Reconstruction of particles produced at different stages of heavy ion collision in the CBM experiment at FAIR

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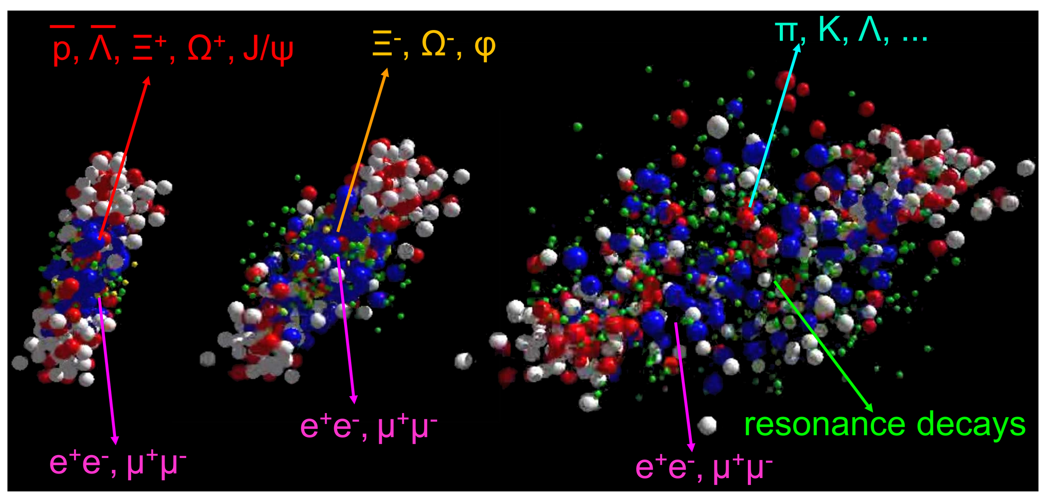
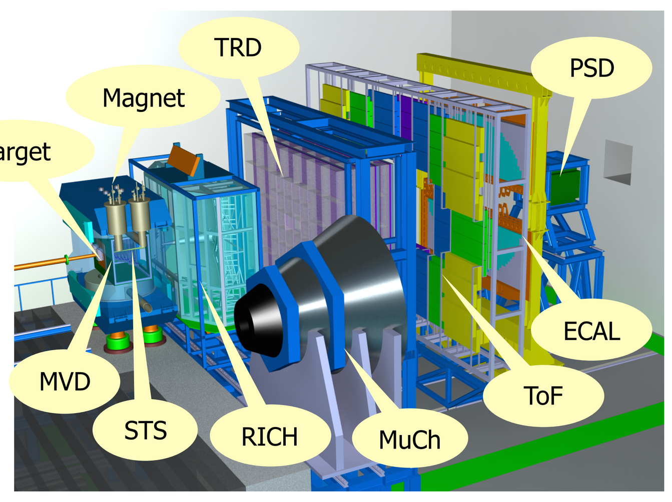
Quark Matter 2017

