Interference in Vector Meson Production in Au+Au Collisions at $\sqrt{s}$ = 200GeV

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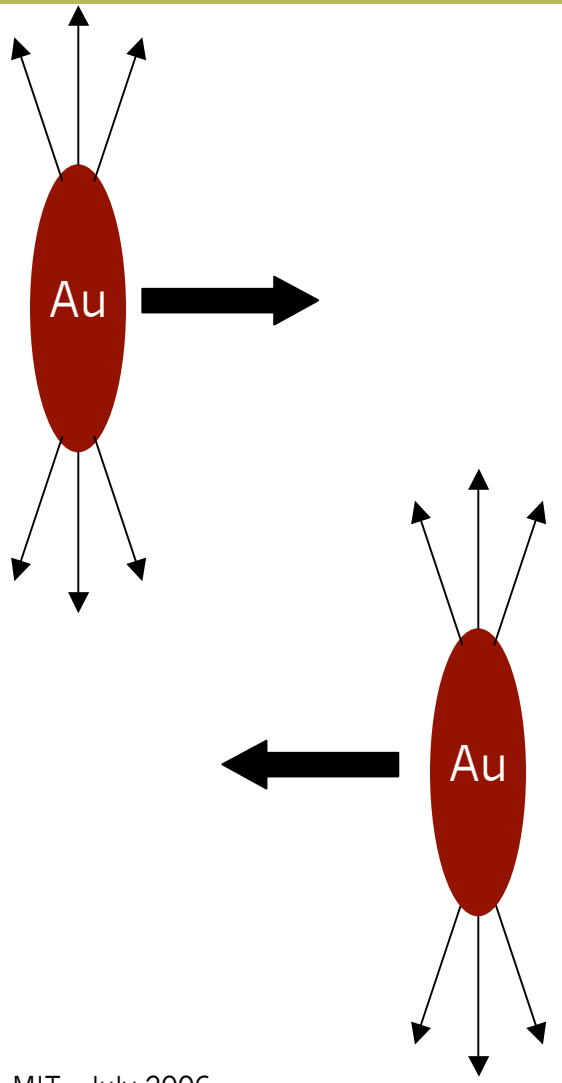
Outline

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

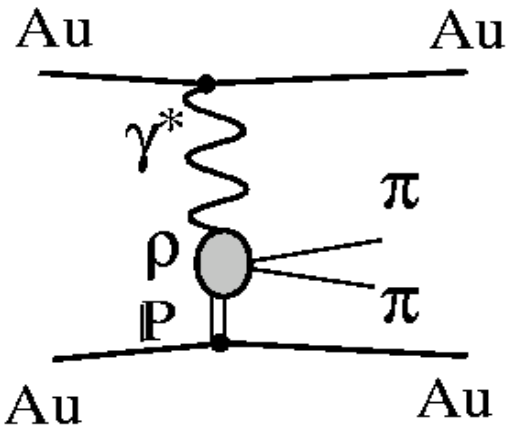
Ultra Peripheral Collisions

- 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
    (J.D. Jackson, Classical Electrodynamics, 3rd Edition, pp.724-729)
- No hadronic interactions



