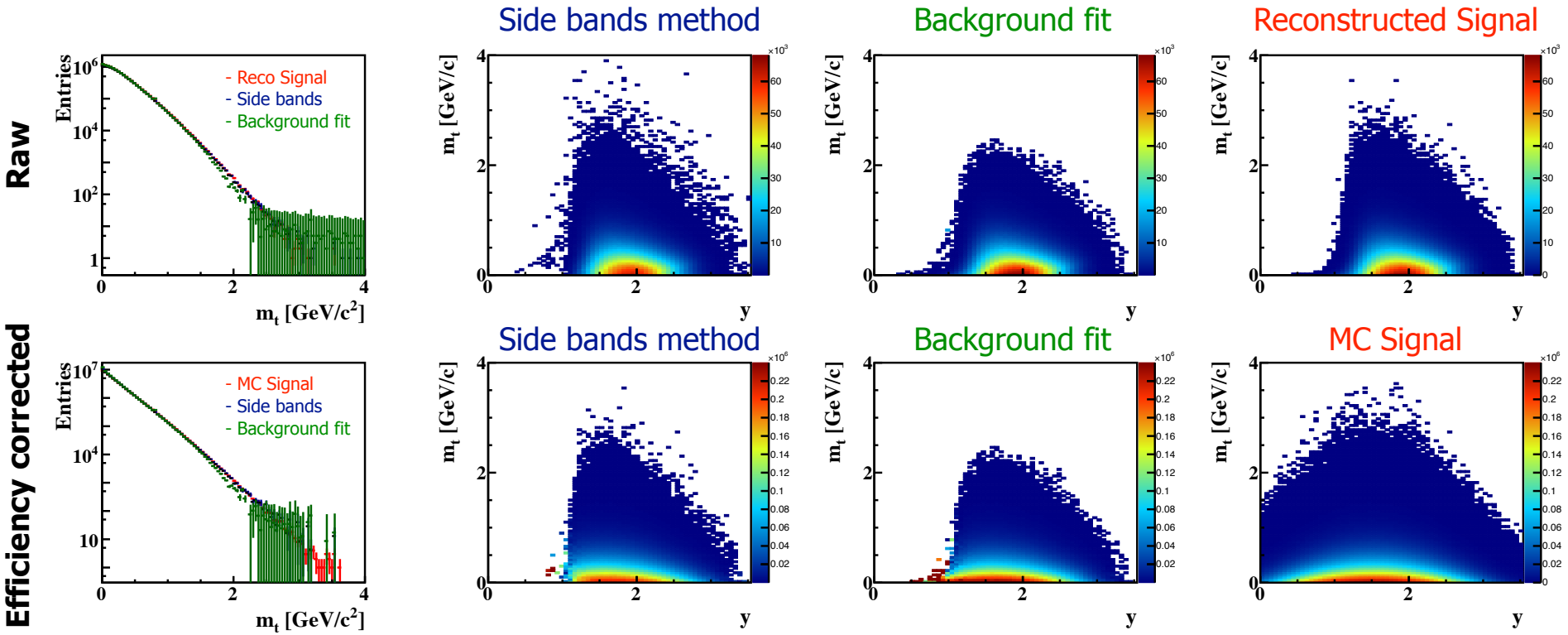
Efficiency corrected spectra in y-p_t bins, K^0_s example



5M central AuAu UrQMD events at 10 AGeV

- Results are shown at the example of $K^0_s \rightarrow \pi^+\pi^-$.
- Similarly to the 1D case, analysis was performed in y-p_t bins.
- Efficiency corrected spectra nicely reproduce MC signal distributions.

