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

- Review of analysis details
- Current status of results
- Latest alterations to the analysis
  - systematic checks
  - theory studies

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STAR Analysis Meeting
March 18 - 21

Ultra Peripheral Collisions

- Photonuclear Interaction
- Two nuclei "miss" each other ($b > 2R_A$), electromagnetic interaction dominates over strong interaction
- Photon flux ~ Z^2
  - Weizsäcker-Williams Equivalent Photon Approximation

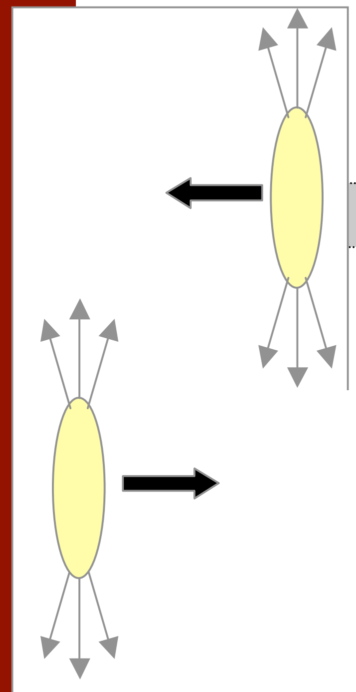
$$\frac{d^3N(k,r)}{dkd^2r} = \frac{Z^2\alpha x^2}{\pi^2 k r^2} K_1^2(x)$$

$$K_1(x) = Modified\ Bessel\ function$$

$$k = photon\ energy$$

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

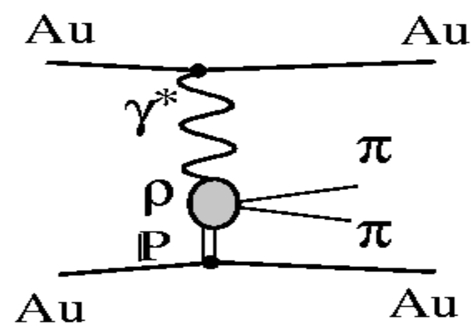
- No hadronic interactions



ρ^0 Production

- Photon emitted by a nucleus fluctuates to virtual qq pair
- Virtual qq pair elastically scatters from other nucleus
- Real vector meson (i.e. J/ψ, ρ^o) emerges

Au+Au → Au+Au+ρ^o

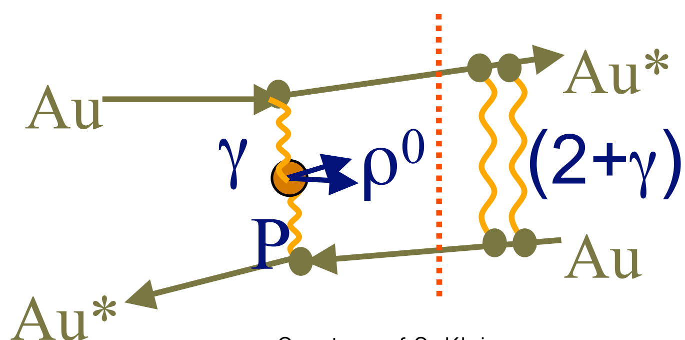


Courtesy of F. Meissner

ρ^0 Production with coulomb excitation

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

Au+Au → Au*+Au*+ρ^o



Courtesy of S. Klein

Interference

Nucleus 1 emits photon which scatters from Nucleus 2

-Or-

Nucleus 2 emits photon which scatters from Nucleus 1

Courtesy of S. Klein

- 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:

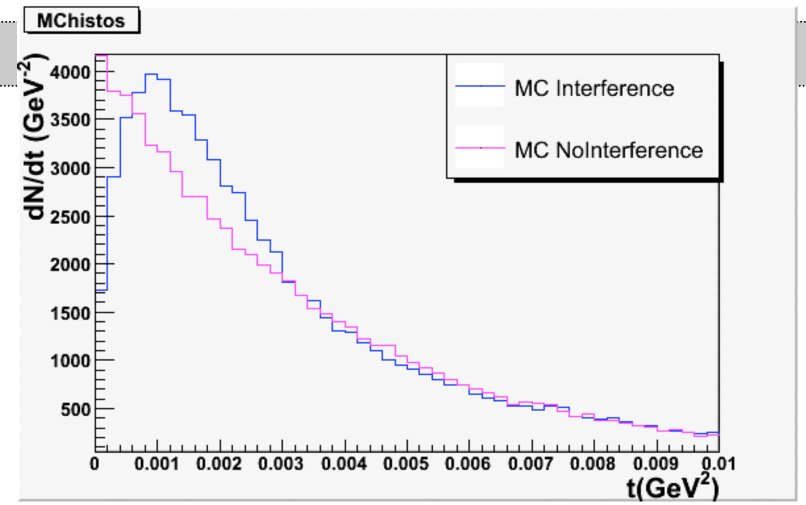
$$\sigma = A^2(p_\perp,y,b) + A^2(p_\perp,y,b) - 2A(p_\perp,y,b)A(p_\perp,-y,b)\times\cos[\phi(y)-\phi(-y)+\vec{p}\bullet\vec{b}]$$

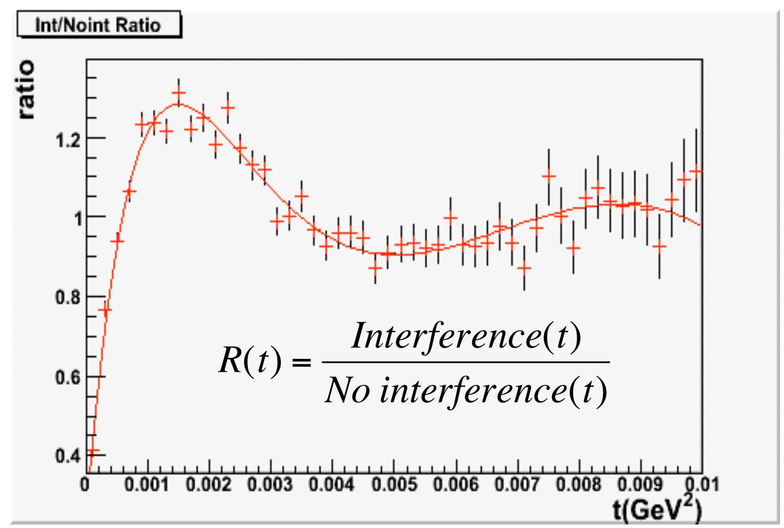
- We can simplify the expression if $y \to 0$:

