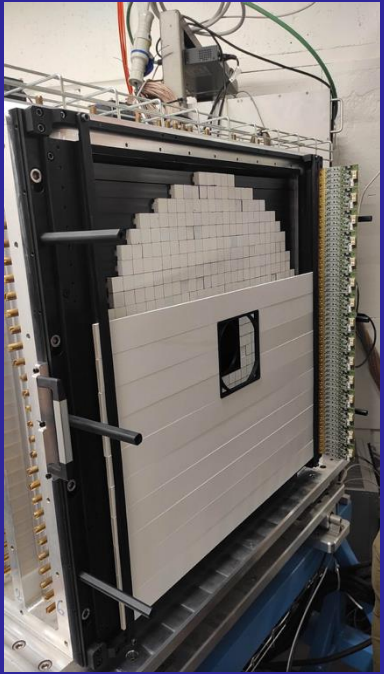
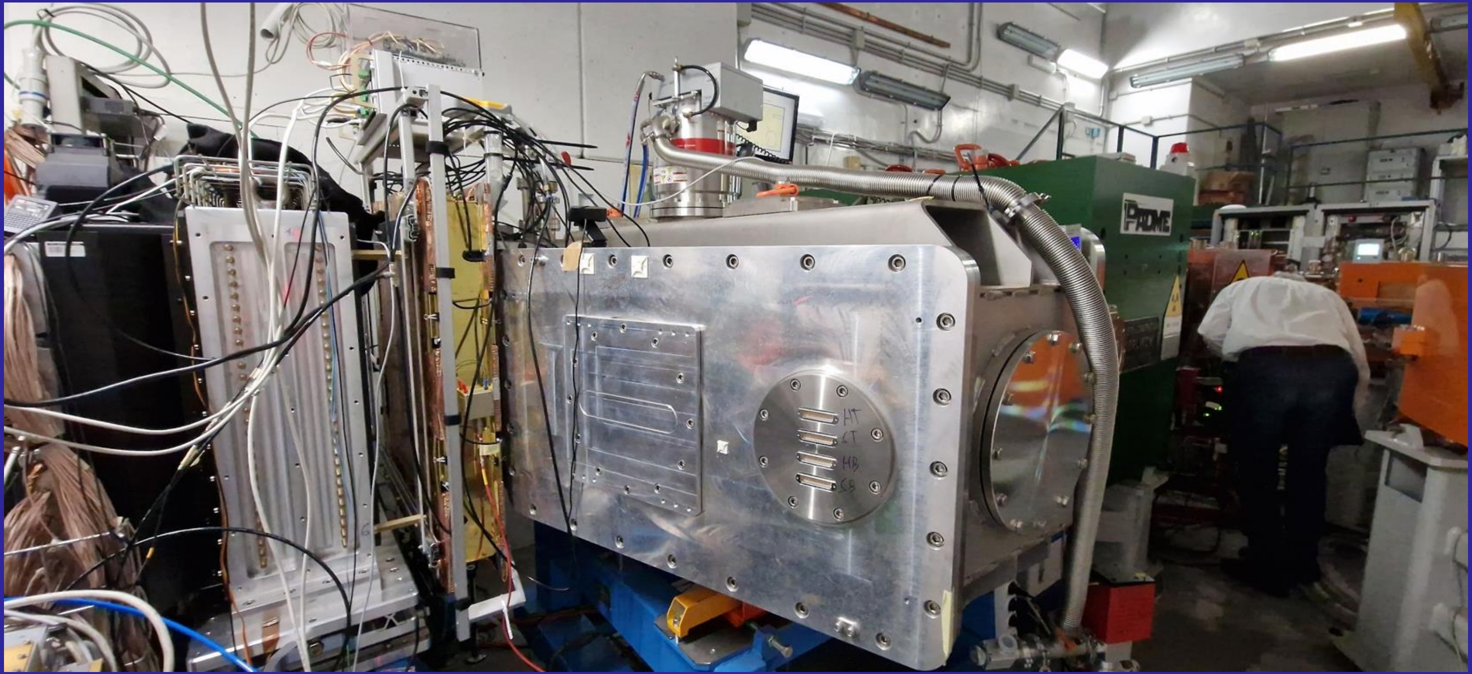
Search for the 17 MeV particle with the PADME detector





Paolo Valente
on behalf of the PADME Collaboration

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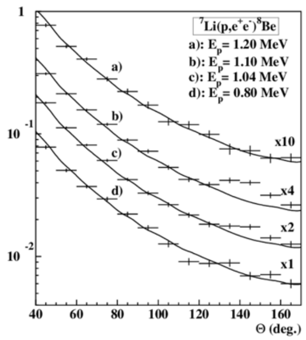
X17 “anomalies”

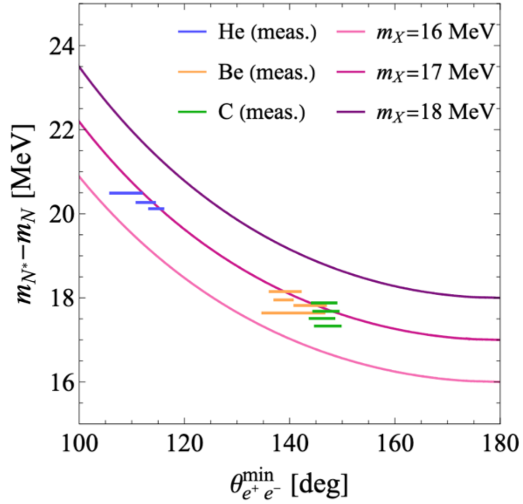
Several anomalies in **angular correlations of e+ e- internally converted** in the radiative disexcitation of nuclear levels excited by a proton beam observed at **ATOMKI**, first in the **decays of ^{8}Be***, then also **^{4}He*, ^{12}C*** [and even in the Giant-Dipole Resonace]

[PRL 116 (2016) 042501]



[PR C 104 (2021) 044003]

[PR C 106, L061601 (2022)]



Interpreted with a **new particle** of mass:

^{8}Be: $M_X = (16.70 \pm 0.35_{stat} \pm 0.5_{syst})$ MeV
^{4}He: $M_X = (16.94 \pm 0.12_{stat} \pm 0.21_{syst})$ MeV
^{12}C: $M_X = (17.03 \pm 0.11_{stat} \pm 0.20_{syst})$ MeV

Observed **also at HUS (Vietnam)** in the **^{8}Be* with a different setup** [Universe 2024, 10(4)]

Angular excesses approx. consistent with being due to a particle of mass **M_X** in a **N* → N X_{17}** transition
[PRD108, 015009 (2023)]:

$\theta_{min} \sim \mathrm{asin}\left(\frac{M_X}{M_{N*}-M_N}\right)$; **$M_X$ =(16.85 ± 0.04) MeV**; χ^2=17.3, ndf=10,P(χ^2) = 7%

The **rate measurements** indicate $\Gamma(N^* \to N\, X_{17}) / \Gamma(N^* \to N\, g) \sim 5\times10^{-6}$

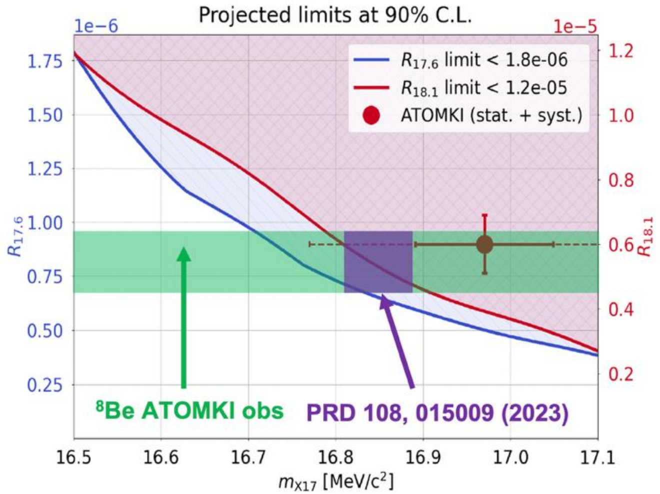
Ongoing experimental initiatives

Recent result from MEG II arXiv:2411.07994

Measurement on ^{7}Li target to reproduce ^{8}Be ATOMKI result, **no signal found**

ULs on $\Gamma(^8\text{Be}^* \rightarrow {}^8\text{Be X(ee)}) / \Gamma(^8\text{Be}^* \rightarrow {}^8\text{Be}\ \gamma)$ **for 17.6, 18.1 MeV** transitions

MEG-II result **still compatible at 1.5 σ** with the **ATOMKI combination** i.e. **M_X = 16.85(4) MeV**
JHEP 04 (2025) 035



Further iniatives:

- **AN2000** electrostatic accelerator at INFN LNL [In data taking]
- At **n_TOF EAR2** neutron line at CERN [2025 proposal]
- **Tandem** accelerator in **Montreal** [JPC Ser. 2391 (2022) 012008]
- **Van de Graaf accelerator at IEAP Prague** [NIM A 1047 (2023) 167858]

Search for a resonance on a thin target

$$\sigma_{res} \propto \frac{g_{V_e}^2}{2m_e} \pi Z\, \delta(E_{res} - E_{beam})$$

- σ goes with α_{em} → **dominant process** wrt other pair production processes (α_{em}^2, α_{em}^3)
- $\sqrt{s}$ as close as possible to expected mass
  → expected **enhancement** in $\sqrt{s}$ over the SM background
- Fine **scan** the e^+ **beam** energy around the resonance [E_{e+}~283 MeV]
  → measure **two-body final state yield N_2** for **each** energy point

N_2(s) = N_{POT}(s) × **B(s)** if **only "background"**, i.e. SM contribution

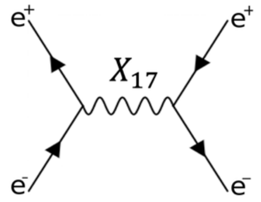
to be compared with:

N_2(s) = N_{POT}(s) × [B(s) + S(s; M_X, g) × ε_S(s)]

- **N_{POT}(s)** number of **positrons on target** **B(s)** expected **background** yield **per POT**
- **S(s; M_X, g)** **signal per POT** for given {mass, coupling} = {M_X, g}
- **ε_S(s)** signal **acceptance** and **selection efficiency**

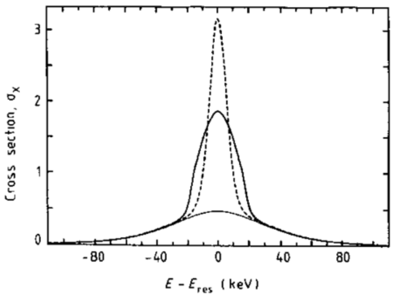
Search for a resonance on a thin target

If **X17** decays to e+e- pairs, it should also be produced in **e+e- annihilations**

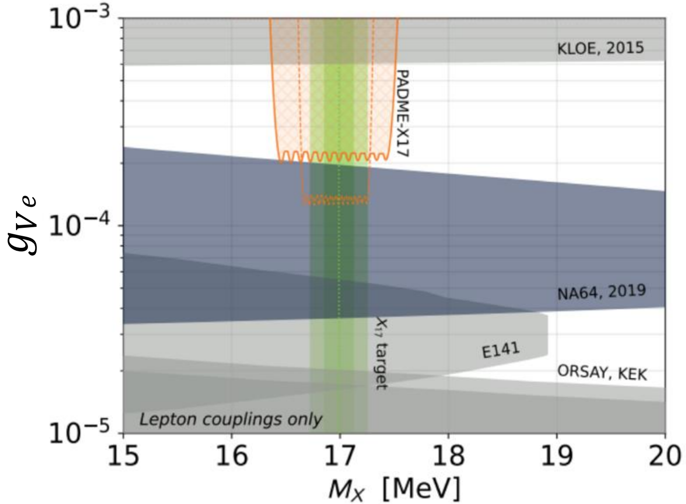


- **The basics of a resonance search are discussed in PRD 106 (2022) 115036**
- Focus on a **Vector state interpretation** for brevity:

$$\mathcal{L}^{\text{Vect.}} \supset \sum_{f=e,u,d} X^{\mu}_{17}\bar{f}\gamma_\mu(g_{vf}+\gamma^5\tilde{g}_{vf})f$$



- The resonance is much narrower wrt the **momentum spread** of the positron **beam**
- Not negligible broadening due to the **electron binding** energy



