

Update on tests and analysis of FD1-XA PDE at MiB

E. Bertolini, C. Brizzolari, C. Cattadori , L. Meazza
Photon Collection Meeting
16/04/2024

Goals of the 2024 data taking campaign

- **Improved our setup facility with OF** (to trigger synchronously the s.p.e. with the LED light pulse)
 - **gain is stable**
- **Goal: Monitor the setup and the XA stability** over multiple days (as done in past campaigns)
 - observed increase over time (causes under study)
 - LAr purity, xt, other
- **Goal: Decouple the effect of the individual components (DF, Viquity btw. SiPMs etc.) on the PDE**
 - under study, preliminary results

The spring 2024 data taking campaign

Date	Configuration	WLS	DF	VB
27/02/24	FD1 Baseline control.	1 pcs	pTP + ZAOT DF	no
04/03/24	FD1	1 pcs	pTP + ZAOT Glass + A	no
05/03/24				
07/03/24	FD1	1 pcs	pTP + Glass no DF	no
08/03/24				
12/03/24	FD1- Improved Light Collection	2 pcs	pTP + Glass no DF	yes
13/03/24				
14/03/24				
15/03/24				
19/03/24	FD1- Improved Light Collection	2 pcs	pTP + ZAOT DF	yes
21/03/24				
22/03/24				
09/04/24	FD1 Improved Light Collection	2 pcs	pTP + ZAOT DF	no
10/04/24				

XA-SC - control measurement

All results presented here are

ZAOT Baseline:

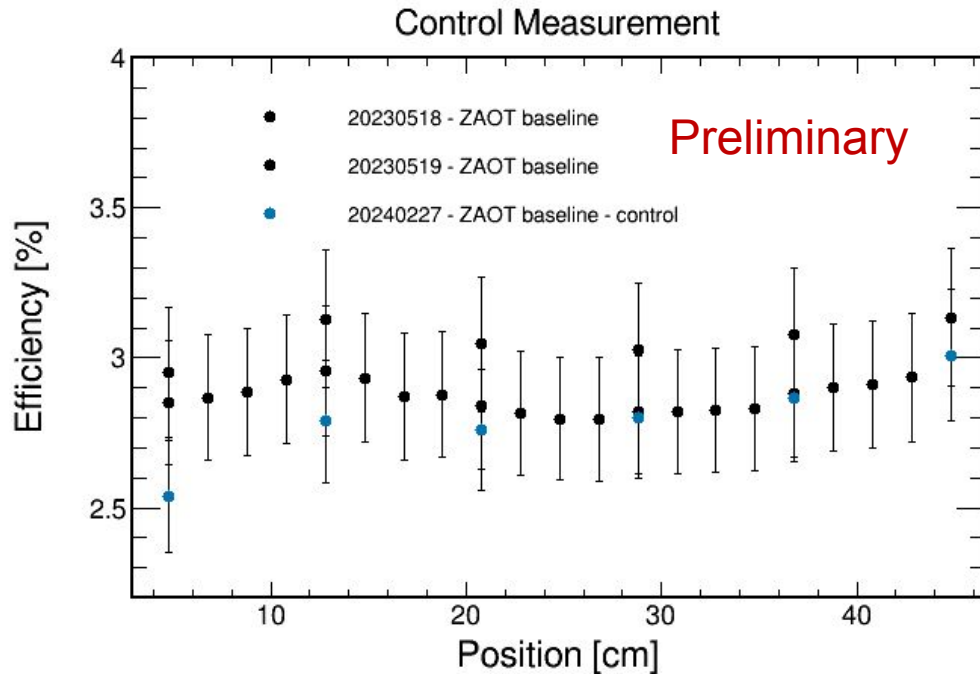
- baseline design except DF are ZAOT
 - OPTO DF were damaged

All Results are

- Preliminary
- xt and LAr purity uncorrected

20240228 control measurement is still not calibrated

- taken with the warm electronics transformer bypassed
- might be higher than the previous day

