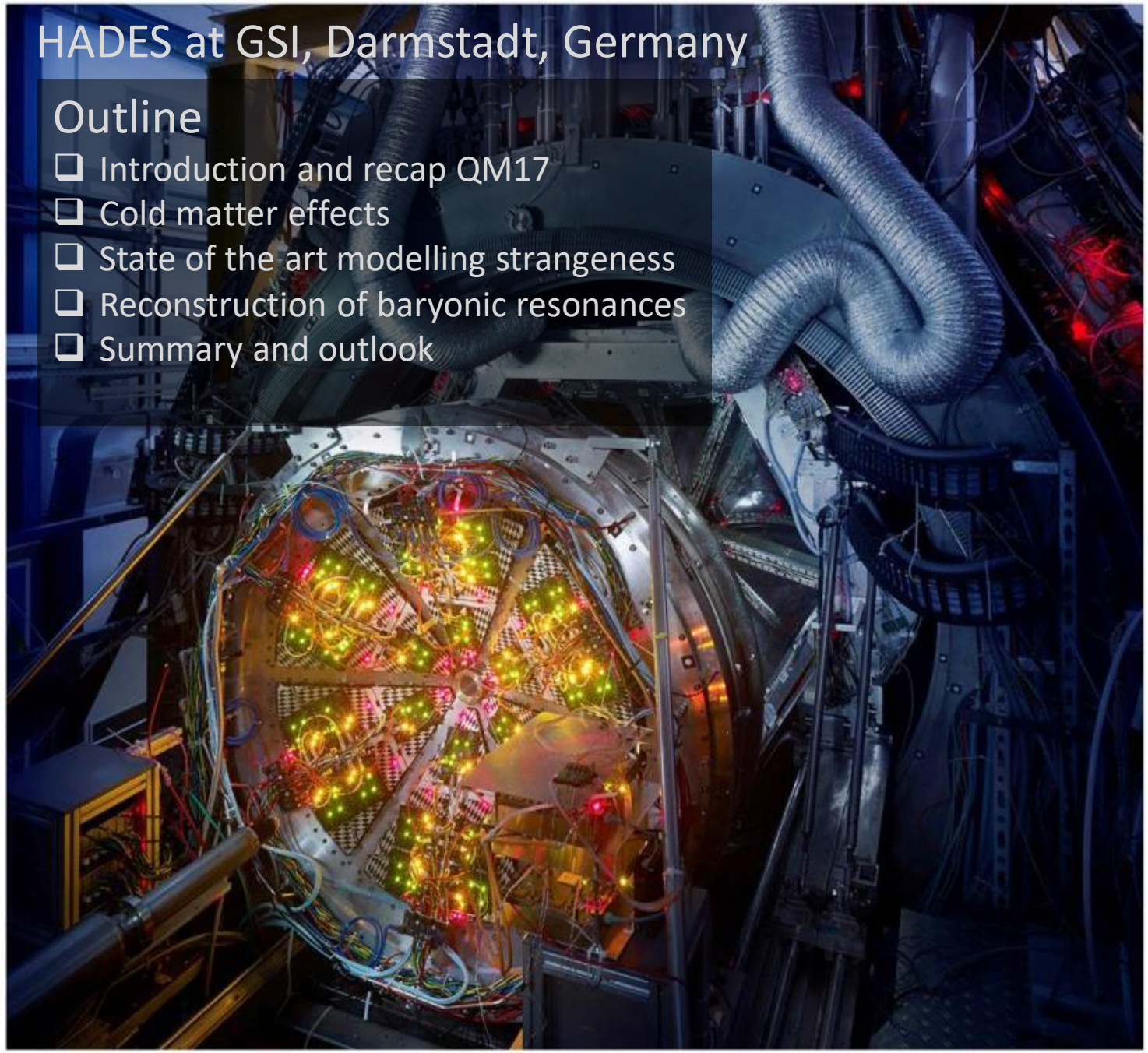


GSI VIP TECHNISCHE UNIVERSITÄT DARMSTADT

Venezia 2018 Quark Matter

Sub-threshold strangeness production measured with

HADES

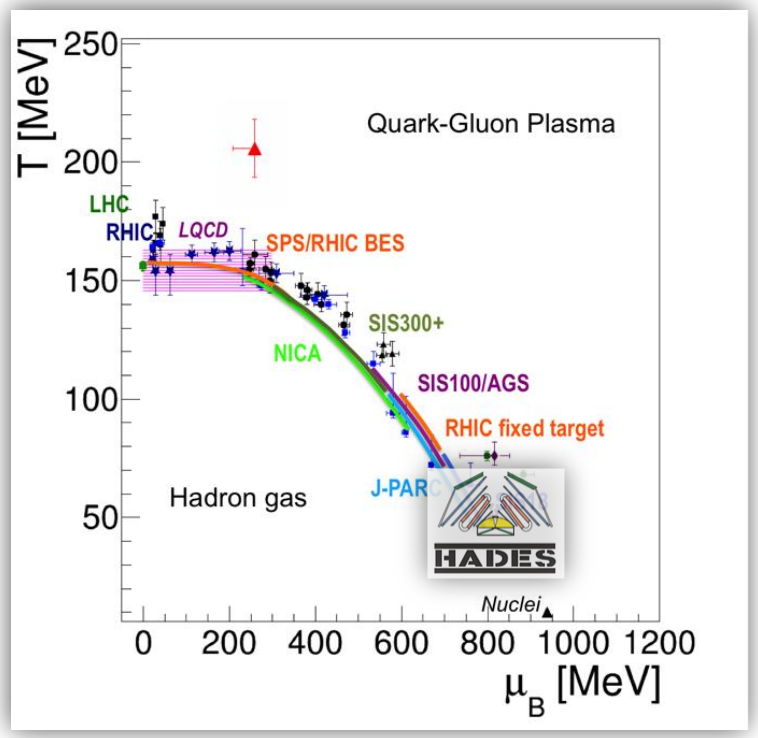
G. Kornakov for the HADES Collaboration

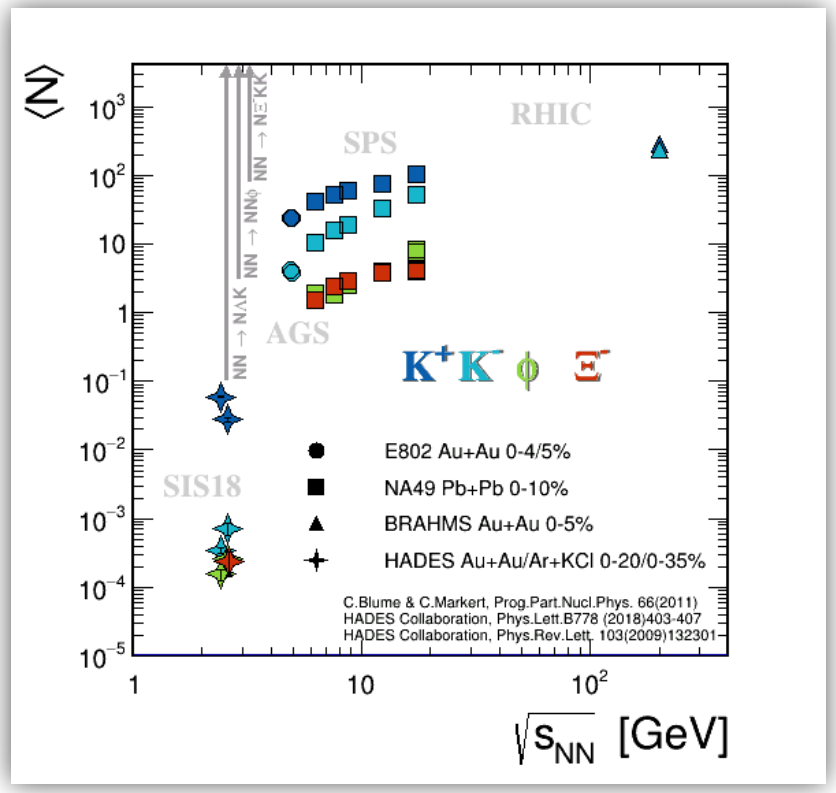
Elementary and heavy-ion beams $\sqrt{s}$ = 2.3-2.7 GeV at SIS18

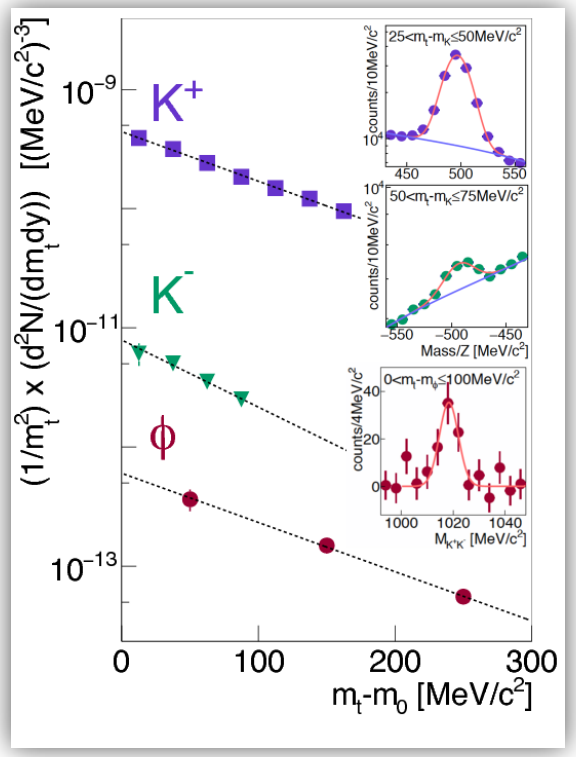
- HADES explores baryon-rich matter
- Strangeness production below $\sqrt{s_{NN}}$ threshold

100 p → 10 π → 10^{-2} K^+ → 10^{-4} K^-

Rare probes:
ϕ → 2×10^{-4}/Event in K^+K^-
~1 event out of 5000!







Phys.Lett. B778 (2018) 403-407

HADES Au+Au $\sqrt{s}$=2.42 GeV

- **Full azimuthal coverage**, 18-85° polar angle
- **Fast detector**: 1.5 x 10^6 Au ions/s (8 kHz)
  - 7x10^9 events recorded

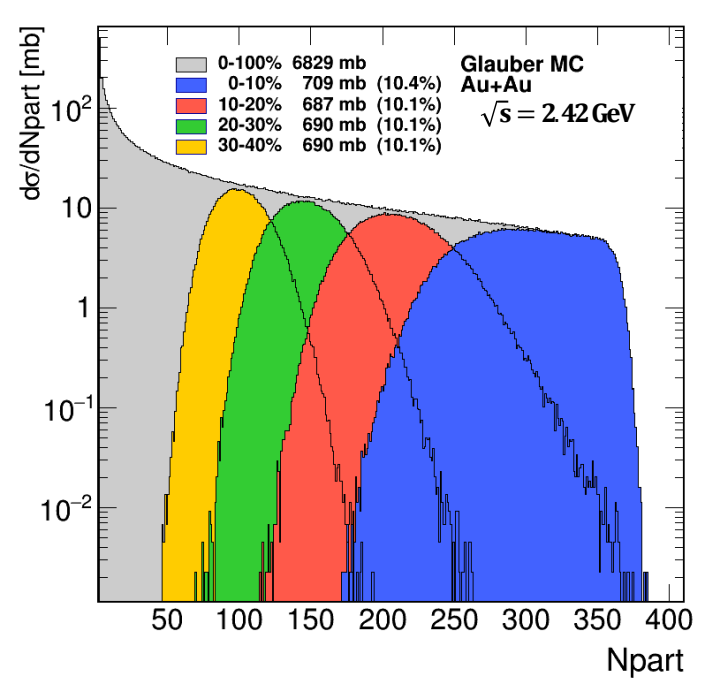
HADES Au+Au $\sqrt{s}$=2.42 GeV

- **Full azimuthal coverage**, 18-85° polar angle
- **Fast detector**: 1.5 x 10^6 Au ions/s (8 kHz)
  - 7x10^9 events recorded

Off-line centrality selection:

Hit/track multiplicity

Forward Wall



[HADES Collaboration]
arXiv:1712.07993 [nucl-ex]

HADES Au+Au $\sqrt{s}$=2.42 GeV

- **Full azimuthal coverage**, 18-85° polar angle
- **Fast detector**: 1.5 x 10^6 Au ions/s (8 kHz)
  - 7x10^9 events recorded

Off-line centrality selection:

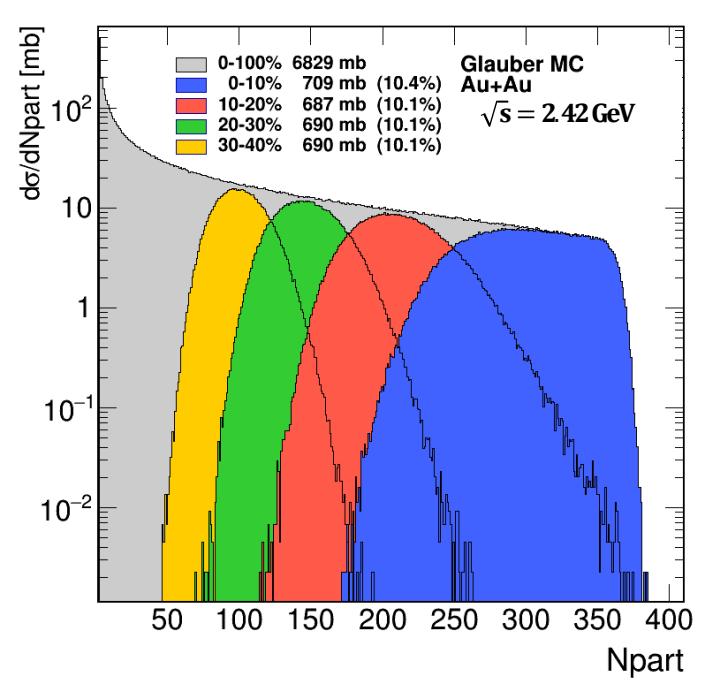
Hit/track multiplicity

Forward Wall

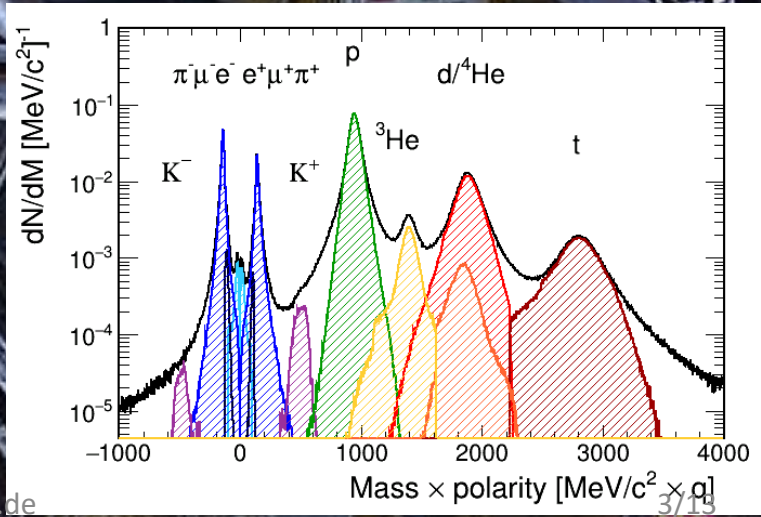
High purity hadron detectors:

MDC: momentum ($\Delta P/P<2\%$) and dE/dx

TOF (Diamond T_0, RPC and Scintillator Walls)

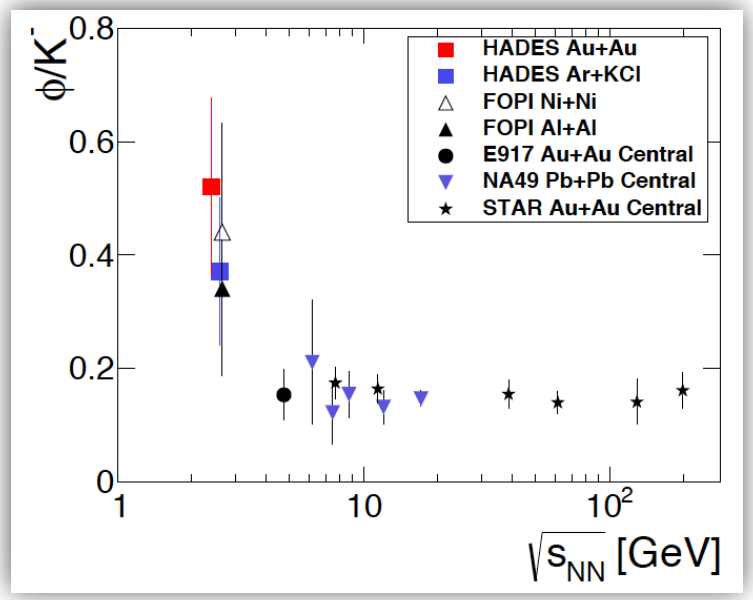


[HADES Collaboration]
arXiv:1712.07993 [nucl-ex]

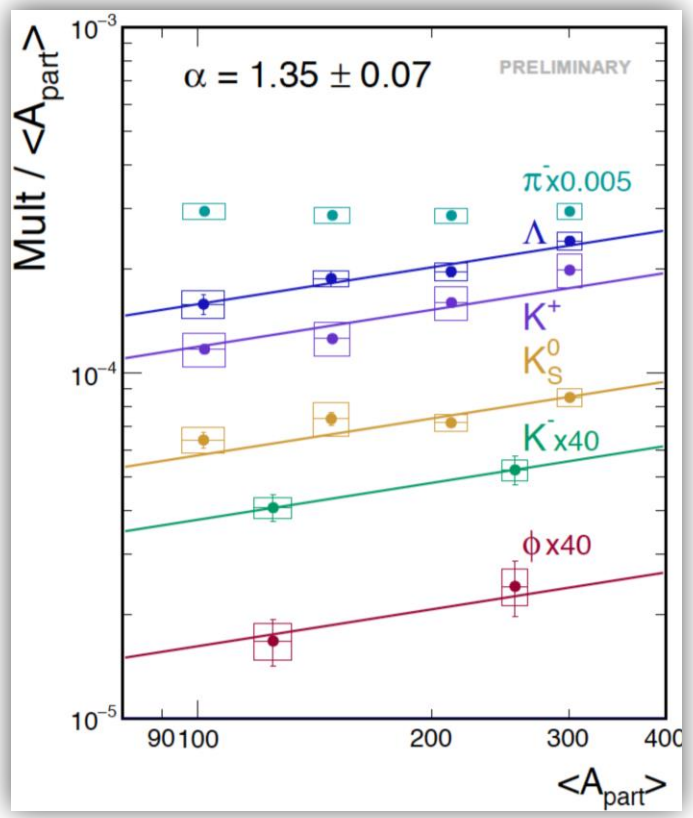


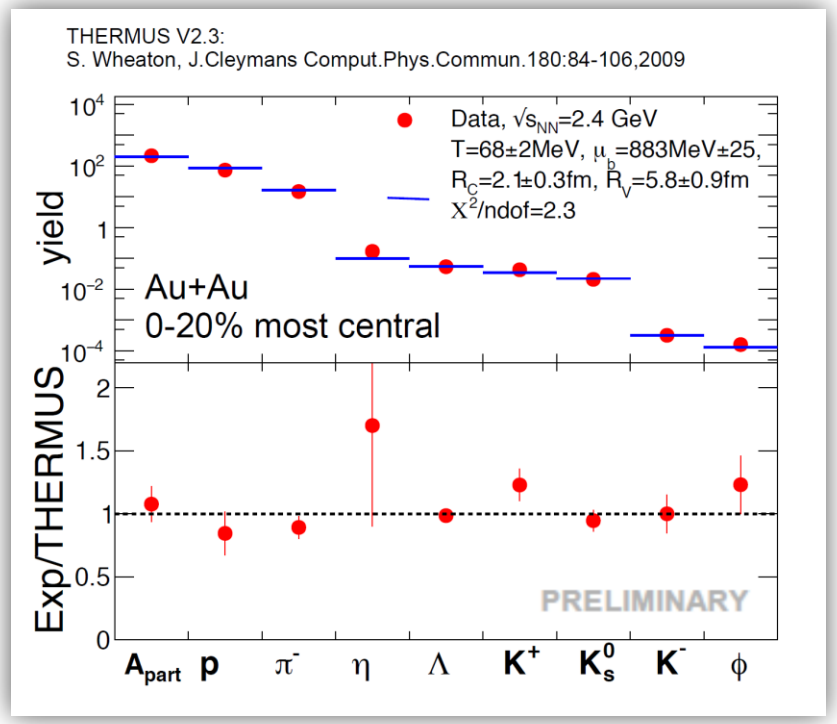
QM-17: Strangeness production consistent with equilibrium at SIS18

QM17 H.Schuldes et al.
QM17 M.Lorenz et al.



