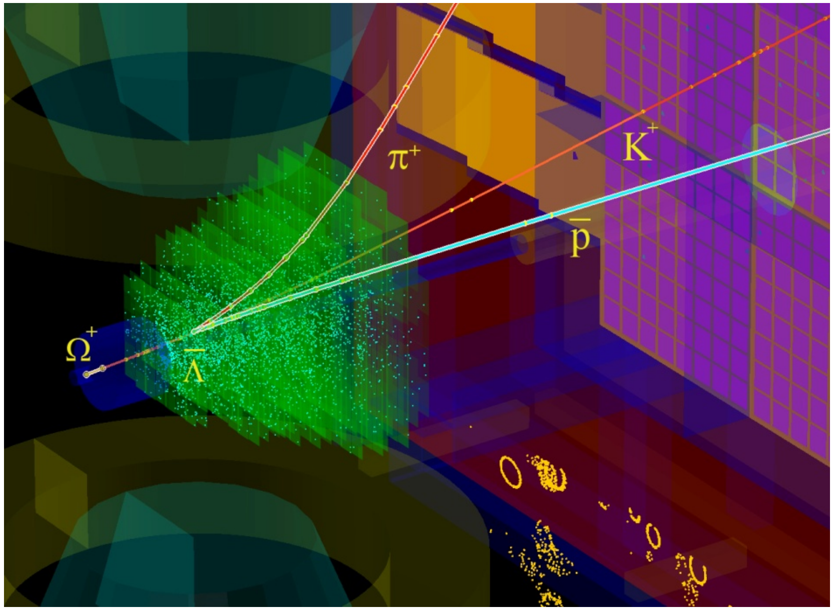
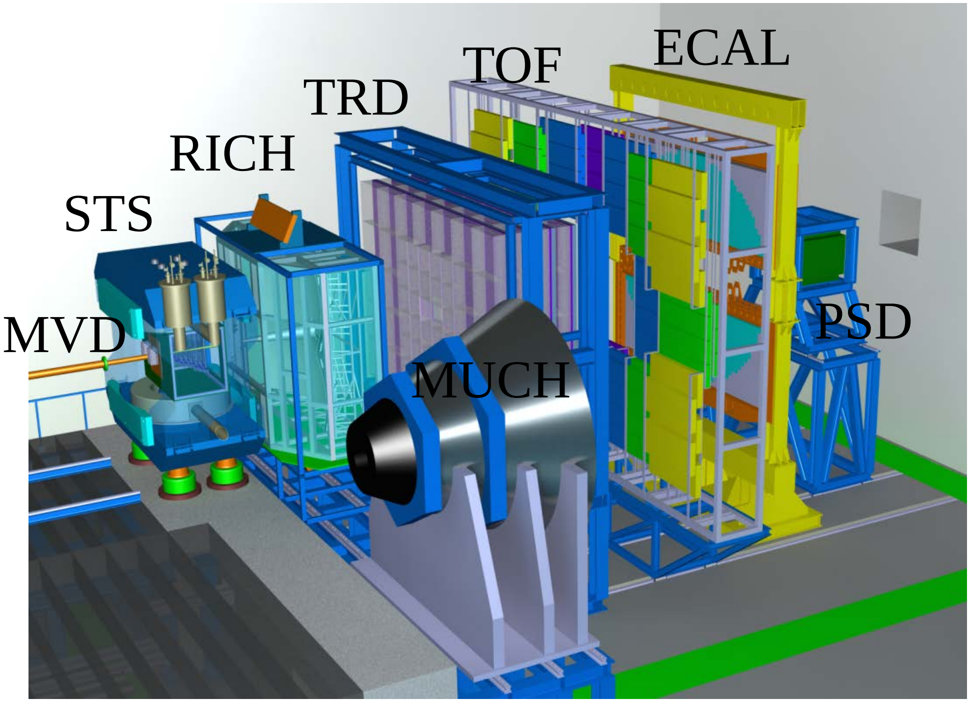
Multi-strange Hyperons and Hypernuclei reconstruction at the CBM experiment



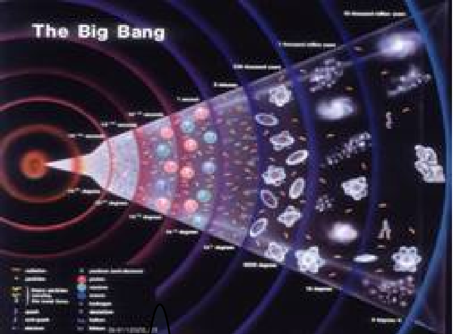
I. Vassiliev, V. Akishina, I.Kisel and M. Zyzak for the CBM Collaboration

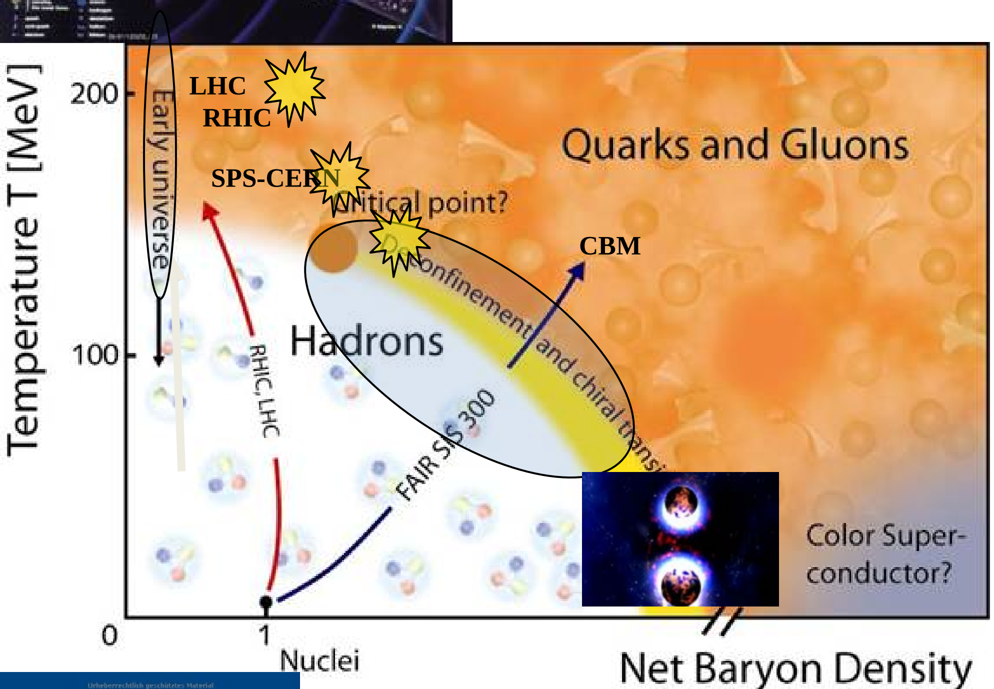


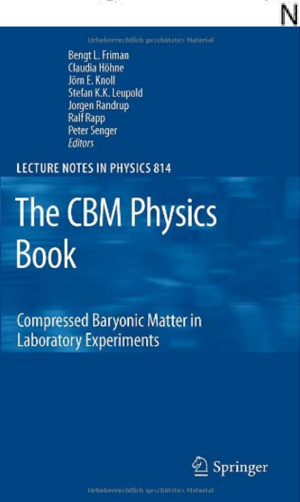
Physics case
Developed methods & tasks
High rate scenario
Conclusions & plans

DPG Munster March 2017

Physics case:
Exploring the QCD phase diagram







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

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

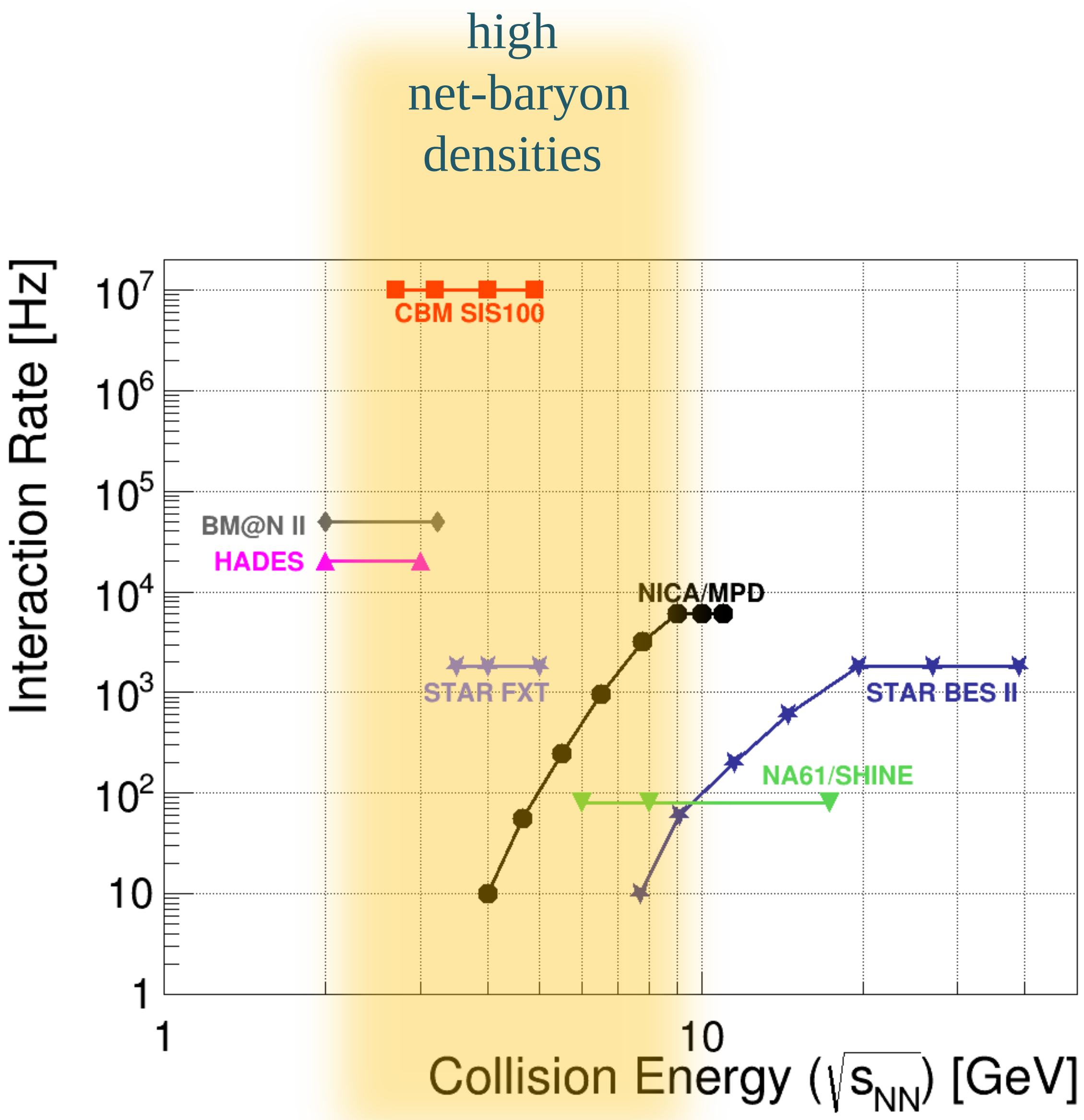
Deconfinement phase transition at high ρ_B
- excitation function and flow of strangeness (**K, Λ, Σ, Ξ, Ω**) and **charm** (**J/ψ, ψ', D^0, D_s, $D^{\pm}$, Λ_c**)

- **Charmonium** suppression, for **J/ψ** and **ψ**

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

Onset of chiral symmetry restoration at high ρ_B
- in-medium modifications of hadrons (ρ,ω,ϕ)
- excitation function of **multi-strange (anti)hyperons (PHSD 4.0)**

