PS-E325
of Chiral Property of Dense Nuclear Matter Through
Measurements of Meson Mass Modification in Medium
$p+A \rightarrow e^+e^- + X$

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for
The KEK-PS E325 Collaboration

Preface

Physics motivation

Our Experiment

Results

Summary

C
$\omega(783)$
$\phi(1020)$
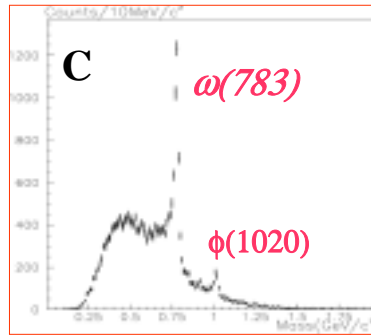
History
1995 March. KEK-PS PAC approved
1996 July. Construction started

	K^+K	e^+e / e^+e
1997 June First Physics Run with K^+K	99	
1998 May First Physics Run with e^+e **Published** in **P.R.L. 86 (2001) 5019**		95 / 12
1999 July First Physics Run with e^+e & K^+K	178	700 / 125
2000 June Production Run with newly installed **Dec.** **Vertex Chamber** & **Lead Glass Calorimeter**		
2001 Nov. Production Run	600	5000× 2 / 1000× 2
2002 Feb. LAST Production Run		

The Biggest Nuclear Experiment @ KEK-PS

Facing at the closing of KEK-PS

1971 April : KEK was established.

1974 December : BOOSTER was completed, @ 500 MeV.

1976 March : KEK-PS was completed, @ 8 GeV.

December : KEK-PS @ 11.8 GeV

1977 May : Experiments were started (bubble chamber and IT)

1978 April : Experiments with slow extracted beams

J/

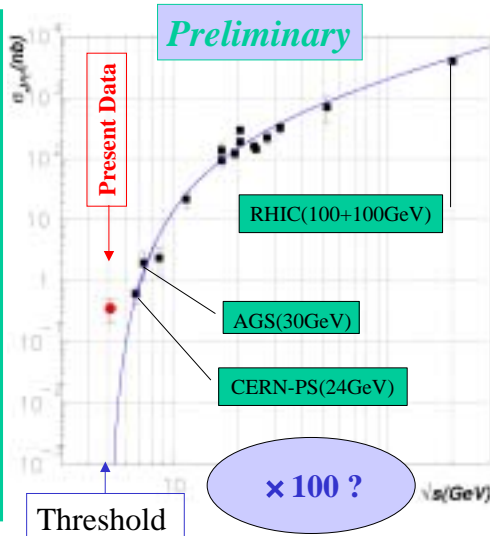Welcome to High Energy Society

Mikamo's exp. e+e-

KEK-PS2004　　　　　　　　　　　　　　　　Hideto En'yo, RIKEN/RBRC　　3
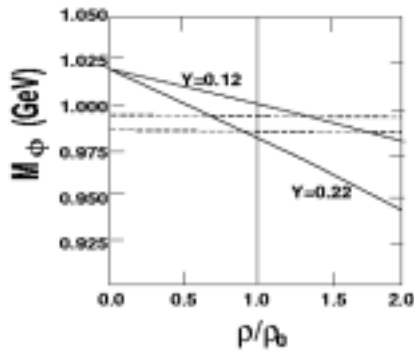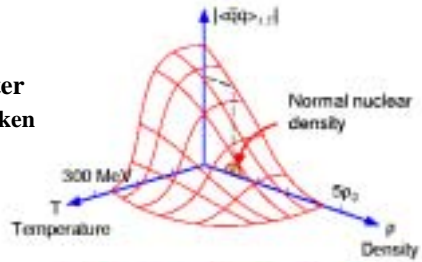

J/ Produced at the Lowest Energy

12GeV *p+C* → *J/* +X

→ e⁺e⁻

Preliminary

Present Data

RHIC(100+100GeV)

AGS(30GeV)

CERN-PS(24GeV)

Threshold

× 100 ?