Phys.Lett. B778 (2018) 403-407

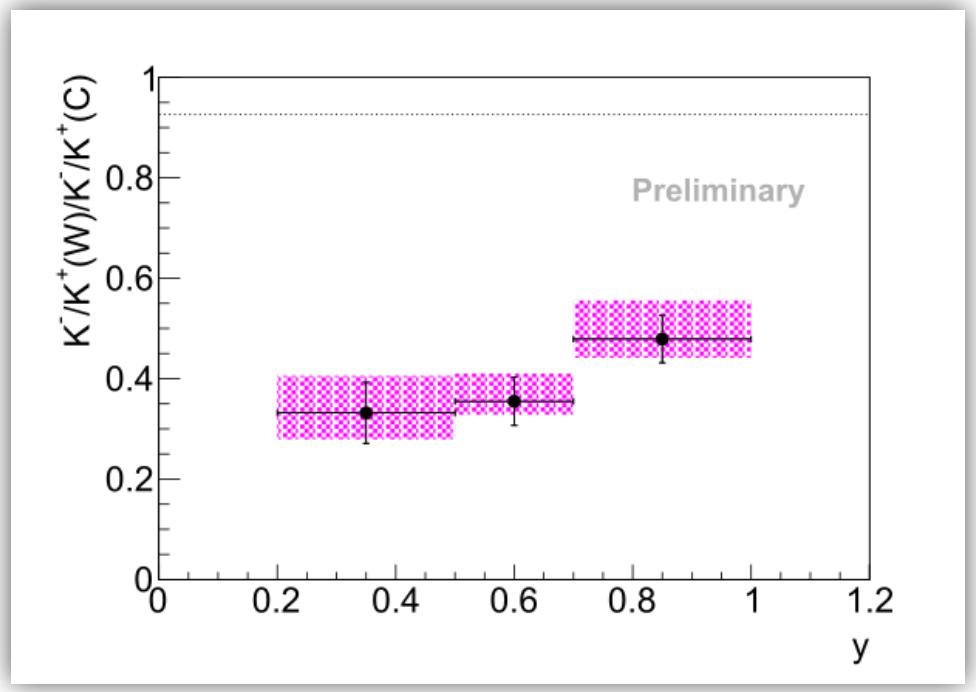




- φ sizeable source for K^-. Feed-down can explain lower effective temperature and rapidity spectrum of K^-
- Universal centrality dependence of strangeness production
- SHM describes hadron yields with global parameters: T, μ_B, R, R_C

Strangeness in cold nuclear matter

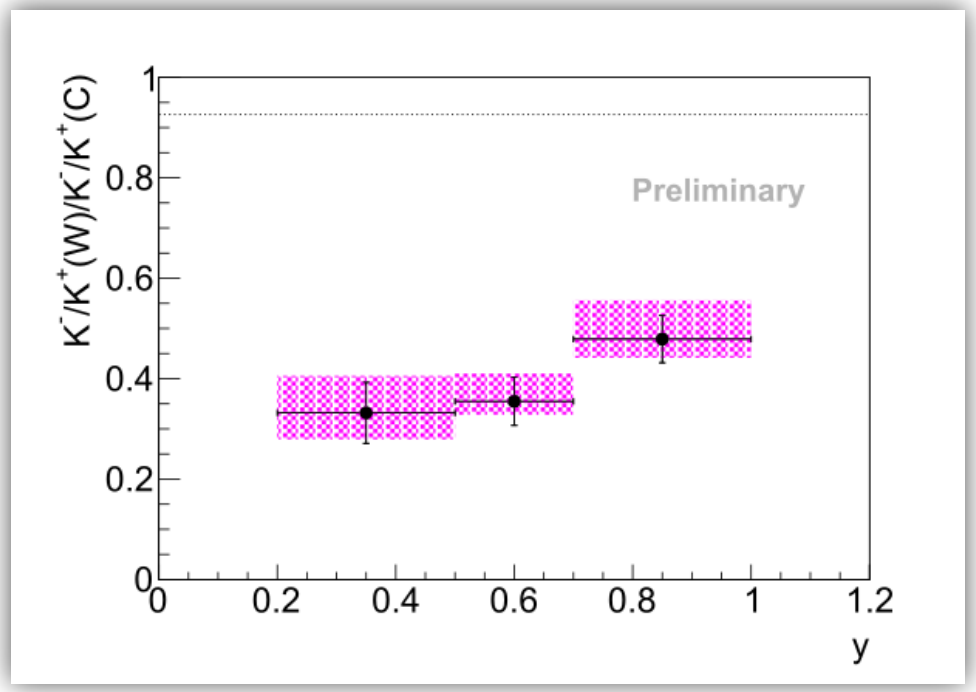
- Secondary pion beam 1.7 GeV/C on C and W targets
- Collected events: $N_C = 10^8$ and $N_W = 1.3\ 10^8$
- Energy: $\sqrt{s_{\pi N}}$ = 2 GeV



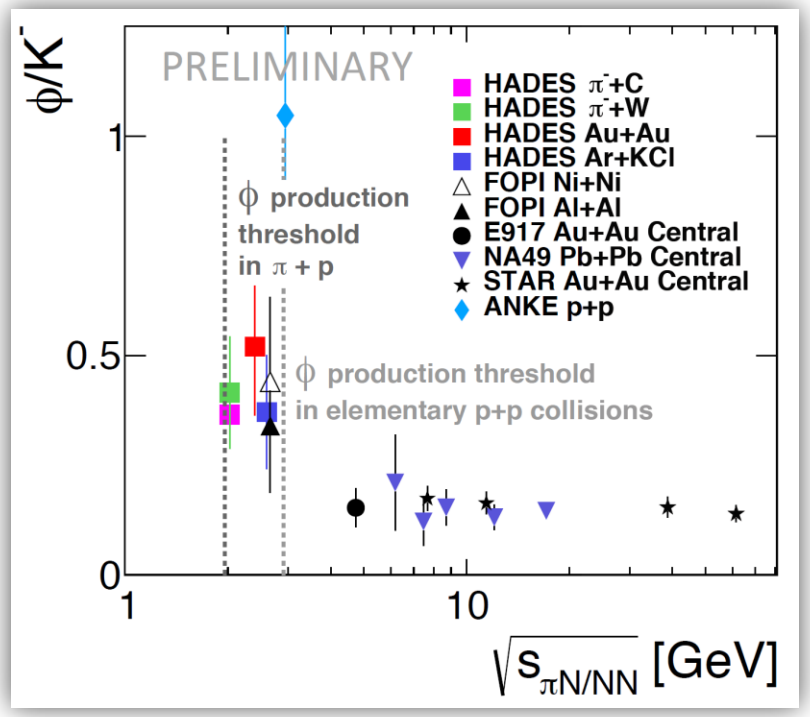
➢ K^- absorption in π^-W with respect to π^-C

Strangeness in cold nuclear matter

- Secondary pion beam 1.7 GeV/C on C and W targets
- Collected events: $N_C = 10^8$ and $N_W = 1.3\ 10^8$
- Energy: $\sqrt{s_{\pi N}}$ = 2 GeV



$\phi_w/K^- \approx \phi_c/K^-$
in acceptance



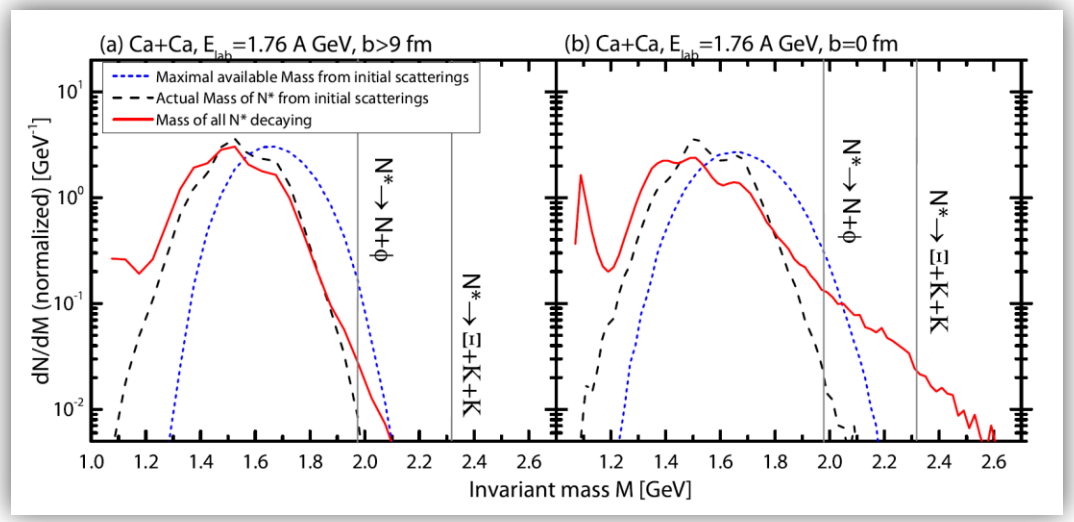
- K^- absorption in π^-W with respect to π^-C
- ϕ/K- ratio the same for C and W

Open question: strangeness production at low energies

- ❑ "Abundant" (multi)-strange particles demand an energy reservoir to be produced sub-threshold

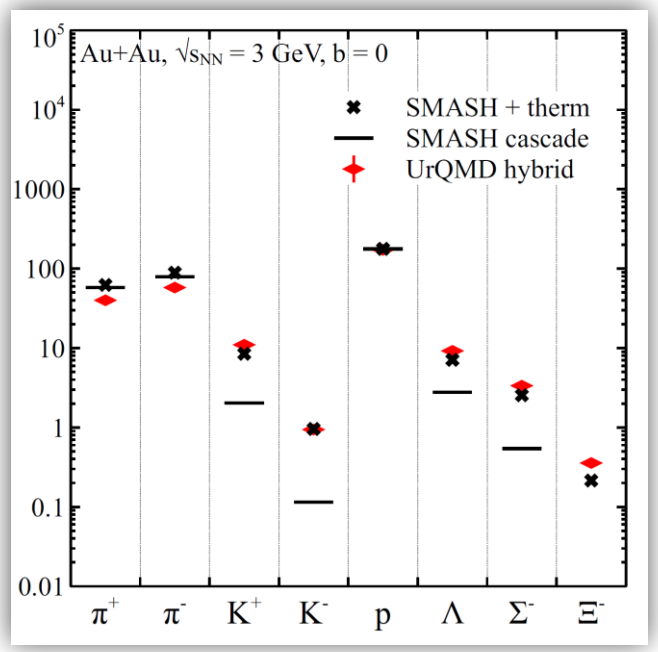
Different approaches:

- ➢ Non equilibrium: branching ratios to strange particles!



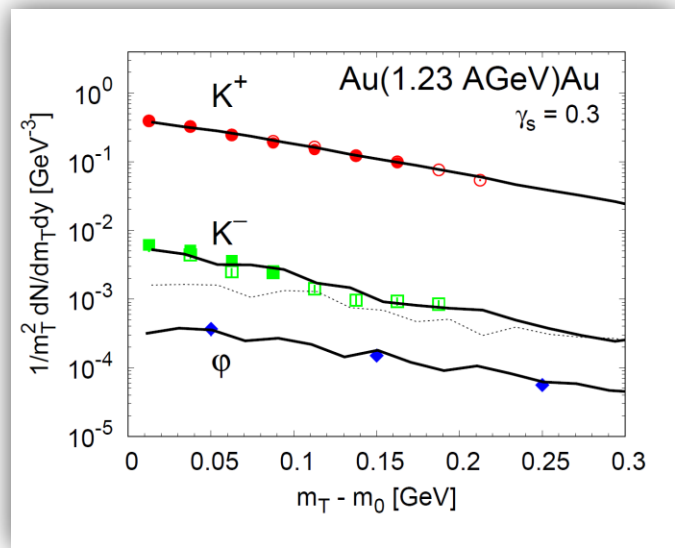
J. Steinheimer and M. Bleicher 2017
J. Phys. Conf. Ser. 779 012017

- ➢ Local forced thermalization



D. Oliinychenko and H. Petersen.
J.Phys. G44 (2017) no.3, 034001

- ➢ Hagedorn states

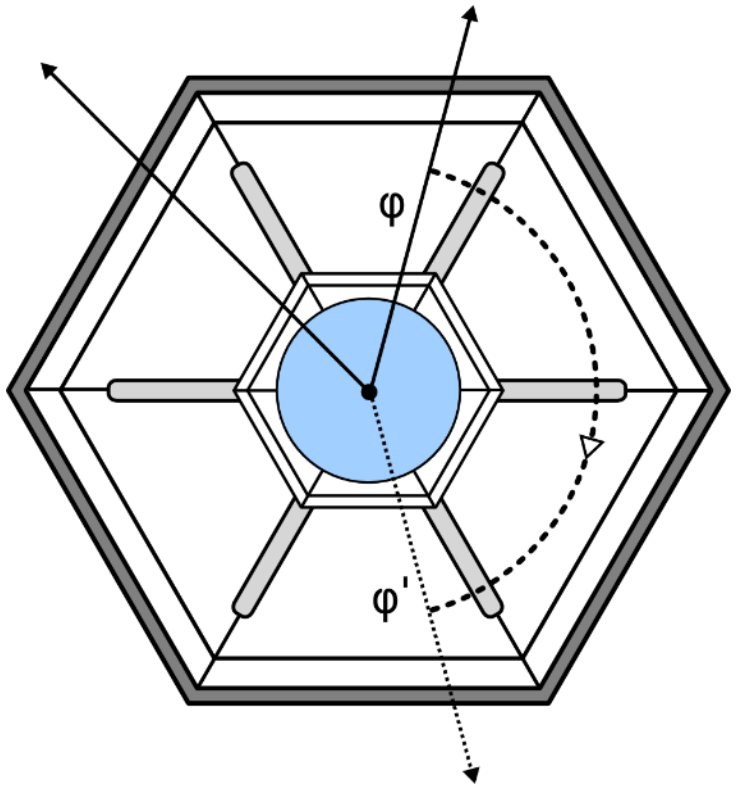


K. Gallmeister, M. Beitel, C. Greiner
arXiv:1712.04018 [hep-ph]

Baryon resonances play a key role!

Can we directly measure resonances and their contributions to strangeness production?

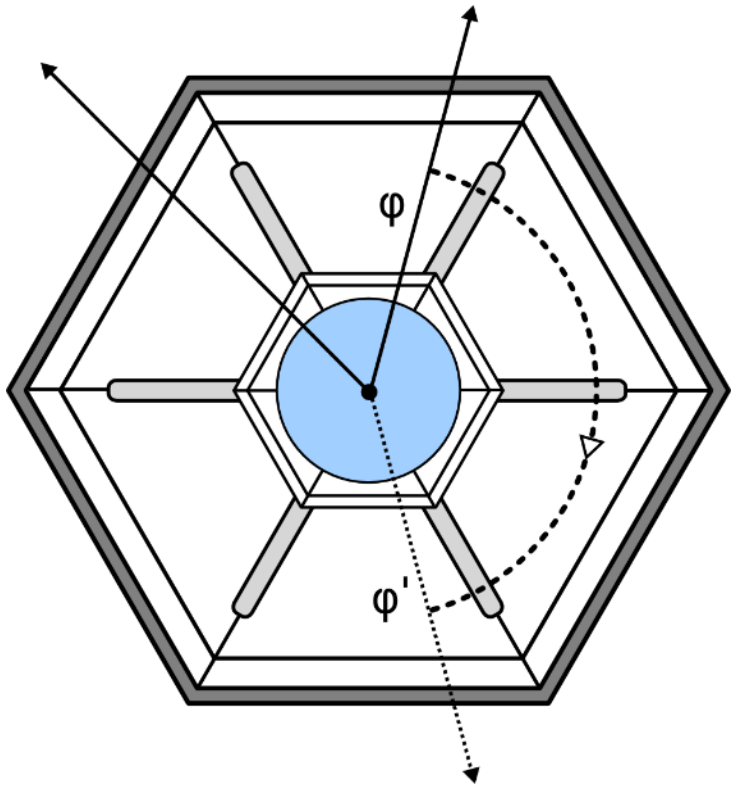
A novel iterative method for estimation of the combinatorial background



The combinatorial background is generated by random rotations of measured tracks.

Rotations preserve E and P_T of the track and the event.

