INDIANA UNIVERSITY

RSL Studies in ProtoDUNE-VD

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ProtoDUNE PDS Sim/Reco meeting
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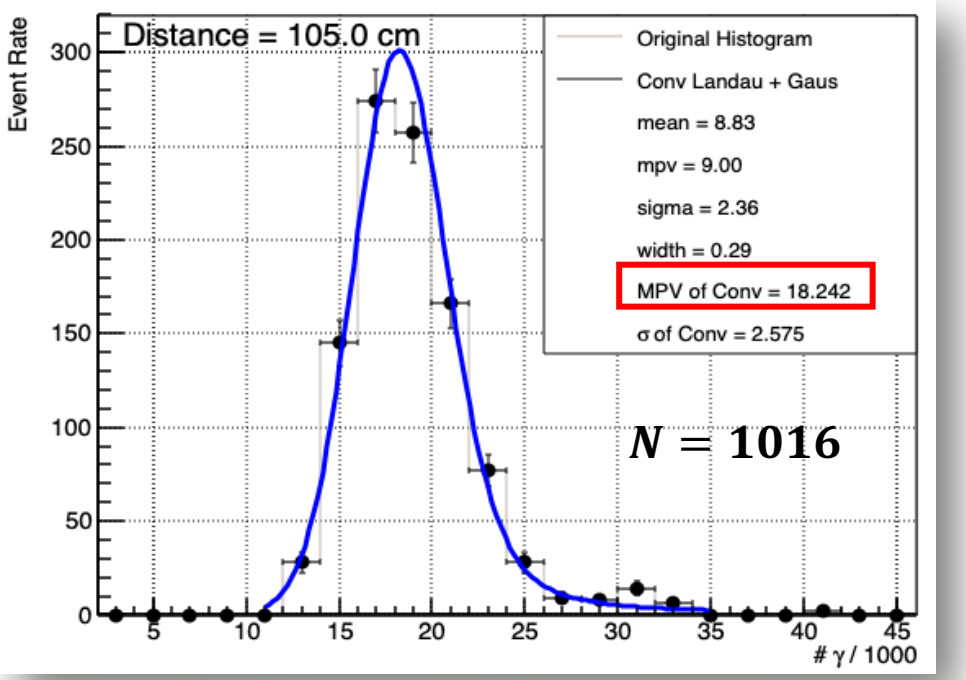
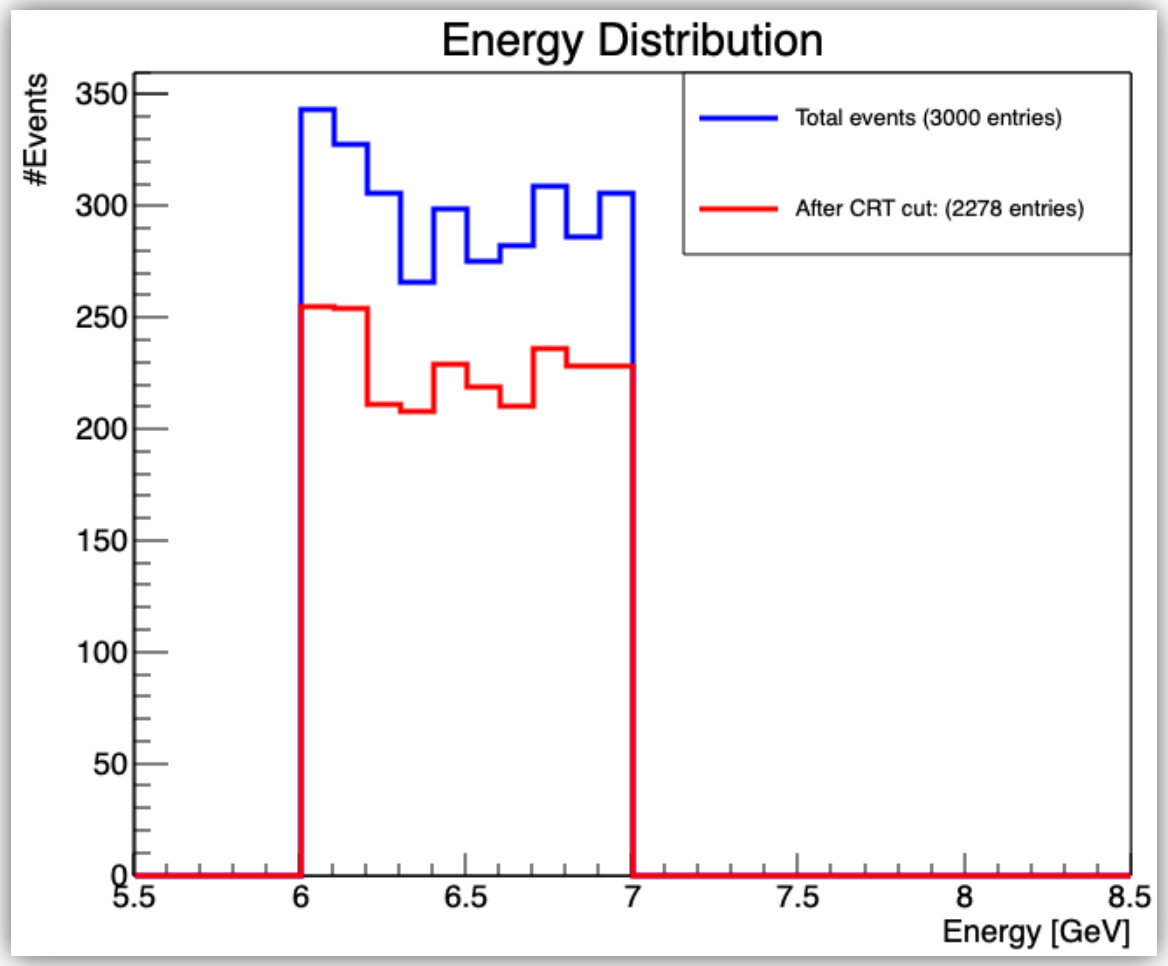
Updates

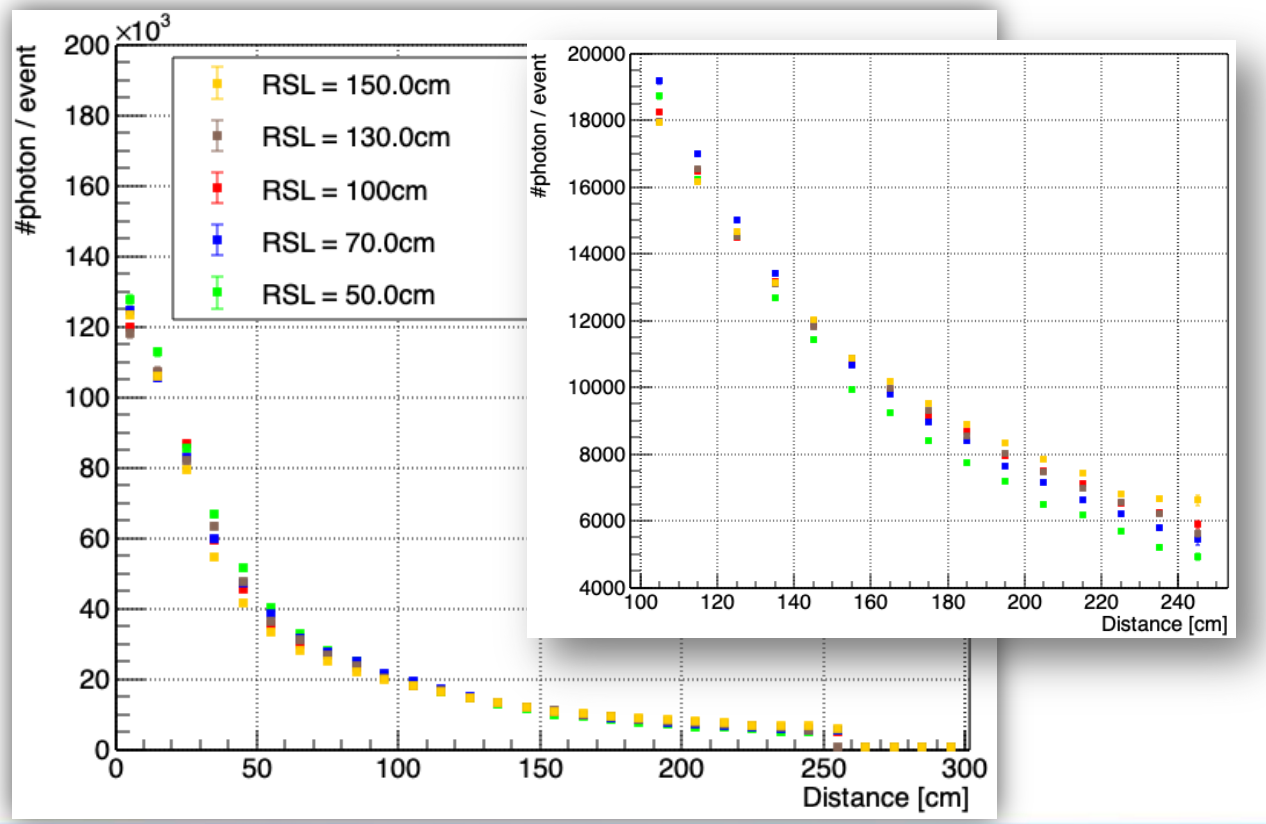
- Previous presentation: https://indico.fnal.gov/event/63845/
- Increase statistics: $2{,}000 \rightarrow 3{,}000$
- Add $\boldsymbol{RSL = 130cm}$ comp graph module
- Thickness of slice: $5cm \rightarrow 10cm$ (increase #event / slice)
- Focus on **MPV** instead of whole distribution, $\sigma_{MPV} = \frac{\sigma_{hist}}{\sqrt{N}}$

