Super-Cell test in Liquid Argon at CIEMAT

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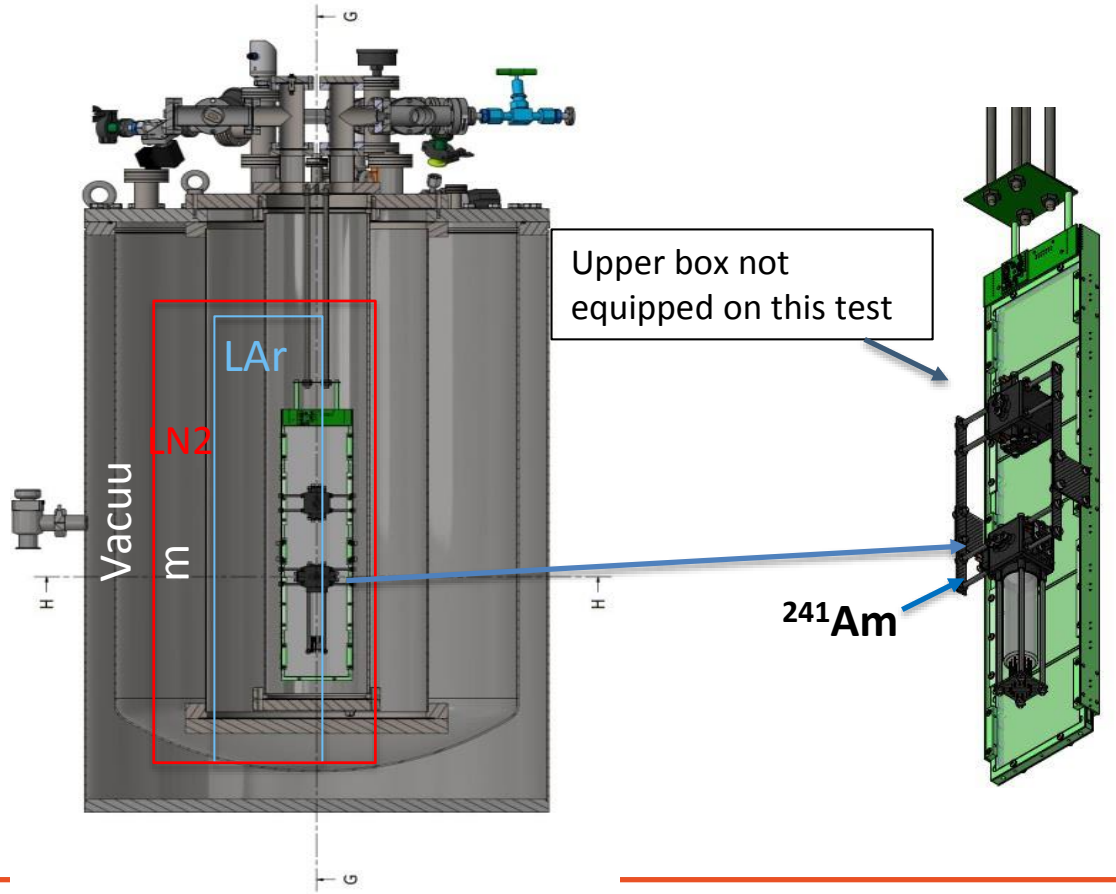
Measurement of the Super-cell PDE: Setup

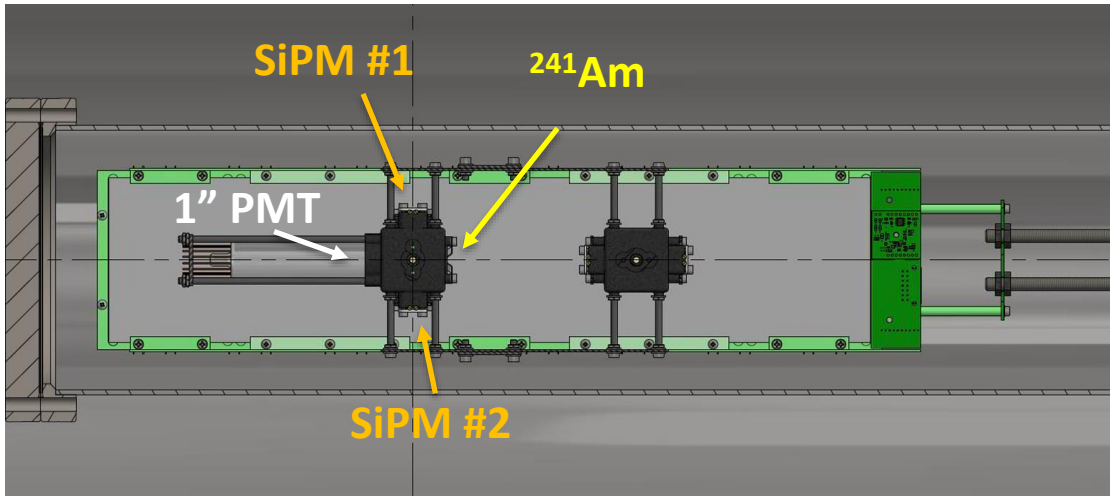
The Super-cell efficiency is measured in LAr with the scintillation light from an ^{241}Am alpha source
The alpha particle deposits its energy inside a small black box with a hole (ø = 23mm) facing the SC, the rest of the SC is covered with a black sheet.

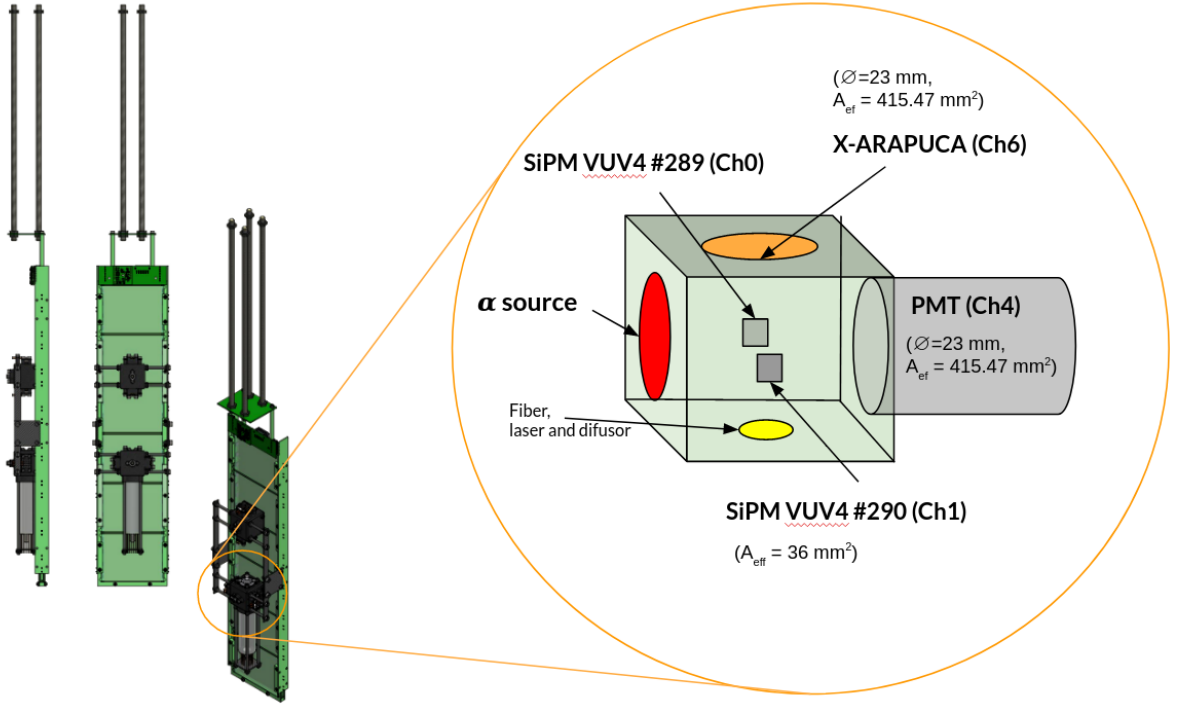
GAr 99.9999% is liquified with LN_2 at 2.7 bar



Measurement of the Super-cell PDE: Setup

- 2 VUV sensitive **SiPMs** with known PDE at RT are symmetrically placed with respect to the SC and the alpha source, in such a way that the fraction of photons per area in each photo-sensor is the same.
- **The SC PDE is measured from the reference SiPMs with known PDE**
- 1" **PMT** (VUV sensitive) is used to get the τ_{slow} and monitorize LAr purity





