



Kaon-Antikaon production in p+A Reactions at ANKE

Michael Hartmann for the ANKE collaboration

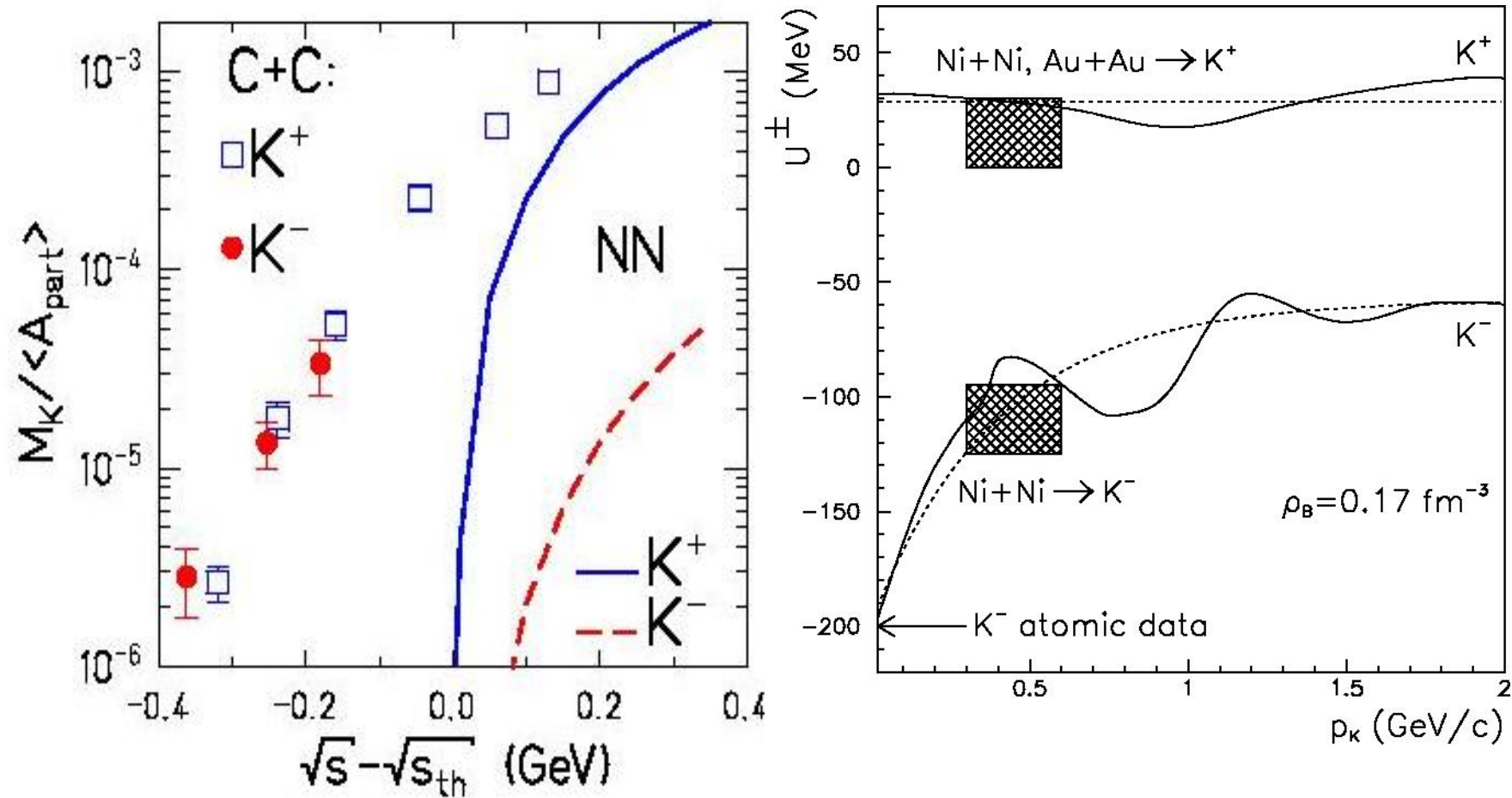
(M.Hartmann@FZ-Juelich.de)



Overview

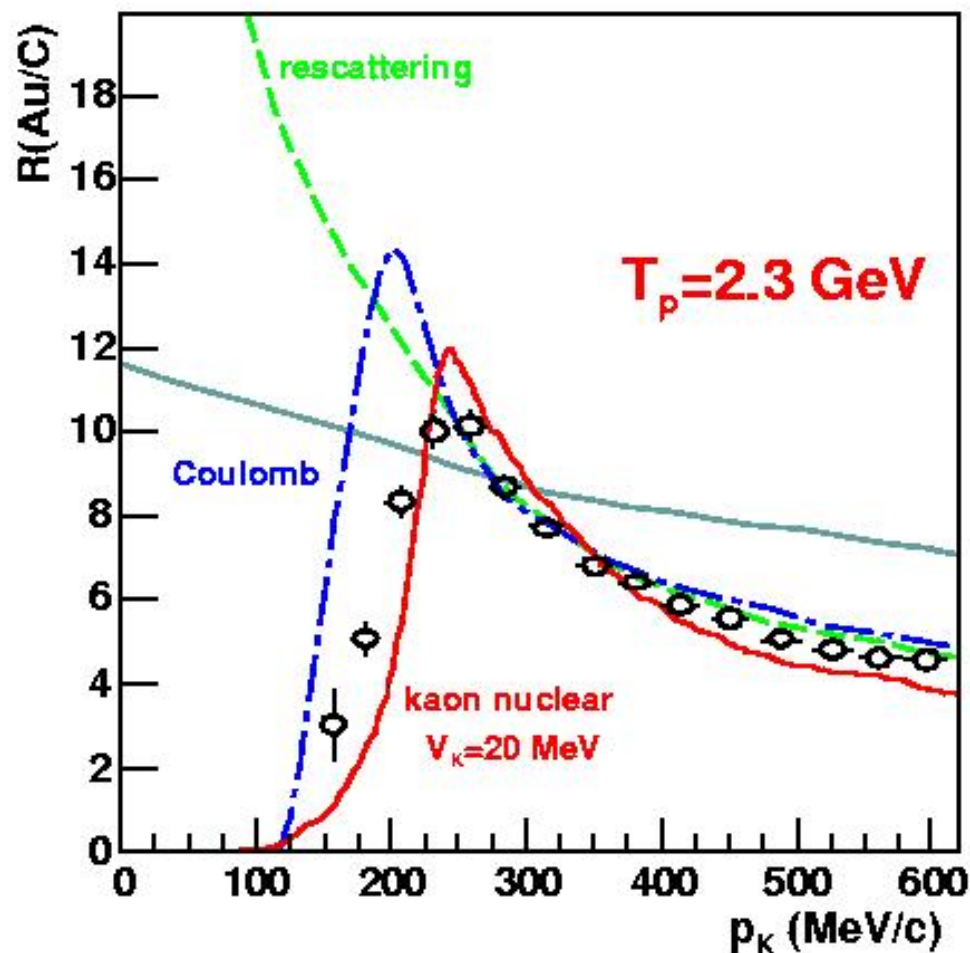
- (Anti-) kaon potential in nuclear matter
 - ⇒ experimental data and their theoretical analysis
- Φ meson in-medium properties
 - ⇒ predictions and recent calculations
 - ⇒ experimental data
- Rate estimation for K^+K^-/Φ production at ANKE
 - ⇒ feasible at ANKE
- Production mechanism
 - ⇒ direct and higher order processes
- Summary

