Online reconstruction of multi-strange hyperons in the CBM experiment

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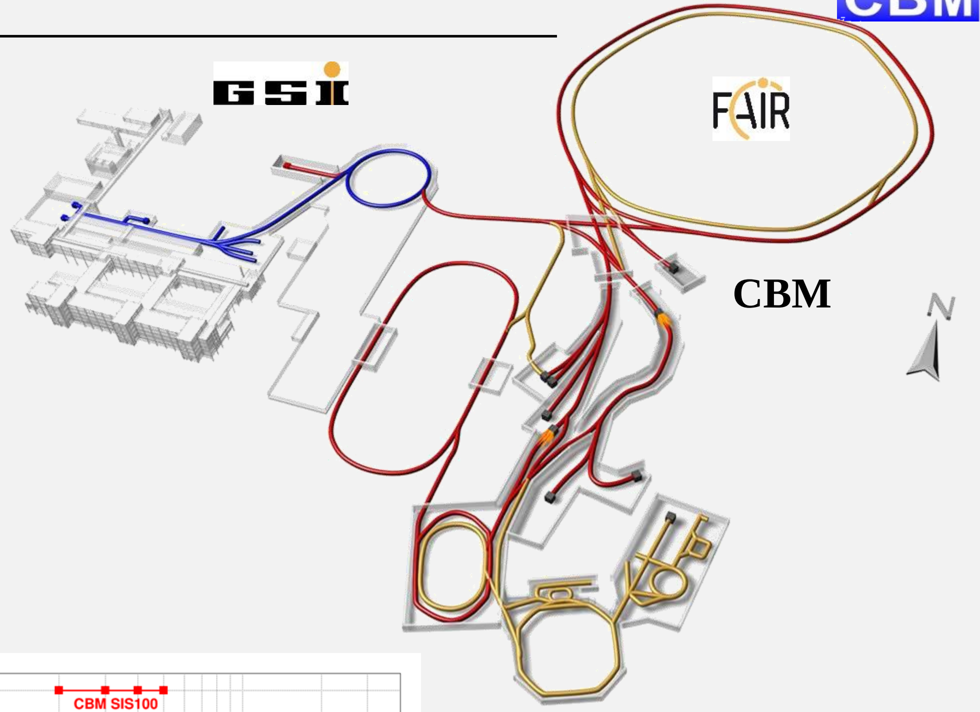
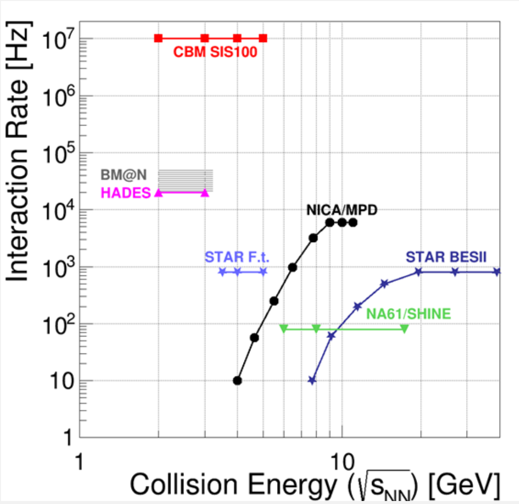
The Compressed Baryonic Matter (CBM) Experiment at FAIR

- Explore QCD phase diagram in the region of high net baryon densities
- Physics program is performed with ions beam delivered by SIS 100/300 accelerator at FAIR
- 1st phase SIS100 with energies up to 11 AGeV for heavy nuclei, 29 GeV for protons
- CBM holds a wide and rich physics program and raises several experimental challenges such as the measurement of very rare probes
- CBM aims to run at extremely high interaction rates up to 10 MHz
- High multiplicity of charged particles produced in heavy ion collisions leads to a huge data rates up to 1 TB/s





