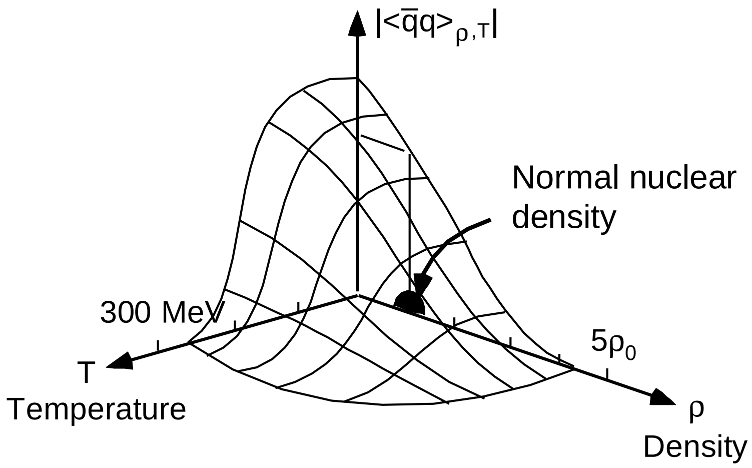
Chiral symmetry restoration

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

$$\Downarrow$$

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



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)

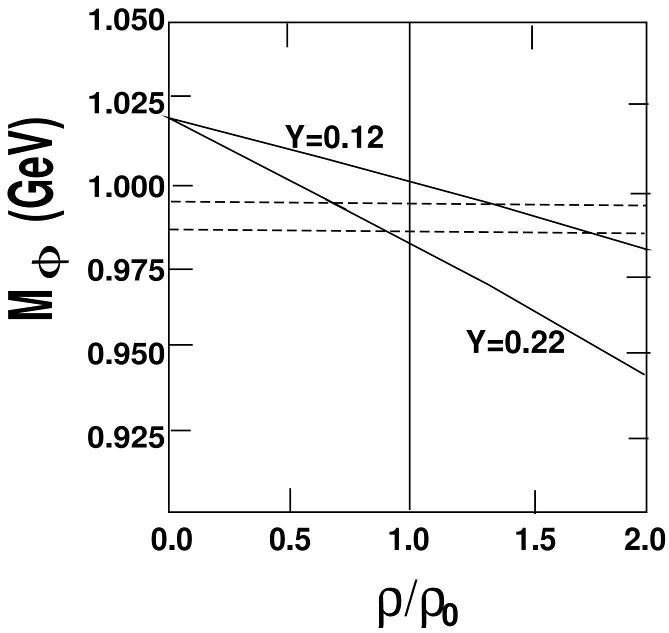
Vector meson modification in dence matter

For example, (Hatsuda and Lee, 1992)

- ϕ-meson mass :

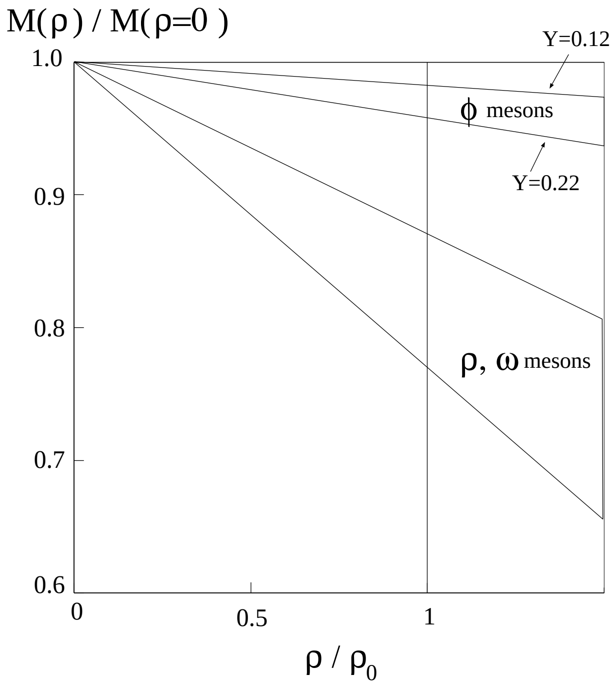
$$\frac{m_\phi^*}{m_\phi} = 1 - (0.02 \pm 0.005)\frac{\rho}{\rho_0}$$