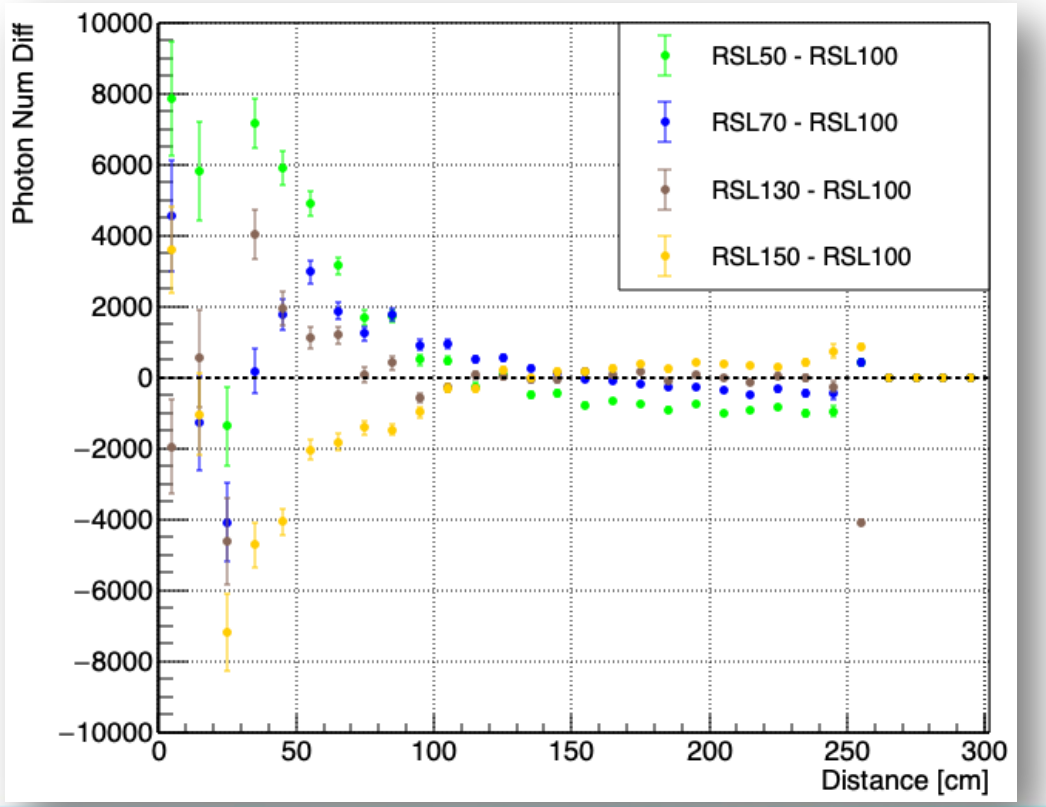




Performance of Cathode X-Arapucas

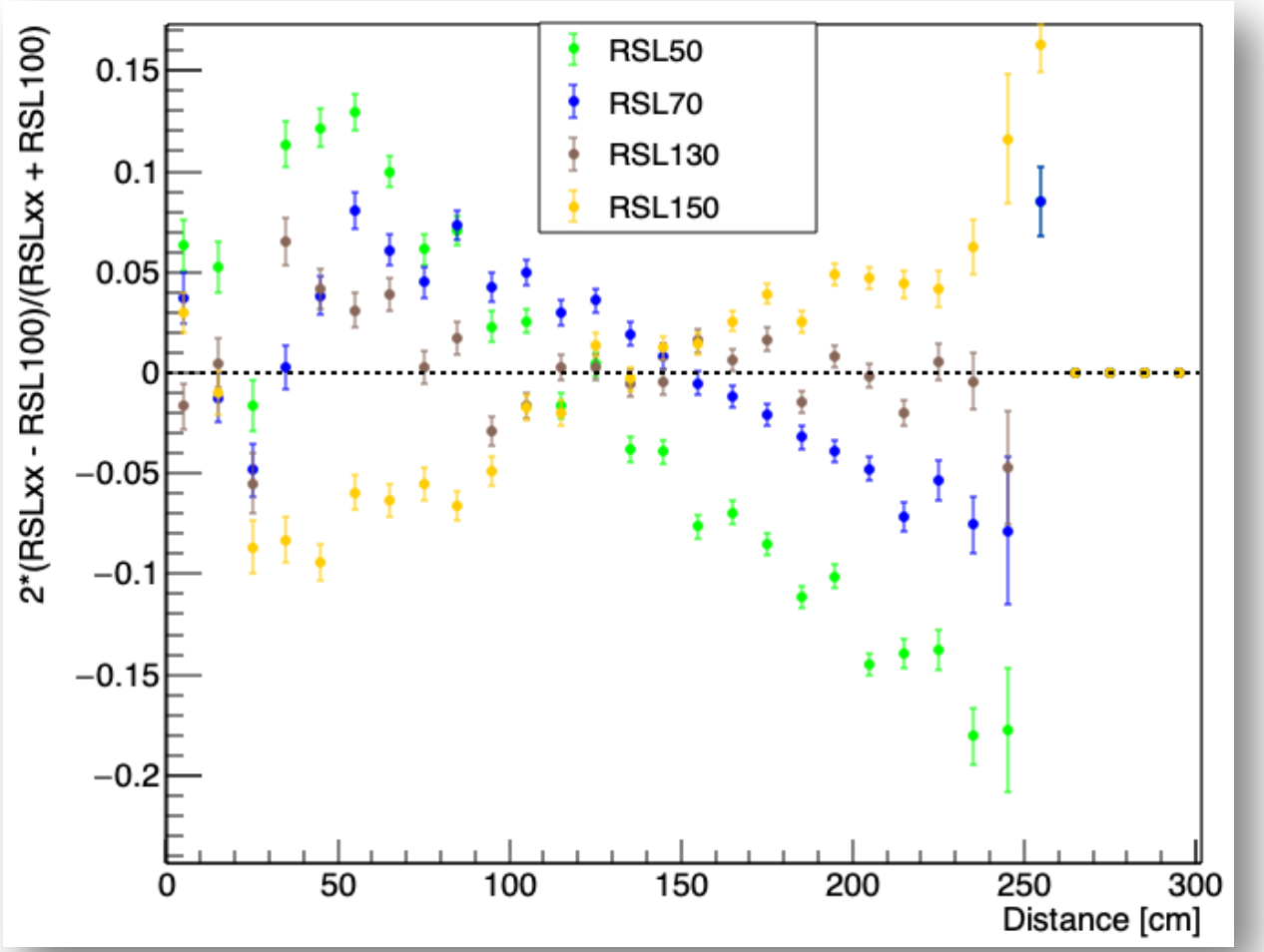
- Date points: **MPV** value with σ_{MPV}
- ($RSL = 100cm$ module) ≡ ($RSL = 99.9cm$ module)
- Good trend for each RSL sample
- Apparent distinctions among RSL50, RSL70, RSL100 and RSL150; RSL130 not clear



