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Hadron Physics with Neutrino Beams

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Nucleon spin structure

What can we learn with neutrino beams ?

Charmed nuclei

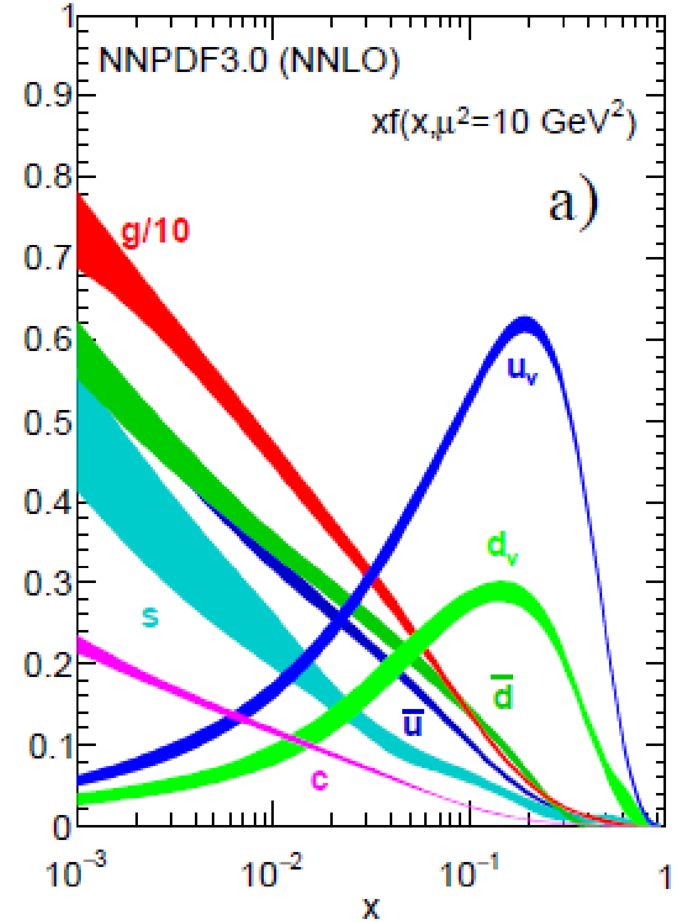
Can we discover charmed nuclei with neutrino beams ?

