Low-mass electron pairs from the PHENIX experiment at RHIC

Alexander Kozlov
Weizmann Institute of Science
(for the PHENIX collaboration)

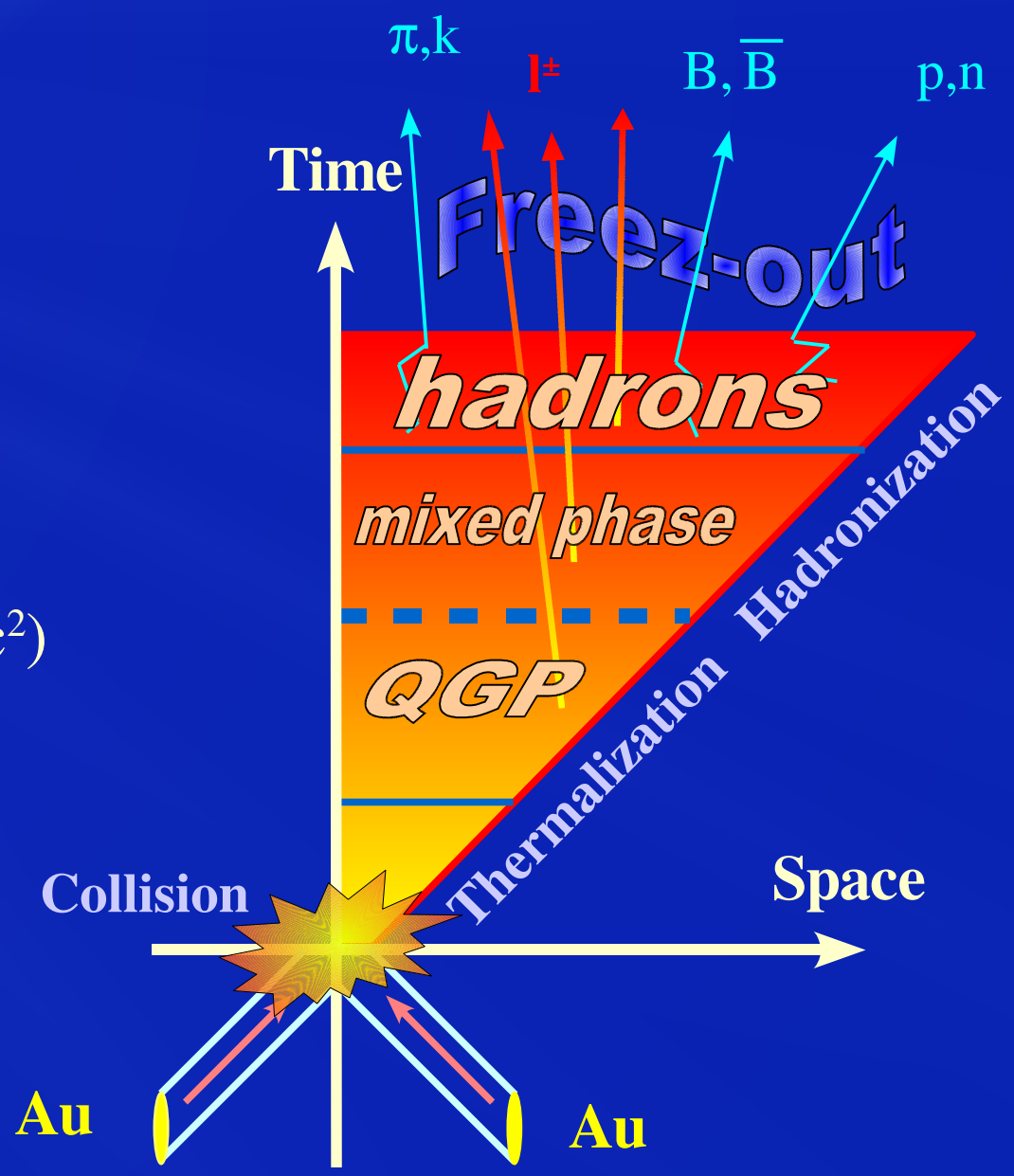
QNP06, Madrid, June 5 – 10

Outline

- Physics motivation:
  - Why dileptons?
  - Theoretical and experimental background
- PHENIX experiment @ RHIC
- How PHENIX measures electrons
- Results
  - ϕ meson
  - dilepton continuum
- Hadron Blind Detector
- Summary

Electromagnetic probes

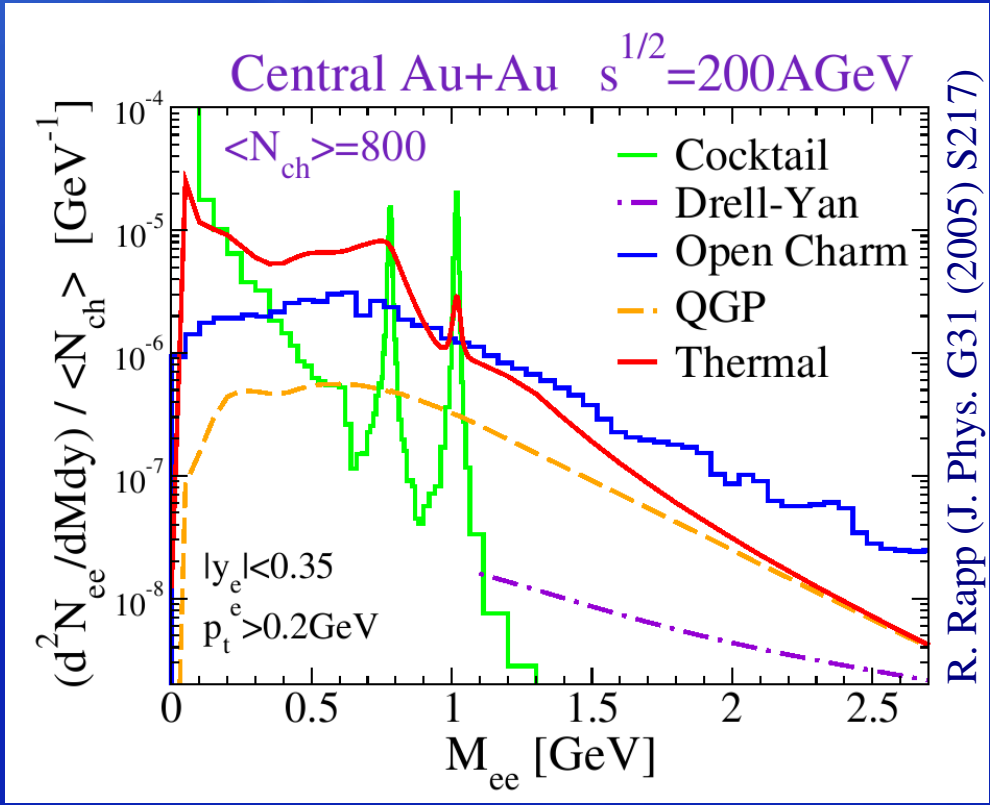
- Powerful diagnostic tool
  - *information about the entire collision lifetime*
  - *do not interact strongly*
- Low-mass dileptons (m<1 GeV/c^2)
  - *Dilepton continuum*
  - *Low-mass vector mesons*



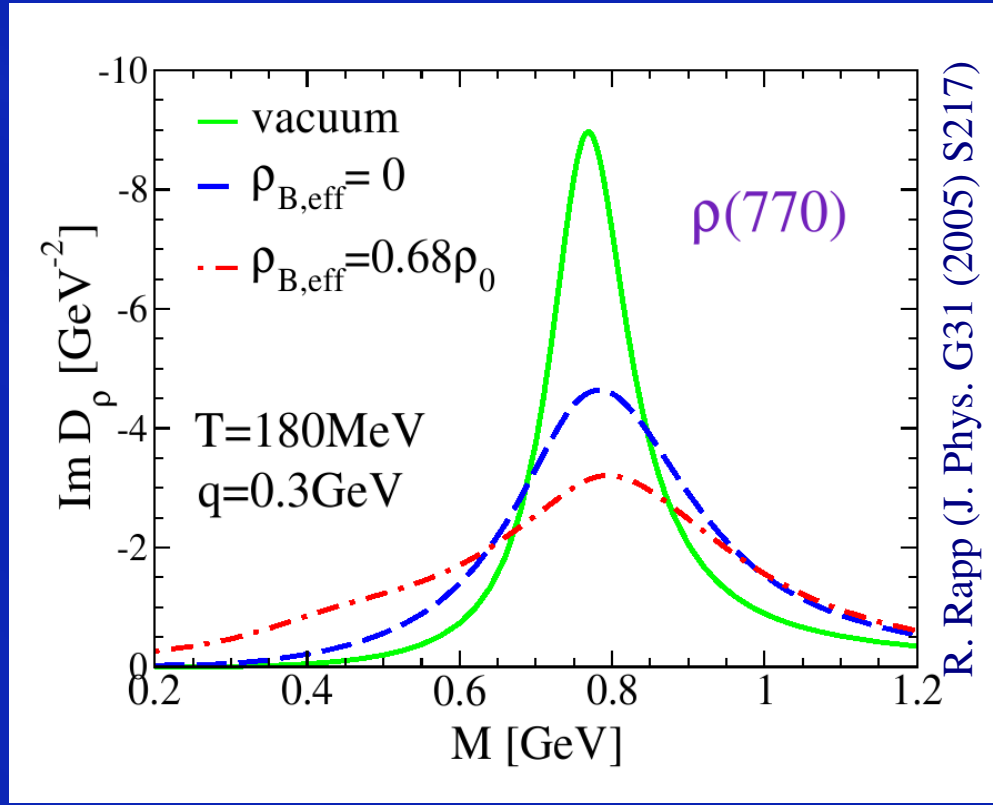
Low-mass dileptons

- Probe of deconfinement
  - ✔ *Shape of the thermal radiation*
- Probe of chiral symmetry restoration
  - ✔ *vector meson's mass/width modification*

Theoretical predictions for RHIC



Dielectron continuum

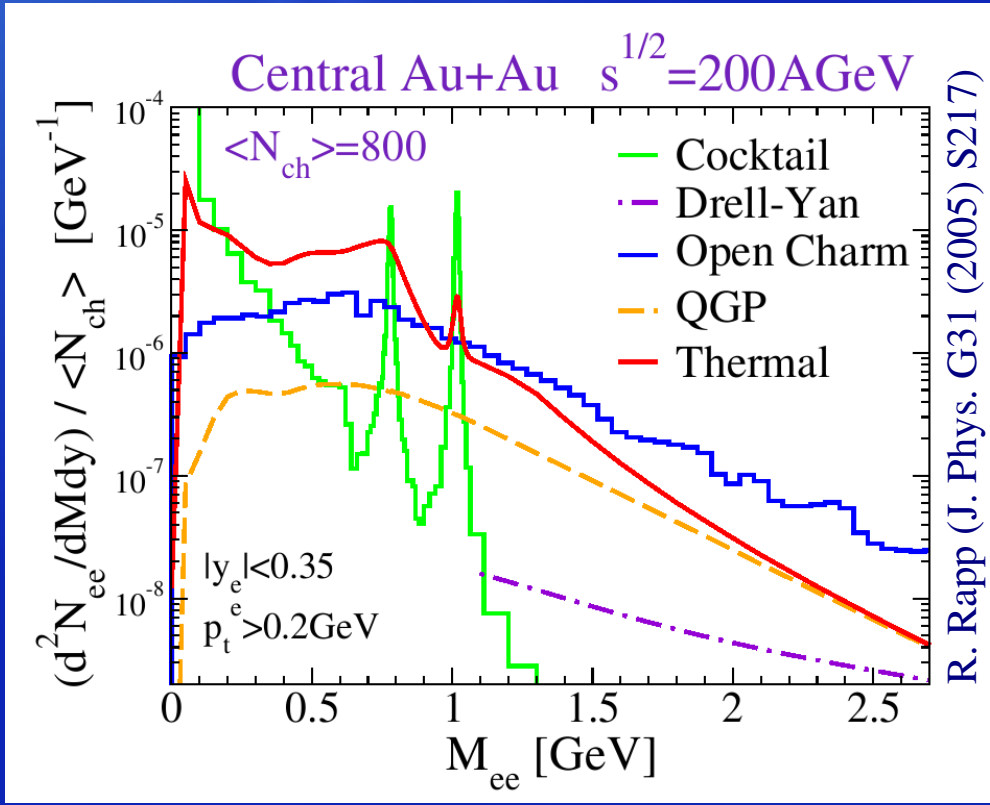


Low-mass vector mesons

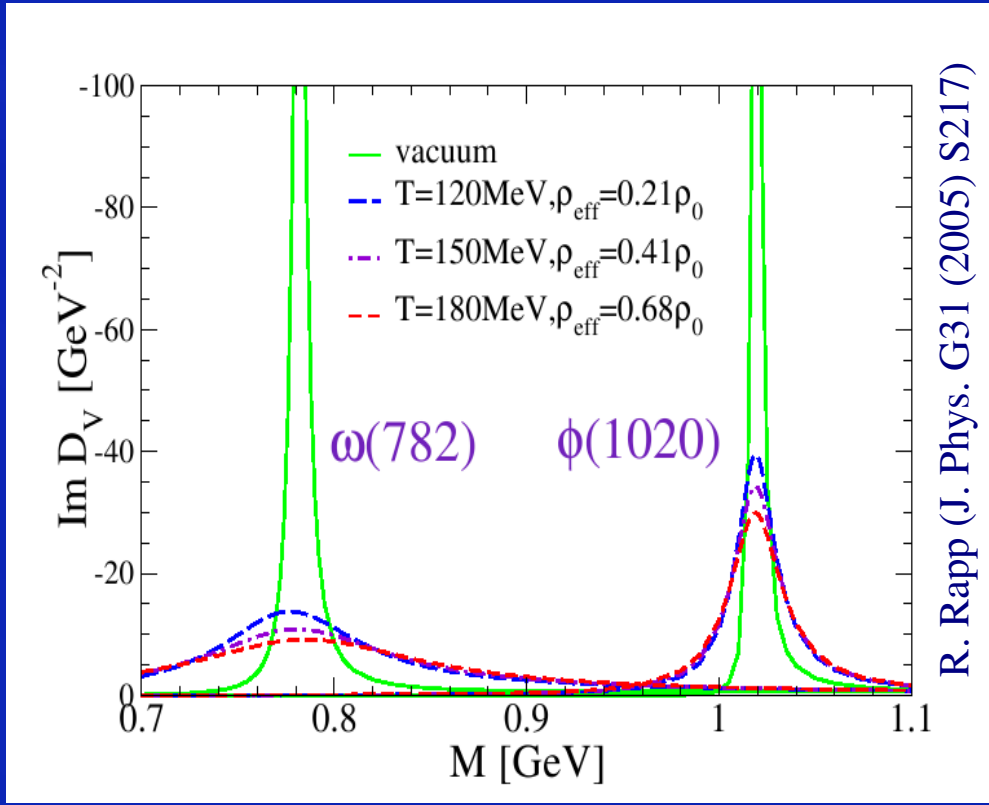
Low-mass dileptons

- Probe of deconfinement
  - ✔ *Shape of the thermal radiation*
- Probe of chiral symmetry restoration
  - ✔ *vector meson's mass/width modification*