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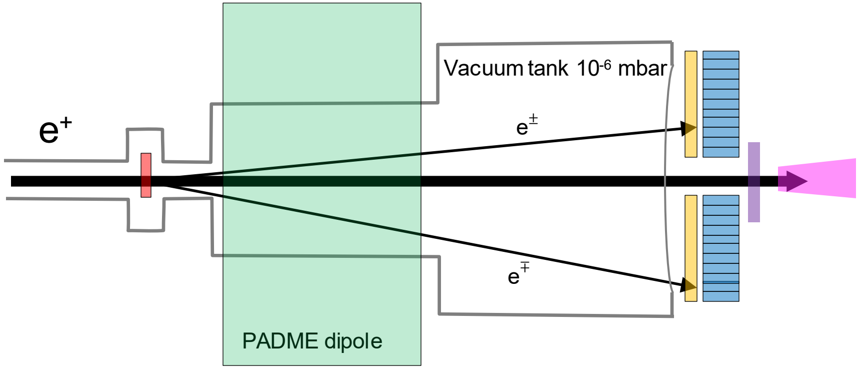
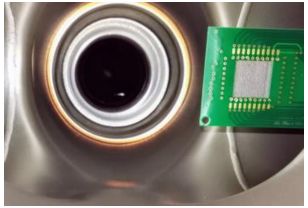
2022 setup

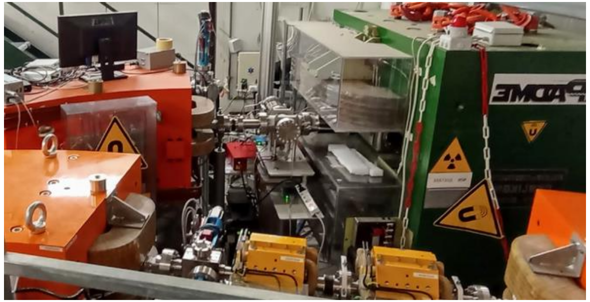


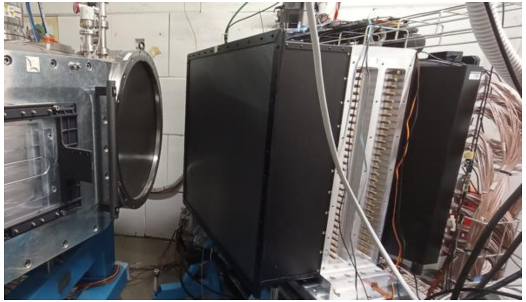
Run I and II dedicated to dark photon searches with associated production

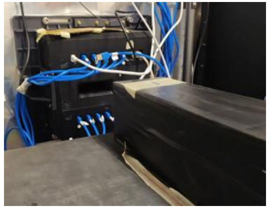
In 2022 PADME setup **specifically adapted** for **Run-III**:

- **Active target**: polycrystalline **diamond** [0.1 mm thick]
- **No magnetic field** [PADME dipole off]
- **Calorimeter:** 616 **BGO** crystals, 21x21x230 mm^3 each
- New scintillating bar **hodoscope** in front of calorimeter for **e/γ**
- **Timepix** silicon detector array for **beam spot monitoring**
- **Lead-glass beam catcher** (OPAL/NA62 LAV)

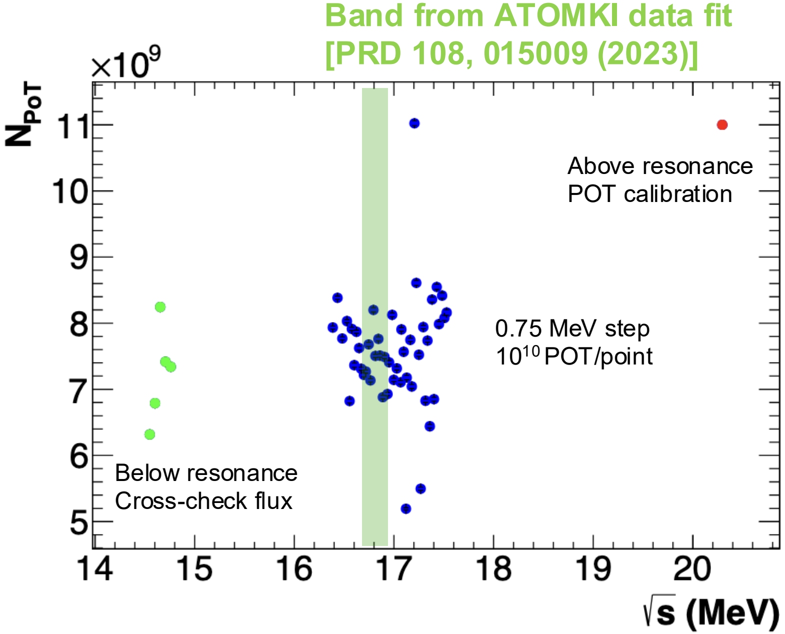






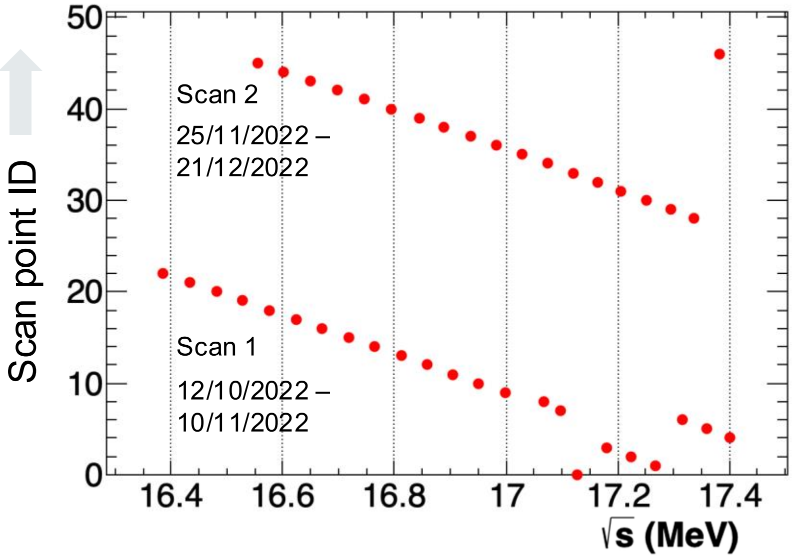


Run III data set



Actually **two interleaved scans**, 1.5 MeV step

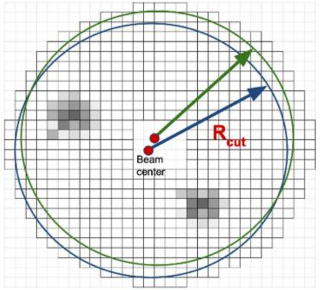
Nearby energy points acquired 1.5 months apart



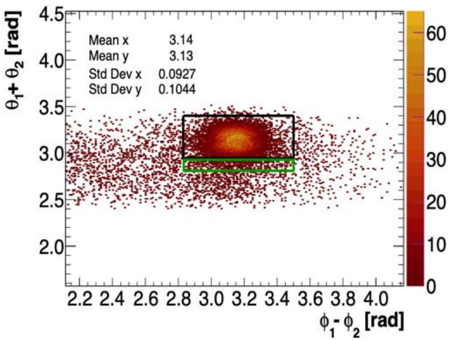
Signal selection

Selection algorithm as **independent** as possible **on the beam variations:**

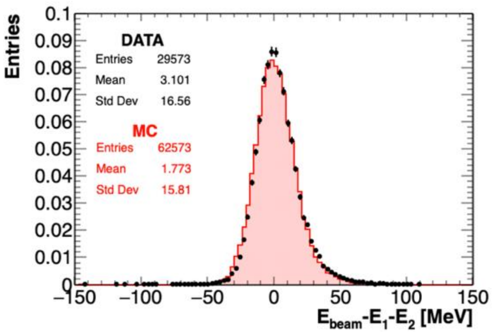
- Retune **beam center** run by run with an error ≪ **mm**
- Overall, make **marginal use** of the cluster **reconstructed energy**

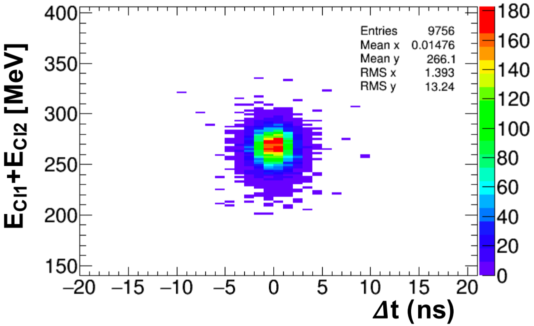


Neglecting **m_e/E terms**, c.m. angles **independent on the lab energies**



Selected events
4% background





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ΔT [ns]

Analysis scheme

Rewrite the yield formula as:

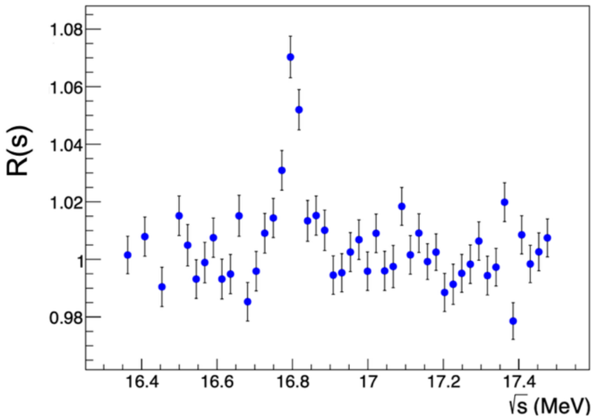
$$\underbrace{\frac{N_2(s)}{N_{POT}(s)\, B(s)}}_{R(s)} = 1 + \frac{S(s;\, MX,\, g)\, \varepsilon_S(s)}{B(s)}$$

R(s)=1 if only SM **"background"**, but different effects can lead to a **deviation** from above: **K(s)**

Question: is **R(s)** more consistent with

- **K(s)** or
- $\mathbf{K(s)} \times \left[1 + \frac{S(s;\, MX,\, g)\, \varepsilon_S(s)}{B(s)} \right]$?

MC with M_X = **16.8 MeV**, g_V = **8×10**$^{-4}$



7 **nuisance parameters** for the **S+B** scenario**:** 2 for **K** and ε_S/**B**, 3 for **S**

Error budget: N_2, B

Source	Error on N_2 [%]
Statistics	~0.6
Background subtraction	0.3
Total	0.65

30k events /energy point

using **angular side-bands** (Bremsstrahlung, 4%)

Source	Error on B [%]
MC statistics	0.40
Data/MC efficiency (Tag&Probe)	0.35
Cut stability	0.04
Beam spot variations	0.05
Total	0.54

Monte Carlo + data-driven checks

Common systematic errors on **B** enter in the scale **K(s)**, e.g.:

Absolute cross section (rad. corr. at 3%), **target thickness** (known 4%)

Source	Correlated B error [%]
Below res. statistics	0.40
Below res. acceptance; s slope	1.80
Total	1.85

Error budget: N_{POT}

Source	Error on N_{POT} [%]
Statistics, ped subtraction	negligible
Energy scale from BES	0.3
Error from rad. induce slope	Variable, ~0.35
Total	0.45

BES from Timepix **beam spot σ_x**

Source	Common error on N_{POT} [%]
pC / MeV	2.0
Energy loss, data/MC	0.5
Rad. induced loss, constant term	0.3
Total	2.1

[*JHEP* 08 (2024) 121]

Analysis scheme: S

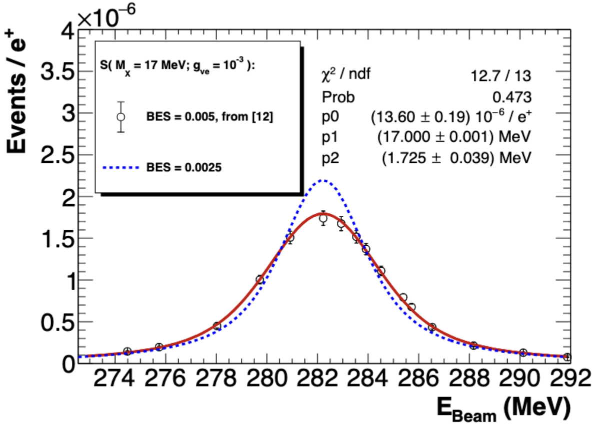
Analysis compares **R(s)** to **K(s)×[1 + S(s; M,g$_v$) ε/B]**

Expected signal **yield** from points taken from **PRL 132 (2024) 261801**, including effect of **motion of the atomic electrons** in the diamond target from Compton profiles

Parameterized **S vs E$_{beam}$** with a **Voigt function:**

- Convolution of the **Gaussian** BES with the **Lorentzian**
- OK in the core within % with some dependence on BES

S(E$_{beam}$; M$_X$ = 17 MeV, g$_v$ = 10^{-3})



Uncertainty in the curve parameters as **nuisances**:

