Measurement of Δs with Neutrino-Nucleon Elastic Scattering at J-PARC

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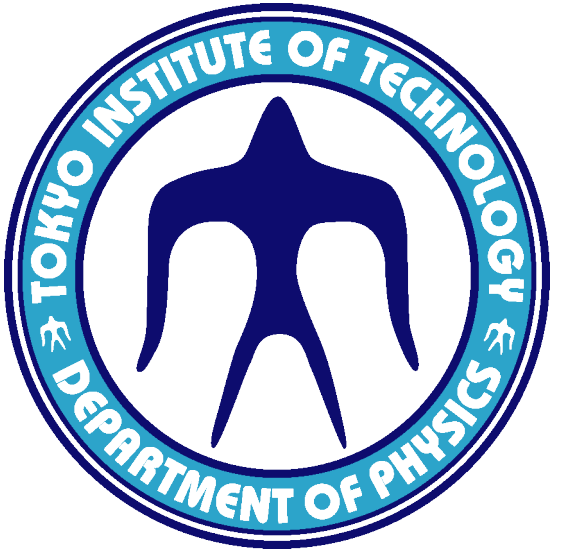
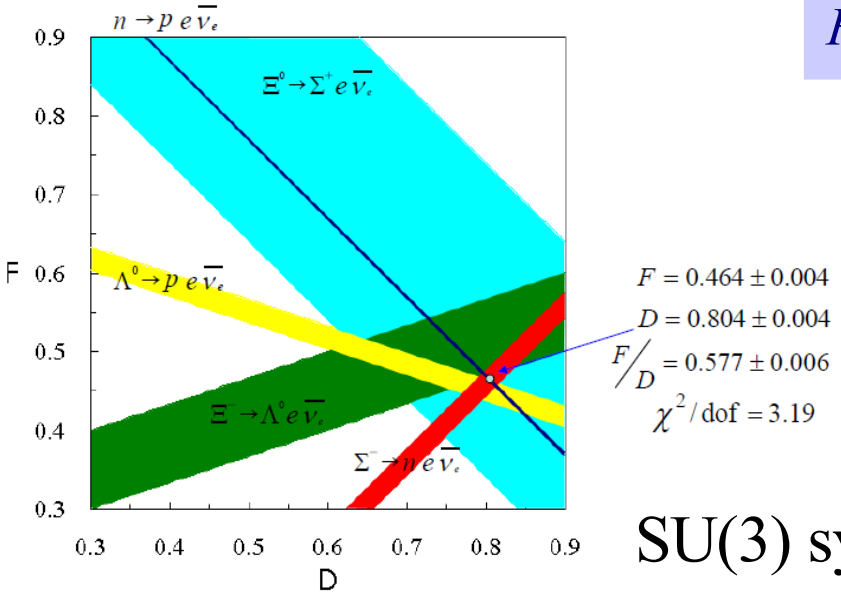
for the NeuSpin study group

- SU(3) breaking and Δs
- Neutrino Scattering and Δs
  - E734
  - Experiment at J-PARC
- Summary



SU(3) breaking and Δs



$F = 0.464 \pm 0.004$
$D = 0.804 \pm 0.004$
$F/D = 0.577 \pm 0.006$
$\chi^2/\mathrm{dof} = 3.19$

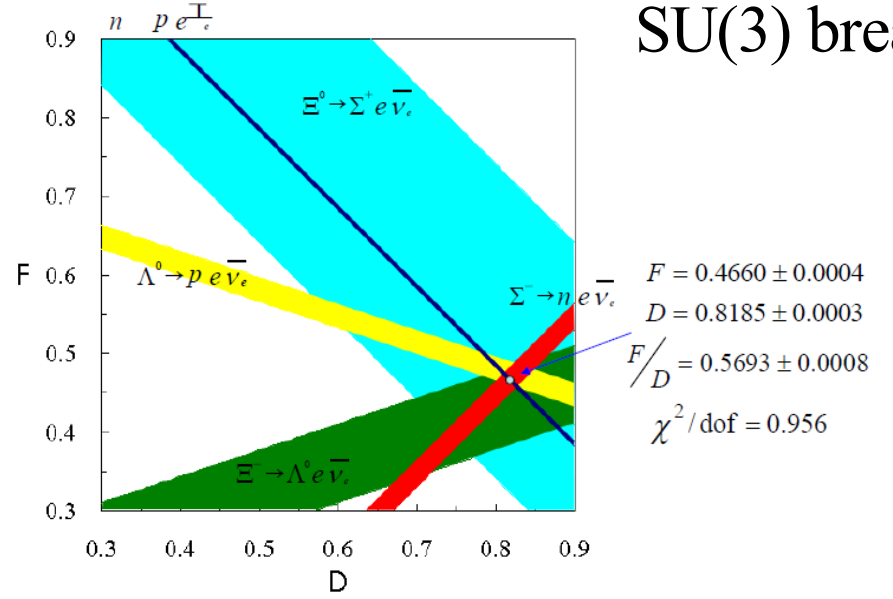
From Yamanishi's talk @ JPS meeting (March 28, 2006)

