Event Topology Reconstruction in the CBM Experiment

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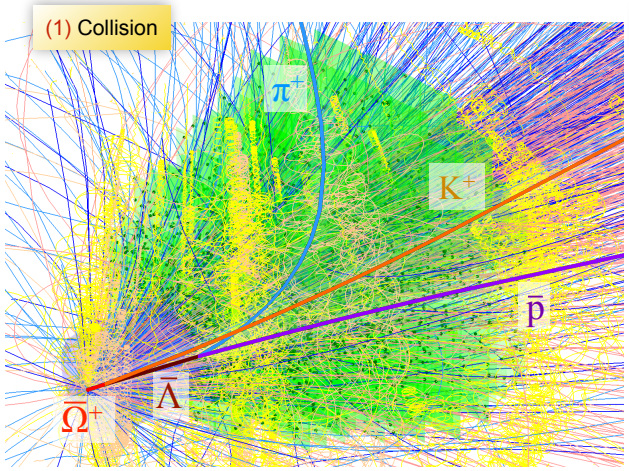
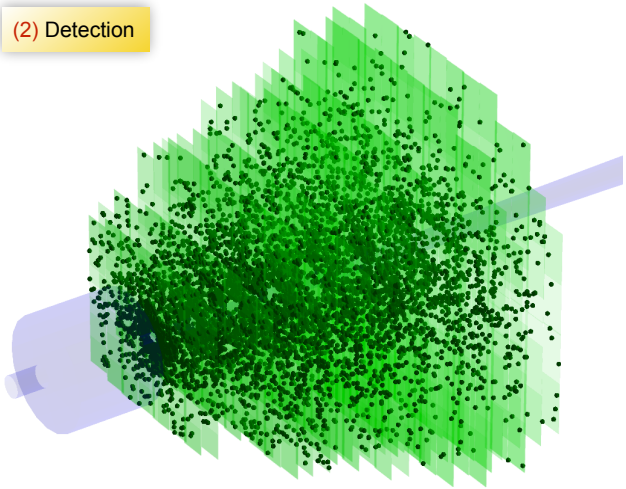
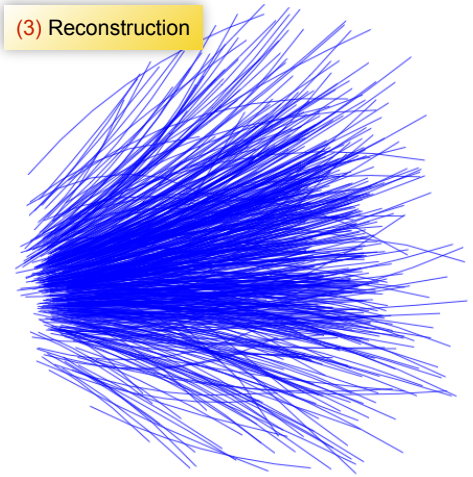
Goethe University Frankfurt am Main
FIAS Frankfurt Institute for Advanced Studies
GSI Helmholtz Center for Heavy Ion Research

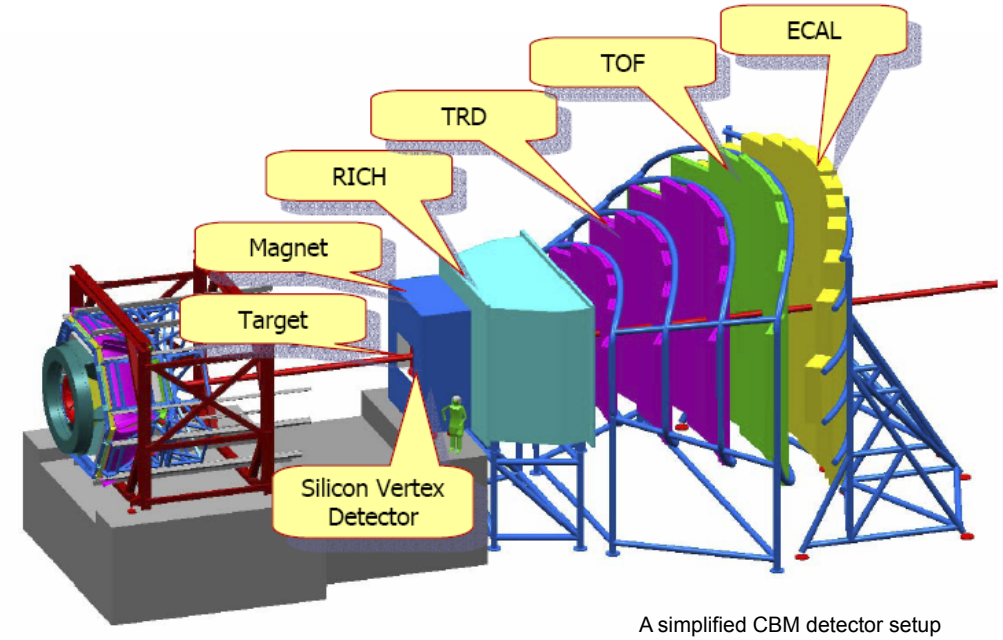
Reconstruction Challenge in CBM





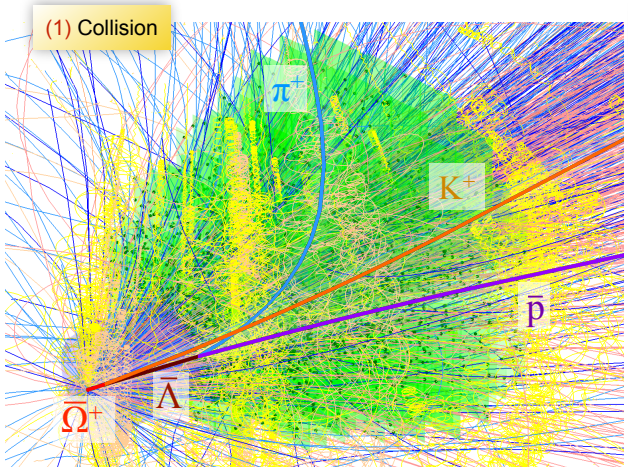


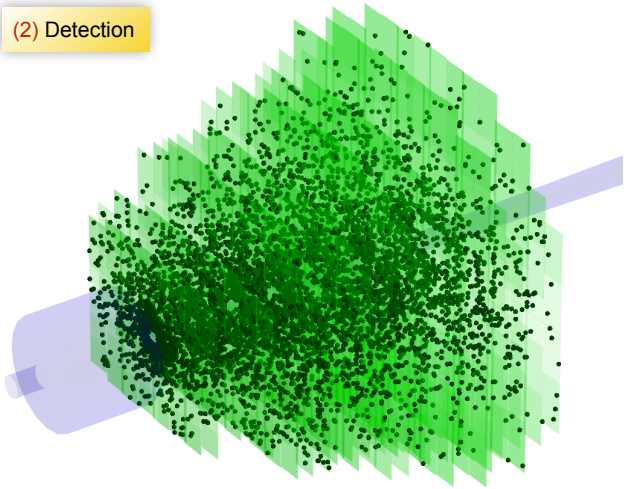
- Future fixed-target heavy-ion experiment at FAIR
- Explore the phase diagram at high net-baryon densities
- 10^7 Au+Au collisions/sec
- ~ 1000 charged particles/collision
- Non-homogeneous magnetic field
- Double-sided strip detectors
- 4D reconstruction of time slices.

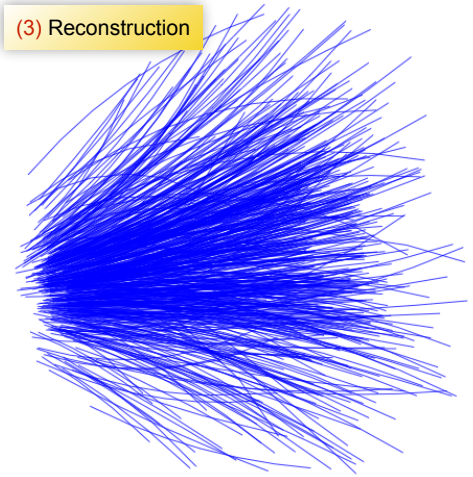


A simplified CBM detector setup

Reconstruction Challenge in CBM



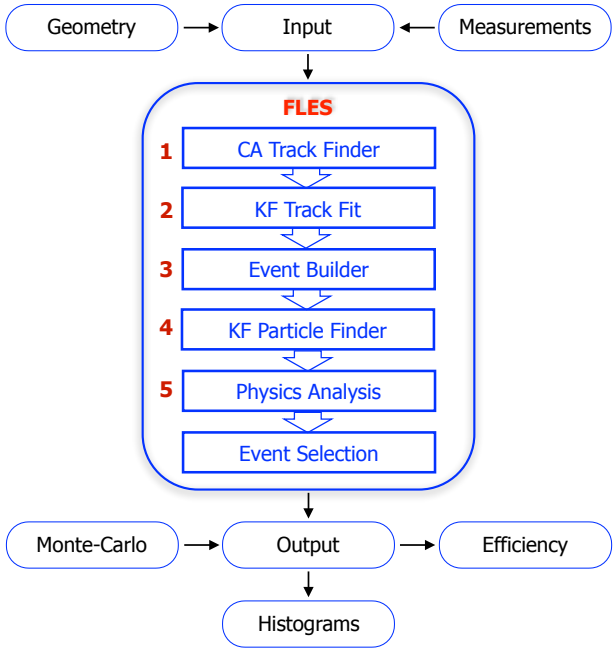




The full event reconstruction will be done on-line at the First-Level Event Selection (FLES) and off-line using the same FLES reconstruction package.

