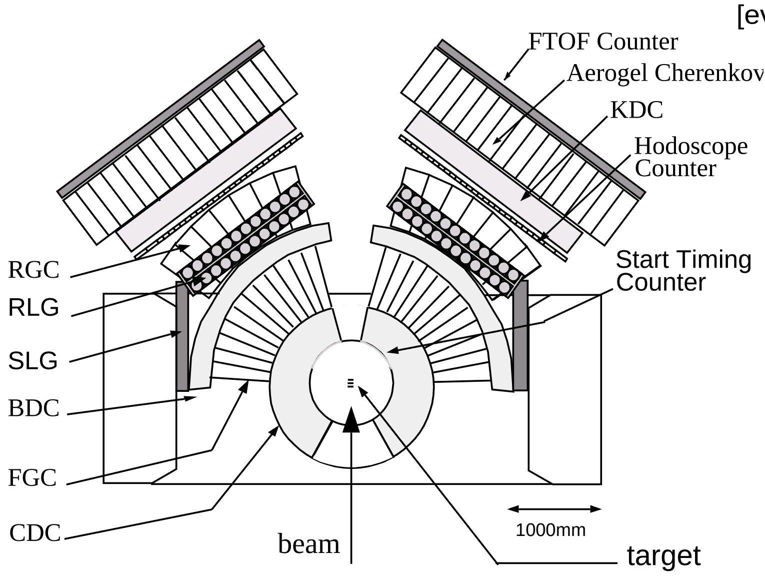
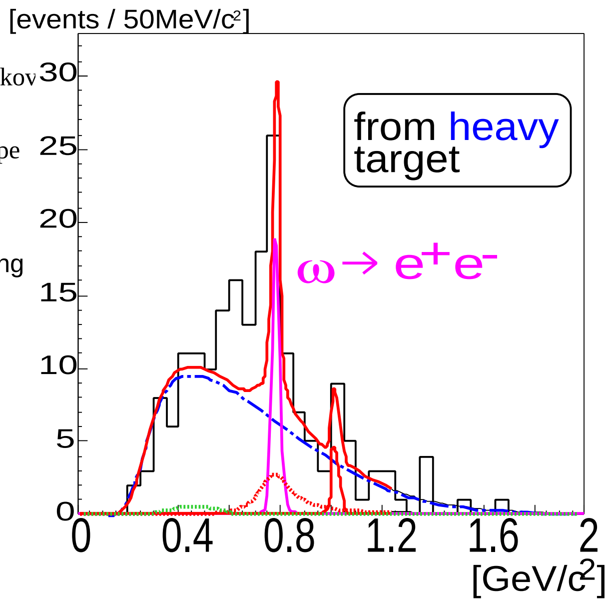
Observation of meson modification in nuclear matter at KEK–PS

S. Yokkaichi, RIKEN

for KEK–PS E325 collaboration





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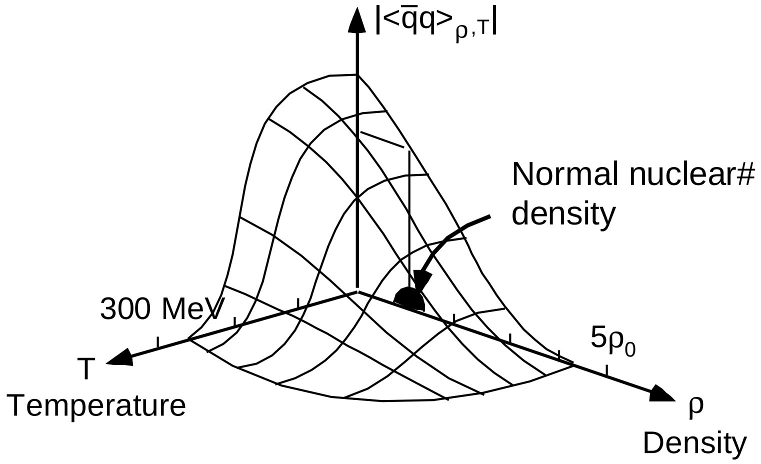
Chiral symmetry restoration

- constituent quark mass (~350MeV) ~ spontaneous braking of chiral symmetry
- quark condensation $\langle \bar{q}q \rangle$ as an order parameter of the chiral symmetry

$$\Downarrow$$

- In hot/dense matter,
  - the (partial) chiral symmetry restoration
  - $\langle \bar{q}q \rangle$ decreasing
  - <u>hadron modification is expected</u>



In dense matter

$$\frac{\langle \bar{q}q \rangle_\rho}{\langle \bar{q}q \rangle_0} = 1 - (0.34 \pm 0.05)\frac{\rho}{\rho_0}$$

(Drukarev *et al.*, 1991)

