Nucleon Resonance Form Factor and Duality

DCC(coupled channel) model

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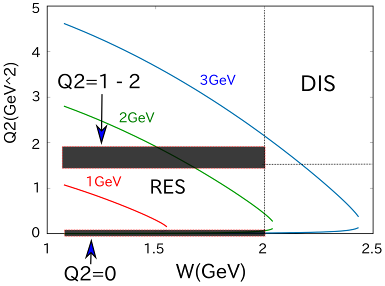
Motivation

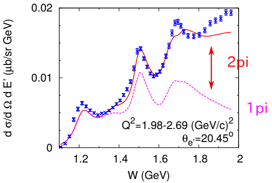


- Purpose: description of lepton(e,ν)-nucleon reactions in the RES ($W < 2GeV$, $Q^2 < 2GeV^2$) region and extract resonance properties. [$\Delta(1232)$+SIS]
- ANL-Osaka DCC model: $\nu N \rightarrow \pi N, \eta N, KY, \pi\pi N$ (res + non-res)
  Vector current $\leftarrow$ electron scattering data
  Axial current $\leftarrow$ PCAC at $Q^2 = 0$.
  Need improvements : low energy Chipt, $\Delta S \neq 0$, $n(e,e')$,ωN..
- DCC model around $Q^2 \sim 1GeV$. $\leftrightarrow$ Parton picture

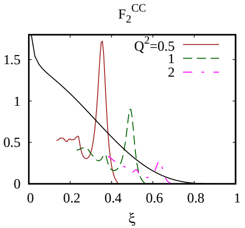
JSPS:16K05354,19H05104,25105010

DCC model around $Q^2 = 1 \sim 2GeV^2$

- Inclusive electron scattering: DCC model vs data
  2π important for high W region



- $(F_{2p}^{CC} + F_{2n}^{CC})/2$: DCC model vs PDF
  missing strength, little contribution of A around $W \sim 2GeV$, $Q^2 > 1GeV^2$



Parton picture vs Hadron picture

- Parton picture(assume Isospin-symmetry, neglect s, without CKM)

$$
\begin{aligned}
F_{2p}^{CC} &= (1+1)xd(x) \\
F_{2n}^{CC} &= (1+1)xu(x) \\
W^{\mu\nu} &\sim Tr[\not{p}'\gamma^{\mu}(1-\gamma_5)\not{p}\gamma^{\nu}(1-\gamma_5)]
\end{aligned}
$$

- Hadron picture

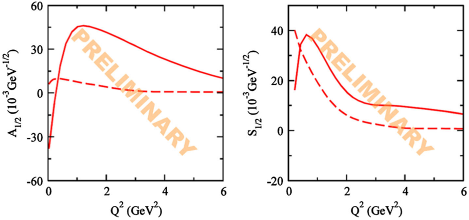
$$
\begin{aligned}
F_2^{CC} &\sim \sum_f [| < f|V_{1+i2}|N > |^2 + | < f|A_{1+i2}|N > |^2] \\
F_{2p}^{CC} &= F_2^{CC}(I=3/2) \\
F_{2n}^{CC} &= \frac{1}{3}[F_2^{CC}(I=3/2) + 2F_2^{CC}(I=1/2)]
\end{aligned}
$$

  - Response of vector current and axial vector current
  - Isospin 3/2 and 1/2 hadronic states

$N \to N^*, \Delta$ Transition form factor

- $p(e, e'\pi), p(e, e'2\pi)$ cross sections indicate resonance contribution remains at high Q^2.
- Extracted $N \to N^*, \Delta$ transition form factors are not monotonically decreasing function of Q^2.

Electromagnetic(Extracted from amplitudes of DCC model $1/2^+1/2$(P11,Roper)



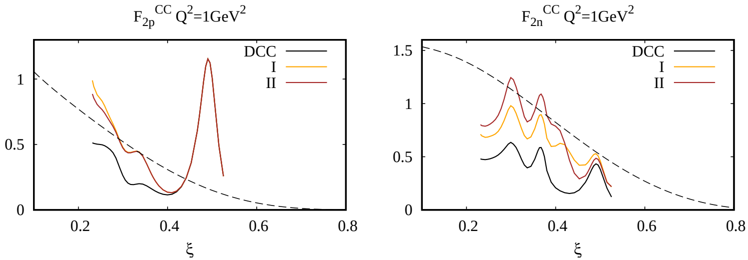
Helicity amplitude(transition form factor)

- Modify dipole form factor of axial vector transition form factors.
- Use Q^2 dependence of iso-vector vector transition form factor determined from the analysis of $N(e,e')$. (except Δ_{33})
- At $Q^2=0$, keep strength determined by PCAC

$$
\begin{aligned}
A^A_x(Q^2,W) &= A^A_x(0,W)\times\frac{A^V_x(Q^2,W)}{A^V_x(0,W)} \quad (x=3/2,1/2,t)\\
A^A_{1/2,L}(Q^2,W) &= A^A_{1/2,L}(0,W)\times\frac{A^V_{1/2}(Q^2,W)}{A^V_{1/2}(0,W)} \quad \text{(I)}\\
& A^A_{1/2,L}(0,W)\times\frac{A^V_{1/2,t}(Q^2,W)}{A^V_{1/2,t}(0,W)} \quad \text{(II)}
\end{aligned}
$$

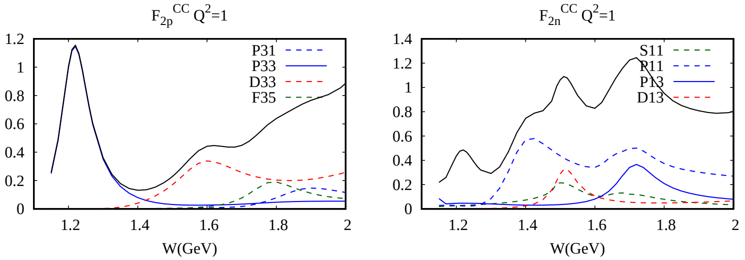
$$
< Res|A^\mu|N >= {\color{red}< Res^0|A^\mu|N >} + \sum_{MB} < Res^0|H_I|MB > G^0_{MB} < MB|A^\mu|N >
$$

Preliminary results



- Increased contribution of Axial vector current. $DCC \to I, II$

Preliminary results



- contribution of top 4 resonances
- F_{2p} $I = 3/2$(P33,P31,D33,F35)
- F_{2n} $I = 3/2$ and $I = 1/2$(P11,P13,S11,D13)
- More has to be examined(Q^2 dependence, F_1, F_3, A and V, 1π and 2π...)

Summary

- ANL-OSAKA DCC model is extended to describe weak meson production reaction up to $W < 2GeV$.
- Transition form factors of axial vector current.
  At $Q^2 = 0$, the DCC model reproduce πN data.
  Comparison with PDF at high Q^2 of current models of neutrino reaction in resonance region , suggests need for more strength at high W region.
  Use of electromagnetic transition form factors of the DCC model for the axial current improves missing strength of axial vector current at high Q^2.