

# ProtoDUNE Photon Detection Update Beam Analysis 2019

Chris Macias  
Indiana University

ProtoDUNE PD Update, Beam Analysis

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# Beam Data- Looking at Electron Tags

- Looking at Raw Beam Data
- Filtering by Cherenkov Tags
- No other filtering has been done, yet.

**0.3/0.5/1/2 GeV/c**

	High Pressure Cherenkov	Low Pressure Cherenkov
Electron	-	1
Pion	-	0
Proton	-	0

**6/7 GeV/c**

	High Pressure Cherenkov	Low Pressure Cherenkov
Electron / Pion	1	1
Kaon	1	0
Proton	0	0

**3 GeV/c**

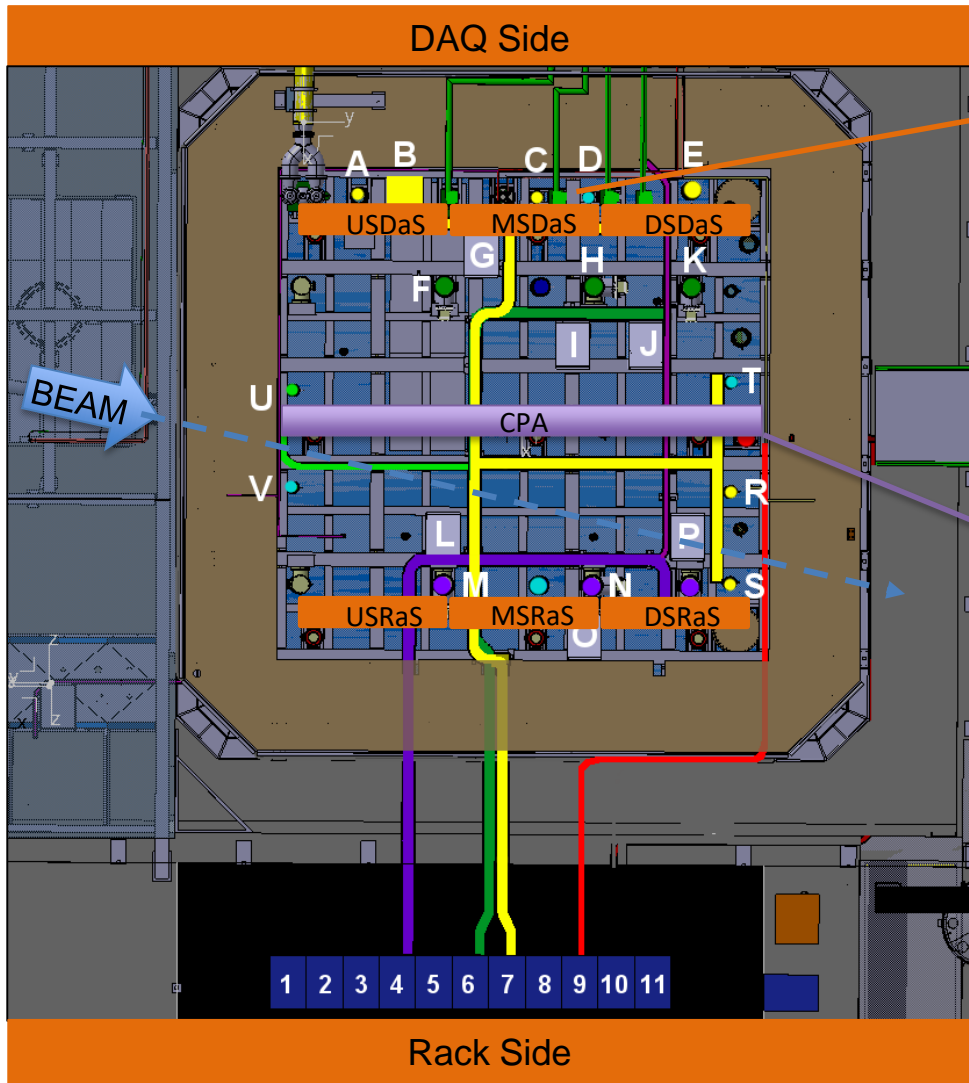
	High Pressure Cherenkov	Low Pressure Cherenkov
Electron	1	1
Pion	1	0
Proton	0	0

- **Tables show how to identify particles with 1 (hit) 0 (no hit) in Cherenkovs**
- **In BeamEvent:**
  - HP is CKov0Status
  - LP is CKov1Status

Dante Totani

```

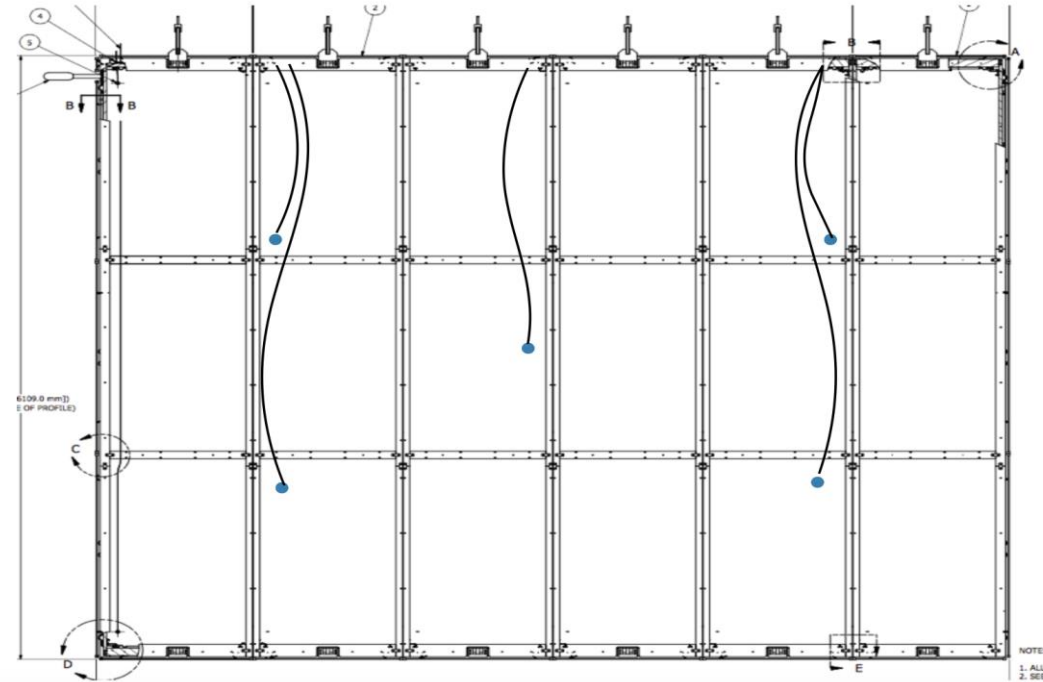
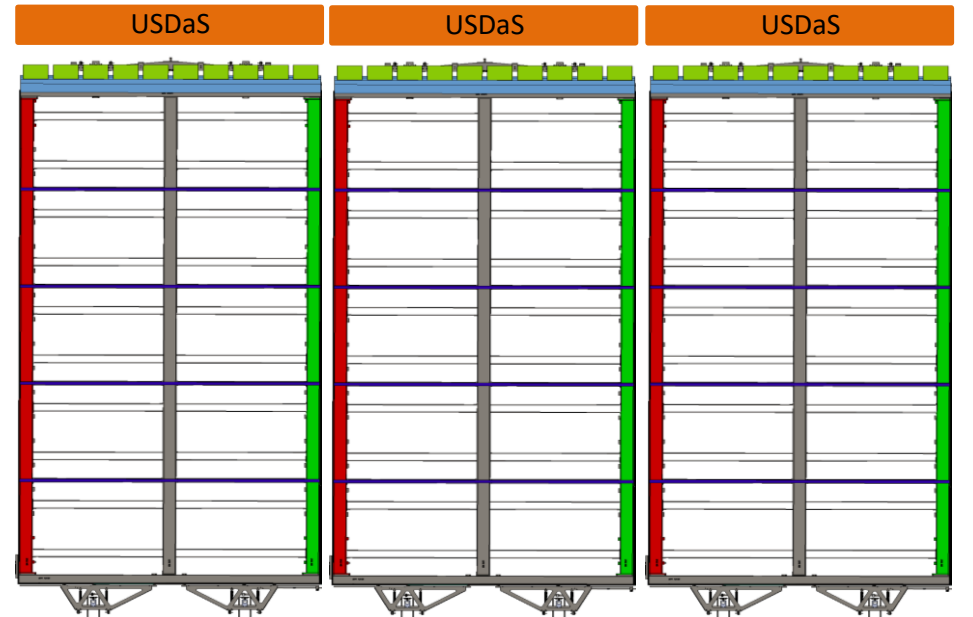
Mod = New(TH2D, "Mod_"+str(mod), "Photons Collected for "+str(sub_direct)+"GeV Electrons; Channel; Photons Collected", n_points, lower_lin, upper_lin, 3, mod-1, mod+1);
if int(sub_direct) > 5:
    ntuple.Draw("module:Photon>>Mod_"+str(mod), "module==" +str(mod) + " && Shower_index > 0.1 && CKov0status==1 && CKov1status==1", "colz")
elif int(sub_direct) == 3:
    ntuple.Draw("module:Photon>>Mod_"+str(mod), "module==" +str(mod)+ " && CKov0status==1 && CKov1status==1", "colz")
else:
    ntuple.Draw("module:Photon>>Mod_"+str(mod), "module==" +str(mod)+ " && CKov1status==1 && CKov0status!=1", "colz")
    
```



