Measurements of vector meson decays in nuclear matter at KEK−PS

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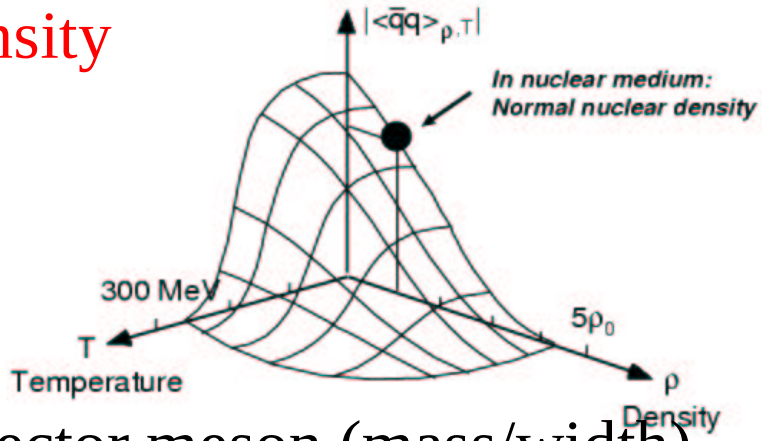
for KEK−PS E325 collaboration

- vector meson modification & chiral symmetry
- performed experiment
- observed invariant mass spectra
- discussion

Chiral symmetry restoration in dense matter

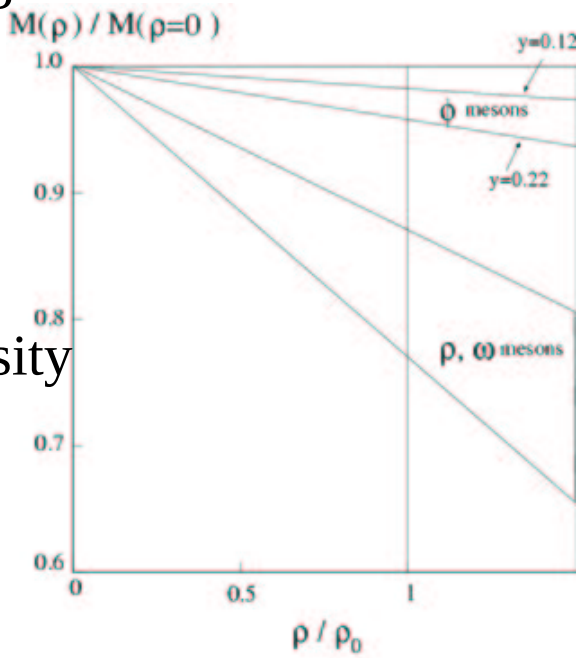
- In hot/dense matter, chiral symmetry is expected to restore
  - hadron modification is expected in such matter
- quark−antiquark condensate (order parameter) is predicted ~2/3 even at the normal nuclear density
  - Achivable at KEK−PS, not RHIC



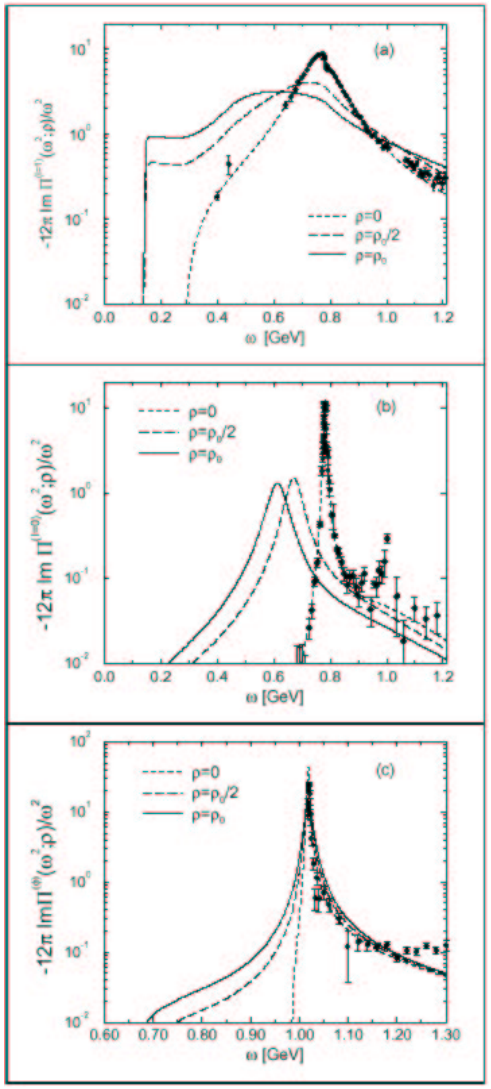
- Various theoretical predictions of vector meson (mass/width) modification in dense medium....
  - Brown, Rho (’91), Hatsuda, Lee (’92) , Klingle, Keiser, Weise (’97), Muroya, Nakamura, Nonaka(’03)....

Hatsuda and Lee, 92,95

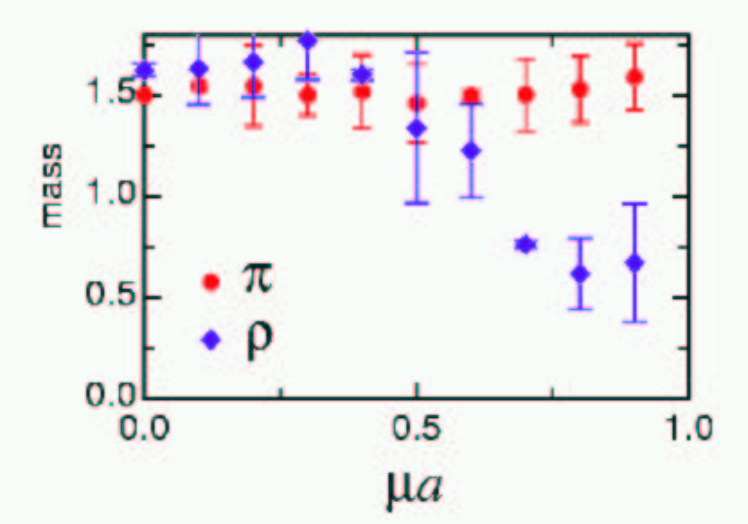
mass decreasing
~16% for ρ/ω
~2−4% for ϕ
at the normal nuclear density



