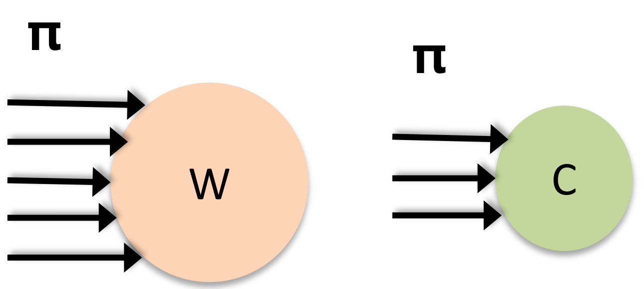
In-Medium Properties of Lambda in Pion-Induced Reactions at 1.7 GeV/c*

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

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

*supported by SFB 1258

Pion-Induced Strange Hadron Production

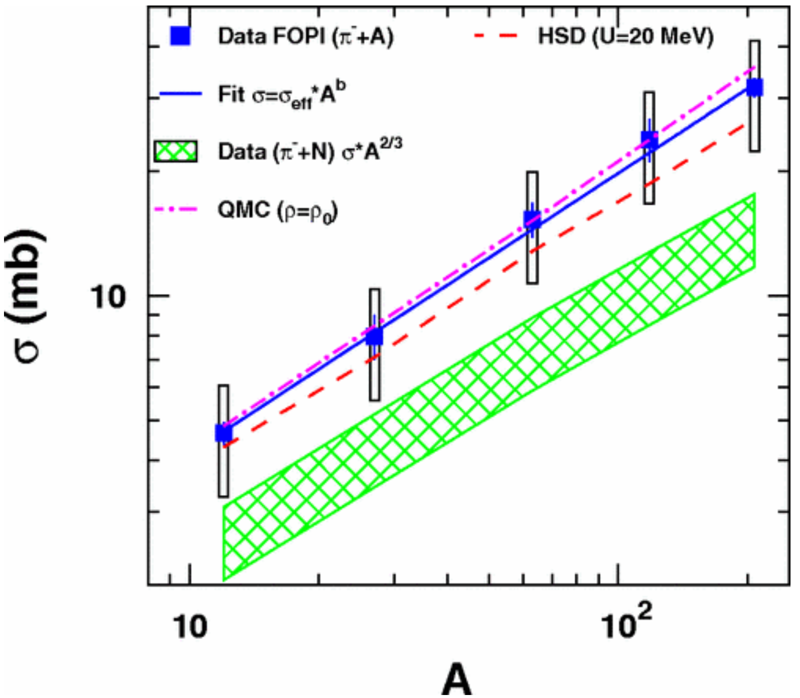


$$\lambda = 1.5 \text{ fm} \ (p_\pi = 1.7 \text{ GeV/c})$$

$$d_{C,W} \approx 5.5,\ 14.2 \text{ fm}$$

→ **π** is likely to undergo reactions with nucleus on the surface of the target nucleus

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



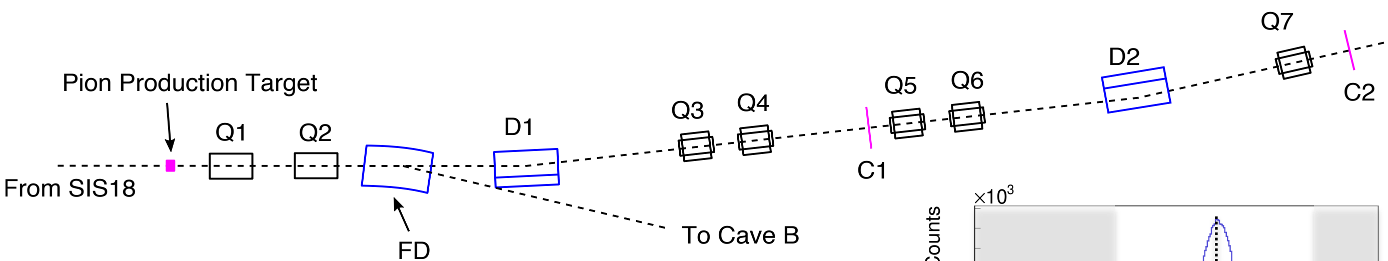
→ K^0 production scales with the surface of the nucleus in pion-induced reactions (@ 1.15 GeV/c)

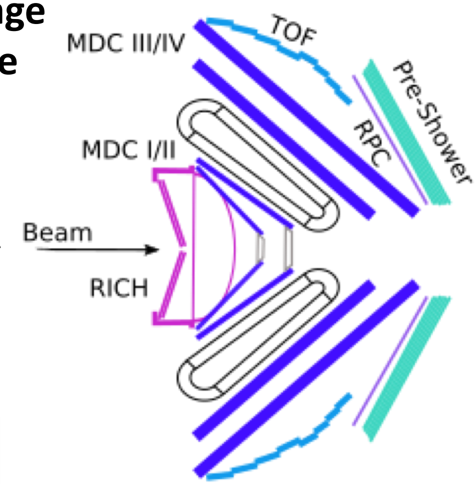
Pion Facility with HADES

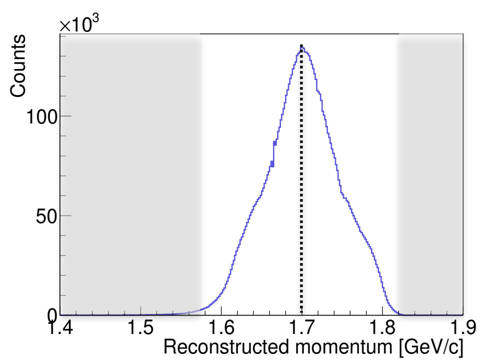
SECONDARY PION BEAM @ 1.7 GeV/c

CEnt**R**al **BE**am **TR**acker for Pi**O**n**S** (TUM)
- → **Two tracking stations (C1, C2)**
- → **High π^- rates ($\leq 10^7$ part./s)**
- → **Self-triggering and $\sigma(p_\pi) < 0.5$ %**

High **A**cceptance **D**i**E**lectron **S**pectrometer
- → **Full azimuthal coverage**
- → **15°–85° in polar angle**
- → **$\sigma(p) \approx (2–6)$ %**

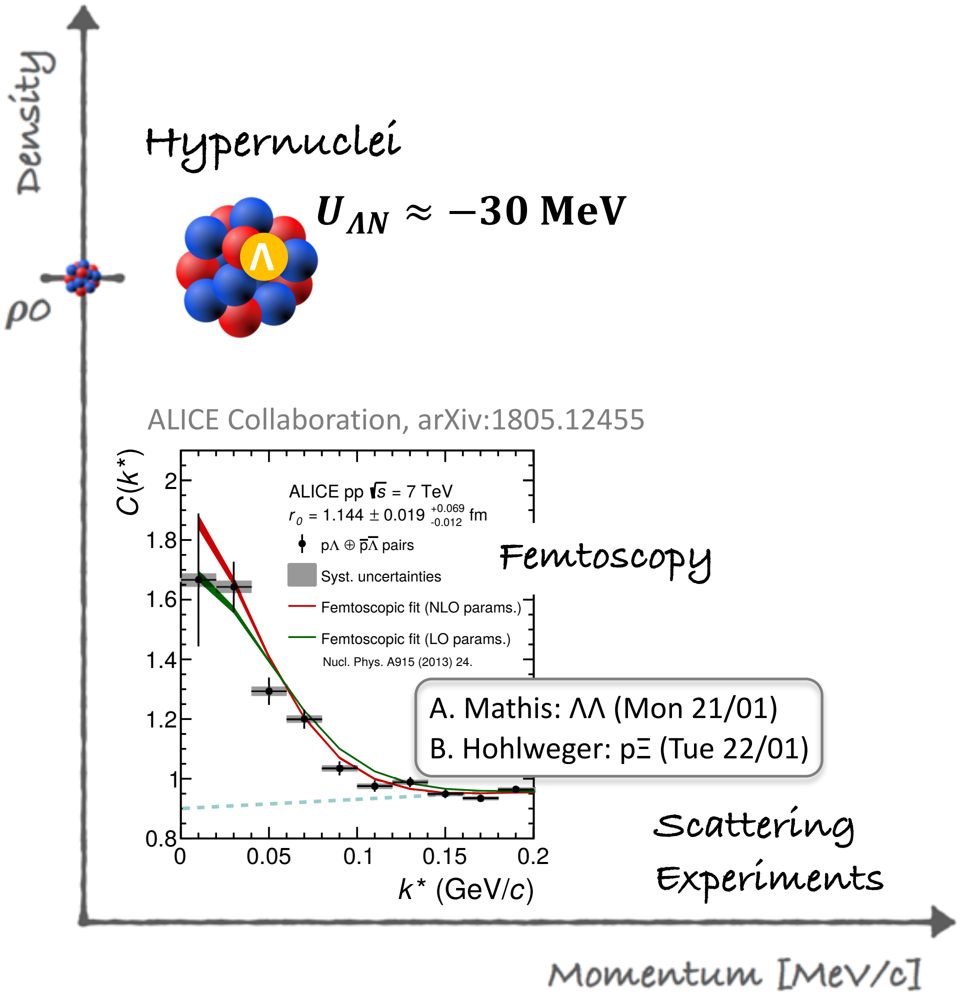






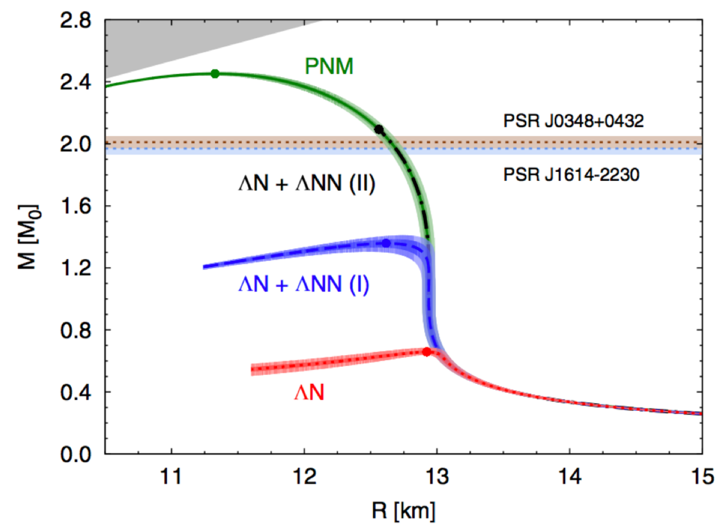
Wirth et al., Nucl. Inst. and Meth., Phy. Res. A, p. 243-244 (2016)
Adamczewski-Musch et al., Eur. Phys. J. A 53, 188 (2017)

