DILEPTON RADIATION FROM COMPRESSED BARYONIC MATTER

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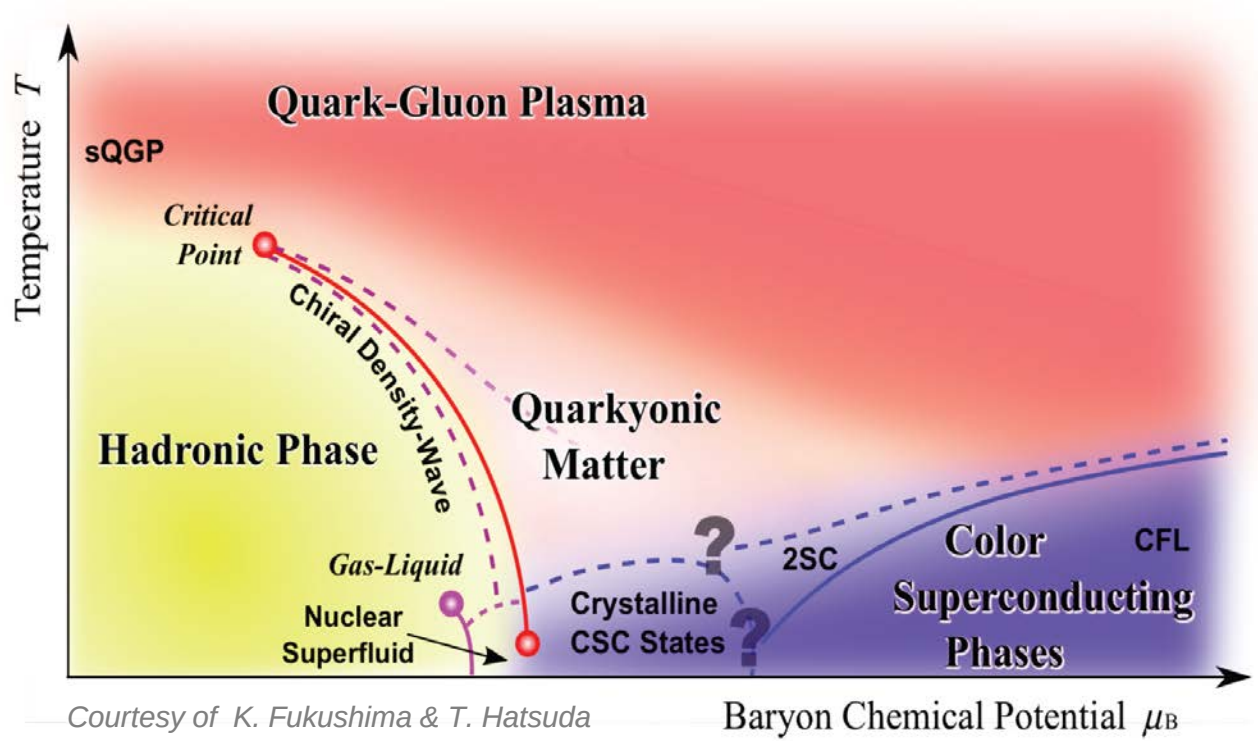
Space like and Time like electromagnetic Baryonic transitions
May 8-12, 2017; ECT*; Trento, Italy

- Motivation
- Spectrometer performance
- Strangeness
- Virtual Photon Radiation
- Future
- Summary

The QCD Phase Diagram



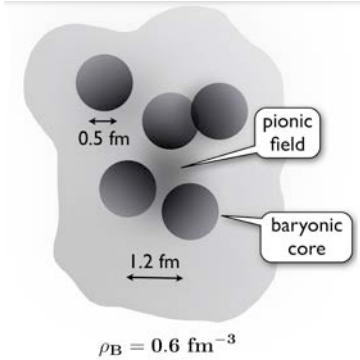
Courtesy of K. Fukushima & T. Hatsuda

Search for:

- New (exotic) phases
- 1. order transition to deconfined matter
- Critical point
- EOS of dense (and hot) QCD matter

Low-temperature approach:

- Chiral perturbation theory

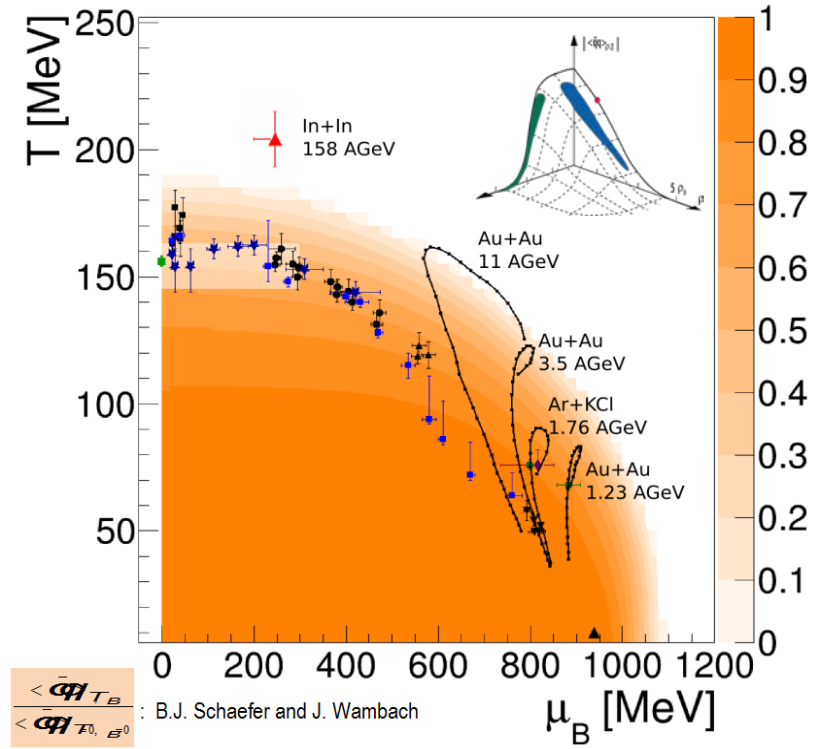


J.W. Holt, M. Rho, W. Weise arXiv1411.6681

The QCD Risotto …

... what, if you cook it too long !?

