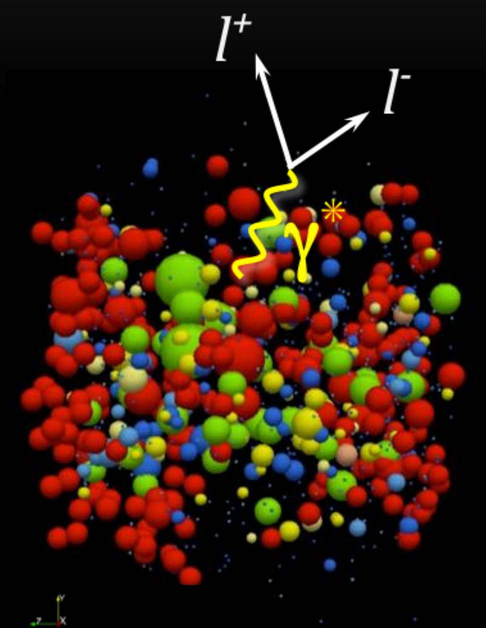
INSTITUTE FOR NUCLEAR THEORY

INT Program INT-16-3 Workshop Week 3
Exploring the QCD Phase Diagram through Energy Scans
October 3 - 7, 2016



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Electromagnetic probes at HADES and CBM

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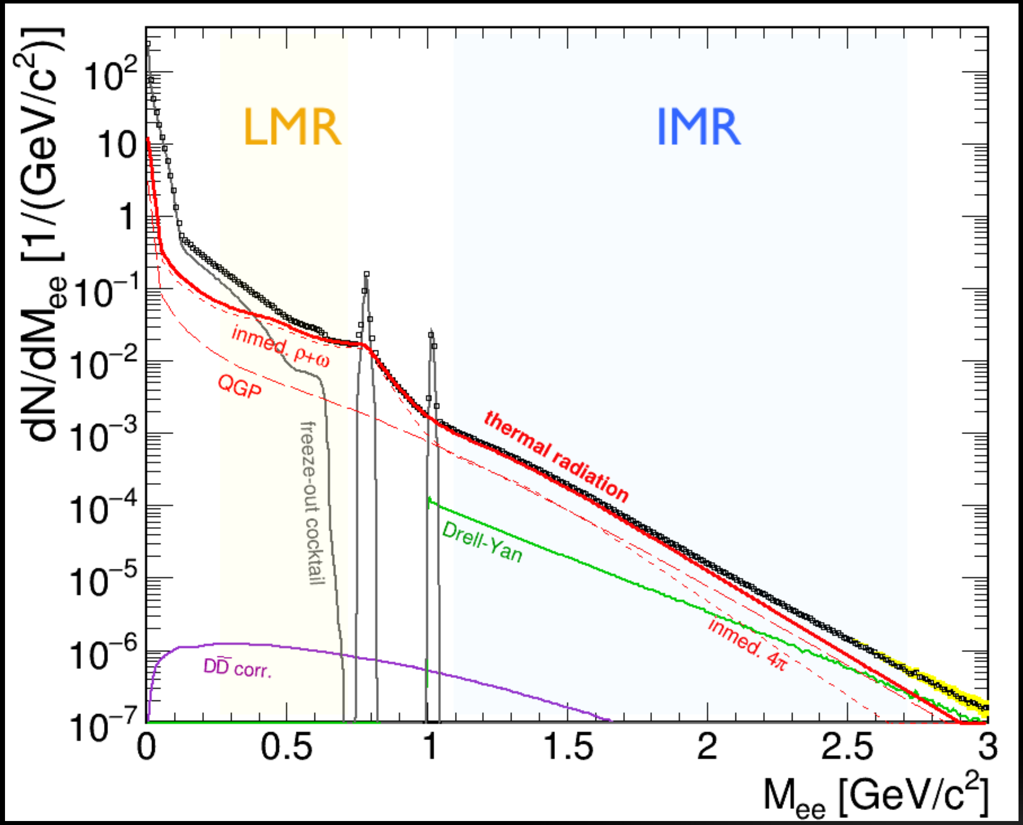
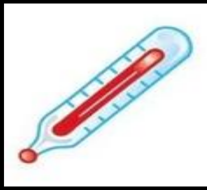
Take home message:

Dileptons carry invaluable information in terms of their four-momentum



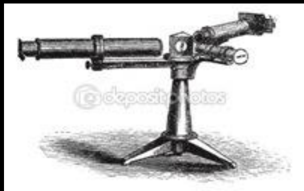
- Chronometer
  - LMR dilepton yield → fireball lifetime

- Thermometer
  - IMR slope → emitting source temperature (true T, no blue shift)



- Barometer
  - LMR+IMR inverse-slope analysis → fireball acceleration

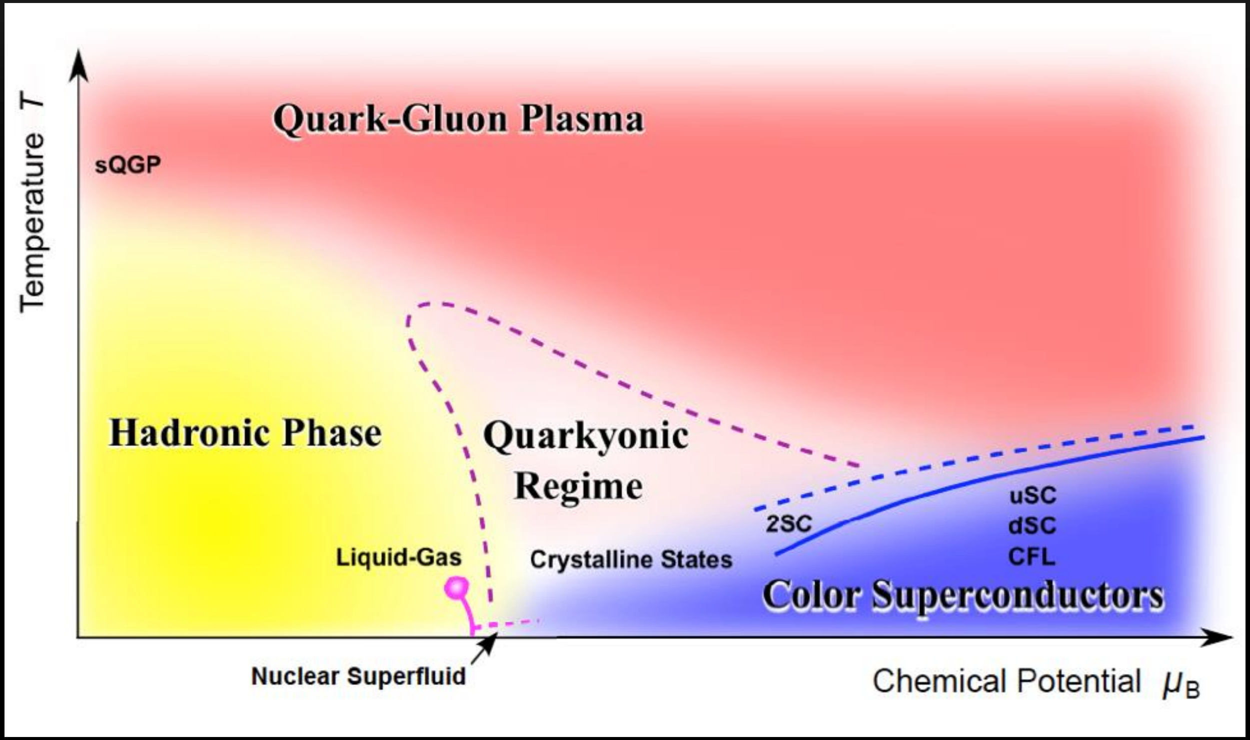
- Spectrometer
  - IMR+IMR shape and yield → restoration of chiral symmetry



Precision measurements are the key!

Exploring the phase diagram of QCD matter

"Even without any sharp structure, the QCD phase diagram contains rich physics at high density" Fukushima, Sasaki, Prog.Part.Nucl.Phys. 72 (2013)



What are the fundamental properties of strongly interacting matter under extreme temperatures and densities?

- Macroscopic: equation of state, transport coefficients
- Microscopic: degrees of freedom (hadronic vs. partonic), spectral functions
- Phase structure and role of condensates

Experimental approach: high energy heavy-ion collisions

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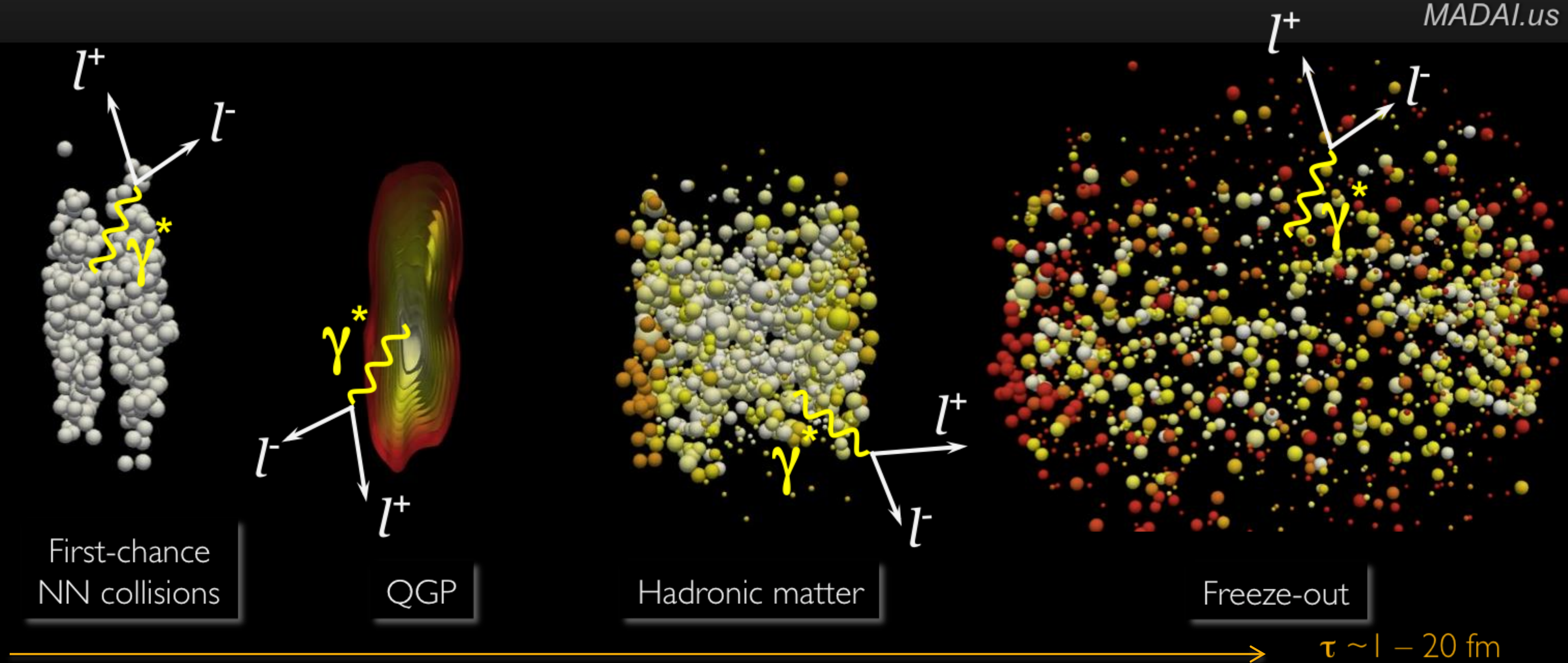


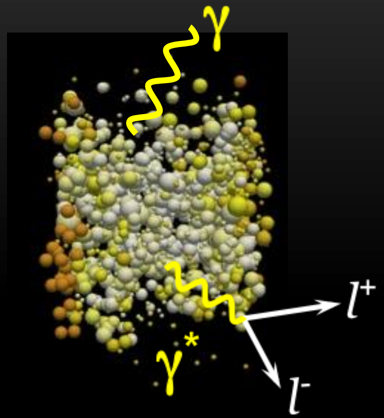
τ ~1 – 20 fm (~10^{-23} s)

Systematic experimental measurements (E_{beam}, A)
→ extract numbers that might be related to the QCD phase diagram

„If you want to detect something new, build a dilepton spectrometer“

S.Ting

Electromagnetic probes: dileptons vs. real photons



Electromagnetic radiation
(photons and lepton pairs) probes the interior of fireballs

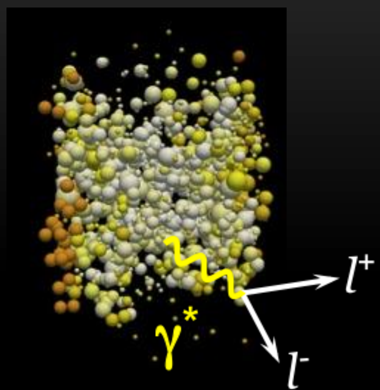
- ❑ The dilepton signal contains contributions from throughout the collision
- ❑ No strong final state interactions → leave reaction volume undisturbed
- ❑ Encodes information on collisions (T, μ_B, τ_{coll})

Photons (γ) : 1 variable: p_T
Lepton pairs (γ^*) : 2 variables: M, p_T

→ Dileptons more rich and more rigorous than photons

- p_T sensitive to temperature and expansion velocity
- M is the only Lorenz-invariant thermometer of the field

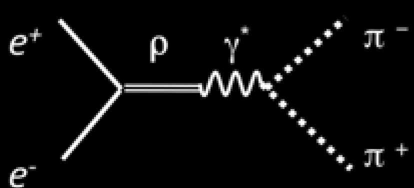
Dilepton Rate in a strongly interacting medium

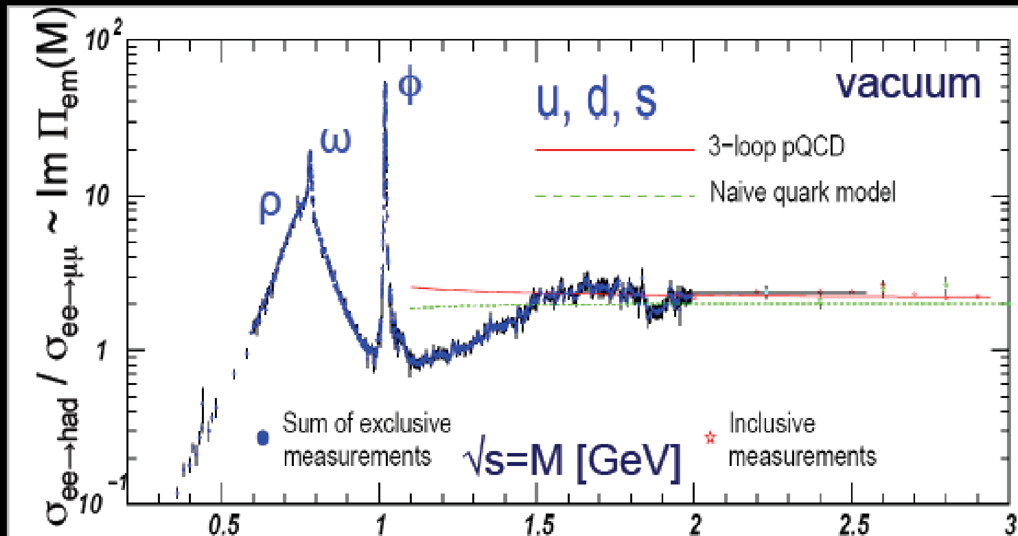


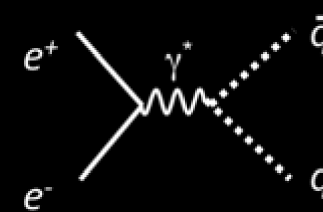
Unique direct access to in-medium spectral function

$$\frac{dN_{ll}}{d^4x\,d^4q} = -\frac{\alpha_{EM}^2}{\pi^3}\frac{L(M)}{M^2} f^B(q_0;T)\ \mathrm{Im}\,\Pi_{EM}^{\mu\nu}(M,q;\mu_B,T)$$

Photon self-energy







Low-mass region, $M_{ll} \leq 1.1$ GeV/c^2
Strong coupling of γ* to ρ → VMD

Intermediate-mass region, $M_{ll} > 1.1$ GeV/c^2
$\bar{q}q$ continuum

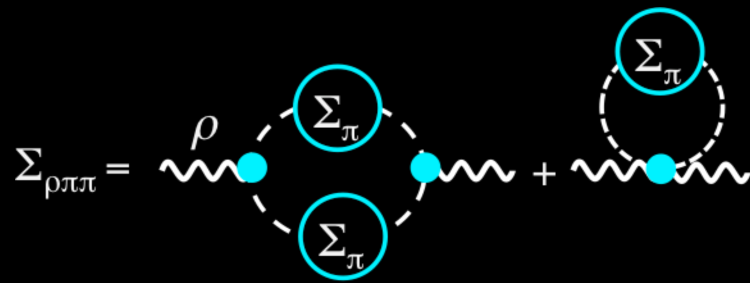
- Hadrons: $Im\ D_{\rho,\omega,\phi}$
  - Change in degrees of freedom?
  - Restoration of chiral symmetry?
- $\bar{q}q$ Continuum
  - Emitting source temperature? "Planck-like" → thermometer

ρ meson in hot and dense medium…

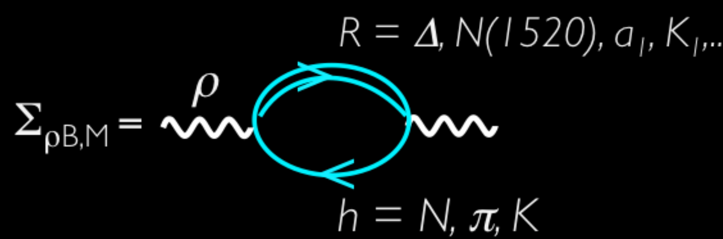
… interacts with hadrons from heat bath → in-medium ρ-propagator

$$D_\rho(M,q;\mu_B,T) = \frac{1}{\left[M^2 - m_\rho^2 - \Sigma_{\rho\pi\pi} - \Sigma_{\rho B} - \Sigma_{\rho M}\right]}$$

- In-medium pion cloud
  [Chanfray et al, Herrmann et al, Urban et al, Weise et al, Oset et al, …]

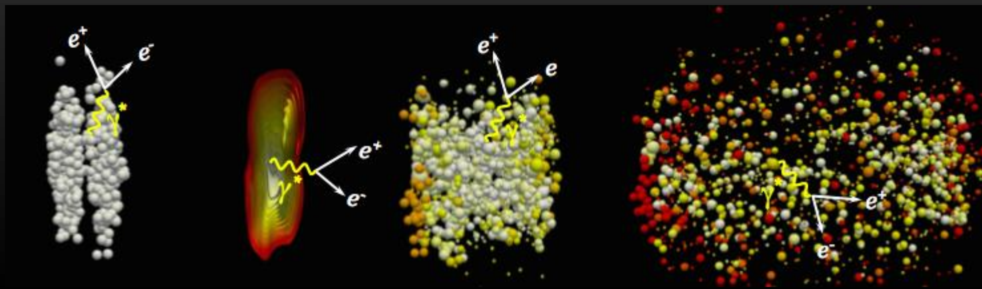


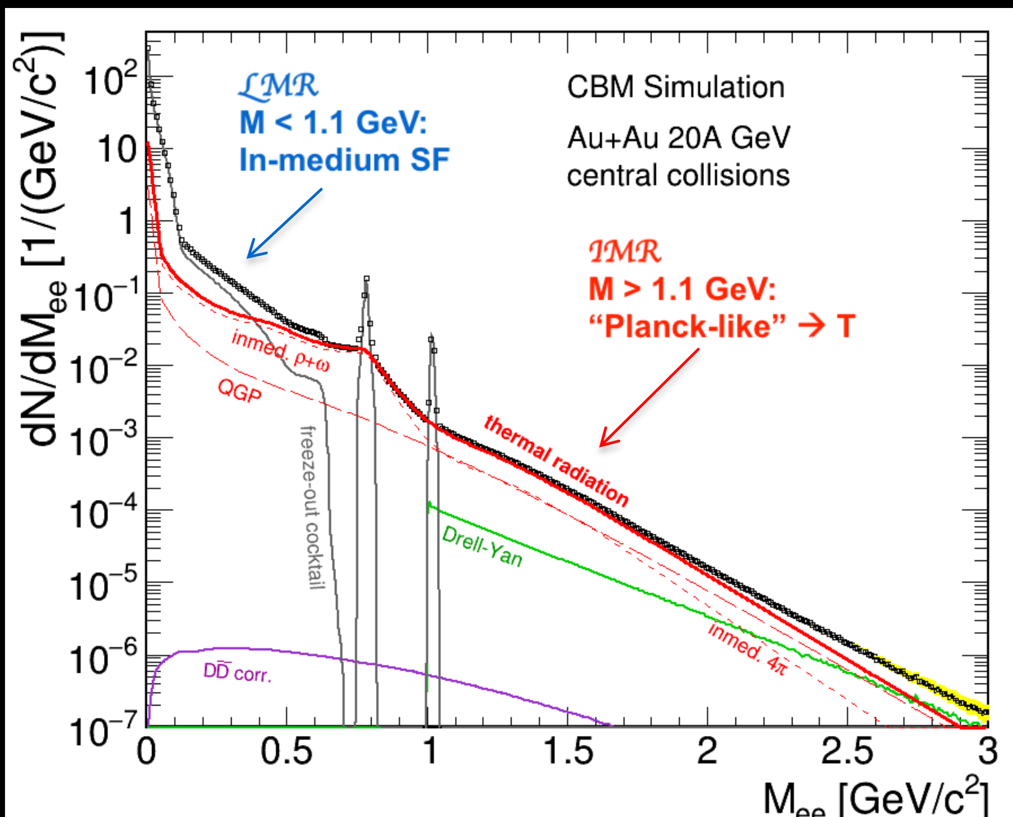
- Direct ρ-hadron Scattering
  [Haglin, Friman et al, Rapp et al, Post et al, …]



