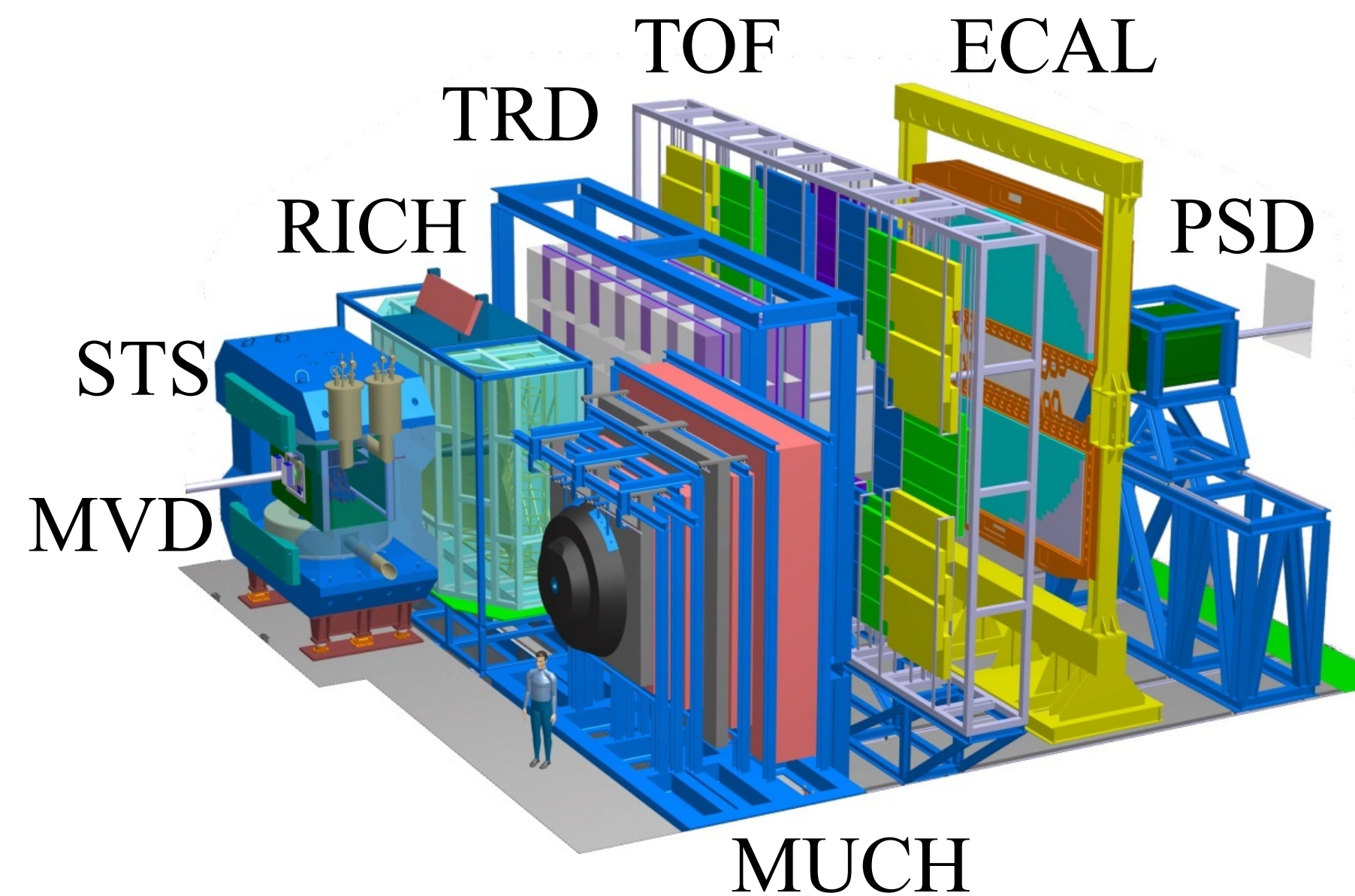
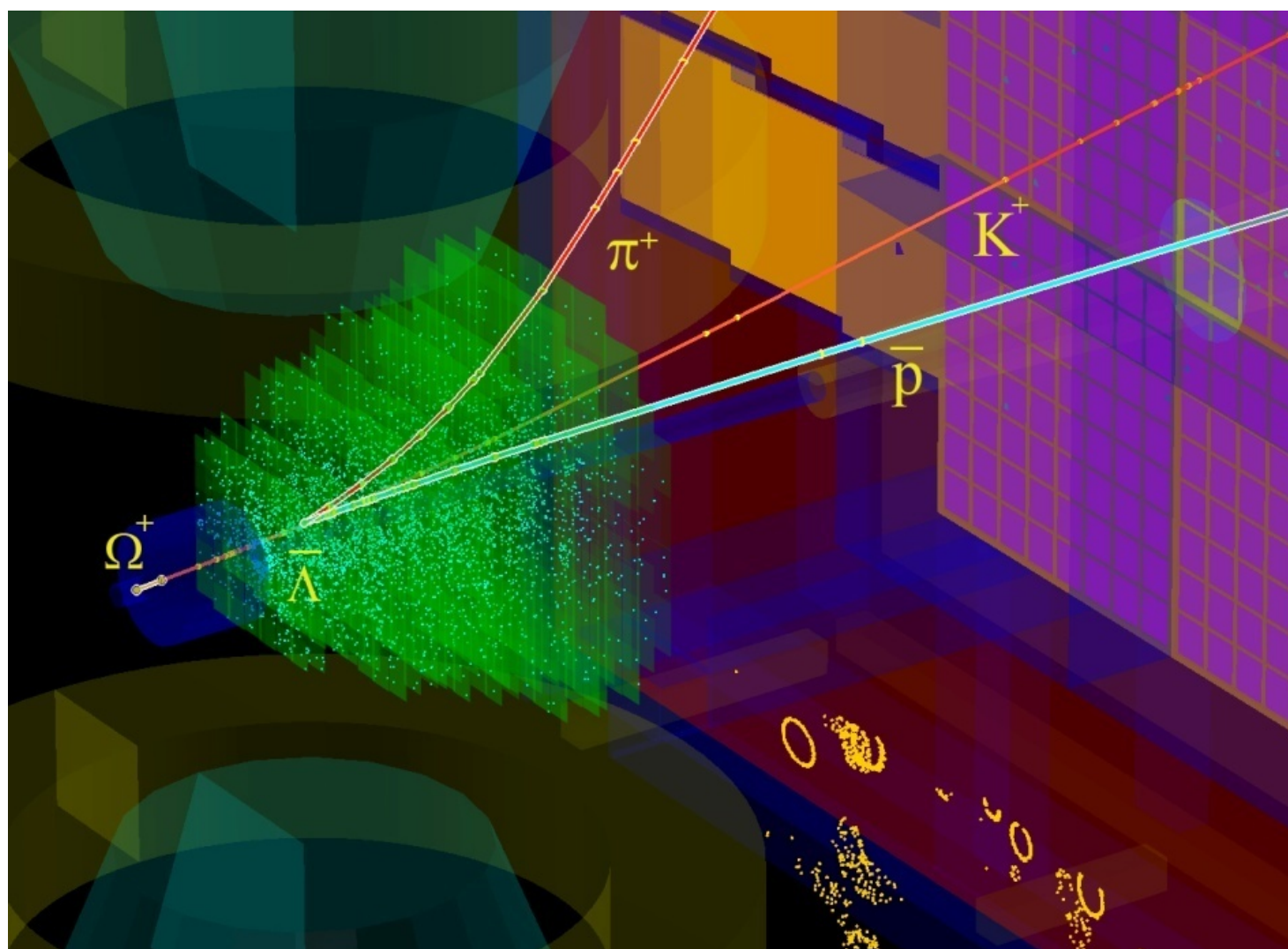


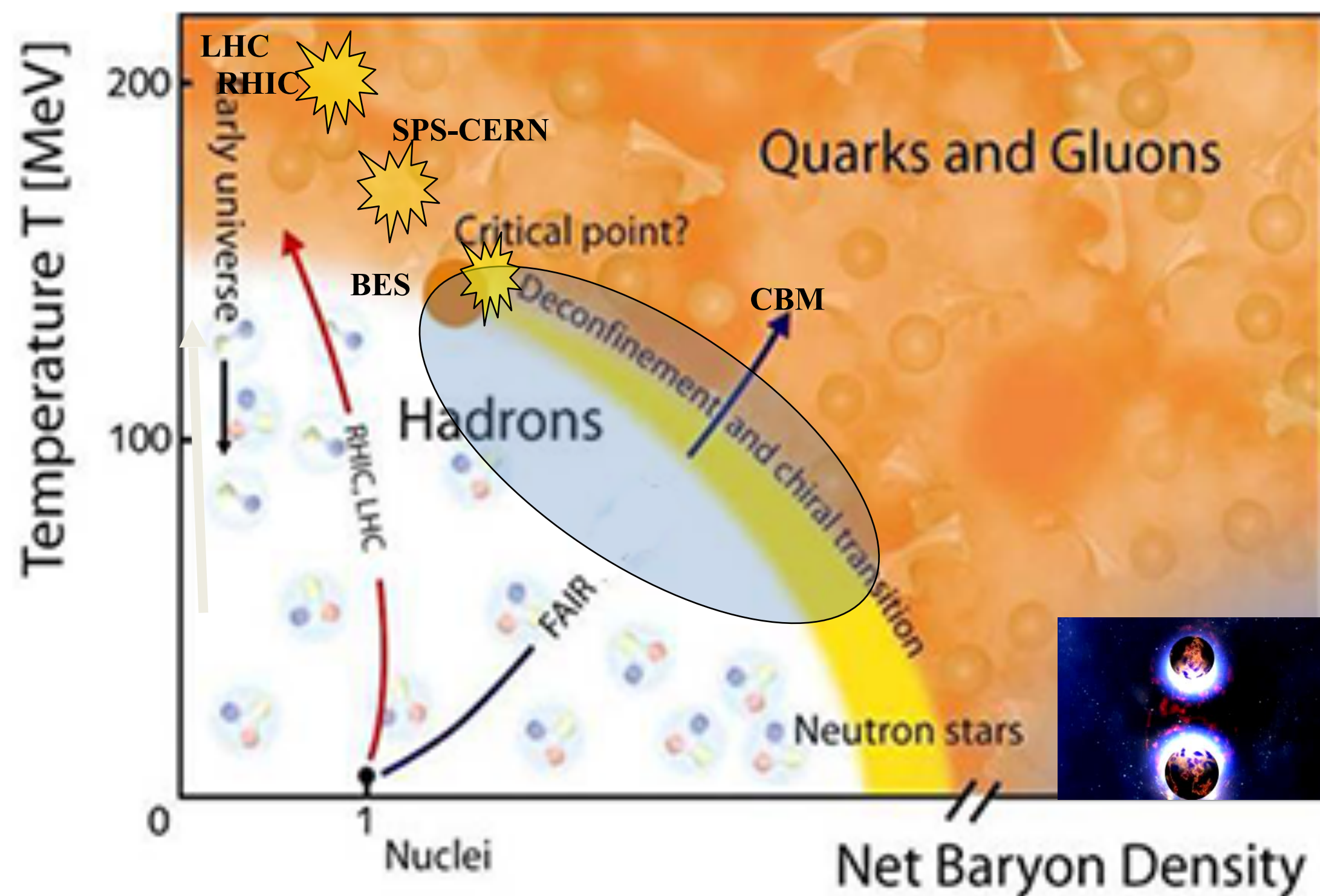
Perspectives on strangeness physics with CBM experiment at FAIR

I. Vassiliev, I. Kisel and M. Zyzak for the CBM Collaboration



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

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**)

Onset of chiral symmetry restoration at high μ_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 ...**)

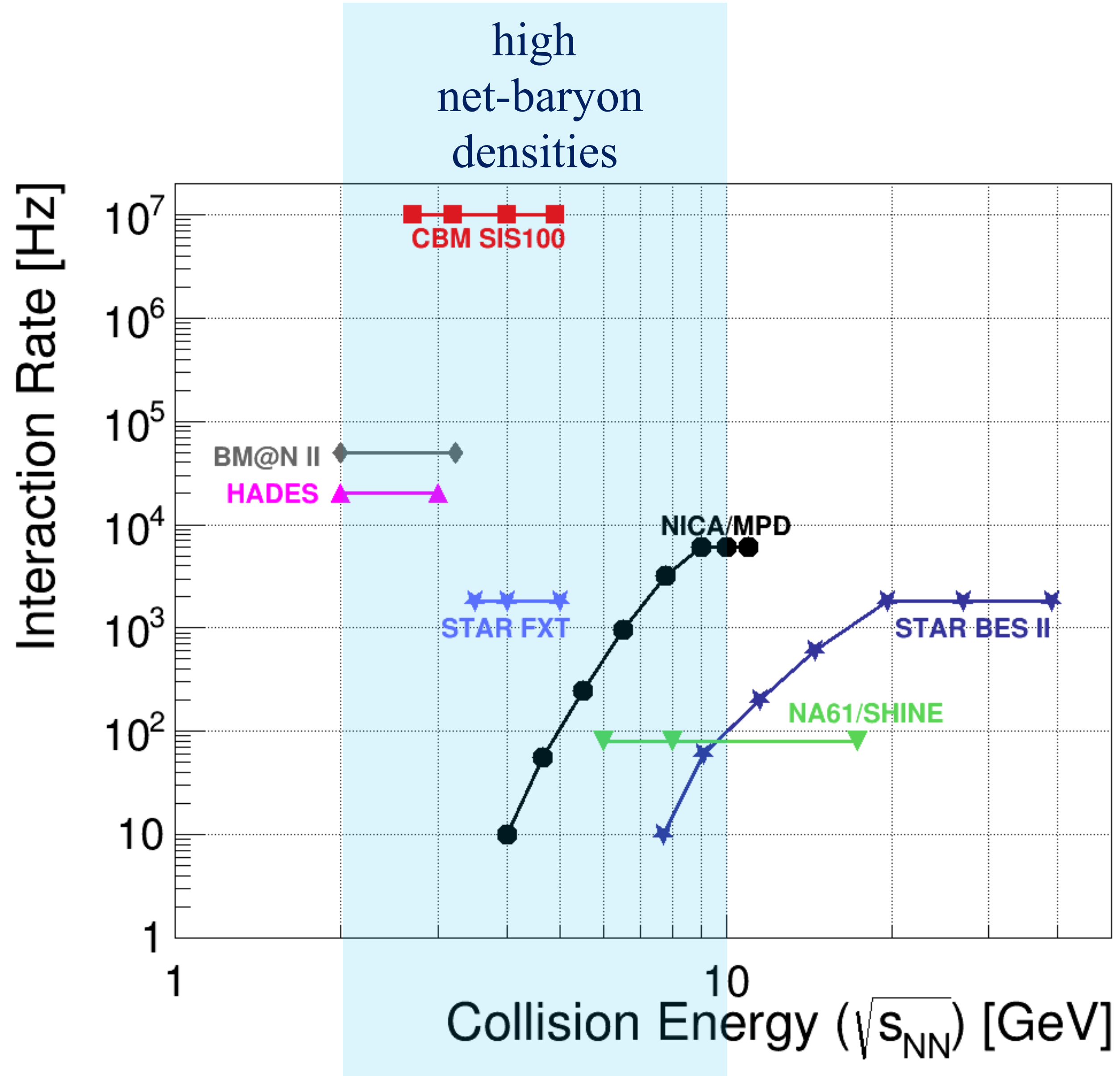
Projects to explore the QCD phase diagram at large μ_B :

RHIC (STAR) beam energy-scan, HADES, NA61@SPS,

MPD@NICA: bulk observables

CBM: bulk and rare observables, high statistic!