Hyperon Stars



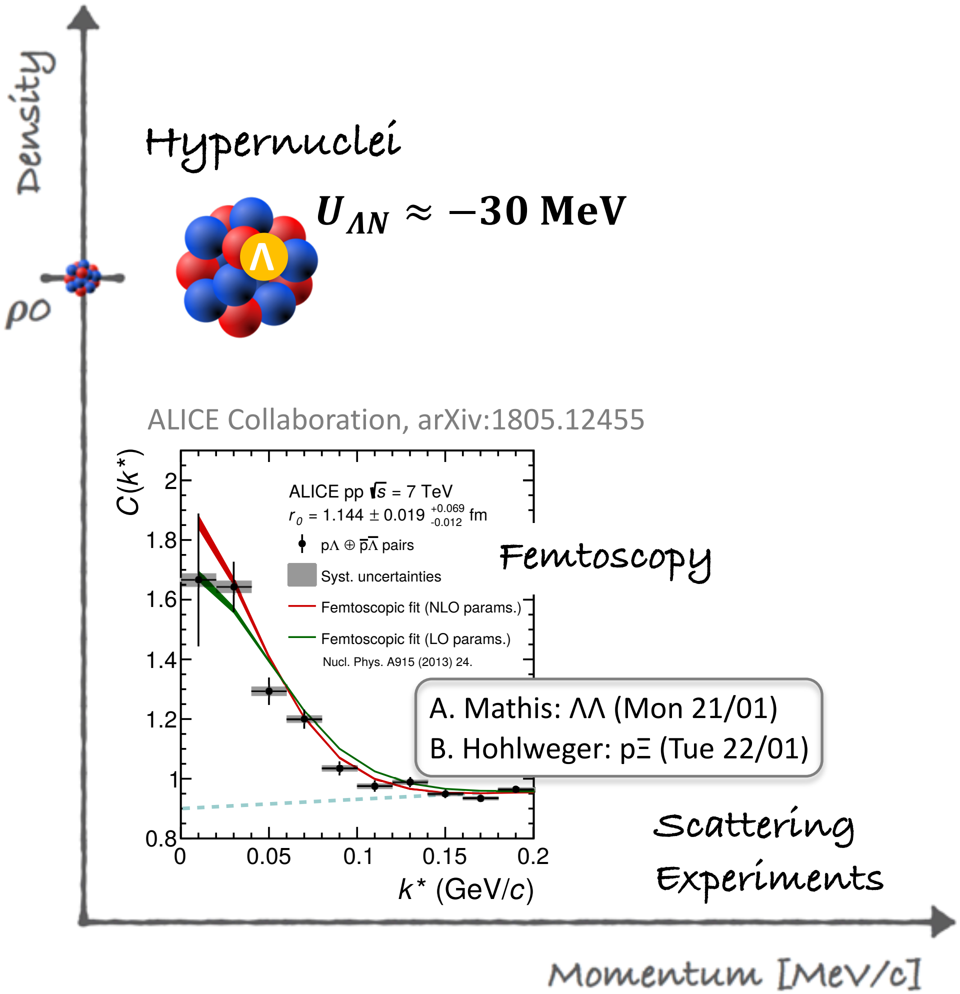
A. Mathis: ΛΛ (Mon 21/01)
B. Hohlweger: pΞ (Tue 22/01)

QMC: Lonardoni et al., Phys. Rev. Lett. 114, 092301 (2015)



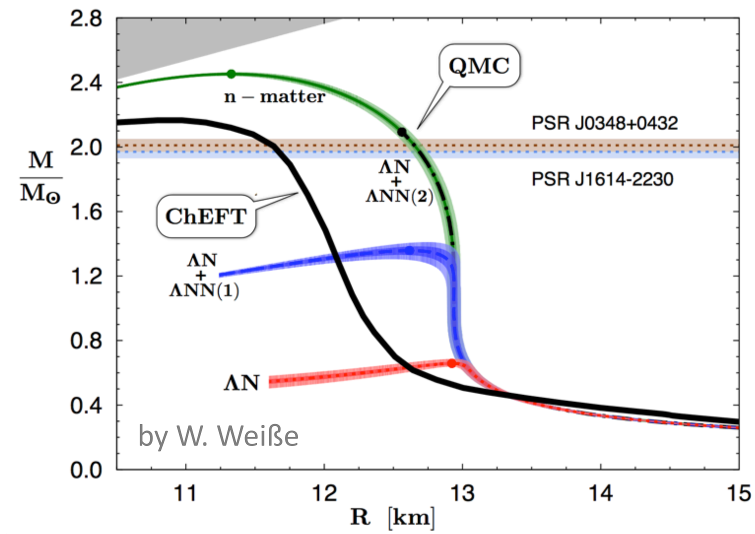
→ **QMC: Attractive ΛN interaction +** (phenom.) **repulsive ΛNN interaction**
→ Hypernuclei ($U_{\Lambda N} \approx -30$ MeV)

Hyperon Stars



QMC: Lonardoni et al., Phys. Rev. Lett. 114, 092301 (2015)

ChEFT: T. Hell et al., Phy. Rev. C 90, 045801 (2014)



→ **QMC: Attractive ΛN interaction +** (phenom.) **repulsive ΛNN interaction**

→ Hypernuclei ($U_{\Lambda N} \approx -30$ MeV)

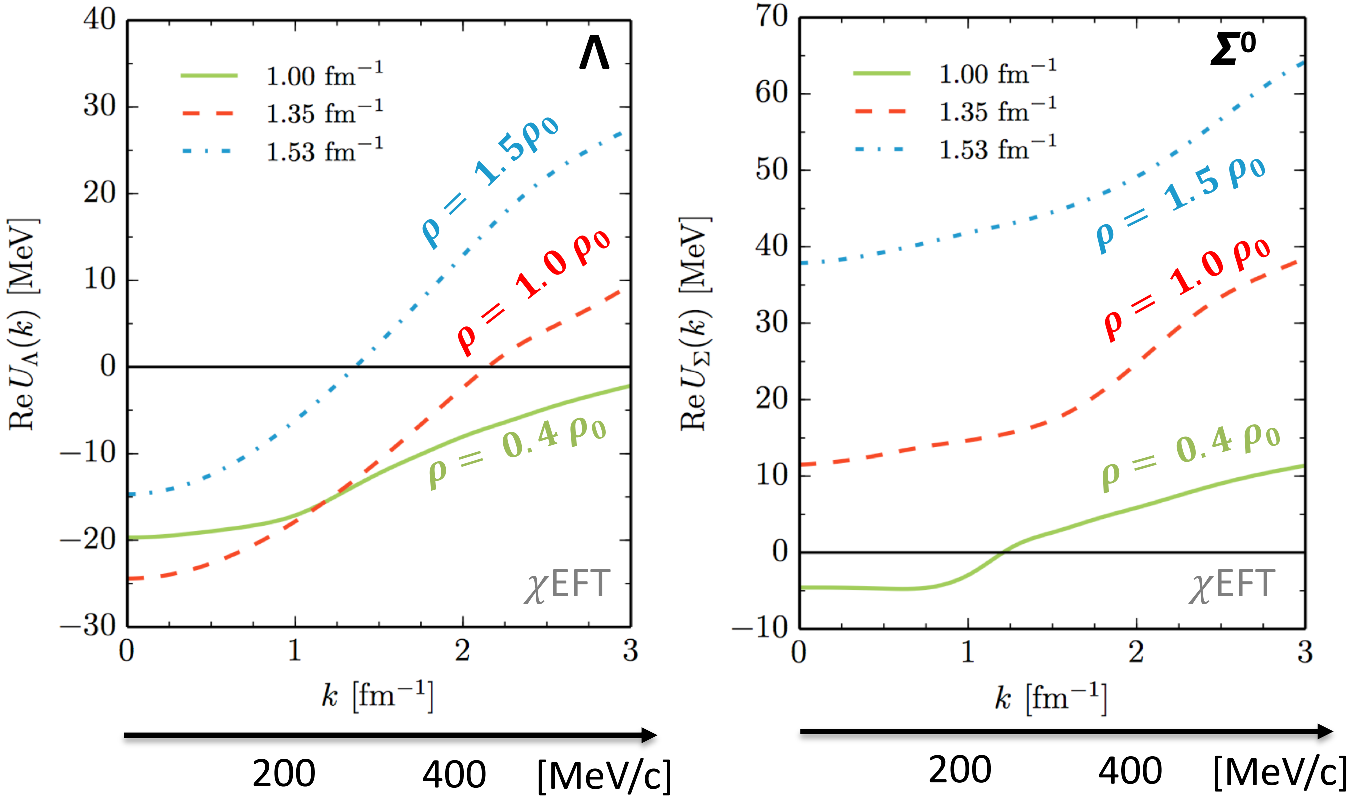
→ **ChEFT:** Scattering data

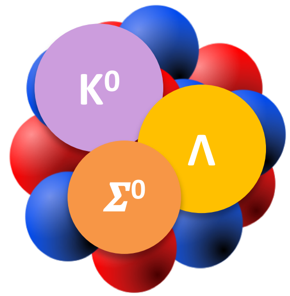
→ Further constraints on **YN** forces needed!!

→ **"Hyperon Puzzle"**

Hyperons inside Nuclear Matter

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





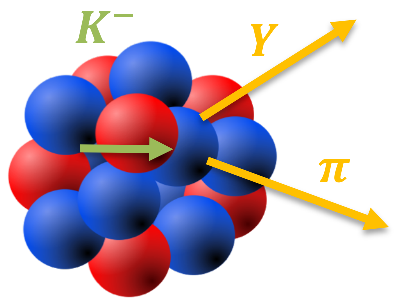
$200 \leq p_\Lambda \leq 800\ \boldsymbol{MeV}/c$

→ $\boldsymbol{\Lambda/\Sigma}$ single particle interaction within the nucleus?

