Dielectron simulations for the CBM-TRD at different energies

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Overview

Physics program for CBM

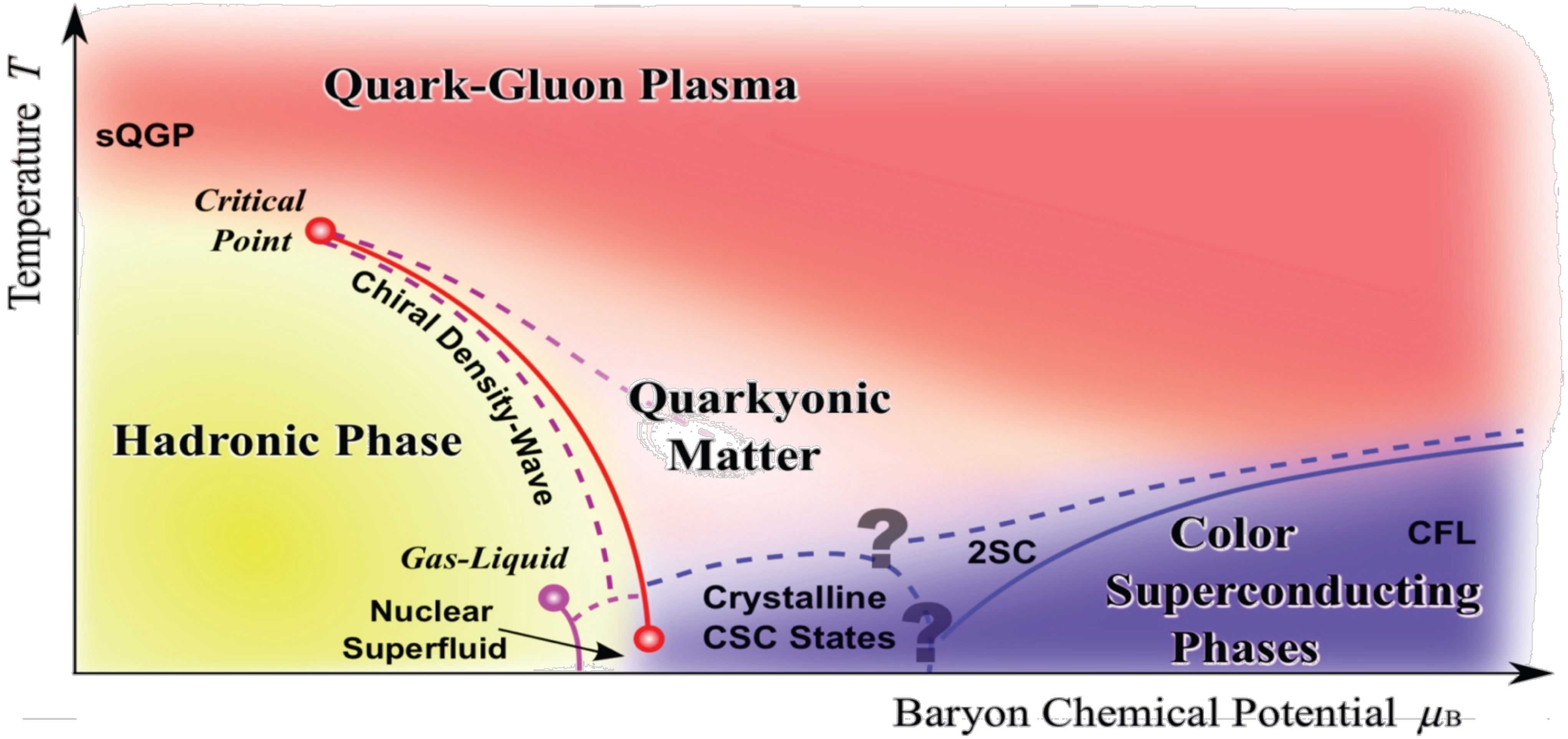
Dileptons as probe in heavy-ion-collisions

The CBM experiment

PID with the transition radiation detector
- Working principle of the TRD
- Likelihood method for electron ID

AuAu Simulations
- 8 A GeV
- 12 A GeV

QCD Phase Diagram



Probing the QCD phase diagram with CBM

High net-baryon densities

Moderate temperatures

Phase transitions: deconfinement + chiral symmetry

Critical end point

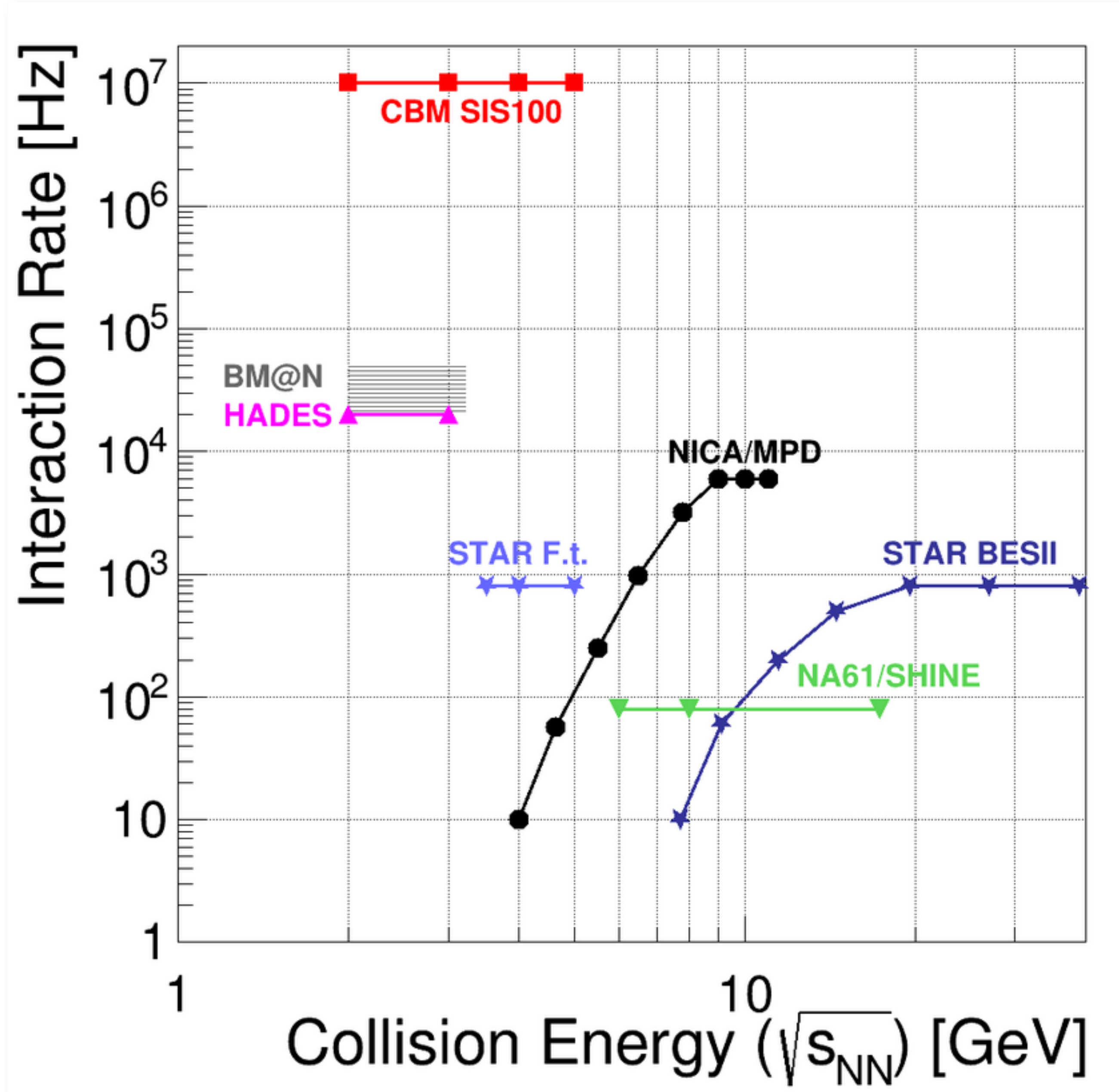
New phases (quarkyonic matter, …)

Experiments in the regime of high net-baryon densities

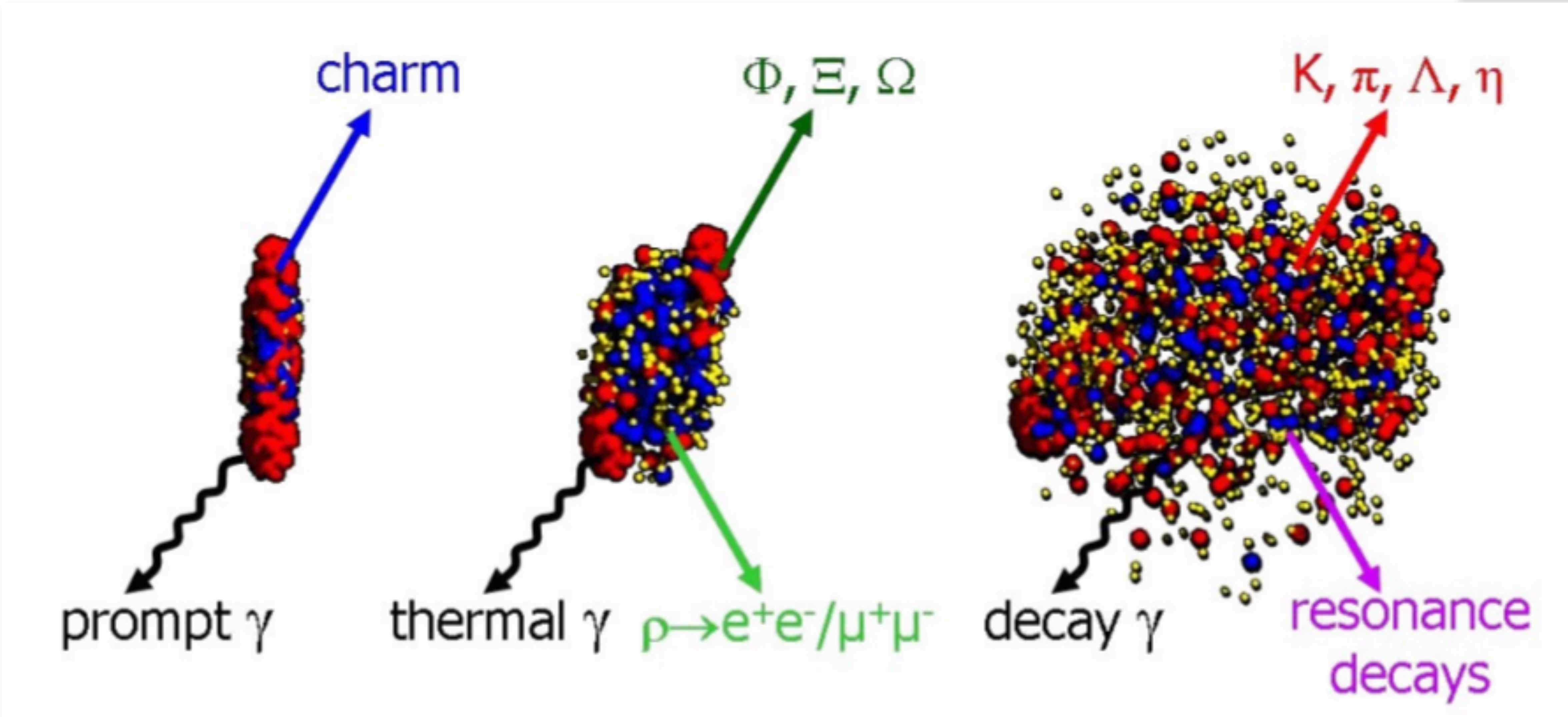
CBM will operate at high rates of up to 10 MHz mean interaction rate

With this it will study very rare processes such as:

- Hypernuclei
- Rare dilepton channels
- Multi strange particles
- Other rare probes



Why dileptons?



Heavy-Ion collisions
Di-leptons originate from all stages of the fireball development
They especially provide access to the early stages
They do not interact strongly and therefore carry information out of the fireball

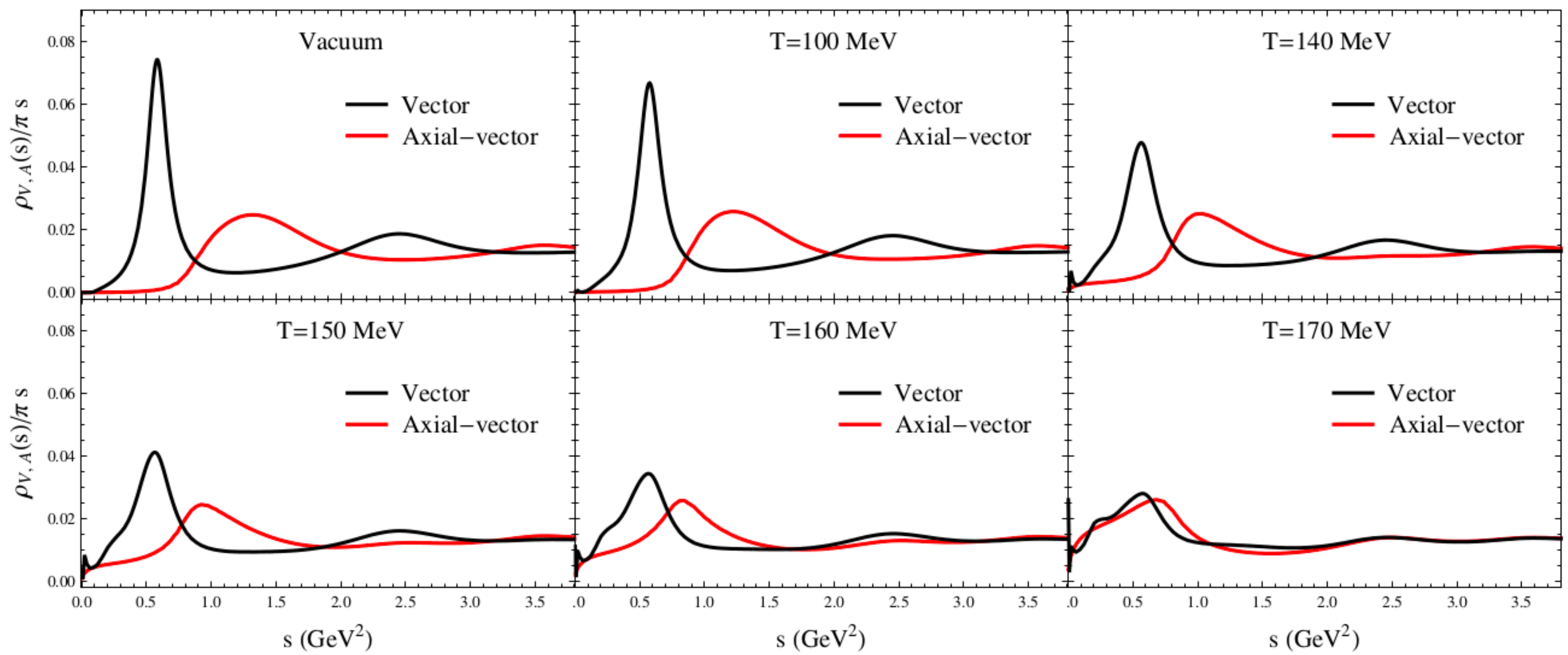
Chiral symmetry restoration in QCD

The chiral symmetry is spontaneously broken in the vacuum

$$\langle 0|\bar{q}q|0\rangle = \langle 0|\bar{q}_L q_R + \bar{q}_R q_L|0\rangle \neq 0$$

