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J-PARC 50 GeV Proton Synchrotron

Addendum to the proposal P29

Study of in medium mass modification for the ϕ meson using ϕ meson bound state in nucleus

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The P29 collaboration

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Abstract

We propose to study in-medium mass modification of the ϕ meson using the formation of ϕ meson bound state. In the previous J-PARC PAC meeting, it was decided that the proposal will be deferred until we explain all questions pointed out by PAC. In this manuscript, the answers to the PAC questions are given, together with more details helping in making the scientific case and its feasibility even more clear.

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1 Introduction

The mass shift of the vector mesons in nuclear media is known to be a powerful tool to investigate the mechanism of generating hadron mass from QCD vacuum. The mechanism is known to be the spontaneous breaking of the chiral symmetry. In the year 2007, KEK-PS E325 experiment reported about 3.4% mass reduction of the ϕ meson in medium-heavy nuclei (Cu) [1]. This result is pointing towards a possible partial restoration of the chiral symmetry in nuclear media, however, it is hard to make strong conclusion using only that data. On the other hand, recently ϕ meson and nucleon cross section have been investigated at LEPS at SPring-8[2] and CLAS[3] at J-LAB using gamma ray induced hadron production processes and presented unexpectedly large cross section between ϕ-N, $\approx$ 20 mb, which can be interpreted as huge broadening of ϕ meson decay width in nuclear media, without mass shift of ϕ meson. Therefore the ϕ meson mass dropping phenomena in nuclear matter is still controversial.

To get definitive information about the possible ϕ meson mass shift in nuclear media, definitely we need to perform new generation experiment. There is the E16 experiment[4] at J-PARC in progress, which intends to measure di-electron spectra in p-A collisions precisely at J-PARC with 100 times more statistics than previous experiment at KEK-PS.

The present proposal instead starts form the 3.4% (=35 MeV/c^2) possible mass reduction of the ϕ mass in nucleus measured by KEK E325 experiment. We plan to confirm (or not) this shift by performing a much more precise experiment. Possible theoretical indications toward the existence of the ϕ-mass shifts are related to the charged kaon behavior in nucleus. Hint is in the situation of Kaon in nucleus. Reference[5] pointed out that mass of the K$^-$ will be reduced in nuclear matter due to strong attractive potential exist between K$^-$ and nucleon. This theoretical prediction indicates that the "mass reduction of ϕ meson in nucleus" will be directly connected with the possible existence of attractive potential between ϕ meson and nucleus. The depth of the potential is expected to be as a same order of the mass reduction which have been measured. Therefore, we have examined a experimental approach to measure ϕ meson properties in nuclear media using formation of ϕ-meson bound state.

The purpose of the proposed experiment is to search for the ϕ-nucleus bound state and measure the binding energy of the system. The measurement must be done with different target nuclei to see the evolution of the binding energy of newly generated nuclear cluster, ϕ-nucleus bound state.

This addendum is organized as follows. In Sec 2, we shortly discuss the concept of our measurement. In Sec 3, we describe the conceptual design of the detector and its basic expected performance. In Sec 4, we summarized the list of the questions from the PAC and finally, our answers to questions from PAC are given in Sec 5.

2 Concept for the measurement

In order to experimentally search for the ϕ meson bound nuclear state, we are focusing on the elementary process $\overline{p}p \rightarrow \phi\phi$ around production threshold. The advantage for this elementary process are (a) relatively low momentum ϕ meson, which is around a few 100 MeV/c, can be produced by the reaction, and (b) it is found experimentally that in the case of double strangeness pair production in $\overline{p}p$ annihilation for this energy, $\phi\phi$ production appears as the dominant production branch. The production of four kaons or ϕKK are highly suppressed [6].

