Study of kaon and neutron yields from a high intensity 8 GeV proton source

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Introduction

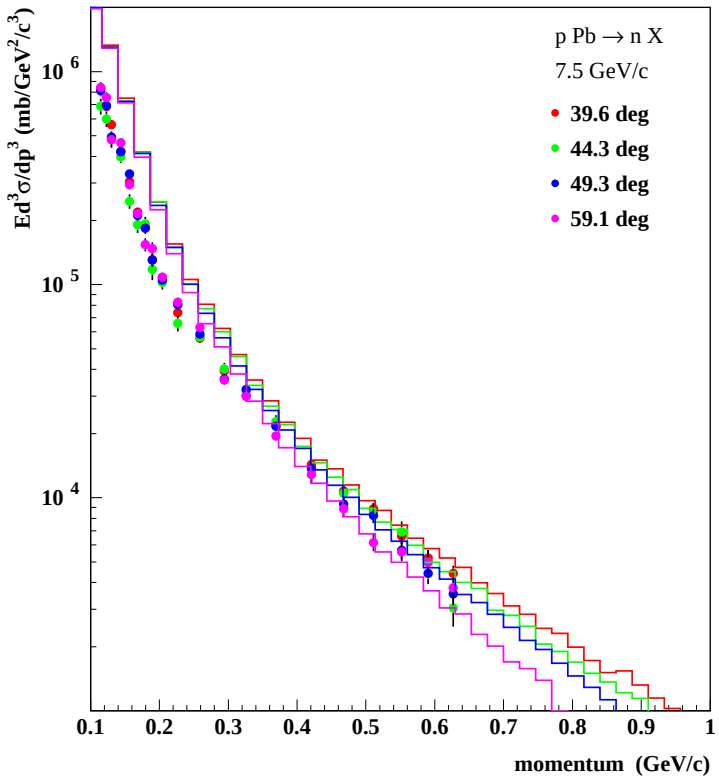
- Goal – estimate large angle neutral kaons and neutrons yield from proton-heavy nucleus interaction at 8 – 24 GeV/c
- There are no enough experimental data in this energy-angle range to make model independent calculation
- Model can be verified using other data:

  charged kaon and proton production in proton nucleus collision and proton-proton measurements

Large angle neturon production in proton-nucleus interaction and LAQGSM

- LAQGSM is Los Alamos version of the Quark-Gluon String Model
- LAQGSM is implemented into MARS code system. It is possible to simulate thick target production.
- LAQGSM agree well with ITEP data on large angle neutron production at p>300 MeV/c
- There are no other published large angle neutron production data at high energies
- Proton and neutron production are in close relation
- If LAQGSM describes well large angle proton data it could be applied to prediction of neutron yield
- All LAQGSM results in this presentation were obtained using MARS-LAQGSM, not with the original LAQGSM!

LAQGSM and ITEP data



Neutron production in p-Pb collision at 7.5 GeV/c

Simulations vs Test Beam Measurements (BNL-E926, 24 GeV/c protons on10 cm platinum target)

Integral number of neutron (1/proton/μsr) above threshold

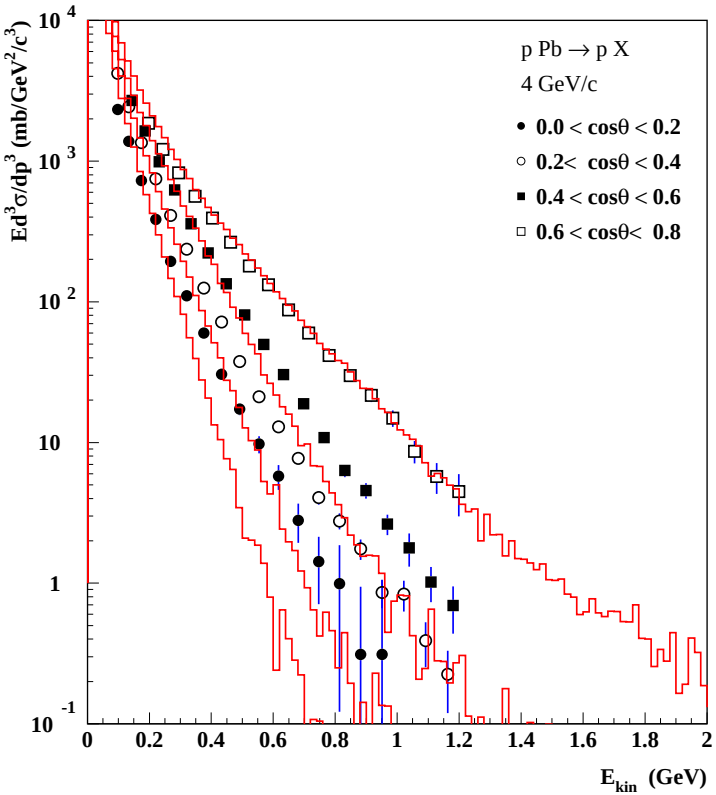
	10 MeV	50 MeV	100 MeV	300 MeV	830 MeV
GFluka	1.11	0.71	0.49	0.07	0.005
Fluka	0.99	0.62	0.45	0.13	0.02
LAQGSM	2.08	1.04	0.71	0.26	0.042
Experiment	2.52	2.10	1.81	1.1	0.43

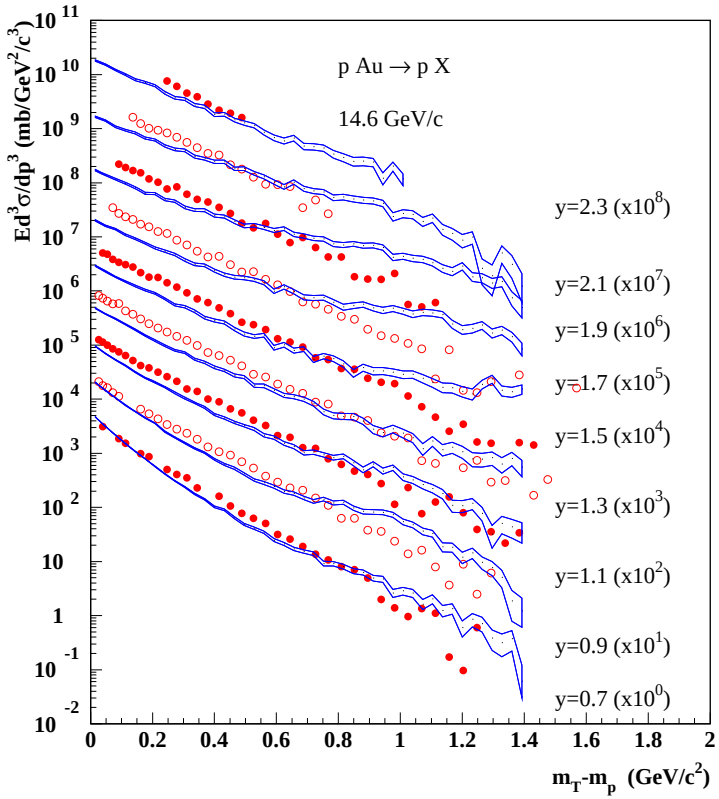
38.5 degree

	10 MeV	50 MeV	100 MeV	300 MeV	830 MeV
GFluka	1.03	0.63	0.42	0.05	0.002
MCNPX	1.72	0.68	0.45	0.11	0.002
Fluka	0.90	0.53	0.37	0.07	0.005
LAQGSM	1.86	0.83	0.53	0.16	0.017
Experiment	1.66	1.26	0.98	0.38	0.064

46.5 degree

Proton production in proton-nucleus interaction and LAQGSM

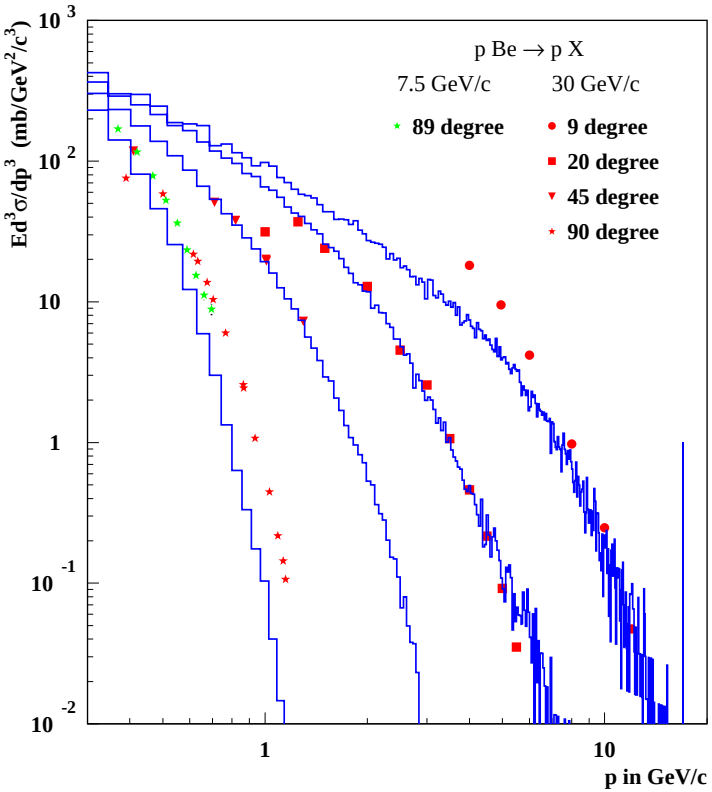


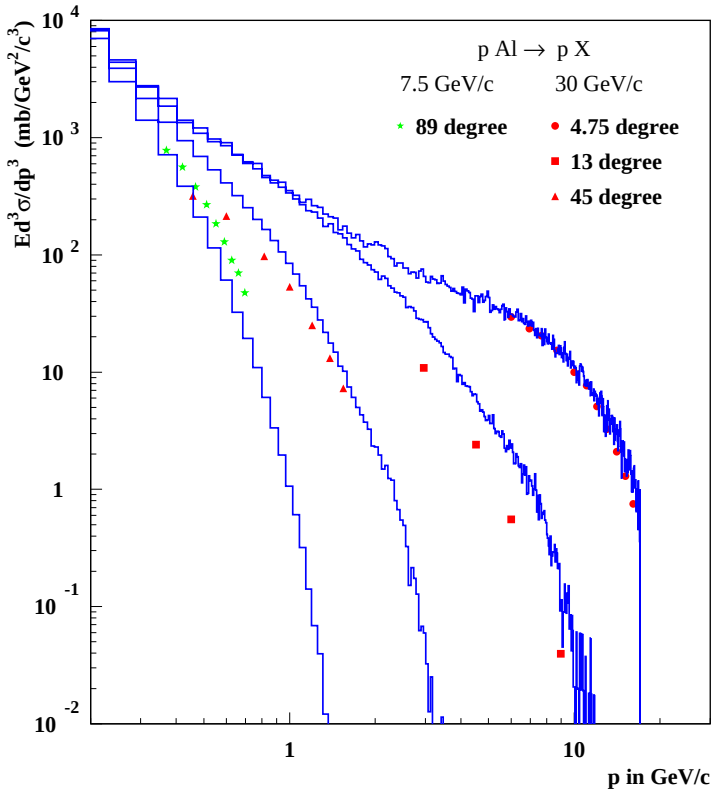


$\cos(45^0)=0.707$

$y=0.7$ and $m_T-m_p=0.5$ GeV $\leftrightarrow$ $p=1.54$ GeV/c and $\theta=45^0$

Proton production in proton-nucleus interaction and LAQGSM





Neutron production in proton-proton interaction

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INCLUSIVE NEUTRON AND LAMBDA PRODUCTION IN PROTON-PROTON INTERACTIONS AT 12 AND 24 GeV/c

Bonn–Hamburg–München (MPI) Collaboration

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A method for the determination of neutron spectra in a bubble chamber experiment is developed. Double differential cross sections for inclusive neutron and lambda production are presented. The n/Λ particle ratios are determined as functions of x and p_T; at $p_T = 0$ GeV/c they are compatible with the ratios measured in pCu interactions at 24 GeV/c. Our neutron spectra are compared with spectra for protons produced near the direction of the incident neutron in pn interactions at FNAL and with neutron spectra measured in pp interactions at the ISR. Exchange mechanisms are studied in the framework of single diffraction dissociation and the triple-Regge model. The scattering of virtual pions and kaons on real protons is investigated.