Proton structure function

- ν+N deep inelastic scattering PDG

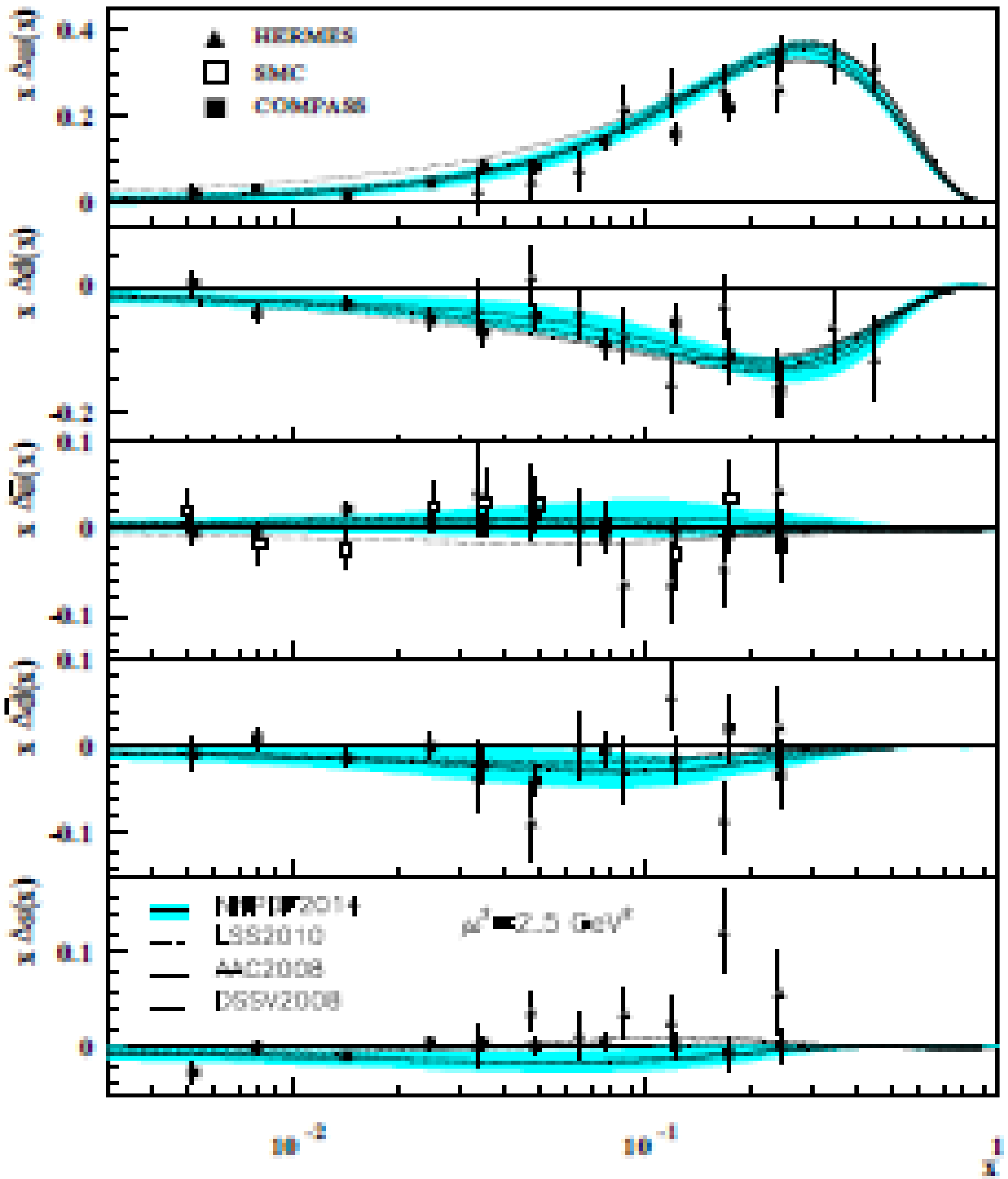
  anti-quark distribution
- ν+N -> μ+μ– X

  s-quark distribution



Quark spin distribution of proton

- PDG



Neutrino-pol.p scattering

- ν+pol.p DIS
  -> anti-quark spin polarization
- ν+pol.p -> $\mu+\mu-$ X
  -> s-quark spin polarization

- Large polarized p/D target
  ~1m pol. T (COMPASS)
- High energy neutrino beam

ν–p elastic scattering

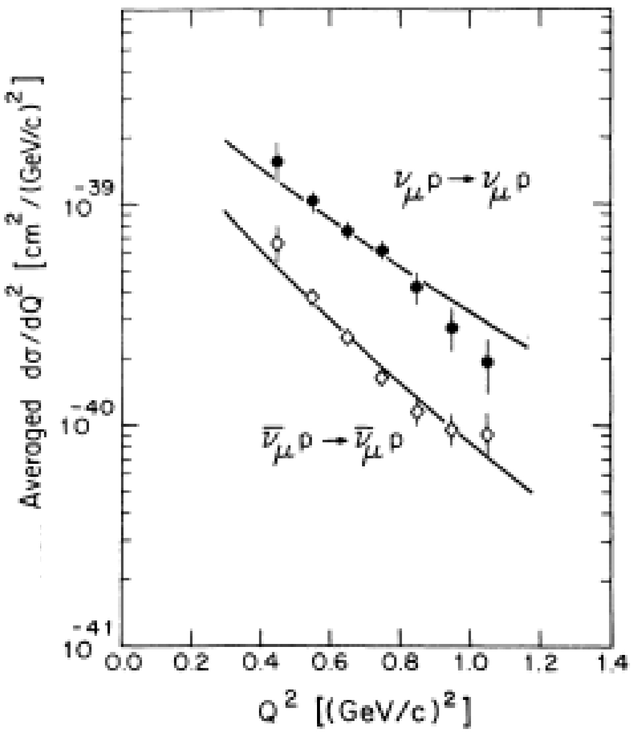
- $d\sigma/dQ^2 \sim G_A(Q^2), F_1(Q^2), F_2(Q^2)$
- axial form factor G_A can be determined by νp elastic scattering
- $G_A = G_A^{(3)} + \delta G_A$
- $G_A^{(3)} = g_A^{(3)}/(1+Q^2/M_A^{\ 2})^2$ $g_A = 1.267$
- $\delta G_A = -\Delta s/(1+Q^2/M_A^{\ 2})^2$ Δs ; s-quark polarization

