Mesons in nuclear matter

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Study of chiral property in dense matter using lepton decays of vector mesons at JHF.

① Physics motivation / experimental signals
② Present experiments
③ Plan of the experiment at JHF and R&D items
④ Summary…

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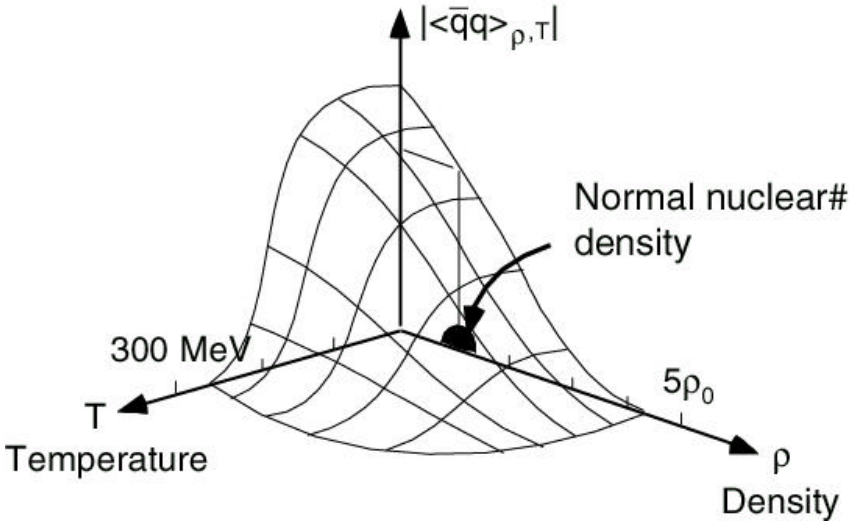
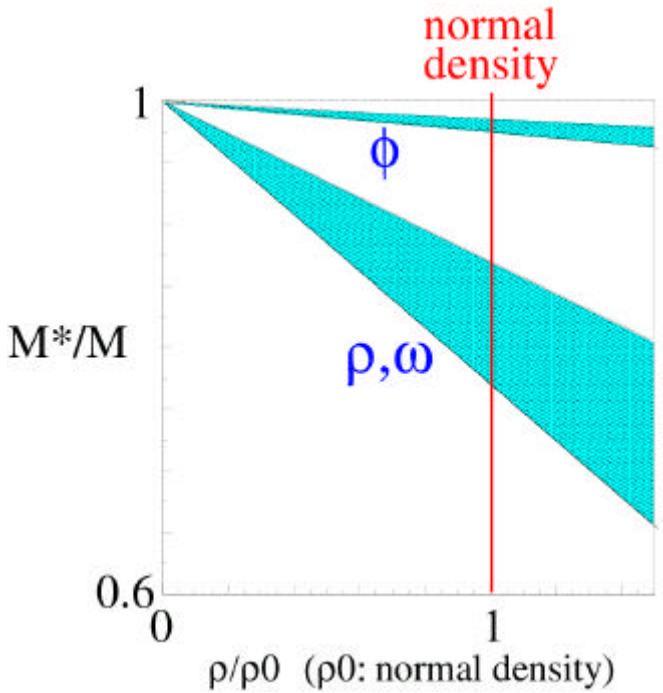
Chiral property of dense nuclear matter

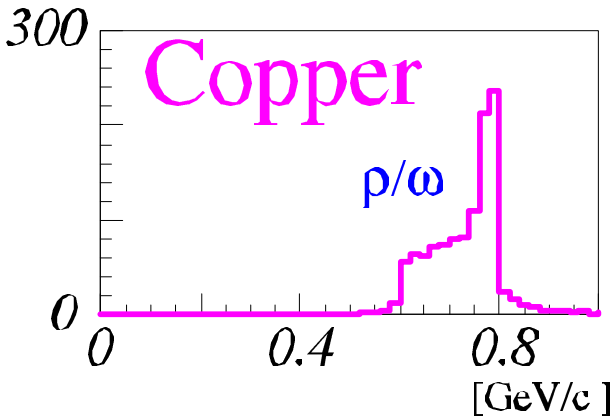
- In free space
  - ➔Spontaneous breaking of chiral symmetry
- In dense matter
  - ➔Partial chiral symmetry restoration
  - ➔Hadron modification is expected