1. Introduction

It is well known that the mechanism of single diffraction dissociation, mediated by the exchange of the pomeron trajectory, gives a large contribution to inclusive proton production in pp interactions. Such a process favours proton emission near the longitudinal phase-space boundaries. Contributions of other mechanisms behave as a relatively flat background. As the pomeron does not couple to the pn and pΛ vertices, the inclusive reactions

$$pp \to nX\,, \qquad (1)$$

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[5] Now at IABG, München-Ottobrunn, Germany.
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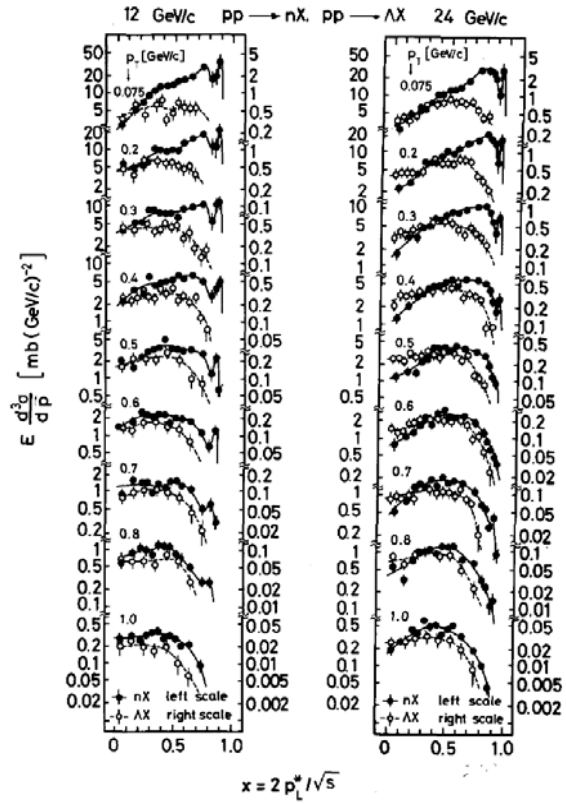


Fig. 5. Invariant differential cross sections of neutrons and lambdas as functions of x and p_T. For neutrons and lambdas use the left and right scale respectively, which are shifted relative to each other by one decade. The curves are drawn to guide the eye.

Neutron production in proton-proton interaction

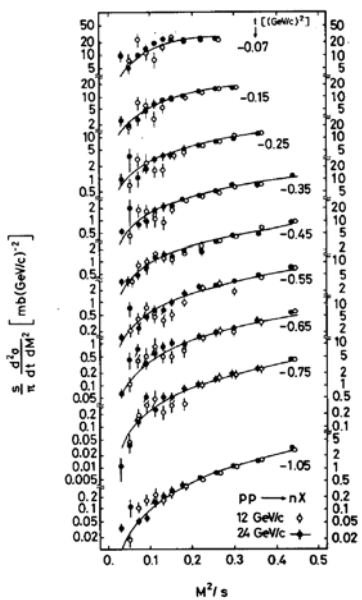
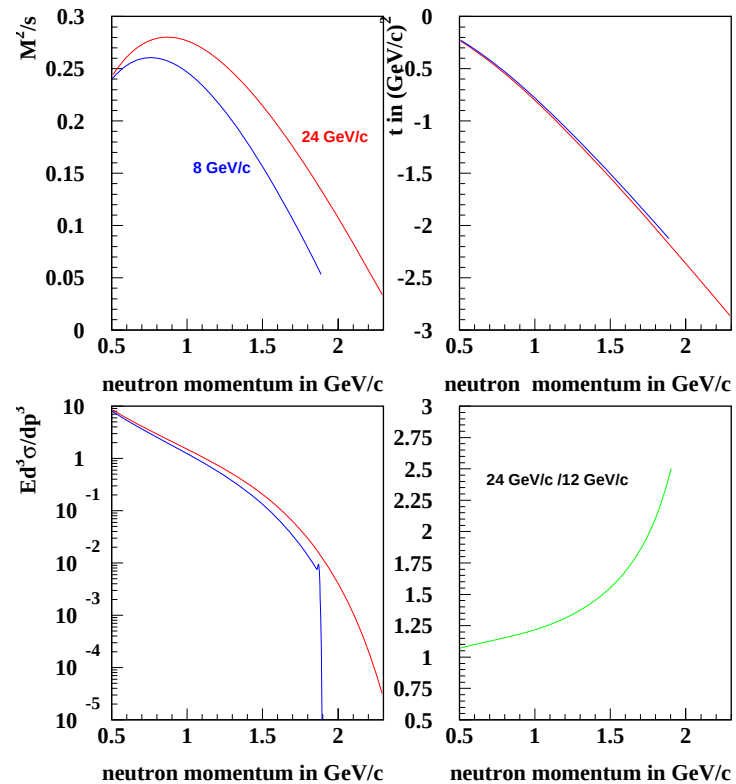


Fig. 12. Invariant differential cross sections of neutrons as functions of M^2/s and t. The curves are predictions of a triple-Regge model described in the text.

metrized by [21] *:

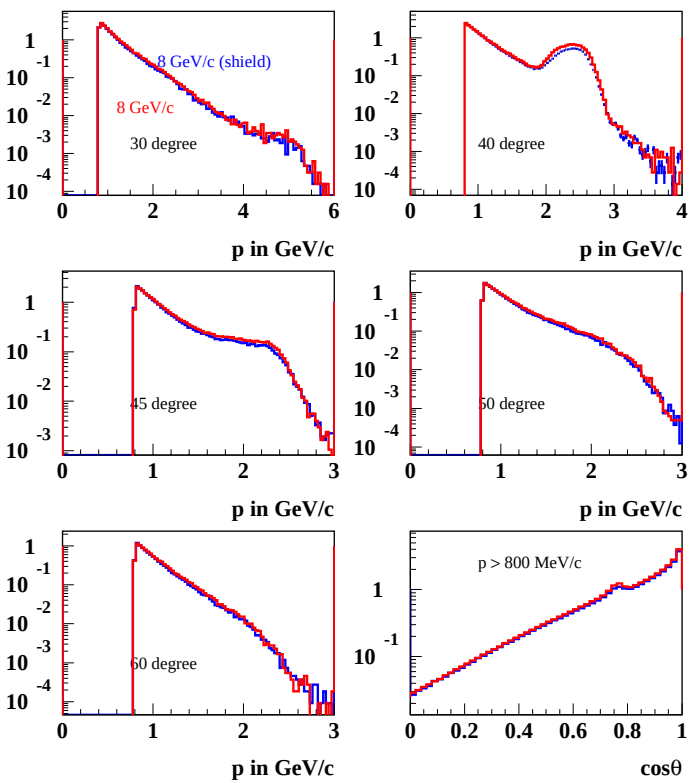
$$\frac{s}{\pi}\frac{d^2\sigma}{dt\,dM^2} = \frac{1}{\pi s}\sum_{i,j,k} G_{ijk}(t)\left(\frac{s}{\nu}\right)^{\alpha_i(t)+\alpha_j(t)} \nu^{\alpha_k(0)} . \qquad (26)$$

$G_{ijk}(t)$ denotes the triple-Regge coupling of the three reggeons labelled i, j and k. $\alpha_i(t)$, $\alpha_j(t)$ and $\alpha_k(t)$ are the trajectories of the three reggeons. The crossing-symmetric variable ν is defined by $\nu = M^2 - t - m_p^2$.

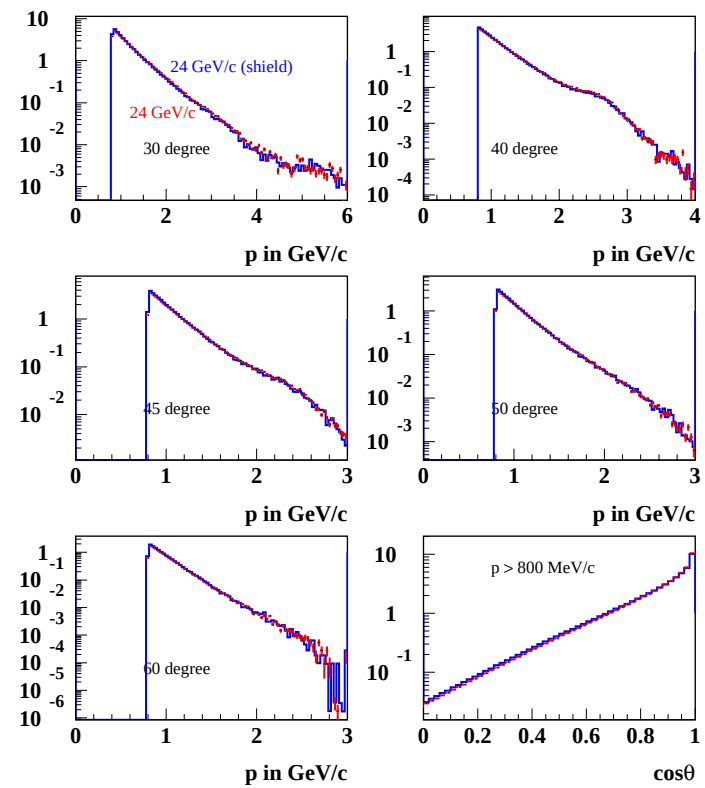


Neutron production in proton-proton collision at 45 degree

Neutron spectra with 7 cm lead filter and without filter



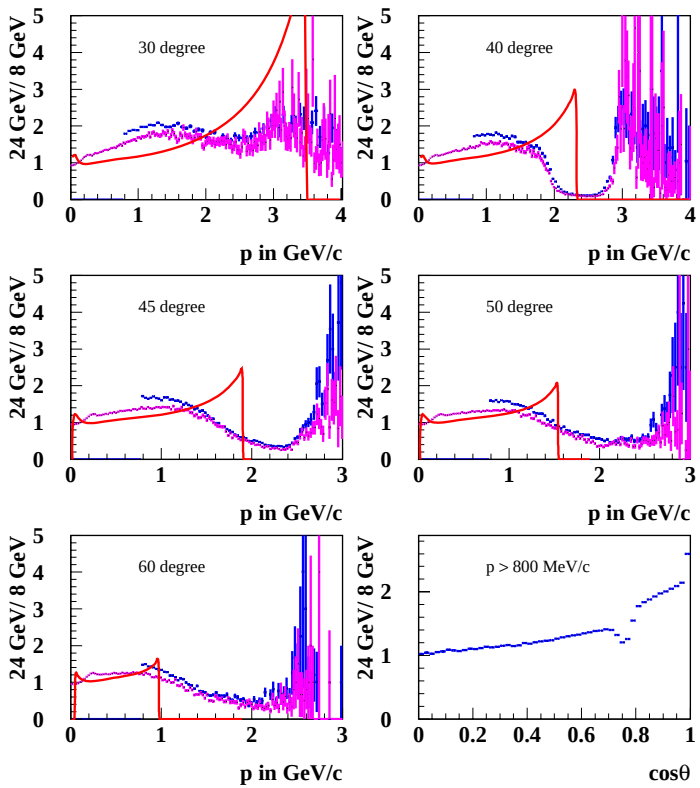
Neutron production from 10 cm platinum target