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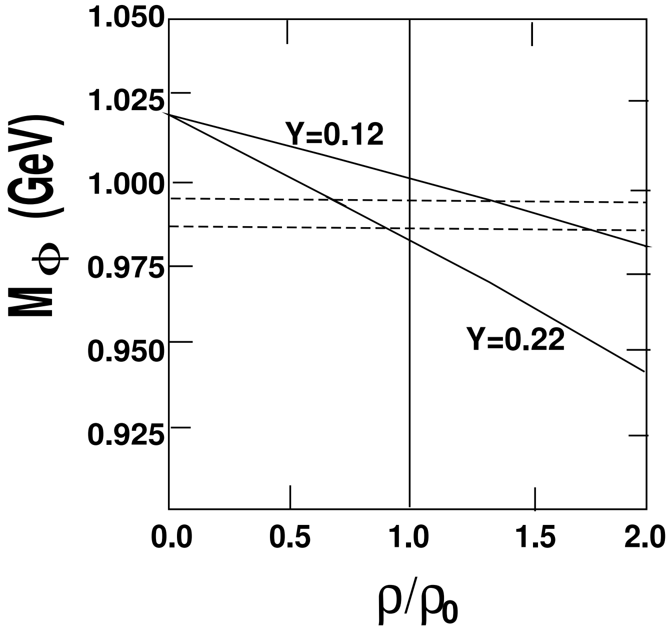
Vector meson modification in dence matter

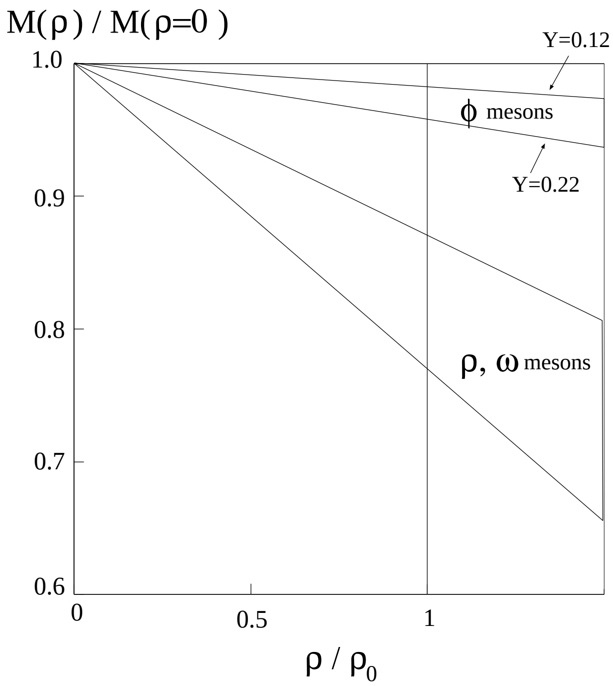
For example, (Hatsuda and Lee, 1992)

- ϕ-meson mass :

$$\frac{m_\phi^*}{m_\phi} = 1 - (0.02 \pm 0.005)\frac{\rho}{\rho_0}$$

$\sim$20MeV shift
at normal nuclear density





- ρ, ω-meson mass :

$$\frac{m_{\rho,\omega}^*}{m_{\rho,\omega}} = 1 - (0.18 \pm 0.05)\frac{\rho}{\rho_0}$$

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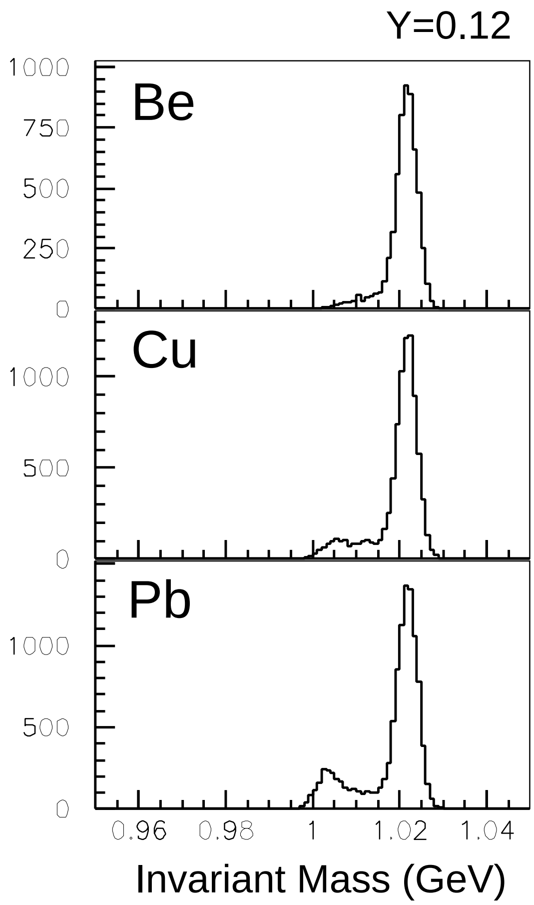
Experimental signal $\sim$ why ϕ

1. invariant mass spectra

- second peak made by ϕ's which decay in nuclei (no width-changing case)
- ee channel: less final-state interaction
- KK channel: small Q-value(=32MeV/c^2) $\Longrightarrow$ width change in nuclei could be seen?



