# Strangeness Spin Contribution to the Nucleon Spin Measured at J-PARC

*NP04, Tokai, August 2-4, 2004*

to be

Naohito Saito (Kyoto)

For

"Strange-Spin in Neutrino Scattering" WG

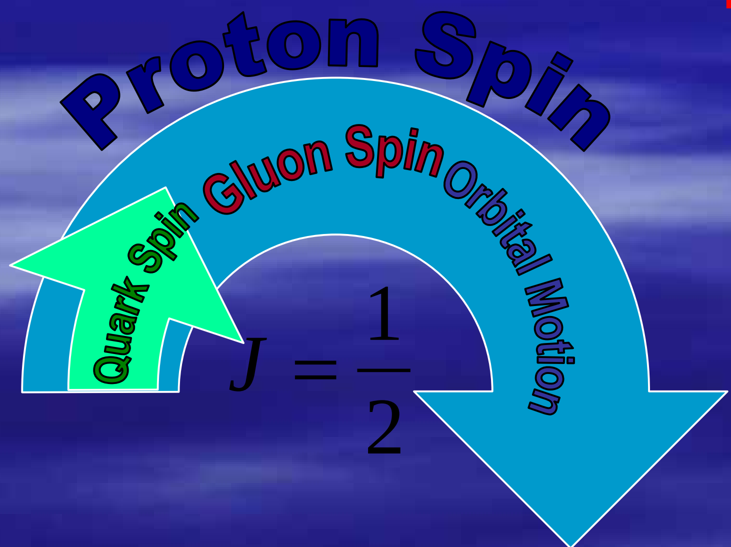
Yoshiyuki Miyachi (TITech)

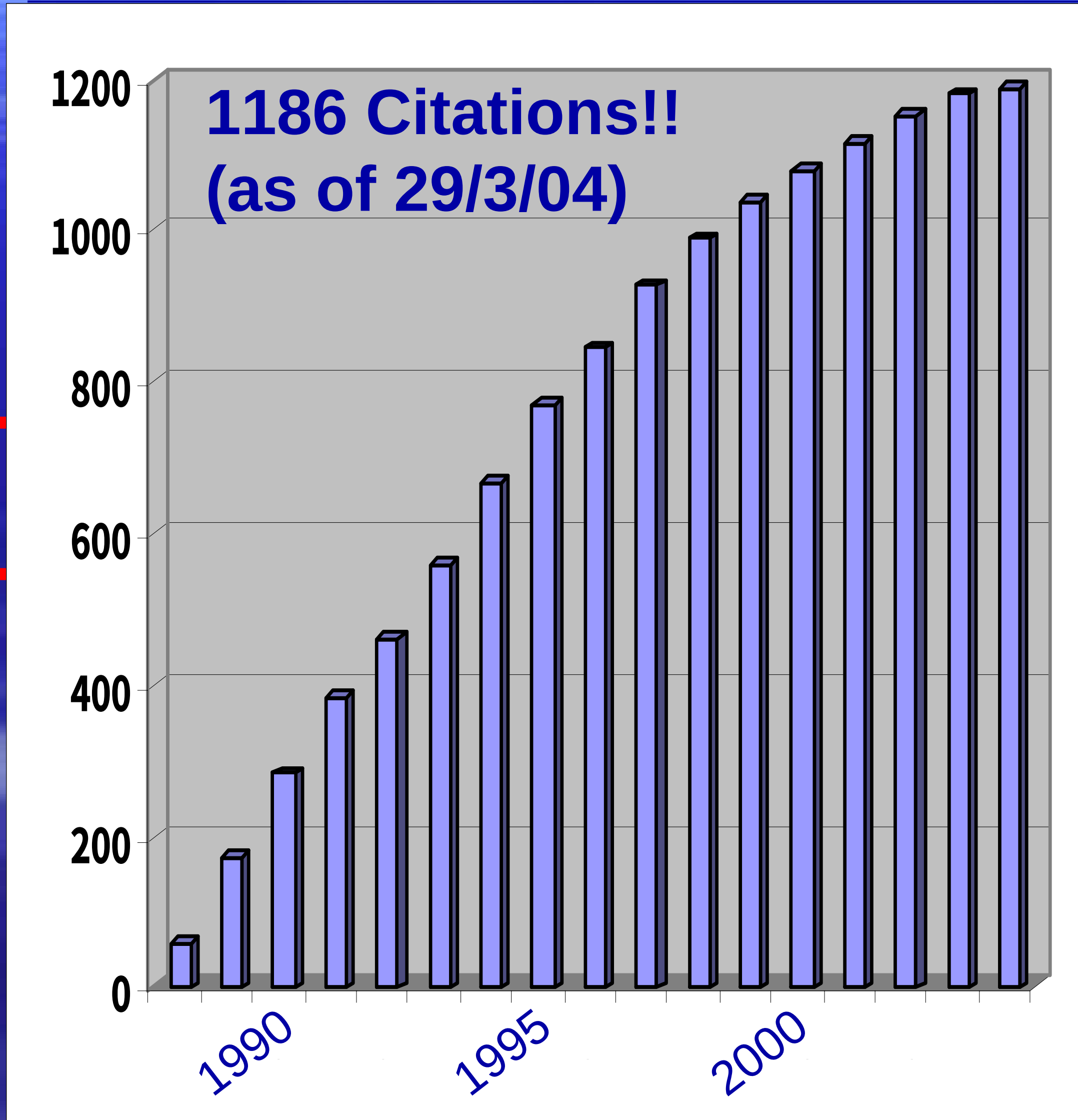
and Toshi-Aki Shibata (TITech) and more

# "Proton Spin Crisis"

## EMC PLB & NP (1988)

- Proton Spin carried by Quark Spin is ZERO??
  - – Gluon Spin ?
  - – Orbital Motion ?