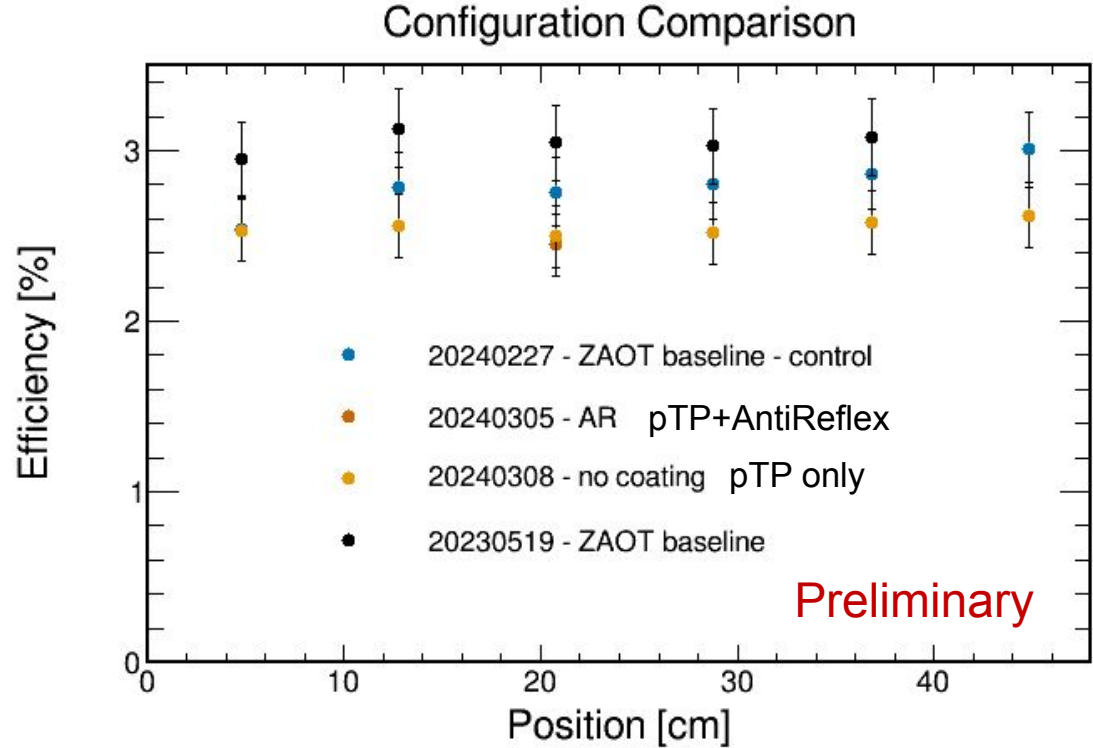


XA-SC - measurements without Dichroic Filters

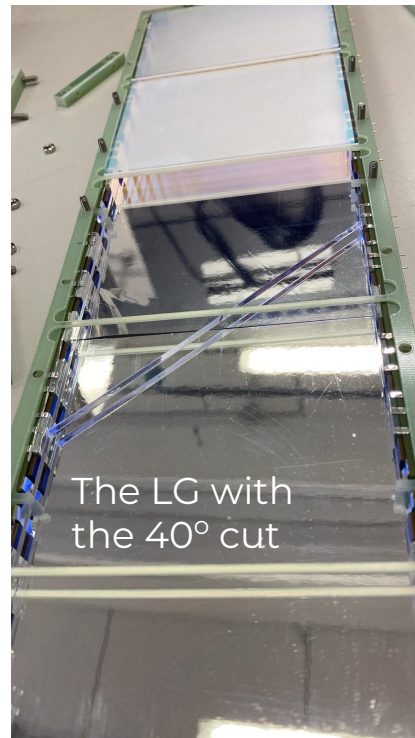
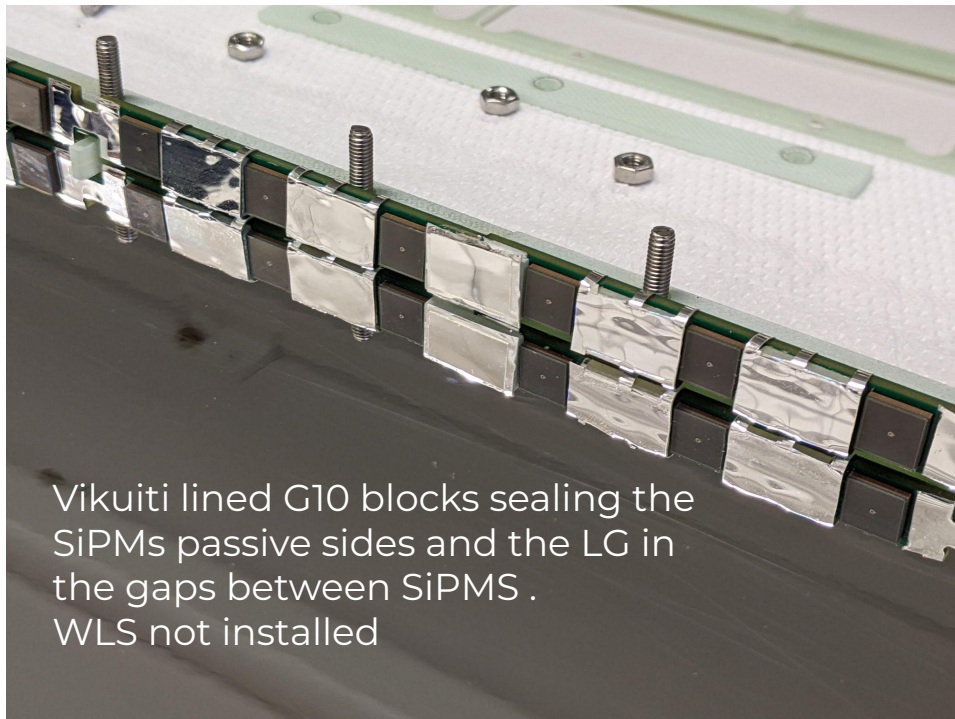
Available two set of **ZAOT** glass substrates (adopted for FD2 M0 & M1 DF)

1. with/w.o. antireflection (AR) coating (substitutes DF) +pTP on other side
2. pTP only and no AR coating

SC configuration **w/ DF** has **+10-15% increase in PDE** depending on the baseline (2023 or 2024)



XA-SC - improved light collection configuration



XA-SC - meas w/o DF, improved light collection

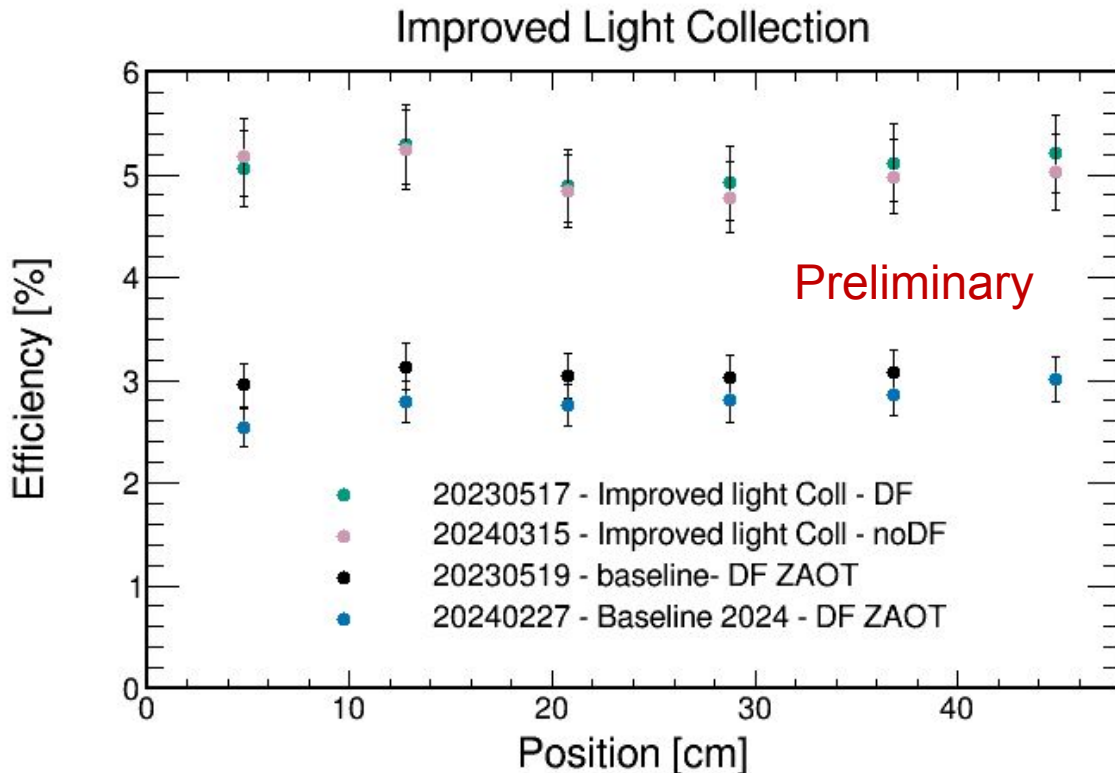
Lightguide (LG) from the pDUNE-HD batch.

