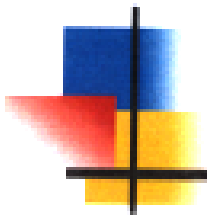

Modification of Vector Mesons in Nuclear Matter measured in 12 GeV p+A reactions at KEK-PS

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① Physics motivation / experimental signals
② E325 experiment (characteristics, setup, detectors)
③ Status / Data ($\rho/\omega \rightarrow e^+e^-$ ('98) / $\phi \rightarrow K^+K^-$ ('99))
④ Summary… I show only the same statistics…

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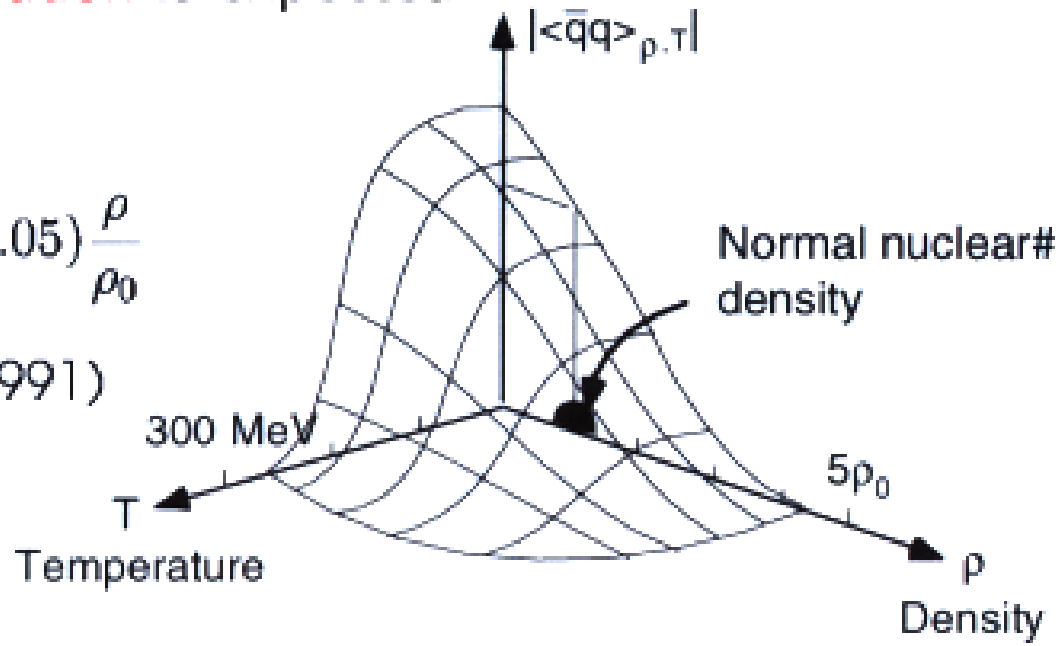
Chiral symmetry restoration in dense matter

- In free space
  - ➔Spontaneous breaking of chiral symmetry
- In dense matter
  - ➔Partial chiral symmetry restoration
  - ➔Hadron modification is expected

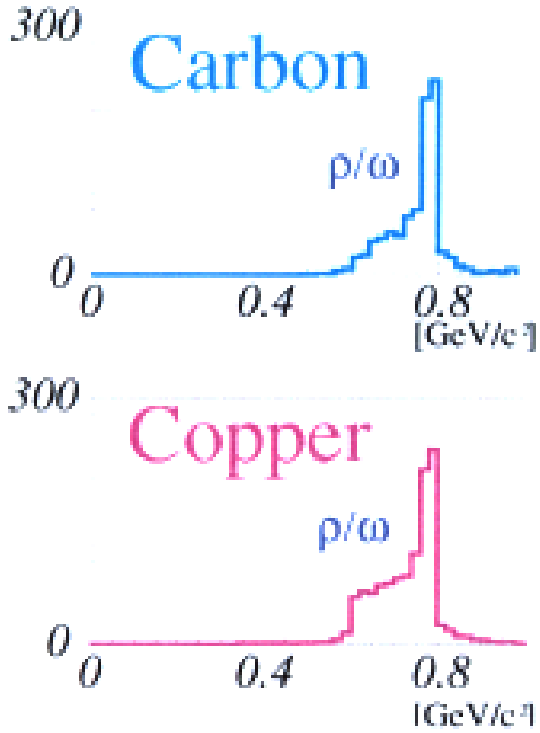
$$\frac{\langle\bar{q}q\rangle_\rho}{\langle\bar{q}q\rangle_0} = 1-(0.34\pm0.05)\frac{\rho}{\rho_0}$$

