Physics performance studies for the CBM-TRD at SIS100 energies

CBM-TRD DPG 2018

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Agenda

The CBM Experiment

- QCD phase diagram
- Observables
  - Dileptons
  - Light nuclei
- Experimental setup

The TRD Detector

- Working principle
- Particle identification

Simulations

- Dileptons
- Light nuclei

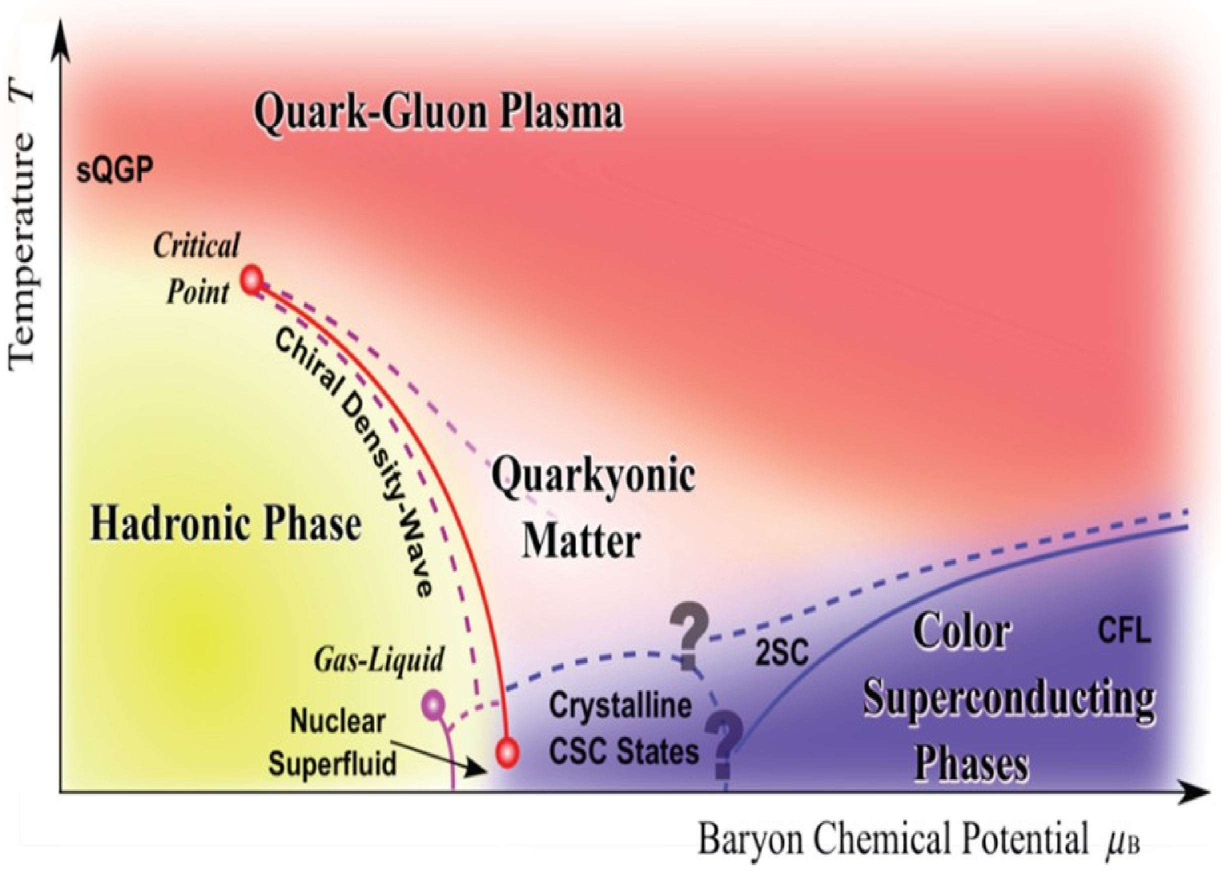
QCD phase diagram

Conditions at SIS100

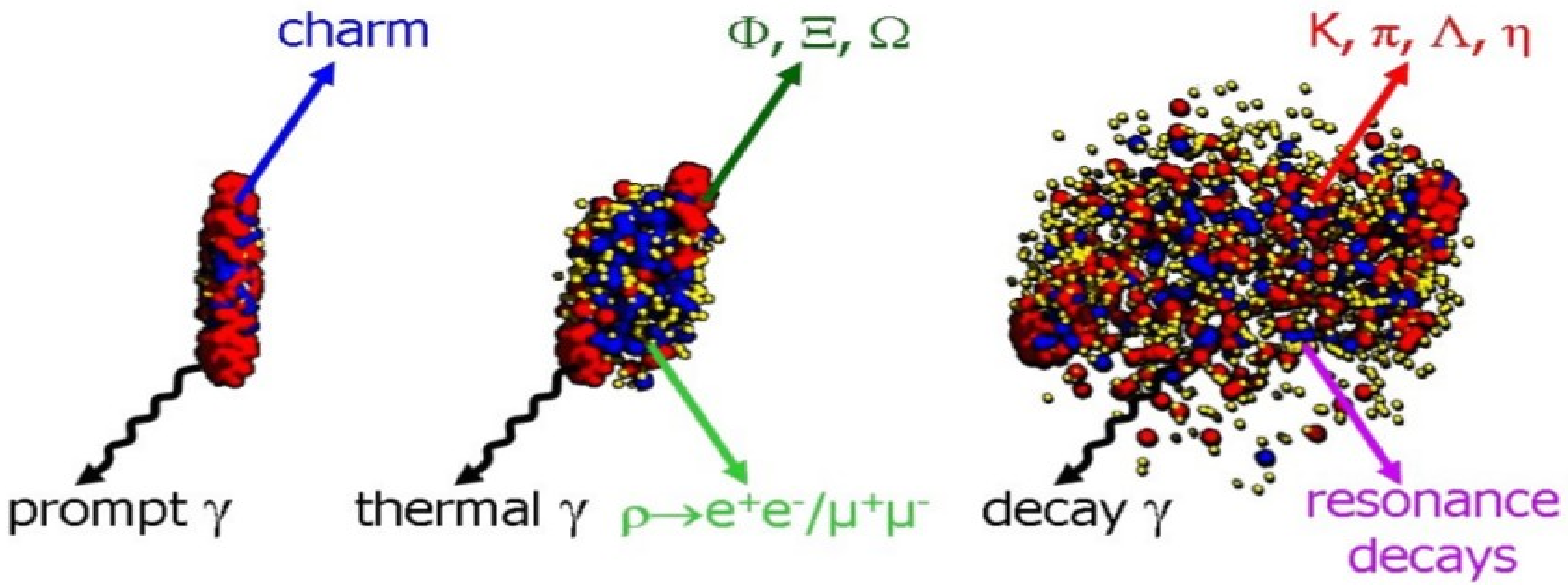
- High net-baryon densities
- Moderate temperatures

Possible features of the QCD phase diagram

- First order phase transition
- Critical end point
- Chiral symmetry restoration
- New Phases (quarkyonic matter,...)