The Quest for In-medium Modifications



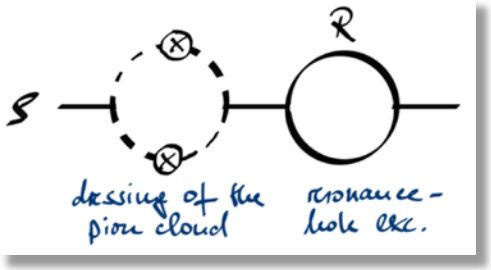
25 years ago:

- Brown/Rho, Hatsuda/Lee: meson shifts as a signal for the restoration of the sbχs.

$$m^* = m\left(1 - 0.18\left[{}^{\rho}/_{\rho_0}\right]\right) \text{ or } m^* = m\left({}^{\langle q\bar{q}\rangle^*}/_{\langle q\bar{q}\rangle}\right)^u$$

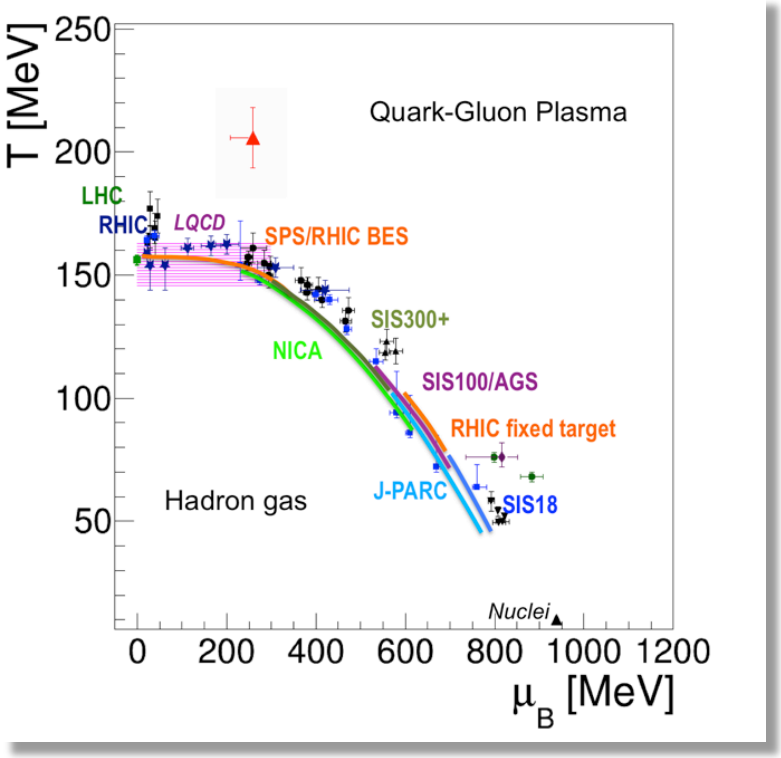
As of today:

- no real evidence for dropping masses,
- instead, ρ strongly broadened (in-medium ρ_0 propag.):



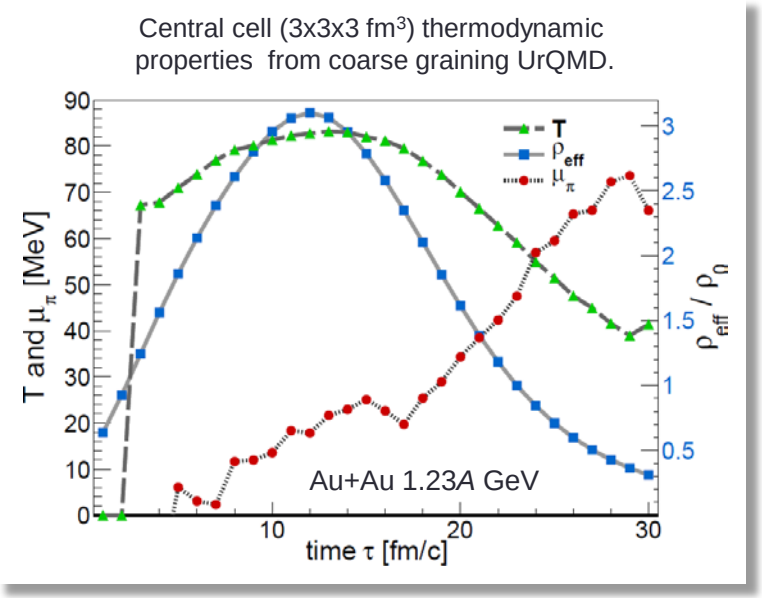
cf. talk by Ralf Rapp

Explore the QCD Phase Diagram at high Density



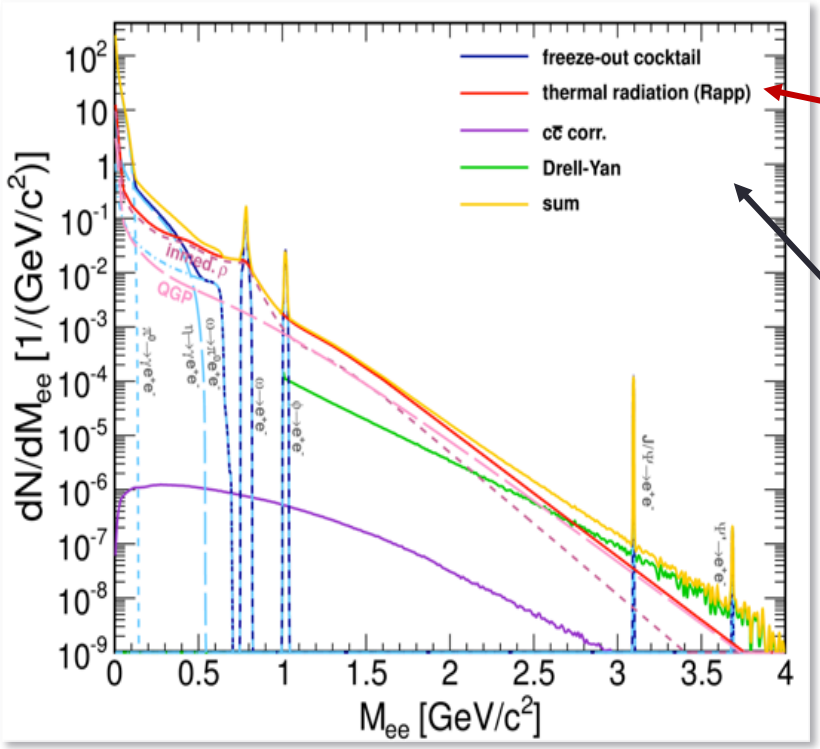
Heavy-ion collision at SIS18 energies:

- Baryon-dominated system throughout the evolution.
- Comparatively long lifetime of the dense ”fireball”.



T. Galatyuk, F. Seck, et al.,arXiv-1512-08688

Theoretical Approaches to Medium Radiation

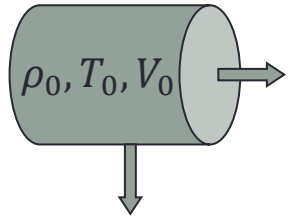


Medium radiation from Thermal Emission Rates:

$$\frac{d^3\dot{N}}{dMdydp_t d\alpha} \equiv \int_{t=0}^{\infty} \frac{d^4\epsilon}{d\boldsymbol{p}}[T(\boldsymbol{x}), \mu_B(\boldsymbol{x}), \vec{v}(\boldsymbol{x})]\, d\boldsymbol{x}$$

