Double - Sided FD-VD X-ARAPUCA PDE @CIEMAT

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Setup & XA-Configs.

XA configurations under test at CIEMAT

VD-XA CONFIGURATIONS						
XA	**WLS Bar** (type | length / width)		**SiPMs**	**Filter**	**Sided**	**Status**
1. DF-XA	G2P (80 mg/kg)	605/3.8 mm	FBK TT	ZAOT	Single	Tested
2. noDF-XA	G2P (80 mg/kg)	605/3.8 mm	FBK TT	*pTP P.E.	Single	Tested
3. noDF-XA_24mg	G2P (24 mg/kg)	607/5.5 mm	FBK TT	*pTP P.E.	Single	Tested
4. DF-XA-DS	G2P (80 mg/kg)	605/3.8 mm	FBK TT	ZAOT	Double	**Tested**
5. noDF-XA-DS	G2P (80 mg/kg)	605/3.8 mm	FBK TT	**pTP ZAOT	Double	**Tested**

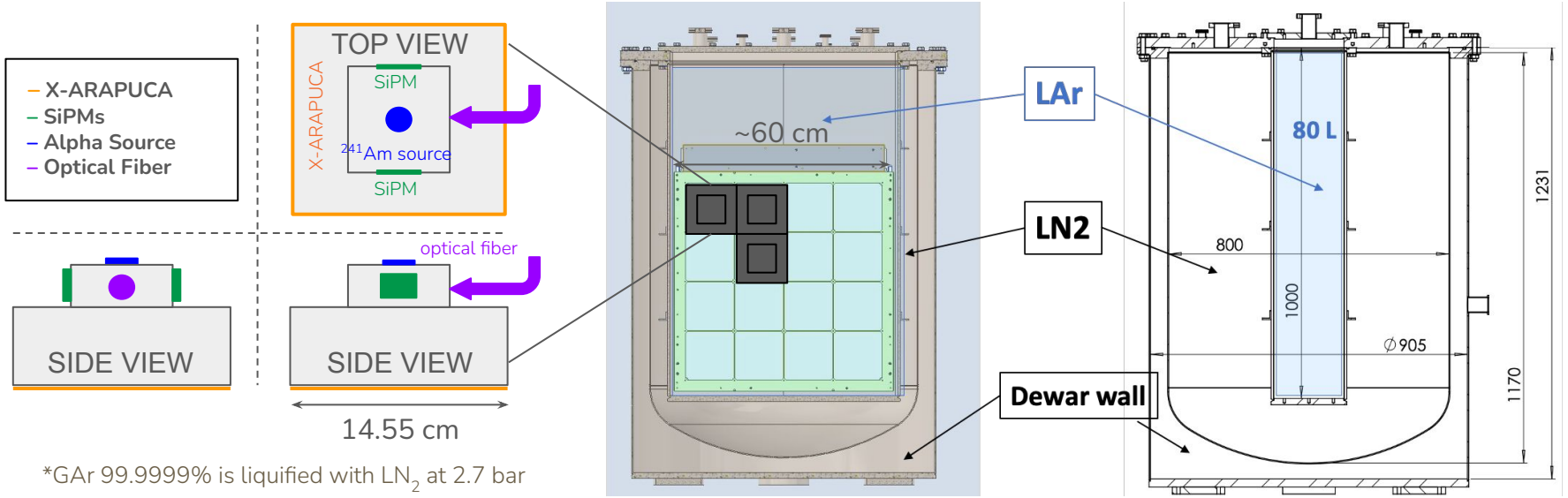
NEW!