Klingle,Keiser,Weise, 97

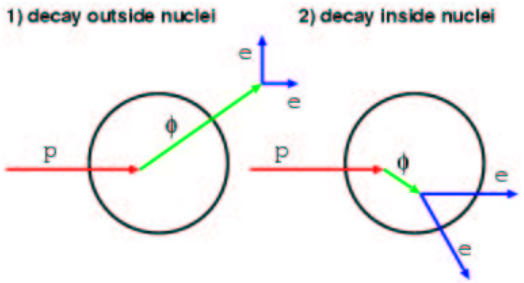


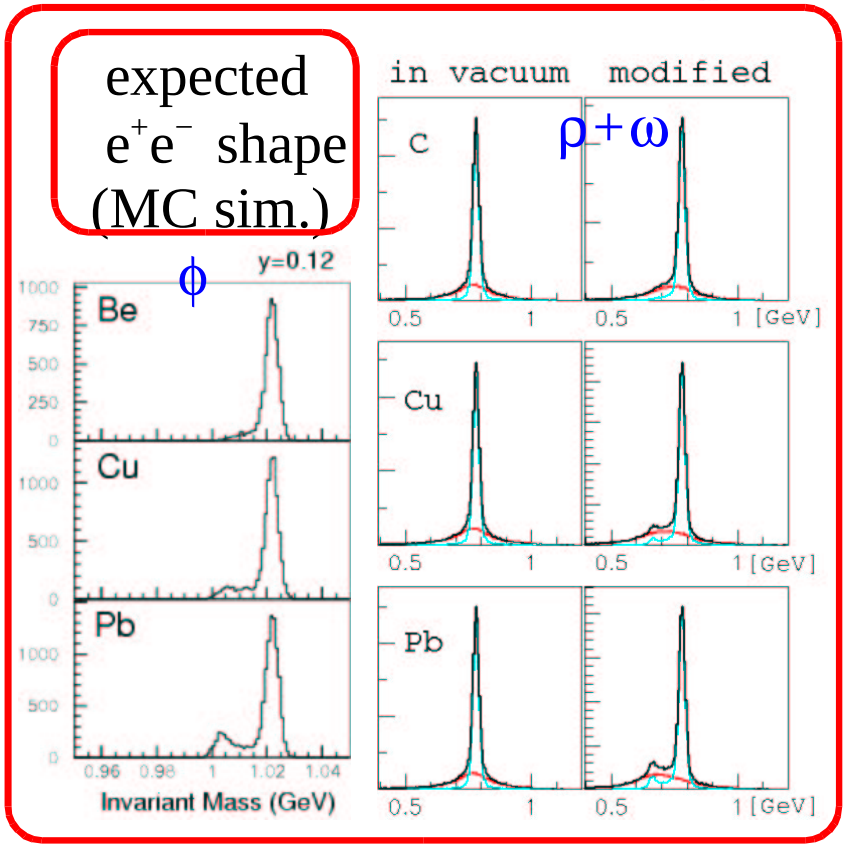
Muroya, Nakamura, Nonaka, 03



Invariant mass spectra in e^+e^- channel

- smaller FSI in e^+e^- decay channel
- double peak or tail−like structure
  - second peak is made by inside−nucleus decay (modified meson)
- comparison of ϕ and ρ
  - ϕ (1020): narrow width
    - smaller decay prob. inside nuclei
    - smaller production CS
  - ρ (770) & ω(783) :
    - larger production CS
    - larger decay prob. inside nuclei
    - cannot distinguish ρ & ω in e^+e^-





Experiment KEK−PS E325

- 12GeV p+A −> ρ/ω/ϕ +X, (ρ/ω/ϕ −>e^+e^- , ϕ−>K^+K^-)
- Experimental key issues:
  - Very thin target to suppress the conversion electron background (typ. 0.1% interaction/0.2% radiation length of C)
  - To compensate the thin target, High intensity proton beam to collect high statistics (typ. 10^9 ppp −> 10^6Hz interaction)
  - Detect slowly moving mesons, which have larger probability decaying inside nuclei (1<βγ<3)

