FD-VD X-ARAPUCA PDE Measurement @CIEMAT:

DF-XA & noDF-XA & noDF-XA_24mg Comparison

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Goals

1. Measurement of the XA-VD **absolute PDE** (single-sided XA)

2. **Optimization** of the XA-VD **PDE**:

   Comparison between XA configurations

   - DF-XA
   - noDF-XA
   - noDF-XA_24mg

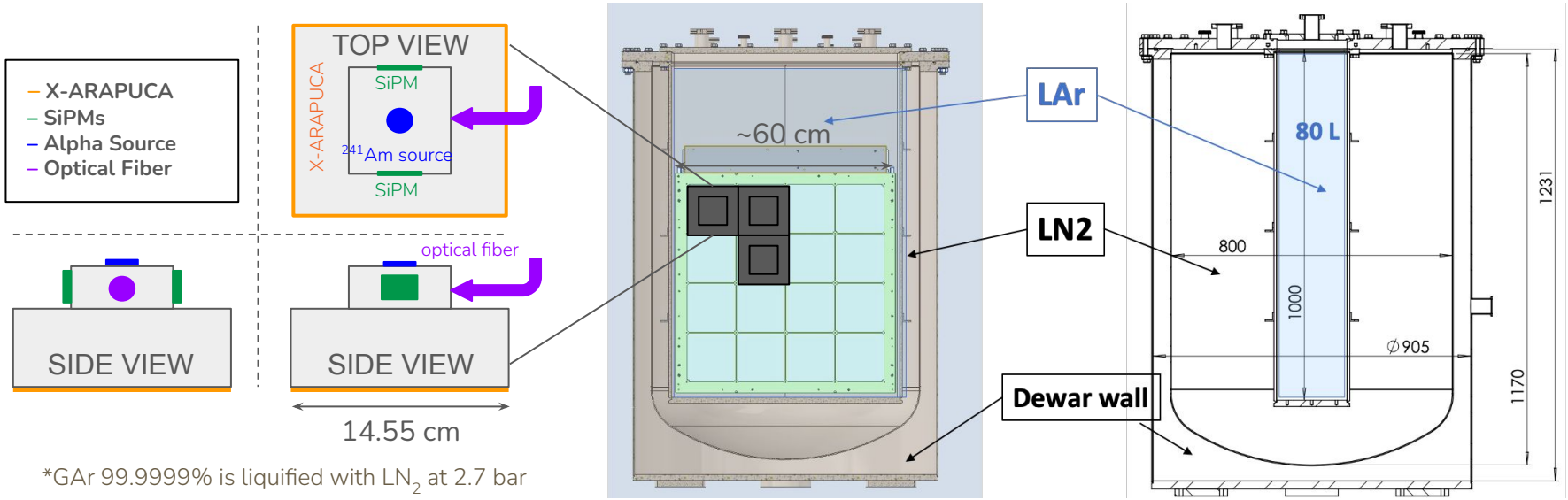
XA configurations under test at CIEMAT

VD-XA CONFIGURATIONS						
XA	**WLS Bar**		**SiPMs**	**Filter**	**Sided**	**Status**
1. DF-XA	G2P (80 mg/kg)	3.8 mm	FBK TT	ZAOT	Single	Tested
2. noDF-XA	G2P (80 mg/kg)	3.8 mm	FBK TT	*pTP PE-subs	Single	Tested
3. noDF-XA_24mg	G2P (24 mg/kg)	5.5 mm	FBK TT	*pTP PE-subs	Single	Tested
4. DF-XA-DS	G2P (80 mg/kg)	3.8 mm	FBK TT	ZAOT	Double	To Be Tested
5. noDF-XA-DS	G2P (80 mg/kg)	3.8 mm	FBK TT	*pTP PE-subs	Double	To Be Tested

***pTP coated substrate (P.E.)** composed of fused silica JGS2

CIEMAT Setup Description

- **Measurement of the XA PDE in LAr** using 2 reference VUV SiPMs facing each other triggering on scintillation light from an ^{241}Am alpha source in 3 black calibration boxes (at the **only 3 not identical XA positions**)

