Mass modification of phi meson measured in 12-GeV p+A reaction at KEK-PS E325

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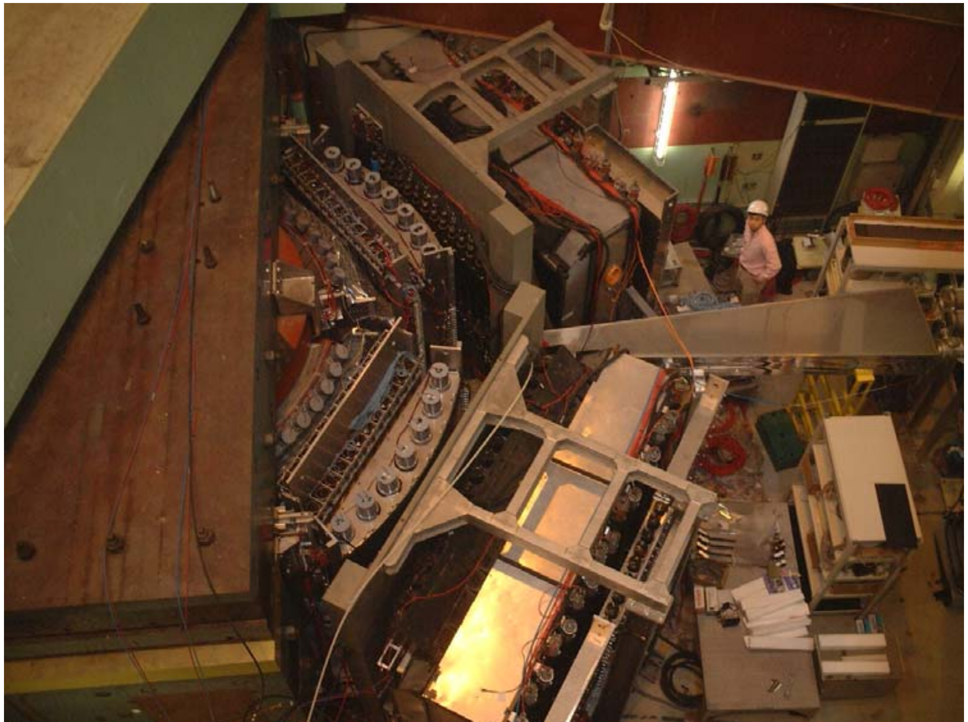


- **Physics motivation**
- **E325 Setup**
- **Data analysis**
- **Summary**

Physics Motivation

Quark Mass

chiral symmetry restoration

bare mass
$m_u \fallingdotseq m_d \fallingdotseq 5\,\mathrm{MeV}/c^2$
$m_s \fallingdotseq 150\,\mathrm{MeV}/c^2$

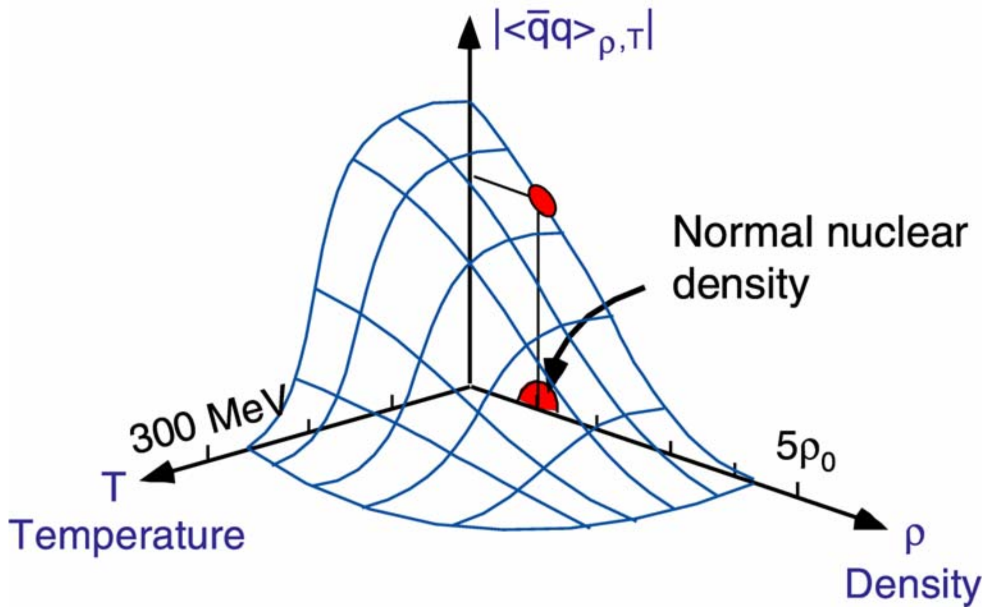
effective mass in QCD vacuum
$m_u \fallingdotseq m_d \fallingdotseq 300\,\mathrm{MeV}/c^2$
$m_s \fallingdotseq 500\,\mathrm{MeV}/c^2$

chiral symmetry braking

How we can detect such a quark mass change?