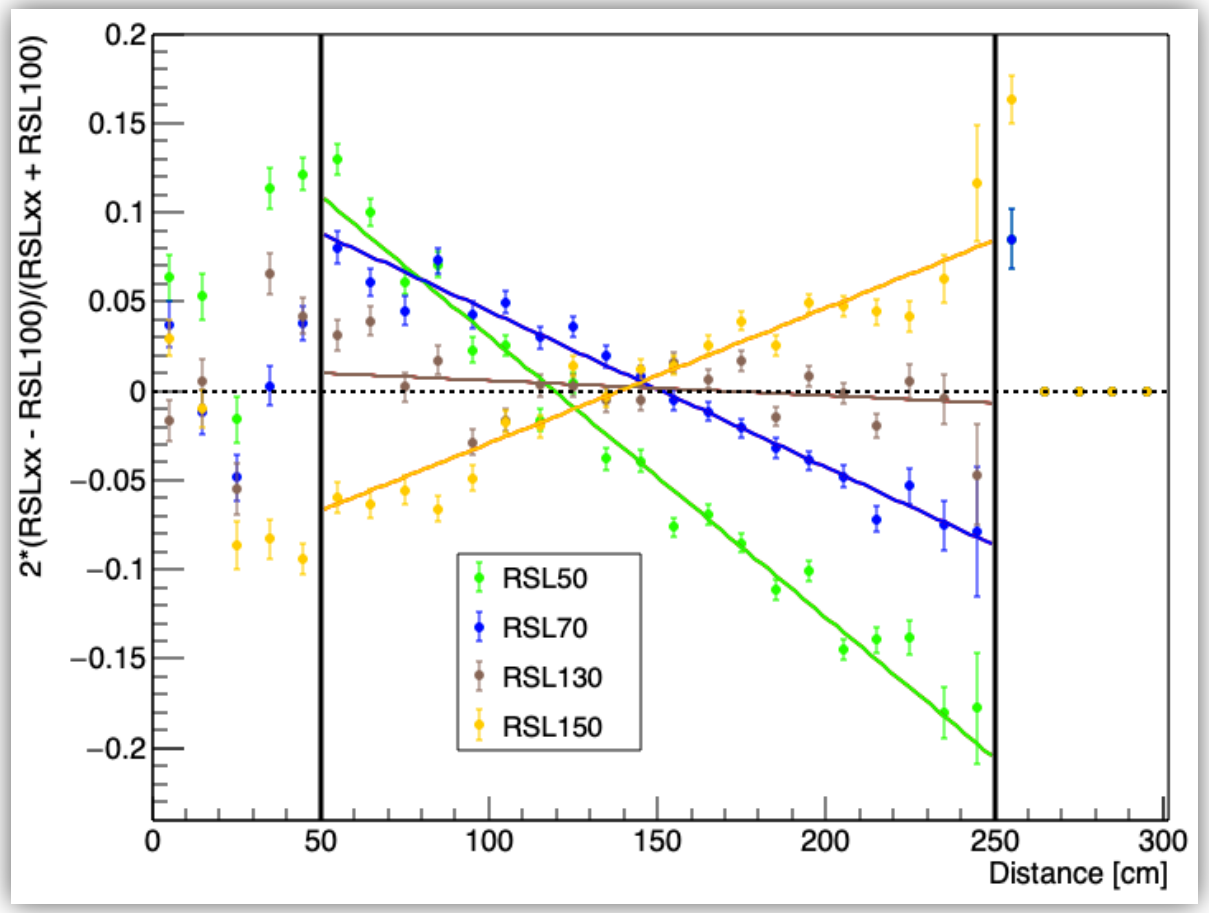


Cathode X-A: “Bias”

- Y axis: $Bias \equiv \frac{2\cdot(A-B)}{(A+B)}$,
- $A = RSLxx, B = RSL100;\ xx = 50, 70, 130, 150$
- Std: $\sigma_{bias} = \frac{4}{(A+B)^2} \cdot \sqrt{B^2 \cdot \sigma_A^2 + A^2 \cdot \sigma_B^2}$



Cathode X-A: Linear Fitting



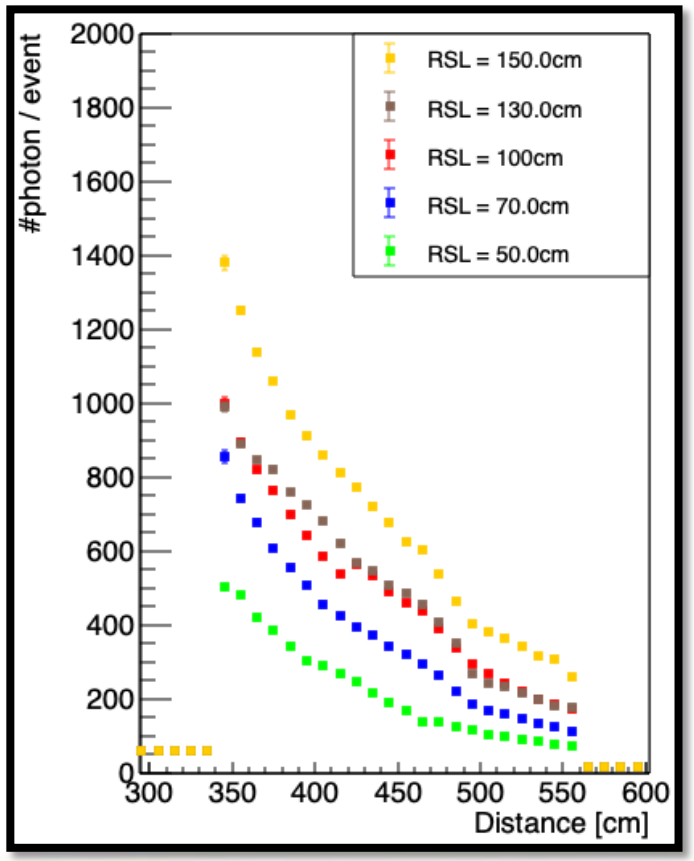
- Fitting range: Distance $\in [50, 250] cm$
- Fitting results: $Bias = k \times Distance + b$

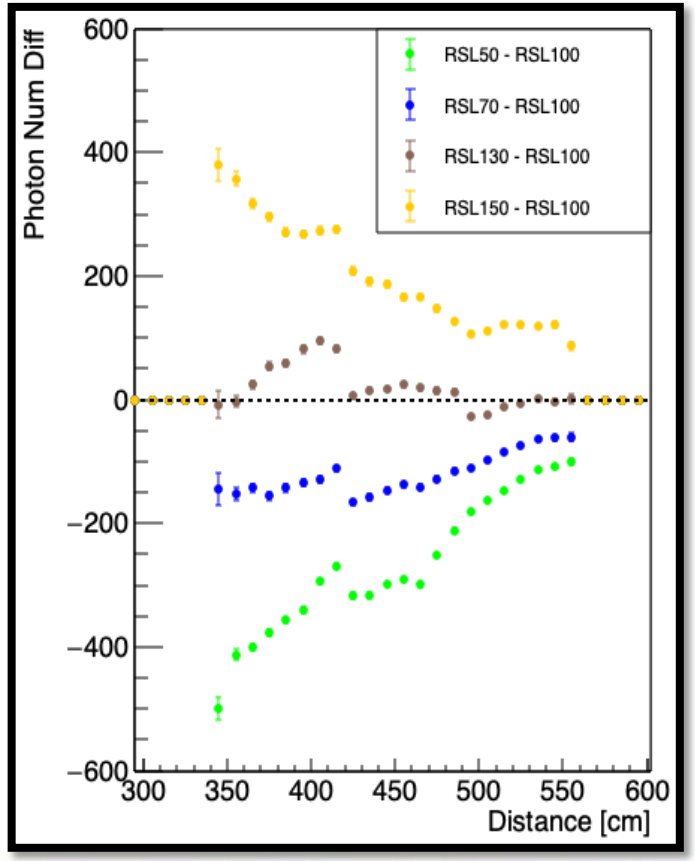
	$k \times 1000$	b	χ^2/ndf
RSL50	1.57 ± 0.03	0.188 ± 0.005	88/18
RSL70	-0.87 ± 0.03	0.132 ± 0.005	31.6/18
RSL130	-0.08 ± 0.03	0.014 ± 0.005	96.6/18
RSL150	0.75 ± 0.03	-0.104 ± 0.005	62.2/18

