# $\pi^- p \to \omega n$反応を用いた$\omega$束縛系と質量の同時測定実験の提案

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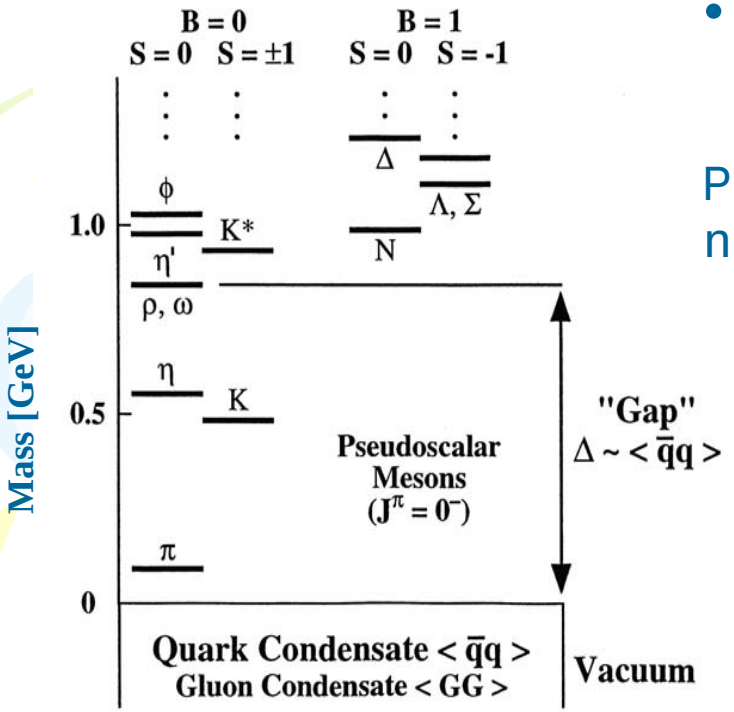
# Motivation




- **hadron can be undestood as excitation of QCD vacuum**

Precise measurements of hadron property at nuclear medium can provide QCD information

Modification of vector meson mass is expected, even at nuclear density.

**G.E.Brown and M. Rho, PRL 66 (1991) 2720**

$$\frac{m^*}{m} \approx \frac{\langle \bar{q}q \rangle^*}{\langle \bar{q}q \rangle} \approx 0.8 \left(\rho \approx \rho_0\right)$$

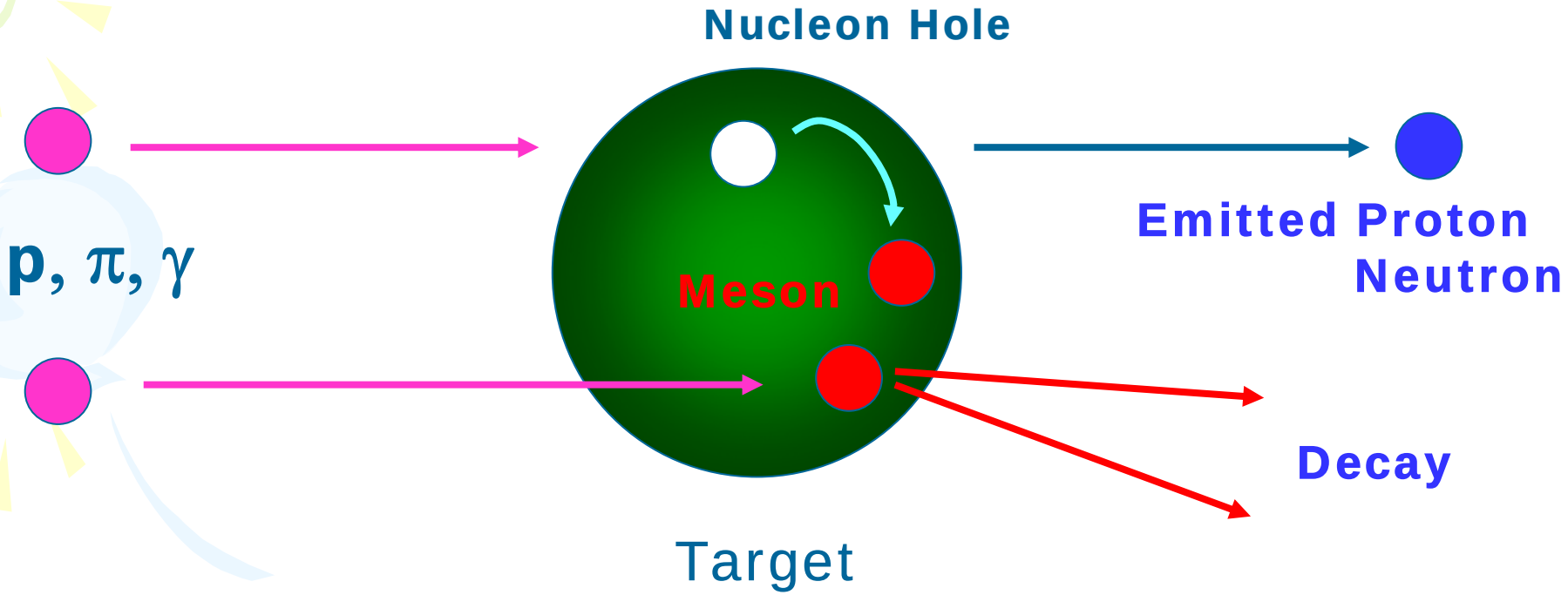
**T.Hatsuda and S. Lee, PRC 46 (1992) R34**

$$\frac{m_V^*}{m_V} = \left(1 - \alpha \frac{\rho_B}{\rho_0}\right) ; \ \alpha \approx 0.18$$

$\Rightarrow$ **many experimental and theoritical efforts to search for and study in-medium modifications of hadrons**