Improved light collection

1. LG with 40° cut
2. LG & SiPMs sides optically sealed by Vikuiti lined blocks

SC configuration w/o DF performs similarly to the 2023 measurement w/ DF

Both show an **improvement over the baseline design** (with ZAOT DF instead of OPTO)



XA-SC - improved light collection DF control

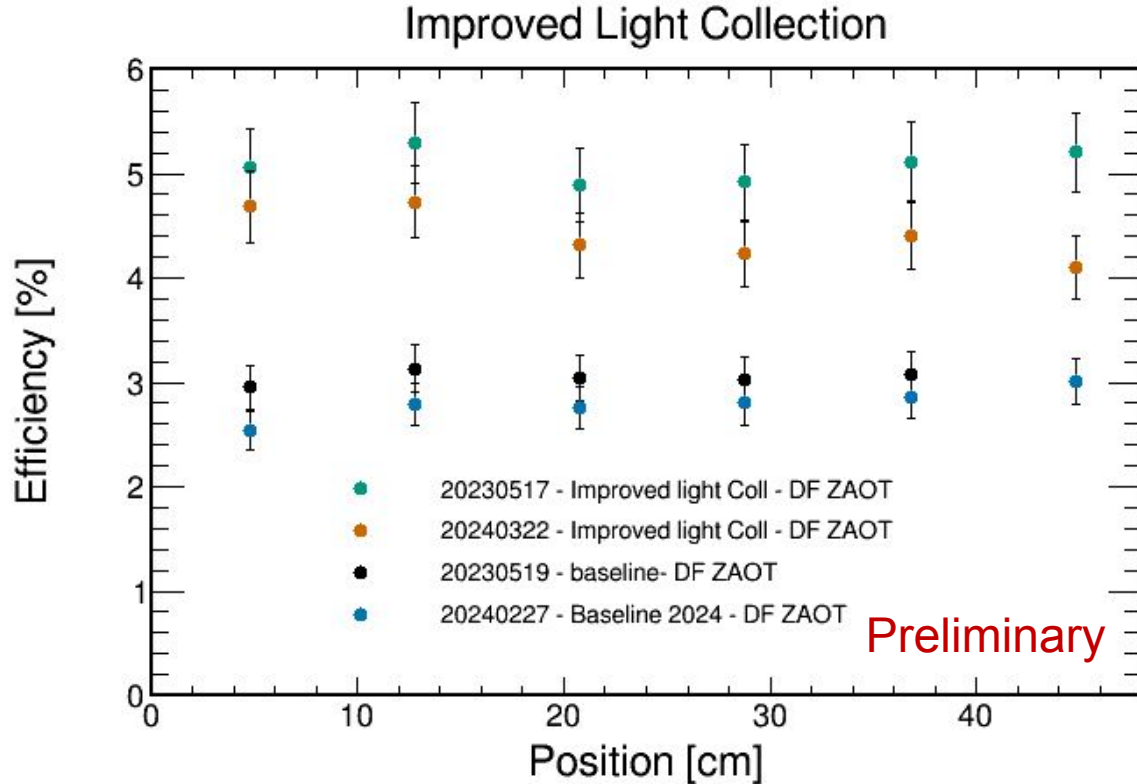
Improved light collection

1. LG with 40° cut
2. LG & SiPMs sides optically sealed by Vikuiti lined blocks

2024 Control measurement performs **~10% worse** than same config in **2023 meas.**

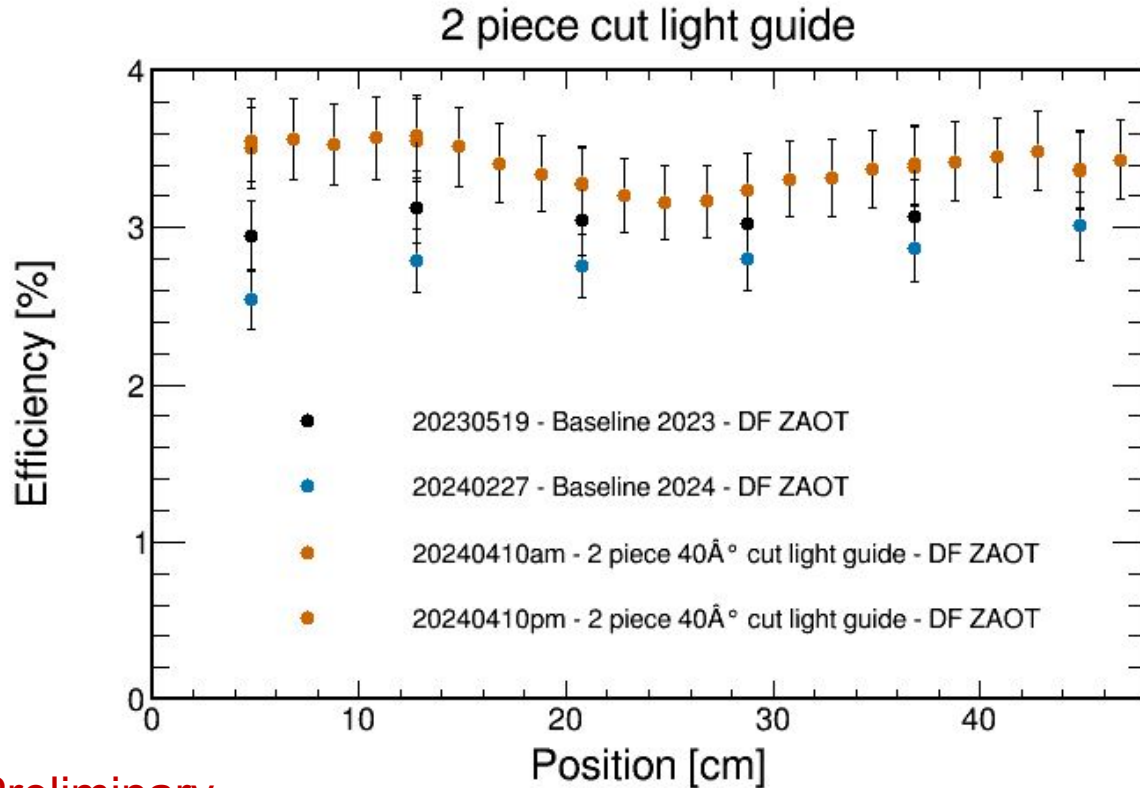
2 possible cases:

- **pTP degraded**: 2024 meas. should be compared to 2023 => **DF provides no improvement**
- **pTP ok, mounting variance**: 2024 meas. should be compared with 2024 control => **DF decreases perf. ~10%**



XA-SC - effect of the 2 piece light guide (40° cut)

- everything else equal, a **40° polished reflective (Vikuiti applied) cut** in the light guide provides a **10-15% improvement in PDE**
- Delta (2023 - 2024) is related to the dismount/ and random remount of the components.
- measurements with the Vikuiti lined blocks between SiPM (slides 7-8) show the combined effect of the **cut with the wider LG enhancing the effect of the VB (=increased light sealing)**



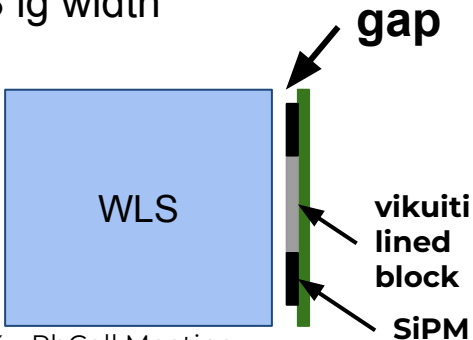
Preliminary

XA-SC - dependence on the lg width

the lower the gap between the light guide and the SiPMs and Vikuiti reflector the higher the trapped light and PDE

- strong dependence $O(0.1\text{mm})$
- being the SiPM boards fixed to the frame this distance is driven by the WLS lg width

SC section viewed from the top

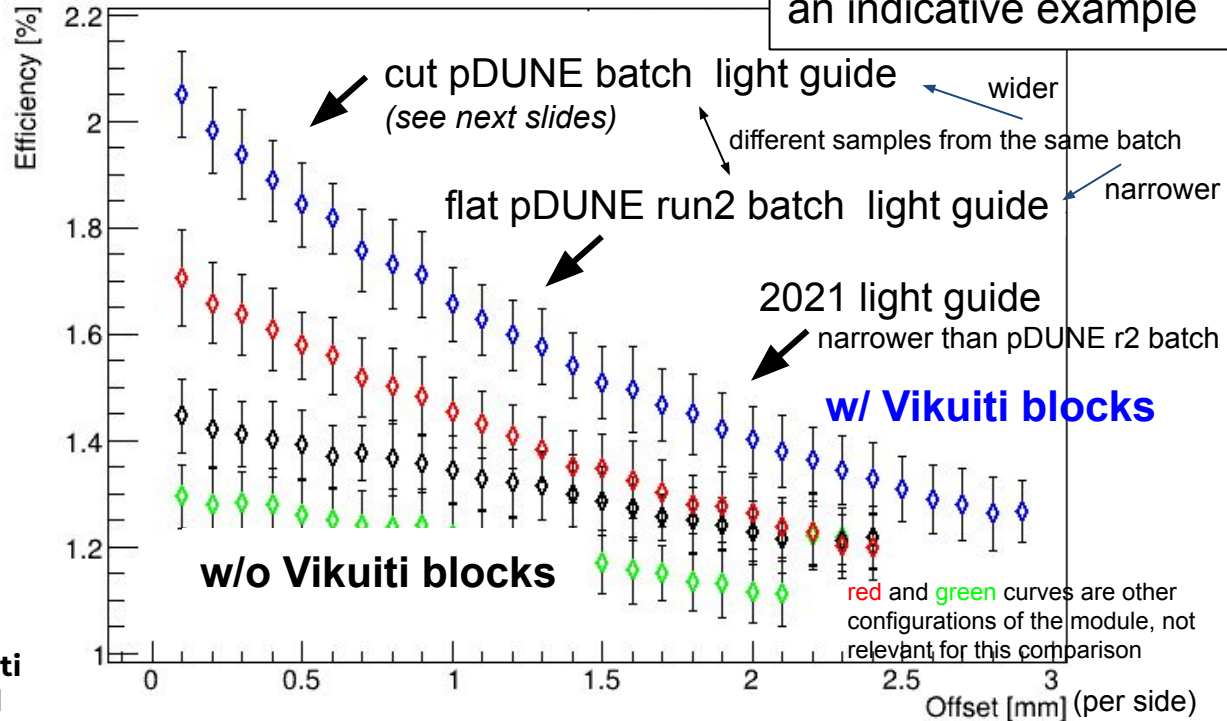


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note: at cold temperature the gap widens 0.5mm due to thermal contraction

