# PADME LNF CSN1 meeting

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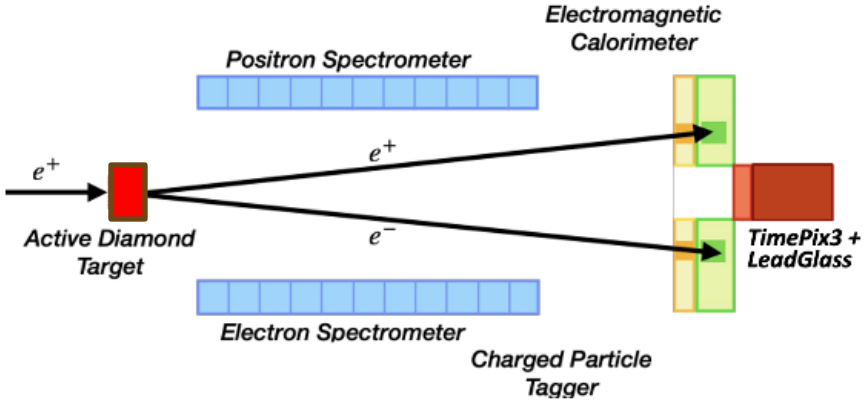
- Lessons from Run III analysis
- Run IV status, perspectives, requests to CSN1, critical points

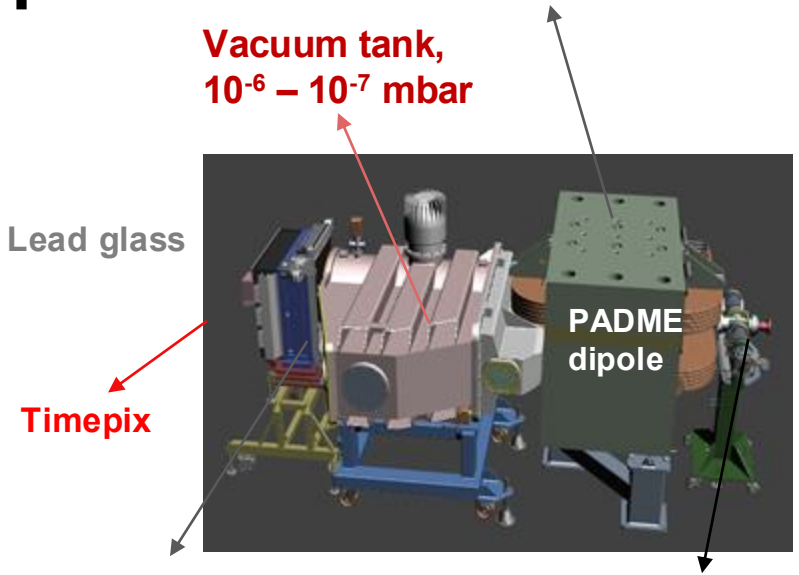
# Run III setup

**2022 Run-III setup adapted for the X17 search:**

- **Active target, polycrystalline diamond**
- **No magnetic field**
- **Charged-veto detectors not used**
- **ECal: 616 BGO crystals, each 21x21x230 mm³**
- **Newly built hodoscope in front of Ecal for e/γ**
- **Timepix silicon-based detector for beam spot**
- **Lead-glass beam catcher (NA62 LAV spare block)**




Charged particle detectors in vacuum



# Run-III concepts: the observable

**At PADME, search for a resonance with $e^+$ annihilation in diamond target:**

- **Scan around $E(e^+) \sim 283$ MeV**
- **Beam-energy spread ~0.25%, $\delta E(e^+) \sim 0.7$ MeV → center of mass steps of 20 keV made**
- **Measure two-body final state yield $N_2$**

**Master formula for each scan point at c.m. energy $s^{1/2}$ :**

$$N_2(s) = N_{POT}(s) \times [\, B(s) + S(s; M_X, g)\, \varepsilon_S(s) \,] \quad \text{vs} \quad N_2(s) = N_{POT}(s) \times B(s)$$

**Fundamental inputs:**

- $N_{POT}(s)$ **number of $e^+$ on target from beam-catcher calorimeter**
- $B(s)$ **background yield expected per POT**
- $S(s; M_X, g)$ **signal production expected for {mass, coupling} = $\{M_X, g\}$**
- $\varepsilon_S(s)$ **signal acceptance and selection efficiency**
- $s^{1/2}$ **measured from magnetic field (Hall probe) run by run**