Measurement of the Super-cell PDE: Setup

Super-cell: X-Arapuca		
48 FBK-TT SiPMs + Ej-286PS-1	(18^{th} - 29^{th}) October	τ_{slow} ~ (1.06 ± 0.11)
	(15^{th} - 22) December	τ_{slow} ~ (1.14 ± 0.05)
	(24^{th} - 26^{th}) January	τ_{slow} ~ (1.07 ± 0.02)
48 HPK 75HQR SiPMs + Ej-286PS-1	(7^{th} - 9^{th}) February	τ_{slow} ~ (0.80 ± 0.11)
48 HPK 75HQR SiPMs + G2P-FB165A	(15^{th} - 19^{th}) February	τ_{slow} ~ (0.83 ± 0.10)

Relative position reference SiPMs-SC **unchanged**

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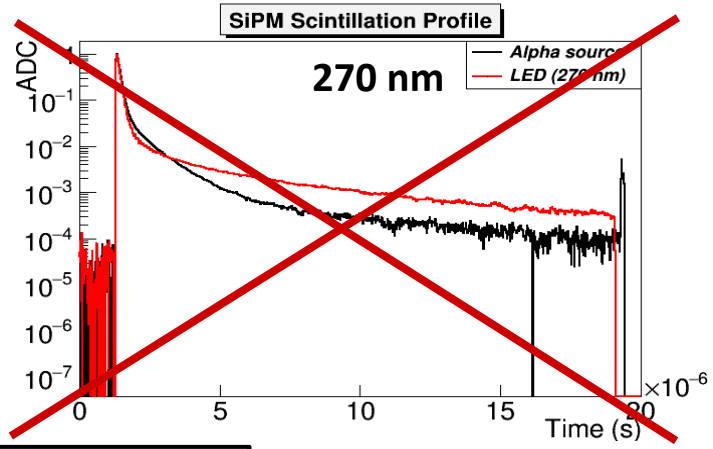
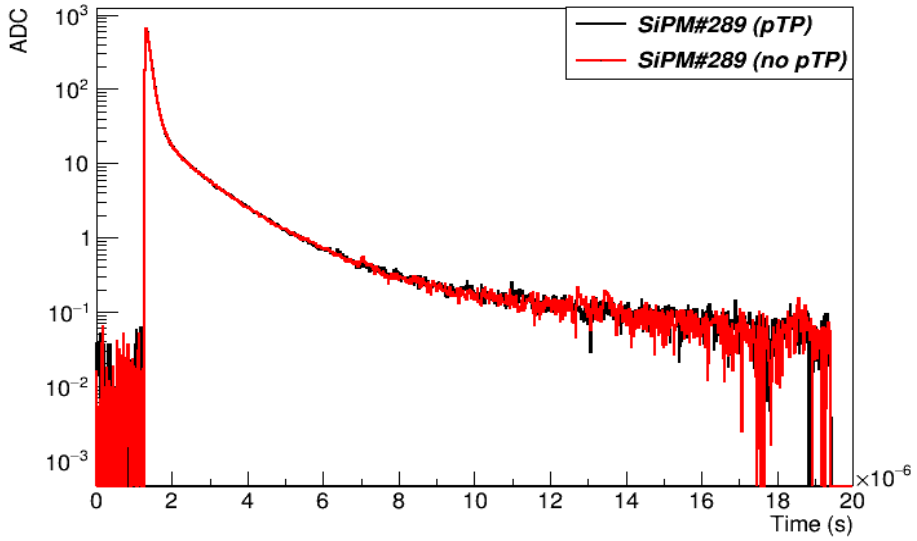
Understood Issues

➔ There was **NO pTP remission** detected by the reference SiPMs.

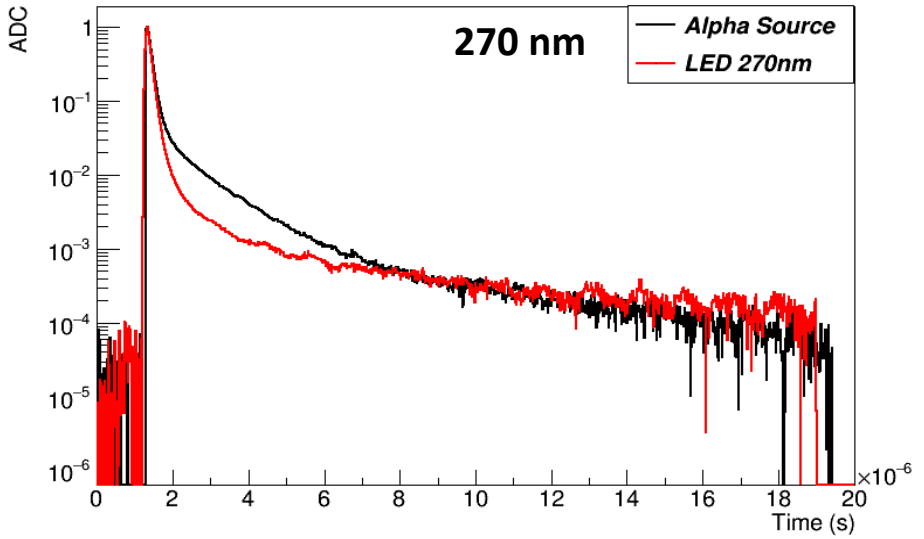
- We developed a **new setup** to cover the SC window and measure the possible effect of the pTP reemission
- 270nm LED pulse had a long decay during switching off



SC filter effect in Scintillation Profile



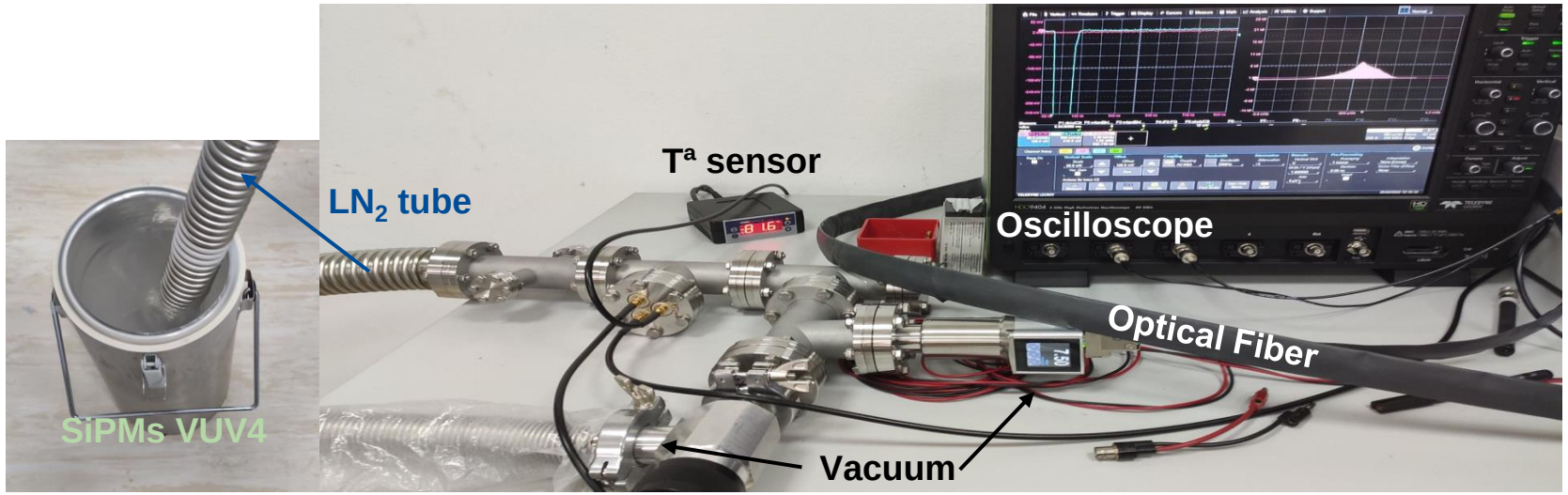
SiPM Scintillation Profile



Observed Issues

Reference SiPMs characteristics & calibration: Hamamatsu VUV4 SiPMs S13370 – 6075CN

	Manufacturer (RT) PDE (%)	CIEMAT (CT) PDE (%)	Gain (10^6)	V_{BR} (V)	V_{OP} (V)
SiPM #289	27.45	~14	6.57	42.2	46.25
SiPM #290	28.64	~14	6.77	42.3	46.25