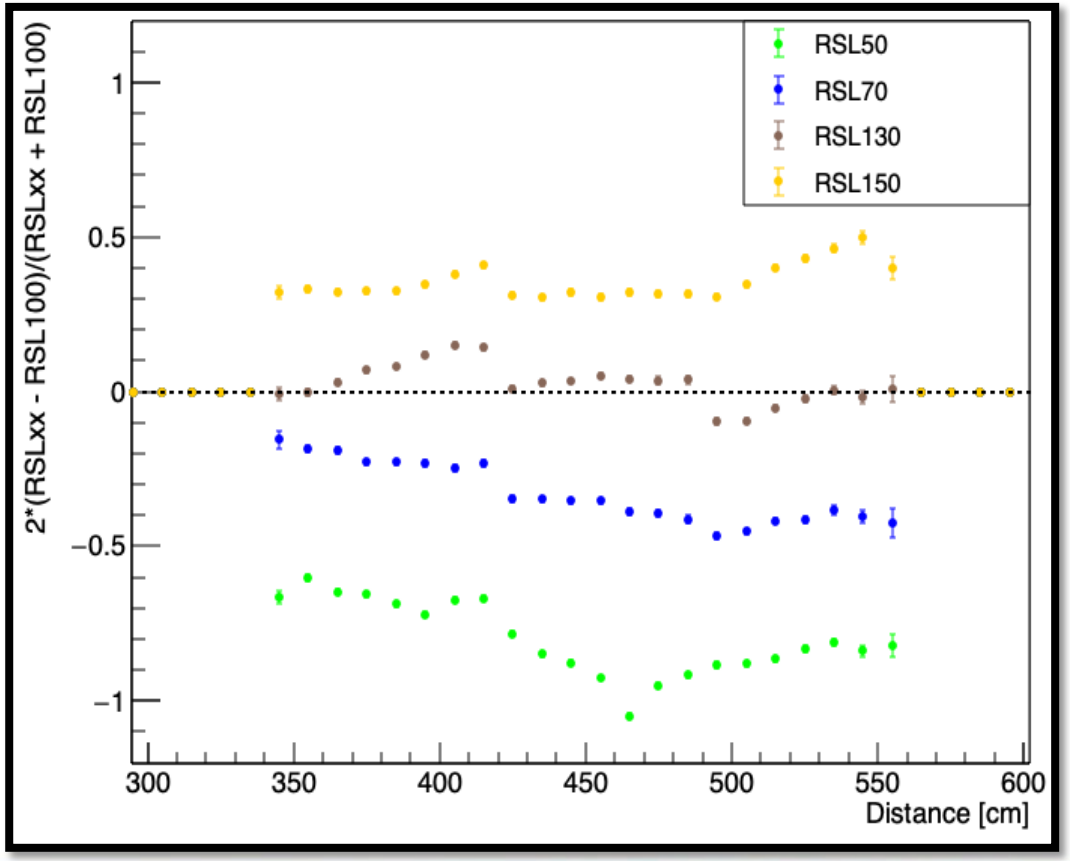
- RSL50, RSL70 & RSL150: good fitting & expected trend
- RSL130: poor fitting, expect $k > 0$

Performance of OpCh 01, 03, 16 & 22

- OpCh 01, 03, 16 & 22: Membrane X-Arapucas away from muon track
- Good distinctions among RSL50, RSL70, RSL100 & RSL150; RSL130 is strange
- Breakpoints @ $Distance = 420cm, 480cm$ ⟵ Dual-peak distributions (opch different, solid angle NOT considered)