Restoration at finite T and μ_B manifests itself via mixing of chiral pairs

This is directly accessible in heavy-ion-collisions



P.M.Hohler and R.Rapp , Phys. Lett. **B731**

Thermal dileptons excitation function

Dileptons can be used as thermometer of the fireball

$$if\ \frac{\mathrm{Im}\,\Pi^{\mu\nu}_{EM}}{M^2} \sim const. \ \Rightarrow \frac{dN_{ll}}{d^4q d^4x} \sim f^{BE}(q_0, T)$$

As chronometer

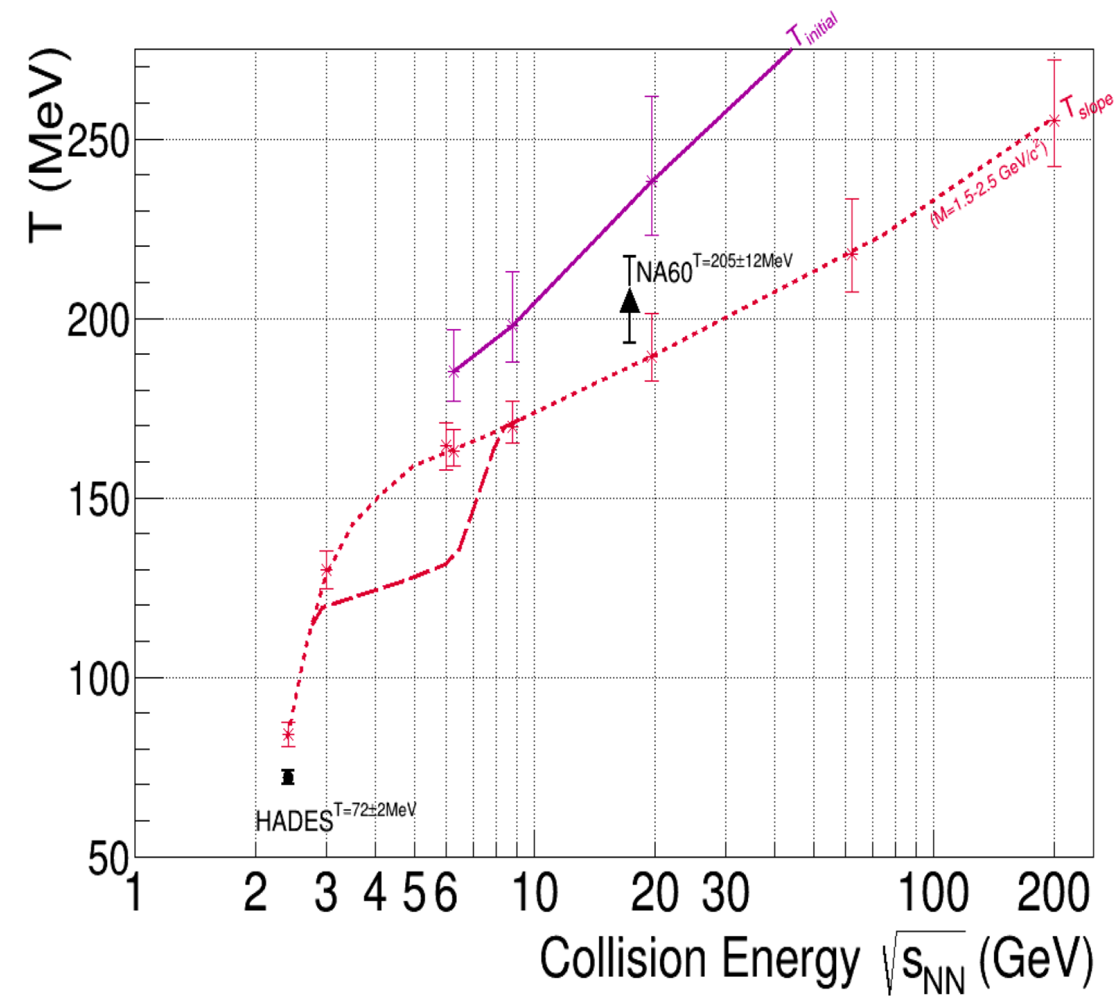
$$\int_{0.3GeV}^{0.7GeV} \frac{dN_{ll}}{dM} \sim \tau_{fireball}$$

As barometer

T_{eff} vs. M_{ll}

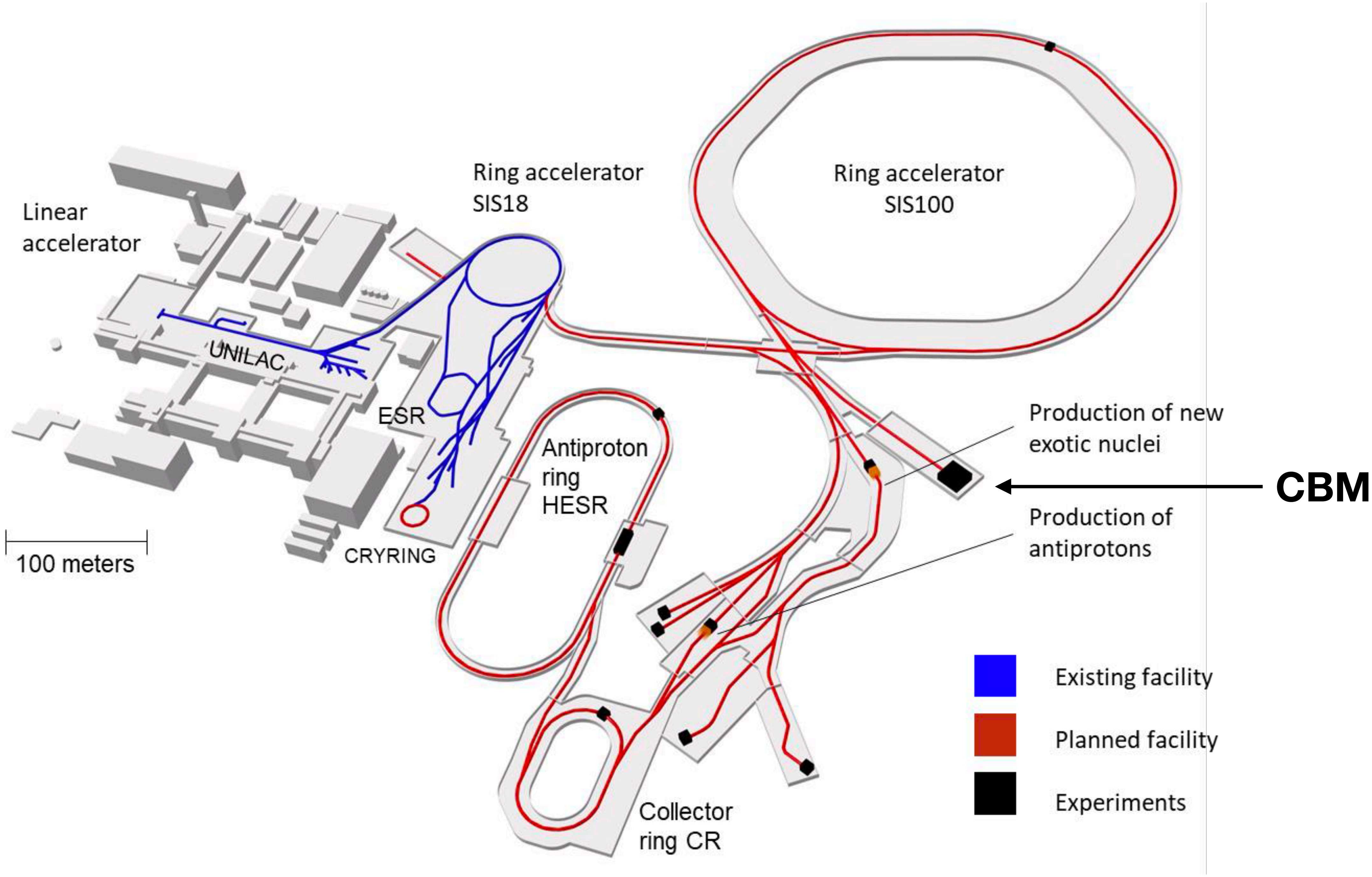
υ_2 vs. M_{ll}

Emitting source T



NA60 Collab., Chiral 2010, AIP Conf.Proc. (2010) 1322
R. Rapp, H. van Hees, PLB 753 (2016) 586

