JOHANN WOLFGANG GOETHE UNIVERSITÄT FRANKFURT AM MAIN

CBM collaboration meeting, February 2007

Low Mass Lepton Pairs
Experiments

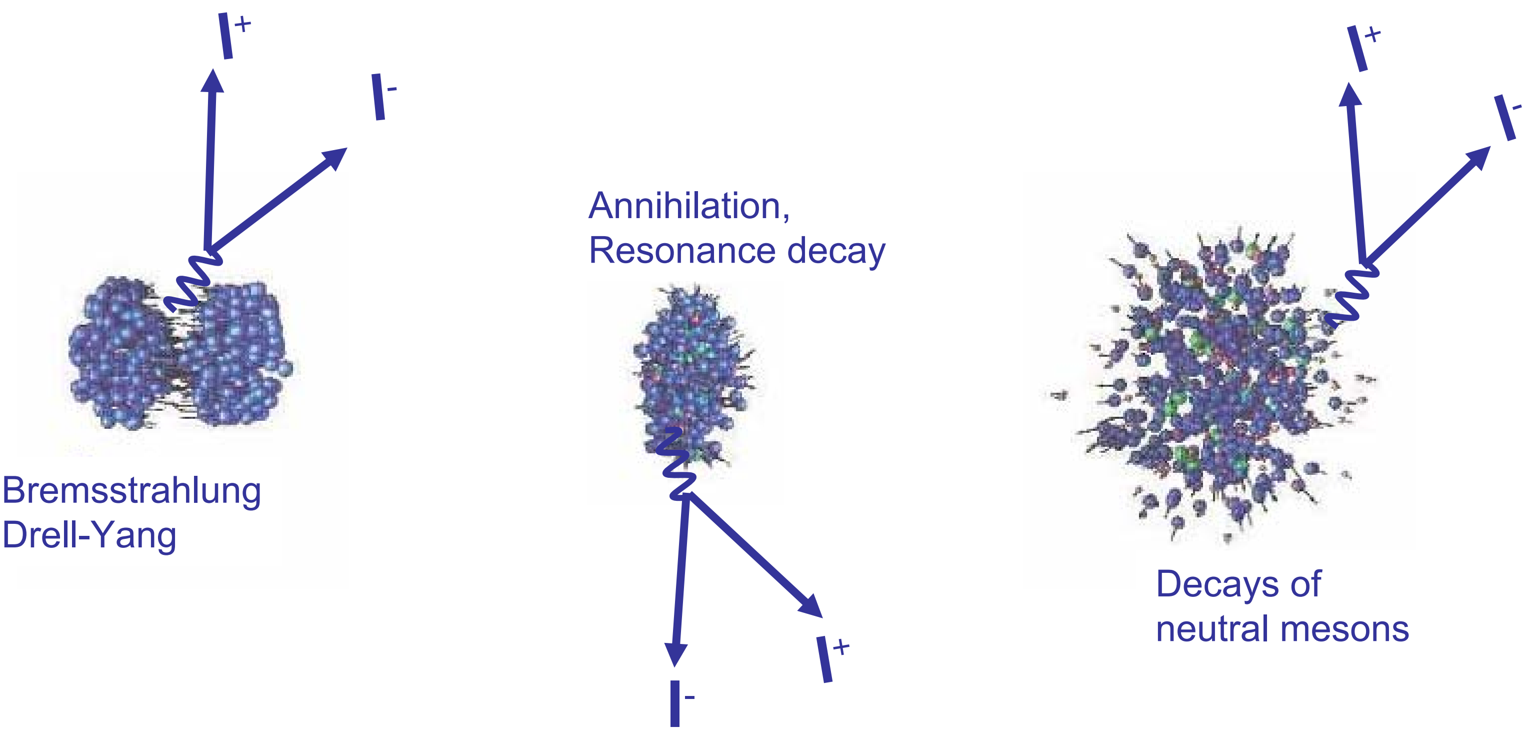
Joachim Stroth, Univ. Frankfurt

Electromagnetic structure of dense/hot matter

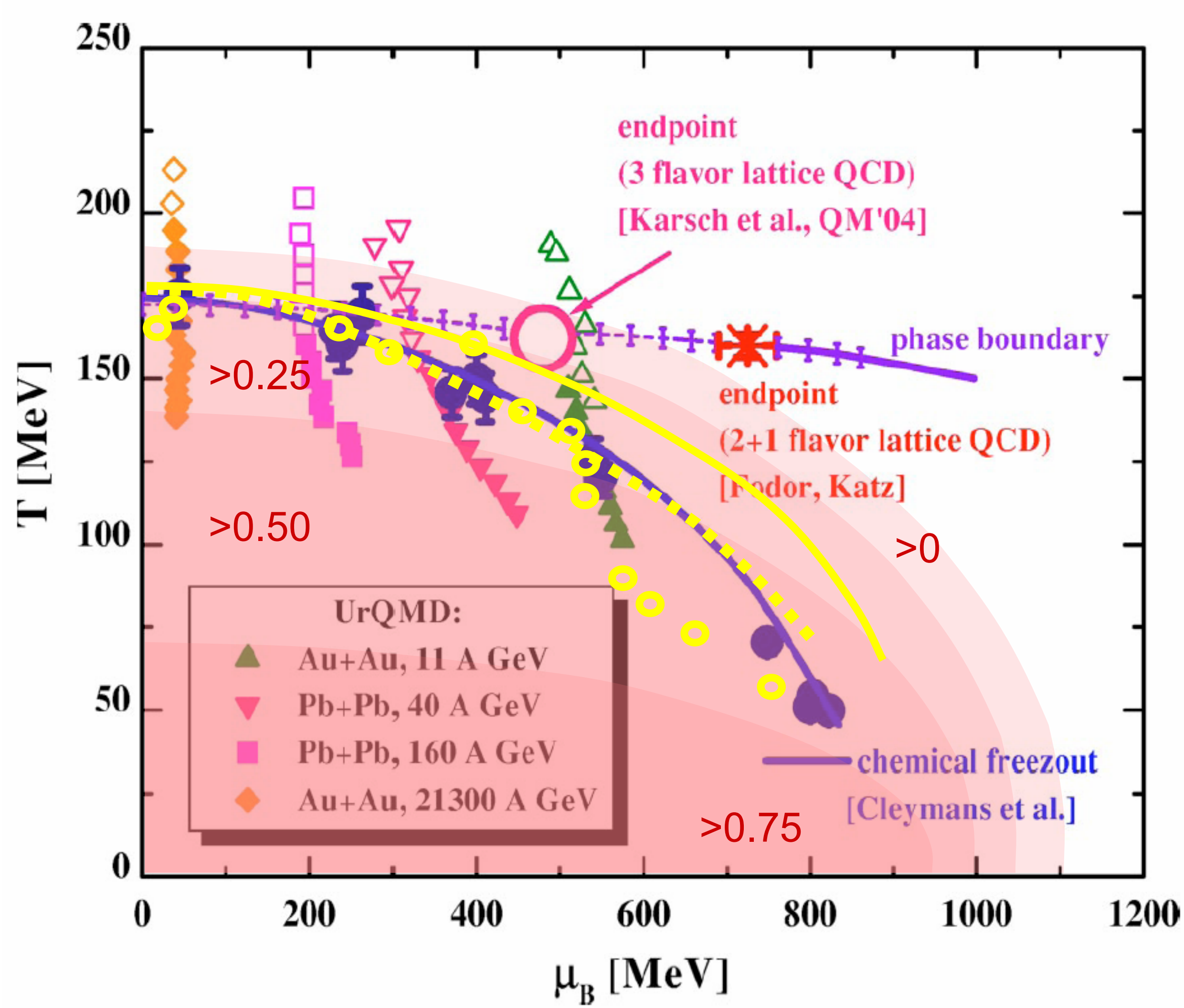
Lepton pairs can probe the electromagnetic structure of nuclear matter under extreme conditions

They couple through time-like photons and test the **spectral properties** of hadronic matter.

☞ time reversed processes of reactions in a e^+e^- collider.



Exploring dense phases of nuclear matter

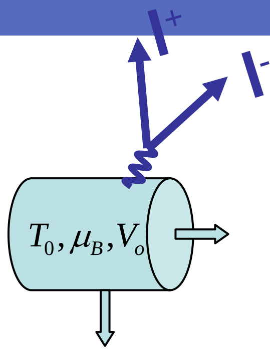


E. Bratkovskaya

J. Wambach, priv. comm.

A. Andronic priv. comm.

The Observable



Thermal emission...

