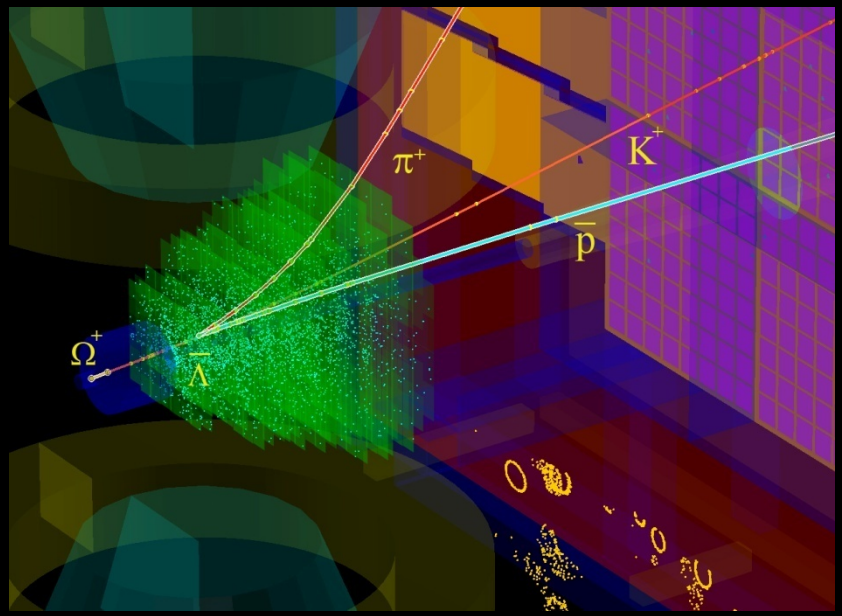
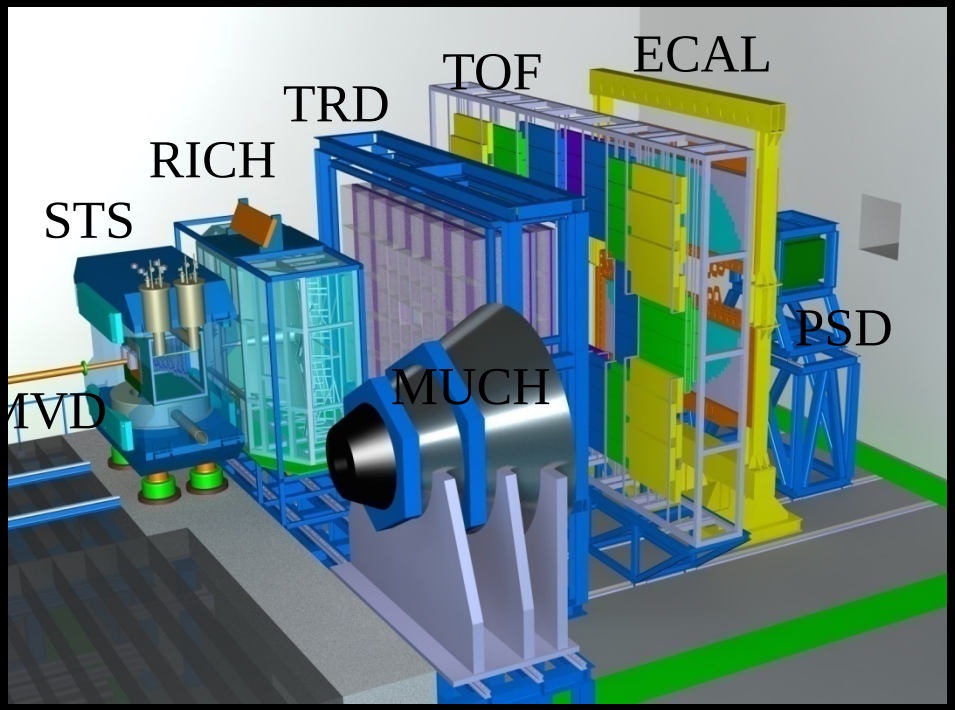
Perspectives on strangeness physics with CBM

I.Vassiliev for the CBM Collaboration

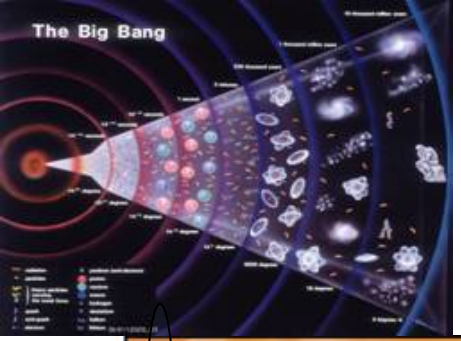


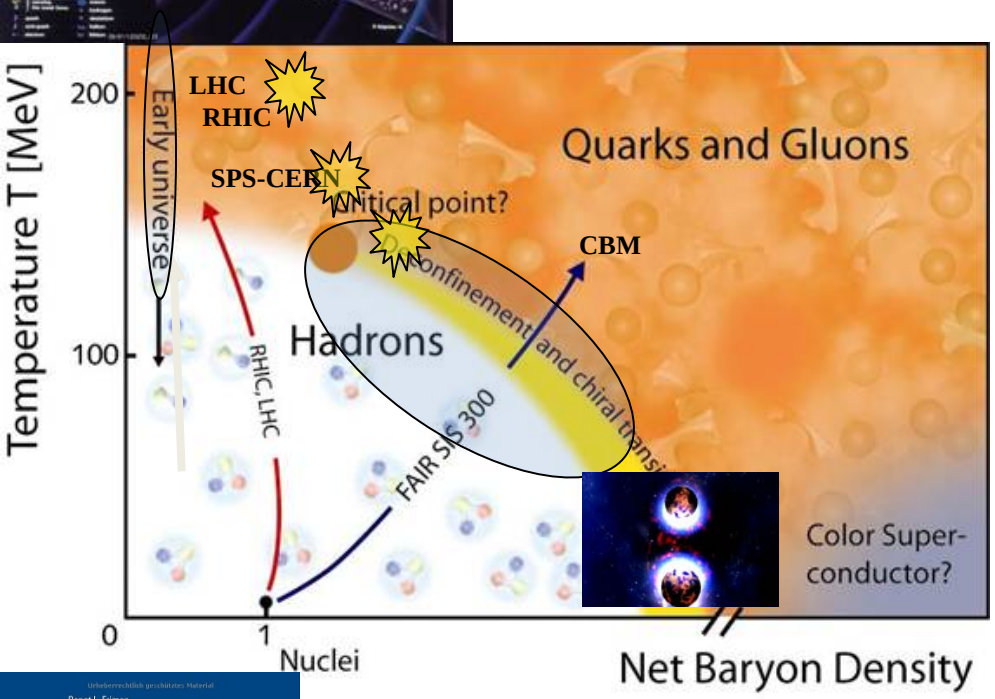


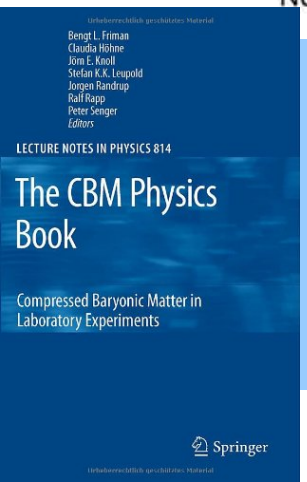
- Physics case
- Developed methods & tasks
- High rate scenario
- Conclusions

November 2017 Turin

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!**

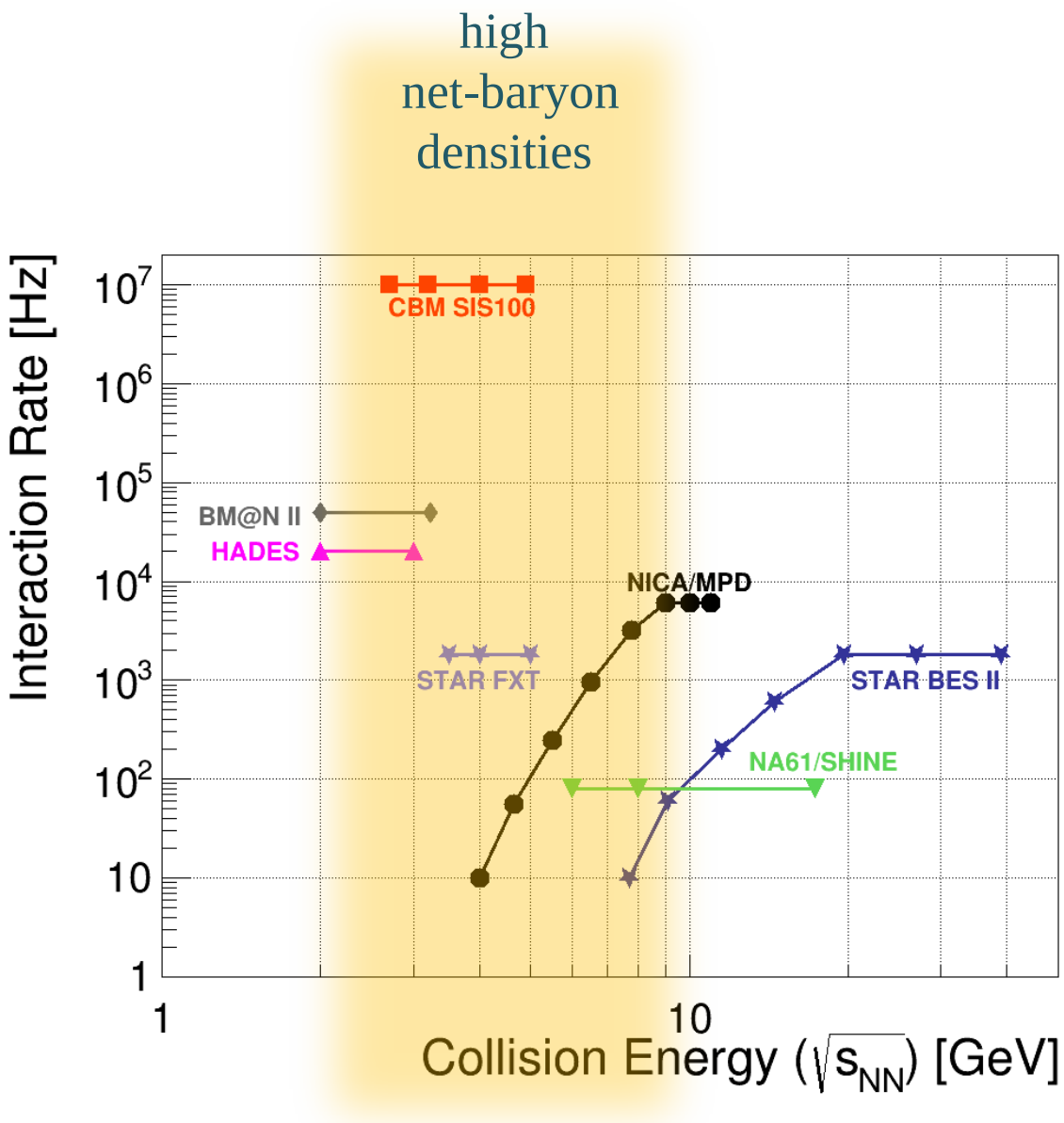
The equation-of-state at high ρ_B
- collective flow of hadrons
- particle production at threshold energies: **open charm,** multi-strange hyperons, HN

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)

