Near–Threshold Production of Kaons and Antikaons in Proton–Nucleus Collisions

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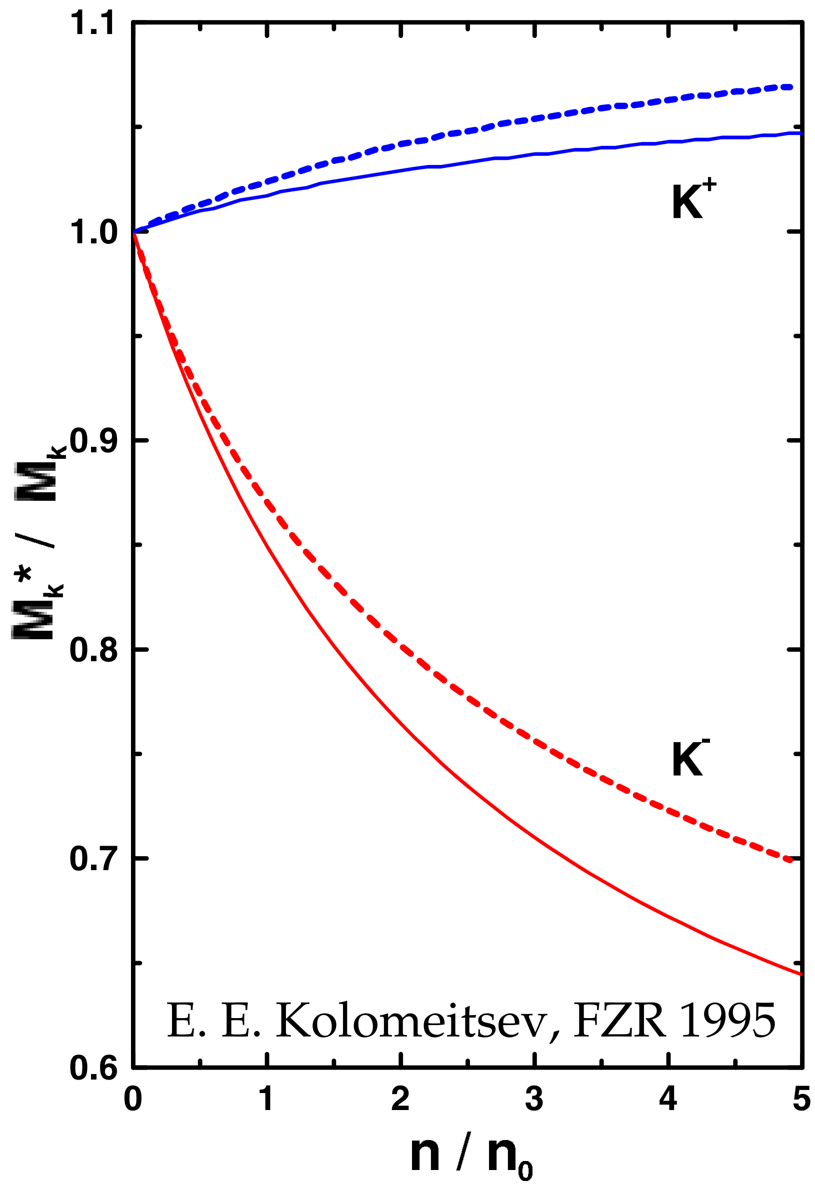
1. Motivation and Background
2. Experiment Setup
3. Results
4. Models and Interpretation

Medium Modifications

- Fermi motion of nucleons
- Multiple collisions accumulate energy:

$$N + N \rightarrow \Delta + N$$
$$\Delta + N \rightarrow K^{+} + K^{-} + N + N$$

- Attractive or repulsive interaction, i.e. decreased or increased effective mass, connected to a partial restoration of the chiral symmetry in the medium



K and π Mesons

	$K^+(u\bar{s})$	$K^-(\bar{u}s)$	$\pi^+(u\bar{d})$	$\pi^-(\bar{u}d)$
Mass [MeV/c^2]	493.7	493.7	139.6	139.6
Life time [ns]	12.4	12.4	26.0	26.0
Strangeness S	1	-1	0	0
Threshold E_P [GeV]	1.581	2.494	0.292	0.287
Threshold reaction	$pn \rightarrow nK^+\Lambda$	$pn \rightarrow pnK^+K^-$	$pn \rightarrow nn\pi^+$	$pn \rightarrow pp\pi^-$