Experiments exploring dense QCD matter



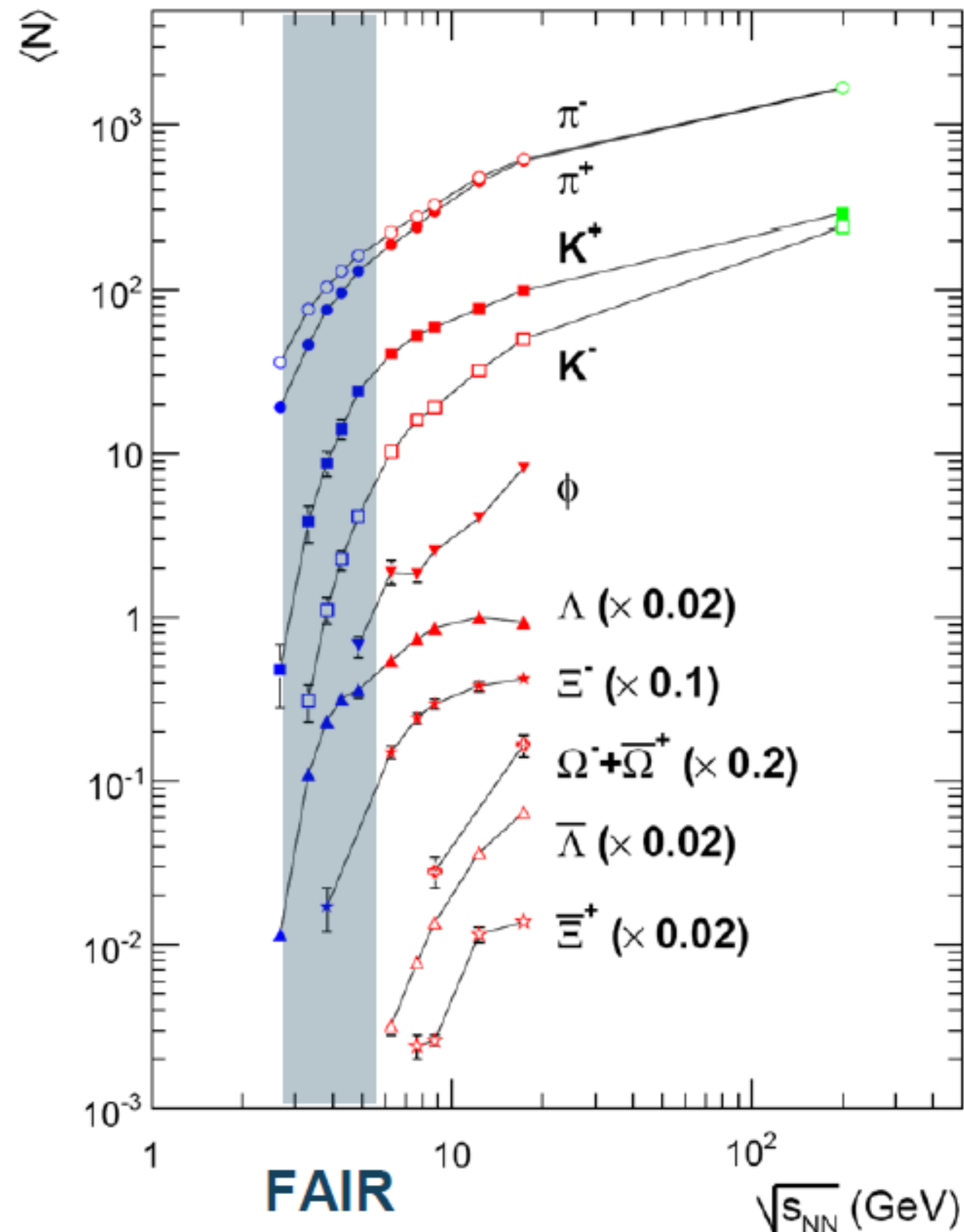
CBM:

unprecedented rate capability

- determination of (displaced) vertices with high resolution ($\approx 50 \mu\text{m}$)
- 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

Pb+Pb, Au+Au (central)



No data available at FAIR energy

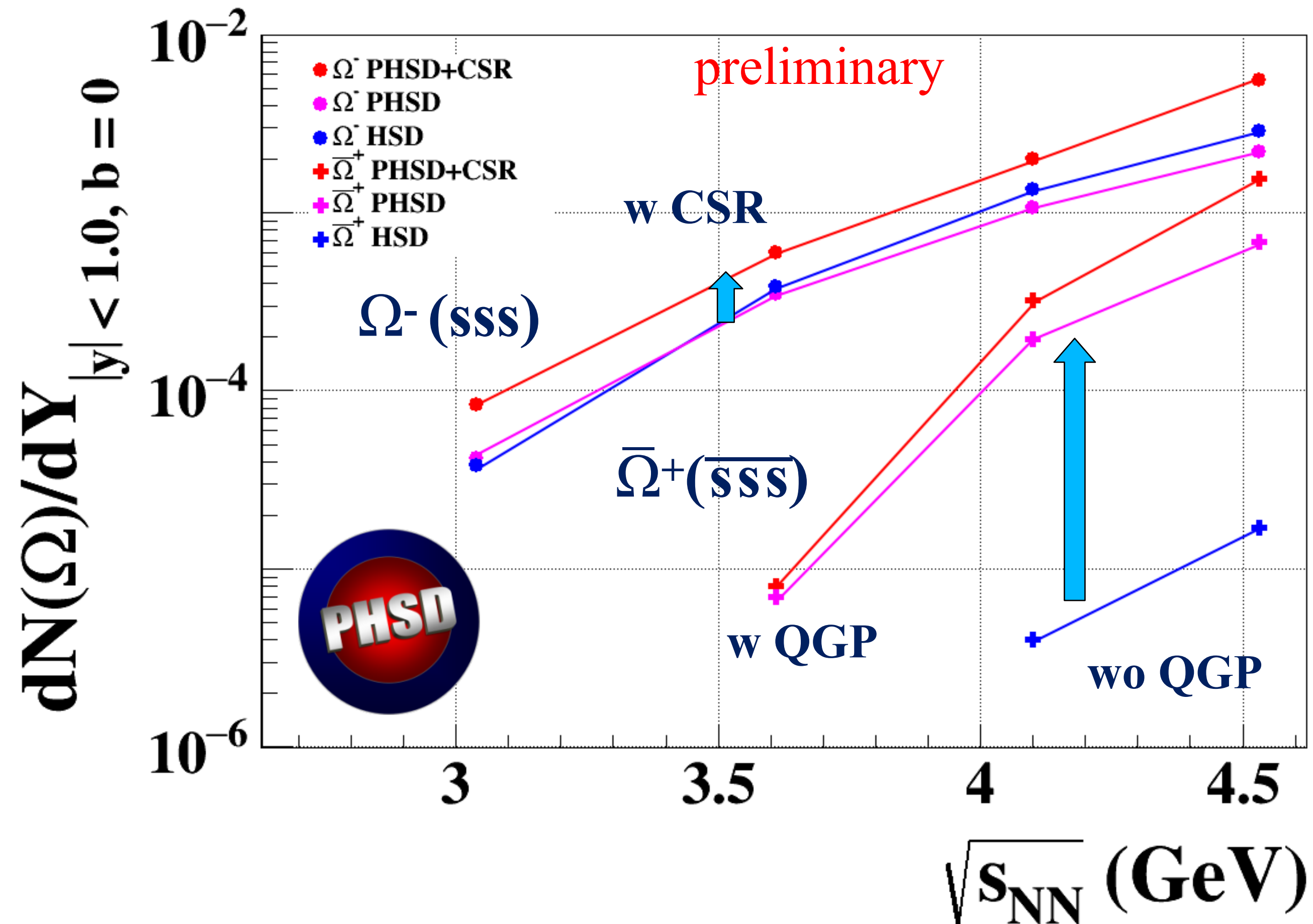
In the AGS (SIS100) energy range, only about 300 Ξ^- hyperons have been measured in Au+Au collisions at 6A GeV

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]

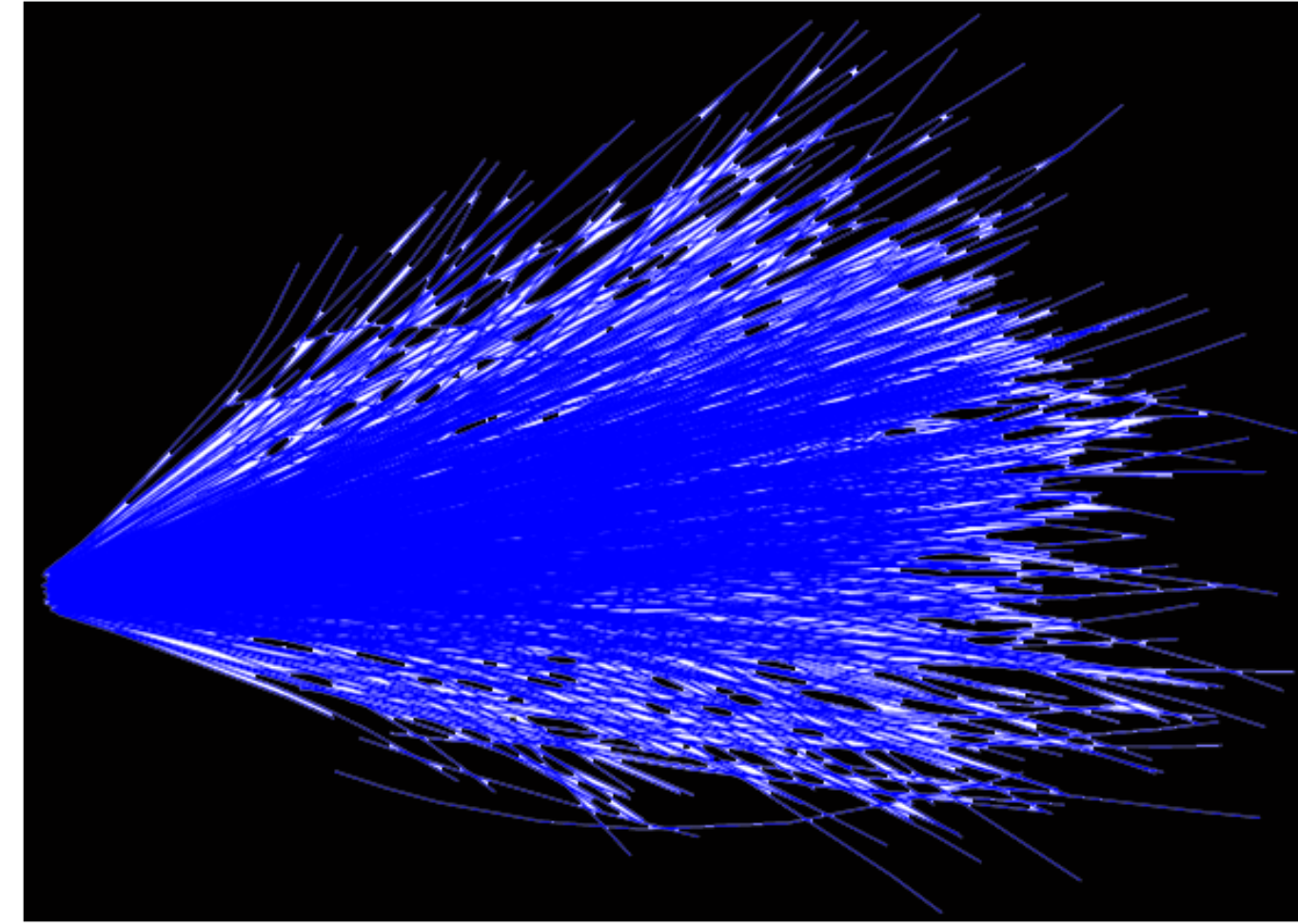
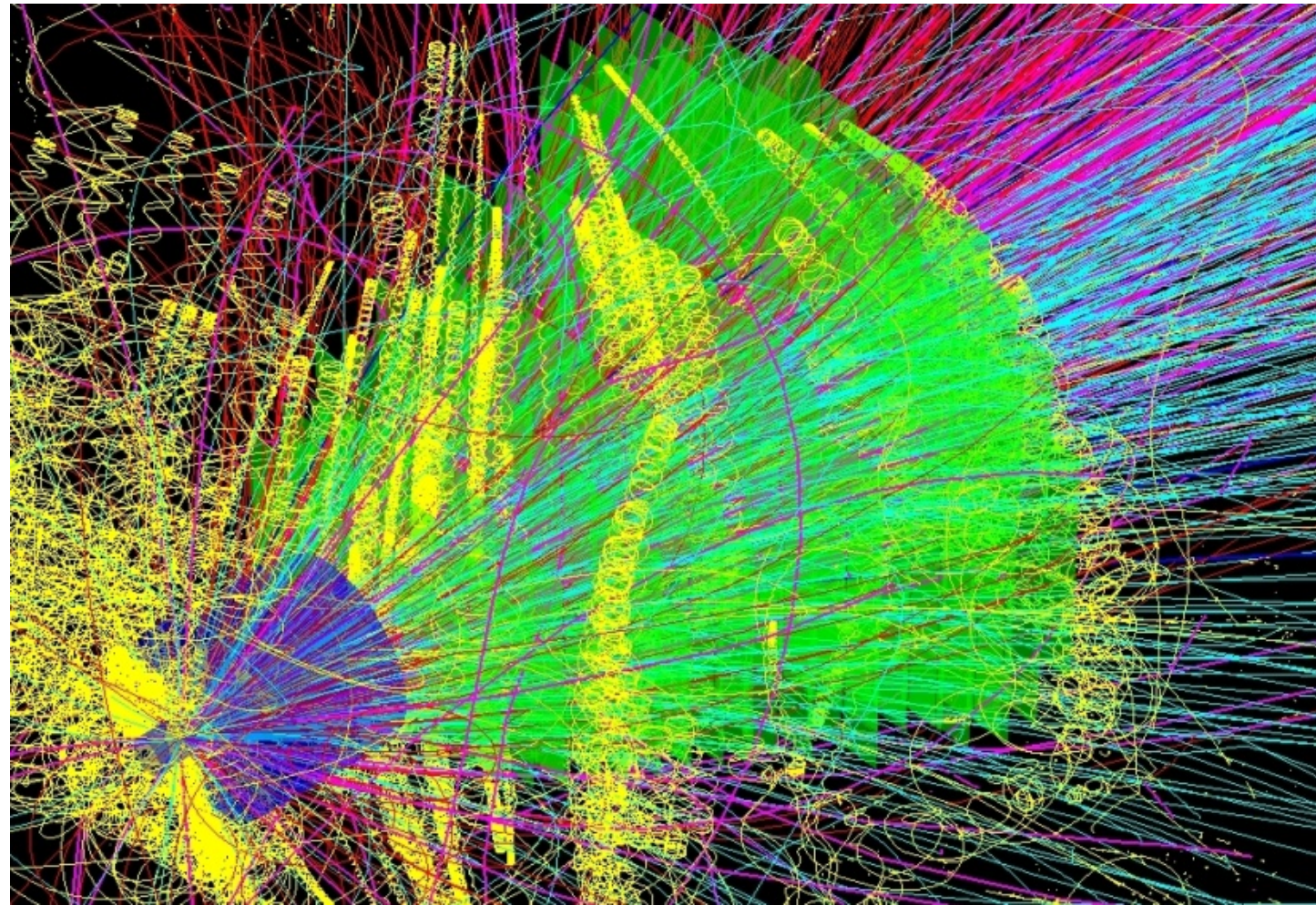