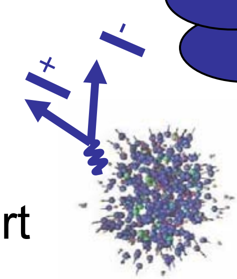
isentropic expansion

Nuclear many body theory, detailed balance, ..

$$\frac{d^3N}{dMdydp_t} \equiv \int_{t=0}^{\infty} M \frac{d^4R}{d\mathbf{p}}\left[T(\mathbf{x}), \mu_B(\mathbf{x}), \vec{v}_{coll}(\mathbf{x}), ..\right] d\mathbf{x}$$

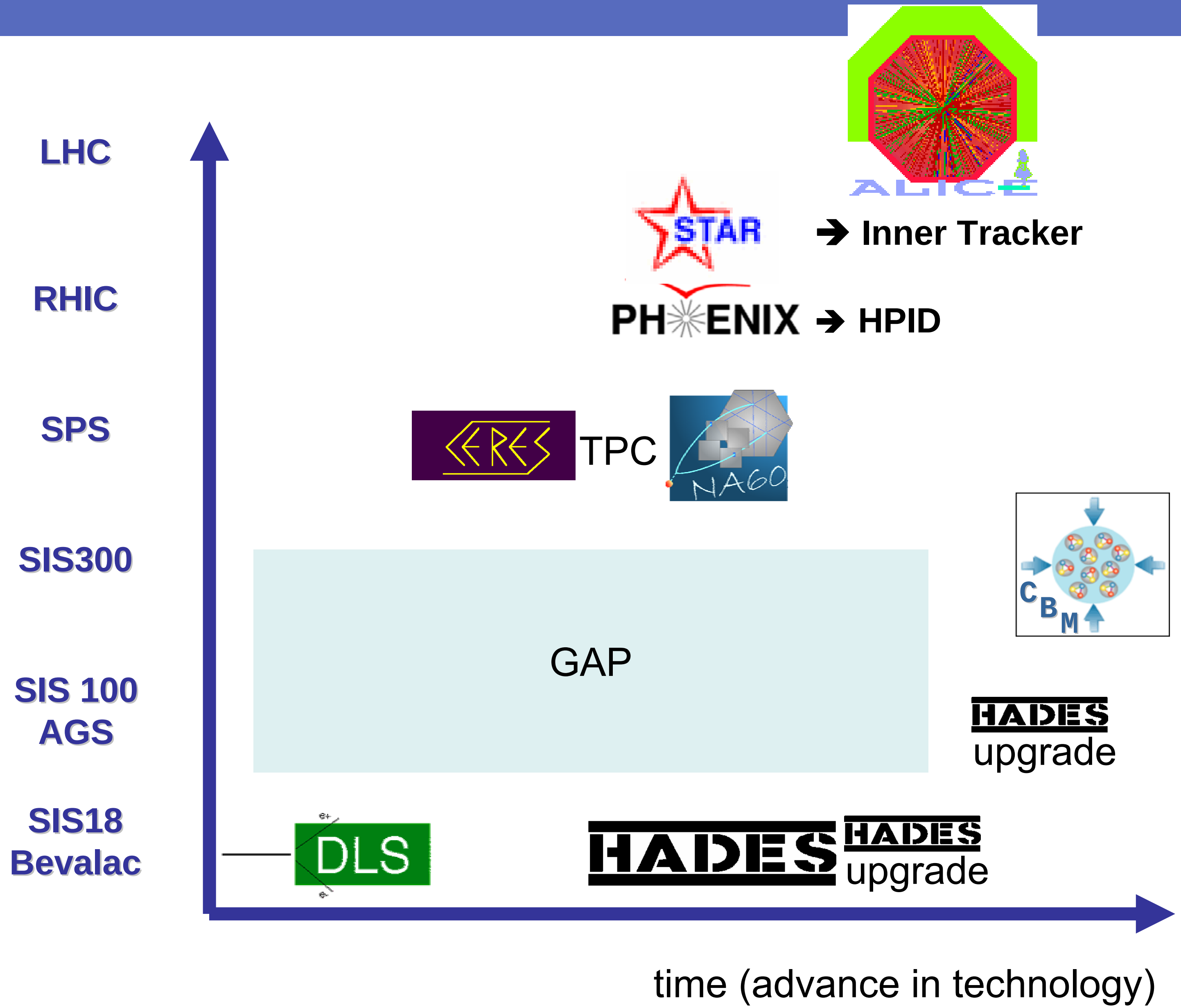
Spectrometer

Hydro, statistical expansion models, ..



... or microscopic transport

Overview on experiments



Experimental challenges

Resolution

Helps to self–analyze the spectral shape

- ✓ Excellent (low-mass tracking)
- ✓ Good statistics

Accuire good statistics

Permits a multi-differential analysis

- ✓ Good pair acceptance ("4π" spectrometer)
- ✓ High trigger rates
- ✓ Trigger

Minimize signal-to-background

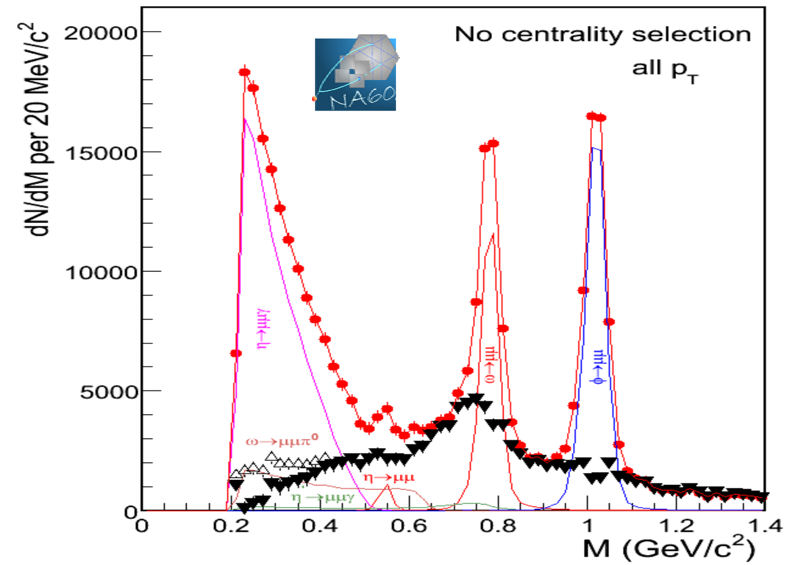
Reduces the systematic and statistical error

- ✓ Physical background $\rightarrow$ rejection strategy
- ✓ Fake tracks $\rightarrow$ excellent detectors

Contributions from conventional sources

Defines systemtic uncertainties

- ✓ partially self-analyzing (see resolution)
- ✓ need to measure neutral mesons or rely on models

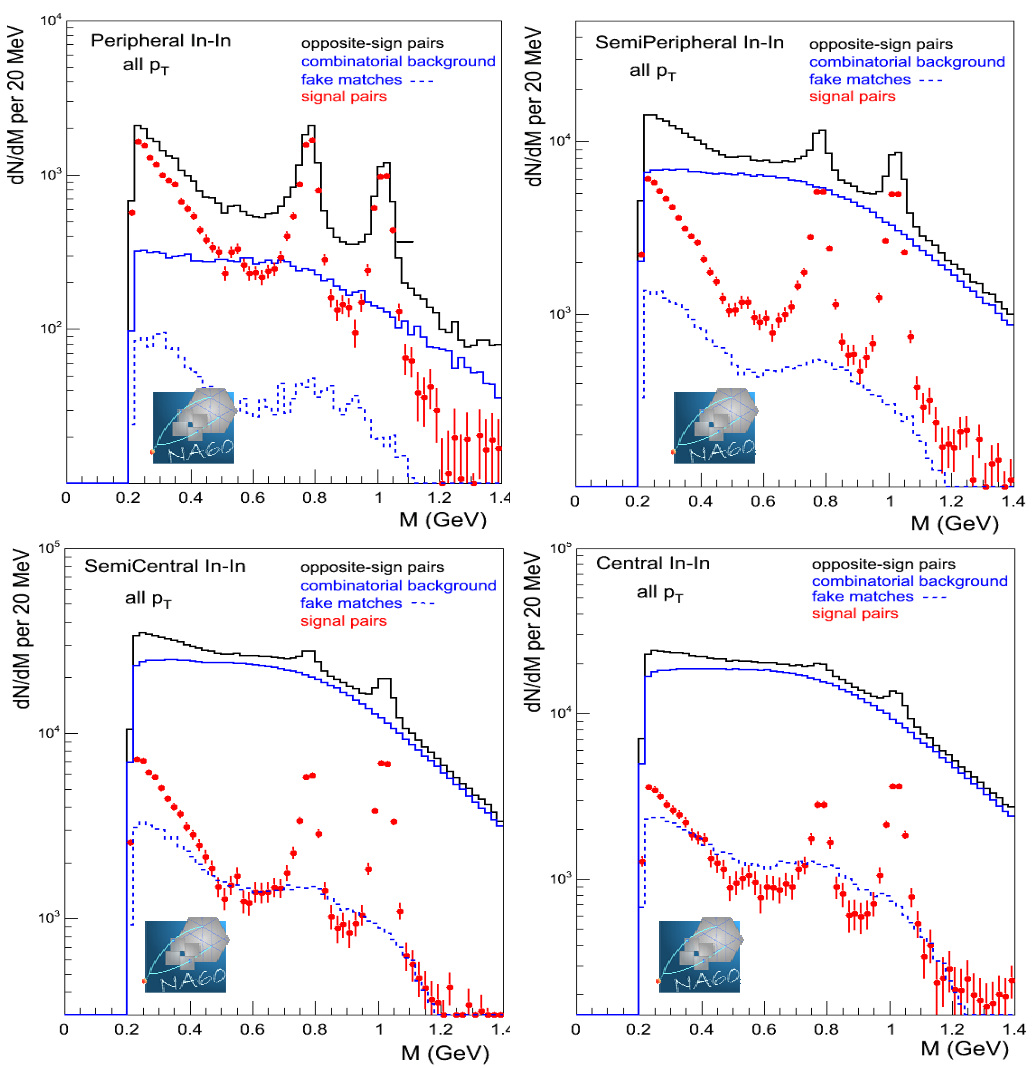


Decay	*BR*	
$\eta\rightarrow\mu^+\mu^-$	$5.8\pm0.8 \cdot 10^{-6}$	PDG
$\eta\rightarrow e^+e^-$	$<7.7 \cdot 10^{-5}$	PDG
$\eta\rightarrow e^+e^-$	$5\pm1 \cdot 10^{-9}$	χPT
$\pi^0\rightarrow e^+e^-$	$6.2\pm0.5 \cdot 10^{-8}$	PDG
$\pi^0\rightarrow e^+e^-$	$7\pm1 \cdot 10^{-8}$	χPT

Compilation by R. Holzmann.