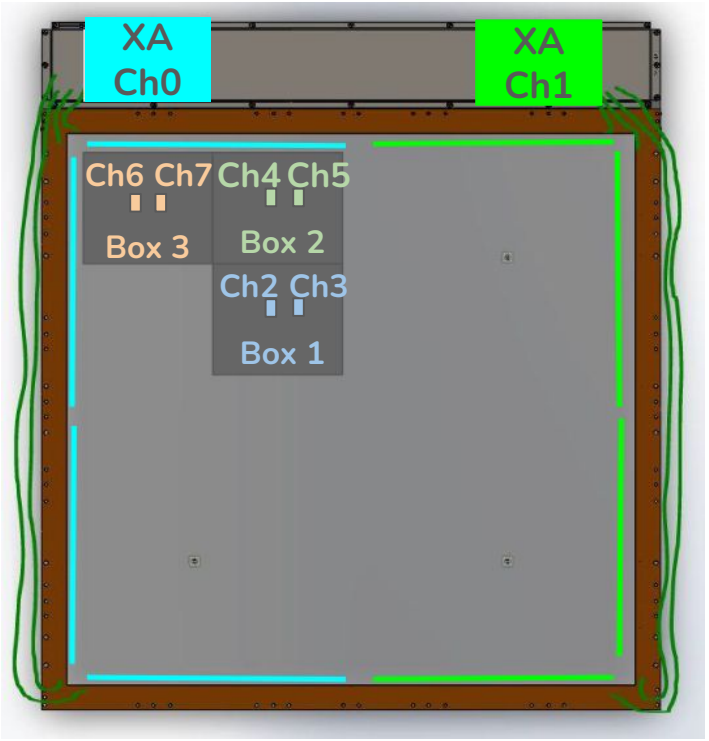


*GAr 99.9999% is liquified with LN_2 at 2.7 bar

Timeline

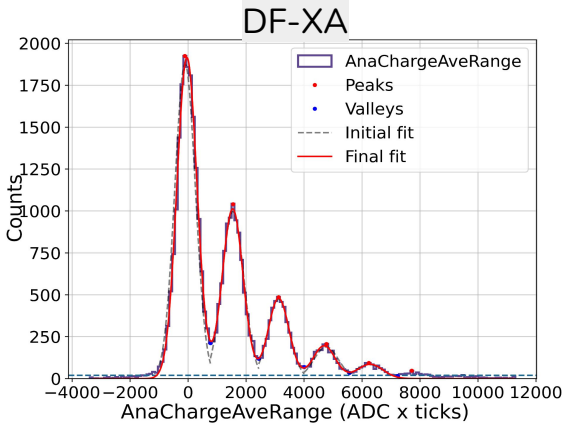
Configuration	Setup Timeline	
1. DF-XA	Membrane XA assembly	Jul. 23
1. DF-XA	LAr setup commissioning	Aug. 23
1. DF-XA	Gain and noise characterization LN_2	Sep. 23
1. DF-XA	LAr PDE Data taking	(13^{th} - 15^{th}) Dec. 23
2. noDF-XA	Noise characterization LN_2	Mar. 24
2. noDF-XA	LAr PDE Data taking	(13^{th} - 14^{th}) Mar. 24
3. noDF-XA_24mg	LAr PDE Data taking	(16^{th} - 17^{th}) Apr. 24

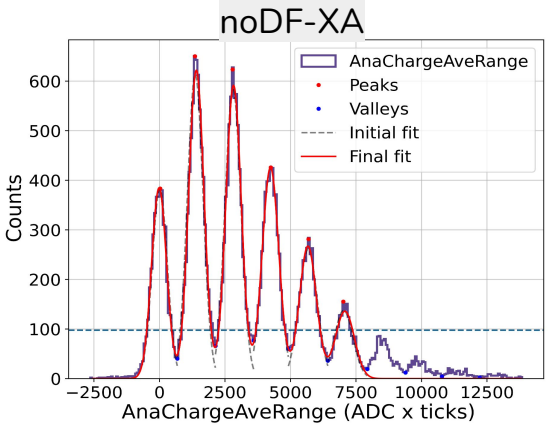
Setup Channel Arrangement

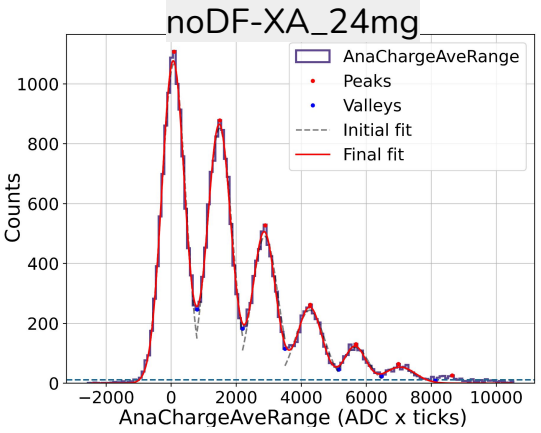


XA Calibration: Gain and S/N

- Example calibration finger plots for the different setups and light levels.
- Showing CH0 - OV 4.5 V for ref.