Interplay with Kaons

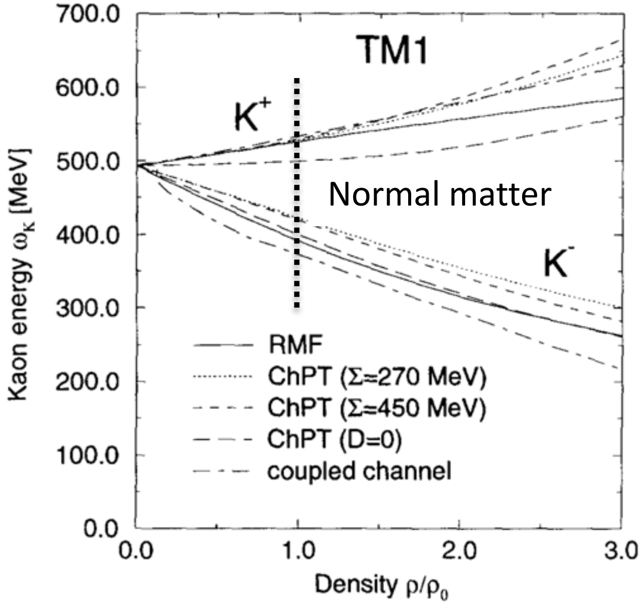
Strangeness exchange in nuclear matter:

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



→ K^- **conversion into Λ**

Schaffner et al., Nucl. Phys. A 625, 325 (1997)



→ **Momentum distribution**

→ **Rapidity distribution**

→ K^- **absorption:**

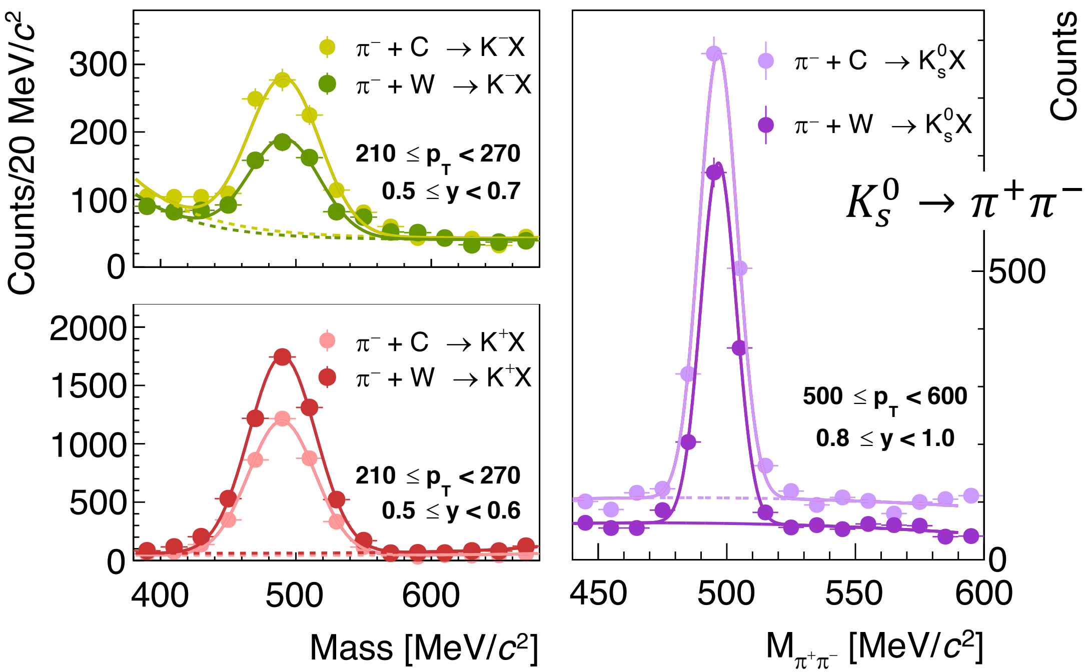
$$\boxed{\frac{K^-}{K^+}(W)\Big/\frac{K^-}{K^+}(C)\left(y, p_T/\Theta, p\right)}$$