Exclusive ρ^o Production

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



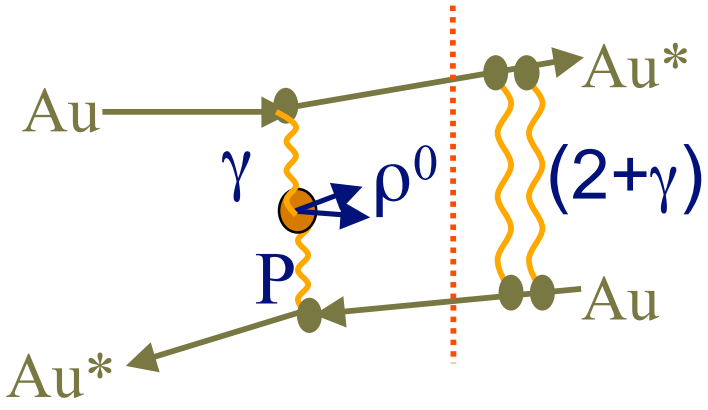
Courtesy of F. Meissner

- 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^o) emerges

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

ρ^o Production With Coulomb Excitation

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



Courtesy of S. Klein

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

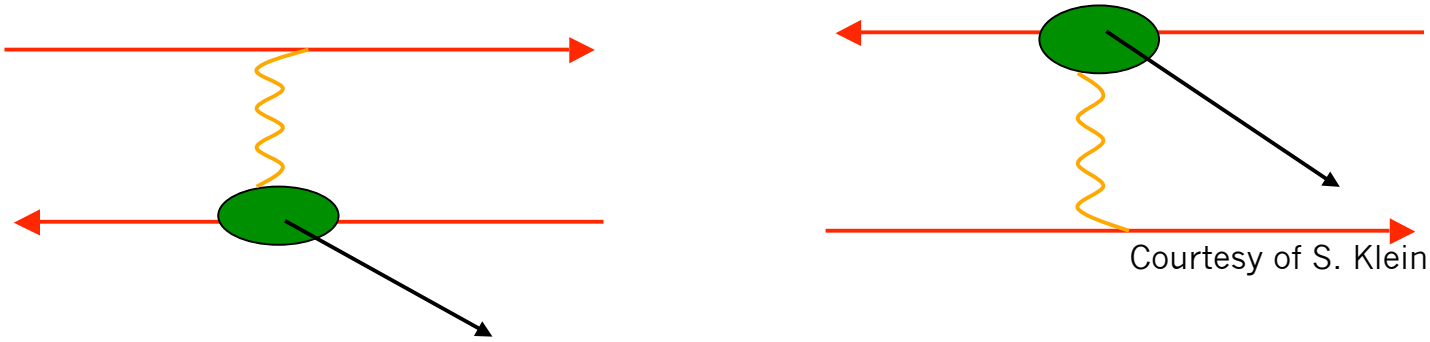
$$\sigma(AuAu \rightarrow Au^* Au^* + \rho^o) = \int d^2b P_{\rho}(b) P_{XnXn}(b)$$

Interference

Nucleus 1 emits photon which scatters from Nucleus 2

-Or-

Nucleus 2 emits photon which scatters from Nucleus 1



Courtesy of S. Klein

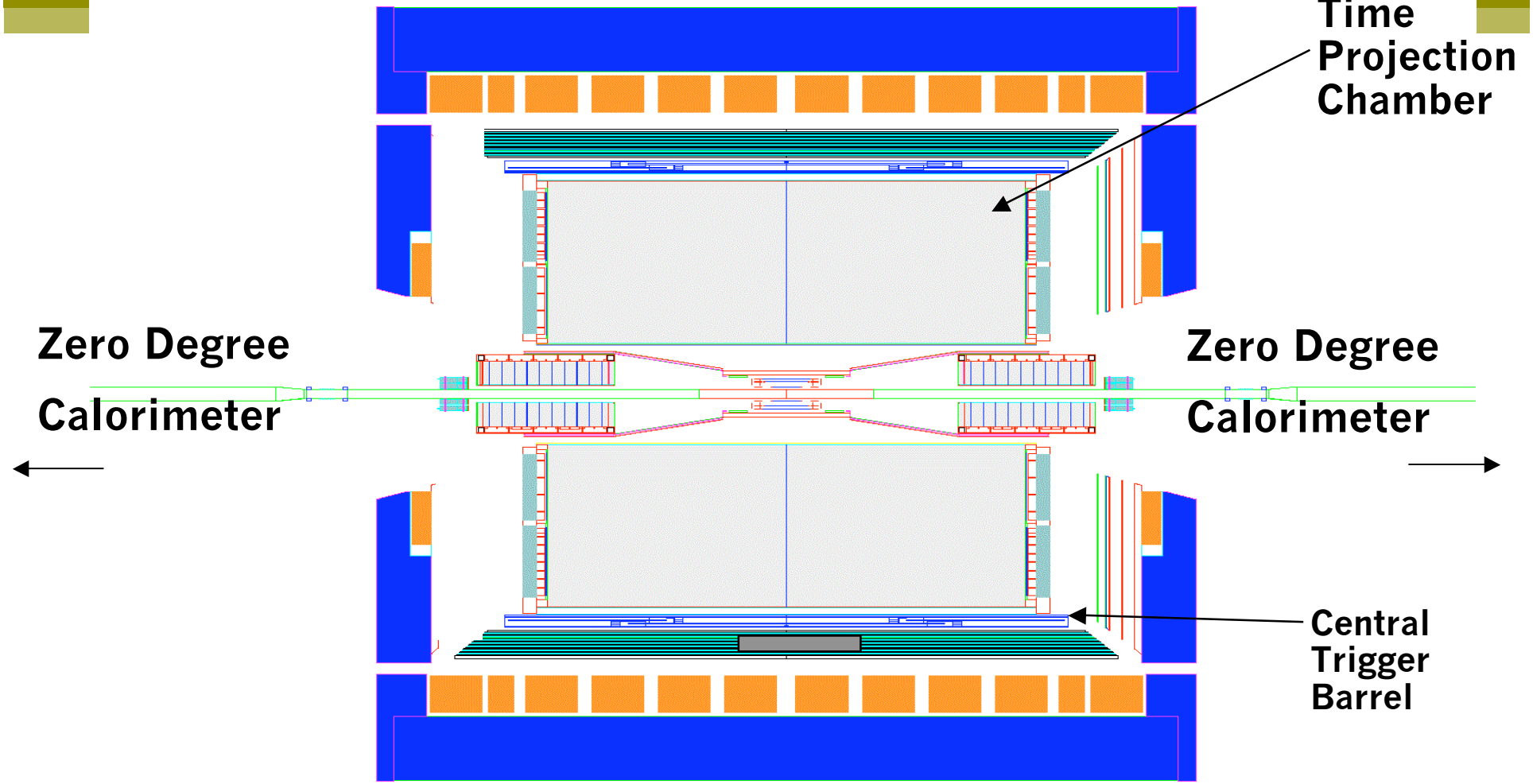
- Possibilities indistinguishable, so amplitudes combine