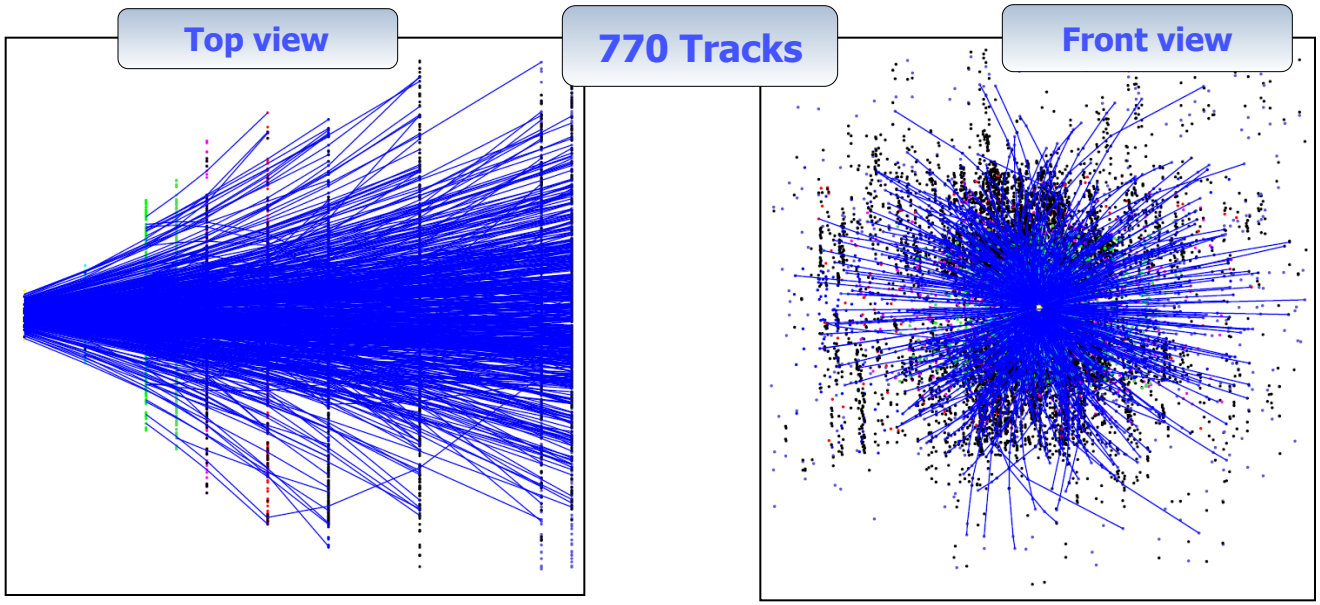
- Cellular Automaton (CA) Track Finder
- Kalman Filter (KF) Track Fitter
- KF short-lived Particle Finder

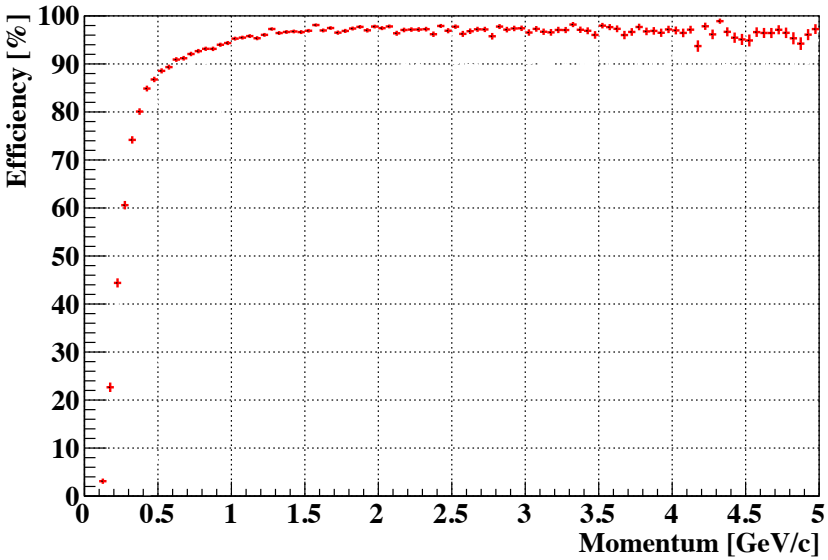
All reconstruction algorithms are vectorized and parallelized.



Cellular Automaton (CA) Track Finder

V. Akishina



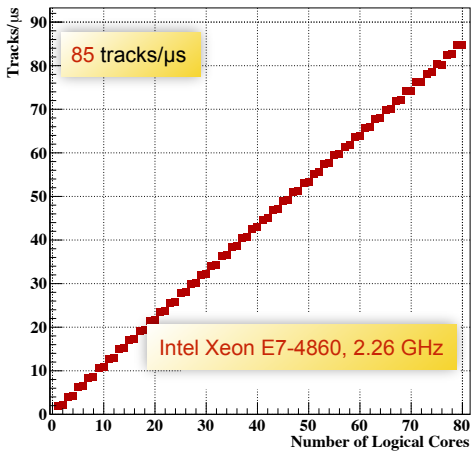


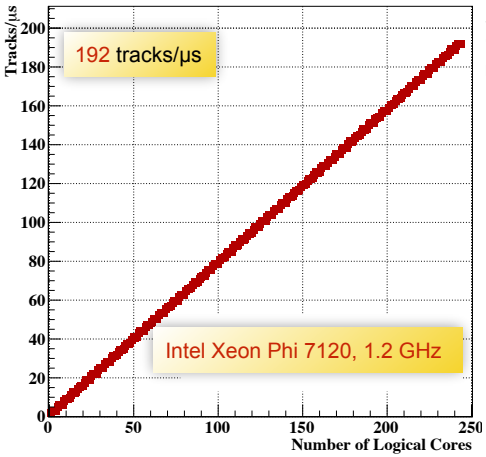
Track category	Eff, %
All tracks	90.9
Primary high-p	97.5
Primary low-p	92.6
Secondary high-p	91.1
Secondary low-p	63.8
Clone level	0.4
Ghost level	5.9
MC tracks found	134
Time, ms/ev	10

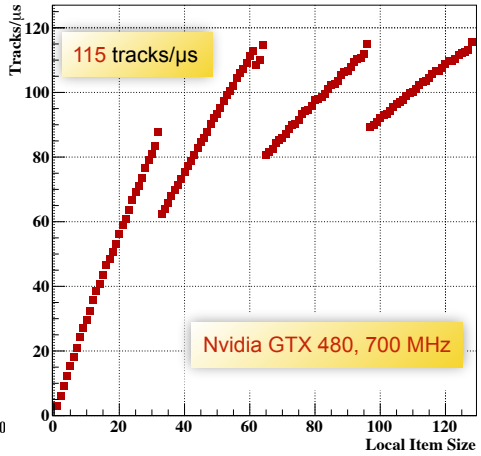
Fast and efficient track finder

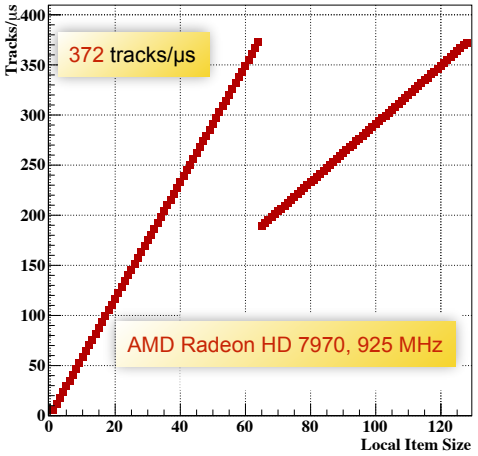
Kalman Filter (KF) Track Fit

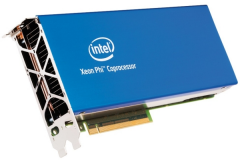
M. Zyzak











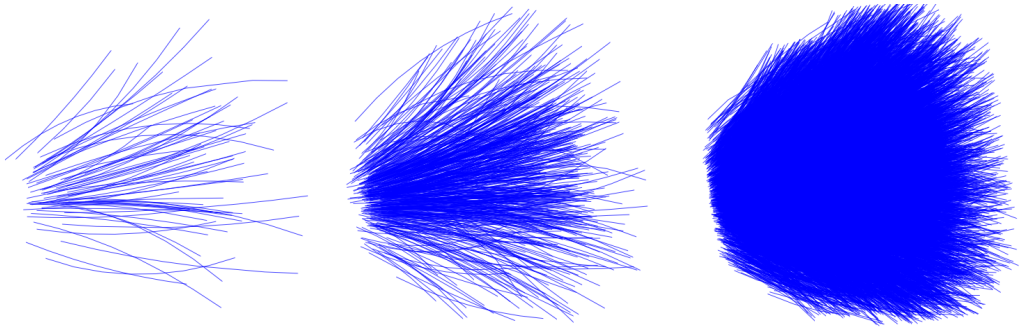
- Precise estimation of the parameters of particle trajectories is the core of the reconstruction procedure.
- The track fit performance on a single node: 2*CPU+2*GPU = 10^9 tracks/s = (100 tracks/event)* 10^7 events/s = 10^7 events/s.
- One computer is enough to estimate parameters of all particles produced at 10^7 interaction rate!