- no absorption, no strange–ness exchange reactions
- large mean free path: 5 fm
- effective mass slightly in–creased in the medium

- high absorption by strangeness exchange:
- small mean fr. path: 0.8 fm
- effective mass strongly re–duced in the medium

$K^-n \rightarrow \pi^-\Lambda$

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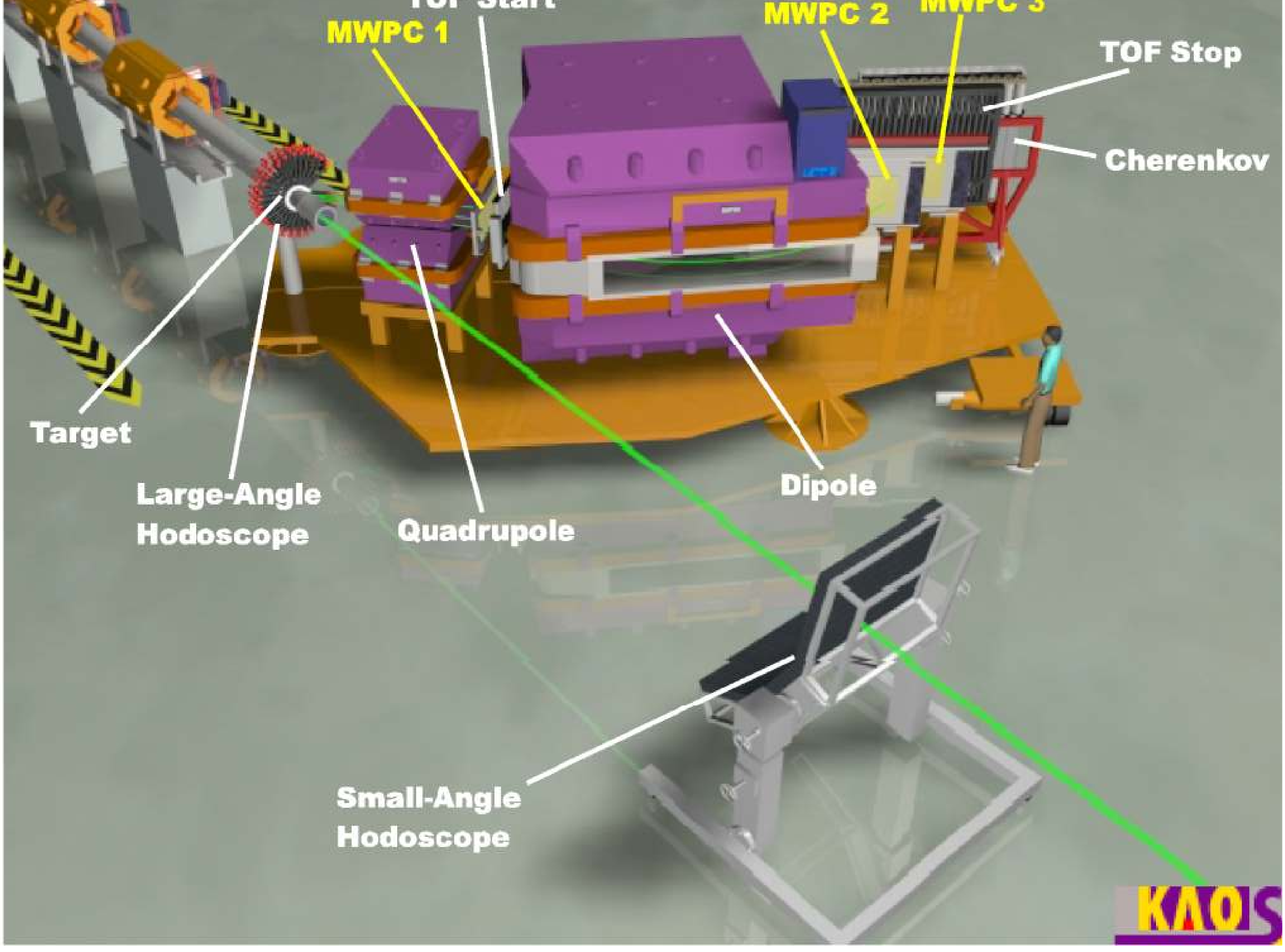
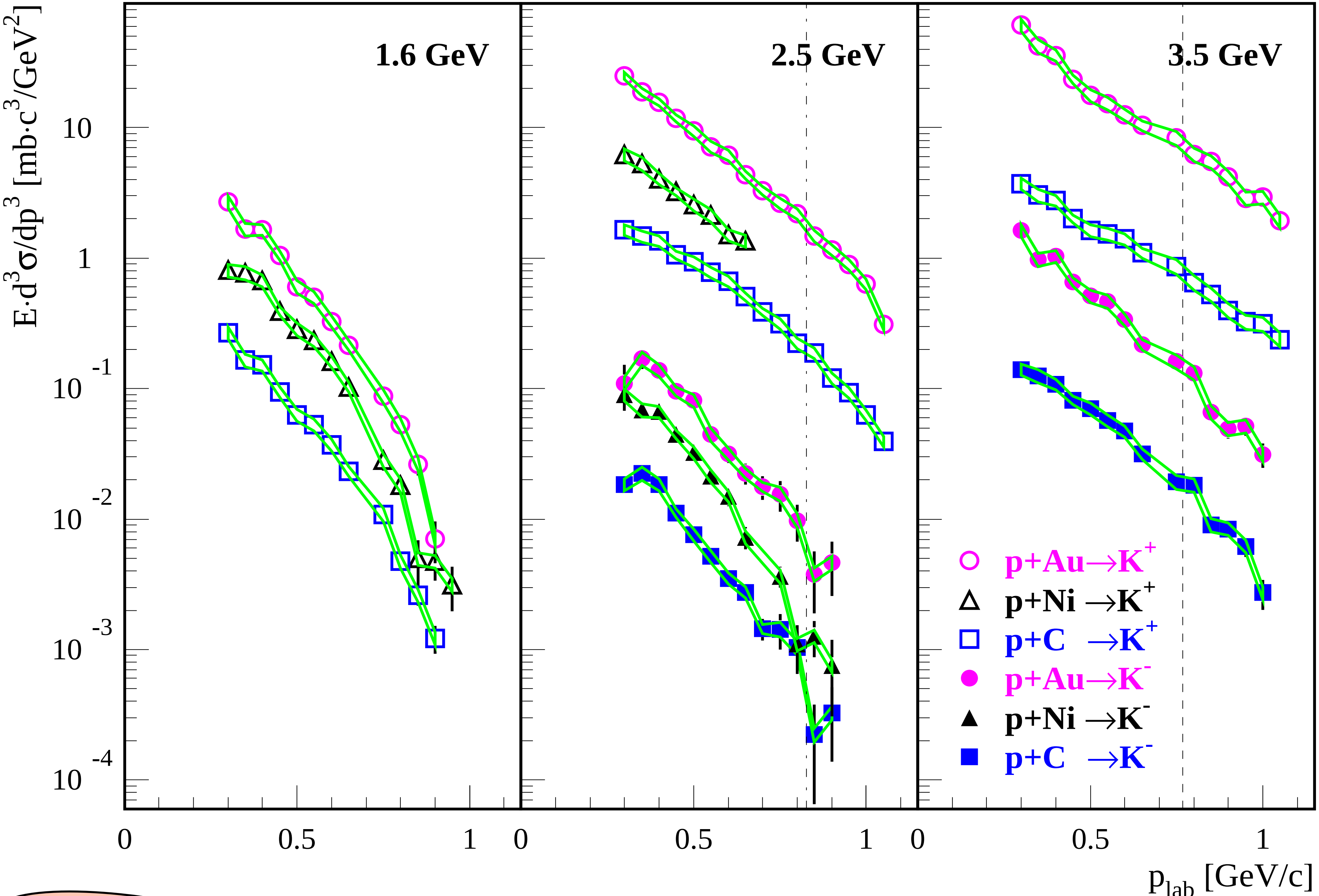
Why p+A?