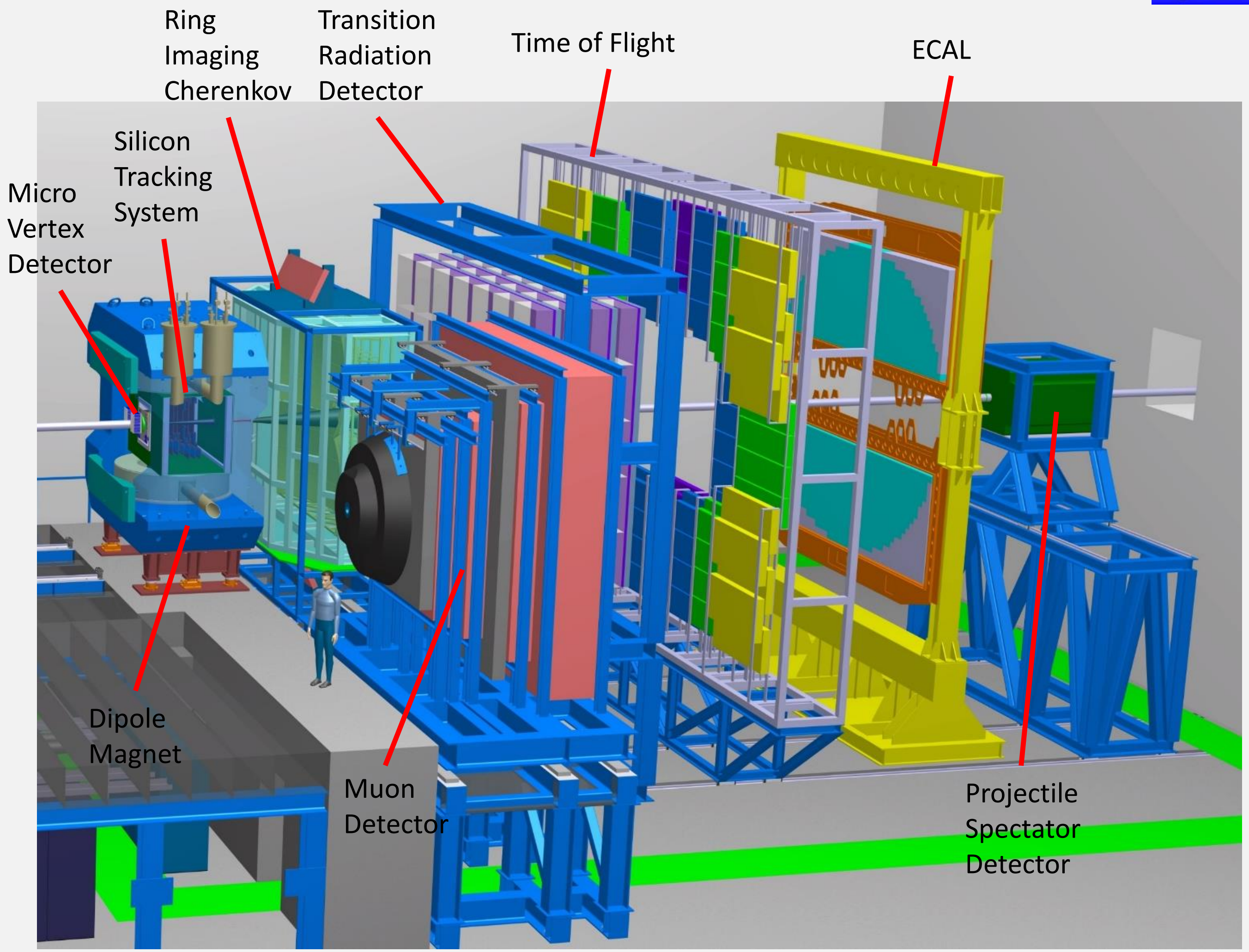
CBM experiment requires:

- Free streaming data transport
- Online event selection
- Reduction factor of 400 or more

The Compressed Baryonic Matter (CBM) Experiment at FAIR

CBM experimental setup:

- Superconducting dipole magnet
- Micro Vertex Detector (MVD)
- Silicon Tracking System (STS)
- Time-of-Flight (TOF)
- Ring Imaging Cherenkov (RICH)
- Transition Radiation Detector (TRD)
- Muon Chamber (MuCh) (alternating with RICH)
- Electromagnetic CALorimeter (ECAL)
- Projectile Spectator Detector (PSD)



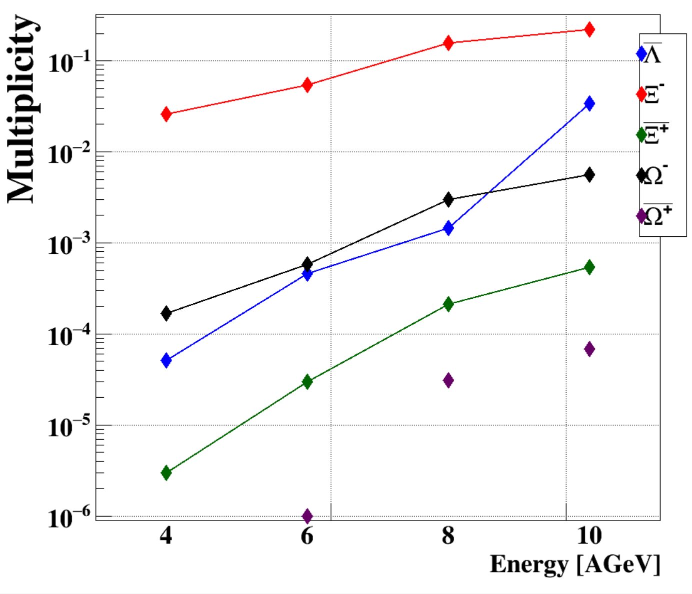
The detector systems of the CBM experiment

Multi-strange (anti-) hyperons in CBM

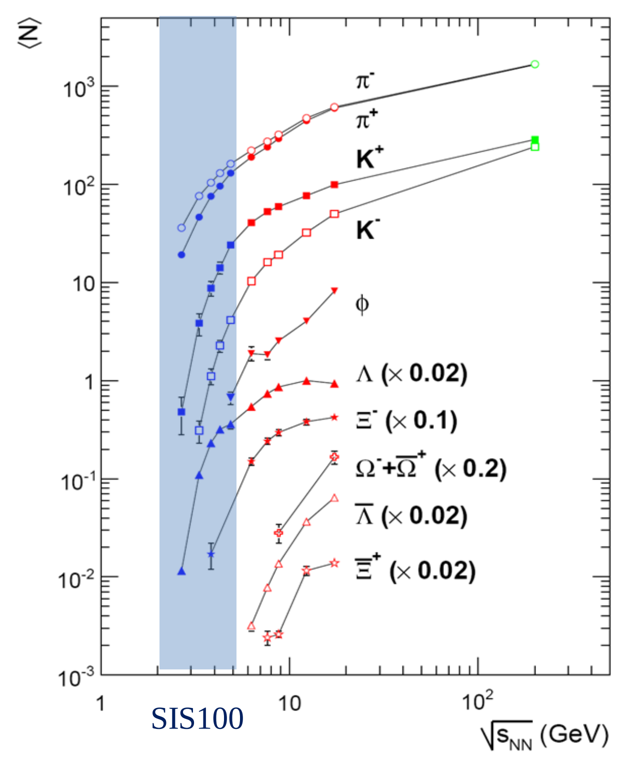
- Strangeness enhancement is one of the earliest proposed signatures of the formation of a deconfined QGP in a heavy ion collision.