Fast, precise and portable Kalman filter track fit

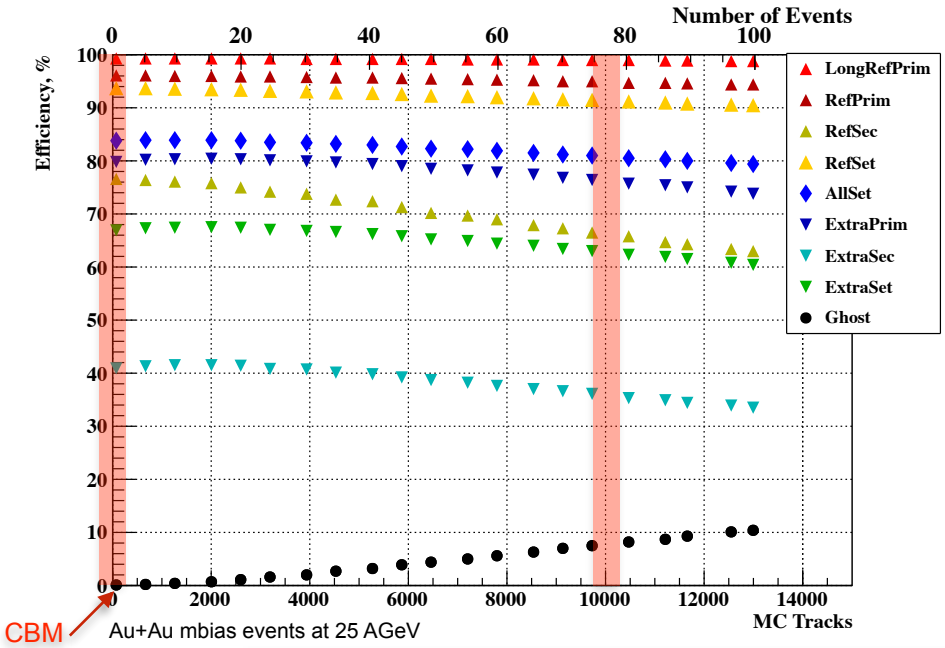
CA Track Finder at High Track Multiplicity

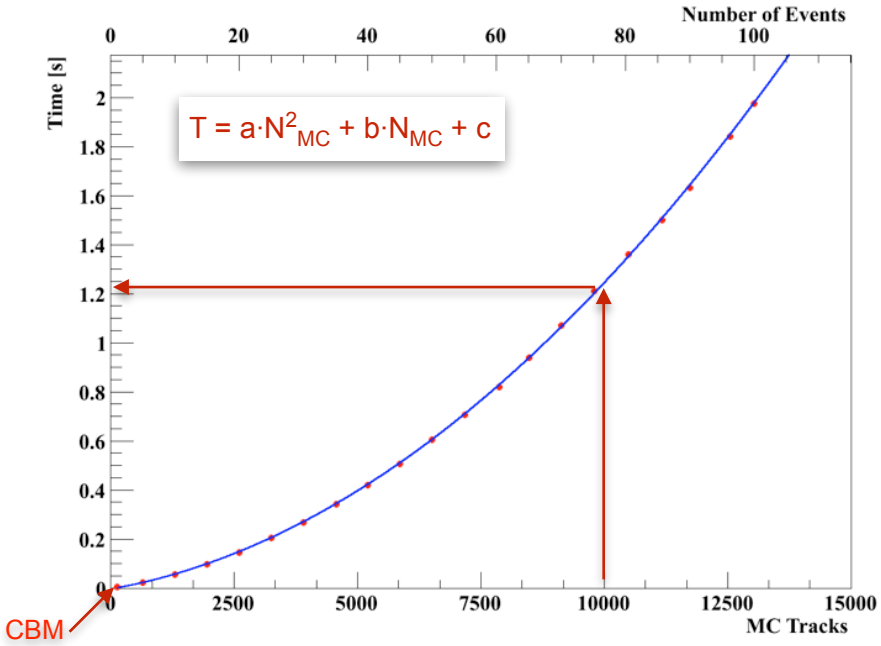
V. Akishina

A number of minimum bias events is gathered into a group (super-event), which is then treated by the CA track finder as a single event.



1 mbias event, $\langle N_{reco} \rangle = 109$ 5 mbias events, $\langle N_{reco} \rangle = 572$ 100 mbias events, $\langle N_{reco} \rangle = 10340$

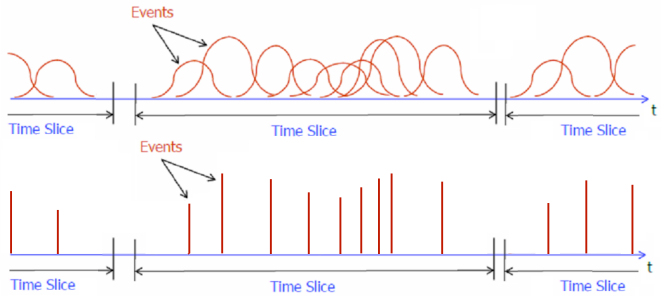




Reliable reconstruction efficiency and time as a second order polynomial w.r.t. to the track multiplicity

Time-based (4D) Track Reconstruction

V. Akishina

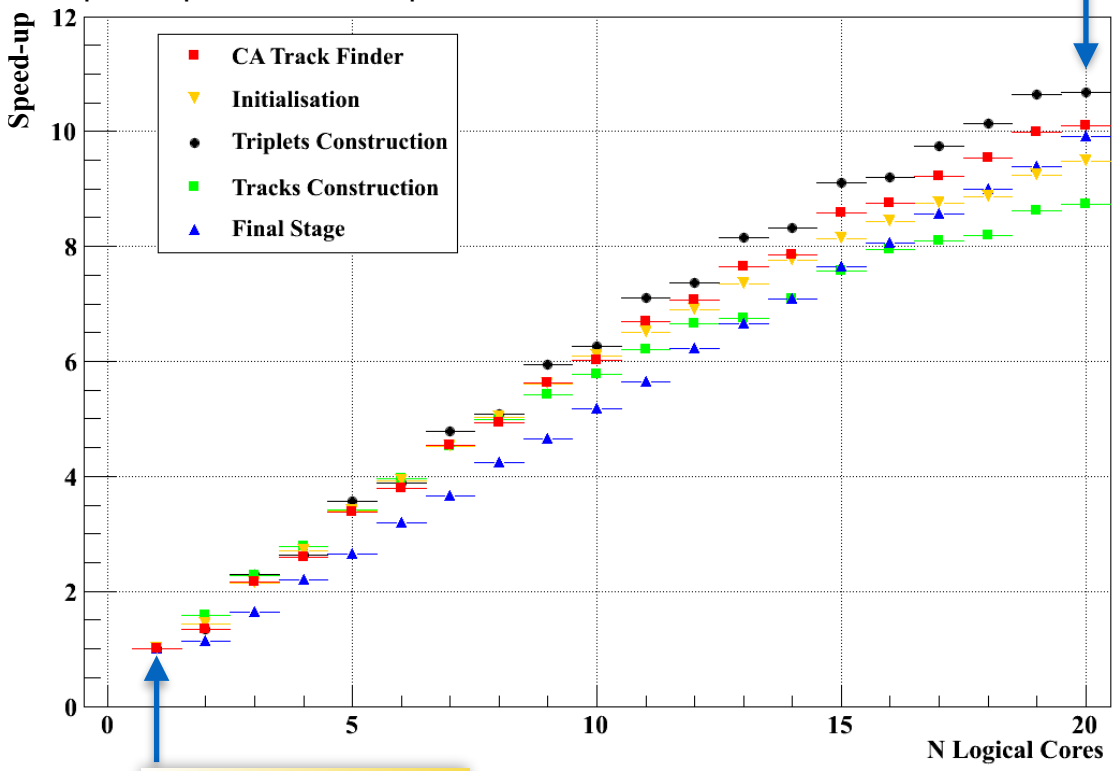


- The beam in the CBM will have no bunch structure, but continuous.
- Measurements in this case will be 4D (x, y, z, t).
- Significant overlapping of events in the detector system.
- Reconstruction of time slices rather than events is needed.

