- Lepton Pair Production at JHF -

Meson Modification in Nuclear Media
&
QCD Chiral Symmetry Restoration

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- Introduction : Chiral Symmetry in QCD and Meson Mass
- The Status of Present and Future experiments
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PHYSICS

Mass in QCD

Current quarks ($M_q \sim 0$) interacts with vacuum, gain an "effective mass", becomes valence quark.

As the consequence, mass of vector meson is described as

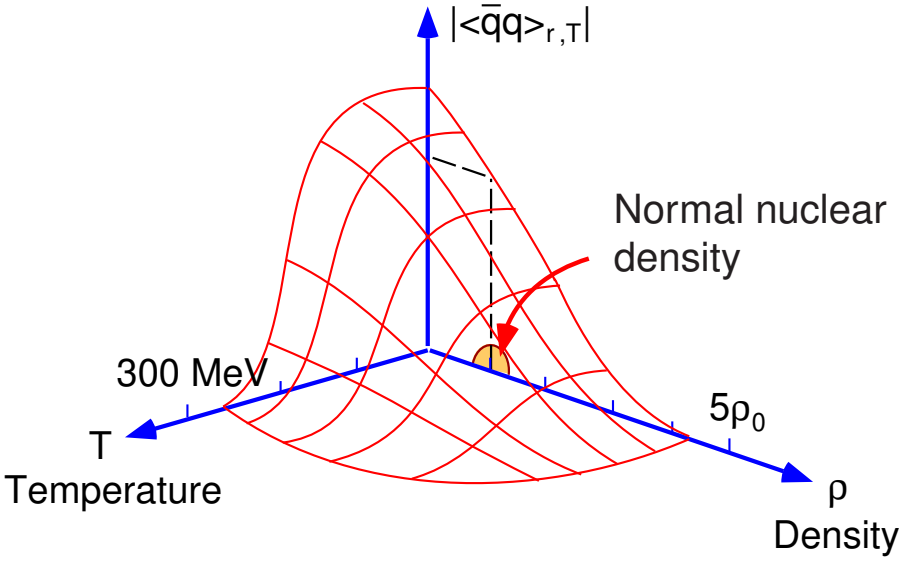
$$M_v = 2 \times M_q^{eff} + (small interaction term). \qquad (1)$$

Meson spectroscopy (in free space) can be considered as the mass spectroscopy for the valence quarks, with which it is difficult to answer "what is the origine of the mass".

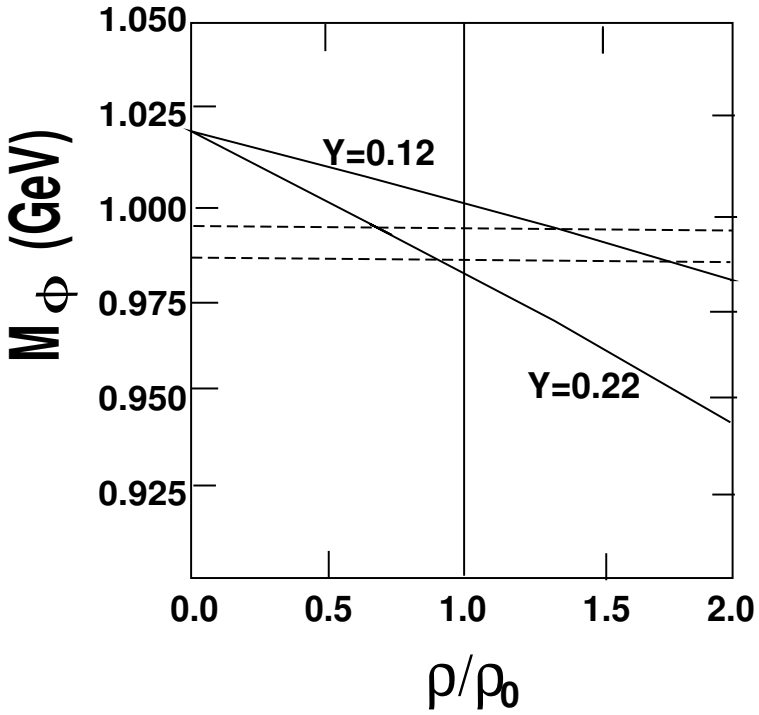
What happens if we changed the vacuum status ?