Compressed Baryonic Matter (CBM) experiment at FAIR



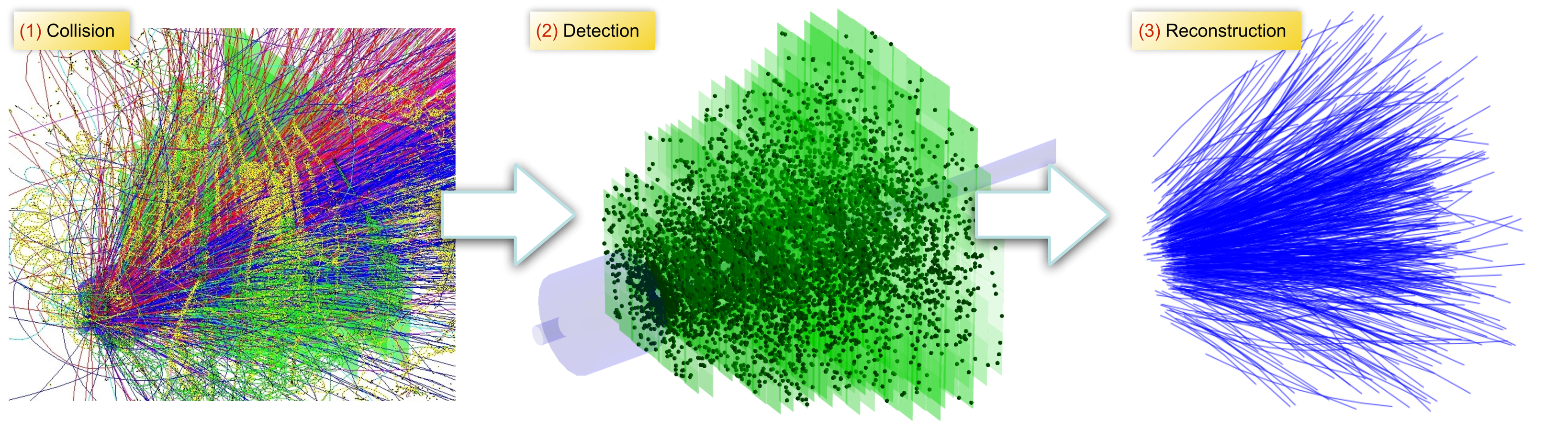


The Compressed Baryonic Matter (CBM) experiment will be one of the major scientific pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. The goal of the CBM research program is to explore the QCD phase diagram in the region of high net baryon densities using high-energy nucleus-nucleus collisions. This includes the study of the equation-of-state of nuclear matter at high densities, and the search for the deconfinement and chiral phase transitions. The CBM detector is designed to measure both bulk observables with large acceptance and rare diagnostic probes such as charmed particles and vector mesons decaying into lepton pairs.

- Future fixed-target heavy-ion experiment
- 10^5-10^7 collisions per second
- Up to 1000 charged particles/collision
- Non-homogeneous magnetic field
- Double-sided strip detectors
- Free streaming data
- No hardware triggers
- On-line event reconstruction and selection

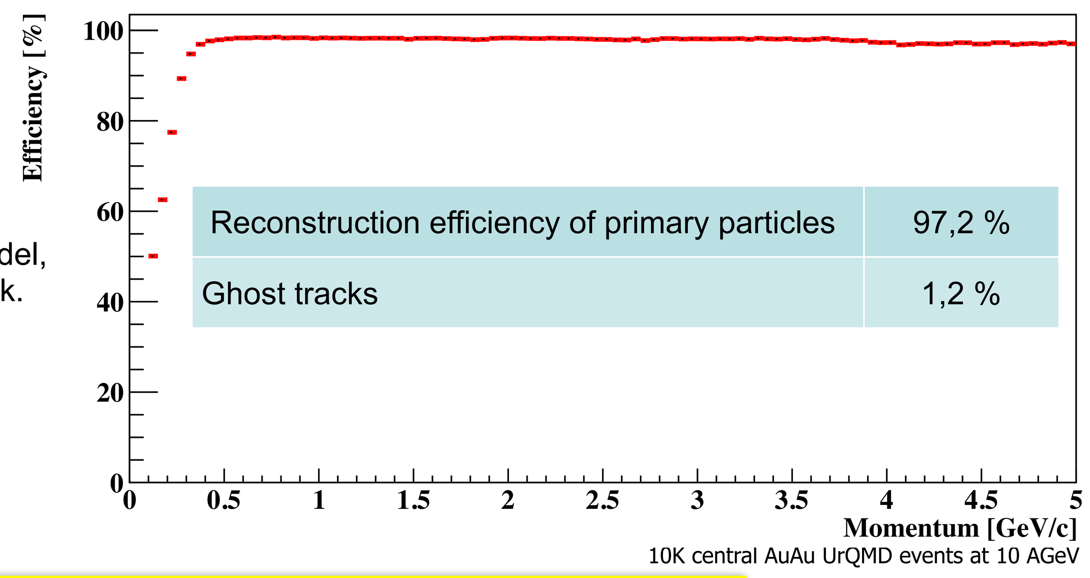
CBM will explore the QCD phase diagram in the region of high baryon densities

