Hypernuclei Production in CBM at FAIR: A Feasibility Study

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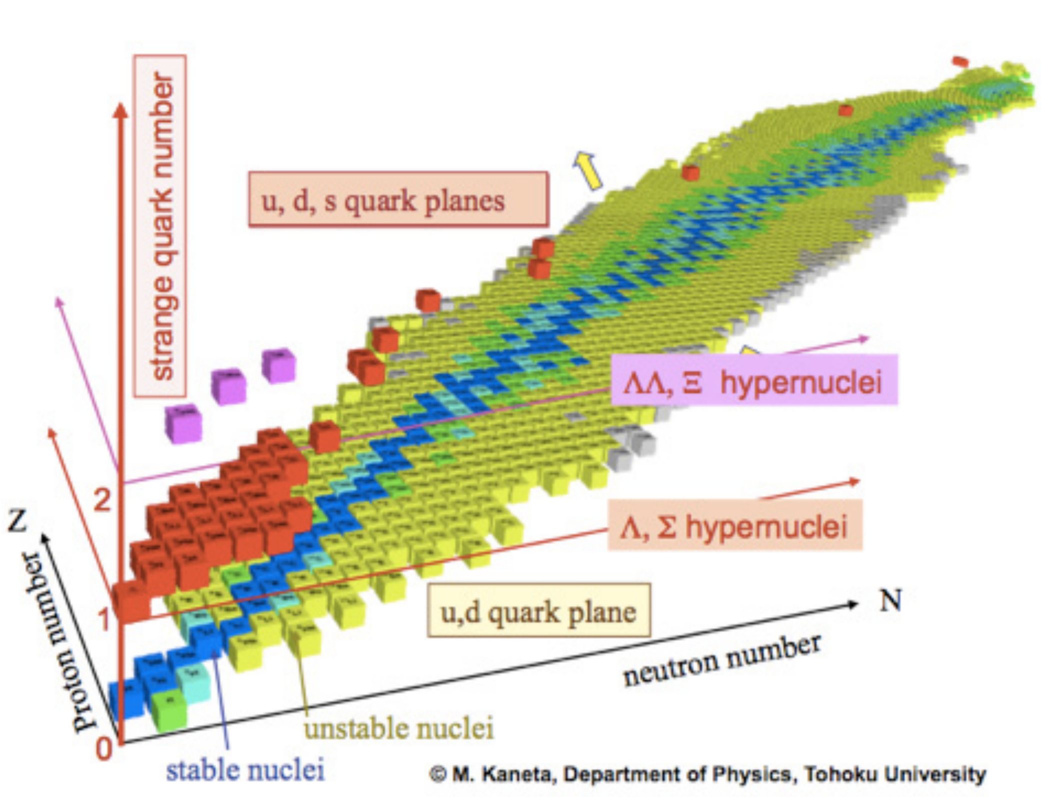
Compressed Baryonic Matter experiment at FAIR



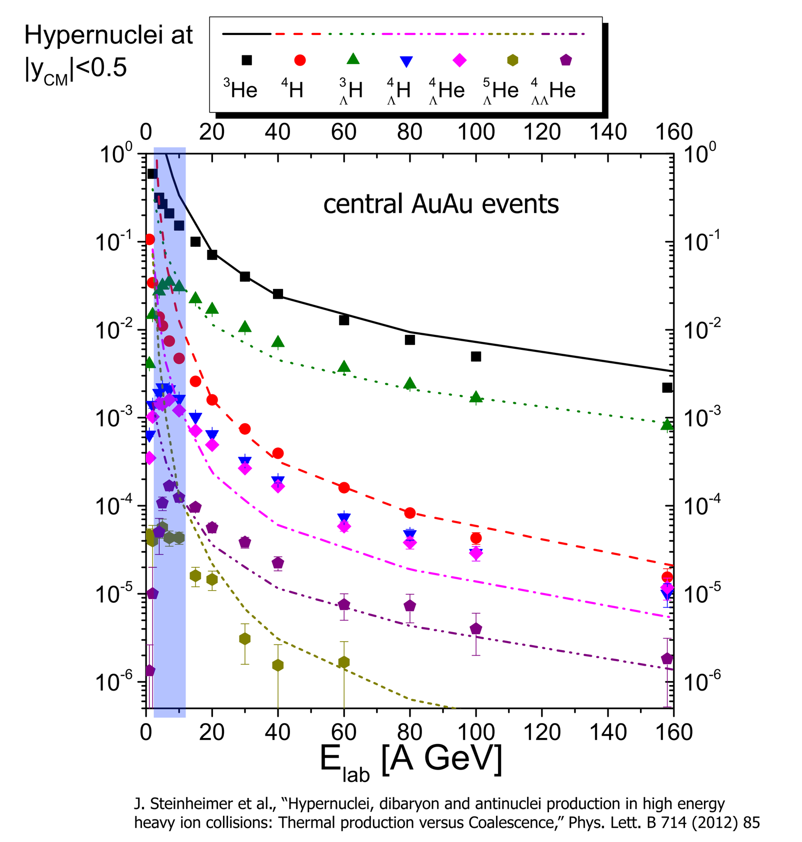
Hypernuclei production at CBM experiment:

