First observation of ϕ meson mass-modification in nuclear medium (KEK-PS E325)

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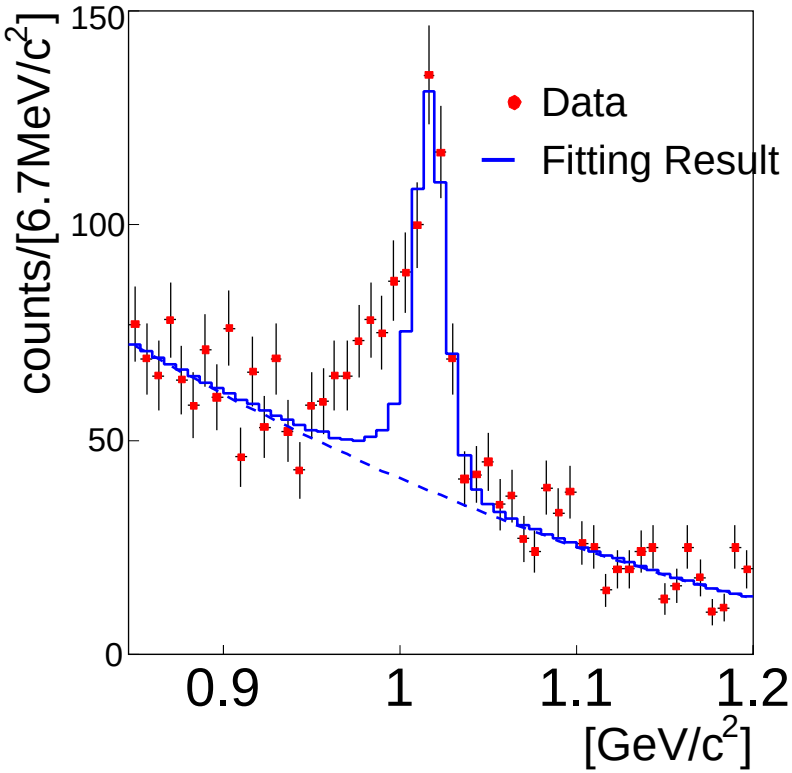
Contents

Our experiment, KEK-PS E325, measured e^+e^- and K^+K^- invariant mass to detect possible vector meson modification in nuclear medium.

$\phi \rightarrow e^+e^-$

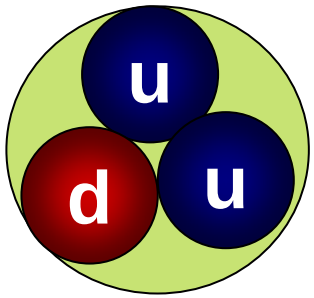
Invariant Mass Distribution



- Physics Motivation
- Experimental Setup
- Result of $\phi \rightarrow e^+e^-$ analyses

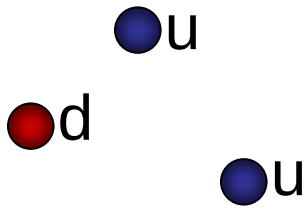
Physics Motivation

In Vacuum



Spontaneous Breaking of Chiral Symmetry

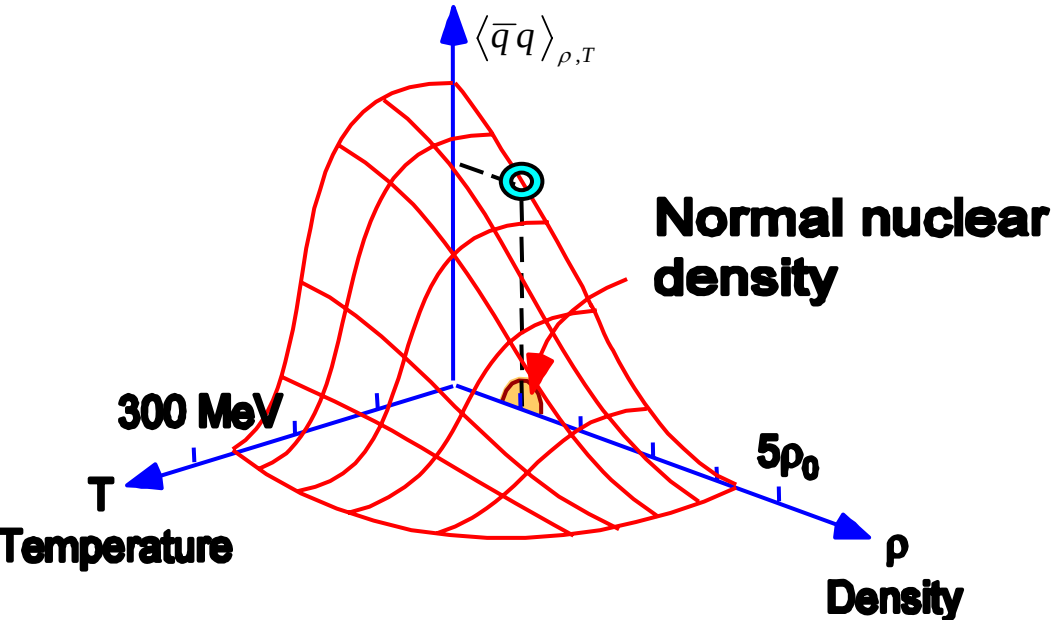
In Hot/Dense Matter



Hadrons ***~1GeV/c²***

Constituent quarks ***~300MeV/c²***

Current quarks ***~5MeV/c²***



How to detect?

Vector meson mass at normal nuclear density

Vector Mesons

Mass of Vector Meson ρ, ω, ϕ

= 2 x M_{quark} + small interaction term

Measure e^+e^- → free from FSI

predictions of vector meson modification in medium

Brown, Rho(1991),
Hatsuda, Lee(1992),
Klingl, Kaiser, Weise(1997), etc.