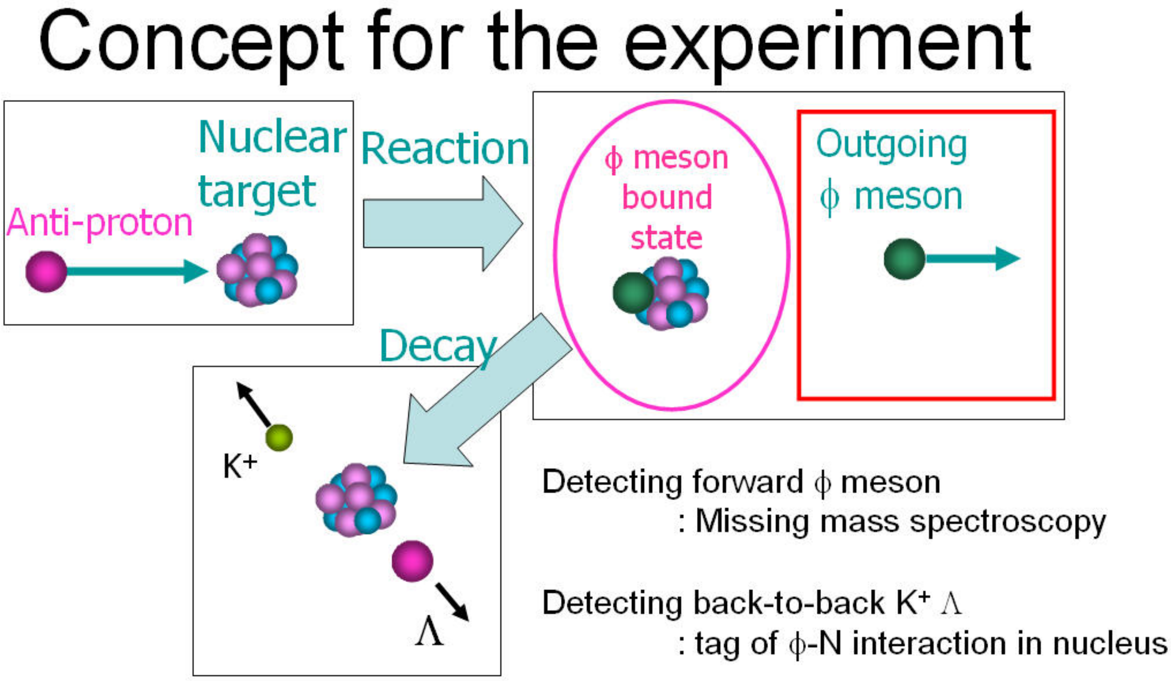

Figure 1: The concept for the proposed experiment

The concept for the experiment is shown in Figure 1. Double ϕ mesons are produced by $\overline{p}p \rightarrow \phi\phi$ on one of the proton in nucleus. The forward going ϕ meson is detected and identified by its decay products of K^+ and K^-. The other ϕ meson, which will be moving backward direction in CM frame of $\overline{p}p$ reaction, will be trapped in nucleus and a ϕ meson bound state will be formed. It should be noted that if we choose incident $\overline{p}$ momentum of about 1.1 GeV/c, the momentum of the backward ϕ meson in lab. frame will be about 240 MeV/c, which is comparable with the Fermi momentum of the nucleon in nucleus if we select heavy nucleus as a target. The sticking probability of ϕ meson to the nucleus, like carbon, is expected to be $\approx 11\%$. Finally, the ϕ meson which is trapped in nucleus will disappear because of ϕ-N interaction. The decay product from the $\phi - N$ interaction is expected to be $\mathrm{K}^+ + \Lambda$ and $K_s^0 + \Lambda$ for ϕ-proton and $\phi - neutron$ interaction, respectively.

The identification of the ϕ meson bound state will be done as follows. First of all, missing mass of the reaction using forward going ϕ meson is analyzed. However, huge number of background events expected from the reaction channel, such as $\overline{p}p \to \phi\pi\pi$ and $\overline{p}p \to K^+K^-\pi^+\pi^-$, the signal coming from the eventual bound state formation will not appear cleanly only in the missing mass spectroscopy. As a second step, we will require Kaon and/or Λ in coincidence to the existence of forward going ϕ meson. The requirement for the of Kaon or Λ together with ϕ meson is essentially selecting the event with double strangeness pairs production. The double ϕ meson production is the dominant process for double strangeness pair production in $\overline{p}p$ annihilation at the energy region we are interested, thus, this requirement will reject almost all background event. The rejection power and expected signal and background will be discuss in the later section.

Therefore, the measurement can be explained as the missing mass spectroscopy using forward going ϕ meson together with Λ production as a tag of double strangeness production.

3 Conceptual design for the spectrometer

3.1 Setup for the experiment

The detector is designed to detect forward going ϕ meson efficiently together with large acceptance for decayed particle from ϕ meson bound state.

The conceptual design for the spectrometer is shown in Figure 2. The target is placed on the center of the dipole magnet. A cylindrical drift chamber(CDC) is surrounding the target to maximize acceptance for the decay particles, namely K^+ and/or Λ. Moreover, the CDC will also be working perfectly for forward going Kaons from the ϕ meson decay.

Three parameters need to be determined to design the tracking detectors, namely, radius of the region where uniform magnetic field will be presented (r), lever arm in the tracking detector (L_{arm}) and the field strength generated by magnet. Those parameters have been chosen to satisfy the required missing mass resolution, $\approx$ 15 MeV/c^2. The values are chosen as L_{arm}=70cm and B$\sim$0.5 T. Those values are used as the basic parameters for detector simulation. The missing mass resolution expected with those parameter is expected to be approximately 13 MeV/c^2 with this parameter.

The Time of Flight (ToF) wall will be installed just outside the CDC for trigger and particle identification(PID).To achieved more than 2 σ separation of pions and kaons up to 700 MeV/c momentum, the time resolution of the ToF wall must be less than 100 ps. Moreover, part of the ToF detector system is going to be in the region where magnetic field is present. To have such high timing resolution under the magnetic field condition, we selected Resistive Plate Chamber(RPC) as a candidate of our detector. R&D project for the ToF wall is also in progress.

The segmented Cherenkov counters(CRK) will be installed just after the ToF wall to