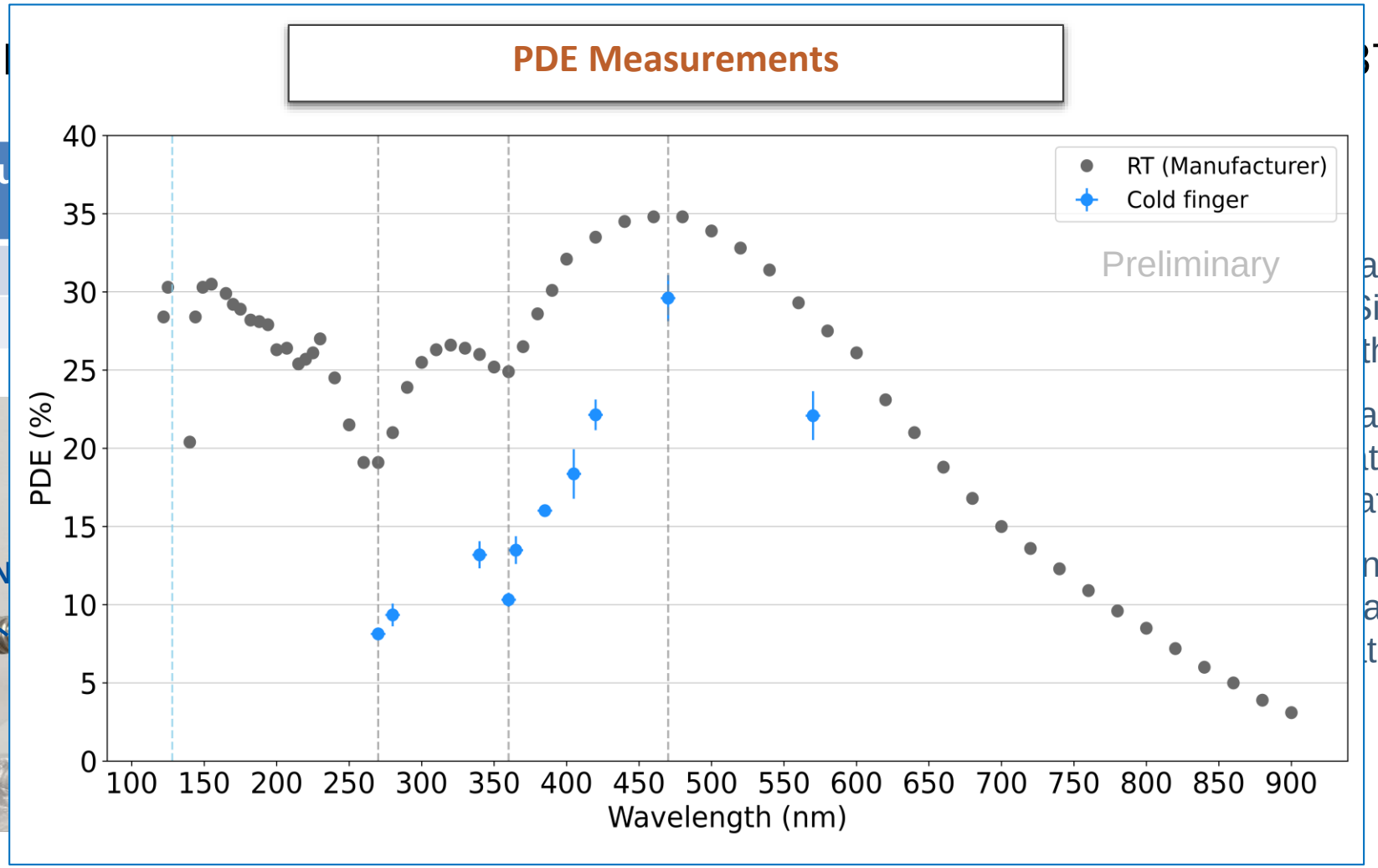
- We developed a **new setup** to cool down the SiPMs instead of submerging all the setup in LN_2
- Preliminary measurements at CIEMAT estimate a decrease of **~50%** for PDE at CT
- We are searching for a company to do an **independent** measurement at 128 nm

Observed Issues

Reference Si

370 – 6075CN

	Manu
SiPM #289	
SiPM #290	



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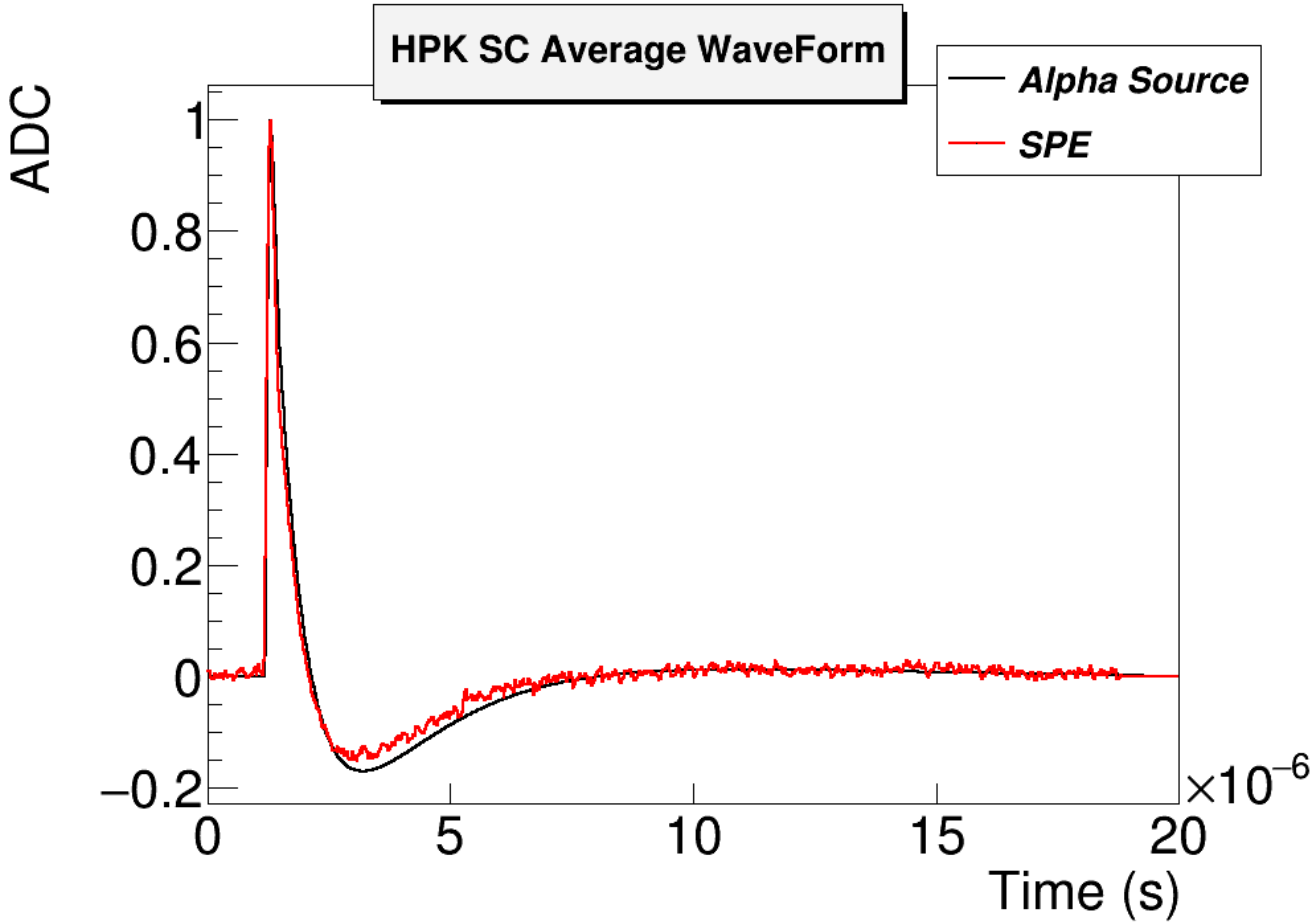
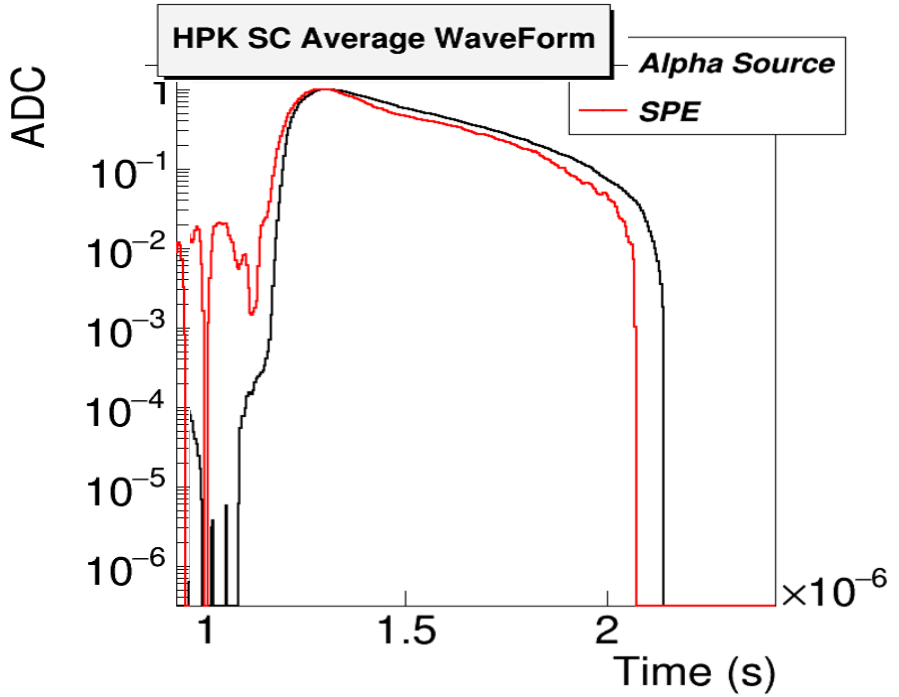
Results: HPK SC Average WaveForms (15th Feb)

