Measurement of the mass spectrum of vector mesons in nuclei at J-PARC.

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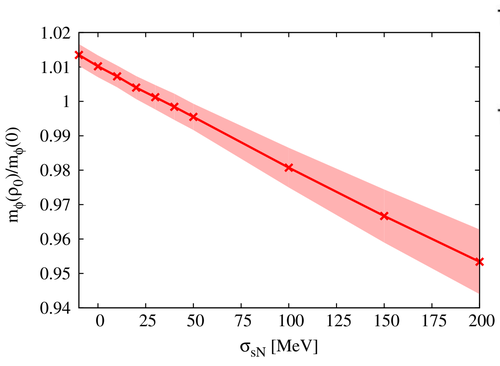
T. N. Murakami for the J-PARC E16 Collaboration.
Department of Physics, Graduate School of Tokyo. Nishina Center for Accelerator-based Science, RIKEN. (e-mail: mtomoki@post.kek.jp)

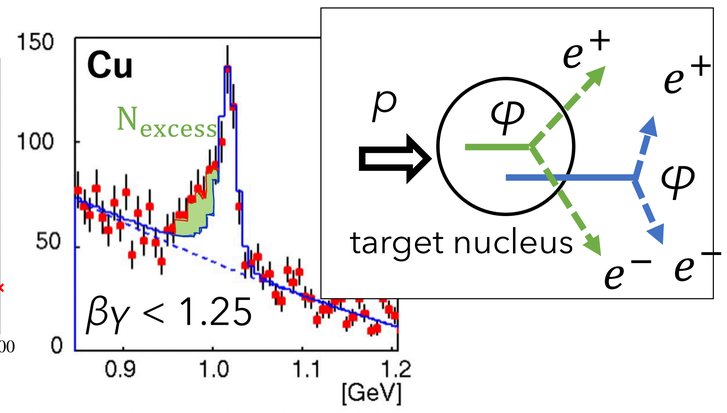
Physics Motivation

- ❑ Investigating the mass of the φ meson at finite density is pivotal for grasping the QCD vacuum description.
- ❑ The KEK-PS E325 Experiment observed a 3% mass reduction of φ mesons, however, more statistics is needed.



Peak positions of the φ meson at density ρ_0 as a function of σ_{sN}

Gubler and Ohtani, Phys. Rev. D. 90 (2014) 094992



Result of KEK-PS E325.
Change of mass spectrum is observed.

R. Muto *et al.*, Phys. Rev. Lett. 98(2007) 042581

J-PARC E16 Experiment

Systematic study of the spectrum of phi meson change in nuclei.

- Nuclear size dependence.
- Mesons' momentum dependence (i.e. dispersion relation of meson in nuclear matter).

Experimental Challenges

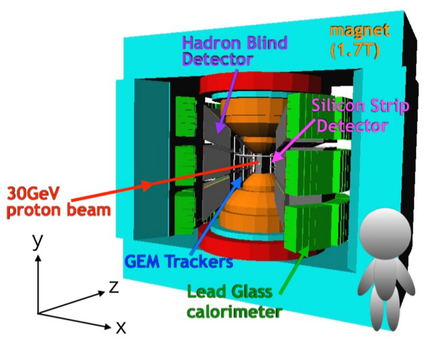
- Branching ratio of $\varphi \rightarrow e^+ + e^-$ ~ 3×10^{-4} is small.
- Thin target (0.5% X_0) is required to suppress the trigger background and radiative tail.

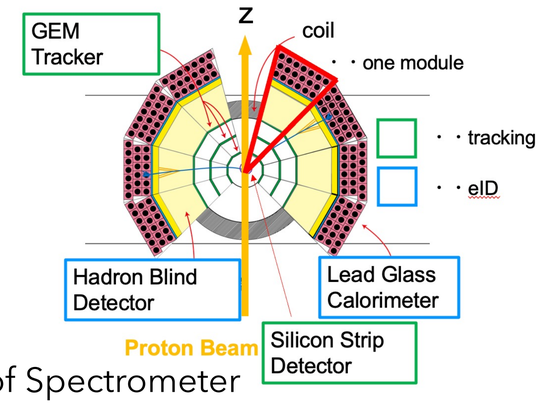
Our Approaches

- 30 GeV primary proton beam at J-PARC (1×10^{10} protons/spill).
- Horizontal ±15° ~ ±135°, vertical ±45° is covered.
- Using various targets (CH_2, C, Cu, Pb)