Pair spectra

$\mu^+\mu^-$ yields (NA60)



J. Seixas, QM06

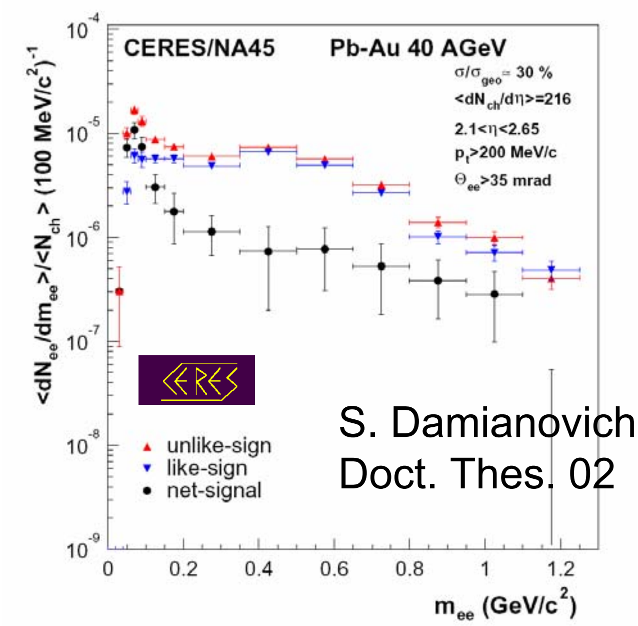
Completed HI runs (results)

– In+In 158 *A*GeV (final))

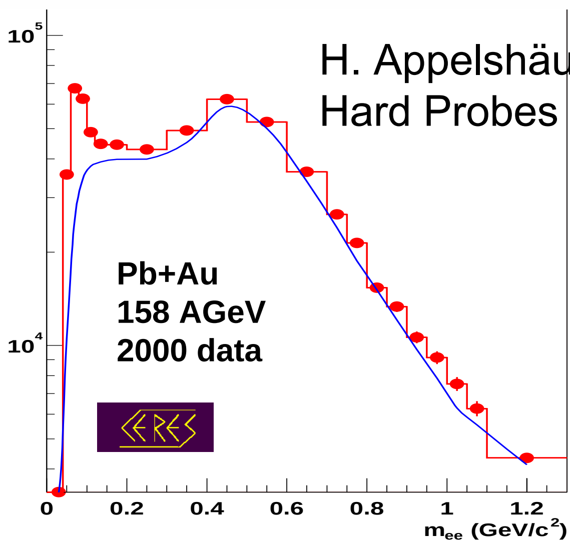
- 1.3 10^8 events (analyzed)
- 3.6 10^5 signal pairs
- 2.7 10^{-3} signal pairs/event

S/B (In+In)		
@ M [GeV/c²]	*0.2*	*0.6*
periph.	5	0.9
semi-periph.	1	0.14
semi-centr.	0.33	0.06
centr.	0.35	0.07

e^+e^- yields (Ceres)



S. Damianovich, Doct. Thes. 02



H. Appelshäuser, Hard Probes 04

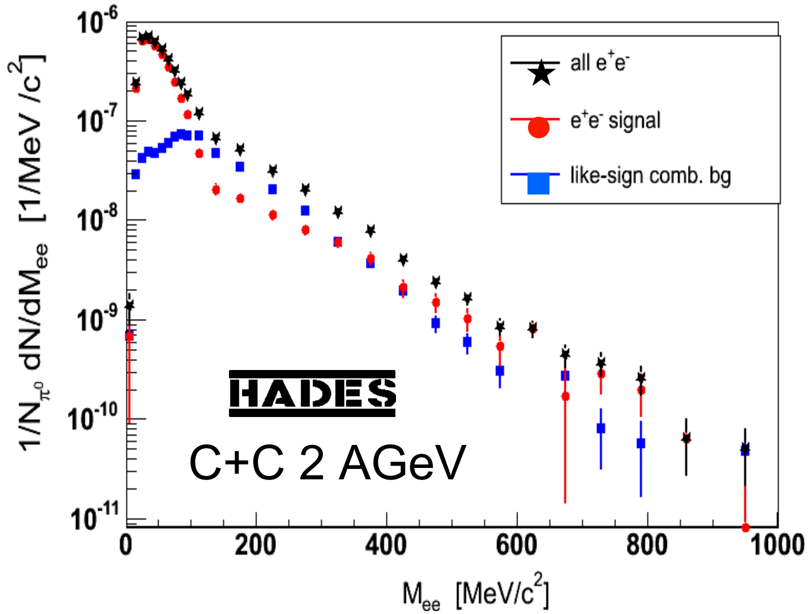
Completed HI runs (results)

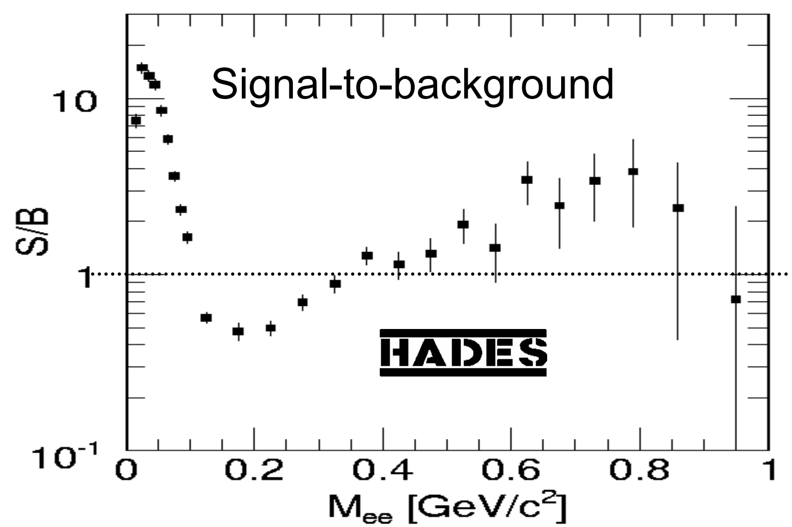
- S+Au 200 AGeV (final)
- Pb+Au 158 AGeV (final)
- Pb+Au* 40 AGeV (final)
- Pb+Au* 158 AGeV (final)
  - $1.8\ 10^7$ events (analyzed)
  - $8.2\ 10^3$ signal pairs
  - $4.6\ 10^{-4}$ signal pairs/event

* with TPC

S/B		
@ M [GeV/c²]	*0.2*	*0.6*
40 AGeV	0.25	0.13
158 AGeV	0.08	0.06

e^+e^- yields (HADES)





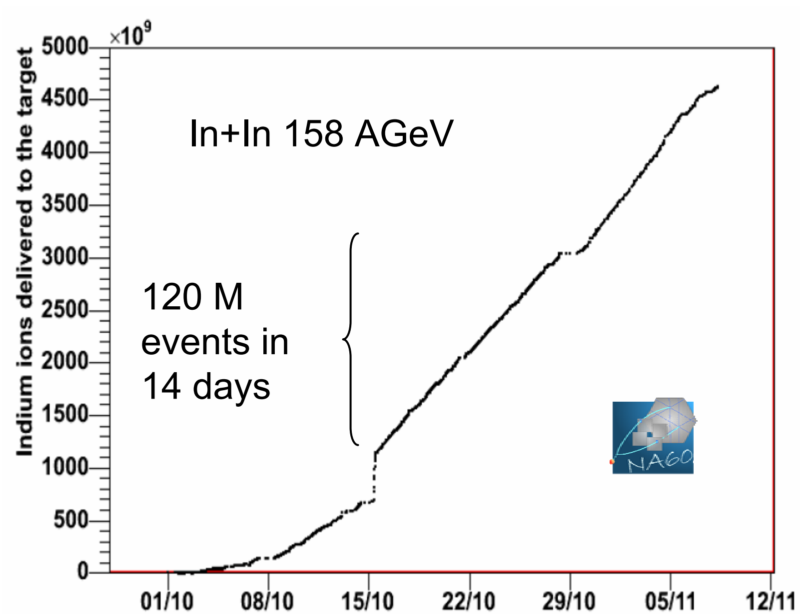
Completed runs (results)

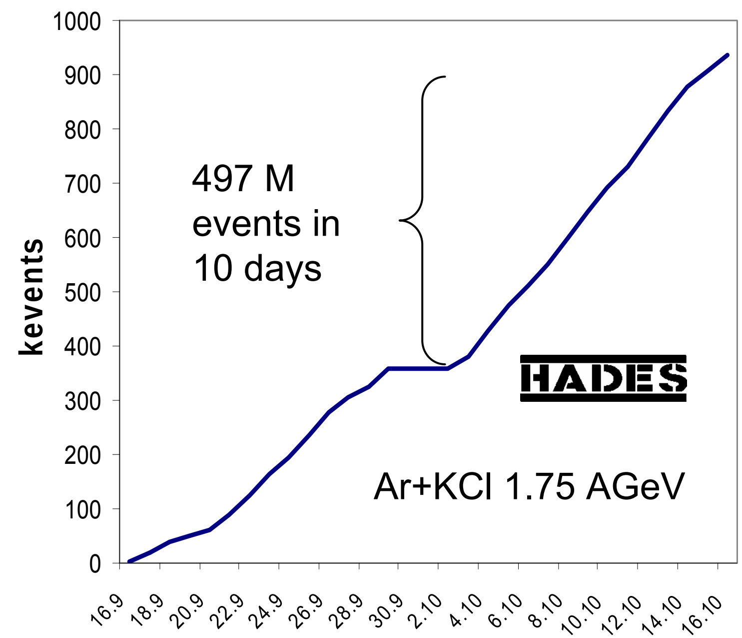
- C+C 2 AGeV (final)
  - 99 M triggered events
  - 23 k s
  - 2.3 10^{-4} signal pairs/event
- C+C 1 AGeV (prelim.)
- Ar+KCl C+C 1.75 AGeV (calibr.)