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)**

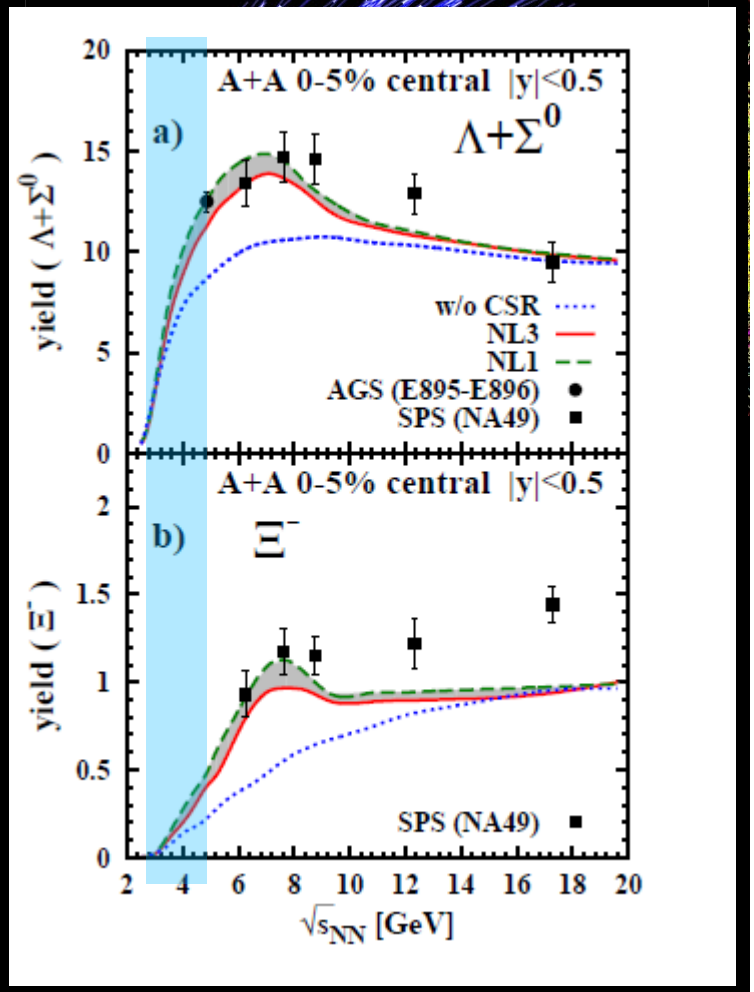
Experiments exploring dense QCD matter

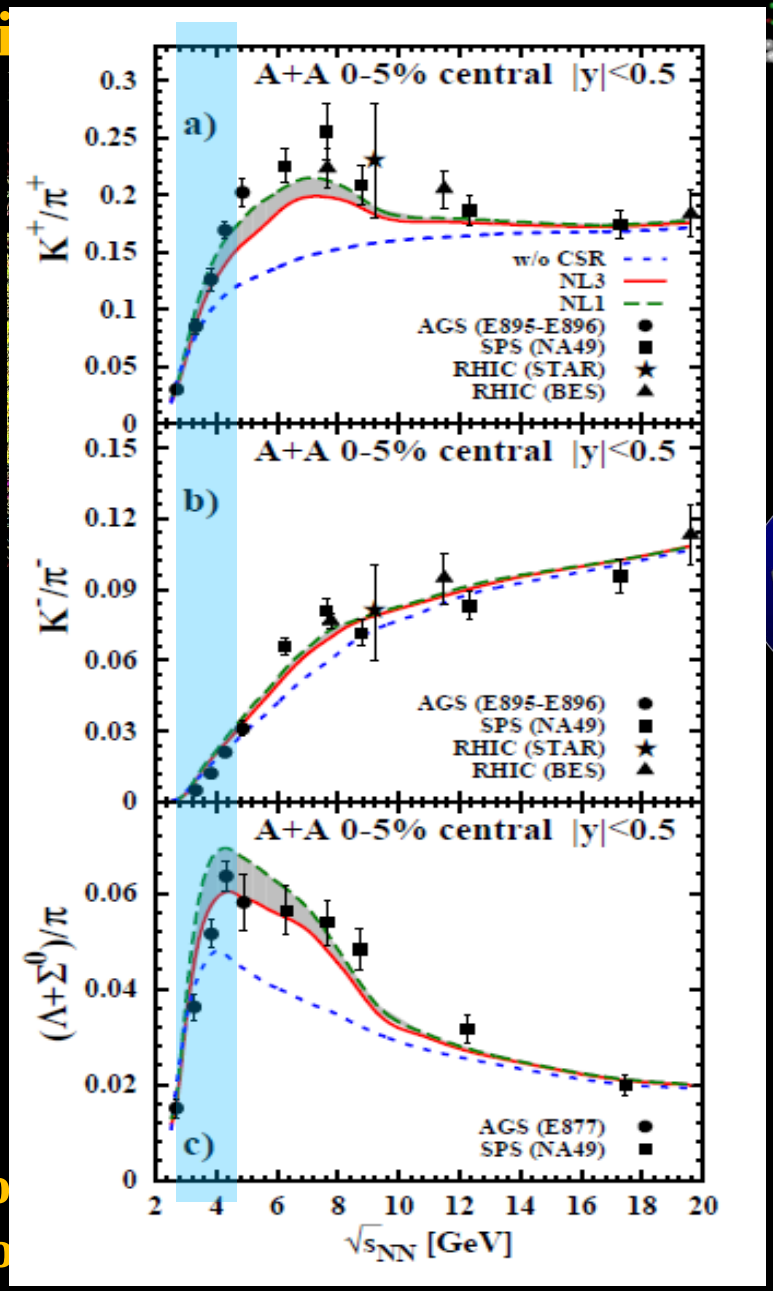


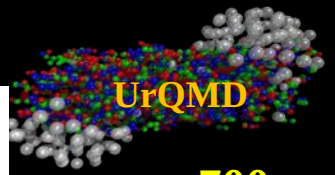
CBM:
world record
rate capability

- 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 and 4D tracking
- software triggers

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







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

PHSD

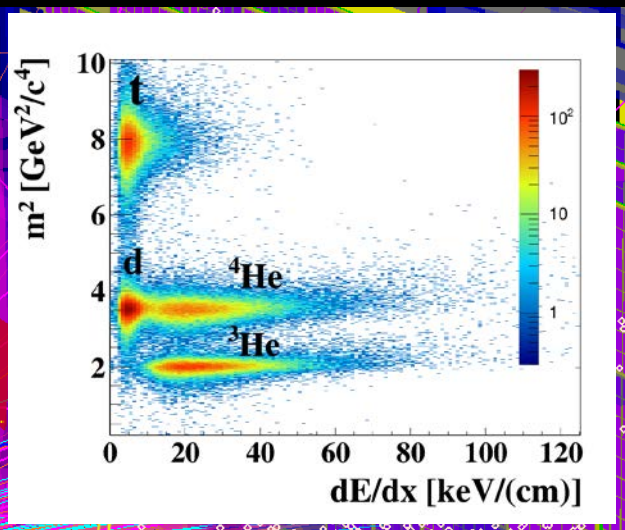
~700 π
174 p
42 K
30 Λ
24 K_S^0
2.4 Ξ^-
0.005 Ω^-

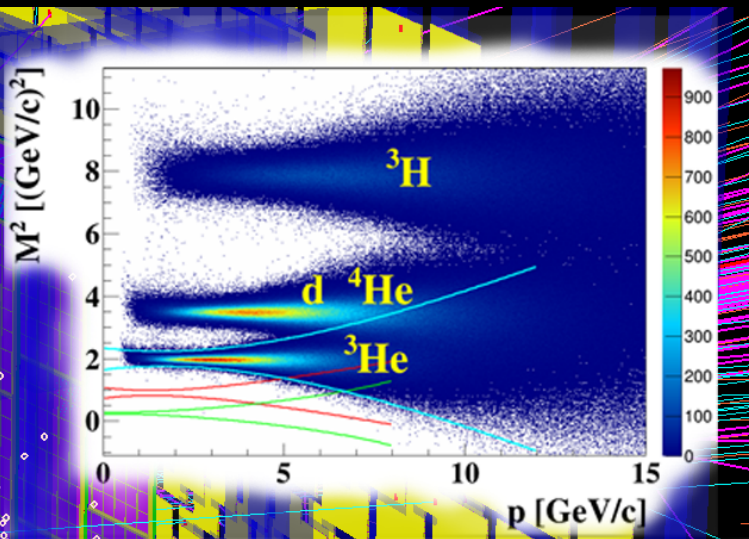
central: 82 (TF) + 16 (PF) ms/co
mbias : 10 (TF) + 2 (PF) ms/co
up to 80 cores/CPU

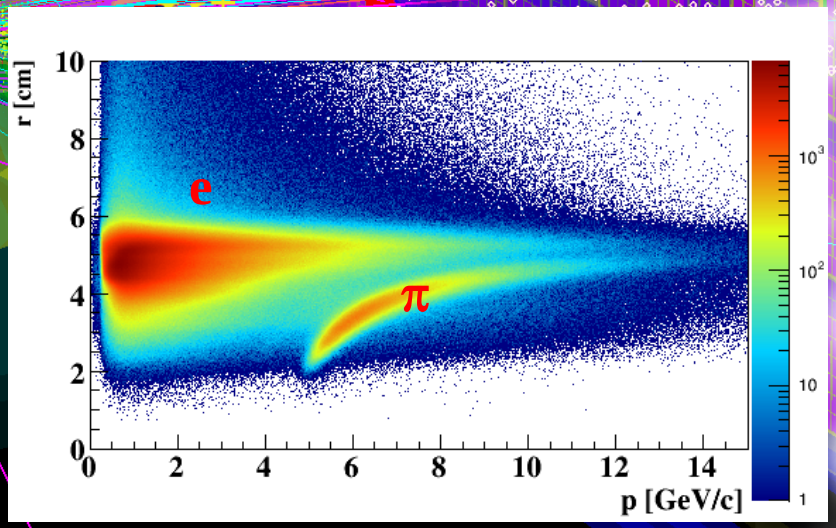
dp/p = 1.2%

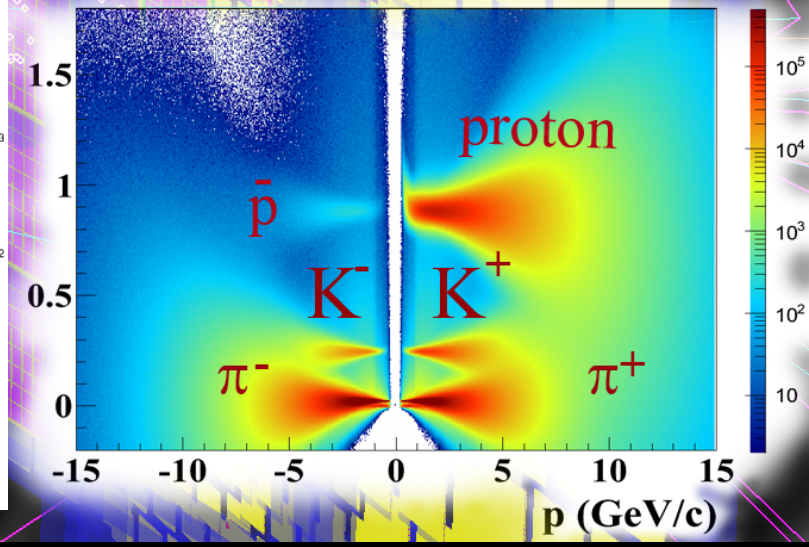
Particle identification with PID detectors

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



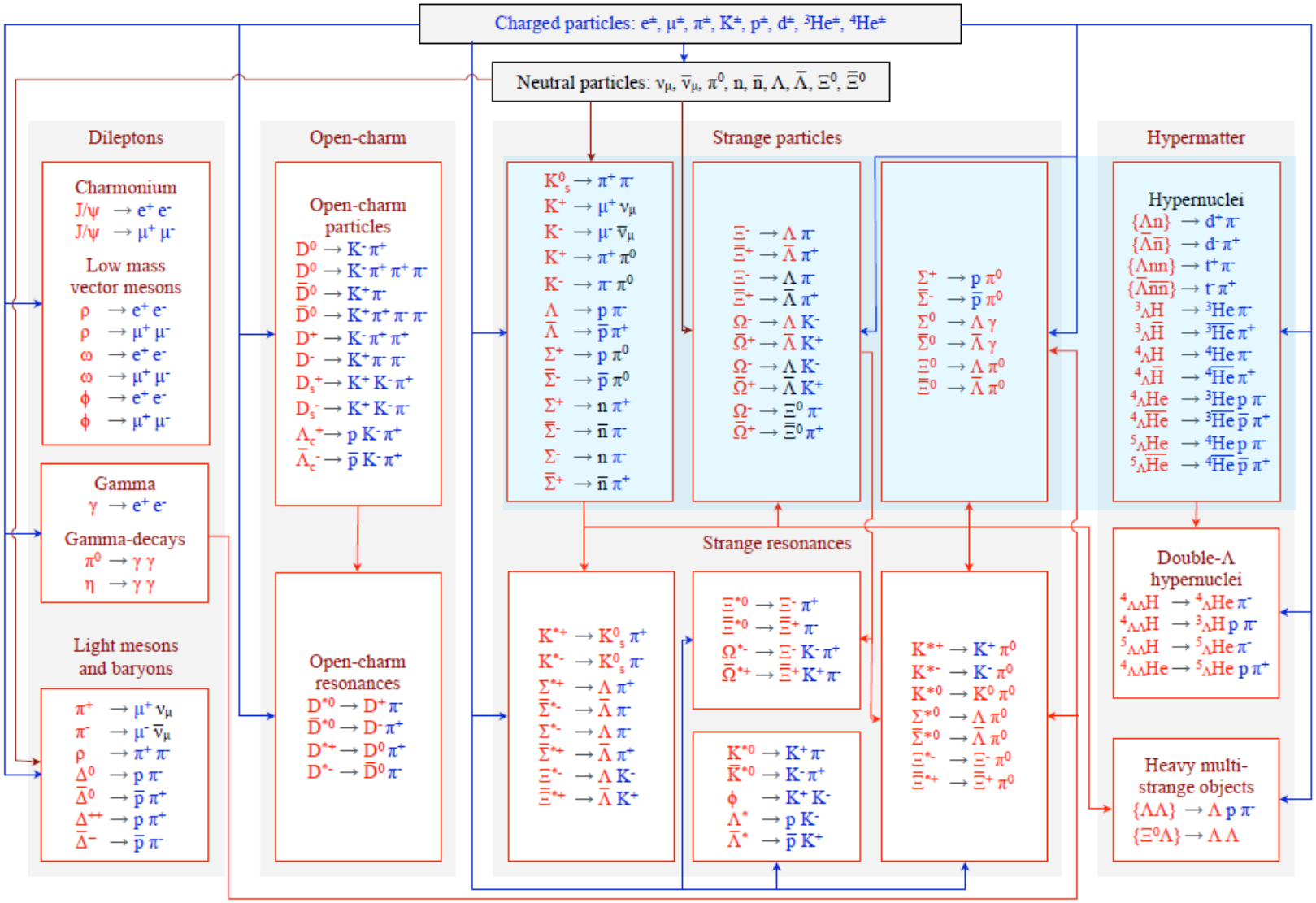






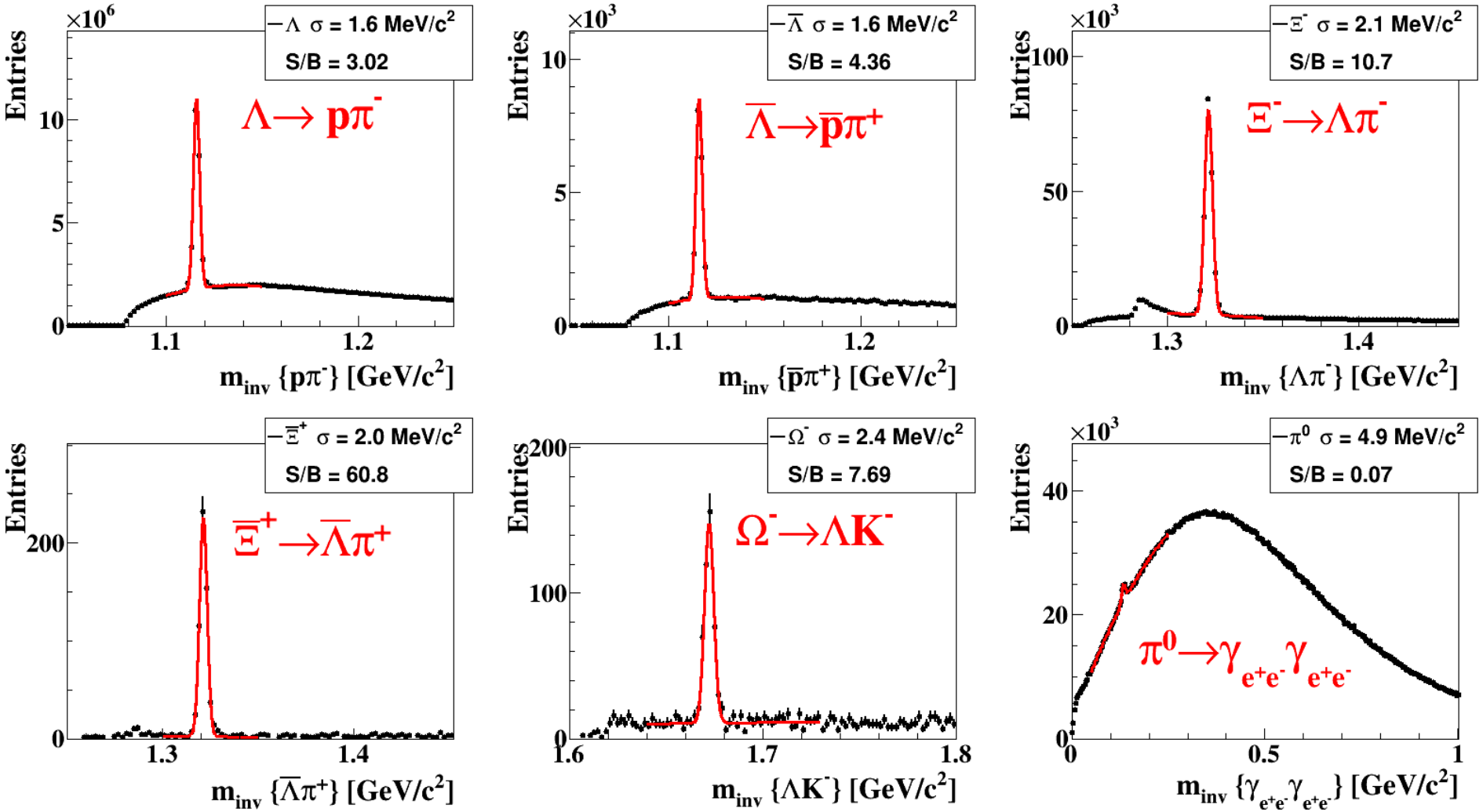
Central event: 40 (TF) + 7 (PF) ms/core with MVD!
(~ 2 faster w/o MVD)