$\sim$20MeV shift
at normal nuclear density



- ρ, ω-meson mass :

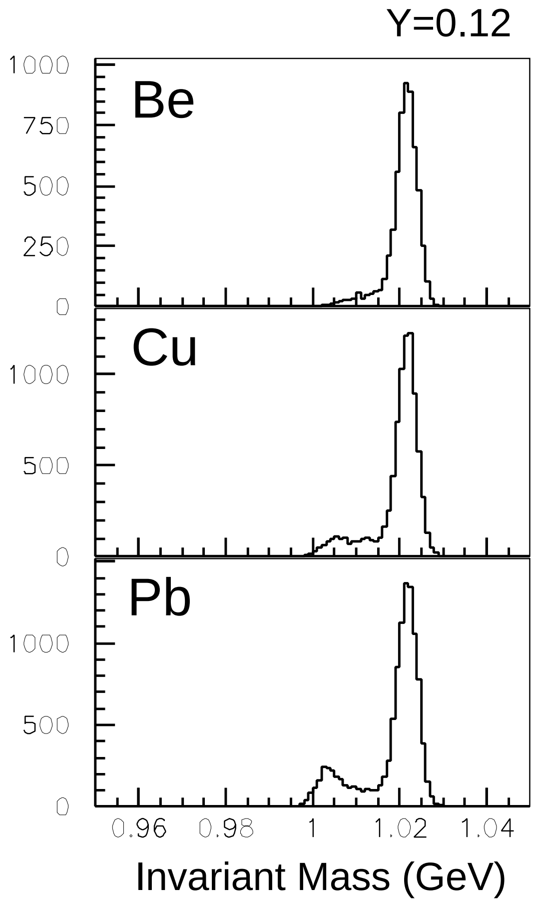
$$\frac{m_{\rho,\omega}^*}{m_{\rho,\omega}} = 1 - (0.18 \pm 0.05)\frac{\rho}{\rho_0}$$



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($=32\text{MeV}/c^2$) $\Longrightarrow$ width change in nuclei could be seen easier



2. branching ratio change

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

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

KEK–PS E325 Collaboration

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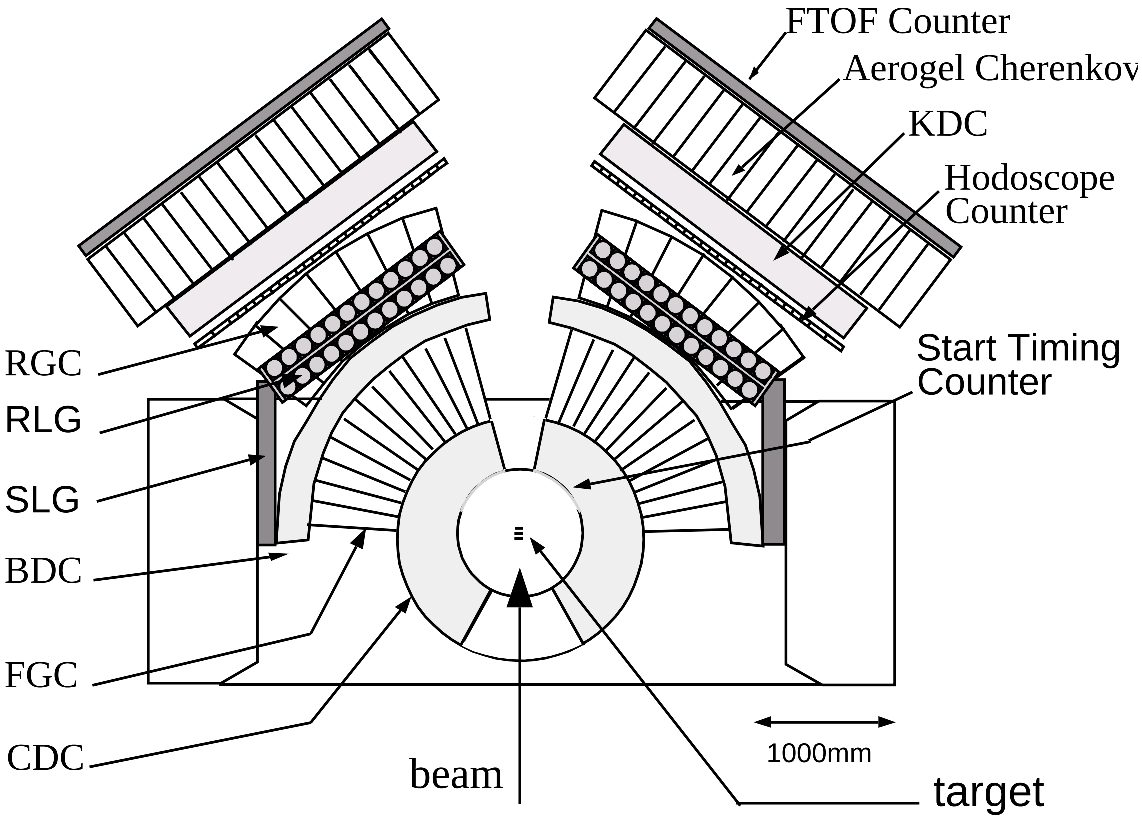
History