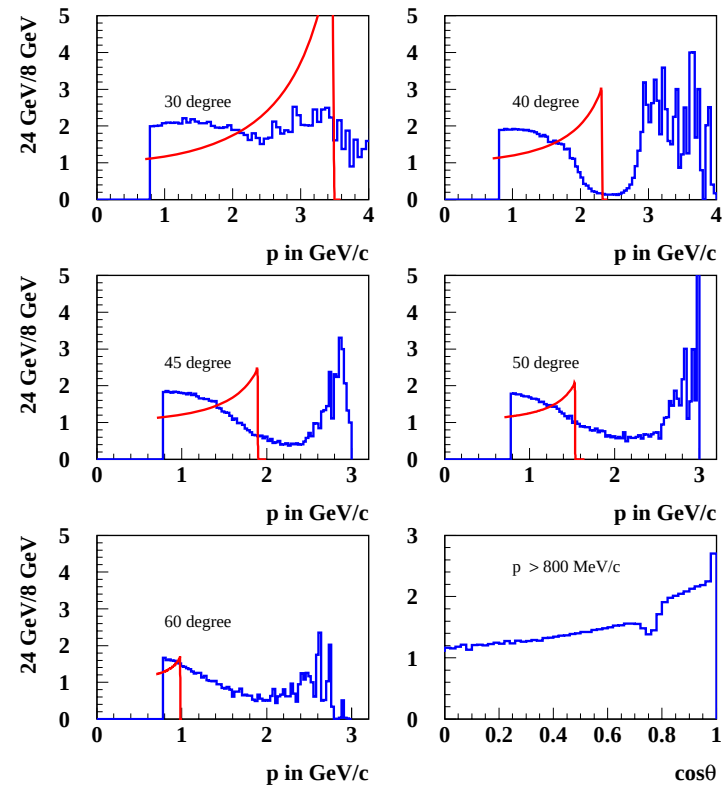
Neutron production from 10 cm platinum target

$\cos(45^0)=0.707$

Ratio of neutron spectra at 24 GeV/c and 8 GeV/c



Neutron production from 10 cm platinum target (with 7 cm lead shield)

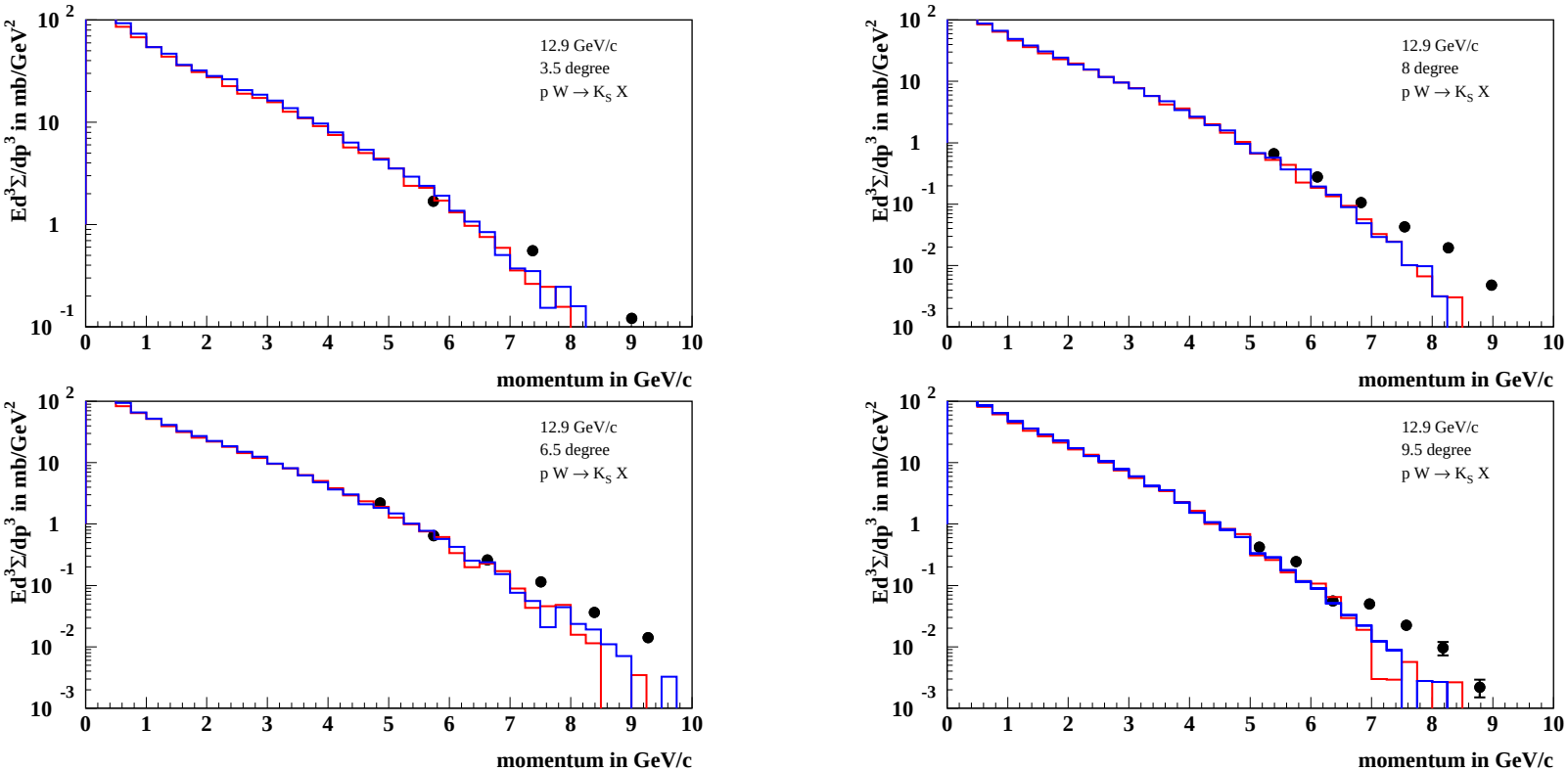


Neutron production from 10 cm platinum target (with 7 cm lead shield)

red – proton proton collisions
magenta – proton lead collisions
blue – proton on 10 cm platinum target

$\cos(45^0)=0.707$

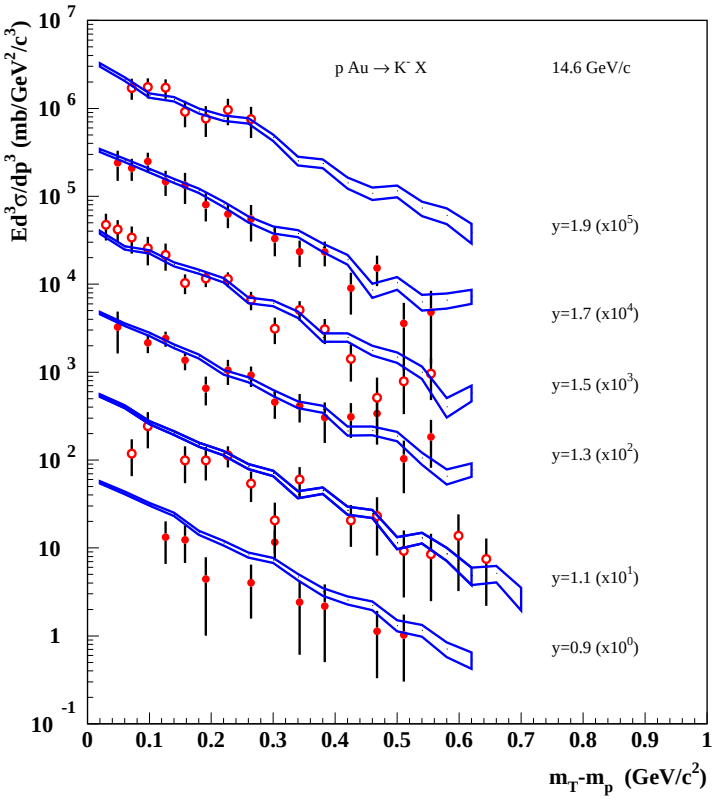
Neutral kaon production in proton-nucleus interaction and LAQGSM

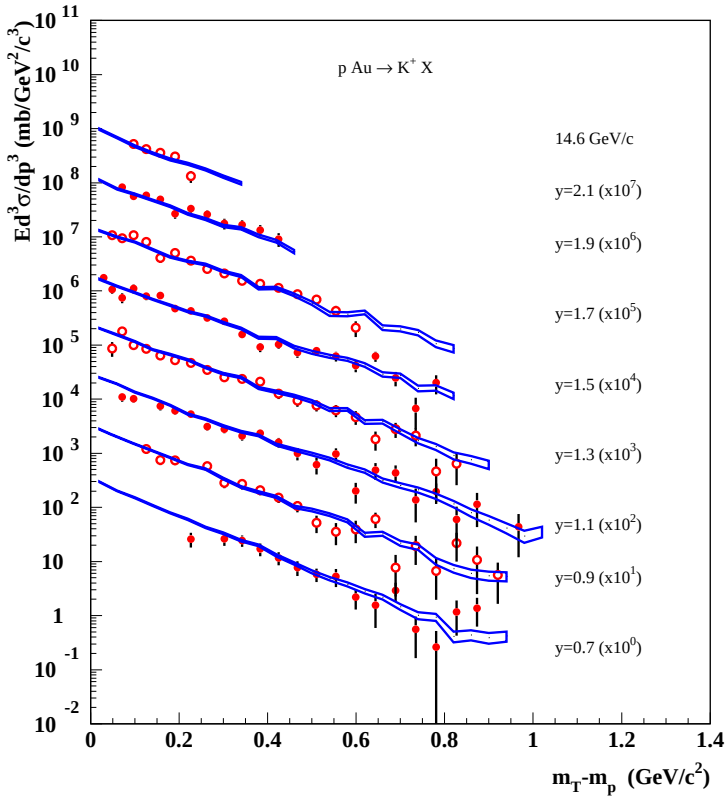


Red histograms – LAQGSM K_s, blue histograms LAQGSM $(K^+ + K^-)/2$

black points – KEK-049 data

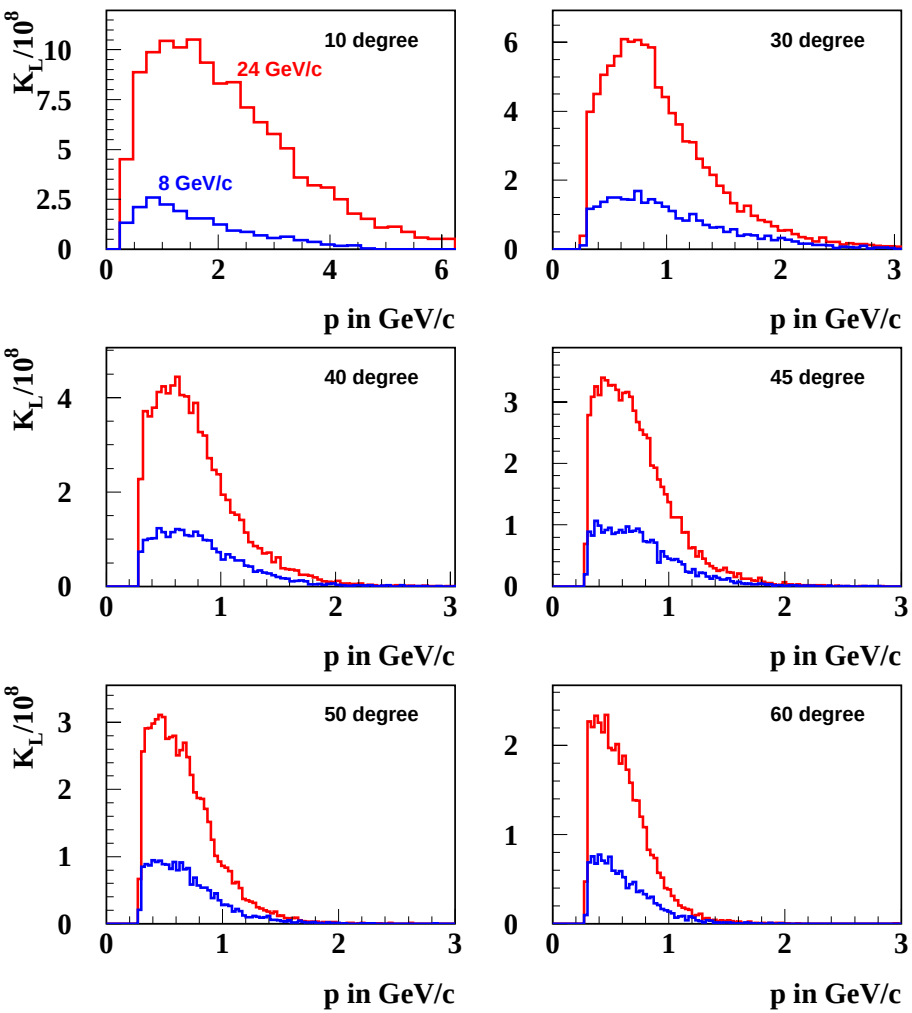
Charged kaon production in proton-nucleus interaction and LAQGSM





y=0.7 and m_T-m_p=0.26 GeV ↔ p=0.81 GeV/c and $\theta=45^0$

LAQGSM vs Kapinos-I



Production of K_L into 500 μsr by 5 10^{13} protons (10 cm platinum target)