K⁺ and K⁻ potential in nuclear matter



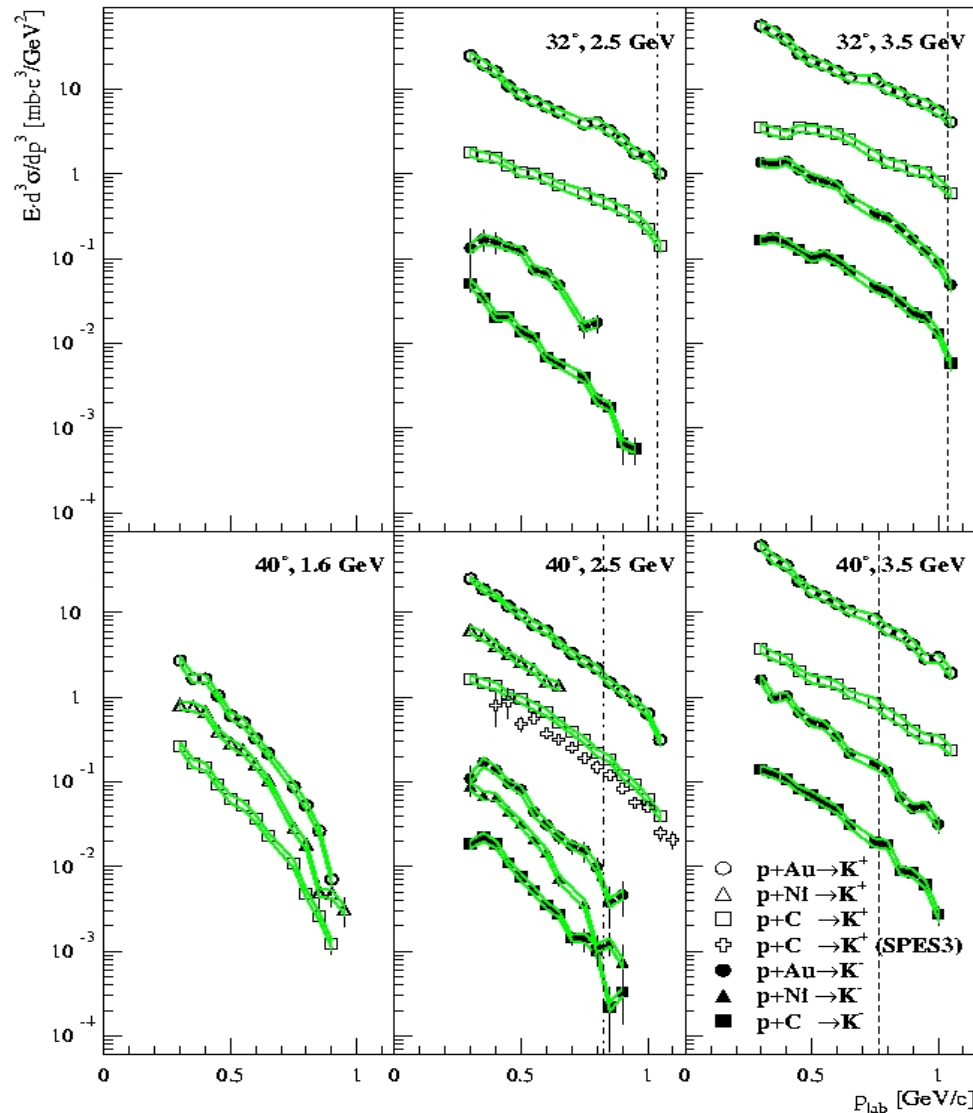
A. Sibirtsev, W. Cassing, Nucl. Phys. A641, p476 (1998)

Strong K^- potential should be visible at ANKE



M. Nekipelov et. al,
Phys. Lett. B540, 207 (2002)

Experimental data from KaoS collaboration



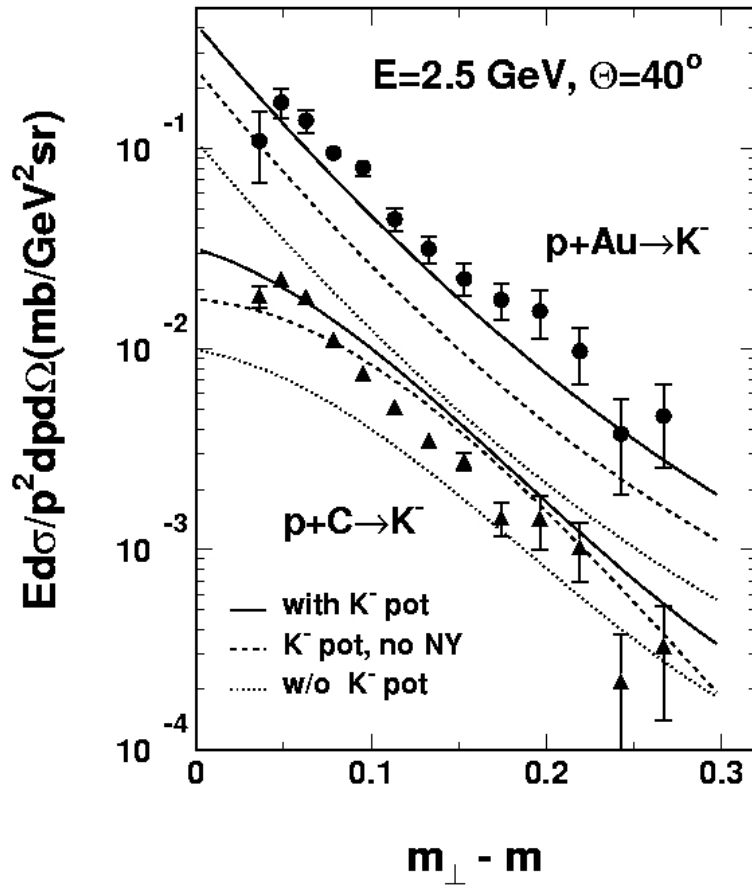
- ANKE

- ⇒ polar angle $< 12^\circ$
- ⇒ p_{K^-} from 150 to 1 GeV/c
- ⇒ Good complementation!

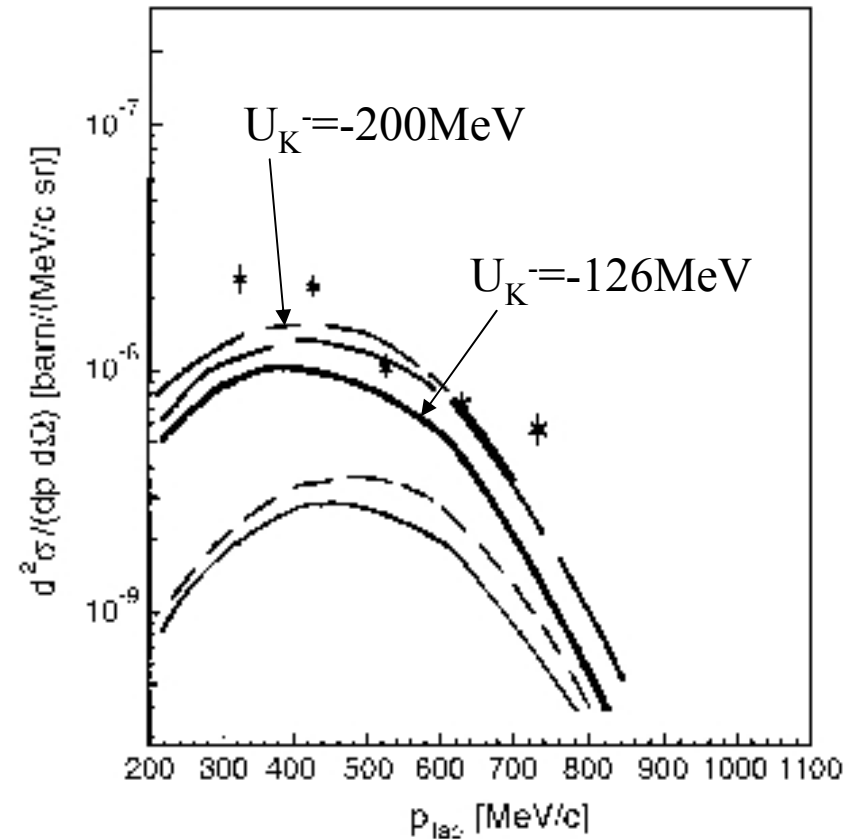
W. Scheinast, PhD., Dresden 2004
(exp. Data: KaoS,
full publication in preparation).

K⁻ potential ?