$g_R(s) = N_2(s)/[\, N_{POT}(s) \times B(s) \,]$ **kept blind in the analysis**

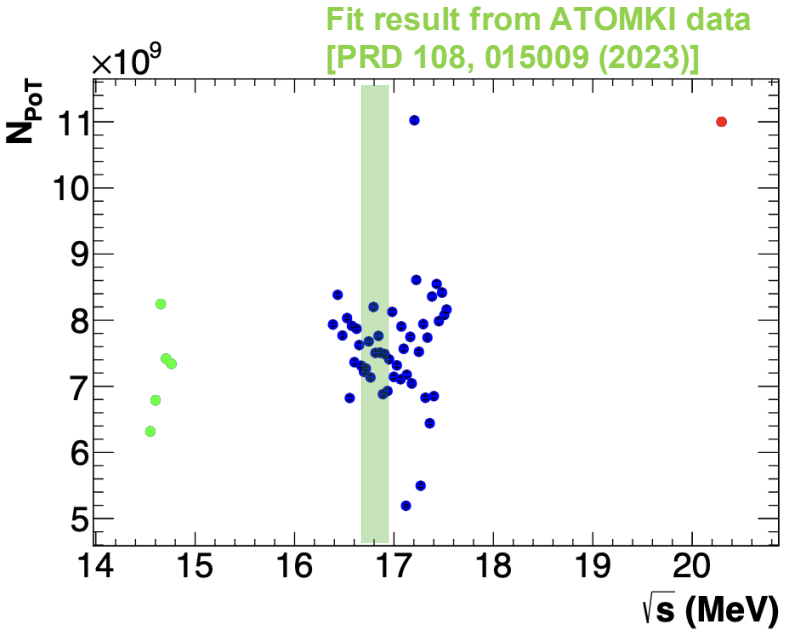
# Run-III concepts: the data set

**Run III** PADME data set contains **3 subset**
- **On resonance points (263-299) MeV**
- **Below resonance points (205-211) MeV**
- **Over resonance, energy 402 MeV**

**1 over resonance energy point**
**Statistics ~2 x $10^{10}$ total**
**Used to calibrate POT absolute measurement**

**On resonance points, mass range 16.4 — 17.5 MeV**
**Beam energy steps ~ 0.75 MeV ~ beam energy spread**
**Spread equivalent to ~ 20 KeV in mass**
**Statistics ~ $10^{10}$ POT per point**

**Below resonance points**
**Beam energy steps ~1.5 MeV**
**Statistics ~ 0.8 x $10^{10}$ POT per point**
**Used to cross-check the flux scale**