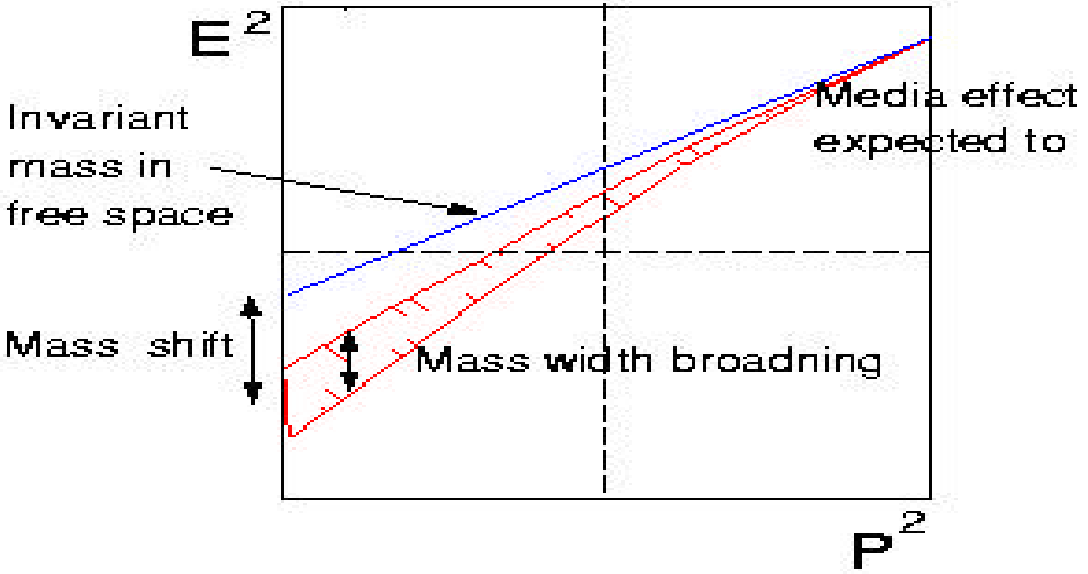




Expected experimental signals

- **Direct measurements of mass modification**
  - **➔Lepton decays of vector mesons**
    - **➔ρ, ω, ϕ, J/ψ**
  - **➔K* -> Kγ**
- **In-media mass modification**
  - ➔shift of resonance position
  - ➔resonance broadening/narrowing
    - **➔We have to measure dispersion relation**
    - **➔Need high statistics**





Experiments

CLUES

Experiment	Measurements	Interests
CERES	ρ modification	Temp. dep. **ρ is modified in Hot Matter**
KEK-TANASHI ES	ρ modification	Density dep. **ρ is modified in He**
GSI	π modification	Density dep. **π is modified in He**

Present & future experiments

RHIC(running)/LHC(2006)

KEK-PS: p+A→φ+X(φ→K+K–/e+e–) (Running)

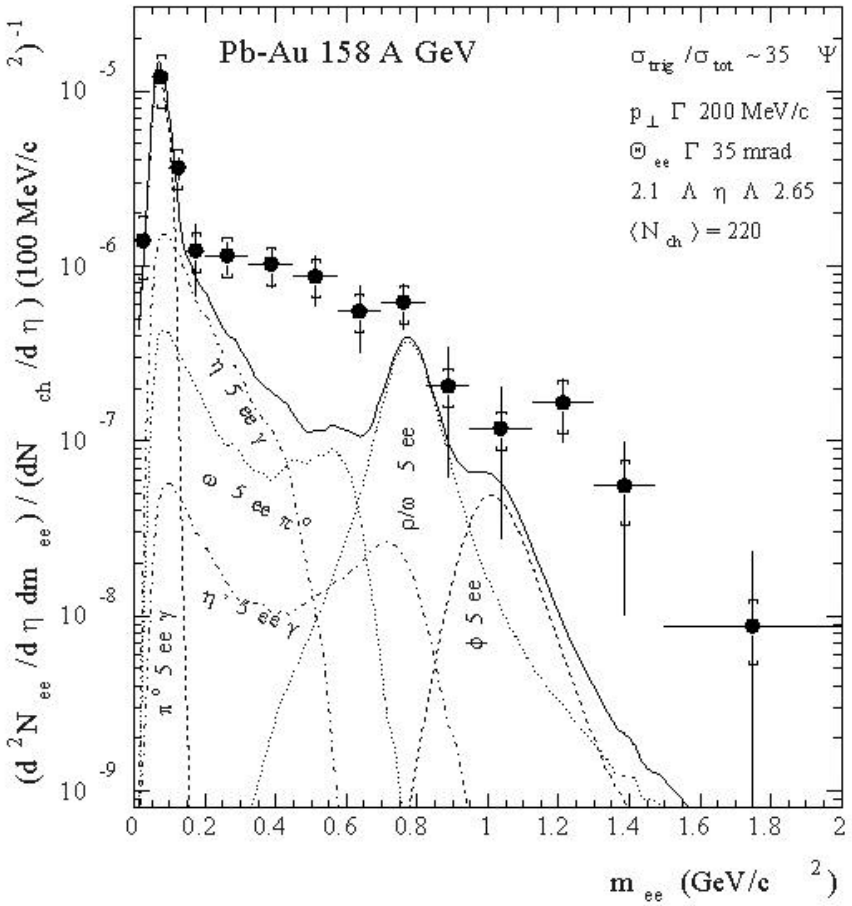
SPring-8: γ + →φ+A*(φ→ K+K–) (Ready to run)

