Partial decay widths of ϕ meson in dense medium, measured in the e^+e^- and K^+K^- decay channels in 12 GeV p+A reactions at KEK-PS E325

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http://www-nh.scphys.kyoto-u.ac.jp/phi/E325_project.html

Physics Motivation

quark mass

chiral symmetry restoration

bare mass
$m_u \fallingdotseq m_d \fallingdotseq 5MeV/c^2$
$m_s \fallingdotseq 150MeV/c^2$

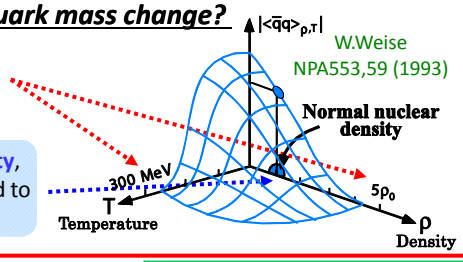
effective mass in QCD vacuum
$m_u \fallingdotseq m_d \fallingdotseq 300MeV/c^2$
$m_s \fallingdotseq 500MeV/c^2$

chiral symmetry breaking

how we can detect such a quark mass change?

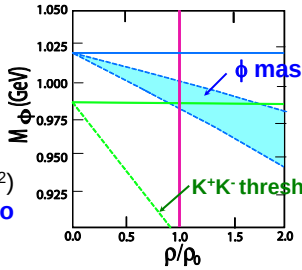
at **very high temperature or density**, the chiral symmetry is expected to restore

even at **normal nuclear density**, the chiral symmetry is expected to restore partially



vector meson, ϕ

- predicted mass decreases
  ~ 20-40MeV/c²
- narrow decay width (Γ=4.3MeV/c²)
  ⇒sensitive to the mass spectrum change
- small decay Q value ($Q_{K^+K^-}$=32MeV/c²)
  ⇒the branching ratio is sensitive to ϕ (or K) meson modification



for example
- ϕ mass decreases
  → $\Gamma_{K^+K^-}$ becomes small
- K mass decreases
  → $\Gamma_{K^+K^-}$ becomes large

ϕ : *T.Hatsuda, S.H.Lee, Phys. Rev.* ***C46****(1992)R34.*

K : *H.Fujii, T.Tatsumi, PTPS* ***120****(1995)289.*

KEK-PS E325 Experiment

measurements

invariant mass of e^+e^-, K^+K^-
in 12GeV p+(C/Cu)→ρ,ω,ϕ+X reactions

slowly moving vector mesons (ρ_{lab}~2GeV/c)
large probability to decay inside a nucleus

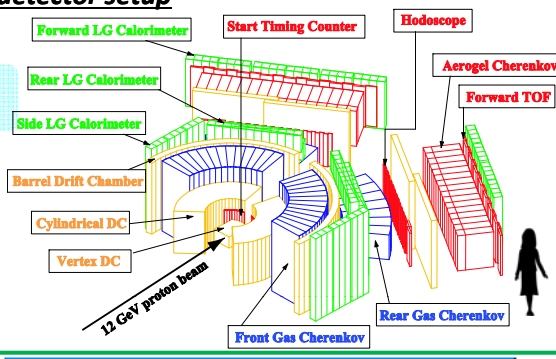
beam

primary proton beam (~10^9/spill/1.8s)

target

very thin targets
e.g. 0.4% radiation length &
0.2% interaction length for C-target

detector setup

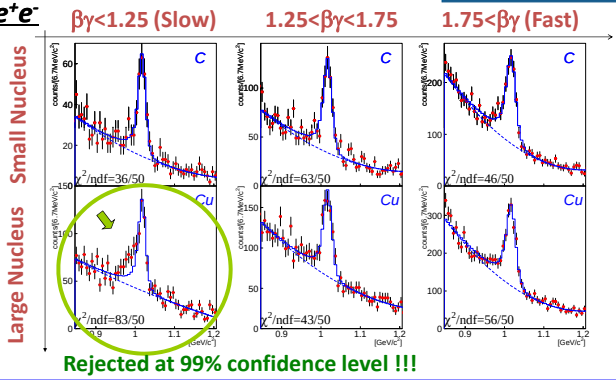


history

'93	proposed
'96	construction start *NIM, A457, 581 (2001).* *NIM, A516, 390 (2004).*
'97	first K^+K^- data
'98	first e^+e^- data *ρ/ω: PRL, 86, 5019 (2001).*
'99~'02	x100 and x6 statistics in e^+e^- and K^+K^- *ρ/ω: PRL 96, 092301 ('06).* ***ϕ→ee: PRL 98, 042501 ('07)*** *α : PRC, 75, 025201 ('06)* ***ϕ →KK, α : PRL 98, 152302 ('07)***