**Run III beam performance:**
**JHEP 08 (2024) 121**

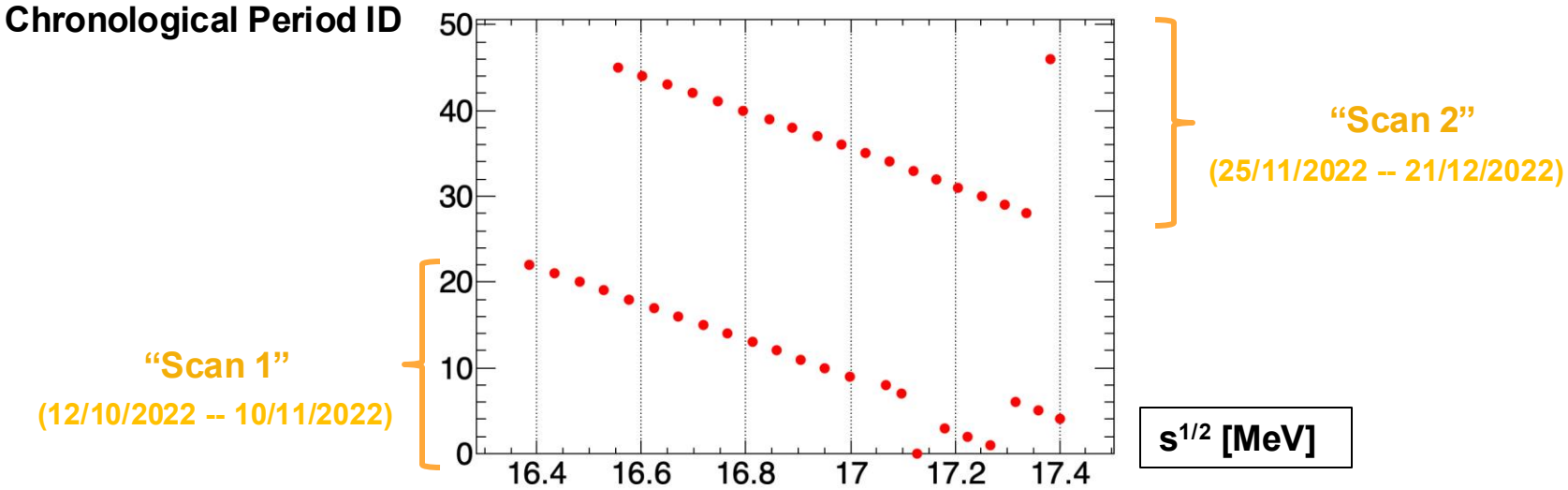
# Run-III concepts: redundancy

"Run": DAQ for ~8 hours, determine beam avg position/angle, ECal energy scale

"Period": a point at a fixed beam energy, typically lasts 24 hours

"Scan" a chronological set of periods typically decreasing in energy

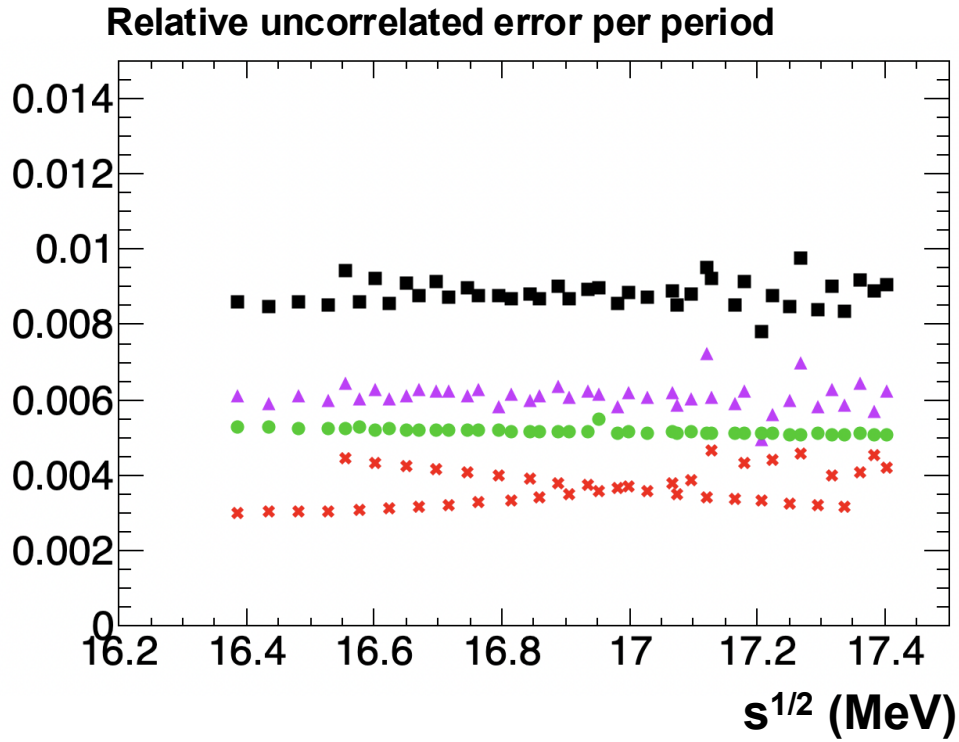
Scan 1 and 2 periods spaced ~ 1.5 MeV but interspersed in energy




Detailed GEANT4-based MC performed for each period

# Run-III result, $g_R$ error budget

## Uncorrelated uncertainty on $g_R(s) = N_2(s) / ( N_{POT}(s)\, B(s) )$:




Uncorrelated errors

| Source | Uncertainty (% per energy point) |
|---|---|
| $N_2(s)$ | 0.60 |
| $B(s)$ | 0.54 |
| $N_{\mathrm{PoT}}(s)$ | 0.35 |
| Total on $g_R(s)$ | 0.88 |

$K(s)$, constant term

| Source | Uncertainty (%) |
|---|---|
| Lead-glass calibration | 2.0 |
| Absolute $B$ yield | 1.8 |
| Energy-loss correction to $N_{\mathrm{PoT}}$ | 0.5 |
| Radiation-induced correction to $N_{\mathrm{PoT}}$ | 0.3 |
| Total | 2.8 |

