

# In-medium mass modification of vector mesons at normal nuclear density

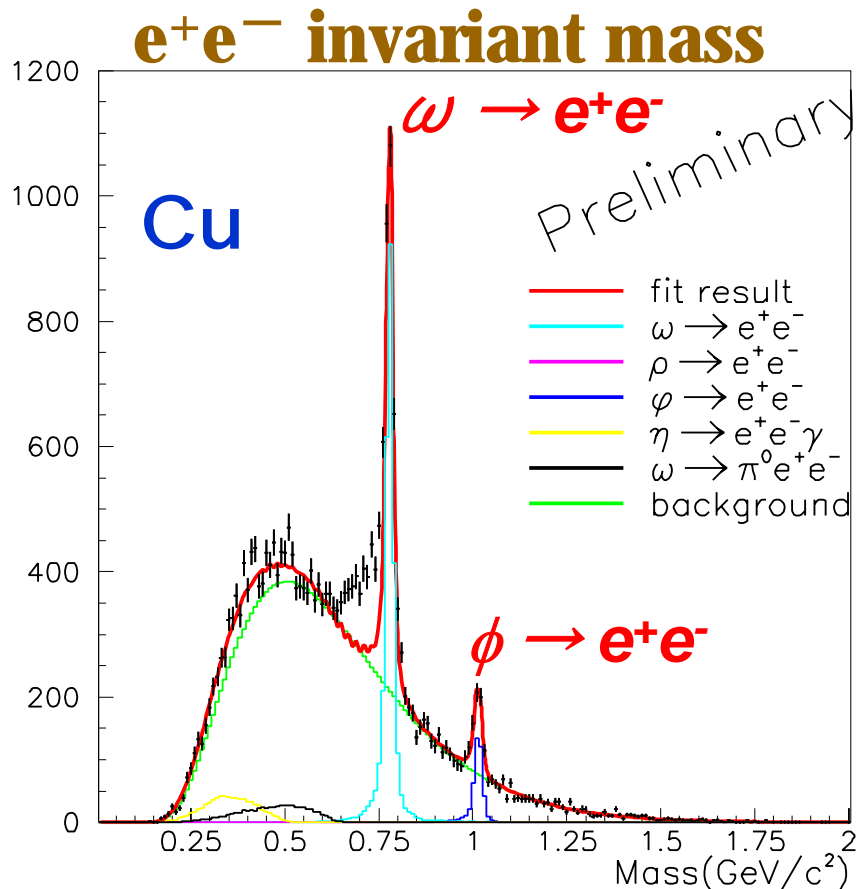
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(KEK-PS *E325* Collaboration)

# Abstract (KEK-PS E325)

We have measured  $e^+e^-$  and  $K^+K^-$  invariant mass spectra to investigate in-medium mass modification of vector mesons in  $12\text{GeV } p + A \rightarrow \rho, \omega, \phi + X$  reactions.

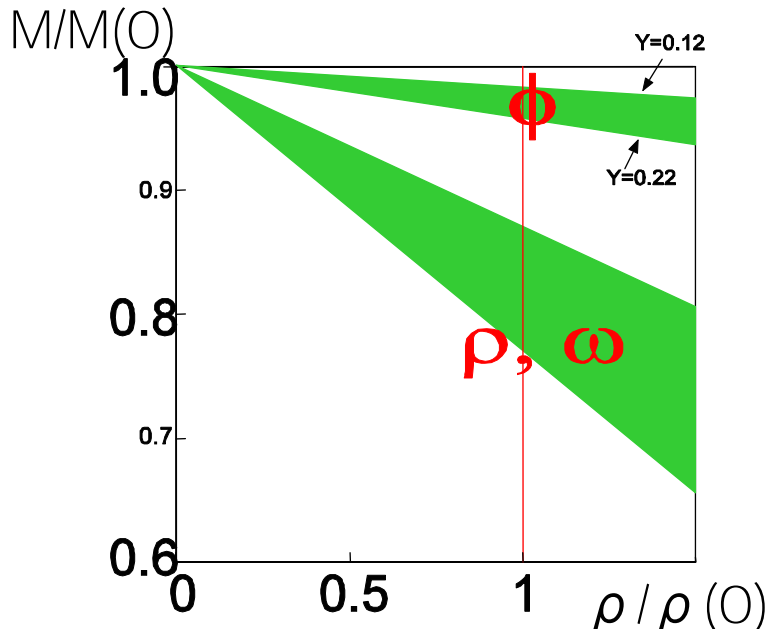
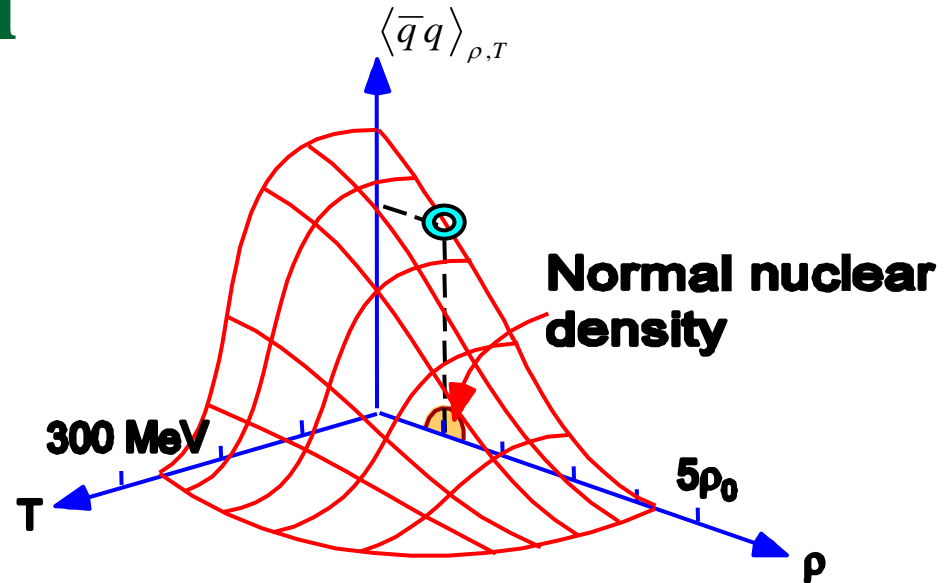


## -Contents-

- Physics Motivation
- Preliminary Result of 2002 data analysis
- Model Calculation

# Physics Motivation

*Spontaneous Breaking  
of Chiral Symmetry*



## Vector Meson Mass

- $\rho, \omega$ 
  - large mass modification at  $\rho = \rho_0 : 150\text{MeV}$
- $\phi$ 
  - small decay width ( $4.4\text{MeV}/c^2$ ) sensitive to mass modification

# Density Dependence

## ■ Mass Shift

- $m^*/m = 1 - 0.16 \rho / \rho_0$  by Hatsuda & Lee
- $m^*/m \approx 0.8$  at  $\rho = \rho_0$ : Brown-Rho scaling

## ■ Spectral Modification

- enhancement below  $\rho$  by Klingl, Kaiser, Weise
  - $\rho$ : small mass shift  $\sim 5\%$ , large width broadening  $\sim 10 \Gamma_0$
  - $\omega$ : small mass shift  $\sim \%$ , no width modification
  - $\phi$ : small mass shift  $\sim 2\%$ , low mass enhancement

# Related Experiments

- CERES
  - 158A GeV Pb – Au collisions
  - $e^+e^-$  spectrum modification
- TAGX@INS
  - $A(\gamma \pi^+ \pi^-)X$  ;  $A=^2\text{H}, ^3\text{He}, ^{12}\text{C}$
  - $\rho \rightarrow \pi^+ \pi^-$  spectrum modification
  - final state interaction, sub threshold production...
- RHIC
  - 200 GeV Au – Au collisions
  - $e^+e^-$ ,  $K^+K^-$  channels