***pTP coated substrate (Photon Export)** composed of fused silica JGS2

****pTP coated substrate (ZAOT)** Borosilicate Glass

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**)



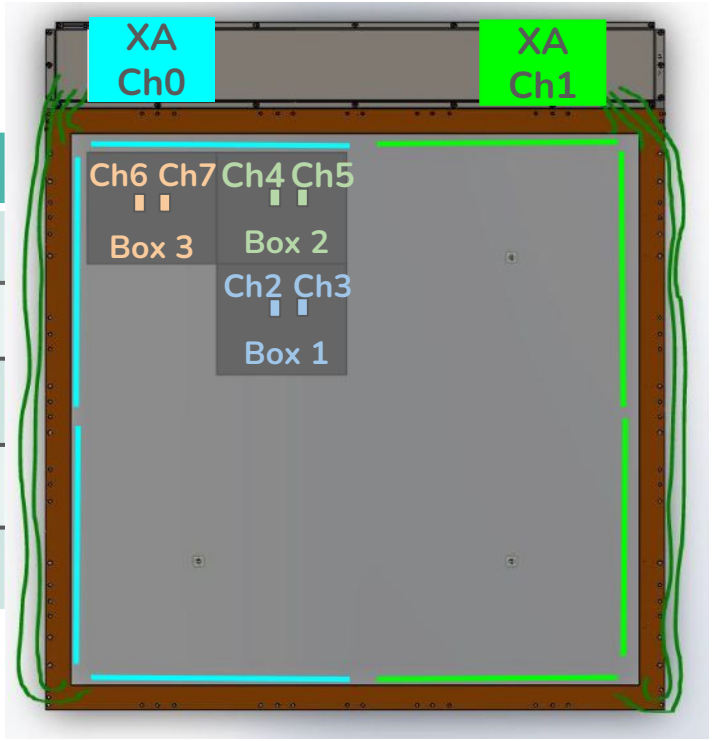
*GAr 99.9999% is liquified with LN_2 at 2.7 bar

Timeline

- Each test requires full disassembly of cryo setup & XA config.

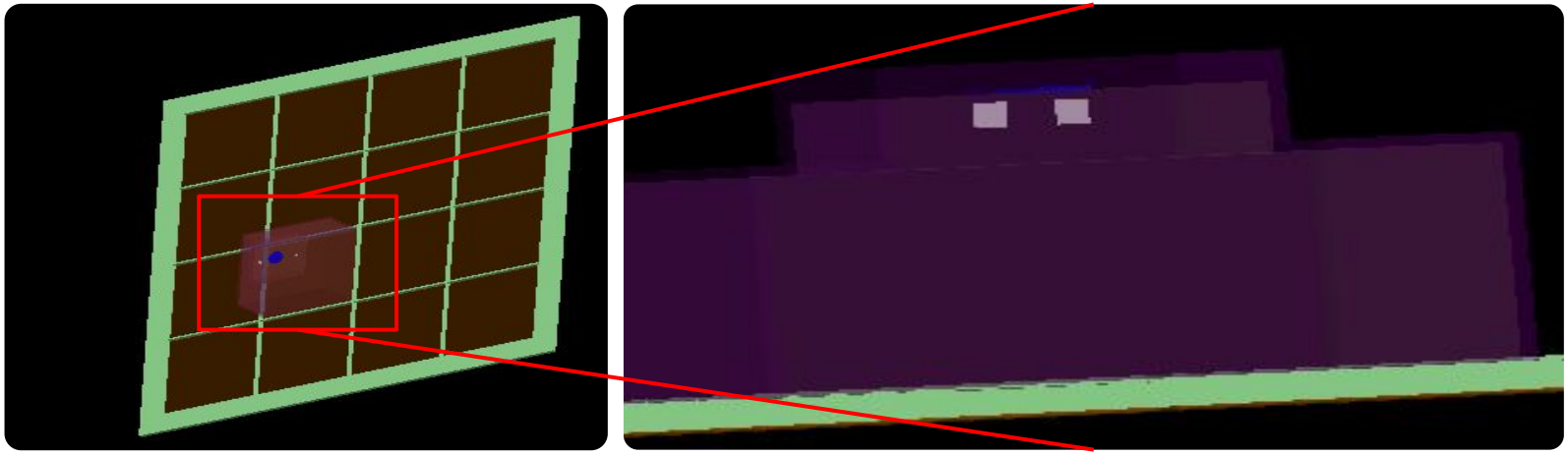
Configuration	Setup Timeline	
1. DF-XA	LAr PDE Data taking	(13^{th} - 15^{th}) Dec. 23
2. noDF-XA	LAr PDE Data taking	(13^{th} - 14^{th}) Mar. 24
3. noDF-XA_24mg	LAr PDE Data taking	(16^{th} - 17^{th}) Apr. 24
4. DF-XA-DS	LAr PDE Data taking	(29^{th} - 30^{th}) May. 24
5. noDF-XA-DS	LAr PDE Data taking	(25^{th} - 26^{th}) Jun. 24

Setup Channel Arrangement



Analysis Collaboration (Naples)

- G. Botogoske (Naples) simulation on geometric factor for CIEMAT setup.
- From scratch geometry generation + alpha propagation.



