Performance Studies on Light Nuclei Measurements with the TRD in the CBM-Experiment

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Motivation

Light nuclei and hypernuclei play an important role in the CBM physics program. In particular, a high statistics measurement of double-Λ-hypernuclei will be a break-through in this field of physics[1]. The TRD significantly extends the number of hypernuclei states accessible with CBM.

Performance studies to:

- ★ evaluate hadron / light nuclei identification capabilites of the TRD
- ★ optimize detector geometry
- ★ improve average energy loss calculations

Identification of $^{6}_{\Lambda\Lambda}$He:

$^{6}_{\Lambda\Lambda}$He $\rightarrow$ $^{5}_{\Lambda}$He + p + π

$^{5}_{\Lambda}$He $\rightarrow$ ^{4}He + p + π

Experimental setup

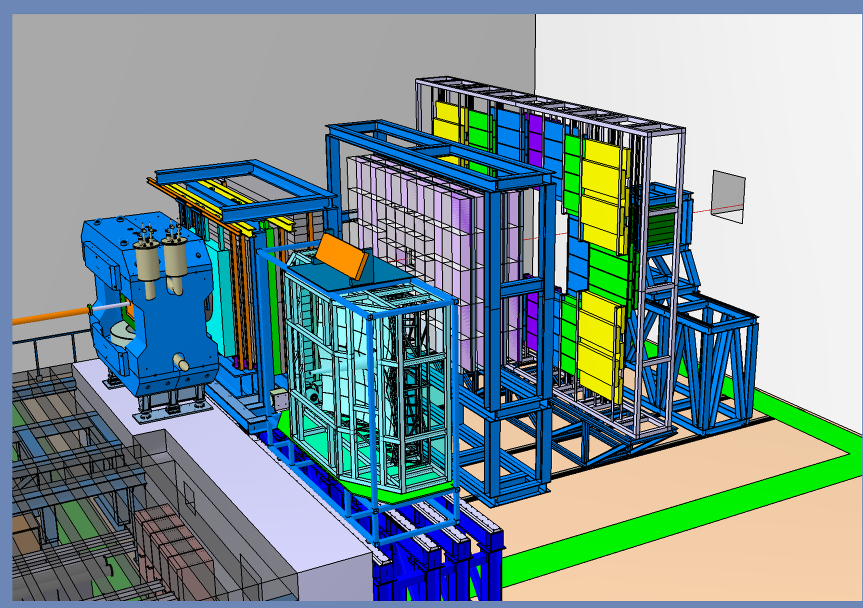
CBM-experiment at FAIR

Exploration of the QCD phase-diagram in the region of high net-baryon densities.

Transition Radiation Detector (TRD)