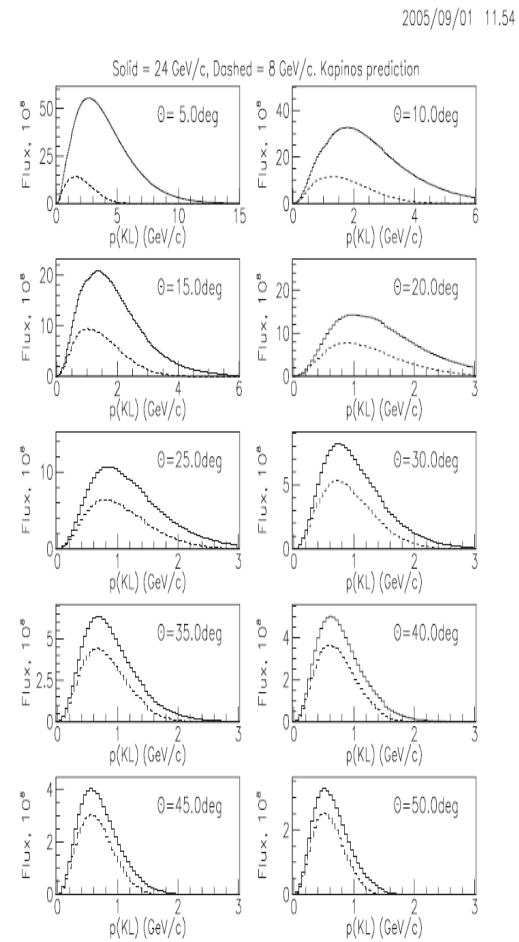
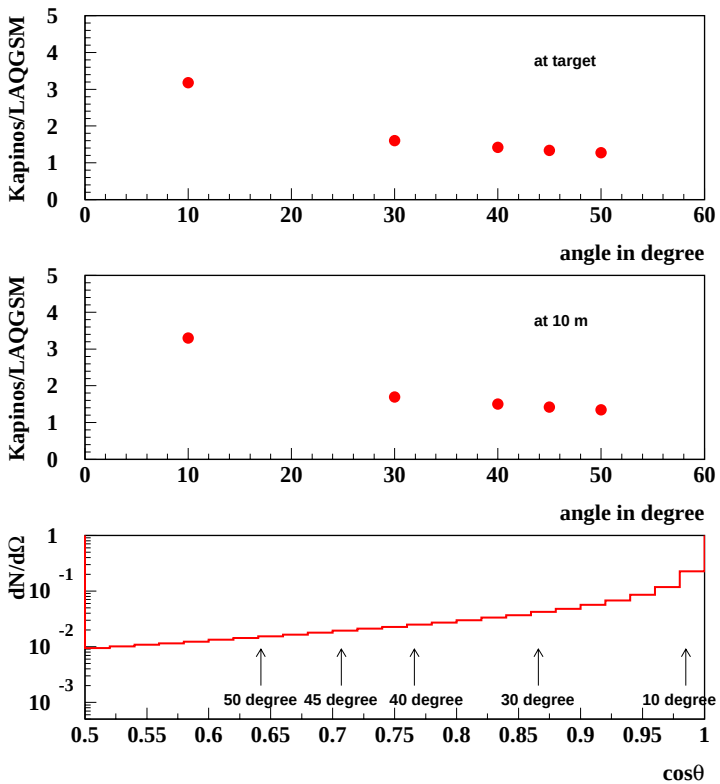


Figure 3: Production of K_L into 500μsr by 5×10^{13} protons for various central lab angles. Solid lines are for 24 GeV protons, dashed lines are for 8 GeV protons.

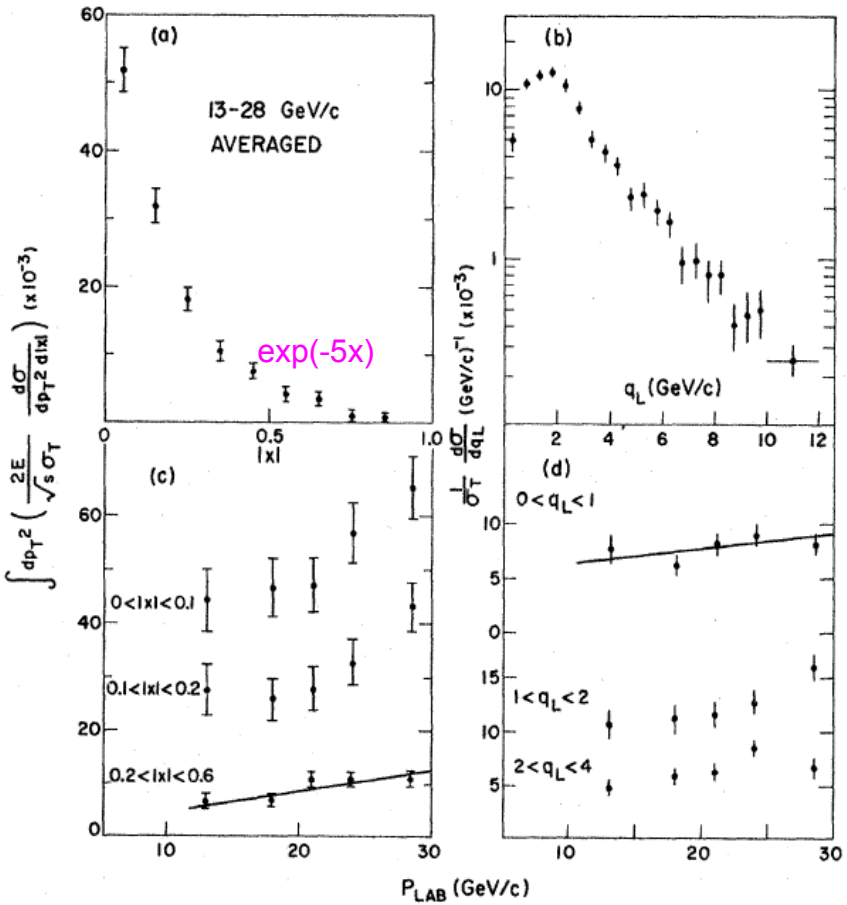
LAQGSM vs Kapinos-II

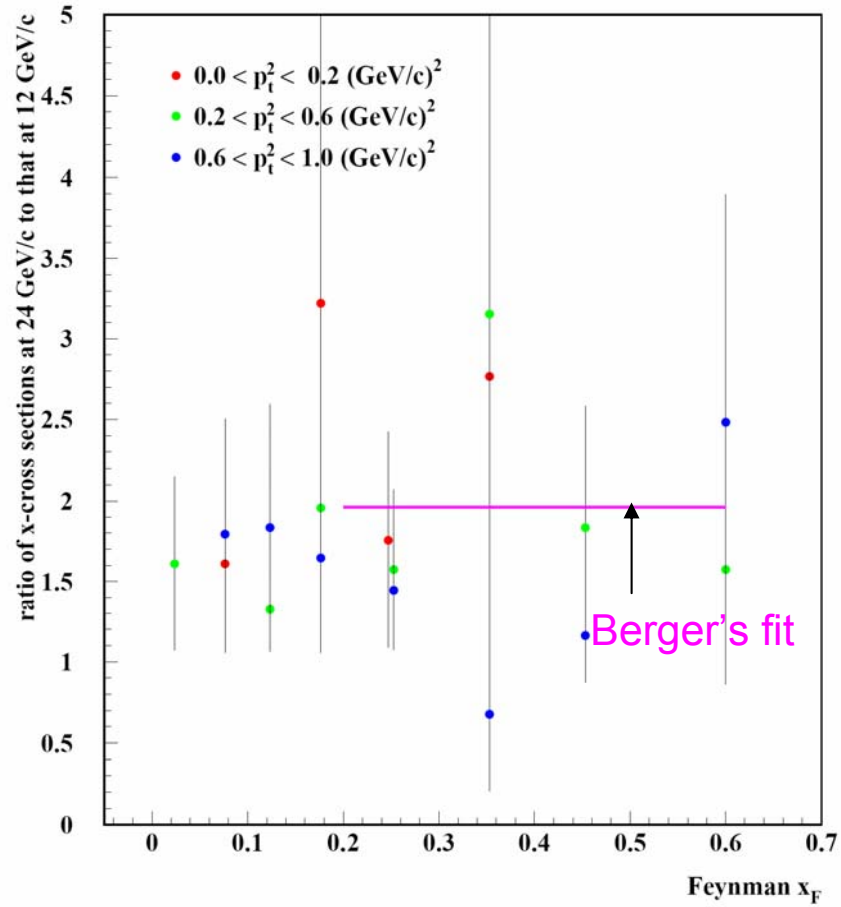
- LAQGSM and Kapinos predictions are in acceptable agreement at 24 GeV/c and large angle
- LAQGSM Monte Carlo scores particles in much large angular bins than 500 μsr. It could be origin of difference at small angles where x-section rises very fast
- LAQGSM predicts much larger number of neutral kaons than Kapinos model at 8 GeV/c



K_L production at 24 GeV/c (10 cm platinum target)

Neutral kaon production in proton-proton interactions



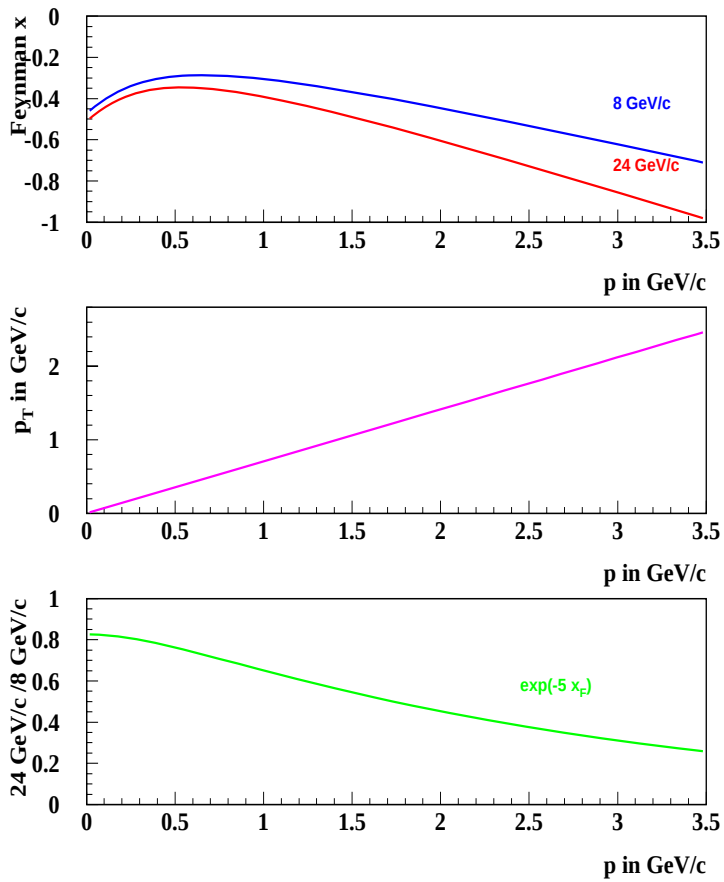


E.L.Berger et al Phys.Rev.Lett. 28, 322 (1972)