(Drukarev *et al.*, 1991)



Expected experimental signals

- **Invariant mass spectra**
  - ➔In ρ / ω meson case, we calculated for finite size nuclei.
  - ➔The mass shifts can be seen clearly. Target nuclear size dependence should be observed.



We assumed

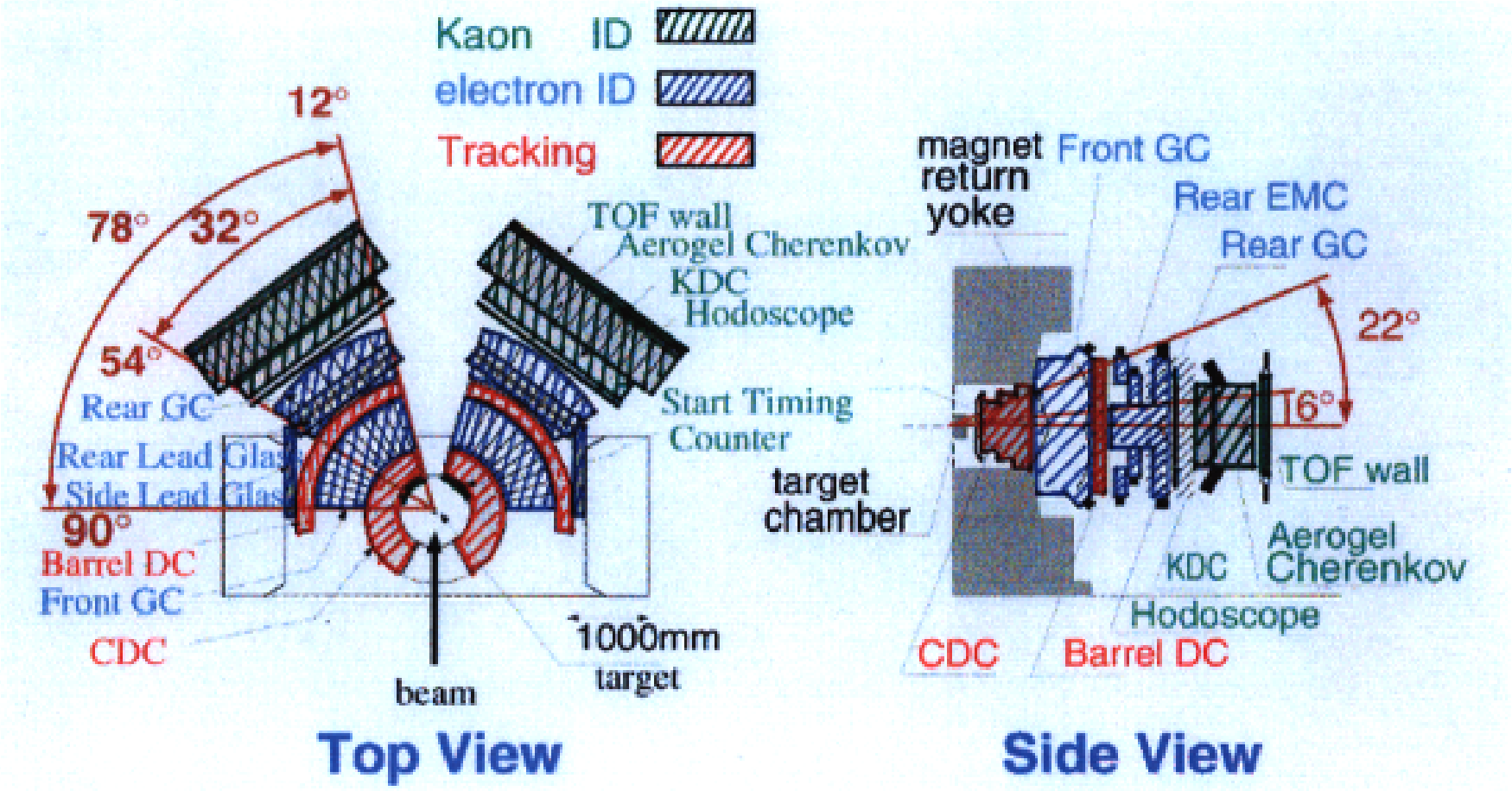
- Hatsuda and Lee ('92) prediction
- Broadening of the width (×3)
- Woods-Saxon distribution
- Generate ρ/ω in the surface of a nucleus.

