HD Supercell PDE measurements in LAr @ MiB: improving light guide sealing

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HD-XA Supercell PDE measurements & simulations

- **measurements** from january and march with **increased light sealing**:
  - **same SC** with **Vikuiti on G10 blocks between SiPMs**
  - **Vikuiti** on one of the **long light guide edge**s
  - **new light guide** (protoDUNE run2 batch)
  - **new light guide** (**ZAOT vs OPTO**)
  - **new light guide** (**OPTO only**)

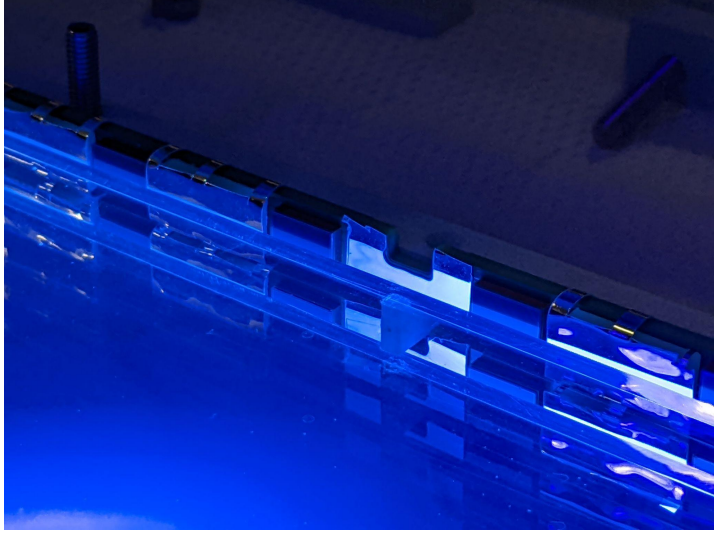
- optical simulation to study ***PDE dependence*** on:
  - light guide edge - SiPM (Vikuiti) **distance**
  - different **light guide configurations**
  - WLS dye concentration (**attenuation length**)

From the 17/01/2023 PhCollector meeting

HD-XA Supercell with Vikuiti blocks

- placing Vikuiti closer to the light guide provides better light sealing
    - could be the reason the previous 2-cell XA version had better PDE

- this week we will measure a SC with Vikuiti on G10 blocks between the SiPMs to verify
- we also planned a measure with half the SiPMs blinded with Vikuiti to check if a better light sealing could allow a lower number of SiPMs to collect the light
    - dependent on the PMMA absorption (known only a lower limit)

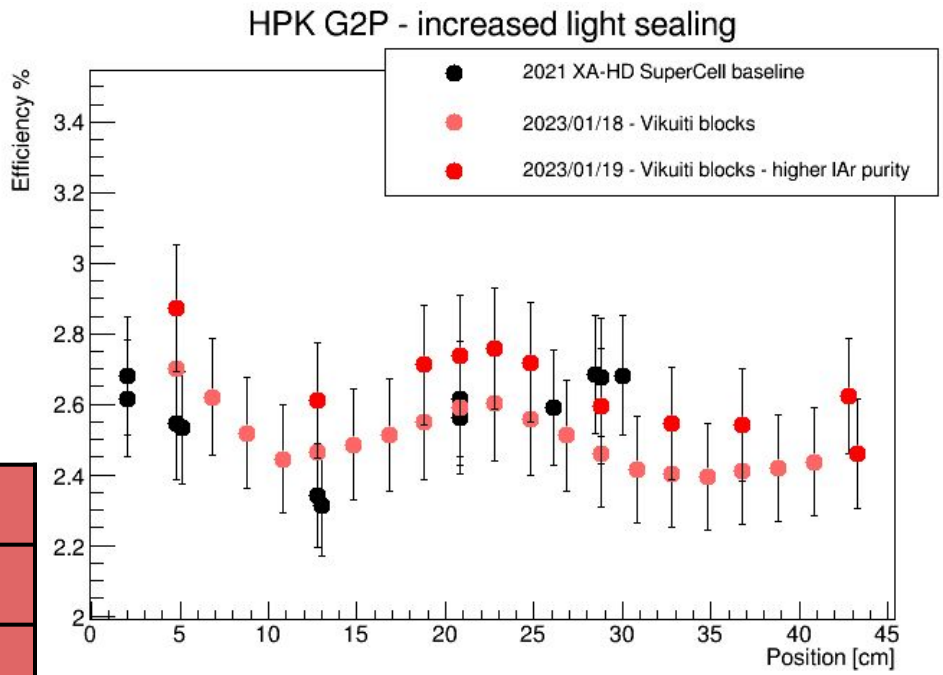


18-19/01/23 - Increased light sealing

- for this measurements the **same SC from 2021** has been used **(frame, HPK SiPMs, G2P lg and OPTO filters)**
- **added Vikuiti covered G10 spacer blocks between each SiPM**

