



Observed vector meson modification in 12-GeV p+A reaction at KEK-PS

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for the KEK-PS E325 collaboration

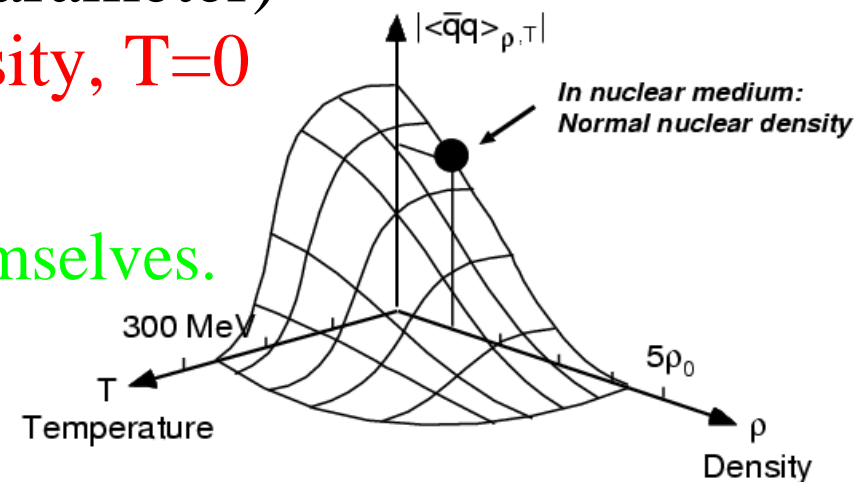
- vector meson modification & chiral symmetry
- performed experiment
- observed invariant mass spectra
- discussion

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)
 $\sim 2/3$ even **at the normal nuclear density, $T=0$**

- **Achievable at KEK-PS in use of nuclear medium of target nuclei themselves.**



- Many theoretical predictions of **vector meson (mass/width) modification** in dense medium, **related (or not related) with CS**

- Brown & Rho ('91) : $m^*(\rho)/m_0 \sim f_\pi^*/f_\pi \sim 0.8$ at $\rho=\rho_0$

- Hatsuda & Lee ('92), Klinge, Keiser & Weise ('97), Muroya, Nakamura & Nonaka('03), etc.