(1) Search for long-lived primary particles



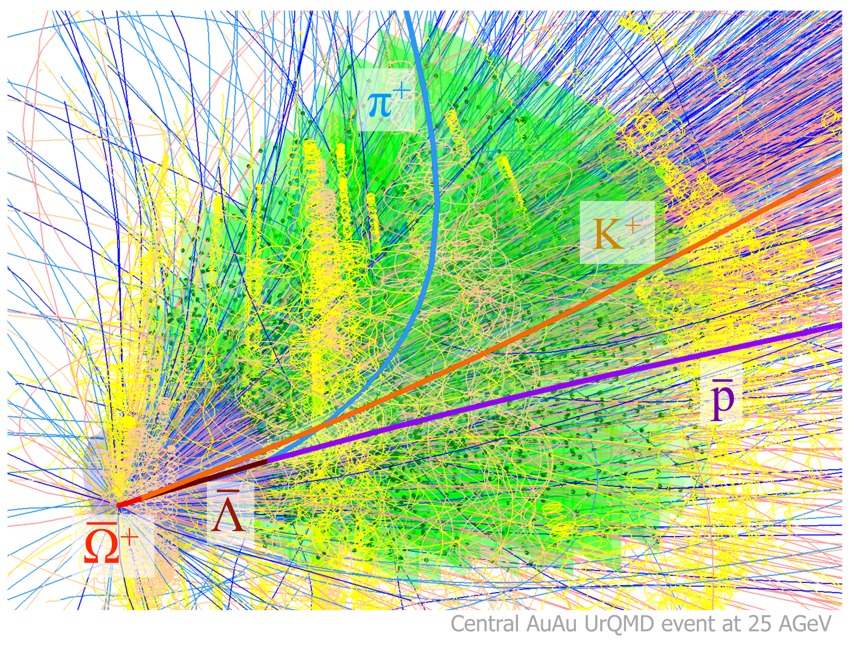
Cellular Automaton (CA) track finder:

1. Build short track segments.
2. Connect them according to the track model, estimate their possible position on a track.
3. Tree structures appear, collect segments into track candidates.
4. Select the best track candidates.



Efficient and clean reconstruction of long-lived primary particles

(2) Search for short-lived particles with charged daughters



Central AuAu UrQMD event at 25 AGeV

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

$\quad\quad \hookrightarrow \bar{p}\, \pi^+$

State vector — Position, direction, momentum and energy

$$\mathbf{r} = \{ x, y, z, p_x, p_y, p_z, E \}$$

Concept:

- Mother and daughter particles have the same state vector and are treated in the same way
- Reconstruction of decay chains
- Kalman filter based
- Geometry independent
- Vectorized
- Uncomplicated usage

```
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
```

Functionality:

- Construction of short-lived particles
- Addition and subtraction of particles
- Transport
- Calculation of an angle between particles
- Calculation of distances and deviations
- Constraints on mass, production point and decay length
- KF Particle Finder

A universal platform for short-lived particles reconstruction and physics analysis on-line and off-line

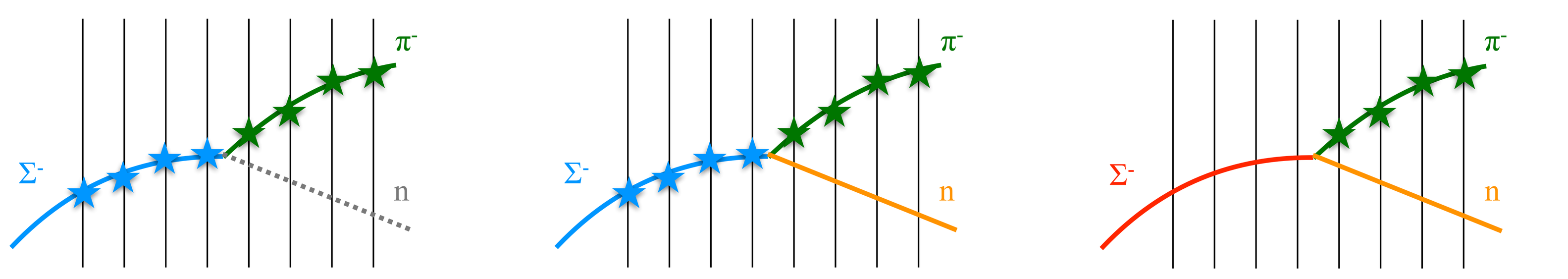
(3) Search for short-lived particles with one neutral daughter

One of possible signals of QGP formation is enhanced strangeness production. Being abundant particles (several particles per collision are produced at the CBM energies), Σ^+ and Σ^- carry out large fraction of produced strange quarks. Reconstruction of Σ-particles together with other strange particles completes the picture of strangeness production and allows to compare yields of Σ and Σ^*, that can be also an indication of the QGP phase. Reconstruction of Σ-particle will open a possibility to investigate *H*-dybarion objects, if such exist, by the decay channel $\Sigma^- p$, which is expected to be the dominant one.