Partial chiral symmetry restoration under normal nuclear density

Vector Meson



Vector Meson

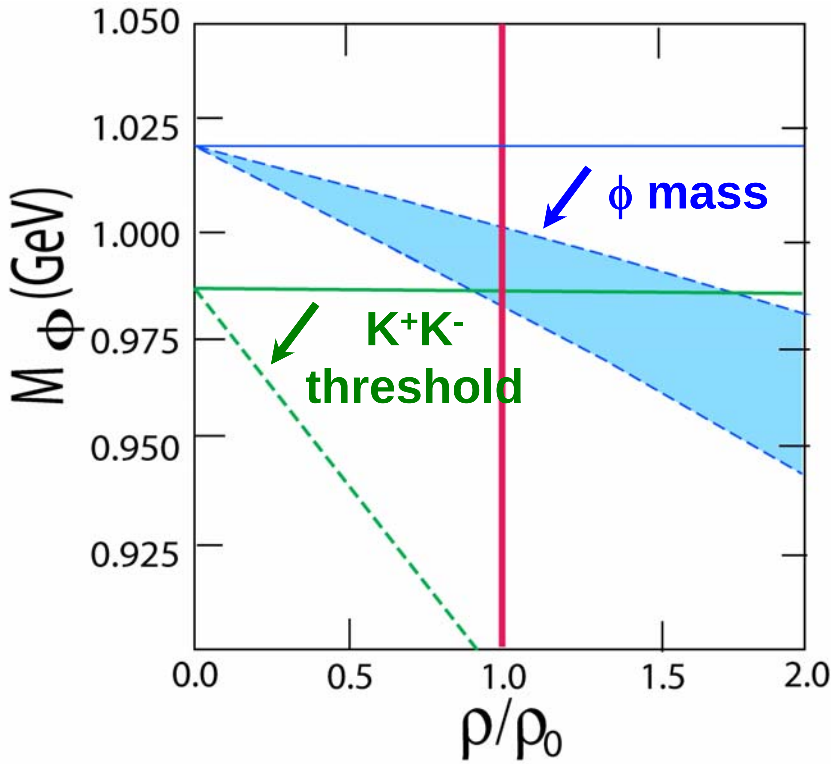
ϕ meson

- ●mass decreases
  ~20-40MeV/c²
- ●narrow decay width (Γ=4.3MeV/c^2)
  ⇒sensitive to the mass spectrum change
- ●small decay Q value (Q_{K+K-}=32MeV/c^2)
  ⇒the branching ratio is sensitive to ϕ (or K) meson modification

For example

■ϕ mass decreases
→ Γ_{K+K-} becomes small
■K mass decreases
→ Γ_{K+K-} becomes large

predictions of vector meson modification in medium
Brown,Rho(1991), Hatsuda,Lee(1992), Klingle,Keiser,Weise(1997),etc.



ρ_0:normal nuclear density

ϕ : *T.Hatsuda, S.H.Lee, Phys. Rev.* ***C46*** *(1992)R34.*

K : *H.Fujii, T.Tatsumi, PTPS* ***120*** *(1995)289.*

Important points for ϕ meson modification
① Invariant mass spectrum, with good mass resolution
② Nuclear size dependence of the branching ratio between the e^+e^- and K^+K^- channels

KEK-PS E325

Measurements

Invariant Mass of e^+e^-, K^+K^-

in 12GeV p+A→ρ,ω,ϕ+X reactions

slowly moving vector mesons (p_{lab}~2GeV/c)

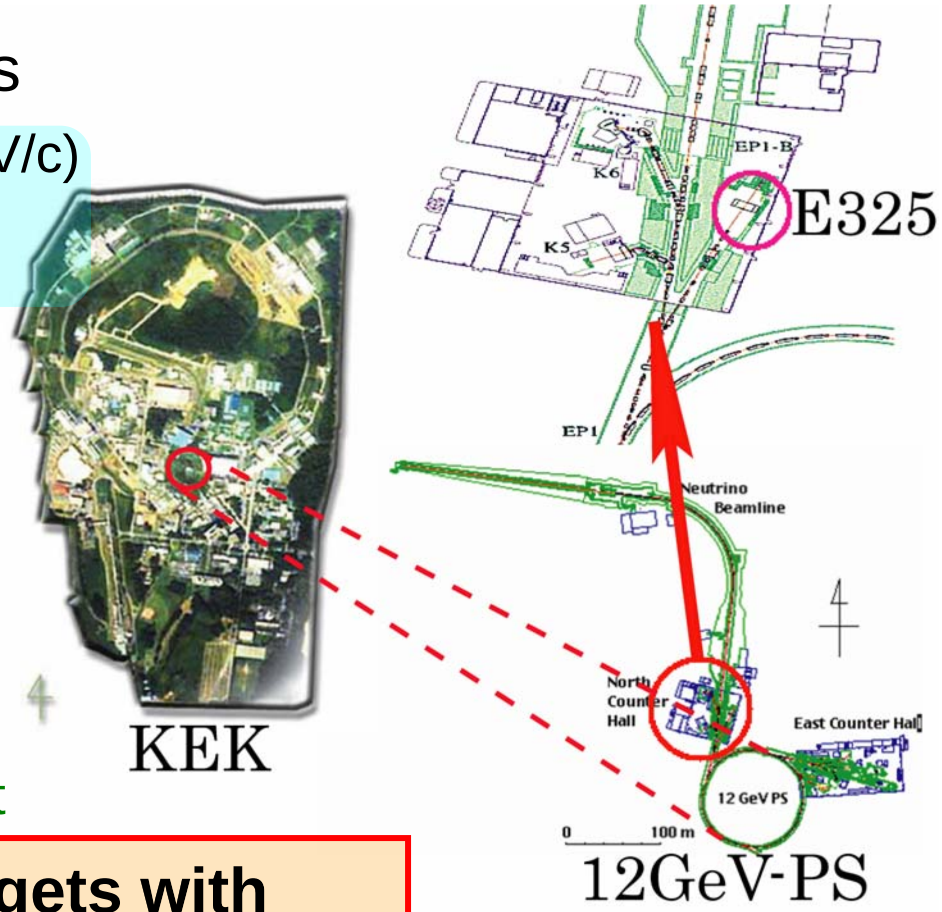
large probability
to decay inside a nucleus