Observables



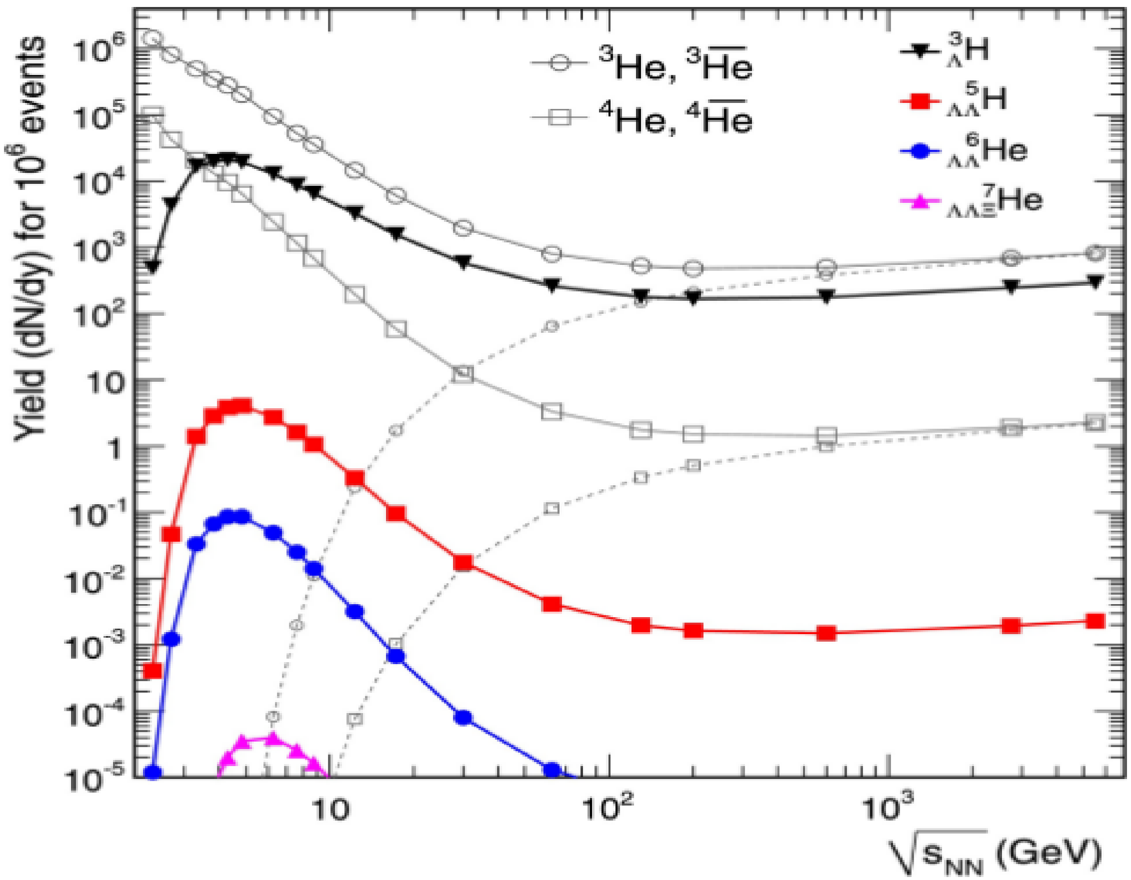
Advantage of dileptons

- Dileptons can be found in all stages
- They do not interact strongly and can carry information out of the fireball

The CBM hypernuclei program

Hypernuclei production

- Predicted hypernuclei yields at mid-rapidity

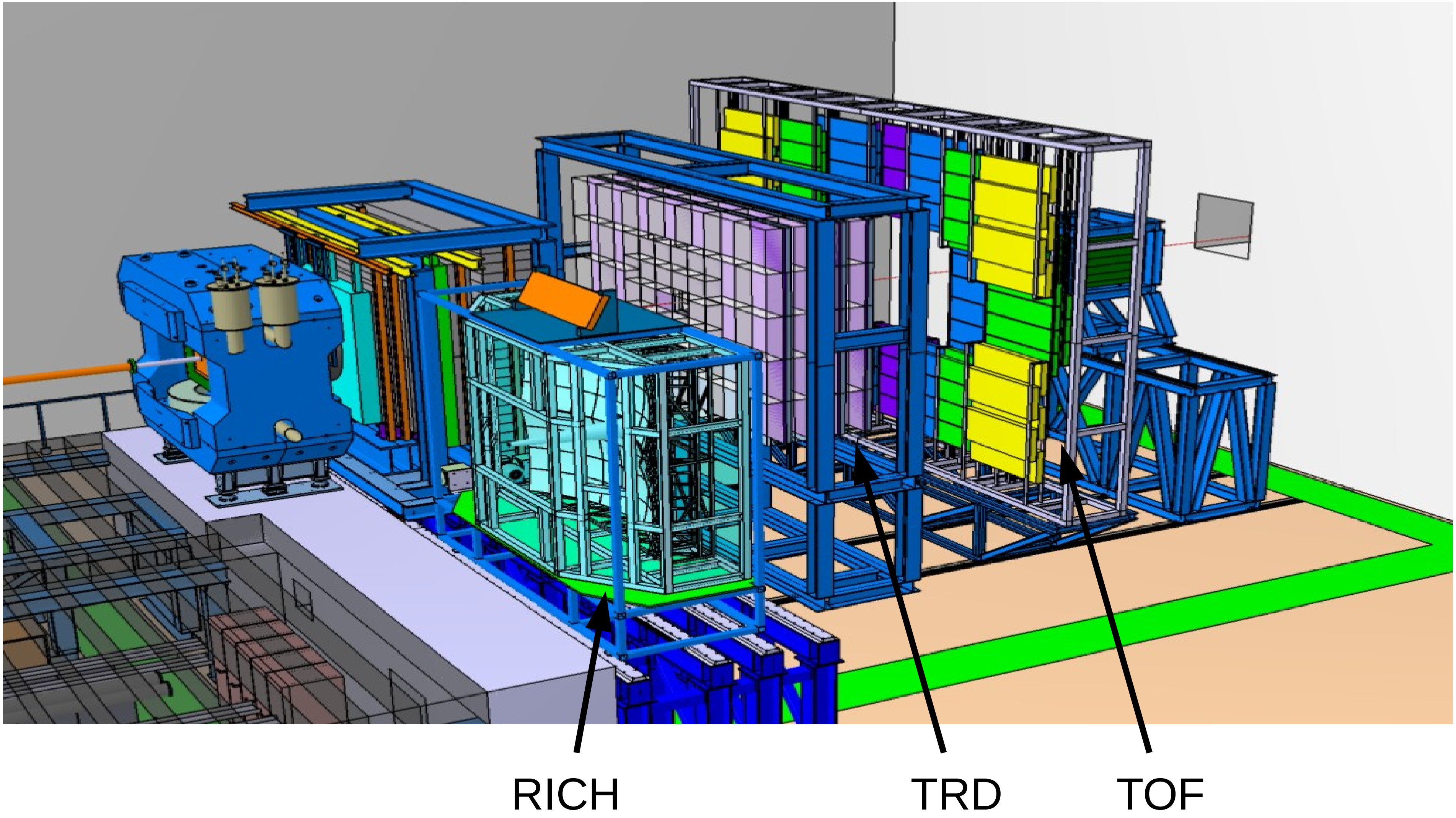


1. $$^{6}_{\Lambda\Lambda}\mathrm{He} \rightarrow\ ^{5}_{\Lambda}\mathrm{He} + \mathrm{p} + \pi^{-}$$
   $$^{5}_{\Lambda}\mathrm{He} \rightarrow\ ^{4}\mathrm{He} + \mathrm{p} + \pi^{-}$$
2. $$^{3}_{\Lambda}\mathrm{He} \rightarrow \mathrm{d} + \mathrm{p} + \pi^{-}$$