GSI: d +A→3He+A* (ηω bound states) (Ready to run)

GSI-HADES: π +A→ ω+A* (ω→e+e–) (Preparation, 2001?)

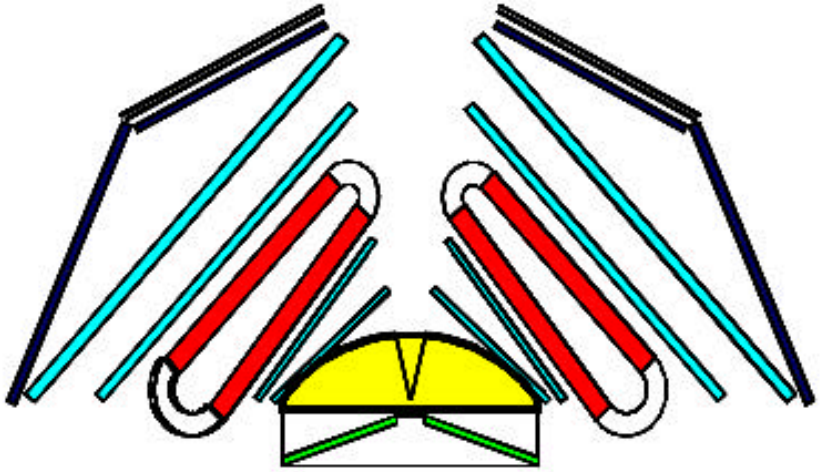
CERN-SPS CERES/NA45

- Low mass electron pair production is measured in Pb – Au collision at 158 A GeV
- They observed an enhancement in the mass region $0.3<M_{ee}<0.7$
  - There is a time evolution of temperature and density and the interpretation of the data is difficult.
  - mass resolution is not so good



GSI HADES

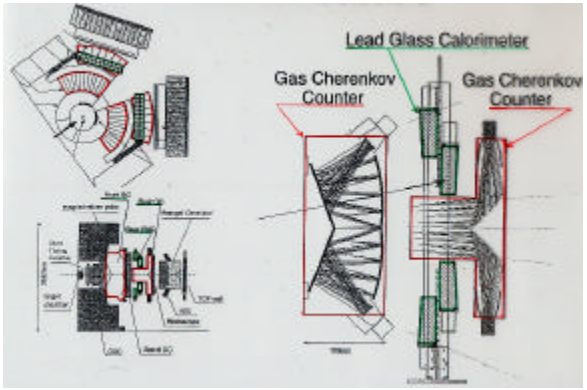
- Invariant mass spectra of ee pairs up to 1 GeV, using 1.0 A GeV heavy ion beam or hadron beams up to a few GeV.
- They are running C+C at 2 GeV/nucleon for a three-week running period beginning November 19.
- They will produce data about the mass modification of ρ,ω mesons.