- Equation-of-state for nuclear matter; astrophysical consequences of decreased K^- mass: neutron stars, supernovae
- There exist data for K^+ and K^- production in p+p and A+A at 1 . . . 3 GeV/nucleon. p+A represents the missing link.
- p+p: in vacuum, nucleon density $n = 0$
  A+A: $n = 2 \ldots 3n_0$; (n_0 normal nucl. density)
  n not precisely known and time dependent.
  How do K^+ and K^- behave at $n = n_0$?
  $\Rightarrow$ p+A


MWPC 1
MWPC 2
TOF Stop
Cherenkov
Target
Large-Angle
Hodoscope
Quadrupole
Dipole
Small-Angle
Hodoscope

Kaons at 40°



p+A → K+X

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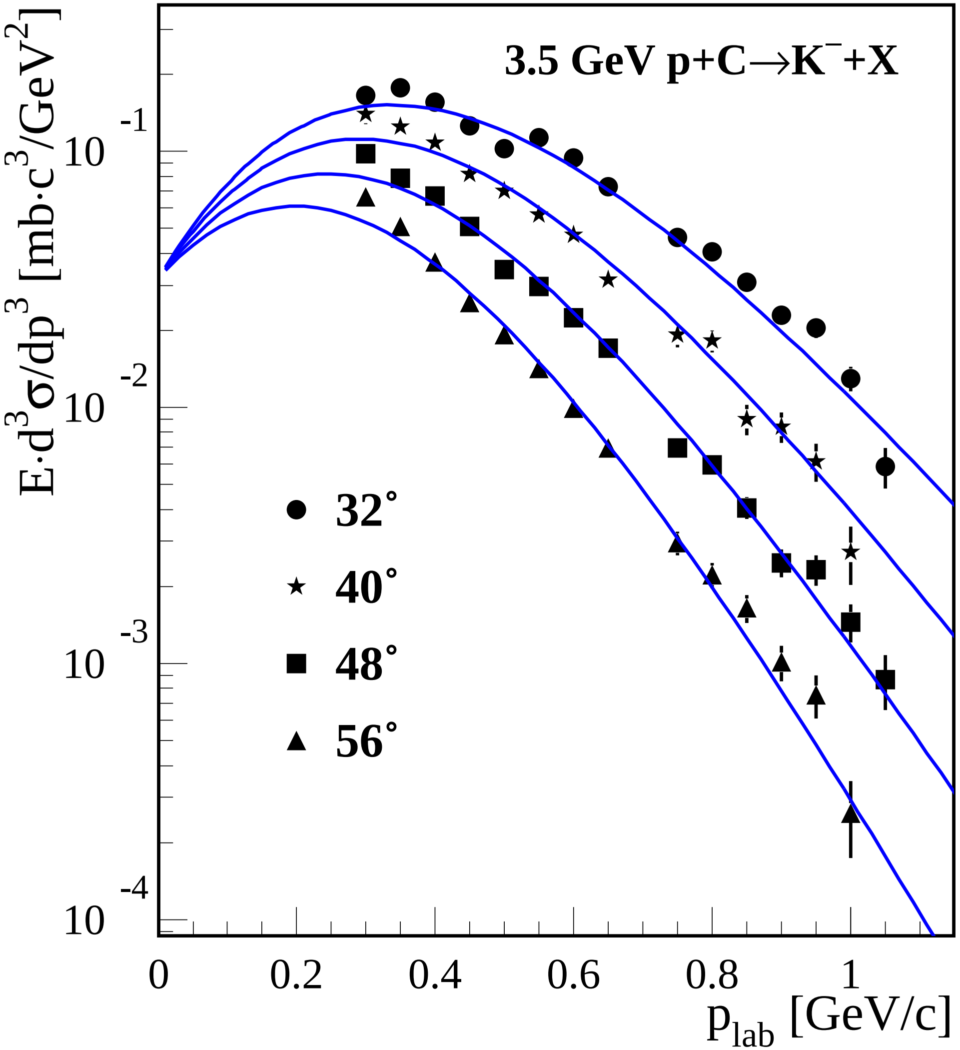
Total Cross Section