2. branching ratio change

$\frac{br(\phi \to K^+K^-)}{br(\phi \to e^+e^-)}$ $\to$ compare with different nuclei

Cu nuclei	KK enhance case ($\Gamma \sim 10MeV$)	normal	KK suppress case ($\Gamma \sim 0MeV$)
$\beta\gamma$=1.0	126%	100%	91%

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KEK–PS E325 Collaboration

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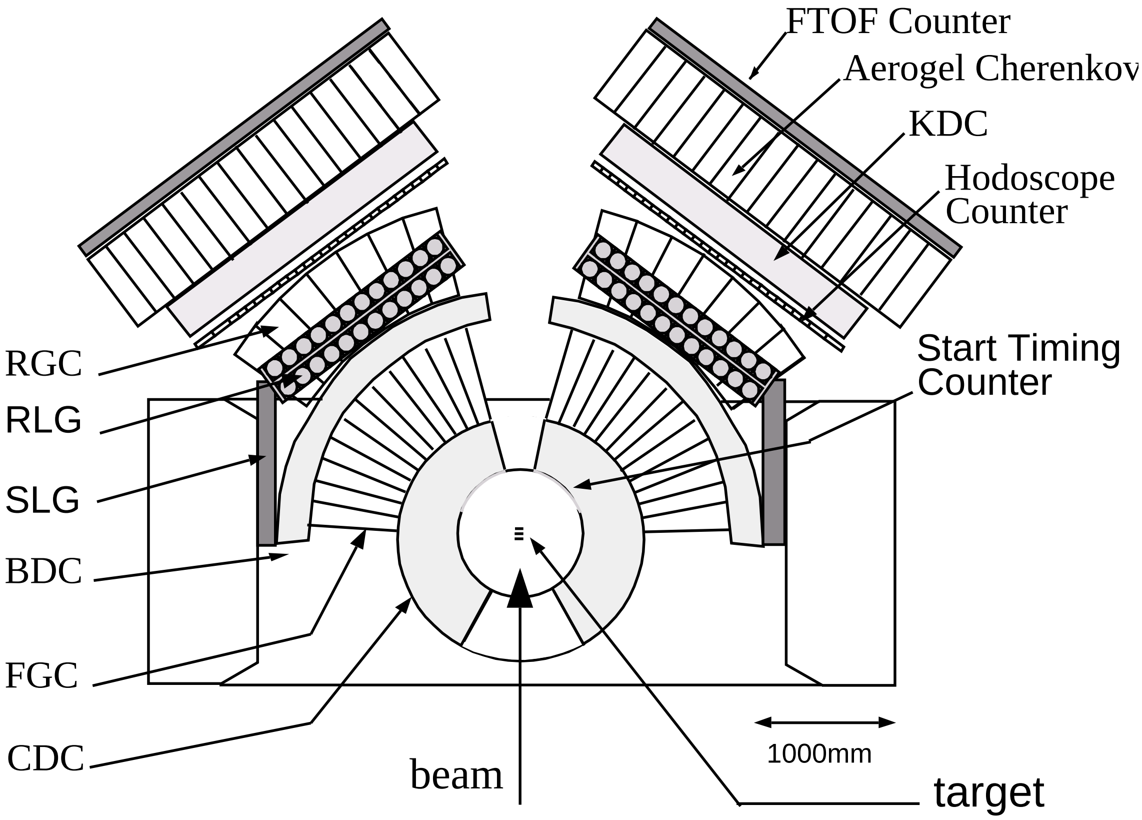
History

			(events)
1993	11	proposal	
1994	4	test experiment start	
1996	6	construction start	
1996	11	first engineering run	
1997	6	**first physics run**	K:100M
1998	4/5	**2nd physics run**	e:100M
1999	7	**3rd physics run**	K75M/e64M
2000	6/12	4th physics run	K95M/e85M
2001	*11/12*	*5th physics run*	

Experimental Setup of E325



- $\int Bdl$=0.81 Tm (r= 0 ~ 1600mm)/ 0.71T at r=0
- typ. 1×10^9Hz proton beam
- three targets in-line (0.1~0.2% int. length) (basically CH_2/C/Cu are used)

Kaon Arm

- vertical $\pm6^\circ$ horizontal $\pm12^\circ \sim \pm54^\circ$
- STC–FTOF
- AGC

Electron Arm

- vertical $\pm22^\circ$ horizontal $\pm12^\circ \sim \pm90^\circ$
- FGC
- RGC/RLG/SLG