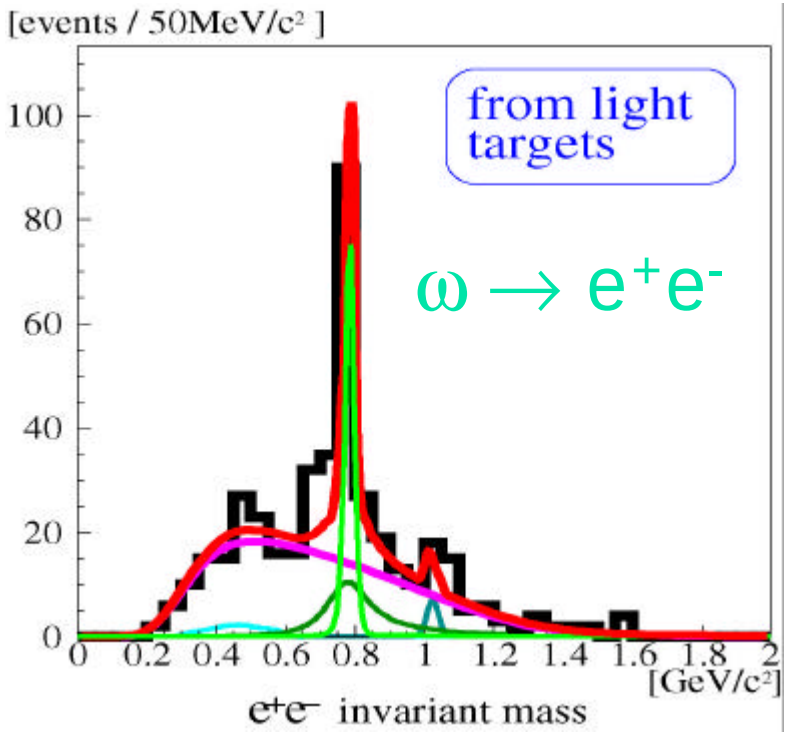


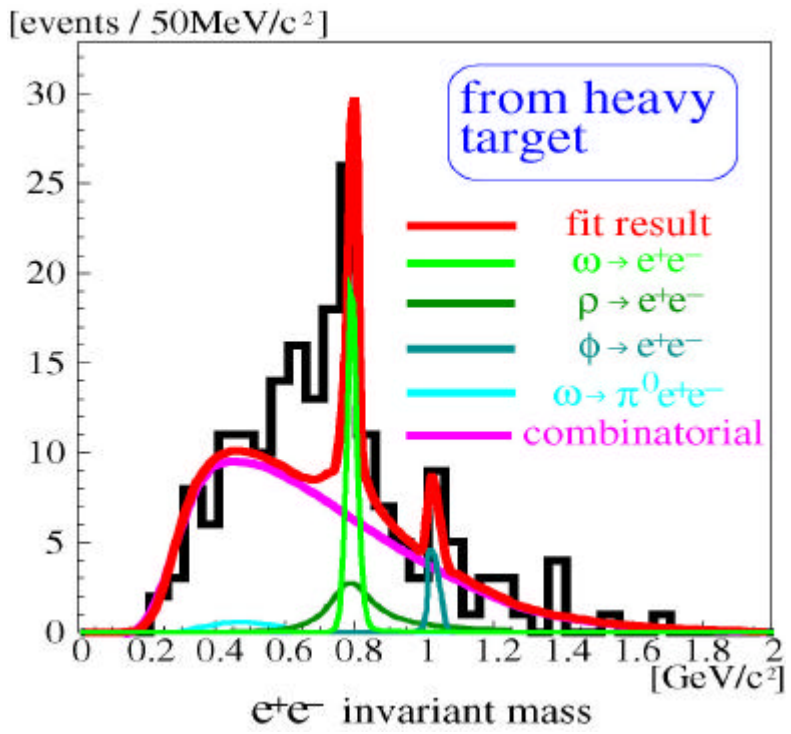
Detector Schematic View

KEK-PS E325 experiment

- p + (C,Cu) → ρ, ω, ϕ + X
- Measure e^+e^- pairs
  - ➔Invariant mass spectra
  - ➔Compare heavy and light nuclei cases

