

# Launch of Physics Data Taking for Dielectron Measurement of Vector Mesons in Nuclei at J-PARC E16

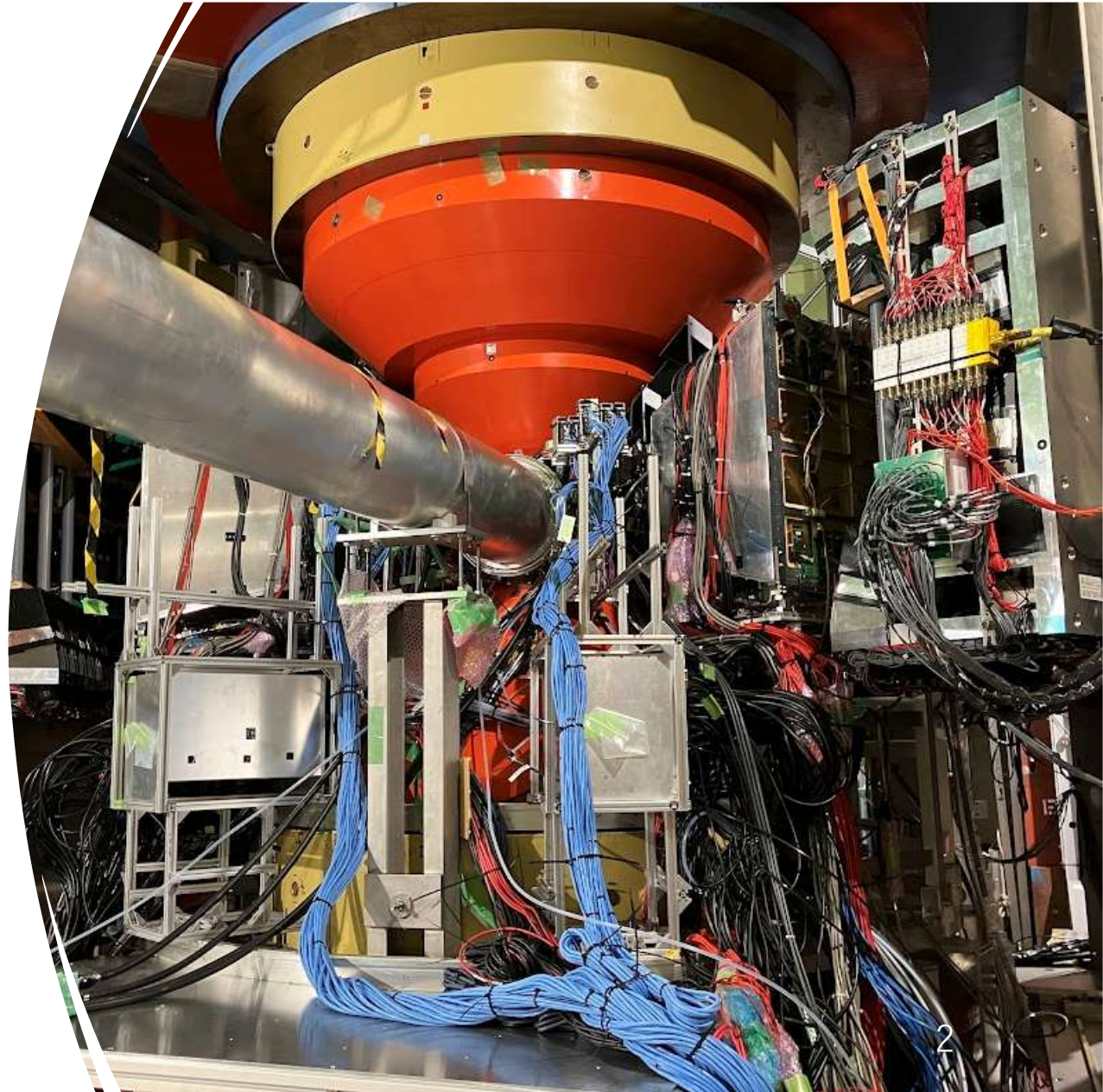
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for the J-PARC E16 Collaboration  
MESON2026, 26<sup>th</sup> June 2026



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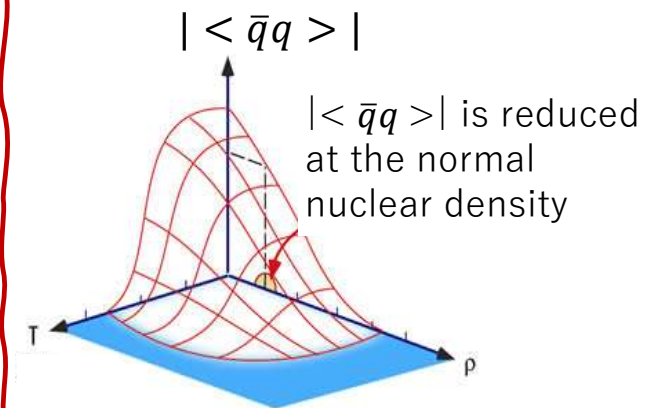
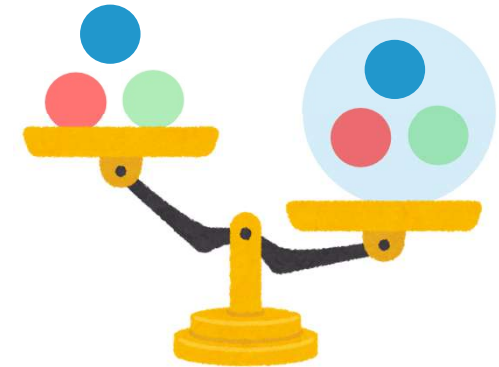
- Introduction
  - Physics motivation
  - The precedent result
- Experimental Setup
- 2024 result and 2025 Run1 status
- Physics prospects
- Summary



# Physics Motivation

- A large part of hadron mass originates from QCD dynamics rather than current quark masses.
  - Spontaneous chiral symmetry breaking and the quark condensate are important to this mass-generation picture.
- Partial restoration of chiral symmetry is expected in finite-density nuclear matter.
  - QCD sum rules relate vector-meson spectra to QCD condensates, including  $\langle \bar{q}q \rangle$ .
- We measure vector mesons in nuclei to search for possible changes in their mass spectra.