- **...no significant increase over baseline**
- increase in PDE after one day -> higher LAr purity?

measure	baseline	18/01	19/01
avg PDE	2.51%	2.49%	2.64%
% wrt bl	-	-1%	+5%



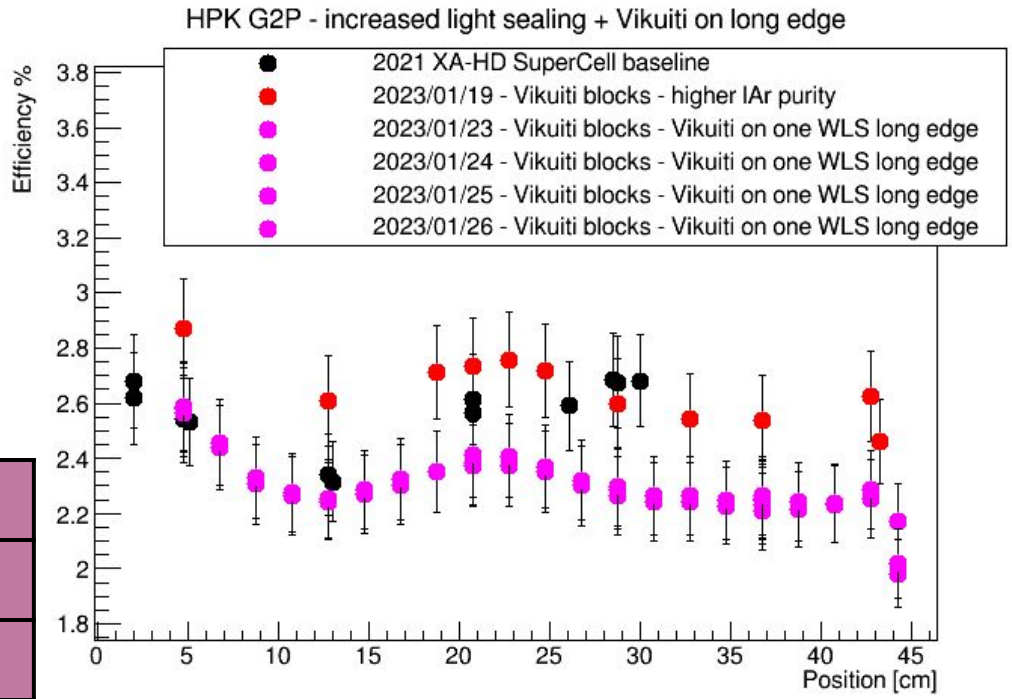
all efficiency values in this talk are WITHOUT x-talk and LAr purity corrections

23-26/01/23 - Vikuiti on light guide long edge

- Vikuiti placed on one of the light guide long edges
  - **⅓ of the SiPM surface blinded (66% active)**

- **lower PDE, as expected, but still 87% of previous meas.**
  - light can easily be reflected to the SiPMs on the other side (~10cm)