See also

HK 9.06

Experimental setup



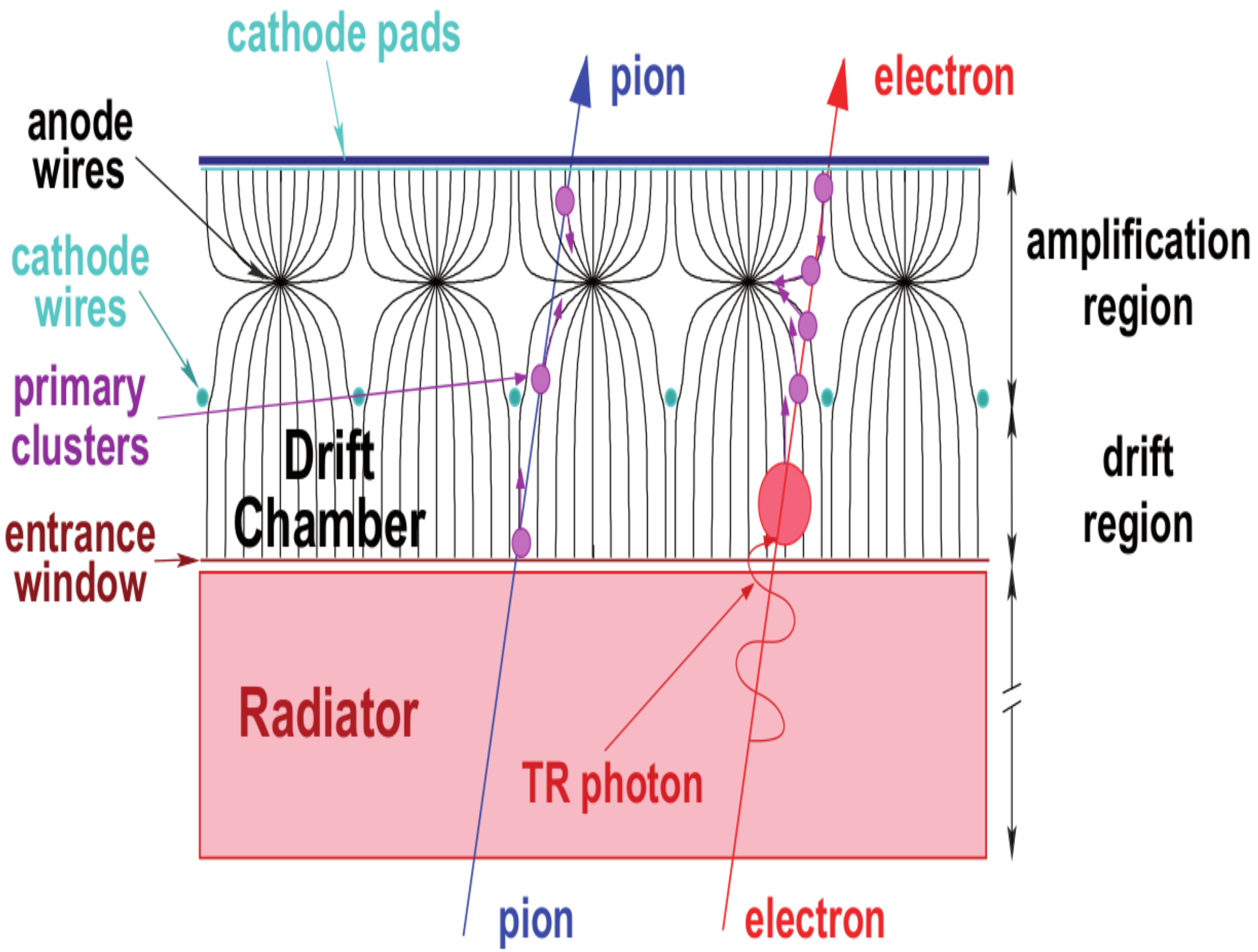
The Transition Radiation Detector

Working principle

- Measures energy loss for charged particles
  - Light nuclei
- Electrons create TR photon
  - Dileptons

TR production

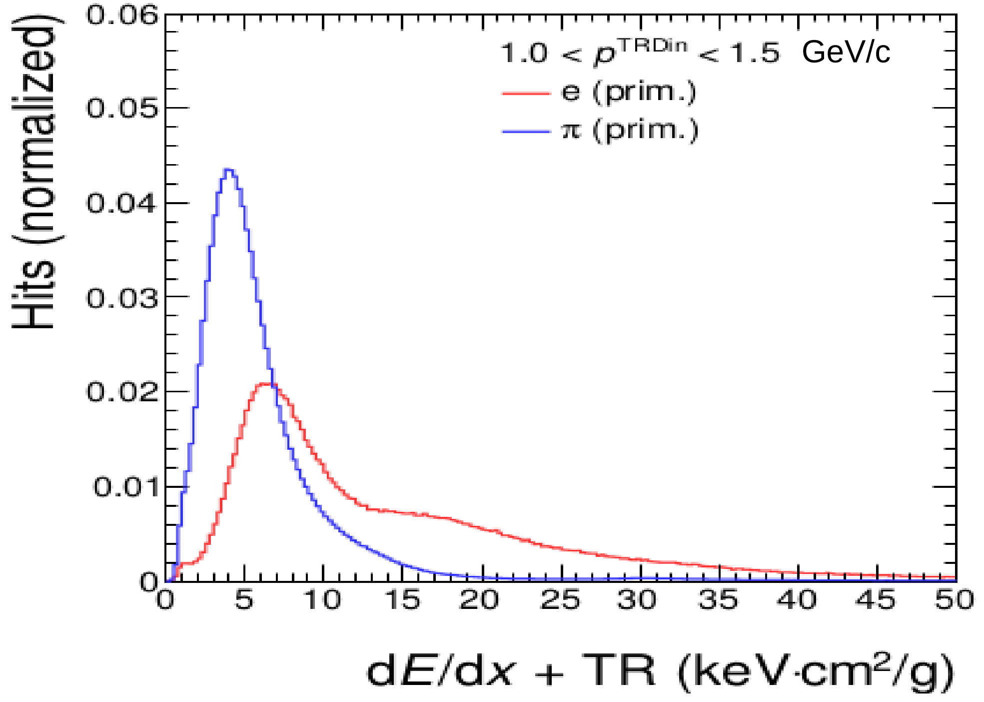
- Depends on the gamma factor of the particle



See also

HK 12.1

Electron ID

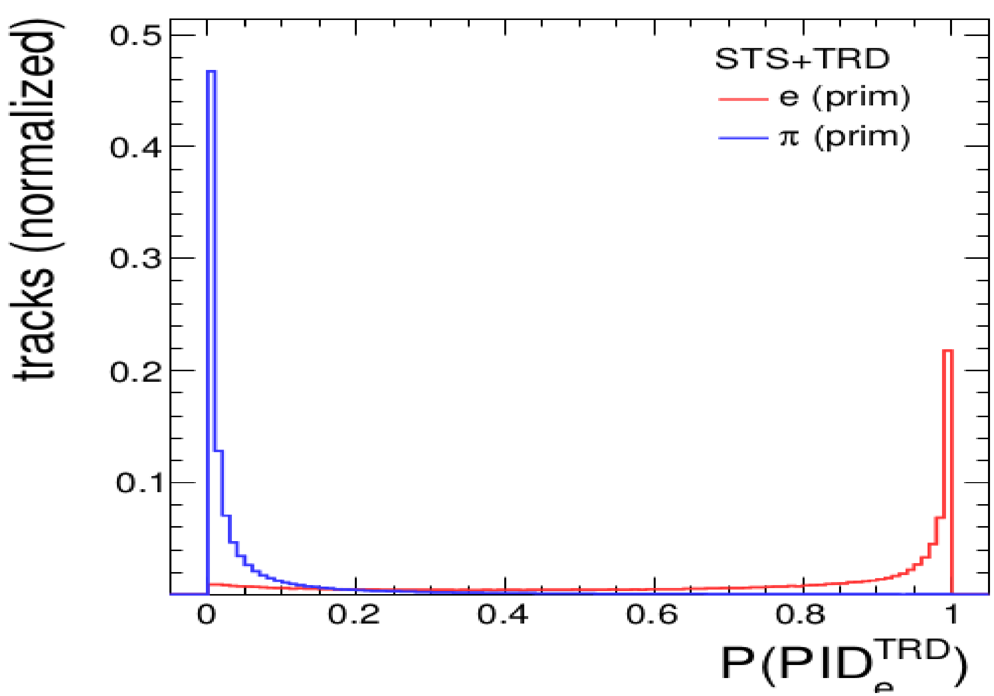


Particle identification

- PID is done with a likelihood method
- Distinguishes between electrons and pions
- Investigated for different numbers of TRD layers

$$L = \frac{P_e}{P_e + P_\pi}$$

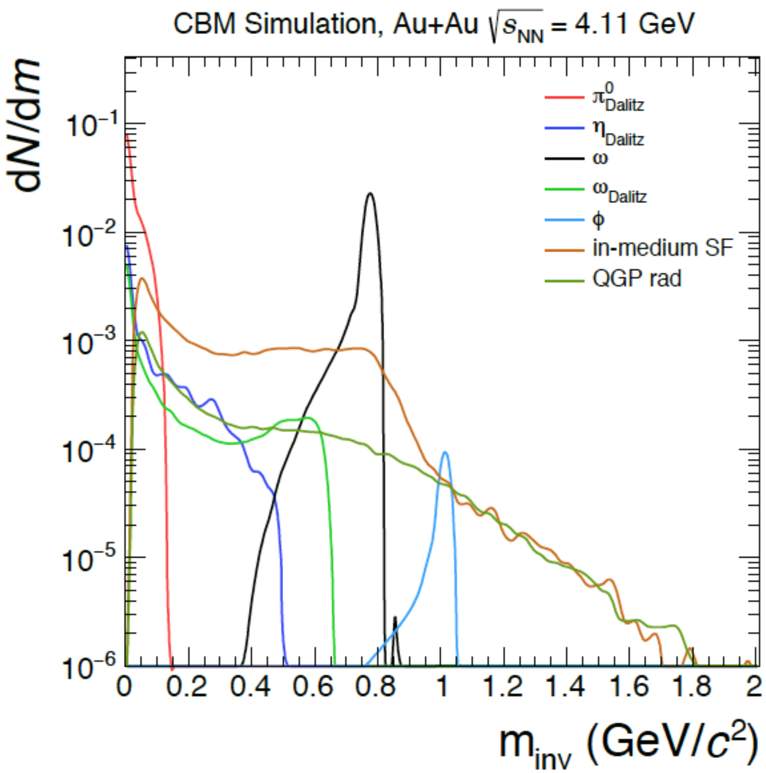
$$P_e = \prod_{i=1}^{N} P(E_i|e), \quad P_\pi = \prod_{i=1}^{N} P(E_i|\pi)$$