- Simulation computes geometric factor f_g = #Photons SiPM / #Photons XA
- **New Simulation f_g = 0.049** (no error estimation yet).
- **Compatible with CIEMAT** results f_g = 0.047 ± 0.001.

Calibration

XA Calibration: Gain and S/N

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	**6.8[illegible]E+05**	7E+03	5.27	0.14
5.5	**5.37E+05**	9E+03	5.94	0.[illegible]	**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	**4.3[illegible]E+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

- Noticed considerable deviation between configs.
  → Reevaluation of calibration method to adapt for changing noise conditions.

XA Calibration: Gain and S/N

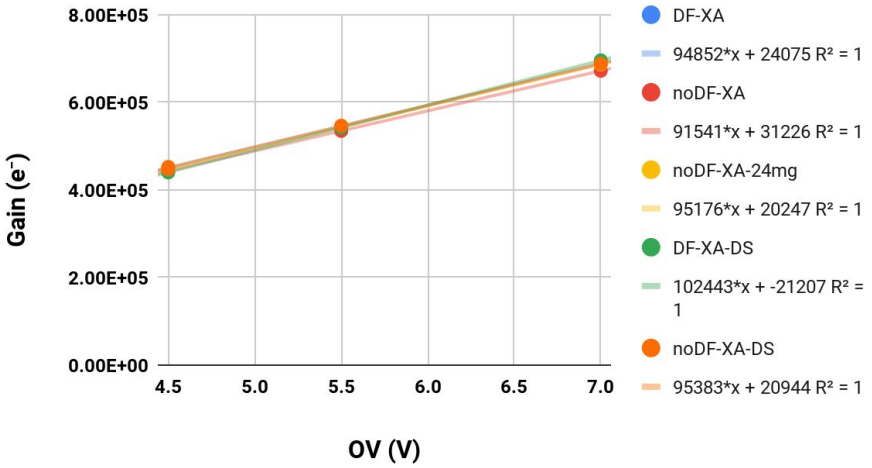
		XA0				XA1			
	OV	Gain e^-	DGain e^-	S/N	ERROR	Gain e^-	DGain e^-	S/N	ERROR
DF-XA	4.5	4.51E+05	2E+03	4.3	0.1	4.54E+05	3E+03	4.6	0.2
	5.5	5.45E+05	2E+03	5.2	0.1	5.50E+05	2E+03	5.5	0.2
	7.0	6.88E+05	5E+03	6.5	0.3	6.93E+05	2E+03	6.8	0.7
noDF-XA	4.5	4.43E+05	3E+03	3.6	0.0	4.51E+05	5E+03	3.9	0.0
	5.5	5.35E+05	4E+03	4.1	0.0	5.47E+05	5E+03	4.6	0.0
	7.0	6.72E+05	5E+03	5.3	0.0	6.91E+05	4E+03	5.6	0.0
noDF-XA_24 mg	4.5	4.49E+05	7E+03	4.1	0.1	4.53E+05	6E+03	4.2	0.4
	5.5	5.44E+05	3E+03	4.4	0.1	5.49E+05	5E+03	4.6	0.4
	7.0	6.86E+05	5E+03	5.7	0.1	6.92E+05	3E+03	5.8	0.3
DF-XA-DS	4.5	4.4E+05	3E+04	3.0	0.6	4.6E+05	1E+04	2.4	1.6
	5.5	5.4E+05	5E+04	3.2	0.9	5.5E+05	2E+04	2.7	0.3
	7.0	7.0E+05	3E+04	3.4	0.2	7.0E+05	1E+04	3.1	0.4
noDF-XA-DS	4.5	4.53E+05	6E+03	2.9	0.1	4.88E+05	8E+03	3.3	0.1
	5.5	5.5E+05	1E+04	3.5	0.1	6.00E+05	8E+03	4.2	0.1
	7.0	6.88E+05	4E+03	4.5	0.1	7.7E+05	2E+04	5.5	0.2

