Phenomenology studies of the resonance lineshape/yield modifications in XeW@2.87 GeV

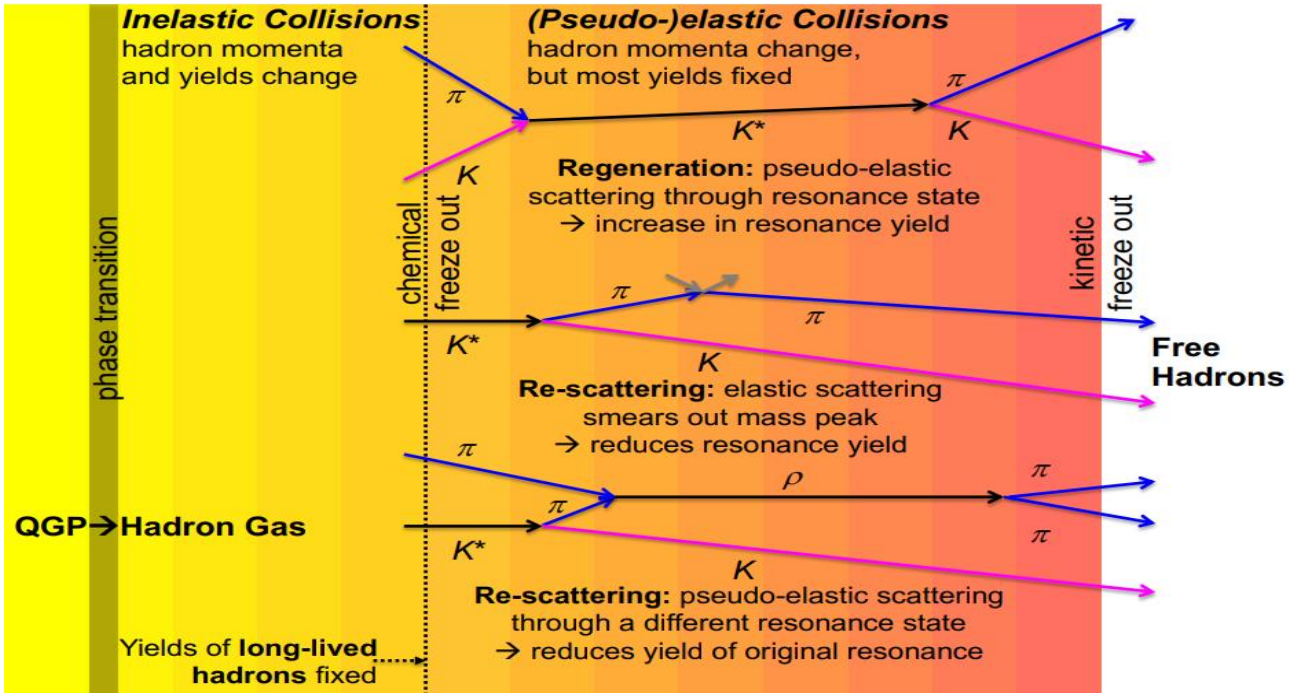
M.Malaev, D. Ivanishchev, V.Riabov

* We acknowledge support from Russian Ministry of Education and Science, state assignment for fundamental research (code FSEG-2025-0009)

Hadronic phase and medium modifications

increasing lifetime →

	ρ(770)	K*(892)	Λ(1520)	Ξ(1530)	ϕ(1020)
cτ (fm/c)	1.3	4.2	12.7	21.7	46.2
$\sigma_{rescatt}$	$\sigma_\pi\sigma_\pi$	$\sigma_\pi\sigma_K$	$\sigma_K\sigma_p$	$\sigma_\pi\sigma_\Xi$	$\sigma_K\sigma_K$



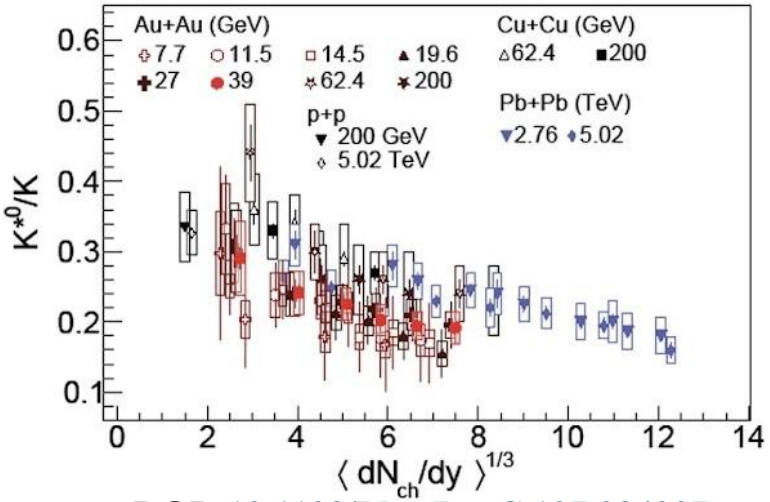
- Resonances have small lifetimes of cτ ~ 1 - 45 fm, part of them decays in the fireball
- Reconstructed resonance yields in heavy ion collisions are defined by:
  - ✓ resonance yields at chemical freeze-out
  - ✓ hadronic processes between chemical and kinetic freeze-outs:

    rescattering: daughter particles undergo elastic scattering or pseudo-elastic scattering through a different resonance → parent particle is not reconstructed → loss of signal

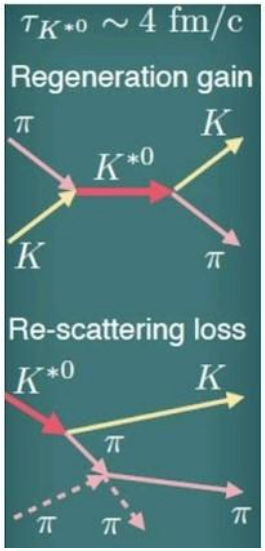
    regeneration: pseudo-elastic scattering of decay products ($\pi K \rightarrow K^{*0}$, $KK \rightarrow \phi$ etc.) → increased yields

Hadronic phase and medium modifications

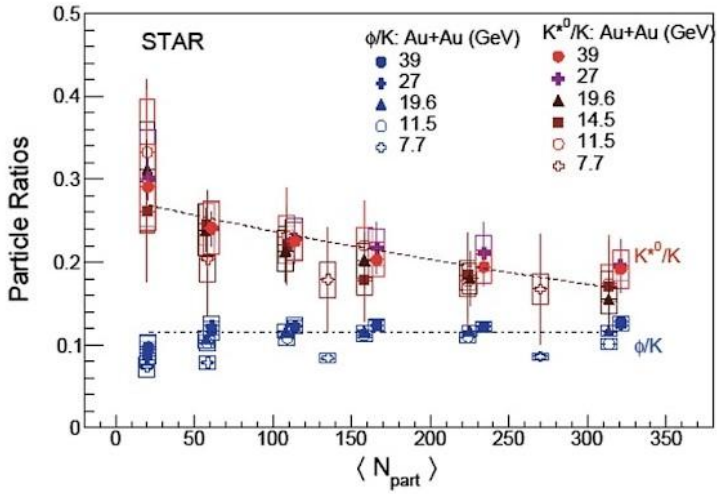
Ratio K^{*0} to K from BES data suggests re-scattering loss in medium due to shorter lifetime of K^{*0}



DOI: 10.1103/PhysRevC.107.034907



The K^{*0}/K ratio shows a centrality dependence and follows the same trend among different collision energies. On the contrary, the ϕ/K ratio is mostly independent of centrality.



increasing lifetime ⟶

	ρ(770)	K*(892)	Σ(1385)	Λ(1520)	Ξ(1530)	ϕ(1020)
cτ (fm/c)	1.3	4.2	5.5	12.7	21.7	46.2
$\sigma_{rescatt}$	$\sigma_\pi\sigma_\pi$	$\sigma_\pi\sigma_K$	$\sigma_\pi\sigma_\Lambda$	$\sigma_K\sigma_p$	$\sigma_\pi\sigma_\Xi$	$\sigma_K\sigma_K$

Reconstructed resonance yields in heavy ion collisions are defined by:

- ✓ resonance yields at chemical freeze-out
- ✓ hadronic processes between chemical and kinetic freeze-outs:

rescattering: daughter particles undergo elastic scattering or pseudo-elastic scattering through a different resonance → parent particle is not reconstructed → loss of signal

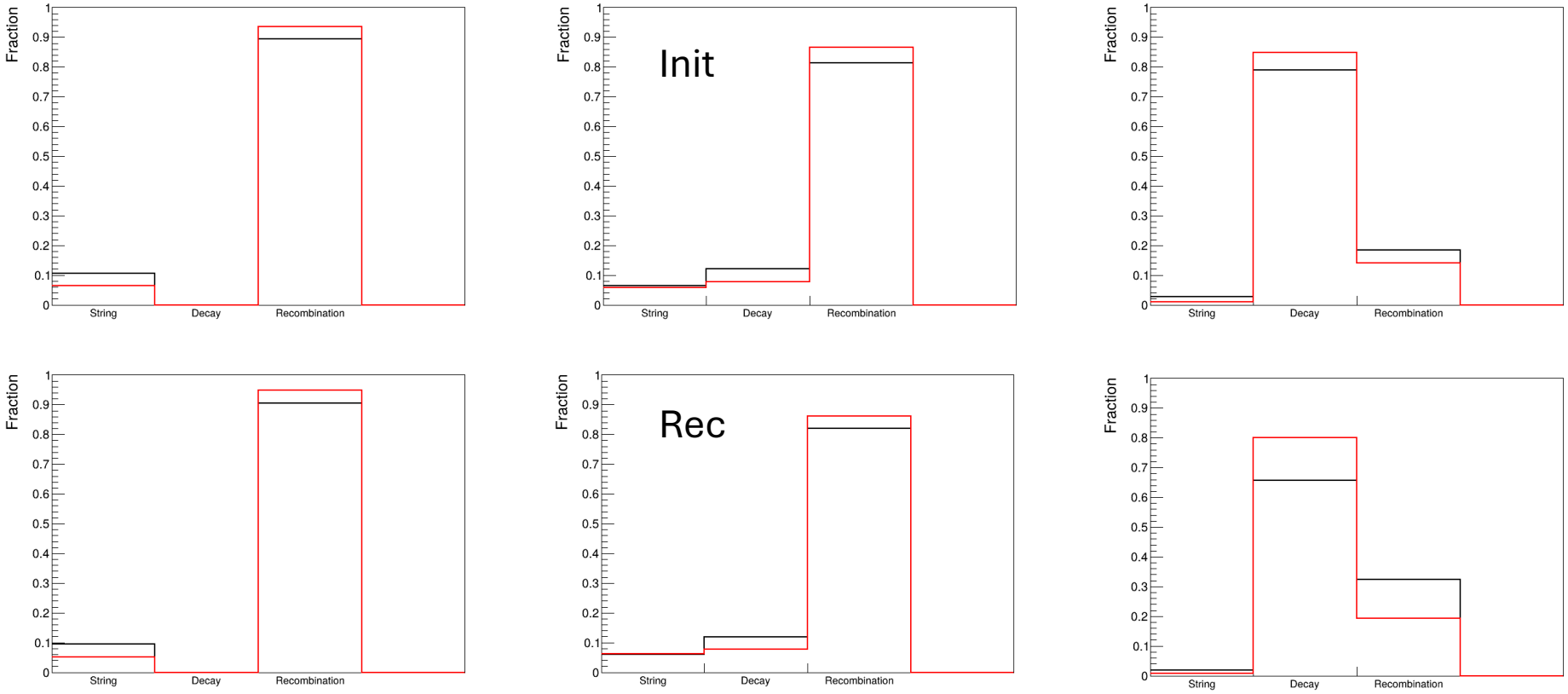
regeneration: pseudo-elastic scattering of decay products ($\pi K \rightarrow K^{*0}$, $KK \rightarrow \phi$ etc.) → increased yields

Analysis Details

- Data: Xe+W@2.87 GeV, UrQMD (v3.4) no specific configurations
- Output.f14 – all final state particles at 200 fm
- Output.f15 – all collisions in the event
- Resonances: $\phi \rightarrow K^{+}K^{-}$ ($c\tau \sim 45$ fm/c), $K^{*}(892)^{0} \rightarrow \pi^{\pm}K^{\pm}$ ($c\tau \sim 4.2$ fm/c), $\rho(770)^{0} \rightarrow \pi^{+}\pi^{-}$ ($c\tau \sim 1.3$ fm/c)
- Rapidity range: $-1.0 < Y_{cms} < 1.0$
- Number of charged hadrons in the event → centrality estimation
- Init distributions – Invariant mass of the resonance reconstructed via daughter particles at decay moment
- Rec distributions – Invariant mass of the resonance reconstructed via daughter particles from Output.f14 (if present) – after all possible interactions in hadron gas stage

Production mechanisms

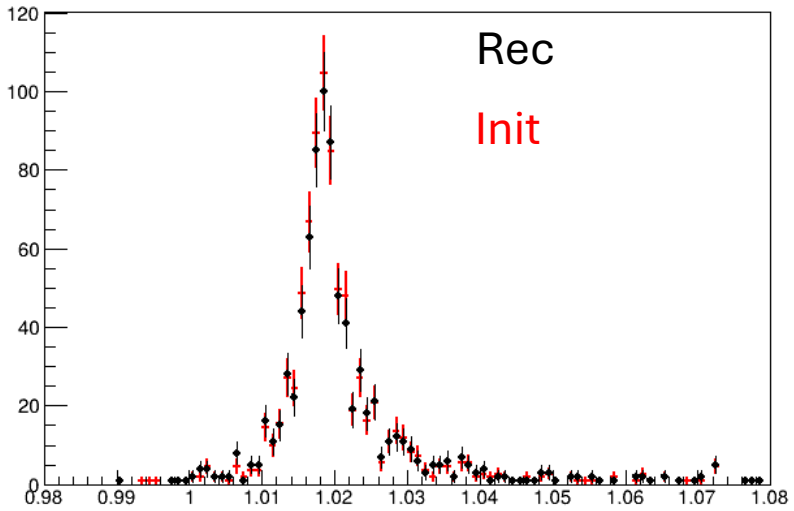
ϕ(1020) K*(892)^0 ρ(770)