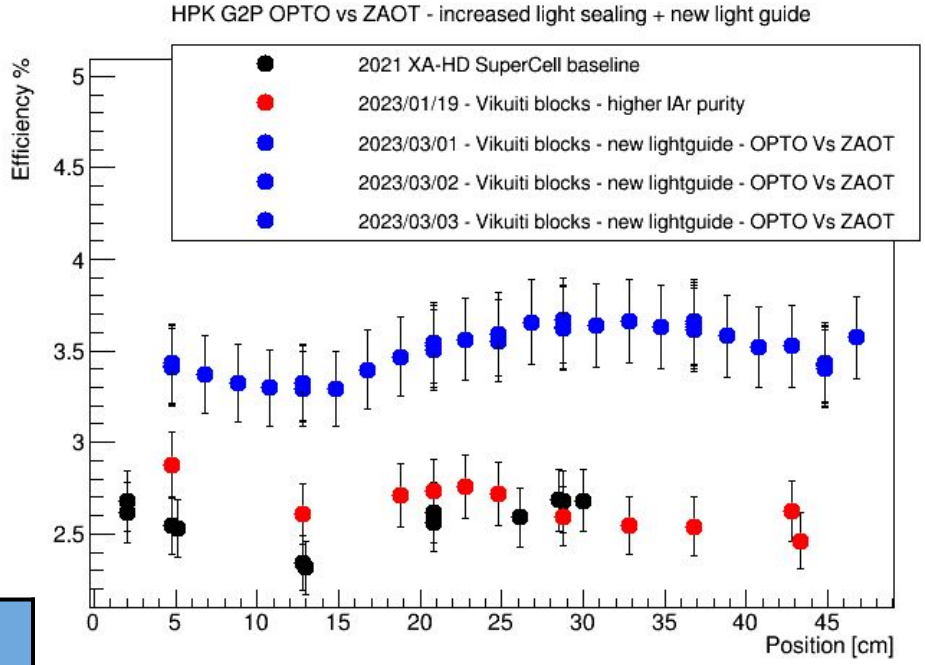
measure	baseline	19/01	23-26/01
avg PDE	2.51%	2.64%	2.29%
% wrt bl	-	+5%	-8%
% wrt 19/01	-	-	-13%



01-03/03/23 - new light guide, OPTO vs ZAOT

- the **light guide** used until last measurement has been exchanged with one from the **protoDUNE run2 batch**
  - same specs but:
  - - slightly wider (92.2mm -> 93mm)
  - - more uniform in width

- **observed 40% increase in PDE wrt baseline as simulations suggest**
  - width?
  - surface finish?

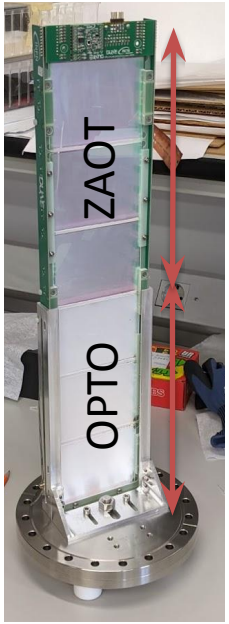


measure	baseline	19/01	01-03/03
avg PDE	2.51%	2.64%	3.49%
% wrt bl	-	+5%	+39%

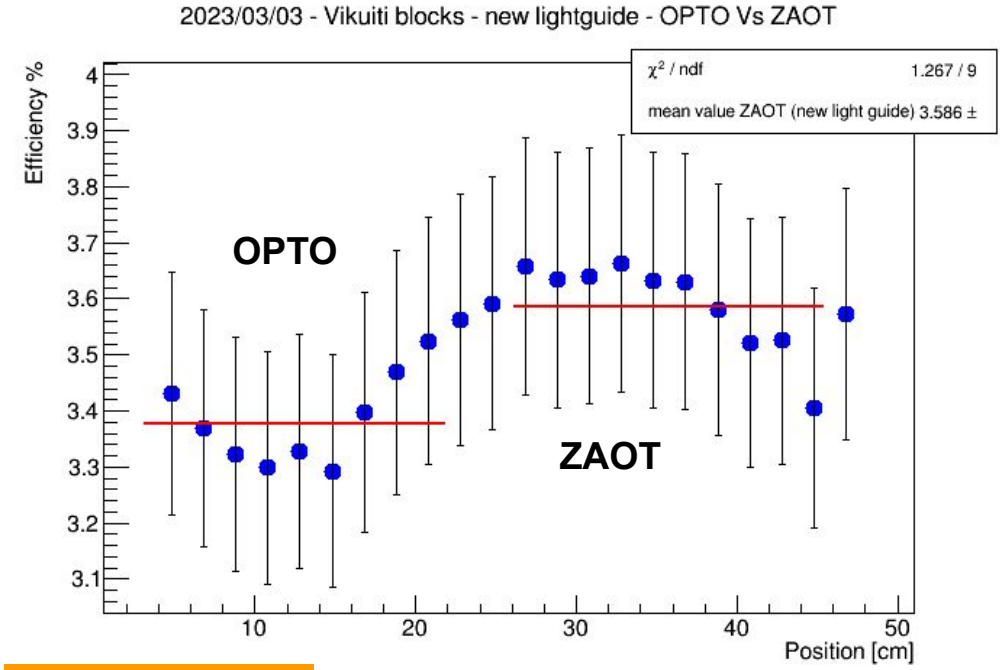
← **average of the entire SC (OPTO and ZAOT)**