ρ, ω

Large mass modification
~120MeV/c^2 at $\rho = \rho_0$

Large cross section

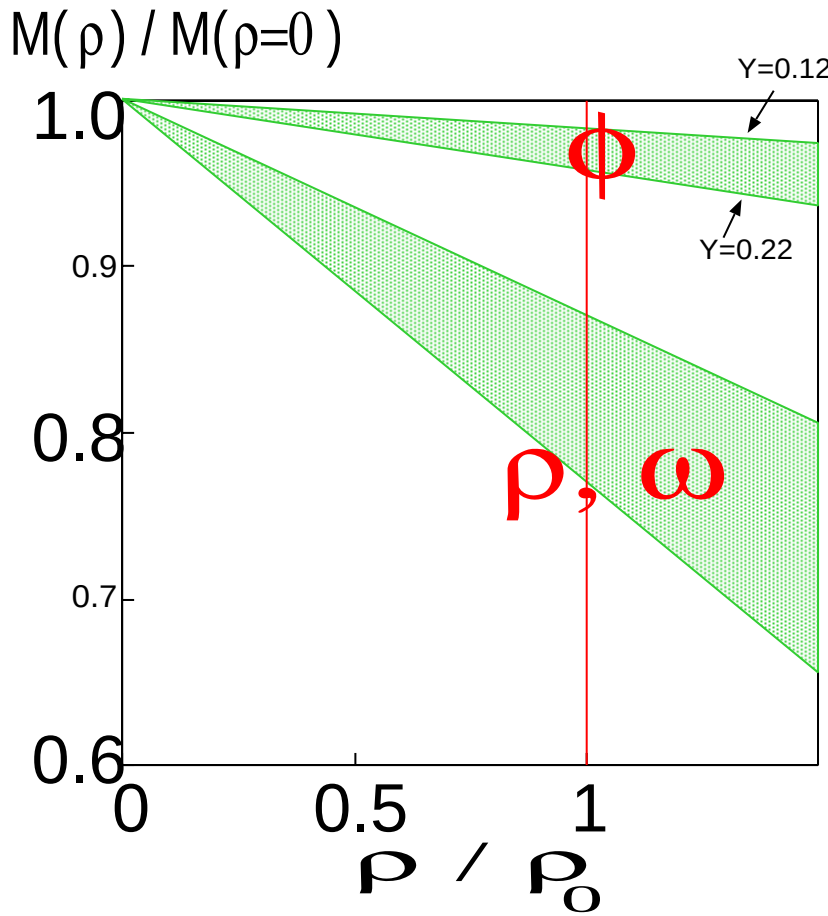
Difficult to separate ρ and ω
on e^+e^- mass spectrum

→ ***See Poster No.194 by M. Naruki***

ϕ

Mass modification **20 ~ 40MeV/c^2**
: relatively small

Small decay width (**4.4MeV/c^2**),
no other resonance nearby
: sensitive to small mass modification



Hatsuda & Lee PRC 46, R34(1992)

E325 Experiment

measures **Invariant Mass of e^+e^-, K^+K^-**
in 12GeV p + A → ρ, ω, ϕ + X reactions
Mass Resolution : ~**8.0MeV/c^2 for ρ / ω**, ~**10.7MeV/c^2 for ϕ**

Beam

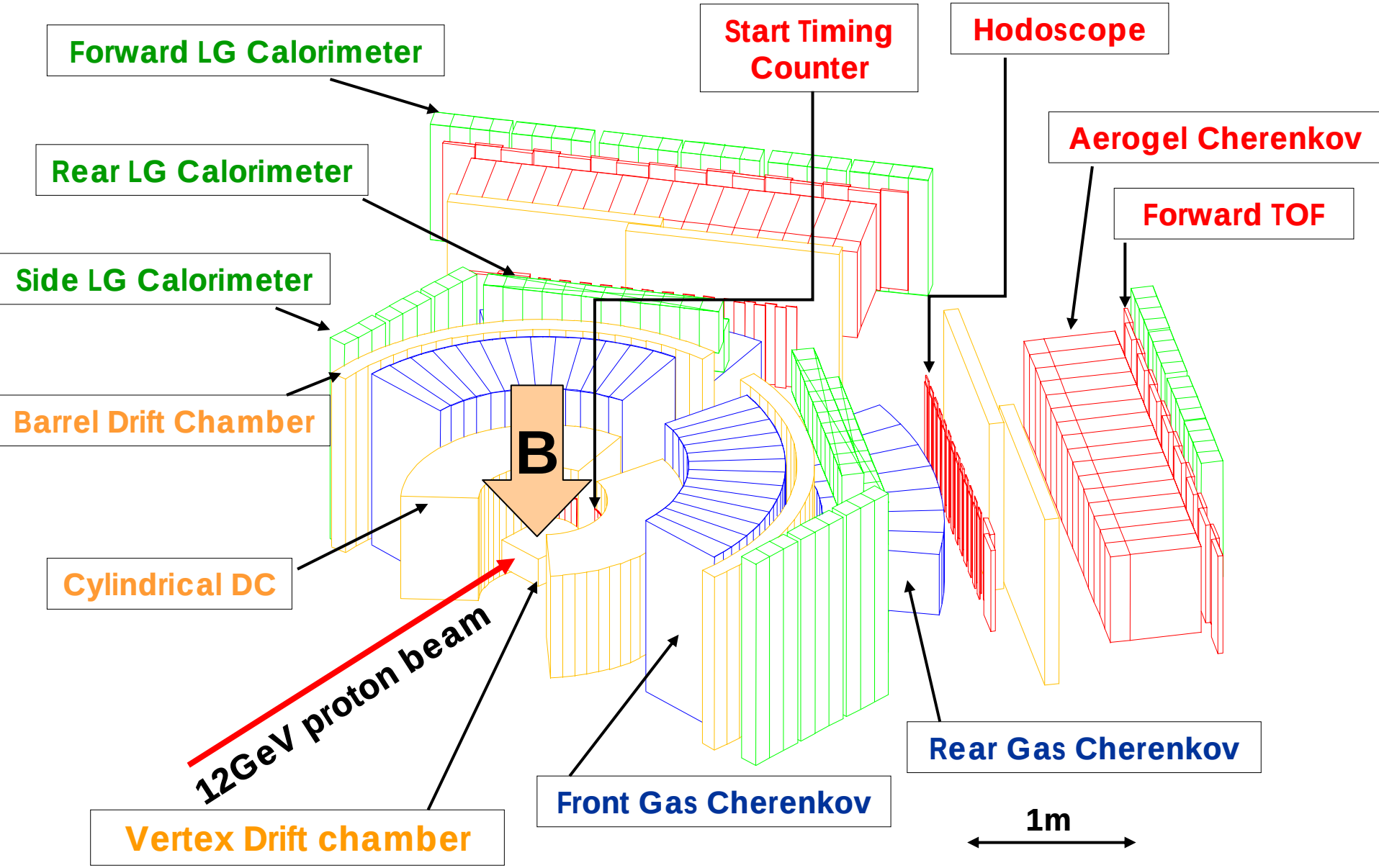
Primary proton beam (~10^9/spill/1.8s)