- Theoretical control:
  → symmetries (gauge, chiral)
  → empirical constraints: decays R → ρN, scattering data γN/γA, πN → ρN…

Characteristic features of dilepton invariant mass



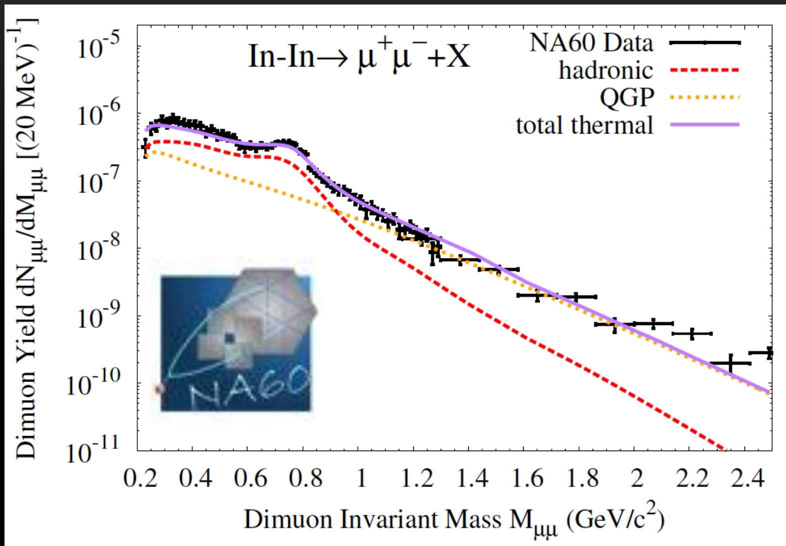


- Dilepton spectra represent the space-time integral of EM radiation
- Mass dependence allows separation of collision stages

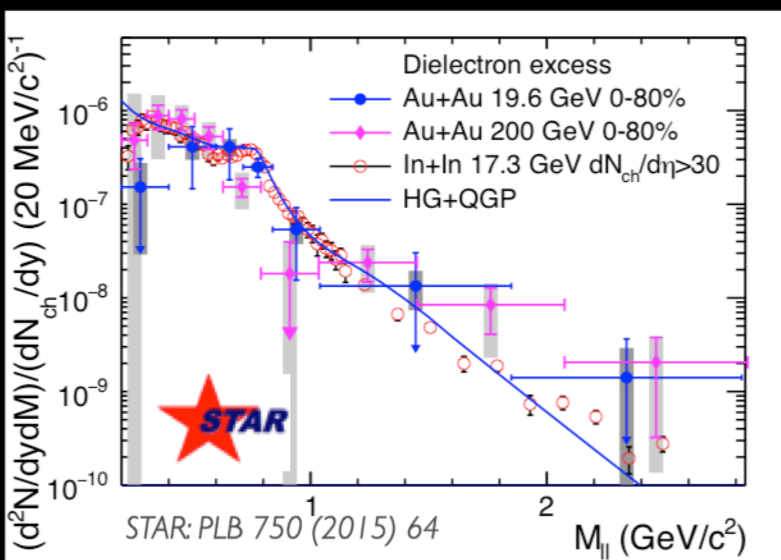
- *Drell-Yan* (NN → l^+l^-X)
- Heavy-flavor: $\bar{c}c \rightarrow l^+l^-$
- Medium radiation (R. Rapp):
  - QGP: $\bar{q}q \rightarrow l^+l^-$
  - In-medium ρ, ω → l^+l^-
  - "4π annihilation": $\pi a_1 \rightarrow l^+l^-$
- Final state decays (hadron cocktail): $\pi^0, \eta \rightarrow \gamma e^+e^-$

CBM Collab., arXiv:1607.01487 [nucl-ex]

What did we learn from UrHIC dileptons?



NA60: H.J. Specht, AIP Conf.Proc. 1322 (2010) 1
Model: R. Rapp, H. van Hees, PLB 753 (2016) 586

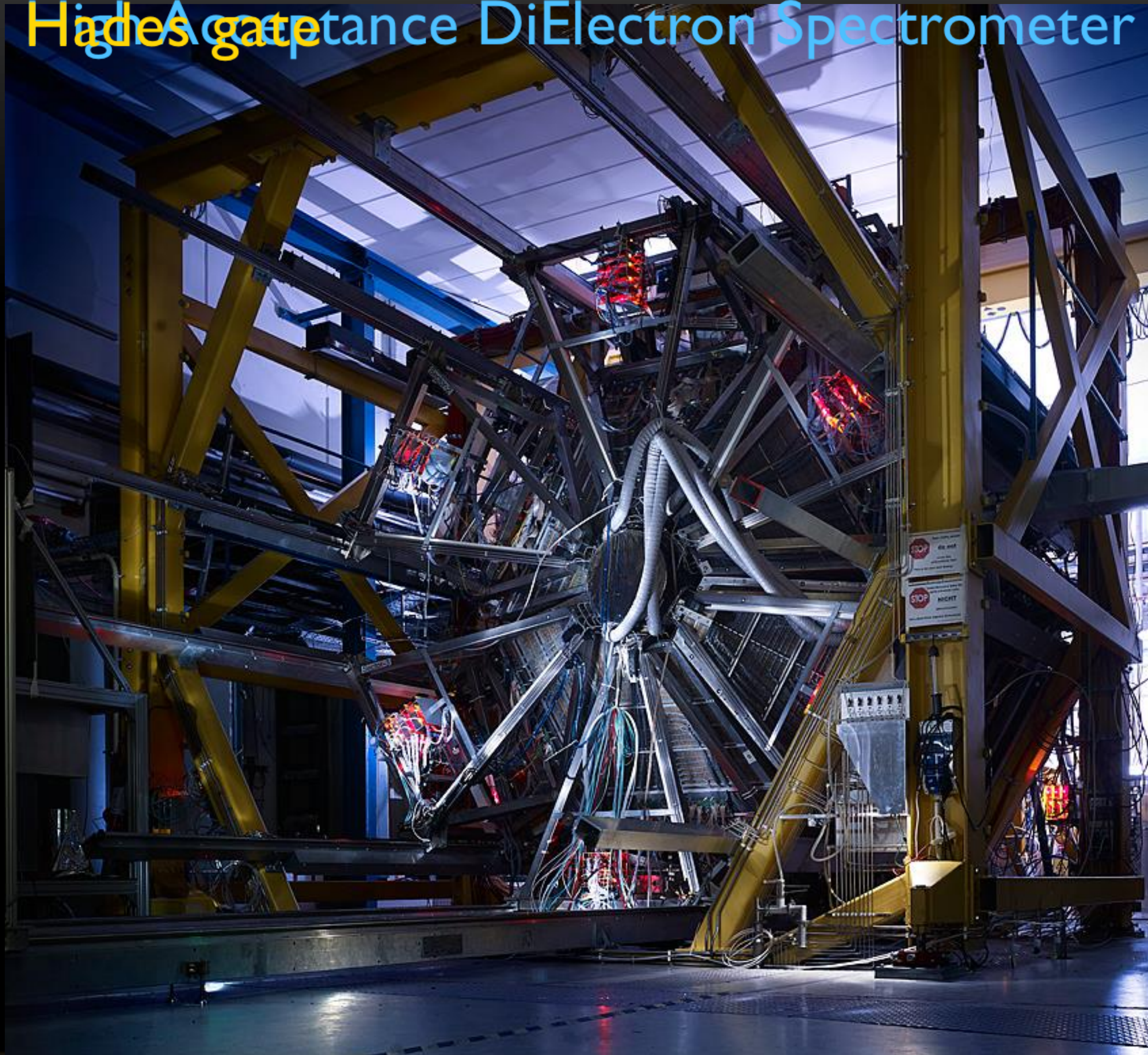


STAR: PLB 750 (2015) 64

- M < 1 GeV/c^2
  - only broadening of ρ observed, no mass shift
  - ρ dominates, "melts" close to T_c
- M > 1 GeV/c^2
  - Partonic emission dominant for IMR
  - ~exponential "fall-off" → "Planck-like", $T=205\pm12$ MeV → $T>T_c \cong 160$ MeV
- ρ - Δ/N* couplings play substantial role in ρ melting observed in UrHIC

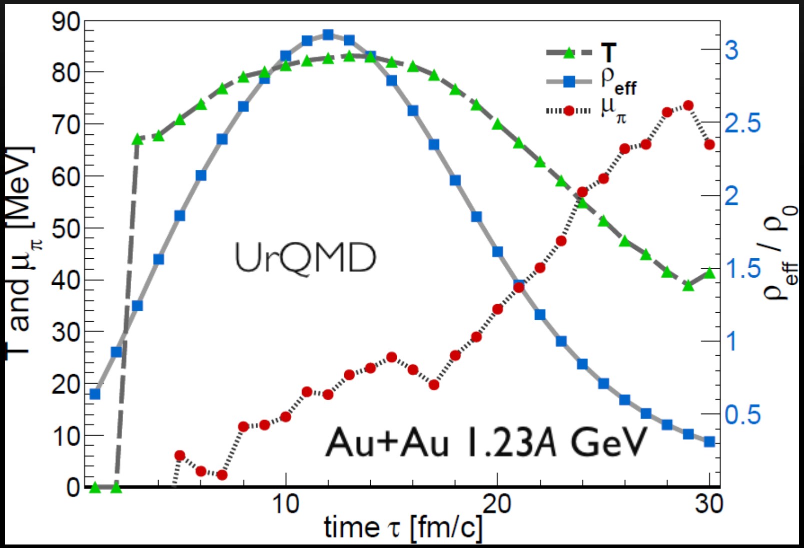
High Acceptance DiElectron Spectrometer

Hades gate



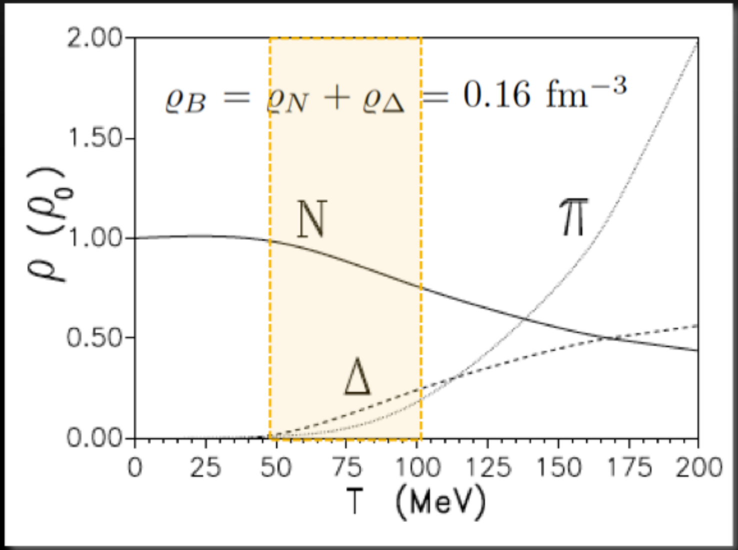
Baryonic matter at 1-2A GeV beam energy

Evolution of average T and ρ_{eff}



TG, et al., Eur. Phys. J. A 52 (2016) 131
Bass et al., Prog. Part. Nucl. Phys. 41 (1998)

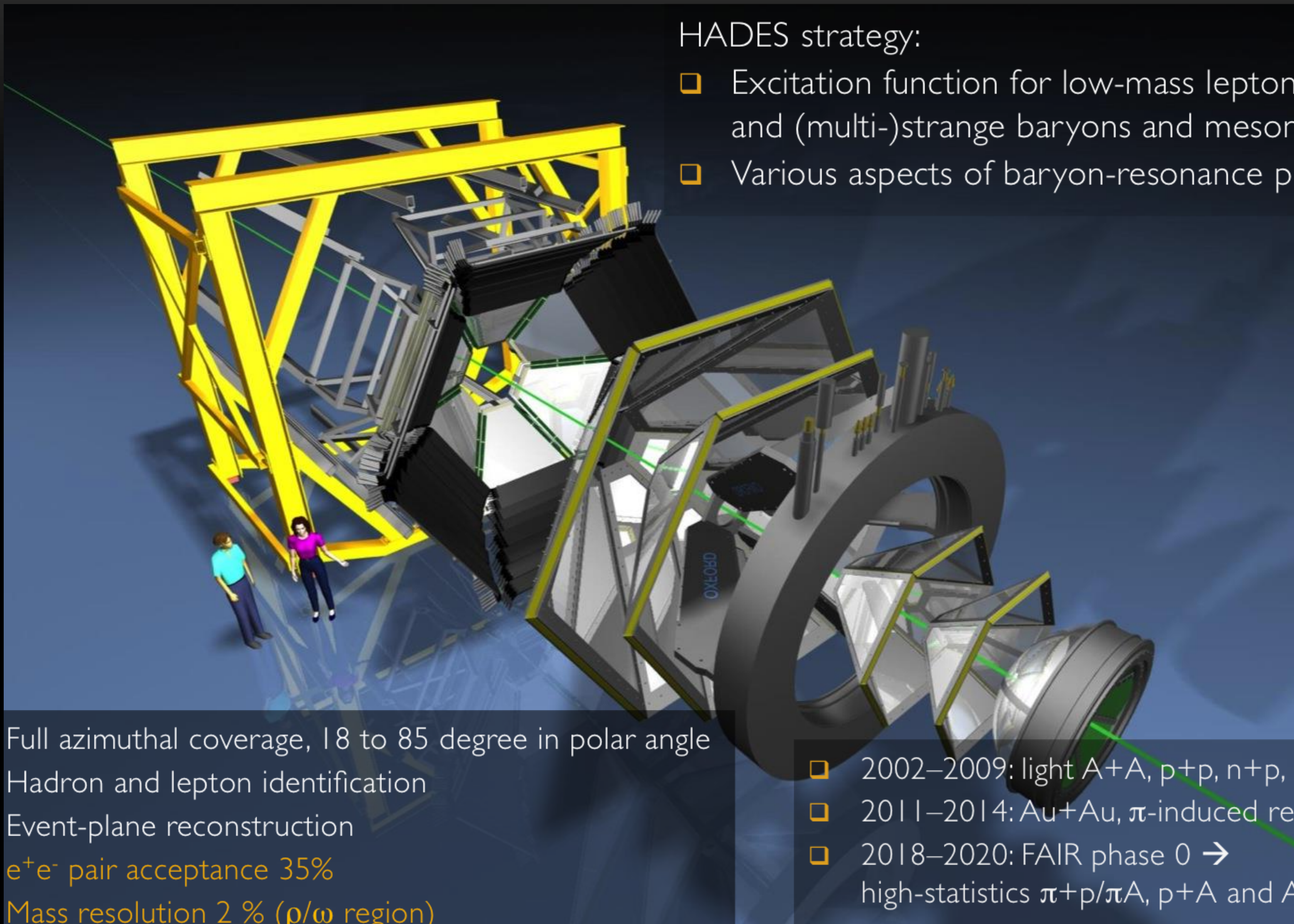
Composition of a hot $\pi\Delta N$ gas



Rapp, Wambach, Adv.Nucl.Phys. 25 (2000)

- High densities: ρ_{max} = 1-3 ρ_0
- Moderate temperatures: T = 50 – 100 MeV
- System stays above ground state matter density for $\Delta\tau$ ~15 fm/c
- Baryon dominated: N_π/A_{part} ≈ 10%

The HADES at GSI, Darmstadt, Germany



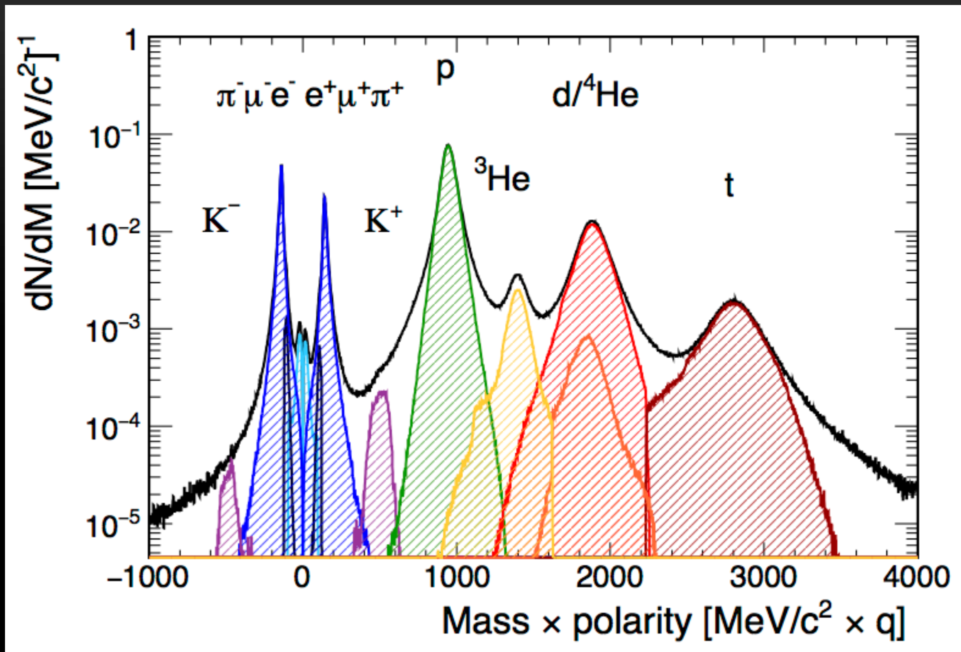
HADES strategy:

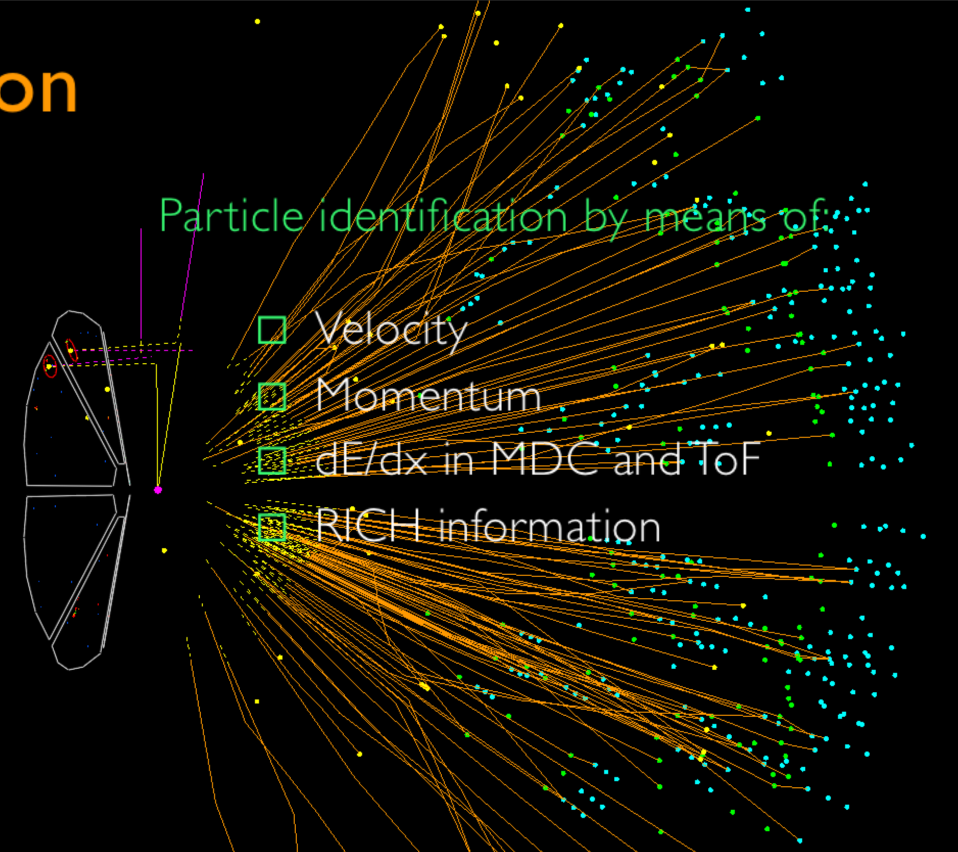
- Excitation function for low-mass lepton pairs and (multi-)strange baryons and mesons
- Various aspects of baryon-resonance physics

