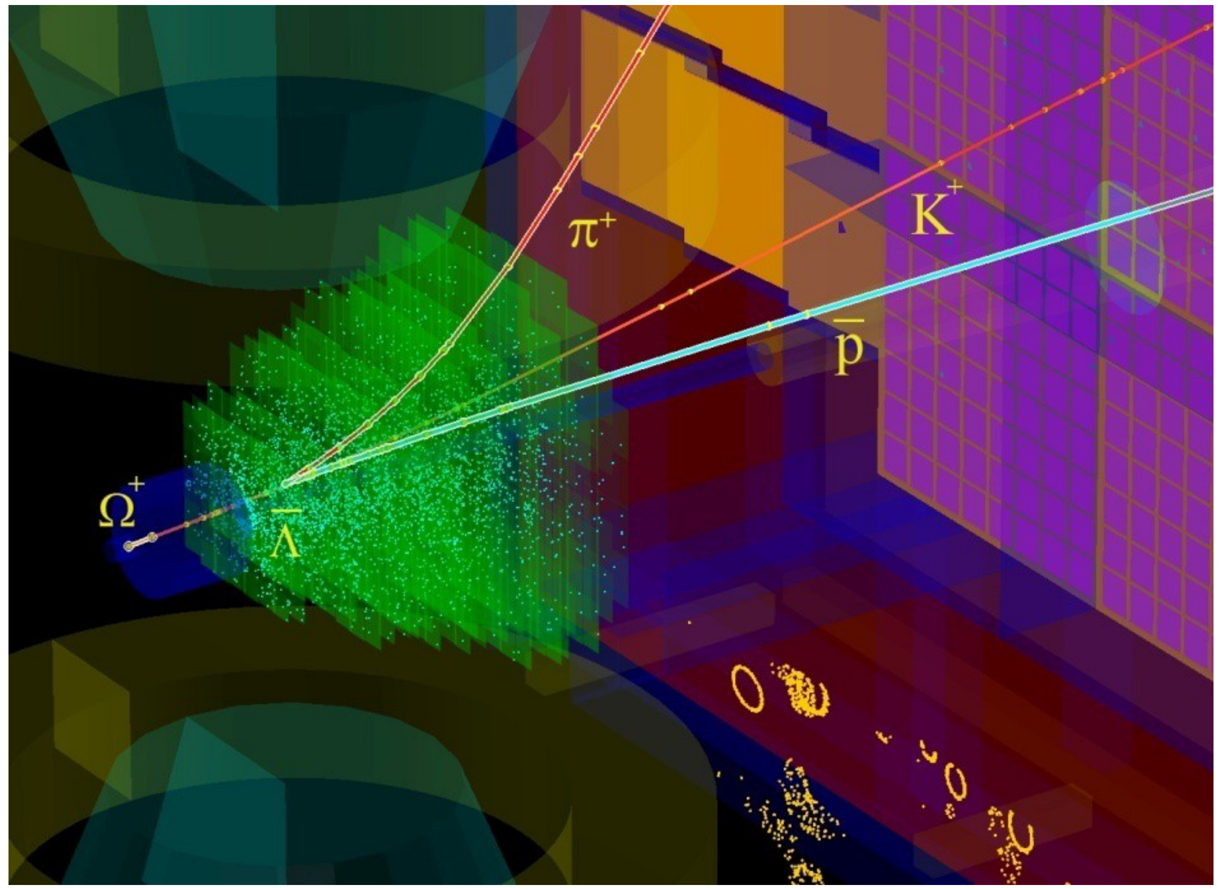
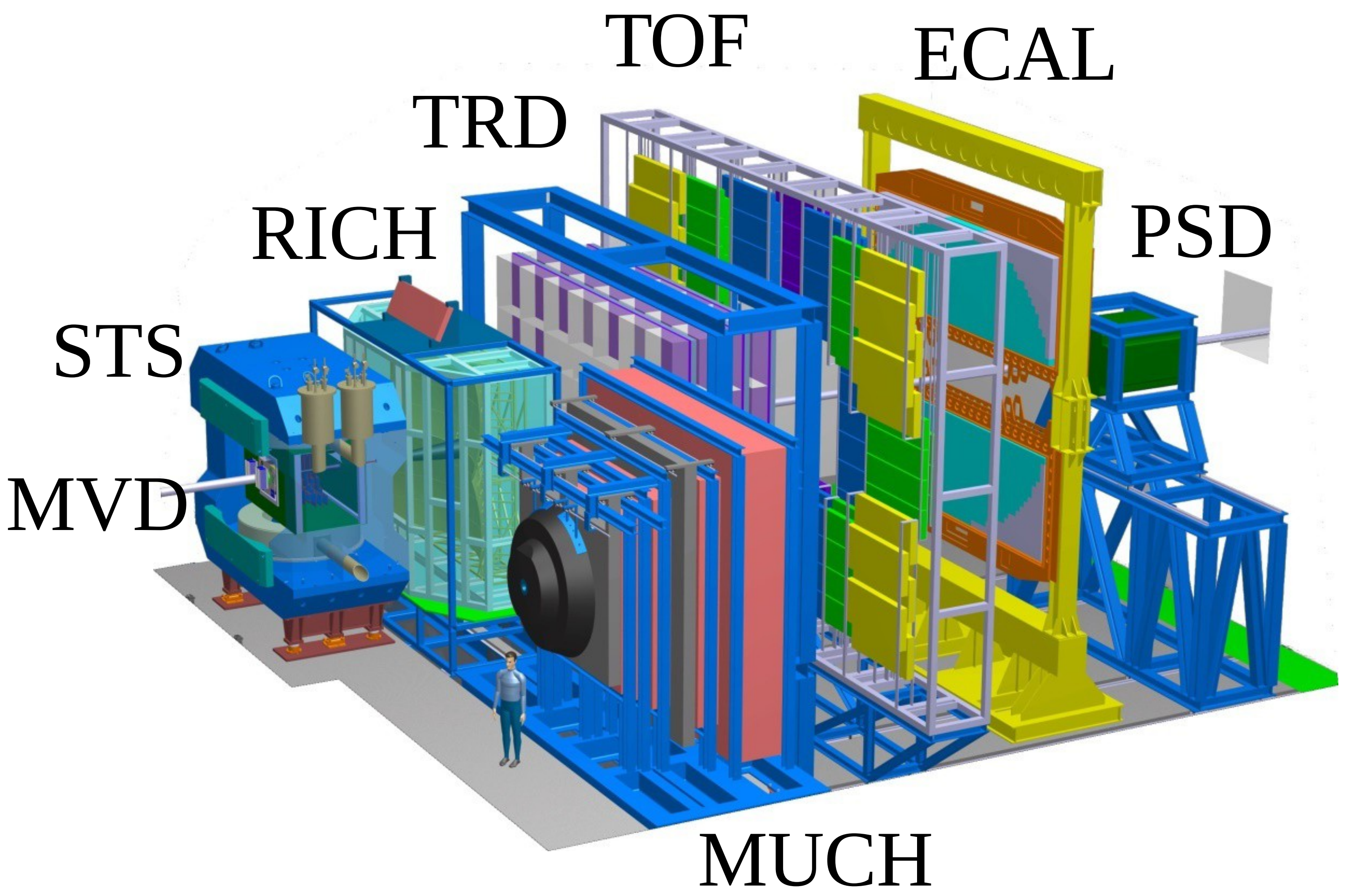
CBM Day-1 measurements with hadronic observables

I.Vassiliev for the CBM Collaboration

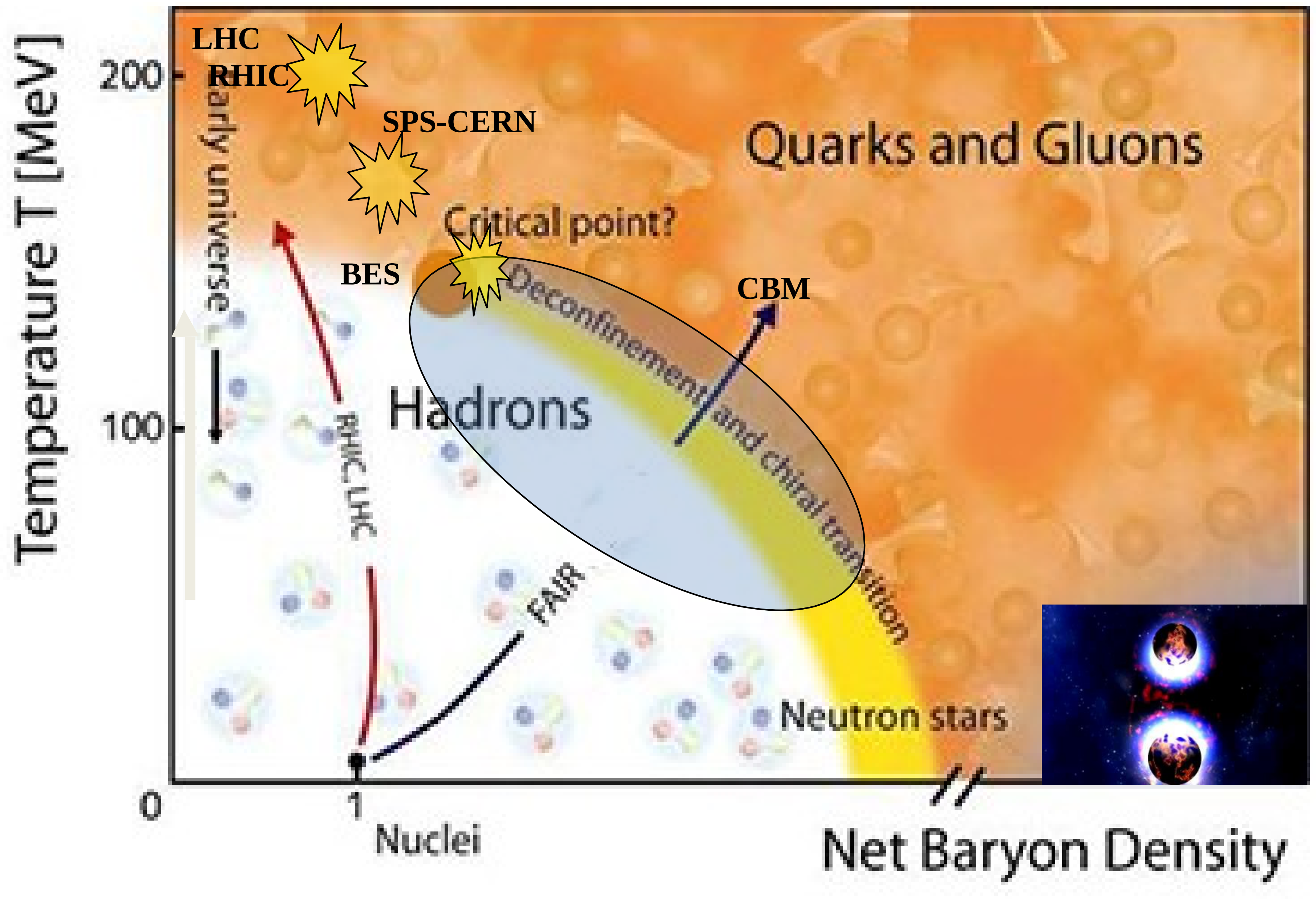




- **Physics case**
- **Multi strange hyperons**
- **Hyper nuclei**
- **Tests with STAR data**
- **Summary**

Oct 2018 Darmstadt

Physics case: Exploring the QCD phase diagram



The equation-of-state at high ρ_B
collective flow of hadrons,
particle production at threshold energies:
multi-strange hyperons, hypernuclei