Experiments exploring dense QCD matter

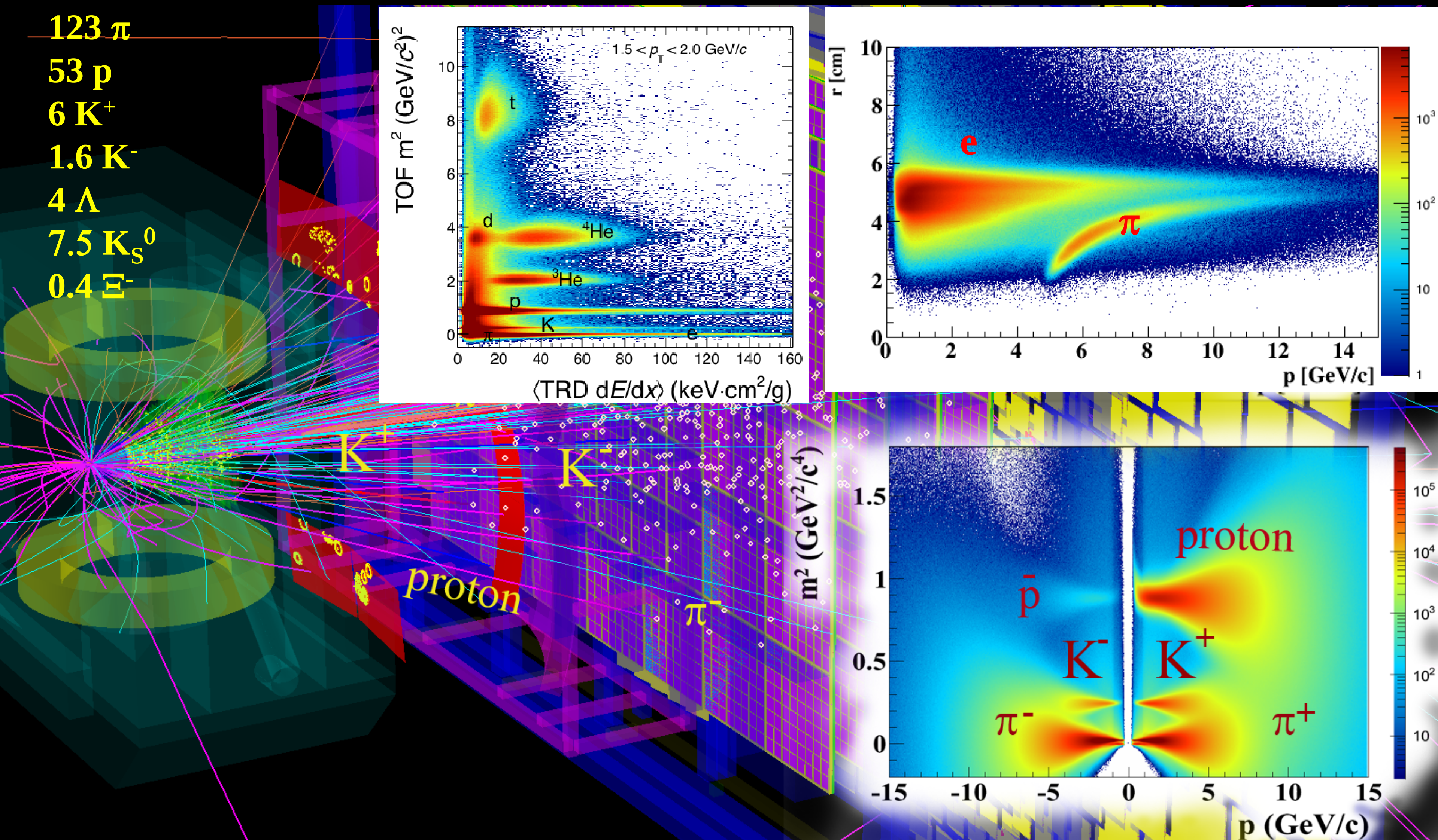


CBM:
world record rate capability

- 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 4-d tracking
- software triggers

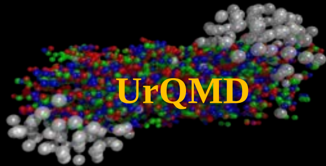
Particle identification with PID detectors

Ni+Ni 15 AGeV
123 π
53 p
6 K^+
1.6 K^-
4 Λ
7.5 K_S^0
0.4 Ξ^-

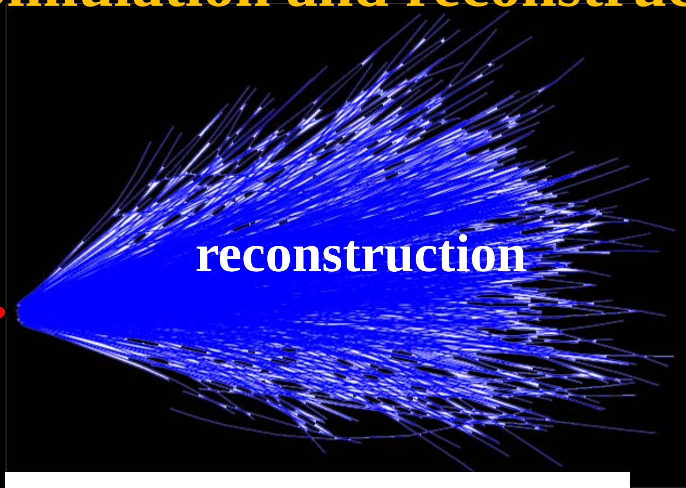


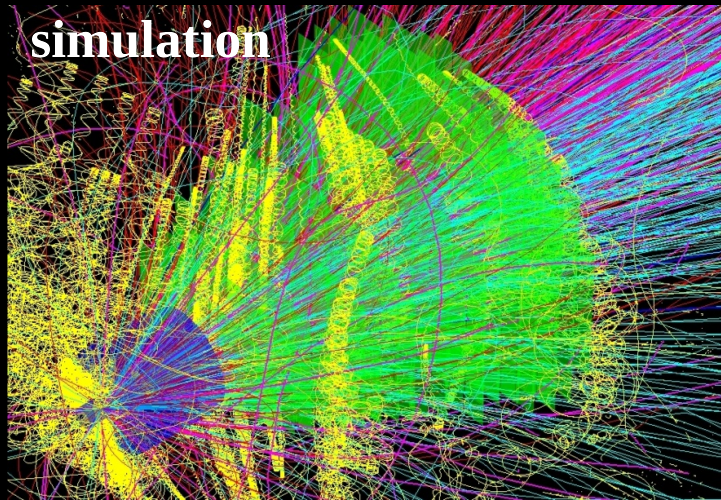
Central event: 40 (TF) + 7 (PF) ms/core with MVD!
(~ 2 faster w/o MVD)

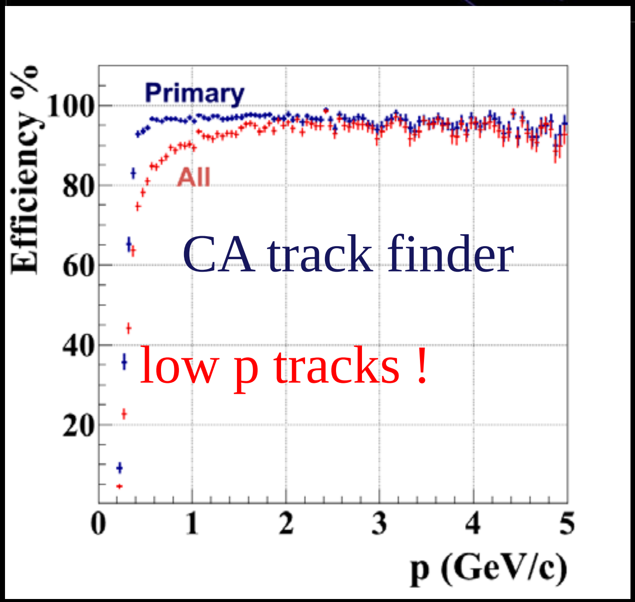
SIS-300: central Au + Au (UrQMD or PHSD) events
Simulation and reconstruction