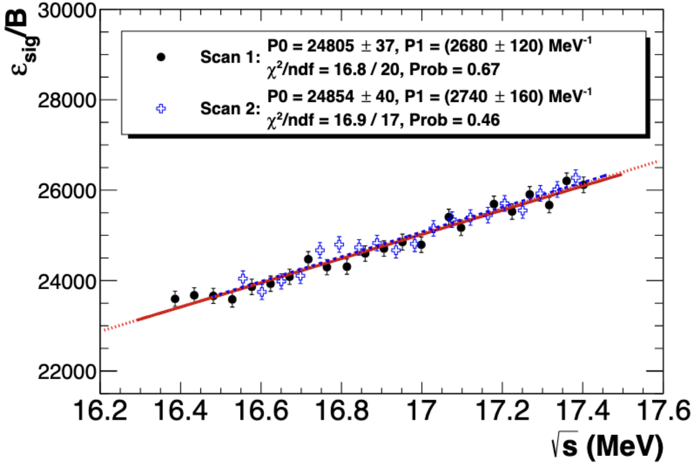
- Peak **yield**: **1.3%**
- **Lorentzian width** around resonance energy: **1.72(4) MeV**
- Relative **BES: 0.025(5)%**

Analysis scheme: ε/B

Analysis compares **R(s)** to **K(s)**$\times$**[1 + S(s; M,g_v) ε/B]**

Efficiency ε determined from MC: large cancellation of systematic errors using ε/B

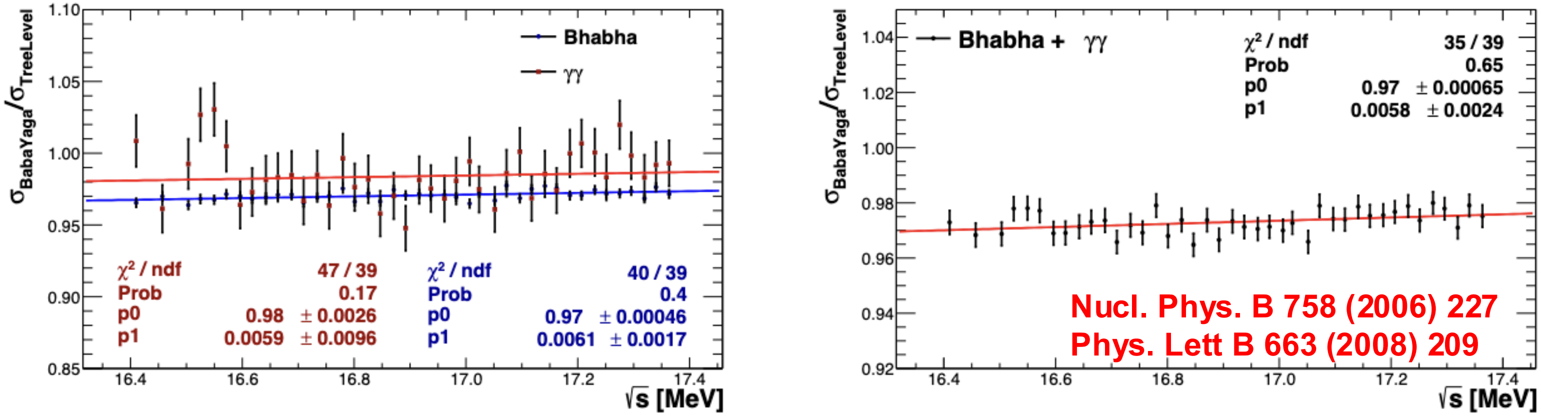
Fit **ε/B($s^{1/2}$)** with a **straight line**, include **fit parameters as nuisances**



- Separate fits for scan 1 and scan 2, mutually compatible
- Reproduced with MC

Possible scale effects, K(s)

Radiative corrections evaluated using **Babayaga, ee(γ) and $\gamma\gamma$(γ)**

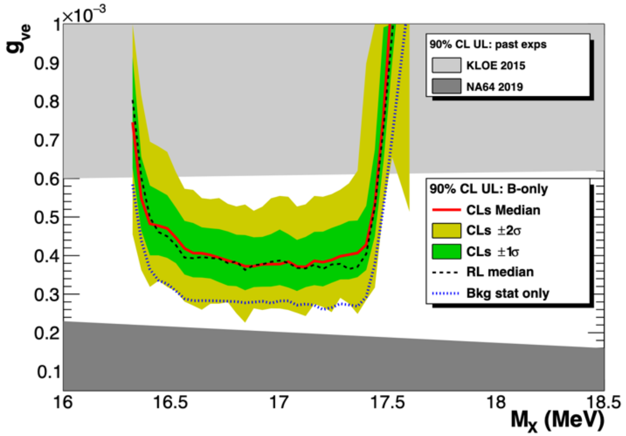


The scaling with the below resonance is affected by a **-1.5(1.5)% shift** because of **radiative corrections**, but the expected total error covers for it: 1.8%(B) + 2.1%(N_{PoT}) = 2.8%

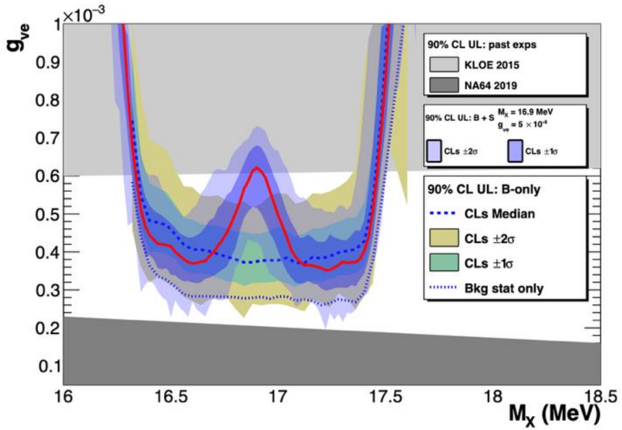
Insertion of **Babayaga-generated events in the MC** (up to 10 γ's) → **no effect on ε**

Analysis scheme: expected sensitivity

- **Evaluate expected 90% CL upper limit in absence of signal**
- **Define Q statistic based on likelihood ratio**: $Q = L_{S+B}(g_v, M_X) / L_B$
- The **likelihood** includes terms for **each nuisance parameter pdf**
- For a **given M_X**, $CLs = P_S / (1 - P_B)$ is used to define the **UL on g_v**



Probabilities **P_S** and **P_B** obtained using **simulations**, where the observables are always sampled, with **nuisance parameters** fixed to the B and S+B fits



In presence of a **signal**, the expected limit is **weaker**, e.g. for **M_X = 16.9 MeV, $g_{ve} = 5\times10^{-4}$**

For details:
arXiv:2503.05650 [accepted by *JHEP*]

The “blind unblinding” procedure

To validate the error estimate applied procedure described in **2503.05650 [hep-ex]**

Define a **side-band** in R(s), **excluding 10 energy points** of the scan in a **blind way**

Masked periods **defined** by **optimizing** the probability of a **linear fit** in $\sqrt{s}$

1. Threshold on the χ^2 fit in side-band **is $P(\chi^2)$ = 20%**, corresponding to reject 10% of the times
2. If passed, check if the **fit pulls** are **Gaussian**
3. If passed, check if a straight-line fit of the pulls has **no slope in $s^{1/2}$ (within 2 sigma)**
4. If passed, check if constant term and slope of the linear fit for K(s) are within two sigma of the expectations, i.e.: +/- 4.8% for the constant, (-0.6 +/- 1.2) % MeV^{-1} for the slope

Successfully applied:
1. $P(\chi^2)$ = 74%
2. Pulls Gaussian fit probability 60%
3. Slope of pulls consistent with zero
4. Constant term = 1.0116(16), Slope = (-0.010 +- 0.005) MeV^{-1}

At **90%CL** additional errors **<1%**

Proceed to box opening

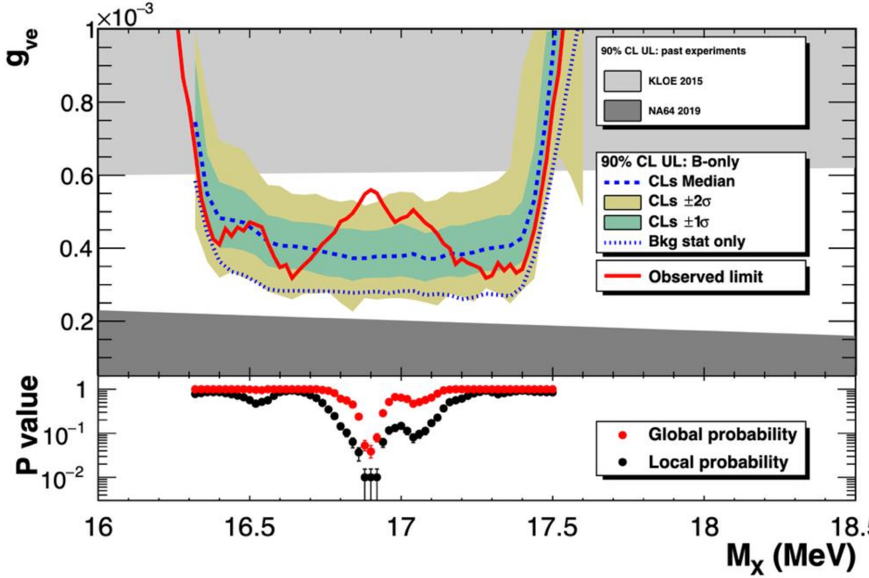
Box opening

Excess is observed **beyond** the **2σ** coverage **(2.5 σ local)**

At $\mathbf{M_X = 16.90(2)}$ **MeV**, $\mathbf{g_{ve} = 5.6 \times 10^{-4}}$, the global probability dip reaches **$3.9_{-1.1}^{+1.5}$ %**

Corresponding to **(1.77 ±0.15) σ one-sided** (look-elsewhere calculated exactly from the toy pseudo-events)

A second excess is present at ~ 17.1 MeV, but the absolute probability there is ~ 40%



If a **3σ interval** is assumed for observation following the estimate $\mathbf{M_X}$ **= 16.85(4)** of **PRD 108, 015009 (2023)**, the p-value dip deepens to **$2.2_{-0.8}^{+1.2}$%** corresponding to **(2.0±0.2) σ one-sided**

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For details: ArXiv:2505.24797 [hep-ex]

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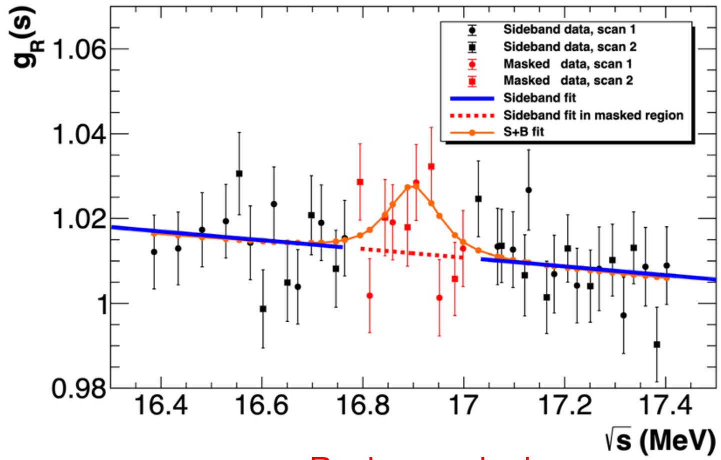
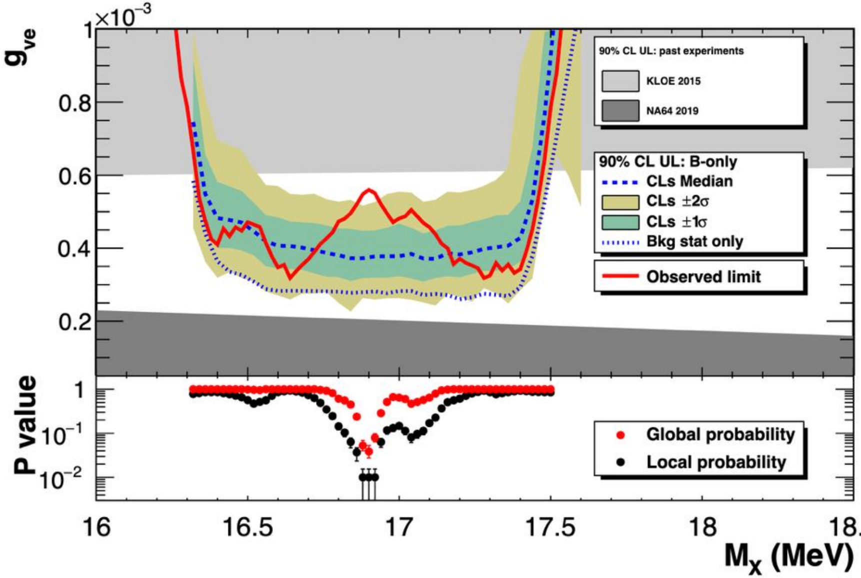
Box opening

