Dielectron Production in Au+Au Collisions from STAR

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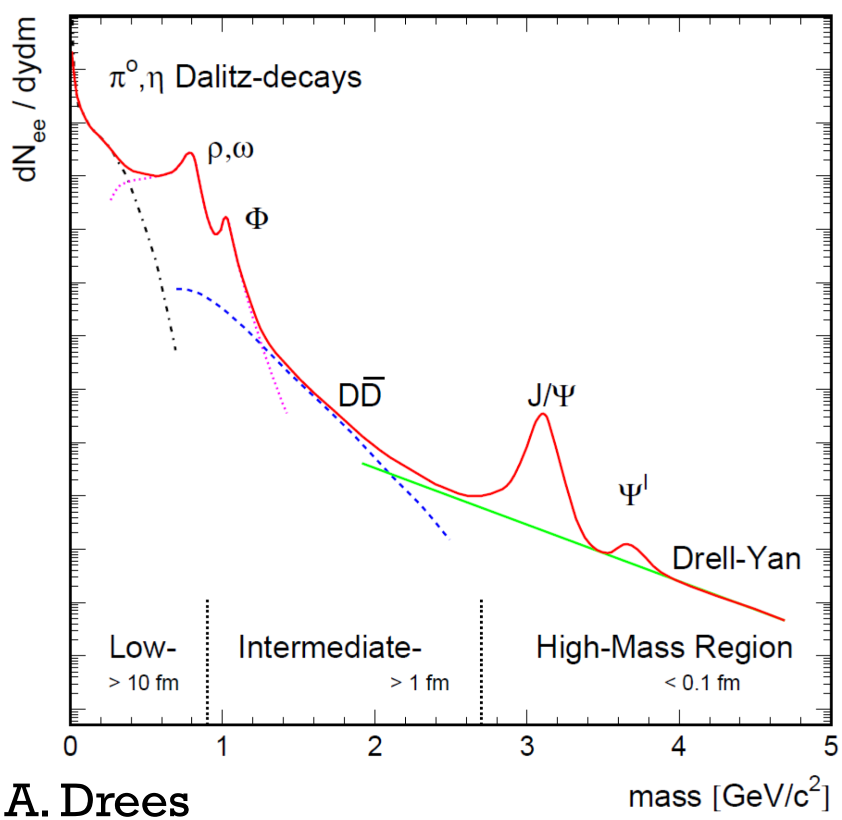
Outline

- Motivation
- STAR
- Analysis Techniques
- Data + Observations
- Summary & Outlook

Dielectrons



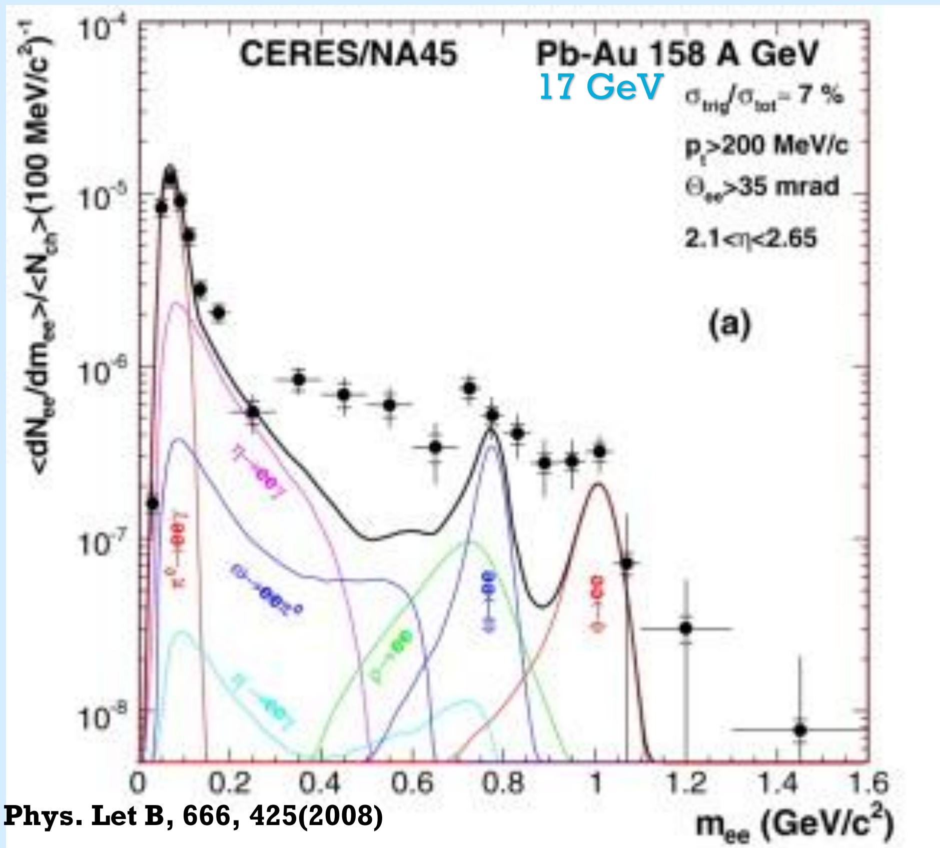
A. Drees

- Excellent Probe
  - Minimal final state interactions
  - Generated at all stages of the collision

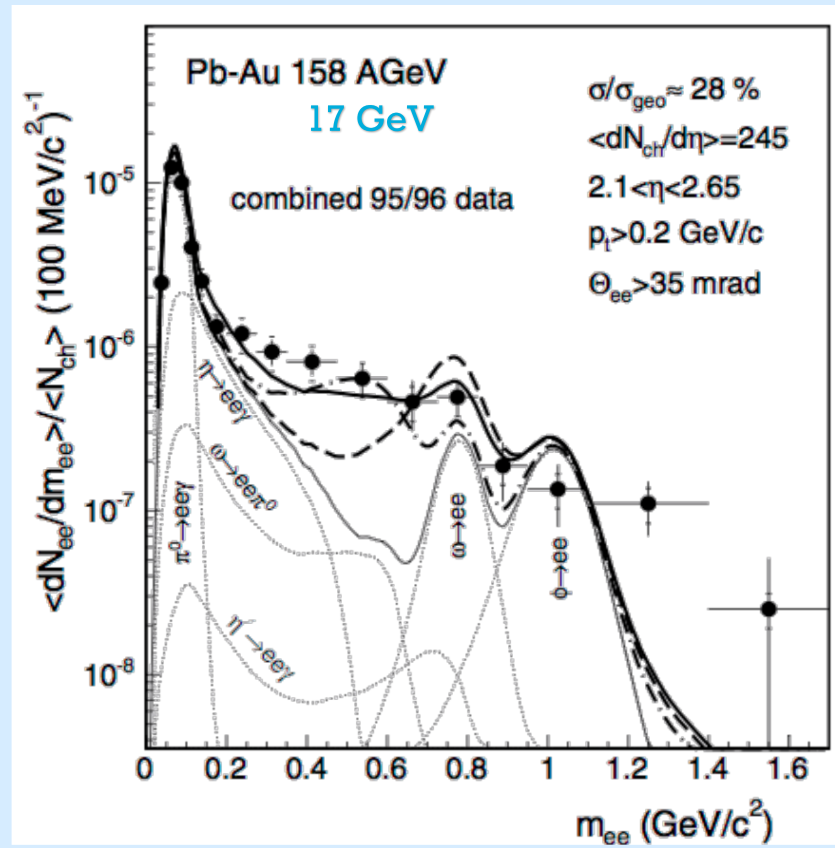
- Chronological Phases [early to latest]
  - High Mass Region [HMR]
    - Drell-Yan
    - J/ψ + Υ suppression
  - Intermediate Mass Region [IMR]
    - Heavy flavor modification
    - QGP thermal radiation
  - Low Mass Region [LMR]
    - Vector meson modification
    - Possible link to chiral symmetry restoration

Modification of ρ-meson

- CERES Measurements
  - Vacuum ρ not sufficient
- Possible explanations
  - Vacuum ρ [dash]
  - Mass dropping [dot-dash]
  - Broadening of spectral function [solid]