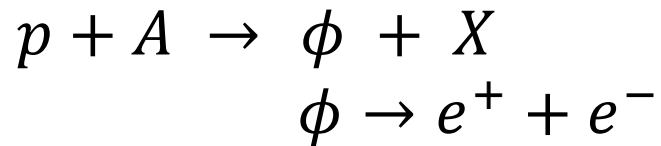
Quark  $\ll$  Hadron  
 $\sim \text{MeV}/c^2$   $\sim \text{GeV}/c^2$



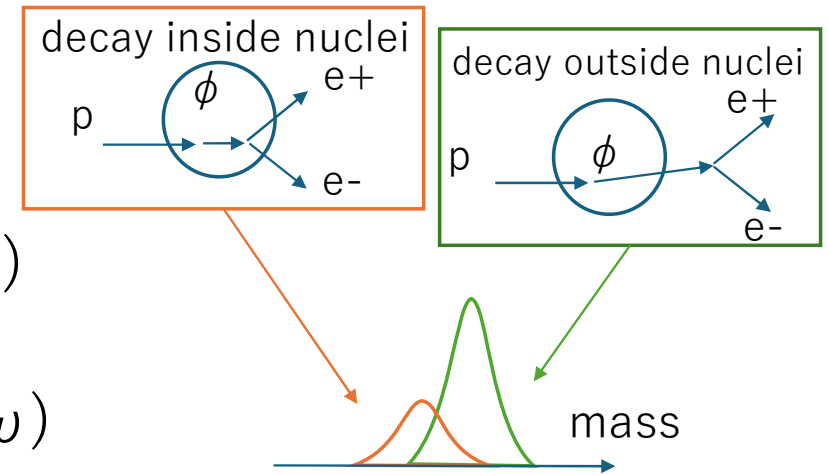
W. Weise, Nucl. Phys. A 553, 59(1993).

# Features of the Experimental Method

- We use the reaction:

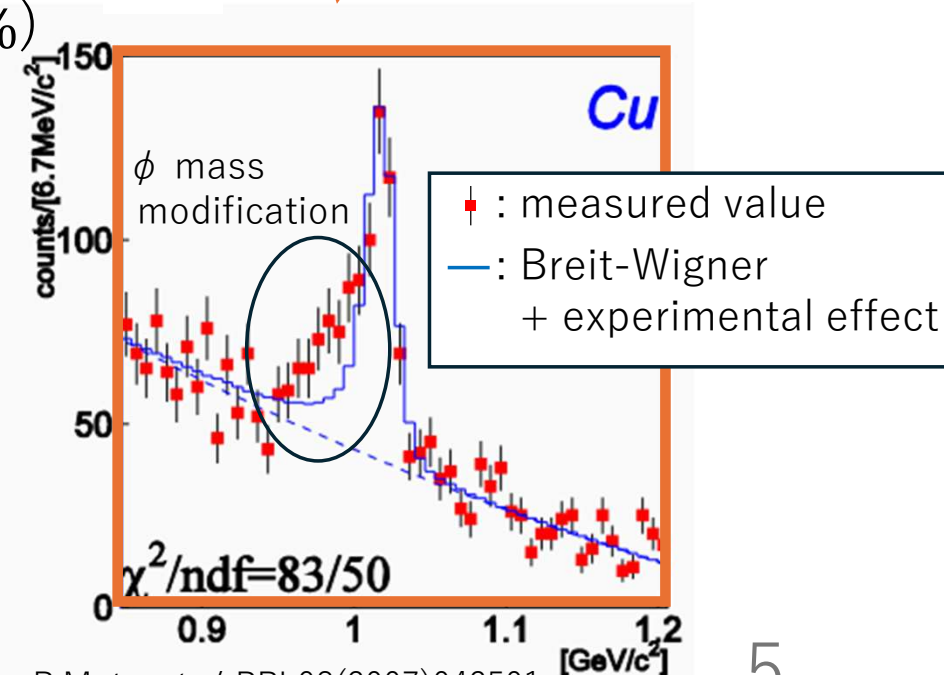
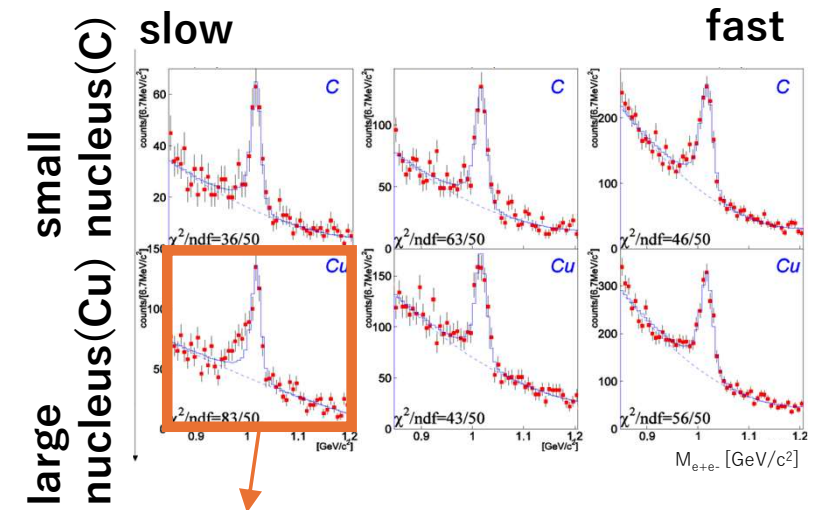


- **Proton-induced** ( $\leftrightarrow$  compared to  $A+A$ )
  - ✓ Cold nuclear matter, good S/N, simpler than  $A+A$  collision
- **$\phi$  meson** ( $\leftrightarrow$  compared to  $\rho / \omega$ )
  - ✓ Separated peak
  - ✗ Limited statistics
- **$e^+e^-$  decay** ( $\leftrightarrow$  compared to  $K^+K^-$  decay)
  - ✓ Small final state interaction
  - ✗ Small branching ratio ( $\sim 0.03\%$ )
- **Thin targets:**  $\sim 0.5\%$  radiation length
  - ✓ The electron background due to gamma conversion is reduced
  - ✓ Also suppresses the radiative tail due to the target material