A novel iterative method for estimation of the combinatorial background



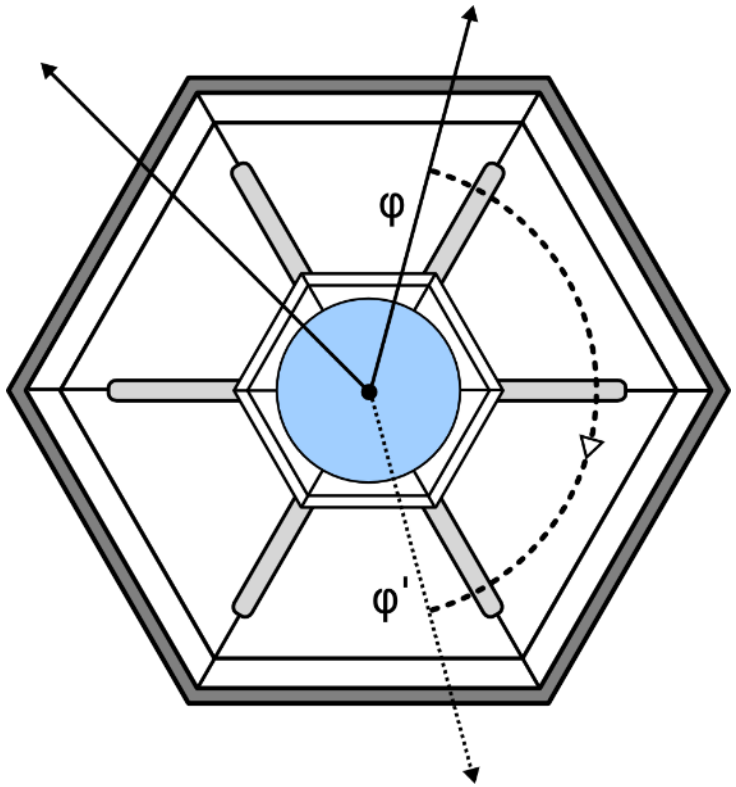
The combinatorial background is generated by random rotations of measured tracks.

Rotations preserve E and P_T of the track and the event.

All reconstructed pair combinations are split into signal and background iteratively.

Solution in M-P_T-Y-θ

A novel iterative method for estimation of the combinatorial background



The combinatorial background is generated by random rotations of measured tracks.

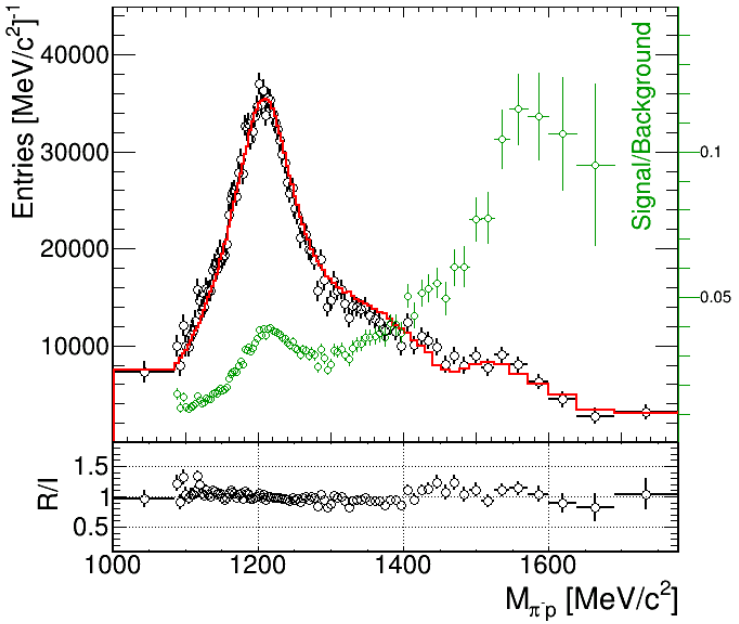
Rotations preserve E and P_T of the track and the event.

All reconstructed pair combinations are split into signal and background iteratively.

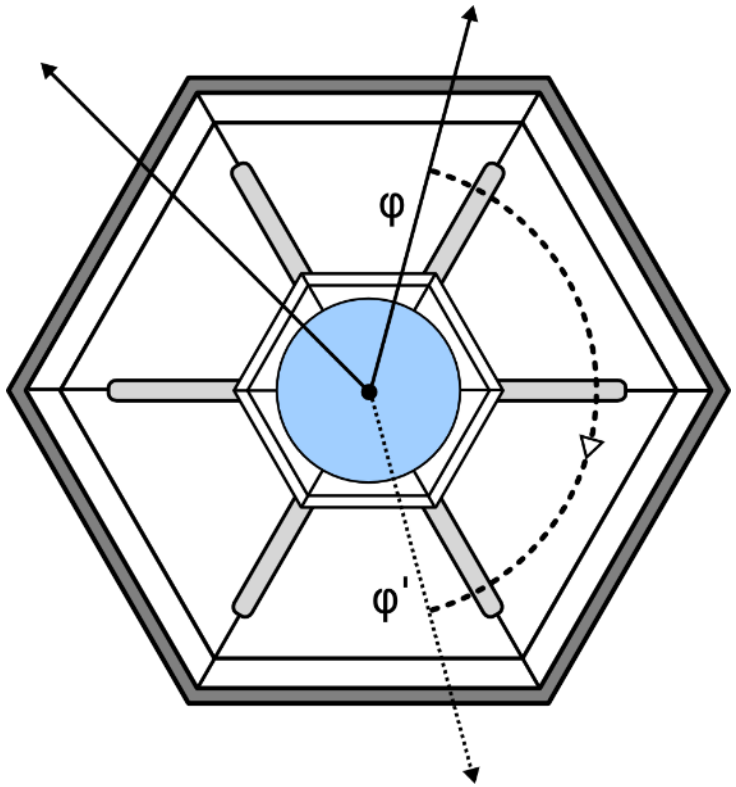
Solution in M-P_T-Y-θ

Validation of the method with simulated* resonance cocktail

* I. Frohlich et al. arXiv:0708.2382 [nucl-ex]



A novel iterative method for estimation of the combinatorial background



The combinatorial background is generated by random rotations of measured tracks.

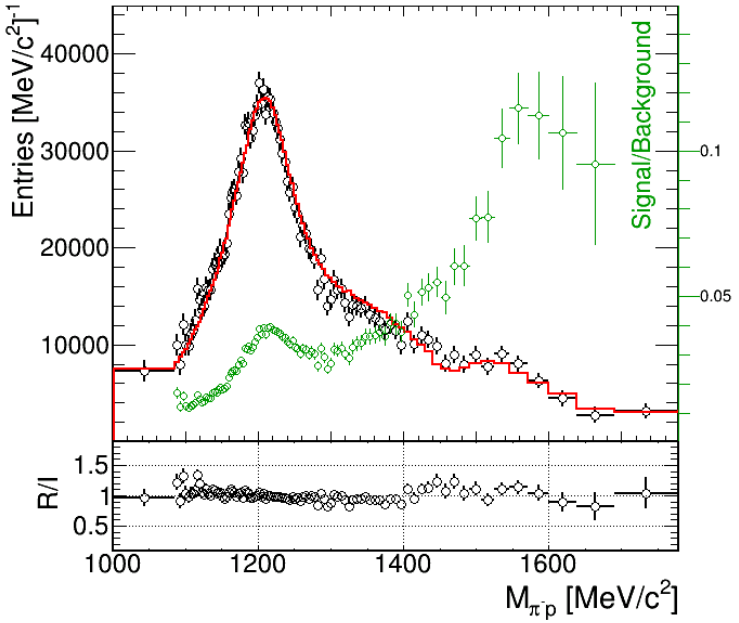
Rotations preserve E and P_T of the track and the event.

All reconstructed pair combinations are split into signal and background iteratively.

Solution in M-P_T-Y-θ

Validation of the method with simulated* resonance cocktail

* I. Frohlich et al. arXiv:0708.2382 [nucl-ex]

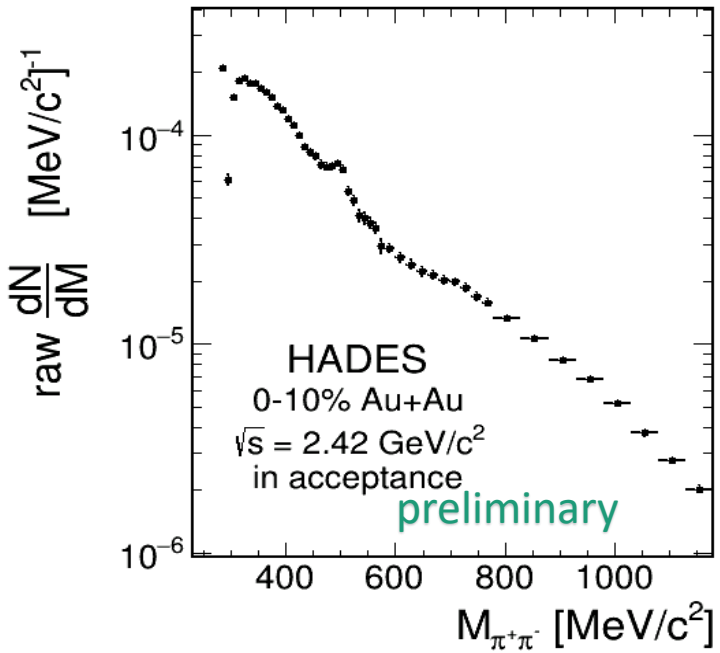


Allows to reconstruct inclusive:

- π^+p
- π^-p
- $\pi^+\pi^-$

Validation with narrow states: Λ and K^0_s

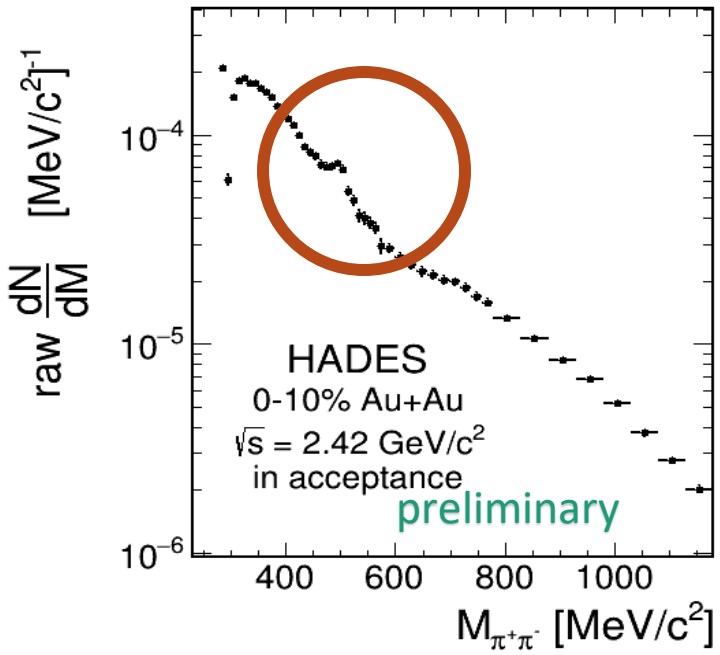
inclusive $\pi^+\pi^-$



No off-vertex condition.
Yield efficiency & acceptance corrected

Validation with narrow states: Λ and K^0_s

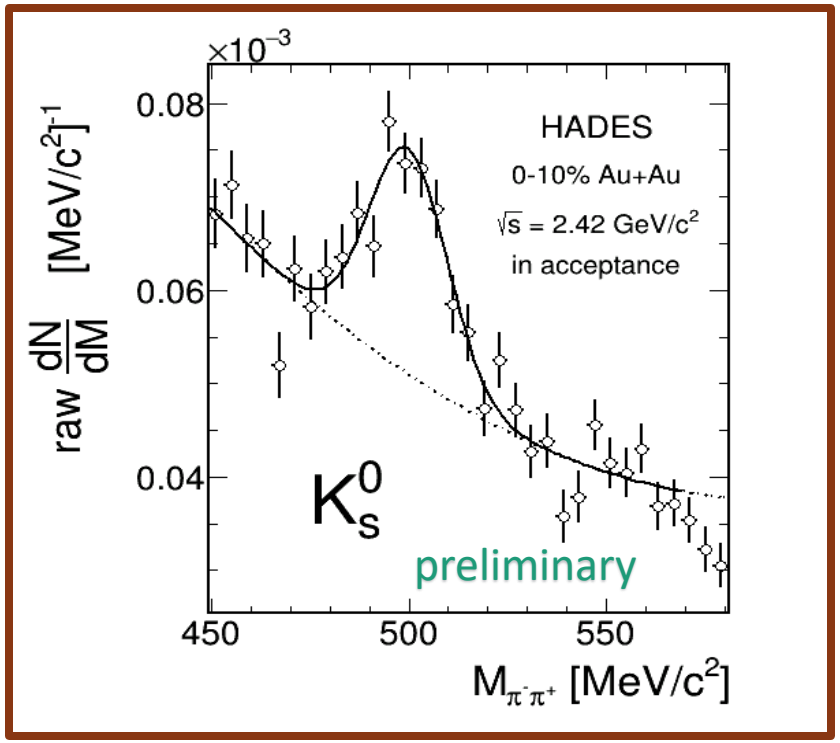
inclusive $\pi^+\pi^-$



No off-vertex condition.
Yield efficiency & acceptance corrected

Validation with narrow states: Λ and K^0_s

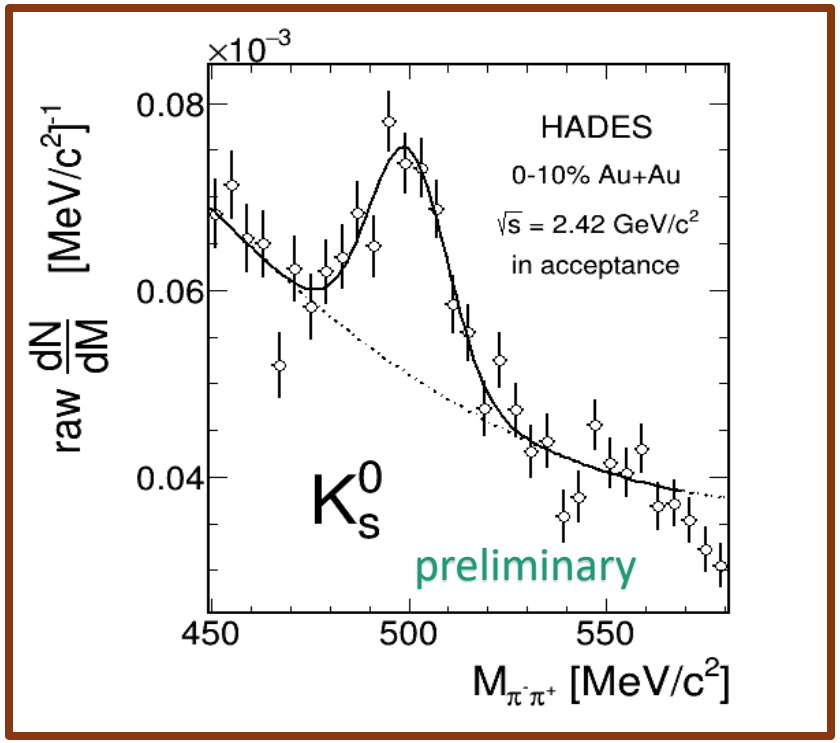
inclusive $\pi^+\pi^-$



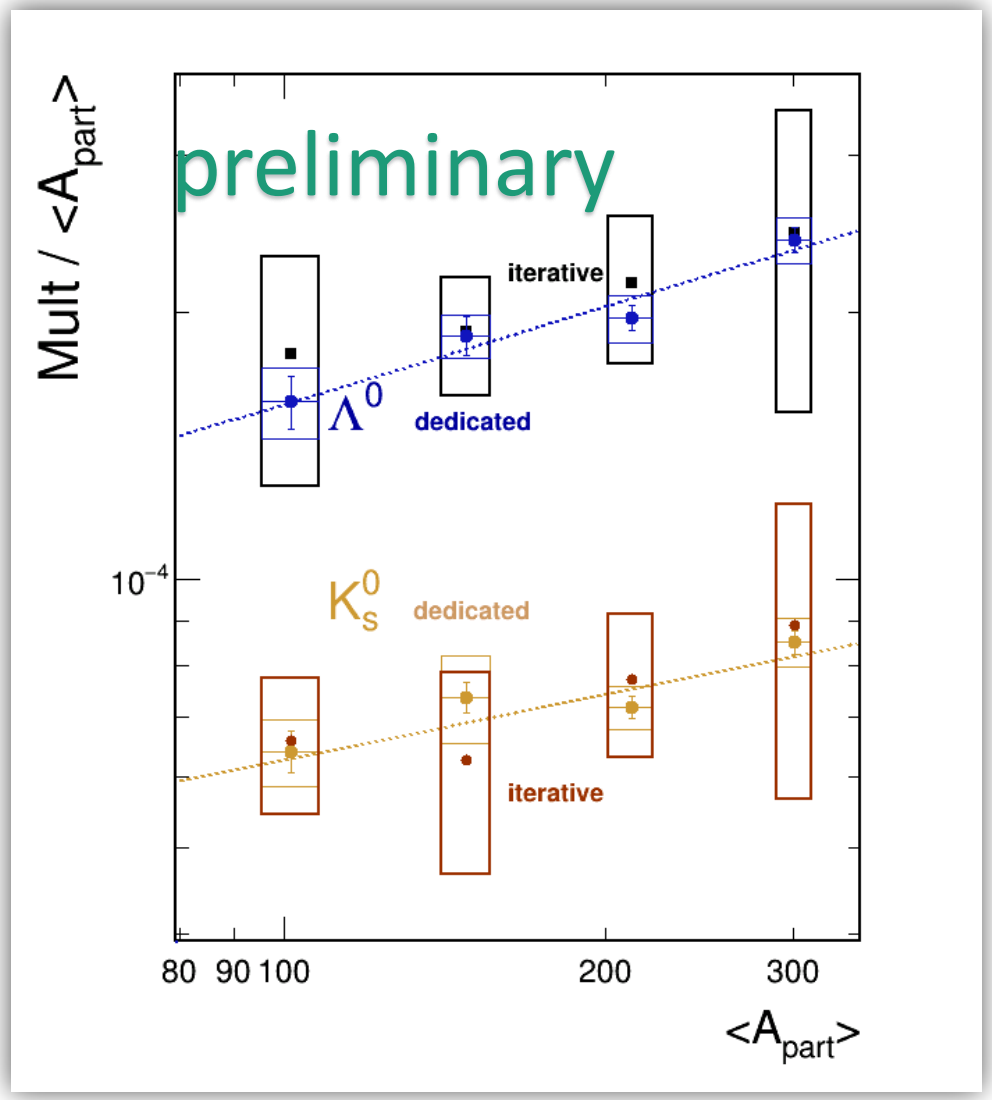
No off-vertex condition.
Yield efficiency & acceptance corrected