Simulation information

Central (10%) Au+Au at 8 *A*GeV

- 5×10^6 UrQMD background events
- LMVM cocktail, yields according to HSD prediction *(W. Cassing et al., Nucl. Phys. A691 (2001) 753)*
- Thermal radiation (T. Galatyuk et al., Eur. Phys. J. A52 (2016) 131)
- Generated via PLUTO
- and added to UrQMD events



Track quality

- STS: $N_{hits} \geq 6$, RICH: $N_{hits} \geq 6$, TRD: $N_{hits} \geq 3$
- χ^2/ndf < 3 to primary vertex
- p_T> 0.2 GeV/c

Electron identification

- RICH: ANN output, with e-efficiency of 90%
- TRD: Likelihood method with 80% e-efficiency
- TOF: Cut on β_{meas} - β_e (± 1.65 σ)

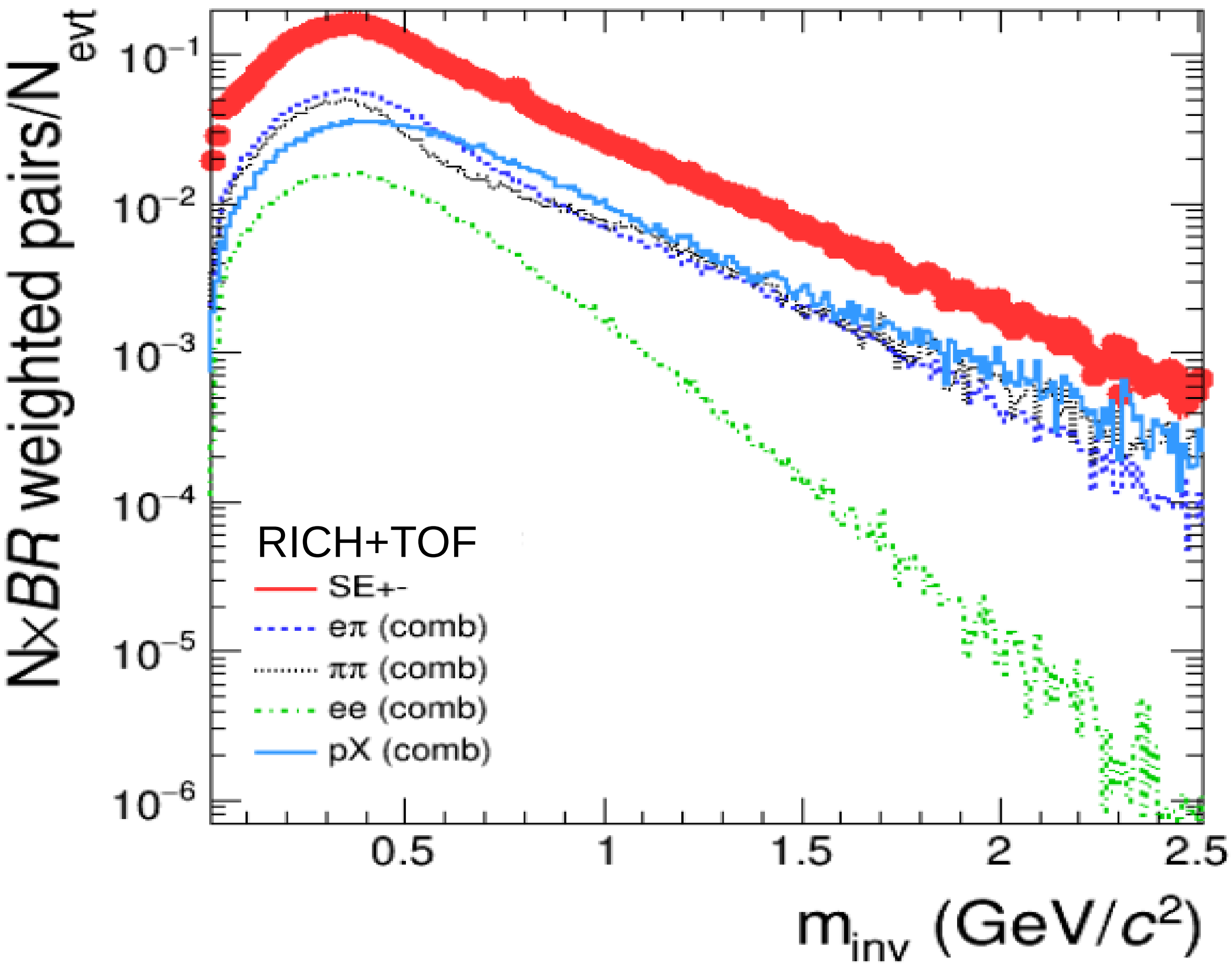
⇒ ~ 90% e-efficiency

Source	$BR_{e^+e^-}$	Total multiplicities p + Au	Total multiplicities Au + Au
ρ^0	$4.72 \cdot 10^{-5}$	$3.4 \cdot 10^{-3}$	9.0
ω	$7.28 \cdot 10^{-4}$	$5.7 \cdot 10^{-3}$	19.0
ϕ	$2.97 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	0.12
$J/\psi(1S)$	$5.97 \cdot 10^{-2}$	$5.1 \cdot 10^{-8}$	—
$\psi(2S)$	$7.89 \cdot 10^{-3}$	$1.3 \cdot 10^{-9}$	—
In-medium radiation	—	—	$2.2 \cdot 10^{-2}$
QGP radiation	—	—	$5.8 \cdot 10^{-3}$

Background contributions without TRD

Signal access

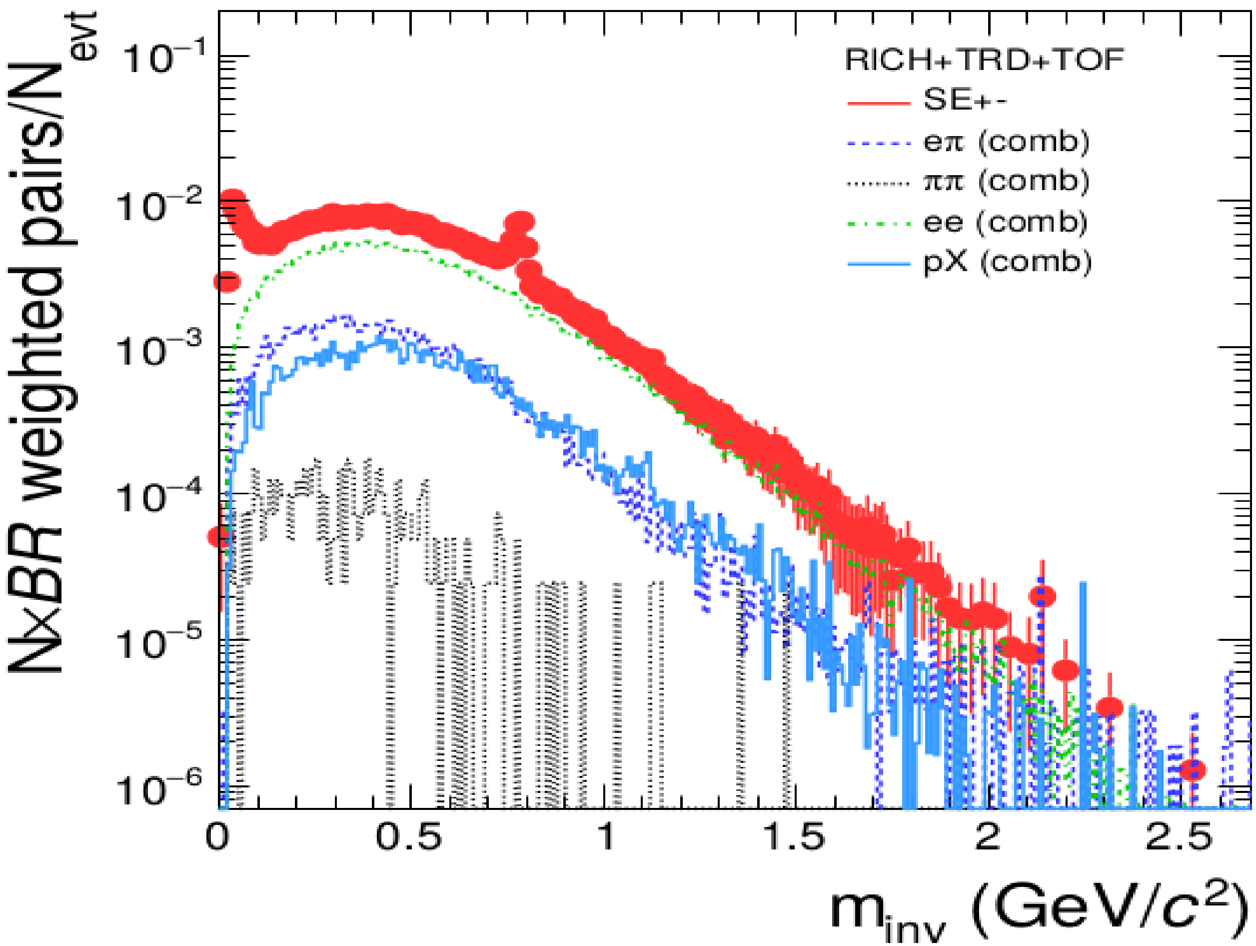
- Large background contributions
- Hadronic contributions are dominant
- No access to the thermal radiation