PHYSICS

Chiral Symmetry Restoration in Nuclear Media



Order parameter $< \bar{q}q >$ is supposed to change in $T \neq 0$ or $\rho \neq$ system.



Hatsuda & Lee's prediction. Mass shift and/or change in the decay ratios are expected.

$\rightarrow$ Mass of vector mesons as a probe of $< \bar{q}q >$.

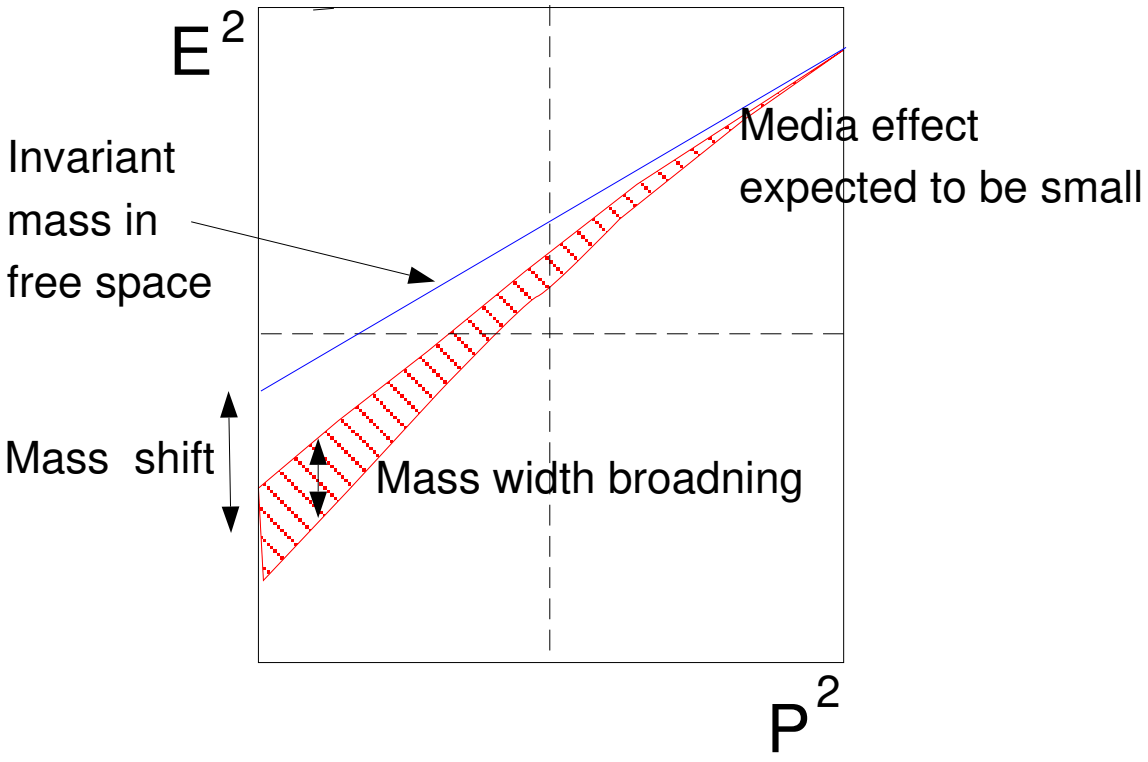
Hurdles
Many Unknown

$< \bar{q}q >$

Temperature dependence of $< \bar{q}q >$
Temperature time evolution
$\rightarrow (CERN/RHIC/LHC)$
Density dependence of $< \bar{q}q >$
Density time evolution
$\rightarrow (BNL/JHF)$

Invariant mass spectroscopy

In-media dispersion of meson mass
In-media mass broadening/narrowing
$\rightarrow$ (Observed mass is not invariant in media)



A lot of inputs from experiments needed, even at the normal nuclear density.