XA Calibration: Gain and S/N

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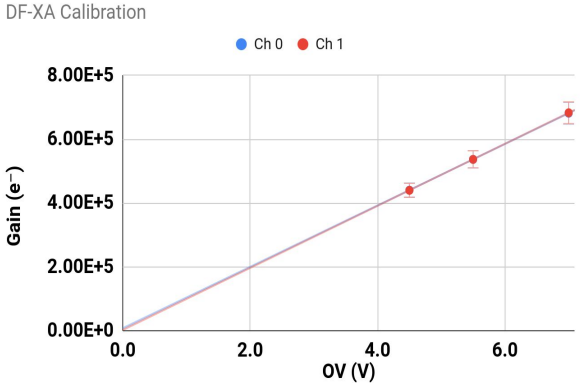
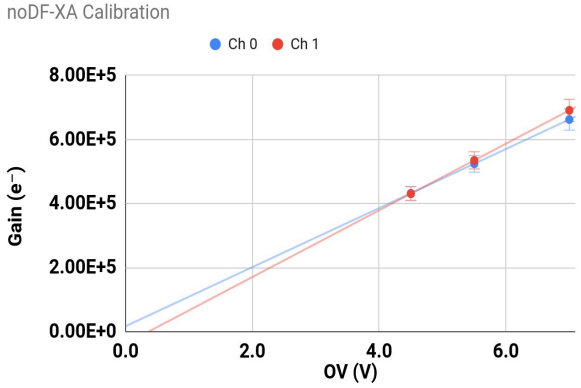
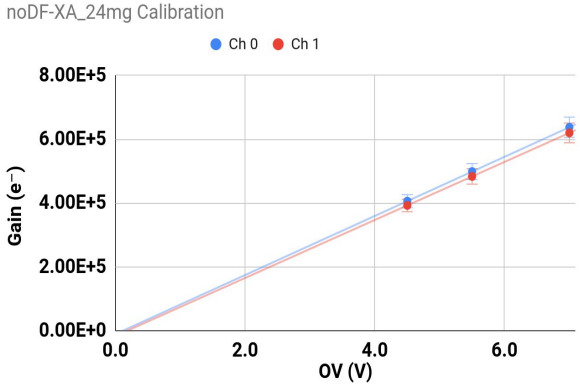
DF-XA



noDF-XA



noDF-XA_24mg



XA Calibration: Gain and S/N

- Both XA-channels successfully calibrated.

DF-XA:

	XA0				XA1			
OV	Gain e^-	DGain e^-	S/N	ERROR	Gain e^-	DGain e^-	S/N	ERROR
7.0	**6.82E+05**	9E+03	4.63	0.27	**6.83E+05**	7E+03	5.27	0.14
5.5	**5.37E+05**	9E+03	5.94	0.08	**5.37E+05**	1.3E+04	6.77	0.21
4.5	**4.41E+05**	3E+03	4.48	0.10	**4.40E+05**	2E+03	4.63	0.04

noDF-XA:

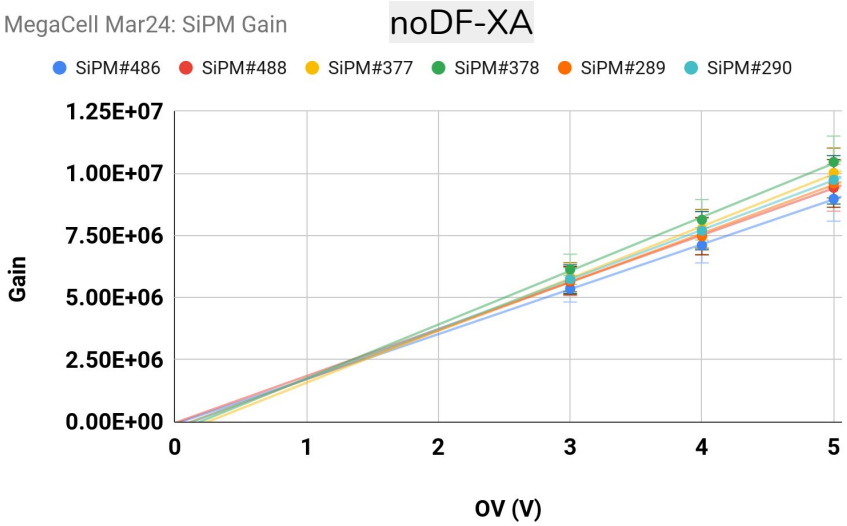
OV	Gain e^-	DGain e^-	S/N	ERROR	Gain e^-	DGain e^-	S/N	ERROR
7.0	**6.63E+05**	7E+03	6.47	0.05	**6.91E+05**	4E+03	5.95	0.08
5.5	**5.24E+05**	1.2E+04	5.37	0.03	**5.35E+05**	6E+03	5.45	0.05
4.5	**4.32E+05**	1.9E+04	4.56	0.02	**4.31E+05**	3E+03	4.57	0.02