Background contributions with TRD

Combinatorial background

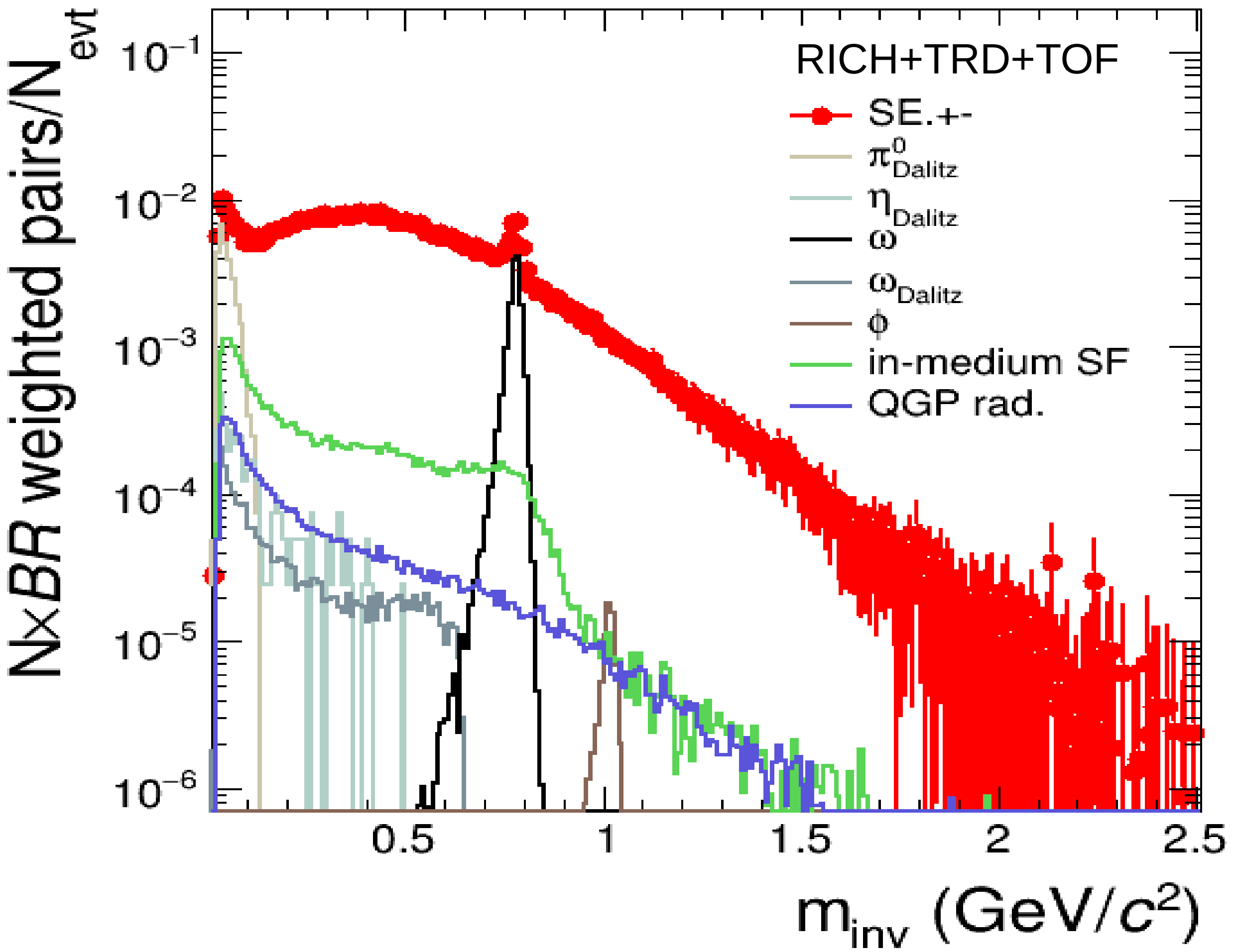
- The dielectron contribution is the primary background
- The hadronic contributions are strongly suppressed



Invariant mass distribution of signals

Signal channels

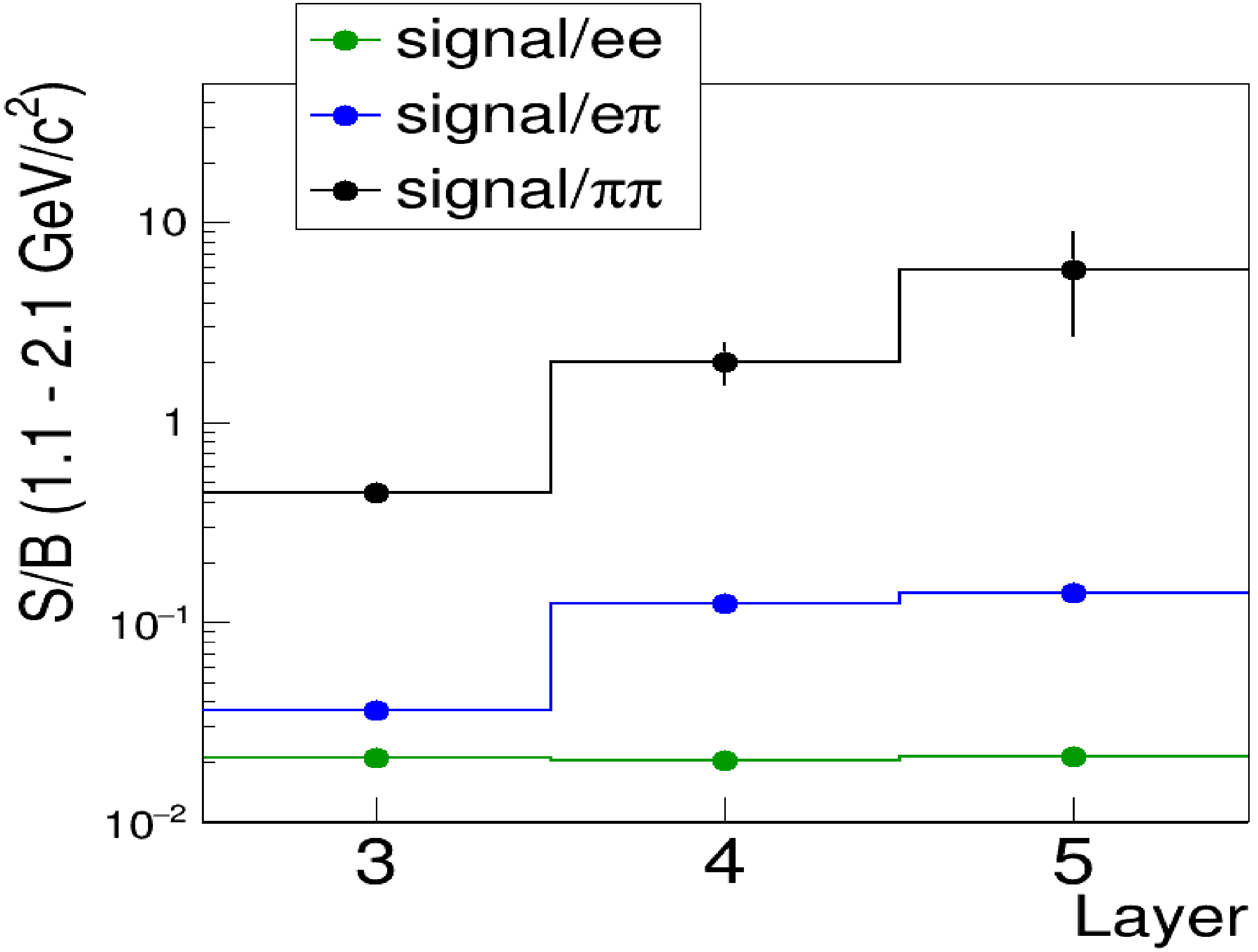
- Different decay channels into dileptons
- Access to thermal radiation above 1 GeV/c²