Efficiency, %	3D	4D
All tracks	83.8	83.0
Primary high-p	96.1	92.8
Primary low-p	79.8	83.1
Secondary high-p	76.6	73.2
Secondary low-p	40.9	36.8
Clone level	0.4	1.7
Ghost level	0.1	0.3
Time/event/core, ms	8.2	8.5

Total CA time = 84 ms

Speed-up factor due to parallelization within the time-slice



Total CA time = 849 ms

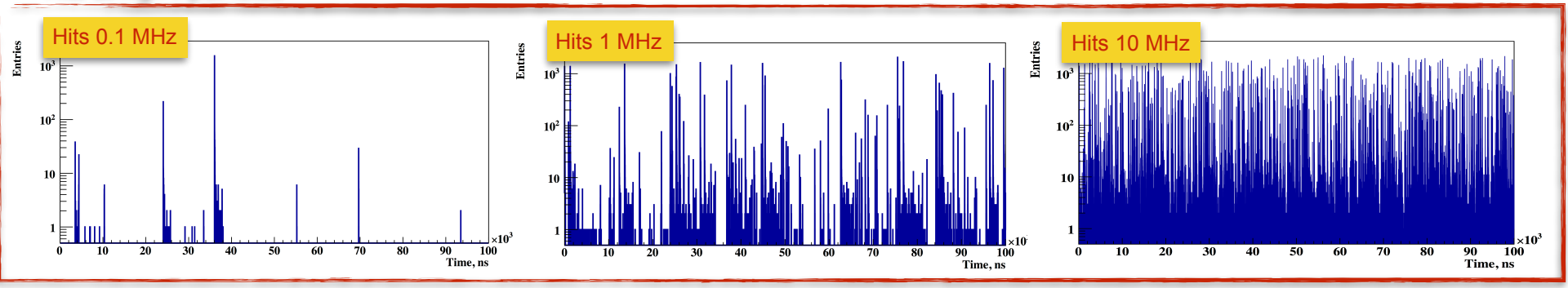
100 mbias events in a time-slice

3D reconstruction time 8.2 ms/event is recovered in 4D case

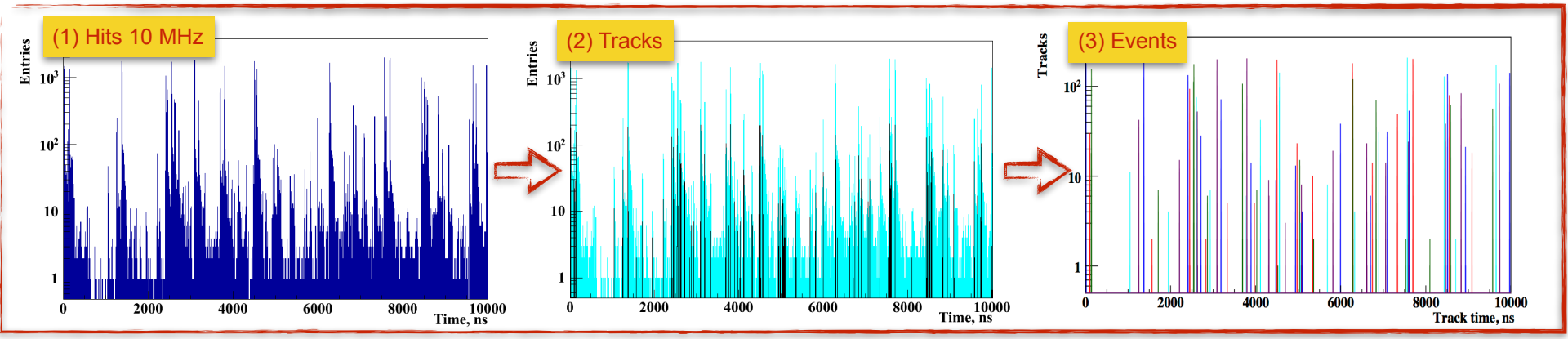
4D Event Building at 10 MHz

V. Akishina

Hits at high input rates



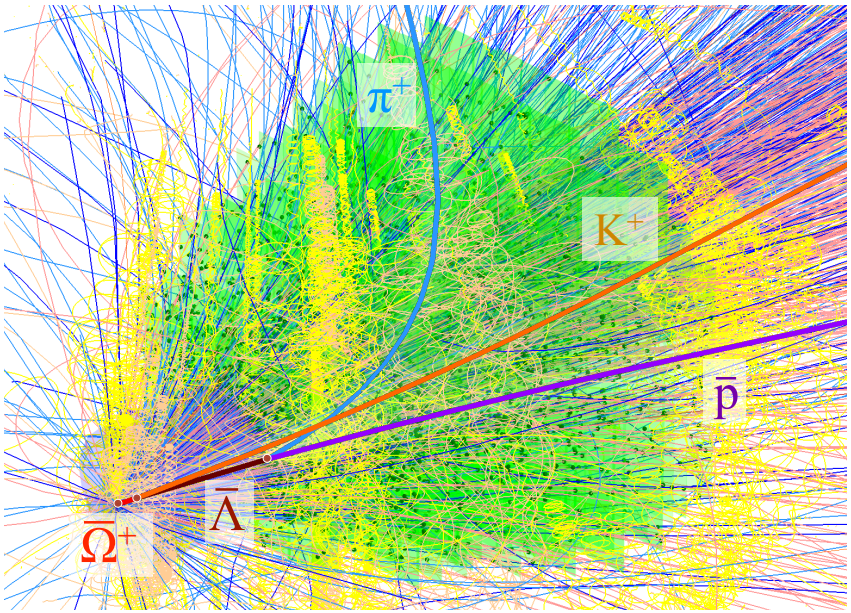
From hits to tracks to events



Reconstructed tracks clearly represent groups, which correspond to the original events:
85% of single events, no splitted events, further analysis with TOF information at the vertexing stage

KF Particle: Reconstruction short-lived Particles

M. Zyzak



Simulated AuAu collision at 25 AGeV

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

```
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
```

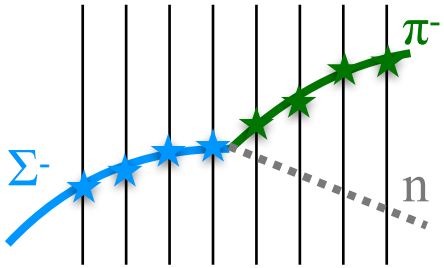
Concept:

- 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

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

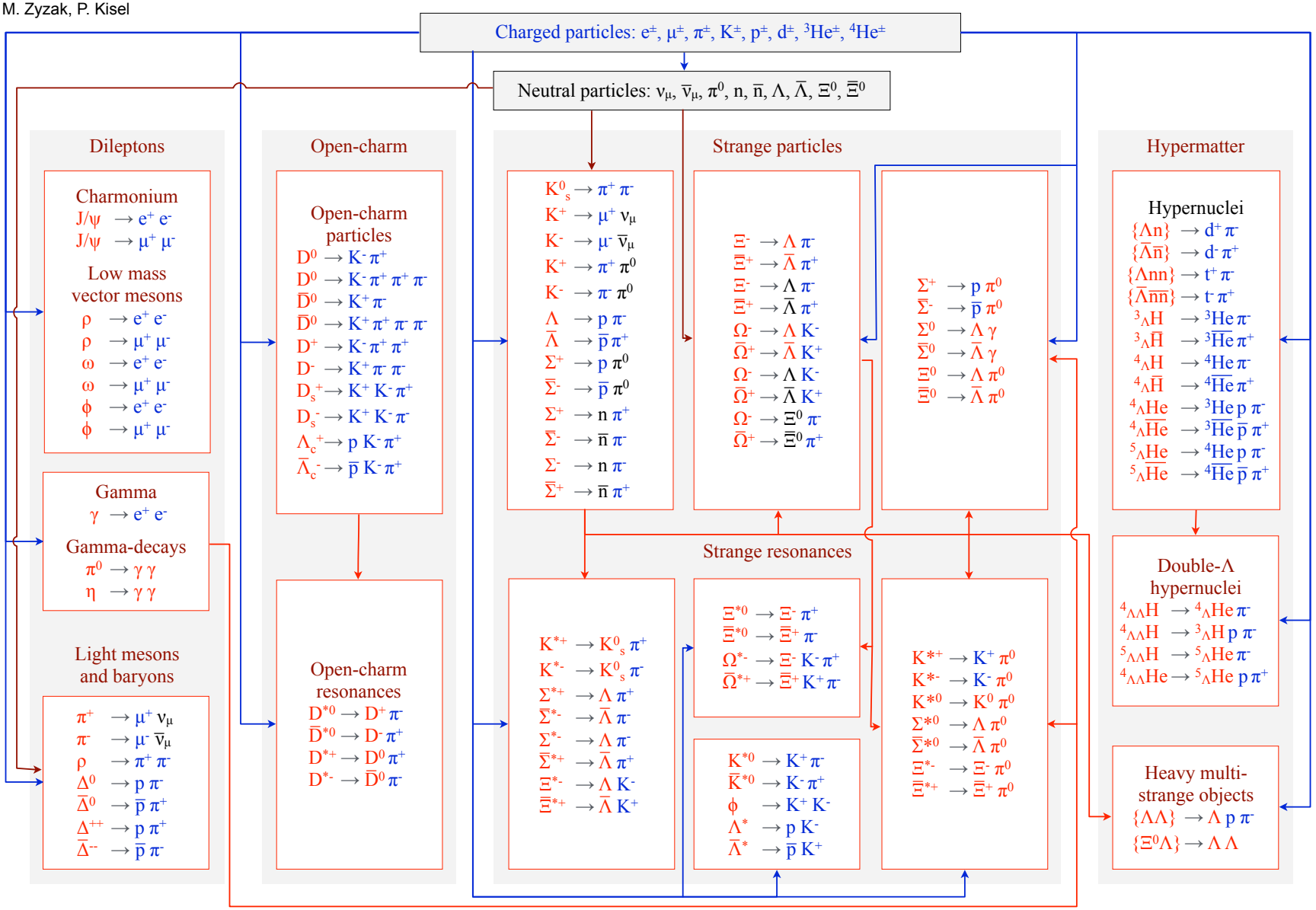
Reconstruction of decays with a neutral daughter
by the missing mass method:



KF Particle provides a simple and direct approach to physics analysis (used in CBM, ALICE and STAR)

KF Particle Finder for Physics Analysis and Selection

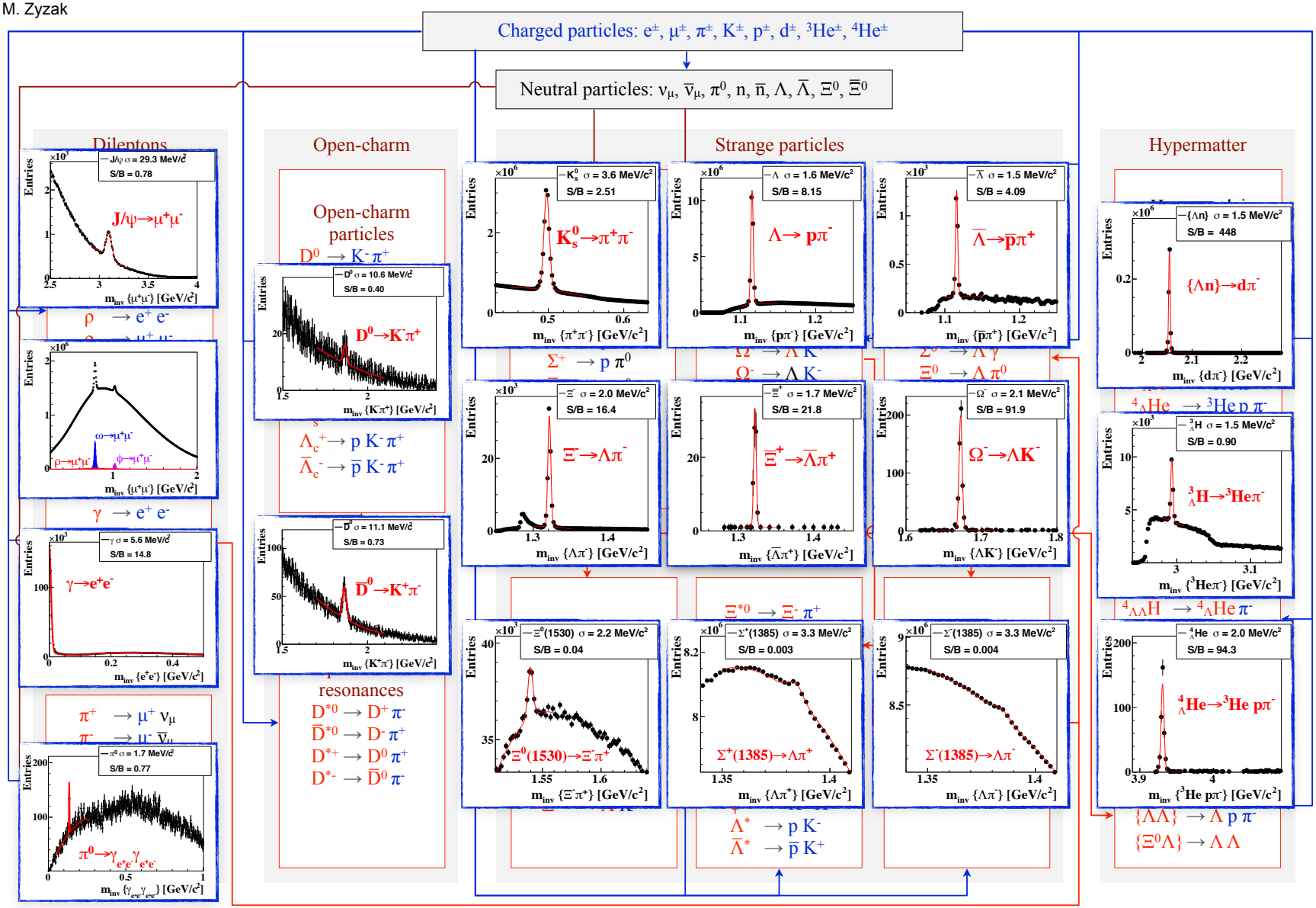
M. Zyzak, P. Kisel



(mbias: 1.4 ms; central: 10.5 ms)/event/core

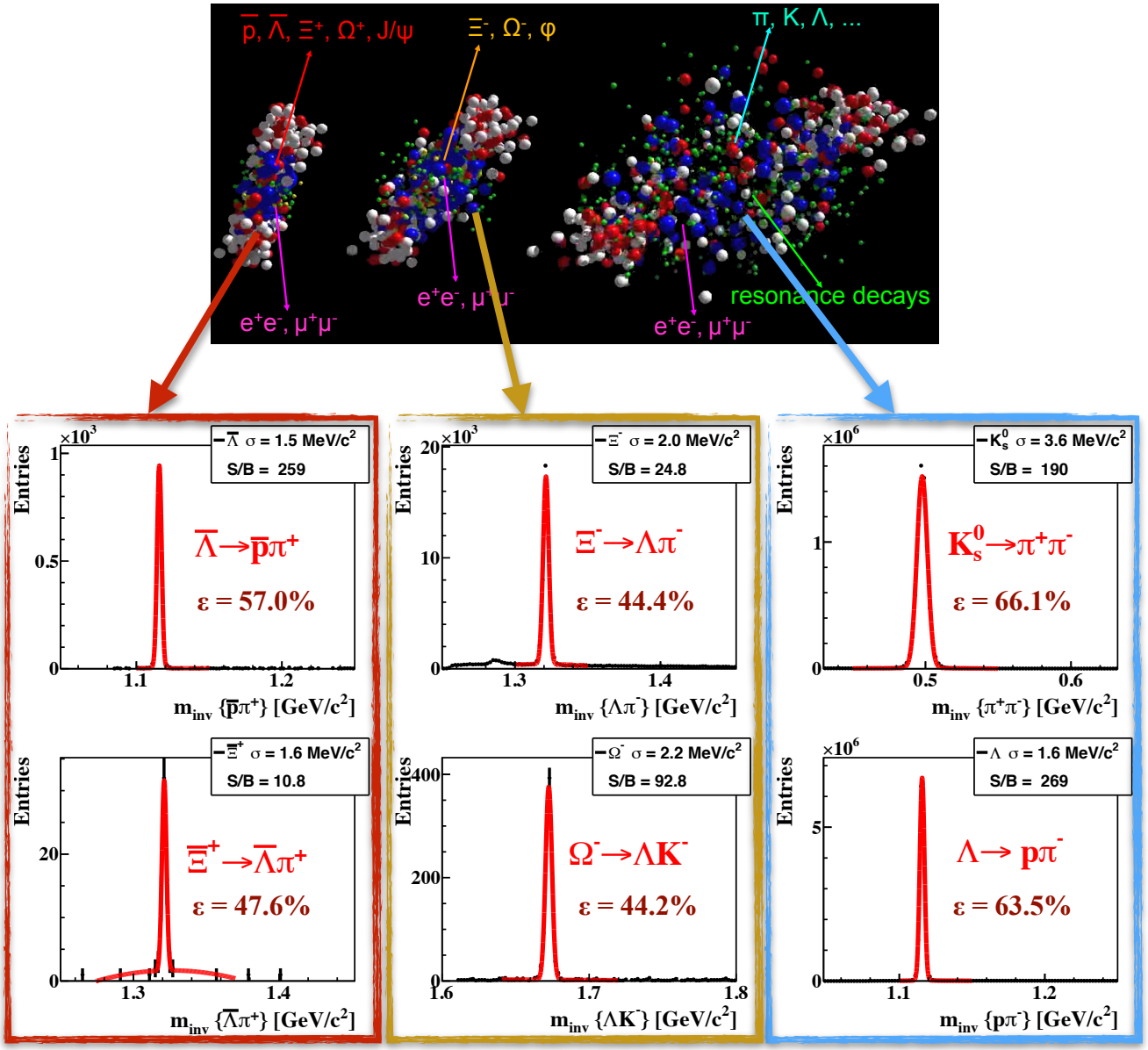
KF Particle Finder for Physics Analysis and Selection