$$\Delta s = 3\Gamma_1^p - \frac{3}{2} D \left(F/D + \frac{1}{9} \right)$$

$$\Gamma_1^p = 0.126 \pm 0.01 \pm 0.015$$

SU(3) symmetry

$$\Delta s = -0.256 \pm 0.054$$



$F = 0.4660 \pm 0.0004$
$D = 0.8185 \pm 0.0003$
$F/D = 0.5693 \pm 0.0008$
$\chi^2/\mathrm{dof} = 0.956$

SU(3) breaking

$$\Delta s = -0.185 \pm 0.054$$

Updated numbers are in Yamanish's talk...

χQM calculation:

(*X. Song et. al., Phys. Rev. D55 (1997) 2624-2629*)

SU(3) breaking: Δs = -0.05

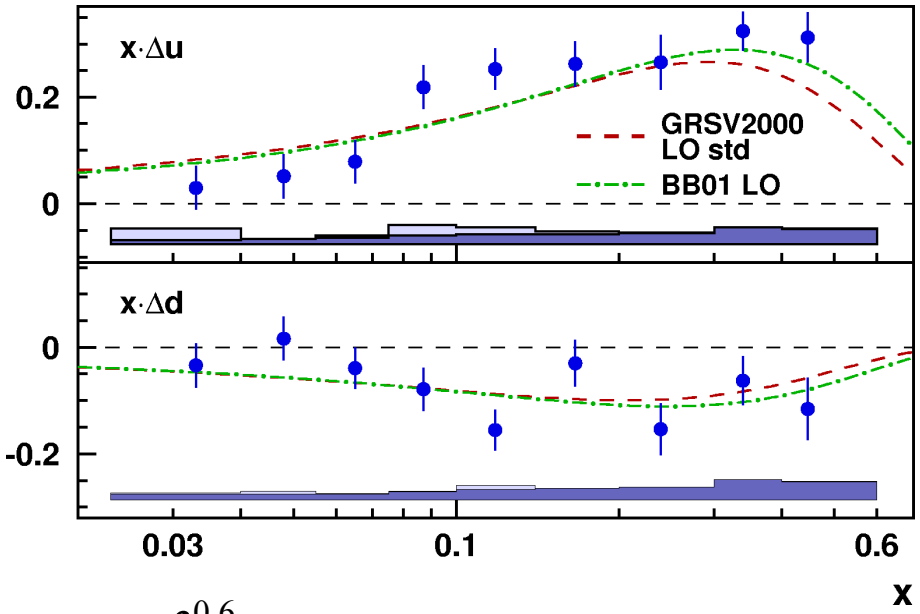
SU(3) symmetry: Δs = -0.1

Δs(x) from SIDIS

- HERMES results -

$\vec{e}+\vec{N}\rightarrow e'+h+X$

$\Delta\bar{s}(x)=0$ assumed



$$\Delta q=\int_{0.023}^{0.6} dx\,\Delta q(x) \qquad Q^2=2.5\,GeV^2$$