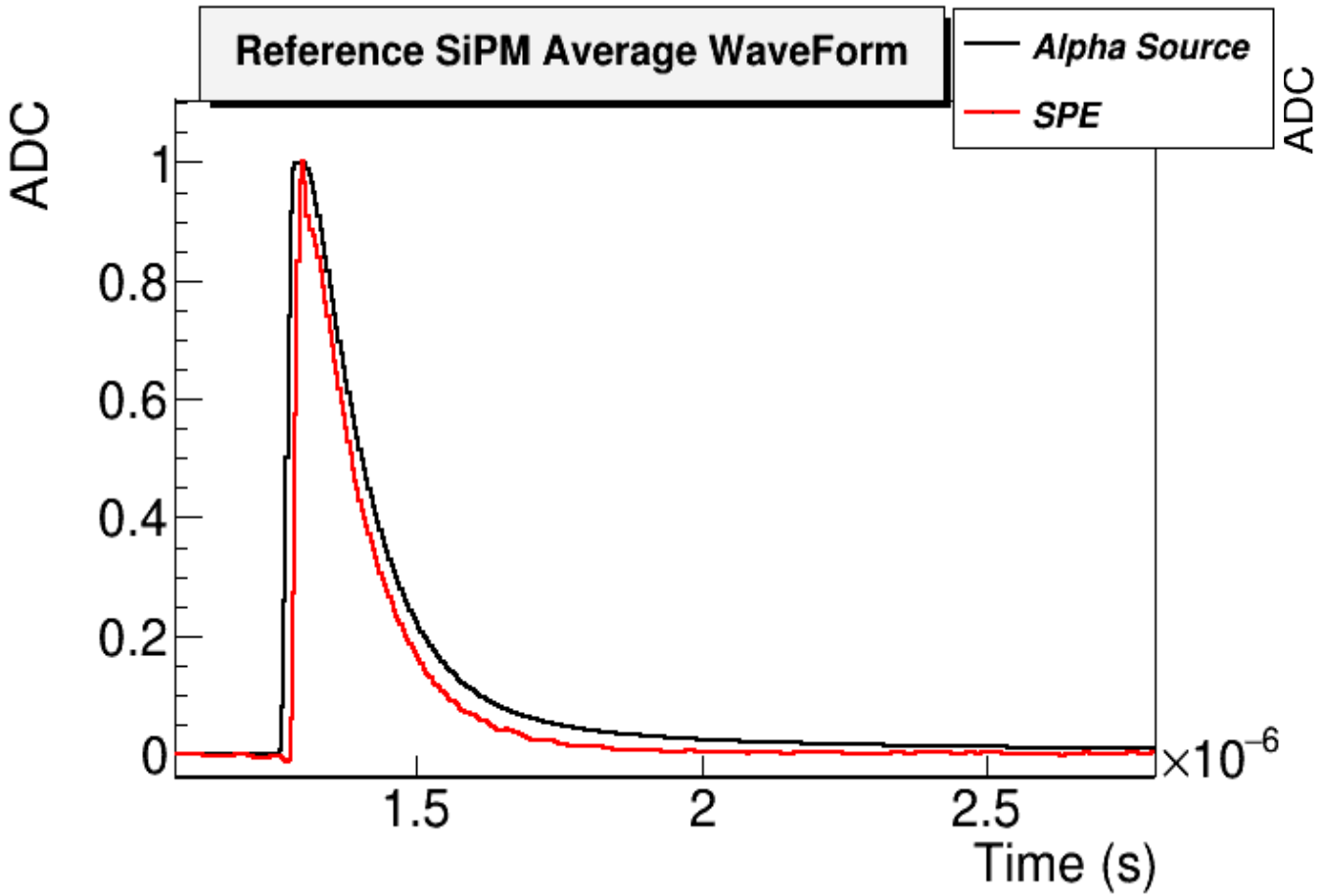


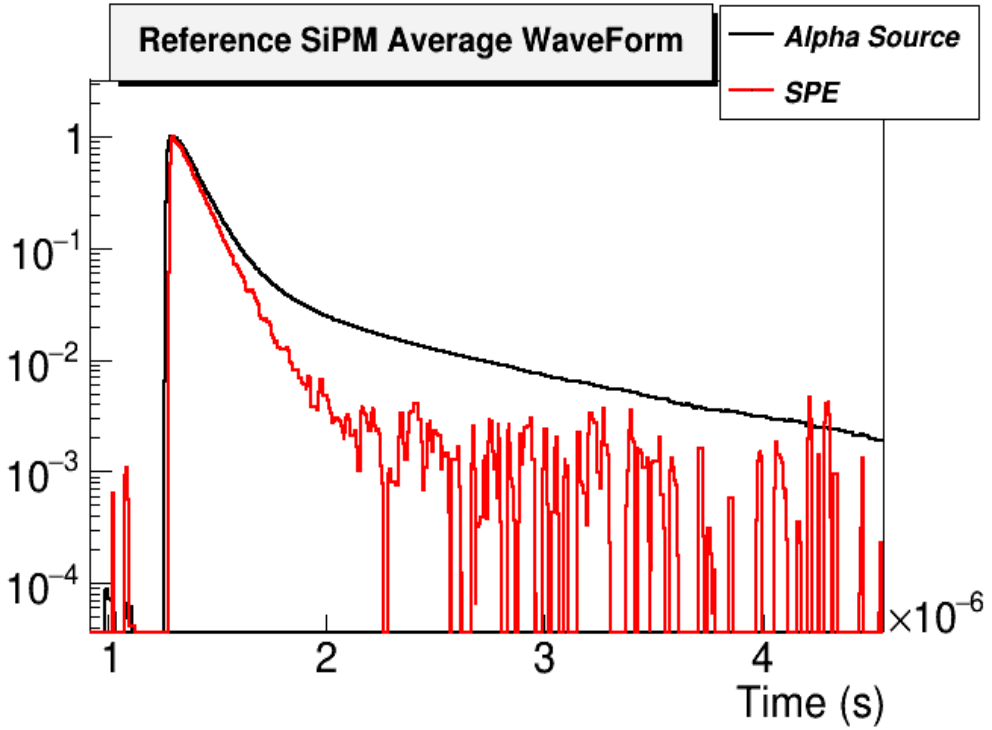


Logarithmic y-scale

Scintillation profile and SPE normalized shapes differences are small → **Problem** for deconvolution

Results: Reference SiPM Average WaveForms (15th Feb)