KF Particle Finder for the CBM Experiment

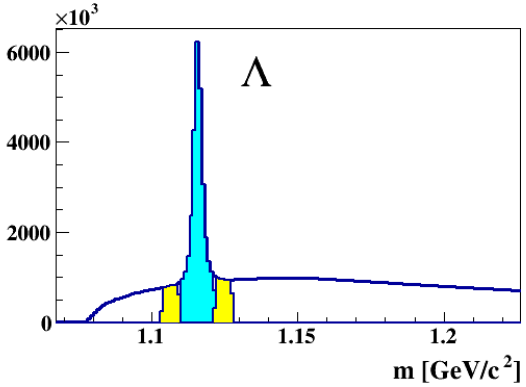


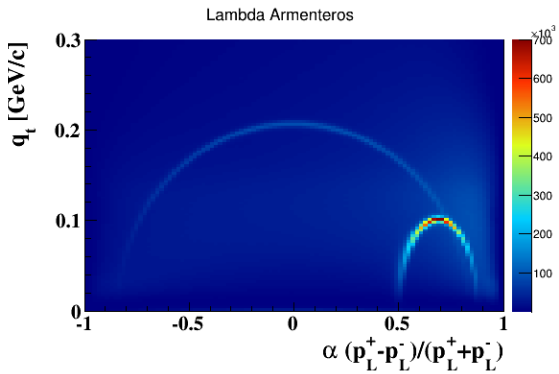
+ STAR, ALICE, PANDA, HADES, NA61

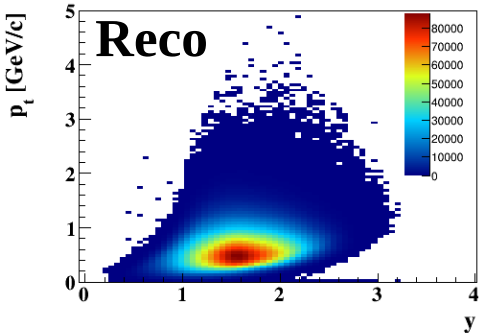
5M central AuAu collisions, 10AGeV

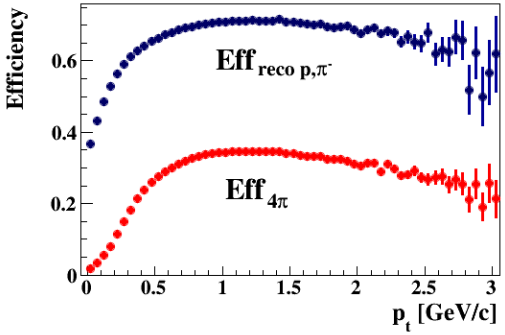


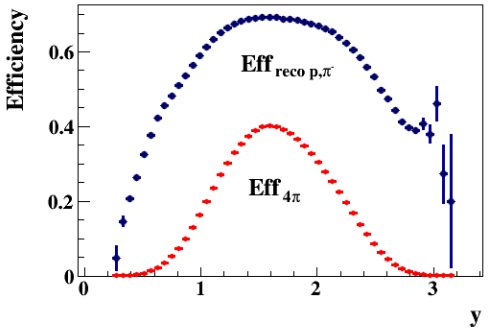
5M central Au Au collisions, 10AGeV (Λ)

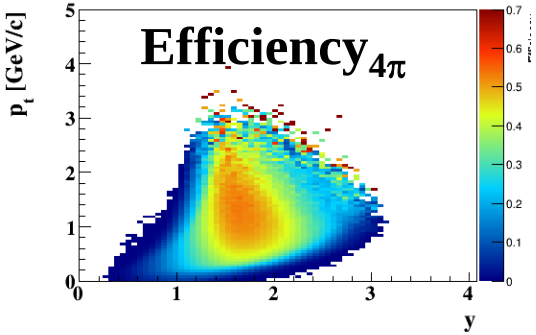


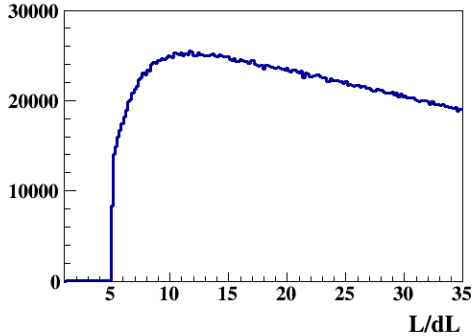


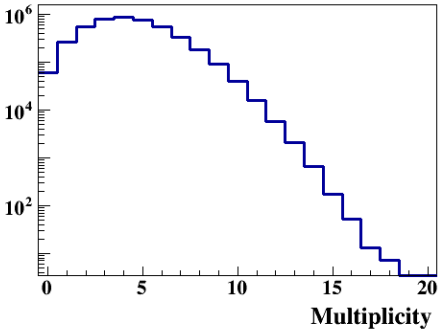


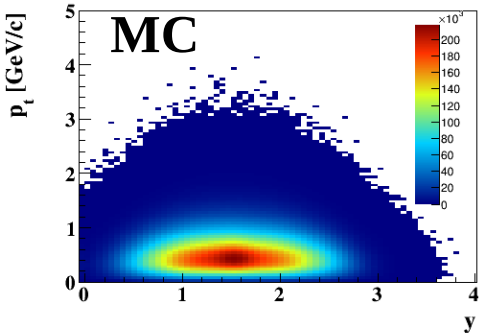




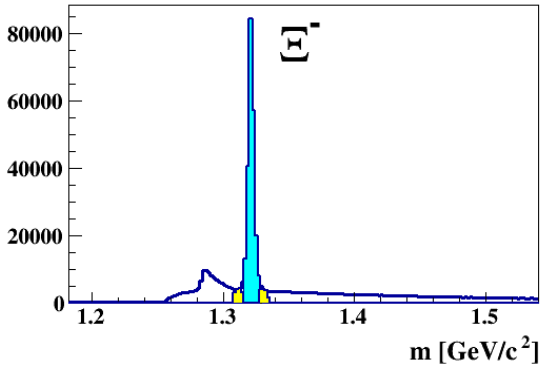


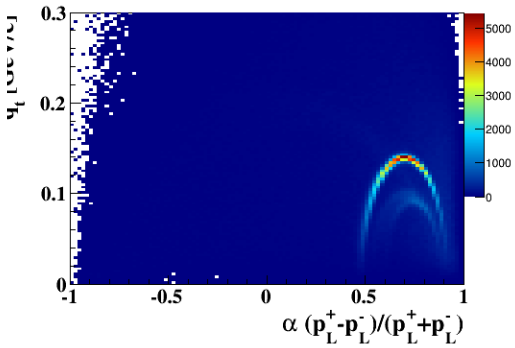


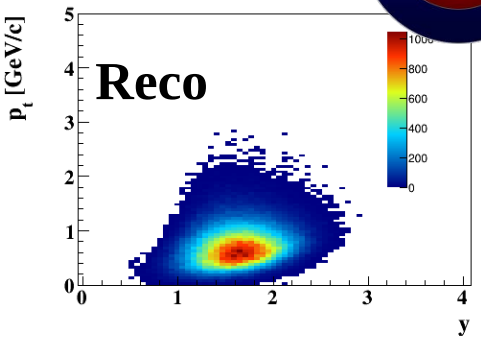


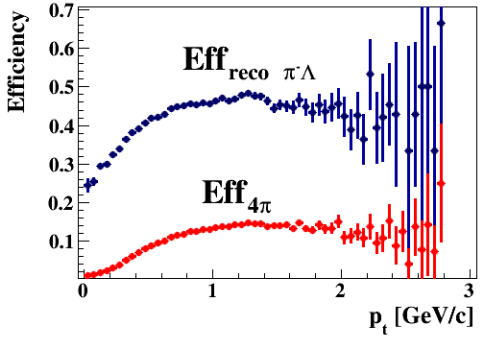


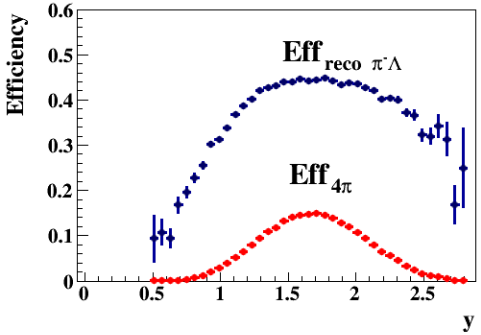
5M central Au Au collisions, 10AGeV (Ξ^-)

