e^+e^- pairs BES Results in Au+Au Collisions at 19.6, 27, 39, and 62.4

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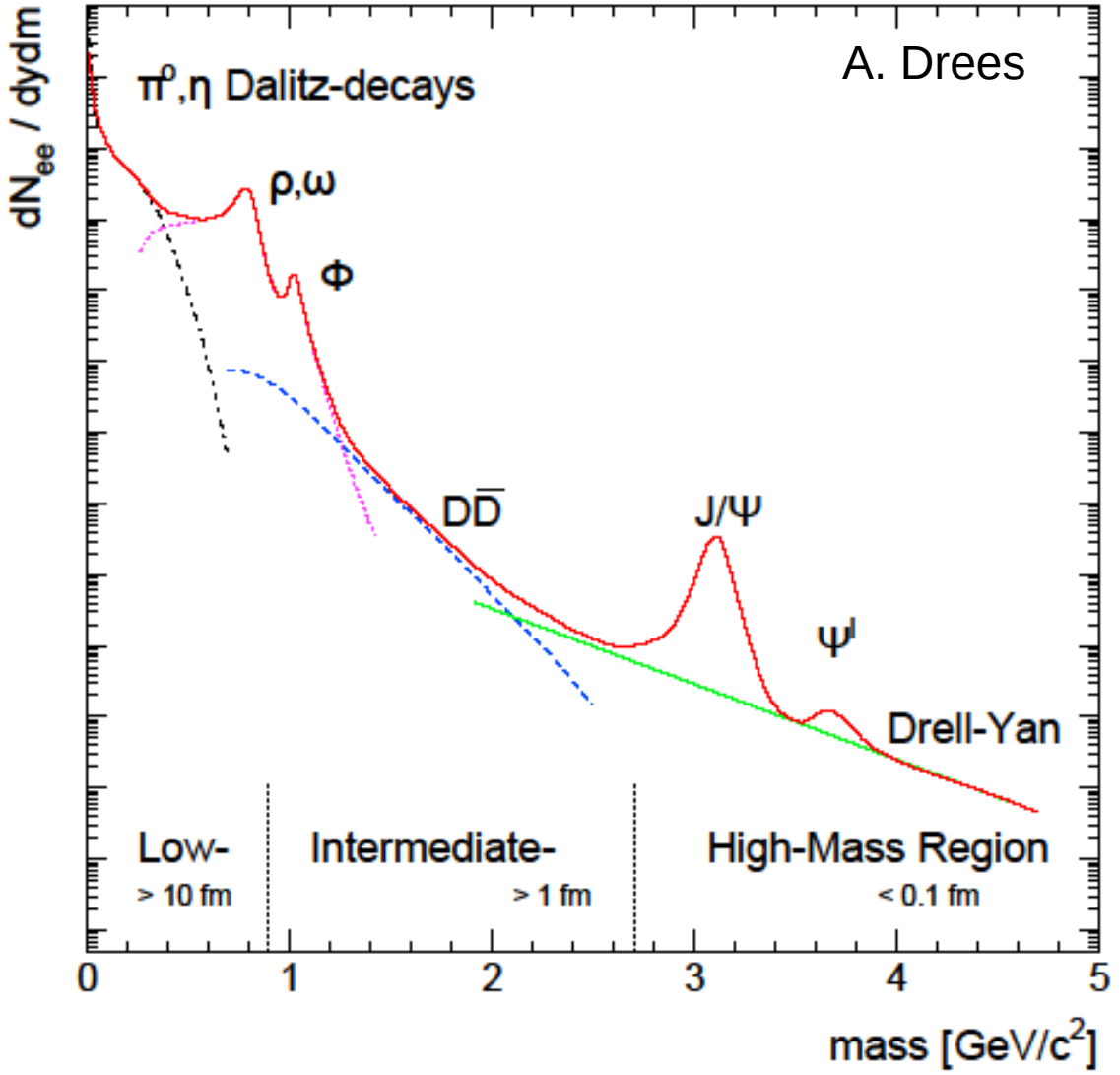
Thermal Photons and Dileptons in Heavy-Ion Collisions, BNL, Upton, NY

Outline

- Motivation
- Experiment
  - STAR
  - Particle Identification
  - Background
- Cocktail
- Model Comparisons
  - M_{ee}
  - p_{Tee}
- Summary

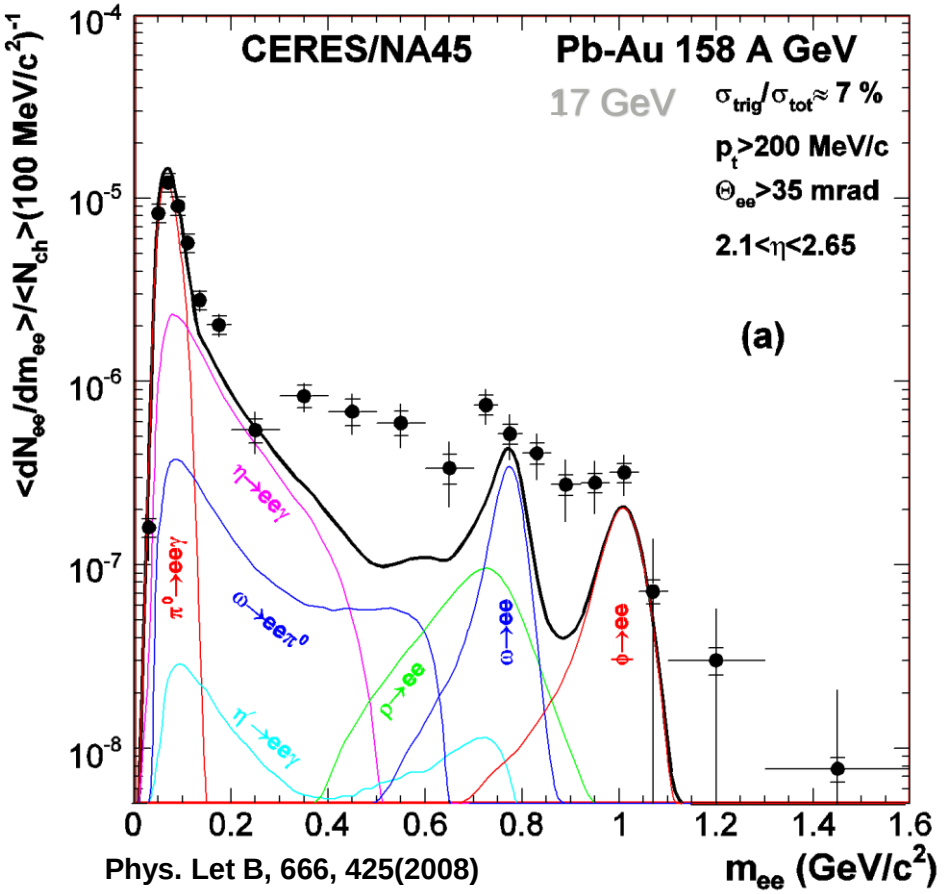
Motivation

- **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 Supression
  - Intermediate Mass Region [IMR]
    - Heavy flavor modification
    - QGP (thermal) radiation
  - Low Mass Region [LMR]
    - Vector meson modification
    - Possible link to chiral symmetry restoration