01-03/03/23 - new light guide, OPTO vs ZAOT

- **ZAOT filters perform better**
  - hard to quantify because the SC is not divided in two
  - we have planned a measurement with ZAOT only



dichroic	PDE [%]
ZAOT	3.58
OPTO	3.38

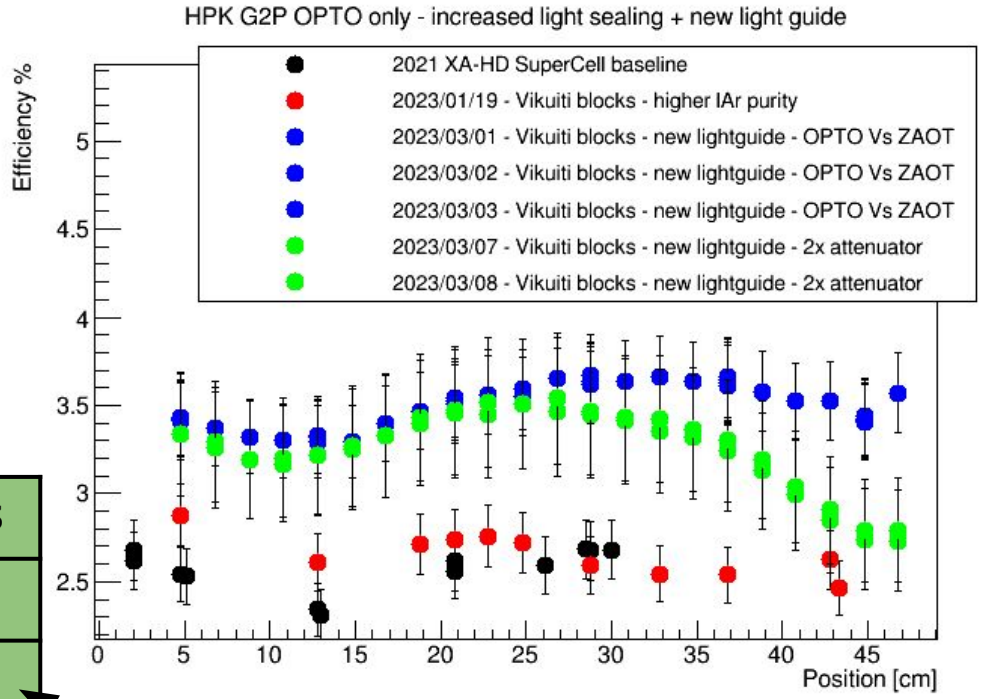


6% higher PDE (lower limit)

07-08/03/23 - new light guide, OPTO only

- **observed same increase in PDE as the previous measurement**
- **OPTO filters perform worse, as expected**
  - decrease in PDE in the top part due to spreading damage on pTP