Approach:

- Σ^+ and Σ^- 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 Σ^+ and $c\tau$ = 4.4 cm for Σ^-.
- Cannot to be identified by the PID detectors.
- Identification is possible by the decay topology using the missing mass method:

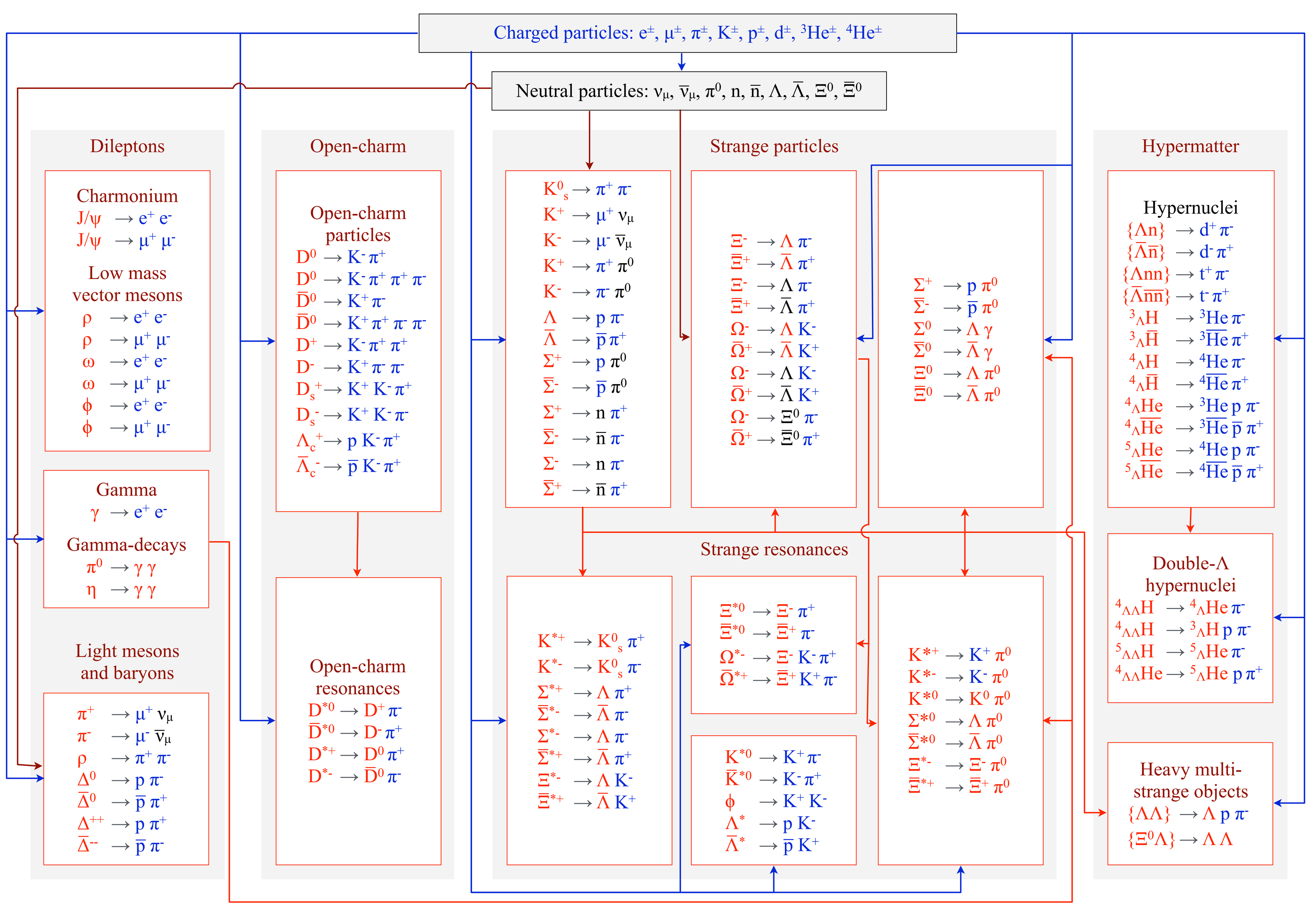
1. Find tracks of Σ and its charged daughter in STS and MVD
2. Reconstruct a neutral daughter from the mother and the charged daughter
3. Reconstruct Σ mass spectrum from the charged and obtained neutral daughters



The method can be applied for reconstruction of other strange particles. Their investigation will allow to recover the efficiency of the corresponding particles and to investigate systematic errors comparing yields of different decay channels.