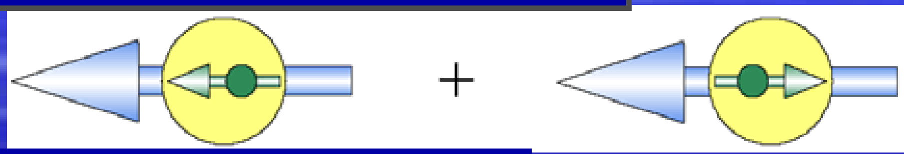



# Parton Distribution Functions

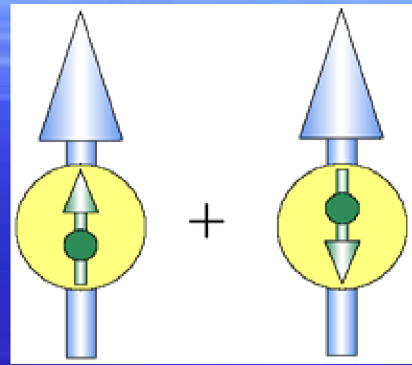
- Quark Distribution

unpolarized distribution

$q(x,Q^2)=$

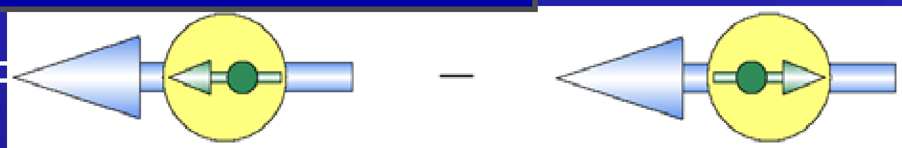


$=$



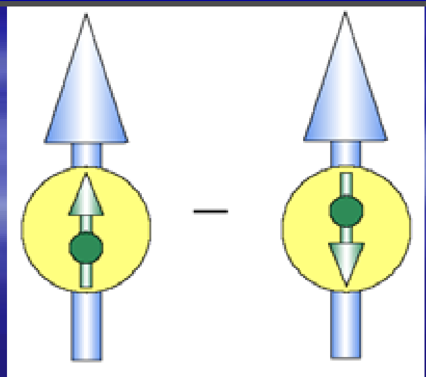
helicity distribution

$\Delta q(x,Q^2)=$



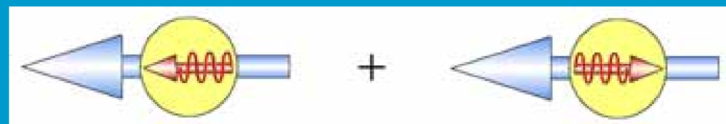
transversity distribution

$\delta q(x,Q^2)=$

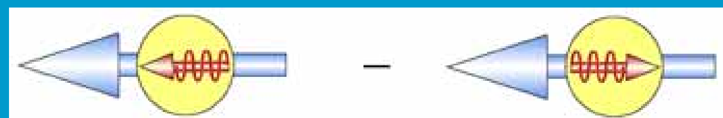


- Gluon Distributions

$g(x,Q^2)=$



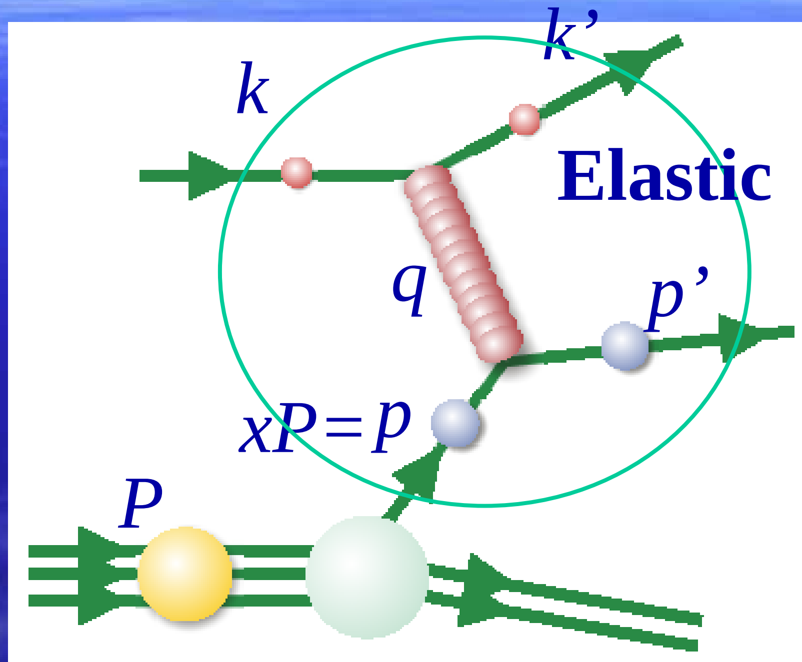
$\Delta g(x,Q^2)=$



**No Transverse Gluon Distribution**

# DIS of Lepton from Nucleon

- Structure Probed by Photon
  - Function of $x$ and $Q^2=-q^2$
  - ∝Charge Squared
    - Not distinguish Down and Strange
    - Insensitive to Gluon




- Objective is

$$\Delta\Sigma = \Delta U + \Delta D + \Delta S$$

- Observables are

Proton
Neutron

$$\begin{cases} g_1^p(x,Q^2) = \frac{1}{2}\left\{\frac{4}{9}\Delta U(x,Q^2) + \frac{1}{9}\Delta D(x,Q^2) + \frac{1}{9}\Delta S(x,Q^2)\right\} \\ g_1^n(x,Q^2) = \frac{1}{2}\left\{\frac{1}{9}\Delta U(x,Q^2) + \frac{4}{9}\Delta D(x,Q^2) + \frac{1}{9}\Delta S(x,Q^2)\right\} \end{cases}$$

# Separation of Pol' Quark Dist's

- Only two independent measurements $g_1^p(x, Q^2)$ and $g_1^n(x,Q^2)$
- Separation into 3 quark dist's relies on
  - 1st moments (employ β-decay const's), **unless**
  - Different coupling with $\Delta g(x)$ thru $Q^2$ evolution

**How much do we know about $\Delta g(x)$?**

Non-Singlet Quark Distribution

$$\frac{\partial \Delta q_{NS}(x,Q^2)}{\partial(\ln Q^2)} = \frac{\alpha_S(Q^2)}{2\pi} \Delta P_{q\pm,NS}(x) \otimes \Delta q_{NS}(x,Q^2)$$