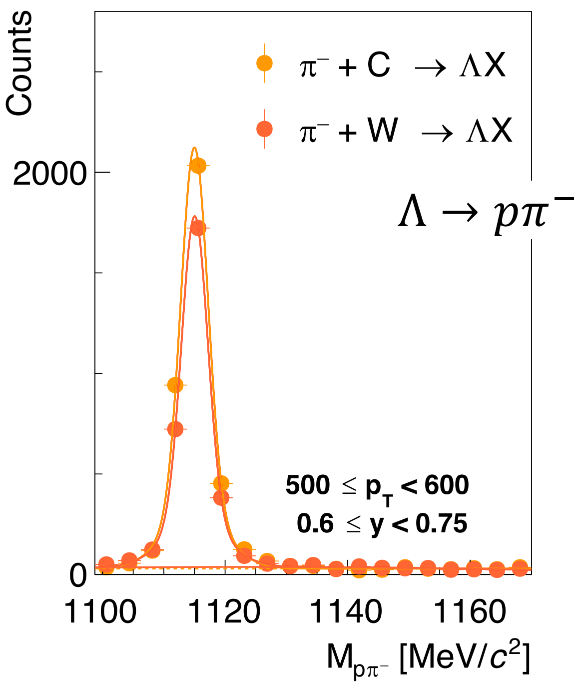
Strange Hadron Selection

π⁻+C/W

Kaon Family

Lambda



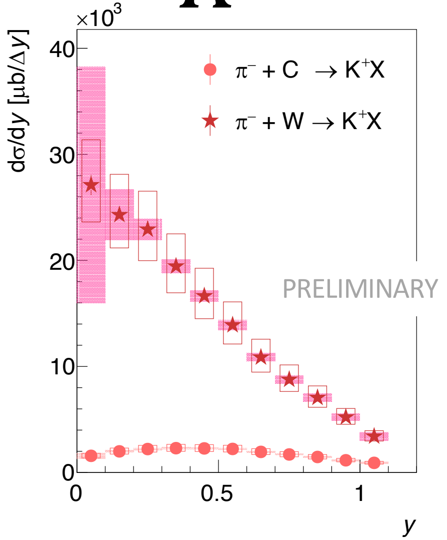


π^-+C/W

Inclusive Diff. Cross-Sections

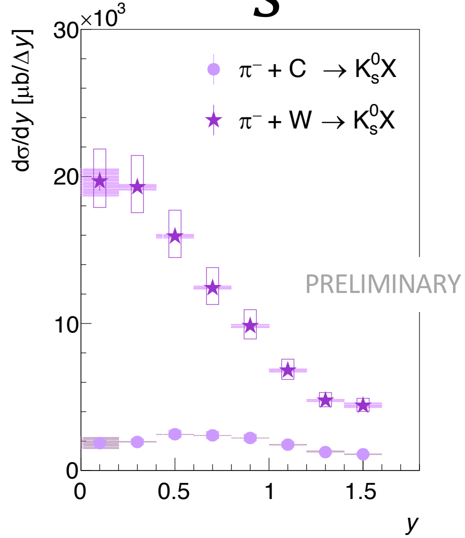
K^- K^+ K^0 Λ

K^+



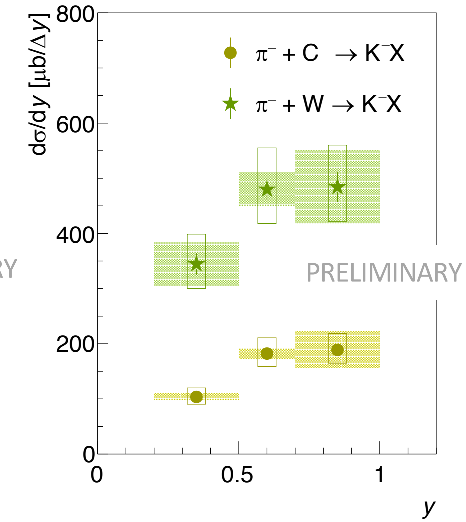
→ KN scattering

K_s^0



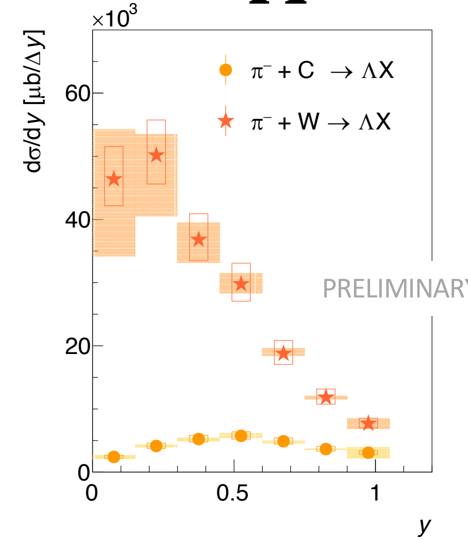
→ KN scattering

K^-



→ $\bar{K}N$ absorption

Λ

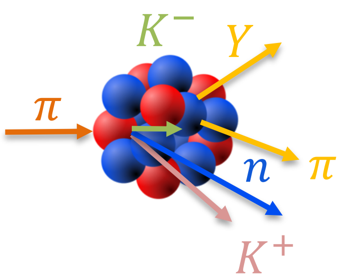


→ ΛN scattering

π^-+C/W

Absorption Processes

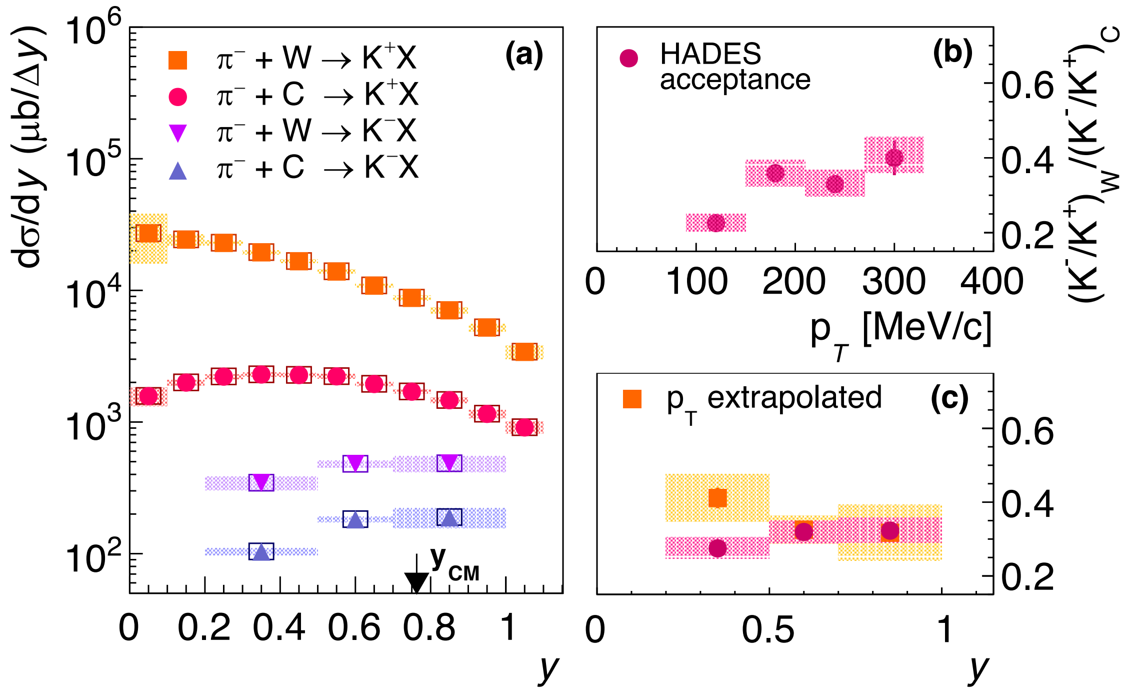
K⁻ K⁺



$K^- N \rightarrow Y\pi$

$K^- NN \rightarrow YN$

HADES Collaboration, arXiv:1812.03728



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

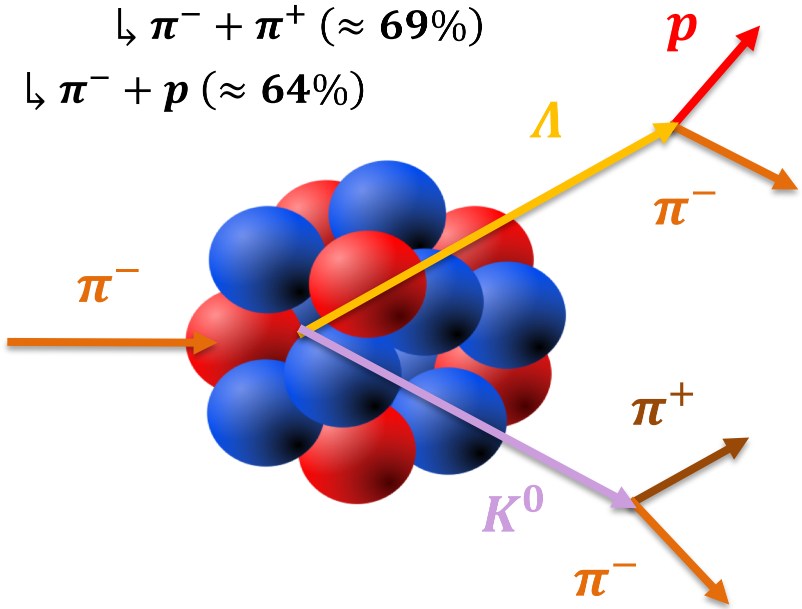
➞ **First observation in heavy nuclei**

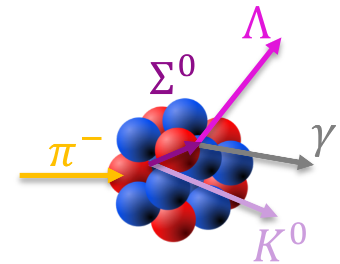
π⁻+C/W

Hyperon Propagation in Matter

Λ Σ^0 K^0

$$\pi^- + p \rightarrow \Lambda + K^0$$
$$\quad \hookrightarrow \pi^- + \pi^+ \ (\approx 69\%)$$
$$\hookrightarrow \pi^- + p \ (\approx 64\%)$$





$$\Sigma^0 \rightarrow \Lambda + \gamma$$
$$(\approx 100\%)$$

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

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

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

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

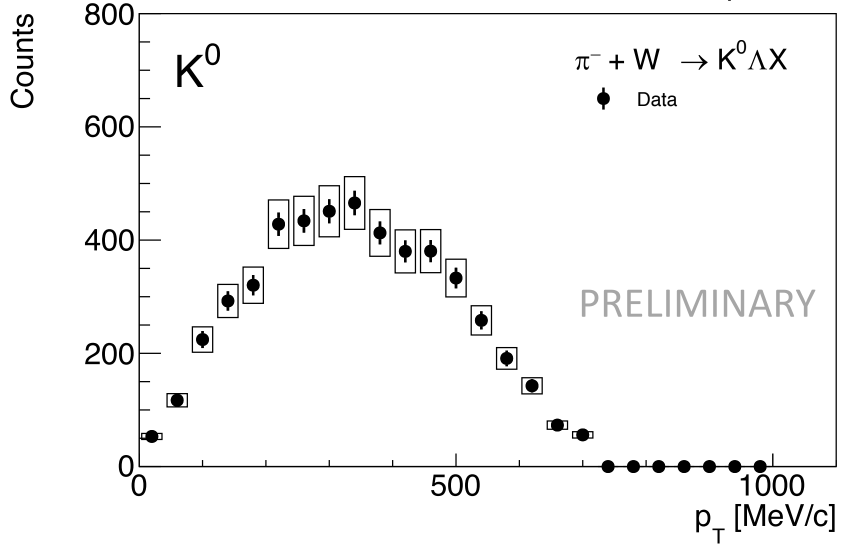
→ **Strangeness conservation**
→ **Λ and K^0 are entangled**

Effects of Hyperon Potentials

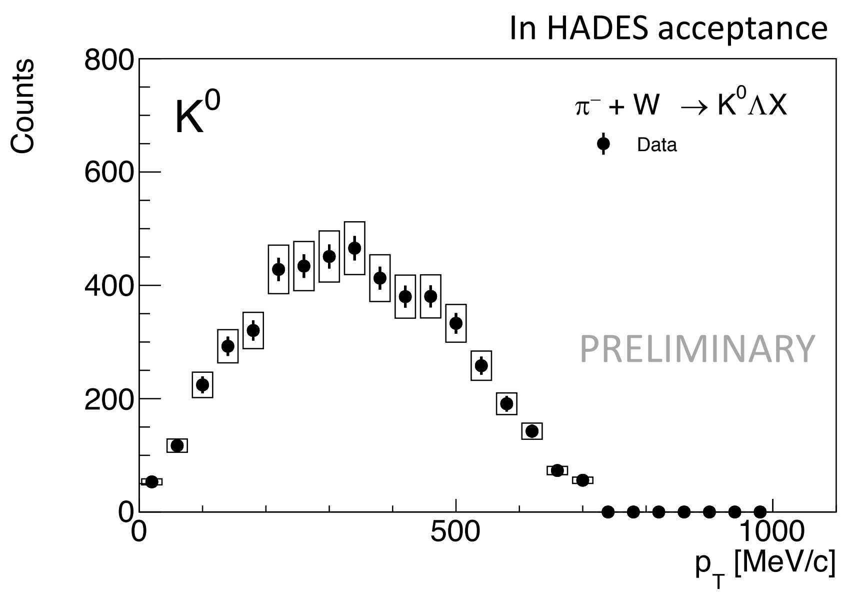
Λ Σ⁰ K⁰

Transport Model: **GiBUU**

In HADES acceptance

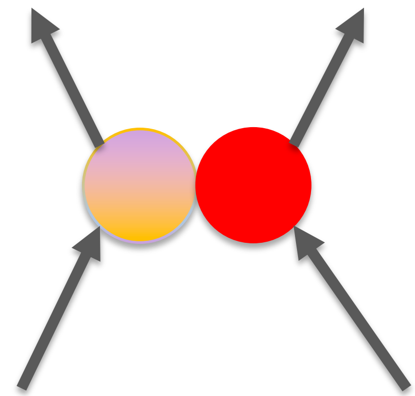


Effects of Hyperon Potentials

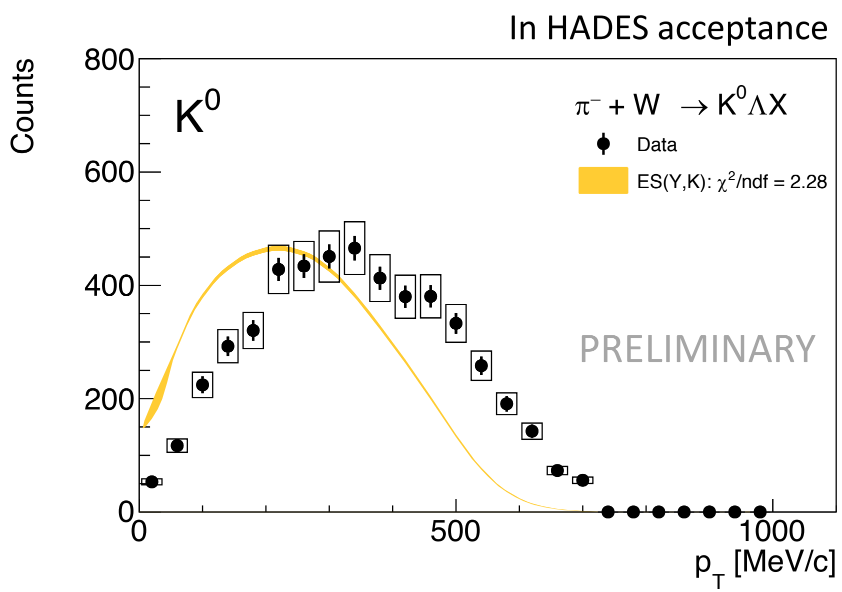


Transport Model: **GiBUU**

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



Effects of Hyperon Potentials



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

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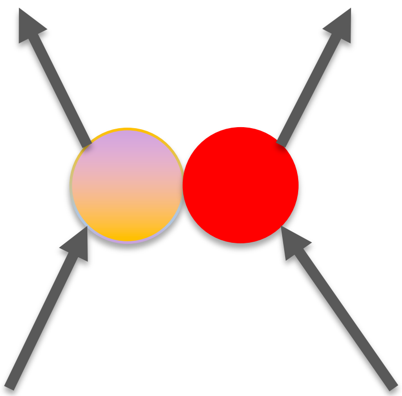

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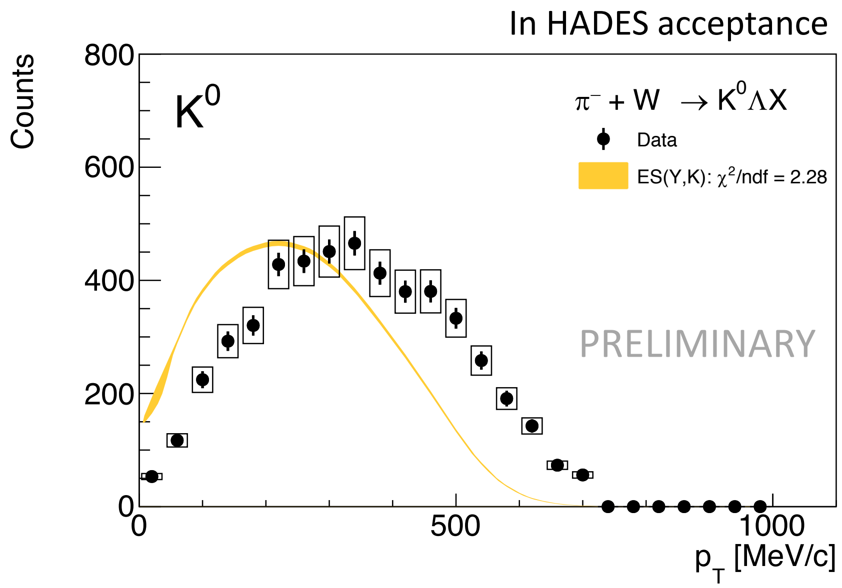