3 APAs

CPA

3 APAs



# PD Channel Mapping

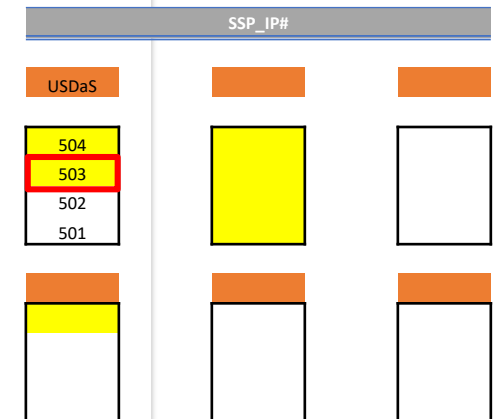
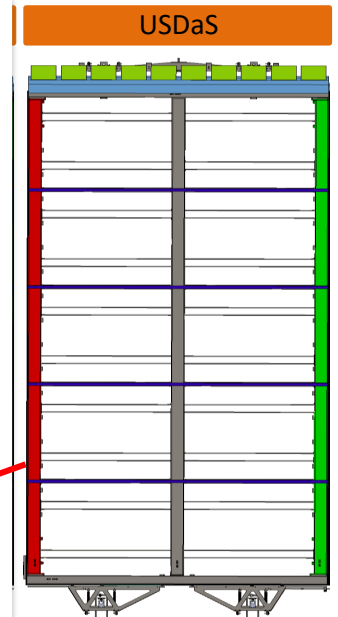
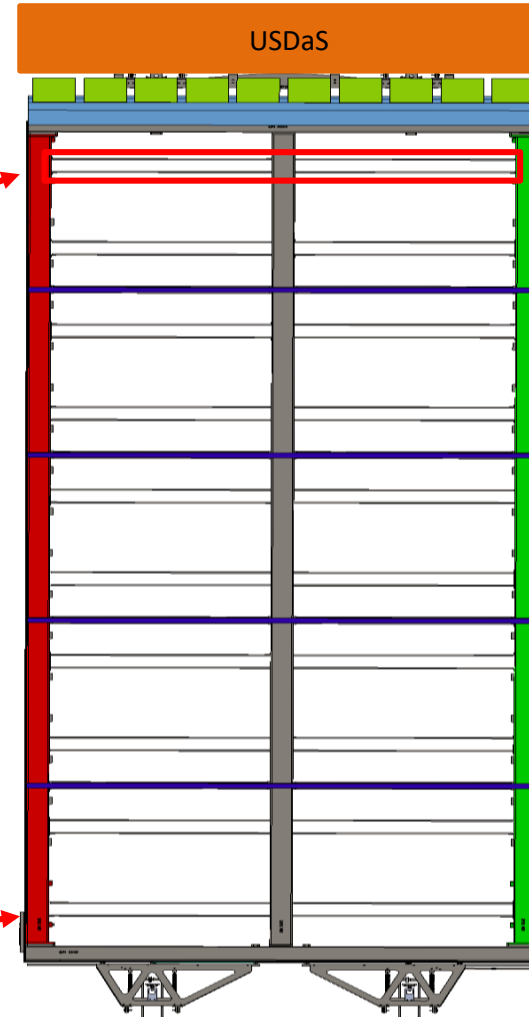
- APA- Face A
- ⊗ APA- Face B

▮ = Readout end

TOP of Cryo #0

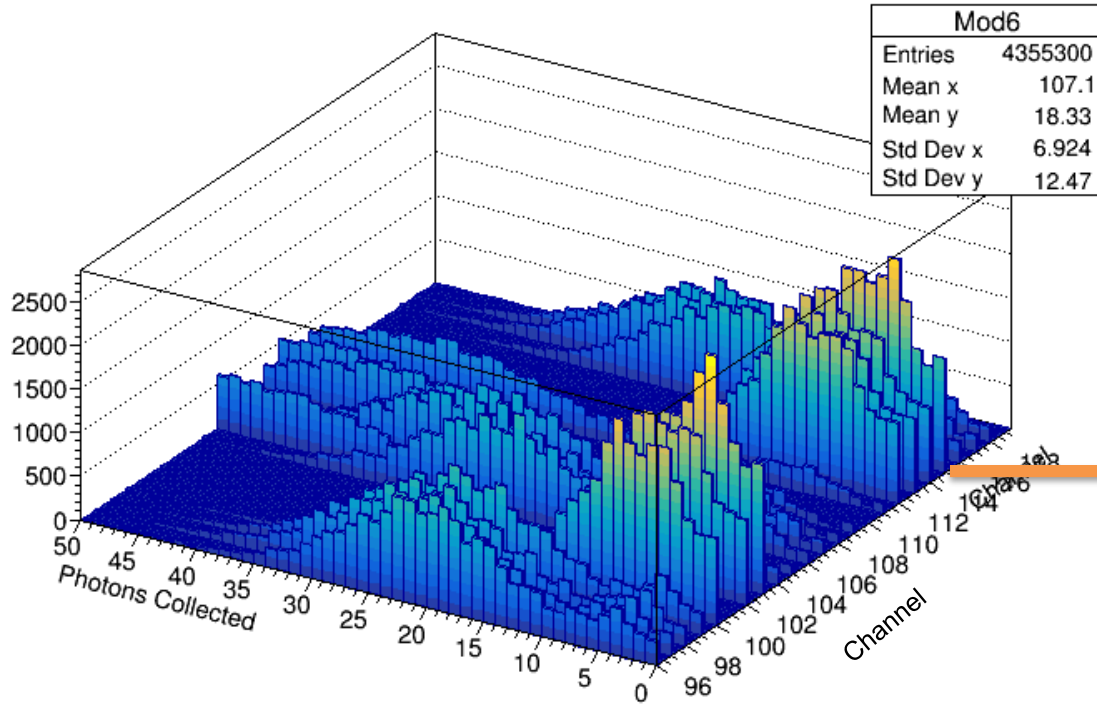
USDaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
002-0047-FL34	Hamamatsu	SSP503	0-3	216-219	41
002-0008-IU54	Hamamatsu	SSP503	4-7	220-223	43
002-0058-FL24	Hamamatsu	SSP503	8-11	224-227	45
002-0063-IU19	Hamamatsu	SSP504	0-3	228-231	47
003-0026-FL07*	SensL-C1	SSP501	0-3	192-195	49
002-0014-IU26	Hamamatsu	SSP504	4-7	232-235	51
003-0024-FL33	SensL-C1	SSP501	4-7	196-199	53
003-0004-IU48	SensL-C1	SSP501	8-11	200-203	55
002-0041-FL36	Hamamatsu	SSP504	8-11	236-239	57
002-0036-IU47	SensL-C1	SSP502	0-3	204-207	59