Present and Future Experiments

CLUES

Experiment	Measurements	Interests
CERES/HELIOS-3	ρ modification	Temperature dep.
KEK-TANASHI ES	ρ modification	Density dep.

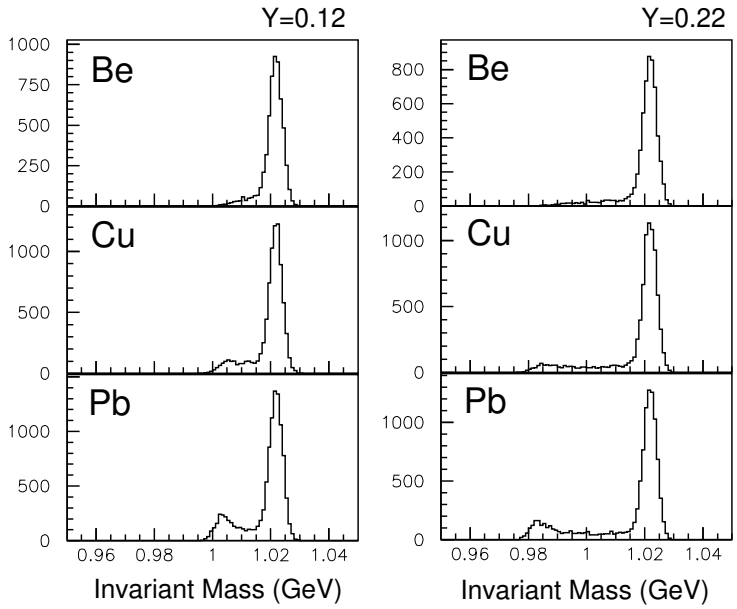
The efforts to be continued at RHIC and LHC (temperature dependence)

Present & future experiments to measure the mass of vector mesons at normal nuclear matter density.

1. KEK(Tanashi)-ES: $\gamma + A \to \rho + A^*$ $(\rho \to \pi^+\pi^-)$
   (Published, Analysing)
2. KEK-PS: $p + A \to \phi + A^*(\phi \to K^+K^-/e^+e^-)$
   (Running)
3. SPring-8: $\gamma + A \to \phi + A^*$ $(\phi \to K^+K^-)$
   (Designing, 1999?)
4. GSI: $d + A \to^3 He + A^*$ to find a bound η and ω states
   (Approved, 1999?)
5. GSI-HADES: $\pi + A \to \omega + A^*$ $(\omega \to e^+e^-)$
   (Preperation, 1998?)

E325 PHYSICS

Expected Signal



- **KEK-PS E325 to measure ϕ decays inside a nucleus**
  - **In $12GeVp + A(C/CH_2/Cu/Pb) \rightarrow \phi + X$**
  - **Observables**
    - **Invariant mass spectrum; $\phi \rightarrow K^+K^-/\phi \rightarrow e^+e^-$**
    - **Branching ratio; $Br\ (\phi \rightarrow K^+K^-\ )/Br\ (\phi \rightarrow e^+e^-\ )$**
  - **Focus on slowly moving ϕ's $(1GeV/c_{lab}\ )$**
  - **10^9/sec primary protons on thin (0.1%) nuclear target to supress γ conversions.**
- **First physics runs in June '97, identified $\phi \rightarrow K^+K-$**
- **Presently $e+e-$ mode has started simultaniousely running with the KK trigger.**

Some Tips of E325

- **Expected mass shift is** $20 \sim 40MeV$ **(Hatsuda-Lee).**
- **About 10%** ϕ**'s are decayed inside a nucleus.**
- **Secondary peak may enchance when low** β ϕ**'s are selected.**
- **Invariant mass and Momentum of the modified** ϕ**'s gives the dispersion relation.**
- **natural width of** ϕ **is narrow (4.4MeV), but some broadning can happen.**
  Clude estimations (the worst case) exist;
  - $\Gamma_\phi = \sigma_{\phi N} \times \beta_\phi \times \rho_0$
    - $\sigma_{\phi N}$ **<10mb, total cross section (elastic included from** $\gamma + A \rightarrow \phi$**)**
    - $\beta_\phi = 0.7,\ \rho_0 = 0.16/fm^3$