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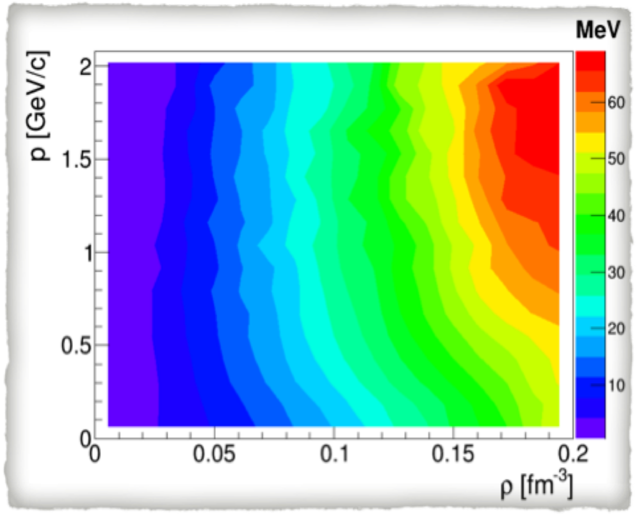
2. **No** Λ/Σ^0N potentials **(ES(Y))**

KN potential

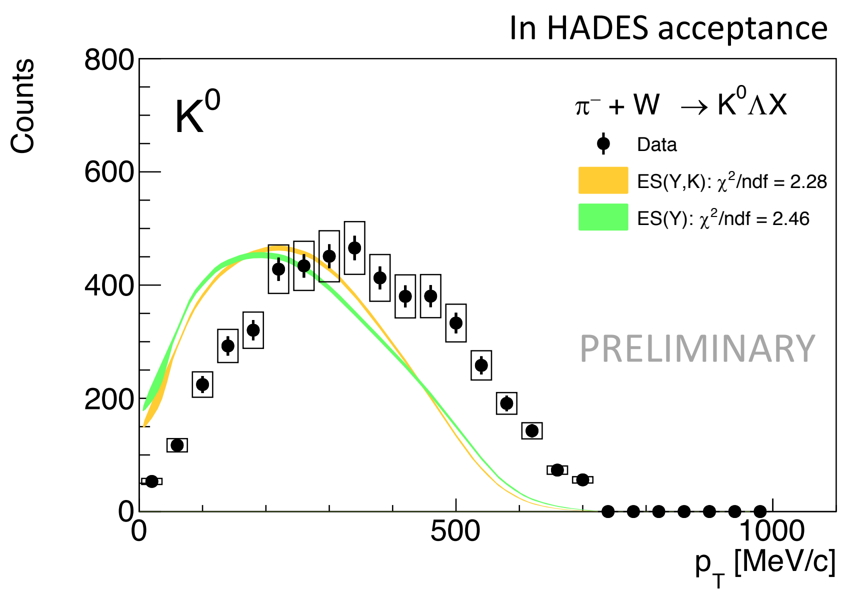


Agakishiev et al., Phys. Rev. C 90, 054906 (2014)

Effects of Hyperon Potentials

$\pi^- + W$

Λ Σ^0 K^0



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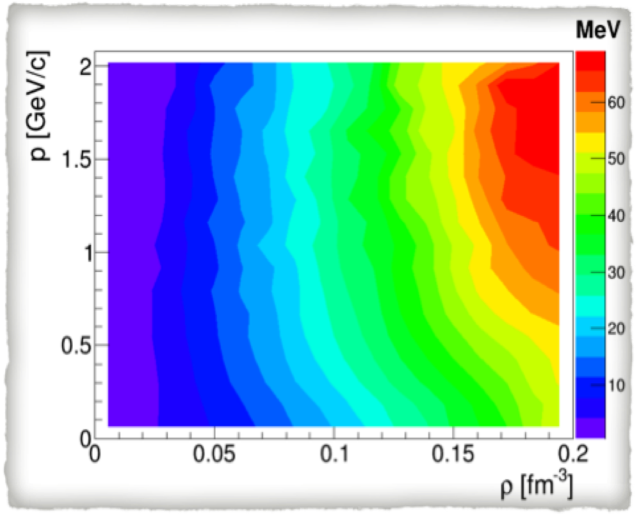

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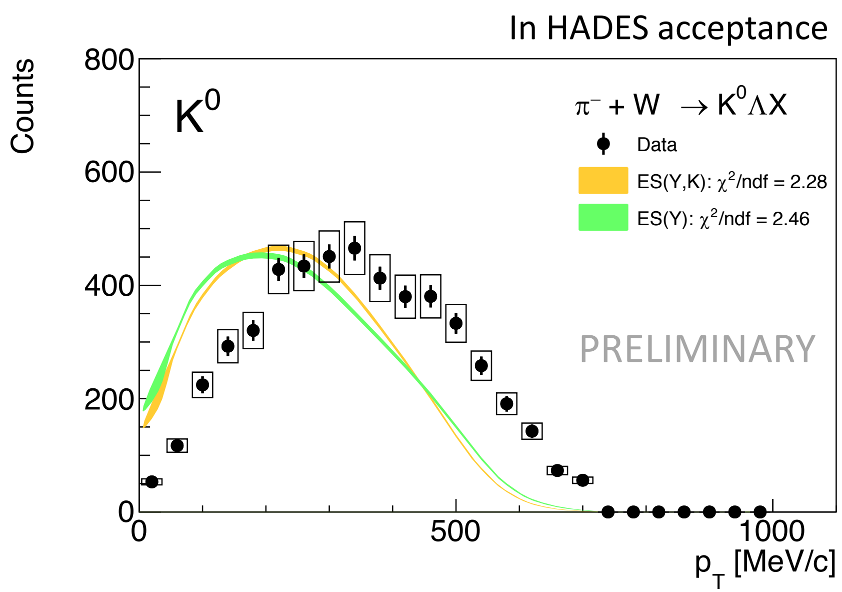
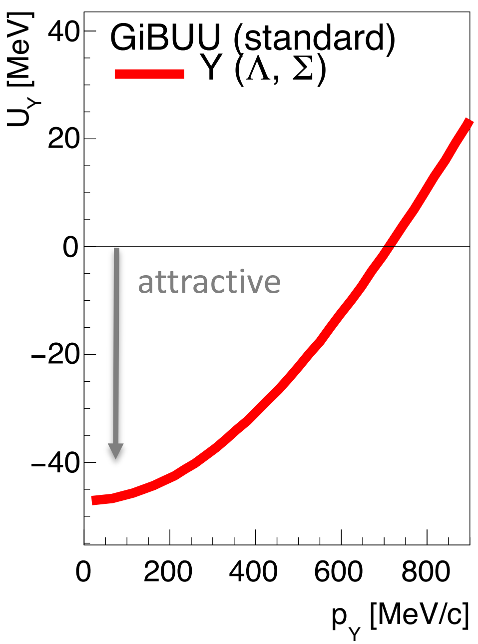


Transport Model: **GiBUU**

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



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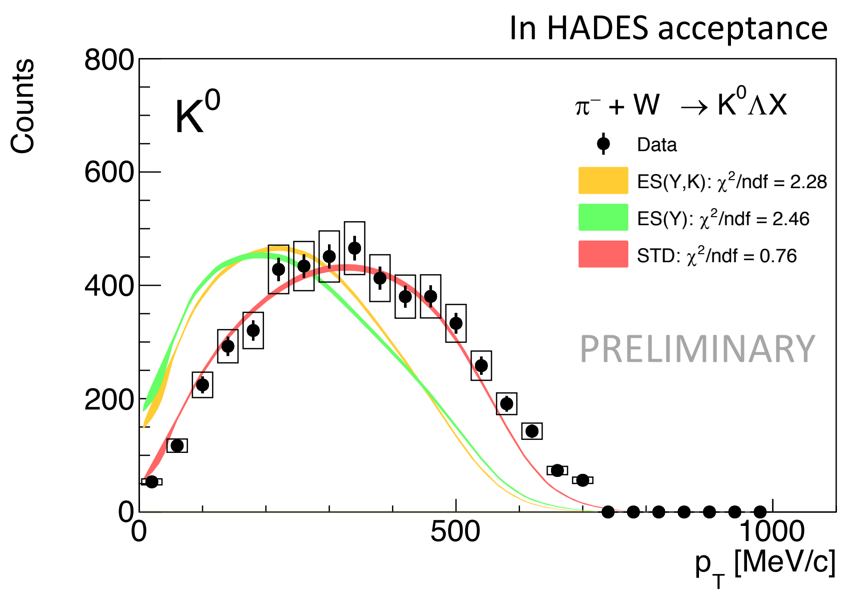
$\pi^- + W$

Λ Σ^0 K^0



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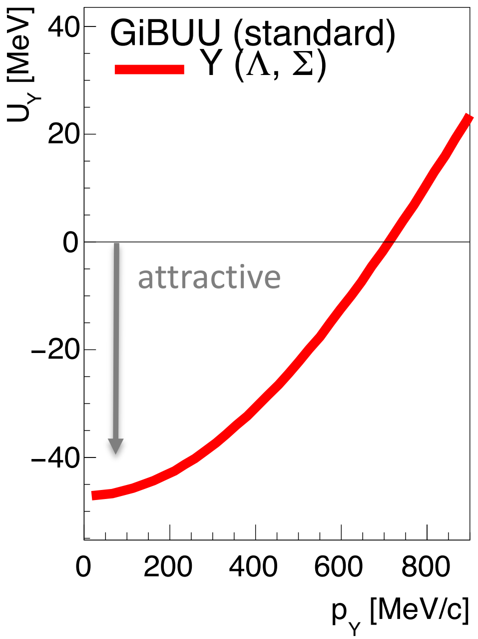

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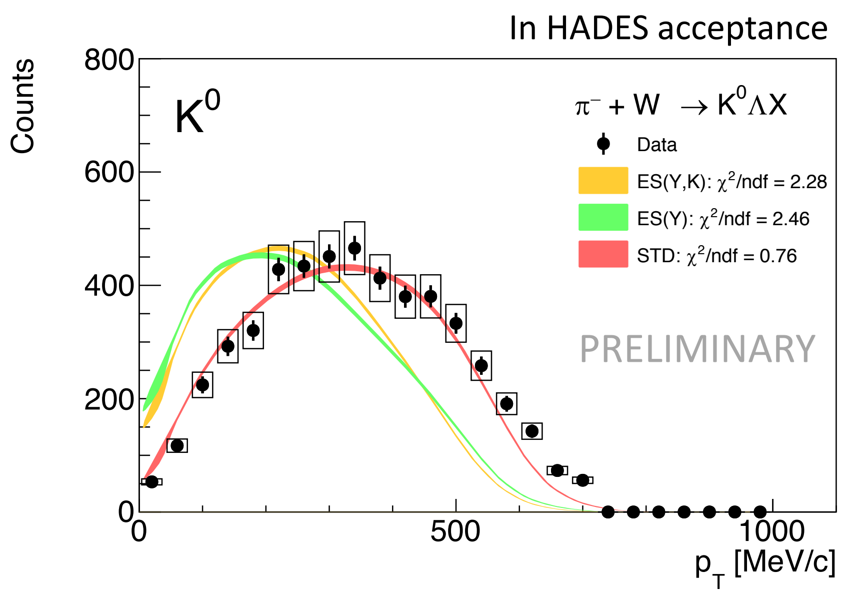