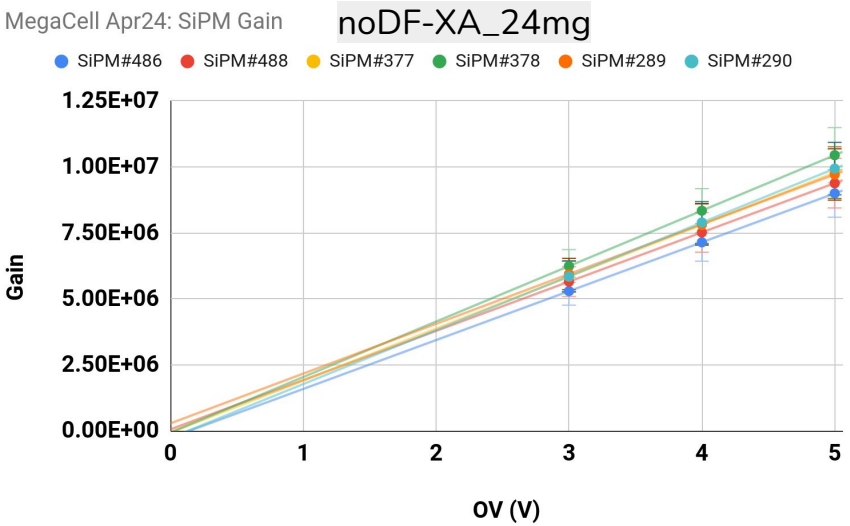
noDF-XA_24mg:

OV	Gain e^-	DGain e^-	S/N	ERROR	Gain e^-	DGain e^-	S/N	ERROR
7.0	**6.4E+05**	1.9E+04	5.41	0.06	**6.20E+05**	6E+03	5.7	0.10
5.5	**5.0E+05**	2.0E+04	4.51	0.04	**4.84E+05**	9E+03	4.6	0.14
4.5	**4.06E+05**	9E+03	4.29	0.04	**3.93E+05**	5E+03	4.3	0.14

