Strange Meson Production in Pion-Nucleus Reactions at 1.7 GeV/c*

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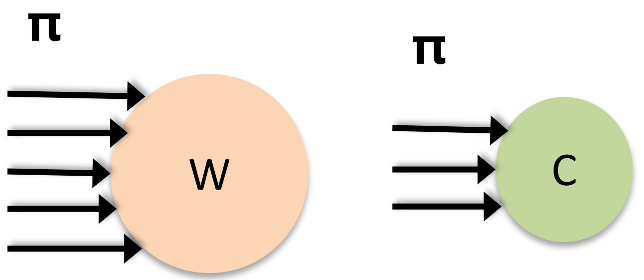
Dense and Strange Hadronic Matter (E62)
Physik Department
Technische Universität München

*supported by SFB 1258

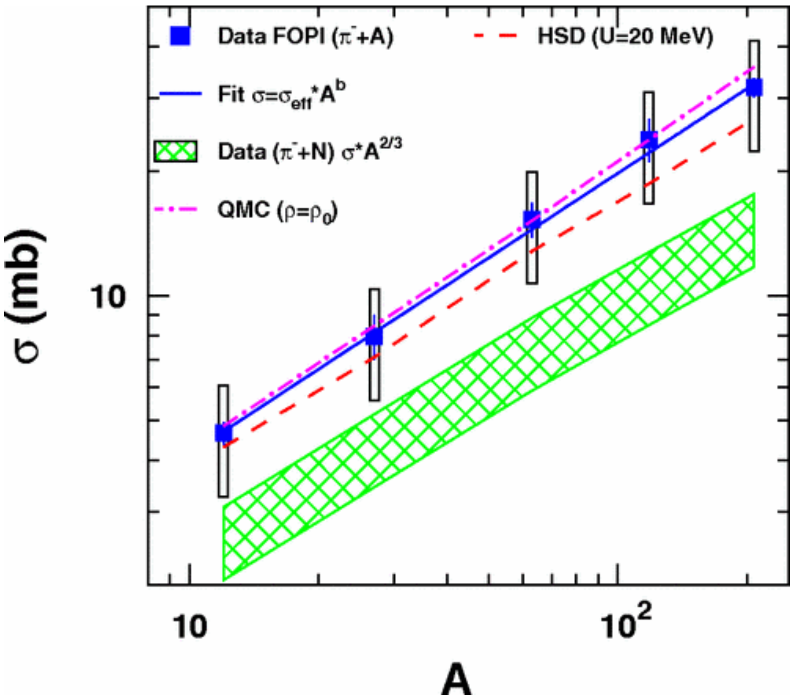
Pion-Induced Strange Meson Production



$$\lambda = 1.5 \text{ fm} \ (p_\pi = 1.7 \text{ GeV/c})$$
$$d_{C,W} \approx 5.5,\ 14.2 \text{ fm}$$

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

Benabderrahmane et al. Phys. Rev. Lett. Bd. 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

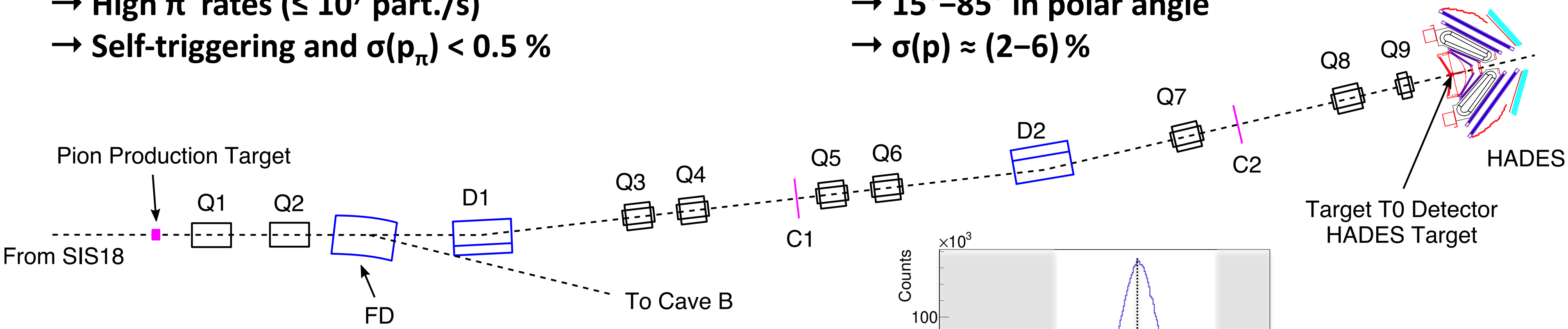
SECONDARY PION BEAM @ 1.7 GeV/c

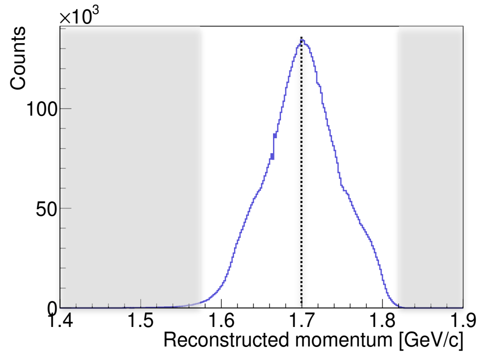
CEnt**R**al **BE**am **TR**acker for Pi**O**n**S** (TUM)

- → **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

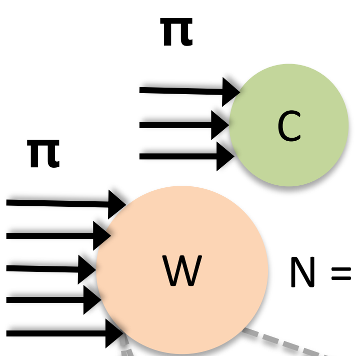
- → **Full azimuthal coverage**
- → **15°–85° in polar angle**
- → **$\sigma(p) \approx (2–6)$ %**





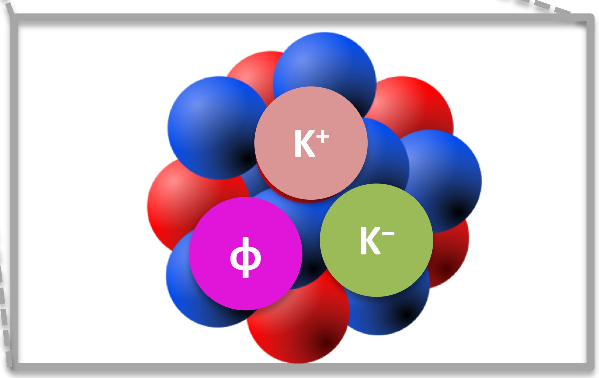
Wirth et al. Nucl. Inst. and Meth., Phy. Res. A, p. 243-244 (2016)
Adamczewski-Musch et al., Eur. Phys. J. A (2017) 53, 188