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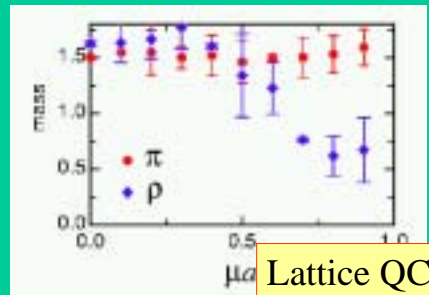
Physics Motivation of PS-E325

• **<qq> quark condensate : order parameter**
  • **to indicate how much the symmetry broken**
  • **but not an observable**

Mass of Vector Meson, ρ ω φ
$$\overline{M_v} = 2 \times M_q^{eff} + \text{small interaction term}$$

Muroya, Nakamura, Nonaka, 03

Lattice QCD

Moving Mesons in Media

$E^2 = M^2 + P^2$

Invariant mass in free space

Media effect expected to be small

Mass shift

Mass width broadning

Outside

Inside

1) decay outside nuclei   2) decay inside nuclei
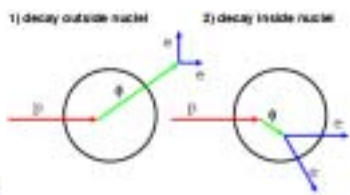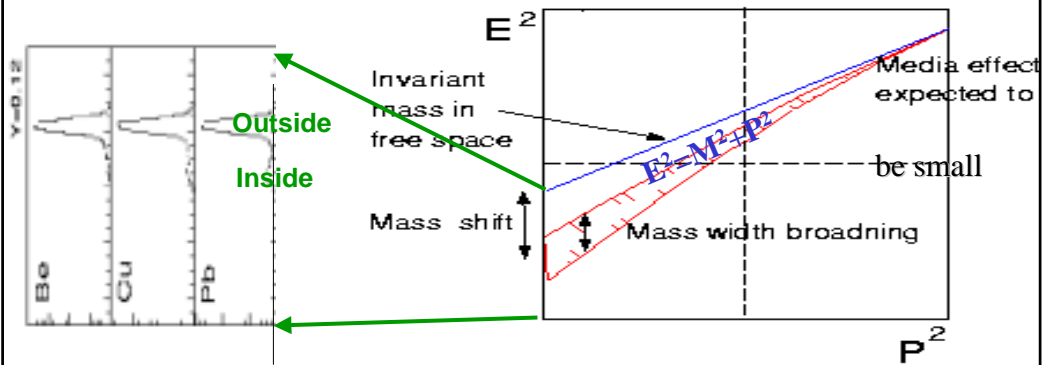
• **In-media meson modification**
  – Observed Mass is not Lorentz Invariant
    • shift of resonance position
    • resonance broadening/narrowing
      DISPERSION

Experiments

CLUES/Signatures

Experiment   Measurements   Interests

CERES/HELIOS-3   ρ modification   Temp. dep.   **is modified in Hot Matter**

KEK-TANASHI ES   ρ modification   Density dep.   **is modified in He**

GSI   π modification   Density dep.   **is modified in Nucleus**

KEK-PS: p+A   /   /+X

K+K–/e+e–)   (Completed / Analyzing)

Present & future experiments

RHIC(running)/LHC(2008?)

SPring-8: γ +   φ+A*(φ   K+K–)   (running)

GSI: d +A   3He+A* (ηω bound states)   (to run soon)

GSI-HADES: π +A   ω+A* (ω   e+e–) (running)

Some Tips of E325

- **Very thin target to suppress the conversion electron background (typ. 0.1% interaction/0.2% radiation length of C)**
- **To compensate the thin target, high intensity proton beam to collect high statistics (typ. 10^9 ppp -> 10^6Hz interaction)**
- **Focus on slowly moving φ,ω,ρ 's, p =~1GeV/c(lab). About 10% of φ's will decay inside a nucleus if nothing happens.**
- **Expected mass shift is 20~40 MeV for   140MeV for**
  - (Hatsuda-Lee).
- **natural width of φ, ω is narrow (4.4, 8.4MeV), but some broadening can happen.. Estimations are:**
  - $\Gamma\phi = \sigma_{\phi N} \beta_\phi \rho_0$ **$\Gamma\phi$ <20MeV**
    - σ{φN} < $10mb, total cross section (from γ+A   φ) β_ϕ=0.7,ρ_0 =0.16/fm3
  - φ   K+*K–*(K–N   ΣX)
    - **Klingle and Weise $\Gamma\phi$ ~44MeV (at rest)**

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E325 collaboration

- Kyoto University
  - H.Funahashi,, M.Kitaguchi, M.Miyabe, T.Murakami, M.Naruki, F.Sakuma, H.D. Sato, S.Yamada
- CNS, University of Tokyo
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- ICEPP, U-Tokyo
  - **S.Mihara, M.Ishino**
- RIKEN
  - **S.Yokkaichi, T.Tabaru, R.Muto**, H. Enyo
- Tohoku University
  - H. Kanda
- KEK
  - J.Chiba, M.Ieiri, O.Sasaki, M.Sekimoto, K.Tanaka
- Osaka University
  - M.Nomachi