			(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
		ρ/ω modification observed	
		$\rightarrow$published in PRL 86(2001)5019(K. Ozawa *et al.*)	
1999	7	**3rd physics run**	K75M/**e64M**
		presented data	
2000	6/12	4th physics run	K95M/e85M
2001	11/12	5th physics run	
2002	2/3	last physics run	K150M/e400M

$\rightarrow$more 1000 of ϕ and 10000 of ω are expected

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 ±6° horizontal ±12° ~ ±54°
- STC–FTOF
- AGC

Electron Arm

- vertical ±22° horizontal ±12° ~ ±90°
- FGC
- RGC/RLG/SLG

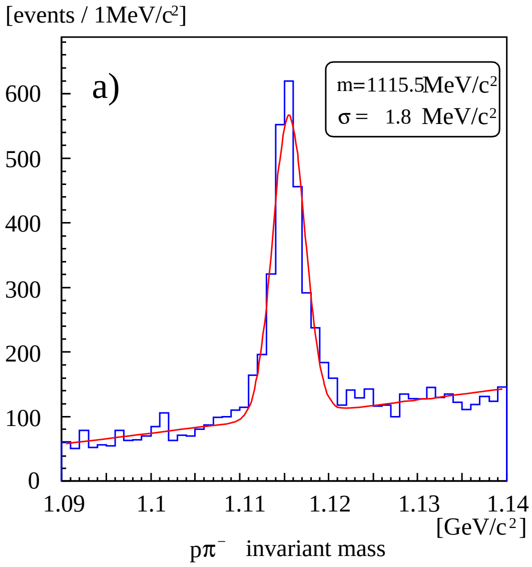
Tracking Chambers

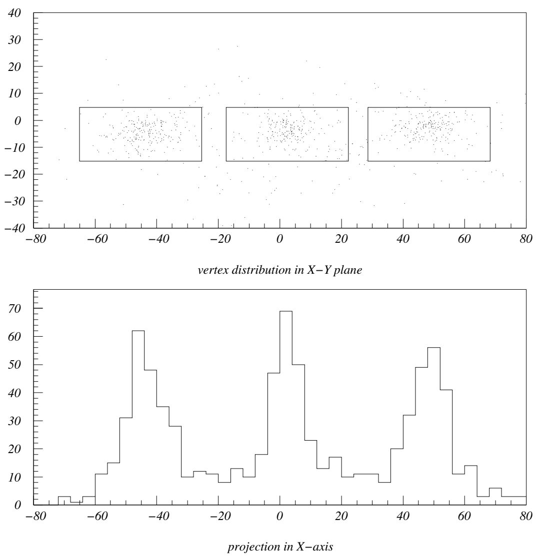
CDC/BDC

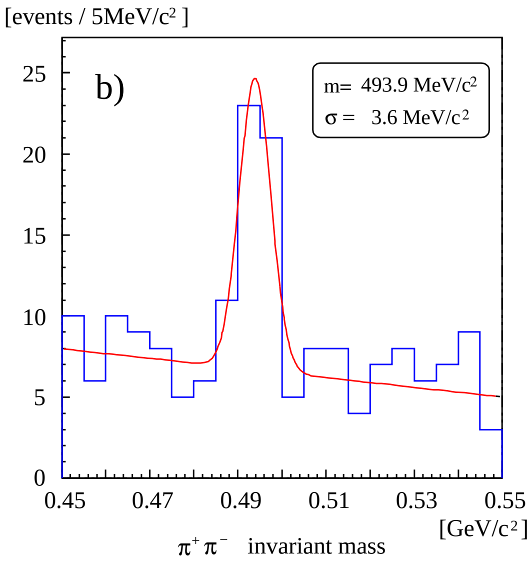
- CDC 10 layers