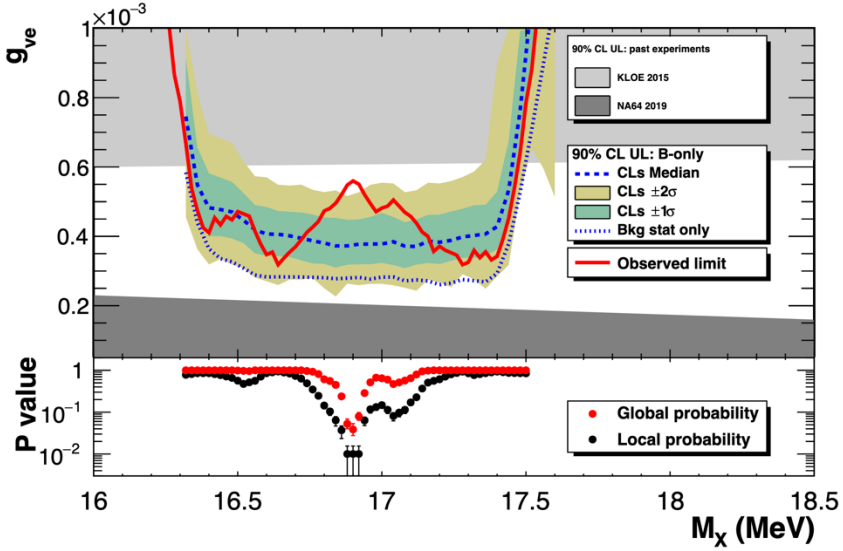
$K(s)$, $\sqrt{s}$-slope

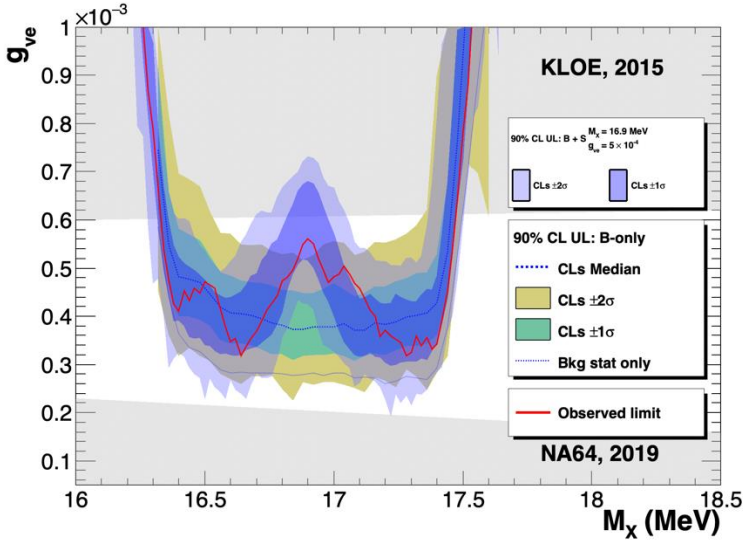
| Source | Expected value (%/MeV) |
|---|---|
| Radiative corrections | $-0.6 \pm 0.2 \pm 0.6$ |
| Total | $-0.6 \pm 0.6$ |