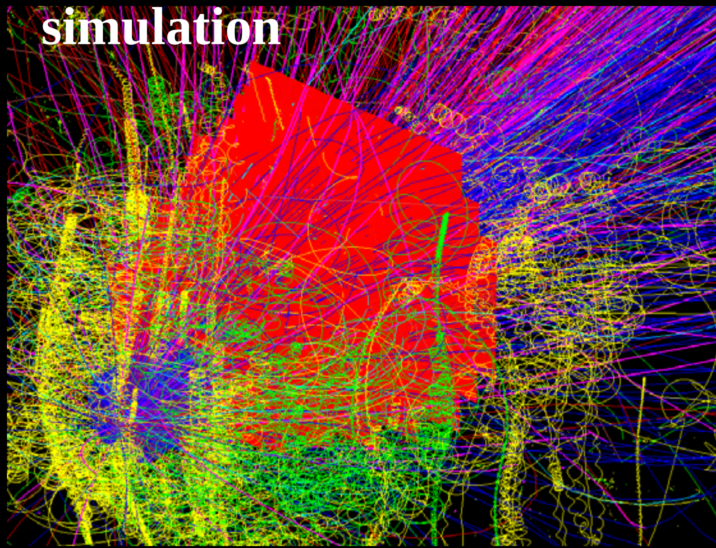


~700 π
160 p
53 K
32 Λ
27 K_S^0
0.44 Ξ^-
0.018 Ω^-







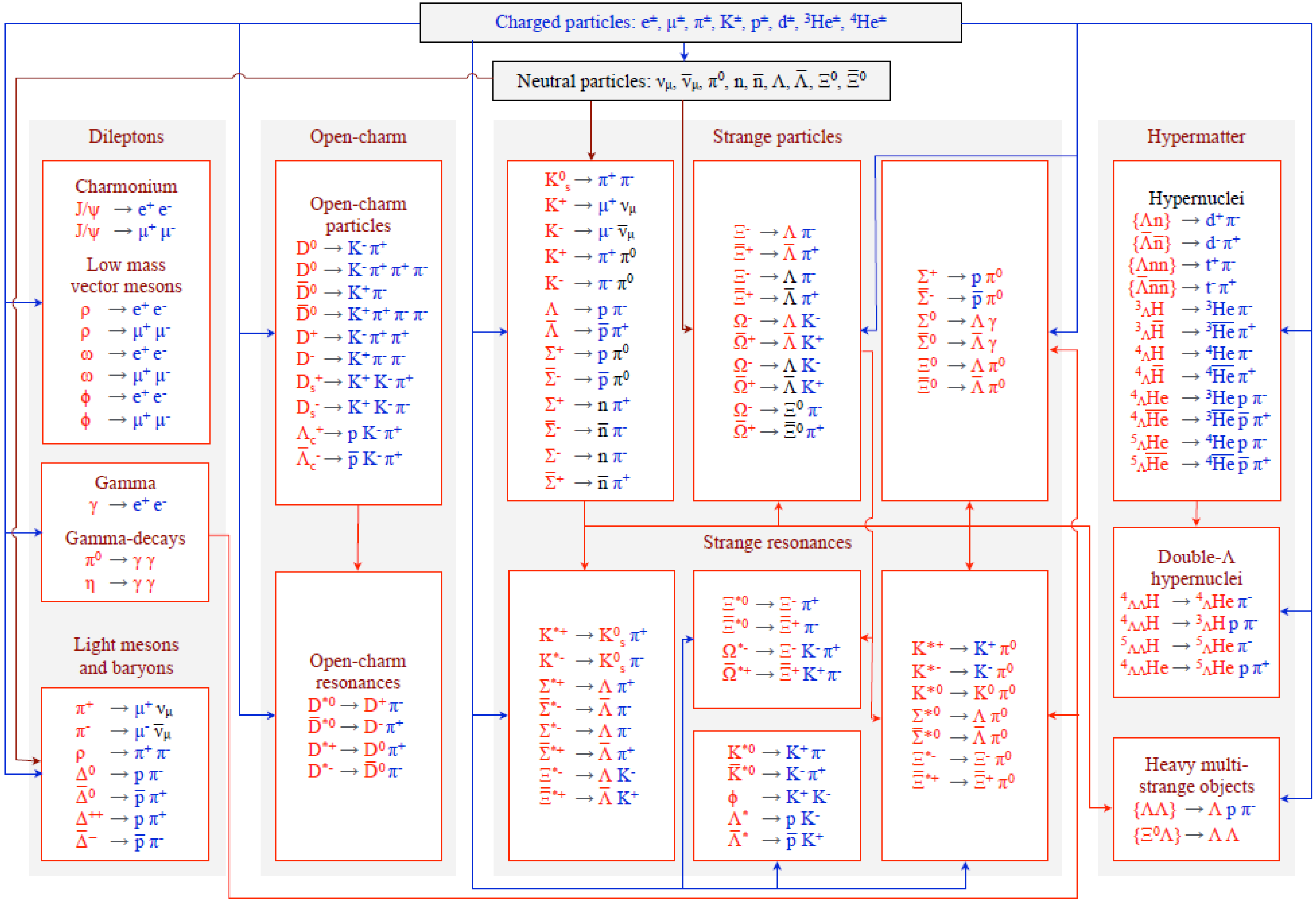


~700 π
174 p
42 K
30 Λ
24 K_S^0
2.4 Ξ^-
0.005 Ω^-

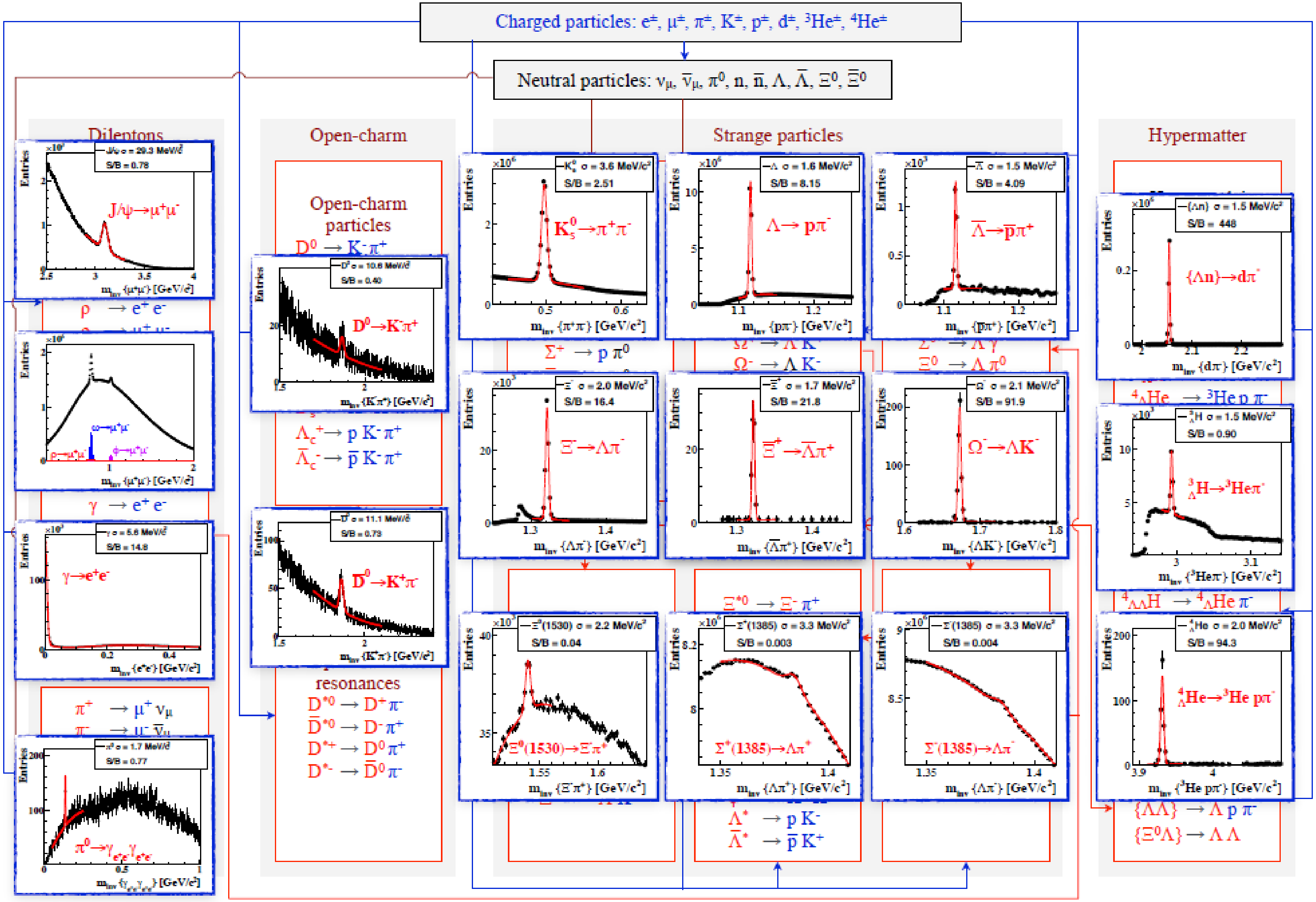
648 recstructed tracks
Ref. prim. eff = 96%
All set eff = 87%
dp/p = 1.2%

central: 82 (TF) + 16 (PF) ms/core
mbias : 10 (TF) + 2 (PF) ms/core
up to 80 cores/CPU

KF Particle Finder for the CBM Experiment

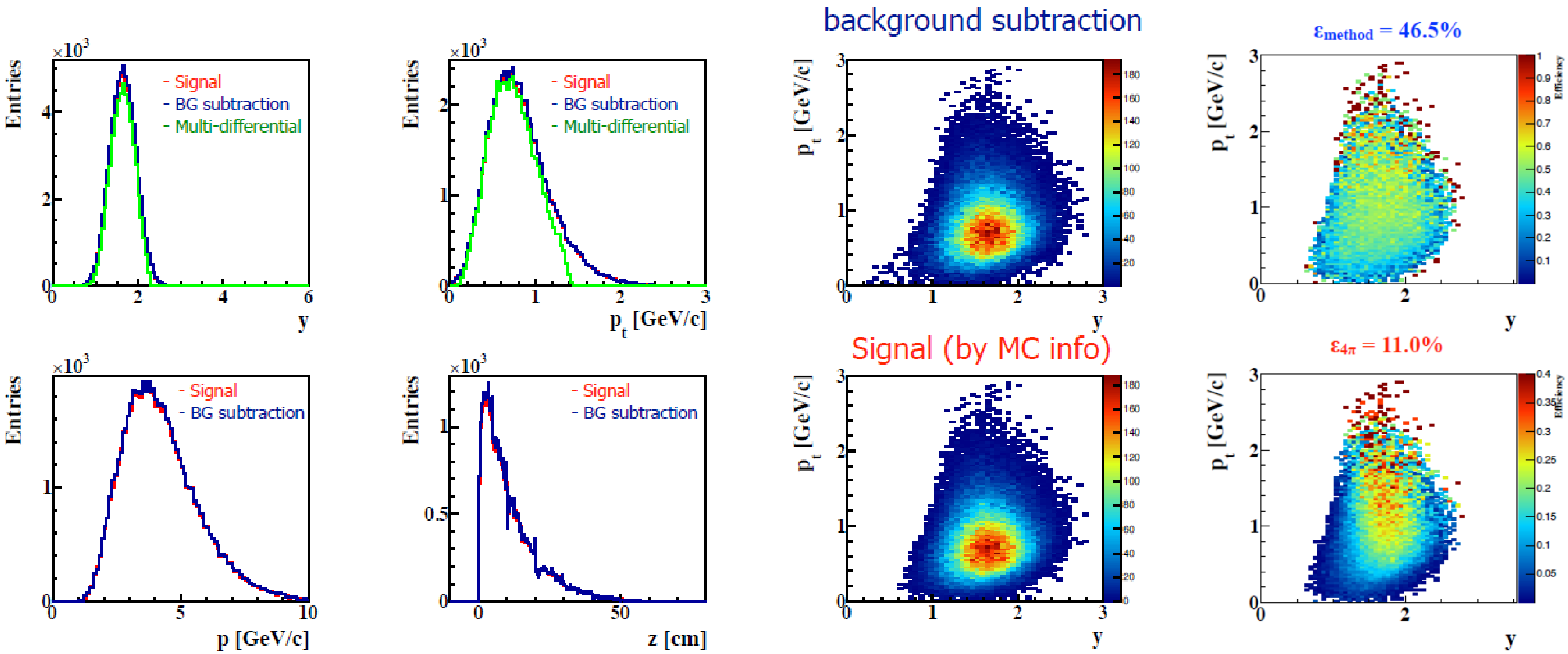


+ STAR, ALICE, PANDA, HADES, NA61



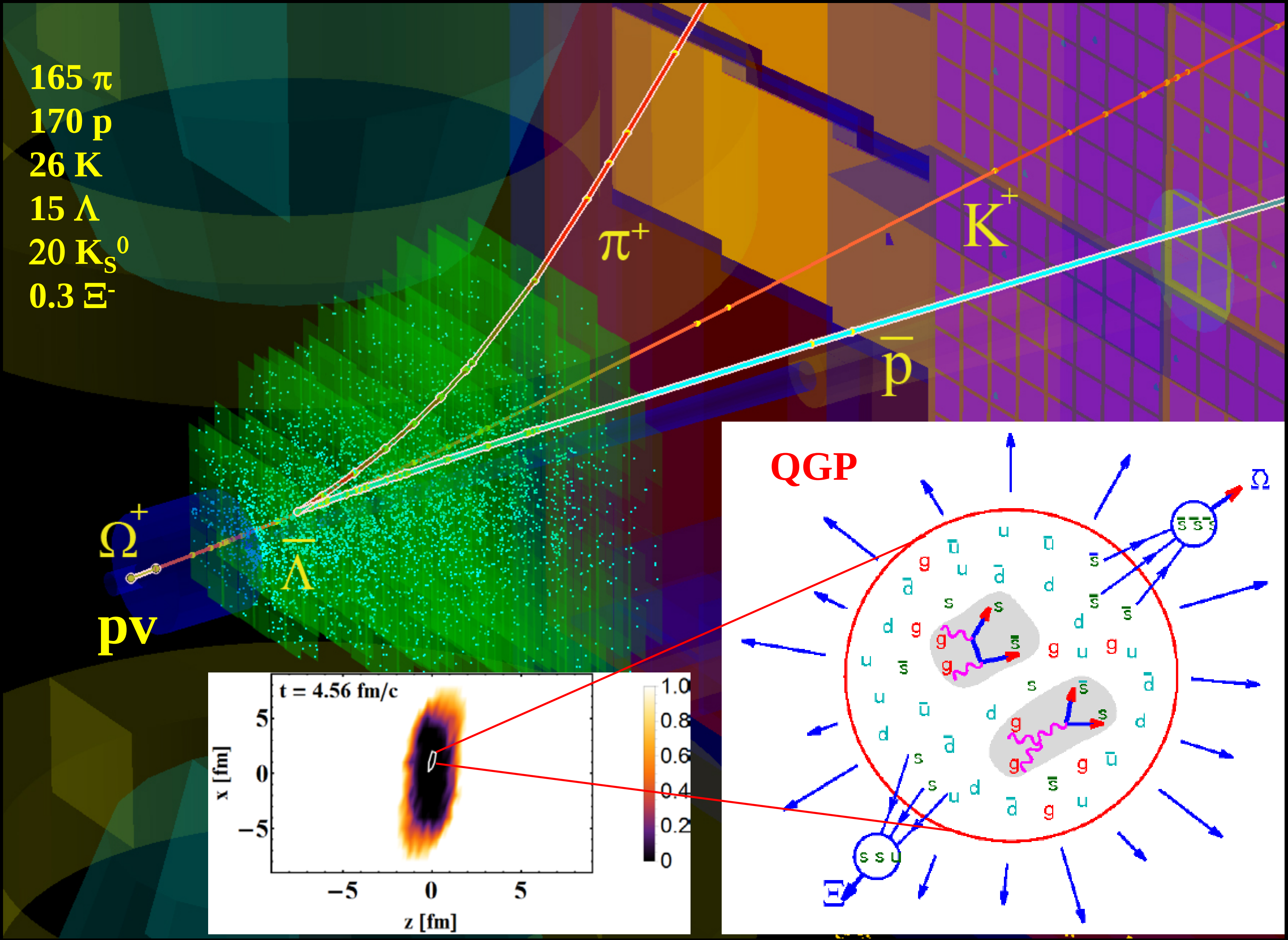
All physics observables are covered by the CBM reconstruction

Signal extraction: Ξ^-

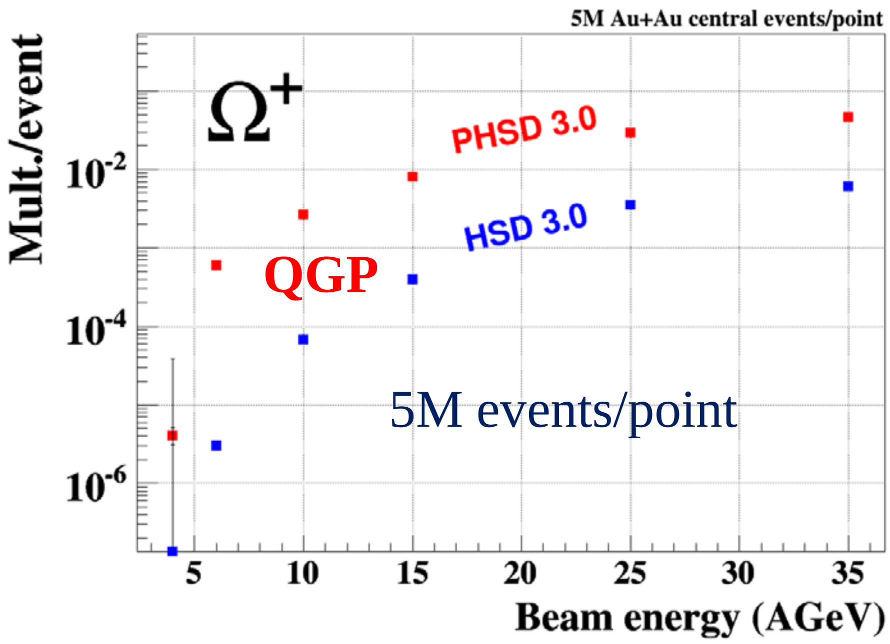


- The signal distribution are nicely described by the BG subtraction method.
- Due to the limited statistics in the outer regions multi-differential analysis can not be applied there, the integral distributions are describing the central region.