- Full azimuthal coverage, 18 to 85 degree in polar angle
- Hadron and lepton identification
- Event-plane reconstruction
- e^+e^- pair acceptance 35%
- Mass resolution 2 % (ρ/ω region)

- 2002–2009: light A+A, p+p, n+p, p+A
- 2011–2014: Au+Au, π-induced reactions
- 2018–2020: FAIR phase 0 → high-statistics π+p/πA, p+A and A+A

HADES event reconstruction

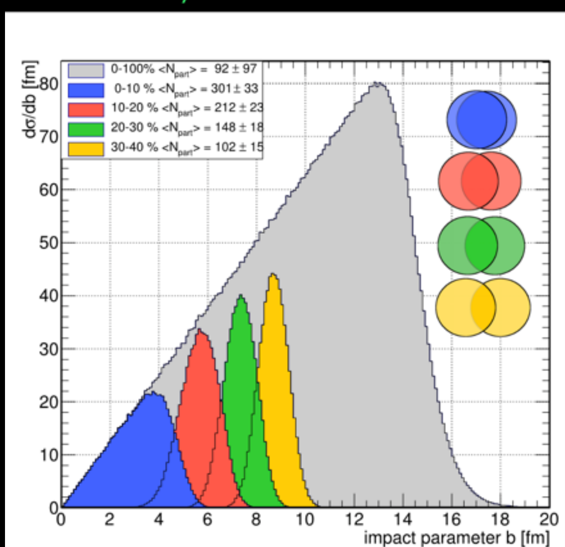




Particle identification by means of:

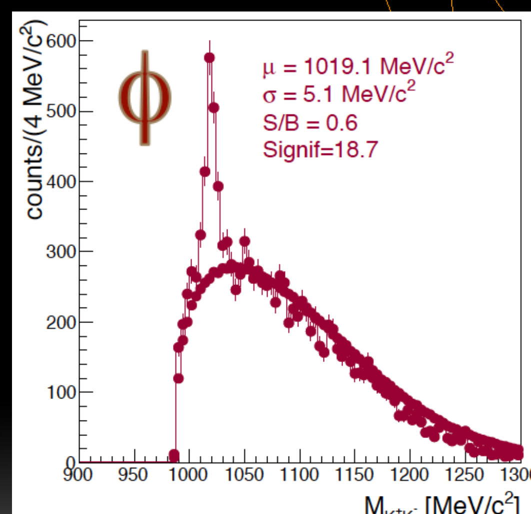
- Velocity
- Momentum
- dE/dx in MDC and ToF
- RICH information

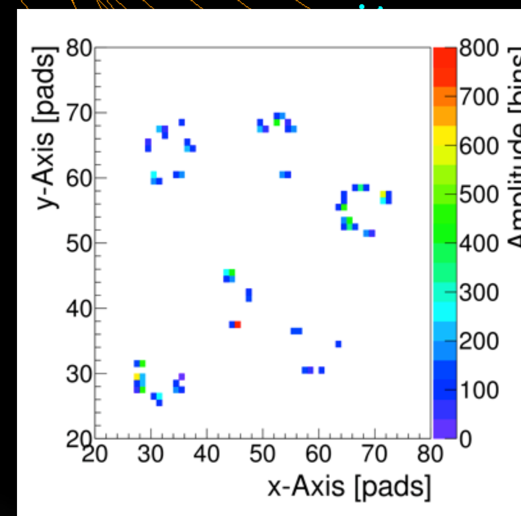
Centrality: Glauber calculation



$\langle A_{part}\rangle$

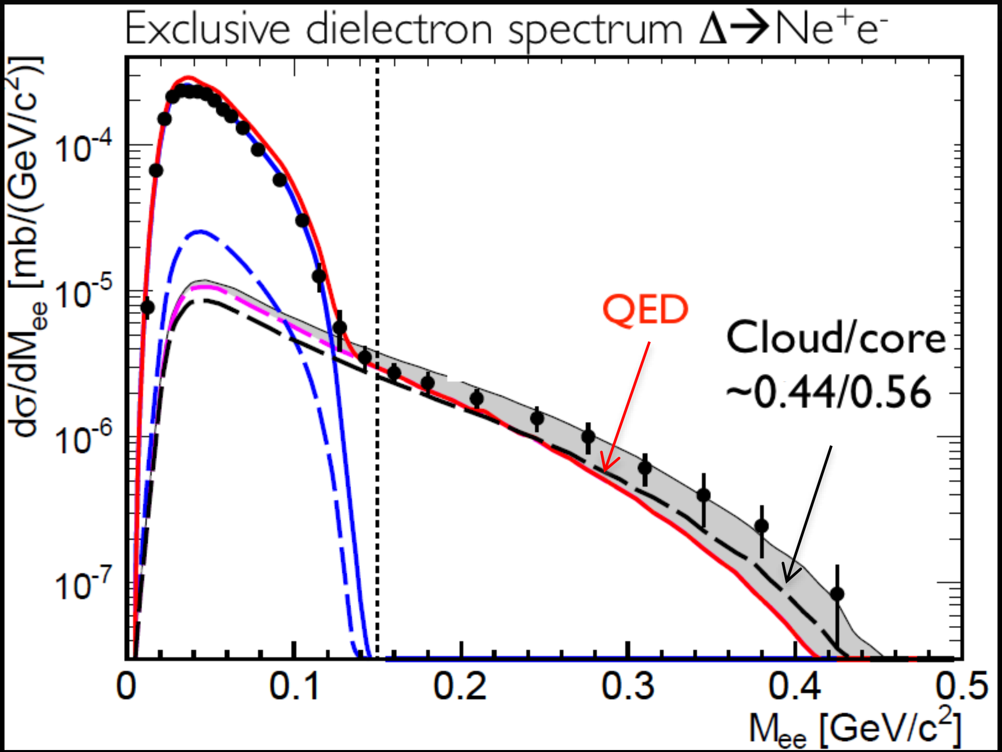
- 0-10% - 301
- 10-20% - 212
- 20-30% - 148
- 30-40% - 102





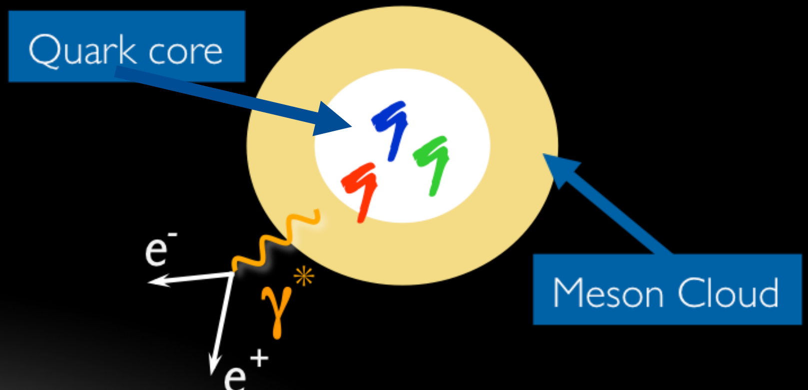
e^+e^- pairs from pp reactions

- Reference measurement for Au+Au
- Exploring hadron electromagnetic structure



pp reactions 1.25 GeV (below free NN η production threshold)

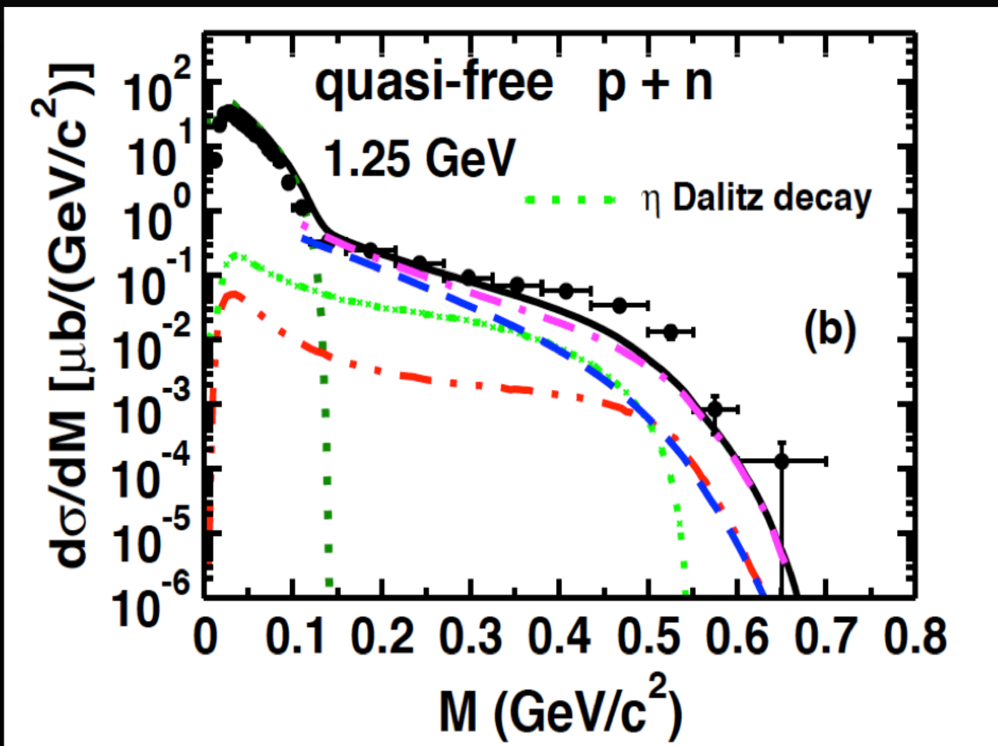
- First direct access to the Δ transition form factor in the time-like region
  BR = 4.42×10^{-5} ± 20%(syst.) ± 9%(stat.)
- Excitation of a baryon can be carried by the meson cloud *[I.G. Aznauryan, V.D. Burkert Prog. Part. Nucl. Phys. 67, 1 (2012)) 1846]*



Data: HADES collab., in preparation
QED: M.I. Krivoruchenko et al. Phys. Rev. D65(2002) 017502
Cloud/core: G. Ramalho, M.T. Peña Phys. Rev. D85(2012) 113014

e^+e^- pairs from np (tagged n) reactions

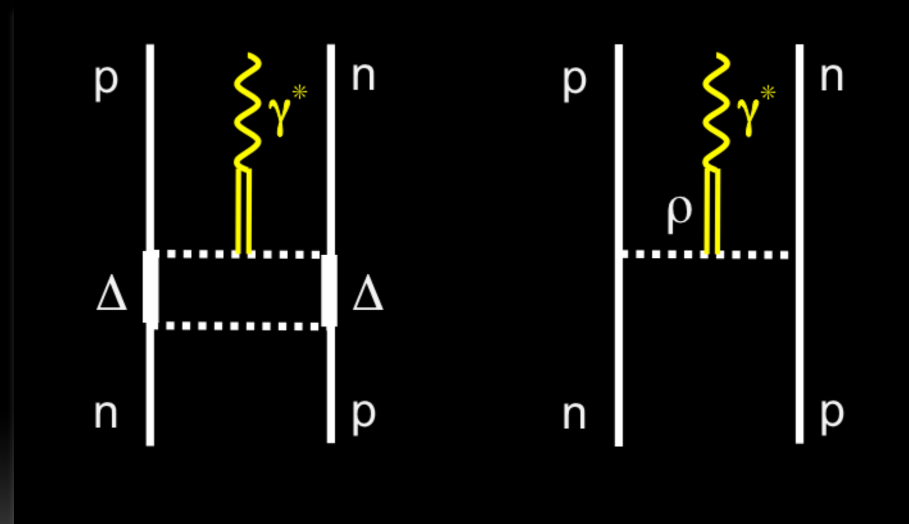
- Reference measurement for Au+Au
- Exploring hadron electromagnetic structure



Data: HADES collab., PLB 690 (2010) 118
R. Shyam and U. Mosel, PRC 82:062201, 2010
M. Bashkanov, H. Clement, Eur. Phys. J. A50, 107, (2014)

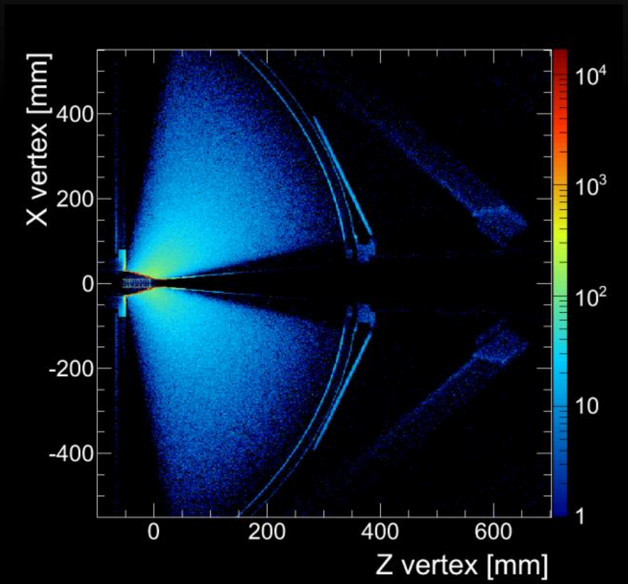
np reactions 1.25 GeV

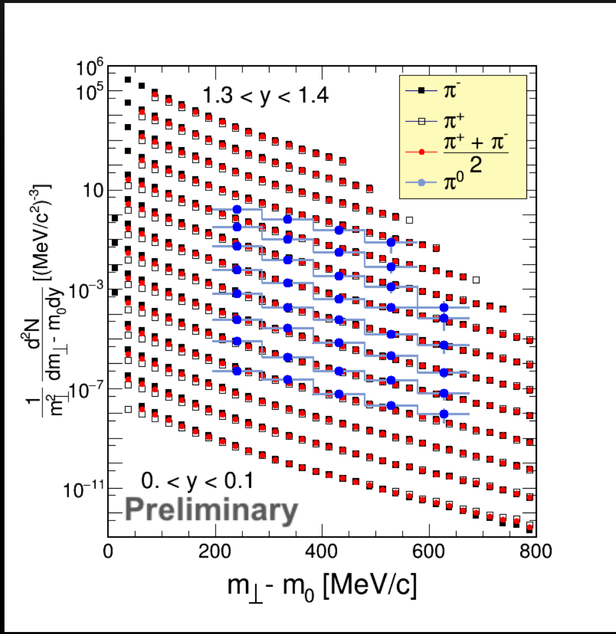
- Remarkable isospin effect
- Radiation from the internal line yields enhanced emission at high invariant masses → off-shell (cloud-cloud) ππ collision

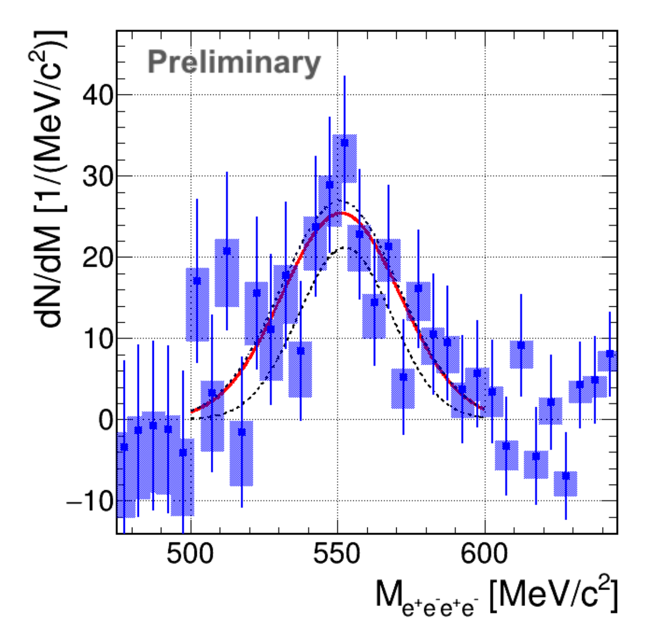


Fixing important components of the hadronic cocktail

Pseudo-scalar mesons measured in HADES via photon conversion





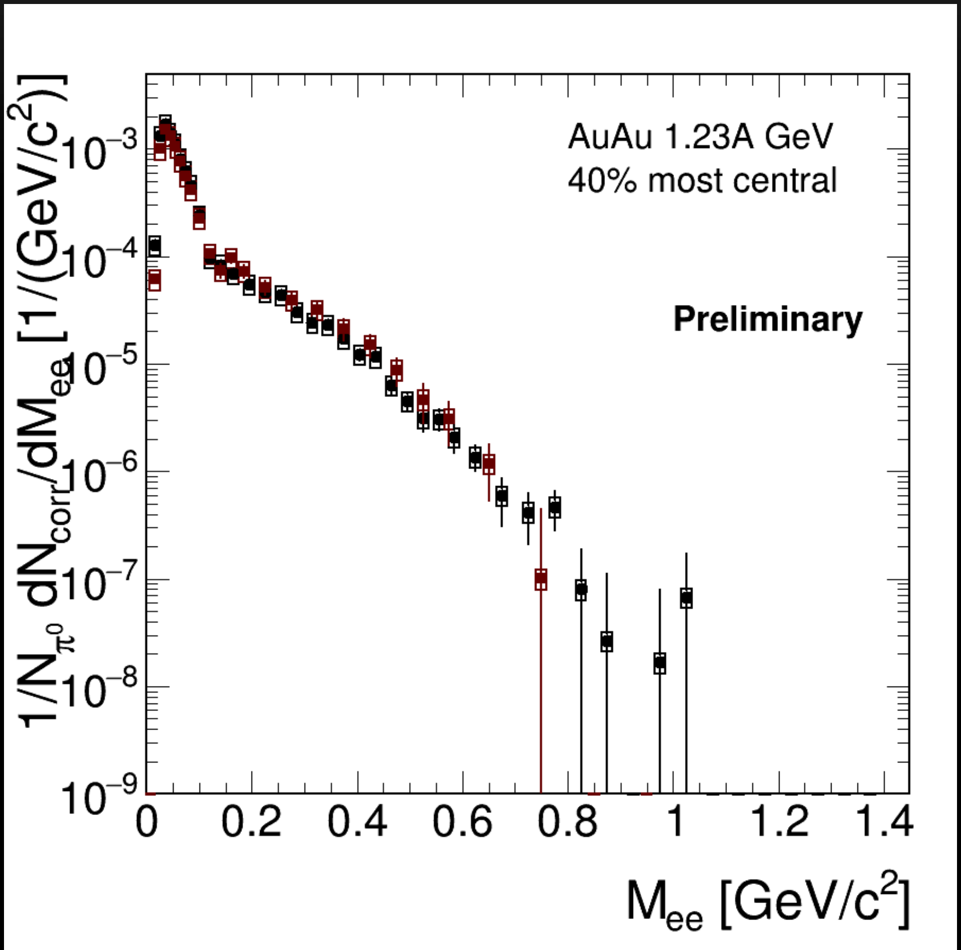


- HADES low mass spectrometer
  - Segmented target
  - RICH: $X/X_0 < 1\%$!
  - MDC: $X/X_0 \approx 0.42\%$