Validation with narrow states: Λ and K^0_s

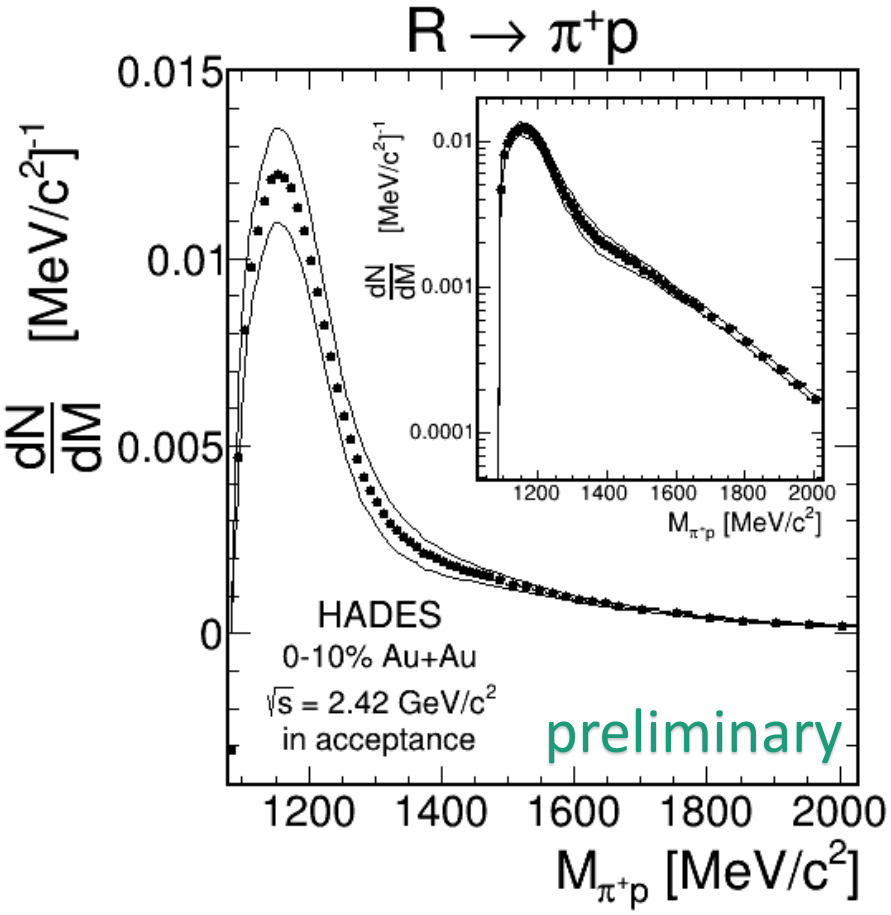
inclusive $\pi^+\pi^-$



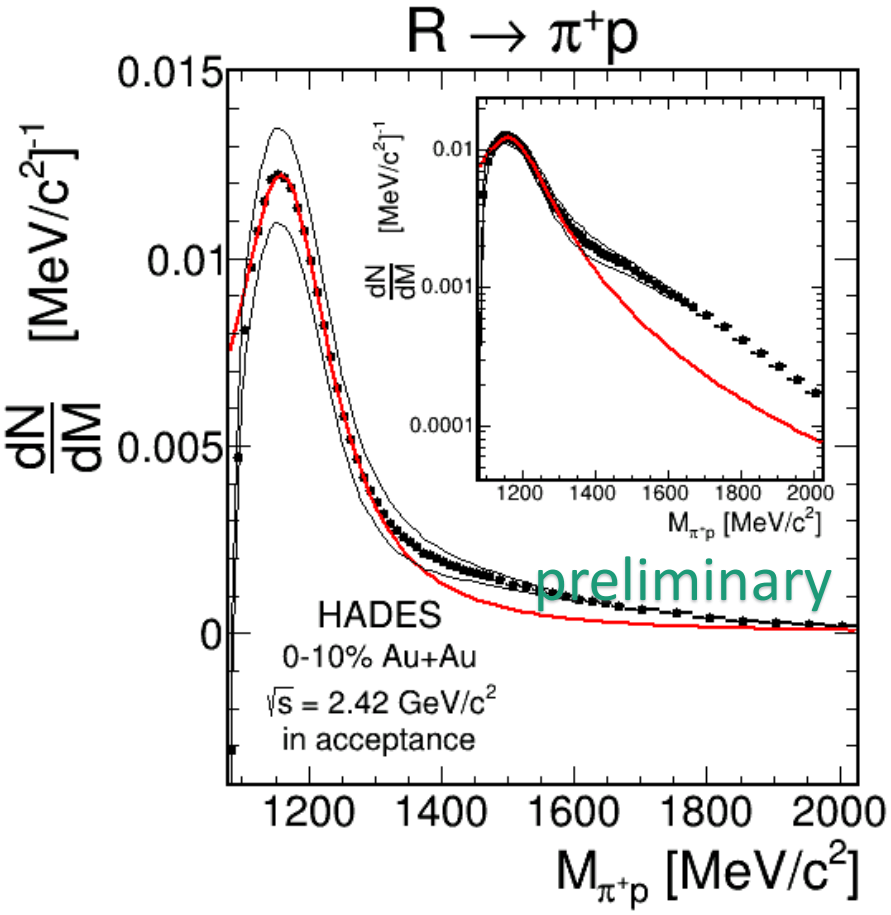
No off-vertex condition.
Yield efficiency & acceptance corrected



Centrality mass and width dependence

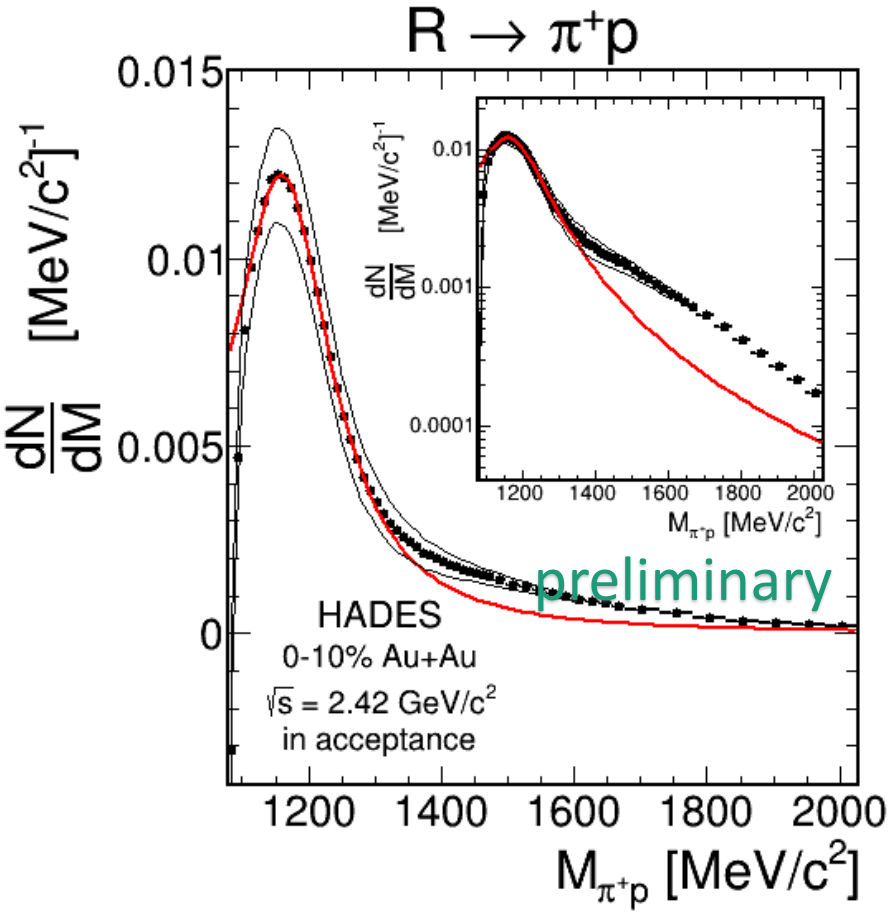


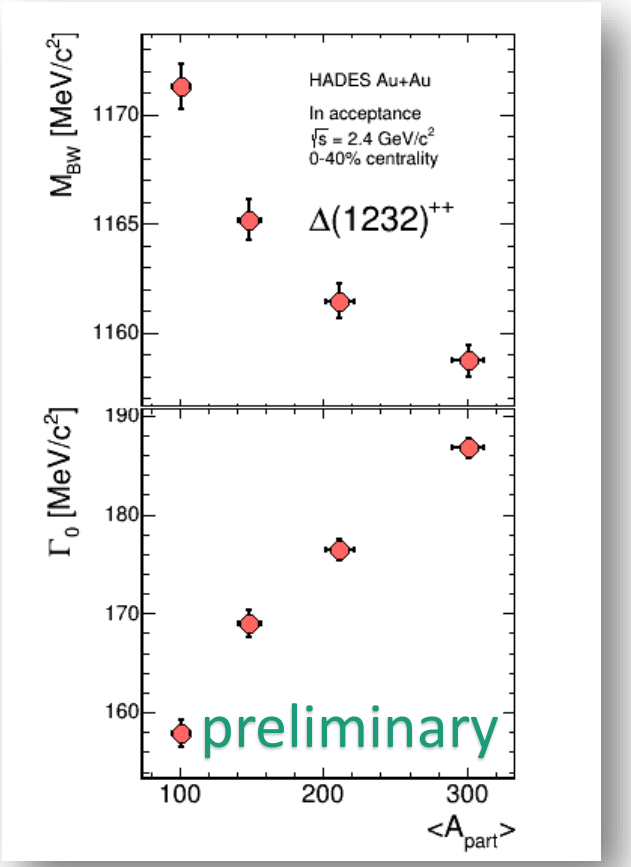
Centrality mass and width dependence



Fit to relativistic BW with mass dependent width.

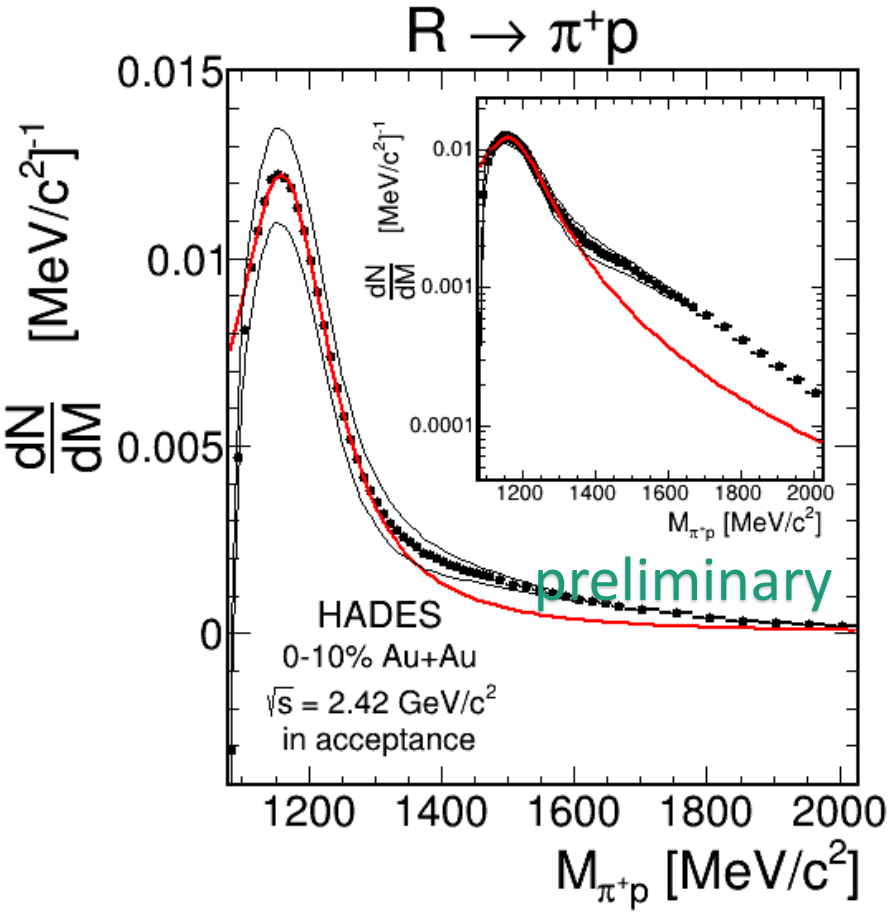
Centrality mass and width dependence



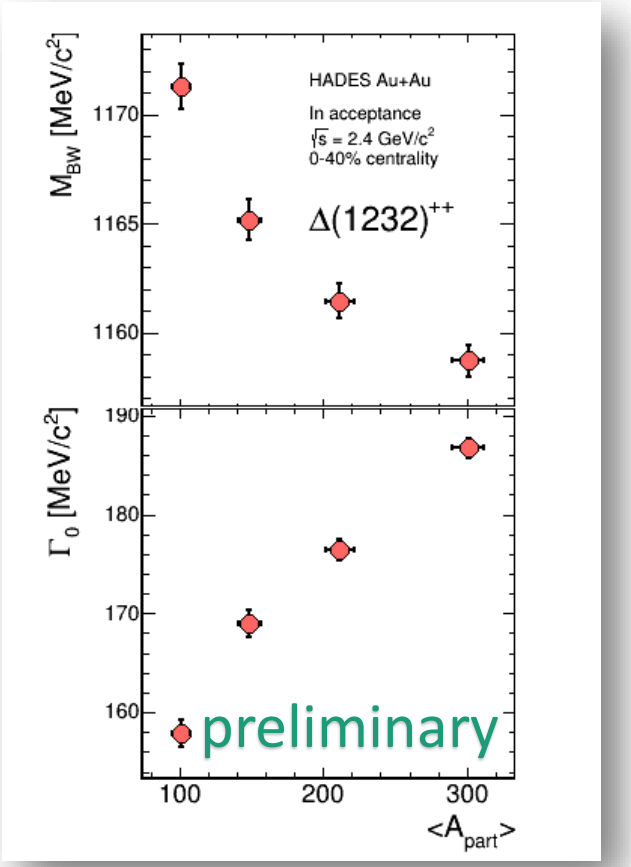


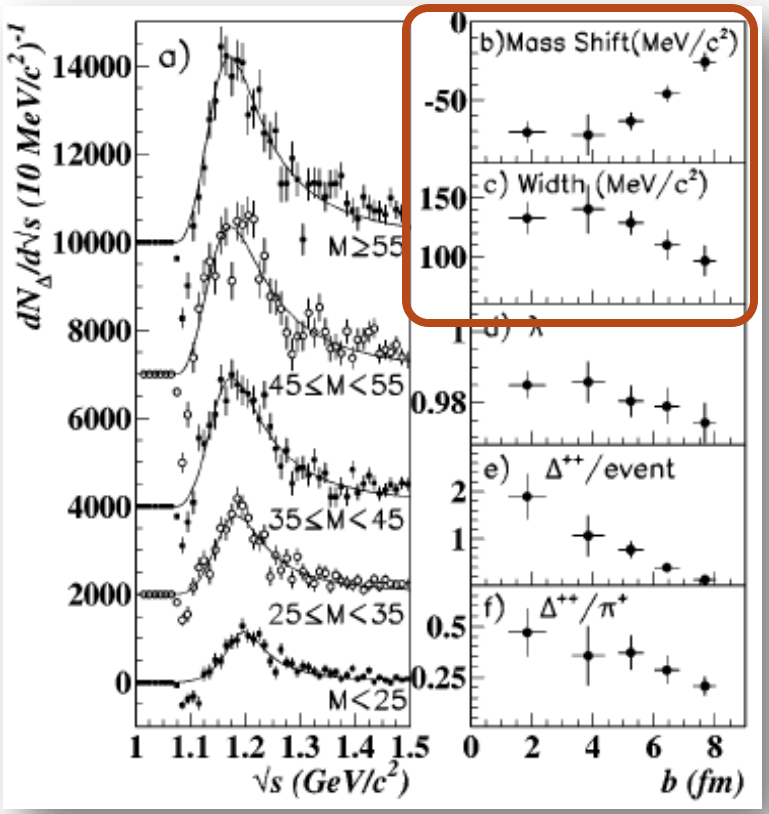
Fit to relativistic BW with mass dependent width.

Centrality mass and width dependence



Fit to relativistic BW with mass dependent width.