The FAIR project



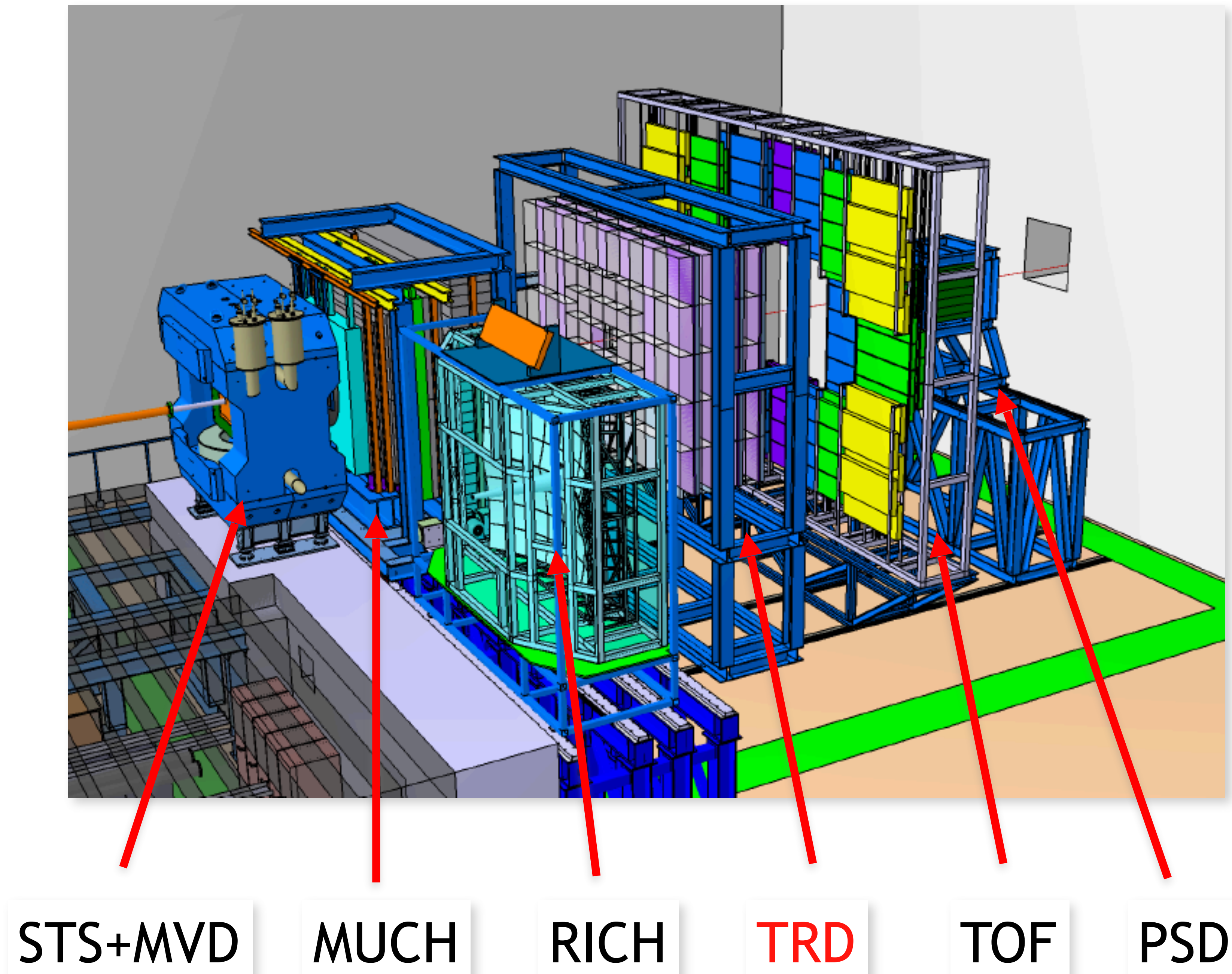
Status of the CBM pit

The CBM experiment

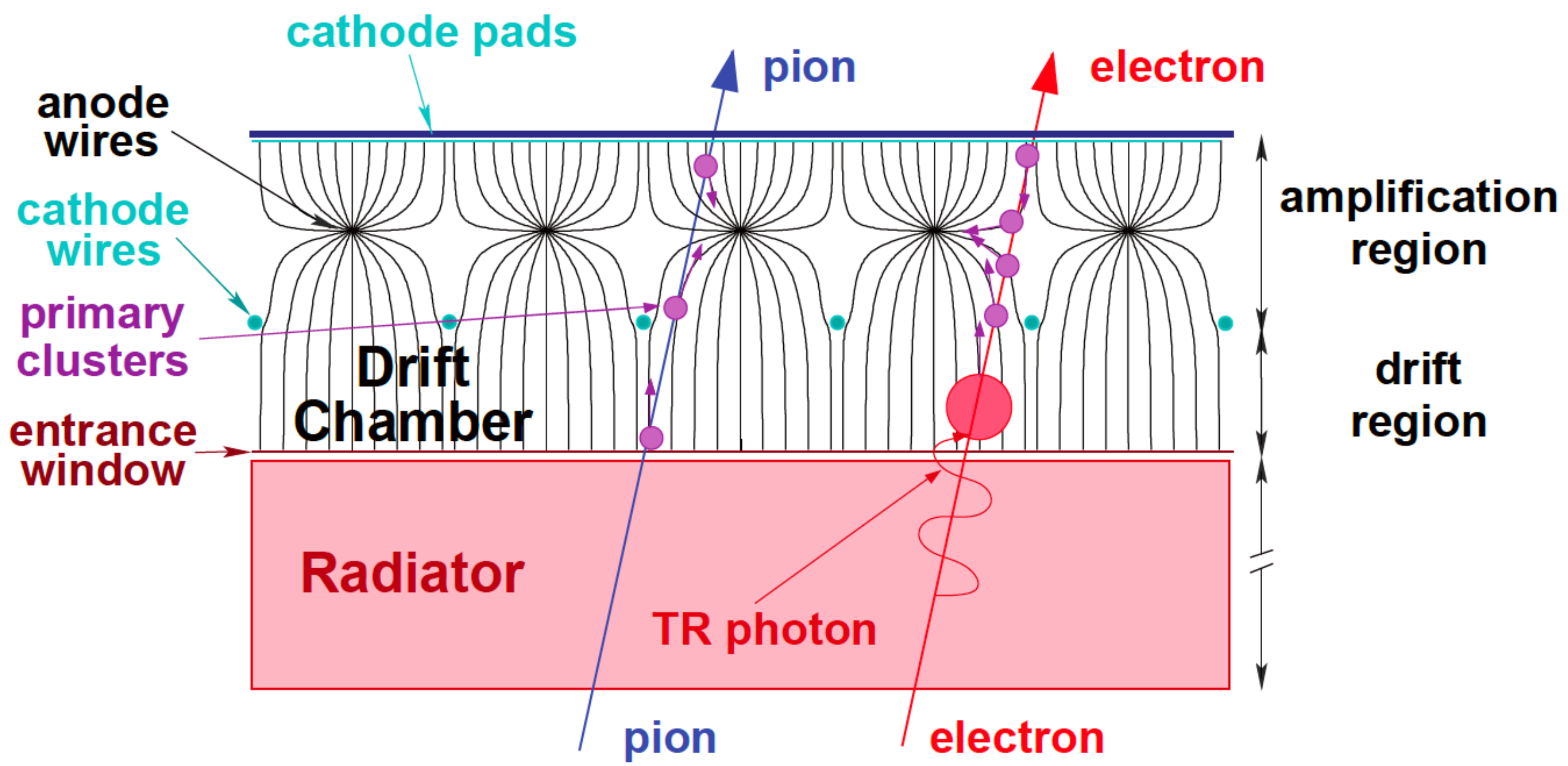
Acceptance
Forward rapidity
p_T > 0

Two experimental setups
- Electron setup with RICH
- Muon setup with MUCH

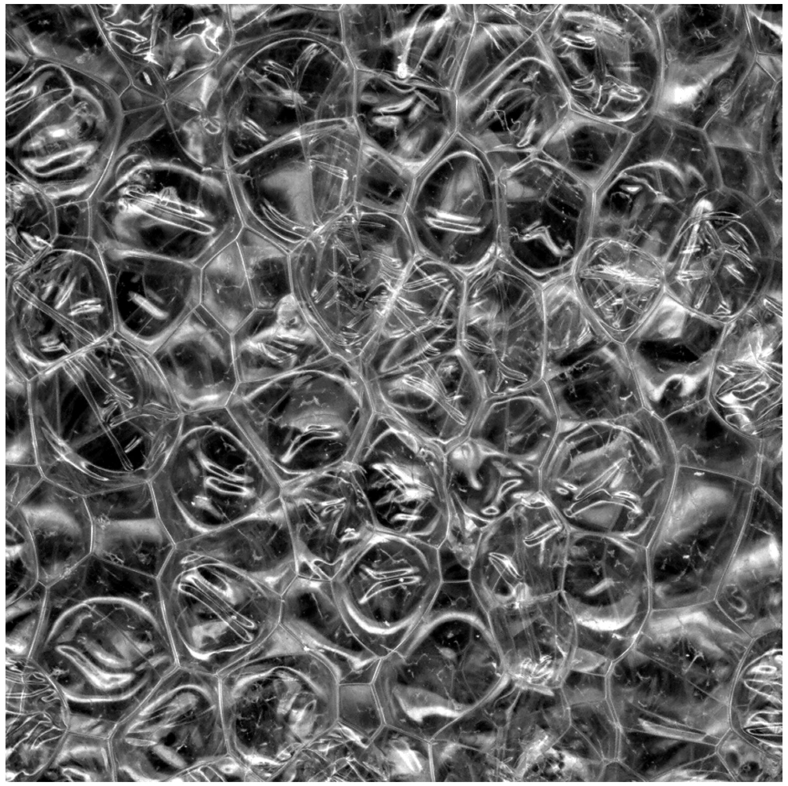
Hadron ID with TOF
Event characterisation with PSD
Tracking with STS and MVD



The transition radiation detector



Irregular radiator

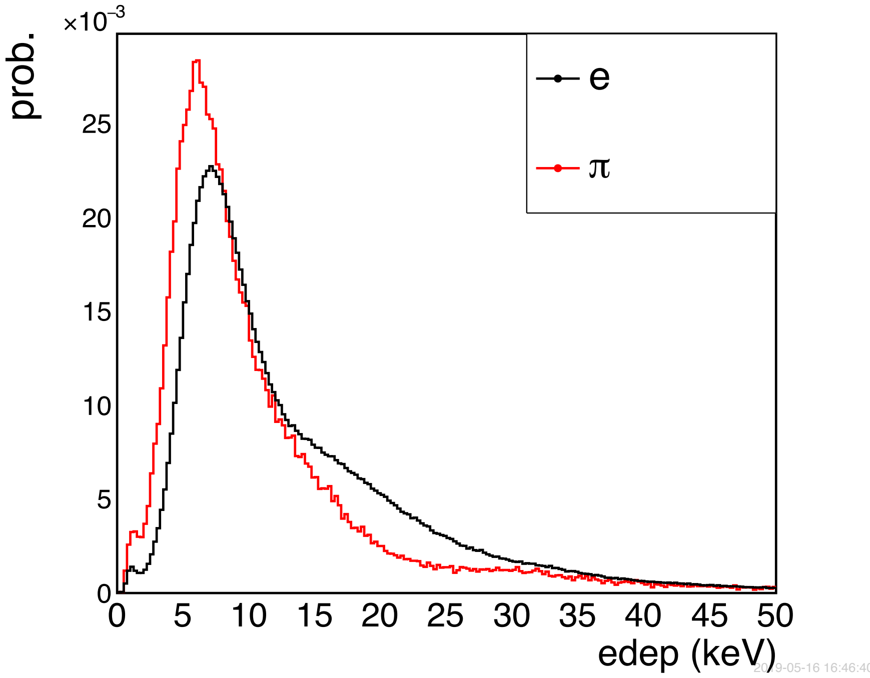


Working principle

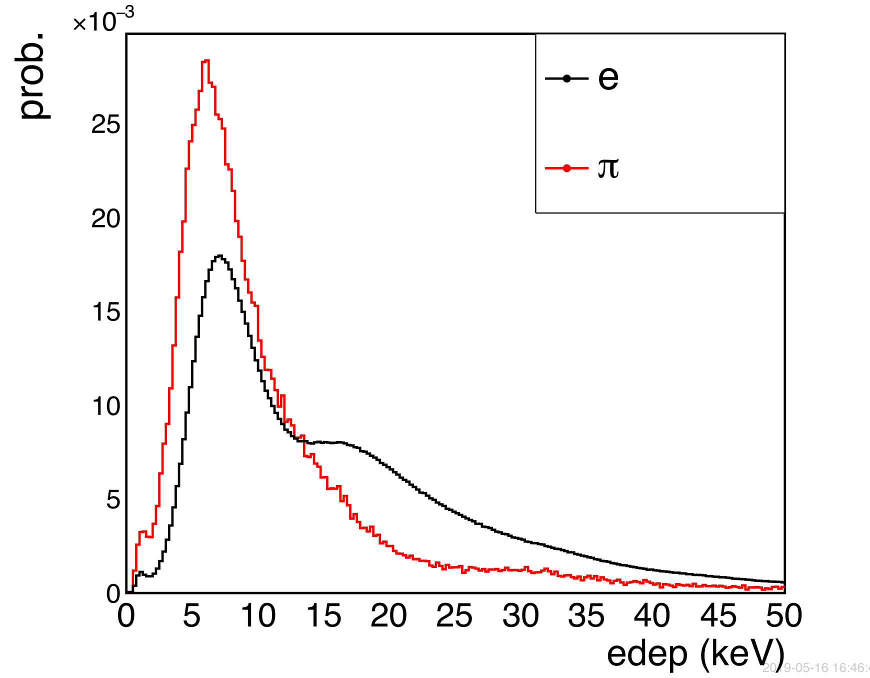
- Charged particles deposit energy in the detector gas
- Electrons create transition radiation in the radiator, which deposits additional energy
- TR production strongly depends on the Lorentz factor of the particle
  - Electrons and pions create very distinct energy deposition spectra