    $< 20MeV$
  - $\phi \rightarrow K^{+*}K^{-*}(K^-N \rightarrow \Sigma X)$

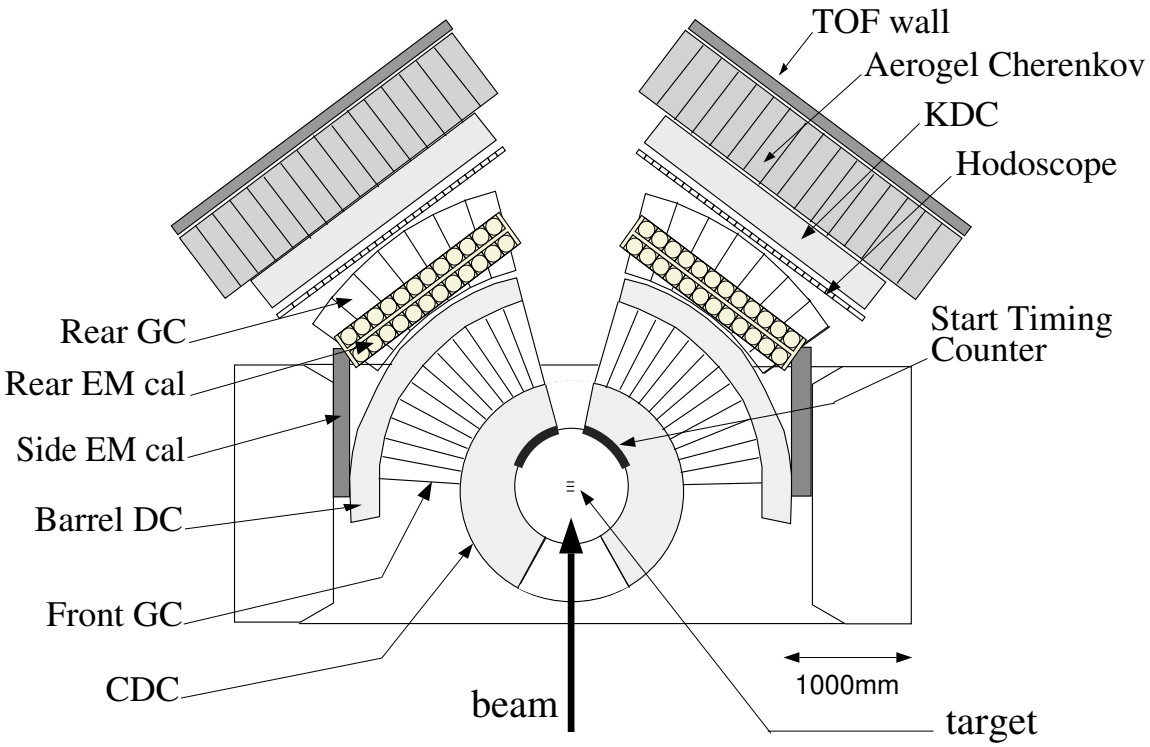
    $< 30MeV$

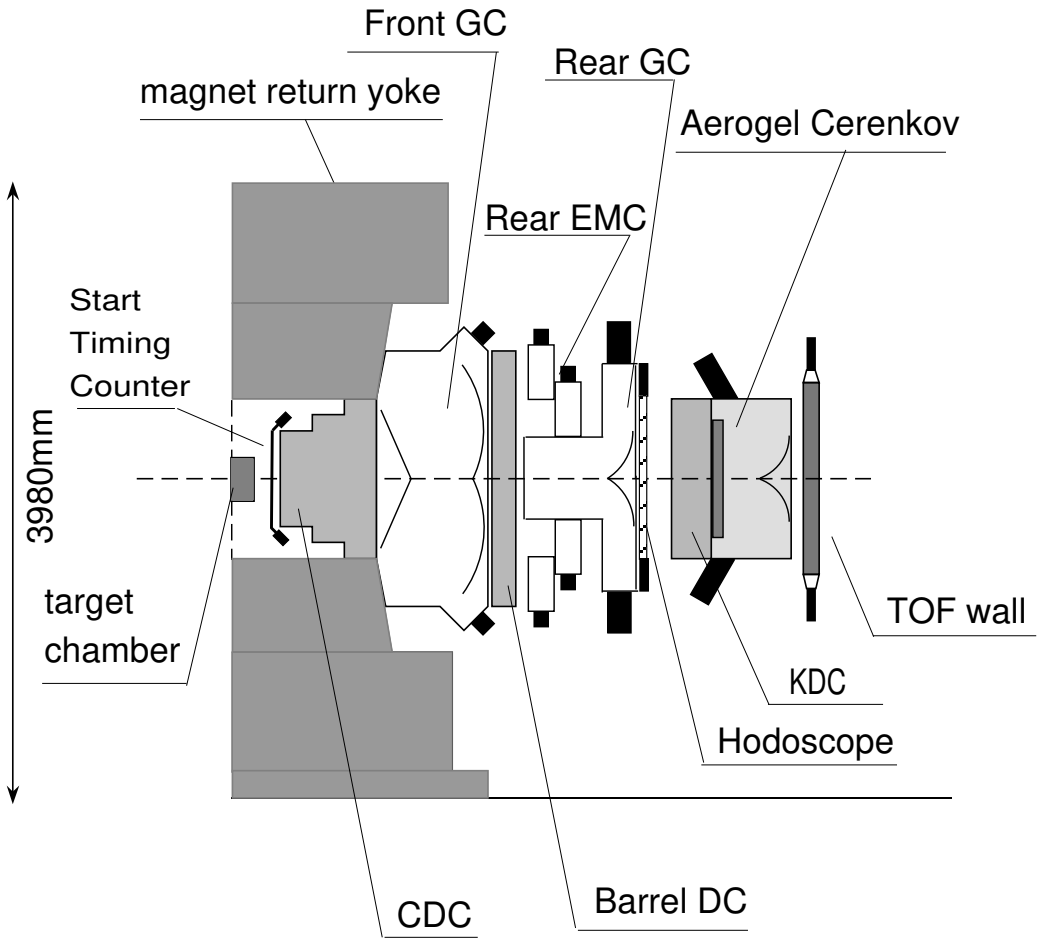
E325 collaboration

note: students presently working hard and students used to be working hard & left