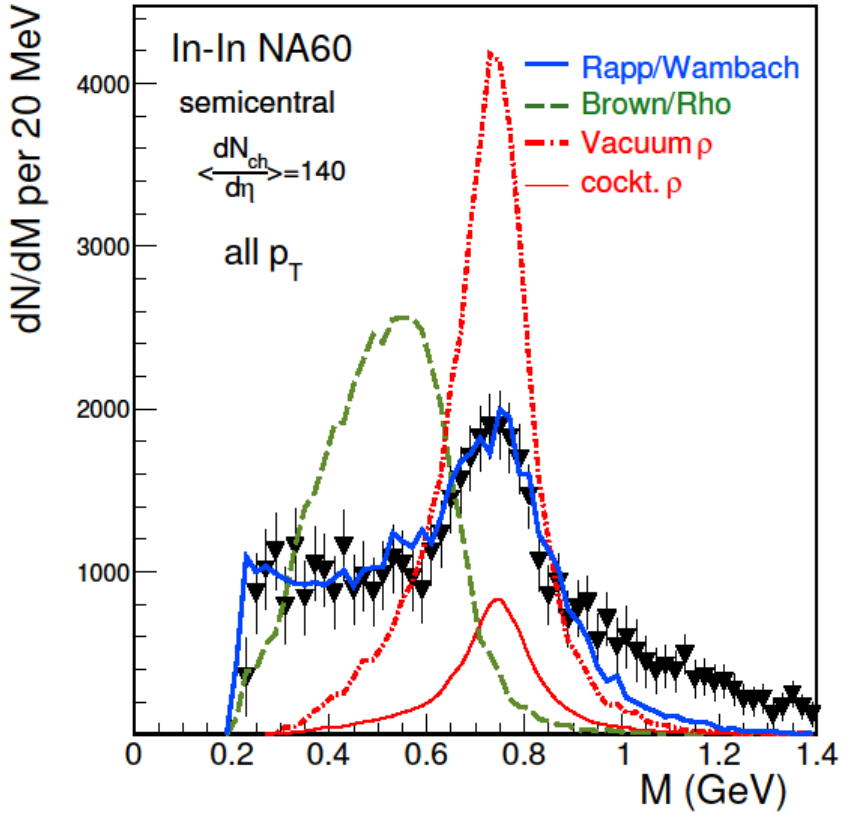


ρ-meson Modification

- CERES
  - Cocktail ρ is insufficient [solid]

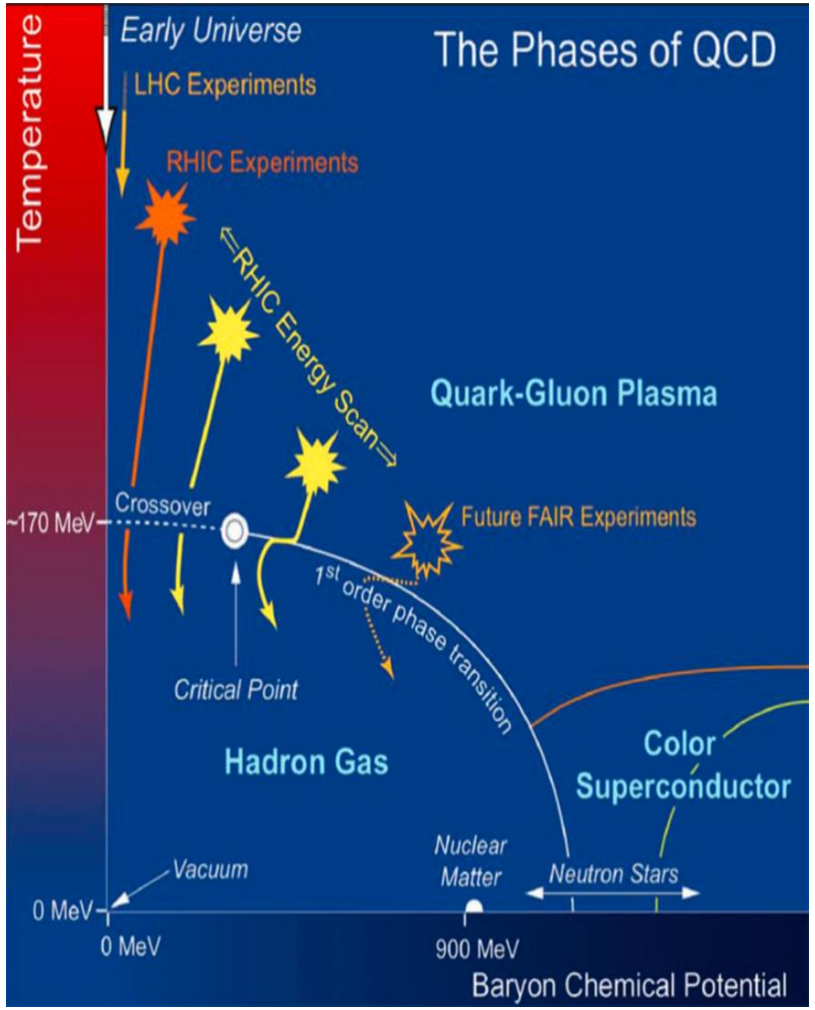


- NA 60
  - Vacuum ρ is insufficient [dash-dot]
  - Excludes mass-dropping [dash]
  - Supports broadening of ρ spectral function [solid]



NA60, AIP. Conf. Proc. 1322 (2010) 1-10.