Strange Mesons with HADES

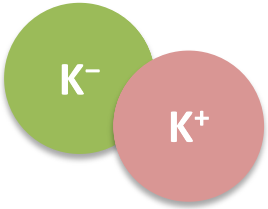


N = 1.3 ·10^8 Events

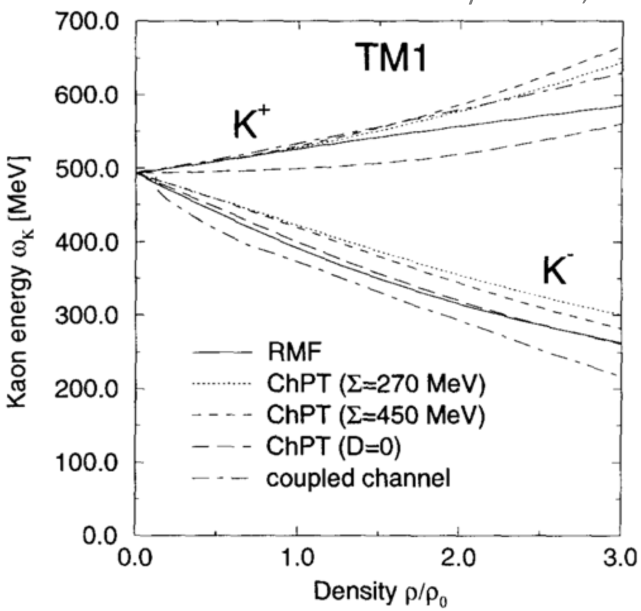
N = 1.6 ·10^8 Events



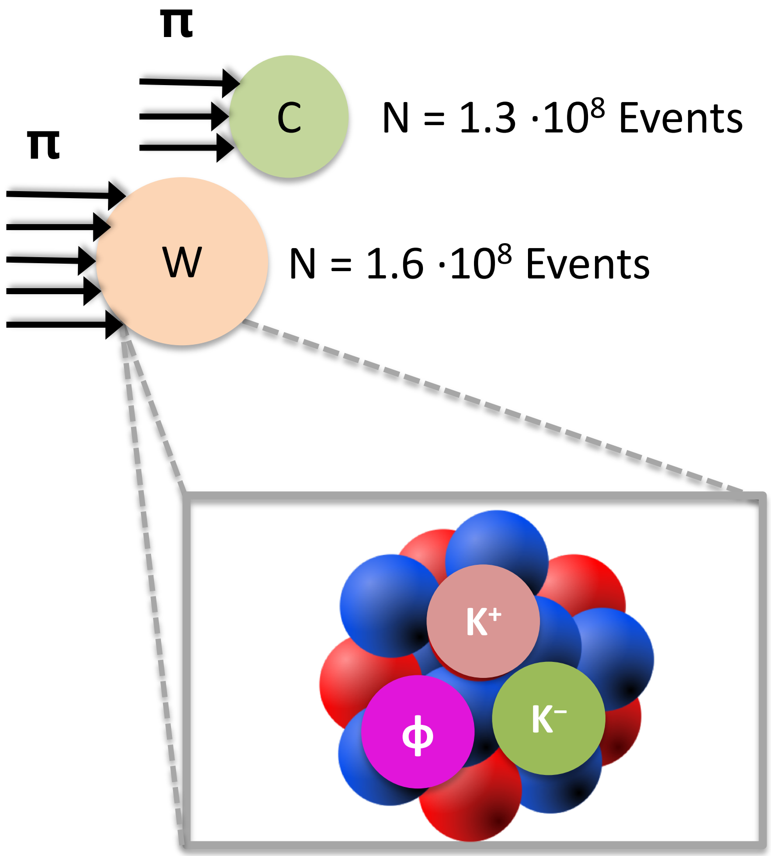
Scattering inside nuclear matter:
→ *Kaon-Nucleon Interaction*
→ *Coulomb*



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



Strange Mesons with HADES



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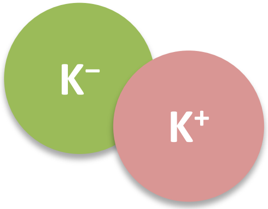
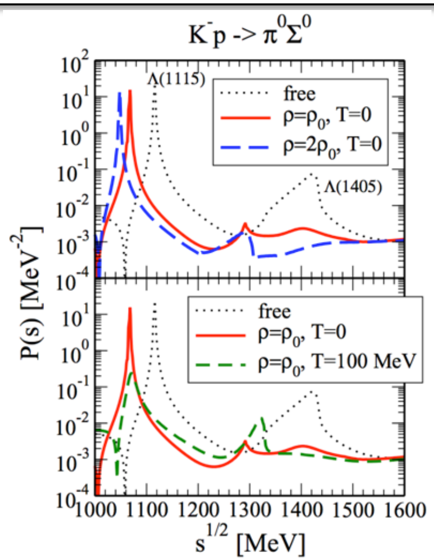


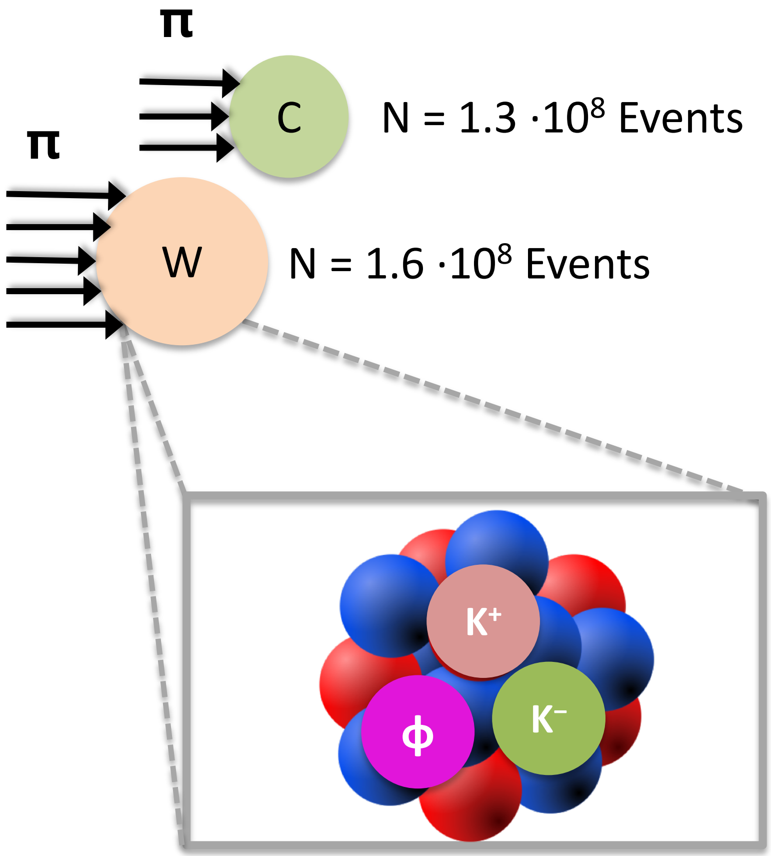
Antikaon absorption in nuclear environment:

$$K^{-}N \rightarrow Y\pi \qquad K^{-}NN \rightarrow YN$$



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

Strange Mesons with HADES



Scattering inside nuclear matter:
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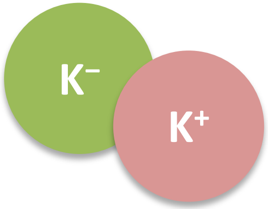


