KEK-Tanashi, 14-Dec-98

Study of Chiral Property of Nuclear Matter through Measurements of phi Meson Decays

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Contents

- Physics Motivation : Chiral Symmetry in QCD and Meson Mass
- The Status of Present and Future Experiments
- KEK-PS E325 to Measure ϕ Decays at Normal Density
- Summary and Outlook

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

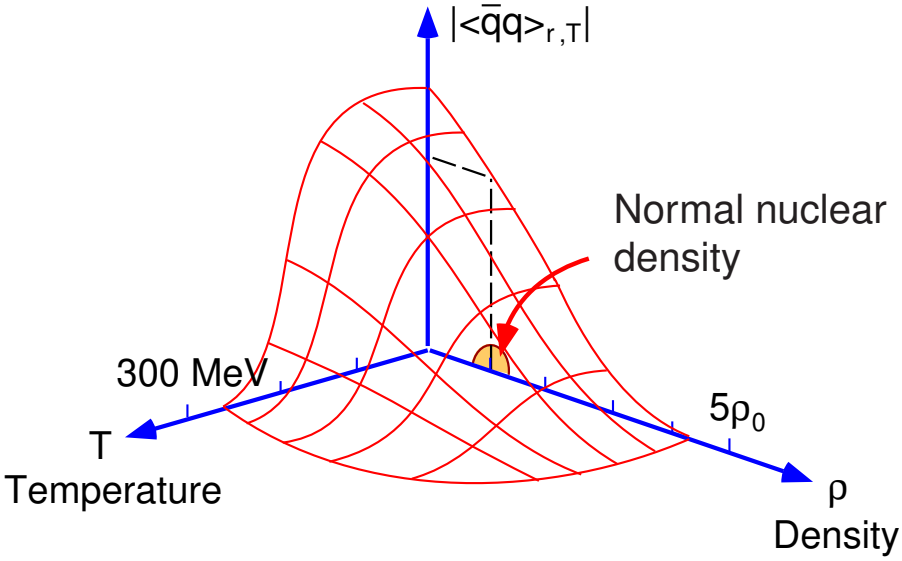
$$M_v = 2 \times M_q^{eff} + (small interaction term). \qquad (1)$$

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 origin of the mass".

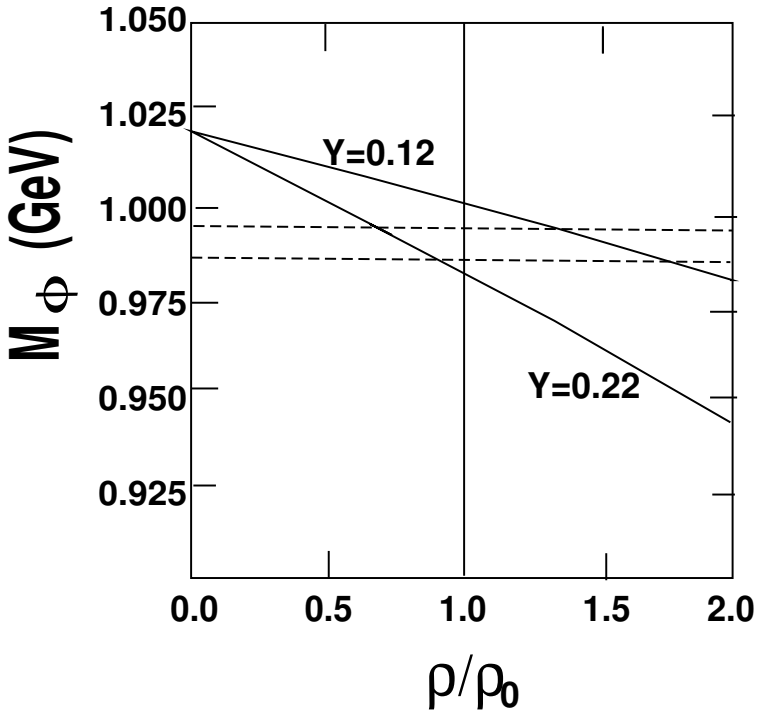
What happens if we changed the vacuum status ?