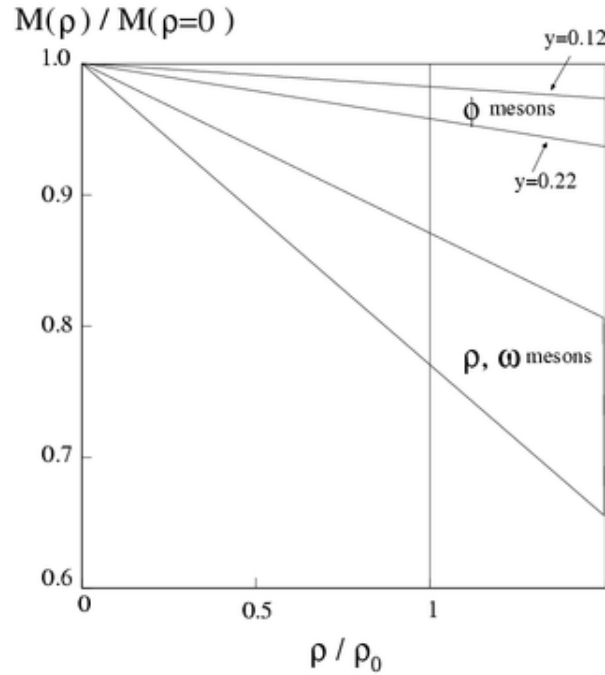
Hatsuda and Lee, 92,95

mass decreasing

~16% for ρ/ω

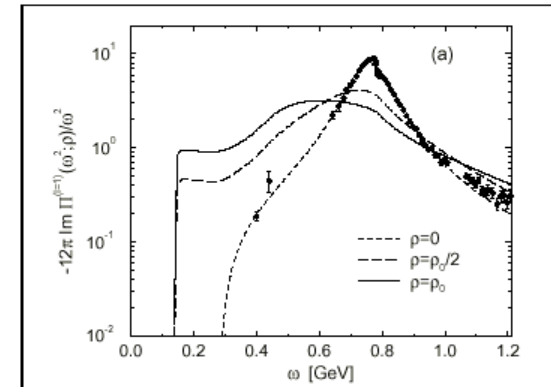
~2-4% for ϕ

at the normal nuclear density

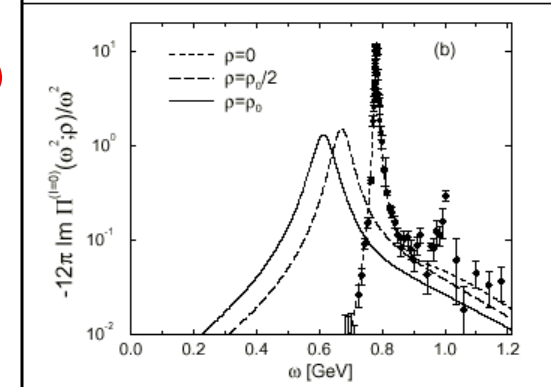


Klinge, Keiser, Weise, 97

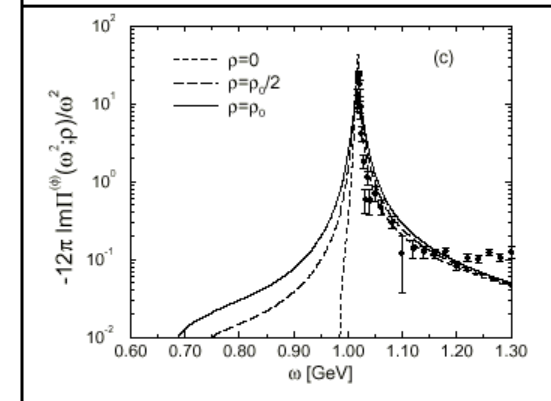
ρ



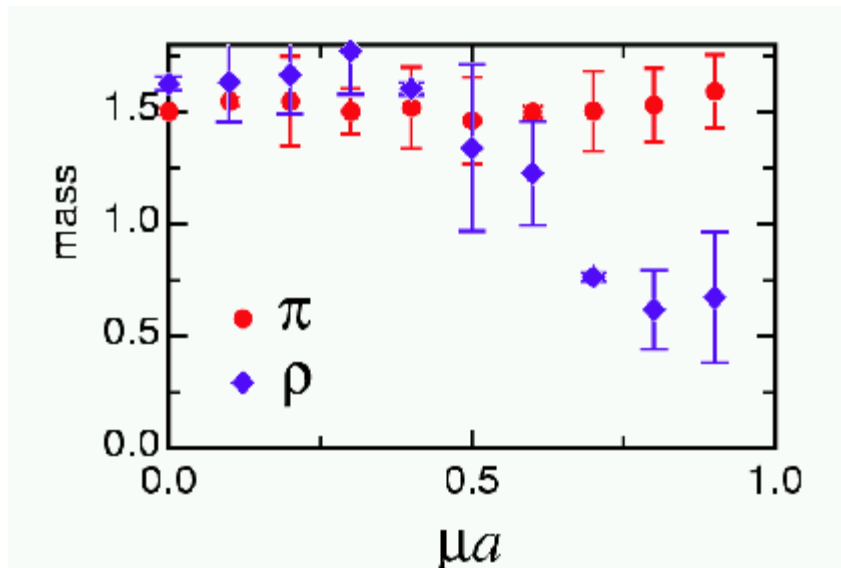
ω



ϕ

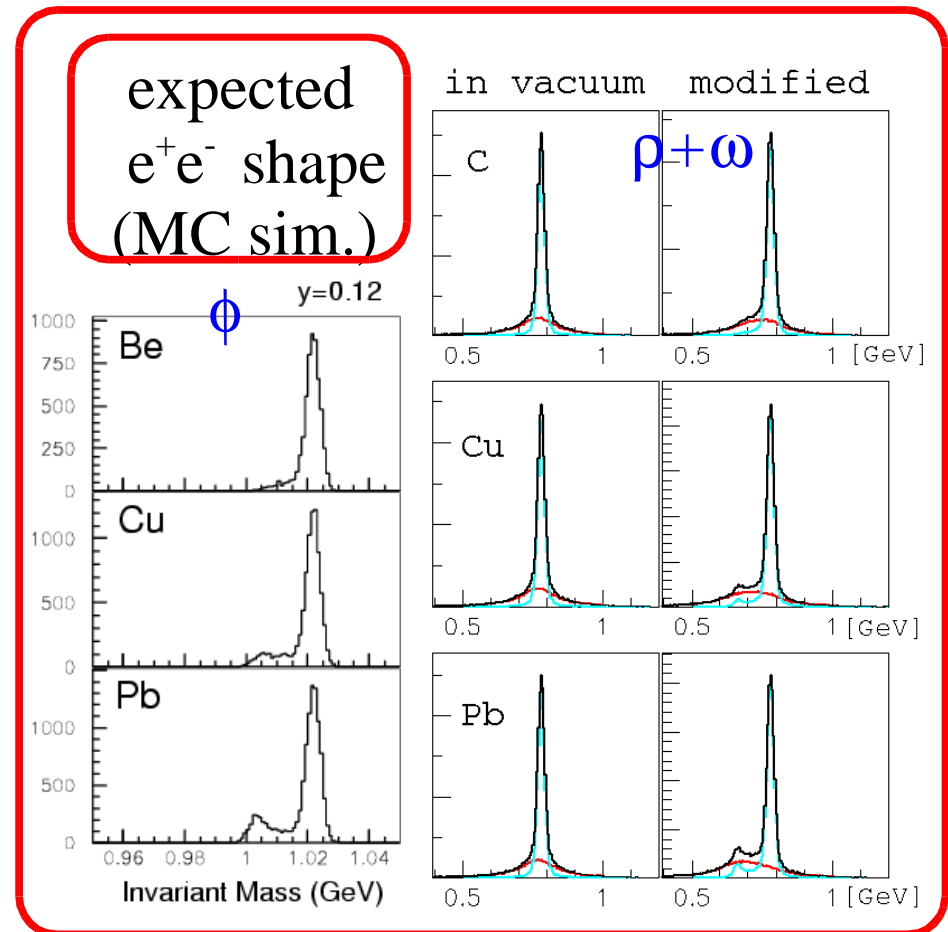
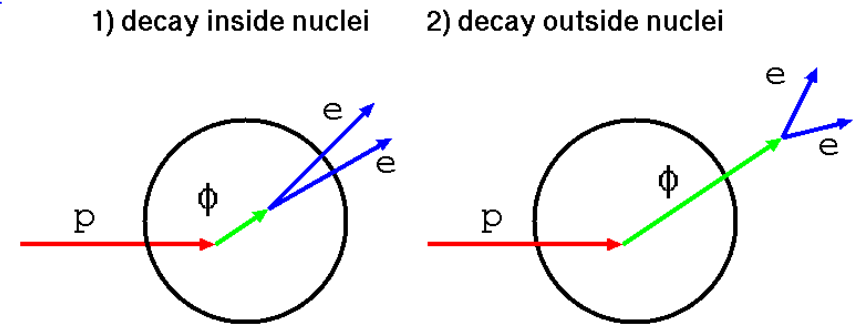


Muroya, Nakamura, Nonaka, 03



Expected 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 ρ and ϕ
 - ρ (770) & ω (783) :
 - larger production cross section
 - larger decay prob. inside nuclei
 - cannot distinguish ρ & ω in e^+e^-
 - ϕ (1020) : narrow width
 - smaller decay prob. inside nuclei
 - smaller production cross section



Experiment KEK-PS E325

- 12GeV $p+A \rightarrow \rho/\omega/\phi + X$ ($\rho/\omega/\phi \rightarrow e^+e^-$, $\phi \rightarrow K^+K^-$)
- 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 \rightarrow **10^6 Hz interaction**)
 - Large acceptance spectrometer to detect **slowly moving** mesons, which have larger probability decaying inside nuclei ($1 < \beta\gamma < 3$)