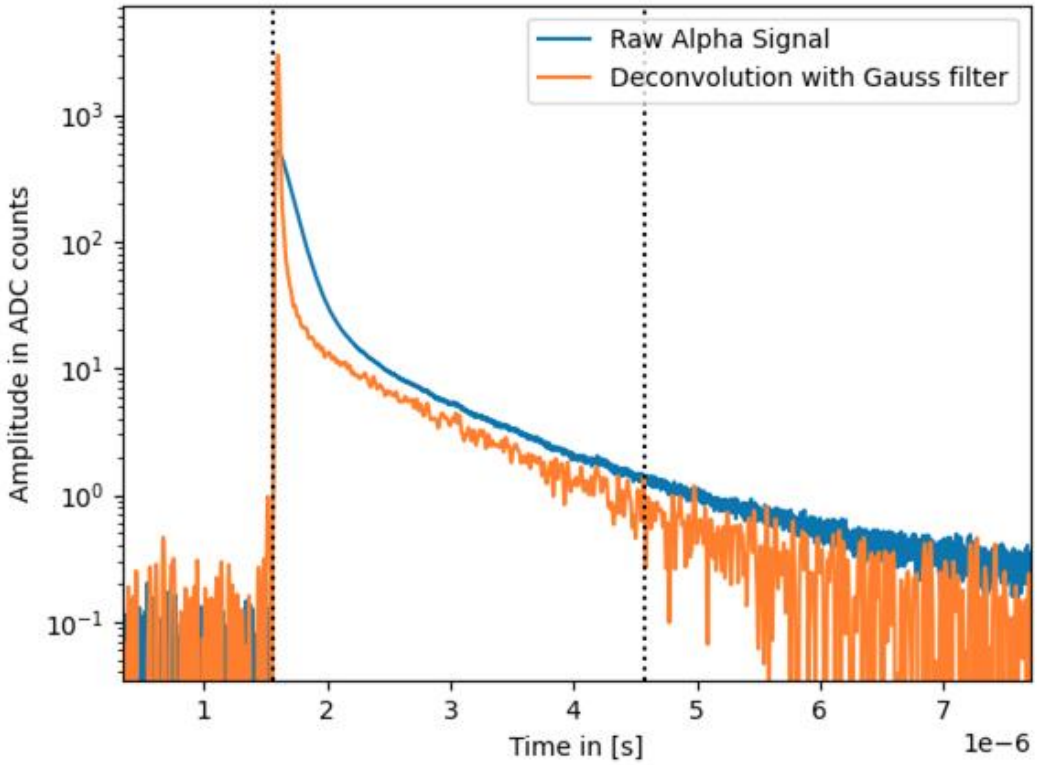
Logarithmic y-scale

Profiles more different →"easier" to deconvolute

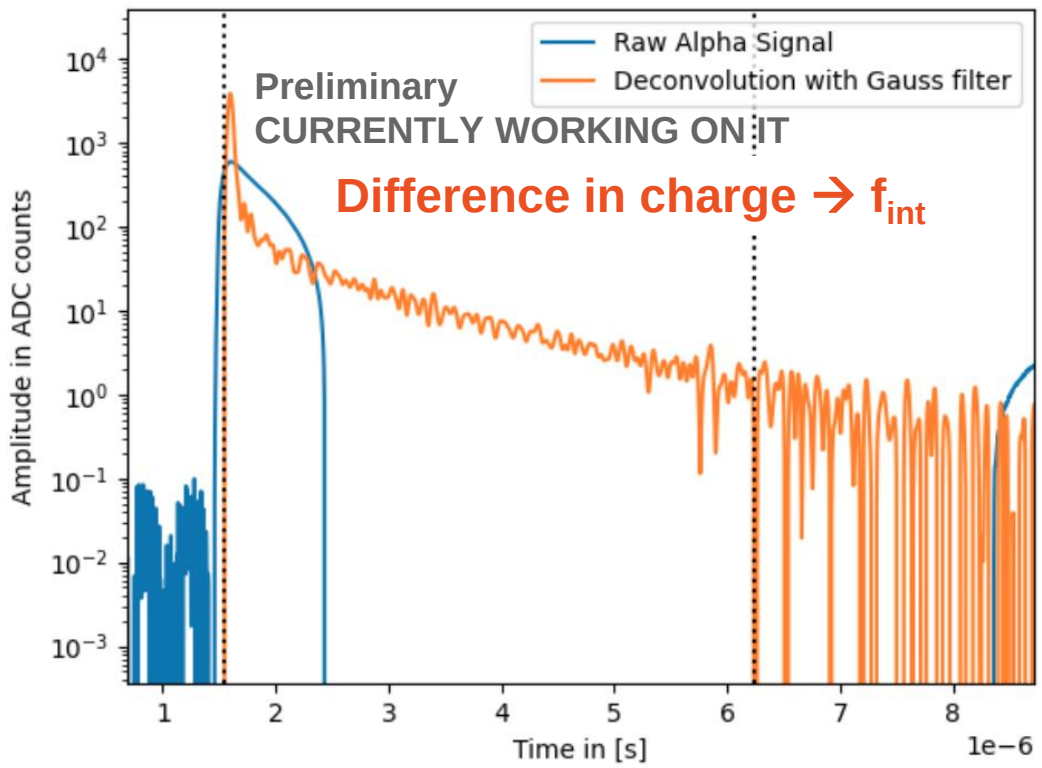
Results: Deconvolution (15th Feb)

- We apply a **Gauss** filter for performing the deconvolution
- **Preliminary** results→ Corrections need to be introduced

SiPM Deconvoluted Average WaveForm

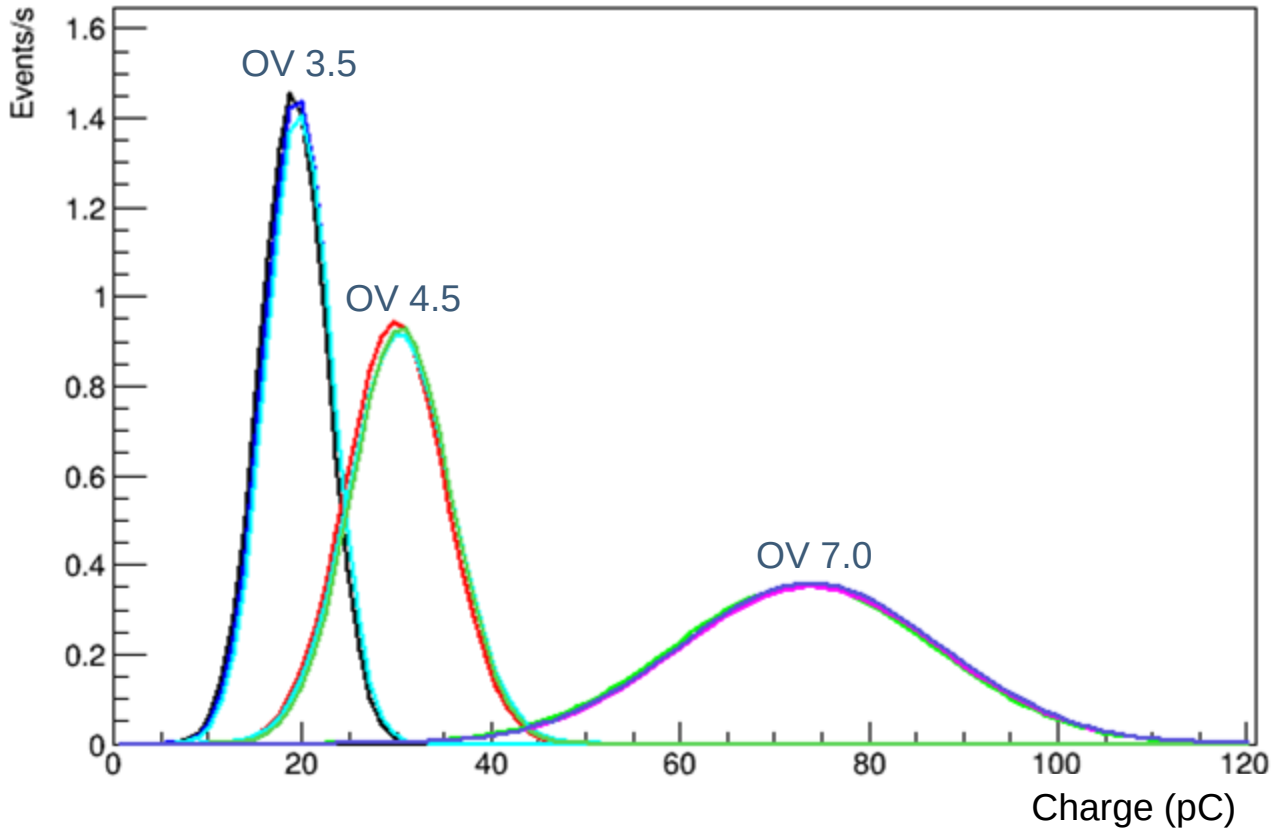


HPK SC Deconvoluted Average WaveForm



Super-cell Results

FBK_TT Super-cell + **Ej-286PS-1** Charge Spectrum from the Alpha Source



Super-cell PDE measurement

$$\epsilon_{raw}(SC) = \left[\frac{PE_{area}(SC)}{PE_{area}(Ref.SiPM)} \right]_{\exp} \cdot f_{geom} \cdot PDE(Ref.SiPM)$$