Target

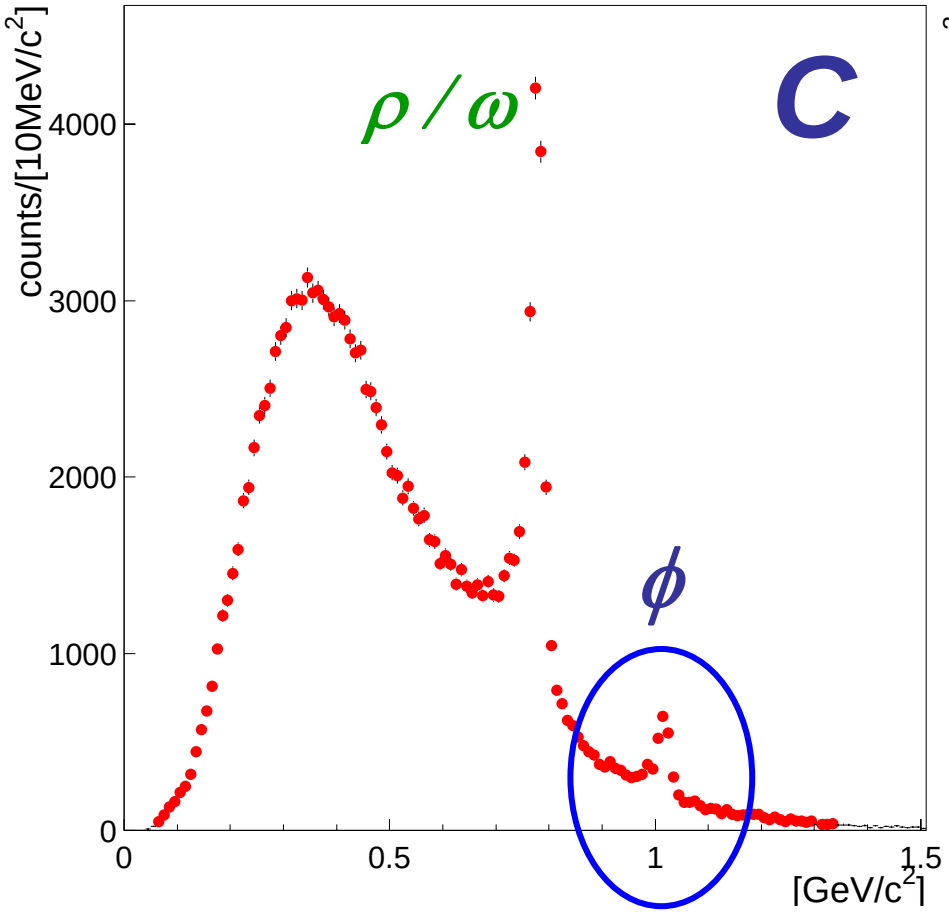
Five targets; Copper x 4 and Carbon x 1 aligned in line
Very thin targets to suppress γ conversion
(0.4% radiation length &
0.2% interaction length for Carbon target)

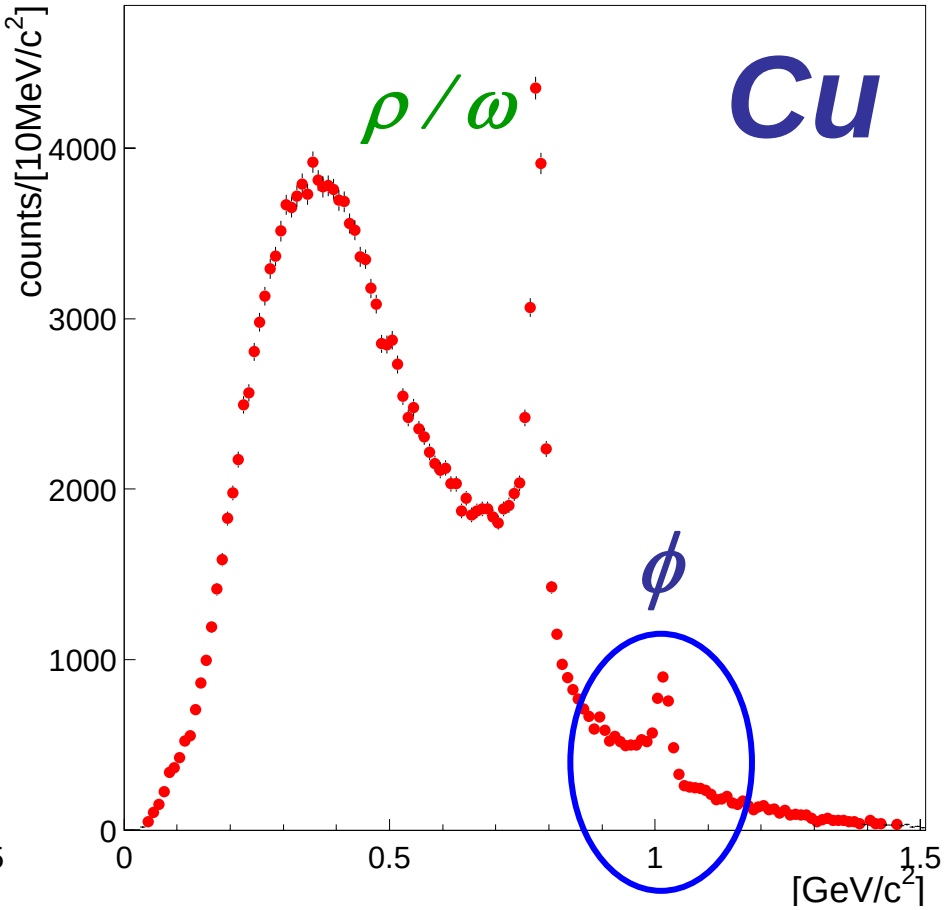
Slowly moving ρ ω ϕ (p_{lab}~2GeV/c)
→ Large Acceptance Spectrometer

