Predictions for Neutrino and Antineutrino Quasielastic Scattering Cross Sections with the Latest Elastic Form Factors

A Review of Weak and Electromagnetic Form Factors

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and
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Argonne National Laboratory

NuInt02 Conference  http://nuint.ps.uci.edu/
UC Irvine, California - Dec 12-15, 2002
http://www.pas.rochester.edu/~bodek/FormFactors.ppt
\[ \sigma_{\text{quasi-elastic neutrinos on Neutrons}} - \text{Dipole} \]

\[ \sigma_{\text{quasi-elastic Antineutrinos on Protons}} - \text{Dipole} \]

DATA - FLUX ERRORS ARE 10%. Note some of the data on nuclear Targets appear smaller (e.g. all the antineutrino data)

Quasi-Elastic Cross Section, GeP GeP GeP = dipole, GeN=0
Examples of Low Energy Neutrino Data: cross sections divided by Energy

\( \sigma_{\text{tot}}/E \) on Iso-scalar target, with Different contributions Quasi-elastic important in the 0-4 GeV region

\( \sigma_{\text{quasit}}/E \) on neutron target
Quasielastic only

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fixed W scattering - form factors

- **Electron Scattering:**
  - Elastic Scattering, Electric and Magnetic Form Factors ($G_E$ and $G_M$) versus $Q^2$ measure size of object (the electric charge and magnetization distributions). Final State $W = M_p = M$
  - ($G_E$ and $G_M$) TWO Form factor measures Matrix element squared $| < p_f | V(r) | p_i > |^2$ between initial and final state lepton plane waves. Which becomes:
    - $| < e^{-i k_2 \cdot r} | V(r) | e^{+i k_1 \cdot r} > |^2 \quad q = k_1 - k_2 = \text{momentum transfer}$
  - $G_{E,P,N}^p (Q^2) = \int \{ e^{i q \cdot r} \rho (r) \} d^3r \quad \text{Electric form factor is the Fourier transform of the charge distribution for Proton And Neutron}$
  - The magnetization distribution $G_{M,P,N}^p (Q^2)$ Form factor is relates to structure functions by:
    - $2x F_1 (x , Q^2)_{\text{elastic}} = x^2 G_{M,\text{elastic}}^2 \delta (x-1)$
      - Neutrino Quasi-Elastic ($W=Mp$)
        - $\nu_\mu + N \rightarrow \mu^- + P \quad (x=1, W=Mp)$
        - Anti-$\nu_\mu + P \rightarrow \mu^+ + N \quad (x=1, W=Mp)$
    - $F_1^V (Q^2)$ and $F_2^V (Q^2) =$ Vector Form Factors which are related by CVC to
    - $G_{E,P,N}^p (Q^2)$ and $G_{M,P,N}^p (Q^2)$ from Electron Scattering
    - $F_A (Q^2) =$ Axial Form Factor need to be measured in Neutrino Scattering.
    - Contributions proportional to Muon Mass (which is small)
    - $F_P (Q^2) =$ Pseudo-scalar Form Factor. estimated by relating to $F_A (Q^2)$ via PCAC, Also extracted from pion electro-production
    - $F_S (Q^2), F_T (Q^2),$ = scalar, tensor form factors=0 if no second class currents.
Need to update -
Axial Form Factor extraction

1. Need to account for Fermi Motion/binding Energy effects in nucleus e.g. Bodek and Ritchie (Phys. Rev. D23, 1070 (1981), Re-scattering corrections etc (see talk by Sakuda in this Conference for feed-down from single pion production)

2. Need to account for muon mass effects and other structure functions besides $F_1^V(Q^2)$ and $F_2^V(Q^2)$ and $F_A^V(Q^2)$ (see talk by Kretzer this conference for similar terms in DIS). This is more important in Tau neutrinos than for muon neutrinos [here use PCAC for $G_p(Q^2)$].