**Estimated errors validated still preserving blind-analysis concept: JHEP 06 (2025) 040**

# Run-III result

**Search for a X17 with Run III data completed: arXiv:2505.24797, to be peer reviewed**



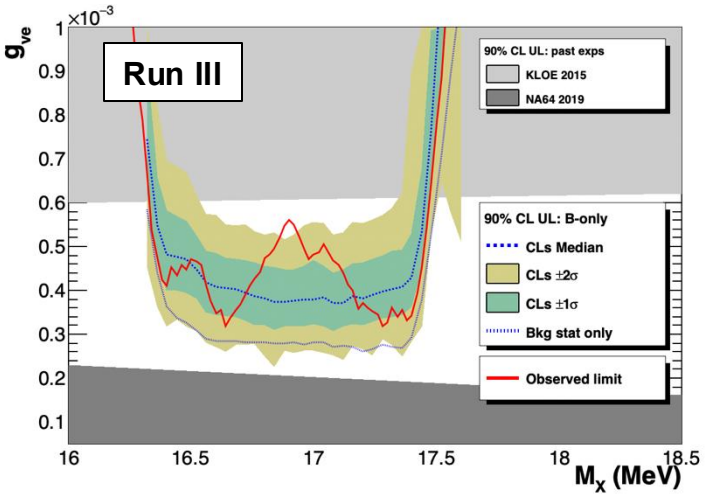



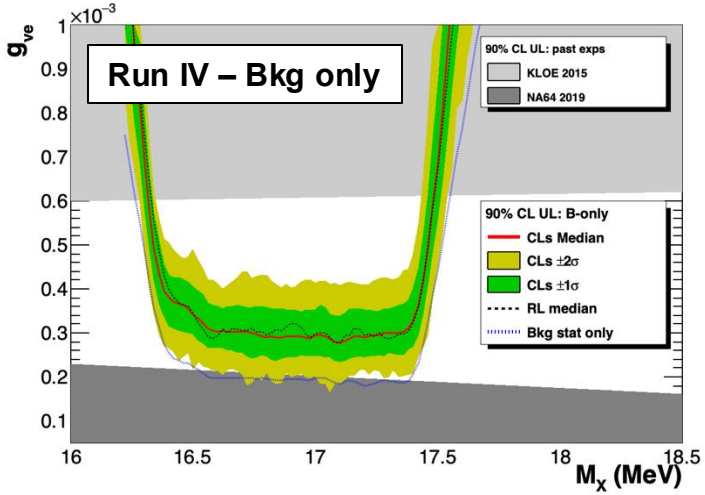

**Excess observed, 2.5 σ local, 1.8(2) σ global significance**

**Just for comparison, check expected UL bands: bkg-only vs B+S(16.9 MeV, $5 \times 10^{-4}$)**

# Run IV to clarify

**See also the CERN EP seminar, https://indico.cern.ch/event/1553077/**




| Source | Uncertainty [%] | | Note |
|---|---|---|---|
| | Run III | Run IV | |
| $N_2$ | 0.6 | 0.3 | Uncorrelated |
| $N_{PoT}$ | 0.35 | 0.3 | Uncorrelated |
| B | 0.55 | 0.3 | Uncorrelated |
| Total | 0.89 | 0.5 | Uncorrelated |

**Separately measure $e^+e^-$ and $\gamma\gamma$ yield in Run IV**

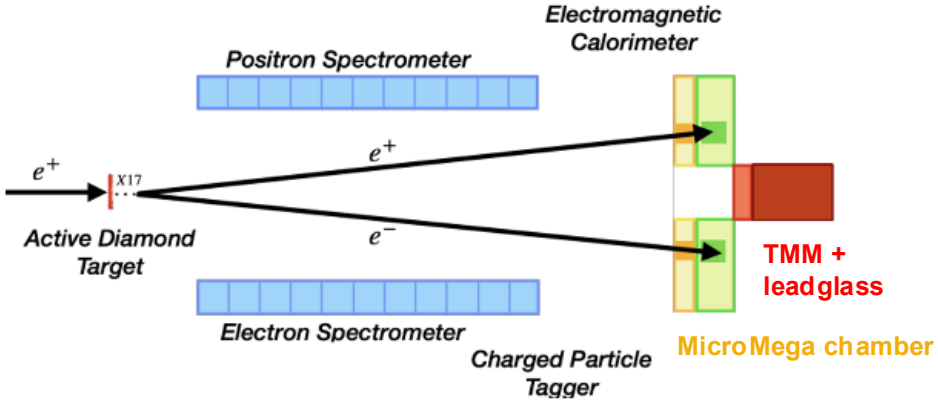
**Presently taking data (Run IV, up to Nov 2025), goal of x4 in statistics with reduced systematics:**

- **Tuned position of target with respect to Ecal to improved acceptance**
- **New micromega-based chamber for $e^+/e^-$ directions and $e^+/e^-$ vs $\gamma$ ID, installed Feb 2025**
- **New micromega-based chamber for beam spot monitoring in front of beam catcher, Apr 2025**
- **Improved monitoring of beam catcher response stability**