Beam Energy Scan Program: Phase I

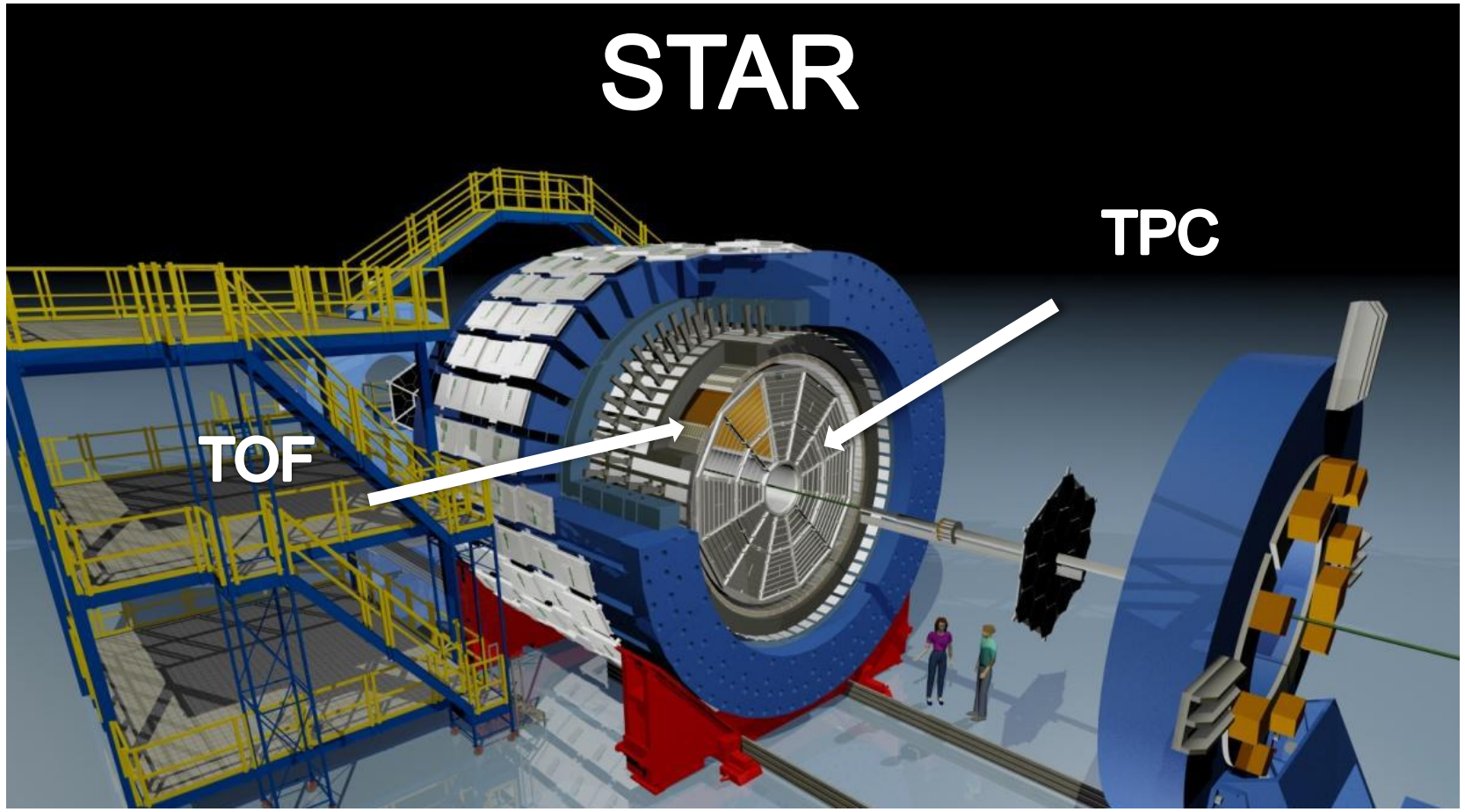


- RHIC Beam Energy Scan Program [2010-2011, 2014]
  - Au+Au @19.6, 27, 39, & 62.4 GeV [14.5 GeV Collected]

$\sqrt{s_{NN}}$ (GeV)	19.6	27	39	62.4
Events (M)	36	70	130	67

  - Same colliding species & detector
  - Opportunity to extensively study ρ spectral function
    - Connect between SPS & RHIC Au+Au 200 GeV
    - Dependence on $\sqrt{s_{NN}}$?
    - Compare to models