simulation: SiPM Offset Scan

not actual placements on the curve, just as an indicative example



light guide - SiPMs (Vikuiti) gap at cold

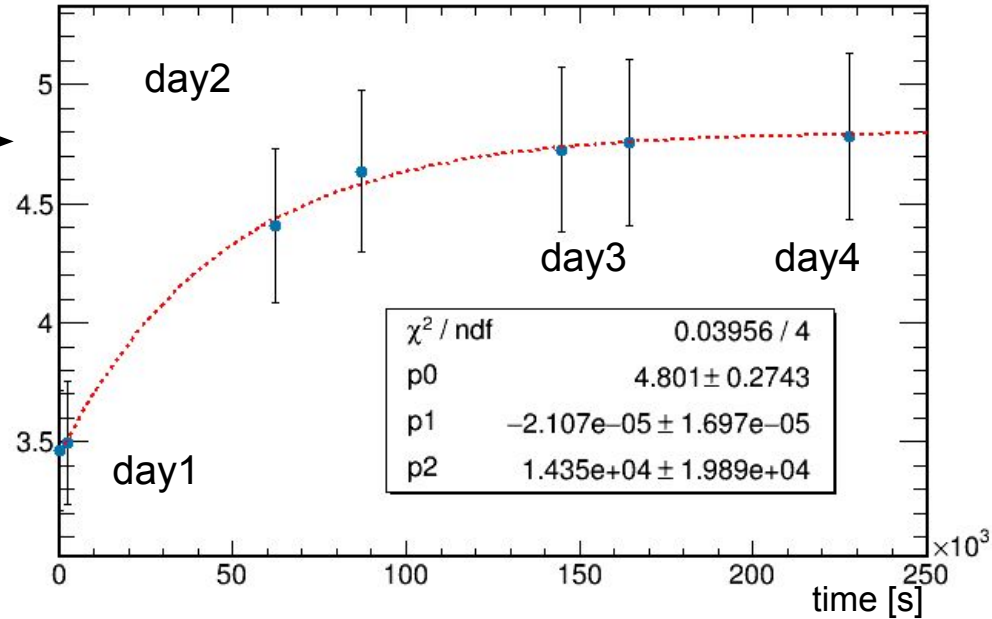
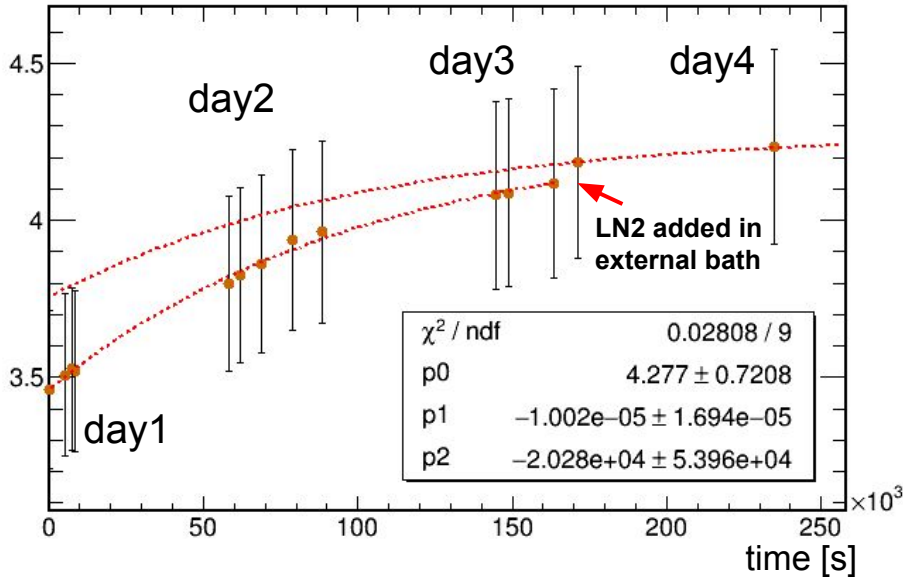
driven by light guide width



XA-SC - integrated charge increase over time

- measurements taken at different times, at the same position on the SC (pos4)
 - 12-15 march 2024
 - 19-22 march 2024

Preliminary



- The initial deficit might be caused by **Argon bubbles** forming on the **SC surfaces** (lg, SiPM)
 - **thermal equilibrium (gas liquefied by LAr)**
 - **SC is the hottest element in the chamber**
 - **bubbles slowly liquify as SC cools down**

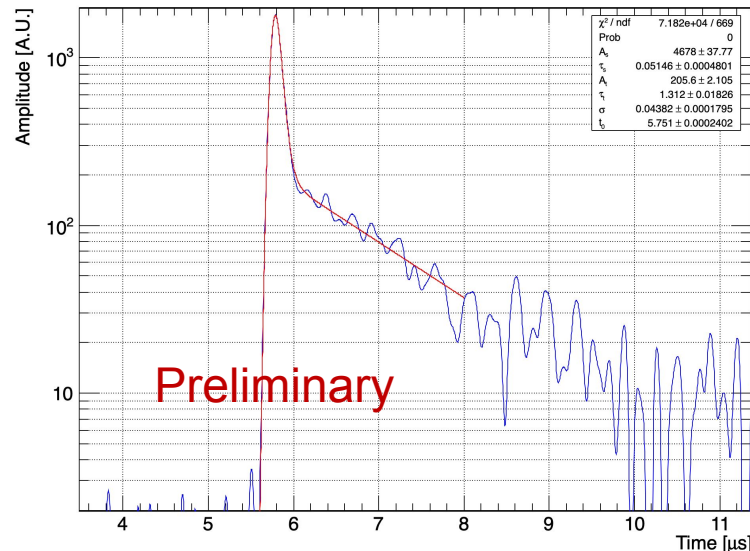
XA-SC - LAr purity

- Purity:
 - studied deconvolving muon waveforms
 - high in all fillings >1000ns
 - at most ~1% effect on PDE

day	tau_triplet [ns]	error [ns]
04/03/2024	1104	12
05/03/2024	1147	13
07/03/2024	1197	14
08/03/2024	1144	13
12/03/2024	1259	16
13/03/2024	1312	18
14/03/2024	1347	17
15/03/2024	1388	18

day	tau_triplet [ns]	error [ns]
19/03/2024	1116	15
21/03/2024	1192	14
22/03/2024	1206	12
09/04/2024	1198	16
10/04/2024	1181	16