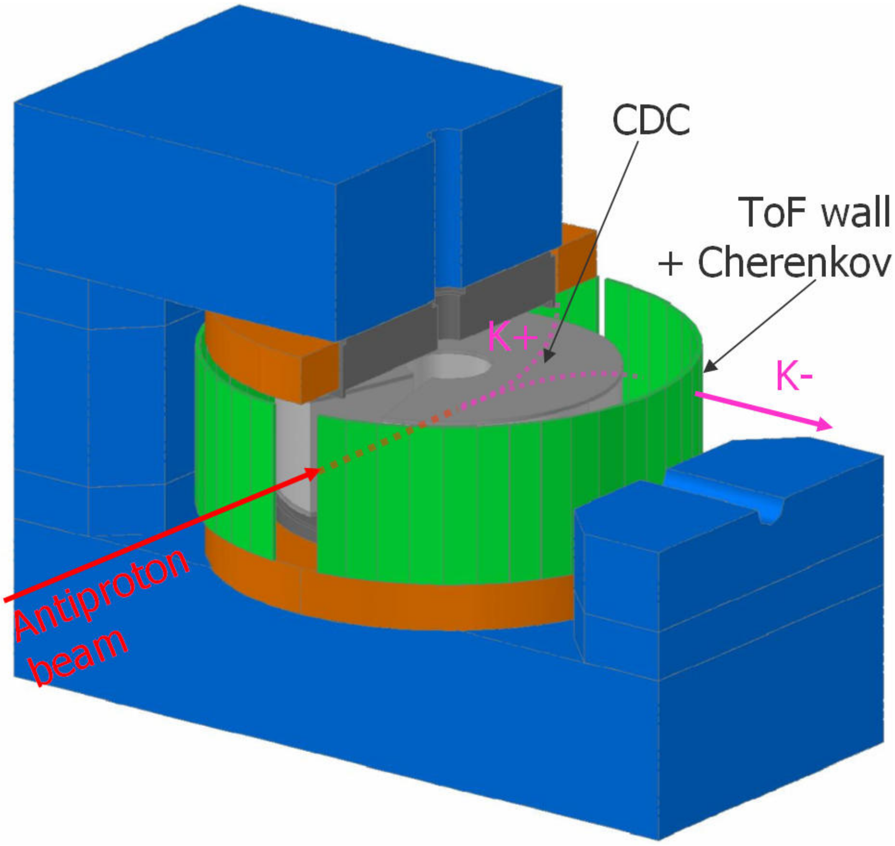

Figure 2: conceptual design for the spectrometer.

reject pions which are mainly coming from multi pion production in the $\overline{p}p$ annihilation processes. The Cherenkov radiator for CRK counter is is chosen to have very efficient in rejecting pions, without killing the kaons from our signal. Figure 3 shows momentum distribution for generated ϕ meson and kaons from the ϕ meson decay. The Kaons from ϕ meson decay are distributed only at small momentum, less than 600 MeV/c, *i.e.* $\beta \approx 0.77$. Therefore, we need to choose the Cherehkov radiator which has the Cherenkov threshold of more than $\beta \approx 0.77$.

One of the candidate satisfying the request to reject pions but not affect kaons with momenta below and around 600 MeV/c is the recently developed high density silica Aerogel which has refraction index(n) of approximately n=1.2. The other possibility is using water, which has refraction index of 1.33. Actual design of cherenkov counter is under the way.

Both ToF and CRK will be divided into 34 segments, each segment will cover 10 degrees in θ angle on x-z(beam direction) plane.

Detail study of expected detector performance and trigger rejection factor will be discussed in the following sections.

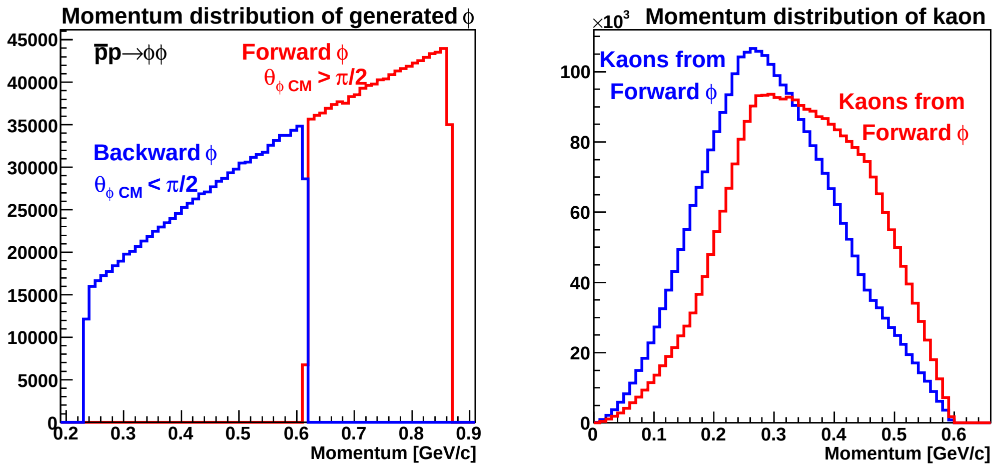

Figure 3: (Left): Momentum distribution of generated ϕ meson. (Right): Momentum distribution of Kaons from ϕ meson decay.

3.2 Detector simulation

Detector simulation is build based on GEANT4 tool kit. All detectors and possible materials have been included in the simulation to obtain realistic background for trigger study, *i.e.* secondary particle produced by interactions with detector material. The basic expected detector performance will be shown in following section.

3.3 Particle Identification (PID)

The PID is performed using reconstructed momentum and ToF of the particle. The ToF resolution is assumed to be 100 ps in the simulation. Flight path length of the particle is calculated reconstructing track length in CDC plus distance from vertex position to first hit position in CDC. The Mass squared has been calculated using the following formula,

$$m^2 = p^2 \left[\left(\frac{ToF}{L} \right)^2 - 1 \right], \tag{1}$$

where p is the momentum of the particle, L is the flight path length from vertex position to the hit position on ToF wall. The typical mass squared distribution is shown as Figure 4. The particle identification criterion on Mass squared cut for Kaon is defined using the Figure 4. Clear pion and Kaon separation can be made up to particle momentum less than 700 MeV/c.

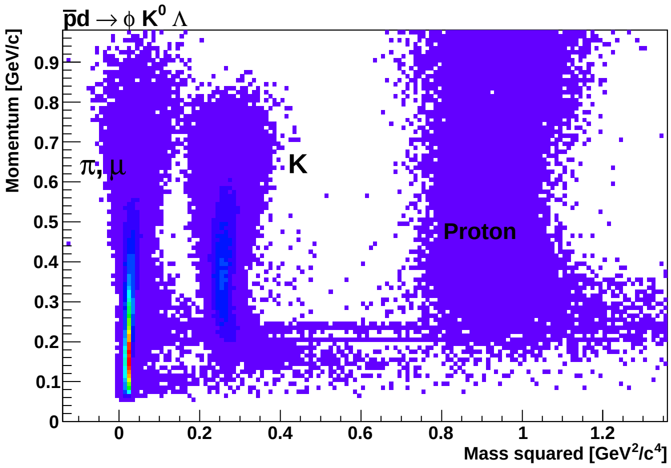

Figure 4: Mass squared distribution of reconstructed particles.