- Single and double hypernuclei
- Precise measurements of hypernuclei lifetime
- Measurement of branching ratios of hypernuclei
- Direct access to the hyperon-nucleon (YN) interaction through measurements of B_Λ in a hypernucleus
- "Hyperon puzzle" in the astrophysics: understanding of YN interaction is crucial for neutron star physics
- Search for strange matter (e.g., heavy multi-strange objects)

Advantages of CBM:

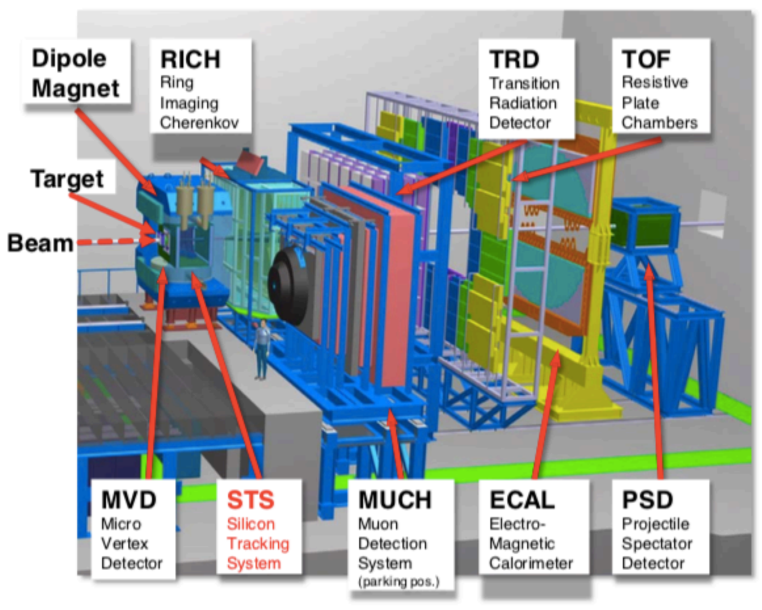
- Highest production cross section for hypernuclei at CBM energies (yet no experimental data)
- Complex topology of decays can be easily identified in CBM and helps suppressing the background thanks to precise tracking and particle finding algorithm
- Reliable identification of produced hypersystems.
- Access to ΛΛ-hypernuclei: high interaction rates, optimal collision energies and clean identification

Theoretical models: SHM, DCM, UrQMD+Hydro

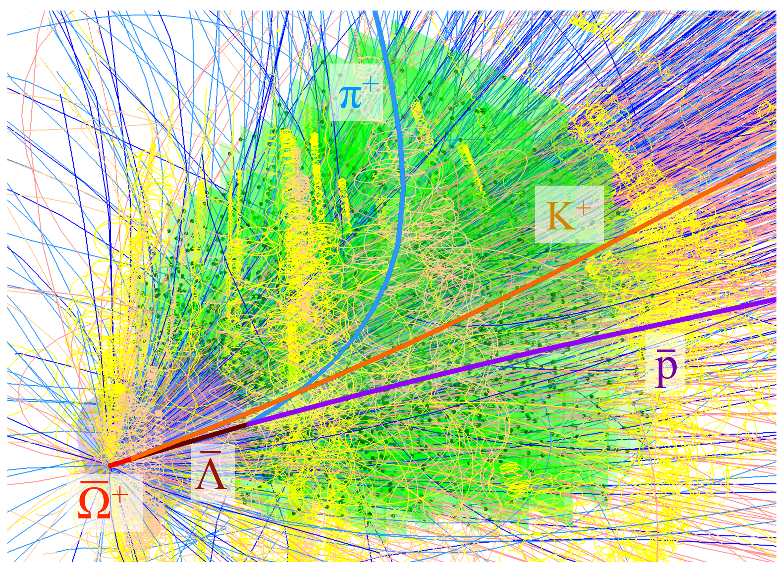


J. Steinheimer et al., "Hypernuclei, dibaryon and antinuclei production in high energy heavy ion collisions: Thermal production versus Coalescence," Phys. Lett. B 714 (2012) 85

