PANIC05, Neutrino satellite meeting on “Future of Neutrino Physics”

Strange Spin measurements at J-PARC

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- **Summary**

Strangeness in nucleon

π-N Σ-term: strange scalar density $y \sim 0.5$

OZI rule violation: polarized strangeness

Parity violating electron scattering: $G_M^s \neq 0, \quad G_E^s \neq 0$

DIS inclusive measurement: $\int_{10^{-5}}^{1} s(x, 2.5\, GeV^2)\, dx \sim 2$

$\int_0^1 \Delta s(x)\, dx = -0.13 \pm 0.06$

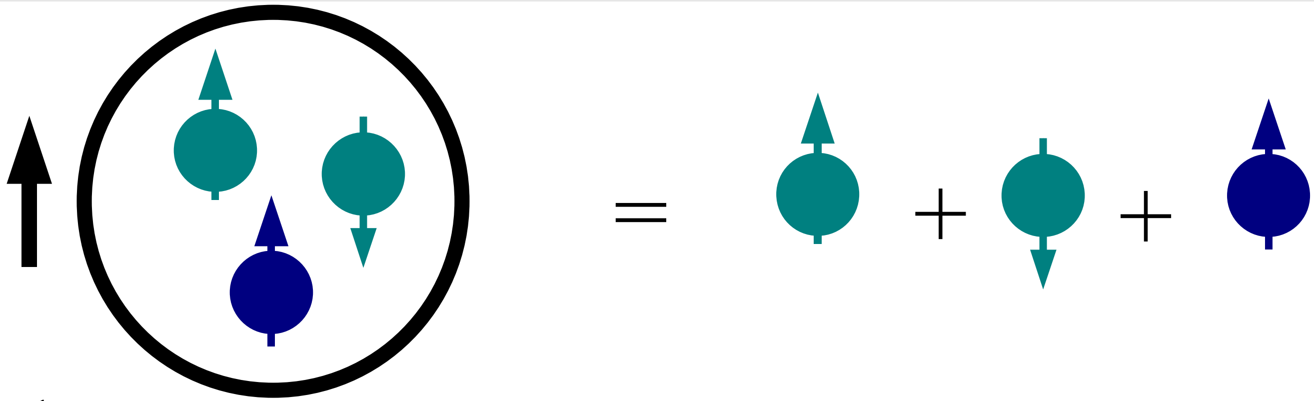
DIS semi-inclusive measurement: $\int_{0.023}^{0.6} \Delta s(x, 2.5\, GeV^2)\, dx = 0.03 \pm 0.03$

Baryon magnetic moment: $\Delta s \sim -0.2$

Lattice calculation: $\Delta s \sim -0.1$

Proton spin problem

Proton spin:



$$\frac{1}{2}=\frac{1}{2}\Delta\Sigma=\frac{1}{2}\left(\Delta u+\Delta d+\Delta s+\Delta\bar{u}+\Delta\bar{d}+\Delta\bar{s}\right) \qquad \Delta q=q^{\uparrow}-q^{\downarrow}$$

The most naive case: $\Delta\Sigma=\Delta u+\Delta d+\Delta s=1$

Naive parton model:

Assuming SU(3) flavor symmetry, taking axial current matrix

$$\Delta\Sigma=\Delta u+\Delta d+\Delta s=a_0$$
$$\Delta u-\Delta d=a_3$$
$$\Delta u+\Delta d-2\Delta s=a_8$$

From weak decay:
$a_3=1.26,$
$a_8=0.58$

if Δs = 0, $\Delta\Sigma$ = a_8 = 0.58

Δq corresponds to axial form factor

$$\Delta q=G_A^q(Q^2=0)$$

Strangeness spin inside proton

- EMC results -

Nucl. Phys. B328 (1989) 1, Phys. Lett. B206 (1988) 364

$$\vec{\mu} + \vec{N} \rightarrow \mu' + X$$

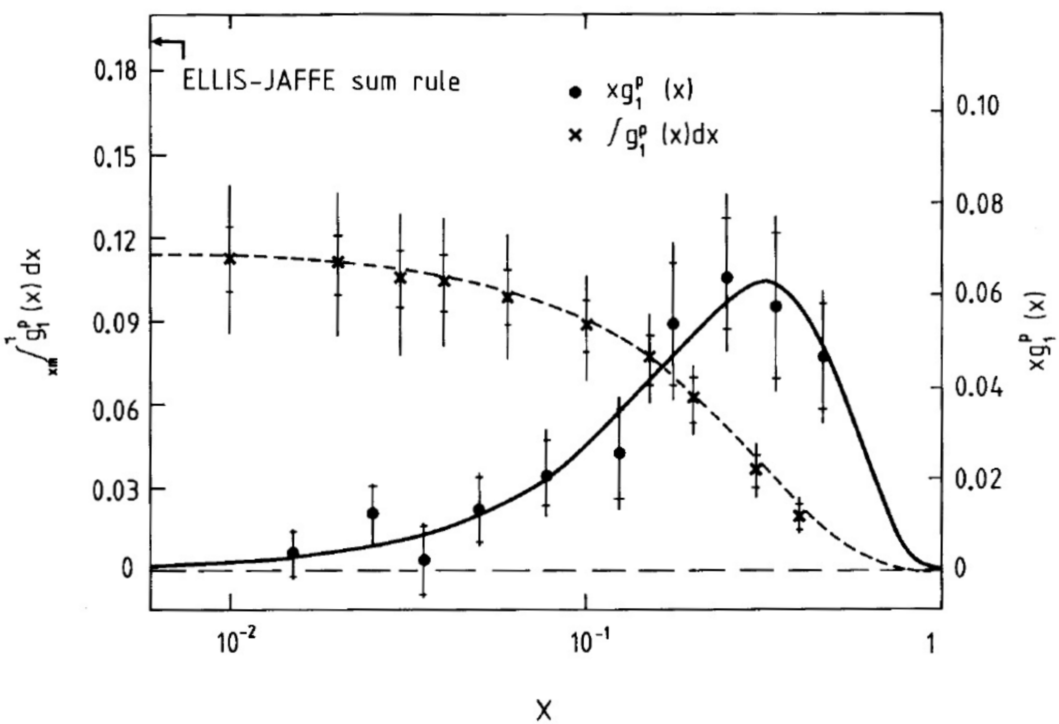
$$\int_0^1 dx\, g_1^p(x) = \frac{1}{9} a_0 + \frac{1}{12} a_3 + \frac{1}{36} a_8$$
$$= 0.126 \pm 0.01 \pm 0.015$$

