In-medium modification of ρ/ω at γ+A reaction

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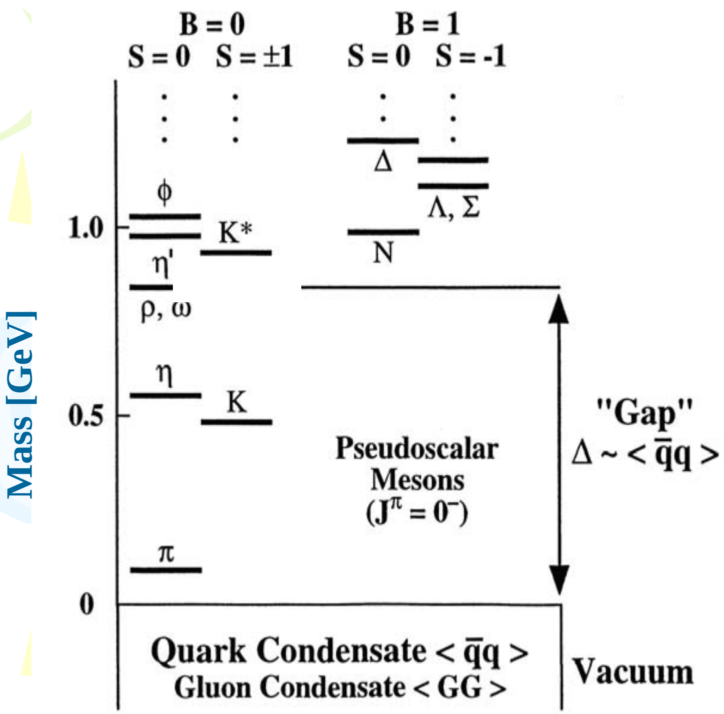
- Previous experiments
- At LEPS2? – just a few comment -
- Summary

In this talk, I take many slides from talks of V. Metag (TAPS), C. Djalali (CLAS), and H. En'yo at YKIS06. Thanks.

Motivation



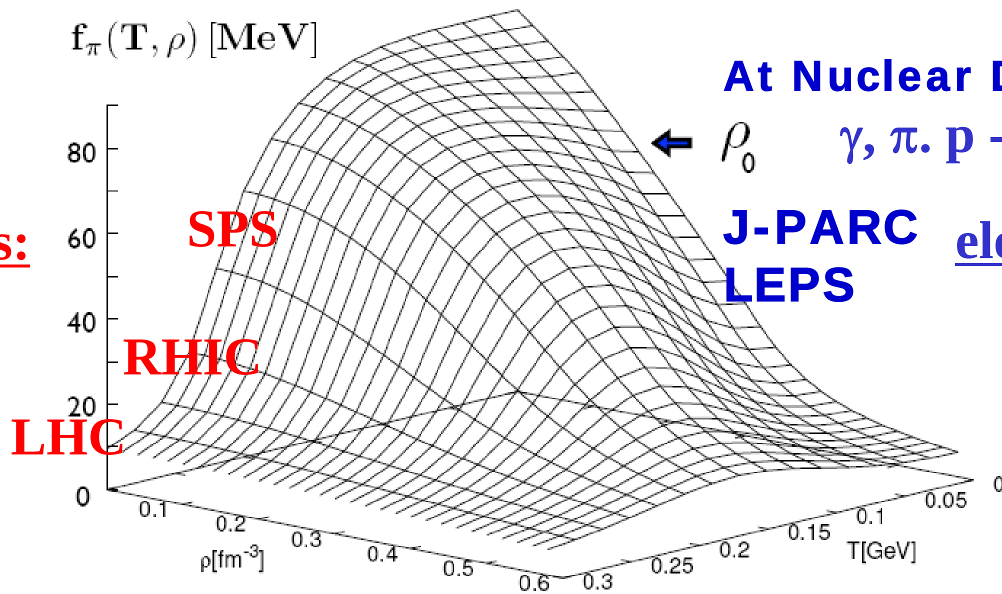
- hadron can be undestood as excitation of QCD vacuum
- QCD-vacuum has complicated structure characterized by condensates
- in the nuclear medium: condensates can be changed

  → Causes change of hadronic properties in the medium

⇒ many experimental and theoritical efforts to search for and study in-medium modifications of hadrons

Explore the medium

C. Ratti, M. Thaler, W. Weise, PRD73 (2006) 014019



At Nuclear Density

γ, π. p - beams

heavy ion reactions:

A+A→V+X

$m_V(\rho >> \rho_0; T>>0)$

elementary reaction:

γ, π → V+X

$m_V(\rho=\rho_0; T=0)$

$$\frac{f_\pi^2(T,\rho)}{f_\pi^2(0)} \simeq \frac{\langle \bar{q}q\rangle_{T,\rho}}{\langle \bar{q}q\rangle_0} \simeq 1 - \frac{T^2}{8f_\pi^2} - \frac{\sigma_N}{m_\pi^2 f_\pi^2}\rho + \ldots$$

