# Establishment of the Electron Identification System for Vector meson Measurement at J-PARC

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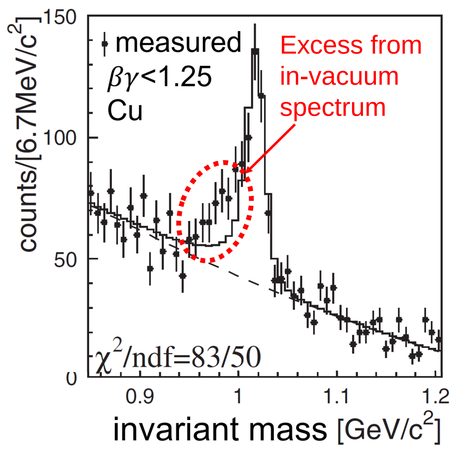
## Abstract

Electron pairs from light vector mesons have been measured to study the chiral symmetry restoration in hot and dense matter. The J-PARC E16 experiment was designed to measure a large number of vector mesons produced in 30 GeV pA reactions to investigate their mass spectrum in nuclei. We had developed two-stage electron identification (EID) detectors, consisting of a lead-glass electromagnetic calorimeter (LG) and a gas Cherenkov detector equipped with GEMs, called a hadron blind detector (HBD). In June 2024, we have finished all planned commissioning runs with a full detector acceptance for the first physics run. We have succeeded in obtaining a clear energy-momentum correlation of electron/positron tracks, demonstrating the establishment of the EID technique in a high-rate environment. **The evaluated electron purity of 92.7 ± 1.2% is sufficient to reconstruct the mass spectrum.**


## Physics Motivation

Observation and systematic study of the spectral change of vector mesons in nuclear matter:

- In nuclear matter, mass spectrum expected to be changed due to chiral symmetry restoration.
- Chiral symmetry relates to the origin of hadron mass.
- Previous experiment (KEK-PS E325) suggested the φ mass modification with a statistical sensitivity of 3 sigma.



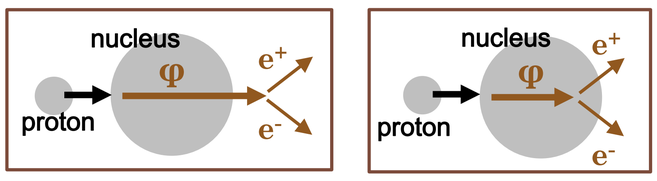

R. Muto *et al.*, Phys. Rev. Lett. 98, 042501 (2007).

→ J-PARC E16 experiment w/ ~30 times higher statistics

## Experimental Overview

### ◆ Method

- produce φ mesons in 30 GeV pA reactions
- measure the invariant mass via $e^+e^-$ decays (no final state interaction)

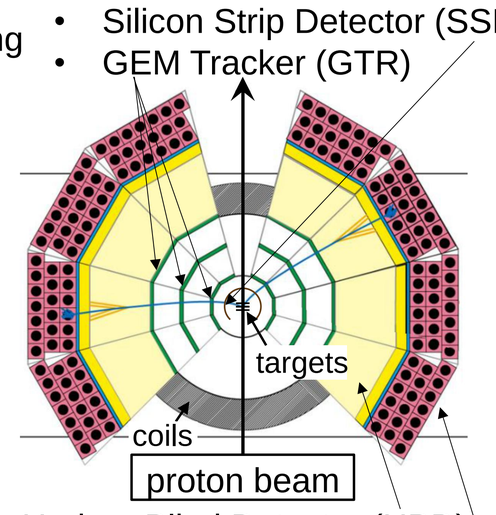



### ◆ Challenges

- Small branching ratio of φ→ee: ~$3\times10^{-4}$
- Huge hadronic background: S/N ~ 1/100 (mainly pions)
- High counting rate: 10MHz interaction @target

### ◆ Setup

Tracking
- Silicon Strip Detector (SSD)
- GEM Tracker (GTR)

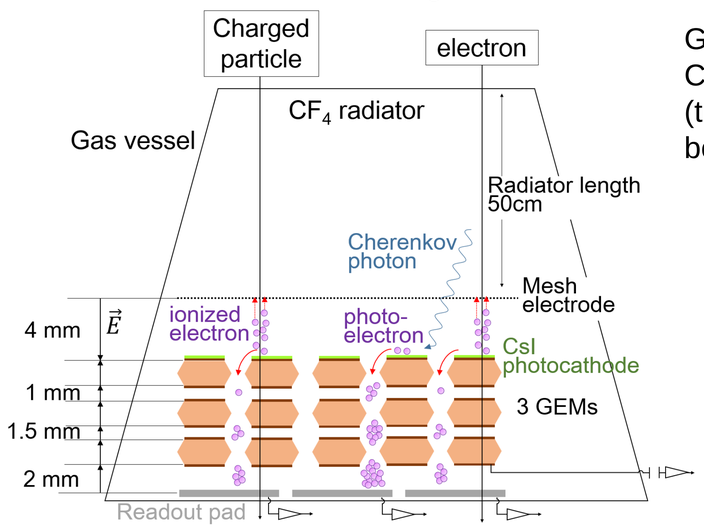



EID
- Hadron Blind Detector (HBD)
- Lead-Glass EM Calorimeter (LG)