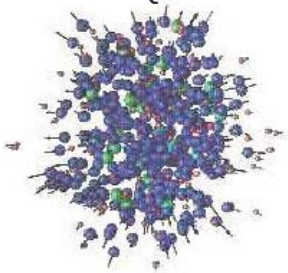
coarse graining

isentropic expansion



shining

UrQMD



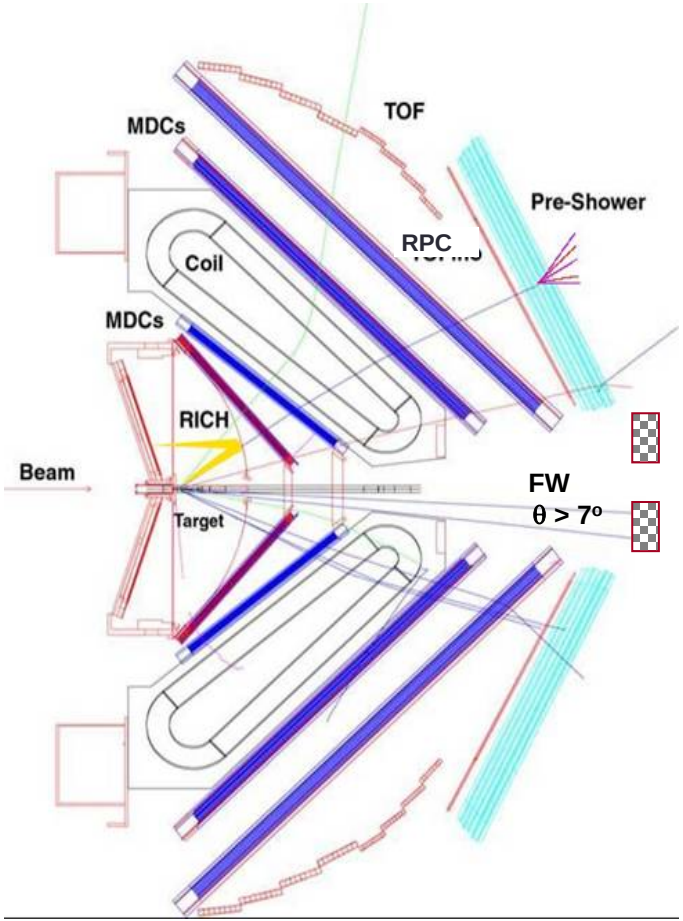
Dilepton emission from Microscopic Transport.

SPECTROMETER PERFORMANCE

The HADES Spectrometer

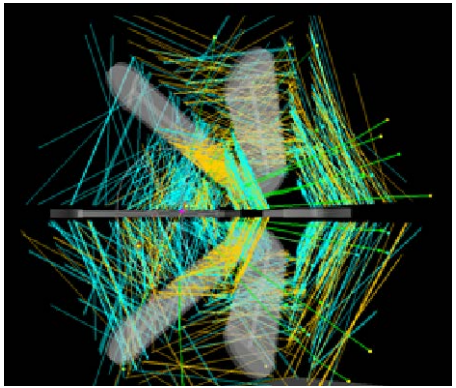
- High Acceptance Di-Electron Spectrometer
  - Designed in the nineties to measure the in-medium ρ mass-shift in 1A GeV Au+Au collisions.
  - combines aspects of hadron physics with (ultra-) relativistic heavy-ion physics.

- Detector design
  - Toroidal spectrometer with six-sector superconducting magnet (momentum kick: 0.3 - 0.15 Tm)
  - Low-mass tracking with drift chambers
  - RICH surrounding the target in field free region
  - RPC and scintillator based time-of-flight systems
  - Electromagnetic Shower Detector
  - Various complementary detector systems (FW, Cerberus, T0)

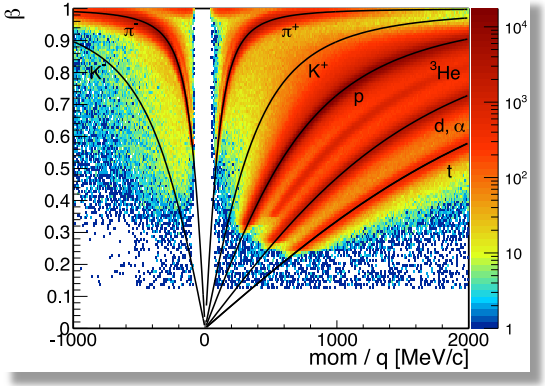


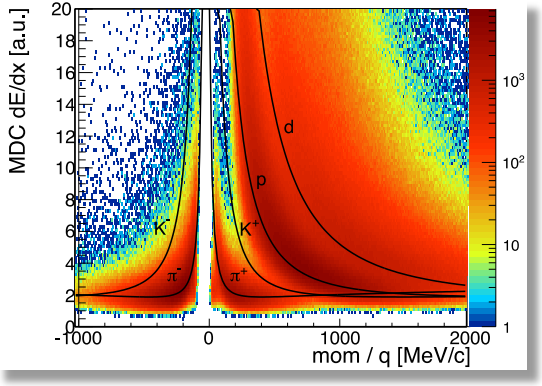
Shower
Tofino
TOF
MDC IV
MDC III
RICH
MDC II
MDC I
Magnet

Performance (hadrons)



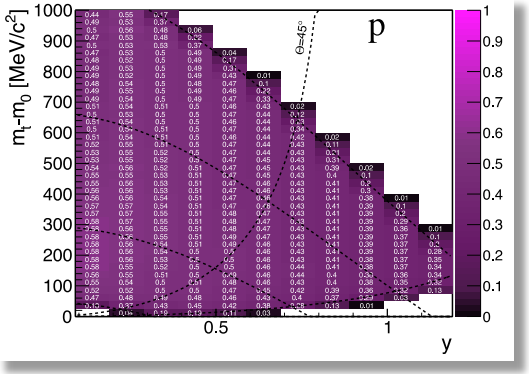
PID $(\mathrm{tof}, dE/dx)$





- Large acceptance around mid-rapidity.
- Centrality and event plane via forward hodoscope (FW)
- reduced acceptance for elementary (exclusive channels)

$\epsilon_{acc.} \times \epsilon_{det.} \times \epsilon_{reco.}$



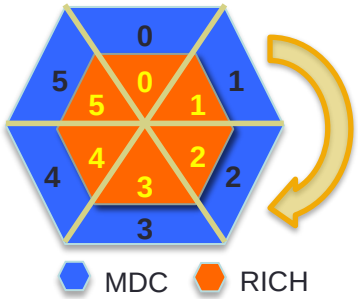
Electron/positron ID

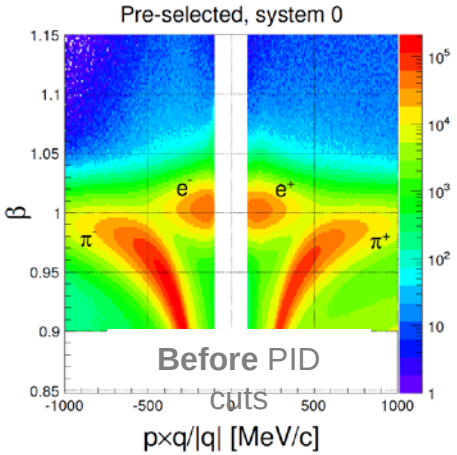
Multivariate analysis (neural network) using:

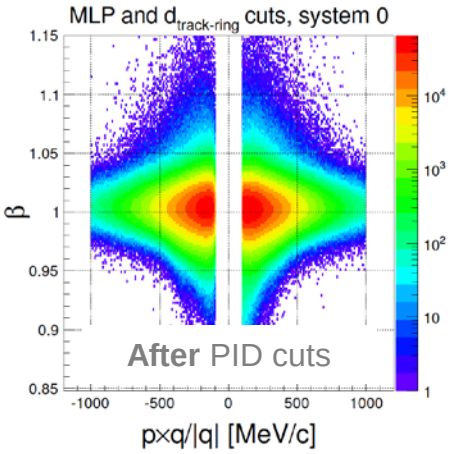
- Particle velocity
- dE/dx in MDC and ToF
- Electromagnetic shower
- Cherenkov radiation

Purity derived from “RICH rotation”

- Random matches

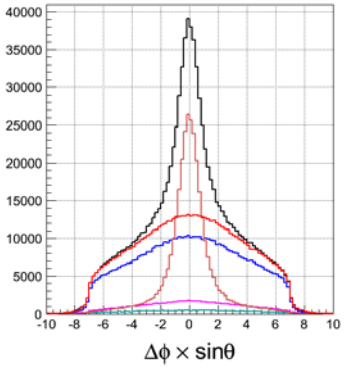




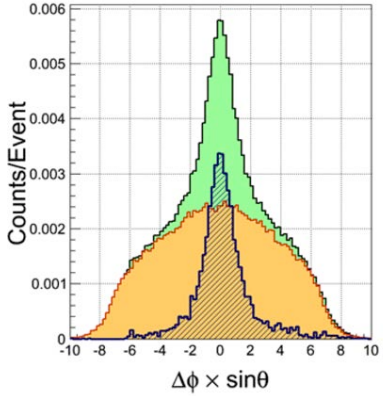


Ring Matching

Monte Carlo



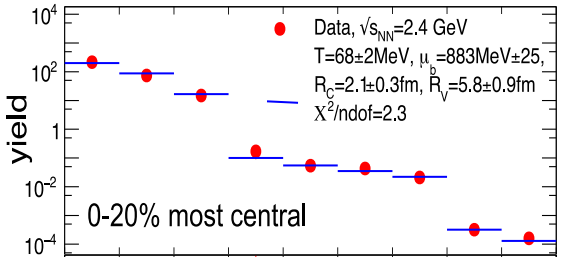
Data



STRANGENESS

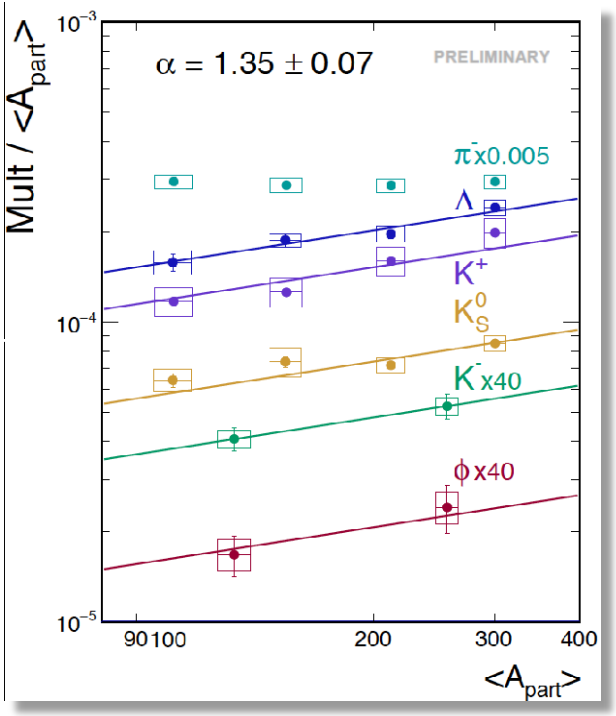
Hadron Production in $Au + Au$ ($\sqrt{s} = 2.4\ A\mathrm{GeV}$)

Hadron yields and their centrality dependence in accord with the assumption of a ”thermalized” system.

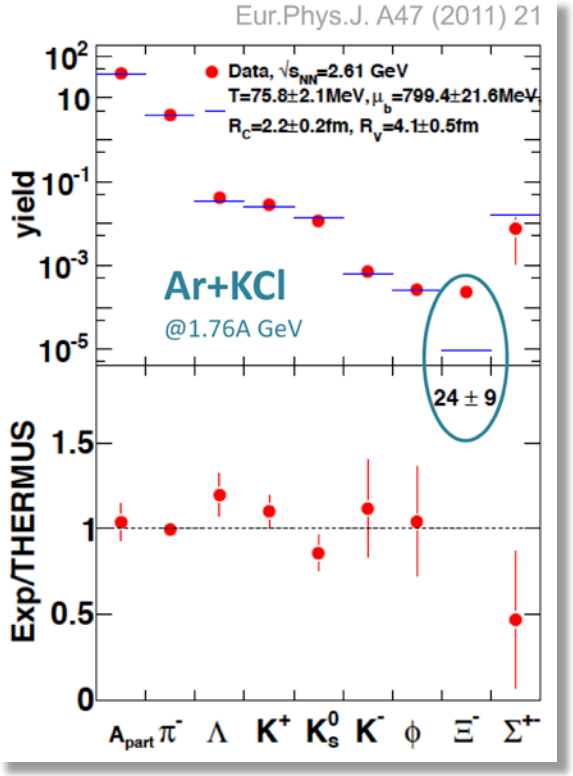


Fit (T, μ_B, R_c, R_V) of a
Statistical Hadronization Model
to the particle yields. Feed-down due to resonance decay taken into account.

Observed universal $\left(M \propto A_{part}^{\alpha}\right)$
Participant Number Scaling
is in contradiction to production via multi-step processes.



Production of Double-strange Hyperons (Ξ^-)

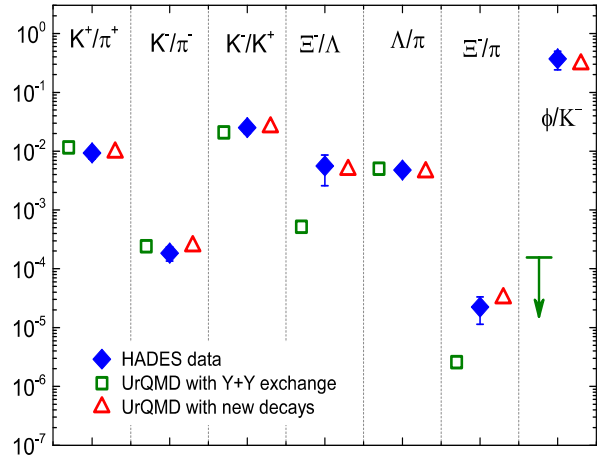


Observed yield in Ar+KCl much above expectation from SHM.

$$P_{\Xi^-} \cong 0{,}1 \cdot P_{\langle s\bar{s}\rangle} \cdot P_{\langle s\bar{s}\rangle}$$

Attempt to explain cascade yield by decay of heavy baryonic resonances (UrQMD).