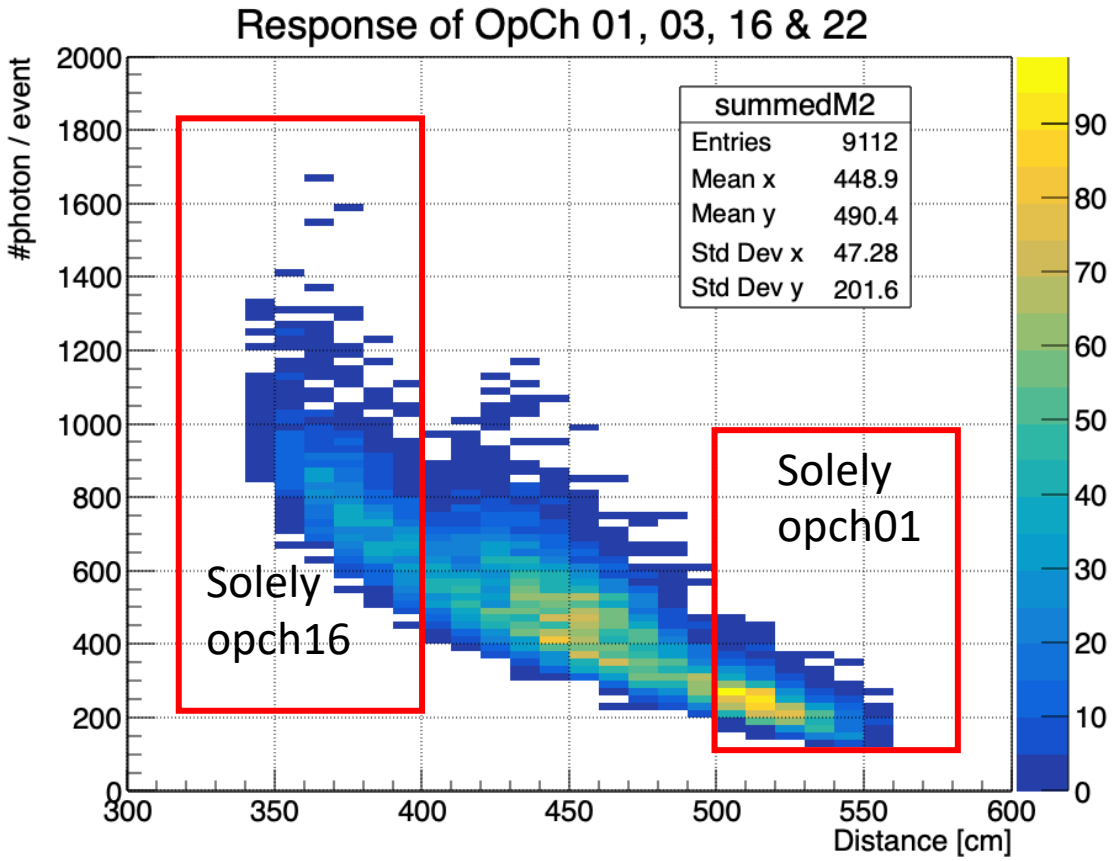


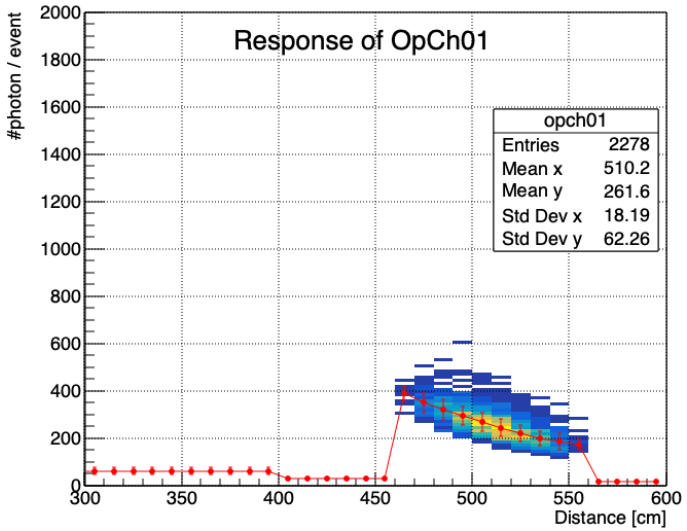


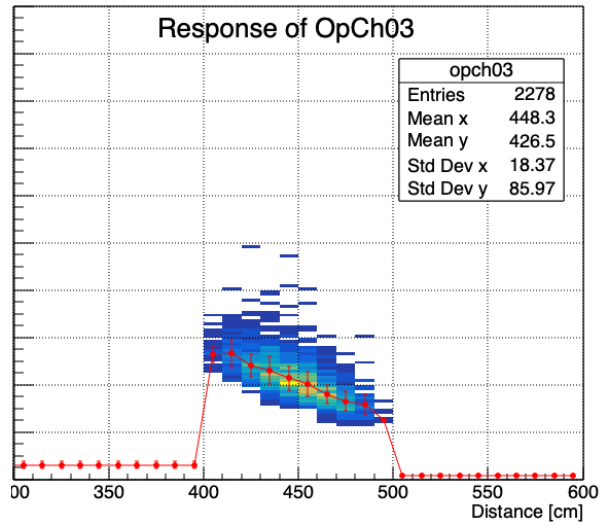


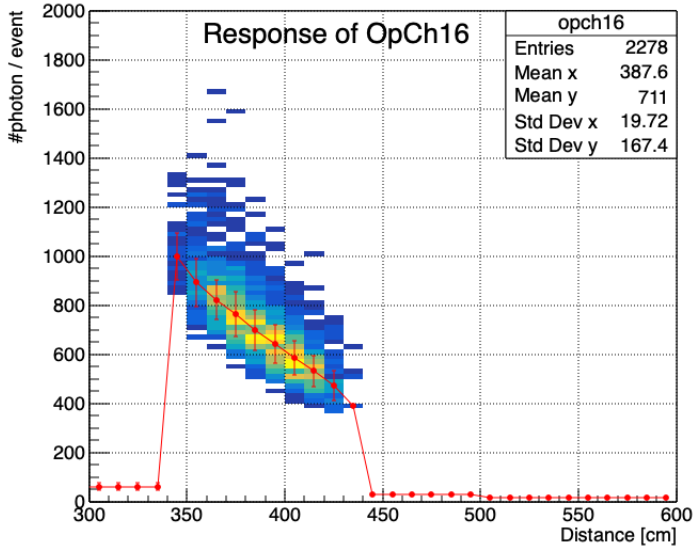
OpCh 01, 03, 16 & 22 Contributions

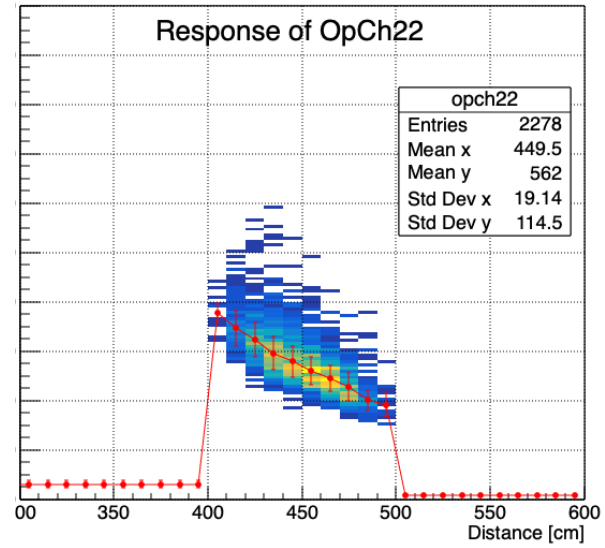
- Based on RSL100, 3,000 events in total





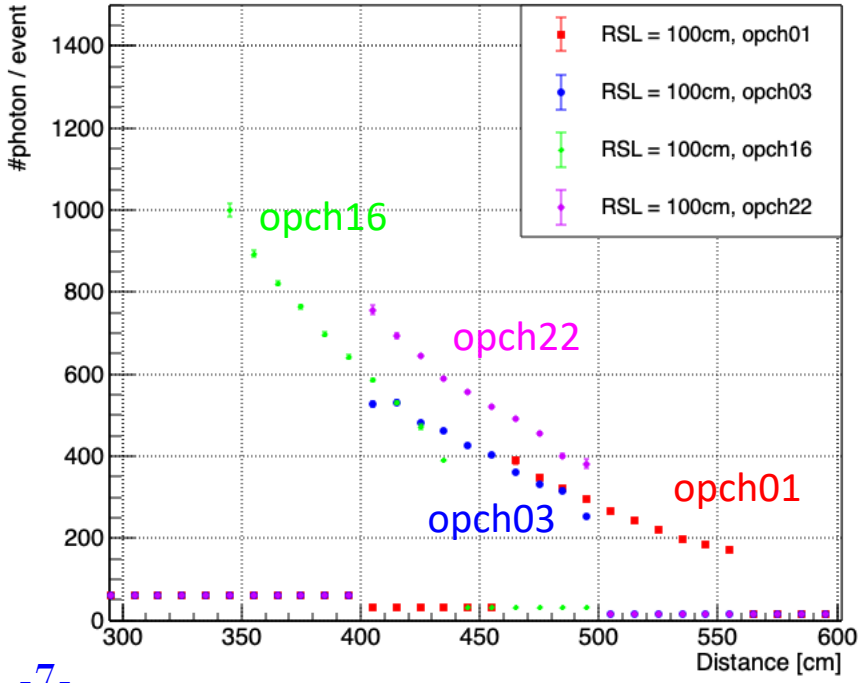


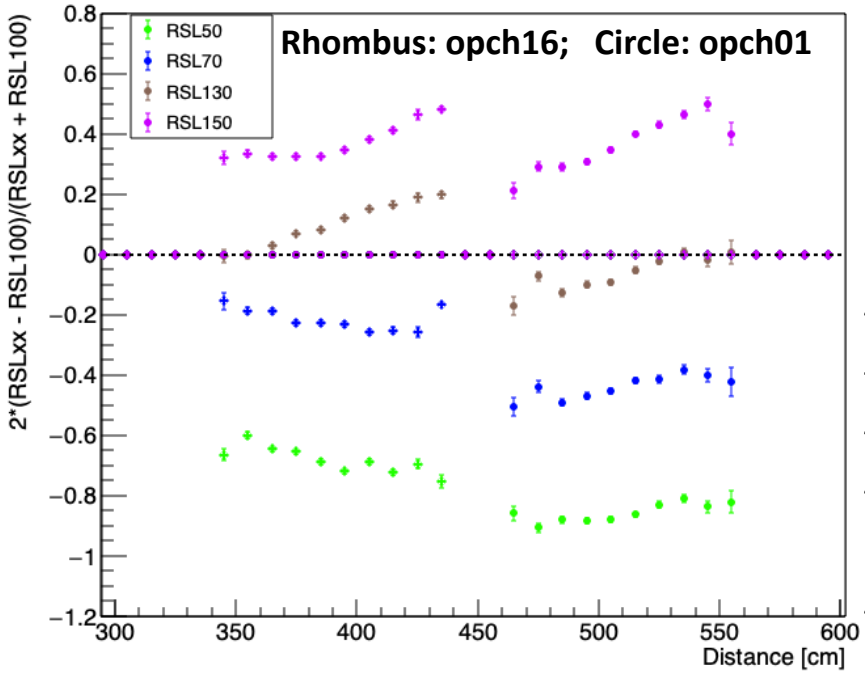


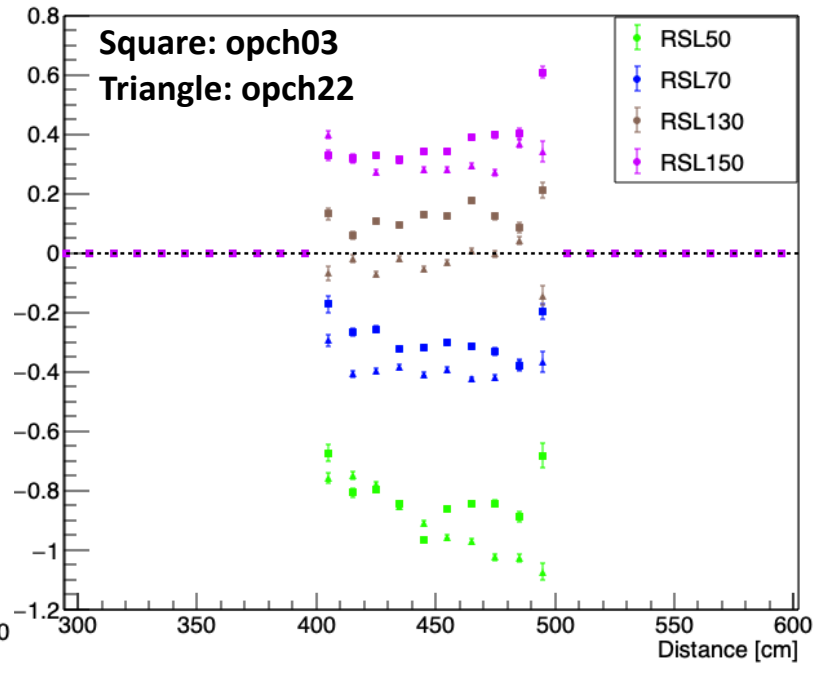


OpCh 01, 03, 16 & 22: Single Fitting

- Fitting: quite good & smooth for different opchs
- Single opch performs differently, maybe improper to combine them and do overall fitting (previous method)
- **Opch01 & opch16**: continuous & good distinctions; RSL130 looks strange
- **Opch03**: RSL150, RSL70, RSL50(certain points can be fixed, better fitting)
- **Opch22**: Not so continuous, need check fitting again