W. Scheinast, PhD., Dresden 2004
(exp. Data:KaoS)



E.Ya. Paryev, Eur. Phys. J. A 17, 145 (2003)
(exp. Data:KaoS, $T_p=2.5$ GeV, Au, $\alpha=40^\circ$)



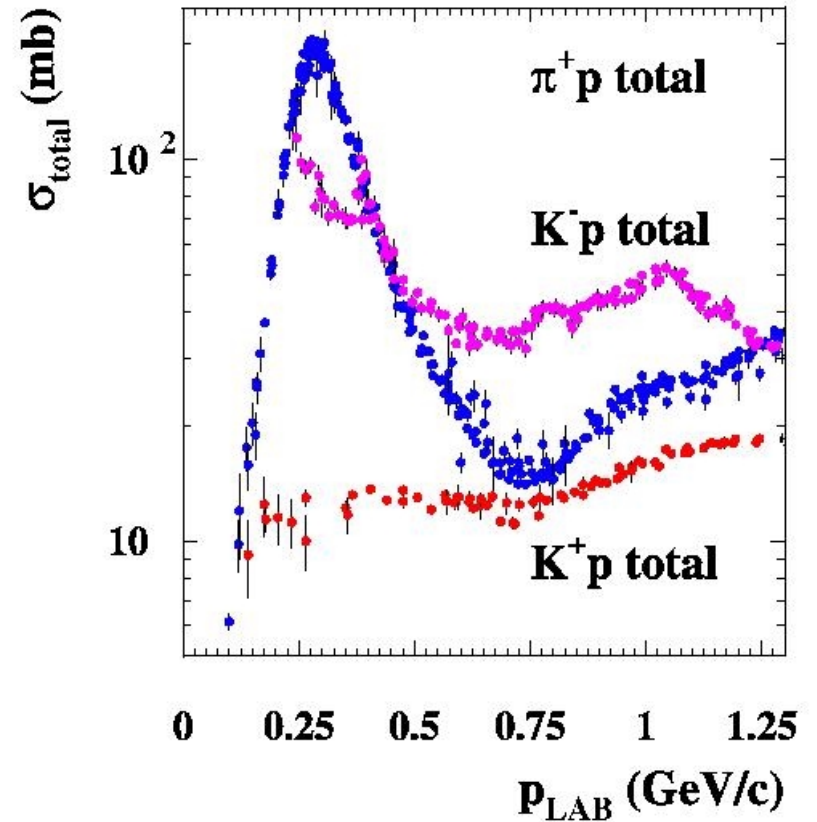
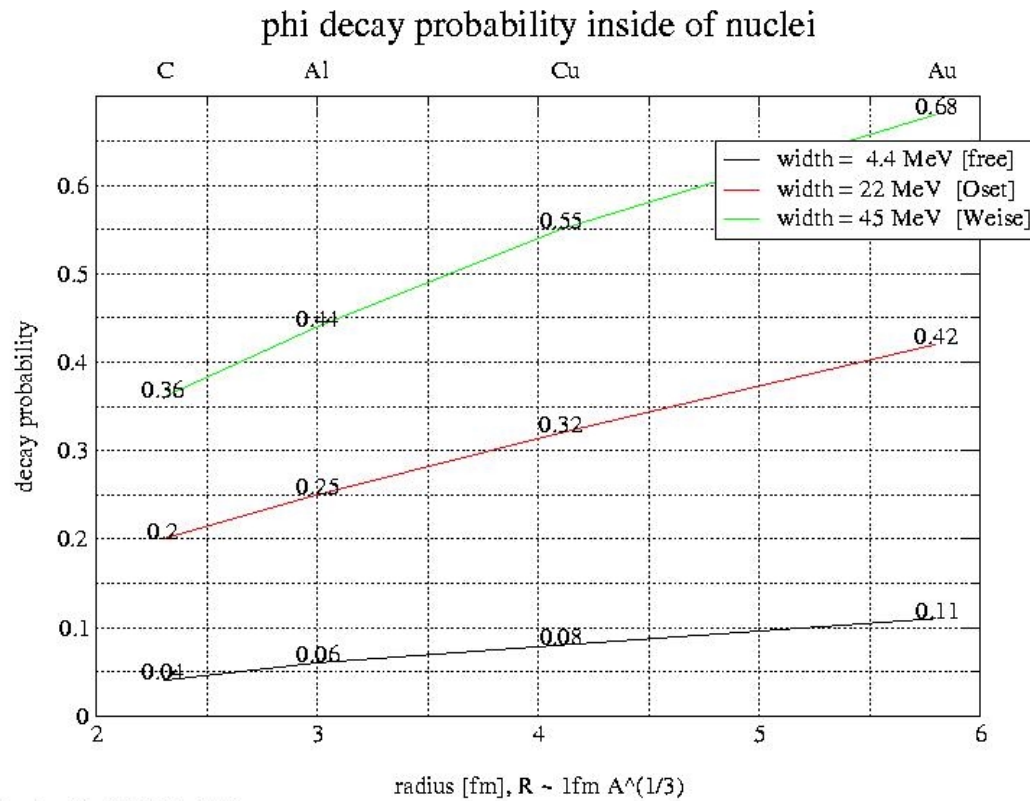


Theoretical predictions for the ϕ properties in nuclear matter

ϕ at rest in ρ_0	Δm_ϕ [MeV]	Γ_ϕ [MeV]
T.Hatsuda and S.H.Lee Phys. Rev. C46 (1992) R24	20 - 40	
F.Klingl, T.Waas, W.Weise Phys. Let. B43 (1998) 245	20 - 40	45
E.Oset and A.Ramos Nucl. Phys. A679 (2001)		22

- Binkley et al., Phys. Rev. Let. 37 (1976) 571
 $\sigma(A) = \sigma(1) A^\alpha$, $\alpha = 0.66 \pm 0.03$
- P.Mülich et. al., Phys. Rev. C46, (2003) 024605
„not visible“

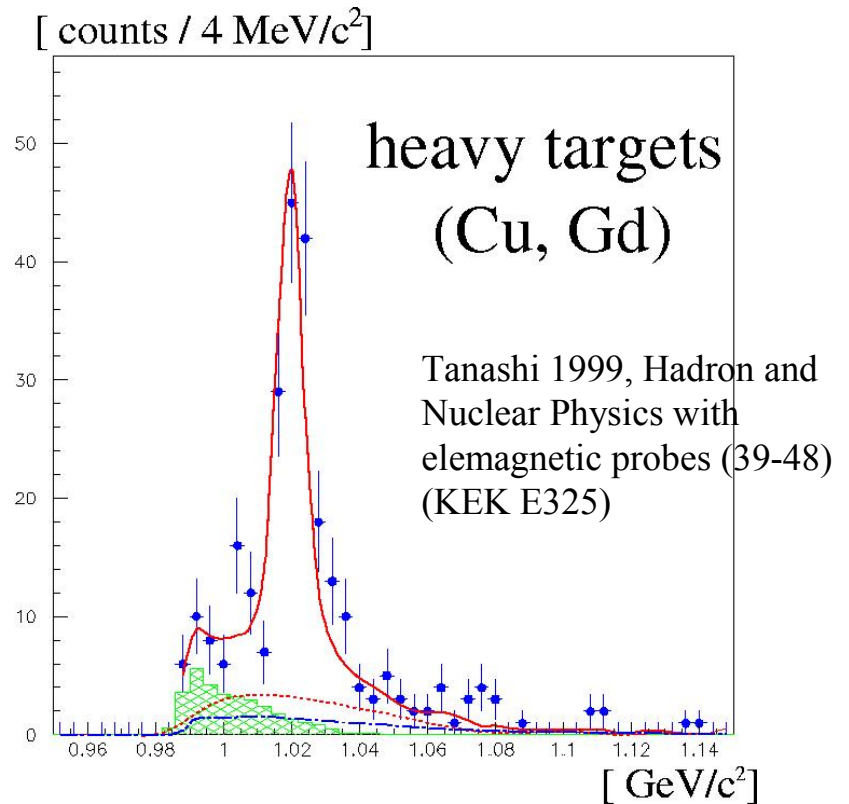
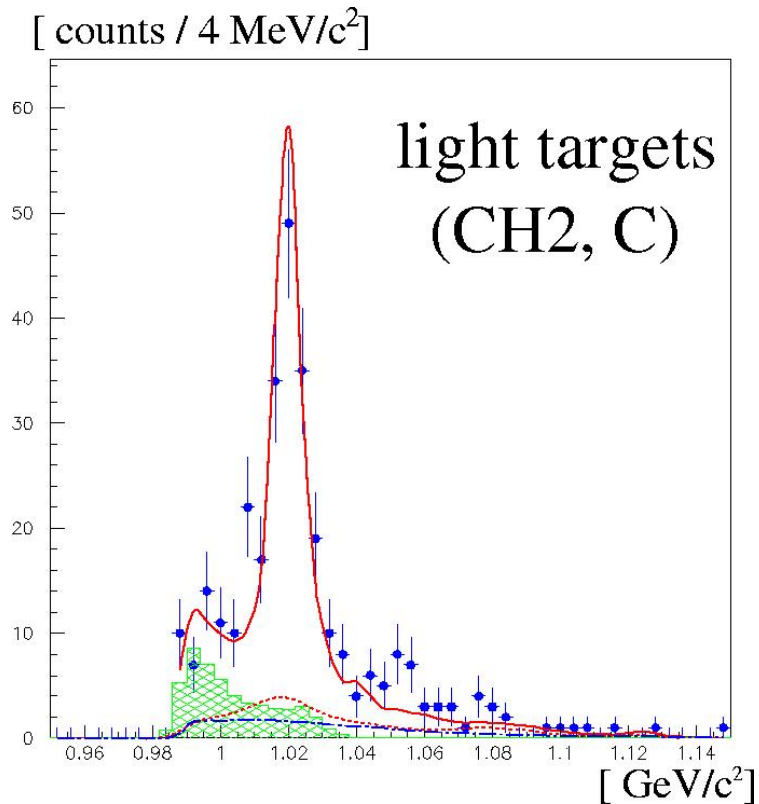
Φ decay probability



