Strange Production from Elementary to Heavy Ion Collisions in the GeV Range*

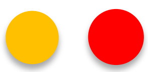
Steffen Maurus, Laura Fabbietti and Joana Wirth for the HADES Collaboration

Dense and Strange Hadronic Matter (E62)
Physik Department
Technische Universität München

*supported by SFB 1258

Collision System Zoo

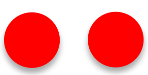
πN



$\pi N \to N^* \to YK$
$\pi N \to N^* \to NK\bar{K}$
$\pi N \to N^* \to \phi N$

→ **Resonance interplay: interference**

NN



$NN \to NN^* \to NYK \ldots$
$\pi N \to N^* \to YK \;\ldots$

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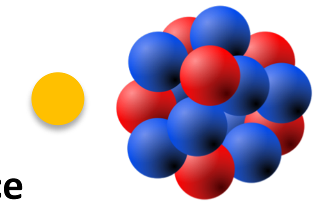
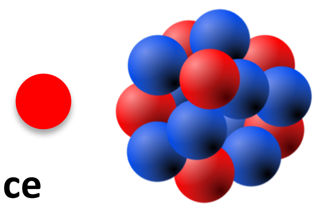
πA



NA



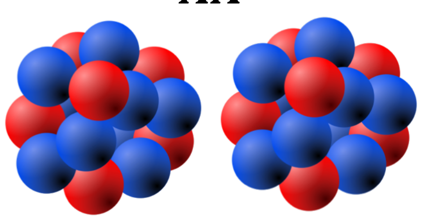
Strangeness exchange:
$\bar{K}N \to \pi Y$
(mediated by resonances)

Feed-down processes:
$\phi \to K\bar{K}$

Absorption processes:
$\phi N \to \pi N$
(OZI violation)

Re-scattering with Nucleons:
$KN, \bar{K}N, \mathrm{YN}, ..$

AA

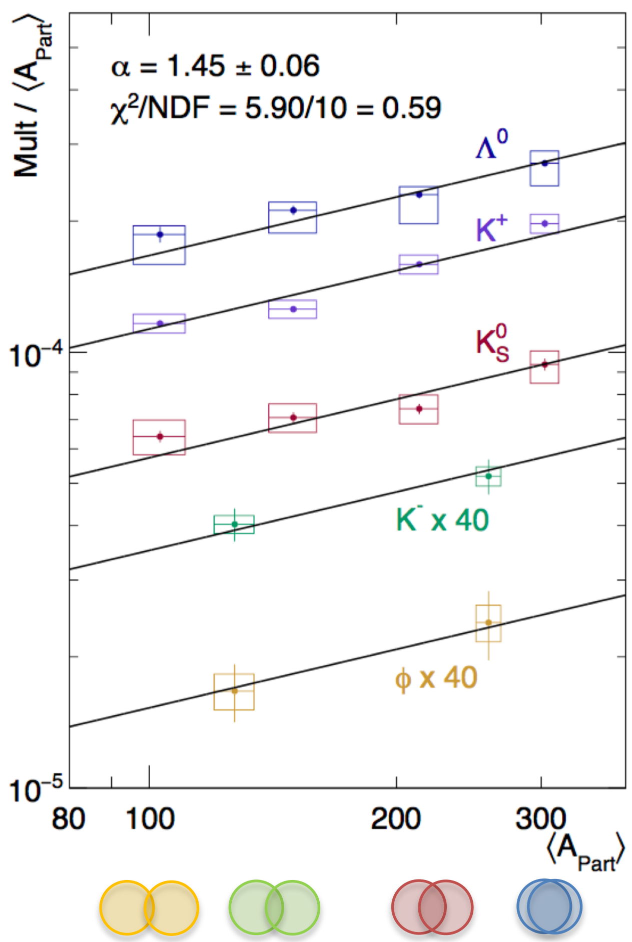


$\sum NN + \pi N$?
→ **Subthreshold strangeness production?**

Universal Strangeness Production

Au+Au

HADES Collaboration, arXiv:1812.07304



→ **All strange hadrons produced below NN threshold:**

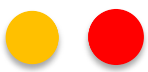
→ $NN \rightarrow N\Lambda K$ (≈ - 150 MeV)

→ $NN \rightarrow NK\bar{K}/NN\phi$ (≈ - 450 MeV)

→ **Universal scaling with A_{part}**

Collision System Zoo

πN



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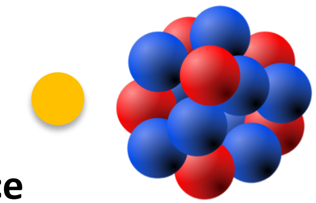

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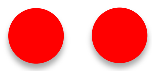
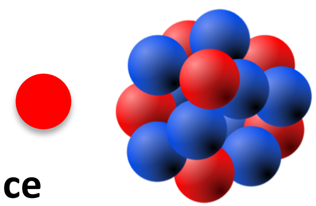


$NN \to NN^* \to NYK \ldots$
$\pi N \to N^* \to YK \;\ldots$

→ **Resonance interplay: interference**

NA



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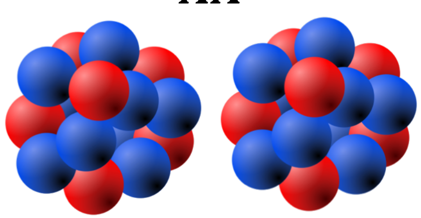
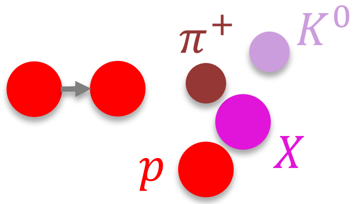


$\sum NN + \pi N$?
→ **Subthreshold strangeness production?**

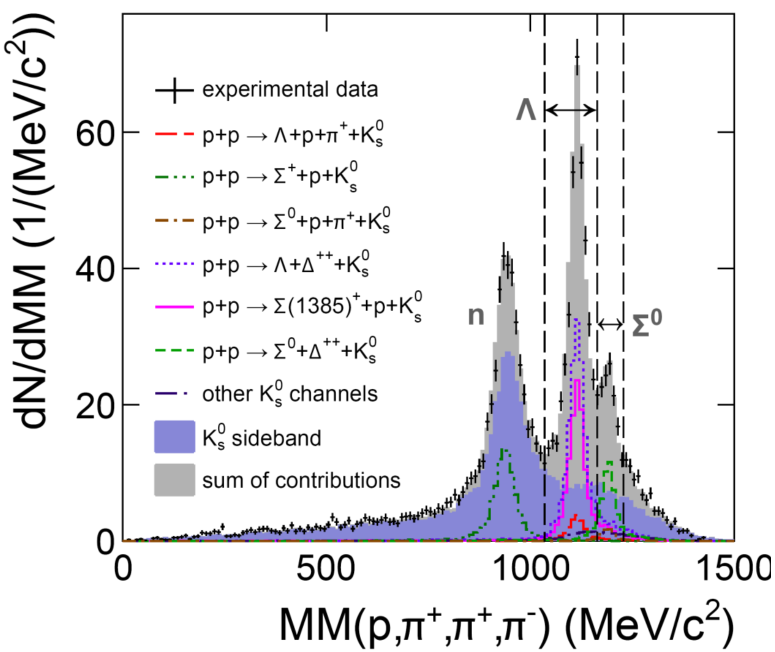
Associated K^0 Production

p+p



Reference measurement of K_s^0 for the interpretation of p+A data (e.g. KN interaction)

Agakishiev et al. Phys. Rev. C90, 015202 (2014)

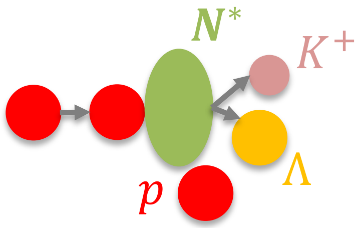


K^0 reactions	$\sigma_{\mathrm{anisotropic}}$ (μb)
$p + p \to \Sigma^+ + p + K^0$	$26.27 \pm 0.64^{+2.57}_{-2.13} \pm 1.84$
$p + p \to \Lambda + p + \pi^+ + K^0$	$2.57 \pm 0.02^{+0.21}_{-1.98} \pm 0.18$
$p + p \to \Sigma^0 + p + \pi^+ + K^0$	$1.35 \pm 0.02^{+0.10}_{-1.35} \pm 0.09$
$p + p \to \Lambda + \Delta^{++} + K^0$	$29.45 \pm 0.08^{+1.67}_{-1.46} \pm 2.06$
$p + p \to \Sigma^0 + \Delta^{++} + K^0$	$9.26 \pm 0.05^{+1.41}_{-0.31} \pm 0.65$
$p + p \to \Sigma(1385)^+ + p + K^0$	$14.35 \pm 0.05^{+1.79}_{-2.14} \pm 1.00$

p+p

N* Excitation Function (pKΛ)

K+
Λ



How many $\boldsymbol{N^*}$ do exist? Interference?
Interference: coherent sum of different amplitudes contributing to final state.

Bonn-Gatchina PWA Framework

Sarantsev et. al., Eur. Phys. J. A 35 (2007)

→ **Cross-section decomposition:** $\boldsymbol{d\sigma \propto |A|^2}$

→ Partial wave composition $\boldsymbol{A}$: sum of transition amplitudes A_{tr}^{α}

→ $A_{tr}^{\alpha} = (\boldsymbol{a_1^{\alpha}} + \boldsymbol{a_3^{\alpha}}\sqrt{\boldsymbol{s}})\boldsymbol{e^{ia_2^{\alpha}}}$

→ $\boldsymbol{N^*(1650), N^*(1710), N^*(1720), N^*(1875), N^*(1880), N^*(1895), N^*(1900)}$

→ Interferences + non-resonant pKΛ production

Münzer et al., Phys. Lett. B 785, 574 (2018)

experiment	T (GeV)
DISTO [20, 21]	2.14
COSY-TOF -TOF [23, 25]	2.16
DISTO [20, 21]	2.5
DISTO [20–22]	2.85
FOPI [24]	3.1
HADES [16]	3.50
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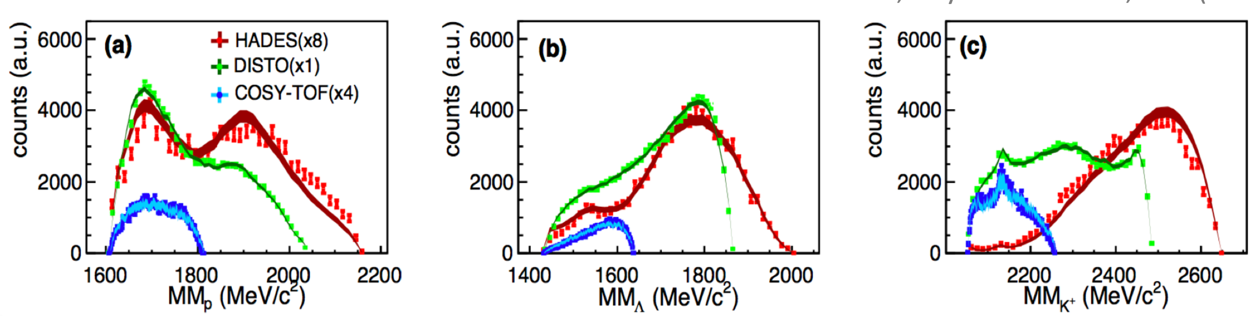

p+p

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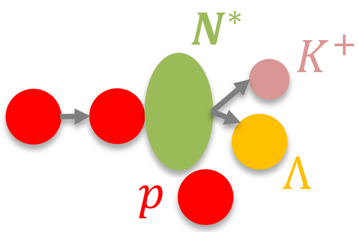

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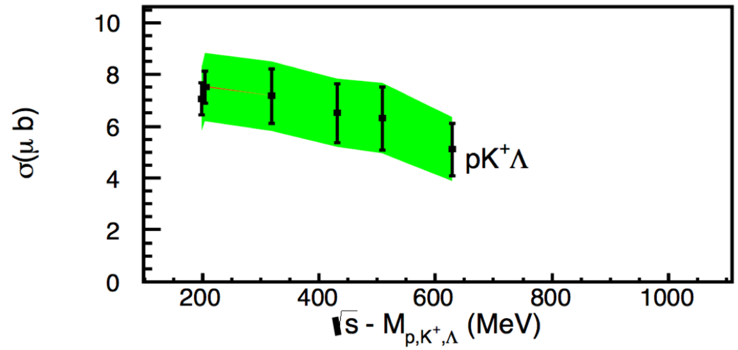
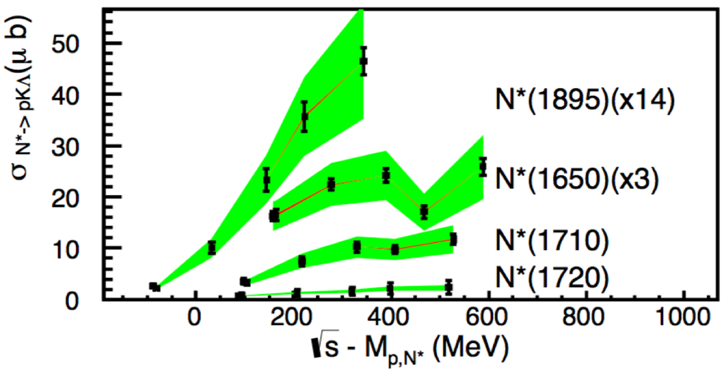
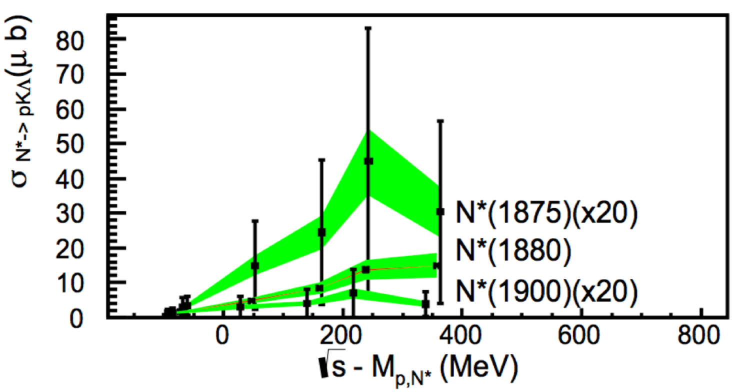




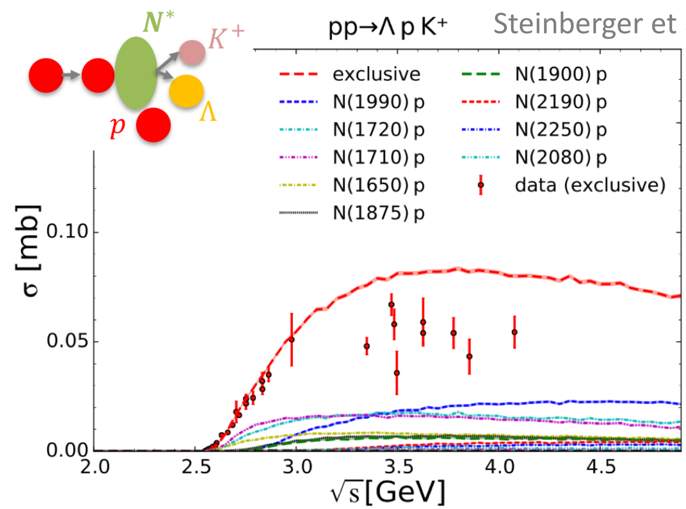


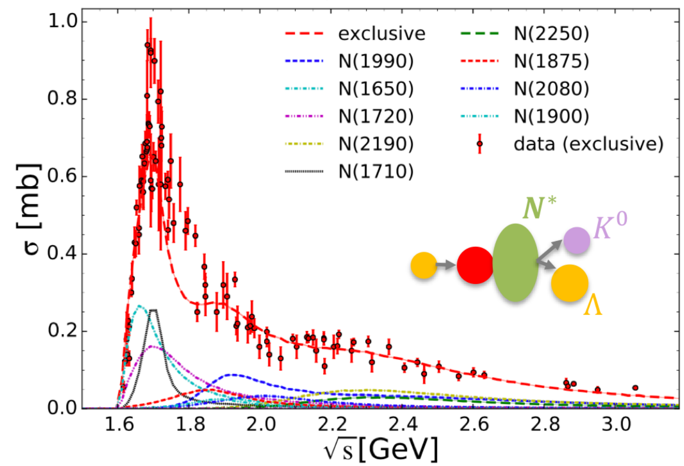
N^*	J^P	Mass ($\frac{GeV}{c^2}$)	Width ($\frac{GeV}{c^2}$)	$\Gamma_{K\Lambda}/\Gamma_{tot}$ (%)
1650	$\frac{1}{2}^-$	1.655	0.15	7 ± 4
1710	$\frac{1}{2}^+$	1.710	0.20	15 ± 10
1720	$\frac{3}{2}^+$	1.720	0.25	8 ± 7
1875	$\frac{3}{2}^-$	1.875	0.20	4 ± 2
1880	$\frac{1}{2}^+$	1.870	0.25	2 ± 1
1895	$\frac{1}{2}^-$	1.895	0.09	18 ± 5
1900	$\frac{3}{2}^+$	1.900	0.26	5 ± 5