S/B (C+C)		
@ M [GeV/c²]	*0.2*	*0.6*
2 AGeV	0.5	2
1 AGeV		

Event collection: NA60 and HADES

	Data volume	Trigger purity	Trigger limitation
NA60 In+In (2003)	4.5 TB	2.7 10^{-3}	Works as long as $\gamma\tau(\pi)$ is large compared to the flight path before absorber At low energies muons have still to traverse the absorber
HADES Ar+KCl (2005)	9 TB	(2.3 10^{-4})	Fake (ring) matches, can be improved if MDC is in the trigger. At high energies by multiplicities of electrons from π^0 (Dalitz and conversion)

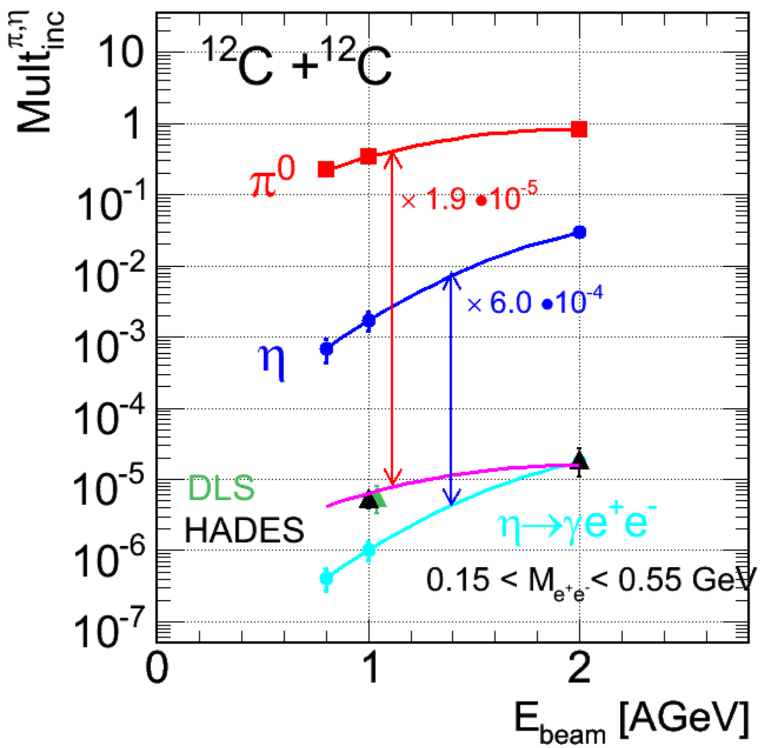


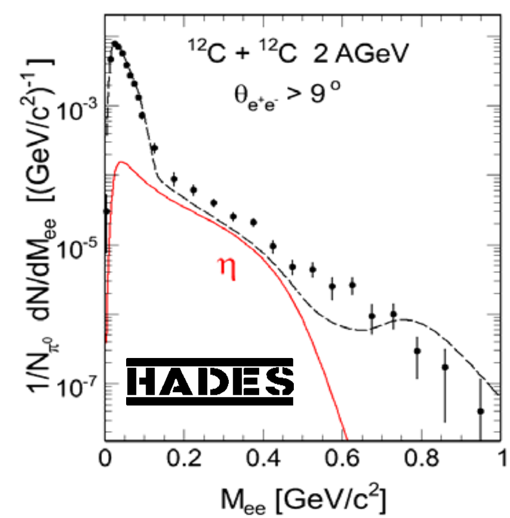


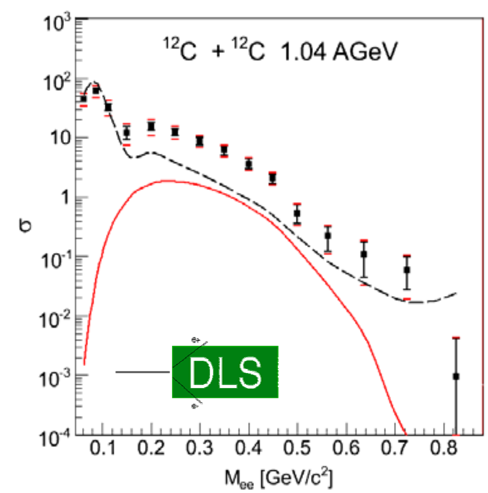
Excess yield

The DLS puzzle

Electron pair excitation function:



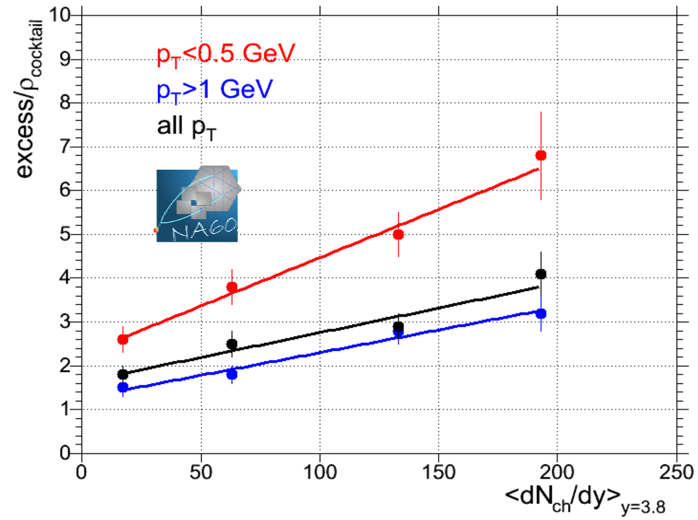




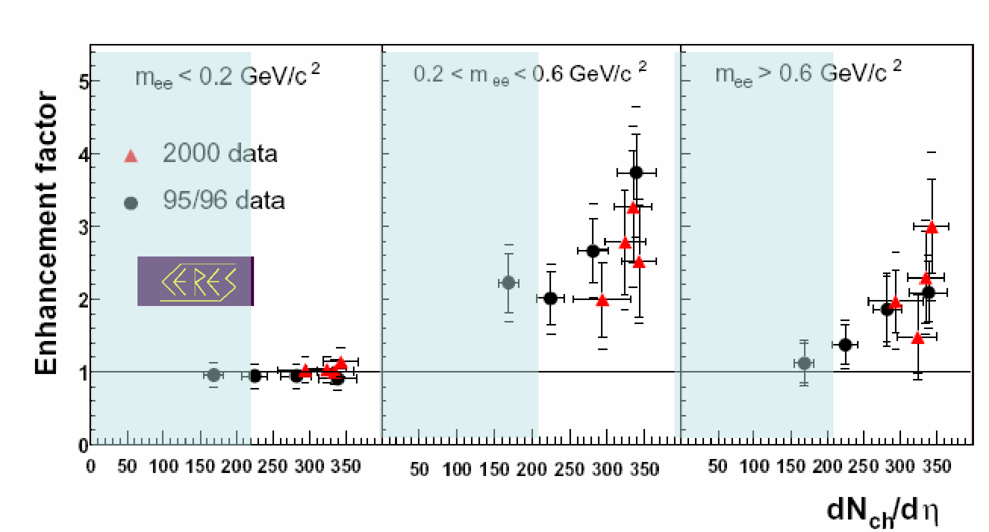
- **No contradiction** between DLS and HADES yet
- Strong evidence for extra contributions from **decays of baryonic resonances**.

Centrality dependence of the excess (SPS)

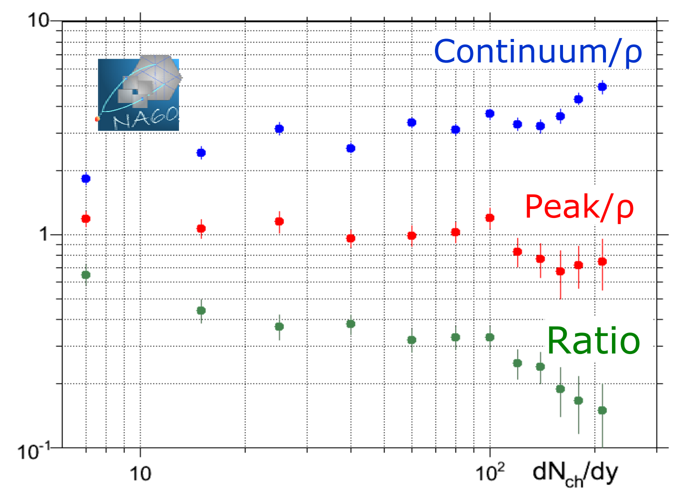
- Enhancement grows with centrality (CERES 158 AGeV)
- Excess yield relative to cocktail ρ grows with centrality (NA60)
- Enhancement grows when going from 158 to 40 AGeV (CERES, not shown here)