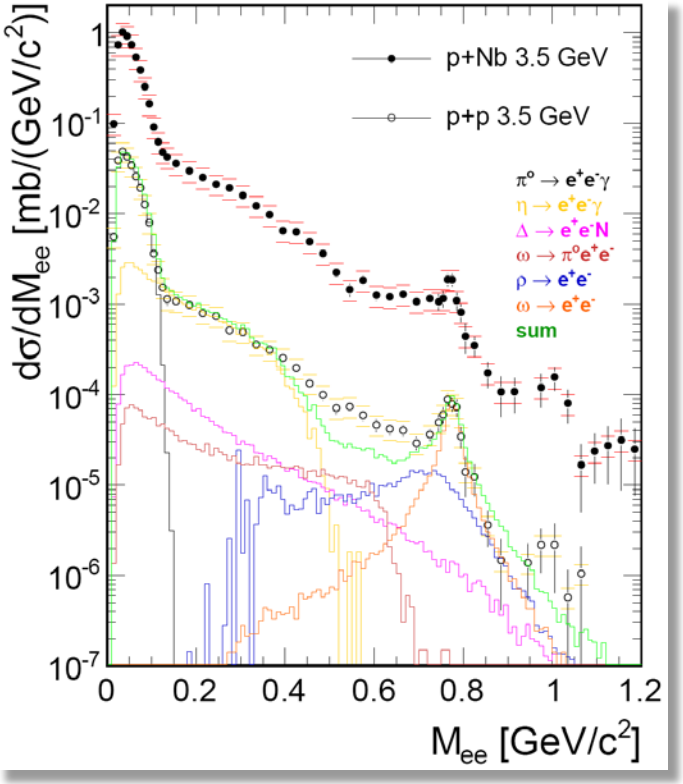
$$N^* \rightarrow \Xi + K + K$$



Jan Steinheimer et al.; arXiv-1503-07305

DILEPTON RADIATION

Dilepton emission in pp and pA collisions

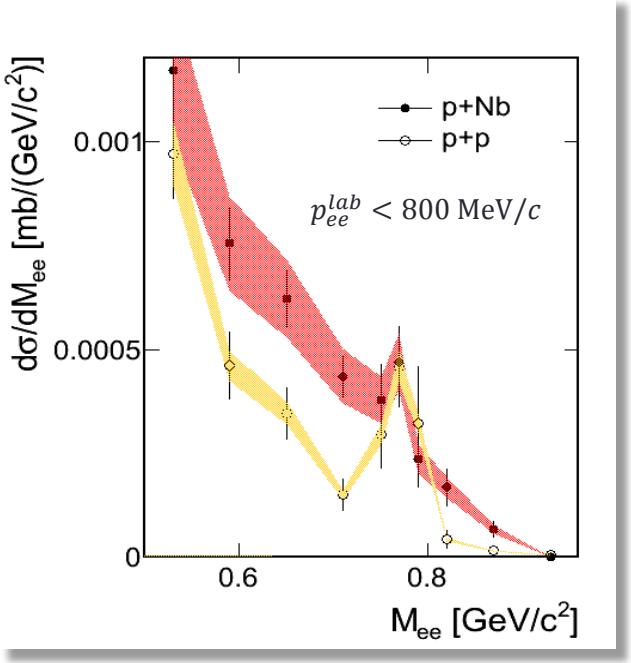


p+p:
extraction of inclusive cross sections by fitting conventional sources to the experimental spectrum:

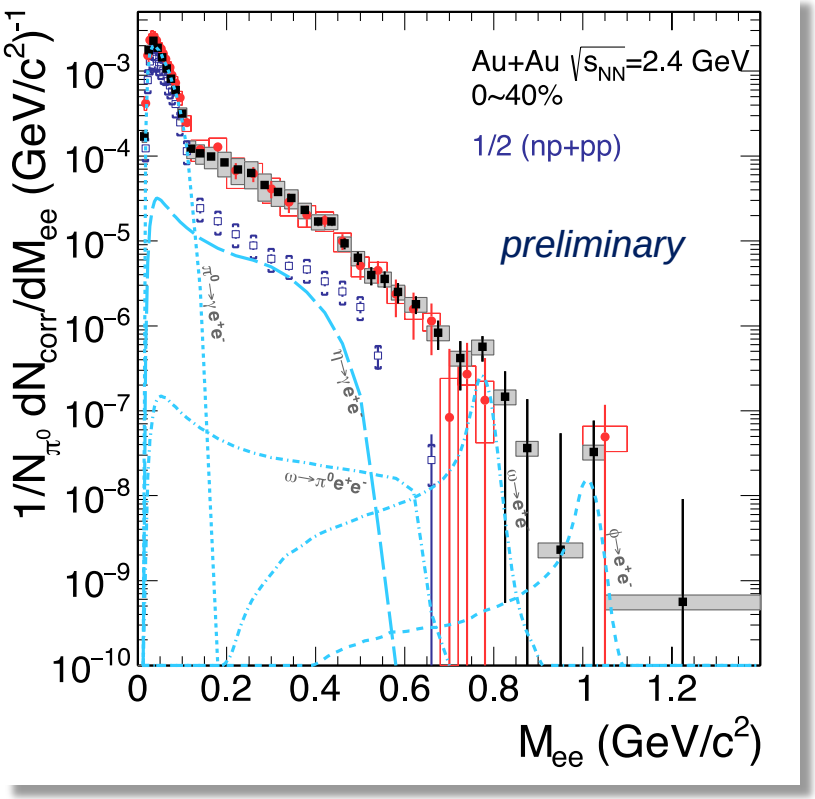
π^o:	17 ± 2.7 ± 1 mb
Δ:	7.5 ± 1.7 mb
η:	1.14 ± 0.2 mb
ω:	0.273 ± 0.07 mb
ρ:	0.223 ± 0.06 mb

p+Nb:
Strong reduction of the ω peak.

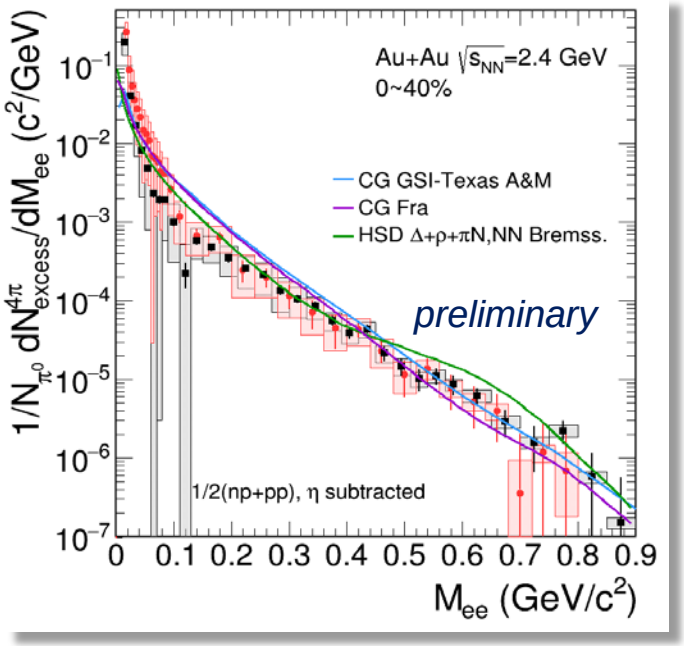
First measurement of ω decay in cold matter in the relevant momentum range. Indication for strong broadening of the ω.