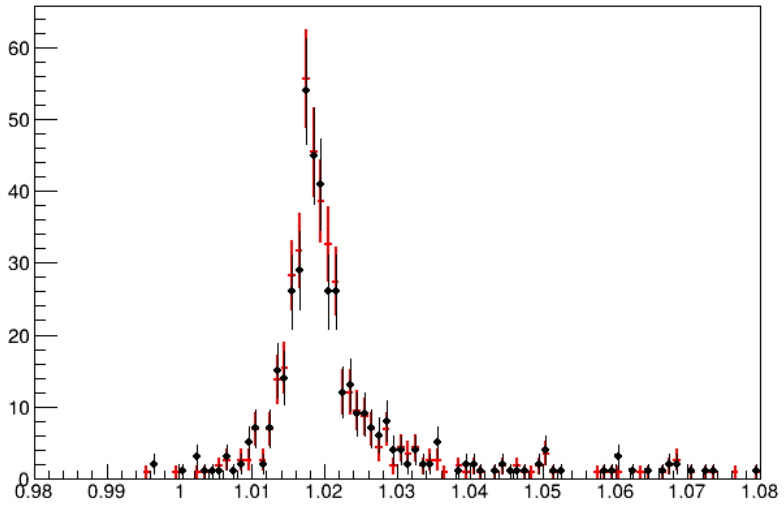
- Fraction of: String, Decay, Recombination (Urqmd prediction)
- Recombination is dominant φ(1020) and K*(892)^0
- Decays is dominant for ρ(770)^0

φ(1020) Peak Shape

Peripheral



Central

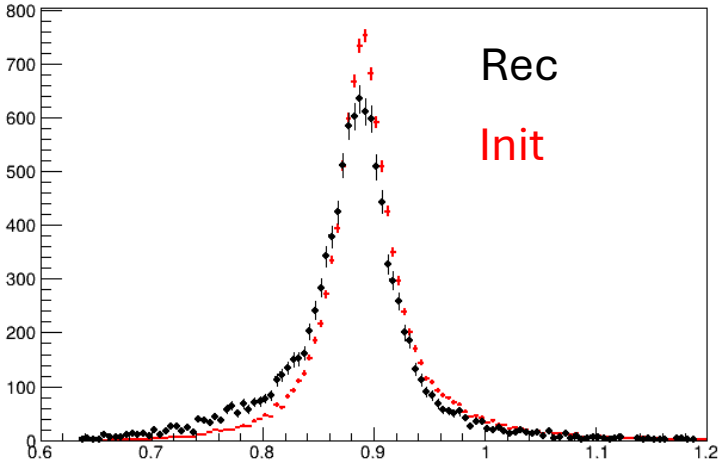


- Resonances are decayed by UrQMD, daughters participate in elastic and inelastic scattering
- Resonance are reconstructed by invariant mass method according to decay channels
- $\phi \rightarrow K^{+}K^{-}$ ($c\tau \sim 45$ fm/c): no line shape modifications

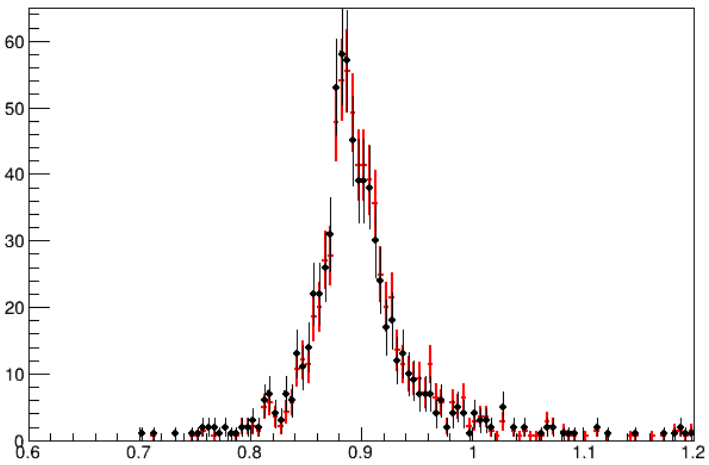
$K^*(892)^0$ Peak Shape

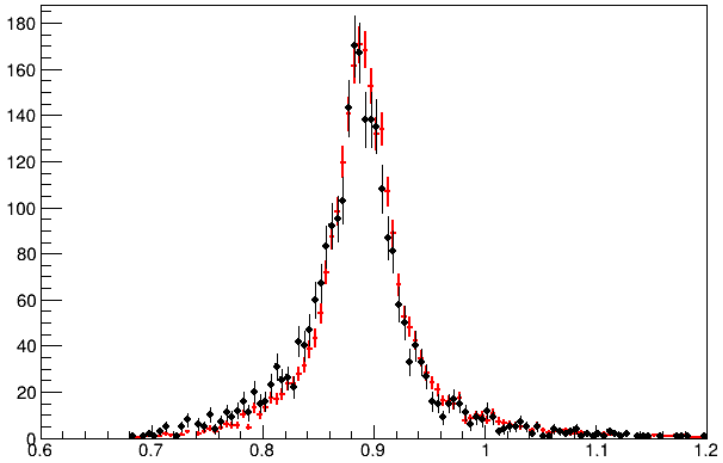
0 < pT < 0.5 GeV/c

pT > 1.5 GeV/c

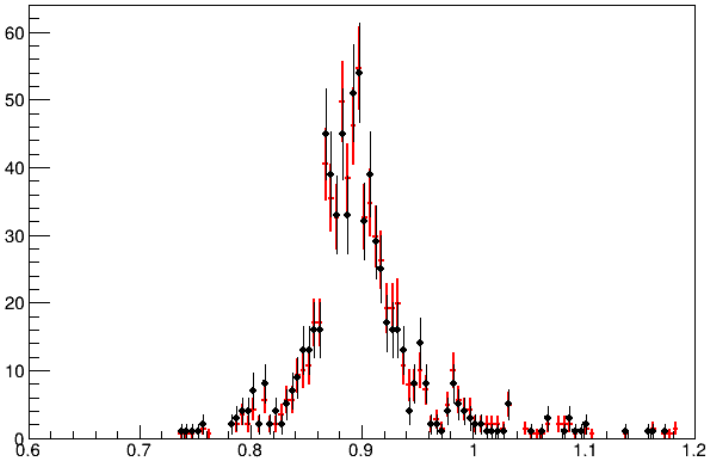


Central





Peripheral

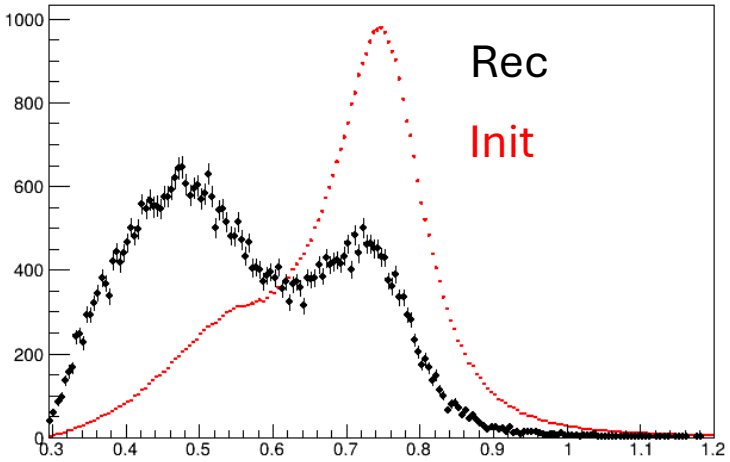


- Resonances are decayed by UrQMD, daughters participate in elastic and inelastic scattering
- Resonance are reconstructed by invariant mass method according to decay channels
- $K^*(892)^0 \rightarrow \pi^{\pm}K^{\pm}$ ($c\tau \sim 4.2$ fm/c): modest line shape modifications in central collisions

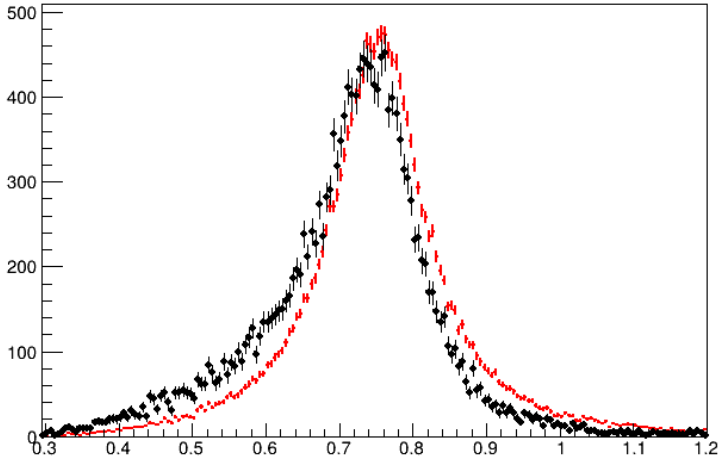
ρ(770) Peak Shape

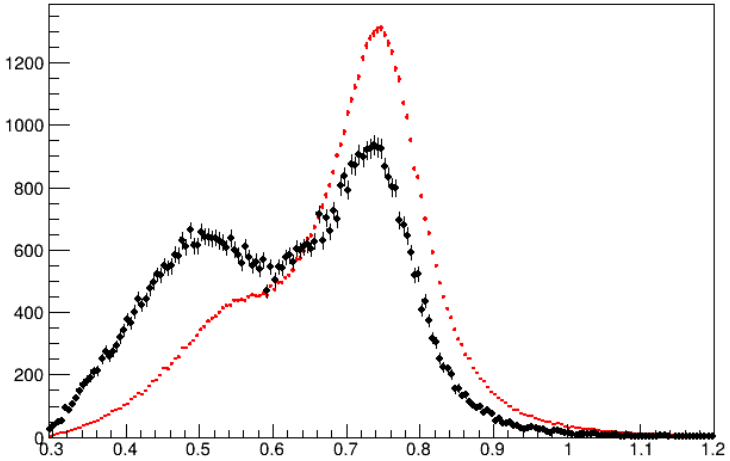
0 < pT < 0.5 GeV/c

pT > 1.5 GeV/c

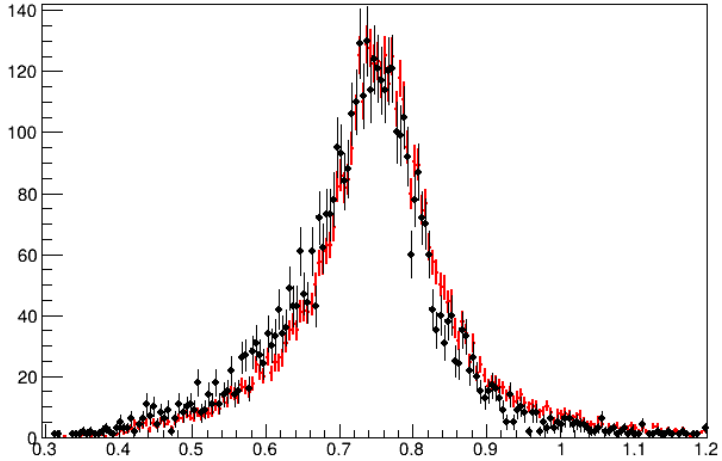


Central



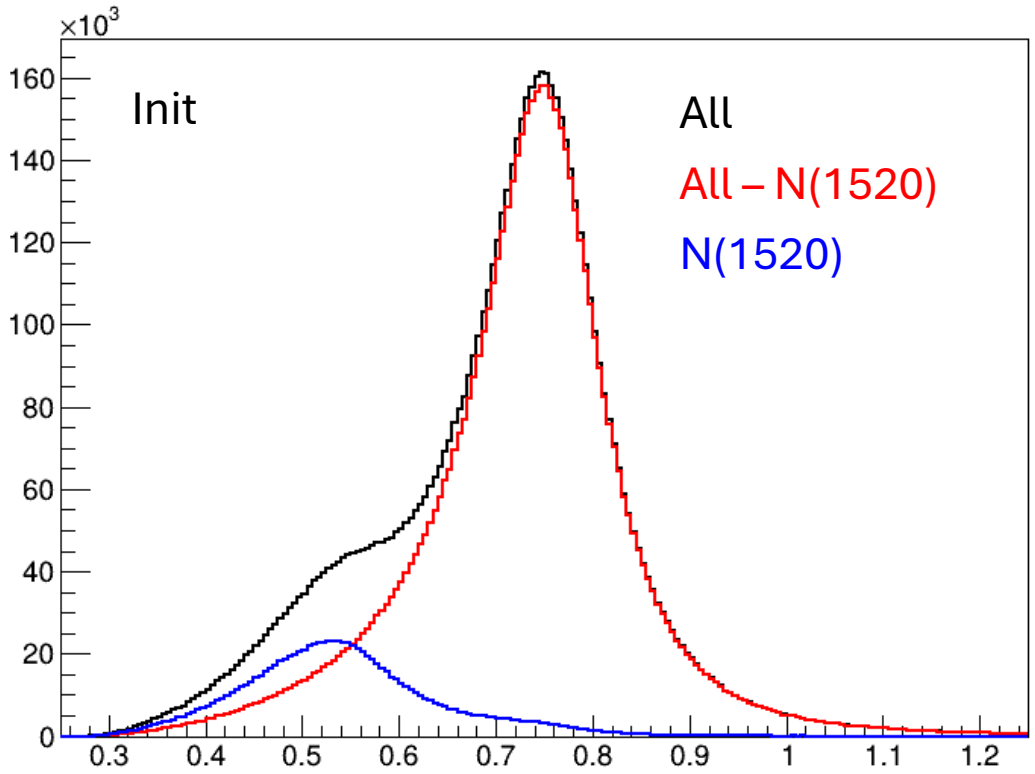


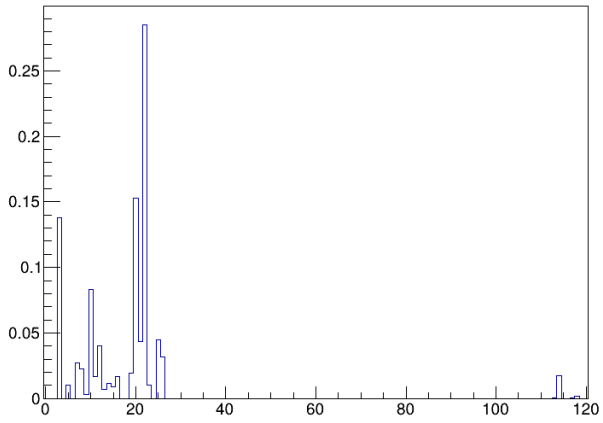
Peripheral



- Resonances are decayed by UrQMD, daughters participate in elastic and inelastic scattering
- Resonance are reconstructed by invariant mass method according to decay channels
- $\rho(770)^0 \rightarrow \pi^+\pi^-$ ($c\tau \sim 1.3$ fm/c): significant line shape modifications at low p_T