Graduation
T.Miyashita
Y.Yoshimura
K.Hamada

**Doctor thesis
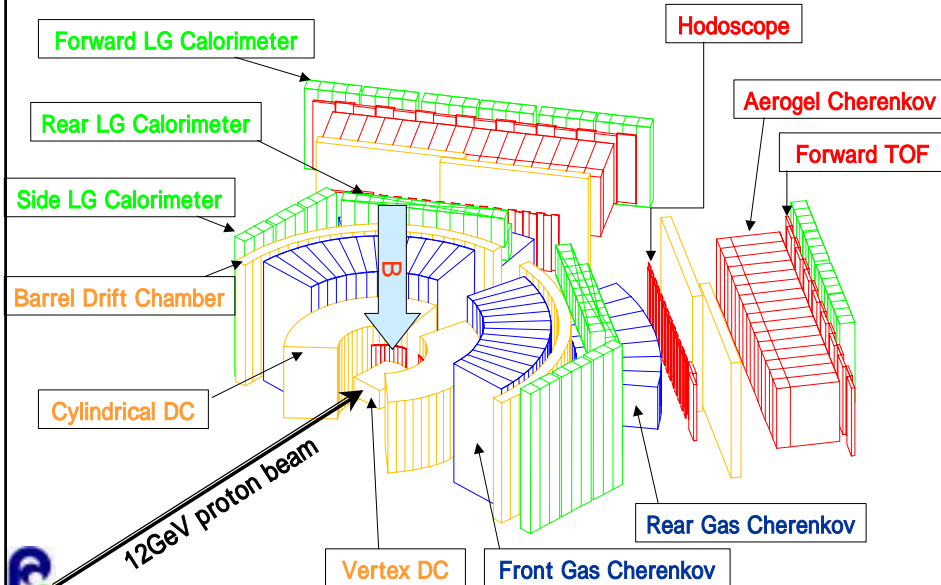4 completed, 4 to come**

**Master Thesis
10 completed**

Set up

Forward LG Calorimeter
Rear LG Calorimeter
Side LG Calorimeter
Barrel Drift Chamber
Cylindrical DC
12GeV proton beam
Vertex DC
Front Gas Cherenkov
Rear Gas Cherenkov
Hodoscope
Aerogel Cherenkov
Forward TOF
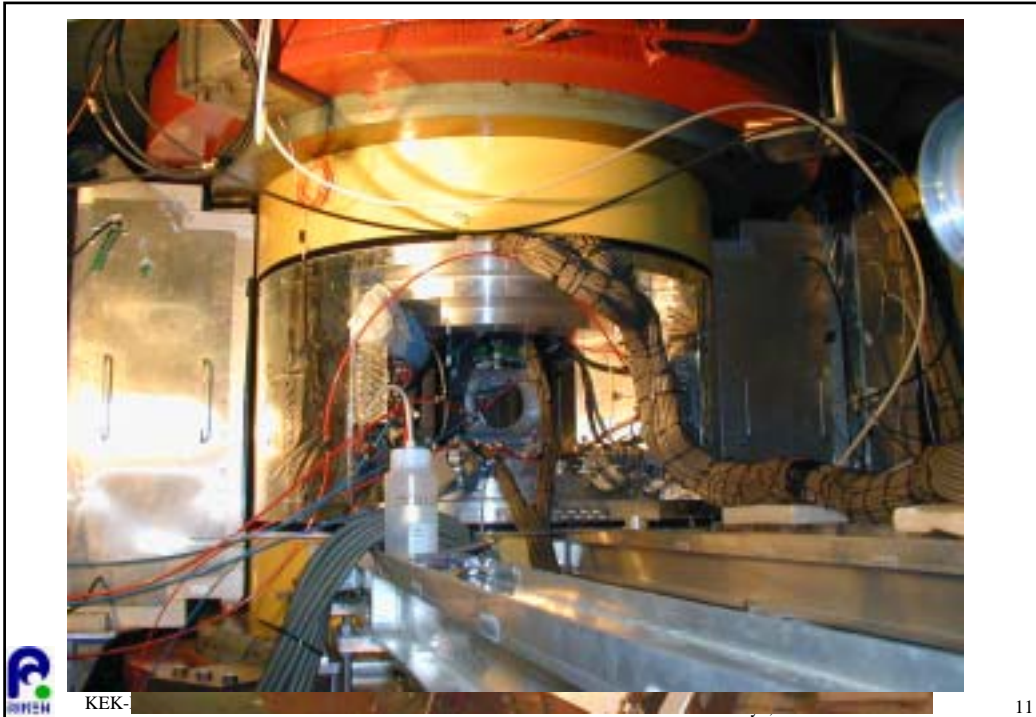
Around the targets