- The measurement of strange hadrons including multi strange (anti-) hyperons is one of the most promising observables for the CBM experiment.

- Multi-strange (anti-) hyperons have low cross section at low energies



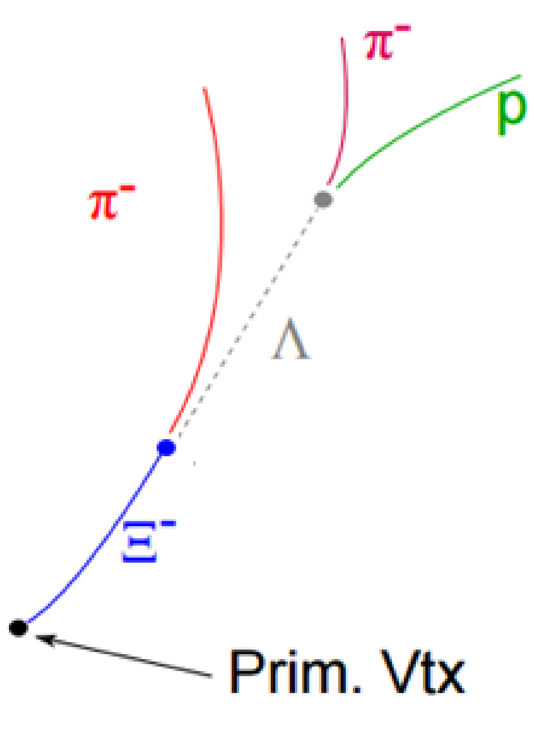
Multiplicity with a UrQMD central Au+Au event at SIS100 energies



Reconstruction of Multi-strange (anti-) hyperons

- Multi-strange hyperons are reconstructed via their weak decay into charged hadrons in STS and using ToF detector for PID:

  $\Lambda \rightarrow p\,\pi$; $\Xi \rightarrow \Lambda\pi$; $\Omega \rightarrow \Lambda\,K$



Simulation includes:

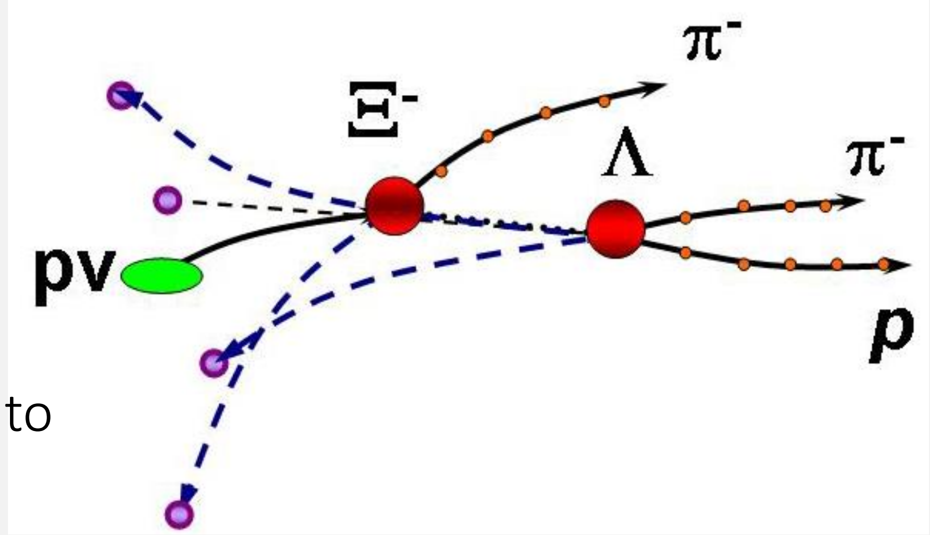
- UrQMD event generator
- Central Au+Au collisions at 10 AGeV
- The magnet, STS and ToF from the CBM setup
- Analysis: CbmRoot + KF Particle Finder

Cuts in KF Particle Finder

- χ^{2}_{geo}: To ensure that the trajectory of the daughter particles intersect in the region of the candidate decay.

- χ^{2}_{topo}: To ensure whether the particle is produced in the primary vertex region

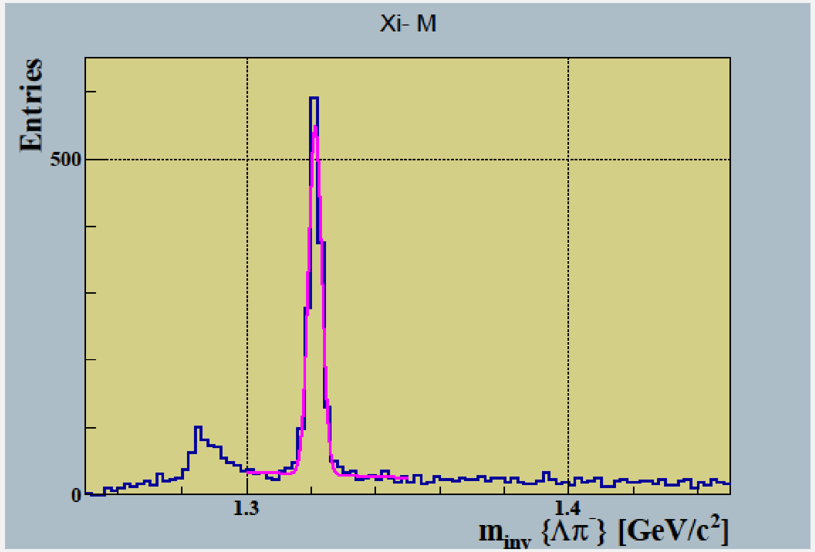
- $l/\Delta l$: Cut on the distance from the decay point of the candidate to the primary vertex