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

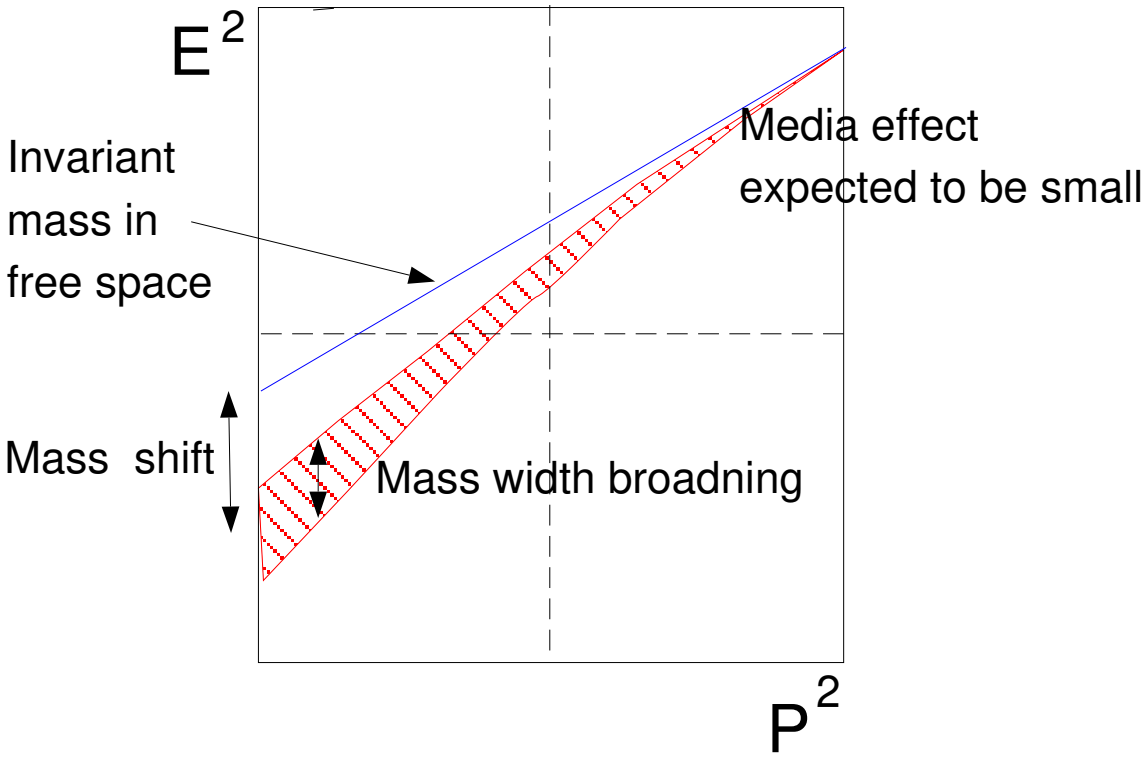
Many Unknown

$< \bar{q}q >$

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.

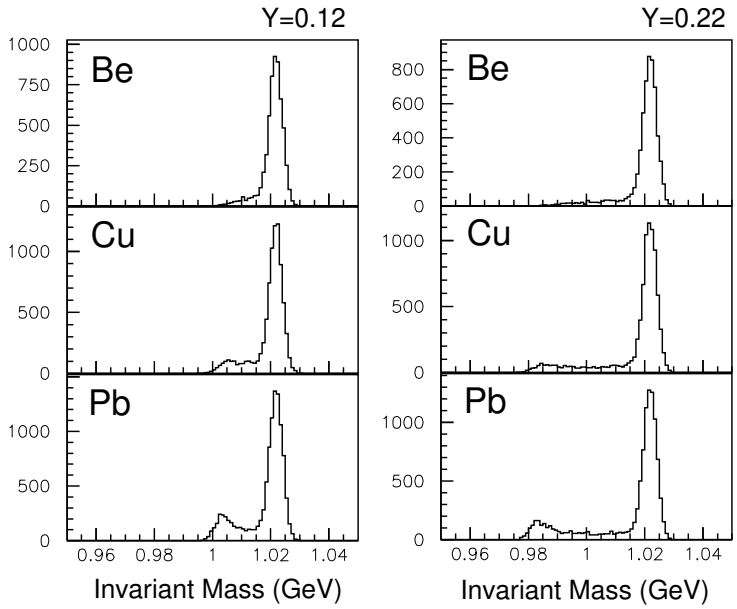
The efforts to be continued at RHIC and LHC (temperature dependence)

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, Analyzing)
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: $d + A \to {}^3He + A^*$ to find a bound η and ω states
   (Approved, 1999?)
5. GSI-HADES: $\pi + A \to \omega + A^*$ $(\omega \to e^+e^-)$
   (Preparation, 1999?)

E325 PHYSICS

Expected Signal



- **KEK-PS E325 to measure ϕ decays inside a nucleus**
  - **In $12GeV p + A(C/CH_2/Cu/Pb) \rightarrow \phi + X$**
  - **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 suppress γ conversions.**

Some Tips of E325

- **Expected mass shift is** $20 \sim 40MeV$ **(Hatsuda-Lee).**
- **About 10%** ϕ**'s will decay inside a nucleus.**
- **Secondary peak may enhance 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 broadening can happen.**
  Crude 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** $\gamma + A \to \phi$**)**
    - $\beta_\phi = 0.7,\ \rho_0 = 0.16/fm^3$