$\langle q\bar{q}\rangle$ is not an observable

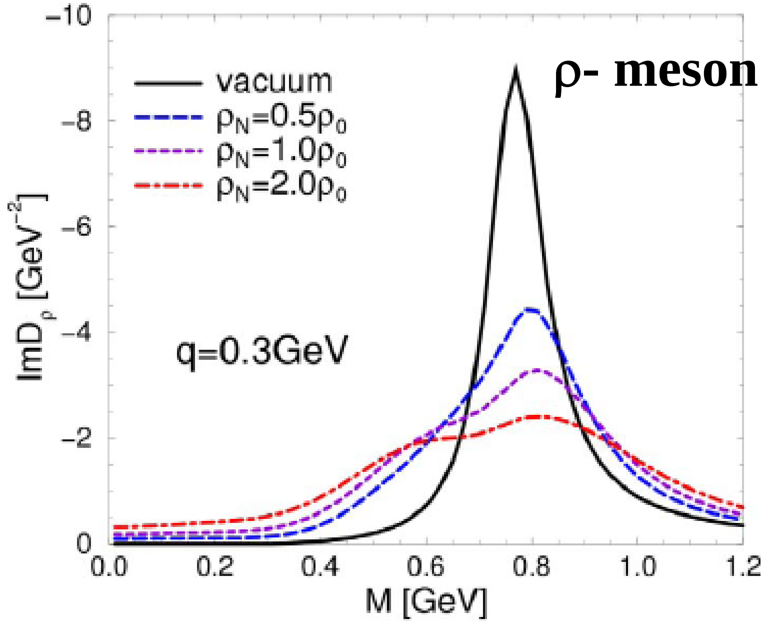
QCD sum rules: provides link between vector meson mass and condensate

G.E.Brown and M. Rho, PRL 66 (1991) 2720
$$\frac{m^*}{m} \approx \frac{\langle \bar{q}q\rangle^*}{\langle \bar{q}q\rangle} \approx 0.8\,(\rho \approx \rho_0)$$

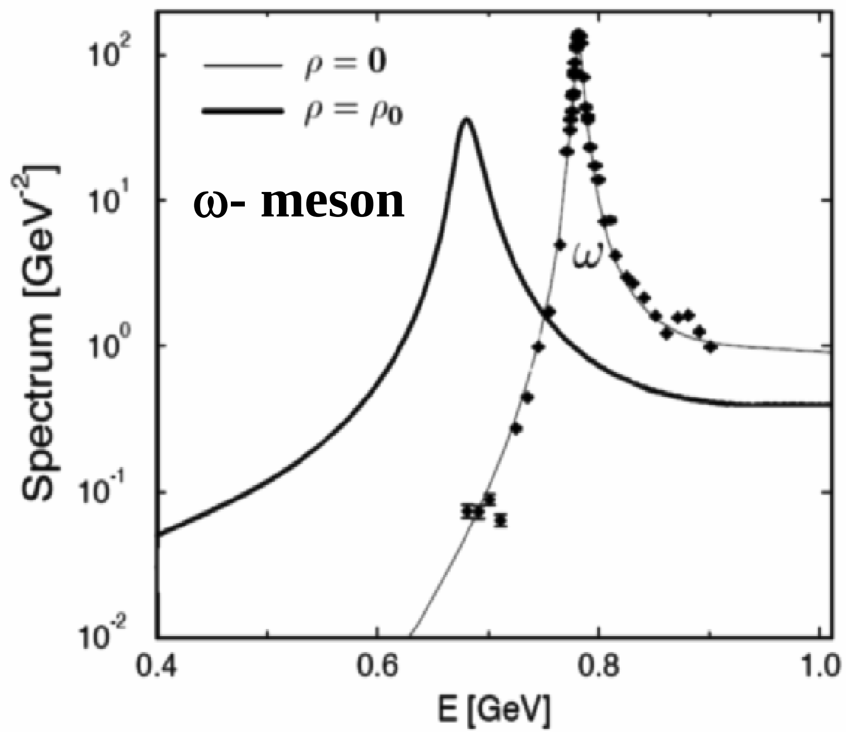
T.Hatsuda and S. Lee, PRC 46 (1992) R34
$$\frac{m_V^*}{m_V} = \left(1 - \alpha\frac{\rho_B}{\rho_0}\right);\ \alpha \approx 0.18$$

Predicted "spectra"

- Situation is not so simple, several theories and models predict spectral function of vector mesons (ρ, ω, φ).
  - Lowering of in-medium mass
  - Broadening of resonance



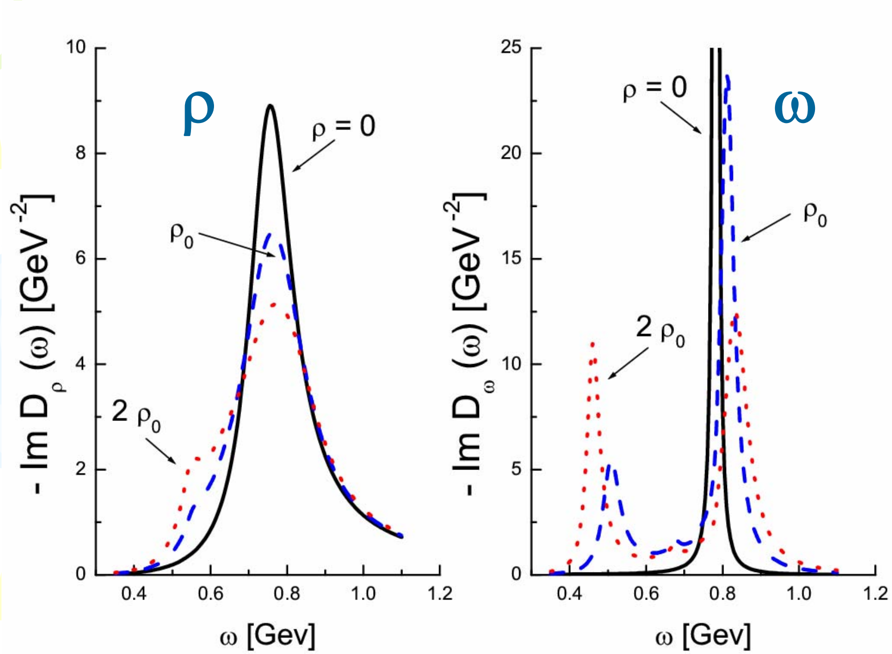
R. Rapp and J. Wambach, EPJA 6 (1999) 415