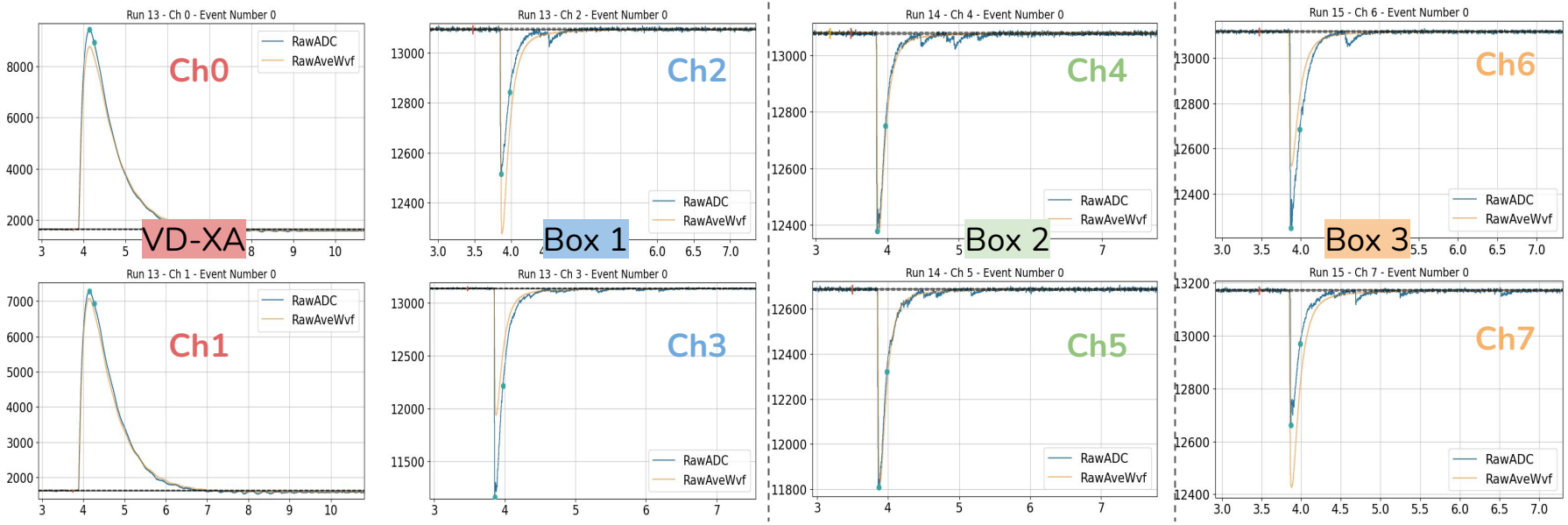
SiPM Calibration

- Showing stability of SiPM calibration curve between different measurements, setups and days



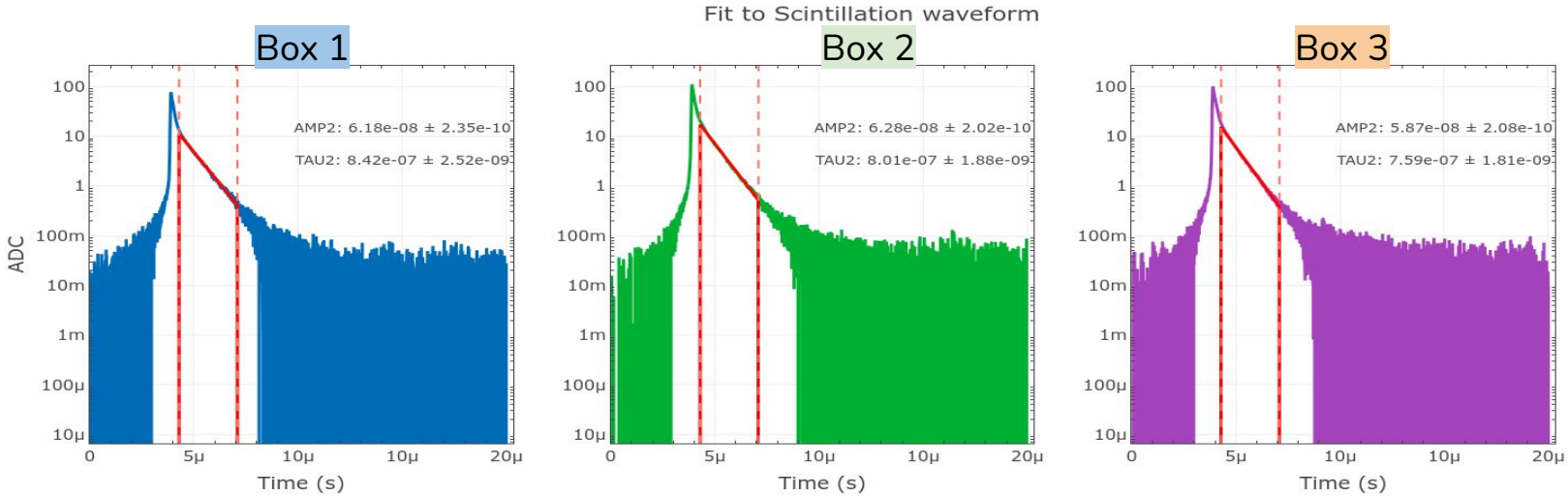


Event examples



- **Ref. sensors in each Box** provide trigger conditions based on **threshold + coincidence**.
- → Clean sample of alpha scintillation signals.

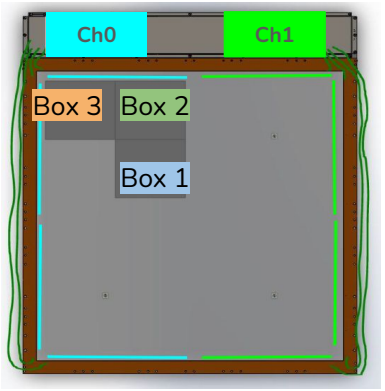
Purity



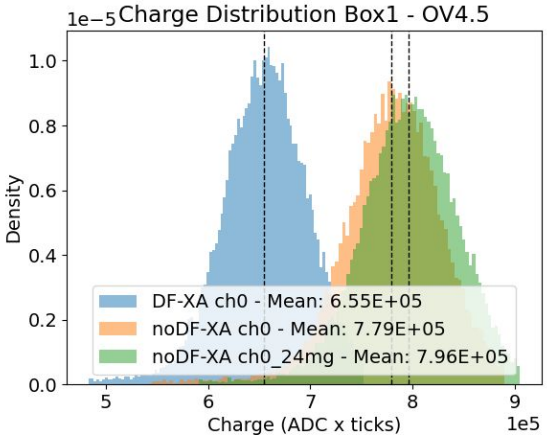
- **Ref. sensors in each Box** also provide purity estimation.
- → ~0.8 us slow component.