$\Delta u=0.601\pm0.039\pm0.049$

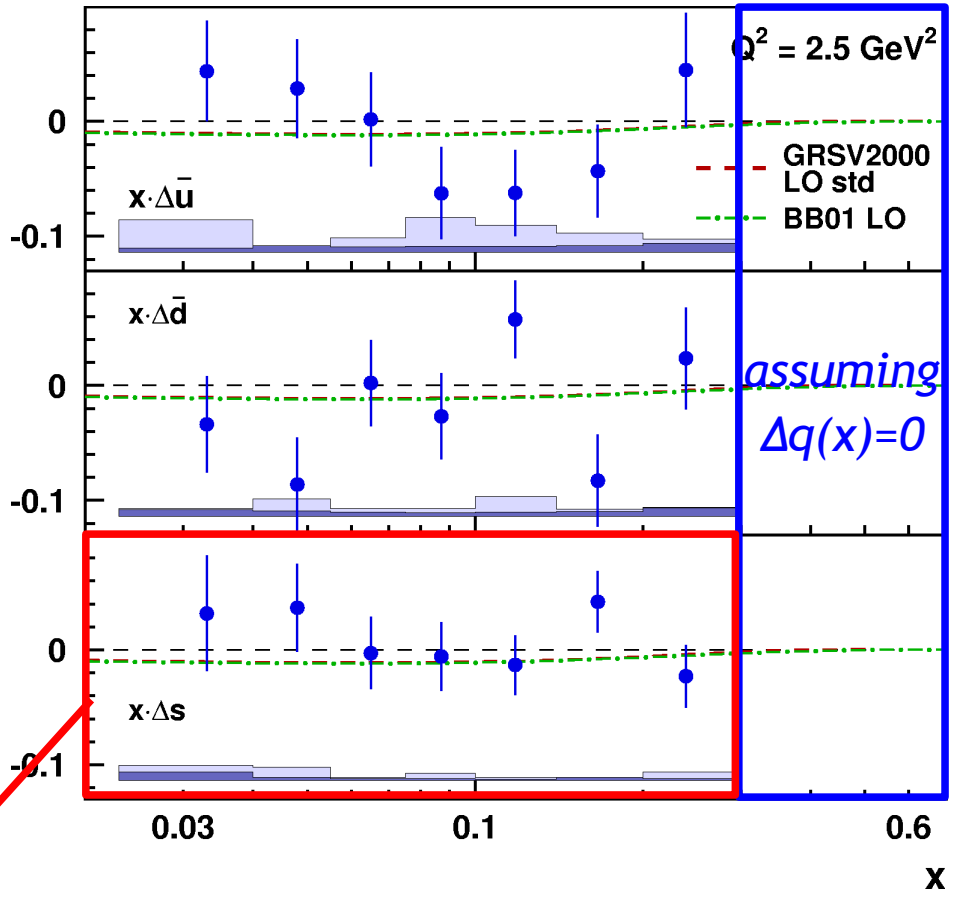
$\Delta d=-.226\pm0.039\pm0.050$

$\Delta\bar{u}=-.002\pm0.036\pm0.023$

$\Delta\bar{d}=-.054\pm0.033\pm0.011$

$\Delta s=0.028\pm0.033\pm0.009$

Phys. Rev D 71 (2005) 012003



- without SU(3) symmetry assumption
- only partial moments are available

Iso-scalar extraction of Δs(x)

Alternative method to extract Δs(x)

Data: Deuteron target

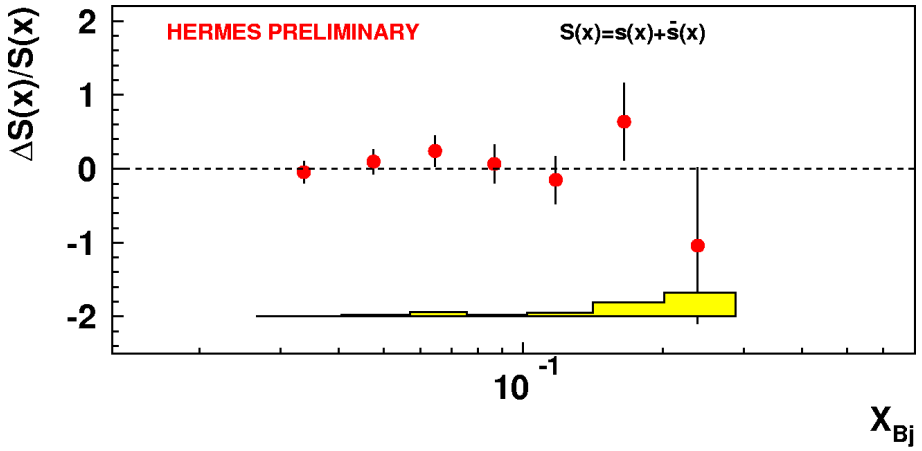
- Inclusive asymmetry
- $K^+ + K^-$ asymmetry
- K multiplicity

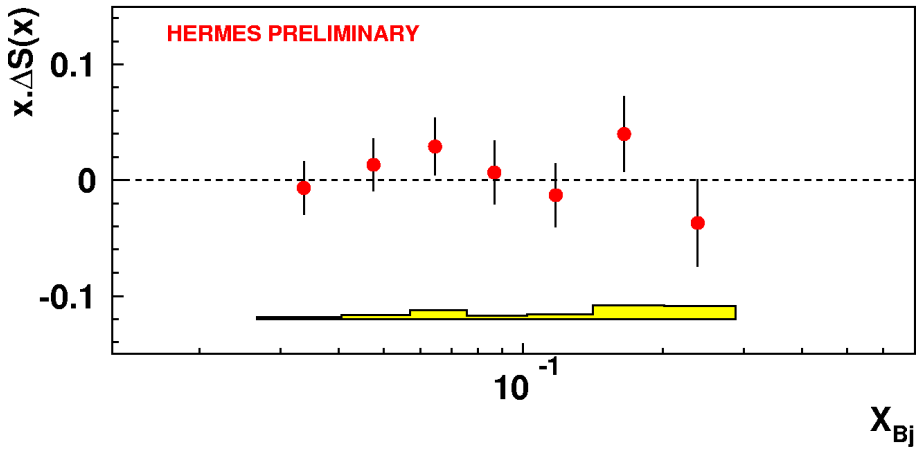
$$\Delta Q(x) = \Delta u(x) + \Delta \bar{u}(x) + \Delta d(x) + \Delta \bar{d}(x)$$