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

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*

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

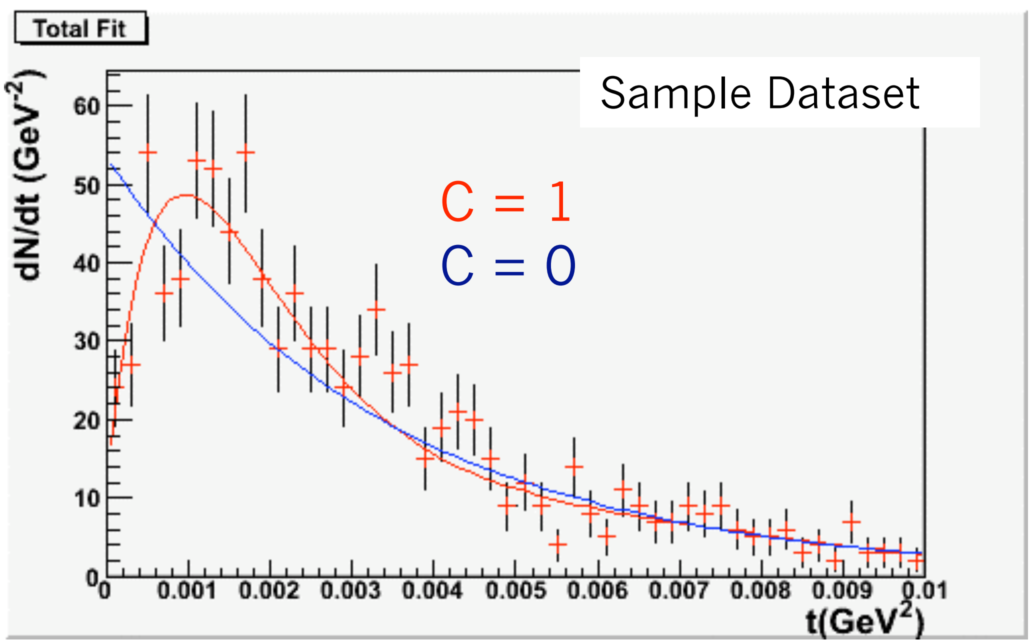


Illustration of Fitting Methodology

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

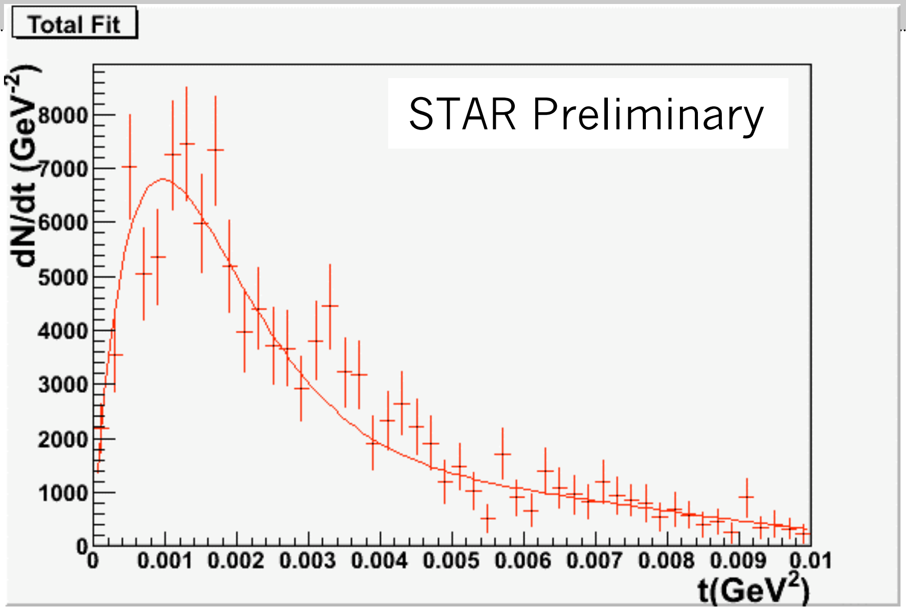
c = 1

expected degree of interference

c = 0

no interference

Results

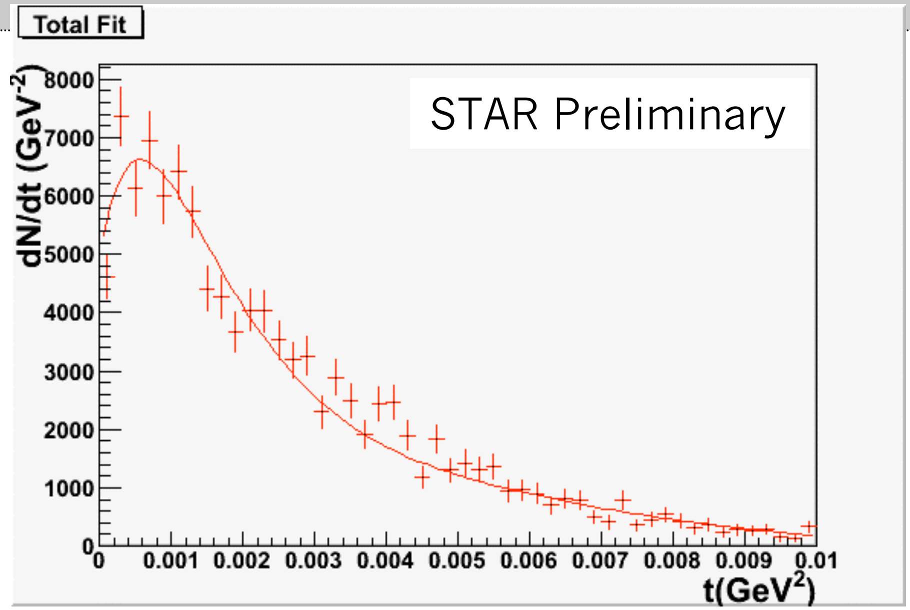


Au+Au → Au*+Au*+ρ°

(Minbias)

C = 1.01±0.08

χ^2/DOF = 51/47



Au+Au → Au+Au+ρ°

(Topology)