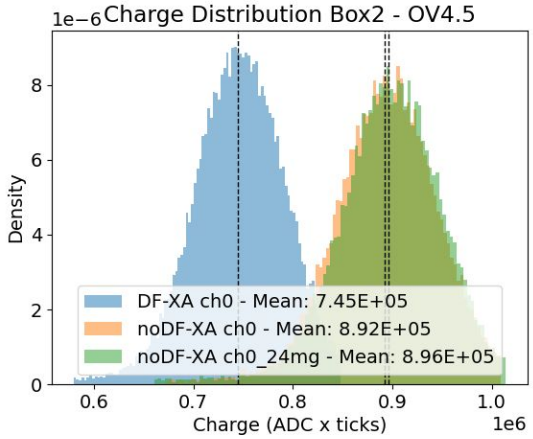
Comparison of XA-VD

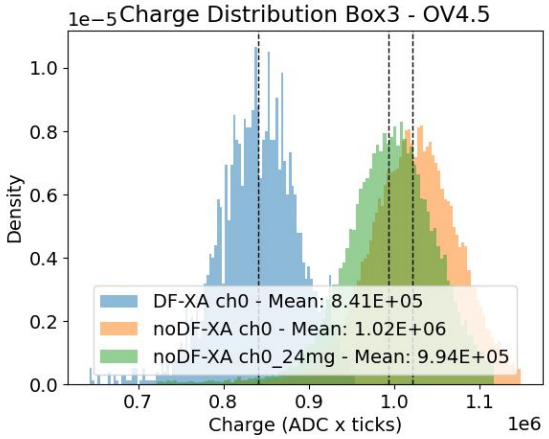
- No significant increase in collected charge for config #2 & #3!
- **noDF-XA/noDF-XA_24mg** sees **~29 - 26%** (for ch0 - ch1) **more charge** than **DF-XA** in every box (after correcting for absolute light diff.)