Check the **data distribution** vs **likelihood fit** to evaluate $Q_{obs}(S+B)$

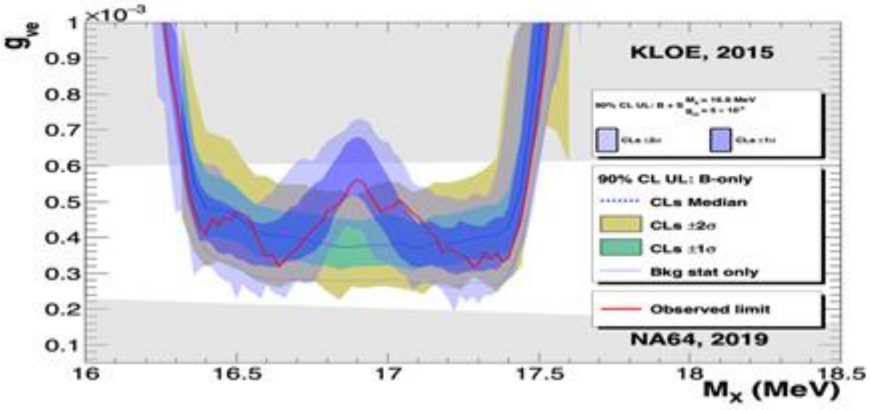
Fit probability is 60%

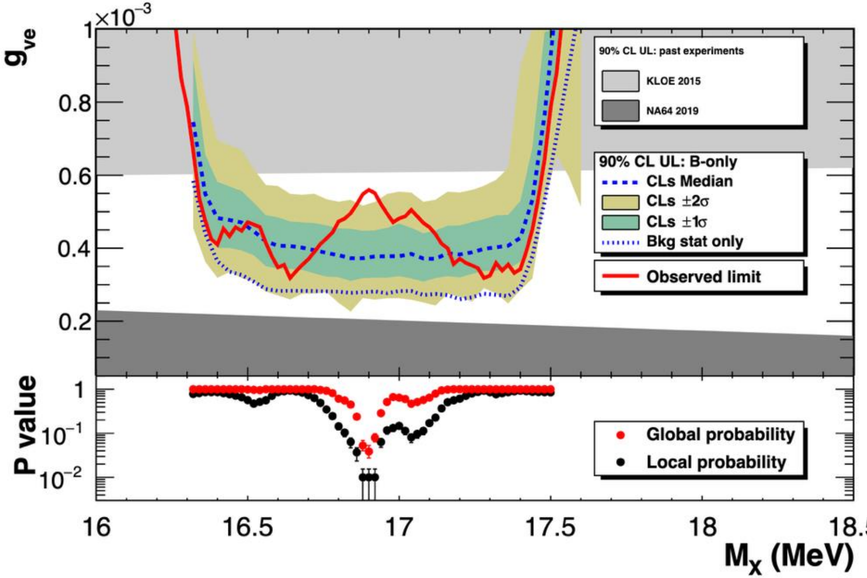


Region masked by automatic procedure



Box opening



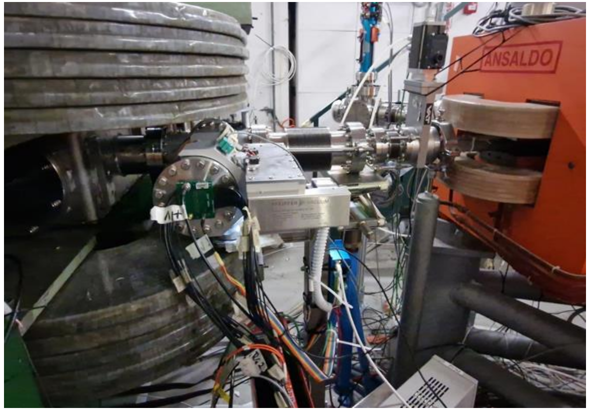


For comparison, check **expected UL bands**
bkg-only vs **B+S(16.9 MeV, 5 × 10^{-4})**

PADME Run IV optimized setup

New data set being acquired to better clarify:

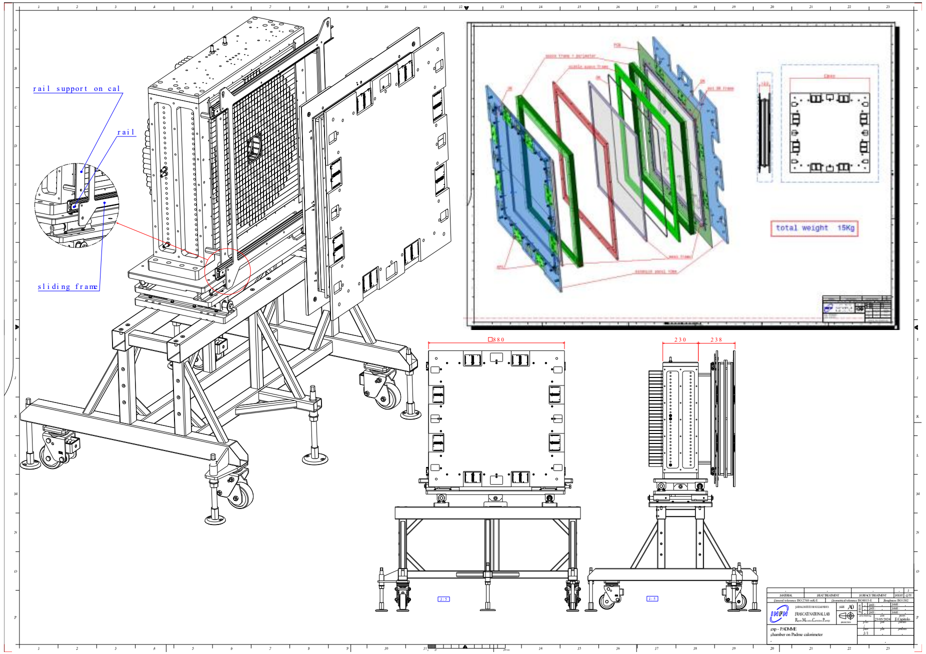
- set the target **closer to the calorimeter**, increase acceptance

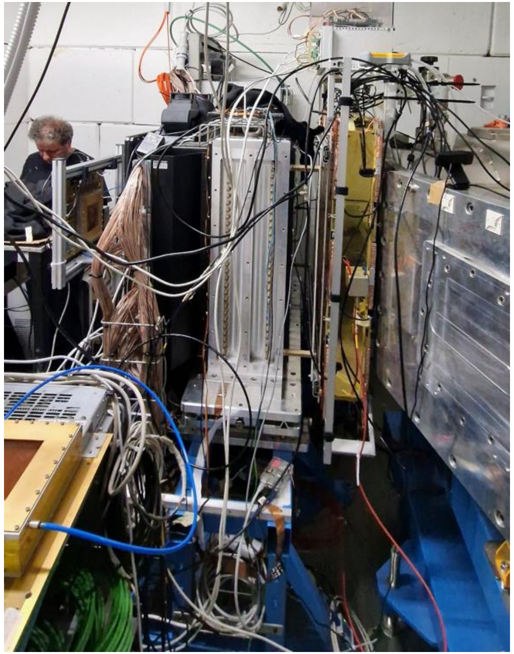


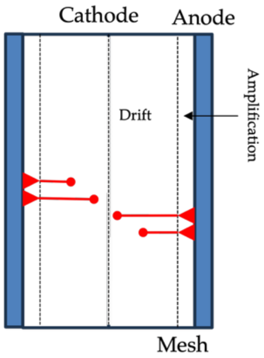
Run IV – new tracking detector

New detector for Run IV [Frascati, Napoli, Roma]:

- ATLAS micromegas-based **tracker** to separately measure the absolute cross sections of **ee/γγ**
- **Improvement in angle resolution, also provides beam spot**







Two 5 cm gaps, can operate in TPC mode

Resistive circuit (common, 3 HV zones)

Run IV assumptions

Improvements wrt Run III:

- **Increase acceptance**: allow even safer treatment for edge effects
- Increase **monitoring** power and **redundancy**: better stability
- **Alternative flux determinations**: $\gamma\gamma$, new end of line monitor, target, chamber
- **Increase statistics**: 1.5×10^{10} POT per energy point

Expectations for Run IV:

- $\times$**2 acceptance** increase
- $\times$**2 statistics** increase
- 2.5 days for data collection, 3000 e^+/spill as in Run III
- Points divided into 2 scans as in Run III

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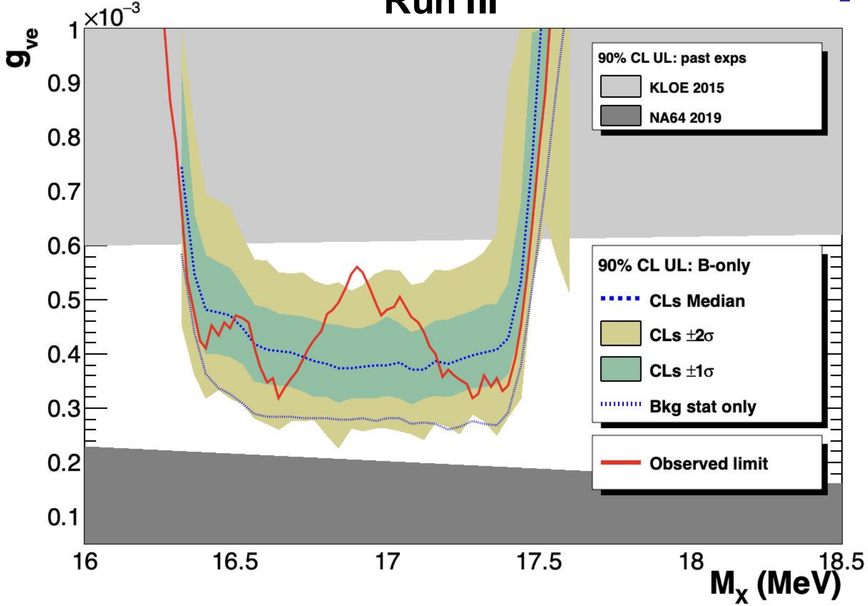
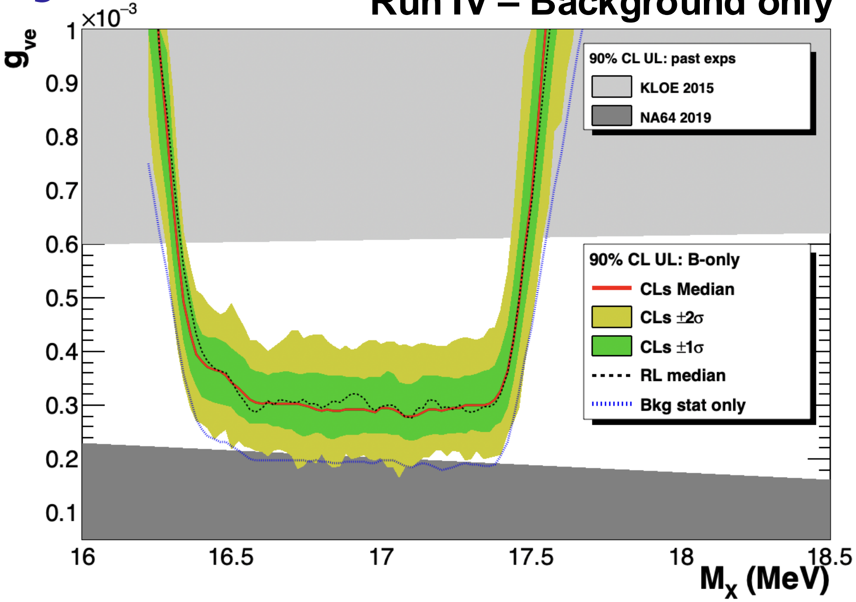
Run IV projections

Run III



Run IV – Background only



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 on g_R	0.89	0.5	Uncorrelated

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Conclusions

The "X_{17}" **excess remains not confirmed** but **not disproved**

No SM explanation viable

The **PADME experiment** is in a **favorable condition to clarify**

Data from **4×10^{11} e^+ on target** used for **resonance search** in the mass region **16.4 –17.4 MeV** with a **blind analysis**

Overall uncertainties of 0.9% on 40+ points have been obtained

No indication of X_{17} with global p-values well beyond 2σ

An excess at 16.90 MeV: local p-value 2.5 σ, global 1.77(15) σ

A **new data taking** with an **upgraded detector** is **ongoing:** Jun-Nov 2025, possible extension beginning of 2026