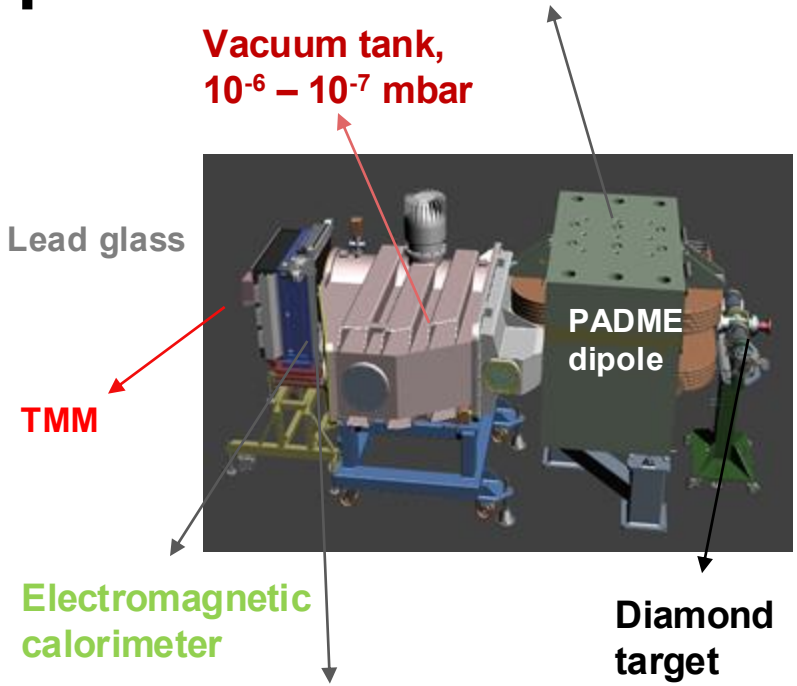
# Run IV setup

**2022 Run-III setup adapted for the X17 search:**

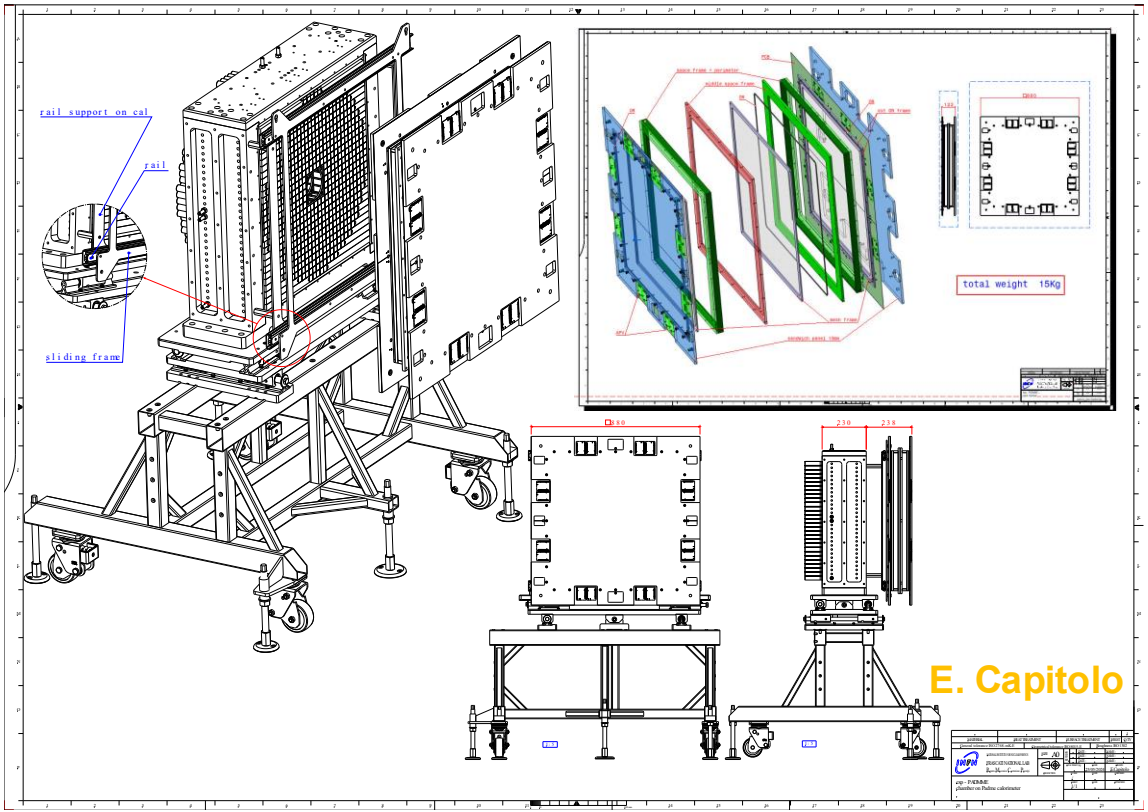
- **Active target moved downstream by 300 mm**
- **No magnetic field**
- **Charged-veto detectors not used → removed**
- **ECal: 616 BGO crystals, each 21x21x230 mm³**
- **~~Hodoscope~~ MicroMega in front of ECal for e/γ**
- **~~Timepix~~ Micromega TMM for beam spot**
- **Lead-glass beam catcher now LED monitored**