Energy deposition in the TRD

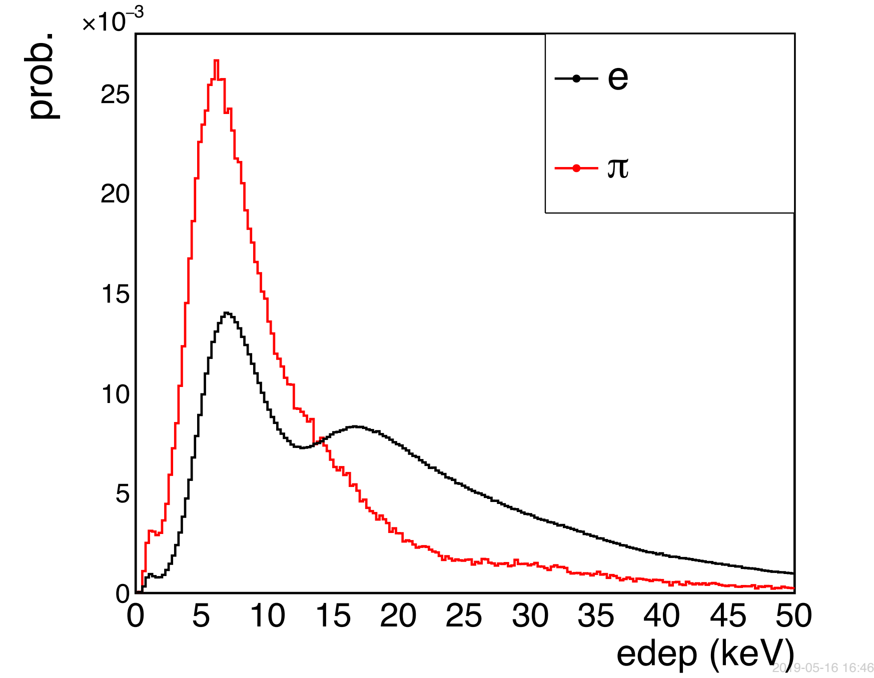
0-1 GeV/c



1-3 GeV/c

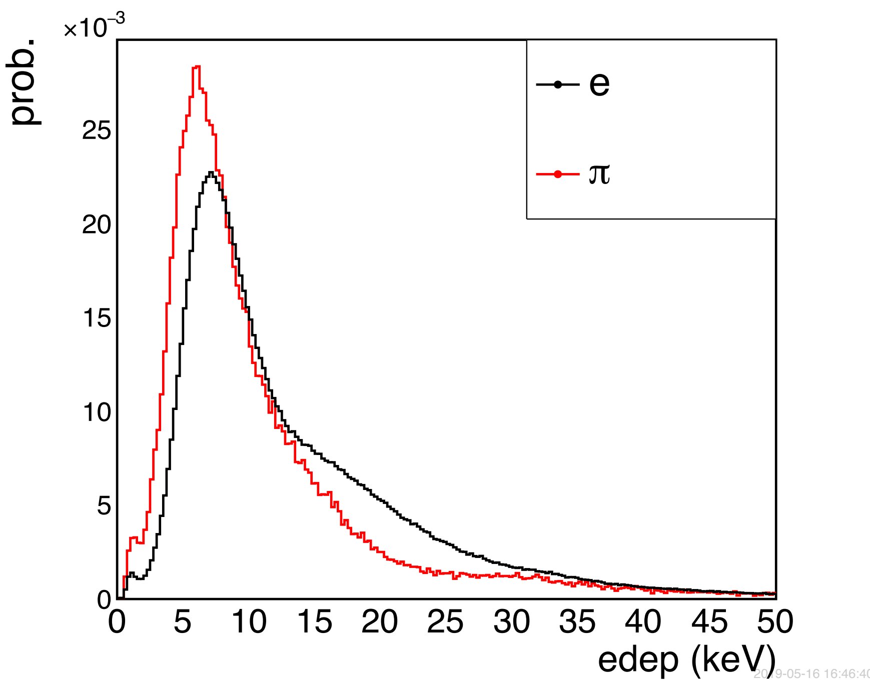


3-20 GeV/c

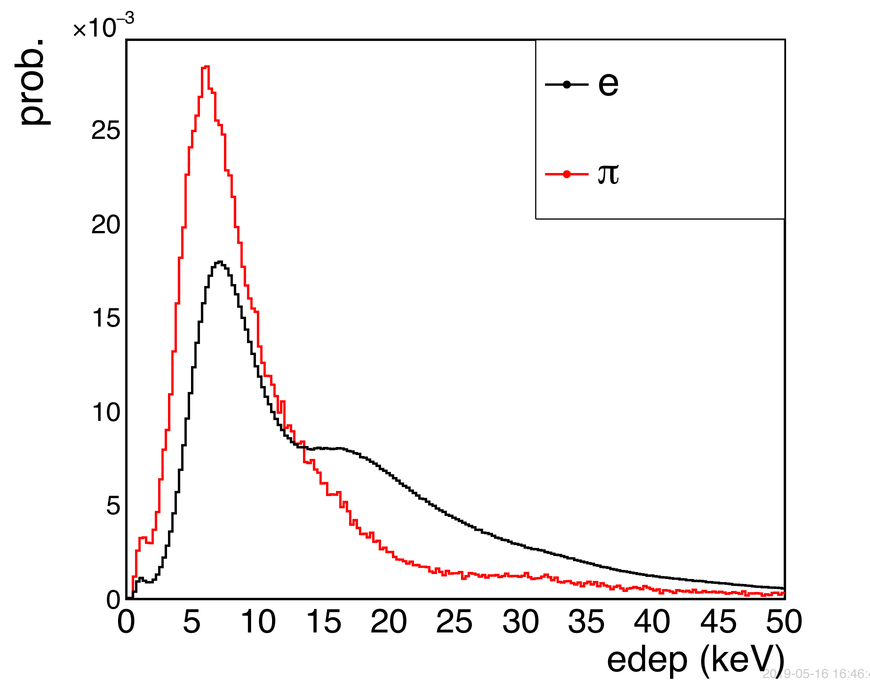


PID with the energy dep. information

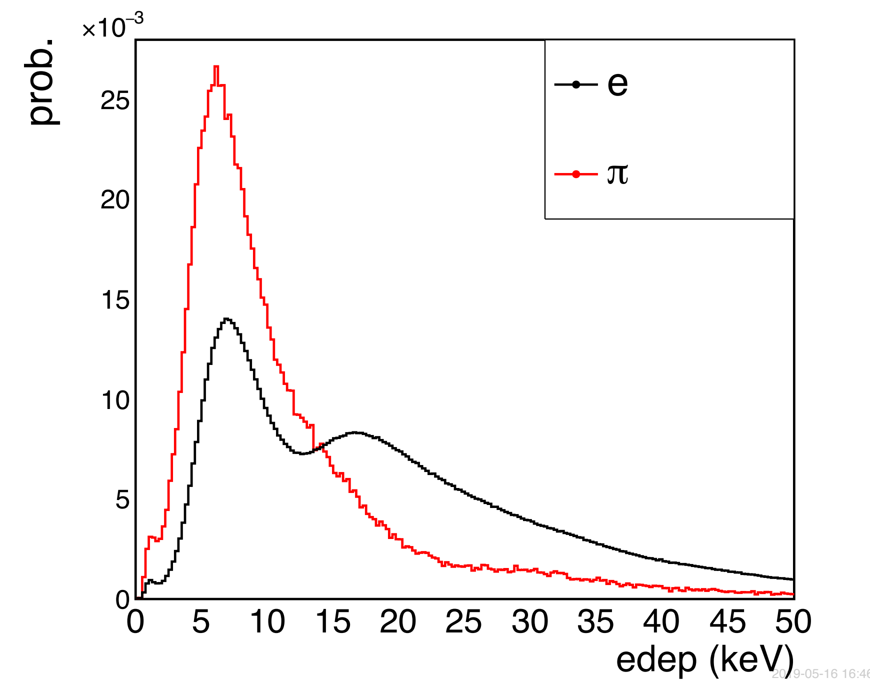
0-1 GeV/c



1-3 GeV/c



3-20 GeV/c

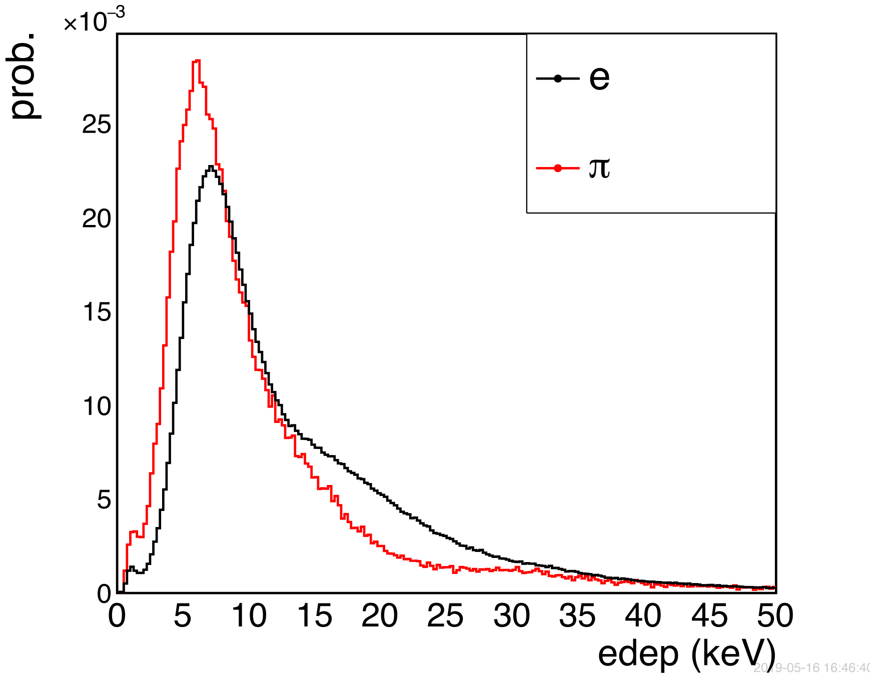


The likelihood of a particle to be an electron can then be calculated via:

$$L_e = \frac{p_e}{p_e + p_\pi}$$

PID with the energy dep. information

0-1 GeV/c



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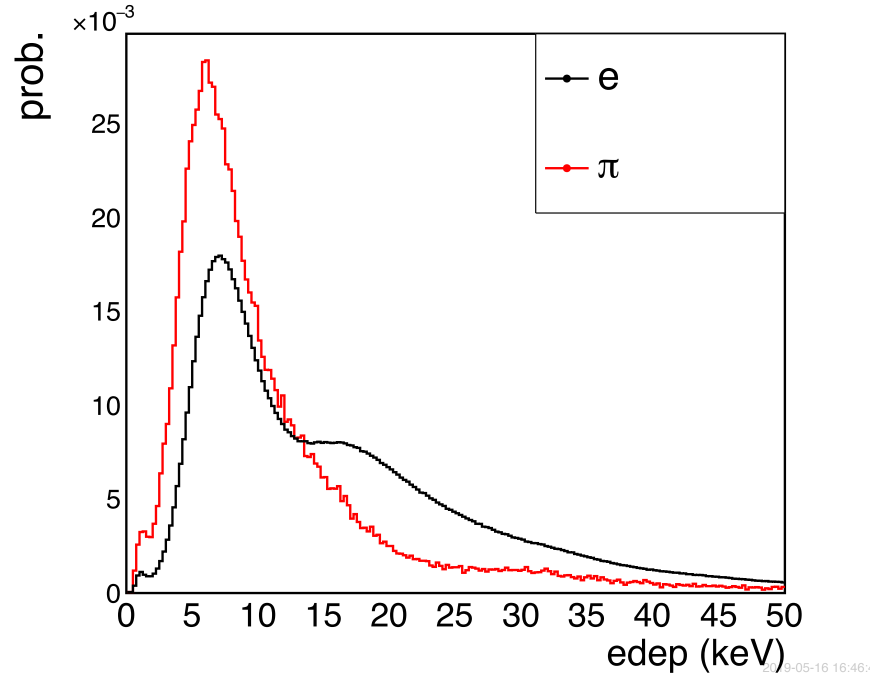
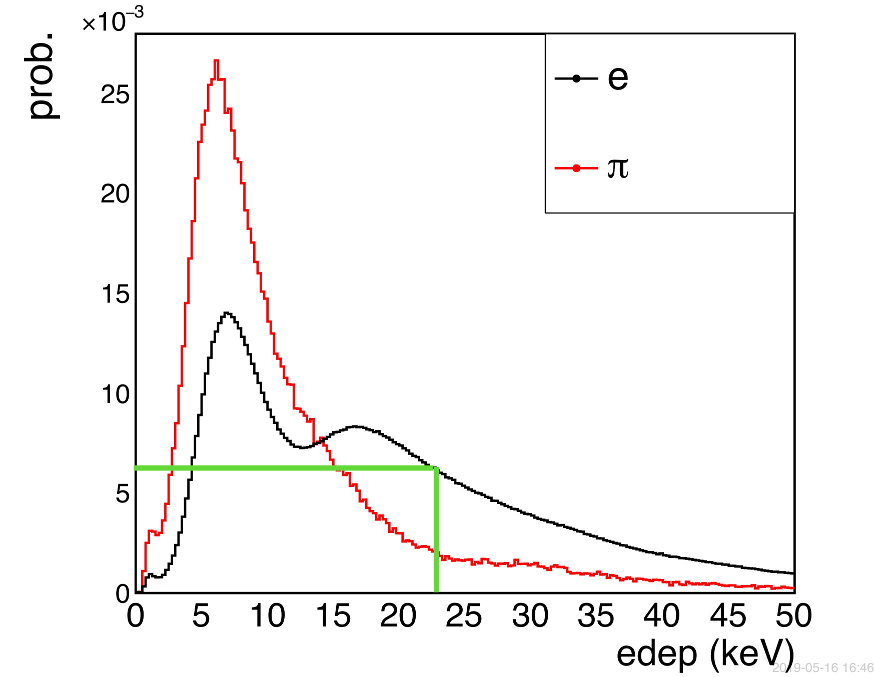


3-20 GeV/c

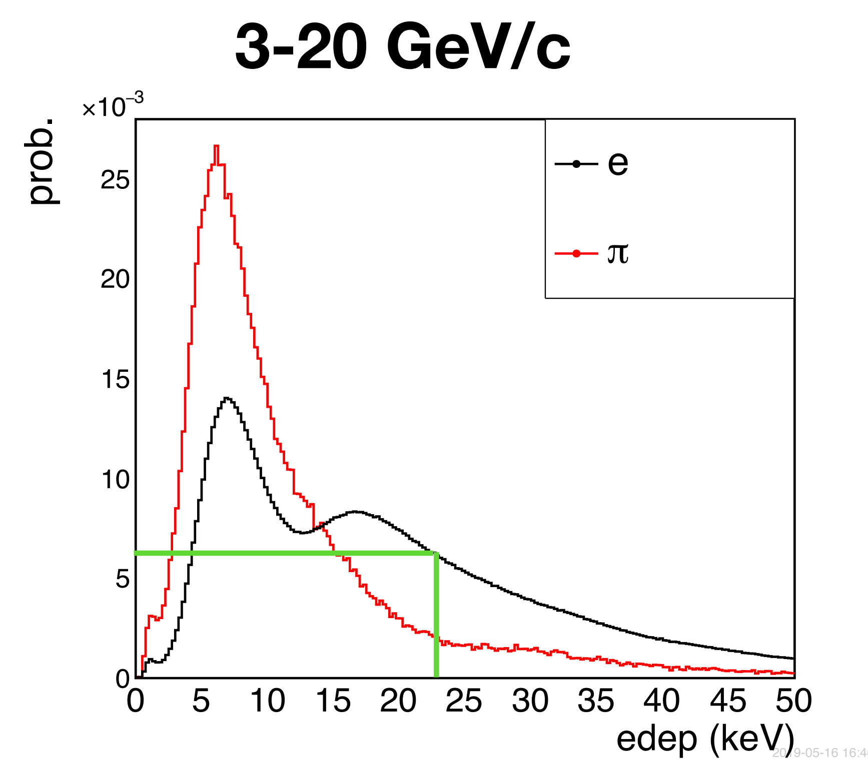


The likelihood of a particle to be an electron can then be calculated via:

$$L_e = \frac{p_e}{p_e + p_\pi} = \frac{0.006}{0.006 + 0.0002} = \frac{3}{4}$$

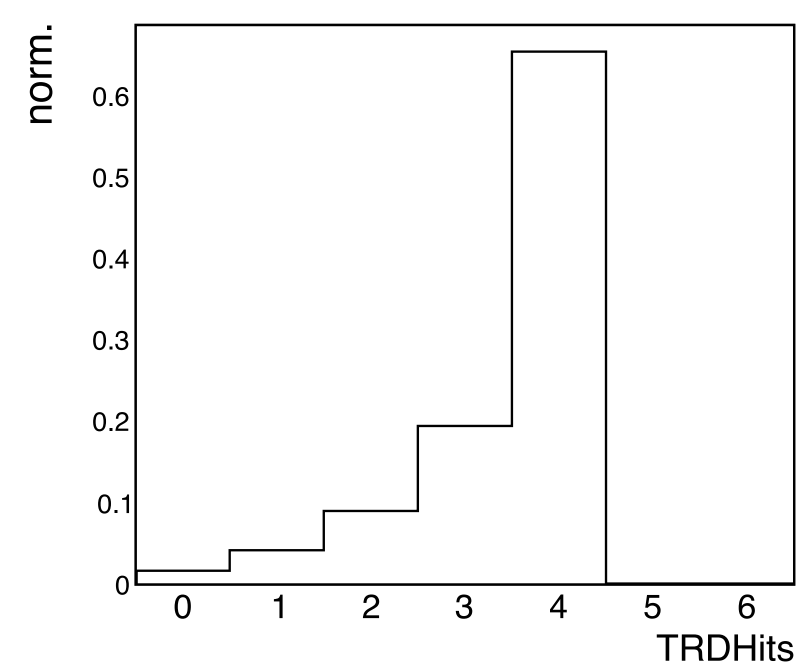
PID with the energy dep. information

$$L_e = \frac{p_e}{p_e + p_\pi} = \frac{0.006}{0.006 + 0.0002} = \frac{3}{4}$$



With multiple hits in the detector this becomes:

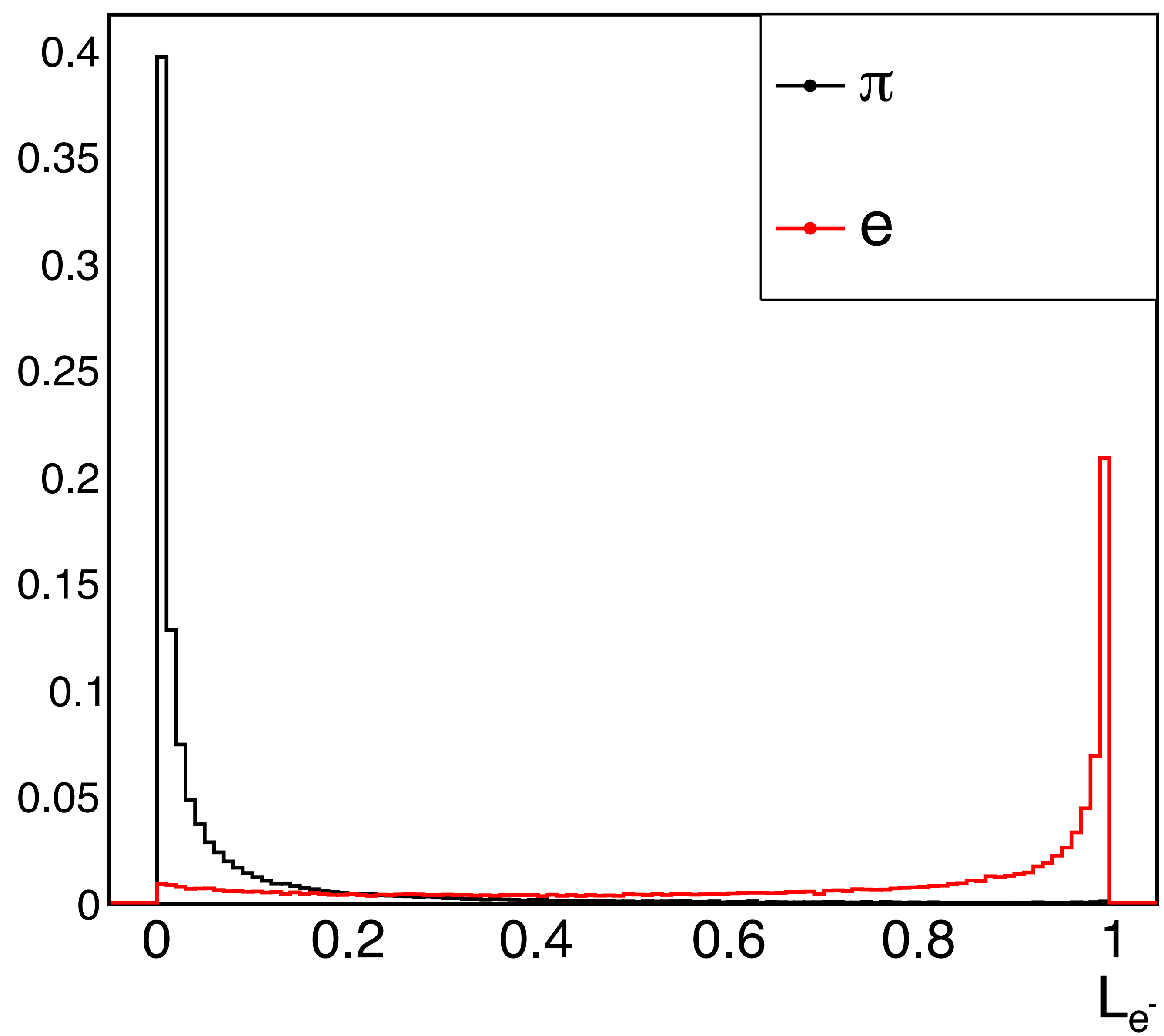
$$L_e = \sum_i \frac{p_{e_i}}{p_{e_i} + p_{\pi_i}}$$



Likelihood PID with the TRD

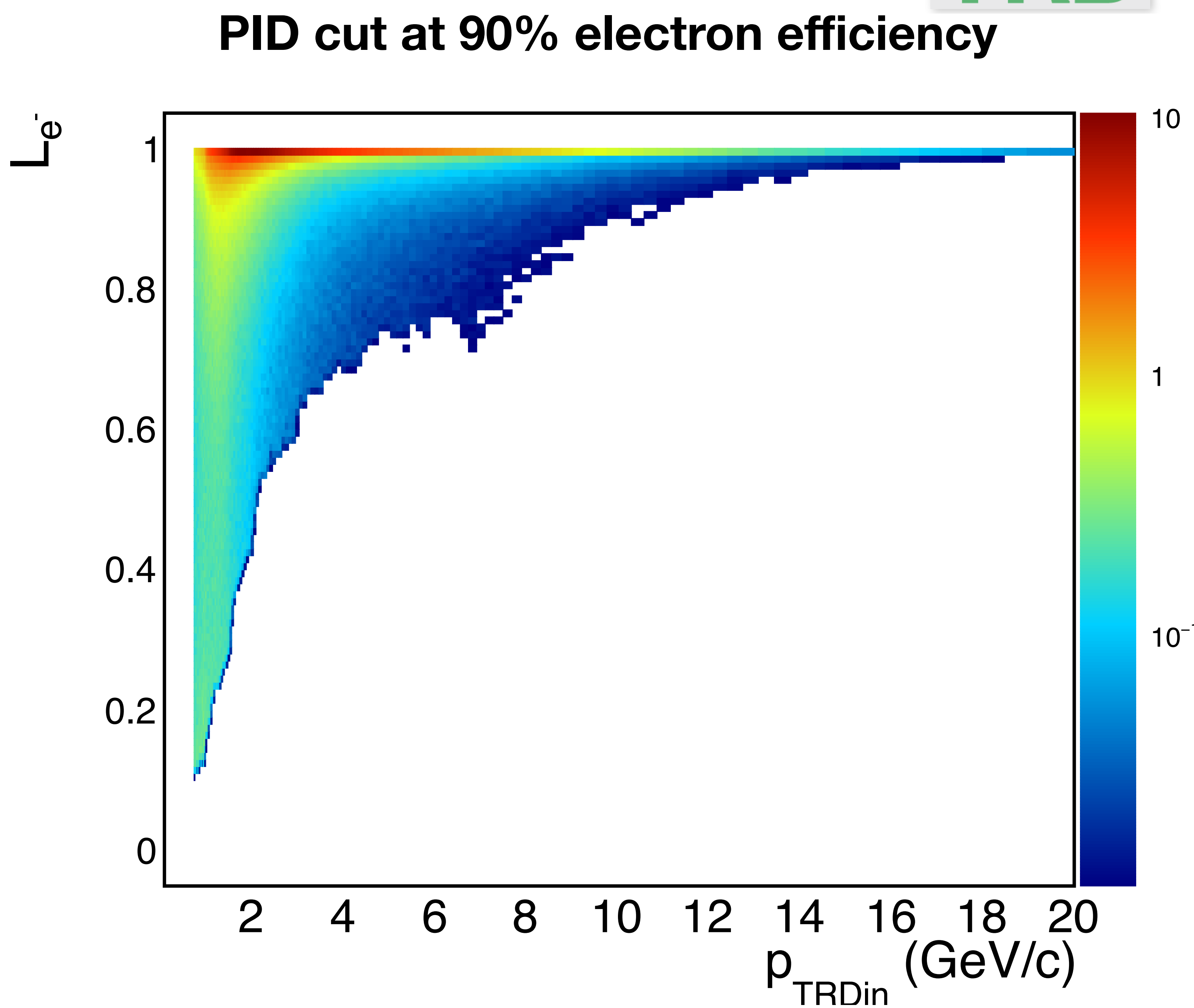
$$L_e = \sum_i \frac{p_{e_i}}{p_{e_i} + p_{\pi_i}}$$

We get two very clear and distinct likelihoods for either electrons or pions



Momentum dependance of the Likelihood method

Due to the momentum dependance of the TR production we need two dimensional PID



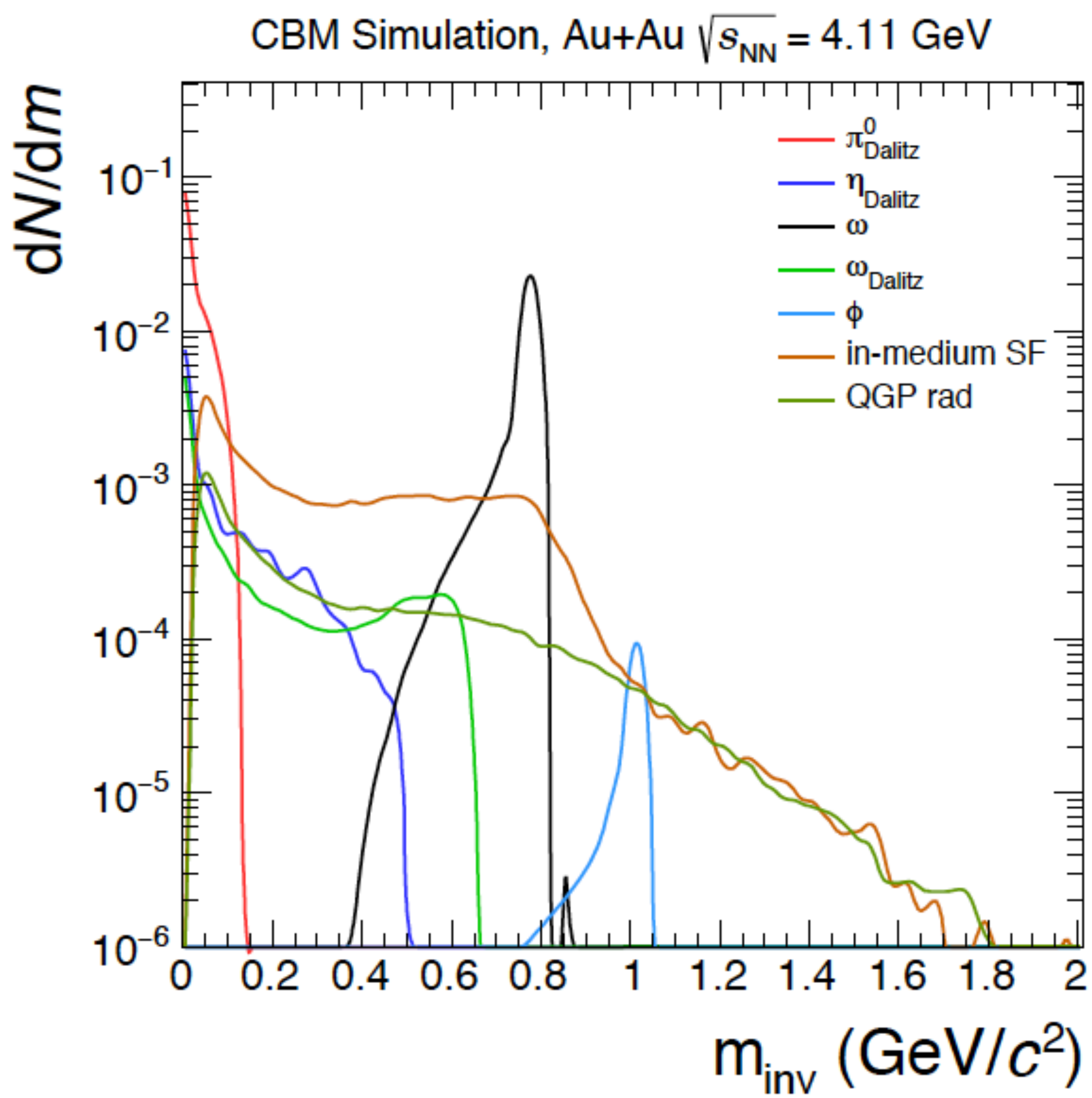
Simulation information

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 obtained with a fireball model and a coarse-graining approach
(T. Galatyuk et al., Eur. Phys. J. A52 (2016) 131)

Electron identification
RICH: ANN output
TRD: Likelihood method
TOF: Cut on β_{meas} - β_e

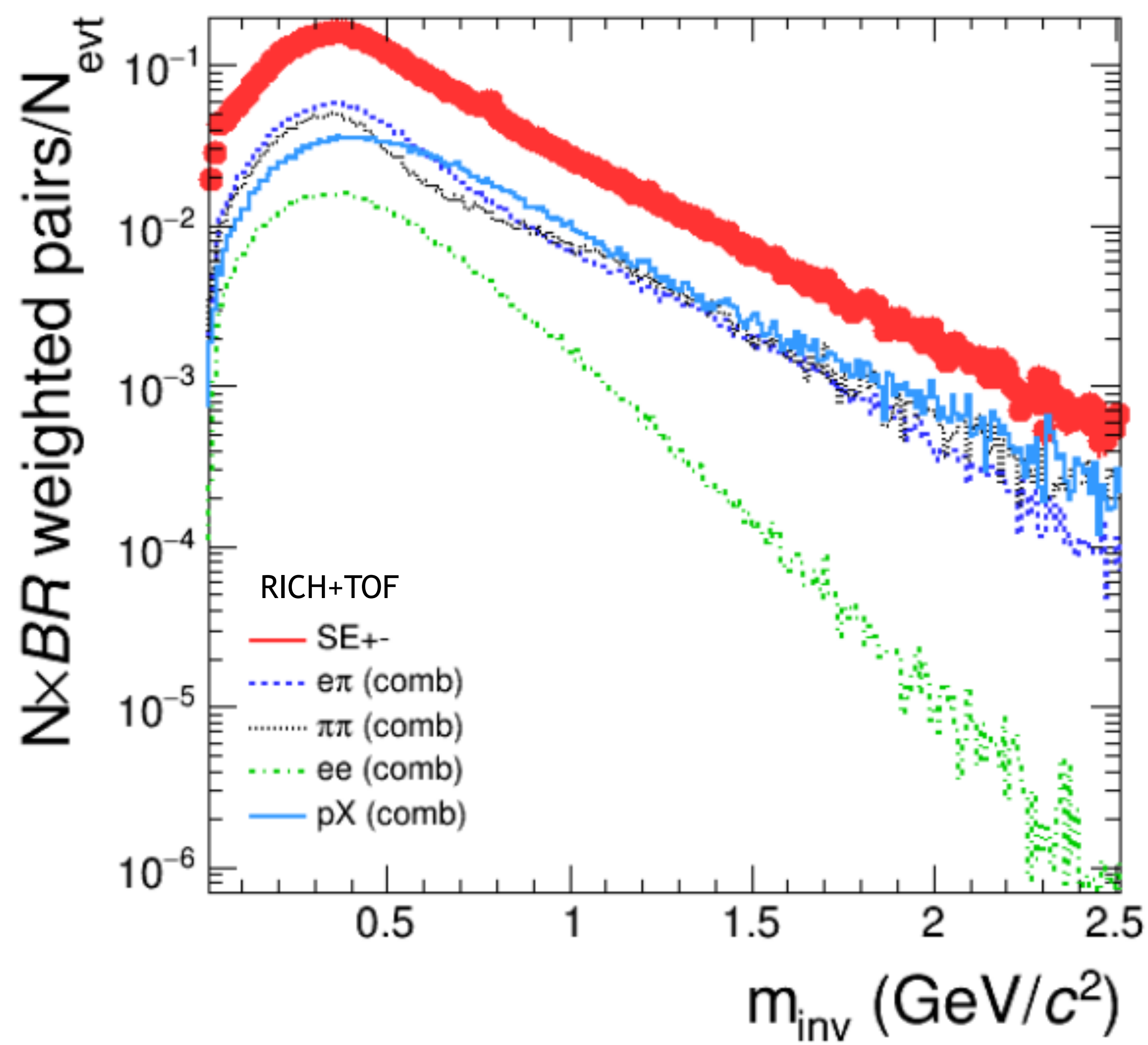


Invariant mass distribution without TRD PID

The selected unlike sign pairs contain a large amount of hadronic background contributions

