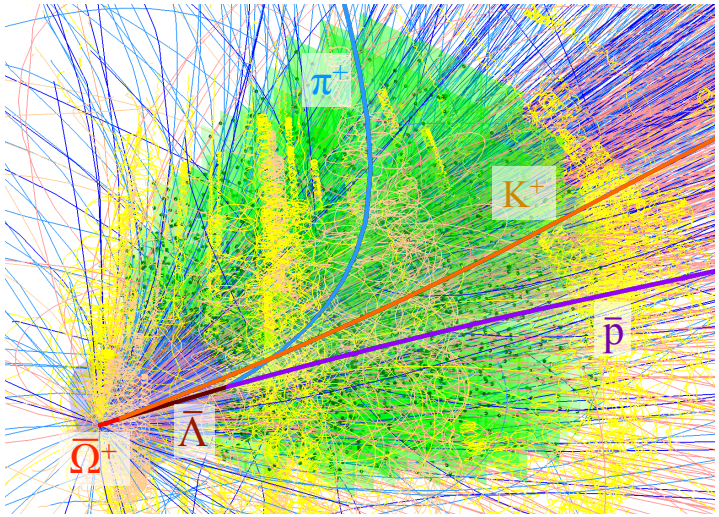
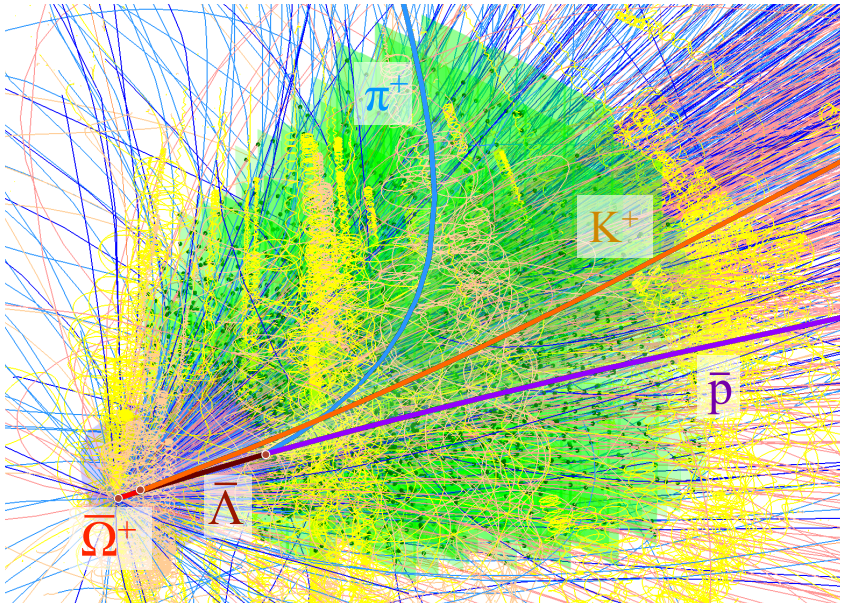
Pavel Kisel

KF Particle Finder: Missing Mass Method for Reconstruction of Strange Particles



KF Particle Library



Simulated AuAu collision at 25 GeV/n, PHSD+GEANT3

$\bar{\Omega}^+ \leftarrow \bar{\Lambda}\ K^+$
$\bar{p}\ \pi^+$

State vector of particle parameters:

$$\mathbf{r} = [x, y, z, p_x, p_y, p_z, E, 1/p]$$

Covariance matrix of their errors:

$$\mathbf{C} = \mathrm{cov}(\mathbf{r}) = \begin{bmatrix} \sigma_x^2 & C_{xy} & C_{xz} & C_{xp_x} & C_{xp_y} & C_{xp_z} & C_{xE} \\ C_{xy} & \sigma_y^2 & C_{yz} & C_{yp_x} & C_{yp_y} & C_{yp_z} & C_{yE} \\ C_{xz} & C_{yz} & \sigma_z^2 & C_{zp_x} & C_{zp_y} & C_{zp_z} & C_{zE} \\ C_{xp_x} & C_{yp_x} & C_{zp_x} & \sigma_{p_x}^2 & C_{p_xp_y} & C_{p_xp_z} & C_{p_xE} \\ C_{xp_y} & C_{yp_y} & C_{zp_y} & C_{p_xp_y} & \sigma_{p_y}^2 & C_{p_yp_z} & C_{p_yE} \\ C_{xp_z} & C_{yp_z} & C_{zp_z} & C_{p_xp_z} & C_{p_yp_z} & \sigma_{p_z}^2 & C_{p_yE} \\ C_{xE} & C_{yE} & C_{zE} & C_{p_xE} & C_{p_yE} & C_{p_zE} & \sigma_E^2 \end{bmatrix}$$

The **KF Particle** library is an essential tool for efficient physics analysis in **STAR**, **ALICE** and **CBM**.