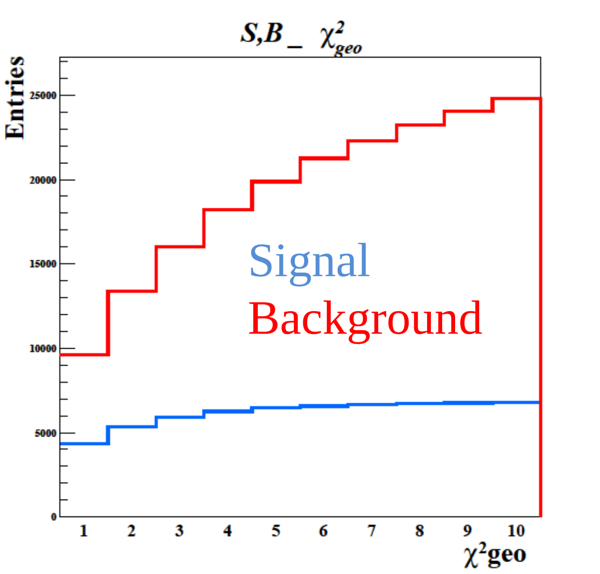
Λ has a large life time that allows to separate them from the PV therefore only 2 cuts are applied χ^{2}_{geo} and $l/\Delta l$

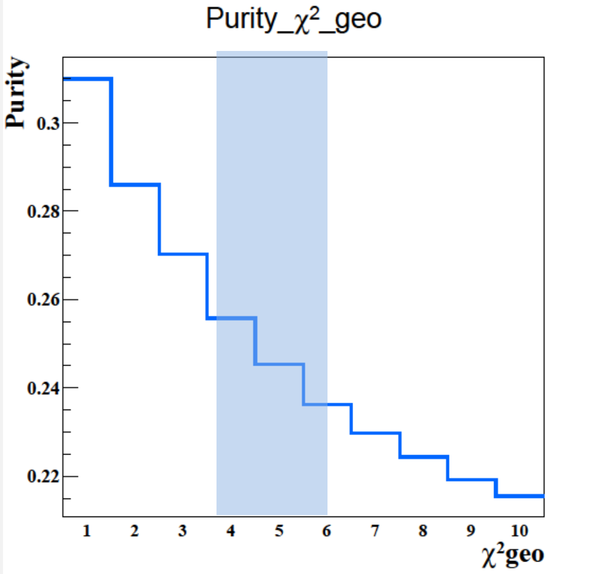
Cuts optimization

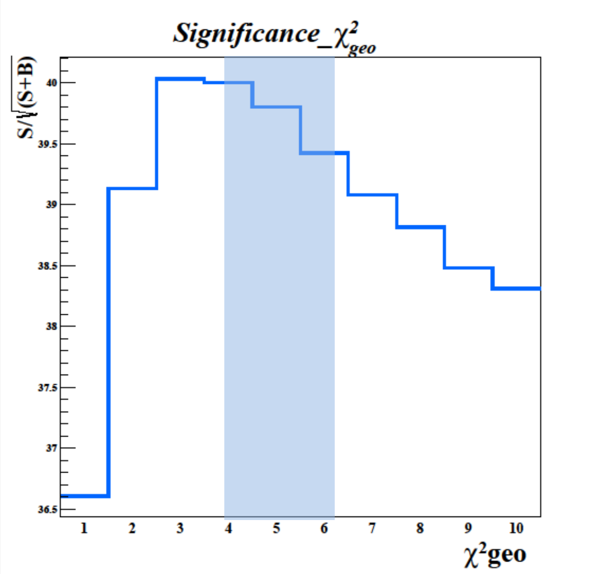
- Study the variation of the Signal S and the Background B
- Signal and Background are calculated with KF Particle Finder
- Signal and background are extracted as well by fitting inside $\pm 3\sigma$ interval around the peak position
- Study the Purity of the signal as a function of the cut value
- Calculate the invariant mass peak significance $S/\sqrt{S+B}$ in order to maximize the ratio
- Study the efficiency of reconstruction as a function of the cut value