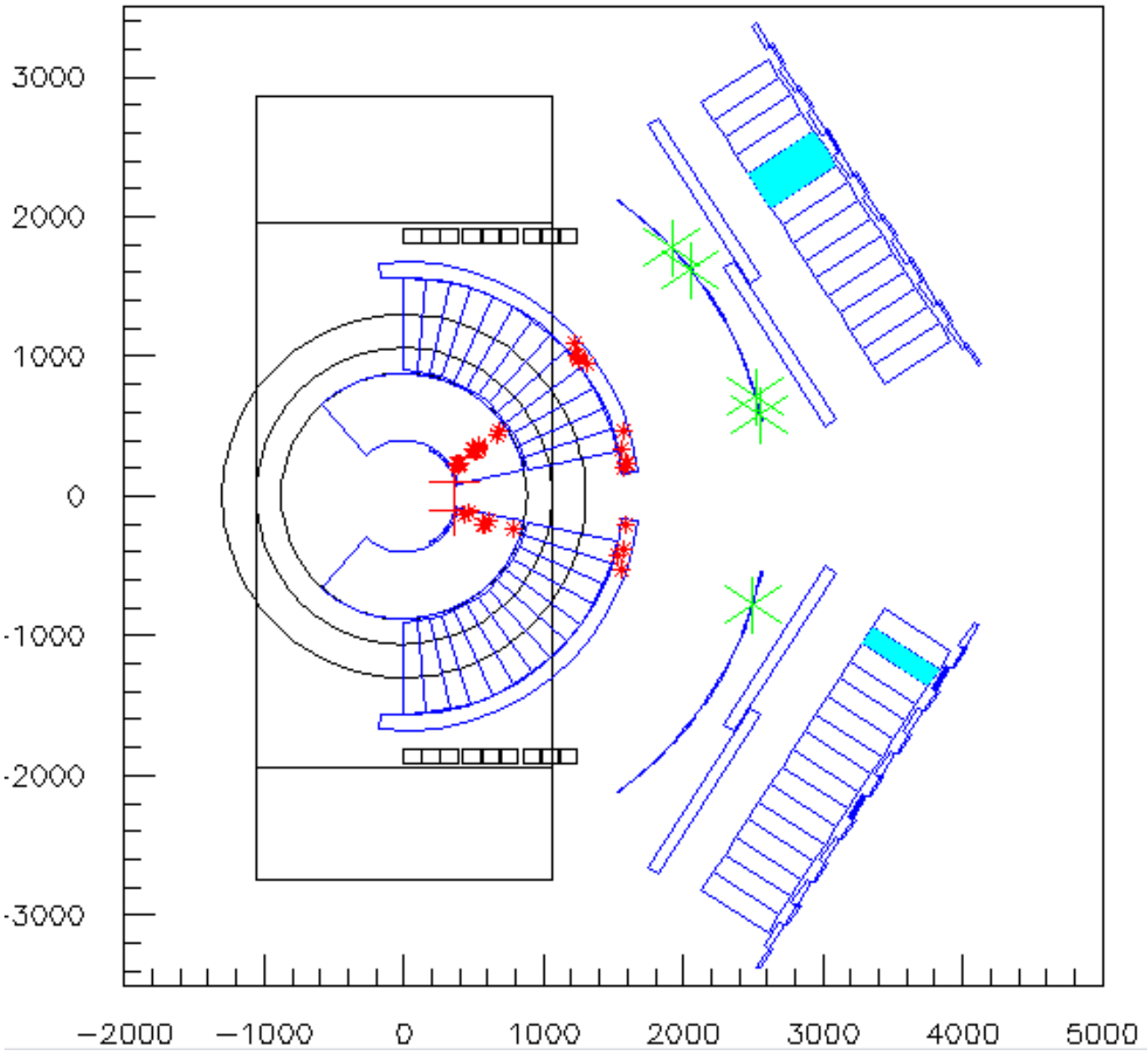
- Kyoto-Univ
  H.Enyo, H.Funahashi, T.Haseyama, M.Ishino, H.Kanda, A.Masaike, Y.Matusda, S.Mihara, T.Miyashita, T.Murakami, Y.Nakada, M.Naruki, K.Ozawa, H.Satoh, T.Tabaru, S.Yokkaichi, Y.Yoshimura
- CNS,Univ.of Tokyo
  H.Hamagaki
- KEK
  J.Chiba, M.Ieiri, O.Sasaki, M.Sekimoto, K.Tanaka
- RCNP
  M.Nomachi
- T.I.T.
  K.Hamada, Y.Sakemi, T.A.Shibata
- Tsukuba-Univ.
  K.Yagi

E325 SETUP


TOF wall
Aerogel Cherenkov
KDC
Hodoscope
Rear GC
Rear EM cal
Side EM cal
Barrel DC
Front GC
CDC
Start Timing Counter
beam
1000mm
target