# Expected Signal

In 12GeV  $p + A \rightarrow \rho, \omega, \phi + X$

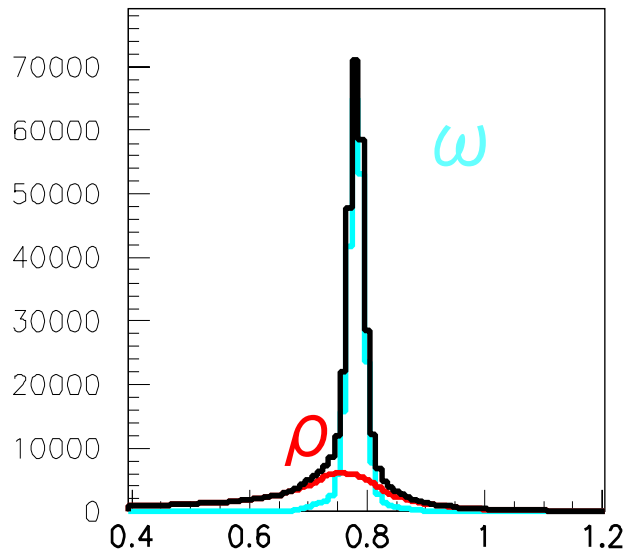
Invariant Mass of  $e^+e^-$ ,  $K^+K^-$

mass modified by the formula

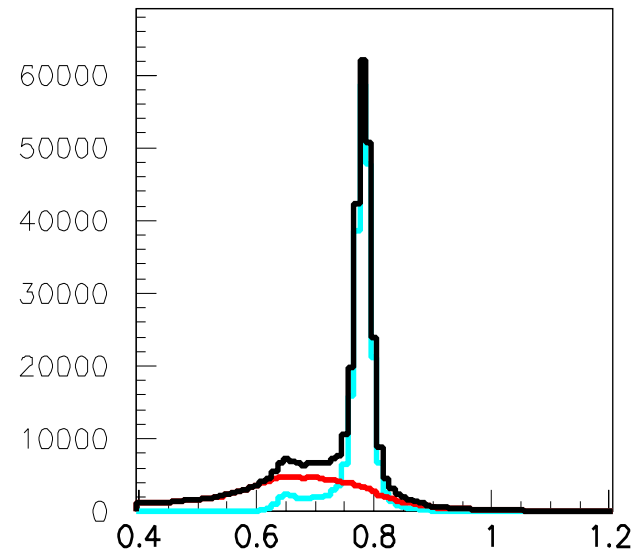
$$m^*/m = 1 - 0.16\rho/\rho_0$$

Prog.Theor.Phys.95(1996)1009

## Expected Invariant Mass distribution of $\rho$ and $\omega$



**Decay in vacuum**

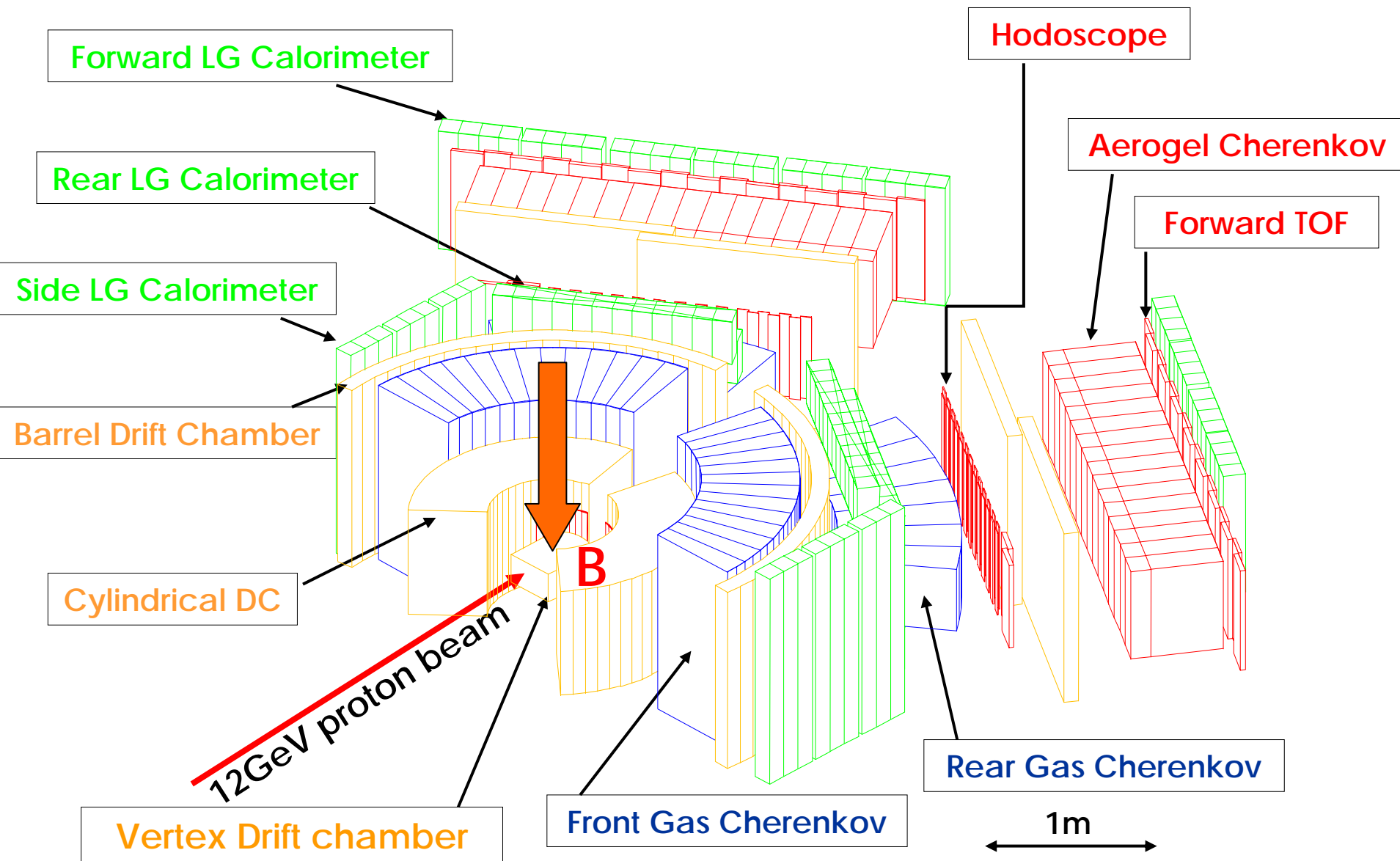


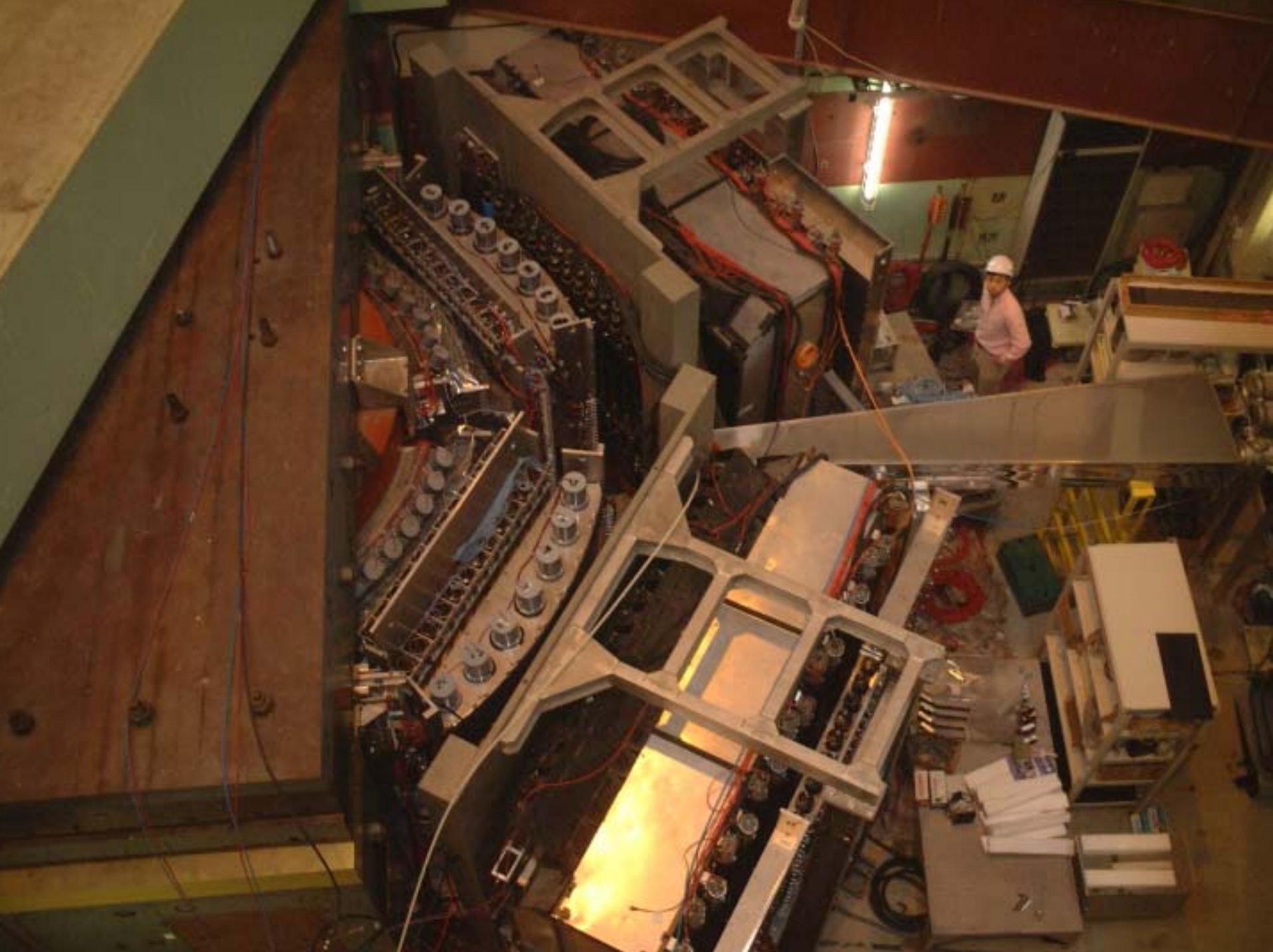
**In Copper Nuclei**

Slowly moving  $\rho, \omega, \phi$  ( $p_{\text{lab}} \sim 2\text{GeV}/c$ )