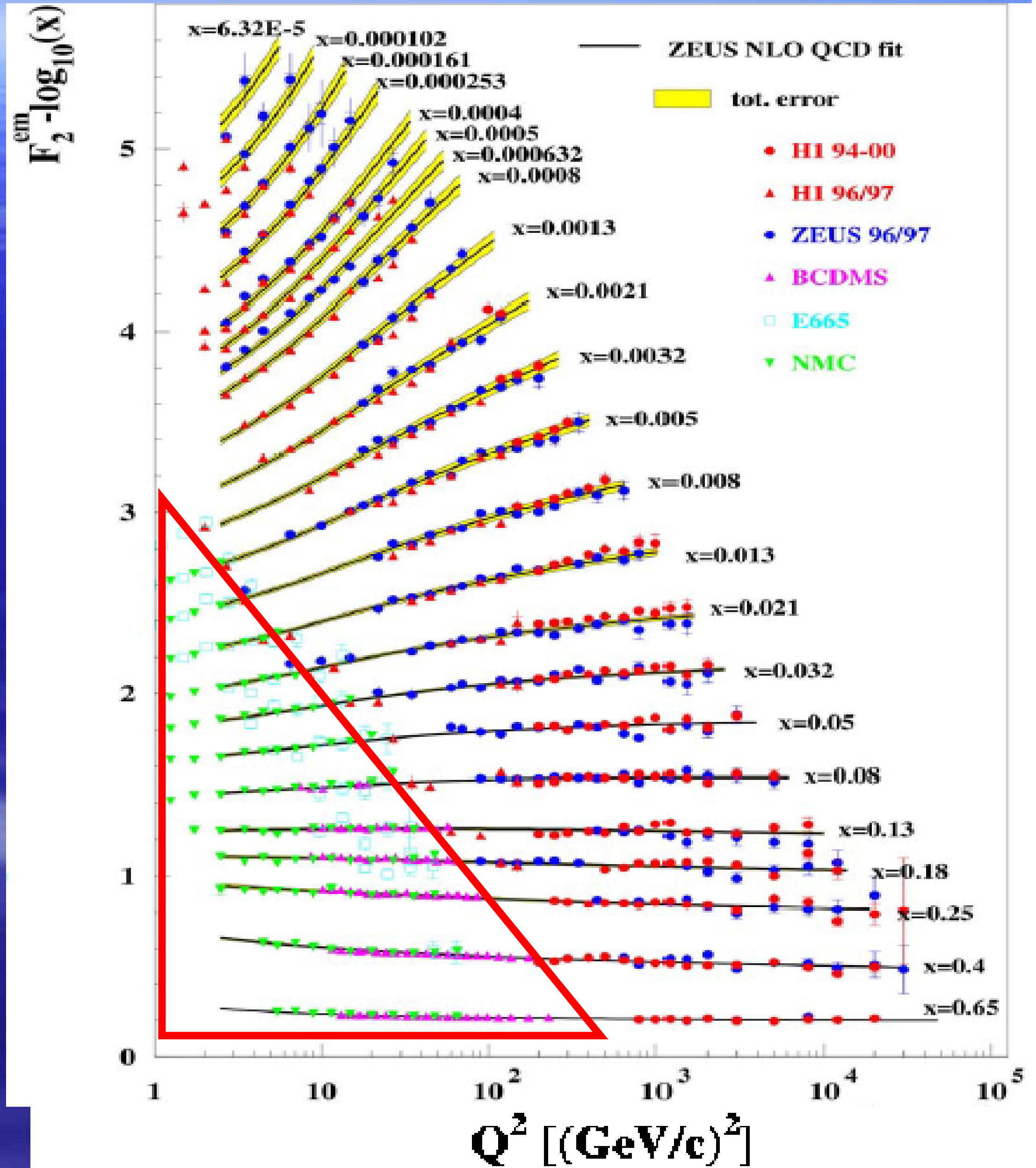
$$\begin{pmatrix} \Delta\Sigma \\ a_3 \\ a_8 \end{pmatrix} = \begin{pmatrix} \Delta U + \Delta D + \Delta S \\ \Delta U - \Delta D \\ \Delta U + \Delta D - 2\Delta S \end{pmatrix}$$

Singlet Quark Distribution

$$\frac{\partial}{\partial(\ln Q^2)} \begin{pmatrix} \Delta\Sigma(x,Q^2) \\ \Delta g(x,Q^2) \end{pmatrix} = \frac{\alpha_S(Q^2)}{2\pi} \begin{pmatrix} \Delta P_{qq}(x) & \Delta P_{qg}(x) \\ \Delta P_{gq}(x) & \Delta P_{gg}(x) \end{pmatrix} \otimes \begin{pmatrix} \Delta\Sigma(x,Q^2) \\ \Delta g(x,Q^2) \end{pmatrix}$$

# Precision Data from DIS

- Precision Data in Wide Kinematical Range
  - $Q^2$ evolution agrees with pQCD
- Notes：
  - Only Fixed Target Spin Experiments so far…
  - Need a Collider to extend kinematical coverage



# From $g_1(x,Q^2)$ to $\Delta\Sigma$

- Integrate over x (0,1)!

$$\Gamma_1^p = \frac{1}{2}\left(\frac{4}{9}\Delta U + \frac{1}{9}\Delta D + \frac{1}{9}\Delta S \ldots\right.$$

$$\Gamma_1^n = \frac{1}{2}\left(\frac{1}{9}\Delta U + \frac{4}{9}\Delta D + \frac{1}{9}\Delta S \ldots\right.$$