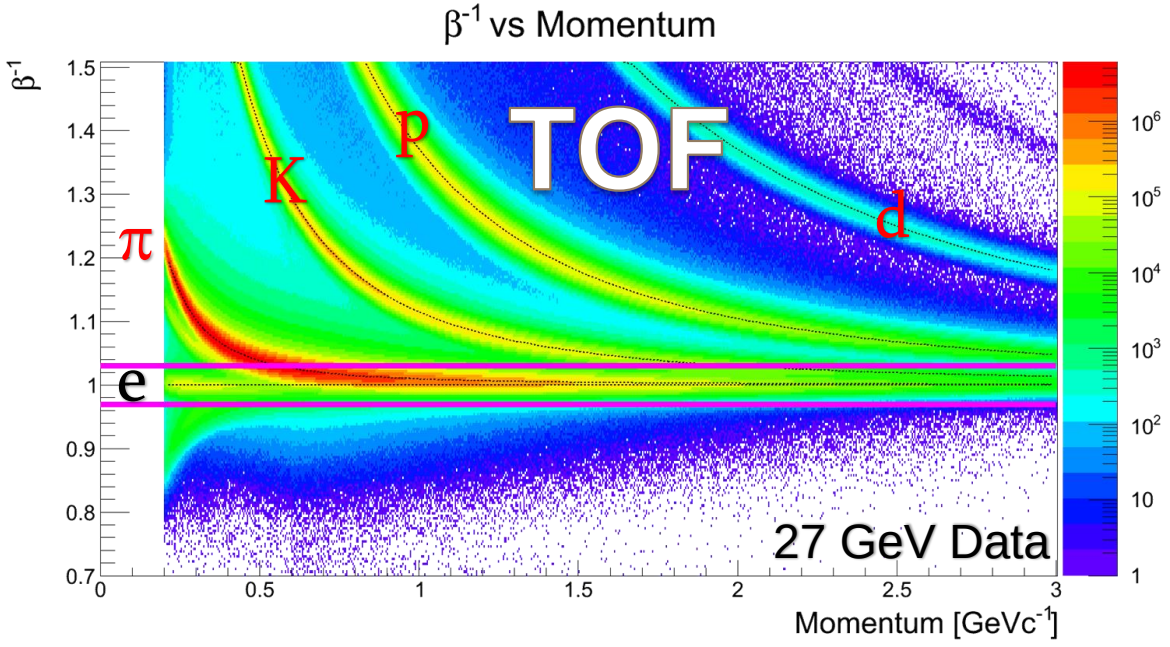
STAR Detector

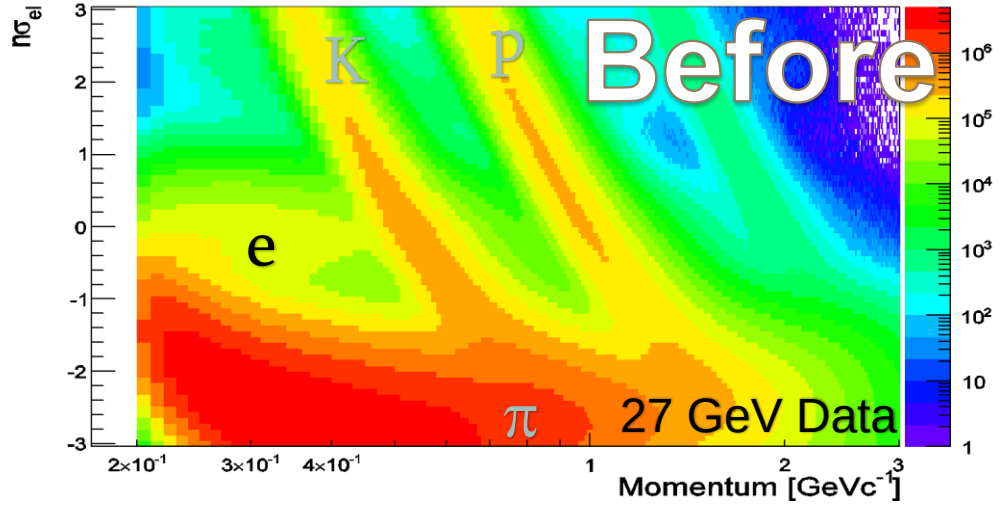


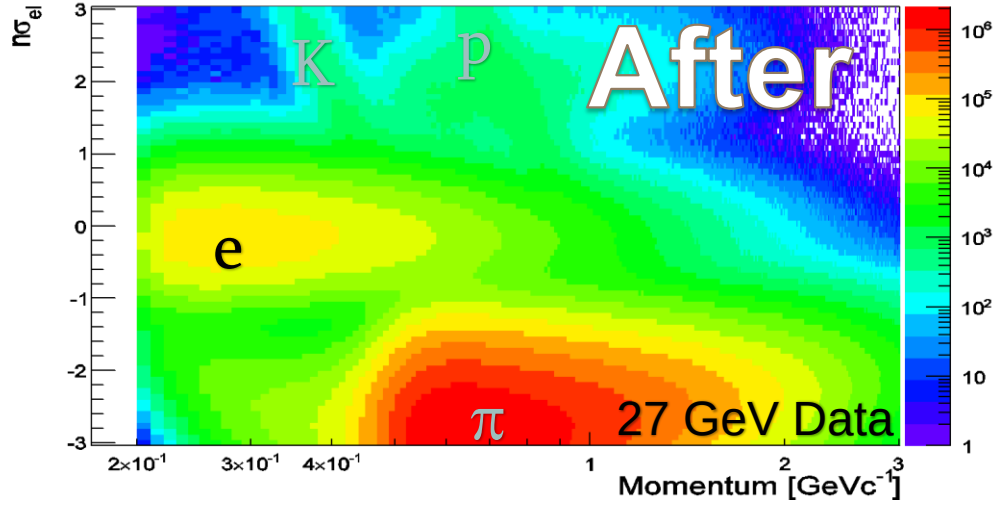
- **Time Projection Chamber [TPC]**
  - Tracking
  - Ionization energy loss
  - Full azimuthal coverage
- **Time of Flight [TOF]**
  - Precise time (resolution < 90 ps)
  - Improves TPC's PID purity
  - Full azimuthal coverage

Electron Identification

- **Use TPC+TOF in tandem**
  - TPC provides particle identification
  - TOF enables slow hadron rejection
    - Improves identification
    - Typical identified $e^{+/-}$ purity ~95%
- **Selection Criteria for 27GeV data [varies for $\sqrt{s_{NN}}$]**
- **TPC**
  - $n\sigma_{el} > -0.663$ w/ $p[GeVc^{-1}] \geq 0.637$ OR $n\sigma_{el} > (1.604 \cdot p - 1.685)$ w/ $p[GeVc^{-1}] < 0.637$
  - $n\sigma_{el} < -0.687 \cdot p[GeVc^{-1}] + 2.1$
- **TOF**
  - $|\beta^{-1}-1| < 0.03$
- Selects ~40M $e^{+/-}$







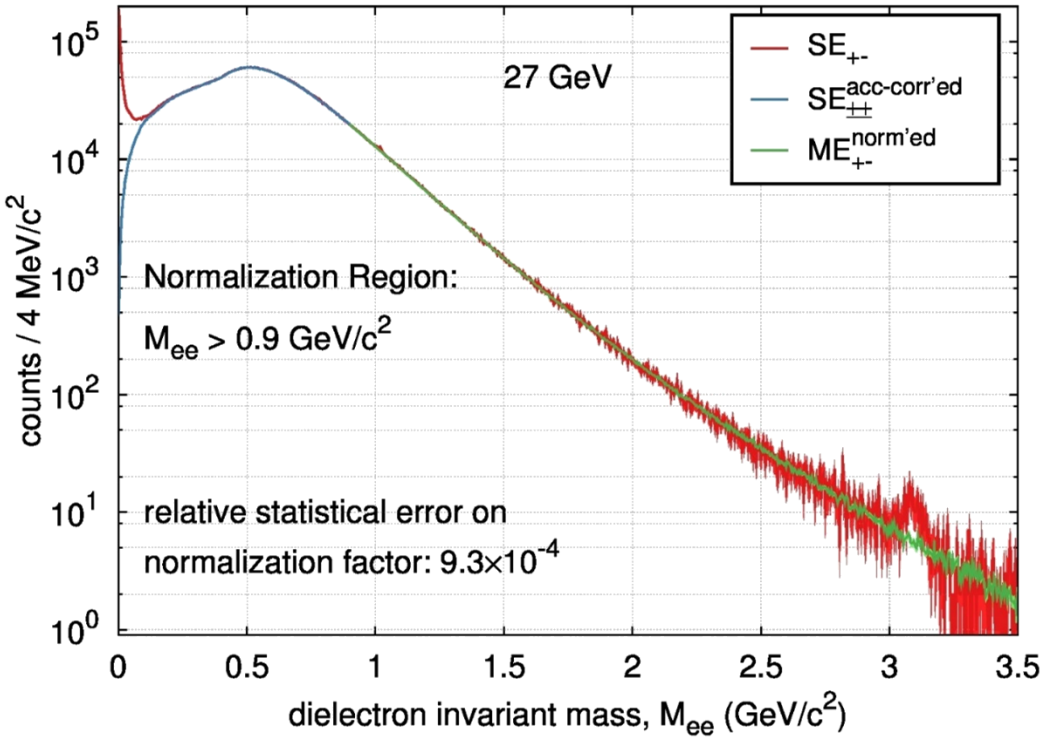
Background

- **Pair Background Sources**
  - Combinatorial, Correlated, Conversion
- **Like-Sign Same Event Method**
  - Combine all like-sign pairs and average
  - Removes combinatorial & correlated
  - Acceptance correction w/ mixed event method

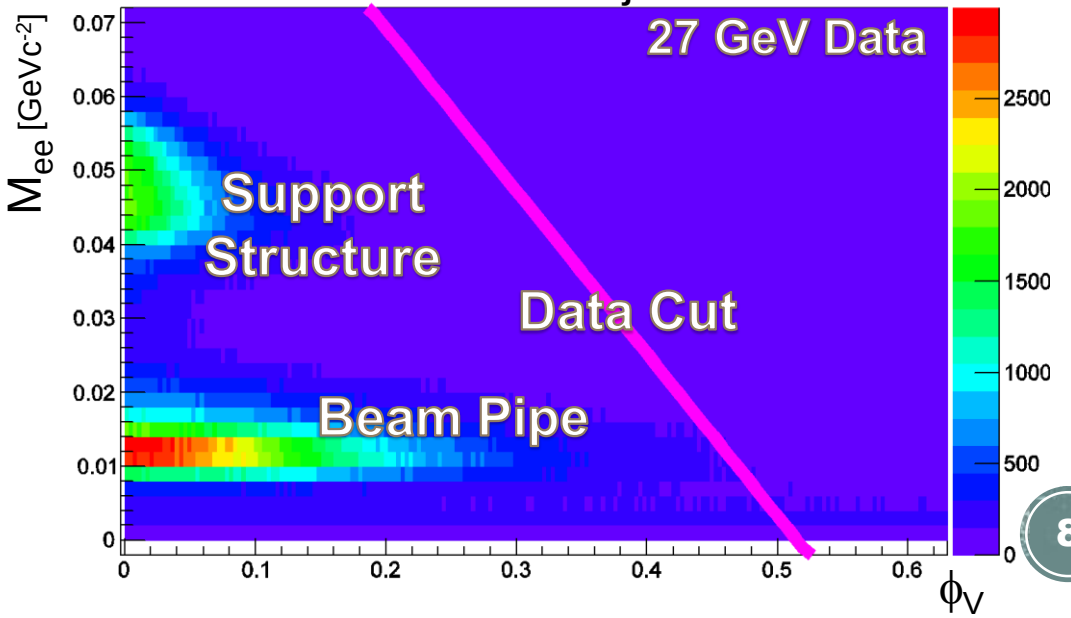
$$2\sqrt{N_{++}N_{--}}\,\frac{ME_{+-}}{2\sqrt{ME_{++}ME_{--}}}$$