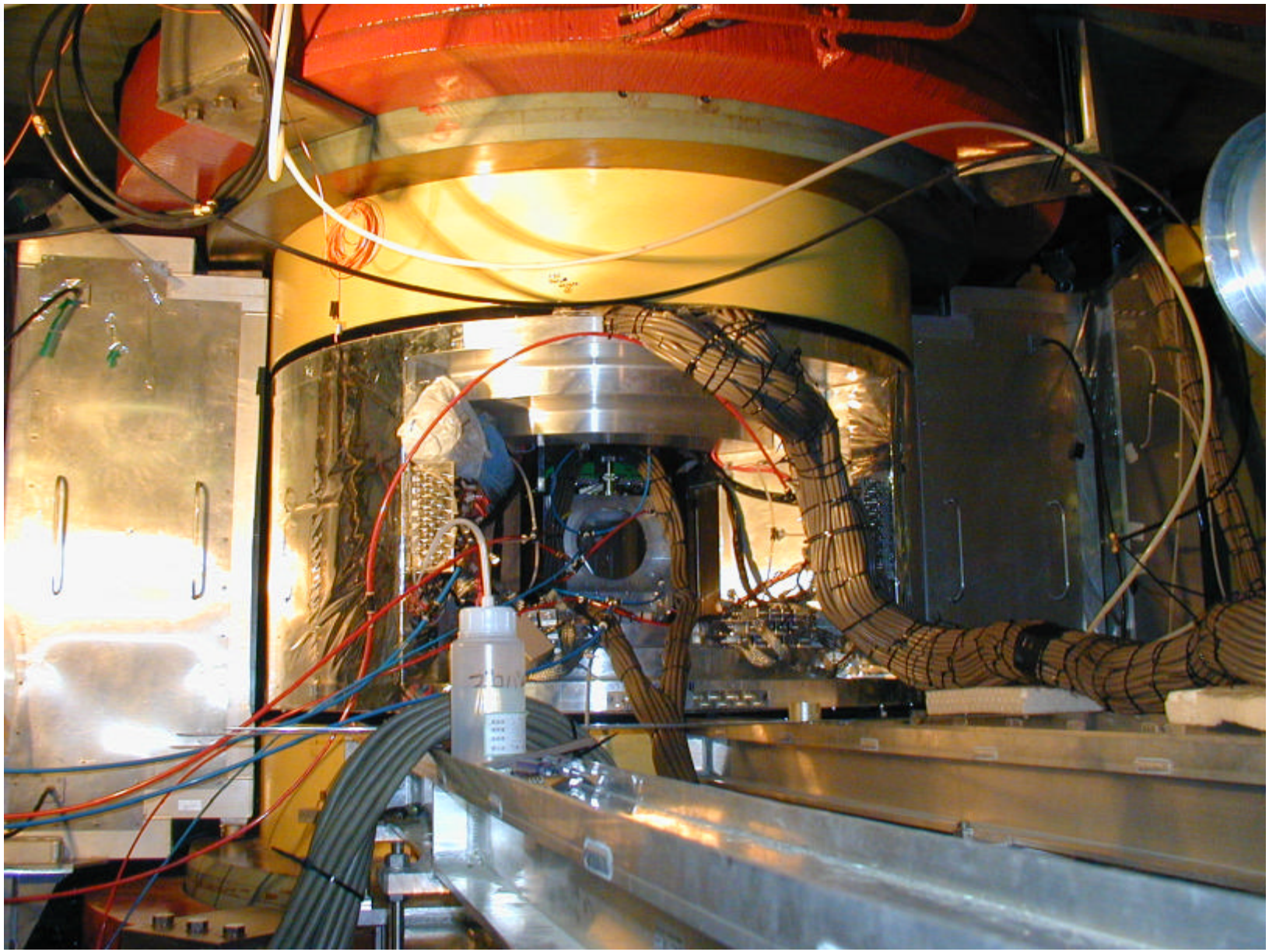






'98 data

E325 Spectrometer

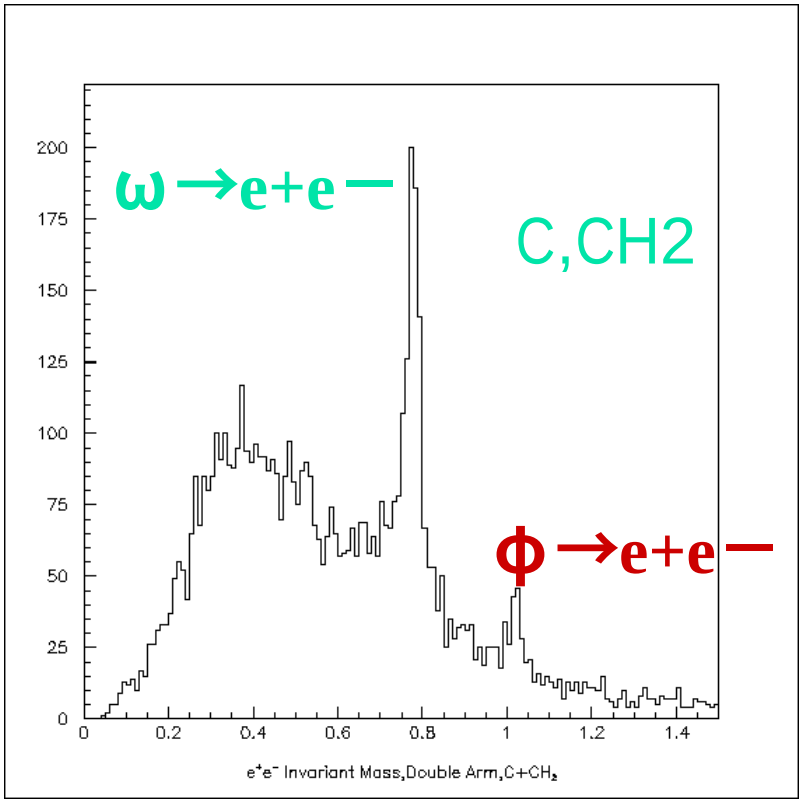


Present status of the experimental results

- **Meson modification is observed in nucleus.**
- Does it means QCD chiral symmetry restoration ?

  →NOT YET

  – **How large the in-media broadening ?**
    - SHAPE
    - DECAY RATE
  – **Other trivial reasons ?**
    - Collisional broadening
    - Phase space effect
- **Need more experimental efforts**
  – Statistics
    - Accurate shape
    - Dispersion
  – **$\phi \rightarrow e^+e^-$**