$$\sigma \approx \left| A_1 - A_2 e^{ip_T b} \right|^2 \quad \Rightarrow \quad A_1 = A_2$$

$$\sigma \approx \sigma_o [1 - \cos(p_T b)]$$

- At midrapidity, they cancel.
- Away from midrapidity, $A_1 \neq A_2$ and interference is reduced

STAR Analysis Detectors

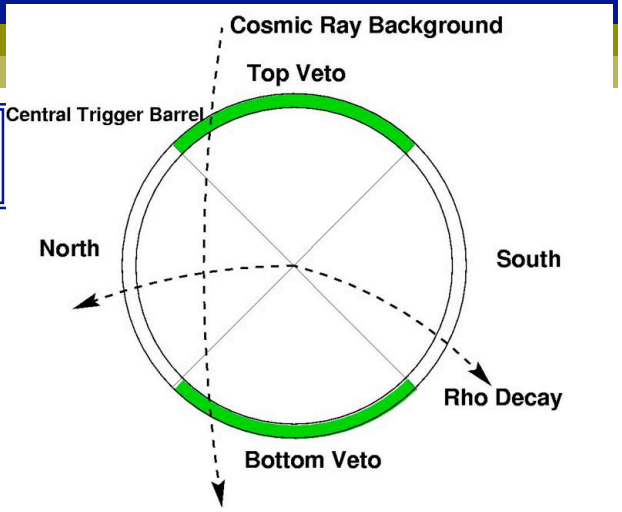


Triggers

Topology(UPC)