→ **Non-resonant contribution to total contribution varies from 40-10% with increasing E_{kin}**

N* Excitation Function

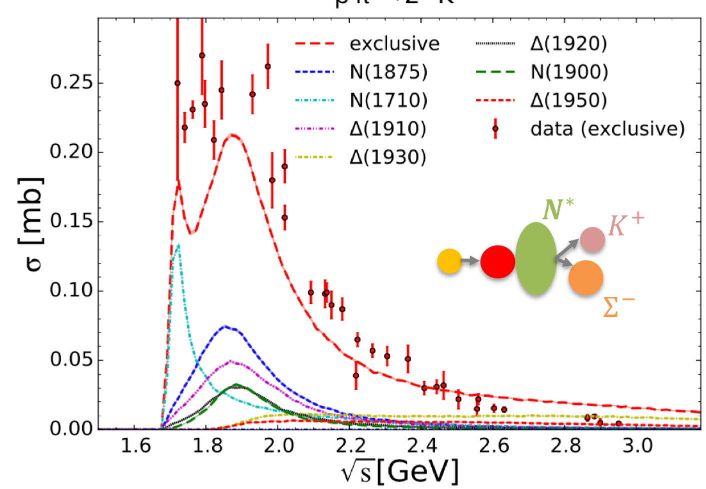
pp→Λ p K⁺ Steinberger et al., arXiv:1809.03828v1 p π⁻→Λ K⁰





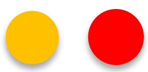
resonance	branching ratio $N^* \to \Lambda K$ PDG	HADES	SMASH
$N(1650)$	$5-15\%$	$7\pm4\%$	4%
$N(1710)$	$5-25\%$	$15\pm10\%$	13%
$N(1720)$	$4-5\%$	$8\pm7\%$	5%
$N(1875)$	>0	$4\pm2\%$	2%
$N(1880)$		$2\pm1\%$	
$N(1895)$		$18\pm5\%$	
$N(1900)$	$2-20\%$	$5\pm5\%$	2%
$N(1990)$			2%
$N(2080)$			0.5%
$N(2190)$	$0.2-0.8\%$		0.8%
$N(2220)$			0
$N(2250)$			0.5%

p π⁻→Σ⁻ K⁺



Collision System Zoo

πN



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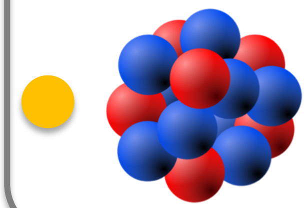
→ **Resonance interplay: interference**

πA



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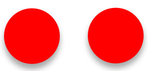

$NN \rightarrow NN^* \rightarrow NYK \ldots$
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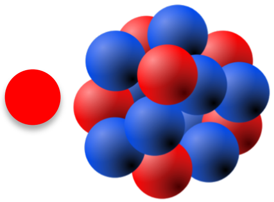
→ **Resonance interplay interference**

NA



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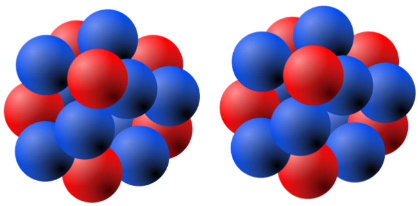
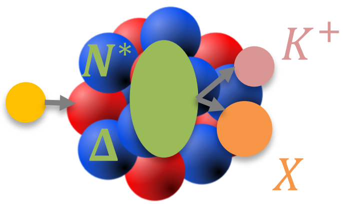


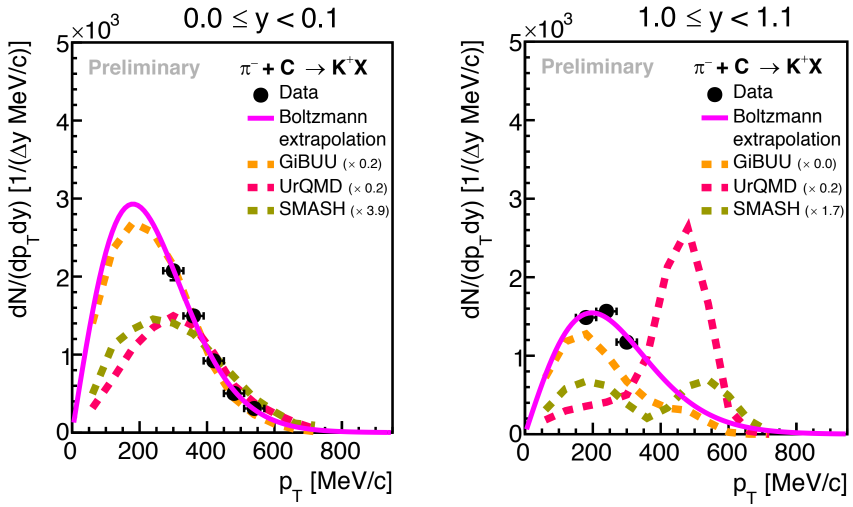
$\sum NN + \pi N$?
→ **Subthreshold strangeness production?**

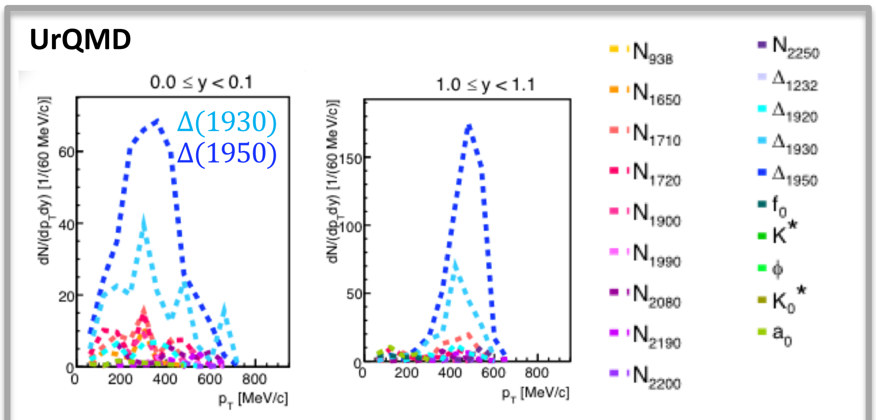
Kinematic Distributions: K^+

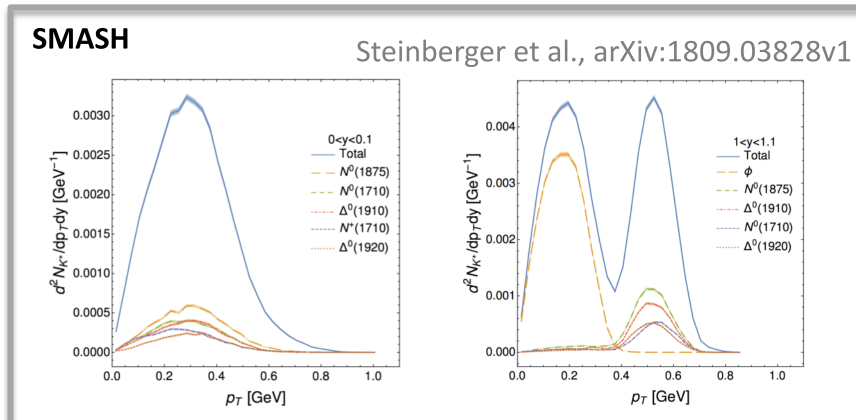
K+

HADES Collaboration, arXiv:1812.03728





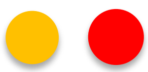




UrQMD 3.4: Prog. Part. Nucl. Phys. 41, 255–369 (1998)

Collision System Zoo

$\boldsymbol{\pi N}$



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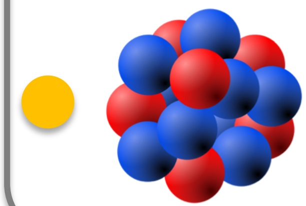
→ **Resonance interplay: interference**

$\boldsymbol{\pi A}$



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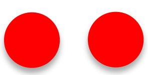

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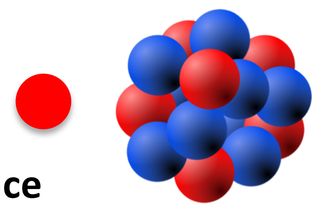

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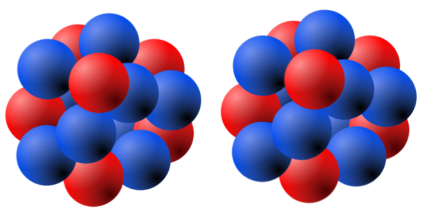


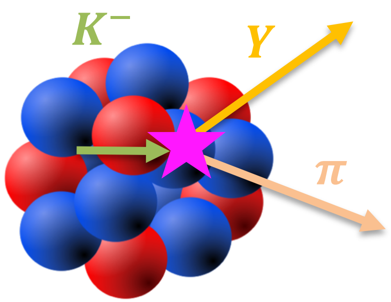
$\sum NN + \pi N$?
→ **Subthreshold strangeness production?**

Interplay of Antikaons with Nucleons

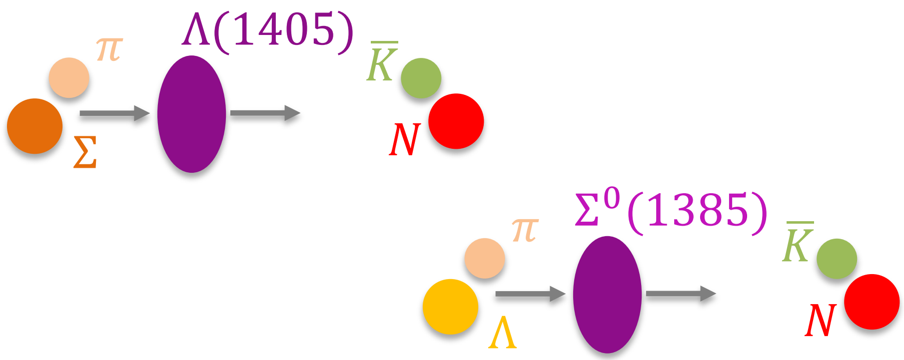
K⁻

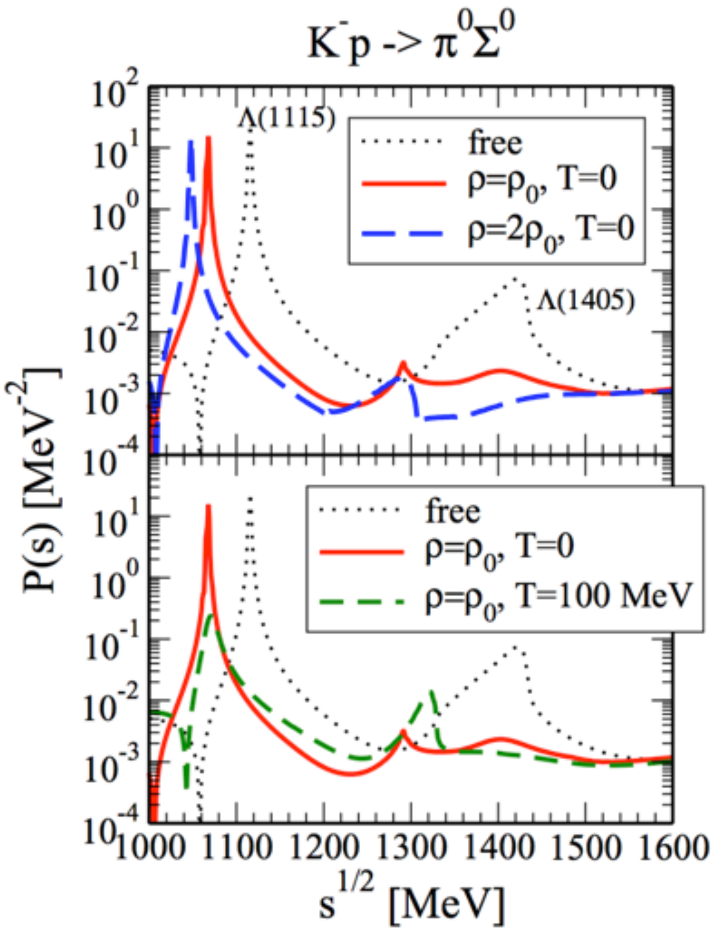
Strangeness exchange in nuclear matter:

$K^- N \leftrightarrow Y\pi$ $\quad$ $K^- NN \leftrightarrow YN$



→ Mediated by resonances Λ(1405), ...

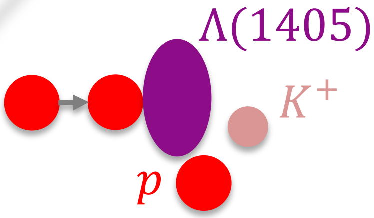


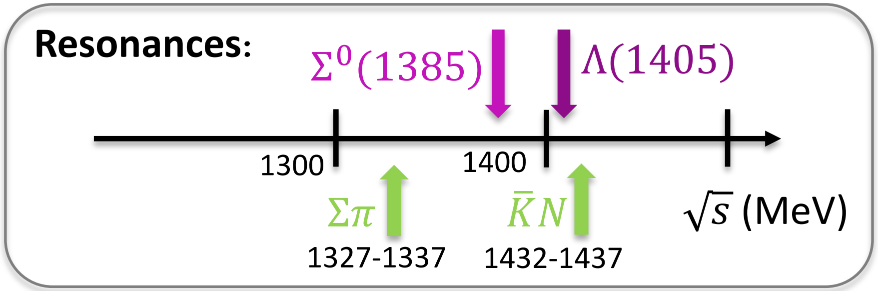


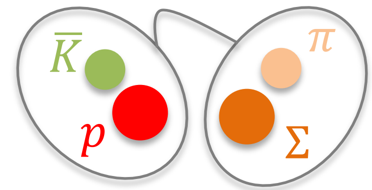
Cabrera et al. Phys.Rev. C 90, 055207 (2014)

Special Resonance: Λ(1405)

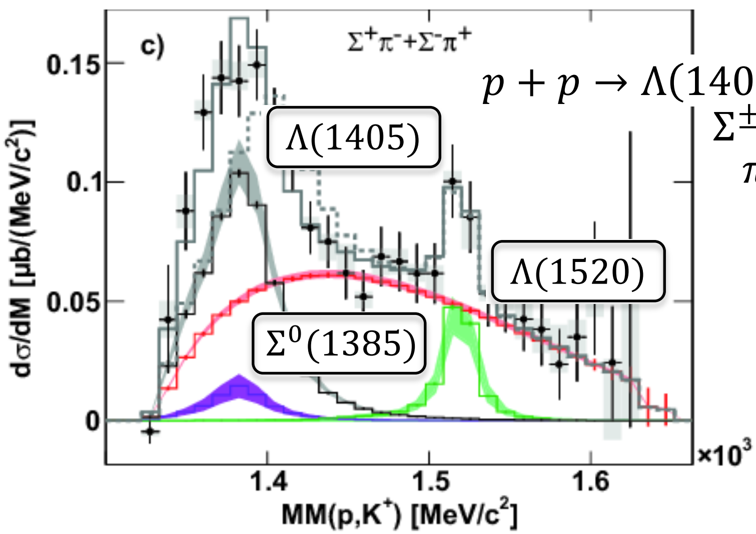
p+p



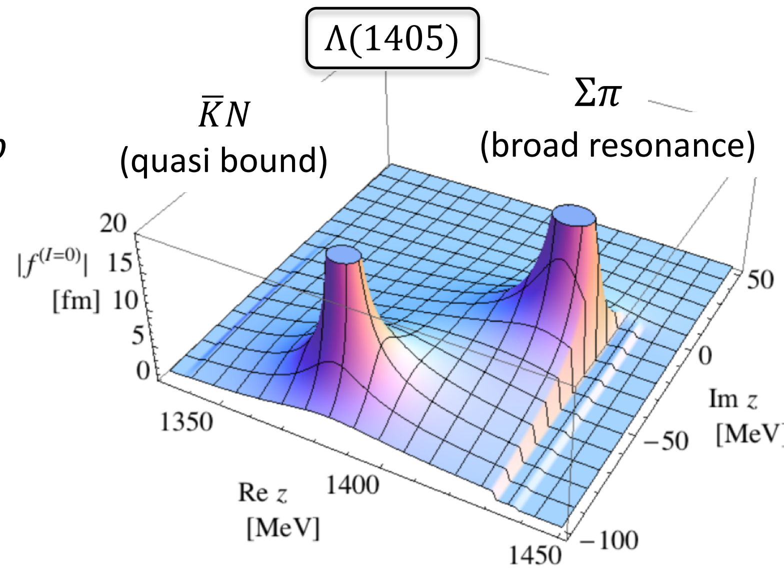




Agakishiev et al., Phys. Rev. C 87, 025201 (2013)
Agakishiev et al., Nucl. Phys. A 881, 178 (2012)