ρ(770) from decays





~28% Δ(1905) decays

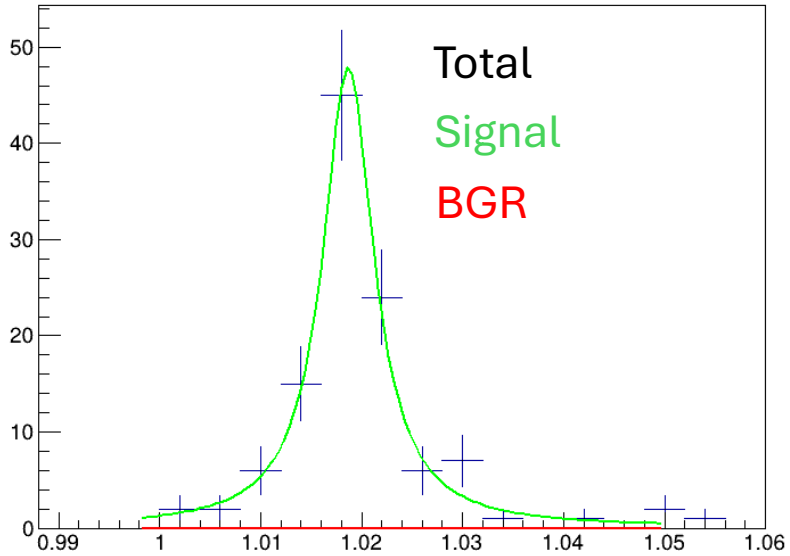
- $\rho(770)^0 \rightarrow \pi^+\pi^-$ ($c\tau \sim 1.3$ fm/c)
- Initial distributions deviate from default peak line shape
- Modification due to ρ from N(1520) decays (N(1520) → N + ρ)

Analysis Details

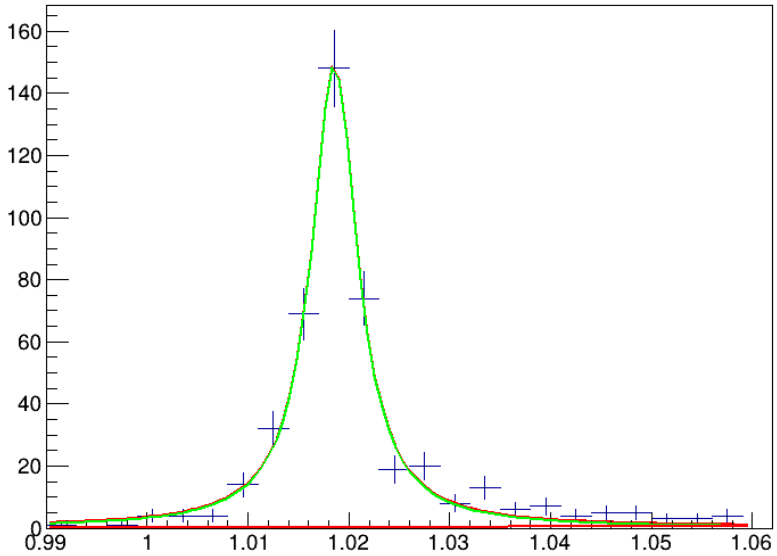
- Resonances: $\phi \rightarrow K^{+}K^{-}$ ($c\tau \sim 45$ fm/c), $K^{*}(892)^{0} \rightarrow \pi^{\pm}K^{\pm}$ ($c\tau \sim 4.2$ fm/c), $\rho(770)^{0} \rightarrow \pi^{+}\pi^{-}$ ($c\tau \sim 1.3$ fm/c)
- Rapidity range: $-1.0 < Y_{cms} < 1.0$
- Init distributions – Invariant mass of the resonance reconstructed via daughter particles at decay moment
- Rec distributions – Invariant mass of the resonances reconstructed via daughter particles from Output.f14 (if present)
- Use fitting function like in real data analysis (no mass resolution factor) for Rec distributions – Signal + BGR

φ(1020) Peak Shape

Peripheral

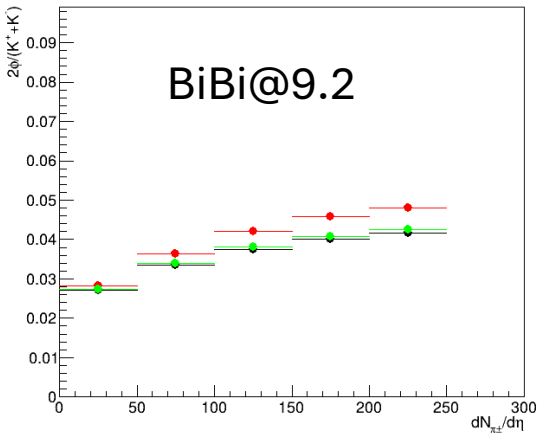


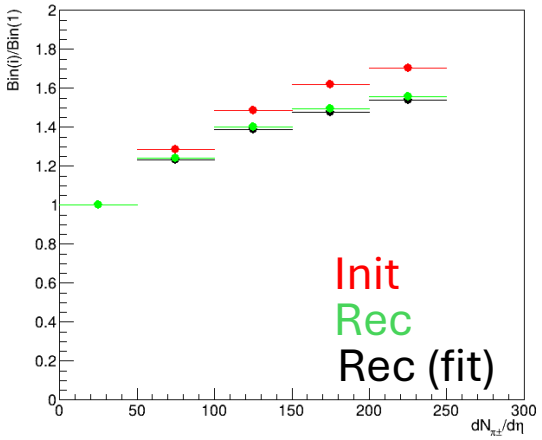
Central

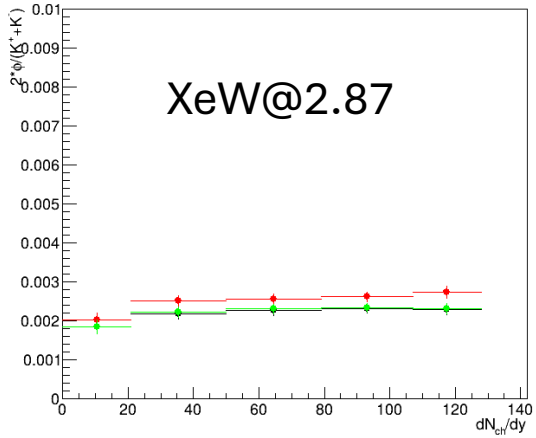


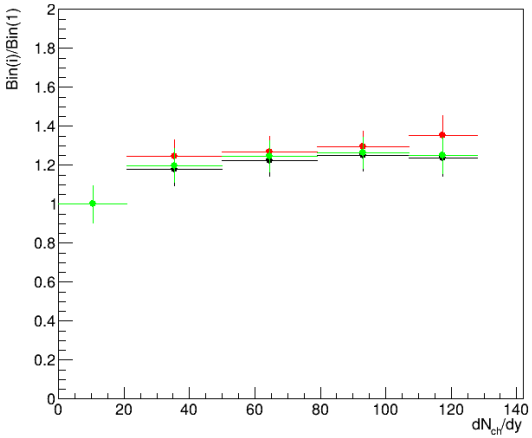
- $\phi \rightarrow K^{+}K^{-}$ ($c\tau \sim 45$ fm/c)
- No peak shape modifications
- Rec peaks described by signal function, no contribution from BGR function

φ(1020) to K ratio

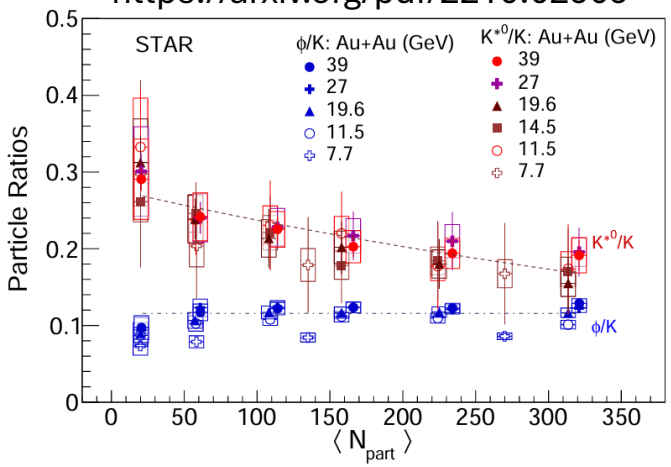






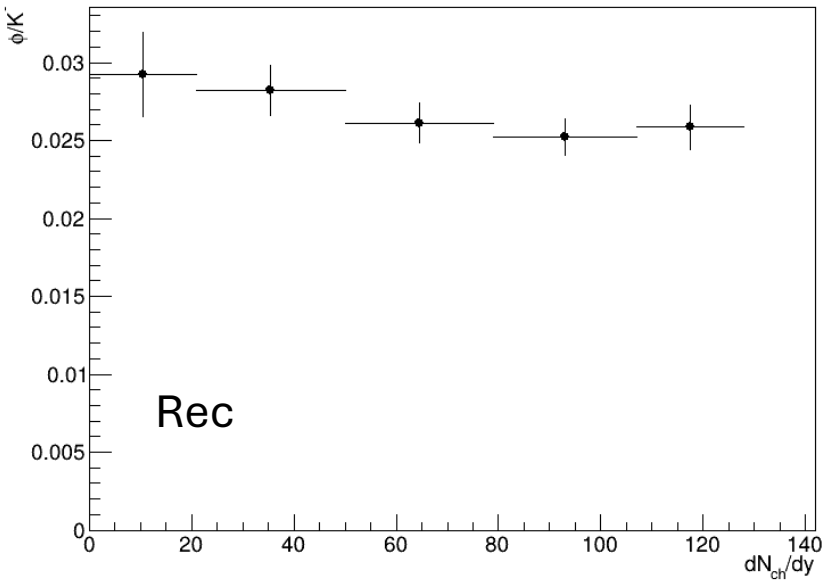


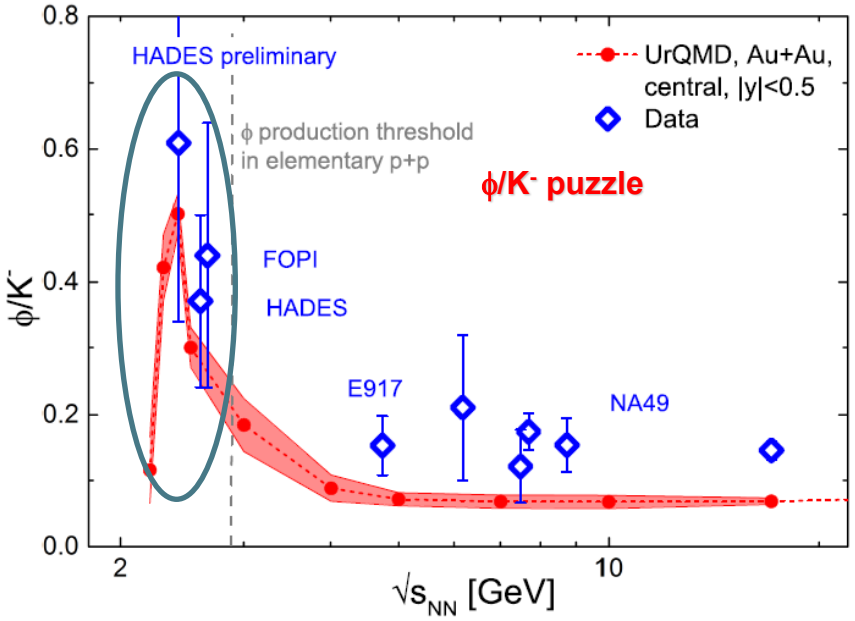
https://arxiv.org/pdf/2210.02909



- $\phi \rightarrow K^{+}K^{-}$ ($c\tau \sim 45$ fm/c),
- No losses due to peak shape modification
- Small losses due to daughter annihilation or inelastic rescattering
- Almost flat distribution
- Urqmd underestimates phi production