Inclusive Dielectron Yields from $Au + Au$ ($\sqrt{s} = 2.4\ AGeV$)

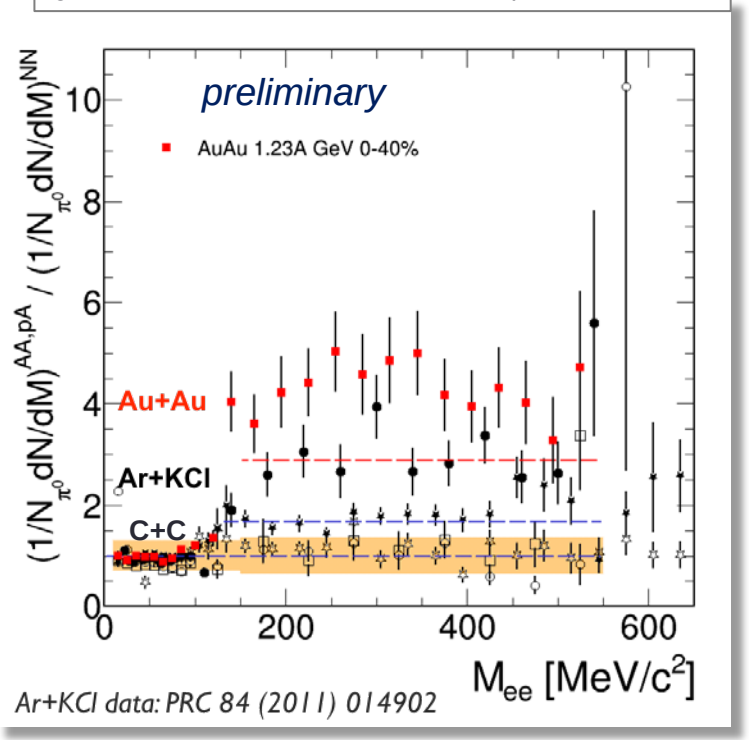


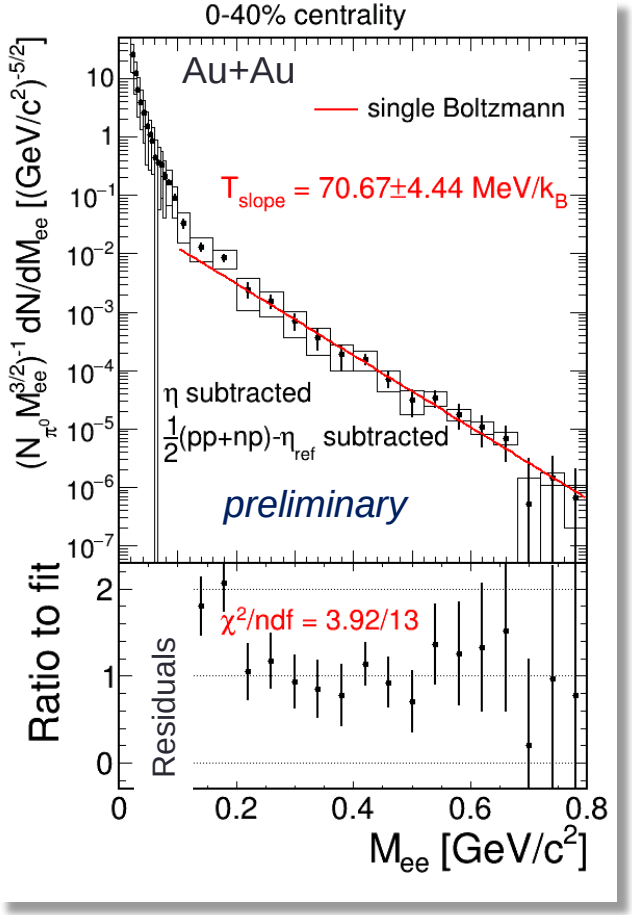
Acceptance corrected excess radiation. Contributions from first chance and late emission subtracted.



Lifetime & Temperature

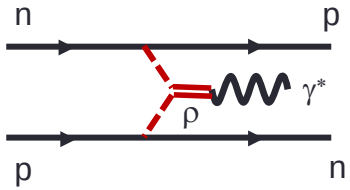
Enhancement in the region above 150 MeV/c^2 reflects generations of resonances before final pion is emitted.

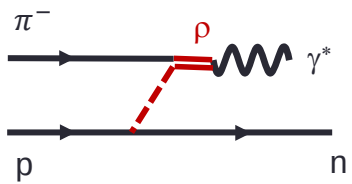


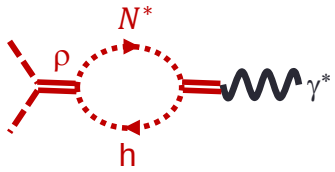


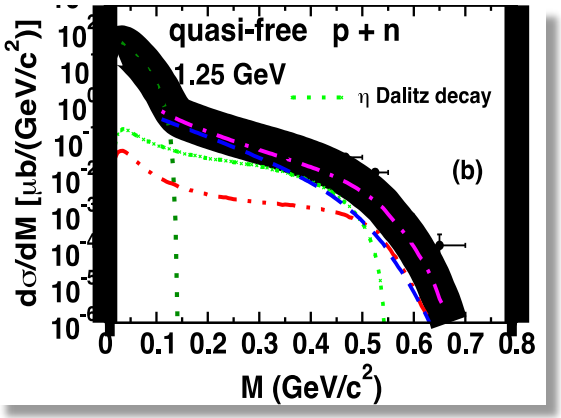
The role of virtual pions in dilepton production

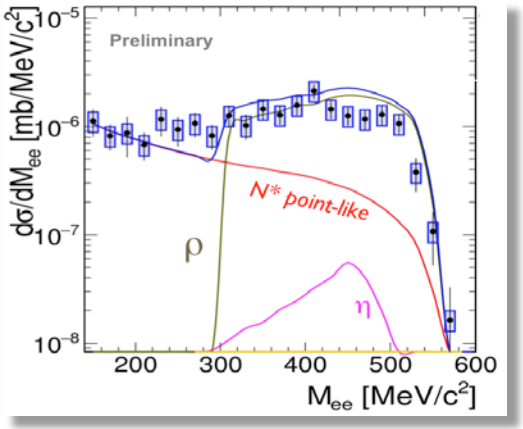
Three different collision systems, three surprises but likely the same underlying mechanism

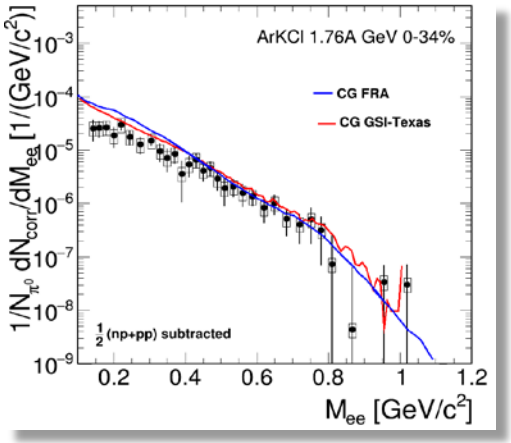












FUTURE

HADES Strategy

Until 2018
(upgrade, preparation for FAIR phase 0)