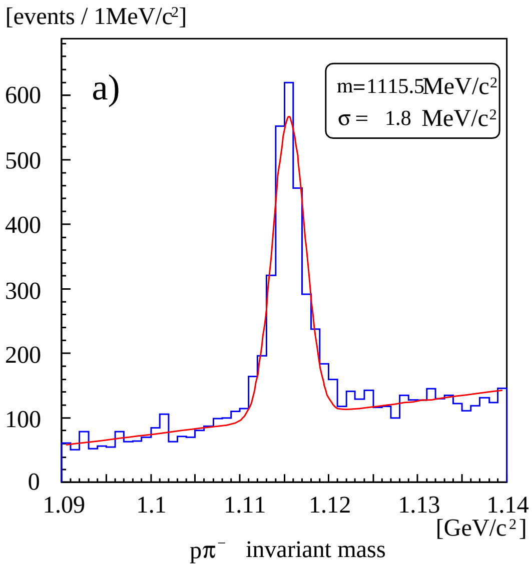
Tracking Chambers

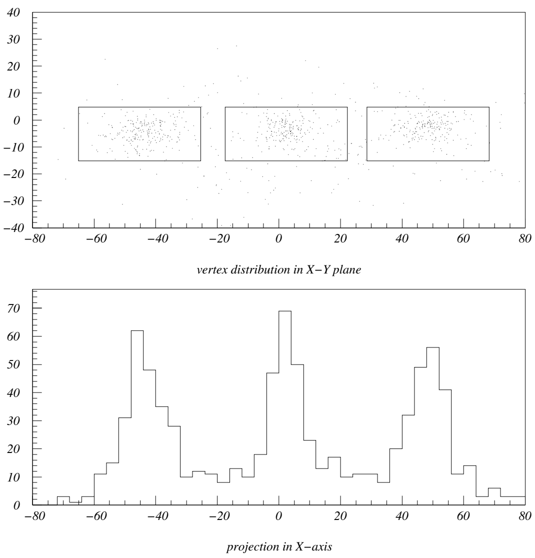
CDC/BDC

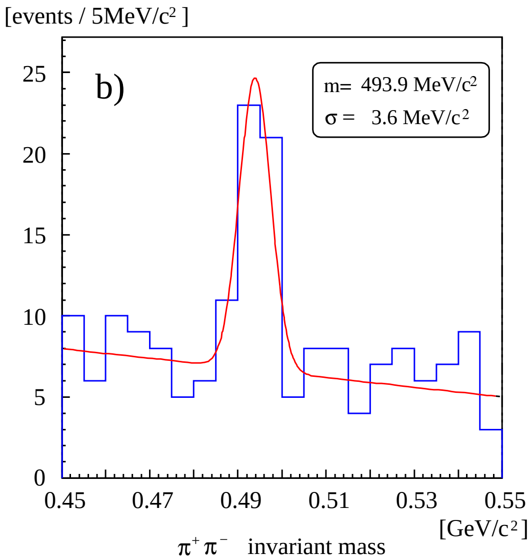
- CDC 10 layers
  (6 vertical and 4 stereo(∼0.1radian))
- BDC 4 layers
  (2 vertical and 2 stereo(∼0.1radian))
- typical position resolution $\sim 300\mu$m

mass resolution of the spectrometer

	σ
Λ	1.8MeV/c^2
K_s	3.6MeV/c^2
$\phi \to K^+K^-$	2.4MeV/c^2
$\omega \to e^+e^-$	9.6MeV/c^2
$\phi \to e^+e^-$	12.0MeV/c^2







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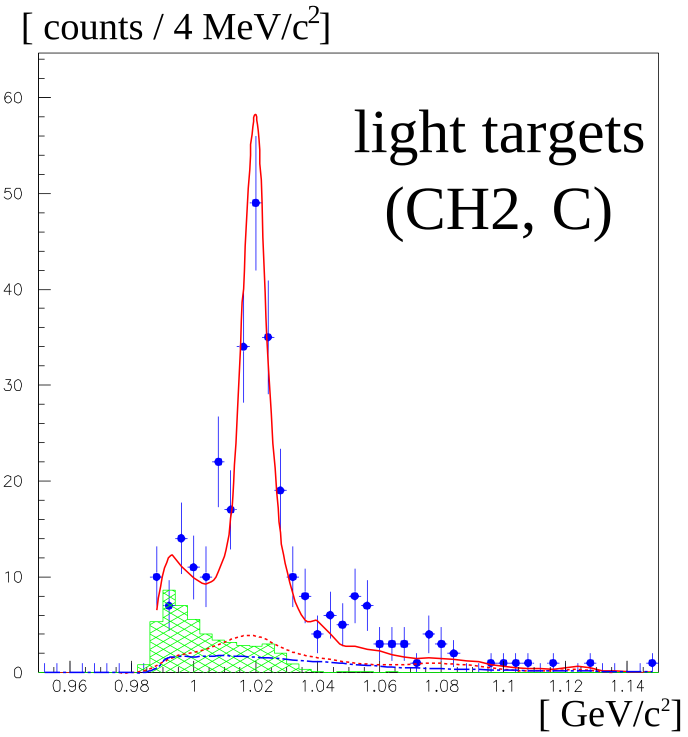
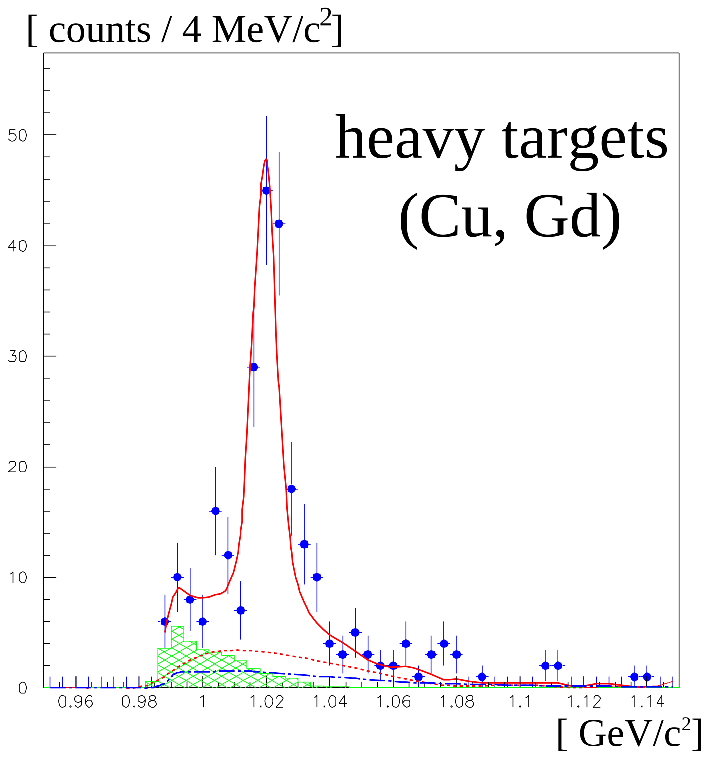
K^+K^- invariant mass spectra('99)