$$\Delta S(x) = \Delta s(x) + \Delta \bar{s}(x)$$

Free from Fragmentation model

reduce systematic uncertainty





$$\int_{0.02}^{0.6} dx\, \Delta Q(x) = 0.286 \pm 0.029 \pm 0.011$$

$$\int_{0.02}^{0.6} dx\, \Delta S(x) = 0.006 \pm 0.026 \pm 0.007$$

Neutrino scattering and Δs

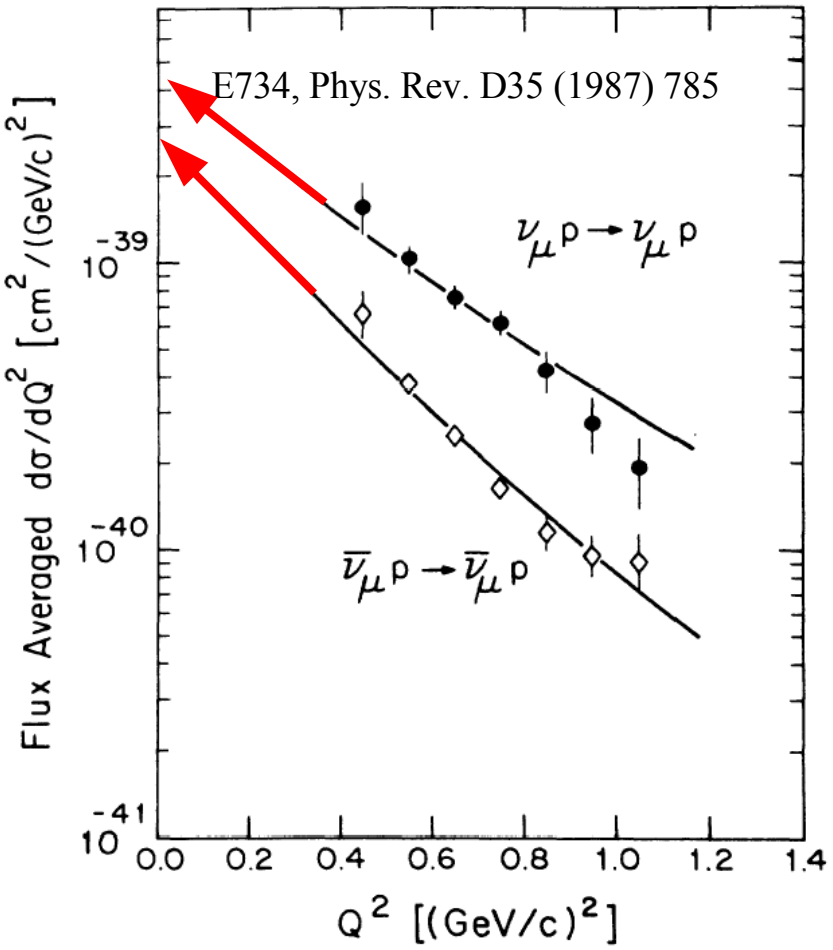
- E734 results -

- **Neutral current elastic scattering cross section**
  - Liquid scintillator + Drift Tube 170 t
  - $<E_\nu>$=1.3 GeV, 0.5E19 POT
  - $<E_{\nu\text{-bar}}>$=1.2 GeV, 2.5E19 POT
- **From $G_A^s(Q^2)$ to Δs**
  - $G_A^s(Q^2 \to 0) = \Delta s = -0.21 \pm 0.10$
- **Further analysis based on E734**

$$R^{\nu}_{NC/CC} = 0.152 \pm 0.007 \pm 0.017$$

$$R^{\bar{\nu}}_{NC/CC} = 0.218 \pm 0.012 \pm 0.023 \quad 0.5 < Q^2 < 1.0\ GeV^2$$

