Quarks and Hadrons at SPring-8

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JAERI/JINR

Part I

Vector mesons (ϕ,ω,ρ)-meson and QCD

Θ^+-pentaquark physics

Parity non-conservation in photo-nuclear processes

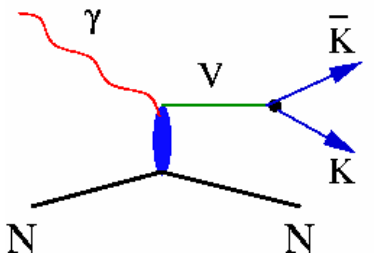
Part II

Concluding Remarks

Part I

Hadron Physics with Polarized Photons at Spring8

ϕ-meson photoproduction and QCD



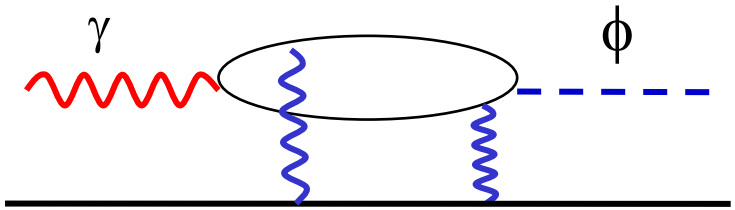
$$T_{\lambda_\gamma \lambda_\phi = \lambda_\gamma} \cdot T^{*}_{\lambda_\gamma \lambda_\phi = \lambda_\gamma}; \quad \lambda_\phi = \pm 1$$

$$W(\cos\Theta, \Phi) \propto \rho_0 Y_{10}{}^2(\Theta, \Phi) + \rho_{11} Y_{11}{}^2(\Theta, \Phi)$$
$$+ \mathrm{Re}\, \rho_{1-1} Y_{1-1}(\Theta, \Phi) Y^{*}{}_{11}(\Theta, \Phi)$$

$$T_{\lambda_\gamma \lambda_\phi = 0} \cdot T^{*}_{\lambda_\gamma \lambda_\phi = 0}$$

$$T_{\lambda_\gamma \lambda_\phi = \lambda_\gamma} \cdot T^{*}_{\lambda_\gamma \lambda_\phi = -\lambda_\gamma}$$

Non-perturbative 2-gluon exchange

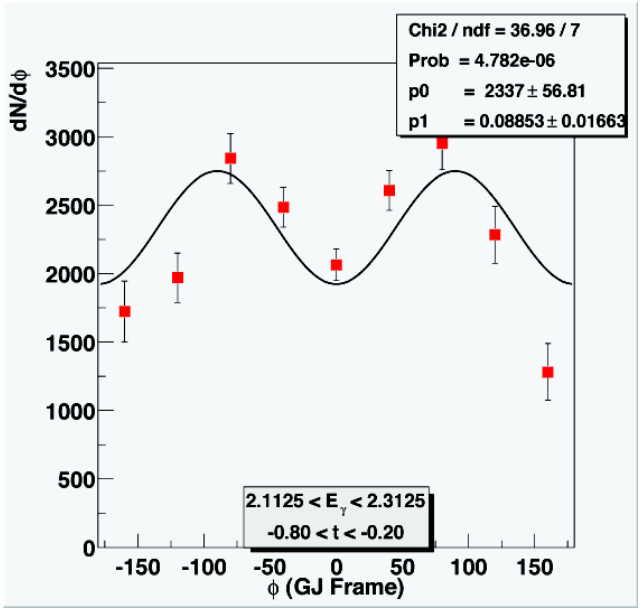


Φ– (*azimuthal angle) distribution*
(as a tool for double spin-flip processes)

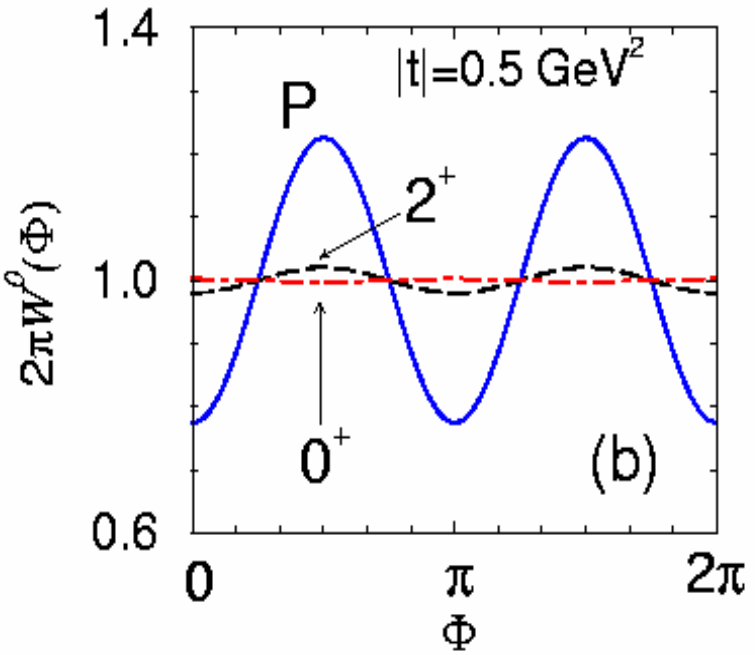
$$W^0(\Phi) = \frac{1}{2\pi}\left(1 - 2\mathrm{Re}\rho^0_{1-1}\cos 2\Phi\right)$$

$$\rho^0_{1-1} = \sqrt{\frac{\sigma(\lambda_\phi = -\lambda_\gamma)}{\sigma_{tot}}}$$

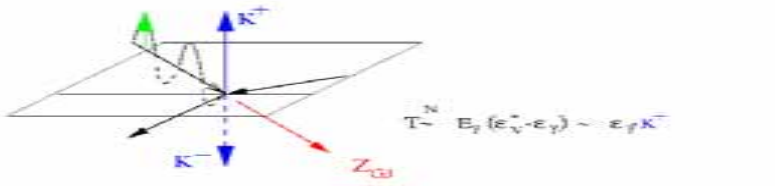
Raw data
CLAS/LEPS



A. Titov, T.-S.H. Lee, PRC 67, 2003



Vector Meson Decay Distribution Depends on the Production Mechanism



$$\Sigma_V = \frac{\sigma^N - \sigma^U}{\sigma^N + \sigma^U} \simeq 1 - 2\alpha^2, \qquad \alpha = \frac{T^U}{T^N} \qquad (\alpha^2 \ll 1)$$

(electric)
Natural-parity exchange

(magnetic)
Unnatural parity exchange

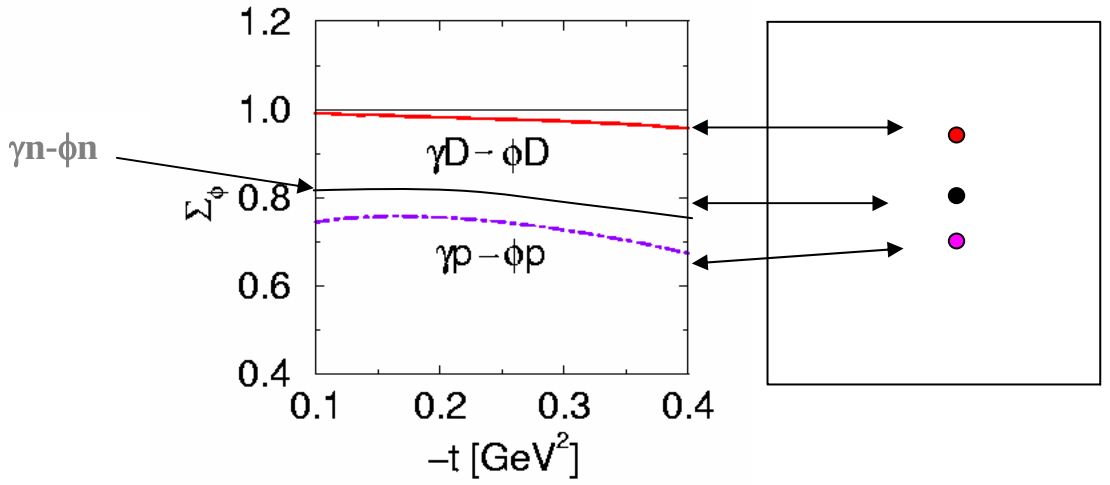
$p: \eta + \pi$

$n: \eta - \pi \quad \eta << \pi$

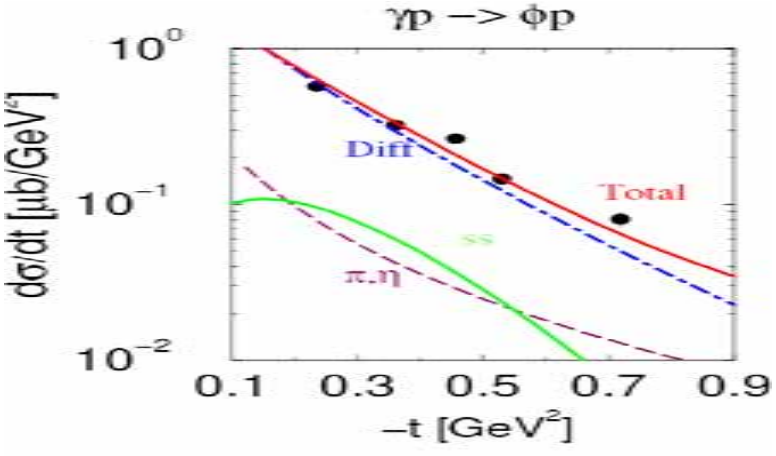
$D: \eta$

A.T., Fujiwara, Lee, PRC, 66,'02

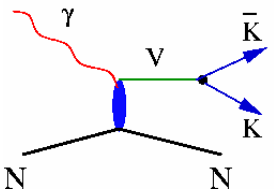
LEPCS, prelim.