(M. Ishino et.al., PRL in prep.)





fit funciton is

$$N_1 f_1(\phi) + N_2 f_2(a_0/f_0) + N_3 f_3(non-resonant) + N_4 f_4(missID)$$

where

function shapes are determined as:

f_1,f_2,f_3 : JAM simulation

f_4 : event mixing

parameters are

N_3/N_1 by JAM

$N_4/(N_1+N_2+N_3+N_4)$ by expelimentally

then, N_1/N_2 and overall normarization are two free parameters of the fit

well reproduced for both case.

$\Rightarrow$ no significant mass modification.

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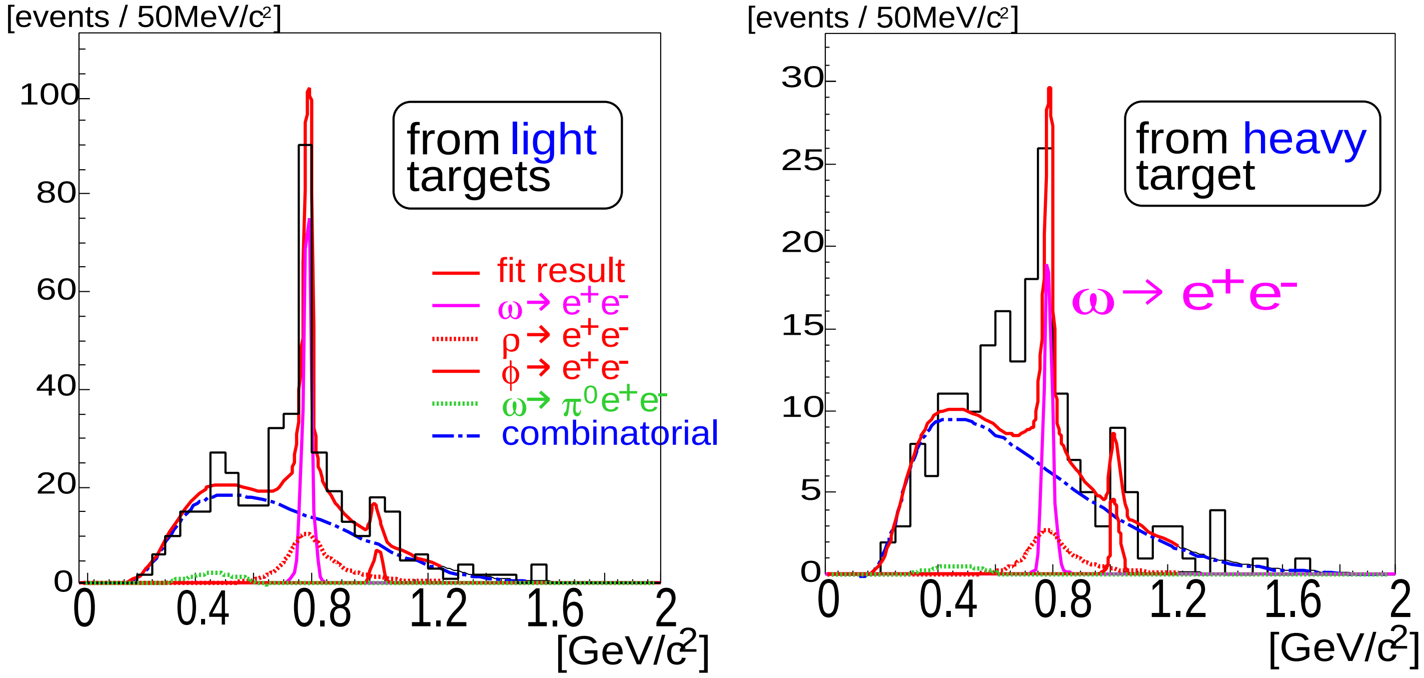
e^+e^- invariant mass spectra ('98)

(K. Ozawa et.al., PRL 86(2001)5019)



low mass region is suppressed due to the detector acceptance

fit funciton:

$$N_1 f_1(\phi \to e^+e^-) + N_2 f_2(\rho \to e^+e^-) + N_3 f_3(\omega \to e^+e^-)$$
$$+ N_4 f_4(\omega \to \pi^0 e^+e^-) + N_5 f_5(\eta \to e^+e^-\gamma)$$
$$+ N_6 f_6(\text{combinatorial})$$

where

function shapes are determined as:

f_1, f_2, f_3 : Breit-Wigner

f_4, f_5 :from the literature

f_6 : event mixing

4 free parameters.