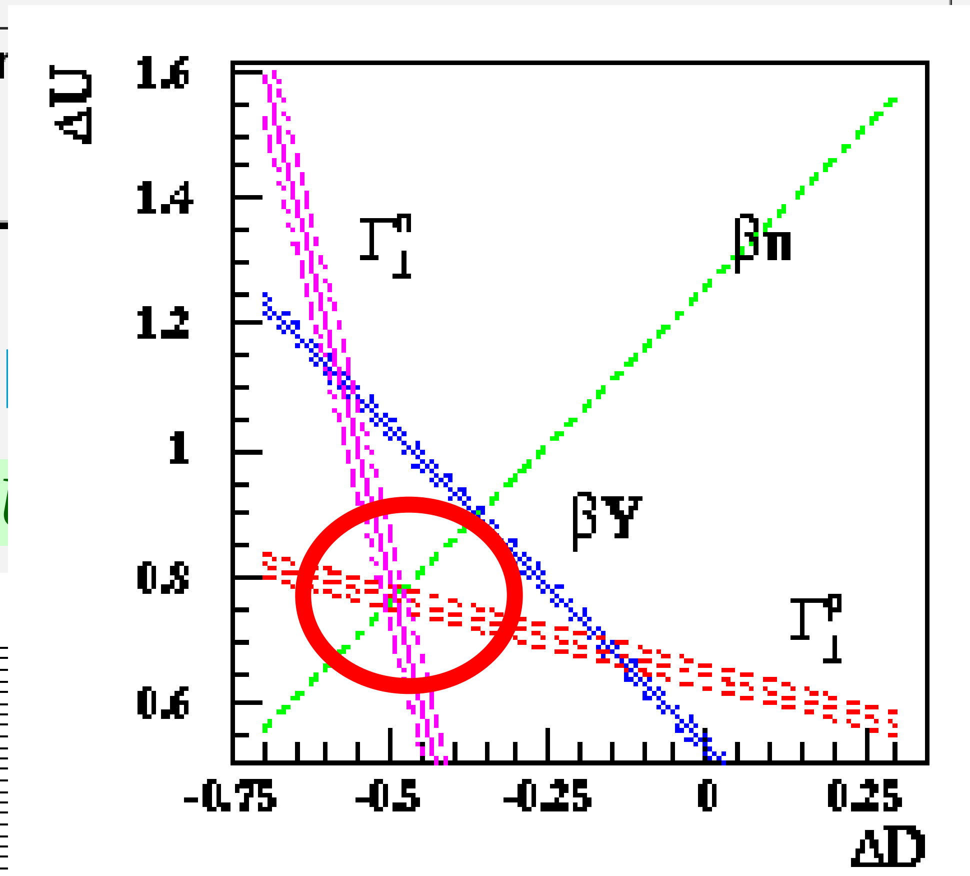
- Utilize Octet Baryon β-…

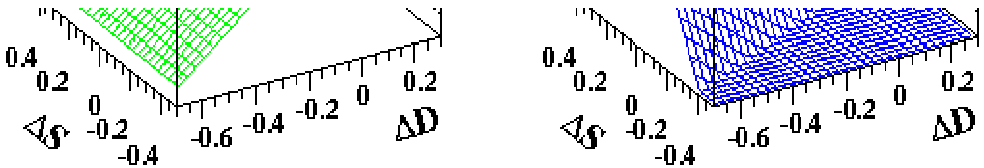
$$\Delta U - \Delta D = 1.2692 \pm 0.0112$$

– SU(2) OK! (Bjorken SR)

$$\Delta\Sigma = 0.213 \pm 0.138$$

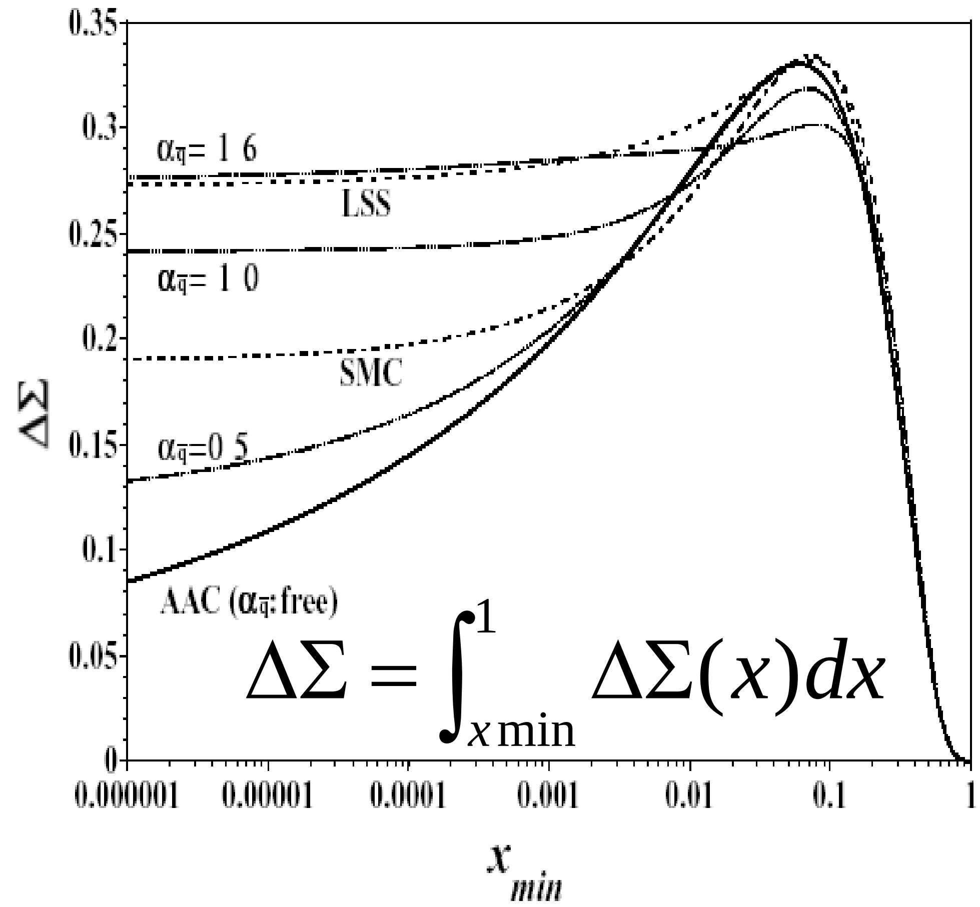
$$(\Delta S = -0.124 \pm 0.046)$$



# Assumptions in $g_1$ to $\Delta\Sigma$

- Relation between St Fn and β-decay const
  - Confirmed Experimentally (Bjorken SR!)
- Extrapolation to Small-x
  - No (solid) guideline from Thery
  - Regge? BFKL? δ-fn at x=0?
- Flavor SU(3) assumption
  - What precision?
  - Require independent determination of…