Multi wire proportional chambers with Xe-CO_2 gas mixture & radiator to

- ★ seperate electrons & pions
- ★ identify hadrons, eg. d & ^{4}He separation

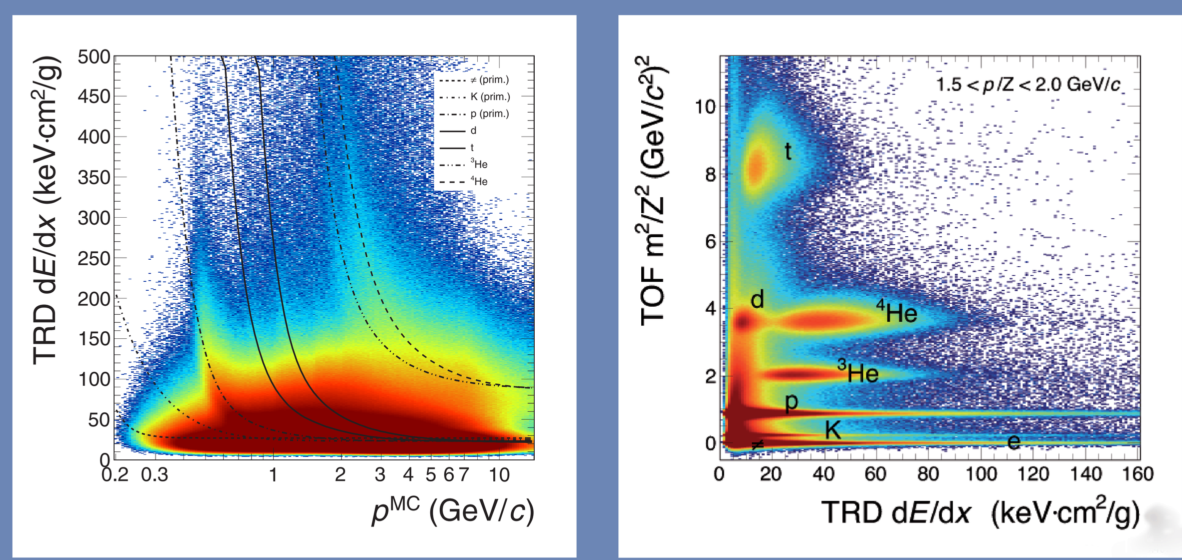


Identification of hadrons & light nuclei

Time of Flight Detector: identifes hadrons via *m/Z* measurement, but is not able to distinguish between two different charge states.

Transition Radiaton Detector: separates charged hadrons & light nuclei with similar *m/Z* via energy loss measurement.

The separation of ^{4}He & d is crucial for the identification of double-Λ-hypernuclei, such as $^{6}_{\Lambda\Lambda}$He.



Left: Averaged *dE/dx* signal as a function of the momentum *p*. The lines depict the expectations for the different particle species. Right: Mass squared as measured by the TOF versus energy loss *dE/dx*.

Simulations of detector performance: ^{4}He & d

Simulated data: Au + Au collisions at 8 AGeV ★ reconstructed with the TRD

Energy loss of ^{4}He & d

- ★ Distributions of the averaged energy loss signal *dE/dx* of d and ^{4}He show a clear separation of d and ^{4}He.
- ★ Fit of *dE/dx*-distributions: Modified Gaussian includes non-Gaussian tails of the distributions via the parameters α and β:

$$f(x) = Ae^{-(|x-\mu|/\sigma\sqrt{2})^{\beta}}\left(1+\alpha\,\mathrm{erf}\left[\frac{x-\mu}{\alpha\sqrt{2}}\right]\right)$$

Purity for different *dE/dx* calculations

- ★ Purity: fraction of ^{4}He relative to the total number of particles (d & ^{4}He) for an interval that includes 90% of all detected ^{4}He.
- ★ Calculation of averaged energy loss based on four TRD hits with *truncation*: systematic elimination of hits to improve matching of statistically distributed energy loss (*Poisson distribution*) with most probable energy loss value.

  Truncation A: Hits with 1st & 2nd lowest *dEdx*
  Truncation B: Hits with 1st · 0.5, 2nd & 3rd · 0.5 lowest *dEdx*
  Truncation C: Hits with 1st · 0.5 & 2nd lowest *dEdx*
  Truncation D: Hit with 2nd lowest *dEdx*
  Truncation E: Hits with 1st, 2nd & 3rd lowest *dEdx*