- **Branching ratio ($N_{\phi\to K^+K^-}$ / $N_{\phi\to e^+e^-}$)**
  - ➔Small Q value (32 MeV) of $\phi \to K^+K^-$
    - →Sensitive to possible mass shift of φ and K

KEK PS E325 experiment

- 12 GeV p + (CH_2, C, Cu) → ρ, ω, ϕ + X
- Measure e^+e^- pairs and K^+K^- pairs
  - ➔Invariant mass spectra (e^+e^-)
  - ➔Branching ratio N_{KK}/N_{ee}
    - ➔Compare heavy and light nuclei cases
- Key points of spectrometer design
  - ➔Large acceptance spectrometer to detect slow mesons
    - ➔Larger matter effect is expected.
  - ➔Clean high intensity beam (~ 10^9 ppp) on thin target
    - ➔To suppress background in e^+e^- channel

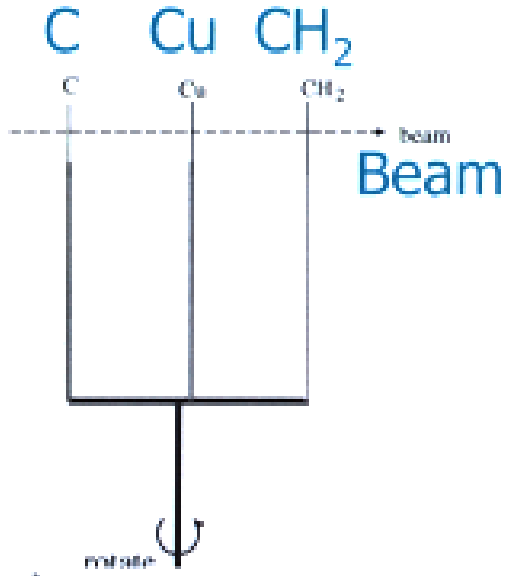
E325 spectrometer setup

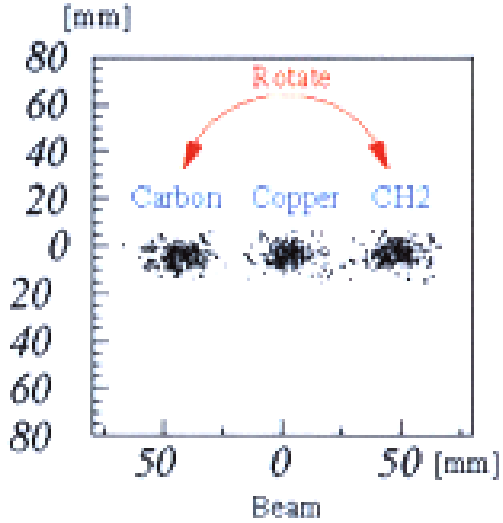


The details are shown in the poster P088 by M. Naruki.

Targets

- We placed three targets in-line along the beam direction.
- Total interaction length
  - ➔0.2 %
- Total radiation length
  - ➔0.5 %
- To minimize the position dependence of the acceptance, the target holder was rotated by 180 degrees in every 12 hours.

