π^--induced production of $K^0\Lambda$ pairs on nuclei at 1.15 GeV/c momentum

Adam Kasparek for the FOPI collaboration

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland

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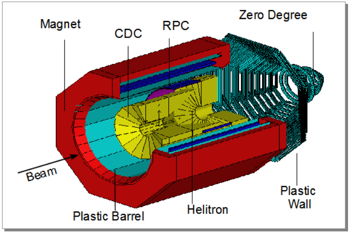
Plan of the talk

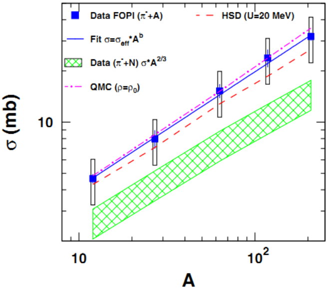
FOPI spectrometer @ GSI, Darmstadt

- Presented in detail yesterday by K.Wisniewski
- Beams from SIS18 accelerator;
- Fixed-target experiments;
- Almost full 4π coverage;
- Partial charge and mass identification up to $A \approx 20$;
- High granulation allowing tracking of many particles;
- Magnetic field $B = 0.6T$
- $1.15\frac{GeV}{c}$ π^- beam produced by collision ^{14}N beam on B_4C target.



FOPI spectrometer

- Intensity: about 3000 π^-/s.
- Targets: C, Al, Cu, Sn, Pb.

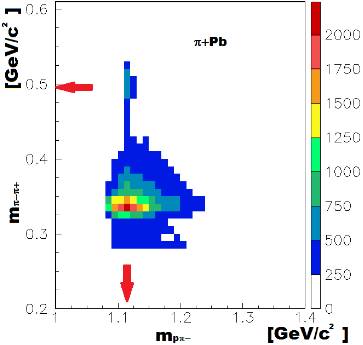


The K^0 inclusive production cross section scales as a $A^{2/3}$ of the target nucleus mass number A.

Bibliography:

- M. L. Benabderrahmane et al. FOPI Collaboration, Phys. Rev. Lett. 102, 182501 (2009)
- T.Matulewicz, K.Wisniewski, Acta Phys. Pol. B 39, 363 (2008)

- Momentum distribution of K^0 can be described with -20 ± 5 MeV repulsive potential is used in HSD model calculations



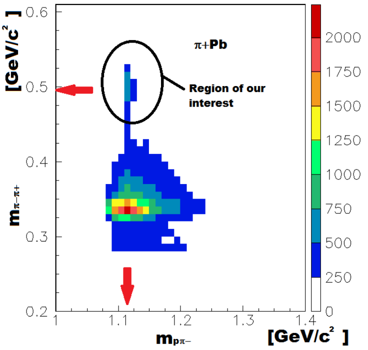
Distribution of $m_{\pi^-\pi^+}$ versus m_{π^-p}

$K^0_S(498)$ decay modes

Mode	Fraction Γ_i/Γ
$\pi^0\pi^0$	$30.69 \pm 0.05\%$
$\pi^-\pi^+$	$69.20 \pm 0.05\%$
$\pi^-\pi^+\gamma$	$(1.79 \pm 0.05) \times 10^{-3}$

$\Lambda(1116)$ decay modes

Mode	Fraction Γ_i/Γ
$p\pi^-$	$(63.9 \pm 0.5)\%$
$n\pi^0$	$(35.8 \pm 0.5)\%$
$n\gamma$	$(1.75 \pm 0.15) \times 10^{-3}$



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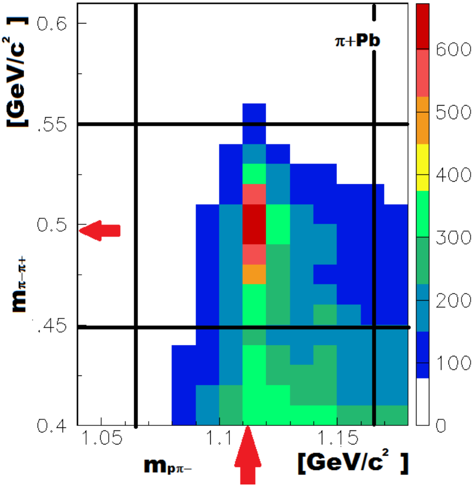
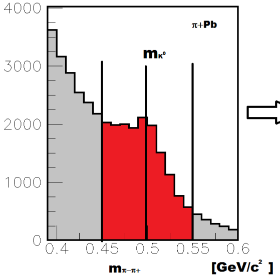