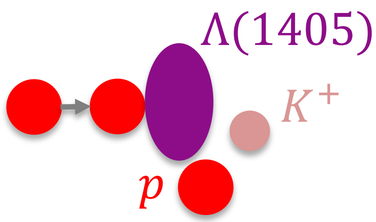


$$p + p \rightarrow \Lambda(1405) + K^+ + p$$
$$\Sigma^\pm + \pi^\pm$$
$$\pi^\pm + n$$



Kamiya, ..., Weise, Nucl. Phys. A 954, 41 (2016)

Special Resonance: Λ(1405)



Agakishiev et al., Phys. Rev. C 87, 025201 (2013)
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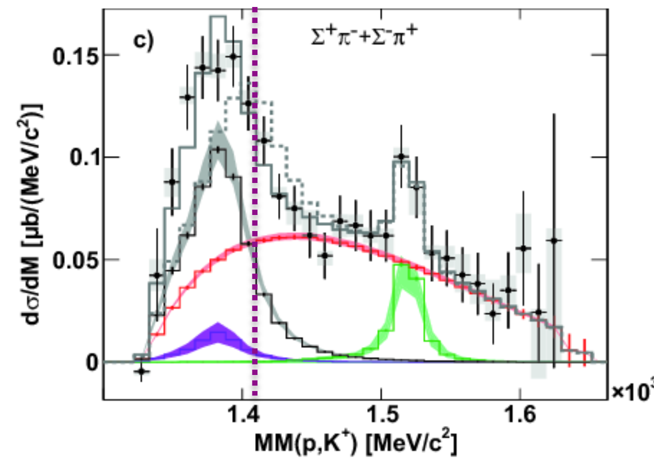
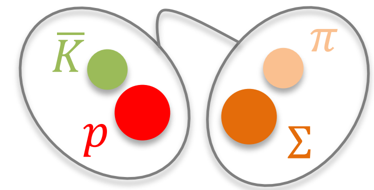
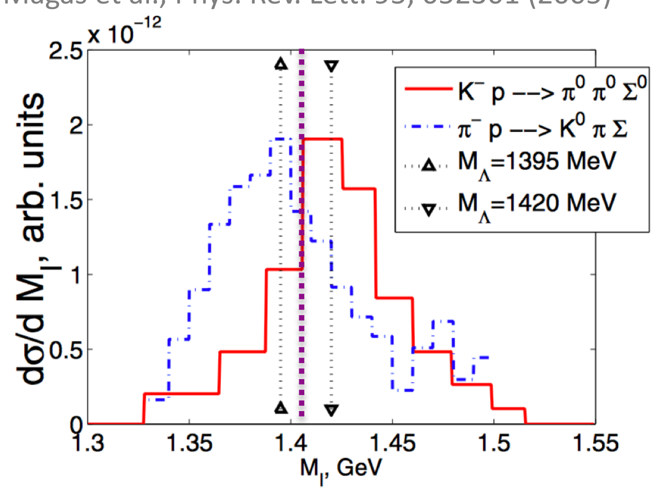
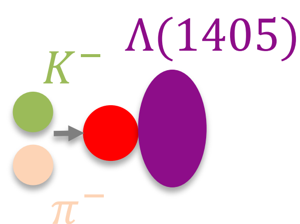


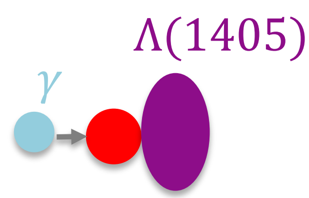


→ Different line shapes in different reactions, dependent on reaction mechanism

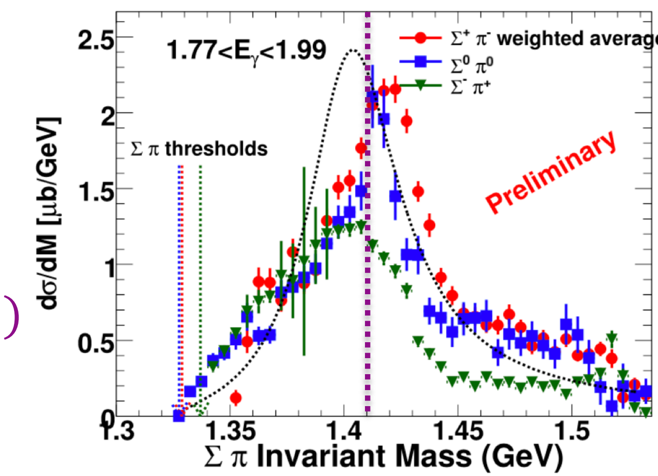
Magas et al., Phys. Rev. Lett. 95, 052301 (2005)







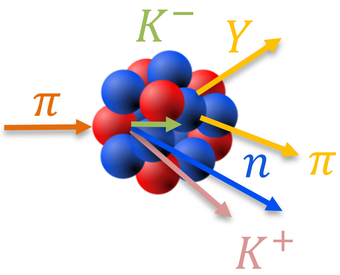
Moriya et al., Nucl. Phys. A 835, 325 (2010)



π⁻+C/W

Strangeness Exchange

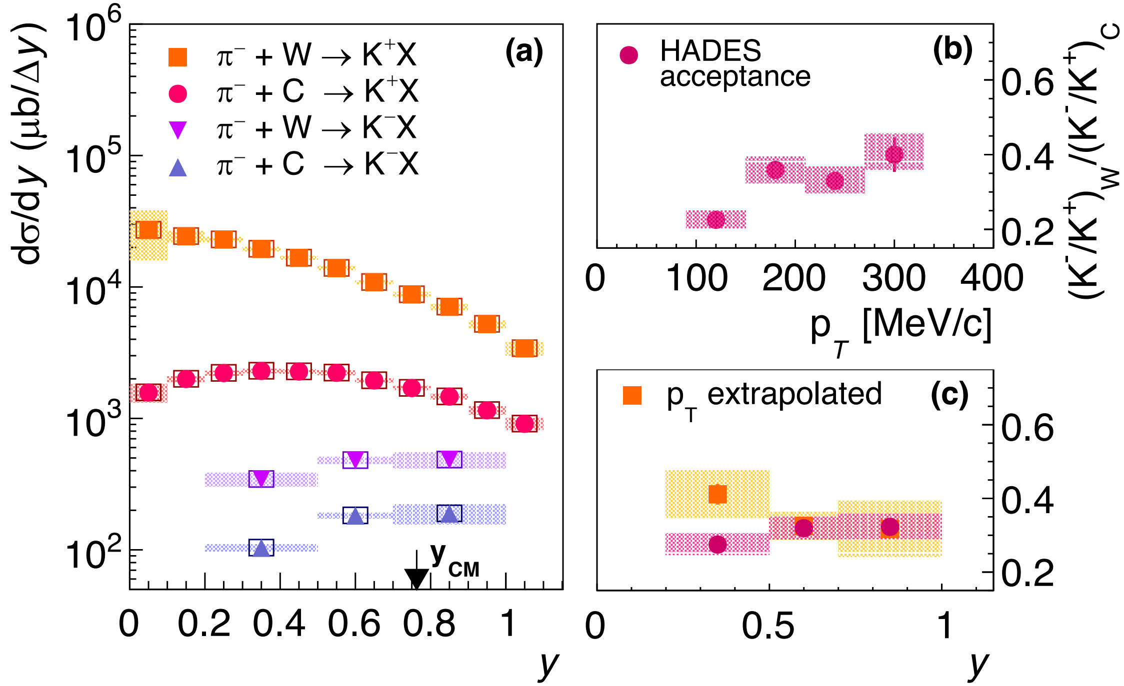
K⁻ K⁺



$K^- N \rightarrow Y\pi$

$K^- NN \rightarrow YN$

HADES Collaboration, arXiv:1812.03728

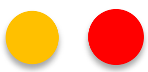


➞ **At least 40% of K^- get absorbed for $\rho \leq \rho_0$**

➞ **First observation in heavy nuclei**

Collision System Zoo

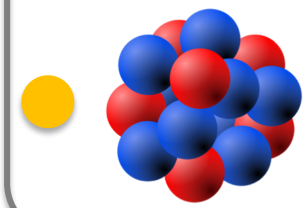
πN



$\pi N \rightarrow N^* \rightarrow YK$
$\pi N \rightarrow N^* \rightarrow NK\bar{K}$
$\pi N \rightarrow N^* \rightarrow \phi N$

→ **Resonance interplay: interference**

πA

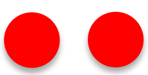


Strangeness exchange:
$\bar{K}N \rightarrow \pi Y$
(mediated by resonances)

Feed-down processes:
$\phi \rightarrow K\bar{K}$

Absorption processes:
$\phi N \rightarrow \pi N$
(OZI violation)

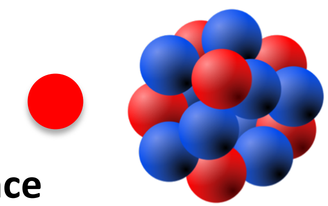
NN



$NN \rightarrow NN^* \rightarrow NYK \ldots$
$\pi N \rightarrow N^* \rightarrow YK \; \ldots$

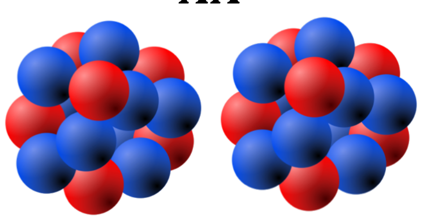
→ **Resonance interplay interference**

NA



Re-scattering with Nucleons:
$KN, \bar{K}N, \mathrm{YN}, ..$

AA

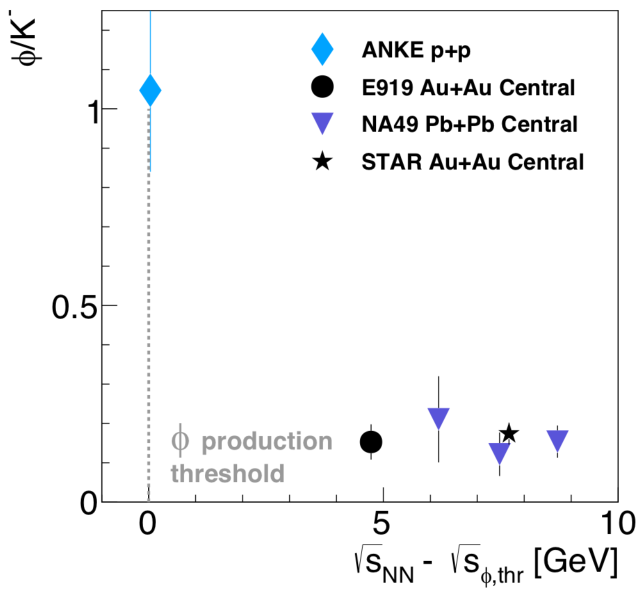


$\sum NN + \pi N$?
→ **Subthreshold strangeness production?**

Strange Meson: ϕ

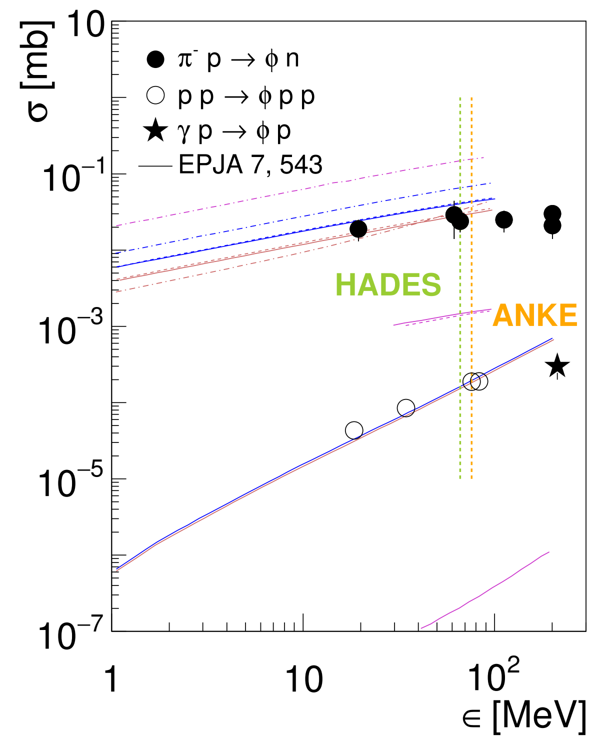
Antikaon from Phi feed-down:

$$\phi \to K^- K^+, \quad BR \sim 49\%$$



- → φ important source for K^- production close NN threshold
- → **K^- from φ feed-down:** $\frac{\phi}{K^-}(C/W)$

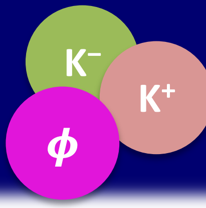
Blume et al., Prog. Part. Nucl. Phys. 66, 834-879 (2011)

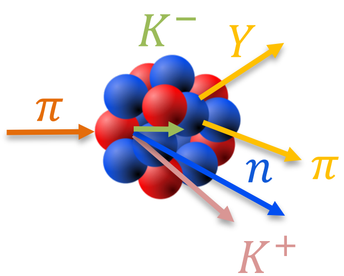


Hartmann et al., Phys. Rev. Lett. 96, 242301 (2006)
Balestra et al. Phys. Rev. C 63, 024004 (2001)
Landolt-Börnstein

$\pi^- + C/W$

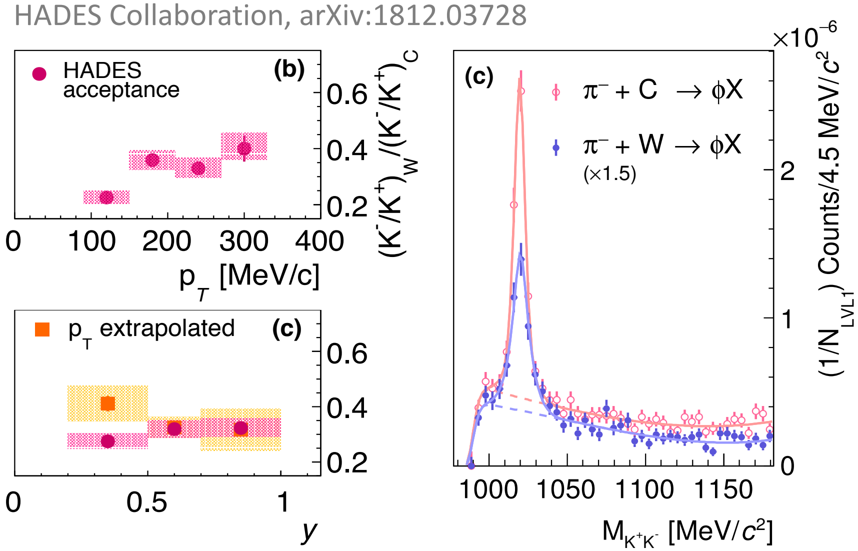
Absorption Processes: ϕ

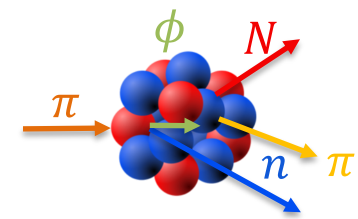




$K^-N \rightarrow Y\pi$

$K^-NN \rightarrow YN$





$\phi N \rightarrow N\pi$

$\phi NN \rightarrow NN$

In HADES acceptance:

$$(\phi/K^-)_C = 0.55 \pm 0.04(stat)\,^{+0.06}_{-0.07}(sys)$$

$$(\phi/K^-)_W = 0.63 \pm 0.06(stat) \pm 0.11(sys)$$

→ First model-independent observation of ϕ absorption

Phi Transparency Ratio

ϕ

Within HADES acceptance (without p_T/y extrapolation)