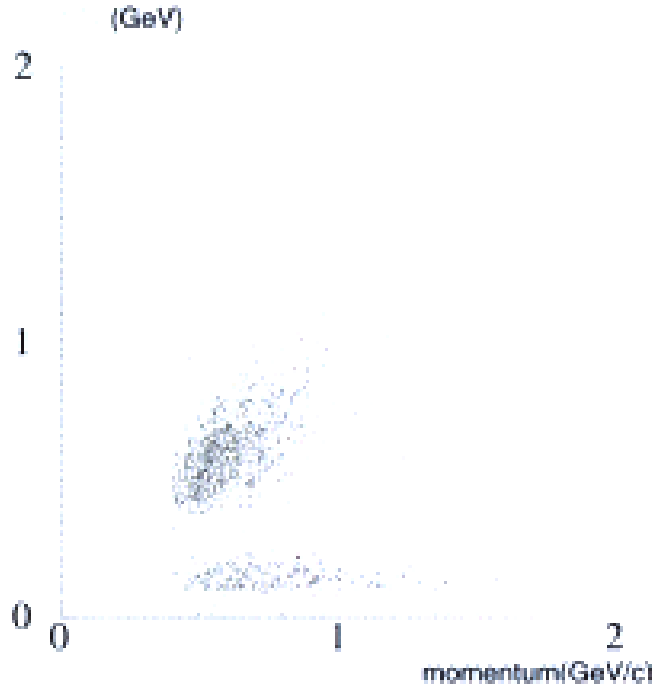




Electron efficiency and pion contamination

- We evaluated the electron efficiency and pion contamination in the momentum range greater than 400 MeV/c.

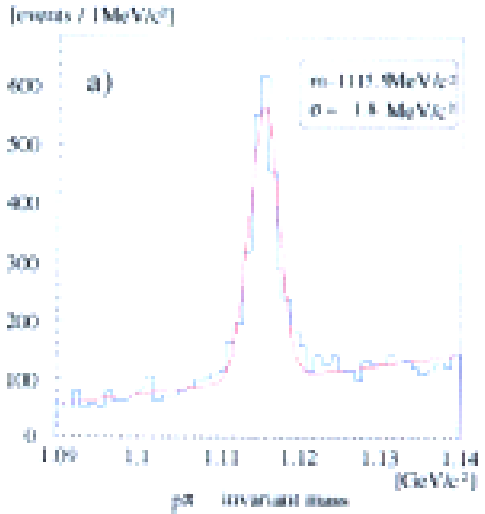
Counter name	e eff.	π rejection
FrontGC	55%	
Rear GC	86%	6.7×10^{-4} with FrontGC
EM cal	85%	3.9×10^{-4} with FrontGC

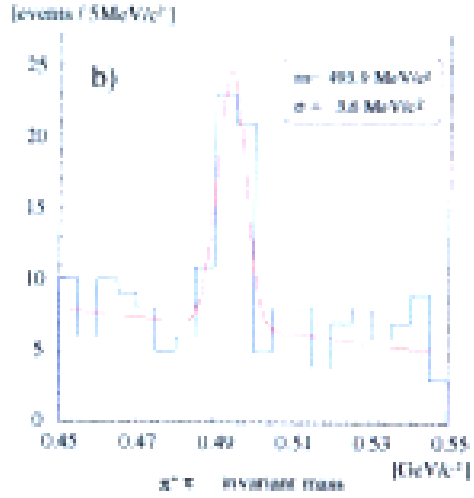


EM cal Energy.vs.Momentum

- The remaining eπ pair background was estimated to be about 13% in the final e^+e^- pair sample.
- The contaminations like ππ pair to be negligibly small.