→ Large Acceptance Spectrometer

# Experimental Setup



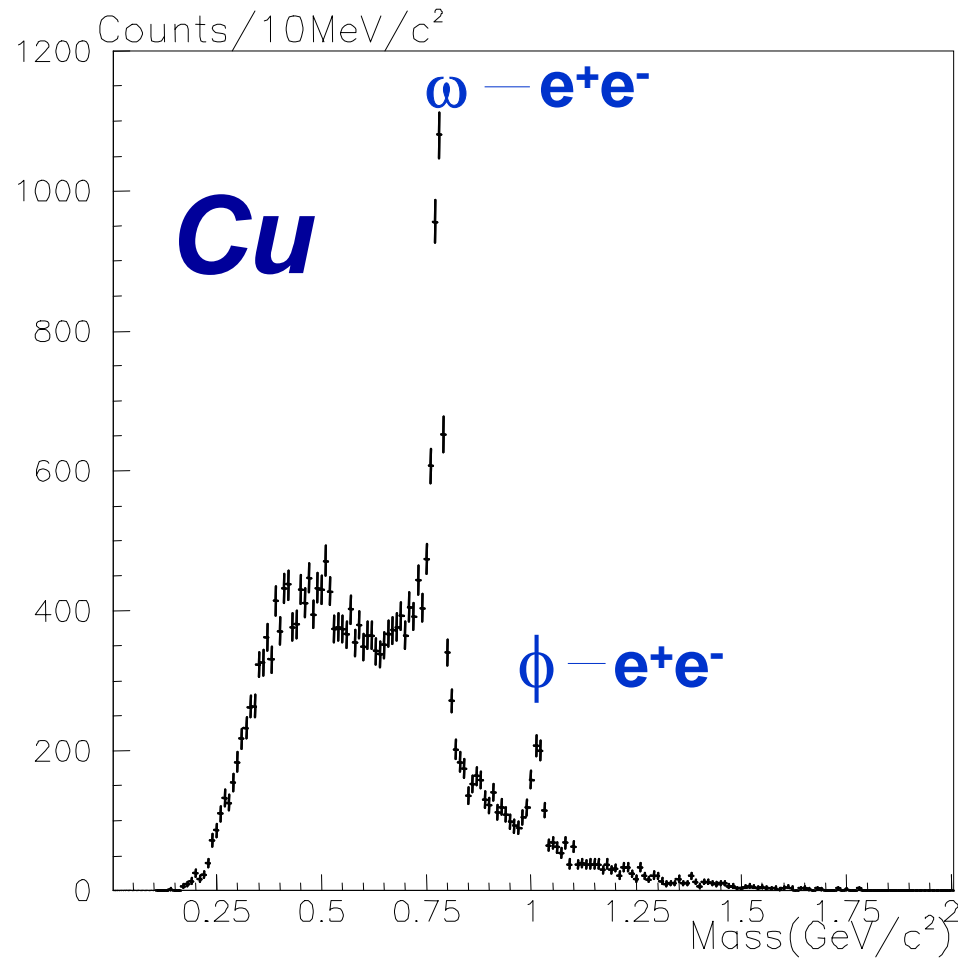
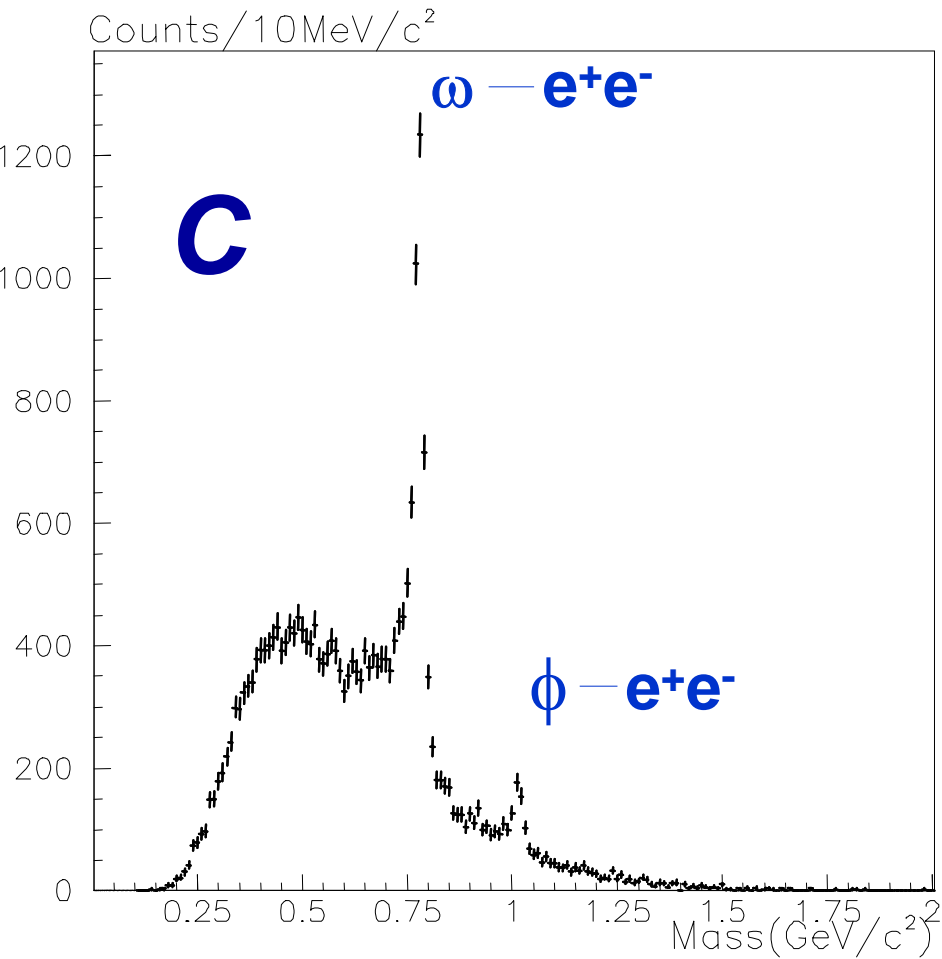




# History

		$\phi \rightarrow K^+K^-$	$\omega \rightarrow e^+e^-$ $\phi \rightarrow e^+e^-$
1997 June	First Physics Run with $K^+K^-$	99	
1998 May	Already Published (P.R.L. 86 (2001) 5019 )		95 12
1999 July	Hawaii JPS/QM2002/PANICO2	178	$\sim 700$ $\sim 125$
2000 June Dec.	Production Run with newly installed Vertex Chamber & Lead Glass Calorimeter		
2001 Nov.	Production Run		$\sim 4800 \times 2$
2002 Feb.	<b>LAST</b> Production Run	$\sim 570$	$\sim 930 \times 2$