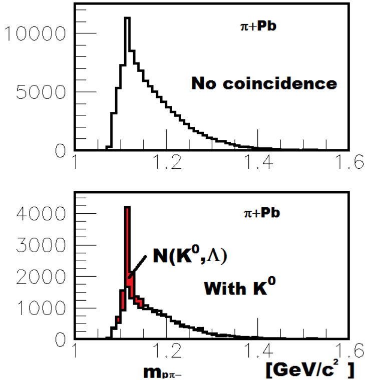
Zoom and applied cuts

Identification of K^0 and Λ pairs



Distribution of $m_{\pi^-\pi^+}$ with borders for K^0 candidates

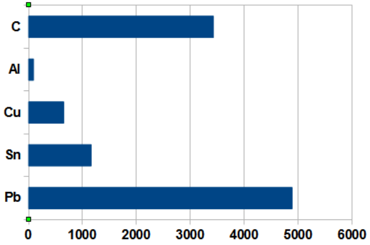
$$\left|m_{\pi^-\pi^+} - m_{K^0}\right| < 50\ \frac{MeV}{c^2}$$



Distribution of m_{π^-p} without and with coincidence

Number of detected pairs ΛK^0

Target	Number of pairs	S/B
C	3430 ± 300	0.22
Al	90 ± 30	0.13
Cu	650 ± 90	0.36
Sn	1160 ± 120	0.31
Pb	4890 ± 300	0.47



Number of detected pairs per target

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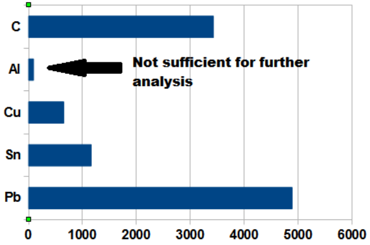
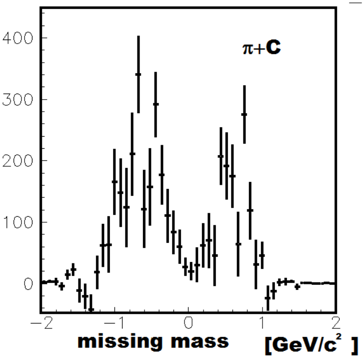


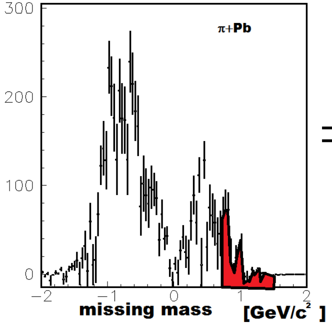
Number of detected pairs per target

Missing mass analysis

- For a single step production mechanism of ΛK^0 pair in the reaction $\pi^- X$ the missing mass (MM) can give information on the mass and momentum of X
- Missing mass is calculated from the energy and momentum conservation rules
- $MM^2 = (E_\Lambda + E_{K^0} - E_{\pi^-})^2 - (\vec{p}_\Lambda + \vec{p}_{K^0} - \vec{p}_{\pi^-})^2$
- MM is defined as $MM = sgn(MM^2) \cdot \sqrt{|MM^2|}$
- Broad structure below 1 GeV$/c^2$ can be attributed to the effective mass of proton in the medium
- Large structure at $MM < 0$ is not single-step processes: indicates multi-step interactions for production of pairs ΛK^0

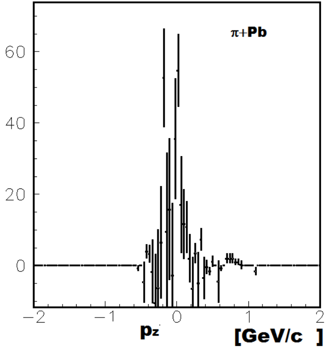


MM distribution for C target



MM distribution for Pb target

⇒

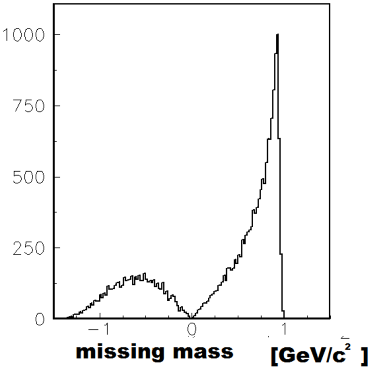


p_z of missing fragment for Pb target and condition MM$> 0.75 GeV/c^2$

p_z and $p_\perp$ are comparable with the Fermi motion of nucleon

Simulation of multi-step reaction

- Simple simulation of multi-step reactions with kinematical constraints and the nucleon Fermi motion was performed: $\pi N \rightarrow R$, $RN \rightarrow \Lambda K^0 N$ (R-resonance)
- No further interactions ΛK^0
- Appearance of MM< 0 events is demonstrated
- Exact shape of MM distribution is different from experimental one