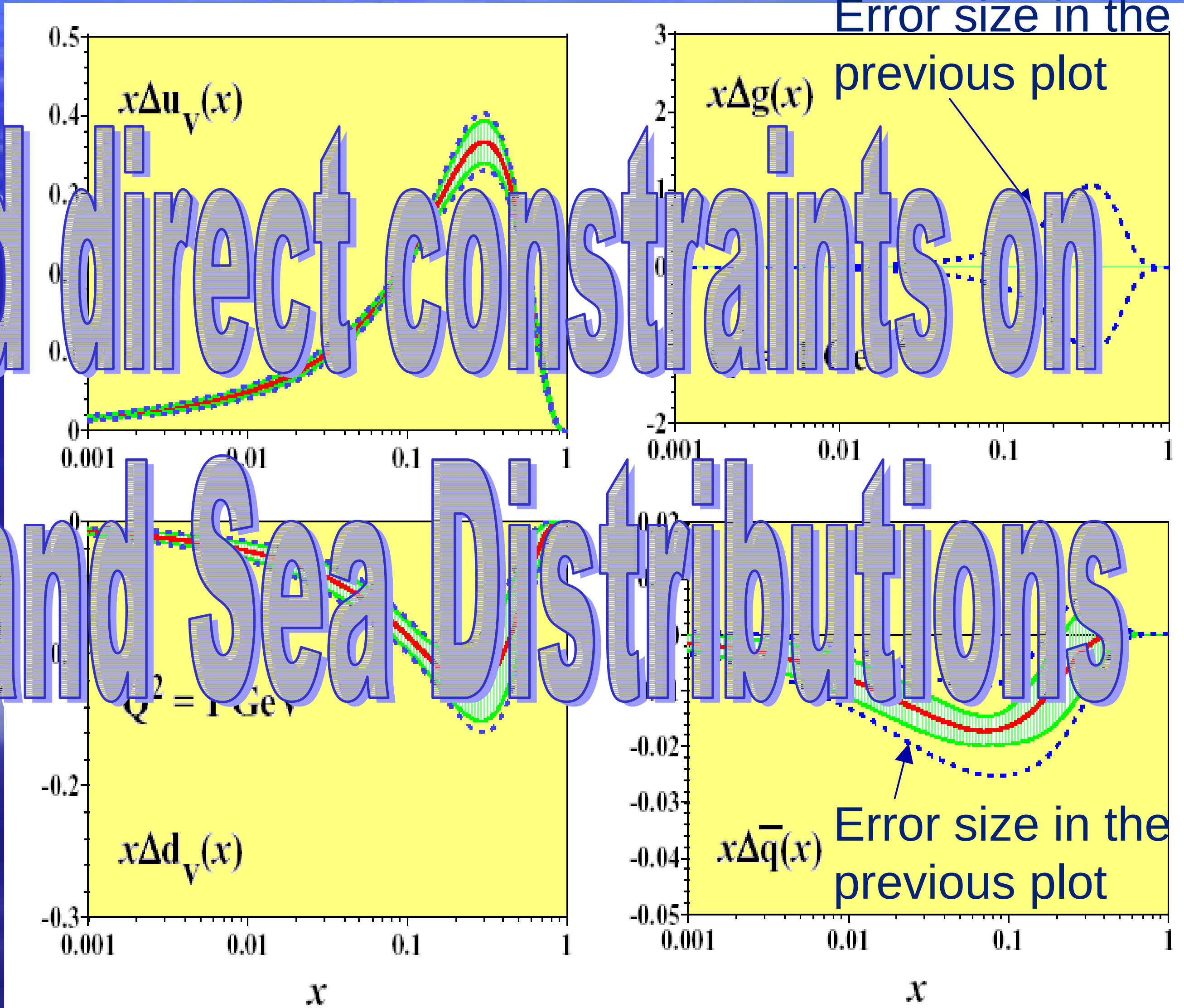

AAC Collaboration in PRD (2000)

# Polarised PDF

Asymmetry Analysis Collaboration

M. Hirai, S. Kumano and N. Saito, PRD (2004)

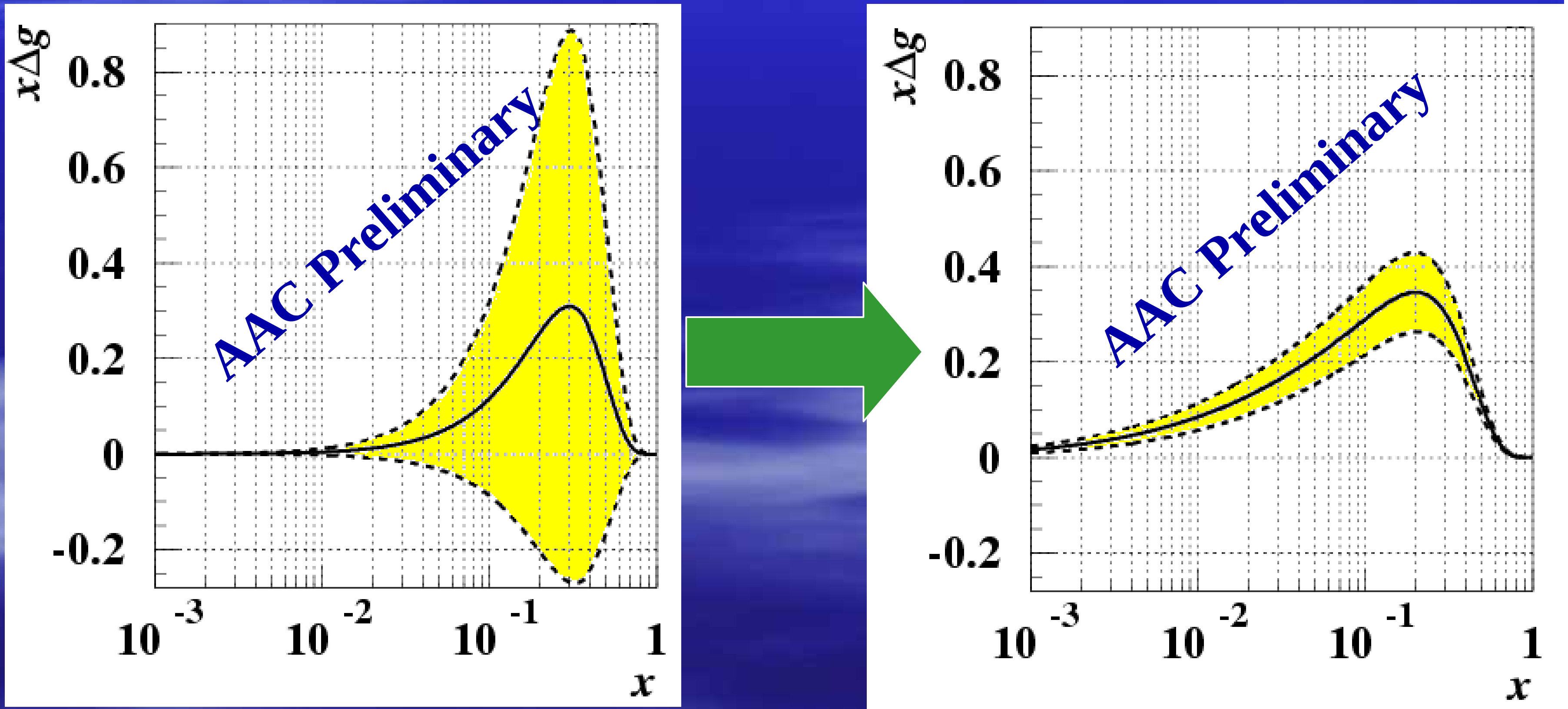
- Valence Dist's are determined we
- Sea ' i poo con e
- Gluon can be either >0, =0, <0
- Eve i we ass 0, Ch cha
  - Sea quark error is reduced