XA-VD Ch0 - OV 4.5 V - Config. Comparison





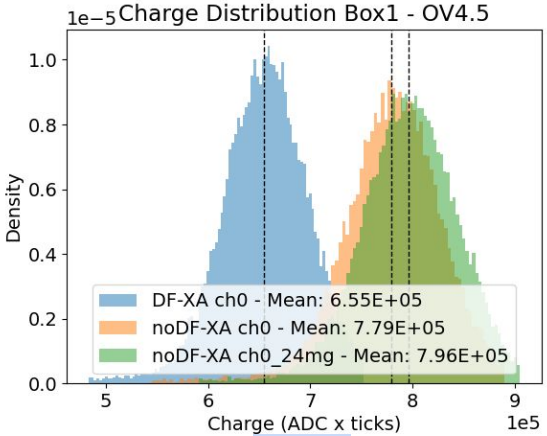


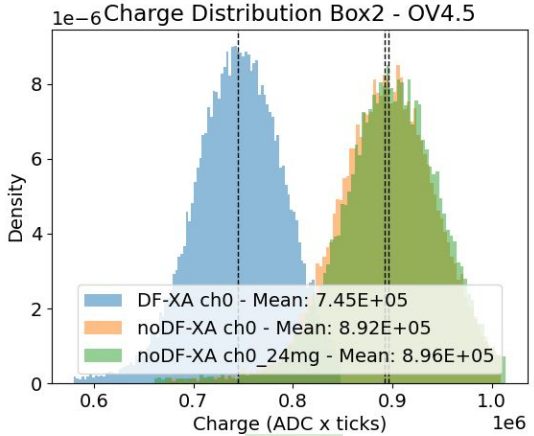
Conclusions

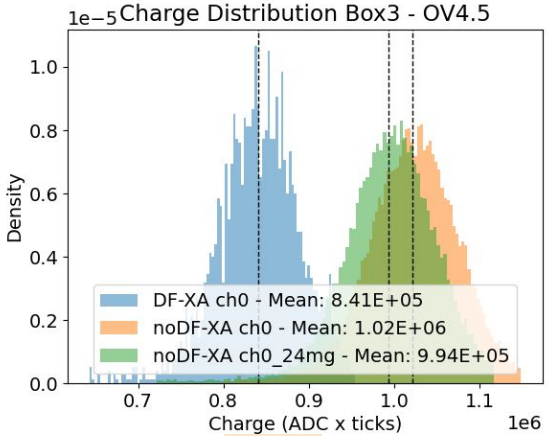
- Setup shows stable measurement conditions among different XA-VD configurations.
- **Preliminary CIEMAT measurement** of the absolute XA-VD PDE @CT in LAr for the 3 different positions and for 3 different XA configurations.
  - No significant charge difference between **noDF-XA & noDF-XA_24mg** (WLS width 5.4 mm).
  - **noDF-XA/noDF-XA_24mg PDE ~30% higher than DF-XA PDE.**
- **Next measurement** (mid May): Double-sided XA
  - We will modify our current XA-VD module with parts delivered by Naples.

BACKUP

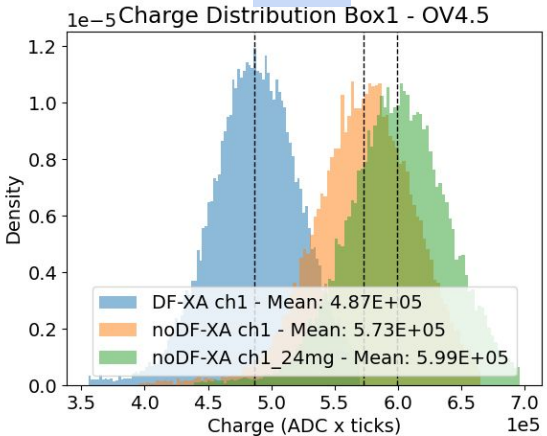
Scintillation Setup Comparison (Day 1 - OV 4.5)



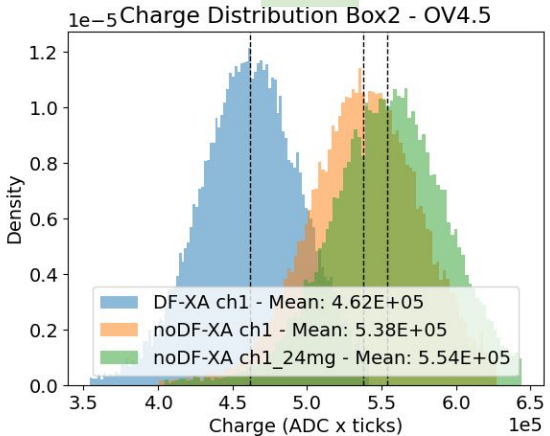




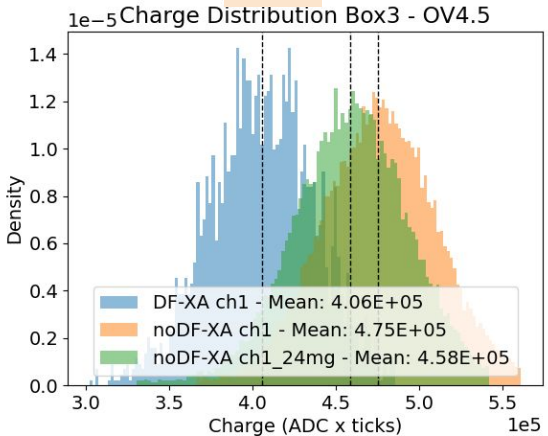
Box 1



Box 2



Box 3



MegaCell Charge Difference

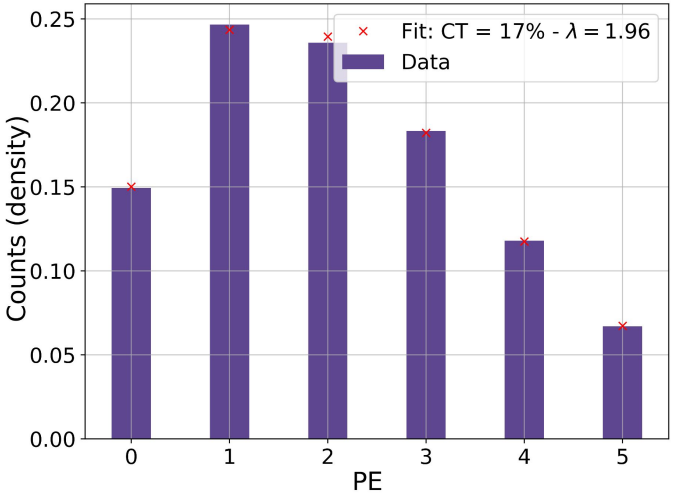
- Comparison of identical runs provides consistent increase in light collection.
- DF-XA charge has been corrected with a factor of 7.2% to account for absolute light differences measured at the SiPMs.