* Outlier under investigation

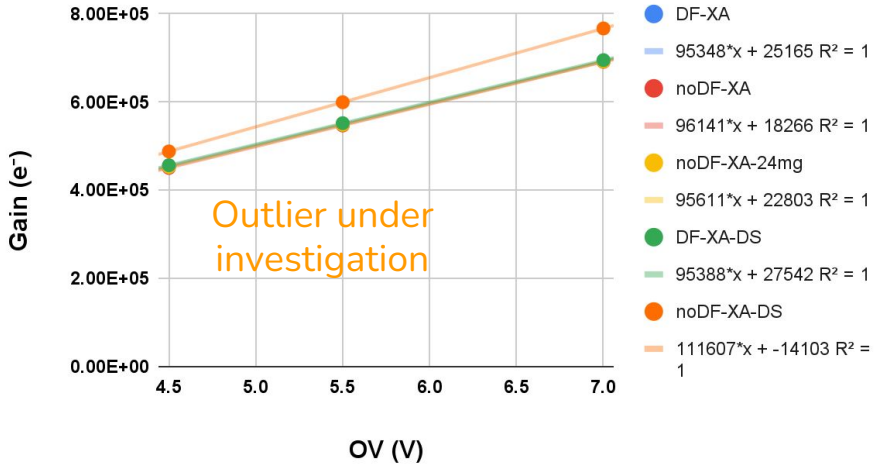
XA Calibration: Gain Comparison

- Calibration values are compatible across different configurations with the expected error except for 1 outlier measurement under evaluation.