# Two approaches

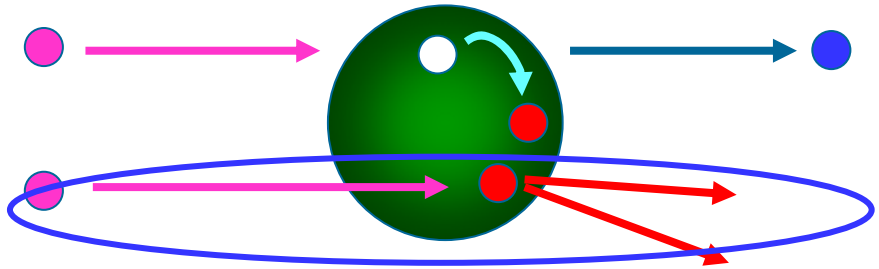
– **Meson spectroscopy**

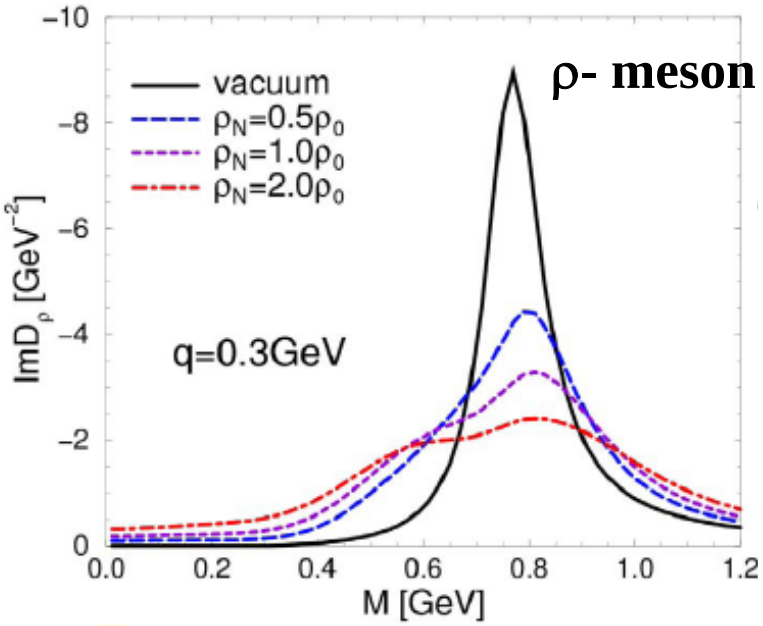



– **Direct measurements of mass spectra**

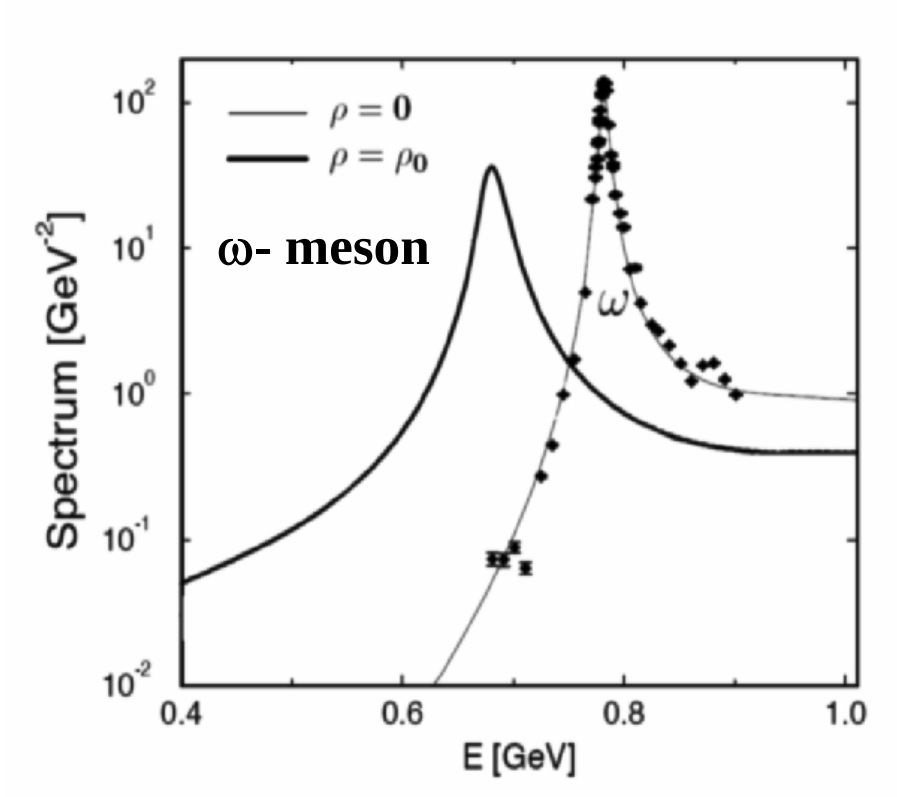
# Mass “spectra”

- Situation is not so simple, several theories and models predict spectral function of vector mesons ($\rho$, $\omega$, $\phi$).
  - Lowering of in-medium mass
  - Broadening of resonance





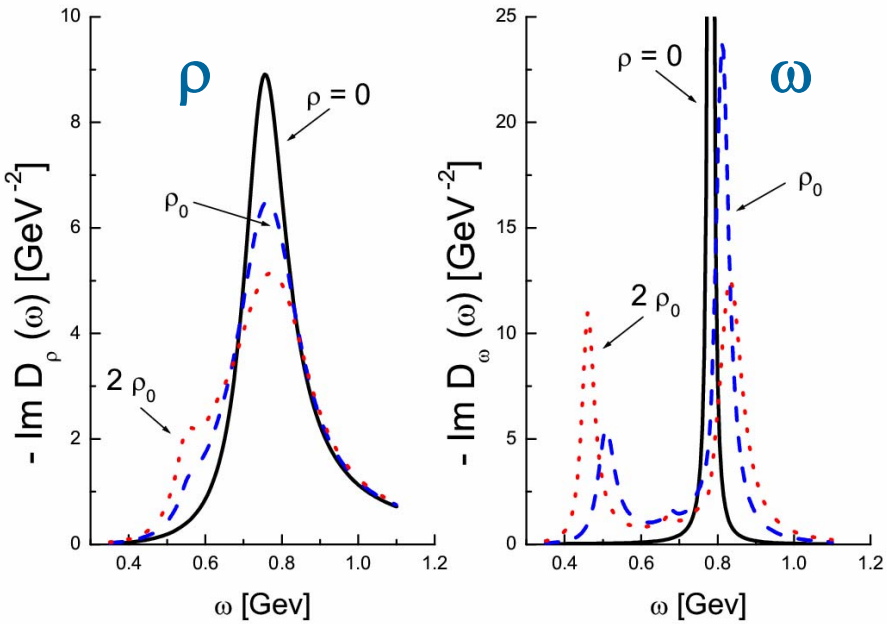

R. Rapp and J. Wambach, EPJA 6 (1999) 415




F. Klingl et al. NPA 624 (1997) 527
NPA 650 (1999) 299

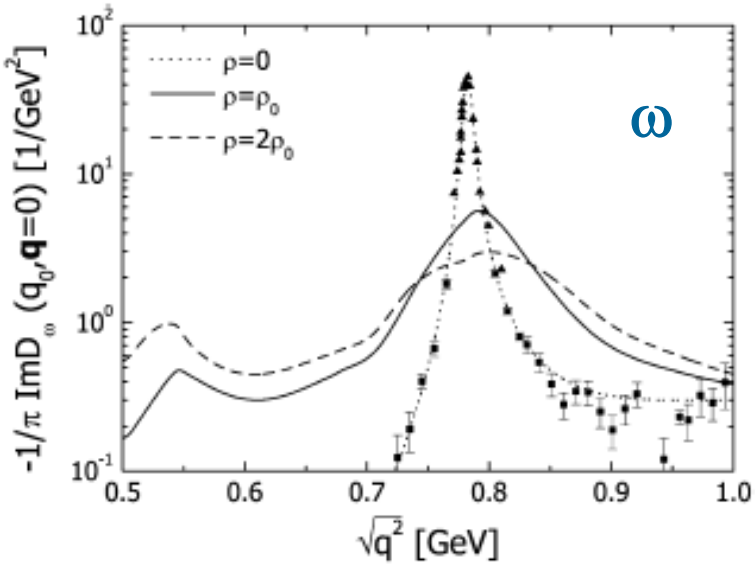
# Mass spectra (cont'd)

**M. Lutz et al. , Nucl. Phys. A 706 (2002) 431**




**structure in spectral function due to coupling to baryon resonances**

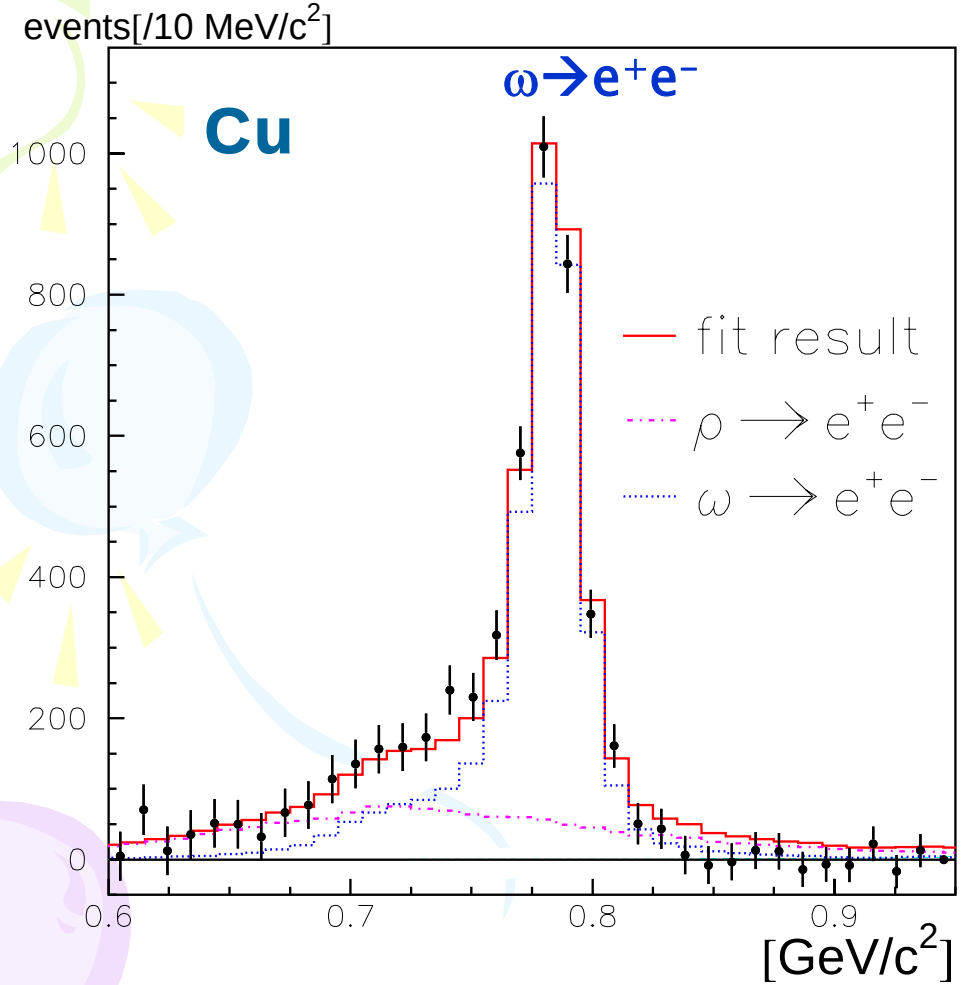
**P. Muehlich et al. , Nucl. Phys. A 780 (2006) 187**




**structure due to coupling to S11,P13 resonances**

**To distinguish several physics processes experimentally, Measurements at exclusive condition are important.**

# KEK E325, $\rho/\omega \rightarrow e^+e^-$




the excess over the known hadronic sources on the low mass side of $\omega$ peak has been observed both in Carbon and Cupper target.