3.4 Trigger for the experiment.

The cross section for $\overline{p}p$ annihilation is quite large. Once we choose incident momentum of the $\overline{p}$ as 1.1 GeV/c, the annihilation cross section is approximately 60 mb. Moreover, for example, the annihilation cross section on nucleus is known to be 120 mb and 500 mb for deuteron and Carbon, respectively. Once we assume 10^6 $\overline{p}$ beam per spill and using 2g/cm^2 target, the total interaction rate will be $\approx$ 50k reaction per spill even for deuteron. In the case of heavier targets, like Carbon or Copper, the expected interaction rate will be more than 500k reaction per spill.

The combination of the signal, $(ToFhit) \times \overline{(CRKhit)}$ will be used to generate a trigger signal for "Kaon like track". The key measurement for the experiment is K^+K^- in the forward direction. Therefore the requirement of two "Kaon like tracks in forward direction" will be the baseline trigger condition for the experiment.

Here we checked hit position distribution on ToF wall from the event from $\overline{p}p \rightarrow \phi\phi$ process, which is the signal we want to collect. The results are shown as Figure 5. From the figure, Kaons from ϕ meson decay made a hit on ToF counter with in ±90 degree respect to the beam direction(z direction). Now we required two Kaon like hits on the ToF wall within ±90 degree in θ angle respect to the beam axis as a trigger condition.

As a first step, trigger condition on total $\overline{p}d$ annihilation is simulated with event generator UrQMD[10] which describes total cross section of $\overline{p}$ annihilation even on nucleus. The generated events are passed through detector simulation and trigger condition. Figure 6 shows hit multiplicity distribution on ToF counters with requiring two Kaon candidate hits in forward counters. The results shows that if we required more than 2 tracks together with two Kaon candidate in forward direction makes survival rate for the background $\overline{p}$ annihilation event to be 1.8%. In the situation when we require more than three ToF hits multiplicity, the survival rate will be 0.9%. Therefore,

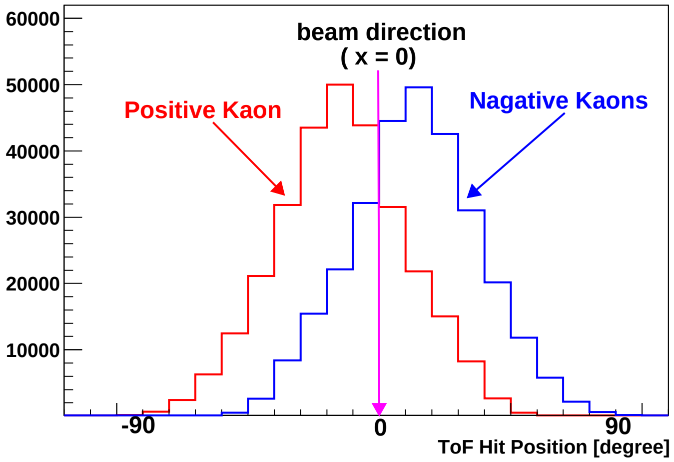

Figure 5: Expected hit position of Kaons from ϕ meson decay on ToF wall. Red line corresponds to the ToF hit position for positive tracks, and blue indicates hit position for negative tracks.

final trigger rate expected with deuteron target will be 900 and 450 triggers/spill, for ToF multiplicity more than two and three, respectively. In the case of Carbon target, the final trigger rate found to be 9k and 4.5k triggers per spill for ToF multiplicity more than two and three, respectively. This is basic trigger condition for the experiment.

4 Questions from the PAC

Four questions are pointed out in the PAC report for this proposed experiment. The list of questions are as follows.

- **Question-1** : It is not clear if double ϕ production which is dominant in $p\bar{p}$ annihilation in the vacuum still dominates in the annihilation in nuclei.
- **Question-2** : The proponent should prepare a simulation showing that the expected signal to background ratio is achievable after all the trigger and final-particle decay selections are made
- **Question-3** : The estimation of the count rate is to be clarified.
- **Question-4** : The K1.1 beamline is not completed yet, so that the proponent should consider as alternative possibility to do this experiment in another beam line.

The answer for those questions are described in the following sections.

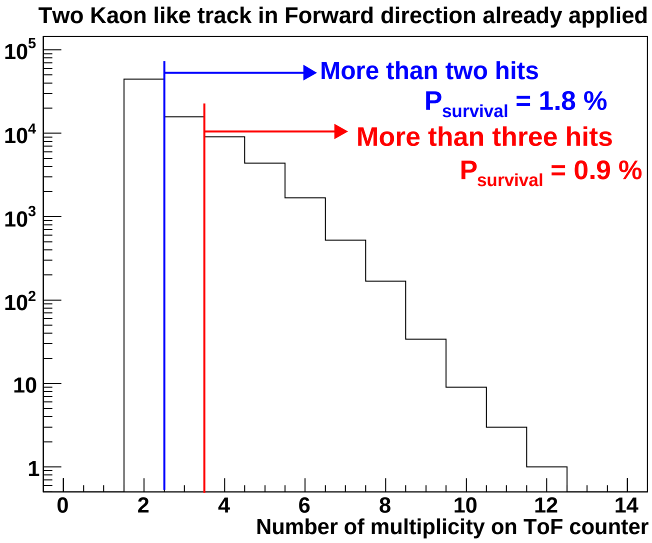

Figure 6: ToF hit multiplicity distribution.

5 Answer for questions from PAC

5.1 Answer to Question-1

The first question was

> **Question-1** : It is not clear if double ϕ production which is dominant in $p\overline{p}$ annihilation in the vacuum still dominates in the annihilation in nuclei.