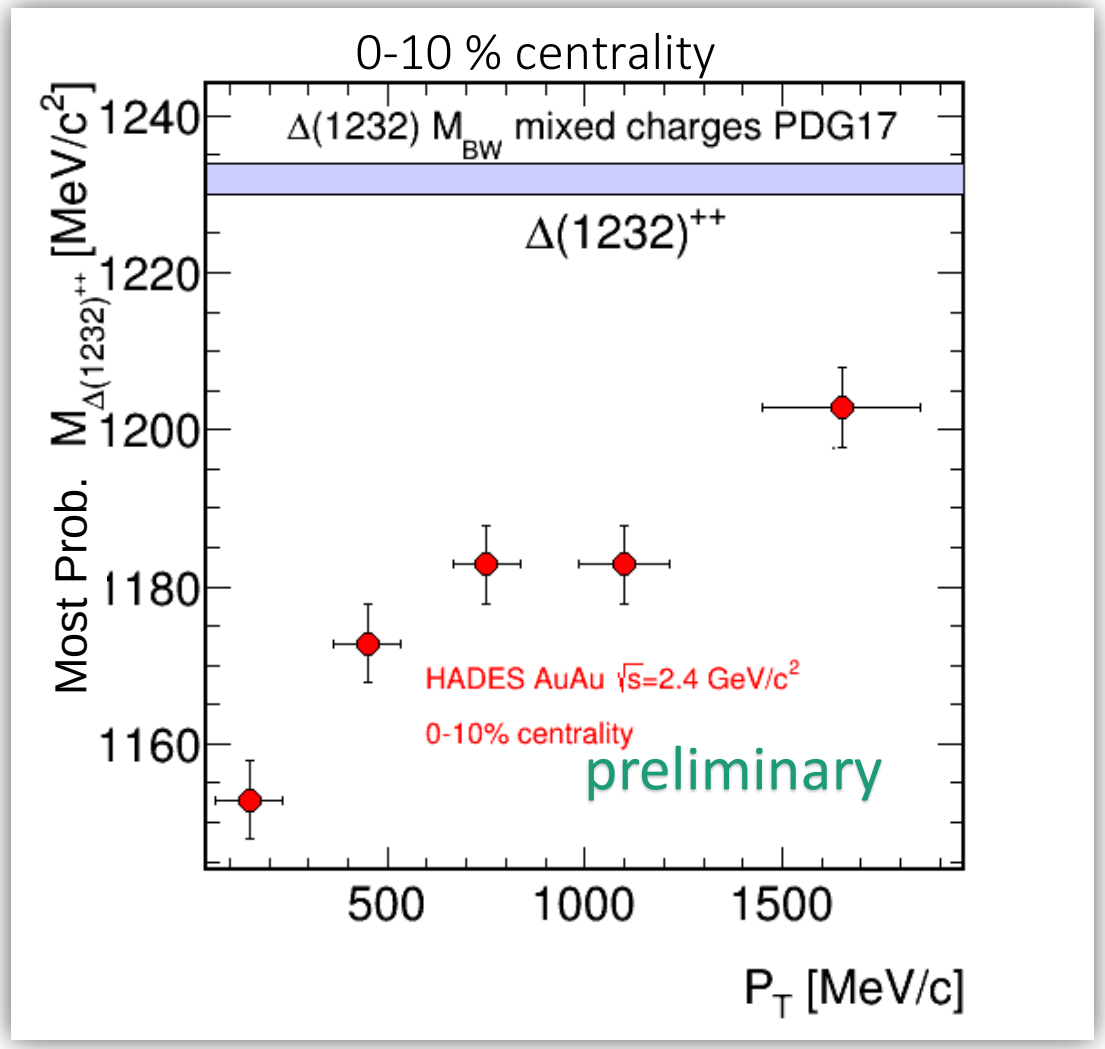




Phys. Rev. Lett. 79, 4345-4348 (1997), E. L. Hjort et al

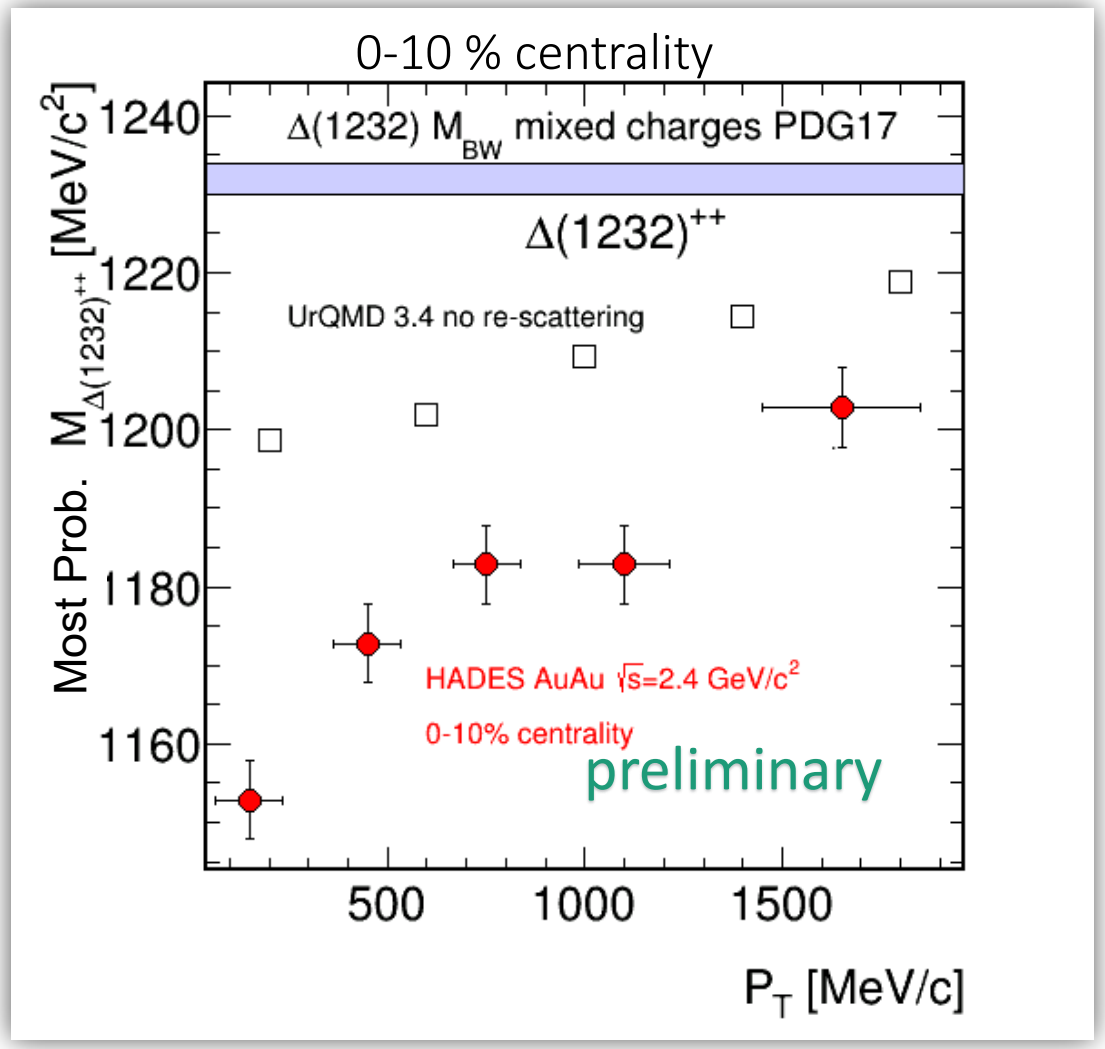
Qualitative agreement with previous results from EOS in NiCu 1.97*A* GeV

Understanding of “kinematical” mass shift



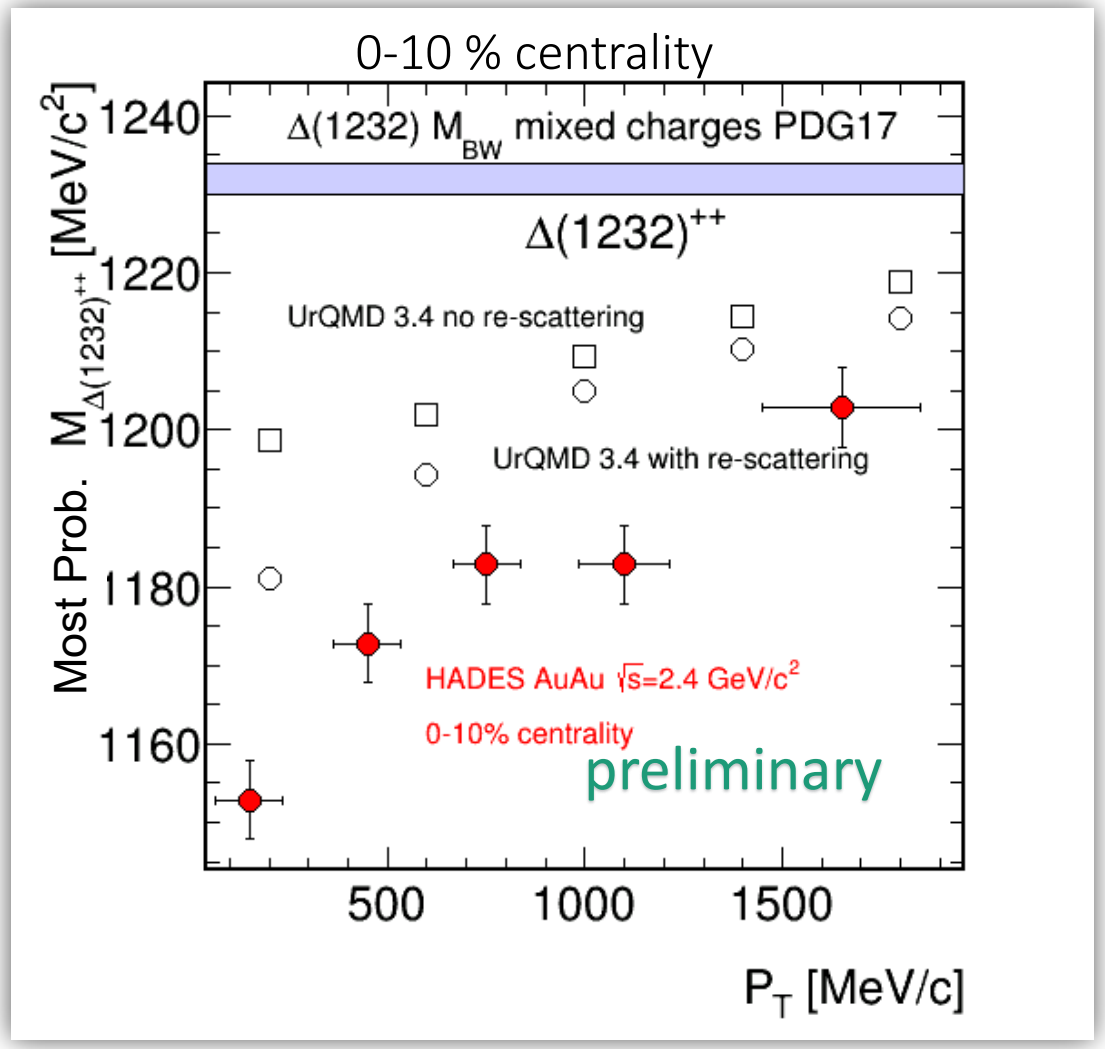
- Most probable π^+p pair mass value as a function of pair P_T

Understanding of “kinematical” mass shift



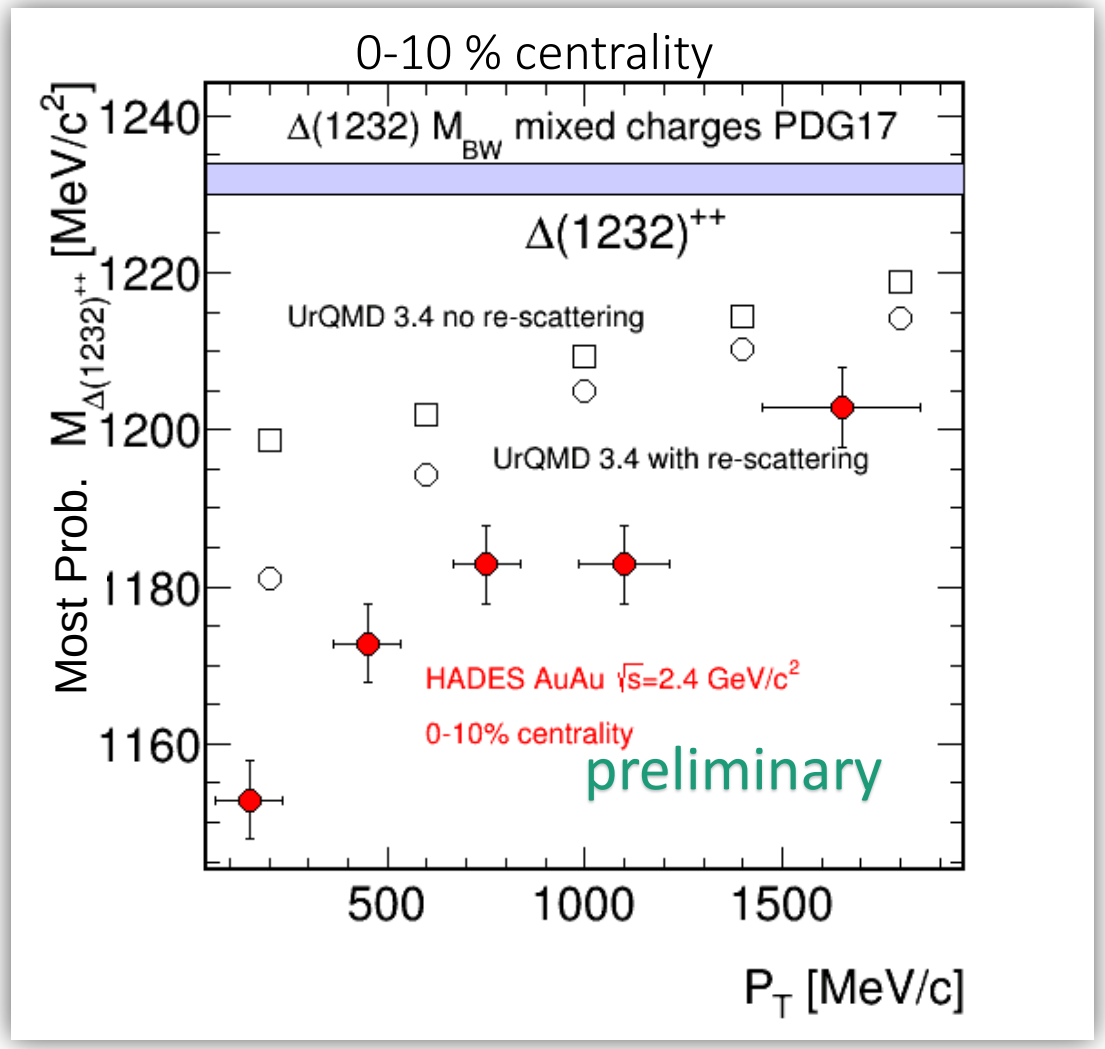
- Most probable π^+p pair mass value as a function of pair P_T
- UrQMD evolution with R→ π^+p with no further re-scattering.

Understanding of “kinematical” mass shift



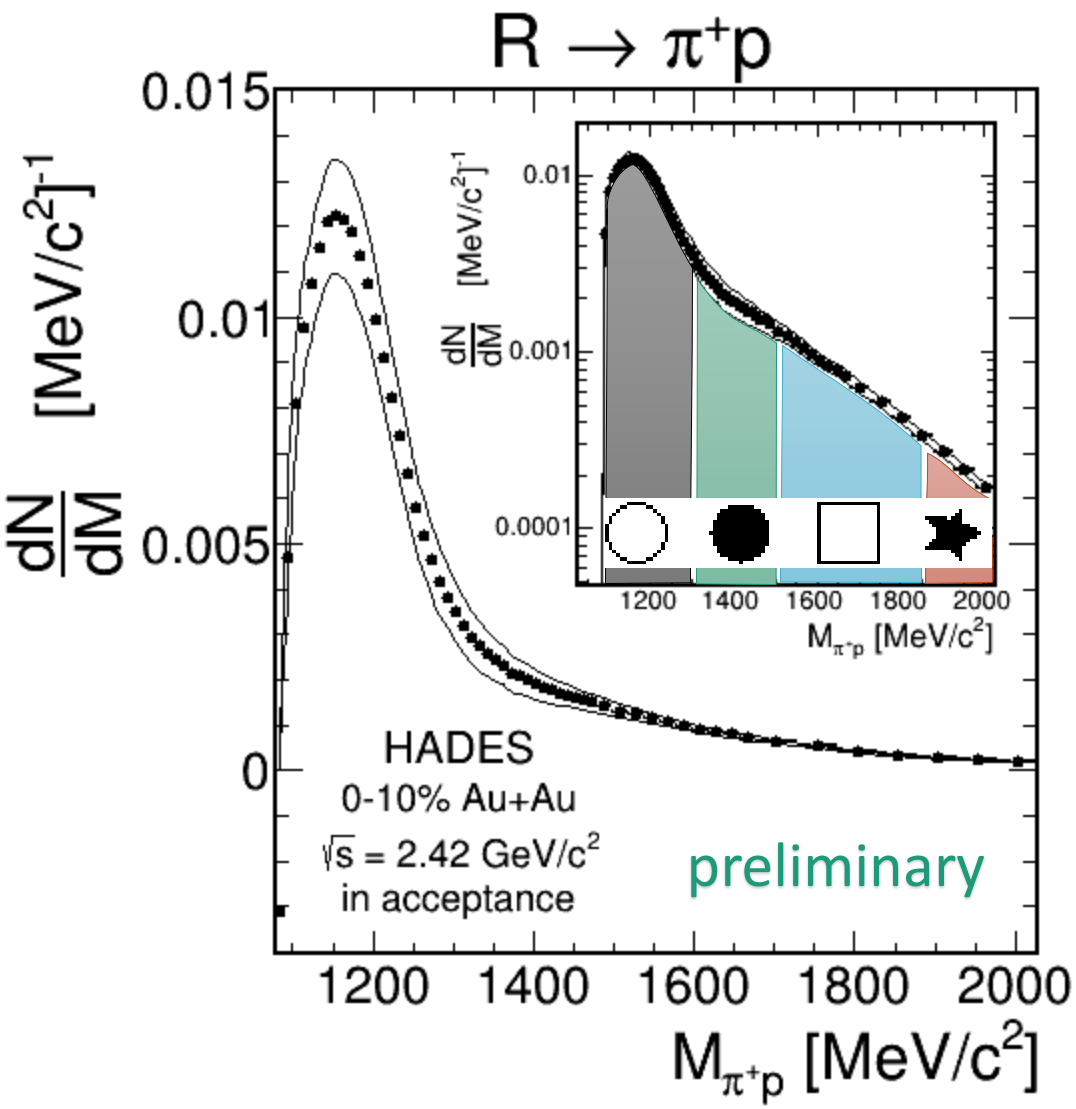
- Most probable π^+p pair mass value as a function of pair P_T
- UrQMD evolution with R→ π^+p with no further re-scattering.
- UrQMD evolution with R→ π^+p with further re-scattering.