Transport Model: **GiBUU(Loniki)**

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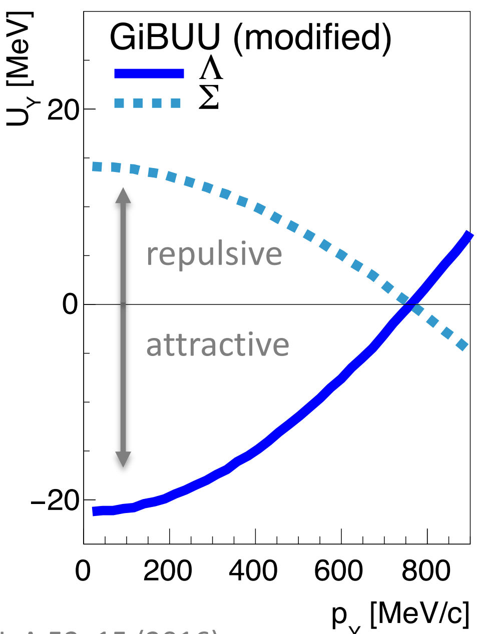
3. **Attractive** $\Lambda/\Sigma^0\mathrm{N}$ potentials **(STD)**
4. **Attractive** $\Lambda\mathrm{N}$**, repulsive** $\Sigma^0 N$ **(RS)**



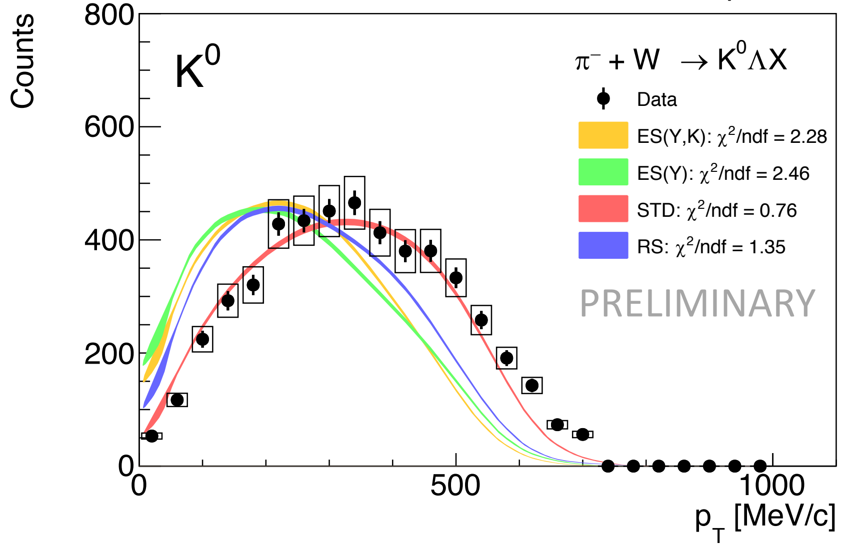
based on χEFT by Haidenbauer et al., Eur. Phys. J. A 52, 15 (2016)

Effects of Hyperon Potentials

$\pi^- + W$

Λ Σ^0 K^0

In HADES acceptance



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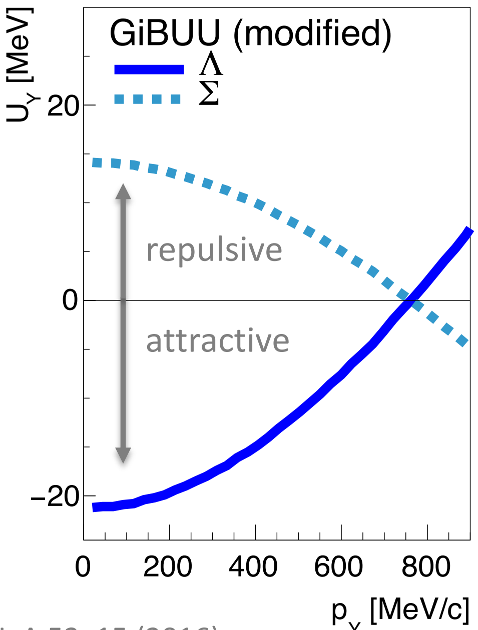
4. **Attractive** ΛN**, repulsive** $\Sigma^0 N$ **(RS)**



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

π^-+W

Effects of Hyperon Potentials

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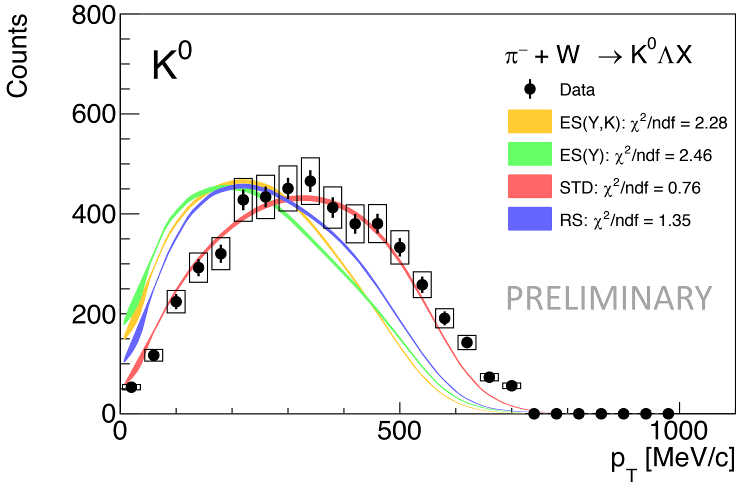

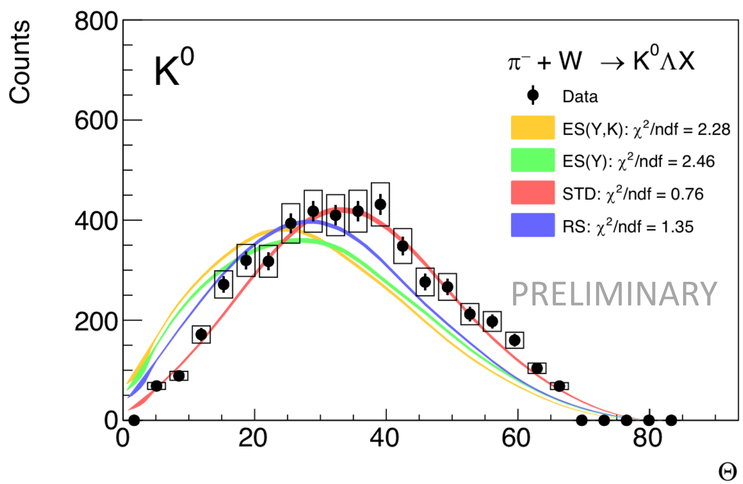

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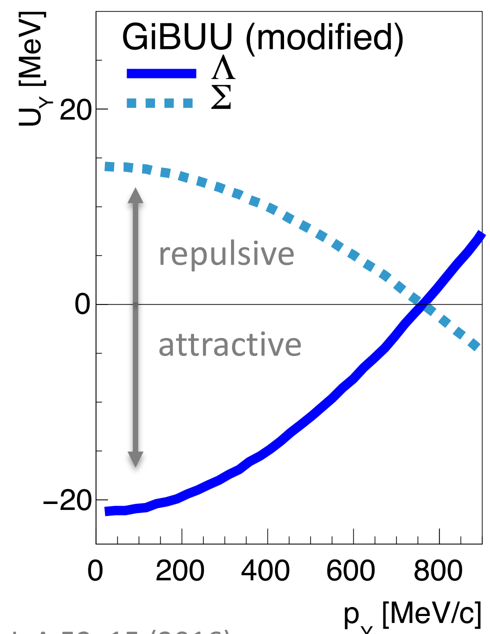

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$\pi^- + W$

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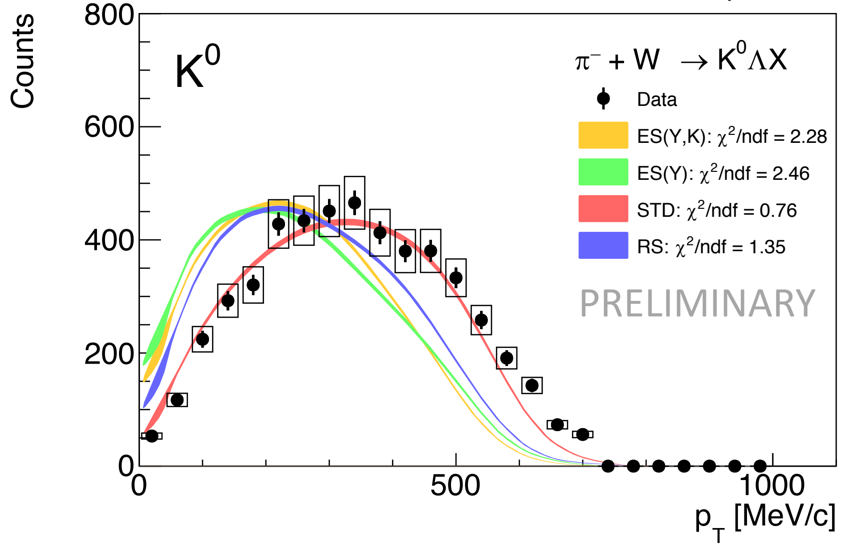

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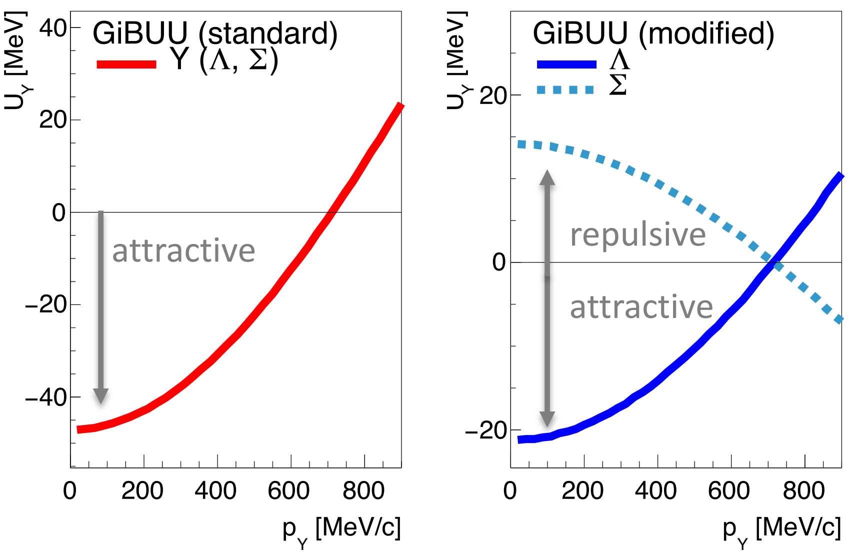