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

- 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



Minbias

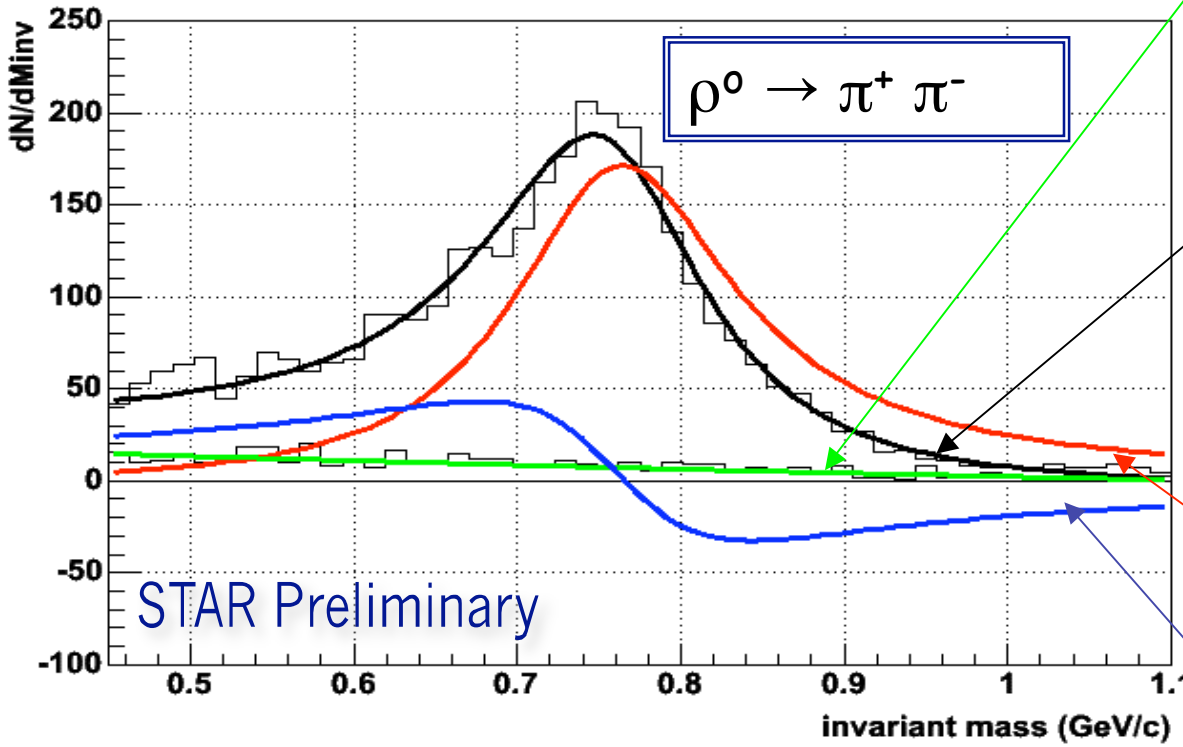
$$Au+Au \rightarrow Au^{*}+Au^{*}+\rho^{o}$$

- 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^o in 200 GeV Au+Au data



Background from like sign pairs

Overall fit

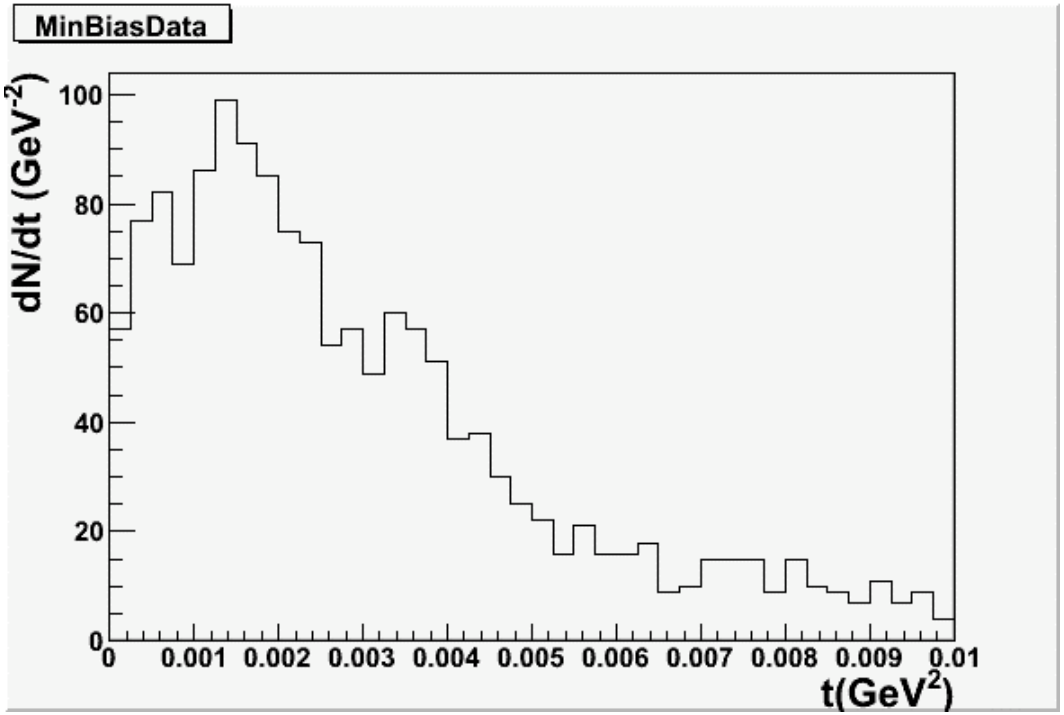
Breit-Wigner mass peak

Interference from direct pion production

- Mass measurement → .766 ± .003 GeV,
  Particle Data Book → .770 GeV
- Width measurement → .165 ± .006 GeV,
  Particle Data Book → .149 GeV