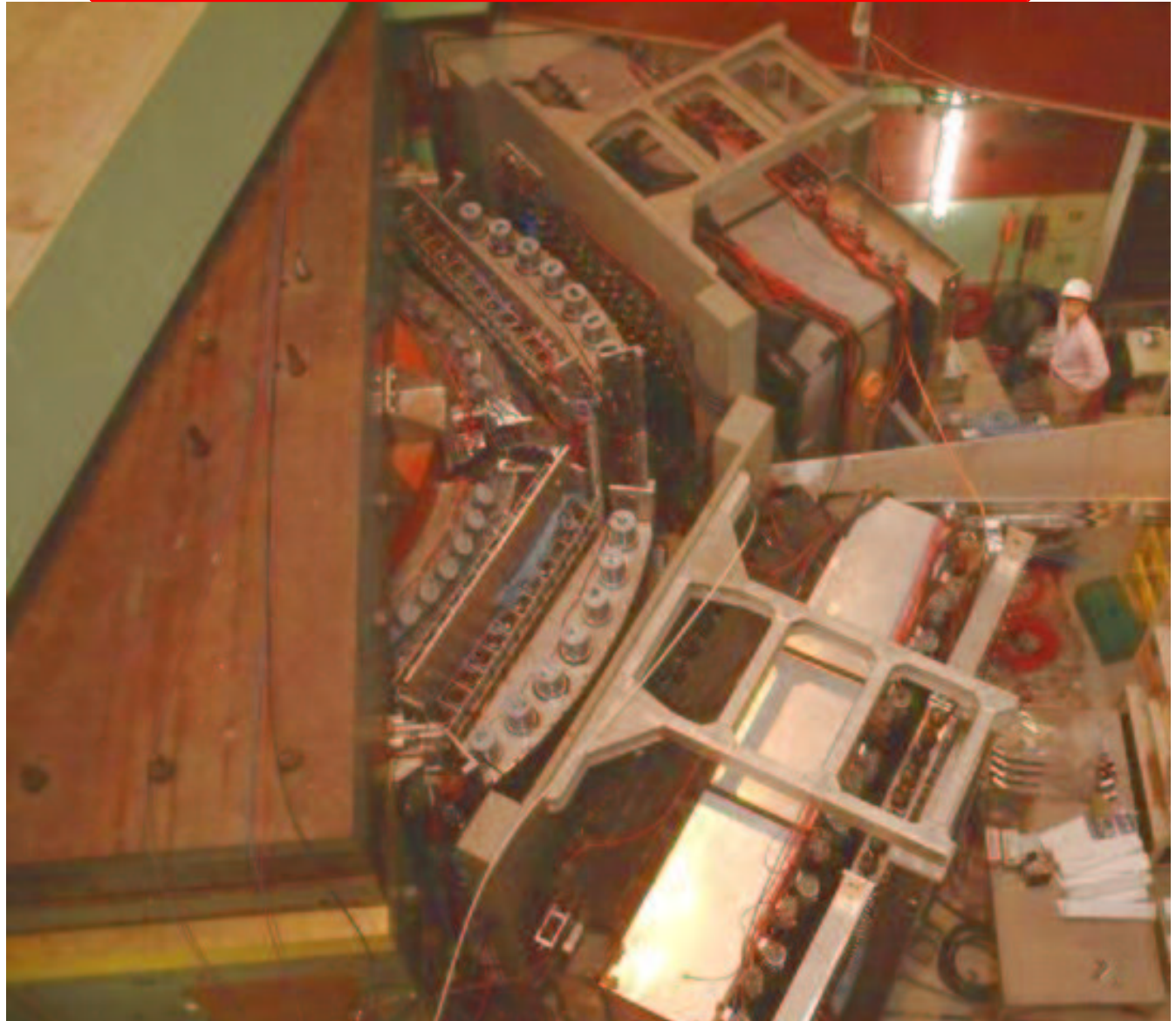
Collaboration

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(Cont'd)

- **History of E325**
 - 1996 const. start
 - '97 data taking start
 - '98 first ee data
 - [PRL86\(01\)5019](#)
 - 99,00,01,02....
 - x100 statistics
 - **presented today**
 - '02 completed
 - spectrometer paper
 - [NIM A516\(04\)390](#)

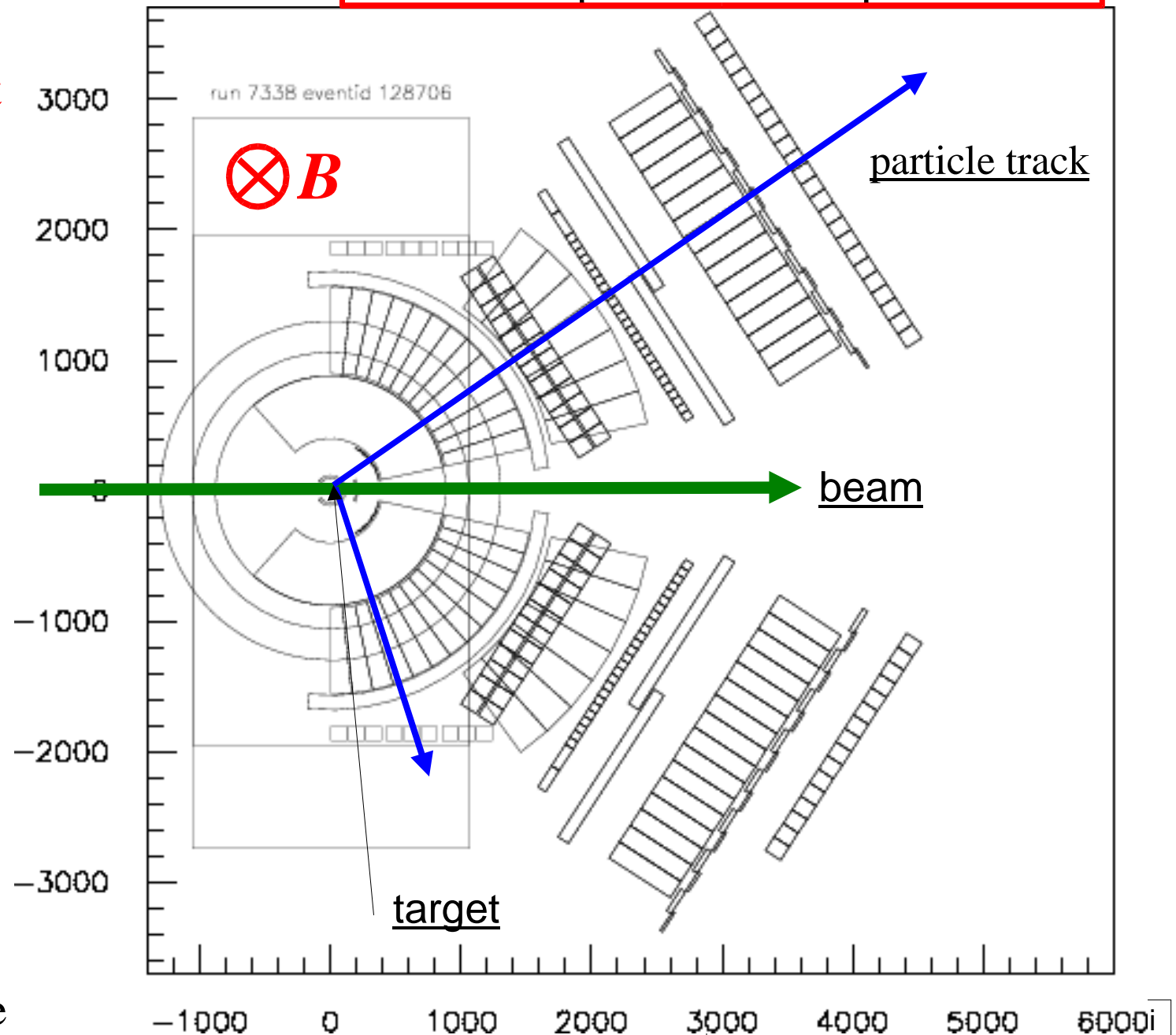
E325 spectrometer
located at KEK-PS EP1-B primary beam line