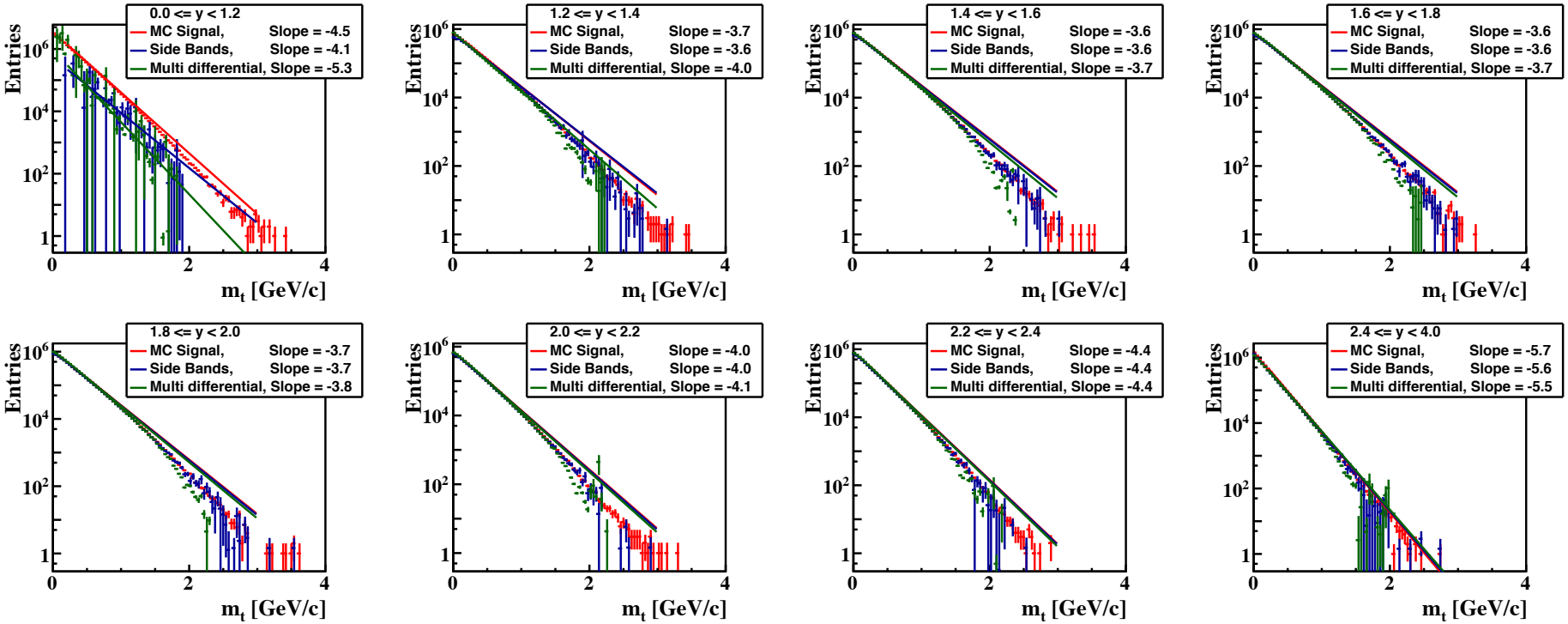
Efficiency corrected spectra in y-m_t bins, K^0_s example



5M central AuAu UrQMD events at 10 AGeV

- Results are shown at the example of $K^0_s \rightarrow \pi^+\pi^-$.
- Similarly to the y-p_t, analysis was performed in y-m_t bins.
- m_t spectra provide a tool for extraction of the inversed slope and, as a result, effective temperature.
- Efficiency corrected spectra nicely reproduce MC Signal distributions.