N_1, N_3, N_5 and N_6

significant excess is seen for heavy(Cu) target

(550 MeV/c^2 $\sim$ 750 MeV/c^2)

	N_ϕ	N_ω	N_{excess}	N_{excess}/N_ω
light	7.4± 5.8	75.5± 9.6	19.6± 11.7	0.26± 0.16
heavy	5.2± 2.7	20.0± 4.8	29.5± 8.7	1.48± 0.56

$\Rightarrow$ meson mass modification is observed.

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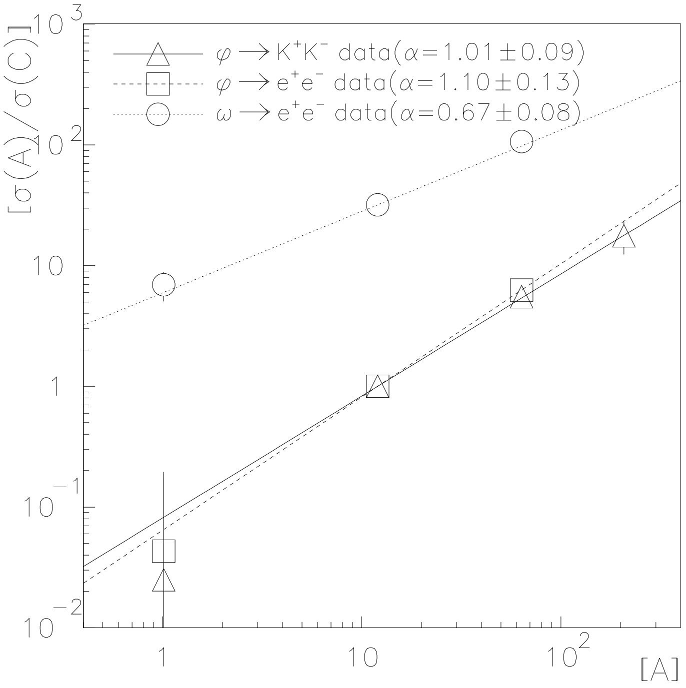
Mass Number dependence (α) of production cross section

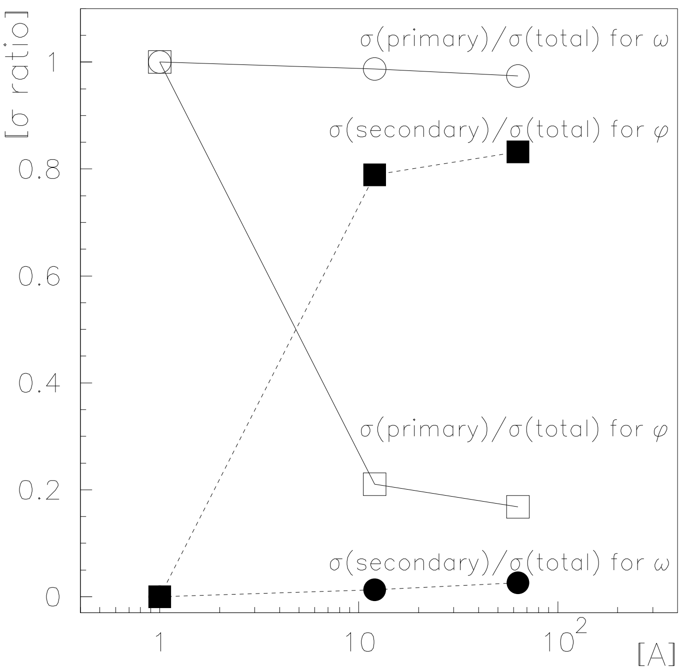
$$(\sigma(A) = \sigma(1) \times A^{\alpha})$$



from '99 data

- $\phi \to K^+K^-$:
  $\alpha = 1.01 \pm 0.09$
- $\phi \to e^+e^-$:
  $\alpha = 1.10 \pm 0.13$
  (preliminary)
- $\omega \to e^+e^-$:
  $\alpha = 0.67 \pm 0.08$
  (preliminary)

... indecates the production mechanisim of mesons in 12GeV p+A interaction



...are dominated by

- ω: primary fragmentation
- ϕ : secondary collisions

in JAM simulation

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Summary

Experiment KEK–PS E325

- explore the chiral symmetry restoration in normal nuclear density in 12-GeV p+A interaction
- measure $\rho/\omega \to e^+e^-$, $\phi \to e^+e^-$ and $\phi \to K^+K^-$

Results from '97-'99 data

- Invariant mass spectra are examined.
  K^+K^-: well reproduced with known sources.
  e^+e^- : significant excess is found below ω.

  $\Rightarrow$ meson mass modification is observed.

- Target mass number dependence of production cross section of ω/ϕ are also measured.