Access to the signal

Thermal radiation

- Constant ee contribution due to efficiency
- Far better pion suppression with 4 layers than with 3
- Reasonable access to the thermal radiation



Light nuclei

Nuclei ID

- Additional physics case for the TRD
- Separate charge states

1. $^{6}_{\Lambda\Lambda}\mathrm{He} \rightarrow {}^{5}_{\Lambda}\mathrm{He} + \mathrm{p} + \pi^-$

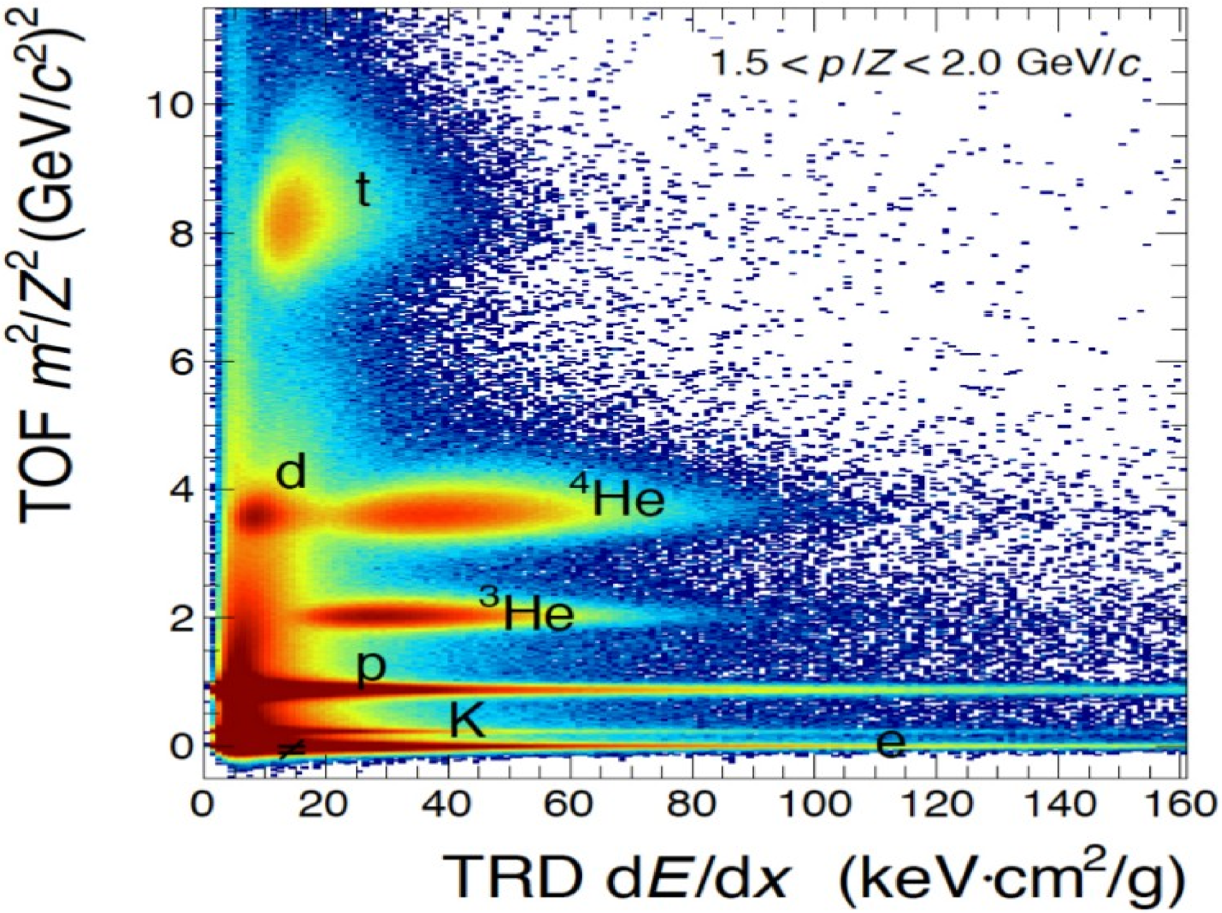
   $^{5}_{\Lambda}\mathrm{He} \rightarrow {}^{4}\mathrm{He} + \mathrm{p} + \pi^-$