Measuring the Interference

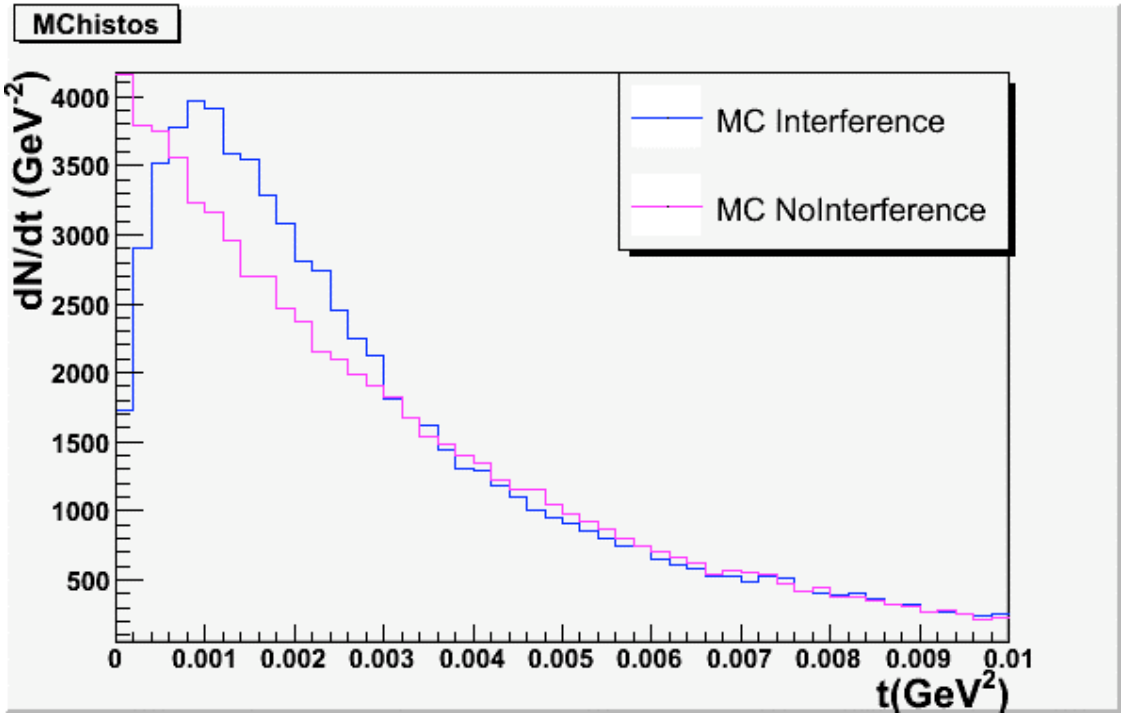
- *Determine ρ^o candidates by applying cuts to the data*



qTot	0
nTot	2
nPrim	2
|zVertex|	< 50 *cm*
|rVertex|	< 8 *cm*
rapidity	> 0.1 < 0.5
M_{Inv}	> 0.55 *MeV* < 0.92 *MeV*
p_T	> 0 *GeV* < 0.1 *GeV*