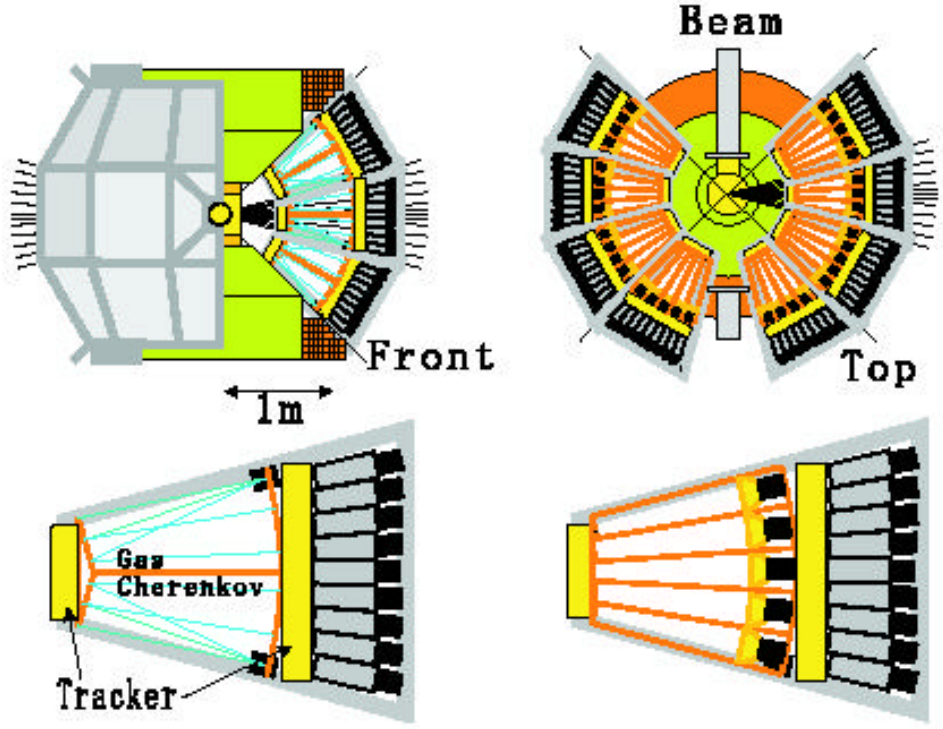
Invariant mass spectrum of '99

Key points of spectrometer design

- Clean high intensity pencil beam (~ 10^9 ppp) on thin target
  - ➔To suppress background in e^+e^- channel
  - ➔Beam spot size of a few hundred of microns
    - ➔Suppress beam halo and fake trigger
    - ➔With wire target, helpful for tracking
- Large acceptance spectrometer to detect slow mesosn with high statistics.
  - ➔Larger matter effect is expected.
  - ➔Detailed study become possible with high statistics.