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

    $< 30MeV$

Brief Mile Stones and Status

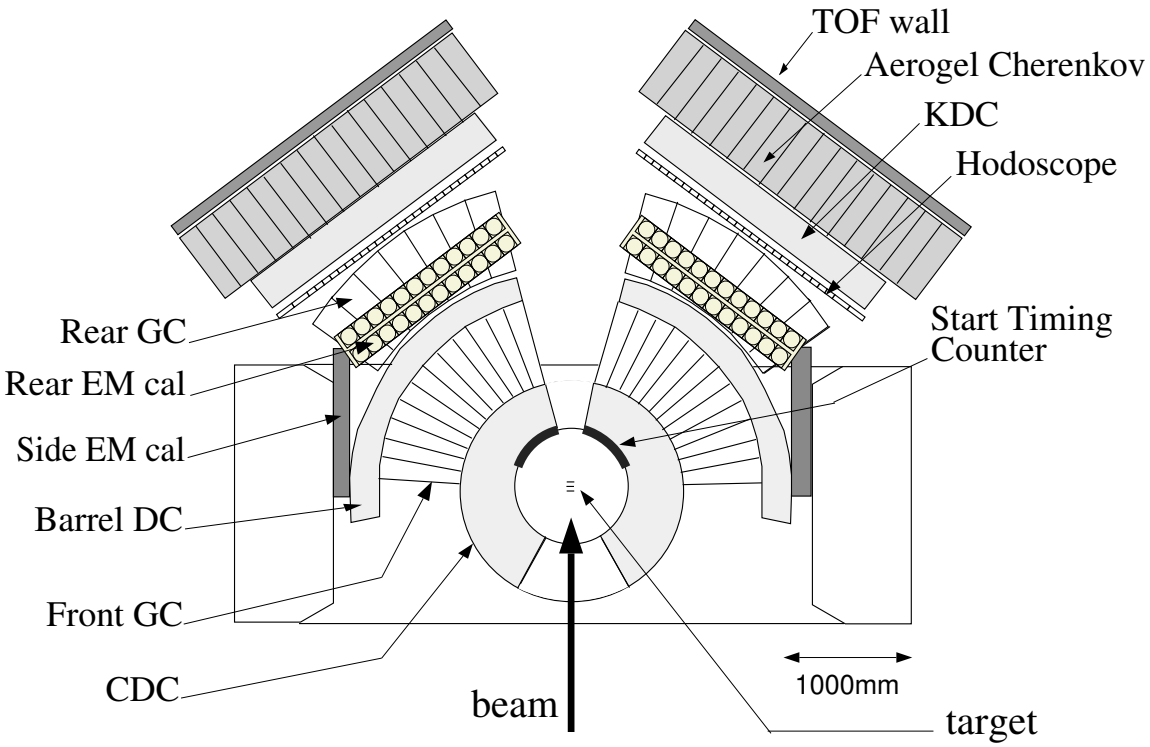
- PreHistory
  - 1994 March KEK-PS PAC conditionally approved
  - 1995 March KEK-PS PAC approved
  - 1996 July- Construction started
  - 1996 November Engineering Run
- 1997 June, First Physics Run with K^+K^-. 17days
  - Data accumulation mainly with K^+K^- channel trigger
  - Beam Intensity $1 \sim 2 \times 10^8$ protons/spill
  - 0.6% interaction target (10^6 interaction/spill)
  - $C/CH_2/Pb$ 3 targets in-line
  - 165GByte Data (160M events) collected in 50 shifts
- 1998 March, Completion of Spectrometer, Data Taking for 13days
  - Setup the last electron counters
  - tuning for the Simultaneous runs for e^+e^- and K^+K^-
  - Beam-dump modified (for $1 \sim 2 \times 10^9$ protons/spill)
- 1998 April -May: Production Running of 85 shifts (29 days)
  - Parallel Trigger (K^+K^- / e^+e^-)
  - Beam Intensity $1 \sim 2 \times 10^9$ protons/spill
  - 0.1% interaction target (10^6 interaction/spill)
  - $C/CH_2/Cu$ 3 targets inline
  - 502GByte Data (180M events) collected in 85 shifts
- 1999 June 80-100 shifts Data Taking Expected