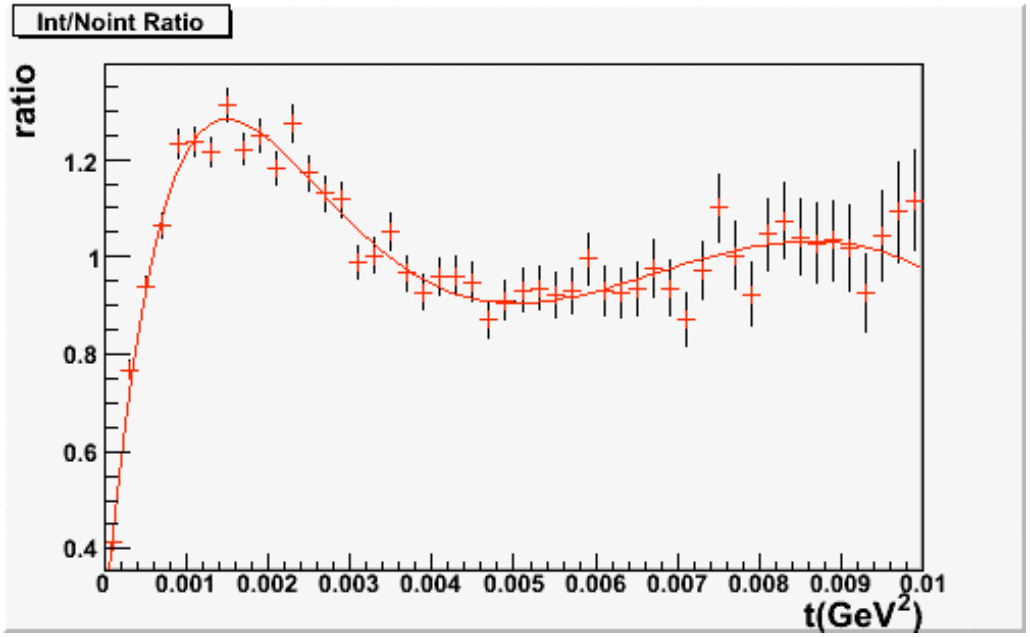
Measuring the Interference

- *Generate similar MC histograms*



Measuring the Interference

- *Generate MC ratio*
- *Fit MC ratio*



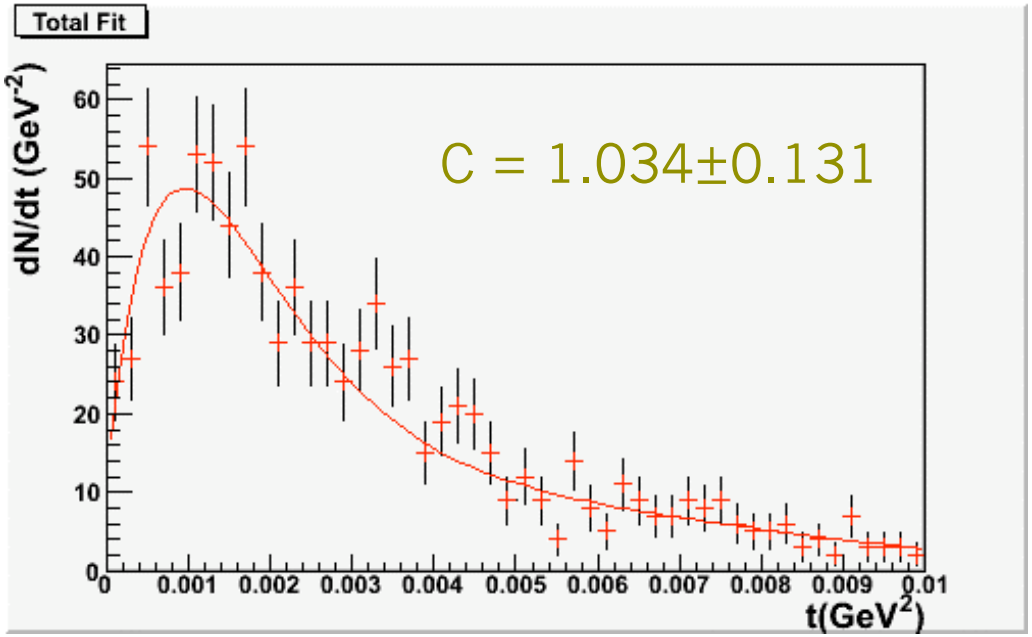
$$f(t) = a + \frac{b}{(t+0.012)} + \frac{c}{(t+0.012)^2} + \frac{d}{(t+0.012)^3} + \frac{e}{(t+0.012)^4}$$