Extended concept:

- Kalman Filter (KF) based mathematics
- mother and daughter particles have the same form of the state vector and the covariance matrix
- works in 3D space, therefore geometry independent
- vectorized to use SIMD of modern computer architectures

Rich in functionality:

- construction of short-lived particles
- transport of a particle state vector to any point
- calculation of an angle between particles
- constraints on mass, production point and decay length
- and many other important features used in physics analysis

The KF Particle library is the software foundation for comprehensive reconstruction and analysis of collisions in online and offline modes

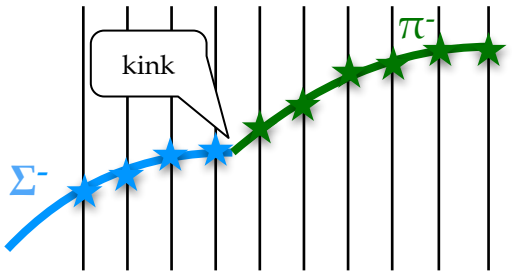
Introduction to the Missing Mass Method

Consider the Missing Mass Method using the decay $\Sigma^- \rightarrow n\pi^-$.

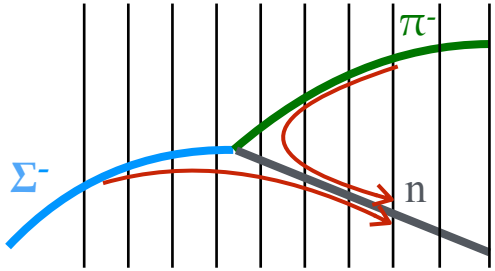
The Missing Mass Method is based on the laws of conservation of energy and momentum:

$$E_\Sigma = E_\pi + E_n \qquad \vec{p}_\Sigma = \vec{p}_\pi + \vec{p}_n$$

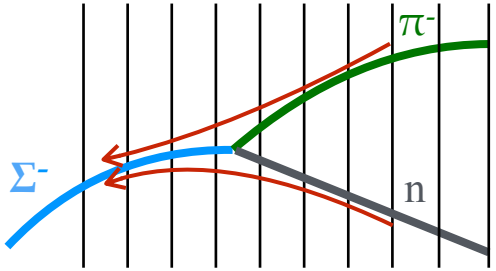
1. Find tracks of Σ^- and π^-



2. Reconstruct n from Σ^- and π^-

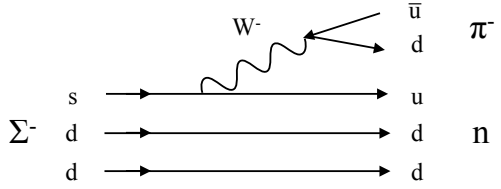


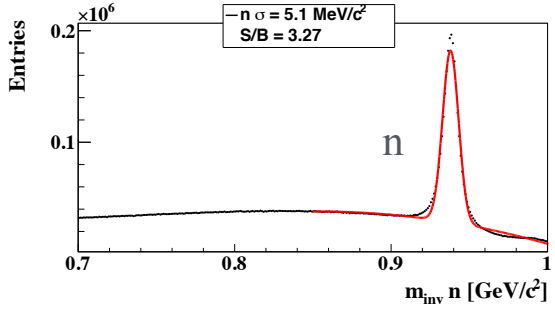
3. Reconstruct Σ^- from n and π^-

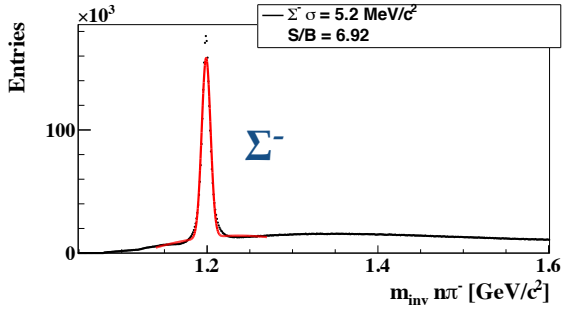


The implementation of the method for $\Sigma^- \rightarrow n\pi^-$ (**BR = 99.8%**) decay has three steps:

1. Find the tracks of Σ^- and its charged daughter particle π^- in the tracking system.
2. Reconstruct the parameters of the neutral daughter particle **n** using the parameters of the mother particle and the charged daughter.
3. Reconstruct the mother particle Σ^- from the charged π^- and obtained neutral **n** daughter particles.