C = 0.84±0.12

χ^2/DOF = 87/47

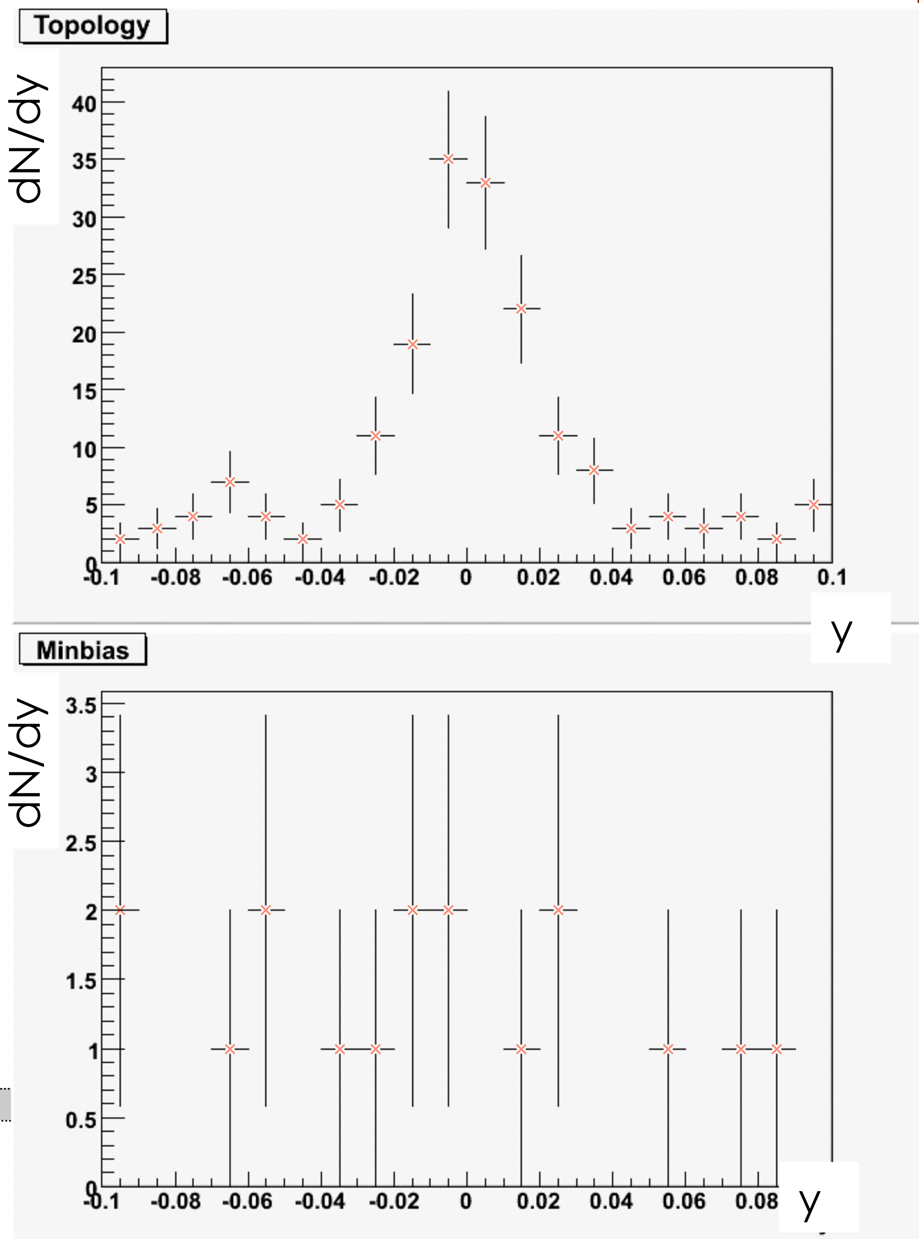
Results Summary

	$c_{preliminary}$	χ^2/dof preliminary	c	χ^2/dof
excitation				
0 < y < 0.5	1.01 ±0.09	50/47	1.01±0.08	51/47
0.5 < y < 1.0	0.78 ±0.13	72/47	0.93±0.11	80/47
No excitation				
0.1 < y < 0.5	0.71 ±0.16	81/47	0.85±0.12	88/47
0.5 < y < 1.0	1.22 ±0.21	50/47	1.06±0.21	84/47

Latest Developments

- Extended rapidity range for minbias analysis
- Systematic Error Studies
  - Fitting scheme
    - Better Fit for R(t)
  - Theory comparisons
    - STARlight
    - KNLite - Adaptation of STARlight by Jim Draper

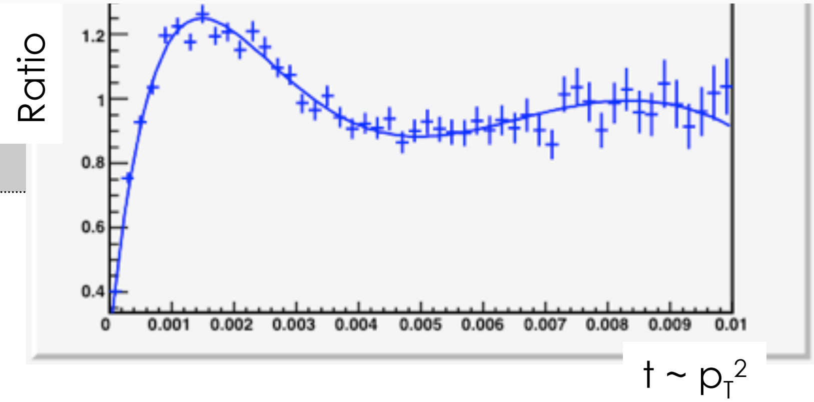
Extended rapidity range



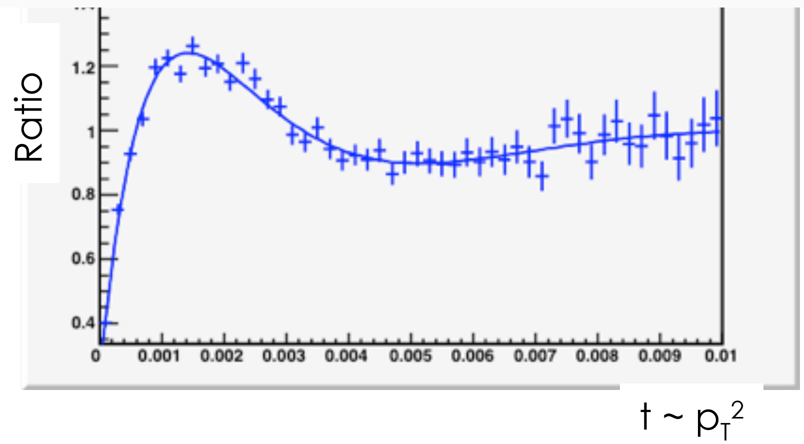
- Two rapidity ranges defined for the analysis
  - 0.1 < y < 0.5
  - 0.5 < y < 1.0
- Cut on midrapidity to eliminate cosmics
  - Effective for topology data, but unnecessary for minbias data