V. Blobel et al Nucl.Phys. B69,454 (1974)

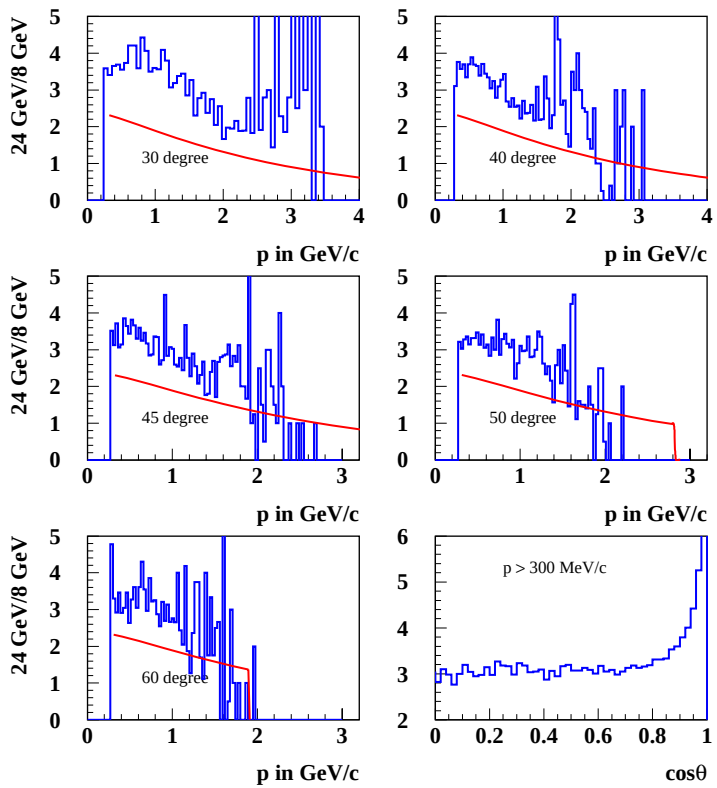
Neutral kaon production in proton-proton interactions

- Extrapolation of Berger et al fit => 24 to 8 GeV/c x-section ratio is about 2.9 at the same x_F (0.2-0.6 range)
- Due to x_F difference this ratio reduces about 15% at 0.5 GeV/c and 45 degree (near energy spectra maximum)
- From proton-proton data we can estimate x-section 24/8 ratio. For neutral kaon momentum of 0.5 GeV/c and 45 degree 24/8 ratio is about 2.2
- Experimental error of extrapolation is very large ~ 50%
- Kapinos 24/8 ratio is about 1.3 at 45 degree near maximum
- LAQGSM 24/8 ratio is about 3.3 at 45 degree near maximum

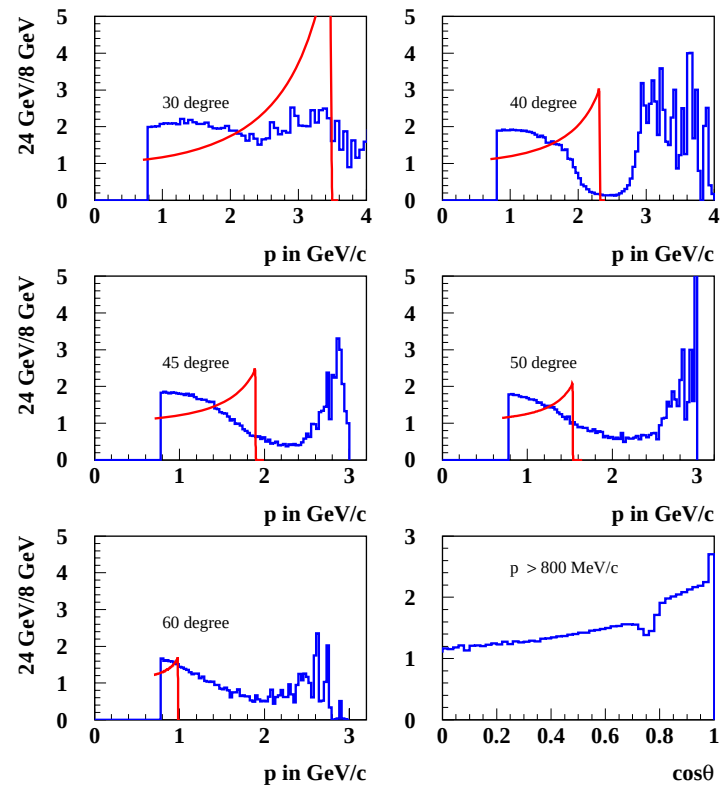


Feynman scaling prediction at 45 degree

Ratio of spectra at 24 and 8 GeV/c



Neutral kaon production from 10 cm platinum target (with 7 cm lead shield)



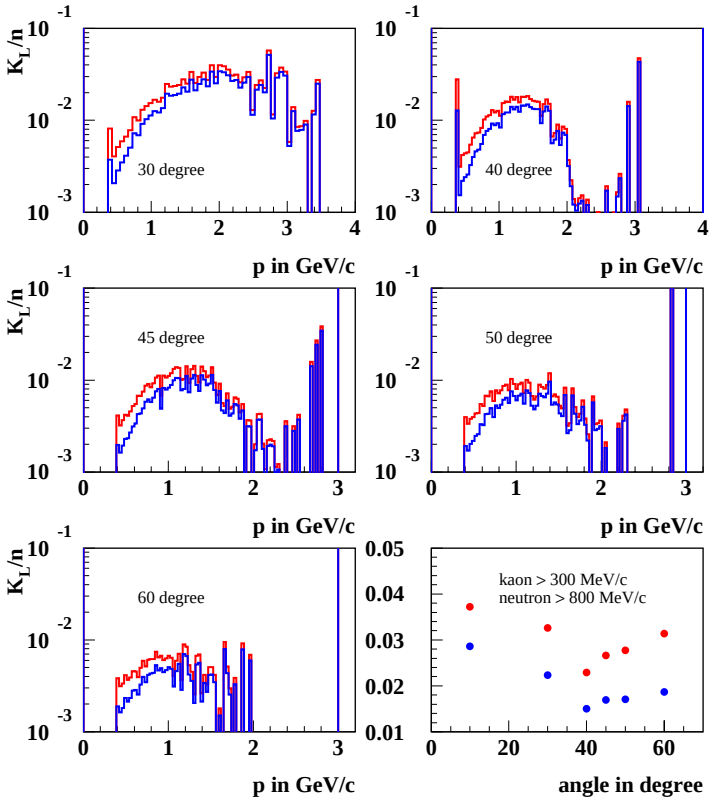
Neutron production from 10 cm platinum target (with 7 cm lead shield)

red – proton proton collisions

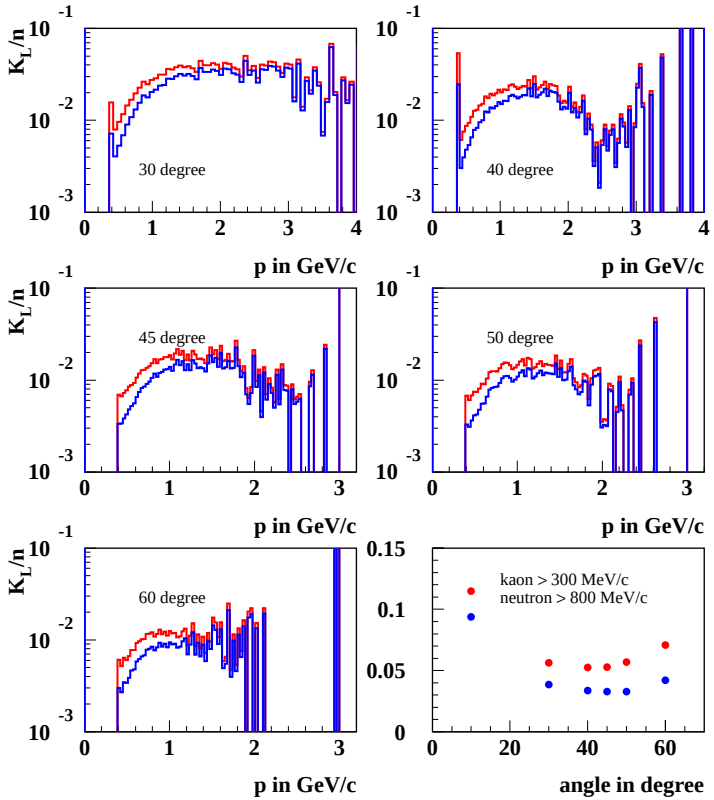
blue – proton on 10 cm platinum target

$\cos(45^0)=0.707$

Neutral kaon/neutron ratio at 24 and 8 GeV/c



Neutral kaon/neutron at 8 GeV/c. 10 cm platinum target with 7 cm lead shield.



Neutral kaon/neutron at 24 GeV/c. 10 cm platinum target with 7 cm lead shield.

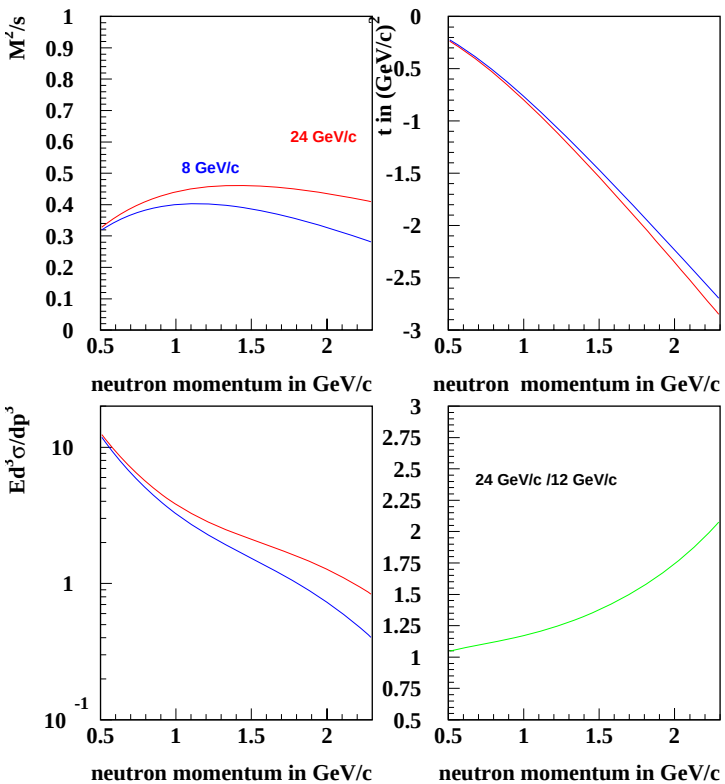
Red – 1m from target, blue – 10 m from target