Past experiment ; BNL-E734

L. Ahrens et al., PRD 35 (1987)

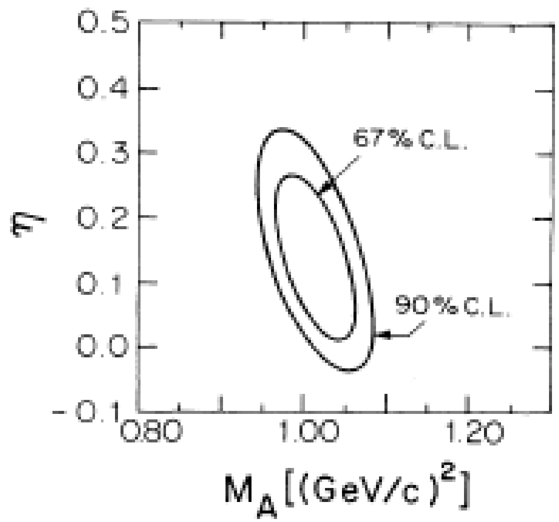
- 2.5×10^{19} POT
- 175ton Liq. Scint. + drift tube

$$G_A(Q^2) = \frac{1}{2}\frac{g_A(0)}{(1+Q^2/M_A^2)^2}(1+\eta)$$



$\eta = 0.12 \pm 0.07$

$\Delta s = -\eta g_A(0)$



~1000 event each

Recent activities

- MiniBooNE, SciBooNE measured $\nu p \to \nu p$
  Statistics is more than BNL E734
  Systematic error is larger?

- $\sigma(\nu n \to \nu n)/\sigma(\nu p \to \nu p)$ is more sensitive to Δs

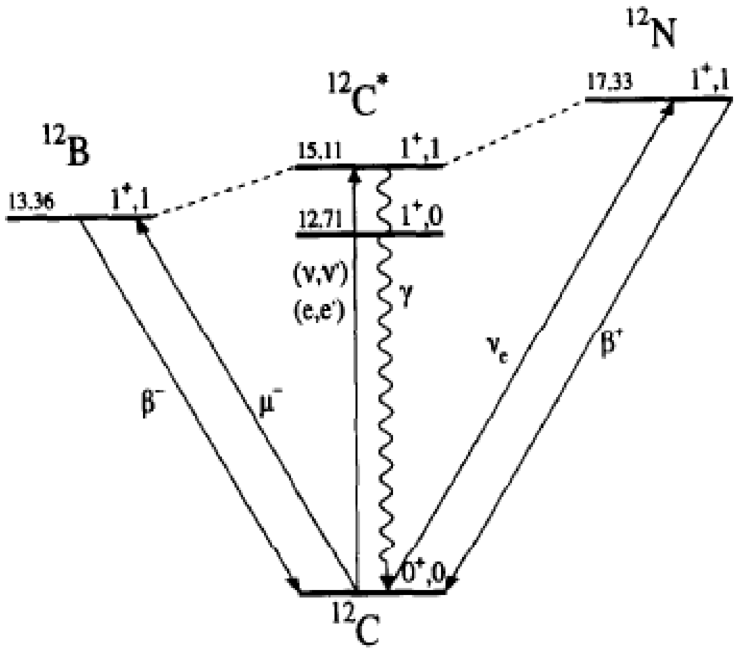
Dedicated experiment is necessary!