Fitting R(t)

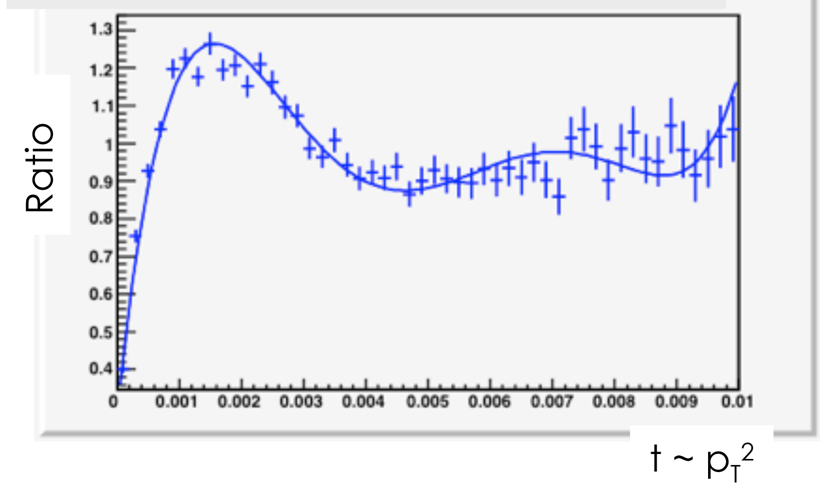
$$R(t) = a + \frac{b}{(t+0.012)} + \frac{c}{(t+0.012)^2} + \frac{d}{(t+0.012)^3} + \frac{e}{(t+0.012)^4}$$



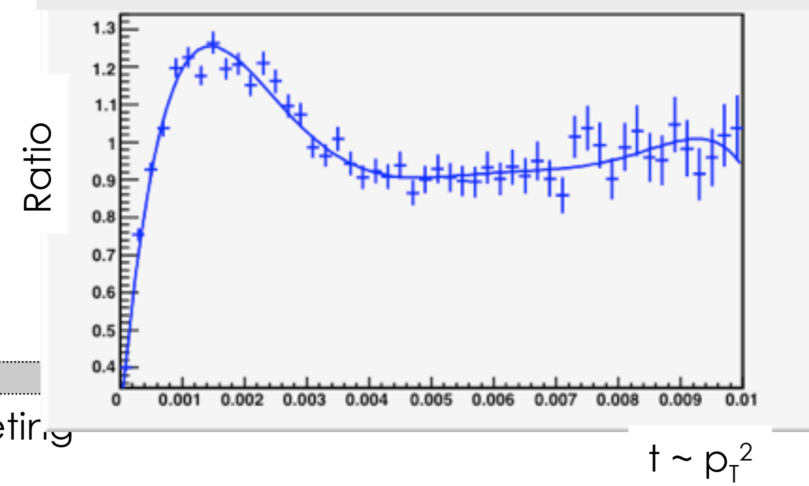
$$R(t) = a + \frac{b}{(t+0.012)} + \frac{c}{(t+0.012)^2} + \frac{d}{(t+0.012)^3} + \frac{e}{(t+0.012)^4} + \frac{f}{(t+0.012)^5}$$



$$R(t) = at^5 + bt^4 + ct^3 + dt^2 + et + f$$



$$R(t) = at^6 + bt^5 + ct^4 + dt^3 + et^2 + ft + g$$



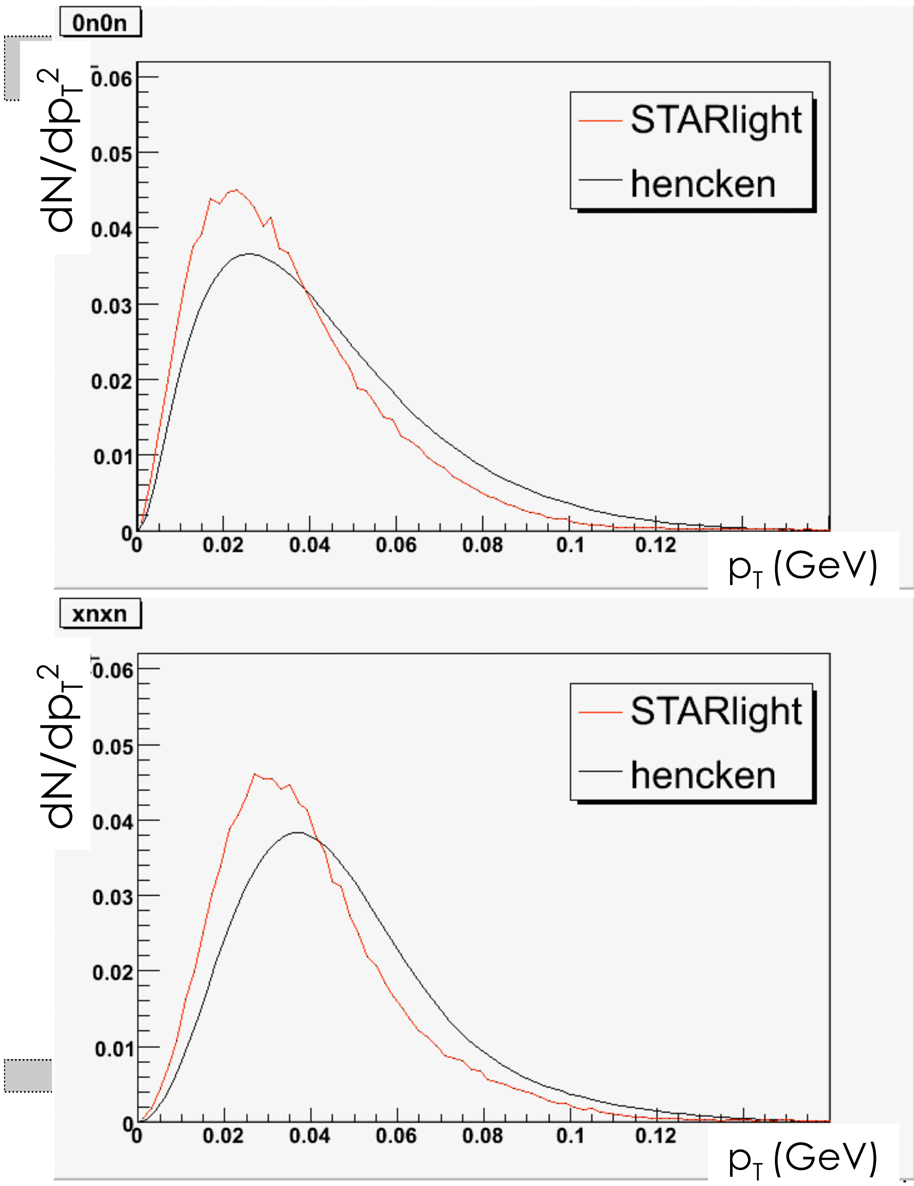
The overall fit is: $$\frac{dN}{dt} = Ae^{-kt}(1 + c[R(t) - 1])$$