- **Unlike-Sign Mixed Event Method**
  - Combine $e^{+/-}$ from different events w/ similar properties*
    - Z Vertex, Ref. Mult., and Event Plane Angle
    - Pools of 20 events
  - Removes combinatorial
- **Conversion Rejection***
  - Selection based on pair's orientation in $\vec{B}$

$* \; Criteria\ vary\ for\ each\ \sqrt{s_{NN}}$



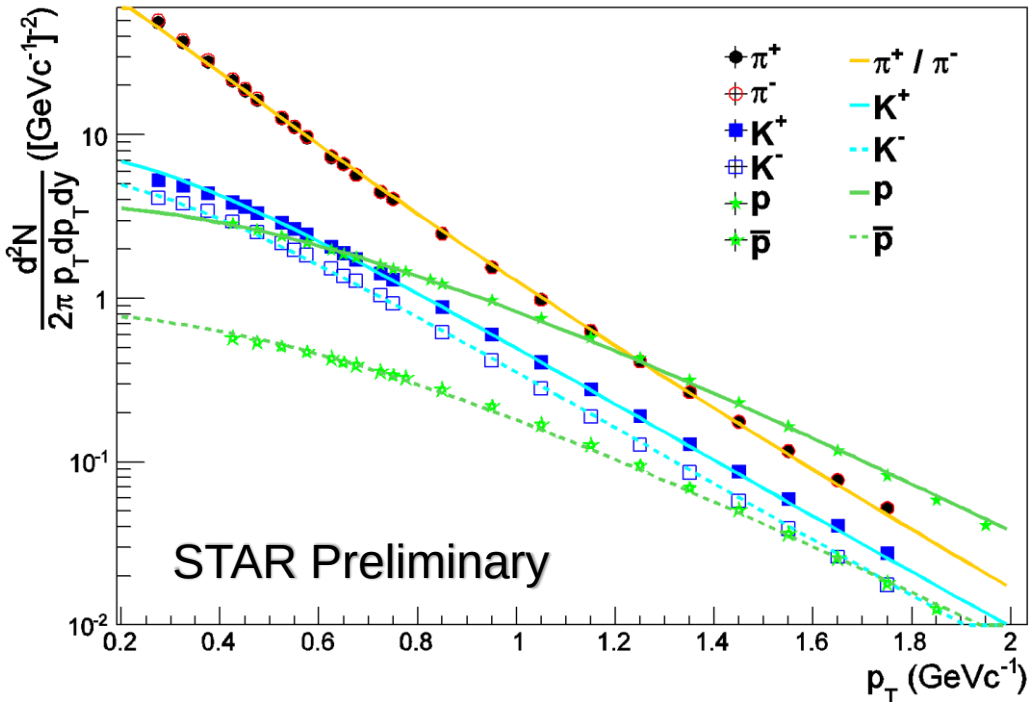
Conversion Rejection



Cocktail

- **Contributions**
  - π^0, η, η', ω, ϕ, J/ψ, $c\bar{c}$ [Note: no ρ]
- **Input**
  - Flat ϕ [0, 2π]
  - η [-1,1]
    - Flat for 39 & 62 GeV.
    - GENESIS for 19 & 27 GeV
  - p_T from Tsallis Blast Wave [TBW] fits
- **Decay**
  - Breit-Wigner/Kroll-Wada Formalism
- **Yield**
  - Meson-to-π^0 ratio from NA45 w/ $\pi^{+/-}$ dN/dy from STAR
- **$c\bar{c}$ Contributions**
  - PYTHIA; Scaled by N_{binary}