Mass resolution and energy scale





$\Lambda \to p\pi^-$

ΔM (measured) $= 1.8 MeV/c^2$

ΔM (M.C.calc.) $= 1.9 MeV/c^2$

$K_s \to \pi^+\pi^-$

ΔM (measured) $= 3.6 MeV/c^2$

ΔM (M.C.calc.) $= 3.5 MeV/c^2$

Consistent

$\omega \to e^+e^-$ ΔM (M.C.calc.) $= 9.6 MeV/c^2$

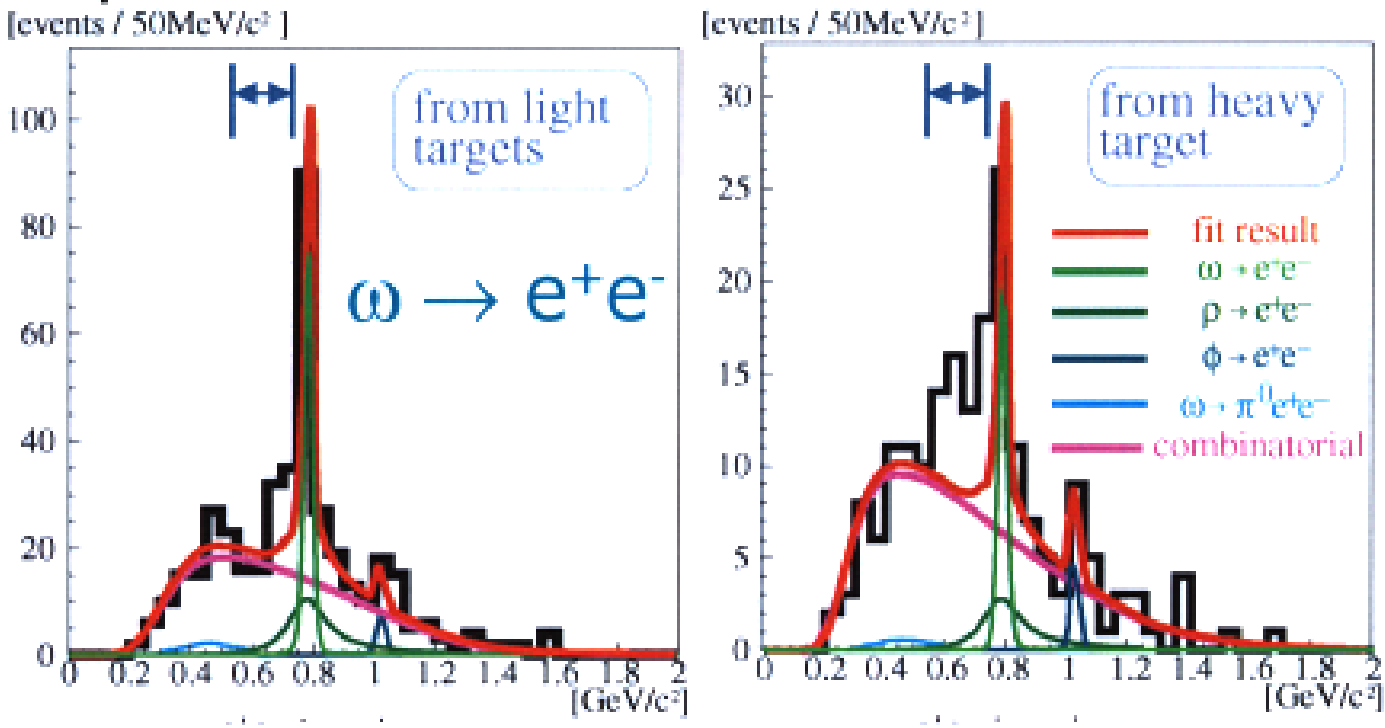
$\phi \to K^+K^-$ ΔM (M.C.calc.) $= 2.4 MeV/c^2$

The energy scale uncertainty was estimated to be less than 1%.