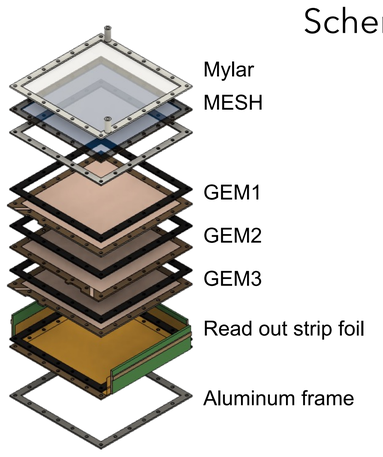
Detectors Design Values

- Tracking : 5.8 MeV mass resolution for slow meson ($\beta\gamma < 0.5$)
  ≒ 100 μm position resolution.
- Pion Rejection : 99.97% with HBD×LG.
- High-rate capability : ~10^7 Hz interaction rate.

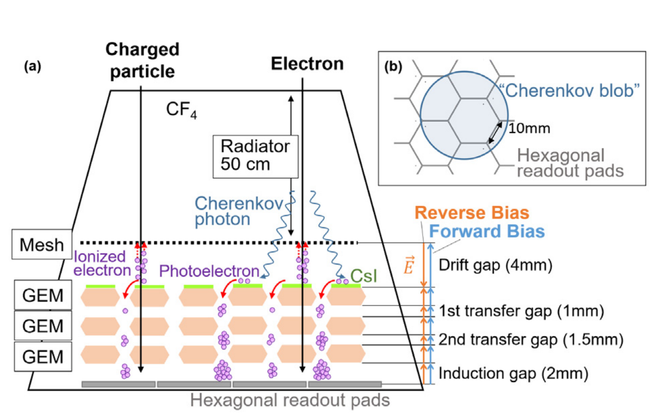




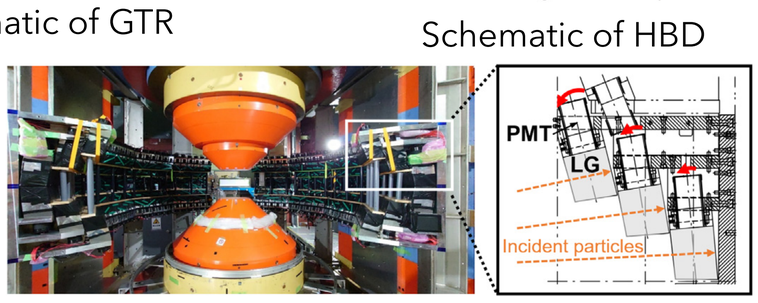
Schematic of Spectrometer



Schematic of GTR



Schematic of HBD



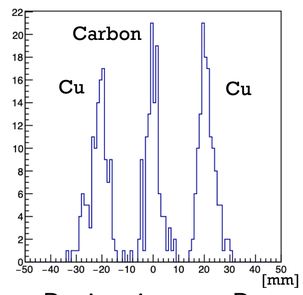
Schematic of LG

Detector Commissioning Run

It was performed in 2020-2021, 403 hours in total.

Tracking Perfomance

- Results are satisfactory as indicated in the table. The hardware was upgraded after the run. Improvements are anticipated.



Target Projection on Beam Axis

Table : Resolution of Each GTR

	X [μm]	Y[μm]
GTR100	236 ± 42	414 ± 81
GTR200	230 ± 52	464 ± 116
GTR300	235 ± 54	477 ± 65

work in progress

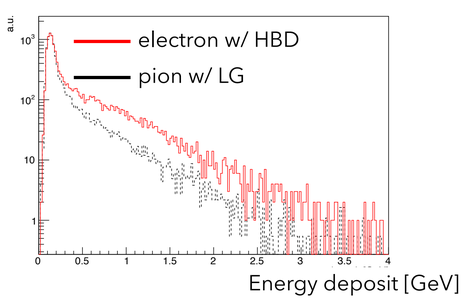
Electron Identification Performance

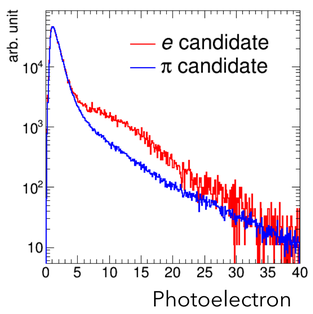
- Achieved required values as shown in the table.