S. Damianovic, HQ06



S. Iouurevich, Doct. Thes. 05

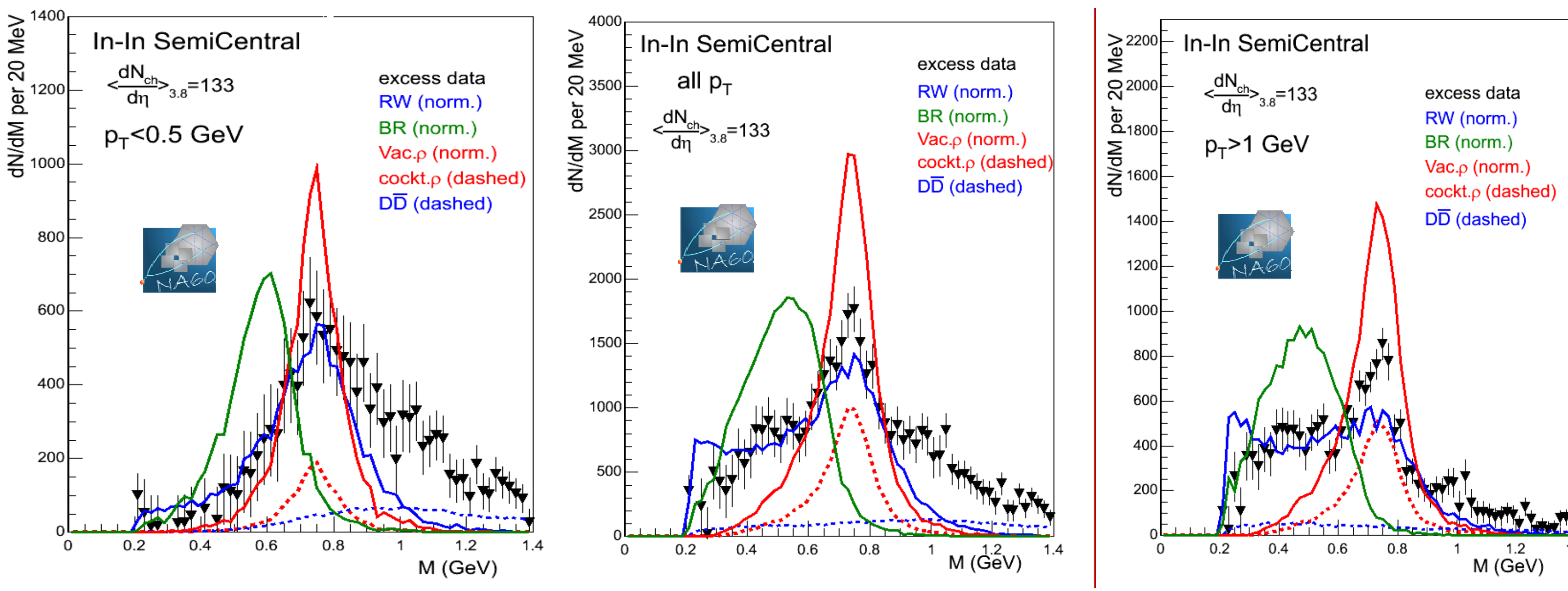


J. Seixas, QM06

Excess yield and thermal emission

Subtracted spectra (NA60)

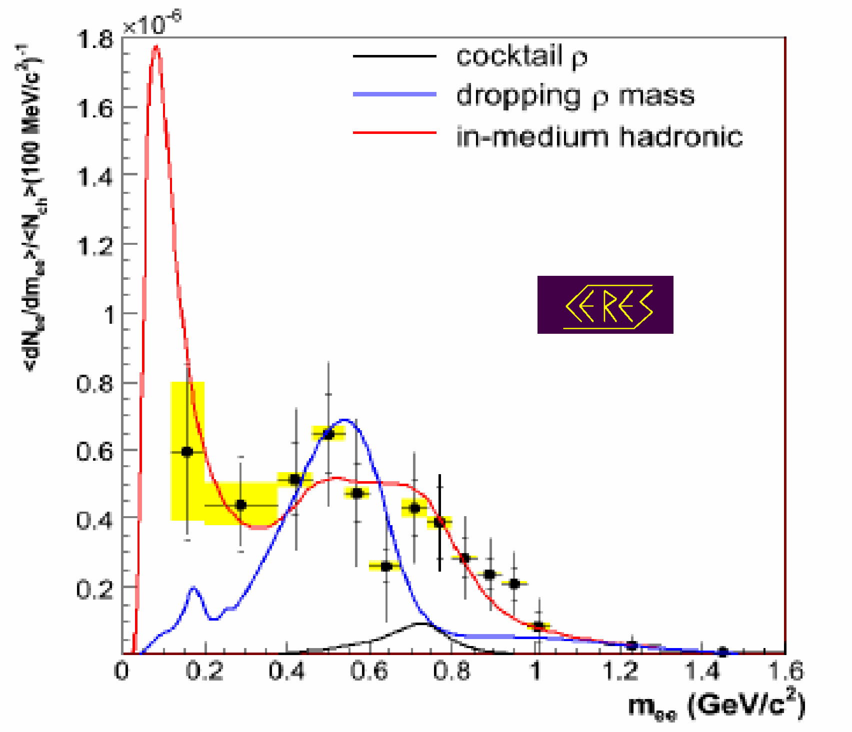
- $\pi\pi$ annihilation now accepted as dominant source
- Data disproves a scenario assuming a purely shifting ρ
- Smallest contribution from cocktail ρ to the excess for p_t < 0.5 GeV/c
  - Excess suppressed on the low-mass side due to acceptance!

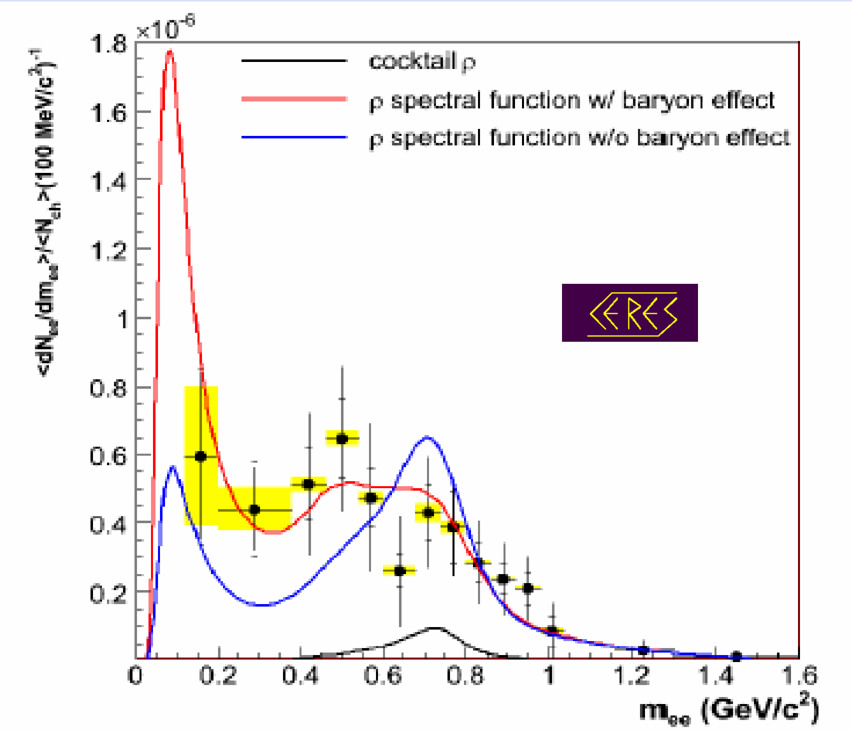


S. Damianovic, HQ06

Subtracted spectra (CERES)

- Broadening of ρ driven by baryonic effects
- Good sensitivity at lower masses
  - Connection to the photon point (Turbide et al., Alam et al.)





CERES coll., nucl-ex/0611022

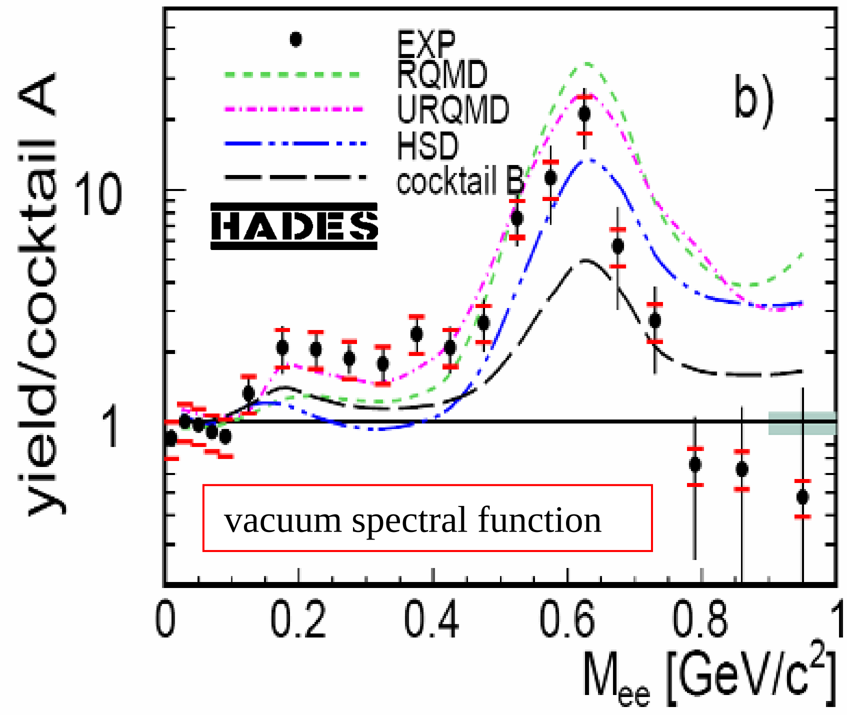
Excess yield and transport

Enhancement and transport

- **RQMD:** M. D. Cozma, C. Fuchs, E. Santini, A. Faessler, Phys. Lett. B 640, 150 (2006)
- **UrQMD:** D. Schumacher, S. Vogel, M. Bleicher, nucl-th/06080401**.**
- **HSD (v2.5):** W. Cassing and E. L. Bratkovskaya, Phys. Rep. 308, 65 (1999).