Detector Setup

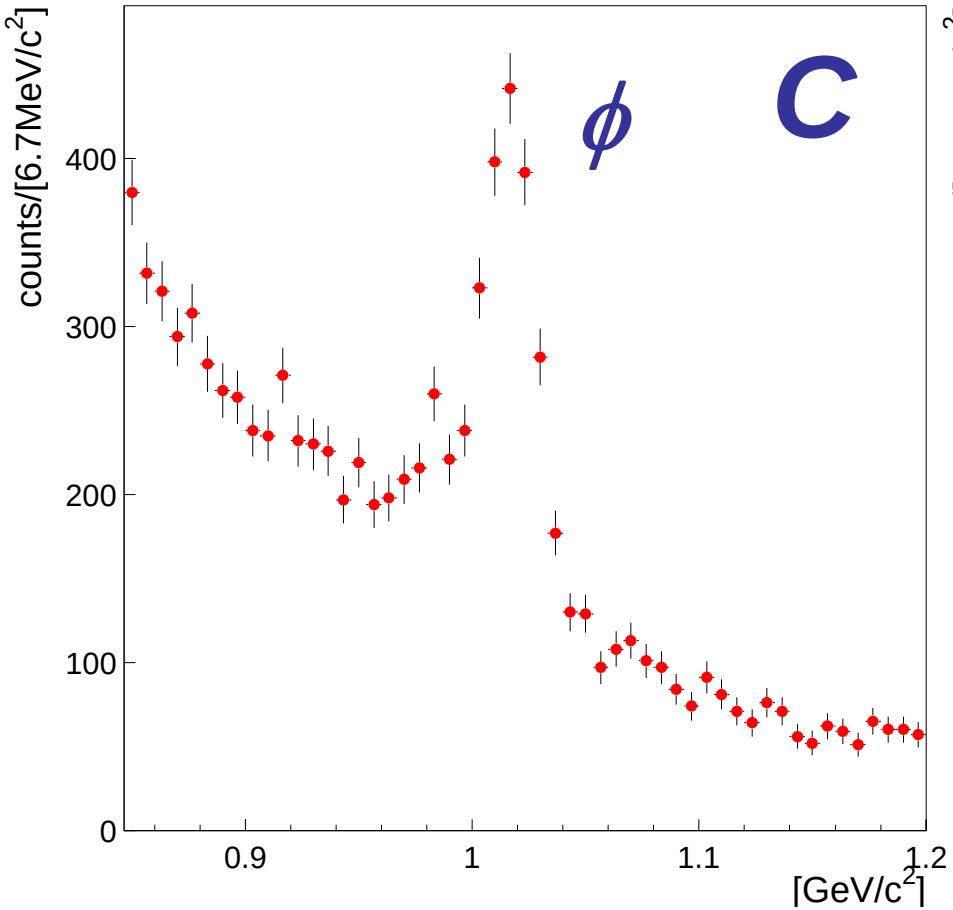


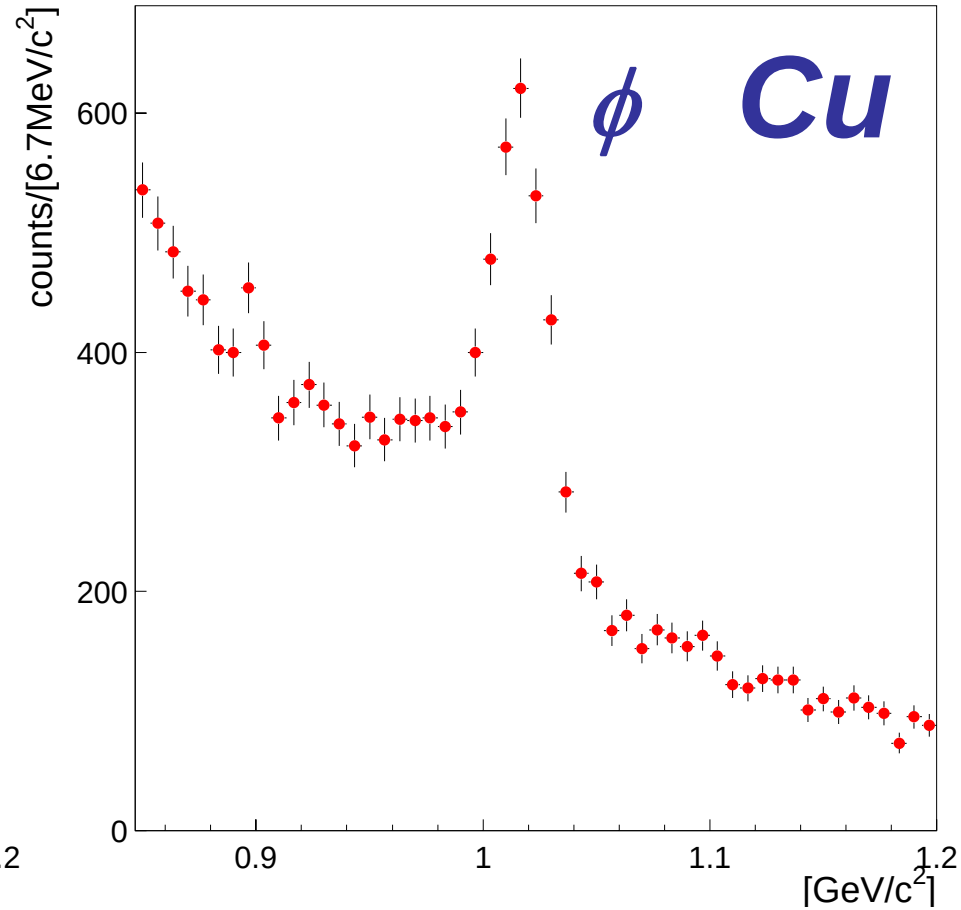
e^+e^- Invariant Mass Distributions





e^+e^- Invariant Mass Distributions





On the Fit

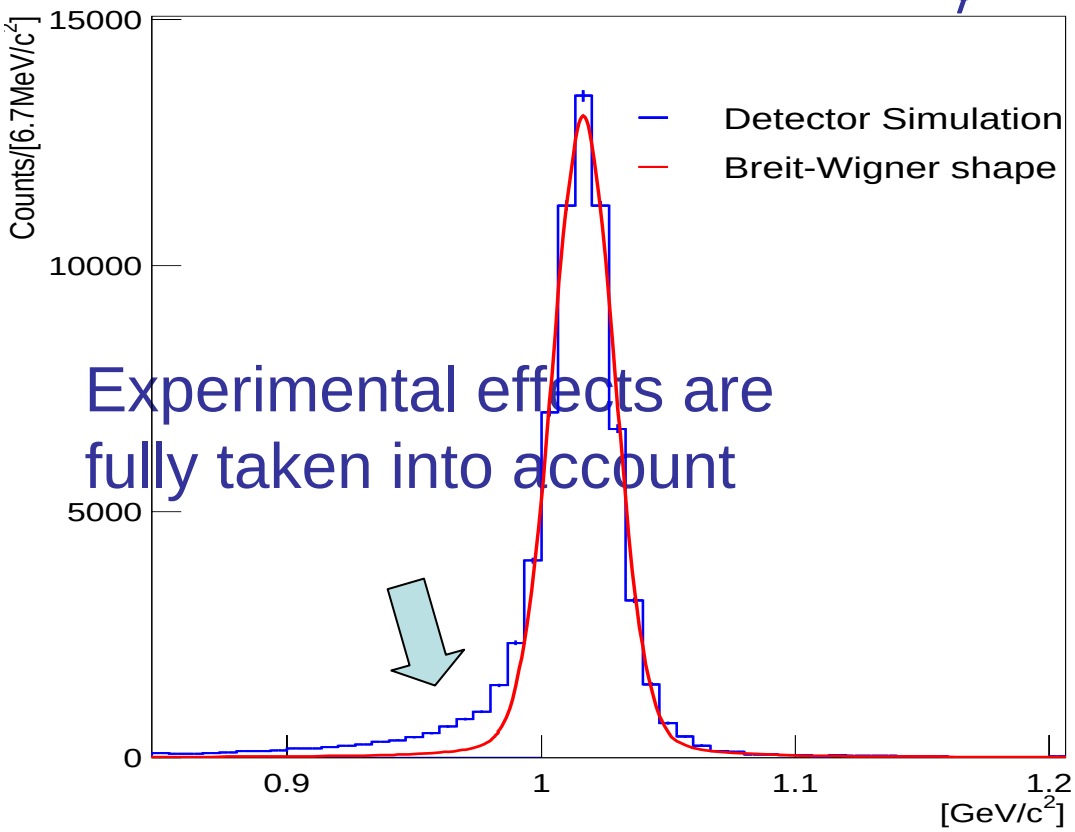
Back Ground : Quadratic curve

ϕ **Resonance Shape** : Breit-Wigner shape

experimental effect estimated by Geant4 simulation

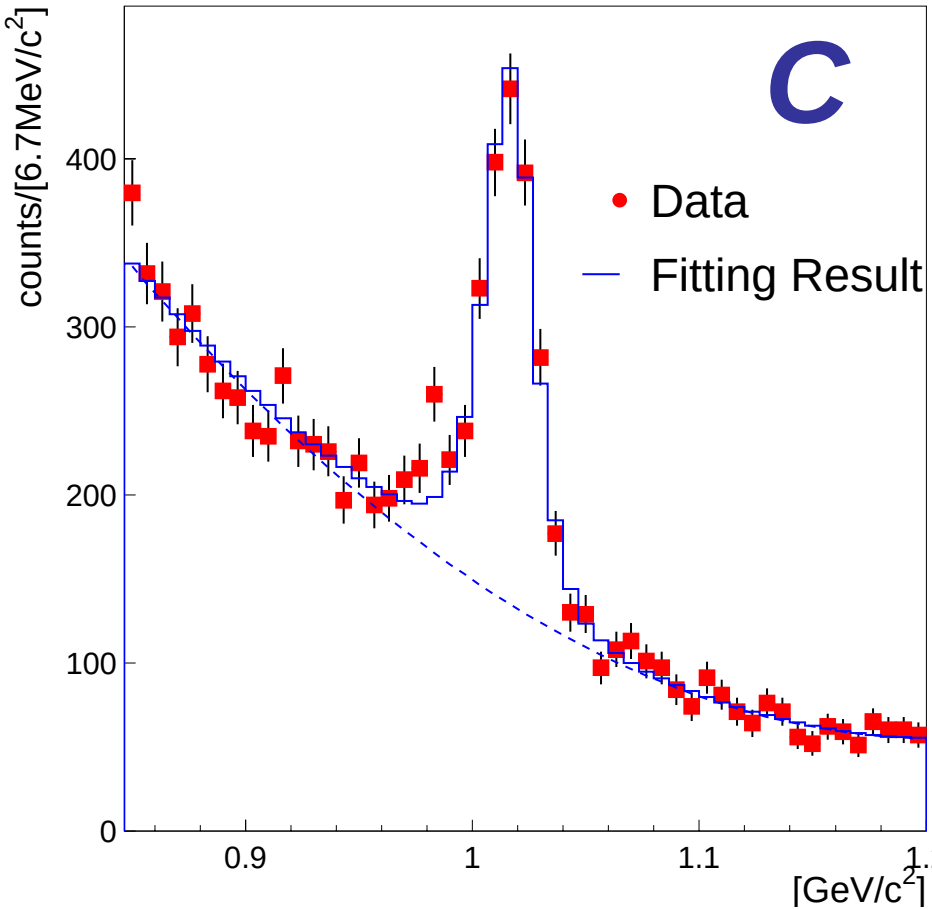
– energy loss, mass resolution, mass acceptance etc.