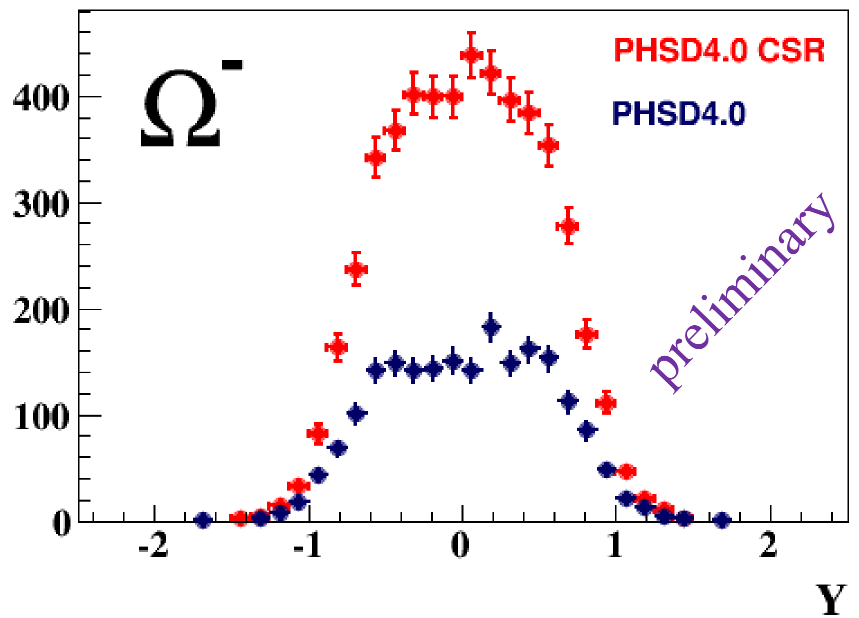
KF Particle Finder with ToF track ID: Au+Au @ 10AGeV SIS100



QGP and CSR signatures at FAIR energies: Multi-strange baryons and antibaryons



PHSD 4.0 Au + Au @ 10 AGeV



- Most of the Ω+ produced by QGP @ FAIR energy
- CSR increase yield of MS Baryons & Antibaryons !?

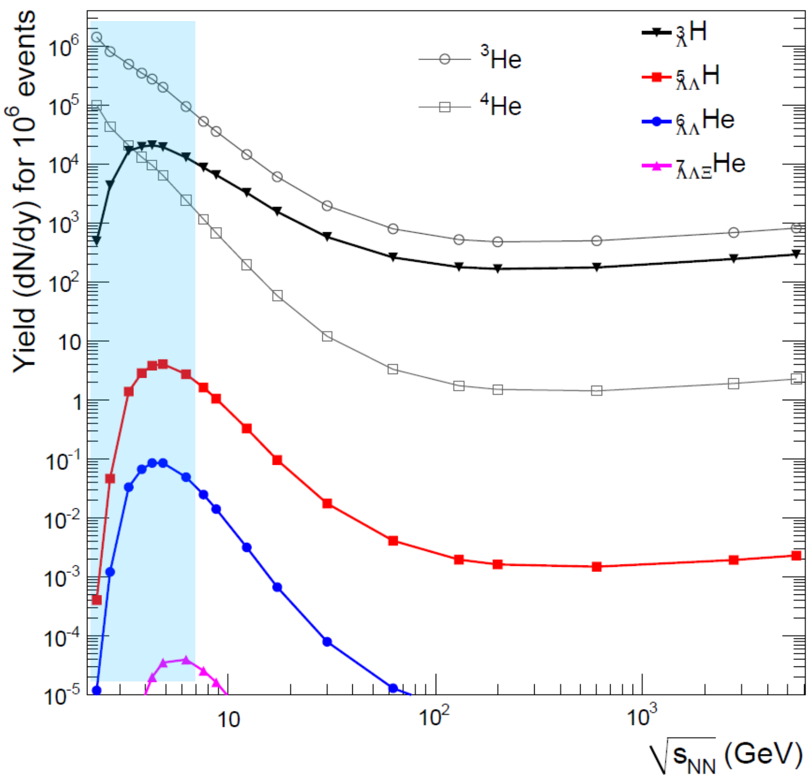
Motivation: CBM physics program (P.Senger)

No data at FAIR energies

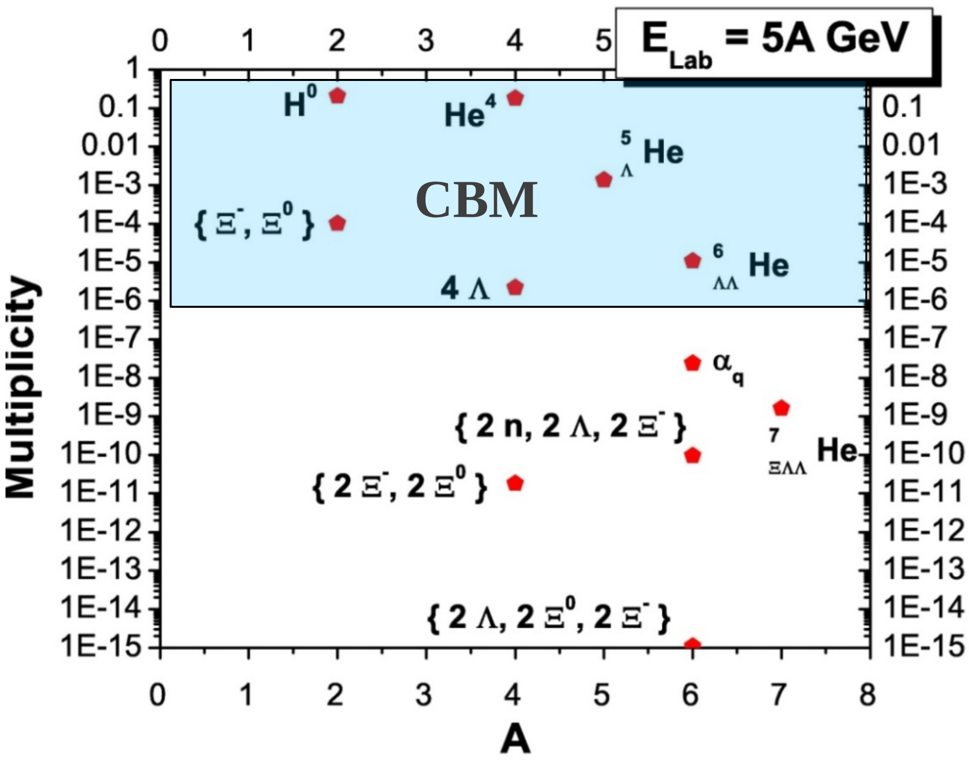
Strange matter

Hypernuclei, strange dibaryons and massive strange objects

Production of hypernuclei via coalescence of hyperons and light nuclei



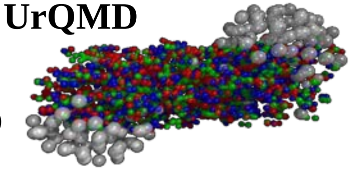
A. Andronic et al., Phys. Lett. B697 (2011) 203



H. Stöcker et al., Nucl. Phys. A 827 (2009) 624c

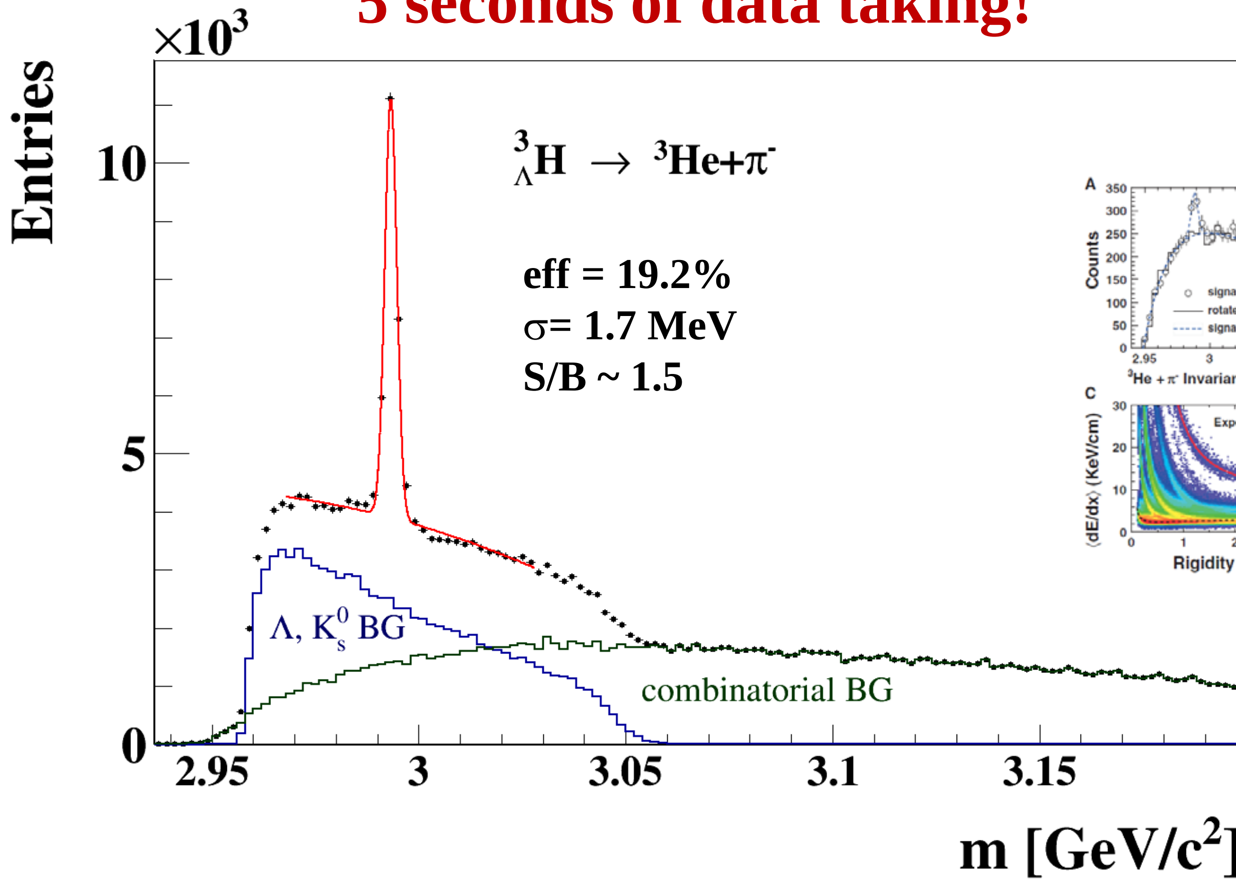
Au+Au 10 AGeV 5M central events

UrQMD

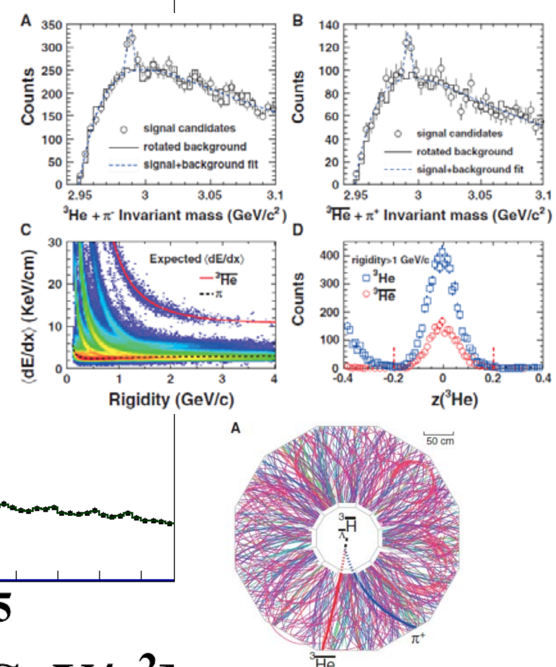


Extended KFParticle Finder $^{3}_{\Lambda}H$

5 seconds of data taking!