Understanding of “kinematical” mass shift

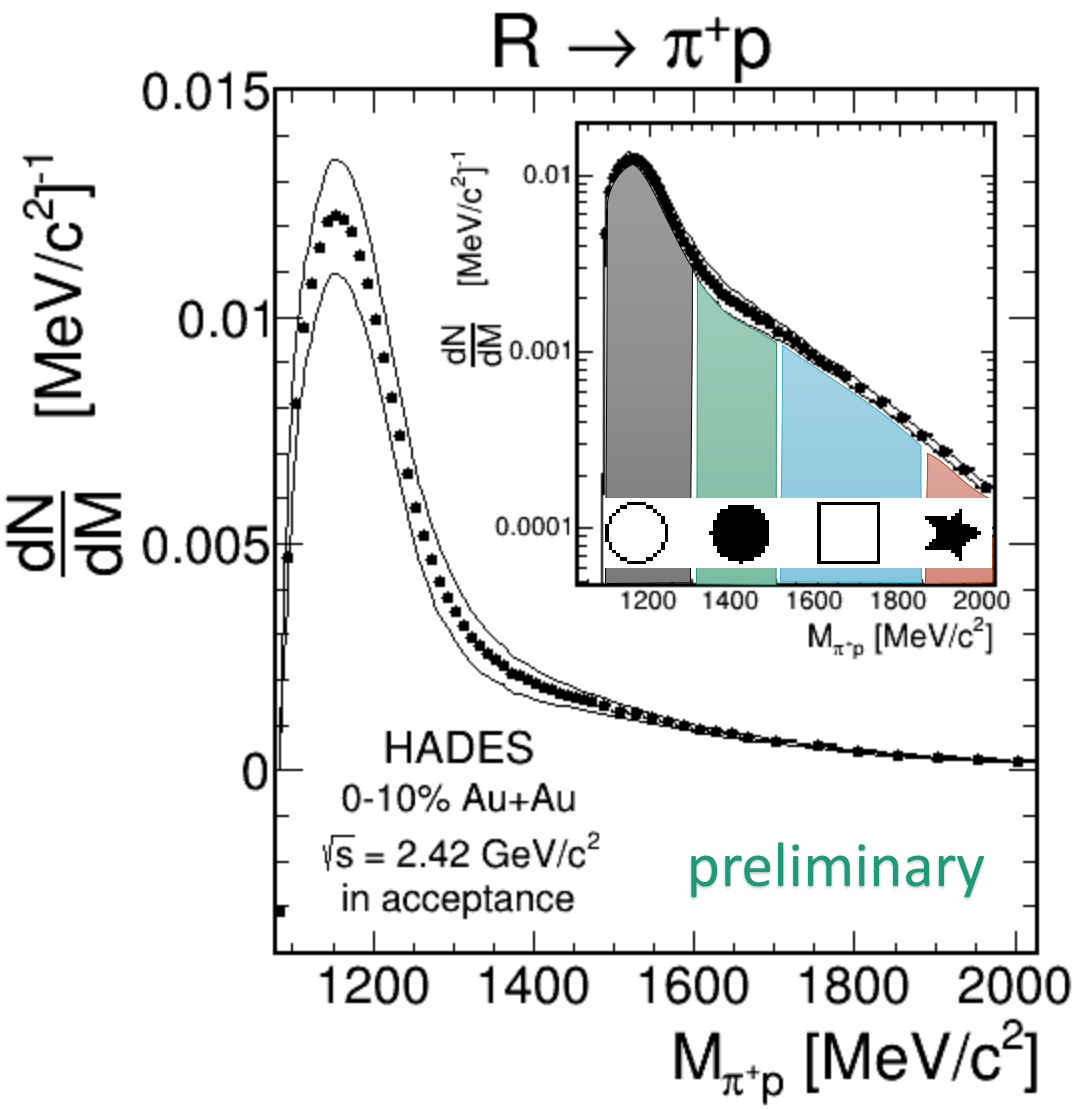


- ❑ Most probable π^+p pair mass value as a function of pair P_T
- ❑ UrQMD evolution with R→ π^+p with no further re-scattering.
- ❑ UrQMD evolution with R→ π^+p with further re-scattering.
- ➢ Qualitative agreement of the trend with transport models: UrQMD

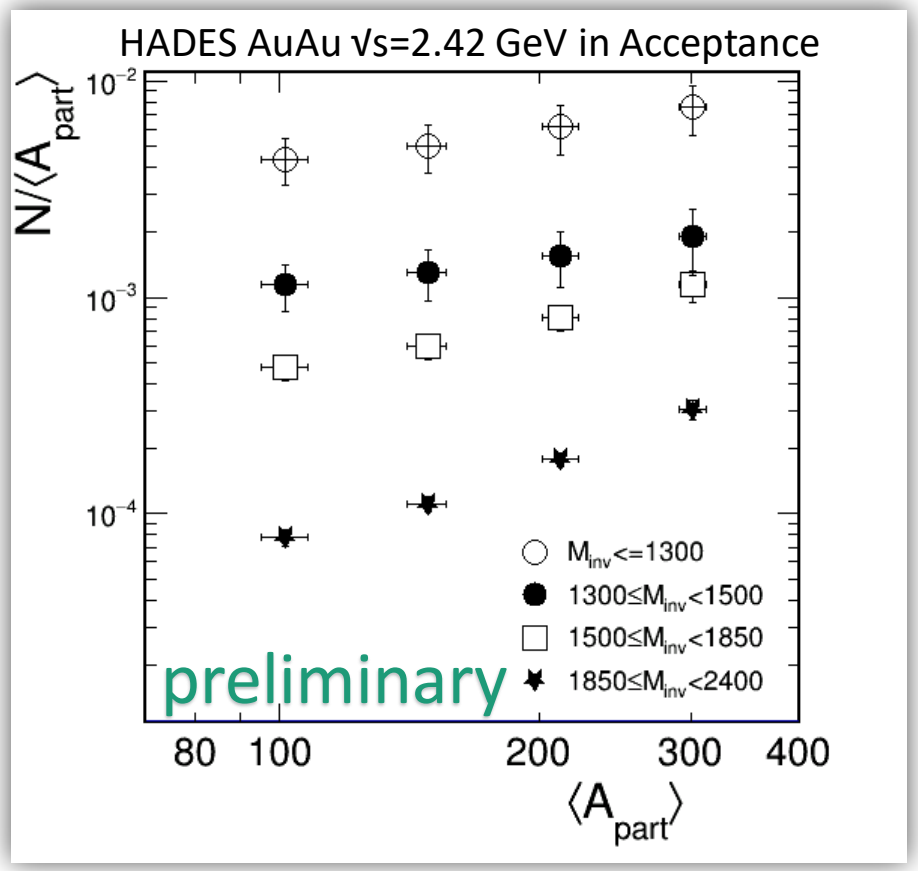
Inclusive spectra of π^+p



Inclusive spectra of π^+p

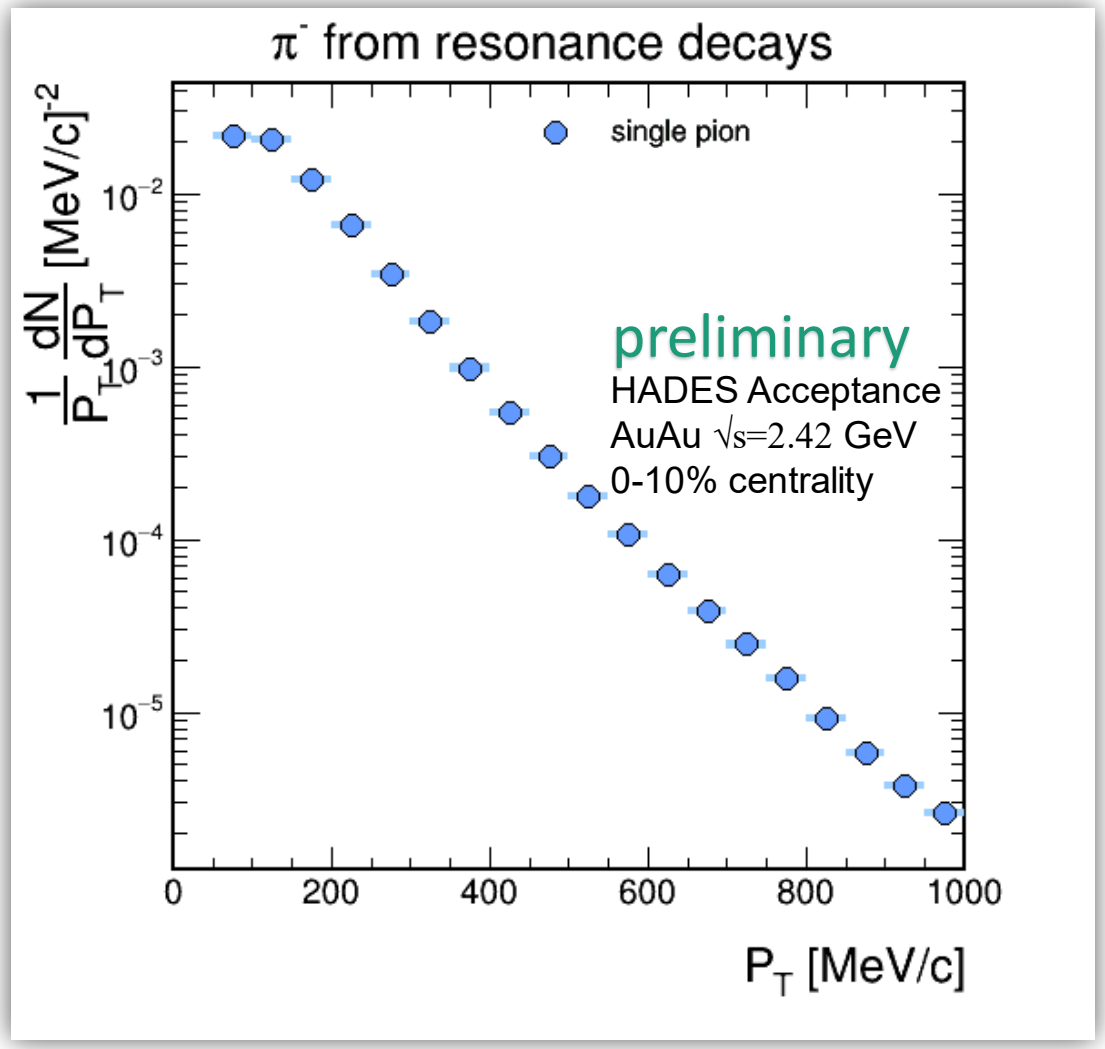


- Mult~ $\langle A_{part}\rangle^{\alpha}$ α = 1.5 +- 0.2 in the Δ^{++} region

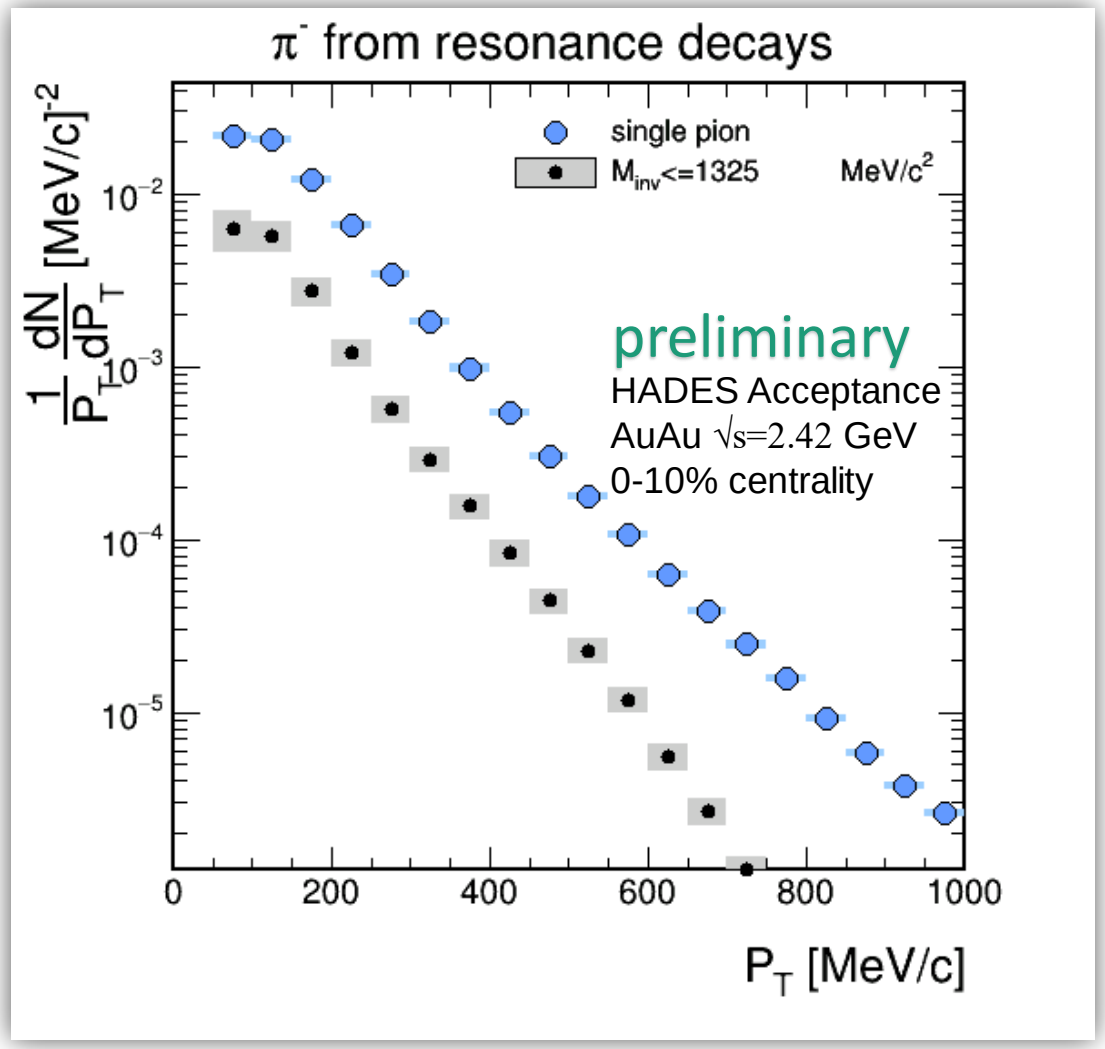


- Interplay between re-generation and re-scattering

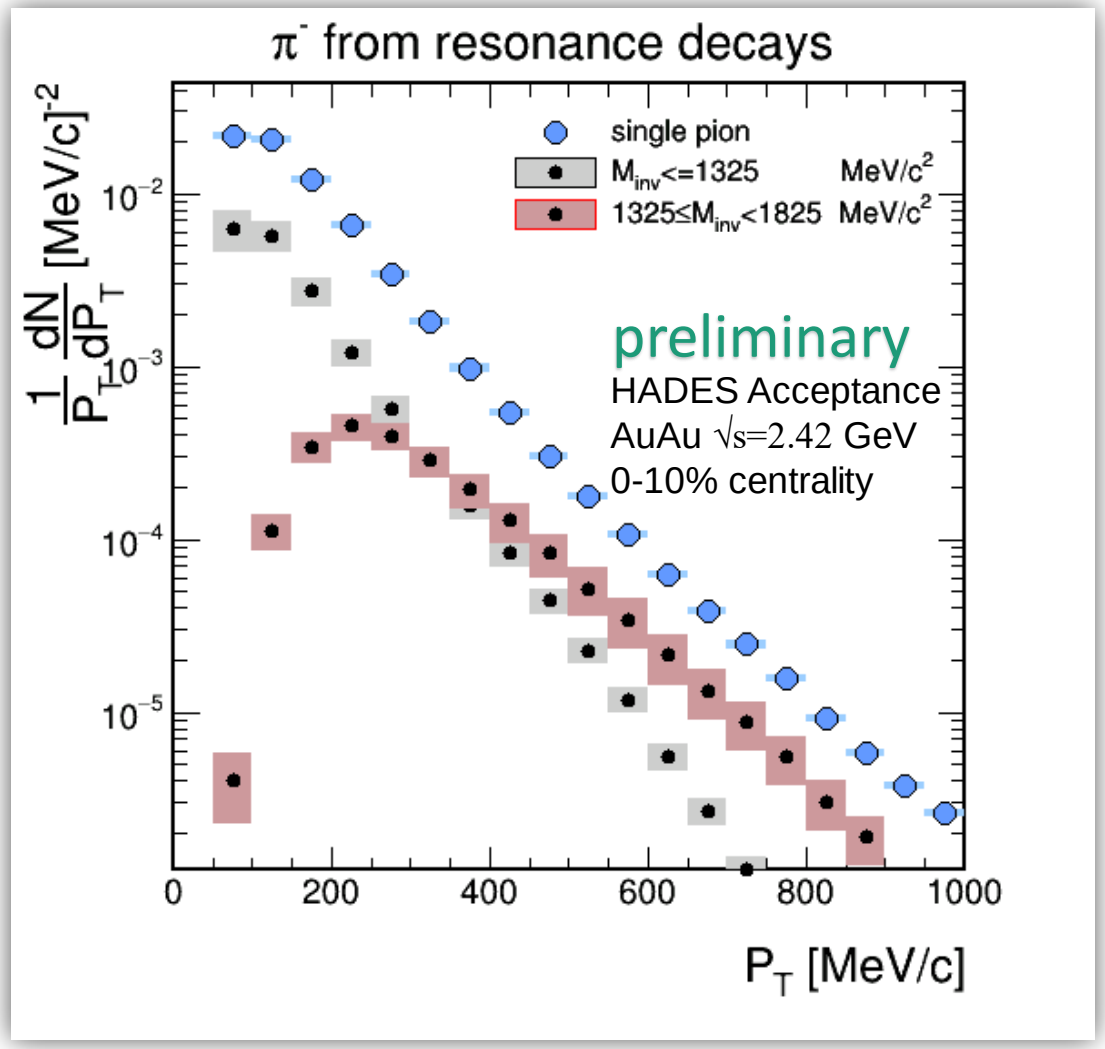
Production of charged pions from resonances: the most ~~simple~~ abundant mesons



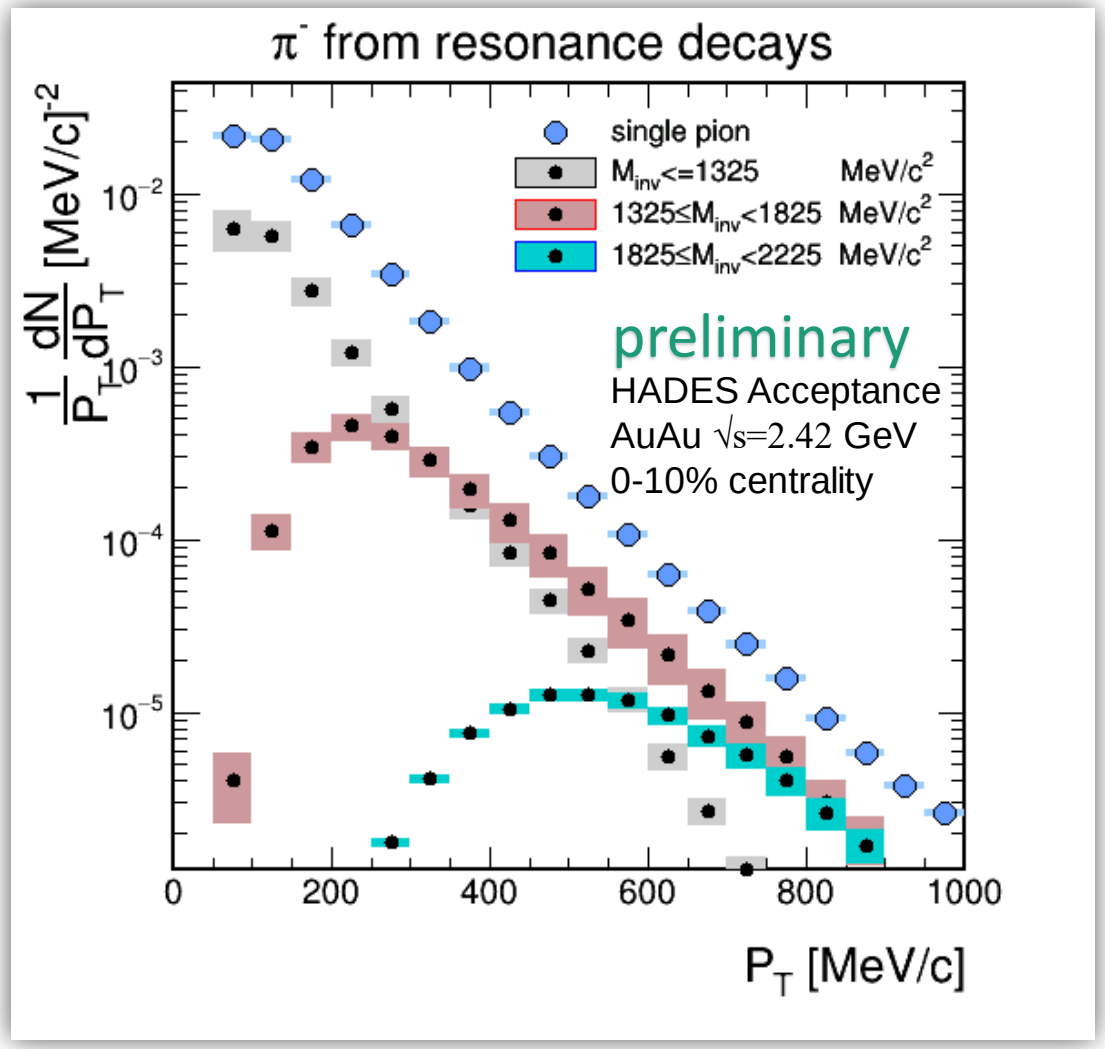
Production of charged pions from resonances: the most ~~simple~~ abundant mesons