Access to the thermal dielectron pairs above 1 GeV/c would not be possible

AuAu (10% most centr.) at 8 A GeV



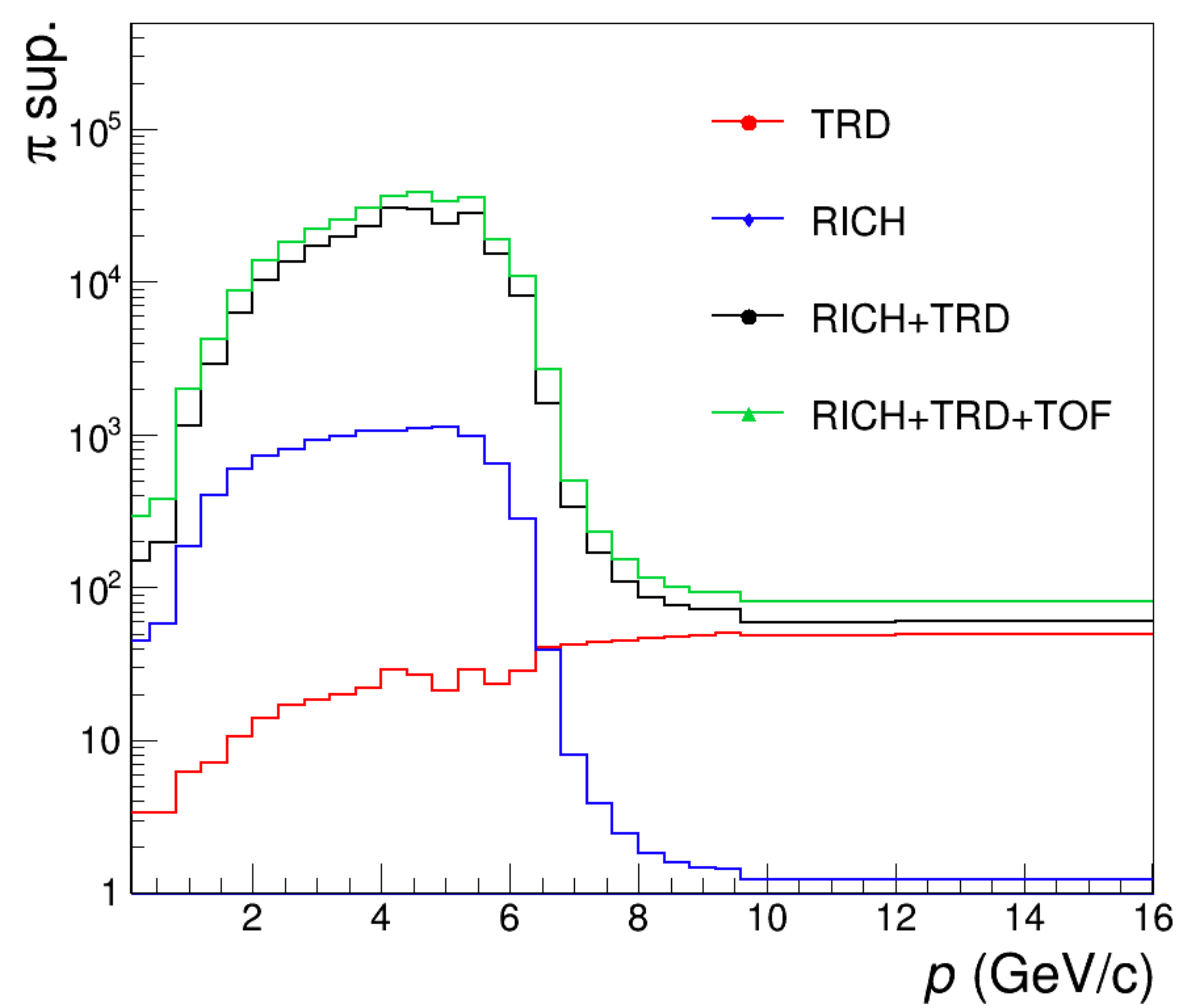
Pion suppression

AuAu (10% most centr.) at 8 A GeV

Very high pion suppression in the low momentum region with the combination of RICH and TRD

Above about 6 GeV/c the TRD delivers the main pion suppression

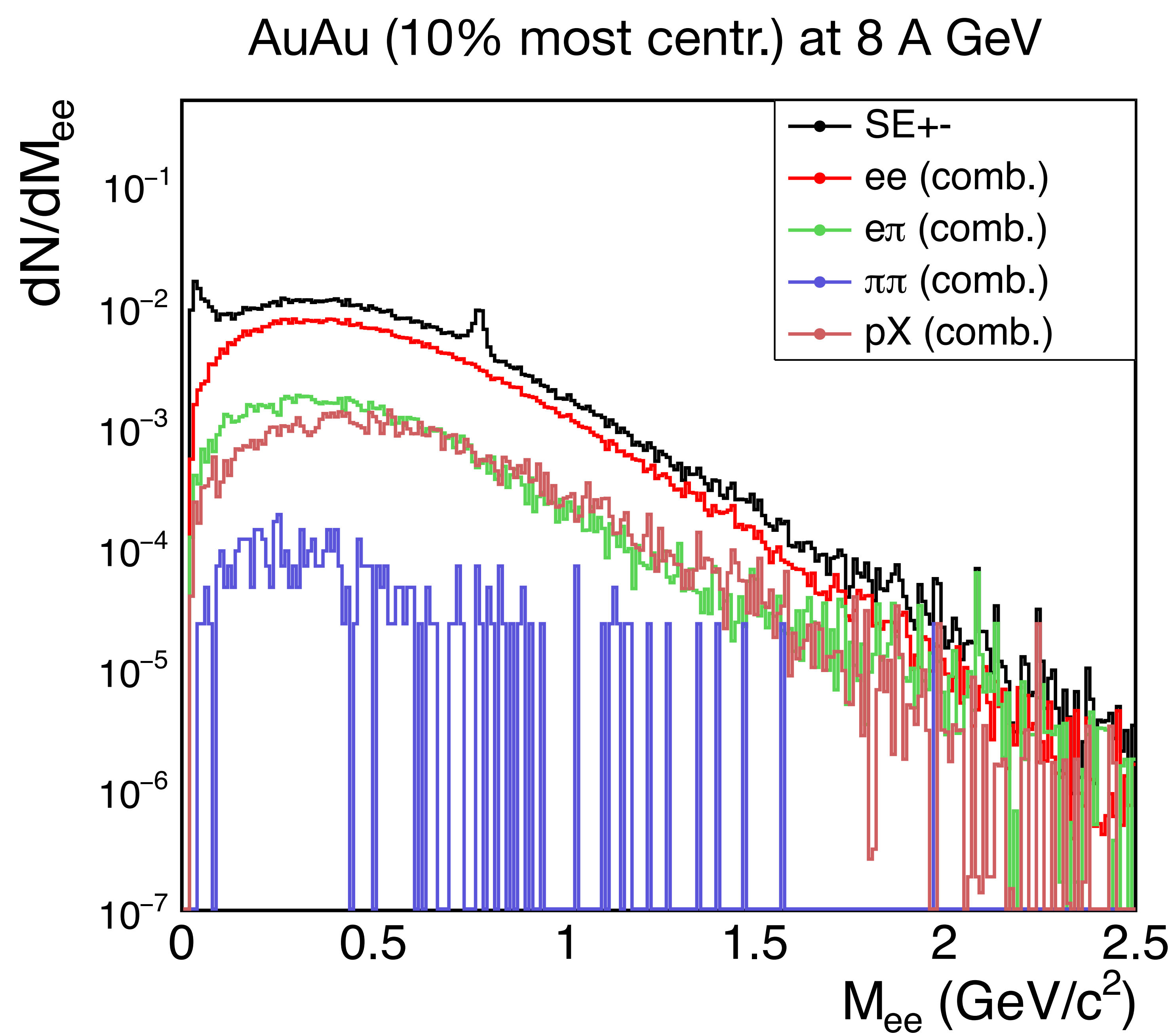
Sufficient pion suppression in the whole momentum region



Invariant mass spectra of background contributions

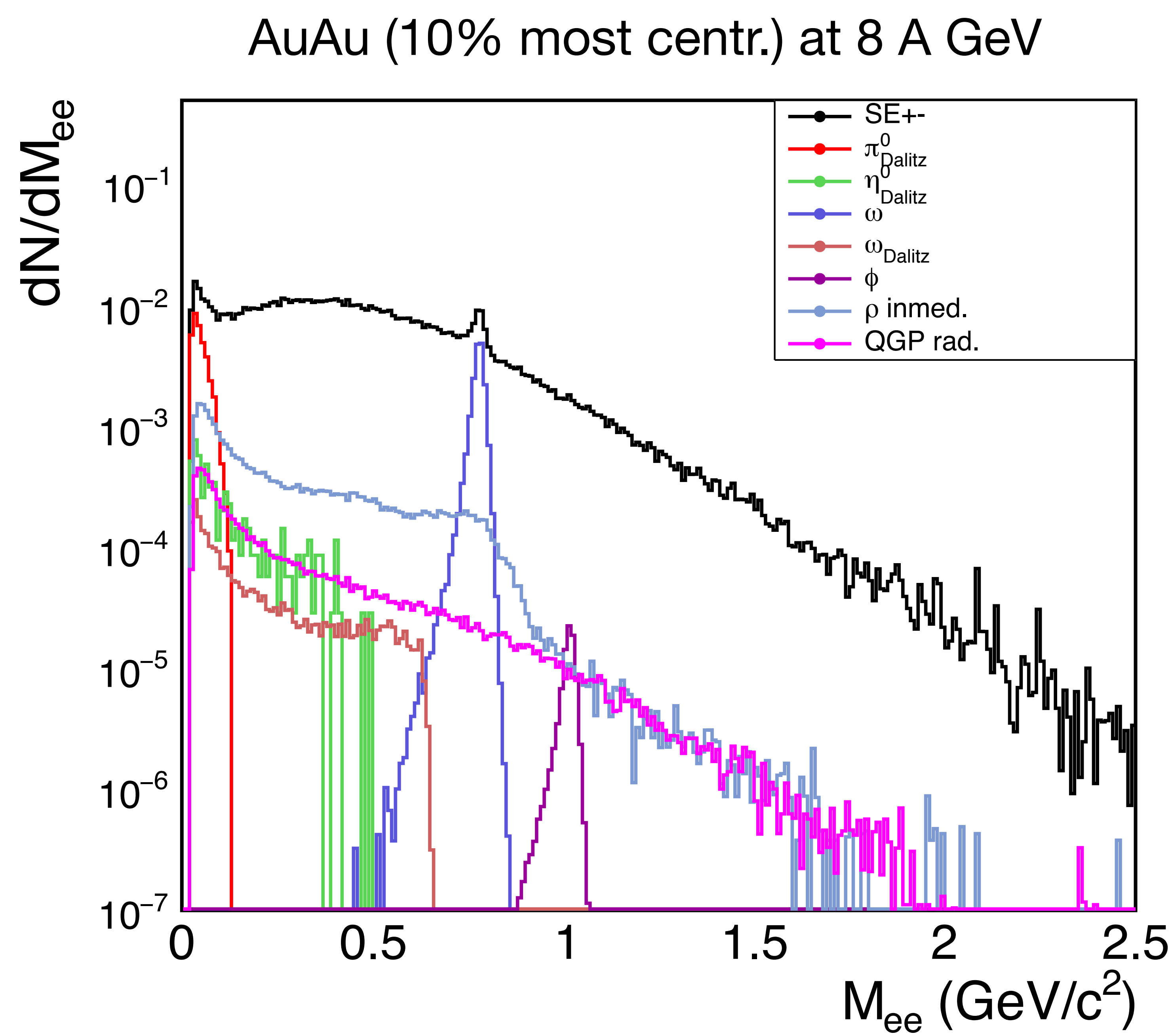
The hadronic background contributions are strongly suppressed