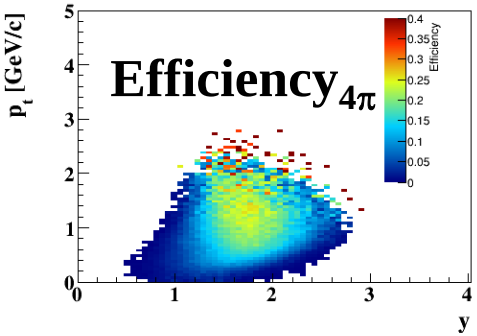


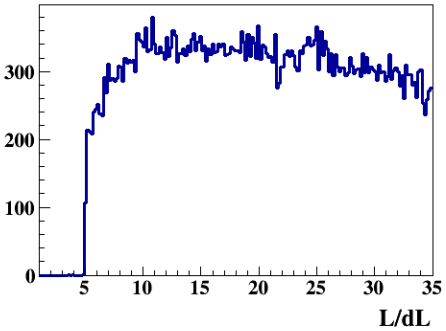


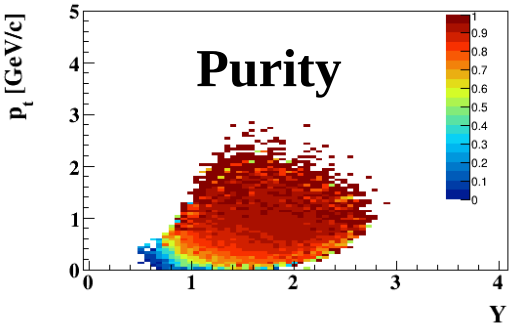


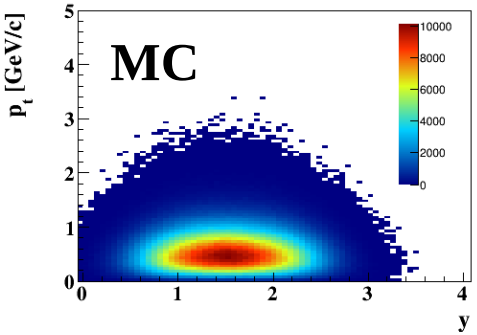




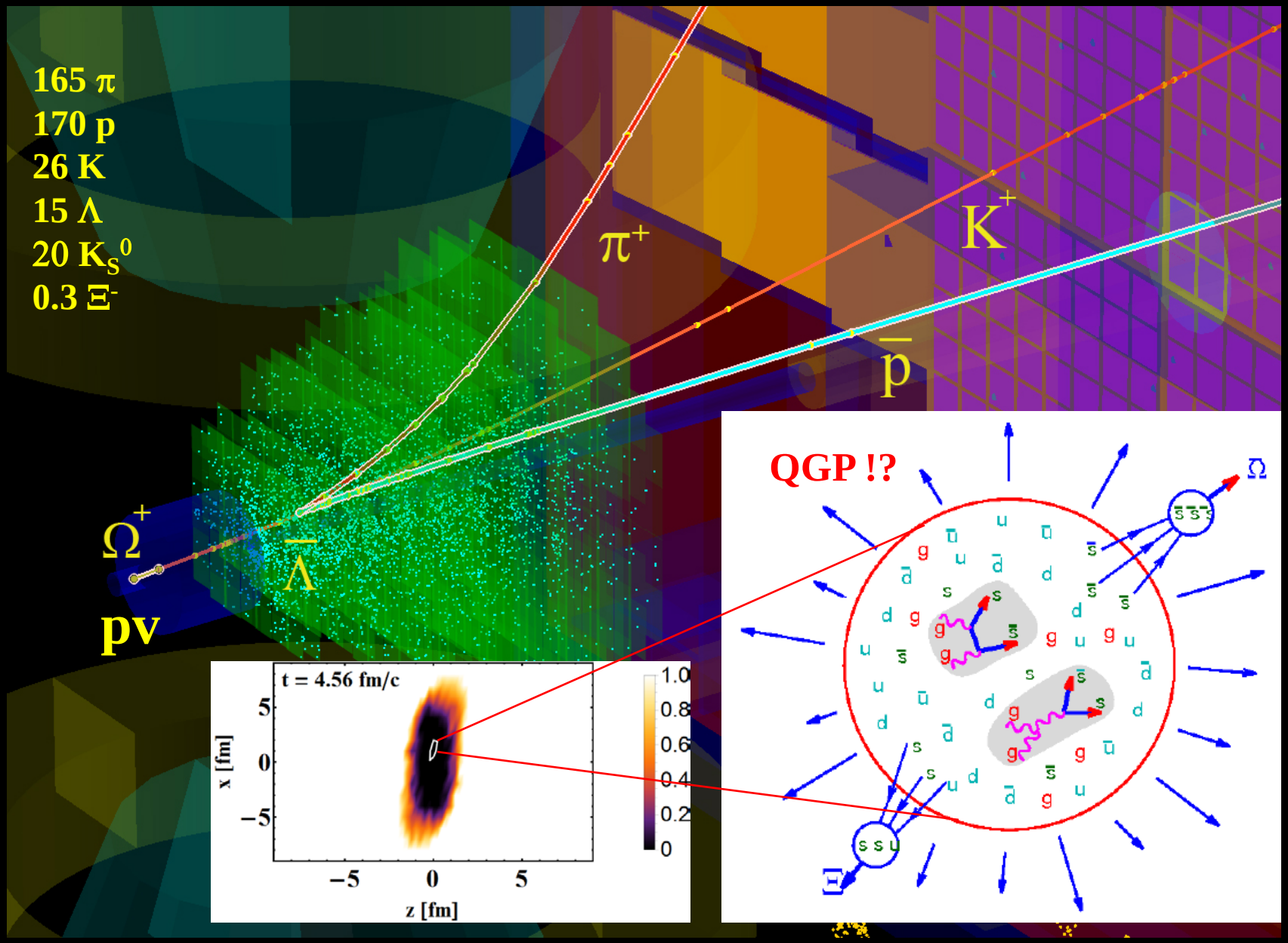




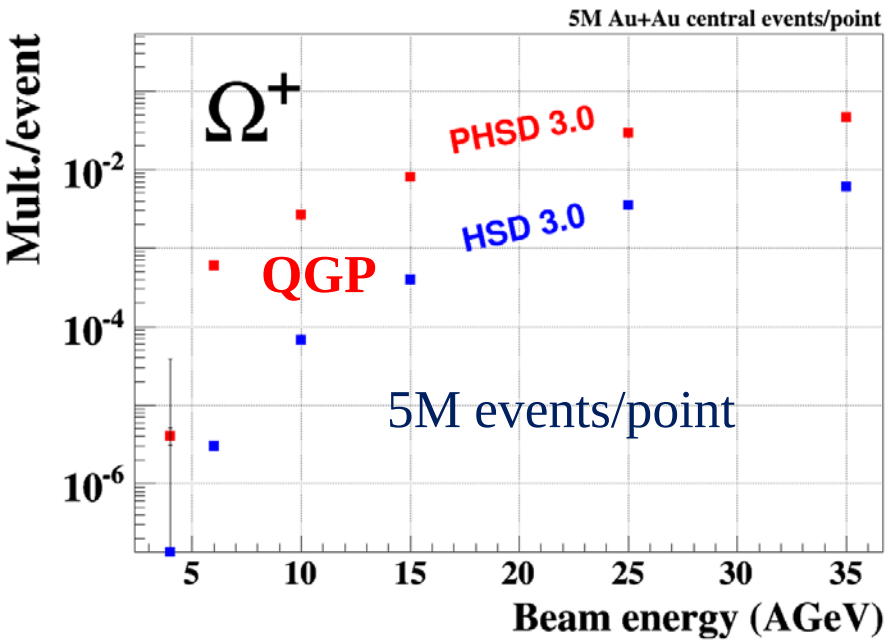




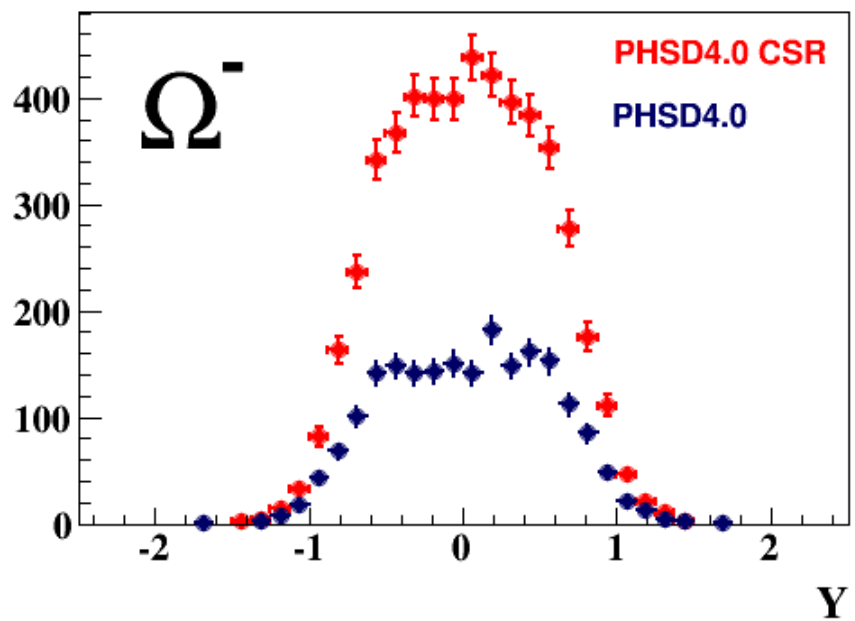
KF Particle Finder with ToF track ID: Au+Au @ 10AGeV



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

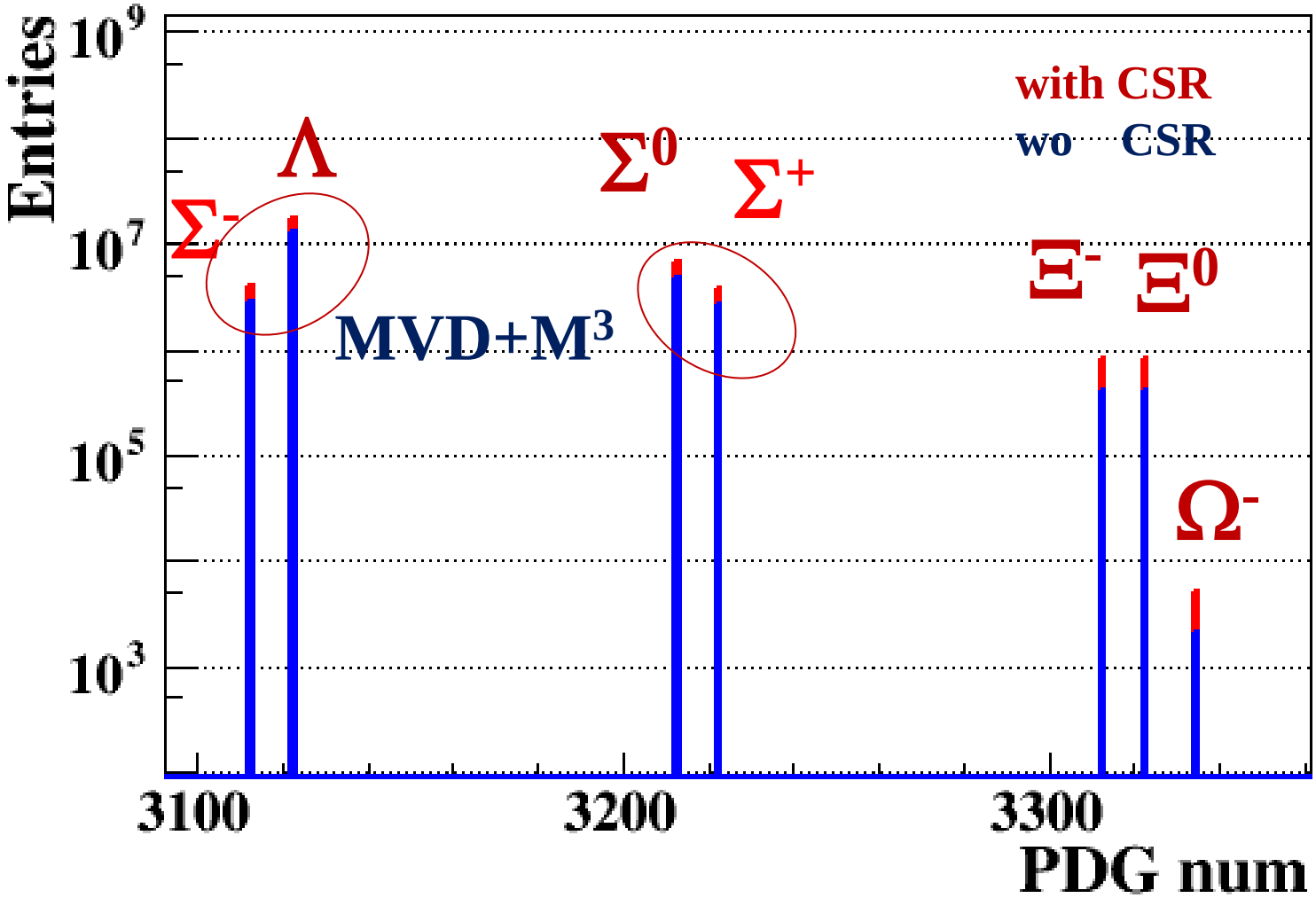


PHSD 4.0 Au + Au @ 10 AGeV



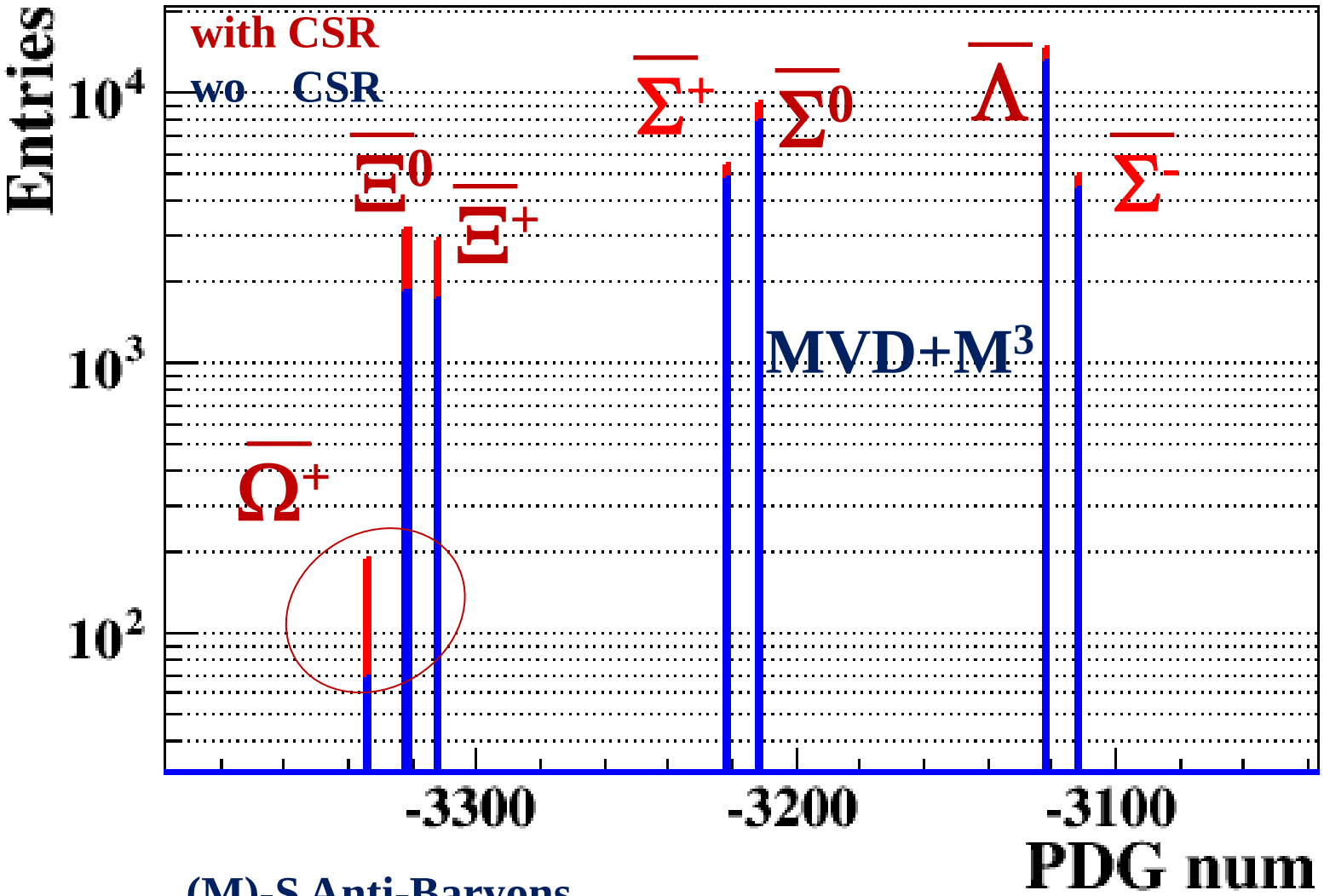
- Most of the Ω+ produced by QGP @ FAIR energy
- CSR increase yield of MS Baryons & Antibaryons