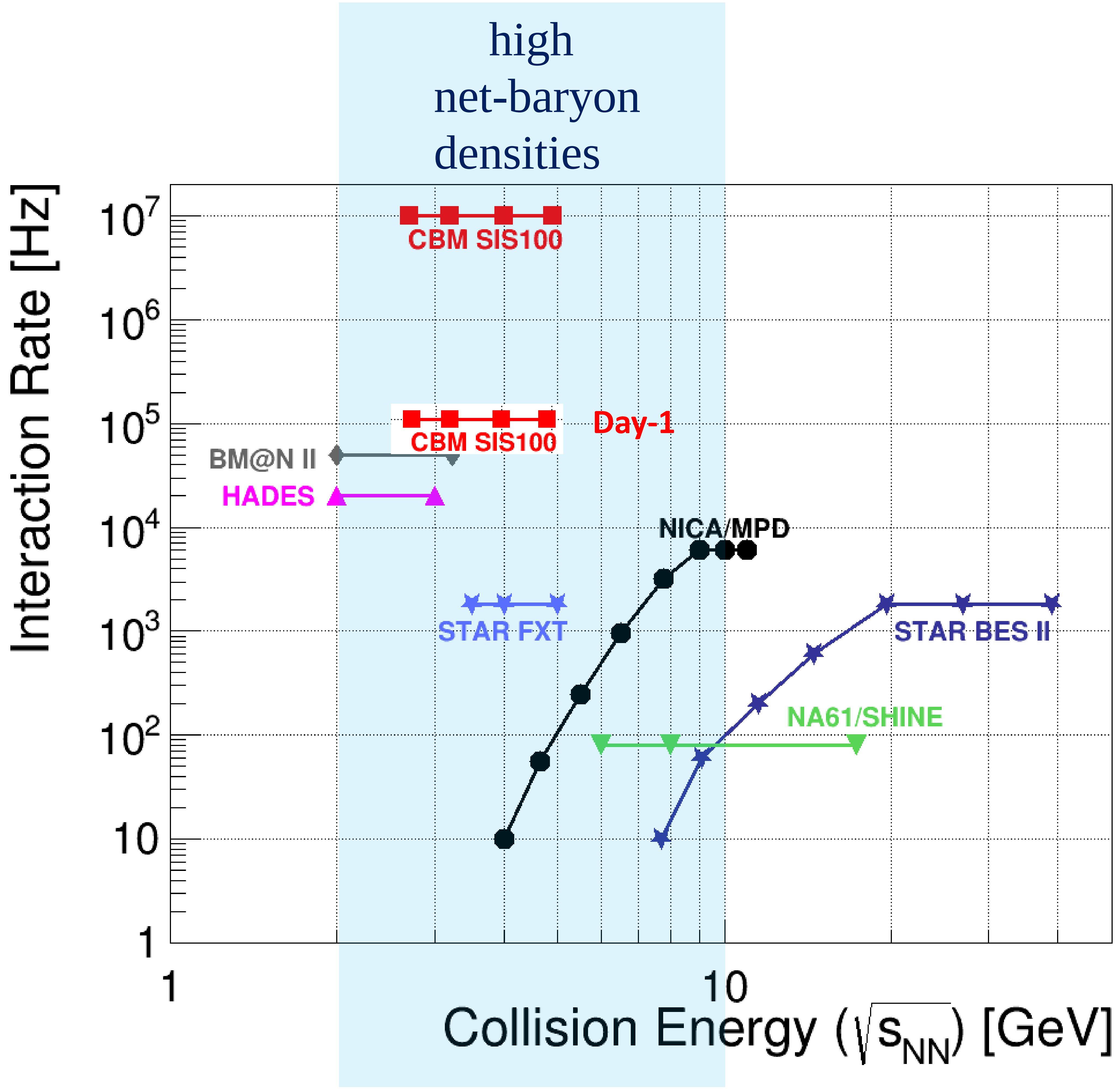
Deconfinement phase transition at high ρ_B
excitation function and flow of
strangeness (K, Λ, Σ, Ξ, Ω and φ)

Chiral symmetry restoration at high ρ_B
in-medium modifications of hadrons (ρ)
excitation function of **multi-strange (anti)hyperons**

QCD critical endpoint
excitation function of event-by-event fluctuations
(π, K, p, Λ, Ξ, Ω…)

Projects to explore the QCD phase diagram at large μ_B:
RHIC (STAR) beam energy-scan, HADES, NA61@SPS,
MPD@NICA: bulk observables
CBM: bulk and **rare observables, high statistic!**

Experiments exploring dense QCD matter

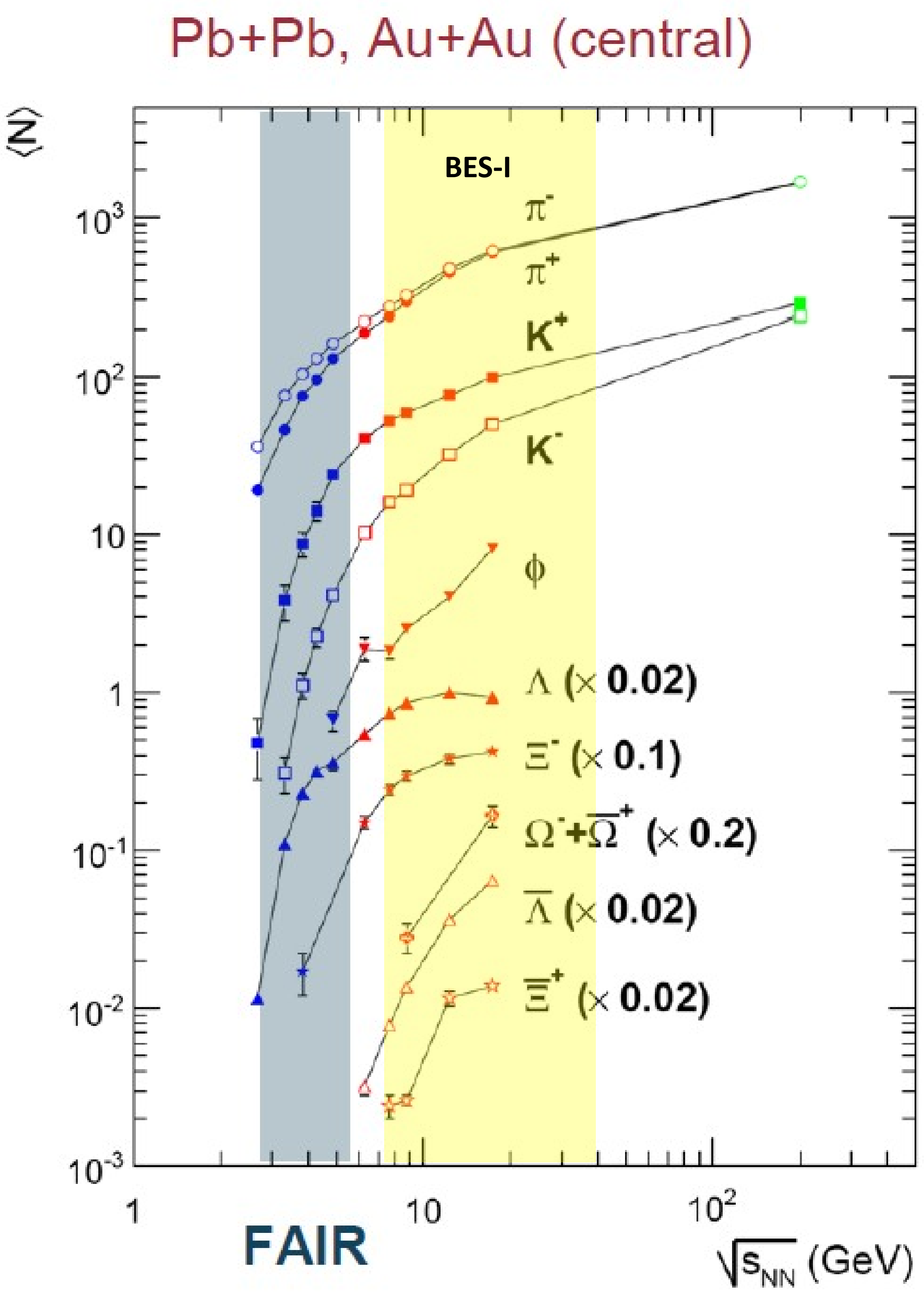


CBM:

unprecedented
(high) rate capability

- determination of (displaced) vertices with high resolution (≈ 50 μm)
- identification of leptons and hadrons
- fast and radiation hard detectors
- self-triggered readout electronics
- high speed data acquisition and
- online event selection
- powerful computing farm *and 4D tracking*
- software triggers

Strangeness world data



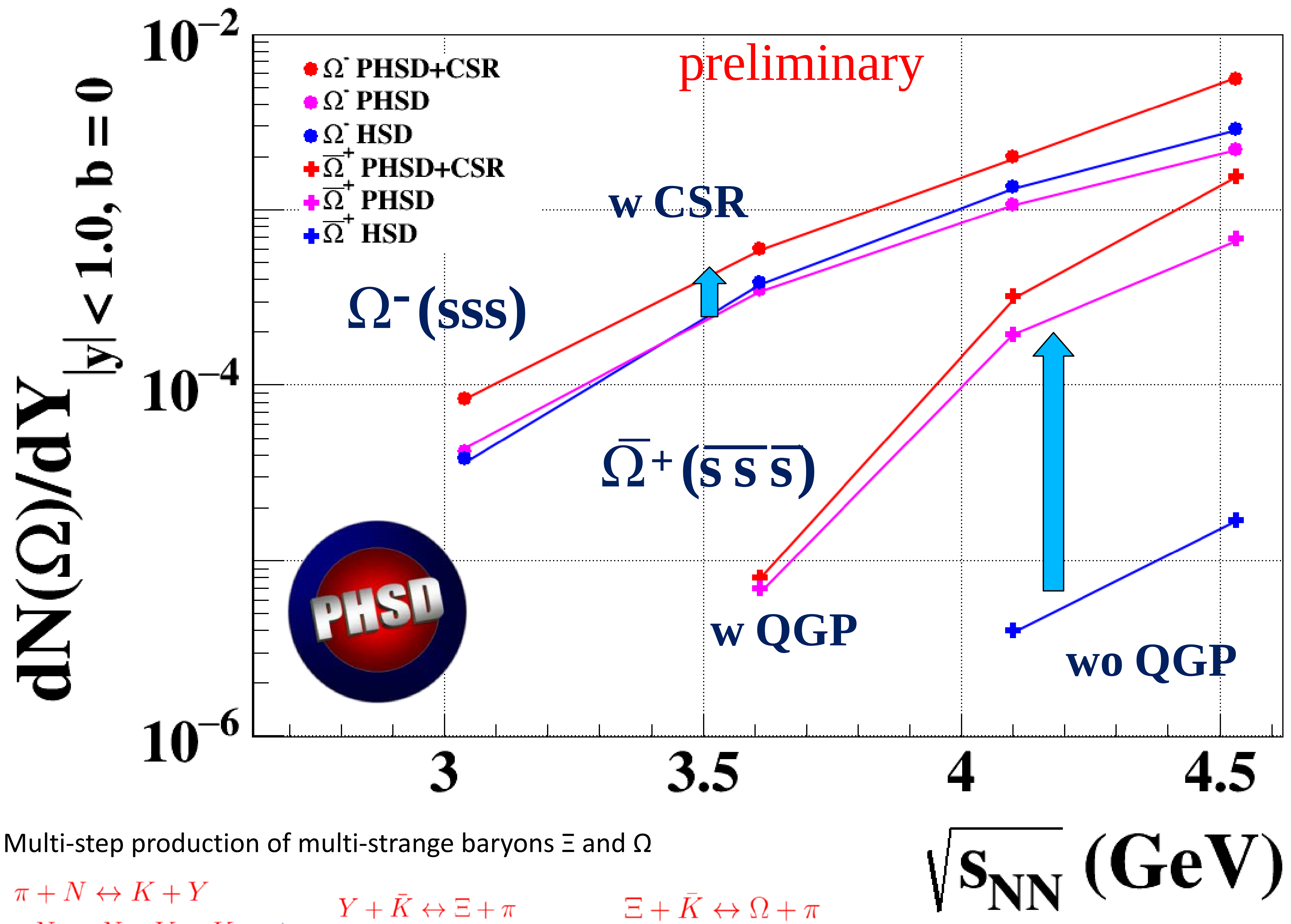
No data available at FAIR energy

In the AGS (SIS100) energy range, only about 300 Ξ^- hyperons have been measured in Au+Au collisions at 6AGeV

High-precision measurements of excitation functions of multi-strange hyperons in A+A collision with different mass numbers A at SIS100 energies have a discovery potential to find a signal for the onset of deconfinement in QCD matter at high net-baryon densities.

QGP and Chiral symmetry restoration

“Chiral symmetry restoration versus deconfinement in heavy-ion collisions at high baryon density”
W. Cassing, A. Palmese, P. Moreau, and E. L. Bratkovskaya Phys.Rev. C93 (2016), 014902, arXiv:1510.04120 [nucl-th]



Chiral symmetry restoration (CSR) change the flavor decomposition – more s-sbar pairs produced.