Beam

Primary proton beam
(~10^9/spill/1.8s)

Target

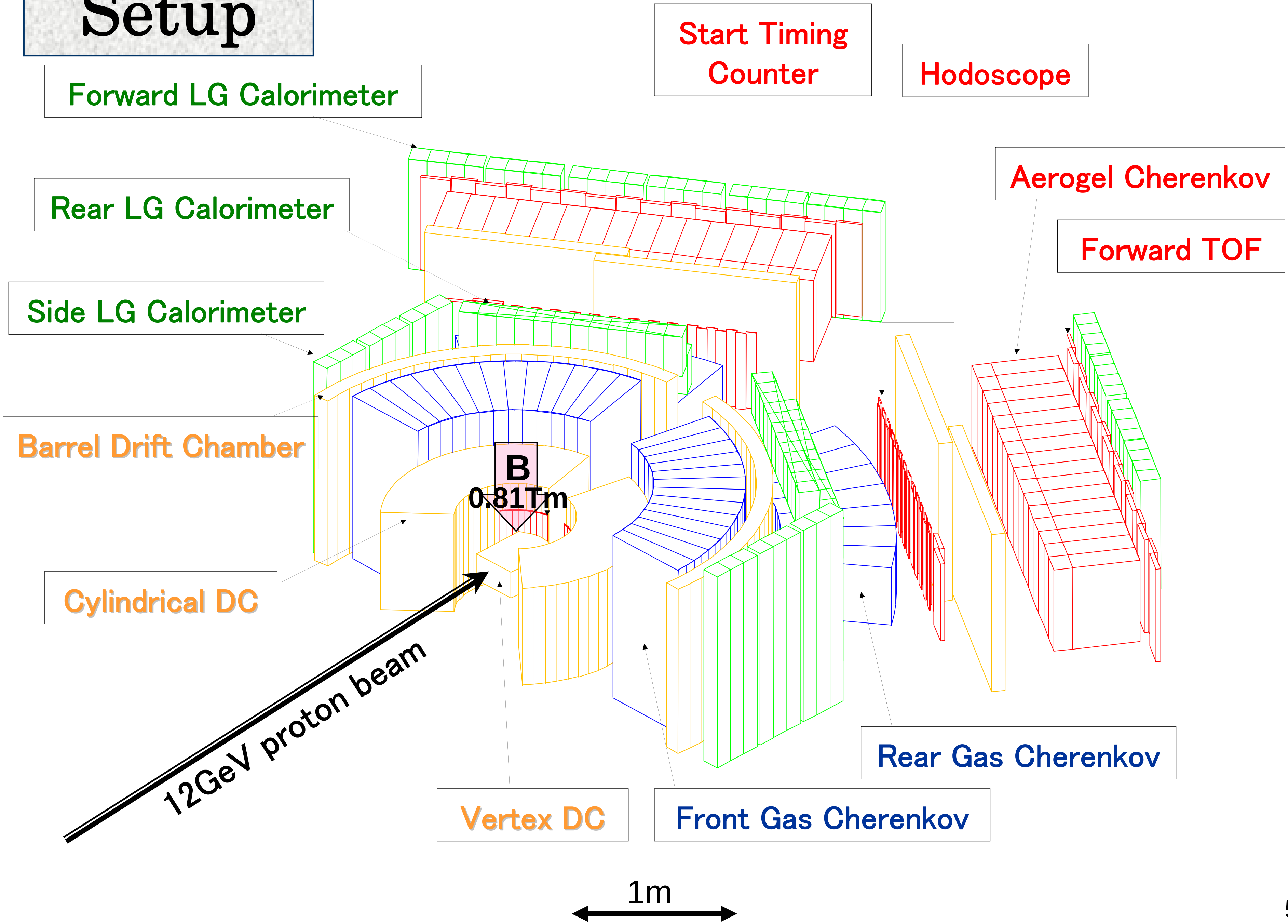
Very thin targets
e.g. 0.4% radiation length &
0.2% interaction length for C-target



A combination of very thin targets with high intensity beam is very important to reduce the background from γ conversion.