Proposed spectrometer for JHF experiment

- A mosaic of 23 identical units, each of which has an aperture of 30 degrees by 30 degrees.
- Major electron identification is given by gas Cherenkov counters.
- EM calorimeter is used to measure not only electrons, but also photons. The measurements of K*->K+γ is available.
- 100 times larger statistics is expected.



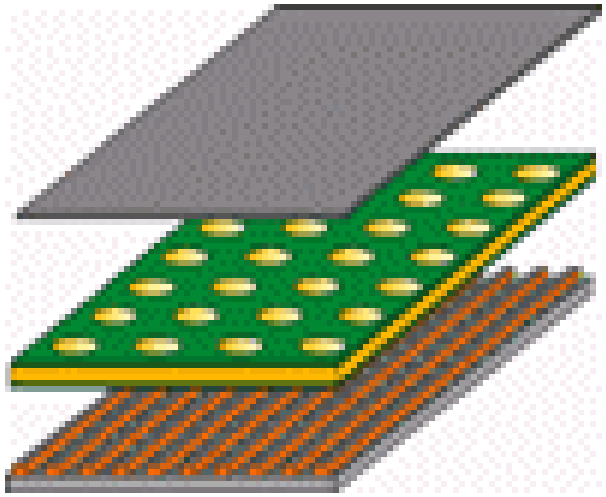
Schematic view of spectrometer

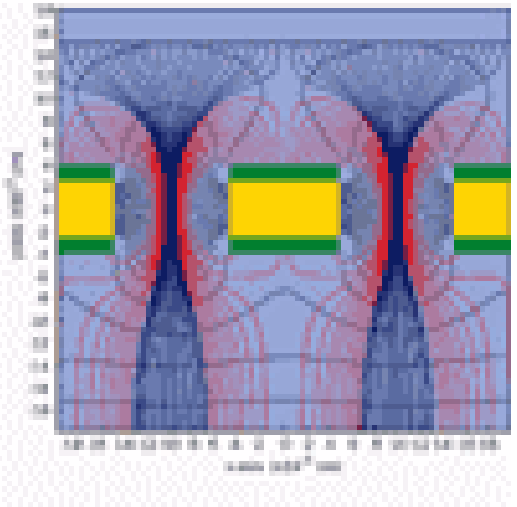
R&D items

- Tracking detector cope with high intensity beam.
  - ➔GEM detector?
- High efficiency electron identification counter with high intensity beam.
  - ➔Gas Cherenkov Counter?
  - ➔Hadron Blind detector?
- Electron or Muon?
  - ➔The mass resolution of muon pair is improved using silicon pixel detector (NA60).
  - ➔Need simulations for determining which one is better.
- Detailed simulations for feasibility study
- Clean high intensity pencil beam. Optimized beam energy.

GEM for High rate tracking

- GEM (Gas Electron Multiplier) detector for high rate counting.
  - ➔A thin sheet of plastic coated with metal on both sides and chemically pierced by a regular array of holes.
  - ➔Applying a voltage (about 500 V) between both side.
  - ➔High electric field in the holes makes an avalanche of electrons.
- No drop of gain up to particle flux of 10^5 Hz/mm





Schematic view of GEM

Hadron Blind Detector for Electron Identification

- Electrons to be detected produce Cherenkov photons in a gas radiator.
  - ➔Photons are detected with CSI photo cathode and gas detector.
  - ➔Propose by Y. Giomataris and G. Charpak.(**Nucl.Instrum.Meth.A310:589-595,1991**)
- Prototype was tested by Stornybrook group.(**Nucl.Instrum.Meth.A400:243-254,1997**)