Chiral symmetry restoration (CSR) change the flavor decomposition – more s-sbar pairs produced.

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

Performance of the CBM track finder



AuAu 10 AGeV/c

165 π

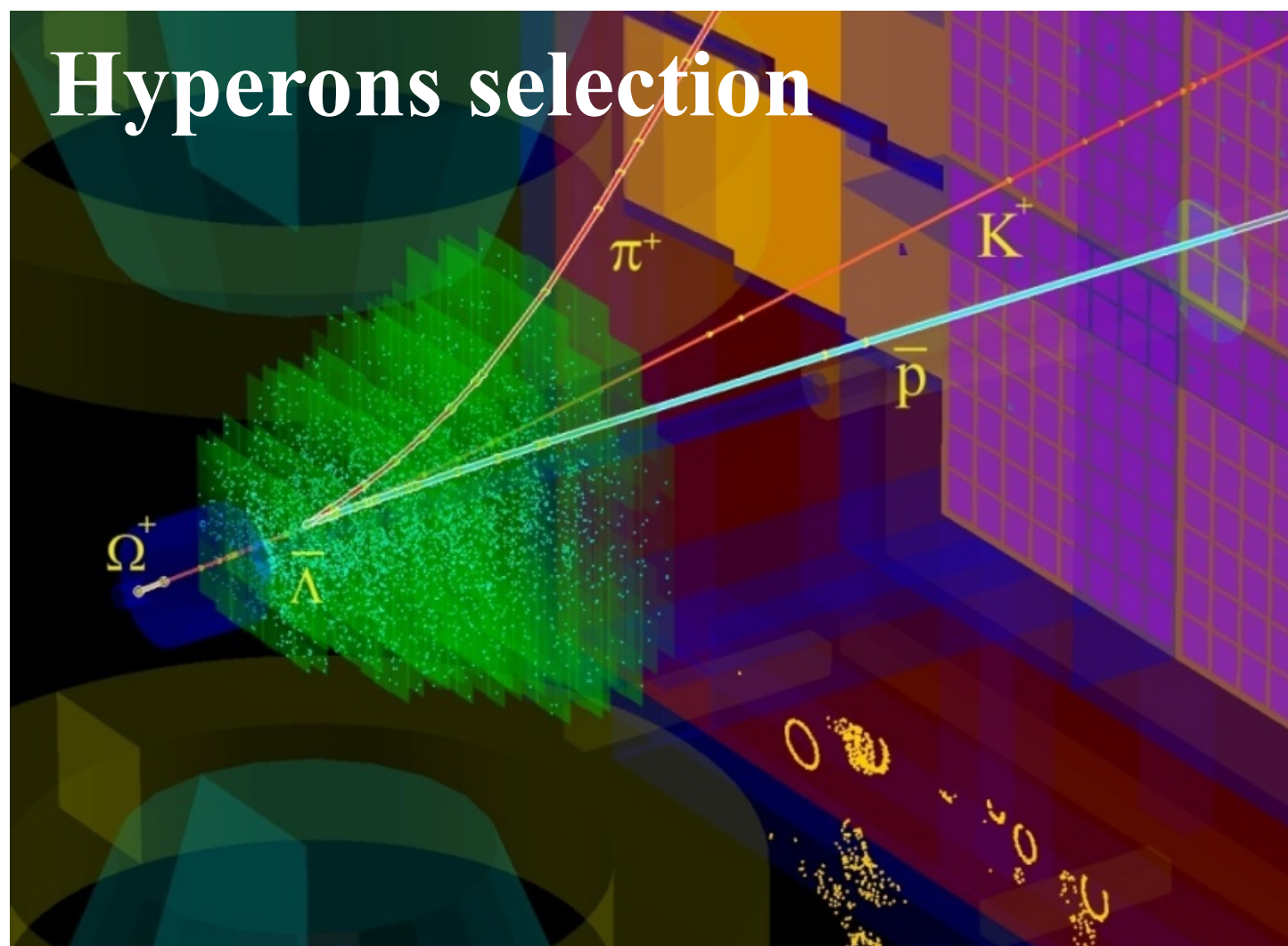
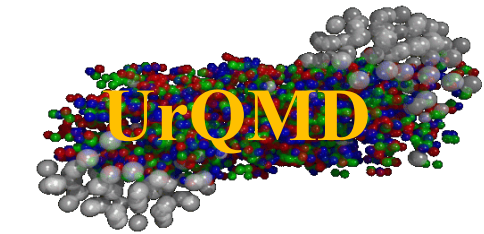
170 p

26 K

15 Λ

20 K_S^0

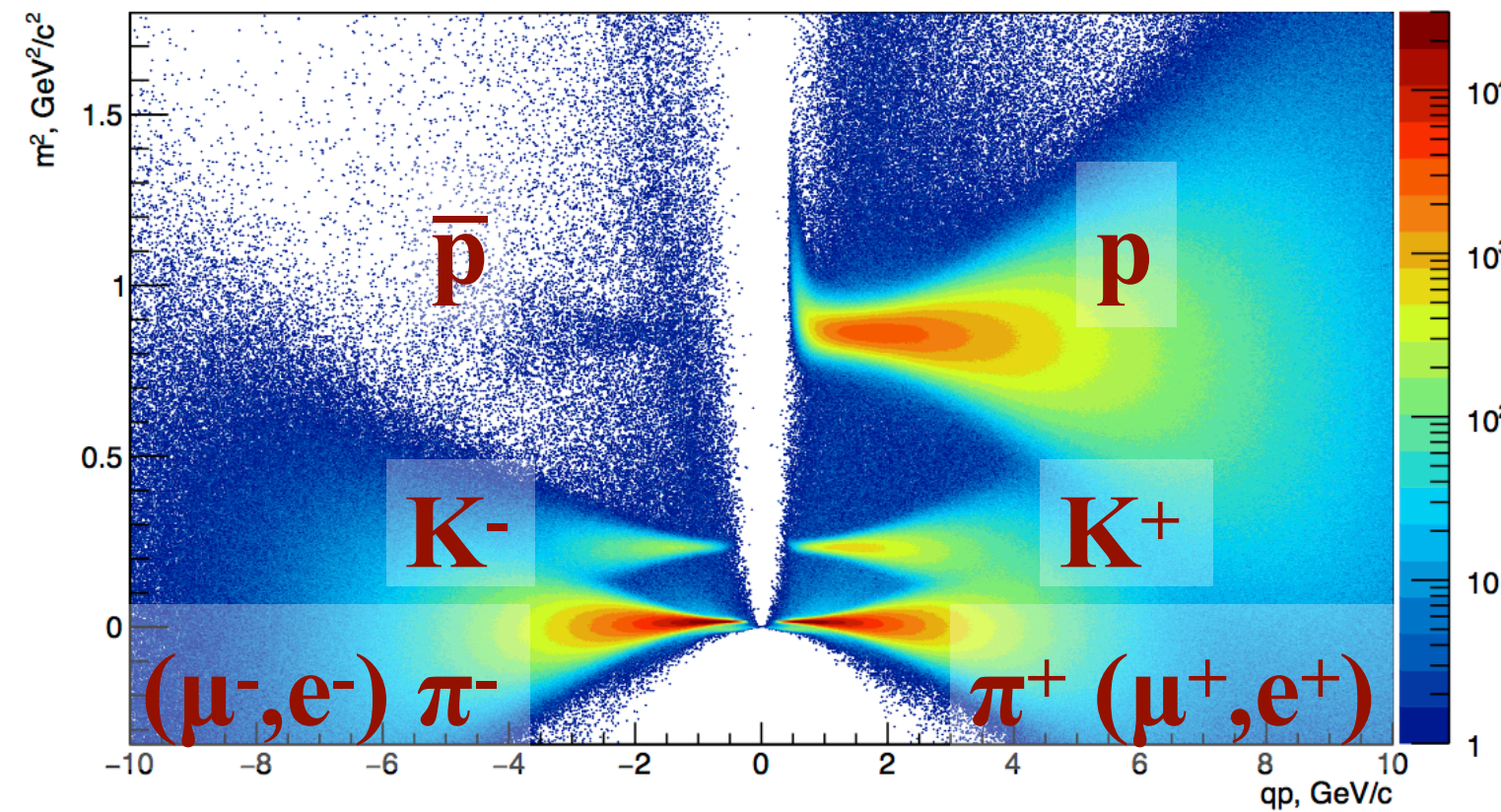
0.3 E^-



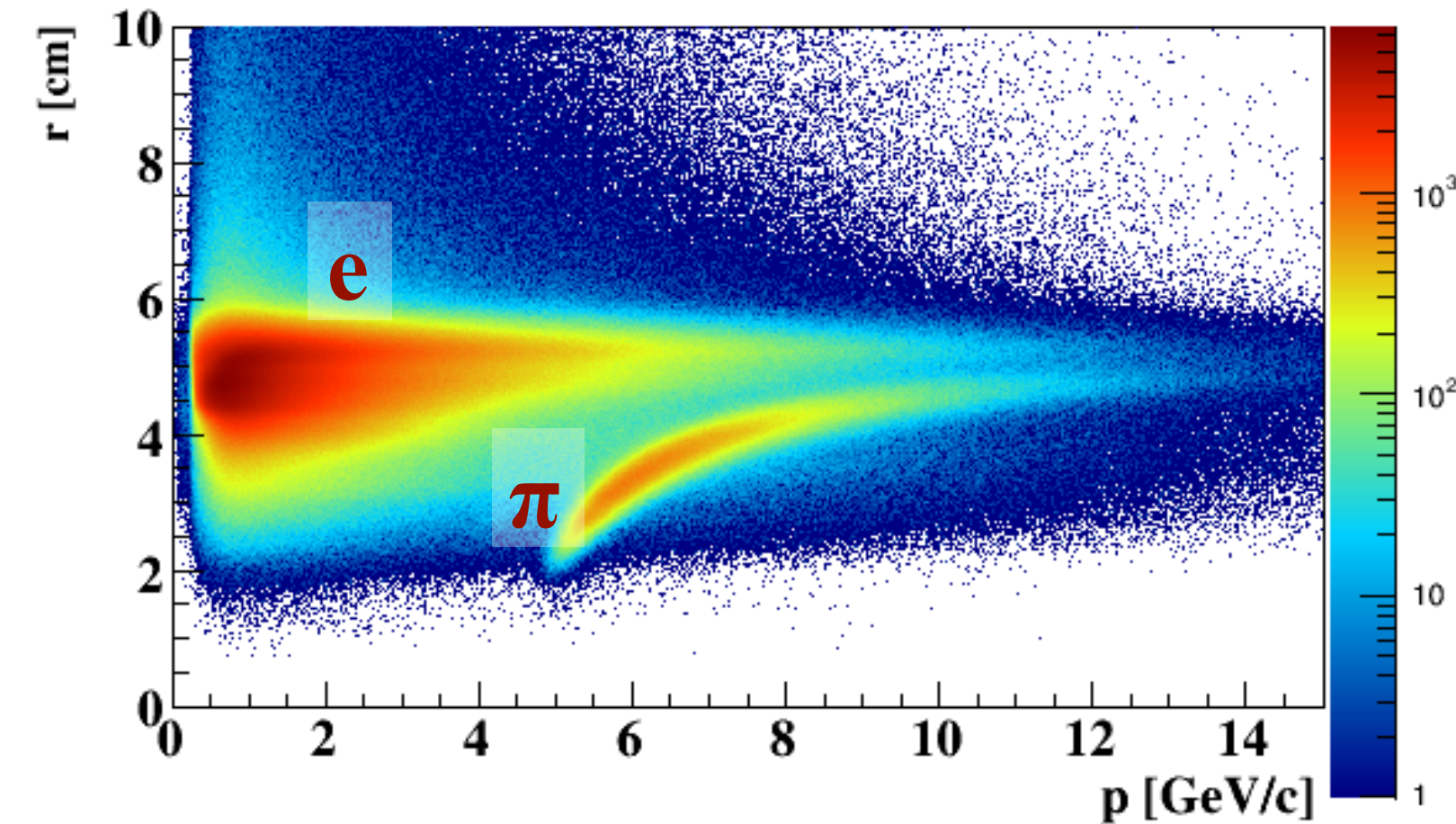
- For studies several theoretical models like UrQMD and PHSD are used.
- Track finder is based on the Cellular Automaton method.
- High efficiency for track reconstruction of more than 92%, including fast (more than 90%) and slow (more than 65%) secondary tracks.
- Time-based track finder is developed,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