Geometrical factor

	PDE (Ref. SiPM) DataSheet (RT)		PDE (Ref. SiPM) CIEMAT (CT)	
	ϵ_{raw}	$\epsilon_{X\text{-}talk}$	ϵ_{raw}	$\epsilon_{X\text{-}talk}$
FBK SC + EJ (PDE 45%)	3.56 ± 0.36	3.16 ± 0.36	1.78 ± 0.36	1.58 ± 0.57
HPK SC + EJ (PDE 45%)	3.61 ± 0.49	3.54 ± 0.49	1.80 ± 0.48	1.77 ± 0.66
HPK SC + G2P (PDE 45%)	4.60 ± 0.42	4.52 ± 0.42	2.30 ± 0.41	2.26 ± 0.61

SiPMs of the SC at 45% PDE

Main uncertainties are:

- SC Gain measurement
- Reference SiPM PDE

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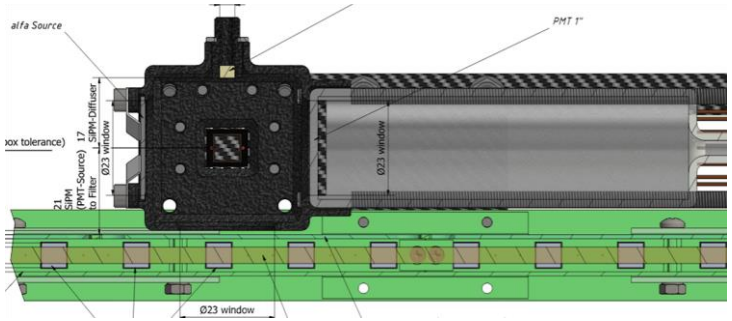
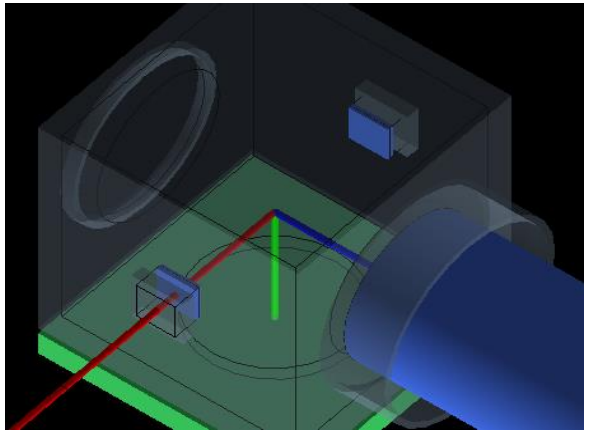
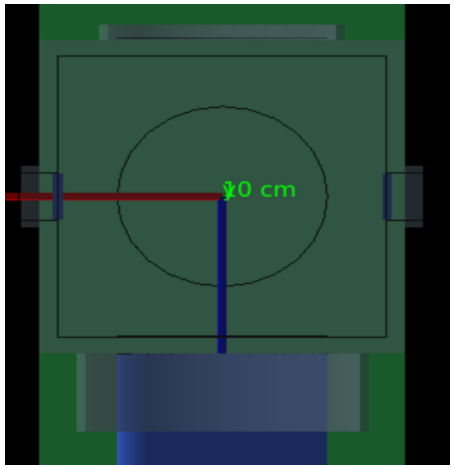
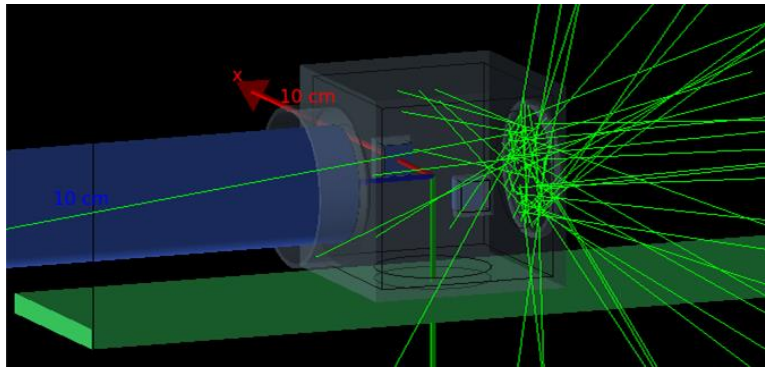
Simulation

- Quantify the fraction of photons arriving to each photo-sensor (reference SiPMs and SC)









	PMT	$SiPM_1$	$SiPM_2$	SC
Simulation_factor	0.02	0.003	0.003	0.02
Effective area (mm^2)	415.47	36.00	36.00	415.47
Relative per mm^2	4.49E-05	**7.32E-05**	**7.57E-05**	**5.91E-05**

f_{geom} = Relative per mm^2 (SiPM/SC) ~ 1.15

$$\epsilon_{SIM} = \frac{PE_{measured}}{PE_{produced}} \frac{1}{f_{SIMULATION}}$$

$$f_{SIMULATION} = \left[\frac{PE_{det}}{PE_{gen}}\right]_{SIMULATED}$$

WE ARE CURRENTLY WORKING ON CORRECTIONS

$$PE_{produced} = LY_{LAr} En_{\alpha} q_{\alpha} = 51000 \cdot 5.48 \cdot 0.72 \sim 2 \cdot 10^5$$

PDE Summary

	PDE (Ref. SiPM) DataSheet (RT)		PDE (Ref. SiPM) CIEMAT (CT)		Simulation	
	ϵ_{raw}	$\epsilon_{X\text{-}talk}$	ϵ_{raw}	$\epsilon_{X\text{-}talk}$	ϵ_{raw}	$\epsilon_{X\text{-}talk}$
FBK SC + EJ (PDE 45%)	3.56 ± 0.36	3.16 ± 0.36	1.78 ± 0.36	1.58 ± 0.57	1.49 ± 0.20	**1.26 ± 0.19**
HPK SC + EJ (PDE 45%)	3.61 ± 0.49	3.54 ± 0.49	1.80 ± 0.48	1.77 ± 0.66	Working on purity corrections	
HPK SC + G2P (PDE 45%)	4.60 ± 0.42	4.52 ± 0.42	2.30 ± 0.41	2.26 ± 0.61		

Next steps

- Independent PDE Measurement of reference SiPM at CT and at 128 nm

- Measurement from simulation:
  - **PURITY CORRECTION**:
    - Absolute correction for January measurements (best purity)
    - Relative correction using the Ref. SiPM measurement (February measurements)
  - Improve the PMT waveform fit to extract τ_{slow} but also the relative normalization **singlet/triplet**.
  - Comparison with **deconvoluted** SC and Ref. SiPMs waveforms fit

- Integration range correction for ϵ_{SIM} → preliminary value seems f_{int} **~(75-80)%**. Computed comparing the difference in charge when we deconvolve SC waveforms.

Conclusions

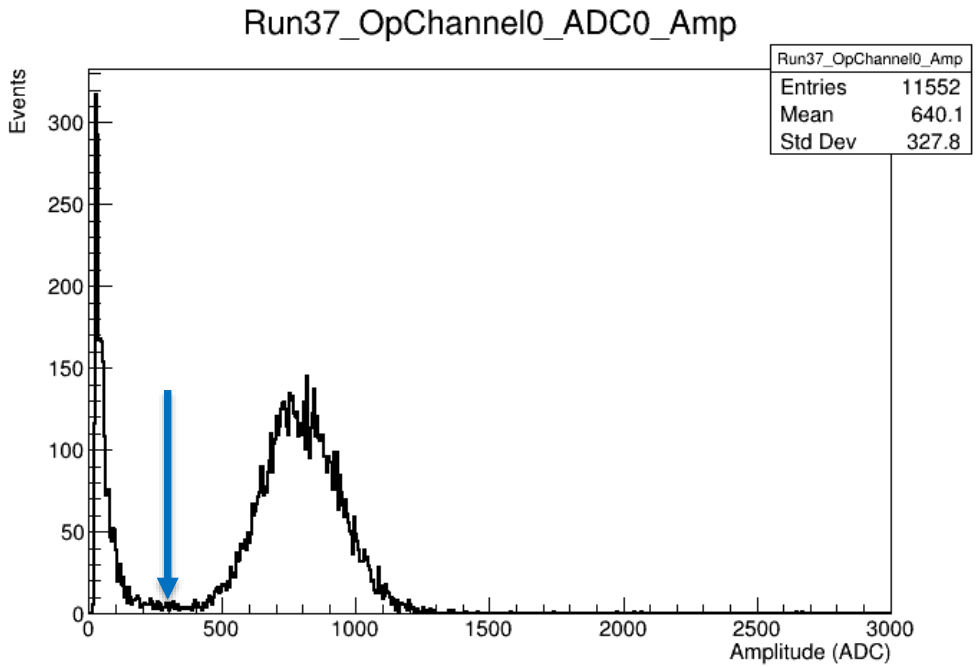
Preliminary measurement of Super-cell PDE equipped with:

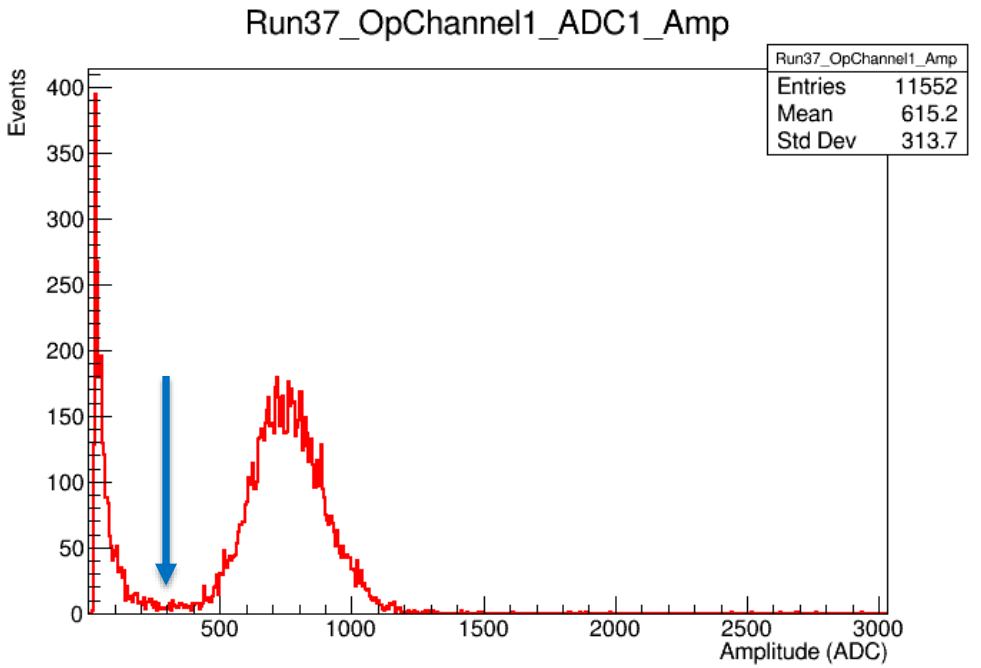
- ➔ **Eljen** WLS bar and **FBK**-TT SiPMs seems to be **<2%**
- ➔ **Eljen** WLS bar and **HPK** 75HQR SiPMs increase around **11%** the efficiency
- ➔ **Glass to power** WLS bar increases the efficiency around **28%**

BACKUP

SC DAQ Trigger

Reference SiPMs signal amplitude > 300 ADC in coincidence

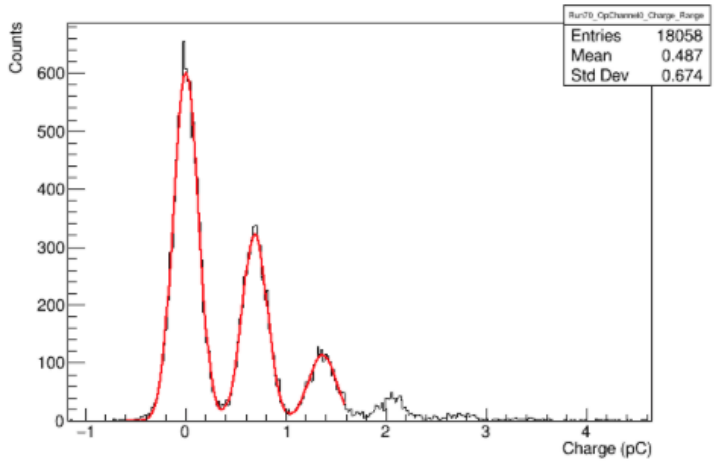




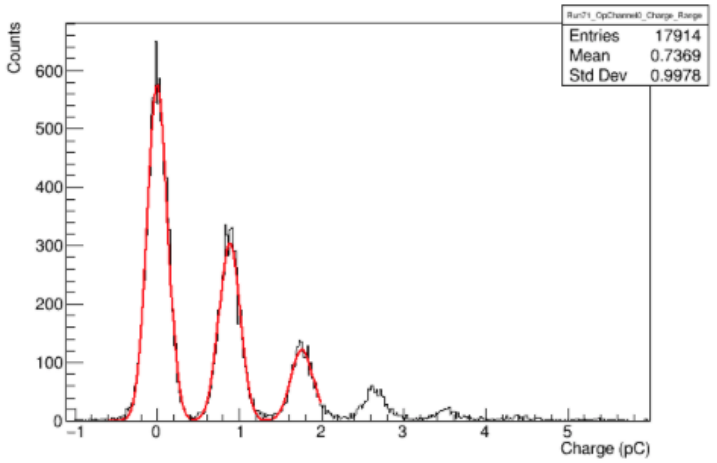
Super-cell Calibration

SuperCell FBK-TT					
PDE (%)	**OV (V)**	**Gain (10^6)**	**SN_0**	**SN_1**	**SN_C**
40	3.5	**2.05 ± 0.10**	3.46 ± 0.07	3.31 ± 0.18	2.39 ± 0.09
45	4.5	**2.67 ± 0.03**	4.92 ± 0.15	4.75 ± 0.09	3.42 ± 0.07
50	7.0	**4.22 ± 0.02**	5.42 ± 0.09	5.21 ± 0.08	3.76 ± 0.05

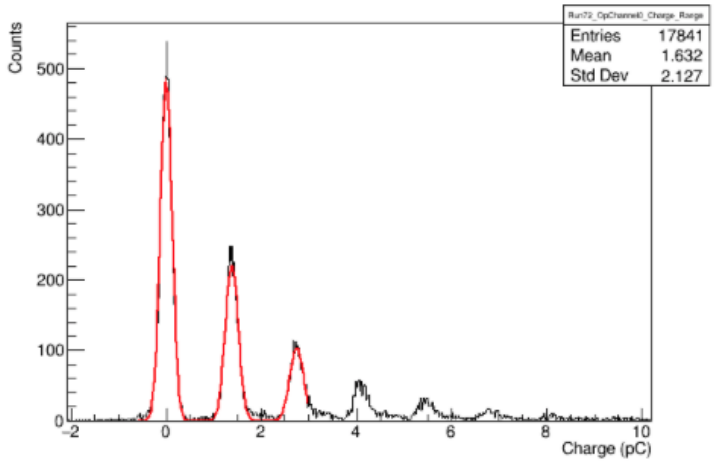
FBK SC - OV = 3.5 V



FBK SC - OV = 4.5 V



FBK SC - OV = 7.0 V



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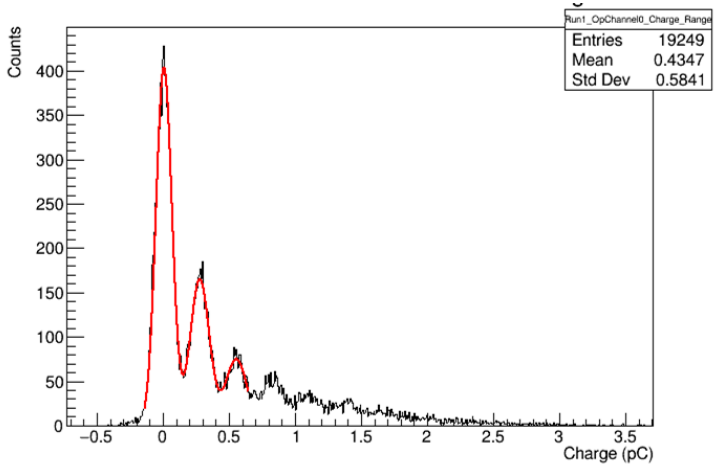
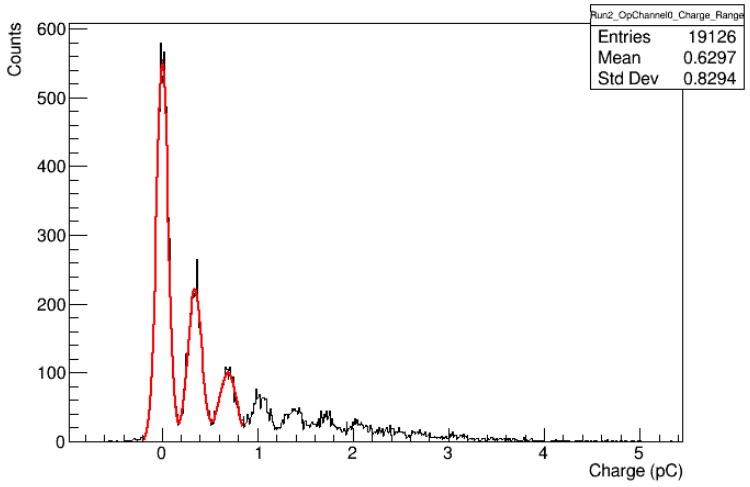
Super-cell Calibration