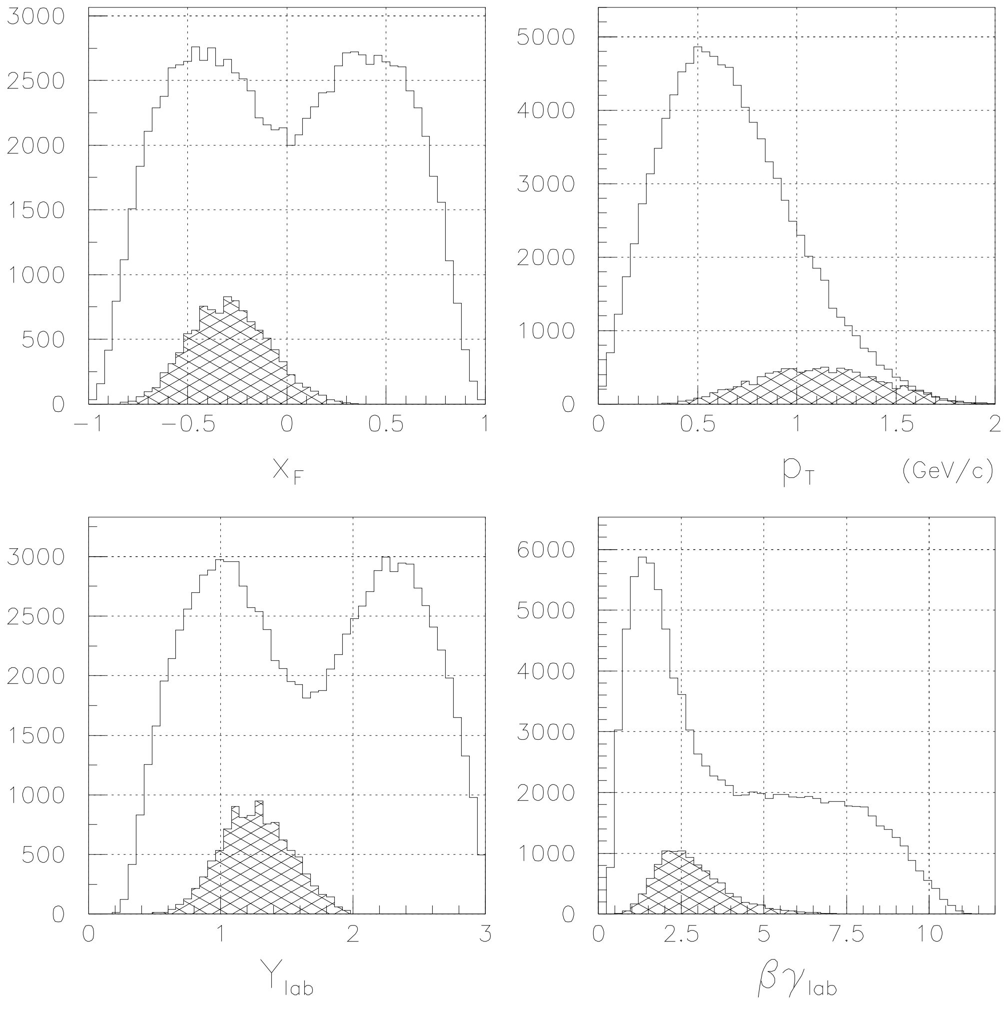
	K^+K^-	e^+e^-(preliminary)	simulation(JAM)
ω	–	0.67 ± 0.08	*0.78*
ϕ	1.01 ± 0.09	1.10 ± 0.13	*1.11*

$\Rightarrow$ ϕ's are produced in the secondary collisions in p+A interaction.

Further statistics will be available in the end of 2001.

Acceptance of the spectrometer

assumed ϕ meson production
(11.75 GeV/c pp$\rightarrow$ppϕ(Arenton *et al.*,1982))



hatched area is acceptance for KK channel,
after multiplied by factor 25

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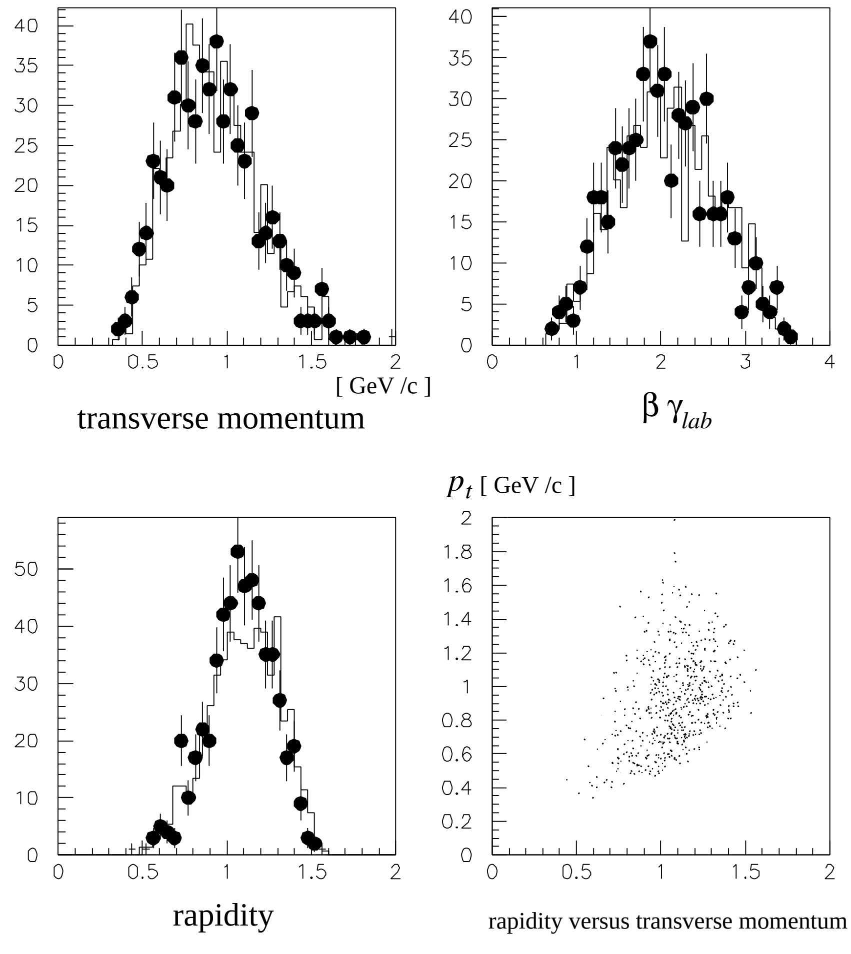
Kinematics for detected $\phi \to K^+K^-$