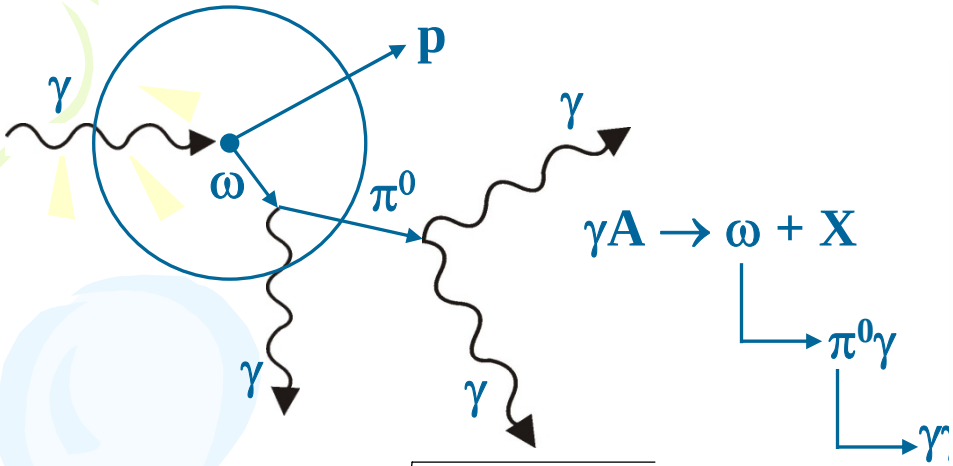
$$m_\rho = m_0 (1 - \alpha \rho/\rho_0) \quad \text{for } \alpha = 0.09$$

The excess for both C and Cu are well reproduced by the model including the 9% mass decrease at $\rho_0$.

CLAS claims no

# Positive experimental result

TAPS, $\omega \rightarrow \pi^0\gamma$ with $\gamma$+A




$$m_\omega = \sqrt{(p_\pi + p_\gamma)^2}$$

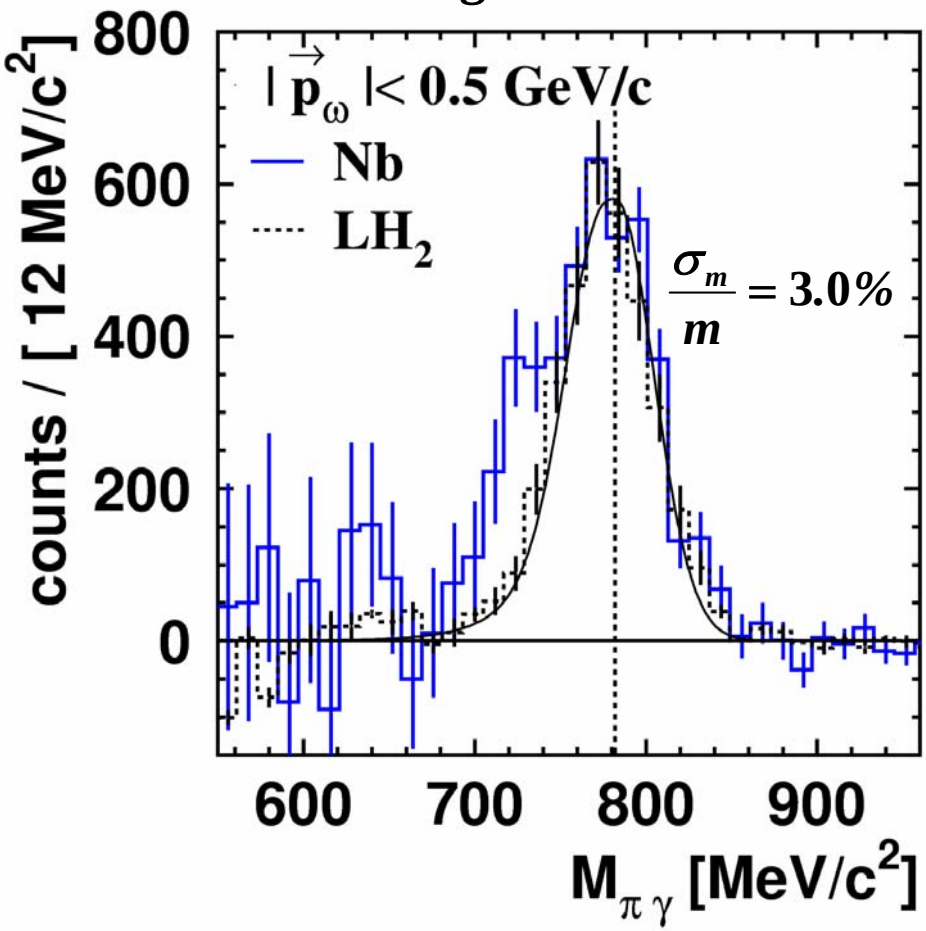
**advantage:**

- $\pi^0\gamma$ large branching ratio (8 %)
- no $\rho$-contribution ($\rho \rightarrow \pi^0\gamma$ : $7 \cdot 10^{-4}$)

**disadvantage:**

- $\pi^0$-rescattering

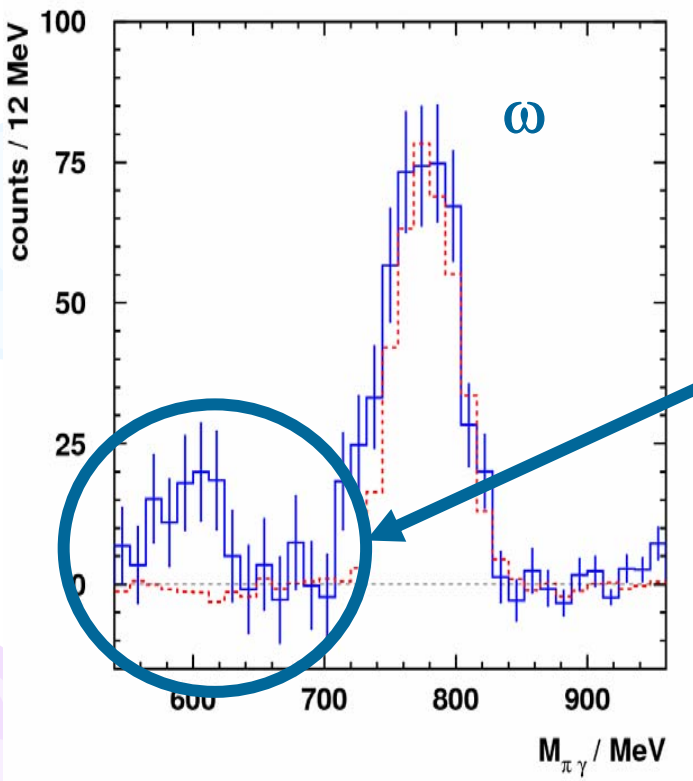
D. Trnka et al., PRL 94 (2005) 192203
after background subtraction




$m_\omega = m_0 (1 - \alpha\, \rho/\rho_0)$ for $\alpha = 0.13$

# TAPS, Updated analysis

**after $LH_2$ background subtraction**




**refined analysis requiring recoil proton and p-ω coplanarity**

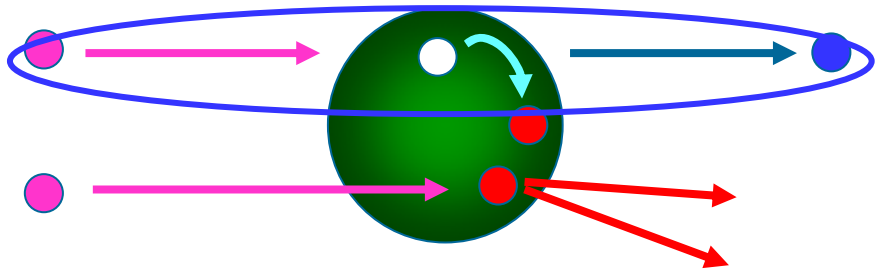
Strange Peak is seen.
It exists on heavier targets.
It does NOT exist in higher momentum region.

It's still preliminary result and under investigation.