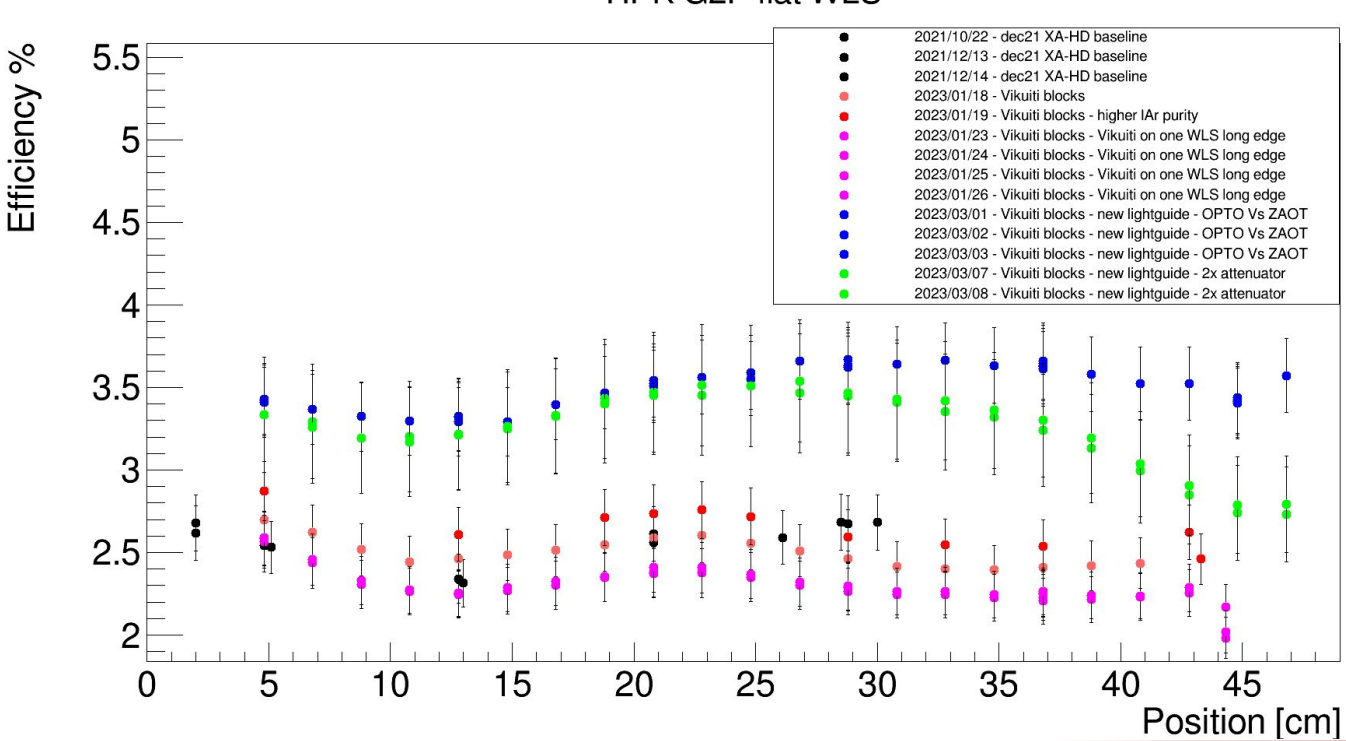
measure	baseline	19/01	01-03/03
avg PDE	2.51%	2.64%	3.35%
% wrt bl	-	+5%	+33%



average of the SC up to 37cm due to pTP damage on the last 2 filters

Measurement summary - January and March 2023

- **higher PDE likely due to better light sealing**



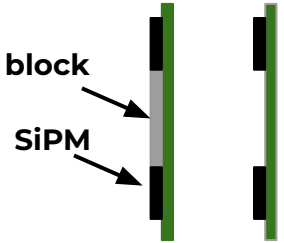
- **baseline 2021**

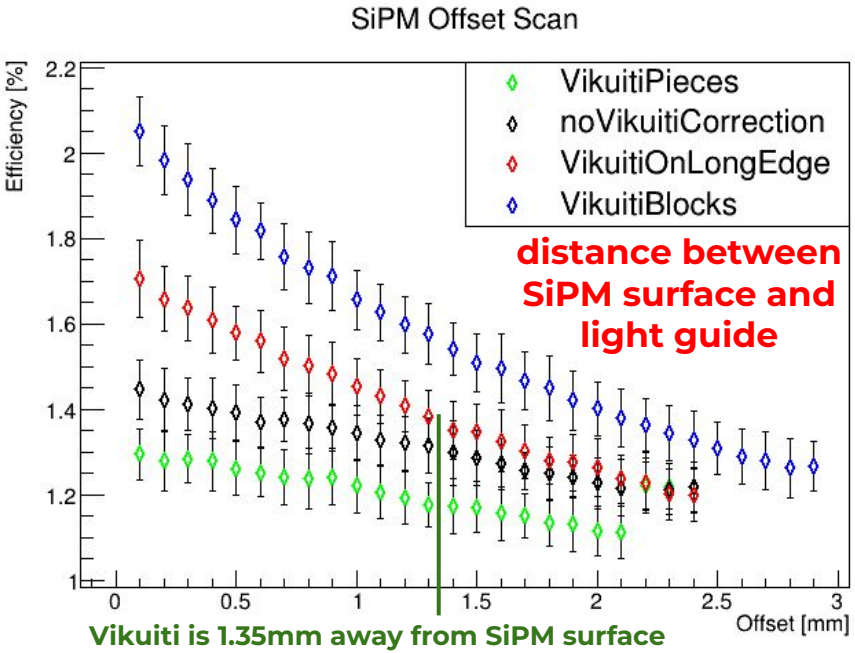
+ improved light sealing
- **same config**
- **Vikuiti on long edge**