CALIBRATION COMPARISON - XA0



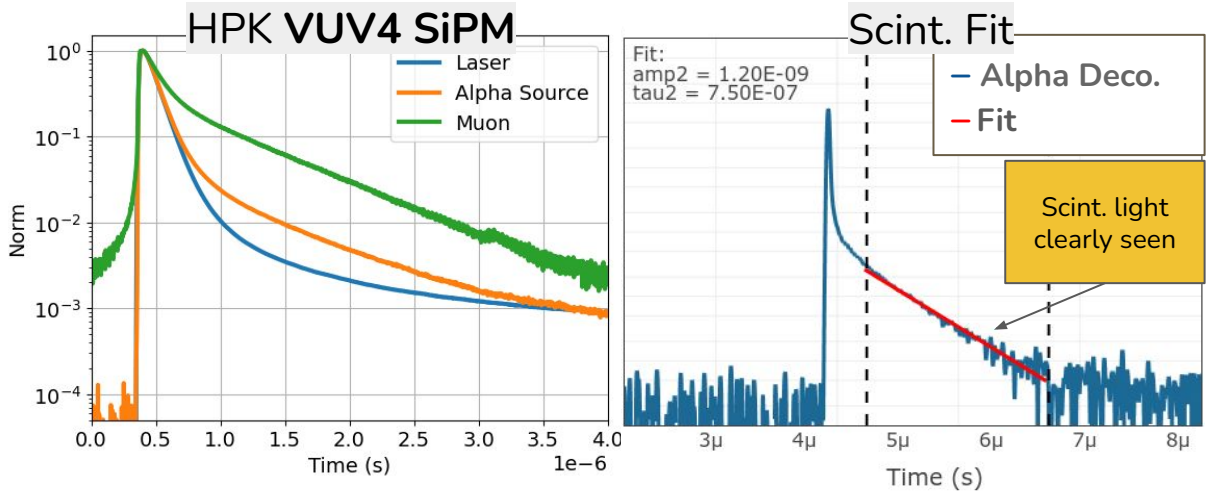
CALIBRATION COMPARISON - XA1



Scintillation

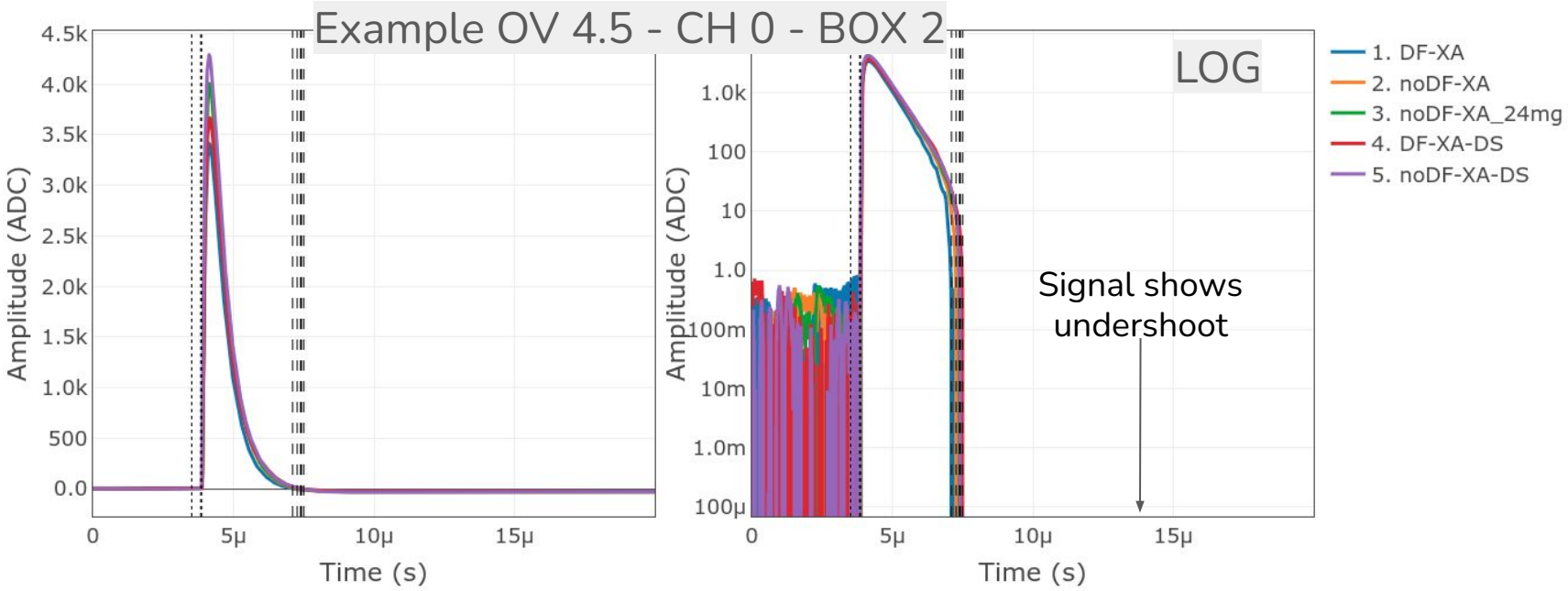
SiPM Scintillation

- Scintillation light seen by ref. SiPM sensors.
- Ref. Sensors serve 2 purposes:
  - Compute reference charge to compute relative PDE.
  - From deco. wvf fit can be performed to extract scintillation parameters.