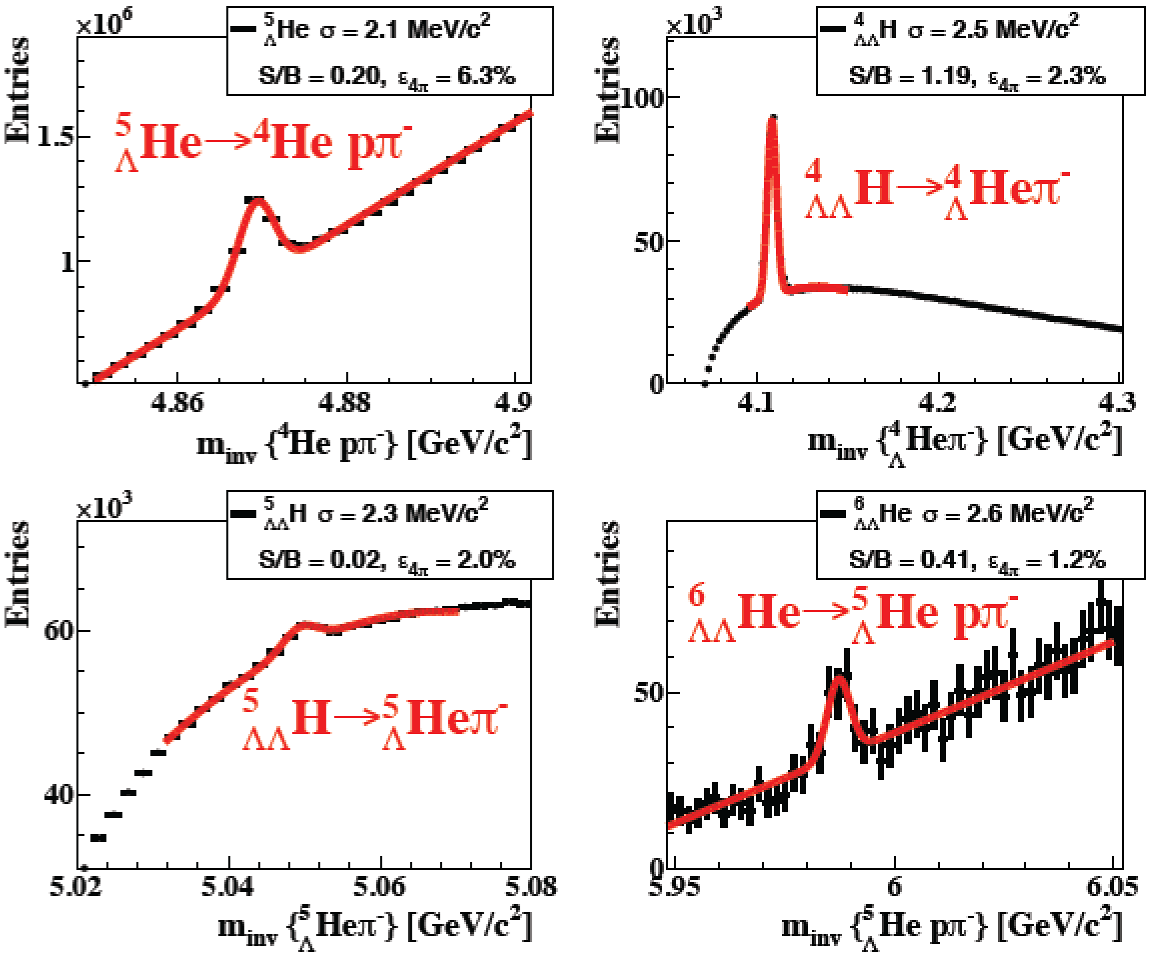


STAR 2010



BR from H. Kamada et al., Phys. Rev., Ser. C 57, 1595 (1998)

Double-Λ hypernuclei

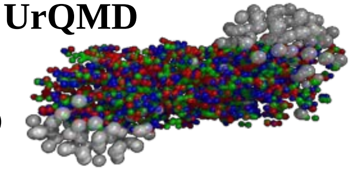


- Background can be further reduced with additional dE/dx PID.
- For $^{5}_{\Lambda}He$ and $^{5}_{\Lambda\Lambda}H$ background will be reduced selecting only primary hypernuclei.

AuAu, 10 AGeV, 10^{12} central events, TOF PID

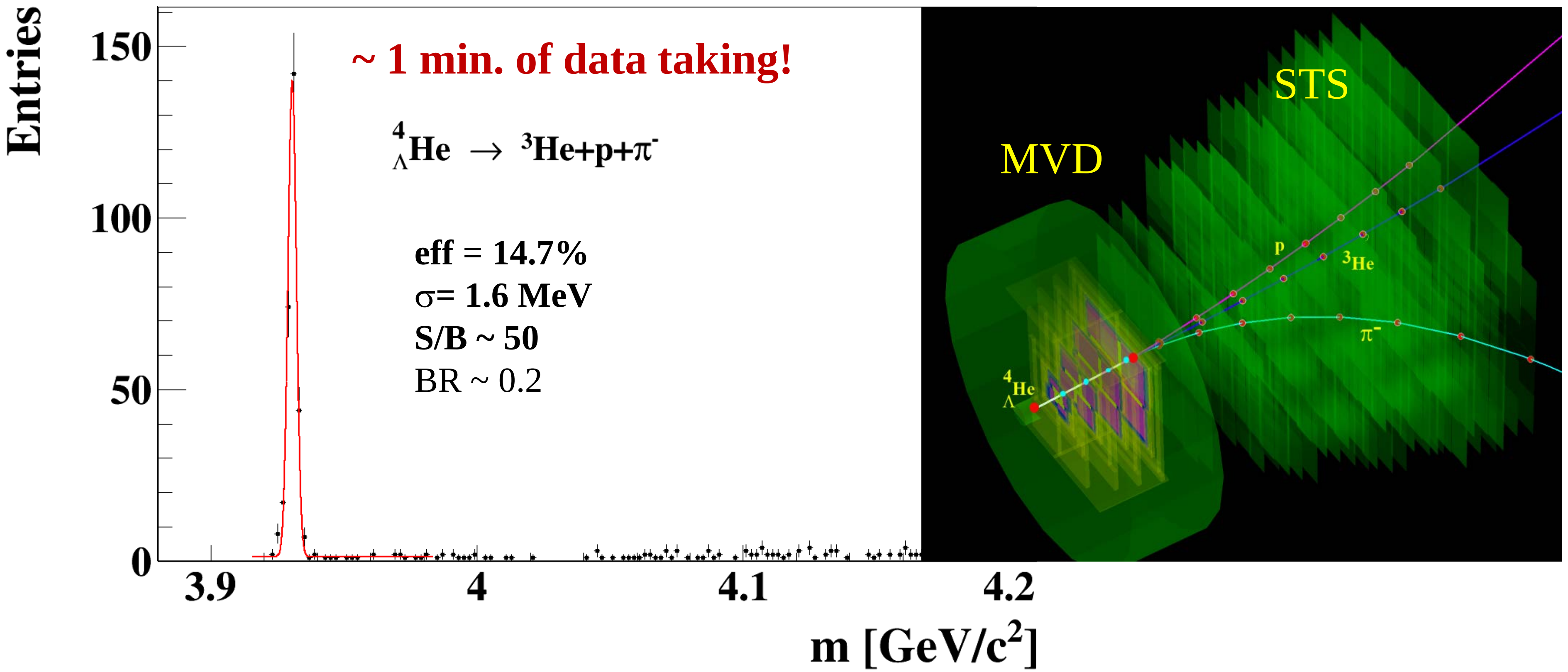
High statistic measurements at 10^7 interaction rates will allow to measure double-Λ hypernuclei

UrQMD



Au+Au 10 AGeV 5M central events

Extended KFParticle Finder ${}^{4}_{\Lambda}$**He**

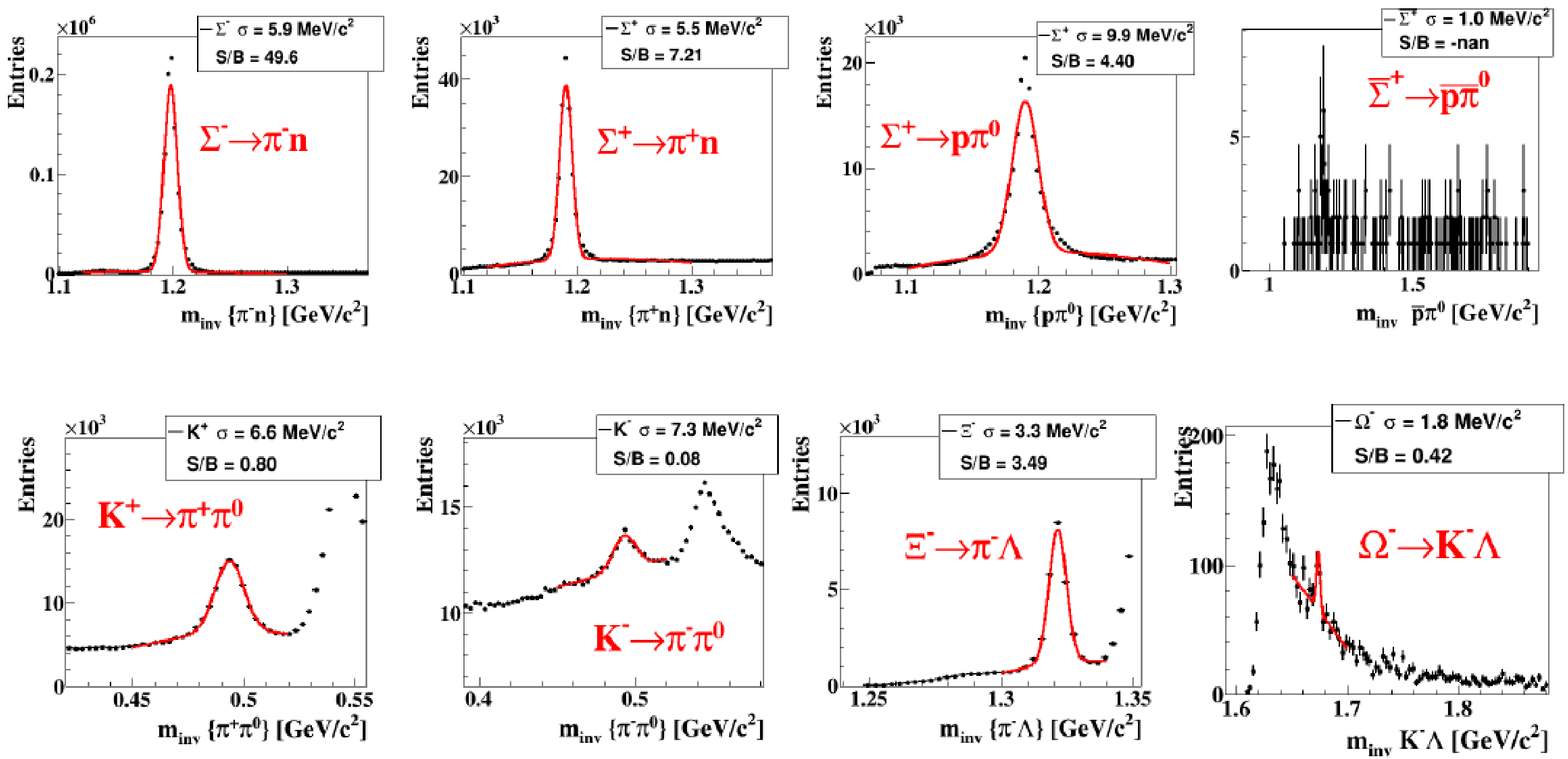


3 prong detached vertex is good signature of ${}^{4}_{\Lambda}$He decay

M from J. Steinheimer et al., Phys. Lett. B**714**, 85, (2012)

Mass Spectra of Reconstructed Particles

New visit card of CBM



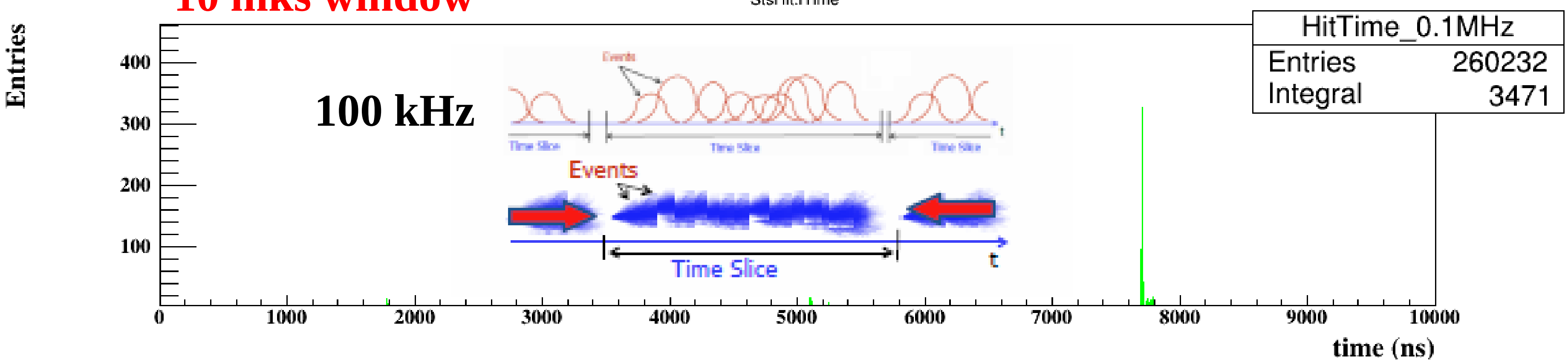
5M Au+Au central events, 10 AGeV, TOF PID