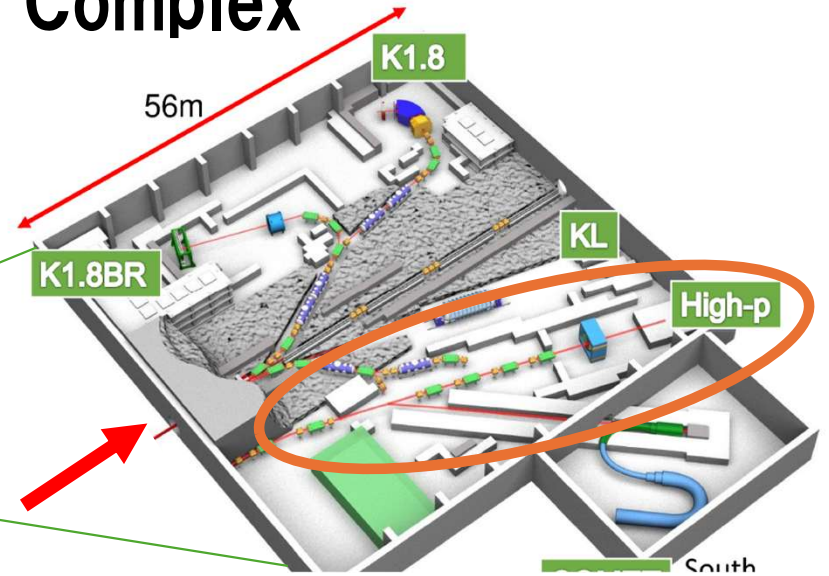
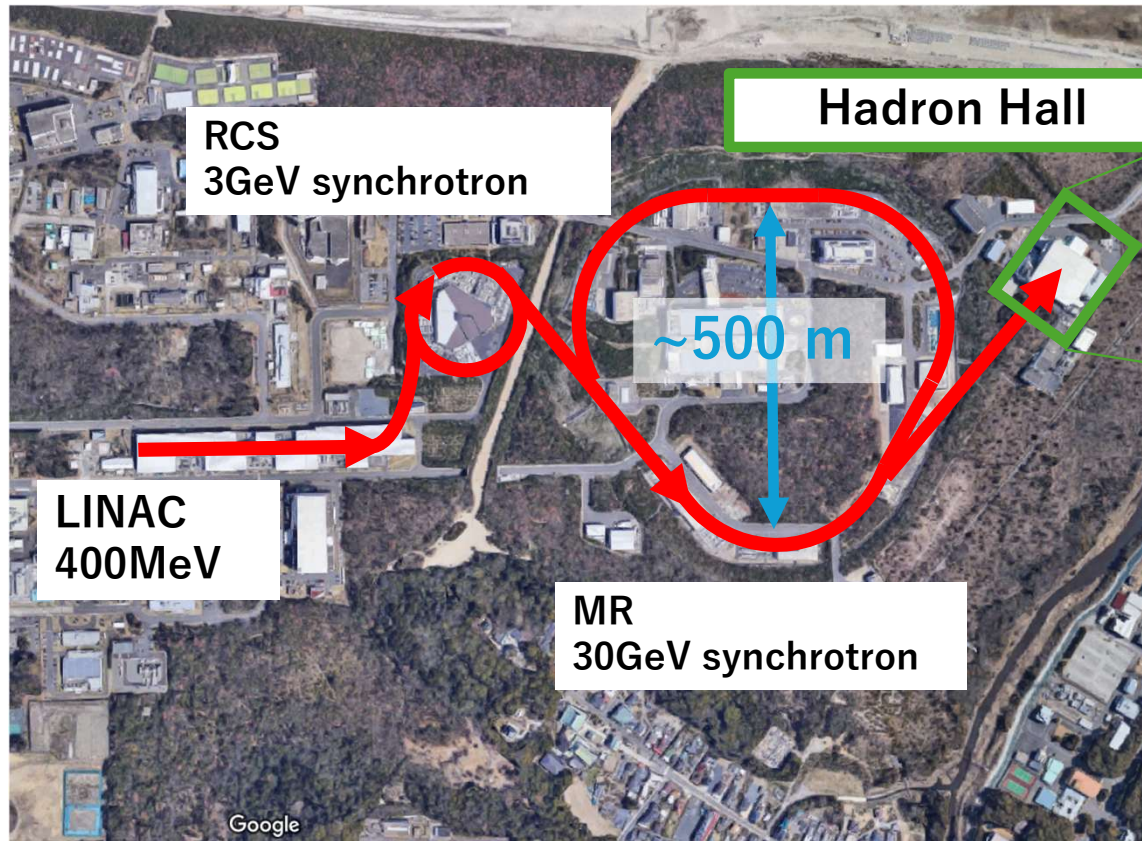
# The Precedent Result: KEK-PS E325 Experiment

- $12\text{GeV } p + C, \text{Cu} \rightarrow \rho, \omega, \phi + X$ 
  - $\sim 1.0 \times 10^9$  protons /spill (2sec)
- $\phi$  mass modification was observed
  - $m_\phi : 1019 \text{ MeV} \rightarrow 984_{-7}^{+6} \text{ MeV} (-3.4_{-0.7}^{+0.6} \%)$
  - $\Gamma_\phi : 4.26 \text{ MeV} \rightarrow 15.3_{-5.1}^{+7.7} \text{ MeV} (\times 3.6_{-1.2}^{+1.8})$
- The effect was seen mainly in Cu and low- $\beta\gamma$   $\phi$  data.
- **→ More precise, higher-statistics experiment: J-PARC E16**