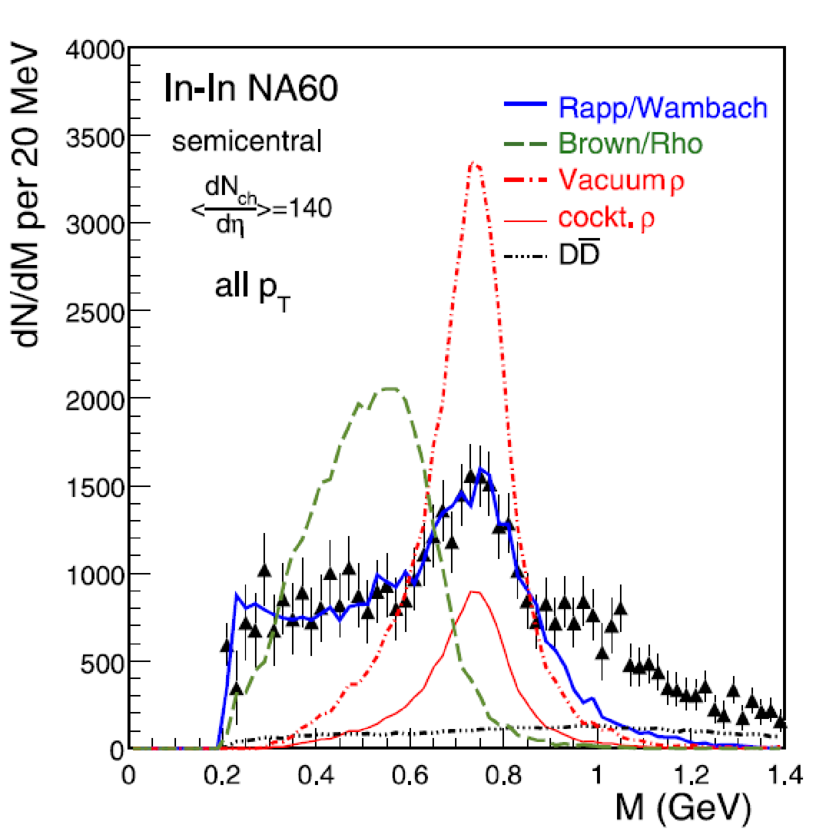
Phys. Let B, 666, 425(2008)

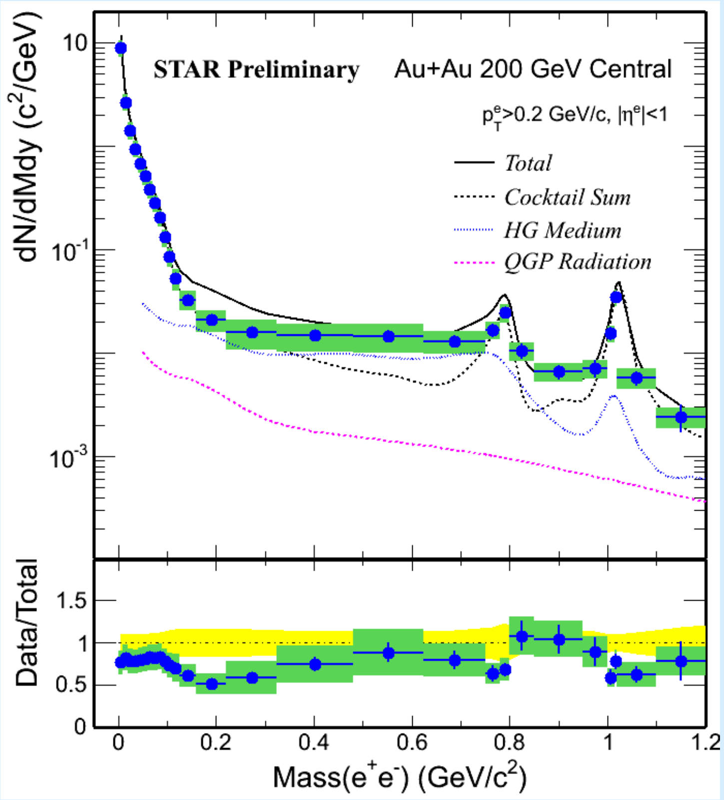


EPJ C41 (2005) 475

Modification of ρ-meson

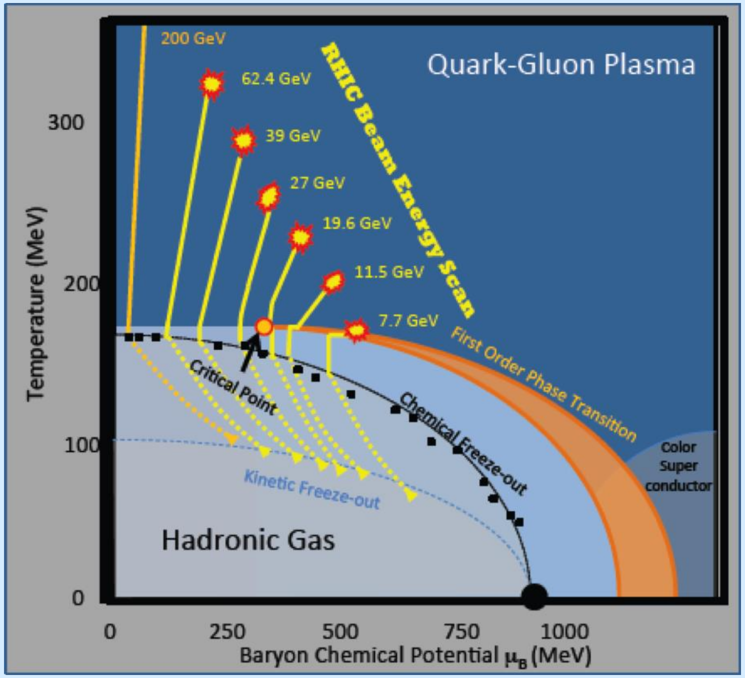
- NA 60
  - Vacuum ρ is inadequate [dash-dot]
  - Excludes mass-dropping [dash]
  - Supports broadening of ρ spectral function [solid]
- RHIC AuAu 200
  - Vacuum ρ inadequate
  - Supports ρ broadening





Beam Energy Scan

- RHIC Beam Energy Scan Program [2010-2011]
  - Au+Au @19.6, 27, 39, & 62.4 GeV
  - Same colliding species & detector
  - Opportunity to extensively study ρ spectral function
    - Connect between SPS & RHIC Au+Au 200 GeV
    - Dependence on $\sqrt{s}$?
    - Compare to models



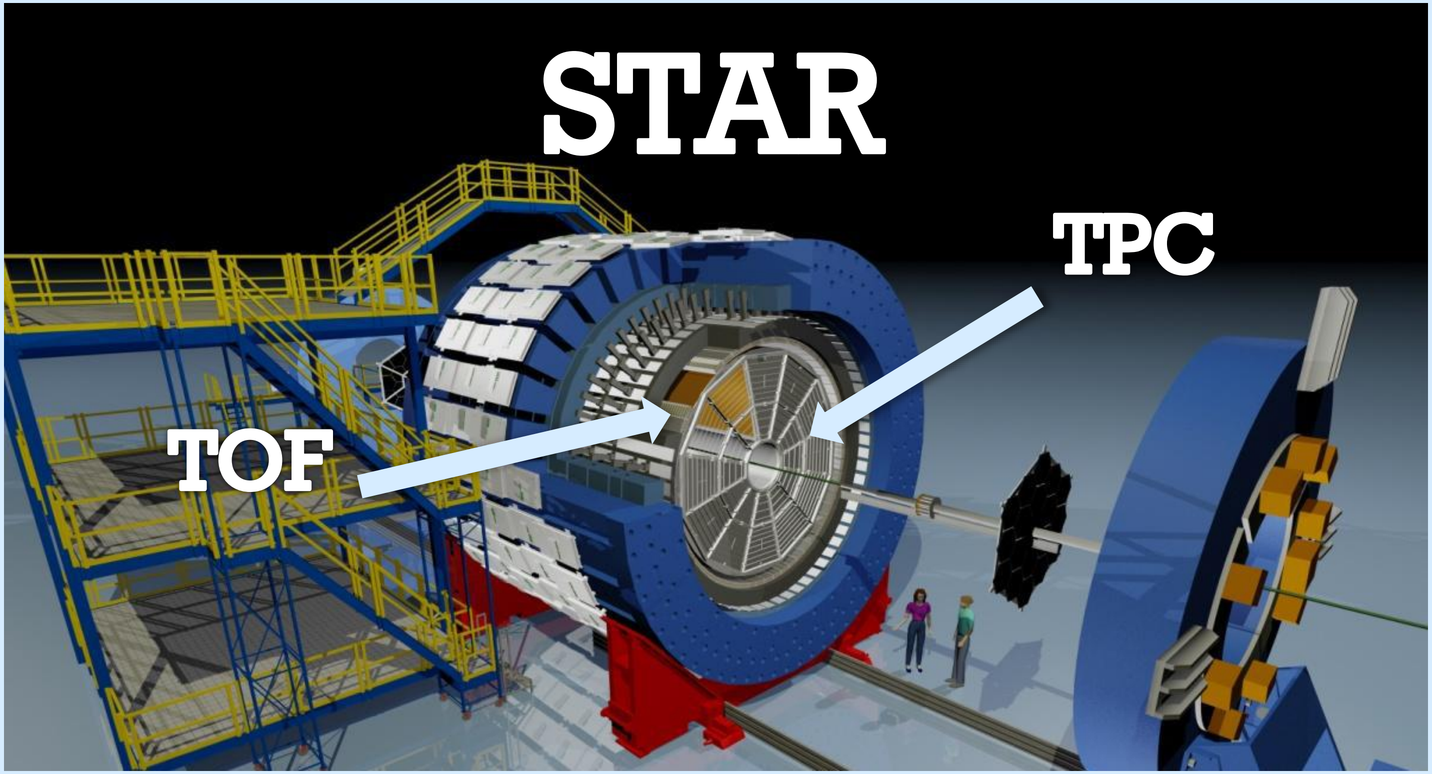
STAR Detector

Time Projection Chamber [TPC]