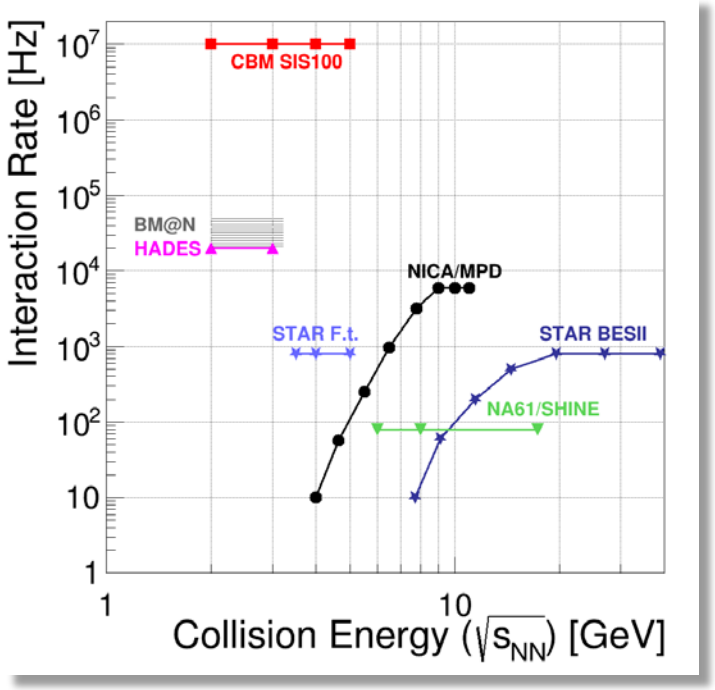
- Installation of CBM/HADES UV photo-detector and ECAL
- Install new forward detection system, STS and fRPC

2018-202x
(experiment campaign at SIS18 - FAIR phase 0)

- DAQ und MDC FEE upgrade – 200 kHz interaction rate
- Backward neutron detector (neuLAND modules)
- Strong physics program at SIS18, 1 run per year

202x on
(HADES at SIS100)

- Transfer spectrometer to new experimental hall
- Cold matter physics (p+A)
- Exclusive measurements (p+p)
- (A+A collisions for comparison)



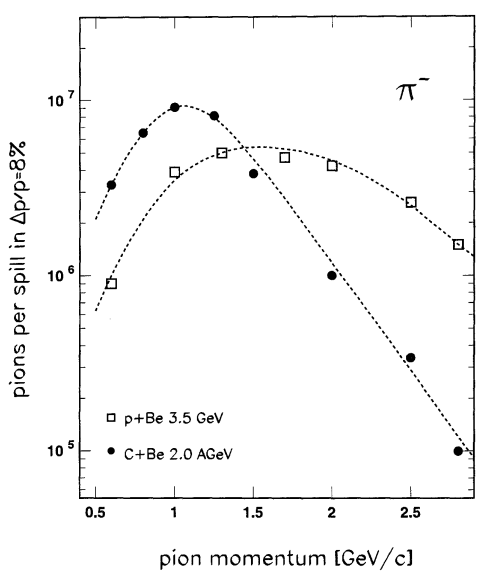
The HADES Pion Beam Facility

- *Primary beam:*
  - *10^{11} N (2 AGeV) /spill*
  - *10^{11} p (3.5 GeV) /spill*
- *SIS fast ramping*
- *Spill: 4s cycle*

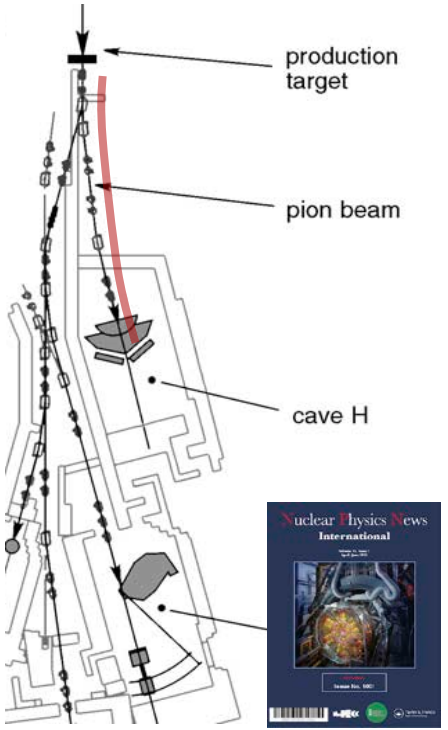
- *Secondary beam (π^-, π^+):*

✓ *Only combination of pion beam with dilepton spectrometer world-wide.*

□ *Can possibly be realized also at JPARC.*



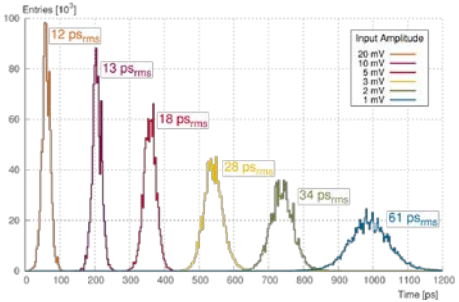
Prog. Part. Nucl. Phys. 42 (1999) 274
Nuclear Physics News 25,2 (2015)

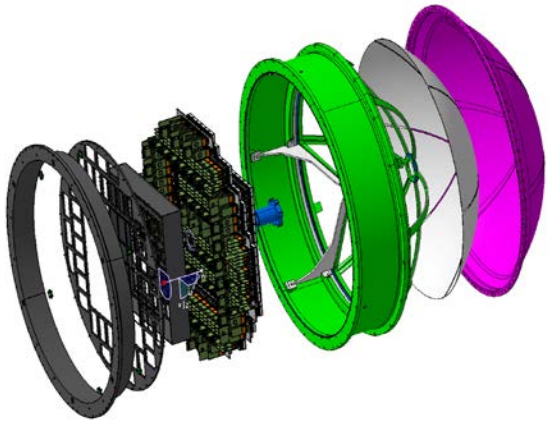


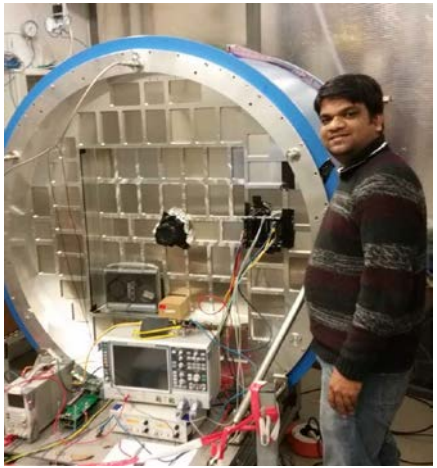
RICH MAPMT UV Detector (with CBM)