The process of double ϕ meson production have not been measured in $\overline{p}A$ reaction. Moreover no solid theoretical explanation exists for the $\phi\phi$ production mechanism on $\overline{p}p$ annihilation, thus it is very hard to lead a solid conclusion whether $\overline{p}p \to \phi\phi$ process really happened in nucleus from the data exist.

We will present in what follows a different point of view of the matter. If our understanding for this question is correct, we will be able to rephrase this question to "How much fraction of double strangeness pairs will be produced by $\overline{p}$ annihilation on two or more nucleons, i.e. multi nucleon absorption process, other than single nucleon annihilation on nucleus?" Now we are starting with the discussion of nuclear mass number dependence of annihilation cross section of $\overline{p}$ reaction.

First, we will start from checking the evolution of the total cross section of $\overline{p}$-A annihilation as a function of nuclear mass number. Figure 7 shows a summary of the $\overline{p}$A annihilation cross section as a function of nuclear mass number, A, which is taken from reference[7]. The figure shows that the $\overline{p} - A$ annihilation cross section clearly

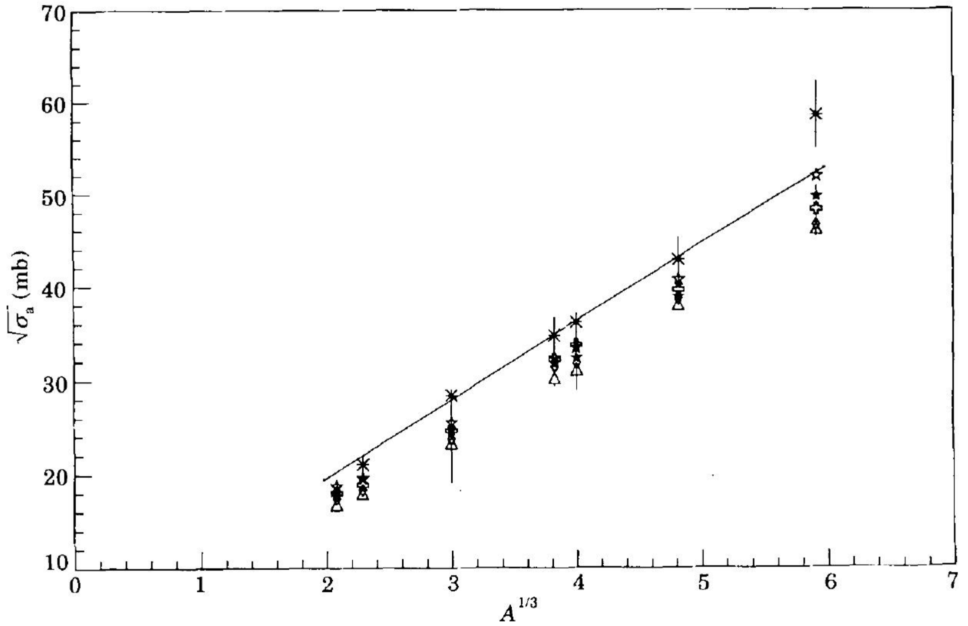

Fig. 28. – Linear dependence of $(\sigma_a)^{1/2}$ on $A^{1/3}$ at different $\bar{\text{p}}$ momenta: ✱ 700 MeV/c, ☆ 950 MeV/c, ★ 1260 MeV/c, ✙ 1530 MeV/c, ◇ 1760 MeV/c, △ 2500 MeV/c. The straight line is according to eq. (3.11) with the values of the parameters given by [Garr 85] (see fig. 25).

Figure 7: $\overline{p}p$ annihilation cross section on nucleus as a function of nuclear mass number(A)[7]. Clear A$^{2/3}$ dependence are seen.

follows liner dependence as a function of the $A^{2/3}(\sigma_{annihilation})$. It indicates that the $\overline{p}p$ annihilation on nucleus will happen mostly on the surface of the nucleus. Moreover in the same reference[7], the summary of the $\overline{\text{p}}$A annihilation cross section over $A^{2/3}$ as a function of the incident momentum of $\overline{p}$ is presented, together with the $\sigma_{\overline{p}p}$ as a function of incident $\overline{p}$ momentum as a dashed line in Figure 8. The very important message contained in the figure is that again the $\sigma_{annihilation}$ clearly follows $A^{2/3}$ dependence for the momentum of incident $\overline{p}$ more than 500 MeV/c. Moreover, if we choose incident momentum of $\overline{p}$ around 1.0 GeV/c, the annihilation cross section of $\overline{p}$ on nucleus is just $A^{2/3}$ times elementary cross section of $\overline{p}p$ annihilation($\sigma_{\overline{p}-A} = \sigma_{\overline{p}p} \times A^{2/3}$).

Therefore the only way to assume the production of double ϕ meson is that the process of $\overline{p}p \to \phi\phi$ might be happen in nucleus and the cross section also expected to be $\sigma_{\overline{p}A\to\phi\phi}$= $Z^{2/3} \times \sigma_{\overline{p}p\to\phi\phi}$, where we used number of proton, Z, instead of mass number A, because $\overline{p}p \to \phi\phi$ only happen on the proton, not the neutron in nucleus.