Sat Jun 16 13:31:14 2001

$$\langle p_{\Phi} \rangle = 1200 \text{ GeV}/c$$

Φ production in pA (KEK, $T_p=12\text{GeV}$)

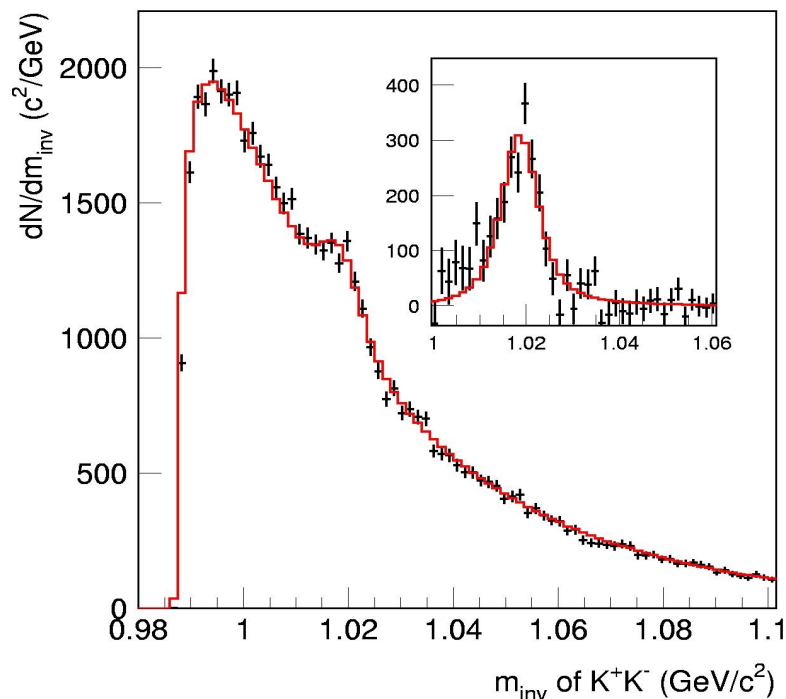


$$\sigma(A) = \sigma(1) A^\alpha, \quad \alpha = 1.01 \pm 0.09 (\Phi \rightarrow K^+ K^-)$$

$$\alpha = 1.27 \pm 0.21 (\Phi \rightarrow e^+ e^-)$$

data not yet published!

Φ production in AuAu (AGS/BNL)



- Experiment E917
 $T_p = 11.7$ AGeV
- $m_\Phi = 1018.99 \pm 0.36$ MeV
 $\Gamma_\Phi = 6.14 \pm 2.59$ MeV
 $\sigma_\Phi = 2.43 \pm 1.11$ MeV

FIG. 2: The invariant mass (m_{inv}) distribution of K^+K^- pairs for minimum-bias events. The ϕ signal after background subtraction is shown in the inset. The ϕ distribution is fitted with a relativistic Breit-Wigner distribution convoluted with a Gaussian plus the background distribution from a mixed-event technique, as described in the text.

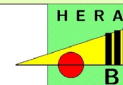
B. Back et. al, Phys. Rev. C69, 054901 (2004)

Φ production in p+A, $T_p=920$ GeV (Hera-B)



K^*0 and ϕ production in 920 GeV proton-nucleus interactions

Presented by Michael Symalla (Michael.Symalla@desy.de) and Christopher van Eldik (Christopher.van.Eldik@desy.de) for the Hera-B collaboration
University of Dortmund, Experimental Physics EV, 44221 Dortmund, Germany



Abstract HERA-B is a fixed target experiment at the HERA proton beam at DESY. Apart from having run a dilepton trigger, HERA-B recorded 210 million minimum bias events during the last data taking period November 2002 – February 2003. In proton collisions with Carbon, Titanium, and Tungsten targets about 900,000 K^*0 -K * and 50,000 ϕ -K * K * in central production were analyzed. First results of the data are presented, focusing on transverse momentum distributions and their dependence on the nuclear mass number A.

Strange particle production Recently, searches for Quark-Gluon-Plasma (QGP) at heavy-ion colliders have revived the interest in data on strange particles, since an enhancement of their production rates is one of the signatures of the formation of QGP. Measurements in proton-nucleus collisions provide a natural reference to disentangle this signature from nuclear effects. Furthermore, measurements of strange resonances provide valuable tests of QCD-based phenomenological production models.

Data sample

- data taking period 2002/2003
- subsample of December 2002
- during HERA-B startup phase
- all data from 0 consecutive proton fills
- events triggered with interaction trigger to reject empty events
- single/multiwire configurations used
- different materials available at any time

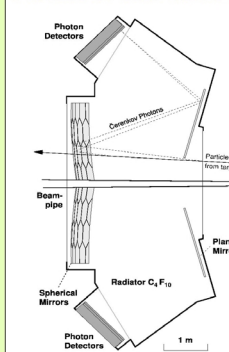
Interaction trigger

- inelastic pN-interactions of beam protons with target wires detected by
- multiplicity cut in RICH (> 20 hits)
- energy deposition in Electromagnetic Calorimeter (> 1 GeV)
- implemented as a software trigger
- logging rate 1000Hz (1.7TByte/day)

statistics used for analysis:

material	events	Luminosity [nb]	# ϕ reconstructed	K^*0 reconstructed	$K^*(bar)$ reconstructed
Carbon	57×10^6	252154	16308 ± 37	197880 ± 1758	150250 ± 1661
Titanium	21×10^6	33736	8018 ± 141	84232 ± 1278	86793 ± 1216
Tungsten	53×10^6	32135	25303 ± 281	263065 ± 2473	197877 ± 2296

Particle ID with the HERA-B RICH



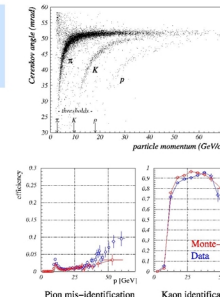
RICH performance (for $\beta \approx 1$ particles)
Cherenkov angle $\theta_c = 52.4$ mrad
33 photons/ring on average
single photon resolution 0.8 (1.0) mrad for inner (outer) part of acceptance

RICH hardware setup

location: about 10 m downstream the target
radiator: 108 m³ of C₂F₄ (radiator length 2.82 m)
 $n=1.00137$, low dispersion
detector: 2240 PMTs (27000 channels)
different granularities for inner and outer acceptance

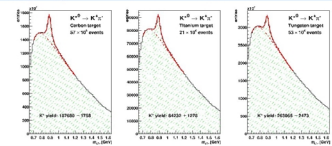
Particle Identification

track based ring search algorithm
likelihood based particle ID
excellent Kaon and Proton identification
efficiency for Kaons ID: 60-95% @ 10-50 GeV
pion mis-identification: about 5%



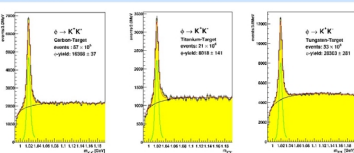
$K^*0 \rightarrow K^{\pm}\pi^{\mp}$ reconstruction

- Selection:**
- 2 opposite charged tracks
 - Kaon identified with RICH (hard cut)
 - $p_{\perp} > 10$ GeV, $\beta > 2$ GeV
 - $-1.2 \leq y_{\text{cm}} \leq 0.7$ (limited by detector acceptance)
- Mass fit:**
- Signal: Gaussian convoluted Breit-Wigner (p-wave)
 - Background: $bg(m) = p_0 \left(\frac{d}{m}\right)^2 e^{-p_1 p_2 - p_3 p^2}$
 - K^*0 -yield: $\int_{m_{\text{min}}-3\Gamma_{\text{res}}}^{m_{\text{max}}+3\Gamma_{\text{res}}} \text{Signal}$ (q: momentum transfer in CMS)