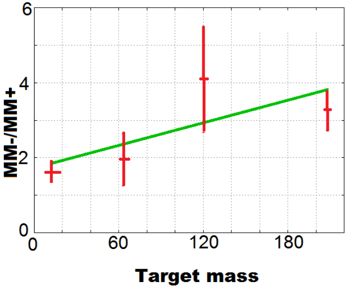
MM distribution for simulated two-step process in $\pi A \rightarrow \Lambda K^0$

Comparison of different targets

Definition:

- MM^- =number of events with MM<0 (multi-step)
- MM^+ =number of events with MM>0 (single and multi-step)

Increase of MM^-/MM^+ with target mass can be interpreted as rising role of multi-step reactions for more massive targets



MM^-/MM^+ ratio as a function of the target mass

Conclusions

- $K^0\Lambda$ pairs produced in π induced reactions on nuclei were identified by FOPI spectrometer at experiment at GSI Darmstadt
- Missing mass analysis shows two structures:
  - around and below proton mass
  - negative MM^2
- Simulation of multi-step explains the $MM < 0$
- Increase of $\mathrm{MM}^-/\mathrm{MM}^+$ ratio evidences rising role of multi-step reactions for more massive targets

Back-up

Invariant mass distribution of Λ for C target

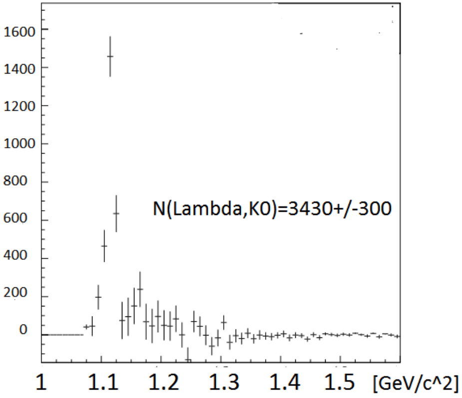


Figure: Invariant mass distribution of Λ for C target

Invariant mass distribution of Λ for Cu target

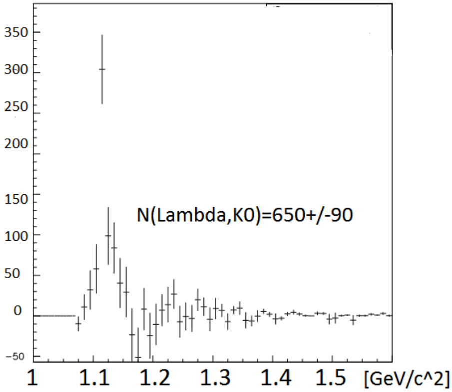


Figure: Invariant mass distribution of Λ for Cu target

Invariant mass distribution of Λ for Sn target

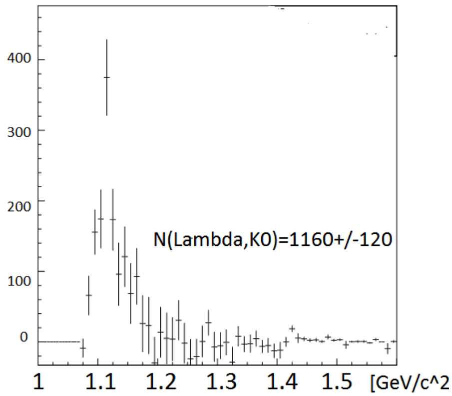


Figure: Invariant mass distribution of Λ for Sn target

Invariant mass distribution of Λ for Pb target

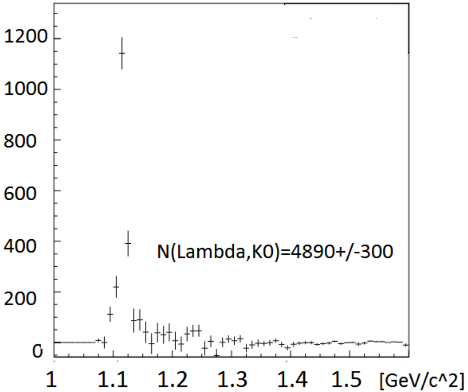
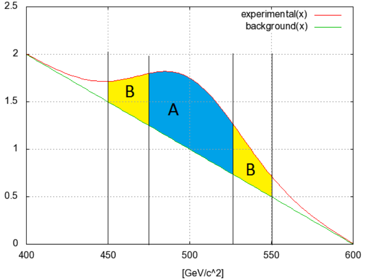