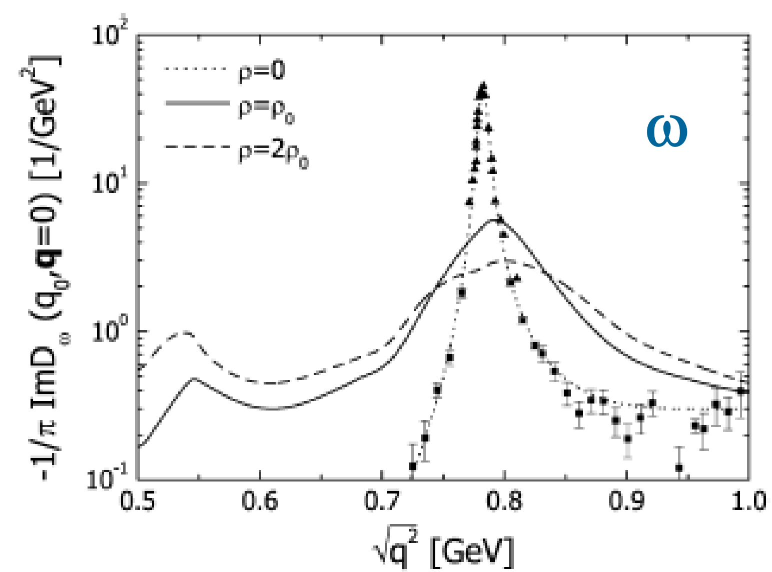
F. Klingl et al. NPA 624 (1997) 527
NPA 650 (1999) 299

Coupling to resonances

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



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



structure in spectral function due to coupling to baryon resonances

structure due to coupling to S11,P13 resonances

To distinguish several physics processes experimentally, large statistics and kinematics dependence are important.

Experimental efforts

Results from first generation experiments are appeared.
(as shown in following slides)
But further information is needed.

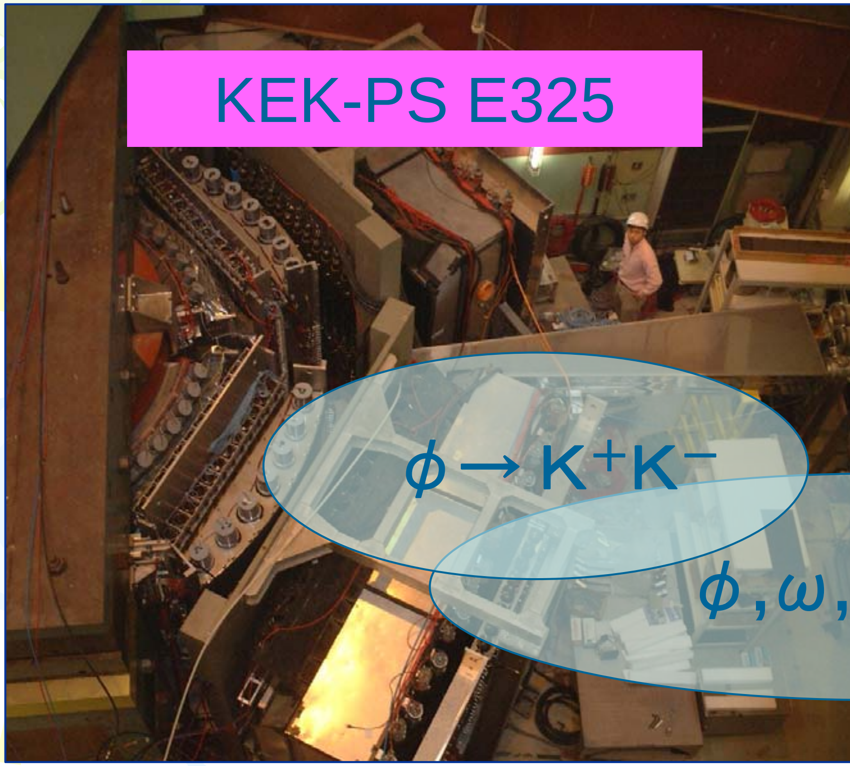
Two approaches:
Direct measurements of mass spectra
Nuclear mass number dependence of production cross section

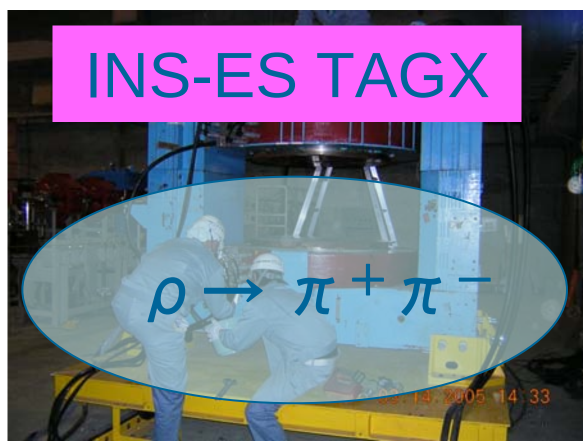
Two interactions:
p+A – KEK E325, J-PARC
γ+A – **LEPS, CLAS, TAPS,** (TAGX)

Two detection techniques:
Lepton (photon) decays
Hadron decays

Due to the final state interaction of hadrons, lepton or photon decay channel will be better in measurements of mass spectra.