# Invariant Mass Spectrum of $e^+e^-$ (2002 data)

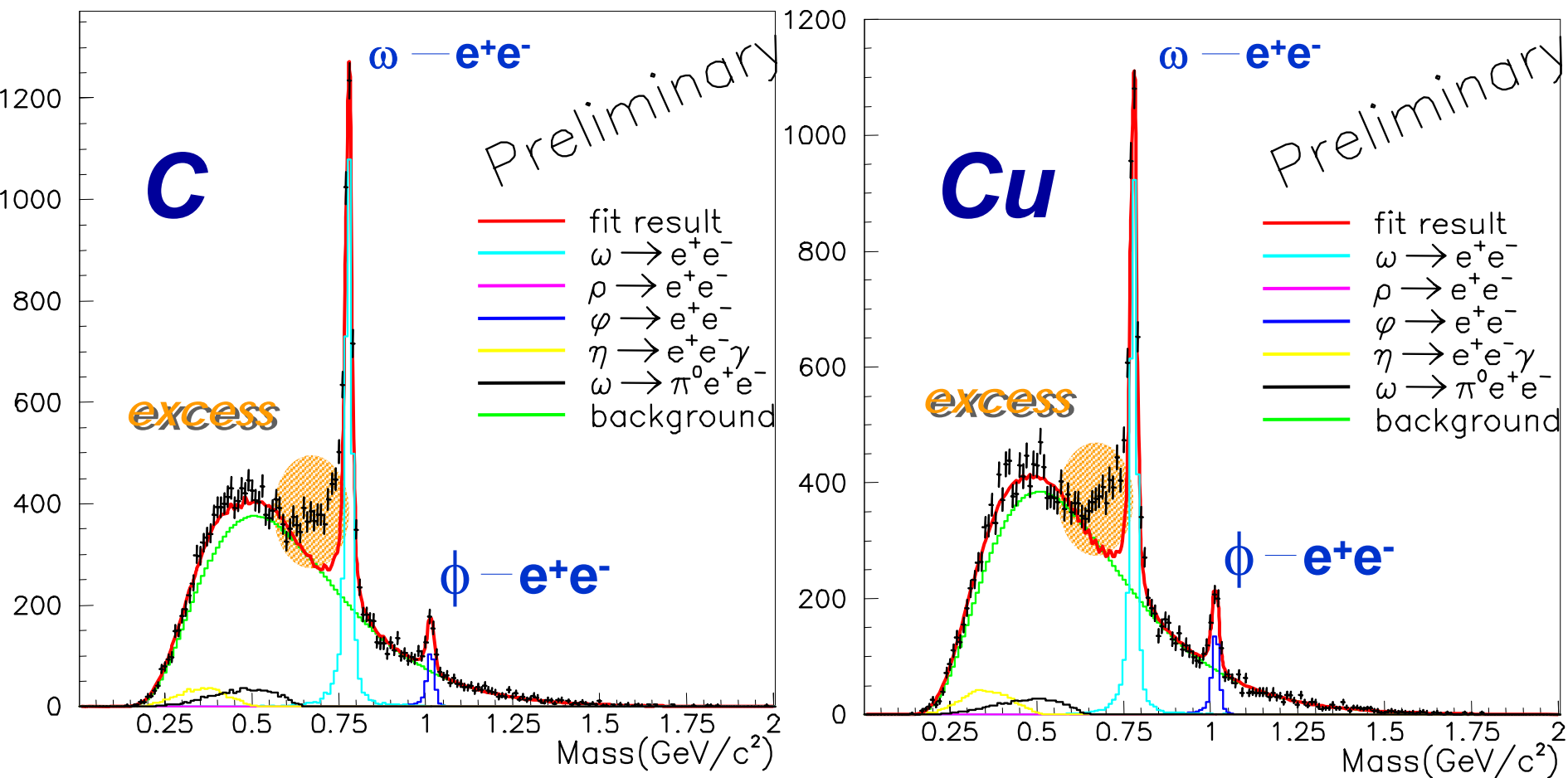


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# On the Fit

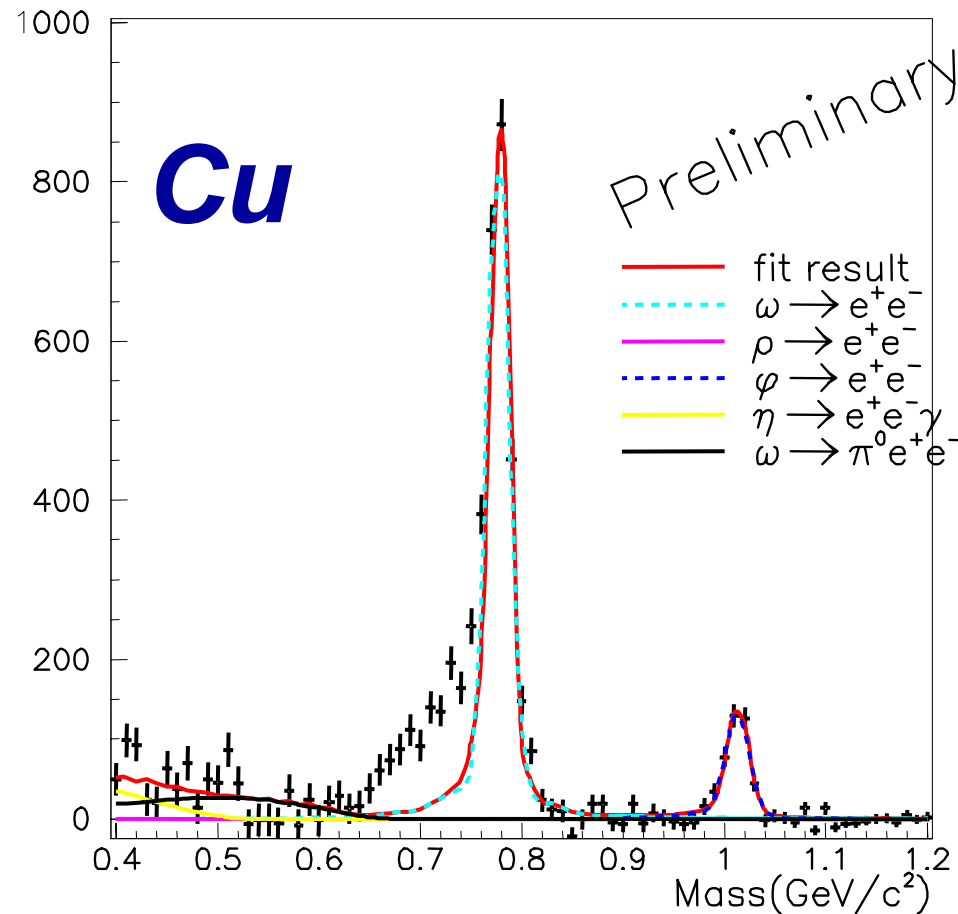
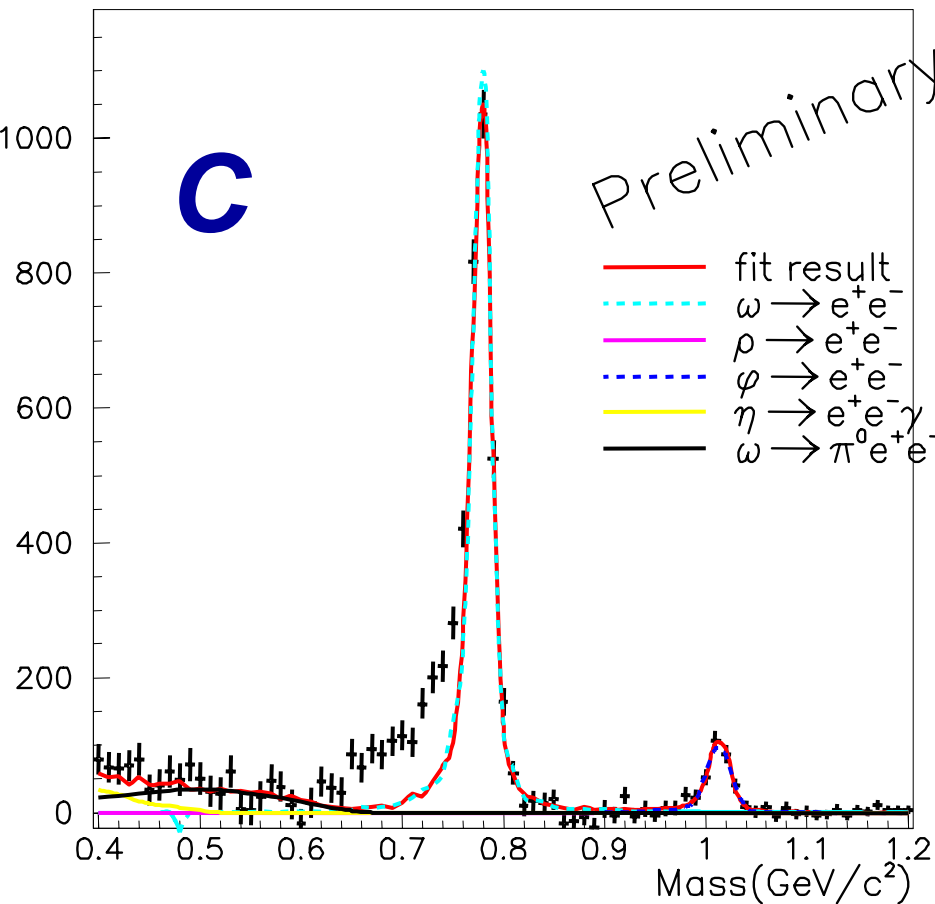
- Resonance
    - Breit-Wigner shape
    - experimental effect estimated by Geant4 simulation – energy loss, mass resolution, mass acceptance etc.
  - Background
    - combinatorial background obtained by mixed events
  - Relative abundances of mesons ( $\rho, \omega, \phi$ ) and background are obtained by the fitting.
-

# Invariant Mass Spectrum of $e^+e^-$ (2002 data)



the **excess over the known hadronic sources** on the low mass side of  $\omega$  peak has been observed.