**We need direct constraints on Gluon and Sea Distributions**

# Impact of PHENIX Prompt Photon

- If we include Future PHENIX Data into Global Analysis…




M. Hirai *et al.*

# Impact of $\Delta s$ Measurement

- Improve Knowledge on Spin Flavor Structure of the Proton
  - Beyond Flavor SU(3) assumption
- Neutron EDM J.Ellis and R.A.Flores PLB377(96)83
  - $n$-EDM predicted using q-EDM and $\Delta q$

$$d_n = \eta^E(\Delta u d_u^E + \Delta d d_d^E + \Delta s d_s^E) \propto m_u \Delta u + m_d \Delta d + m_s \Delta s$$

- Dark Matter

J.Ellis and M. Karliner Lecure at Erice School 95 hep-ph/96012

  - Better determination of Dark-Matter reaction

$$\sigma(\chi p \to \chi p) \propto \frac{4}{9}\Delta u + \frac{1}{9}(\Delta d + \Delta s) \text{ (photino) or}$$

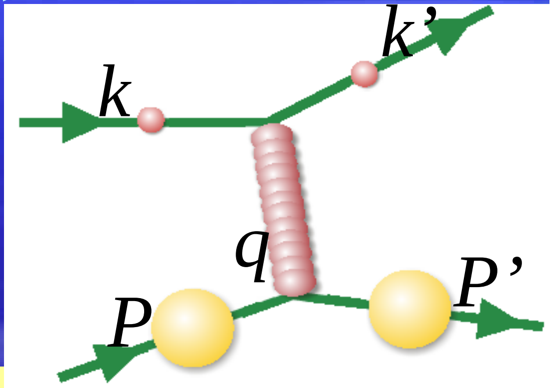
$$\propto \frac{17}{36}\Delta u + \frac{5}{36}(\Delta d + \Delta s) \text{ (pure } U(1) \text{ gaugino)}$$

# νN Elastic Scattering

- Cross section for νN elastic Scattering

$$\frac{d\sigma}{dQ^2} = \frac{G_F^2}{2\pi}\frac{E_\nu^2}{Q^2}\left[A \pm BW + CW^2\right] \quad + \text{for } \nu; - \text{for } \bar{\nu}$$

$$W = 4(E_\nu / M_p - \tau); \tau = Q^2 / 4M_p^2$$




– Where ($Q^2$ dropped for brevity)

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

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

$$G_1(Q^2) = \frac{-0.631}{(1+Q^2/M_A^2)^2} + \frac{G_1^s(Q^2)}{2}$$

$$C = \frac{1}{16}\frac{M_p^2}{Q^2}\left[G_1^2 + F_1^2 + \tau F_2^2\right]$$

$$G_1^s(0) = \Delta s$$

# BNL-Experiment 734

(L.A.Ahrens et.al PRD35(87)785; Reanalysis G.T. Garvey et. al PRC48(93)761)

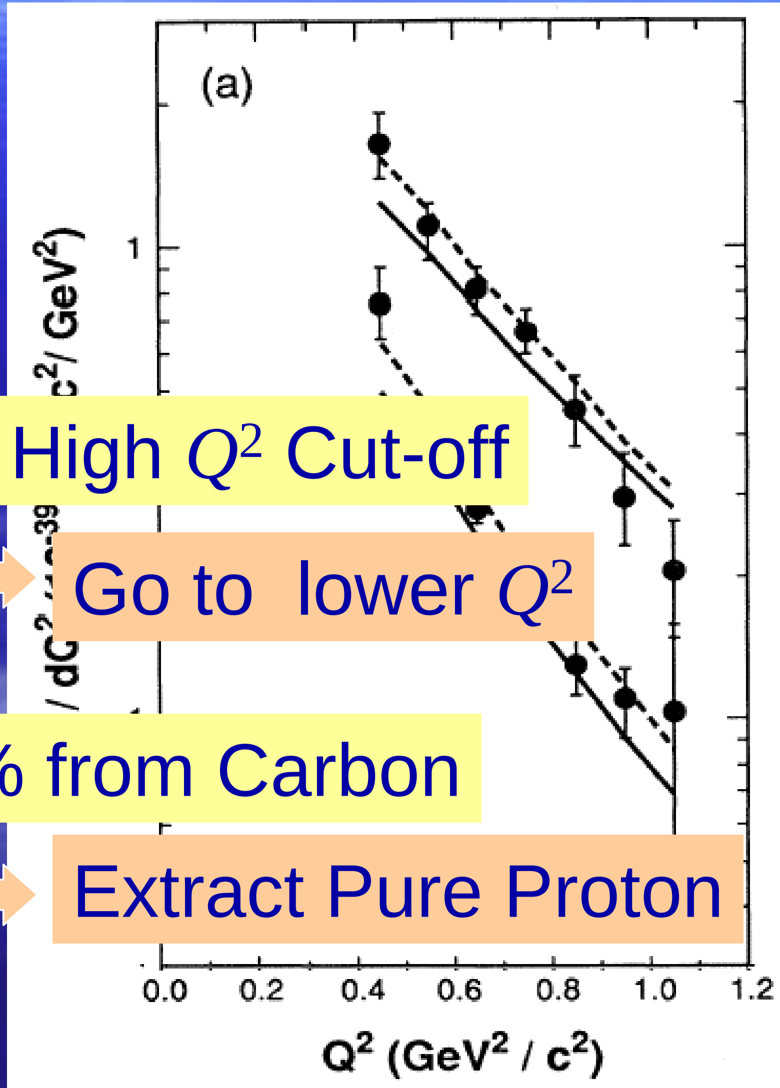
- Measured elastic scattering cross section