Experimental efforts



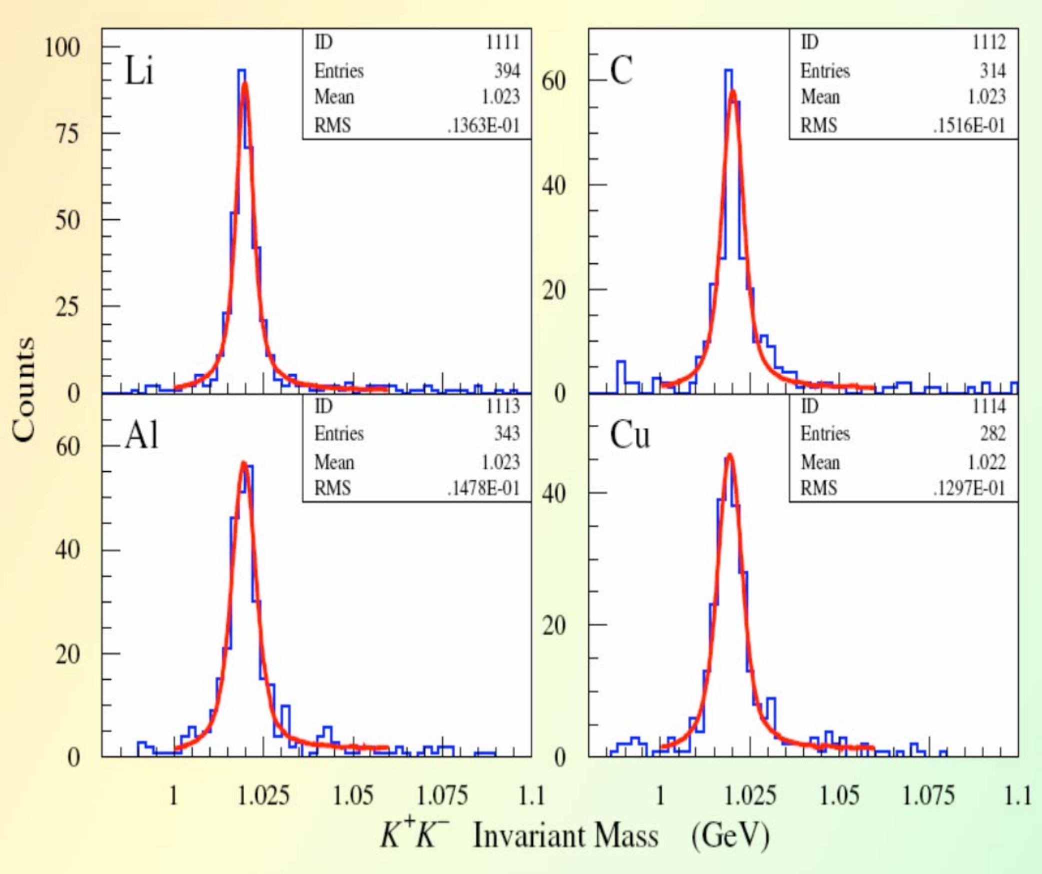


Score board at a glance

Produced by H. Enyo

	Proton induced		γ induced (E_γ GeV)			
E_{inc}	12GeV		0.6-2.5	0.8-1.1	1.5-2.4	0.6-3.8
Exp	KEK		TAPS	TAGX	LEPS	CLAS
A	12, 64		1, 93	2, 3, 12	7, 12, 27, 64	2,12,48,56,207.
ϕ	e^+e^-	K^+K^-			K^+K^-	e^+e^-
	Shift 3.4 $\pm$0.6%	No hint in IMS. Limits on Γ*			No hint in IMS In-media broadening ?	seen No report yet
ω	e^+e^-		$\pi^0\gamma$			e^+e^-
	Shift 9.2 $\pm$ 0.2% Not very sensitive for ω mod.		Shift 14%			No shift 2$\pm$2% (1σ) Not very sensitive for ω mod.
ρ				$\pi^+\pi^-$		
				Shift 5~8%		