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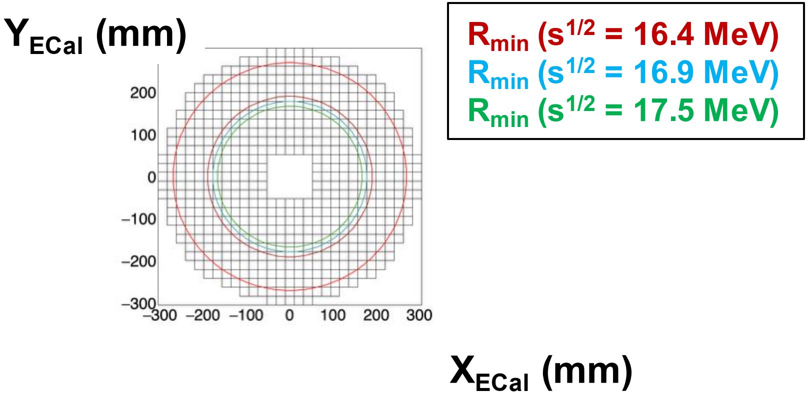
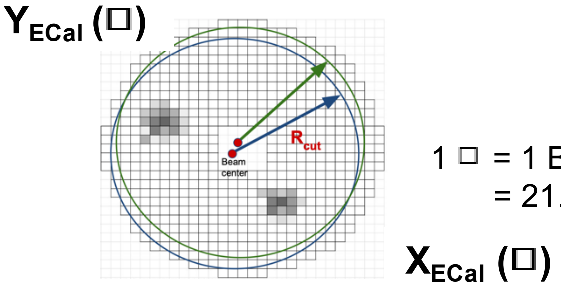
Additional material

Run-III concepts – the signal selection

Select any two-body final state (ee, γγ) with both daughters in ECal acceptance:

1. **Fix R_{Max} at Ecal, away from Ecal edges**
2. **Given s, derive R_{Min}, E_{Min}, E_{Max}**
3. **Select cluster pairs:**
   - **With Energy > E_{min} x 0.4**
   - **In time within 5 ns**
   - **Clus1: In (R_{min}- D, R_{max}), D = 1.5 L3 crystals**
   - **Clus2: R > R_{min}- D**
4. **Select pairs back-to-back in the c.m. frame**





1 □ = 1 BGO crystal
= 21.5 x 21.5 mm

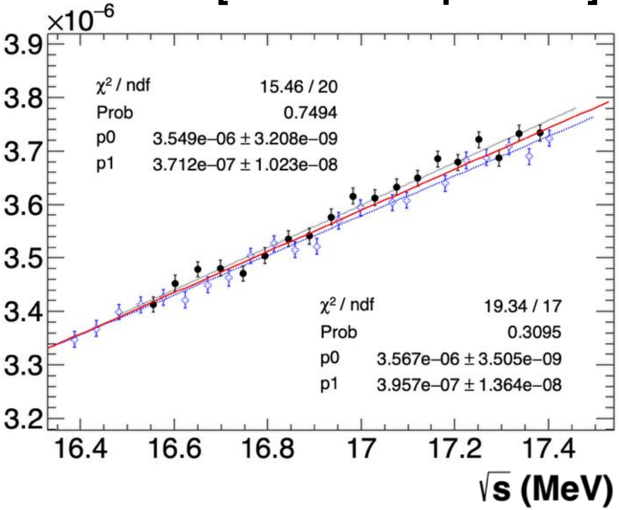
Rmax chosen to be away from Ecal edges by more than the size of 1 BGO crystal cell for any period in the data set

Details on expected background: s dependence

Expected background B determined from MC, stat error per period: $\delta B \sim 4\times10^{-3}$

Fit of $B(s^{1/2})$ with a straight line (only including statistical errors here)

B [10^{-6} events per POT]



Fit mode	P0 [10^{-6}]	P1 [10^{-7} / MeV]	Corr	Fit prob
Only scan1	3.549(3)	3.71(10)	0.12	75%
Only scan2	3.567(4)	3.96(13)	-0.19	31%
All periods	3.558(2)	3.85(8)	-0.008	9%

Background curve slightly depend on the scan

Considered in alternative analysis (see later)

Box opening – III Other checks

Checked other sensitivity methods

Perform the automatic procedure but fit with a constant:

Result:
1. $P(\chi^2) = 37\%$
2. Pulls gaussian fit prob > 30%
3. Slope of pulls consistent with zero
4. Constant = 1.0112(14)

Original version:
1. $P(\chi^2) = 74\%$
2. Pulls gaussian fit probability > 45%
3. Slope of pulls consistent with zero
4. Constant = 1.0116(16), Slope = (-0.010 +- 0.004) MeV^{-1}

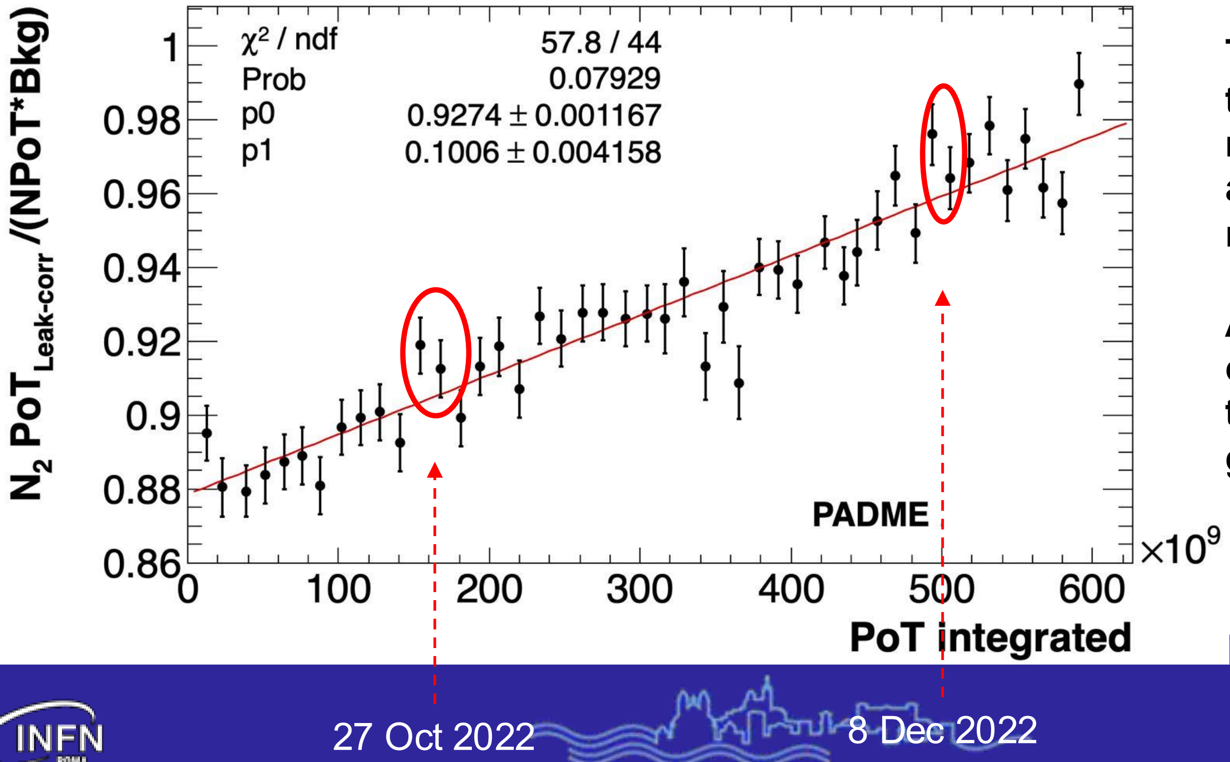
The center of the masked region does not change: 16.888 MeV
The excess also remains basically of the same strength: 1.6σ

Use scan1-scan2 separate parametrizations for B(s) instead of using B(s) / point:
Excess region only slightly affected and equivalent to ~1.6 σ

Check the PCL method using CLsb, equivalent number of σ = 1.62 +- 0.13

Box opening – IV Check of correction

After box opening, can check ageing correction applied, slope was 0.097(7)
Fully consistent (observed excess alters only marginally)

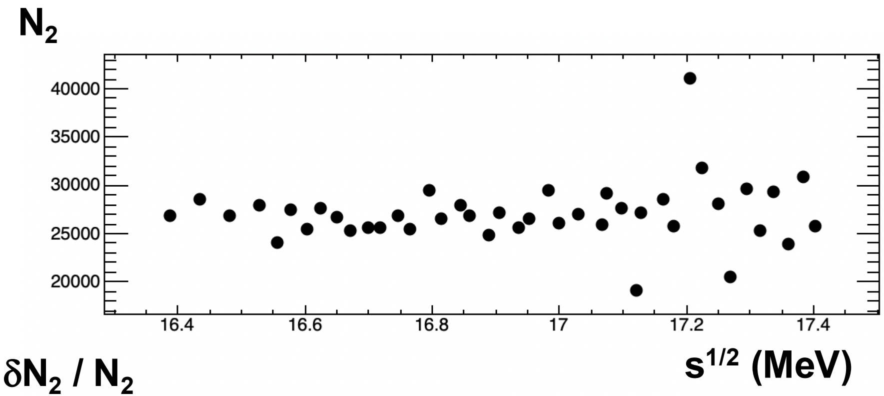


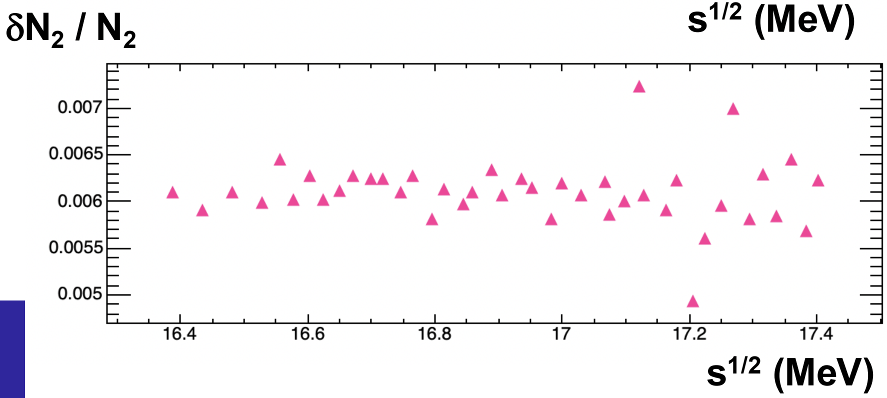
The slope has been used to correct for the radiation-induced effect, acting as a separate nuisance

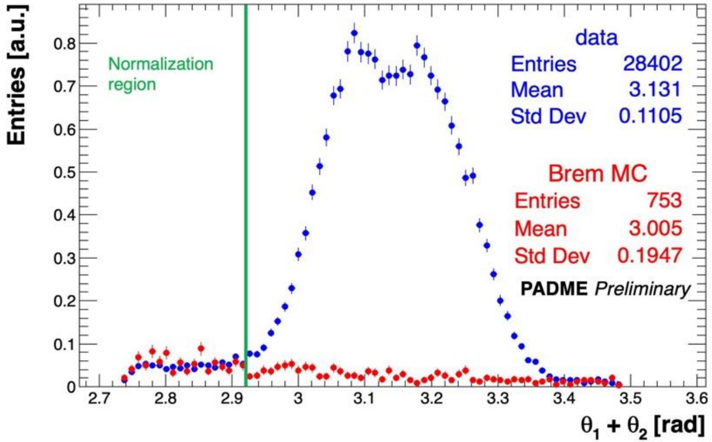
Again no significant change in the location of the excess and in the global p-value

Details on the event count N_2

Background subtraction using side-bands (bremsstrahlung, ~4%)
Correction relative variation +-1%, statistical uncertainty on $\delta N_2 \sim 0.3\%$







Shape of ee signal due to residual magnetic field (MNP CERN SPS type)

Fully modeled using MC + detailed map

Details on background: cut stability

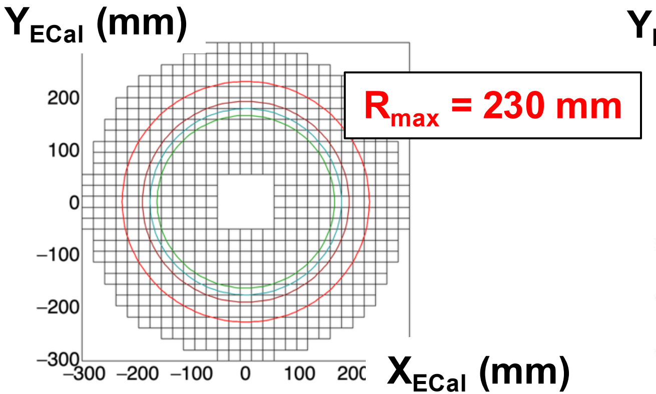
Check if MC and data yields stable vs R_{min}, R_{max} (edge effects, leakage)