Experimental setup

schematic plan view of spectrometer

- **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: $\sim 0.1\%$ interaction length
- **Primary proton beam**
 - 12.9 GeV/c
 - $\sim 1 \times 10^9$ in 2sec duration, 4sec cycle



Experimental setup - Detectors

Electron ID counters

Gas Cherenkov &
Lead Glass EMC

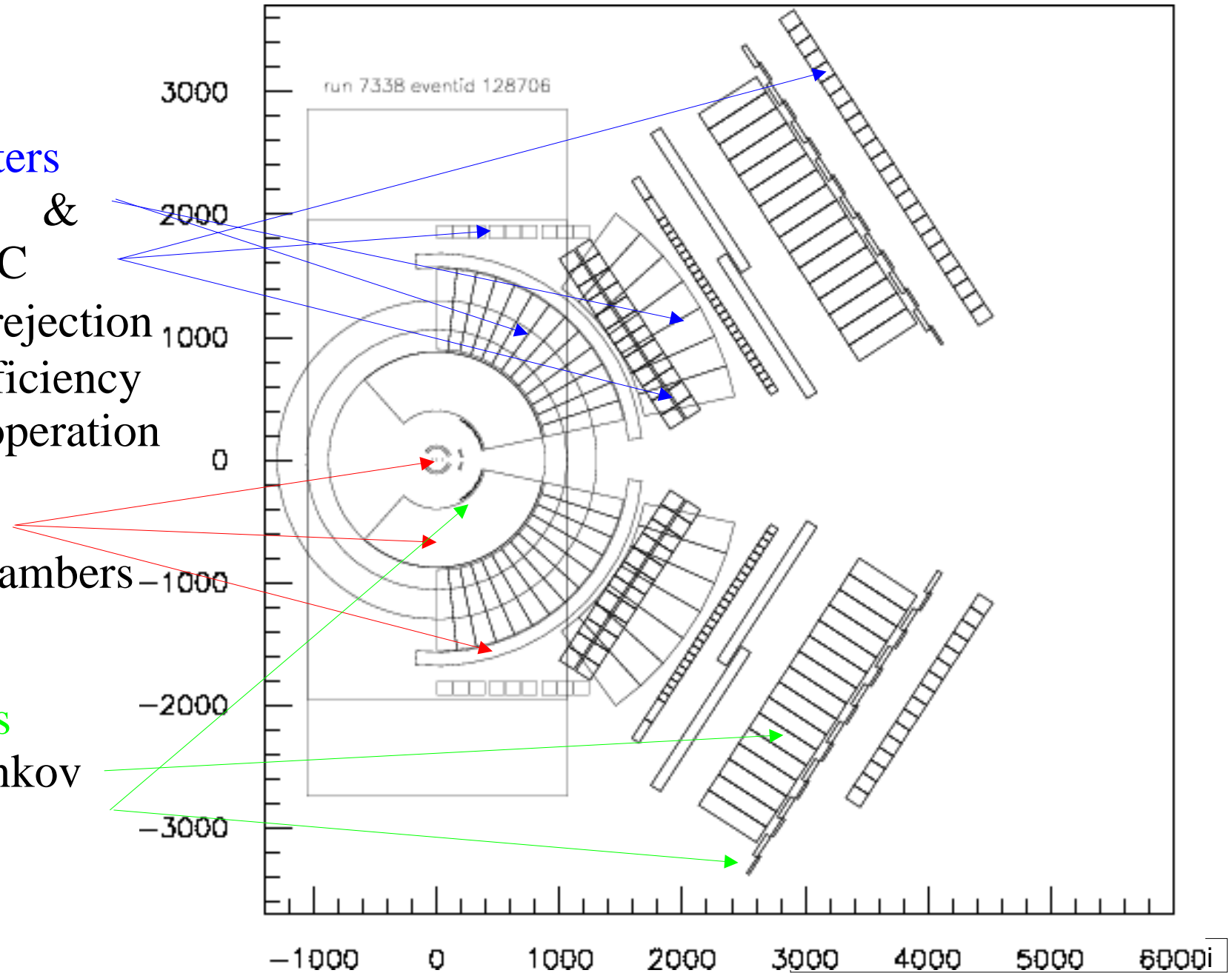
total 3×10^{-4} π rejection
with 78% e efficiency
in two-stage operation