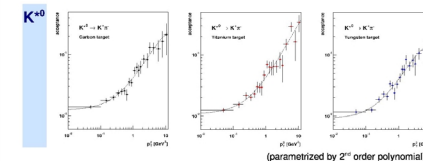


$\phi \rightarrow K^+K^-$ reconstruction

- Selection:**
- 2 opposite charged tracks
 - K^+ , K^- identified with RICH (soft cut)
 - $p_{\perp} > 10$ GeV
 - $-0.85 \leq y_{\text{cm}} \leq 0.4$ (limited by detector acceptance)
- Mass fit:**
- Signal: Gaussian convoluted Breit-Wigner (p-wave)
 - Background: $bg(m) = p_0 (m - 2m_{\text{kaon}})^2 e^{-p_1 p_2 - p_3 p^2}$
 - ϕ -yield: $\int_{m_{\text{min}}-3\Gamma_{\text{res}}}^{m_{\text{max}}+3\Gamma_{\text{res}}} \text{Signal}$



Acceptances



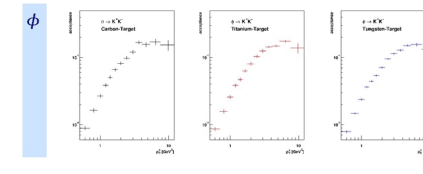
Acceptance determination

- based on MC-simulation
- FRITIOF for primary interaction
 - GEANT for detector-simulation
- same cuts as for real data

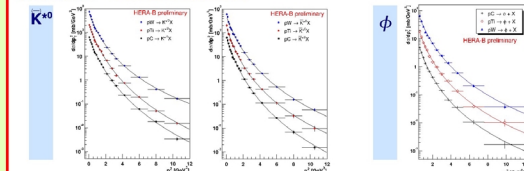
Acceptance properties

- acceptance depends on
- target position (geometrical acceptance)
 - target material (multiplicity dependent reconstruction efficiency)
 - acceptance ratios are flat

acceptance for K^*0 (ϕ) between 1.2% (0.8%) and 34% (16%)
main acceptance loss due to Kaon momentum cut
 ϕ acceptance smaller mainly due to double Kaon identification



Results Differential cross sections

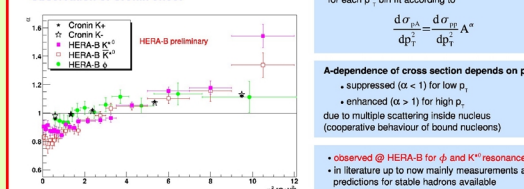


$\frac{d\sigma}{dp_{\perp}^2} \left(1 - \frac{p_{\perp}^2}{p_1^2}\right)^{\beta} = \frac{d\sigma}{dp_{\perp}^2}$ parametrization describes complete spectra

material	K^*0		$K^*(bar)$		ϕ	
	β	χ^2/ndf	β	χ^2/ndf	β	χ^2/ndf
Carbon	6.02 ± 0.18	31.71/7	6.10 ± 0.22	27.91/7	4.32 ± 0.31	5.79/10
Titanium	5.83 ± 0.23	30.31/7	5.29 ± 0.25	20.41/7	4.29 ± 0.34	8.78/10
Tungsten	4.42 ± 0.11	42.51/7	5.31 ± 0.19	33.71/7	4.34 ± 0.23	20.36/10

simple exponential ansatz valid up to about 1.5 GeV²

Observation of Cronin effect



Outlook

- To complete the presented analysis, the following topics are currently under study:
- Rapidity dependent differential cross sections will explore the production in terms of the longitudinal momentum at mid-rapidity
 - The total cross sections will be calculated by extrapolating to full phase space
 - The A-dependence of the total cross sections will be determined
- All studies are in a close-to-preliminary state.
This work has been supported by the Bundesministerium für Forschung und Entwicklung, FRG, under contract number 05-7D0-56P.



Φ production in p+A, $T_p=920\text{GeV}$ (Hera-B)

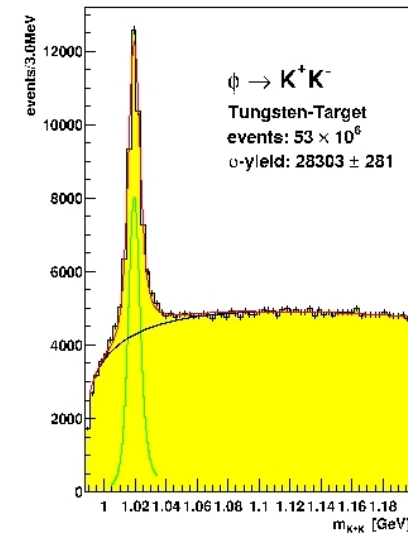
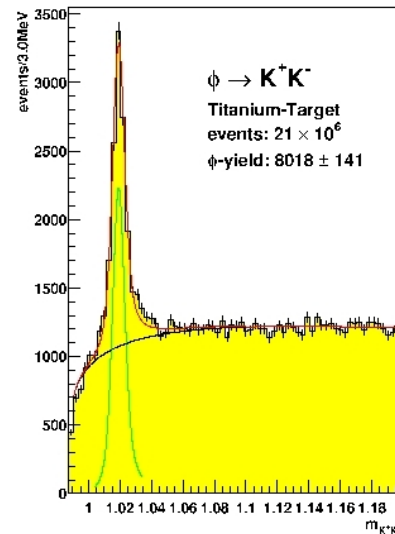
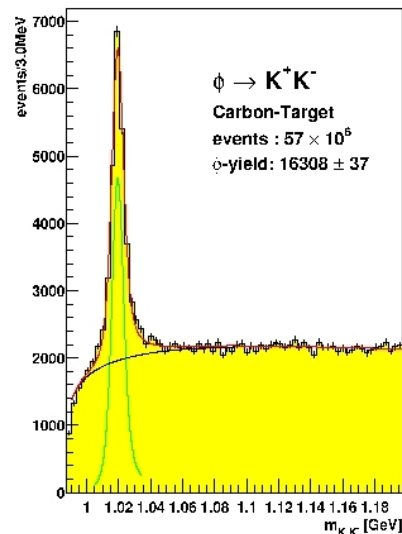
$\phi \rightarrow K^+K^-$ reconstruction

Selection:

- 2 opposite charged tracks
- K^+ , K^- identified with RICH (soft cut)
- $p_{K^+,K^-} > 10\text{ GeV}$
- $-0.85 \leq y_{\text{CM}} \leq 0.4$ (limited by detector acceptance)

Mass fit:

- Signal: Gaussian convoluted Breit-Wigner (p-wave)
- Background: $bg(m) = p_0 (m - 2m_{\text{kaon}})^{p_1} \cdot e^{-p_2 m - p_3 m^2}$
- ϕ -yield: $\int_{m_\phi - 3.5\Gamma_{\text{PDG}}}^{m_\phi + 3.5\Gamma_{\text{PDG}}} \text{Signal}$



Recent Φ calculations in nuclear matter (BUU)

H.W. Barz et. al, Phys. Rev. C69, 024605 (2004)