We develop an estimate of the systematic error due to the fit by trying different fit functions.

Theory Comparisons

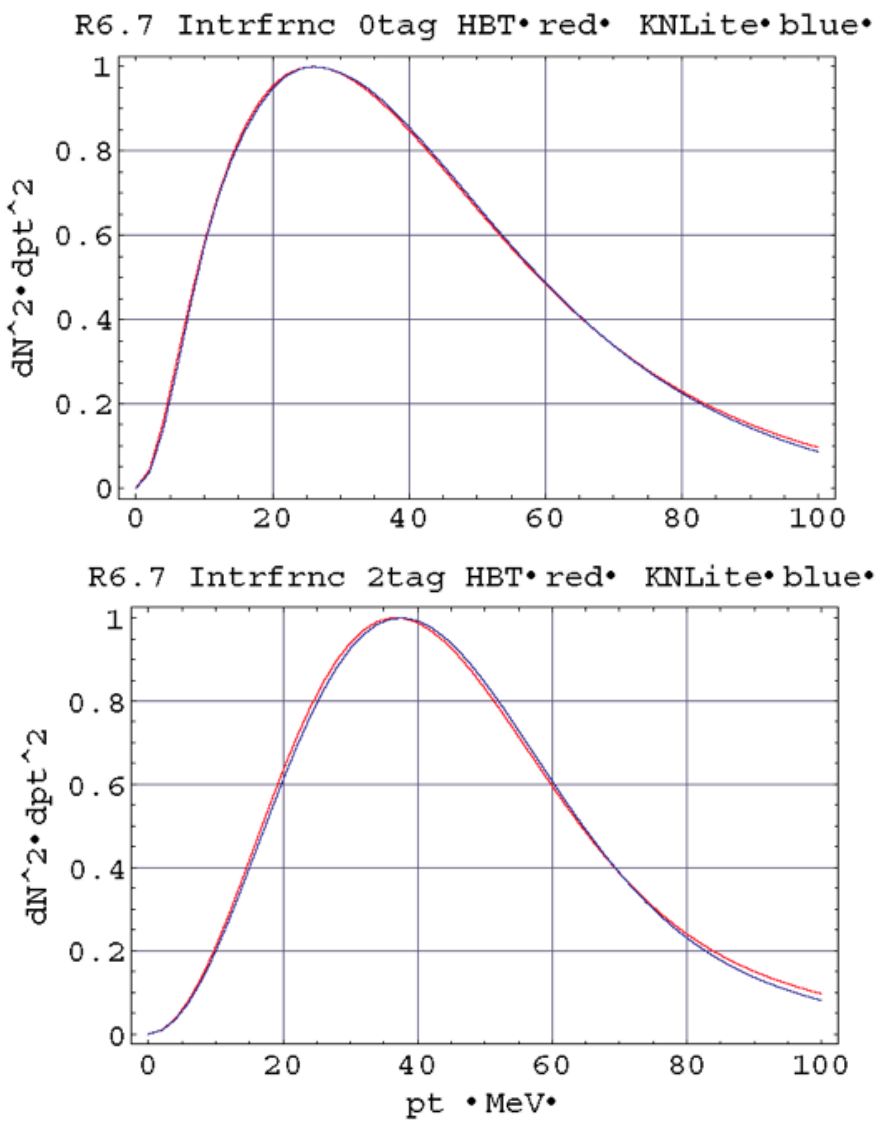
- 2 main theories describing interference:
  - STARlight - S. Klein and J. Nystrand
  - Hencken, Baur, Trautmann (HBT) PRL96(2006)012303
- New model KNLite, adaptation of STARlight - Jim Draper
  - Better understanding of R(t) [interference] out to 300 MeV
  - Better match to HBT
  - Studies of sensitivity to Nuclear Radius
  - Studies of sensitivity to m_ρ

Theory Comparisons - STARlight



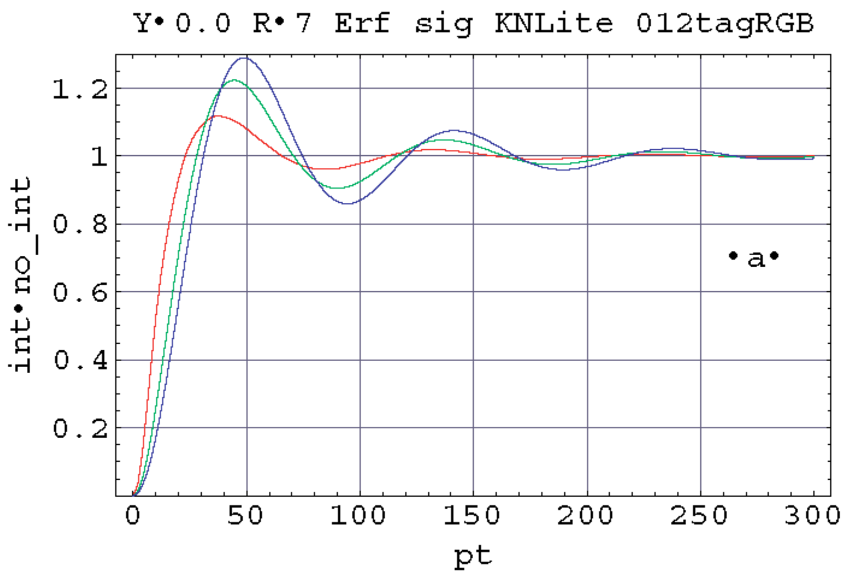
- STARlight vs. HBT predictions
  - Top = no nuclear excitation
  - Bottom = multiple nuclear excitation