Tracker

Three Drift Chambers

Kaon ID counters

Aerogel Cherenkov
& TOF

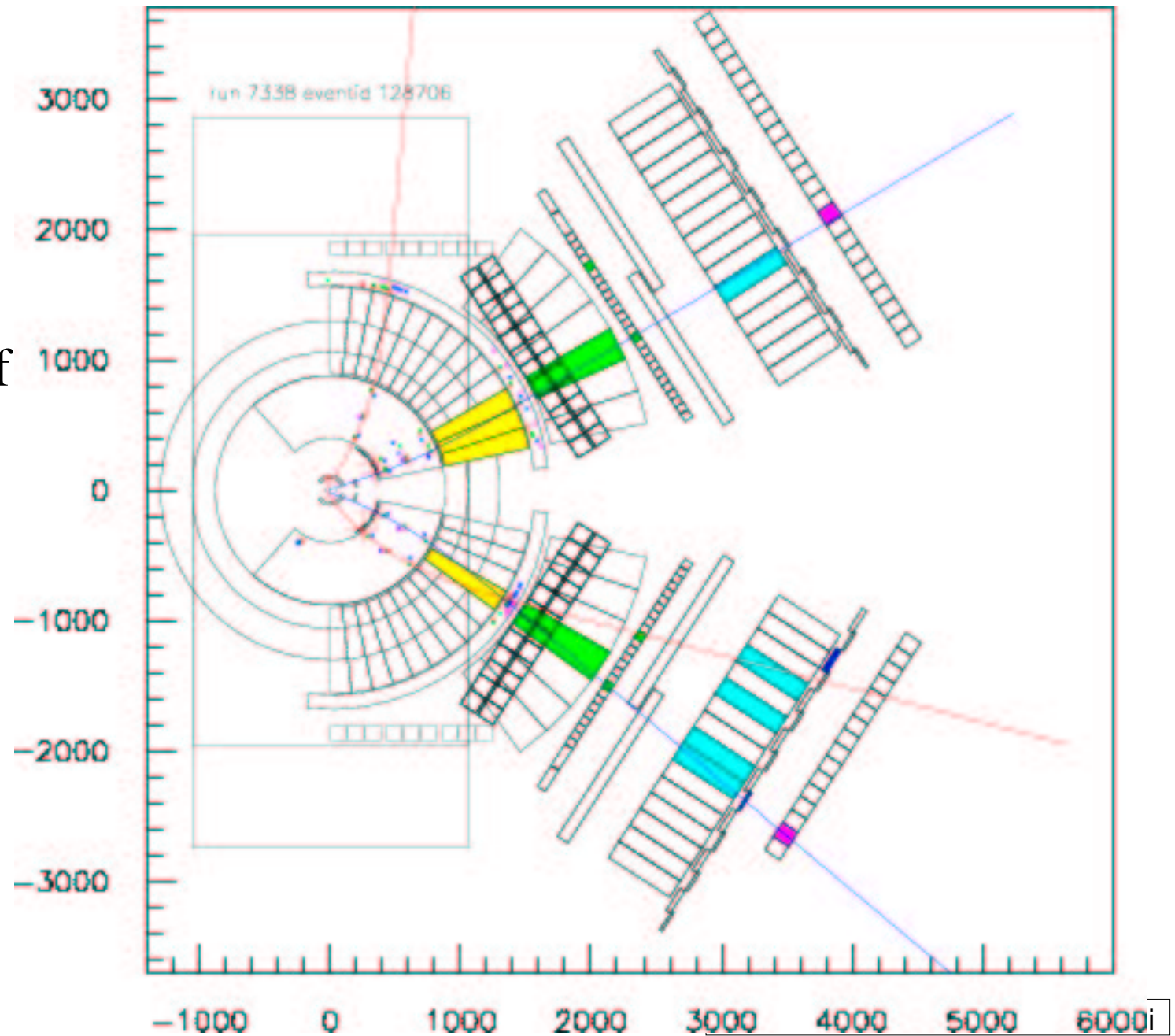


- Typical e^+e^- Event

- blue:electron

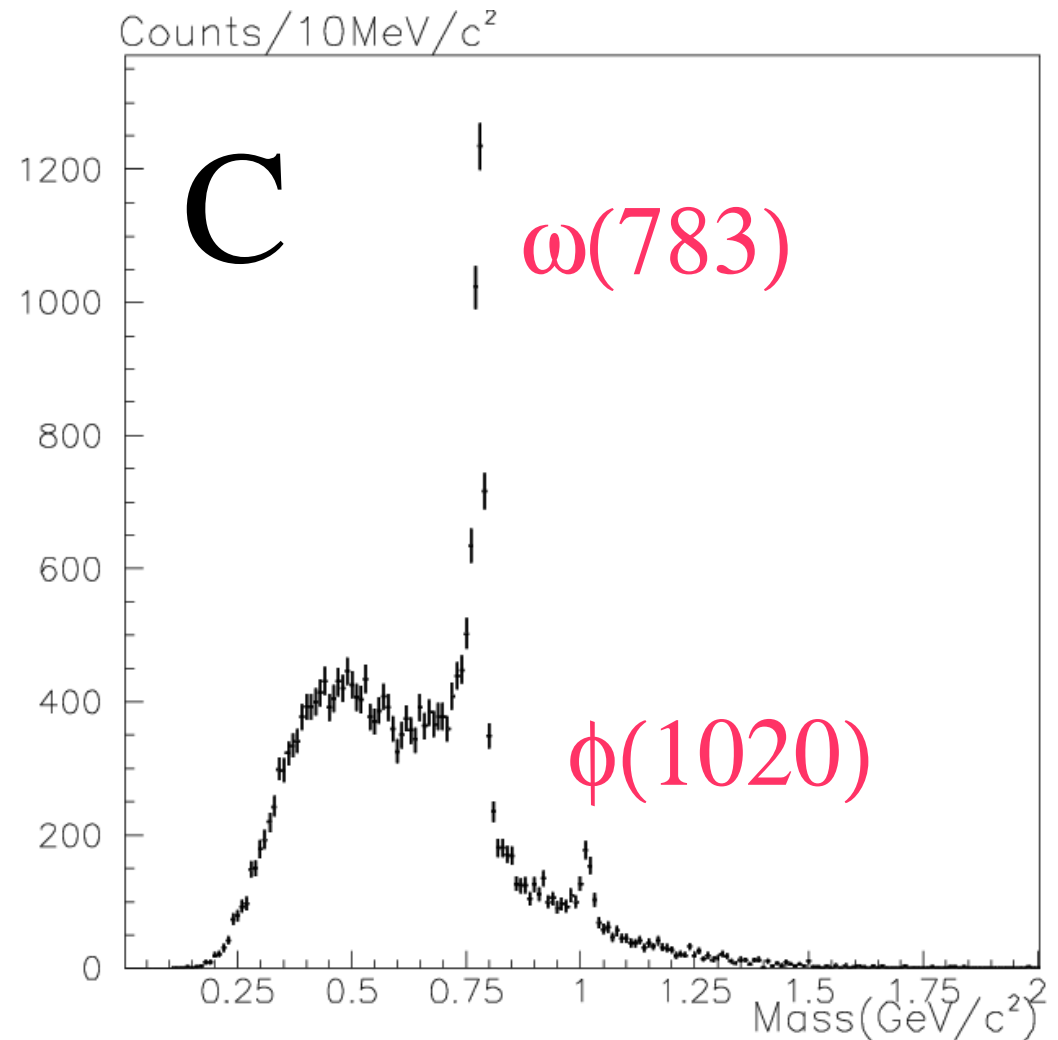
- red : other

- invariant mass of electron pair is calculated



Observed e^+e^- invariant mass spectra

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

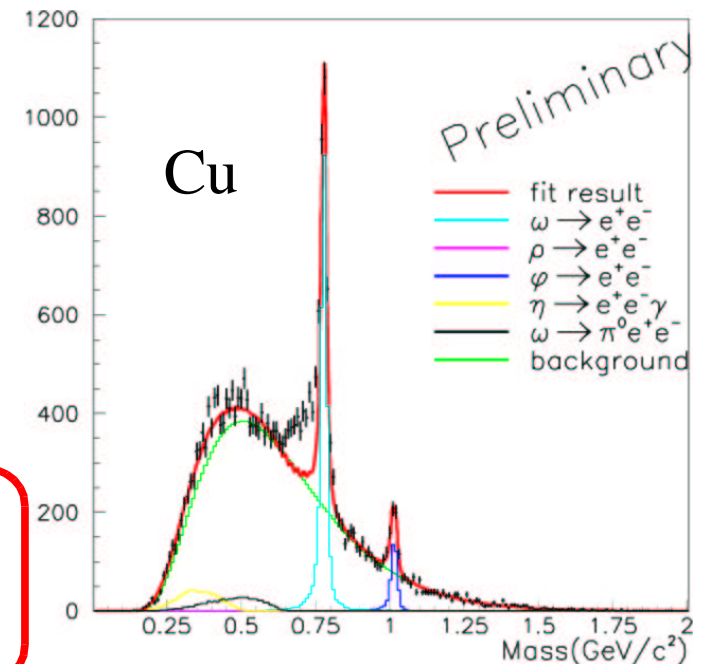
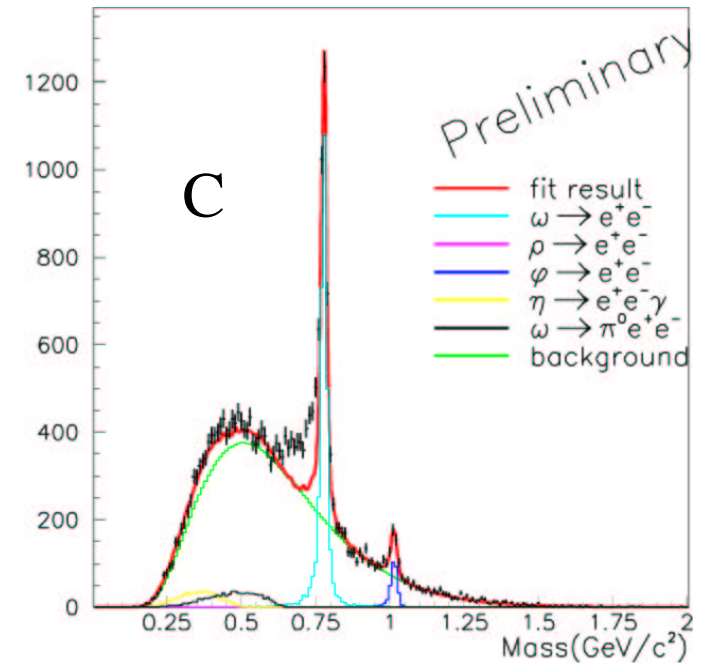