Collaboration

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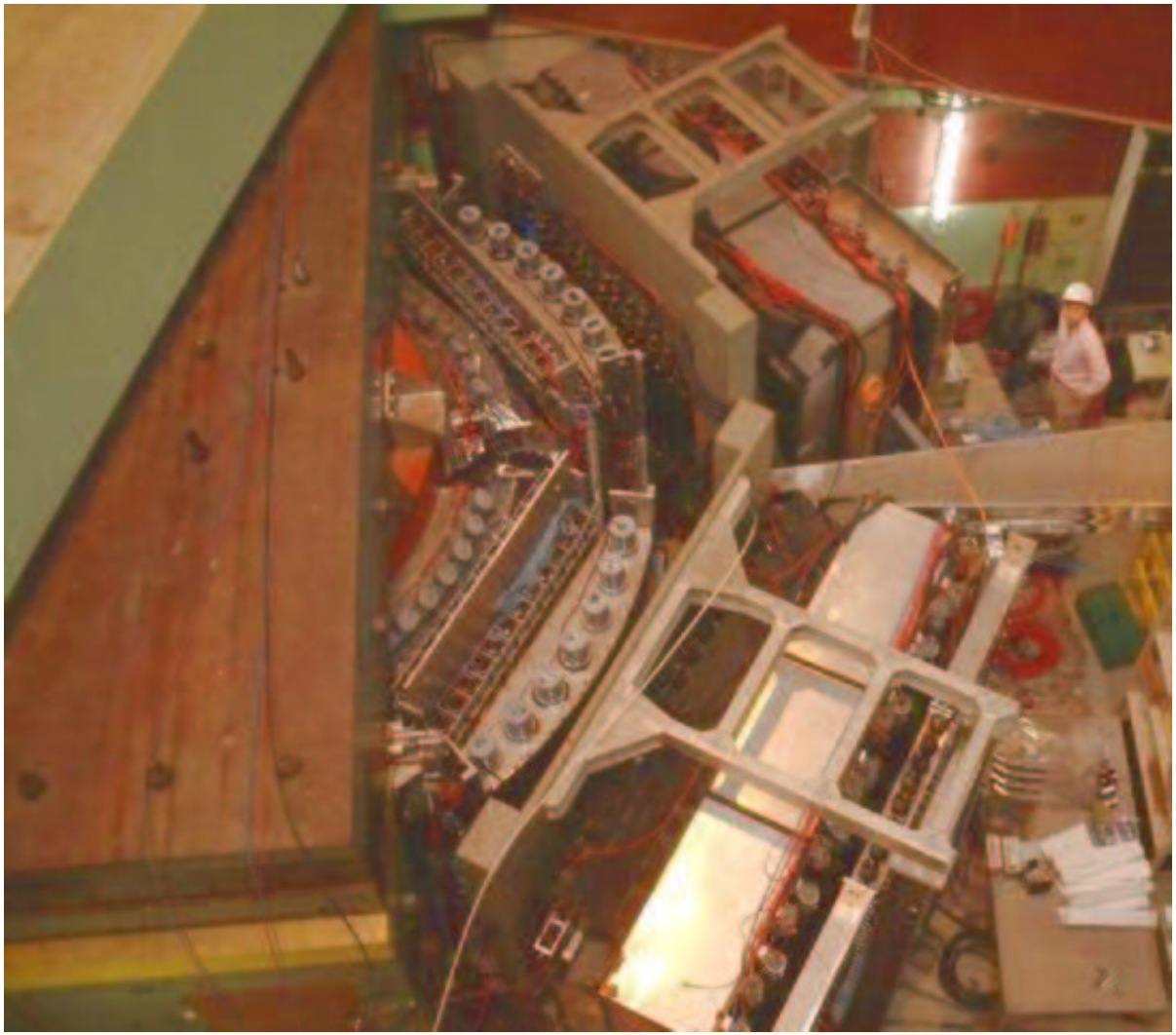
(Kyoto Univ. , RIKEN, KEK, CNS−U.Tokyo, ICEPP−U.Tokyo, Tohoku−Univ.)

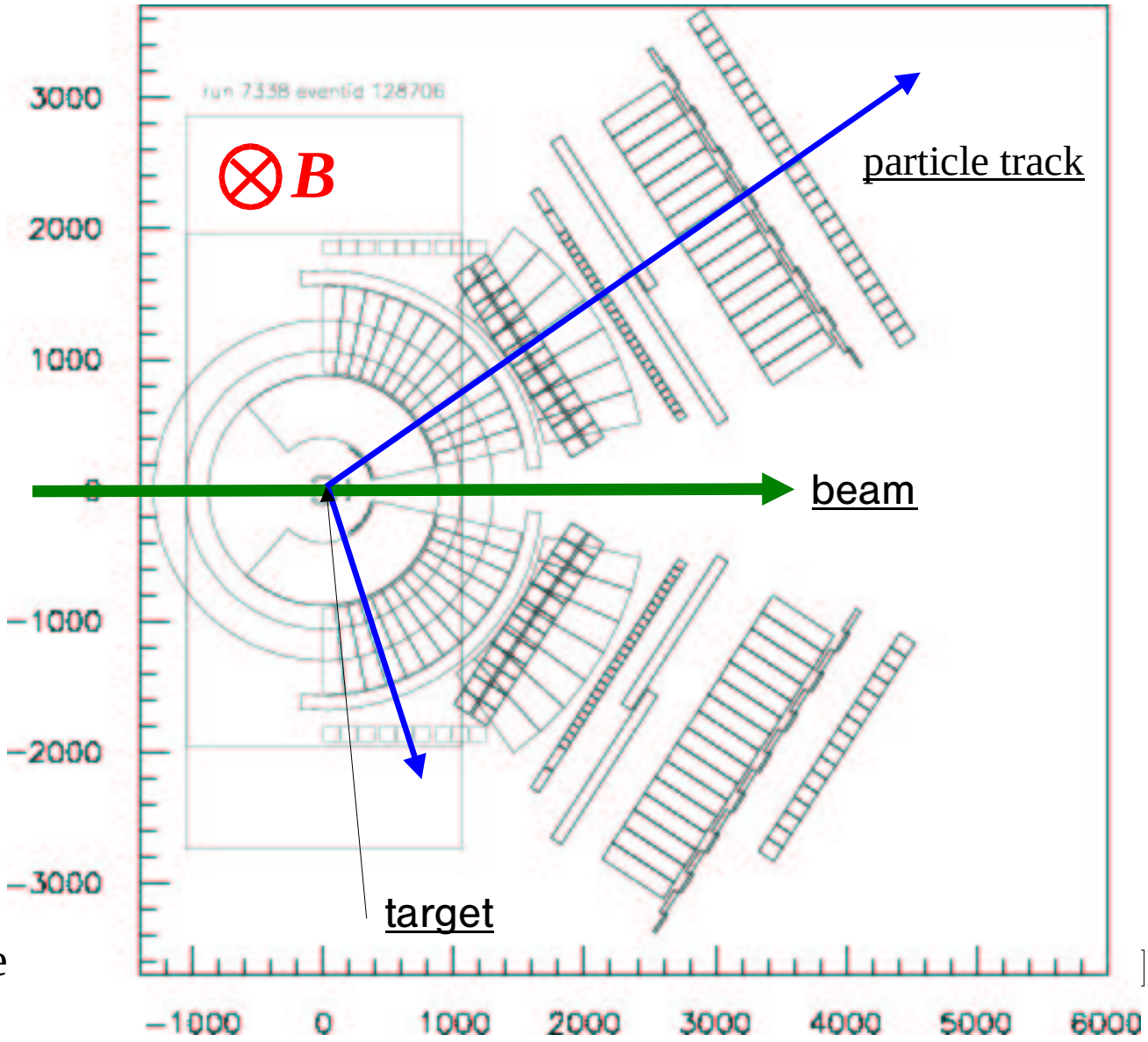
E325 spectrometer

- KEK−PS EP1−B primary beam line
- 1996 const. start
- ’97 data taking start
- ’98 ee data is published
  - PRL86(01)5019
- 99,00,01,02....
- ’02 completed