φ(1020) to K ratio

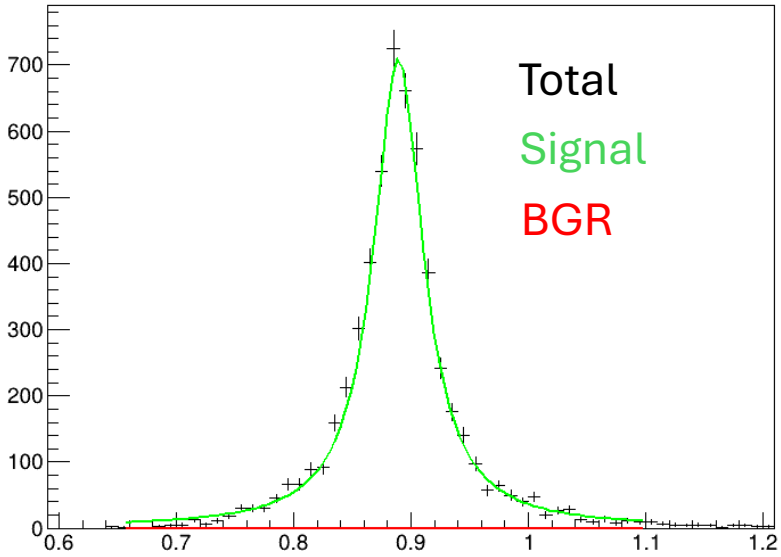




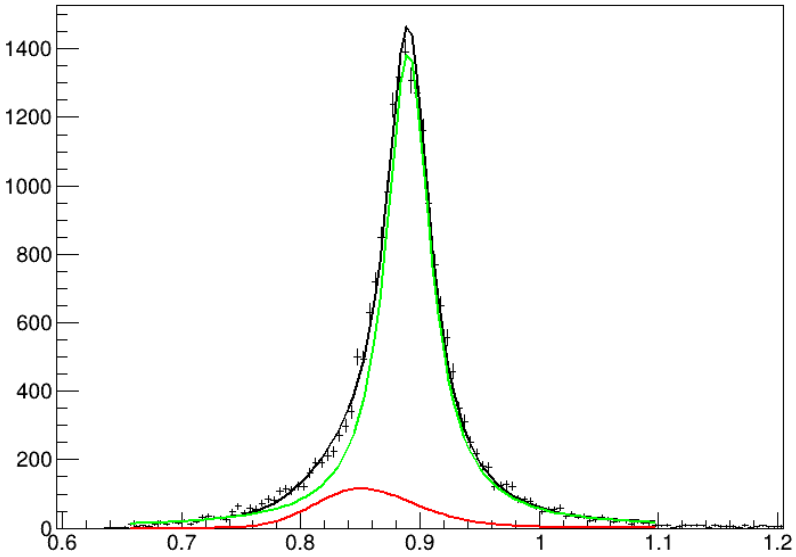
- ϕ/K⁻ puzzle,
- Experimentally observed considerable increasing of ϕ / K⁻ ratio at low collision energies (< 3-4 GeV)
- Obtained ratio is much lower than expected
- Possible reasons: lighter colliding system, wide rapidity range

$K^*(892)^0$ Peak Shape

Peripheral

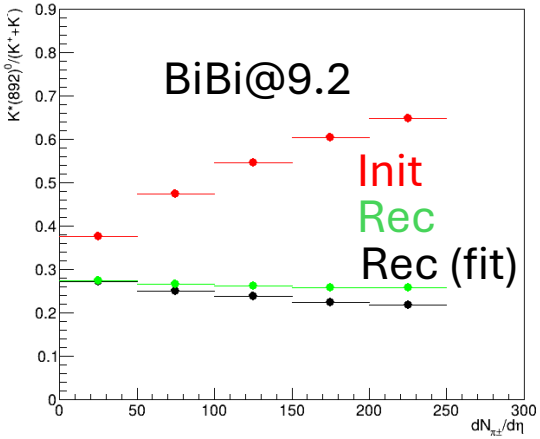


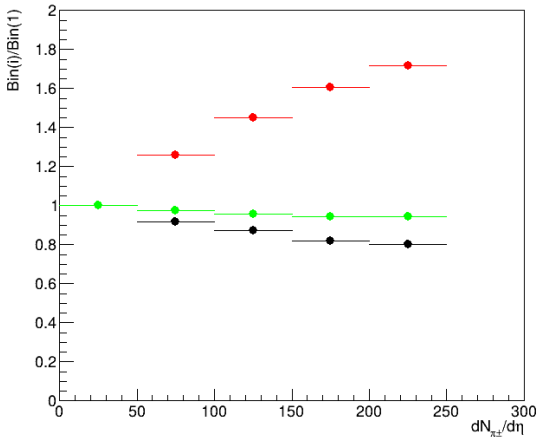
Central

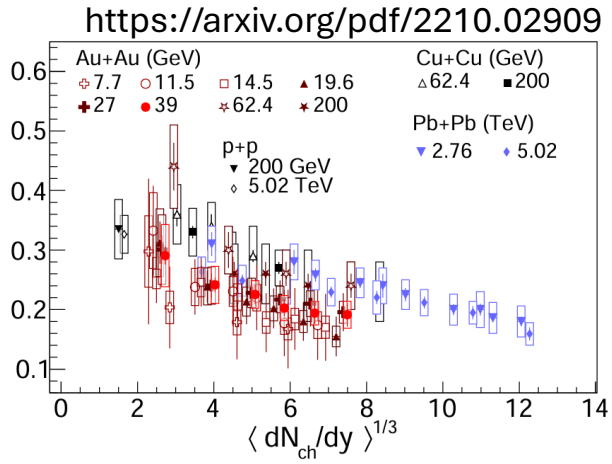


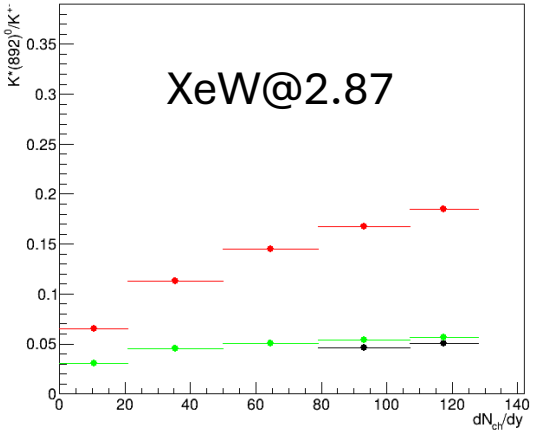
- $K^*(892)^0 \rightarrow \pi^{\pm}K^{\pm}$ ($c\tau \sim 4.2$ fm/c)
- Modest peak shape modifications in high multiplicity events (central collisions)
- Rec peaks described by signal function in low multiplicity events, contribution from BGR function in high multiplicity events

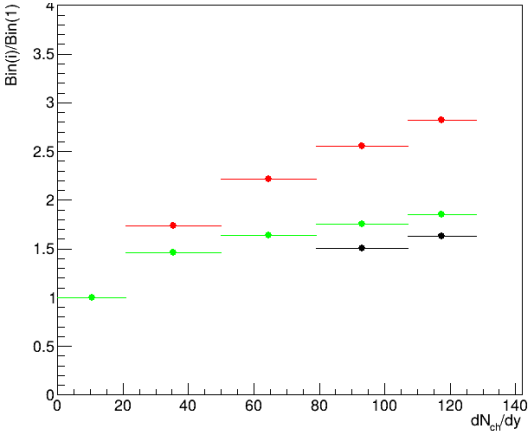
$K^*(892)^0$ to K ratio







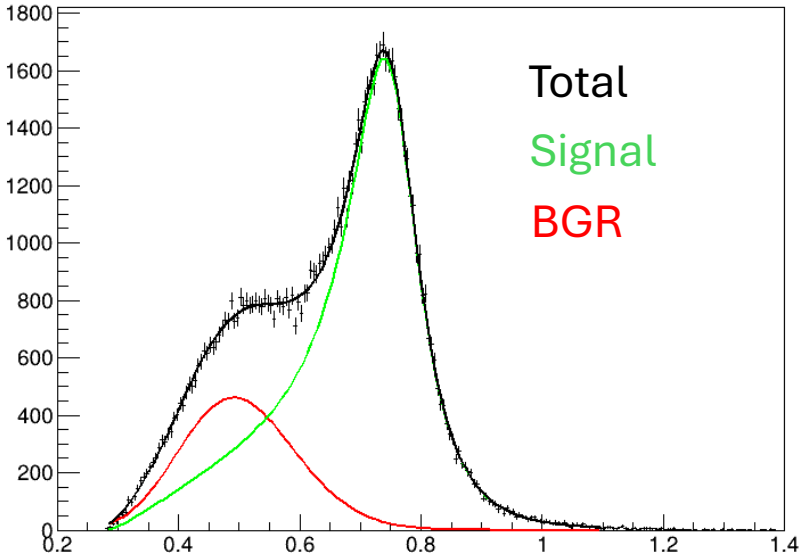




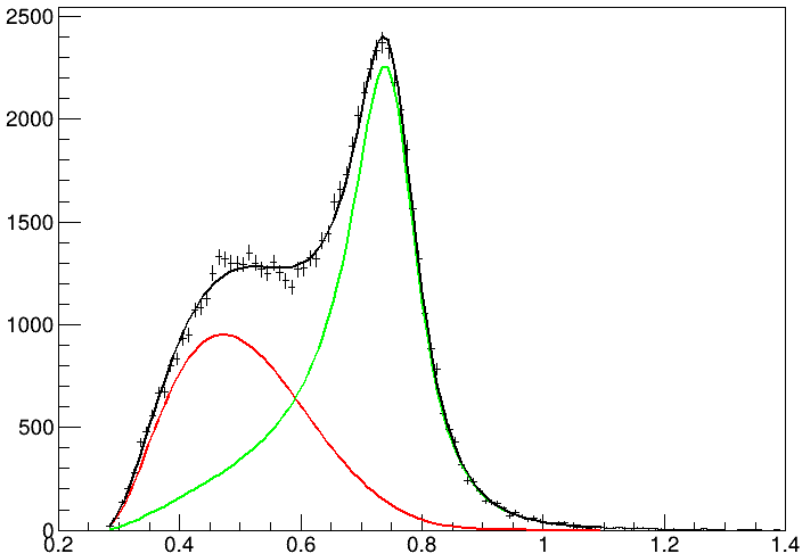
- $K^*(892)^0 \rightarrow \pi^{\pm}K^{\pm}$ ($c\tau \sim 4.2$ fm/c)
- Very modest losses due to peak shape modification in most central collisions
- Losses due to daughter annihilation or inelastic rescattering
- Increasing trend with increasing centrality

ρ(770) Peak Shape

Peripheral

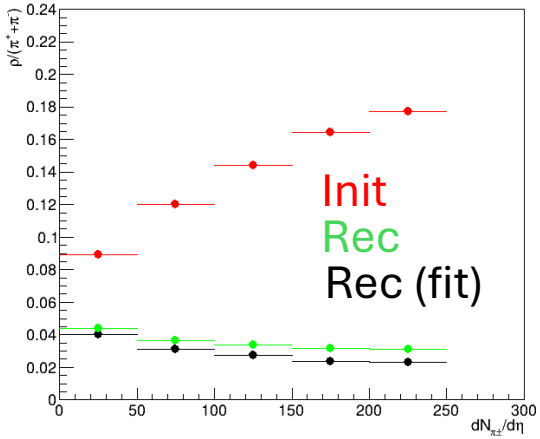


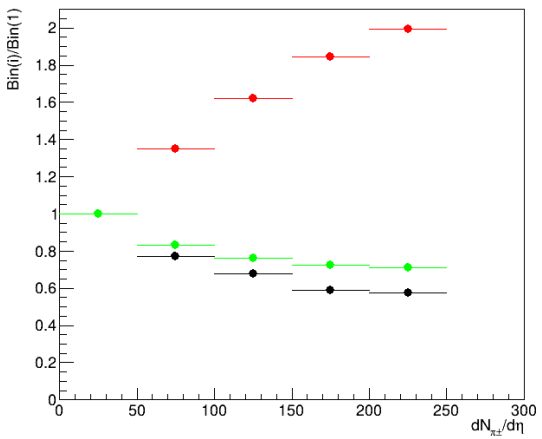
Central



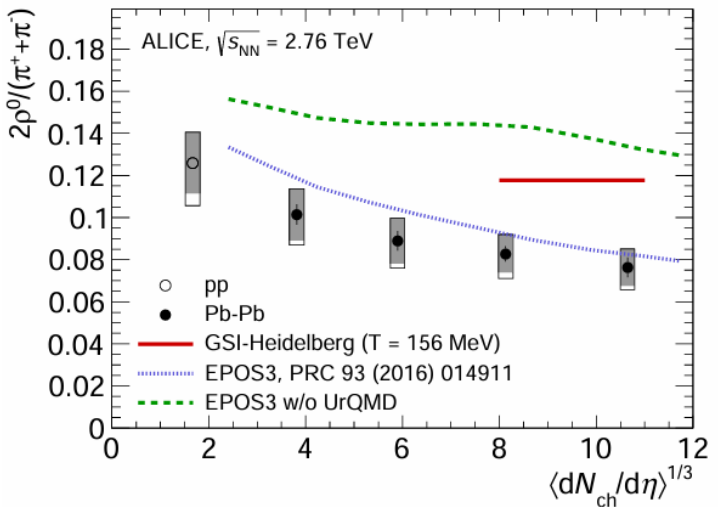
- $\rho(770)^0 \rightarrow \pi^+\pi^-$ ($c\tau \sim 1.3$ fm/c)
- Significant peak shape modifications even in low multiplicity events at low momentum
- Rec peaks described only by combination of signal and background, considerable contribution from BGR function