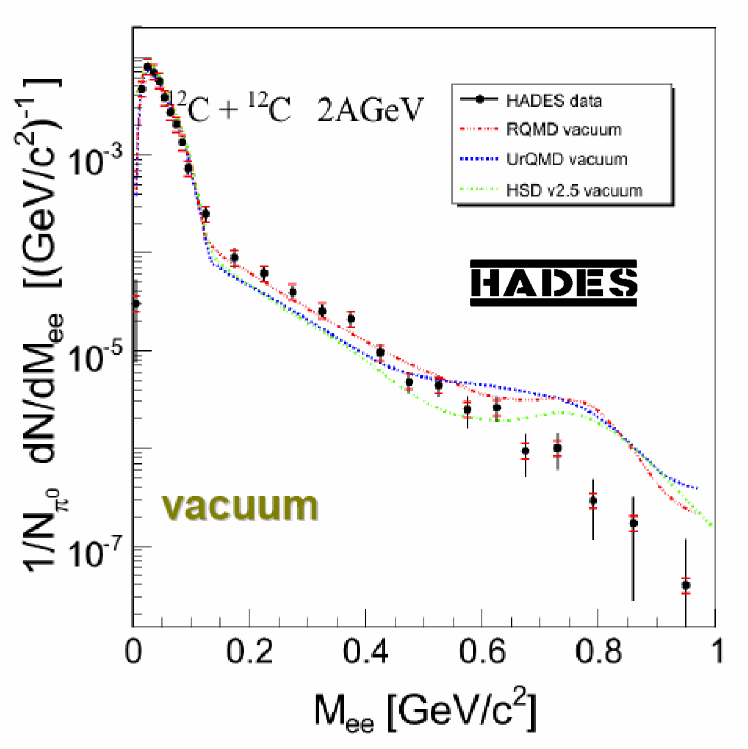
transport calculations

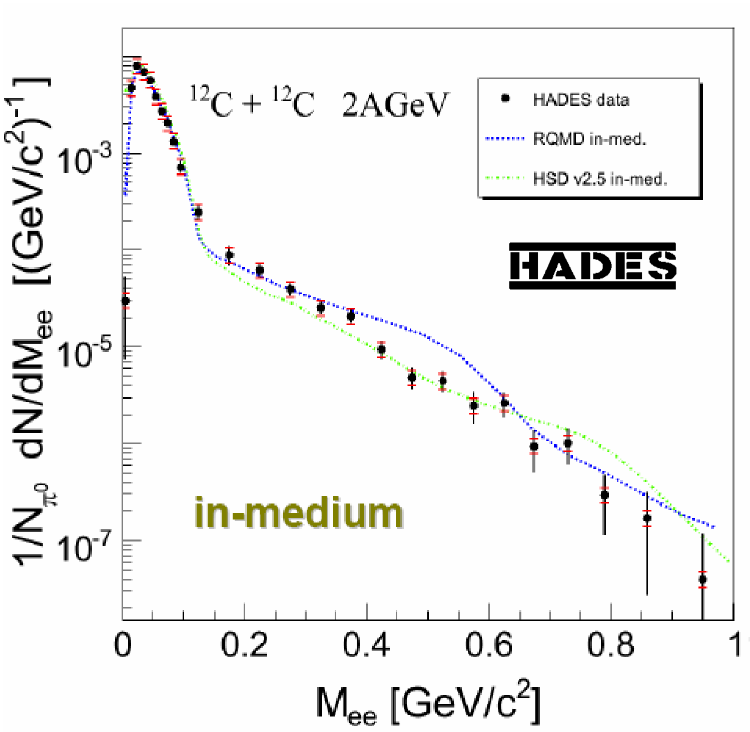
- Qualitatively describe the data
- Undershoot between $200<M_{ee}<500$ MeV/c^2
- Overshoot for $M_{ee}> 700$ MeV/c^2



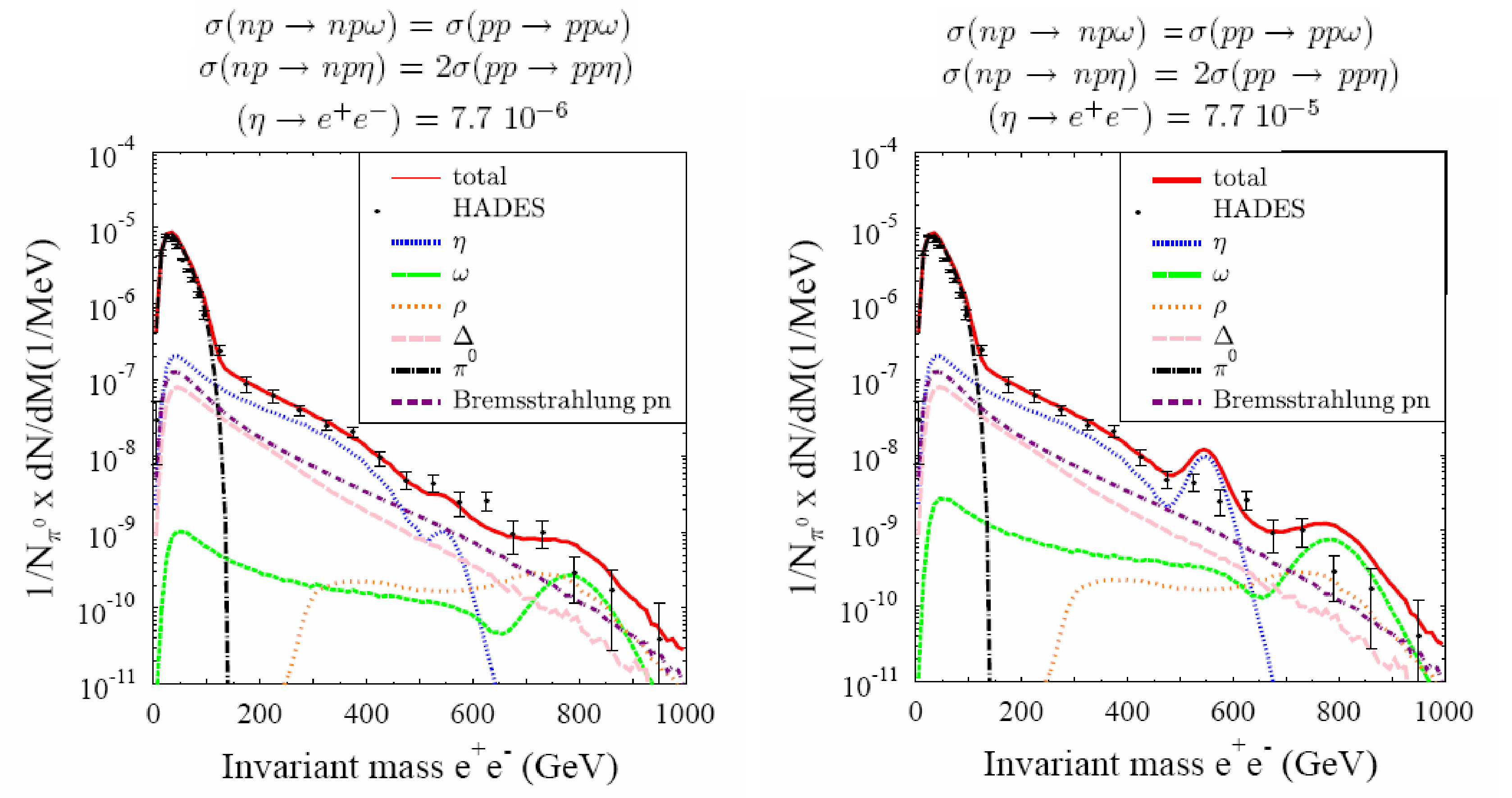
Medium modifications in transport (HADES)

RQMD: M. D. Cozma, C. Fuchs, E. Santini, A. Faessler, Phys. Lett. B 640, 150 (2006)
UrQMD: D. Schumacher, S. Vogel, M. Bleicher, nucl-th/06080401.
HSD (v2.5): W. Cassing and E. L. Bratkovskaya, Phys. Rep. 308, 65 (1999).





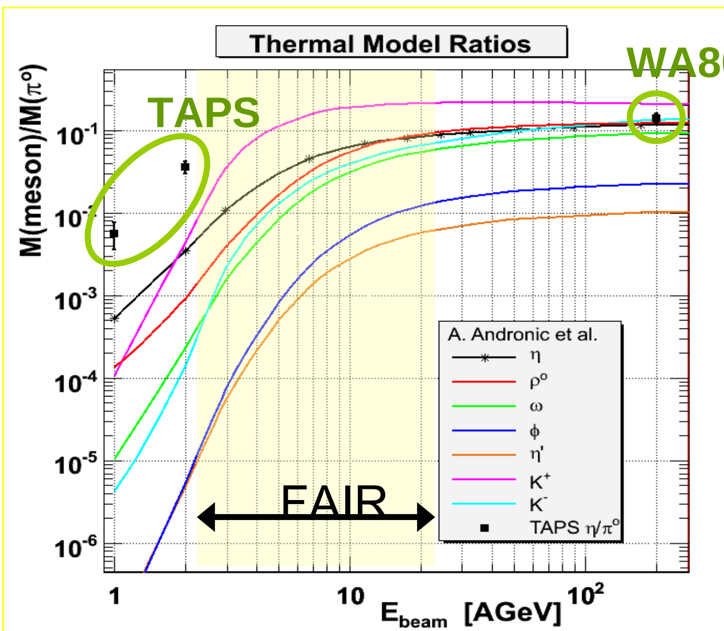
Uncertainties in the η and ω production

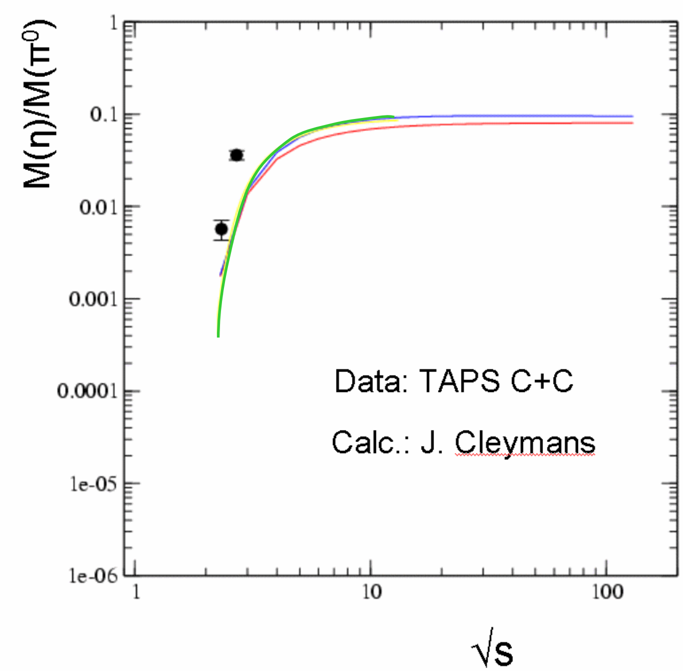


J. Aichelin et al., nucl-th/0702004

η production in the statistical model

- Iso-spin effects in η production not fully under control (see arXiv:nucl-th/0702004v1)
- Validity of statistical model at low energies questionable