Fitting with known sources

- Hadronic sources of e^+e^- :
 - $\rho/\omega/\phi \rightarrow e^+e^-$, $\omega \rightarrow \pi^0 e^+e^-$, $\eta \rightarrow \gamma e^+e^-$
 - 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 the fitting

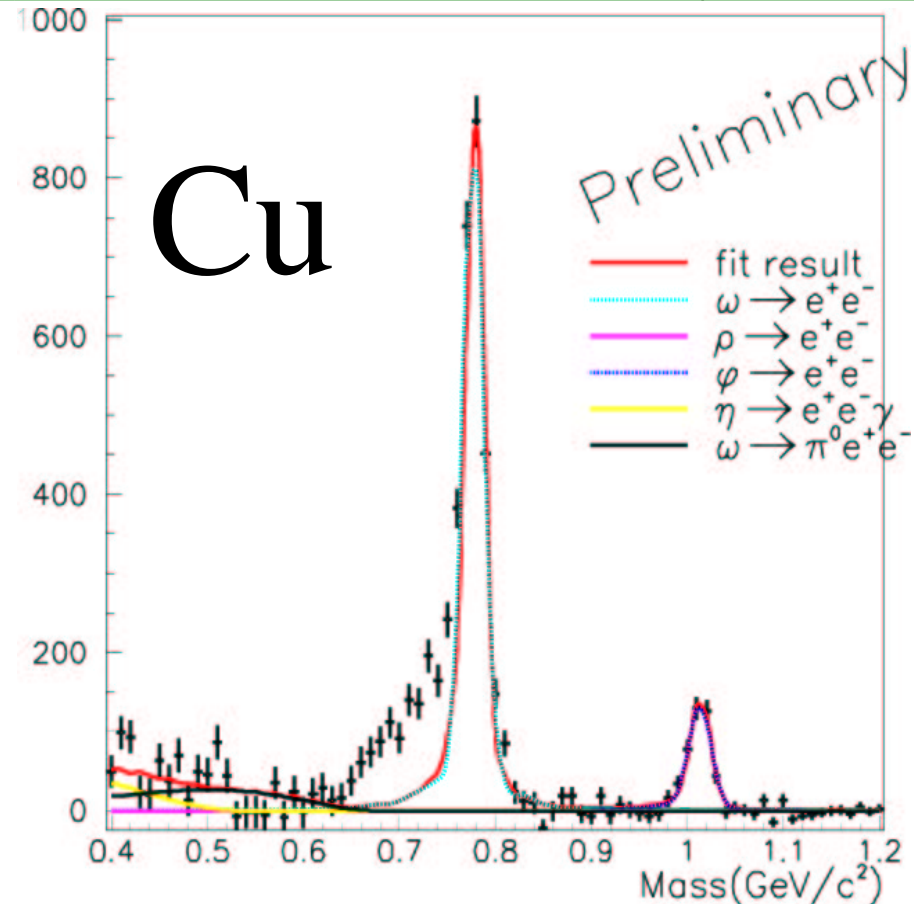
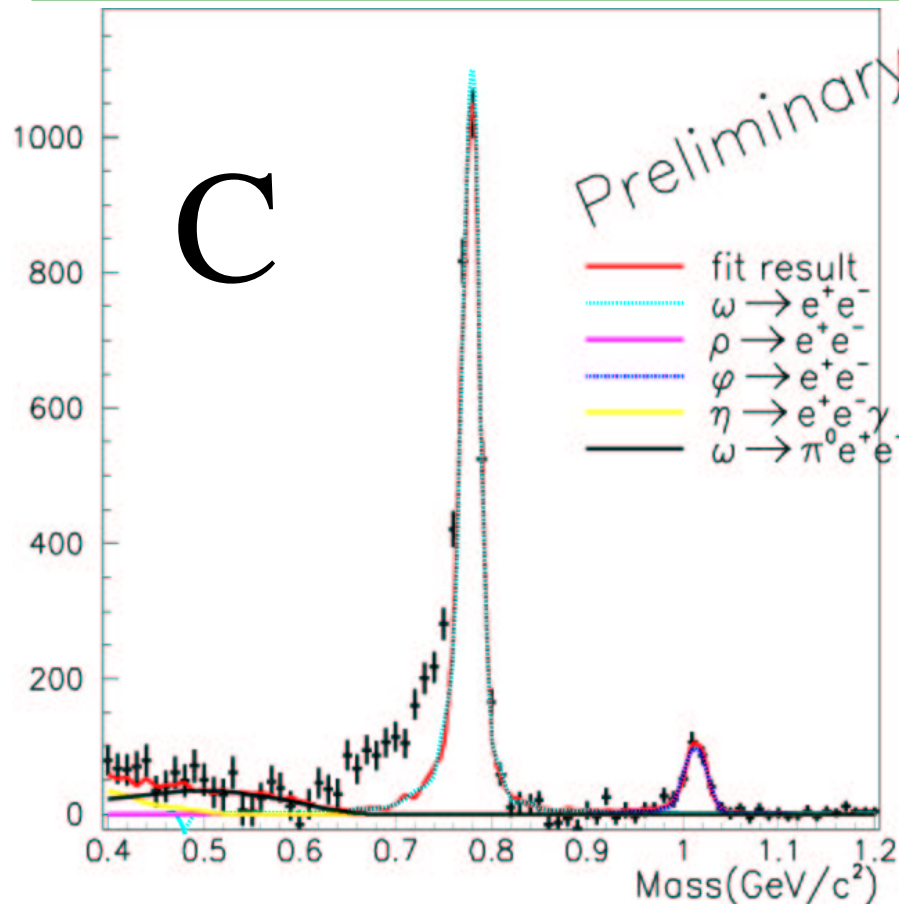


- **excess** at the low-mass side of ω (0.6~0.75 GeV)
- ρ -meson component seems to be **vanished** !