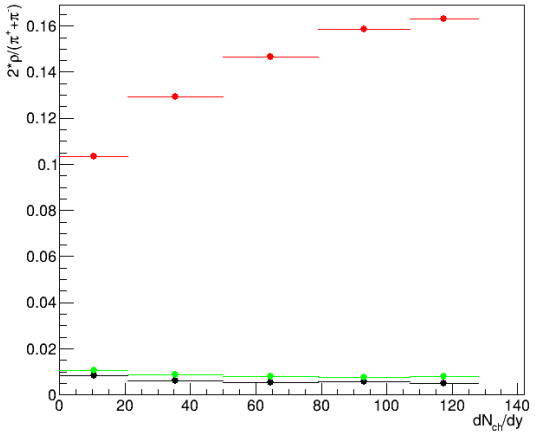
ρ(770) to π ratio

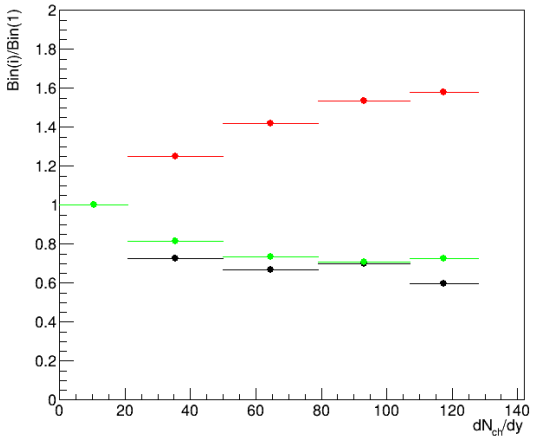


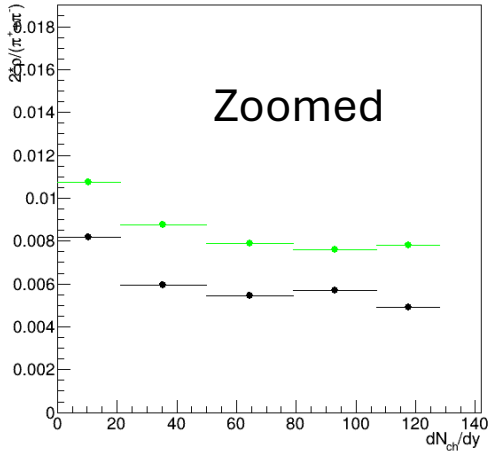


https://arxiv.org/pdf/1805.04365







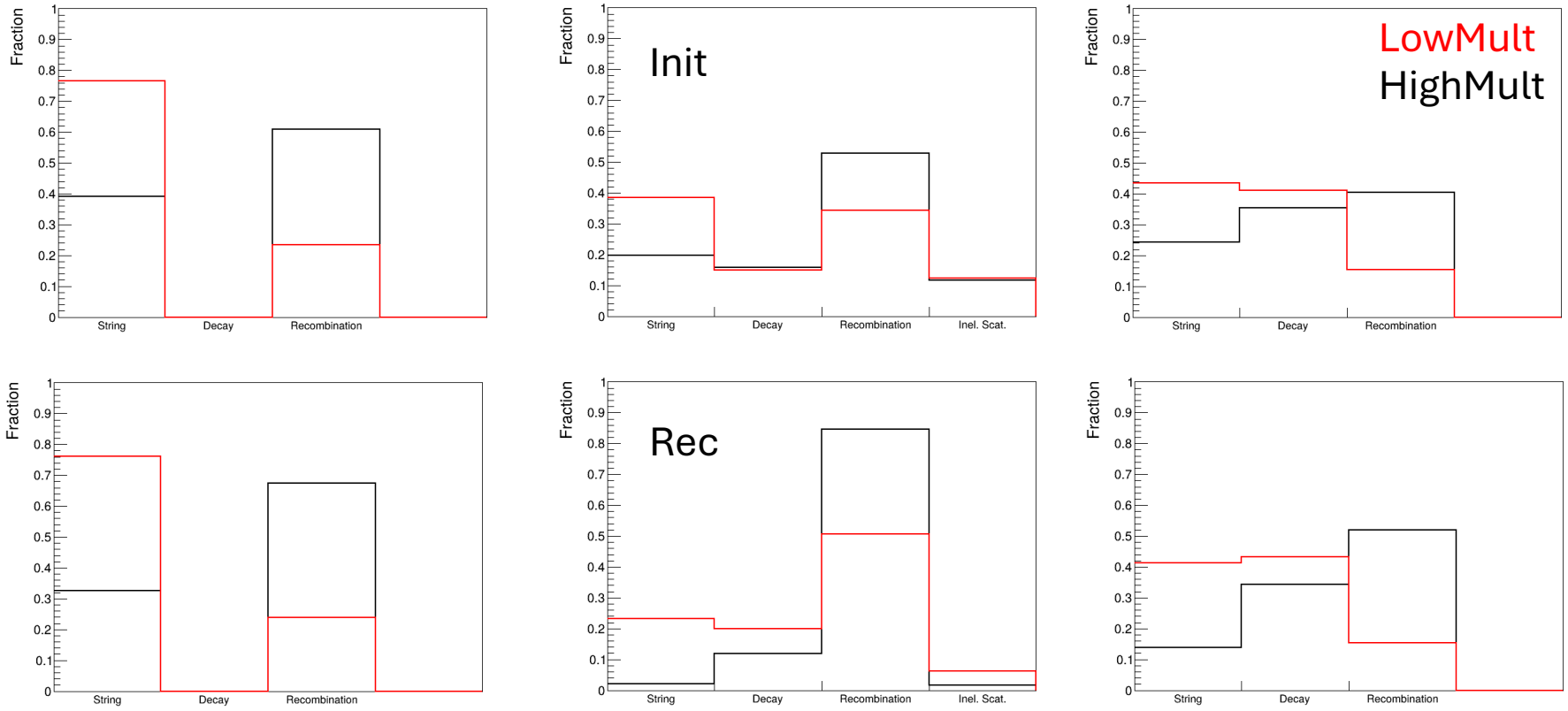


- $\rho(770)^0 \rightarrow \pi^+\pi^-$ ($c\tau \sim 1.3$ fm/c)
- Losses due to peak shape modification at low momentum (mostly due to initial modification)
- Losses due to daughter annihilation or inelastic rescattering
- Decreasing trend with increasing centrality

$\Delta(1232)^{++}$ in Bi+Bi@9.2 GeV (URQMD)

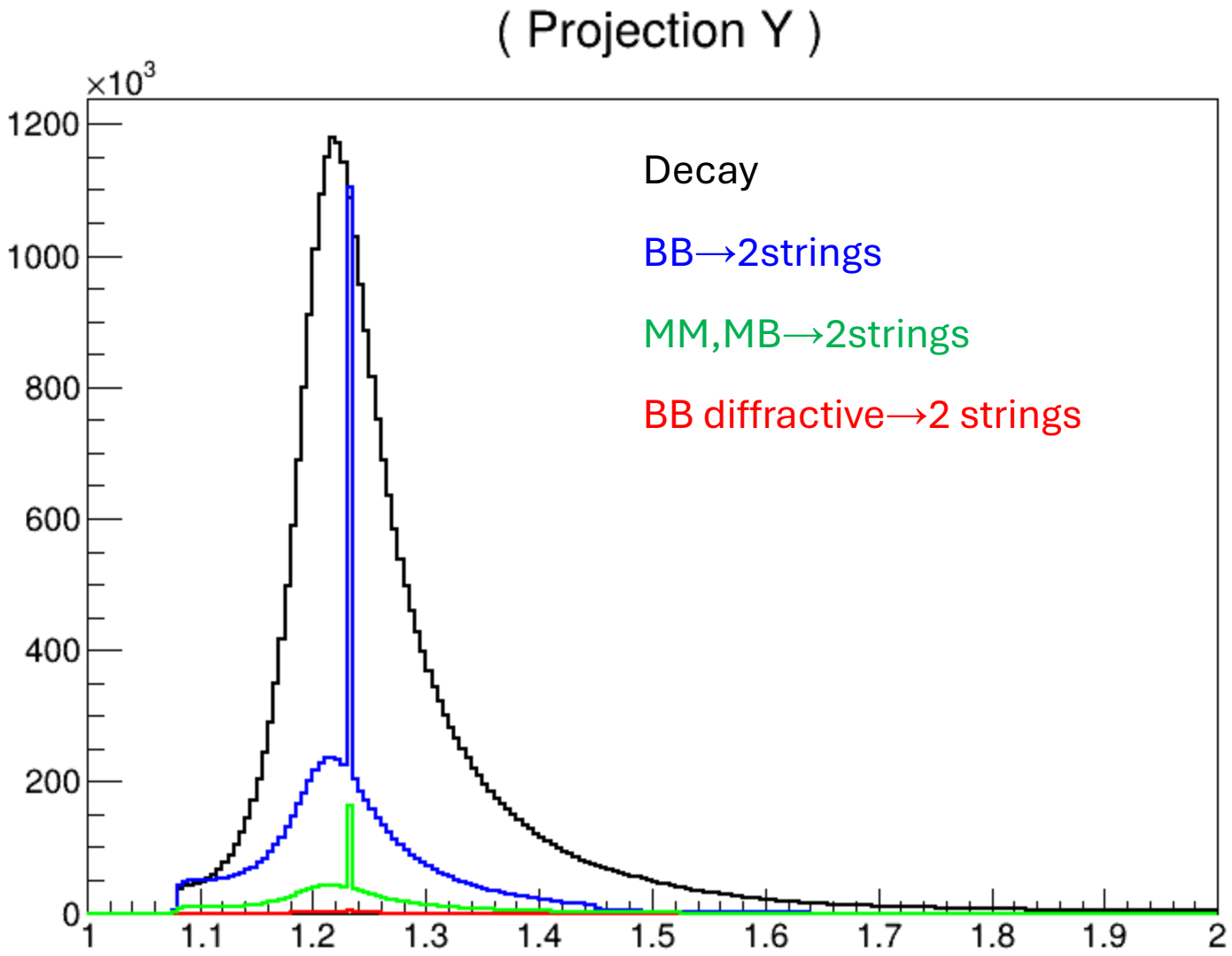
Production mechanisms

ϕ(1020) | Δ(1232)$^{++}$ | ρ(770)



- Fraction of: String, Decay, Recombination + Inelastic scattering (for delta)
- String is dominant for LowMult, Recombination is dominant for HighMult events
- Most of reconstructed deltas are produced via recombination

$\Delta(1232)^{++}$ Peak Shape



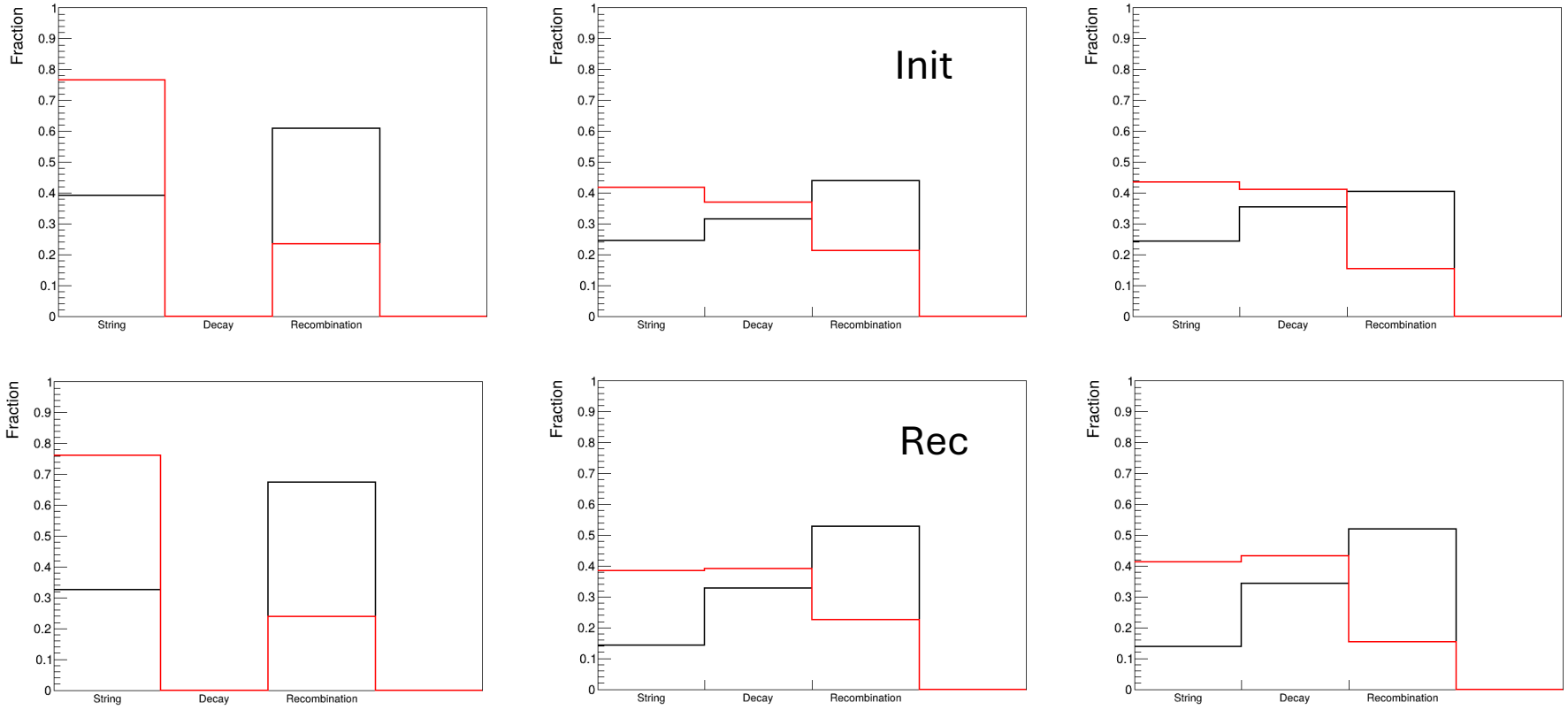
Summary

- Results of peak shape modifications studies for φ(1020), $K^*(892)^0$ and ρ(770) – resonances in XeW@2.87GeV collisions
- Peak shape modifications are less pronounced in case of XeW collisions at 2.87 GeV
- Plans:
  - ✓ Started studies of BiBi collisions at 9.2 GeV with PHSD generator
  - ✓ Plan to study baryonic resonances – delta(1232)

Backup

Production mechanisms (BiBi@9.2GeV)

ϕ(1020) K*(892)^0 ρ(770)