• This Talk (What is the difference in the quasi-elastic cross sections if:
  1. We use the most recent very precise value of $g_A = F_A^V(Q^2) = 1.263$ (instead of 1.23 used in earlier analyses.) Sensitivity to $g_A$ and $m_A$,
  2. Sensitivity to knowledge of $G_p(Q^2)$
  3. Use the most recent Updated $G_E^{P,N}(Q^2)$ and $G_M^{P,N}((Q^2)$ from Electron Scattering (instead of the dipole form assumed in earlier analyses) In addition

• There are new precise measurements of $G_E^{P,N}(Q^2)$ Using polarization transfer experiments
Neutrino Cross Sections

H. M. Gallagher and M. C. Goodman

\[ \frac{d\sigma}{dq^2} (\nu n \rightarrow l^- p) = \frac{M^2 G^2 \cos^2 \theta_c}{8\pi E_\nu^2} \left[ A(q^2) + B(q^2) \frac{(s - u)}{M^2} + C(q^2) \frac{(s - u)^2}{M^4} \right]. \]  

They implemented The Llewellyn-Smith Formalism for NUMI

In this expression, G is the Fermi coupling constant and \( \theta_c \) is the Cabibbo mixing angle (\( G = 1.16639 \times 10^{-\text{8}} \text{GeV}^{-2} \)). The functions A, B, and C are convenient combinations of the nucleon form factors.

Contraction of the hadronic and leptonic currents yields:

\[ A = \frac{(m^2 - q^2)}{4M^2} \left[ \left( 4 \frac{q^2}{M^2} \right) |F_A|^2 - \left( 4 + \frac{q^2}{M^2} \right) |F_V|^2 \right] - \frac{q^2}{M^2} \left( \frac{|F_A|^2}{M^2} + |F_V|^2 \right) \left( \frac{q^2}{4M^2} \right) - \frac{4q^2}{M^2} Re F_V^* \xi F_V \]  

\[ B = -\frac{q^2}{M^2} Re F_A^*(F_V^* + \xi F_V^2) - \frac{m^2}{M^2} Re \left[ \left( F_V^2 + \frac{q^2}{4M^2} \xi F_V \right) F_S - \left( F_A + \frac{q^2 F_P}{2M^2} \right) F_T \right] \]  

\[ C = \frac{1}{4} \left[ |F_A|^2 + |F_V|^2 - \frac{q^2}{M^2} \frac{|\xi F_V|^2}{2} - \frac{q^2}{M^2} |F_T|^2 \right], \]

where m is the final state lepton mass. Ignoring second-class currents (those which violate G-parity) allows us to set the scalar and tensor form factors to zero. According to the CVC
The electromagnetic form factors are determined from electron scattering experiments:

\[
F^V_P(q^2) = \left(1 - \frac{q^2}{4M^2}\right)^{-1} \left[G^V_E(q^2) - \frac{q^2}{4M^2} G^V_M(q^2)\right]
\]

\[
\xi F^V_P(q^2) = \left(1 - \frac{q^2}{4M^2}\right) \frac{1}{2} \left[G^V_M(q^2) - G^V_E(q^2)\right].
\]

The situation is slightly more complicated for the hadronic axial current. \( F_A(q^2 = 0) = -1.261 \pm 0.004 \) is known from neutron beta decay. The \( q^2 \) dependence has to be inferred or measured. By analogy with the vector case we assume the same dipole form:

\[
M_A = 1.032 \pm 0.036 \text{ GeV} \ [7].
\]

The inclusion of \( F_P \) leads to an approximately 5% reduction in both the \( \nu_\tau \) and \( \bar{\nu}_\tau \) quasi-elastic cross sections. The only remaining parameters needed to describe the quasi-elastic cross section are thus \( M_V \) and \( M_A \). \( M_V = 0.71 \text{ GeV} \), as determined with high accuracy.


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Axial structure of the nucleon  Hep-ph/0107088 (2001)