Remaining dielectron contribution is dominant up to 2.5 GeV



Invariant mass spectra of different signals

Clear access to low mass vector mesons and thermal radiation

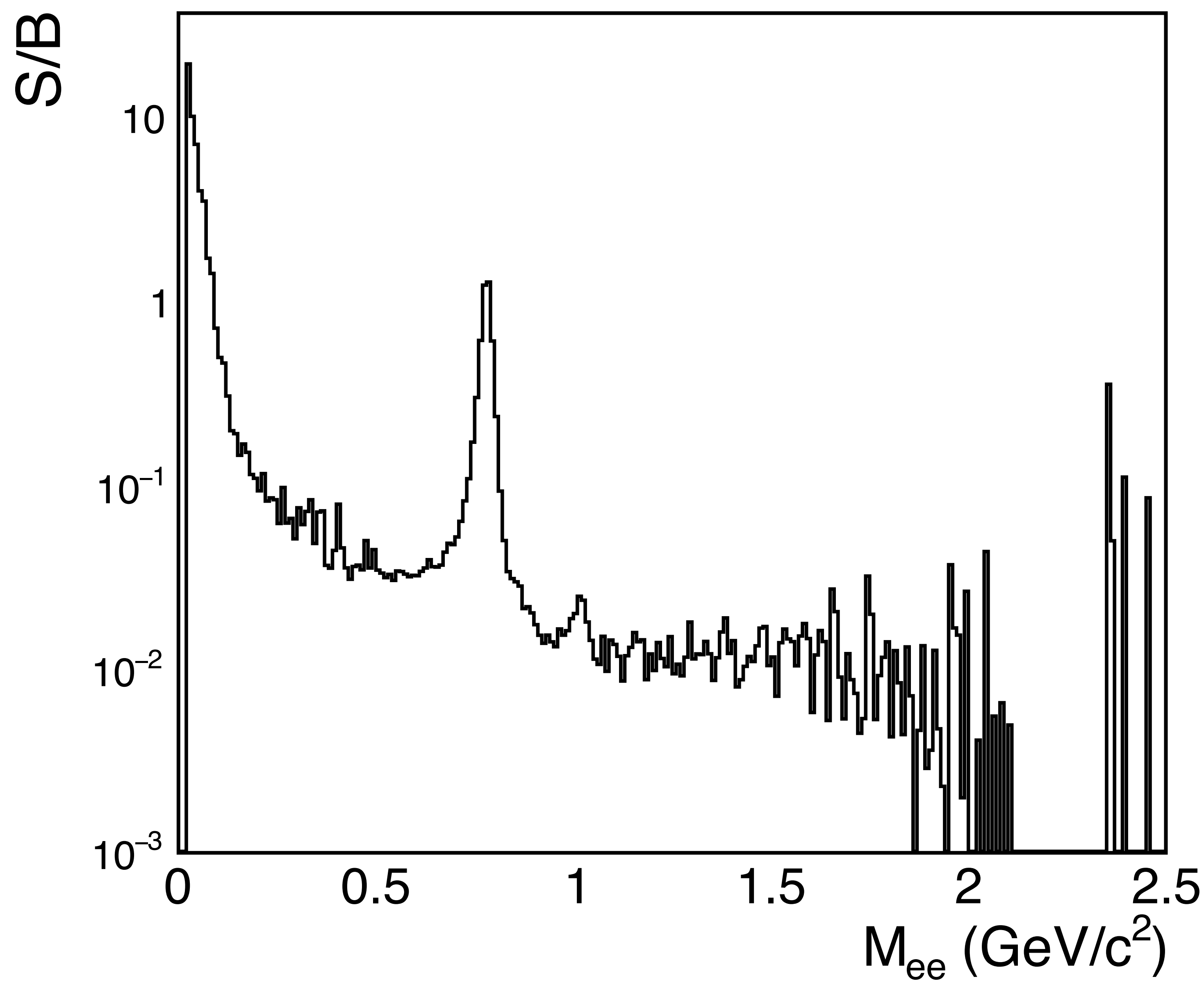


Signal-to-background ratio

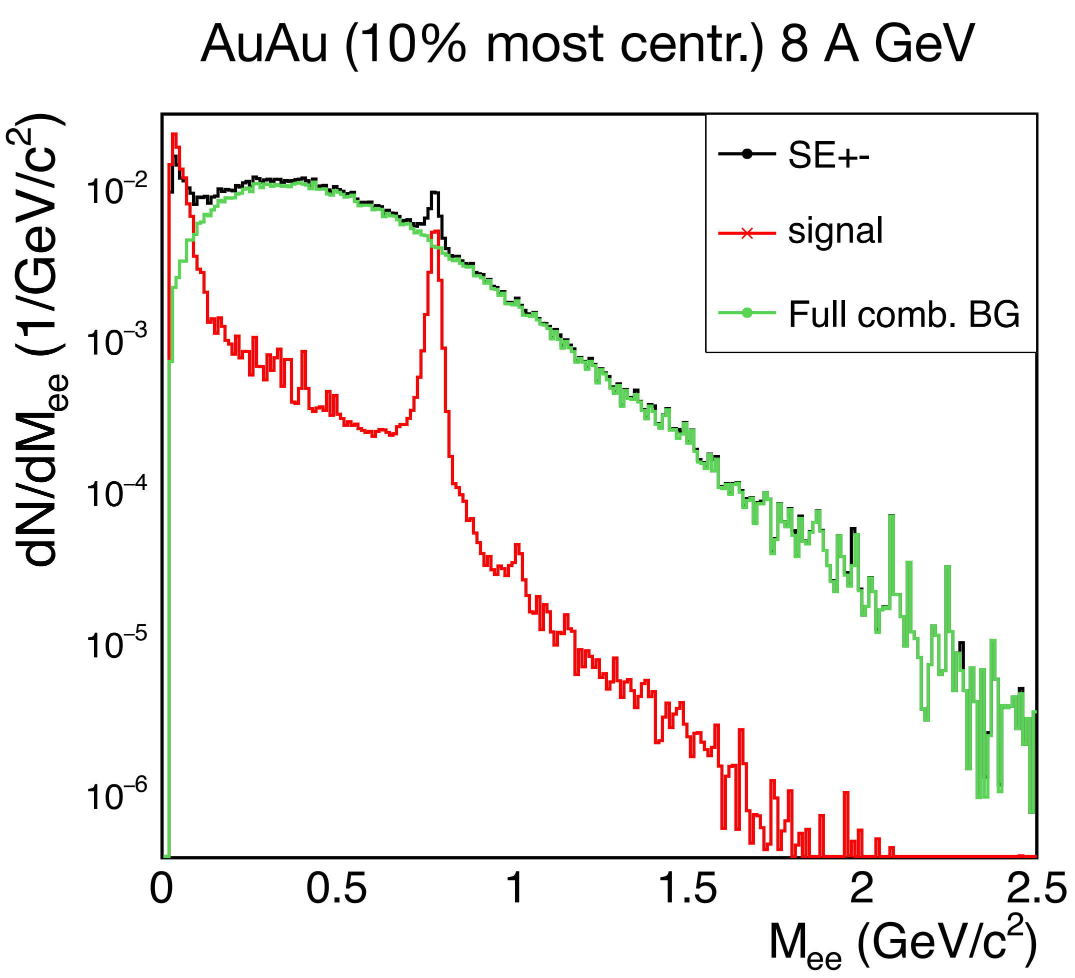
Low mass region and vector mesons show strong peaks in the signal-to-background ratio