Particle identification with PID detectors

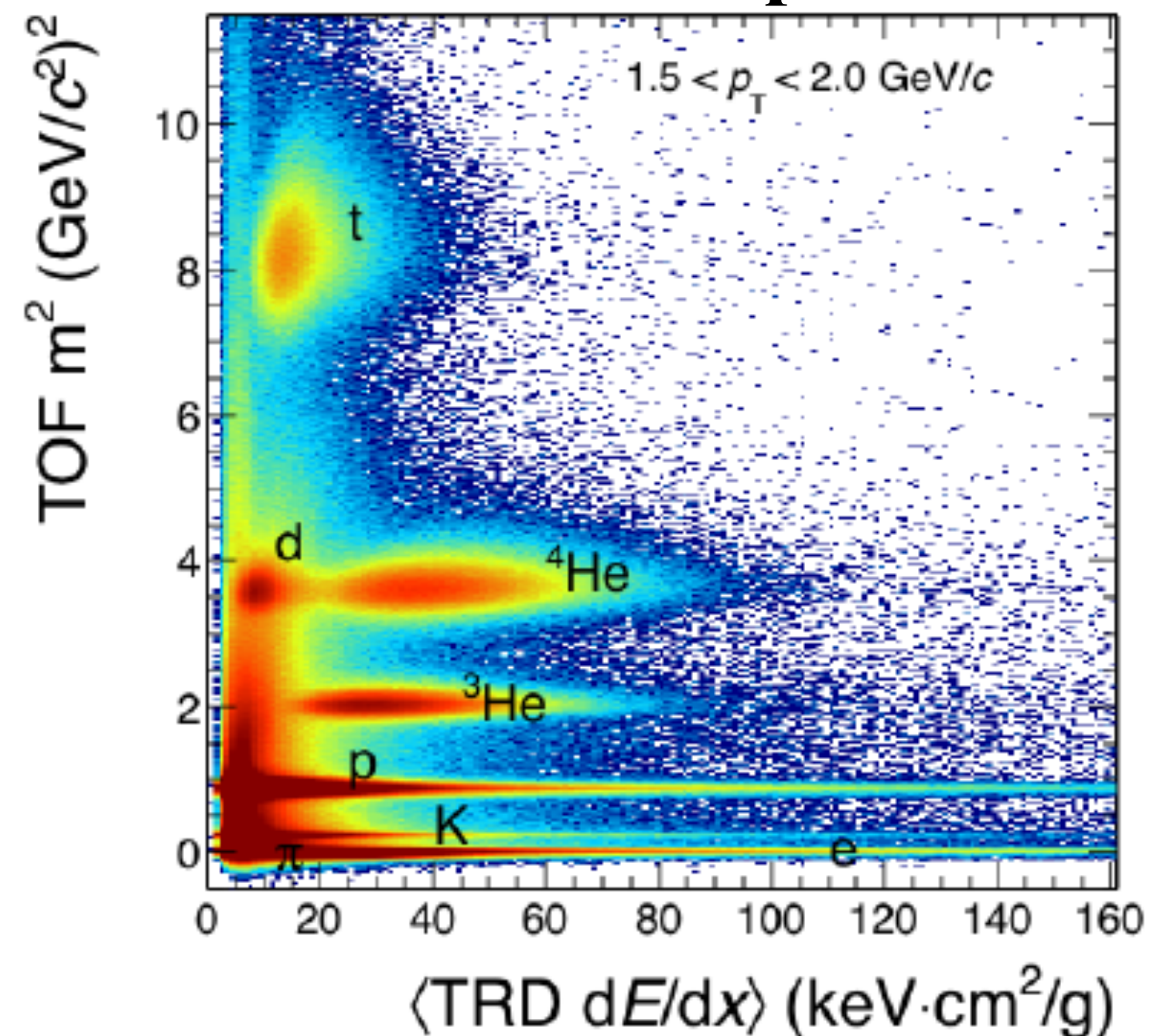
ToF: hadron identification



RICH: electron identification



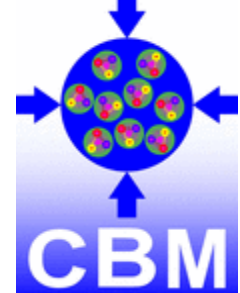
TRD: d-He separation



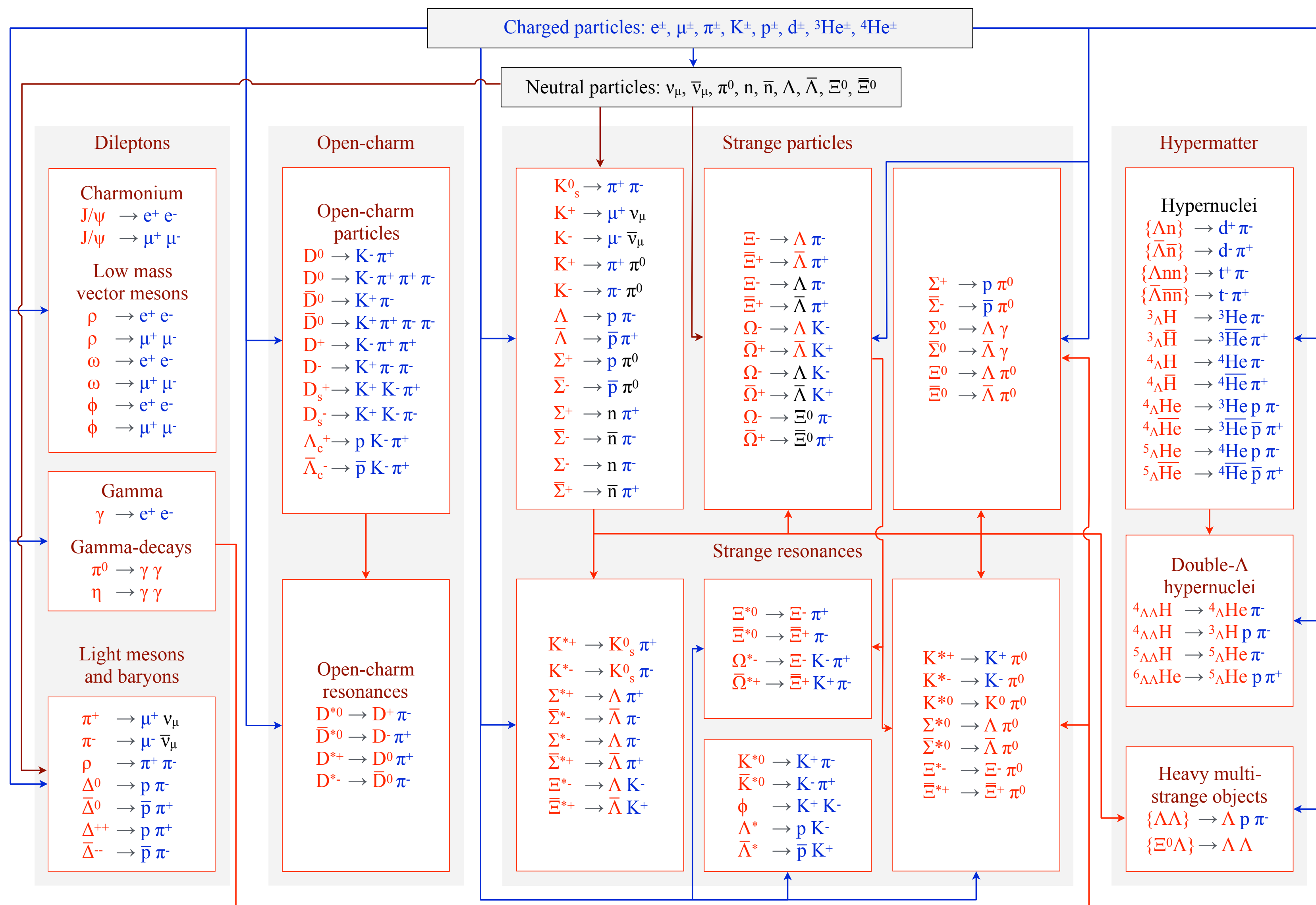
PID detectors:

- ToF (Time of Flight) — 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.



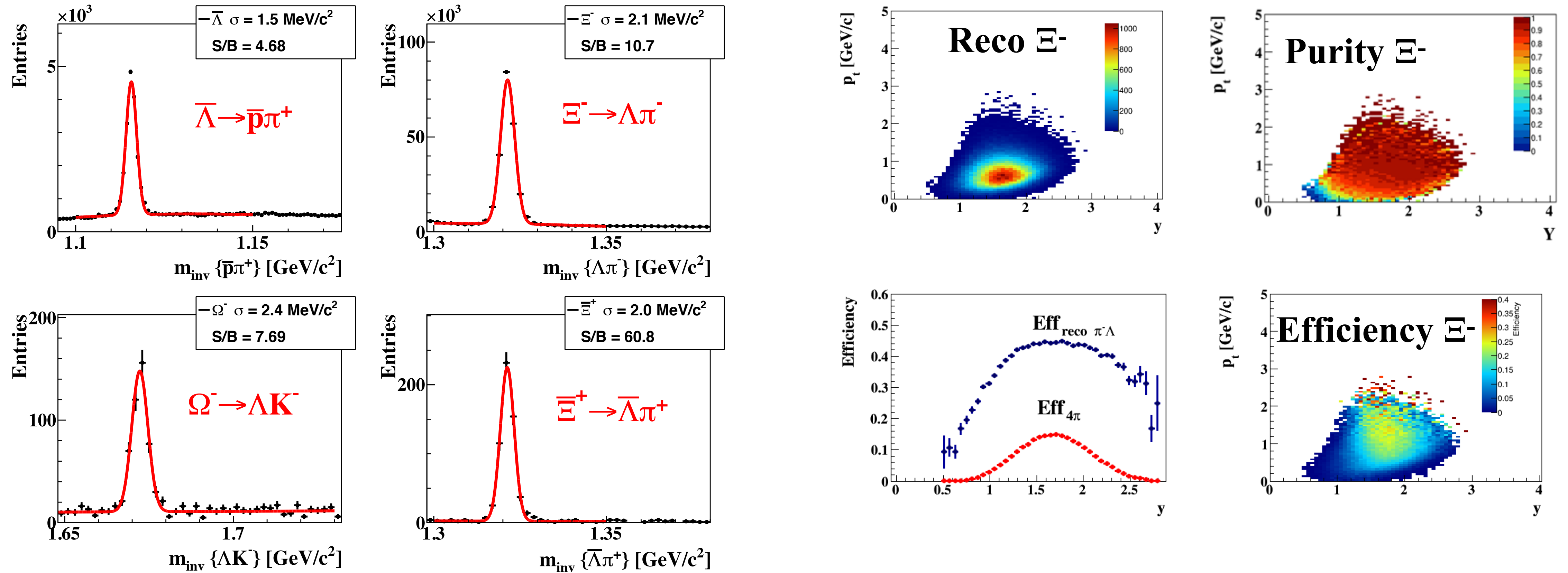
KF Particle Finder for the CBM Experiment