central AuAu collisions, 10AGeV



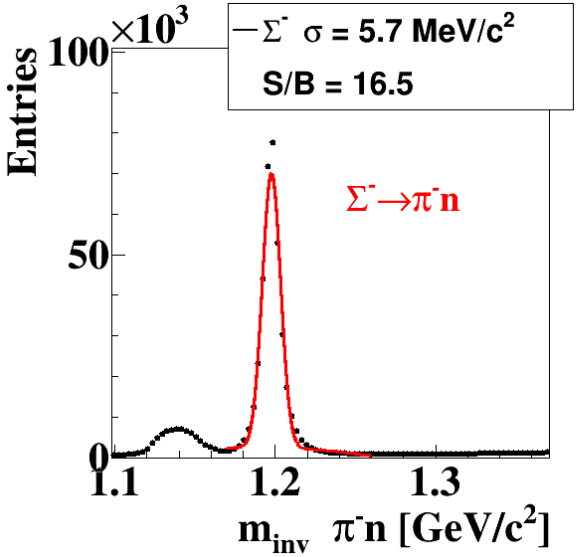
(M)-S Baryons

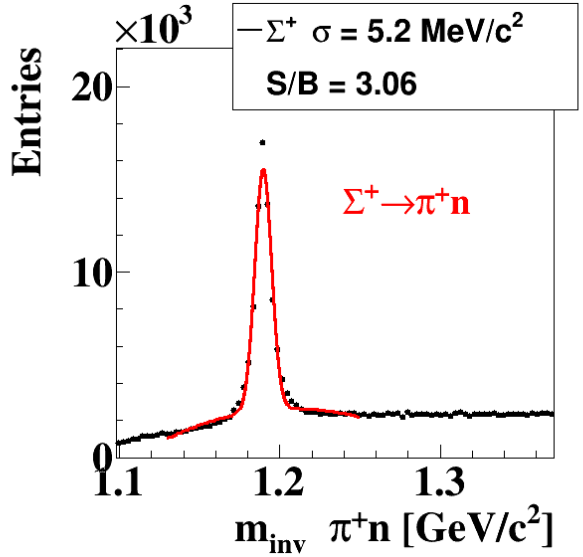
central AuAu collisions, 10AGeV

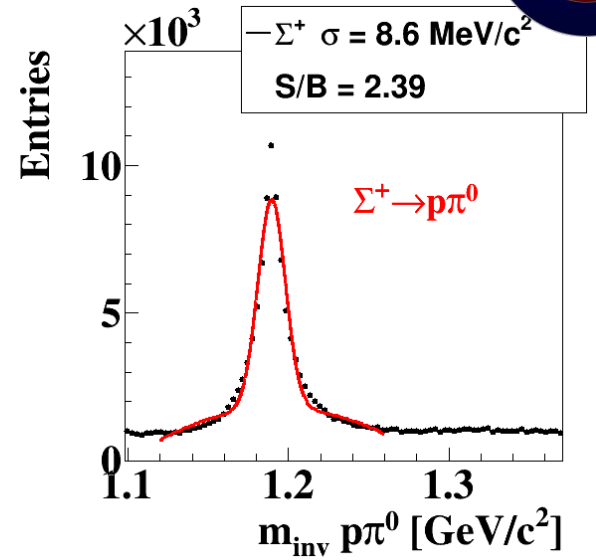


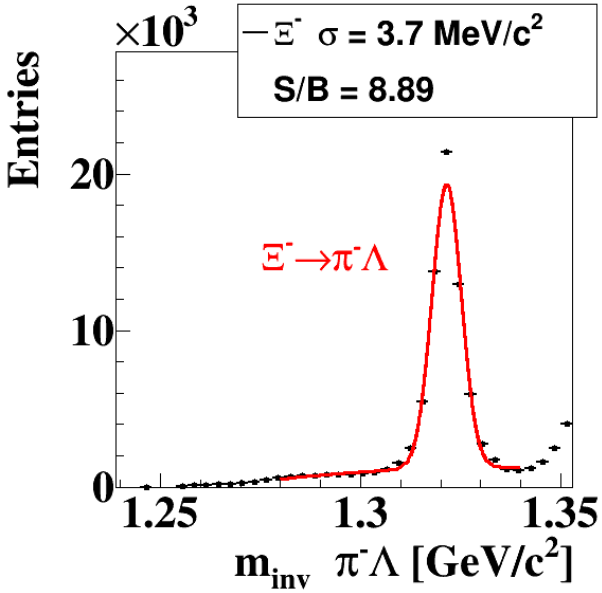
(M)-S Anti-Baryons

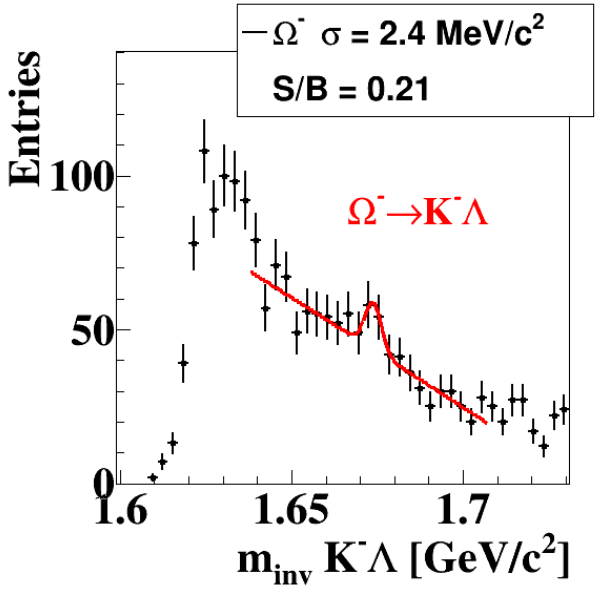
PHSD 4.0 (CSR) 5M central Au +Au collisions , M^3 (P. Kisel)

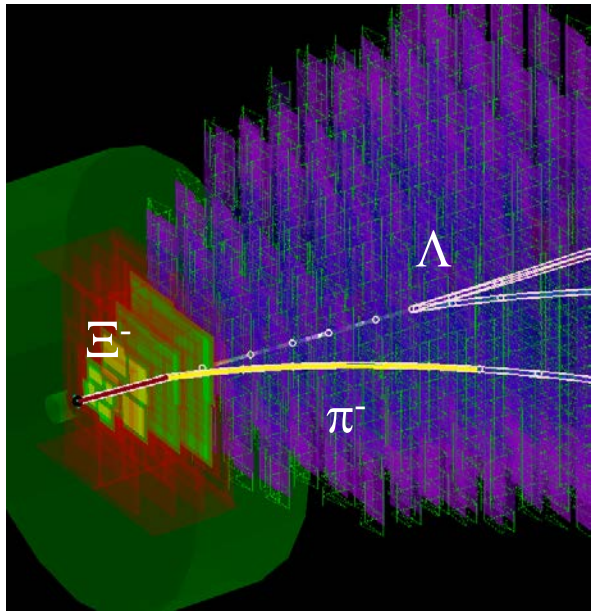




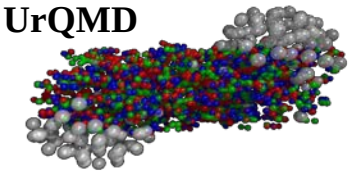




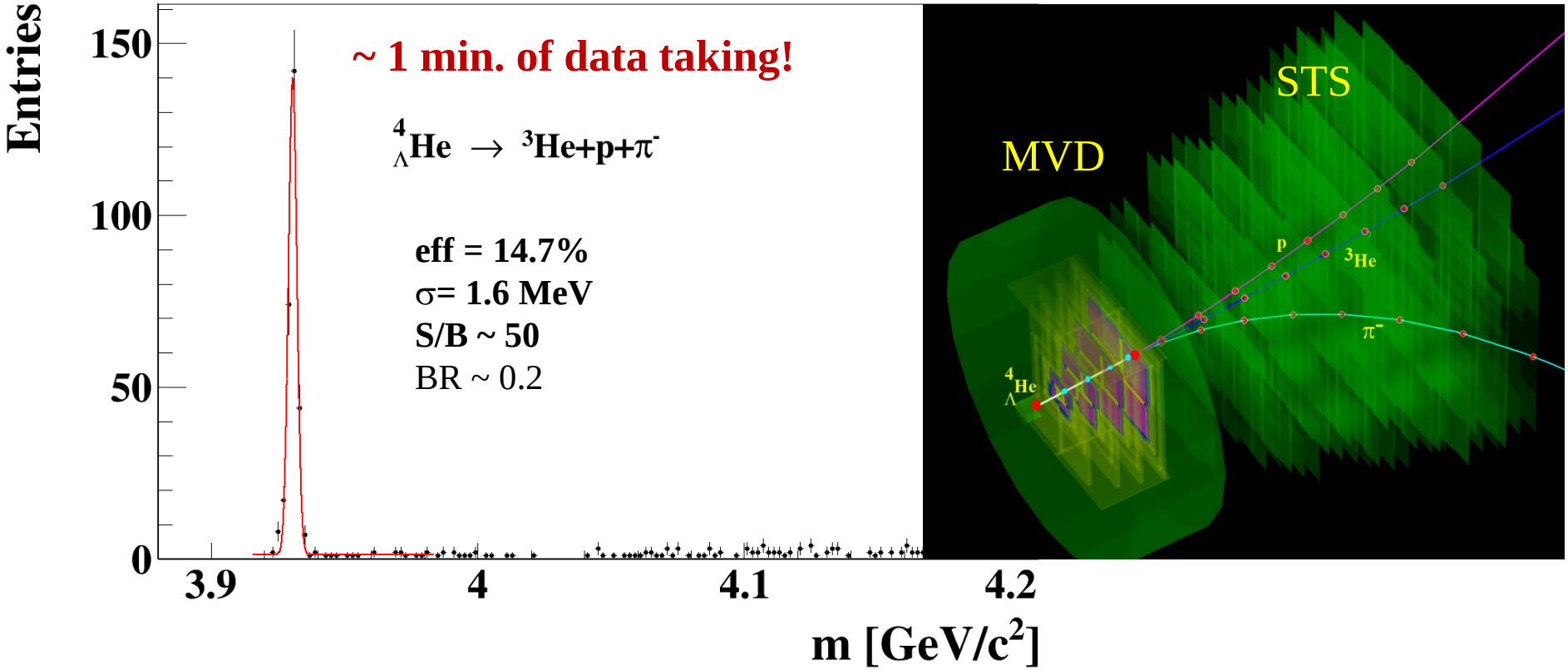




Au+Au 10 AGeV 5M central events



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

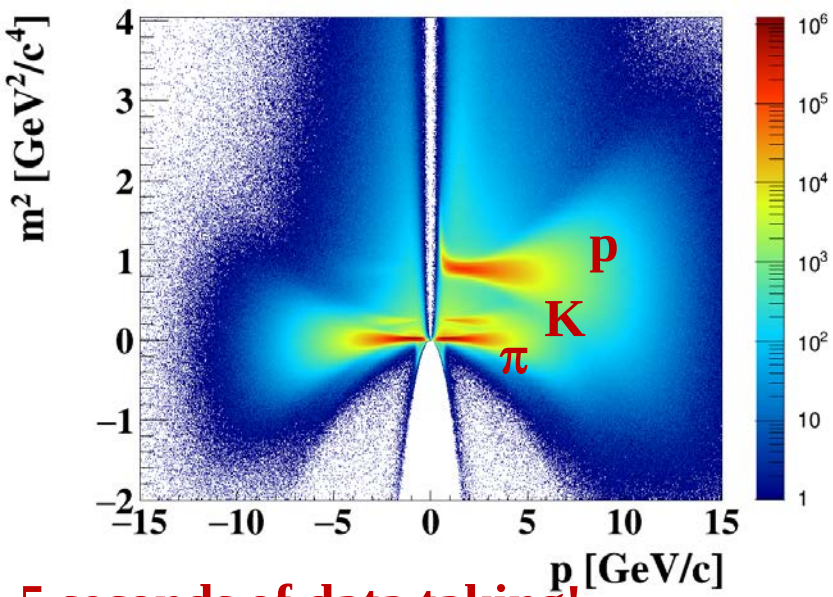


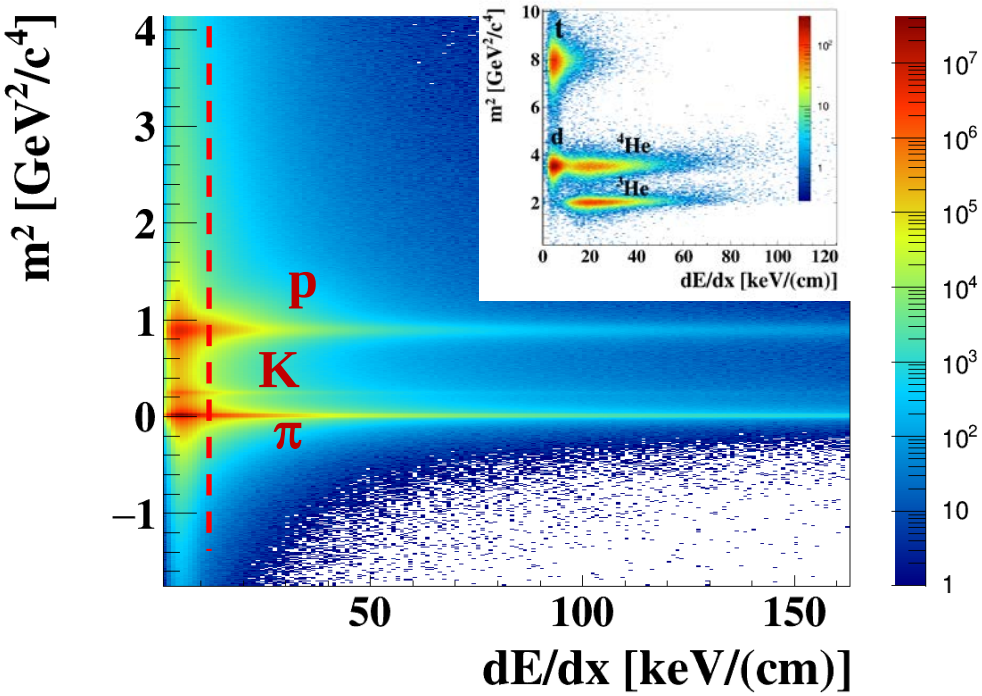
3 prong detached vertex is good signature of $^{4}_{\Lambda}$He decay

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

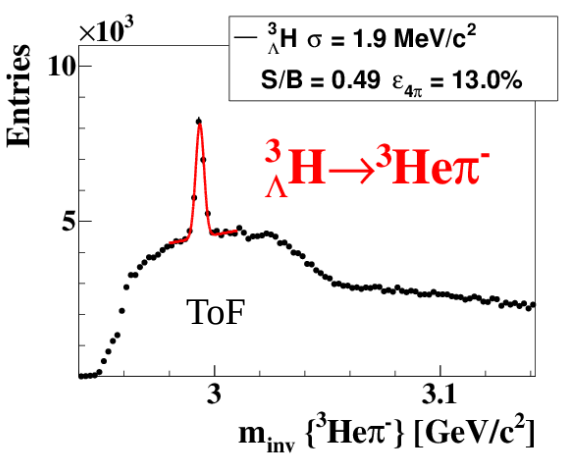
5M mbias AuAu collisions, 10AGeV

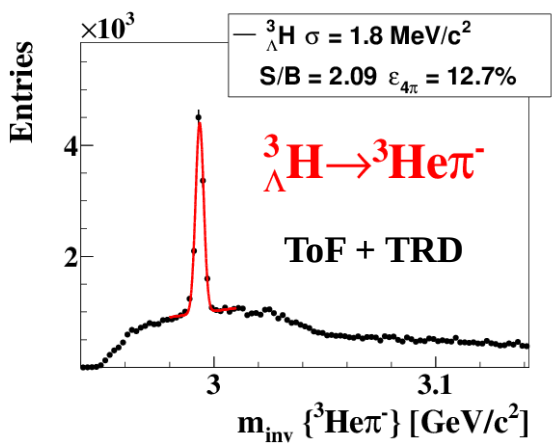
Extended KFParticle Finder $^{3}_{\Lambda}H$

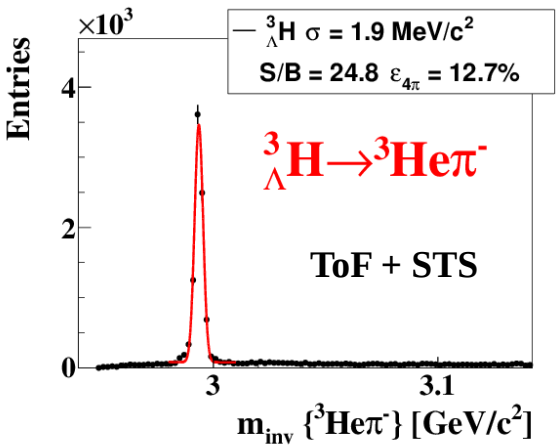




5 seconds of data taking!