It's gone after further analysis. Information by M. Naruki at workshop

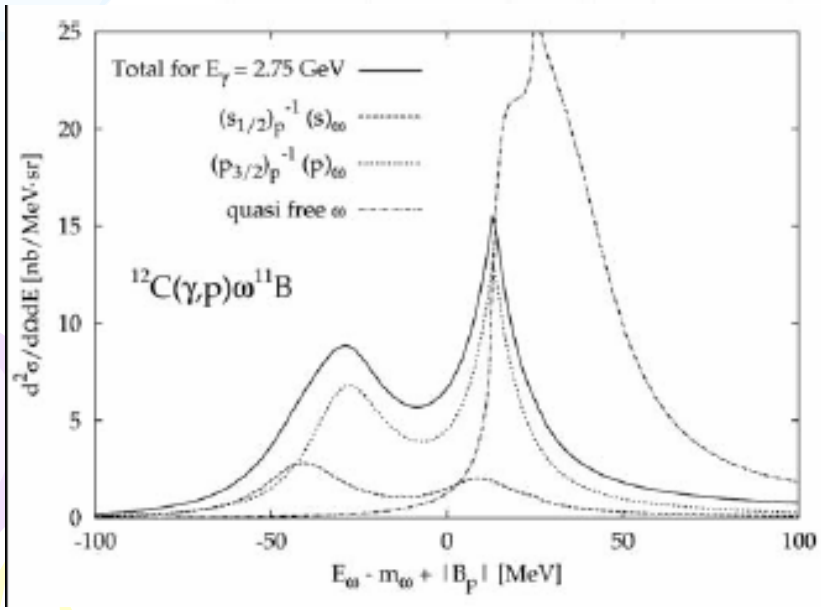
# Missing mass spectroscopy

Energy level of bound state has information about interaction between nucleus and meson.

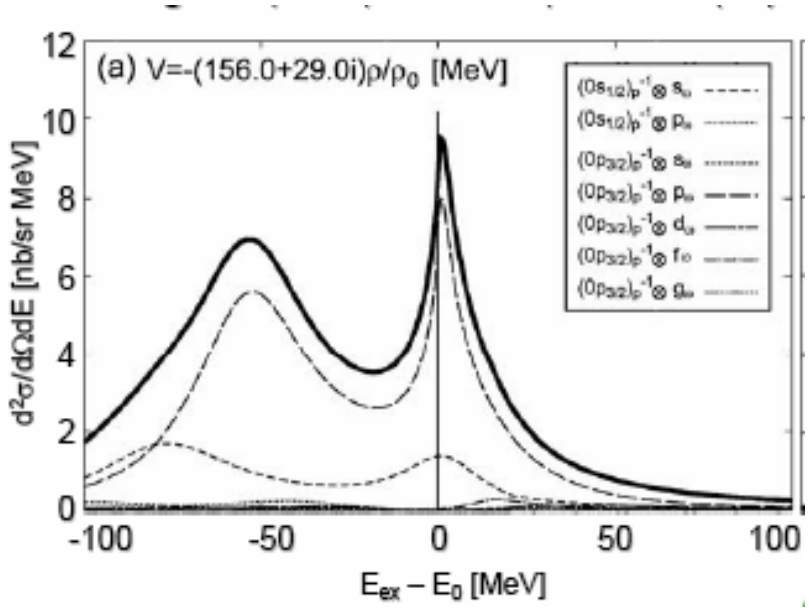


Theoretical prediction for ω bound states

Marco,Weise, PLB502(01)59

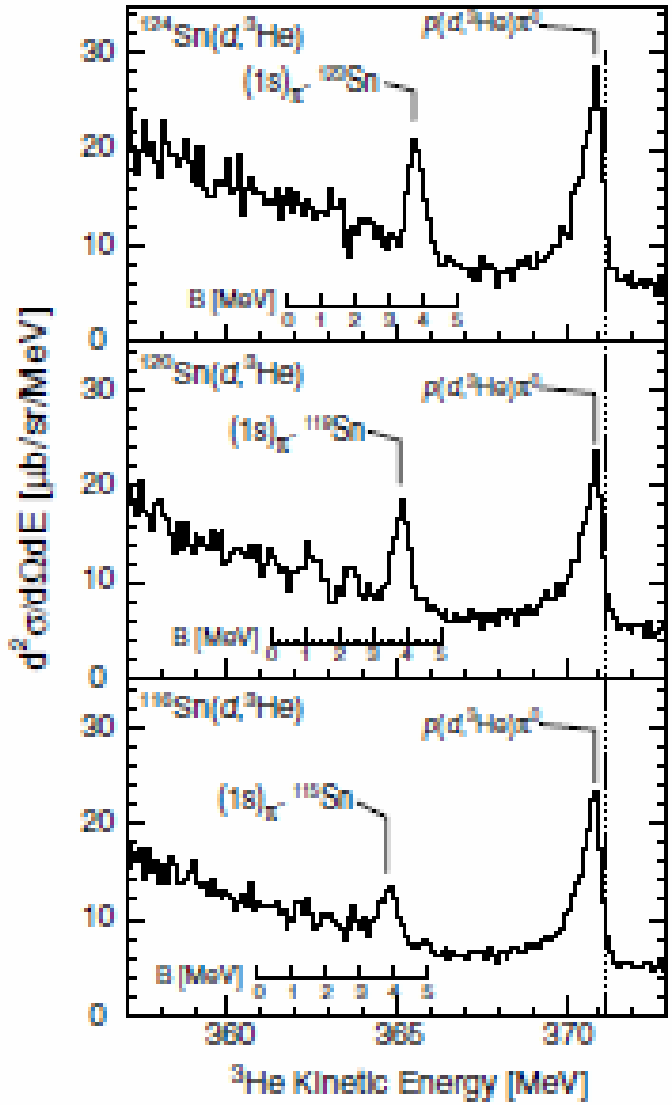



Nagahiro, Jido, Hirenzaki, NPA761(05)92



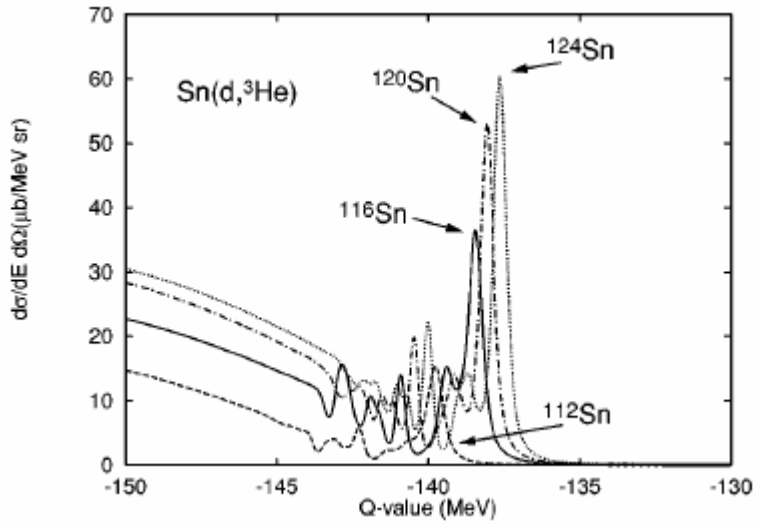
# Example: $\pi$ bound state

K. Suzuki et al., Phys. Rev. Let., 92(2004) 072302




$\pi$ bound state is observed in Sn(d, $^3$He) pion transfer reaction.

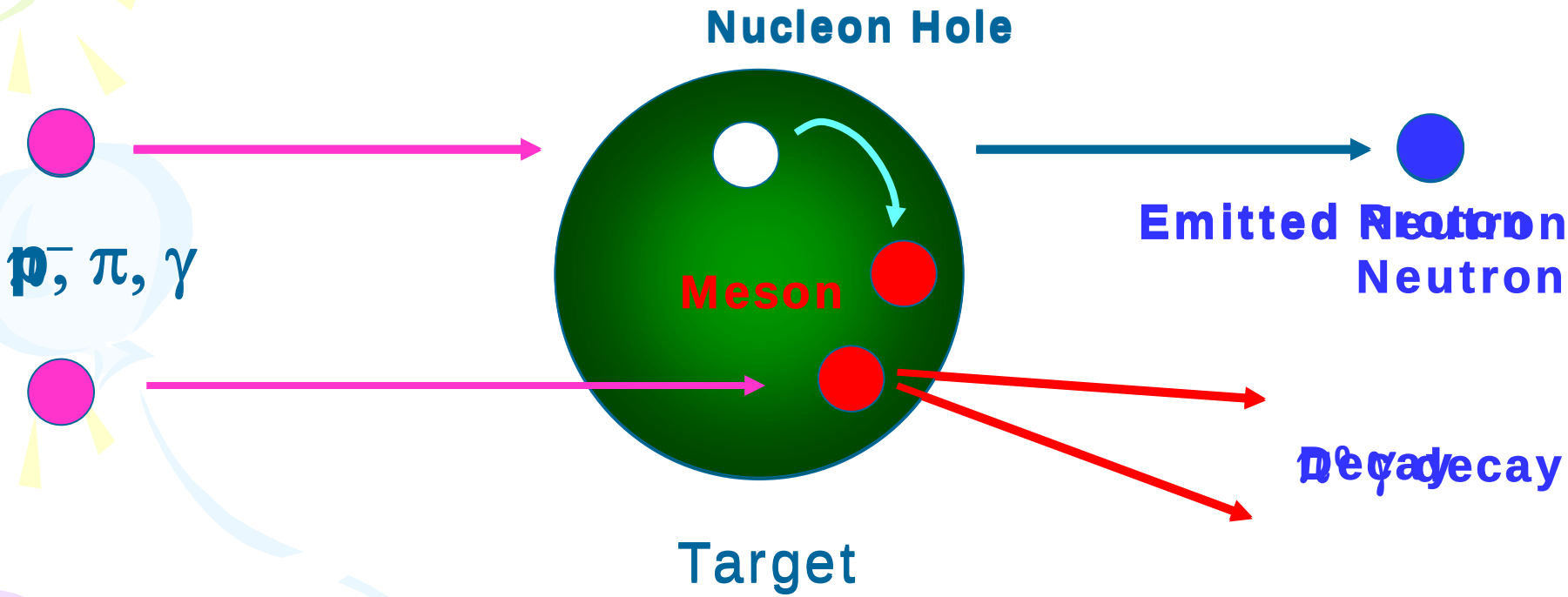
Reduction of the chiral order parameter, $f^*_\pi(\rho)^2/f_\pi^2 = 0.64$ *at the normal* nuclear density, $\rho = \rho_0$ *is indicated.*