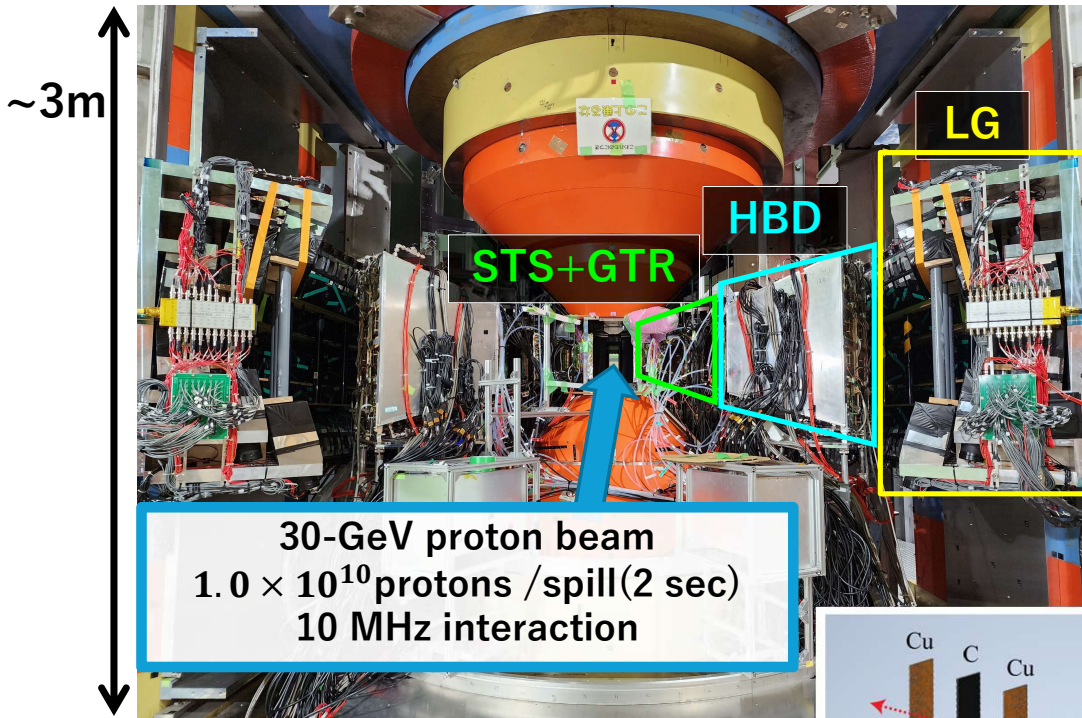
# J-PARC

## Japan Proton Accelerator Research Complex

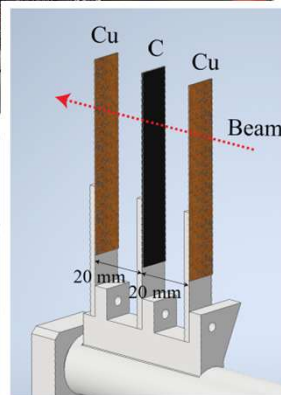


- 30-GeV primary proton beam from the Main Ring by slow extraction to the Hadron Experimental Facility
- 100-kW-class beam,  $O(10^{14})$  protons/spill (2 sec)
- E16 uses a fraction of this primary beam in the High-p beam line.

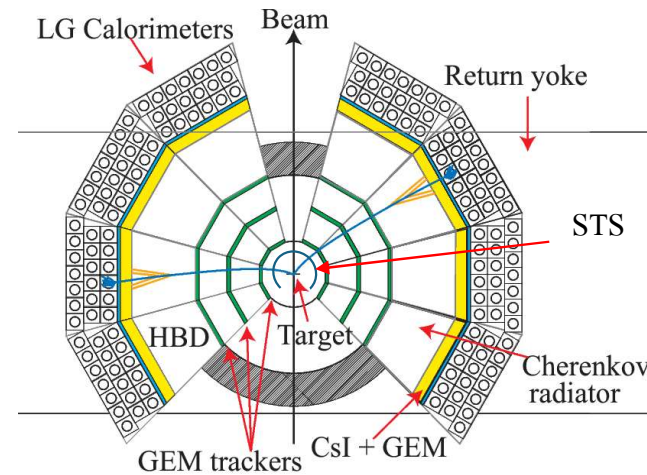
# E16 Spectrometer



Target	Thickness	Interaction length	Radiation length
Cu x2	80 $\mu$ m, 70.8 mg/cm <sup>2</sup>	0.052%	0.55%
C x1	500 $\mu$ m, 89.6 mg/cm <sup>2</sup>	0.102%	0.21%



## top view



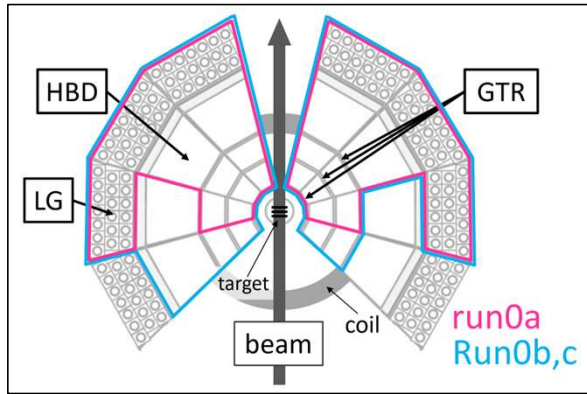
### 4 layers for tracking

- Silicon Tracking System (STS)  
SSD, developed with GSI
- GEM Tracker (GTR)  
Tracker using GEM foils

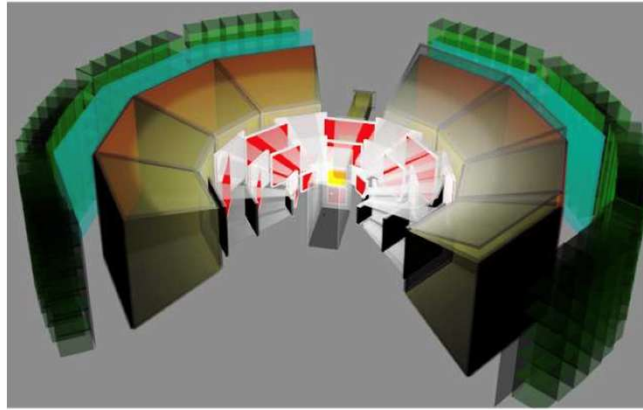
### 2 stages of electron ID

- Hadron Blind Detector (HBD)  
Cherenkov detector
- Lead Glass (LG)  
Calorimeter