$a_3 = 1.26, \quad a_8 = 0.58$

$a_0 \sim 0.1$

→ $\Delta\Sigma = 0.1, \quad \Delta s + \Delta\bar{s} \sim -0.19$

→ $a_0 = \Delta\Sigma - 3\frac{\alpha_s}{2\pi}\Delta G$ *with* $\Delta G > 0$

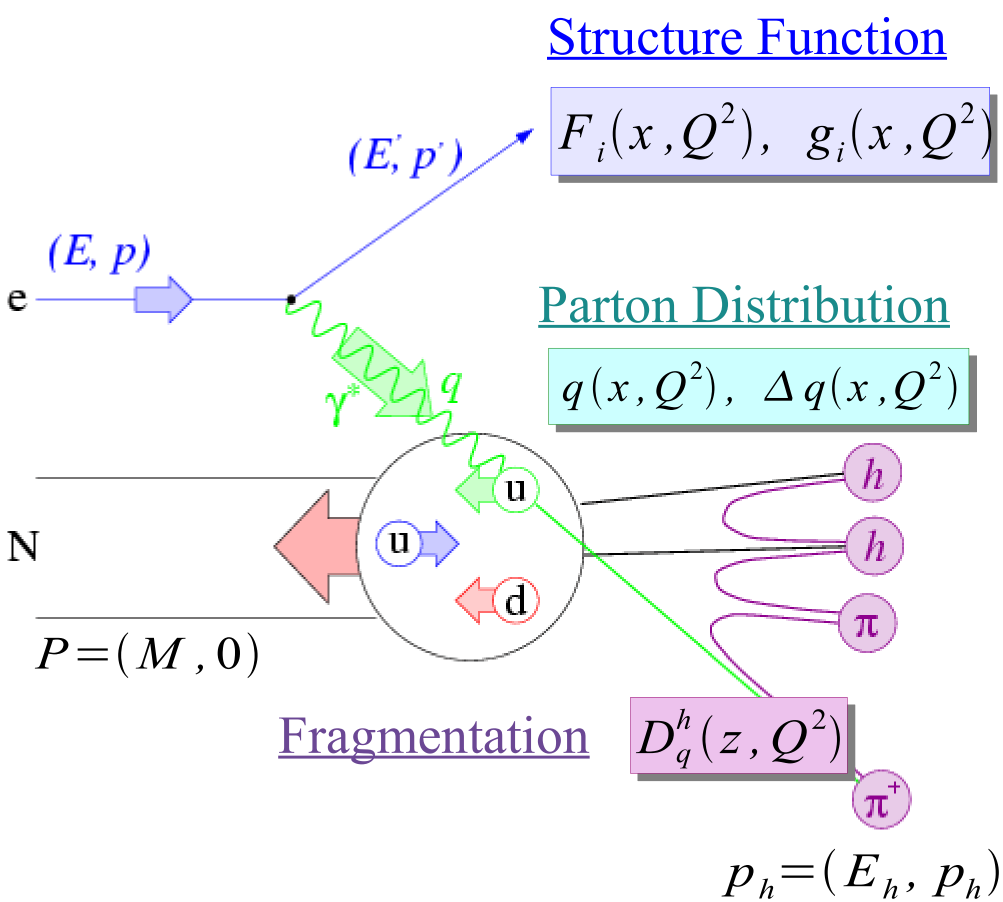


Flavor tagging in DIS

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

$$\frac{d^3 \Delta \sigma^h}{dx\, dz\, dQ^2} \propto \sum_i e_q^2 \Delta q(x, Q^2) D_q^h(z, Q^2)$$