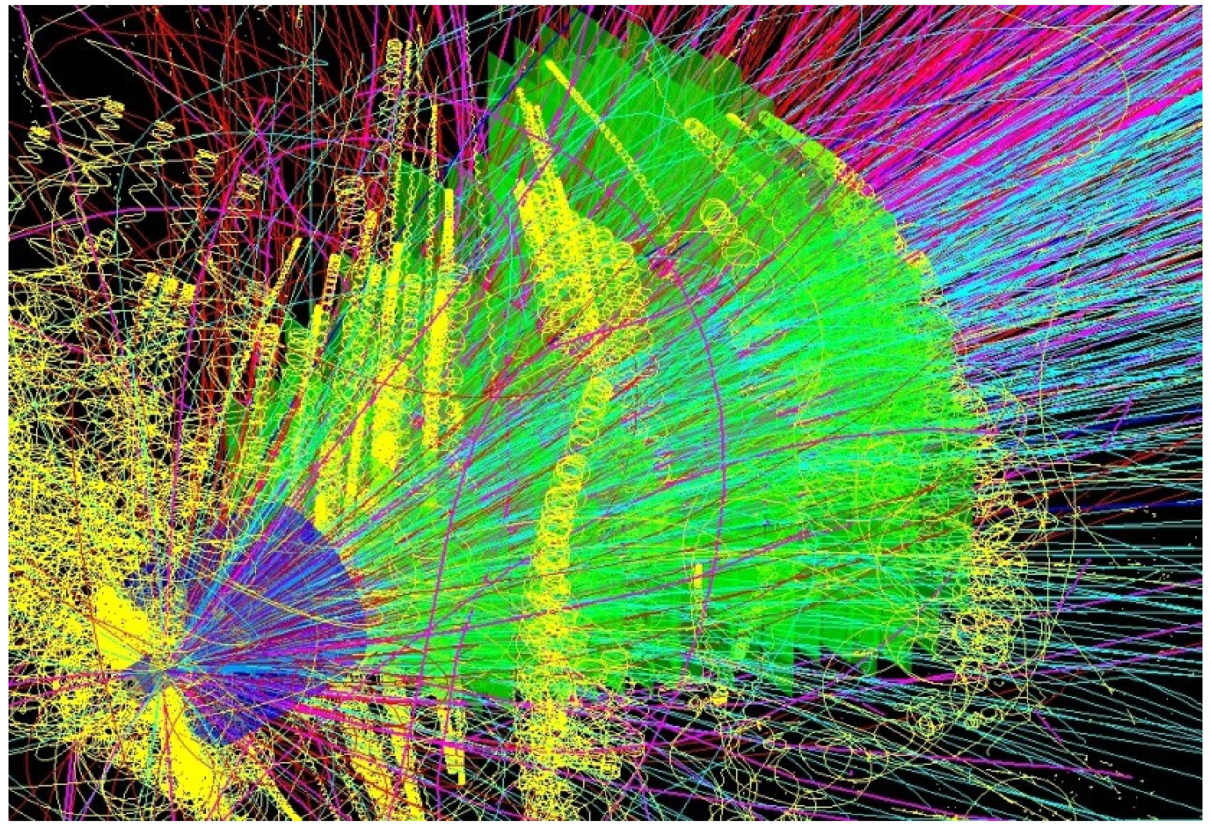
Droplets of QGP allow to interact s-sbar quarks and create more multi-strange (anti)baryons.

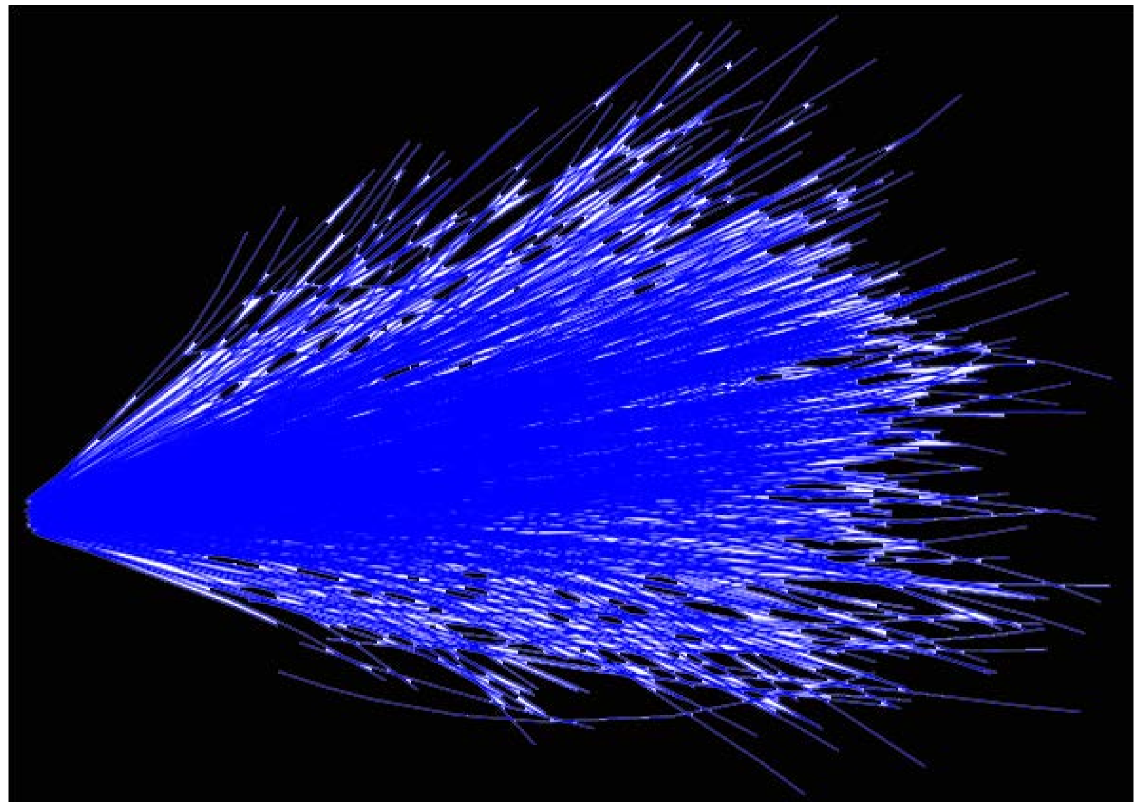
- Presence of QGP significantly increase yield of Ω^+ at FAIR energy
- CSR effect increase yield of Ω^- and Ω^+ at FAIR energy

Multi-step production of multi-strange baryons Ξ and Ω

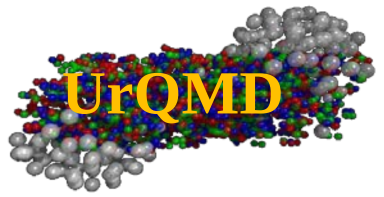
$$\pi + N \leftrightarrow K + Y \quad N + N \leftrightarrow N + Y + K \quad N + \bar{K} \leftrightarrow Y + \pi$$
$$\Rightarrow \quad Y + \bar{K} \leftrightarrow \Xi + \pi \quad Y + Y \leftrightarrow \Xi + N$$
$$\Rightarrow \quad \Xi + \bar{K} \leftrightarrow \Omega + \pi \quad \Xi + \Xi \leftrightarrow \Omega + Y$$

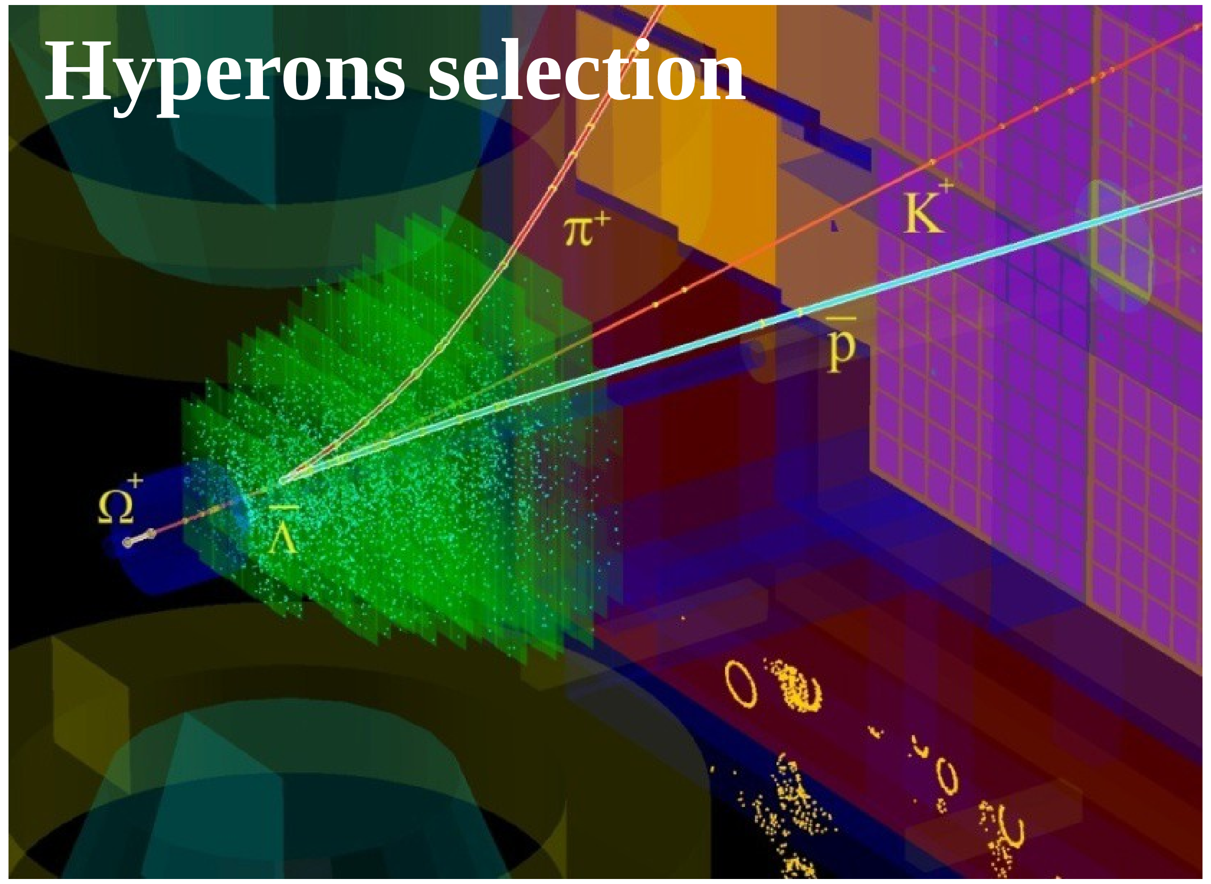
Performance of the CBM track finder





AuAu 10 AGeV/c
165 π
170 p
26 K
15 Λ
20 K_S^0
0.3 Ξ^-



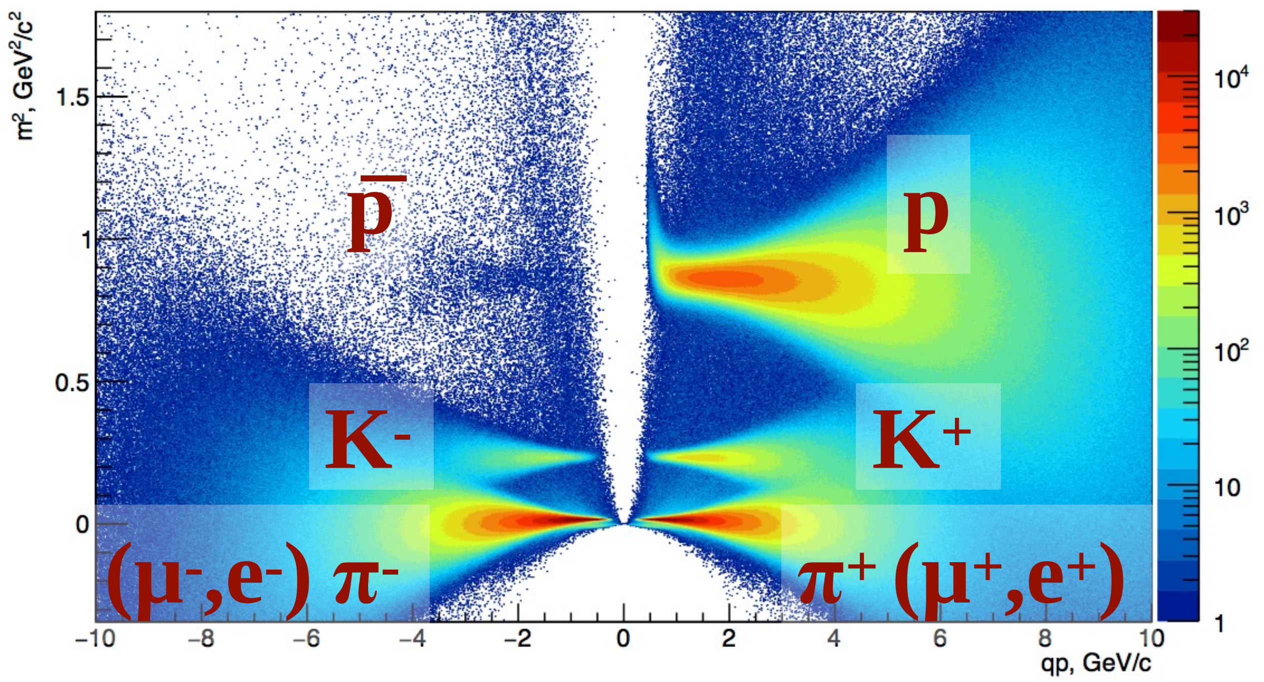


- For studies several theoretical models like UrQMD and PHSD are used.
- Track finder is based on the Cellular Automaton method.
- High efficiency for track reconstruction of more then **92%**, including fast (more then 90%) and slow (more then 65%) secondary tracks.
- Time-based track finder is developed, efficiency is stable with respect to the interaction rate.
- Low level of split and wrongly reconstructed (ghost) tracks.