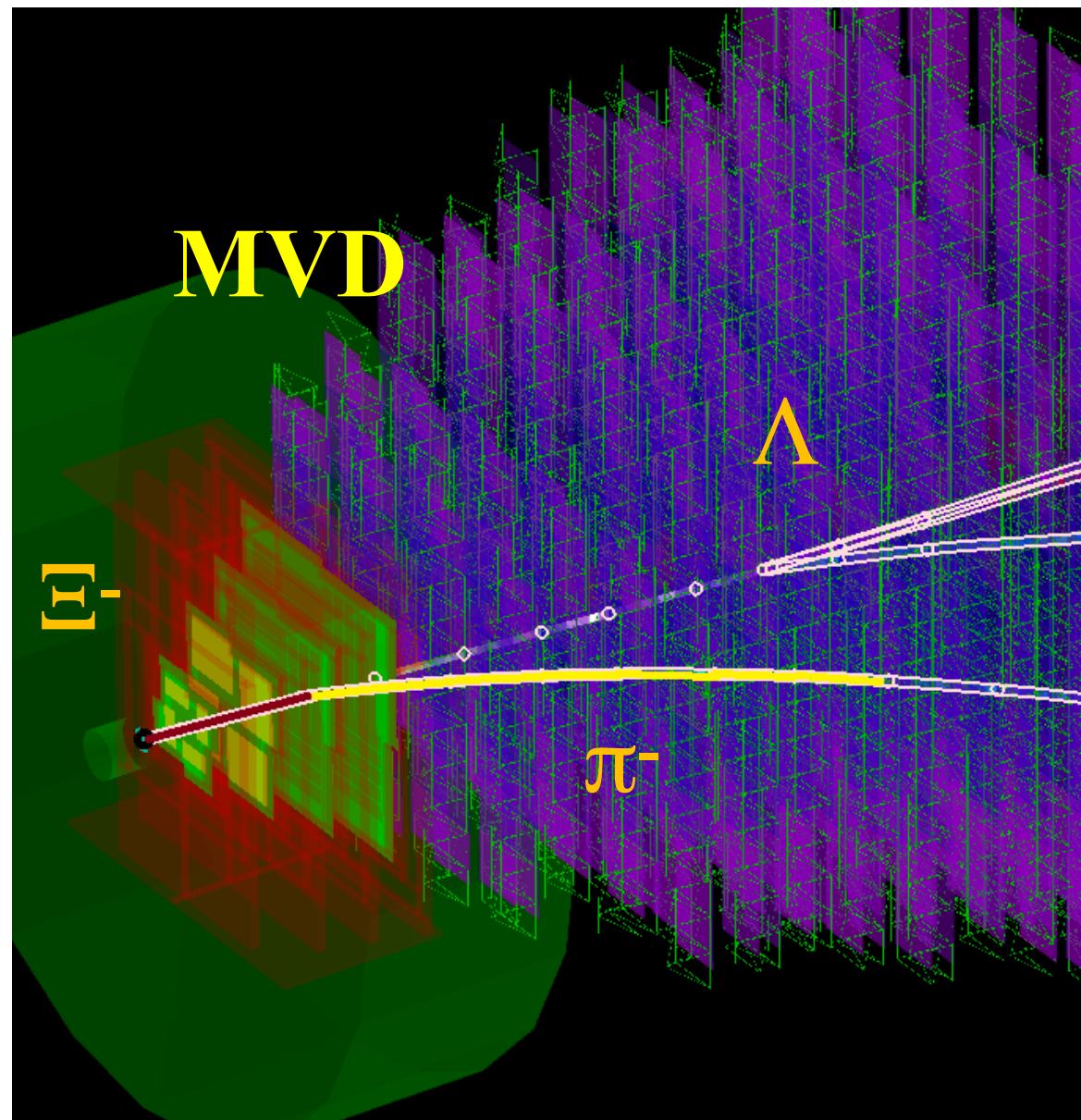
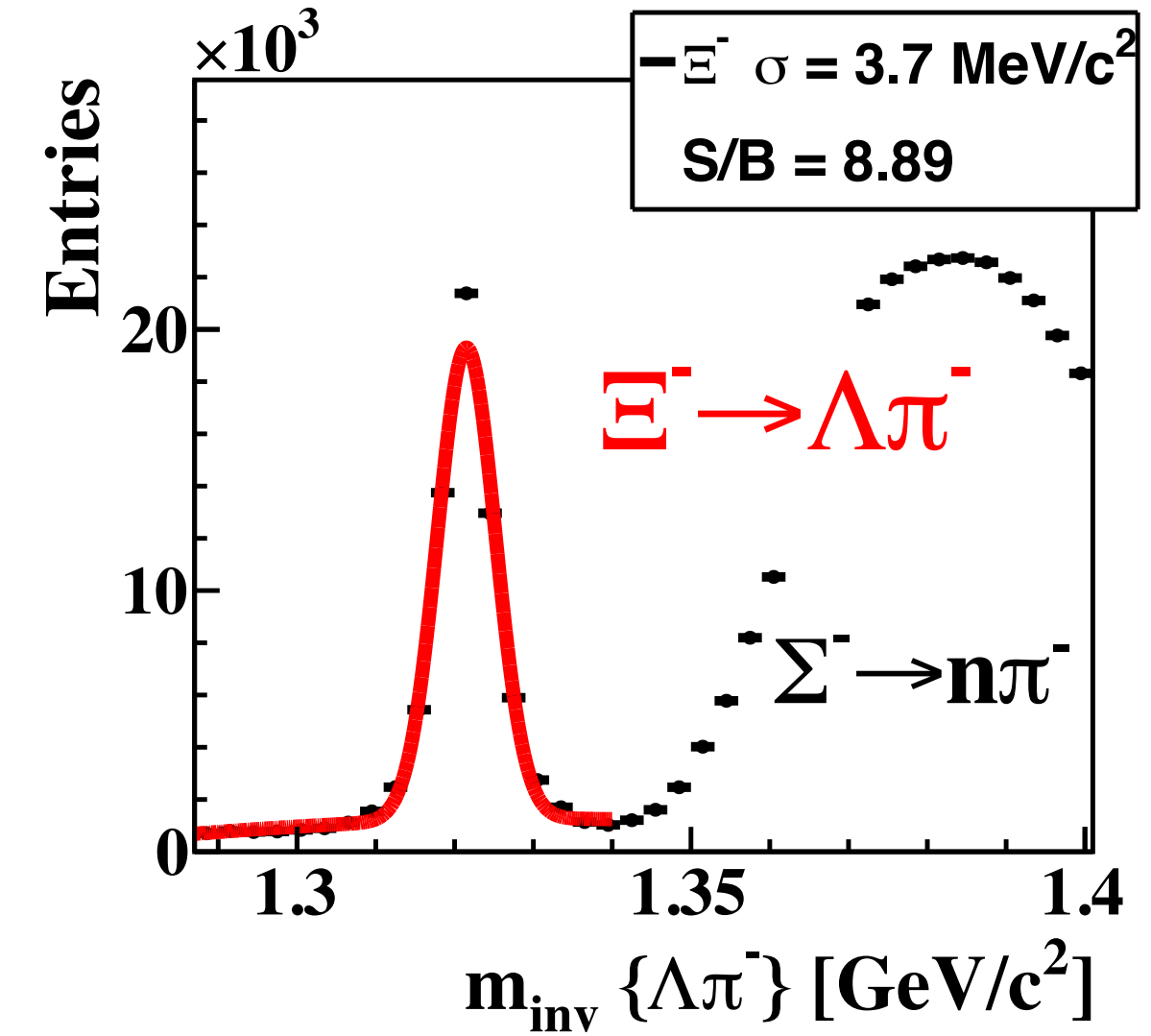
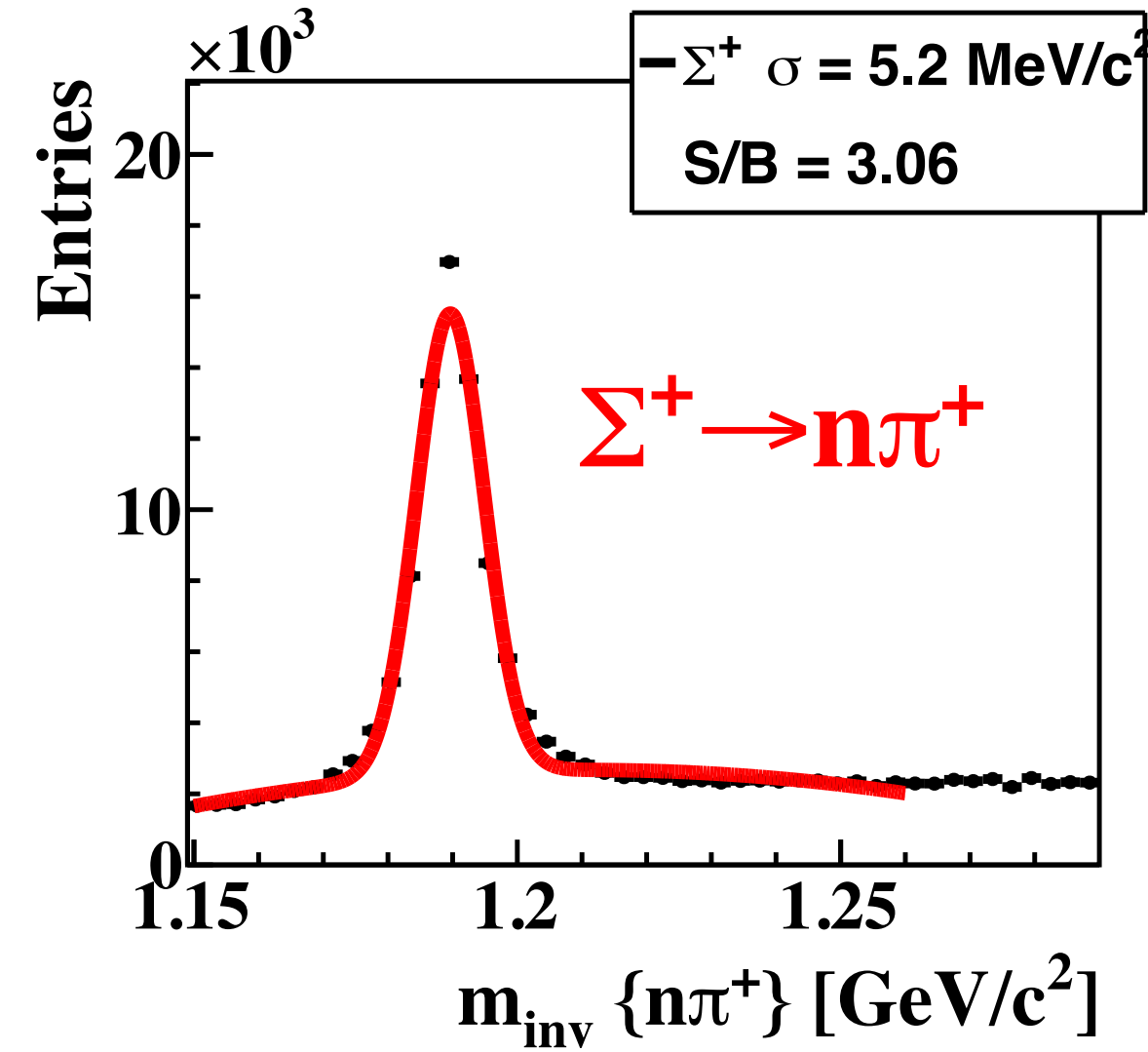
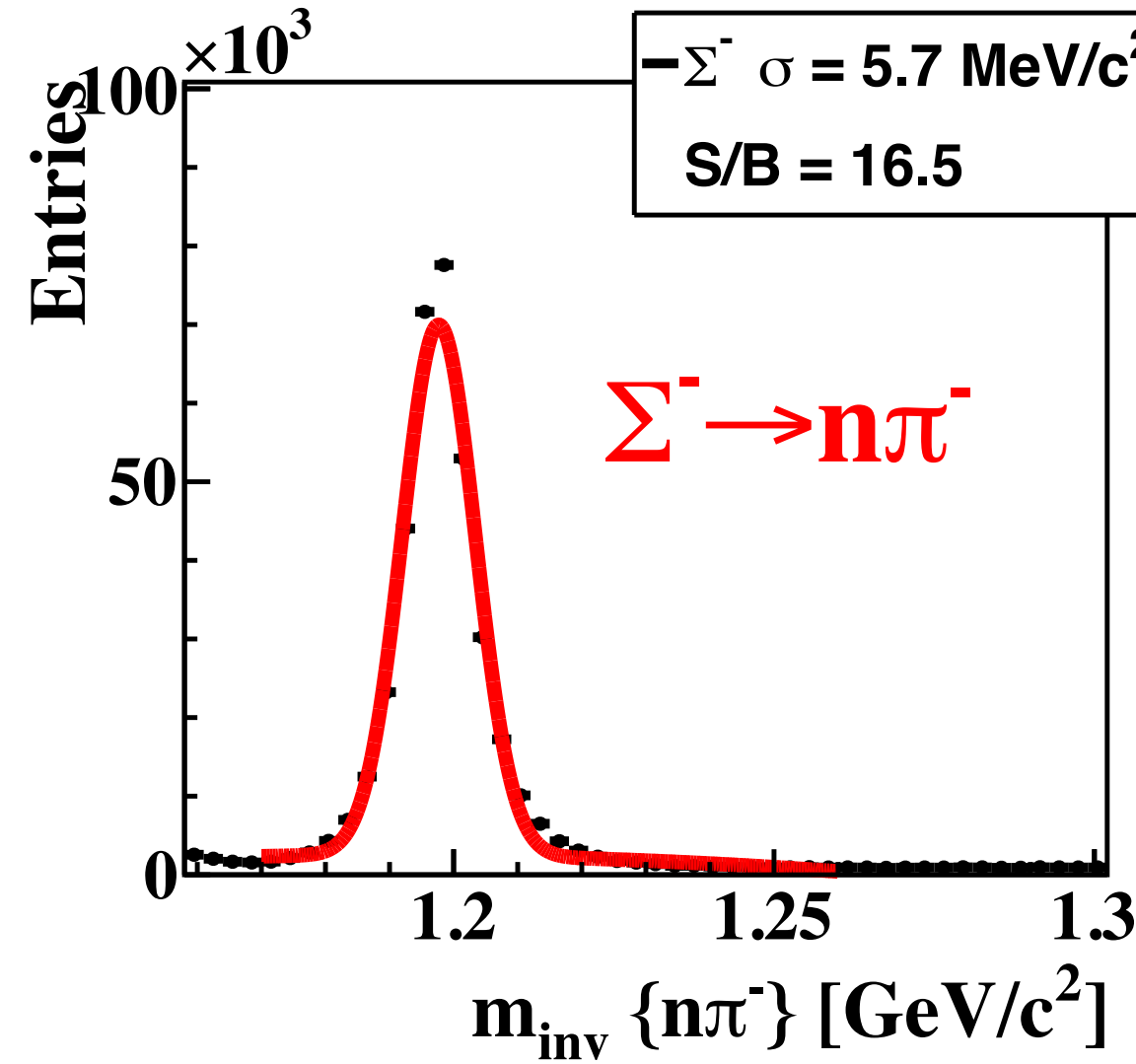
- More than 100 decays.
- All decays are reconstructed in one go.
- Based on the Kalman filter method — mathematically correct parameters and their errors.
- Available in and approbated within **STAR**, ALICE, PANDA.