Conclusions

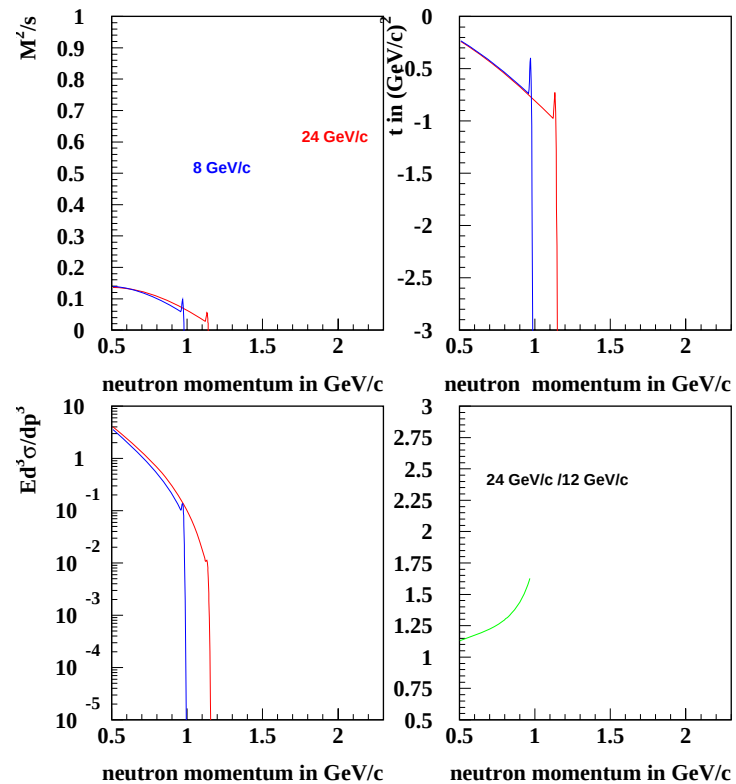
- LAQGSM agrees well with data on neutron/proton production at large angles and heavy target
- LAQGSM are in good agreement with data on neutral/charged kaon production at 12 and 14.6 GeV/c
- LAQGSM are in acceptable agreement with Kapinos model of neutral kaon production at 24 GeV/c and large angels
- LAQGSM and Kapinos models differ about 2.5 times at 8 GeV/c
- Extrapolation of proton-proton data to 8 GeV/c is closer to LAQGSM, but errors are too big to make definite conclusion
- Comparison with another codes (FLUKA, FRITIOF, UrRQMD …) is needed to verify neutral kaons yield at 8 GeV/c
- MARS-LAQGSM simulations predict that neutral kaon/neutron ratio at 8 GeV/c and 45 degree is about 2 times smaller than at 24 GeV/c

Backup slides

Neutron production in proton-proton interaction

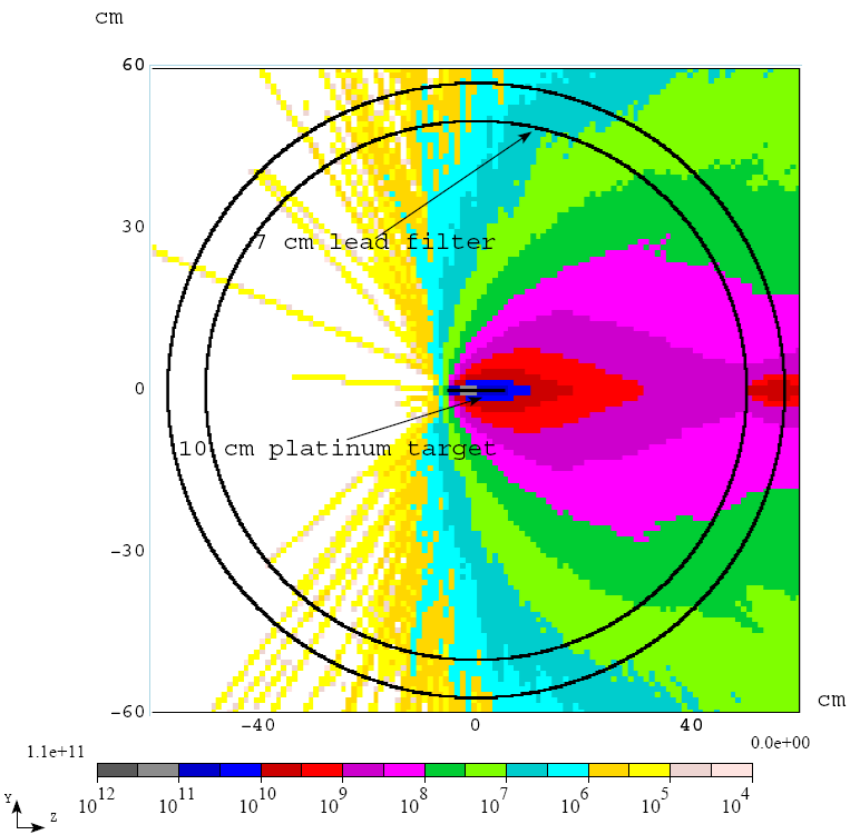


Neutron production in proton-proton collision at 30 degree

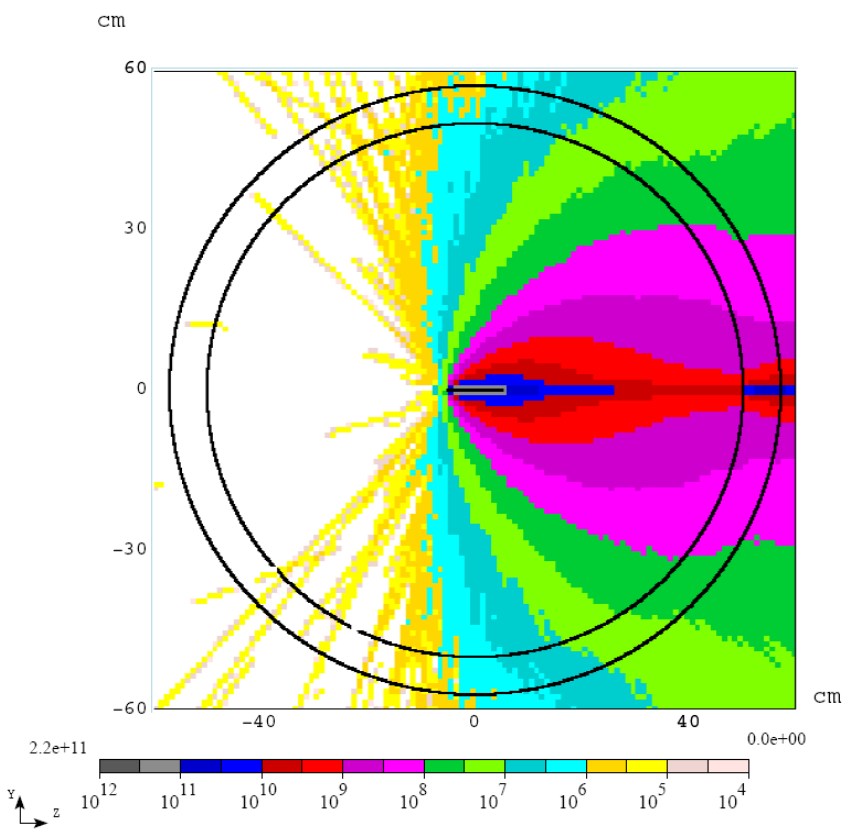


Neutron production in proton-proton collision at 60 degree

Protons on 10 cm platinum target. Neutron flux (1/cm^2/10^{12} protons in target)



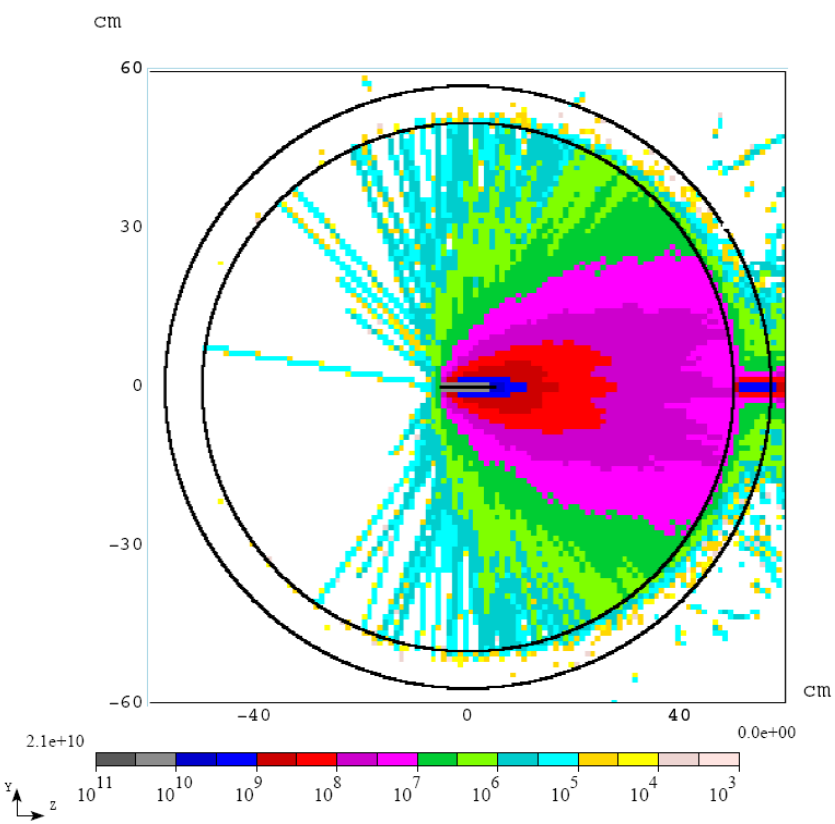
8 GeV/c



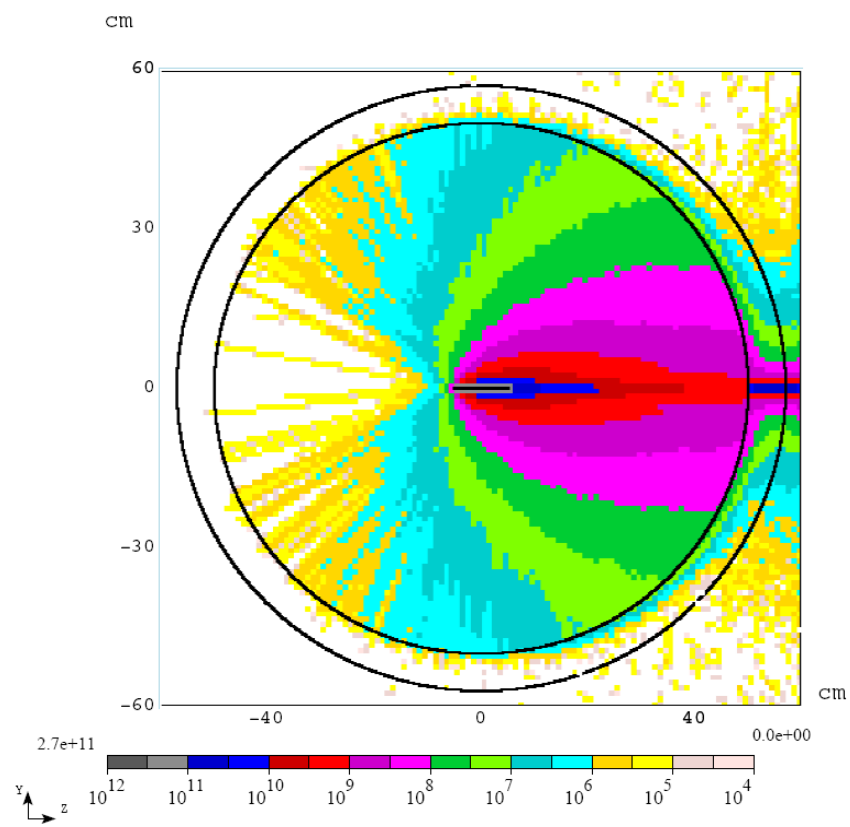
24 GeV/c

kinetic energy of neutrons > 294 MeV ↔ momentum > 800 MeV/c

Protons on 10 cm platinum target. Gamma flux (1/cm^2/10^{12} protons in target)