Measuring the Interference

- *Apply overall fit*

$$\frac{dN}{dt} = Ae^{-kt}(1 - cR(t))$$

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



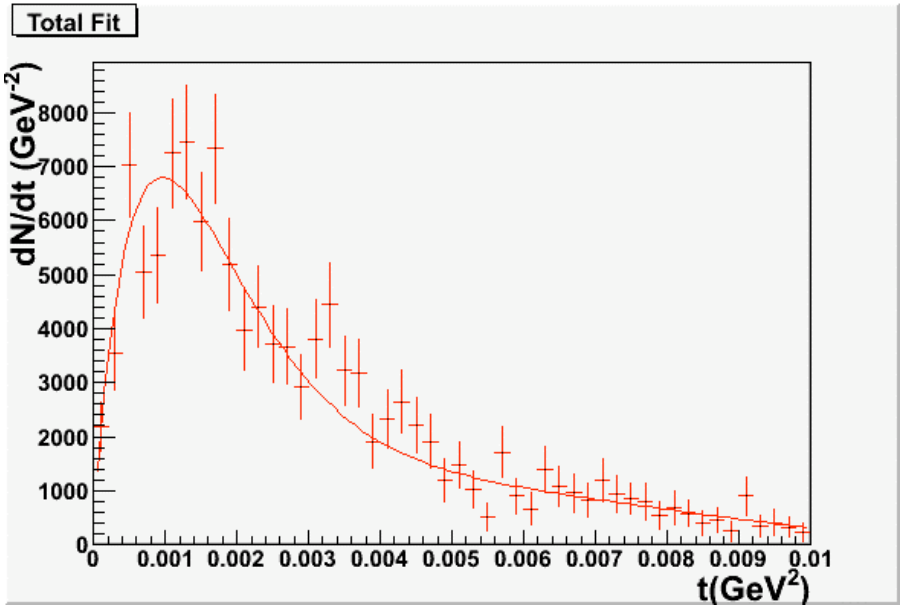
c = 1

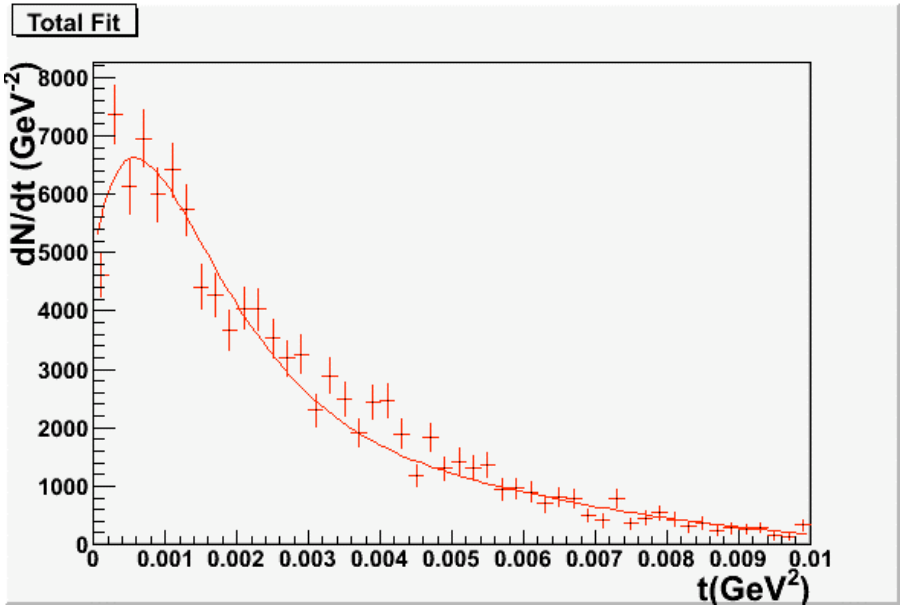
expected degree of interference

c = 0

no interference

Results





Minbias

Au+Au → Au*+Au*+ρ°

C = 1.009±0.081

χ^2/DOF = 50.77/47

Topology

Au+Au → Au+Au+ρ°

C = 0.8487±0.1192

χ^2/DOF = 87.92/47

Results Summary

	c	χ^2/dof
Minbias		
0.5 > y > 0.1	1.009± 0.081	50.77/47
1.0 > y > 0.5	0.9275± 0.1095	80.18/47
Topology		
0.5 > y > 0.1	0.8487± 0.1192	87.92/47
1.0 > y > 0.5	1.059± 0.208	83.81/47

Systematic Error Study

	Standard Cut	Varied Cut	Data Set	Uncertainty
zVertex	|zVertex| < 50	zVertex > 0	minbias	0.0422
			topology	0.1883
		zVertex < 0	minbias	0.1188
			topology	0.0379
rapidity	0.1 < y < 0.5	0.1 < y < 0.5	minbias	0.0935

Systematic Error Study

Fit	Data Set	Uncertainty	
6 parameter	minbias	0.013	1.3%
	topology	0.008	0.9%

Summary

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
  $c_{avg} = 0.96 \pm 0.28(stat.) \pm 0.08(sys.) \pm 0.15(theory)$
- Currently in the process of systematic error study and refining fitting scheme.