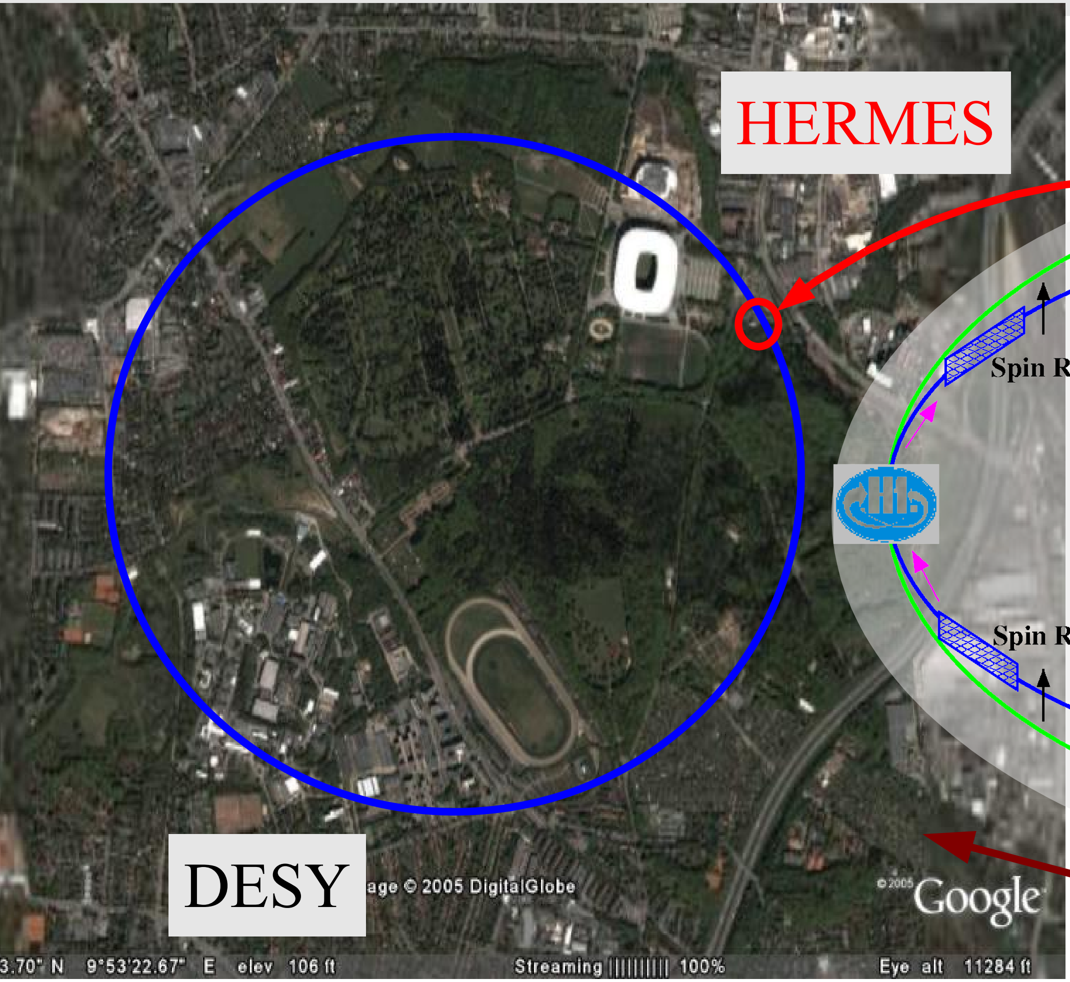
$$z = \frac{P \cdot p_h}{P \cdot q} = \frac{E_h}{\nu}$$

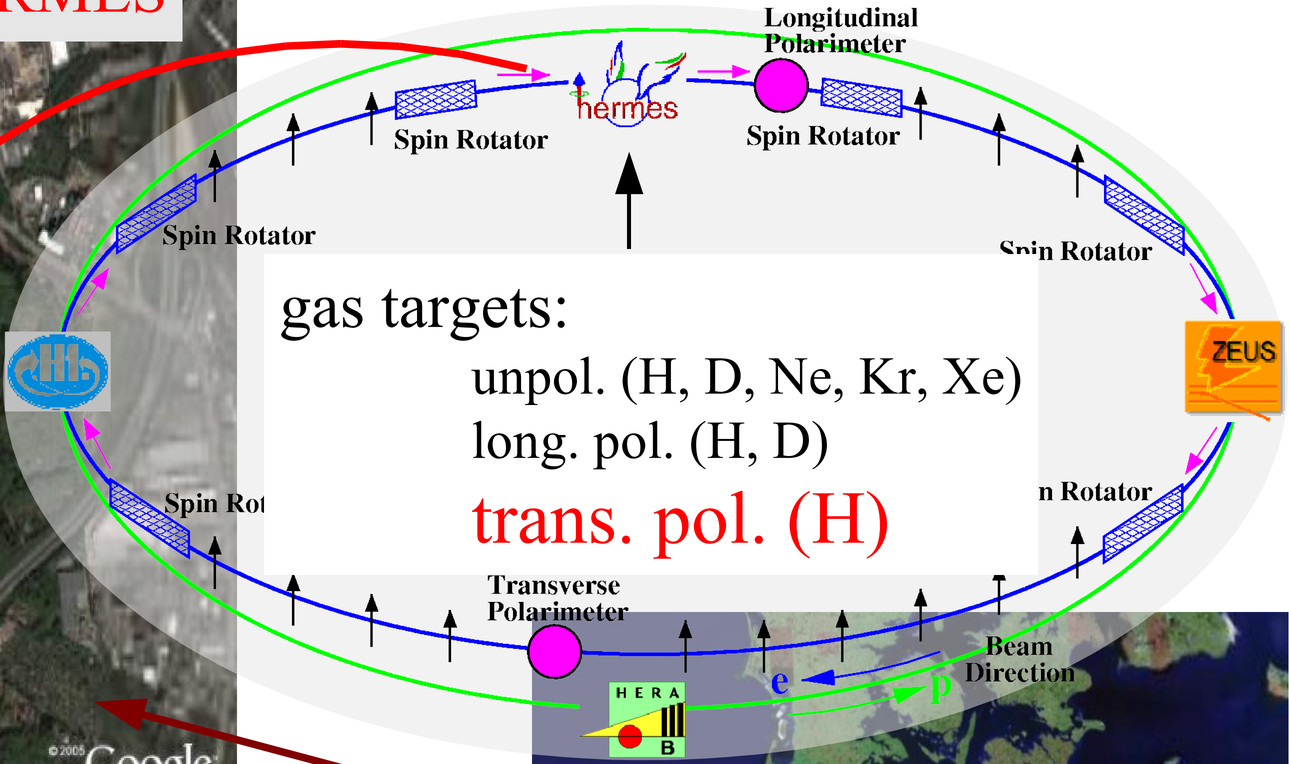


Flavor Tagging:

Hadron carries information on
quark flavor
through fragmentation function

HERMES at DESY



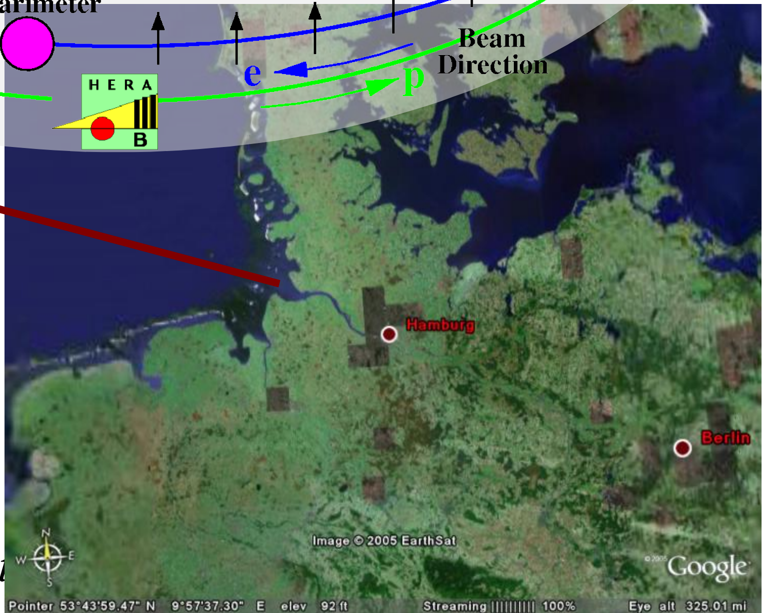


gas targets:

unpol. (H, D, Ne, Kr, Xe)

long. pol. (H, D)

trans. pol. (H)



HERA:

pol. electron/positron @ 27.5GeV

polarization about 55%

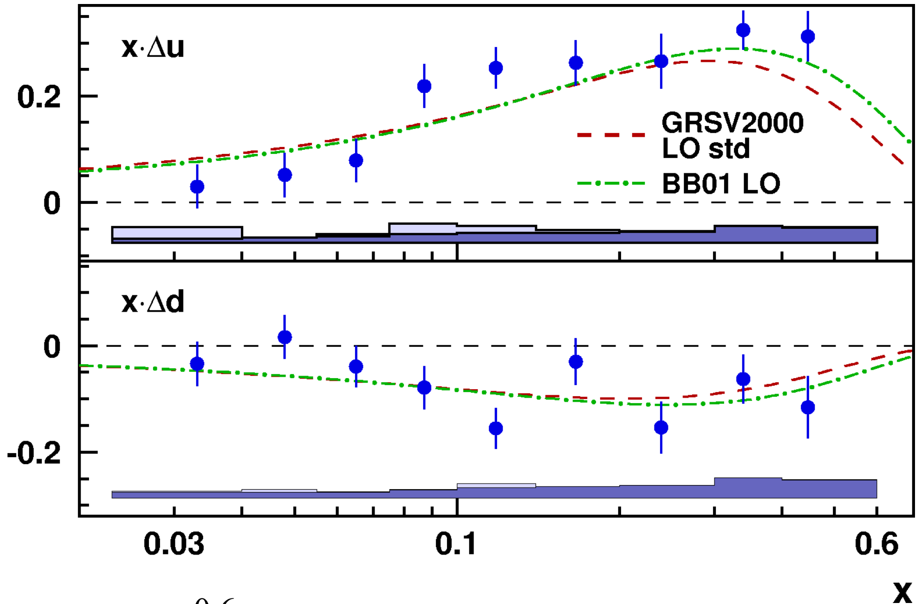
Strangeness spin inside proton

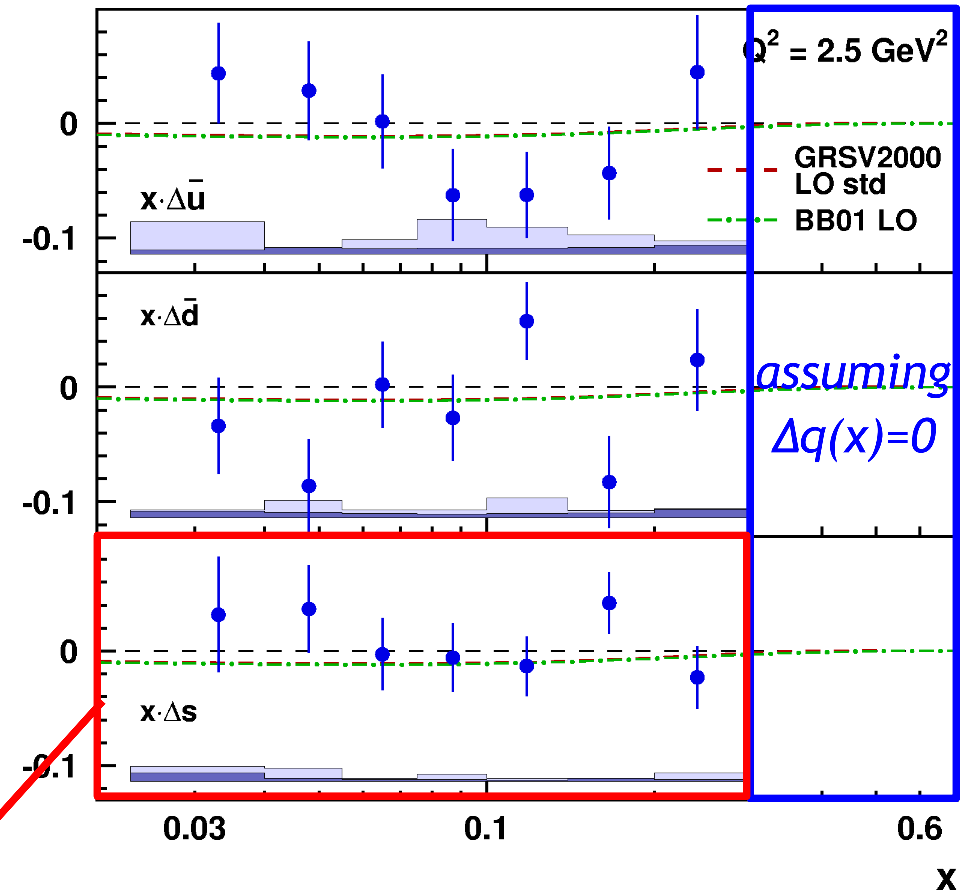
$\vec{e}+\vec{N}\rightarrow e'+h+X$

- HERMES results -

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

Phys. Rev D 71 (2005) 012003





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

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

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

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

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

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

Iso-scalar method

- strangeness spin extraction -

Alternative method to extract Δs(x)