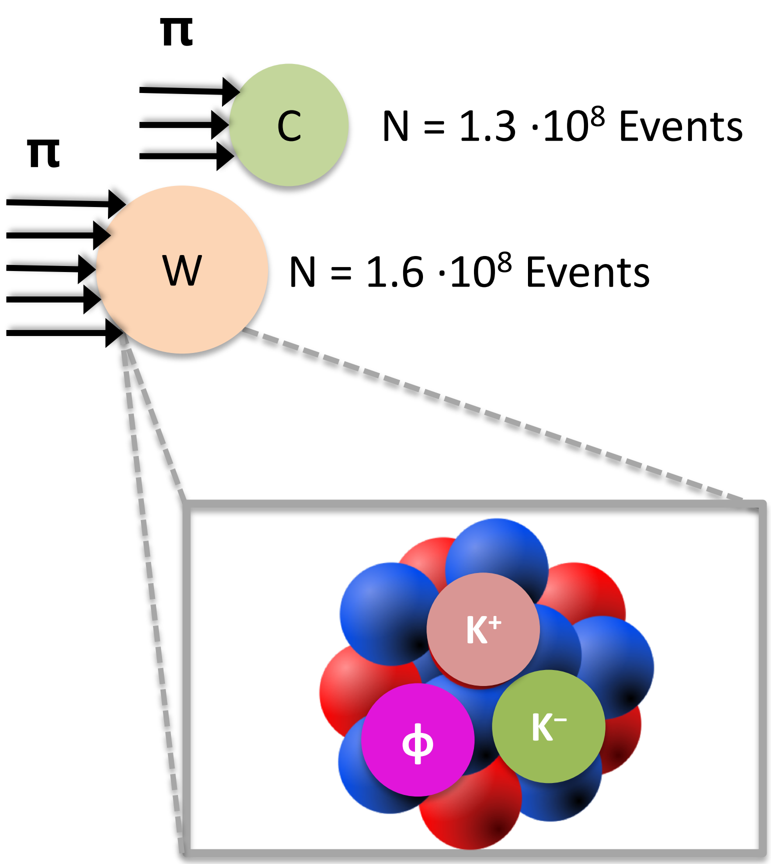
Antikaon absorption in nuclear environment:

$$K^{-}N \rightarrow Y\pi \qquad K^{-}NN \rightarrow YN$$

- → **Momentum distribution**
- → **Rapidity distribution**
- → **K^{-} absorption:**

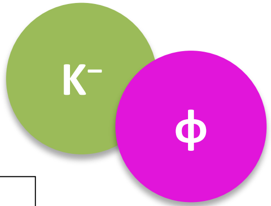
$$\frac{K^{-}}{K^{+}}(W) \Big/ \frac{K^{-}}{K^{+}}(C)\left(y, p_T / \Theta, p\right)$$

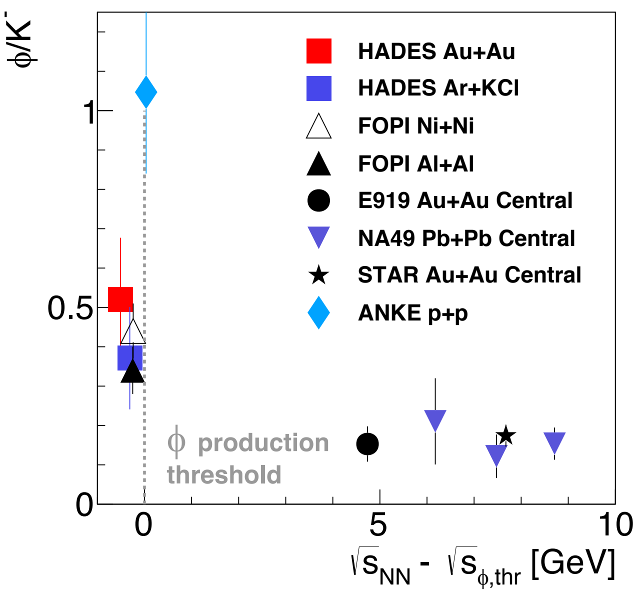
Strange Mesons with HADES



Antikaon from Phi feed-down:

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



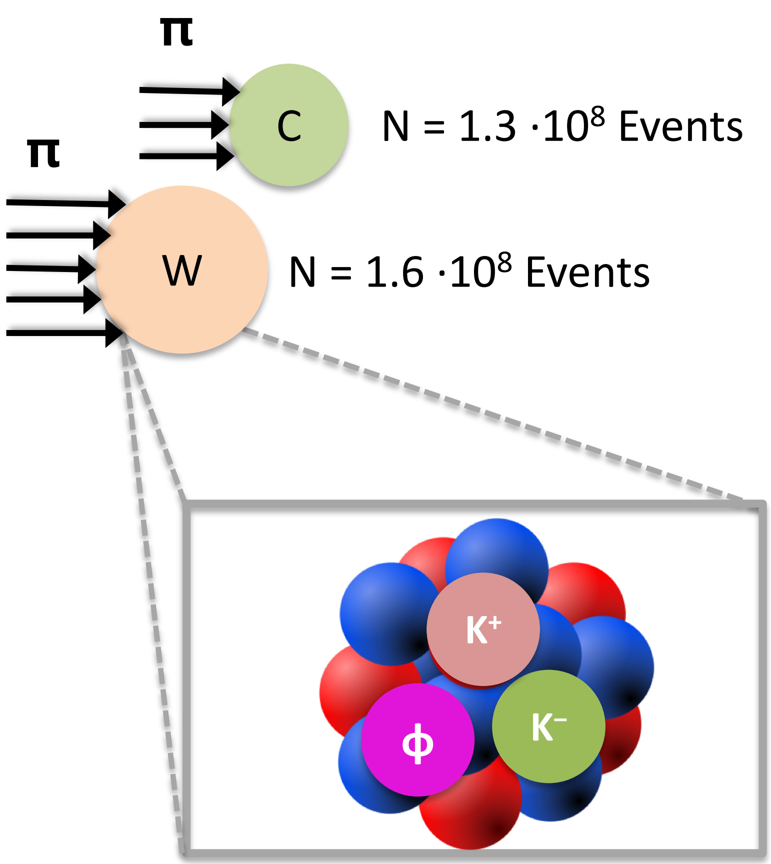


→ ϕ important source for K− production below NN threshold

→ **K− from ϕ feed-down:** $\frac{\phi}{K^-}(C/W)$

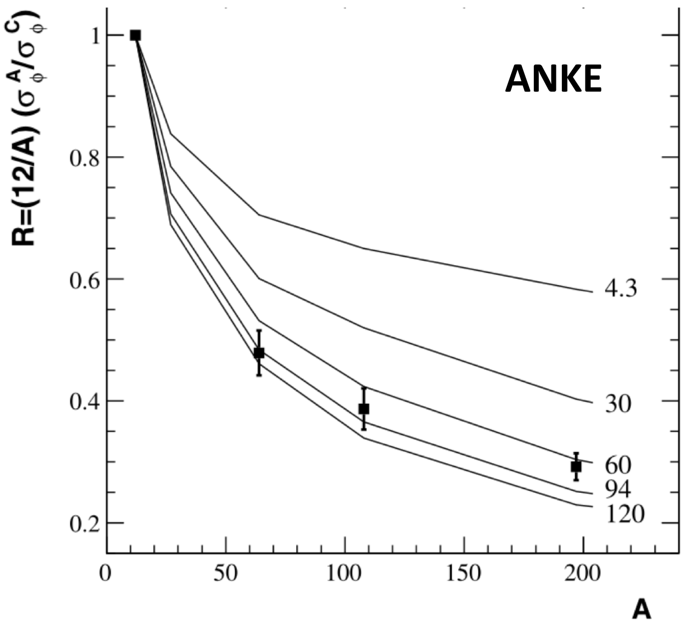
Blume et al. Prog. Part. Nucl. Phys. 66, 834-879 (2011)
Adamczewski-Musch et al. Phys. Lett. B 778, 403 (2018)

Strange Mesons with HADES



Phi transparency ratio:

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



→ Transparency ratio of ϕ decreasing for increasing A (p + A)

→ **ϕ transparency ratio:** $(12/184)\,(\sigma_\phi^W/\sigma_\phi^C)$

(Anti)Kaons

π^-+C/W

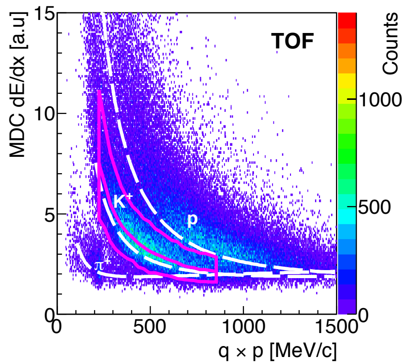
Kaon Selection

Event Selection:

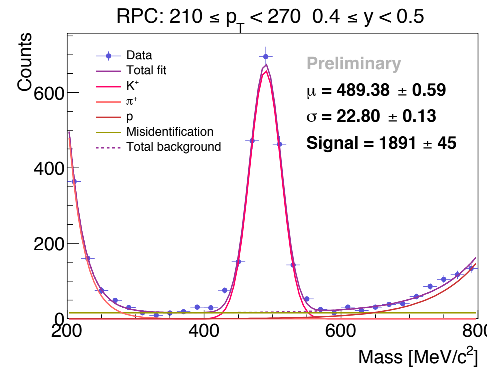
- Primary vertex:
  - - 80 < z vertex < 5 mm
  - r(x,y vertex) ≤ 20 mm
- Velocity: 0 < β < 1

Energy loss and magnetic field correction

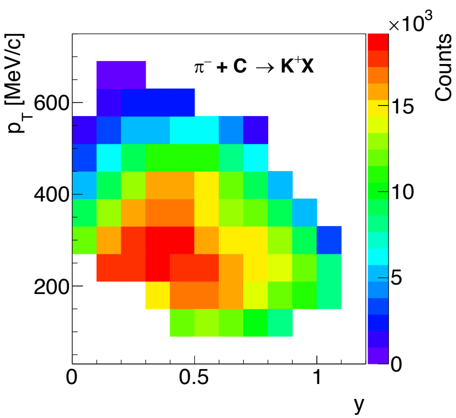
Kaon Identifaction:

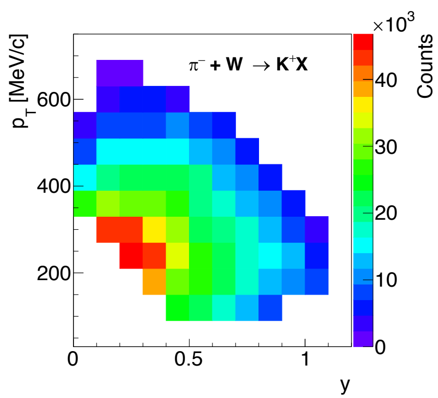


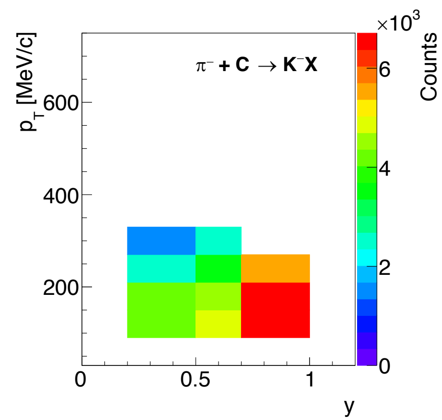
Kaon Yield Extraction:

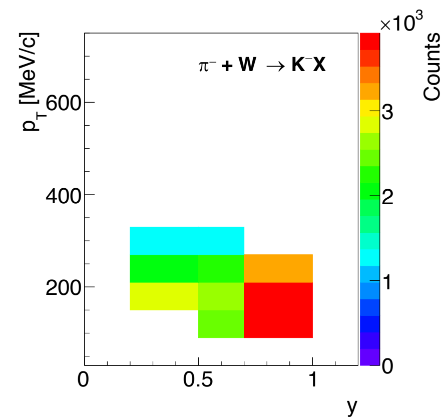


Corrected Kaon Yield*:





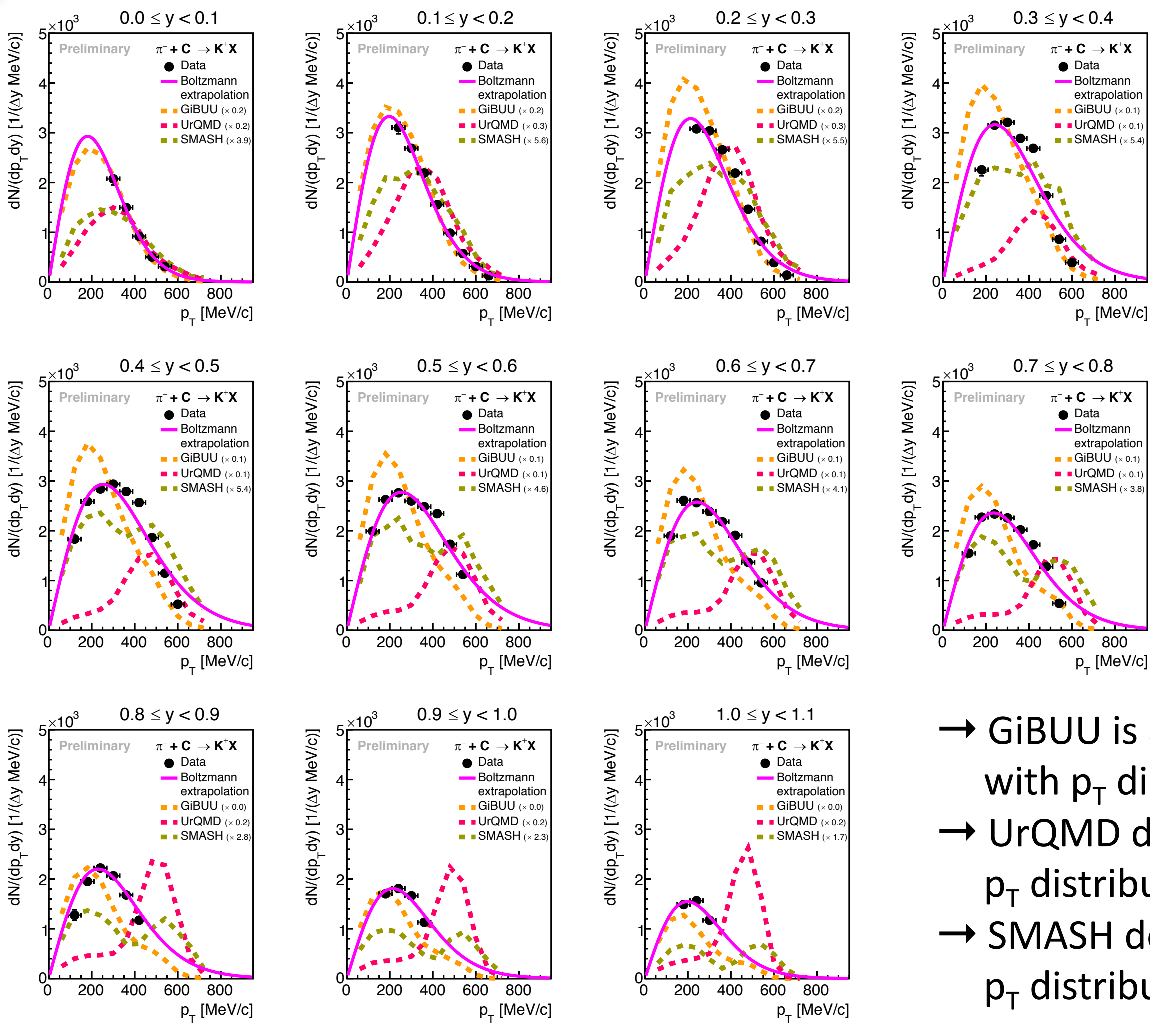




*Acceptance⊗efficiency corrected (GiBUU)

$\pi^- + C$

p_T-y Distribution: K^+



Yield extrapolation in p_T:

$$\frac{d^2N}{dp_T dy} = A\, p_T \sqrt{p_T^2 + m_0^2}\, e^{-\frac{\sqrt{p_T^2+m_0^2}}{T_B}}$$

→ GiBUU is almost in agreement with p_T distributions

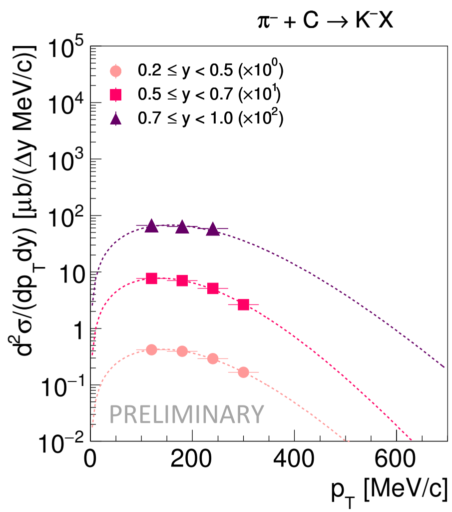
→ UrQMD does not describe p_T distributions in all y bins

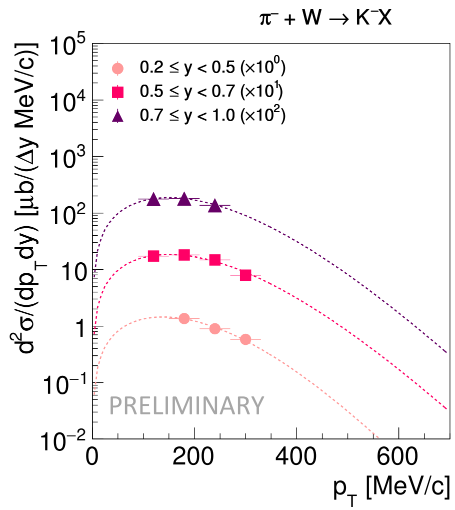
→ SMASH does not describe p_T distributions in all y bins