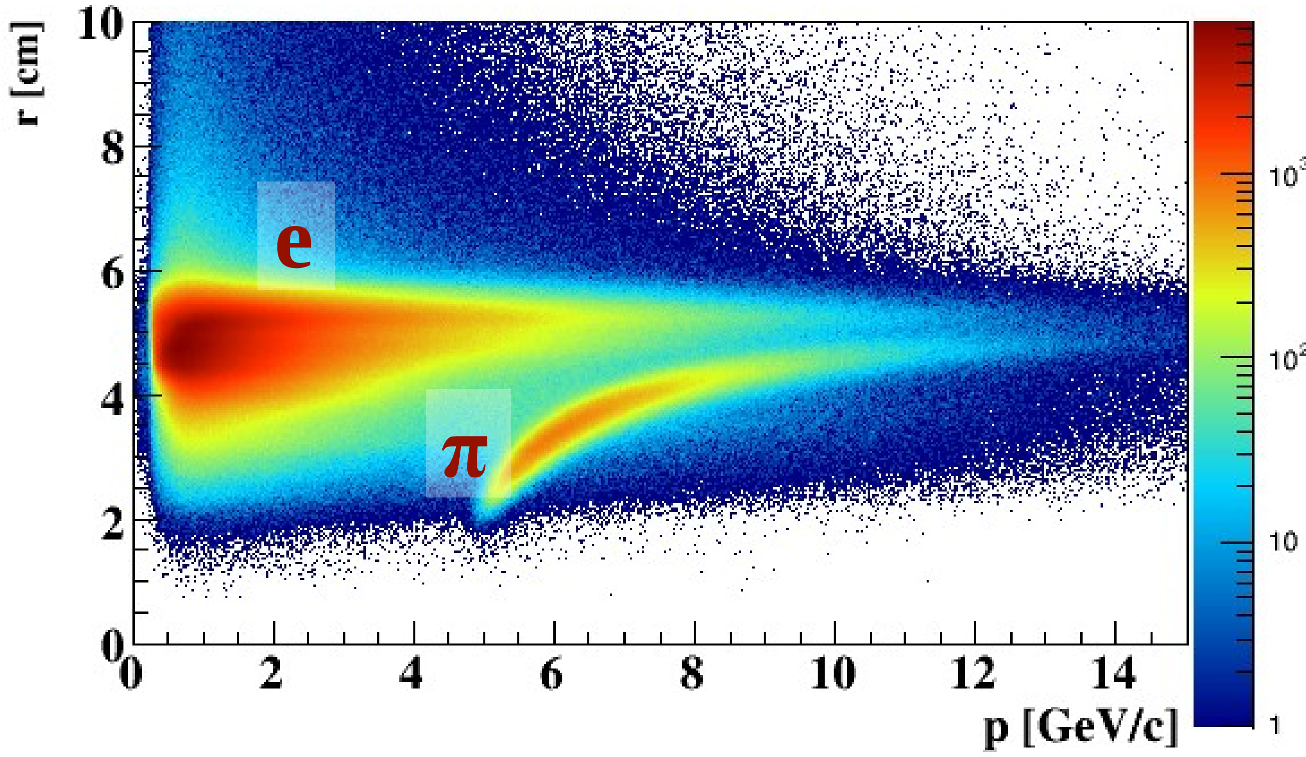
minimum bias : 6ms/core track finder, 1 ms/core particle finder

Particle identification with PID detectors

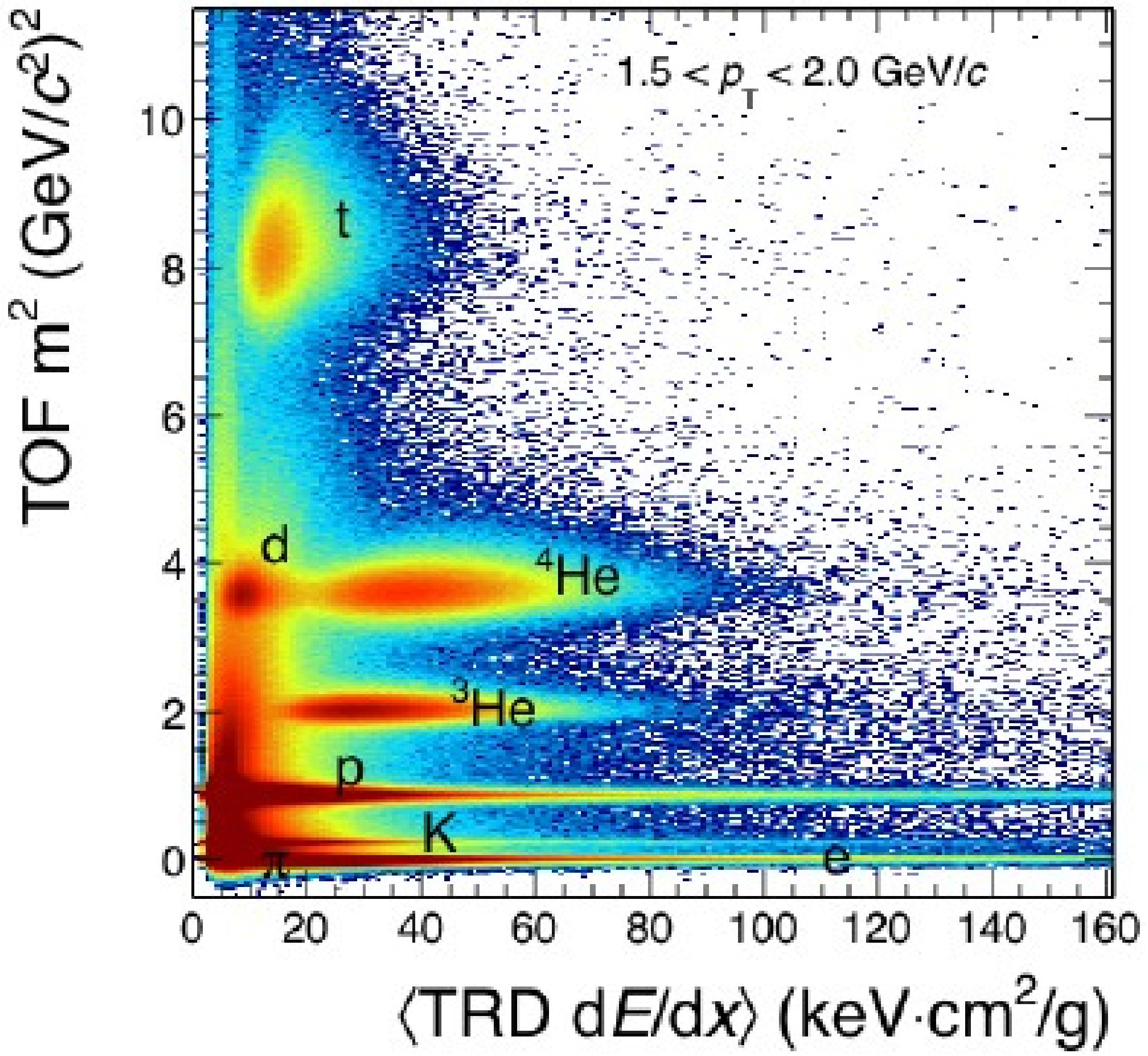
ToF: hadron identification



RICH: electron identification



TRD: d-He separation

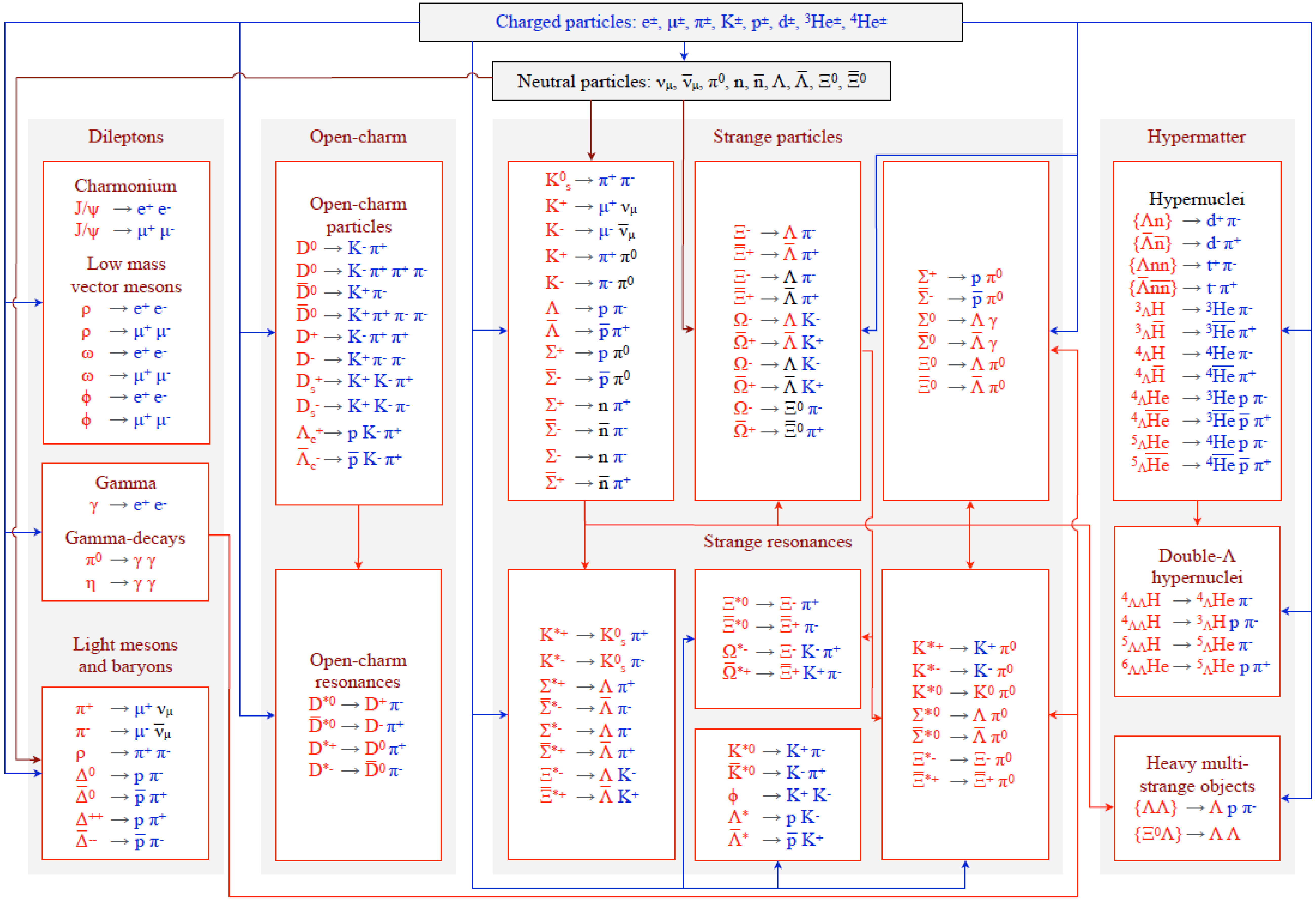


PID detectors:

- ToF (Time of Filght) — hadron identification;
- RICH (Ring Imaging CHerenkov detector) — electron identification;
- TRD (Transition Radiation detector) — electron and heavy fragments identification.

PID detectors of CBM will allow a clear identification of charged tracks.

KF Particle Finder for the CBM Experiment



More than 100 decays.

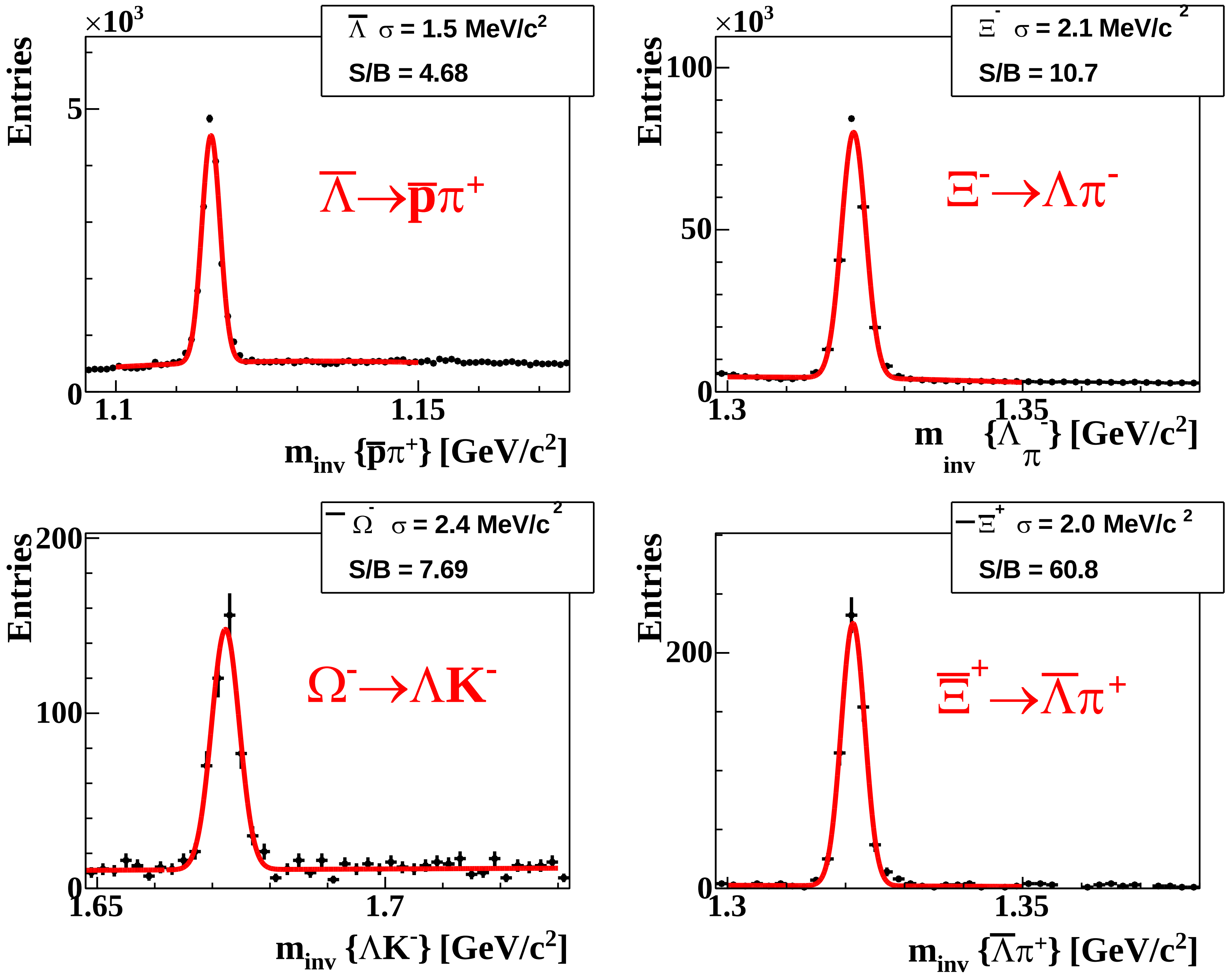
All decays are reconstructed in one go.