Experimental challenges at CBM

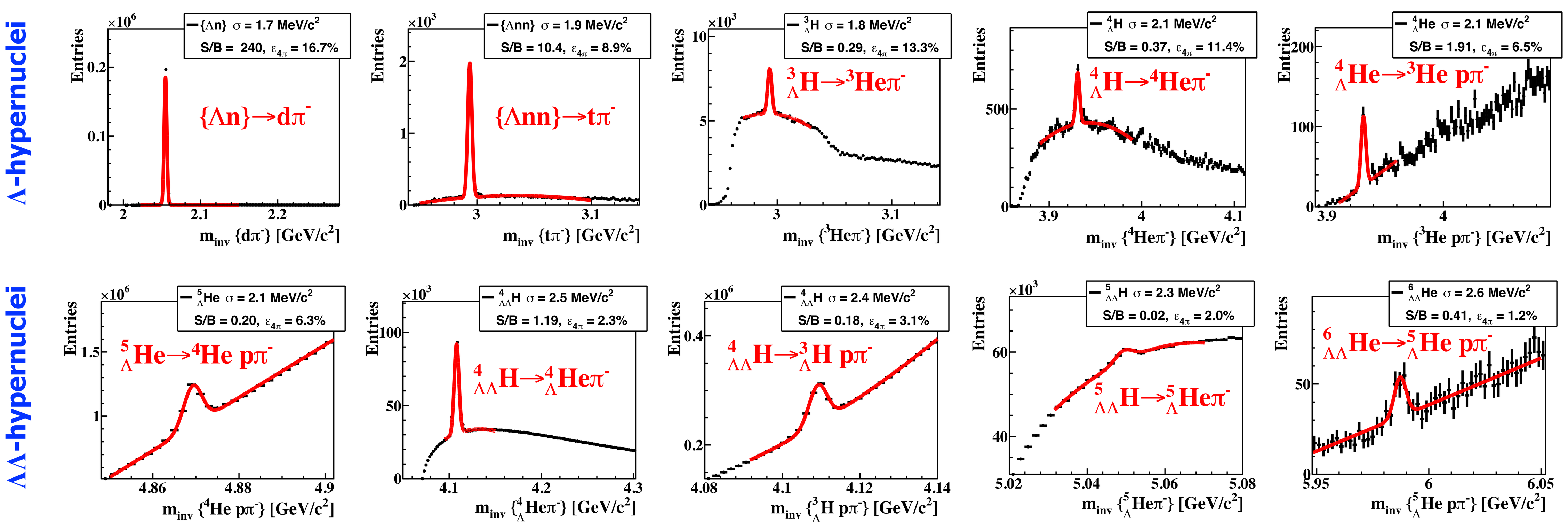


- CBM — future fixed-target heavy-ion experiment at FAIR, Darmstadt, Germany.
- 10^5-10^7 collisions per second.
- Up to 1000 charged particles/collision.
- Free streaming data.
- No hardware triggers (HLT only).
- On-line event reconstruction and selection is required in the first trigger level.



- On-line reconstruction at the on-line farm with 60000 CPU equivalent cores.
- High speed and efficiency of the reconstruction algorithms are required.
- The algorithms have to be highly parallelised and scalable.
- CBM event reconstruction: Kalman Filter and Cellular Automaton.