Theoretical predictions for RHIC

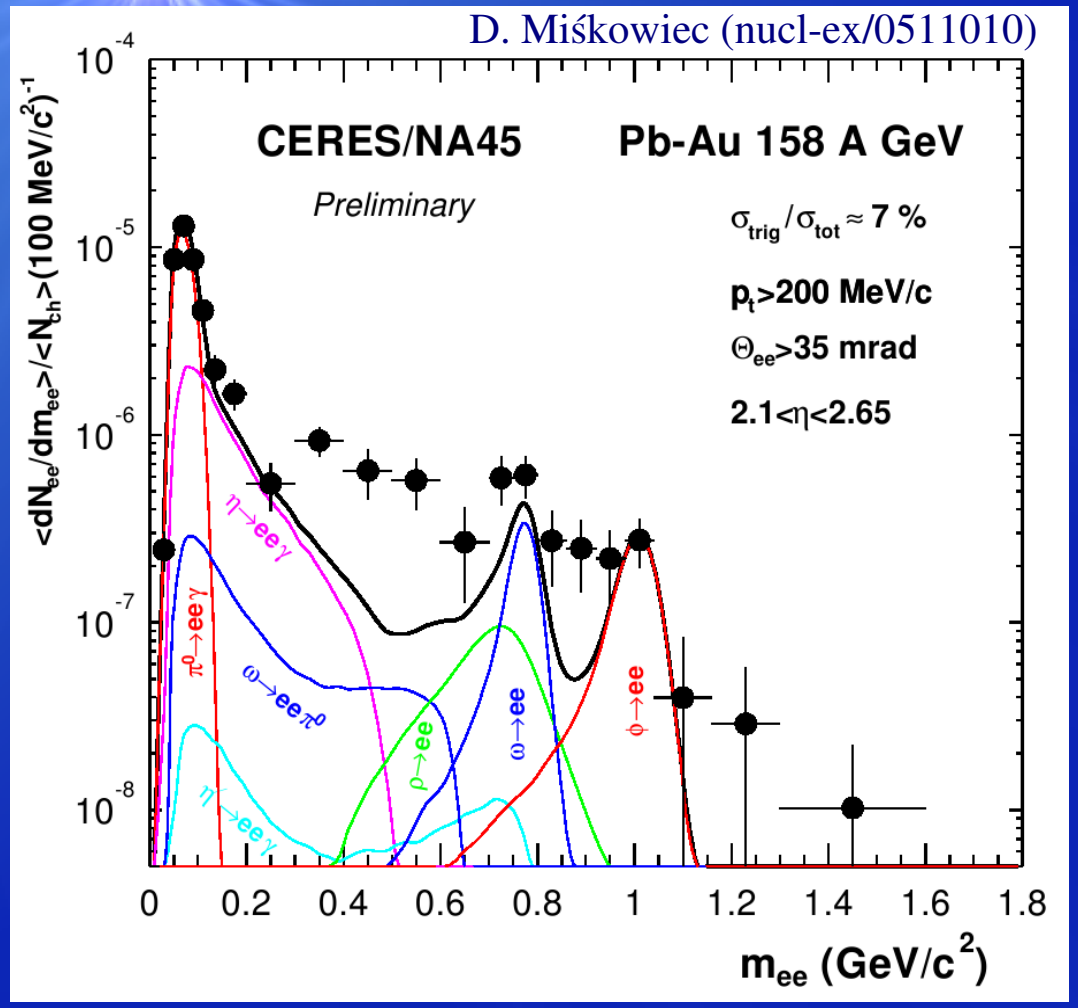


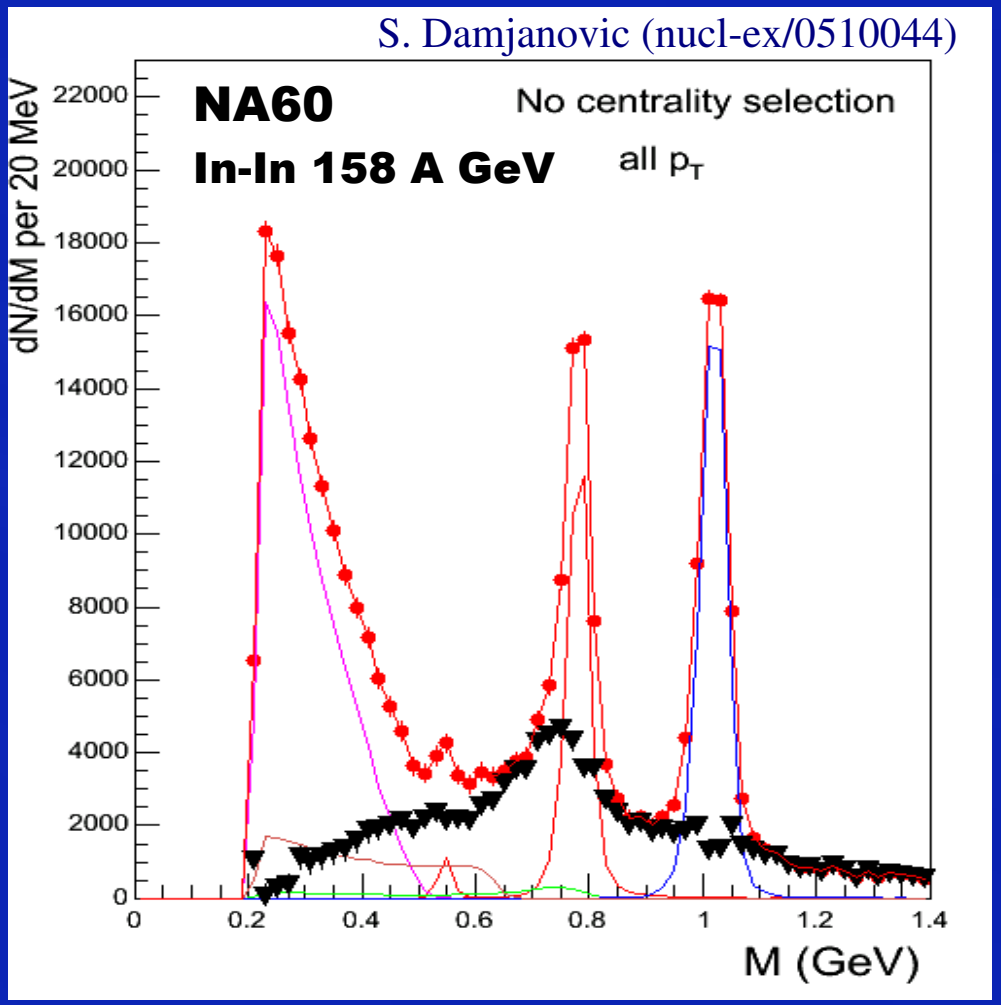
Dielectron continuum



Low-mass vector mesons

Low-mass dileptons @ SPS





- *Both CERES and NA60 demonstrated clear excess for $0.2 \leq m \leq 0.6$ MeV/c^2*
- *NA60: first measurement of the ρ meson shape*

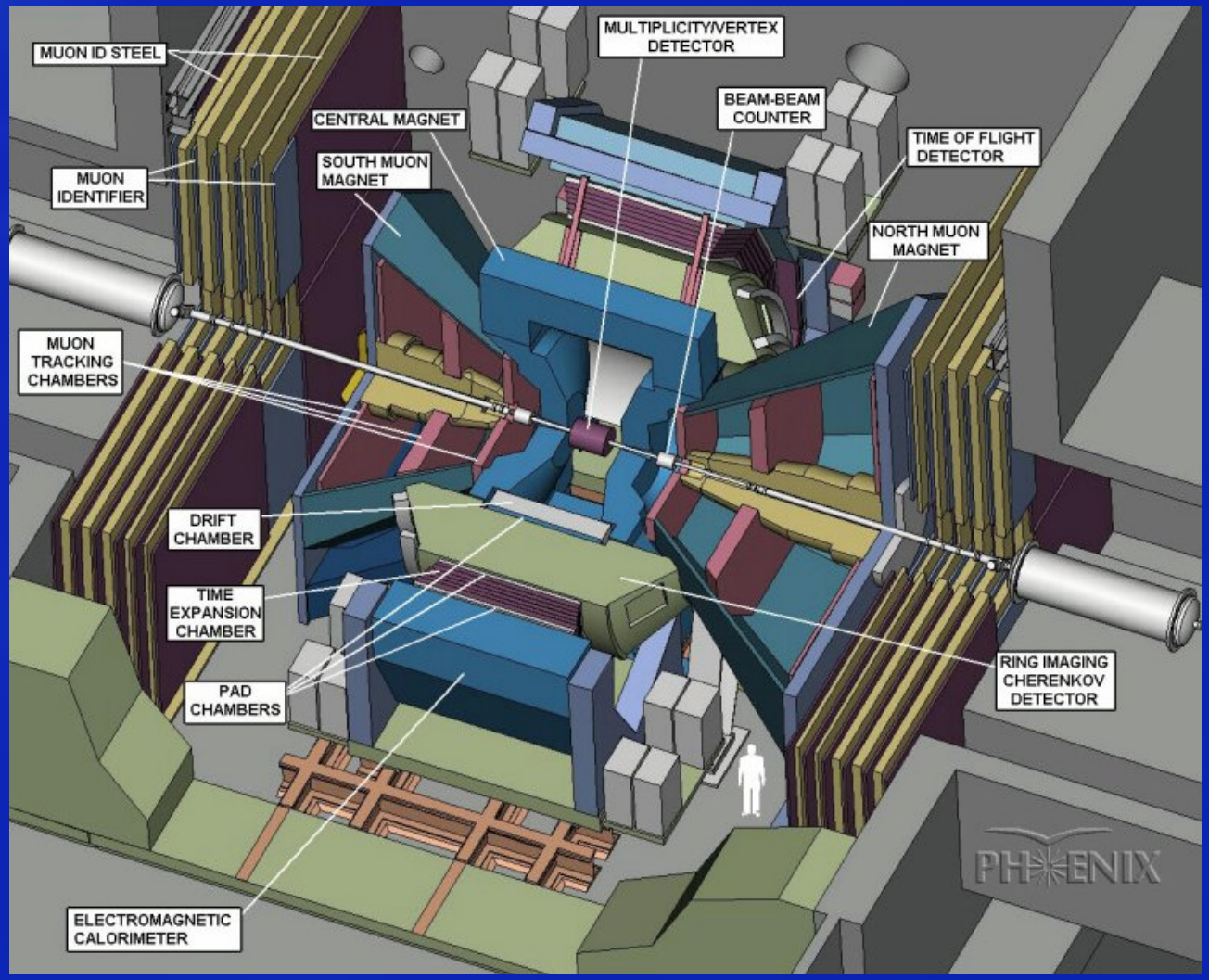
PHENIX experiment

Global detectors:

BBC, ZDC

Central Arm:

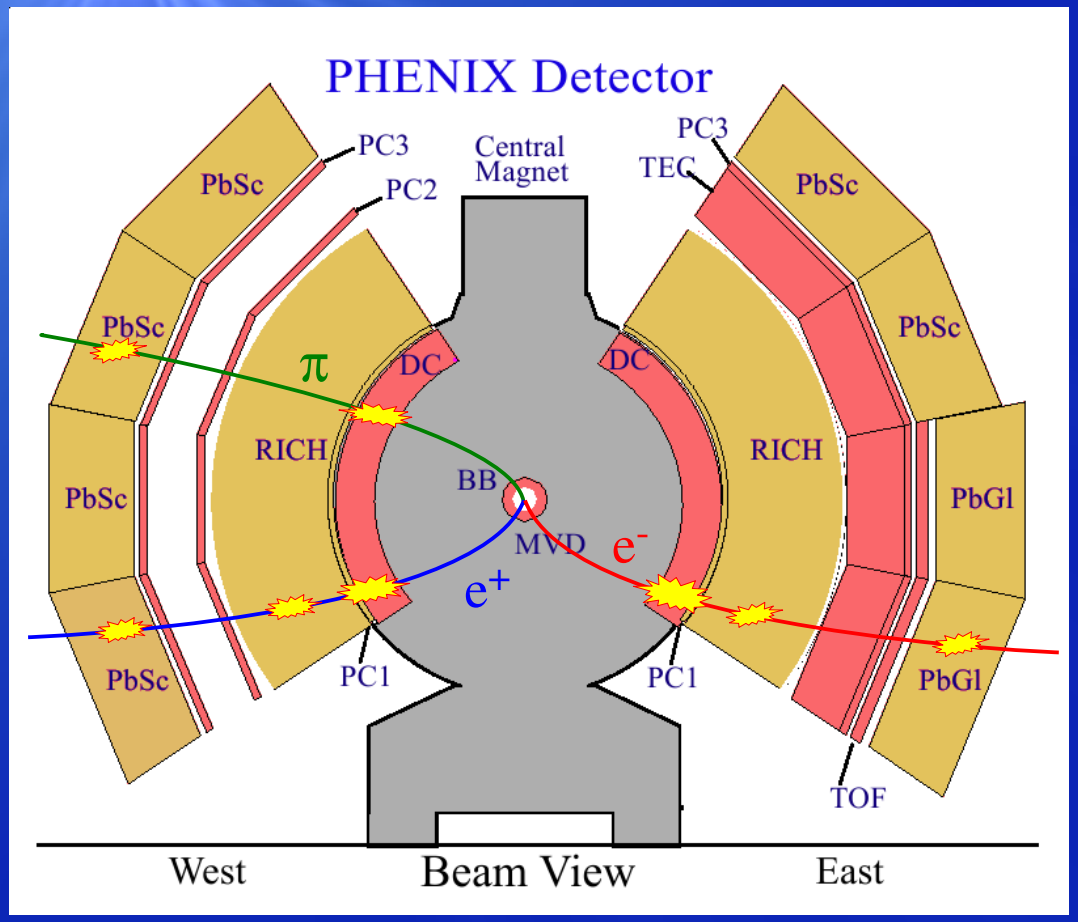
- Acceptance
  - ✔ $|\eta| < 0.35$
  - ✔ $\Delta\varphi = 2 \times 90^0$
- Tracking: DC-PC
  - ✔ Momentum, $\delta p/p \sim 1\% p$ (GeV/c)
- Electron ID
  - ✔ RICH, EMCal (E/p)
- Hadron ID
  - ✔ TOF, EMCal

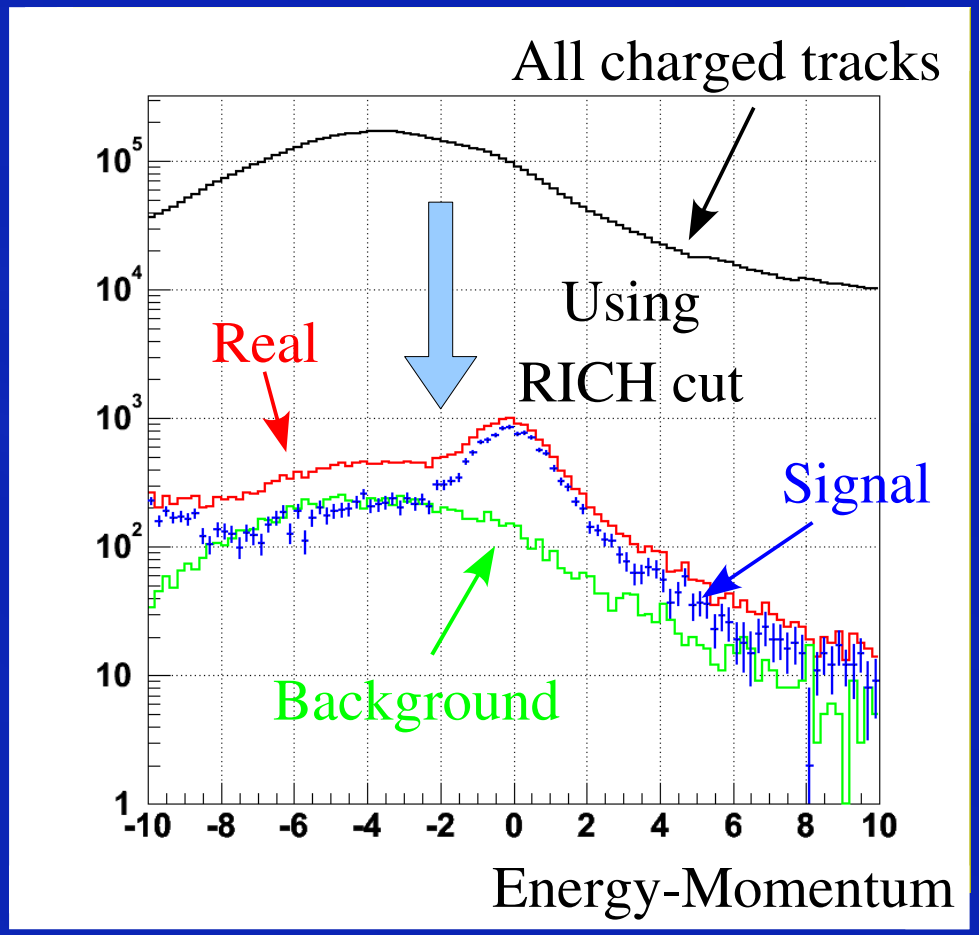


Muon Arm

- Acceptance
  - ✔ $1.1 < |\eta| < 2.4$

Electron measurements in PHENIX





I. Ring information (RICH)

II. Energy-momentum matching

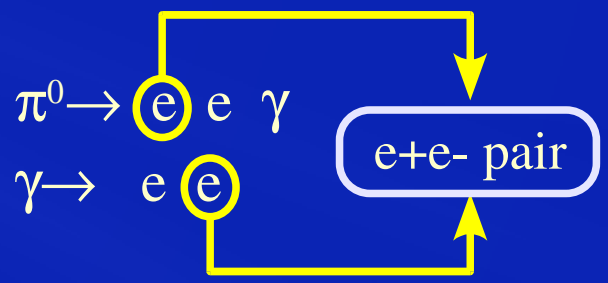
Challenge

Sources of electrons

- Dalitz decay of light mesons:
  - ✔ $\pi^0, \eta, \eta' \rightarrow ee\gamma$
  - ✔ $\omega \rightarrow ee\ \pi^0$
- Conversion in material
  - ✔ $\pi^0 \rightarrow \gamma\gamma \rightarrow ee\gamma$
  - ✔ $\gamma \rightarrow ee$
- Two-body decay of vector mesons
  - ✔ ρ, ω and $\phi \rightarrow ee$
- Thermal radiation
  - ✔ $qq \rightarrow \gamma^* \rightarrow ee$
  - ✔ $\pi\pi \rightarrow \rho \rightarrow \gamma^* \rightarrow ee$
- Other

Large combinatorial background:

unrecognized conversions and π^0 – Dalitz decays



PHENIX performance

RUN	YEAR	Species	$\sqrt{s_{NN}}$ (GeV)	N_{EVT} (10^6 MB)
Run 1	2000	*Au + Au*	130	10
Run 2	2001/2002	*Au + Au* *p + p*	200 200	170 3700
Run 3	**2002/2003**	***d + Au*** *p + p*	**200** 200	**5500** 6600
Run 4	**2003/2004**	***Au + Au*** *Au + Au*	**200** 62.4	**1530** 58
Run 5	2004/2005	*Cu + Cu* *Cu + Cu* *p + p*	200 62.4 200	1780 425 85100
Run 6	2006	Polarized Proton Operation		

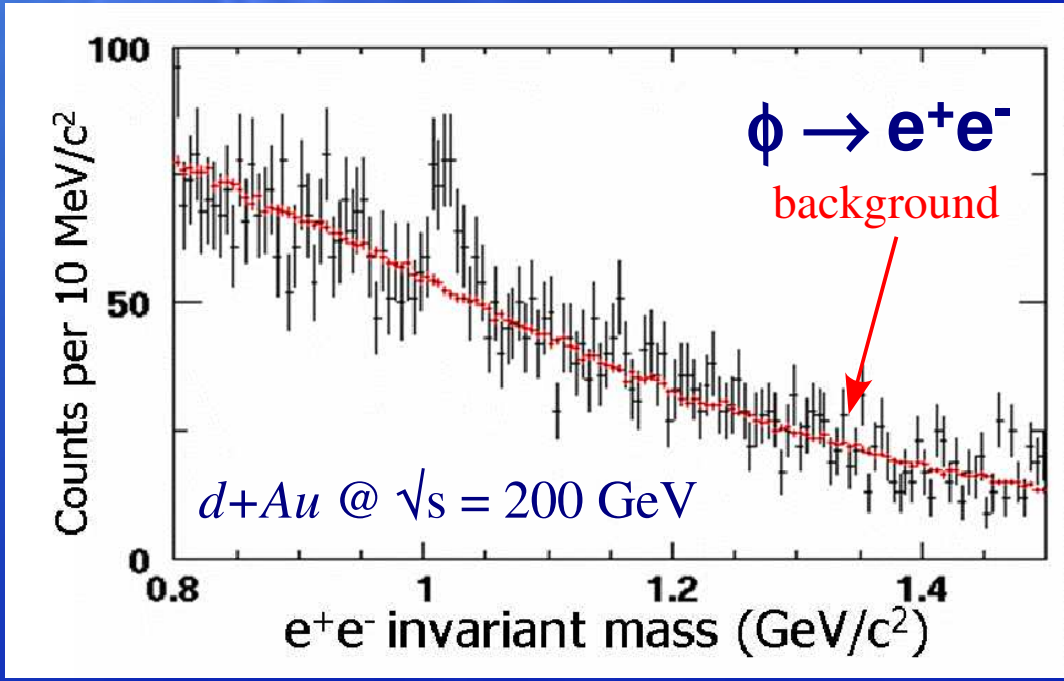
ϕ meson

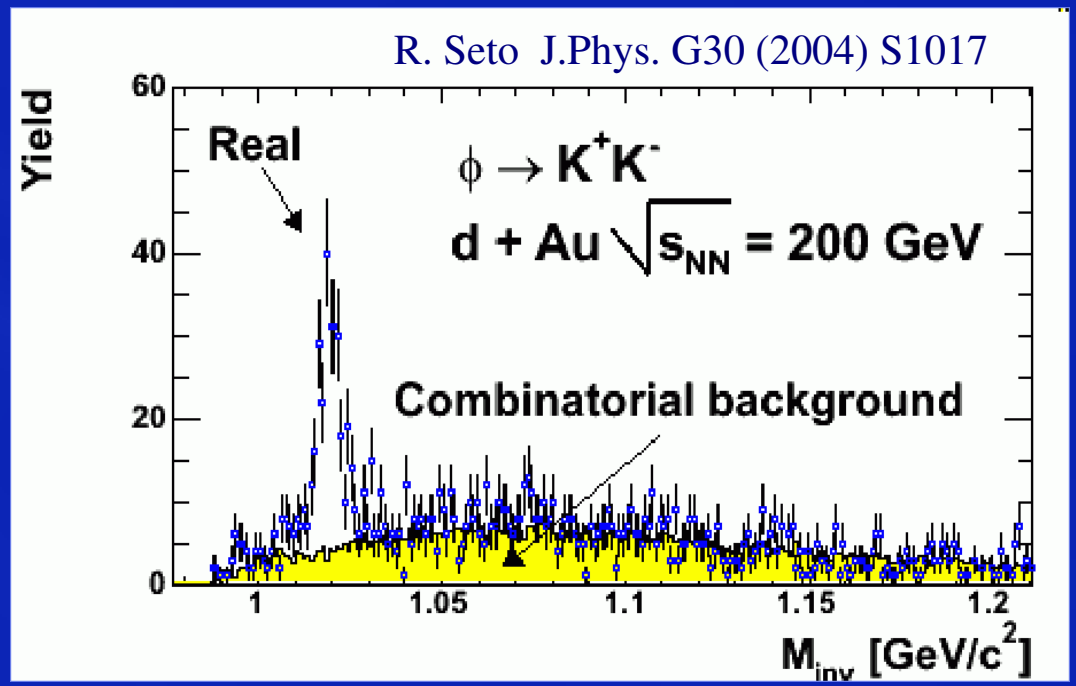
- Line shape analysis
  - ✔ line shape (peak position and/or width) modifications: $\tau_\phi = 46$ fm/c, $\tau_{QGP} \sim 10$ fm/c $\Rightarrow$ small fraction of ϕ decays inside fireball producing a very small modification in the line shape.
- Yield analysis
  - ✔ Yield (dN/dy) through e^+e^- compared to the K^+K^- channel. ($m_\phi \sim 2m_K \Rightarrow$ small changes in the ϕ or K can induce significant change in the BR).

PHENIX has the unique capability to measure both decay channels simultaneously!