Setup

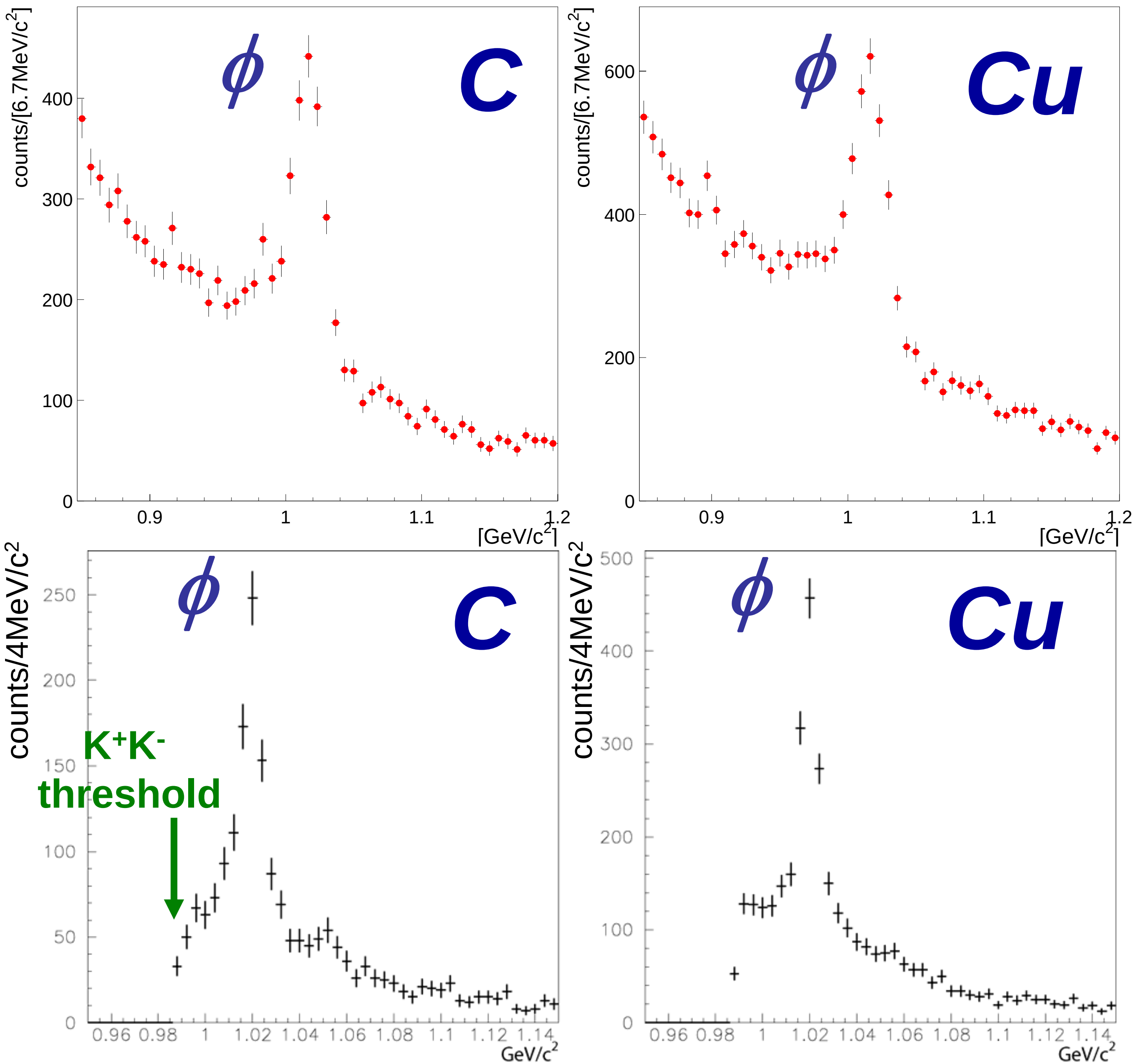
M. Sekimoto *et al.*, Nucl. Inst. Meth. A516 (2004) 390.