M. Zyzak



Clean Probes of Collision Stages

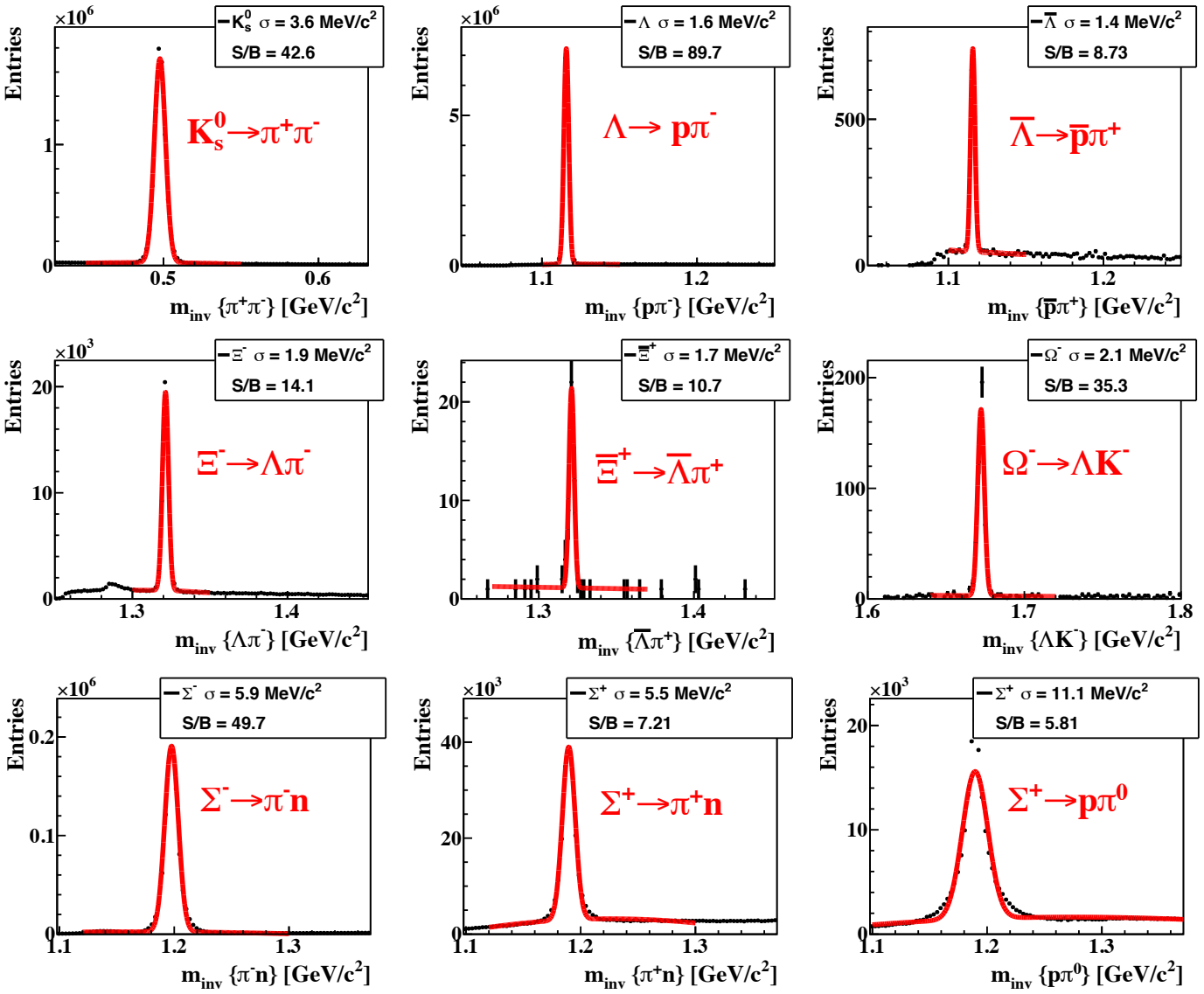
M. Zyzak



AuAu, 10 AGeV, 3.5M central UrQMD events, MC PID

Clean Probes of Collision Stages

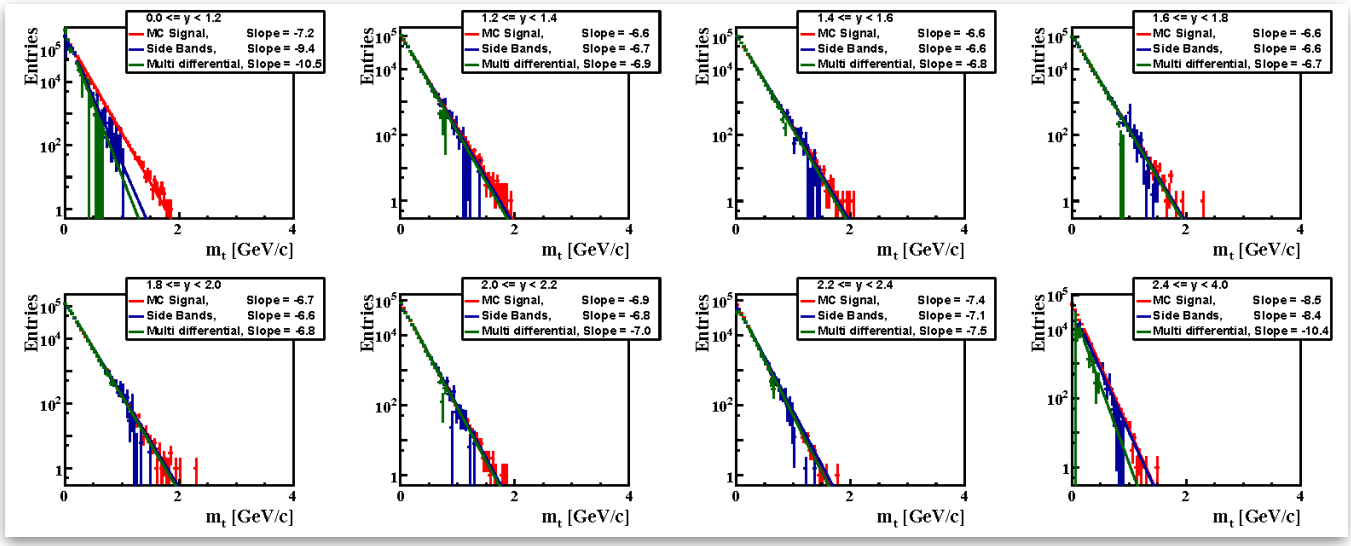
M. Zyzak, P. Kisel

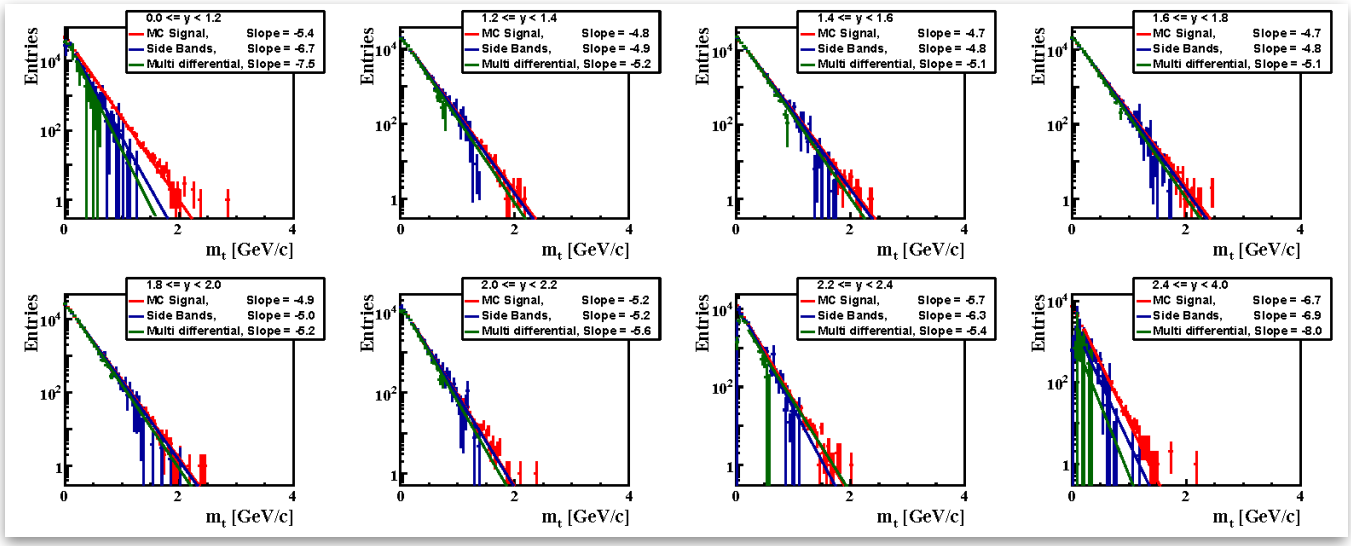


5M central AuAu UrQMD events at 10 AGeV with realistic PID

Effective Temperature for Ξ^-

I. Vassiliev





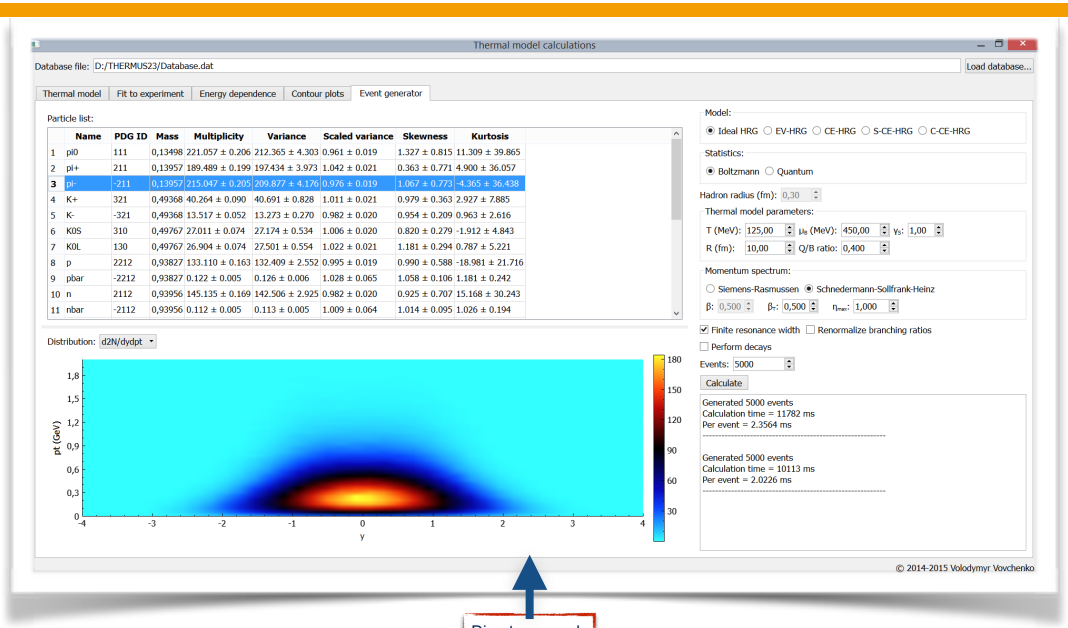
The inverse slope parameter (the effective temperature) of the transverse mass distribution for Ξ^-