ϕ meson in *d+Au* collisions

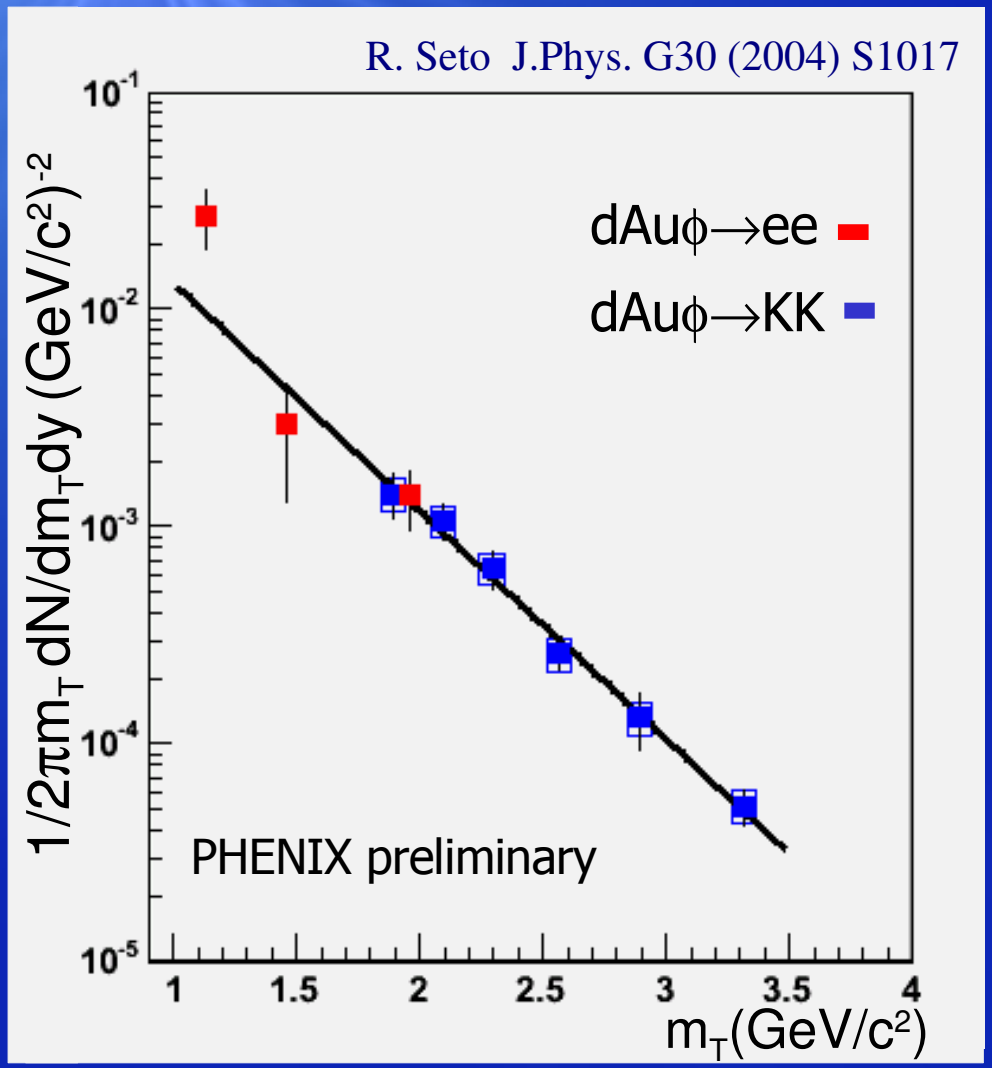
(*cold matter effects*)

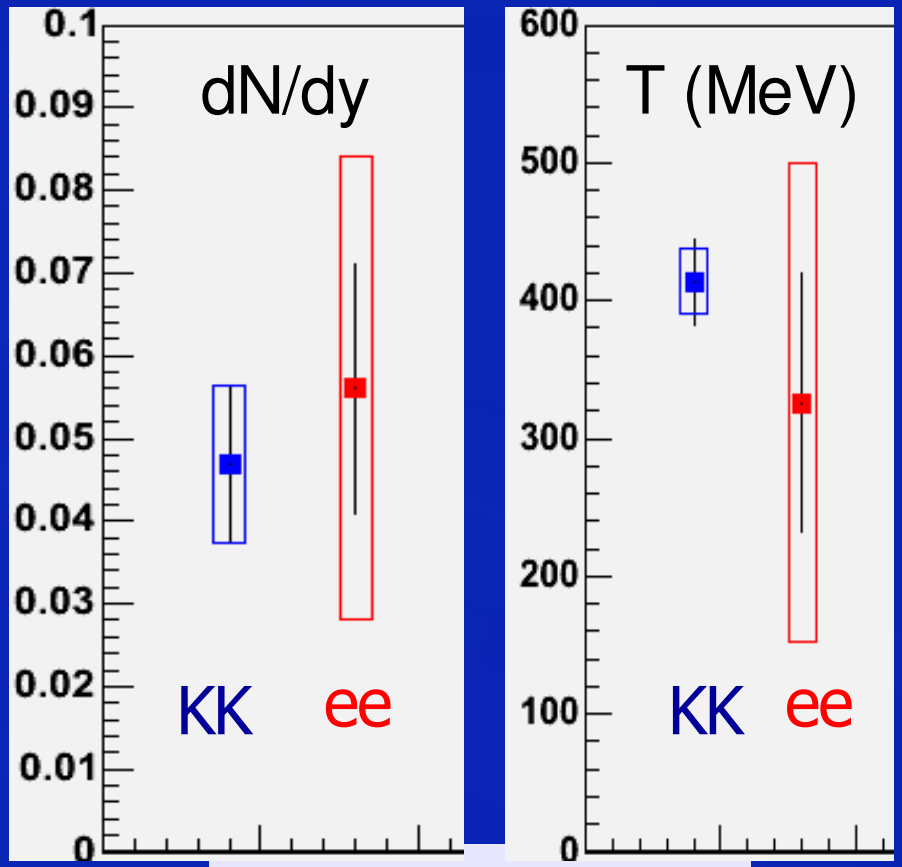




- Extract yield:
  - ✔ ϕ → ee: ~ 120 counts; ϕ → KK: ~ 207 counts;
- Divide yield into m_T bins
- Derive dN/dy and T

dN/dy and T (*d+Au*)



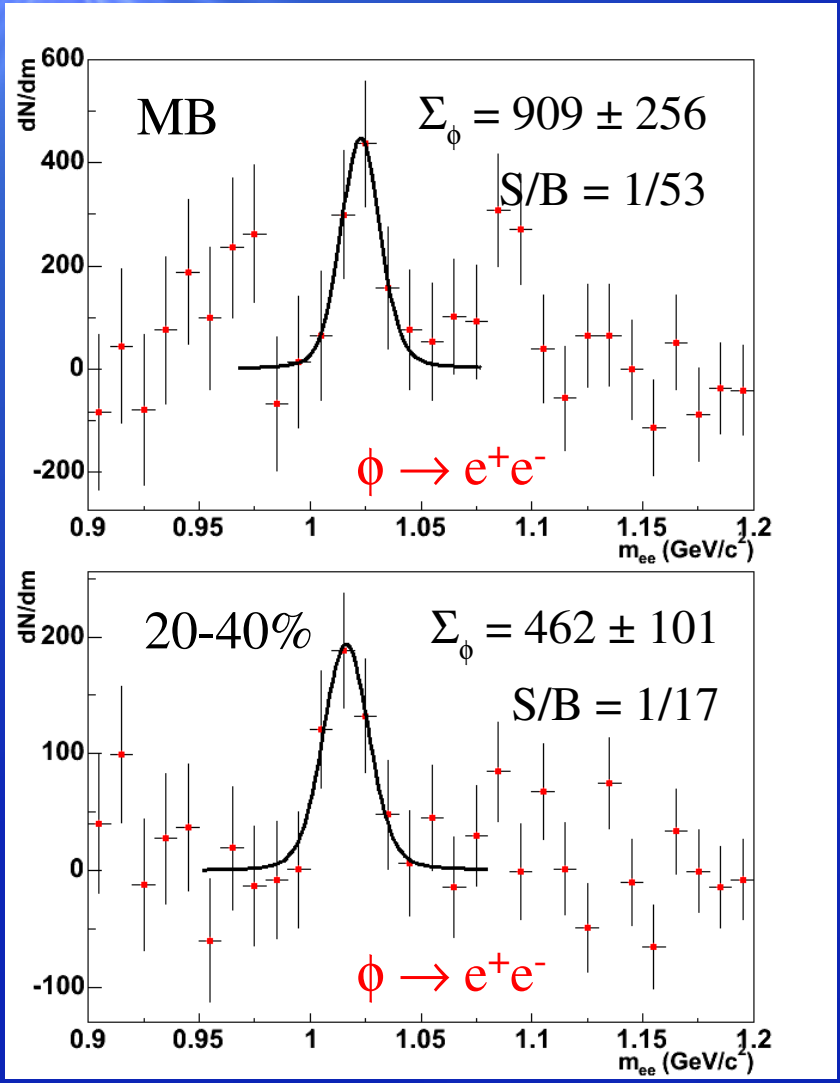


PHENIX preliminary

both dN/dy and T measured in e^+e^- and K^+K^- decay channels are consistent within errors (stat. and syst.)