- To discuss Δs, higher precision is necessary
- Systematic errors should be reduced, especially nuclear effect.
- Data at Low Q^2 is important.

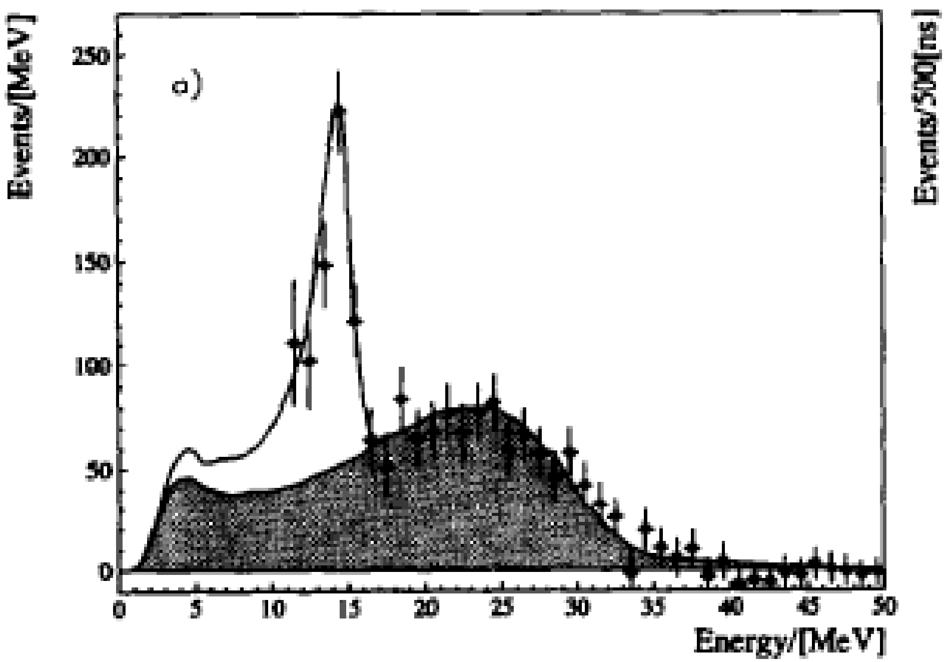
- Hydrogen bubble chamber seems suitable for this measurement. BEBC 2 ton H

D_2 bubble chamber may give $\sigma(\nu n \text{->} \nu n)$

$^{12}C\ (\nu,\nu')^{12}C^*$



KARMEN collaboration
470 events/ 56 ton liq. scint.
$6x10^{13}\nu/cm^2$
σ=10.9+-0.7+-0.8 $x10^{-42}cm^2$



γ spectrum from $^{12}C^*$

Spin-isospin filter of weak hadronic current

Charmed Nuclei

- Hyper-nuclei

  Λ (Σ, Ξ,) in nuclei

Spectroscopic study of hyper-nuclei is one of major physics at Hadron Hall at J-PARC

(Possibility of K-nuclei)

- Charmed nuclei (Super-nuclei)

  Λc in nuclei (D in nuclei)

discovery of a charmed nucleus will expand a field of nuclear and hadron physics

Theoretical prediction

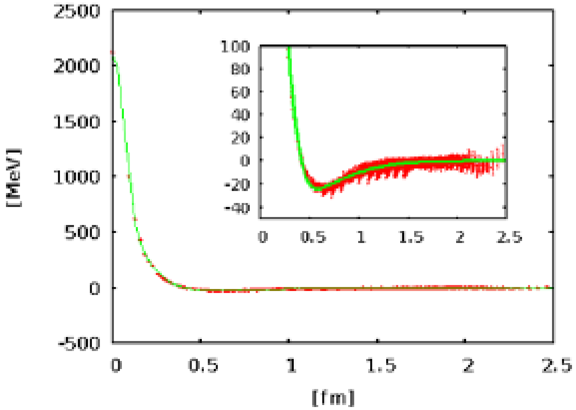
- Charmed nuclei should exist !