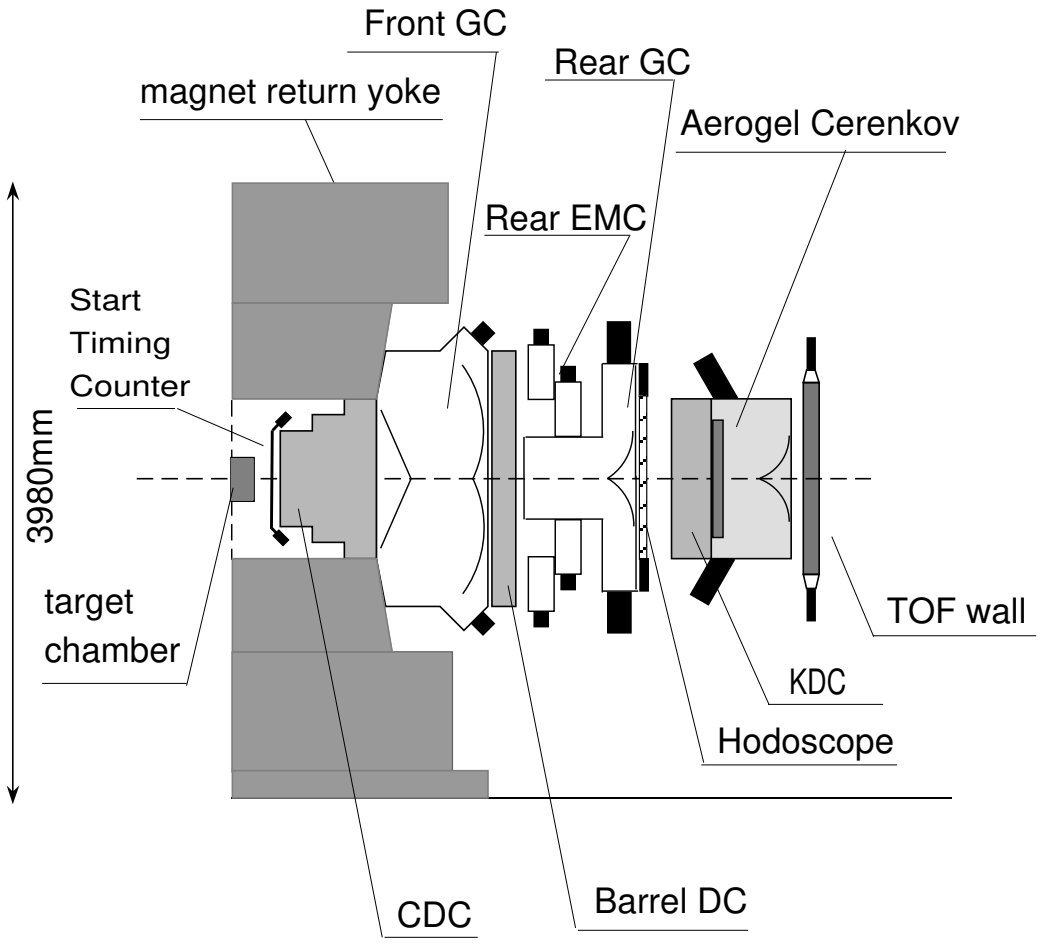
E325 collaboration

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

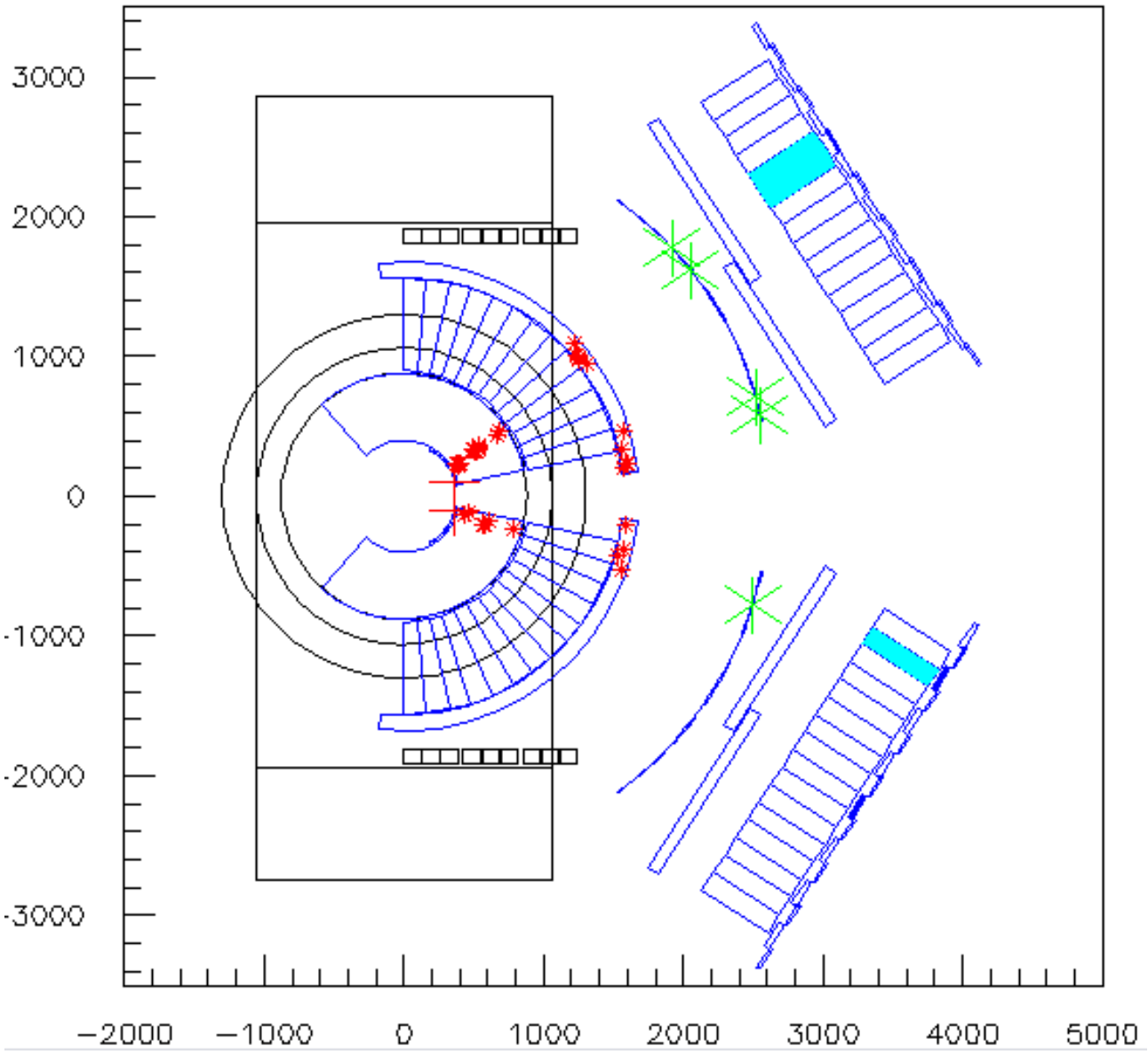
- Kyoto-Univ
  H.Enyo, H.Funahashi, T.Haseyama, M.Ishino, H.Kanda, S.Mihara, T.Miyashita, T.Murakami, R.Muto, M.Naruki, K.Ozawa, H.D. Sato, T.Tabaru, S.Yamada,S.Yokkaichi, Y.Yoshimura
- CNS,Univ.of Tokyo
  H.Hamagaki
- KEK
  J.Chiba, M.Ieiri, O.Sasaki, M.Sekimoto, K.Tanaka
- RCNP
  M.Nomachi
- T.I.T.
  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