- Tracking
- Ionization energy loss
- Full azimuthal coverage

Time of Flight [TOF]

- Precise timing (<90ps)
- Improves TPC's purity
- Full azimuthal coverage

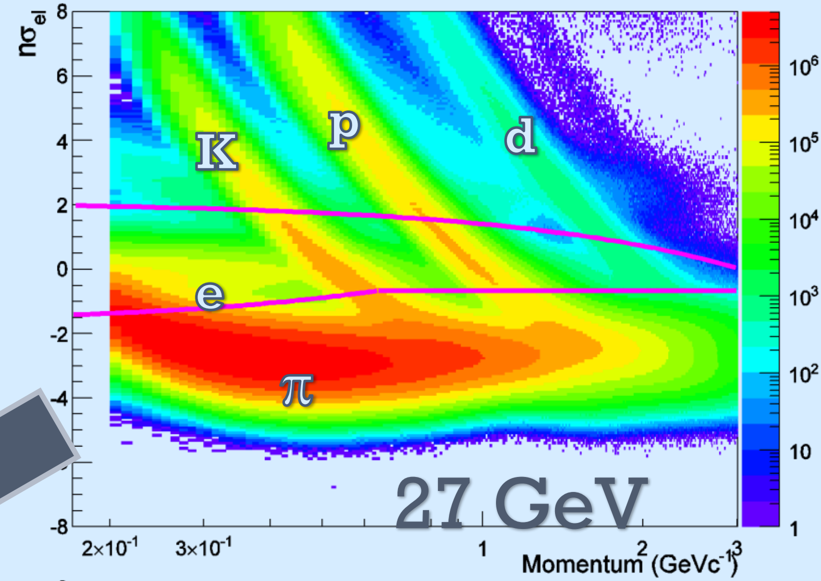


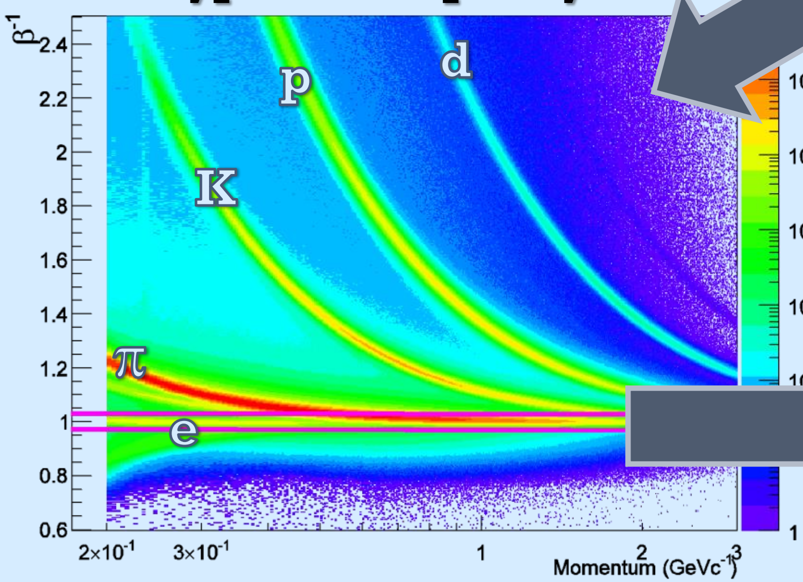
Electron Identification

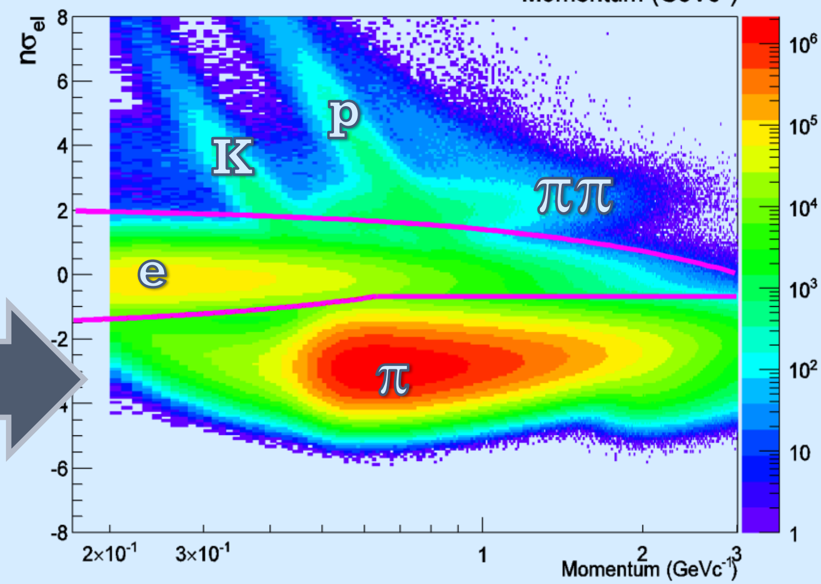
- **Combine the TPC+TOF**
  - **TPC provides:**

$$n\sigma_{el} = \left(R_{dE/dx}\right)^{-1} \ln \frac{\langle dE/dx \rangle^{\exp}}{\langle dE/dx \rangle_{el}^{th}}$$

  - **Use TOF to remove slow hadrons**
    - **Improves purity**
    - **Typical eID purity ~95%**

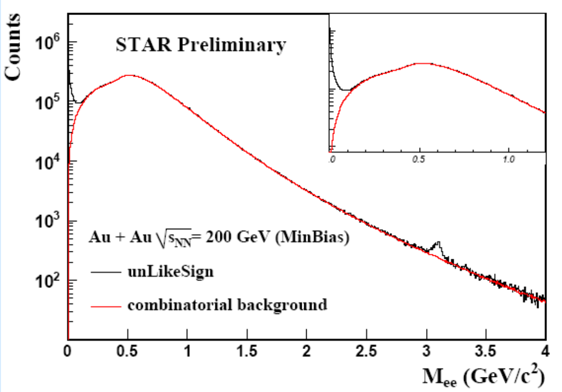


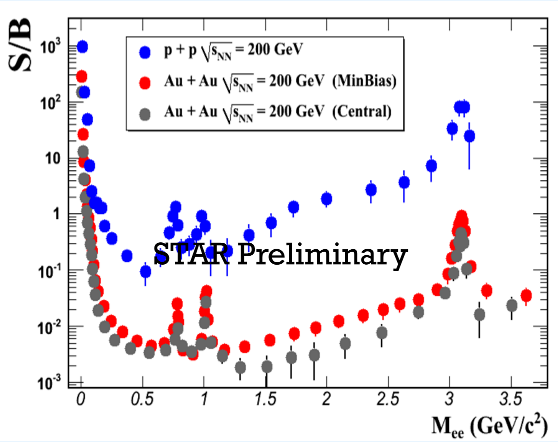


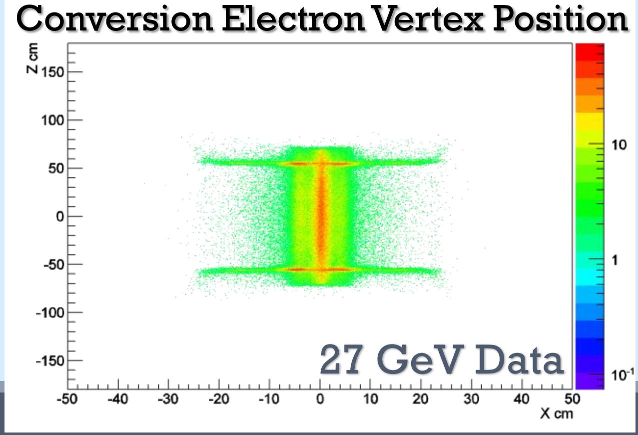


Background Removal

- Types of background: 3 C's
  - Combinatorial, Correlated, & Conversion
- Techniques
  - Same event like-sign pairs [LS]
    - Combine all like-sign pairs & average
    - Removes combinatorial & correlated
    - Like-sign/unlike-sign acceptance difference
      - Corrected with mixed events
  - Mixed event pairs [ME]
    - Pair e^+/e^- from different events w/ similar properties
    - Removes combinatorial
  - Pair cuts [PC]
    - Removes conversions