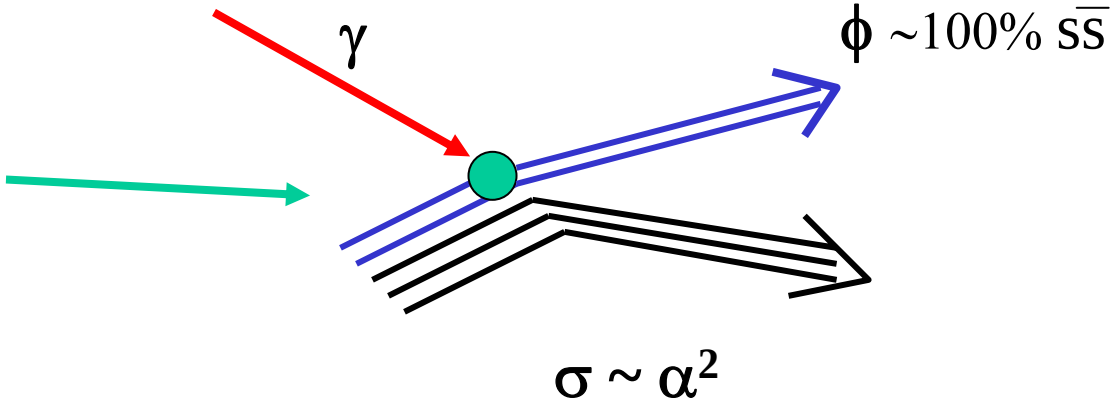
ϕ-meson photoproduction and hidden strangeness



ϕ-meson photoproduction is dominated by the diffractive channels (Pomeron exchange)

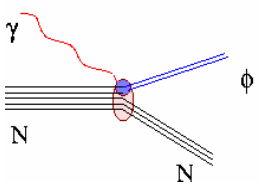


$|N\rangle = \alpha\,|3q\rangle + |5q=3q+s\bar{s}\rangle$

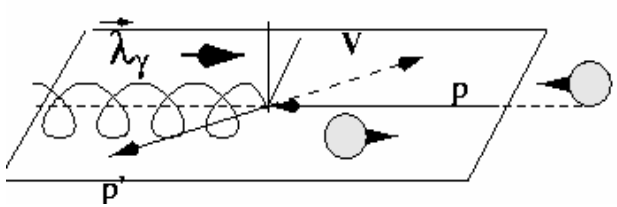


Henly, et al, ('94); S.N.Yang, Oh, Morii, A.T. ('94-'99)

Beam-target asymmetry and exotic processes with unnatural parity exchange (ss-knockout)



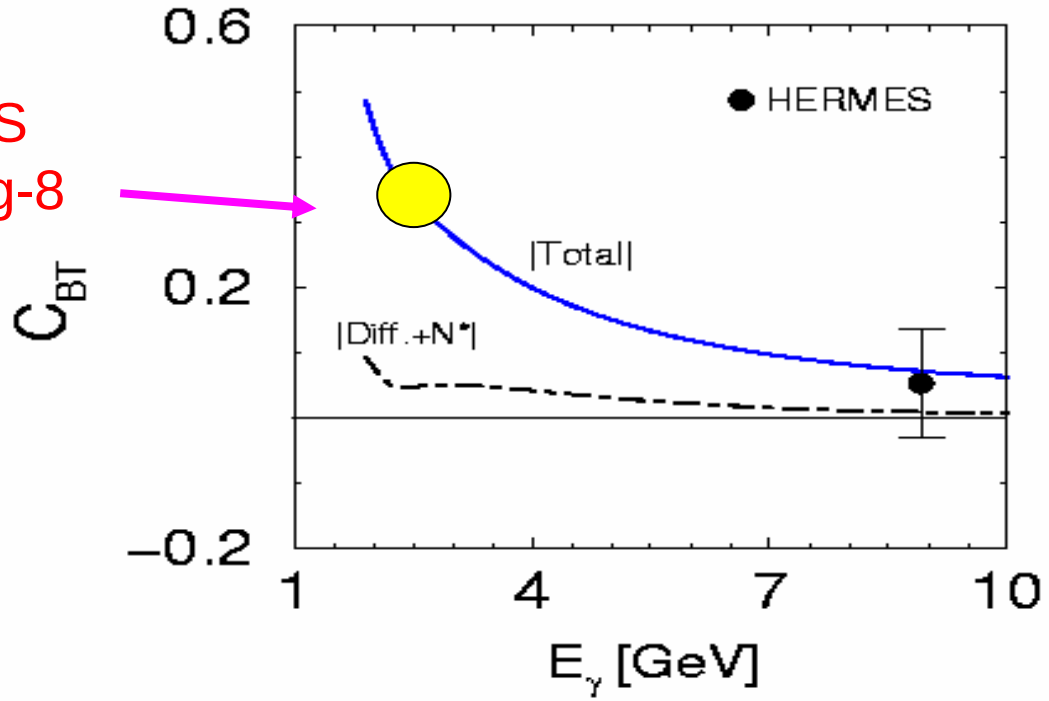
$$C^{BT} = \frac{d\sigma(\overrightarrow{\rightarrow}) - d\sigma(\overleftarrow{\rightarrow})}{d\sigma(\overrightarrow{\rightarrow}) + d\sigma(\overleftarrow{\rightarrow})}$$



$$\gamma^{p}_{BT} \simeq 2|\alpha^{pU}|\cos\delta^{p}_{\mathrm{N-U}},$$

$$\alpha^{pU} \simeq \sqrt{\frac{\sigma^{pU}}{\sigma^{p}_{\mathrm{tot}}}}$$

LEPS
SPring-8

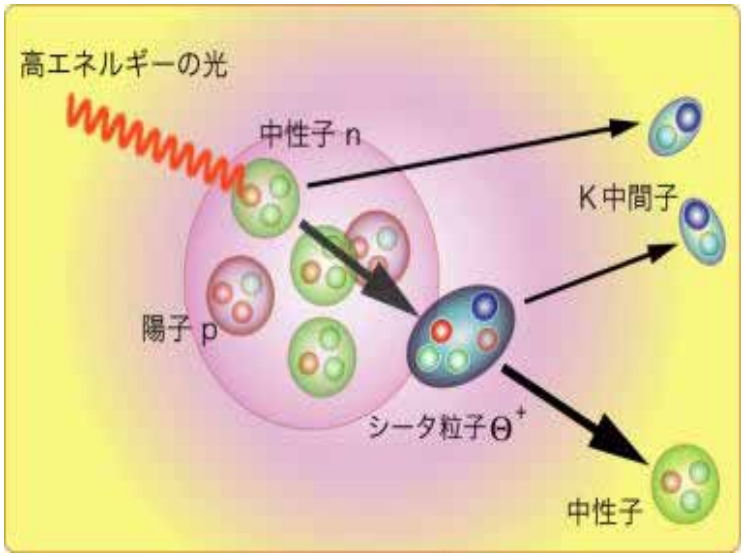


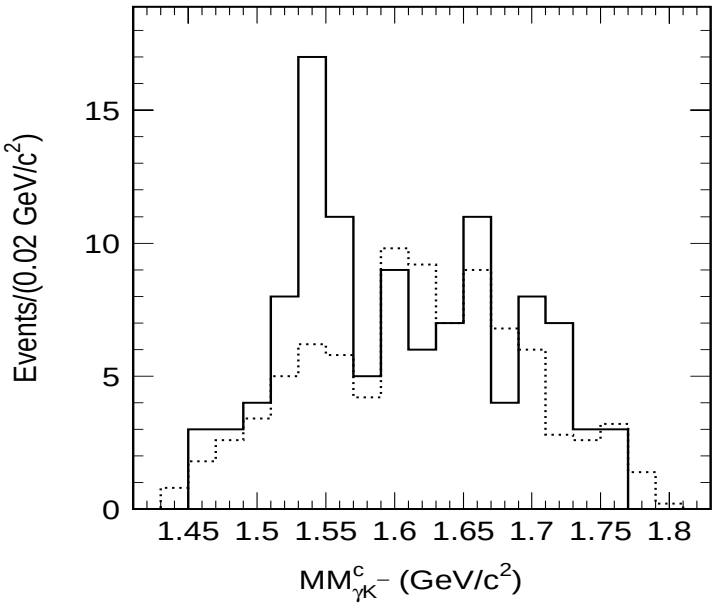
Θ^+ – *photoproduction at Spring-8*

LEPS Collaboration. T.Nakano et al.

Phys. Rev. Lett. 91, 012002 (2003)

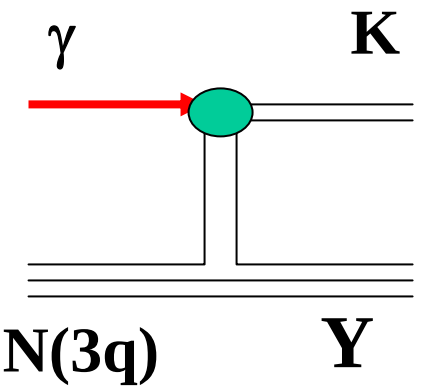
The reaction $\gamma n \rightarrow \Theta^+ K^-$,
where $\Theta^+ \rightarrow nK^+$
(LEPS)