Experimental status

- Preparation start: May 1994
- First physics Run: Jun. 1997
  - ➔ 100M events (kaon trigger)
- Second physics Run: May 1998
  - ➔ 100M events (electron trigger) ⇒ Present Data
- Third physics Run: Jul. 1999
  - ➔ 75M events (kaon trigger) ⇒ Present Data
  - ➔ 64M events (electron trigger)
- Fourth physics Run: Jun. and Dec. 2000
  - ➔ 95M events (kaon trigger)
  - ➔ 85M events (electron trigger)

Invariant mass distribution of electron pair



- N_{ω} = 75.5 ± 9.0 20.0 ± 4.8
- N_{ϕ} = 7.4 ± 5.8 5.2 ± 2.7
- N_{excess} = 19.6 ± 11.7 29.5 ± 8.7
- N_{excess} / N_{ω} = 0.26 ± 0.16 1.48 ± 0.56

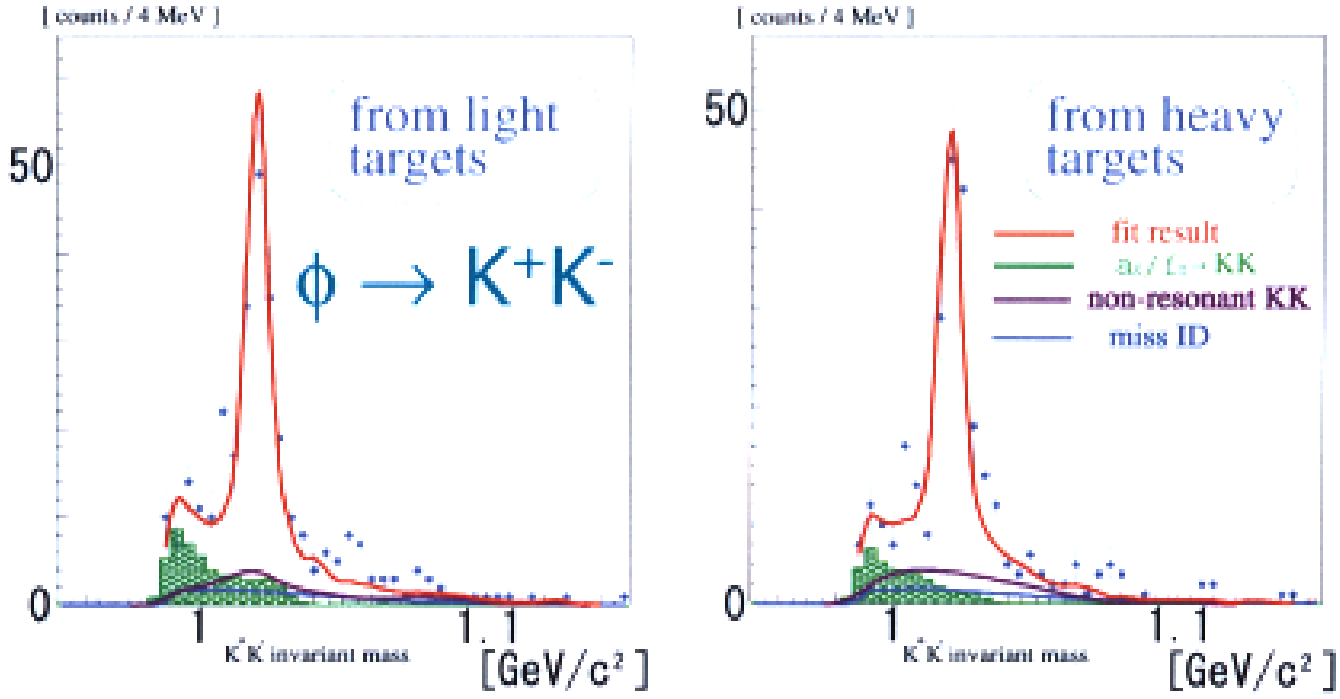
The fit with 4 parameters: N_{ω} N_{ϕ} N_{η} $N_{combinatorial}$

We assumed σ_{ρ} equal to σ_{ω}.

Combinatorial B.G. was obtained by the event mixing.

$N_{\eta \to e e \gamma}$ turned out to be negligible.

Invariant mass distribution of kaon pair



The fit with 2 parameters: N_ϕ $N_{a/f}$

The ratio of non-resonant KK pair to $\phi \rightarrow KK$ obtained by the JAM calc.

The background due to the miss ID was estimated by the PID analysis.

- The spectra were well described with $\phi \rightarrow KK$, $a_0/f_0 \rightarrow KK$ and non-resonant KK pairs.