Fitting results (BKG subtracted)

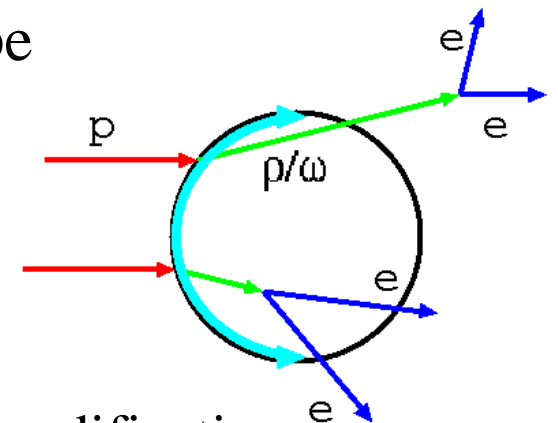
$$\rho/\omega = 0.0 \pm 0.01(\text{stat.}) \pm 0.2(\text{sys.}) , \quad 0.0 \pm 0.05(\text{stat.}) \pm 0.5(\text{sys.})$$



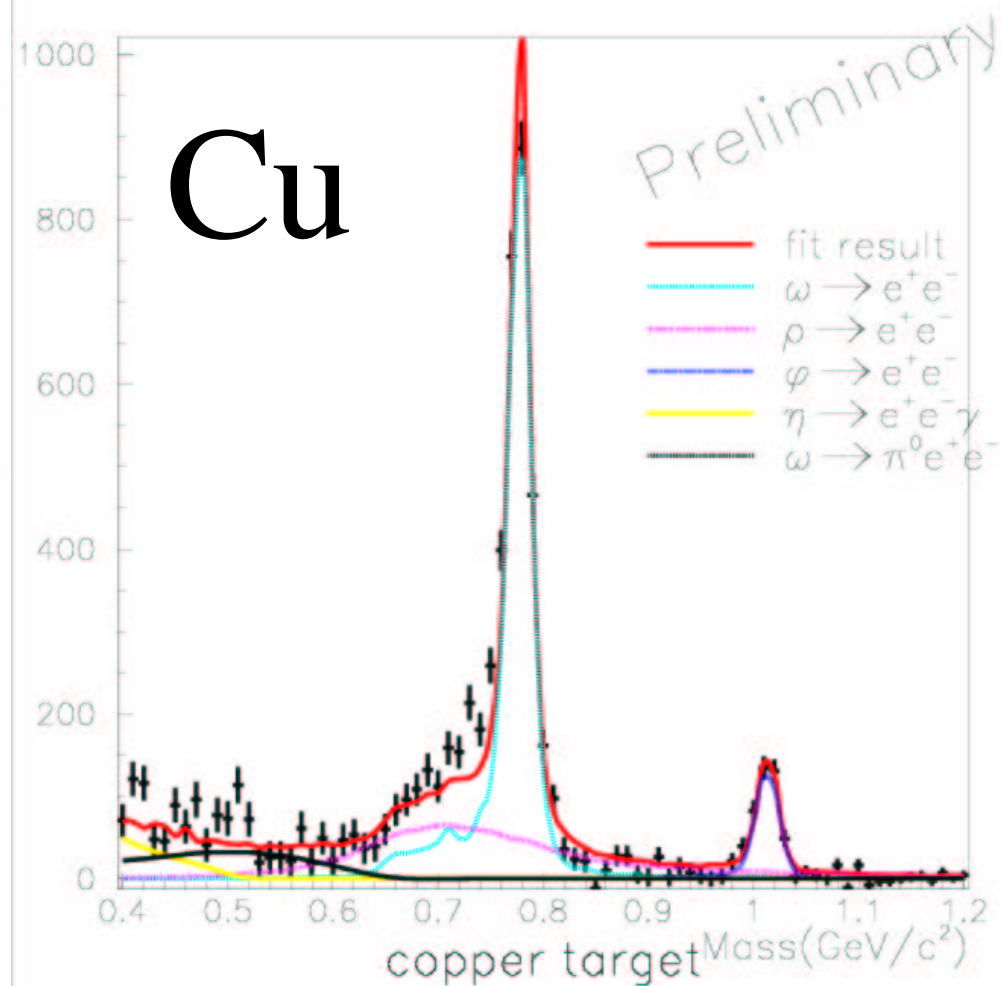
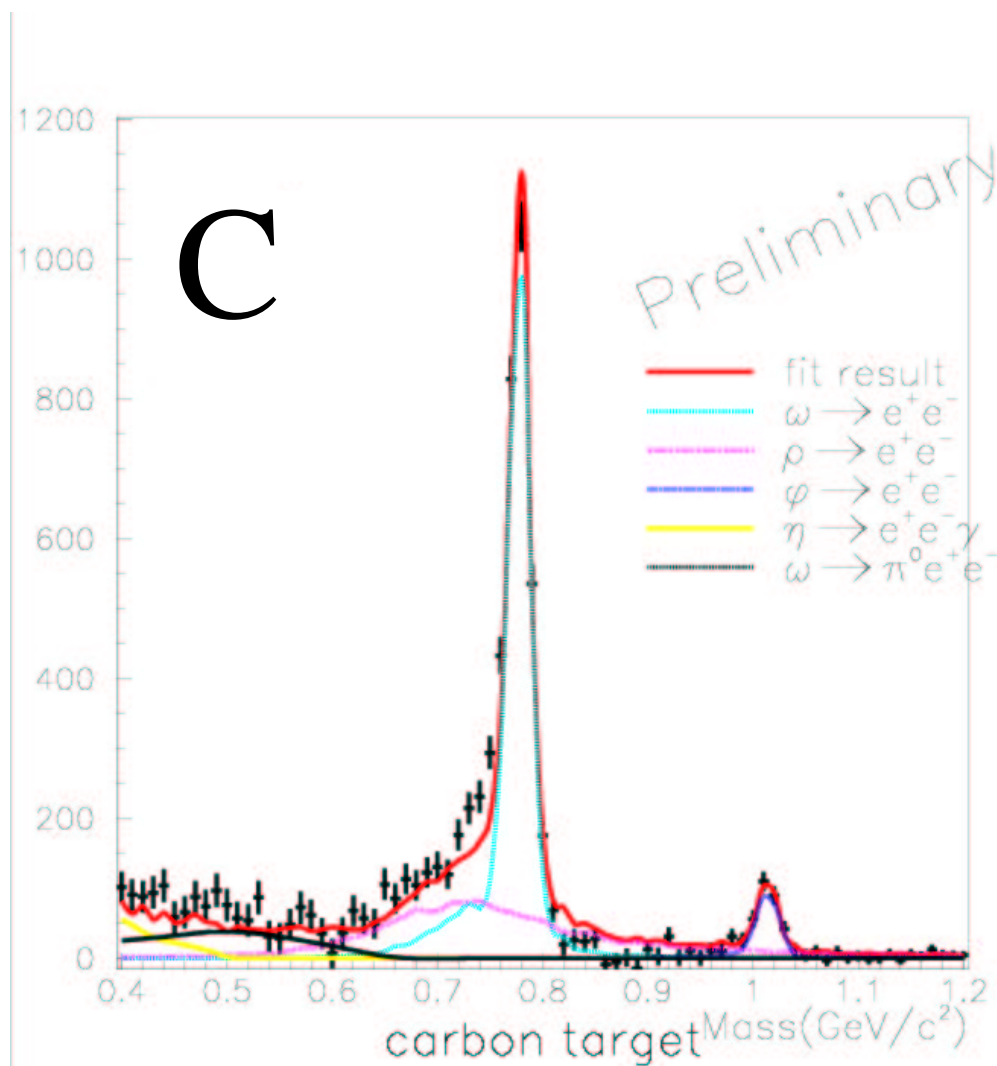
- However, $\rho/\omega \sim 1$ in former experiment (p+p, 1974)
..... suggests the excess is from modified ρ mesons?