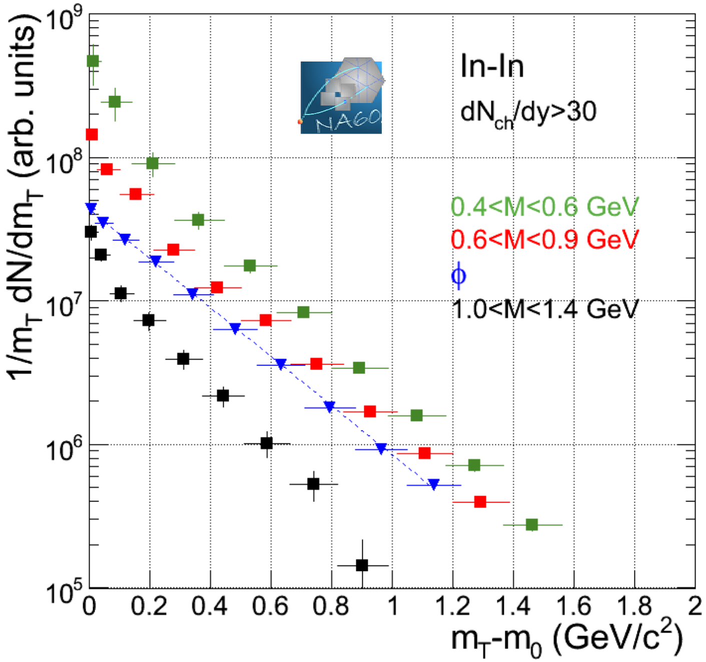


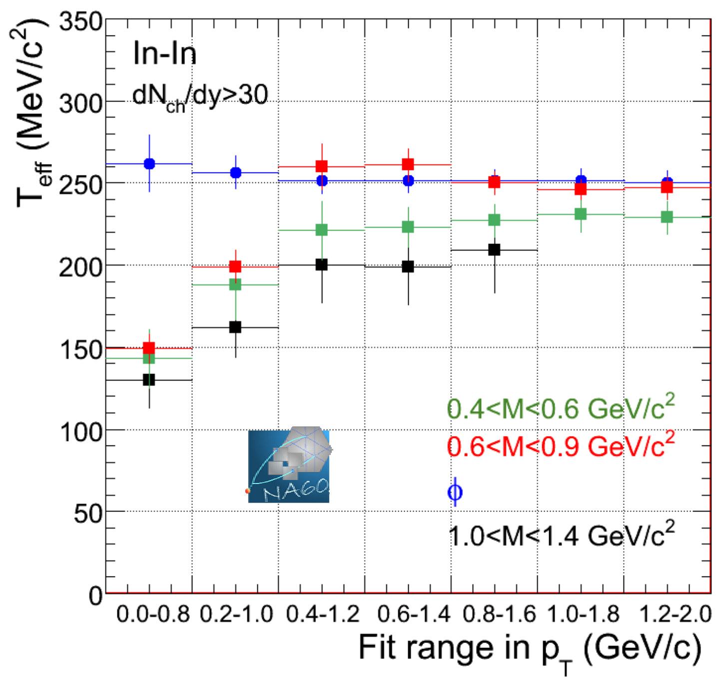
Compilation by R. Holzmann and A. Andronic, priv. comm.

P_t distributions

Acceptance corrected p_t spectra (NA60)

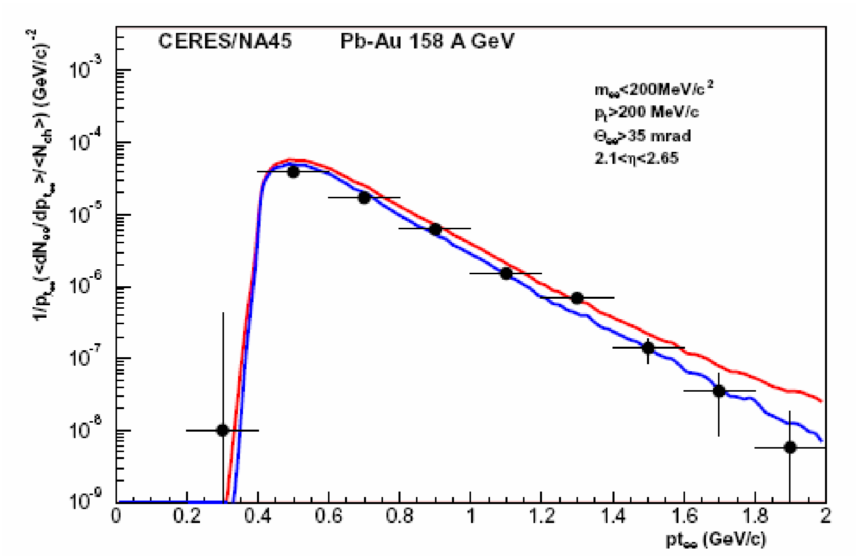
- Excess yield dominantely at low p_t
- p_t slopes show weak centrality dependence (not shown below)
- Systematic uncertainties (not shown below):
  - grow with centrality and towards lower p_t

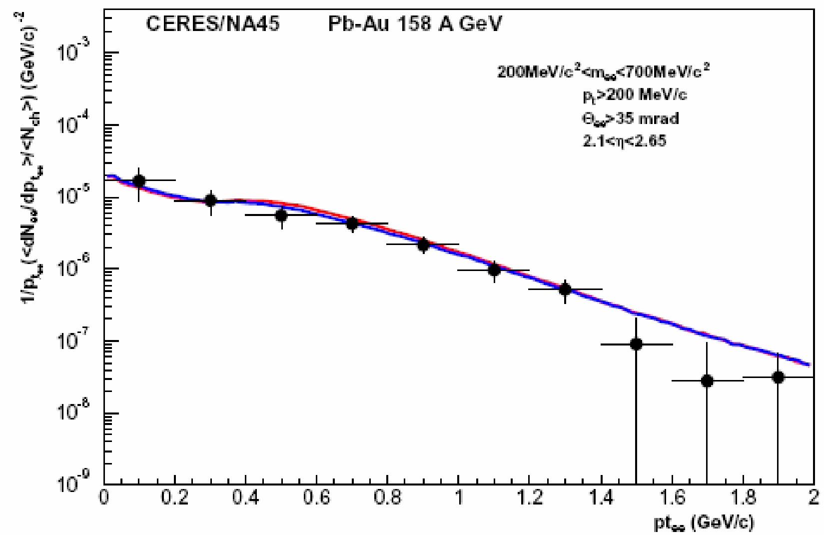




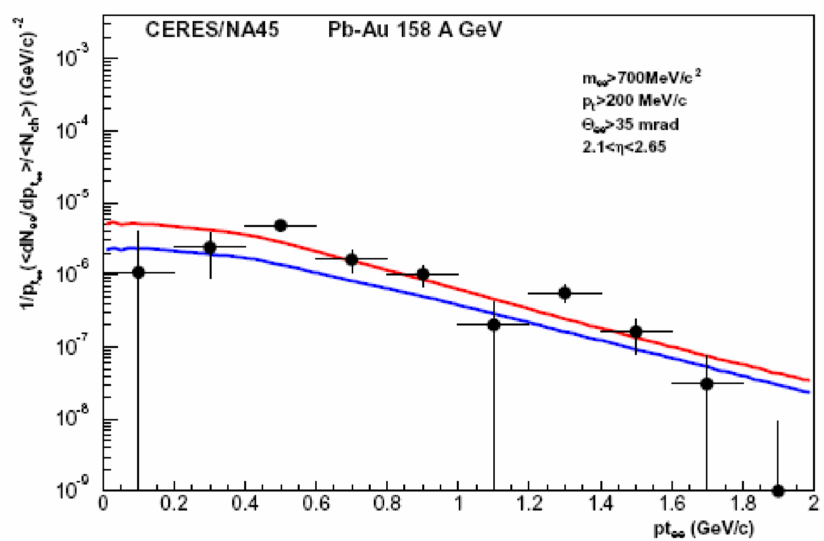
J. Seixas, QM06

p_t spectra (CERES)