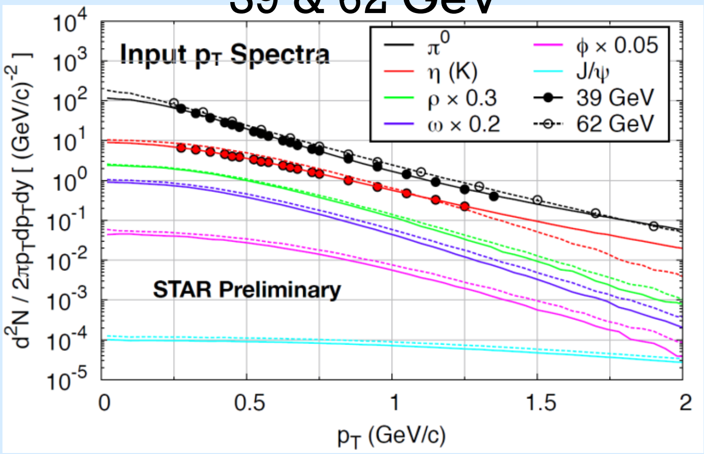




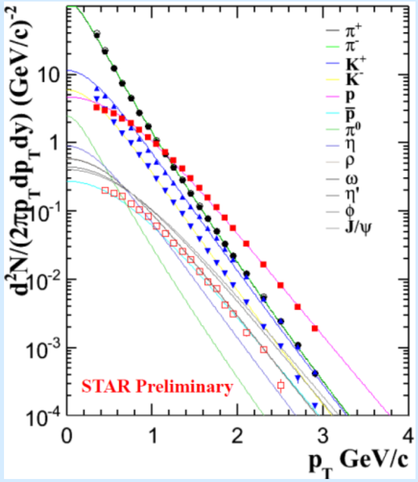


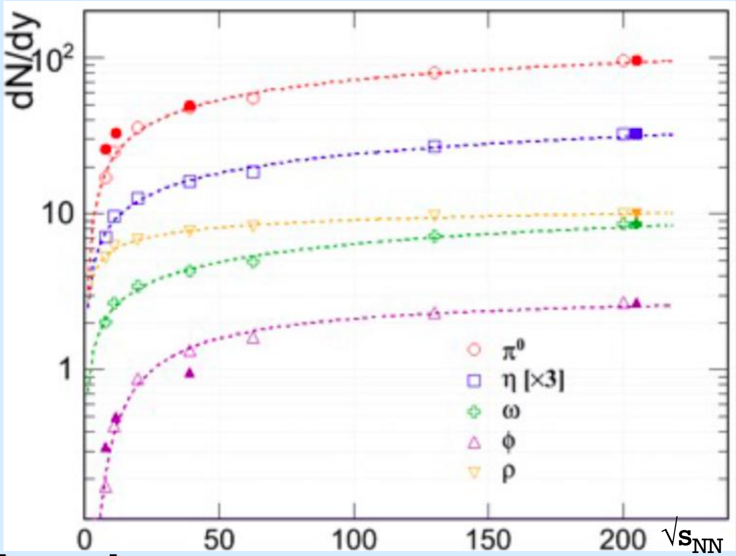
Cocktail Determination

39 & 62 GeV



19.6 GeV





- Simulation Inputs
  - Flat ϕ & η
  - p_T spectra
    - 19.6 GeV
      - Tsallis fits to NA49
    - 39 & 62 GeV
      - π^0 from $\pi^{-/+}$ & η from K spectra @ STAR
      - Everything else: AMPT
  - Decay
    - Kroll-Wada Formula (VM $\rightarrow \gamma^* \rightarrow \ell^+\ell^-$)
  - Yields
    - 19.6 GeV
      - Meson/π^0 ratio from NA49 & π from STAR
    - 39 & 62 GeV
      - Extrapolated from STAR 200GeV using AMPT's $\sqrt{s}$-dependence
    - Correlated charm decays
      - Simulated with PYTHIA and scaled by N_{binary}

Beam Energy Scan Inv. Mass

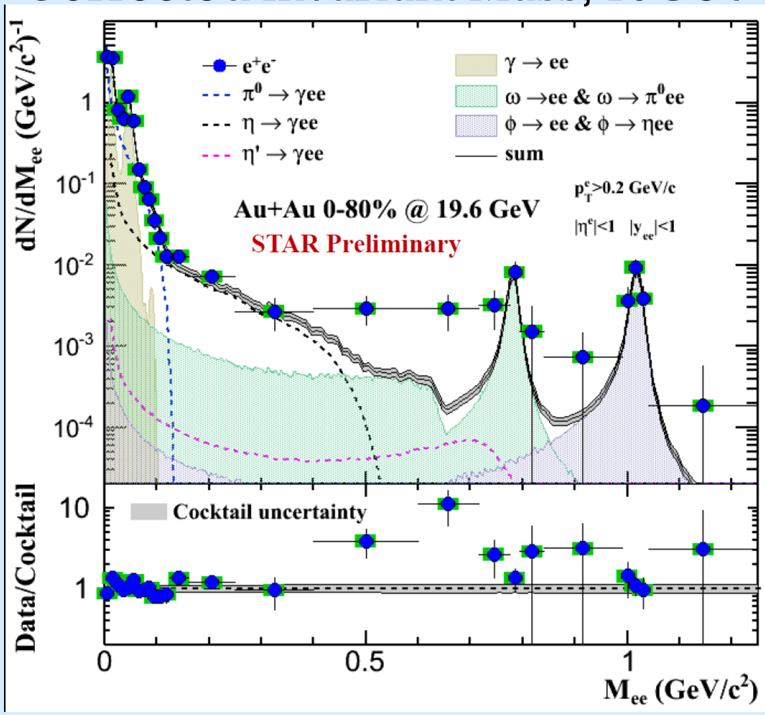
$\sqrt{s_{NN}}$ [GeV]	19.6	27	39	62	200(Y10)
Min. Bias Events	28M	70M	99M	55M	240M

STAR Acceptance cuts:

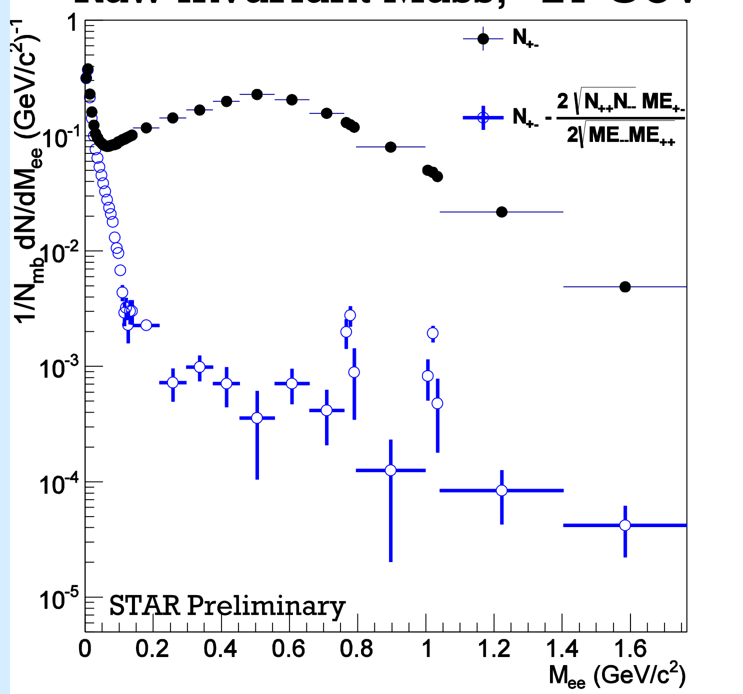
$p_{Te} > 0.2$ GeV/c, $|\eta_e| < 1.$, and $|Y_{ee}| < 1$

[Y_{ee} not used in 27GeV]