  (6 vertical and 4 stereo(∼0.1radian))
- BDC 4 layers
  (2 vertical and 2 stereo(∼0.1radian))
- typical position resolution $\sim 300\mu$m

mass resolution of the spectrometer

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

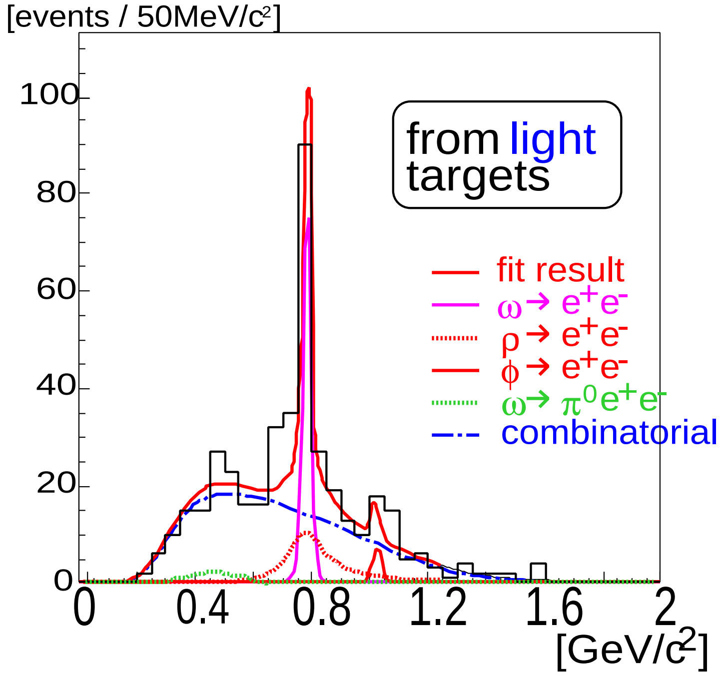


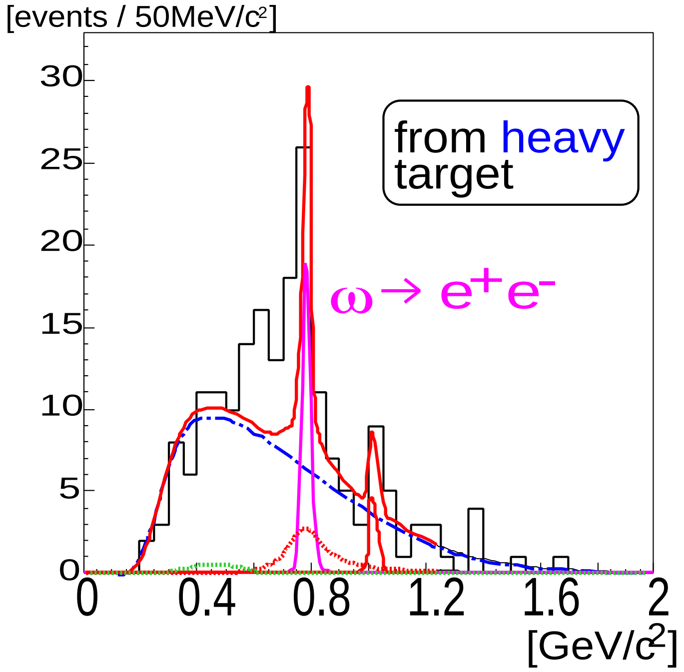




e^+e^- invariant mass spectra('98)

(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 ~ 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.

e^+e^- analysis status

For '99 data,

- Statistics: $\sim$ five times as much as '98 data

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

- Uncertainty of background 'shape' estimation

- However, 'excess' is again confirmed for Cu target.