  - C. B. Dover and S. H. Kahana, Phys. Rev. Lett. 39, 1506 (1977).
  - H. Bandō and S. Nagata, Prog. Theor. Phys. (1983) 69.

  Λc-N interaction is attractive like NN (OBE model in SU(4))

- Lattice QCD (HAL collaboration)

  Λc-N is attractive but charmed deuteron may not be bound.

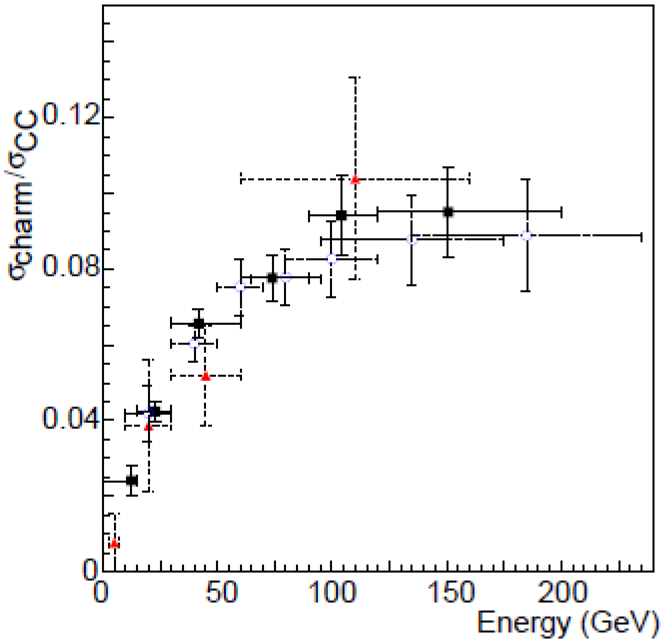


- D-nuclei (D-N bound state ?) S. Yasui

Charm production rate by ν_μ

CHORUS collaboration

$f_{D^0} = (43.7 \pm 4.5)\%$ $f_{\Lambda_c^+} = (19.2 \pm 4.2)\%$ $f_{D^+} = (25.3 \pm 4.4)\%$ $f_{D_s^+} = (11.8 \pm 4.7)\%$.



Charm fraction by neutrino is much much higher than hadron induced production !