- Spectrometer Magnet
  - 0.71T at the center
  - 0.81Tm in integral
- Targets
  - at the center of the Magnet
  - C & Cu are used typically
  - very thin: ~0.1% interaction length
- Primary proton beam
  - 12.9 GeV/c
  - ~1x10^{9} in 2sec duration, 4sec cycle

schematic plan view of spectrometer



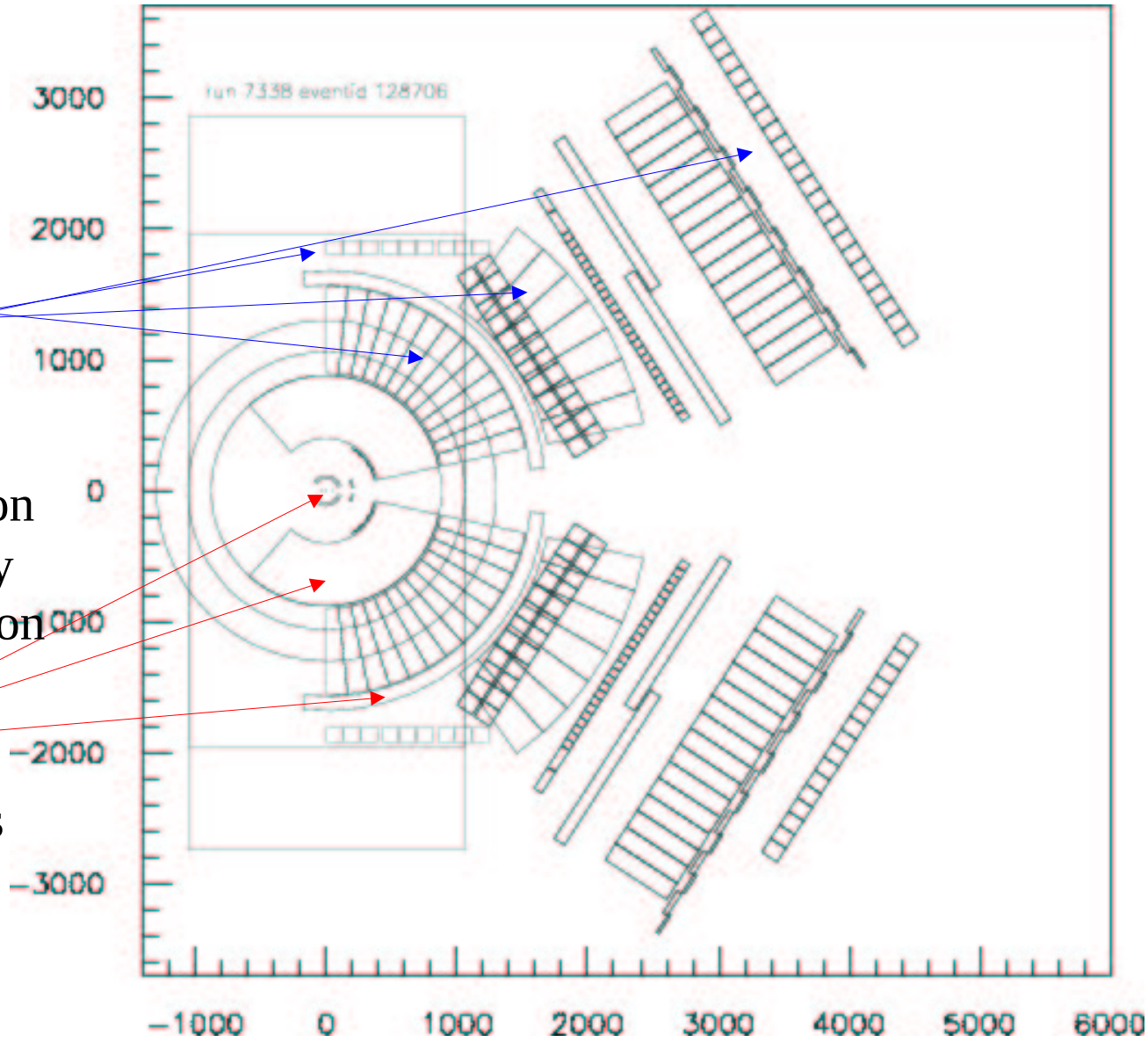