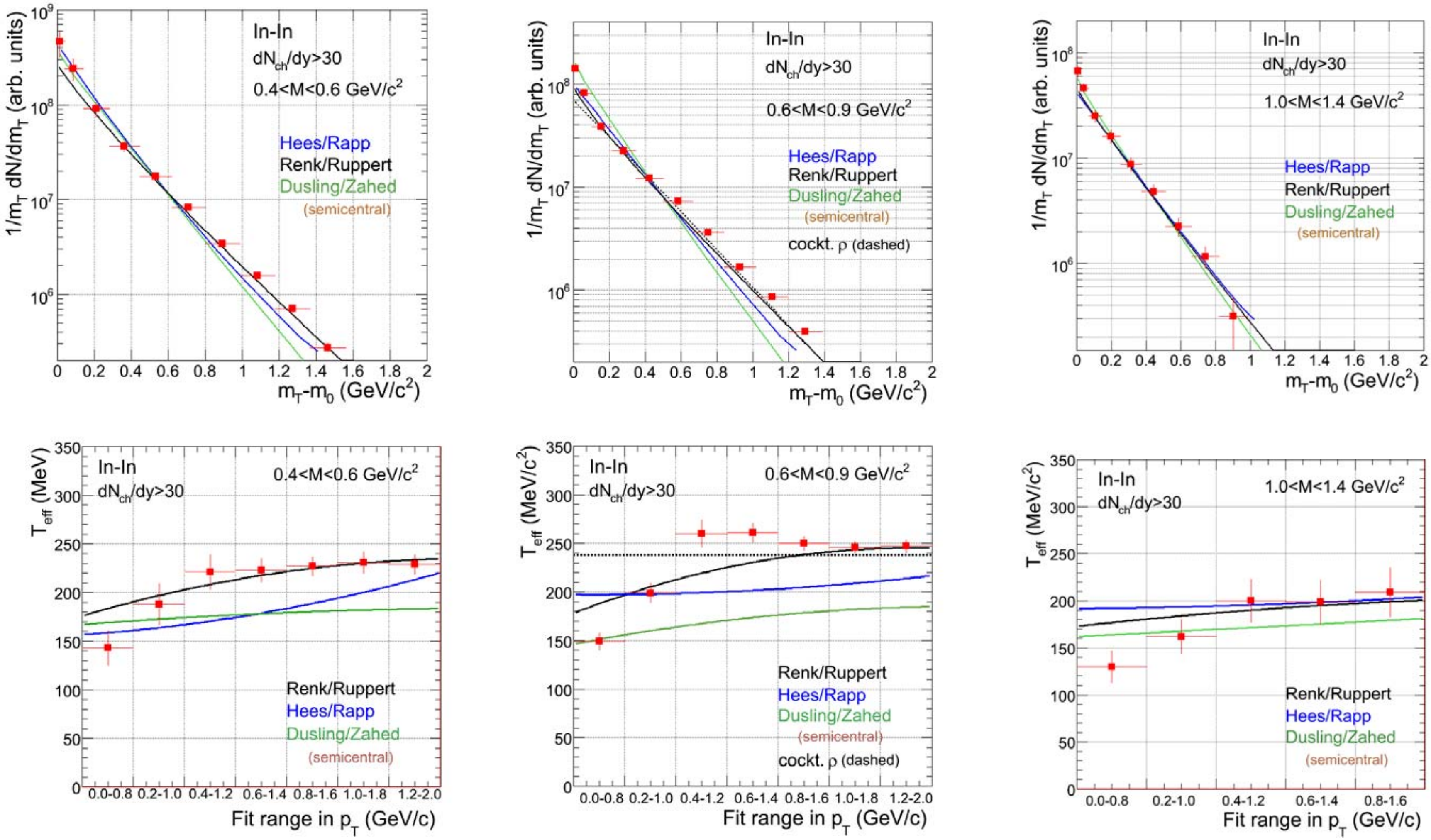


p_t weakly sensitive on type of spectral function in a $\pi\pi$ annihilation scenario



S. Iouurevich, Doct. Thes. 05

p_t: closer look (NA60)

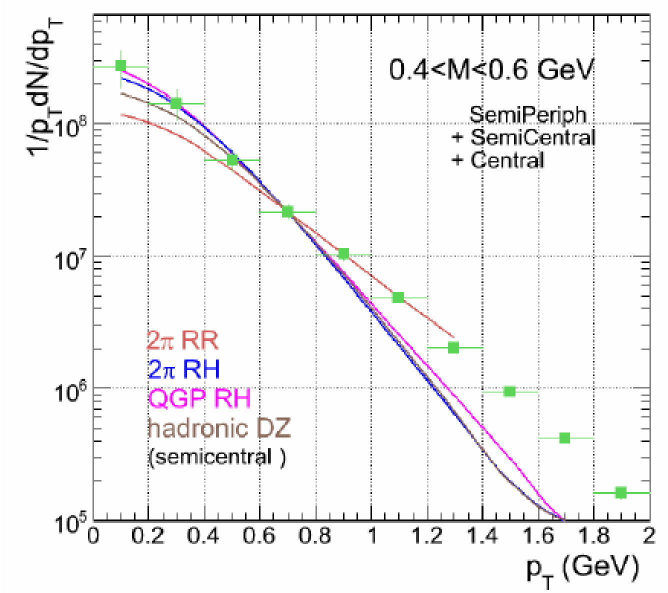


Compilation by S. Damianovic, from T. Renk QM06

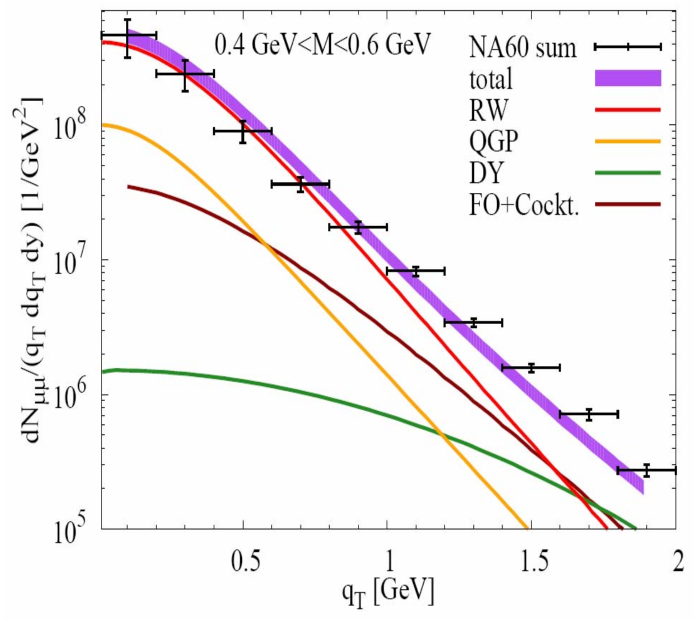
Double-differential plots

Improved expansion model (H: van Hees, R. Rapp ..):

1. initial hard processes ↔ Drell Yan
2. “core” ↔ emission from thermal source
3. “corona” ↔ emission from “cocktail” mesons
4. after thermal freeze-out ↔ emission from “freeze-out” mesons



J. Seixas, QM06



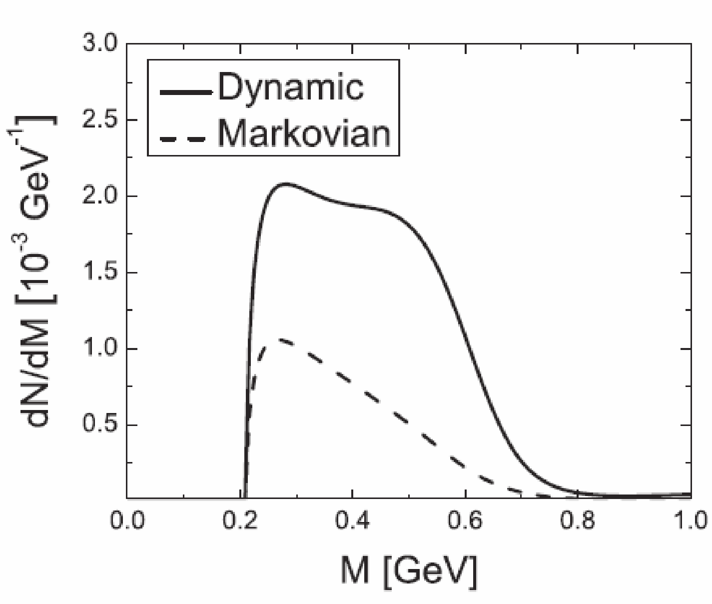
H. v. Hees, QM06

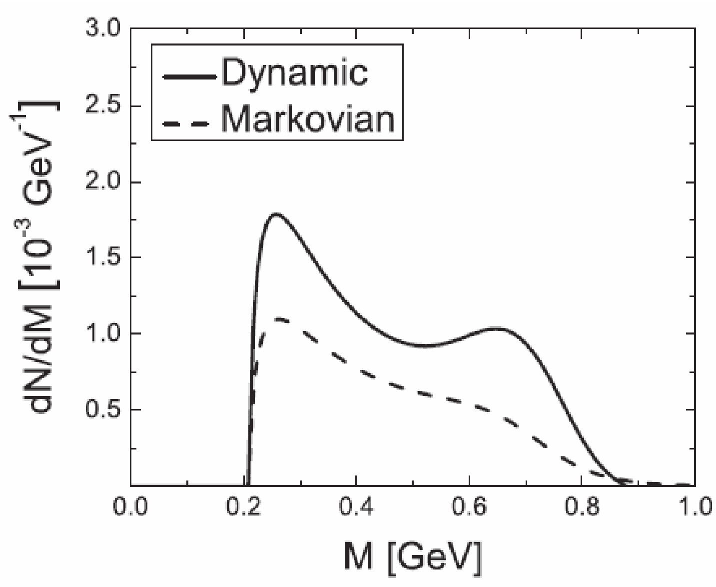
News from theory

Non-equilibrium effects in lepton pair emission

- Affects in particular the spectral function of dropping mass scenarios.
- Two scenarios are used for demonstration in a paper by B. Schenke and C. Greiner.

$$\rho \to \mu^+ \mu^-$$





$$m_\rho^* = m_\rho (1 - 0.15 n_{\text{Baryon}}/n_0)[1 - (T/T_c)^2]^{0.3},$$

$$m_\rho^* = m_\rho (1 - 0.15 n_{\text{Baryon}}/n_0),$$

B. Schenke, C. Greiner, PRL 98, 022301 (2007)

(My) conclusions

- The quality of data will finally be determined by systematical errors
- High statistics needed to permit multi-differential analyses
- Understanding the cocktail requires the measurement of neutral mesons (η, ω)
- Systematic measurements are needed to fully exploit the capabilities of low-mass lepton pair spectroscopy:
  - Compare low / high beam energies to study effects of the fireball expansion
  - Use elementary reactions to constrain spectral functions
- Trigger:
  - e^+e^-: most likely not possible
  - $\mu^+\mu^-$: difficult without introducing huge bias
- Excitation function of the enhancement can possibly signal a critical slowing-down of the expansion