OV	Box	1.DF-XA	2.noDF-XA	3.noDF-XA_24mg	Rel. (2-1)/1	Rel. (3-1)/1	1.DF-XA	2.noDF-XA	3.noDF-XA_24mg	Rel. (2-1)/1	Rel. (3-1)/1
Config		Cannel 0					Channel 1				
7.0	1	1.48E+06	1.89E+06	1.95E+06	28.21%	32.26%	1.13E+06	1.43E+06	1.52E+06	27.10%	34.97%
7.0	2	1.66E+06	2.19E+06	2.17E+06	31.99%	30.85%	1.07E+06	1.38E+06	1.41E+06	28.84%	31.79%
7.0	3	1.86E+06	2.40E+06	2.38E+06	29.31%	28.02%	9.59E+05	1.20E+06	1.19E+06	24.95%	24.43%
4.5	1	6.10E+05	7.83E+05	7.98E+05	28.41%	30.92%	4.53E+05	5.76E+05	6.01E+05	26.94%	32.48%
4.5	2	6.94E+05	8.96E+05	9.00E+05	29.22%	29.77%	4.29E+05	5.40E+05	5.56E+05	25.67%	29.46%
4.5	3	7.82E+05	1.02E+06	9.98E+05	30.93%	27.56%	3.76E+05	4.76E+05	4.60E+05	26.51%	22.10%
3.5	1	4.05E+05	5.13E+05	5.12E+05	26.65%	26.54%	2.98E+05	3.74E+05	3.82E+05	25.45%	28.03%
3.5	2	4.59E+05	5.87E+05	5.77E+05	27.88%	25.78%	2.81E+05	3.49E+05	3.51E+05	24.40%	25.07%
3.5	3	5.14E+05	6.73E+05	6.44E+05	30.89%	25.22%	2.45E+05	3.08E+05	2.89E+05	25.93%	18.23%

Updated XTalk Computation!

- Selected method for computation **Vinogradov model:** Fit composite poissonian to describes the effect of cross-talk.

e.g. OV 4.5 - Ch0 - XTalk Estimation Fit



XTalk Summary

XA	Ch 0	Ch 1
OV	XT %	XT %
7	33±6.6	34±2.4
4.5	19±3.8	19±1.3
3.5	14±2.7	13±0.9

Duplication Factor

XA	Ch 0	Ch 1
OV	KDUP	KDUP
7	0.67±0.07	0.66±0.03
4.5	0.81±0.05	0.81±0.02
3.5	0.86±0.04	0.87±0.01

XA PDE computation

Direct Method (Comparison with ref. SiPM efficiency)

$$\epsilon(\mathrm{XA}) = \frac{\#PE_{\mathrm{XA}}}{\#PE_{\mathrm{Ref.SiPM}}} \cdot \epsilon(\mathrm{Ref.SiPM}) \cdot f_{corr}$$

#PE$_{XA}$: PEs detected by the XA

#PE$_{refSiPM}$: PEs detected by the reference SiPMs

ε(ref SiPM): absolute measurement at CT by CIEMAT

Correction factors ($f_{corr} = f_{geo} * f^{XA}_{XT} / f^{SiPM}_{XT}$):

- f_{geo}: Geometrical Factor → correction for different distance of sensor to alpha source.
- f_{XT}: XTalk Correction → from dedicated measurements of FBK/HPK SiPMs

Updated XTalk Computation!

- Using XTalk values (XT%) measured in the labs for FBK TT sensors.
- X-Check method from Vinogradov model (see backup).

XTalk Summary

XA	FBK TT
OV	XT %
7	32.5 ± 0.5
4.5	16.1 ± 0.3
3.5	12.7 ± 0.3

Correction Factor f_{XT}

XA	FBK TT
OV	f_{XT}
7	0.68 ± 0.02
4.5	0.840 ± 0.005
3.5	0.873 ± 0.004

$$f_{\mathrm{XT}} = \frac{1}{1 + K_{\mathrm{dup}}}$$

$$K_{\mathrm{dup}} = \frac{\mathrm{XT\%}}{1 - \mathrm{XT\%}}$$