→ specially optimized to minimize conversion and multiple scattering

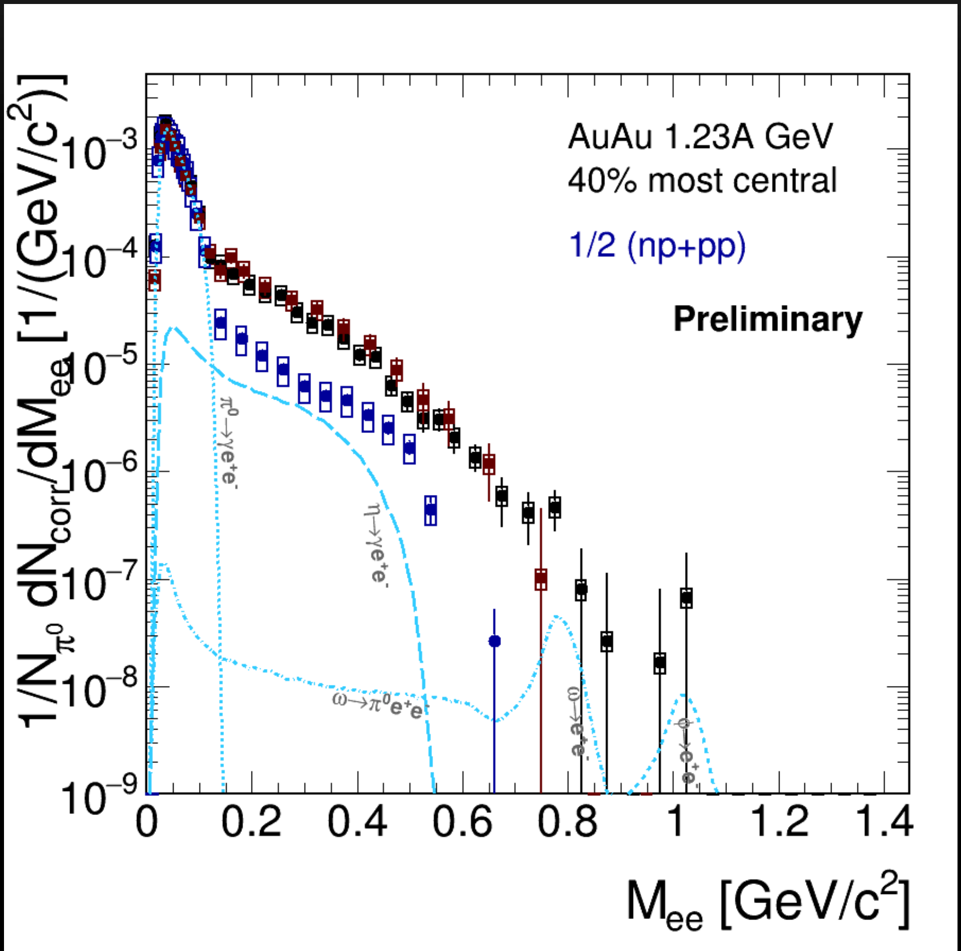
- Very high-statistics π sample
- π^0 consistent with ½($\pi^+ + \pi^-$)
- N_η = 424 ± 133stat - important component of the cocktail

Virtual photon emission in Au+Au collisions



- Normalization to number of neutral pions N_{π}
  - Fireball dominated by incoming nucleons at lower energies
  - Number of charged particles N_{ch} not a good proxy for thermal excitation energy
- Almost exponential spectrum up to vector meson region!

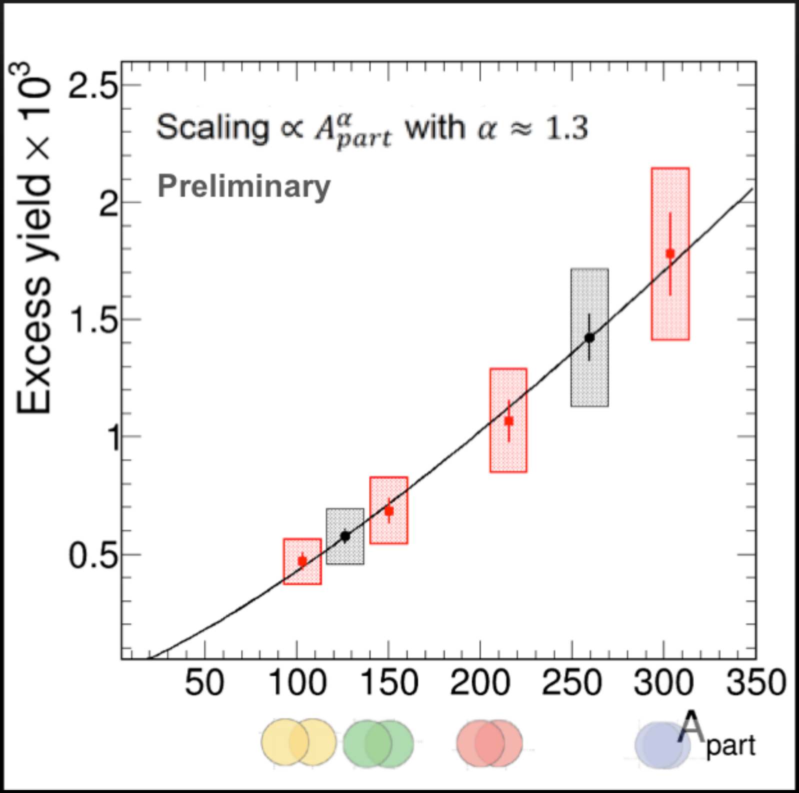
Virtual photon emission in Au+Au collisions

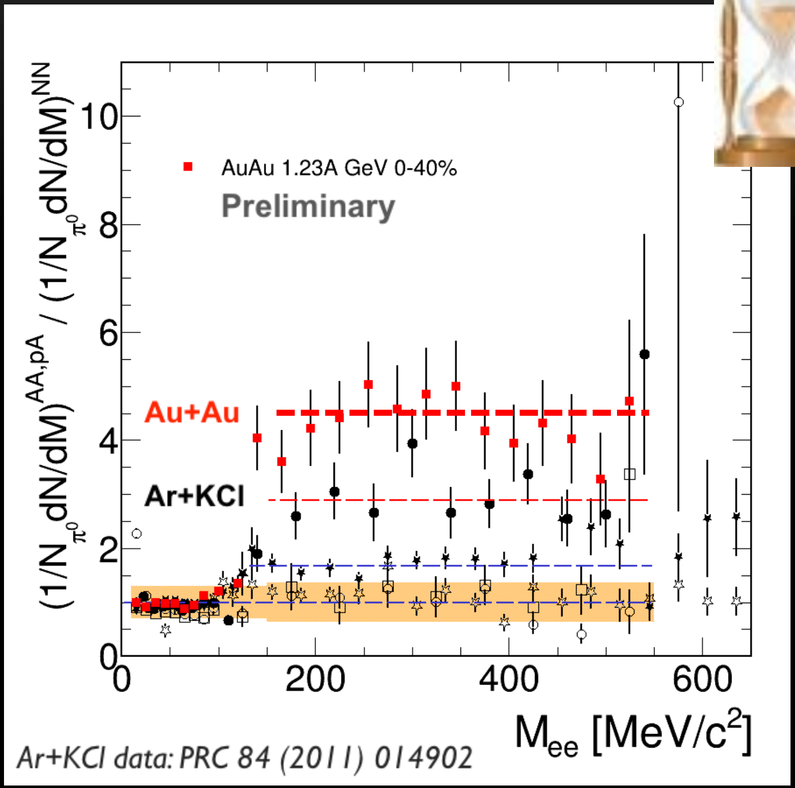


- Comparison to e^+e^- cocktail accounting for decays of mesons (π^0, η, ω, ϕ) at freeze-out
- Strong enhancement above π^0 (in-medium radiation, baryons..)
- Comparison to e^+e^- measured in NN collisions scaled to same A_{part}
- Excess yield $0.2 < M < 0.5$ GeV/c^2 → true in-medium effect

Centrality and system size dependence of the excess

Excess radiation 0.3 < M < 0.7 GeV/c^2

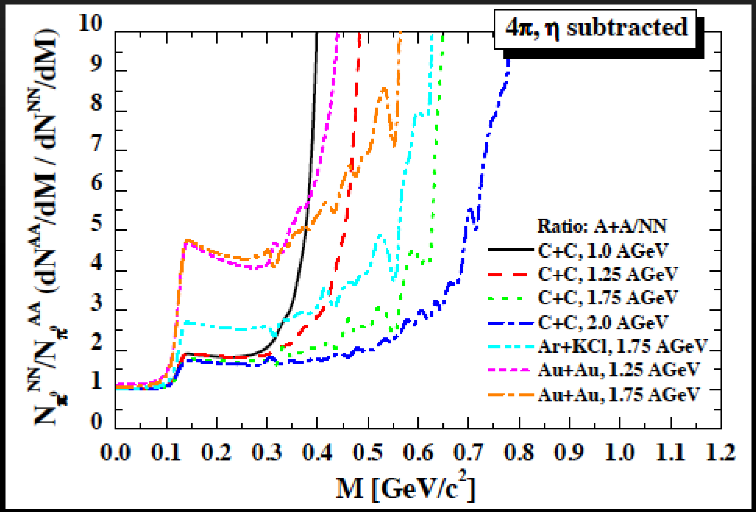




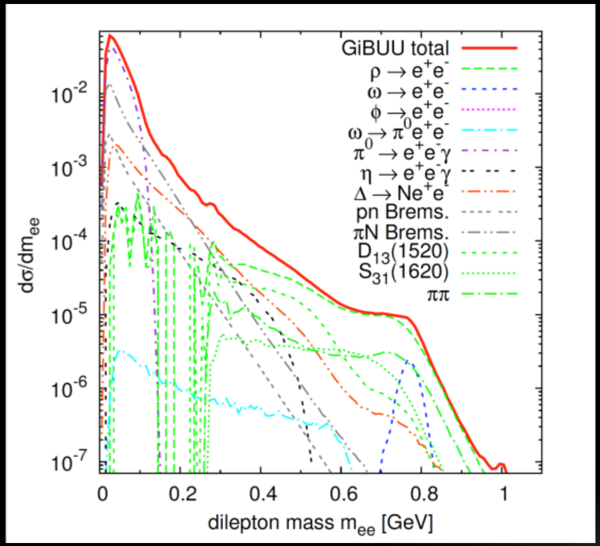
- Strong excess (~$A_{part}^{1.3}$, interplay V ⊗ τ_{coll})
- Dilepton chronometer of the collision time

- Medium radiation goes beyond what is expected from a superposition of incoherent NN collisions
  - → Regeneration of baryonic resonances
  - → Subsummed into spectral functions

Transport treatment of e^+e^- production



Bratkovskaya, Aichelin, et al., PRC 87 (2013) 064907

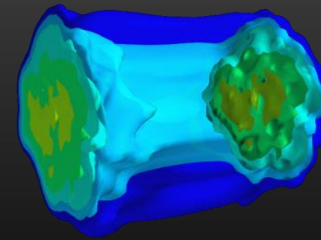


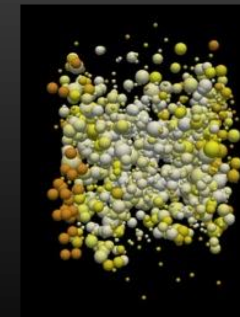
GiBUU J. Weil et al.

- In HSD, dilepton excess above NN due mostly to Δ regeneration & decay
- In GiBUU more baryon resonances are included, e.g. N*(1520)
- The interference of elastic and inelastic channels is neglected
- Difficulties to incorporate in-medium physics - vacuum SFs used

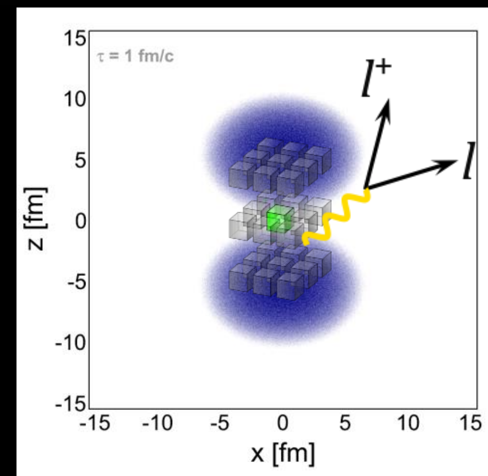
→ comparison with data in preparation

Coarse-grained transport approach



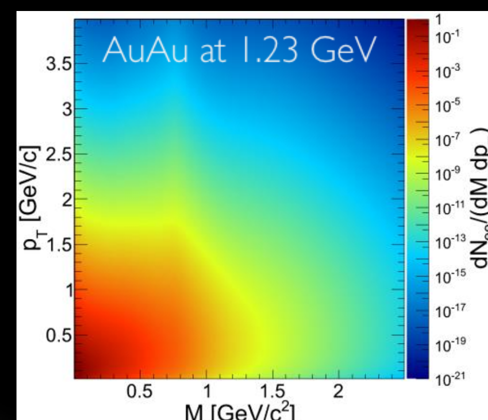


- "Combine" the advantages of both descriptions: hydrodynamics & transport
- Simulate events with a transport model
  → ensemble average to obtain smooth space-time distributions



- Divide space-time evolution into 4-dimesional cells
  21 x 21 x 21 space cells ($1 fm^3$), 30 time steps → ~ 280 k cells
- Determine for each cell the bulk properties like T, μ_B , μ_π, collective velocity

- Apply in-medium ρ & ω spectral functions to compute EM emission rates
  → parameterization of RW in-medium spectral function
- Sum up the contributions of all cells



Similar approaches by

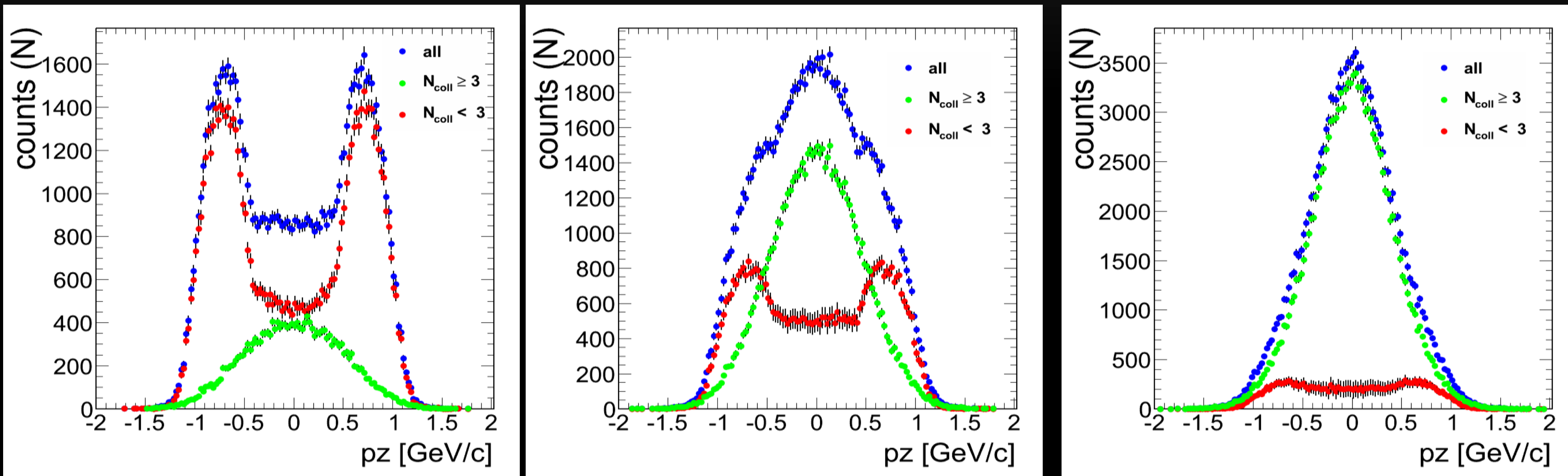
Huovinen et al., PRC 66 (2002) 014903

Endres et al.: PRC 91 (2015) 054911, PRC 92 (2015) 014911, PRC 93 (2016) 054901, arXiv:1604.06414

Local thermalization

Momentum distributions of nucleons, Au+Au 1.23A GeV, central cell

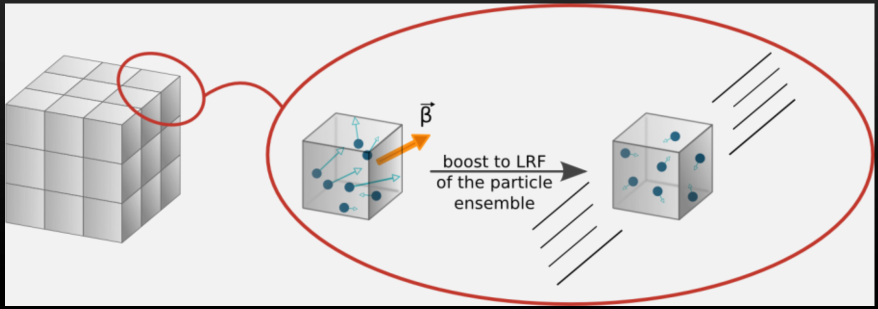
τ = 2 fm/c τ = 3 fm/c τ = 5 fm/c



- Gaussian shaped p_z distribution builds up for nucleons with $n_{coll} \geq 3$
- m_t spectra have exponential shape
- Check for every cell → deviations are kept in space-time evolution

Determination of bulk properties

- Baryon density via 4-current
- Lorentz-boost to local rest frame (LRF) where the baryon current vanishes

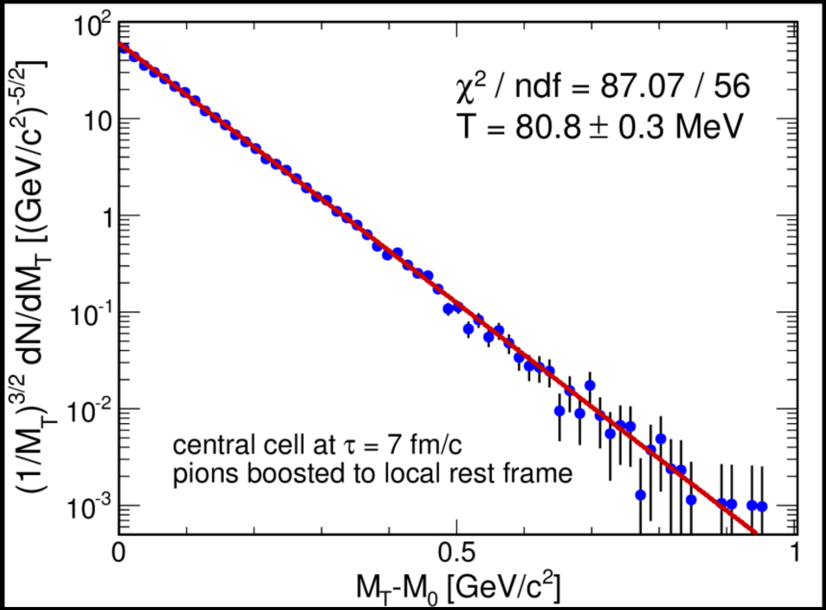


- In Boltzmann approximation

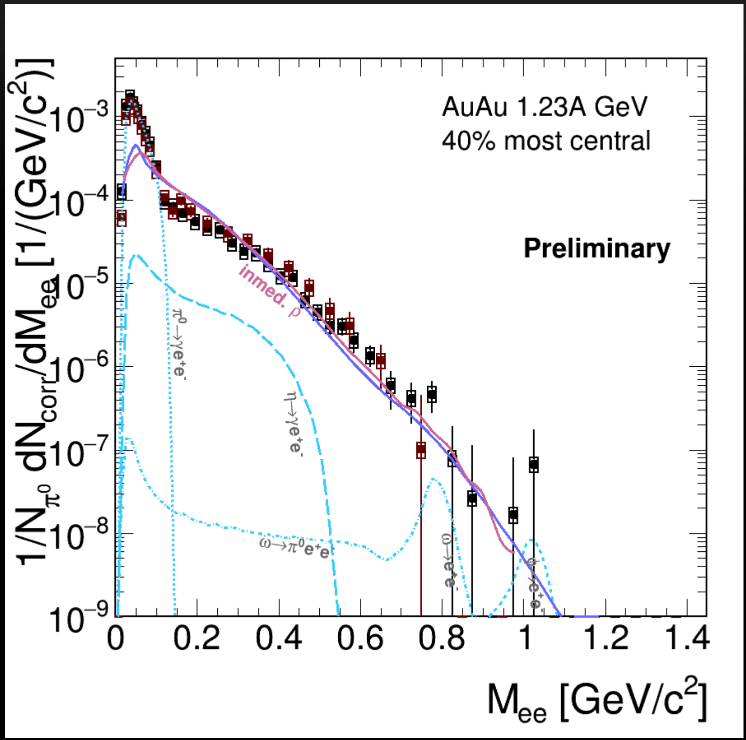
$$\frac{d^3N}{d\vec{p}} = \frac{d^3N}{dp_z\, p_t\, dp_t\, d\theta} \propto \exp(-E/T)$$

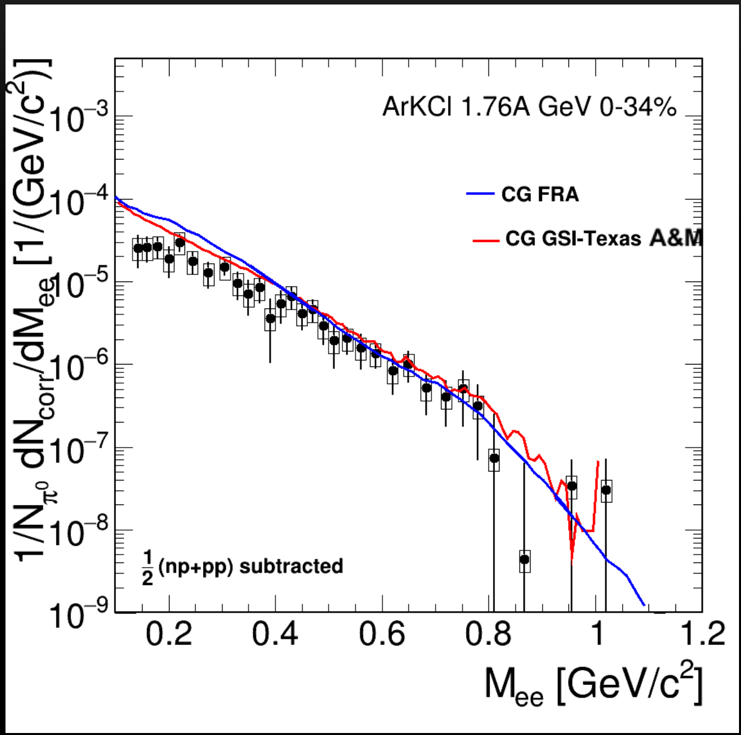
$$\frac{1}{m_t^{3/2}} \frac{dN}{dm_t} \propto \exp(-m_t/T)$$

- Fill m_t spectra with particle momenta in LRF (mean flow v_{coll} vanishes)
- Fit exponential function to extract T (species of choice: pions)



Thermal dilepton emission at SIS18?