Bottom of Cryo #9

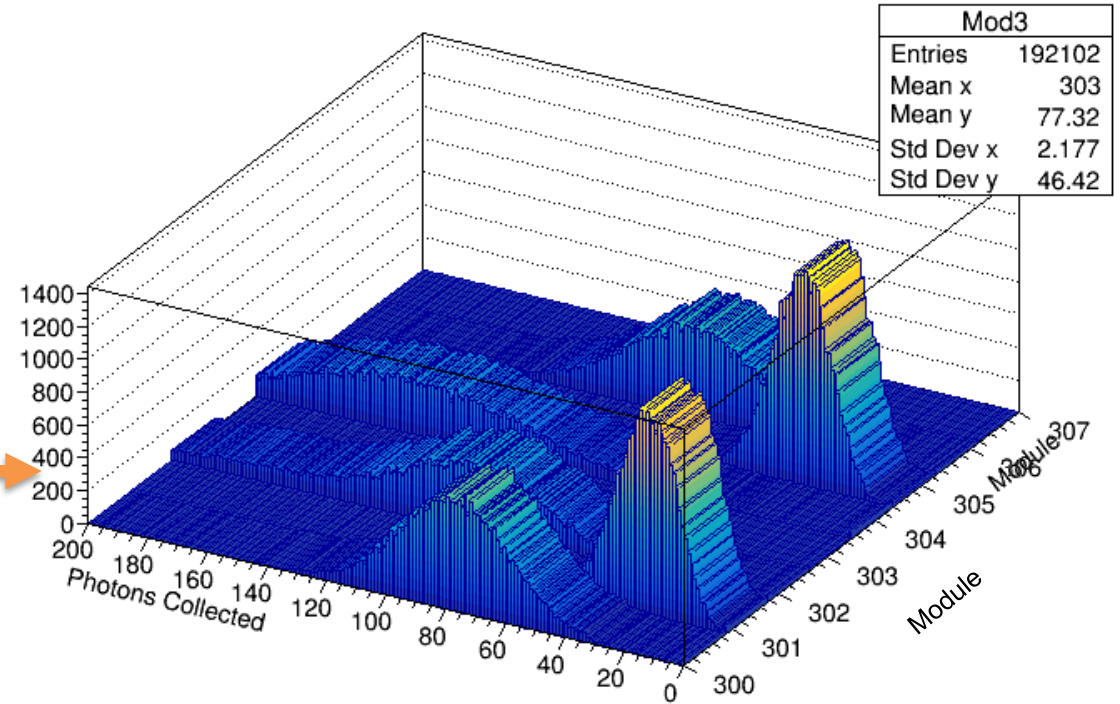


# Beam Data- Summing Channels → Modules

Photons Collected for 7GeV Electrons



Photons Collected for 7GeV Electrons



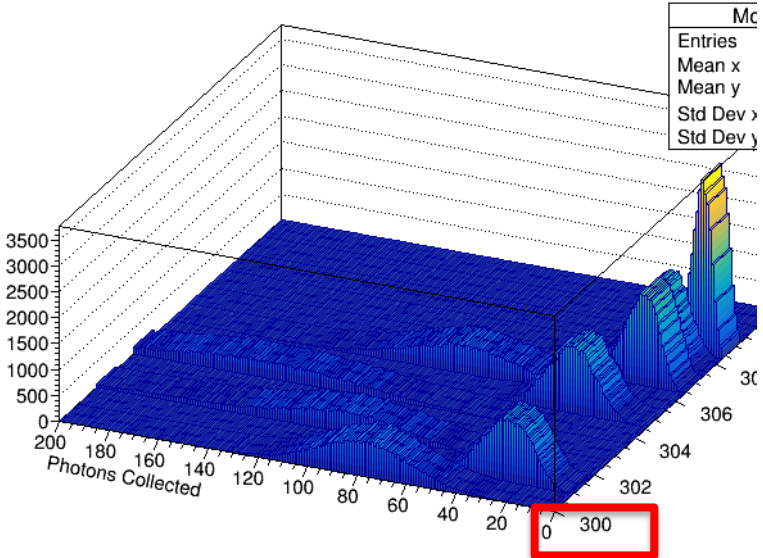
Module ID

- <APA Number>+ '0' +<Module Number>
- Ex: APA3-mod0 == 300

# Looking at 7GeV Electrons w/ APAs 1-3

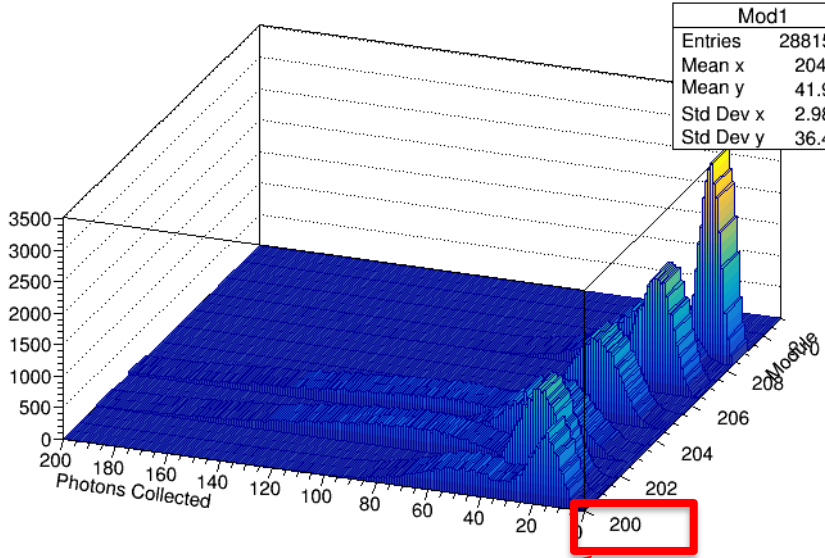
APA3

Photons Collected for 7GeV Electrons



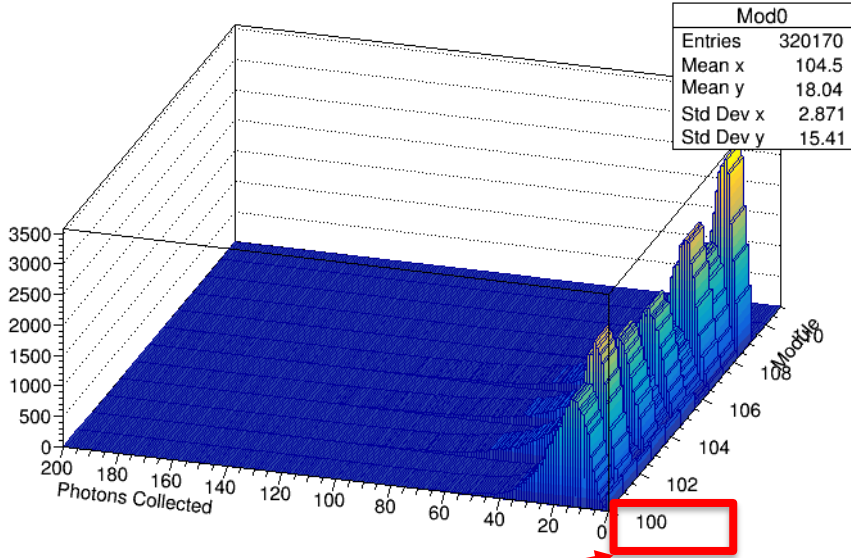
APA2