# Invariant Mass Spectrum of $e^+e^-$ (background subtracted)



**$\rho / \omega$  ratio is consistent with zero**

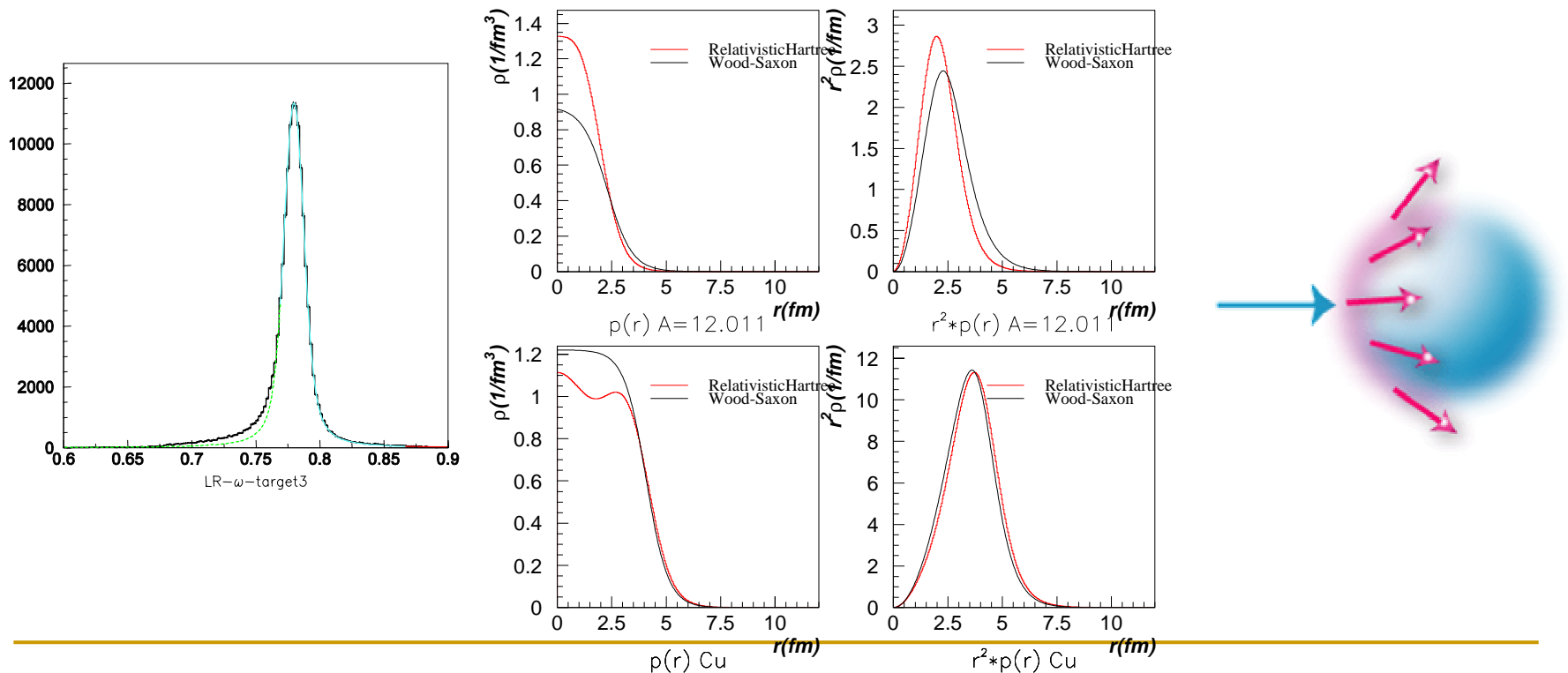
$0.0 \pm 0.01$  (stat.)  $\pm 0.2$  (sys.)

$0.0 \pm 0.05 \pm 0.5$

The excess can be understood as modified  $\rho$  mesons.

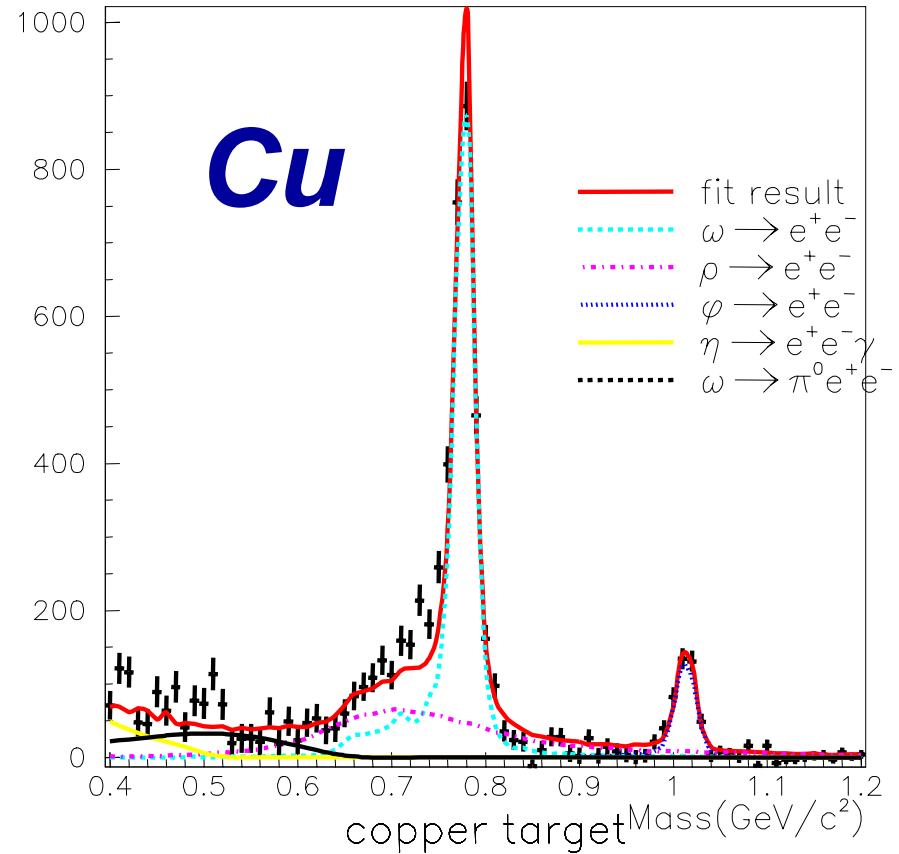
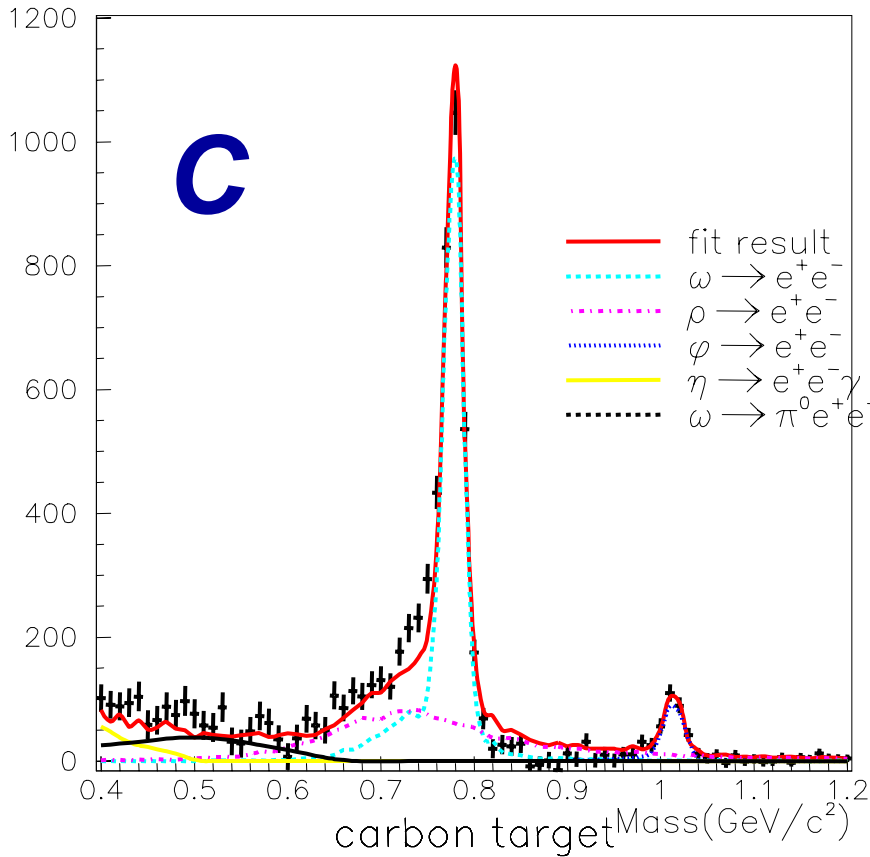
# Model Calculation

- spectral function : Breit-Wigner + Detector Sim. + mass modification.
- mass modification :  $m^*/m = 1 - 0.16 \rho^*/\rho$
- density distribution : Woods-Saxon
- generate on surface of forward hemisphere of the nucleus