It should be noted that the discussion above is true for total annihilation cross section. However, it is not really trivial whether we can use same discussion for the strangeness production. It is more complicated for the case of double ϕ meson, *i.e.* double strangeness pair ($\overline{s}s$), production. Because available data for the double

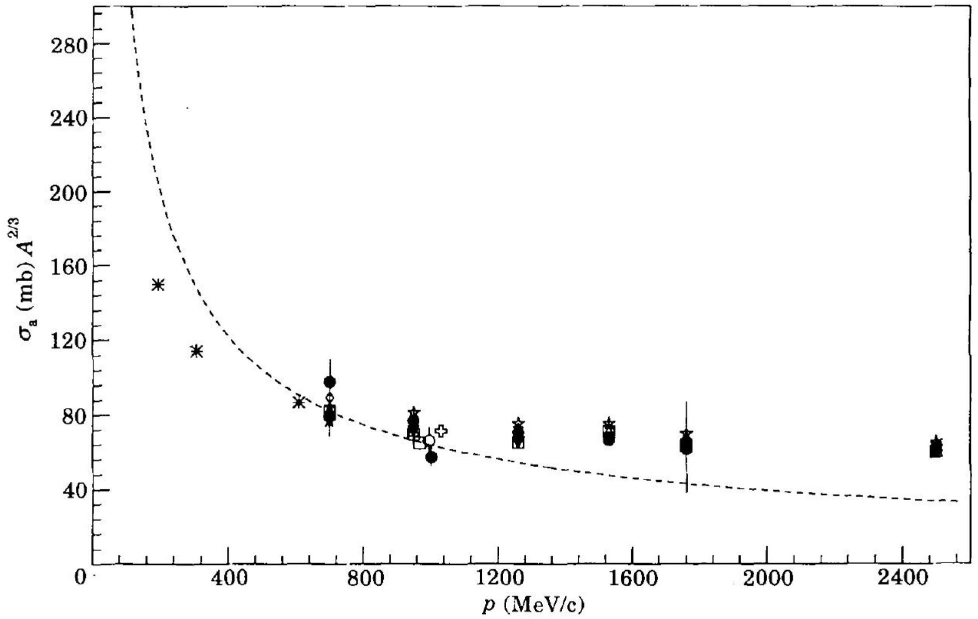

Fig. 27. – Comparison of σ_a ($\bar{p}$-nucleus)/$A^{2/3}$ and $\sigma_a(\bar{p}p)$. The dotted line follows eq. (7) of table II – -- – ^{1}H. ✱ ^{4}He. ☆ ^{9}Be. ★ ^{12}C. ✙ ^{16}O. ◇ ^{27}Al. ∧ ^{56}Fe. □ ^{63}Cu. ○ ^{108}Ag. ▼ ^{112}Cd. ● ^{207}Pb.

Figure 8: $\overline{p}$ annihilation cross section divided by A$^{2/3}$ as a function of incident $\overline{p}$ momentum, together with $\overline{p}p$ annihilation cross section[7].

strangeness production in $\overline{p}p$ annihilation are in-flight reaction of $\overline{p}p \to \phi\phi$, stopped $\overline{p}$ on ^{4}He target[8] and stopped $\overline{p}$ on Xe target[9]. Thus it is very hard to conclude whether production of double ϕ meson really happened in nucleus from the data exist.

Therefore to answer the question from the PAC clearly, we need to to measure double ϕ meson production on nucleus, even though it is not listed in original proposal. To making life a little easy, we would like to start by using simple nucleus as a target material, such as deuteron. The point here is that if $\overline{p}$ only interact with single nucleon in deuteron, *i.e.* proton, double ϕ meson produced and neutron act simply as spectator. Therefore final state particle for the reaction will be just K$^+$K$^-$K$^+$K$^-$ and spectator neutron, moreover all charged particles will be forward boosted. In this case, production cross section for the double ϕ production will be equal to the one on the $\overline{p}p$ annihilation cross section. However, if two nucleon absorption process exist or dominate in the reaction, final state particle will be ϕ, K^0 and Λ. In this case, three final state particles will be distributed equally within the phase space. For this measurement, we will be able to evaluate, how much faction of "two nucleon absorption" type of reaction exist for double strangeness production or we may see suppression of double strangeness pairs production in nucleus. The result give us an information for the production mechanism of double ϕ mesons in $\overline{p}p$ annihilation.

Detail expected spectra and event rate will be discussed in the next section together with the answer for question-2.

5.2 Answer to Question-2

The second question was

> **Question-2** : The proponent should prepare a simulation showing that the expected signal to background ratio is achievable after all the trigger and final-particle decay selections are made

The signal of ϕ-meson bound state production on Carbon nucleus together with possible major sources of the background, $\overline{p}p \to K^+K^-\pi^+\pi^-$ and $\overline{p}p \to \phi\pi^+\pi^-$ processes have been analyzed. For the ϕ meson bound state signal, the values of 3.4% mass reduction and 3.6 times width broadening in nucleus, which is the experimental result by KEK-PS the E325 experiment, have been used. First of all, the reconstructed ϕ meson and Λ with proper sum of expected background event based on cross section of elementary process are shown in Fig 9. The expected Signal/Background is found to be ≈ 2. As a next step, the spectra of background has been evaluated by the simulation. The results are shown in Figure 10. Top figure shows the missing mass obtained just requiring event with ϕ meson reconstructed. Huge background is coming from the contribution of $\phi\pi\pi$ and $KK\pi\pi$ events. Then, the Λ reconstruction is required to tag double strangeness production on the event. The result is shown in bottom on Figure 10. The result shows that even such a huge background from the $\phi\pi\pi$ and $KK\pi\pi$ processes exist, requiring a Λ in the final state is really suppressing the background efficiently. It should be noted that in the simulation we also including events from two nucleon absorption, *i.e.* $\overline{p}$ – ”pp” $\to \phi K\Lambda$. There are no experimental data nor theoretical explanation of how much fraction of such a event expected. Therefore we