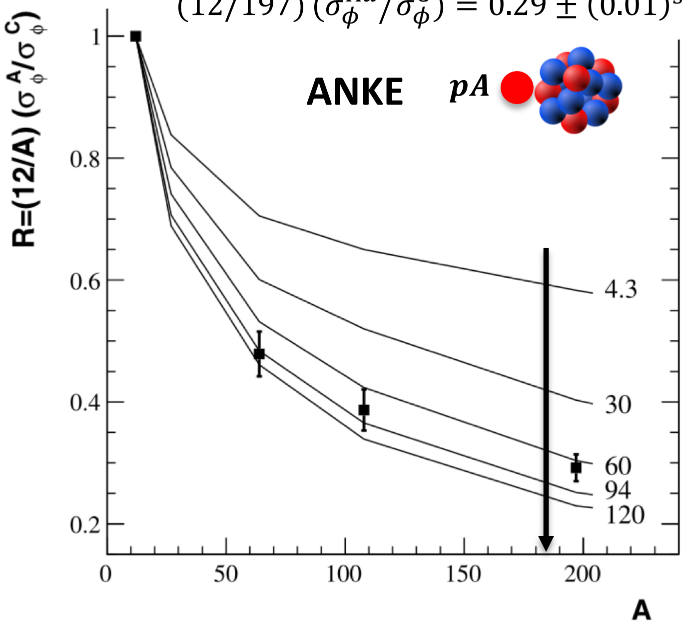
HADES Collaboration, arXiv:1812.03728

πA

$$(12/184)\,(\sigma_{\phi}^{W}/\sigma_{\phi}^{C}) = 0.18 \pm (0.02)^{stat} \pm (0.11)^{sys} \begin{pmatrix} +0.04 \\ -0.03 \end{pmatrix}^{norm}$$

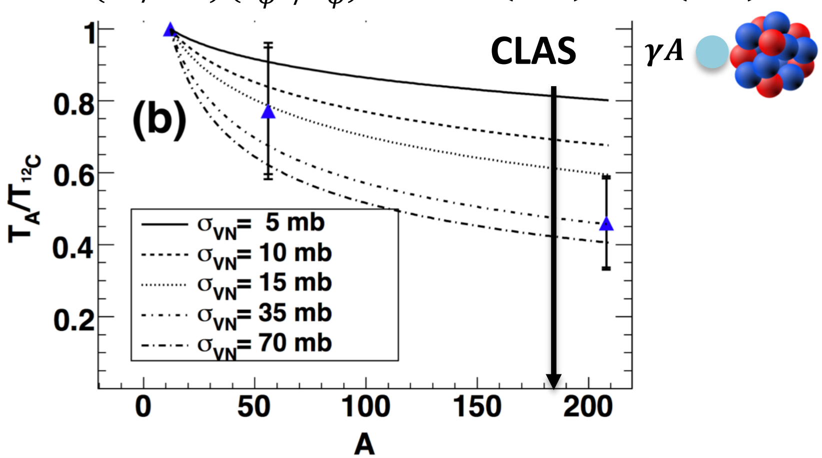
Polyanskiy et al. Phys. Lett. B 695, 741 (2011)

$$(12/197)\,(\sigma_{\phi}^{Au}/\sigma_{\phi}^{C}) = 0.29 \pm (0.01)^{stat} \pm (0.02)^{sys}$$



Wood et al. Phys. Rev. Lett. 105, 112301 (2010)

$$(12/208)\,(\sigma_{\phi}^{Pb}/\sigma_{\phi}^{C}) = 0.46 \pm (0.12)^{stat} \pm (0.13)^{sys}$$



→ Extracted transparency ratio lower in $\pi^- + A$ reactions compared to proton- (ANKE) and photo-induced (CLAS) reactions

→ Signature of ϕ absorption

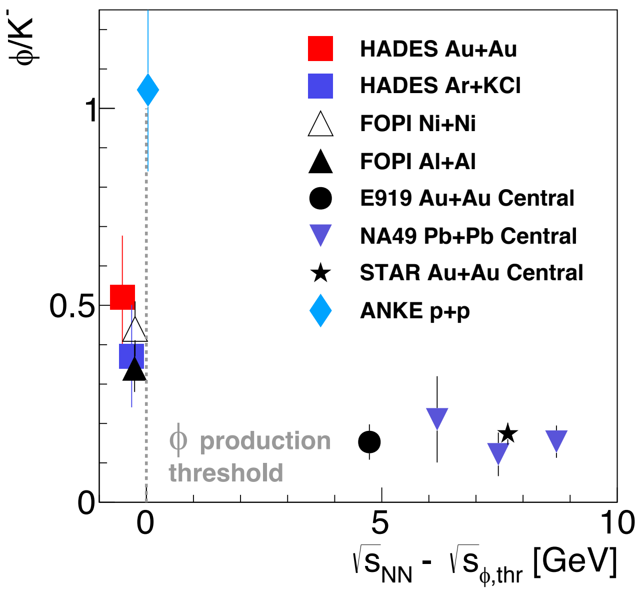
Au+Au

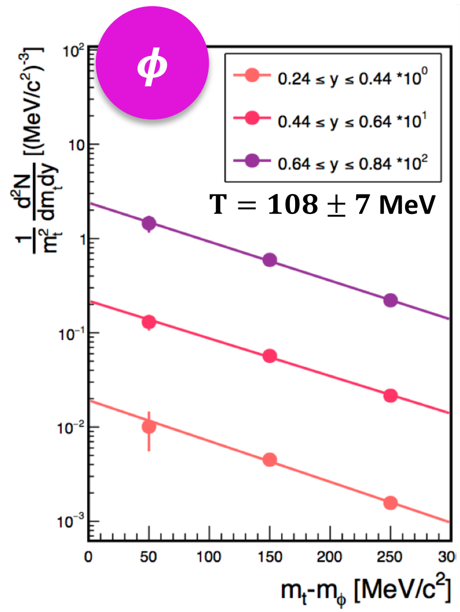
ϕd-Down

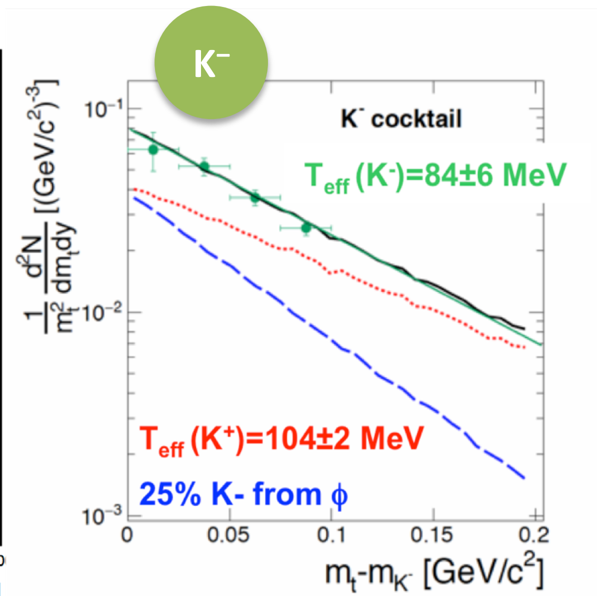
K⁻ ϕ

Antikaon from Phi feed-down:

$\phi \rightarrow K^- K^+, \quad BR \sim 49\%$







→ ϕ important source for K^- production below NN threshold

→ ϕ contribution to (final) $\mathbf{K}^-$ yield around 25%

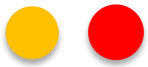
→ Feed-down from ϕ can account for different slopes observed for $\mathbf{K}^-$ and $\mathbf{K}^+$

→ Role of absorption? Production mechanism?

Blume et al. Prog. Part. Nucl. Phys. 66, 834-879 (2011)
Adamczewski-Musch et al. Phys. Lett. B 778, 403 (2018)

Collision System Zoo

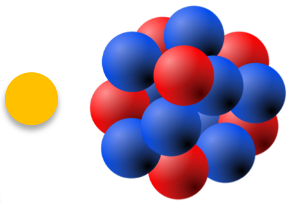
πN



$$\pi N \rightarrow N^* \rightarrow YK$$
$$\pi N \rightarrow N^* \rightarrow NK\bar{K}$$
$$\pi N \rightarrow N^* \rightarrow \phi N$$

→ **Resonance interplay: interference**

πA



Strangeness exchange:

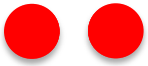
$$\bar{K}N \rightarrow \pi Y$$

(mediated by resonances)

Feed-down processes:

$$\phi \rightarrow K\bar{K}$$

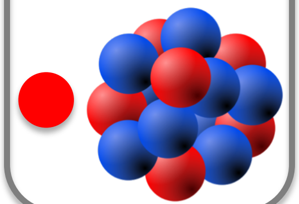
NN



$$NN \rightarrow NN^* \rightarrow NYK \ldots$$
$$\pi N \rightarrow N^* \rightarrow YK \ \ldots$$

→ **Resonance interplay interference**

NA



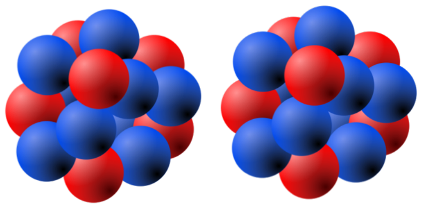
Absorption processes:

$$\phi N \rightarrow \pi N$$

(OZI violation)

Re-scattering with Nucleons:
$KN, \bar{K}N,$ YN, . .

AA



$\sum NN + \pi N$?

→ **Subthreshold strangeness production?**

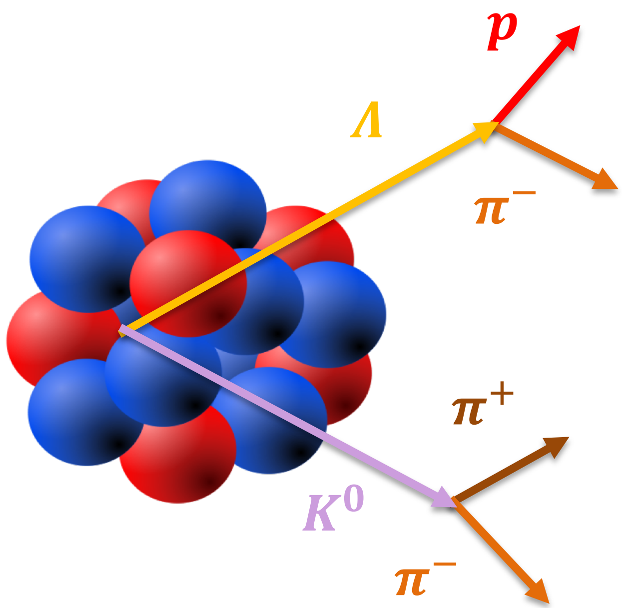
π^-+C/W

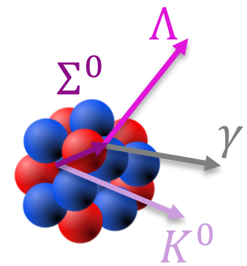
Kaon-Hyperon Coupling

Λ Σ^0 K^0

→ **Strangeness conservation**

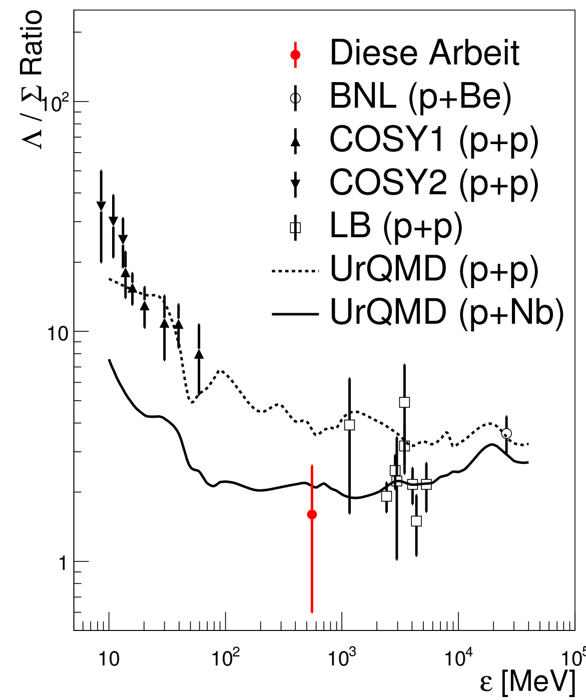
→ **Λ and K^0 are entangled**





$\boldsymbol{\Sigma^0 \rightarrow \Lambda + \gamma}$
(≈ 100%)

Adamczewski-Musch et al.,
Phys. Lett. B 781, 735 (2018)



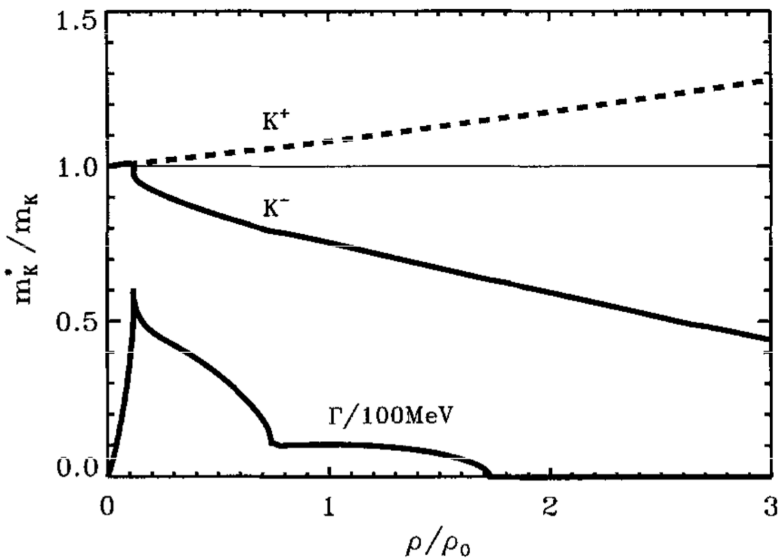
K^0 Kaon $(d\bar{s}, m = 498\text{ MeV})$

Λ Σ^0 Lambda $(uds, m = 1116\text{ MeV})$
Sigma $(uds, m = 1193\text{ MeV})$

(Anti)Kaon in Medium

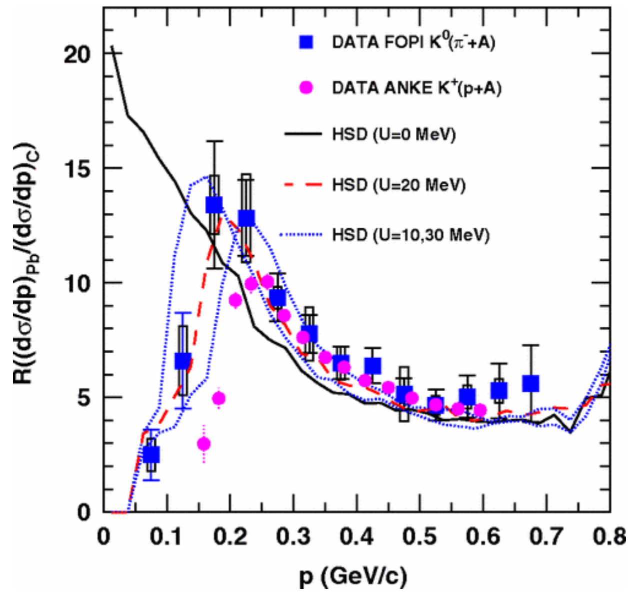
Kaon-Nucleon Interaction

Waas, Kaiser, and Weise, Phys. Lett. B 379, 34 (1996)



$K^0{}_s$ properties: Ar + KCl, p + Nb (p + p)
Agakishiev et al. Phys. Rev. C82, 044907 (2010)
Agakishiev et al. Phys. Rev. C90, 054906 (2014)