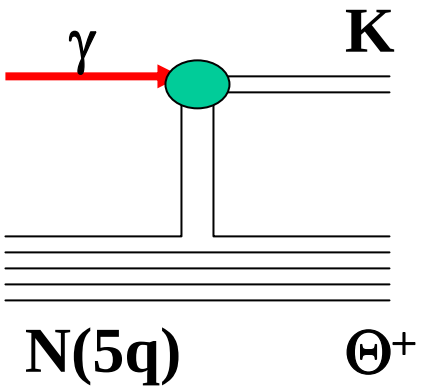


Hidden strangeness and Θ^+– pentaquark

$\gamma N \to \Sigma^+ K$



$\gamma N \to \Theta^+ K$



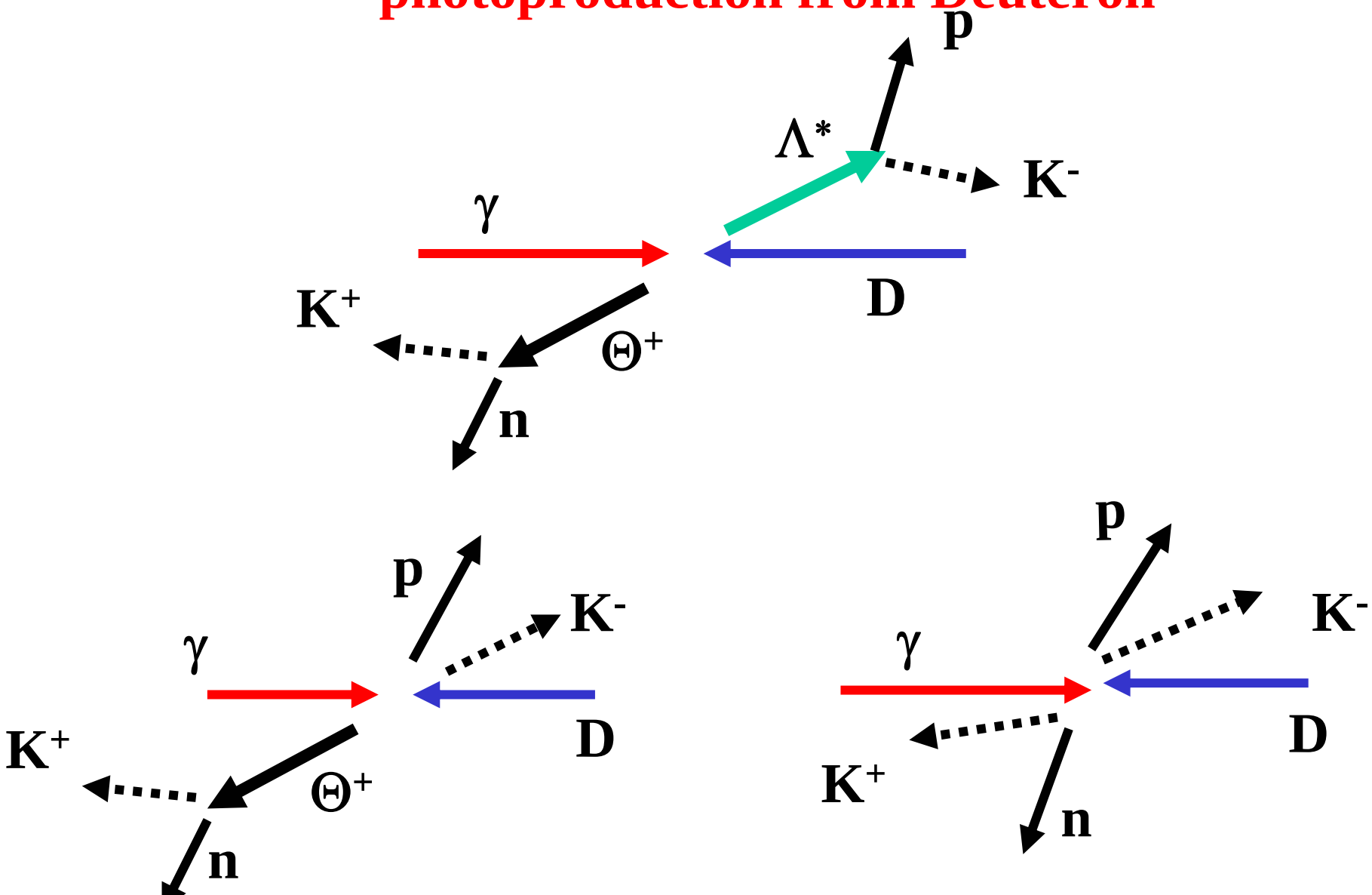
$$|N\rangle = \sqrt{1-\alpha^2}\,|N(3q)\rangle + \alpha\,|N(5q)\rangle$$

$$\alpha^2 \approx \frac{\langle NK\,|\,\Theta^+\rangle^2}{\langle N\,|\,KY\rangle^2}; \qquad \langle NK\,|\,\Theta^+\rangle^2 \propto \Gamma_{\Theta^+\to NK} \approx 1 \text{ MeV};$$

$$\alpha^2 \approx 10^{-2}$$

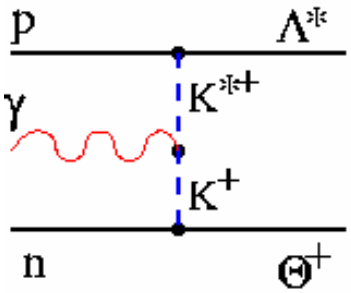
A.T., Hosaka, Date',Ohashi, PRC,70,'04

Coherent Λ*(1520) and Θ+ (1540) photoproduction from Deuteron

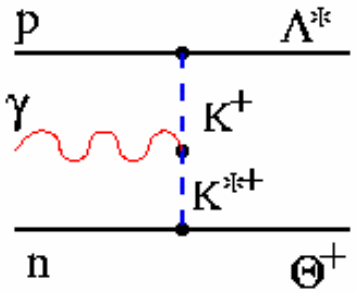


Main processes

$\langle D |$

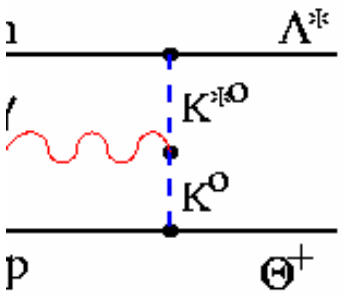


(a)

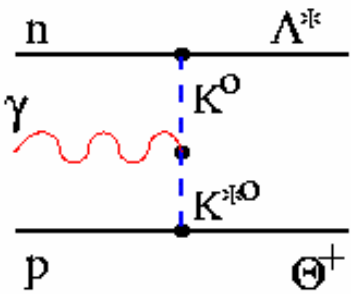


(b)

$\langle D |$



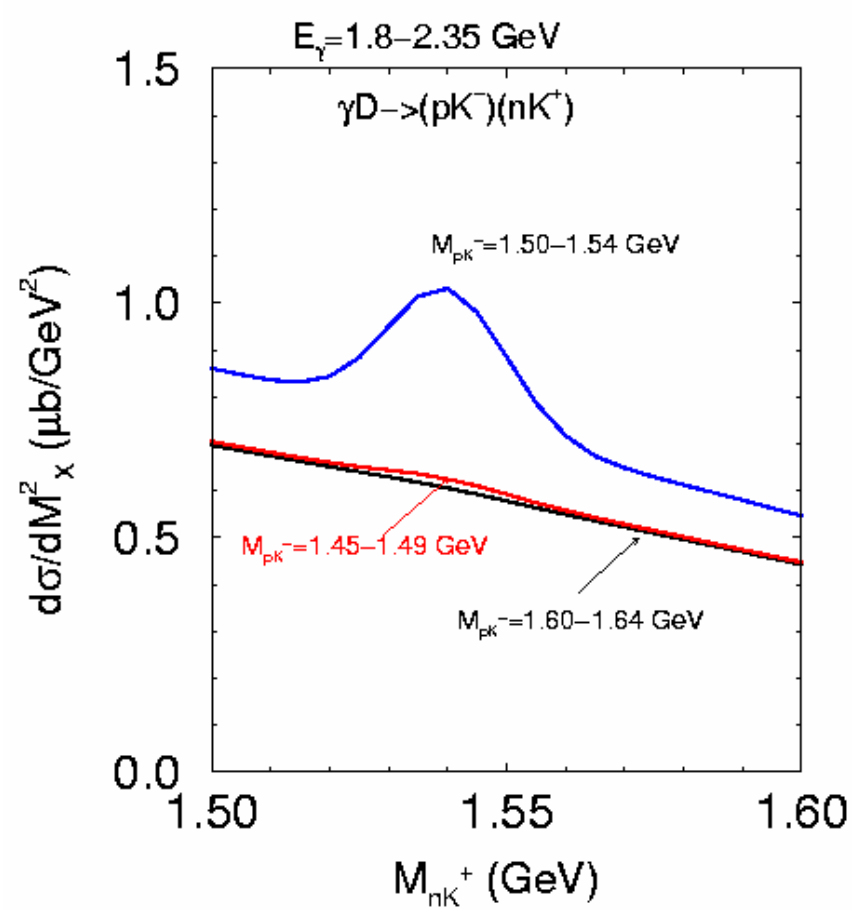
(c)

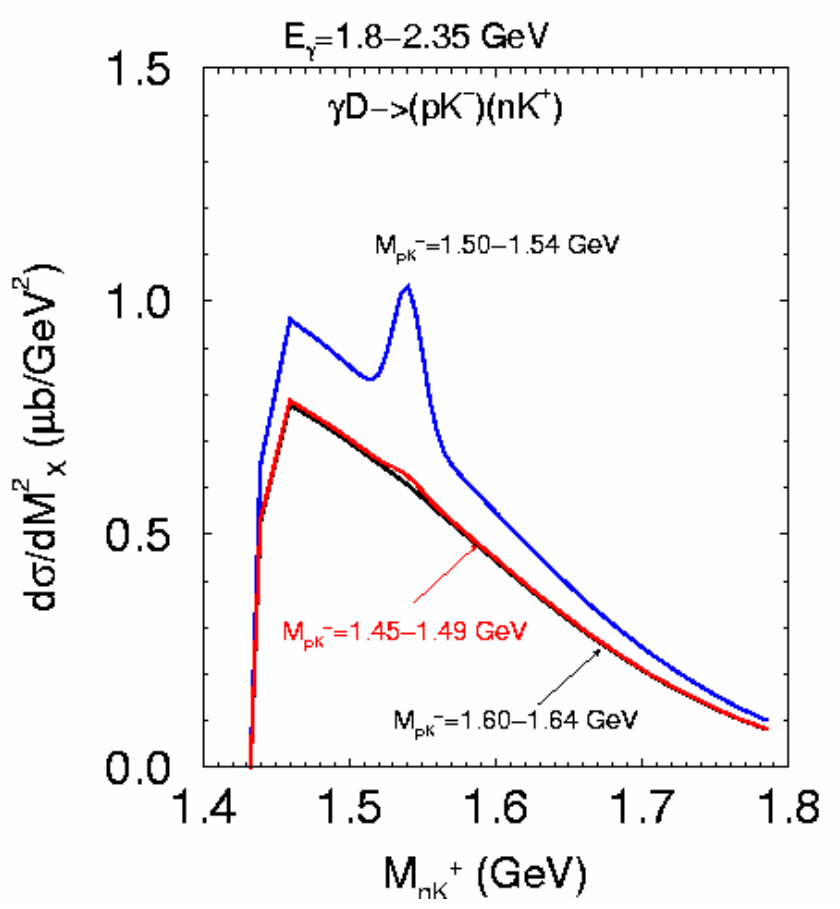


(d)

+ < 20 more!!!