Y. Umemoto et al., Phys. Rev. C62(2004) 024606

# New experiment @ J-PARC

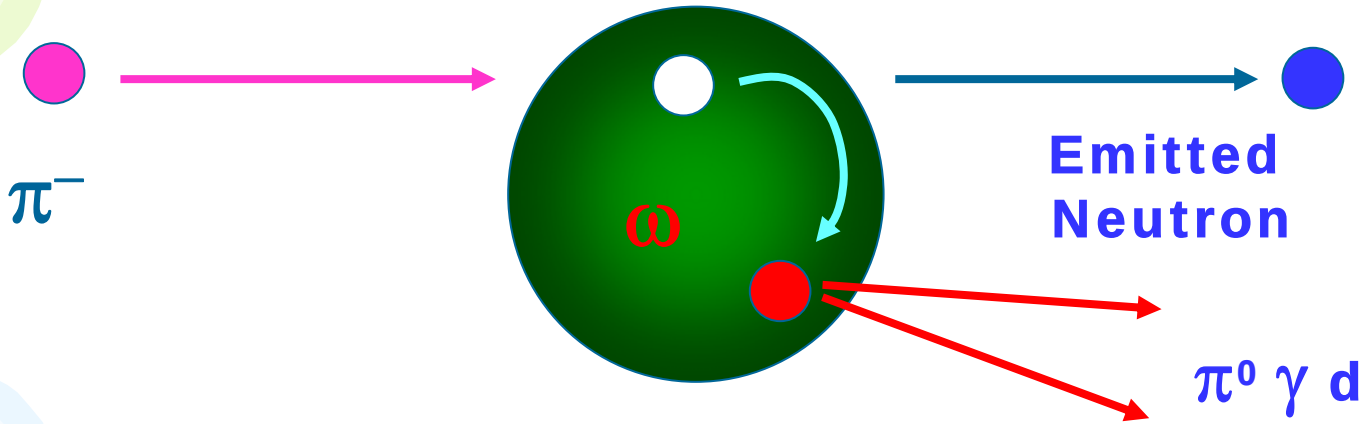
– **Meson spectroscopy**

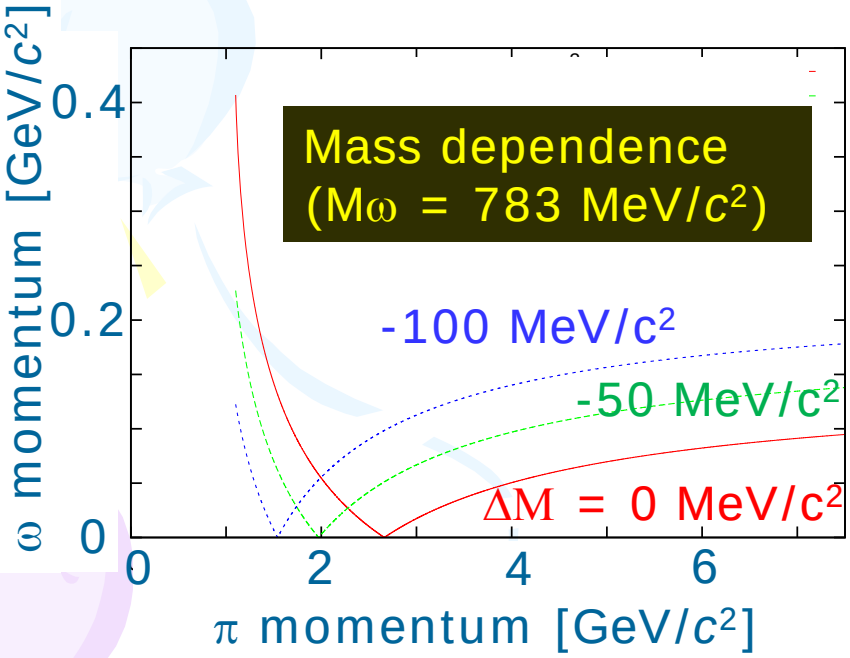


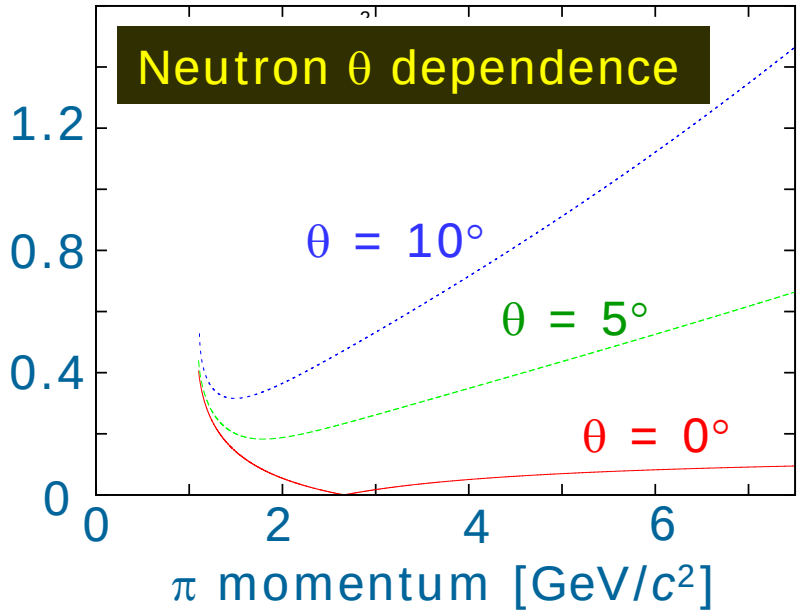

– **Direct measurements of mass spectra**

Simultaneous measurement!