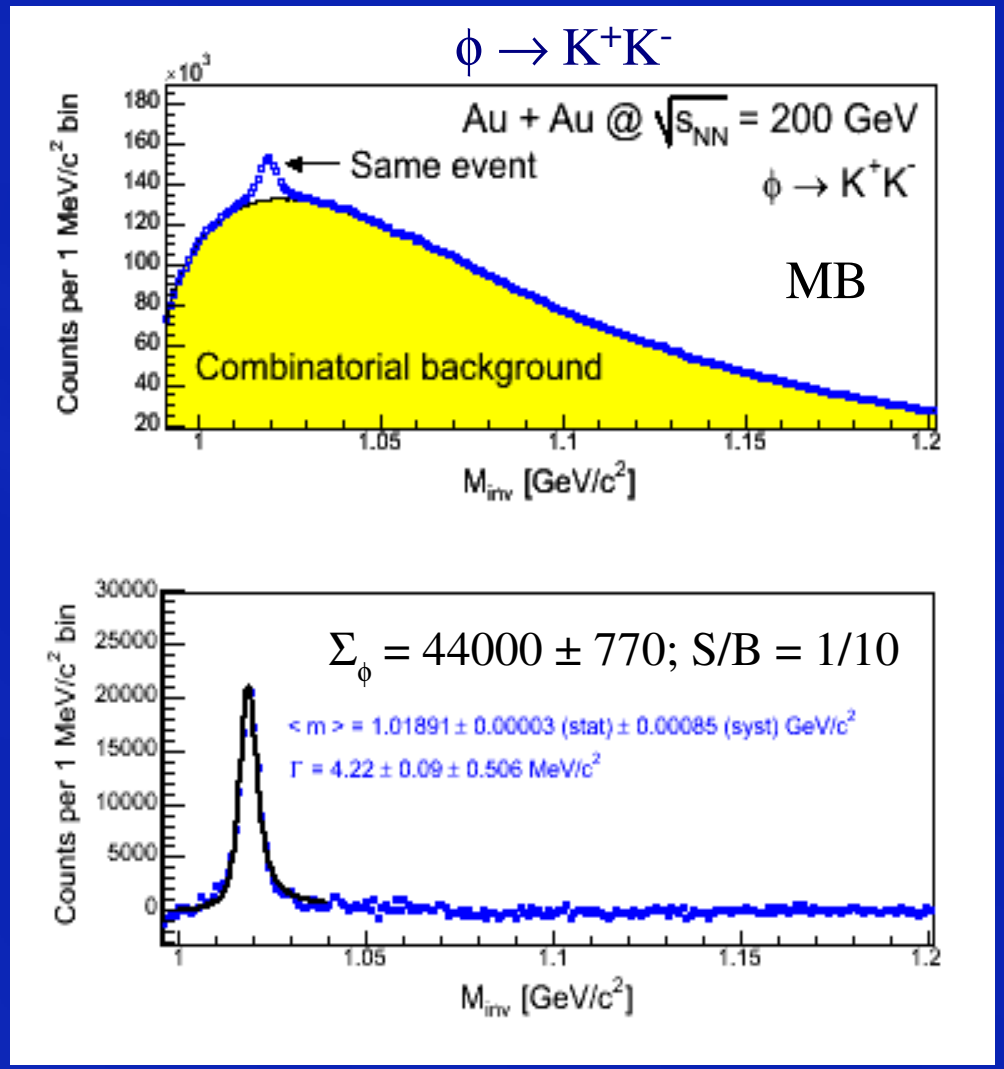
ϕ meson in *Au+Au* collisions

ϕ is fitted with relativistic Breit-Wigner & Gaussian for the mass resolution



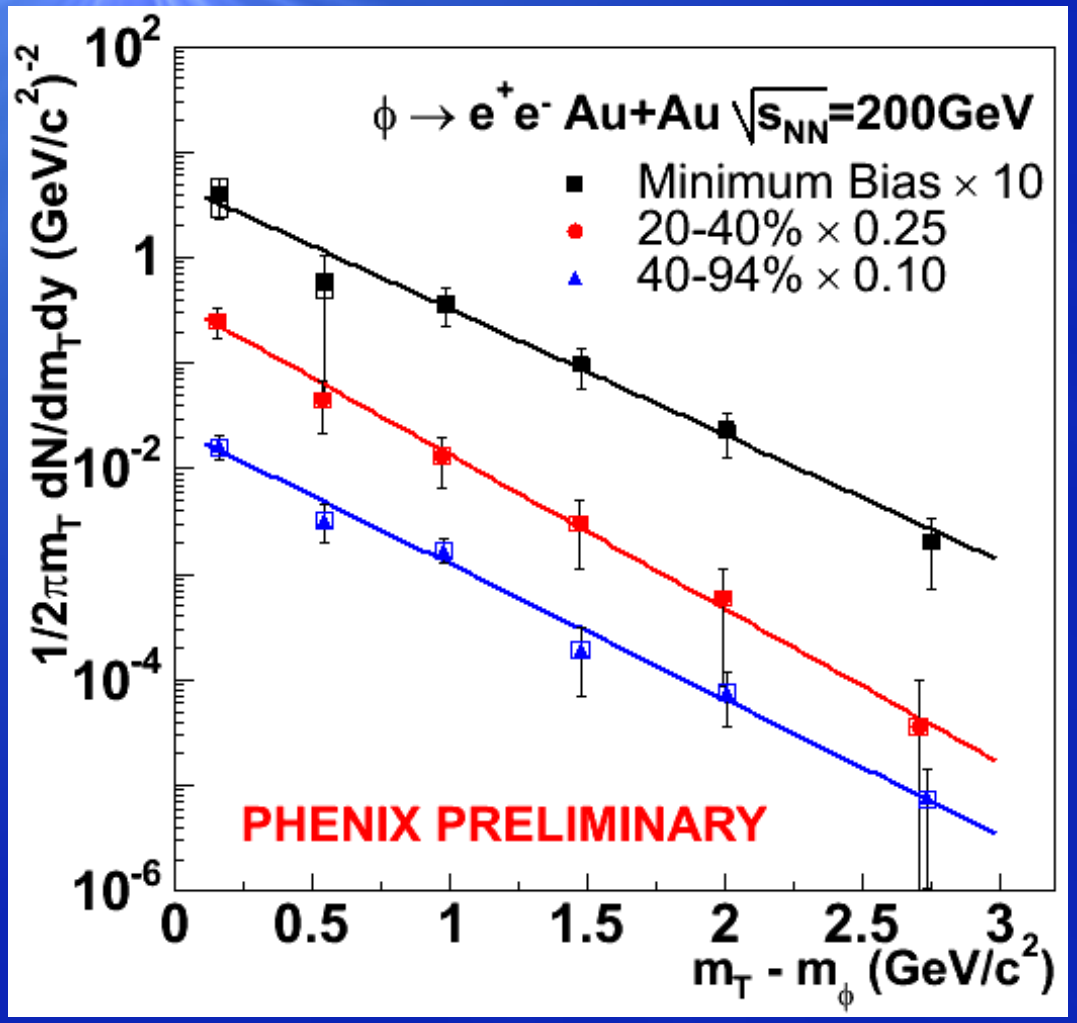
m_T - spectra for MB, 20-40%, > 40% centralities

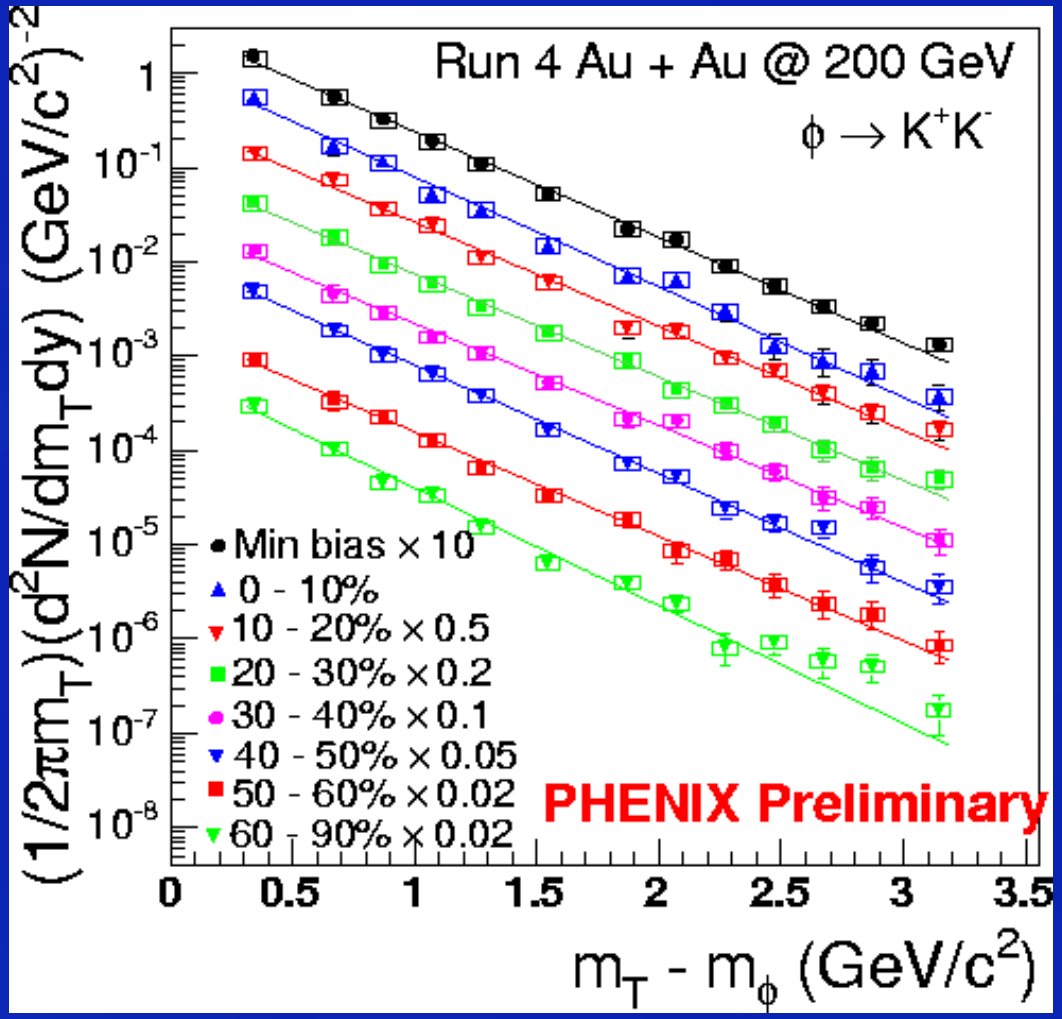
for 0-20% centrality used integral yield.



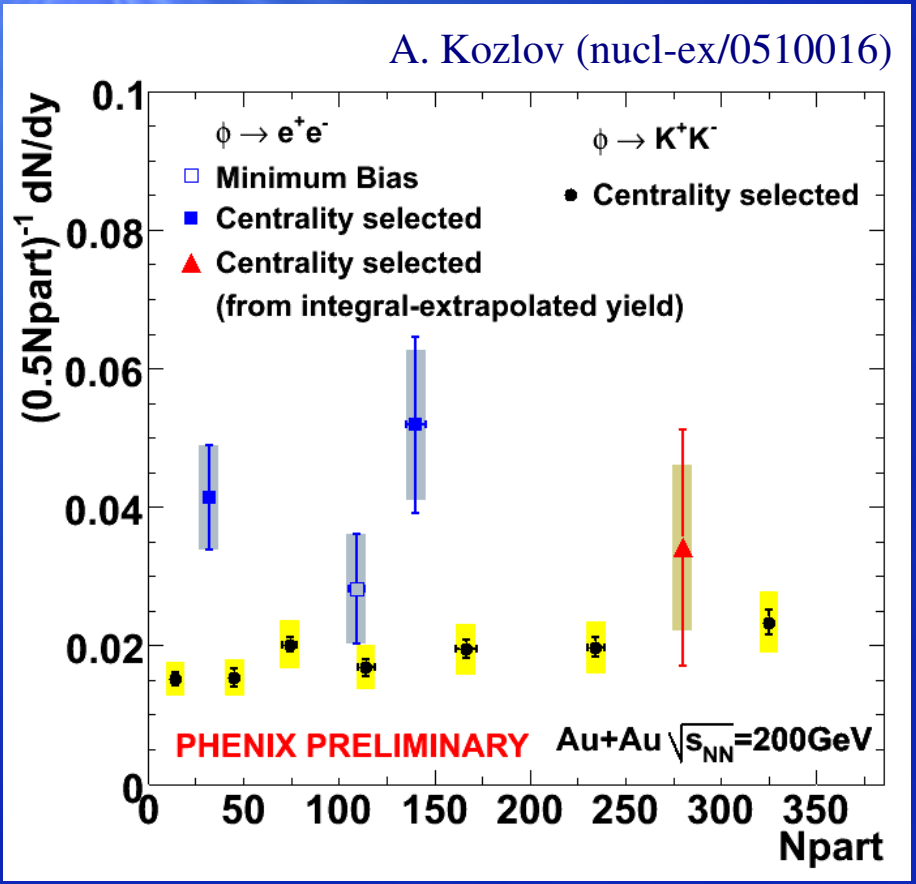
m_T - spectra for MB and 7 centrality bins

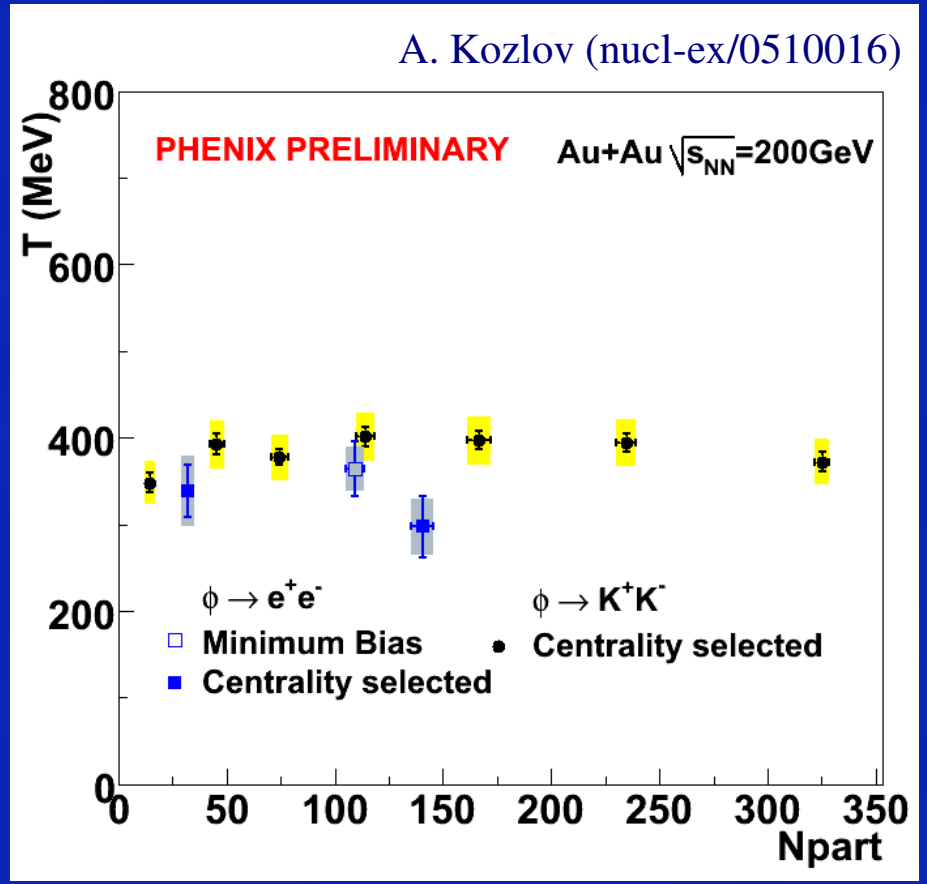
Transverse mass spectra





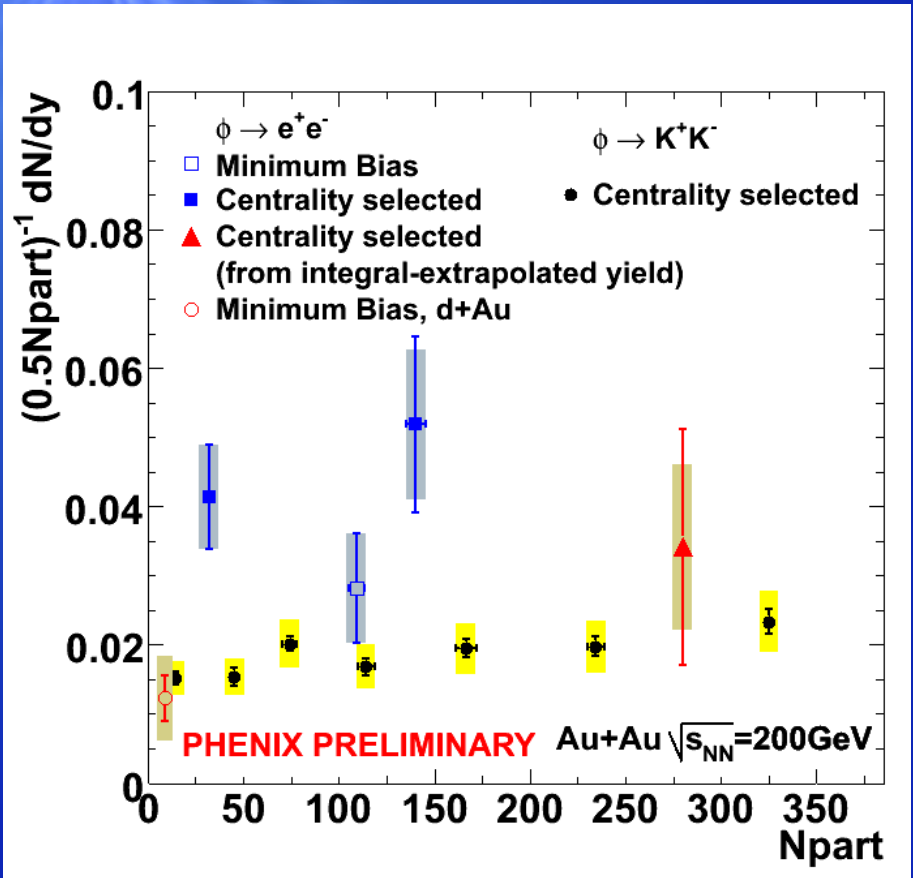
dN/dy and T (*Au+Au*)