Invariant mass distribution





Spin observables? Beam asymmetry

$$\Sigma_B = \frac{\sigma^{\perp} - \sigma^{\parallel}}{\sigma^{\perp} + \sigma^{\parallel}}$$

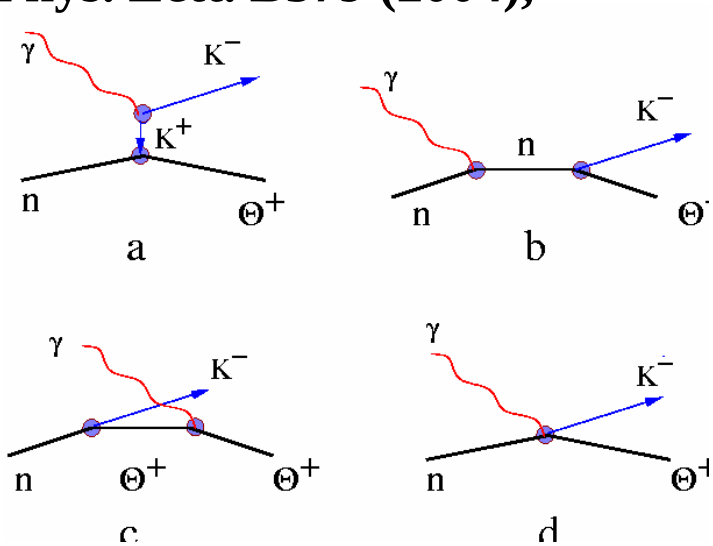
Nakayama & Tsushima:

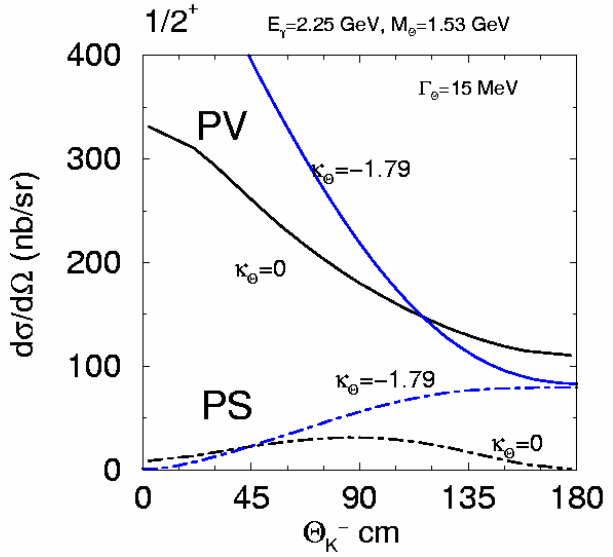
Phys. Lett. **B583**, 269(2004)

for the positive
parity of Θ^+ the beam asymmetry
is significantly positive,
whereas for the negative parity of Θ^+
beam asymmetry is significantly negative

Ambiguity of the production mechanism

S.I. Nam, A. Hosaka, and H.C. Kim, Phys. Lett. B579 (2004),





PS, PV

$g_{\Theta NK}$

κ_Θ

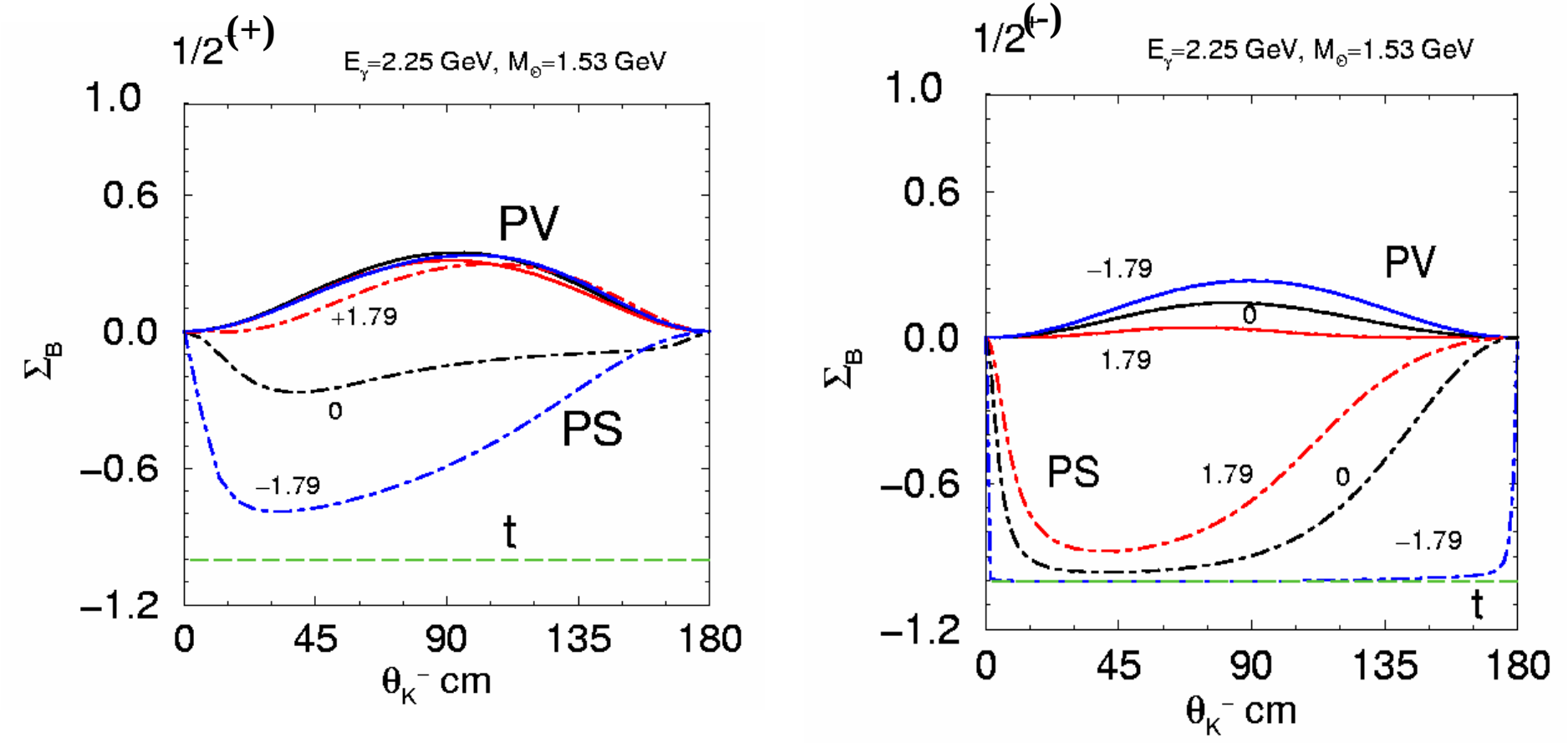
$\mathrm{Fstu}(\Lambda, p^2) + \text{gauge inv.}$

$$|g^{\pm}_{\Theta NK}|^2 = \frac{2\pi\Gamma_\Theta M_\Theta}{p_F(\sqrt{M^2 + p_F^2} \mp p_F^2)}$$

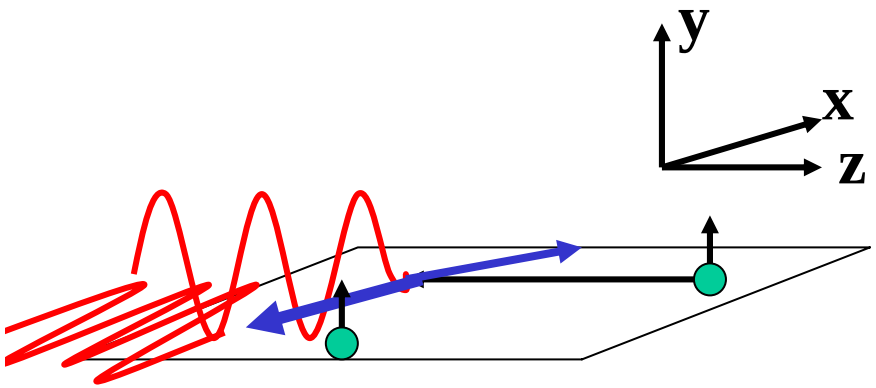
$g_{\Theta NK^*}$; κ^*_Θ

$$|g^{+}_{\Theta NK}|^2 >> |g^{-}_{\Theta NK}|^2$$

Predictions are not strict: the single spin observables are not sufficient to fix the Θ^+– parity



Beam asymmetry at fixed $\vec{S}_i, \vec{S}_f$



$$\Sigma_{BYY} = \frac{\sigma^{\perp} - \sigma^{\parallel}}{\sigma^{\perp} + \sigma^{\parallel}}$$

Bohr`s theorem (2→2-reaction):

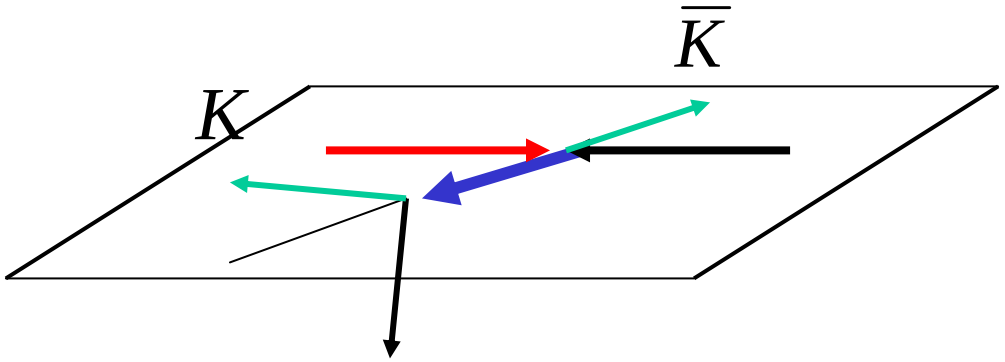
$$\pi_{\Theta}(-1)^{M_i - M_f} = +1 \qquad \textbf{for} \quad \perp$$

$$\pi_{\Theta}(-1)^{M_i - M_f + 1} = +1 \qquad \textbf{for} \quad \parallel$$

$$\pi_{\Theta} = +1 \Rightarrow \sigma(\perp) = \textit{finite}; \quad \sigma(\parallel) = 0 \Rightarrow \Sigma_{BYY} = +1$$

$$\pi_{\Theta} = -1 \Rightarrow \sigma(\perp) = 0; \quad \sigma(\parallel) = \textit{finite} \Rightarrow \Sigma_{BYY} = -1$$