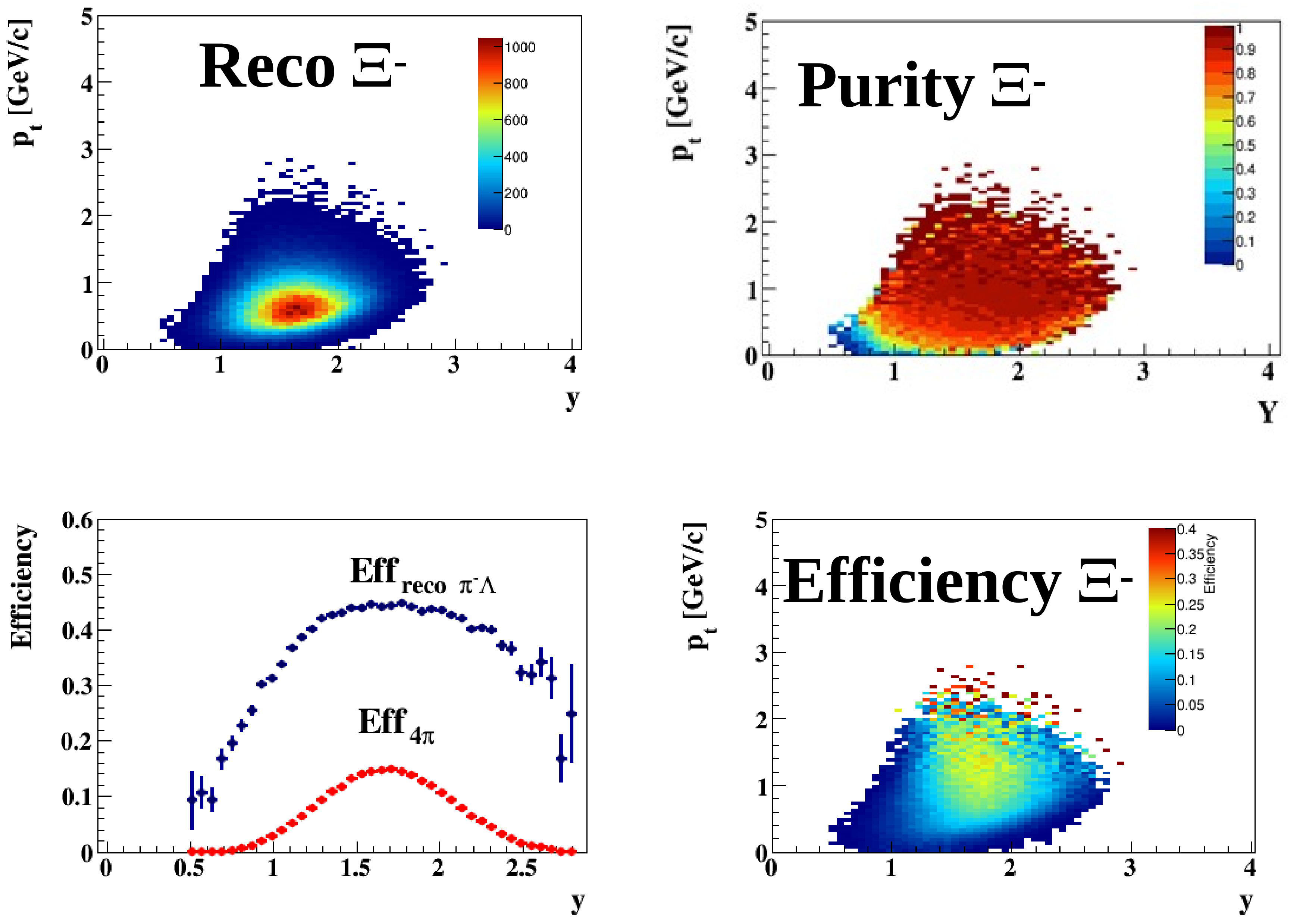
Based on the Kalman filter method - mathematically correct parameters and their errors.

Available in and approbated within STAR, ALICE, PANDA.

Strange particle reconstruction performance

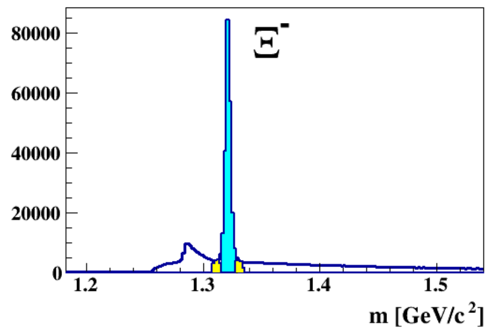
5M central AuAu collisions 10AGeV/c



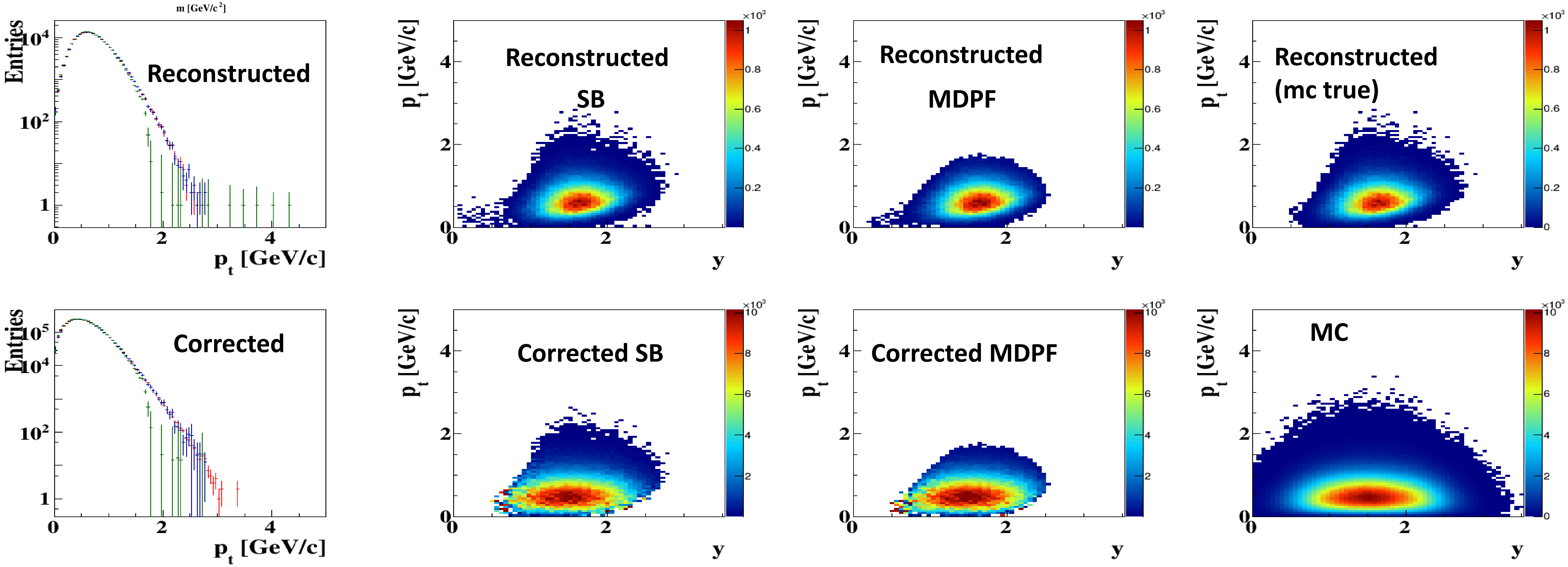


- CBM will allow clean reconstruction of rare strange probes with high efficiency and high statistics.
- Tools for the multi-differential physics analysis are prepared.

Strange particle reconstruction performance



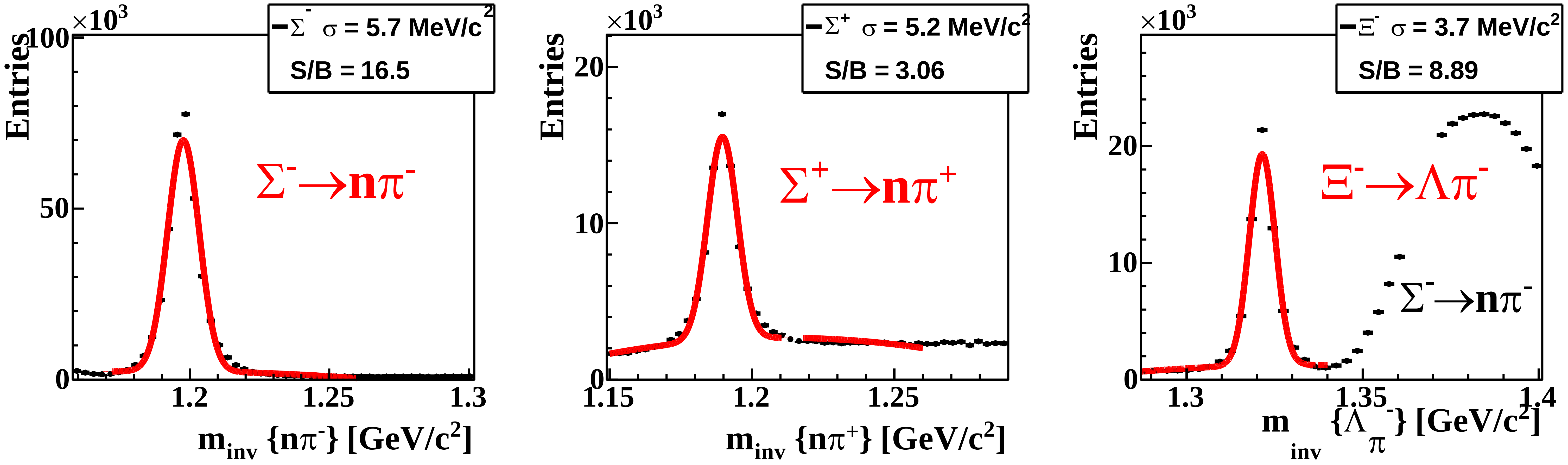
5M central AuAu collisions 10AGeV/c (Ξ^-)

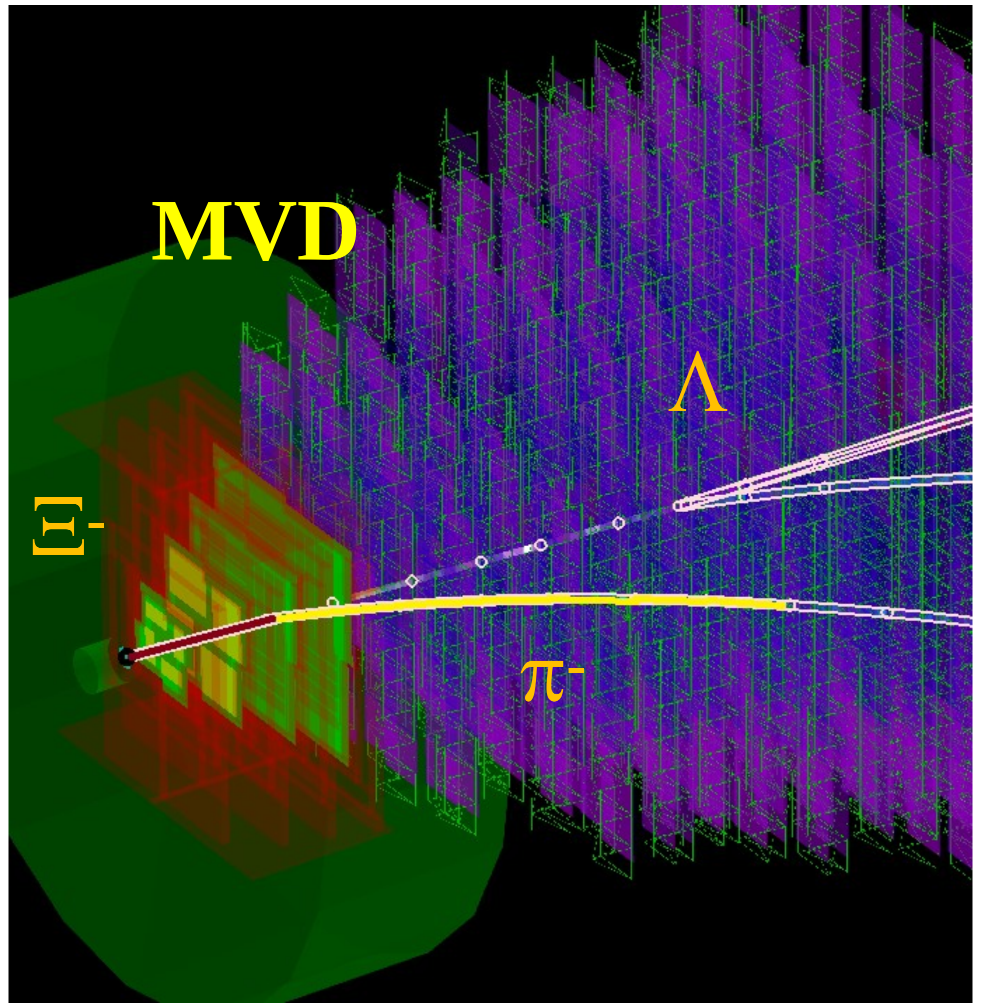


- CBM will allow clean reconstruction of rare strange probes with high efficiency and high statistics.
- Tools for the multi-differential physics analysis are prepared.