$$R^{\nu/\bar{\nu}}_{NC} = 0.302 \pm 0.019 \pm 0.037$$

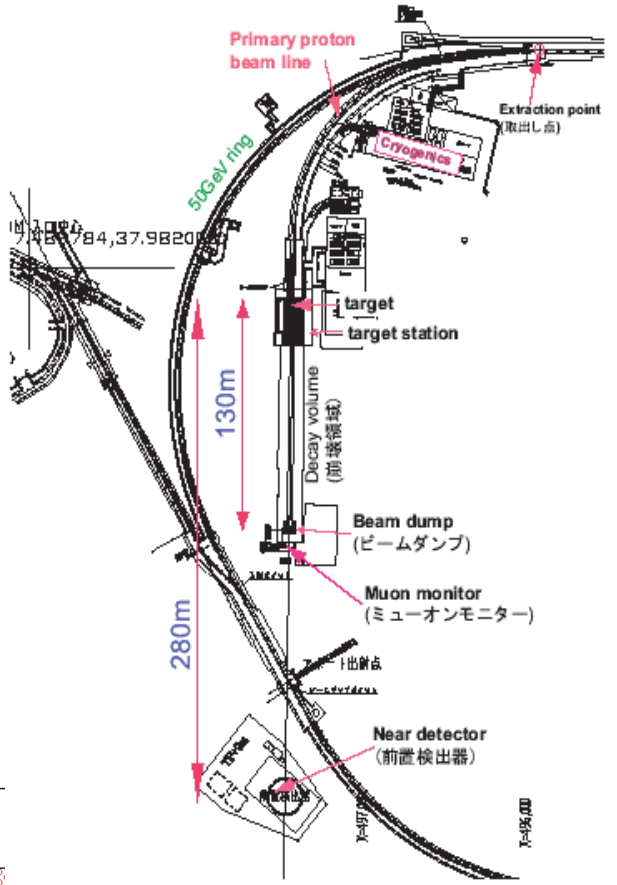


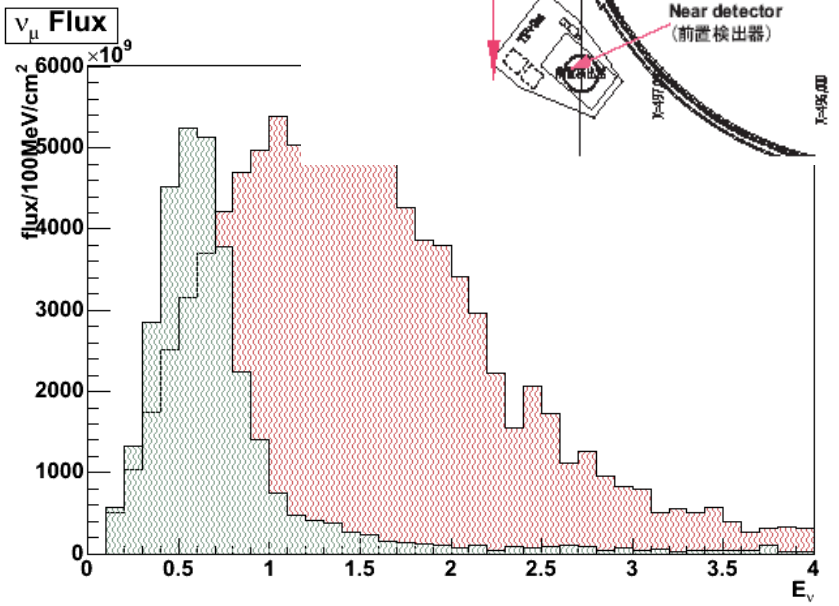
$-0.21 < \Delta s < 0$ strong correlation with the axial mass M_A

J-PARC ν-beam line

- **Beam flux**
  - 1 GeV for "on-axis"
  - < 1GeV for "off-axis"
- **10^{21} POT/year (130 days)**
  - 30 times BNL-E734
- **anti-neutrino beam**
  - neutrino anti-neutrino asymmetry measurement