Electron ID counters

Gas Cherenkov &
Lead Glass EMC

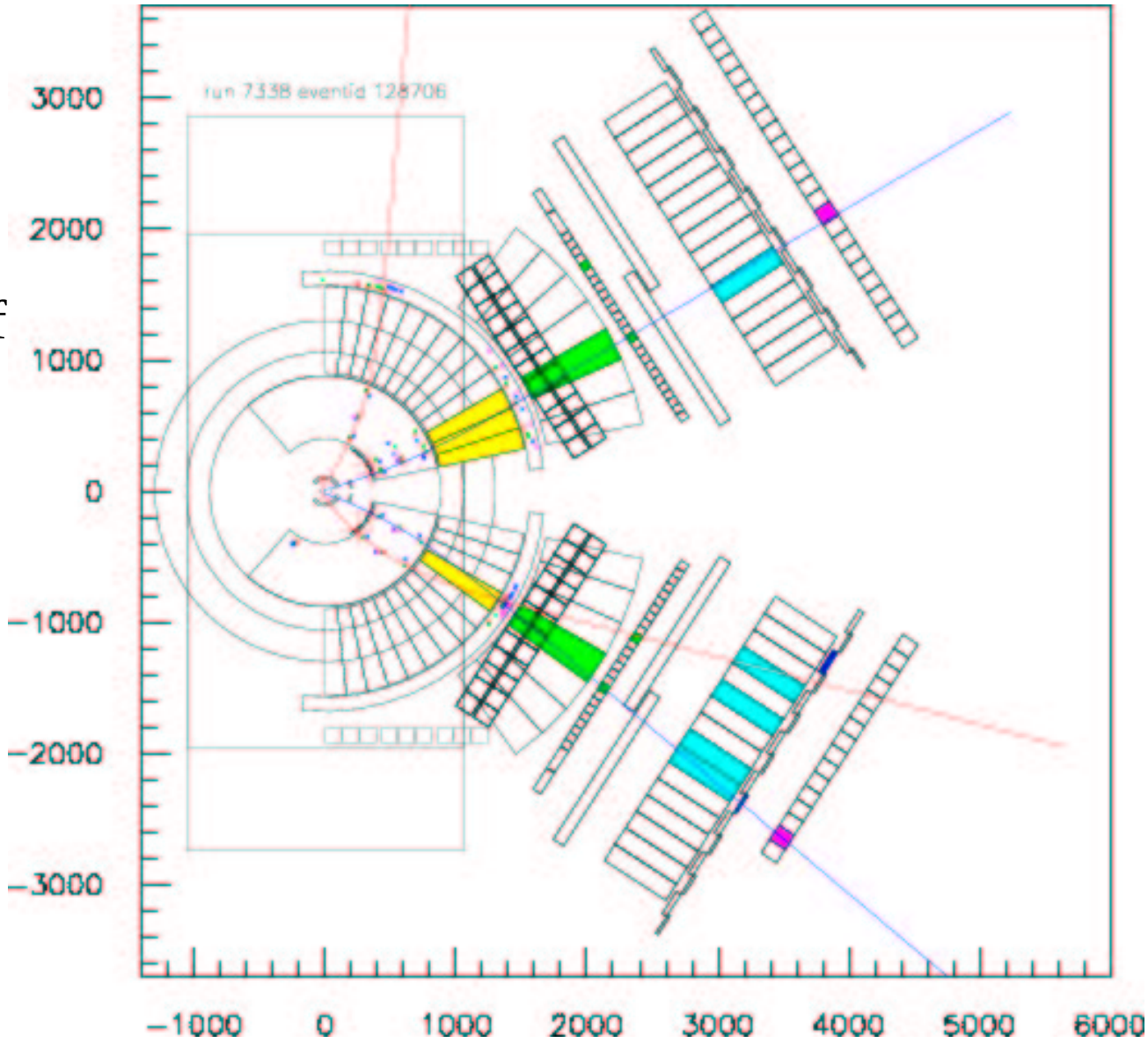
total 3×10^{-4} π rejection
with 78% e efficiency
in two−stage operation

Tracker

Three Drift Chambers

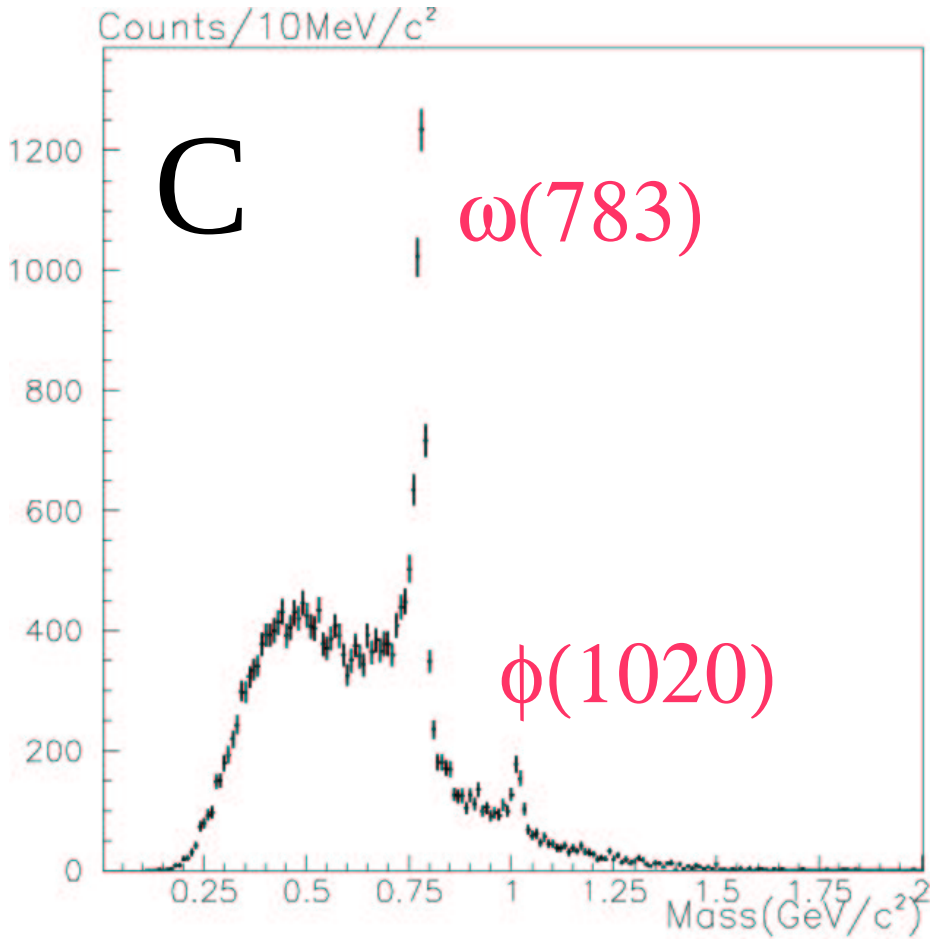


- Typical e^+e^- Event
  - blue:electron
  - red : other
  - invariant mass of eletron pair is calculated