In real case Θ^+ decays to NK



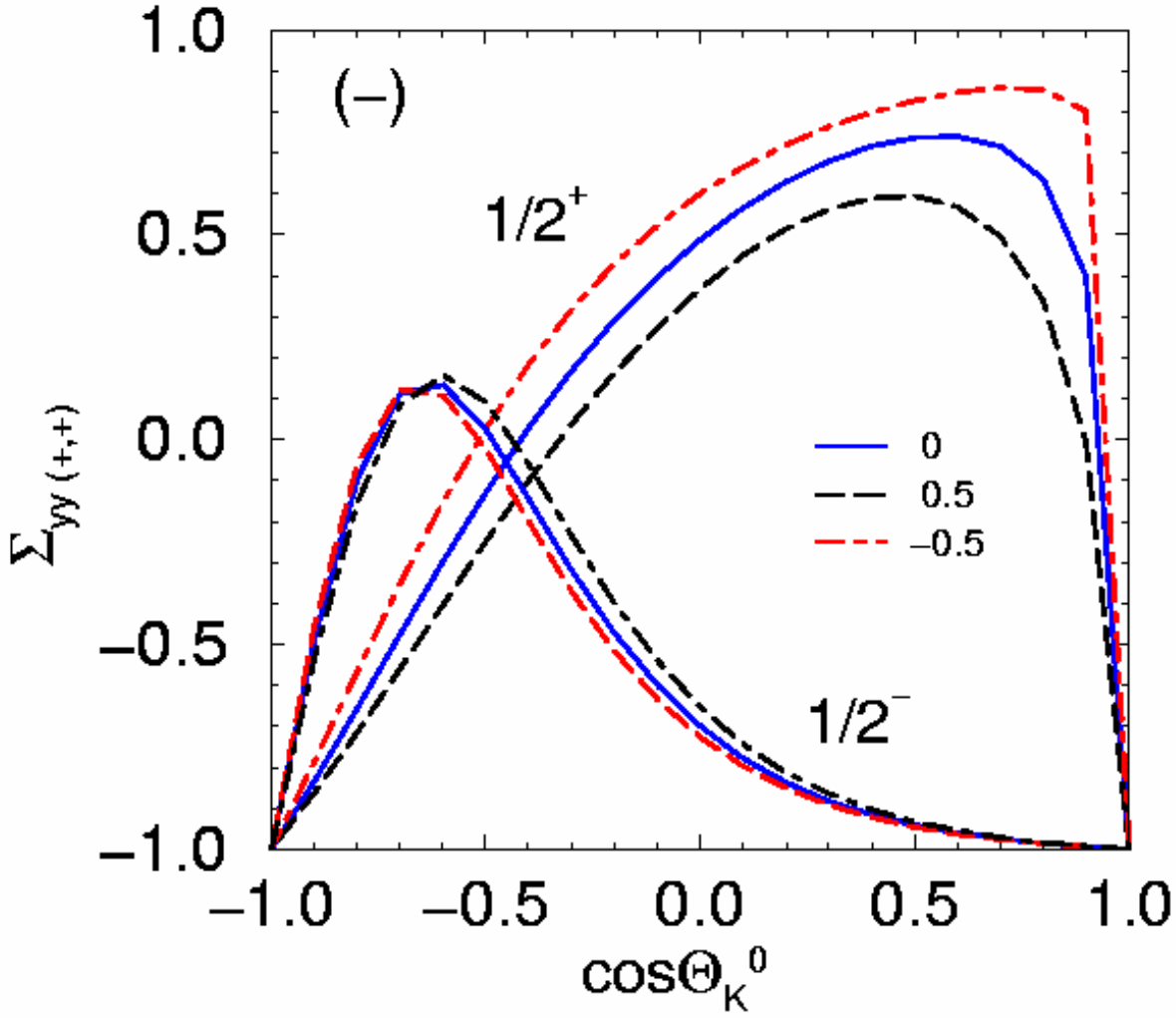
Bohr`s theorem (2→3-collinear reaction):

$$(-1)^{M_i - M_f + 1} = +1 \quad \textbf{for} \quad \perp$$

$$(-1)^{M_i - M_f} = +1 \quad \textbf{for} \quad \parallel$$

$$\Sigma_{BYY} = -1$$

The triple spin asymmetry



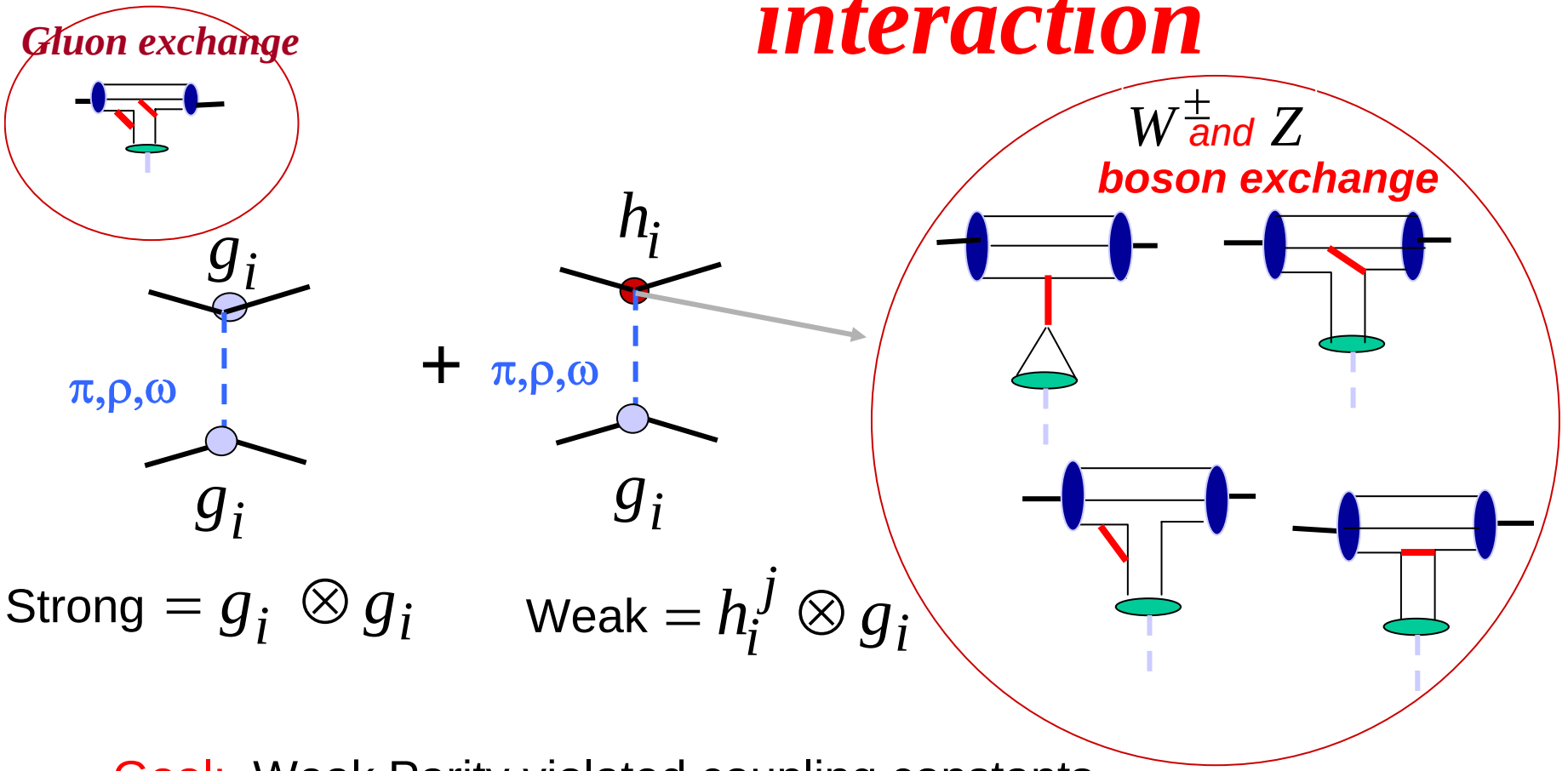
A.T., Ejiri, Haberzettl, Nakayama, nt/0411098

Parity Non-Conservation in Nuclear Reactions

$$\gamma A \rightarrow A^{*} \rightarrow \gamma A,$$

$$\gamma D \rightarrow np$$

Parity non-conservation in NN interaction



Strong $= g_i \otimes g_i$ Weak $= h_i^j \otimes g_i$

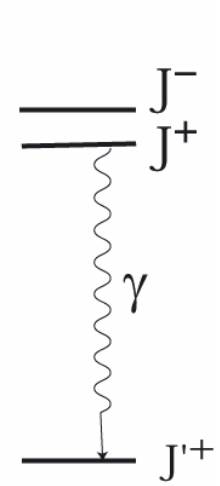
Goal: Weak Parity violated coupling constants

$$h_\rho^0, h_\rho^1, h_\rho^{1'}, h_\rho^2, h_\omega^0, h_\omega^1, f_\pi^1 \rightarrow$$ **Weak interaction** $\otimes$ **NP-QCD**

Experiment: study of parity doublets

PNC–observable: asymmetry of circularly polarized photons

$$\lambda = \vec{S}_\gamma \cdot \vec{n}_\gamma$$



$$\left|\Psi_{J^+}\right\rangle = \cos\alpha\left|\Phi_{J^+}\right\rangle + \sin\alpha\left|\Phi_{J^-}\right\rangle$$

$$\left|\Psi_{J^-}\right\rangle = \cos\alpha\left|\Phi_{J^-}\right\rangle - \sin\alpha\left|\Phi_{J^+}\right\rangle$$

Weak coupling constants

Nuclear matrix elements

$$\alpha \approx \frac{\left\langle \Phi_{J^-}\left|H_{PNC}\right|\Phi_{J^+}\right\rangle}{E_+ - E_-} \approx \frac{\sum h_i N^i_{J^-J^+}}{E_+ - E_-}$$