  $\nu p \rightarrow \nu p$ and $\bar{\nu} p \rightarrow \bar{\nu} p$

  – Liquid scintillator + Drift Tube 170 t

  – 0.5E19 POT for neutrino and 2.5E19POT for anti-neutrino

  – $Q^2$>0.40 GeV$^2$




Too High $Q^2$ Cut-off

Go to lower $Q^2$

79% from Carbon

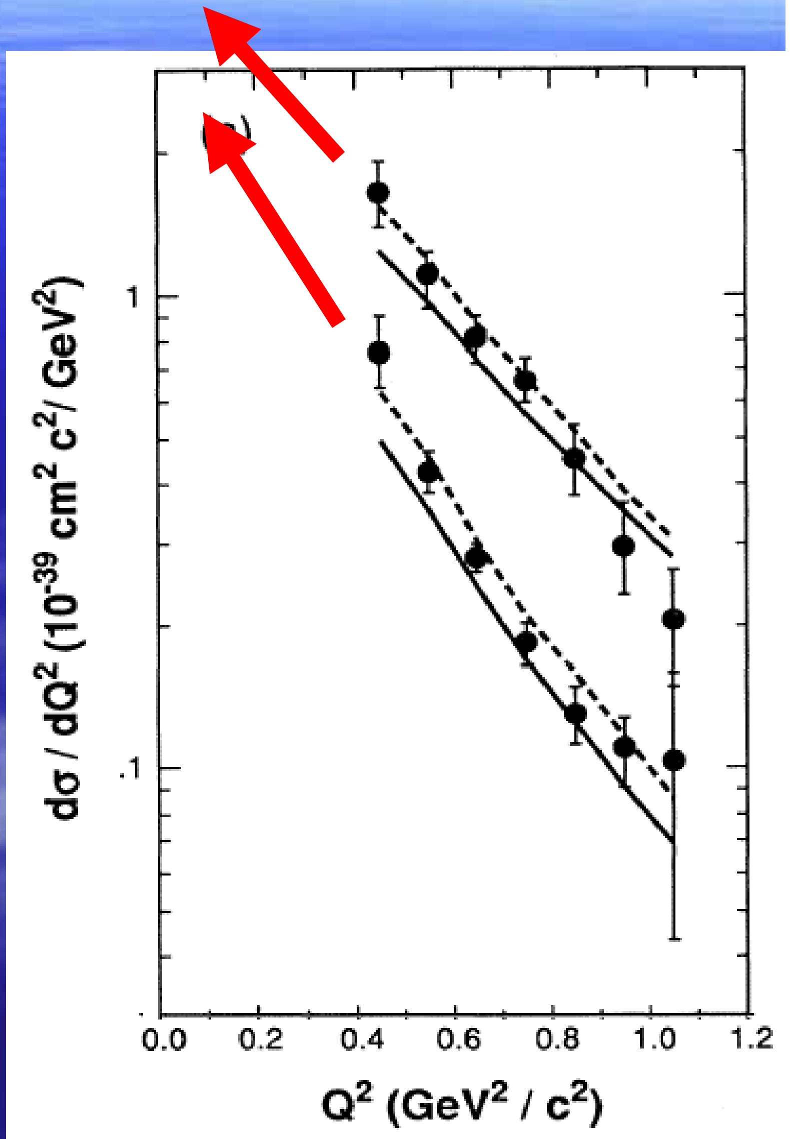
Extract Pure Proton

# $\nu N$-Elastic Scattering Exp at J-PARC

- On-axis at near detector hall for T2K Experiment
- Utilize both two types of LiqScintillator with different H/C mixture for pure proton signal
  - e.g Bicron BC510A (H/C=1.212) and BC-533 (H/C=1.96)
  - Pure Carbon can be extracted for $\nu$A Xsection
  - e.g. $5x5x5m^3$ ~ 125 t
- 1E21 POT possible in one year (130 days)
  - 30 times BNL-E734
  - Require polarity change for $\nu$ and $\bar{\nu}$

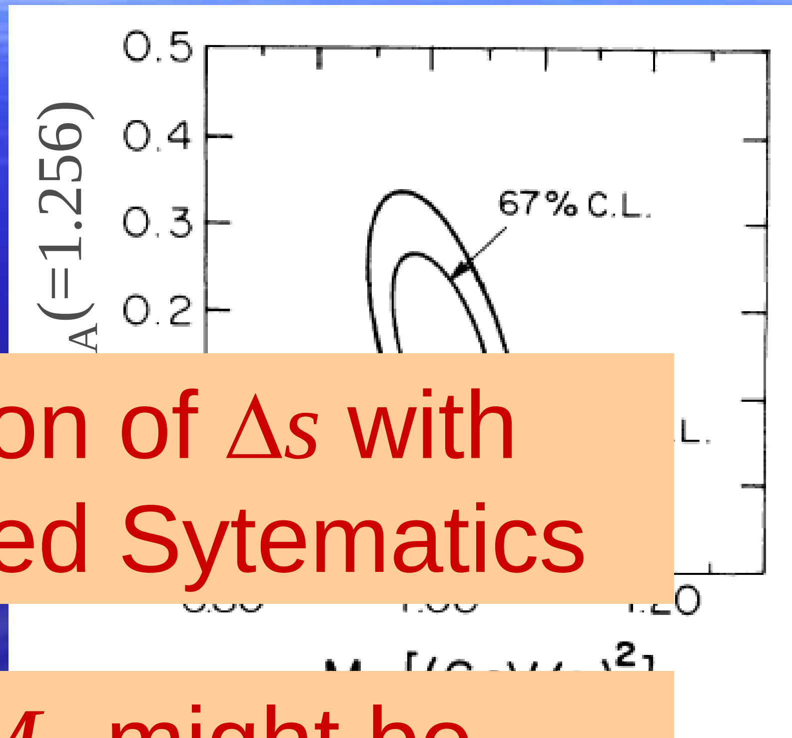
# Sensitivity for $\Delta s$

- Assumptions
  - 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
  - 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