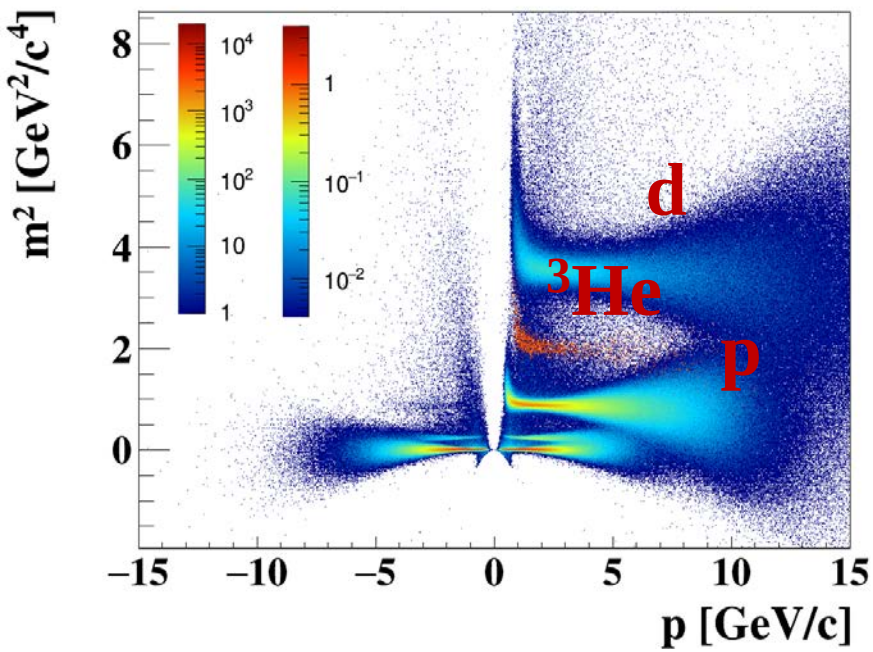




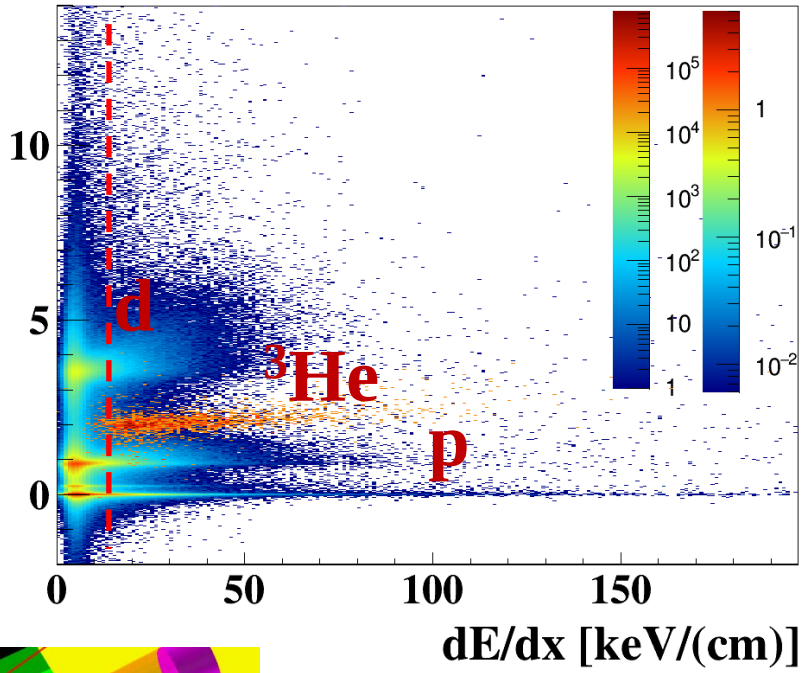


DCM with CBM detector 5M mbias C + C collisions

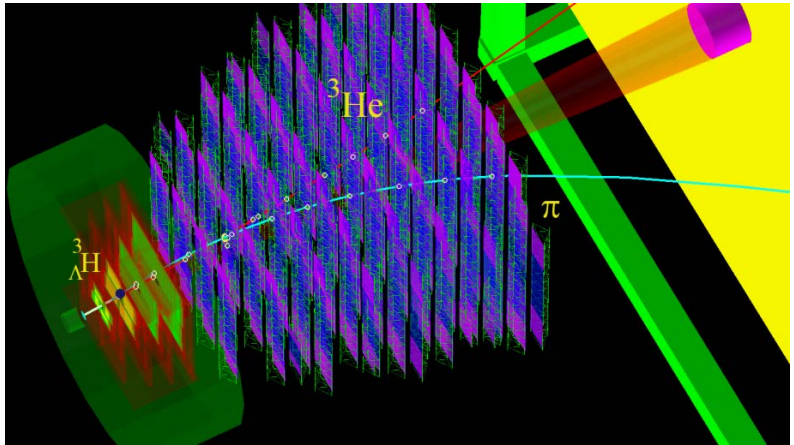
A.S.Botvina, K.K.Gudima, J.Pochodzalla.
Production of hypernuclei in peripheral relativistic ion collisions.
Phys. Rev. C , v. 88, p. 054605, 2013.



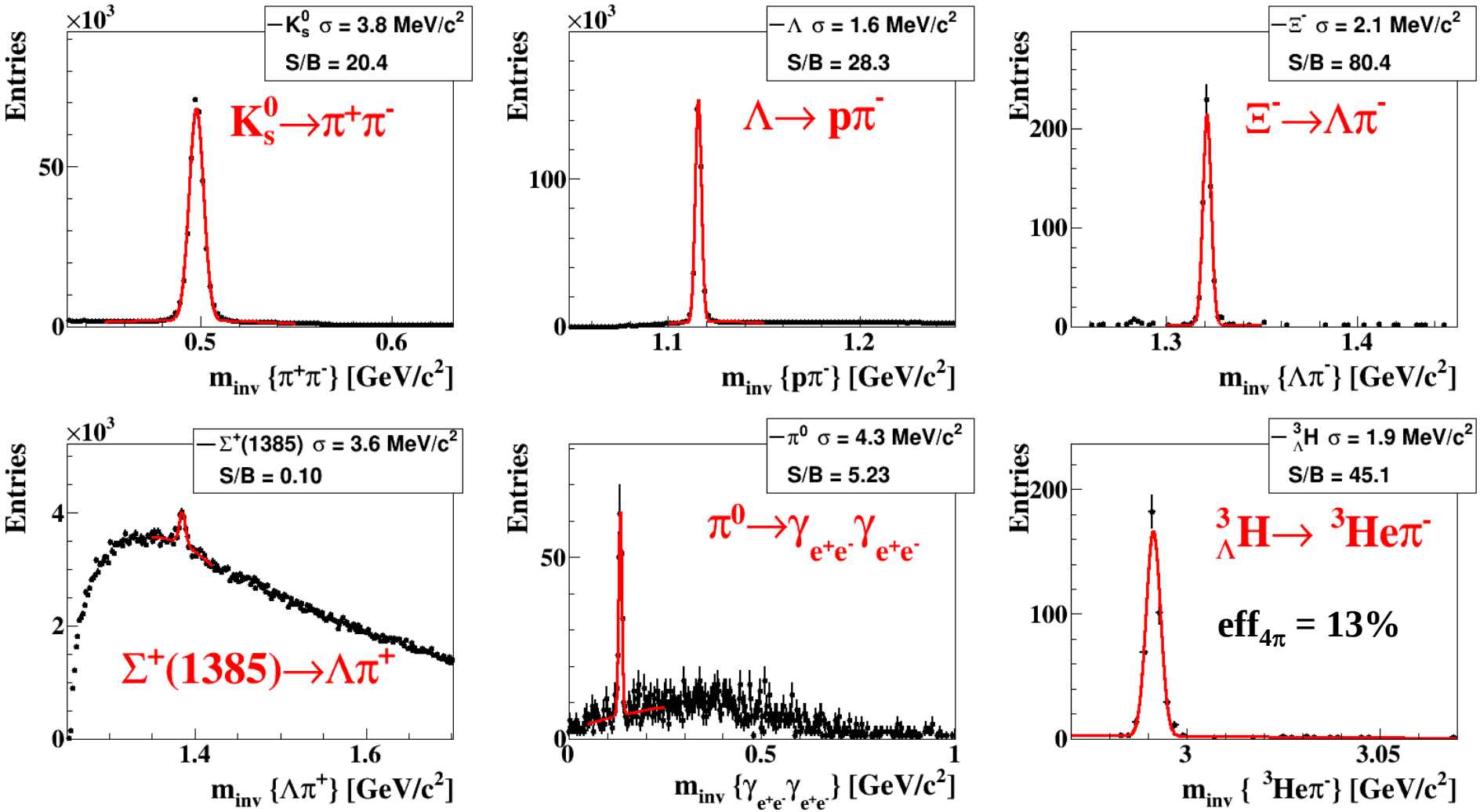
10 AGeV



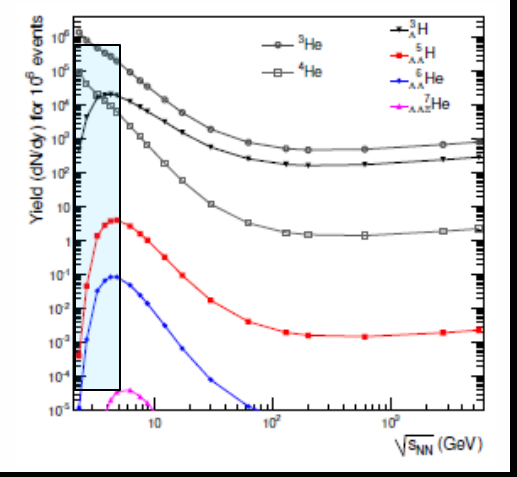
$^{3}_{\Lambda}H \rightarrow {}^{3}He + \pi^{-}$



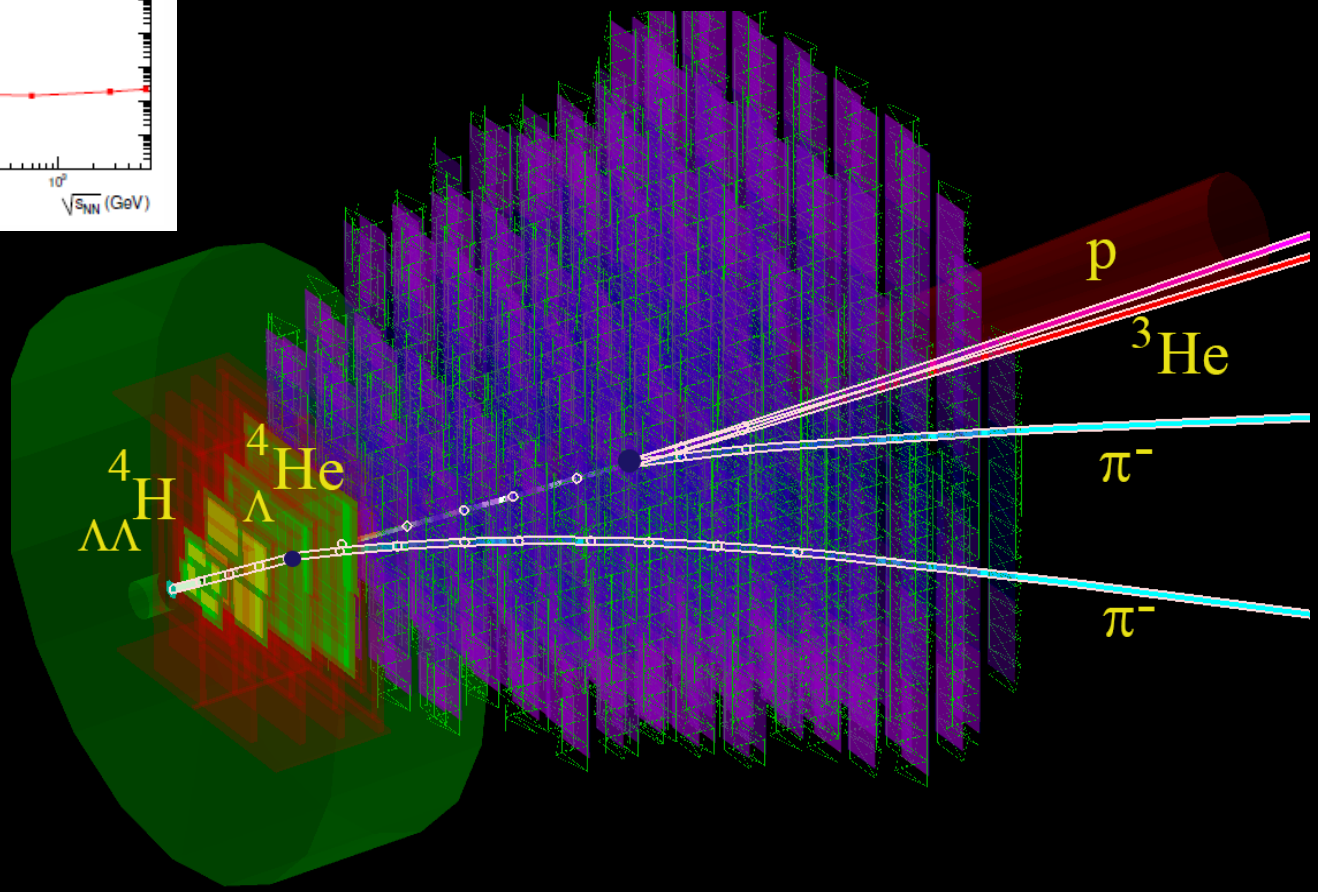
DCM with CBM detector 5M mbias C + C collisions
About 10 sec of data taking assuming $5*10^5$ IR