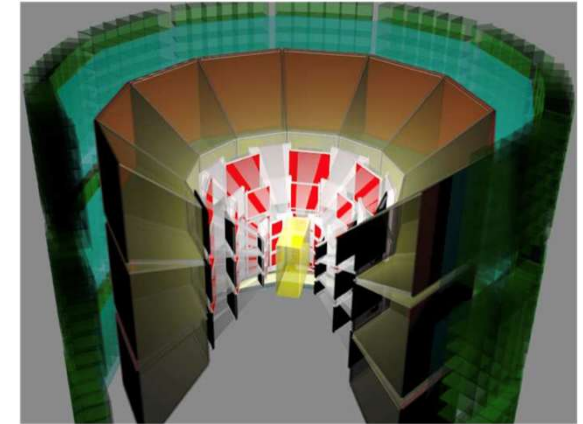
# Staging Plan of E16



2020-2021



2023-2024, and Run1



Run2

## Commissioning (2020-2021)

- C, Cu targets
- commissioning of beam line and detectors

## Beam · trigger study (2023-2024) **done!**

- C, Cu targets
- Beam optics, trigger parameter optimization
- Collection of vector meson data

## Physics Run (Run1)

**data taking started!**

- Started in Nov. 2025
  - Additional beam time requests are planned
- $\phi \sim 15000$  @Cu (E325 stats. x 6)

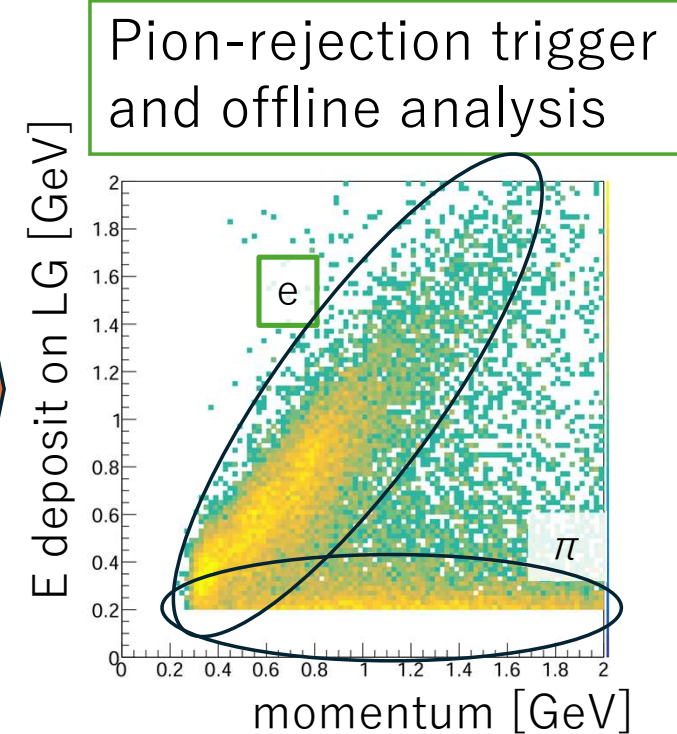
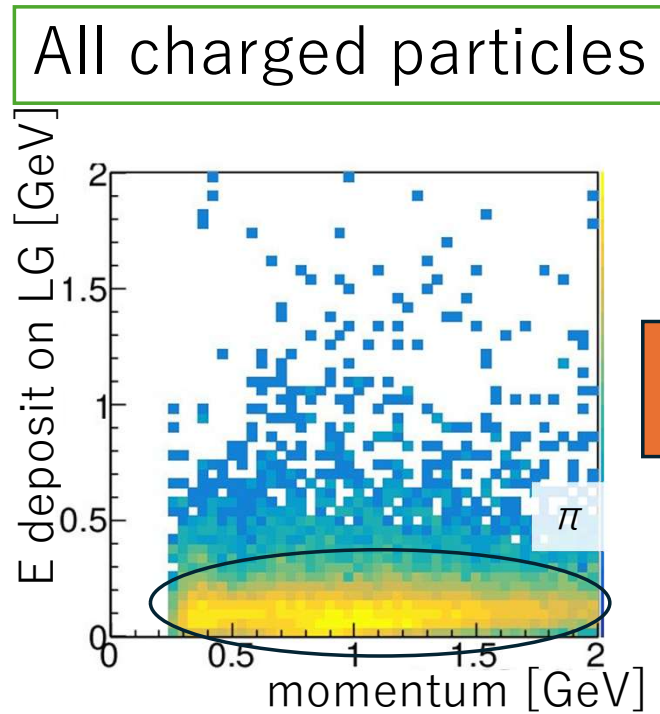
## Physics Run (Run2)

**in progress**

- CH<sub>2</sub>, C, Cu, Pb
- Larger acceptance

# EID Performance (2024 data)

- A key point of this experiment: **electron ID**
  - $\pi/e \approx 100$  before electron ID
- 2 stages of electron ID
  - Hadron Blind Detector (HBD)
  - Lead Glass Calorimeter (LG)
- **The electrons are successfully identified!**
  - The achieved performance is close to the design values.