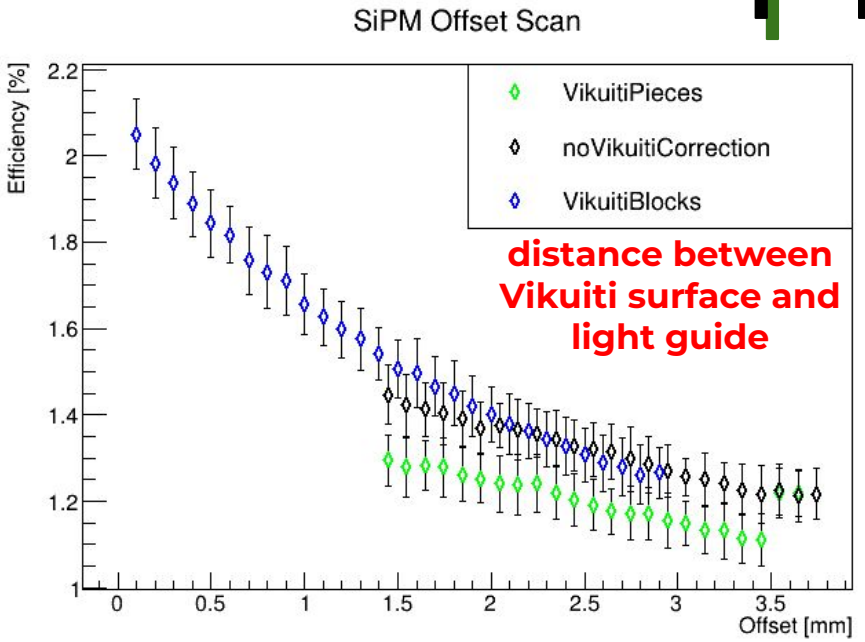
+ new light guide:
- **OPTO vs ZAOT**
- **OPTO only**

Simulation - distance between SiPMs and light guide

- **PDE is strongly dependent on the SiPM-lg distance**
  - **distance of the Vikuiti reflector** seems to be the main factor

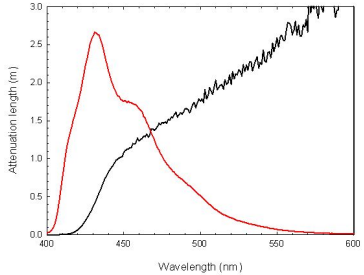


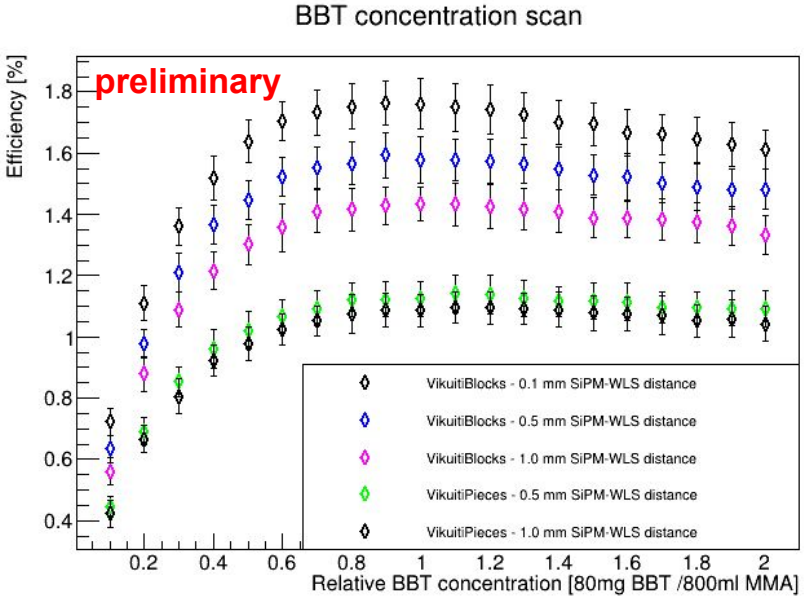




Simulation - WLS dye concentration (Attenuation length)

- G2P provided us the **attenuation curve** of the **PMMA with BBT dye**
  - **attenuation length depends on the BBT concentration**
  - through simulation, different attenuation curves can be tested to **obtain the optimal concentration for a given geometry**





