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

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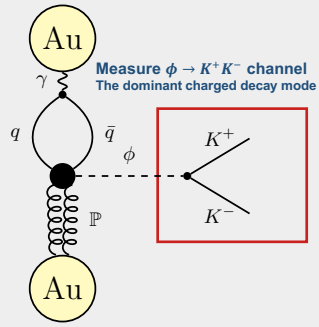
Motivation

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.

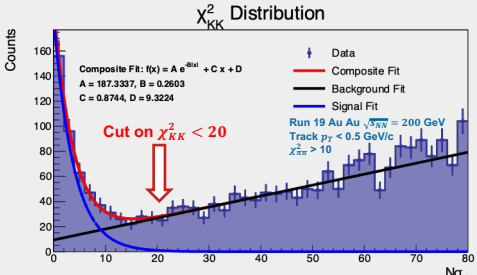
Why ϕ ?

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



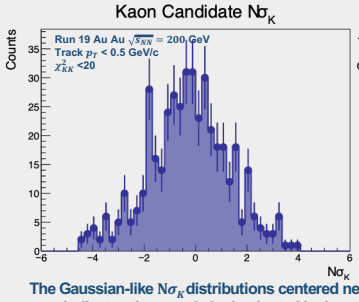
Particle Identification

- 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 $\chi^2_{KK} \equiv$ Nσ^1_k+ Nσ^2_k.

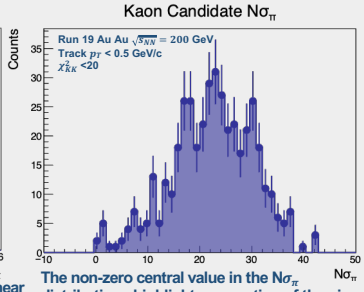


- Figure showing χ^2_{KK} distribution of Run19 Au Au $\sqrt{s_{nn}}$= 200 GeV Data.
- The distribution is fitted by a composite function(red) of a Lorentzian signal peak(blue) and a first-degree polynomial background(black).

- **Kaon Candidates(events that pass PID cut) Quality Check**
  After pair-wise PID selection, the track-wise Nσ distributions for kaons and pions are shown.



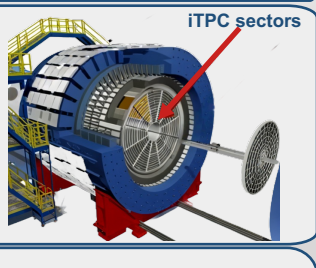
The Gaussian-like Nσ_K distributions centered near zero indicates the sample is dominated by kaons.



The non-zero central value in the Nσ_π distributions highlights separation of the pion background.

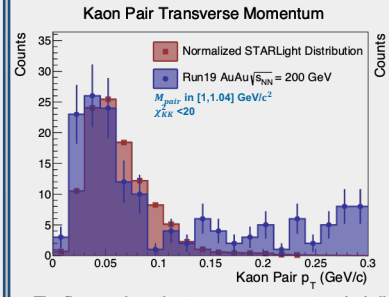
Data Set

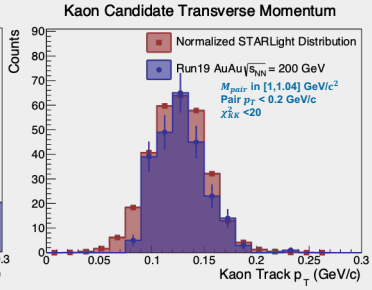
- Run 19 Au+Au $\sqrt{s_{NN}} = 200$GeV
- First data set with the STAR inner Time Projection Chamber(iTPC) upgrade fully operational.
- The iTPC upgrade significantly improves acceptance for low-momentum kaons, which is crucial for reconstructing coherent ϕ mesons.



Coherent Event Selection

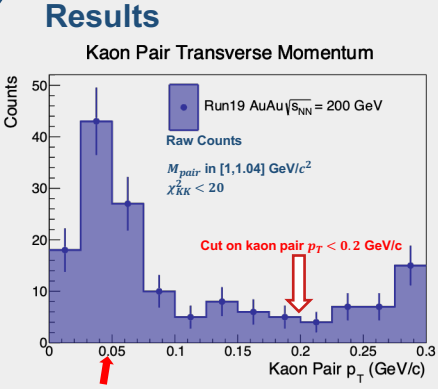
- Coherent ϕ production refers to ϕ meson production off the entire nucleus, leaving it intact and resulting in low transverse momentum due to minimal momentum transfer.
- Coherent ϕ production is of interest due to its clear, narrow kinematic peak at low transverse momentum, where energy-loss PID is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

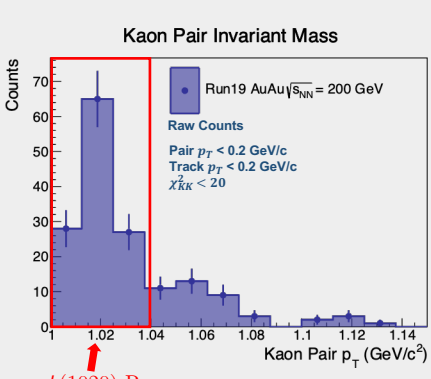




The figures show the transverse momentum (p_T) distributions of individual kaon tracks and kaon pairs, compared to normalized STARLight Monte Carlo simulations. A good agreement is observed between data and simulation, indicating that coherent events can be effectively selected by requiring each kaon track to have p_T < 0.2 GeV/c and the reconstructed kaon pair to also have p_T < 0.2 GeV/c.

Results





Conclusion and Outlook:

1. Illustrated clear coherent peak at low pair transverse momentum.
2. Demonstrated clear resonance peak at the ϕ invariant mass.
3. Cross section calculation is in. This will provide a step toward constraining model calculations for vector meson photoproduction.
4. Data production that possibly contains ~100x more coherent ϕ is on-going at STAR. This will enable differential cross section studies in forward and backward rapidity, potentially revealing suppression effects from gluon saturation.

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