Strange particle reconstruction performance

5M central AuAu collisions 10A GeV/c

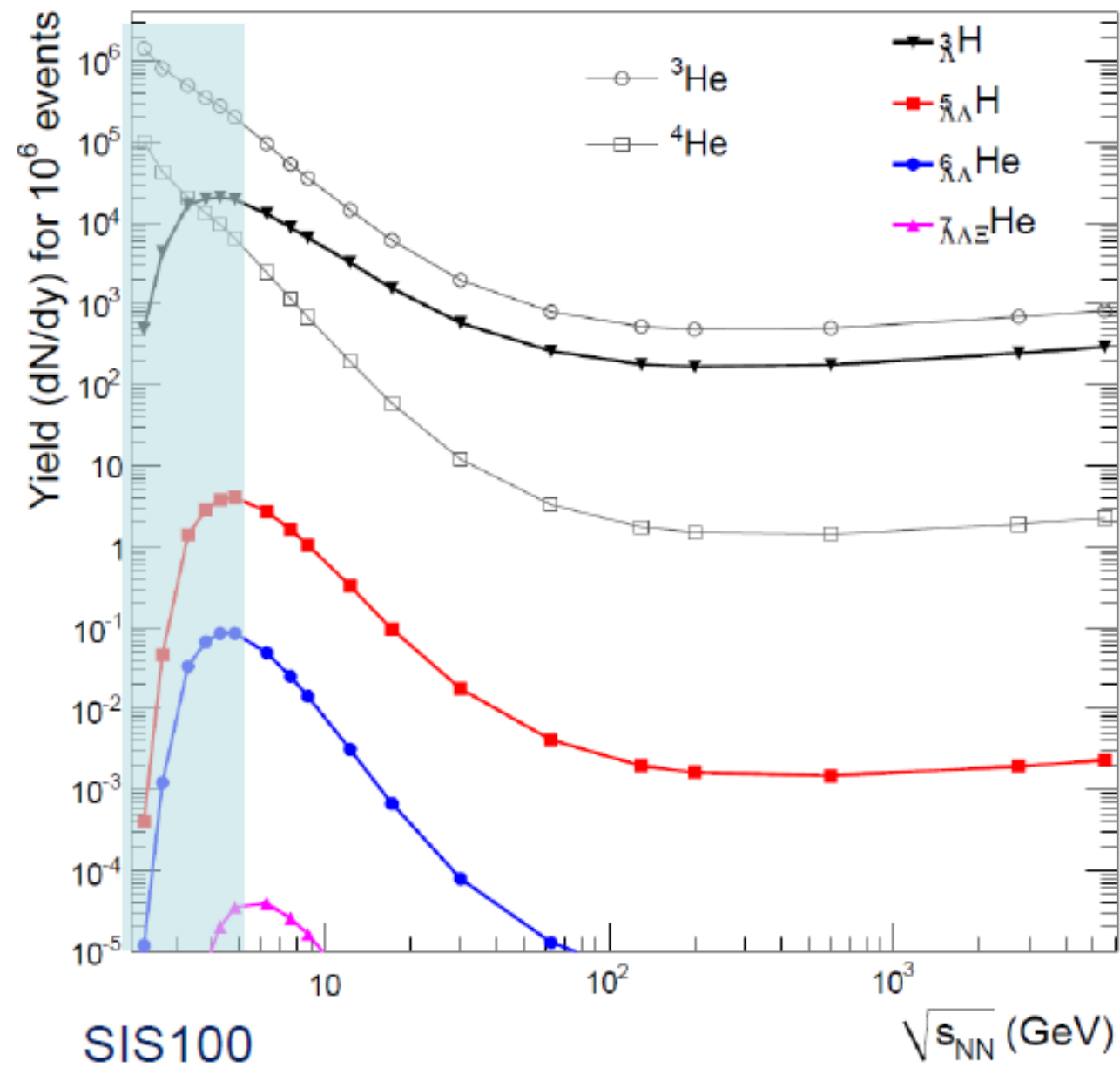


- CBM will allow clean reconstruction of rare strange probes with high efficiency and high statistics.
- Tools for the multi-differential physics analysis are prepared.



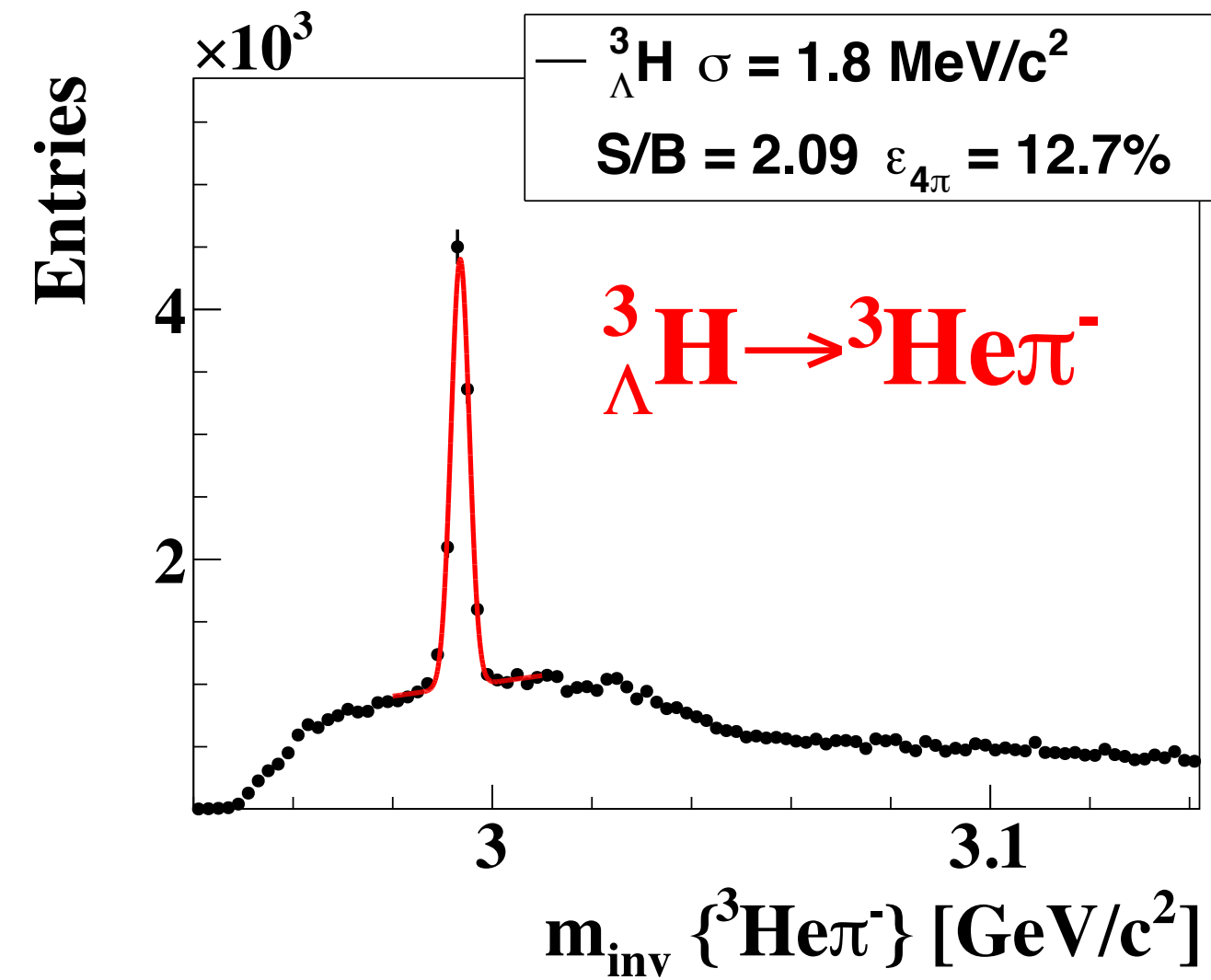
- Σ^+ and Σ^- physics:
 - completes the picture of strangeness production: abundant particles, carry out large fraction of strange quarks;
 - reconstruction of resonances, like $\Lambda(1405)$;
 - reconstruction of hypothetic particles, like H-dybarion.
- Having high acceptance for Σ hyperons CBM is 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.

Hypernuclei production in A+A collisions

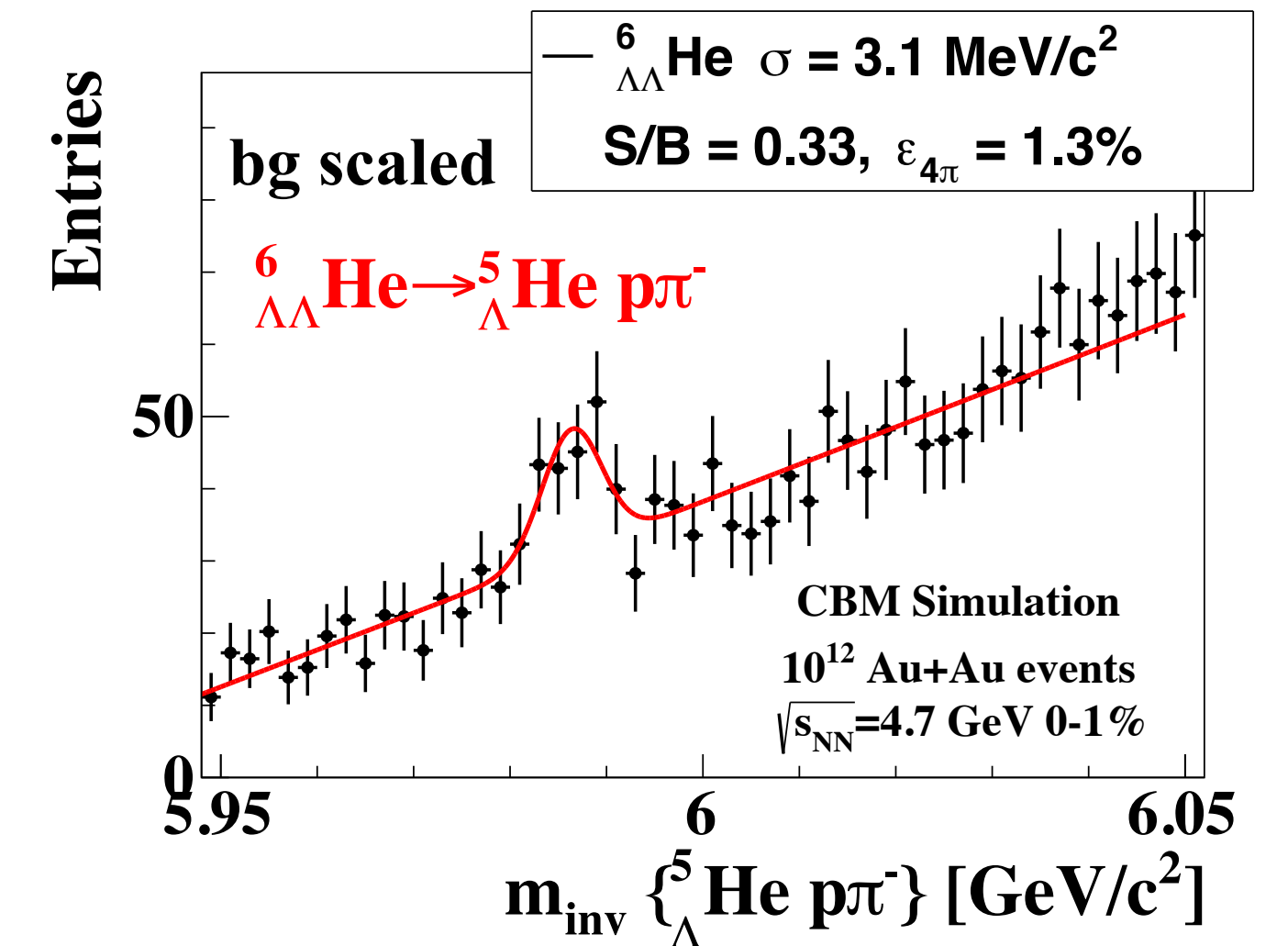


A. Andronic et al., Phys. Lett. B697 (2011) 203

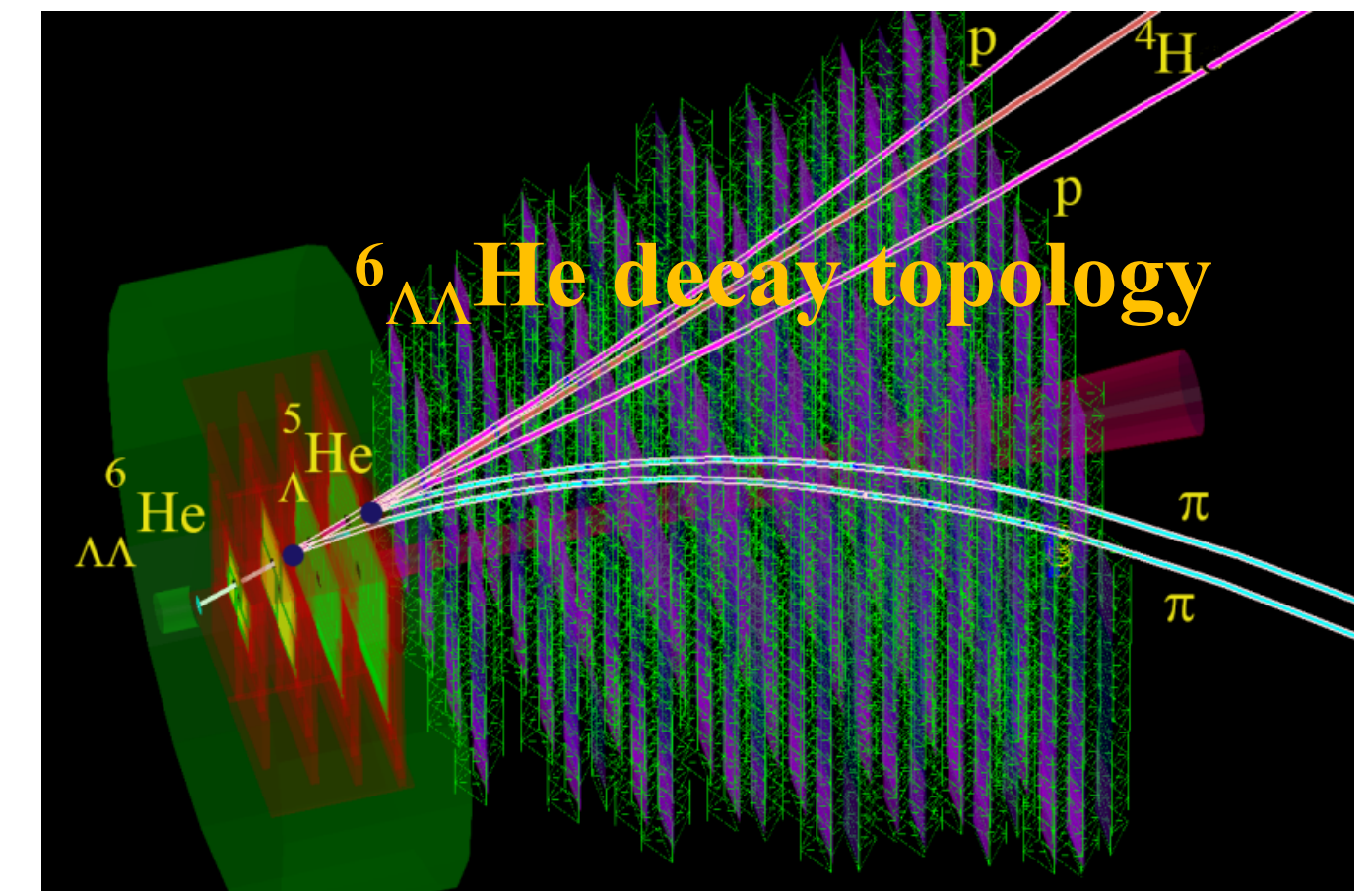
5M mbias events Au+Au at 10A GeV/c
5 sec at 1MHz IR (1.8 k/sec)