π^-+C/W

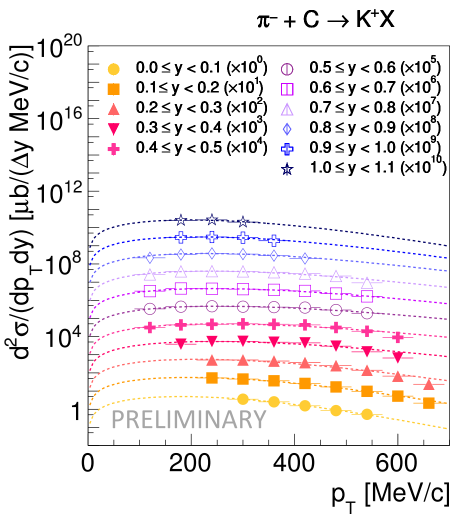
p_T-y Distribution: K^+/K^-

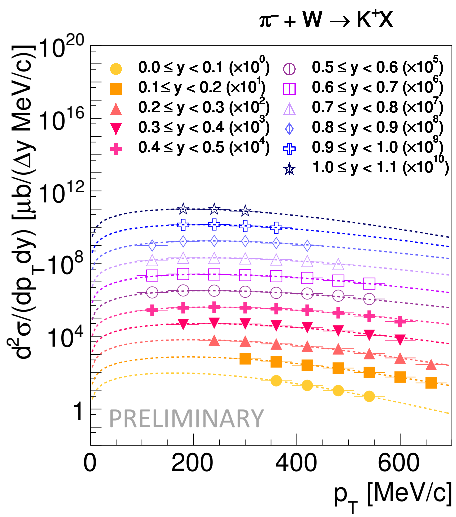
K^-





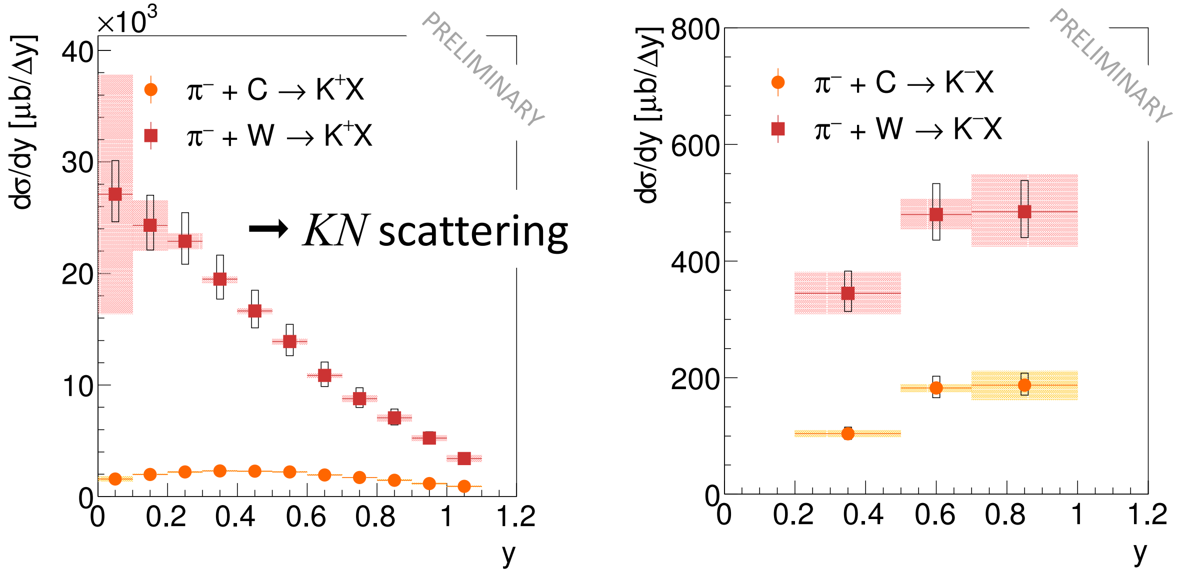
K^+



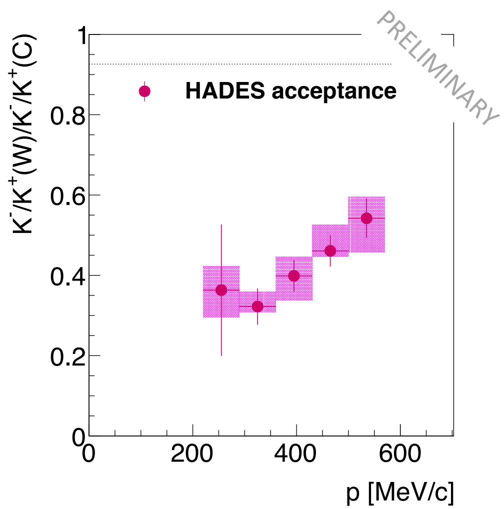


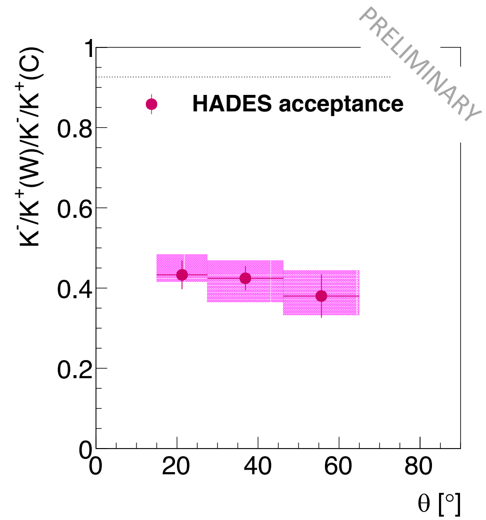
Rapidity Distribution: K^+/K^-

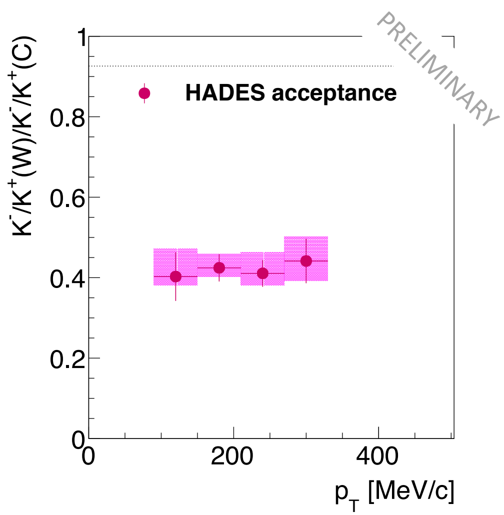
K^+ K^-

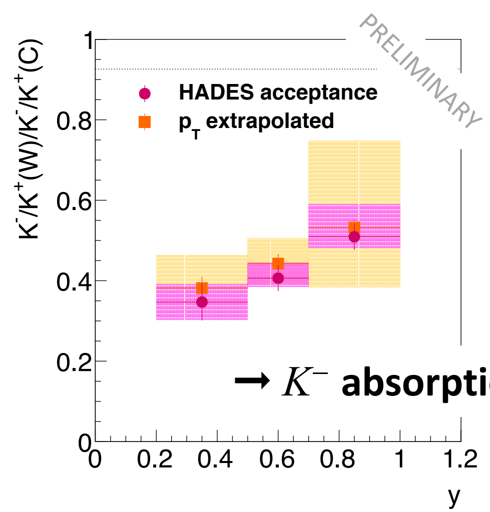


Ratio: $K^-/K^+(W)/K^-/K^+(C)$





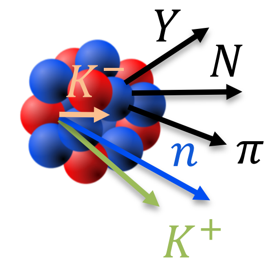




Strangeness exchange:

$K^- N \rightarrow Y N \pi$

$K^- N N \rightarrow Y N$



→ K^- **absorption** in all kinetic observables

Phi

Phi Reconstruction

π⁻+C/W

Event and Kaon Selection:

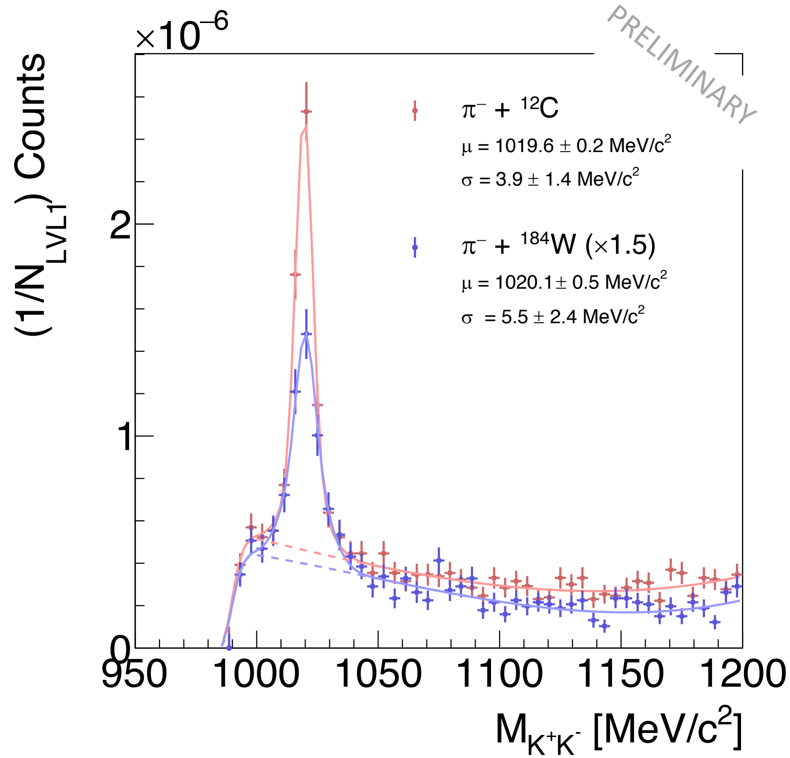
- Primary vertex:
  - $-80 < z$ vertex < 5 mm
  - $r(x,y$ vertex$) \leq 20$ mm
- Particle identification via β and p
  - $(\beta \lesssim (p/\sqrt{(p^2+m_K^2)} \pm 0.5)$
- Kaon mass: $400 < M_K < 600$ MeV/c^2

Energy loss and magnetic field correction

Phi Yield Extraction:

- Signal: "gauss + gauss"
  - σ_1: finite resolution effects
  - σ_2: multiple scattering
- Background: "polN · (1 – gauss(x, threshold, σ))"

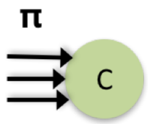
(Event-by-event acceptance⊗efficiency corrected (Pluto))



π^-+C/W

Antikaons from Phi Feed-Down

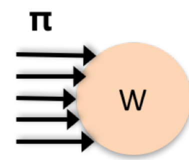
Within HADES acceptance (without p_T/y extrapolation)



$$\phi/K^-(p_T, y) = 0.24/BR \pm 0.044(stat)$$

$$\phi/K^-(p, \theta) = 0.30/BR \pm 0.043(stat)$$

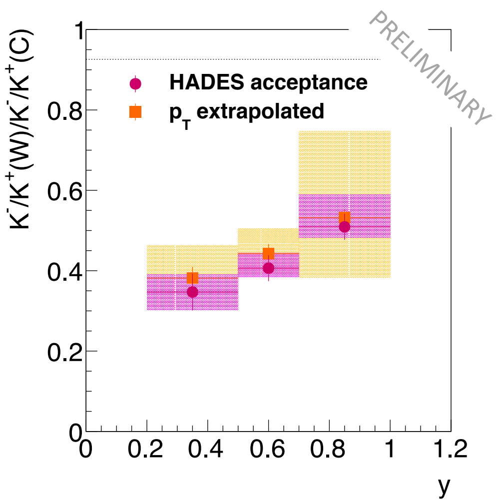
$$\phi/K^- = 0.58 \pm (0.044)^{stat} + \binom{+0.059}{-0.061}^{sys}$$



$$\phi/K^-(p_T, y) = 0.26/BR \pm 0.056(stat)$$

$$\phi/K^-(p, \theta) = 0.36/BR \pm 0.057(stat)$$

$$\phi/K^- = 0.63 \pm (0.057)^{stat} + \binom{+0.099}{-0.100}^{sys}$$



- → ϕ/K^- ratio is the same in π^- + C and π^- + W
- → K^- is absorbed in Tungsten
- → Signature of ϕ absorption in Tungsten compared to Carbon

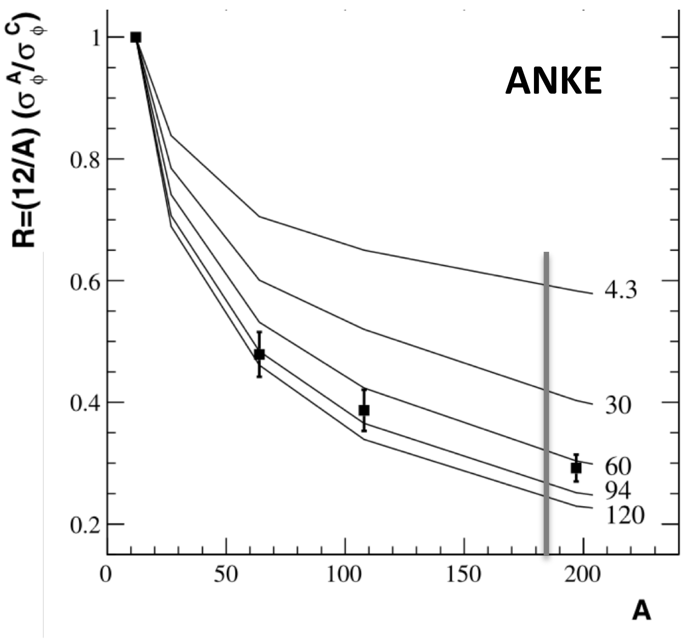
BR: 48.9%

Phi Transparency Ratio

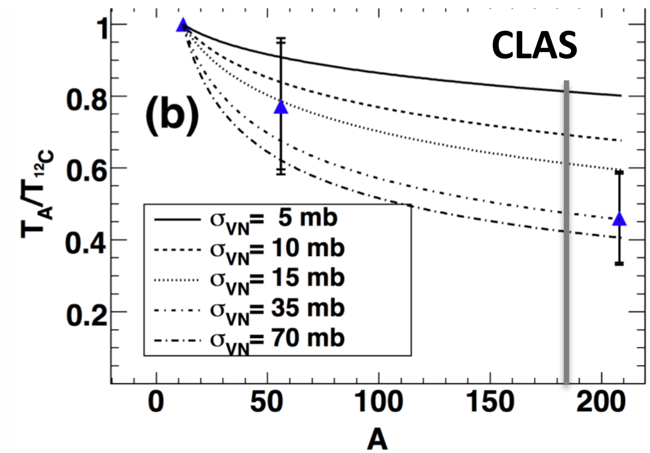
Within HADES acceptance (without p_T/y extrapolation)

$$(12/184)\,(\sigma_\phi^W/\sigma_\phi^C) = 0.189 \pm (0.005)^{stat} + \binom{+0.039}{-0.038}^{sys} + \binom{+0.033}{-0.027}^{norm}$$