# Kinematics

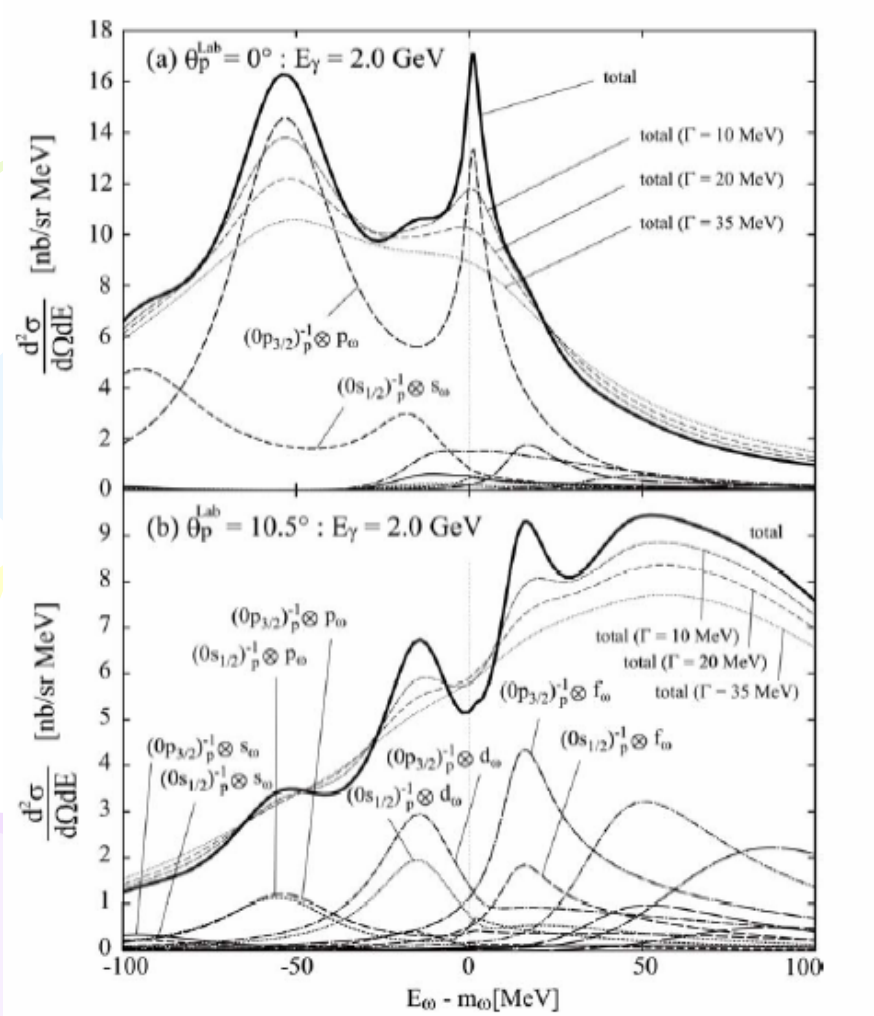


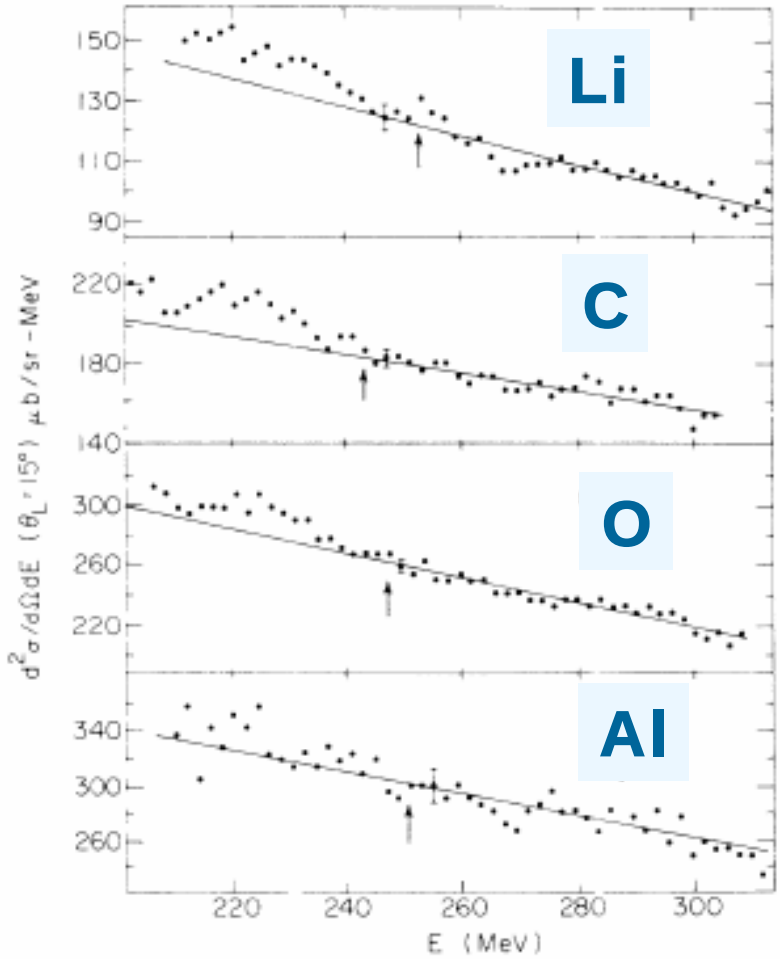

"Almost" stopped ω mesons are created.