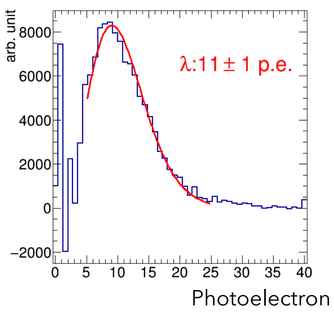
Table : Performance of HBD and LG

	Pion Rejection power observed [*required*] [%]	Electron detection efficiency observed [*required*] [%]
HBD	(99.1 ± 0.2) [*99.4*]	(61 ± 4) [*63*]
LG (for 0.4-0.6 GeV/c)	(95.2 ± 0.1) [*95*]	(79 ± 17) [*90*]

preliminary





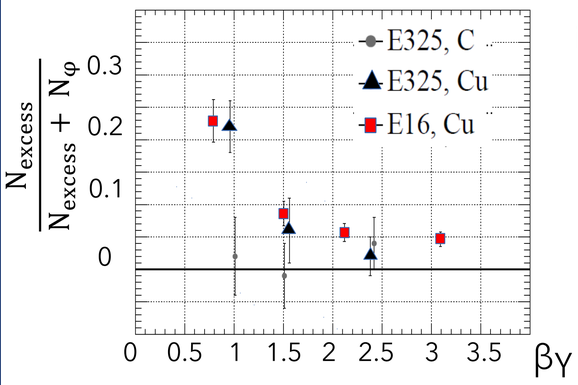


Left : Measured energy deposit with LG for electron and pion selected by HBD.
Middle: Measured Pulse-height distribution of HBD.
Right : Difference of two histograms on the middle panel. 11 ± 1 p.e. is consistent with expected performance.

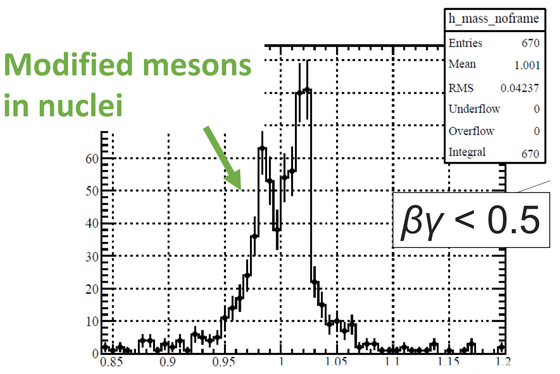
S.Nakasuga *et al.*, Proc. of 16th VCI, (NIMA 1041 (2022) 167335)
K. Kanno *et al.*, Proc. of 7th MPGD, (JINST 18 (2023) C06021)

Expected Results

- ❑ Examine $\beta\gamma$ dependence of excess ratio.
  - Only slow/Cu φ is significant in E325.
  - All bins for Cu will be significant in E16 Run1 (2024-)
- ❑ Pb target will be installed in Run2 (After 2024).
  - Clear separated peaks could be seen selecting $\beta\gamma < 0.5$.
  - Target nuclear-size dependence can be investigated more systematically.



Expected excess ratio in Run1.



Expected mass spectrum of the φ meson using Pb target in Run2, selecting very slow mesons.

Summary

- ❑ The J-PARC E16 experiment has been launched to investigate the mass modification of vector mesons in nuclei.
- ❑ Detector commissioning run was performed in 2020-2021 and achieved required (enough) performances for eID (tracking).
- ❑ The dependence of excess on $\beta\gamma$/targets demonstrates the existence of spectral change of mesons in nuclei. Furthermore, the momentum dependence of mass will be measured.