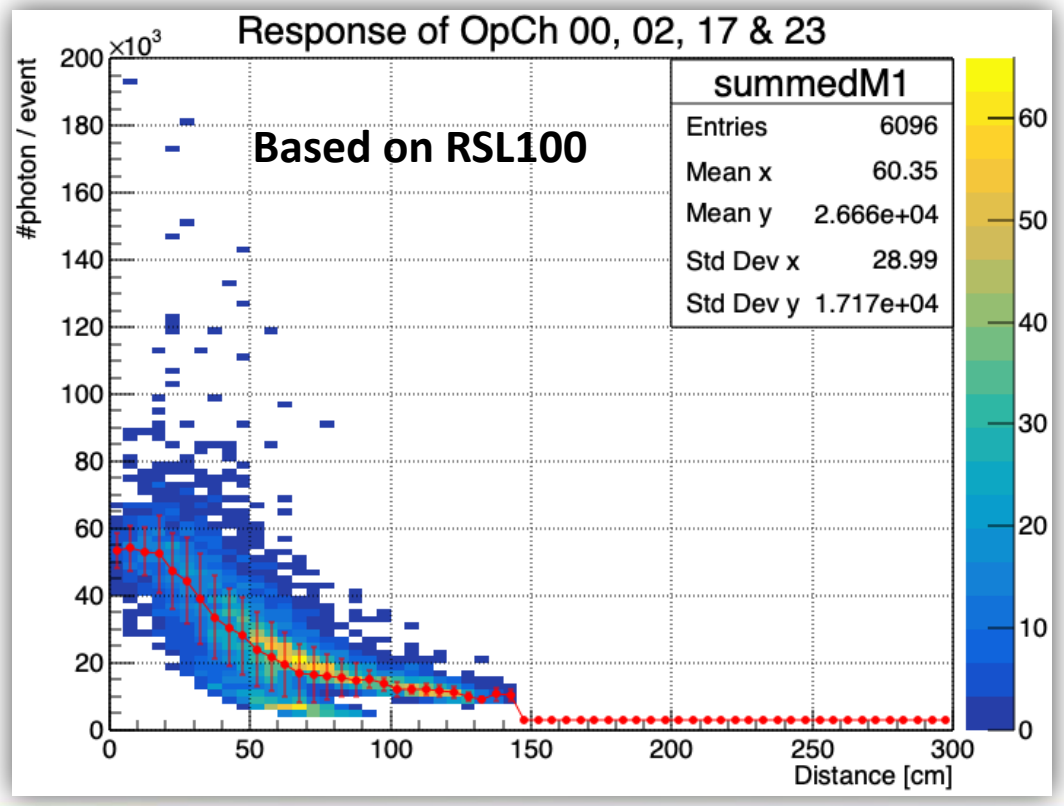


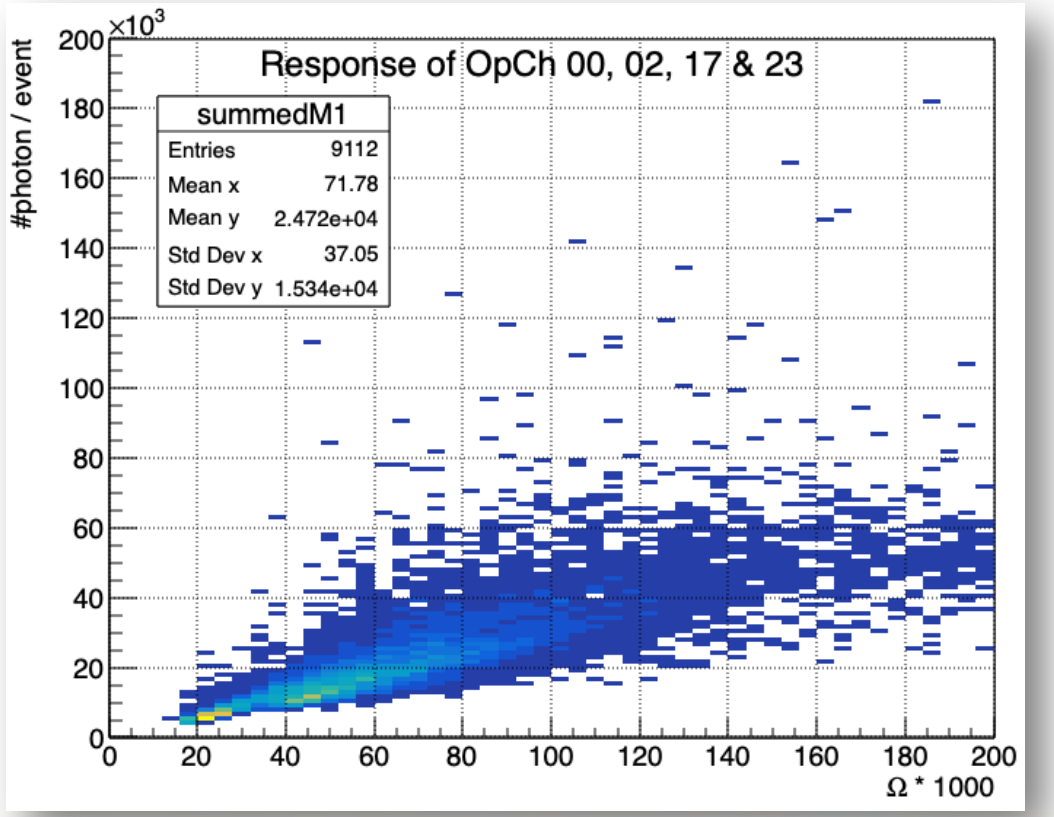




OpCh 00, 02, 17 & 23

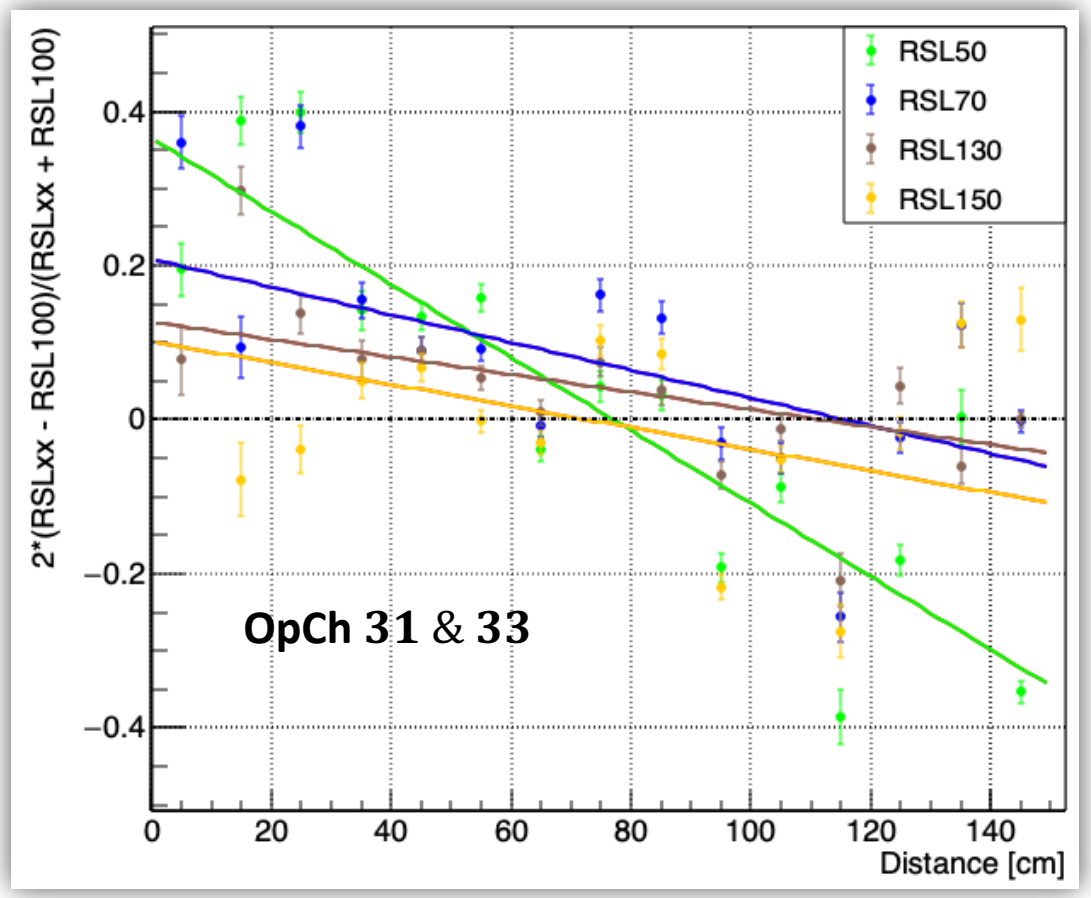
- Previous result (left): fitting NOT good ⟵ Dual-peak distributions (opchs too close to muon track)
- "Distance" NOT good for this group
- New variable: "**averaged solid angle**": choose multiple points of the track and calculate solid angles of opch, then get the average (I will explain in detail next time!)