2. $^{3}_{\Lambda}\mathrm{He} \rightarrow \mathrm{d} + \mathrm{p} + \pi^-$

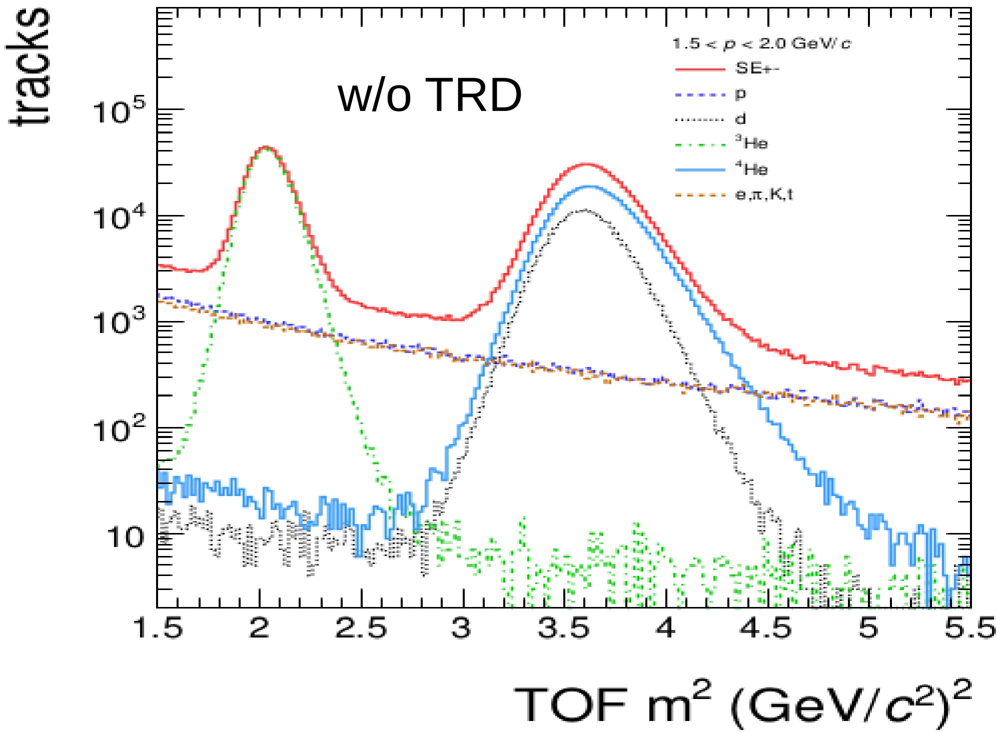
See also

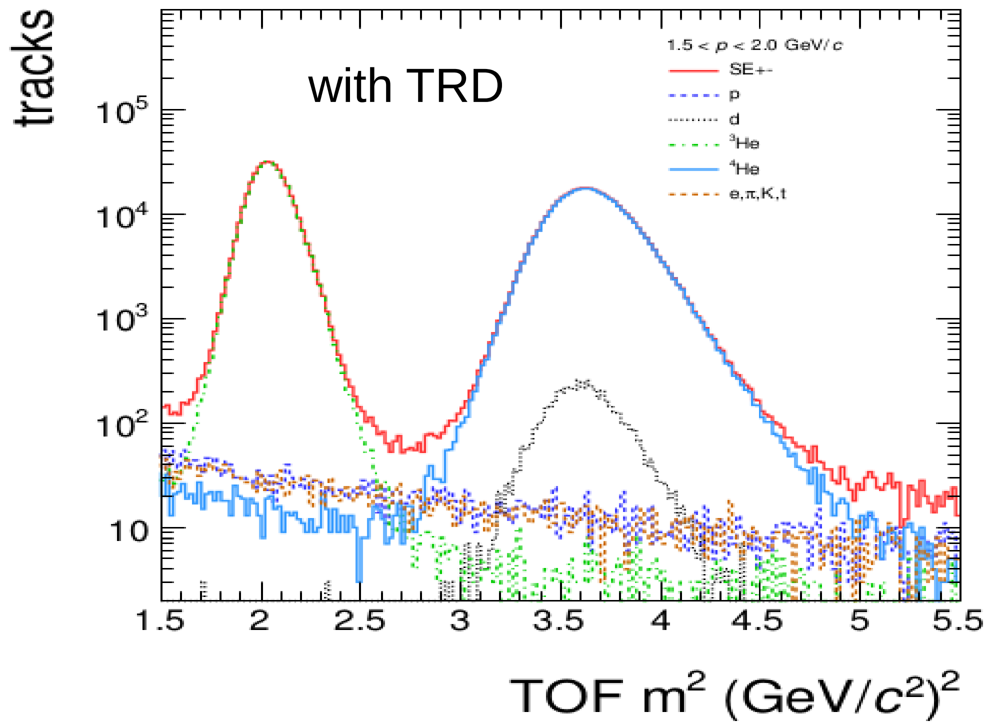
HK 52.12

(Poster by Susanne Glässel)