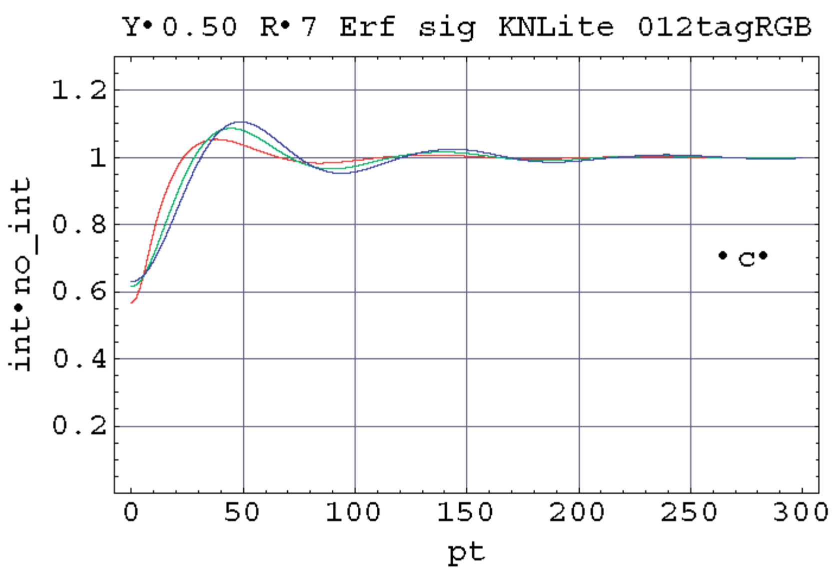
Theory Comparisons - KNLite



- KNLite vs HBT predictions
  - HBT = red, KNLite = blue
  - Top = no nuclear excitation
  - Bottom = multiple nuclear excitation