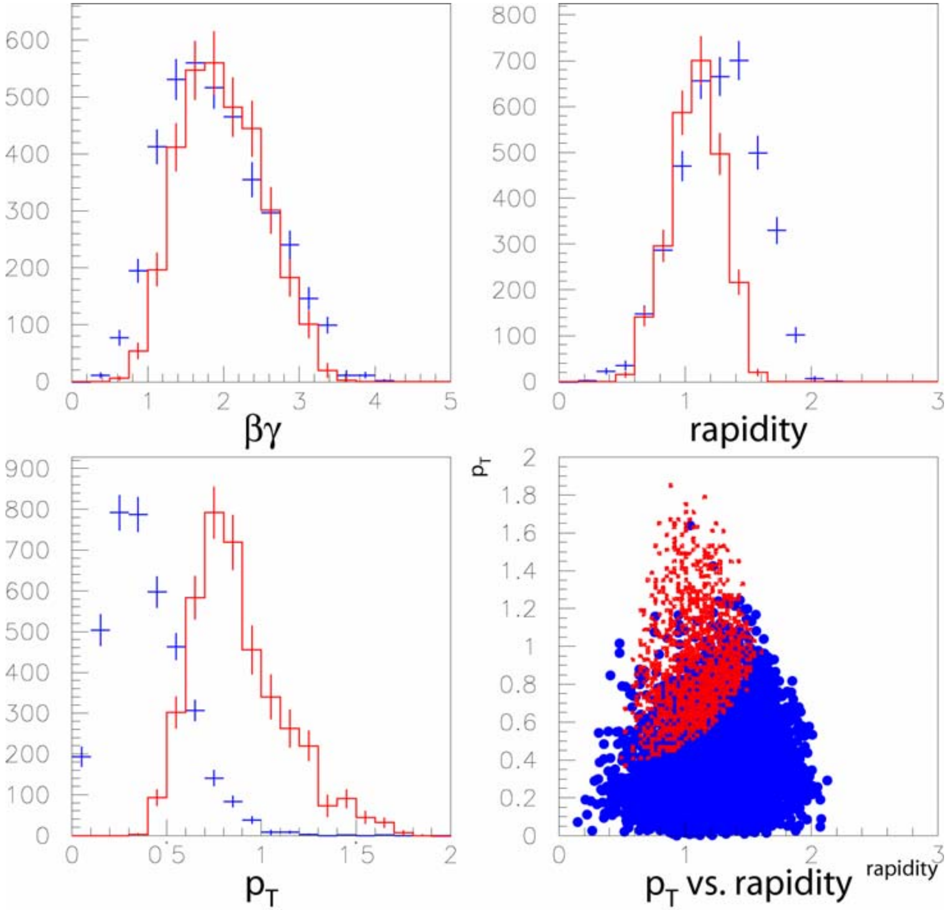
Mass Spectra

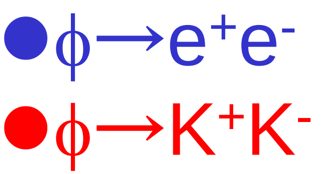
e^+e^-

K^+K^-



Kinematical Distributions for observed ϕ





The detector acceptance is different between e+e- and K^+K^-
→ But there is an overlap region

Slowly moving ϕ meson should have larger probability to decay inside a nucleus

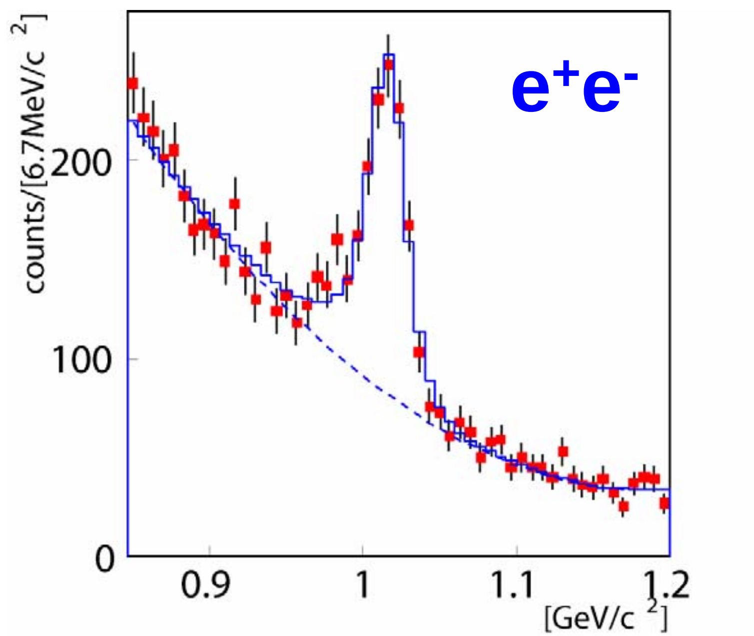
Fitting Methods

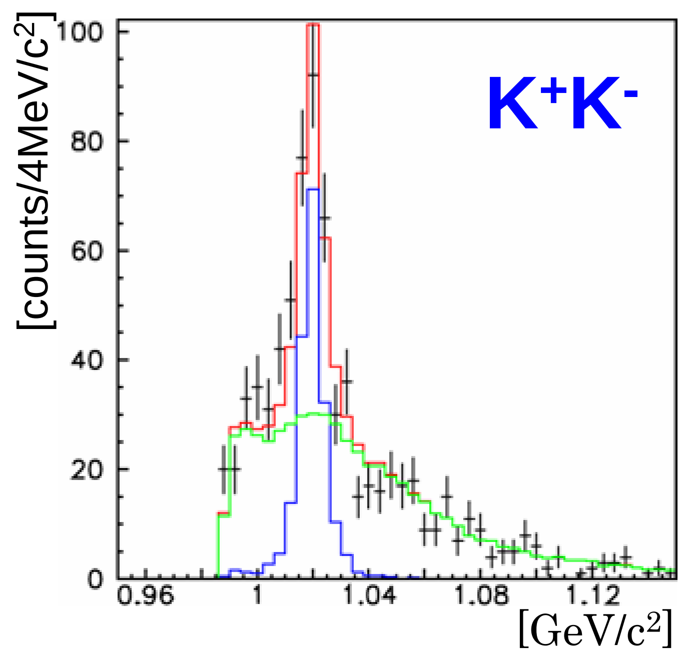
- **Background** : quadratic curve (e^+e^-)
  mixed event method (K^+K^-)
- **ϕ Shape** : Breit-Wigner distribution