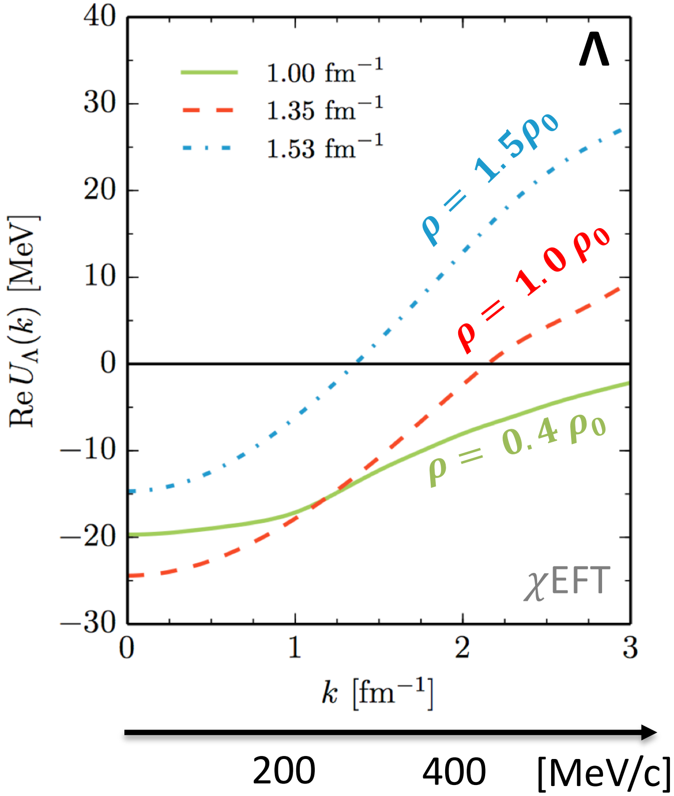
Benabderrahmane et al. Phys. Rev. Lett. 102, 182501 (2009)

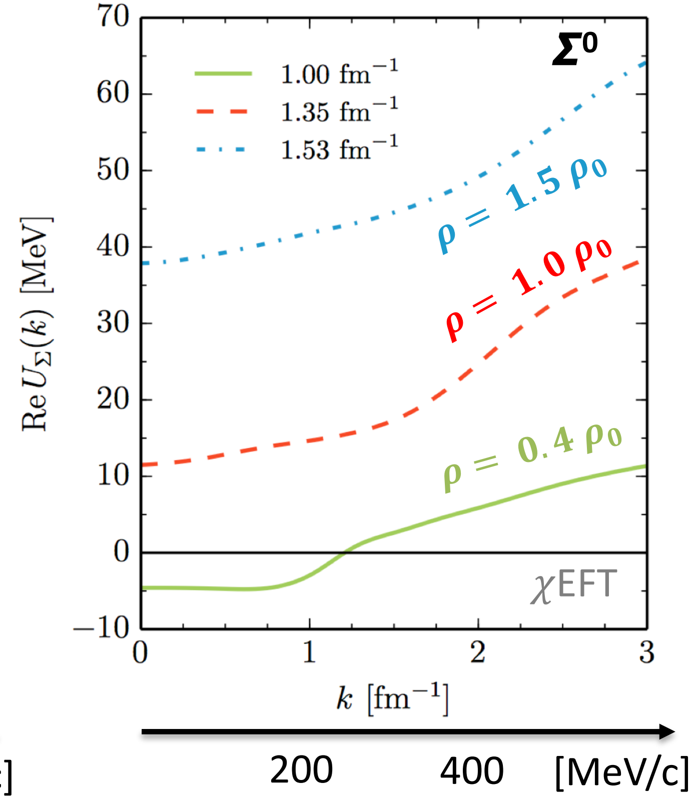


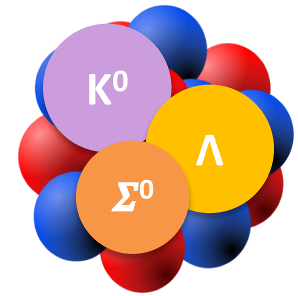
System (energy)	Experiment	Potential [MeV]
$\pi + A\ (1.02\ GeV)$	FOPI	20 ± 5
$p + A\ (2.3\ GeV)$	ANKE	20 ± 5
$Ar + KCl\ (1.76\ GeV)$	HADES	39
$p + Nb\ (3.5\ GeV)$	HADES	40

Hyperons inside Nuclear Matter

Petschauer et al., Eur. Phys. J. A 52, 15 (2016)







$200 \le p_\Lambda \le 800\ \boldsymbol{MeV}/c$

→ Λ/Σ single particle interaction within the nucleus?

Hyperon Propagation in Matter

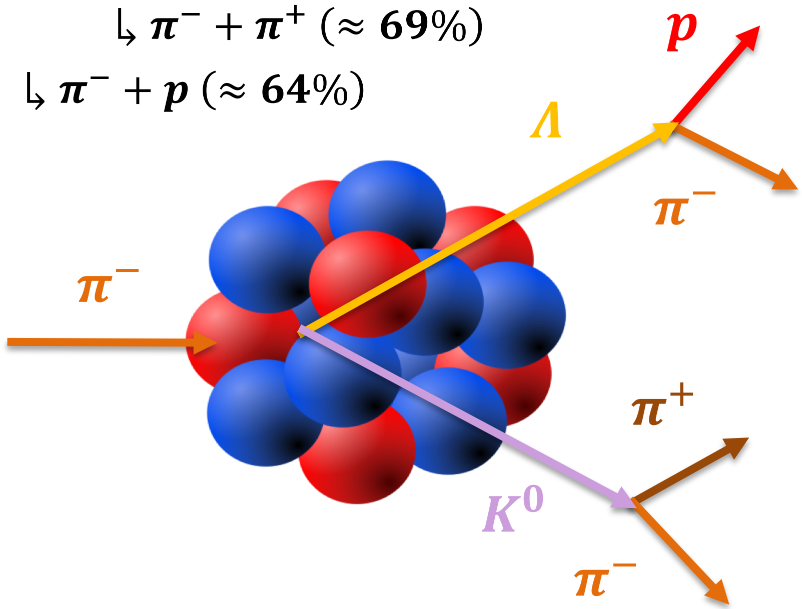
π^-+C/W

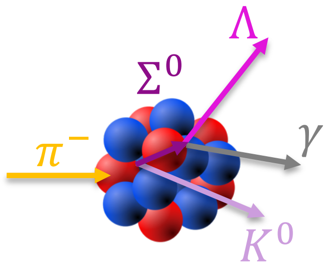
Λ Σ^0 K^0

$\boldsymbol{\pi^- + p \rightarrow \Lambda + K^0}$

$\quad\quad\quad\quad \hookrightarrow \boldsymbol{\pi^- + \pi^+ \ (\approx 69\%)}$

$\quad\quad \hookrightarrow \boldsymbol{\pi^- + p \ (\approx 64\%)}$





$\boldsymbol{\Sigma^0 \rightarrow \Lambda + \gamma}$
$(\approx \mathbf{100\%})$

$\Lambda_{all}/\Sigma^0 = 2.3 \pm 0.2(stat) \pm 0.6(sys)$

Adamczewski-Musch et al., Phys. Lett. B 781, 735 (2018)

K^0 Kaon $(d\bar{s}, m = 498 \text{ MeV})$

Λ Σ^0 Lambda $(uds, m = 1116 \text{ MeV})$
Sigma $(uds, m = 1193 \text{ MeV})$

→ **Strangeness conservation**

→ ***Λ* and K⁰ are entangled**

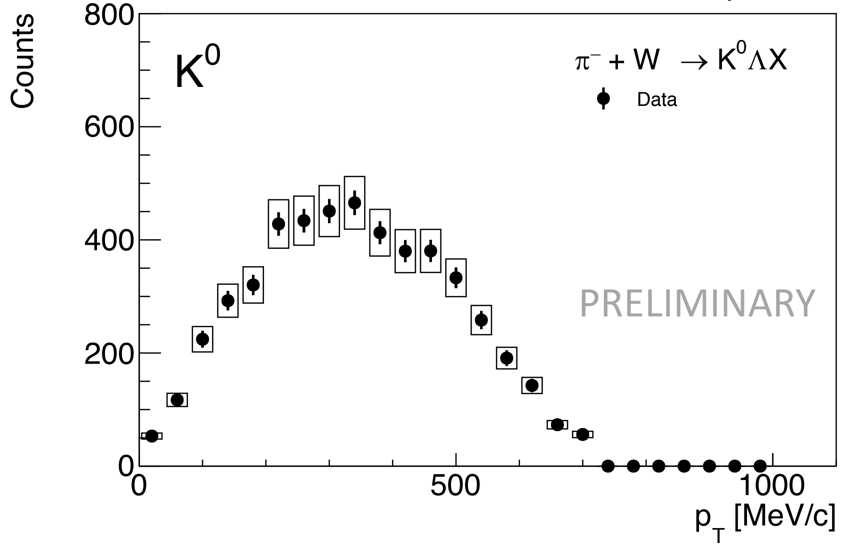
Effects of Hyperon Potentials

$\pi^- + W$

Λ Σ⁰ K⁰

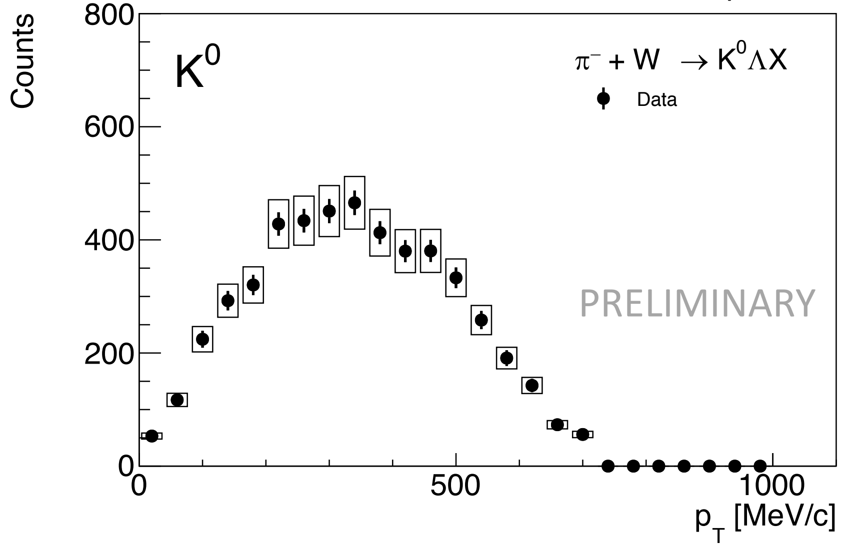
Transport Model: **GiBUU**

In HADES acceptance



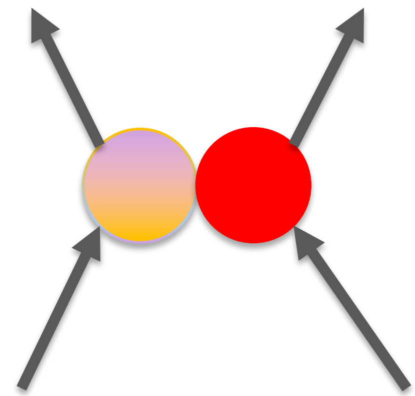
Effects of Hyperon Potentials

In HADES acceptance



Transport Model: **GiBUU**

1. **No** $K^0/\Lambda/\Sigma^0 N$ potentials **(ES(Y,K))**

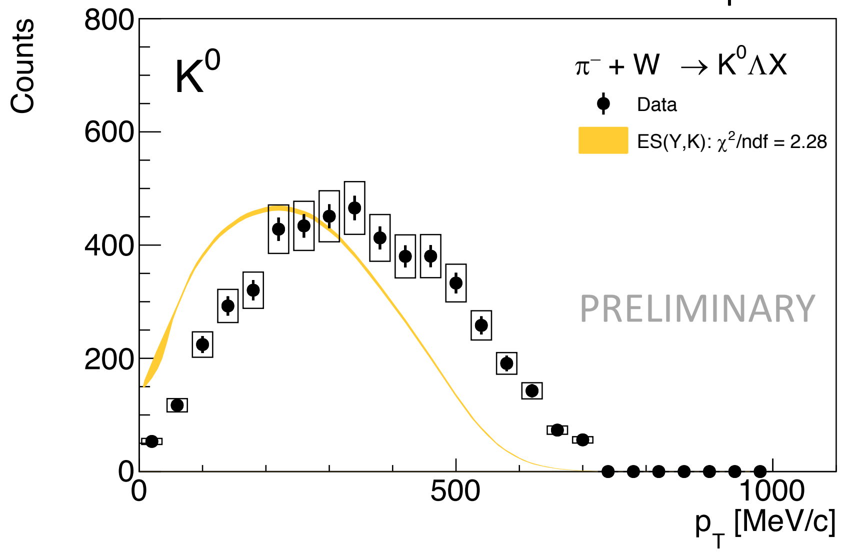


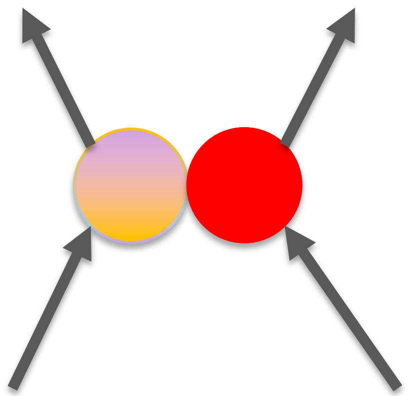
Effects of Hyperon Potentials

Transport Model: **GiBUU**

1. **No** $K^0/\Lambda/\Sigma^0\mathrm{N}$ potentials **(ES(Y,K))**

In HADES acceptance



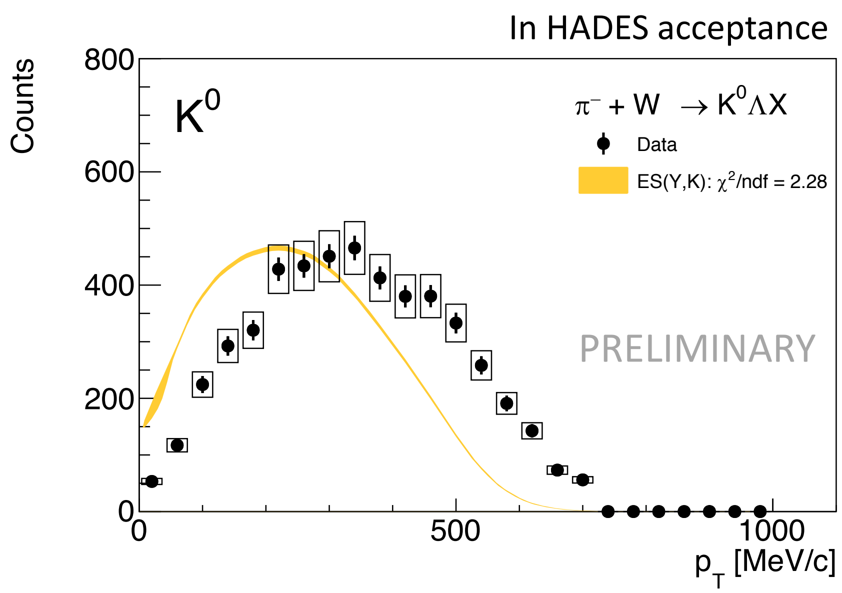


→ **Simultaneous fit of all kinematic observables:** $\boldsymbol{K^0(p_T, y, p, \Theta)}$ and $\boldsymbol{\Lambda(p_T, y, p, \Theta)}$

Effects of Hyperon Potentials

$\pi^- + W$

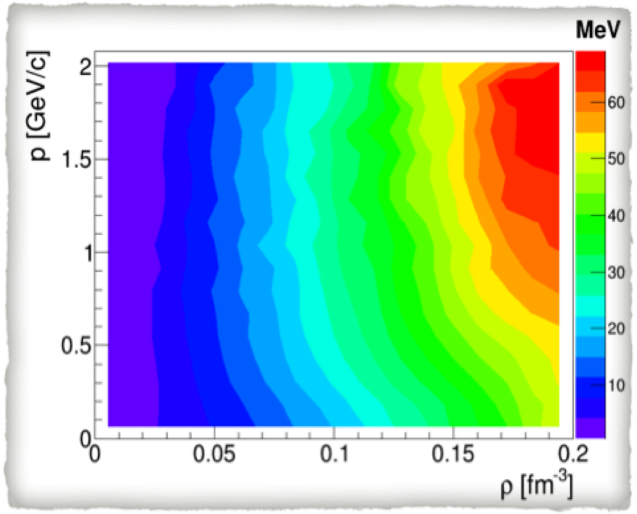
Λ Σ^0 K^0



Transport Model: **GiBUU**

1. **No** $K^0/\Lambda/\Sigma^0\mathrm{N}$ potentials **(ES(Y,K))**
2. **No** $\Lambda/\Sigma^0\mathrm{N}$ potentials **(ES(Y))**