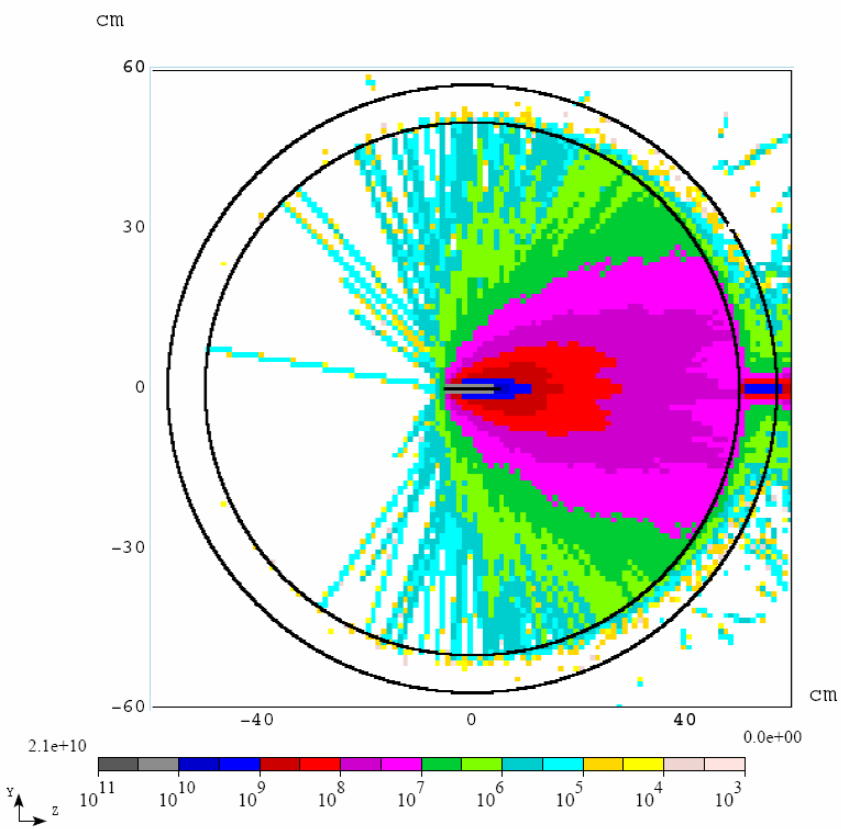
8 GeV/c



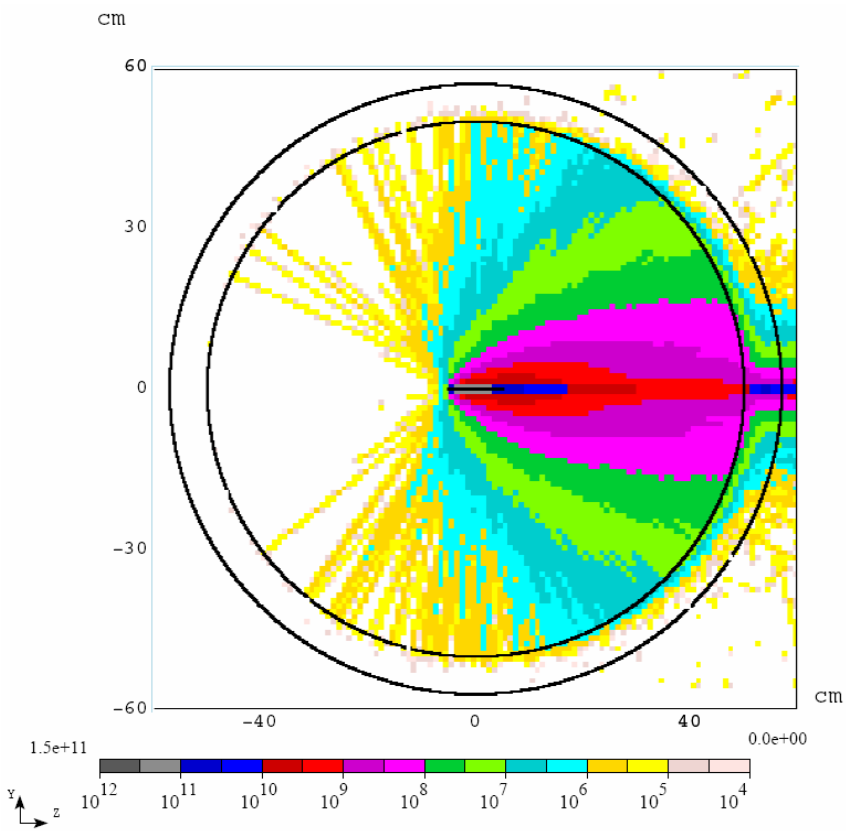
24 GeV/c

kinetic energy of gammas > 294 MeV

Protons on 10 cm platinum target. Electron flux (1/cm^2/10^{12} protons in target)



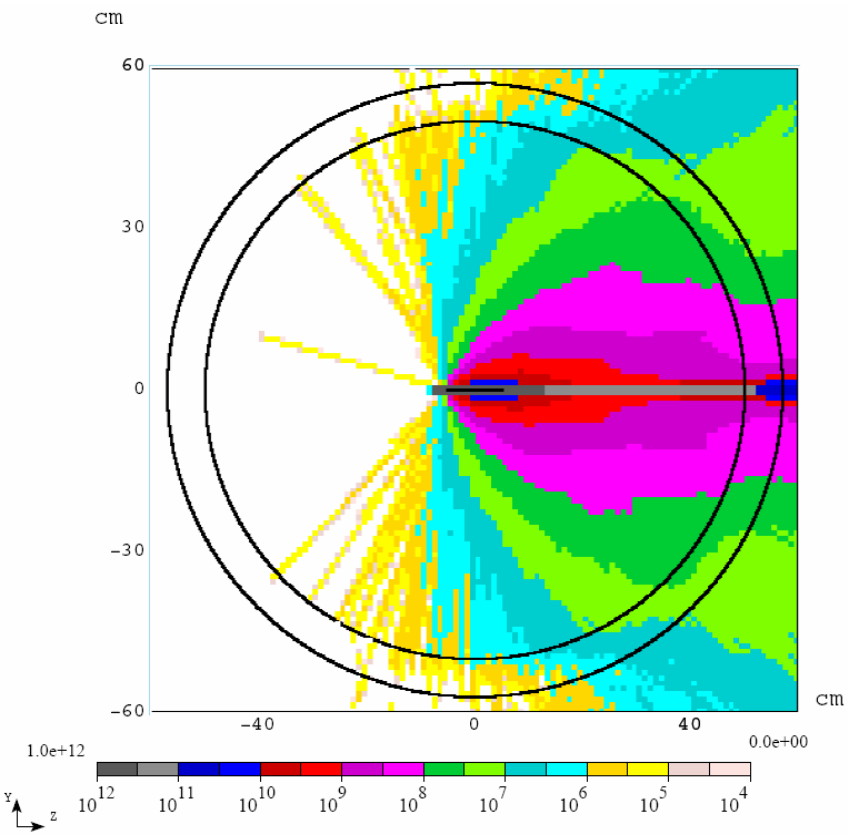
8 GeV/c



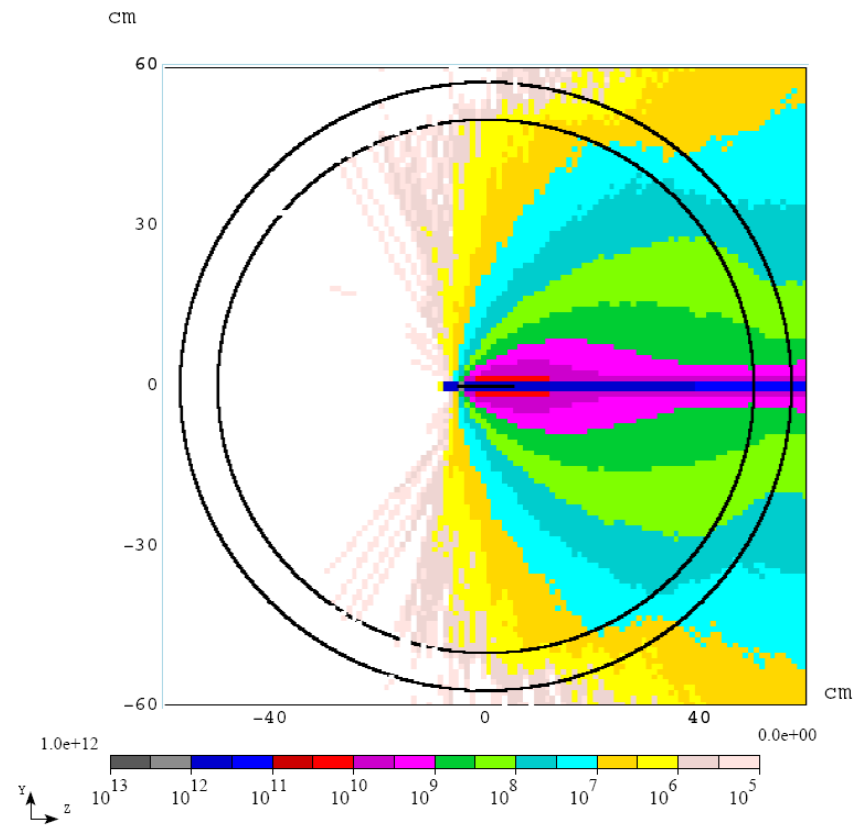
24 GeV/c

kinetic energy of electrons > 294 MeV

Protons on 10 cm platinum target. Proton flux (1/cm^2/10^{12} protons in target)