SuperCell HPK 75HQR					
PDE (%)	**OV (V)**	**Gain (10^6)**	**SN_0**	**SN_1**	**SN_C**
40	2.0	**1.72 ± 0.02**	4.19 ± 0.41	3.52 ± 0.38	2.69 ± 0.28
45	2.5	**2.11 ± 0.01**	5.14 ± 0.56	4.48 ± 0.28	3.37 ± 0.28
50	3.0	**2.54 ± 0.02**	6.17 ± 0.63	5.20 ± 0.36	3.97 ± 0.33

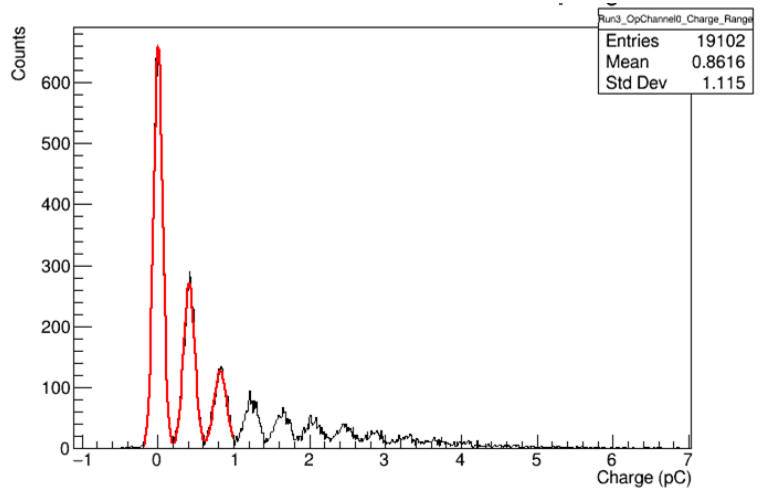
HPK SC - OV = 2.0 V



HPK SC - OV = 2.5 V



HPK SC - OV = 3.0 V



Super-cell PDE measurement

Raw charges (per mm^2) used in the PDE computation

$$\in_{raw}(SC) = \left[\frac{PE_{area}(SC)}{PE_{area}(Ref.SiPM)} \right]_{\exp} \cdot f_{geom} \cdot PDE(Ref.SiPM)$$

Simulation factor

	#PE/mm^2		
	FBK SC + EJ	HPK SC + EJ	HPK SC + G2P
PDE 40%	0.12 ± 0.03	0.11 ± 0.03	0.15 ± 0.03
PDE 45%	0.14 ± 0.03	0.13 ± 0.04	0.17 ± 0.04
PDE 50%	0.22 ± 0.03	0.14 ± 0.05	0.20 ± 0.05

	#PE/mm^2			PDE (Ref. SiPM) DataSheet (RT)	PDE (Ref. SiPM) CIEMAT (CT)
	(24th - 26th) January	(7^{h} - 9th) February	(15th - 19th) February		
Ref. SiPM VUV4 (PDE 45%)	1.54 ± 0.07	1.25 ± 0.08	1.26 ± 0.08	28.04 ± 0.65	14.02 ± 0.59

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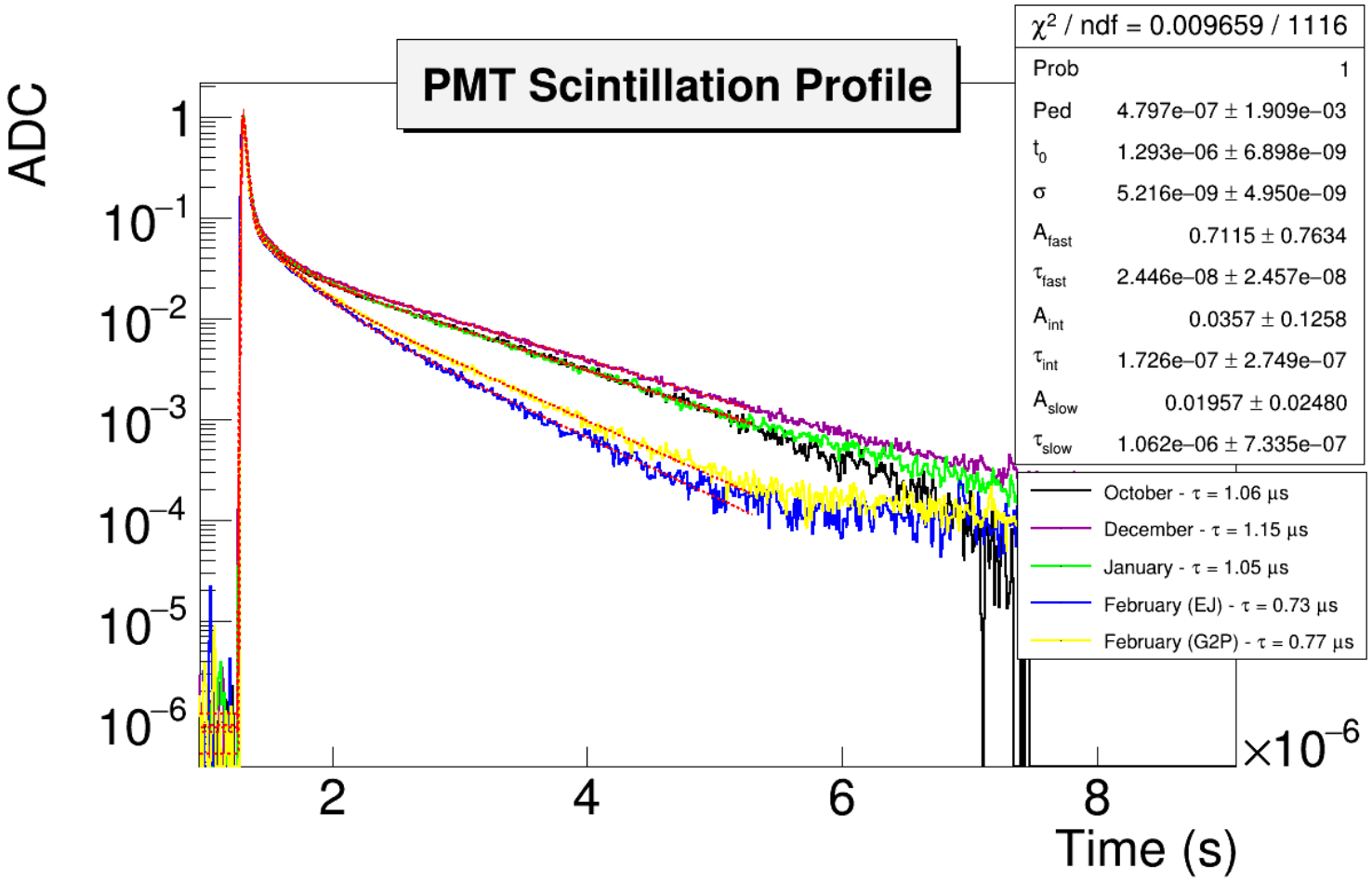
Fitting the Scintillation Profile: τ_{slow} estimation



PMT HPK R6836	
(18^{th} - 29^{th}) October	τ_{slow} ~ (1.06 ± 0.11)
(15^{th} - 22) December	τ_{slow} ~ (1.14 ± 0.05)
(24^{th} - 26^{th}) January	τ_{slow} ~ (1.07 ± 0.02)
(7^{th} - 9^{th}) February	τ_{slow} ~ (0.80 ± 0.11)
(15^{th} - 19^{th}) February	τ_{slow} ~ (0.83 ± 0.10)