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

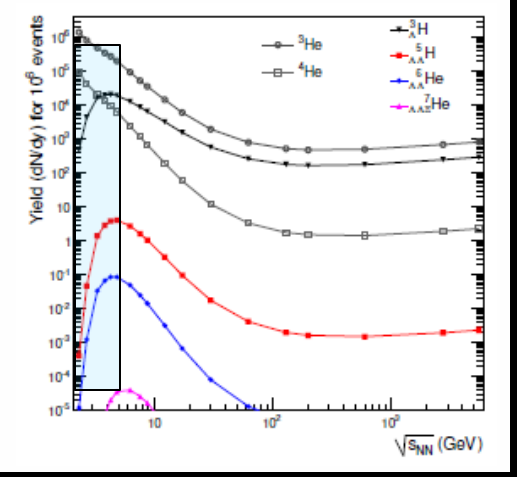


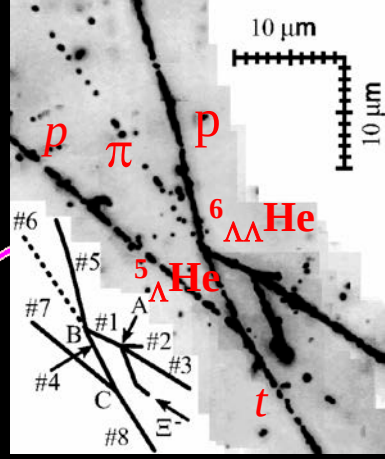
$^4_{\Lambda\Lambda}$H decay topology

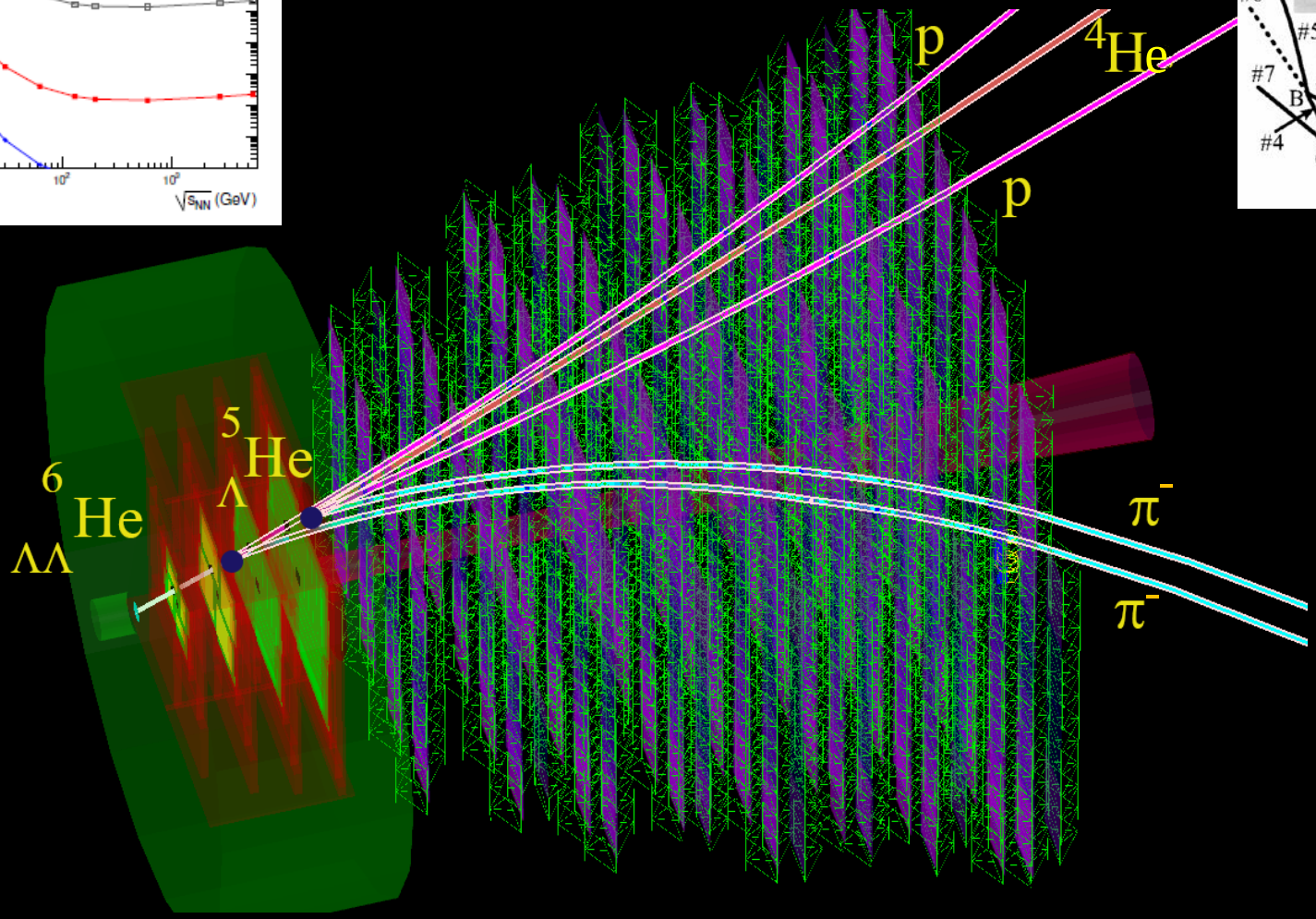


$^4_{\Lambda\Lambda}$H decay reconstructed with CBM detector

$^{6}_{\Lambda\Lambda}$He decay topology

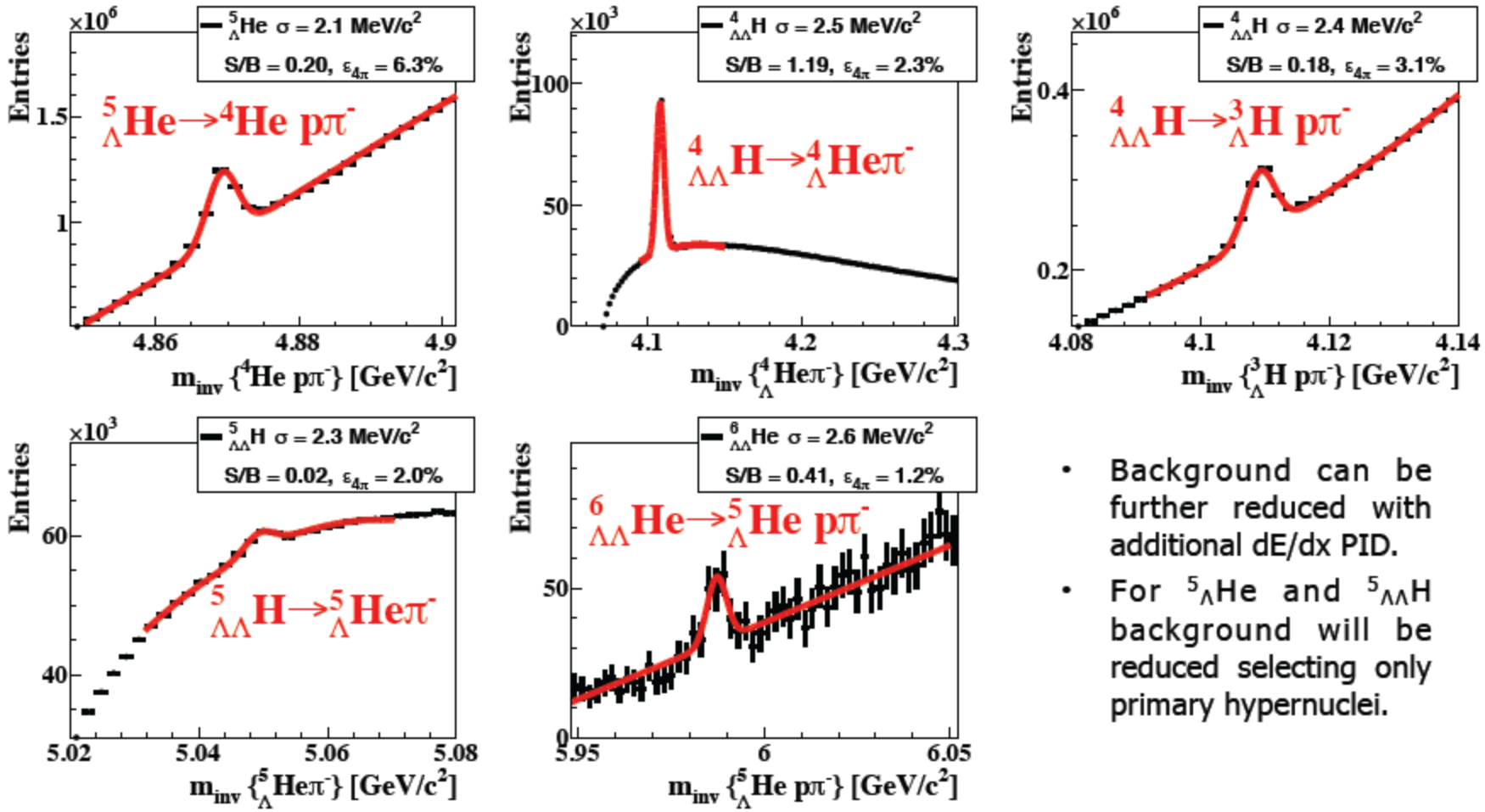






$^{6}_{\Lambda\Lambda}$He decay reconstructed with CBM detector

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.

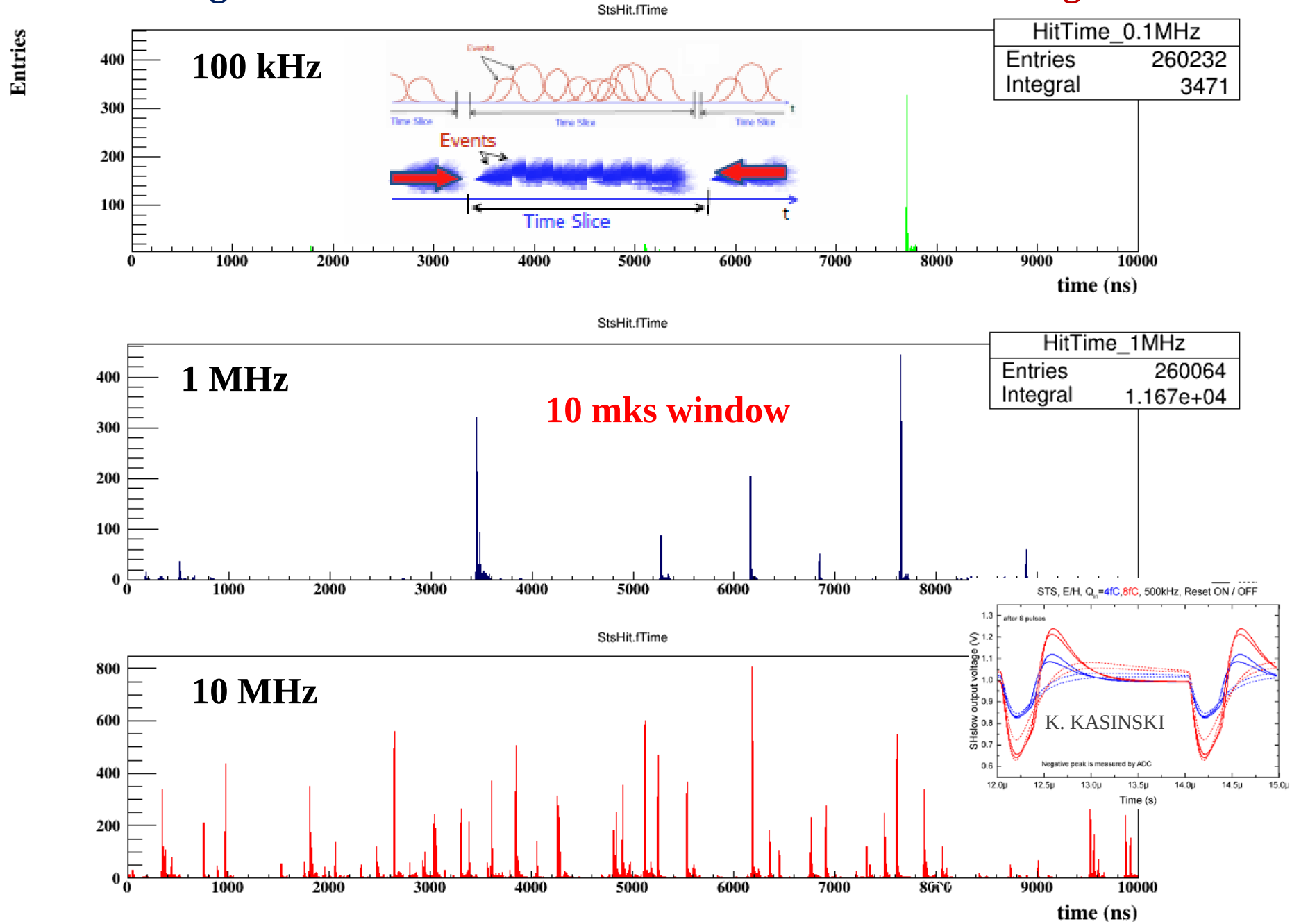
AuAu, 10 AGeV, 10^{12} central events, TOF PID

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

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)	$4.6\cdot10^{-4}$	0.034	$\bar{p}\pi^+$	0.64	11	1.1	81.3	$6.6\cdot10^{6}$	$2.2\cdot10^{8}$	**10**
Ξ^- (1321)	0.054	0.222	$\Lambda\pi^-$	1	6	$3.2\cdot10^{3}$	$1.3\cdot10^{4}$	$1.9\cdot10^{10}$	$7.8\cdot10^{10}$	**10**
Ξ^+ (1321)	$3.0\cdot10^{-5}$	$5.4\cdot10^{-4}$	$\bar{\Lambda}\pi^+$	1	3.3	$9.9\cdot10^{-1}$	17.8	$5.9\cdot10^{6}$	$1.1\cdot10^{8}$	**10**
Ω^- (1672)	$5.8\cdot10^{-4}$	$5.6\cdot10^{-3}$	ΛK^-	0.68	5	17	164	$1.0\cdot10^{8}$	$9.6\cdot10^{8}$	**10**
Ω^+ (1672)	-	$7\cdot10^{-5}$	$\bar{\Lambda}K^+$	0.68	3	-	0.86	0	$5.2\cdot10^{6}$	**10**
${}^{3}_{\Lambda}H$ (2993)	$4.2\cdot10^{-2}$	$3.8\cdot10^{-2}$	${}^{3}He\pi^-$	0.25	19.2	$2\cdot10^{3}$	$1.8\cdot10^{3}$	$1.2\cdot10^{10}$	$1.1\cdot10^{10}$	**10**
${}^{4}_{\Lambda}He$ (3930)	$2.4\cdot10^{-3}$	$1.9\cdot10^{-3}$	${}^{3}Hep\pi^-$	0.32	14.7	110	87	$6.6\cdot10^{8}$	$5.2\cdot10^{8}$	**10**
${}^{5}_{\Lambda\Lambda}He$(5047)		$5.0\cdot10^{-6}$	${}^{3}He2p2\pi$	0.01	1		$5\cdot10^{-3}$		$3\cdot10^{4}$	**10**
${}^{6}_{\Lambda\Lambda}He$(5986)		$1.0\cdot10^{-7}$	${}^{4}He2p2\pi$	0.01	1		$1\cdot10^{-4}$		600	**10**