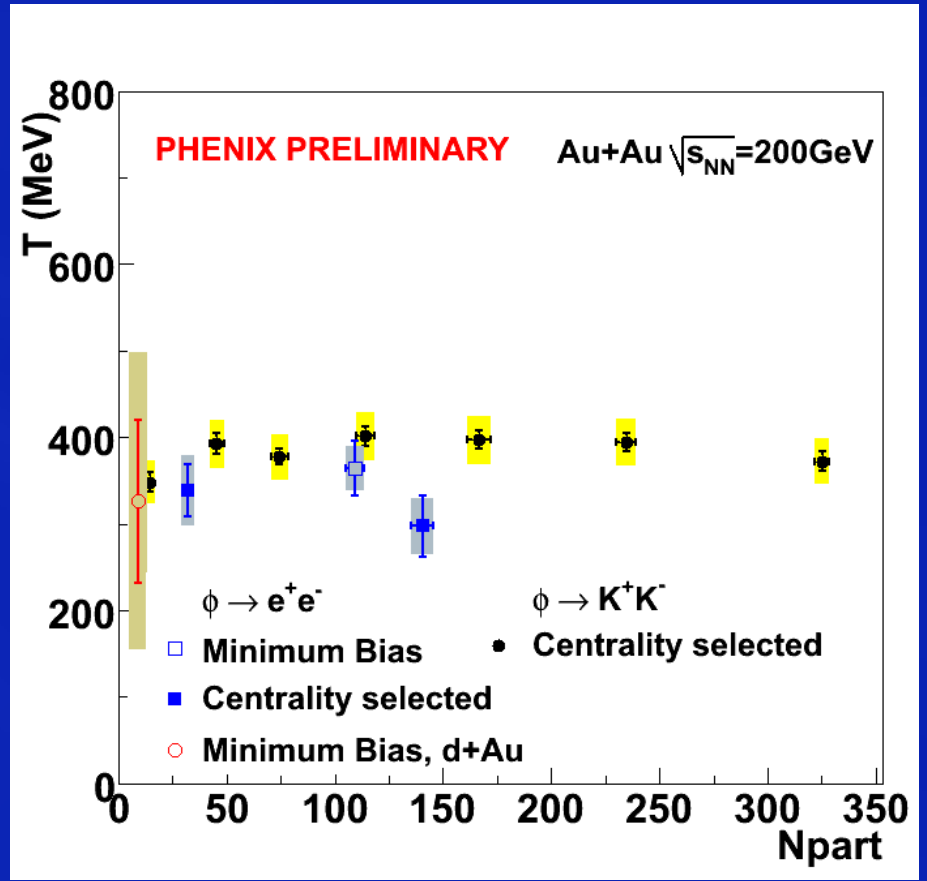




- dN/dy ($\phi \rightarrow e^+e^-$) seems to be larger than dN/dy ($\phi \rightarrow K^+K^-$), but ERRORS are too large for a definitive statement.
- Temperatures measured in two decay channels are consistent.

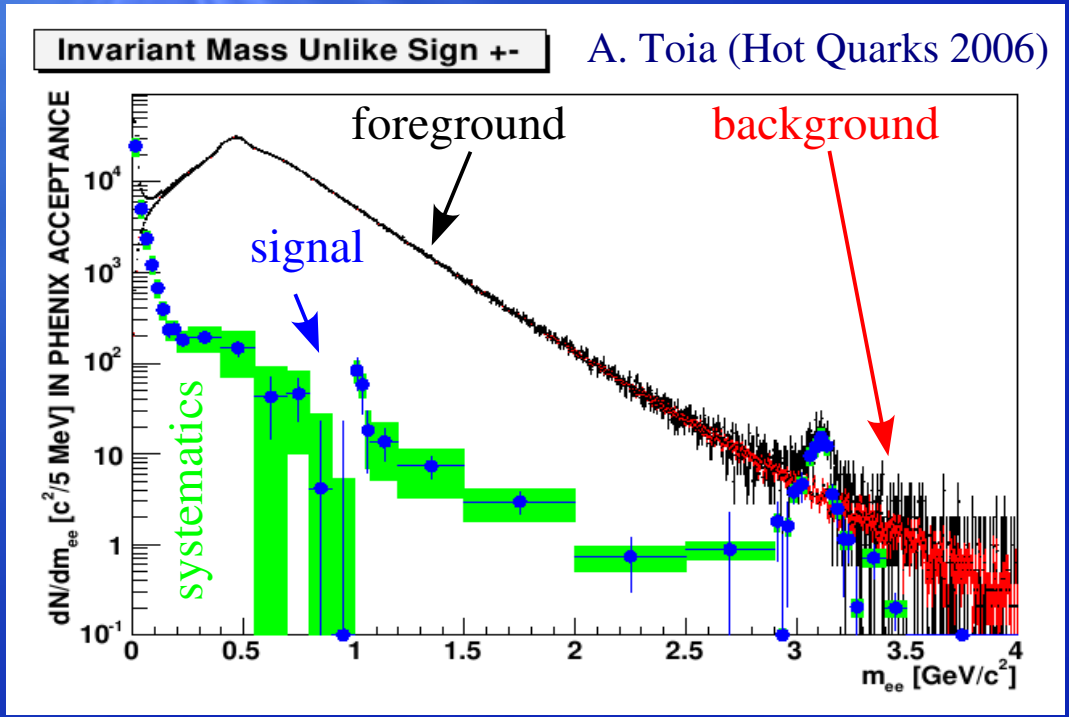
dN/dy and T (*Au+Au* & *d+Au*)

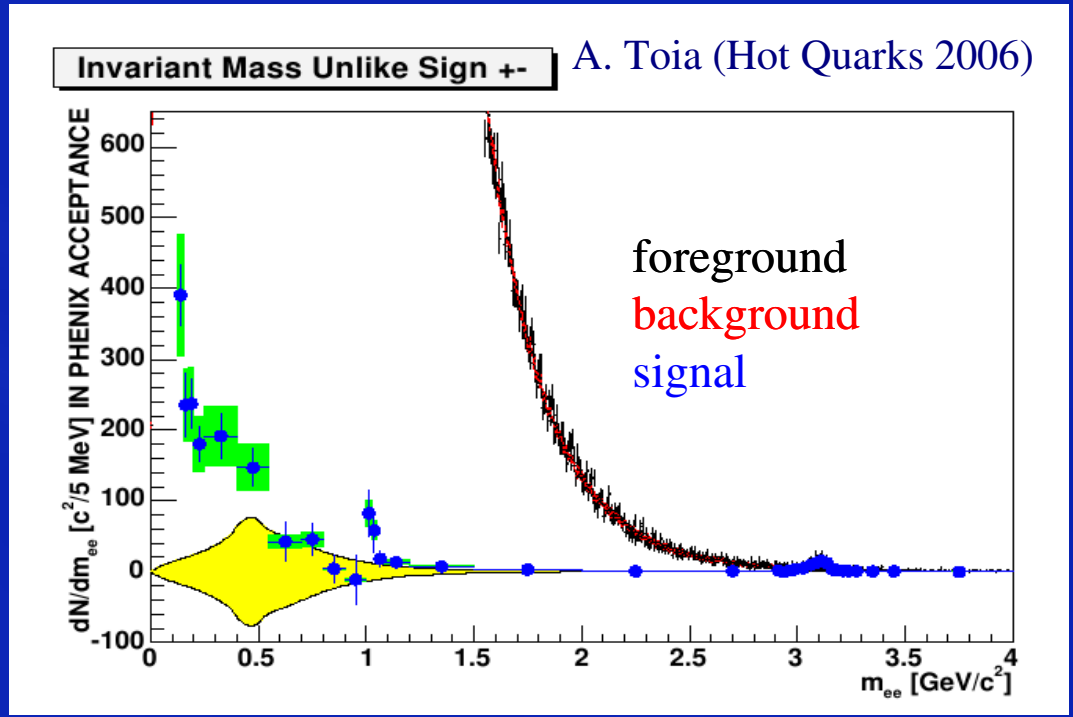




- Yield and temperature measured in *d+Au* are consistent with dN/dy and T measured in peripheral *Au+Au* collisions via KK decay channel

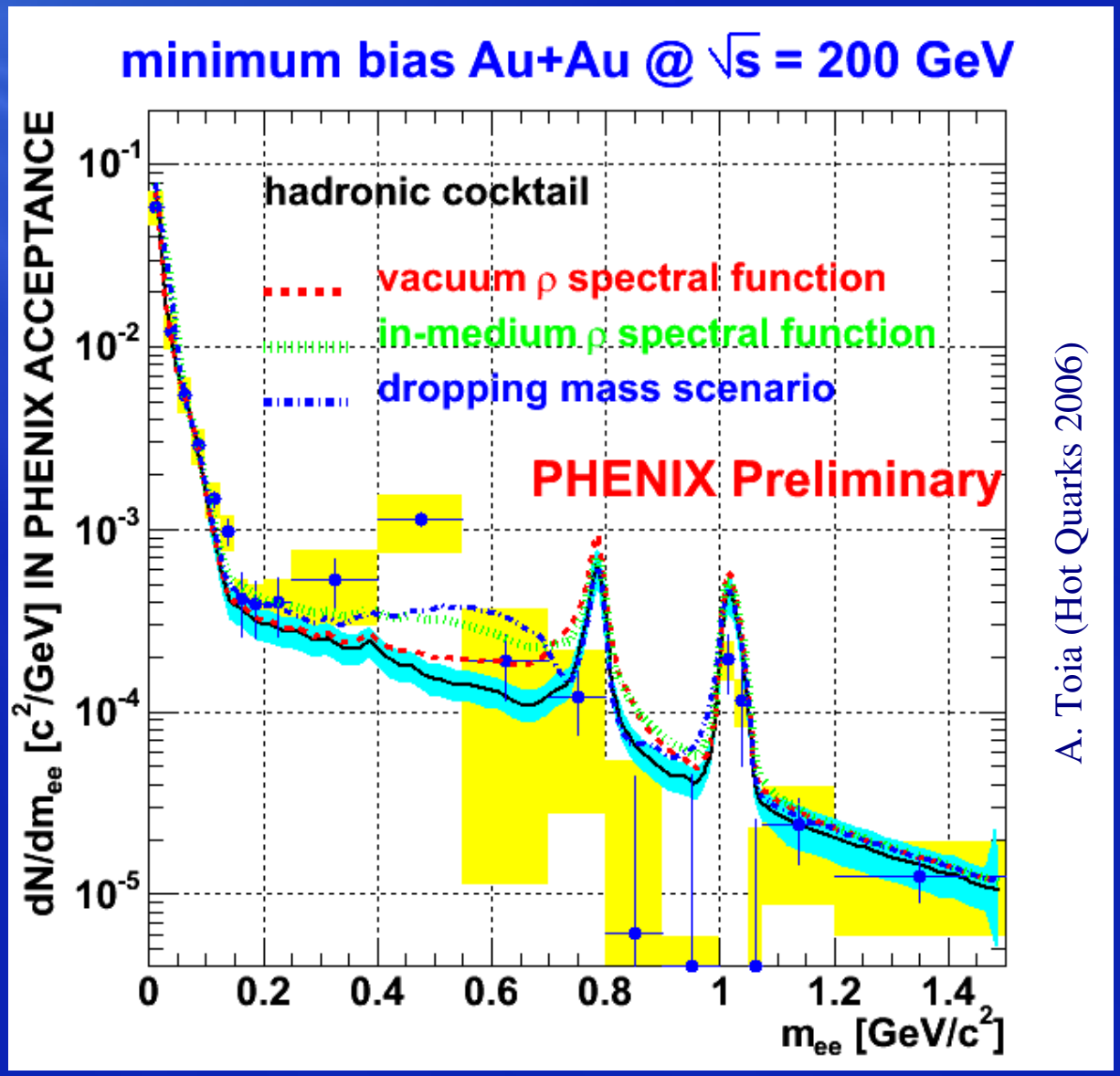
e+e- invariant mass spectrum
Au+Au collisions





- Background
  - ✔ mixed event technique (unlike- , like-sign spectra)
  - ✔ BG is normalized to the measured like-sign spectra
  - ✔ BG reproduces FG with 0.1% accuracy!
- S/B ratio is small: at m ≈ 400 MeV/c² S/B ~ 1/150
- Main source of systematic errors is background normalization