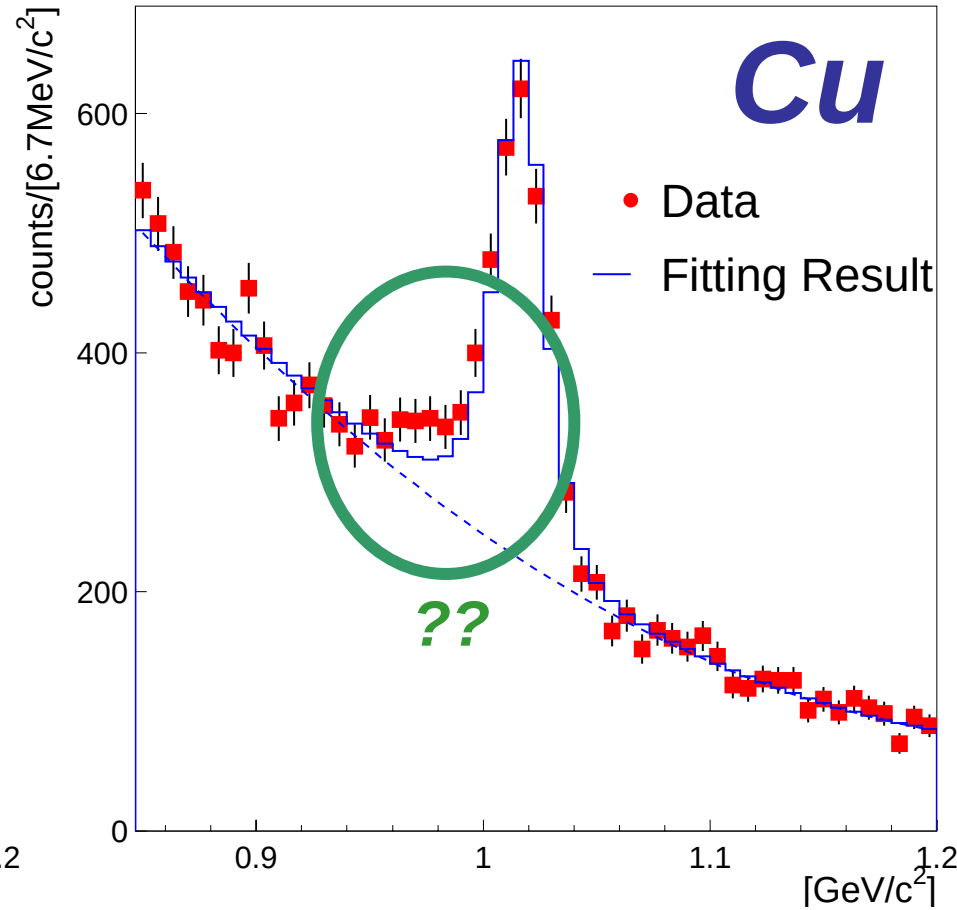
detector simulation for ϕ



- **Blue** histogram : Detector Simulation
- **Red** line : Breit-Wigner (gaussian convoluted) fitting result

Fit Results


C
Data
Fitting Result
counts/[6.7MeV/c^2]
[GeV/c^2]
0
100
200
300
400
0.9
1
1.1
1.2

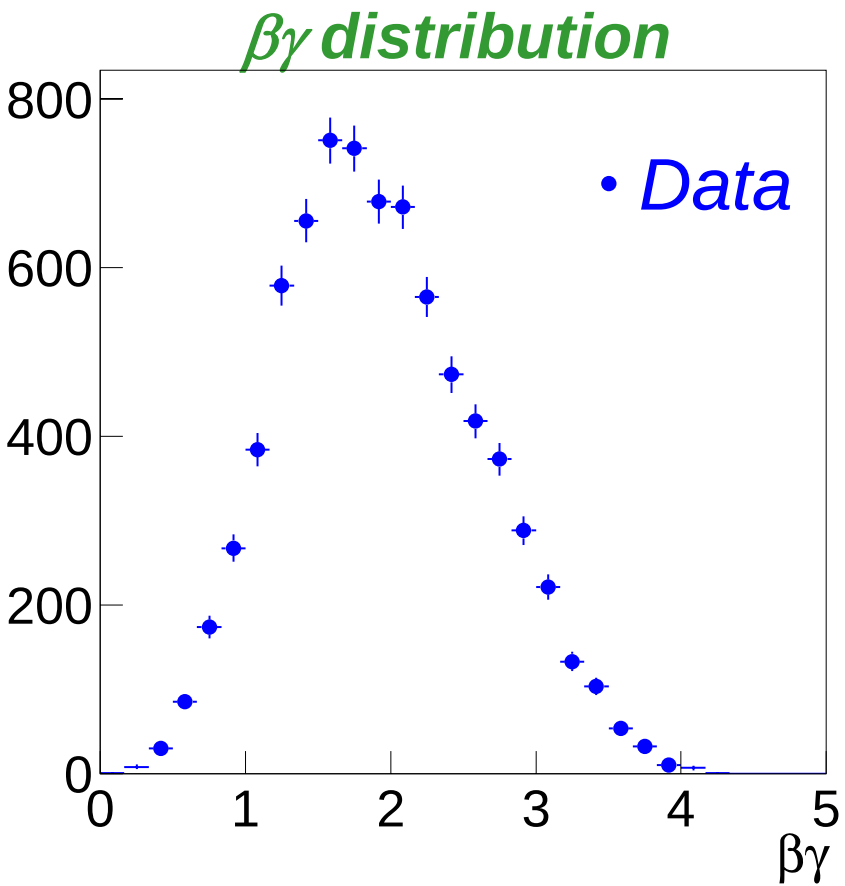

Cu
Data
Fitting Result
??
counts/[6.7MeV/c^2]
[GeV/c^2]
0
200
400
600
0.9
1
1.1
1.2