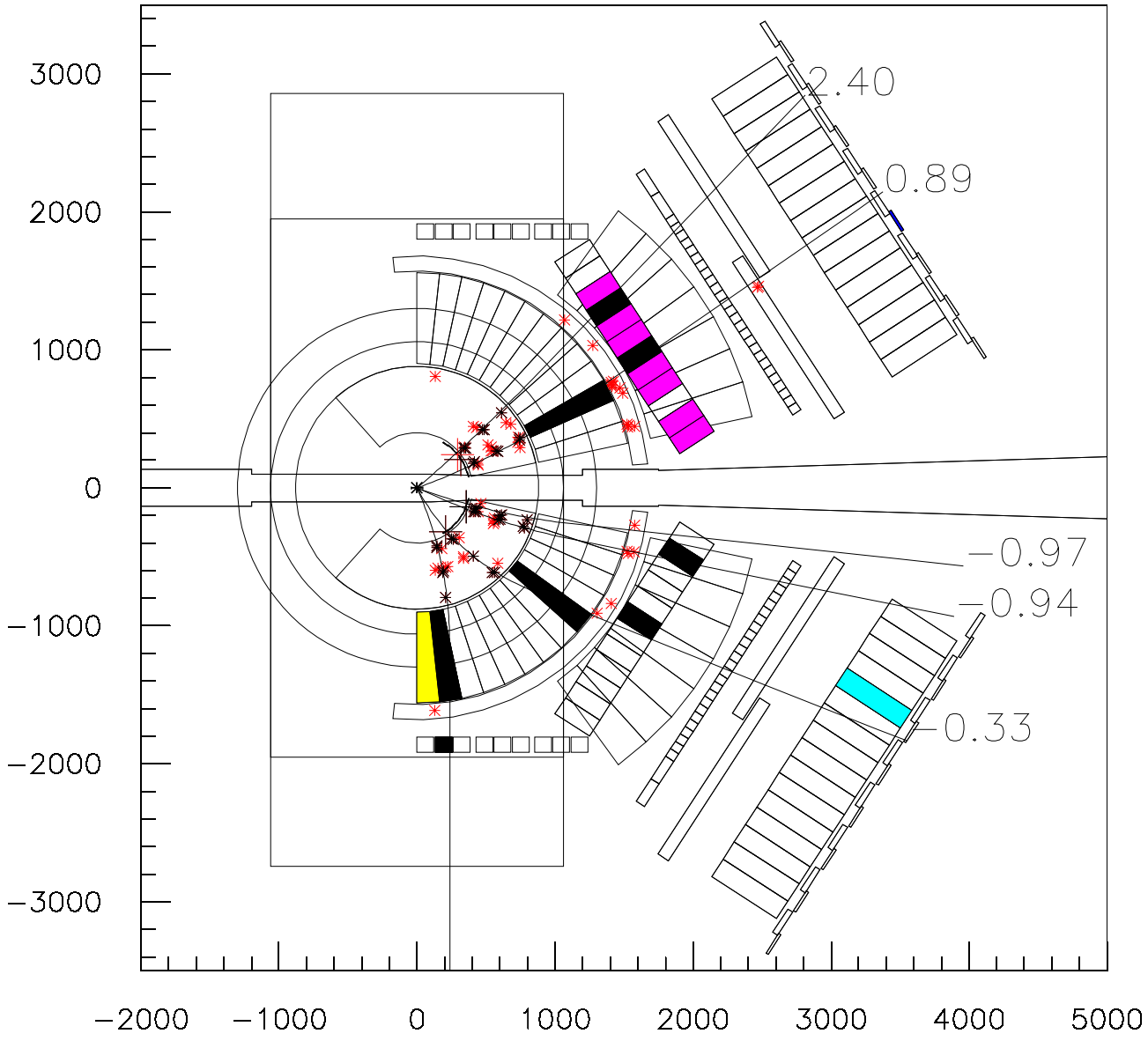

Front GC
Rear GC
magnet return yoke
Aerogel Cerenkov
Rear EMC
Start Timing Counter
3980mm
target chamber
TOF wall
KDC
Hodoscope
CDC
Barrel DC

Typical Event



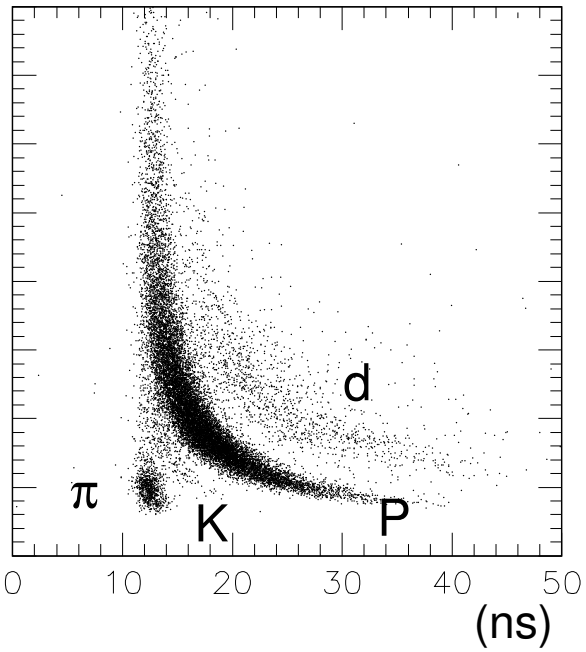
- $\pi^+\pi^-$ **event**
- **CDC hits, BDC hits, AC hits and TOF hits**