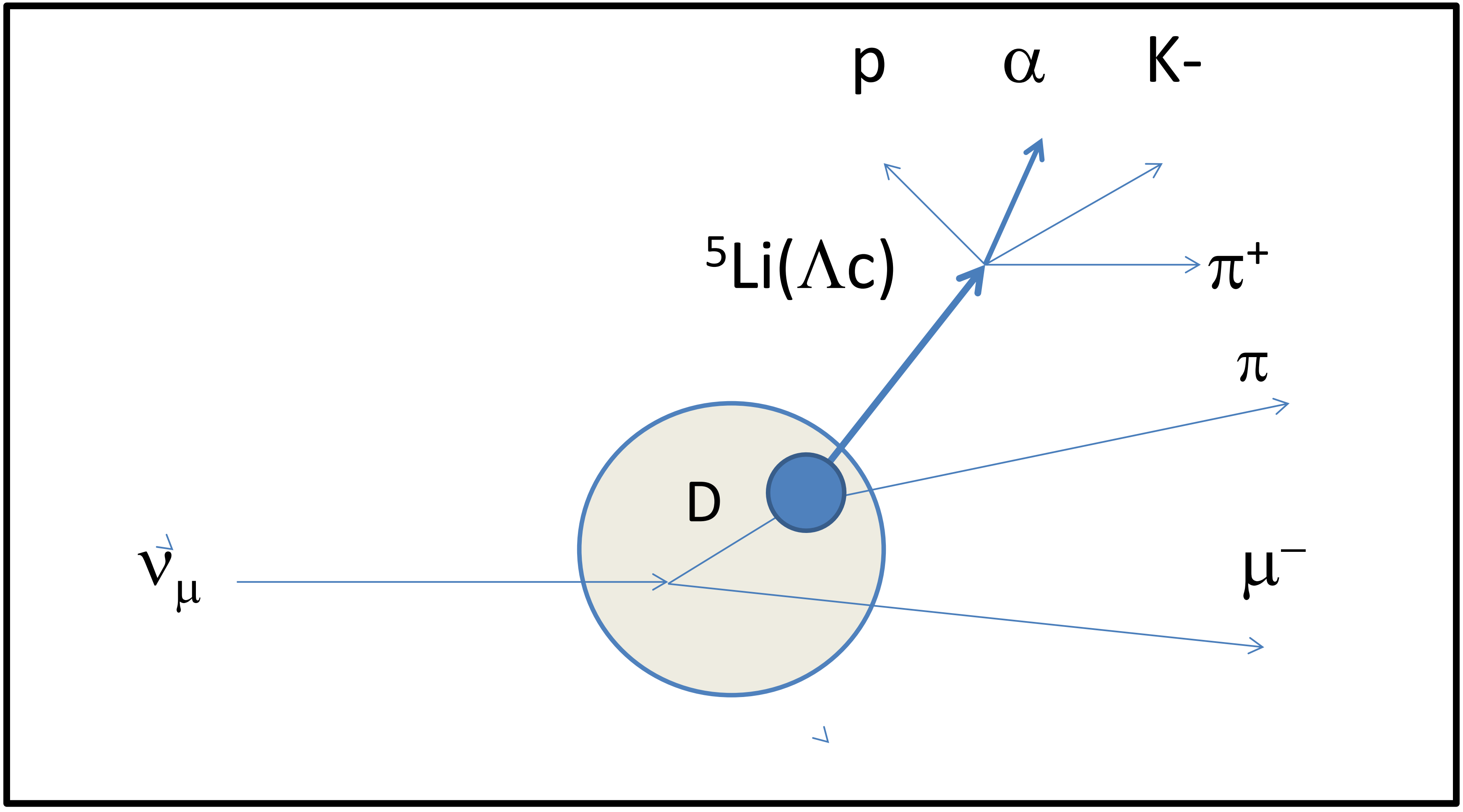
How to produce charmed nucleus with neutrino beam

- Hyperfragments were observed at the rate of ~5% of K^--nucleus reactions in the emulsion at P_{K-} up to 2 GeV/c.
- Λ momentum is small in K-N->$\pi\Lambda$ reaction and possibility of Λ trapping by a nucleus or its fragment is high.
- DN->$\pi\Lambda$c reaction has similar kinematics. There exists "magic momentum" around 0.8 GeV/c.
- To produce low momentum D, neutrino energy should not very high. Threshold energy for D is about 4 GeV.
- Emulsion seems only detector to identify a charmed nucleus.

  $c\tau(\Lambda c+)$ = 60μm, Λc+ -> pK-π+ 5%

  ^{5}Li(Λc+) -> α p K- π+ ($^5He_\Lambda$ -> α p π-)

$^{5}Li(\Lambda c)$ by neutrino



Very rough estimation of possible charmed nucleus production

- According to CHORUS
  2000 charmed hadrons
  / $5x10^{19}$ POT/ 700Kg emulsion target
- 10% of D interact in the same nuclei
- 5% of D reactions produce charmed nuclei
- 20% Detection efficiency

- 20000 D / $1x10^{21}$ POT -> 20 events !!

Summary

Neutrino experiments can

1) *provide a new insight on nucleon spin structure, especially anti-quark and strange quark.*
2) *produce charmed (super) nuclei.*

High intensity neutrino beams and dedicated experiments will be necessary.

Neutrino from neutron source