Corrected Invariant Mass, 19GeV



Raw Invariant Mass, 27 GeV



Beam Energy Scan Inv. Mass

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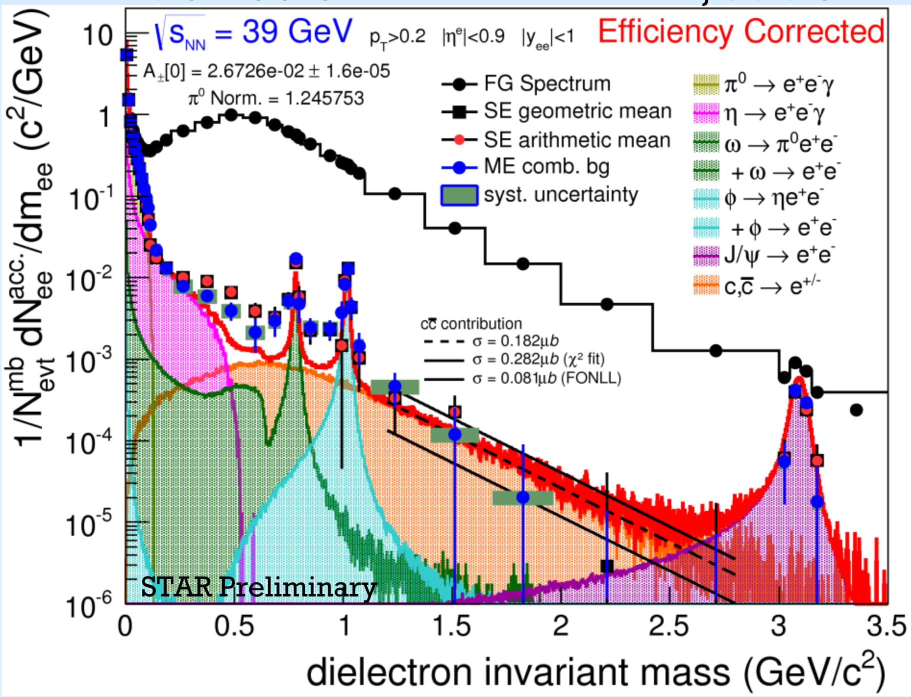
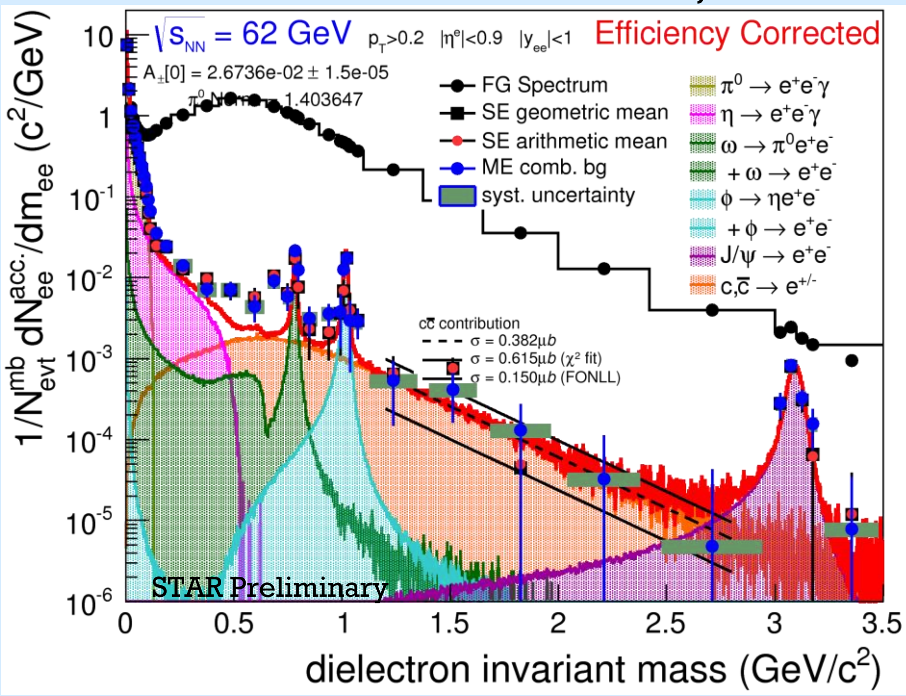
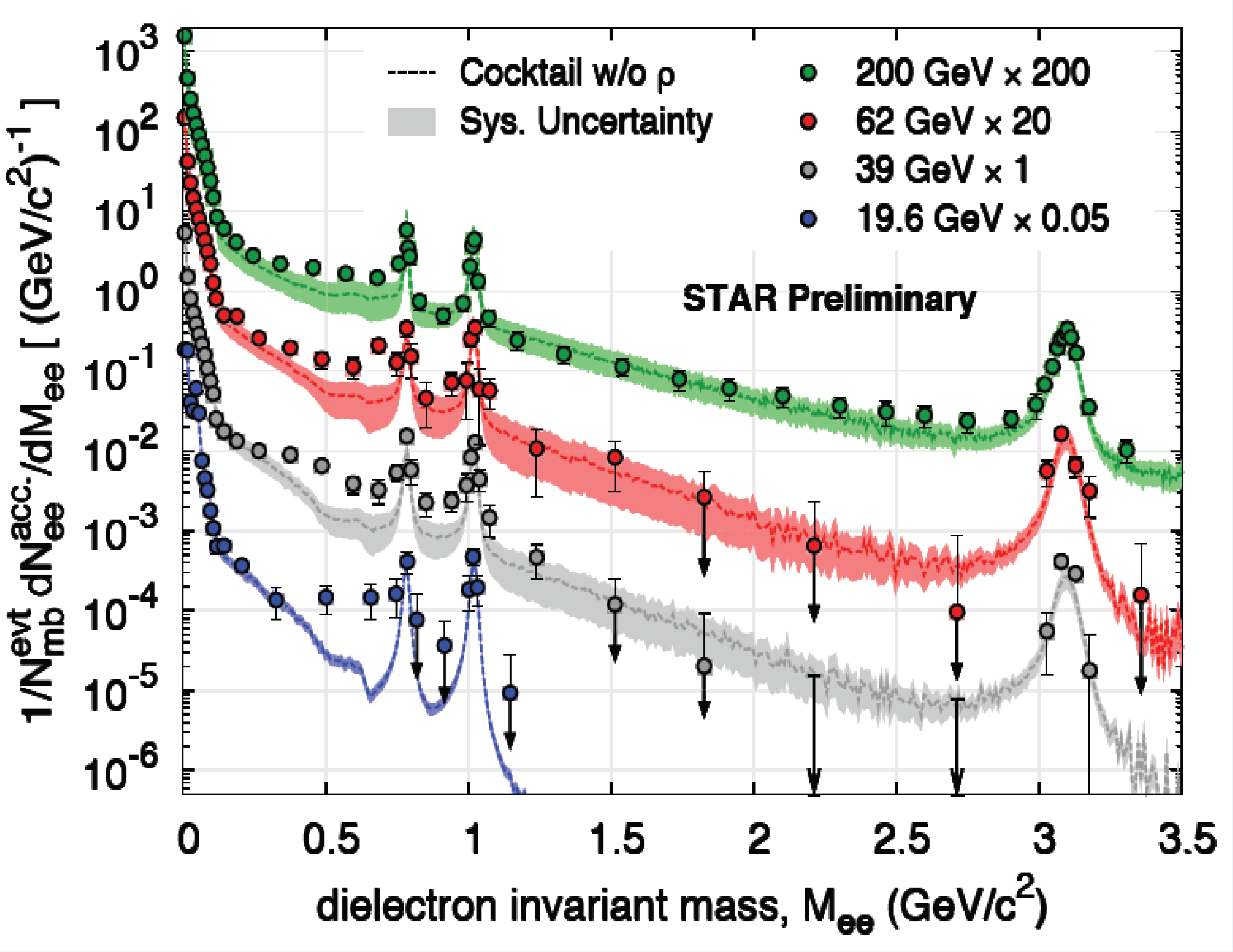
Corrected Invariant Mass, 39GeV