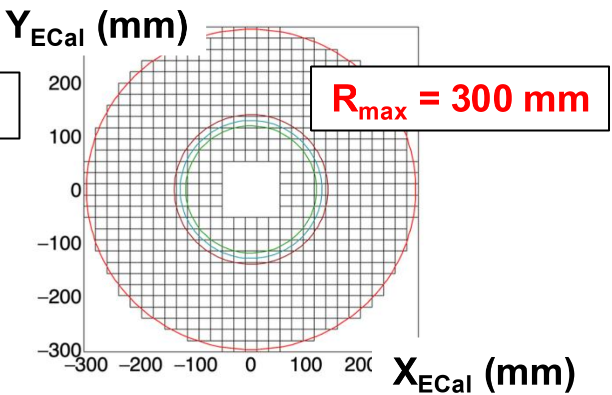
Vary R_{max} by +-2 E_{Cal} cells around nominal cut of 270 mm: 230 mm → 300 mm

Yield variation: ~10%

Uncorrelated error 0.3%

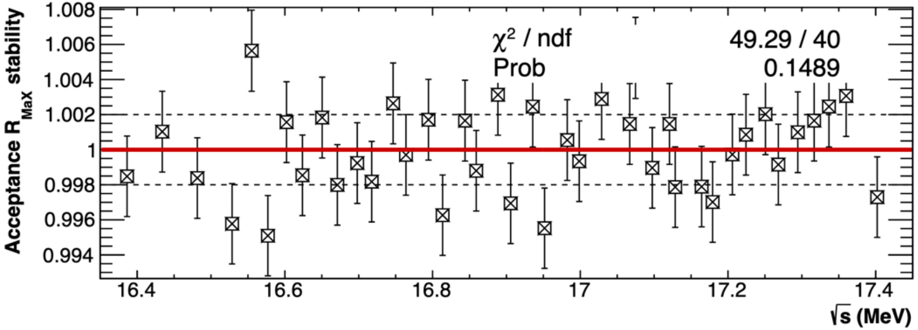
R_{min} -1.5 D ($s^{1/2}$ = 16.4 MeV)
R_{min} -1.5 D ($s^{1/2}$ = 16.9 MeV)
R_{min} -1.5 D ($s^{1/2}$ = 17.5 MeV)





Stability is observed within a coverage band of +-0.2%, add 0.035% uncorrelated systematic error on B

Cut relative stability



INFN ROMA

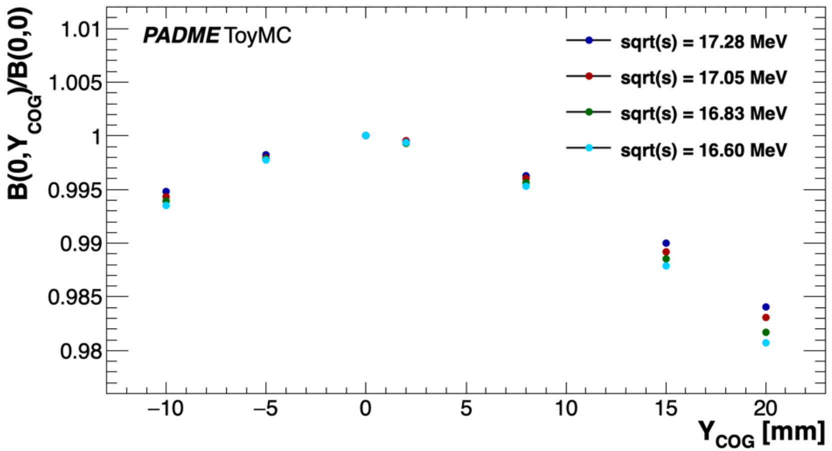
Details on background: acceptance variations

The selection makes use of the expected beam direction, from the spot measured at the diamond target and the center of gravity (COG) of 2 body final states at ECal

Systematic shifts in the COG position translate into acceptance systematic errors

Largest effect in y due to acceptance limitations (rectangular magnet bore)
Fractional variations range from 0.08% to 0.1% mm^{-1} for $s^{1/2}$ from 16.4 to 17.4 MeV

An error of 1 mm in the COG is a conservative estimate → systematic error < 0.1%

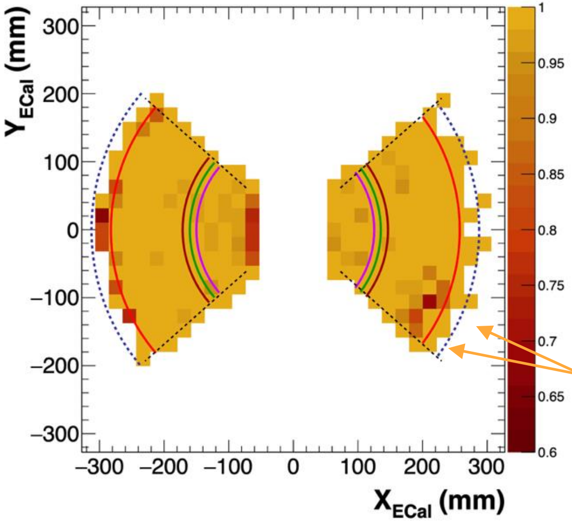


Details on background: cluster reconstruction

Efficiency around 1 within few % except in specific regions (Ecal edges, dead cells)

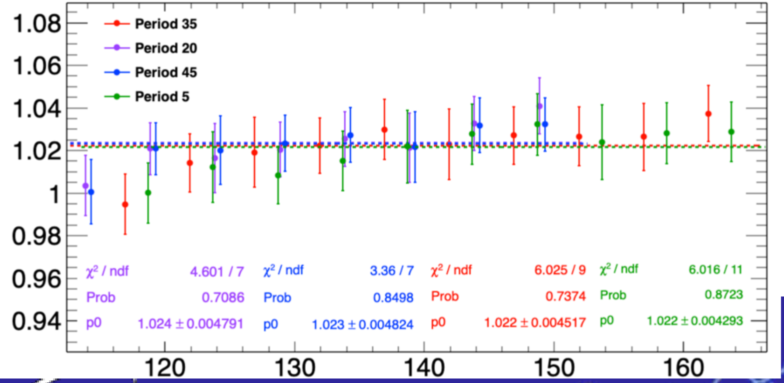
Tag & probe: method-induced bias 2.3(2)%, stable along the data set

Data/MC method efficiency stable along the data set and at the few per mil



R_{min} ($s^{1/2}$ = 16.4 MeV)
R_{min} ($s^{1/2}$ = 16.9 MeV)
R_{min} ($s^{1/2}$ = 17.5 MeV)

Efficiency <Method /MC true>



Expected cluster energy (MeV)

Details on background: cluster reconstruction

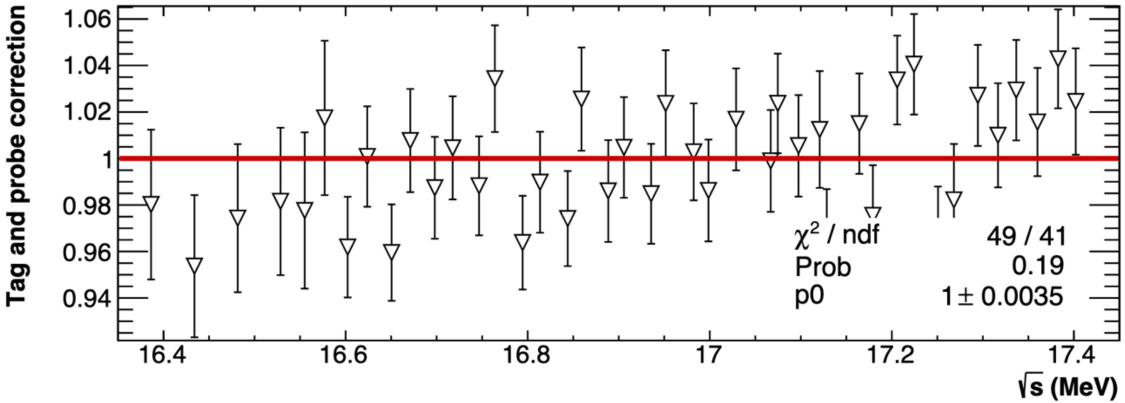
Check of reconstruction efficiency:

- Efficiency for data and MC evaluated using tag-and-probe technique
- Statistical error dominated by background subtraction at tag level

Data/MC energy-flat, compatible with 1, error O(1%) per period

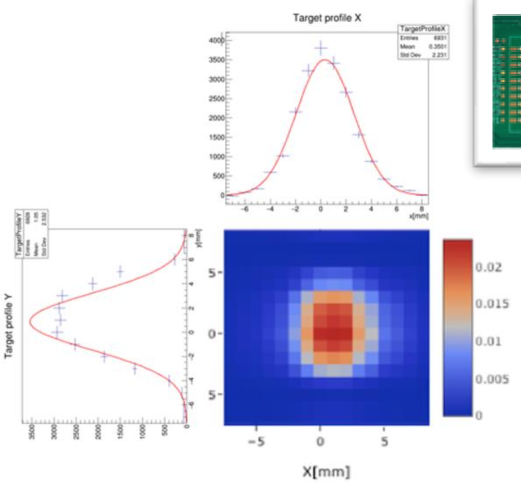
<Data/MC> vs period, P_{Fit}(const) ~ 20%

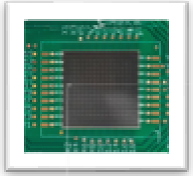
No correction applied per period, statistical-systematic error of 0.35%

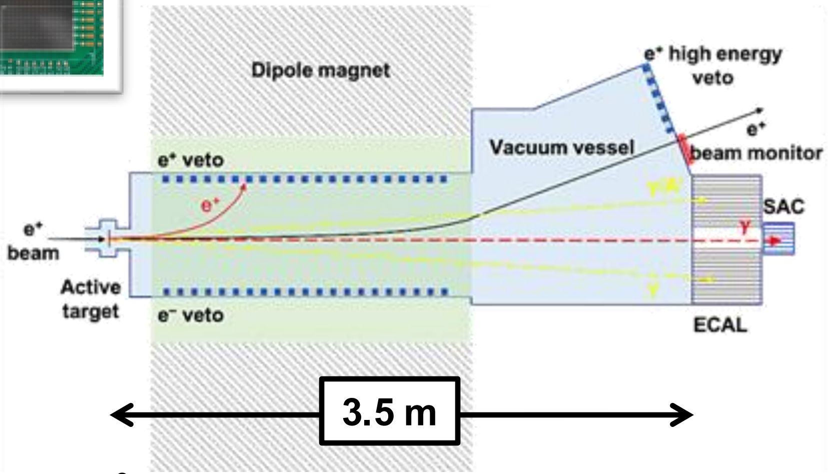


What’s PADME – the detector: beam monitors

1.5 × 1.5 mm^2 spot at active, 100 μm diamond target: position, multiplicity
1 × 1 mm^2 pitch X,Y graphite strips [NIM A 162354 (2019)]







CERN MBP-S type dipole: 112×23 mm^2 gap, 70 cm long
Beam monitor (Si pixels, Timepix3) after bending: $\sigma_P/P_{beam} < 0.25\%$

What's PADME – the TDAQ concepts

Three trigger lines: Beam based, Cosmic ray, Random

Trigger and timing based on custom board [2020 IEEE NSS/MIC, doi: 10.1109/NSS/MIC42677.2020.9507995]

Most detectors acquired with Flash ADC's (CAEN V1742), O(10^3) ch's:

- **1 μs digitization time window**
- **1 V dynamic range, 12 bits**
- **sampling rates at 1, 2.5, 5 GS/s**

Level 0 acquisition with zero suppression, ×10 reduction → 200 KB / ev.
Level 1 for event merging and processing, output format ROOT based

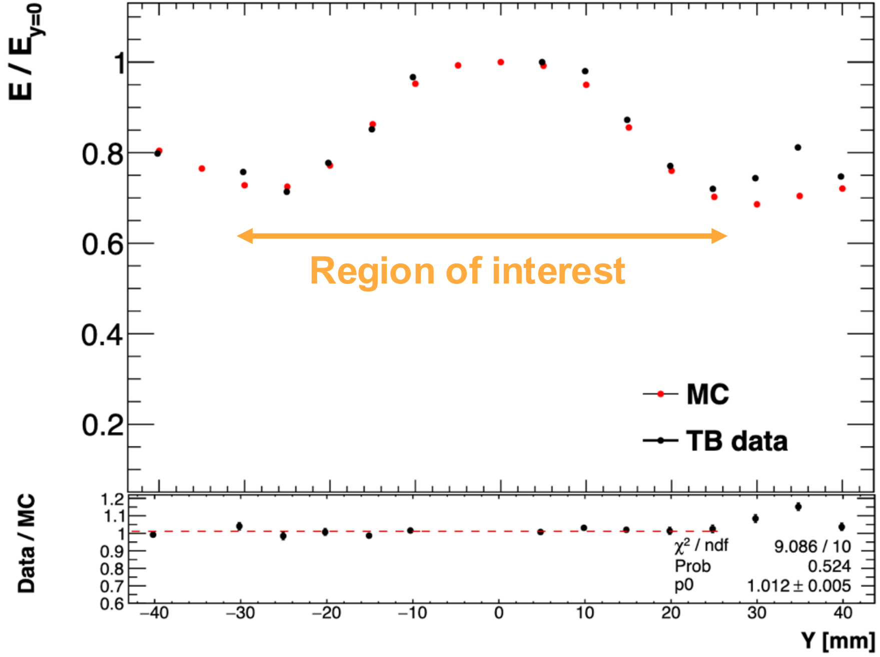
First experiment goal (A' invisible search) required 10^{13} POT, O(80 TB)