$T_{eff} \approx 150$ MeV (PHSD) and $T_{eff} \approx 200$ MeV (UrQMD)

5M central AuAu, 10 AGeV

Real-Time Physics Analysis

V. Vovchenko

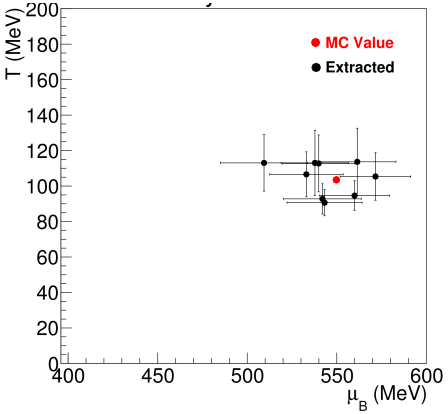


Direct approach

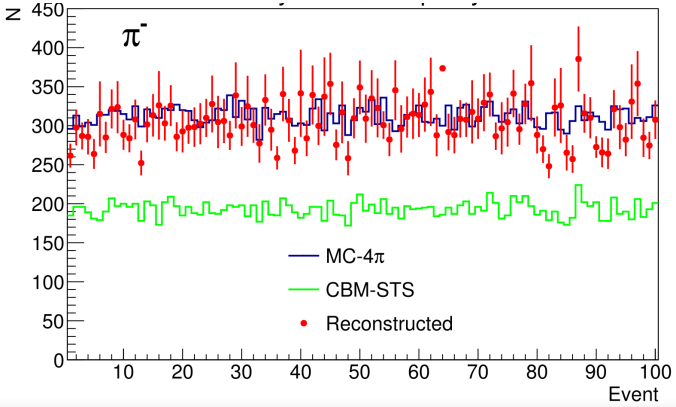
Theoretical model (T, μ,V, σ,...) $\omega_p \frac{dN}{dp^3}$ (observable)

Inverse approach

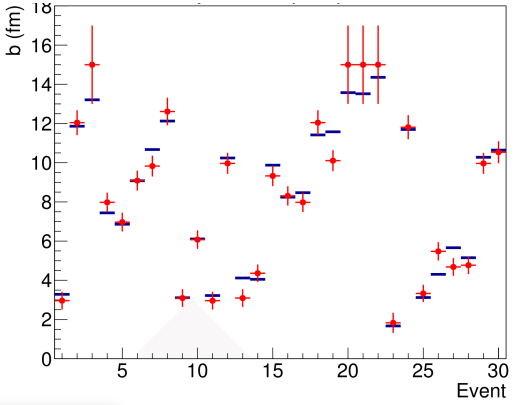
E.-by-E. extraction of T and μ_B (HRG)



E.-by-E. yield estimate incl. acceptance (Blast-Wave)

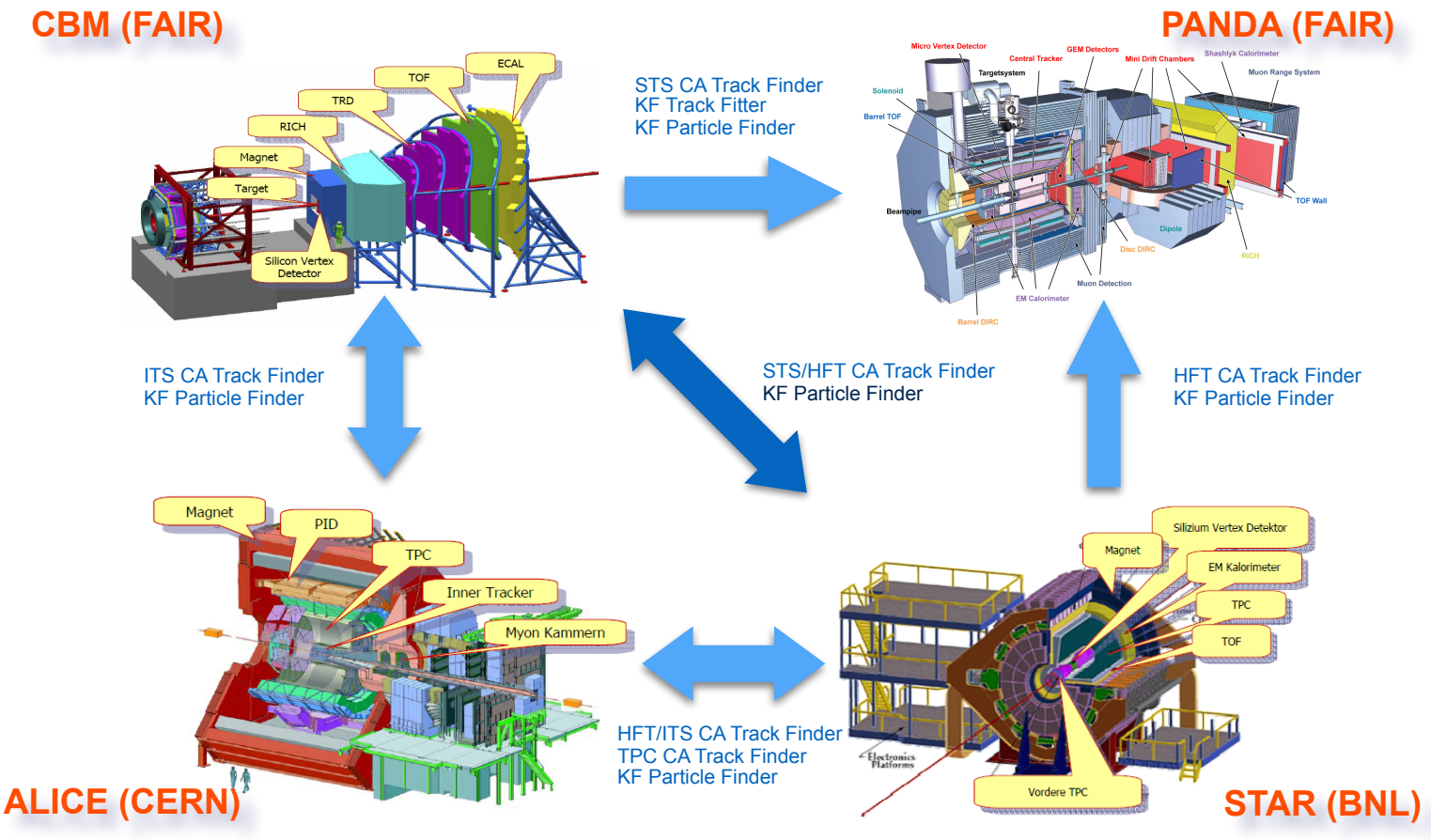


E.-by-E. impact parameter (Glauber)



A package to estimate the medium parameters is implemented

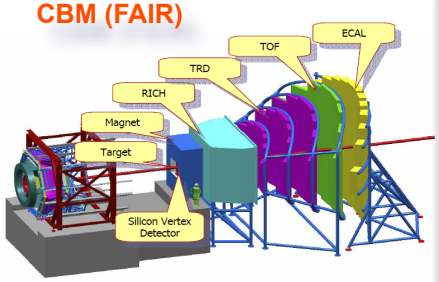
Consolidate Efforts: A Common Reconstruction Package