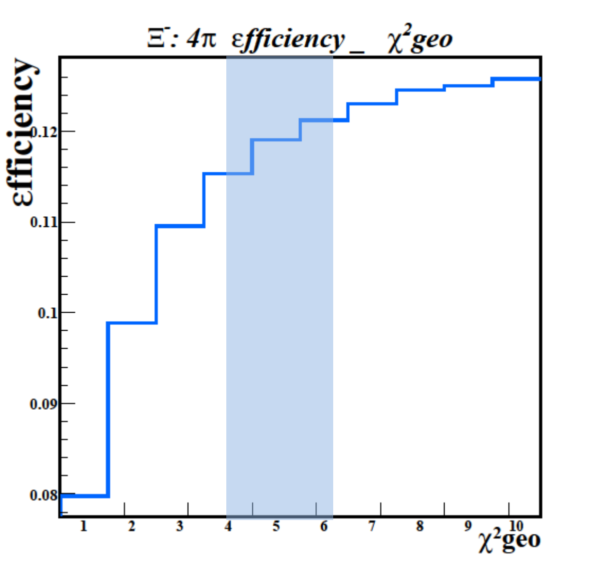


χ^2_{geo} : Ξ^- as example









Variation Signal and background as function of different value of χ^2_{geo}

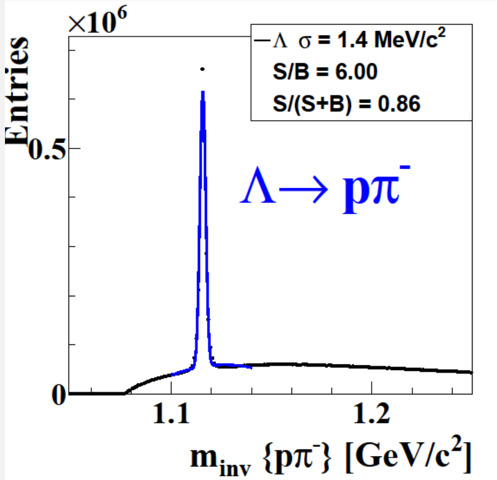
Purity = S/(S+B)

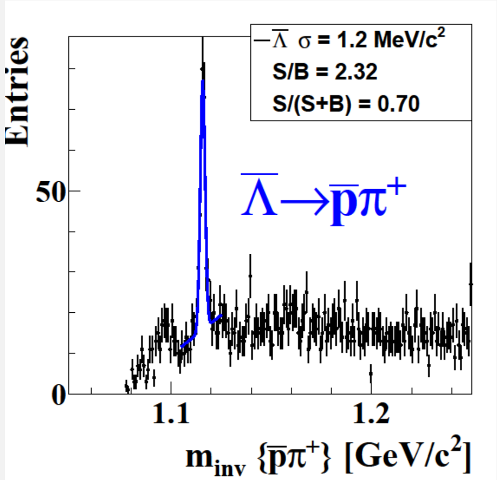
Variation Significance as function of different value of χ^2_{geo}

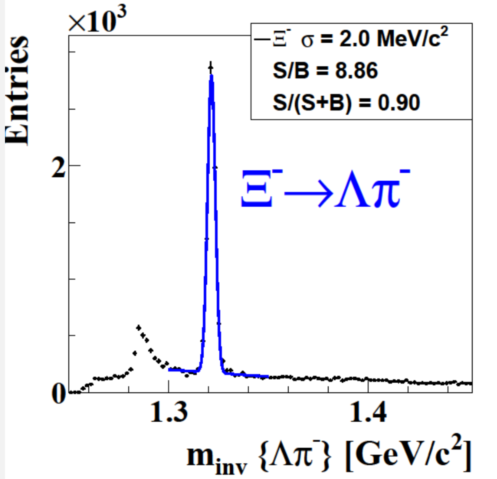
Efficiency as function of χ^2_{geoo}

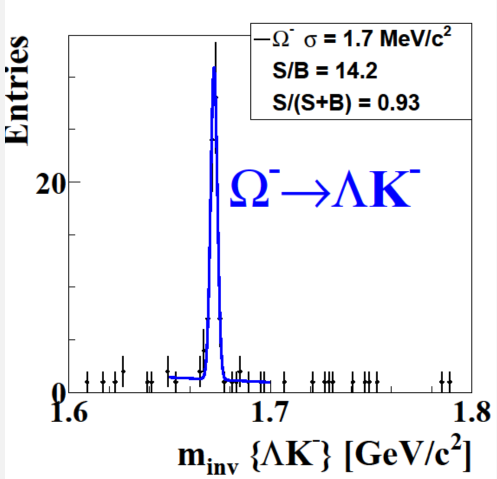
Cuts optimization

Follow the same procedure for all cuts for all multi_strange (anti-) hyperons: Λ , Ξ and Ω