Signal-to-background ratio in the IMR is in the order of 1%

AuAu (10% most centr.) at 8 A GeV



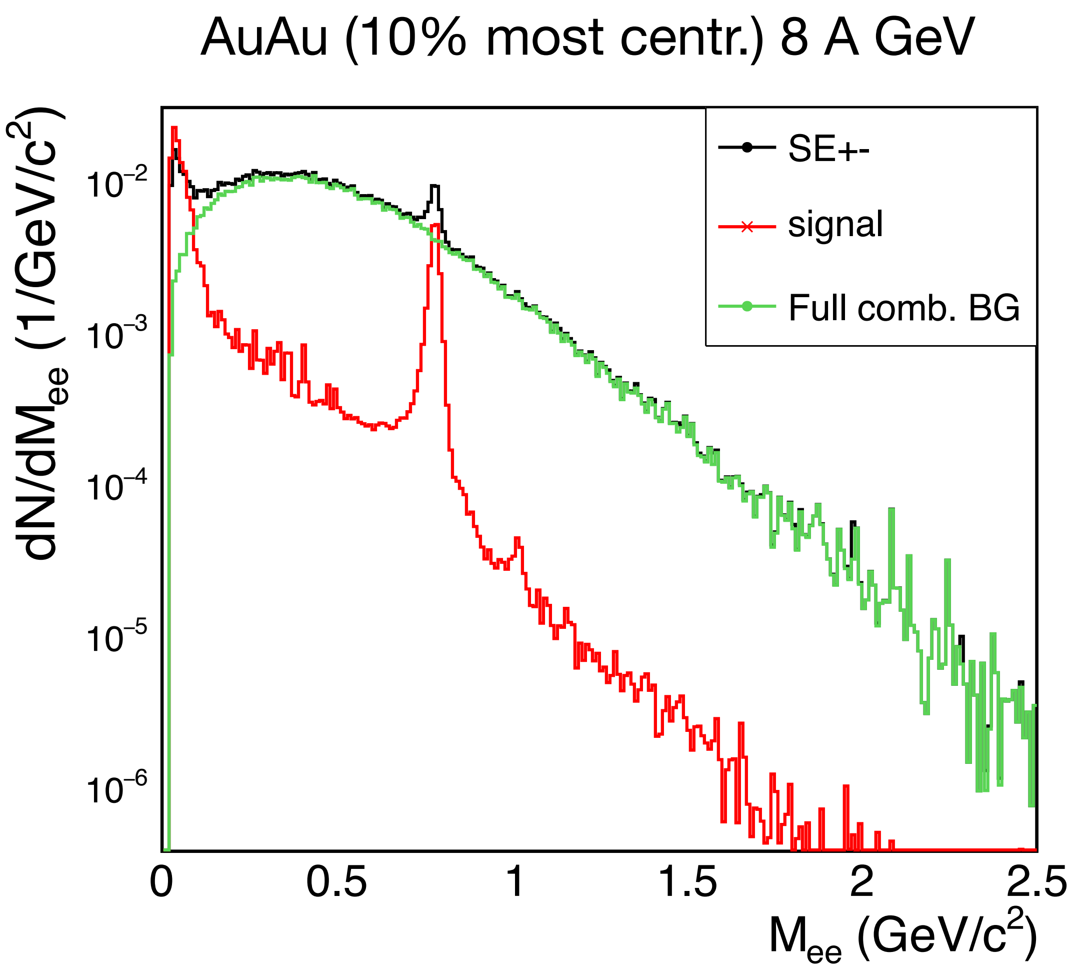
Combinatorial background subtraction

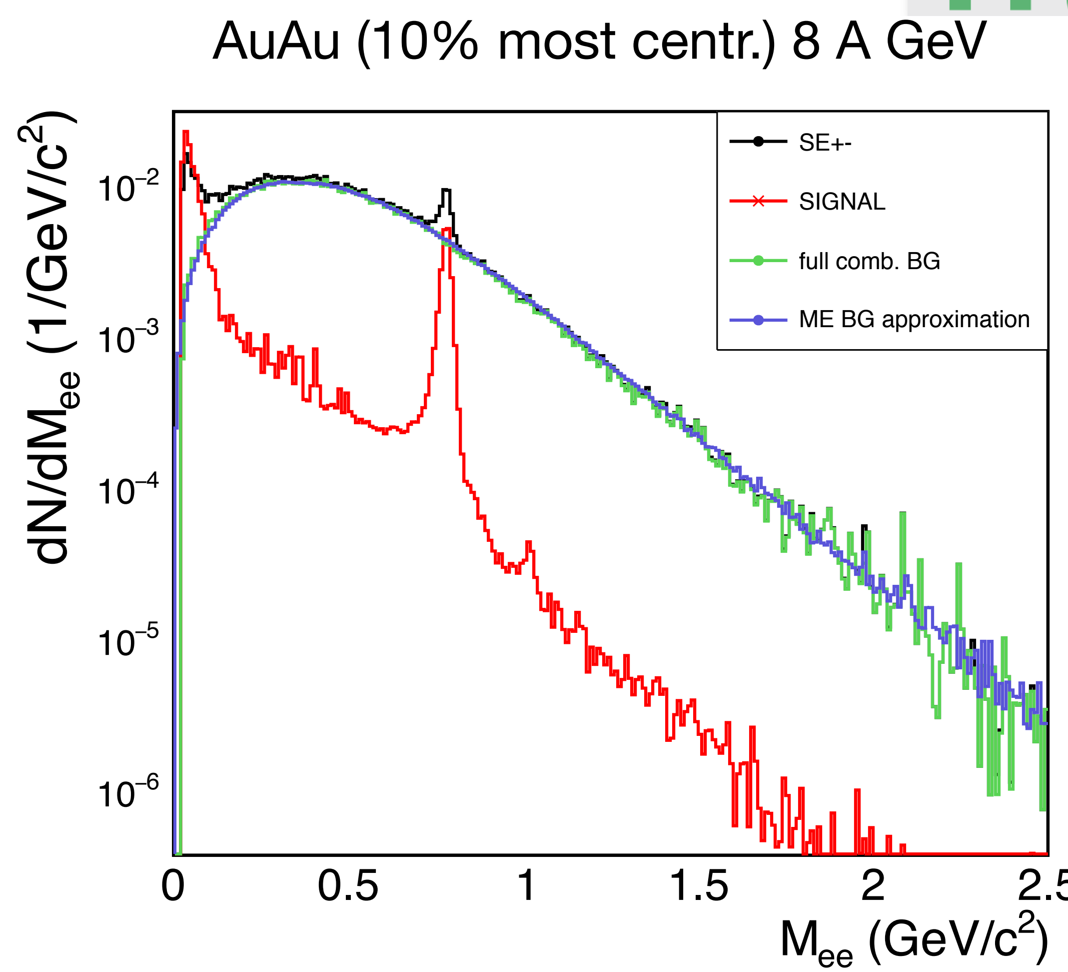


The green line has to be subtracted from the selected unlike sign pairs

Common methods are via the like sign pairs or via event mixing

Combinatorial background subtraction





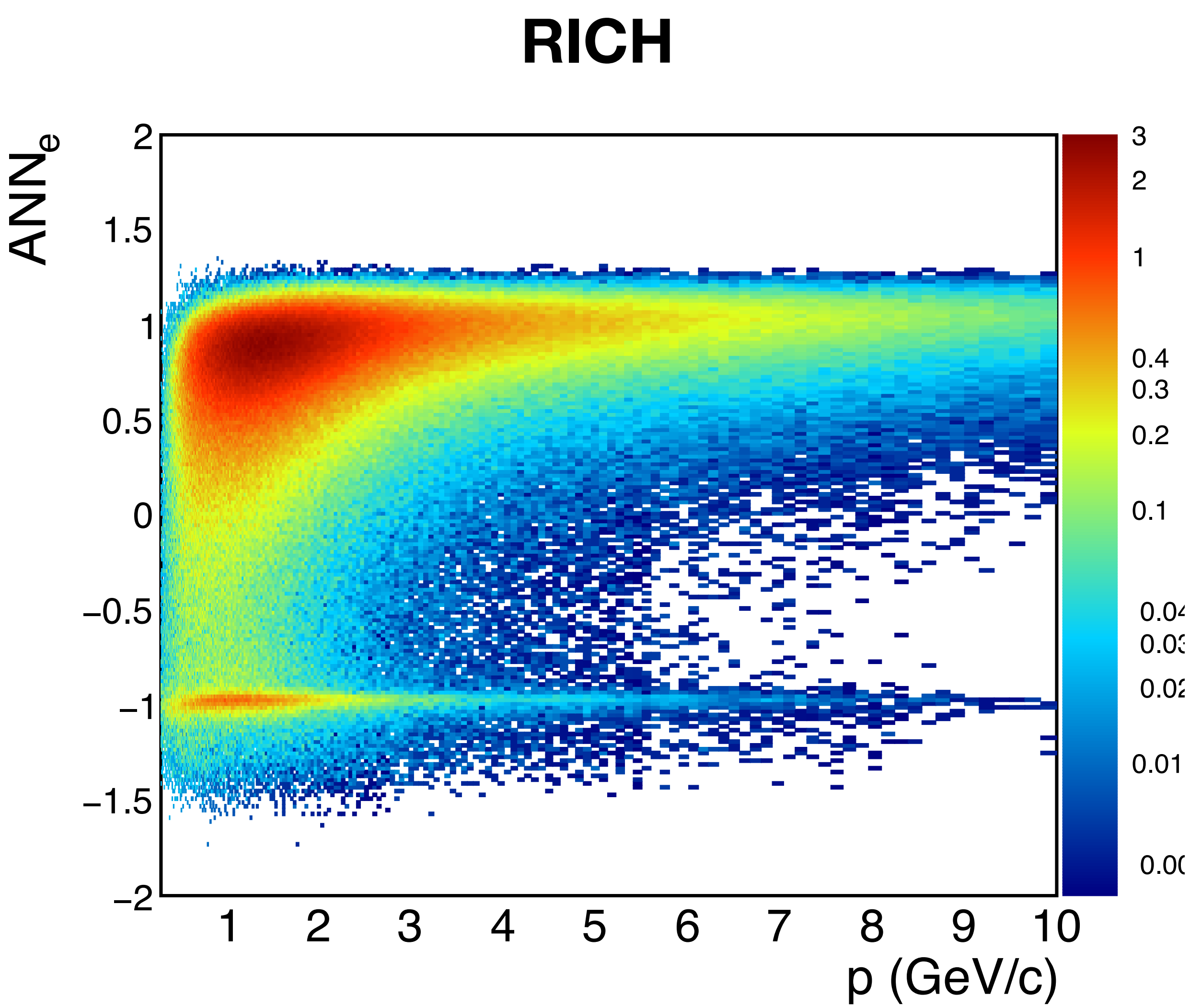
The green line has to be subtracted from the selected unlike sign pairs

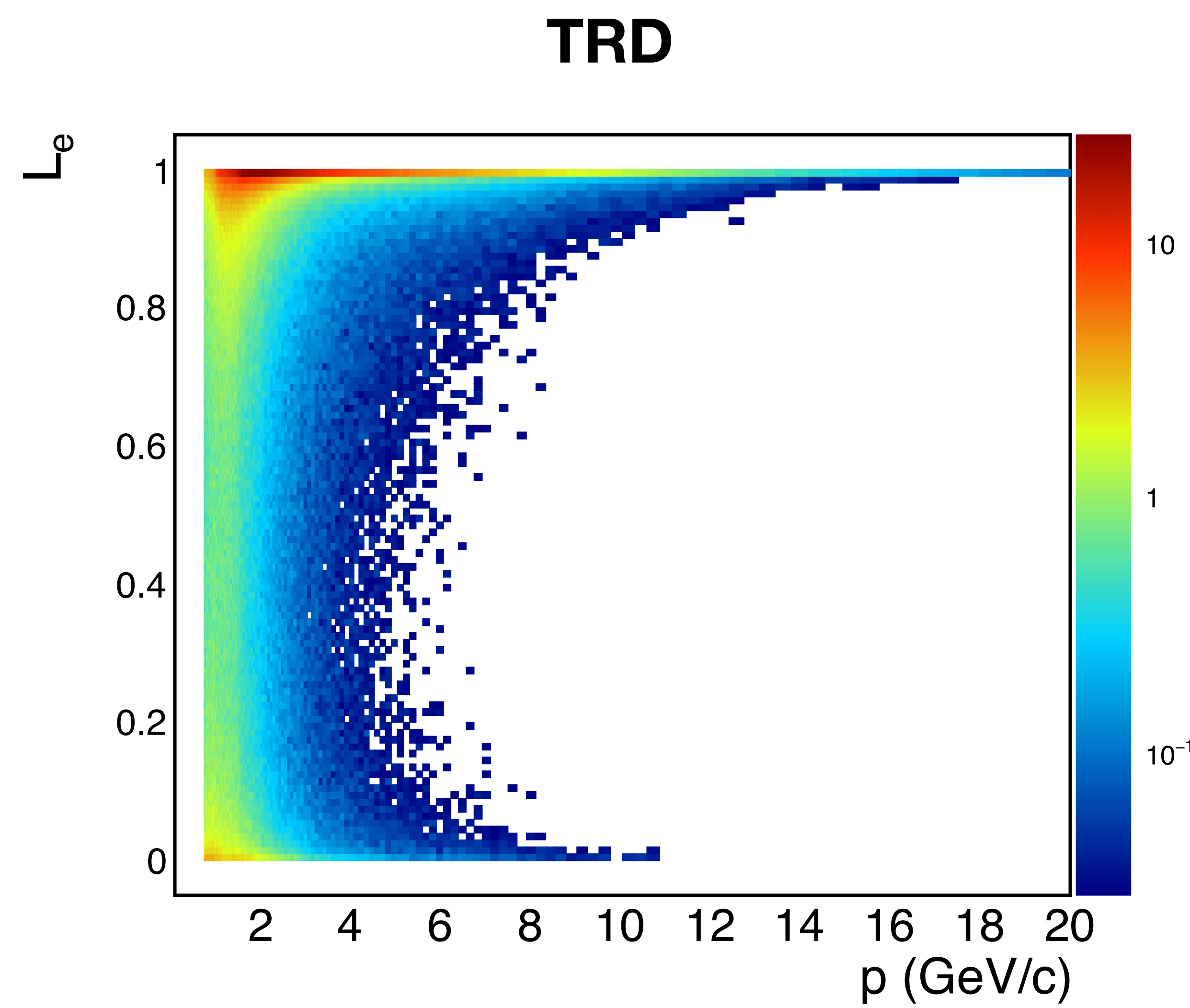
Common methods are via the like sign pairs or via event mixing

Mixed events describes the combinatorial background very well

Simulation statistics still to low for full evaluation

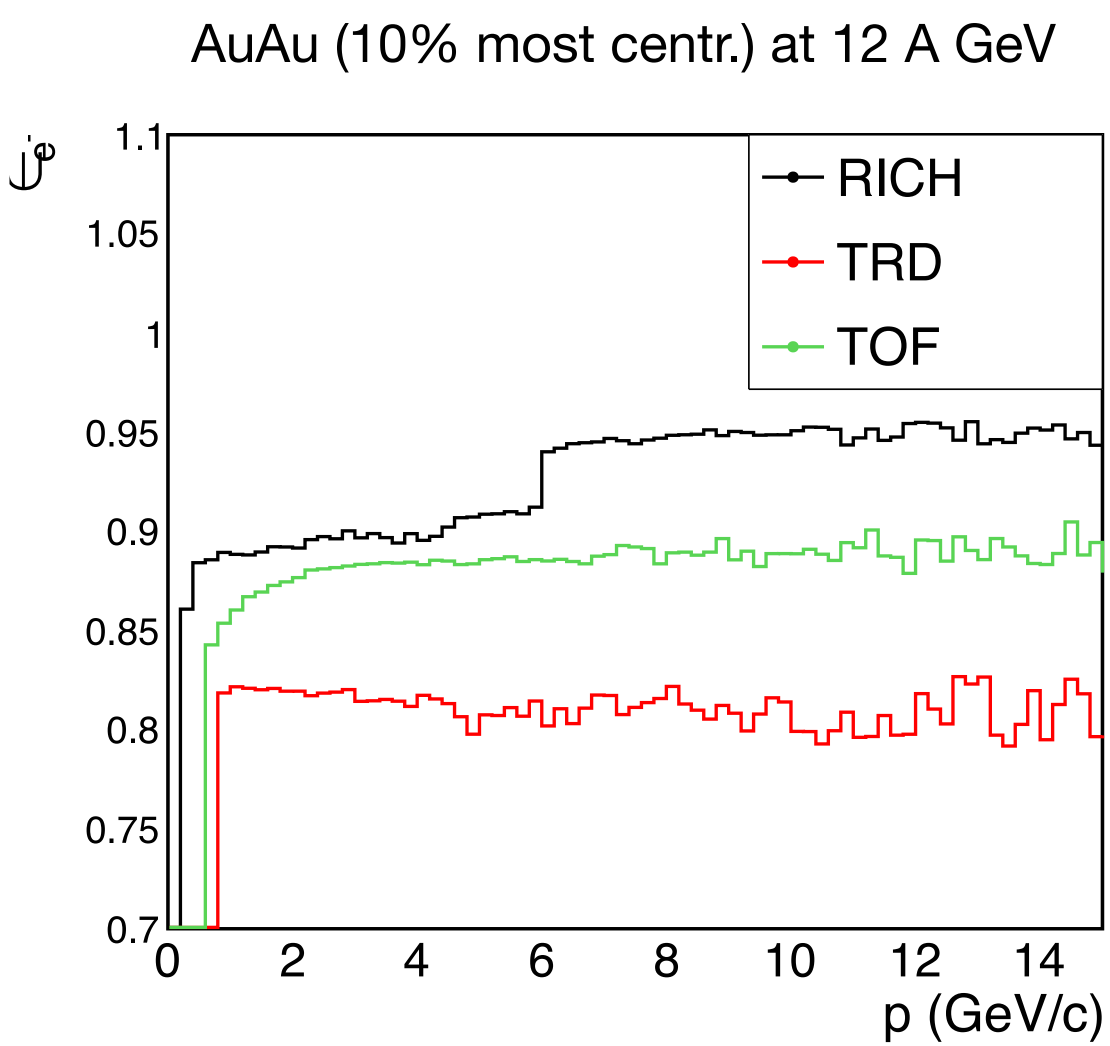
12 A GeV PID information for electron tracks

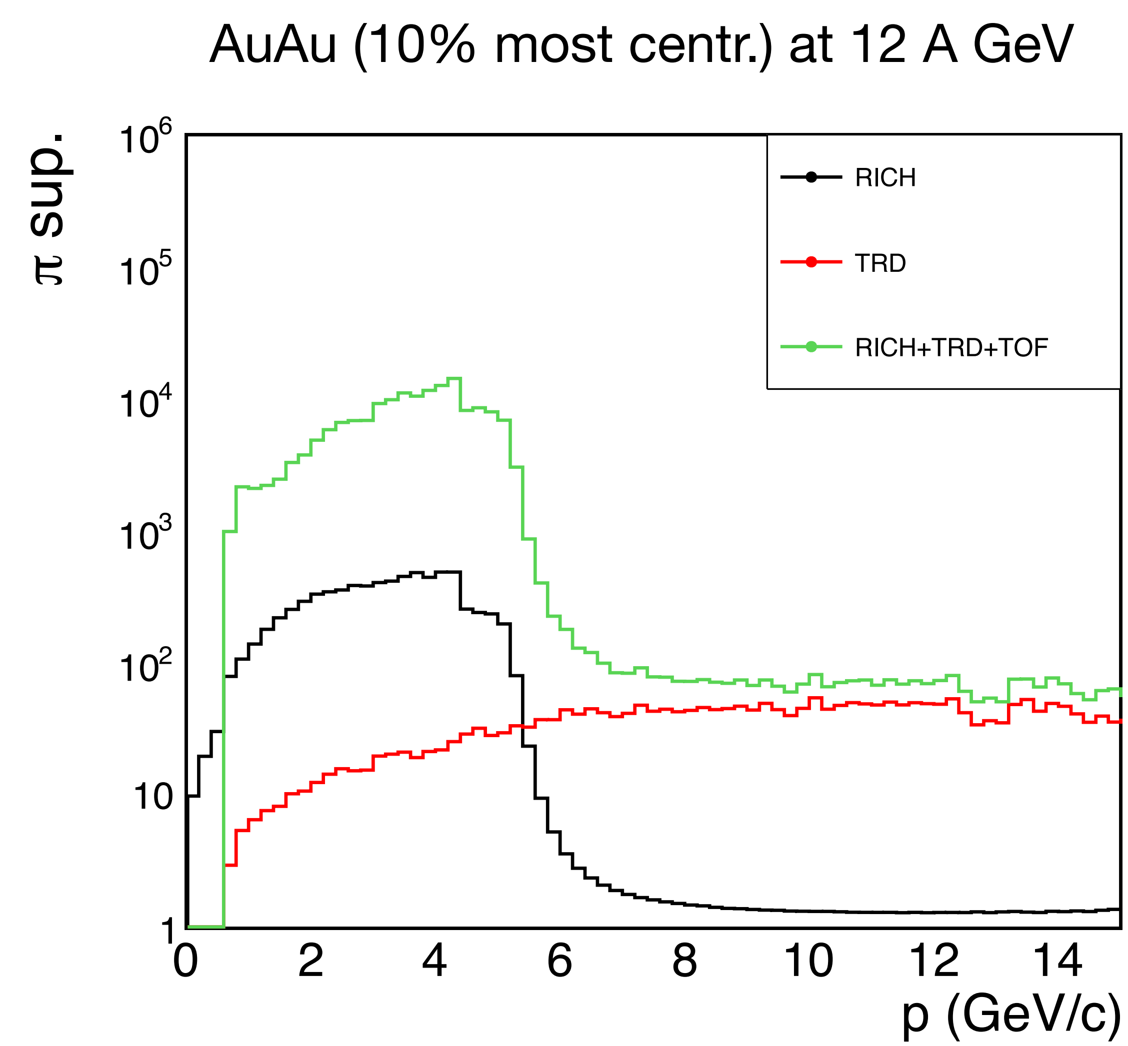




12 A GeV simulations already
shows good electron ID

Electron efficiency and pion suppression at 12 A GeV





We already see again a good pion suppression in the whole momentum region

Conclusion

CBM

The CBM experiment provides unique opportunities to measure up to now unexplored observables in the CBM energy region

TRD

The TRD will deliver very crucial PID information to access the rare dielectron channels in the IMR

Also important for the CBM hypernuclei program

Dileptons

The dilepton program of CBM promises to give essential insight into the fireball parameters

Outlook

Finalise 12 A GeV and 5 A GeV simulations to explore the whole energy range of the future CBM experiment