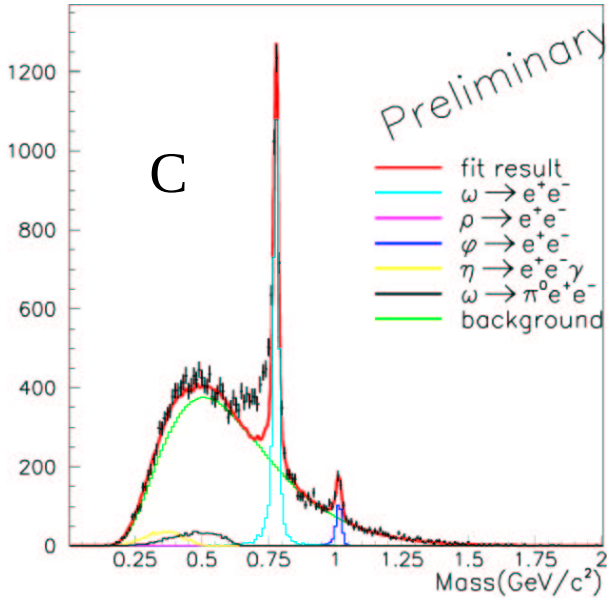
Observed e^+e^- invariant mass spectra

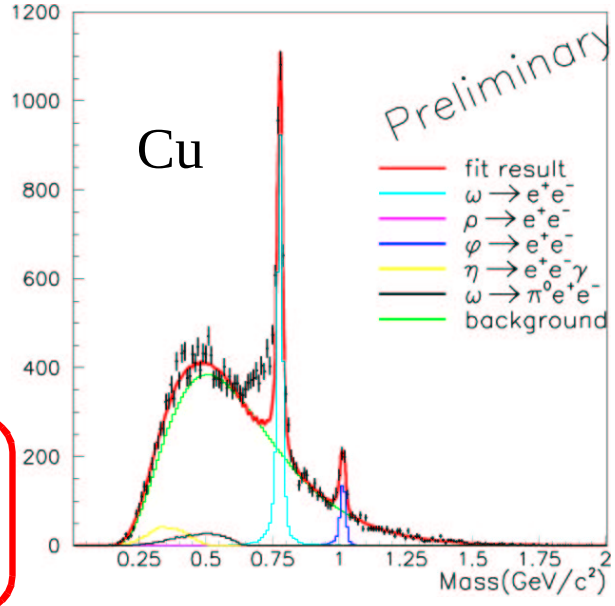
- from 2002 run data (~70% of total data)
- C & Cu target
- clear resonance peaks
- m<0.2 GeV is suppressed by detector acceptance
- acceptance uncorrected



Fitting with known sources

- Hadronic sources of e^+e^-:
  - $\rho/\omega/\phi \rightarrow e^+e^-$, $\omega \rightarrow \pi^0 e^+e^-$, $\eta \rightarrow \gamma e^+e^-$
  - simple Breit−Wigner shape (no modification is assumed)
  - Geant4 detector simulation (energy loss of e^+/e^- in detector, acceptance, etc.)
- Combinatorial background : event mixing method
- ... relative abundance of these components are determined by fit

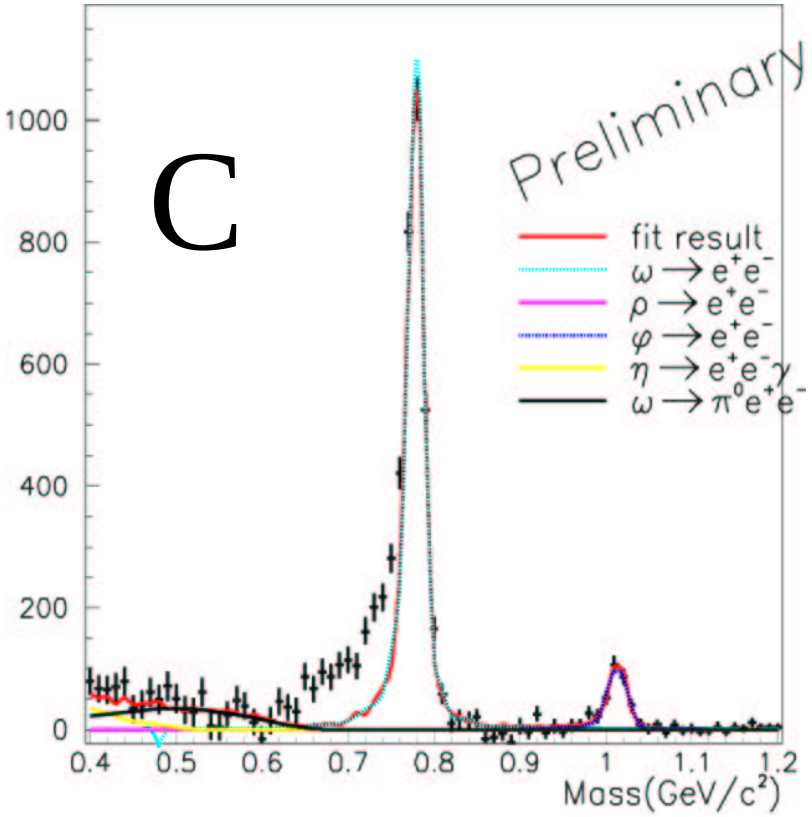


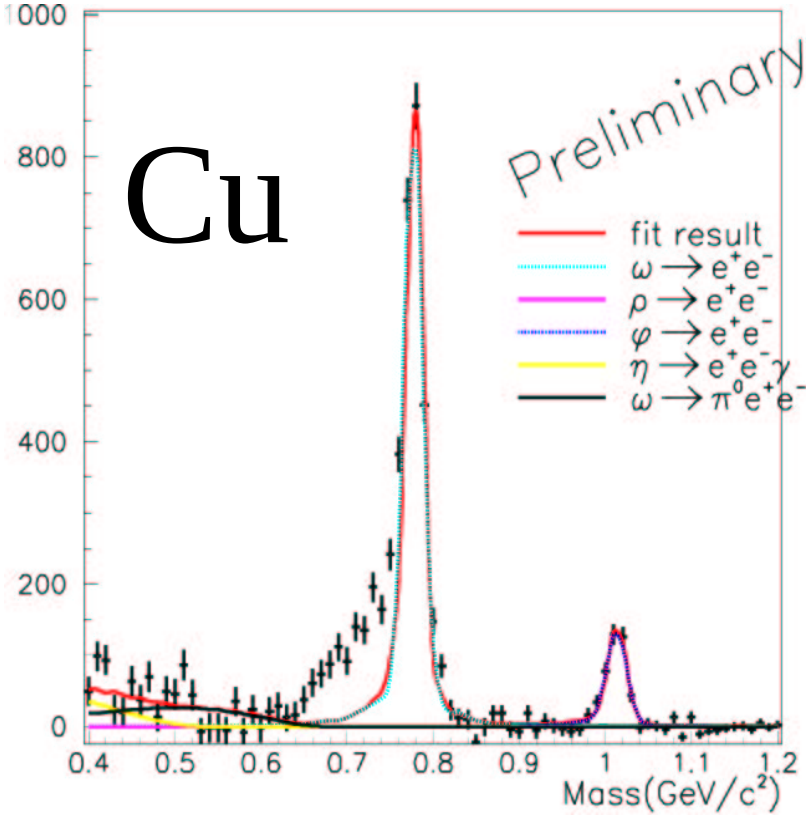


- excess at the low−mass side of ω (0.6~0.75 GeV)
- ρ–meson component seems to be vanished !