**removed veto detectors in vacuum**



# The design of the micromega chamber



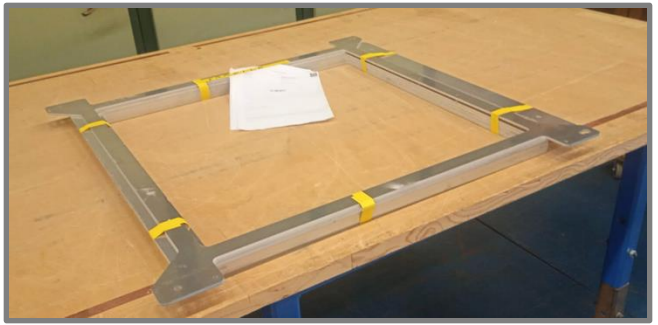

Pannelli sandwich

Mesh frame

Space frame

Middle space frame

PCB

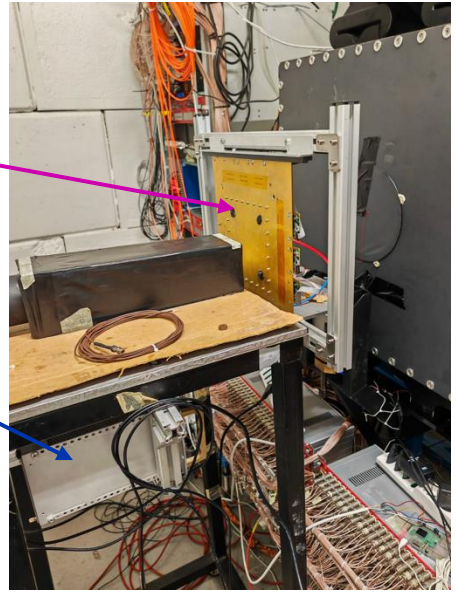


**Installed and precisely aligned at the beginning of Run IV**

# Status of the Run IV data taking - commissioning

**Commissioning longer than expected due to:**

- **Problems with TimePix detector: albeit working perfectly up to Nov. 2024, internal trigger transmission problems appeared in Feb. 2025**
- **Problems with diamond target motor driver, replaced with a new Ethernet controller (bought by Sofia U.)**
- **TimePix sent to Advacam (Prague) for repair, waiting for cost estimate**
- **TimePix replaced with a 10 x 10 $cm^2$ active-area MM chamber: so-called TMM**
- **Had to buy SRS minicrate for acquisition at CERN (3.8 kCHF ~ 4.1 kE)**



# Status of the Run IV data taking - commissioning

**Commissioning longer than expected due to:**

- **Severe problems with the ECal HV boards:**
  - **Numerous intermittently faulty boards (undervoltage errors, faulty channels)**
  - **Problems never seen in the past, but the HW is 8 years old, still not well understood, probably power glitches are present**
  - **Boards repaired by CAEN, but possible effects of SY mainframe remain**
  - **Investigation of possible glitches from general voltage supply, to no avail**

- **Damage observed to 20 ECal PMT dividers not necessarily HV-related**

# HV problems during spring physics run

**SY 4725 with standard PS unit [A4531] + booster [A4532] 600 + 600 W**

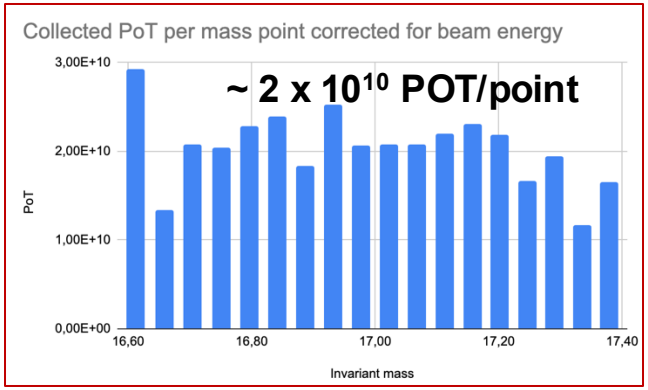
**Present status after many forced re-mappings**

- **Up to 6 HV boards [A7030N] in warning, each w multiple channels in under voltage**
- **2 spare HV board sent to CAEN for repair, no spare left → request funds for 2 more**
- **No spares available for HV mainframe and controller**


# Overview of Run IV status – before the summer

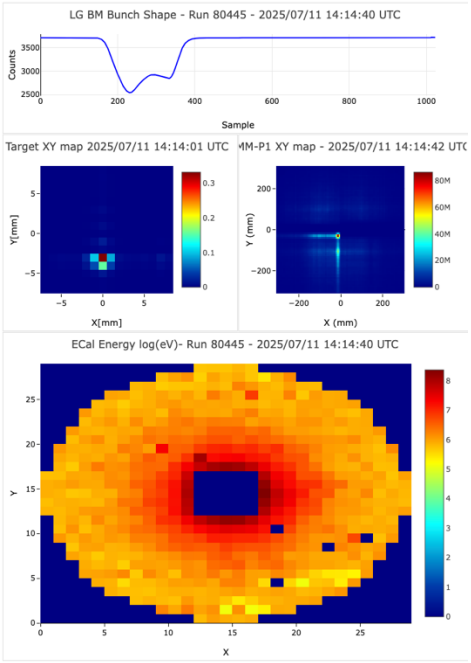
## Run IV physics started 14 June, ended 20 July:

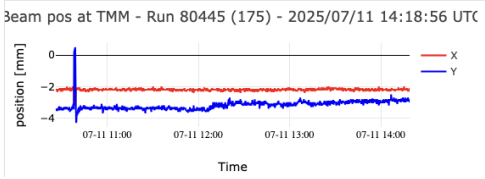
- **18 scan points** taken + **6 no-target** points
- Schedule: resume activities 15 Sep, end 17 Nov
- Acceptance increase w new setup validated