- C target shows also a hint of 'excess', but weaker than Cu.

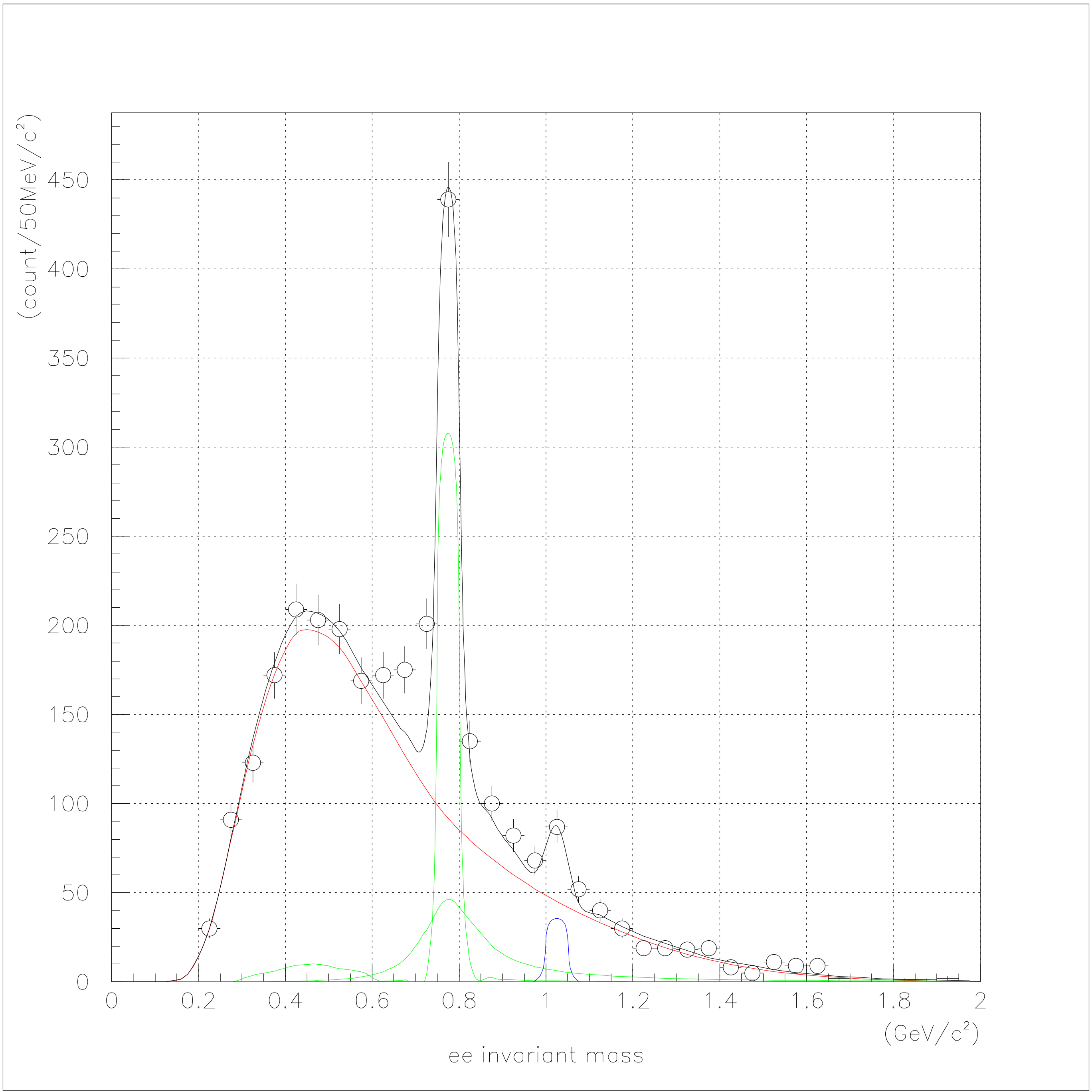
- We also have a clue of ϕ mass shift....

For 2000-2002 data,

- We have more $5 \sim 10$ times of statistics to be analyzed.

e^+e^- invariant mass ('99/preliminary)

C target



e^+e^- invariant mass ('99/preliminary)

Cu target