# Model Calculation

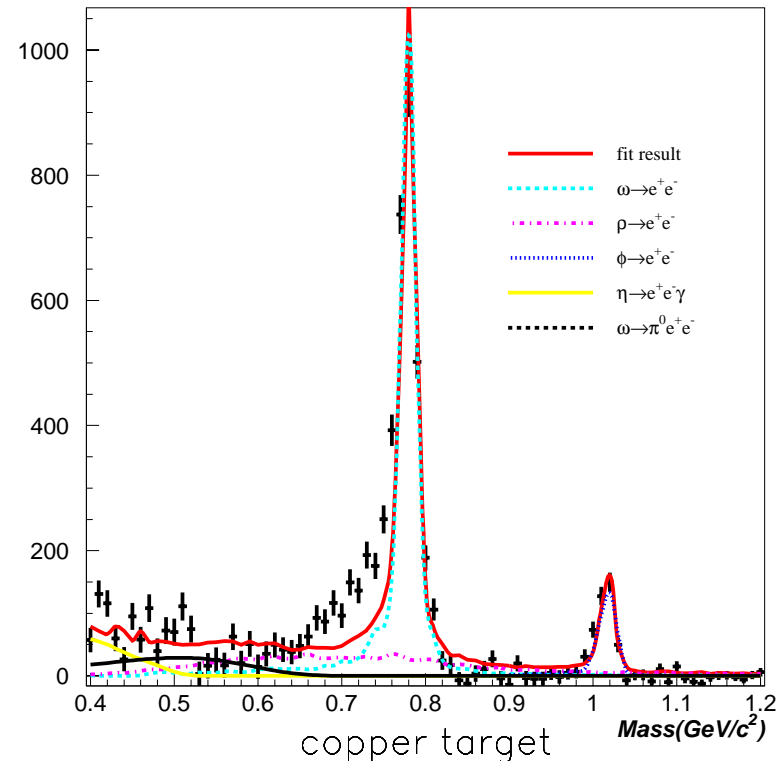
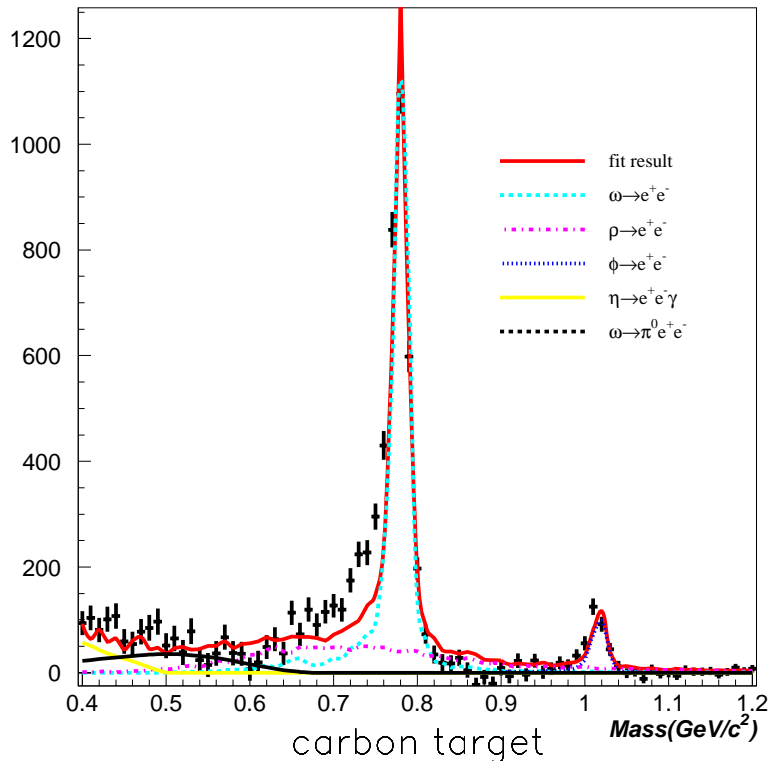
With the formula :  $m^*/m=1-0.16\rho/\rho_0$



# Model Calculation

With the formula :  $m^*/m=1-0.32\rho/\rho_0$

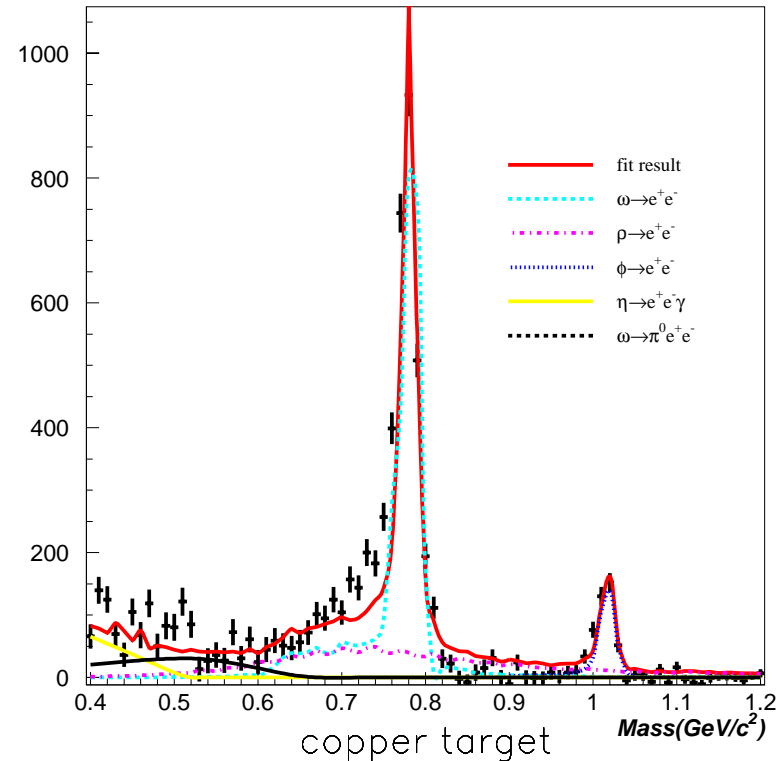
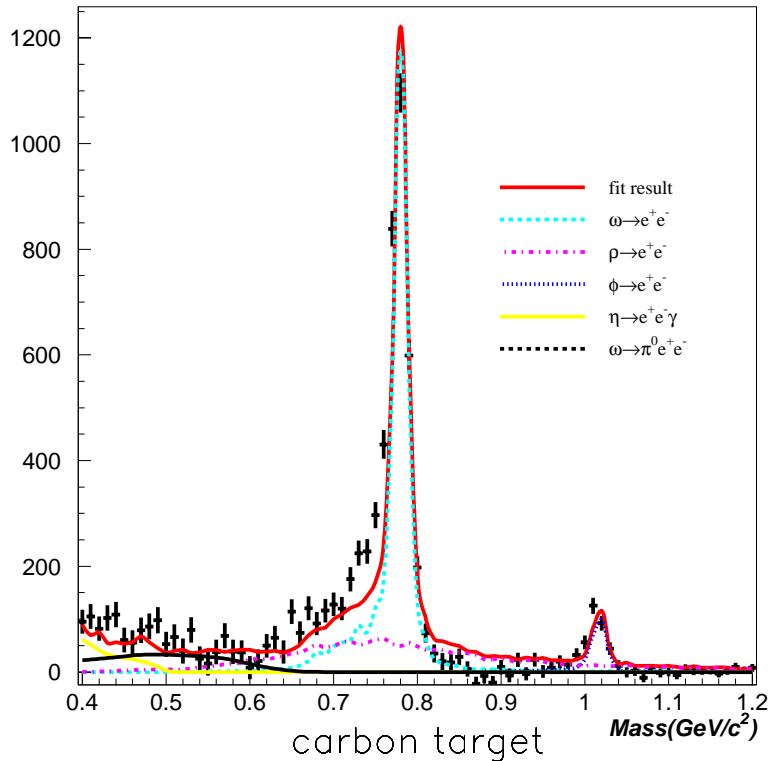
- rho spectrum is too broad.