$$U_{\Phi} = -0.025 m_{\Phi} \frac{n}{n_0}$$

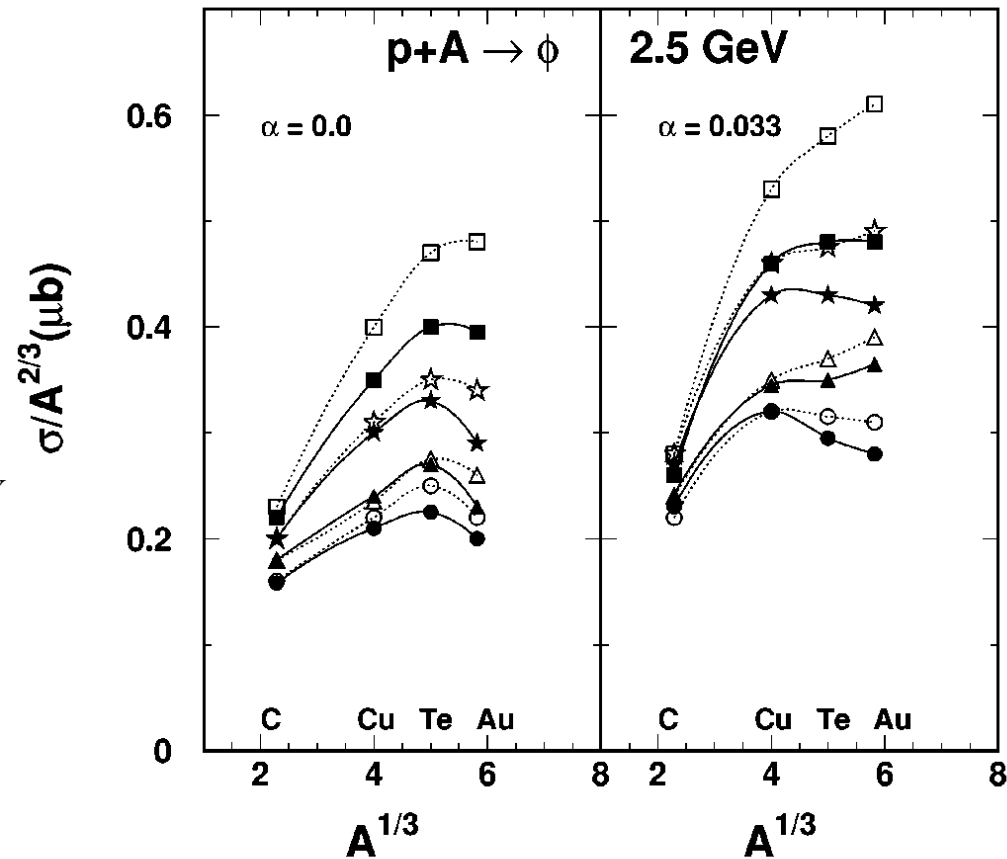
$$U_{K^+} = +0.04 m_K \frac{n}{n_0}$$

$$U_{K^-} = -0.29 m_K \frac{n}{n_0}$$

$$U_{K^-} = -[0.11 + 0.266 \exp(\frac{-p}{p_1})] m_{K^+} \frac{n}{n_0}, p_1 = 0.4 \text{ GeV}$$

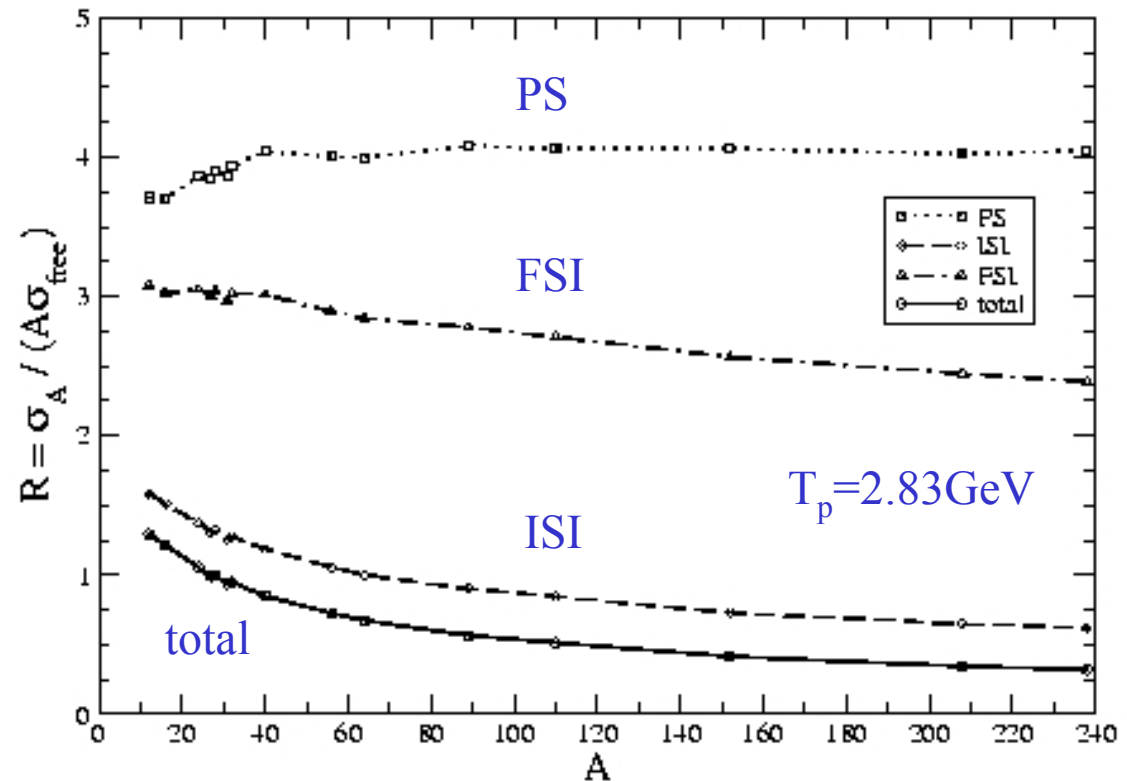
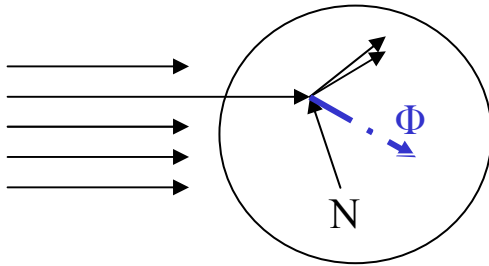
$$\Gamma = \Gamma_0 \frac{(m_{\Phi} + U_{\Phi})^2}{m_{\Phi}^2} \frac{p_{med}^3}{p_0^3}, \Gamma_0 = 4.4 \text{ MeV}$$

$$m_{\phi}^{med} = m_{\phi}^{vac} (1 - \alpha \frac{n}{n_0})$$



Recent Φ calculations in nuclear matter (Glauber)

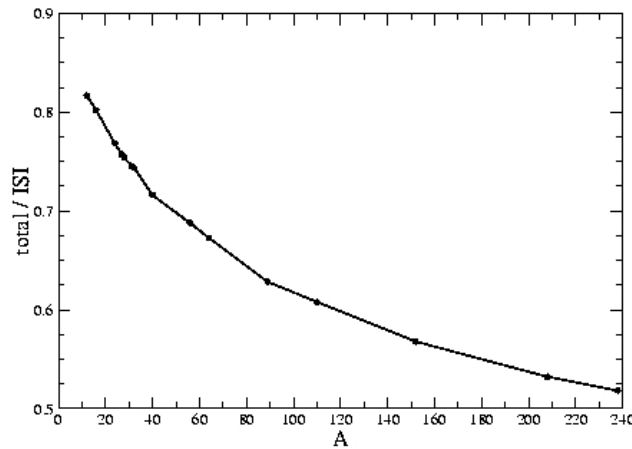
V.K. Magas, L. Roca and E. Oset,
arXiv:nucl-th/0403067 (2004)



$$\Gamma_{\Phi}(\rho \approx \rho_0) \sim 5 \cdot \Gamma_{\Phi_{\text{free}}} \approx 22 \text{ MeV},$$

meaningful A-dependence!

Recent Φ calculations in nuclear matter (Glauber)



← (ISI+FSI)/ISI

Figure 4: Ratio of the total cross section to ISI. Calculations are done for $T_p = 2.83$ GeV.