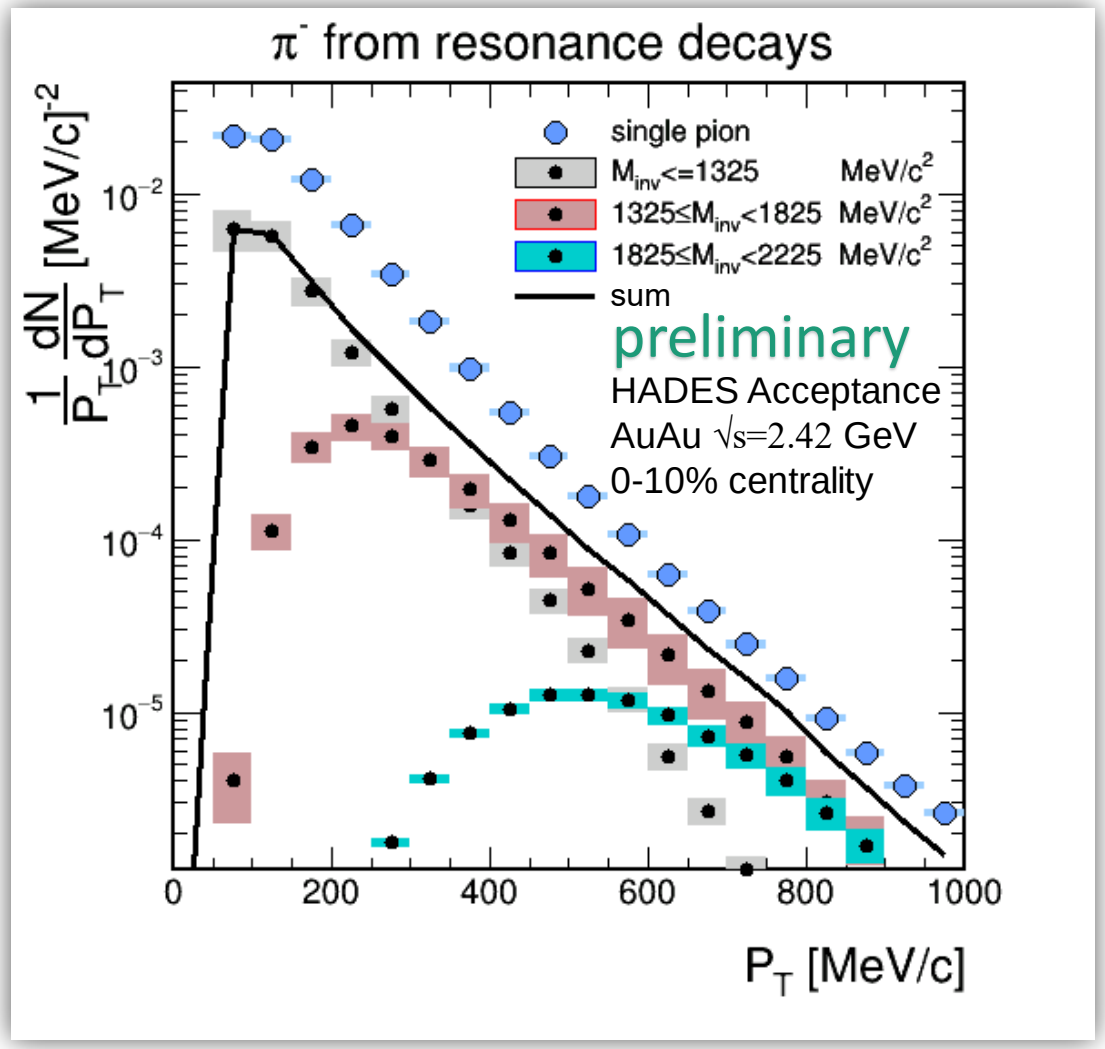
Production of charged pions from resonances: the most ~~simple~~ abundant mesons



Production of charged pions from resonances: the most ~~simple~~ abundant mesons

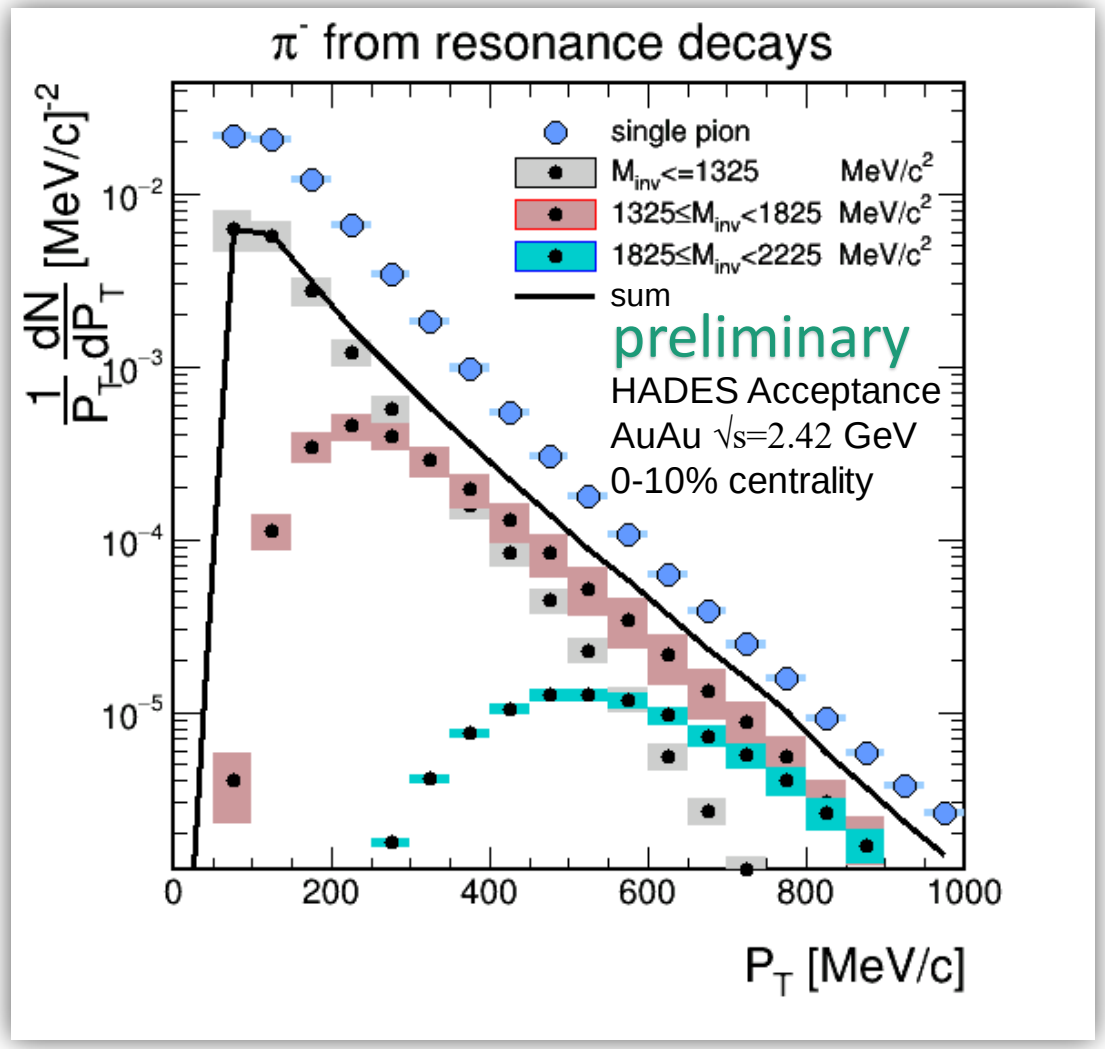


Production of charged pions from resonances: the most ~~simple~~ abundant mesons



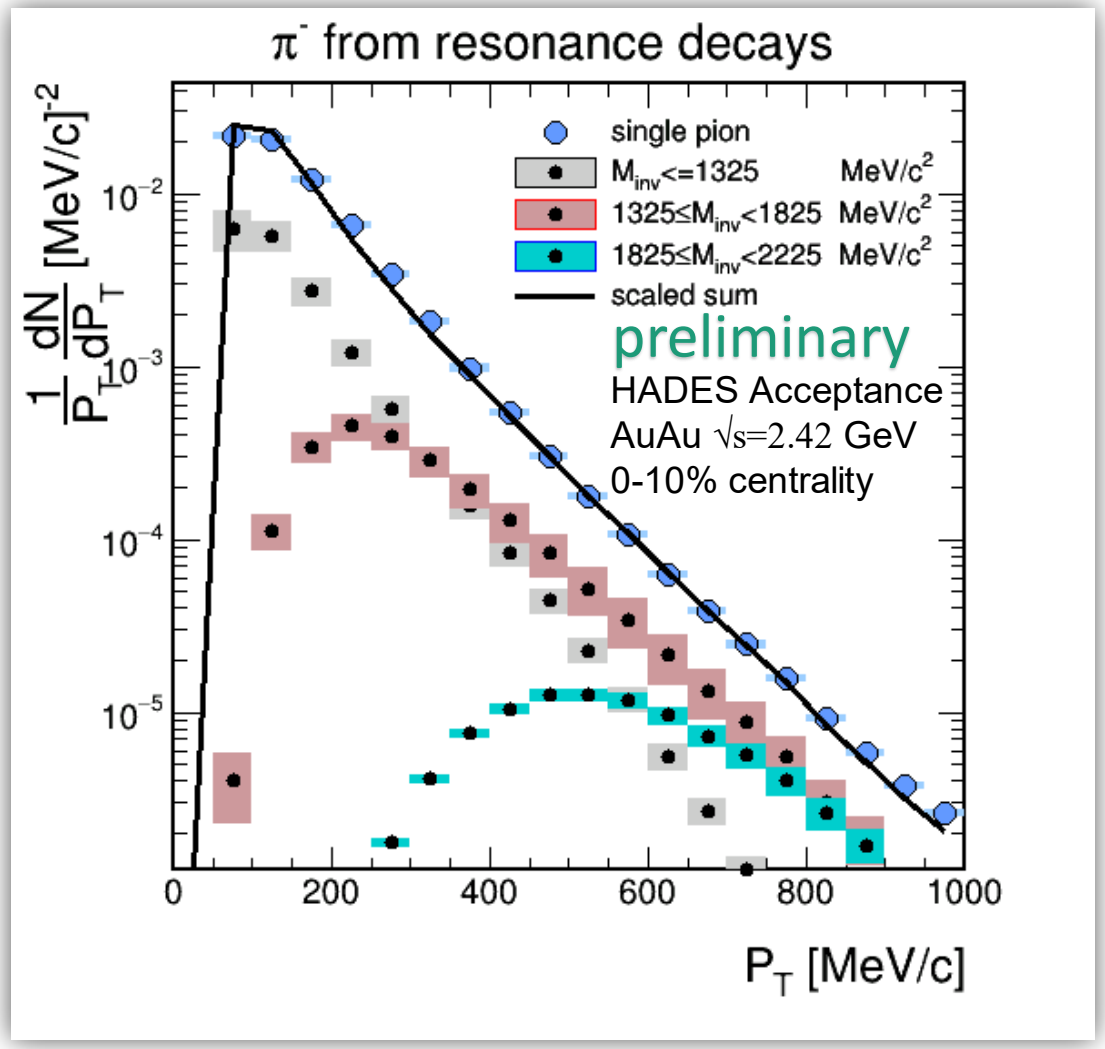
Production of charged pions from resonances: the most ~~simple~~ abundant mesons

- Assuming equally produced $\Delta^{-/0/+/++}$ at freeze-out:
  π^- yield should be scaled by 4
- Pions from high-mass resonances are scaled by 4/3



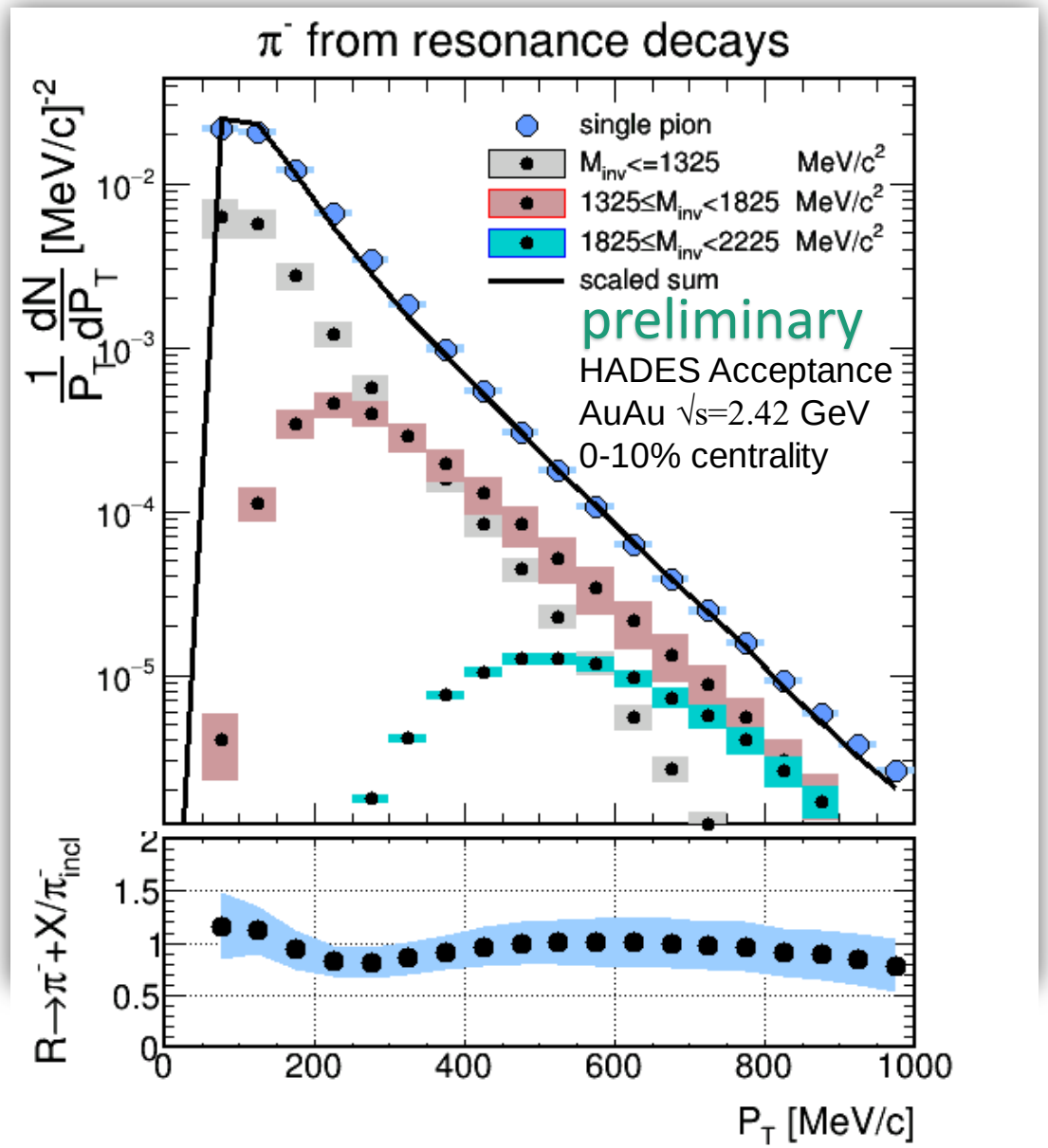
Production of charged pions from resonances: the most ~~simple~~ abundant mesons

- Assuming equally produced $\Delta^{-/0/+/++}$ at freeze-out:
  π^- yield should be scaled by 4
- Pions from high-mass resonances are scaled by 4/3