Dielectron Continuum



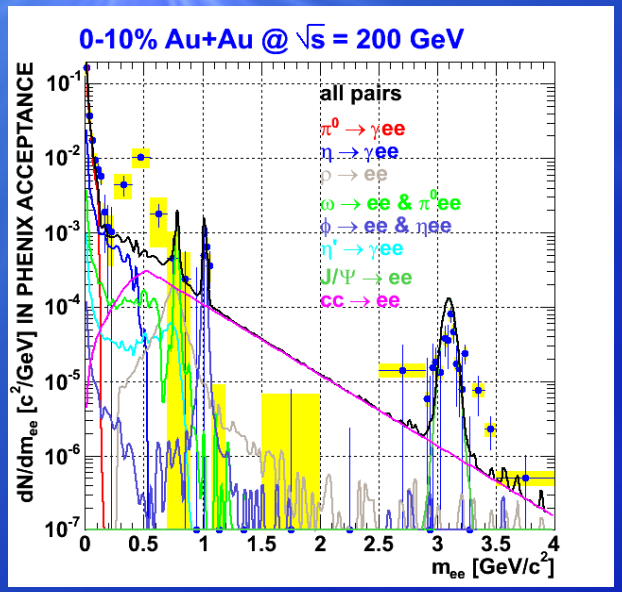
A. Toia (Hot Quarks 2006)

Theory:
R.Rapp, Phys.Lett. B 473 (2000)
R.Rapp, Phys.Rev.C 63 (2001)
R.Rapp, nucl/th/0204003

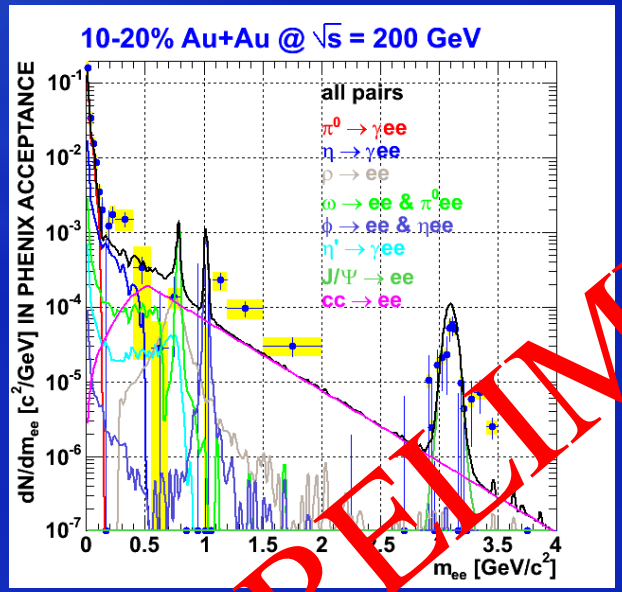
Systematic uncertainties are too large to interpret results

Centrality dependence

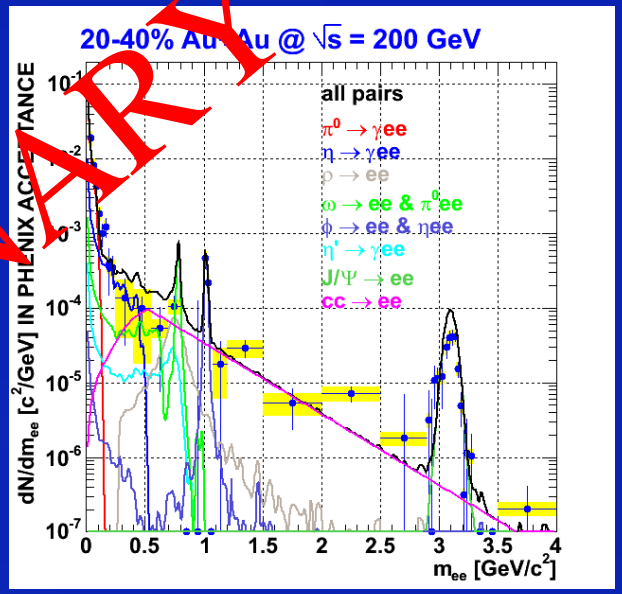
0-10%



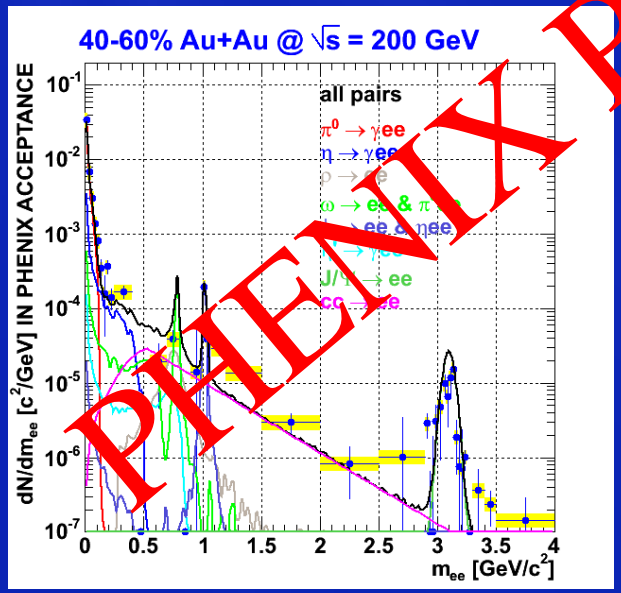
10-20%



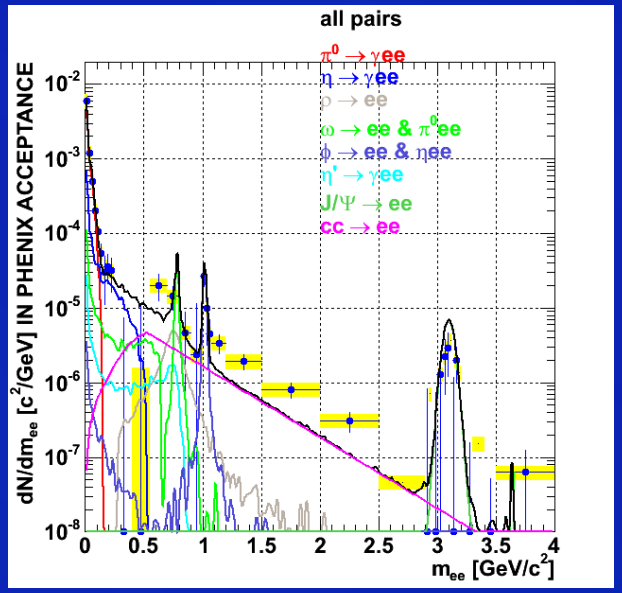
20-40%



40-60%



60-100%

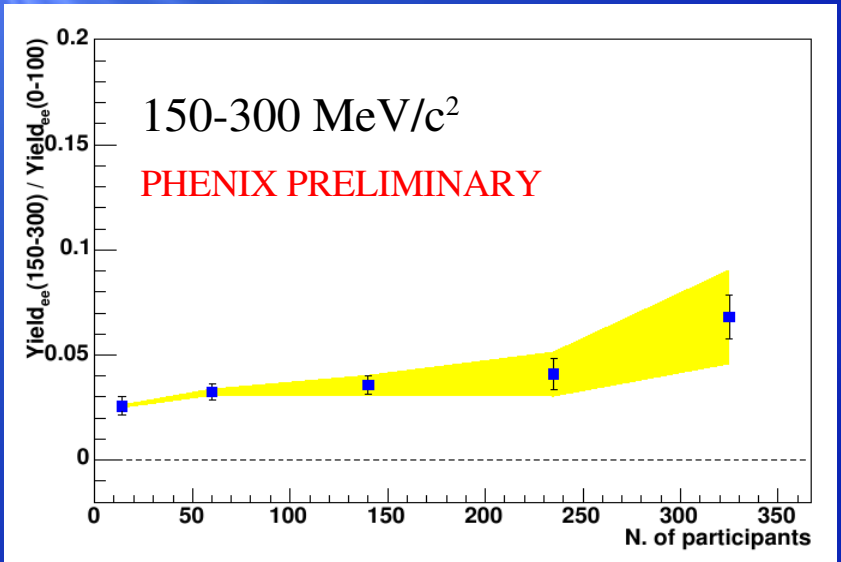


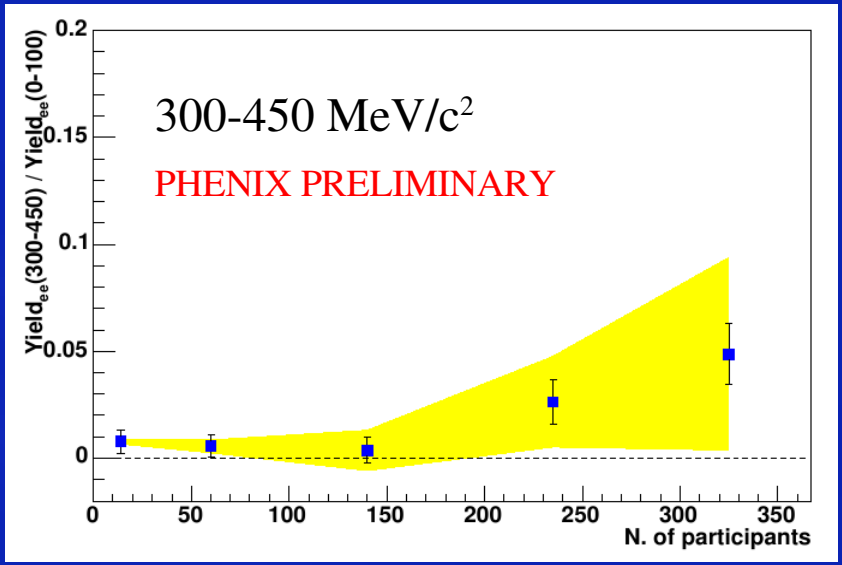
PHENIX PRELIMINARY

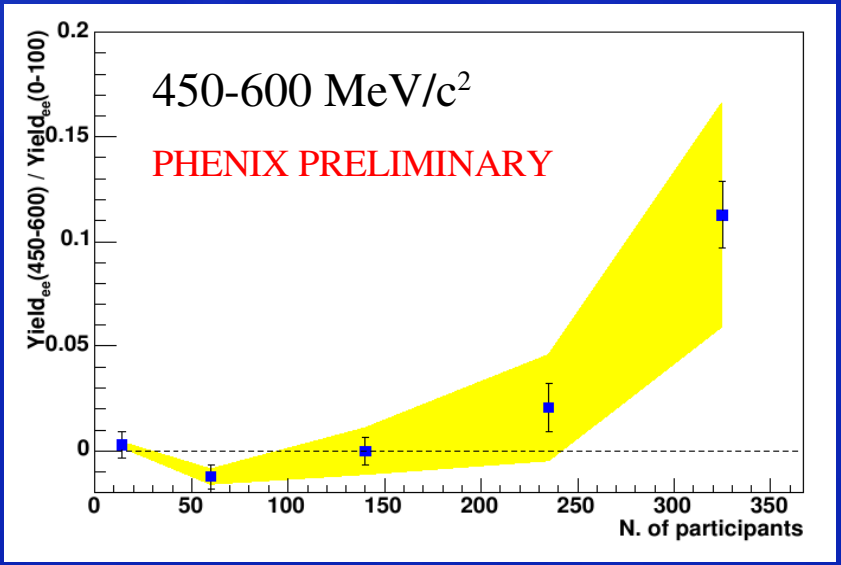
A. Toia (Hot Quarks 2006)

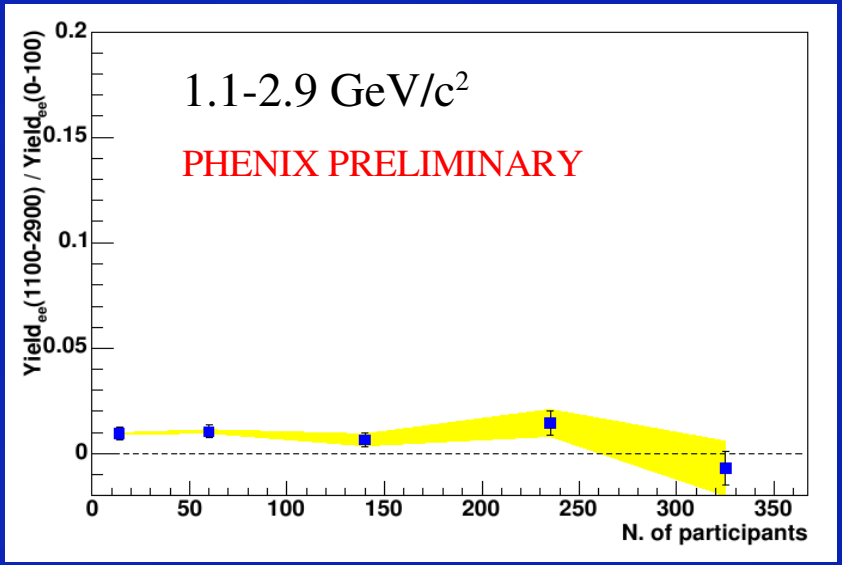
Mass ratios

Ratio of different mass intervals to π^0 yield (0-100 MeV)







