Observation of Coherent $\phi(1020)$ Resonance in Photonuclear Ultra-Peripheral Collisions at STAR

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Motivation

Physics Goals

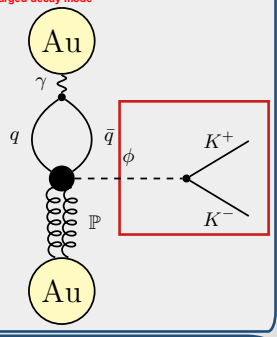
- Utilize ultra-peripheral collisions for clean electromagnetic interactions with minimal hadronic background.
- Leverage meson production for sensitivity to the nuclear gluon density profile.
- Probe gluon distributions at low Bjorken-*x* using ϕ meson photoproduction.
- Test and constrain vector meson production cross-section models, including Vector Meson Dominance and Color Dipole Model.

Why ϕ ?

- Larger dipole size than J/ψ.
- Larger invariant mass(1019 MeV) than the ρ meson(770 Mev).
- The larger color dipole size enhances ϕ's sensitivity to saturation effects compared to J/ψ
- Unlike the ρ meson, ϕ's higher mass enables more reliable perturbative QCD calculations.
- UPC Photoproduction cross section has not been measured for ϕ.

Measure $\phi \to K^+K^-$ Decay Channel

The dominant charged decay mode



Particle Identification

- Kaons are identified via TPC dE/dx, using Nσ_K(the deviation from the expected kaon energy loss) for each track, and combining both tracks' PID information with $\chi^2_{KK} \equiv N\sigma_K^1 + N\sigma_K^2$.

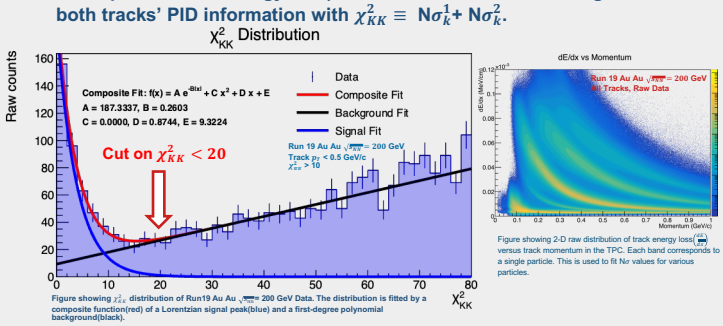
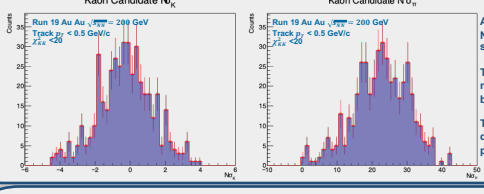


Figure showing χ^2_{KK} distribution of Run19 Au Au $\sqrt{s_{NN}}$ = 200 GeV Data. The distribution is fitted by a composite function(red) of a Lorentzian signal peak(blue) and a first-degree polynomial background(black).

Figure showing 2-D raw distribution of track energy loss $\left(\frac{dE}{dx}\right)$ versus track momentum in the TPC. Each band corresponds to a single particle. This is used to fit Nσ values for various particles.

- Kaon Candidates(events that pass PID cut) Quality Check



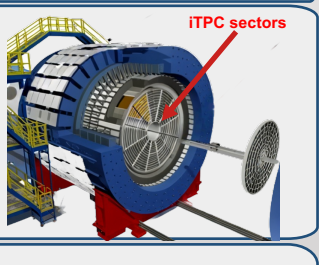
After pair-wise PID selection, the track-wise Nσ distribution for kaons and pions are shown.

The Gaussian-like N$\sigma_K$distribution centered near 0 indicates the sample is dominated by kaons.

The non-zero central value in the Nσ_π distribution highlights suppression of the pion background.

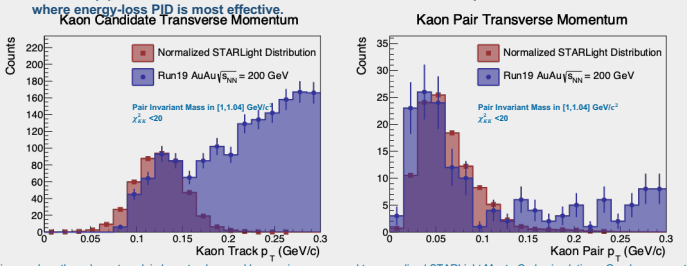
Data Set

- Run 19 Au+Au $\sqrt{s_{NN}} = 200$GeV
- First data set with the STAR inner Time Projection Chamber(iTPC) upgrade fully operational.
- The iTPC upgrade significantly improves acceptance for low-momentum kaons, which is crucial for reconstructing coherent ϕ mesons.



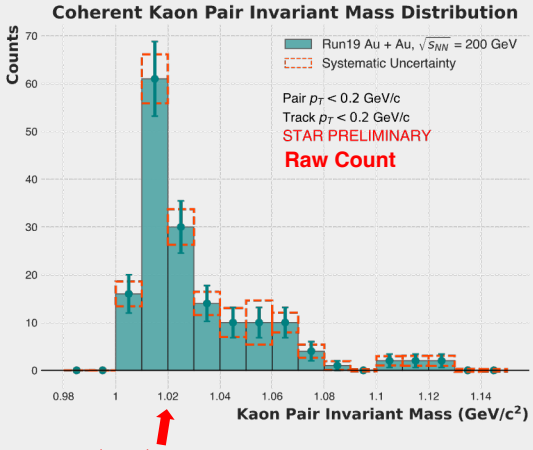
Coherent Event Selection

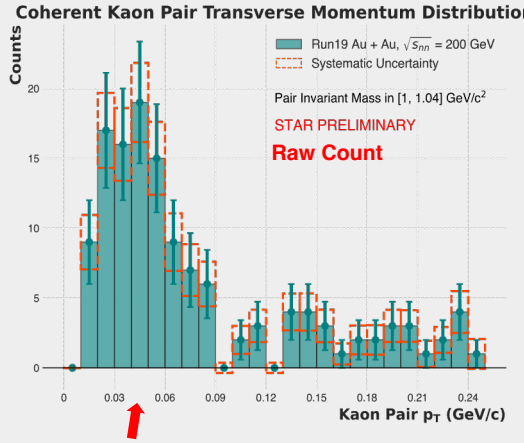
- Coherent ϕ production refers to ϕ meson production off the entire nucleus, leaving it intact and resulting in low transverse momentum due to minimal momentum transfer.
- Coherent ϕ production is of interest due to its clear, narrow kinematic peak at low transverse momentum, where energy-loss PID is most effective.



Figures show the coherent peak in kaon track p_T and kaon pair p_T compared to normalized STARLight Monte Carlo simulations. Good agreement is observed between data and STARLight, suggesting that coherent events can be selected by requiring each kaon track $p_T < 0.2$ GeV/c and reconstructed kaon pair $p_T < 0.2$ GeV/c .

Results





Conclusion and Outlook:

1. Illustrated Clear resonance in both invariant mass and pair transverse momentum.
2. Cross section calculation work in progress.
   Provides a step toward constraining model calculations for vector meson photoproduction.
3. Data production that possibly contains ~100x more coherent ϕ is on-going at STAR.
   Enables differential cross section studies in forward and backward rapidity, potentially revealing suppression effects from gluon saturation.

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