Vertex Distribution

- 3 target plate inline

  – C/CH2/Cu

  – 10^9/s protons
  – 10^6/s interactios

- Vertex chamber
  – 1.75mm drift length
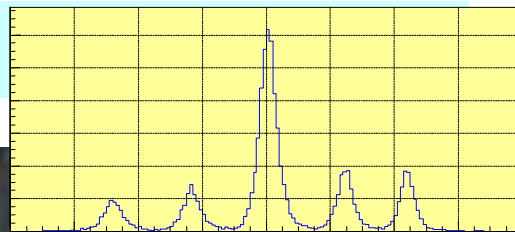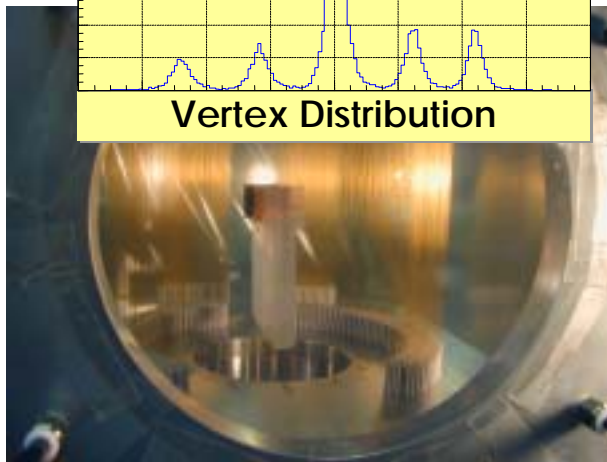
KEK-PS2004

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Spectrometer Performance

[events / 1MeV/c²]   p   ⁻

m=1115.5MeV/c²
σ = 1.8 MeV/c²

500

200
100
O

1.09 1.1 1.11 1.12 1.13 1.14
[GeV/c²]

K⁰   +   ⁻

Counts/2MeV/c²

m=497.3MeV/c²
σ=3.5MeV/c²

200

100

0
0.46   0.5   0.54
(GeV/c²)
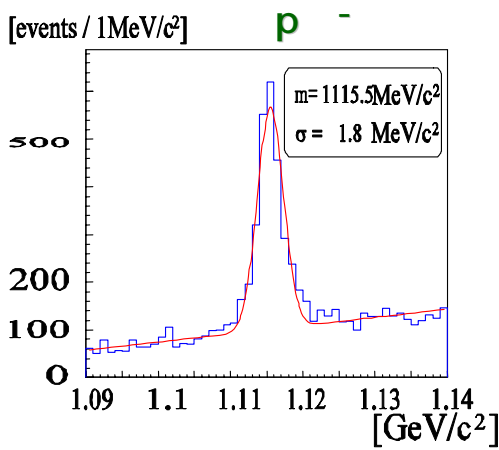
M_Λ= 1115.5MeV/c² (PDG1115.7MeV/c²)
σ_Λ = 1.8MeV/c²   (Sim. 1.9MeV)
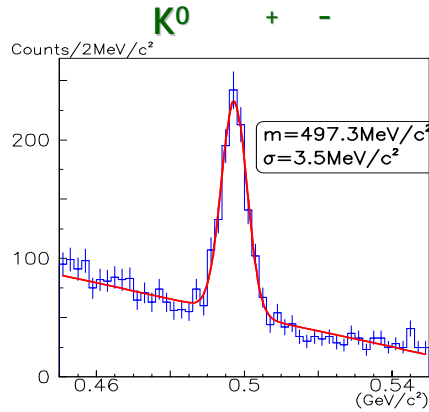
M_K= 497.6MeV/c² (PDG 497.7MeV/c²)

σ_K = 3.8MeV/c²   (Sim. 4.1MeV)

Mass and Width are well reproduced by MC.

'98 data (Electron Channel)

[events / 50MeV/c²]   from light targets

$\omega \rightarrow e^+e^-$

[events / 50MeV/c²]   from heavy target

fit result
ω→e⁺e⁻
ρ→e⁺e⁻
φ→e⁺e⁻
ω→π⁰e⁺e⁻
combinatorial

e⁺e⁻ invariant mass

e⁺e⁻ invariant mass

- e+e   Significant Difference between C and Cu
- The first observation of in-medium decay of vector mesons.