smeared by taking the experimental effects into account using Geant4 simulation

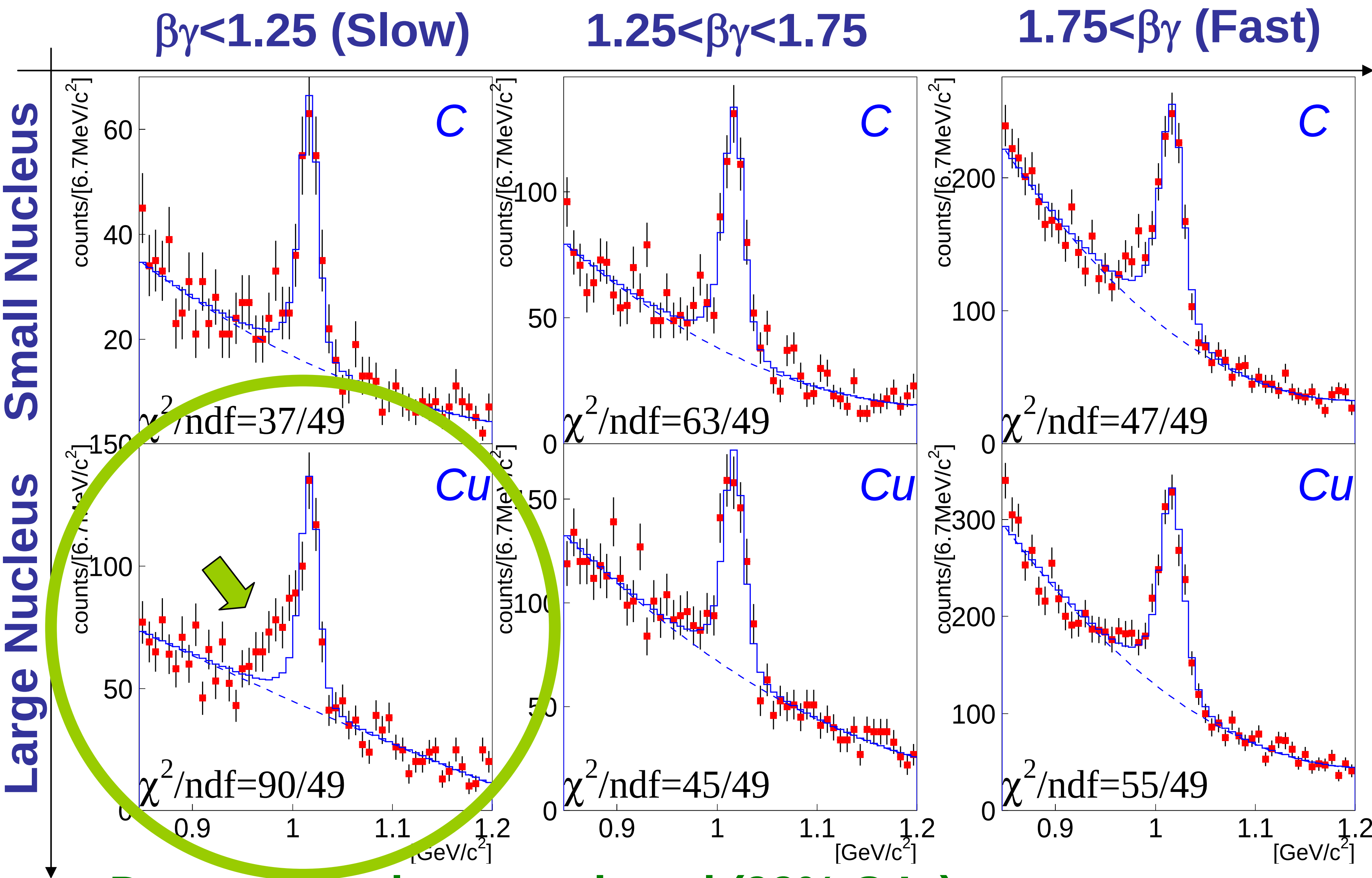
– physical processes and detector effects

- **Examine the mass shape as a function of $\beta\gamma$** →Next





Fit Results for e^+e^- (divided by $\beta\gamma$)



Data cannot be reproduced (99% C.L.)

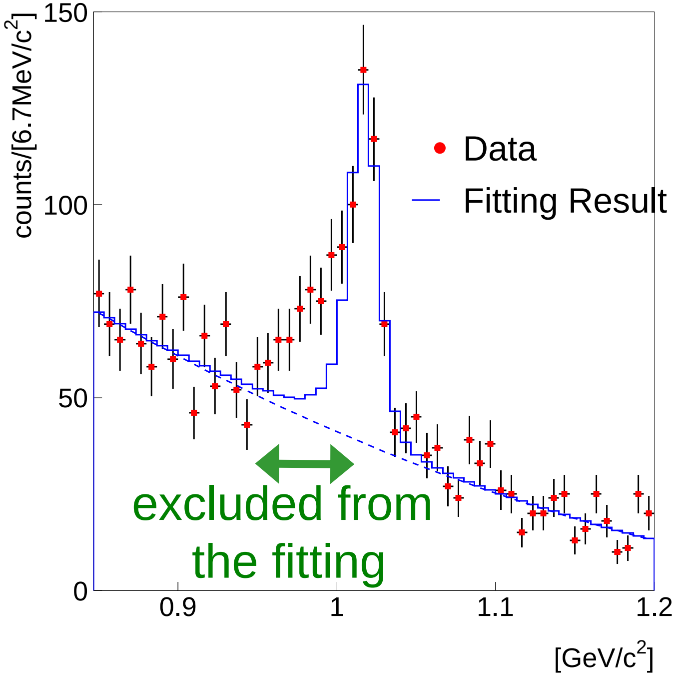
Mass Shape for e^+e^-

A significant enhancement is seen in the Cu data, in $\beta\gamma<1.25$

➢the excess is attributed to the ϕ mesons which decay inside the nucleus and are modified