Details on the flux N_{POT}: leakage correction

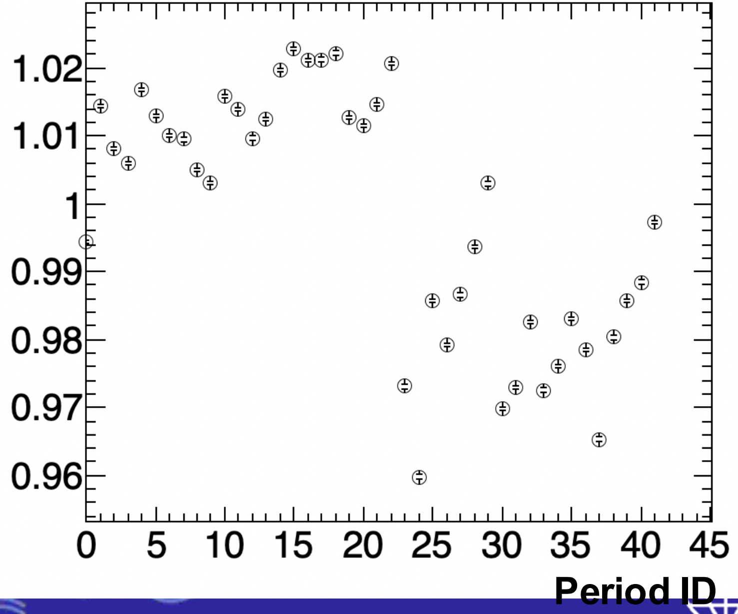
Loss from detailed MC vs vertical position checked against data in test beam

Very good data-MC agreement, correction 1.2%, systematic error 0.5%

Significant period-by-period variation of the correction: -4% to +2%



Relative leakage correction



Details on the flux N_{POT}: rad-induced correction

The literature indicates possible changes in SF57 transparency for O(krad)

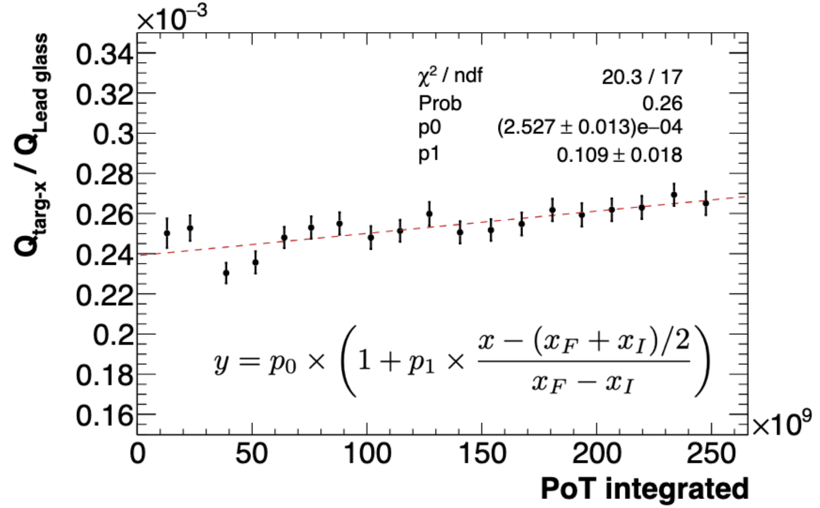
Estimate of Run-III dose: 2.5 krad

Estimated from 3 flux proxy observables: Qx target, $\langle E_{Ecal} \rangle$, period multiplets

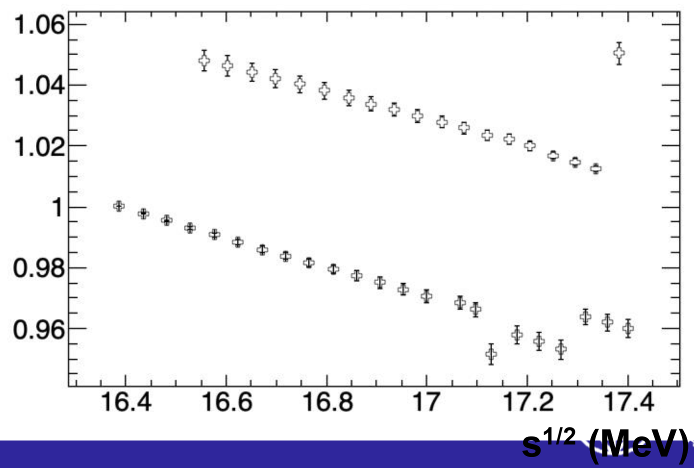
Leadglass yield decreases with relative POT slope of 0.097(7)

Constant term uncertainty of 0.3% added as scale error

Slope error included in POT uncertainty



Relative rad-induced correction



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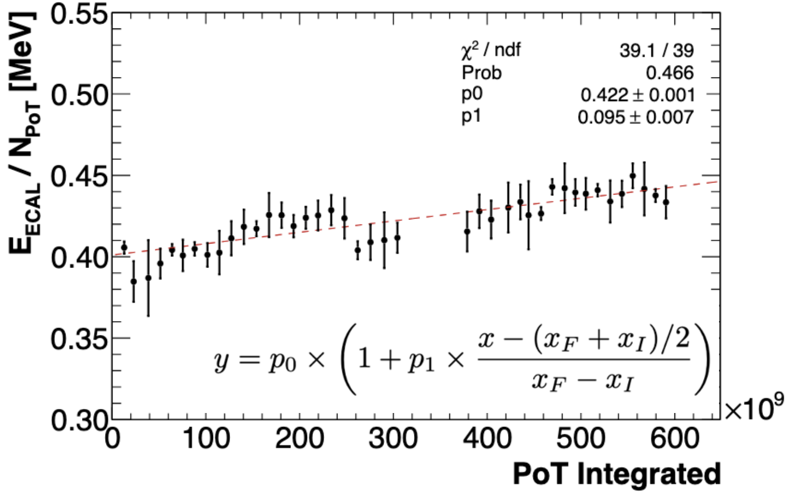
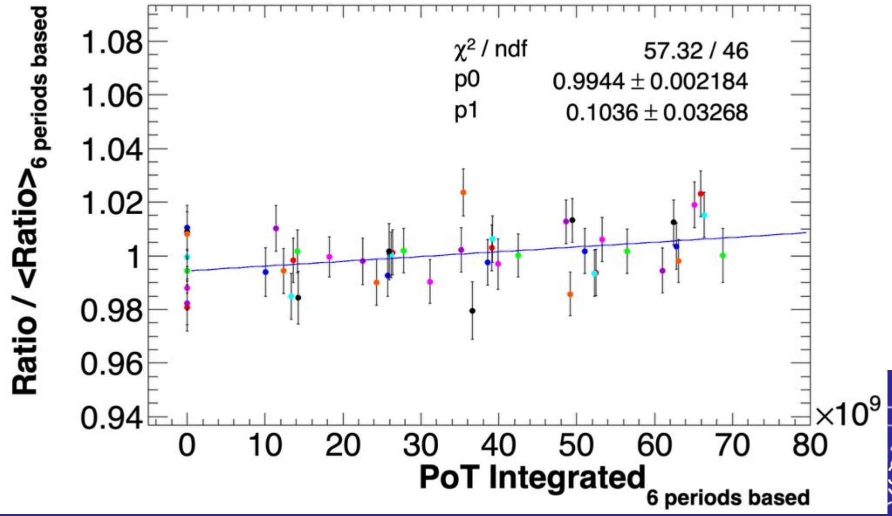




Measurement of $e^+e^- \rightarrow \gamma\gamma$: data set and concept

Using < 10% of Run II data, $N_{POT} = (3.97 \pm 0.16) \times 10^{11}$ positrons on target

Expect $N_{ee\rightarrow\gamma\gamma}$ ~0.5 M, statistical uncertainty < 1%

Include various intensities, e^+ time profiles for systematic studies

Evaluate efficiency corrections from MC + data

Master formula:

$$\sigma_{e^+e^-\rightarrow\gamma\gamma} = \frac{N_{e^+e^-\rightarrow\gamma\gamma}}{N_{POT} \cdot n_{e/S} \cdot A_g \cdot A_{mig} \cdot \epsilon_{e^+e^-\rightarrow\gamma\gamma}}$$

N_{POT} from diamond active target

Uncertainty on e^- density $n_{e/S} = \rho N_A Z/A\, d$ depends on thickness d

Run #	NPOT [10^{10}]	e^+/bunch [10^3]	length [ns]
30369	8.2	27.0 ± 1.7	260
30386	2.8	19.0 ± 1.4	240
30547	7.1	31.5 ± 1.4	270
30553	2.8	35.8 ± 1.3	260
30563	6.0	26.8 ± 1.2	270
30617	6.1	27.3 ± 1.5	270
30624	6.6	29.5 ± 2.1	270
30654	No-target	~ 27	~ 270
30662	No-Target	~ 27	~ 270

$e^+e^- \rightarrow \gamma\gamma$: POT, target thickness

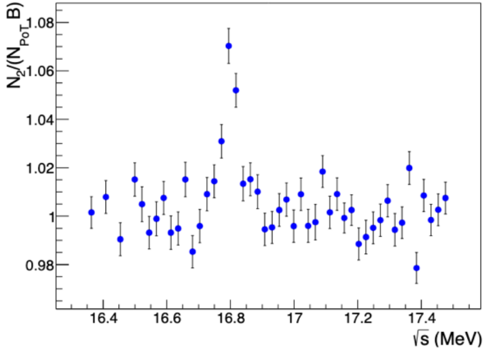
N_{POT} from active target, uncertainty is 4%:

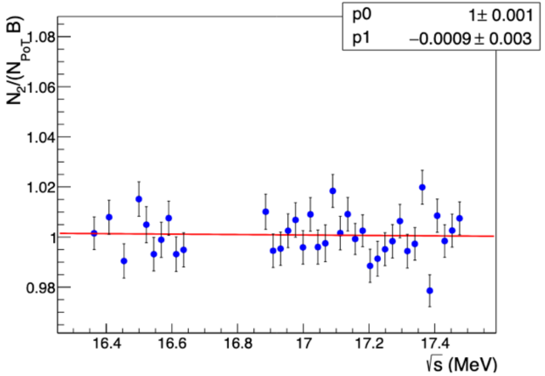
1. Absolute calibration by comparing with lead-glass calorimeter fully contained from 5k to 35k e+/bunch
2. When focusing beam into 1-2 strips, non-linear effects observed

$n_{e/S}$ from target thickness, uncertainty is 3.7% (i.e., ~3.7 μm)

1. Measured after assembly with profilometer with 1 μm resolution as difference with respect to the supporting surface
2. Correction due to roughness (quoted as 3.2 μm by producer): compare precision mass and thickness measurements on similar diamond samples

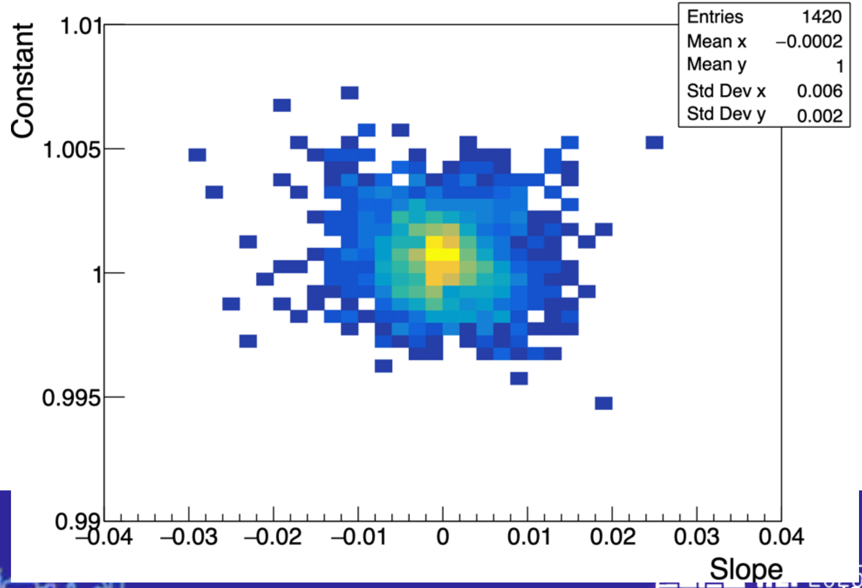
The blind unblinding procedure: details





Constant term and slope of the optimized fit estimate the true values for K(s)