Typical Event

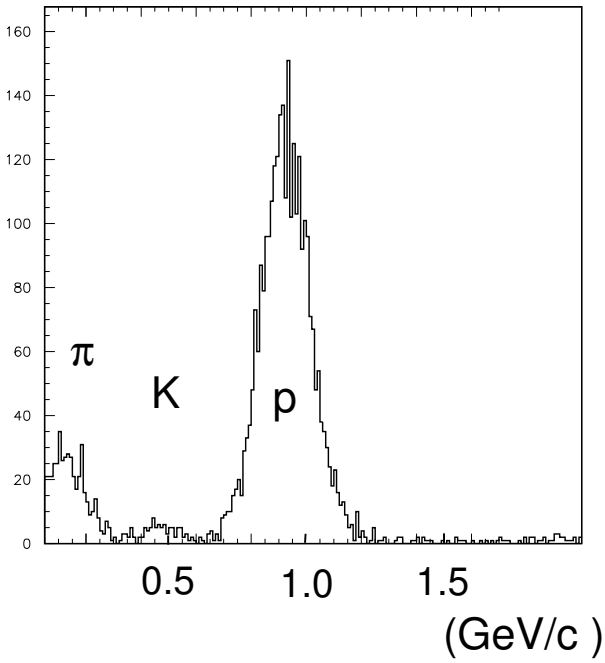


- e^+e^- **event**
- **CDC track, FGC/RGC/RLG hits**

Particle Identification

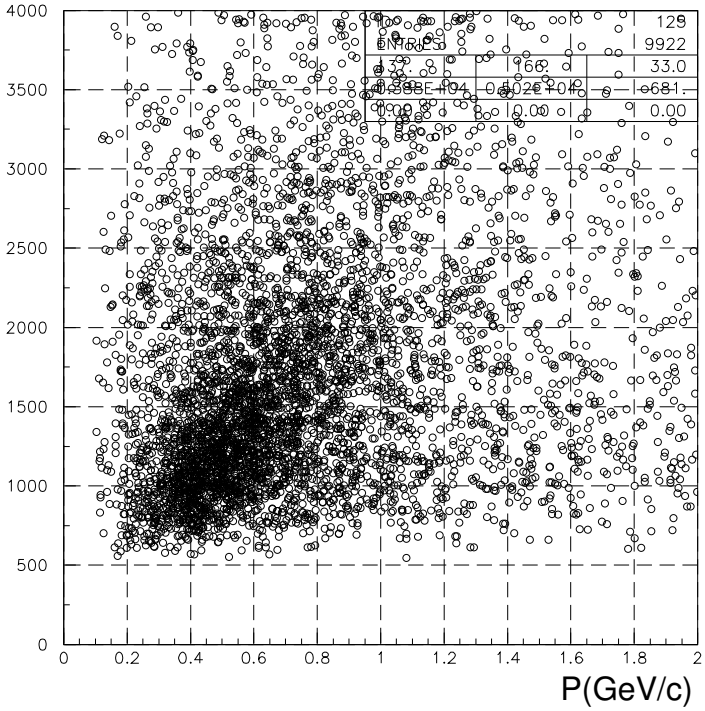


TOF

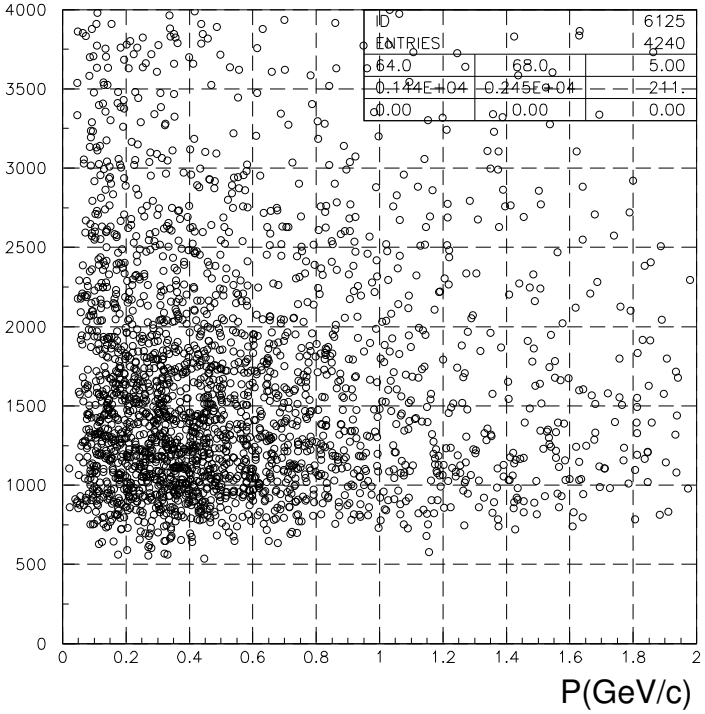


Mass

- **All positive particles with AC veto (Threshold = ∼500MeV/c).**
- **Kaons are identifed.**