Data: Deuteron target

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

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

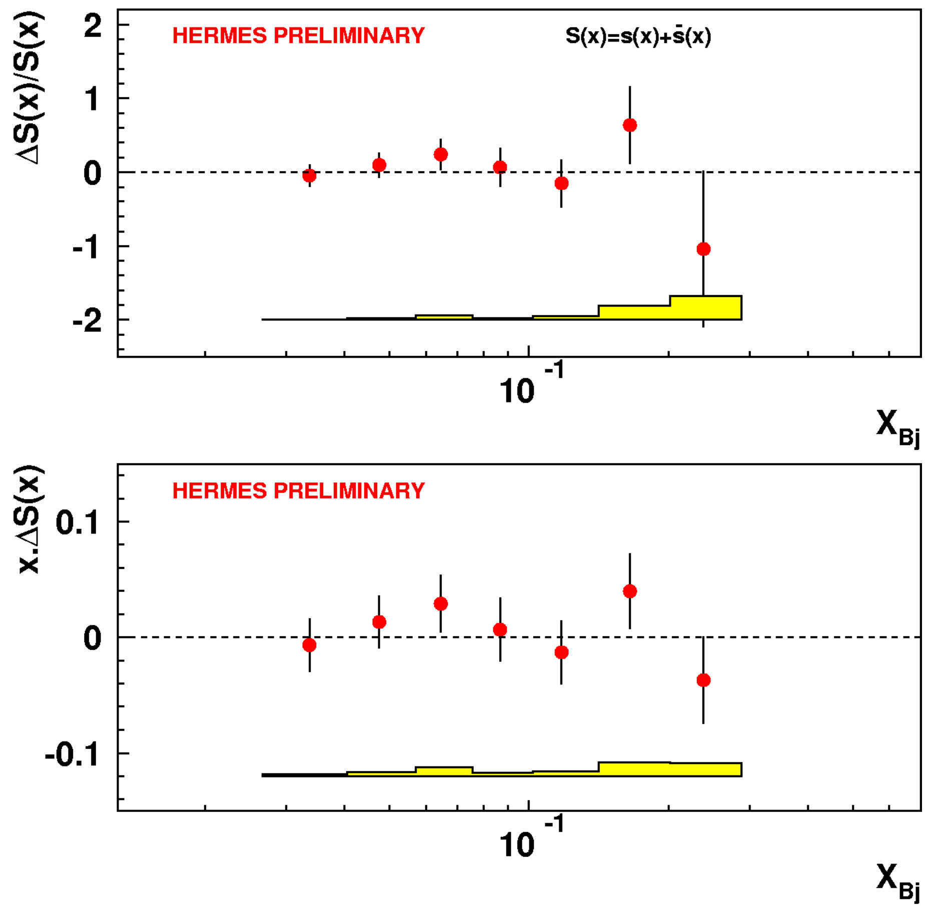
$$\Delta S(x)=\Delta s(x)+\Delta \bar{s}(x)$$

Free from Fragmentation model

reduce systematic uncertainty

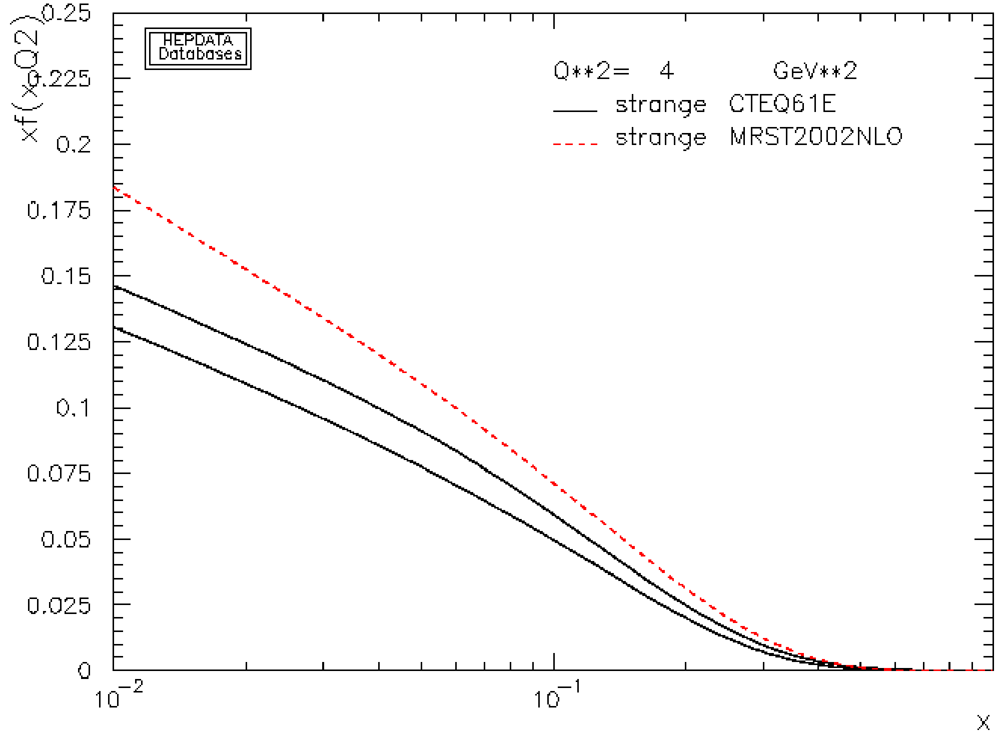
$$\int_{0.02}^{0.6} dx\, \Delta Q(x)=0.286\pm0.029\pm0.011$$