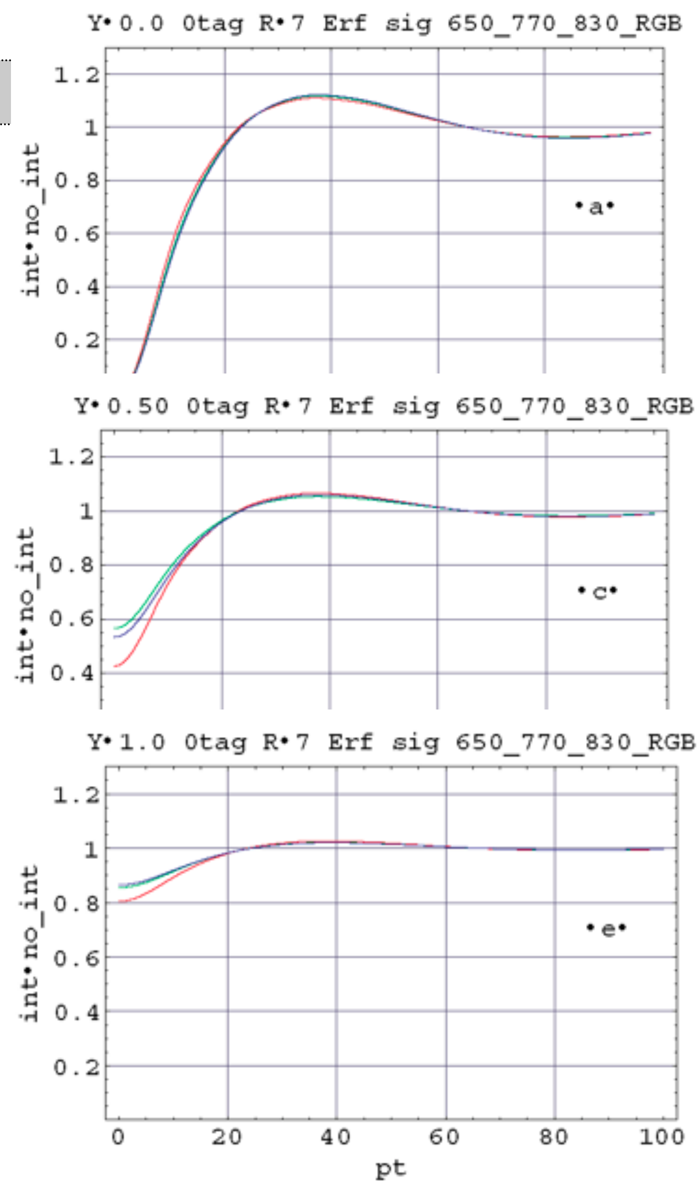
Theory Comparisons - KNLite





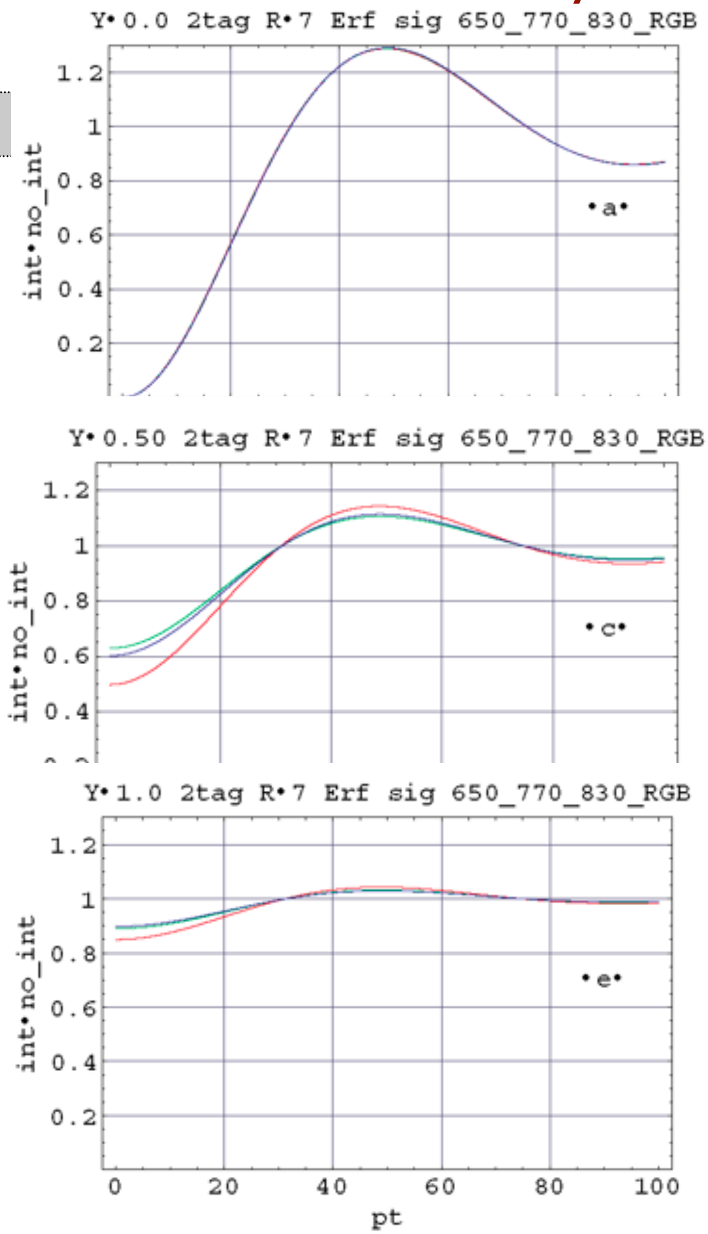
- Ratio of Interference to No Interference p_T spectra
  - Two rapidity bins: y = 0, y = 0.5
  - Red = no nuclear excitation
  - Green = single excitation
  - Blue = double excitation
- Clear evidence of interference out to 300 MeV

Theory Comparisons - KNLite



- Ratio of Interference to No Interference p_T spectra - mass dependence
  - no nuclear excitation
  - Top - y = 0
  - Middle - y = 0.5
  - Bottom - y = 1.0
  - Three mass assumptions
    - Red = ρ^0 mass = 650 MeV
    - Green = ρ^0 mass = 770 MeV
    - Blue = ρ^0 mass = 830 MeV

Theory Comparisons - KNLite



- Ratio of Interference to No Interference p_T spectra - mass dependence
  - double nuclear excitation
  - Top - y = 0
  - Middle - y = 0.5
  - Bottom - y = 1.0
  - Three mass assumptions
    - Red = ρ^0 mass = 650 MeV
    - Green = ρ^0 mass = 770 MeV
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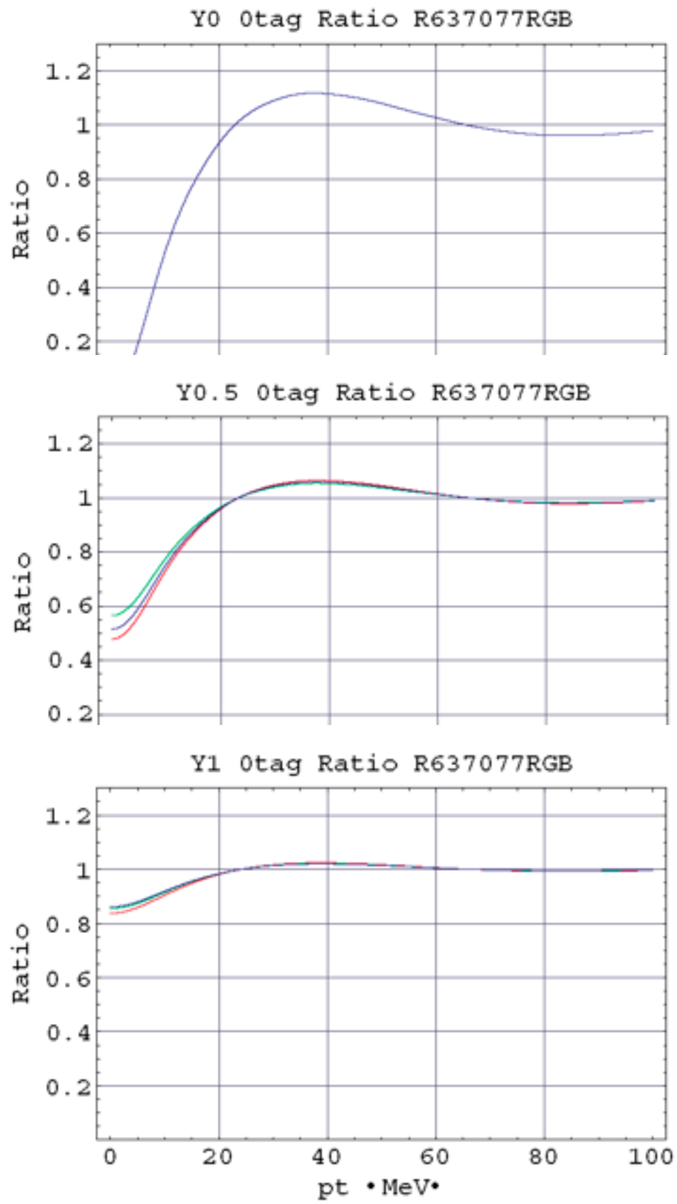
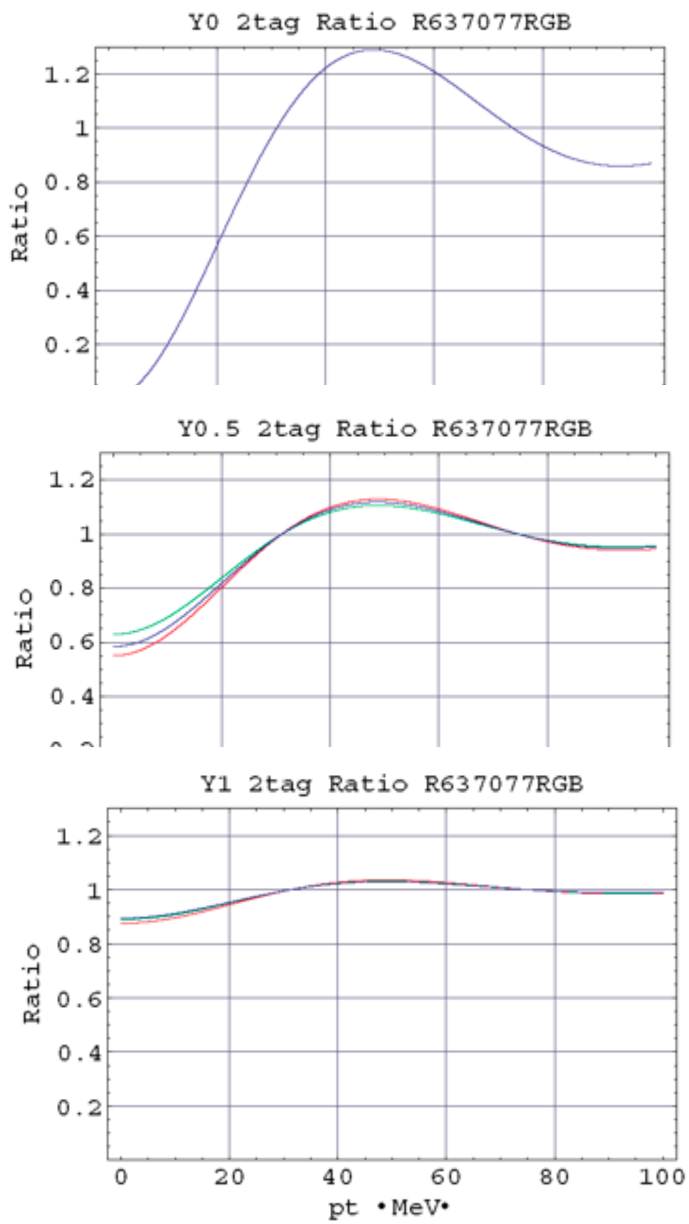
Theory Comparisons - KNLite



