Interference in vector meson production in Au+Au Collisions $\sqrt{s_{NN}}$ = 200 GeV from STAR

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Outline

- Ultra Peripheral Heavy Ion Collisions (UPCs)
  - What is a UPC?
  - Vector Meson Production / Interference
  - Triggers
- Analysis of UPC events
  - Fitting Scheme
  - Observation of interference effects in t spectrum

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Ultra Peripheral Collisions

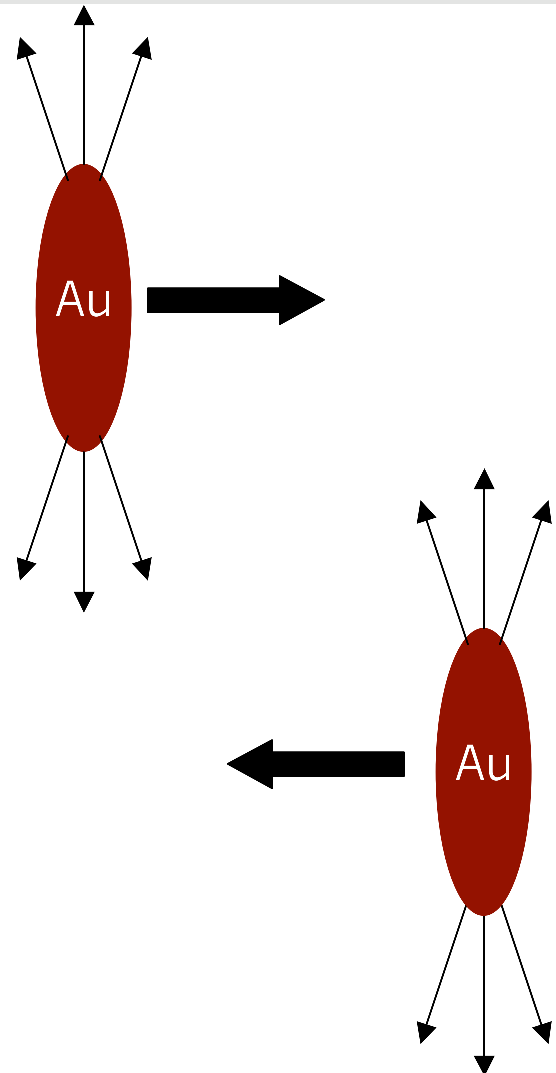
- What is a UPC?
  - Photonuclear interaction
  - Two nuclei “miss” each other (b > $2R_A$), electromagnetic interaction dominates over strong interaction
  - Photon flux ~ Z^2
    - Weizsacker-Williams Equivalent Photon Approximation