Figure: Invariant mass distribution of Λ for Pb target

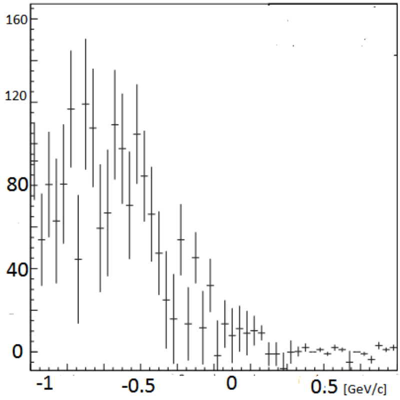
Comparison of different cuts

- Cut A
  $|m_{\pi^-\pi^+} m_{K^0}| < 50\frac{MeV}{c^2}$
- Cut B
  $|m_{\pi^-\pi^+} m_{K^0}| < 25\frac{MeV}{c^2}$
- $\frac{N_{\Lambda K^0}(Cut\ B)}{N_{\Lambda K^0}(Cut\ A)} = 0.79 \pm 0.06$
- $\frac{N_{K^0}(Cut\ B)}{N_{K^0}(Cut\ A)} = 0.75 \pm 0.04$



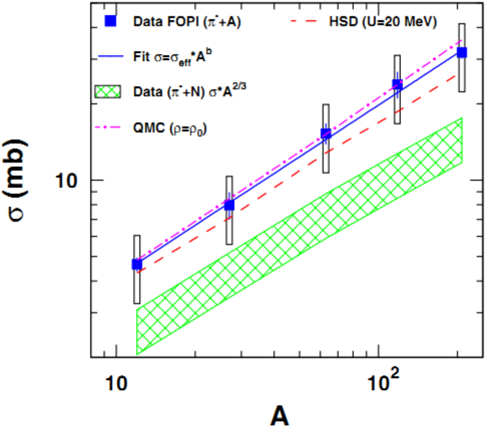
Scheme of comparison cuts

p_z of missing fragment



p_z of missing fragment for Pb target

Mass scaling of K^0 cross section



The K^0 inclusive production cross section as a function of the

p_z of missing fragment for events with MM$> 0.75 GeV/c^2$

- Cut on events MM$> 0.75 GeV/c^2$ (presumably proton)
- Mean p_z of "'proton"'$= 0.01 \pm 0.31 GeV/c$
- Fermi motion $p_F \approx 0.27 GeV/c$

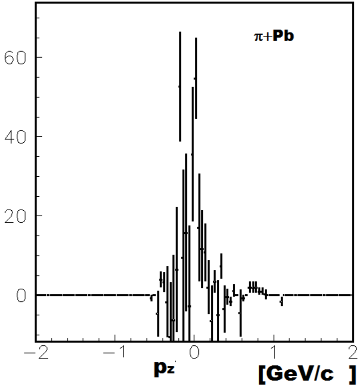


Figure: p_z of missing fragment for C targets and condition MM$> 0.75 GeV/c^2$

- Ratio $\frac{\sigma_{Pb}(K^0)}{\sigma_C(K^0)}$ for diffrent K^0 momentum was analysed.
- For low momentum ($p < 170 \frac{MeV}{c}$) production on Pb is supressed compared to production on C.
- It can be explained by repulsive potential KN.
- $U = 20 \pm 5 MeV$ is fitted.

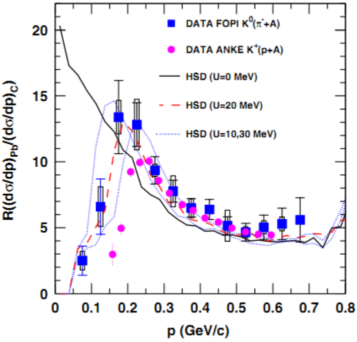


Figure: The ratio of K^0 (K^+) yields produced by pions (protons) on heavy and light targets plotted as a function of the momentum p in the lab system.

- Angular distribution of produced K^0 is not isotropic and show strong forward-backward assymetry.
- Ratio $N_C(K^0)/N_{Pb}(K^0)$ was analysed for different angles.
- Analysis shows strong mass dependence for small angles.
- It evidences reabsroption of K^0 by nuclear matter.
- Results of analysis was compared to IGMD transport model.

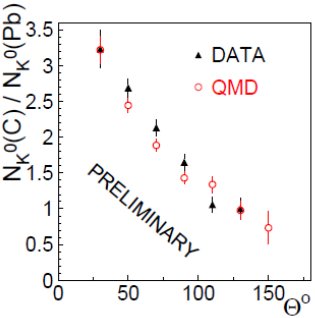


Figure: The ratio of the experimental (full triangles) angular distribution of K^0 mesons on C target to that on Pb target, compared to the IQMD model calculations.