Invariant Mass Spectrum of e+e- (2002 data)

Preliminary

fit result
$\omega \to e^+e^-$
$\rho \to e^+e^-$
$\varphi \to e^+e^-$
$\eta \to e^+e^-\gamma$
$\omega \to \pi^0 e^+e^-$

Mass(GeV/c²)

ρ / ω ratio is consistent with zero
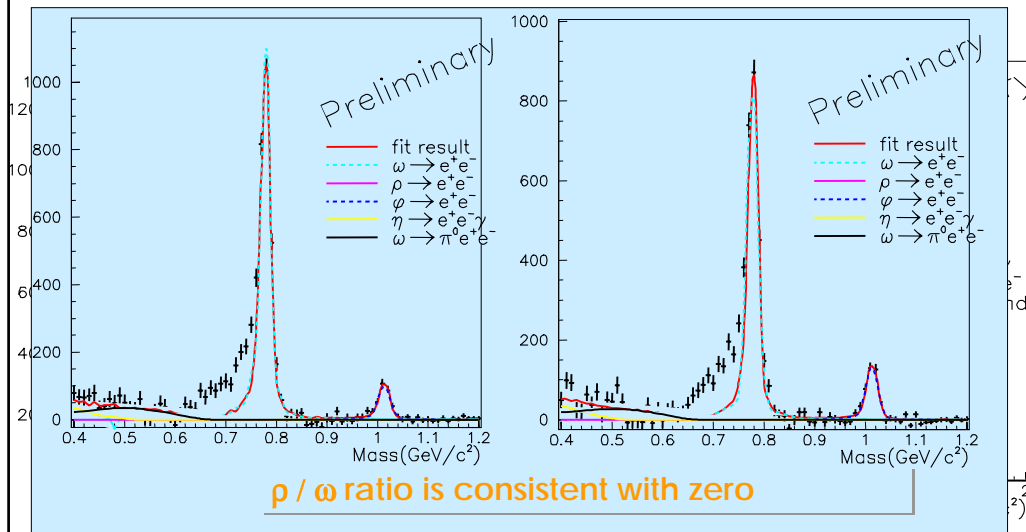
the excess over the known hadronic sources on the low mass side of ω peak has been observed.

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Toy model analysis including modification

- Assumptions to include the nuclear size effect in the fitting shape

  – nuclear density distribution : Woods-Saxon form

  – meson production point : incident surface of nuclei

  – fly through the nucleus, decay with modified mass if ... inside nuclei
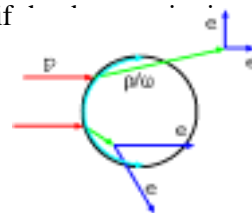
  – modification as : $m^*/m_0 = 1 - 0.16 \, \rho^*/\rho_0$
    (Hatsuda & Lee, '92,'95)

    (width modification & momentum dependence of modification are not taken into account)