Corrected Invariant Mass, 62GeV

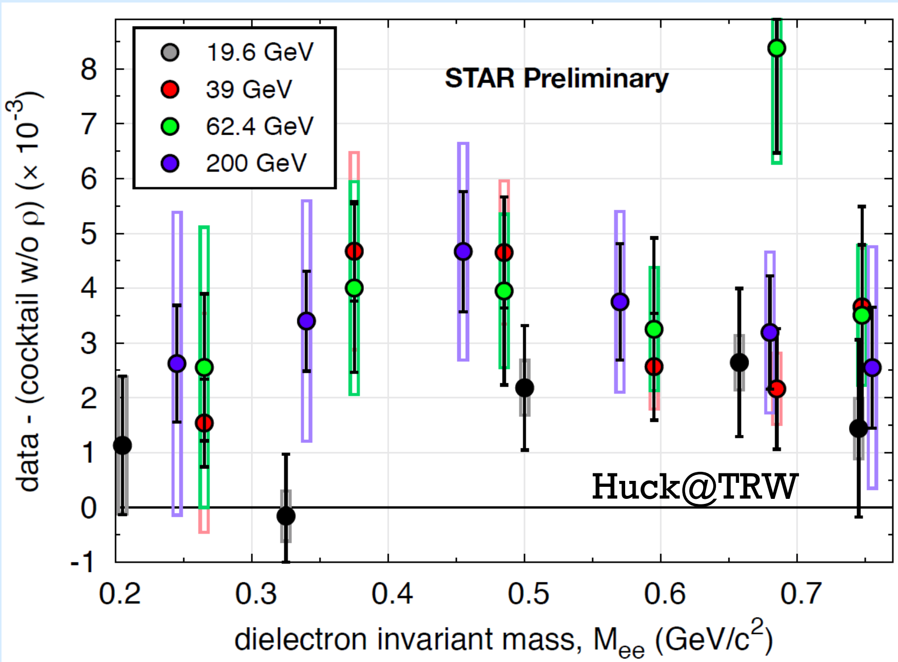


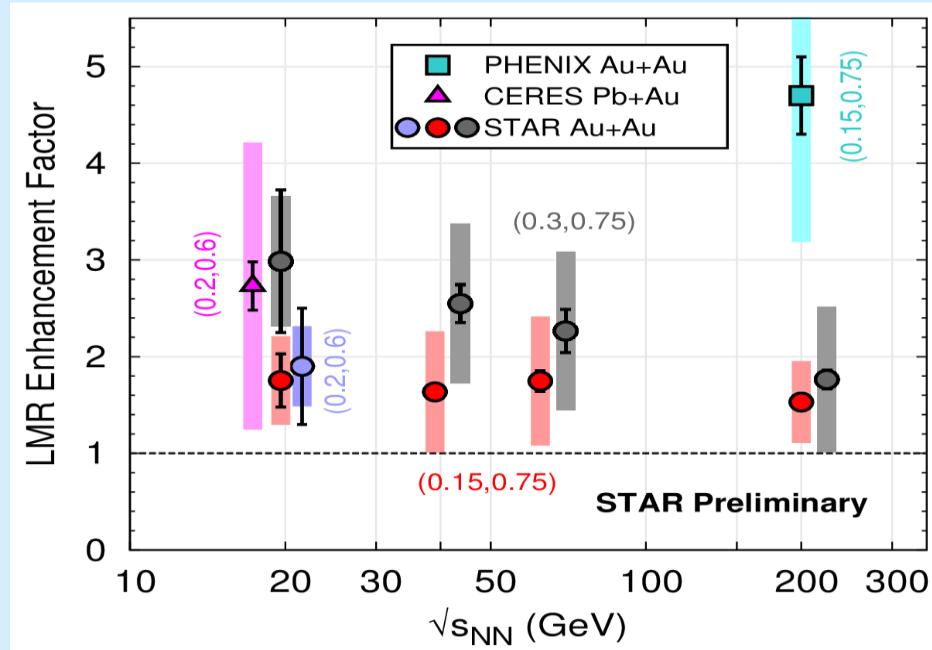
Observations



- Cocktail does not include ρ-meson
- LMR excess at all $\sqrt{s_{NN}}$

Observations II

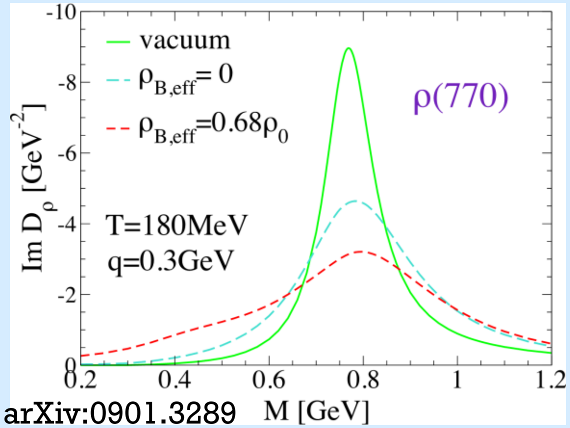




- CERES + PHENIX have different acceptances than STAR

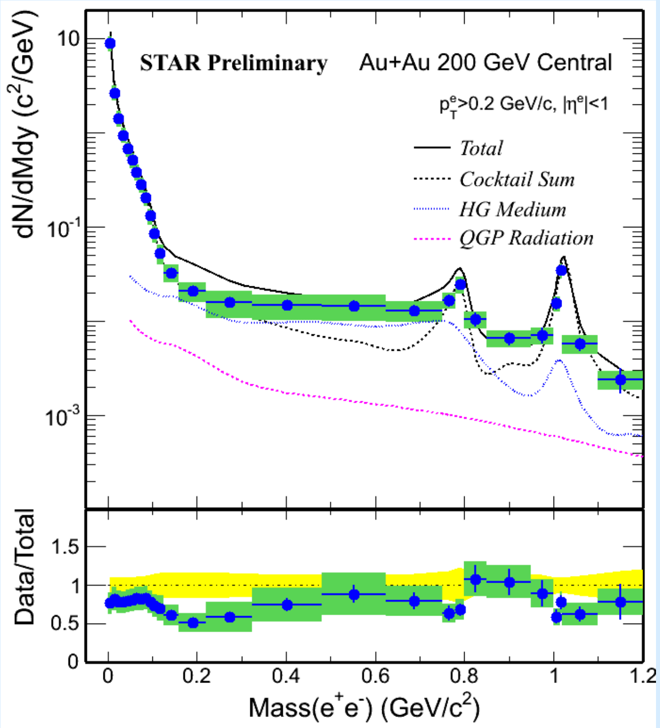
- ρ-meson modifications at all $\sqrt{s_{NN}}$
- The absolute excess yield(data – cocktail) shows no significant $\sqrt{s_{NN}}$ dependence given uncertainties
- The Enhancement Factor is sensitive to the mass range selected
  - The charm component in the cocktail baseline increases with $\sqrt{s_{NN}}$

Theory: Rapp, Wambach, van Hees[RWvH]



arXiv:0901.3289

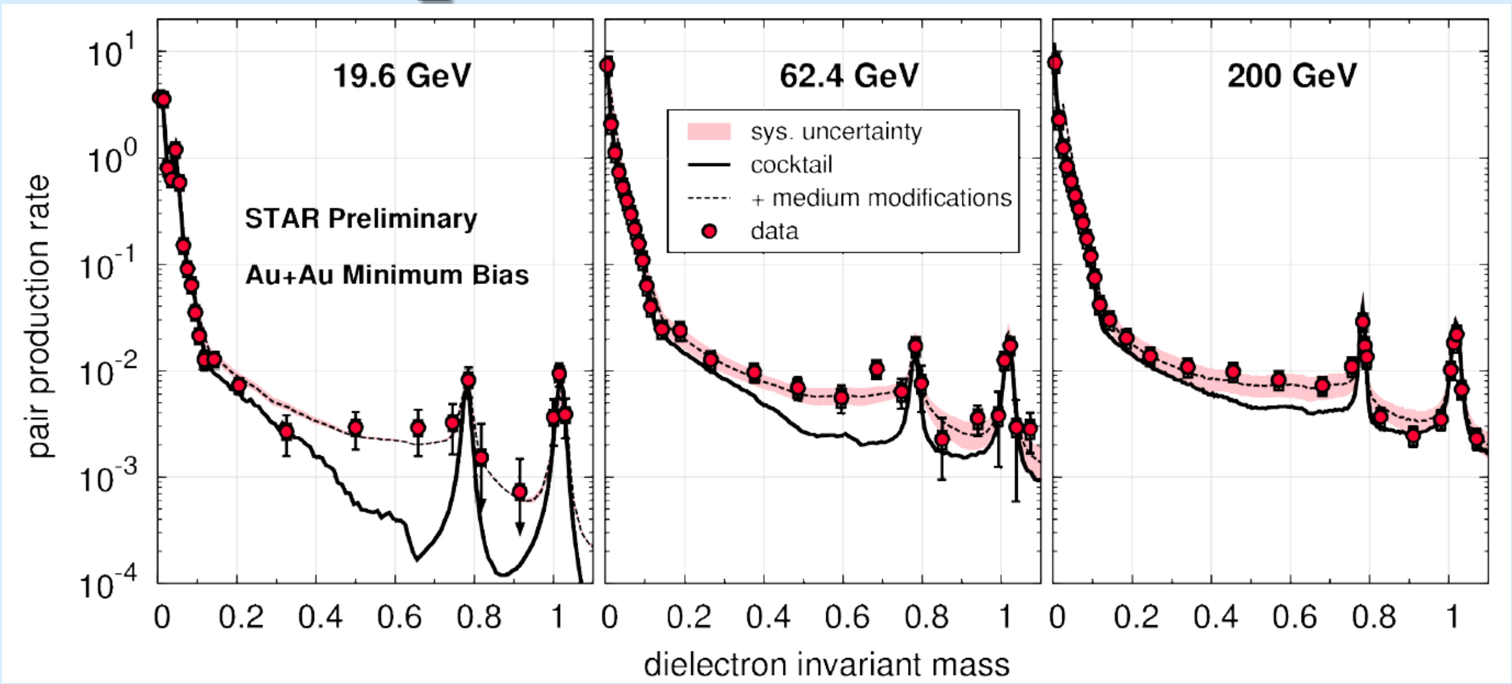
- Hadronic phase: ρ-meson "melts" when extrapolated to phase transition boundary
  - Total baryon density dependent
- Top-down extrapolated QGP rate coincides with bottom-up extrapolated hadronic rates



- STAR's Run 10 AuAu Central 200GeV
- Model curves provided by Rapp
- Complete evolution (HG + QGP)
- Agrees within uncertainties

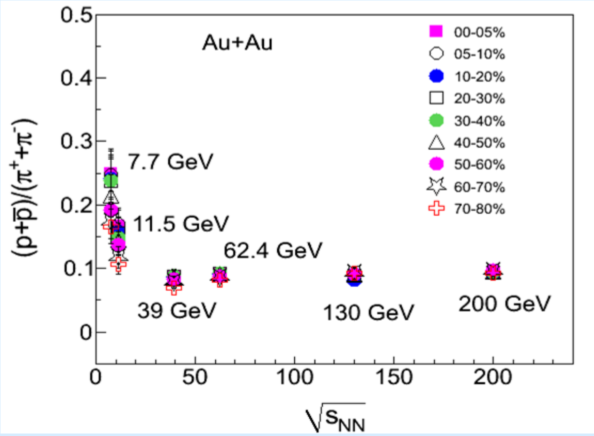
R.Rapp, PRC 63 (2001) 054907. Rapp & Wambach, EPJ A 6 (1999) 415. Calculations via Priv. Comm. w/ Rapp