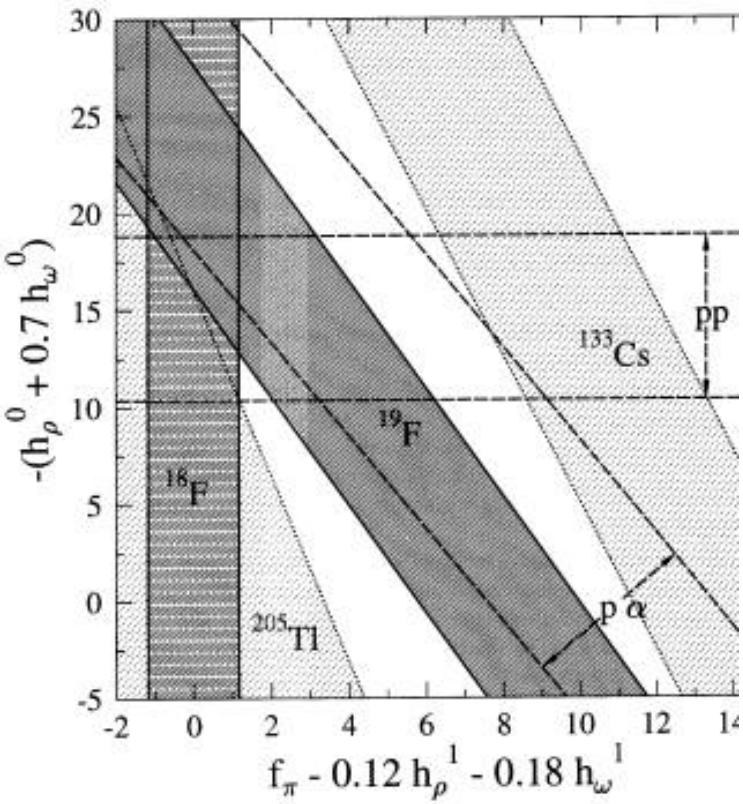
$$P_\gamma \approx 2\alpha \frac{M_L E_L}{E_L^2 + \alpha^2 M_L^2} \approx 2 \cdot \frac{\sum h_i N_i}{E_+ - E_-} \cdot \frac{M_L}{E_L} \sim 10^{-2} \cdots 10^{-6}$$

^{21}Ne: $P_\gamma \approx (0.8 \pm 1.4) \times 10^{-3}$

Experiment

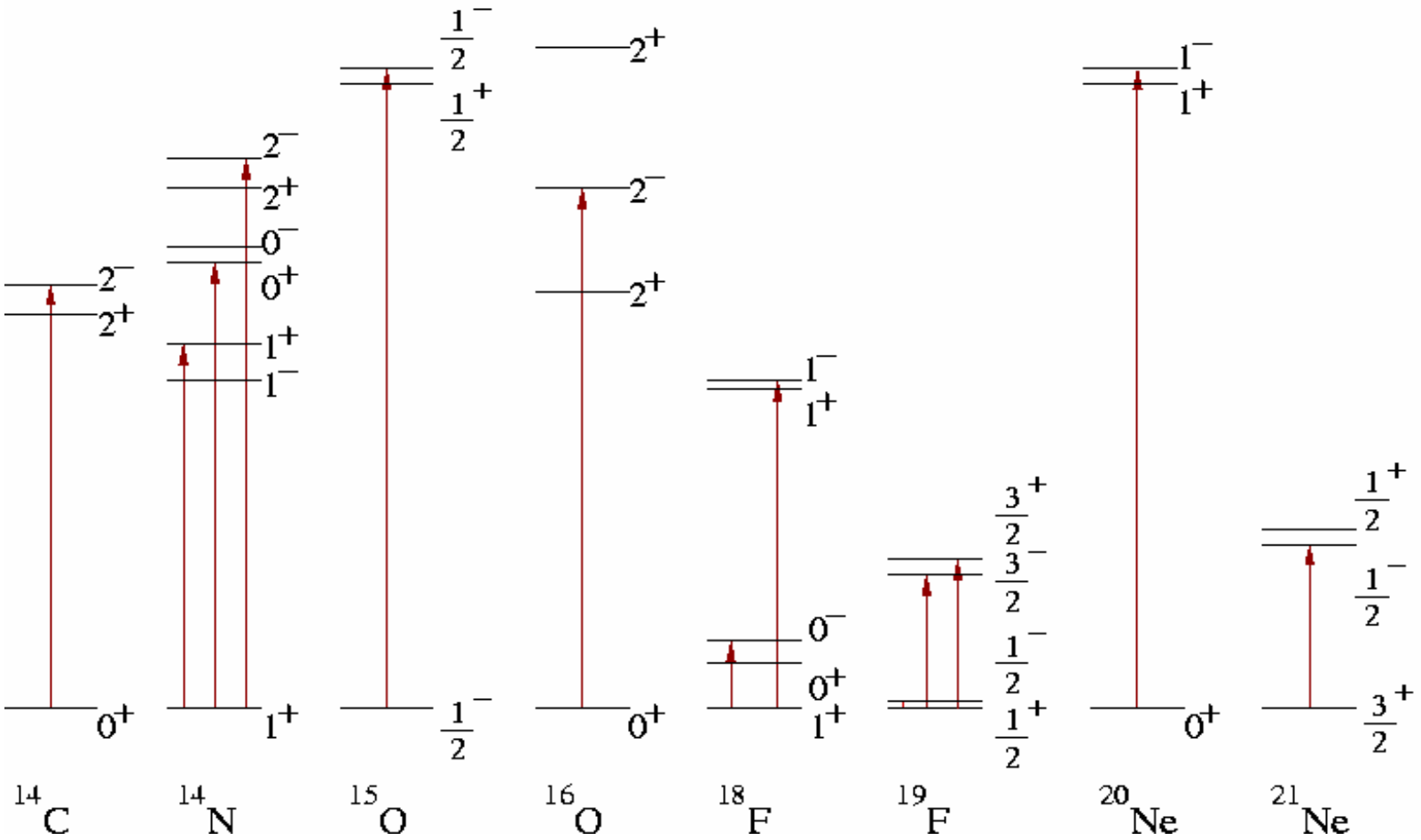
constraints for PNC coupling constants

Haxton, Liu, Ramsei-Musolf, Phys. Rev. C 65, '02

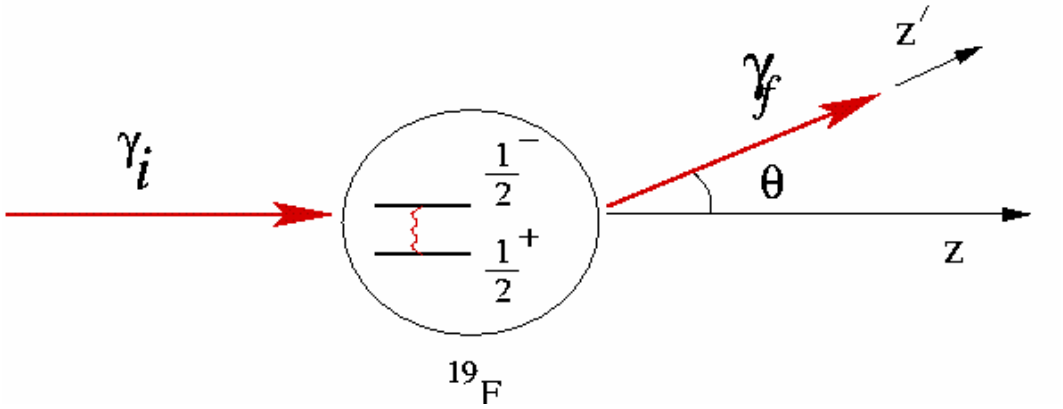


Future experiment at Spring-8?

absorption of circularly polarized photons by "parity doublets" (M. Fujiwara)



Angular correlations in Nuclear Fluorescence



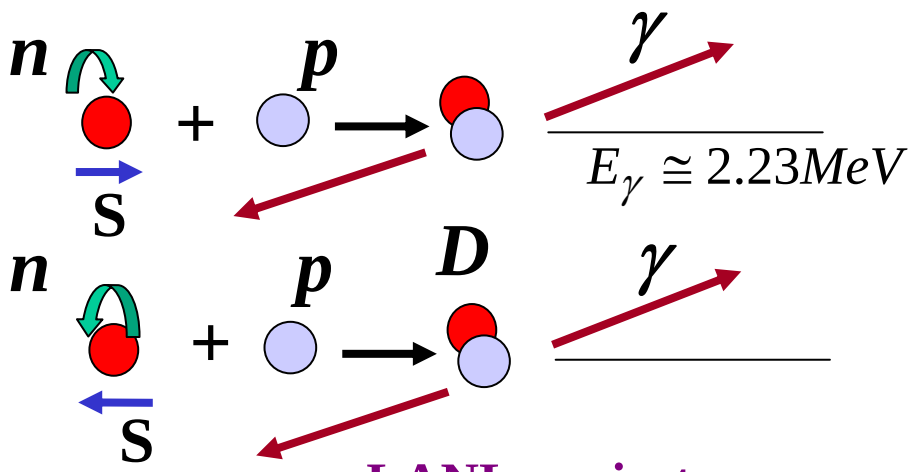
$$\lambda_i = 1;\ m_i = -\frac{1}{2},\ m_f = +\frac{1}{2}. \qquad m'_f = \pm\frac{1}{2}. \qquad \left|m'\right\rangle = d^{\frac{1}{2}}_{mm'}(\theta)\left|m\right\rangle$$

$$A_\gamma(\theta) = (1+\cos\theta) < A_\gamma >$$

A.T., Fujiwara, Kawase, 2004

Capture of thermal neutron by proton

(i) polarized neutron and unpolarized γ



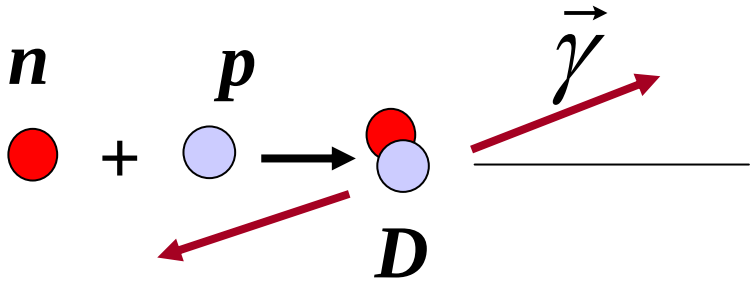
LANL project

$$W \propto 1 + 2A_\gamma^{PNC} \vec{S}_n \cdot \vec{n}_\gamma$$

$$A_\gamma^{PNC} = (6 \pm 21) \cdot 10^{-8}$$

$$A_\gamma^{PNC}(theor) \sim 5 \cdot 10^{-8}$$

(ii) unpolarized neutron and polarized γ

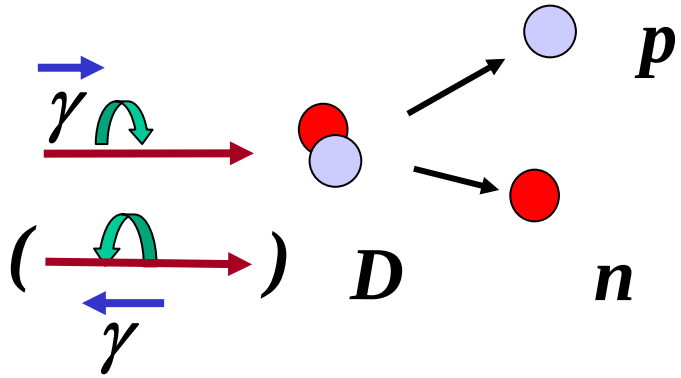


$$P_\gamma^{PNC} = (18 \pm 18) \cdot 10^{-8}$$

$$P_\gamma^{PNC}(theor) = (1 \sim 6) \cdot 10^{-8}$$

Deuteron photo-disintegration

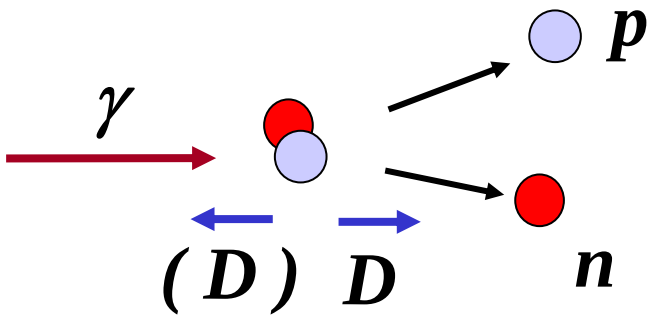
(i) circularly polarized γ and unpolarized deuteron