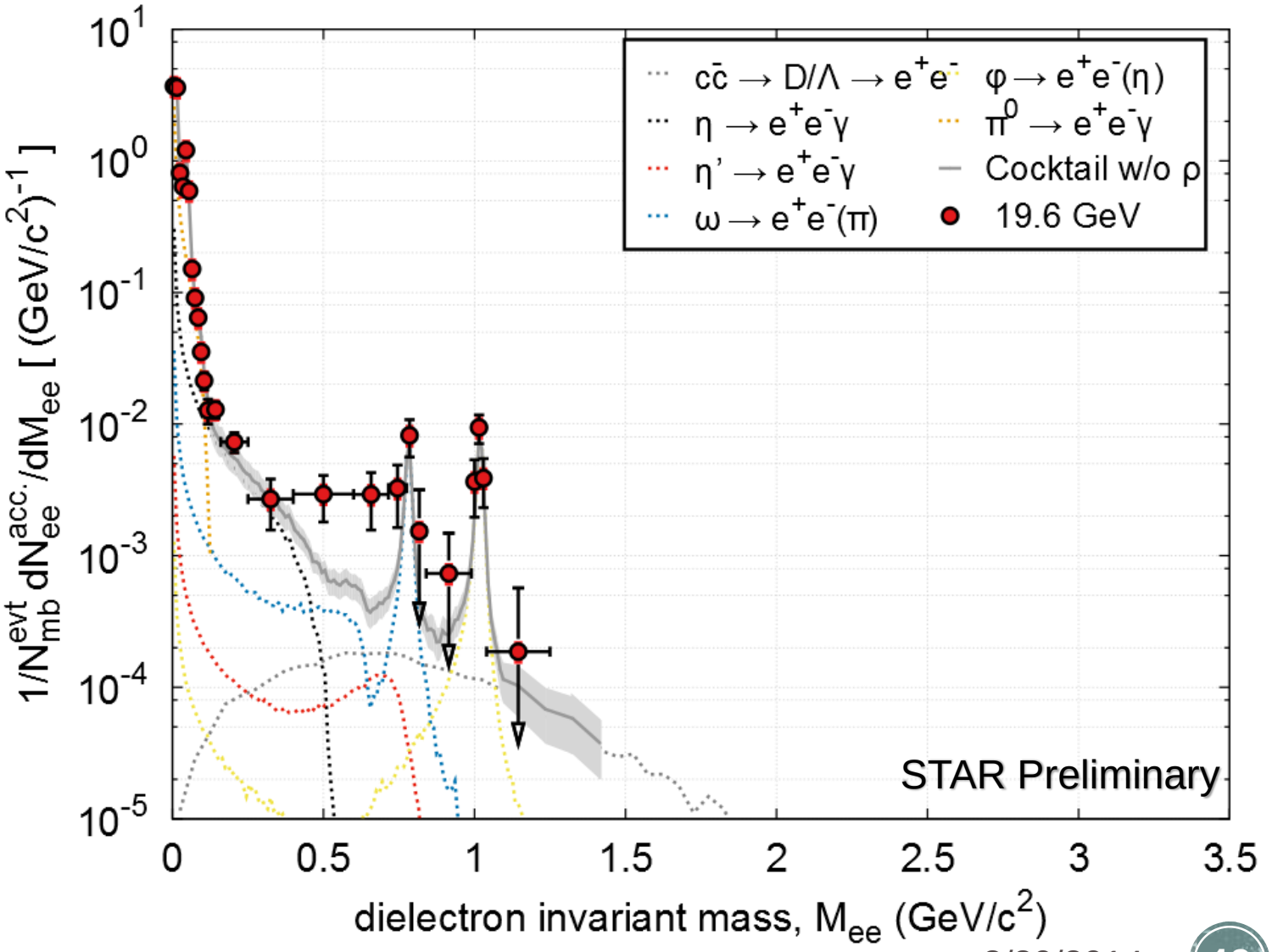
27 GeV TBW Fits



Meson	π^0	η	ω	ϕ	η'	J/ψ
Meson/π^0	1.0	0.085	0.069	0.018	0.078	6.2E-6

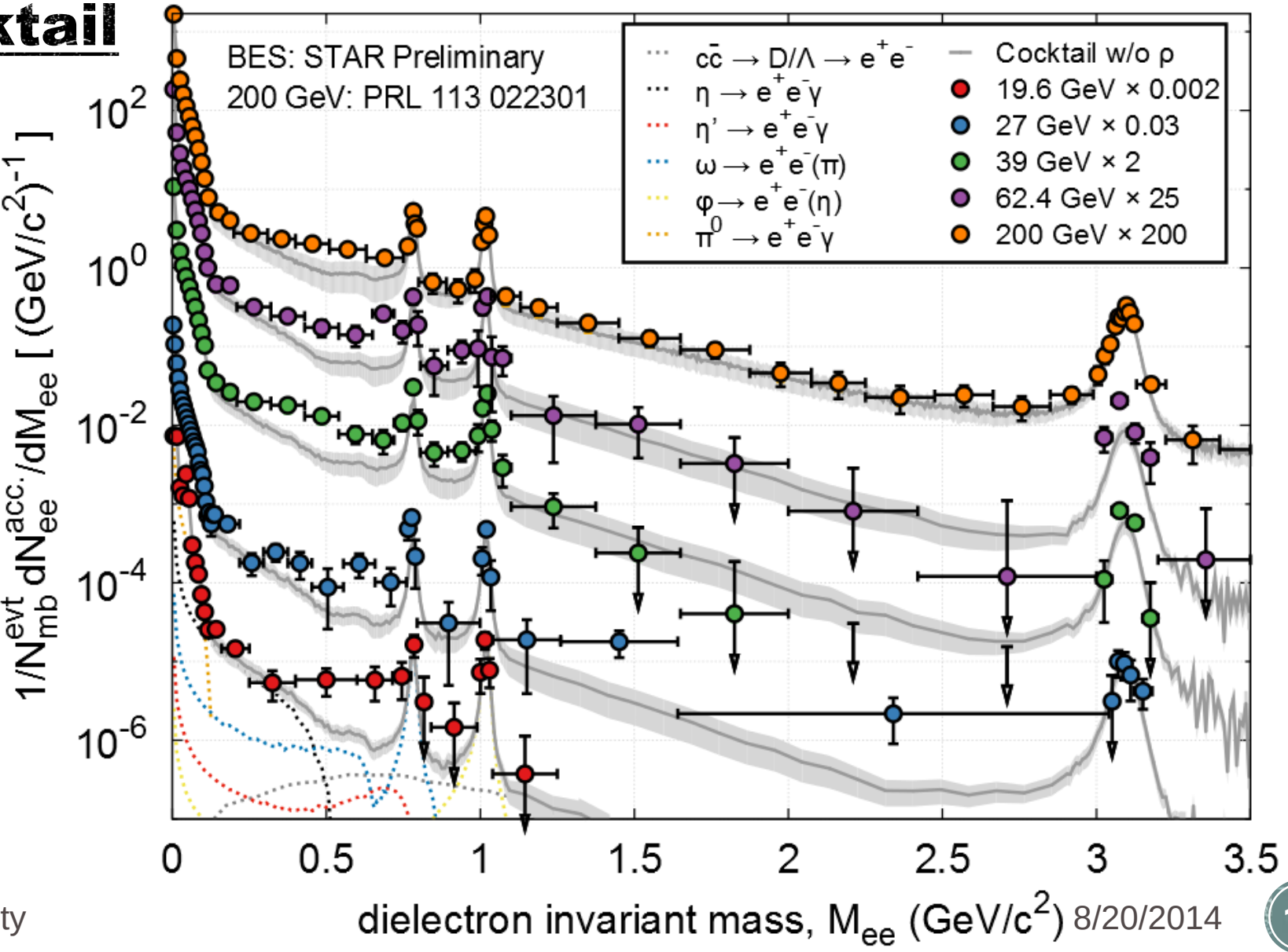
Invariant Mass:
Data vs. Cocktail

- Au+Au 19.6 GeV MB
- $p_{Te} > 0.2$ GeV/c, $|\eta_e| < 1$, $|y_{ee}| < 1$
- Broad excess over LMR
  - ρ contribution missing