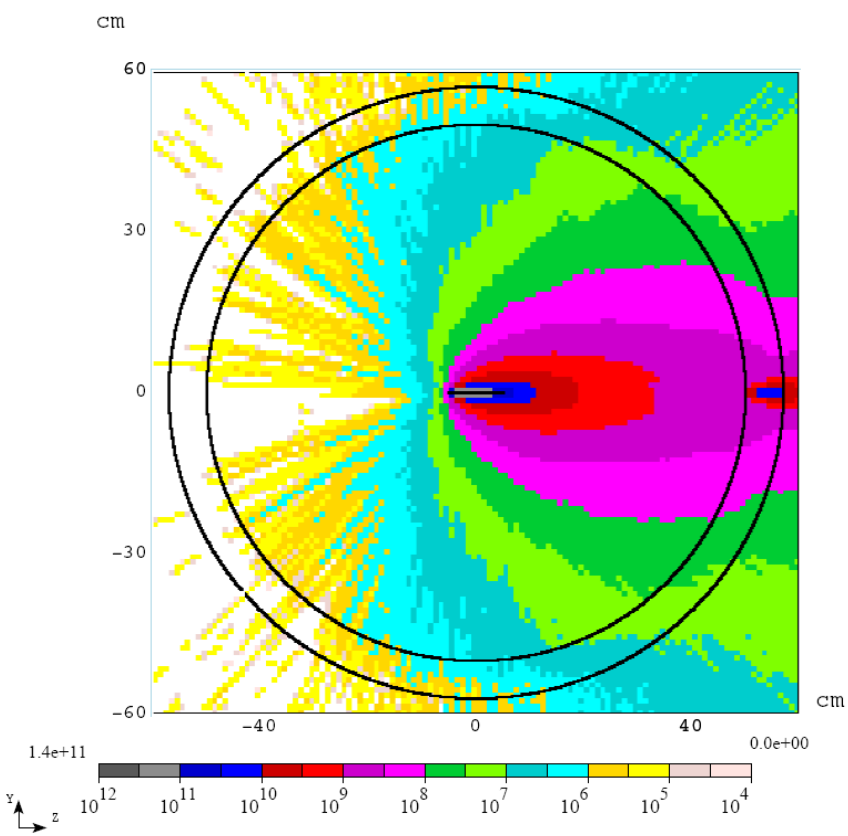
8 GeV/c



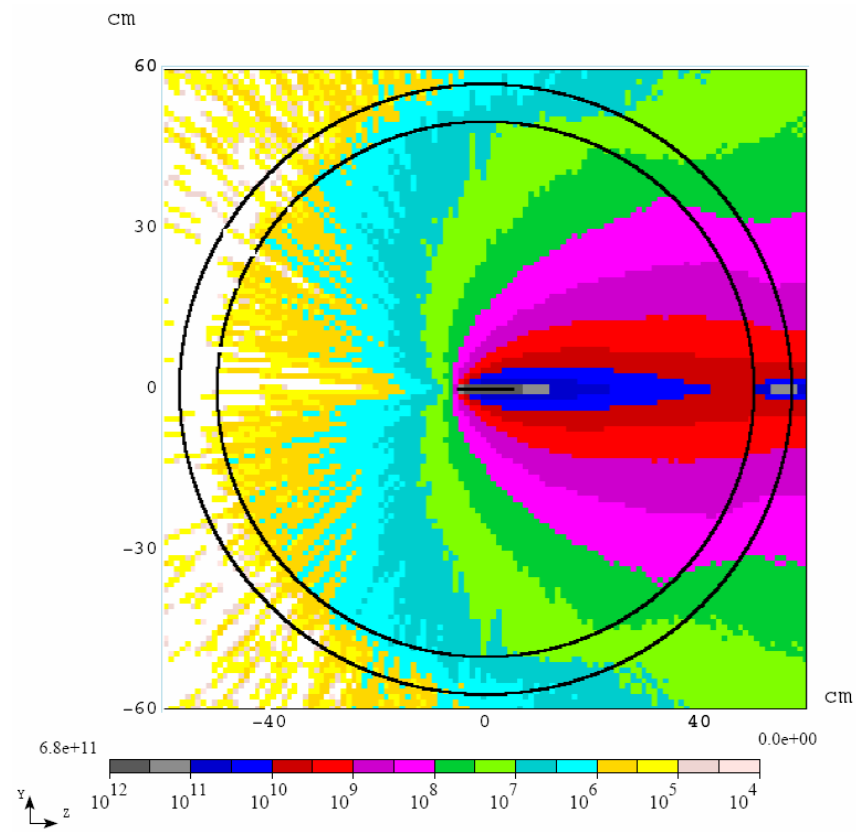
24 GeV/c

kinetic energy of protons > 294 MeV

Protons on 10 cm platinum target. Charged mesons flux ($1/cm^2/10^{12}$ protons in target)



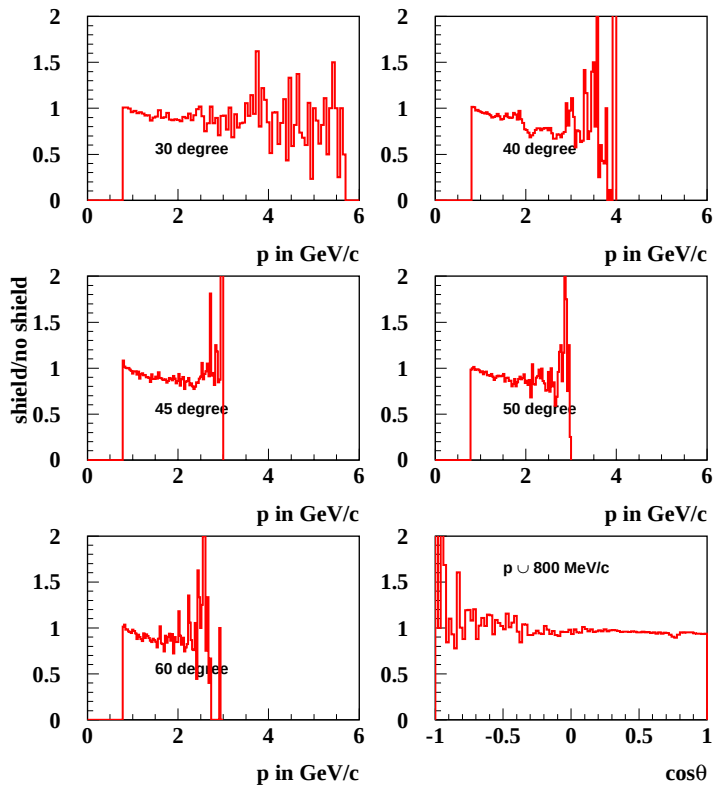
8 GeV/c



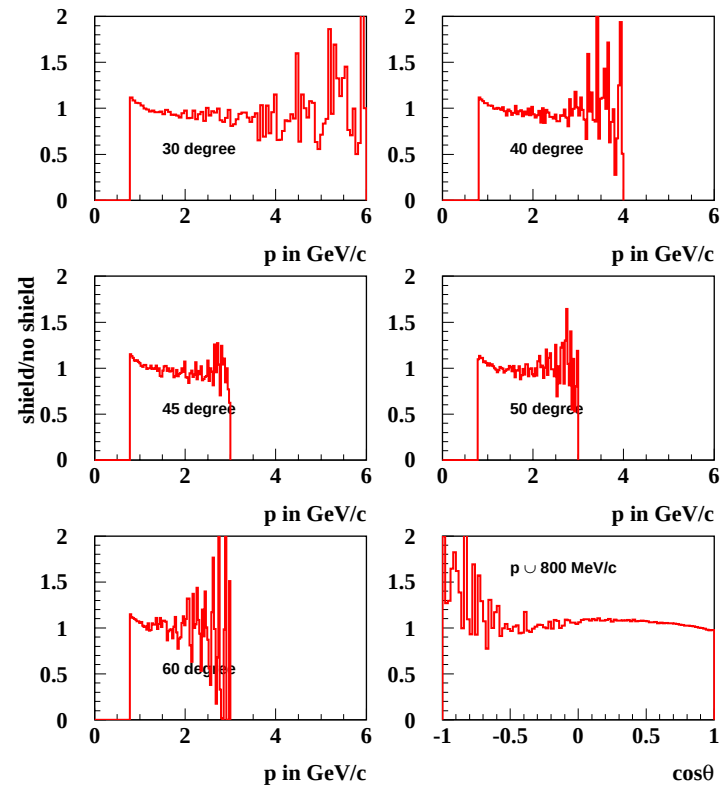
24 GeV/c

kinetic energy of mesons > 294 MeV

Ratio of neutron spectra with 7 cm lead filter and without filter



Neutron production from 10 cm platinum target at 8 GeV/c

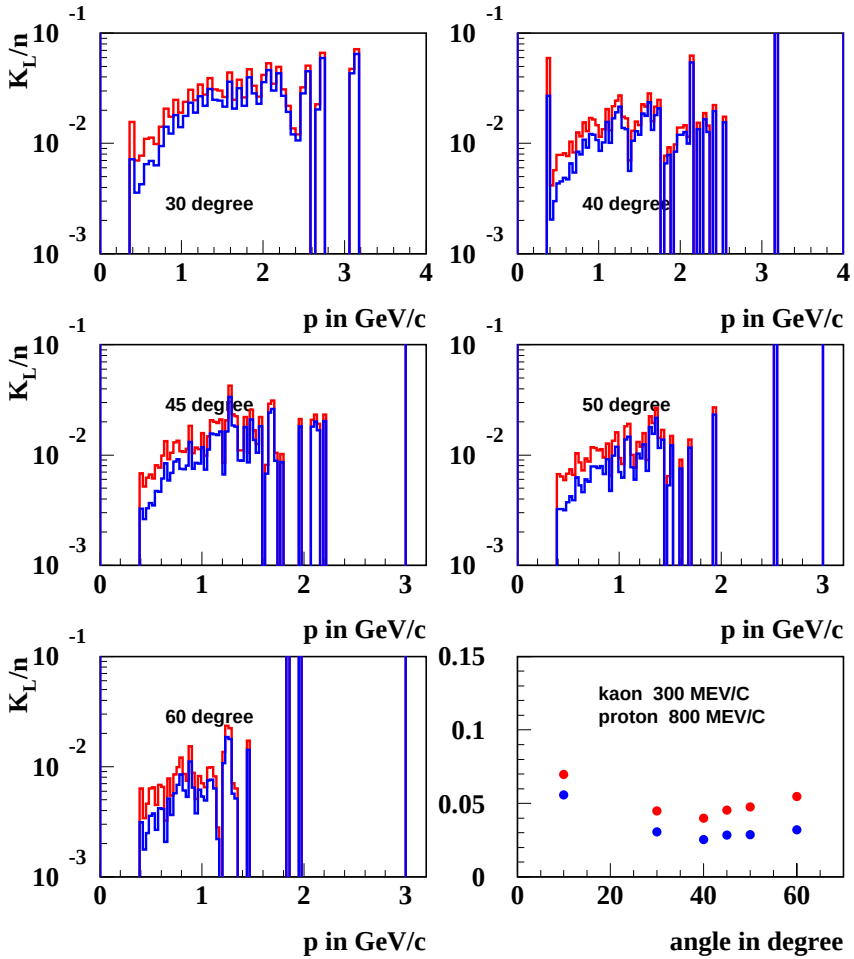


Neutron production from 10 cm platinum target at 24 GeV/c

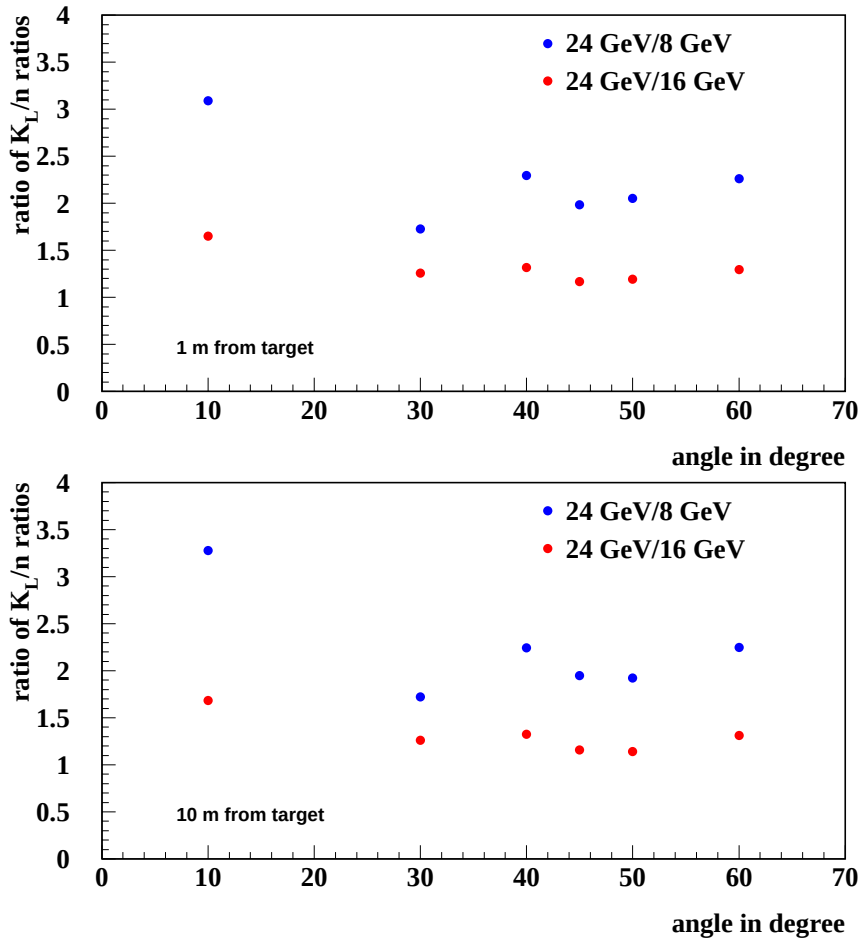
$\cos(45^0)=0.707$

Neutral kaon/neutron ratio at 8, 16 and 24 GeV/c

Red – 1m from target, blue – 10 m from target



Neutral kaon/neutron at 16 GeV/c. 10 cm platinum target with 7 cm lead shield.



Neutral kaon/neutron ratio at 8, 16 and 24 GeV/c.