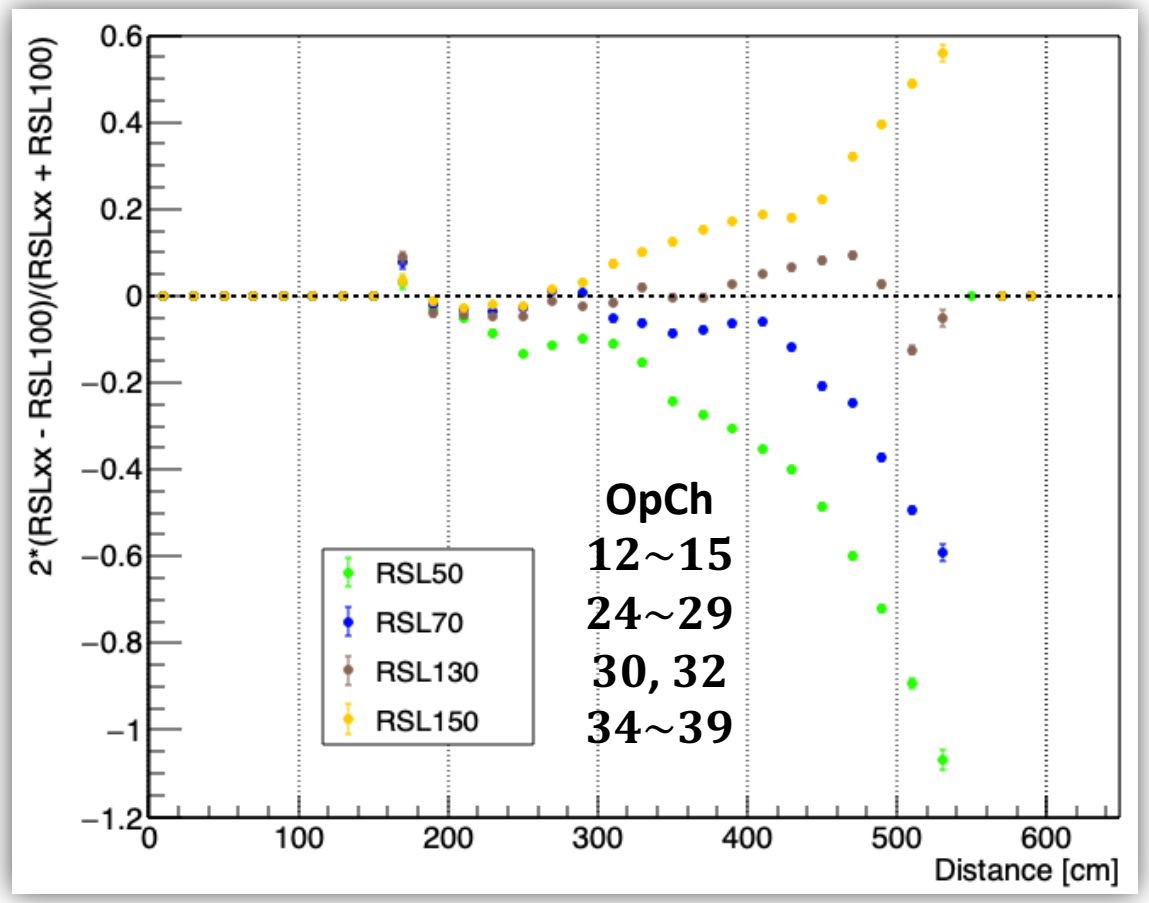




Performances of PMTs

- OpCh 31 & 33: Distinctions are poor ⟵ opchs too close to muon track
- Other PMTs (opCh 12, 13, etc): Good distinctions among RSL50, RSL70 & RSL150; RSL130 still strange





Summaries

- Cathode opChs work quite well to distinguish different RSLs
- RSL130 also strange (latter check found training incorrect: based RSL100 sample; New training undergoing)
- Membrane opChs away from muon track (opch01, 03, 16 & 22): Good @ RSL distinctions
- Membrane opChs close to muon track (opch00, 02, 17 & 23): Poor @ RSL distinctions; New variable “averaged solid angle” may help
- PMT opCh31 & 33 perform badly also due to close to muon track, new “averaged solid angle” would help
- Other PMT opchs Good @ RSL distinctions
- Further steps:

1. Train new RSL130 graph modules
2. Work new variable – “averaged solid angle”
3. Explore photon yield out of field cage
4. Background research
5. …

Thank you!

Backups

X-Arapuca Labels in v4 geometry

Beam enter point: $\sim(210, 150, 0)$
CRP height: $\pm 342cm$
Thickness of XA: $\sim 2.5cm$

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Cryo Boundaries
Xmin: -375 Xmax: 415 Ymin: -427.4 Ymax: 427.4 Zmin: -277.75 Zmax: 577.05
 drift coordinate: 1 (X direction)
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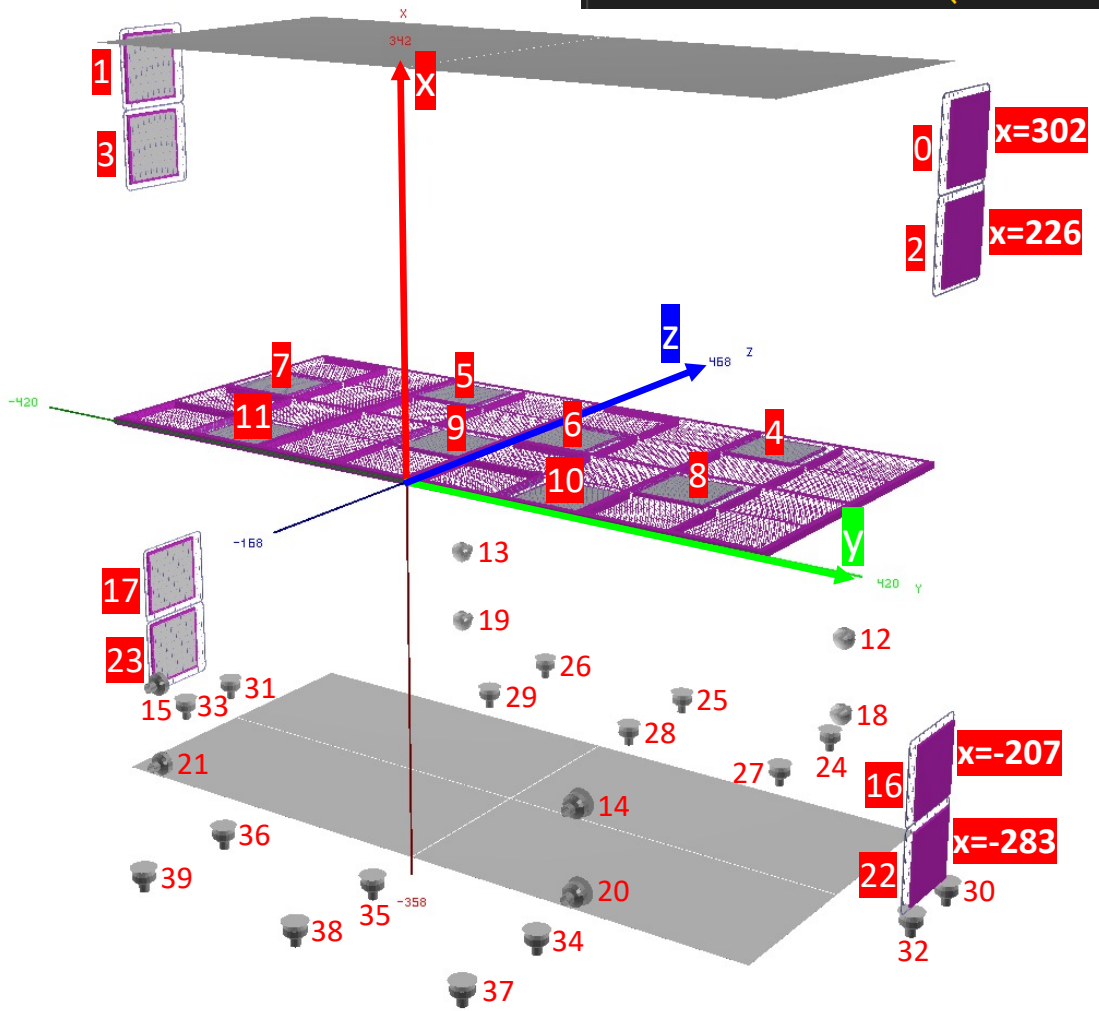
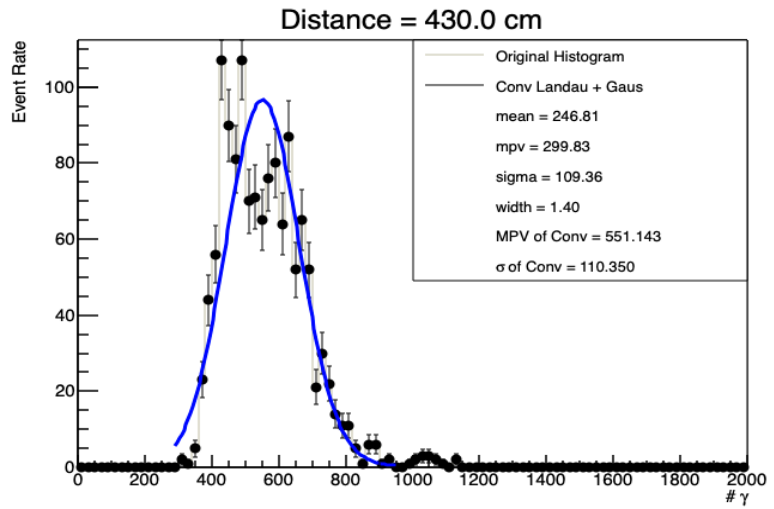
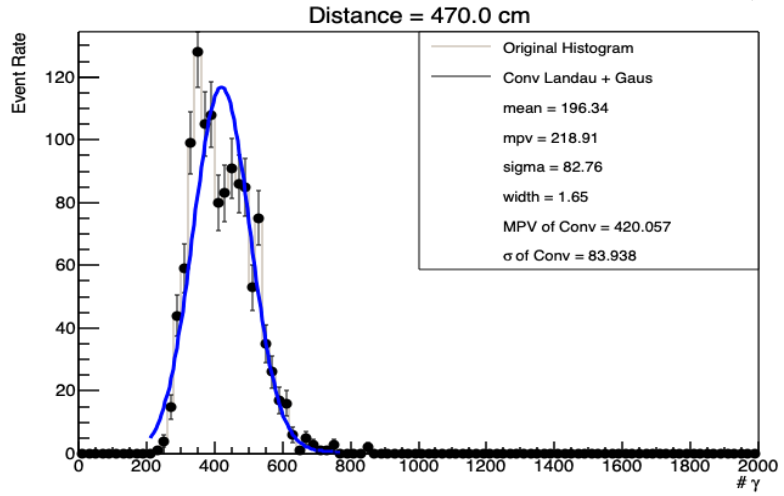