including two-step
mechanism

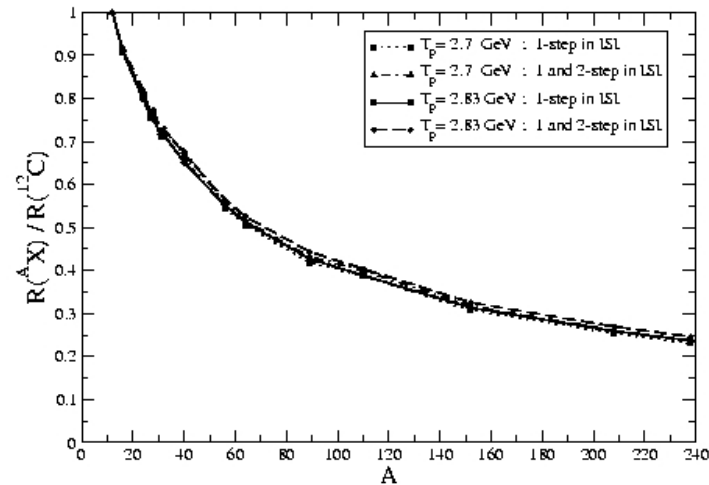
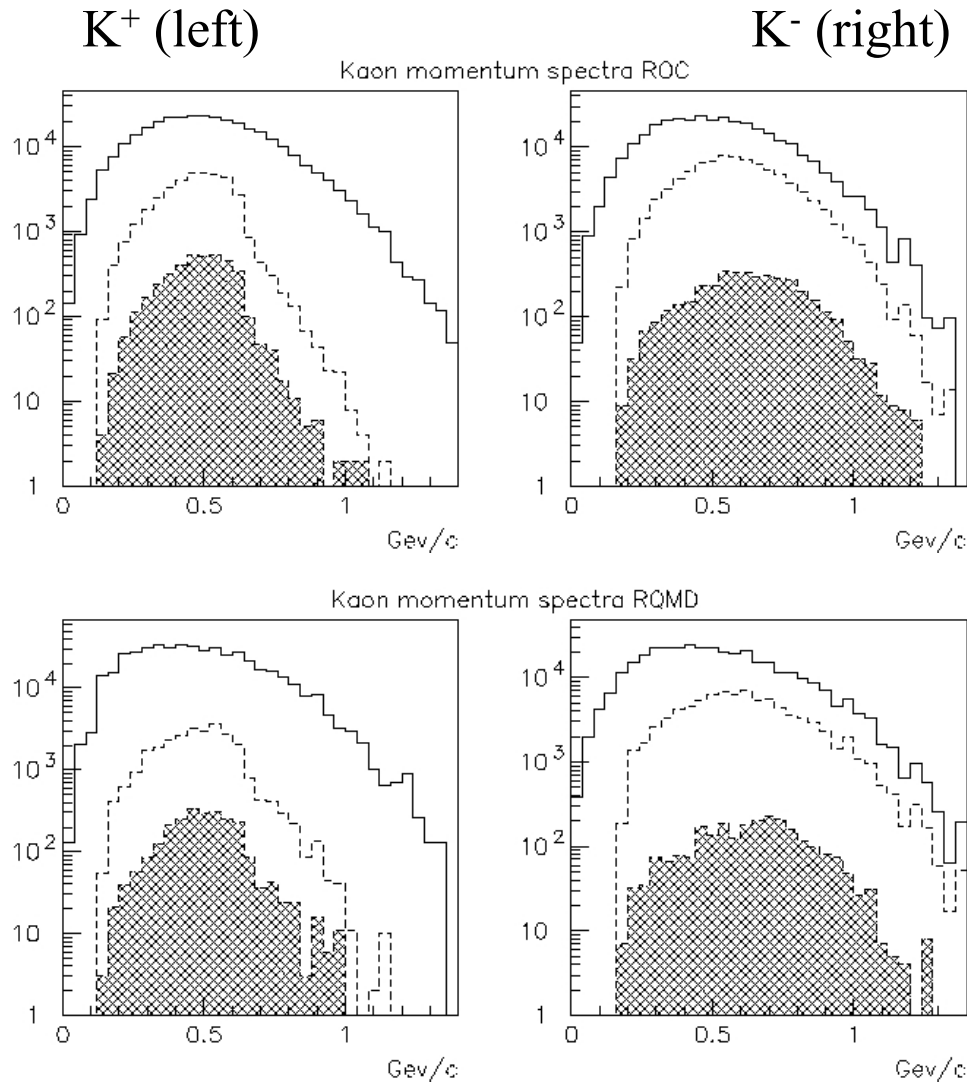


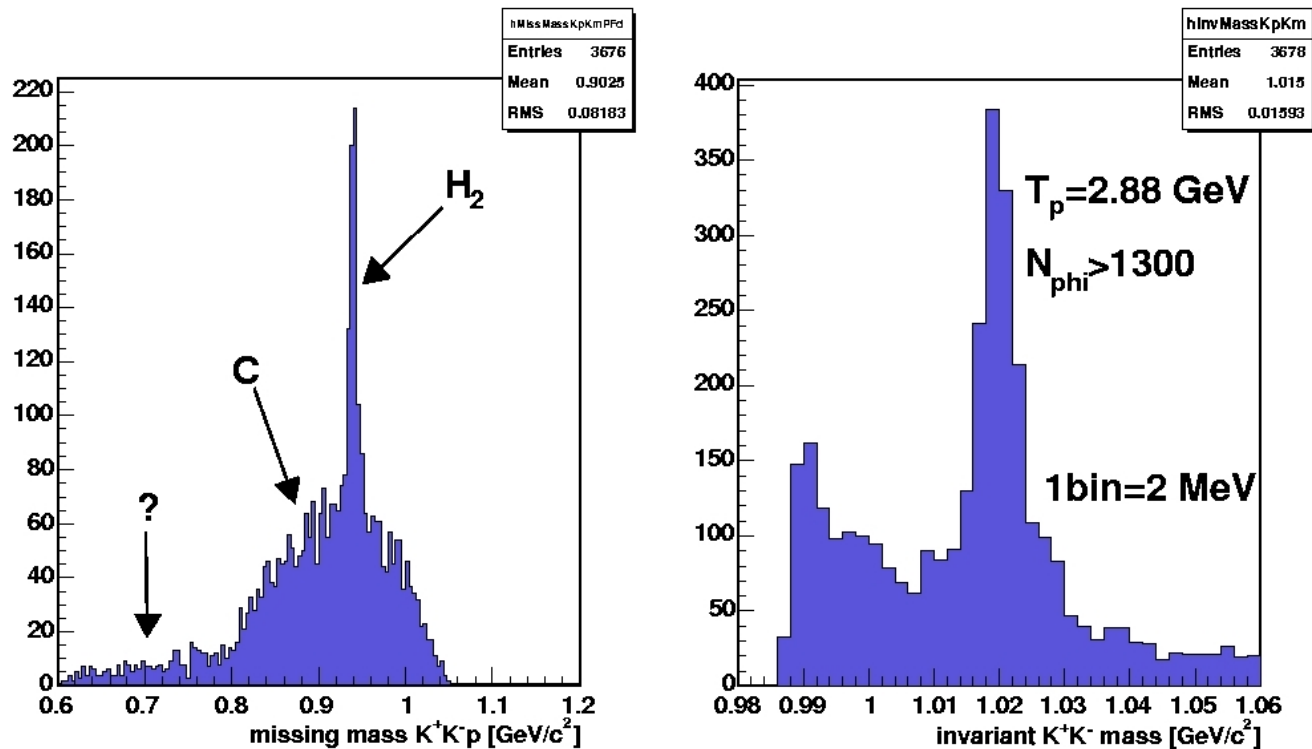
Figure 6: Ratio of the nuclear cross section normalized to ^{12}C for different proton kinetic energy and for the inclusion or not of the two-step mechanism in the evaluation of the ISI. The two-step process has been evaluated with $\Delta E = 400$ MeV.