Véronique Bernard†, Latifa Elouadrhiri‡, Ulf-G Meißner§

For updated $M_A$ expt. need to be reanalyzed with new $g_A$, and $G_E^N$

**Figure 1.** Axial mass $M_A$ extractions. Left panel: From (quasi)elastic neutrino and antineutrino scattering experiments. The weighted average is $M_A = (1.026 \pm 0.021)$ GeV. Right panel: From charged pion electroproduction experiments. The weighted average is $M_A = (1.009 \pm 0.010)$ GeV. Note that value for the MAMI experiment contains both the statistical and systematical uncertainty; for other values the systematical errors were not explicitly given. The labels SP, DR, FPV and BNR refer to different methods evaluating the corrections beyond the soft pion limit as explained in the text. $M_A$ from neutrino expt. No theory corrections needed.
For the weak coupling constant, instead of $G_F = 1.16637 \times 10^{-5}$ GeV$^{-2}$ employed in NSGK, we adopt here $G_F' = 1.1803 \times 10^{-5}$ GeV$^{-2}$ obtained from $0^+ \rightarrow 0^+$ nuclear $\beta$-decays [26]. $G_F'$ subsumes the bulk of the inner radiative corrections.\textsuperscript{5} The K-M matrix element is taken to be $V_{ud} = 0.9740[26]$ instead of $V_{ud} = 0.9749$ used in NSGK.

\begin{align}
G_D(q_\mu^2) &= \left(1 - \frac{q_\mu^2}{0.71\text{GeV}^2}\right)^{-2}, \\
G_A(q_\mu^2) &= \left(1 - \frac{q_\mu^2}{1.04\text{GeV}^2}\right)^{-2},
\end{align}

(19)

(20)

where $\mu_p = 2.793$, $\mu_n = -1.913$, $\eta = -\frac{q_\mu^2}{4m^2}$ and $m_\pi$ is the pion mass. For $g_A$, we adopt the current standard value $g_A = 1.267[29]$, instead of $g_A = 1.254$ used in NSGK. In addition, as the axial-vector mass in Eq.(20), we use the value which was obtained in the latest analysis[28] of (anti)neutrino scattering and charged-pion electroproduction. The change in $G_A(q^2)$ is in fact not consequential for $\sigma_{\nu d}$ in the solar-$\nu$ energy region. Regarding $f_p$, we assume PCAC and pion-pole dominance. A contribution from this term is known to be proportional to the lepton mass, which leads to very small contribution from the induced pseudoscalar term in our case. Although deviations from the naive pion-pole dominance of $f_p$ have been carefully studied[30], we can safely neglect those.
Effect of $g_A$ and $M_A$

Use precise

Value $g_A = 1.267$ from beta Decay- with $M_A = 1.02$
(Nakamura 2002)

Compare to $g_A = 1.23$ with $M_A = 1.032$ (used by MINOS)


Note: $M_A$

Should be re-extracted with new the value of $g_A = 1.267$
 Parametrization of Fits to Form Factors

**GEP, GMP:** - Simultaneous fit to $1/(1+p_1q+p_2q^2+...)$ and $\mu_p/(1+...)$ - Fit to cross sections (rather than the Ge/Gm tables).

- Added 5 cross section points from Simon to help constrain $Q^2<0.1$ GeV$^2$
- Fit normalization factor for each data set (break up data sets from different detectors).
- Up to $p_6$ for both electric and magnetic
- Fits with and without the polarization transfer data. Allow systematic error to 'float' for each polarization experiment.

**GEP, GMP : CROSS SECTION DATA ONLY FIT:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_1$</td>
<td>-0.53916</td>
</tr>
<tr>
<td>$p_2$</td>
<td>6.88174</td>
</tr>
<tr>
<td>$p_3$</td>
<td>-7.59353</td>
</tr>
<tr>
<td>$p_4$</td>
<td>7.63581</td>
</tr>
<tr>
<td>$p_5$</td>
<td>-2.11479</td>
</tr>
<tr>
<td>$p_6$</td>
<td>0.33256</td>
</tr>
</tbody>
</table>

$\chi^2_{dof} = 0.81473$

**q1** - $q_6$ are parameters for GEP

**GEP, GMP: CROSS SECTION AND POLARIZATION DATA**

**Fit:**

**GMP**

<table>
<thead>
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<th>Value</th>
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<td>$p_2$</td>
<td>6.18608</td>
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<td>$p_3$</td>
<td>-6.25097</td>
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<td>$p_4$</td>
<td>6.52819</td>
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<tr>
<td>$p_5$</td>
<td>-1.75359</td>
</tr>
<tr>
<td>$p_6$</td>
<td>0.28736</td>
</tr>
<tr>
<td>$q_1$</td>
<td>-0.21867</td>
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$\chi^2_{dof} = 0.95652$