XA Integration Limits

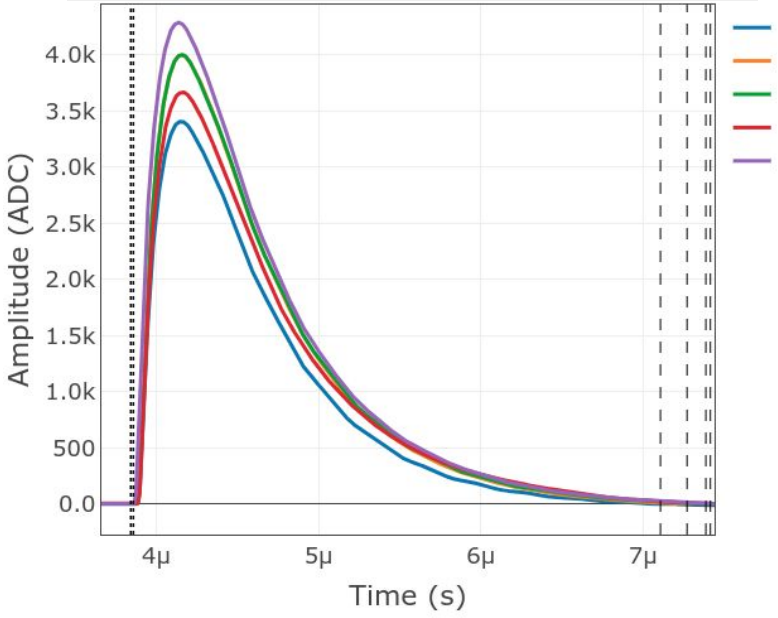
- Integration range determined by each run's **average wvf.** with baseline.
- ~ 3.5 us for scintillation runs.



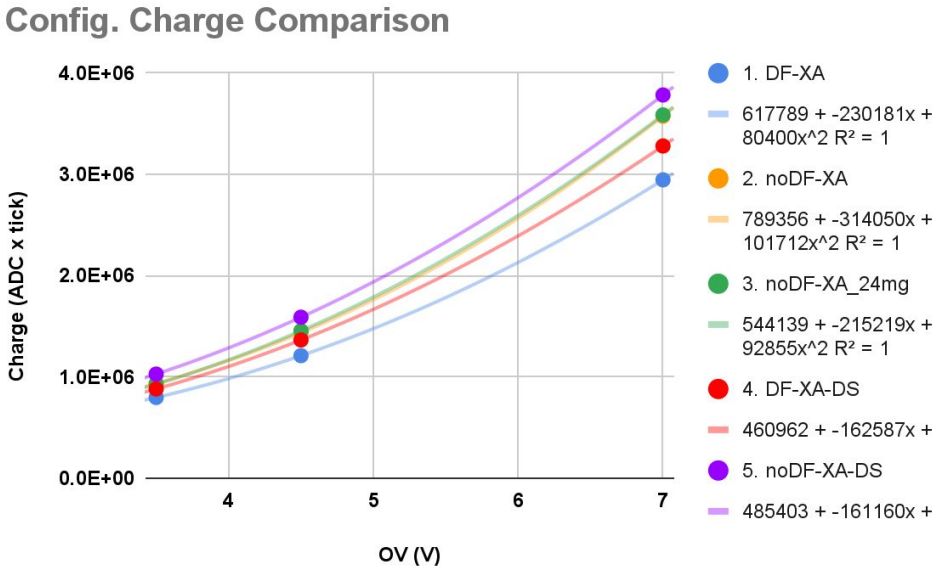
XA Integration Limits

- Showing **charge difference** between XA configurations.
- Notice noDF-XA and noDF-XA_24mg overlap.

Example OV 4.5 - CH 0 - BOX 2



Combined - BOX 2



Results

PRELIMINARY VD-XA PDE RESULTS

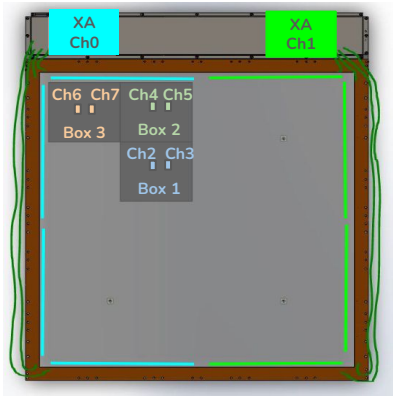
- Latest PDE results averaged over 3 box positions.