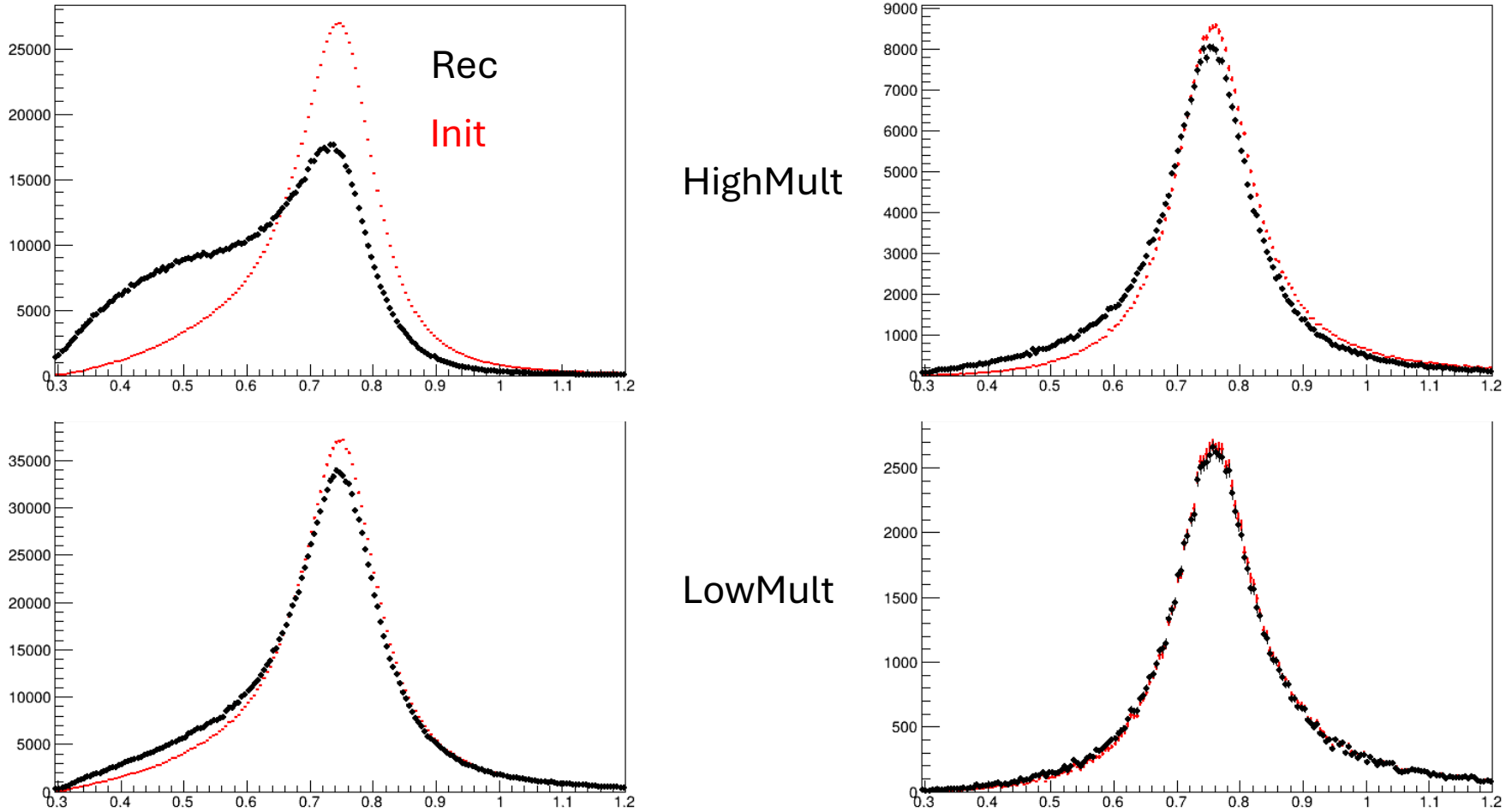


- Fraction of: String, Decay, Recombination (Urqmd prediction)
- String is dominant for LowMult, Recombination is dominant for HighMult events
- Similar distribution for Rec and Init cases for φ(1020)
- For K*(892)^0 and ρ(770) in HighMult recombination fraction is higher in Rec than in Init

ρ(770) Peak Shape (BiBi@9.2GeV)

0 < pT < 0.5 GeV/c

pT > 1.5 GeV/c



- Resonances are decayed by UrQMD, daughters participate in elastic and inelastic scattering
- Resonance are reconstructed by invariant mass method according to decay channels
- $\rho(770)^0 \rightarrow \pi^+\pi^-$ ($c\tau \sim 1.3$ fm/c): significant line shape modifications in central collisions at low p_T

Delta(1232)++ URQMD

Process ID#	Description
1	$NN \rightarrow N\Delta$
2	$NN \rightarrow NN^*$
3	$NN \rightarrow N\Delta^*$
4	$NN \rightarrow \Delta\Delta$
5	$NN \rightarrow \Delta N^*$
6	$NN \rightarrow \Delta\Delta^*$
7	$NN \rightarrow N^*N^*, N^*\Delta^*, \Delta^*\Delta^*$
8	$N\Delta \rightarrow \Delta\Delta$
30	$N\Delta \rightarrow NN$
31	$\Delta\Delta \rightarrow \Delta N$
32	$\Delta\Delta \rightarrow NN$
35	$N\Delta$ inelastic

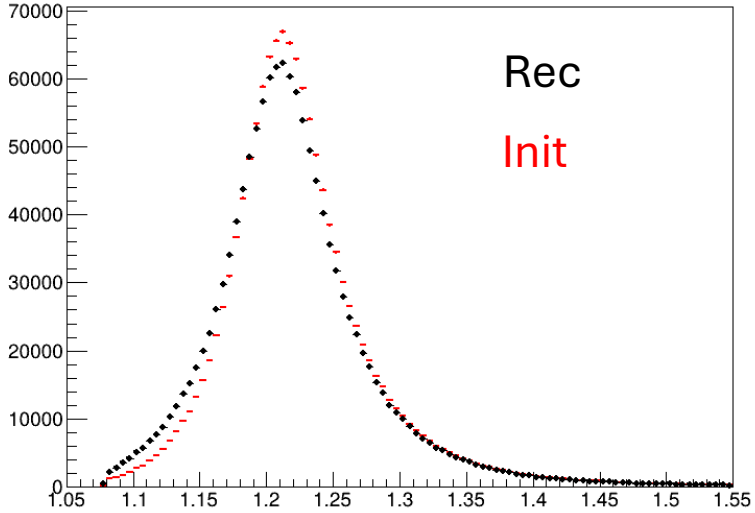
$\Delta(1232)^{++}$ Peak Shape (all)