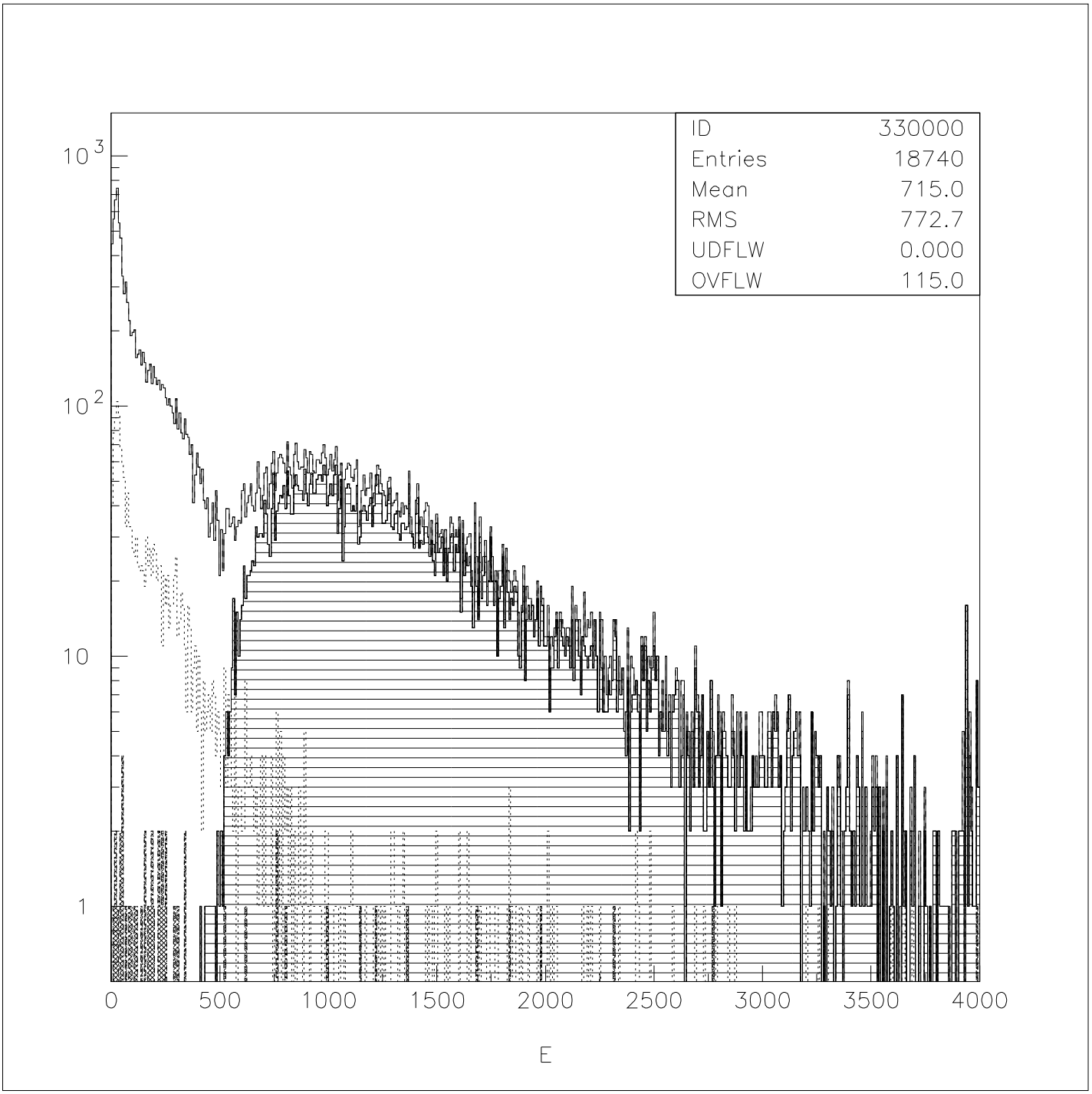
electron candidates



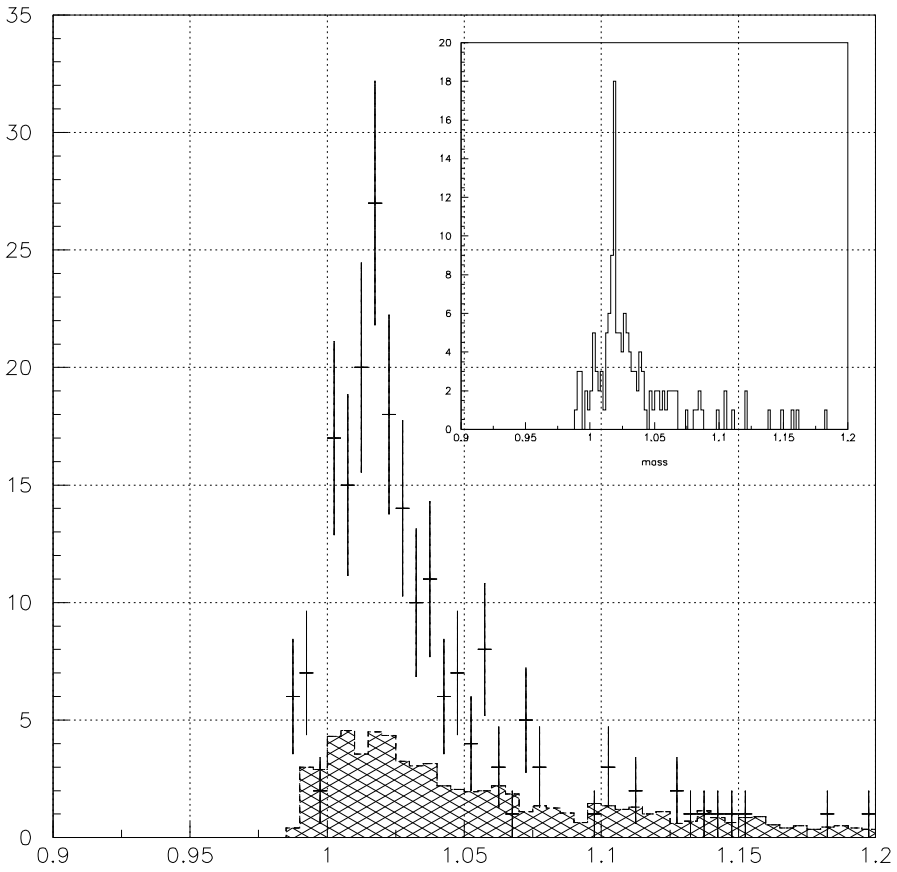
pion candidates

- **Responce of Lead Glass Counter**

Particle Identification (cont.)