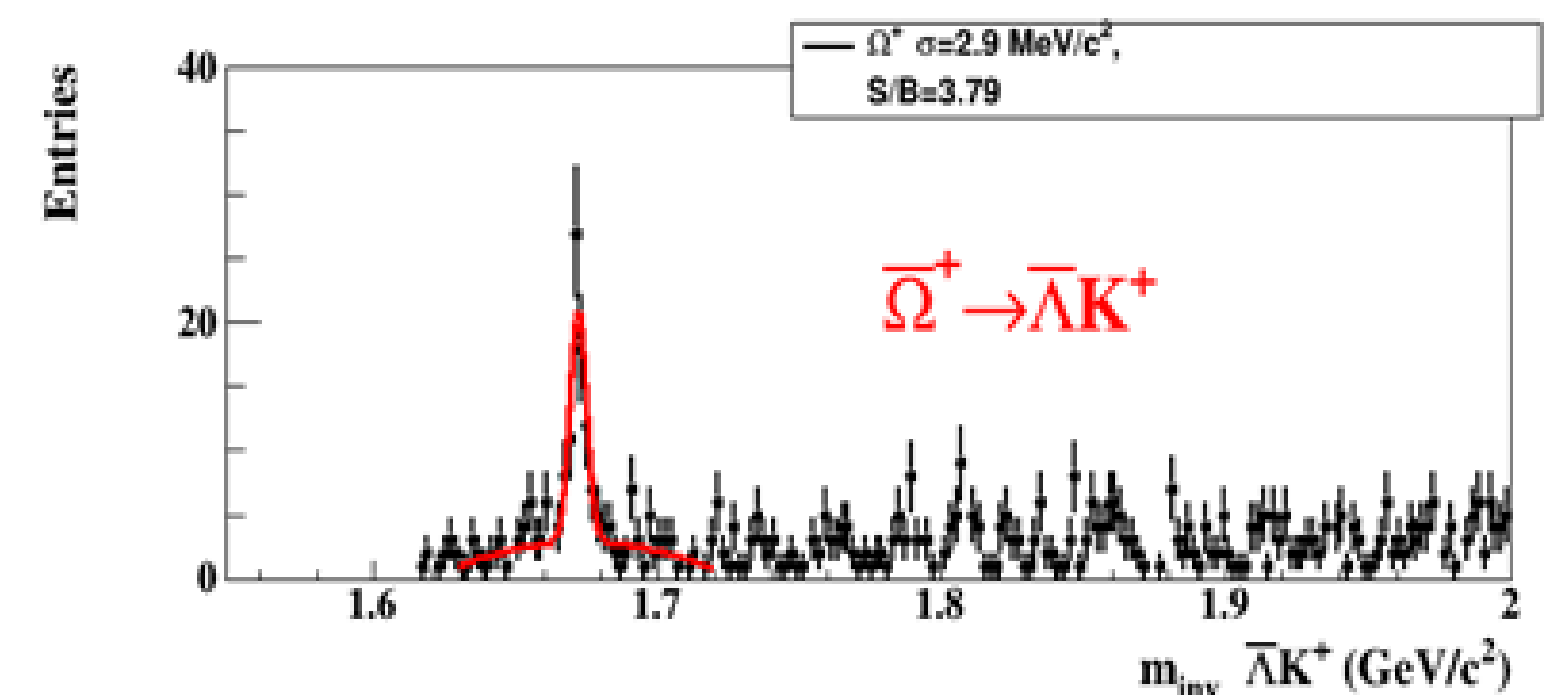
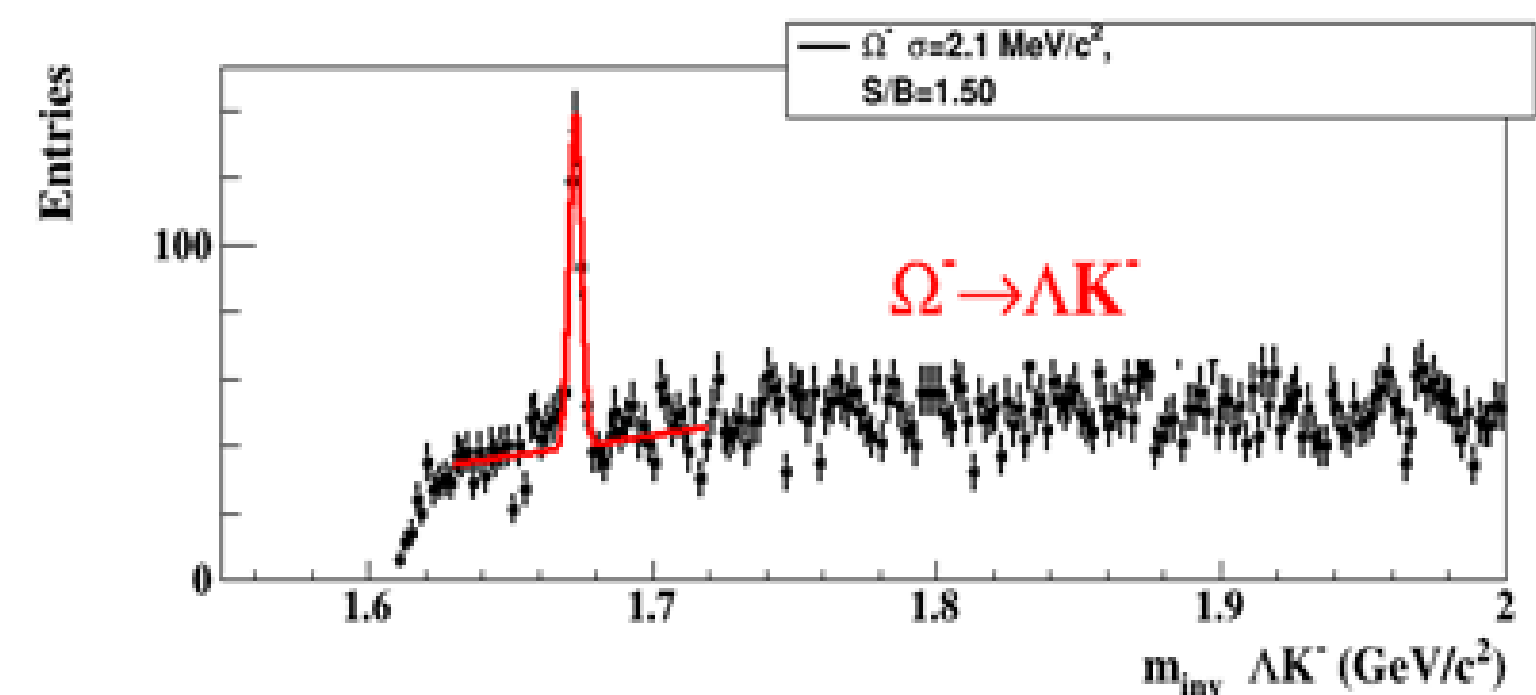
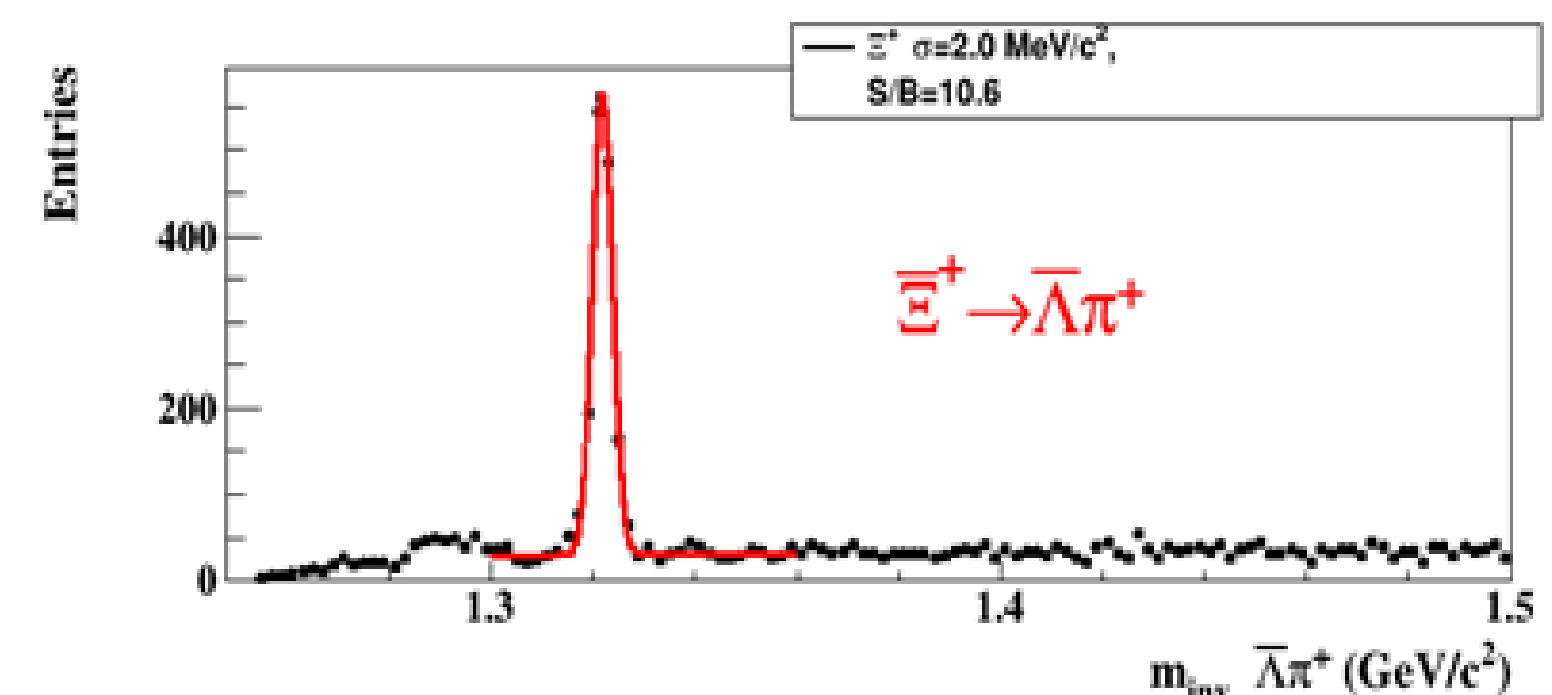
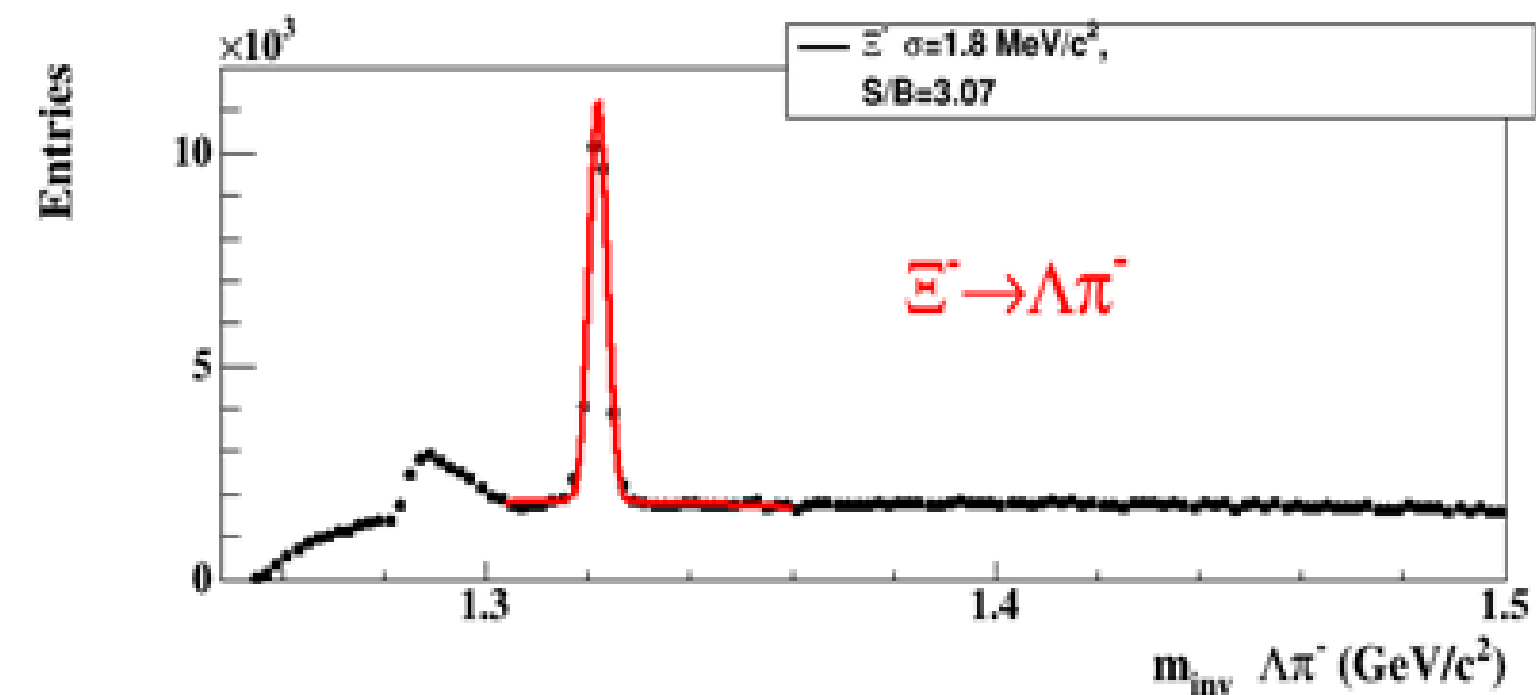
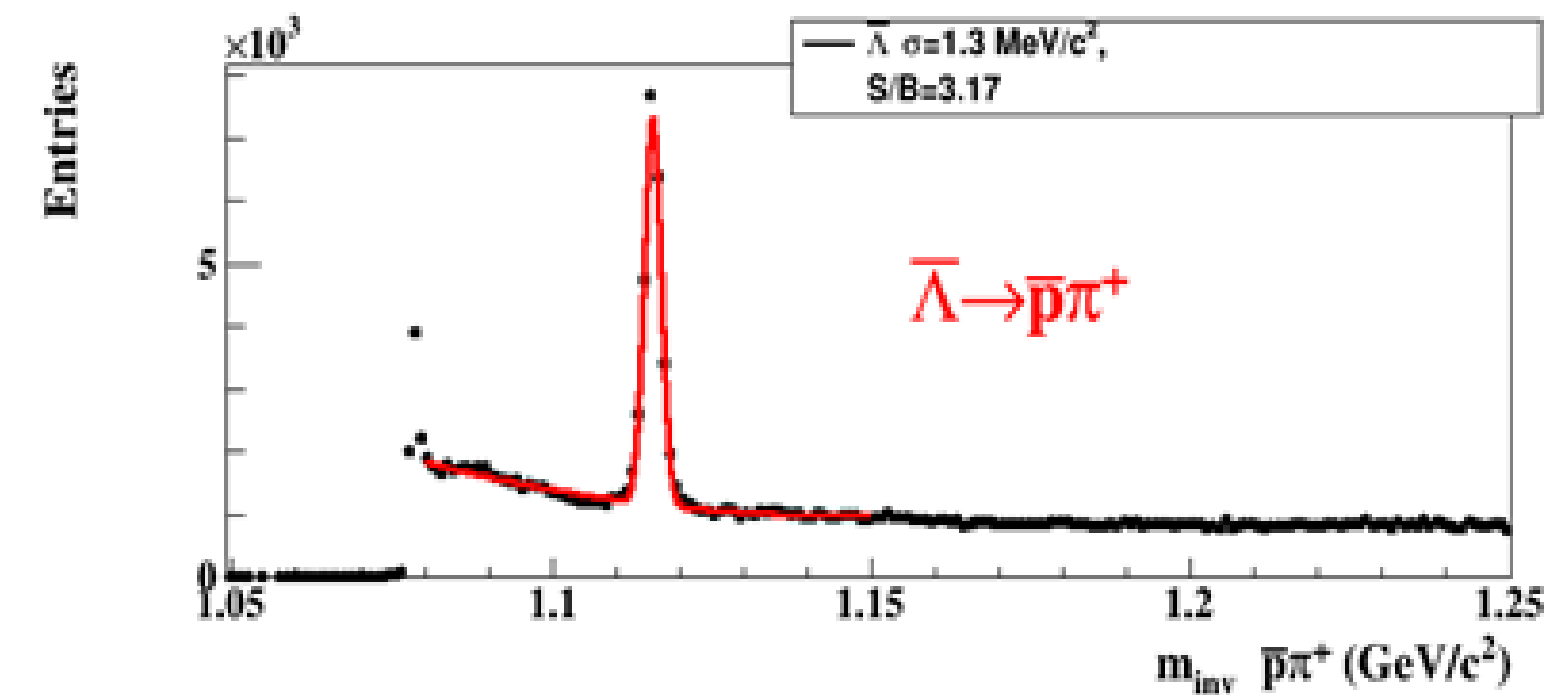
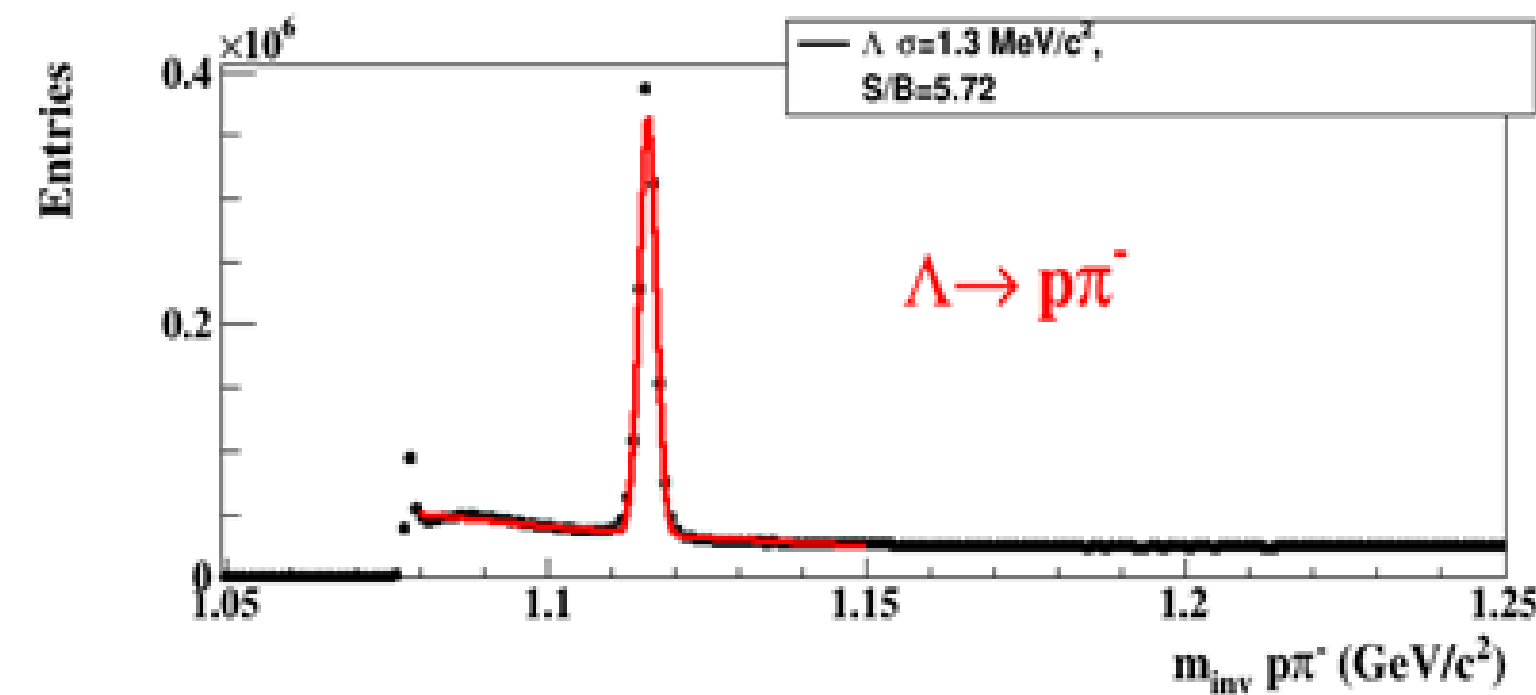
Expected collection rate: ~ 60 ${}^6_{\Lambda\Lambda}\text{He}$
in 1 week at 10MHz IR