- Ratio of Interference to No Interference p_T spectra - nuclear radius dependence
  - no nuclear excitation
  - Top - y = 0
  - Middle - y = 0.5
  - Bottom - y = 1.0
  - Three radius assumptions
    - Red = 6.3 fm
    - Green = 7.0 fm
    - Blue = 7.7 fm

Theory Comparisons - KNLite



- Ratio of Interference to No Interference p_T spectra - nuclear radius dependence
  - double nuclear excitation
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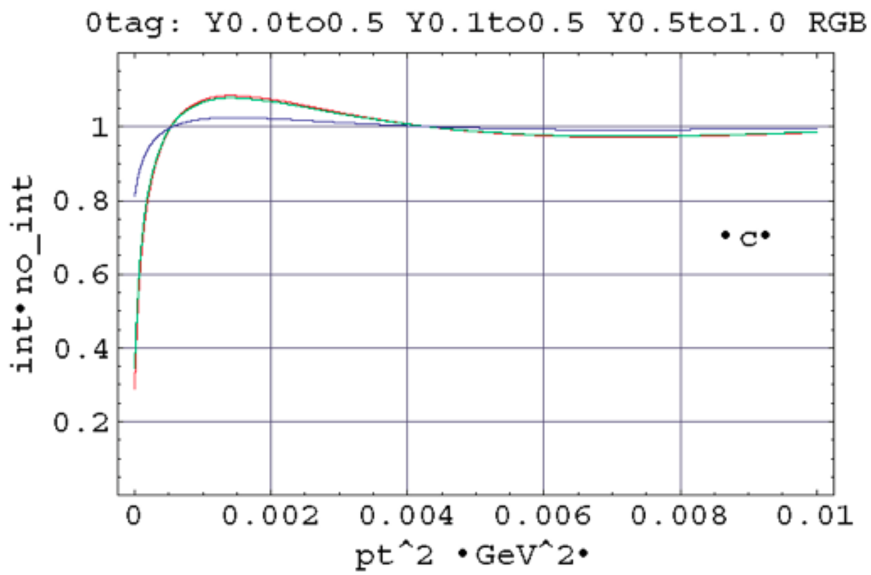
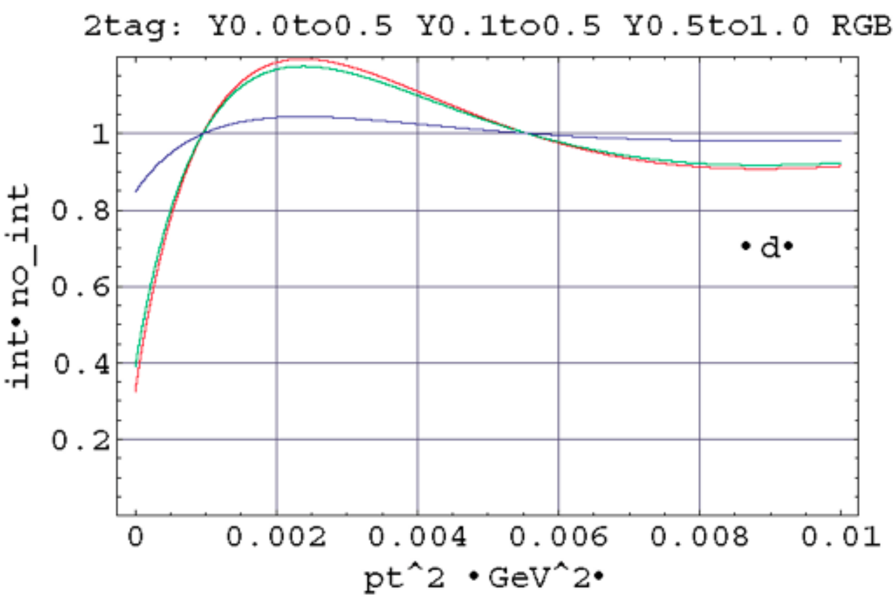
Theory Comparisons - KNLite





- Ratio of Interference to No Interference p_T^2 spectra
  - Top = no nuclear excitation
  - Bottom = double excitation
  - Three rapidity ranges
    - Red = 0.0 < y < 0.5
    - Green = 0.1 < y < 0.5
    - Blue = 0.5 < y < 1.0

Conclusions and Outlook

- Fitting scheme well refined
  - Still trouble with χ^2 on several of the fits
    - considering scaling data by $\sqrt{\chi^2}$ as outlined in particle data guide
- Good handle on systematics
  - Theory has provided biggest trouble
  - KNLite provides better idea of systematics and better comparisons to established theory
  - Likely KNLite will be used to define R(t) in the final data fits
- Paper draft currently being worked on