Rate estimations and kaon momenta at ANKE



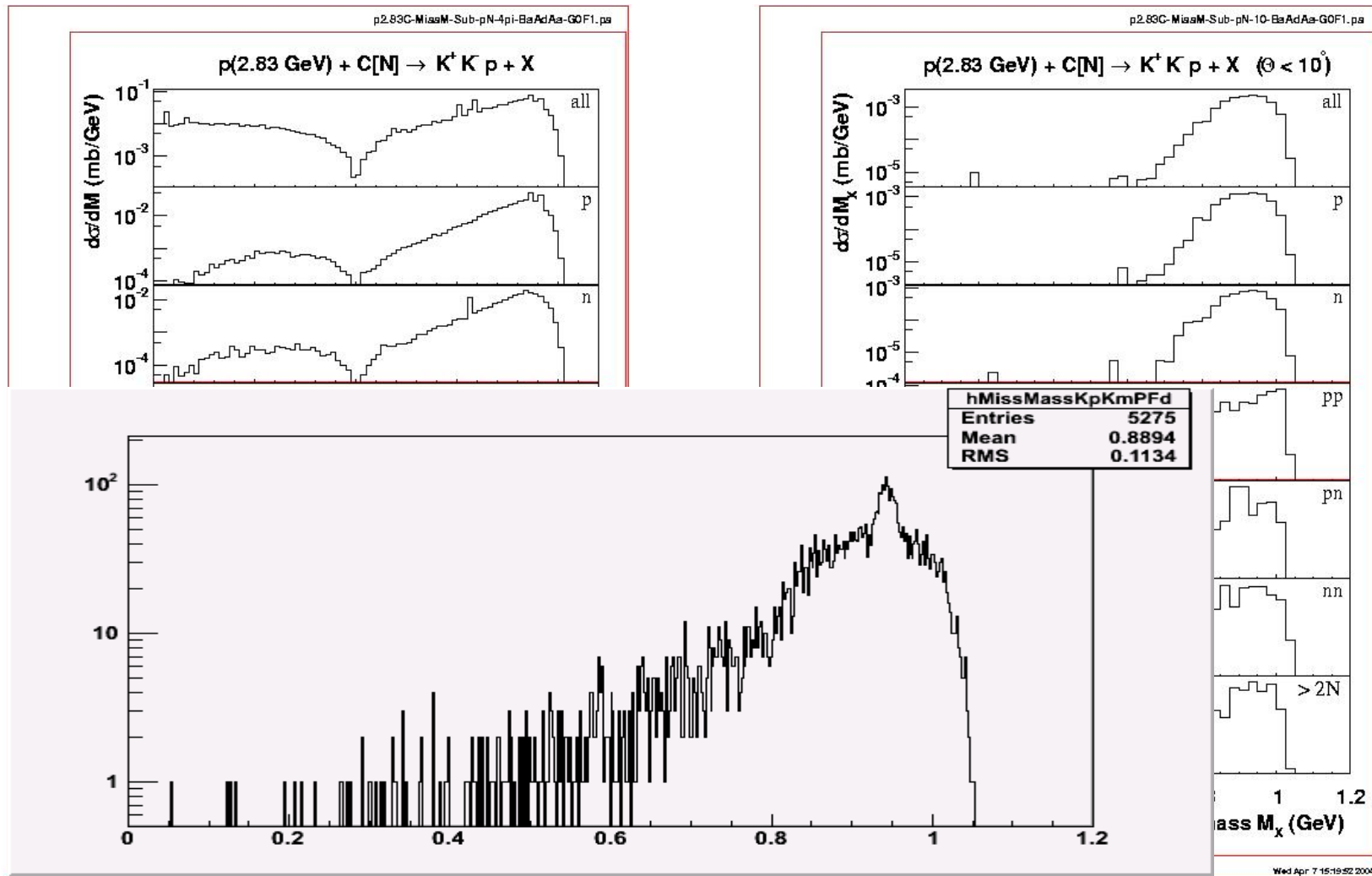
- ROC (G4, M.Hartmann, 2000)
ROC, RQMD, BUU (G3, V.Dimitrov, 2003)
- Luminosity = $1 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$
 $p\text{C} \rightarrow \text{K}^+ \text{K}^- \text{X}$, $T_p = 2.5 \text{GeV}$
- 200 K⁺K⁻ pairs/hour on tape
(with delayed VETO trigger)
- pC: 10.000 in 2 days
pCu: 10.000 in 6 days (exp.)
pAu: 10.000 in 8 days (exp.)

First Φ production in p+A (CH₂) at ANKE

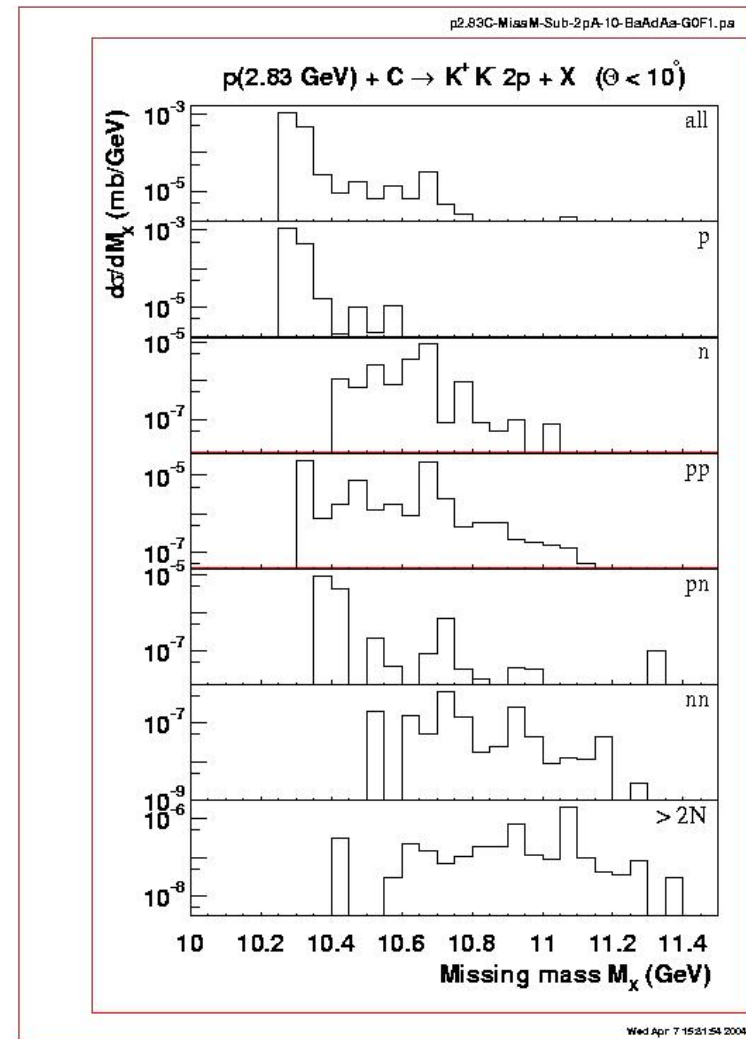
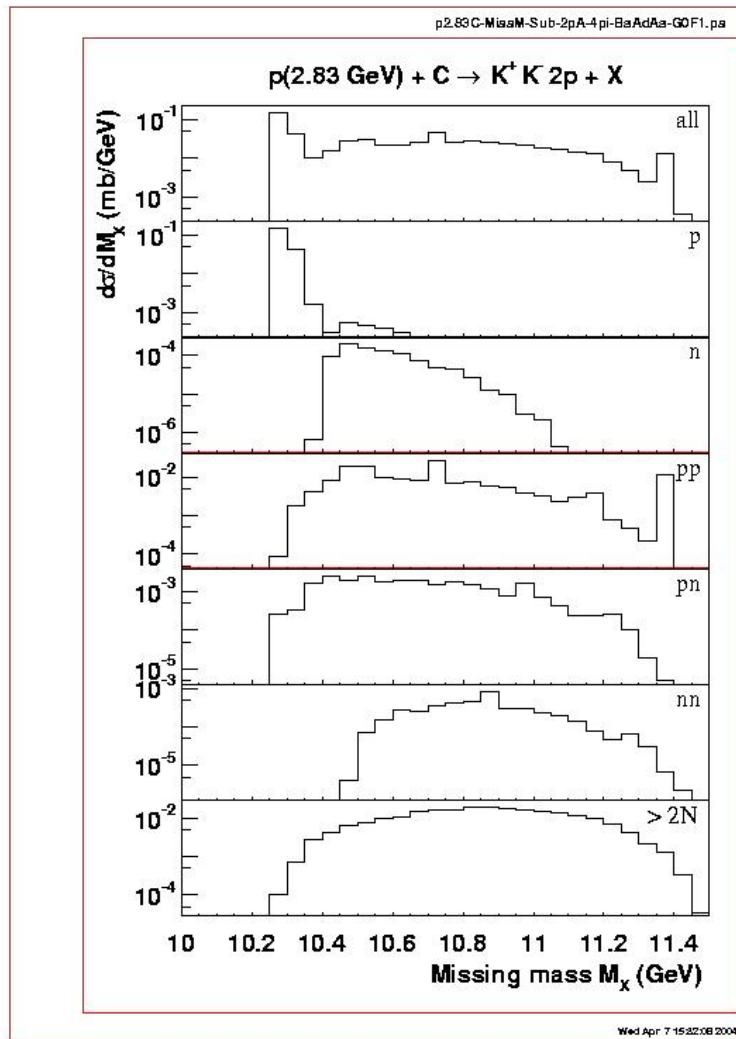


- 60% of the collected data
- No contradiction to the simulated rate estimation before (but hardly comparable!)

Production mechanism/ROC calculations



Production mechanism/ROC calculations





Summary / K^+K^- correlation at ANKE

- **Rate estimation and first experimental data shows that kaon-antikaon correlation can be studied at ANKE:**
 - ⇒ possible, with good statistic and reasonable resolution and with
 - ⇒ low background in the invariant K^+K^- mass distribution
 - ⇒ Cross-section (30%) and the A -dependence (ratios, 10%) which
 - ⇒ provide potentially information of the Φ in-medium properties,
 - ⇒ the Antikaon potential and
 - ⇒ maybe also about the production mechanism(??).
- **NEW proposal**
 - ⇒ First 2-3 weeks at highest energy ($T_p=2.83$ GeV) for the Φ in-medium investigation.
 - ⇒ Second 2-? weeks beam-time ('s) at lower energy around the free NN threshold or below (has to be discussed!).