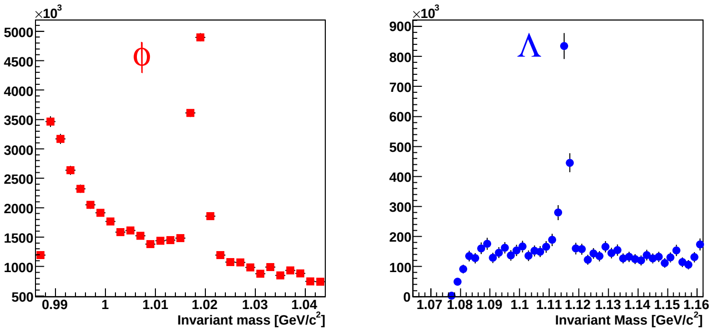

Figure 9: Missing mass spectra of reconstructed ϕ and Λ with expected background from $\phi\pi\pi$ and KK$\pi\pi$ events.

assumed 20% double strangeness production in nucleus are coming from those type of the event. The number 20% is taken from the fraction of two nucleon absorption by anti-kaon at rest. The value will be smaller in case of in-flight reaction. However, we used this value as a background estimation for upper limit.

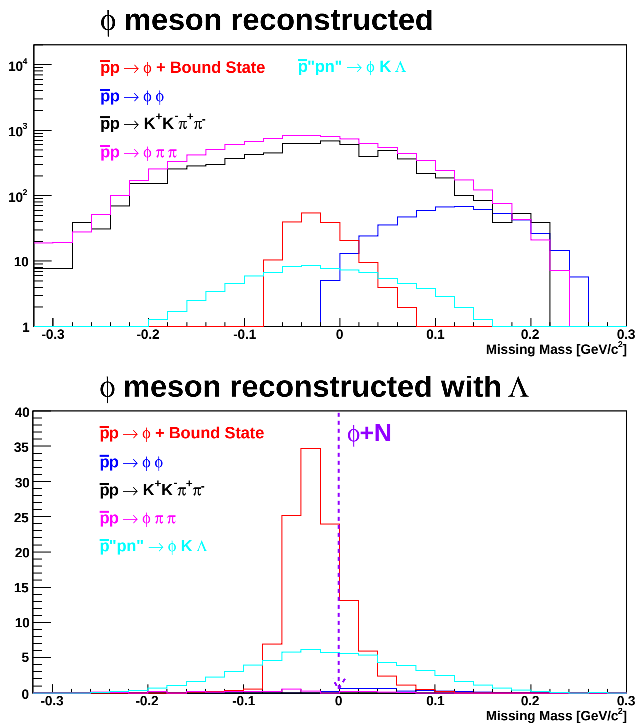

Figure 10: Missing mass spectra for signal from bound state with possible background sources.

5.3 Answer to Question-3

The third question was

Question-3 : The estimation of the count rate is to be clarified.

To answer the question, all factors, acceptance of the spectrometer, decay rate and sticking probability etc. are evaluated again with using GEANT4 based detector simulation. In fact, we found over estimation on the acceptance for "the forward spectrometer" in the original proposal, we would like to correct the error in this addendum.

The beam intensity expected is $10^6/3.5$s for K1.1 beam line. Target thickness, 2.0 g/cm^2 will be used for all materials.

The sticking probability(Capture rate) of the produced ϕ meson to the nucleus is estimated to be 11 % of the produced ϕ meson.

The branching ratio of $\phi \rightarrow \mathrm{K}^+\mathrm{K}^-$, $\sim$ 49.2 %, is already taking into account in the acceptance calculation. For the decay from bound state side, we took branching ratio of (ϕ-N) goes to at least single Λ, as 76 %[11]. The reason we just take single Λ is as follows. The signal we are looking for is double strangeness pair production in nucleus. For the measurement, single pair of strangeness is tagged by forward ϕ meson. If we also tag another strangeness pair in backward region, namely K^+ and Λ or K_s^0 and Λ, cleanest data sample can be obtained. However, it is also true, that only single strangeness, either, Kaon or Λ will give us already good tagging for the "effective" double strangeness production. Therefore for the measurement, we just use single Λ tag to clean the signal of bound state from background. The final number of the detector acceptance including decay of particles is found to be 4.8×10^{-3}.

The summary of all numbers together with final expected number of events are listed as table 1.

Target		Cu	Carbon	deuteron
mass number	A	63.5	12.0	1.88
charge number	Z	29	12	1
Target thickness (g/cm^2)	L	2.0	2.0	1.35
cross section ($Z^{2/3} \times \sigma_{\bar{p}p}$) ($\mu b$)	$\sigma_{\bar{p}^A_Z X}$	23.	7.9	2.4
$\bar{p}$ intensity (/spill)	$\mathrm{I}_{\bar{p}}$	10^6	10^6	10^6
Number of target nucleus (/cm^2)	N_{Tgt}	0.19×10^{23}	1.0×10^{23}	4.1×10^{23}
Acceptance for decay particles	ϵ_{Decay}	4.8×10^{-3}	4.8×10^{-3}	1.45×10^{-3}
Averaged Sticking probability	$\mathrm{P}_{sticking}$	0.11	0.11	(N/A)
Analysis and DAQ efficiency	$\epsilon_{Analysis}$	0.7	0.7	0.7
expected yield/spill		1.6×10^{-4}	2.9×10^{-4}	$24.\times10^{-4}$

Table 1: Expected event rate

For this proposed experiment, we will request two weeks of beam tuning and 120 shift of data taking. Here we assumed that 1000 [spill/hour] and 7 [hours/shift] for effective running time. The final number of yield expected for each target for 120 shifts are,

Copper target : 160/120 shifts
Carbon target : 200/120 shifts
deuteron target : 2000/120 shifts

Therefore final number of shifts requested for proposed experiment is two week of beam tuning, follows by 120 shift of physics data taking with deuteron target to evaluate double ϕ meson production in $\bar{p} - A$ annihilation and additional 120 shift for

Carbon or Copper target to search for ϕ meson bound state with 270 kW J-PARC PS operation.