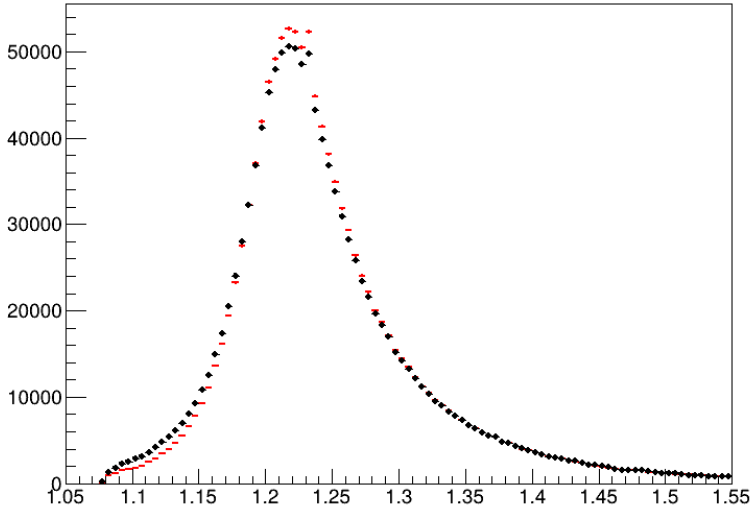
0 < pT < 0.5 GeV/c

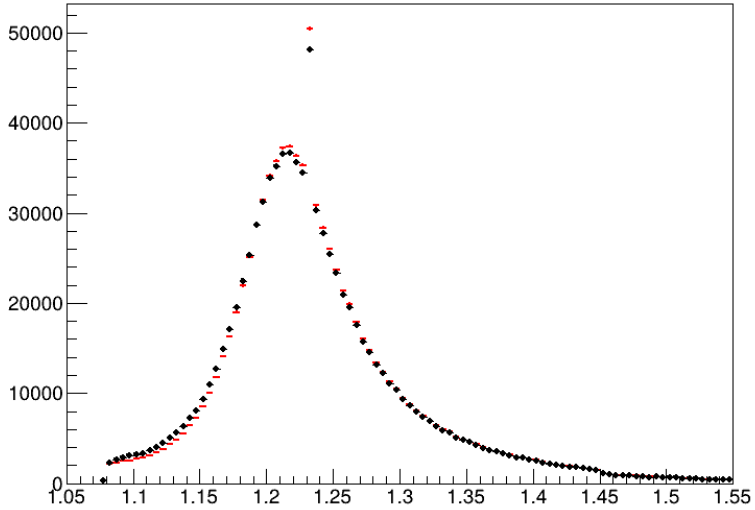
pT > 1.5 GeV/c

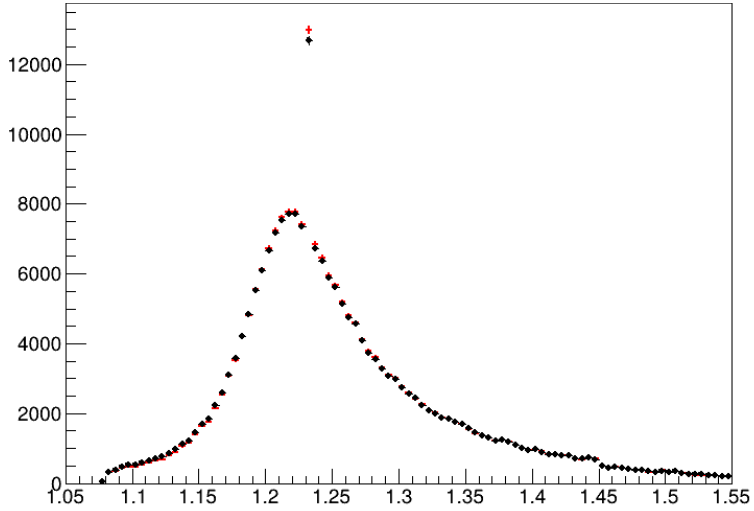
HighMult

LowMult



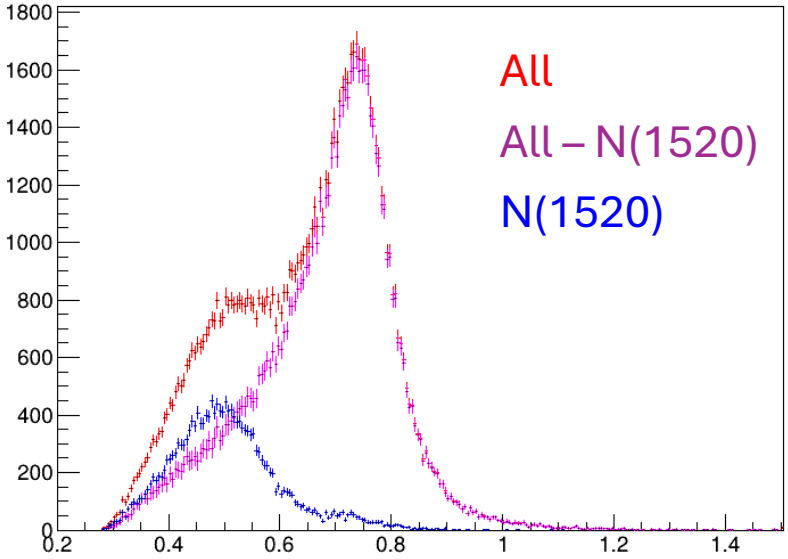


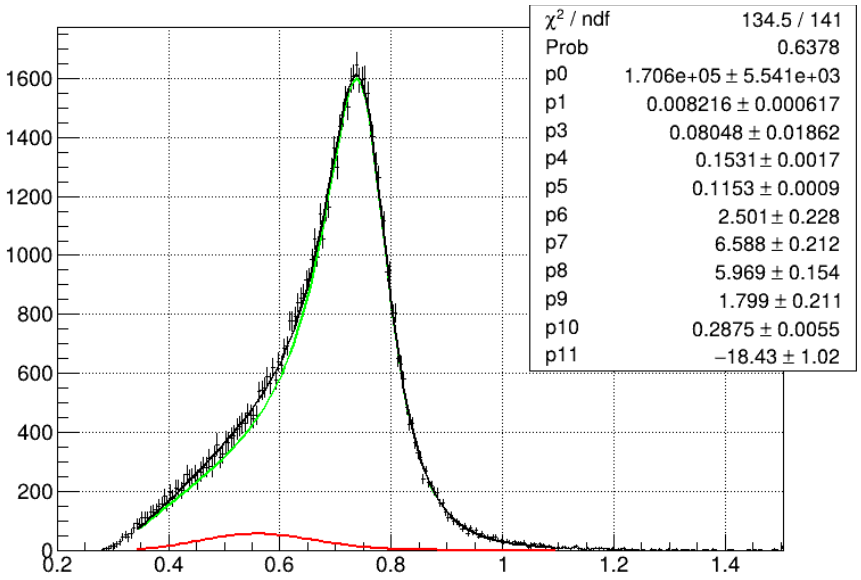




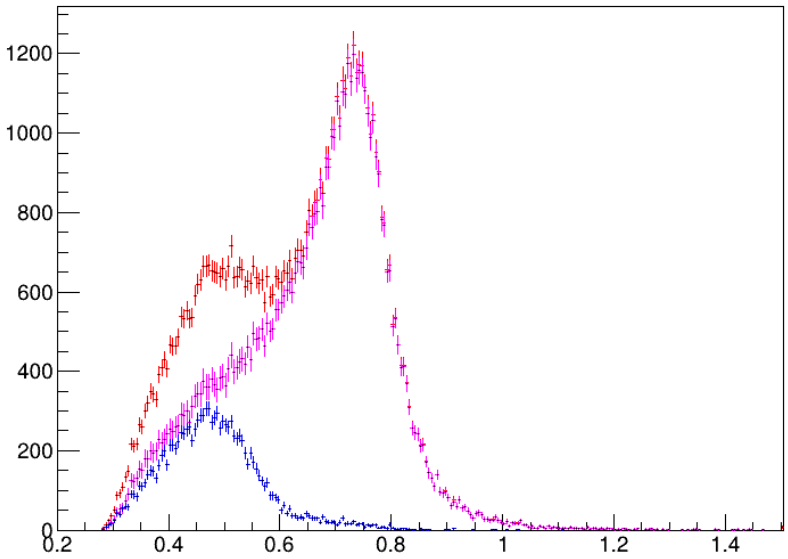
ρ(770) Peak Shape

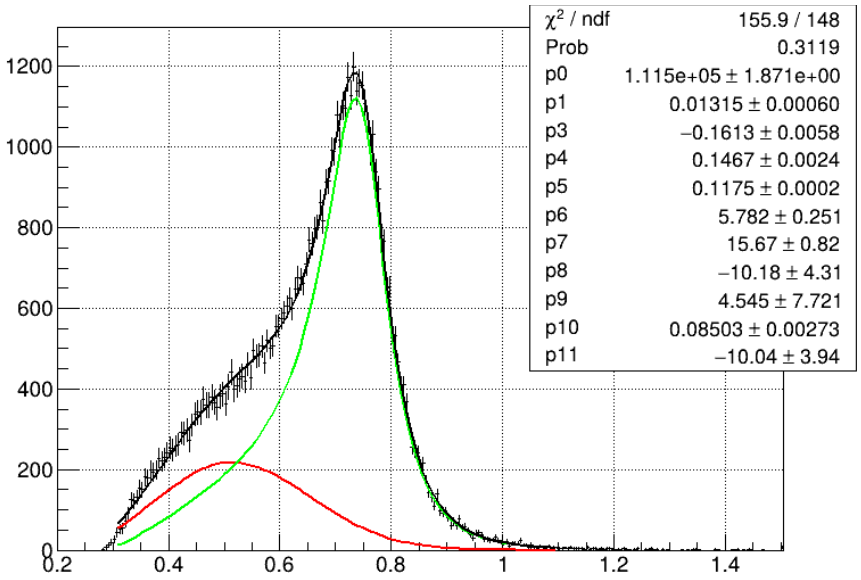
LowMult





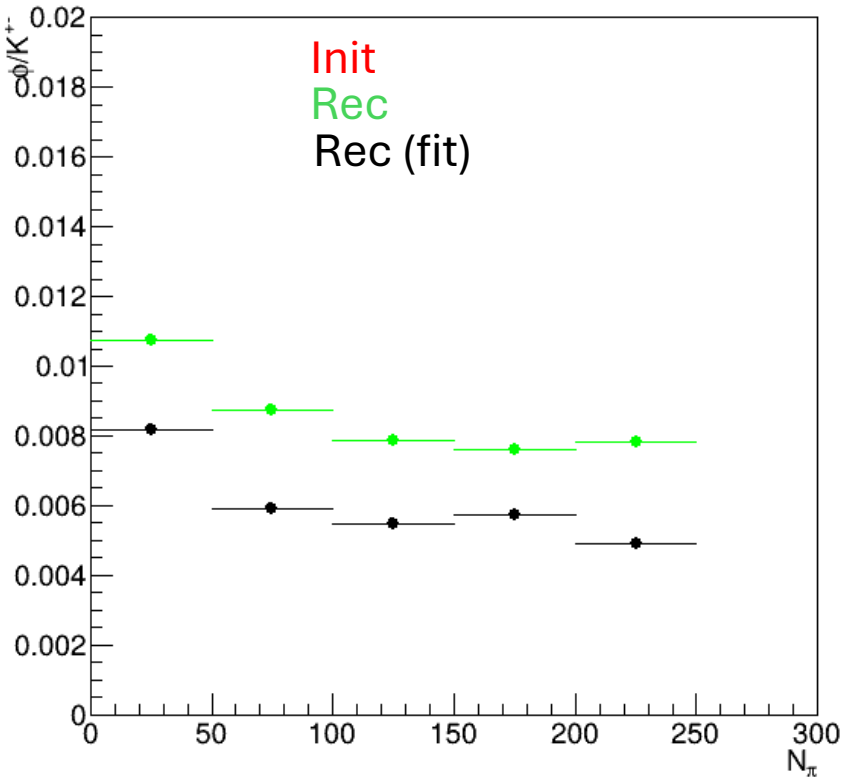
HighMult



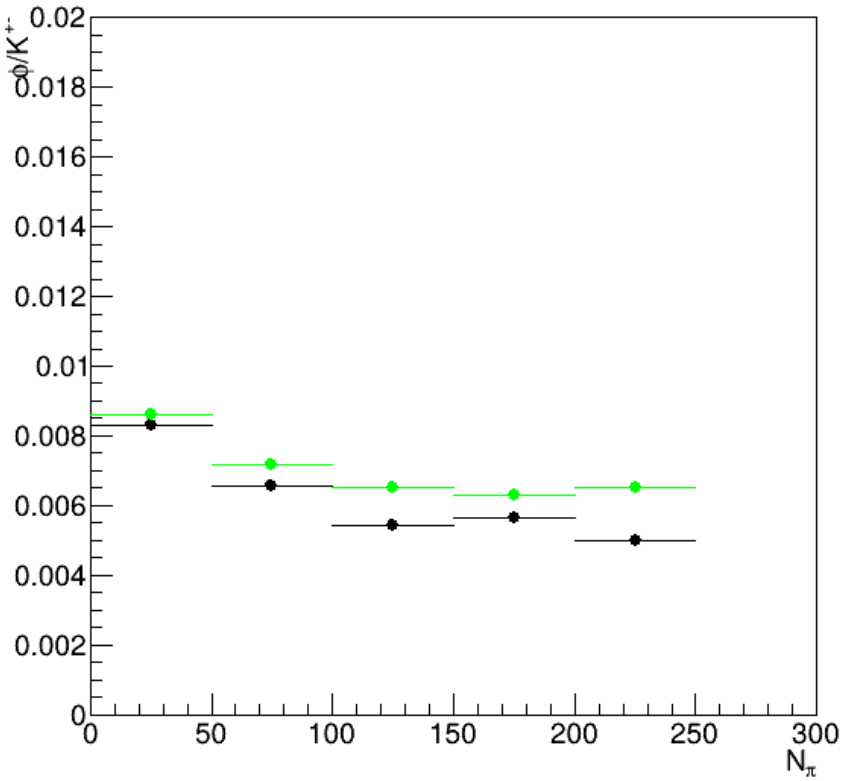


ρ(770) to π ratio

All Rho

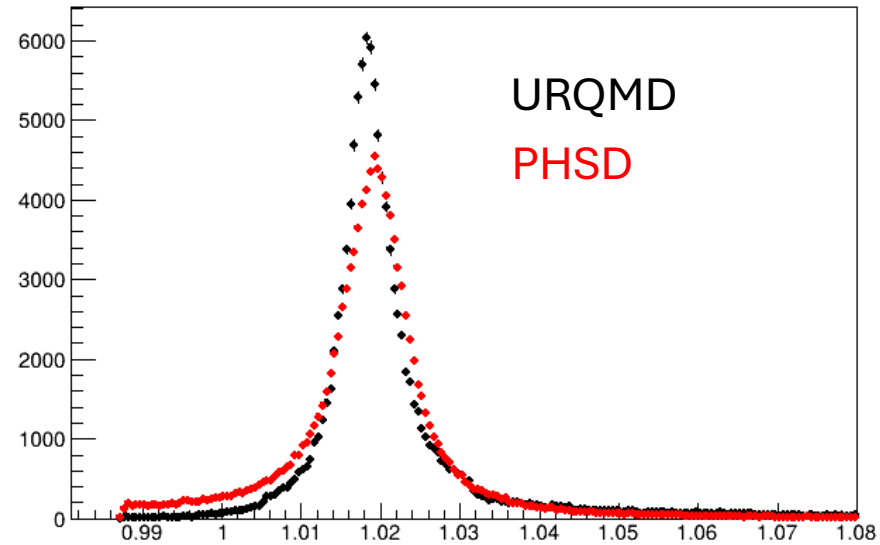


W/o N(1520) decays



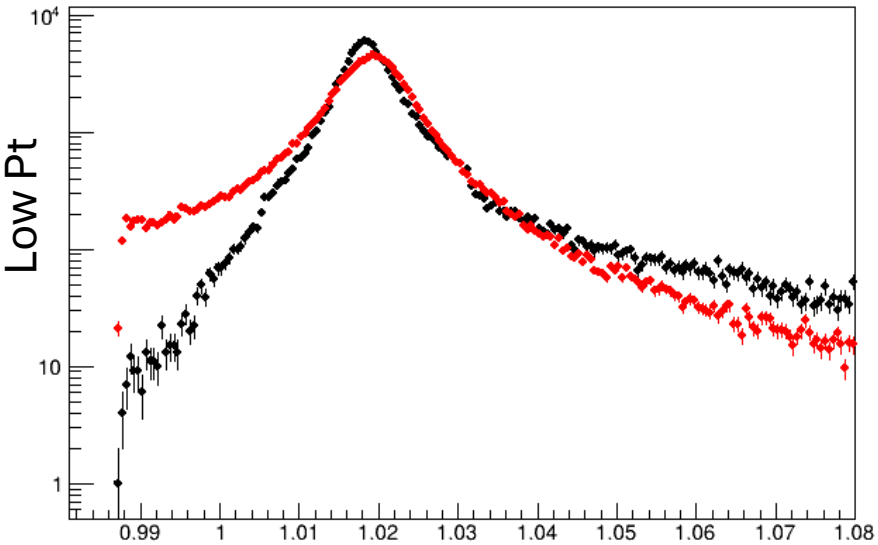
φ(1020) Peak Shape