Photons Collected for 7GeV Electrons

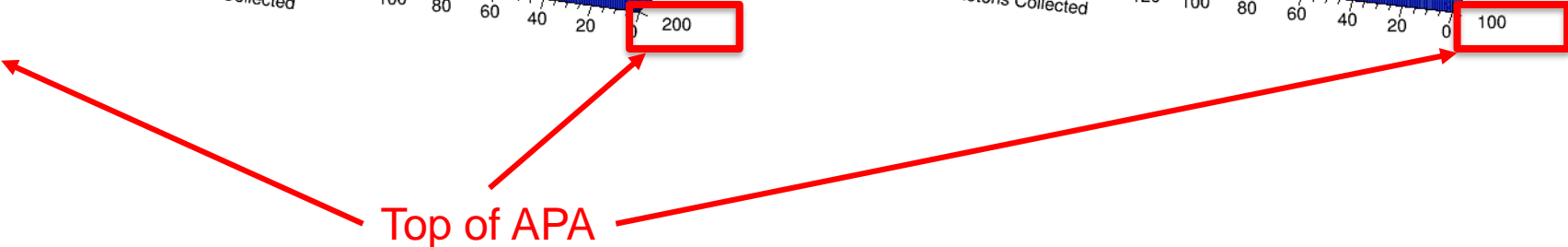


APA1

Photons Collected for 7GeV Electrons



Top of APA

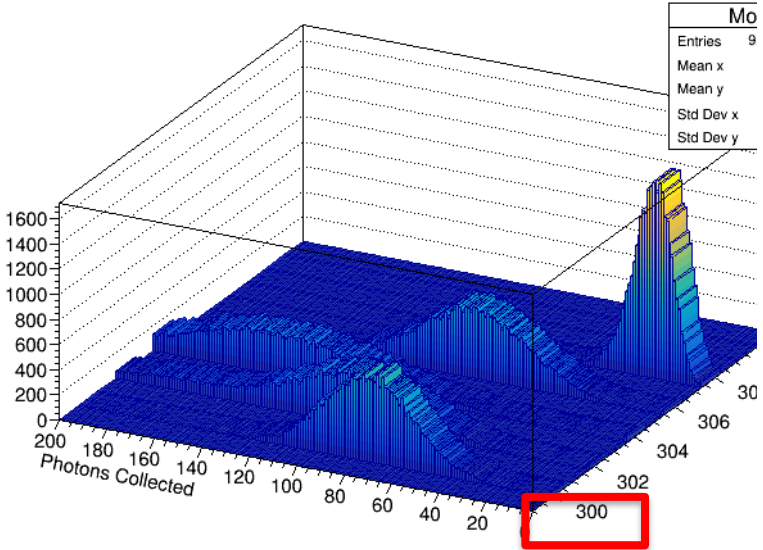




# Looking at 7GeV Electrons w/ APAs 1-3- IU Modules

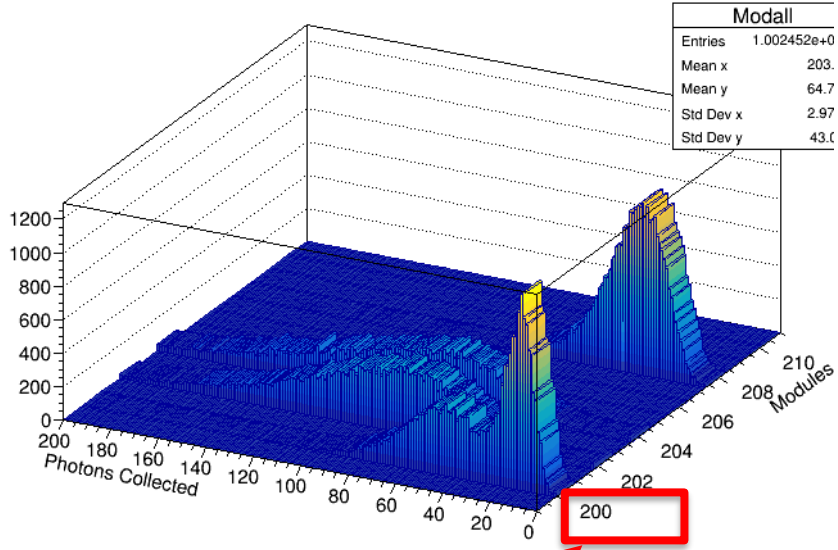
APA3

Photons Collected for 7GeV Electrons



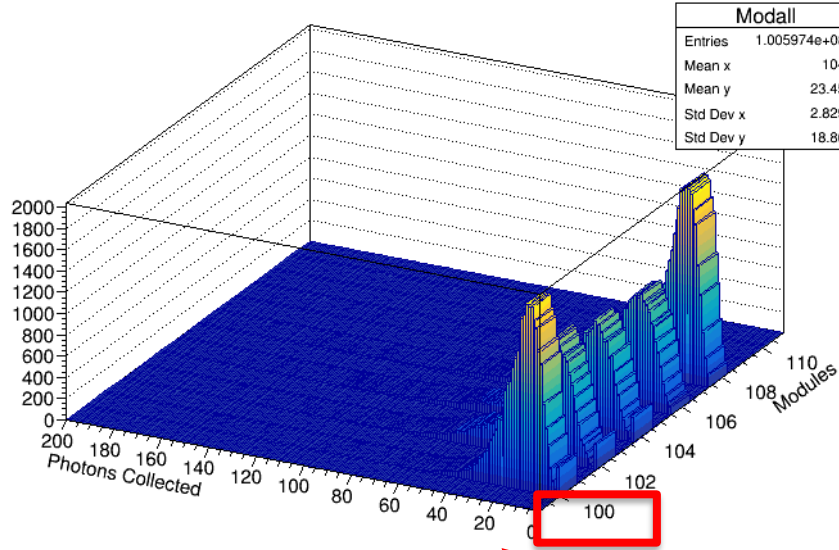
APA2

Photons Collected for 7GeV Electrons

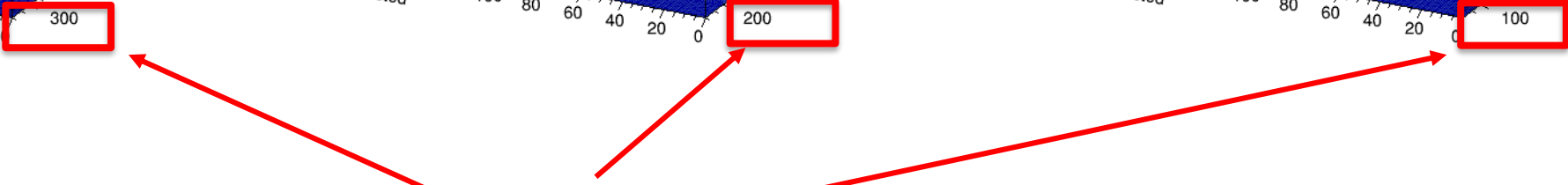


APA1