  ρ/ω ratio is fixed to unity as measured in former exp.
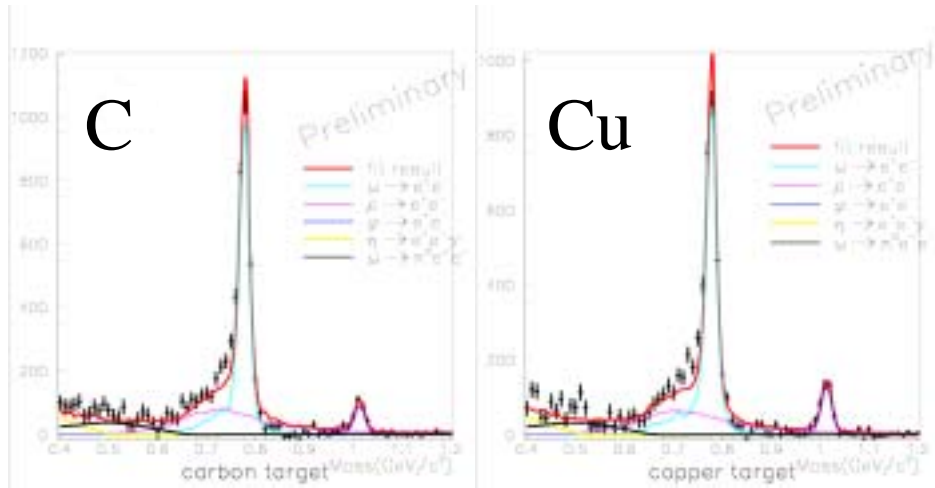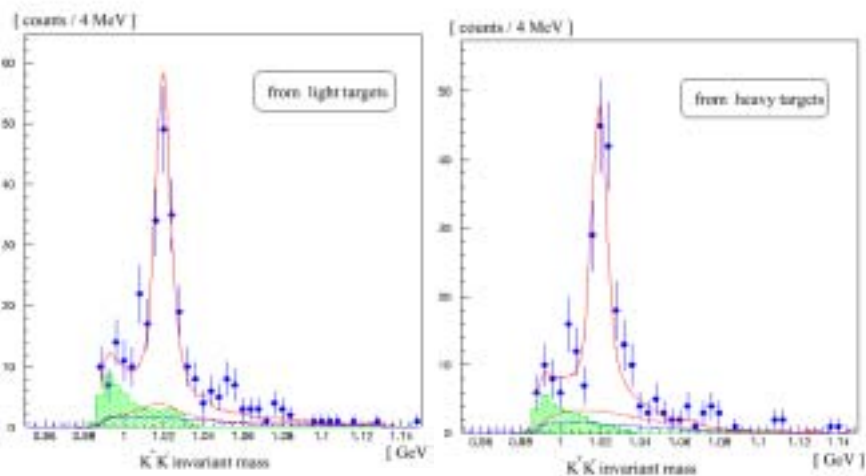
Fitting results by the toy model

C   Cu

Tendency of the data are reproduced qualitatively by the model

(KK mode)   to be published

Invariant Mass Spectrum of φ → e⁺e⁻
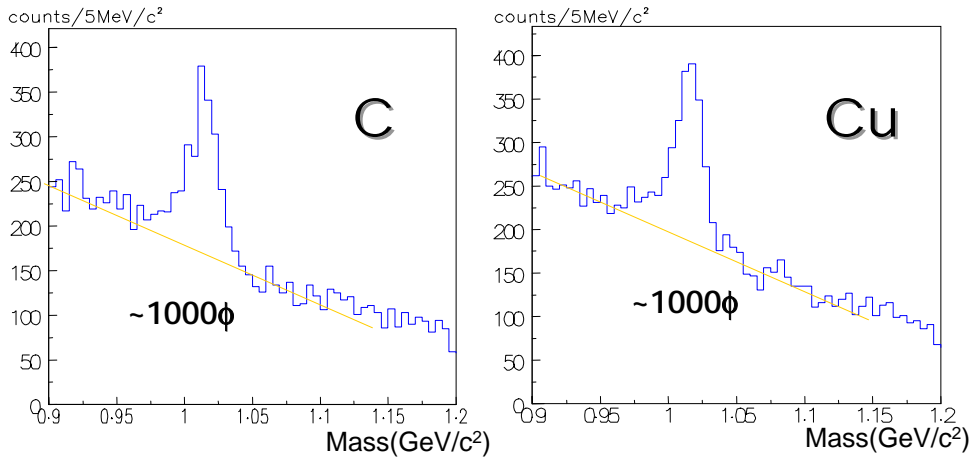
Byproducts
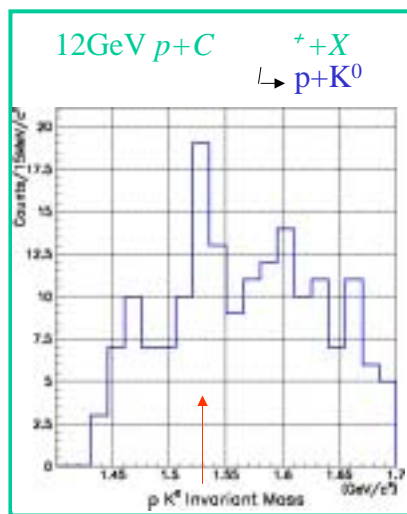
Conclusions

- KEK-PS E325 measured the $e^+e^-(\&K^+K^-)$ decay of slowly moving vector mesons in nuclei produced by 12GeV proton beam, to explore the chiral symmetry restoration at the normal nuclear density.
- Observed e^+e^- invariant mass spectra have excesses below the ω meson peak, which cannot be explained by known hadronic sources in normal (unmodified) shape. These suggest modification of (at least) ρ meson.
- Simple model calculation including predicted modification reproduces the observed spectra qualitatively.
- Analysis on φ meson is on going...
- Signals seen for **J/**