ToF + TRD measurements

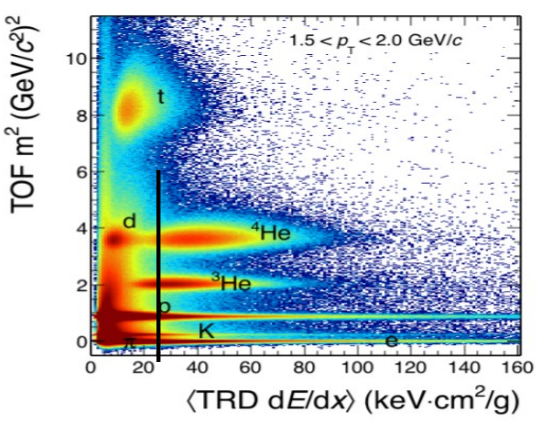




Nuclei ID

- Strong improvement of the identification capabilities

- A suppression of deuterons by about 20 can be achieved

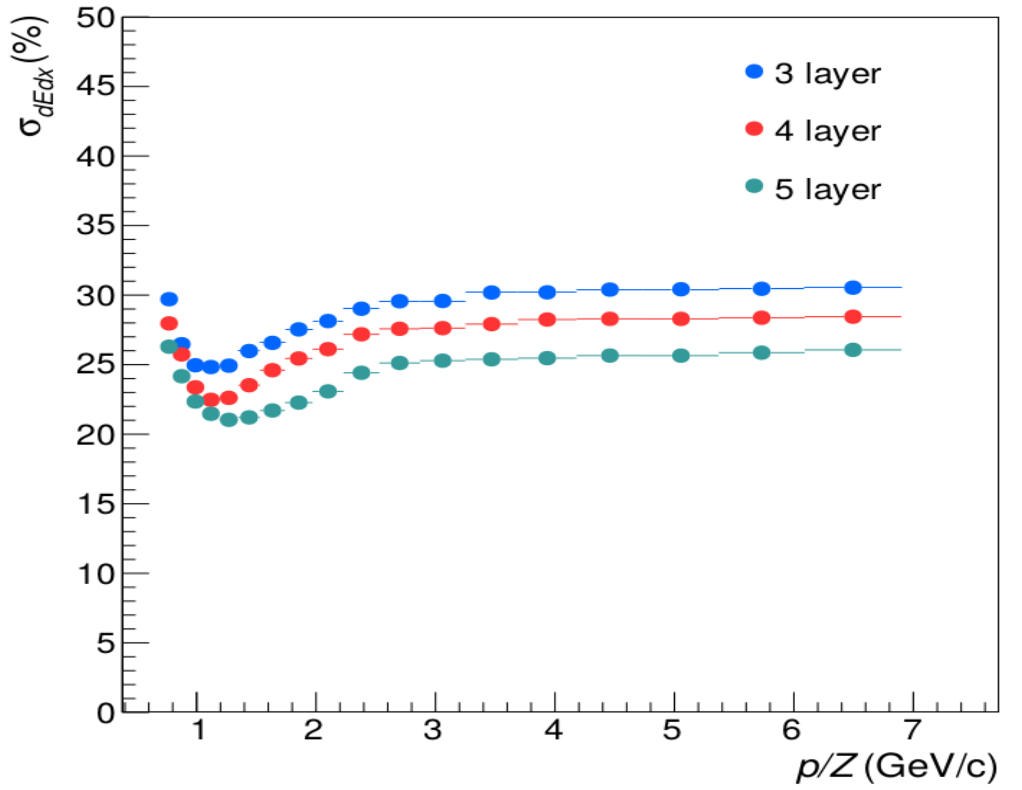


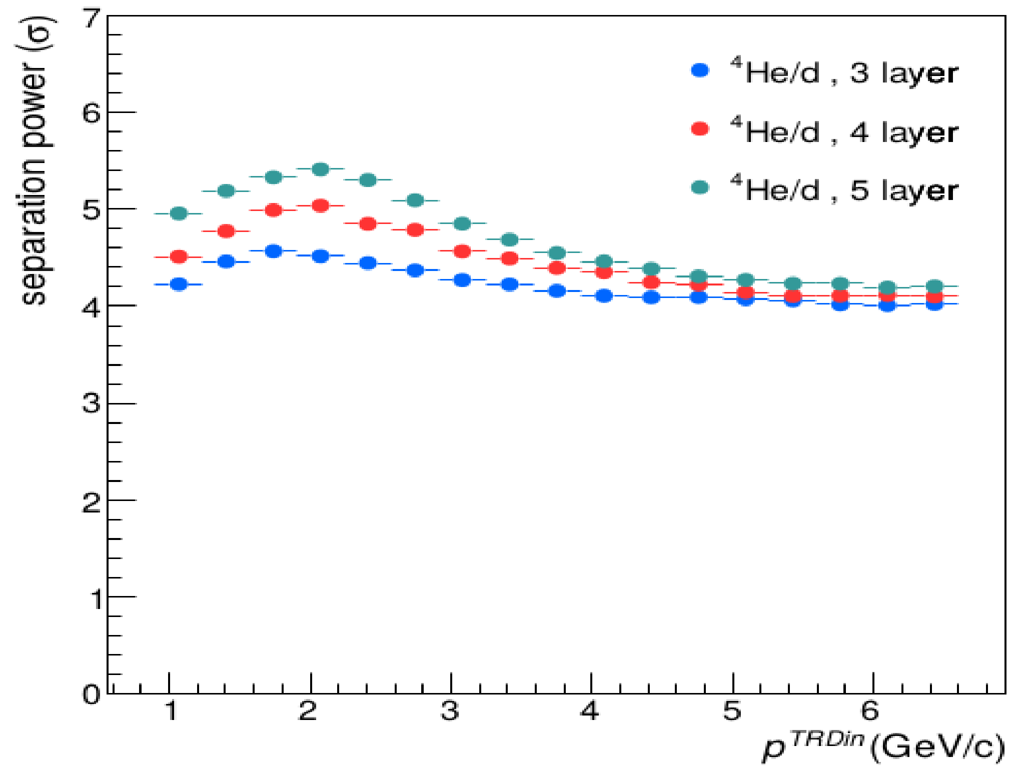
Nuclei ID

Separation power

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

- Clearly above 4 sigma
- Energy resolution around 25%





Summary and conclusion

Dileptons

- The invariant mass spectra show very good background suppression

Light nuclei

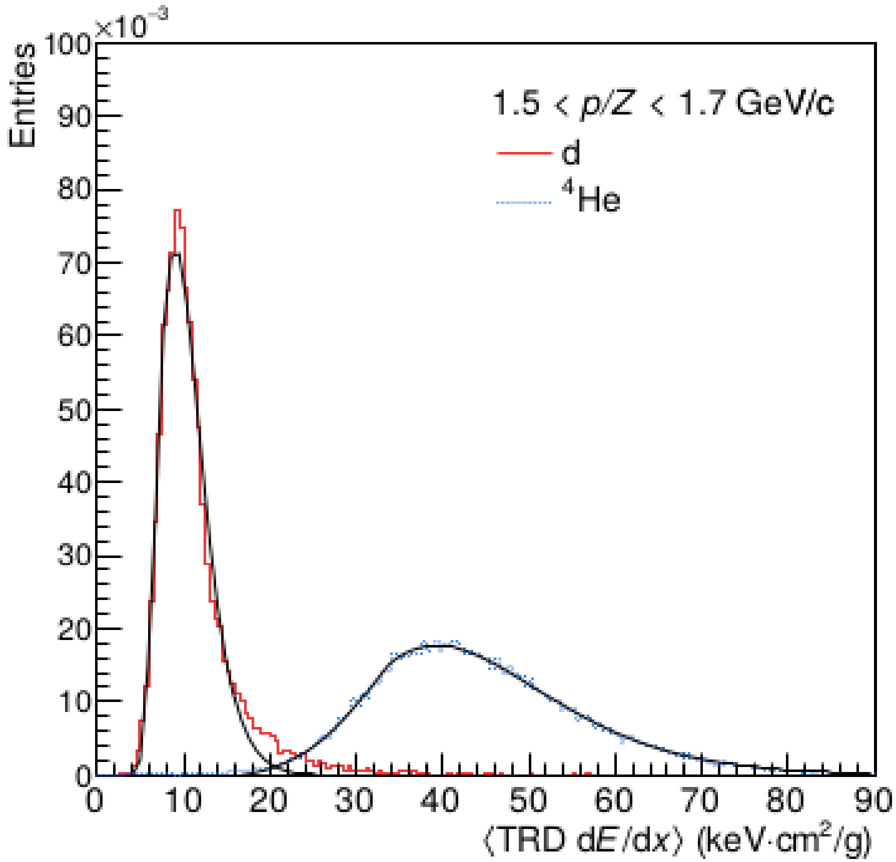
- The dE/dx measurement is an important aspect of the hypernuclei program
- The energy loss resolution is sufficient for the separation of charge states

The detector

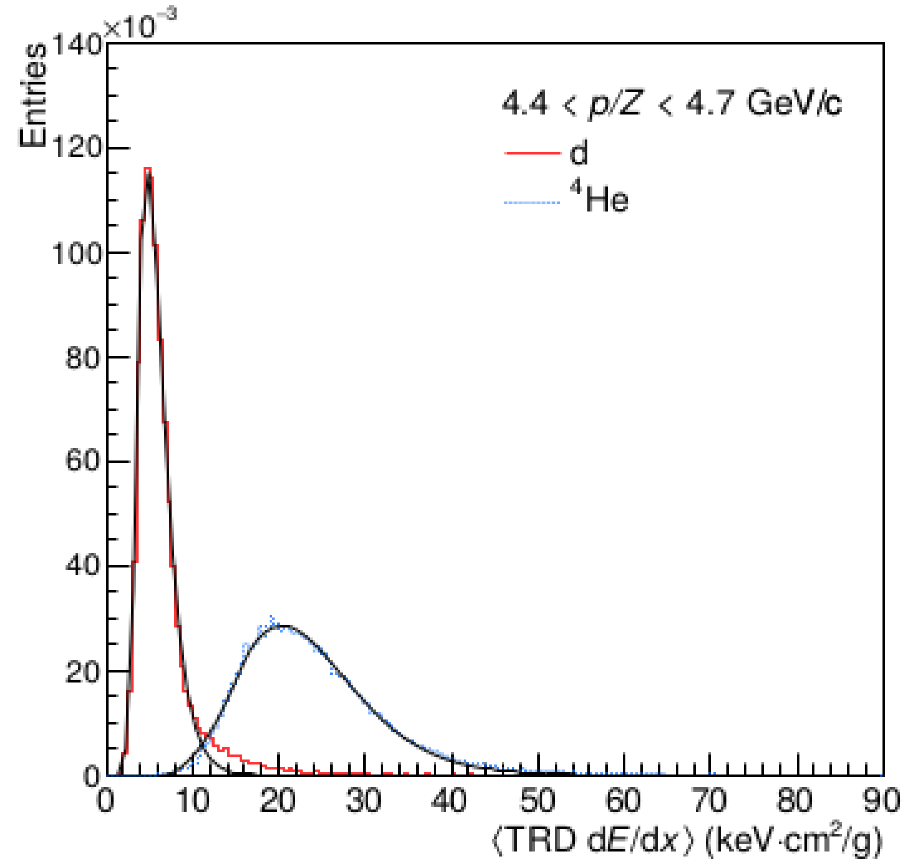
- 4 TRD stations provide the required performance

Backup

Backup

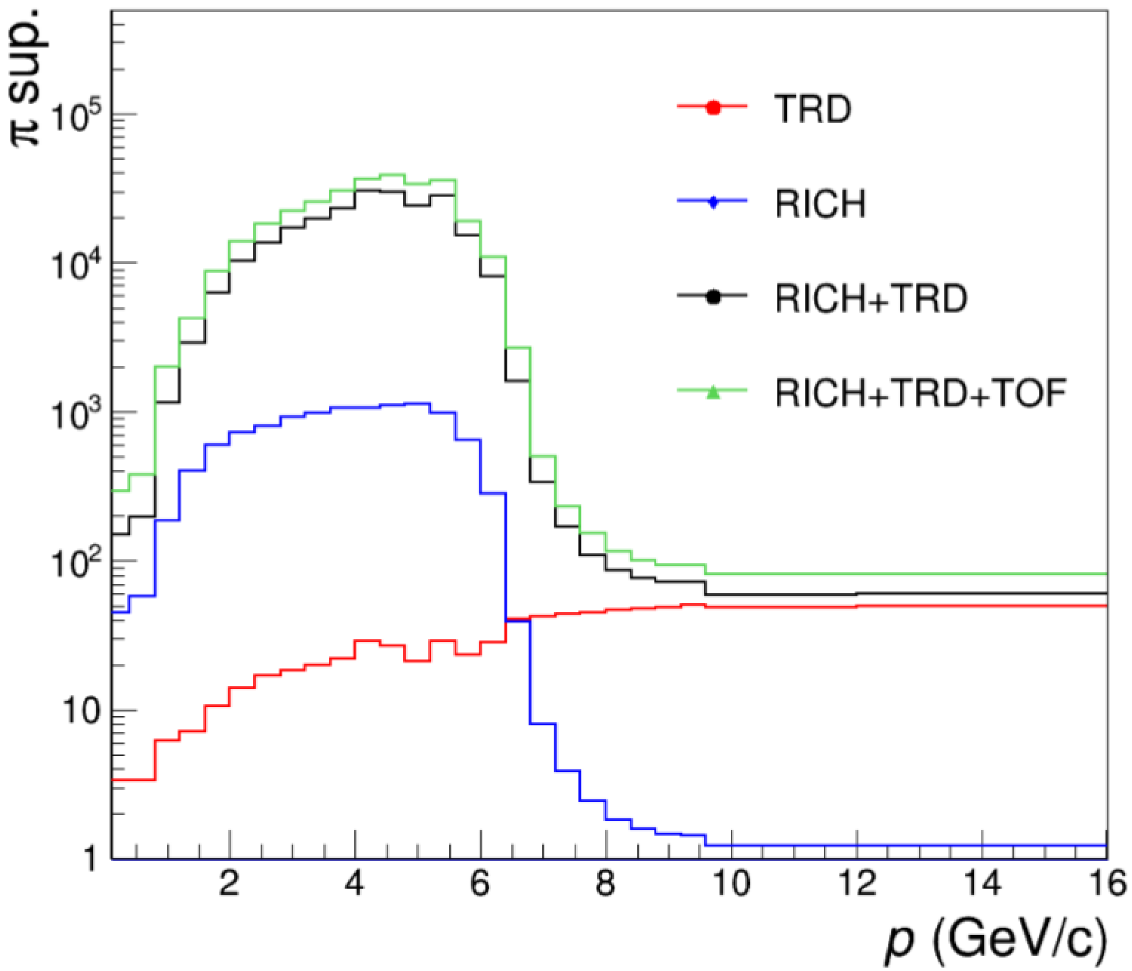


×10⁻³
Entries
1.5 < p/Z < 1.7 GeV/c
d
⁴He
⟨TRD dE/dx⟩ (keV·cm²/g)



×10⁻³
Entries
4.4 < p/Z < 4.7 GeV/c
d
⁴He
⟨TRD dE/dx⟩ (keV·cm²/g)

Backup



π sup.
1
10
10²
10³
10⁴
10⁵
2
4
6
8
10
12
14
16
p (GeV/c)
TRD
RICH
RICH+TRD
RICH+TRD+TOF