LG	Achieved	Design
$\pi$ rejection	$95.0 \pm 0.2\%$	95.0%
e efficiency	92%	90%

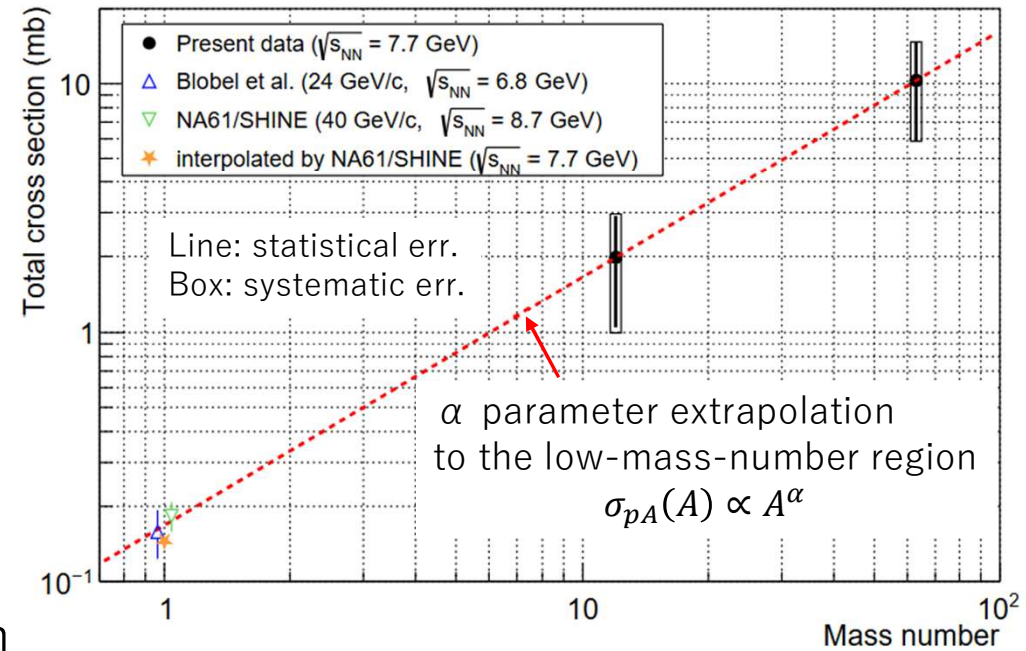
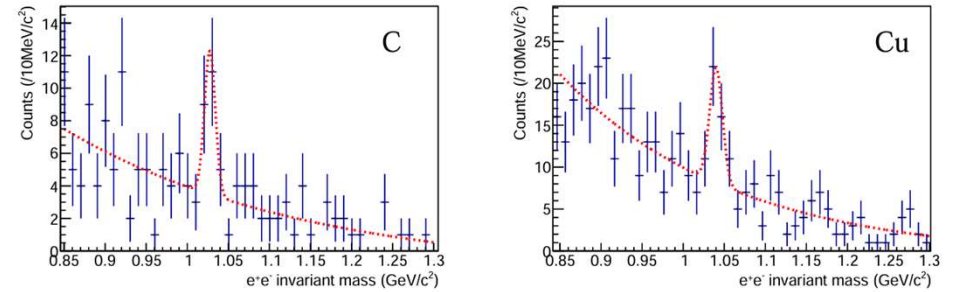
HBD	Achieved	Design
$\pi$ rejection	$99.1 \pm 0.2\%$	99.4%
e efficiency	$61 \pm 4\%$	64%

# First 30-GeV p+A $\phi$ production measurement

- Using the ee-trigger data in 2024, 23k spills in total
  - Data were taken with the 8-module Run1 setup; this analysis used the 4 forward modules
- $\phi \rightarrow e^+e^-$  peaks were reconstructed in C and Cu
- First  $\phi$  production cross sections at 30-GeV p+A:
  - C:  $2.0 \pm 0.9 \pm 1.0$  mb
  - Cu:  $10.3 \pm 4.4 \pm 4.4$  mb
- A-dependence:
  - $\alpha = 0.99 \pm 0.38 \pm 0.34$
  - consistent with  $\alpha \approx 1$  and previous dilepton measurements

The measured cross sections are consistent with the assumption used in the proposal.

→ **This result is an important milestone toward high-statistics in-medium studies in Run1.**



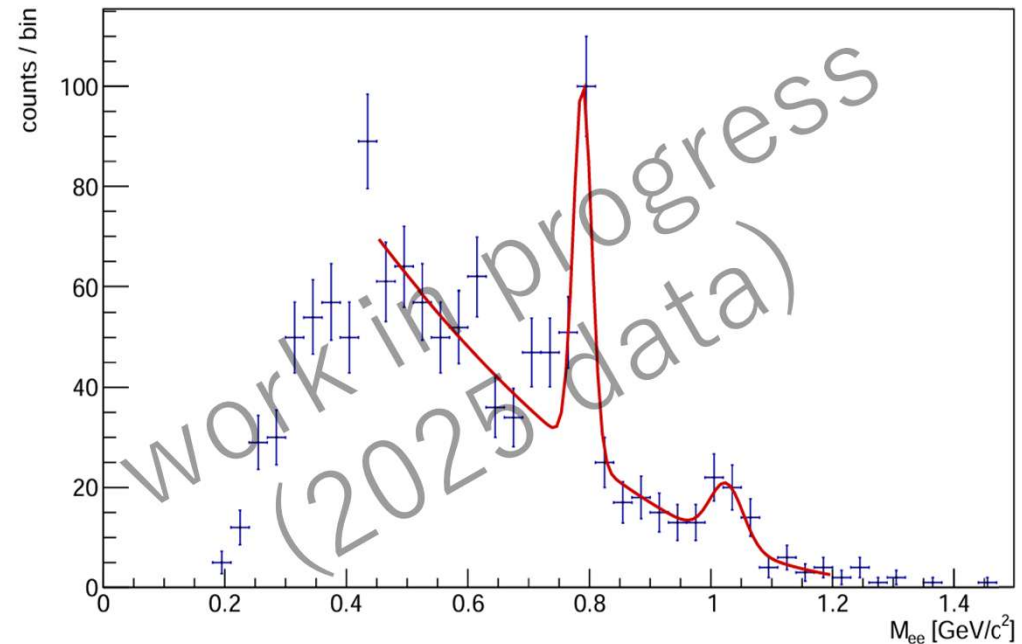
S. Nakasuga *et al.*, PTEP 2026, 043D03

Detailed  $\phi$ -production analysis:

S. Nakasuga, parallel session

# Analysis of the 2025 data is on-going

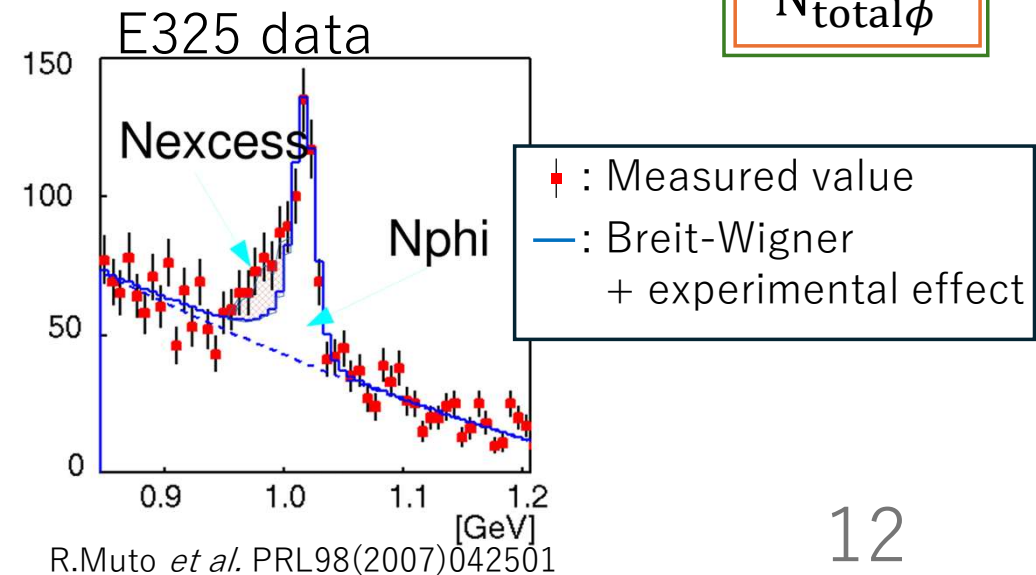
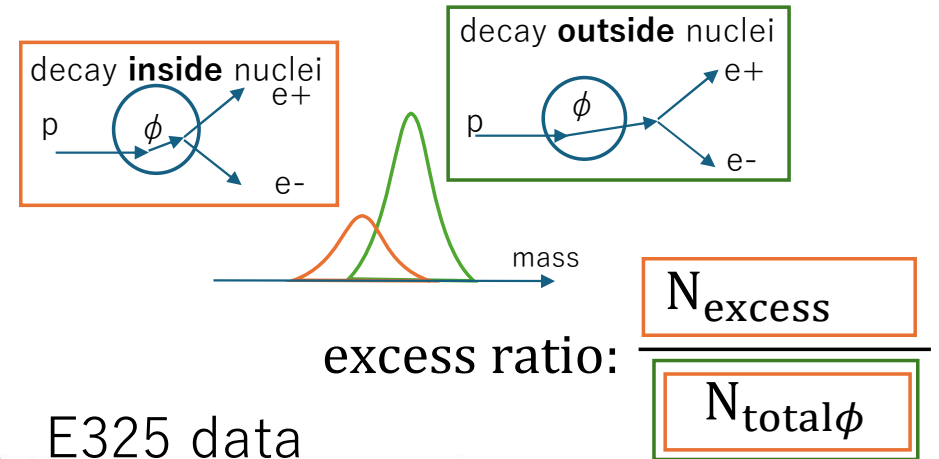
- Run1 (physics data taking) started in Nov. 2025 with the 8-module setup and C/Cu targets
- About 104k spills of the ee-trigger data were accumulated.
- Data-quality evaluation is ongoing
  - Initial reconstruction sample: four forward modules, ~30% of 2025 data
- $\omega$  and  $\phi$  peaks are observed in the spectrum, while the work is still in progress



Preliminary, C+Cu targets are summed  
Fit with a quadratic curve + two Gaussians  
(peaks and widths are determined by fit)

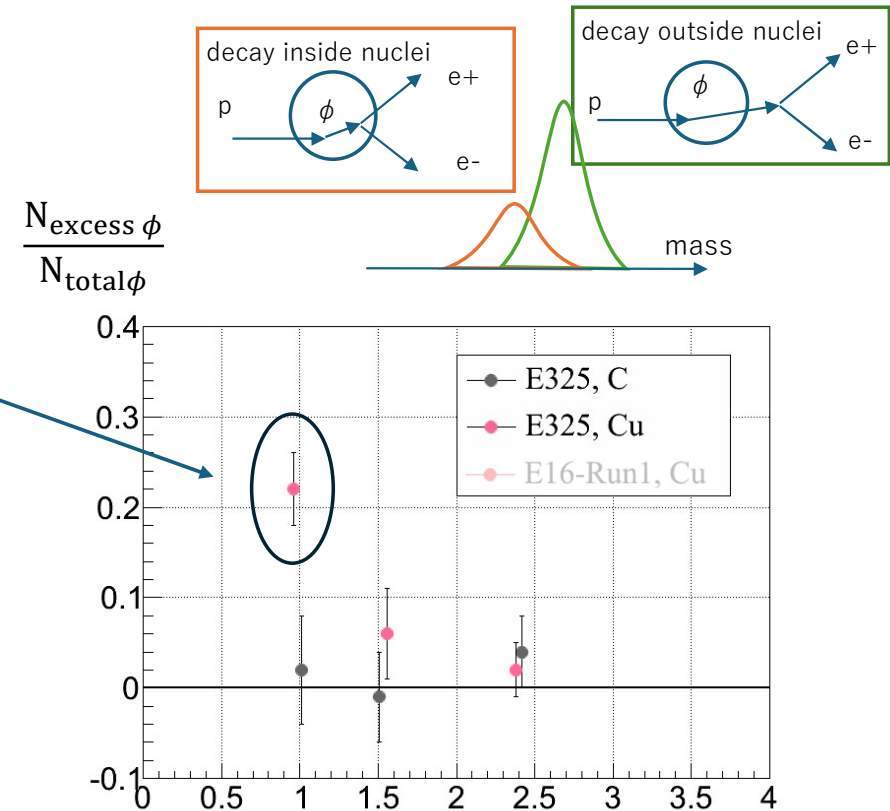
# Expected Result: Excess yield in the mass spectrum

- $N_{\text{excess}}$  :  
Yield above the unmodified  $\phi$  spectral shape.
- The precedent experiment (E325) obtained this value by subtracting an unmodified spectrum (Breit-Wigner + experimental effects) from the measured spectrum.
- Excess ratio can be calculated as an indicator of the modification



# Expected Result: $\beta\gamma$ Dependence of Mass Spectra

- The precedent experiment E325 data had **limited statistics**.
  - The significant effect was observed in only one dataset.
    - The largest nucleus (Cu) and the slowest mesons.