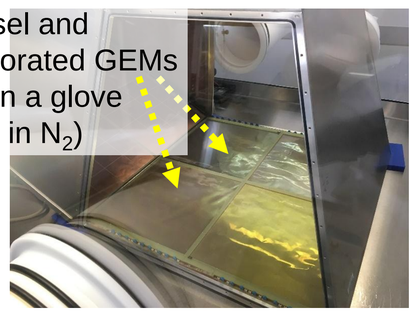
## Hadron Blind Detector (HBD)

### ◆ Configuration

"Windowless and mirrorless" gas Cherenkov detector → large acceptance!

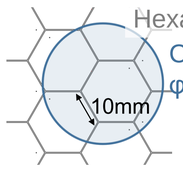



Gas vessel and CsI evaporated GEMs (treated in a glove box filled in $N_2$)



GEM configuration
- Size: 30 cm x 30 cm
- Hole diameter/pitch: 55/110 μm
- Made by Japanese company
- CsI is evaporated by Hamamatsu

### ◆ Readout




- e → some pads
- π → 0~1 pad

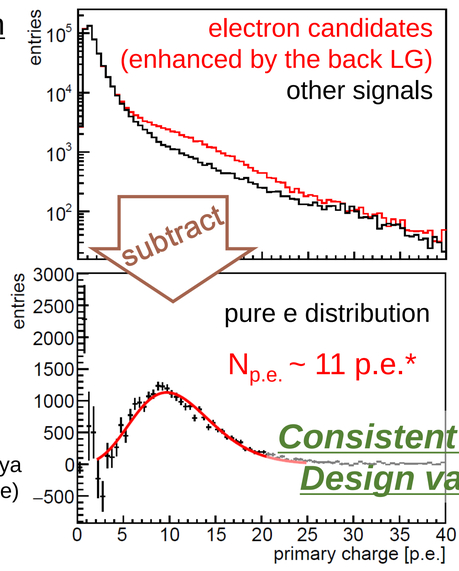
### ◆ Frontend Electronics

APV25 hybrid card
- for waveform sampling
- Developed by RD51
- Operated at 31.25 MSPS, 15 samples

HBD-ASD board
- for trigger signal, induced at the bottom side of the bottom GEM
- Developed by ourselves

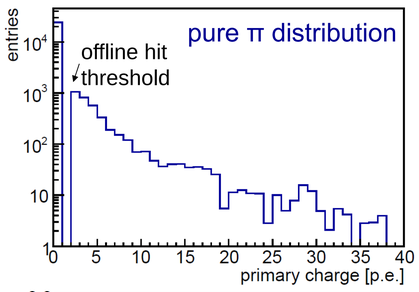
### ◆ Response to Electrons/Pions

Electron

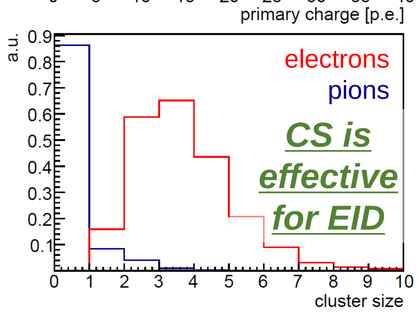



*fitted by the poisson + polya + gauss (noise) distribution

Pion




Cluster Size

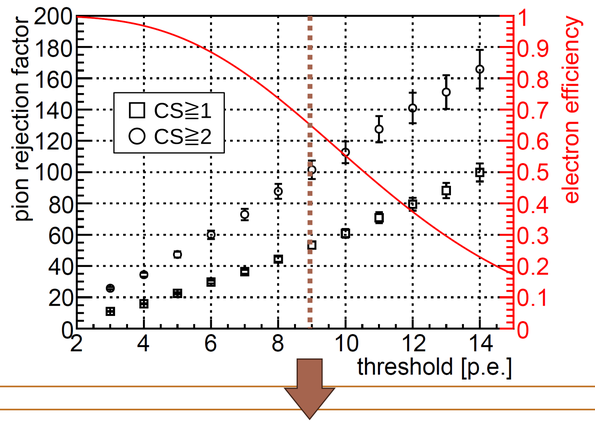



### ◆ EID Performance

Expected value
Electron efficiency: 68%
Pion rejection factor (CS≧1): 50
(CS≧2): 167