To see βγ dependence

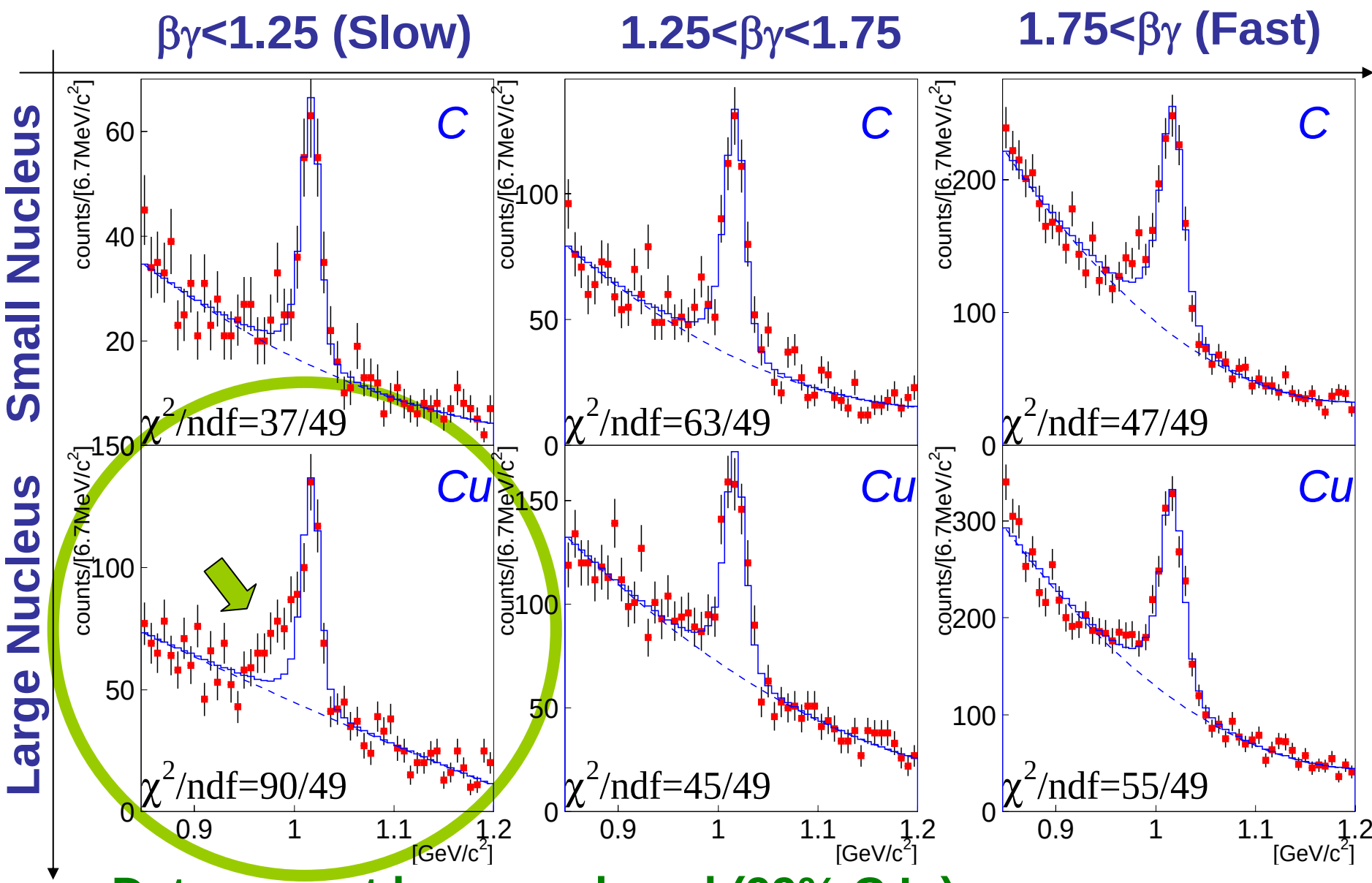
Slowly moving ϕ mesons have a larger probability to decay inside the target nucleus.

We divided the data into three by βγ;

$\beta\gamma<1.25$, $1.25<\beta\gamma<1.75$ and $1.75<\beta\gamma$.



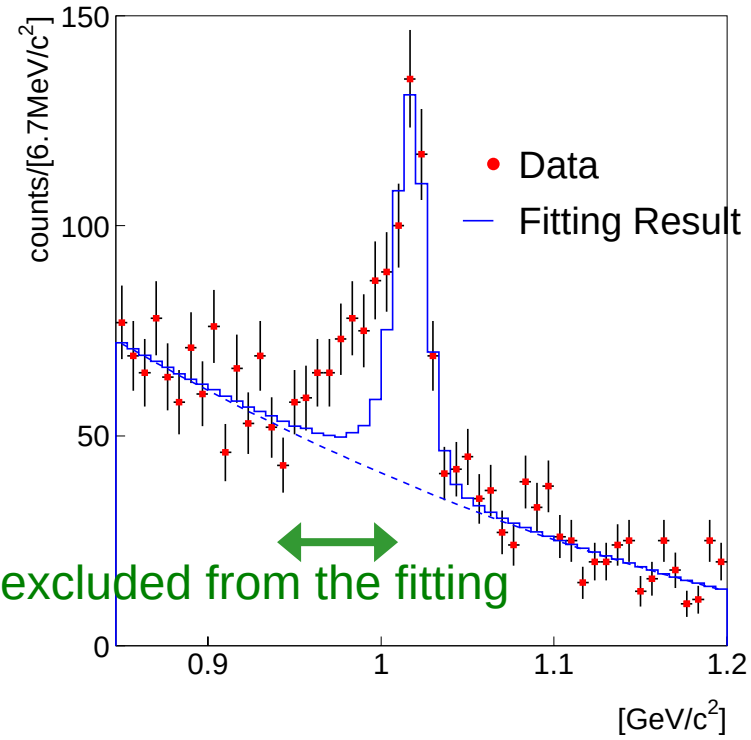
Fit Results (divided by βγ)