Photons Collected for 7GeV Electrons

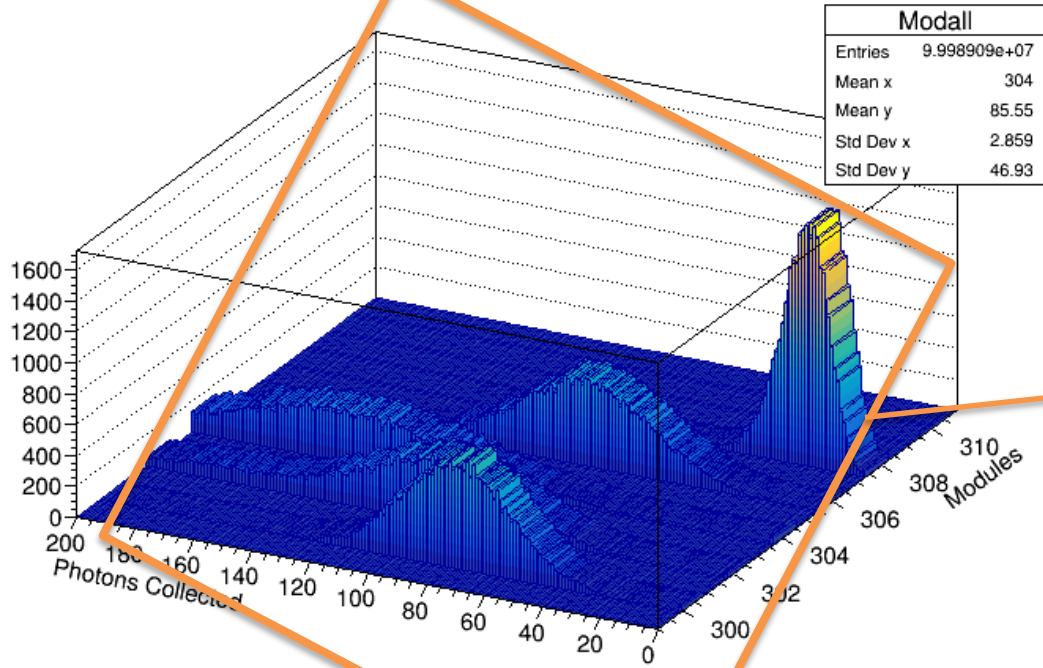


Top of APA

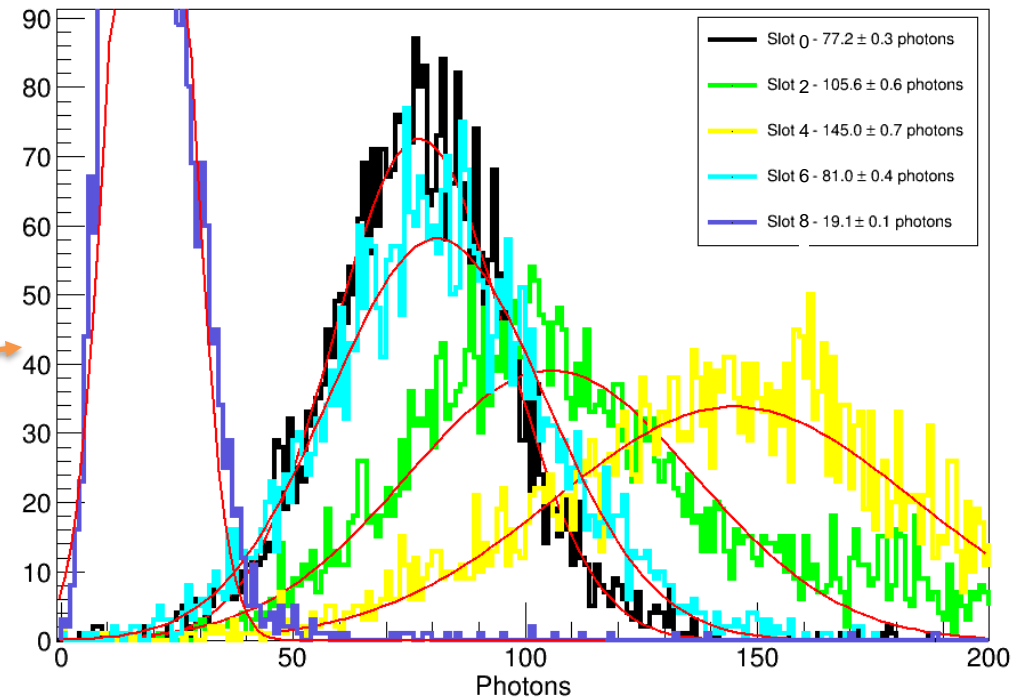


# Looking at 7GeV Electrons w/ IU Modules in APA3

Photons Collected for 7GeV Electrons



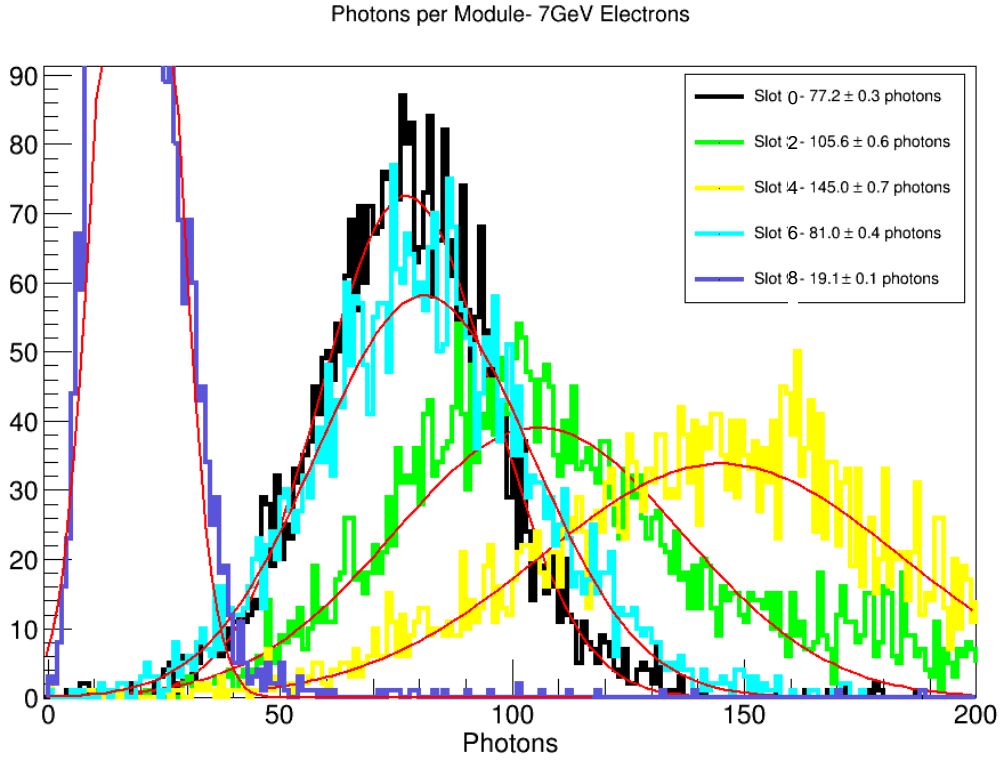
Photons per Module- 7GeV Electrons



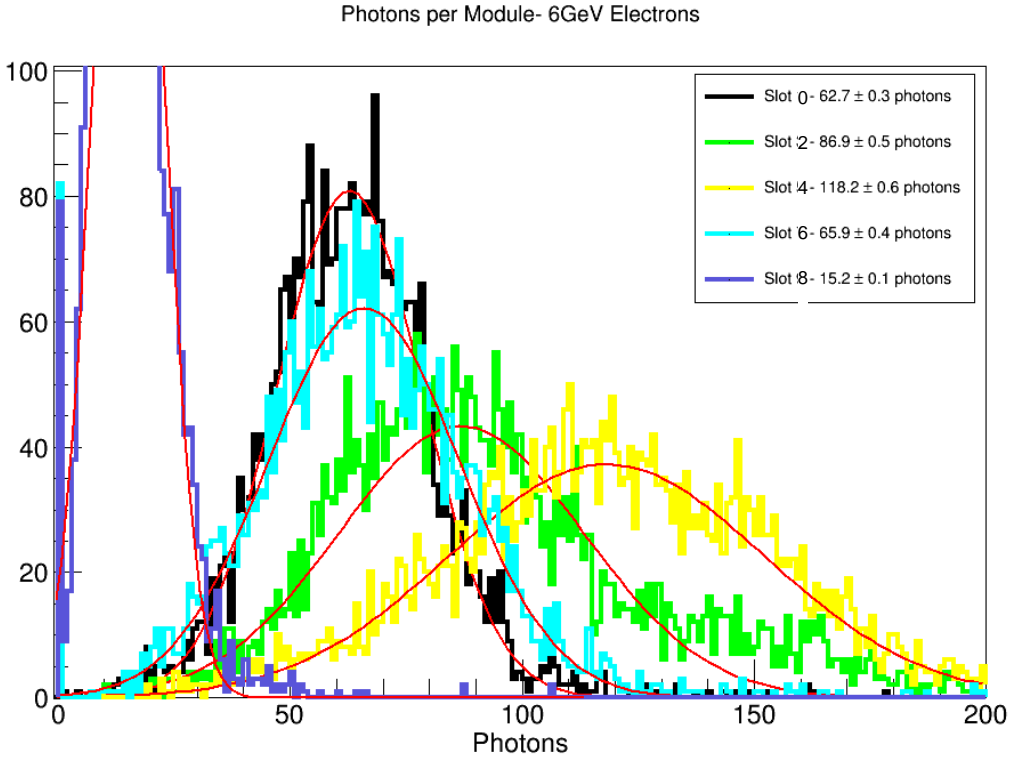
- Looking at IU Modules
- 300,302,304,306,308



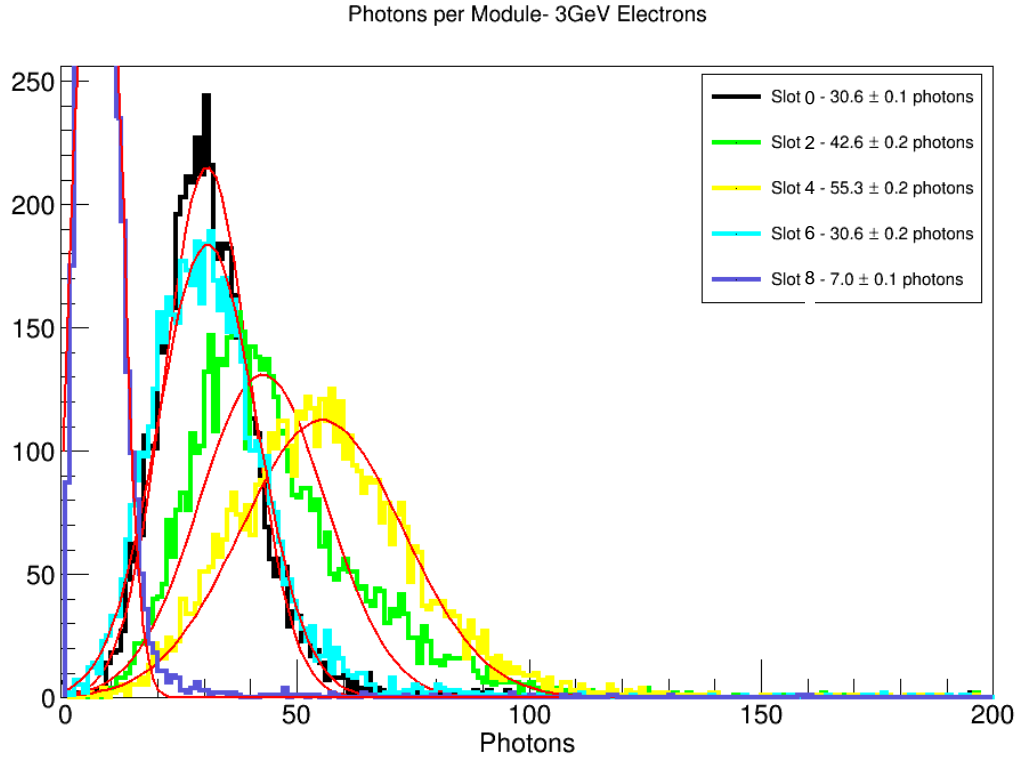
# Scan Through w/ IU Modules in APA3- 7GeV