# 0 degree measurement




H. Nagahiro et al,
Calculation for $^{12}C(\gamma, p)^{11}B_\omega$

R.E. Chrien et al., Phys. Rev. Let., 60 (1988) 2595

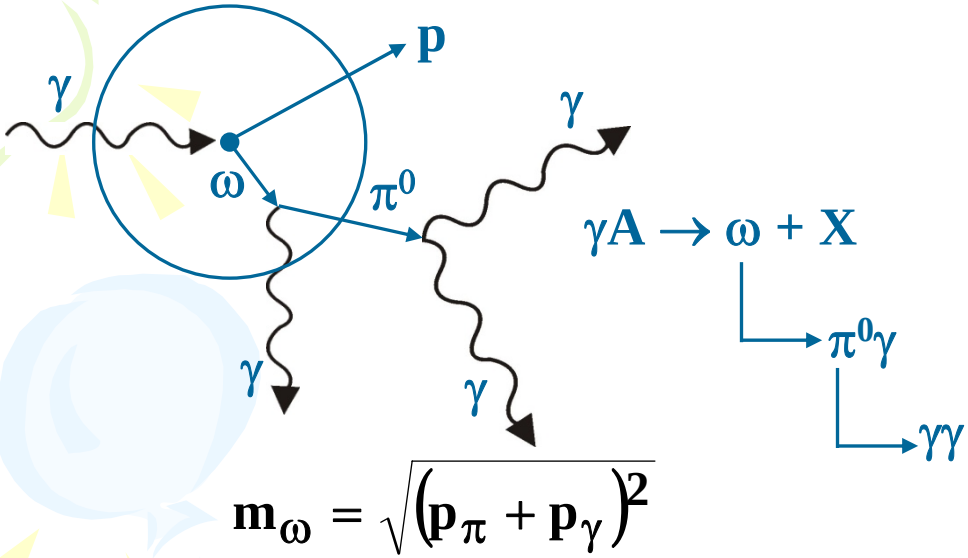



Negative results for $\eta$
Measurements @ 15°

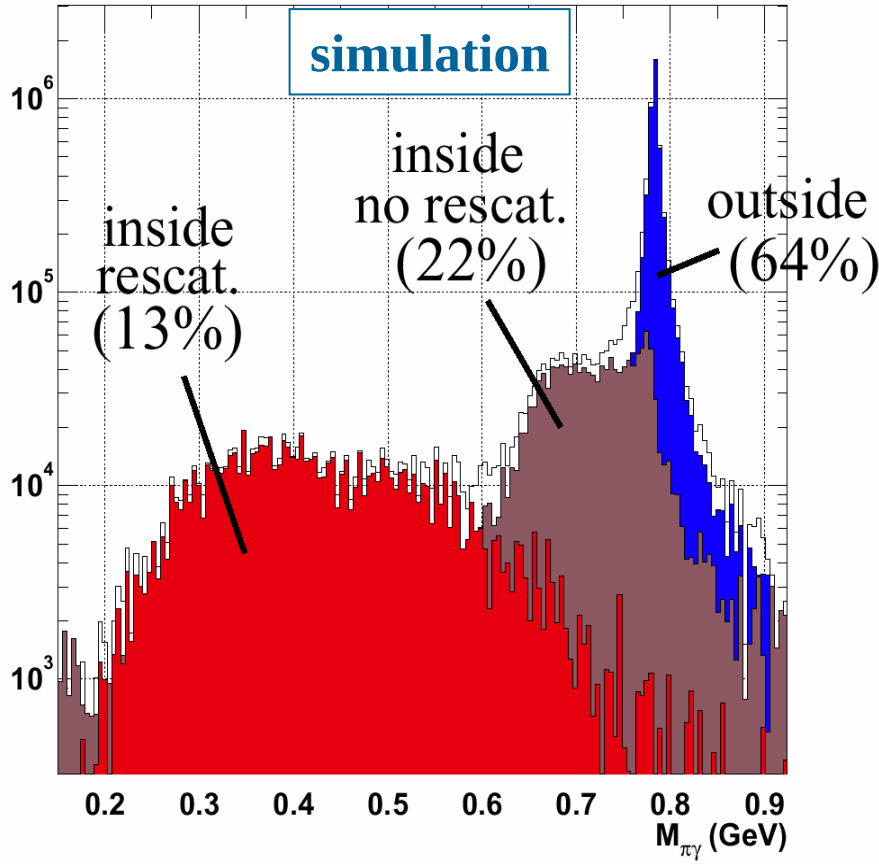
# Final state interaction

J.G.Messchendorp et al., Eur. Phys. J. A 11 (2001) 95

$\gamma + Nb$ @ 1.2 GeV




$$m_\omega = \sqrt{(p_\pi + p_\gamma)^2}$$

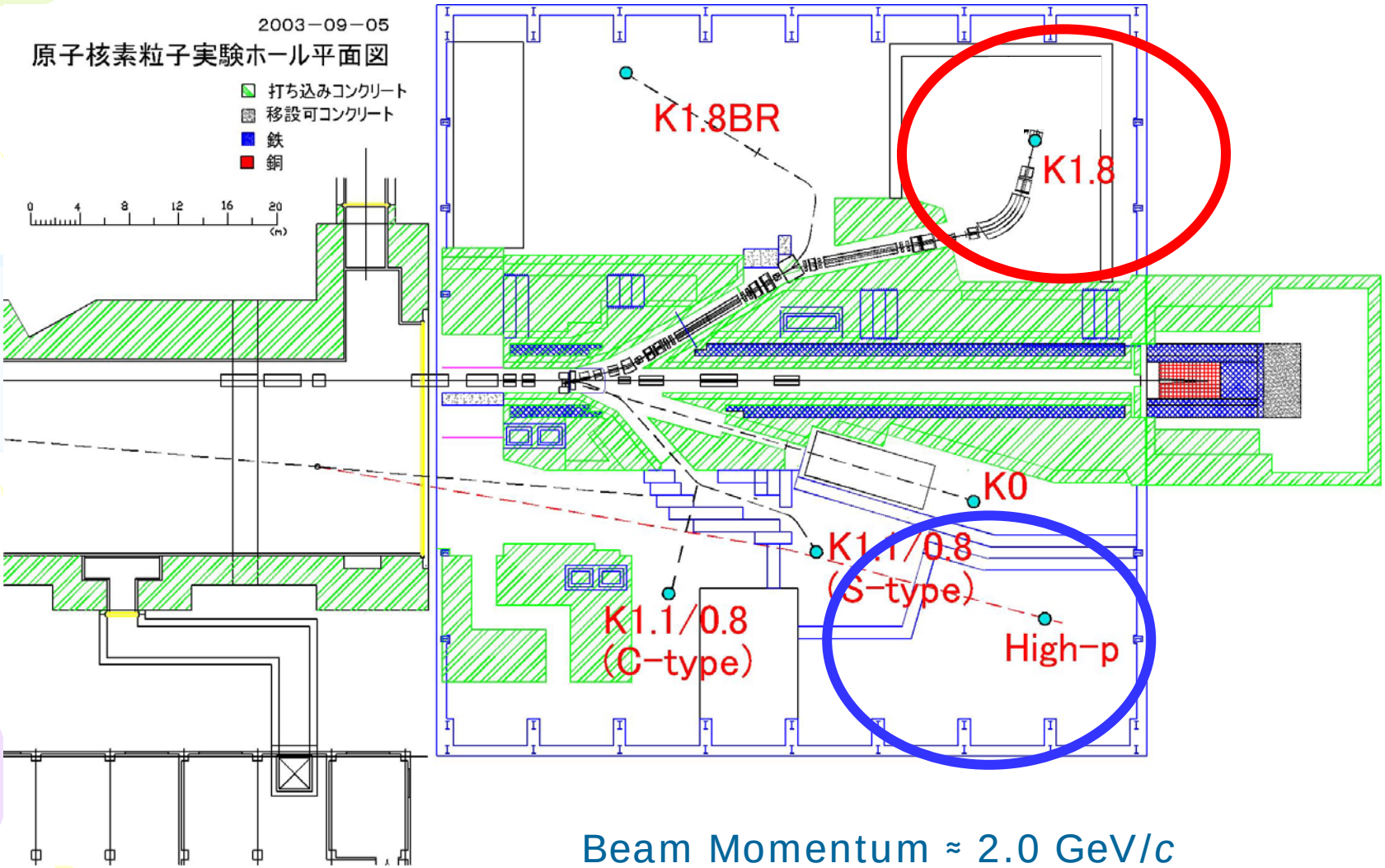



**disadvantage:**

- $\pi^0$-rescattering

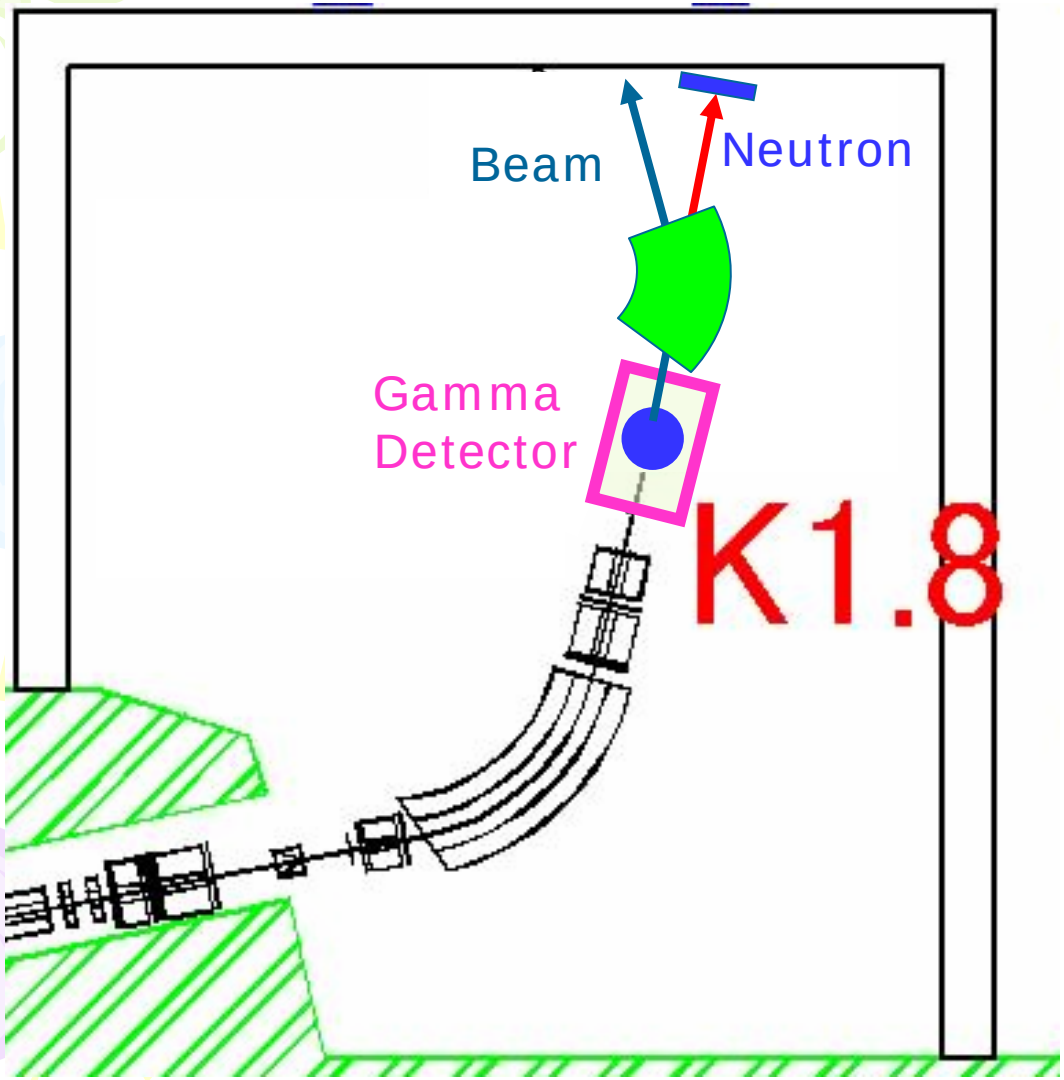
**no distortion by pion rescattering expected in mass range of interest; further reduced by requiring $T_\pi$>150 MeV**

# Beam line




Beam Momentum ≈ 2.0 GeV/*c*
K1.8 or High Momentum Beam line

# Spectrometer




$\pi^- p \rightarrow \omega n$ @ 2.0 GeV/$c$

$\hookrightarrow \pi^0 \gamma$

$\hookrightarrow \gamma\gamma$

Target: Carbon 1cm

Neutron Detector

Flight length 7m

Gamma Detector

Borrow from

T-violation

Charged Track sweep

SKS?