# Comparison with E734

- If $\Delta s$ is the only parameter to be determined
  - E734: $\Delta s = -0.10 \pm 0.08$
  - J-PARC: $\Delta s = -0.10 \pm 0.03$
- But… $\Delta s$ and $M_A$ coupled sig




Better determination of $\Delta s$ with Significantly improved Sytematics

Separation with $M_A$ might be Problematic

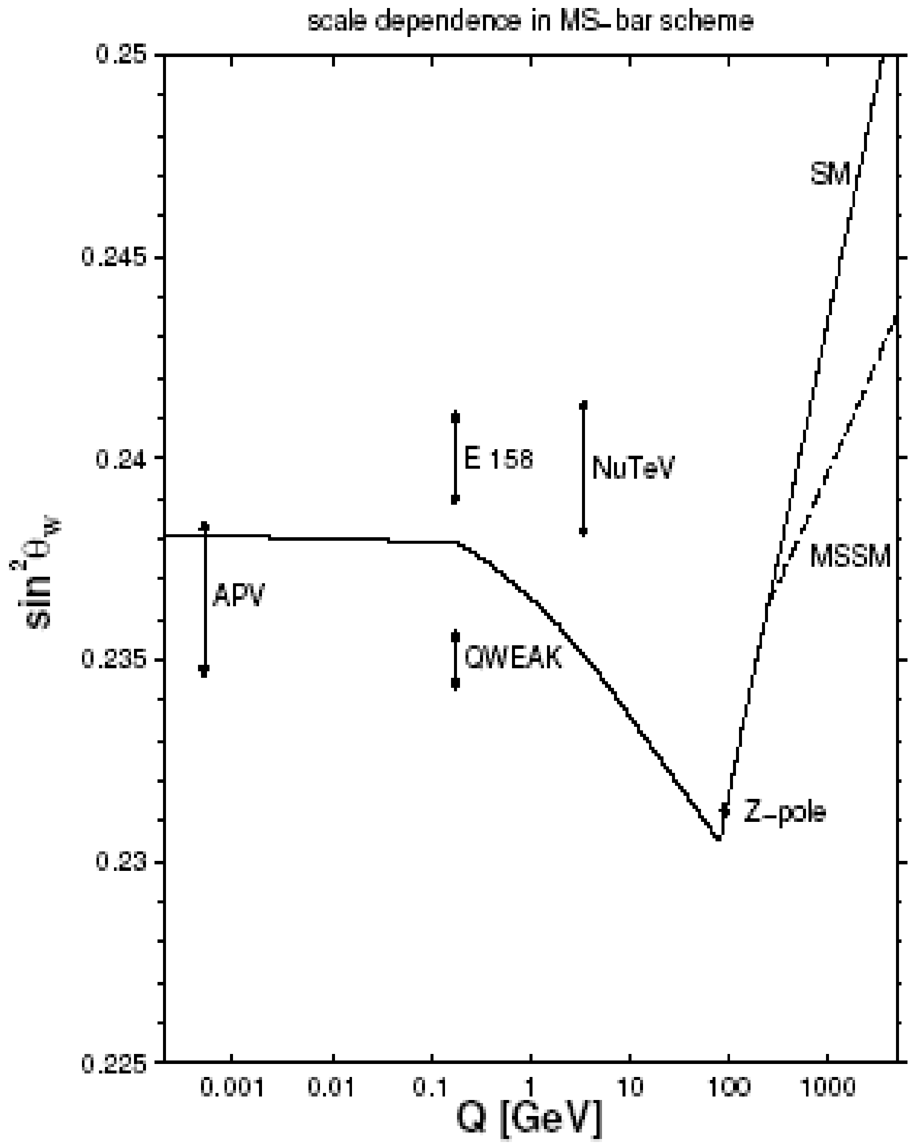
| Fit | $G_1^s(0)$ | $F_1^s$ | $F_2^s(0)$ | $M_A$ | $\chi^2/N_{DOF}$ |
|---|---|---|---|---|---|
| I | 0 | 0 | 0 | 1.086±0.015 | 14.12/14 |
| II | −0.15±0.07 | 0 | 0 | 1.049±0.019 | 9.73/13 |
| III | −0.13±0.09 | 0.49±0.70 | −0.39±0.70 | 1.049±0.023 | 9.28/11 |
| IV | −0.21±0.10 | 0.53±0.70 | −0.40±0.72 | 1.012±0.032 | 8.13/11 |

# Other Existing Efforts

- Semi-Inclusive DIS
  - DESY-HERMES and CERN-COMPASS
  - Subject to FF Uncertainties: BELLE measurement of FF
  - Limited in x-region
- RHIC Spin (Polarized pp Collider at BNL)
  - Clear determination of u-bar and d-bar with W production, however limited in x-region
  - Measurement of Ds requires charm-associated W production : small xsection
- FINeSSE experiment proposed at FNAL; BNL
  - Extend to lower $Q^2$ (as we discussed)
  - Seem to propose only neutrino measurements
    - Only quadratic combination will be determined → subject to two solution problem
  - Subject to Nuclear Effects (Liq Scintillator)

# Other physics topics to be investigated

- Neutrino-Nuclear cross section
  - Interesting by its own; important subject of Nuclear/Hadron Physics
  - Also provide a better control in oscillation physics
- Weak-Mixing Angle measurements
  - Low-Q2 determination of $\sin^2\theta_W$
  - Interests triggered by NuTeV, Atomic PV, and PV in eN scattering
  - Q: Testing EW? Or Testing Hadron Physics?



# Summary

- Strangeness Polarization in the Proton $\Delta s$ is still missing key to resolve *"Proton Spin Crisis"*
- Impact of the better determination is huge in Particle/Nuclear Physics
- New measurement at J-PARC is considered

Let's Work Together to solve
one of the most important problems
in Hadron Physics!

http://www.nucl.phy.titech.ac.jp/~sspin/