# Scan Through w/ IU Modules in APA3- 6GeV



# Scan Through w/ IU Modules in APA3- 3GeV

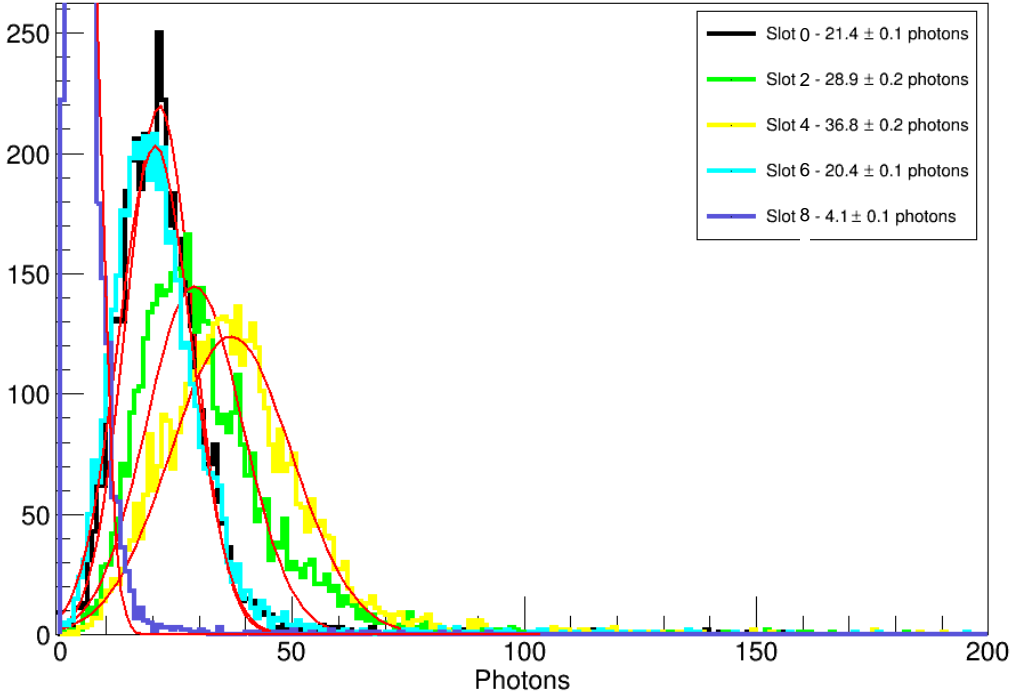




# Scan Through w/ IU Modules in APA3- 2GeV



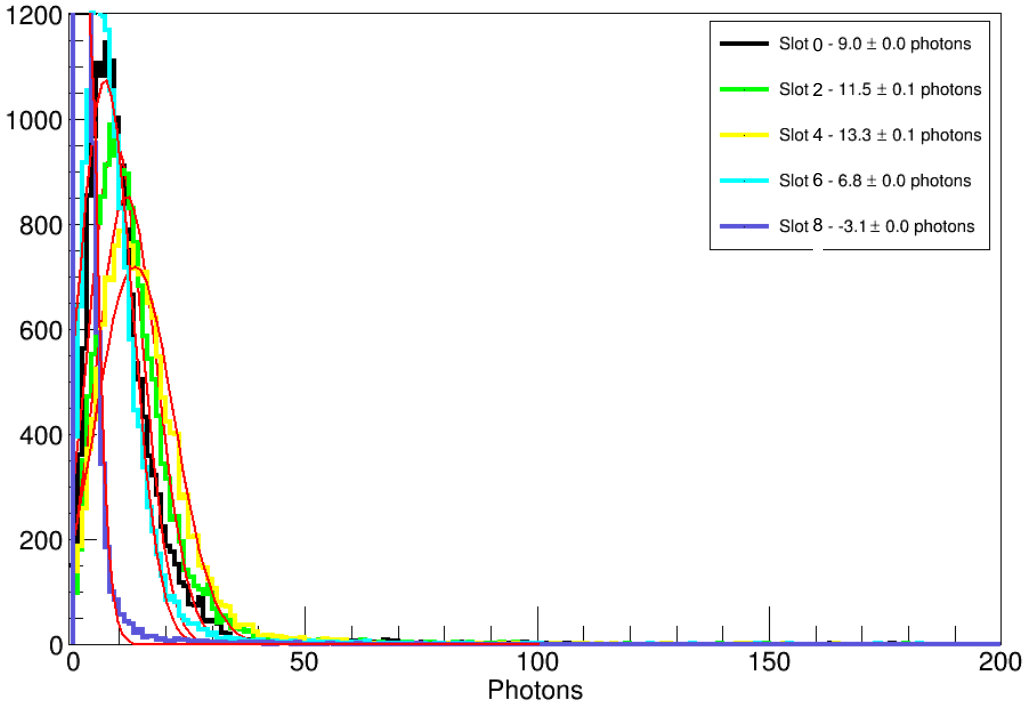
Photons per Module- 2GeV Electrons



# Scan Through w/ IU Modules in APA3- 1GeV

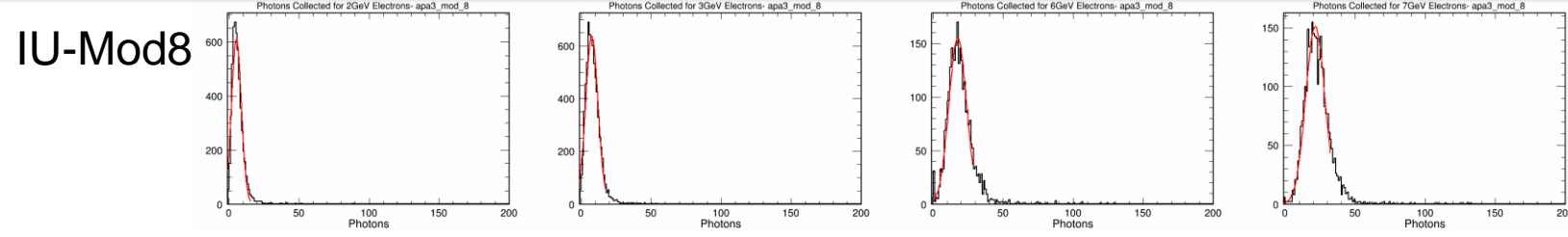
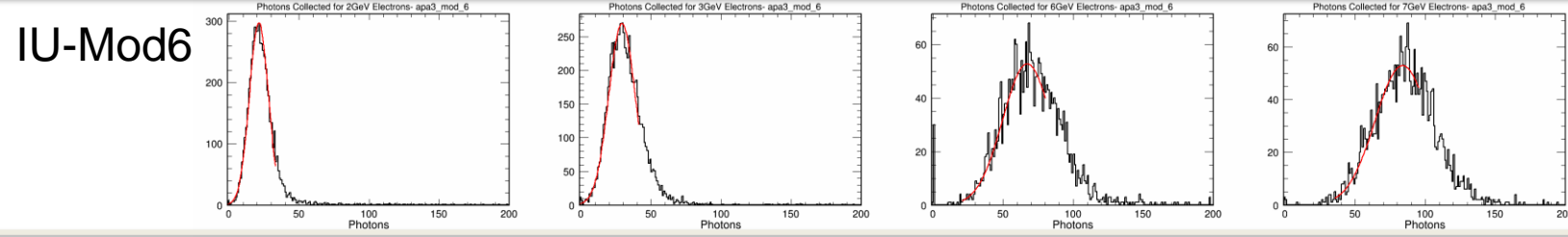
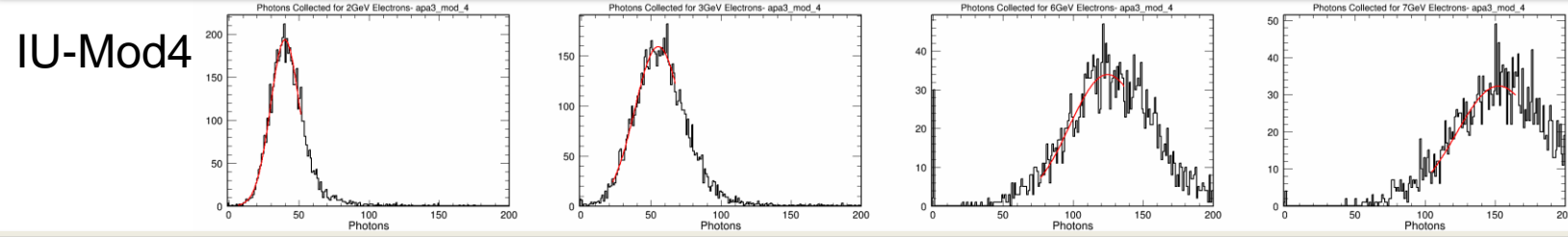
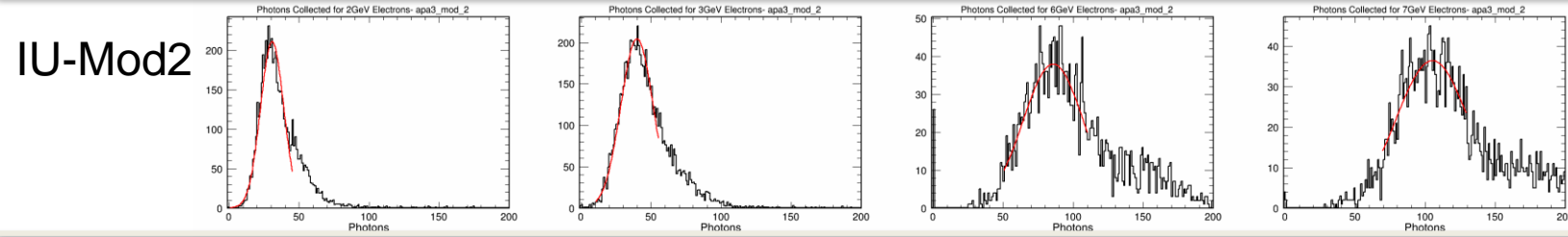
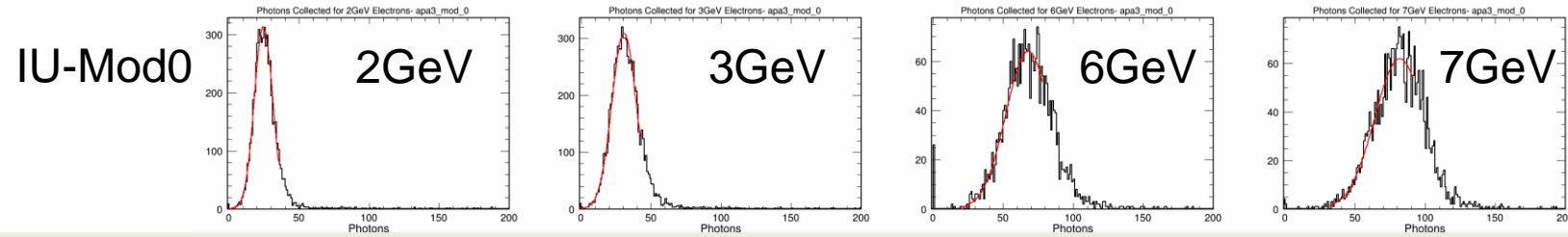