Results and Discussions

$\phi \to e^+e^-$



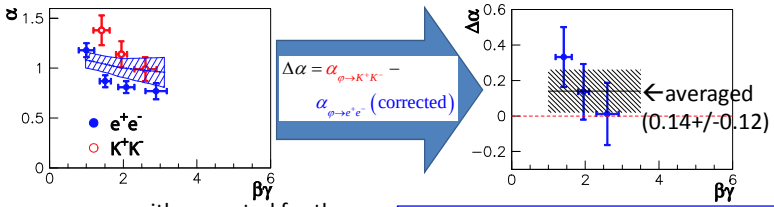
Rejected at 99% confidence level !!!

the excess is attributed to the ϕ mesons which decay inside a nucleus and are modified

nuclear mass-number dependences of $\phi \to e^+e^-$ & $\phi \to K^+K^-$

- $\Gamma_{\phi\to K^+K^-}/\Gamma_{\phi\to e^+e^-}$ increases in a nucleus → $N_{\phi\to K^+K^-}/N_{\phi\to e^+e^-}$ becomes large
- the lager modification is expected in the larger nucleus and slowly moving ϕ mesons

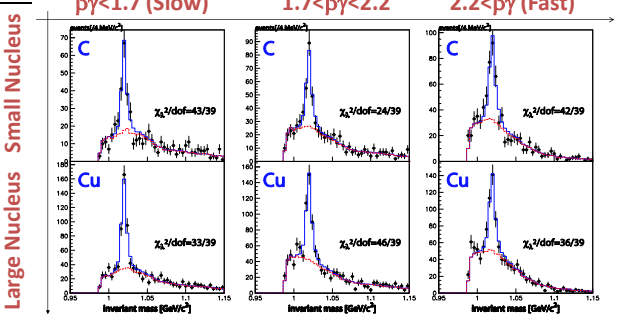
$$\sigma(A) = \sigma(A=1)\times A^{\alpha} \quad \Rightarrow \quad \Delta\alpha = \alpha_{KK} - \alpha_{ee} \propto \ln\left\{\frac{\Gamma_{KK}(A_2)}{\Gamma_{ee}(A_2)} \Big/ \frac{\Gamma_{KK}(A_1)}{\Gamma_{ee}(A_1)}\right\}$$



= $\alpha_{e^+e^-}$ with corrected for the K^+K^- acceptance

$\alpha_{\phi\to K^+K^-}$ and $\alpha_{\phi\to e^+e^-}$ are consistent within errors

$\phi \to K^+K^-$



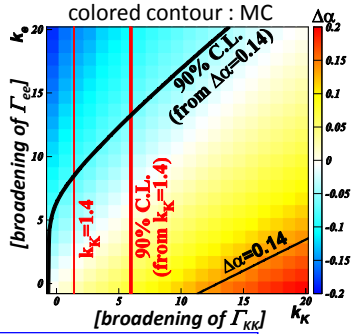
mass-spectrum changes are NOT statistically significant , because the detector acceptance is different between e^+e^- and K^+K^-

discussion on $\Gamma_{\phi\to e^+e^-}$ and $\Gamma_{\phi\to K^+K^-}$

$$\Gamma^*_{\phi}/\Gamma^0_{\phi} = 1 + k_{tot}(\rho/\rho_0),$$
$$\Gamma^*_{\phi\to K^+K^-}/\Gamma^0_{\phi\to K^+K^-} = 1 + k_K(\rho/\rho_0),$$
$$\Gamma^*_{\phi\to e^+e^-}/\Gamma^0_{\phi\to e^+e^-} = 1 + k_e(\rho/\rho_0)$$

$k_{tot} \simeq k_K$

- the measured $\Delta\alpha$ provides constraints on width broadening k_K and k_e
- width broadening k_K was obtained from the amount of excess in $\phi \to K^+K^-$ spectra
  k_K = 1.4+/-1.1(stat)+/-2.1(syst)



the first experimental limits assigned to the in-medium broadening of the partial decay widths