Feasibility study

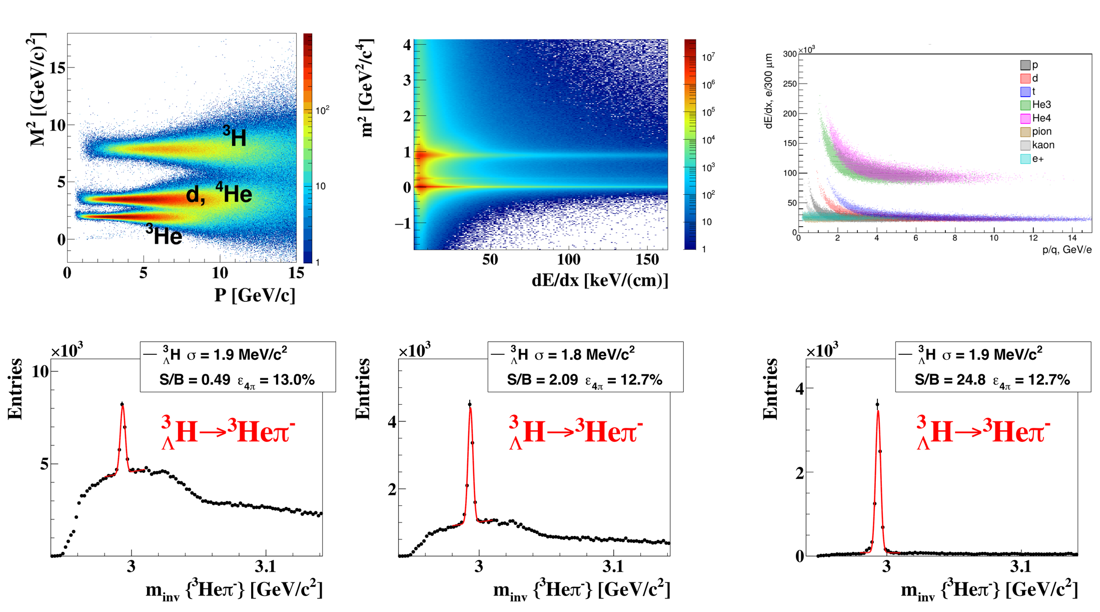


- AuAu, 10 AGeV, 5M central UrQMD events + thermal isotropic signal, TOF PID.
- Background can be further reduced with additional dE/dx PID.
- For $^4_\Lambda$He background can be reduced selecting only primary hypernuclei.

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

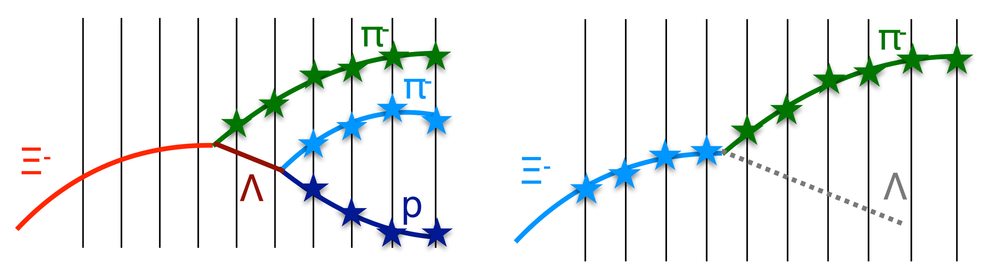
Further improvements

TOF | TOF + TRD | TOF + STS



- CBM can perform dE/dx PID in two detectors: STS based on silicon strip detectors and TRD based on gaseous detectors.
- The expected resolution should be enough to separate 1 and 2-charged particles and clean up ³He from proton contamination and ⁴He spectra from protons and deuterons.
- The studies of including dE/dx are ongoing.

Conventional method | **Missing mass method**



- The missing mass method for reconstruction of short-lived particles with a neutral daughter particle was developed and added to the KF Particle Finder package.
- Originally developed for the reconstruction of Σ, Ξ, Ω hyperons, the method can be applied to the hypernuclei.
- For better control over the systematic errors, all possible channels should be studied.

Possible decays to be studied:

$^3_\Lambda$H → ³He π
d p π
p p n π
t π⁰

$^4_\Lambda$H → ⁴He π
t p π
d d π
³He n π
p p n π

$^4_\Lambda$He → ³He p π
d p p π
p p p n π
⁴He π⁰
d d π⁰
t p π⁰

Conclusions

- ✓ CBM is perfectly suited for detection of hypernuclei thanks to PID precise and precise tracking.
- ✓ Algorithms developed for reconstruction hypernuclei with high efficiency and statistical significance.
- ✓ Observation of ΛΛ-hypernuclei is possible given the optimal energy at 10^7 s^{-1} interaction rate
- ✓ Missing mass method: measurement of more hypernuclei decay channels → direct measurements of branching ratios + tools for the control over systematic errors

Plans:

- ✓ Improve daughter particle PID using dE/dx method
- ✓ Add more decay channels
- ✓ Study systematic errors

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