# Neutron Detector

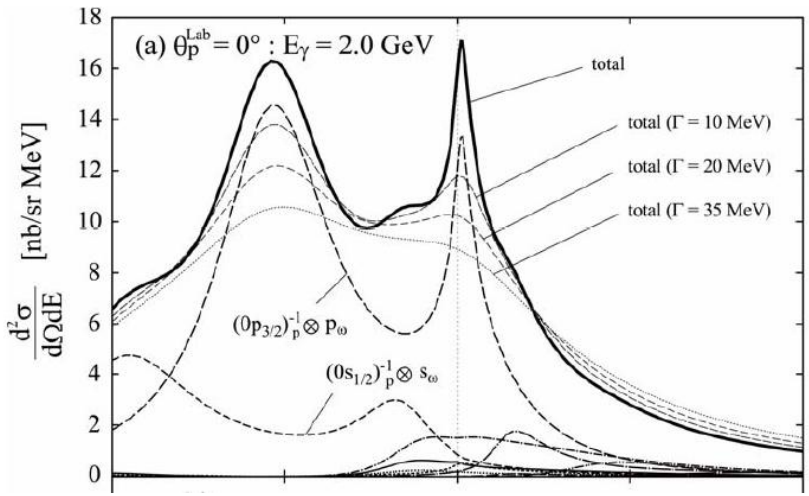
Neutron Detector

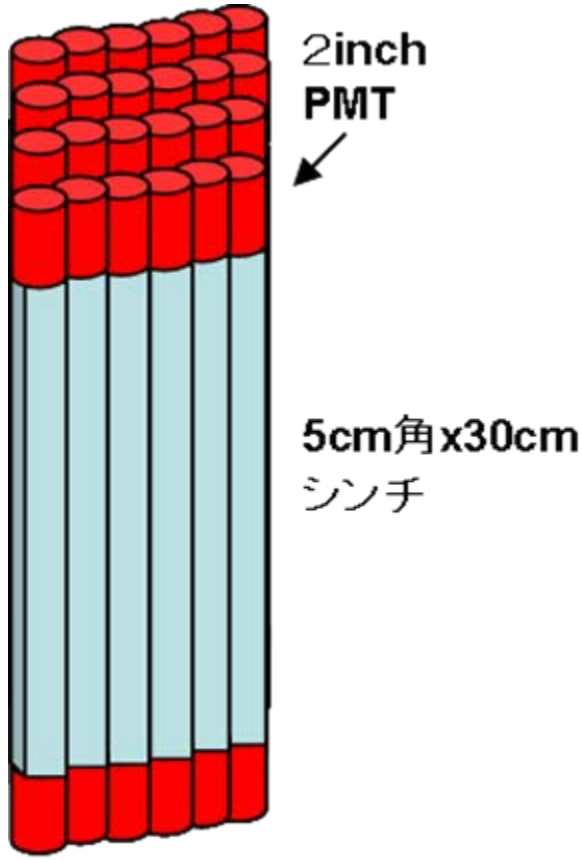
Scintillation counter or Resistive Plate

To achieve 30 MeV/$c^2$ of missing mass resolution, 80 ps timing resolution is required

7 m flight path 30 MeV/$c^2$

20 m flight path 8.9 MeV/$c^2$




図：中性子検出器

cf :proton & SKS 1.3 GeV/c 100° bending 0.17%

2.0 GeV/c 36 ° bending 0.47%

missing mass resolution @ ω mass ~8 MeV/$c^2$

# Gamma detector

CsI EMCalorimeter
Borrow from T-violation experiment

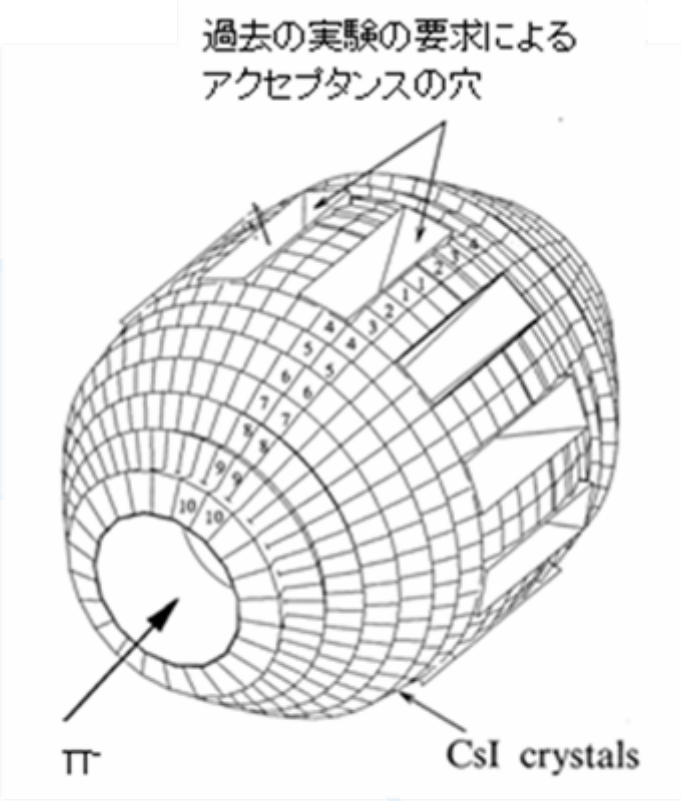
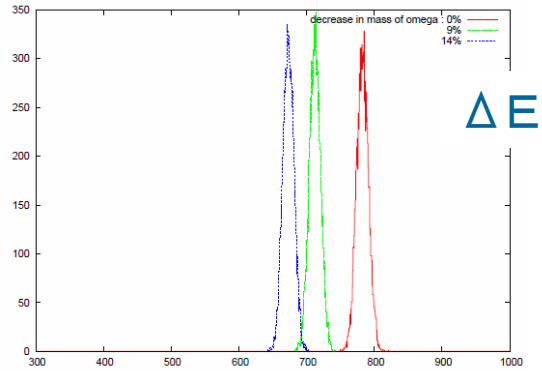
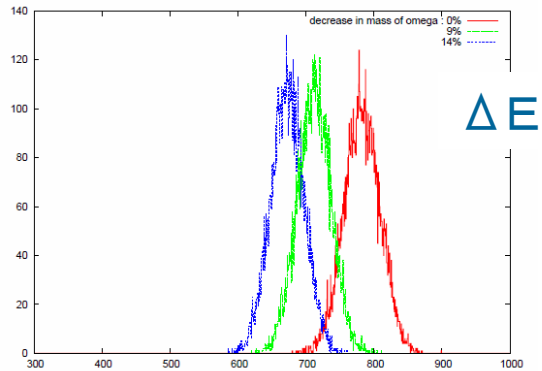



図: 使用予定のγ線検出器(E246より)

Mass resolution




$\Delta E/E = 1\ \%/\sqrt{E}$



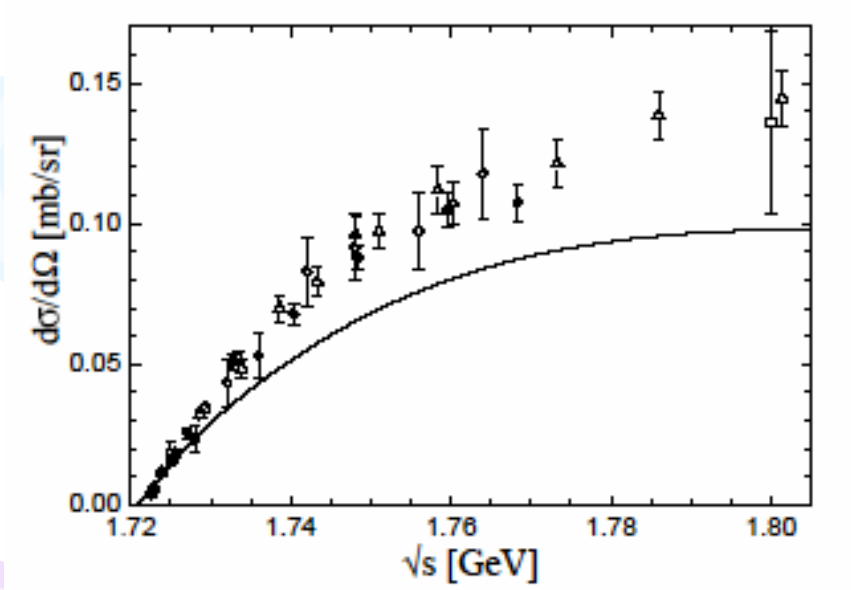

$\Delta E/E = 3\ \%/\sqrt{E}$

$\Delta E/E = 2.8\ \%$ @ 200MeV ($\Delta E/E = 1.7\ \%/\sqrt{E}$ ? )

(D.V. Dementyev *et al.*, Nucl. Instrum. Meth. A440(2000), 151)

# Yield Estimation

Summary plot of $\pi^- p \rightarrow \omega n$ for backward $\omega$
(G. Penner and U. Mosel, nucl-th/0111024,
J. Keyne et al., Phys. Rev. D 14, 28 (1976))




0.14 mb/sr @ $\sqrt{s}$ = 1.8 GeV
same cross section is assumed.

Beam intensity
$10^7$ / spill, 3 sec spill length)

Neutron Detector acceptance
$\Delta\theta = 1^\circ$ (30 cm x 30 cm @ 7m

Gamma Detector acceptance
75 % for single, 42% for triple
Branching Ratio: 8.9%

**Optimistic obtained yield is 31650**

# Summary

- New experiment for exploring hadron mass property in nuclear medium is being proposed.
- K1.8 beam line can be used. High momentum beam line is suitable.
- Proposed experiment aims performing two measurements simultaneously. The experiment seems feasible, at least not impossible.

# Next tasks for proposal

- Background and trigger should be considered carefully.
  - Quasi free reaction
  - $\pi^- p \rightarrow \pi^0 n$
  - $2\ \pi 0 \rightarrow 4\ \gamma$ (1 gamma missing)
- Detector R&D should be done soon.

# Thanks


- R.S. Hayano (University of Tokyo)
  - Y. Kuroda, A. Ishida, T. Ichikawa
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- T. Takahashi (KEK)
- H. Nagahiro (RCNP)
- S. Hirenzaki (Nara W University)