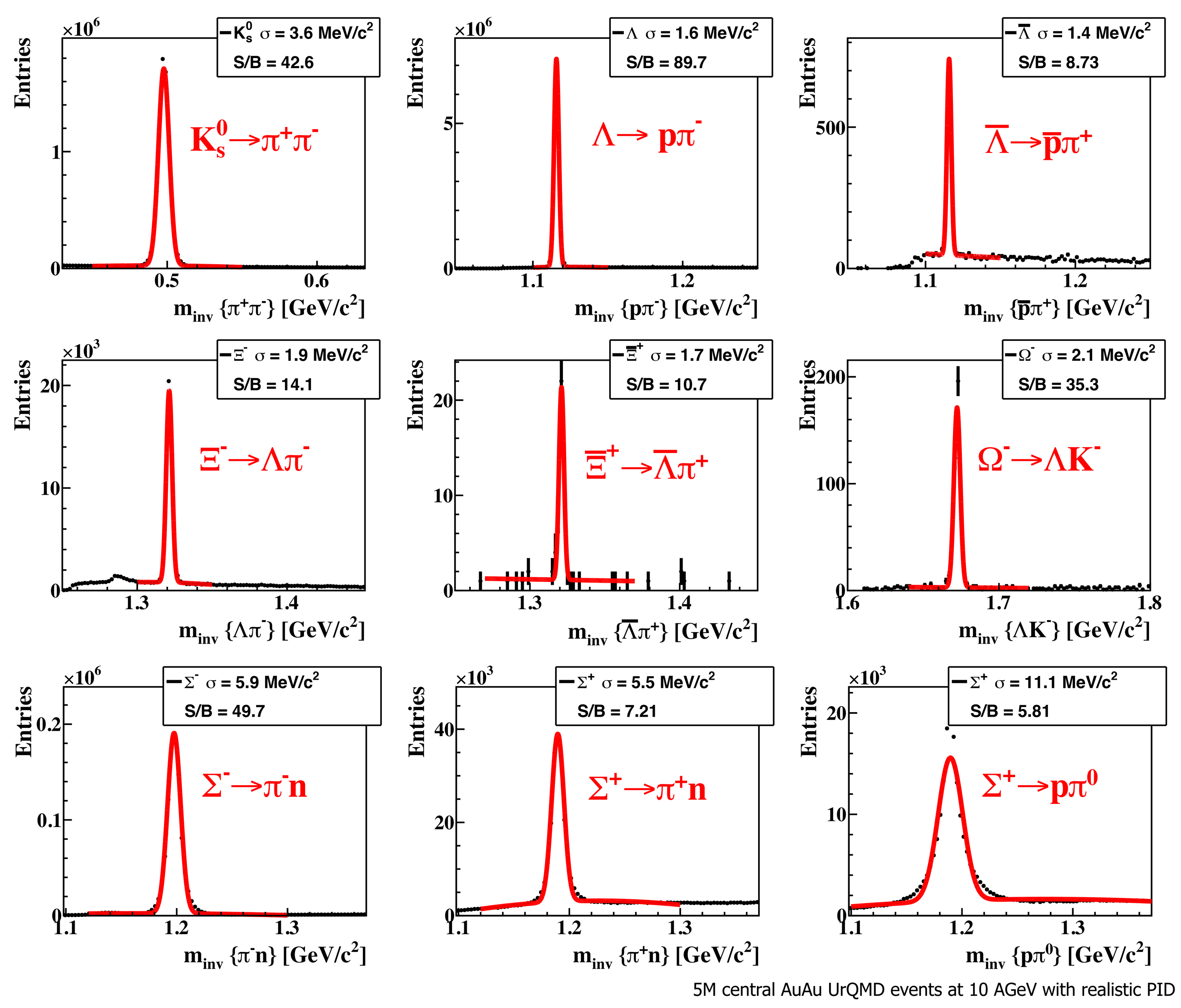
Reconstruction of short-lived particles with one neutral daughter using the missing mass method

Kalman Filter (KF) particle finder



Highly parallelized and vectorized for use on many-core CPU/Phi/GPU computer architectures

Short-lived particle probes of different stages in collision



Clean reconstruction of short-lived particles produced at different stages of heavy-ion collisions

Conclusions

- ✓ CBM will explore the QCD phase diagram in the region of high net baryon densities
- ✓ Efficient and clean reconstruction of long-lived primary particles with the CA track finder
- ✓ KF particle finder is a universal platform for short-lived particles reconstruction and physics analysis in on-line and off-line modes
- ✓ Reconstruction is highly parallelized and vectorized for use on many-core CPU/Phi/GPU computer architectures
- ✓ Clean reconstruction of long- and short-lived particles produced at different stages of heavy-ion collisions