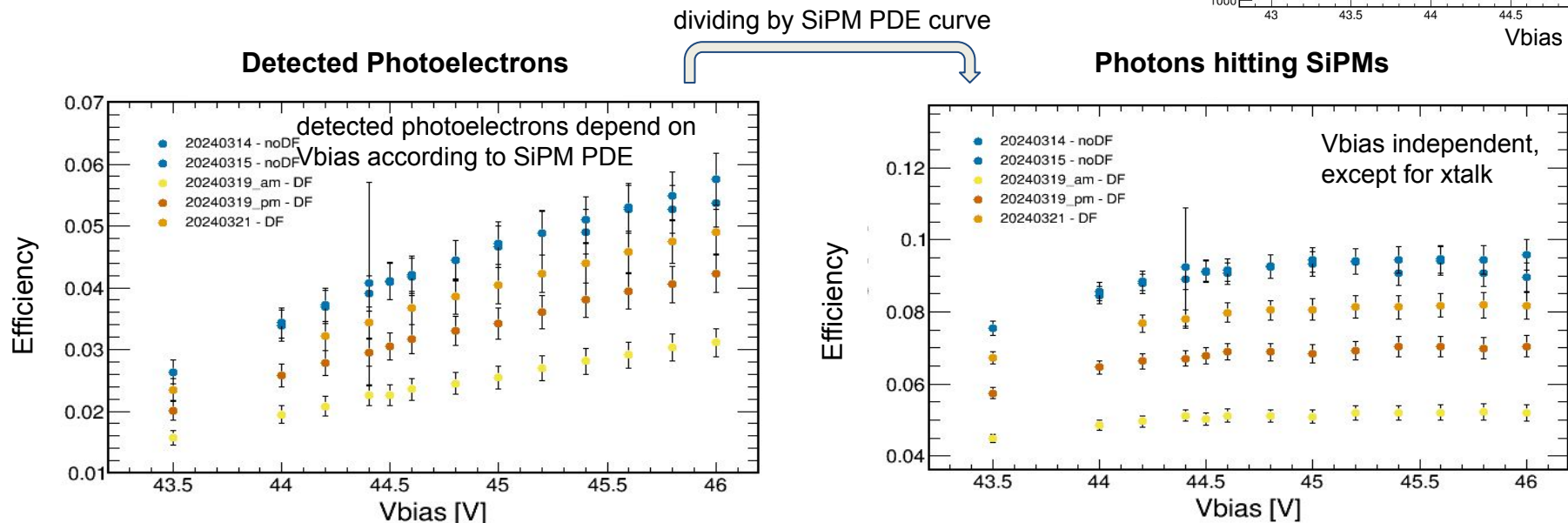
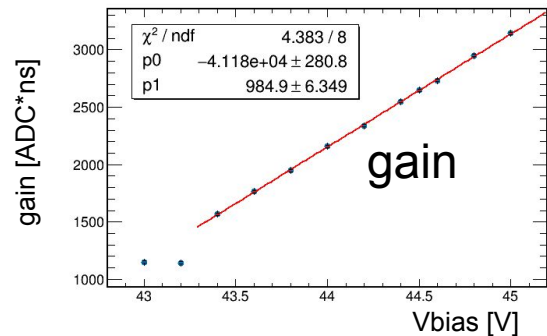
with the current electronics we expect at most a 2% correction with this approximation



- Usually the increase in PDE is correlated with an increase in triplet tau constant
 - the **approximation** only involves the **triplet component**
 - but we observed the **increase also in the singlet component**

XA-SC - alpha voltage scan

- measured alphas varying Vbias
 - not corrected for xtalk



- Subtracting the internal xt, in the right plot might remain an additional component caused by optical xt (see testing conducted in [Valencia](#), Photosensor Meeting 27 Feb 2024, J. Ureña)

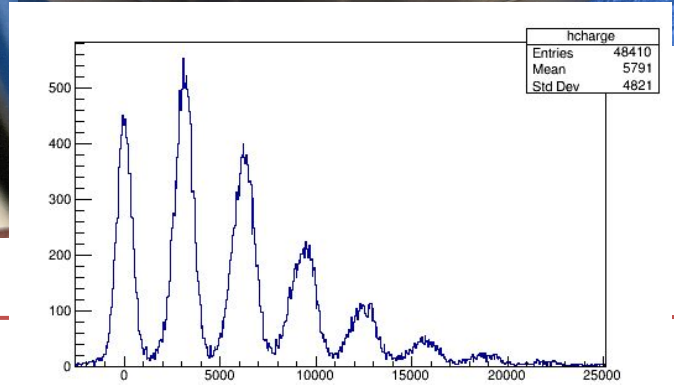
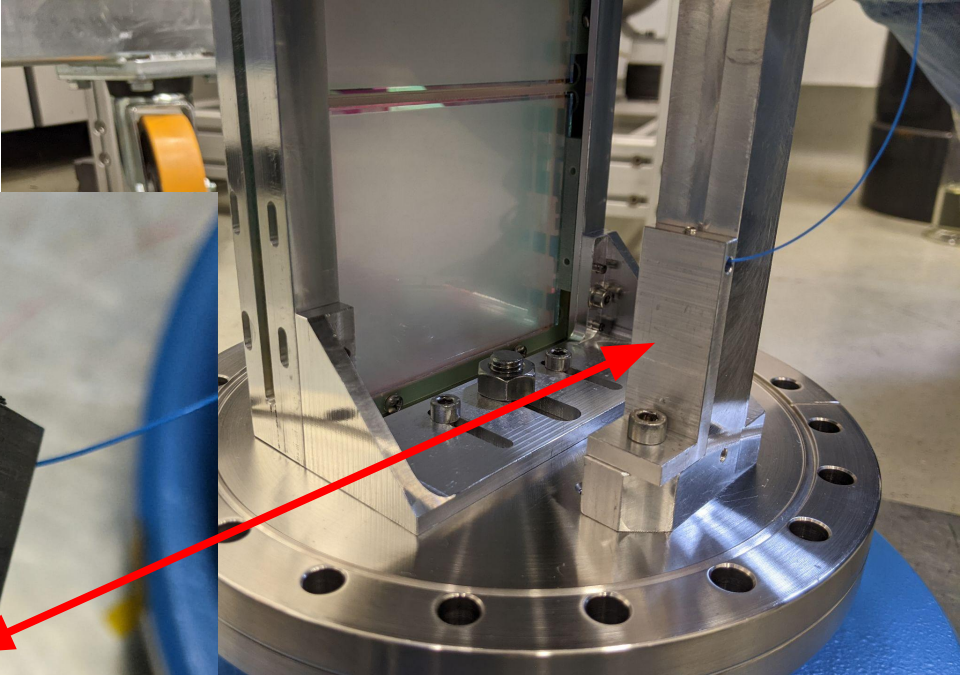
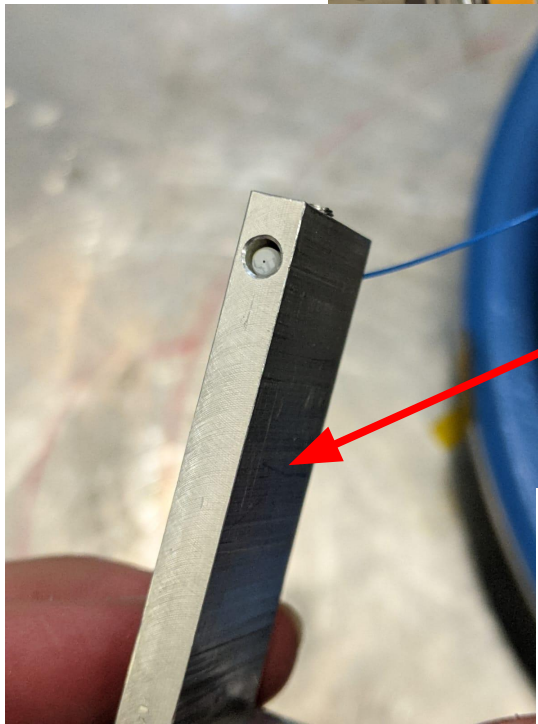
Preliminary Conclusions and next steps