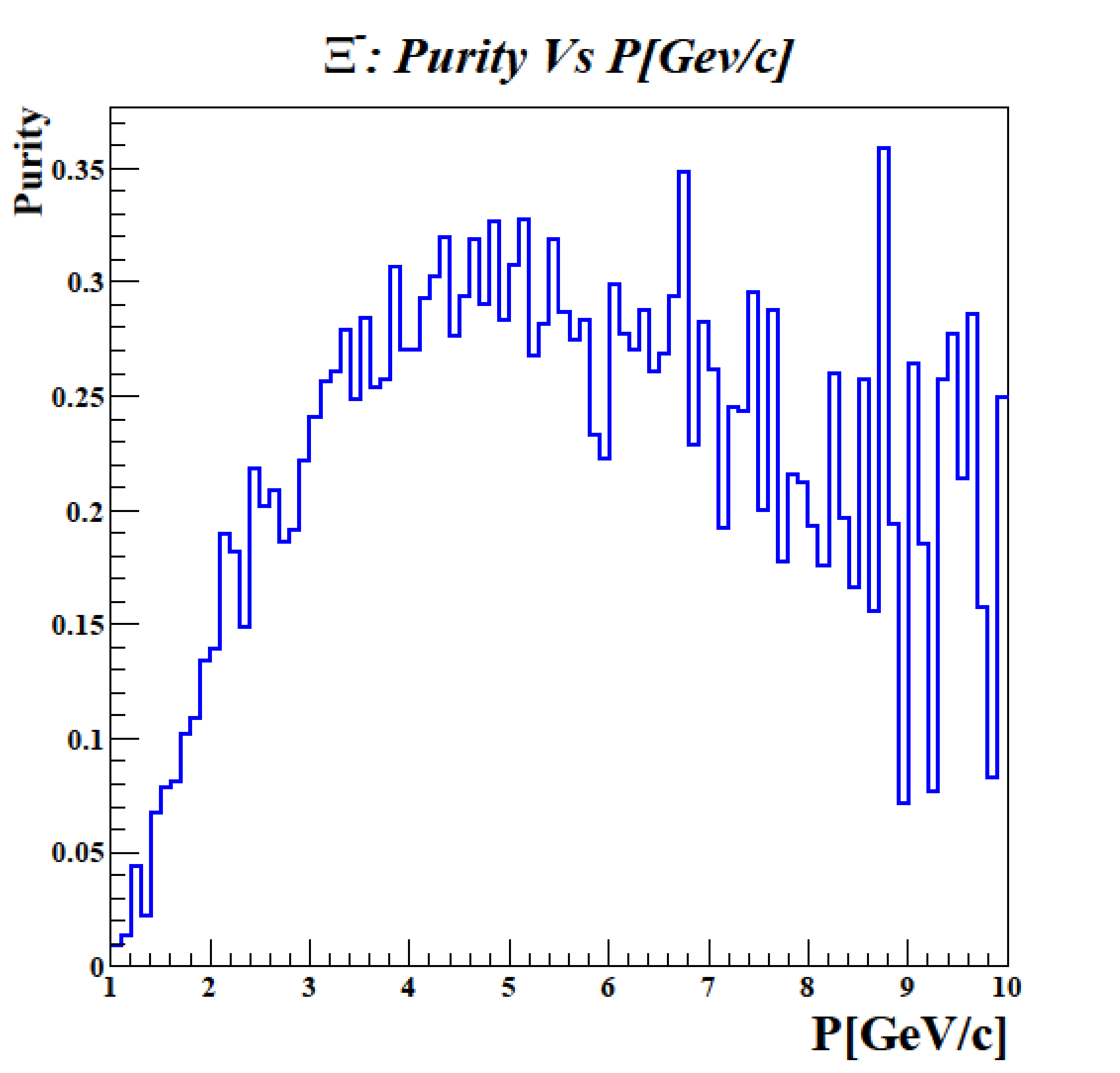


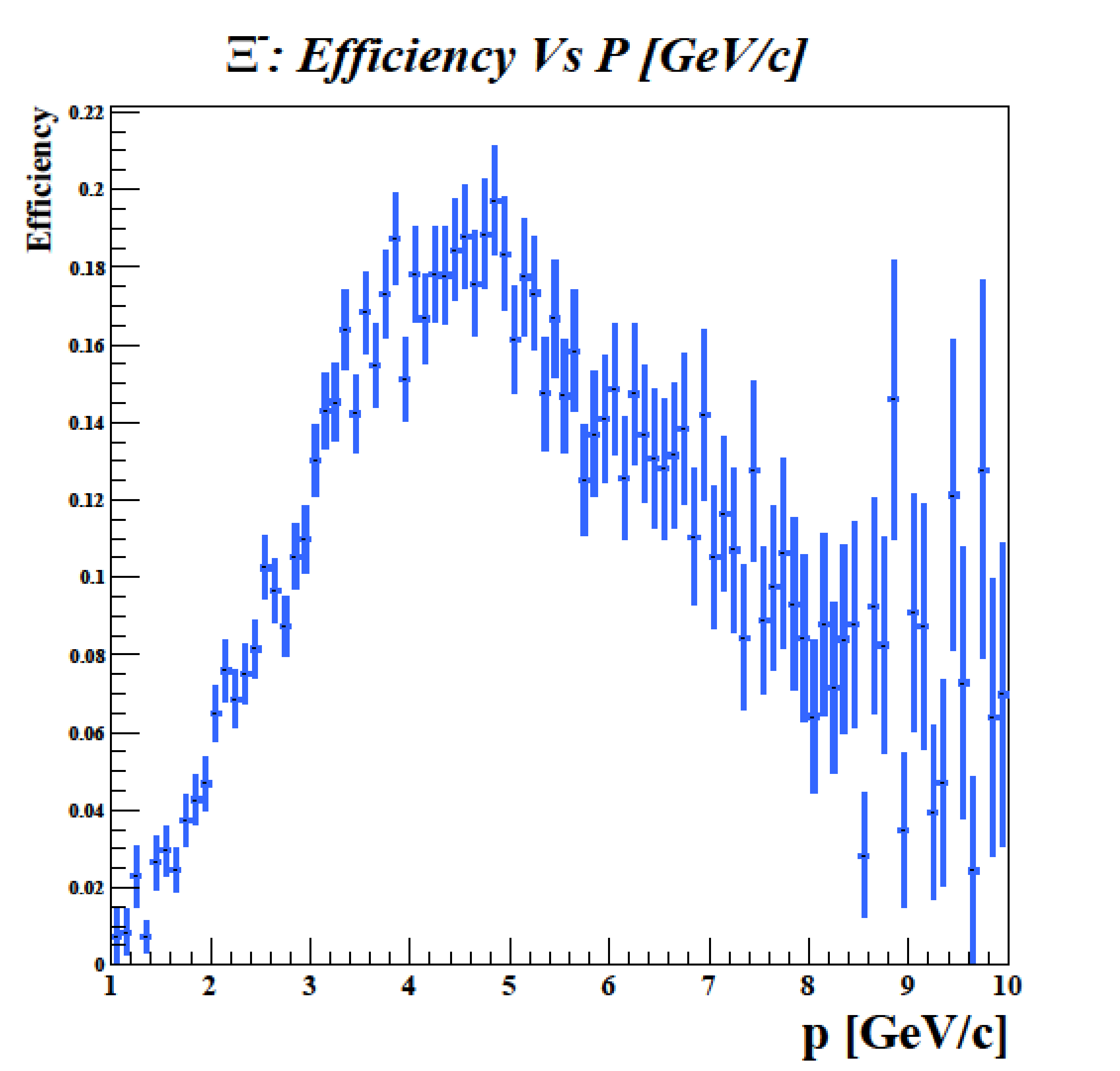


Standard cuts	$\chi^2 topo$	$\chi^2 geo$	ldl
Λ	-	3	5
Ξ	5	6	5
Ω	5	6	5

Standard Cuts in KF Particle Finder

Ξ^- : Purity & Efficiency Vs Momentum





Efficiency

5M central Au+Au collision at 10 AGeV

	Λ	$\overline{\Lambda}$	Ξ^-	$\bar{\Xi}^+$	Ω^-	$\overline{\Omega}^+$
(a) : KF Particle Finder efficiency (%)	70.7	43.6	47.6	30.6	15.9	12.9
(b) : 4π efficiency (%)	26.6	16.5	10.2	6.8	4.6	3.9

(a) : The efficiency of the particle reconstruction and cuts on the candidates including PID in ToF

(b) : The total efficiency which take into account the acceptance of the detector and the inefficiencies of track reconstruction and PID algorithms