→ Data agrees best with **attractive** $\boldsymbol{\Lambda N}$ and **attractive** $\boldsymbol{\Sigma^0 N}$ potentials (@ρ_0)

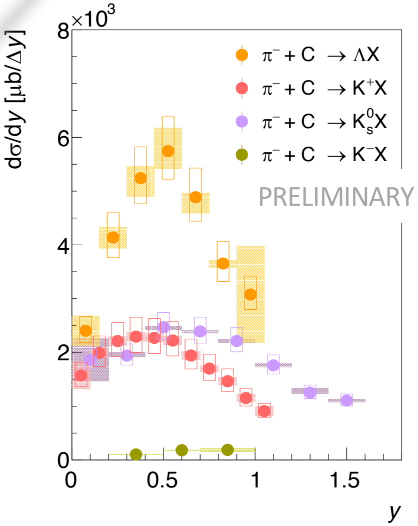
→ Also favored for lighter target (C)

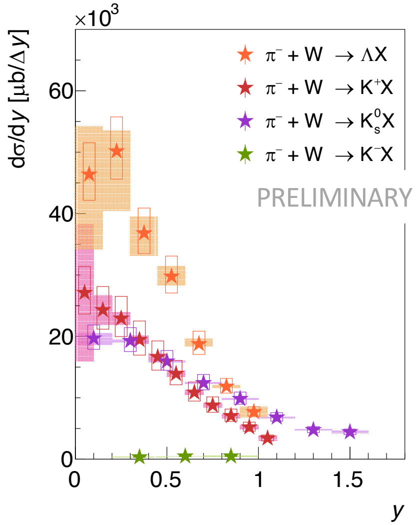
→ **Possibility of testing single particle potentials with χEFT**

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

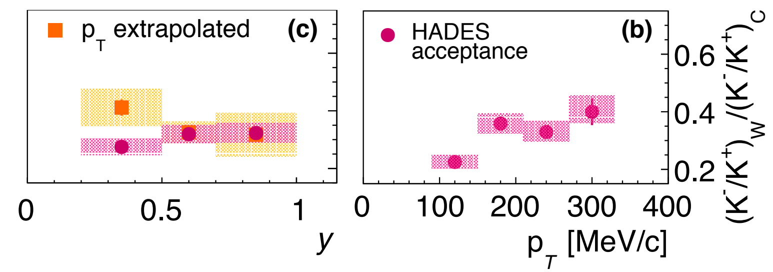
Summary

π⁻+C/W

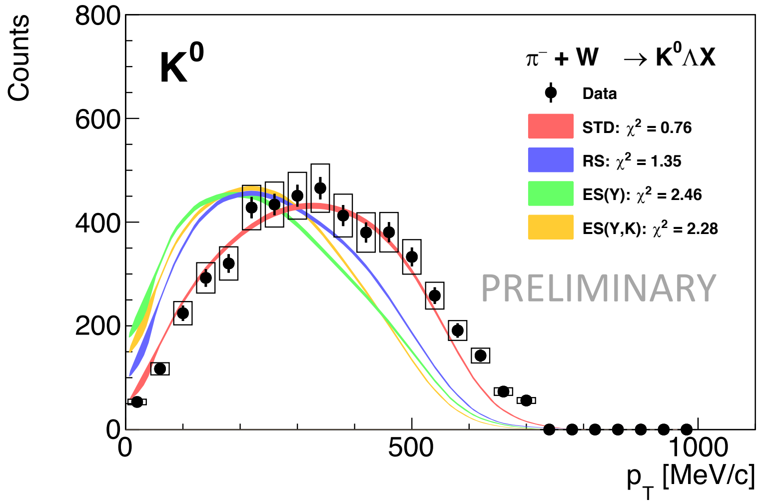




HADES Collaboration, arXiv:1812.03728



$$(\phi/K^-)_C = 0.55 \pm 0.08$$
$$(\phi/K^-)_W = 0.63 \pm 0.13$$

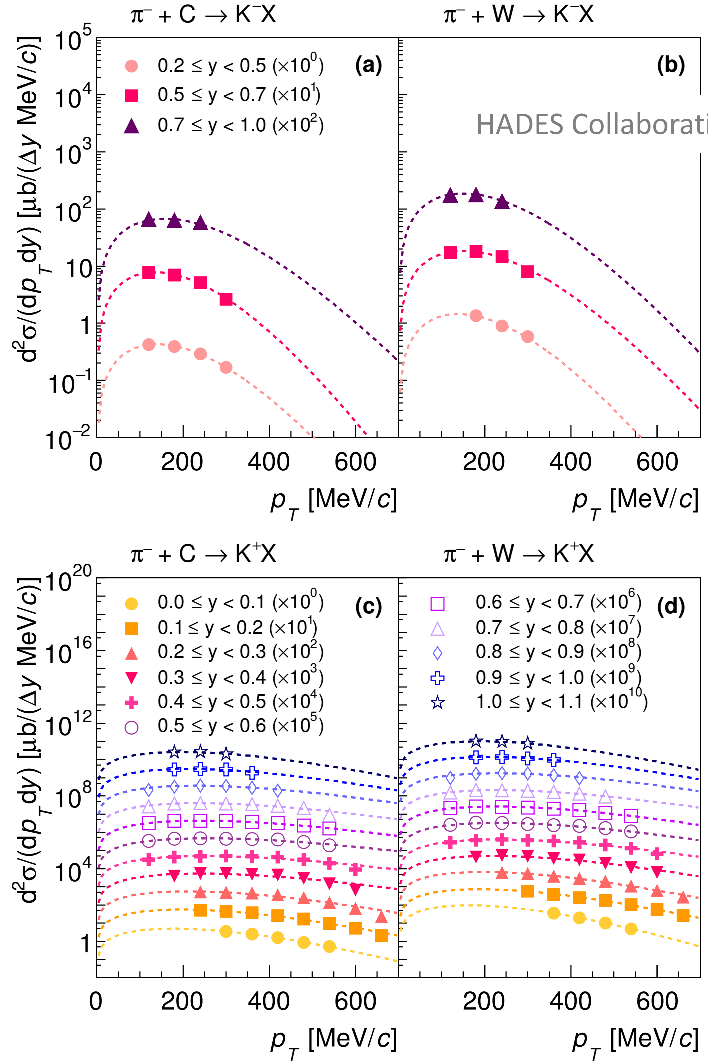


→ K^+/K^0N scattering in heavy target (W)
→ **Strong K^- absorption** in heavy target (W)
→ **Strong ϕ absorption** in heavy target (W)
→ **Attractive ΛN** and **attractive $\Sigma^0 N$** potentials (@ρ_0) preferred by data