KN potential

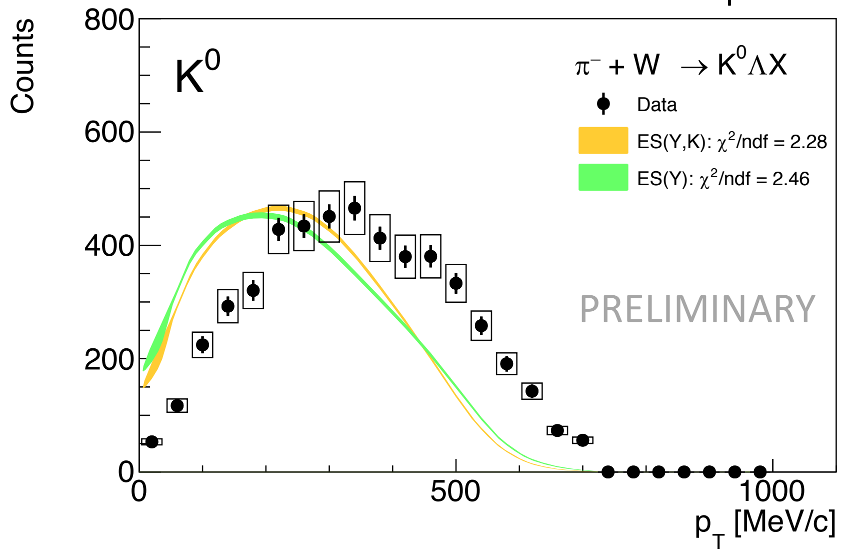


Agakishiev et al., Phys. Rev. C 90, 054906 (2014)

Effects of Hyperon Potentials

Λ Σ⁰ K⁰

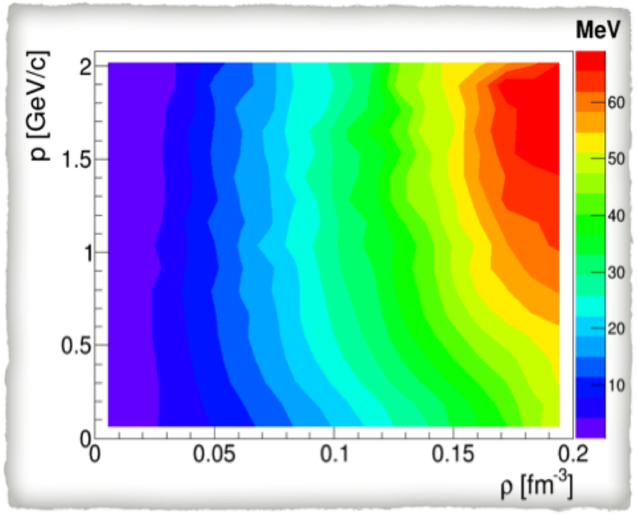
In HADES acceptance



Transport Model: **GiBUU**

1. **No** $K^0/\Lambda/\Sigma^0$N potentials **(ES(Y,K))**
2. **No** Λ/Σ^0N potentials **(ES(Y))**

KN potential

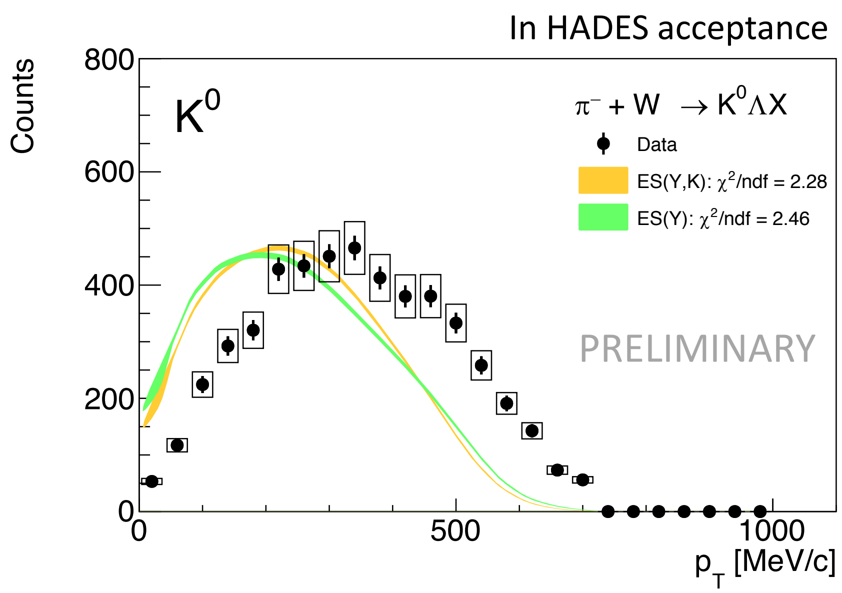


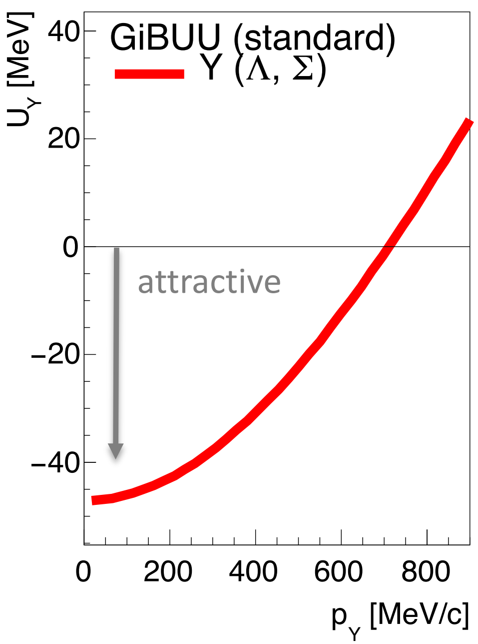
Agakishiev et al., Phys. Rev. C 90, 054906 (2014)

Effects of Hyperon Potentials

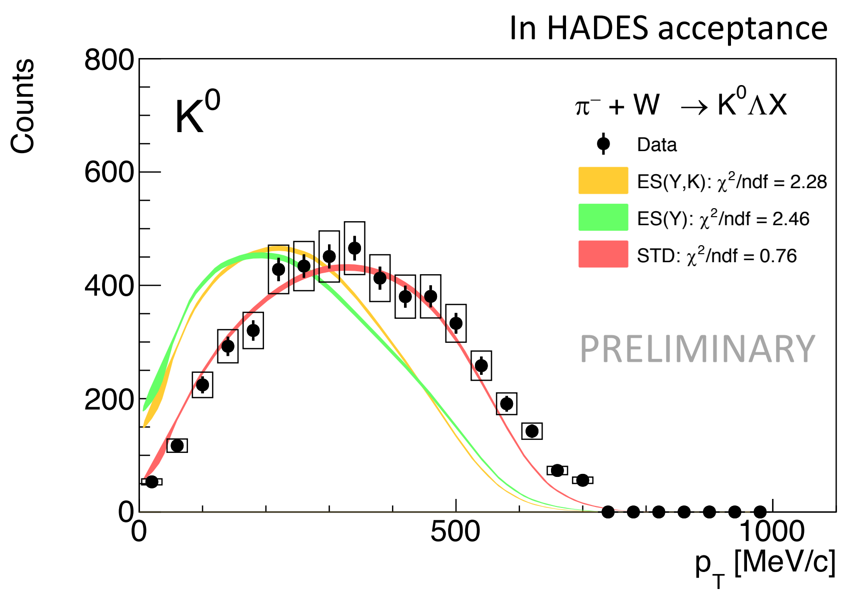
Transport Model: **GiBUU**

1. **No** $K^0/\Lambda/\Sigma^0$N potentials **(ES(Y,K))**
2. **No** Λ/Σ^0N potentials **(ES(Y))**
3. **Attractive** Λ/Σ^0N potentials **(STD)**





Effects of Hyperon Potentials



Transport Model: **GiBUU**

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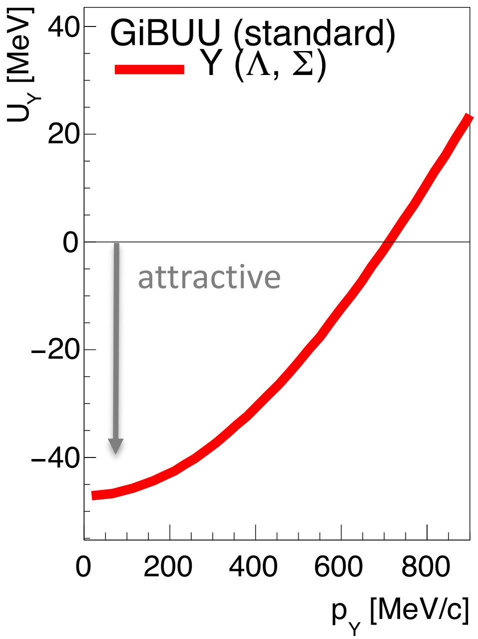
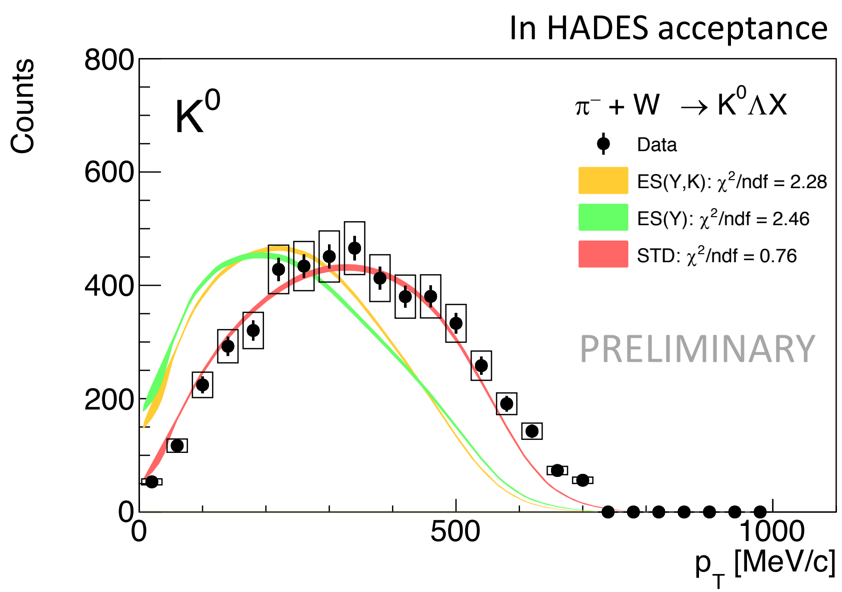


Effects of Hyperon Potentials

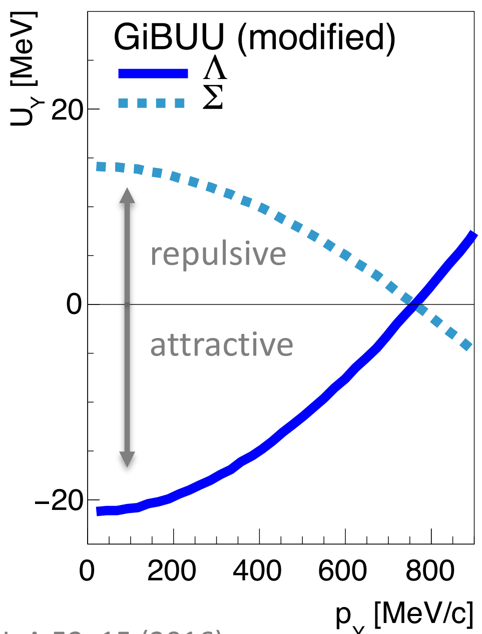
$\pi^- + W$

Λ Σ^0 K^0



Transport Model: **GiBUU(Loniki)**

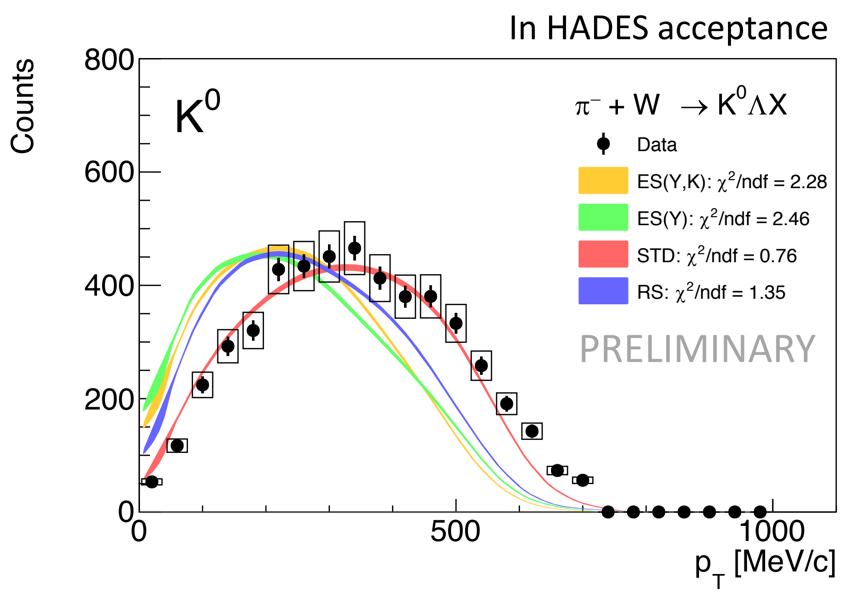
1. **No** $K^0/\Lambda/\Sigma^0$N potentials **(ES(Y,K))**
2. **No** Λ/Σ^0N potentials **(ES(Y))**
3. **Attractive** Λ/Σ^0N potentials **(STD)**
4. **Attractive** ΛN**, repulsive** $\Sigma^0 N$ **(RS)**



based on χEFT by Haidenbauer et al., Eur. Phys. J. A 52, 15 (2016)

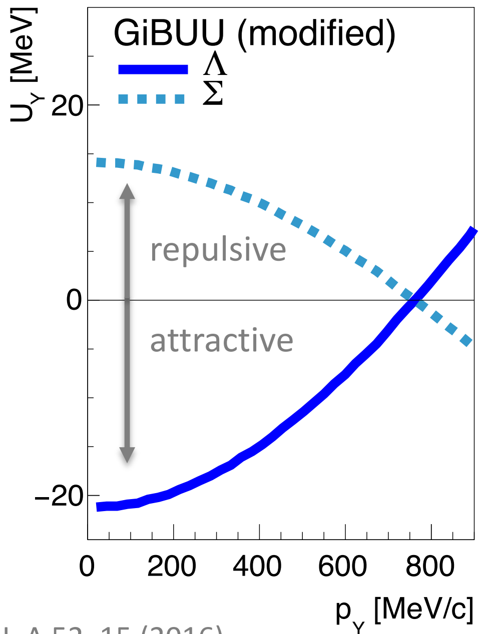
π^-+W

Effects of Hyperon Potentials



Transport Model: **GiBUU(Loniki)**

1. **No** $K^0/\Lambda/\Sigma^0$N potentials **(ES(Y,K))**
2. **No** Λ/Σ^0N potentials **(ES(Y))**
3. **Attractive** Λ/Σ^0N potentials **(STD)**
4. **Attractive** ΛN**, repulsive** $\Sigma^0 N$ **(RS)**



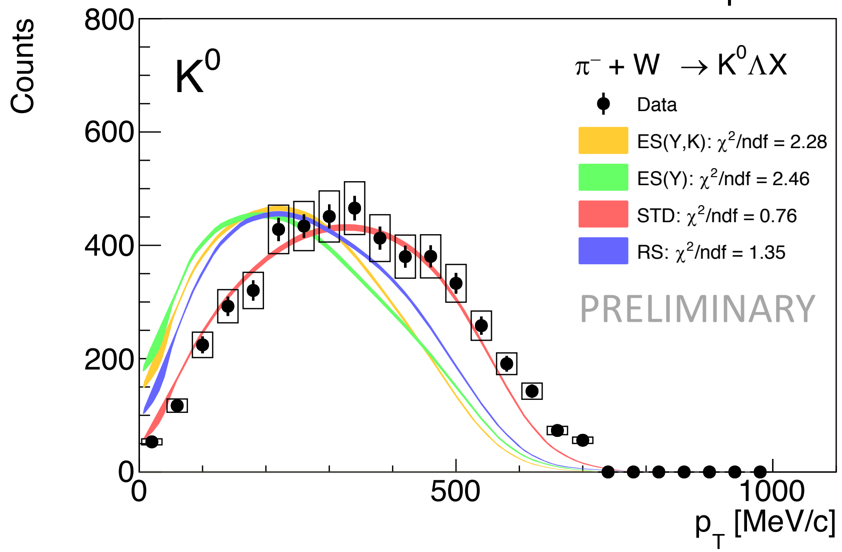
based on χEFT by Haidenbauer et al., Eur. Phys. J. A 52, 15 (2016)