Measured rejection factor
59±2,108±5 (CS≧1,2) @e eff 65%

*The lower performance of CS≧2 may be caused by the high counting rate.*

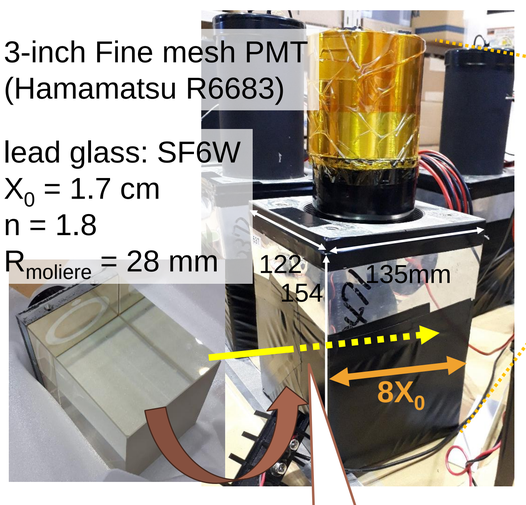



## Lead-Glass Calorimeter (LG)

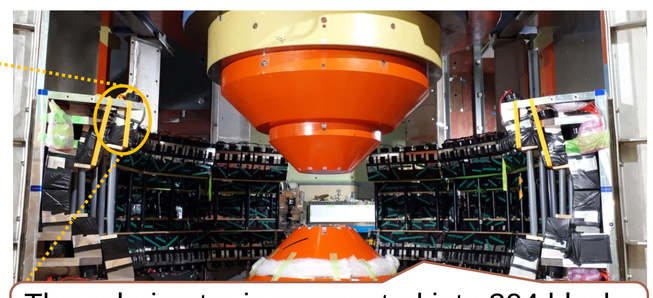
### ◆ Configuration

3-inch Fine mesh PMT (Hamamatsu R6683)

lead glass: SF6W
$X_0$ = 1.7 cm
n = 1.8
$R_{moliere}$ = 28 mm



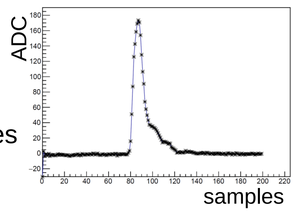

Particles are incident parallel to the PMT photocathode to suppress BG pion signal.



The calorimeter is segmented into 304 blocks to reduce the counting rate to ~1MHz.

### ◆ Frontend Electronics

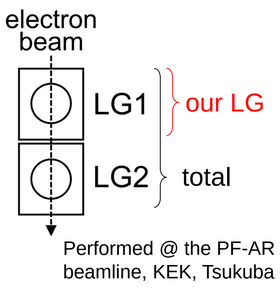
DRS4QDC module
- Waveform sampling
  - on DRS4 chips developed by PSI
  - 960 MSPS, 200 samples (max 2048 samples)
- Discriminator output



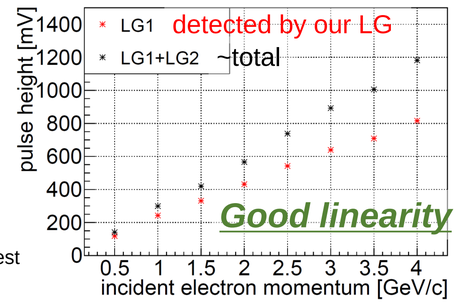

T.N. Takahashi *et al.*, IEEE Trans. Nucl. Sci. 68 (2021) 1907.

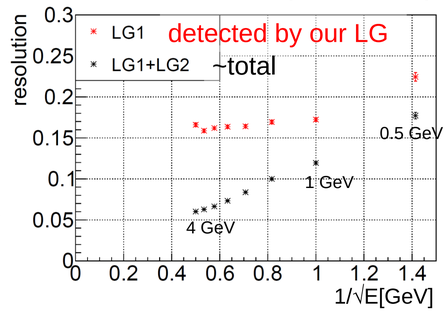
### ◆ Basic Response

We compare the response of our LG (LG1 only) with that of the total shower (LG1+LG2).




Performed @ the PF-AR test beamline, KEK, Tsukuba




### ◆ EID Performance

Gain Calibration
1. Peak positions of pion signals (Cherenkov photons from pions) are aligned channel by channel.
2. Systematic dependence of the momentum (~horizontal scattering angle) is corrected based on the E/p peak positions.

***Finally, all channels are well calibrated.***







Expected value
Pion rejection 95% @e efficiency 90%

Measured value
pion rejection 95.0±0.2% @e efficiency 92%

### ◆ Overall Performance

Practical electron purity is 92.7 ± 1.2%. It is slightly below the expected value of ~95% but ***sufficient for mass reconstruction.***

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