5M central AuAu collisions 10AGeV/c Missing Mass Method

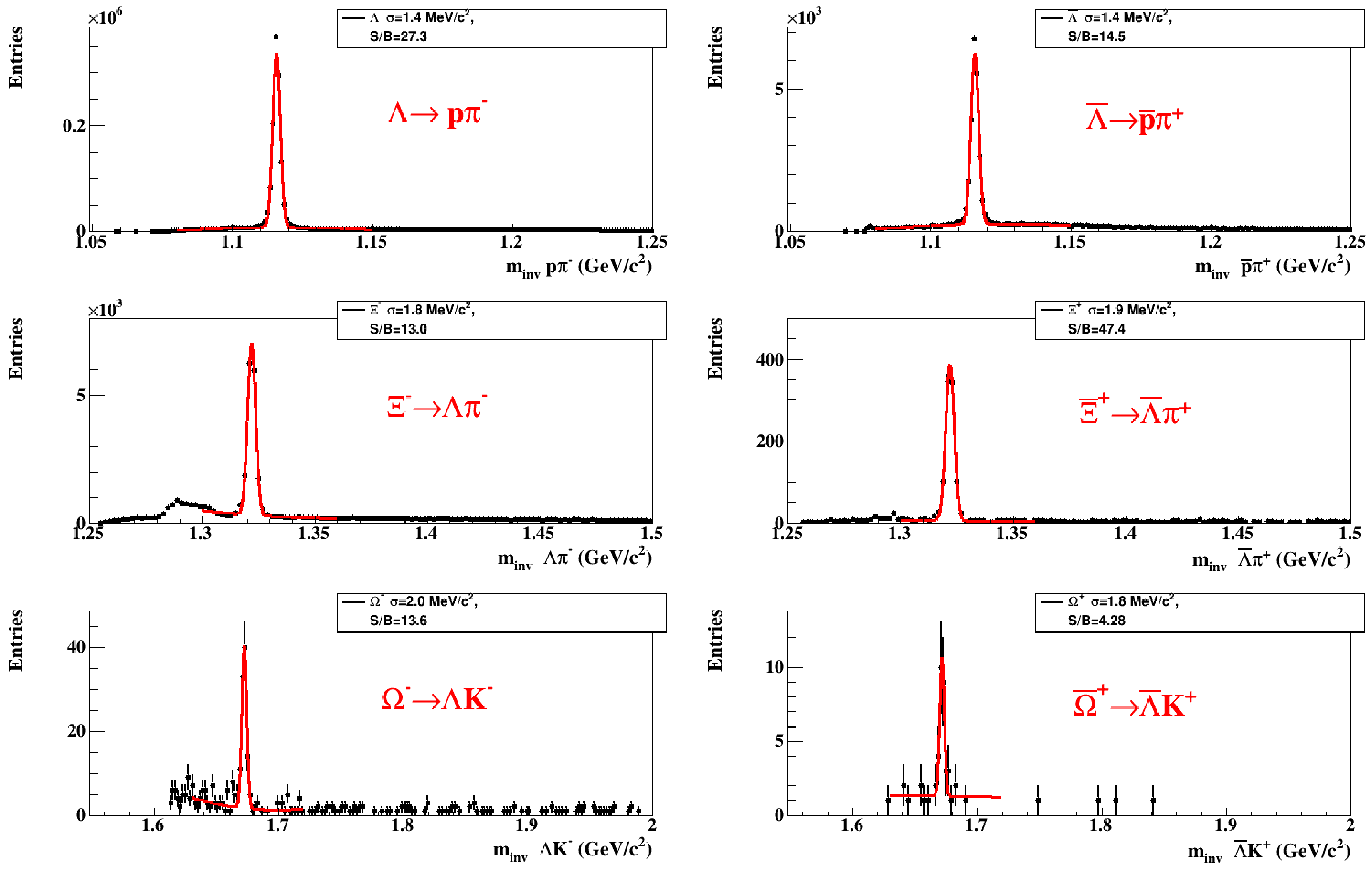
P.Kisel for (PWG "H")



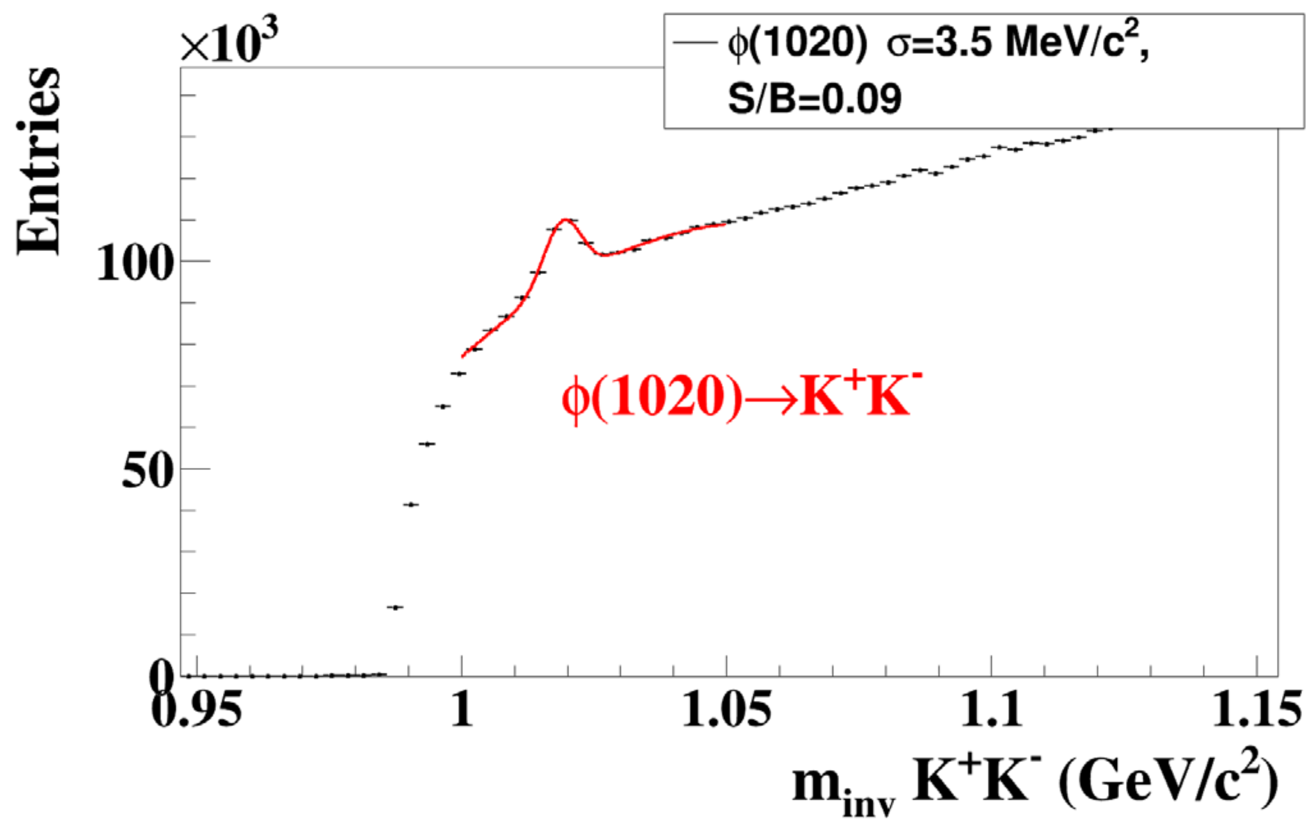


- Σ^+ and Σ^- physics:
  - completes the picture of strangeness production: abundant particles, carry out large fraction of strange quarks;
  - reconstruction of resonances, like Λ(1405);
  - reconstruction of hypothetic particles, like H-dybarion.
- Having high acceptance for Σ hyperons CBM is capable to reconstruct them by the **Missing Mass Method**.
- The method provides also independent way for reconstruction of Ξ and Ω hyperons, that will allow systematics study.