LEPS, $\phi \rightarrow K^+K^-$ with γ+A



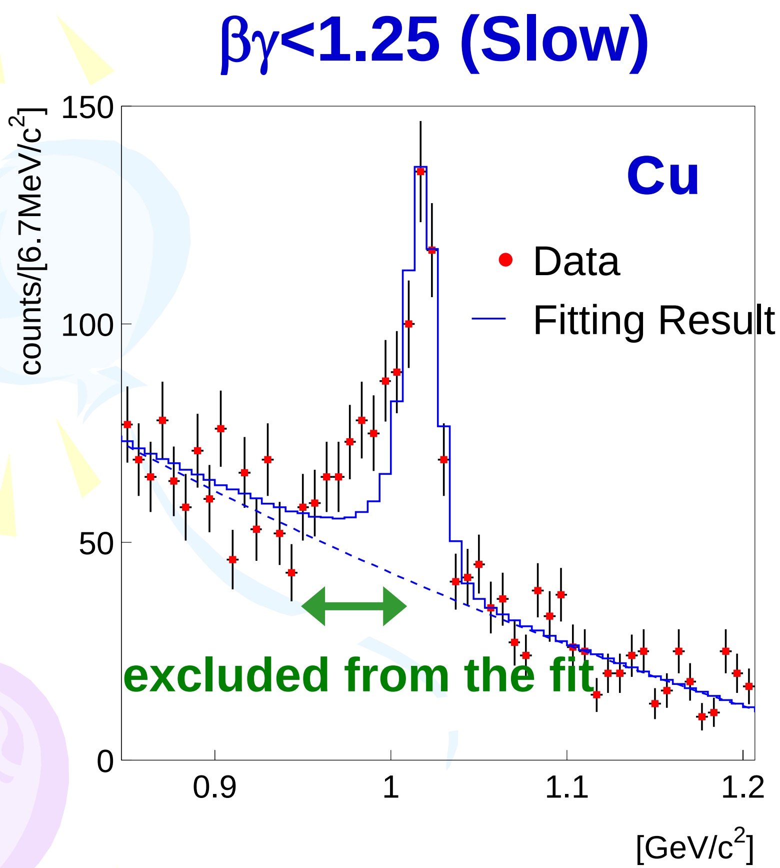
No significant spectral modification in mass distribution.

$\sigma(A) \propto A^{0.74 \pm 0.06}$,
$\sigma_{\phi N} = 30 + 12 - 8$ mb

?? $\Gamma^* \sim \Gamma_0$ X 3~5 ??

KEK E325, $\phi \rightarrow e^+e^-$ with *p*+A

Induce 12 GeV protons to Carbon and Cupper target, generate vector mesons, and detect e+e- decays with large acceptance spectrometer.



Invariant mass spectrum for slow ϕ mesons of Cu target shows a excess at low mass side of ϕ.

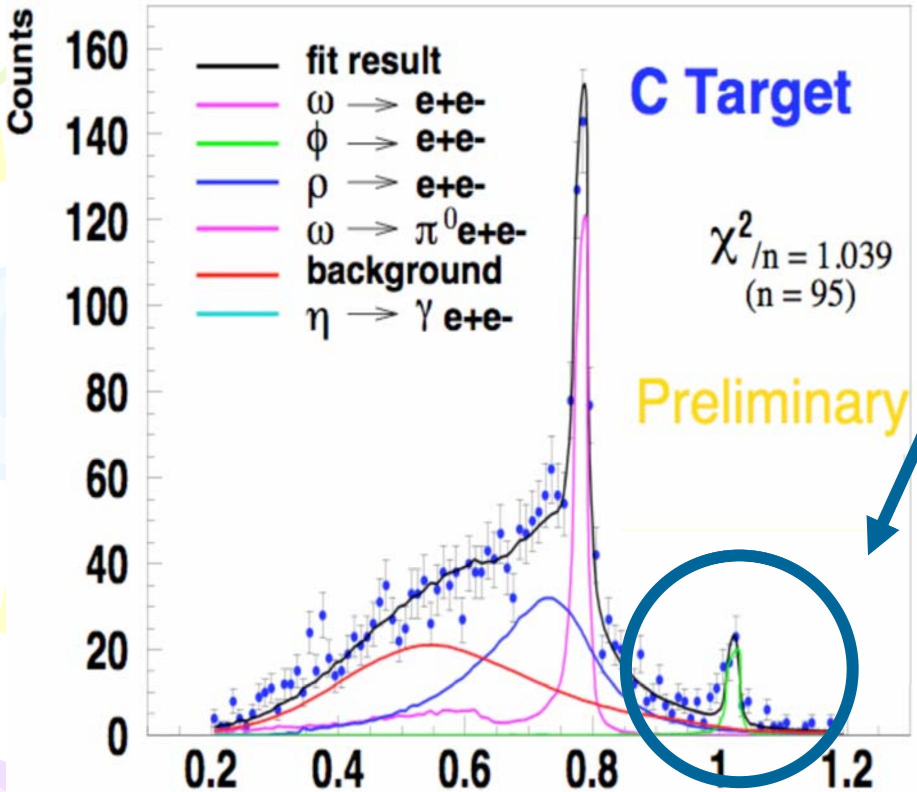
To explain the amount of mass decreasing and the amount of excess yield, simultaneously, 3 times larger mass width in nuclear is needed.

It may consistent with LEPS data.

$$m_\phi = m_0 (1 - \alpha\, \rho/\rho_0) \text{ for } \alpha = 0.03$$

$\phi \rightarrow e^+e^-$ with γ+A ?

CLAS Carbon Target



Preliminary results from CLAS.

The data shows a clear peak.

No detailed report from CLAS.