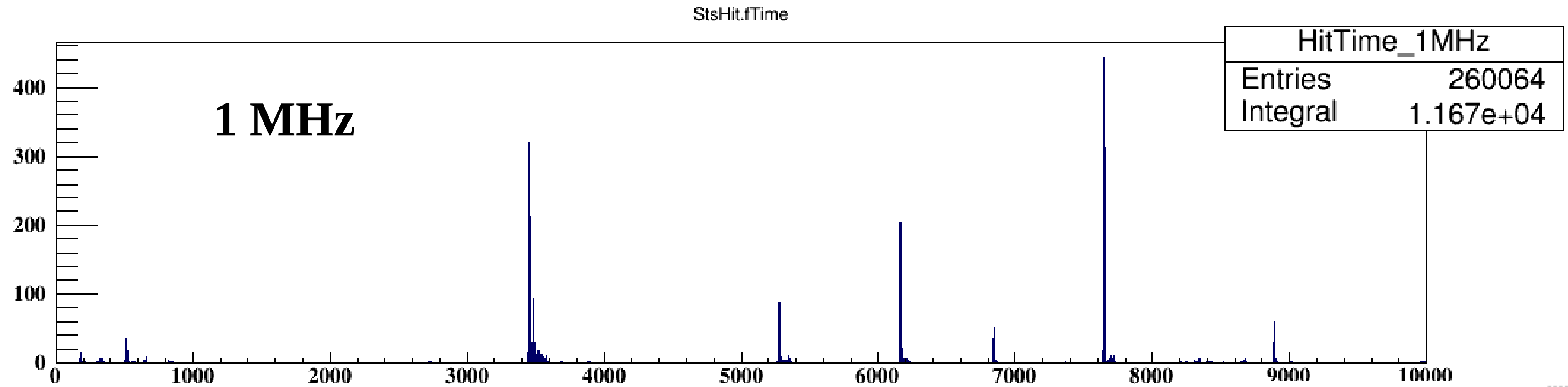
Expected particle yields Au+Au @ 6, 10 AGeV

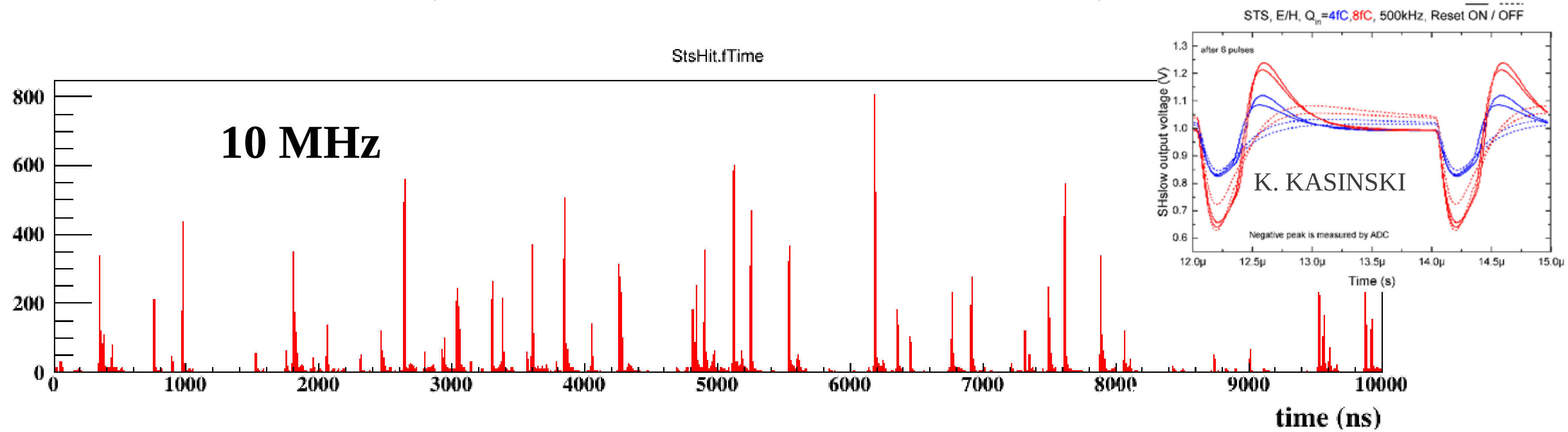
Particle (mass MeV/c^2)	Multi-plicity 6 AGeV	Multi-plicity 10 AGeV	decay mode	BR	ε (%)	yield (s^{-1}) 6AGeV	yield (s^{-1}) 10AGeV	yield in 10 weeks 6AGeV	yield in 10 weeks 10 AGeV	IR MHz
$\bar{\Lambda}$ (1115)	$4.6 \cdot 10^{-4}$	0.034	$p\pi^+$	0.64	11	1.1	81.3	$6.6 \cdot 10^6$	$2.2 \cdot 10^8$	**10**
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**
$\bar{\Xi}^+$ (1321)	$3.0 \cdot 10^{-5}$	$5.4 \cdot 10^{-4}$	$\Lambda\pi^+$	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**
$\bar{\Omega}^+$ (1672)	-	$7 \cdot 10^{-5}$	ΛK^+	0.68	3	-	0.86	-	$5.2 \cdot 10^6$	**10**
${}^3{}_\Lambda H$ (2993)	$4.2 \cdot 10^{-2}$	$3.8 \cdot 10^{-2}$	${}^3He\pi^-$	0.25	19.2	$2 \cdot 10^3$	$1.8 \cdot 10^3$	$1.2 \cdot 10^{10}$	$1.1 \cdot 10^{10}$	**10**
${}^4{}_\Lambda He$ (3930)	$2.4 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	${}^3Hep\pi^-$	0.32	14.7	110	87	$6.6 \cdot 10^8$	$5.2 \cdot 10^8$	**10**
${}^4{}_{\Lambda\Lambda} H$ (4108)	-	$3.7 \cdot 10^{-5}$	${}^4{}_\Lambda He\pi^-$	0.2	2.6	-	0.6	-	$3.8 \cdot 10^6$	**10**
${}^6{}_{\Lambda\Lambda} He$ (5986)	-	$2.5 \cdot 10^{-8}$	${}^5{}_\Lambda Hep\pi^-$	0.2	1.3	-	$2.6 \cdot 10^{-4}$	-	$1.6 \cdot 10^3$	**10**

4D time based analysis !
New tools;
A lot to learn;

10 mks window







V. Akishina

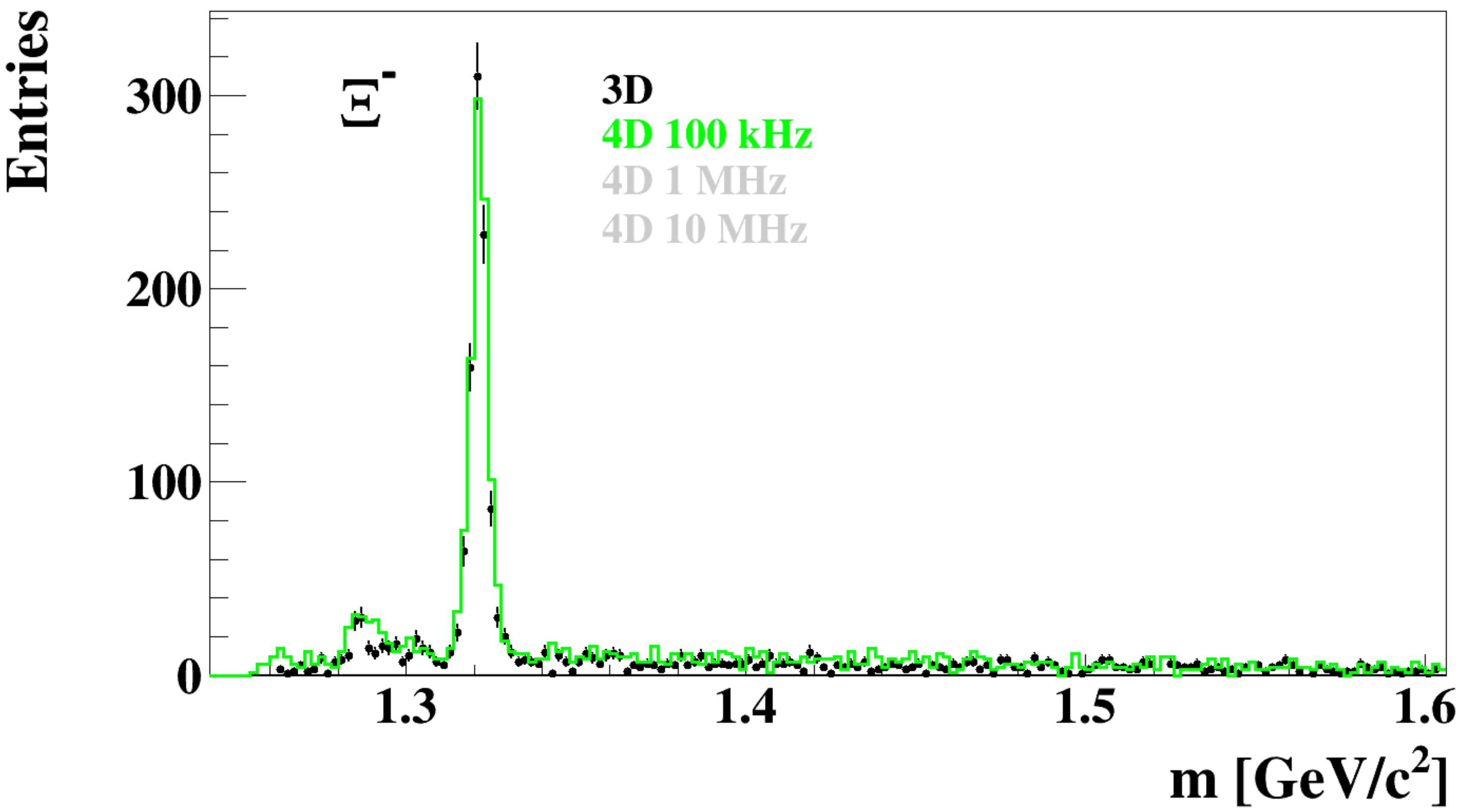
4D Track Finder in CBMROOT

100 AuAu 10 AGeV mbias events

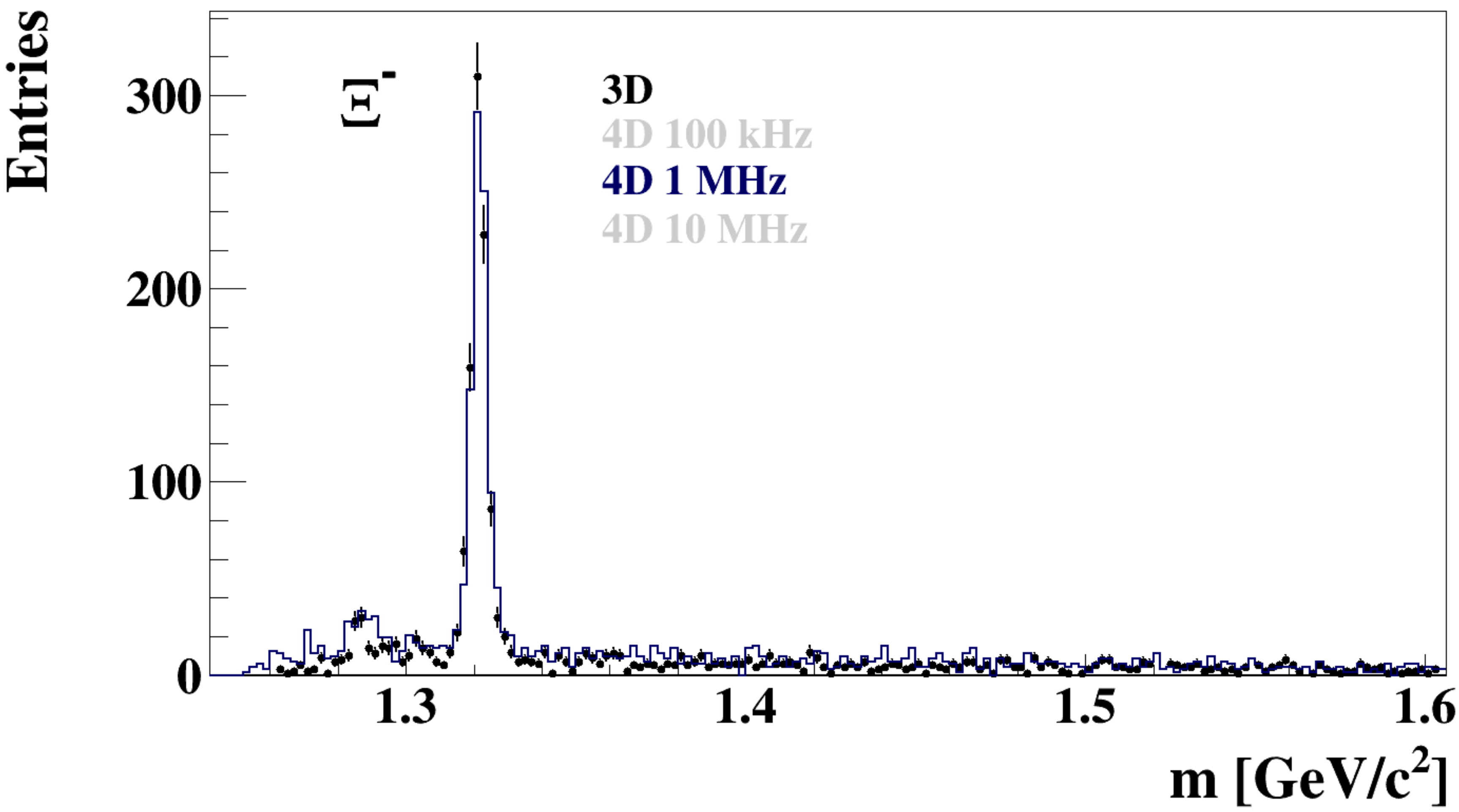
Efficiency, %	3D	0.1 MHz	1 MHz	10 MHz
All tracks	92.5 %	93.8 %	93.5 %	91.7 %
Primary high-p	98.3 %	98.1 %	97.9 %	96.2 %
Primary low-p	93.9 %	95.4 %	95.5 %	94.3 %
Secondary high-p	90.8 %	94.6 %	93.5 %	90.2 %
Secondary low-p	62.2 %	68.5 %	67.6 %	64.3 %
Clone level	0.6 %	0.6 %	0.6 %	0.6 %
Ghost level	1.8 %	0.6 %	0.6 %	0.6 %
True hits per track	92%	93 %	93 %	93%
Hits per MC track	7.0	7.0	6.97	6.70