To evaluate
the amount of the excess

I. Fit the spectra again by excluding the excess region, 0.95~1.01GeV/c^2
II. Integrate the spectra in the excess region
III. Subtract the background and the normal phi meson shape which are determined by the fit

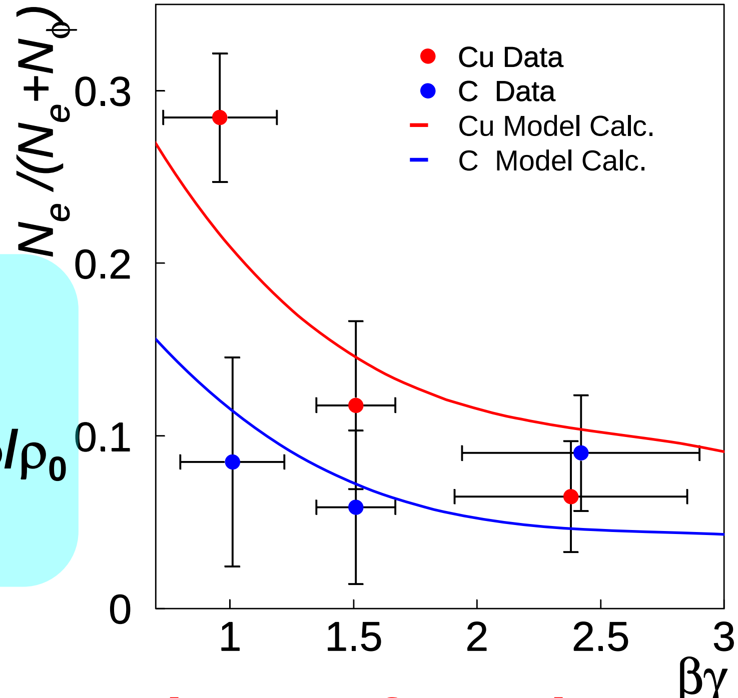


Model Calc.

$$m^*/m = 1 - k_1\,\rho/\rho_0$$

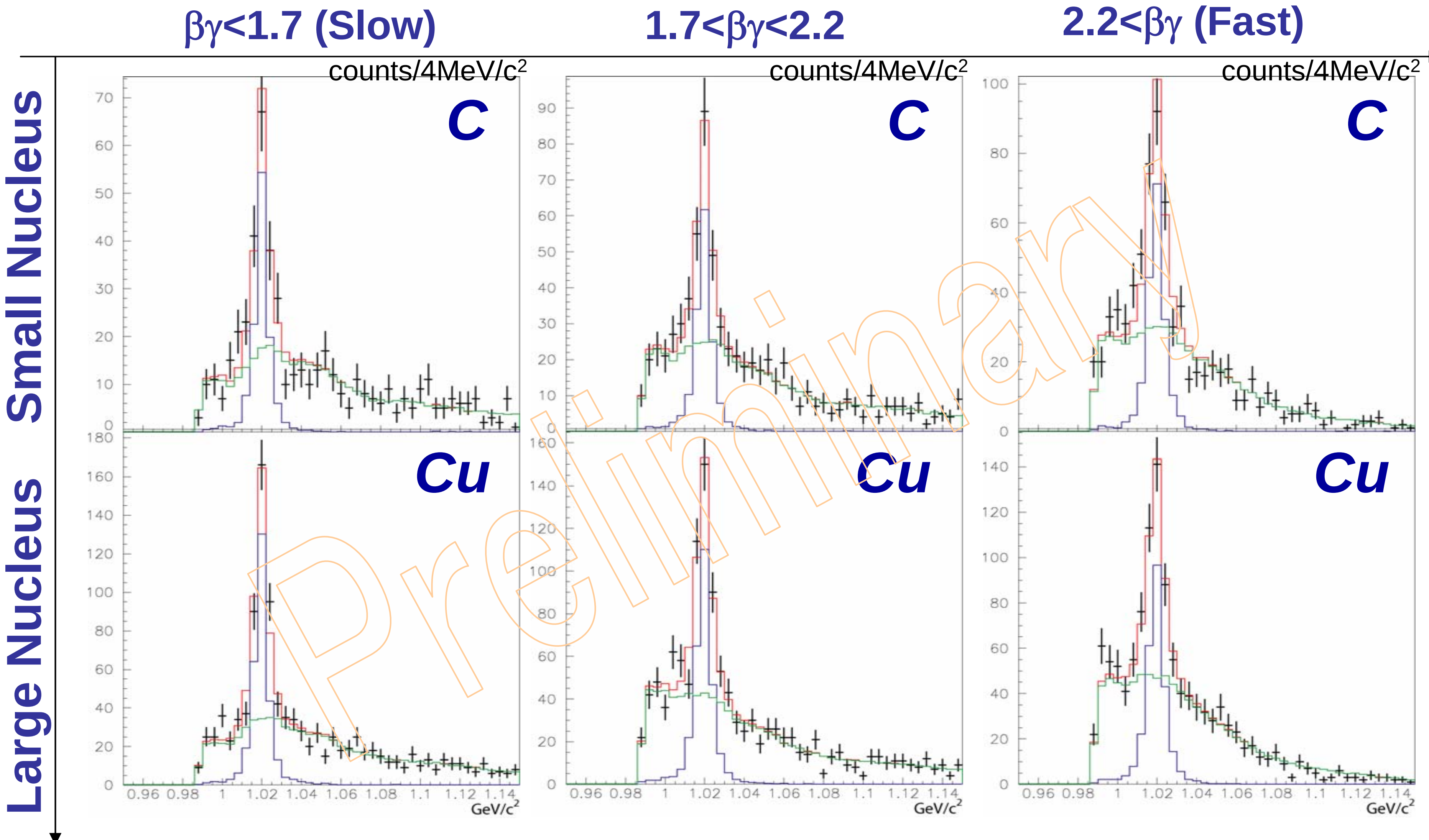
$$\Gamma_{ee}^*/\Gamma_{ee} = 1 + k_2\,\rho/\rho_0$$