**GEP**

<table>
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<tr>
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<th>Value</th>
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</thead>
<tbody>
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<td>$q_2$</td>
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</tr>
<tr>
<td>$q_3$</td>
<td>-9.96209</td>
</tr>
<tr>
<td>$q_4$</td>
<td>16.23405</td>
</tr>
<tr>
<td>$q_5$</td>
<td>-9.63712</td>
</tr>
<tr>
<td>$q_6$</td>
<td>2.90093</td>
</tr>
<tr>
<td>$\chi_2_{dof}$</td>
<td>0.95652</td>
</tr>
</tbody>
</table>

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GMN: - Fit to $-1.913/(1+p1*q+p2*q^2+...)$
- NO normalization uncertainties included.
- Added 2% error (in quadrature) to all data points.
  Typically has small effect, but a few points had <1% errors.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>-0.40468</td>
</tr>
<tr>
<td>P2</td>
<td>5.6569</td>
</tr>
<tr>
<td>P3</td>
<td>-4.664</td>
</tr>
<tr>
<td>P4</td>
<td>5</td>
</tr>
<tr>
<td>P5</td>
<td>3.8811</td>
</tr>
</tbody>
</table>

GEN: Use Krutov parameters for Galster form see below


Krutov-> (a = 0.942, b=4.61)

vs. Galster ->(a=1 and b=5.6)


$$G_E^n(Q^2) = -\mu_n \frac{a}{1 + b\tau} G_D(Q^2), \quad G_D(Q^2) = \left(1 + \frac{Q^2}{0.71}\right)^{-2}, \quad \tau = \frac{Q^2}{4M^2}. \quad (13)$$

The neutron magnetic moment $\mu_n = -1.91304270(5)$ $[49]$. $Q^2$ in $G_D(Q^2)$ is given in $(\text{GeV}^2)$. 

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Neutron $G_M^N$ is negative

**Neutron ($G_M^N / G_M^N$ dipole)**


\[ \frac{G_M^N}{G_M^N \text{ dipole}} \]
Effect of using Fit to $G_M^N$ versus using $G_M^N$ Dipole

Neutron $G_M^N$ is negative

Neutron $(G_M^N / G_M^N \text{ dipole})$

\[ \nu + n \rightarrow p + e^+ \]
\[ \bar{\nu} + p \rightarrow n + e^+ \]
Neutron, $G_E^N$ is positive

\[
G_E^n(Q^2) = -\mu_n \frac{a \tau}{1 + b \tau} G_D(Q^2),
\]
\[
G_D(Q^2) = \left(1 + \frac{Q^2}{0.71}\right)^{-2}, \quad \tau = \frac{Q^2}{4M^2}. \quad (13)
\]

The neutron magnetic moment \(\mu_n = -1.91304270(5)\) [49]. \(Q^2\) in \(G_D(Q^2)\) is given in (GeV\(^2\)).

[14, 39]:
\[
\left.\frac{dG_E^n}{dQ^2}\right|_{Q^2=0} = 0.0199 \pm 0.0003 \text{ fm}^2. \quad (14)
\]

The fitting of the slope (14) gives \(a=0.942\) with the accuracy \(\approx 1.5\%\).

This value of \(a\) gives the slope of \(G_E^n(Q^2)\) at \(Q^2 = 0\) which is measured directly in the experiment.

The parameter \(b\) is fitted using the \(\chi^2\) criterion. If we use all the 35 points we obtain \(b = 4.61\) with \(\chi^2 = 69.0\). Note that the fit DRN–GK(3) [39] of 23 points has \(\chi^2 = 63.9\).

If we exclude the points \# 4–8 then the 30–point fitting gives \(b = 4.62\) with \(\chi^2 = 61.5\).


Effect of using $G_E^N$ (Krutov) or (Galster) versus using $G_E^N = 0$ (Dipole Assumption). Krutov and Galster very similar.
Extract Correlated Proton $G_M^p$, $G_E^p$ simultaneously from e-p Cross Section Data with and without Polarization Data

Proton $G_M^p$

Compare Rosenbluth Cross section Form Factor Separation Versus new Hall A Polarization measurements

Howard Budd, L
Proton $G_E^p$

Compare Rosenbluth Cross section Form Factor
Separation Versus new Hall A Polarization measurements

Proton $G_E^p / G_M^p$

JRA Fit [ Cross sections ]

Cross Section Data
Pol data not shown

JRA Fit [ $\sigma$ + Polarization ]