$$\int_{0.02}^{0.6} dx\, \Delta S(x)=0.006\pm0.026\pm0.007$$



Strangeness outside the coverage

http://durpdg.dur.ac.uk/hepdata/pdf3.html



CTEQ5:

$$\int_{10^{-5}}^{1} dx\, s(x) \sim 2$$

$$\int_{0.023}^{0.6} dx\, s(x) \sim 0.15$$

$$Q^2 = 2.5\ GeV^2$$

$$\int_{0.023}^{0.6} dx\, \Delta s(x) \sim 0 \xrightarrow{?} \int_{0}^{1} dx\, \Delta s(x) = ?$$

Other impacts of Δs measurements

- **Neutron EDM** **(J. Ellis and R. A. Flores *PLB377 (1996) 83*)**
  - n-EDM predicted using q-EDM and Δq
  - $d_n \propto m_u \Delta u + m_d \Delta d + m_s \Delta s$
- **Dark Matter** **(J.Ellis and M. Karliner hep-ph/9601280)**
  - Better determination of Dark-Matter reaction

$$\sigma \propto \frac{4}{9}\Delta u + \frac{1}{9}(\Delta d + \Delta s) \quad \text{photino}$$

$$\sigma \propto \frac{17}{36}\Delta u + \frac{5}{36}(\Delta d + \Delta s) \quad \text{pure U(1) gaugino}$$

Neutrino-Nucleon Scattering

Measurement of strange spin inside nucleon

Neutrino-Nucleon scattering

$$\frac{d\sigma}{dQ^2} = \frac{G_F^2}{2\pi}\frac{Q^2}{E_\nu^2}\left(A \pm BW \pm CW^2\right)$$

$$W = \frac{4E_\nu}{m_p} - \frac{Q^2}{m_p^2}$$

$$A = \frac{1}{4}\left[G_1^2(1+\tau) - \left(F_1^2 - \tau F_2^2\right)(1-\tau) + 4\tau F_1 F_2\right]$$

$$\tau = \frac{Q^2}{4\mathrm{m}_p^2}$$

$$B = -\frac{1}{4}G_1\left(F_1 + F_2\right)$$

$$C = \frac{1}{16}\frac{m_p^2}{Q^2}\left(G_1^2 + F_1^2 + \tau F_2^2\right)$$

NC-EL/CC-QE

Neutral Current

$$F_{1,2} = \left[\left[\frac{1}{2} - \sin^2\theta_W\right]\left[F_{1,2}^p - F_{1,2}^n\right] - \sin^2\theta_W\left[F_{1,2}^p + F_{1.2}^n\right] - \frac{1}{2}F_{1,2}^s\right]$$

$$G_1 = \left[-\frac{G_A}{2}\tau_z + \frac{G_A^s}{2}\right]$$

$$G_A^s(Q^2=0) = \Delta s$$

Neutrino scattering and Δs

- E734 results -

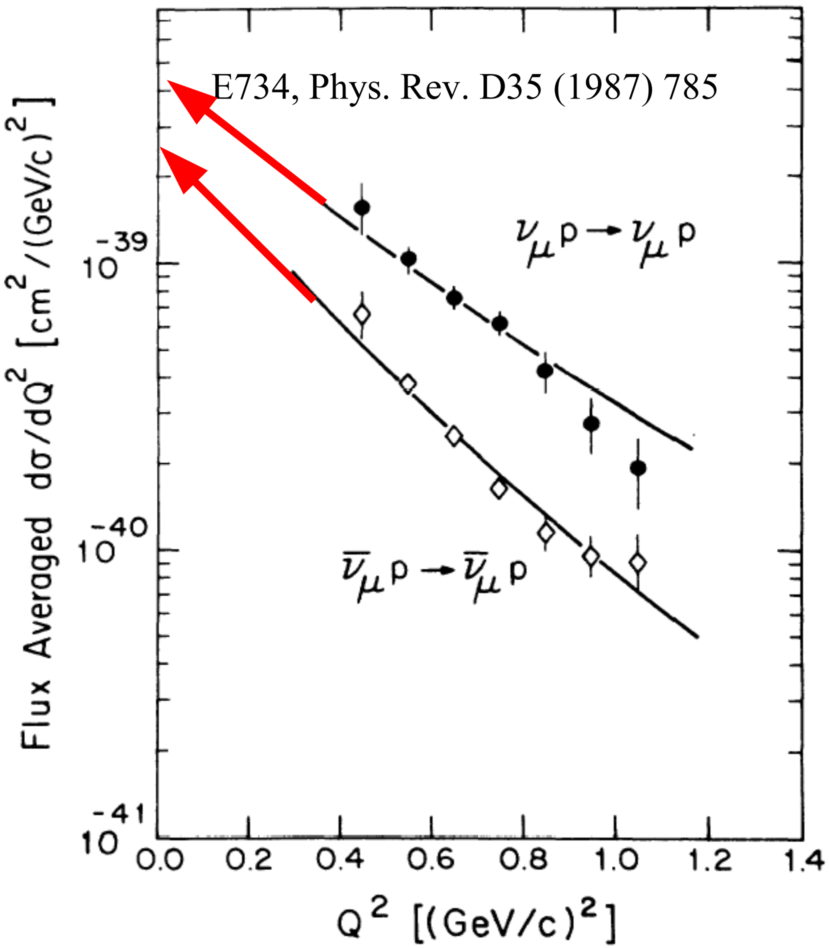
- **Neutral current cross section → strange axial form factor**
  - Liquid scintillator + Drift Tube 170 t
  - 0.5E19 POT for neutrino
  - 2.5E19POT for anti-neutrino
- **From $G_A^s(Q^2)$ to Δs**
  - $G_A^s(Q^2 \to 0) = \Delta s = -0.21 \pm 0.10$
- **Further analysis:** (Alberico et al.)