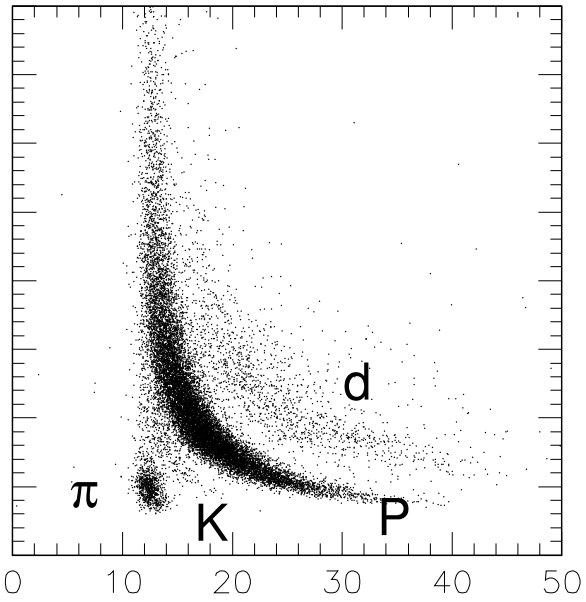

Front GC
Rear GC
magnet return yoke
Aerogel Cerenkov
Rear EMC
Start Timing Counter
3980mm
target chamber
TOF wall
KDC
Hodoscope
CDC
Barrel DC