$$\frac{d^3N(k,r)}{dkd^2r} = \frac{Z^2\alpha x^2}{\pi^2 kr^2} K_1^2(x)$$

$$x = \frac{kr}{\gamma}$$

$$K_1(x) = \textit{Modified Bessel function}$$

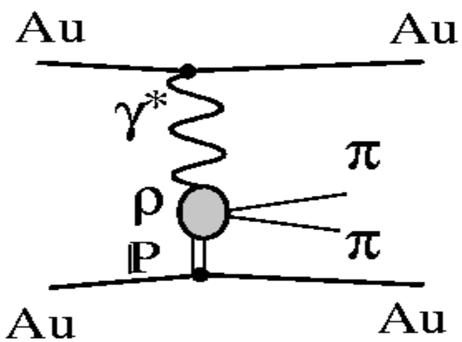
$$k = \textit{photon energy}$$



  - No hadronic interactions

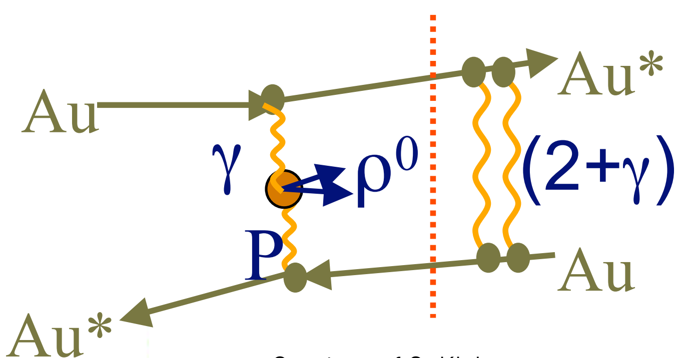
ρ° Production Mechanisms

Au+Au → Au+Au+ρ°



Courtesy of F. Meissner

Au+Au → Au*+Au*+ρ°



Courtesy of S. Klein

- Photon emitted by a nucleus fluctuates to virtual $q\bar{q}$ pair
- Virtual $q\bar{q}$ pair elastically scatters from other nucleus
- Real vector meson (i.e. J/ψ, ρ°) emerges

- Photon and pomeron are emitted coherently
- Coherence condition limits transverse momentum of produced ρ

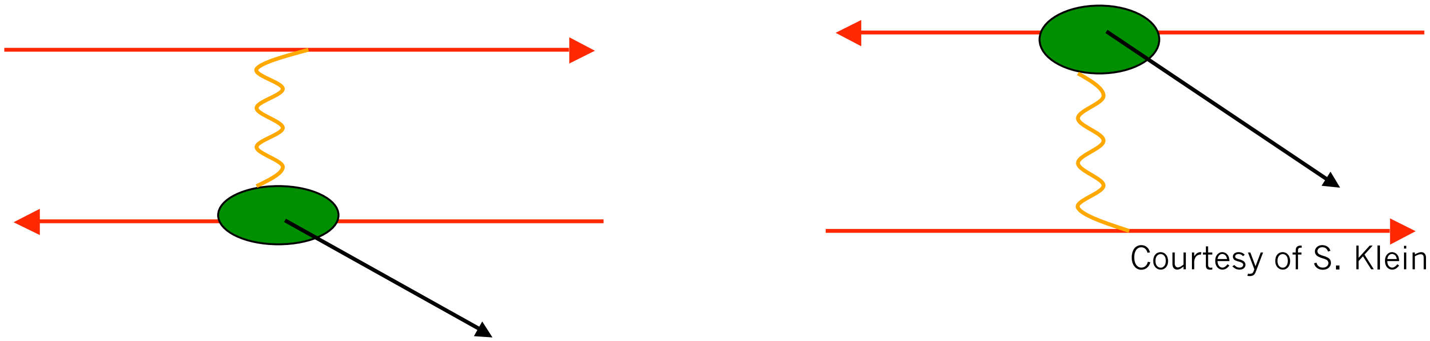
$$p_T < \frac{h}{2R_A}$$

Coulomb Excitation

- Photons exchanged between ions give rise to excitation and subsequent neutron emission
- Process is independent of ρ° production

$$\sigma(AuAu \rightarrow Au^* Au^* + \rho^o) = \int d^2b P_\rho(b) P_{XnXn}(b)$$

Interference



- Amplitude for observing vector meson at a distant point is the subtraction (since ρ parity is negative) of two plane waves:

$$A_o(x_o,\vec{p},b) = A(p_\perp,y,b)e^{i[\phi(y)+\vec{p}\bullet(\vec{x}-\vec{x}_o)]} - A(p_\perp,-y,b)e^{i[\phi(-y)+\vec{p}\bullet(\vec{x}-\vec{x}_o)]}$$

- Cross section comes from square of amplitude:

$$\sigma = A^2(p_\perp,y,b) + A^2(p_\perp,y,b) - 2A(p_\perp,y,b)A(p_\perp,-y,b)\times\cos[\phi(y)-\phi(-y)+\vec{p}\bullet\vec{b}]$$

- We can simplify the expression if y → 0:

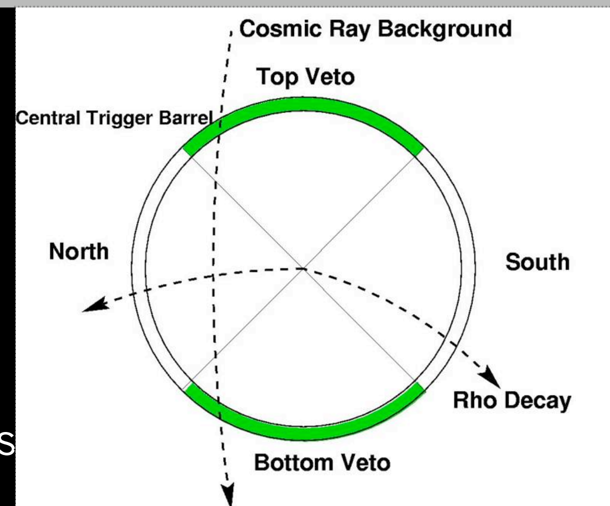
$$\sigma = 2A^2(p_\perp,b)(1-\cos[\vec{p}\bullet\vec{b}])$$

Triggers

$Au+Au \rightarrow Au+Au+\rho^{o}$

(UPC Topology)

- Central Trigger Barrel divided into four quadrants
- Verification of ρ decay candidate with hits in North/South quadrants
- Cosmic Ray Background vetoed in Top/Bottom quadrants



$Au+Au \rightarrow Au^{*}+Au^{*}+\rho^{o}$

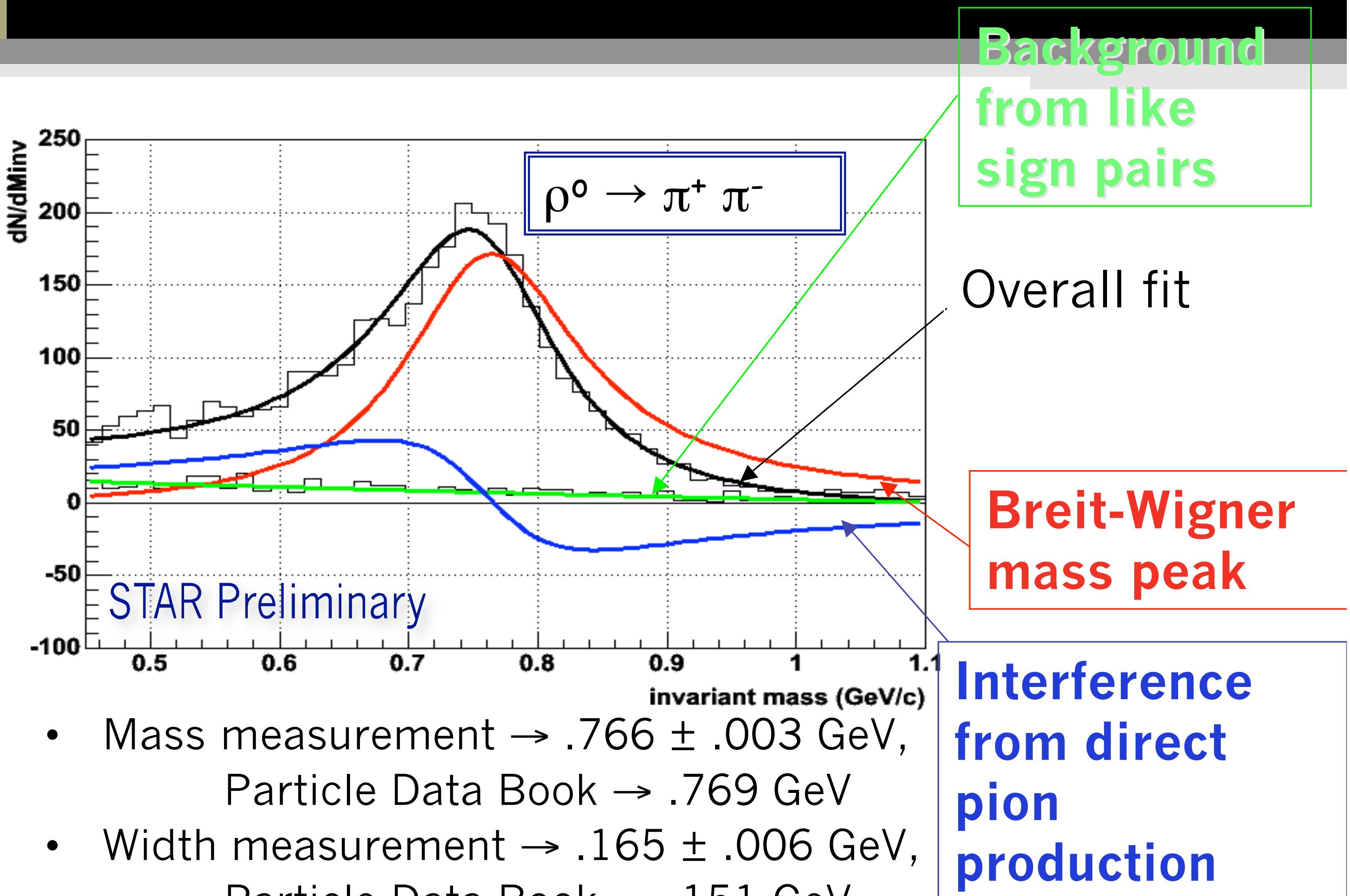
(UPC Minbias)