Timeslices from CBMROOT
Timebased digitisation, cluster and hit finder

High rate scenario: MSH reconstruction with 4D tracking

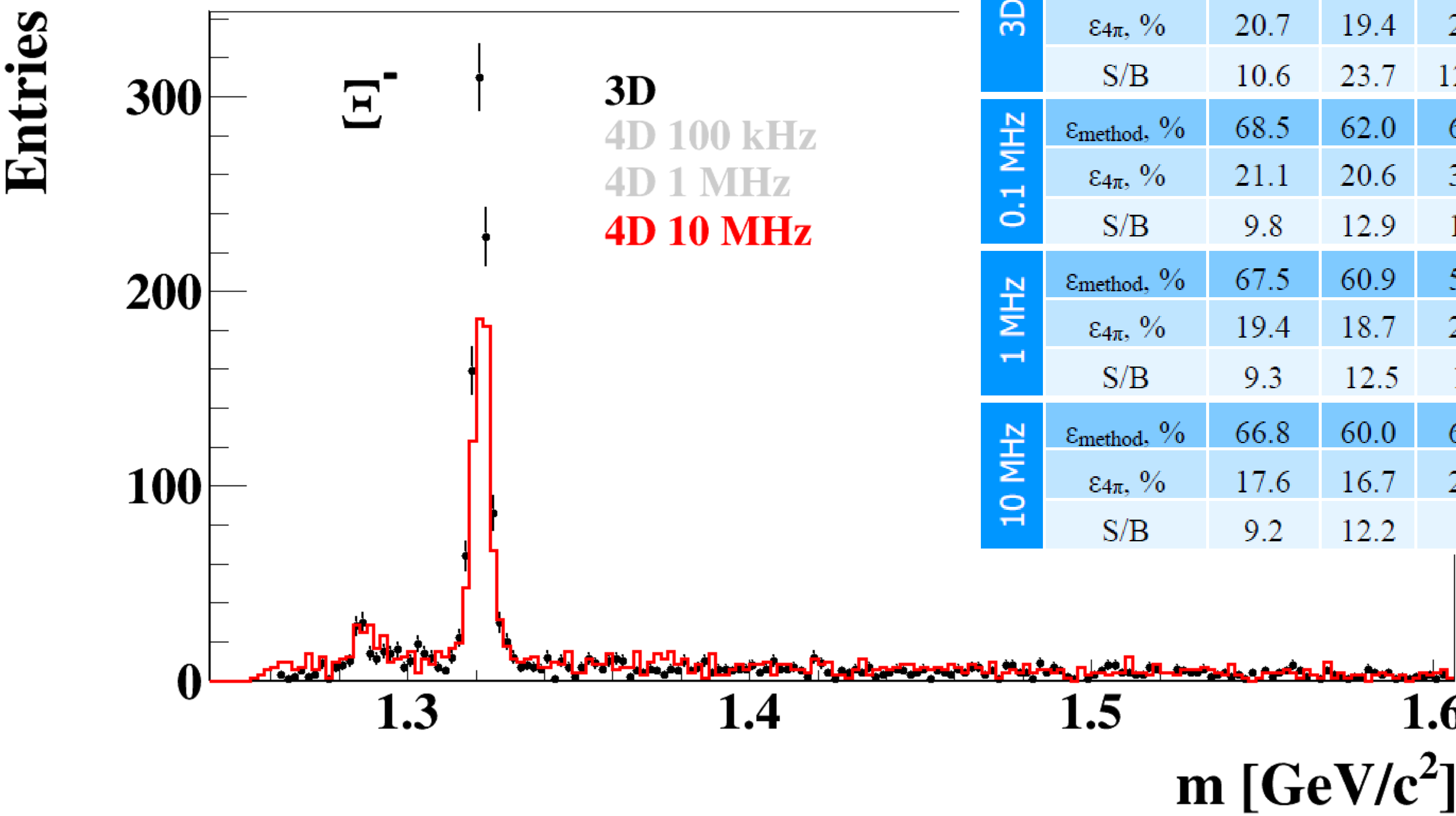


High rate scenario: MSH reconstruction with 4D tracking

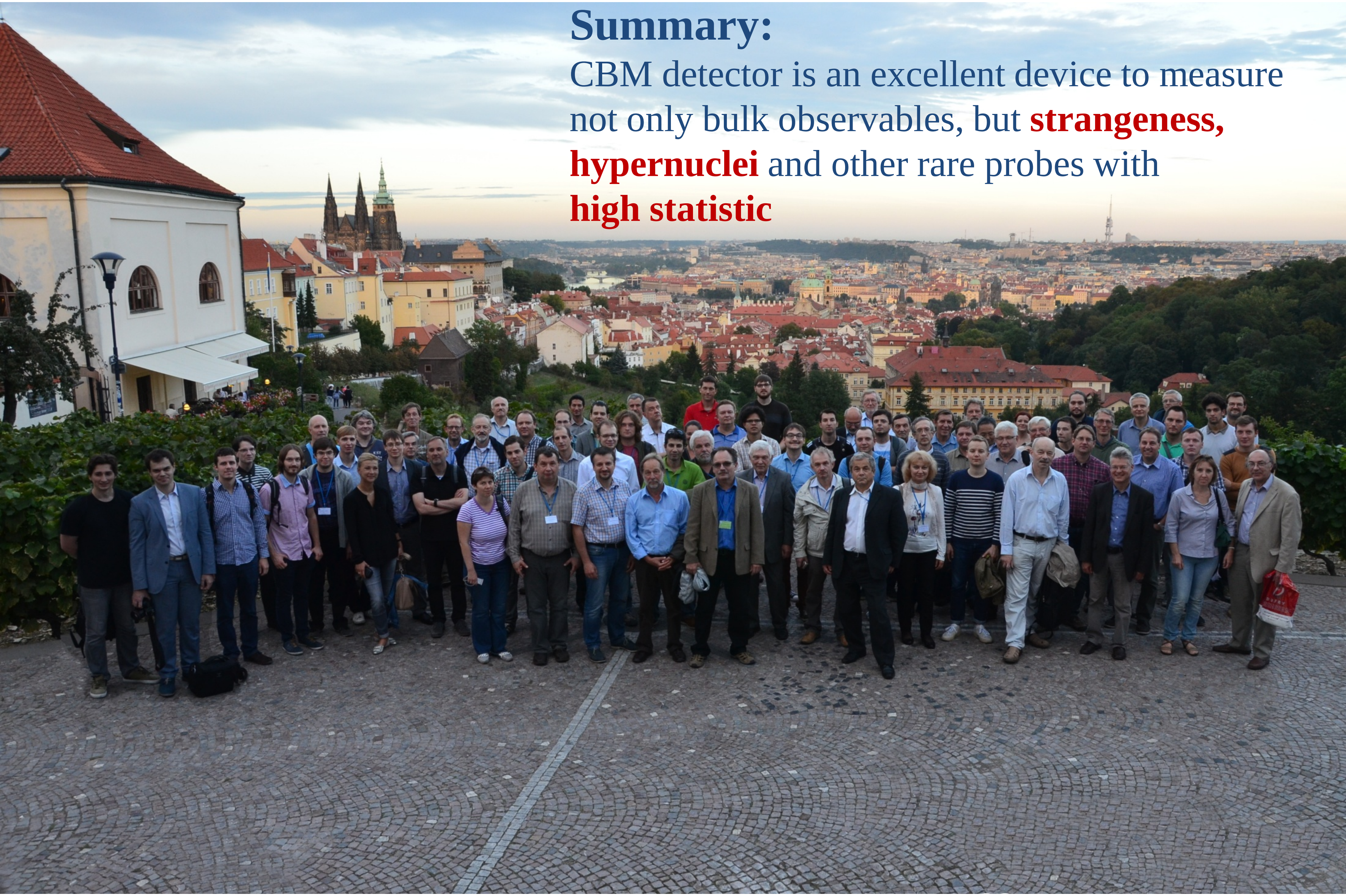


High rate scenario: MSH reconstruction with 4D tracking

		K0s	Λ	$\bar{\Lambda}$	Ξ^-
3D	ε_{method}, %	68.6	61.2	67	46.7
	$\varepsilon_{4\pi}$, %	20.7	19.4	28	10.5
	S/B	10.6	23.7	12.7	21.8
0.1 MHz	ε_{method}, %	68.5	62.0	62	45.2
	$\varepsilon_{4\pi}$, %	21.1	20.6	32	11.7
	S/B	9.8	12.9	10	14.2
1 MHz	ε_{method}, %	67.5	60.9	59	46.0
	$\varepsilon_{4\pi}$, %	19.4	18.7	26	10.6
	S/B	9.3	12.5	10	12.3
10 MHz	ε_{method}, %	66.8	60.0	64	41.8
	$\varepsilon_{4\pi}$, %	17.6	16.7	28	8.2
	S/B	9.2	12.2	8	11.7