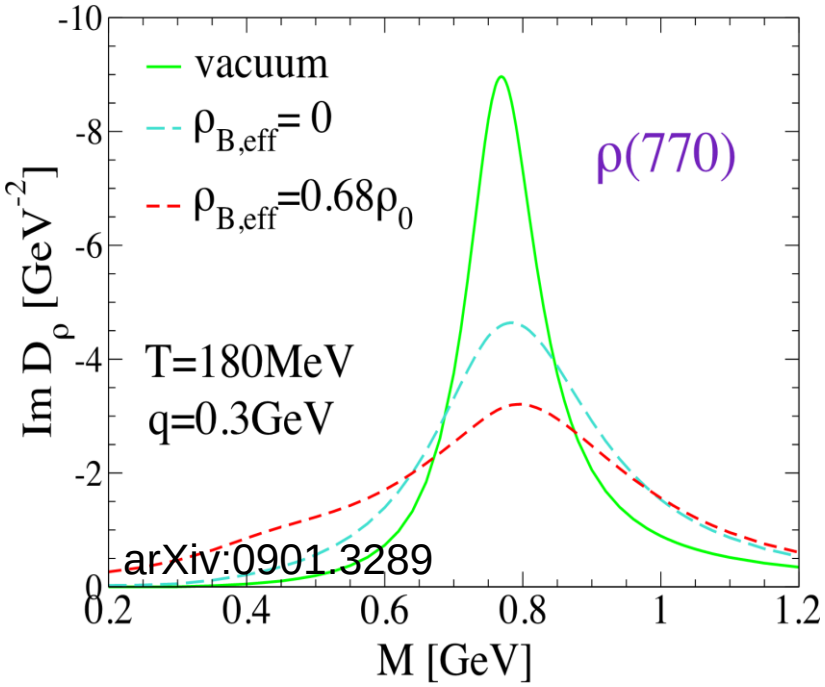
Invariant Mass:
Data vs. Cocktail

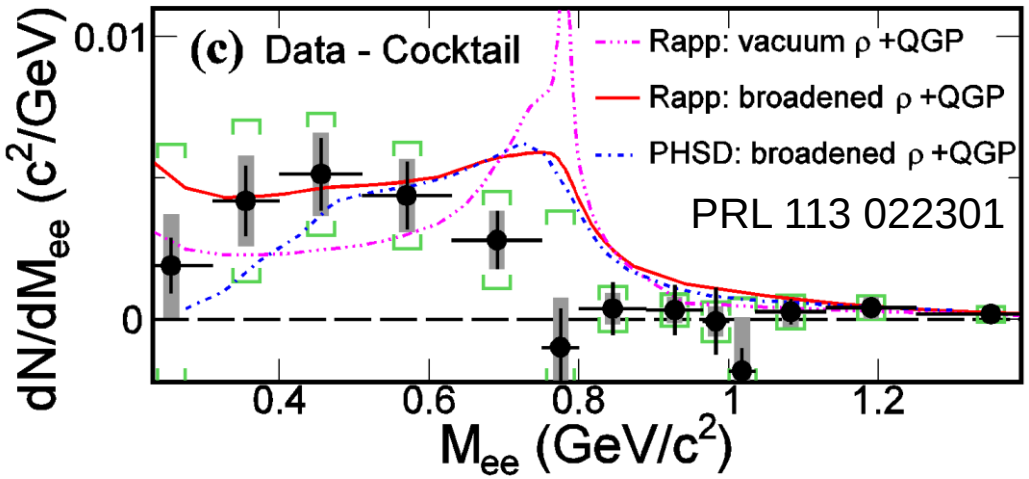
- Au+Au 19.6, 27, 39, 62.4, & 200 GeV MB
- $p_{Te} > 0.2$ GeV/c, $|\eta_e| < 1$, $|y_{ee}| < 1$
- Broad excess over LMR
  - ρ contribution missing



Model: Rapp, Wambach, van Hees

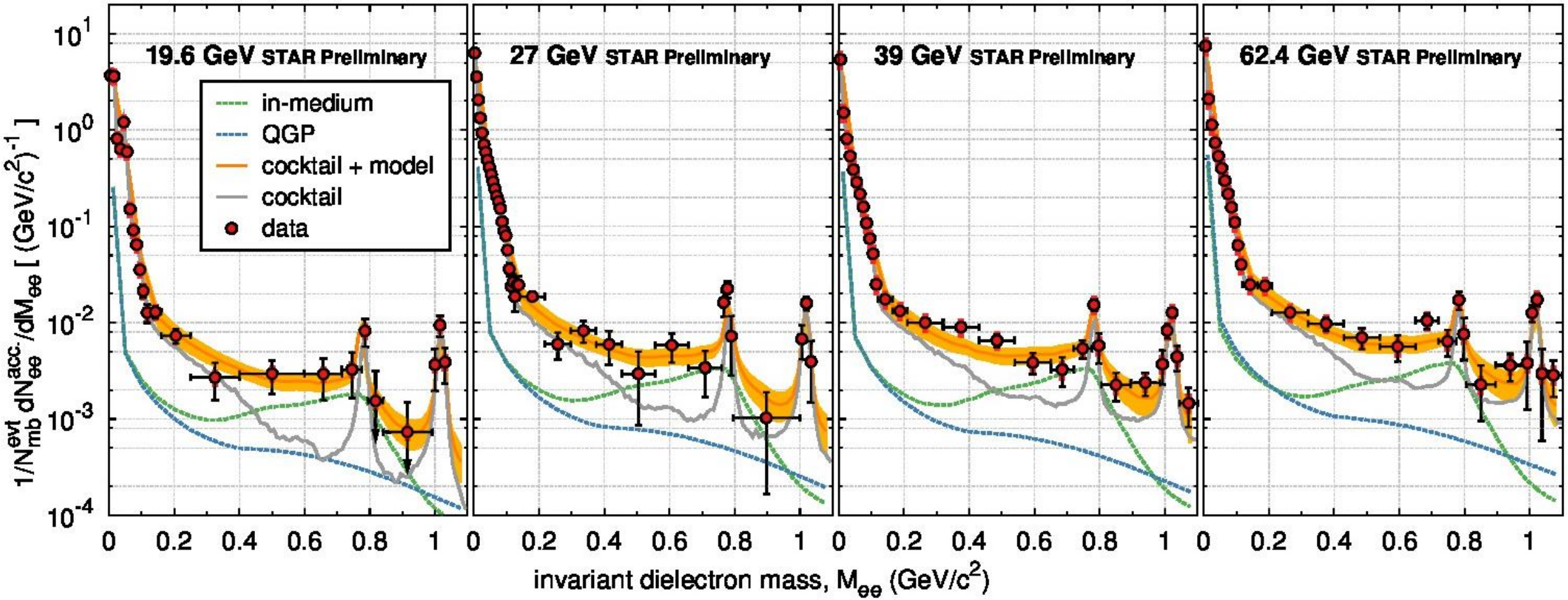
- Complete evolution (Hadron Gas + QGP)
- In-medium modified ρ spectral function—"ρ melts"
  - Dependent on total baryon density
- QGP emission rates that are lattice QCD inspired





- Run 10 AuAu 200 GeV MB
- Vacuum ρ gives an insufficient description
- **Model** agrees within uncertainties