- Minimum one neutron in each Zero Degree Calorimeter required
- Low Multiplicity

Trigger Backgrounds

- Cosmic Rays
- Beam-Gas interactions
- Peripheral hadronic interactions
- Incoherent photonuclear interactions

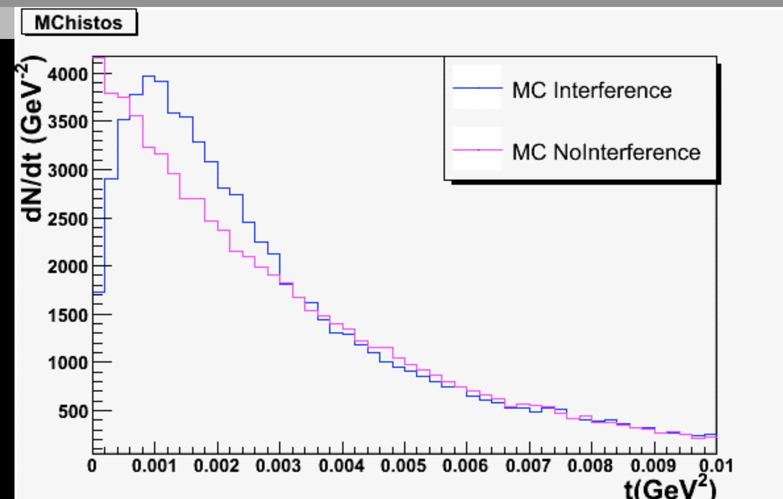
Finding the ρ° in 200 GeV Au+Au data

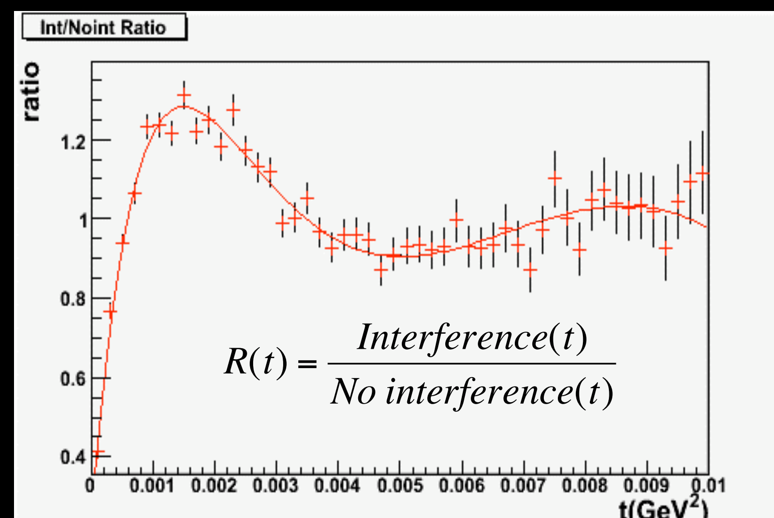


- Mass measurement → .766 ± .003 GeV,
  Particle Data Book → .769 GeV
- Width measurement → .165 ± .006 GeV,
  Particle Data Book → .151 GeV