CBM KFParticle Finder @ STAR 4.4M Au+Au events sqrt(s) = 7.7

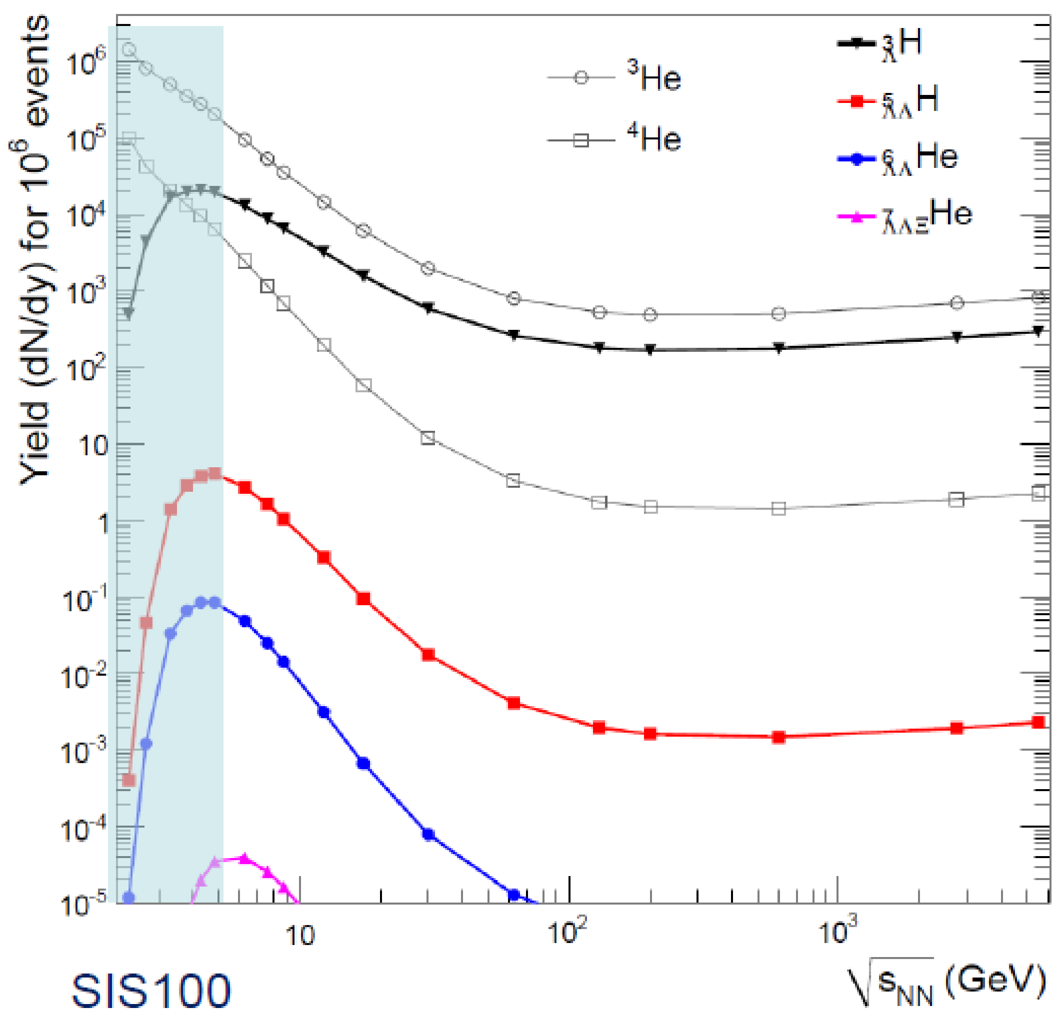


all centralities, no cuts on rapidity



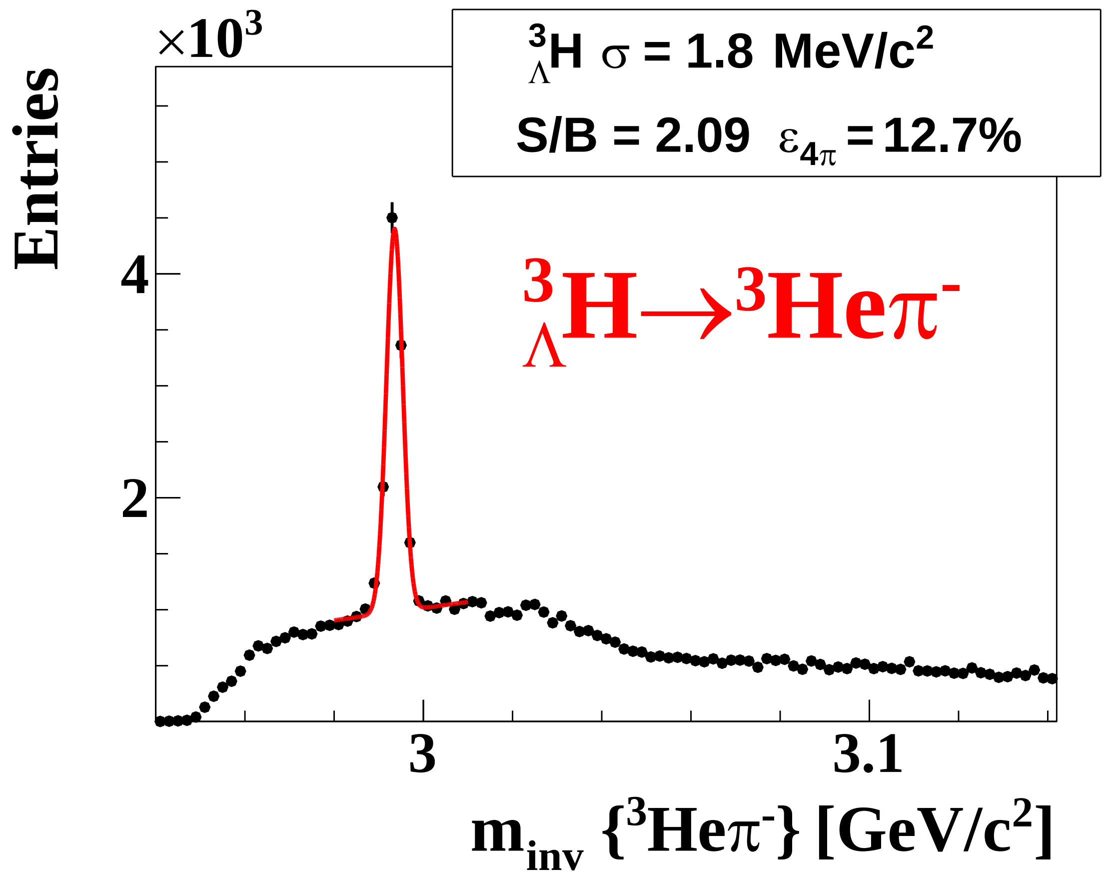
- CBM KF Particle Finder is successfully applied to the STAR data in a wide energy range.
- STAR data are excellent platform to test and improve our reconstruction software.

Hypernuclei production in A+A collisions

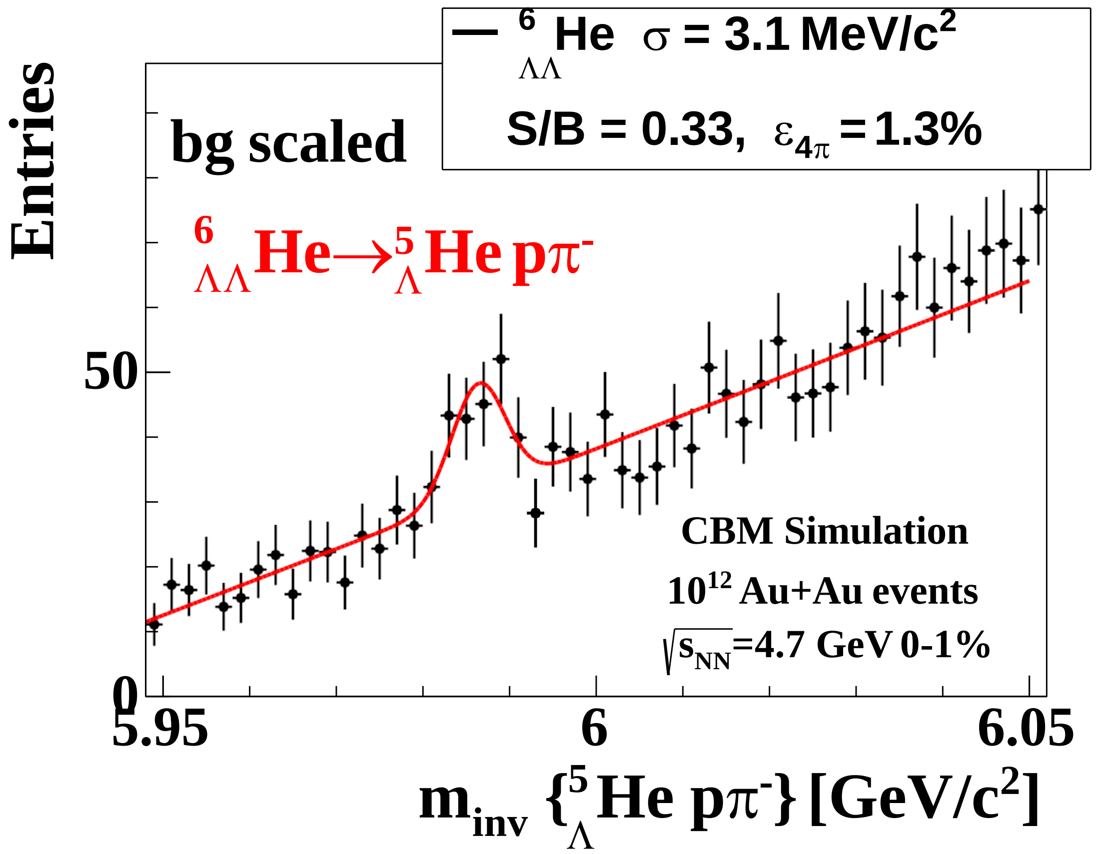


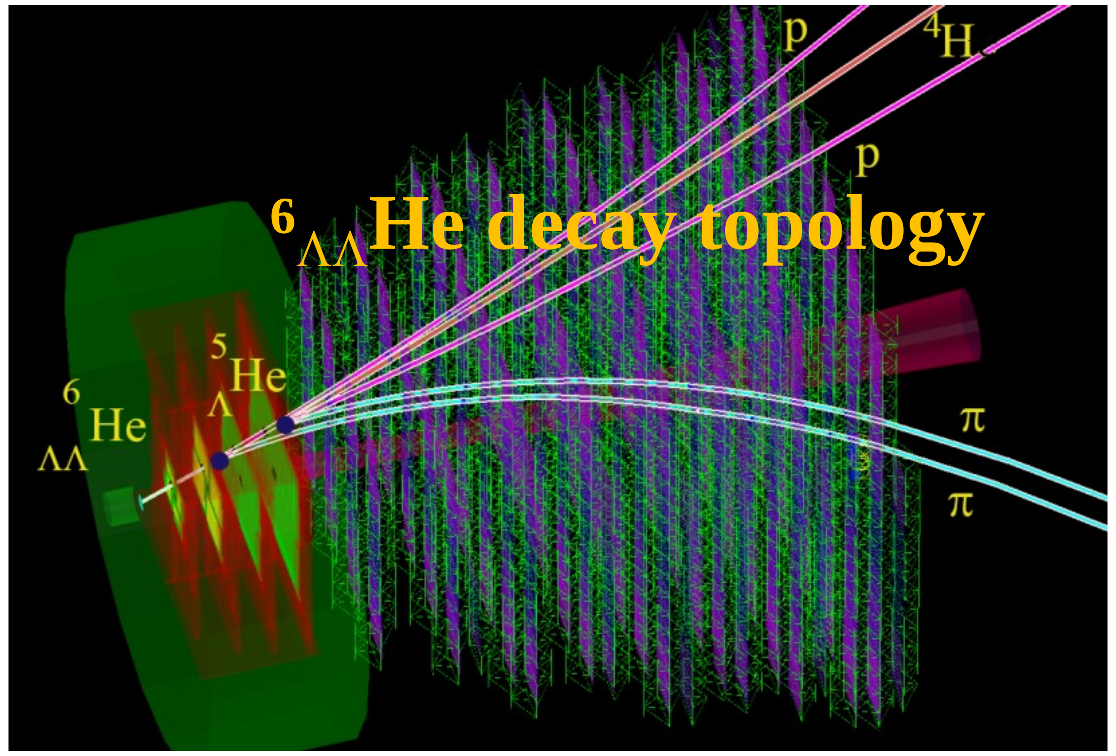
A. Andronic et al., Phys. Lett. B697 (2011) 203

5M mbias events Au+Au at 10AGeV/c
50 sec at 0.1MHz IR (1.8 k/sec)



Expected collection rate: ~60 $^6_{\Lambda\Lambda}$He in 1 week at **10MHz IR** (not day-1)

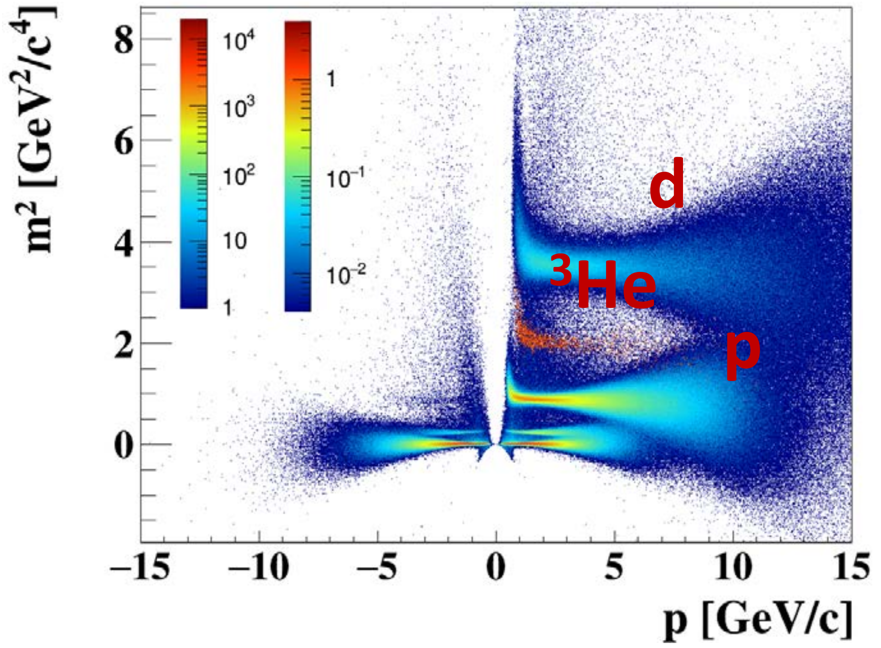


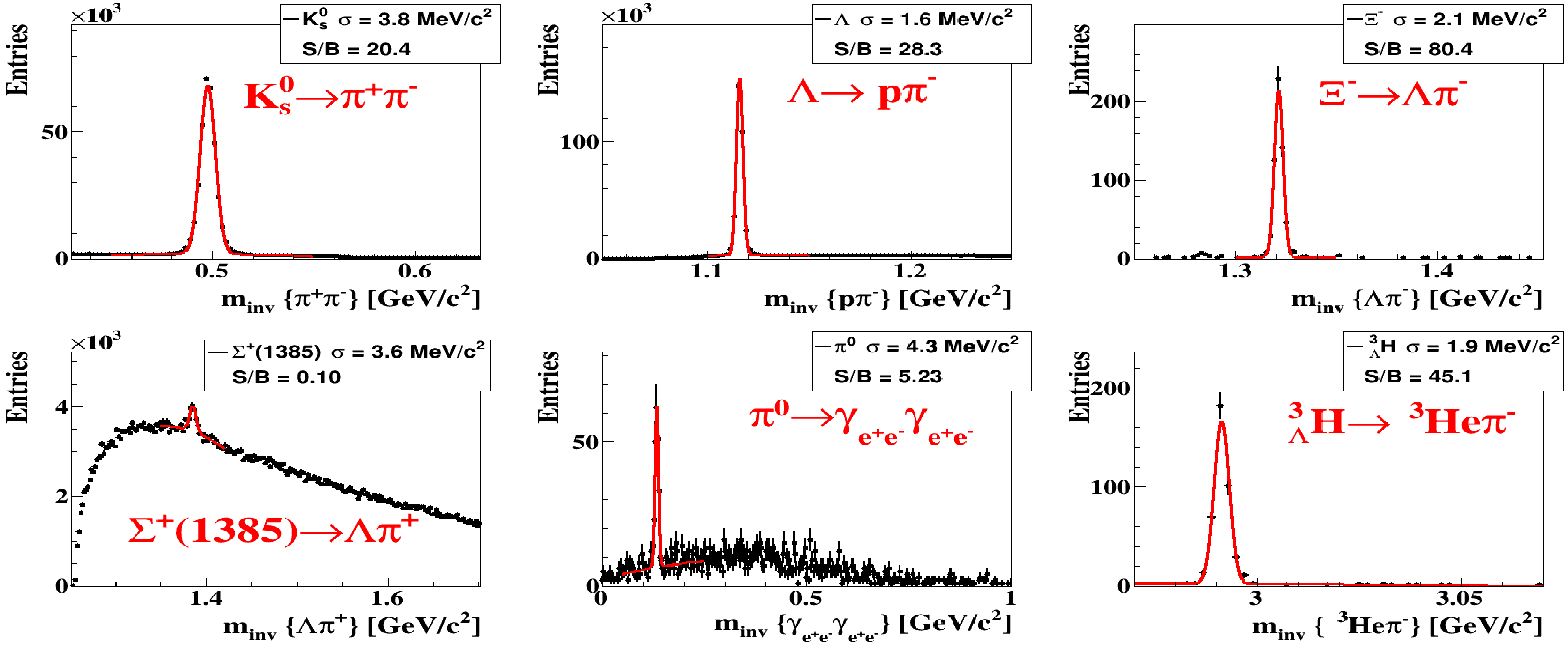


- According to the current theoretical predictions CBM will be able to perform comprehensive study of hypernuclei, including:
  - precise measurements of lifetime;
  - excitation functions;
  - flow.
- It has a huge potential to register and investigate double Λ hypernuclei.