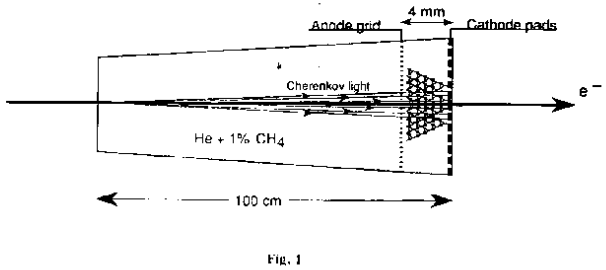


Fig. 1

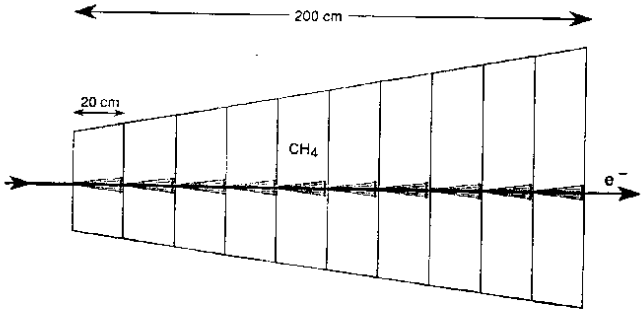


Fig. 2

Schematic view of HBD.

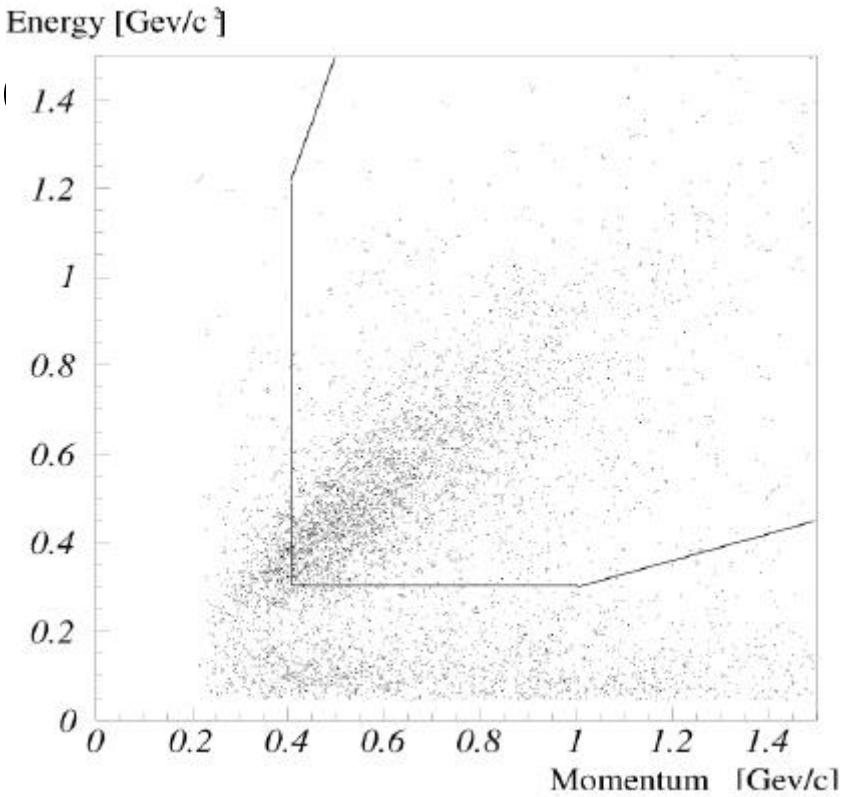
Summary

- There are several kinds of experimental efforts to address an important question on the chiral property at finite density.
- Mass modification of vector mesons is reported by several groups.
- At KEK-PS, in the e^+e^- spectra, a significant shape difference was observed between the light and the heavy nuclear target.
- To study details of chiral properties in dense nuclear matter, high statistics data is needed.
- At JHF, spectrometer and beam will be improved and 100 times larger statistics is expected.

Electron efficiency and pion contamination

- We evaluated the electron efficiency and pion contamination in the momentum range greater than 400 MeV/c.

Counter name	e eff.	π rejection
FrontGC	55%	
Rear GC	86%	6.7×10^{-4} with FrontGC
EM cal	85%	3.9×10^{-4} with FrontGC



EM cal Energy.vs.Momentum

- The remaining eπ pair background was estimated to be about 13% in the final e^+e^- pair sample.
- The contaminations like ππ pair to be negligibly small.