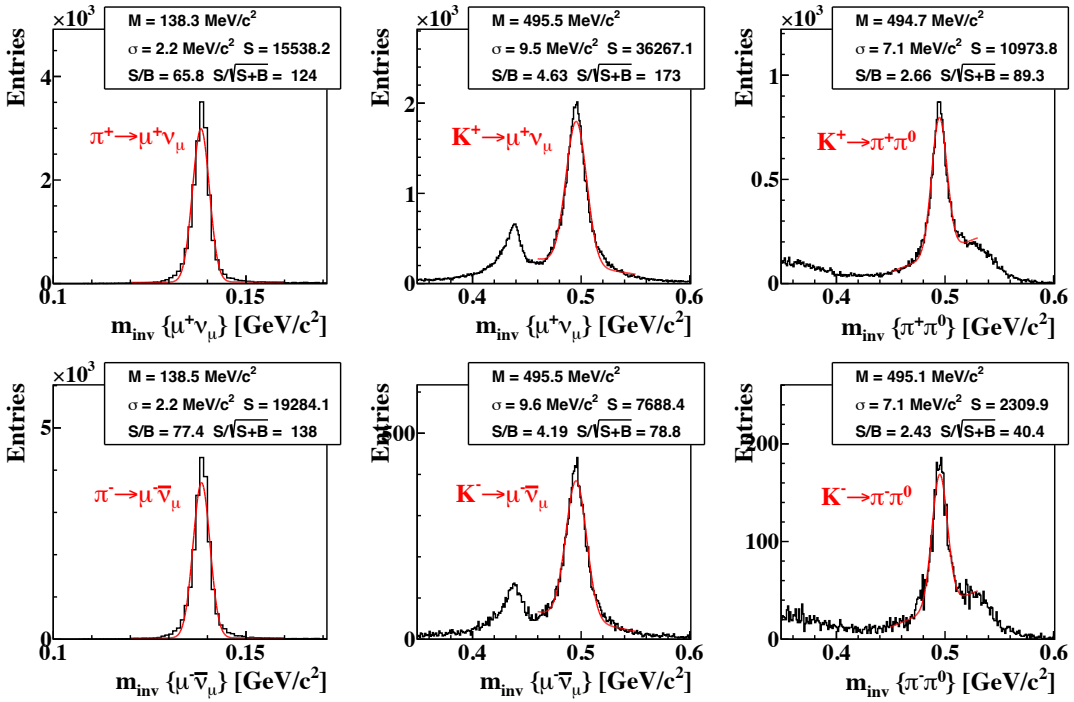






The Missing Mass Method significantly extends the possibilities of studying strange particles