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

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

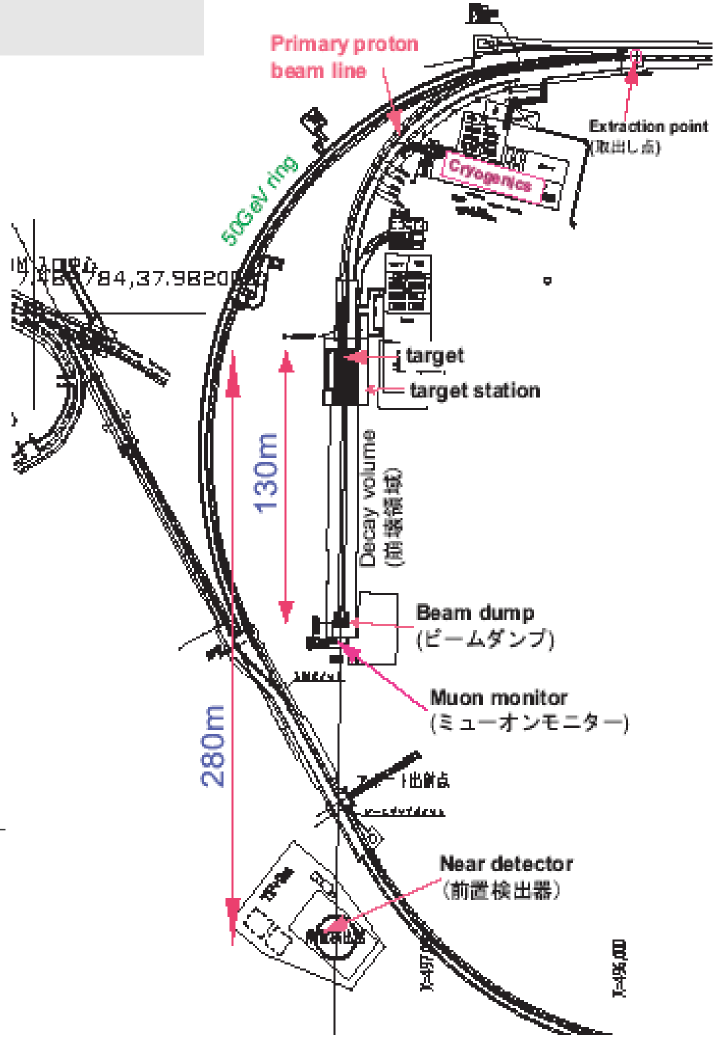
$R^{\nu/\bar{\nu}}_{NC} = 0.302 \pm 0.019 \pm 0.037$

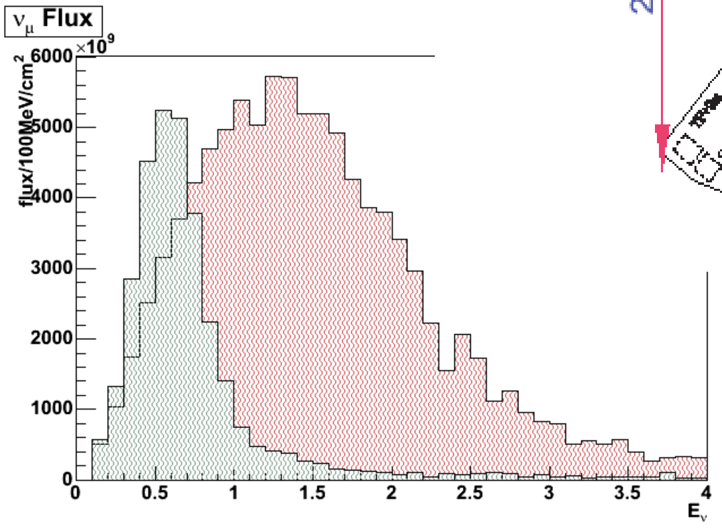
$-0.21 < \Delta s < 0$ strong correlation with the axial mass M_A