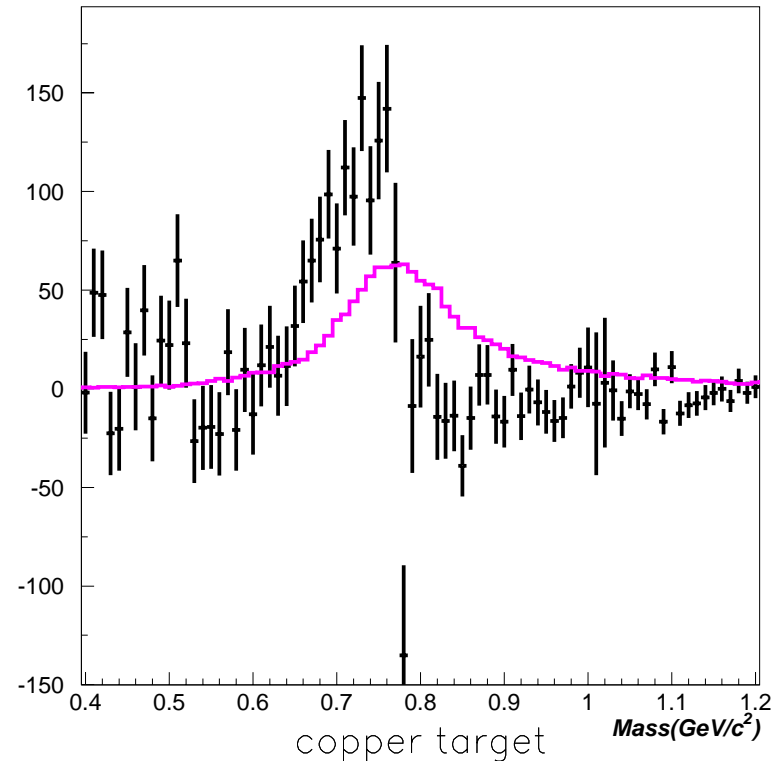
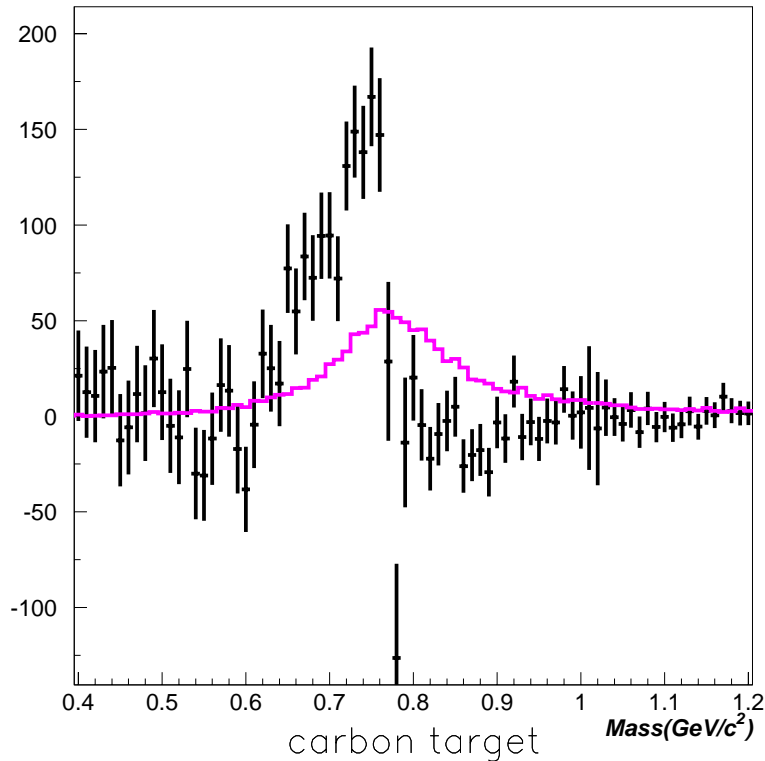
# Model Calculation

$$m^*/m = 1 - 0.16 \rho / \rho_0 \quad \text{width } 2\Gamma$$

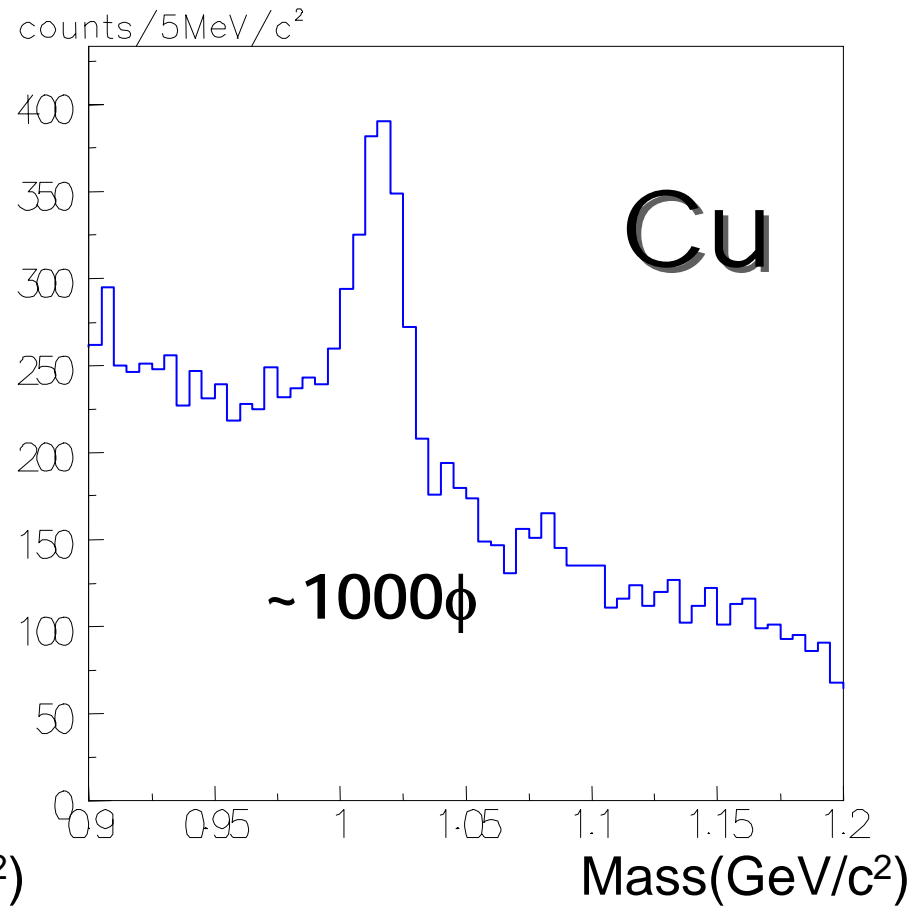
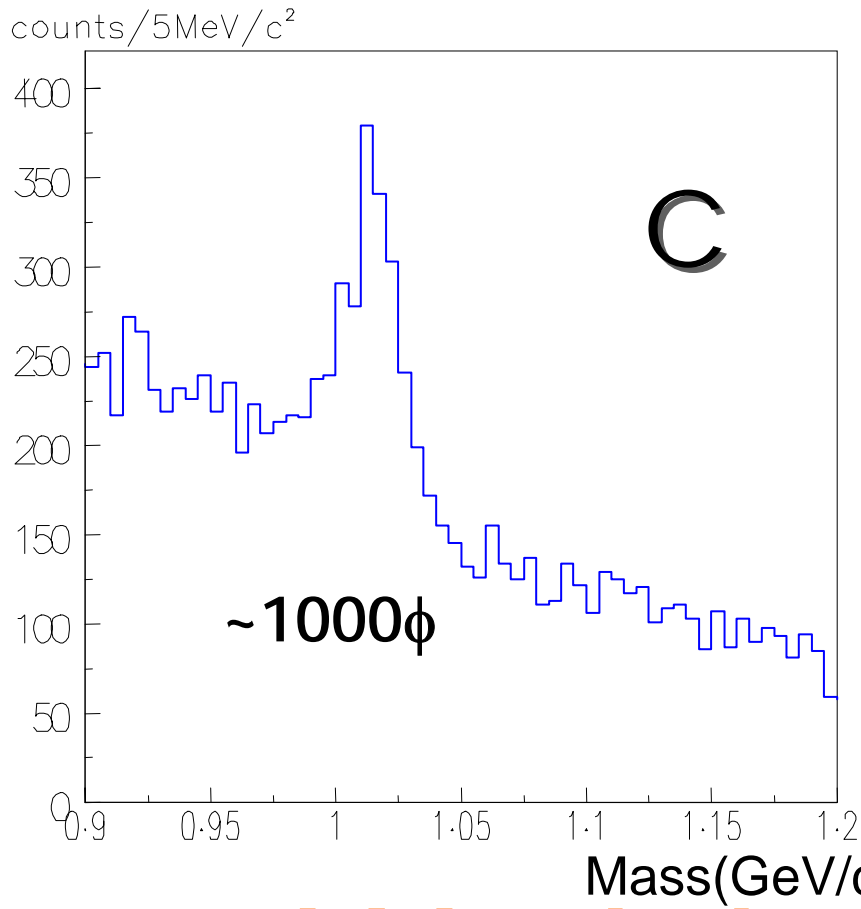


# Modified $\rho$ Meson Shape?

- all resonance subtracted.
- normalized rho spectrum overplotted with magenta.