$$k_1 = 0.04,\ k_2 = 10$$



The model calculation reproduces the tendency of our data

Fit Results for K^+K^- (divided by βγ)



Mass spectrum changes are NOT statistically significant

- the statistics in the K^+K^- mode is much less than those in the e^+e^- mode
- K^+K^- data is extremely limited in βγ<1.25

$\Gamma_{K+K-}/\Gamma_{e+e-}$ and Nuclear Size Dependence α

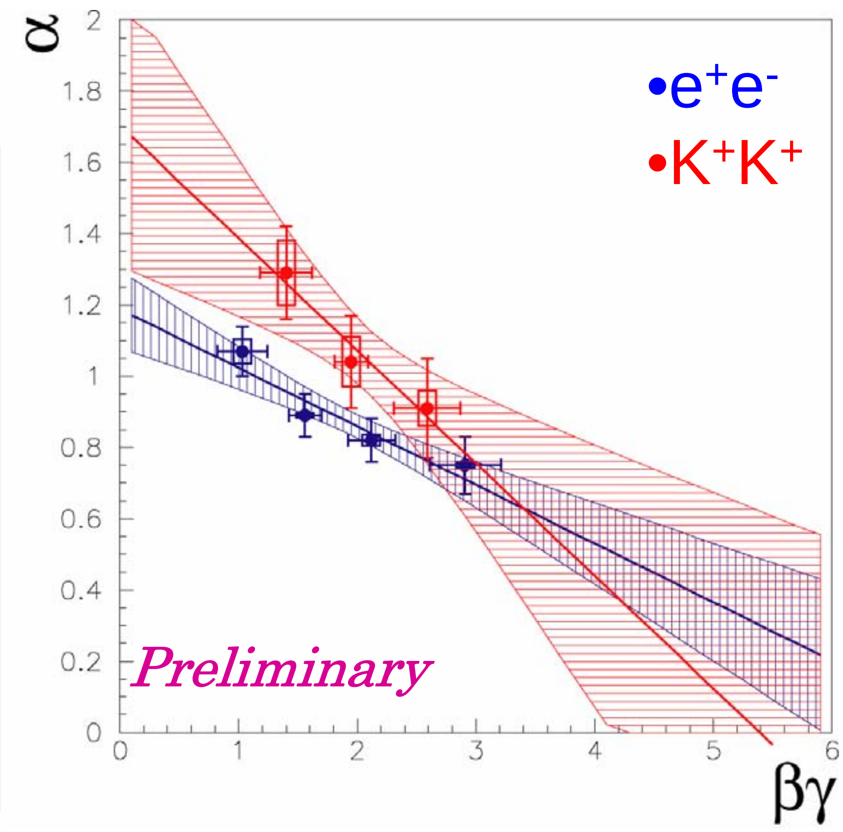
$$\sigma(A) = \sigma(A=1) \times A^{\alpha}$$

example of α change

- $\Gamma_{K+K-}/\Gamma_{e+e-}$ increases in a nucleus
  → $N_{\phi \to K+K-} / N_{\phi \to e+e-}$ becomes large
- The lager modification is expected in the larger nucleus

⬇

- **$\alpha_{\phi \to K+K-}$ becomes larger than $\alpha_{\phi \to e+e-}$**
- **The difference of α is expected to be enhanced in slowly moving ϕ mesons**



$\alpha_{\phi \to K+K-}$ looks larger than $\alpha_{\phi \to e+e-}$ in lower $\beta\gamma$ region

Summary

- KEK PS-E325 measures e^+e^- and K^+K^- invariant mass distributions in 12GeV p+A reactions.

- **Significant enhancement** is seen on the **e^+e^-** invariant mass distributions at the low-mass side of the ϕ meson peak in the Cu data, in $\beta\gamma < 1.25$ region. Model calculations reproduce the tendency of our data when the mass modification of ϕ is taken into account.

- Mass spectrum changes are **NOT** statistically significant in **K^+K^-** invariant mass distributions. Our statistics in the K^+K^- decay mode are quite low in the $\beta\gamma$ region in which we see the enhancement in the e^+e^- mode.

- $\alpha_{\phi\to K+K-}$ looks **larger** than $\alpha_{\phi\to e+e-}$ in lower $\beta\gamma$ region. This is very interesting observation, because it can be related to the ϕ and Kaon modification in nuclear matter.