Photons per Module- 1GeV Electrons



# IU Modules: Function(p) – APA3

Top of APA 3

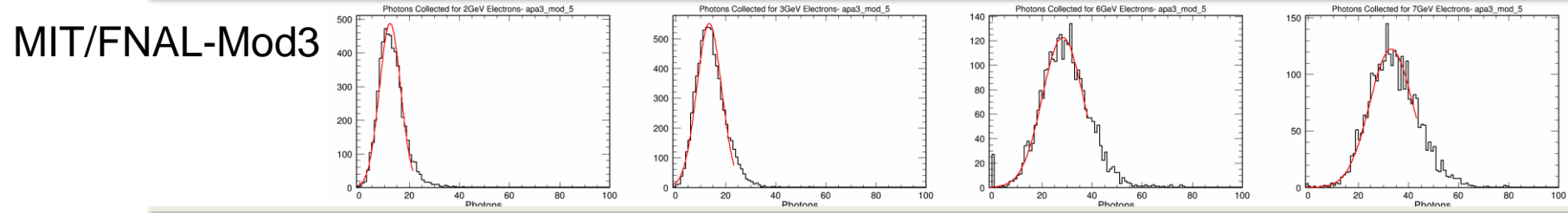
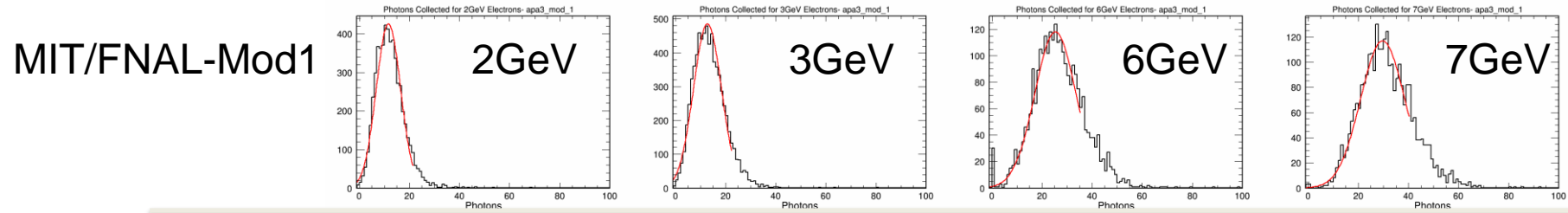


Bottom of APA 3

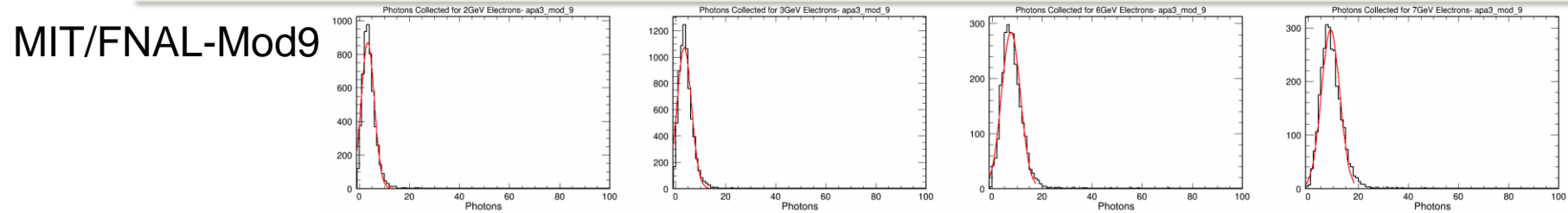
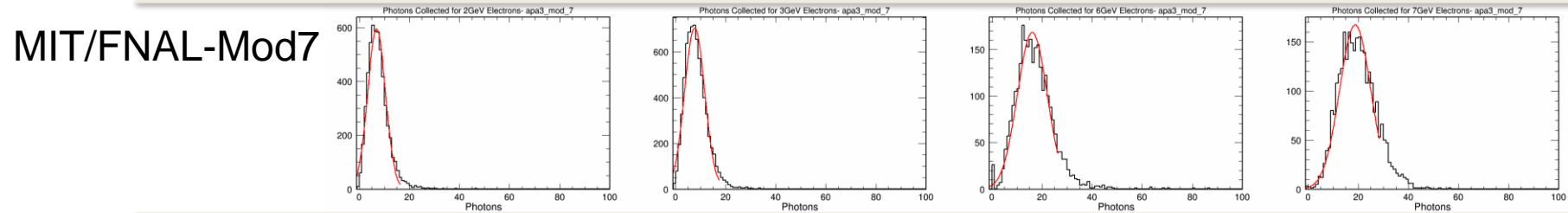


# MIT/FNAL Modules: Function(p) – APA3

Top of APA 3



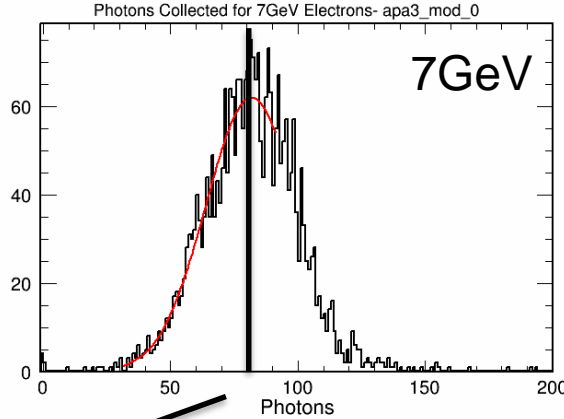
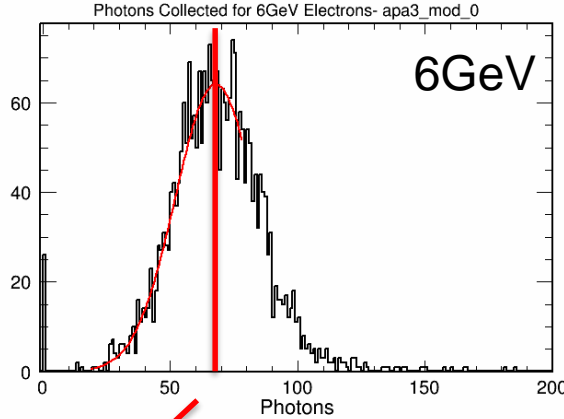
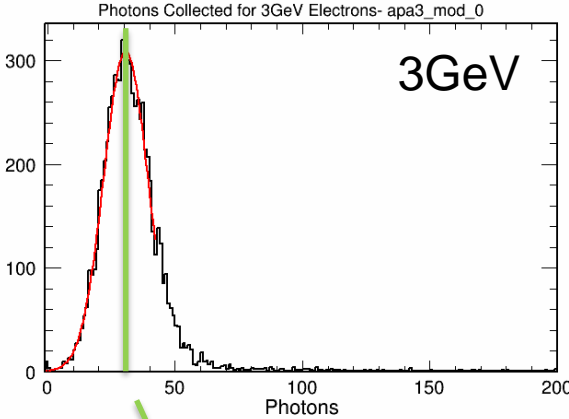
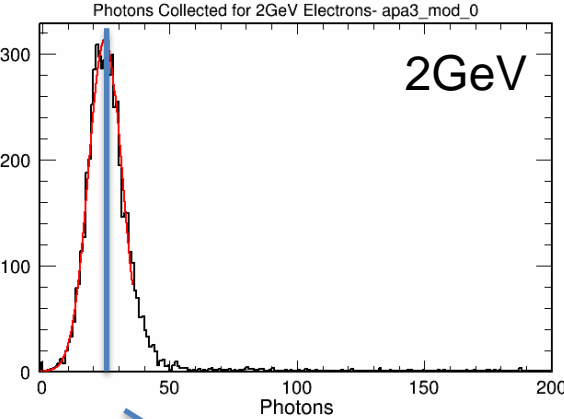
ARAPUCA