STAR, Run 20, HLT Online Production



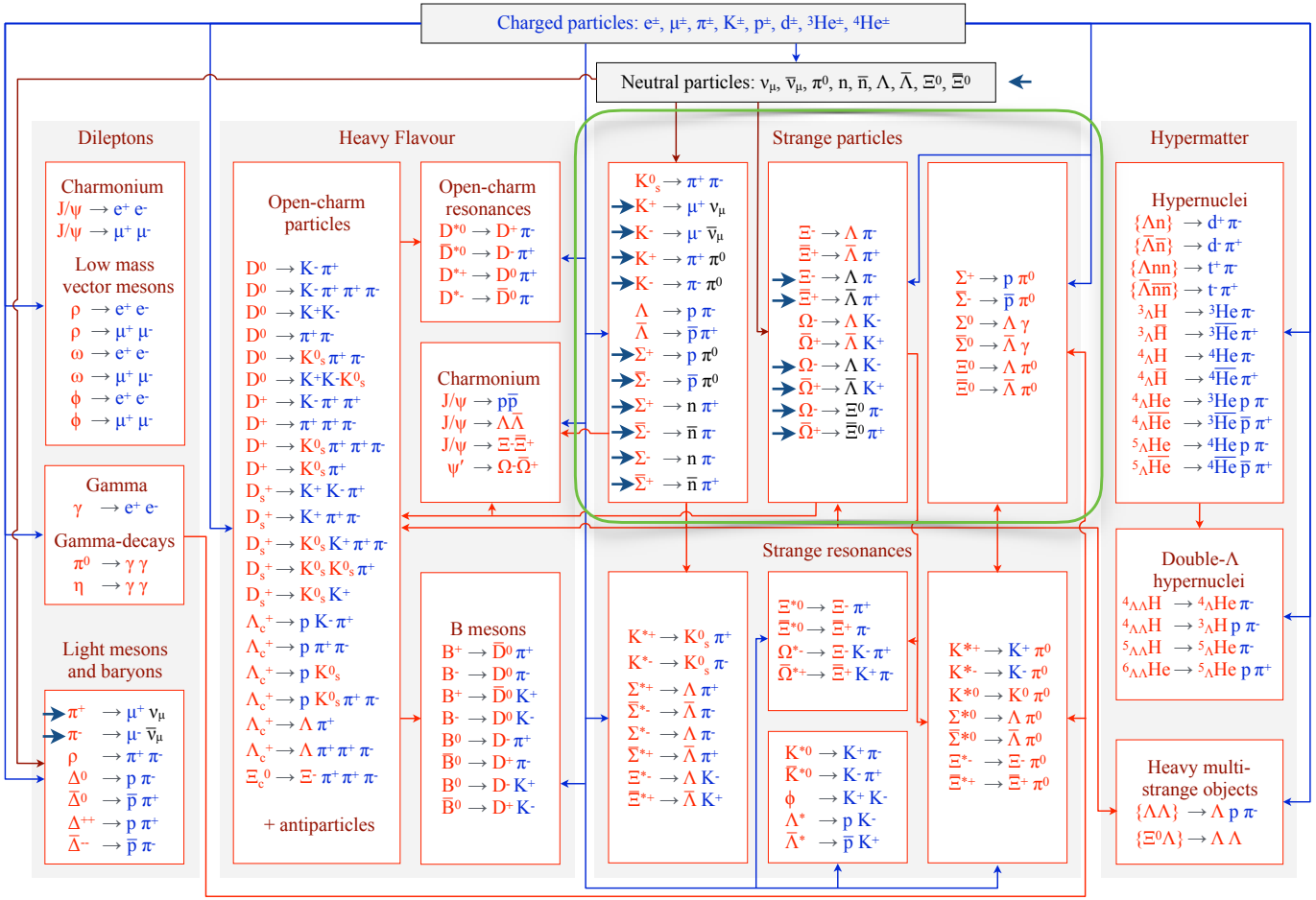
2M AuAu collisions with 5.75+7.3+9.8+26.5 GeV/n, 2020

	$\pi^+ \to \mu^+\nu$		$\pi^- \to \mu^-\nu$		$K^+ \to \mu^+\nu$		$K^- \to \mu^-\nu$		$K^+ \to \pi^+\pi^0$		$K^- \to \pi^-\pi^0$	
	Signal	Signif.	Signal	Signif.	Signal	Signif.	Signal	Signif.	Signal	Signif.	Signal	Signif.
Initial	340	18.2	505	22.3	19415	130	4117	59.9	5609	66.5	1181	30.6
Final	15538	124	19284	138	36267	173	7688	78.8	10973	89.3	2309	40.4
Factor	**45.7**	6.8	**38.1**	6.2	**1.87**	1.33	**1.87**	1.32	**1.96**	1.34	**1.96**	1.32

- The Missing Mass Method was applied to real data 2016 offline, and to 2020 and 2021 BES-II FXT data processed on HLT.
- Here is a comparison of the initial and final versions on real STAR data collected in 2020, where the advantage of the final version became clearly evident in the pion decay channels.

In the final version in the channels $\pi^\pm \to \mu^\pm\nu$ the signal increased by a factor of 40, and the significance increased by a factor of 7, in the channels $K^\pm \to \mu^\pm\nu$ and $K^\pm \to \pi^\pm\pi^0$ the signal increased by a factor of 2, and the significance by 33%

KF Particle Finder



- The task of the KF Particle Finder package is to search in real time for all short-lived particles of interest.
- All procedures of the package are vectorized and parallelized, and its running time is on average 1.4 ms/event/core.
- Currently the package contains procedures for searching more than 150 decays of short-lived particles of different types.
- Based on the Missing Mass Method, the procedures for searching 9 neutral particles, 2 decays of light mesons, and 16 decays of strange particles have been created.

In the KF Particle Finder, 55% (16 of 29) of decays of strange particles are reconstructed by the Missing Mass Method