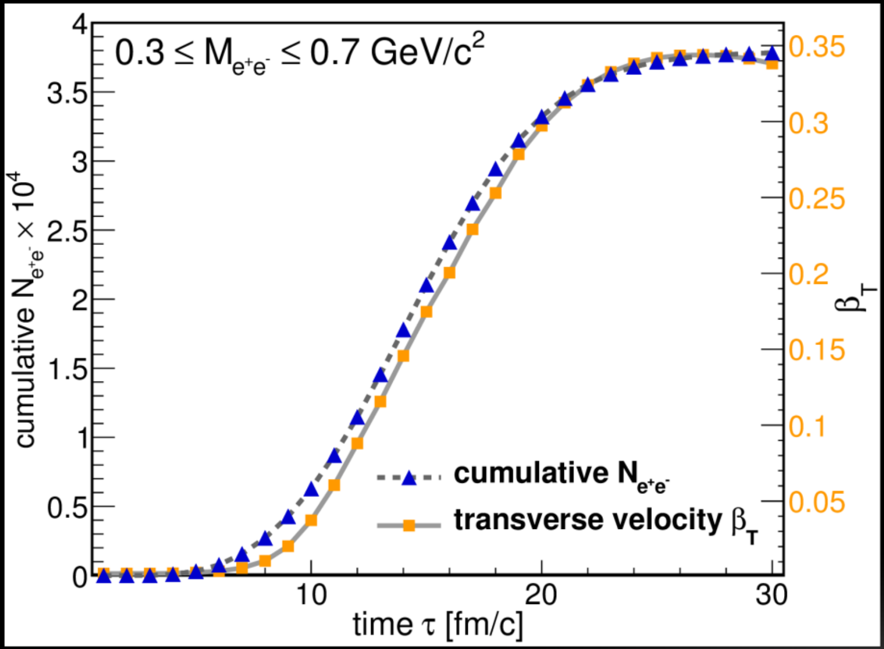


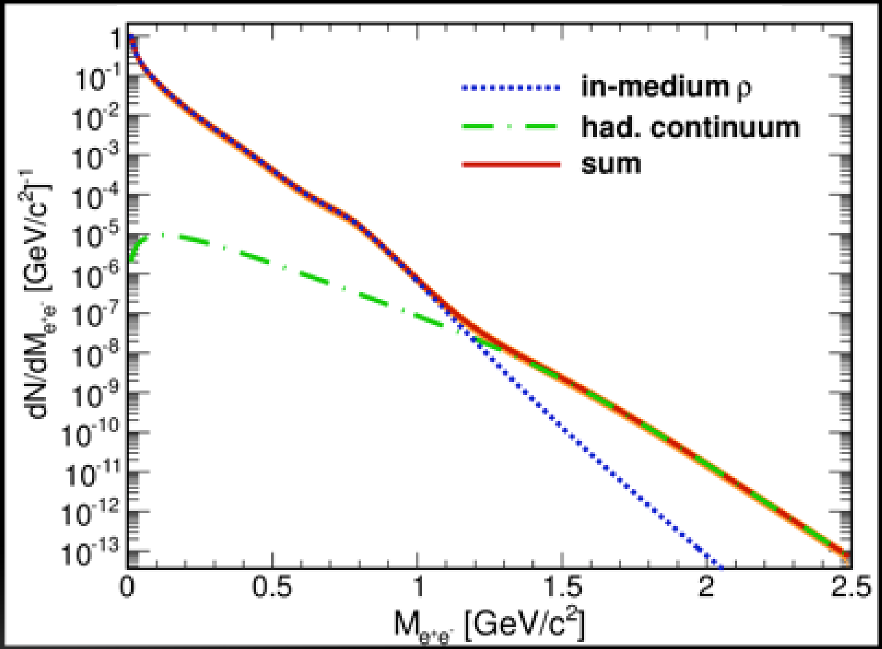
CG FRA: Phys. Rev. C 92, 014911 (2015)
CG GSI-Texas A&M: Eur.Phys.J. A52 (2016) no.5, 131

- Coarse-graining method works at low energies
- Supports baryon-driven medium effects at UrHIC (SPS and RHIC)!
- Robust understanding across QCD phase diagram

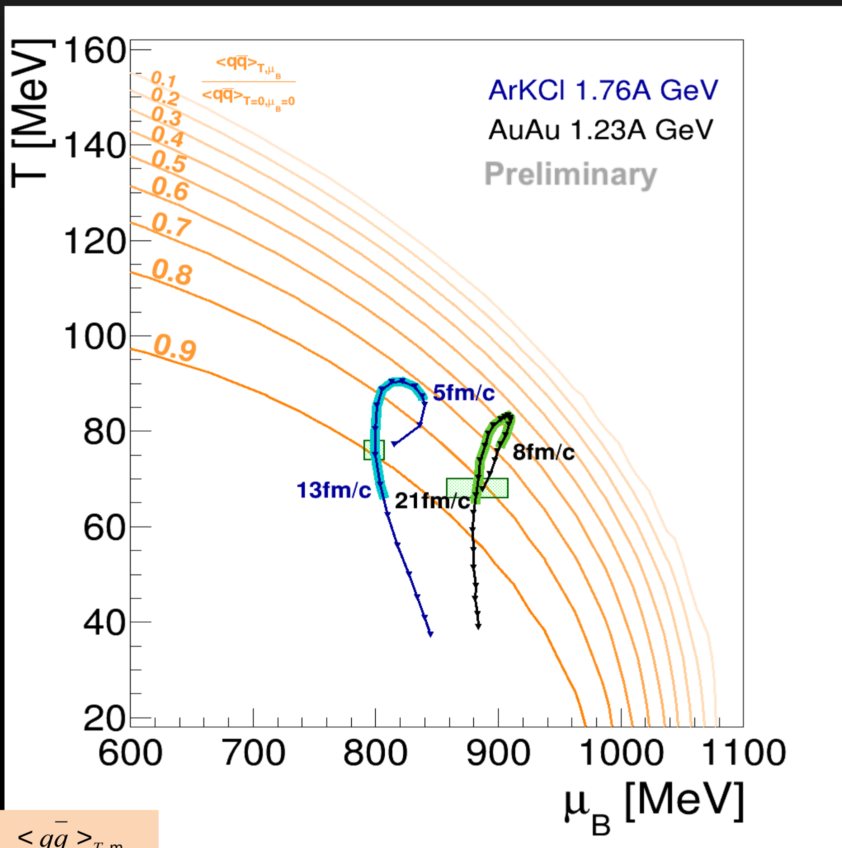
Dileptons as fireball probes

- Time evolution of cumulative dilepton yield in mass window M = 0.3-0.7 GeV/c^2
- Active radiation window ~13 fm/c follows build-up of collective medium flow ➡ fireball lifetime
- Strong medium effects on ρ-meson ➡ remarkably structure-less low-mass spectrum
- $\mathrm{d}R_{ll}/\mathrm{d}M \propto (MT)^{3/2}\exp(-M/T)$
- Inverse slope parameter: T_S = 88 ± 5 MeV in IMR, T_S = 64 ± 5 MeV in LMR





HADES and QCD phase diagram of matter

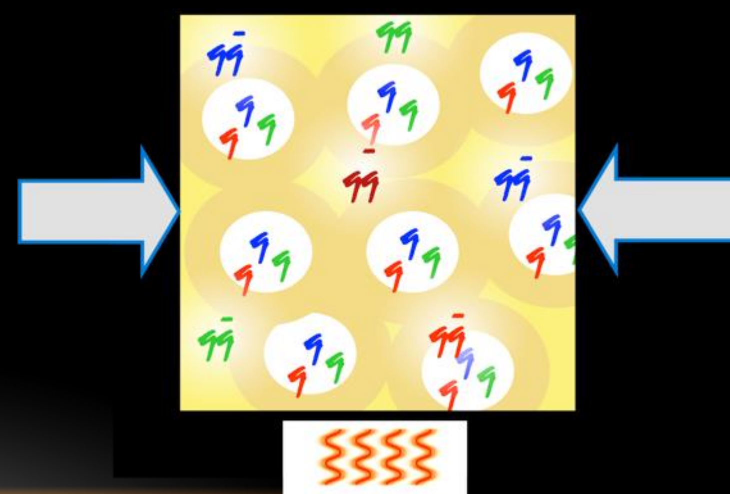


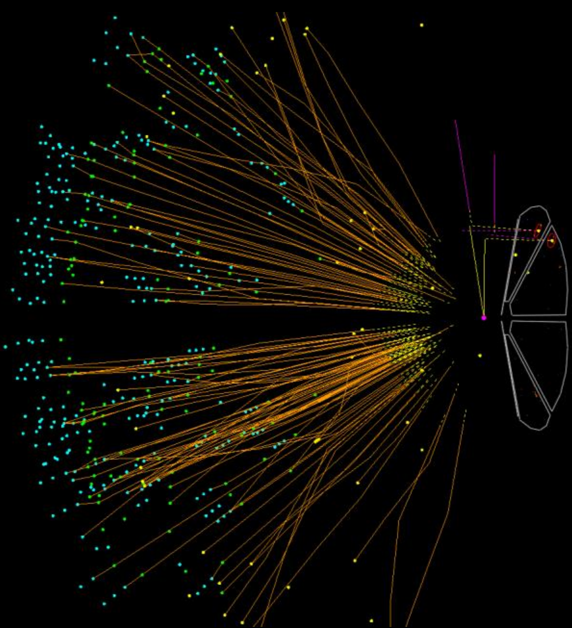
$\frac{<q\bar{q}>_{T,m_B}}{<q\bar{q}>_{T=0,m_B=0}}$: *B.J. Schaefer and J. Wambach*

HADES Ar+KCl data: Nucl. Phys. A931 (2014) c785

ArKCl (70±2 MeV, 749±5 MeV)
AuAu (68±2 MeV, 883±55 MeV)

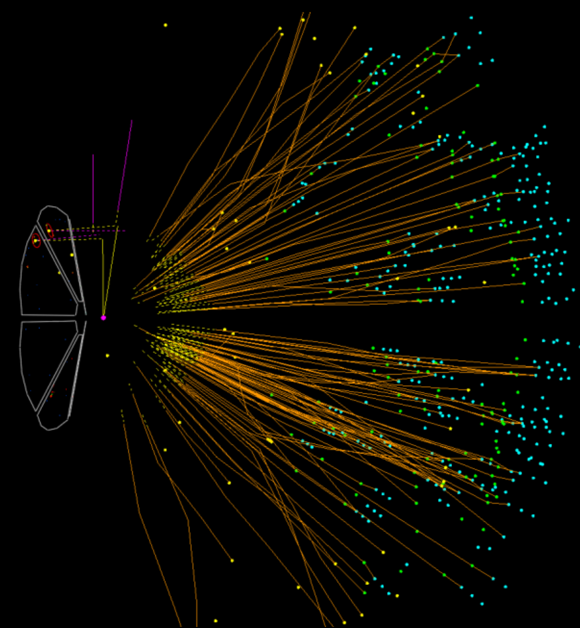
- Chemical freeze-out from measured particle yields analyzed with SHM
- Trajectories extracted from inner cube of cells with coarse-grained UrQMD
- Time-window of dilepton emission
  - Radiation stops shortly after chemical freeze-out
  - Access to hot and dense stage of the heavy-ion collision
- Excitation of the vacuum (melting of condensate) matches spectral medium effects!





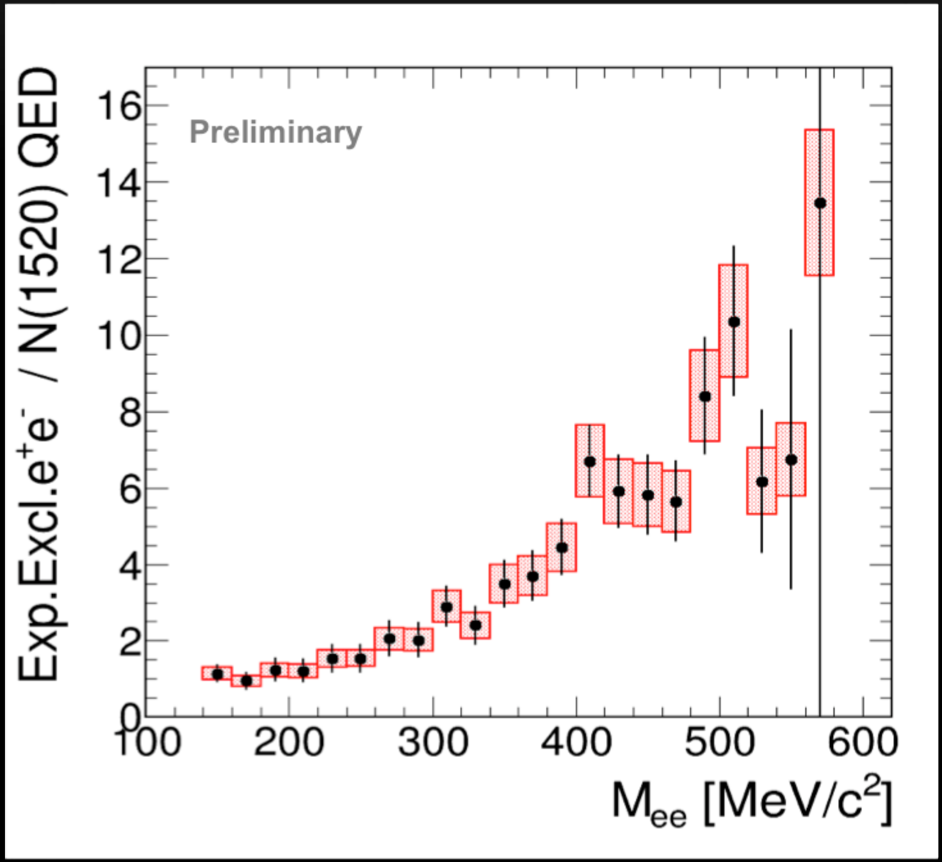
”If you are out to describe the truth, leave elegance to the tailor”
A. Einstein

HADES π-beam



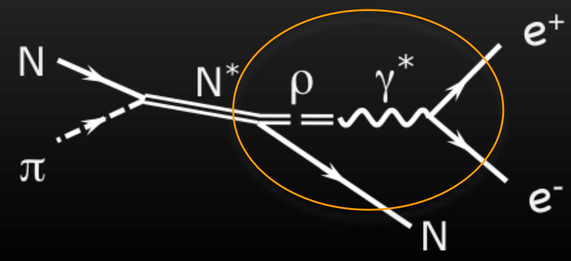
Verify the ρ-baryon coupling mechanism

Exclusive $\pi^- p \rightarrow n e^+ e^-$ at $\sqrt{s}$ = 1.49 GeV



ρ meson contribution from the measured $\pi^+\pi^-$ channel and using the strict VMD:

$$\frac{d\sigma}{dM_{ee}} = \frac{d\sigma}{dM_{\pi\pi}} c_p \left(\frac{m_\rho}{m_{ee}}\right)^3$$

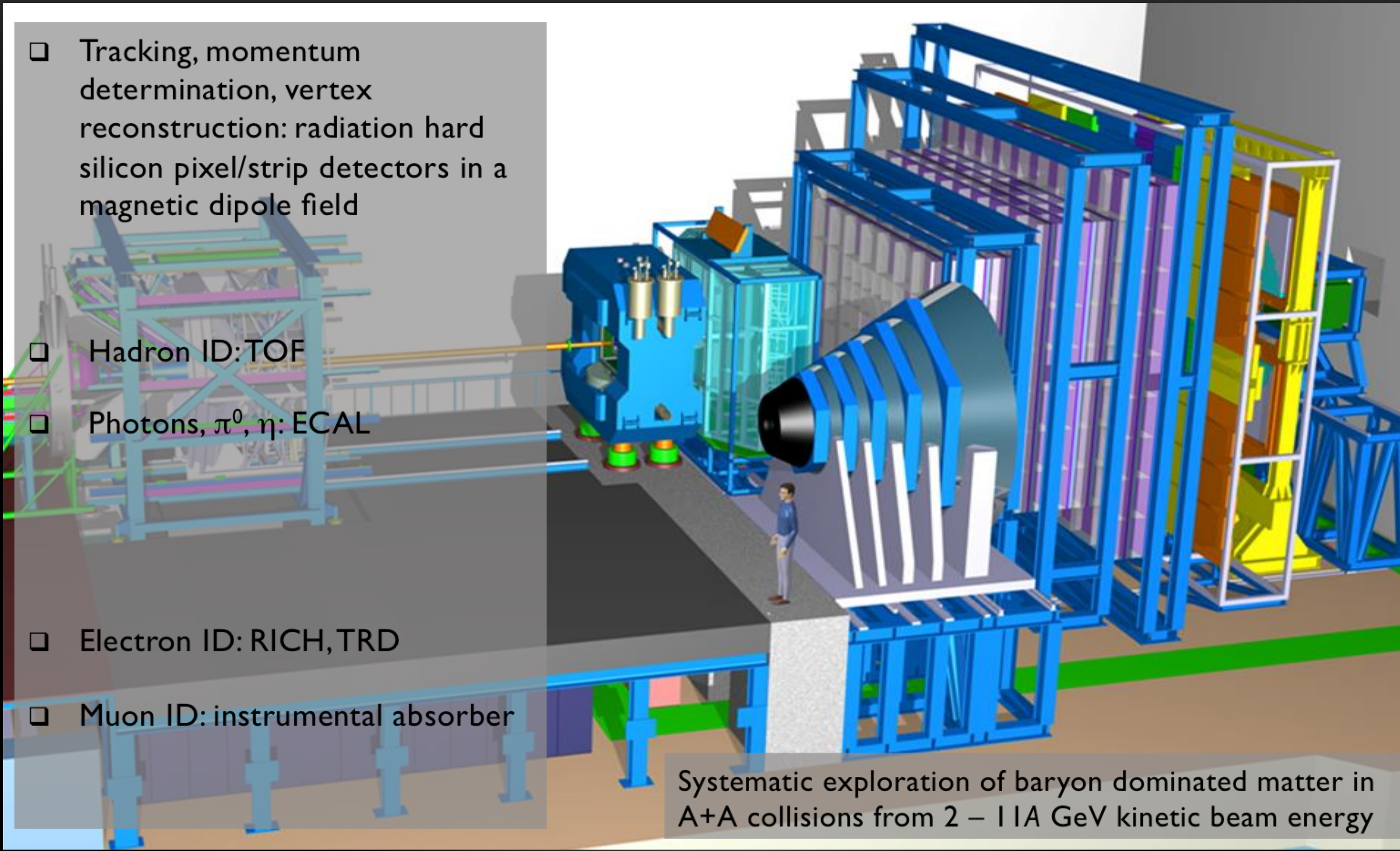


- Vector Meson Dominance: the basis of emissivity calculations for QCD matter.
- Crucial to support the validity of the model by elementary reactions

→ Virtual excitation of ρ-meson states in the baryons' meson cloud?