Effects of Hyperon Potentials

π⁻+W

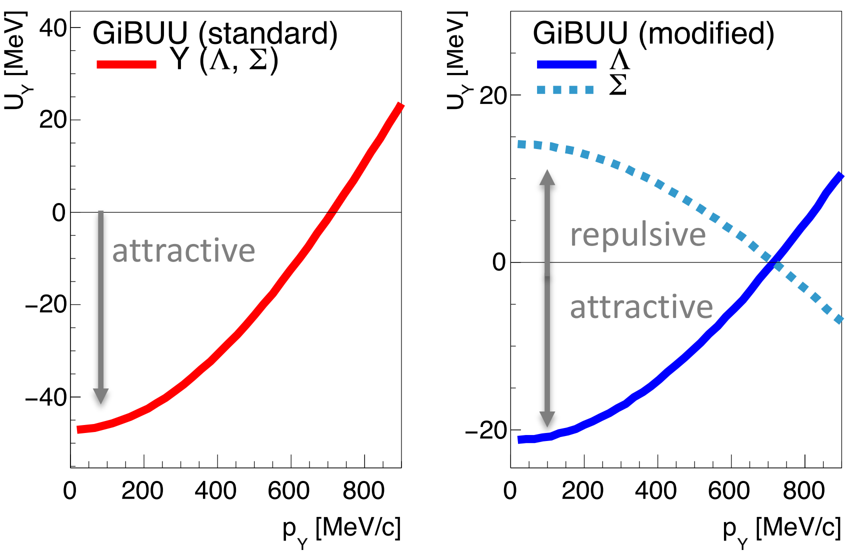
Λ Σ⁰ K⁰

In HADES acceptance



Transport Model: **GiBUU(Loniki)**

1. **No** $K^0/\Lambda/\Sigma^0$N potentials **(ES(Y,K))**
2. **No** Λ/Σ^0N potentials **(ES(Y))**
3. **Attractive** Λ/Σ^0N potentials **(STD)**
4. **Attractive** ΛN**, repulsive** $\Sigma^0 N$ **(RS)**



→ Data agrees best with **attractive** ΛN and **attractive** $\Sigma^0 N$ potentials (@ρ_0)

→ Also favored for lighter target (C)

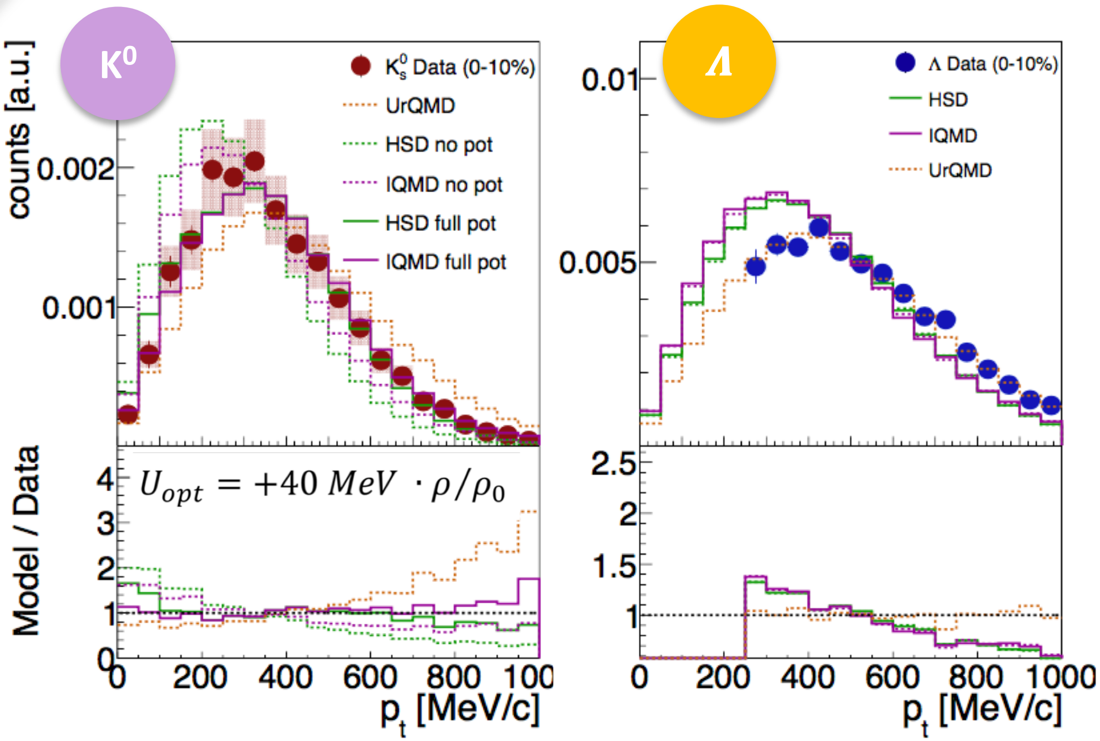
→ **Possibility of testing single particle potentials with** χ**EFT**

based on χEFT by Haidenbauer et al., Eur. Phys. J. A 52, 15 (2016)

Au+Au

Effects of Kaon Potentials

HADES Collaboration, arXiv:1812.07304



→ K_s^0: better agreement with simulation including kaon potential

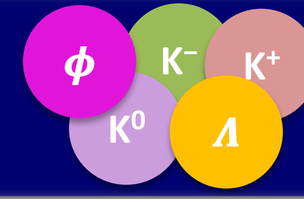
→ Λ: better agreement with UrQMD (w/o) potentials, but inclusion of higher mass resonances

→ **No simultaneous description of K_s^0 and Λ**

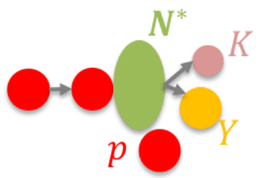
→ **Role of Σ^0?**

HSD v711n: Phys. Rep. 308, 65–233 (1999)
IQMD c8: Eur. Phys. J. A 1, 151–169 (1998)
UrQMD 3.4: Prog. Part. Nucl. Phys. 41, 255–369 (1998)

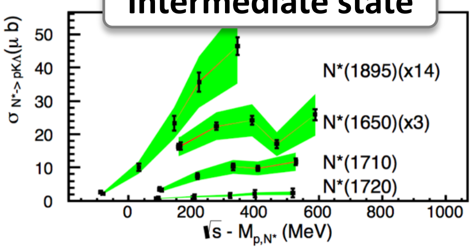
Summary



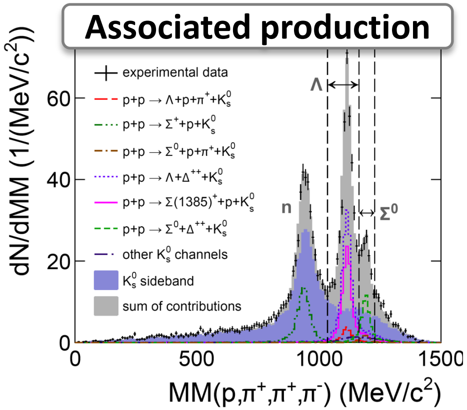
Elementary reactions



Intermediate state



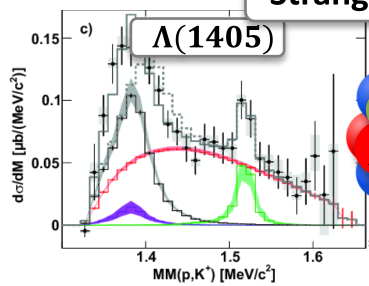
Associated production

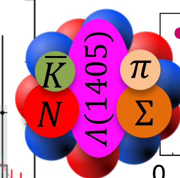


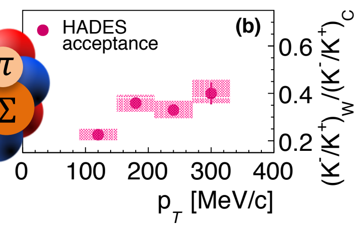
→ **Input to transport models**

Hadron-Nucleus reactions

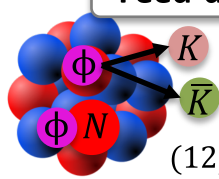
Strangeness exchange







Feed-down + Absorption



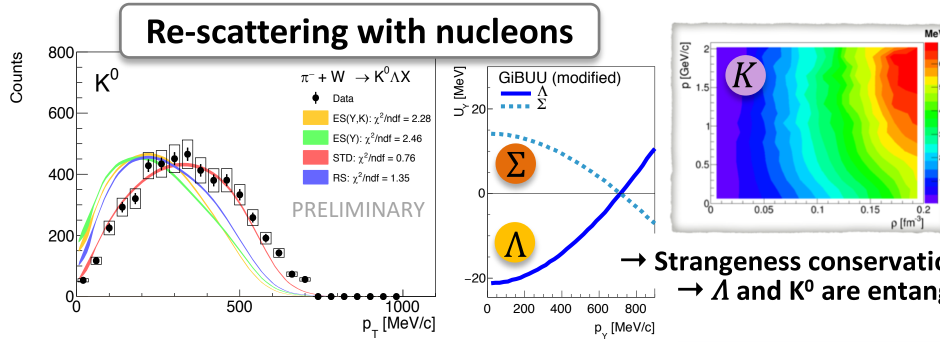
$(\phi/K^-)_{\pi C} = 0.55 \pm 0.08$

$(\phi/K^-)_{\pi W} = 0.63 \pm 0.13$

$(12/184)\,(\sigma_\phi^{\pi W}/\sigma_\phi^{\pi C}) = 0.18 \pm 0.12$

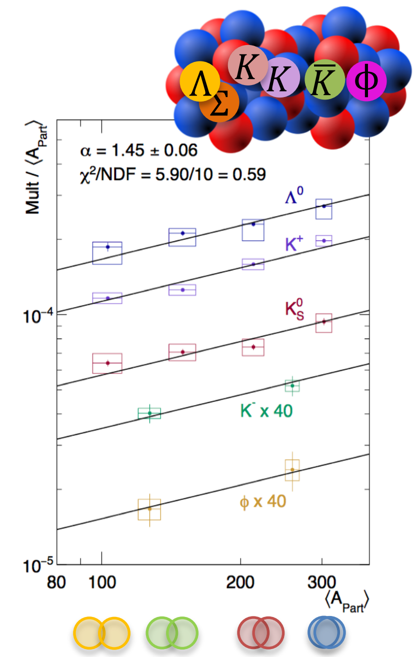
$(12/197)\,(\sigma_\phi^{pAu}/\sigma_\phi^{pC}) = 0.29 \pm 0.02$