for all targets.

P_T $\beta\gamma$

rapidity(y) P_T VS y

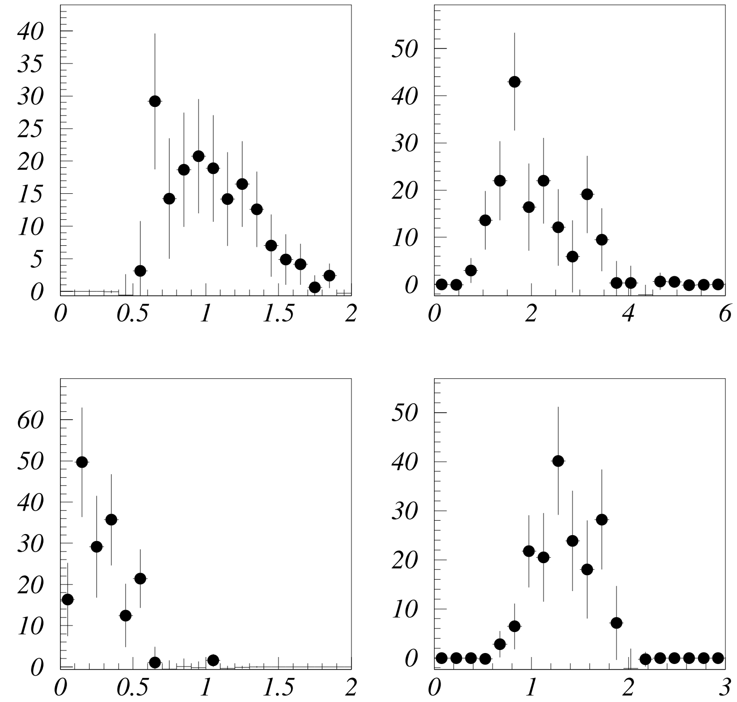


Kinematics for detected $\omega \rightarrow e^{+}e^{-}$

for light(C/CH_2) targets.

opening $\beta\gamma$

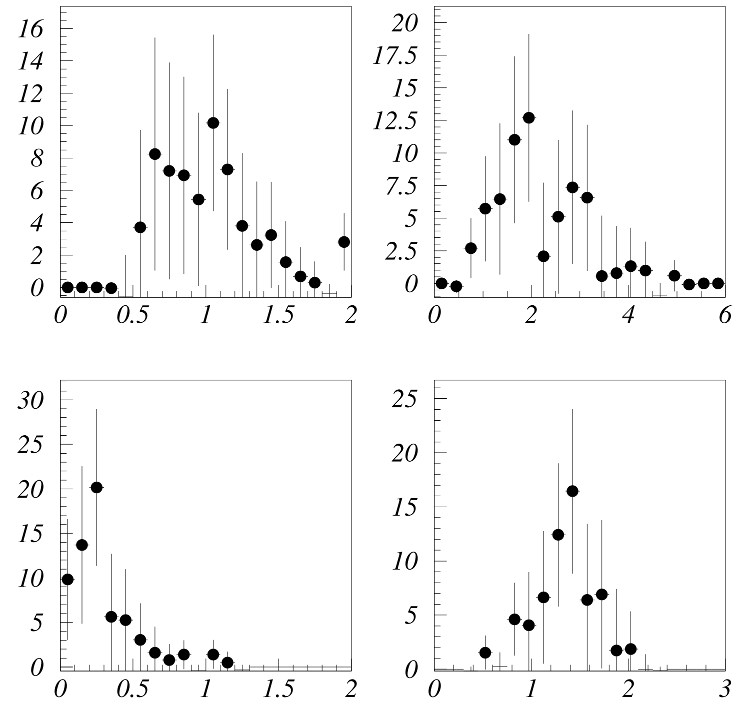
P_T rapidity



for heavy(Cu) target

opening $\beta\gamma$

P_T rapidity



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