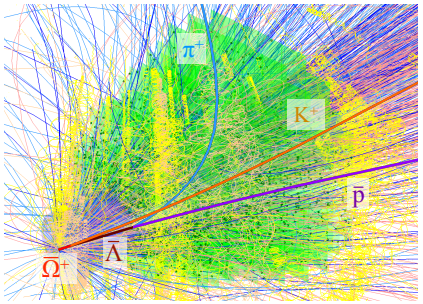


Search for short-lived Particles in CBM and STAR

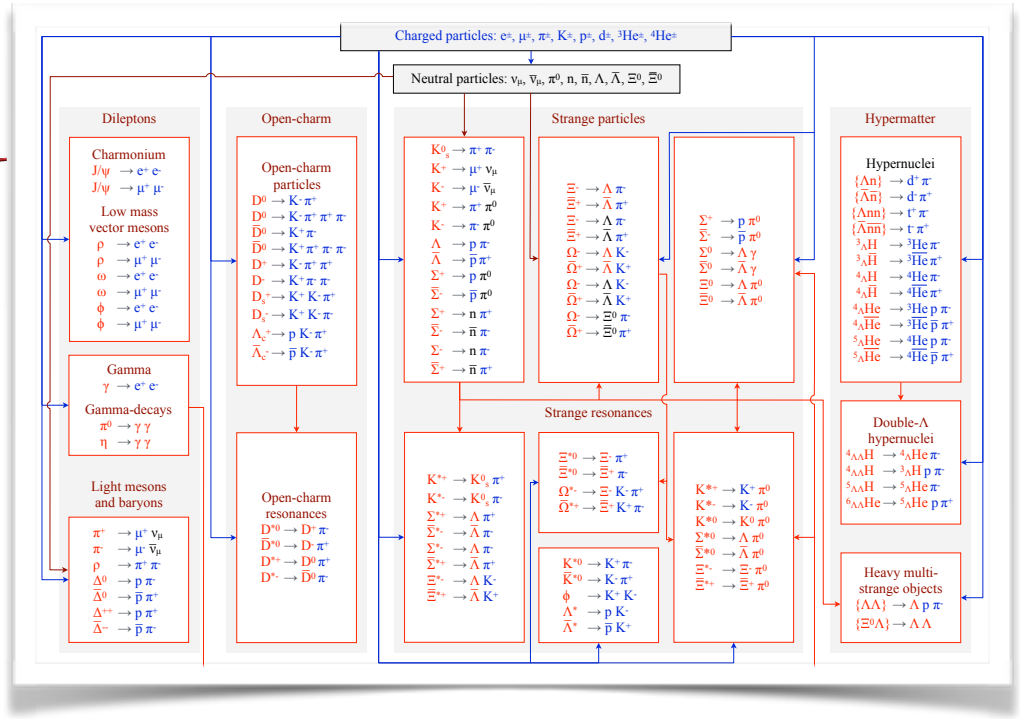
Within the FAIR Phase-0 program the CBM KF Particle Finder has been adapted to STAR and applied to real data of 2014, 2016 and BES-I.

CBM (FAIR)

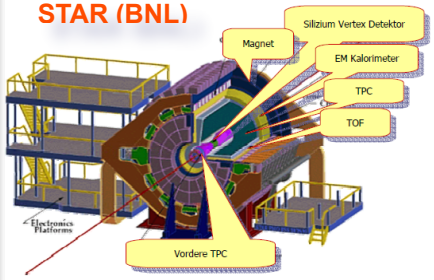


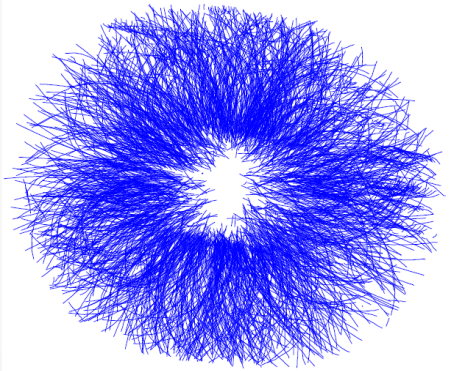


$\bar{\Omega}^+ \rightarrow \bar{\Lambda} K^+$
$\hookrightarrow \bar{p} \pi^+$

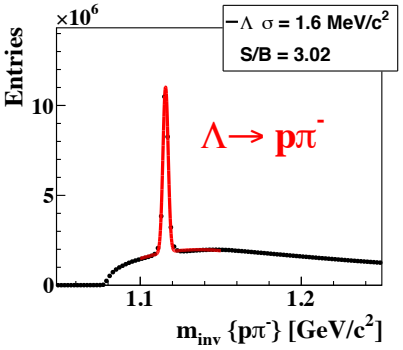


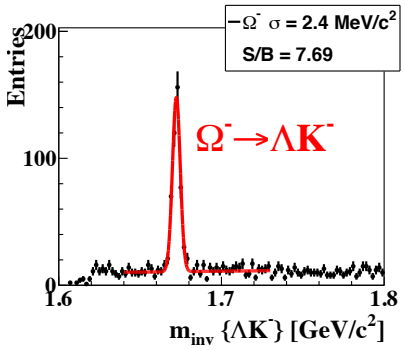
STAR (BNL)



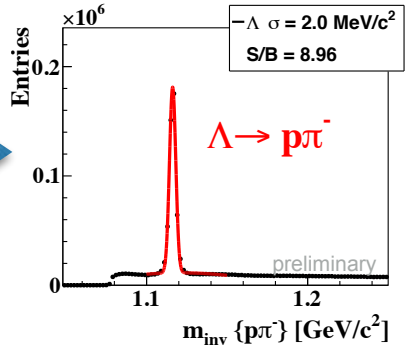


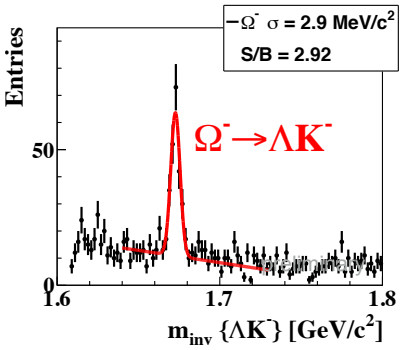
CBM, 5M central Au+Au, 10 AGeV, PHSD





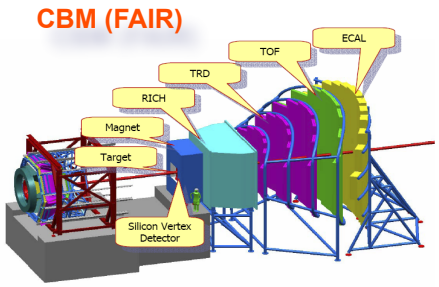
STAR, 1.3M mbias Au+Au, 200 AGeV, Run 2016

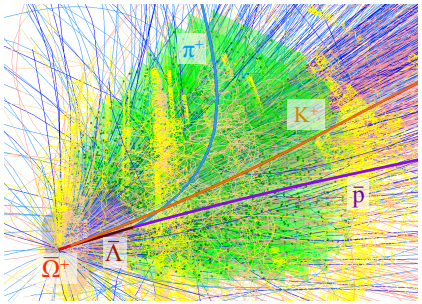




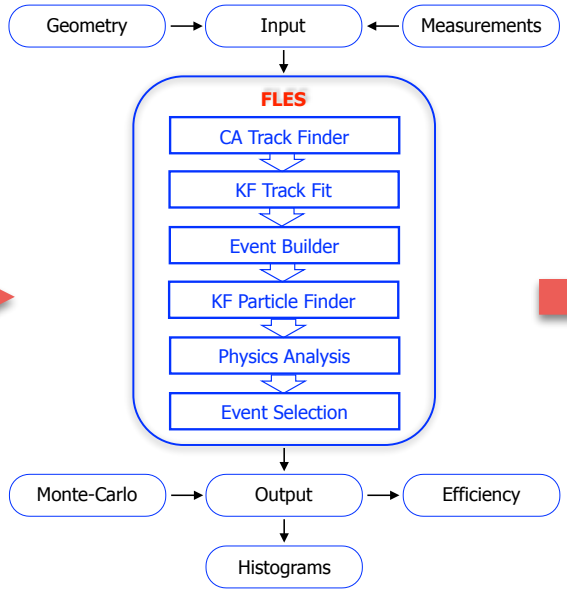
Preparation for the real-time physics analysis during the BES-II runs is in progress

Summary

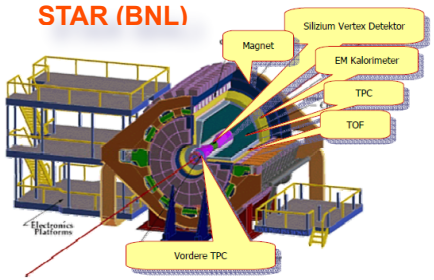


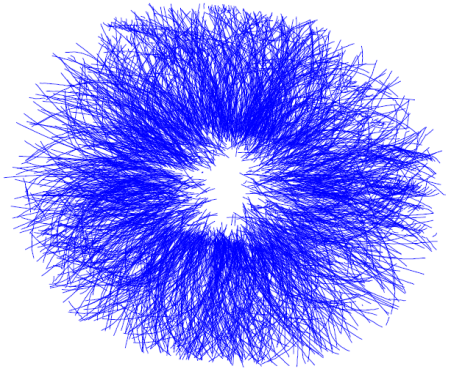


Phase-0



BES-II





- ✓ CBM will explore the QCD phase diagram in the region of high net-baryon densities at 10^7 interaction rate.
- ✓ The fast and efficient First Level Event Selection (FLES) package ($10^7 \rightarrow 10^3$) has been developed for the CBM experiment.
- ✓ The KF particle finder provides clean reconstruction of short-lived particles produced at different stages of heavy-ion collisions.
- ✓ The KF particle finder is ported to STAR for the real-time physics analysis in BES-II.
- ✓ Still many things have to be implemented:
  - » TMVA multi-variate analysis, centrality classification, elliptic flow calculation, etc.
  - » Which other properties of the collision medium can be estimated online?
  - » How to compare them with the theoretical models in real time?