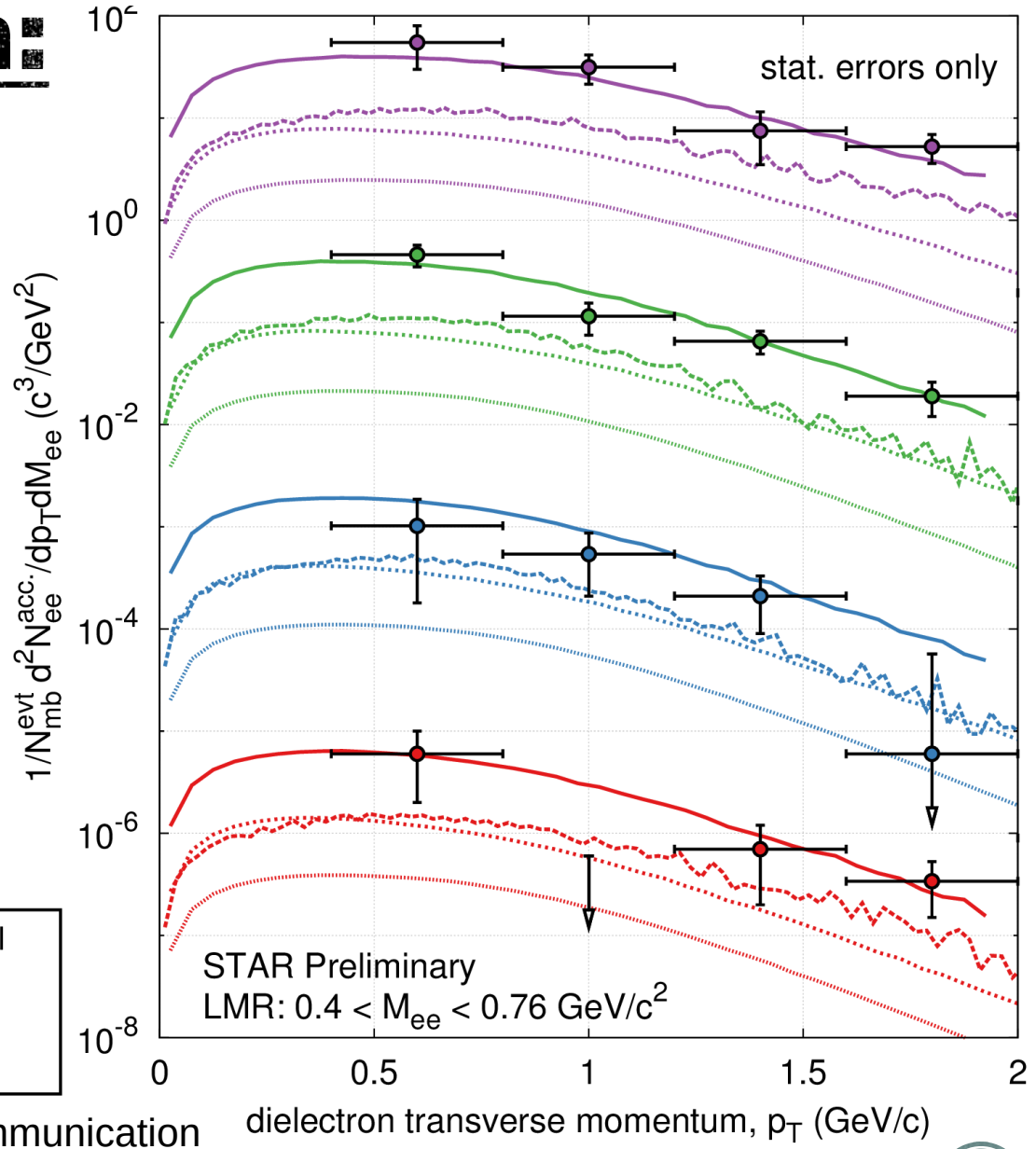
Invariant Mass:
Data vs. Cocktail+Model



Rapp + Wabach, private communication
Adv. Nucl. Phys. 25, I (2000), Phys. Rept. 363, 85(2002),
PRC 63 (2001) 054907, Adv. High Energy Phys. 2013 148253

Transverse Momentum:
Data vs. Cocktail+Model

- Au+Au 19.6, 27, 39, & 62.4 GeV MB
- $p_{Te} > 0.2$ GeV/c, $|\eta_e| < 1$, $|y_{ee}| < 1$
- Cocktail + Model contributions consistent with Data as a function of M_{ee} & p_{Tee}

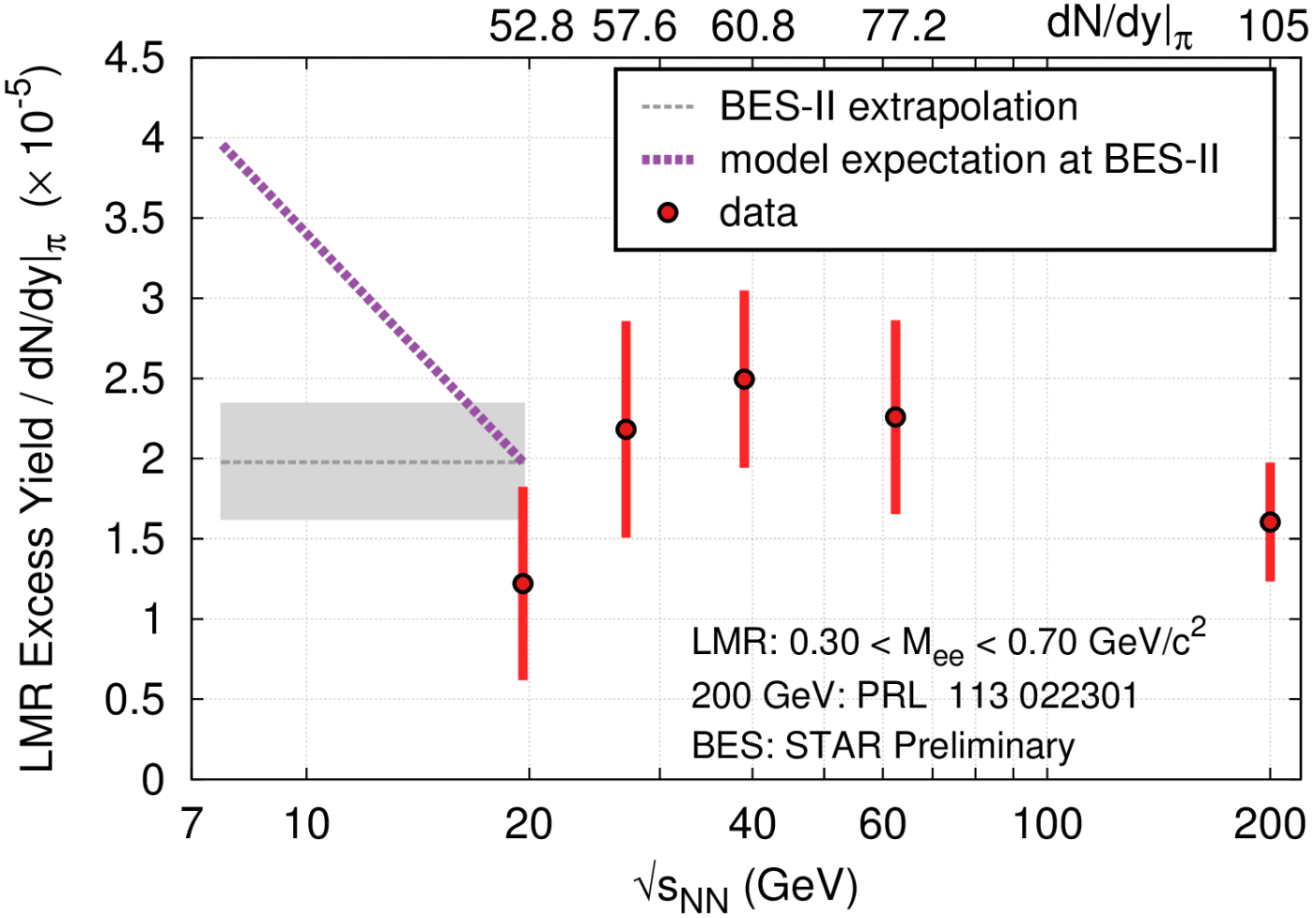


Rapp + Wabach, private communication
Adv. Nucl. Phys. 25, I (2000), Phys. Rept. 363, 85(2002),
PRC 63 (2001) 054907, Adv. High Energy Phys. 2013 148253

Beam Energy Scan Program: Phase II

- **BES: Phase II**
  - Build upon the success of Phase I
  - Enhanced statistics
    - Eg.: 19 GeV with 200 GeV MB Stat. Uncert.
  - Detector upgrades –
    - iTPC, Muon Telescope Detector
  - Test total baryon density dependence

- **Total baryon density dependence**
  - In-medium modification of ρ's spectral function
  - Excess yield of e^+e^-
  - Statistics allow testing



O. Linnyk, private communications
W. Cassing, E.L. Bratkoskaya, S. Juchem, Nucl. Phys. A 674 (2000) 249.

Summary

- e^+e^- continuum measurements across $\sqrt{s_{NN}}$ of 19.6, 27, 39, and 62.4 GeV
- At each $\sqrt{s_{NN}}$, there is an excess with respect to the hadronic cocktail
  - No strong $\sqrt{s_{NN}}$ dependence
- Excess consistent w/ model calculations involving a medium modified ρ spectral function
  - Demonstrated for the excess as a function of M_{ee} & p_{Tee}!
- Beam Energy Scan Program: Phase II enables further understanding of the low mass region

Thank you!