Fitting results (BKG subtracted)

ρ/ω=0.0+−0.01(stat.)+−0.2(sys.) , 0.0+−0.05(stat.)+−0.5(sys.)



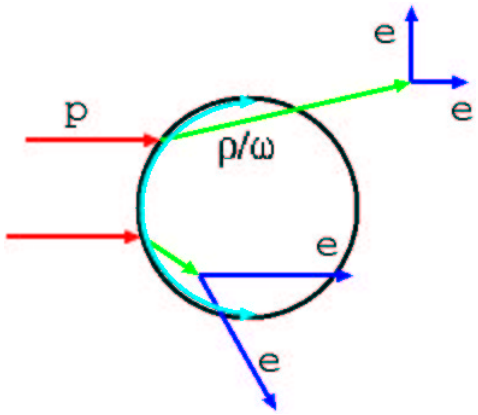


- However, ρ/ω ~1 in former experiment (p+p, 1974)
  ..... suggests the excess is from modified ρ mesons?

Discussion: Toy model including modification

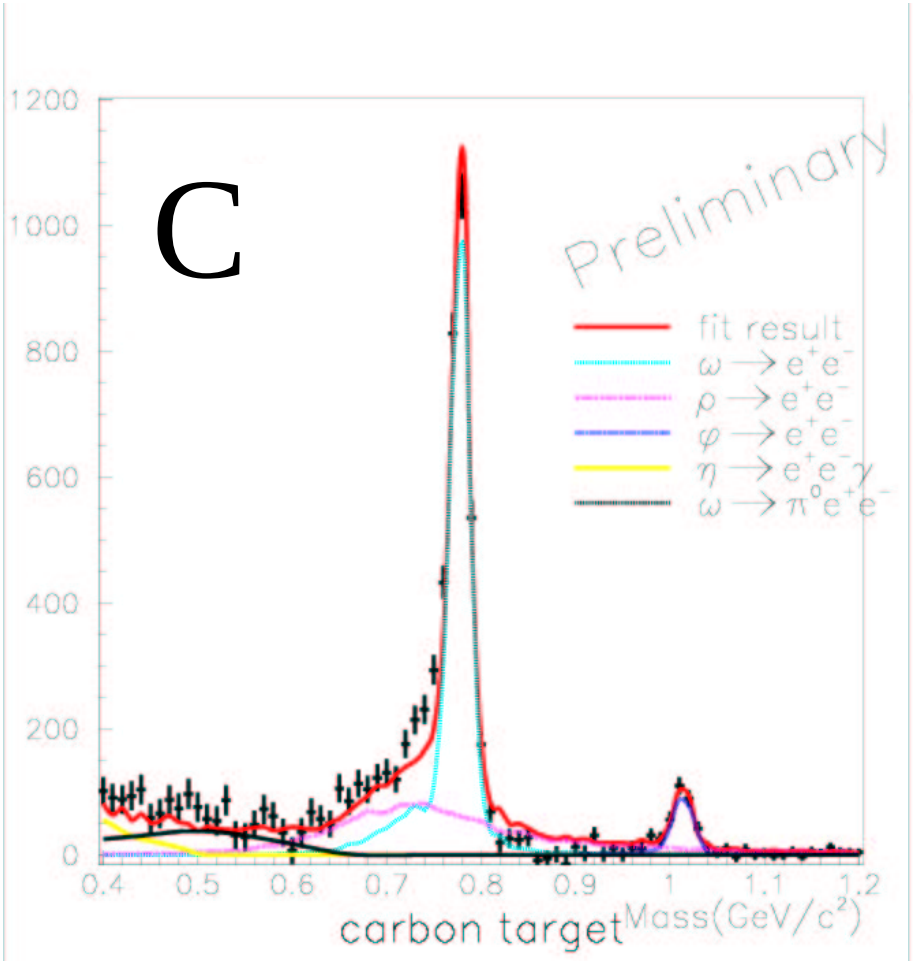
- Assumptions to include the nuclear size effect in the fitting shape
  - nuclear density distribution : Woods−Saxon form
  - meson production point : incident surface of nuclei
  - fly through the nucleus, decay with modified mass if the decay point is inside nuclei
  -
  -
  - modification as : $m^*/m_0 = 1 - 0.16\ \rho^*/\rho_0$

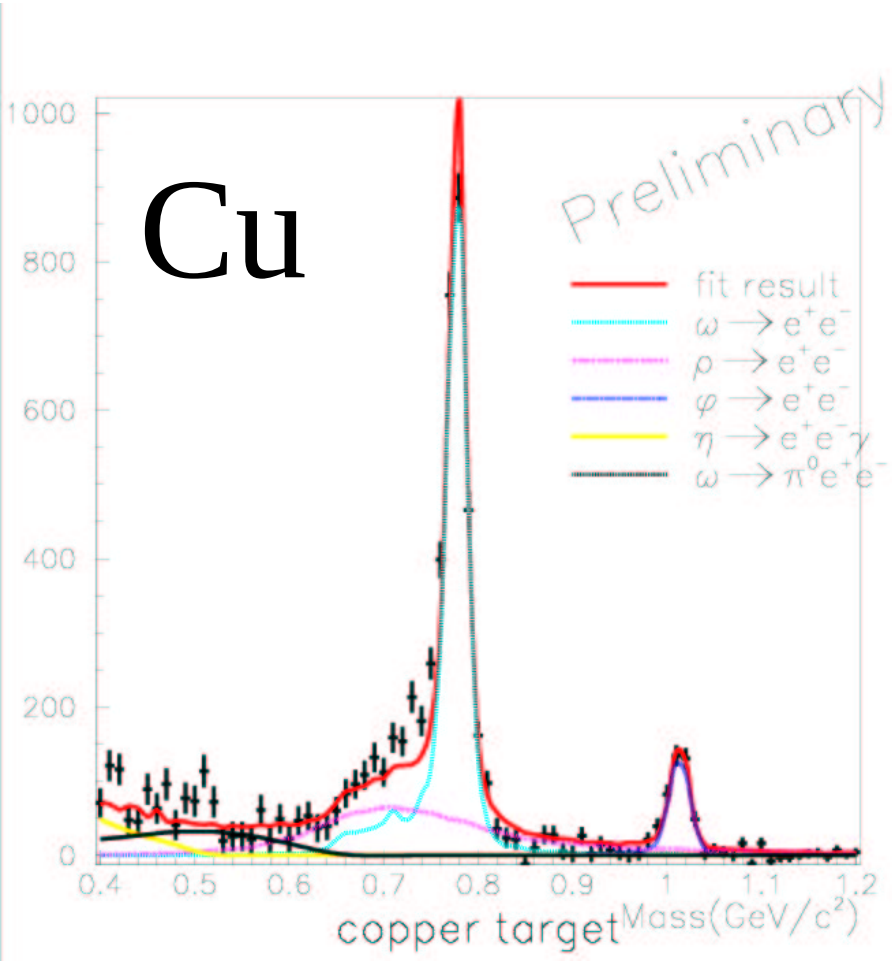
    (Hatsuda & Lee, ’92,’95)