- **Analysis is preliminar and still ongoing.**
- We can already say that:
 - with the baseline design **DFs increase PDE (+10-15%)**
 - when increasing the light trapping in lg (cut + VB) the **DFs become less effective** (possibly degrading PDE)
- The **2 piece WLS light guide (40° cut)** provides a **+10-15% increase in PDE**
 - 2023 measurements give the combined effect of (cut+VB) no disentangling
 - 2024 measurements allowed to disentangle the two components (wls width, cut)
- **Light guide edge sealing (Vikuiti blocks) increases PDE** as a function of the gap at cold between SiPM(Vikuiti) and light guide edges **(+20-50%)**
 - high variance (difficult to control variables)
- Test module/setup variance related to disassembly/reassembly gives (a minor) uncertainty on conclusions.
 - Data collected w. warm transformer bypassed(no undershoot) tbd

Backup

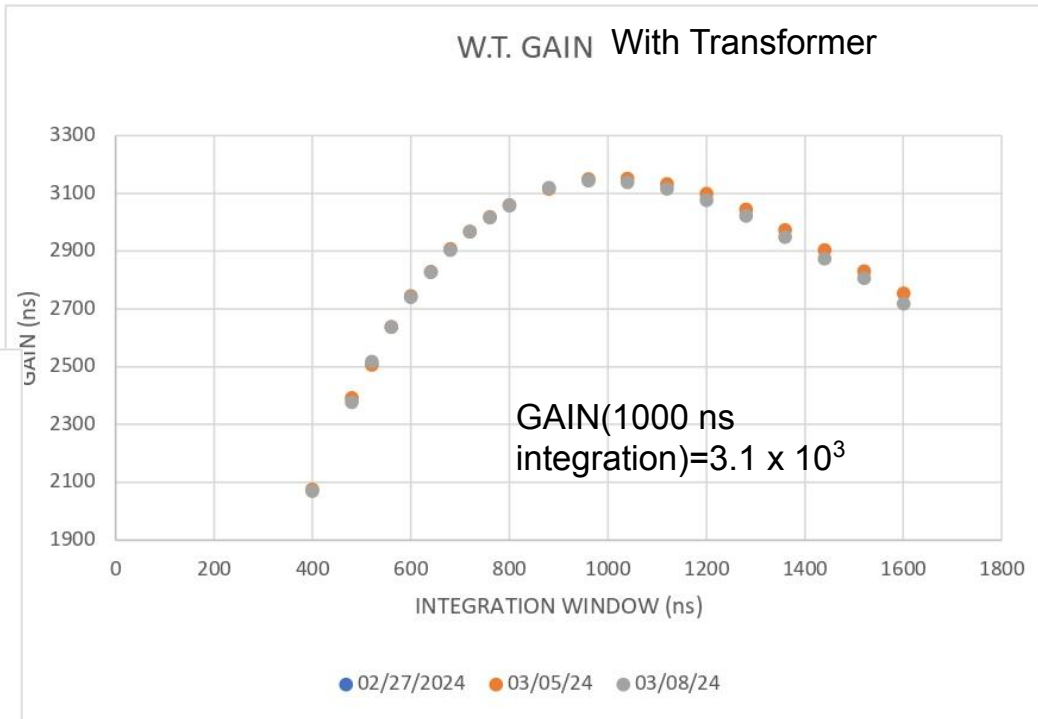
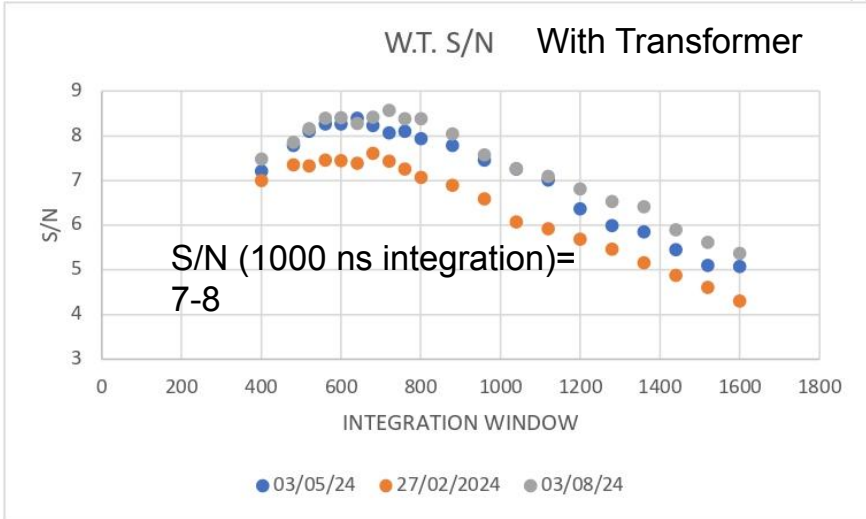
XA-SC - MiB test setup upgrade

- added **optical fiber**
 - mounted next to the source rail
 - we can now **trigger on sphe**s instead of searching for them in alpha pretrigger
- new **second stage** (warm) electronics **with transformer bypass**
 - 3% undershoot
 - **now under study**