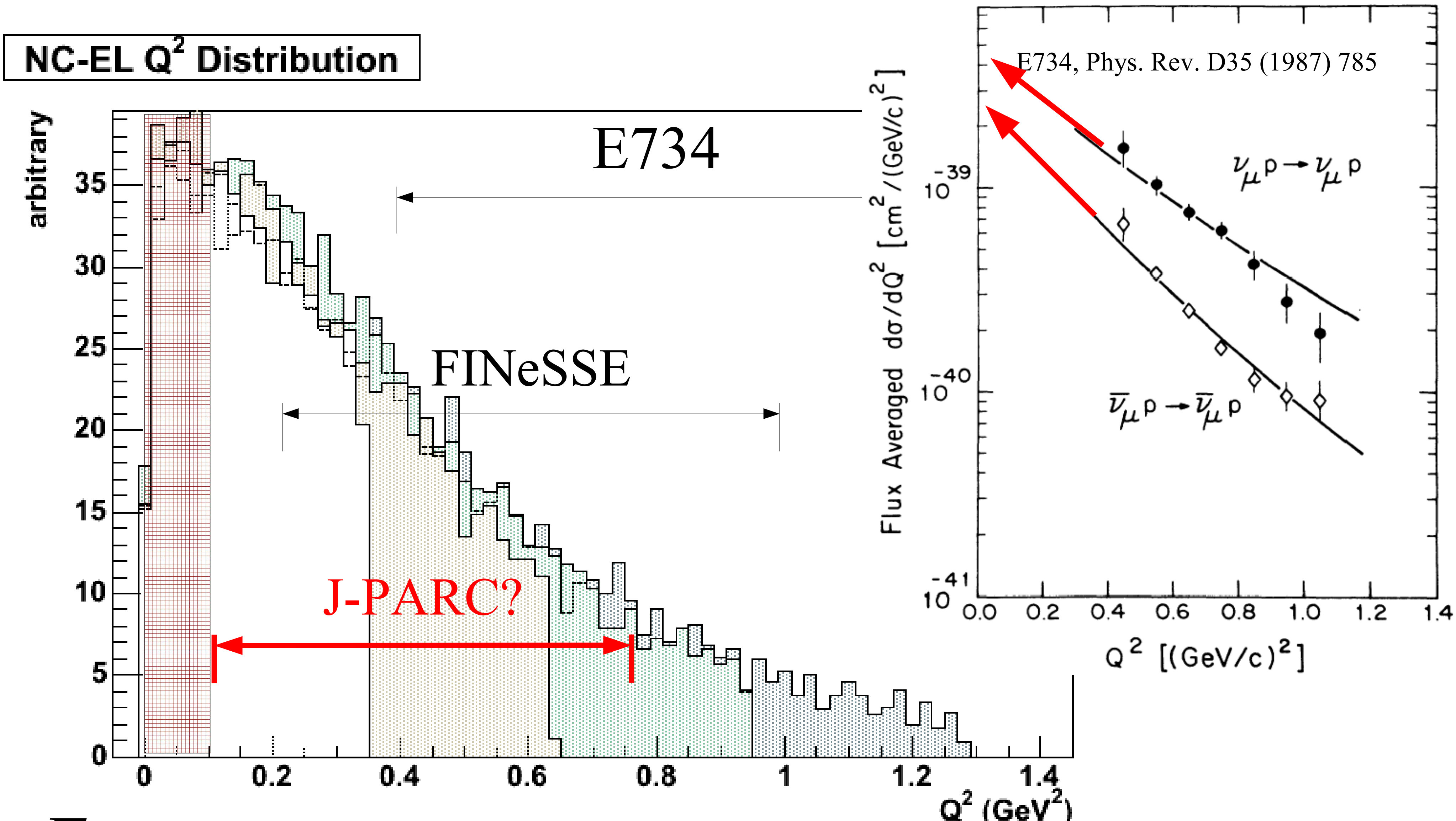
J-PARC ν-beam line

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





Neutrino elastic scattering cross section



$E_\nu =$ 0.4 0.6 0.8 1.0 GeV

Experiment at J-PARC

- **Off-axis beam line: peak energy < 1.0 GeV^2**
- **Liquid scintillator with different H/C mixture**
  - FINeSSE type detector
  - e.g Bicron BC510A (H/C=1.212) and BC-533 (H/C=1.96)
    - Pure Carbon can be extracted for nA Xsection
  - e.g. 5x5x5m^3 ~ 125 t
  - Recoil proton with T_p = 40 MeV: Q^2 ~ 0.1 GeV^2
    - **High pressure hydrogen TPC dedicated for low Q^2 measurements?**
- **1E21 POT possible in one year (130 days)**
  - 30 times BNL-E734

Sensitivity at J-PARC

- Similar Detection Efficiency to E734:
  - 7.6% for neutrino-N elastic, 5.4% for anti-neutrino-N elastic
- However with lower Q^2 cut-off : 0.1 GeV^2
  - Achievable with more uniform detector
    - Hydrogen TPC was not included in this estimation.
- 25 times more statistics but pure proton only 1/6
  - Factor 2 reduction in statistical error
- Systematic control improvements to ~5%
  - E734 7.6% dominated by Beam Flux and Nuclear Effects
  - Possible to remove Nuclear Effects which could be larger in lower Q^2 region

$$\delta(\Delta s)=0.08 \quad (\mathrm{E734})$$
$$\delta(\Delta s)=0.03 \quad (\mathrm{J\text{-}PARC})$$

Summary

- **Strangeness in the nucleon**
  - has been studied with various probes
    - π-N Σ-term, OZI violation, Deep Inelastic Scattering, ...
  - Proton spin problem
    - Relates strange spin inside nucleon: positive? negative? zero?
- **Neutrino scattering**
  - Unique tool for studying strange spin inside nucleon
    - nucleon axial form factor measurement
  - Key points: nuclear effects, Q^2 extrapolation to Q^2=0
  - Measurement at J-PARC
    - **$\delta(\Delta s) \sim 0.03$** expected (E734: $\delta(\Delta s) \sim 0.08$)

Recent activities

Presentations:

NP04, Aug. 2 - 4, 2004, Tokai
"Determining strangeness quark spin in neutrino scattering at J-PARC (T.-A. Shibata)"
NP04 Neutrino session, Aug. 24 - 26, 2004, KEK
"Polarized Parton Distributions in the Nucleon (Y. Miyachi)"
"Strangeness Spin Contribution to the Nucleon Spin measured at J-PARC (N. Saito)"
NuFact05, June 21 - 26, 2005, Rome
"Study for the Neutrino Coherent Pion Production Experiment (Y. Sakemi)"
NuInt05, September 26 – 29, 2005, Okayama
" Strangeness in Nucleon -- a summary from electron scattering experiments and projection on neutrino scattering experiment (Y. Miyachi)"

R&D: Liquid scintillator test and detector simulation

Working group homepage (in Japanese)

`http://www.nucl.phys.titech.ac.jp/~sspin/`

Mailing list for the working group:

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