Expected ν flux (MC data) →

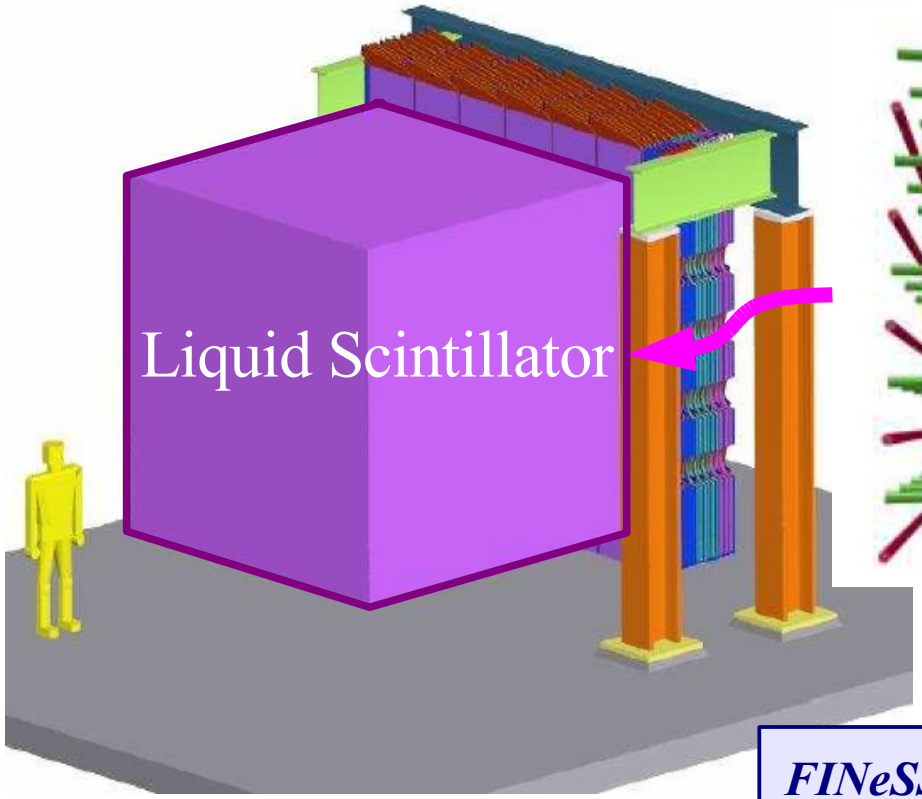


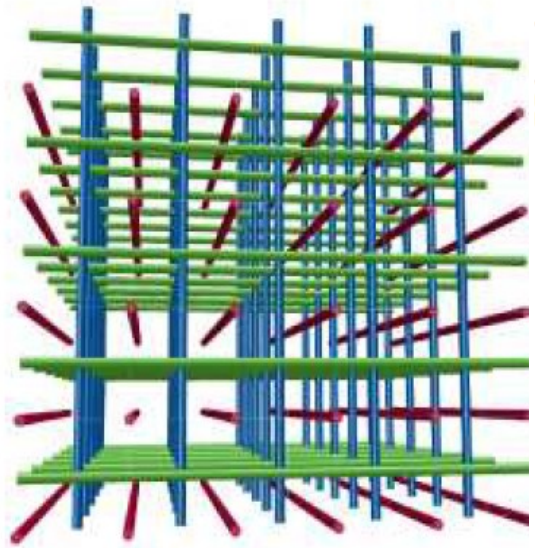


Nuclear Effect on Δs extraction

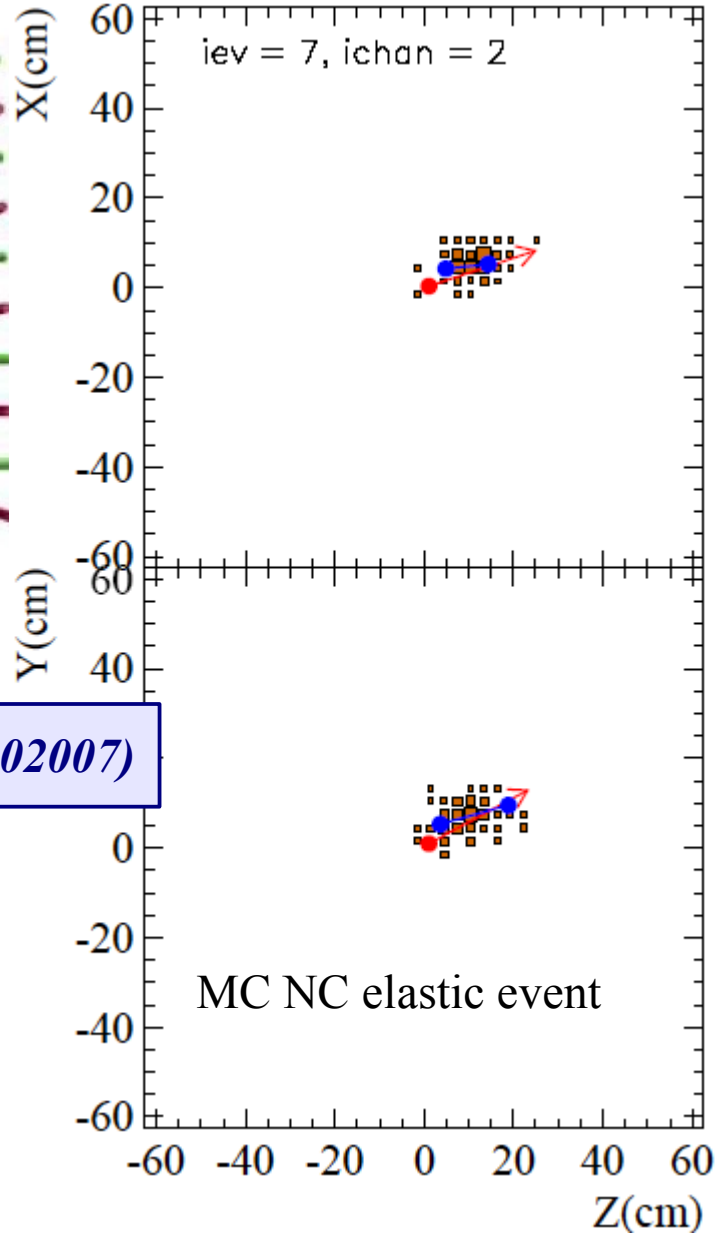
- **Nuclear effect (ex. C target):**
  - Nuclear model uncertainty on Δs extraction
- **ν-H scattering extraction: SciBath detector**
  - Using two targets with different mixture of H and C
    - Separation of ν-H and ν-C scattering becomes possible
  - Neutrino flux information is needed to extract the cross section.
- **R(NC/CC) measurements: SciBar detector**
  - Neutrino flux should be canceled. It also suppresses the nuclear effect.
  - Nuclear effects in NC and CC at the small Q^2?