DCM with CBM detector 5M mbias C + C collisions
About 50 sec of data taking assuming 10^5 IR

A.S.Botvina, K.K.Gudima, J.Pochodzalla.
Production of hypernuclei in peripheral relativistic ion collisions.
Phys. Rev. C , v. 88, p. 054605, 2013.

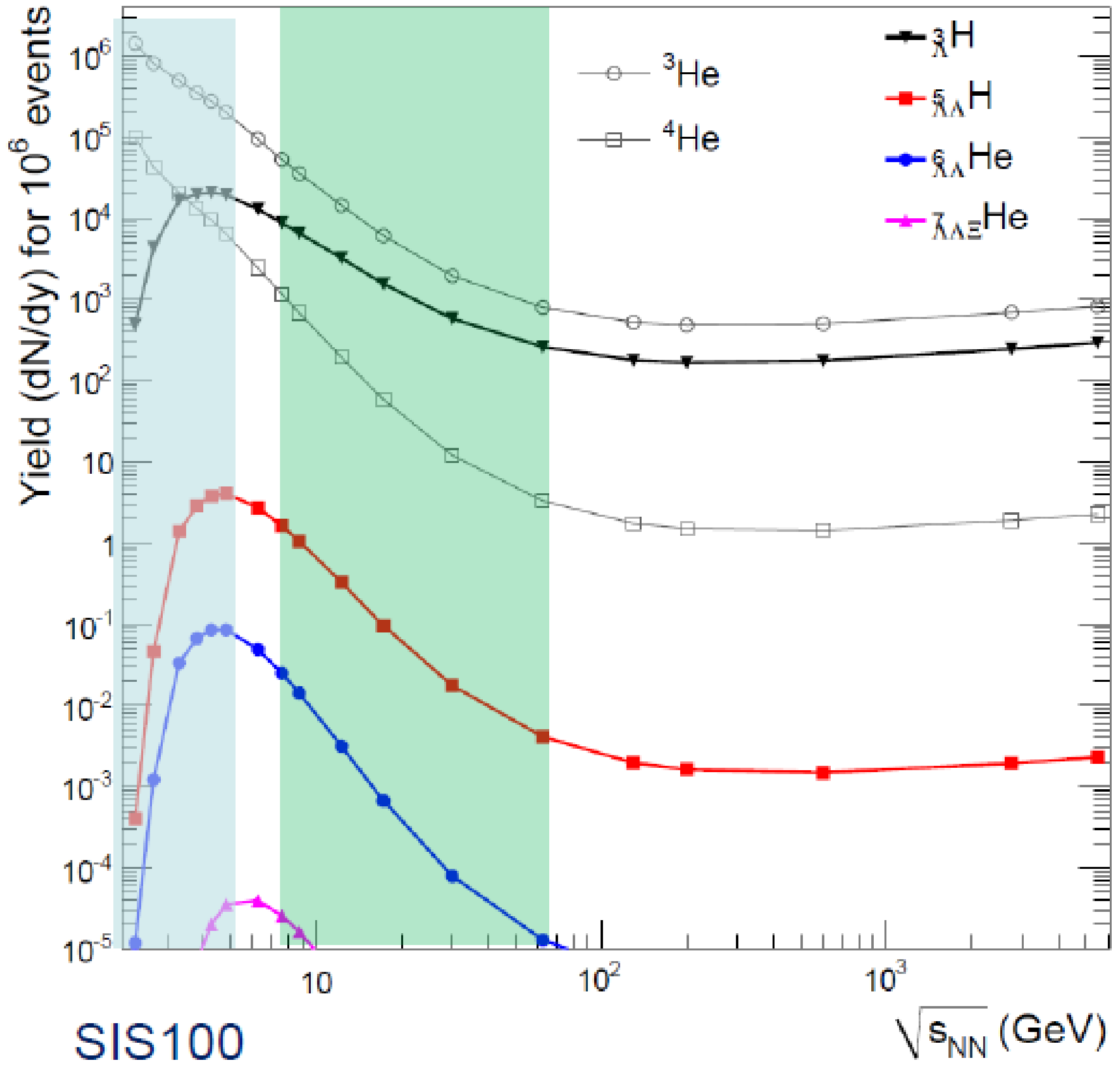




Λ N, ΛNN, $^4{}_\Lambda$H and $^4{}_\Lambda$He

CBM KFParticle Finder – test: Hypernuclei Reconstruction @ STAR BES I
Au+Au events 4.4M at sqrt(s) = 7.7 + 12M at sqrt(s) =11 GeV

Team:
M. Zyzak
Yu. Fisyak
I. Vassiliev



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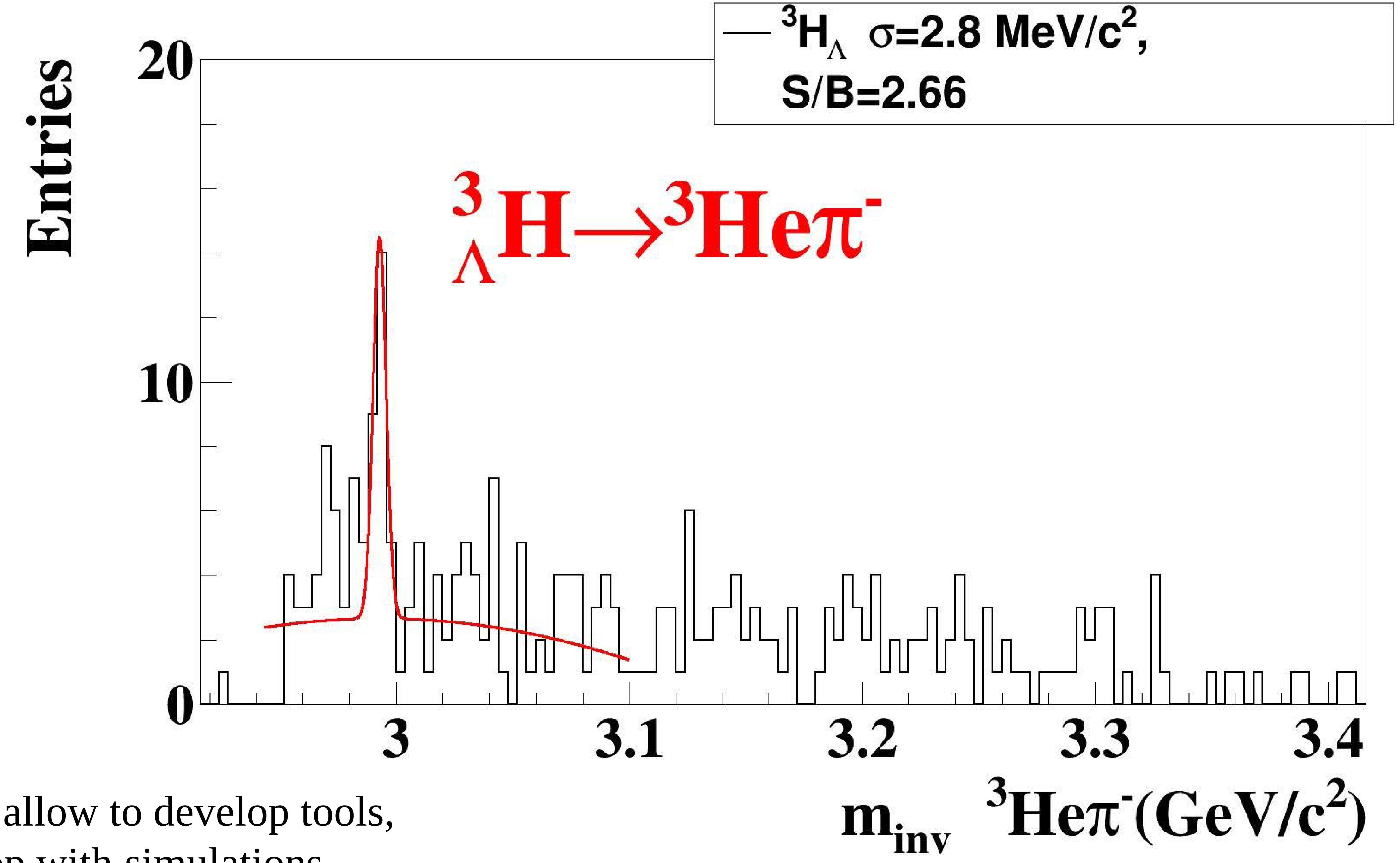

- Approbation with the real data allow to develop tools, which are complicate to develop with simulations.

Day-1: Expected particle yields Au+Au @ 6, 10 AGeV

Particle (mass MeV/c^2)	Multiplicity central ev. 6 AGeV	Multiplicity central ev. 10 AGeV	decay mode	BR	ε (%)	yield in 90 days 6AGeV	yield in 90 days 10 AGeV	IR MHz
$\bar{\Lambda}$ (1115)	$4.6 \cdot 10^{-4}$	0.034	$\bar{p}\pi^+$	0.64	19.7	$1.1 \cdot 10^{7}$	$8.3 \cdot 10^{8}$	**0.1**
Ξ^- (1321)	0.054	0.222	$\Lambda\pi^-$	1	9.9	$1.0 \cdot 10^{9}$	$4.3 \cdot 10^{9}$	**0.1**
Ξ^+ (1321)	$3.0 \cdot 10^{-5}$	$5.4 \cdot 10^{-4}$	$\bar{\Lambda}\pi^+$	1	8.7	$5.0 \cdot 10^{5}$	$9.1 \cdot 10^{6}$	**0.1**
Ω^- (1672)	$5.8 \cdot 10^{-4}$	$5.6 \cdot 10^{-3}$	ΛK^-	0.68	4.4	$3.4 \cdot 10^{6}$	$3.3 \cdot 10^{7}$	**0.1**
Ω^+ (1672)	-	$7 \cdot 10^{-5}$	$\bar{\Lambda}K^+$	0.68	3.9	0 (QGP?)	$3.8 \cdot 10^{5}$	**0.1**
${}^{3}_{\Lambda}H$ (2993)	$4.2 \cdot 10^{-2}$	$3.8 \cdot 10^{-2}$	${}^{3}He\pi^-$	0.25	12.7	$2.7 \cdot 10^{8}$	$2.5 \cdot 10^{8}$	**0.1**
${}^{4}_{\Lambda}He$ (3930)	$2.4 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	${}^{3}He p\pi^-$	0.32	11.4	$1.7 \cdot 10^{7}$	$1.4 \cdot 10^{7}$	**0.1**
${}^{5}_{\Lambda\Lambda}He$(5047)		$5.0 \cdot 10^{-6}$	${}^{3}He2p2\pi$	0.01	3	15	250	**0.1**
${}^{6}_{\Lambda\Lambda}He$(5986)		$1.0 \cdot 10^{-7}$	${}^{4}He2p2\pi$	0.01	1.2			**0.1**

Summary

- CBM detector is an excellent device to measure not only bulk observables, but strangeness, hypernuclei and other rare probes with high statistic.
- The CBM experiment will provide multidifferential high precision measurements of strange hadrons including multi-strange (anti)-hyperons.
- High precision measurements of excitation functions of multi-strange hyperons in A+A collision with different mass numbers A at SIS100 energies have a discovery potential to find a signal for the onset of deconfinement in QCD matter at high net-baryon densities
- The discovery of (double-) Λ hypernuclei and the determination of their lifetimes will provide information on the hyperon-nucleon and hyperon-hyperon interactions, which are essential ingredients for the understanding of the nuclear matter EoS at high densities, and, hence, of the structure of neutron stars.
- KF Particle Finder is successfully applied to the STAR data in a wide energy range.
- STAR data are excellent platform to test and improve our reconstruction software.
- Approbation with the real data allow to develop tools, which are complicate to develop with simulations.

CBM Collaboration: 64 Institutes, ~600 members