Used target may be too thick to state mass modification of ϕ
- Radiation tail is too large

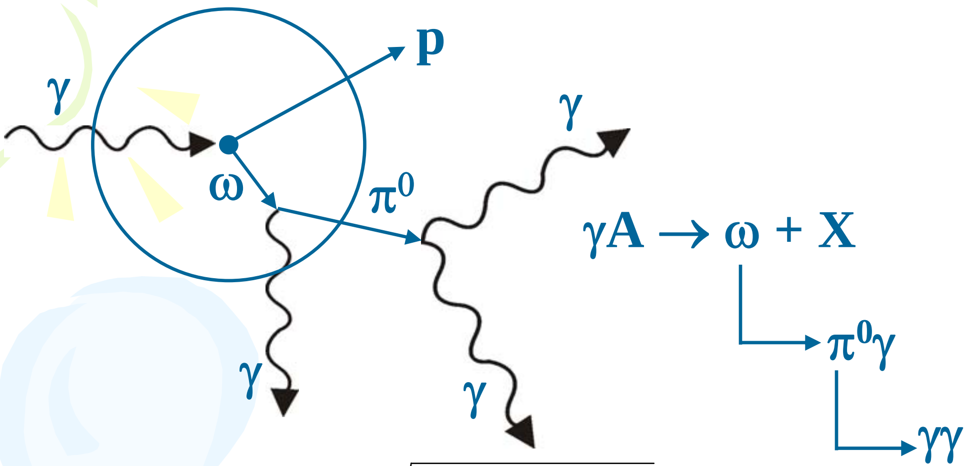
CLAS: 1 g/cm²
E325: 0.07 g/cm² (Cu)

My motivation #1: See $\phi \rightarrow e^+e^-$ at LEPS2!

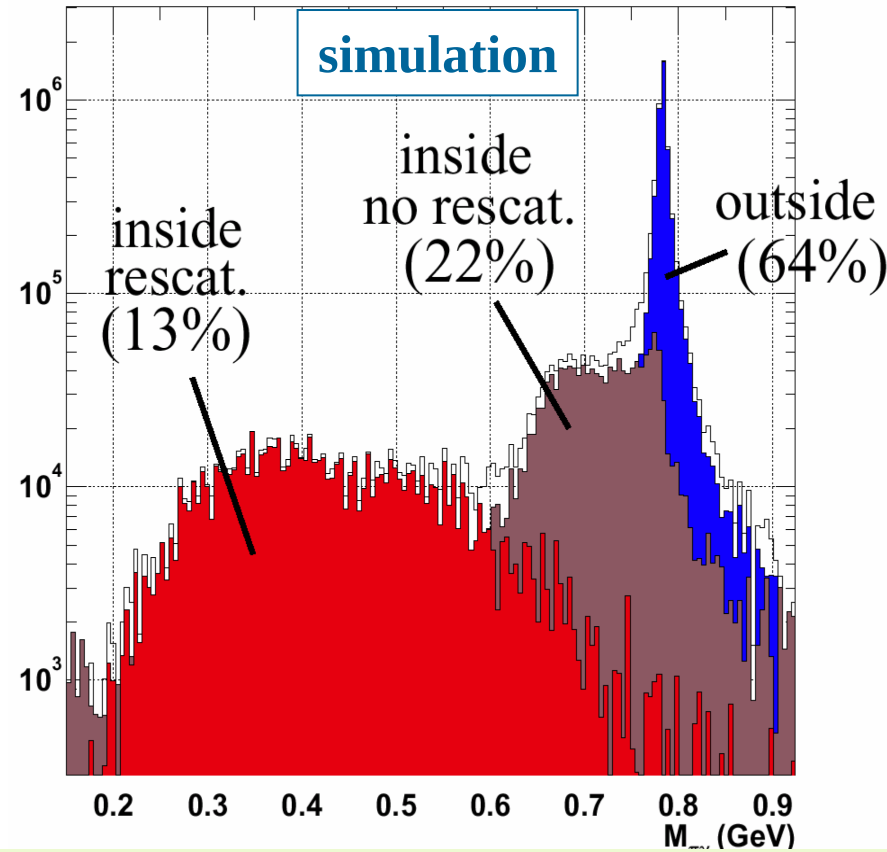
TAPS, $\omega \rightarrow \pi^0\gamma$ with γ+A

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

γ + Nb @ 1.2 GeV



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



advantage:

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

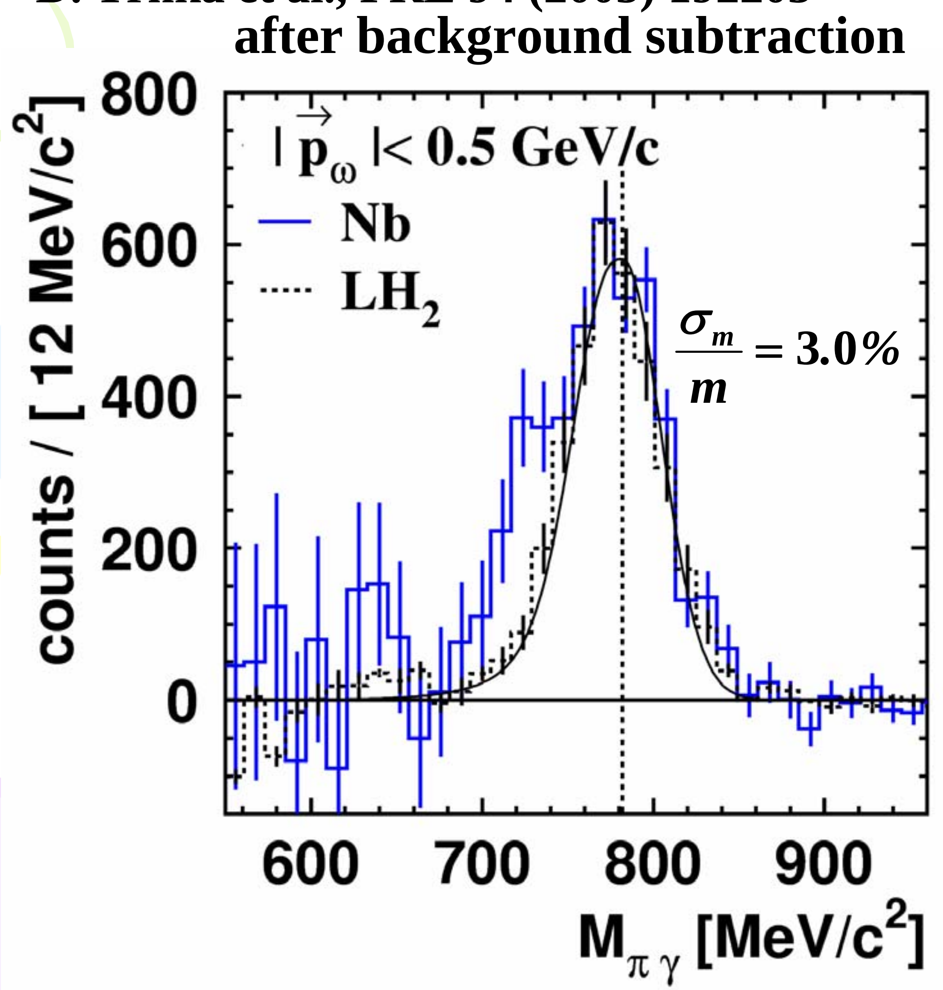
disadvantage:

- π^0-rescattering

no distortion by pion rescattering expected in mass range of interest; further reduced by requiring T_π>150 MeV

TAPS, mass spectra

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



difference in line shape of ω signal for proton and nuclear target consistent with

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

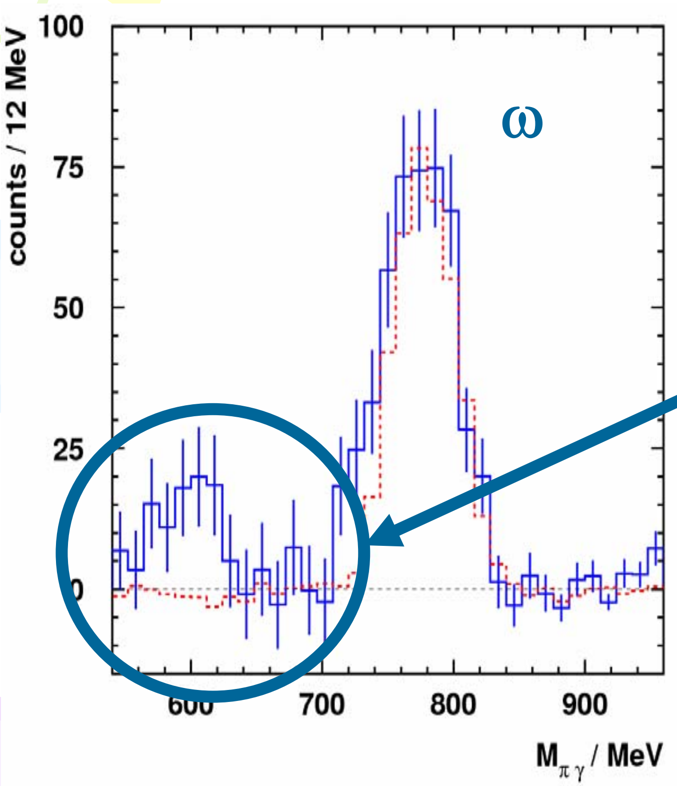
The result is not inconsistent with KEK, since ρ/ω is expected to have larger mass decreasing.

Width broadening is not shown in the spectrum itself.

Note: Dr. Oset does not believe the BG shape.
It's difficult to convince it.

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.