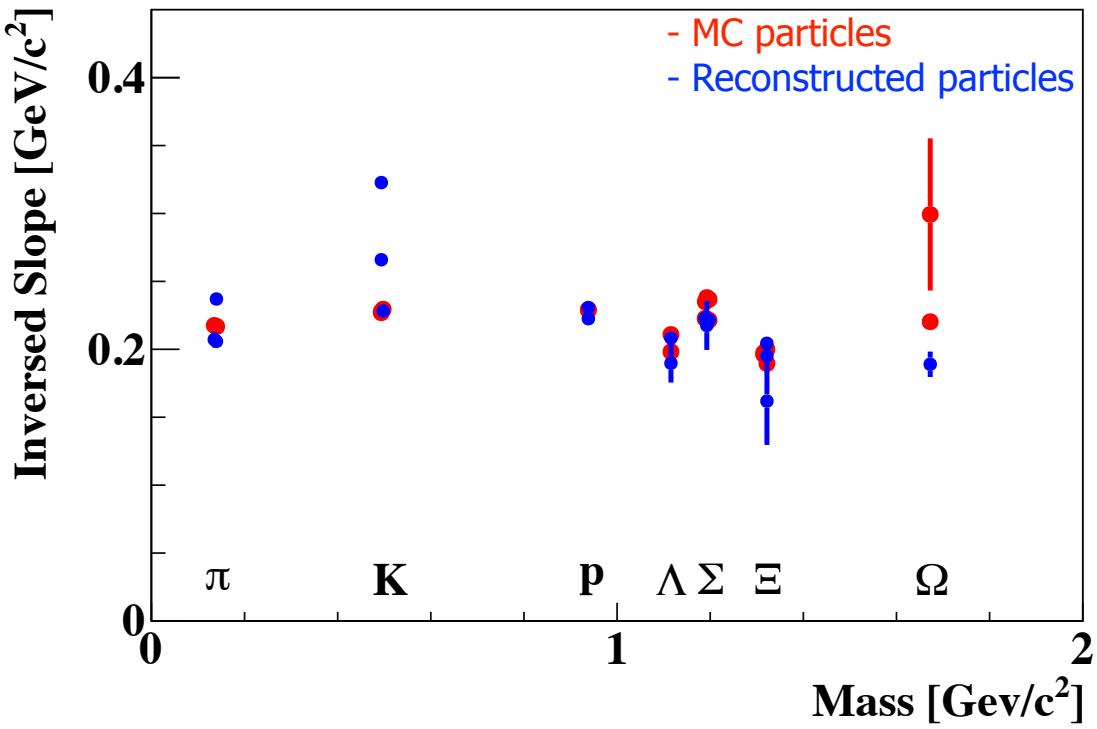
Extraction of the slope from efficiency corrected spectra, K^0_s



5M central AuAu UrQMD events at 10 AGeV

- Results are shown at the example of $K^0_s \rightarrow \pi^+\pi^-$.
- The total efficiency corrected y-m_t spectrum was divided into several y-bins, in each bin m_t spectrum was collected.
- Each m_t spectrum was fitted with the exponential function $f(x) = A \cdot \exp(-m_t/\text{Slope})$.
- Due to the acceptance, results obtained in the first y-bin do not reproduce the MC spectrum, in all other bins they are in a good agreement with the simulated data.

Inverse slope of hadrons



5M central AuAu UrQMD events at 10 AGeV

- To test the machinery the "Nu Xu plot" was calculated using UrQMD events for two sets:
  - MC particles: $\pi^+, \pi^-, \pi^0, K^+, K^-, K^0_s, p, \bar{p}, \Lambda, \bar{\Lambda}, \Sigma^+, \bar{\Sigma}^-, \Sigma^-, \bar{\Sigma}^+, \Sigma^0, \bar{\Sigma}^0, \Xi^-, \bar{\Xi}^+, \Xi^0, \bar{\Xi}^0, \Omega^-, \bar{\Omega}^+$;
  - Reconstructed particles: $\pi^+, \pi^-, \pi^0, K^+, K^-, K^0_s, p, \bar{p}, \Lambda, \bar{\Lambda}, \Sigma^+, \Sigma^-, \Sigma^0, \Xi^-, \bar{\Xi}^+, \Omega^-$.
- Inverse slope of the reconstructed set is in a good agreement with the MC data.
- Further improvements are required:
  - select only primary kaon, pion, proton (one-track long-lived particles) particles;
  - cleanup kaon, pion, proton spectra;
  - add resonances.

Summary and plans

Summary

- Methods for extraction of signal parameters (p, y, p_t, Z, etc.) have been added to KF Particle Finder.
- Tools for extraction of the efficiency corrected spectra have been developed.
- Reconstructed results are in a good agreement with the simulated data.

Plans

- Apply analysis for the 4D reconstruction.