→ Strong deviation from unity show the time-like contribution to the resonance decay and along strict VMD!

The CBM experiment

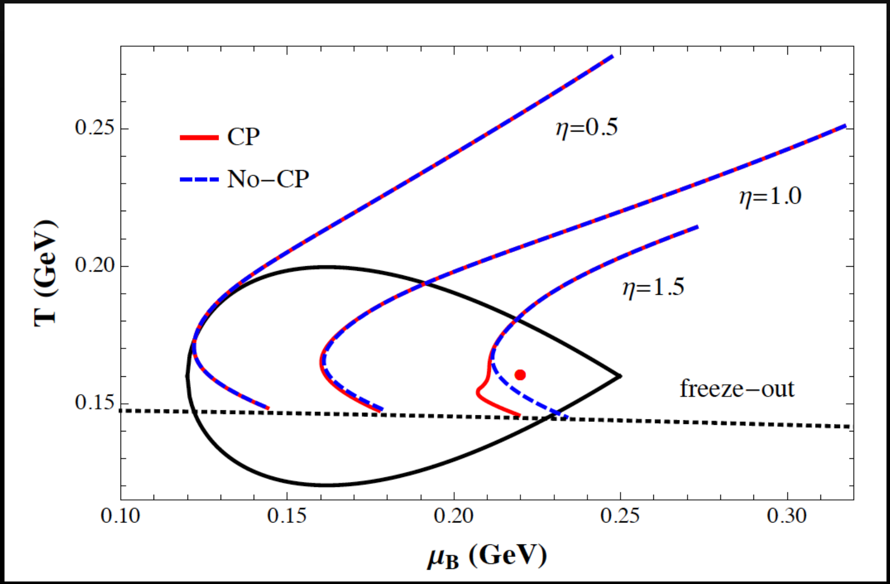


- Tracking, momentum determination, vertex reconstruction: radiation hard silicon pixel/strip detectors in a magnetic dipole field
- Hadron ID: TOF
- Photons, π^0, η: ECAL
- Electron ID: RICH, TRD
- Muon ID: instrumental absorber

Systematic exploration of baryon dominated matter in A+A collisions from 2 – 11A GeV kinetic beam energy

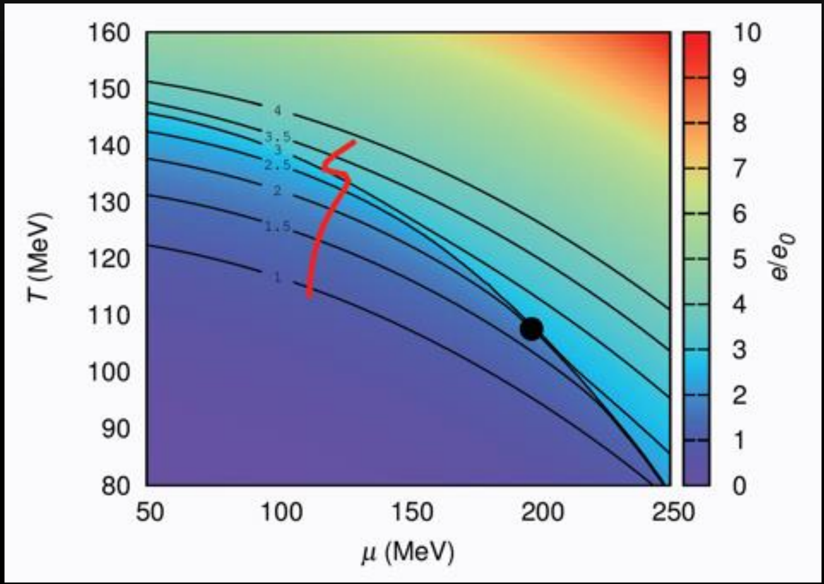
Mapping QCD phase diagram with dileptons

Hydrodynamic evolution trajectories



A. Monnai, S. Mukherjee, Y. Yin: arXiv: 1606.00771

Event-averaged trajectory near the critical point (black dot)



C. Herold, M. Nahrgang, Y. Yan and C. Kobdaj, PRC93 (2016)

Diverging bulk viscosity at QCD critical point

$$\zeta \sim \tau_{\Pi} \sim \tau_{\sigma} \sim \xi^3$$

Bulk viscosity

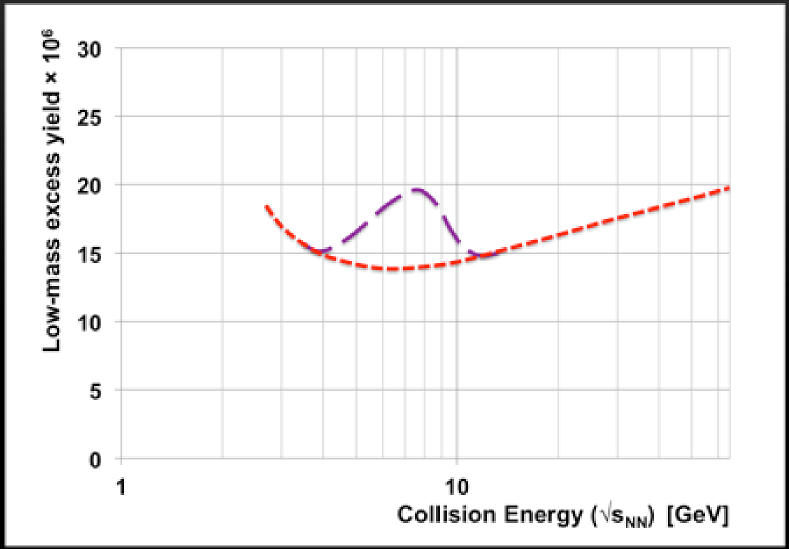
Bulk relaxation time

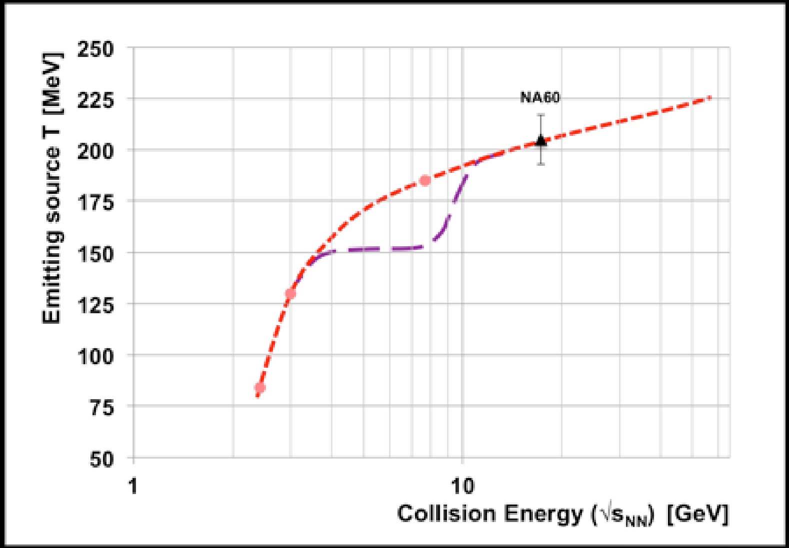
Relaxation time for the critical mode

Correlation length³

What are the possible signatures in dilepton radiation?

Mapping QCD phase diagram with dileptons





Dashed violet curve corresponds to a speculated shape with phase transition

- Yield in low-mass window tracks fireball lifetime
  - Measure excitation function of ρ spectral function
  - Search for anomalous fireball lifetime around phase transition & CP

- Intermediate mass slope measures the emitting source temperature (true, no blue shift)
  - Measure T_{slope} (note, $T_{slope} < T_{initia}$) "caloric curve"
  - Plateau around onset of deconfinement? *(see e.g. M. D'Agostino et al. NPA 749 (2005) 5533)*

Future experiments allow for overlap and independent confirmation of results!

Connection to the fundamental properties of the QCD → Chiral symmetry

Weinberg Sum Rules…

Weinberg '67, Das et al '67

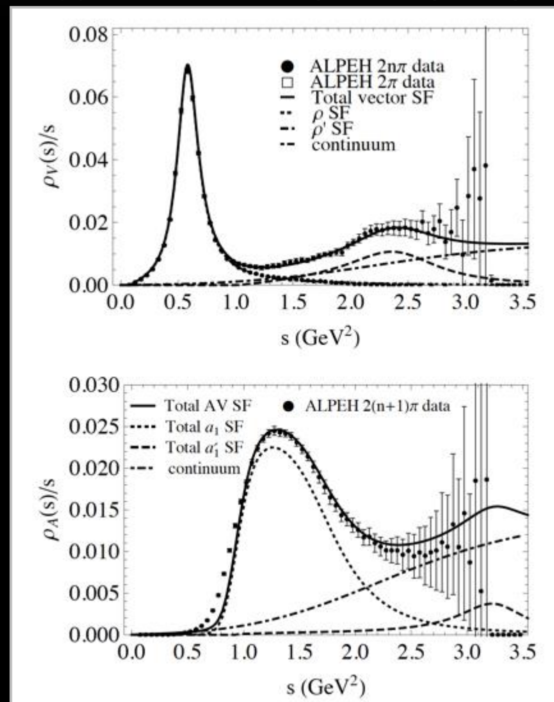
$$\int \frac{ds}{\pi}\frac{1}{s}(\rho_V - \rho_A) = f_\pi^2$$

$$\int \frac{ds}{\pi}\,(\rho_V - \rho_A) = -m_q \langle \bar{q}q \rangle$$

$$\int \frac{ds}{\pi}\, s\,(\rho_V - \rho_A) = c\alpha_s \langle (\bar{q}q)^2 \rangle$$

…valid in vacuum

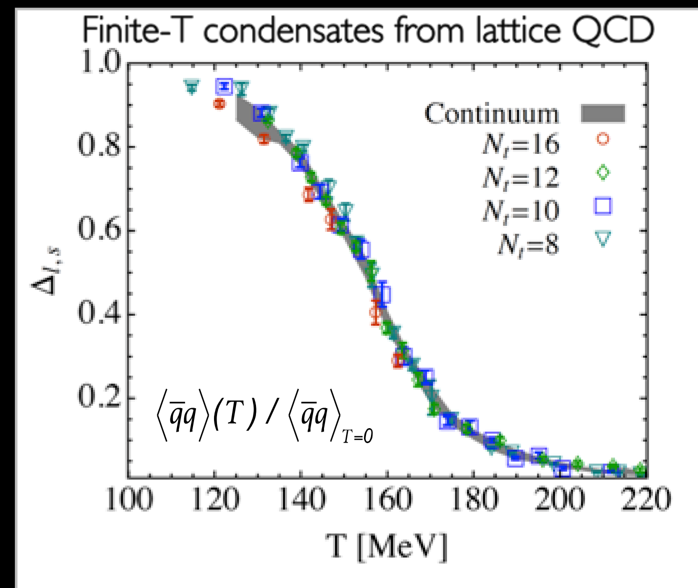
Rapp et al, Annals Phys. 368 (2016)



ρ-a$_1$ mass splitting due to χ_s breaking (~f_π, $\langle q\bar{q} \rangle$)

… remain valid in medium

J. Kapusta, E. Suryak '94



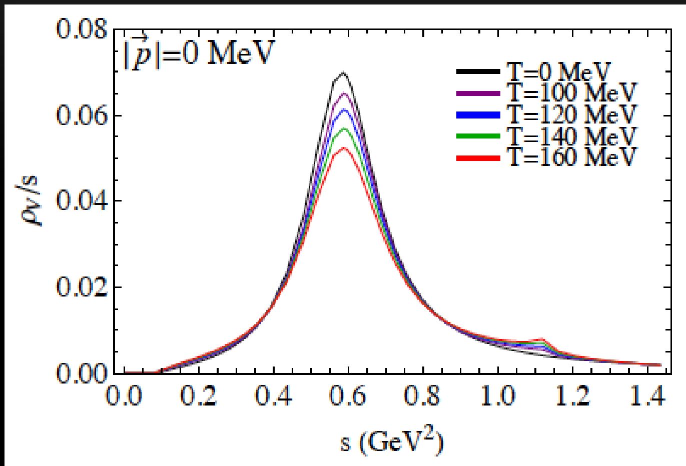
S. Borsanyi et al., JHEP 1009 (2010) 073

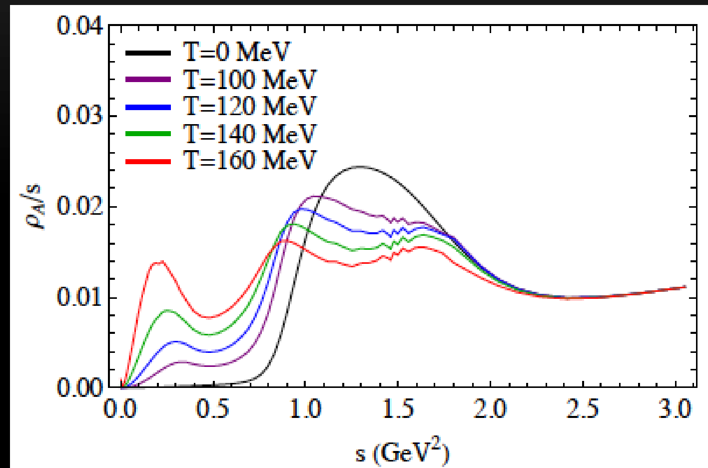
ρ-a$_1$ mass degeneracy

→ Test in-medium ρ spectral function

→ Dropping mass vs. broadening

ρ-a_1 spectral functions and chiral symmetry





P. Hohler, R.Rapp, arXiv:1510.00454v1 [hep-ph] 2 Oct 2015

- Vector and axial-vector spectral functions in a pion gas
- No baryon effects accounted for yet

- 4π processes: πa_1 → γ^* → l^+l^- (chiral mixing) is a dominant hadronic source in IMR
  - No correlated charm contribution!
  - No Drell-Yan!
  - No QGP!?
- Results in elementary collisions provide an important baseline for future explorations in HIC
  → HADES: high statistic π+p and π+A in 2018

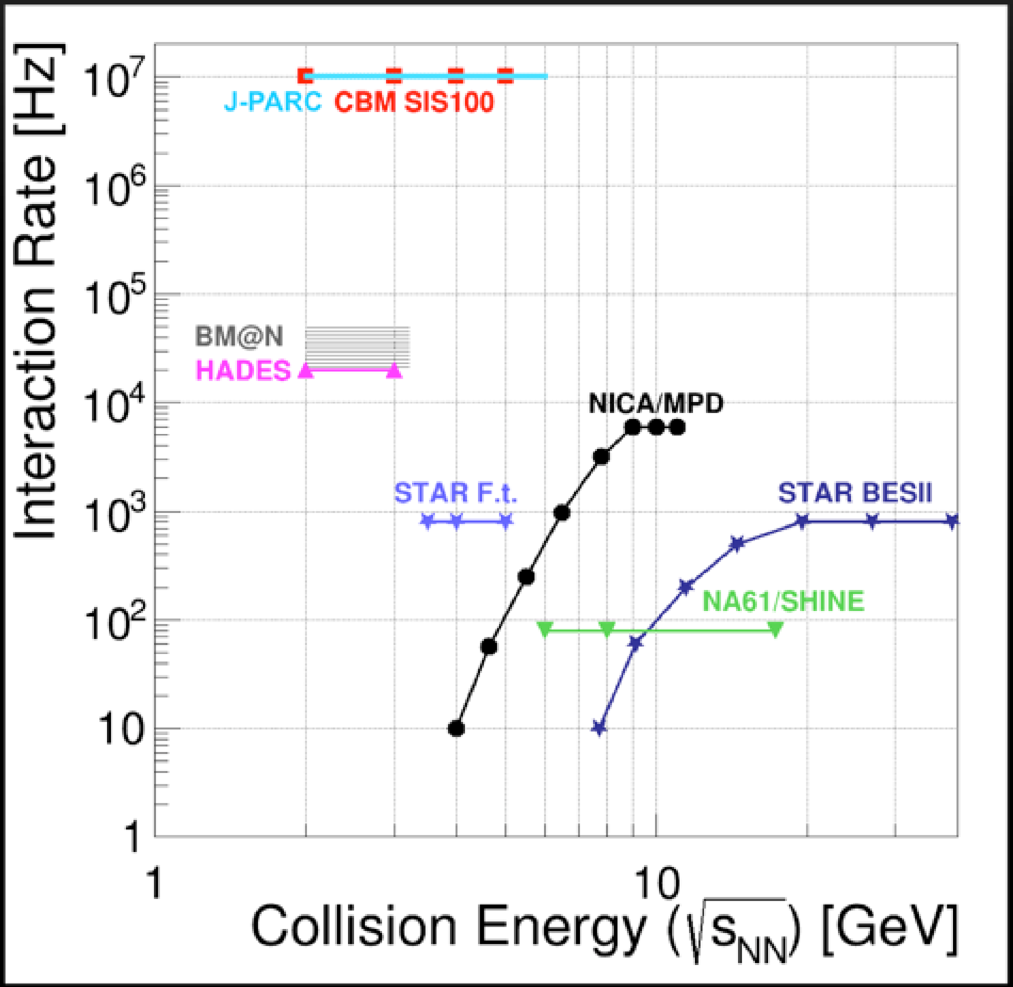
"You may say I'm a dreamer… but I'm not the only one"

		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
HADES	SIS18			2.5 GeV + pA, πA							
STAR BES	RHIC				8 – 20 GeV			200GeV			
MPD	NICA				4 – 11 GeV						
CBM	SIS100							2 – 5 GeV			
ALICE*	LHC	5.5 TeV					5.5 TeV				
	J-PARC**			pA 8 GeV							2 –5GeV
NA60+	SPS		LOI						6 – 17 GeV		
PHENIX	RHIC	200 GeV									
STAR	RHIC	200 GeV	pp(500)								
sPHENIX								200 GeV			
BM@N	Nuclotron		2 – 3 GeV								

* - ITS, 50kHz, lower field

** - Proposal to J-PARC in 2016, If approved, construction of HI injector and detectors in 10 years ?

The ion experiments



CBM collab., arXiv:1607.01487 [nucl-ex]

Colliders not competitive to fixed-target experiments in terms of interaction rate
→ Rare probes difficult to access

CBM running scenario:

- Au ion beams on Au target (1% λ_i)
- Energy scan: 3.5 – 5 – 7 – 9 – 11A GeV
- 50kHz - 1MHz interaction rate
- 20 days / energy

Numbers are from:

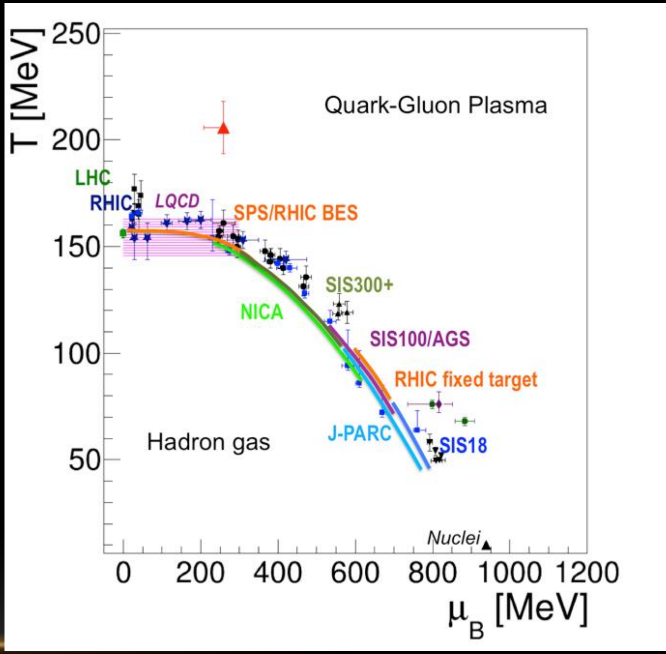
- NICA: A. Sorin, CPOD 2014
- RHIC: C. Montag, D. Cebra, CPOD 2014
- STAR Fixed Target: G. Odyniec, CPOD 2013
- SPS: G. Usai TPD workshop'14
- NA61: M. Gazdzicki, CBM Symposium 2014
- HADES: J. Michel et al., IEEE Trans.Nucl.Sci. 58 (2011)
- J-PARK: http://silver.j-parc.jp/sako/white-paper-v1.21.pdf

Encouraging prospects for studying QCD matter in the region of finite μ_B with dileptons

- HADES: Unique possibility of characterizing properties of baryon dominated matter with rare and penetrating probes:
  - Long-lived states of compressed resonance matter are produced in heavy-ion collisions in the few-GeV energy regime
  - This state of matter might be much more exotic than a hadron gas

- CBM: establish a complete excitation function of dilepton production from SIS18 up to SIS100
  - Change in degrees of freedom
  - Chiral symmetry restoration
  - Emitting source temperature

- Future experiments allow for overlap and independent confirmation of results

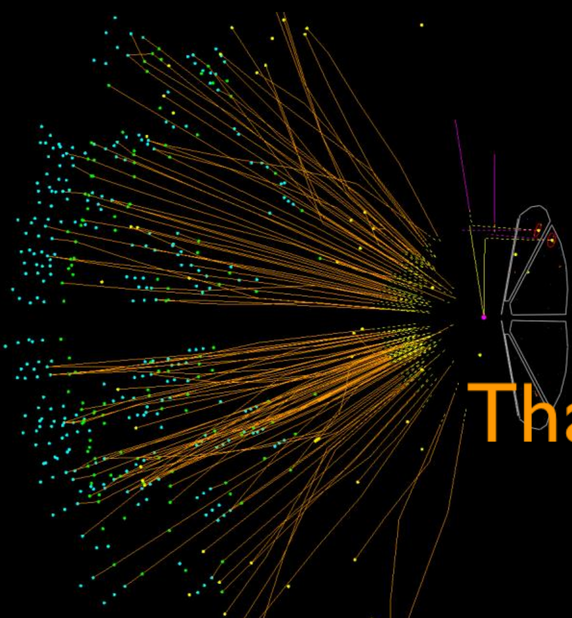



CBM collaboration
56 institutions, > 500 members

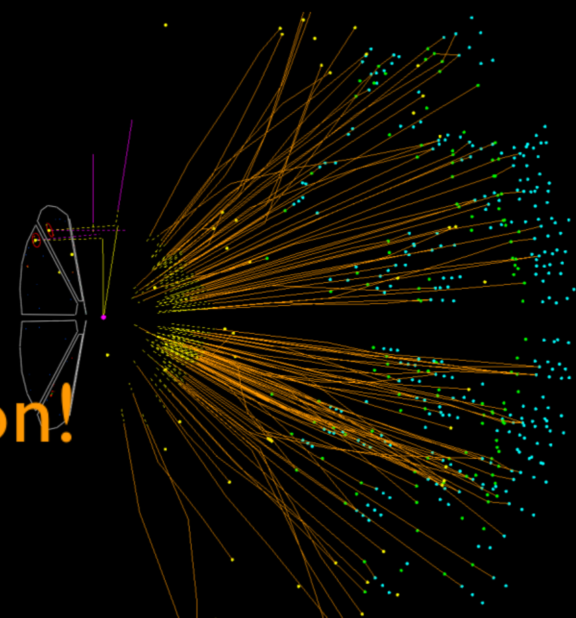
CBM

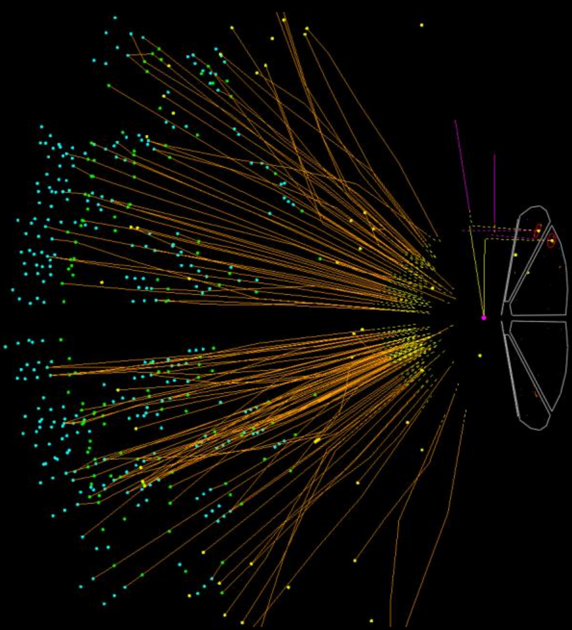

The HADES Collaboration
14 institutions, ~100 collaborators

HADES

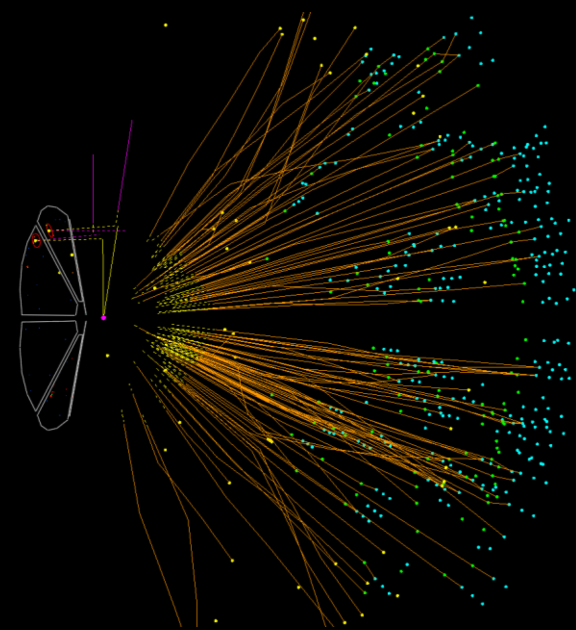


Thank you for your attention!

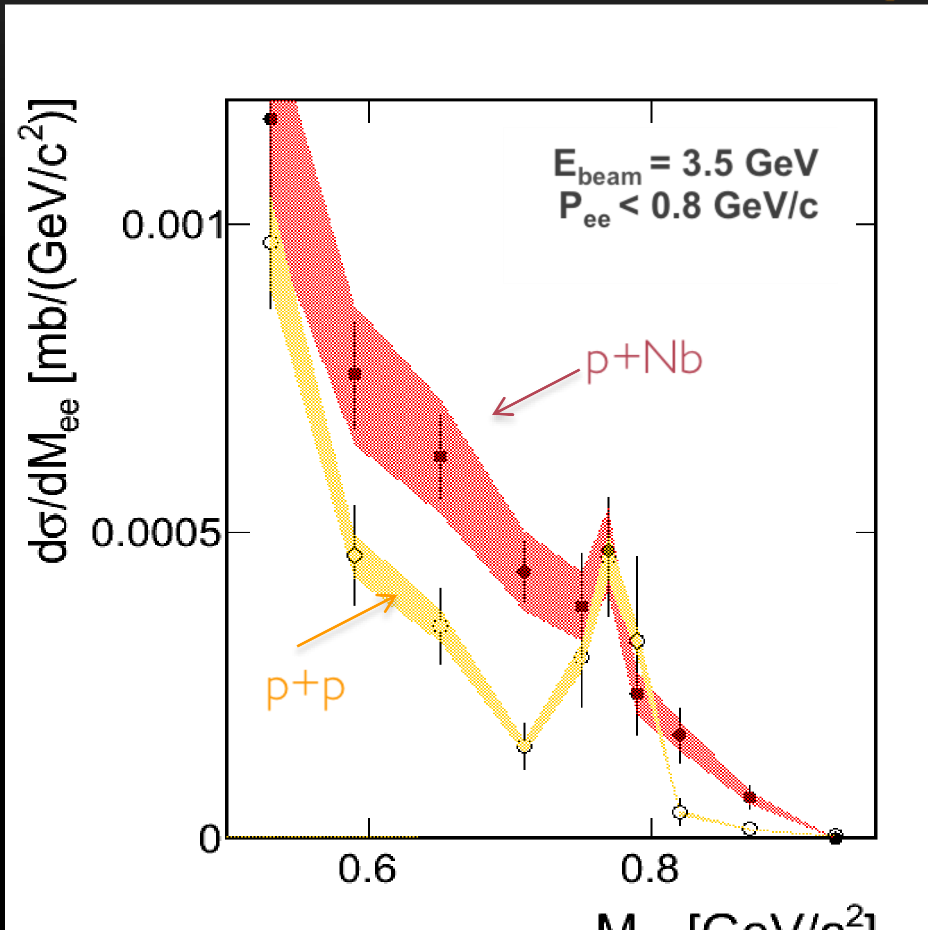




Bonus slides



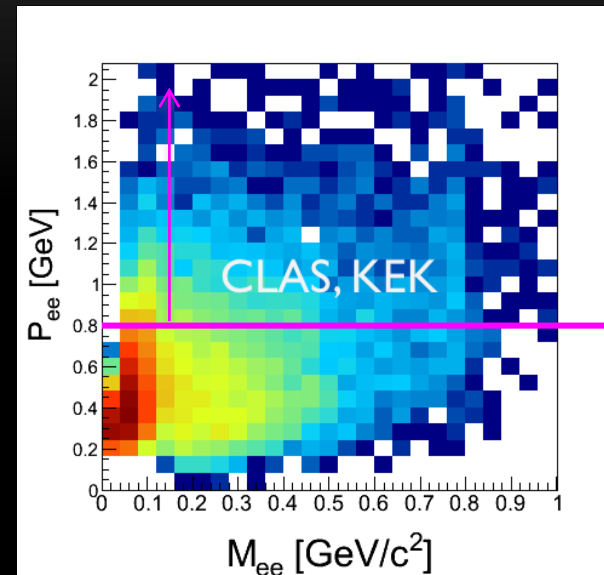
Are there narrow in-medium vector meson states with substantially shifted pole mass?



HADES collab.: Phys.Lett. B715 (2012)

PDG Entry 2012, 2014
BR($\eta \rightarrow e^+e^-$) < 2.5x10^{-6} (90% CL)

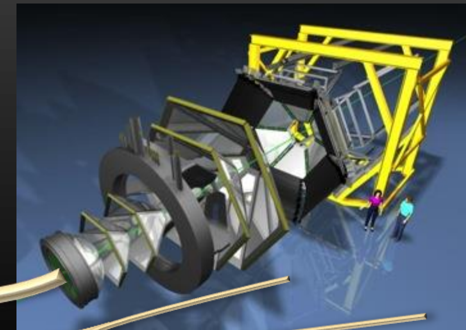
HADES acceptance

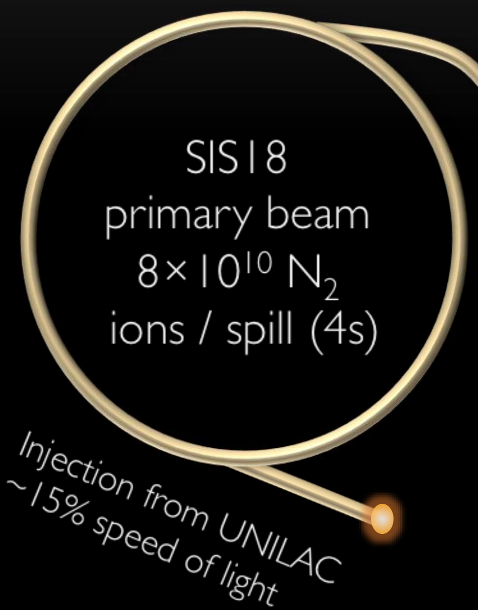


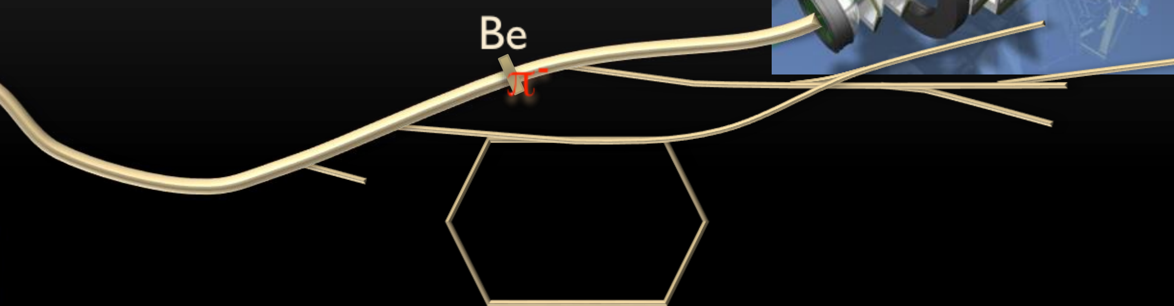
- First measurement of in-medium vector meson decays in the relevant momentum region (P_{ee} down to 0.2 GeV/c)
- HADES sees rather a melting than a shift
- p+p reactions: significant contribution from higher (than Δ) mass resonances

HADES π-beam

"If you are out to describe the truth, leave elegance to the tailor"
A. Einstein





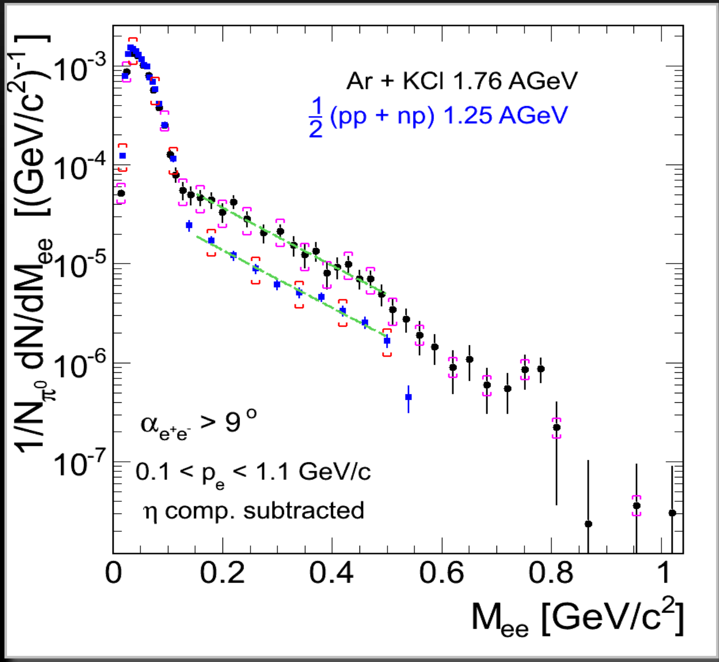


- Physics with πN experiments:
  - First measurements of resonance-Dalitz decays
  - Special emphasis on sub-threshold vector meson production
  - In-medium effects ($K^\pm$, K^0, φ, ω, ρ)

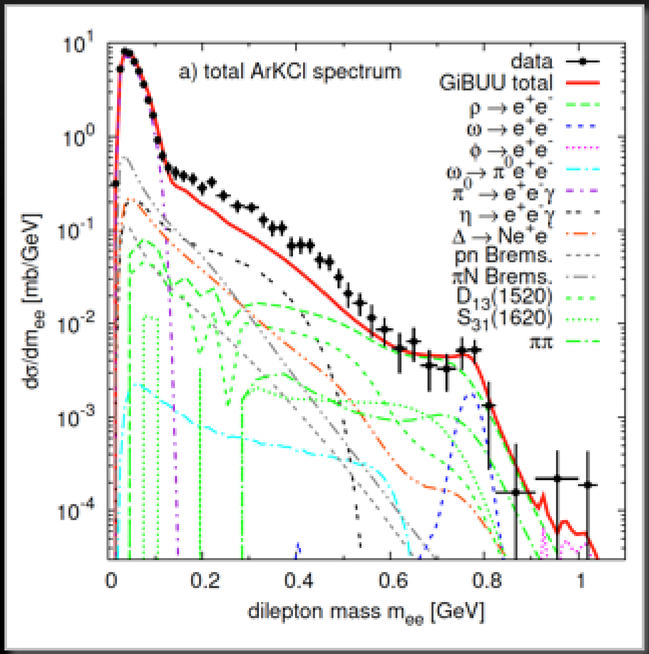
- π-beam 5×10^5 / spill
  - HADES starts from $\sqrt{s}$ = 1.46-1.55 GeV
    → N^*(1520) resonance region
  - Pion tracking with two double-sided silicon strip detectors in the beam line $\delta p/p$ = 0.3%

HADES collab., Nucl.Phys.News 25 (2015) no.2

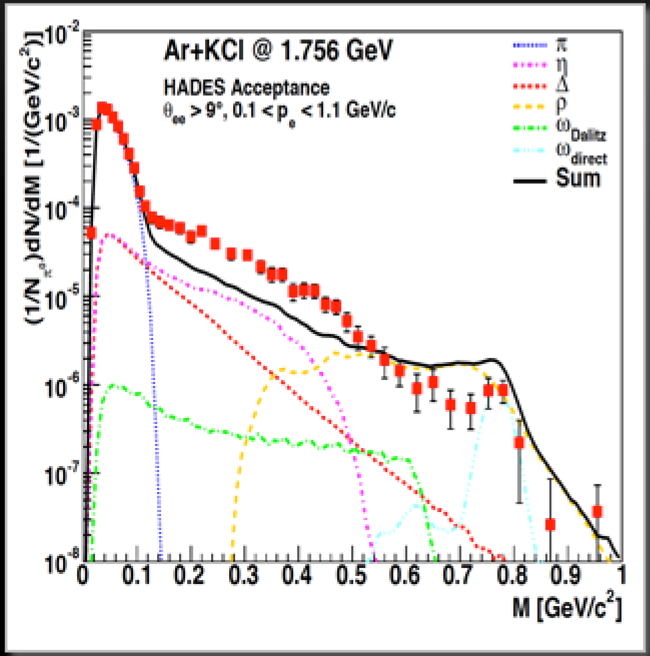
HADES ArKCl and transport models



HADES: *Phys.Rev.C 84 (2011) 014902*



J. Weil
J.Phys.Conf.Ser. 426 (2013) 012035

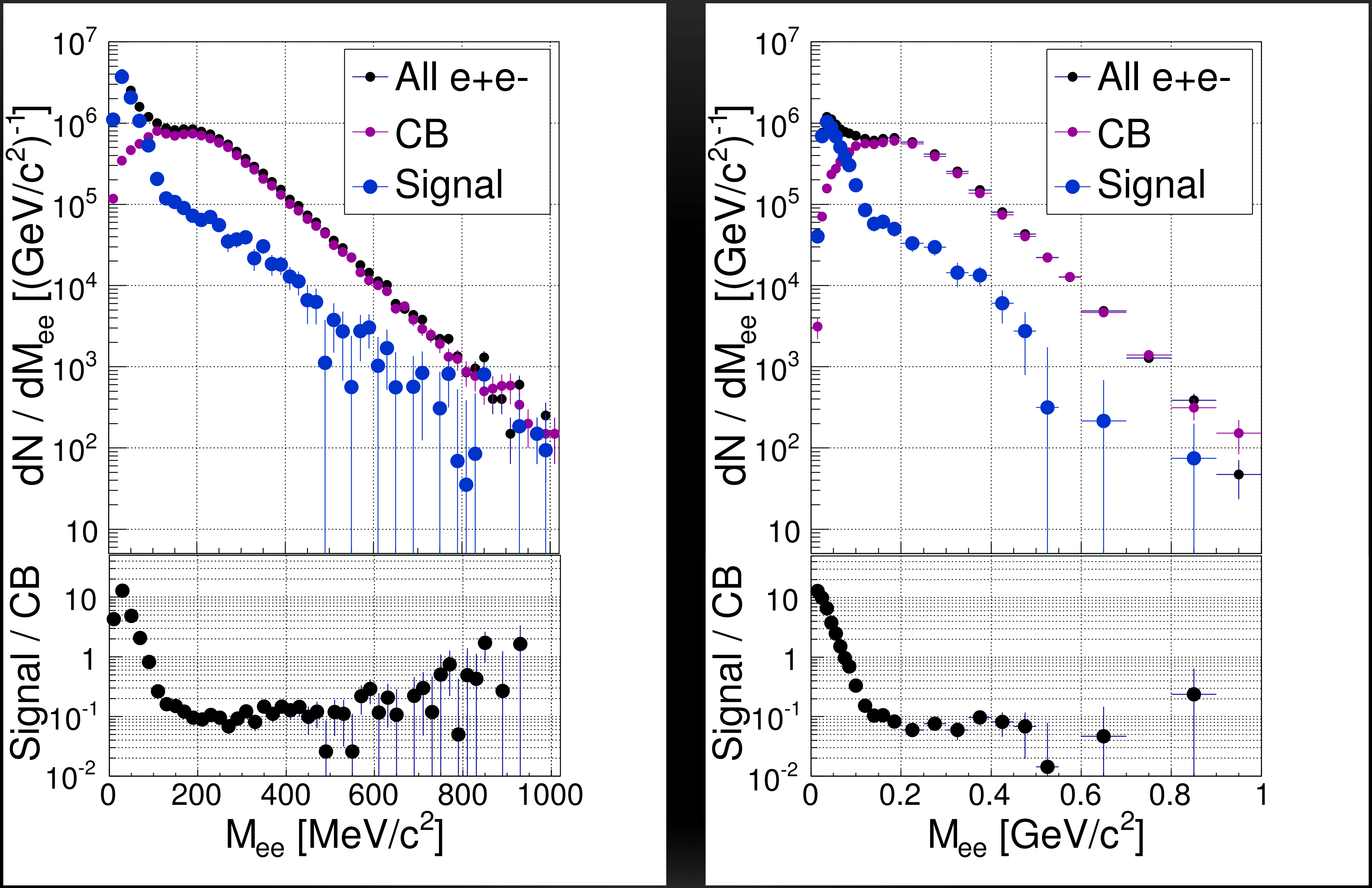


S. Endres
J.Phys.Conf.Ser. 503 (2014) 012039

- First evidence for radiation from the "medium" in this energy regime!