# Expected Result: $\beta\gamma$ Dependence of Mass Spectra

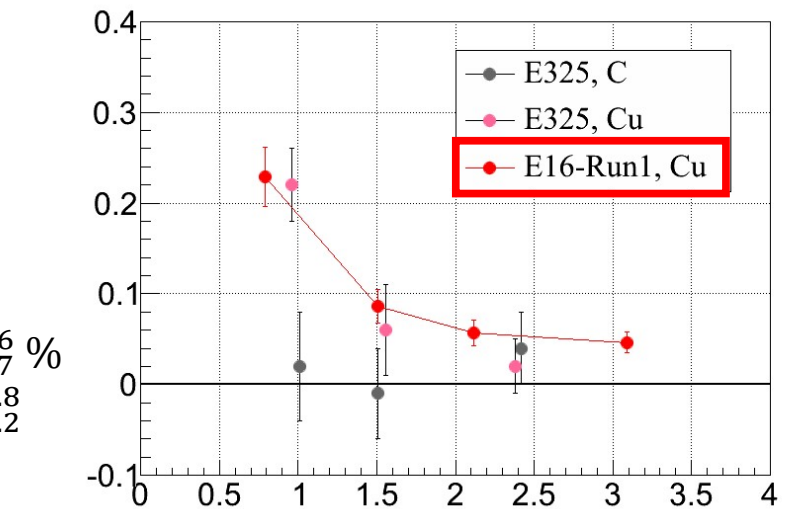
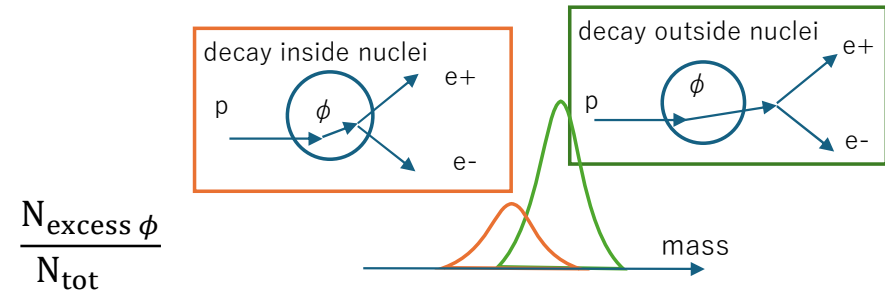
- The precedent experiment E325 data had **limited statistics**.
  - The **significant effect** was observed **in only one dataset**.
    - The largest nucleus (Cu) and the slowest mesons.

- The E16 can obtain **larger statistics**
  - Statistically significant effect will be **observed across a broad  $\beta\gamma$  range**

- Assumption:

- Same modification with E325
- x6 as much statistics as E325
- Kinematical distribution of  $\phi$ : using JAM

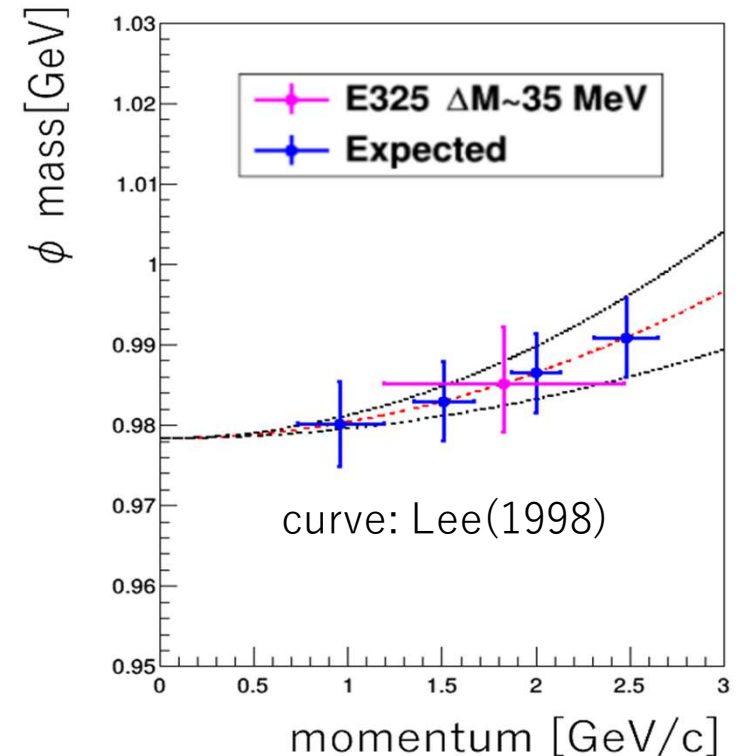
$$\left\{ \begin{array}{l} m_\phi: -3.4^{+0.6}_{-0.7} \% \\ \Gamma_\phi: \times 3.6^{+1.8}_{-1.2} \\ \phi: \sim 15000 \end{array} \right.$$



# Expected Physics: Dispersion Relation

- In-medium mass-momentum relation of the  $\phi$  meson
  - Predicted by QCD sum-rule calculations
    - S.H. Lee Phys. Rev. C 57, 927 (1998)
    - H.J. Kim and P. Gubler, Phys. Lett. B 805, 135412 (2020)
  - Not measured yet
    - E325 statistics were not sufficient to test the momentum dependence.
    - **E16 statistics can provide several momentum bins.**

Expectation in E16 stats.  
(E325 stats. x 6)



# Summary

- J-PARC E16 studies **vector-meson spectra in nuclei** using **30-GeV p+A reactions and  $e^+e^-$  decays**.
  - Commissioning established electron identification and  $\phi \rightarrow e^+e^-$  reconstruction.
  - The first 30-GeV p+A  $\phi$ -production cross sections were published from the 2024 commissioning data.
- **Run1a physics data taking started** in November 2025:
  - $\omega$  and  $\phi$  peaks are observed in an initial Run1a sample; full Run1a analysis is still ongoing.