Required: Extrapolation to entire phase space.
Suggestion: Fit a Boltzmann distribution

$$\frac{d^3\sigma}{dp^3} = A\exp\left(-\frac{E}{T}\right)$$

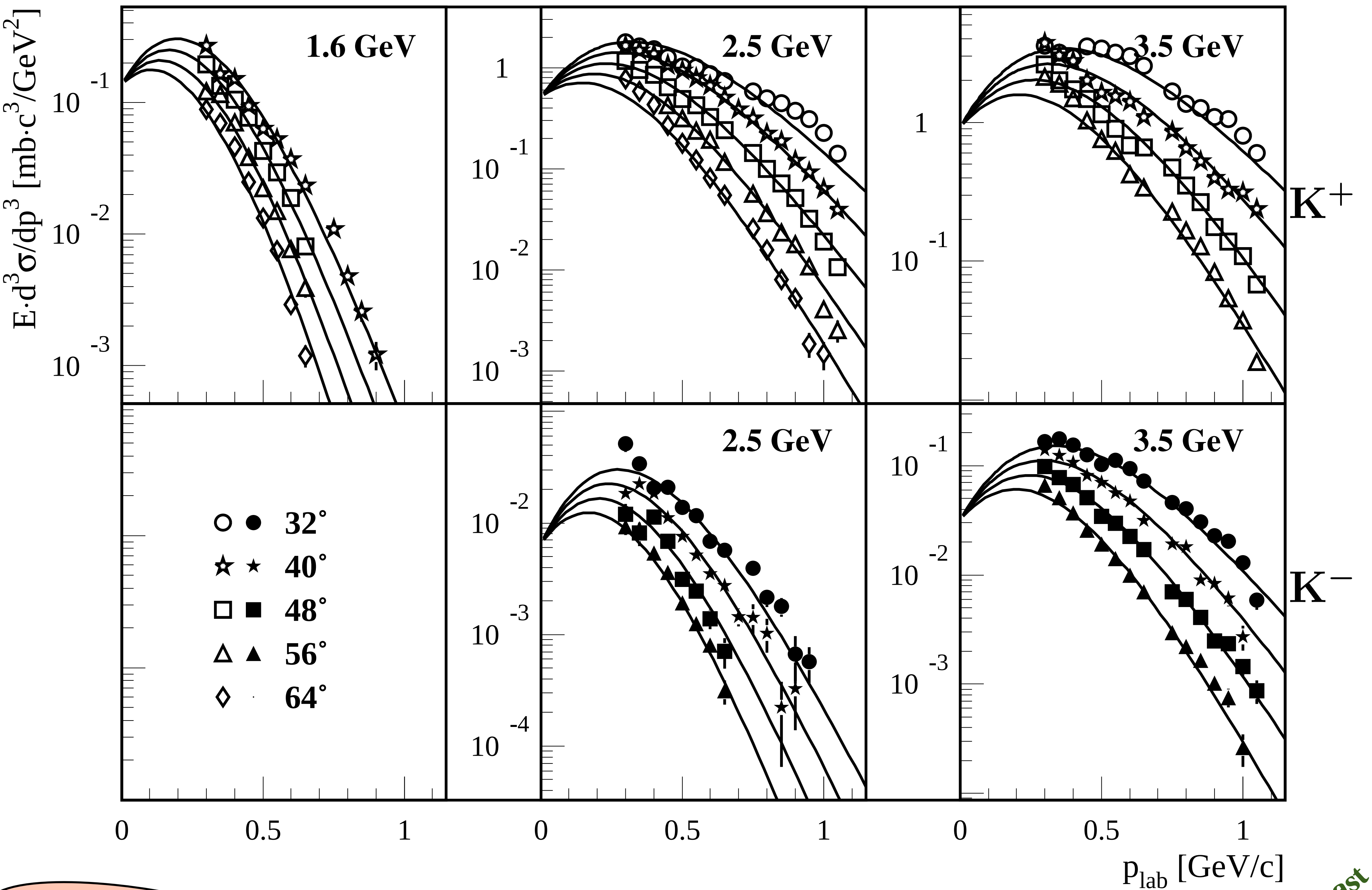
... in which reference frame?