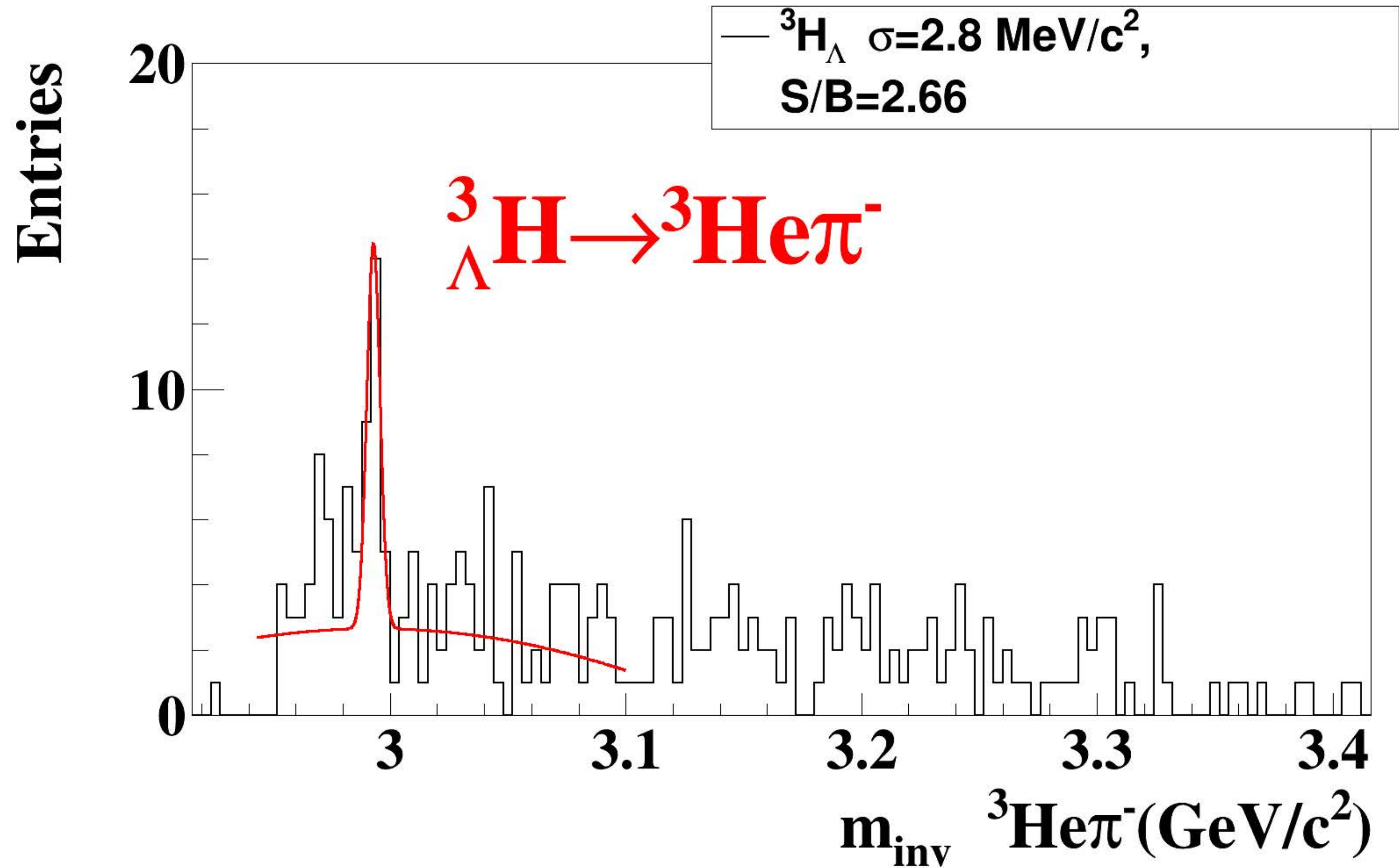
- According to the current theoretical predictions CBM will be able to perform comprehensive study of hypernuclei, including:
 - precise measurements of lifetime;
 - excitation functions;
 - flow.
- It has a huge potential to register and investigate double Λ hypernuclei.



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

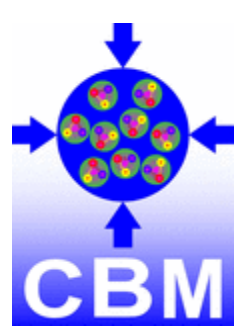


CBM KFParticle Finder @ **STAR** Au+Au events
4.4M at sqrt(s) = 7.7+ 12M at sqrt(s) =11 GeV



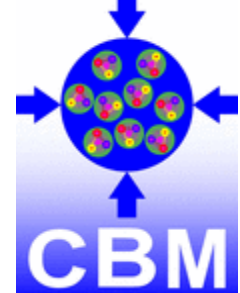
Expected particle yields Au+Au @ 6, 10 AGeV

Particle (mass MeV/c ²)	Multi- plicity 6 AGeV	Multi- plicity 10 AGeV	decay mode	BR	ϵ (%)	yield (s ⁻¹) 6AGeV	yield (s ⁻¹) 10AGeV	yield in 10 weeks 6AGeV	yield in 10 weeks 10 AGeV	IR MHz
$\bar{\Lambda}$ (1115)	$4.6 \cdot 10^{-4}$	0.034	$\bar{p}\pi^+$	0.64	11	1.1	81.3	$6.6 \cdot 10^6$	$2.2 \cdot 10^8$	10
Ξ^- (1321)	0.054	0.222	$\Lambda\pi^-$	1	6	$3.2 \cdot 10^3$	$1.3 \cdot 10^4$	$1.9 \cdot 10^{10}$	$7.8 \cdot 10^{10}$	10
Ξ^+ (1321)	$3.0 \cdot 10^{-5}$	$5.4 \cdot 10^{-4}$	$\bar{\Lambda}\pi^+$	1	3.3	$9.9 \cdot 10^{-1}$	17.8	$5.9 \cdot 10^6$	$1.1 \cdot 10^8$	10
Ω^- (1672)	$5.8 \cdot 10^{-4}$	$5.6 \cdot 10^{-3}$	ΛK^-	0.68	5	17	164	$1.0 \cdot 10^8$	$9.6 \cdot 10^8$	10
Ω^+ (1672)	-	$7 \cdot 10^{-5}$	$\bar{\Lambda}K^+$	0.68	3	-	0.86	0	$5.2 \cdot 10^6$	10
$^3_{\Lambda}\text{H}$ (2993)	$4.2 \cdot 10^{-2}$	$3.8 \cdot 10^{-2}$	$^3\text{He}\pi^-$	0.25	19.2	$2 \cdot 10^3$	$1.8 \cdot 10^3$	$1.2 \cdot 10^{10}$	$1.1 \cdot 10^{10}$	10
$^4_{\Lambda}\text{He}$ (3930)	$2.4 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	$^3\text{He}\pi\pi^-$	0.32	14.7	110	87	$6.6 \cdot 10^8$	$5.2 \cdot 10^8$	10
$^5_{\Lambda\Lambda}\text{He}$ (5047)		$5.0 \cdot 10^{-6}$	$^3\text{He}2p2\pi$	0.01	1		$5 \cdot 10^{-3}$		$3 \cdot 10^4$	10
$^6_{\Lambda\Lambda}\text{He}$ (5986)		$1.0 \cdot 10^{-7}$	$^4\text{He}2p2\pi$	0.01	1		$1 \cdot 10^{-4}$		600	10



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