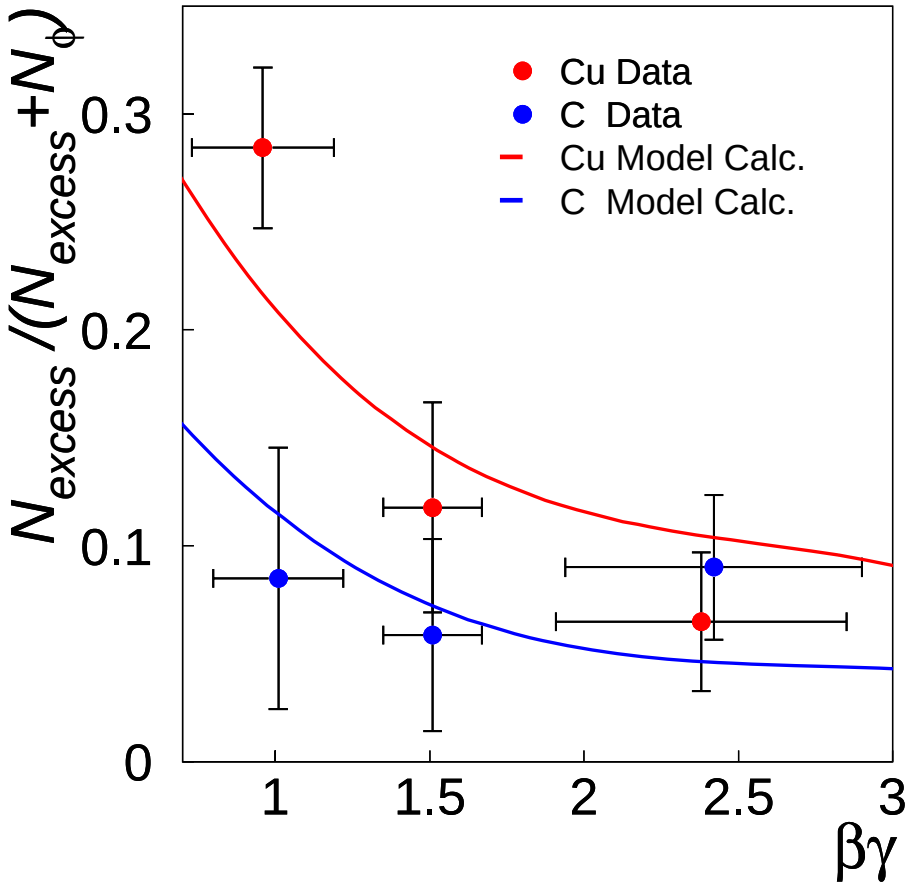


Data cannot be reproduced (99% C.L.)

The amount of the Excess

- Fit again excluding the region where the excess was seen;
  0.95~1.01GeV/c^2
- Integrate the amount of the excess in the above region
  (0.95~1.01 GeV/c^2) → N_{excess}





Model Calc. including Mass Modification

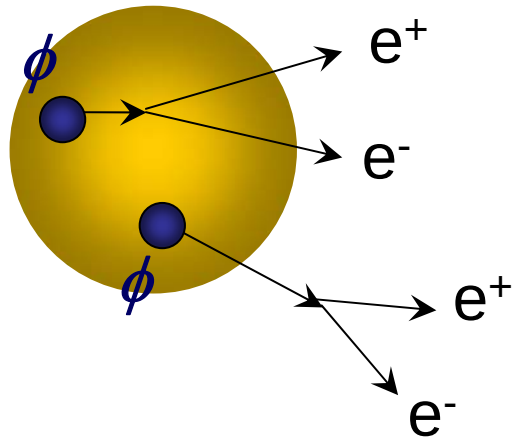
- ϕ mesons are generated uniformly in target nucleus
- momentum distribution: measured
- pole mass: $\mathbf{m^*/m = 1 - k_1 \rho/\rho_0}$

  (from Hatsuda, Lee)

  → We set $\boldsymbol{k_1 = 0.04}$
- decay width: $\mathbf{\Gamma^*/\Gamma = 1 + k_2 \rho/\rho_0}$

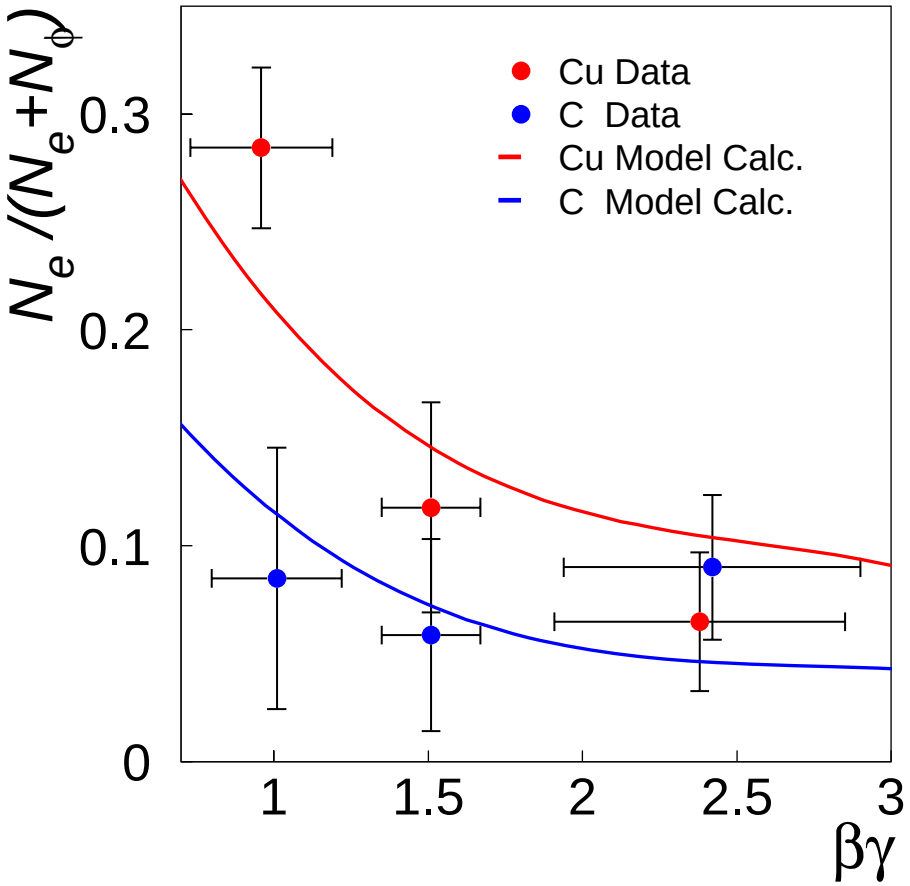
  → We set $\boldsymbol{k_2 = 10}$

  (at $\rho=\rho_0$, Γ^*~48MeV (from Klingl *et.al*))
- density distribution
  - Woods-Saxon
  - radius: C:2.3fm/Cu:4.1fm