$$E = E(\beta_{\rm em}, \vec{p}_{\rm lab}),\ \beta_{\rm em} = ?$$

$\Rightarrow$ 3 fit parameters: $A, T, \beta_{\rm em}$

$$\sigma_{\rm tot}(A, T, \beta_{\rm em}) = \int \frac{d^3\sigma}{dp^3}\, dp^3$$

Fits for $p + C \to K^{\pm} + X$



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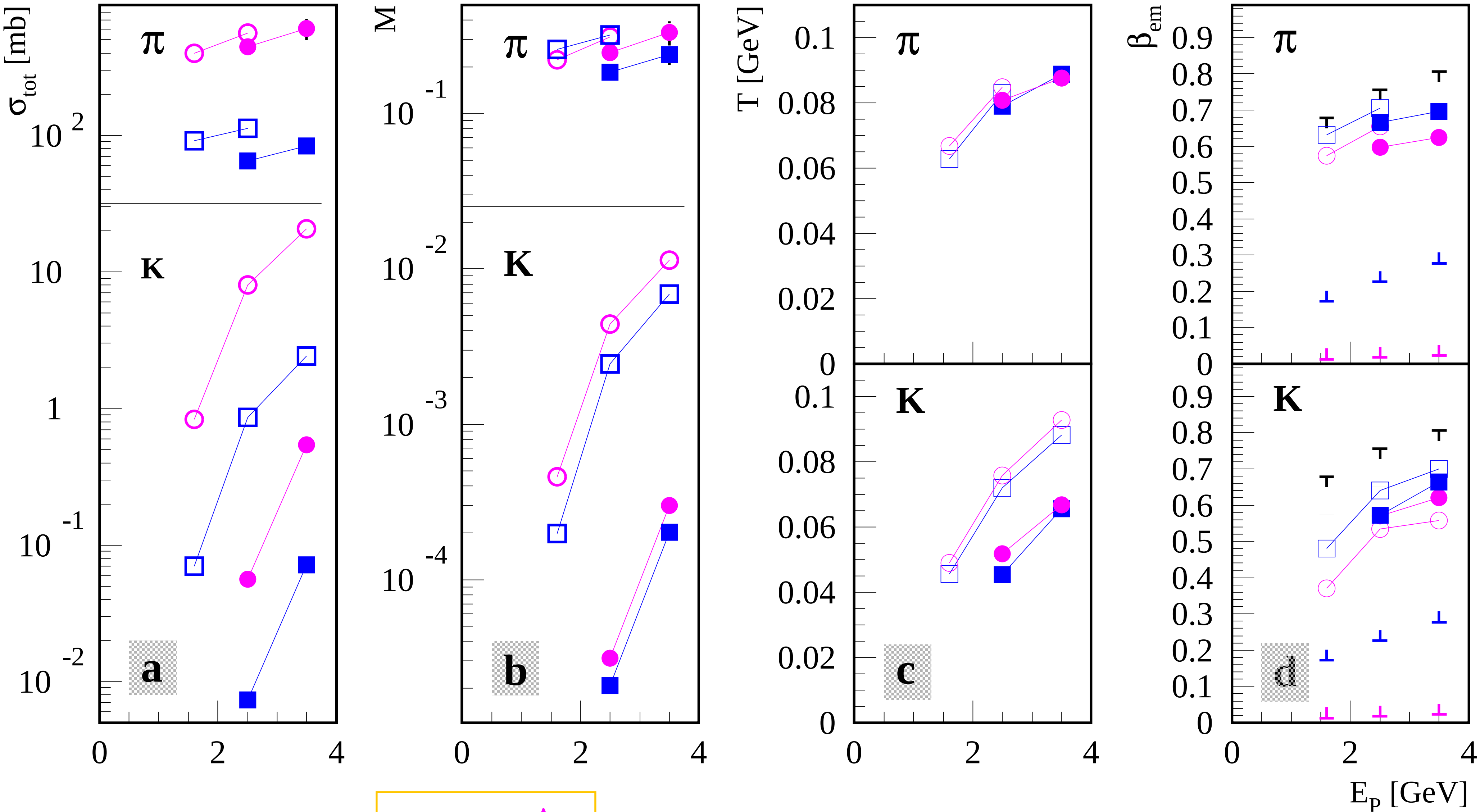
Overview of Parameters



○ ● **p+Au**

□ ■ **p+C**

σ_{tot} is 50–70 % extrapolated.