Software trigger in CBM

The huge data rate need a software trigger in order to select interesting events

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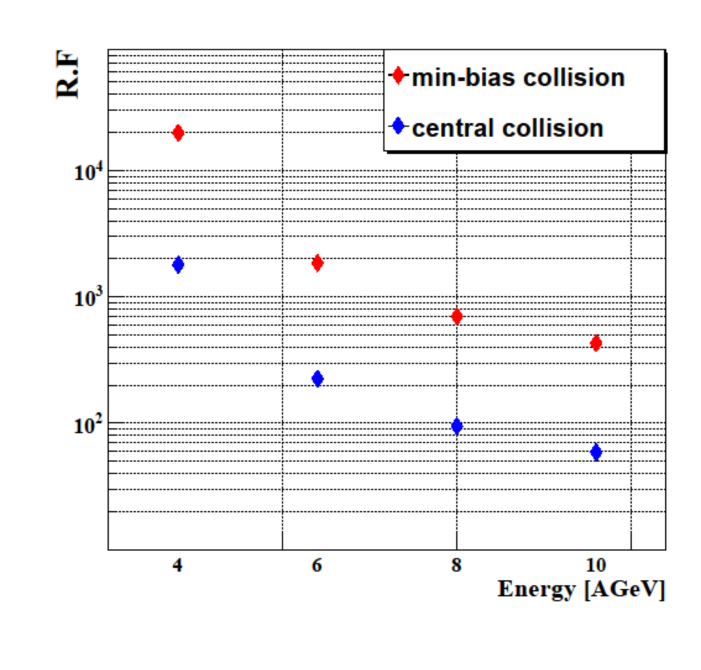
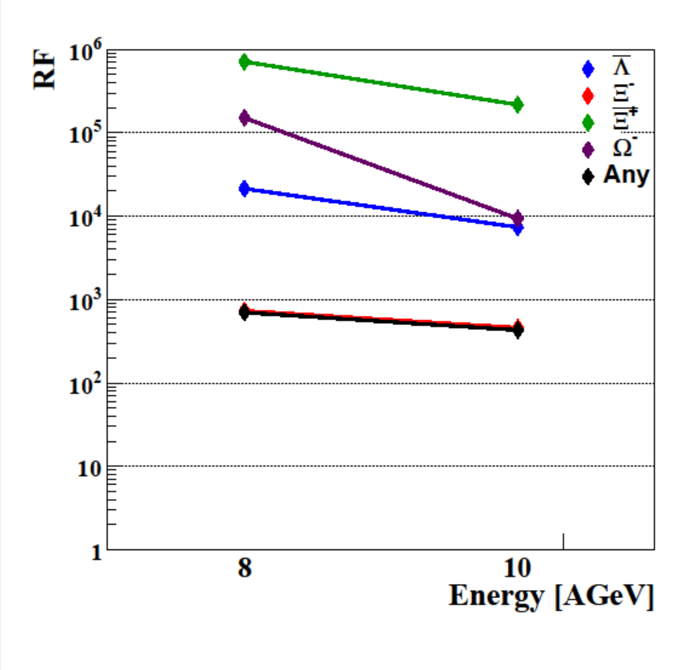
Software trigger:

- Selection of events containing multi-strange hyperons : $\bar{\Lambda}$, Ξ^-, $\bar{\Xi}^+$, Ω^-, and $\bar{\Omega}^+$ or any other combination.
- The RF is calculated by dividing the total number of events by the number of selected events containing multi-strange hyperons

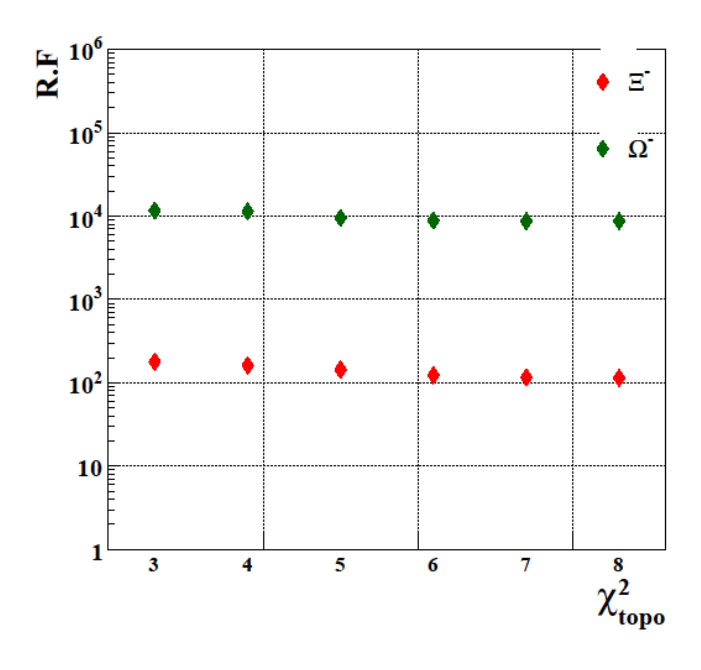
Software trigger in CBM



RF for the combined trigger calculated for central and minimum bias collisions at different energies