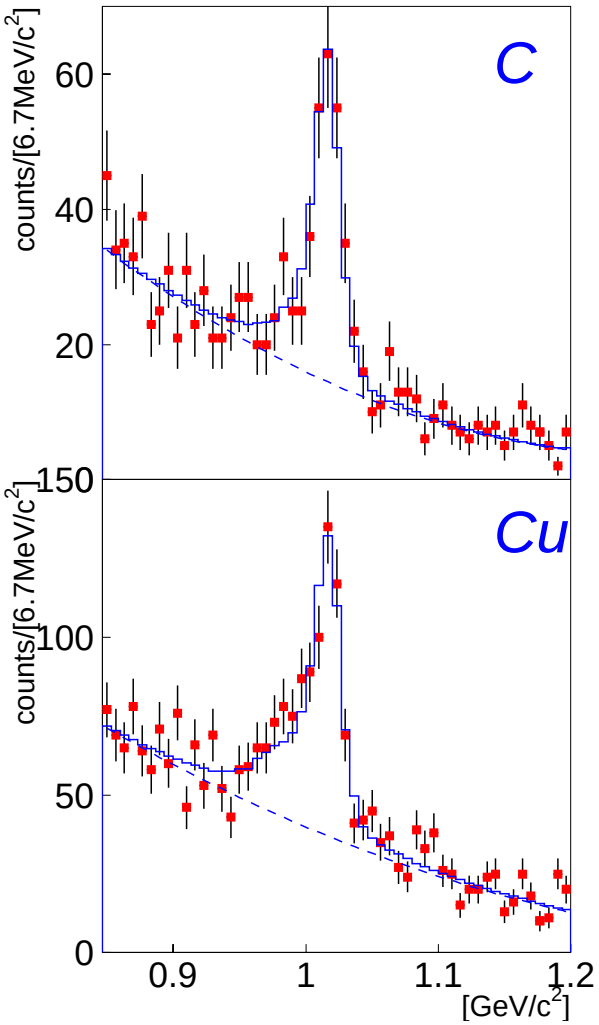


Results of Model Calc. with k_1=0.04, k_2=10

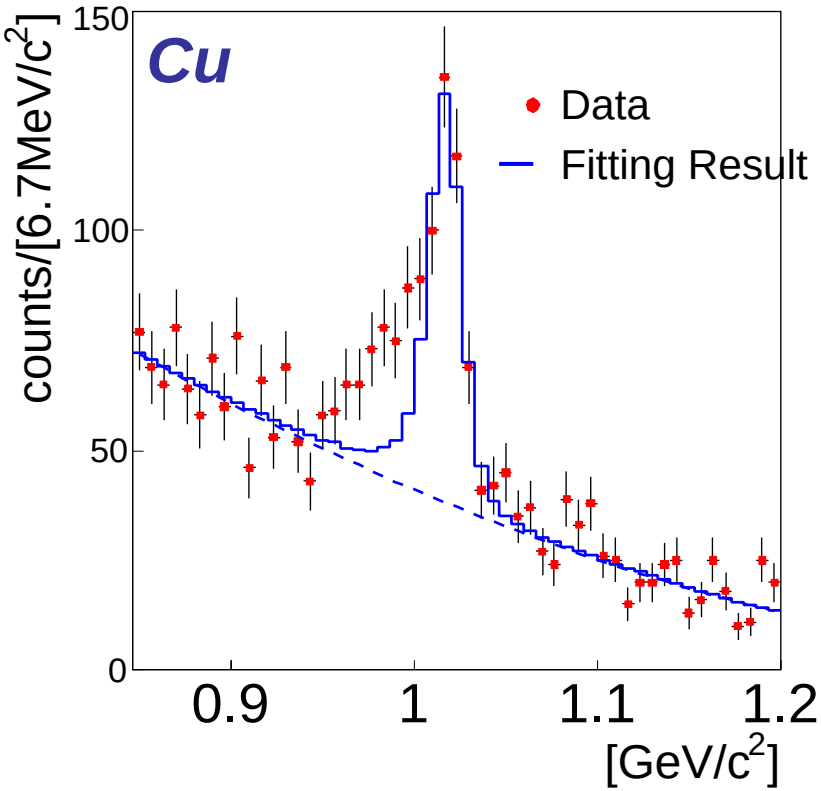
Amount of Excess by Model Calc.



βγ<1.25 (Slow)

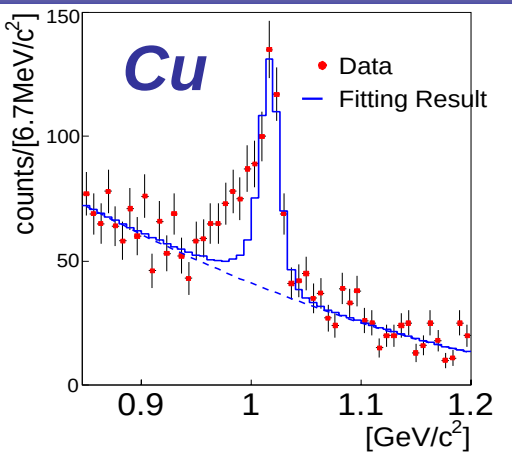


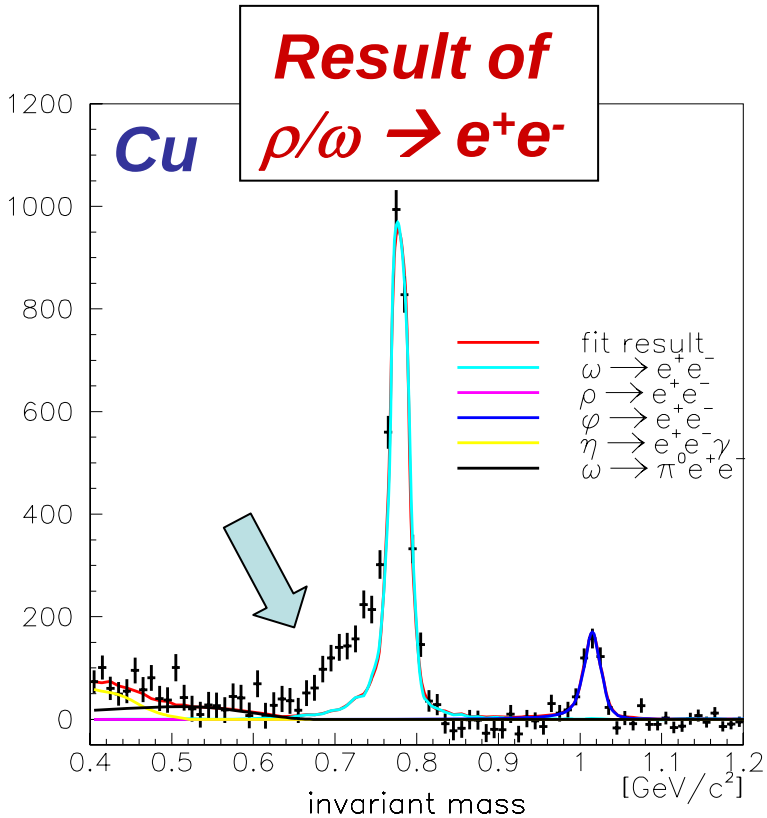
Summary



- KEK PS-E325 measured e^+e^- and K^+K^- invariant mass distributions in 12GeV p + A reactions.
- Significant enhancement was 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.
- This observation is comparable to the model calculation including in-medium mass modification.

Summary





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- Significant enhancement was 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.
- This observation is comparable to the model calculation including in-medium mass modification.
- We observed the signature of the in-medium mass modification **both in ϕ and ρ / ω mesons**. (for ρ / ω results, see ***poster No.194*** by M. Naruki)