$M = \sigma_{tot}/\sigma_{geo}$

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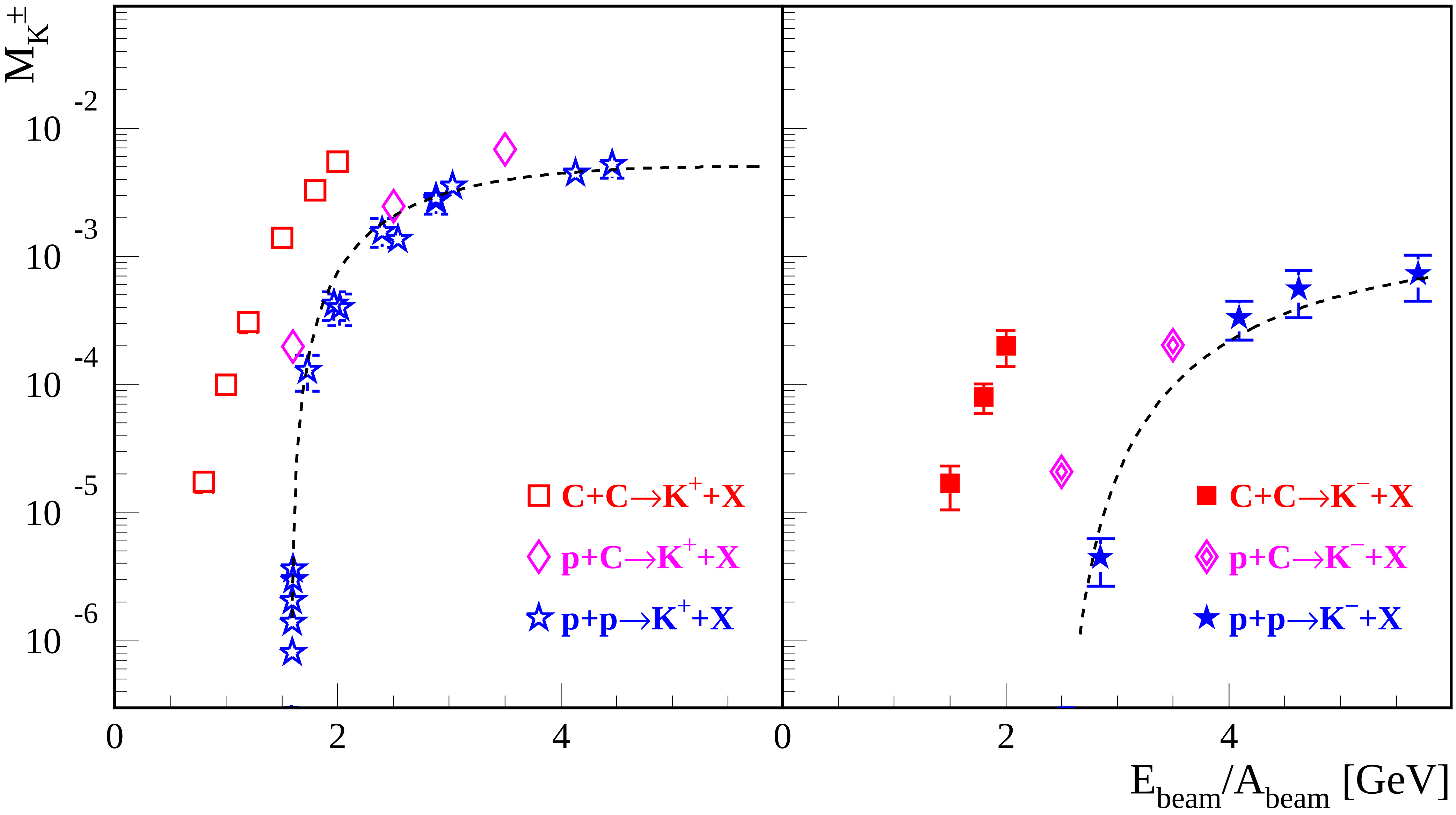
Medium Effects