Pol data not shown

Global L/T analysis
Polarization transfer – Hall A
E01-001 Projected Uncertainties

Polarization Transfer data
Effect of $G_M^N$, and $G_M^P$, $G_E^P$ (using cross section data) (with $G_E^N = 0$) 
Versus Dipole Form factor

![Graph showing the ratio $\sigma/\sigma_{	ext{reference}}$ vs. $E_\nu$ (GeV) with data points and fits for neutrino and antineutrino reactions.]

using cross section data

Pol data not shown
Effect of $G_N^M$, $G_P^M$, $G_P^E$ (using POLARIZATION data) (with $G_N^E=0$) Versus Dipole Form Factor

Using POLARIZATION Transfer data

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Jha_D0DD.png

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Effect of $G_M^N$, $G_M^P$, $G_E^P$ (using cross section data AND non zero $G_E^N$ Krutov) Versus Dipole Form
Effect of $G_M^N + (G_M^P, G_E^P$ using POLARIZATION data AND non zero $G_E^N$ Krutov) - Versus Dipole Form

$\rightarrow$ Discrepancy between $G_E^P$ Cross Section and Polarization Data Not significant for Neutrino Cross Sections

$G_M^P, G_E^P$ extracted with both e-p Cross section and Polarization data

$G_M^P, G_E^P$ extracted With e-p Cross Section data only
**Axial structure of the nucleon**

Véronique Bernard†, Latifa Elouadrhiri‡, Ulf-G Meißner§

The induced pseudoscalar form factor is the least well known of all six electroweak nucleon form factors.

Seonho Choi, et al
PRL V71 page 3927 (1993) Near Threshold Pion Electro-production and lowest Q2 point from Ordinary Muon Capture (OMC) both agree with PCAC

A third way to measure gp. is from Radiative Muon Capture (RMC), but the first measurement is factor of 1.4 larger

**Figure 5.** The “world data” for the induced pseudoscalar form factor $G_P(Q^2)$. The pion electroproduction data (filled circles) are from reference [65]. Also shown is the world average for ordinary muon capture at $Q^2 = 0.88 M^2$ (diamond). For orientation, we also show the theoretical predictions discussed later. Dashed curve: Pion-pole (current algebra) prediction. Solid curve: Next-to-leading order chiral perturbation theory prediction.

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Table 1. Pseudoscalar coupling constant determined from OMC in light nuclei.

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>$g_P$</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^3\text{He}$ (capture to triton)</td>
<td>8.6 ± 1.5</td>
<td>[58]</td>
</tr>
<tr>
<td>$^{12}\text{C}$ (capture to ground state)</td>
<td>8.3 ± 2.5</td>
<td>[59]</td>
</tr>
<tr>
<td>$^{16}\text{O}$ (capture to $^{16}\text{N}(0^-)$)</td>
<td>10.0 ± 1.2</td>
<td>[60] [61]</td>
</tr>
</tbody>
</table>

background. Precisely for this reason only very recently a first measurement of RMC on the proton has been published [62, 63]. The resulting number for $g_P$, which was obtained using a relativistic tree model including the $\Delta$-isobar [64] to fit the measured photon spectrum, came out significantly larger than expected from OMC,

$$g_P^{\text{RMC}} = 12.35 \pm 0.88 \pm 0.38 \simeq 1.4 g_P^{\text{OMC}},$$

and thus also about 40% above all theoretical expectations (see section 4.1). It should

$$g_P = (8.74 \pm 0.23) - (0.48 \pm 0.02) = 8.26 \pm 0.16.$$
Note, one measurement of $g_P$ from Radiative Muon Capture (RMC) at $Q=\text{Mmuon}$ quoted in the above Review disagrees with PCAC by factor of 1.4. PRL V77 page 4512 (1996).

In contrast Seonho Choi, et al PRL V71 page 3927 (1993) from OMC, agrees with PCAC.

The plot (ratio_gp15_D0DD.pict) shows the sensitivity of the cross section to a factor of 1.5 increase in $g_P$.