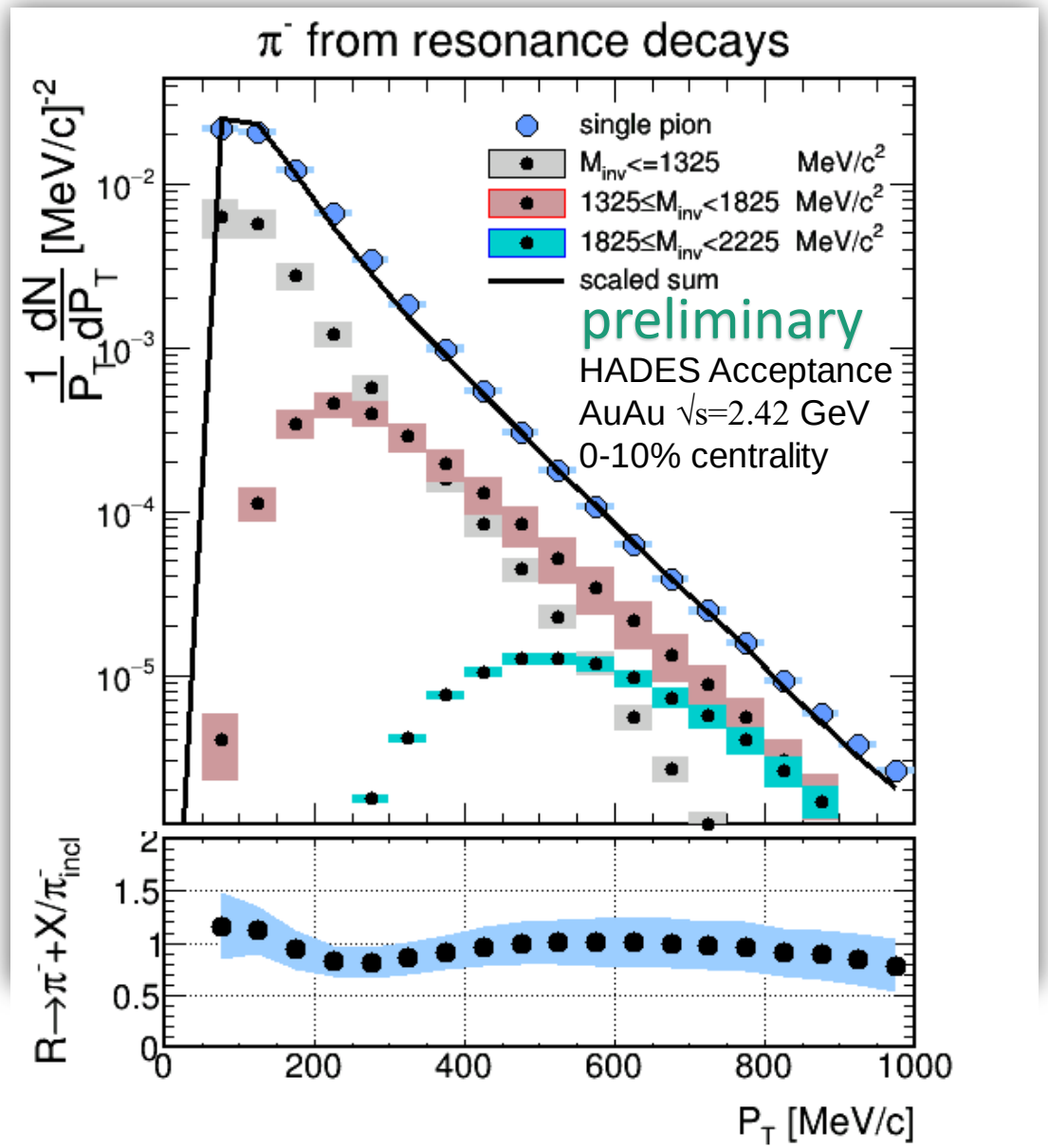
Production of charged pions from resonances: the most ~~simple~~ abundant mesons

- Assuming equally produced $\Delta^{-/0/+/++}$ at freeze-out:
  π^- yield should be scaled by 4
- Pions from high-mass resonances are scaled by 4/3



Production of charged pions from resonances: the most ~~simple~~ abundant mesons

- Assuming equally produced $\Delta^{-/0/+/++}$ at freeze-out: π^- yield should be scaled by 4
- Pions from high-mass resonances are scaled by 4/3



- Measured charged pions in 0-10% central collisions are well reproduced from decay of baryonic resonances

Summary

- Universal centrality dependence of strangeness production
- K^- and ϕ equally absorbed in cold nuclear matter in pion induced reactions at $\sqrt{s_{\pi N}} = 2$ GeV
- Baryon resonances are relevant for modelling strangeness production.
- A novel iterative technique allows to reconstruct signals with large combinatorial background.
- First steps toward strangeness production from measured baryonic resonances: description of single pion spectra in central collisions.

Summary

- Universal centrality dependence of strangeness production
- K^- and ϕ equally absorbed in cold nuclear matter in pion induced reactions at $\sqrt{s_{\pi N}} = 2$ GeV
- Baryon resonances are relevant for modelling strangeness production.
- A novel iterative technique allows to reconstruct signals with large combinatorial background.
- First steps toward strangeness production from measured baryonic resonances: description of single pion spectra in central collisions.

Outlook

- Understand production of resonances as a function of centrality.
- Calculate kaon spectra.

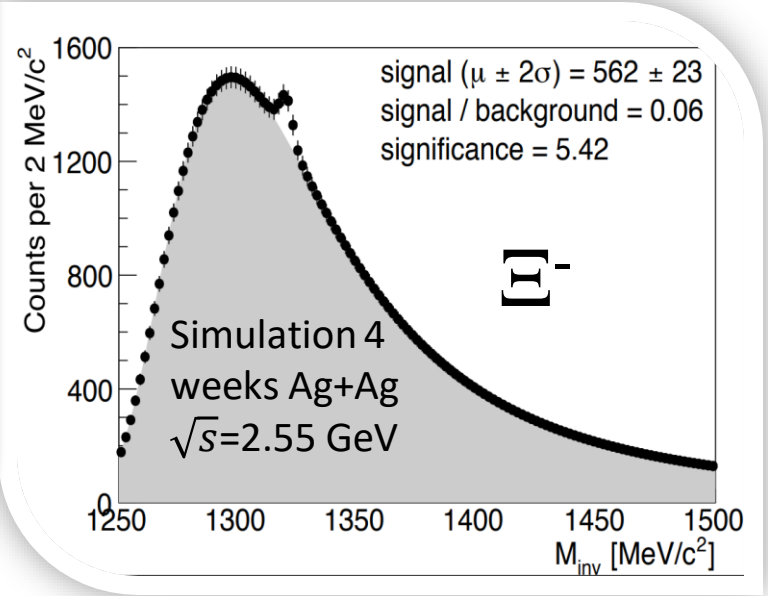
Summary

- Universal centrality dependence of strangeness production
- K^- and ϕ equally absorbed in cold nuclear matter in pion induced reactions at $\sqrt{s_{\pi N}} = 2$ GeV
- Baryon resonances are relevant for modelling strangeness production.
- A novel iterative technique allows to reconstruct signals with large combinatorial background.
- First steps toward strangeness production from measured baryonic resonances: description of single pion spectra in central collisions.

Outlook

- Understand production of resonances as a function of centrality.
- Calculate kaon spectra.

Ag+Ag 1.65*A* GeV August 18



Summary

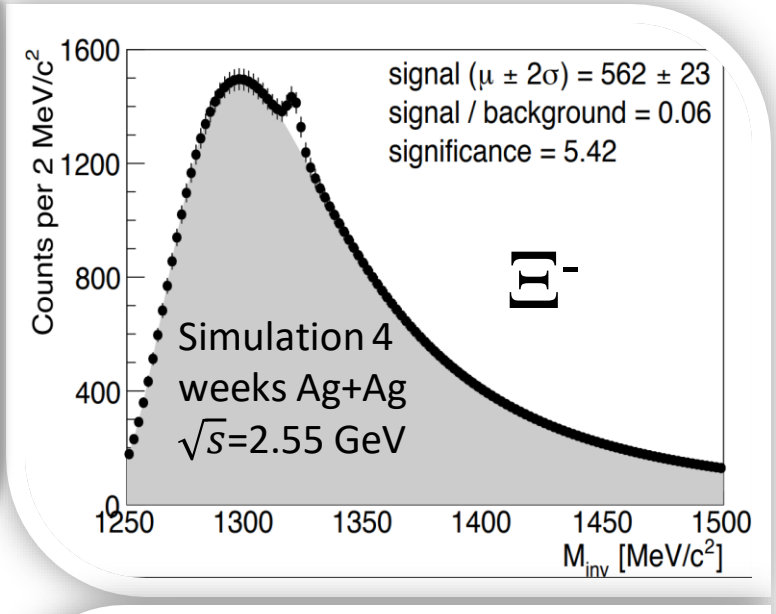
- Universal centrality dependence of strangeness production
- K^- and ϕ equally absorbed in cold nuclear matter in pion induced reactions at $\sqrt{s_{\pi N}} = 2$ GeV
- Baryon resonances are relevant for modelling strangeness production.
- A novel iterative technique allows to reconstruct signals with large combinatorial background.
- First steps toward strangeness production from measured baryonic resonances: description of single pion spectra in central collisions.

Outlook

- Understand production of resonances as a function of centrality.
- Calculate kaon spectra.

Ag+Ag 1.65*A* GeV August 18

- ECAL
  - Access to decays with neutral particles in the final state.
  - Direct photons.



Summary

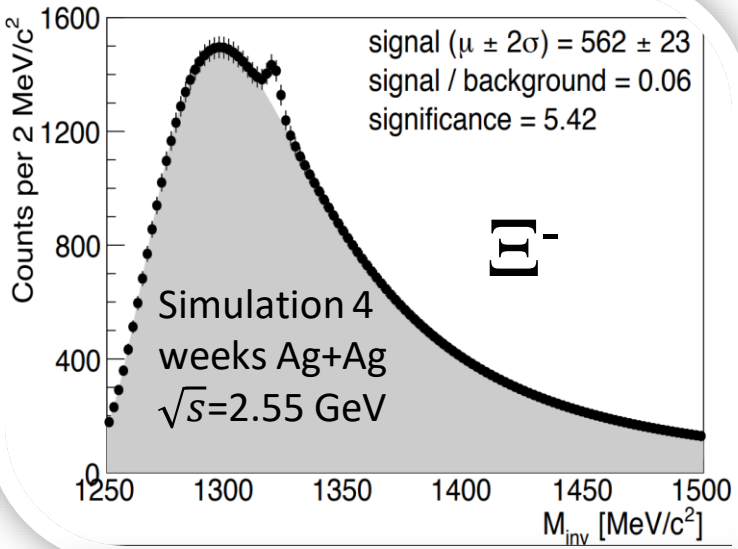
- Universal centrality dependence of strangeness production
- K^- and ϕ equally absorbed in cold nuclear matter in pion induced reactions at $\sqrt{s_{\pi N}} = 2$ GeV
- Baryon resonances are relevant for modelling strangeness production.
- A novel iterative technique allows to reconstruct signals with large combinatorial background.
- First steps toward strangeness production from measured baryonic resonances: description of single pion spectra in central collisions.

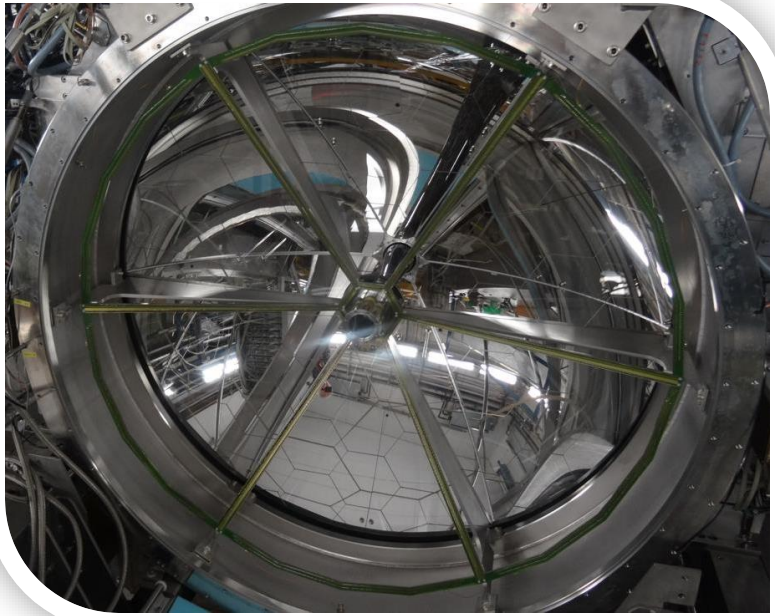
Outlook

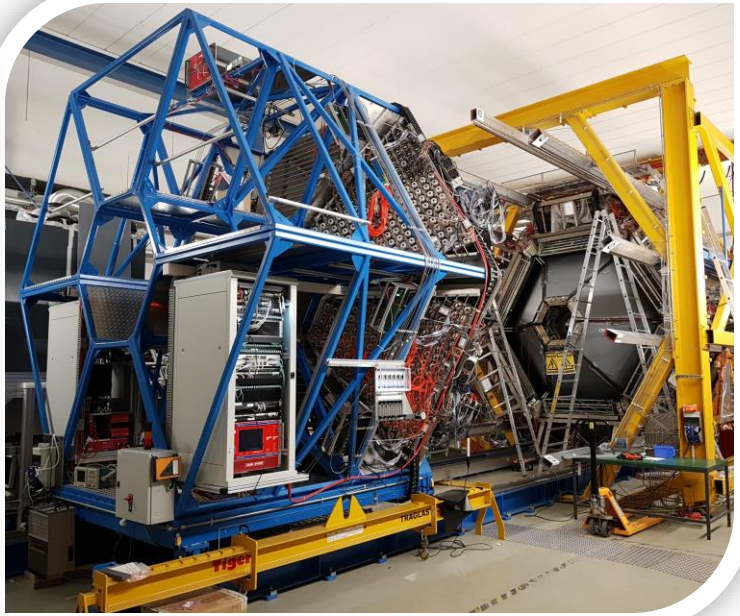
- Understand production of resonances as a function of centrality.
- Calculate kaon spectra.

Ag+Ag 1.65*A* GeV August 18

- ECAL
  - Access to decays with neutral particles in the final state.
  - Direct photons.
- RICH upgrade
  - higher e+e- efficiency



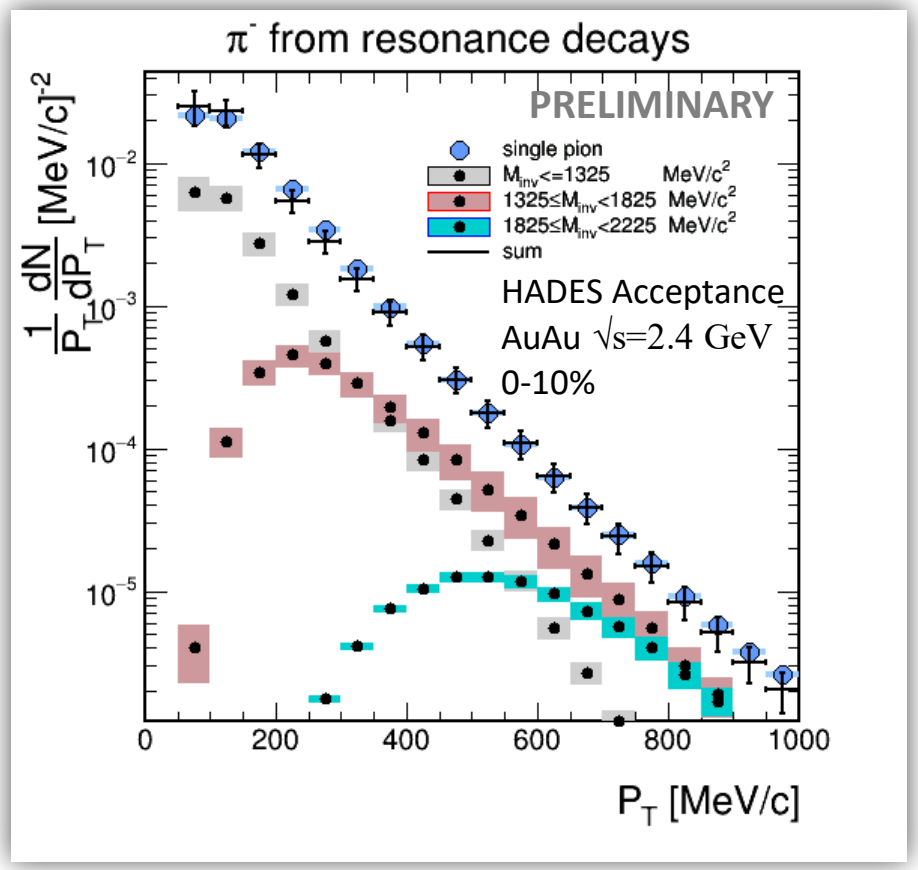




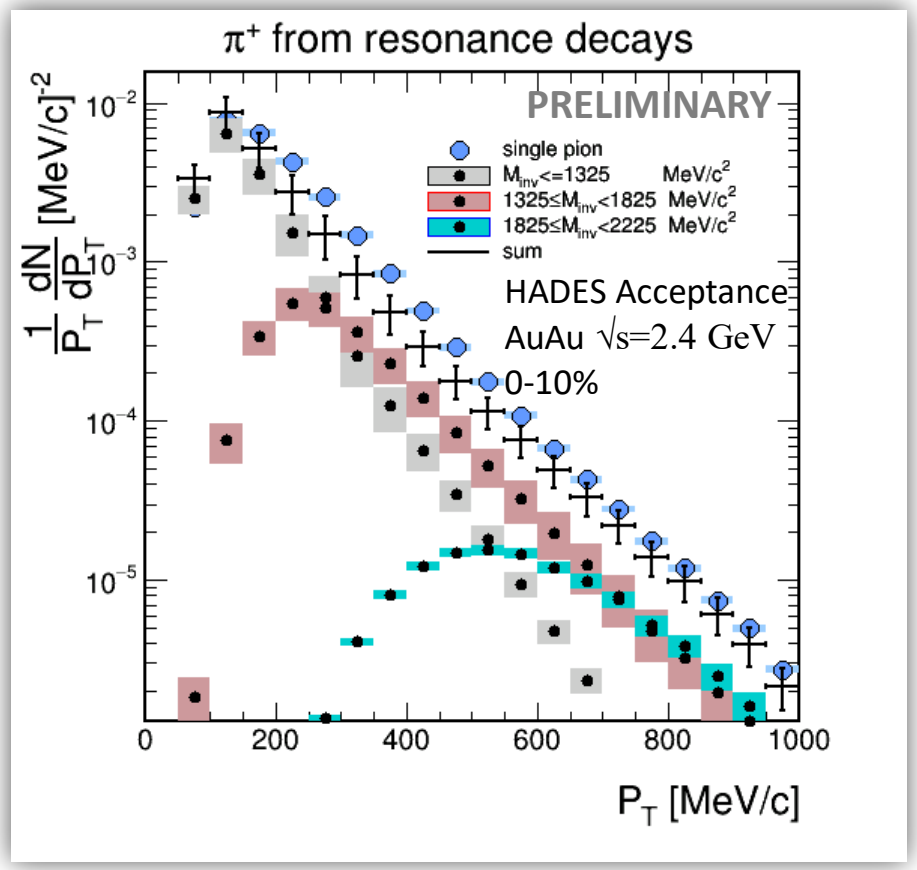

HADES
Thank you for your attention!

Production of charged pions from resonances: the most ~~simple~~ abundant mesons

- Assuming equally produced $\Delta^{-/0/+/++}$ at freeze-out:
  - π^- yield should be scaled by 4
  - π^+ scaled by 4/3
- Pions from high-mass resonances are scaled by 4/3



- The deficit of intermediate PT p+ is due to inexistence of N→ π^+p channel



➢ Measured charged pions in 0-10% central collisions from excitation of baryonic resonances