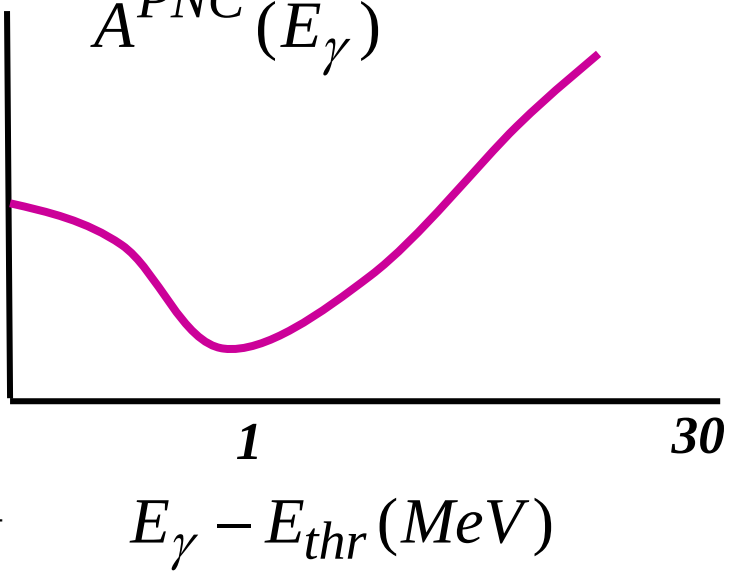
$$A_{RL}^{PNC}(E_\gamma) = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$$A_{RL}^{PNC}(E_\gamma \approx 2.23) = P_\gamma^{PNC}$$

(ii) unpolarized γ and polarized deuteron

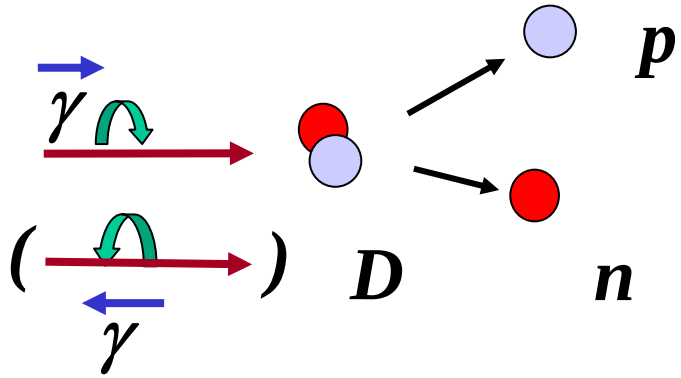


$$A_D^{PNC}(E_\gamma) = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

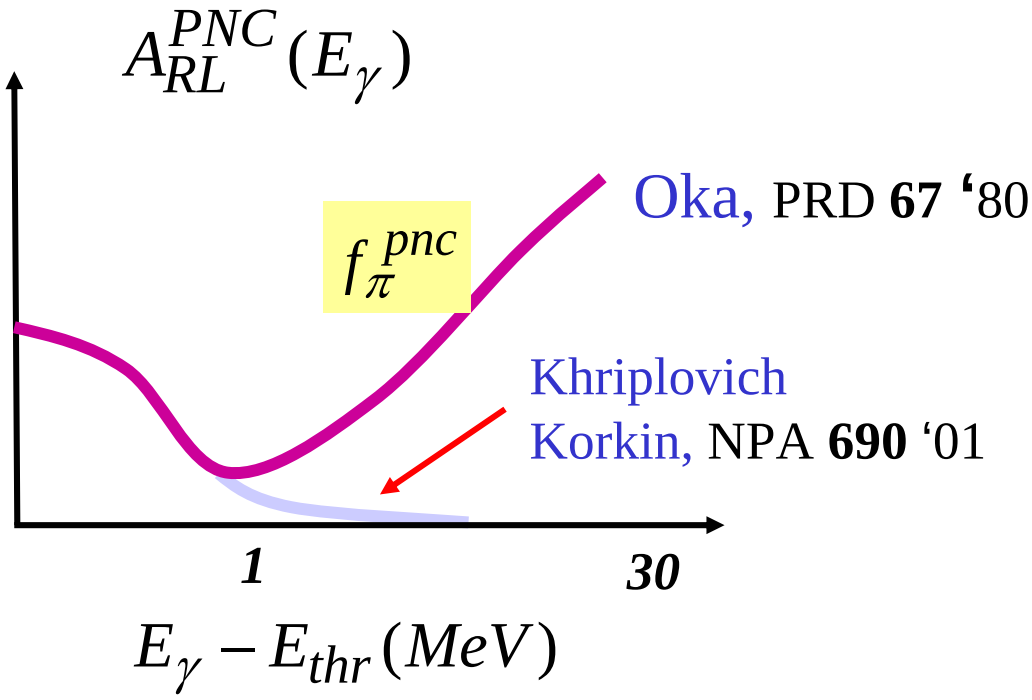


Deuteron photo-disintegration

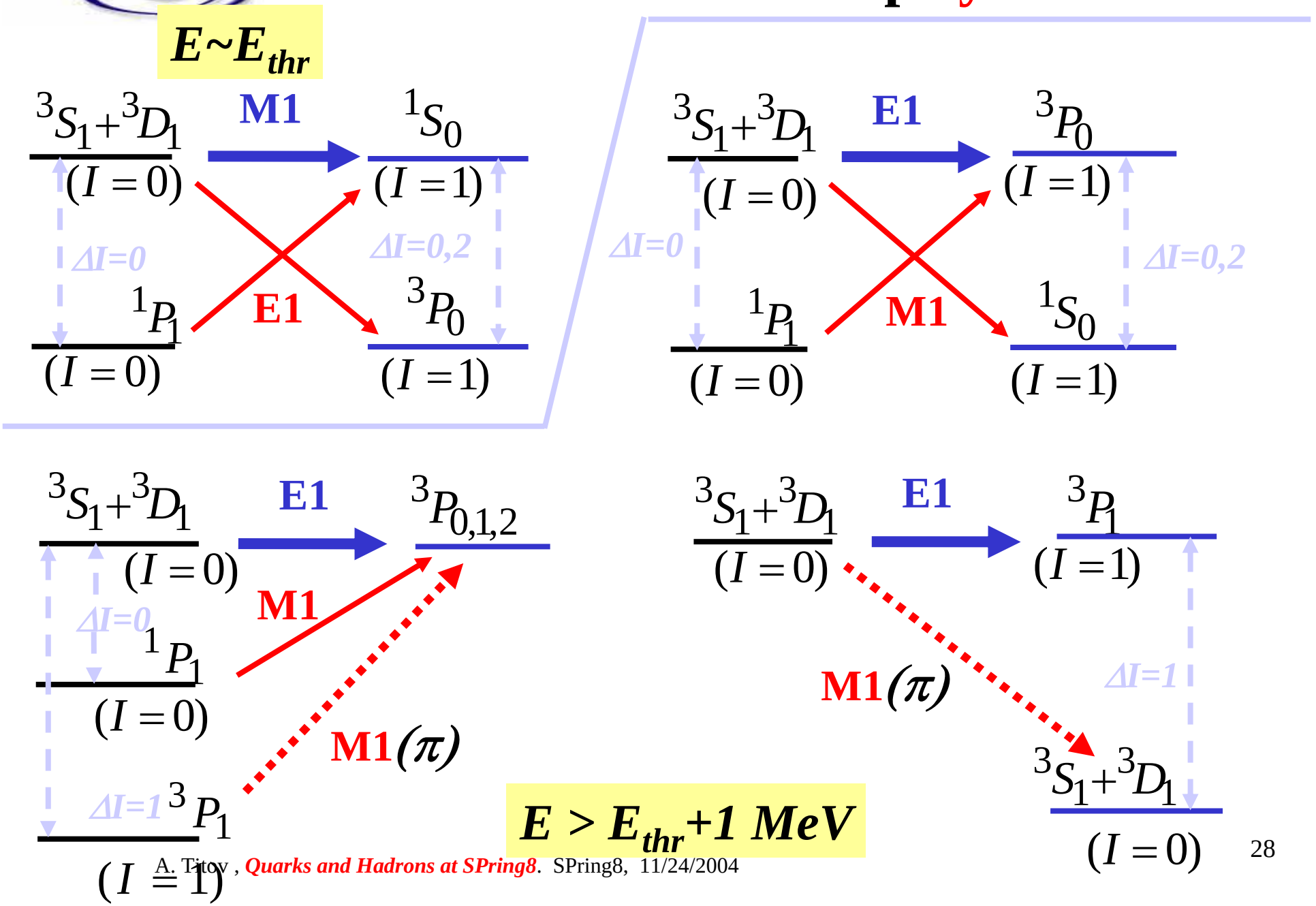
circularly polarized γ and unpolarized deuteron