SciBath Detector: FINeSSE





WLS readout



FINeSSE Proposal (hep-ex/0402007)

- Isotropic detector
- Different H:C mixture targets exist:
  BC501A(H/C~1), BC533(H/C~2)

Sensitivity at J-PARC

- **Beam: (using T2K neutrino beam MC data)**
  - 1E21 POT, off-axis (2.5°), 280m from the production target
    - 30 times BNL-E734, peak energy E_ν=0.6 GeV and narrow width
- **SciBath: Liquid scintillator dual target**
  - Dual 2.5x2.5x2.5 m^3 (using BC501A and BC533)
    - Nuclear effect free extraction
  - Neutrino interaction generator: NEUGEN 3.0
    - the dipole form factor, Fermi motion, Pauli Blocking
  - Detection efficiency from FINeSSE proposal: hep-ex/0402007
  - Lower Q^2 cut-off : 0.1 GeV^2

$$\delta(\Delta s)=0.03 \quad \text{(J-PARC)}$$

Statistical error only. The normalization error is under investigation.

Nuclear Effect on Δs extraction

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SciBar detector: K2K, SciBooNE, T2K

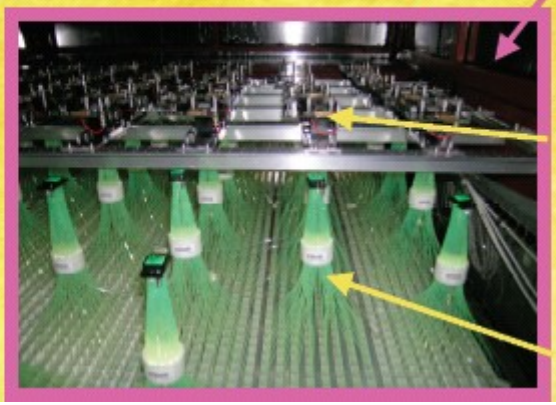
SciBar Detector

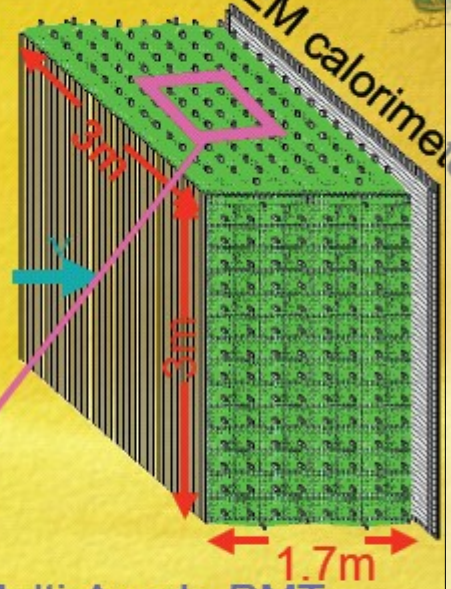
(NuFact06, H. Tanaka)

- Extruded scintillators with WLS fiber readout
- Scintillators are the neutrino target
- 2.5 x 1.3 x 300 cm^3 cell
- ~15,000 channels
- Identify short tracks (>8cm)
- Distinguish a proton from a pion by dE/dx
- Total 15 tons

➔High track finding efficiency (>99%)

➔Clear identification of ν interaction process





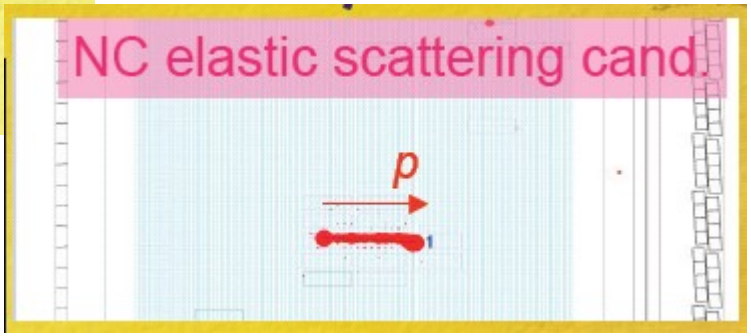
Multi-Anode PMT
(64 channels)