Ref. Method:

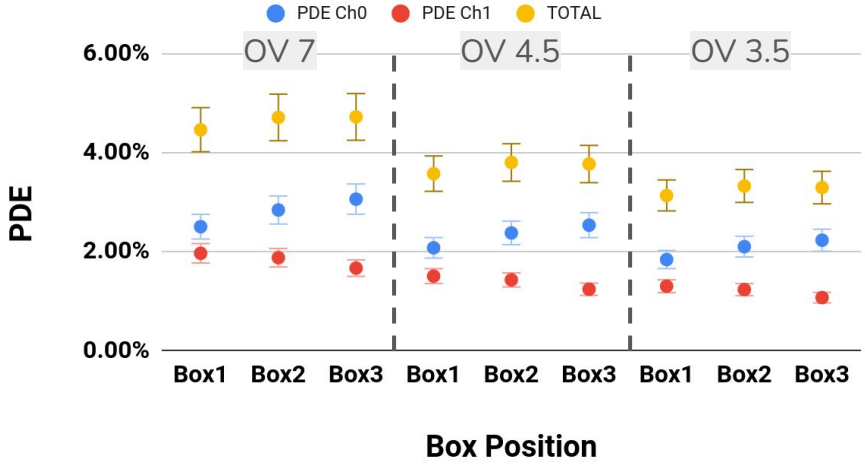
OV	1. DF-XA	2. noDF-XA	3. noDF-XA_24mg	4. DF-XA-DS	5. noDF-XA-DS
3.5	2.9% ± 0.3%	3.7% ± 0.3%	3.4% ± 0.3%	3.3% ± 0.3%	3.5% ± 0.3%
4.5	3.3% ± 0.4%	4.2% ± 0.4%	4.0% ± 0.4%	3.7% ± 0.4%	4.1% ± 0.4%
7	4.2% ± 0.4%	5.4% ± 0.5%	5.1% ± 0.5%	4.7% ± 0.5%	5.2% ± 0.5%

VD-XA PDE - Position Dependence

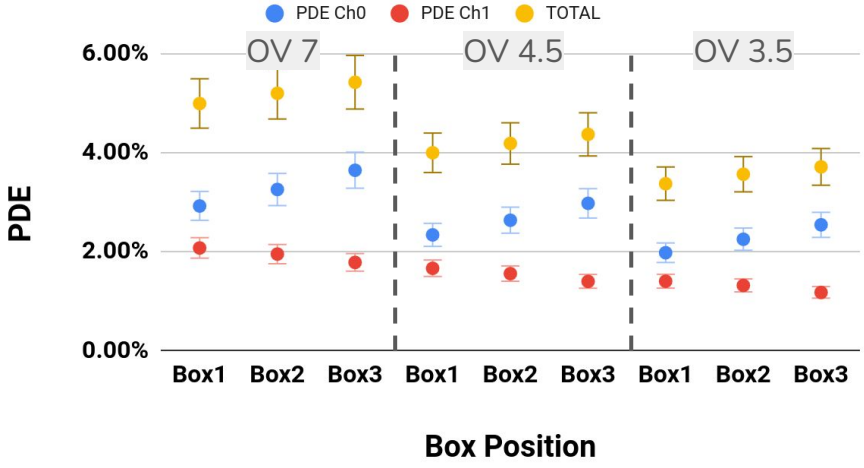
- Showing per channel PDE for the 3 box positions.
- Similar average CH0/TOTAL:
  - DF-XA-DS: 58% Box 1 - 62% Box 2 - 67% Box3
  - noDF-XA-DS: 58% Box 1 - 63% Box 2 - 68% Box3