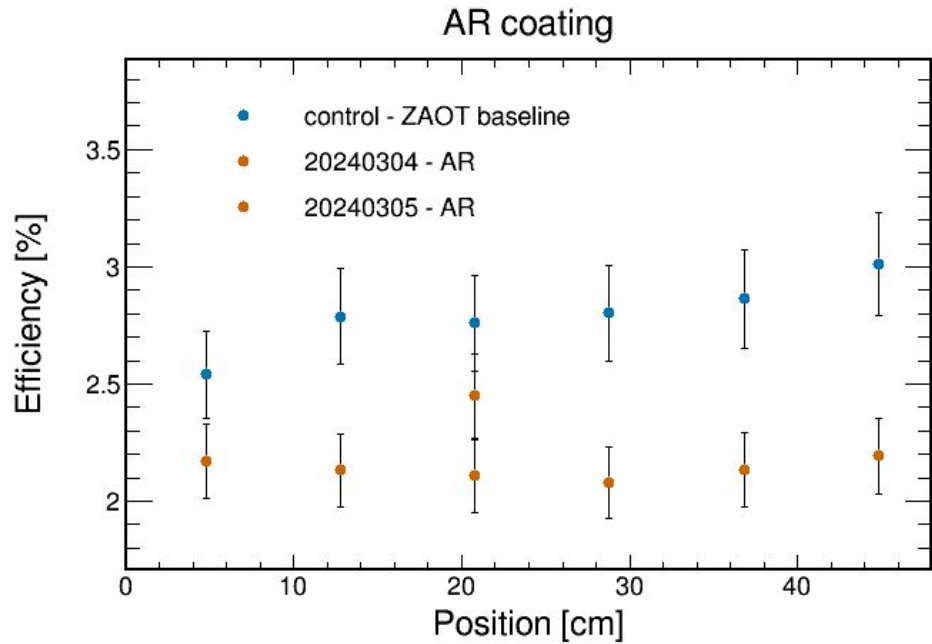


XA-SC - MiB setup upgrade

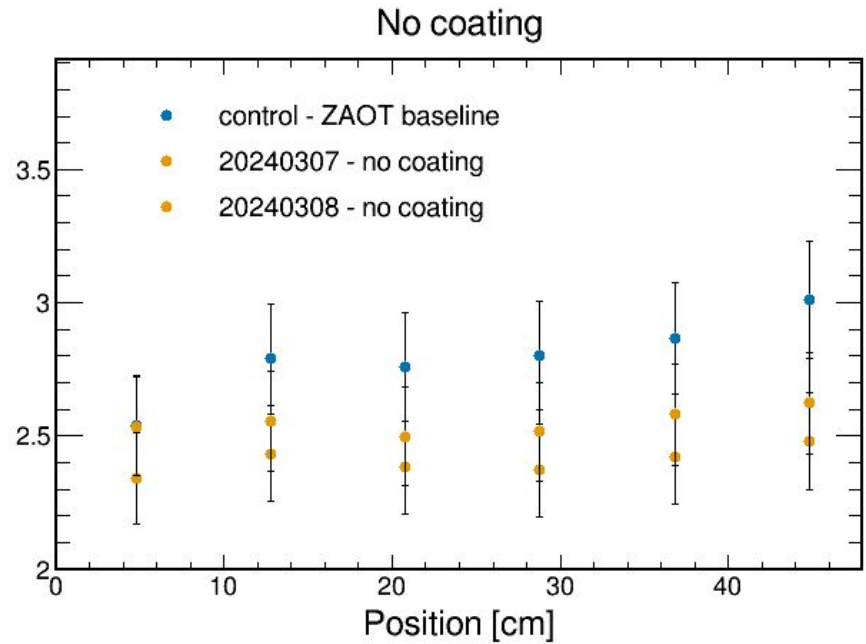
- electronics gain is stable throughout the measurement campaign
- **consistent within 2-3 % with the value adopted in 2022-2023 (spe search in the pretrigger)**



XA-SC - integrated charge increase over time

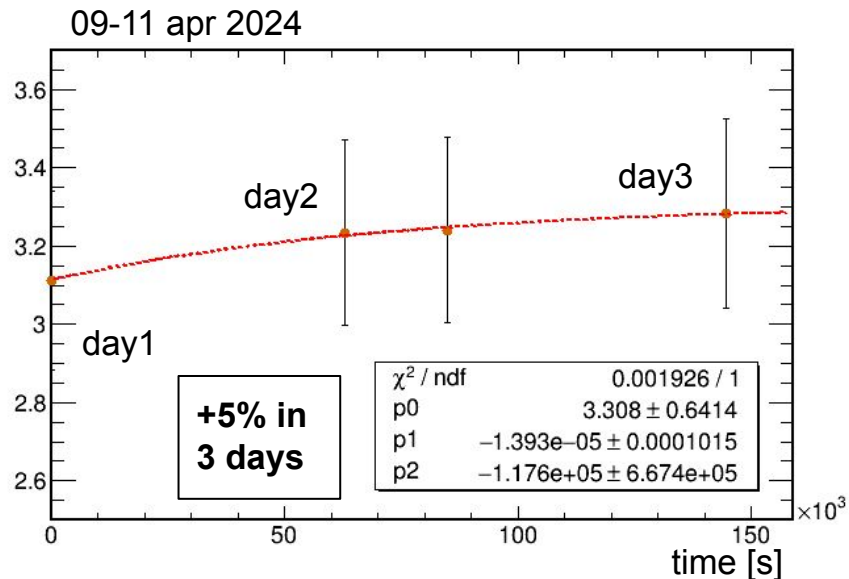
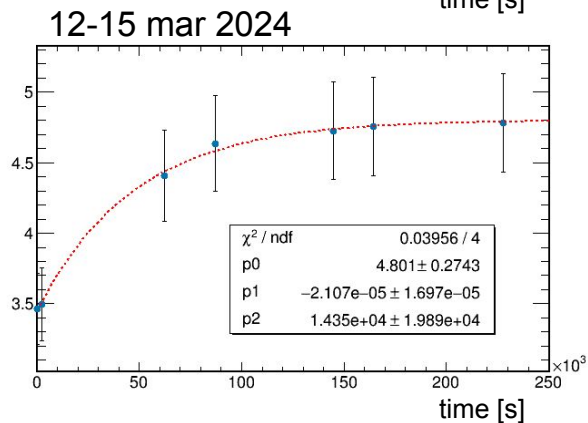
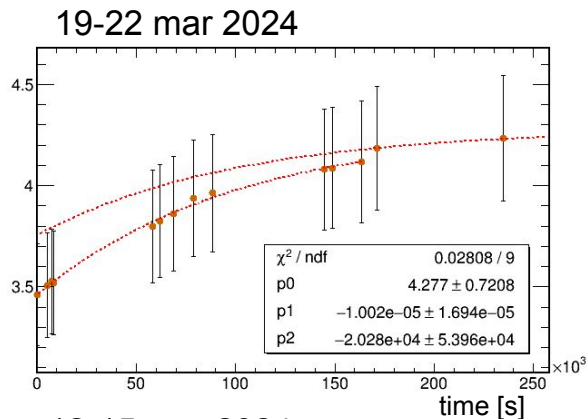


+10%



+5%

XA-SC - integrated charge increase over time



- the increase over time is usually limited
 - all days have been shown in efficiency plots, in previous meetings slides
- possible dependence on filling procedure
 - under study