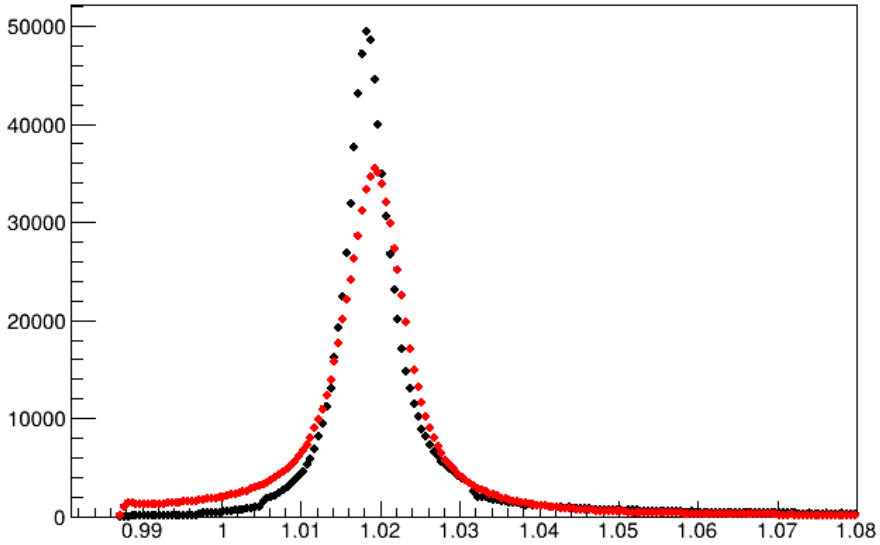
Normal



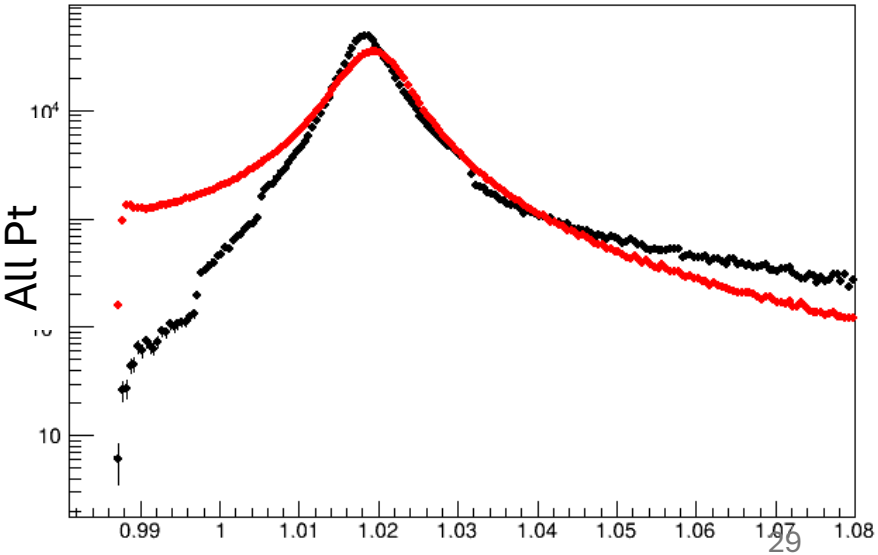
Log scale

High Mult
Low Pt



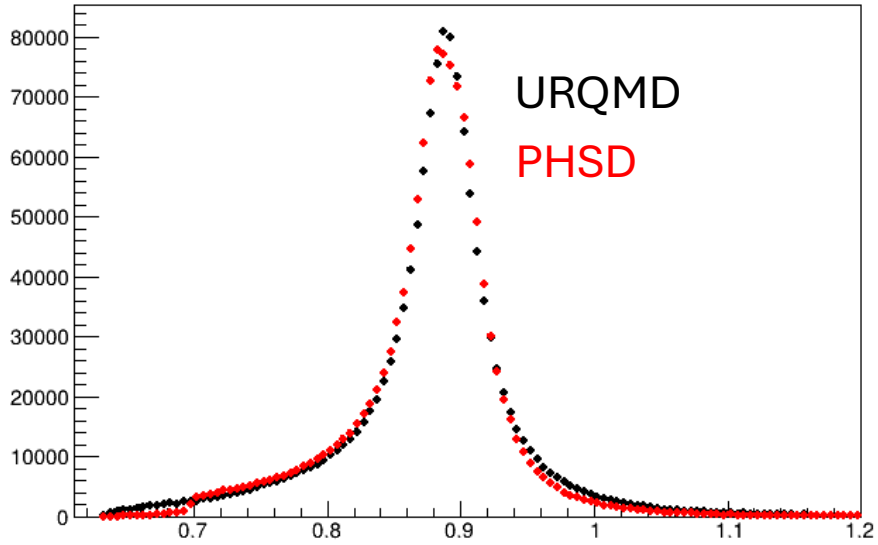


All Mult
All Pt

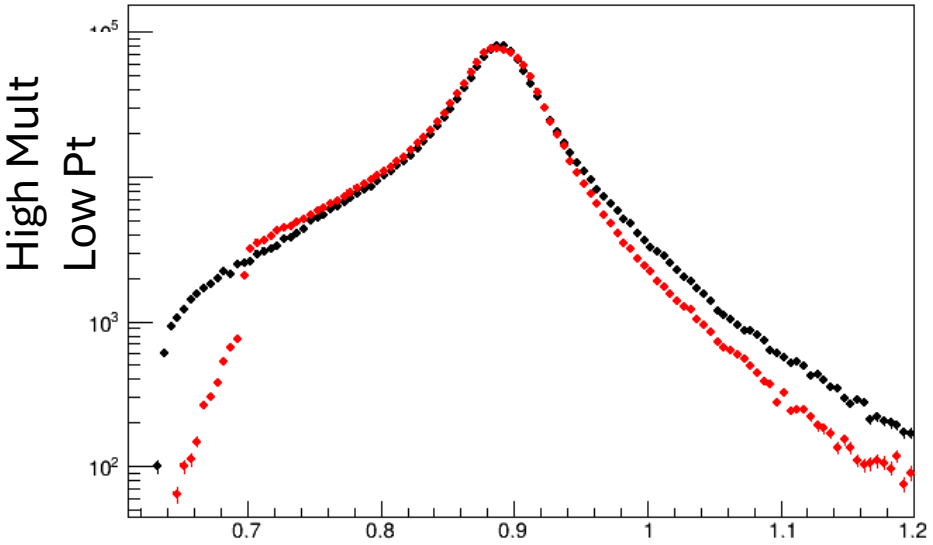


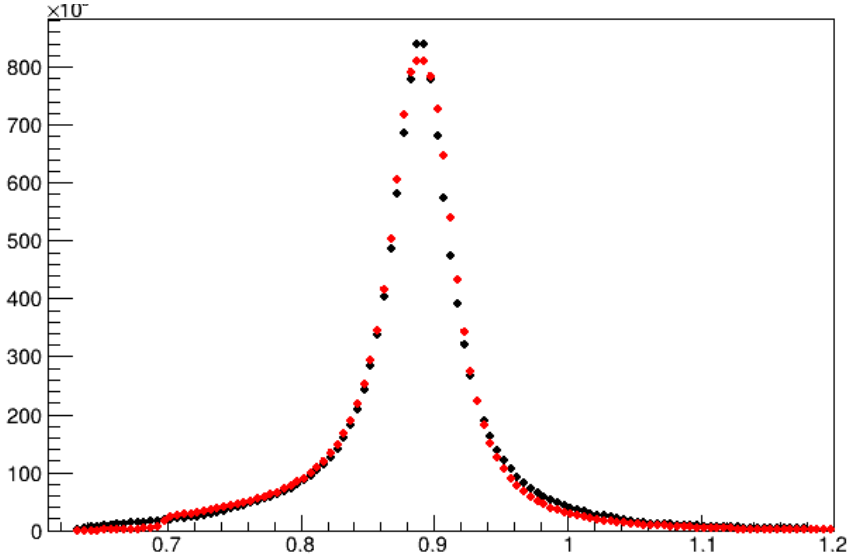
K*(892)^0 Peak Shape

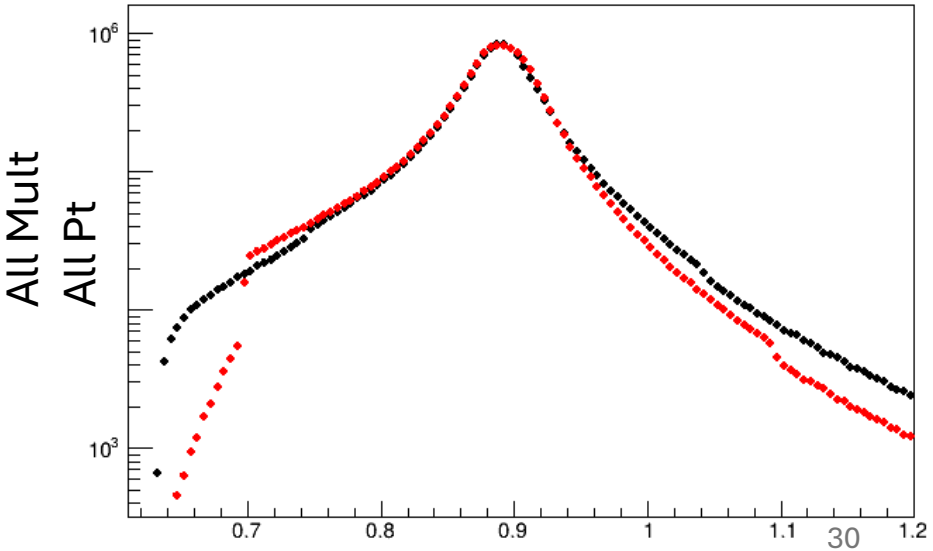
Normal



Log scale

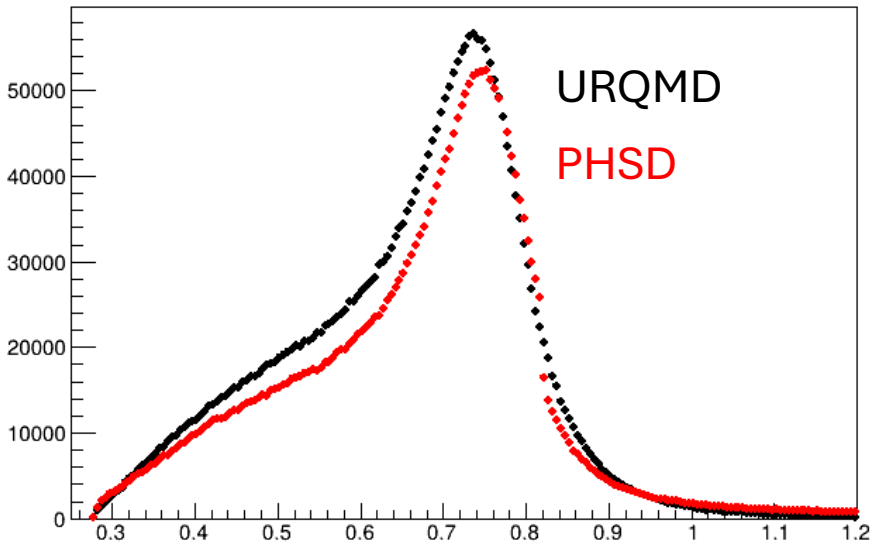




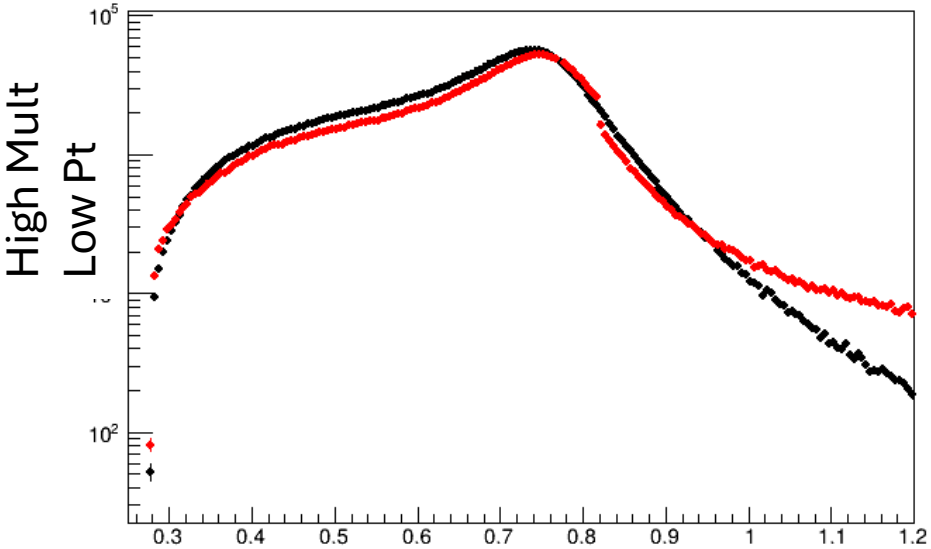


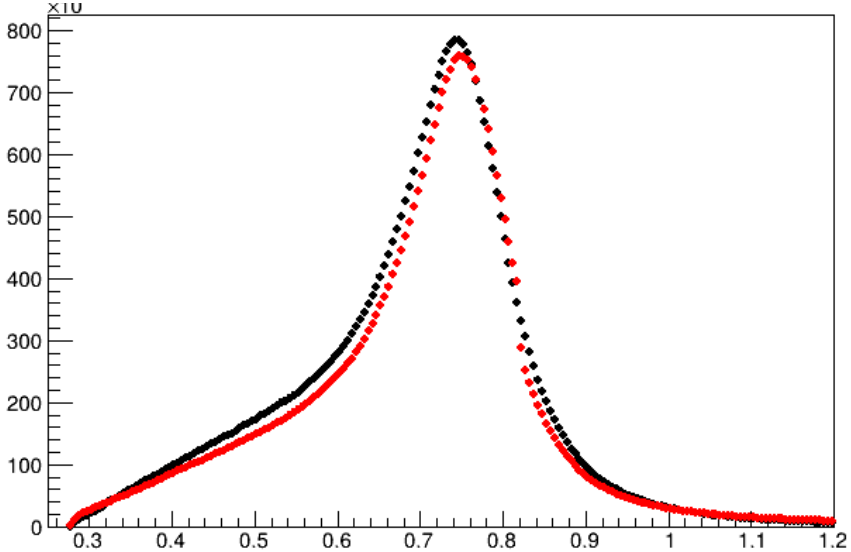
ρ(770) Peak Shape

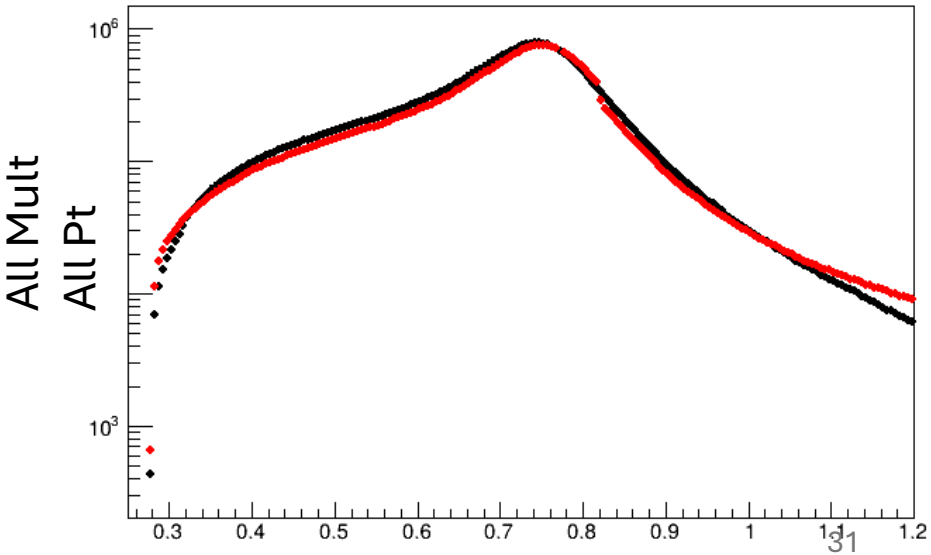
Normal



Log scale

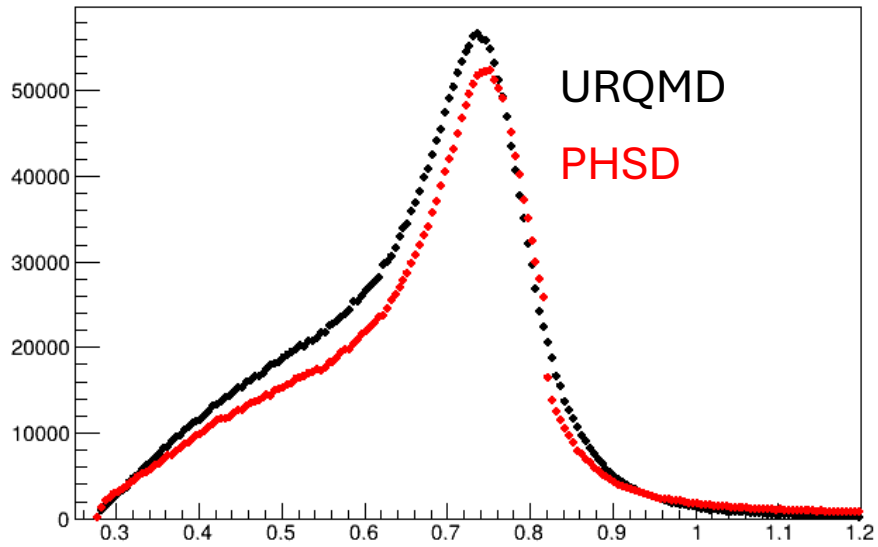






ρ(770) Peak Shape (unzoomed)

Normal



UnZoomed