$$A_{RL}^{PNC}(E_\gamma) = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$



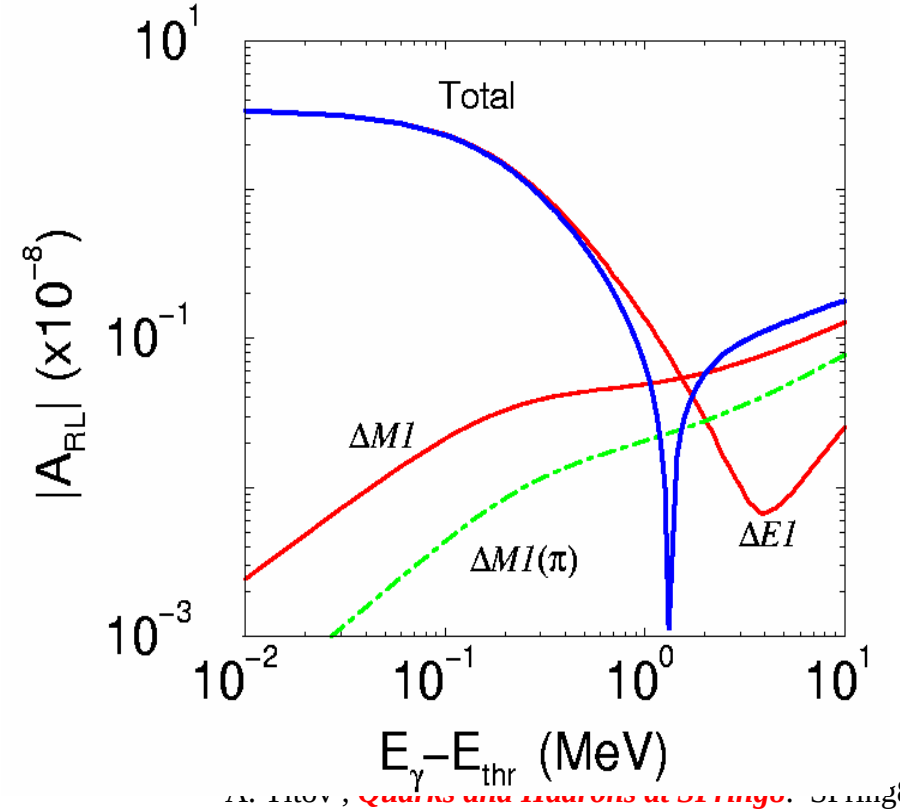
PNC transitions in np-system



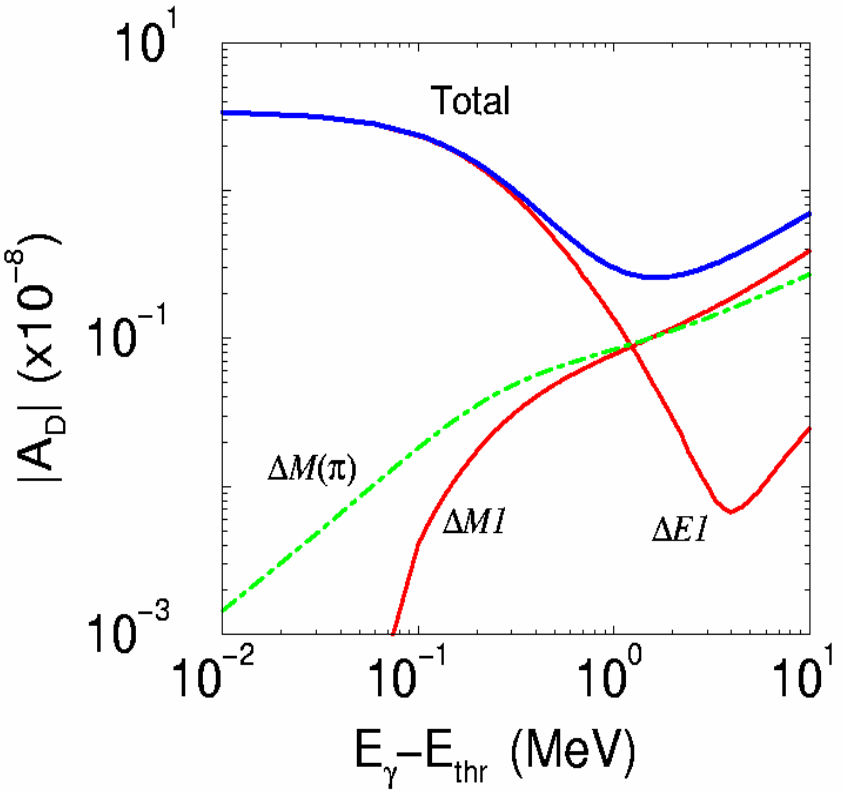
PNC - Asymmetries in $\gamma D \rightarrow np$ reactions

M. Fujiwara, A.Titov, PRC69, 2004

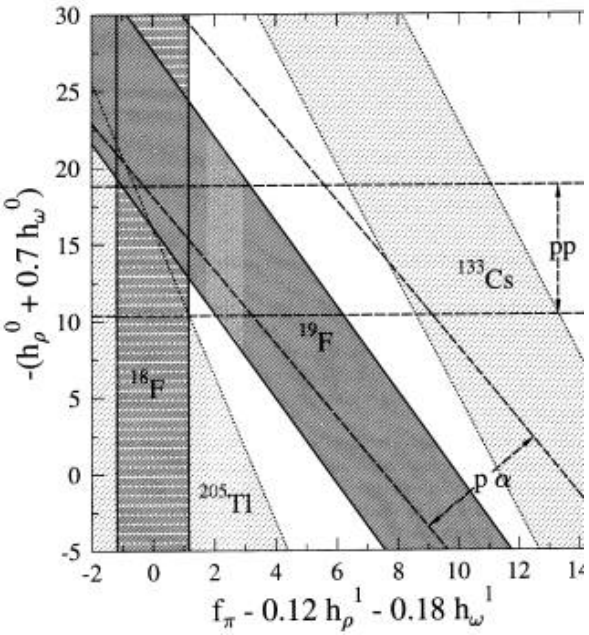
Polarized beam and unpolarized target

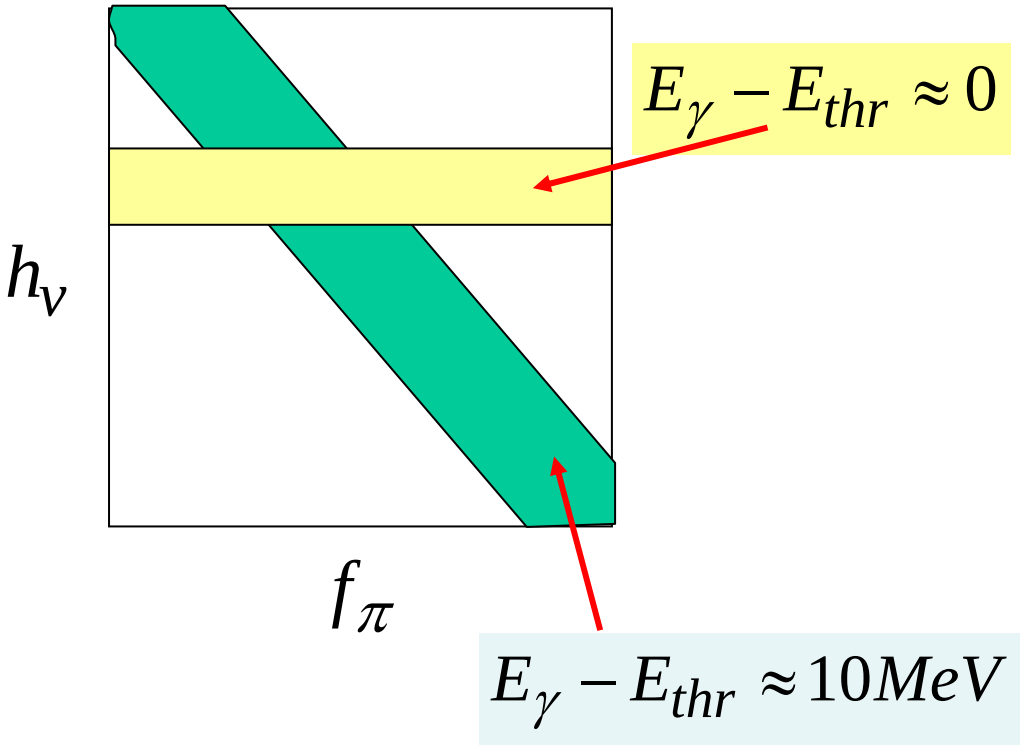


Polarized target and unpolarized beam



Summary: *we found a principle possibility to obtain constraints for PNC coupling constants using only the simplest nuclear object: np-system*





Summary

- ***High intensity highly polarized photon beam at high energy is rather useful for many problems in hadronic physics and QCD***
- ***Energy of 2-3 GeV has advantage for studying exotics (Θ^+, N*, ss, etc)***
- ***Low energy high intensity, highly polarized photon beam is desirable for studying in nuclear physics (PNC effects, nuclear exotic states etc.)***

Part II

Concluding Remarks

History

Key persons

1993	**Russia-Japan "Boat Conference" Vladivostok-Tsuruga -Vladovostok-Otaru**	**Profs. Fujii, Akaishi, Namiki**
1996	**Kobe University**	**Prof. Morii**
1998	**RCNP, Osaka University**	**Profs. Fujiwara, Toki Ejiri, Nagai**
2002-04	**JAERI, SPring8**	**Profs. Fujiwara, Ejiri, LEPS group, JAERI people**

My cordial thanks to LEPS group for fruitful common work, help and encouragement








I appreciate all JAERI people for help and excellent atmosphere








I especially thank Sae-san, Hiroko-san and Yuko-san for help and kindness


名峰雪彦山


日本百景
日本三彦山
兵庫県五名山
雪彦峰山県立自然公園
雪彦山登山案内図
至鹿ケ壺
至三辻山・峰山方面
至虹ケ滝方面
至峰山
林道雪彦峰山線
現在地
至前之庄
経由姫路駅
登山を楽しくするために
●計画をしっかりたてること
●リーダーをハッキリきめること
●登山のマナーを守ること
●登山の装備は山行に合せて選ぶこと
●体力に応じた山行計画をたてること
●登山届を必ず提出すること
コース案内
所要時間
登山口より出雲岩を通り大天井岳山頂まで 70分
登山口より虹ケ滝・地蔵岳を通り大天井岳山頂まで 85分
大曲より虹ケ滝・地蔵岳を通り大天井岳山頂まで 80分
大天井岳より鹿ケ壺まで 110分
大天井岳より通称鉾立山・虹ケ滝を通り登山口まで 175分
※上記の時間は目安です。個人差がありますので適切な時間配分をして下さい。（休憩時間は含んでいません）


段ケ峰
標高 1,103m