Optical Channels positions:	40	
0	302.18	417.61	149.65
1	302.18	-417.61	149.65
2	226.38	417.61	149.65
3	226.38	-417.61	149.65
4	0	205.65	258.525
5	0	-131.35	258.525
6	0	39.15	187.275
7	0	-297.85	187.275
8	0	205.65	112.025
9	0	-39.15	112.025
10	0	131.35	40.775
11	0	-205.65	40.775
12	-205.9	221	380.988
13	-205.9	-221	380.988
14	-205.9	221	-68.1242
15	-205.9	-221	-81.6884
16	-207.23	417.61	149.65
17	-207.23	-417.61	149.65
18	-281.7	221	380.988
19	-281.7	-221	380.988
20	-281.7	221	-68.1242
21	-281.7	-221	-81.6884
22	-283.03	417.61	149.65
23	-283.03	-417.61	149.65
24	-336.474	170	455.65
25	-336.474	1.13687e-13	455.65
26	-336.474	-170	455.65
27	-336.474	170	353.65
28	-336.474	1.13687e-13	353.65
29	-336.474	-170	353.65
30	-336.474	405.3	217.75
31	-336.474	-405.3	217.75
32	-336.474	405.3	149.65
33	-336.474	-405.3	149.65
34	-336.474	170	-54.35
35	-336.474	1.13687e-13	-54.35
36	-336.474	-170	-54.35
37	-336.474	170	-156.35
38	-336.474	1.13687e-13	-156.35
39	-336.474	-170	-156.35

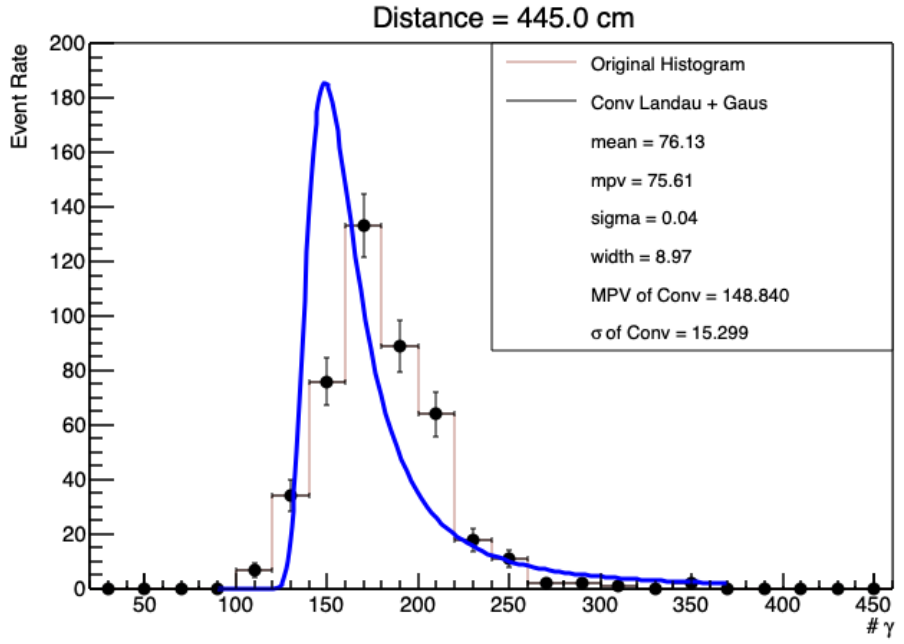
Fitting Eamples

❖ For P5, RSL100

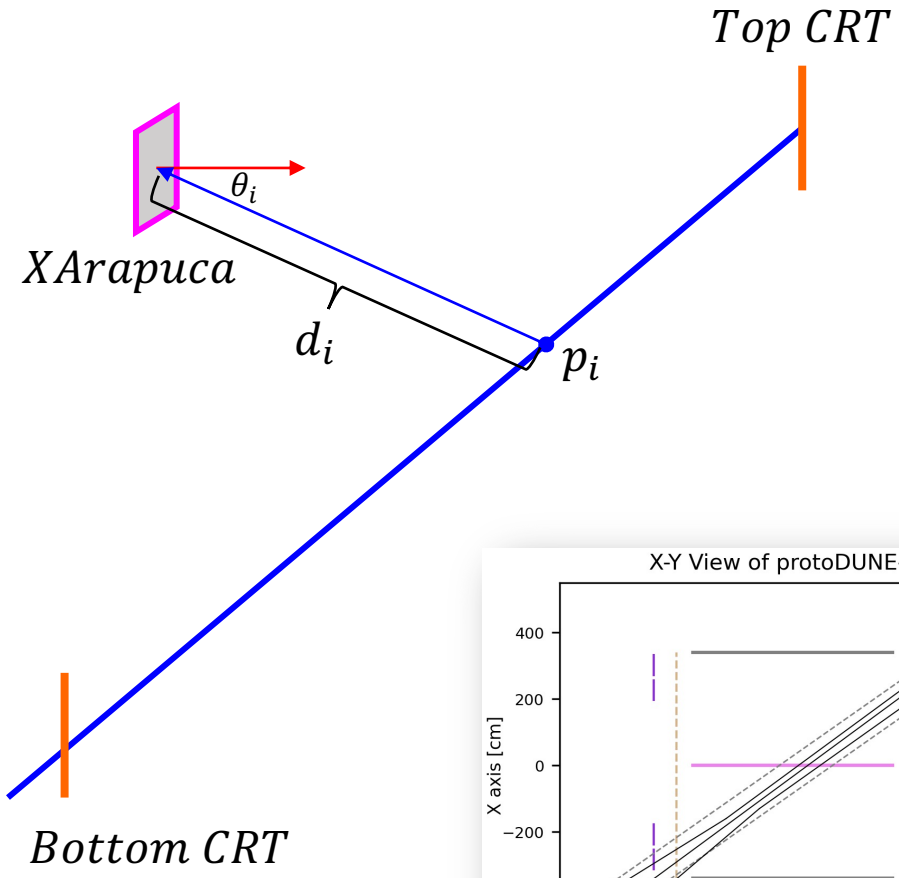




❖ For P5, RSL50, opch03:



New Variable: Averaged Solid Angle



- Solid angle of X-Arapuca to point p_i:

$$\Omega_i = \frac{(60cm)^2 \cdot cos\theta_i}{d_i^2}$$

- Choose N **equally spaced points** between$y \in [-417.6, 417.6]$, then get the averaged solid angle:

$$\Omega = \frac{1}{N}\sum \Omega_i$$

- The bigger N the getter; start with $N = 16$, then consider performances and computing time, choose different N values: $32, 64, 128, 256, 512, 1024$ …

- Should work for cathode X-Arapucas