Transverse Momentum

π^-+C/W

K⁻ K⁺



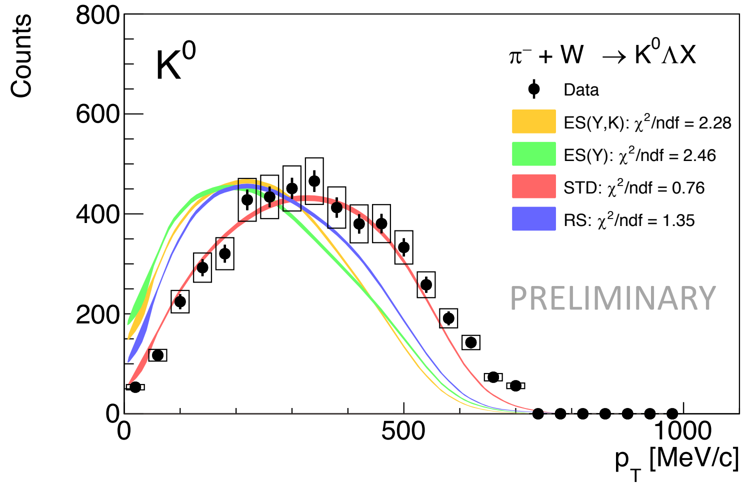
HADES Collaboration, arXiv:1812.03728

π^-+W

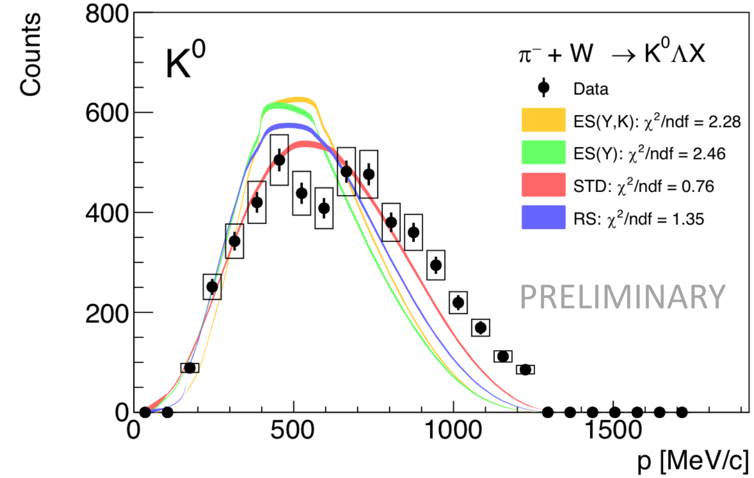
Effects of Hyperon Potentials

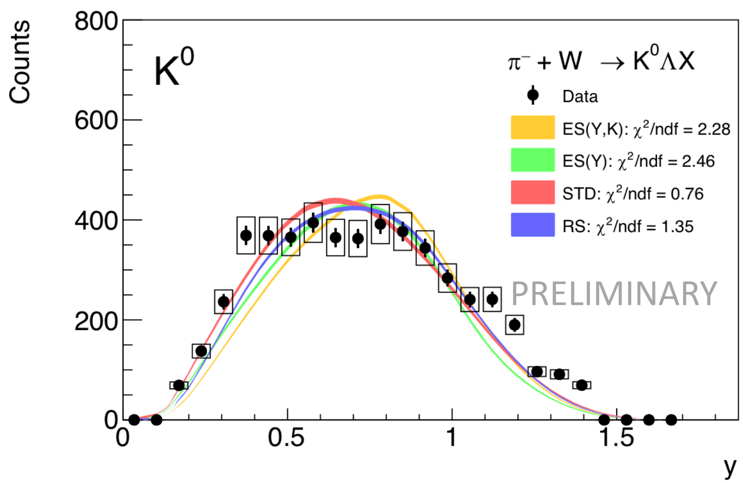
Λ Σ^0 K^0

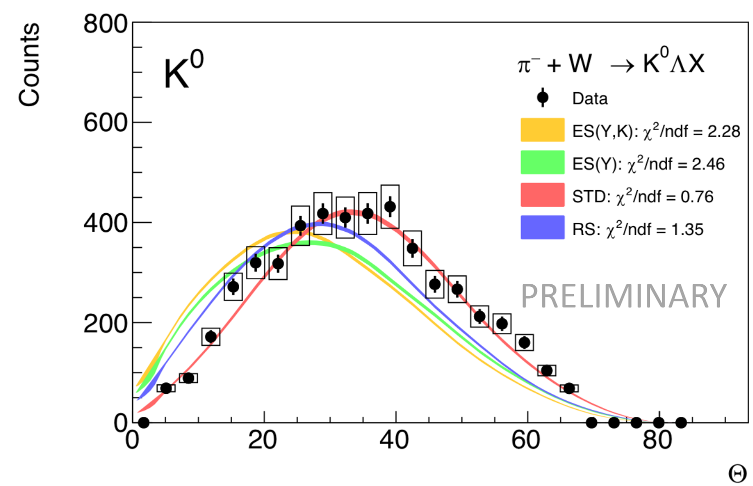
In HADES acceptance



In HADES acceptance







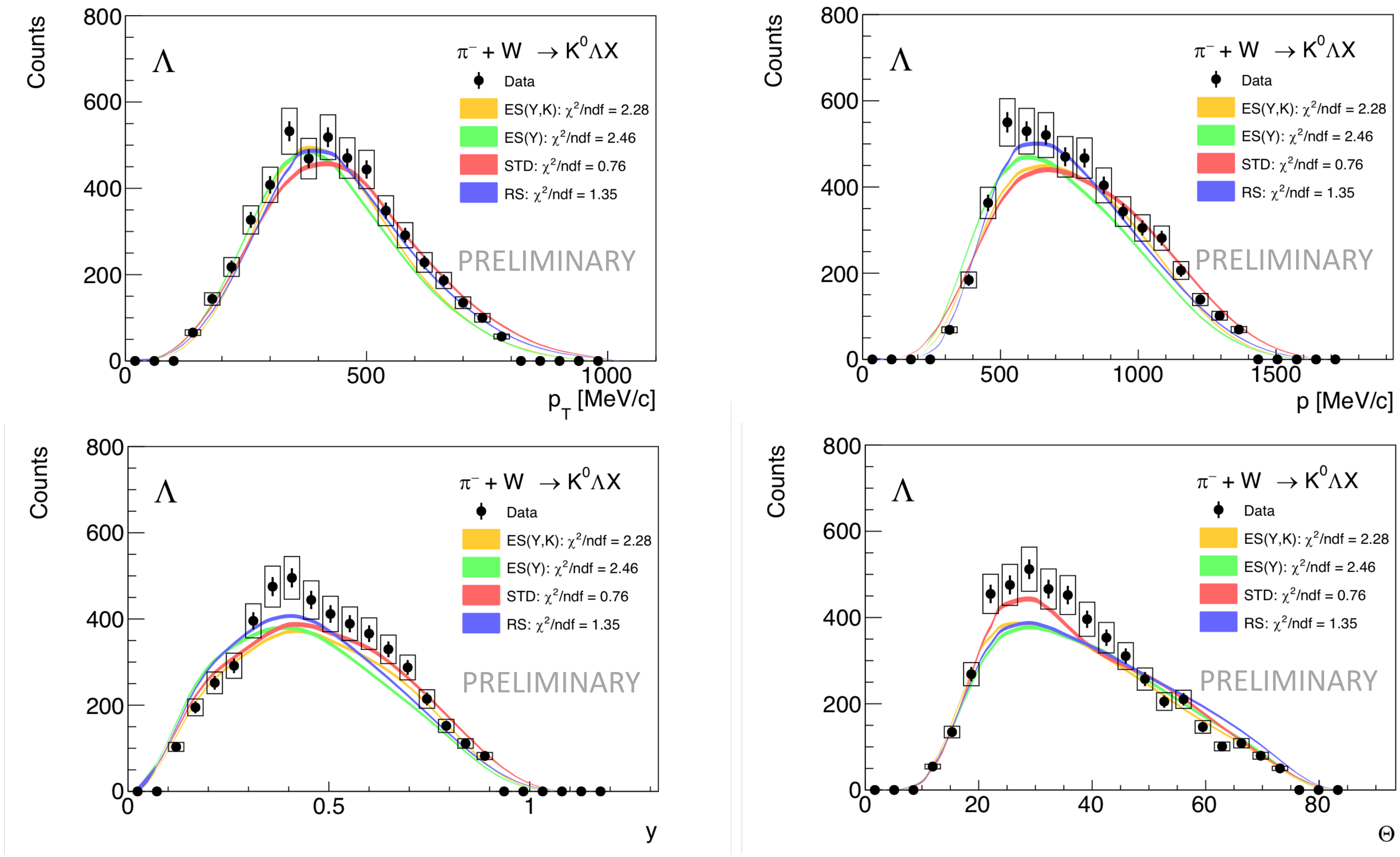
π^-+W

Effects of Hyperon Potentials

Λ Σ^0 K^0

In HADES acceptance

In HADES acceptance

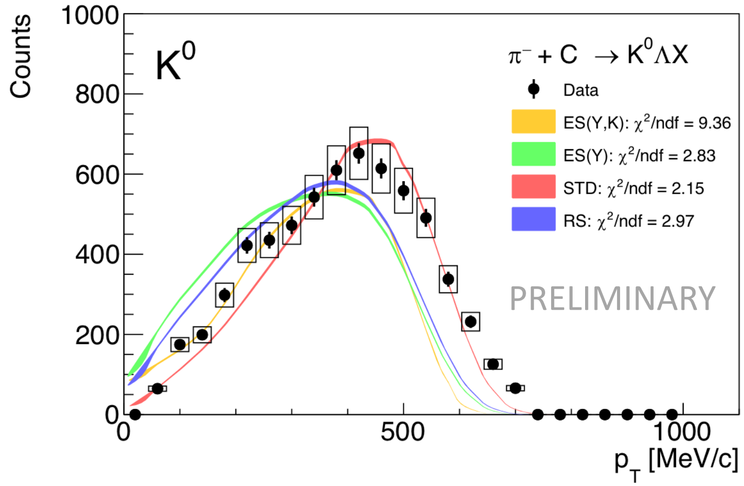


π^-+C

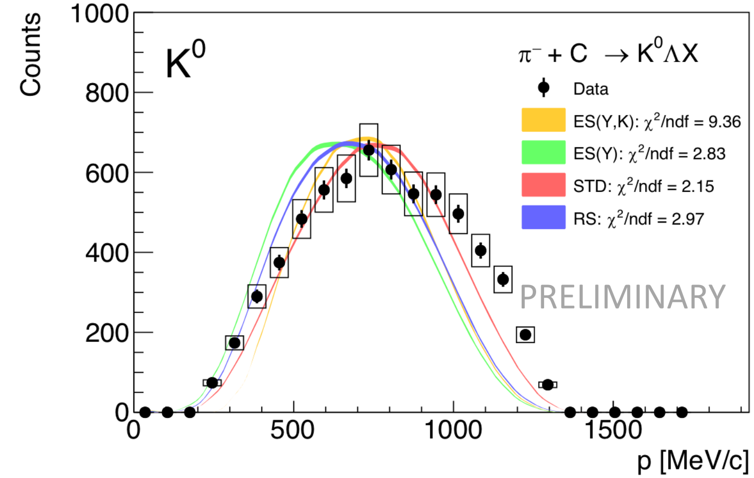
Effects of Hyperon Potentials

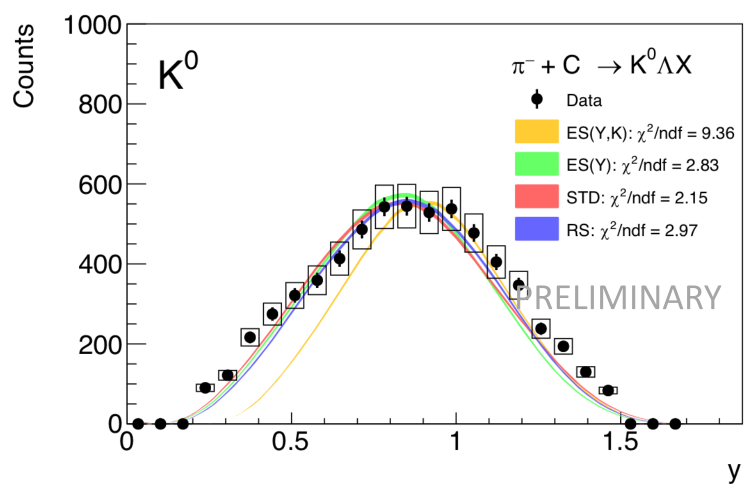
Λ Σ^0 K^0

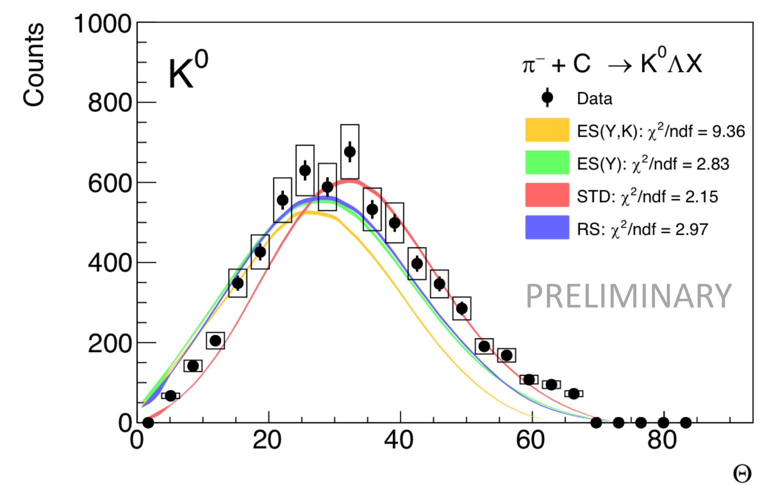
In HADES acceptance



In HADES acceptance







Effects of Hyperon Potentials

$\pi^- + C$

Λ Σ^0 K^0

In HADES acceptance

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