**IT IS ONLY IMPORTANT FOR the lowest energies.**
Conclusions

1. Non Zero Value of $G_{EN}$ is the most important (5% effect)

2. We plan to do re-analysis of neutrino quasielastic data for $d\sigma/dQ^2$ to obtain update values of $M_A$ with
   - Latest values of $G_{EN}, G_{MN}, G_{MP}, G_{EP}$ which affect the shape.
   - Latest value of $g_A$ (not important if normalization is not used in $d\sigma/dQ^2$ Flux errors are about 10%).
Thanks To: The following Experts (1)

Will Brooks, Jlab - Gmn brooksw@jlab.org


• Recent, moderate precision low Q2 data nucl-ex/0208007

• The best high Q2 data:
  http://prola.aps.org/pdf/PRL/v70/i6/p718_1
  http://prola.aps.org/pdf/PRL/v70/i6/p718_1
  They will have a new Gmn measurement from Q2=0.2 or 0.3 out to Q2 approaching 5 GeV². plot of the expected data quality versus old data (shown as Ratio to Dipole).
The new jlab experiment for GMN is E94-017. It has much more sensitivity (in the sense of statistical information that influences a fit) than existing measurements, just not much more Q2 coverage. The errors will be smaller and will be dominated by experimental systematic errors; previous measurements were dominated by theory errors that could only be estimated by trying different models (except for the new data below 1 GeV). The new experiment's data will dominate any chi-squared fit to previous data, except for the new high-precision data below 1 GeV2 where it will rival the new data. Time scale for results: preliminary results this coming spring or summer, publication less than 1 year later.
Thanks To: The following Experts (2)

Gen: Andrei Semenov, - Kent State, semenov@jlab.org

Who provided tables from (Dr. J.J. Kelly from Maryland U.) on Gen, Gmn, Gen, Gmp.

The new Jlab data on Gen are not yet available, but is important to confirm since non-zero Gen effect is large. The experiment is JLab E93-038. Data were taken in Jefferson Lab (Hall C) in October 2000/April 2001. Data analysis is in progress.

The New Jlab Data on Gep/Gmp will help resolve the difference between the Cross Section and Polarization technique. However, it has little effect on the neutrino cross sections. For most recent results from Jlab see: hep-ph/0209243
Neutrino Cross Section Data

http://neutrino.kek.jp/~sakuda/nuint02/

charged current quasi-elastic neutrino
Gargamelle 79  ccqe.nu.ggm79.vec,
ccqe.nub.ggm79.vec -- CF3Br target

cqe.serpukhov85.vec,
cqe.nub.serpukov.vec -- Al. target

charged current quasi-elastic neutrino
Gargamelle 77  ccqe.ggm77.vec
- Propane-Freon

cqe.nu.skat90.vec
  ccqe.nub.skat90.vec -- CF3Br
ccqe.nu.bebc90.vec -- D2

Cross section in units of $10^{-38}$ cm$^2$.
E  Xsection X +-DX  Y +-DY or (x1, x2)  y +-dy

Note more recent
$M_A$ is more reliable-
Better known flux
Examples of Low Energy Neutrino Data:
Quasi-elastic cross sections-Absolute

σ_{quasi-elastic} neutrinos
On Neutrons
From MINOS Paper and MINOS dipole MC

σ_{quasi-elastic} neutrinos on Neutrons -Dipole
σ_{quasi elastic} Antineutrinos on Protons -Dipole

elas_D0DD.pitf
This assumes Dipole form factors $G_E^N = 0$

Replace by $G_E^V = G_E^P - G_E^N$

-->note $G_E^N$ is POSITIVE

Replace by $G_M^V = G_M^P - G_M^N$

-->note $G_M^N$ is NEGATIVE
Old LS results with Old $g_a=-1.23$ and MA below)

10. Cross sections for the quasielastic process in the conventional theory with $m=0$ and dipole forms

\[ \sigma = \left( \frac{F(0)}{1 - \frac{q^2}{0.73 \text{GeV}^2}} \right)^2 \]

for the form factors $F_A$ and $F_\nu^{1,2}$. \(^{12}\) (the dotted line is the limit $q \rightarrow 0$ and $\sigma_D$ as $F \rightarrow \infty$).
Compare to Original Llewellyn Smith Prediction

Quasi-Elastic CS, GEp GMp GMp=dipole, GEN=0, m=0.85, g=1.23

\( \sigma (10^{-38} \text{cm}^2) \)

\( E_\nu (\text{GeV}) \)