# Invariant Mass Spectrum of $\phi \rightarrow e^+e^-$



*Work in progress*

# Summary

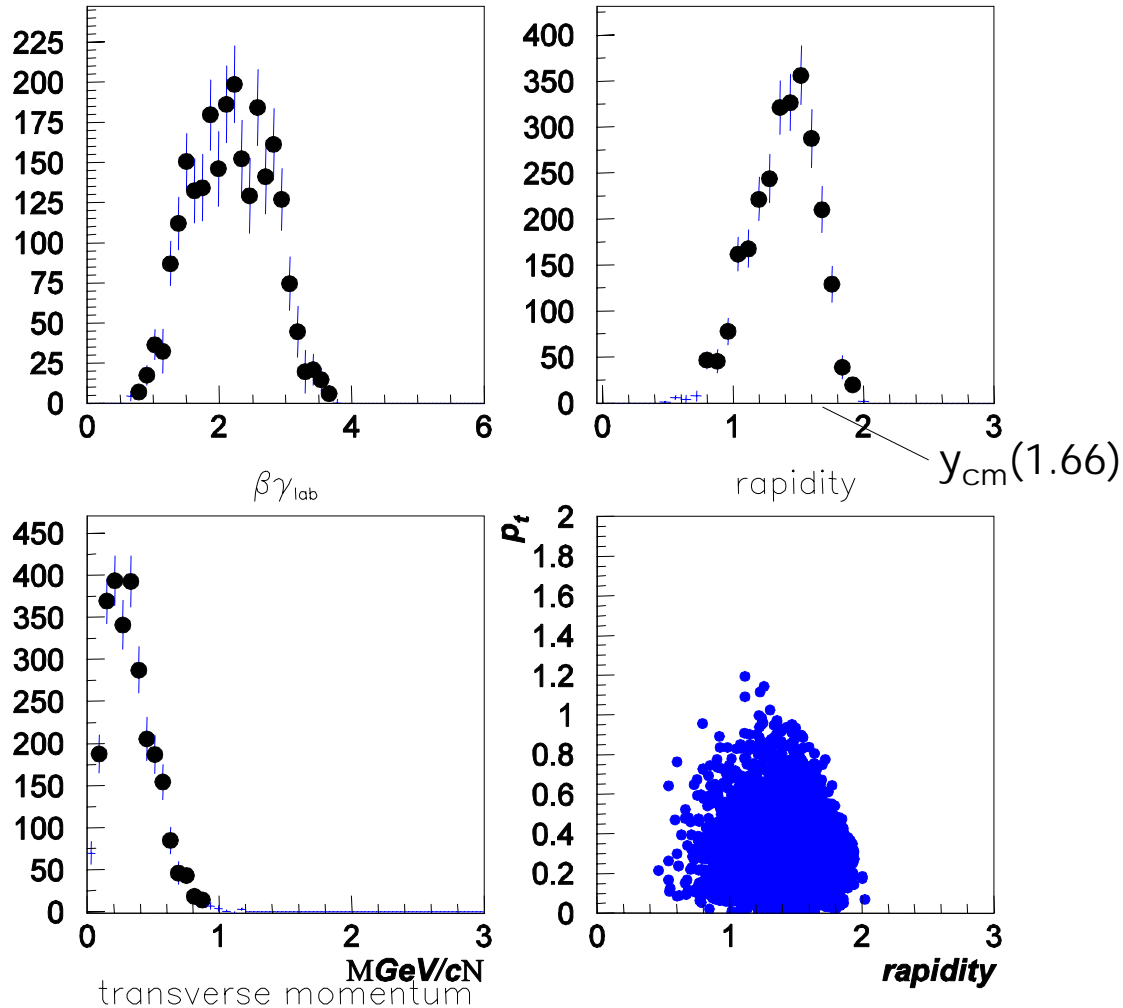
- KEK PS-E325 experiment measured  $e^+e^-$  and  $K^+K^-$  pairs to investigate invariant mass of vector mesons decaying in nuclear matter.
- In 2002  $e^+e^-$  data, we have observed the **excess over the known hadronic sources** below the  $\omega$  peak. Obtained  $\rho / \omega$  ratio indicates that this excess is mainly due to the **modification of  $\rho$  mesons**.
- Model calculation well reproduced the tendency of data.
- Analysis on phi meson is now in progress.

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# Backup Transparencies

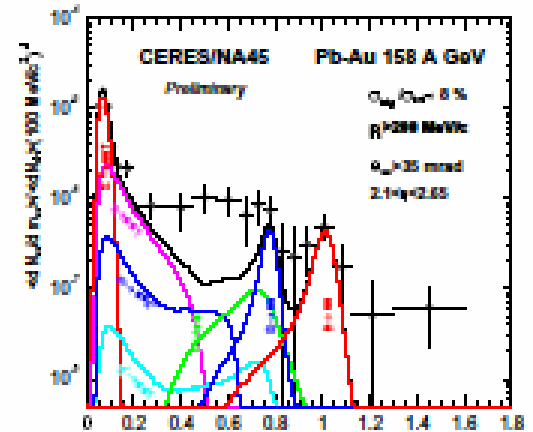
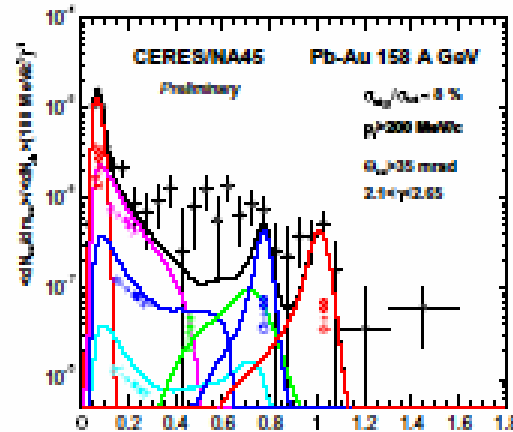
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# $\omega$ Measured Kinematical Distribution



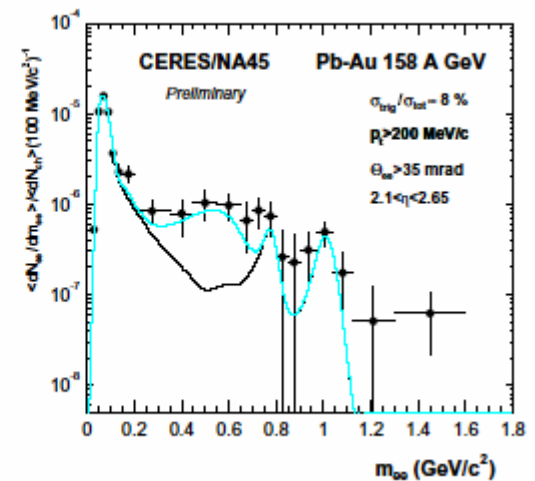
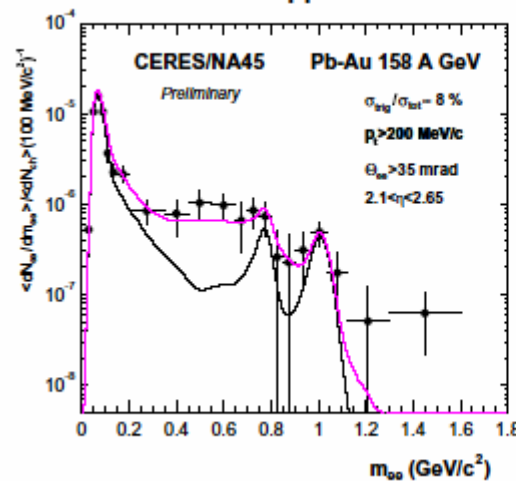
# CERES

- 158 GeV Pb-Au collisions

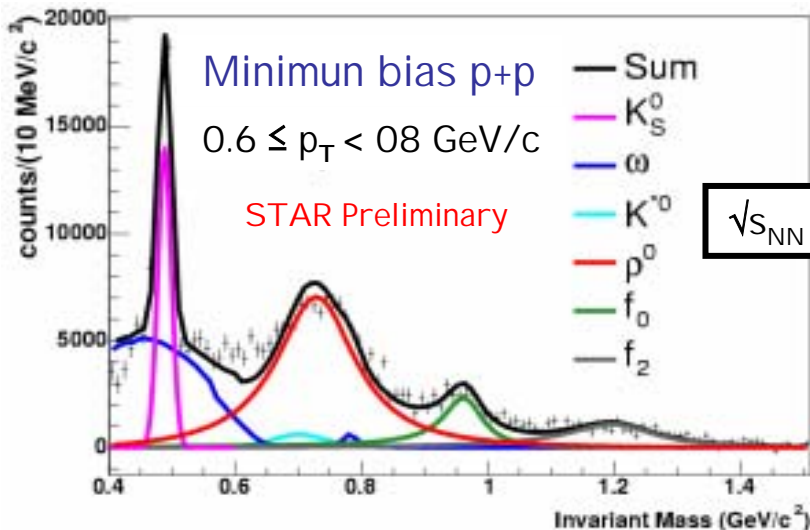


Rapp/Wambach

Braun-Rho



# Raw Invariant Mass Distribution from Data -III



Statistical error only