Studying the Interference

- *Generate MC*
  t spectra with and without interference
- *Calculate MC ratio in order to illustrate interference effect*
- *Fit MC ratio*





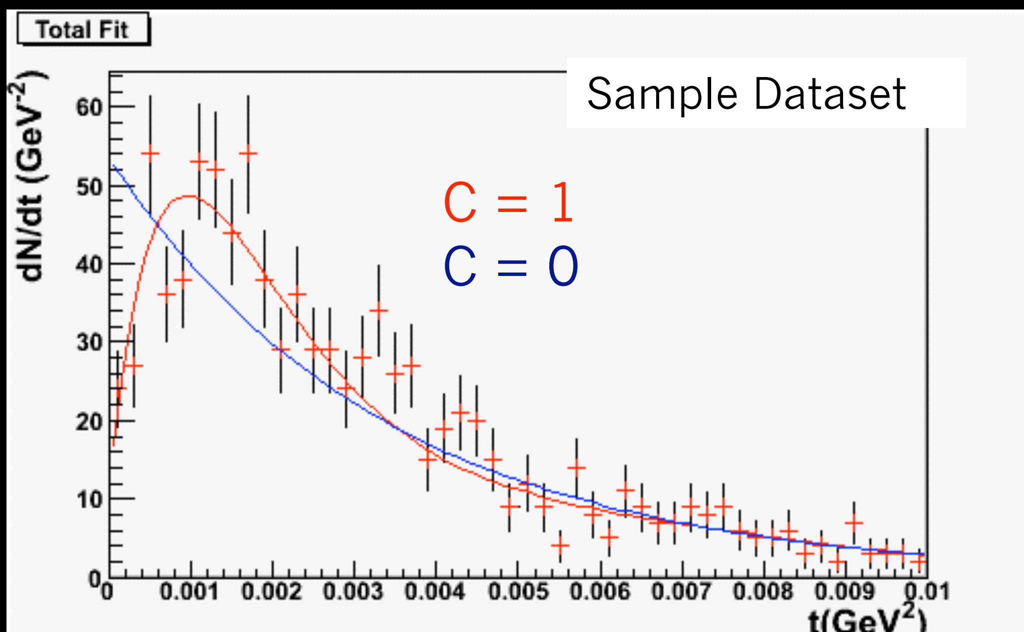
$$R(t) = a + \frac{b}{(t+0.012)} + \frac{c}{(t+0.012)^2} + \frac{d}{(t+0.012)^3} + \frac{e}{(t+0.012)^4}$$