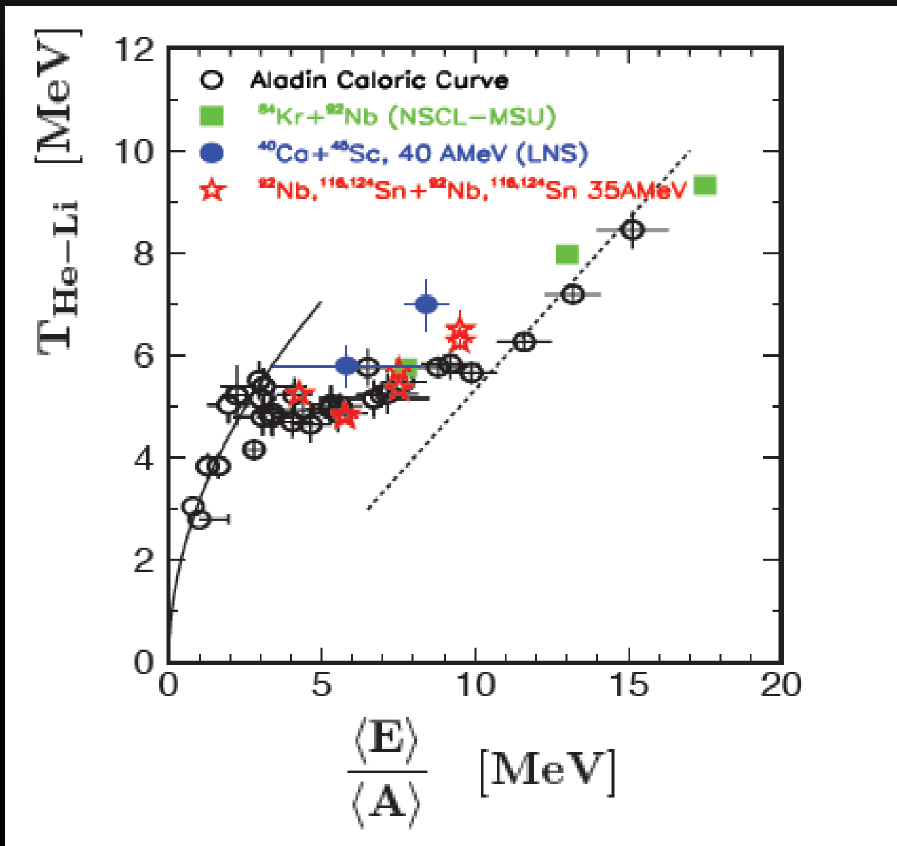
- Models with vac. SF misses data → room for medium modifications!
  See also [Bratkovskaya et al , Kämpfer et al, Weil et al,…]

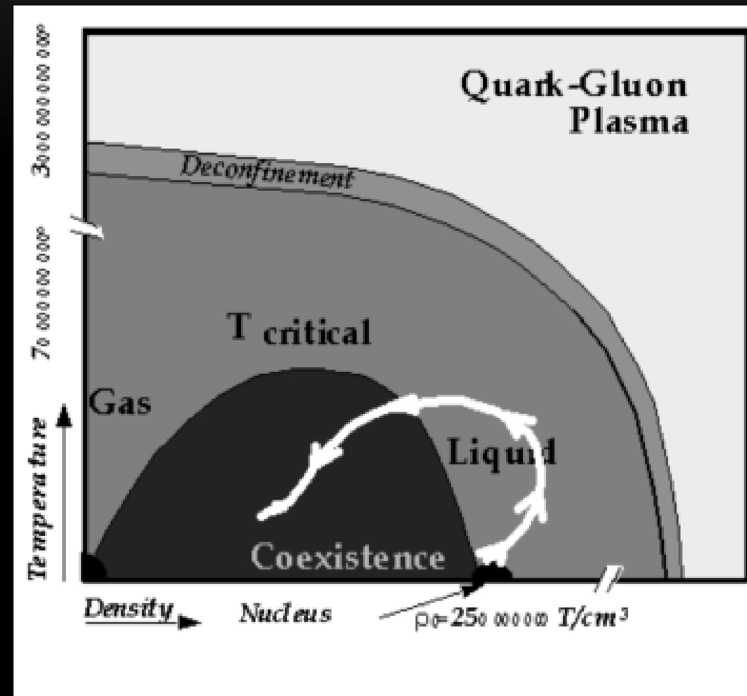
HADS AuAu Raw spectra



Nuclear liquid-gas transition

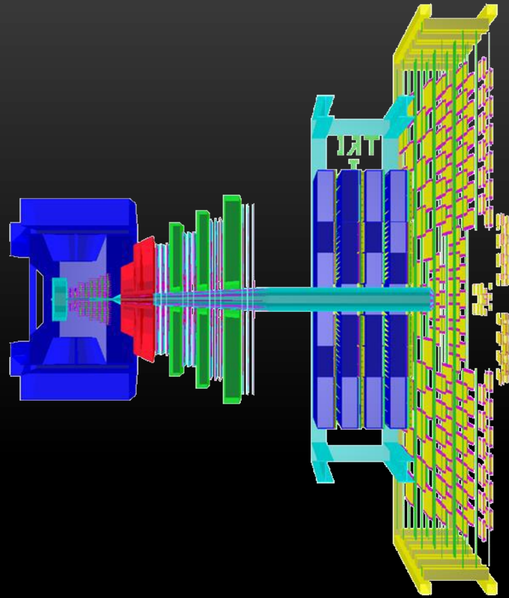
From multi-fragmentation measurements in heavy-ion collisions



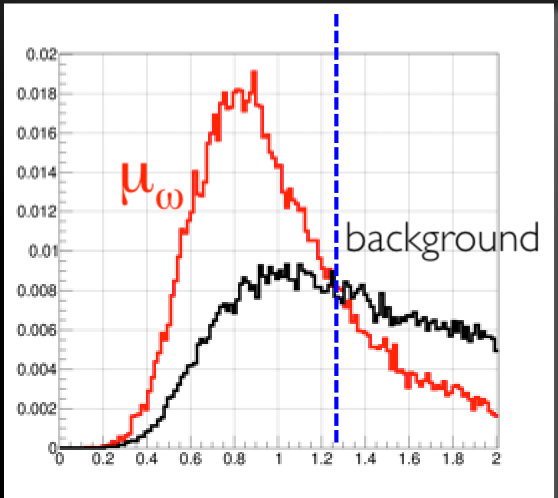


J. Pochodzalla et al. Phys. Rev. Lett. 75 (1995) 1040
M. D'Agostino et al. Nucl. Phys. A 749 (2005) 5533
P. Chomaz Nucl. Phys. A 685 (2001) 274

Dimuon channel performance

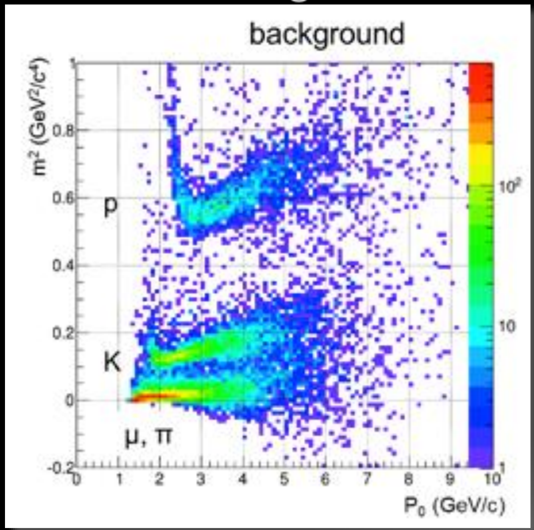


Quality of the muon track (χ^2_{MuCh})

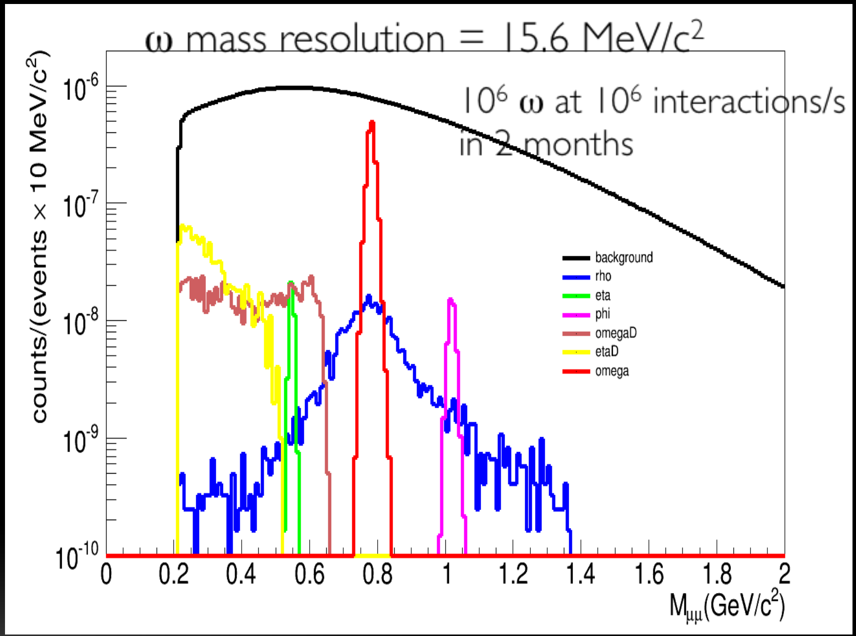


- Tracking: $\chi^2_{vertex} < 2$ and ≥ 6 STS hits
- MuCh: $\chi^2_{MuCh} < 1.25$ and ≥ 14 MuCh hits
- TOF: $m^2 < 0.01$

Punched through hadrons in ToF

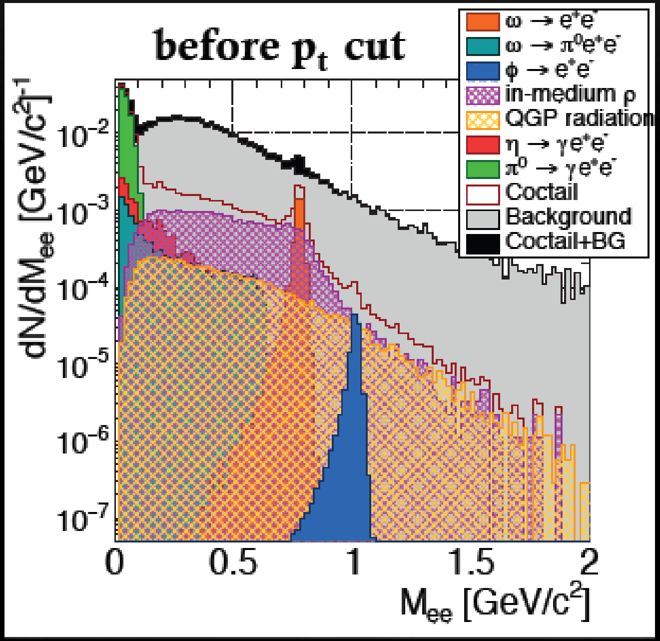


SIS100 Au+Au 8A GeV

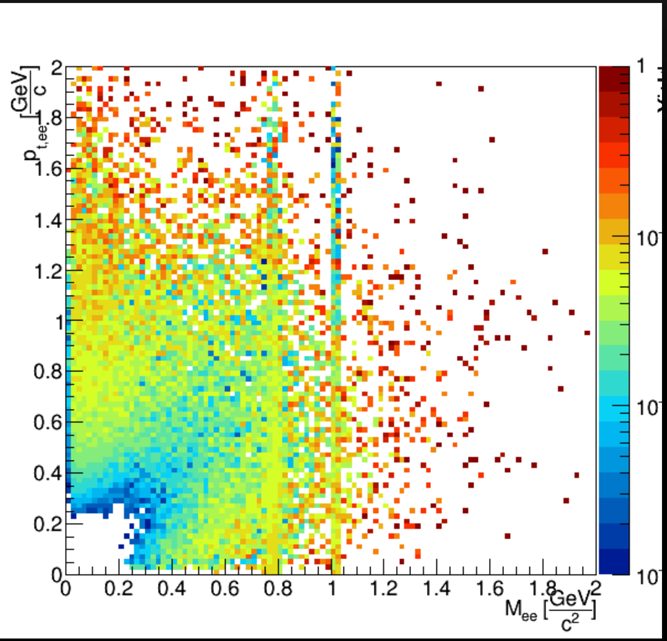


Dielectron channel performance

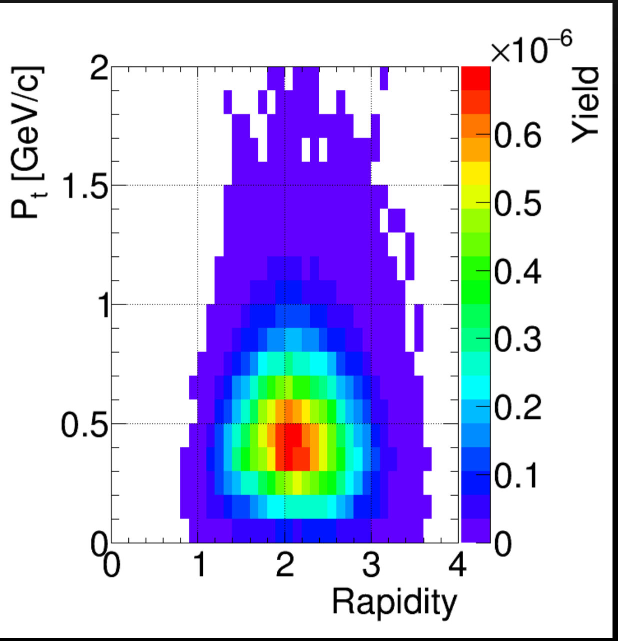
Invariant mass after all BG rejection cuts



Pair detection probability

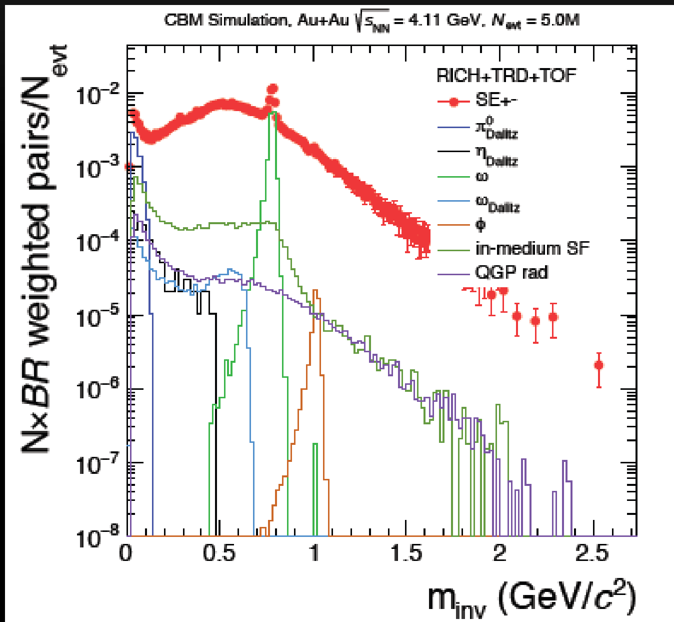


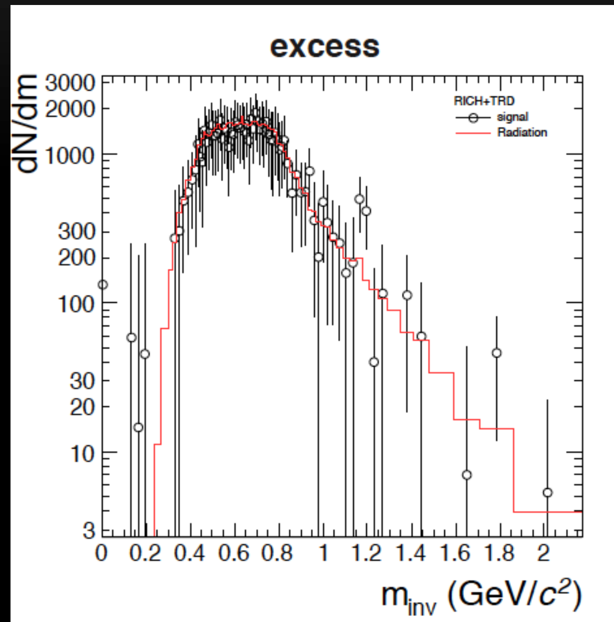
ρ phase space coverage

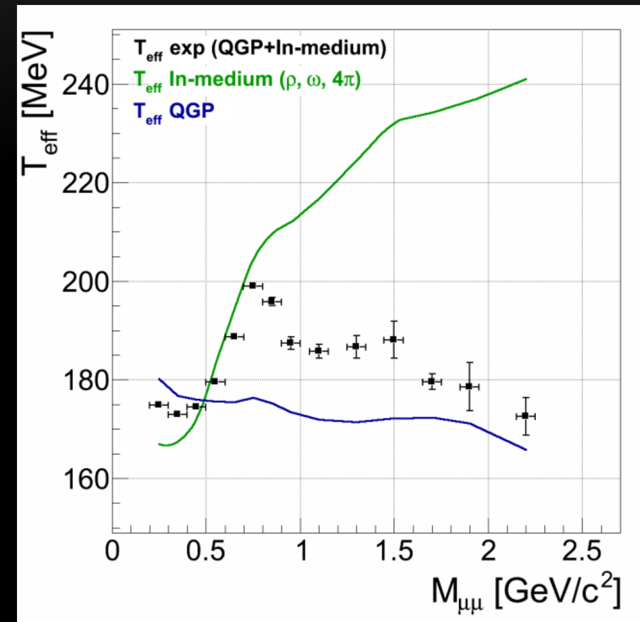


- 1M central Au+Au collisions at E_{beam} = 8A GeV
- Signal detection probability ~5-6%
- Signal / CB ratio: LMR ~ 10% , IMR ~1% → allows precise measurement
- Mass resolution: $\sigma_M(\omega)$= 14 MeV/c^2

Signal extraction, work in progress







- Subtract combinatorial

- Isolate excess pairs up to M=2.5 GeV/c^2
- Extract emitting source Temperature: fit IMR with $dN / dM \propto M^{3/2} \times e^{-M/T}$
- Extract T_{eff} vs. m_{inv} via Boltzmann fit to the m_T spectra

→ precision of few MeV is required!