BES Comparisons to RWvH

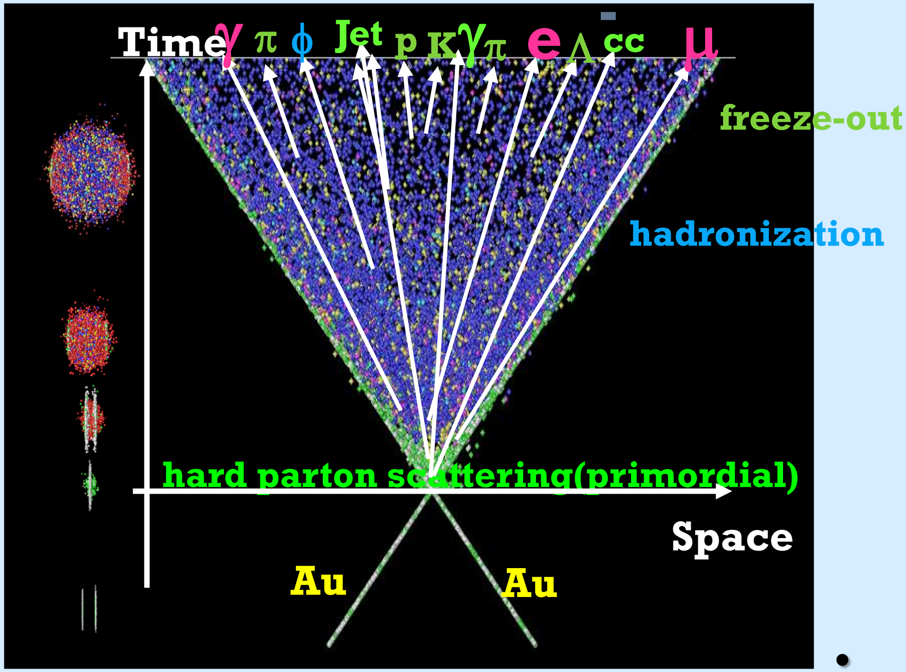


Rapp + Wambach, Adv. Nucl. Phys. 25, 1 (2000). Phys. Rev. 363, 85 (2002). Calculations via Priv. Comm. w/ Rapp

- Cocktail w/out ρ contributions [solid curve]
- Cocktail w/ medium modified ρ [dashed line]
- Data consistent with ρ-meson broadening
  - Model dependent on total baryon density
- Tests extensive function of the ρ–meson's spectral function



Study on Direct Virtual Photon



- Ideal probe to study the evolution of the medium by selecting different kinematics
- 1~4GeV/c
  - Study the properties of QGP
- High p_T(>6GeV/c):
  - Study the photon produced in the primordial step, distinguish initial- and final-state suppression

- Relation between real photon production and the associated ee pair production

$$\frac{d^2N_{ee}}{dm_{ee}\,dp_T} = \frac{2\alpha}{3\pi}\frac{1}{m_{ee}}L(m_{ee})S(m_{ee},p_T)\frac{dN_\gamma}{dp_T}$$

$$L(m_{ee}) = \sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)$$

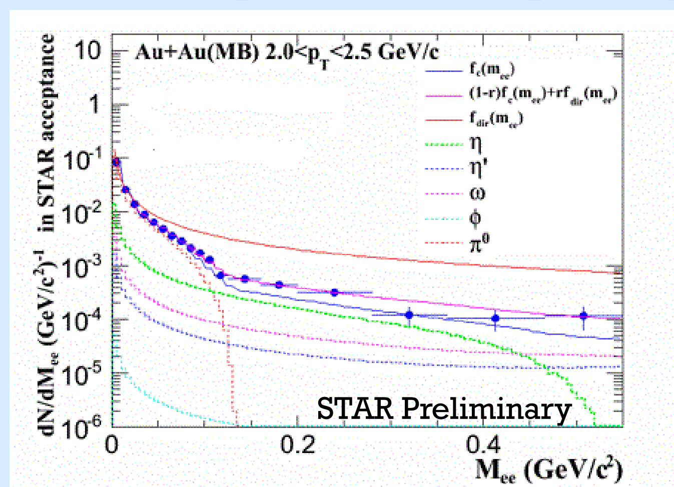
for $m_{ee} >> m_e$ && $p_T >> m_{ee}$

$S \sim 1$ $L \sim 1$

$$\frac{d^2N_{ee}}{dm_{ee}} \approx \frac{2\alpha}{3\pi}\frac{1}{m_{ee}}dN_\gamma$$

Normalize f_{dir}

- Two component fit to quantify the excess



$f = (1-r)f_c + rf_{dir}$

cocktail component

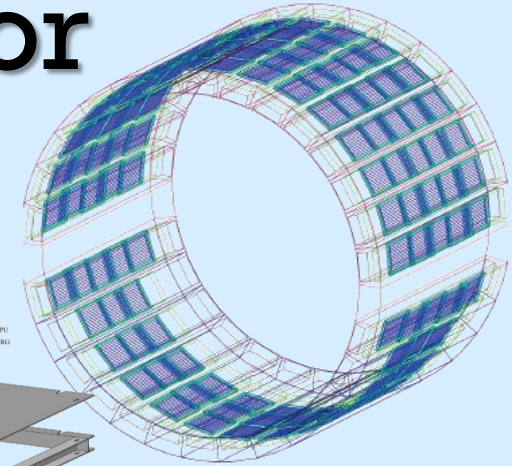
direct virtual photon component

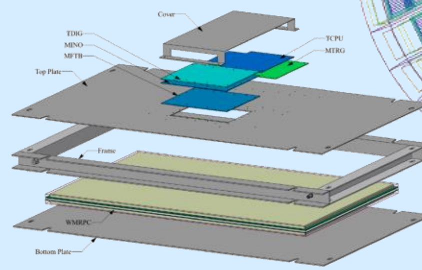
Beam Energy Scan

- AuAu 15 GeV [Feb. 2014]
  - Continue extensive study
  - Test baryon density dependence

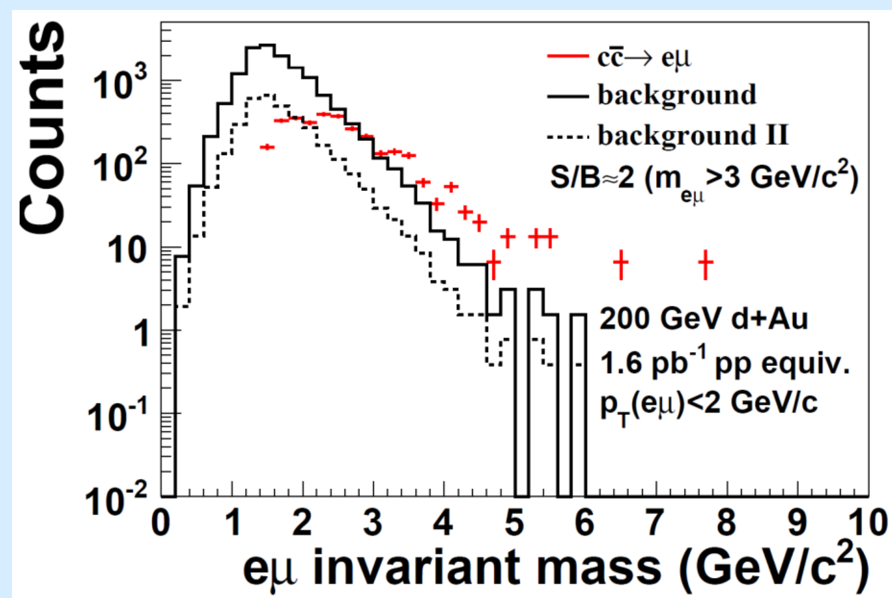
- Future: BES II [~2018+2019]
  - iTPC, Enhanced Statistics, Dimuons

Muon Telescope Detector





- Multi-gap Resistive Plate Chamber detector
  - Similar to STAR's TOF
  - Located outside the magnet
  - Fully installed for AuAu 200GeV next year
- Dimuon
  - Pros vs dielectrons: Less background, triggering possible, less Dalitz decay
  - Measure thermal radiation
    - Determine excess dimuon
    - Fit slope m_T-M slope to find T_{eff}
- Electron-muon
  - Better handle on charm contribution
    - To better understand background in IMR
    - Aides dielectron thermal radiation study



Summary

- Observed excess w.r.t. the hadronic cocktail and the excess is consistent with model calculations involving broadened-ρ spectra

- No strong energy dependence of the LMR excess from 19.6 – 200 GeV

Outlook

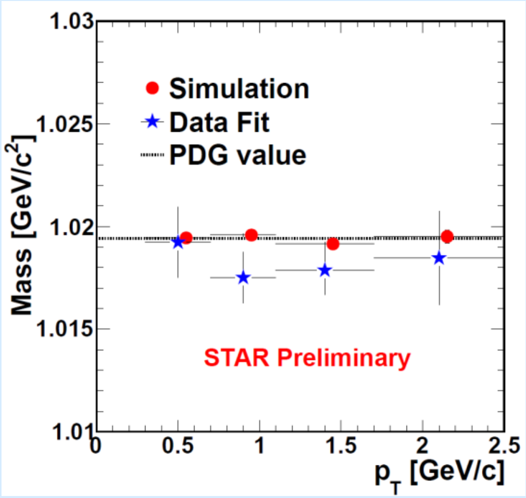
- Direct Virtual Photon
- Beam Energy Scans [I & II]
- Muon Telescope Detector

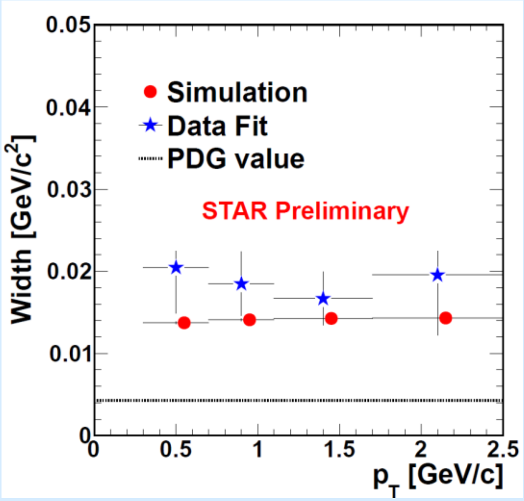
Thank you!