Mass number dependence of the ϕ production

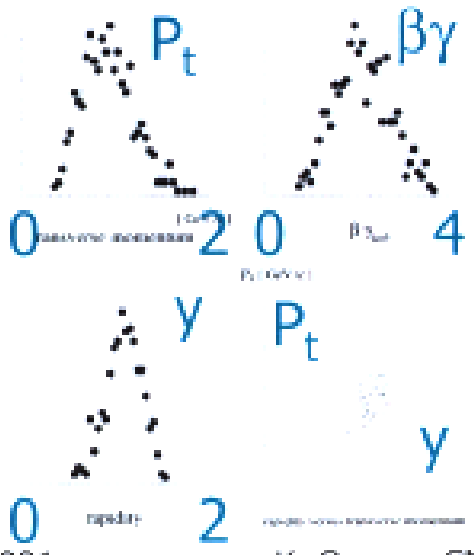
- In the $\phi \rightarrow K^+K^-$ channel

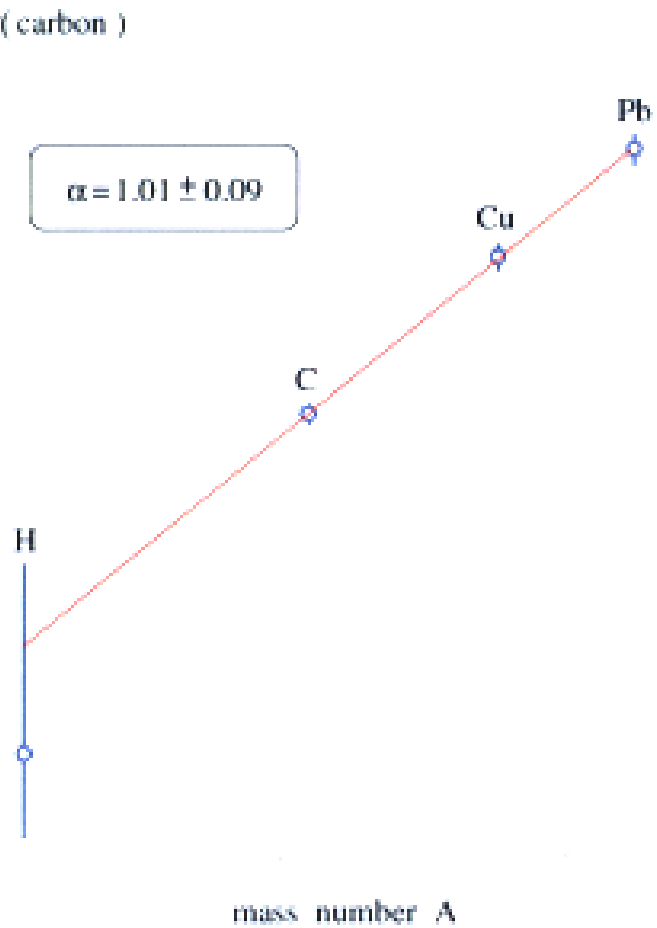
  ➔ From the data,
  $\alpha = 1.01 \pm 0.09$.

  ➔ From Monte Carlo (JAM),
  $\alpha = 1.08 \pm 0.01$.

  $\sigma(A) = A^{\alpha} \bullet \sigma(1)$

- Kinematical distribution.





Summary

- The present experiment, KEK-PS E325, addresses an important question on the QCD vacuum and the chiral symmetry at finite density.
- We have measured vector meson decays, $\phi,\omega,\rho \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$, in 12 GeV p+A reactions.
- In the e^+e^- spectra, a significant shape difference was observed between the light and the heavy nuclear target.
  (nucl-ex 0011013)
- The K^+K^- spectra were well described with $\phi \rightarrow KK$, $a_0/f_0 \rightarrow KK$ and non-resonant KK pairs.
  (M. Ishino, Ph.D. Thesis, Kyoto University)
- The data taken in 1999 and 2000 is in the analysis process. Statistics will be improved.