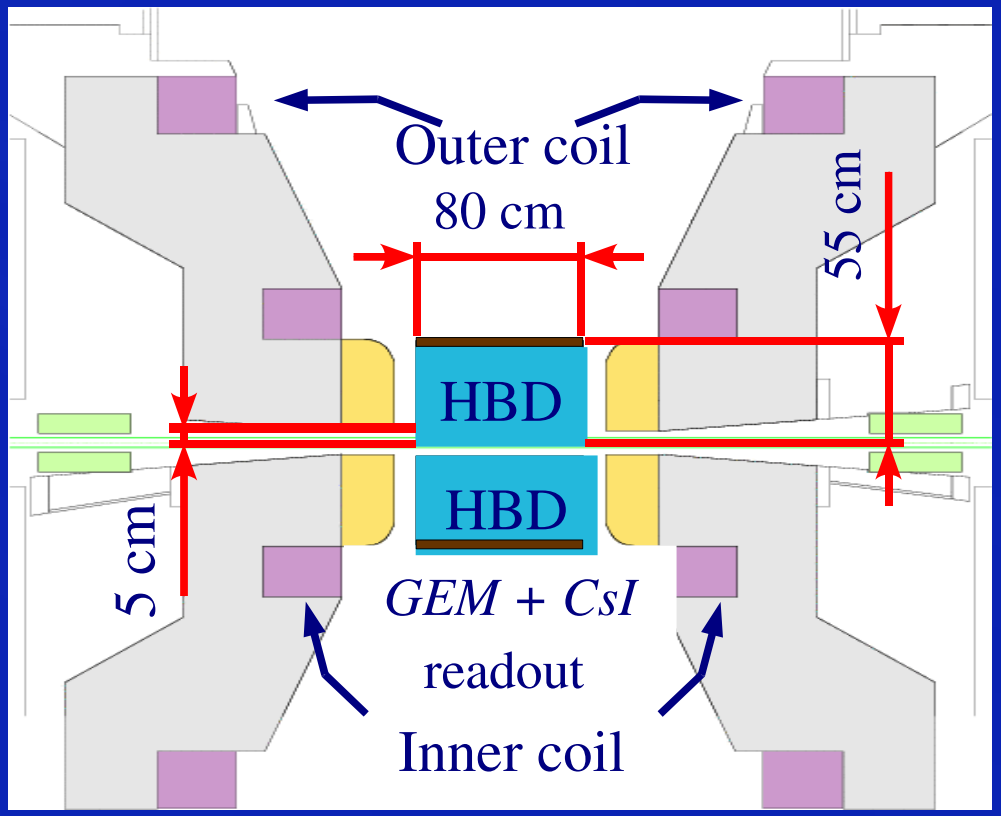


A. Toia (Hot Quarks 2006)

Future: Hadron Blind Detector

- HBD goal: improvement of the PHENIX capability to measure low-mass dielectron pairs.

- HBD strategy:
  - ✔ Zero field to keep opening angle of background pairs
  - ✔ Identification of low mass electrons
  - ✔ Cut on pair opening angle + veto area
  - ✔ S/B is improved by factor ~ 100

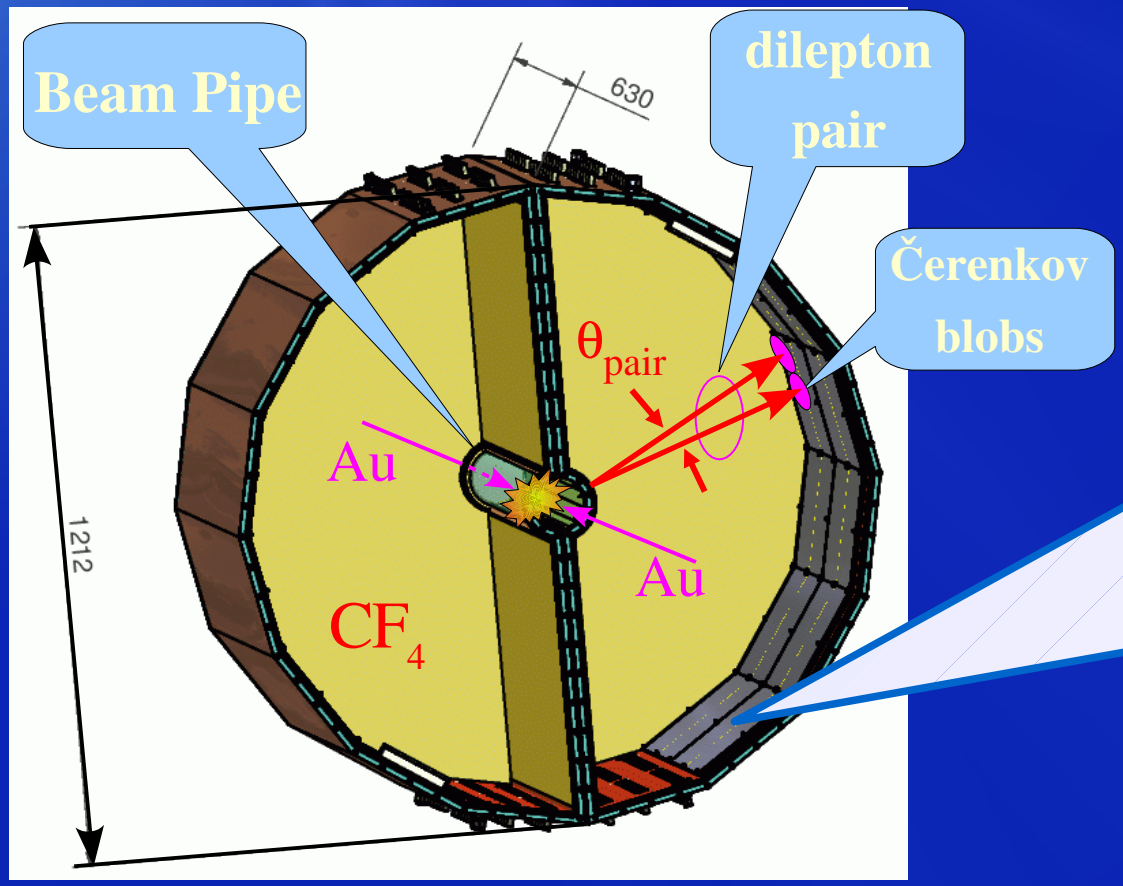


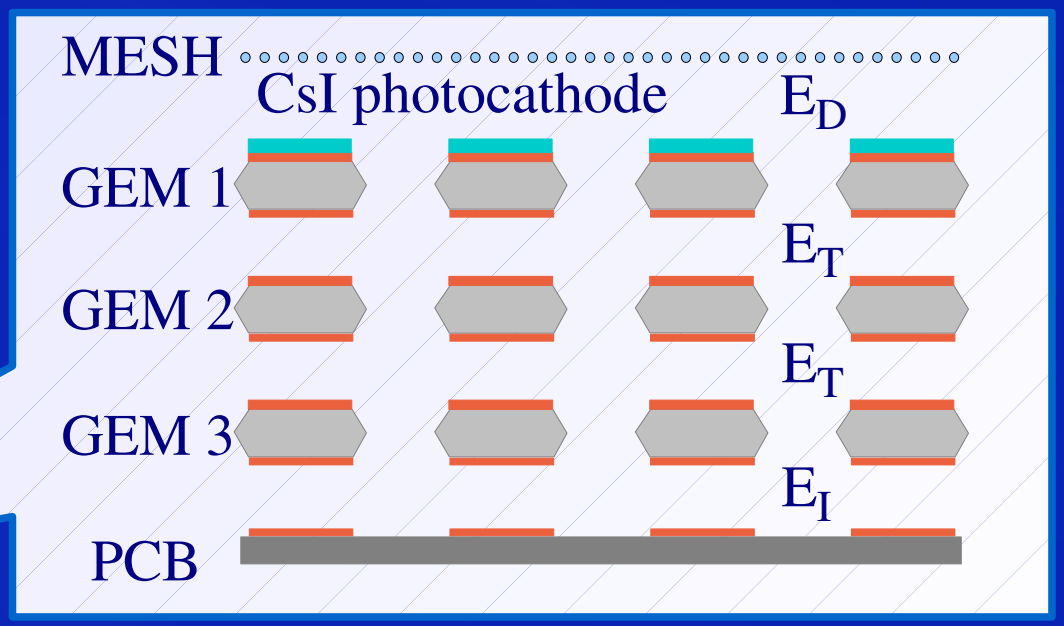
A. Kozlov *et al.*, NIM A 523 (2004)

Z. Fraenkel *et al.*, NIM A 546 (2005)

HBD Concept

- HBD concept:
  - ✔ Windowless Čerenkov detector operated in pure CF_4. Broad bandwidth (from 6 to 11.5 eV) and large number of photoelectrons ($N_{pe} \approx 36$ in 50 cm radiator).
  - ✔ Detector element: triple Gas Electron Multiplier (GEM) + CsI photocathode





Z. Fraenkel *et al.*, NIM A 546 (2005)

Summary

- *PHENIX is capable to measure dielectron continuum and vector mesons*
- *First measurements of the low-mass dielectron in Au-Au collisions at* $\sqrt{s_{NN}} = 200$ *GeV*
  - ✔ *e+e- continuum*
  - ✔ ϕ *– meson*
- *Further improvement will be achieved with upgrade of the PHENIX detector*
- *The installation of Hadron Blind Detector is foreseen in 2006*

PHENIX

- University of São Paulo, São Paulo, Brazil
- Academia Sinica, Taipei 11529, China
- China Institute of Atomic Energy (CIAE), Beijing, P. R. China
- Peking University, Beijing, P. R. China
- Charles University, Faculty of Mathematics and Physics, Ke Karlovu 3, 12116 Prague, Czech Republic
- Czech Technical University, Faculty of Nuclear Sciences and Physical Engineering, Brehova 7, 11519 Prague, Czech Republic
- Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague, Czech Republic
- Laboratoire de Physique Corpusculaire (LPC), Universite de Clermont-Ferrand, 63 170 Aubiere, Clermont-Ferrand, France
- Dapnia, CEA Saclay, Bat. 703, F-91191 Gif-sur-Yvette, France
- IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406 Orsay, Fra
- Laboratoire Leprince-Ringuet, Ecole Polytechnique, CNRS-IN2P3, Rout Saclay, F-91128 Palaiseau, France
- SUBATECH, Ecòle des Mines at Nantes, F-44307 Nantes France
- University of Muenster, Muenster, Germany
- KFKI Research Institute for Particle and Nuclear Physics at the Hungari Academy of Sciences (MTA KFKI RMKI), Budapest, Hungary
- Debrecen University, Debrecen, Hungary
- Eövös Loránd University (ELTE), Budapest, Hungary
- Banaras Hindu University, Banaras, India
- Bhabha Atomic Research Centre (BARC), Bombay, India
- Weizmann Institute, Rehovot, 76100, Israel
- Center for Nuclear Study (CNS-Tokyo), University of Tokyo, Tanashi, Tokyo 188, Japan
- Hiroshima University, Higashi-Hiroshima 739, Japan
- KEK - High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
- Kyoto University, Kyoto, Japan
- Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki, Japan
- RIKEN, The Institute of Physical and Chemical Research, Wako, Saitama 351-0198, Japan
- RIKEN – BNL Research Center, Japan, located at BNL
- Physics Department, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima, Tokyo 171-8501, Japan
- Tokyo Institute of Technology, Oh-okayama, Meguro, Tokyo 152-8551, Japan
- University of Tsukuba, 1-1-1 Tennodai, Tsukuba-shi Ibaraki-ken 305-8577, Japan
- Waseda University, Tokyo, Japan
- Cyclotron Application Laboratory, KAERI, Seoul, South Korea
- Kangnung National University, Kangnung 210-702, South Korea
- Korea University, Seoul, 136-701, Korea
- Myong Ji University, Yongin City 449-728, Korea
- System Electronics Laboratory, Seoul National University, Seoul, South Korea
- Yonsei University, Seoul 120-749, Korea
- IHEP (Protvino), State Research Center of Russian Federation "Institute for High Energy Physics", Protvino 142281, Russia
- Joint Institute for Nuclear Research (JINR-Dubna), Dubna, Russia
- Kurchatov Institute, Moscow, Russia
- PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
- Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119992, Russia
- Saint-Petersburg State Polytechnical Univiversity, Politechnicheskayastr, 29, St. Petersburg, 195251, Russia

13 Countries; 62 Institutions; 550 Participants*

- Lund University, Lund, Sweden
- Abilene Christian University, Abilene, Texas, USA
- Brookhaven National Laboratory (BNL), Upton, NY 11973, USA
- University of California - Riverside (UCR), Riverside, CA 92521, USA
- University of Colorado, Boulder, CO, USA
- Columbia University, Nevis Laboratories, Irvington, NY 10533, USA
- Florida Institute of Technology, Melbourne, FL 32901, USA
- Florida State University (FSU), Tallahassee, FL 32306, USA
- Georgia State University (GSU), Atlanta, GA, 30303, USA
- University of Illinois Urbana-Champaign, Urbana-Champaign, IL, USA
- Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
- Los Alamos National Laboratory (LANL), Los Alamos, NM 87545, USA
- Lawrence Livermore National Laboratory (LLNL), Livermore, CA 94550, USA
- University of New Mexico, Albuquerque, New Mexico, USA
- New Mexico State University, Las Cruces, New Mexico, USA
- Department of Chemistry, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
- Department of Physics and Astronomy, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
- Oak Ridge National Laboratory (ORNL), Oak Ridge, TN 37831, USA
- University of Tennessee (UT), Knoxville, TN 37996, USA
- Vanderbilt University, Nashville, TN 37235, USA

***as of March 2005**