Extras

ω & ϕ Spectra in AuAu @ 200GeV

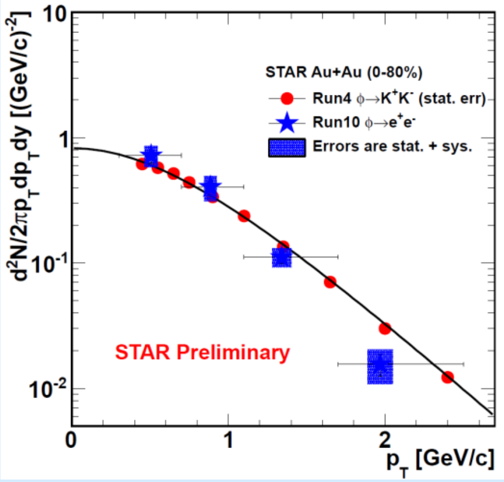
- ϕ consistent with no broadening/mass shift given uncertainties
  - Detector resolution limiting factor
  - ω being studied

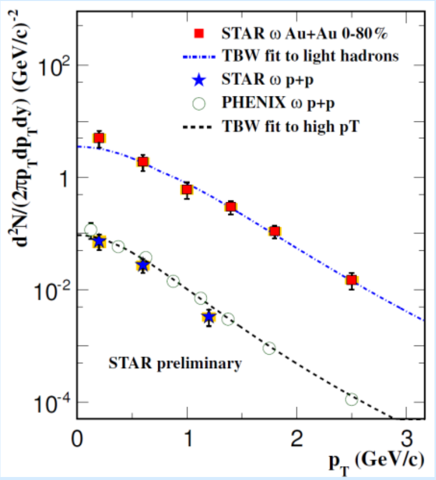




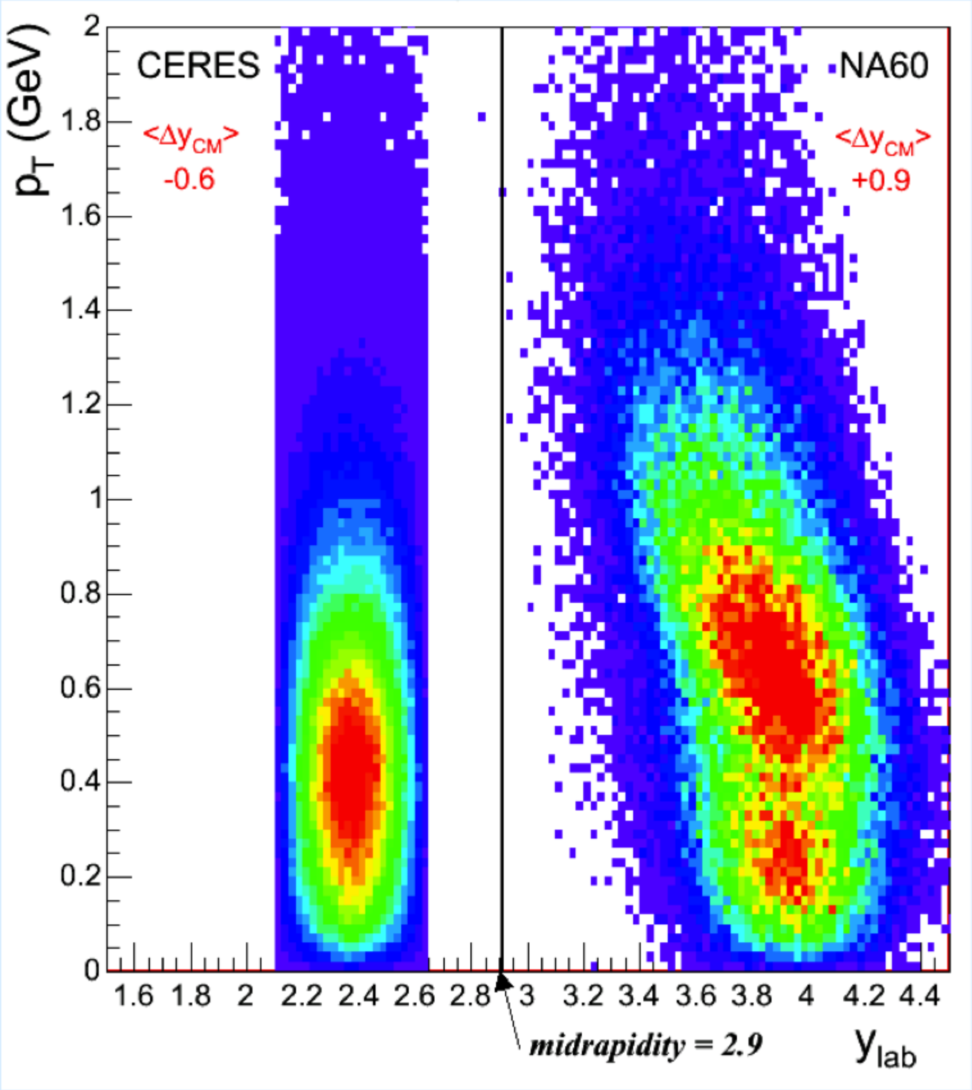
- ϕ decay yields are consistent between K^+K^- and e^+e^- channels

- ω p_T spectra matches that of PHENIX and light hadrons



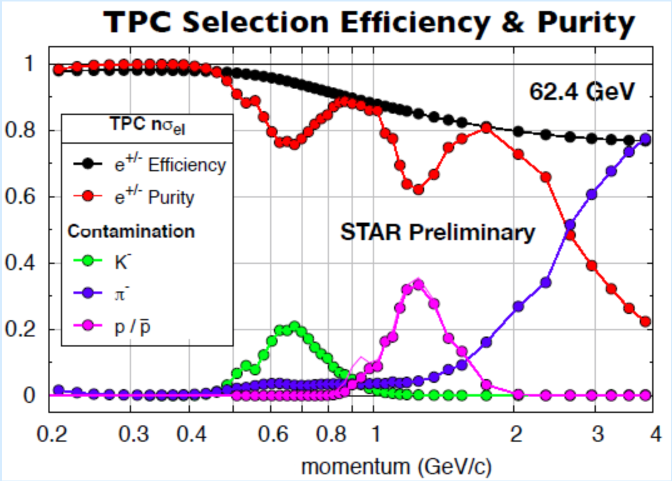


CERES + NA60 Acceptance



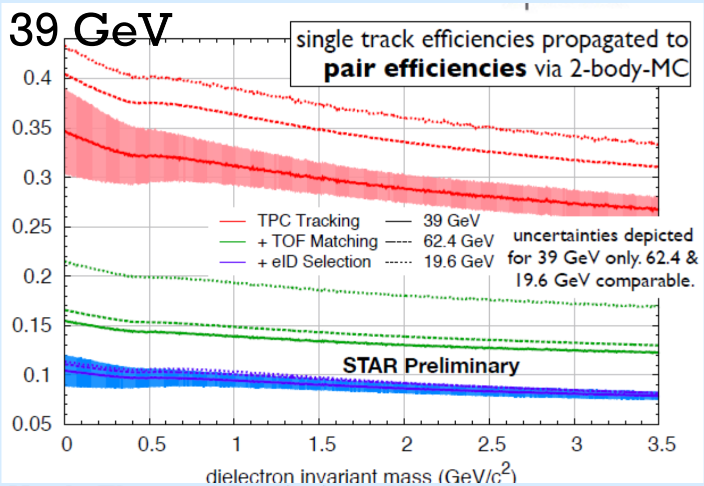
Efficiency Corrections

62 GeV



Huck, Thermal Radiations Workshop

39 GeV



Huck, Thermal Radiations Workshop

- Pair efficiencies based on single track eff.
  - Pair Methods
    - ToyMC: $\gamma^* \rightarrow e^+e^-$
    - Apply STAR acceptance
  - Single Track
    - Tracking [Embedding]
    - Matching tracks to TOF detector [Data]
    - Electron Identification [Data]

Pair acceptance correction