Wave-Length
Shifting fiber

For Δs measurement:

- Difficult to realize dual targets with different H-C mixture.
- Non-isotropic detector
- R(CC/NC) measurement

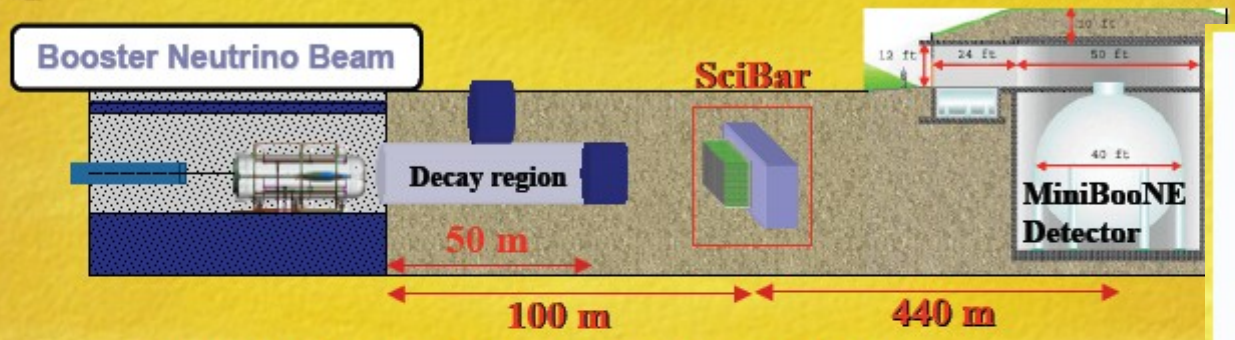
ex.) K2K Data



SciBooNE at FNAL

SciBooNE Experiment

FNAL Booster ν-beam + SciBar detector

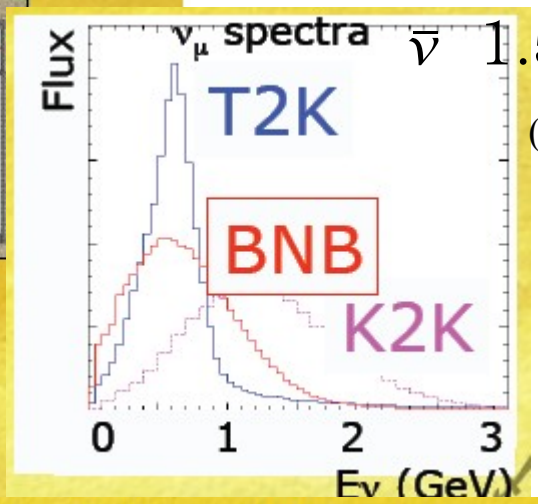


- FNAL Booster Neutrino Beam (BNB)
  - BNB has been providing neutrinos to MiniBooNE experiment since late 2002.
- SciBar detector
  - Near detector used in K2K experiment
  - Fine grained tracking detector

Combine well developed detector and well understood running beam
➔ Short timescale and modest cost

(NuFact06, H. Tanaka)

ν 0.5E20 POT
$\bar{\nu}$ 1.5E20 POT
(1 year data taking)



–Mar. 2005:	K2K ended
–Nov. 2005:	Submit proposal to FNAL
–Dec. 2005:	Approved
–Feb. 2006:	SciBar/EC disassembly
–Jun. 2006:	Ship detector to FNAL from KEK
–Jul. 2006:	Detectors arrived @FNAL
–Aug. 2006:	Civil construction contract
–Fall 2007:	Assembly
–Dec. 2006:	Detector Hall complete
–Jan. 2007:	Installation
–Feb. 2007:	Commissioning @SciBooNE hall
–Mar. 2007:	Beam data

σ : CC-1π, NC-1π^0, CCQE(ν-bar)

Summary

- **Proton spin problem**
  - Δs is a key.
- **Neutrino scattering: NC elastic scattering**
  - Unique tool for studying Δs (direct access to the first moment)
    - Nuclear effect: Dual SciBath, R(NC/CC)
    - Q^2 extrapolation to $Q^2=0$, normalization
  - Measurement at J-PARC
    - Sensitivity study:
      - 1E21 POT neutrino beam at 280 m away from the production target
      - Dual SciBath detector (BC501A and BC533)
      - **$\delta(\Delta s) \sim 0.03$** expected (E734: $\delta(\Delta s) \sim 0.08$)
    - Feasibility of SciBar will be investigated at SciBooNE

End