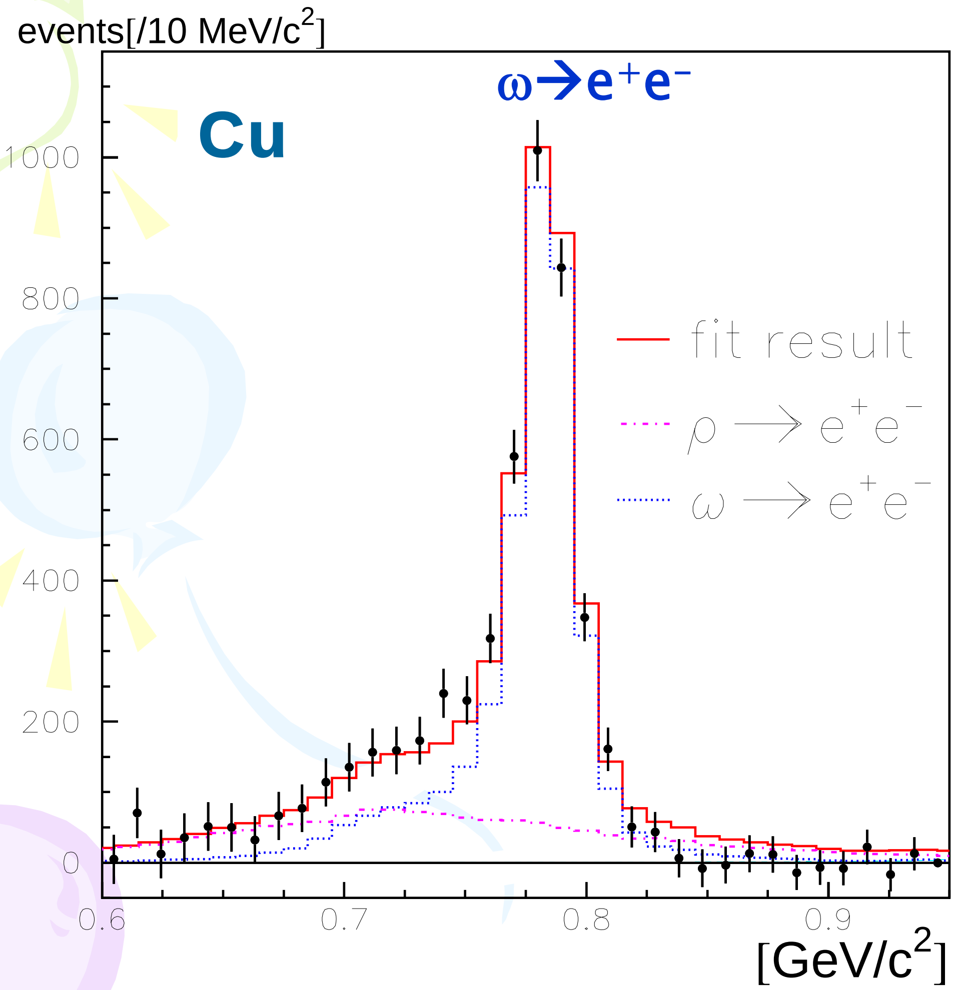
My motivation #2: See the strange peak at LEPS2!

$\omega \rightarrow \pi^0\gamma$ with p+A?

As far as I know, there is no results in terms of mass modification.

OK.
Let's write a proposal at J-PARC!

KEK E325, $\rho \to e^+e^-$ with p+A



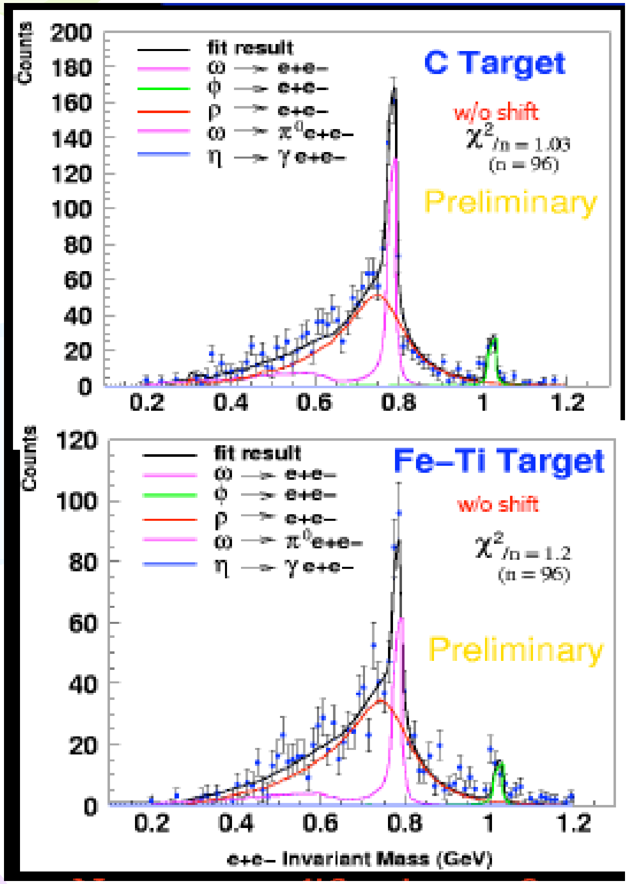
the excess over the known hadronic sources on the low mass side of ω peak has been observed both in Carbon and Cupper target.

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

The excess for both C and Cu are well reproduced by the model including the 9% mass decrease at ρ_0.

The result reasonably agrees with CLAS results.

CLAS, $\rho \rightarrow e^+e^-$ with γ+A



No excess over the known hadronic sources on the low mass side of ω peak.

$$m_\rho = m_0 (1 - \alpha\, \rho/\rho_0) \quad \text{for } \alpha = 0.02$$

CLAS results are not consistent with KEK results.

Contradiction?
Physics?

My motivation #3: See ρ modification at LEPS2!

Score board at a glance

Produced by H. Enyo

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ρ				$\pi^+\pi^-$ Shift 5~8%		

No Information!

Strange Peak!

Contradiction?

Feasible at LEPS2?

Let me think. I will start the evaluation.

- Yield
  - Beam intensity (LEPS2 ~ 10^7 Hz photons)

My motivation #4: LEPS2 has high intensity!

  - Acceptance
    - Large E949 detector
    - Reuse of KEK E325 detectors?
  - Production cross section does not have strong energy dependence. Higher energy may not help so much.
- Particle Identification
  - Electron or Muon?
  - Enough resolution for photon?
    - Can the detector identify both photon and electron?

Any Suggestions are VERY welcome!!

Summary

- Motivation #1
  - No information on lepton decays of ϕ.
- Motivation #2
  - Strange peak in measurements of ω at TAPS.
- Motivation #3
  - CLAS does not show ρ modification.
- Motivation #4
  - LEPS 2 has higher intensity than LEPS.
- Evaluation of experimental condition at LEPS2 is underway.