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



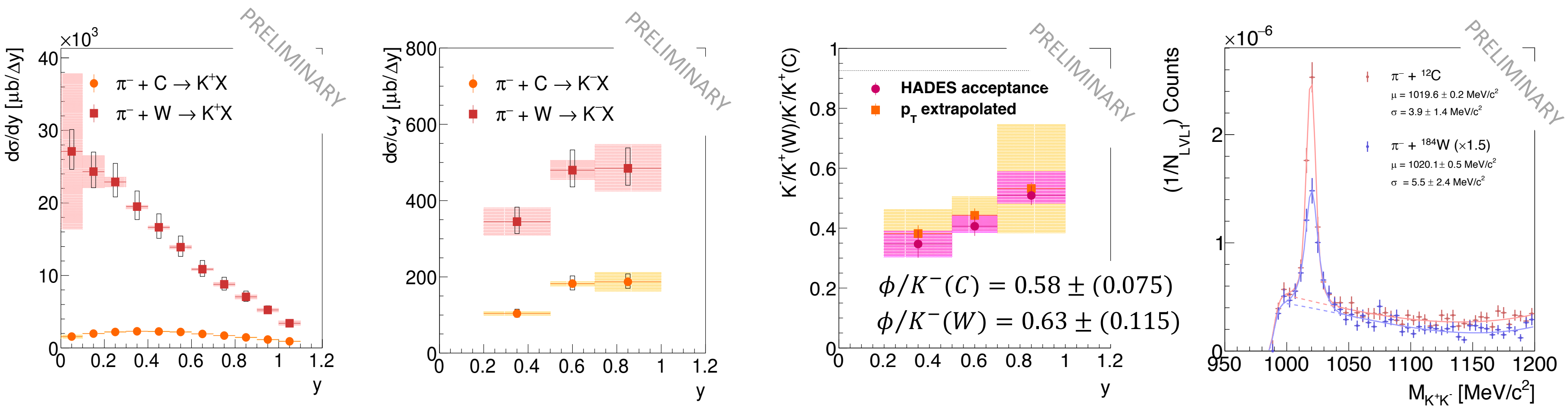
Wood et al. Phys. Rev. Lett. 105, 112301 (2010)



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

→ Signature of ϕ absorption

Summary



→ K^+ scattering in π⁻ + W with respect to π⁻ + C

→ K^- absorption in π⁻ + W with respect to π⁻ + C

→ ϕ/K^- ratio constant for π⁻ + W and π⁻ + C

→ ϕ disappearance as well as K^-

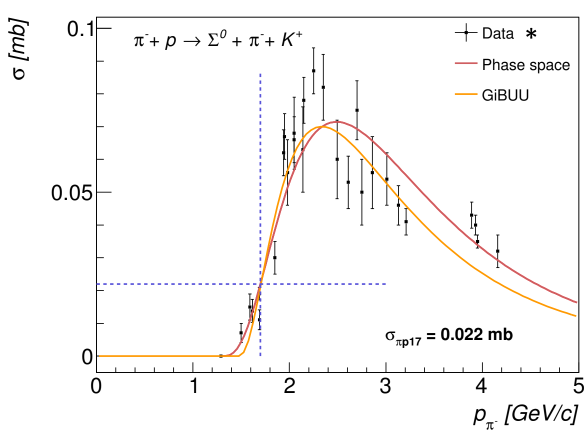
Ratio: $K^-/K^+(W)/K^-/K^+(C)$

	Tungsten	Carbon
Z	74	6
A	184	12
N	110	6

$$\frac{K^-}{K^+}(W)\Big/\frac{K^-}{K^+}(C)=\frac{\cancel{A_W^b}\left(\frac{Z_W}{A_W}\sigma_{\pi p\to K^-X}+\frac{N_W}{A_W}\sigma_{\pi n\to K^-X}\right)}{\cancel{A_W^b}\left(\frac{Z_W}{A_W}\sigma_{\pi p\to K^+X}+\frac{N_W}{A_W}\sigma_{\pi n\to K^+X}\right)}\Bigg/\frac{\cancel{A_C^b}\left(\frac{Z_C}{A_C}\sigma_{\pi p\to K^-X}+\frac{N_C}{A_C}\sigma_{\pi n\to K^-X}\right)}{\cancel{A_C^b}\left(\frac{Z_C}{A_C}\sigma_{\pi p\to K^+X}+\frac{N_C}{A_C}\sigma_{\pi n\to K^+X}\right)}=0.926$$

π^-+p	Threshold p_{lab} [GeV/c]
$\Lambda\pi^+2\pi^-K^+$	1.711
$\Lambda\pi^0\pi^-K^+$	1.407
$\Lambda\pi^-K^+$	1.144
$\Sigma^+\pi^0 2\pi^-K^+$	1.861
$\Sigma^+2\pi^-K^+$	1.568
$\Sigma^0\pi^+2\pi^-K^+$	1.879
$\Sigma^0\pi^-K^+$	1.290
$\Sigma^-\pi^+\pi^0\pi^-K^+$	1.879
$\Sigma^-\pi^+\pi^-K^+$	1.585
$\Sigma^-\pi^0K^+$	1.290
Σ^-K^+	1.035
$\Sigma^0(1385)\pi^-K^+$	1.680
$\Sigma^-(1385)\pi^0K^+$	1.680

π^-+p	Threshold p_{lab} [GeV/c]
$\Sigma^-(1385)K^+$	1.399
$p\pi^0K^0K^-$	1.785
$p\pi^-K^+K\_$	1.790
pK^0K^-	1.497
$n\pi^+K^0K^-$	1.801
$n\pi^-K^+K^0$	1.801
nK^+K^-	1.495
$n\Phi$ (BR: 0.49)	1.559
π^-+n	
$\Sigma^-\pi^-K^+$	1.296
$p\pi^-K^0K^-$	1.792



* Landolt-Börnstein