Added value

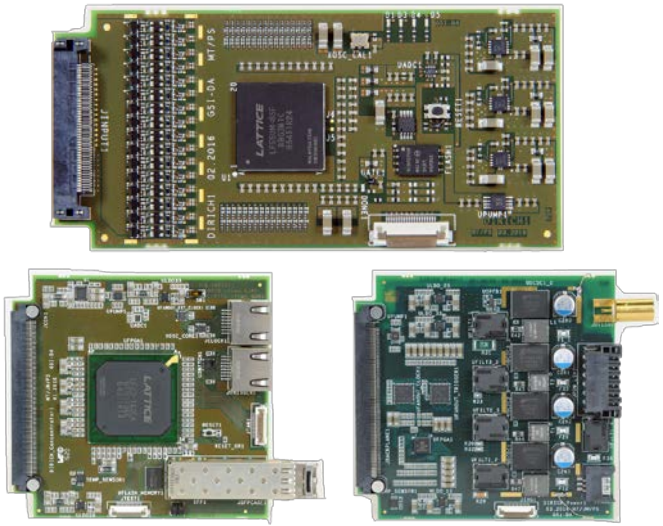
- Replaces aging CsI photo detector
- will provide substantially improved detection efficiency





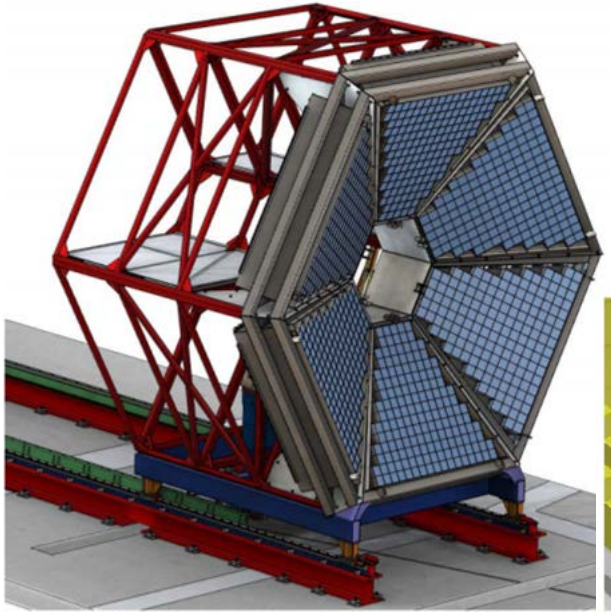


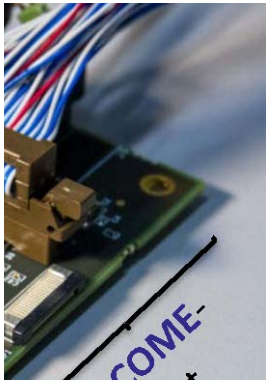
- MAPMT (Hamamatsu) based detector modules
- Joint design and realization effort
- Design compatible for use in HADES and CBM RICH

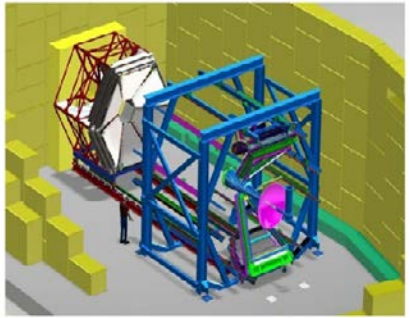


The Electromagnetic Calorimeter

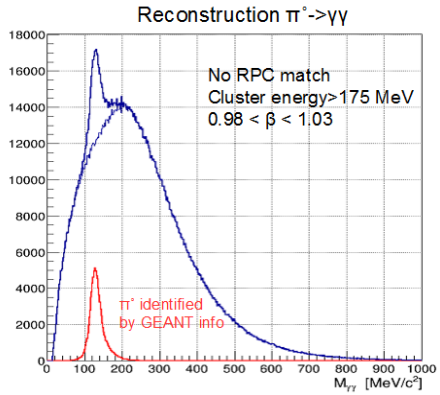
- Based on **recycled OPAL lead glass**.
- TDR approved 2013
- Replaces SHOWER







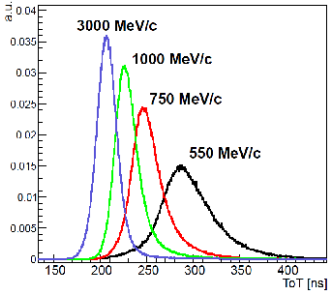
- Added value:
  - Neutral mesons
  - Electromagnetic decays of baryons / hyperons
  - Augments e^- e^+ identification



Forward detector system (with PANDA)

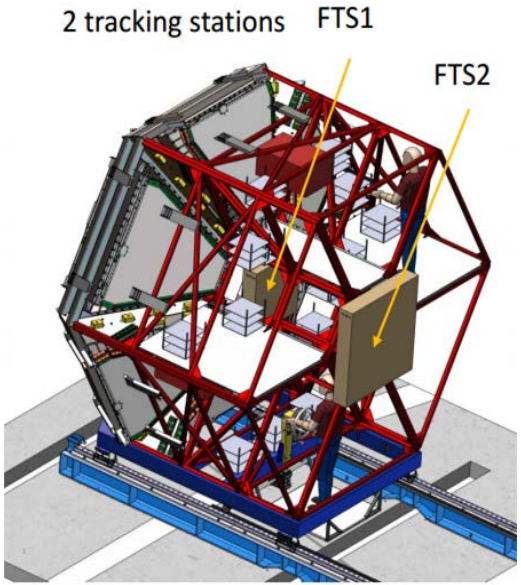
- **Tracking stations** (FTS1, FTS2) based on PANDA Straw technology
- **Forward TOF** based on RPC prototypes developed for neuLAND.

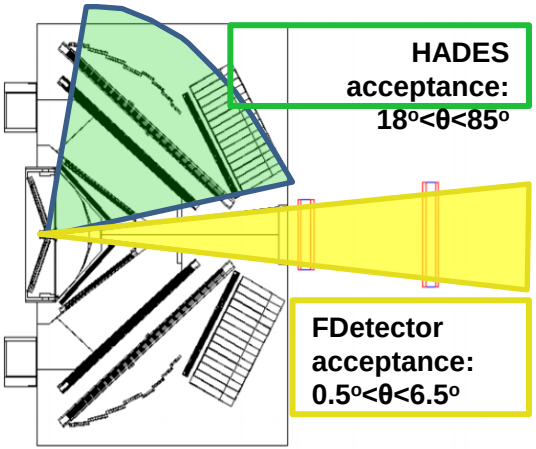
dE/dx via ToT



Added value

- Substantially increased acceptance for exclusive channels.
- Will not be used for A+A runs.





HADES Program for Phase-0

- Electromagnetic structure of baryons in the time-like region.
- Strangeness in (baryonic, non-strange) resonances.
- Excitation spectrum of strange resonance.
- Microscopic structure of dense & hot matter and cold matter (SRC).
- Signatures for exotic properties of dense baryonic matter.

SIS18

$\pi, p \rightarrow PE$

$\pi, p \rightarrow A$

$A \rightarrow A$

Program will be optimized w.r.t. beam time available, accelerator performance, spectrometer upgrade

The HADES Collaboration