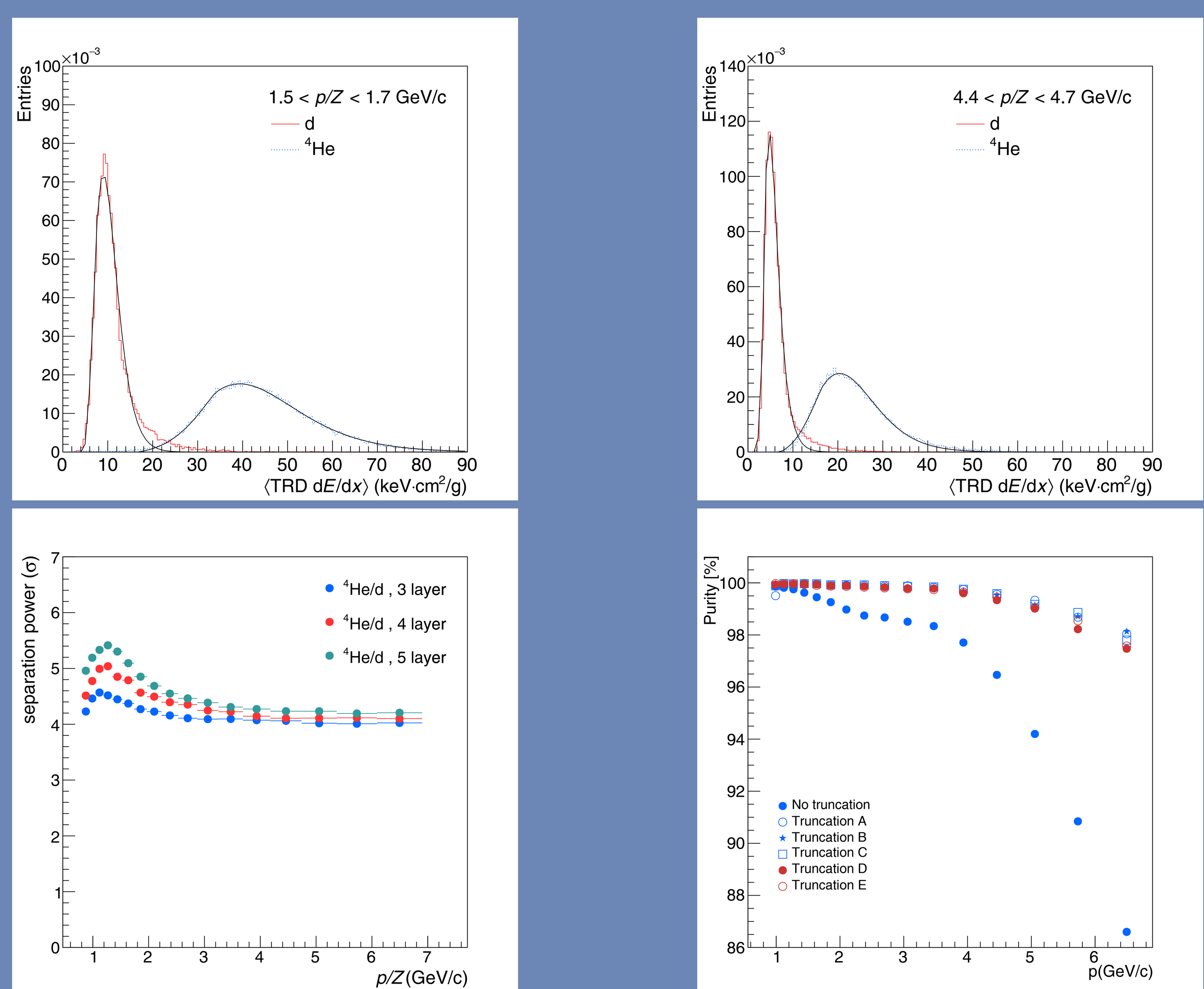
- ★ Purity is above 90 % for a momentum range of up to 6 GeV/*c*.
- ★ A significant improvement to a purtiy level of above 98 % can be achieved with *truncation*.

Separation power for different detector setups

- ★ Separation power for the particle species *i* and *j* based on the averaged energy loss *dE/dx* and σ (*p/Z*) of the distribution:

$$S_{ij}(p) = \frac{\langle dE/dx\rangle_i(p/Z) - \langle dE/dx\rangle_j(p/Z)}{\sigma_i(p/Z)}$$

- ★ A separation of d and ^{4}He on a level of σ ≥ 4 is achievable in the whole accessible momentum range for setups with three, four and five TRD layers.
- ★ Optimal solution, also considering cost efficiency aspects, is a geometry with four TRD layers.



Top: *dE/dx* distributions for d and ^{4}He for two momentum intervals, fitted with a modified Gaussian. Bottom left: *Separation power* for d and ^{4}He as a function of momentum *p*. Bottom right: *Purity* of ^{4}He as a function of momentum *p*, calculated with and without *truncation*.

[1] T. Ablyazimov et al., "Challenges in QCD matter physics – The scientific programme of the CBM experiment at FAIR.", Eur. Phys. J. (2017), A53(3):60.

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