High rate scenario: MSH reconstruction with 4D tracking



V. Akishina

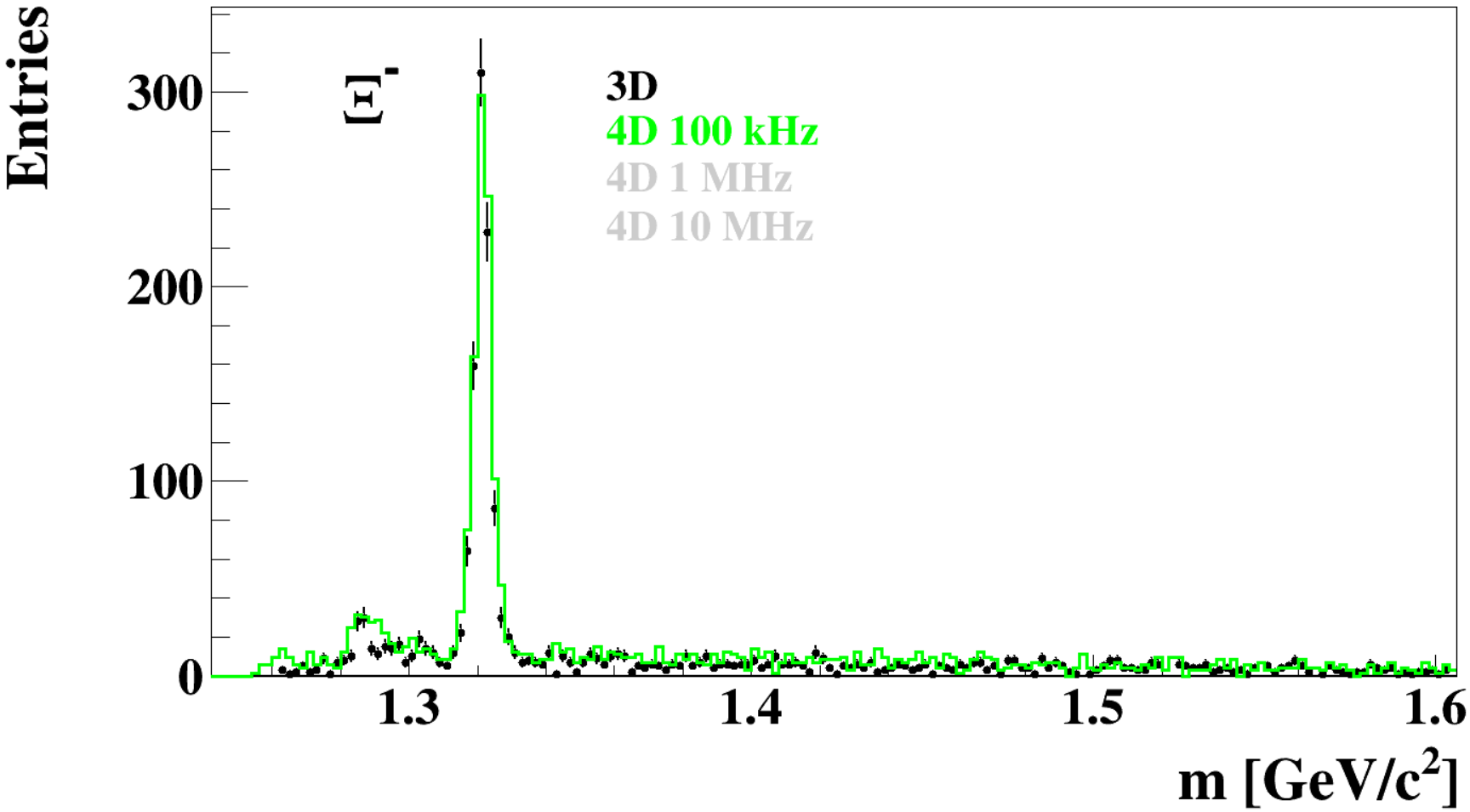
4D Track Finder in CBMROOT

100 AuAu 10 AGeV mbias events

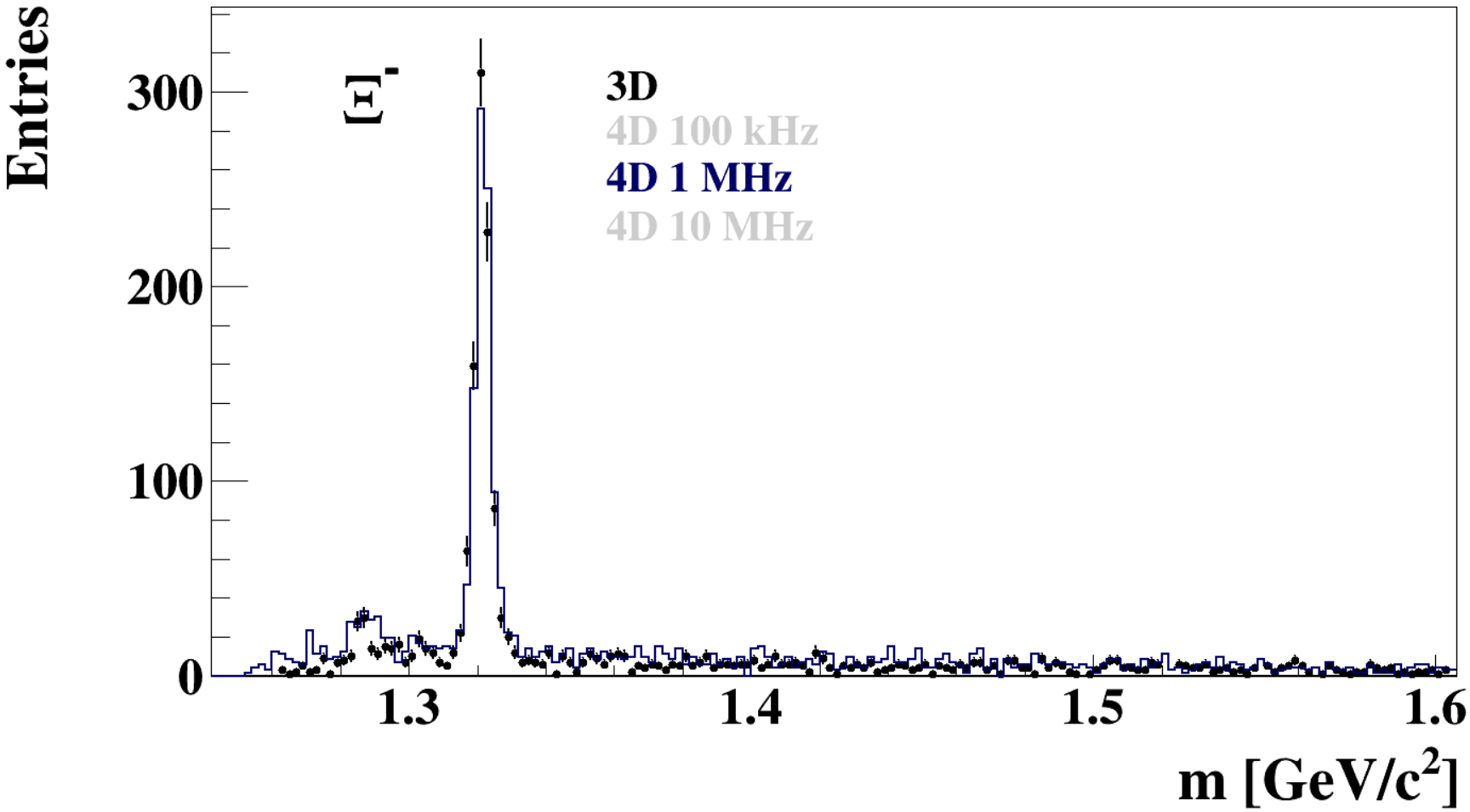
Efficiency, %	3D	0.1 MHz	1 MHz	10 MHz
All tracks	92.5 %	93.8 %	93.5 %	91.7 %
Primary high-p	98.3 %	98.1 %	97.9 %	96.2 %
Primary low-p	93.9 %	95.4 %	95.5 %	94.3 %
Secondary high-p	90.8 %	94.6 %	93.5 %	90.2 %
Secondary low-p	62.2 %	68.5 %	67.6 %	64.3 %
Clone level	0.6 %	0.6 %	0.6 %	0.6 %
Ghost level	1.8 %	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

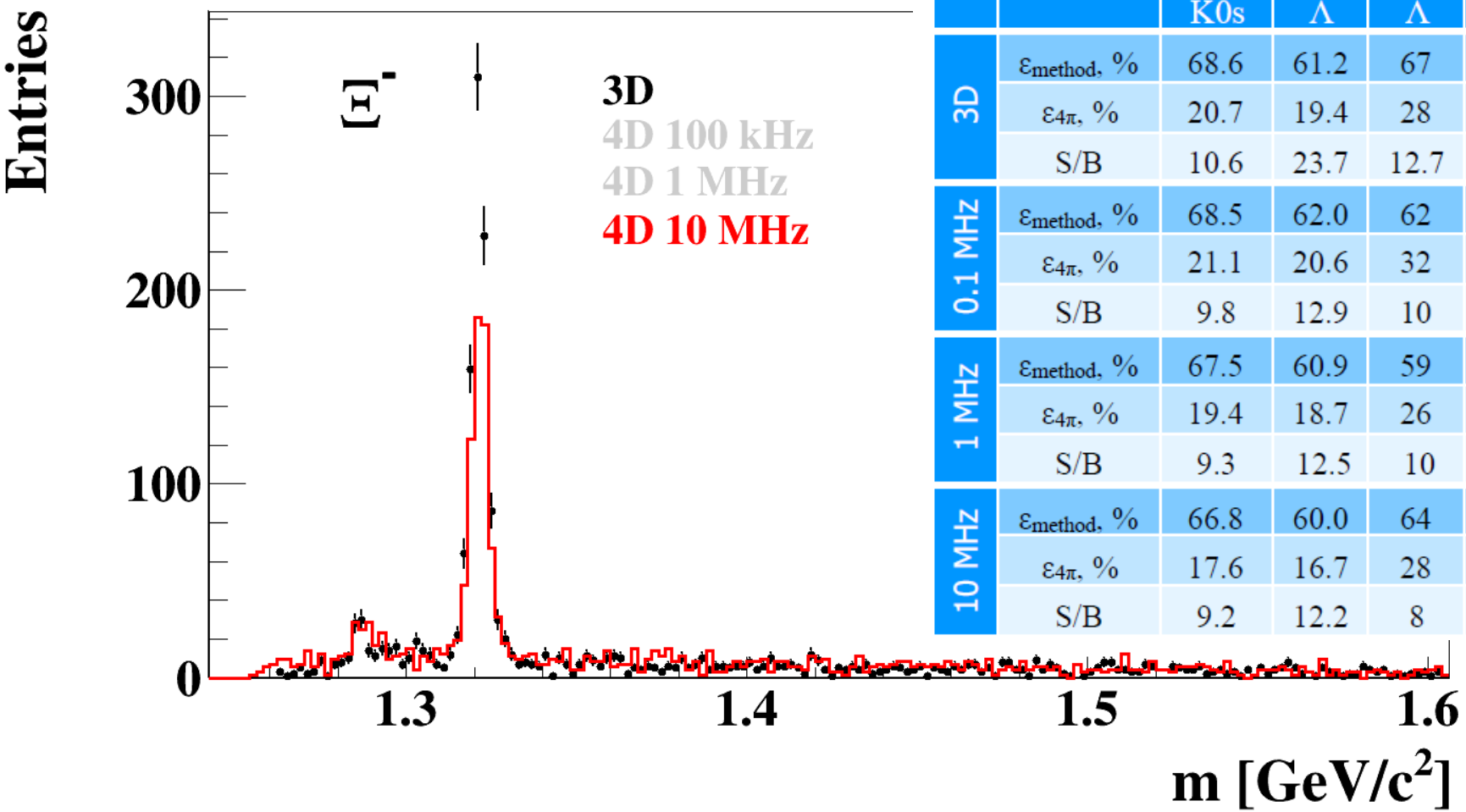
High rate scenario: MSH reconstruction with 4D tracking



High rate scenario: MSH reconstruction with 4D tracking

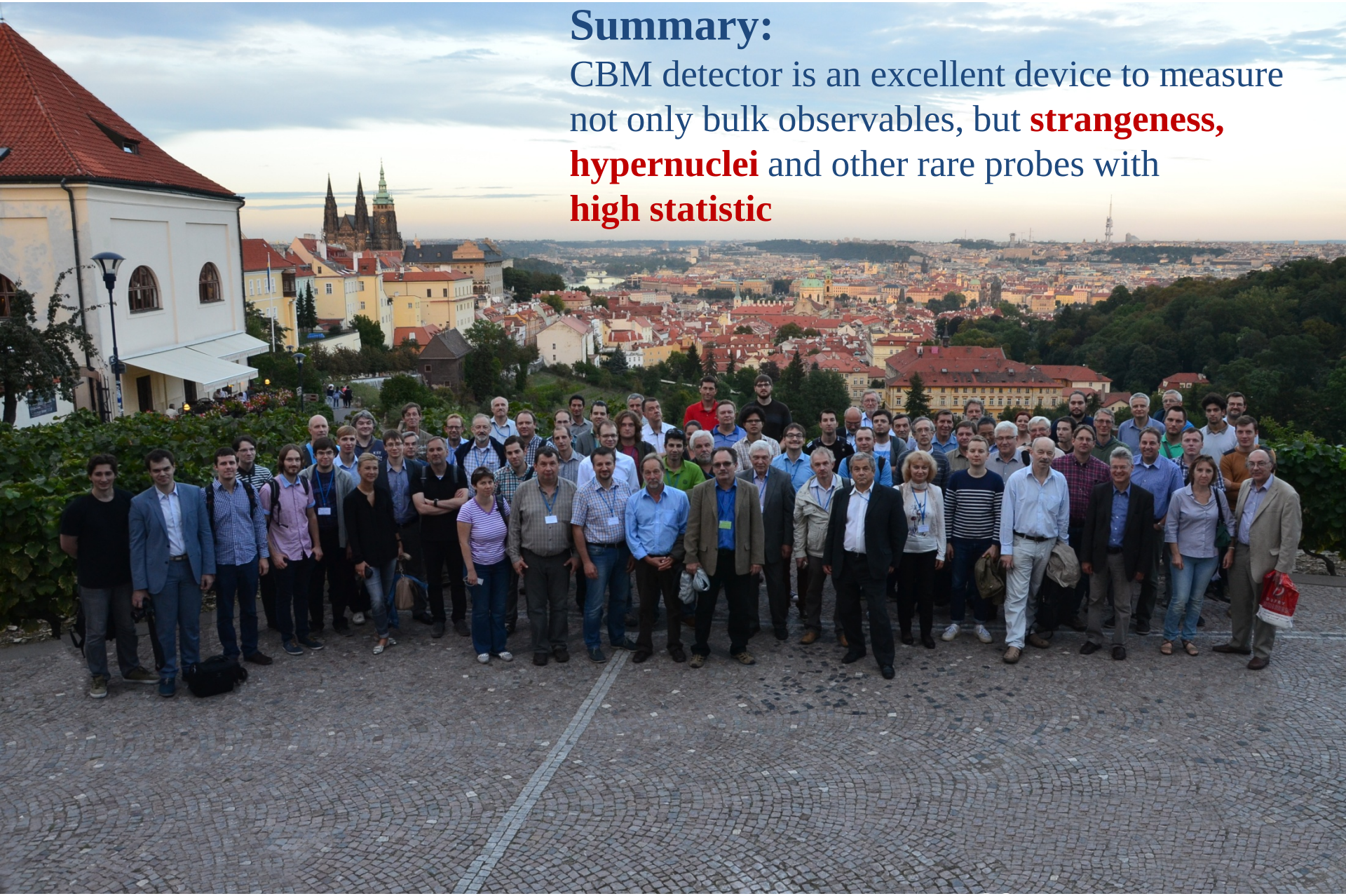


High rate scenario: MSH reconstruction with 4D tracking



		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**