Discussion: Toy model including modification

- Assumptions to include the nuclear size effect in the fitting shape
 - meson fly through the nucleus, decay with modified mass if the decay point is inside nuclei
 - meson production point : incident **surface** of nuclei
 - meson momentum : measured distribution in our experiment
 - nuclear density distribution : **Woods-Saxon** type
 - - 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.

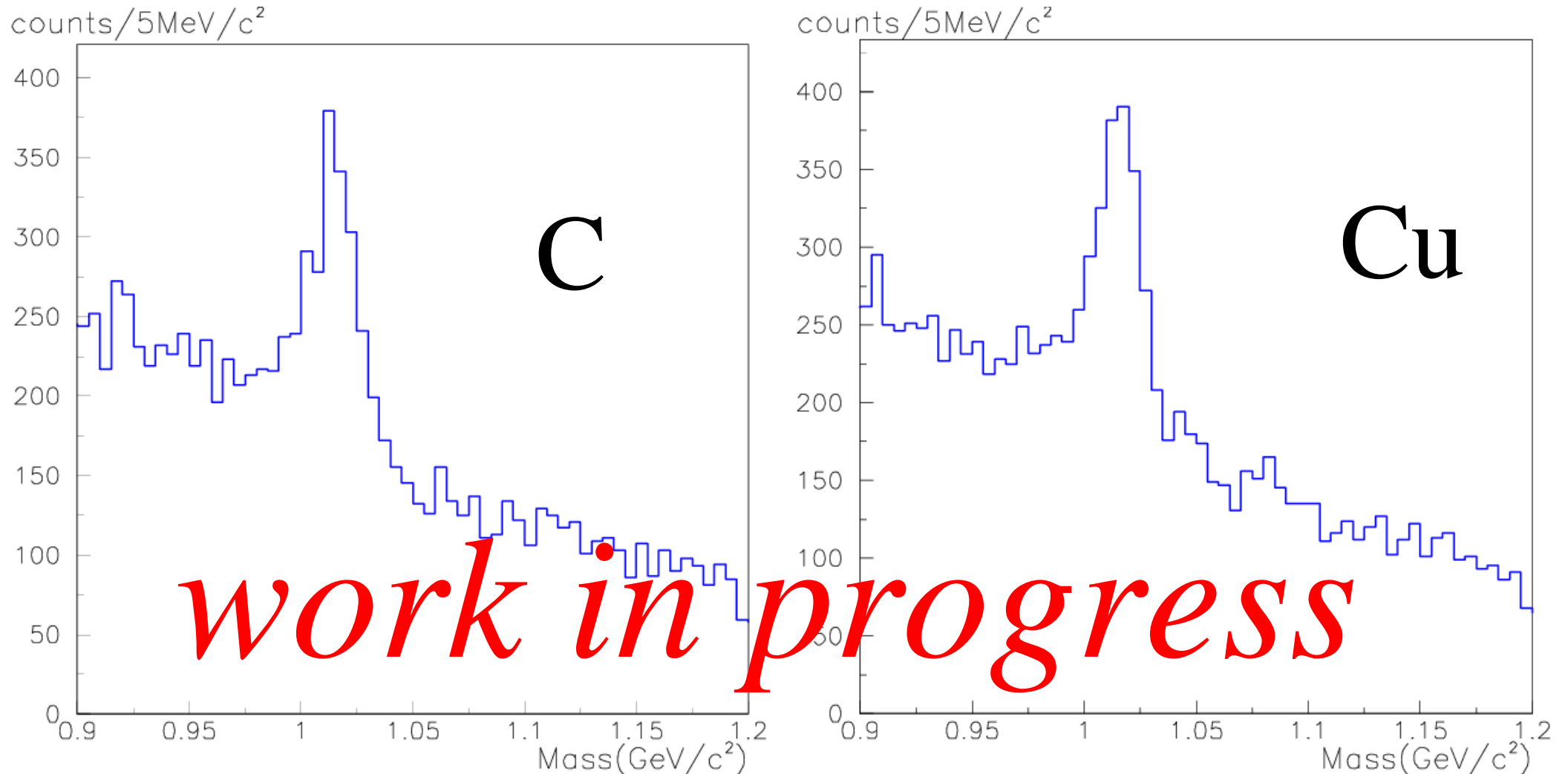


Fitting results by the toy model



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

e^+e^- spectra of ϕ meson



- Clear peak is already seen, ~ 1000 ϕ s for each target
- precise analysis is on going

Summary

- KEK-PS E325 measured the e^+e^- (& K^+K^-) decay of slowly moving vector mesons in nuclei produced by 12-GeV 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** (e^+e^- & K^+K^-) is also on going.