RF calculated for trigger on individual hyperon compared to the RF for the combined trigger in minimum bias Au-Au collisions at 8 and 10 AGeV



RF calculated as with different value of χ^2_{topo}

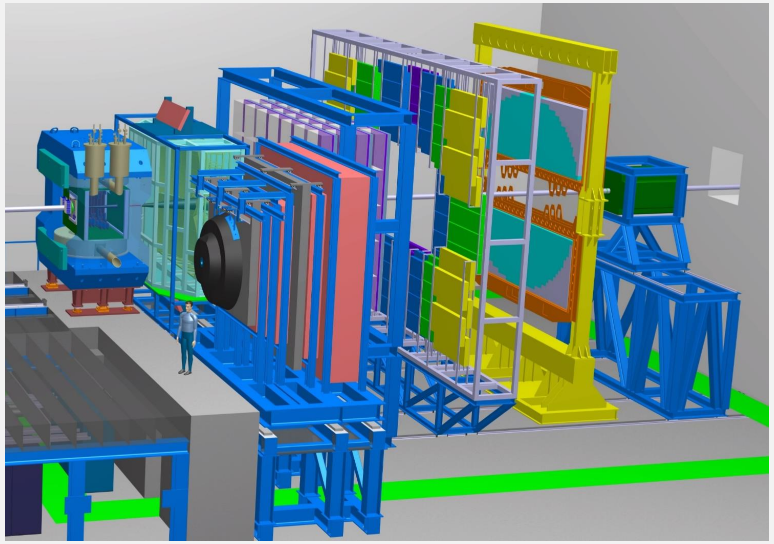
Summary

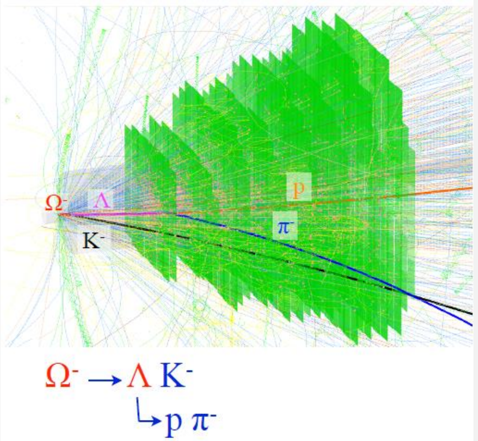
- ✓ The CBM experiment is designed to perform measurements at high interaction rate to explore a new area in the QCD phase diagram at high net baryon densities and moderate temperature

- ✓ The reconstruction of multi-strange (anti-) hyperons in the CBM experiment shows a high efficiency and significance

- ✓ Multi strange (anti-) hyperons cuts are optimized

- ✓ CBM reaches the reduction factor required with the selection of mutli-strange hyperons





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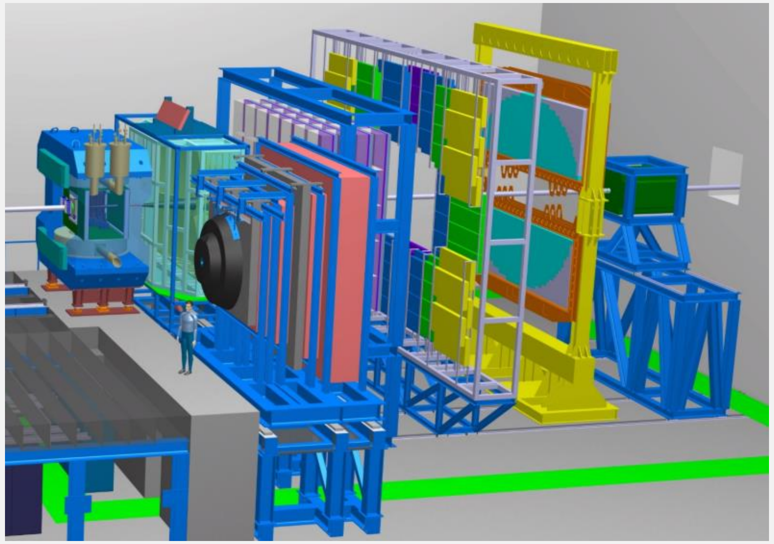

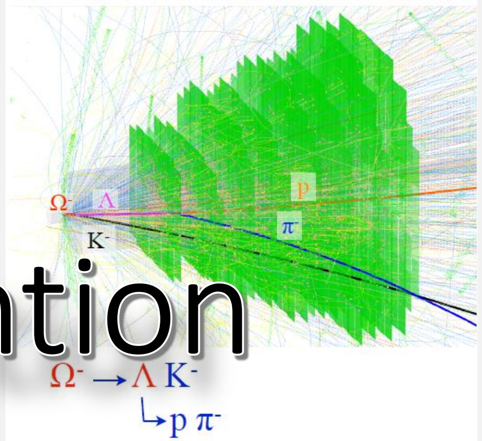

Thank you for your attention