Measuring the Interference

- *Apply overall fit*

$$\frac{dN}{dt} = Ae^{-kt}(1 + c[R(t) - 1])$$

- A= overall normalization
- k = exponential slope
- c = degree of interference



c = 1

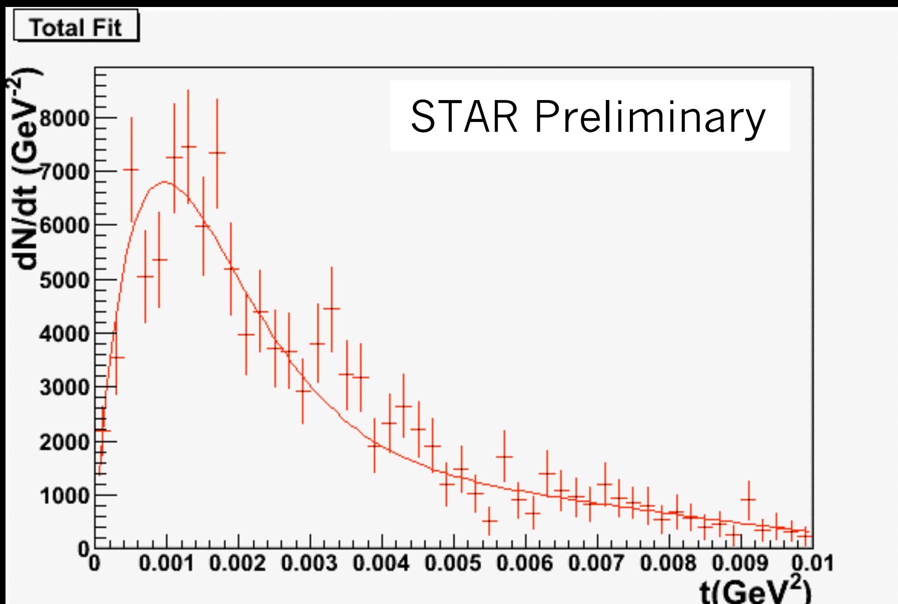
expected degree of interference

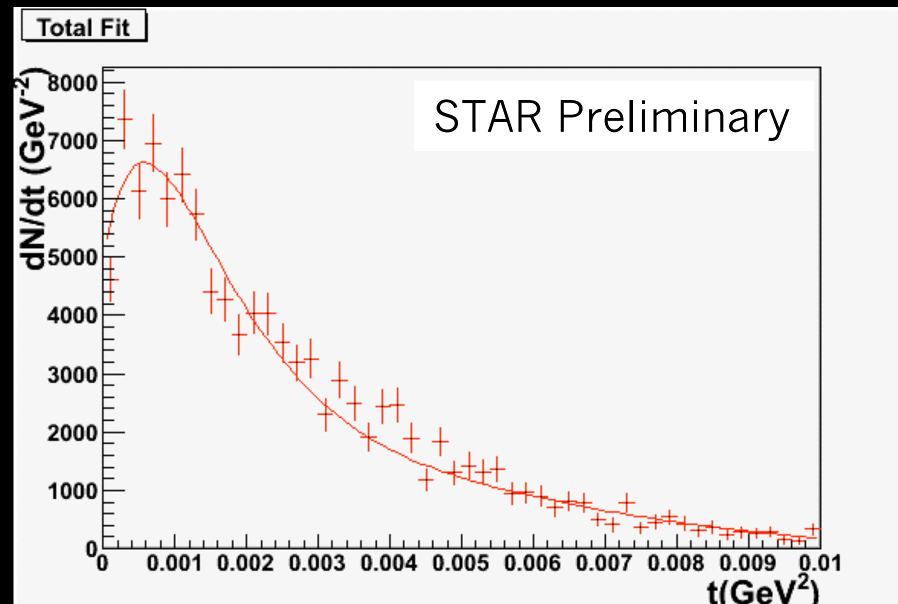
c = 0

no interference

Illustration of Fitting Methodology

Results





Au+Au → Au*+Au*+ρ°

(Minbias)

C = 1.00±0.08

χ^2/DOF = 50/47

Au+Au → Au+Au+ρ°

(Topology)

C = 0.84±0.12

χ^2/DOF = 87/47

Results Summary

	c	χ^2/dof
excitation		
0 < y < 0.5	1.01±0.08	51/47
0.5 < y < 1.0	0.93±0.11	80/47
No excitation		
0.1 < y < 0.5	0.85±0.12	88/47
0.5 < y < 1.0	1.06±0.21	84/47

Systematic Error Study

$$\frac{dN}{dt} = Ae^{-kt}(1 + c[R(t) - 1])$$

Fitting Systematics

- Sensitivity of overall fitting to ratio fit
  - Different fits applied to ratio (intMC/nointMC):
  - Extract interference parameter *c*
- Sensitivity of fitting to slope ($\sim R_A^2$) parameter
  - Apply fit and extract *k*
  - Fix *k* to 100%, 90%, 80% of extracted value
  - Re-fit spectrum and extract interference parameter *c*

Theoretical Systematics

- Comparison between models
  - Hencken, Baur, Trautmann, Phys.Rev.Lett.96:012303,2006
  - Klein, and Nystrand, Phys.Rev.Lett. 84:2330,2000

Detector Effects

- Momentum resolution
- Forward/Backward comparison

Summary & Outlook

Interference in vector meson production has been observed at STAR.

- At small t, the predicted downturn is clearly seen.
- The measured degree of interference is consistent with unity.
- Currently in the process of systematic error study and refining fitting scheme.