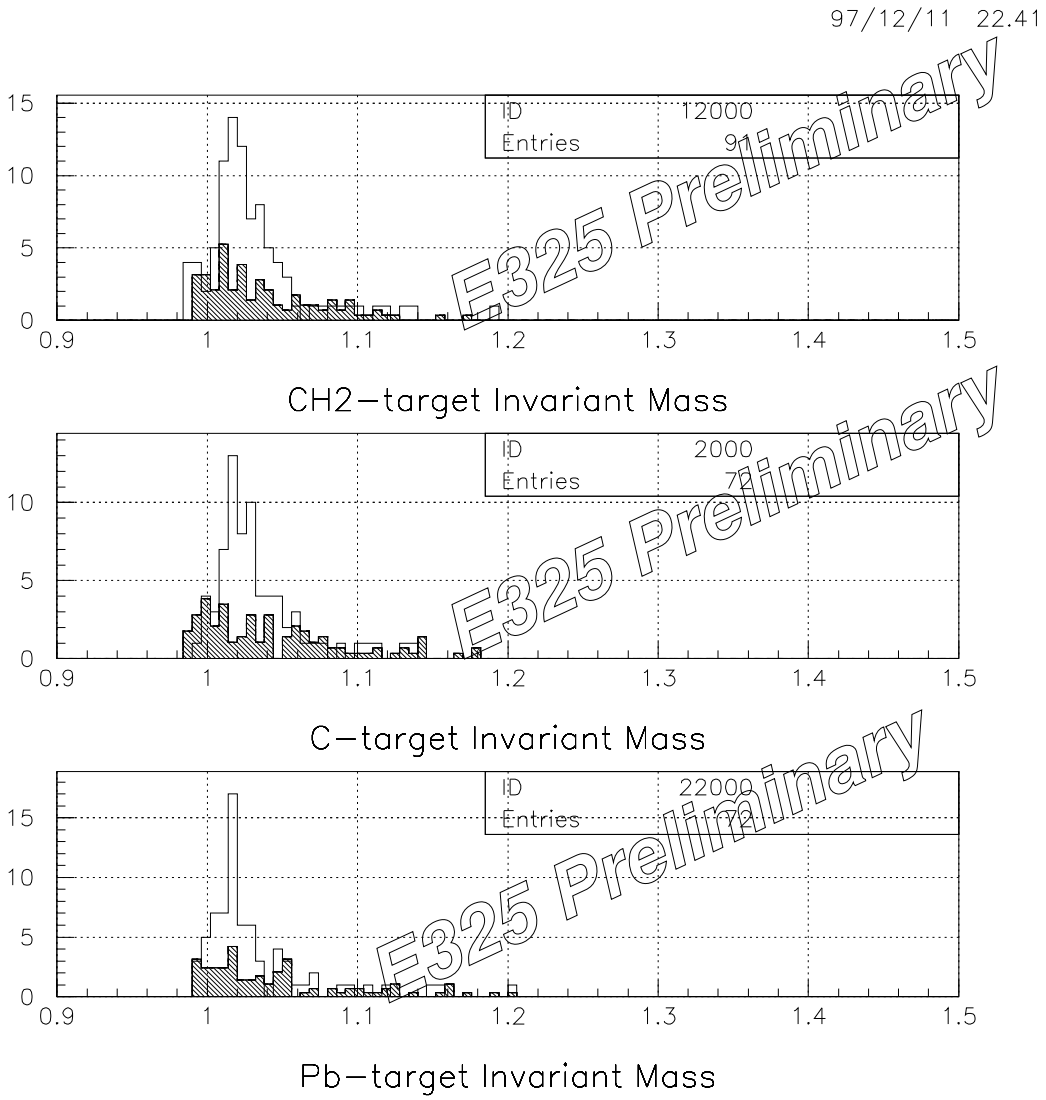
K^+K^- invariant mass spectrum



- $P_{kaon} < 1.2 GeV/c$
- $0.3 < Mass_{kaon} < 0.7 GeV/c^2$
- **Two kaons are in the same arm.**
- **TOF consistency in the Hodoscope and the TOF counters.**
- **Mixed event background is overplotted (shaded area).**

K^+K^- invariant mass spectrum

Target Mass Dependence



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 region
    possible to measure $\phi \to \mu^+\mu^-$

  → **Explore the density dependence**

Summary and Outlook

- – The experiment, E325, at KEK 12GeV PS measures 12 GeV $p + A \rightarrow \phi + X$ reactions in both $\phi \rightarrow K^+K^-$ and $\phi \rightarrow e^+e^-$ channels. Especially we put an emphasis on the detection of slowly moving ϕ mesons ($\sim$ 1GeV/c in lab., thus decay in Nuclea Media).
  - – To observe a possible change of the ratio, $Br(\phi \rightarrow K^+K^-)/Br(\phi \rightarrow e^+e^-)$, and of the shape of the mass peak under the normal nuclear density ($\rho = \rho_0$ and $T = 0$), $p+A$ and $p+p$ interactions are to be compared.
  - – When Hatsuda's prediction is correct, the second peak (or shoulder) will appears in the e^+e^- invariant mass spectra.
  - – About 10000 $\phi \rightarrow e^+e^-$ decays are to be collected using the large spectrometer at the new primary beam line in KEK-PS.
  - – If the changes are observed, the results give the property of the meson in nuclear media, which leads to the information of the chiral symmetry restoration.
- – 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.