5.4 Answer to Question-4

The 4-th question was

> **Question-4** : The K1.1 beamline is not completed yet, so that the proponent should consider as alternative possibility to do this experiment in another beam line.

A possible beamline where we will be able to perform the experiment is K1.8BR. The big difference between K1.8BR and K1.1 is the momentum acceptance for the beam line spectrometer. The momentum acceptance for K1.8BR is 2.5mSr%, while the expected acceptance for K1.1 beamline is 4.5mSr%. Therefore, we will expect 1.8 times more beam particles on target for K1.1 than K1.8BR. Figure 11, 12 show the expected $\overline{p}$ beam intensity per pulse(=3.5s) as a function of beam momentum for both K1.8BR and K1.1. The experiment can be done at, of course, K1.8BR beam line which has been constructed and now is operational. However, due to the factor 1.8 less beam intensity expected in K1.8BR than K1.1, the beam time request will be 1.8 times longer the one necessary if we could perform the experiment at K1.8BR.

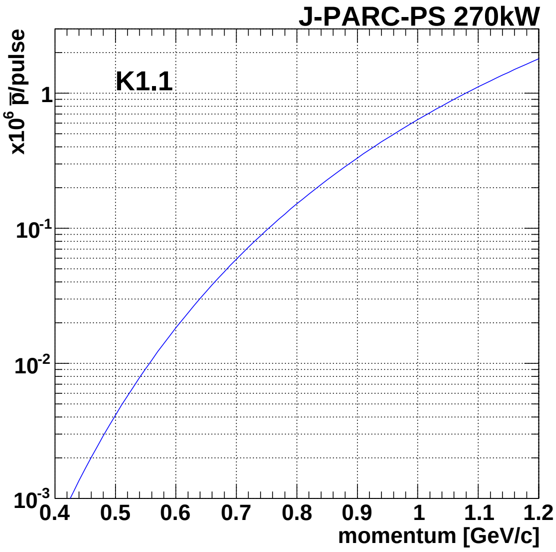

Figure 11: Expected $\overline{p}$ beam intensity at K1.1 beam line

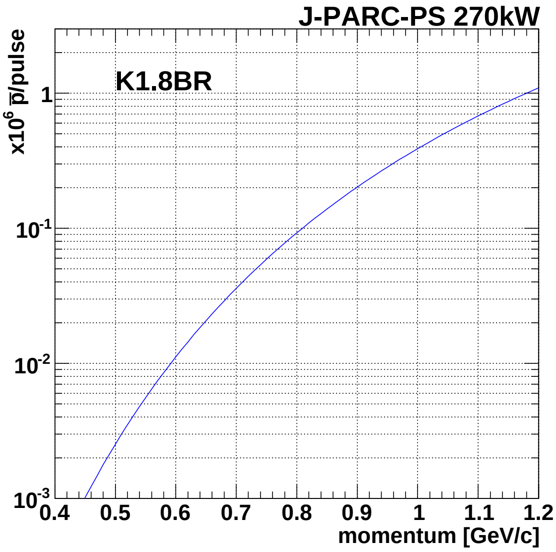

Figure 12: Expected $\overline{p}$ beam intensity at K1.8BR beam line

6 Summary and conclusion

In this addendum, we tried to answer all questions pointed out by the PAC. The most significant difference with respect to the original proposal is as follows. To answer the question from the PAC, question-2, we need to request to have data with deuteron target as a first step for the proposed experiment. For the original proposal, we thought that we can evaluate cross section for elementary process $\overline{p}p \rightarrow \phi\phi$ using proton inside CH_2 target. To obtain clean proton sample, we need to subtract contribution from interaction on Carbon. That is the reason why we though we need three target for the proposed experiment. However, as we already discussed in this addendum, deuteron target will be a much better to evaluate elementary process, $\overline{p}p \rightarrow \phi\phi$ reaction, and to also estimate the existence of multi nucleon absorption type events in nucleus. Therefore the target to be used for the proposed experiment as a first step is the deuteron and later Copper target will be used for the production target for the ϕ meson bound state.

The requested beam time for the experiment is not changed from the original proposal, ı.e, two weeks of beam tuning, follows by 120 shift of physics data taking with deuteron target to evaluate double ϕ meson production in $\overline{p} - A$ annihilation and additional 120 shift for heavy nucleus target to search for ϕ meosn bound state with 270 kW J-PARC PS operation.

References

[1] R. Muto *et al.*, Phys. Rev. Lett. **98** (2007) 042501.

[2] T. Ishikawa et al. Nov 2004. 12pp.Phys.Lett.B608:215-222,2005.

[3] X. Qian *et al.*], Phys. Lett. B **680**, 417 (2009) [arXiv:0907.2668 [nucl-ex]].

[4] S. Yokkaichi *et al.*, J-PARC E16 proposal,
http://j-parc.jp/NuclPart/pac_0606/pdf/p16-Yokkaichi_2.pdf

[5] T. Waas, Mannque Rho, W. Weise ,Nucl.Phys.A617(1997)449

[6] C. Evangelista *et al.*, Phys. Rev. D57(1996) 5370.

[7] G. Bendiccioli and D. Kharzeev, Nuovo Cimento **17** (1994) 1

[8] G. Bendiscioli *et al.*, Nucl. Phys. **A 797**(2007)109

[9] V.V. Barmin *et. al*, Phys. Lett. **B 464** (1999)323

[10] M. Bleicher *et al.* J. Phys. G: Nucl. Part. Phys. **25** (1999) 1859-1896

[11] E. Oset *et al.*, Acta Phys. Hung. A **27** (2006) 115.