Study of $\phi$ mass modification with $K^+K^-$ decay in $p+A$ collisions at J-PARC

Susumu Sato$^1$,


$^1$Japan Atomic Energy Agency, $^2$University of Tsukuba, $^3$KEK, $^4$Academia Sinica, $^5$Kyoto Univ., $^6$RIKEN, $^7$Univ. of Tokyo, $^8$Tsukuba Univ. of Technology, $^9$BNL

(*)susumu.sato@j-parc.jp
In order to study the modification of \( \phi \) mass in the nuclear matter, we propose to measure the \( \phi \rightarrow K^+K^- \) decay in proton-nucleus (p+A) collisions, where a slow \( \phi \) is produced inside the nucleus. We measure the invariant mass spectrum and the branching ratio of the decay.

Since the \( \phi \) mass is very close to the \( K^+K^- \) decay threshold, the branching ratio is expected to be sensitive to the change of \( \phi \) mass.

- The advantages of the \( K^+K^- \) decay is that high statistics measurement is possible due to larger branching ratio (49.2\%) that is higher by 3 order than that of \( e^+e^- \) (2.973 \times 10^{-4}).

- On the other hand, the measured invariant mass is affected by final-state interactions with nucleons inside the target nucleus, while it is not the case for the \( e^+e^- \) decay. The change of the \( \phi \rightarrow K^+K^- \) yield is furthermore influenced by the mass modifications of \( K^\pm \) inside the nucleus. It thus includes complex physics, which needs to be disentangled and understood to properly interpret the corresponding experimental data. Therefore, the formulation of theoretical models incorporating information on both \( \phi \)-N and \( K^\pm \)-N interactions will be needed.
We proposed J-PARC E88 experiment, which is aiming for high-statistics invariant mass and yield measurements (100 x KEK-E325) for:

- A-dependence (C, Cu, Pb)

- Focus on slow $\phi$ ($\beta\gamma < 2$) : to enhance $\phi$ stop probability inside the nucleus

- Comparison to $\phi \rightarrow e^+e^-$ in J-PARC-E16

**Experimental Setups at J-PARC, and Calculated mass spectra**

**HSD model** (*) calculates invariant mass spectrum:
- w/ GEANT4 simulation
- In acceptance
- With momentum resolution

(*) HSD model, is developed for $\phi \rightarrow KK$ calculations, by P. Gubler (JAEA), S. H. Lee (Yonsei Univ.), E. Bratkovskaya, T. Song (Frankfurt U./GSI)

It contained:
- K± in-medium modified spectral function
- K-N interaction based on chiral unitary model including off-shell effects
- Scattering and absorption of K± in nucleus
- $\phi$ spectral function of Breit-Wigner shape
- Mass shift of $\Delta m = -34 MeV$ (based on KEK-E325)
We performed GEANT4 simulation with JAM event generator to estimate the yields in the two low $\beta\gamma$ bins ($\beta \gamma < 1.25$, and $1.25 \leq \beta \gamma < 1.75$), which are shown above table.

The assumptions are:

(i) Beam time: 30 days with 30 GeV proton beam at $1 \times 10^9$/spill, and

(ii) Target of C(0.1% int.) + Cu(0.1% int.) + Pb(0.1% int.).
For hadron-identification (π/K/p), the MRPC time-of-flight detector, with heating-system is being developed.

- Time resolution is improved, by raising the temperature from 19[deg.C] to 30[deg.C], increase of gain and improvement of detection efficiency <--- High-rate tolerance will be expected.

- Time resolution (so far is 130ps) will be simply improved by much the gas tightness at the inlet towards the poly-carbonate gas enclosure case.

- Detection efficiency is ~99%