DF-XA-DS PDE



noDF-XA-DS PDE

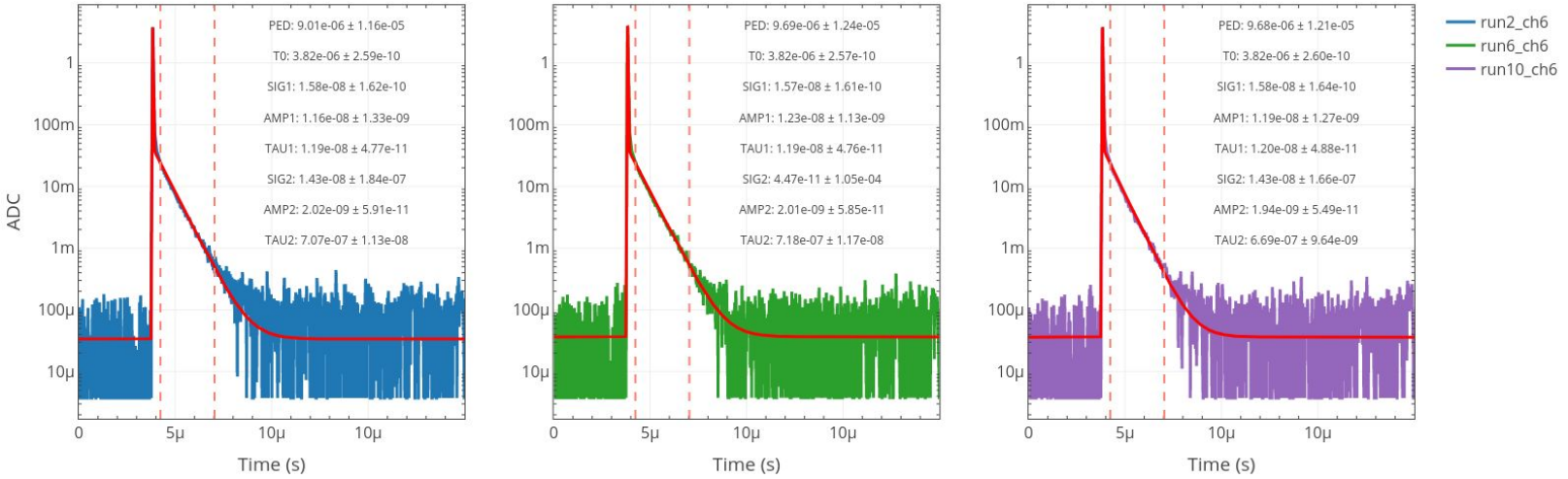


Purity

Purity

- **Ref. sensors in each Box** provide purity estimation.
- $\tau < 0.7$ us for slow scintillation component.

Example Scintillation Fits



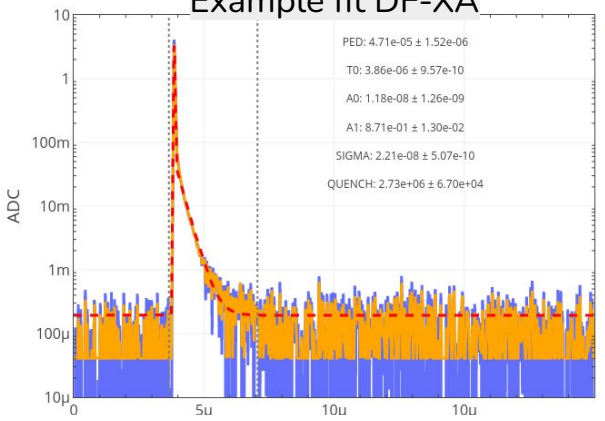
Purity Correction

- Studying purity **correction factor** from a combination of the **N_2 "quenching" fit** (which affects both fast and slow comp.) **+ global offset** (parametrized to reconcile fitted A values with theory).

- **Theoretical input** values:
  - τ_s = 7.1E⁻⁹ - τ_t = 1.66E⁻⁶ - A_t/A_s=0.3.

- Sim. Method provides compatible relative results but ~ 0.5% offset wrt. ref. method.

Example fit DF-XA



$$\ell'(t) = \frac{A'_S}{\tau'_S}\exp\left(-\frac{t}{\tau'_S}\right) + \frac{A'_T}{\tau'_T}\exp\left(-\frac{t}{\tau'_T}\right)$$

$$A'_j([N_2]) = \frac{A_j}{1+\tau_j k_Q\,[N_2]}$$

$$\frac{1}{\tau'_j}([N_2]) = \frac{1}{\tau_j} + k_Q\,[N_2]$$

Conclusions

- The **VD-XA has a PDE ~ 4% at 4.5 OV.**
- **Removing DF** has shown an **increase in PDE of 15 - 30%.**
- **Measured** for the first time XA-VD **double-sided configuration** with compatible results to previously measured configs. (4.5 OV):
  - DF-XA-DS (3.7 ± 0.4) %
  - noDF-XA-DS (4.1 ± 0.4) %

BACKUP