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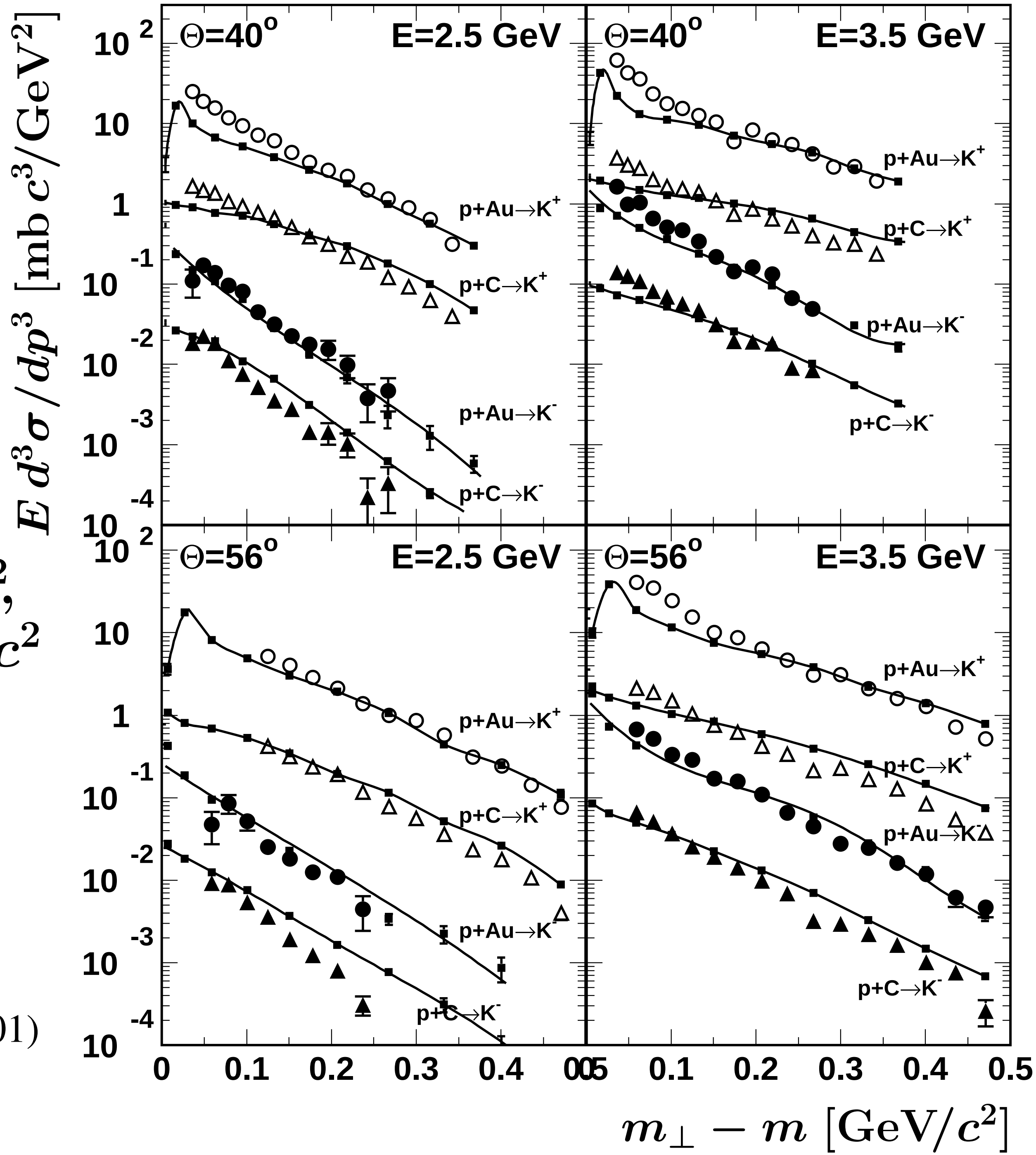
Comparison with a BUU model

Transport calculation with eff. mass
$\Delta m(\mathrm{K}^+) = +25\,\mathrm{MeV}/c^2$,
$\Delta m(\mathrm{K}^-) = -100\,\mathrm{MeV}/c^2$

$$m_\perp c = \sqrt{p_\perp^2 + m^2c^2}$$



(Barz, Naumann: PRC 68 (2003), 041901)

Summary

- First comprehensive measurement of K^- production cross sections in p+A for $E \leq 3.5\,\mathrm{GeV}$; systematic expansion of the amount of data for K^+ and $\pi^\pm$.

- Kinematic range is sufficient for an extrapolation to the entire phase space $\longrightarrow$ total cross section.

- σ_{tot} comparable to the system p+p rather than to A+A, however: pronounced medium effects around the threshold.

- Transport calculations require modified masses to describe K^+ and K^-, also consistent with A+A data.

Outlook

Question to Theoreticians:

Could K^- production measurements in the region of light nuclei (p+Li, Li+Li?) shed more light on the differences between p+p and p+C? Could one learn, where the medium effects emerge?

Question to Experimentalists:

Is it possible to measure total K^- cross sections < 1 μb?