Re-scattering with nucleons



→ **Strangeness conservation**
→ **Λ and K⁰ are entangled**

Nucleus-Nucleus reactions



Backup

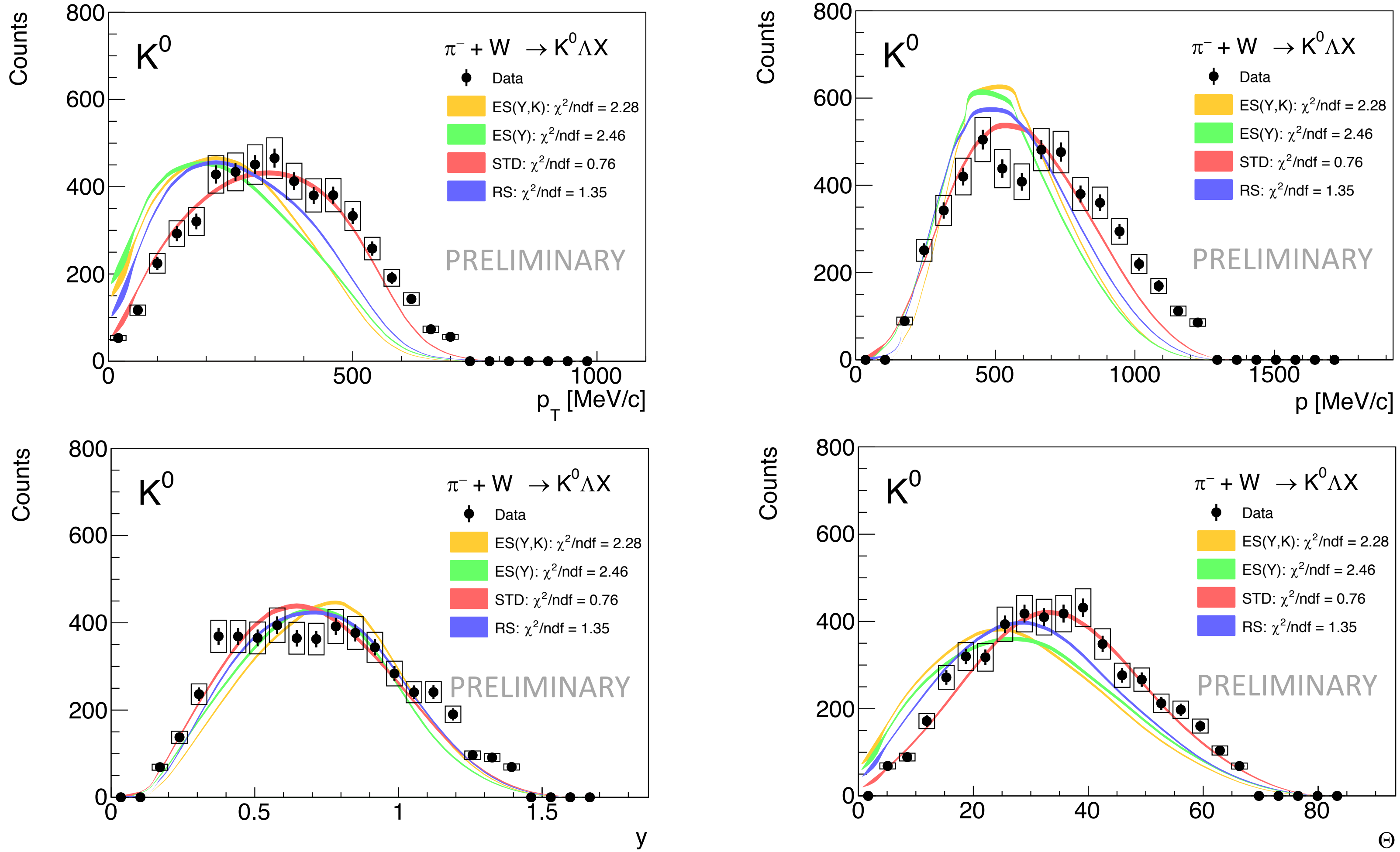
$\pi^- + W$

Effects of Hyperon Potentials

Λ Σ^0 K^0

In HADES acceptance

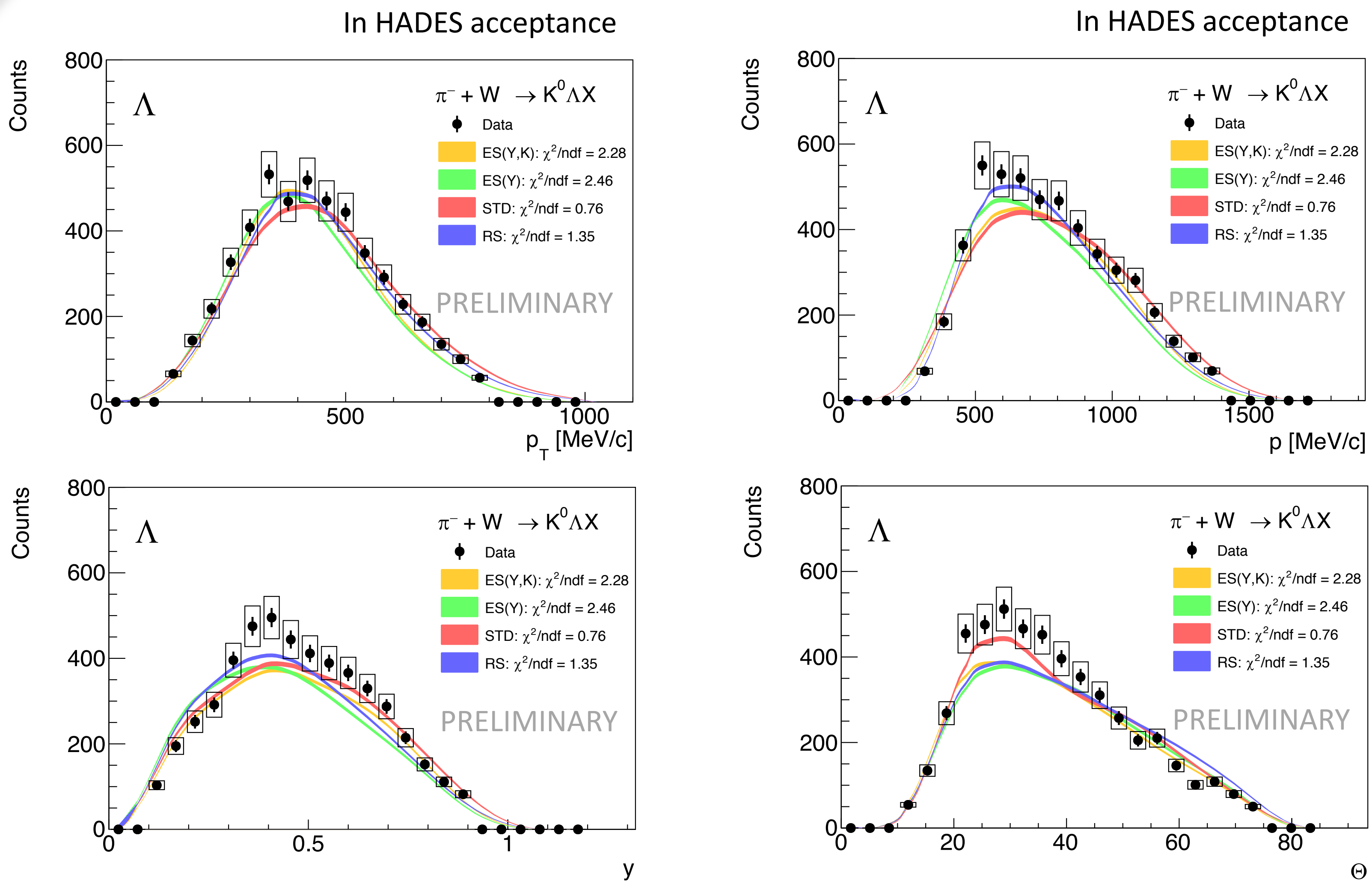
In HADES acceptance



Effects of Hyperon Potentials

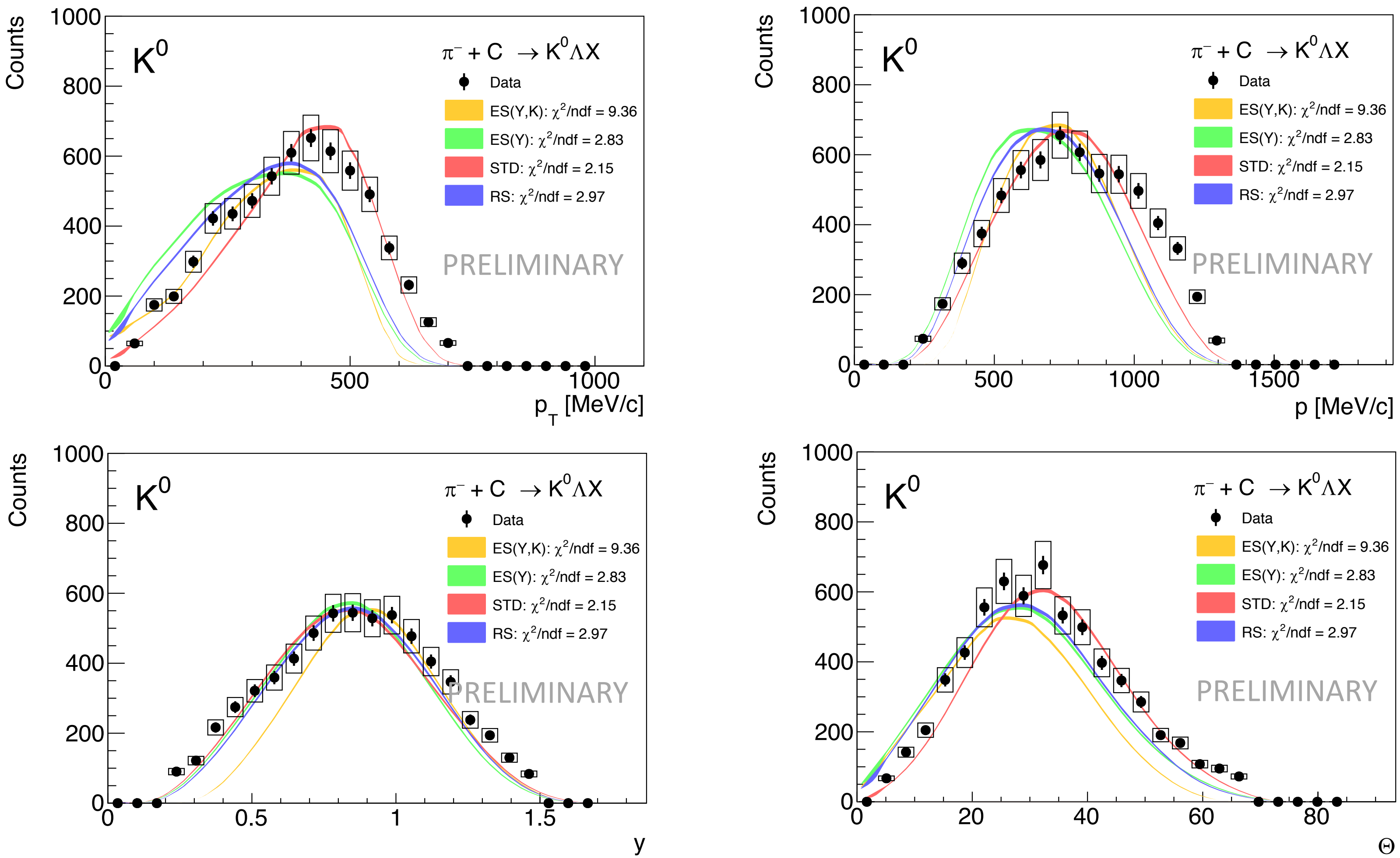
π⁻+W

Λ Σ⁰ K⁰

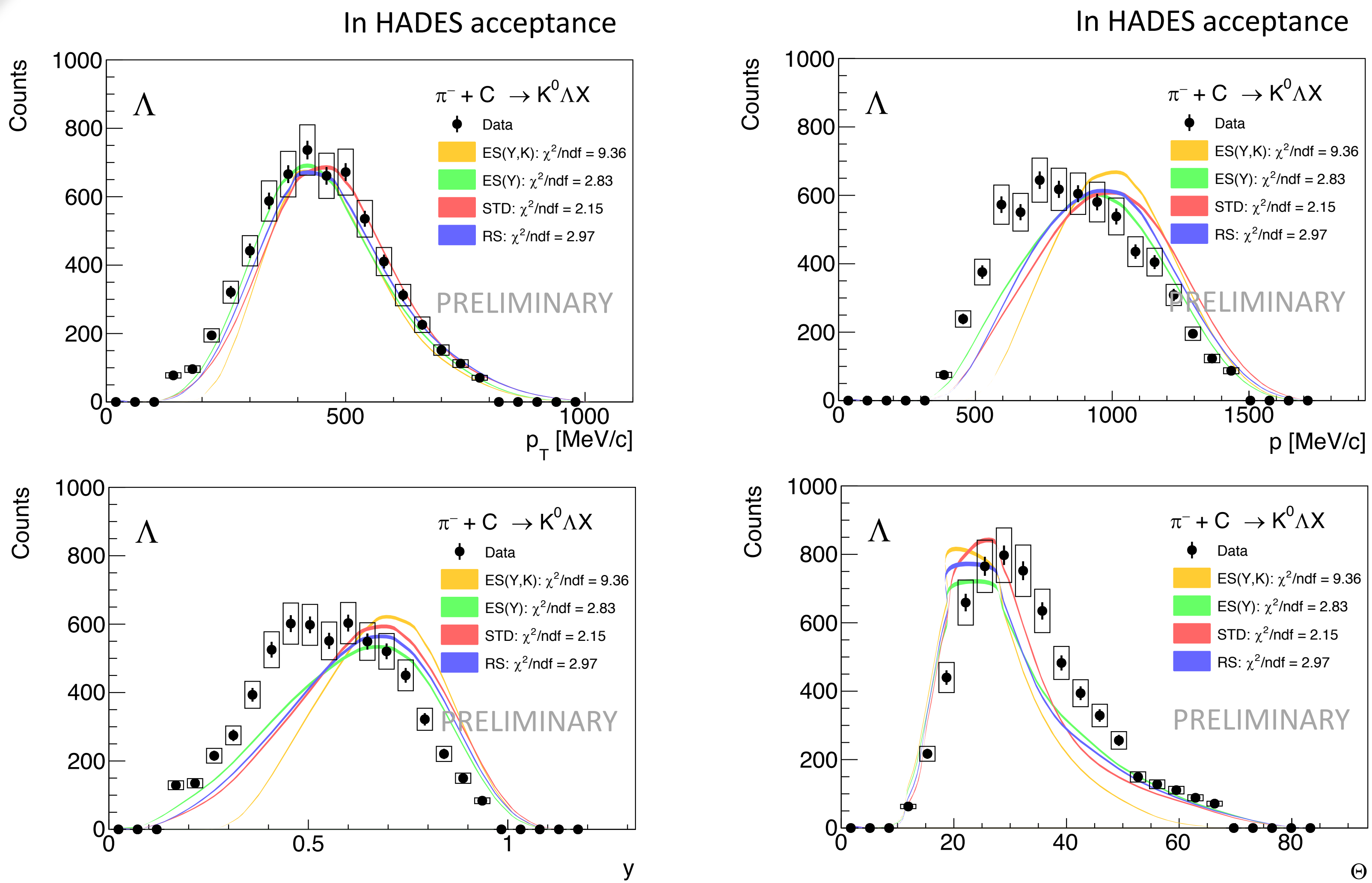


Effects of Hyperon Potentials

In HADES acceptance



Effects of Hyperon Potentials

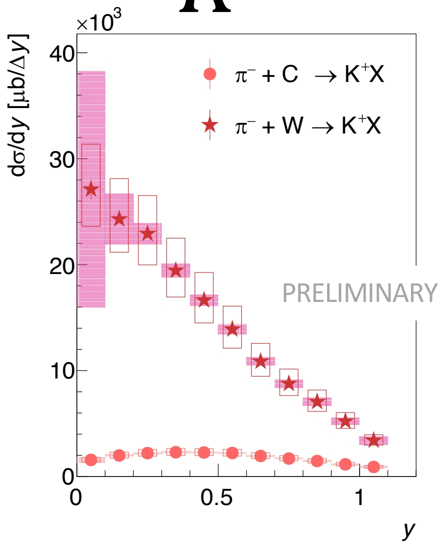


π^-+C/W

Inclusive Diff. Cross-Sections

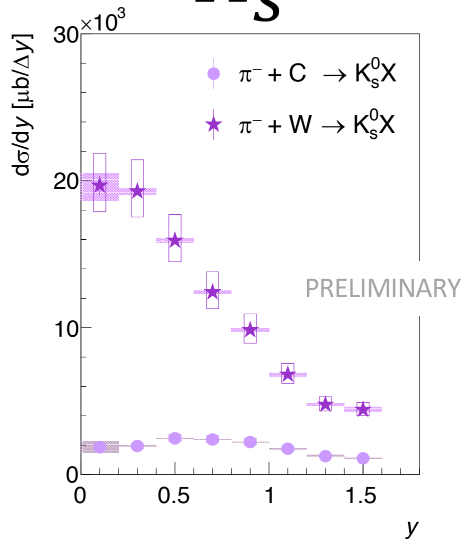
K⁻ K⁺ K⁰ Λ

K^+



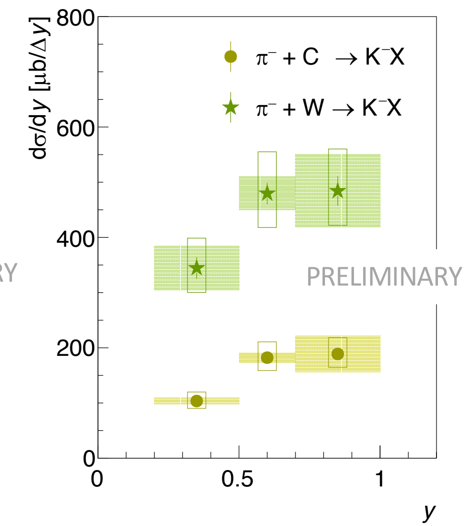
→ KN scattering

K_s^0



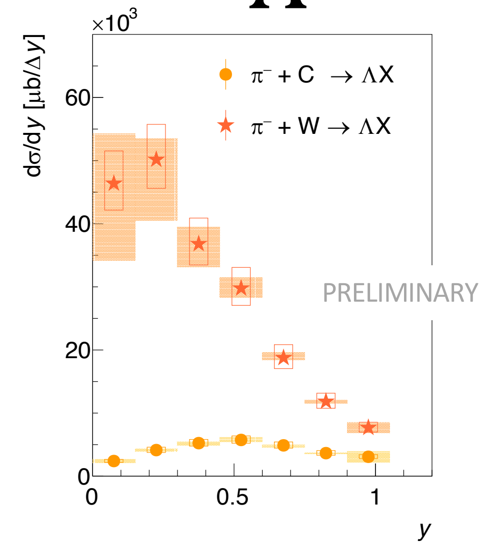
→ KN scattering

K^-



→ $\bar{K}N$ absorption

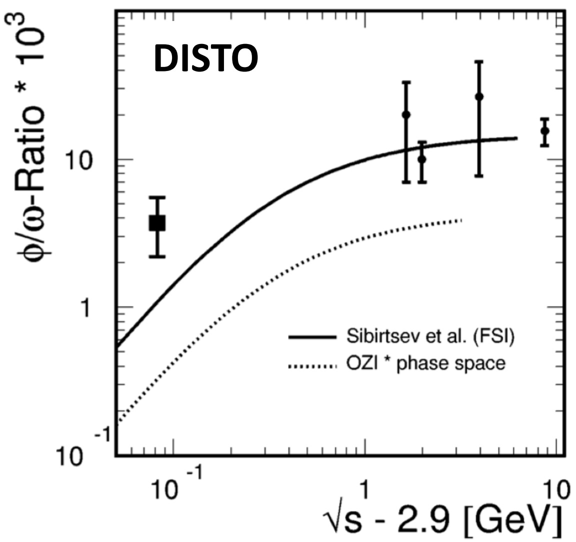
Λ



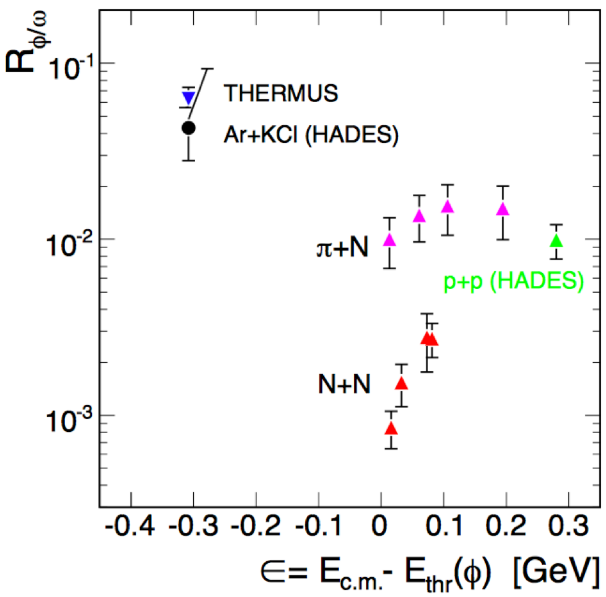
→ ΛN scattering

Phi – Omega Mixing

Balestra et al. Phys. Rev. Lett. 81, 0572 (1998)



Marek Palka PhD Thesis with HADES (2011)



$$R_{\phi/\omega} = \frac{A + B \to \phi + X}{A + B \to \omega + X} = tan^2(\delta\theta_v)f = 4.2\ 10^{-3}$$

f: Ratio of phase space factors

→ $R_{\phi/\omega}$ clearly exceeds native application of OZI rule

Ar+KCl: Agakishiev et al. Phys. Rev. C 85, 014902 (2011)