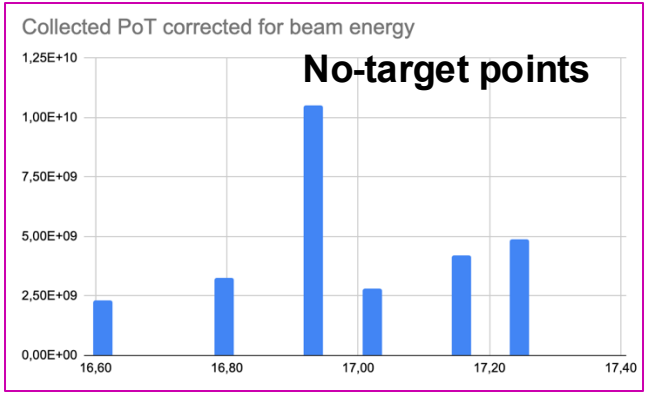



## Online monitor info:

- Beam spill vs time
- Beam spot @ target
- Beam spot @ micromega
- Beam halo @ calorimeter
- Beam spot @ TMM



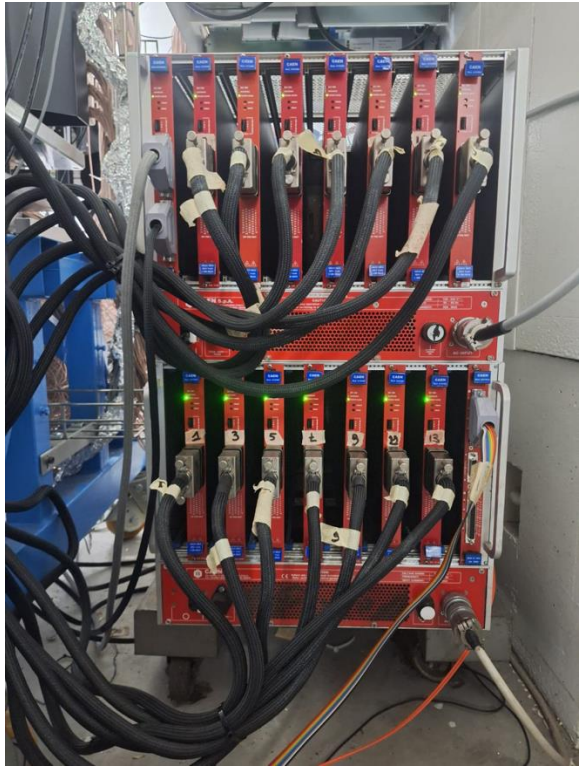



# Activities before Autumn run start

**Run IV planned to restart week 39 (22—28 Sep), scheduled to end Nov 17:**

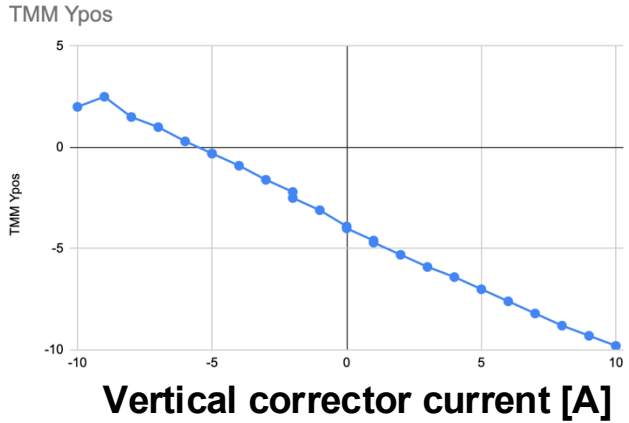
- During the summer micromega chamber gas closed then flux in Ar
- 2 new HV boards shipped to LNF 1 Sep, 6 HV boards repaired by CAEN
- An additional mainframe SY 4527 taken on loan, the boards are now shared
- Trigger boards were inspected for inconsistent pin connection, spacers have been placed (R. Lenci)
- Problematic PMTs seem to not impose efficiency loss
- Work ongoing to use Grafana where possible



# Activities before Autumn run start

**Run IV physics scheduled to end Nov 17:**

- **Beam commissioning started Sep 22**
- **Detector commissioning started Sep 23, smooth (2 HV ch's with problems)**
- **PADME commissioning with beam started Sep 24**
- **Lead-glass HV scan done**
- **Vertical position scan done, good linearity measured at TMM**
- **Plan to acquire first physics data point already today, Sep 30**



# Conclusions

## Analysis of Run III done in a blind way

- "Blind unblinding" procedure published as a separate paper
- Validation of total uncertainty at 0.9% per energy point
- Result presented and made public on the arXiV

## Run IV planned to significantly improve sensitivity:

- 6 months of data taking
- Detector upgraded with new micromega tracker + TMM end of line monitor

## Commissioning completed May 2025:

- Problems with the ECal HV → special 2025 request for board purchases
- Not fully granted by CSN1

## Physics-grade acquisition started mid June 2025:

- 18 energy points acquired before summer stop, 2 x $10^{10}$ POT / point
- Commissioning quickly done after first beam available
- Run IV up to Nov 17 2025, physics data taking started Sep 30