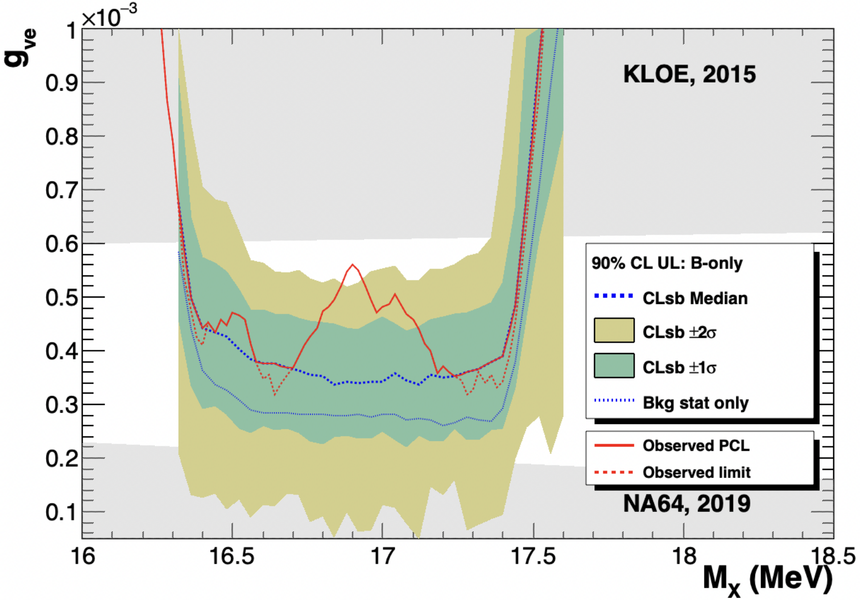
Results of the procedure ran on toy experiments with constant = 1, slope = 0

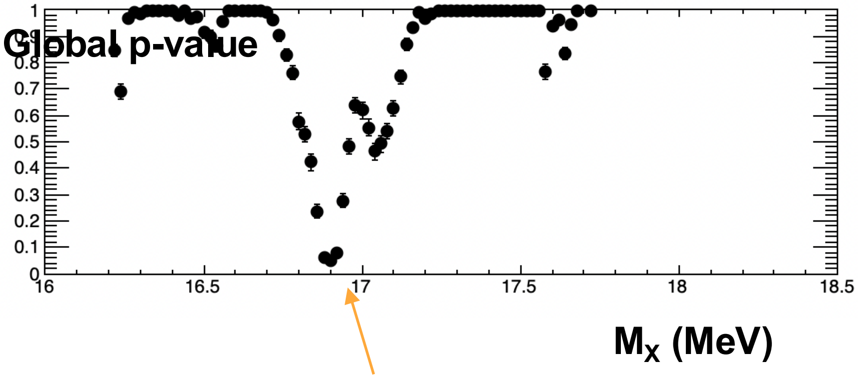


Moreover the procedure correctly finds the central location of signals when present

The PCL method

Using CLsb but clipping to the median every downward fluctuation of the limit





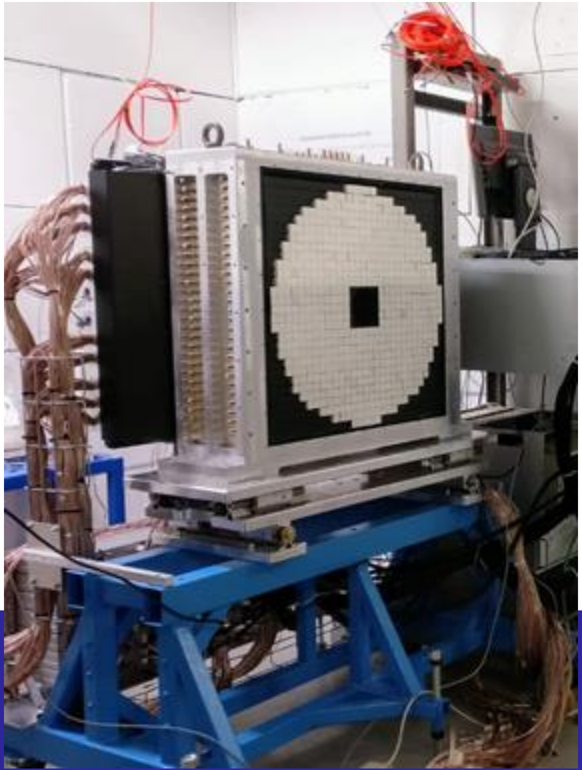
equivalent to (1.63 +- 0.13) σ

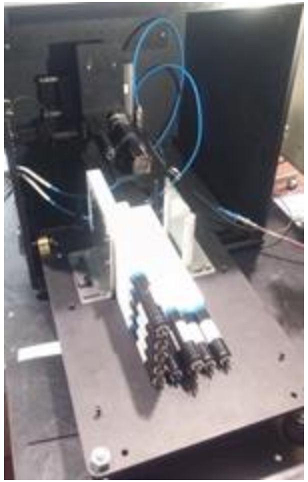
The global p-value is only slightly affected, consistent with the coverage modifications of this method

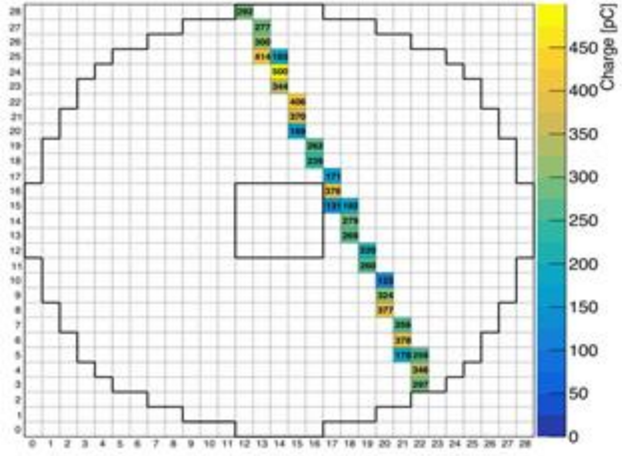
The PADME ECal

The main detector for the signal selection [JINST 15 (2020) T10003]:

- 616 BGO crystals, 2.1 x 2.1 x 23 cm^3
- BGO covered with diffuse reflective TiO_2 paint + 50–100 μm black tedlar foils (optical isolation)







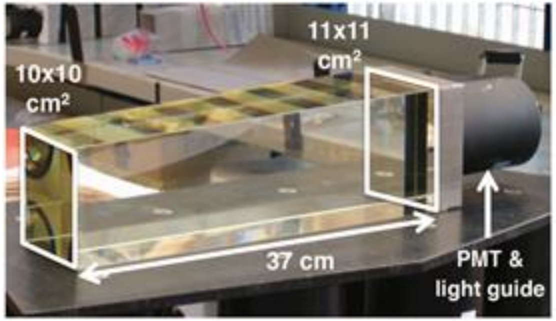
Calibration at several stages:

- BGO + PMT equalization with ^{22}Na source before construction
- Cosmic-ray calibration using the MPV of the spectrum
- Temperature monitoring + scale correction data driven

The PADME beam catcher calorimeter

The main detector for the flux determination [JHEP 08 (2024) 121]:

- SF57 block, reused from OPAL, tested for the NA62 LAV detector [JINST 12 (2017) 05, P05025]
- Several testing campaigns
  - A few positrons
  - O(2000) PoT - cross-calibration with the BTF FitPix



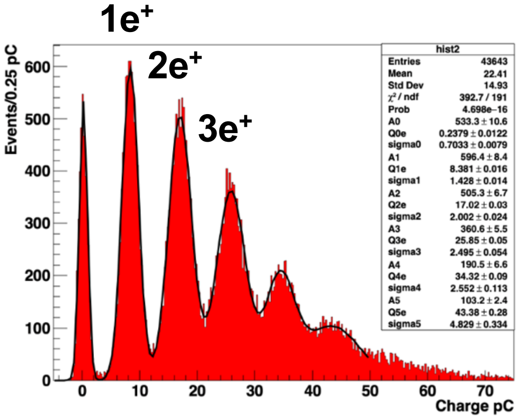


Figure 16. Single particle charge spectrum.

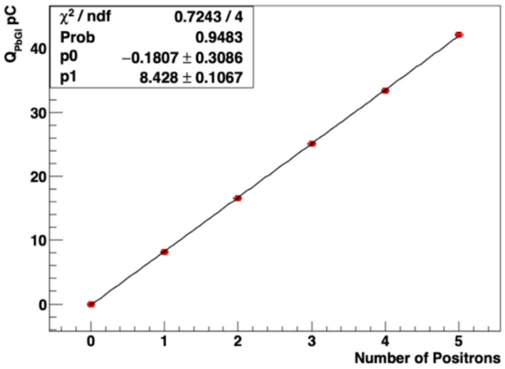
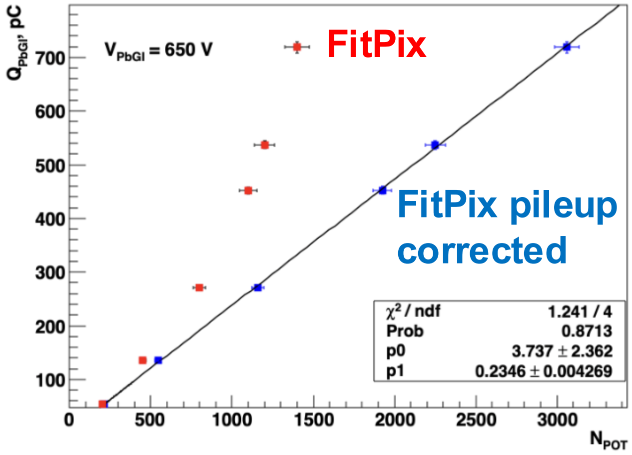


Figure 17. Fit to the single particle response.

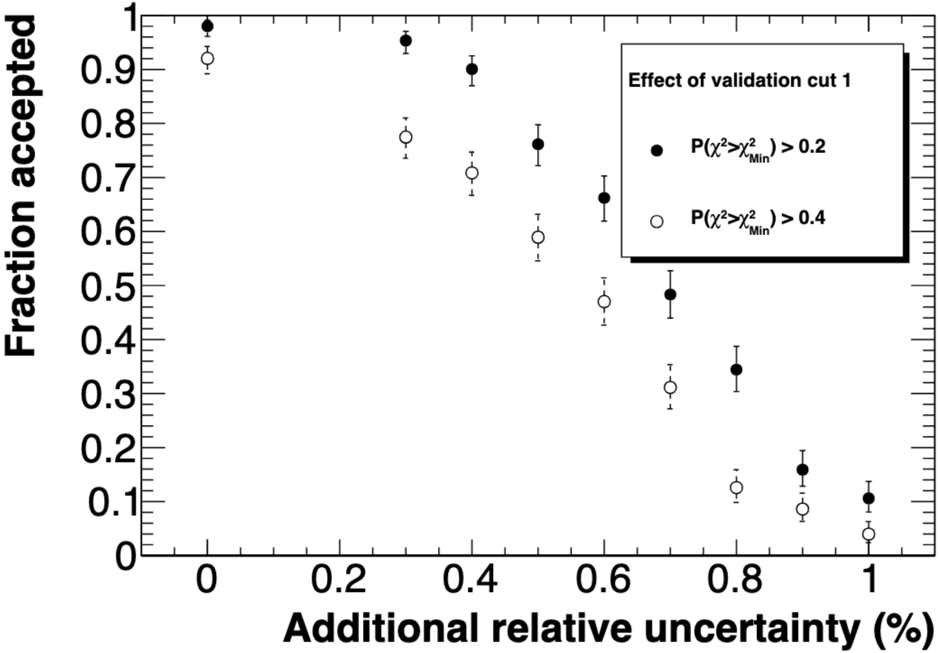


The blind unblinding constraining power

Determine the number of times an experiment outcome would be rejected in presence of additional uncorrelated errorsx

- **With the cut applied, errors > 1% are excluded at 90% CL**

- **Had we put a tighter condition, we would have excluded additional errors at 0.8% but at the cost of risking to reject by statistical fluctuations ~8% of the outcomes**



The new micromega-based tracker

Detector installed with the novel diamon-shaped readout

- Outer dimensions 88 x 88 cm^2
- Readout by APV25
- Time window up to 675 ns (drift time ~500 ns)
- Gas mixture: Ar:CF_4:Isobutane = 88:10:2
- Provides beam spot with uncertainty $\sigma_{x,y}$ ~ 30 μm
- Track points with $\sigma_{x,y}$ ~ 350 μm and σ_z ~ 2 mm per point