  - (width modification & momentum dependence of modification are not taken into account)
- ρ/ω ratio is fixed to unity as measured in former exp.

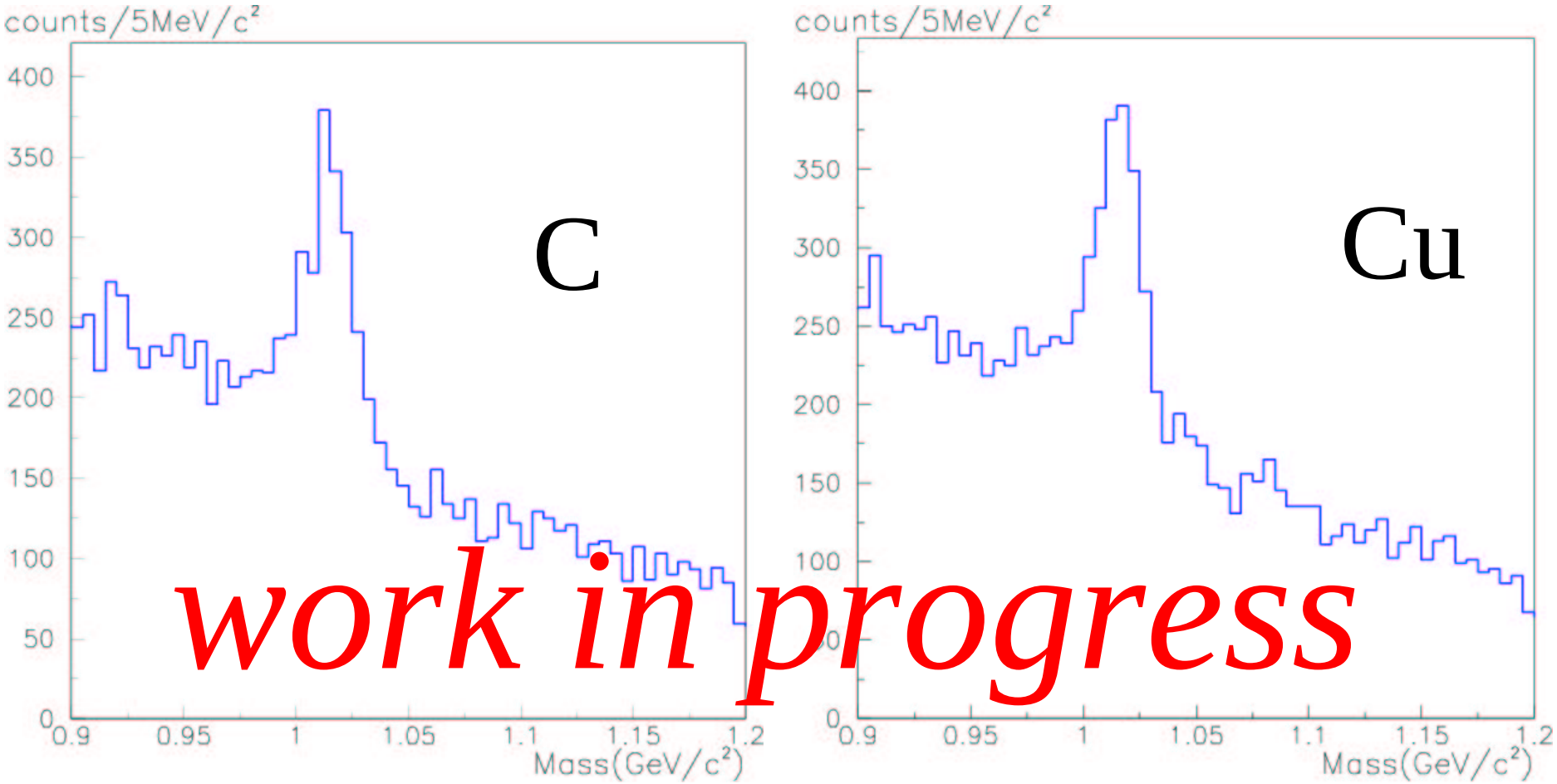
Fitting results by the toy model





- the tendency of the data are reproduced qualitatively by the model

e^+e^- spectra of ϕ meson



work in progress

- all statistics for ϕ meson... ~1000 ϕ s for each target.

Summary

- KEK−PS E325 measured the e^+e^-(&K^+K^-) decay of slowly moving vector mesons in nuclei produced by 12GeV proton beam, to explore the chiral symmetry restoration at the normal nuclear density.
- Observed e^+e^- invariant mass spectra have excesses below the ω meson peak, which cannot be explained by known hadronic sources in normal (unmodified) shape. These suggest modification of (at least) ρ meson.
- Simple model calculation including predicted modification reproduces the observed spectra qualitatively.
- Analysis on ϕ meson is also on going...