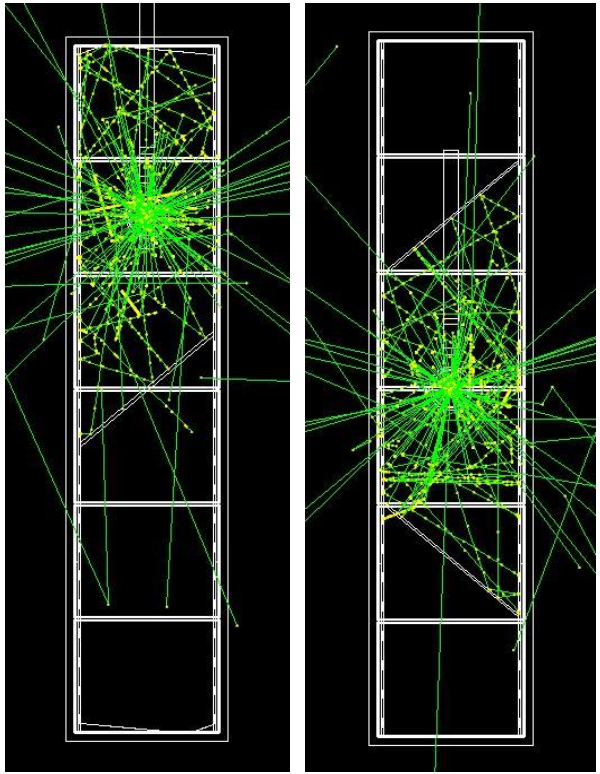
- the higher the curve the higher the light sealing in the plot shown here
- a higher light sealing increases the maximum light path
  - light is better trapped
- a lower dye concentration allows light to travel more in the light guide

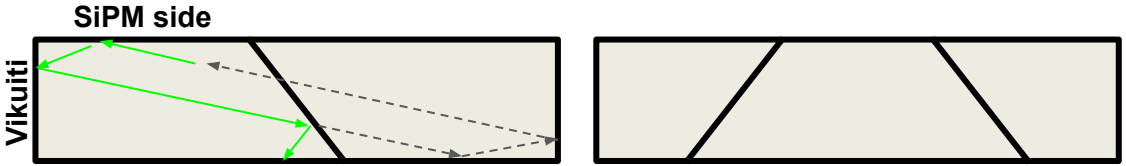
=> an optimum is found at lower dye concentration when the possible light path is higher

Simulation - light guide configurations

- **a different geometry of the light guide could improve the PDE**
- **cutting the lg with an angle (about 40°) can help more light escape**
  - also decreases the distance light has to travel to reach a SiPM
  - mechanical constraints?

- simulated configurations:
  - **2 piece WLS, one 40° cut in the middle**
  - **3 piece WLS, two cuts (+-40°)** (problem with lg supports)