60 Institutes, 600 members



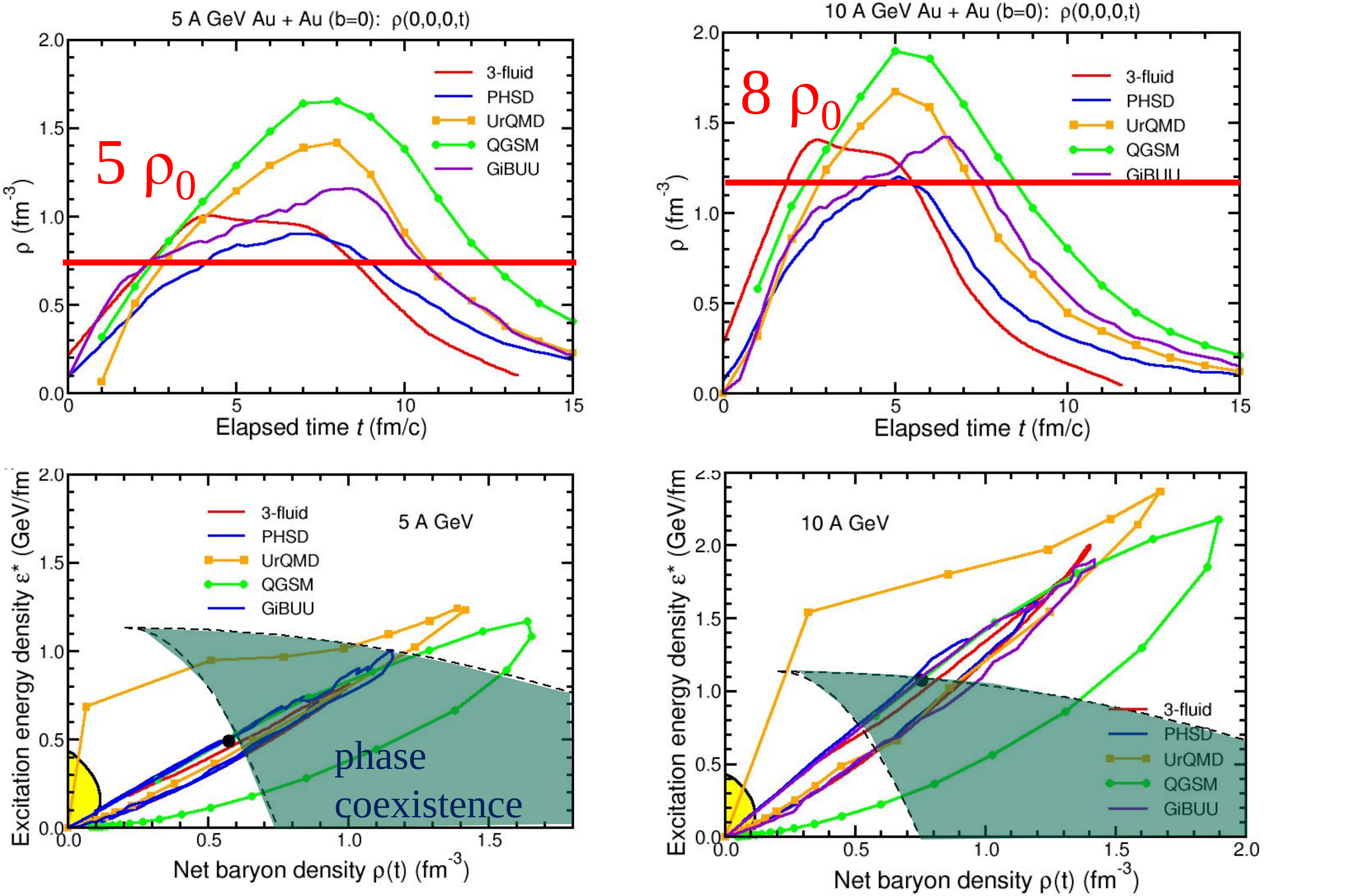
Summary:

CBM detector is an excellent device to measure not only bulk observables, but **strangeness, hypernuclei** and other rare probes with **high statistic**

Baryon densities in central Au+Au collisions

I.C. Arsene et al., Phys. Rev. C 75, 24902 (2007)

5 A GeV **10 A GeV**

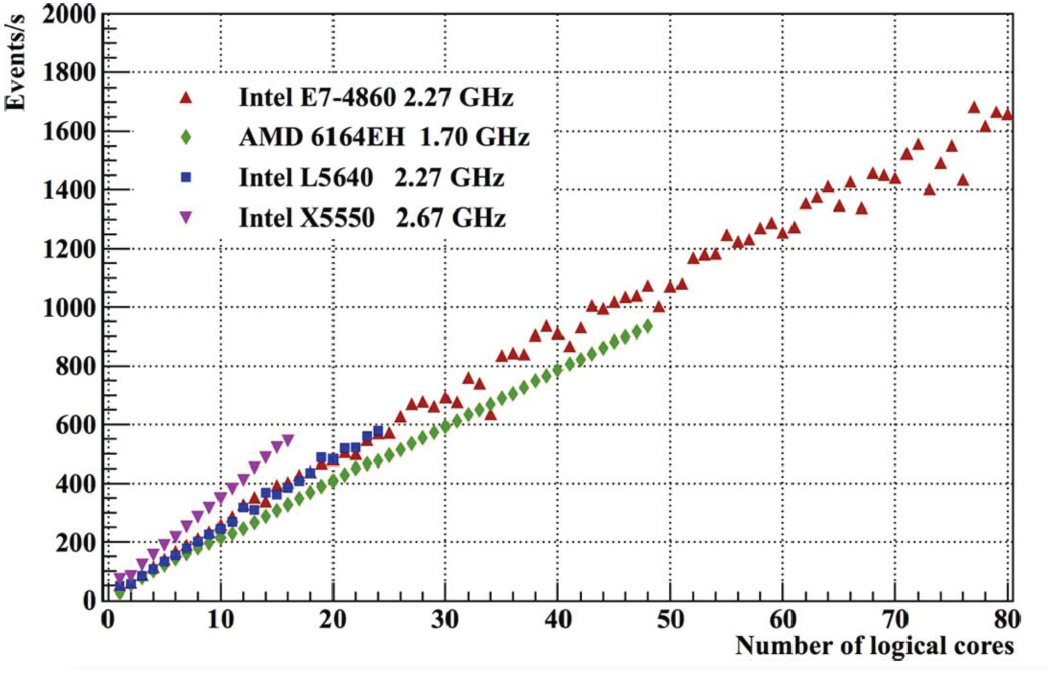


CBM First Level Event Selection (FLES)

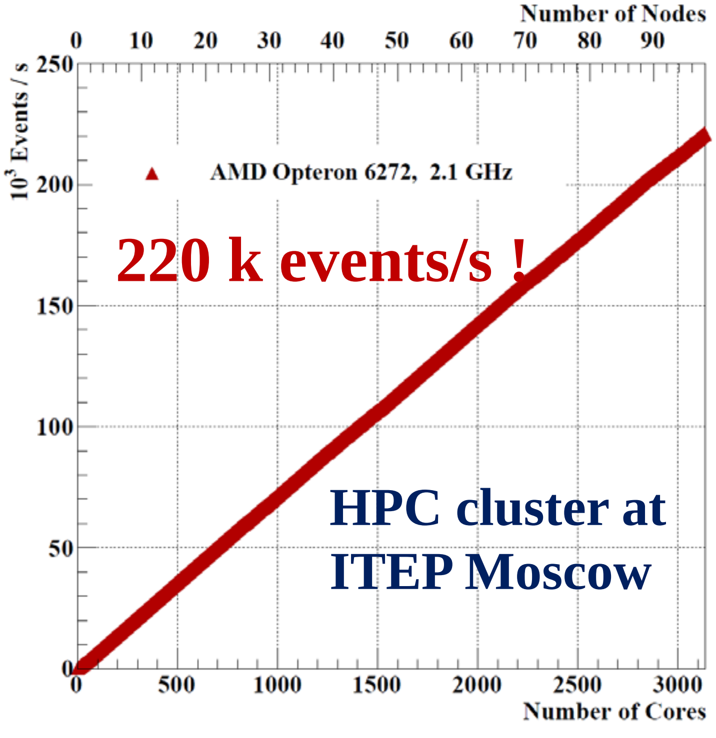
The FLES package is
vectorized, parallelized, portable and scalable up to 3 200 cores

<u>Example:</u>
Full track reconstruction including KF particle analysis of multi-strange (anti) hyperons for min. bias Au+Au collisions at 25 A GeV.

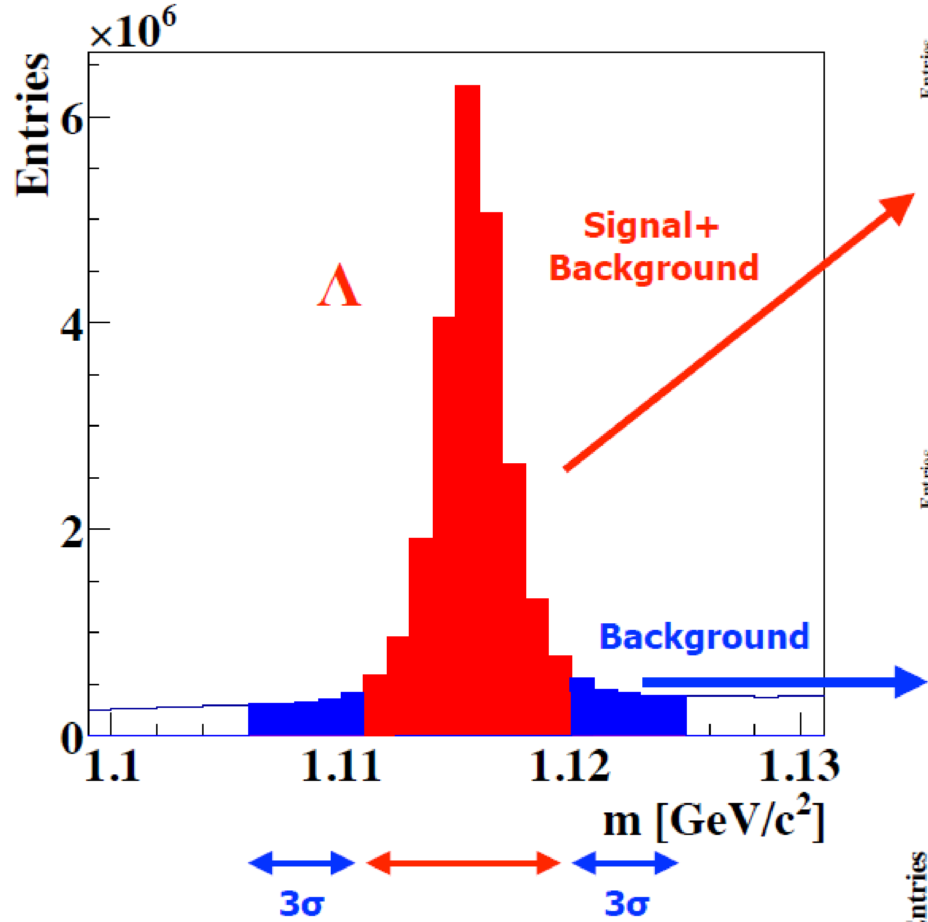
Single node with up to 80 cores

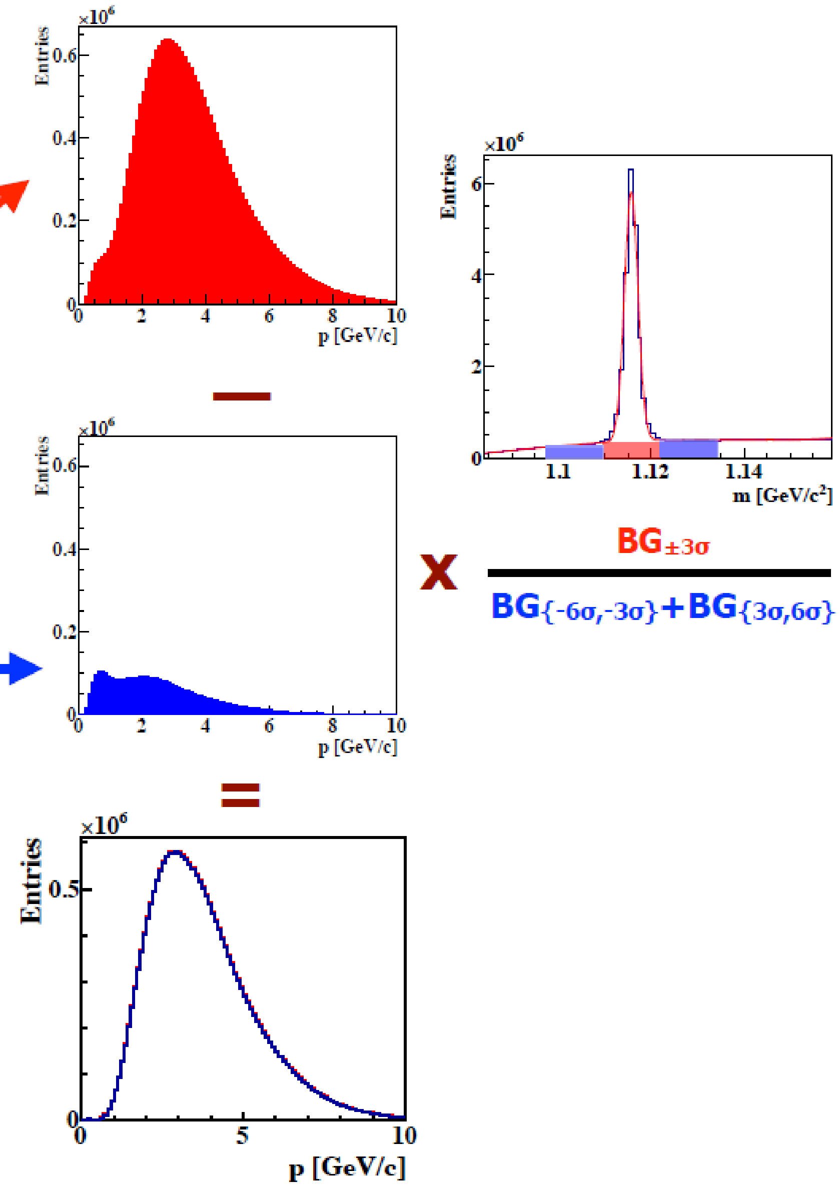


100 nodes with 32 cores each



Extraction of the signal: background subtraction





- Collect spectra (M, p, p_t, y, Z…) for the signal+BG (particles within the mass peak) and BG (particles near the peak).
- Calculate the correction factor using the fitted BG.
- Subtract the corrected BG.