Typical Event

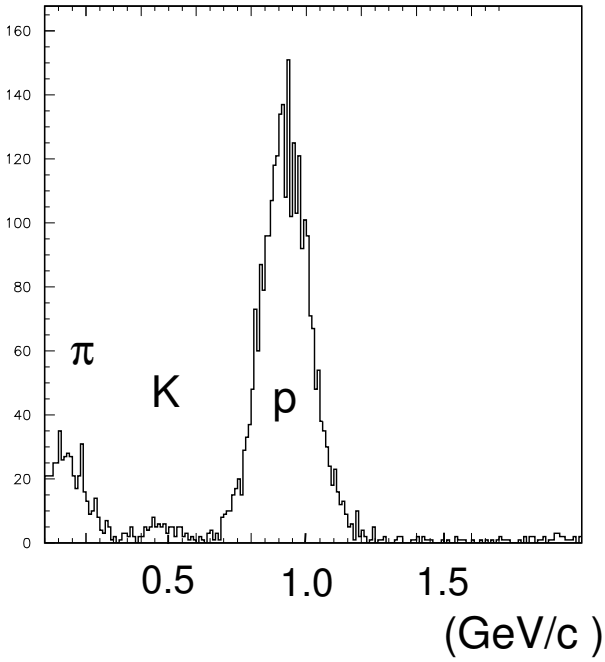


- $\pi^+\pi^-$ **event**
- **CDC hits, BDC hits, AC hits and TOF hits**

Particle Identification



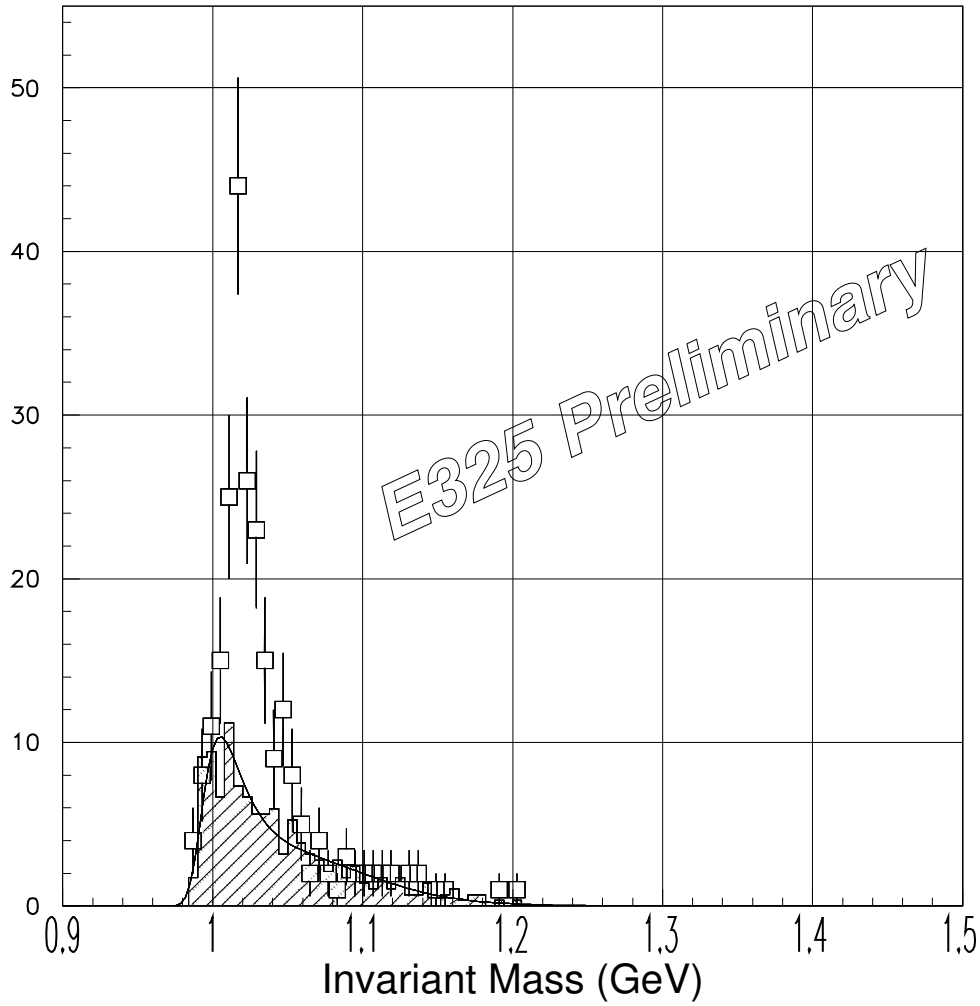
TOF



Mass

- **All positive particles with AC veto (Threshold = ∼500MeV/c).**
- **Kaons are identifed.**
- **Problems in TOF resolution and tracking.**

K^+K^- invariant mass spectrum



- $P_{kaon} < 1.2 GeV/c$
- $0.3 < Mass_{kaon} < 0.7 GeV/c^2$
- **Two kaons are in the same arm.**
- **TOF consistency in the Hodoscope and the TOF counters.**
- **Mixed event background is overplotted (shaded area).**
- **Present mass resolution is** $\sim 10 MeV/c^2$**.** $\sim 1 MeV/c^2$ **foreseen in the end.**

Towards JHF

AT 2005, suppose that RHIC discovered ϕ modification at high temperature.... Bound omega state discovered at GSI..... E325 established the mass shift of the ϕ as the density meter...

- **Further study of ϕ's at normal nuclear density (E325 like).**
  - **Use primary protons with 50GeV beam, larger ϕ production (phenomenological scaling low exists)**

$$\frac{M^3}{\Gamma}\sigma_V(\tau) \propto \frac{1}{\sqrt{\tau}}(1-\sqrt{\tau})^{10},\ (1/\tau = s/M^2) \qquad (2)$$

branch	cross section(μb)			
	24GeV BNL exp.	12GeV KEK-PS scaled	12GeV ZGS exp.	50GeV) JHF scaled
$pp\phi$	2.2±1.3	0.7±0.2	0.75	5.1±3.0
$pp\ m(\pi^+\pi^-)\ \phi$	6.6±2.4	2.2±0.8		15.3±5.6
total	158±35	54±10		366± 81

  - **Use secondary Kaons to produce ϕ**
    When we have $\sim 10^7$ kaons/sec, production cross section of ϕ becomes comparable to 10^9 protons.

  → **Explore the dispersion of mesons in media**

- **Extend E325 to study ϕ's at higher density.**
  - **Use primary HEAVY IONs**
    requires measurements at the central reagion
    possible to measure $\phi \to \mu^+\mu^-$

  → **Explore the density dependence**

Summary and Outlook

- Many experimental studies on the chiral property of nuclear media are in place all over the world.
- Some hints already exist for the mass modification of vector mesons.
- Many other experimental results will be available towards year 2000.
- If the studies goes to the fruitful direction, JHF will have a key to access;
  - the density dependence of the chiral property,
  - detail studies for the meson property at normal nuclear density
- Feedback from the experience (mainly technical) from the present experiments are indispensable to plan the new experiment in JHF.