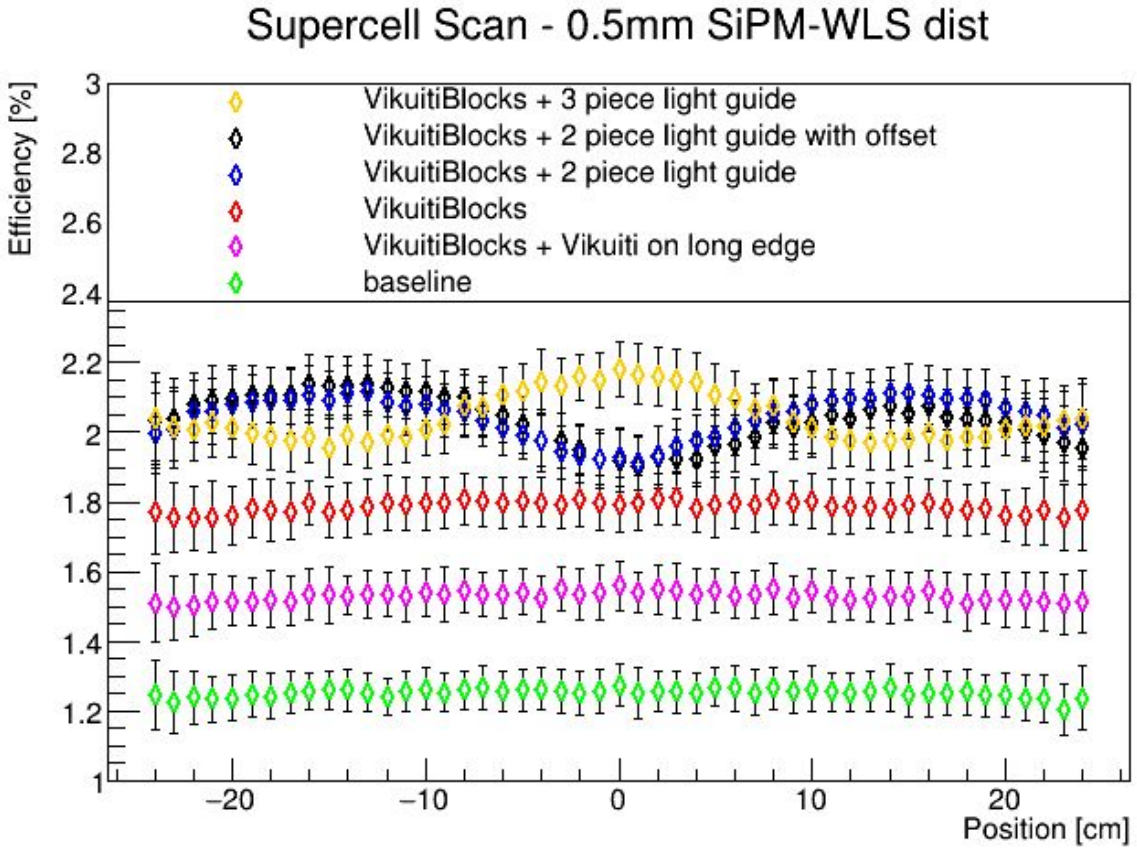
Simulation - light guide configurations

- cutting the SC also causes **disuniformity in the light collection** along the Z direction
  - less increase in PDE near the cut

- **simulated different SC configs Z scans with the SiPM distance fixed at 0.5mm**
  - then average all the positions

- **this plot can vary a lot depending on the fixed variables**
  - SiPM distance
  - light guide attenuation length
  - ...

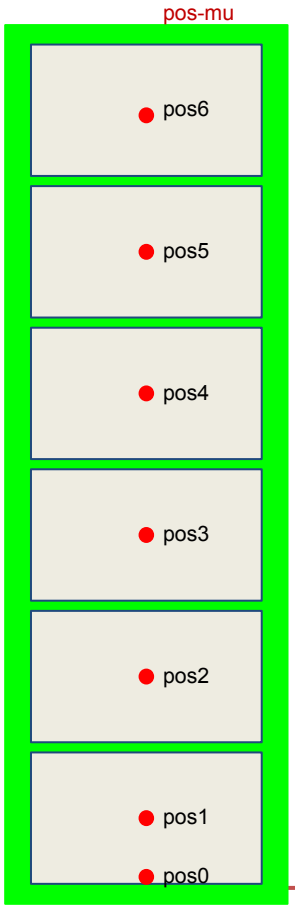
Simulation - light guide configurations



config	average PDE*	% wrt baseline
baseline	1.25	-
VB + VonLE	1.53	+22%
Vikuiti Blocks	1.79	+43%
VB + 2 piece WLS	2.04	+63%
VB + 2 piece offs	2.04	+63%
VB + 3 piece WLS	2.04	+63%

Backup

Method & Data taking



z-scanning of the SC with the ^{241}Am α (5.480 MeV) source at the following positions:

1. **pos0**: (the lowest possible): ~2 cm above the flange.
2. **pos1, 2, 3, 4, 5, 6**: the center of each dichroic filter.
   Acquired: 10^4 x 4 wfms; 20 μs length; ~5 μs pretrigger.

3. Source at the topmost position (~49 cm from the flange) and ~ out of LAr:
   - one **μ run** (10^4 x 4 events; 20 μs, 5 μs pretrigger)
   - one **s.ph.e. run** (10^4 x 8 events; 20 μs length; 1.6 μs pretrigger)

Source-to-dichroic filter distance: (55 +/- 1) mm.

Noise Run: $V_{bias} = V_{bd}$-1V for FFT and filter shape&cutoff definition

From the 17/01/2023 PhCollector meeting

[pTP - glass substrate - dichroic] modeling

- in geant4 the modeling of the pTP deposit and dichroic filter is difficult:
  - need to know pTP refractive index and opacity
    - determine the amount of light able to escape the pTP volume
  - only one dichroic surface can be defined…
    - at least 2 needed since the dichroic behaviour should depend on the material the light is travelling through (lAr or glass)

- i.e. a large improvement in geant4 is given by an increased glass substrate refractive index
  - this changes the a.o.i of the light coming from the pTP to the dichroic
  - a change in the dichroic behaviour wrt material RI could negate this improvement

ZAOT nov22 substrate RI	PDE	% wrt 1.49
1.49	2.30%	-
1.55	2.74%	+19%
1.7	4.02%	+75%
1.8	4.35%	+89%

=> for now the amount of light entering the SC is not accurately modeled…