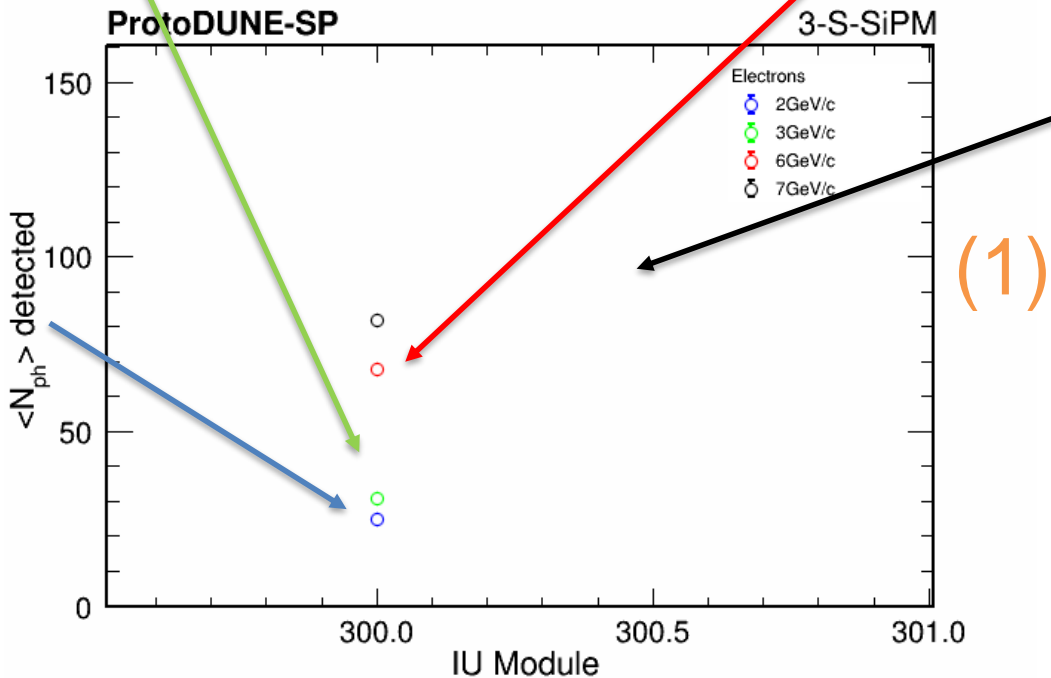
Bottom of APA 3

# First Look at UNcorrected Efficiency Results- Function(p)

## APA3 - IU-Mod0



$Err = \text{Sigma}/\text{sqrt}(N)$



# Expected <Photons> Incident/Module

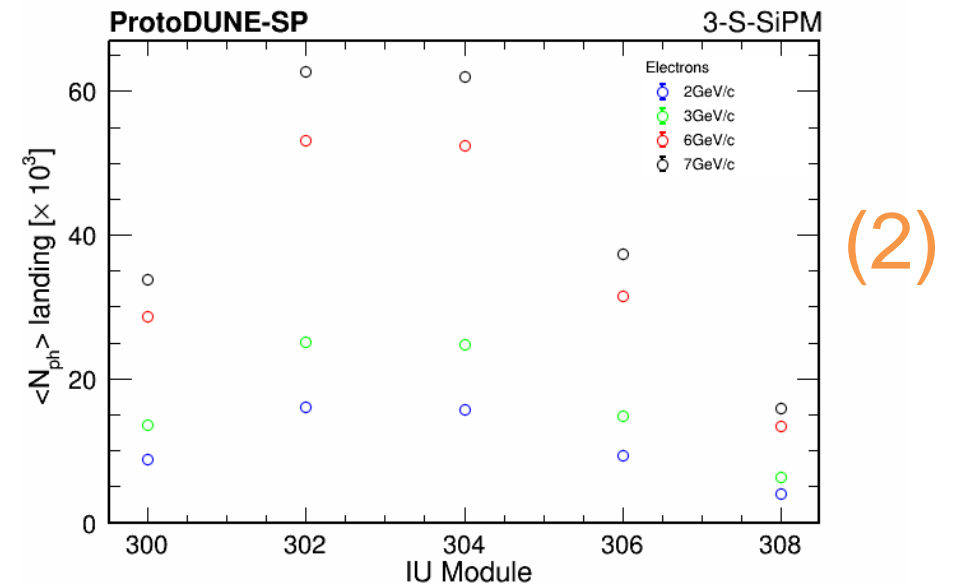
- Using Laura's MC Output
  - Mean number of incident photons landing on each PD module
- 450k photons/Voxel
- Rayleigh scattering = 90cm
- Applied Correction Factors
  - Active area correction (x ~77%)
  - Transmission factor (x 70%)

Used to determine UNcorrected IU & MIT/FNAL Efficiency

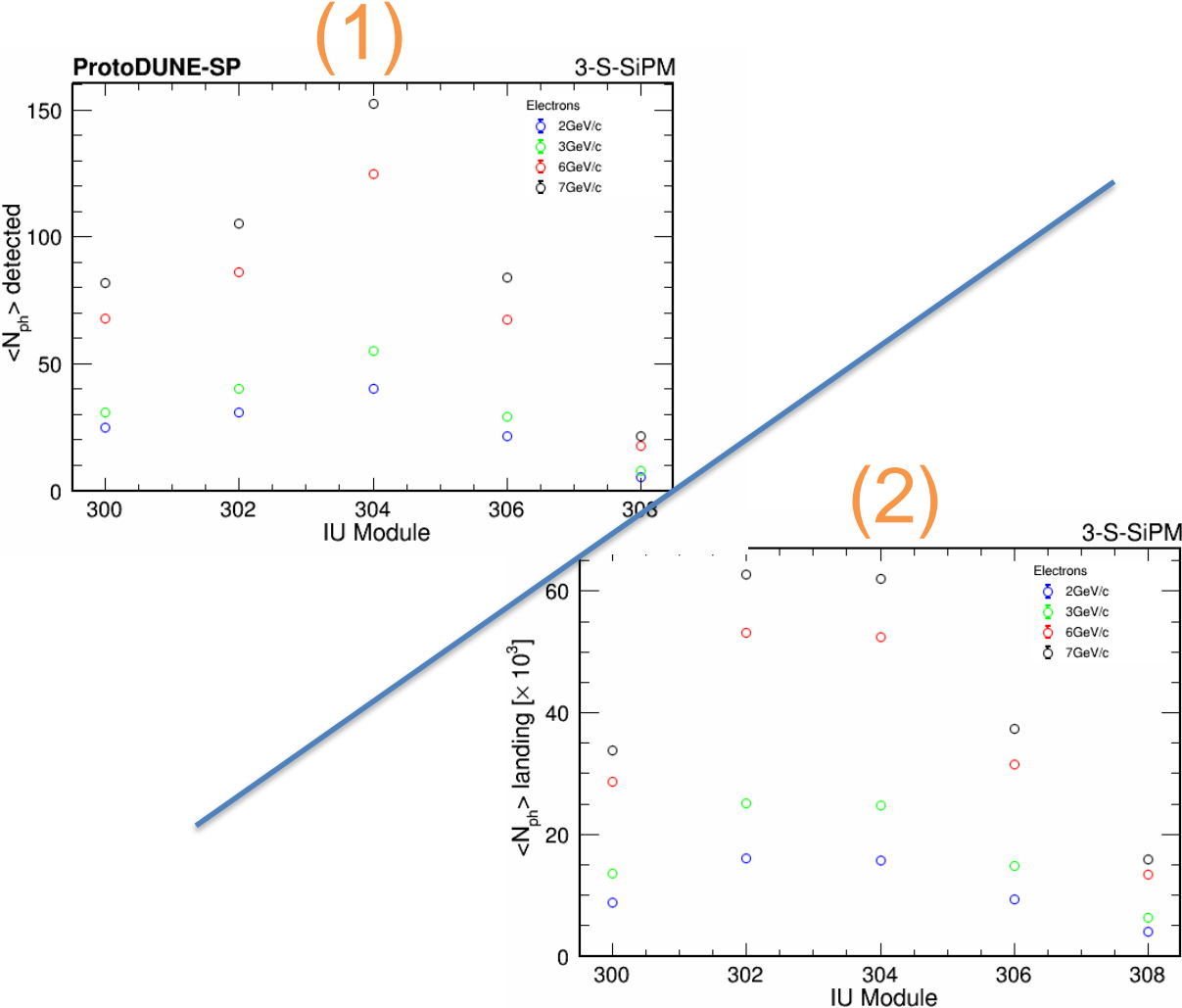
- $Eff = \langle N_{ph} \rangle_{detected} (Data) / \langle N_{ph} \rangle_{landing} (MC)$

## <N\_ph> landing

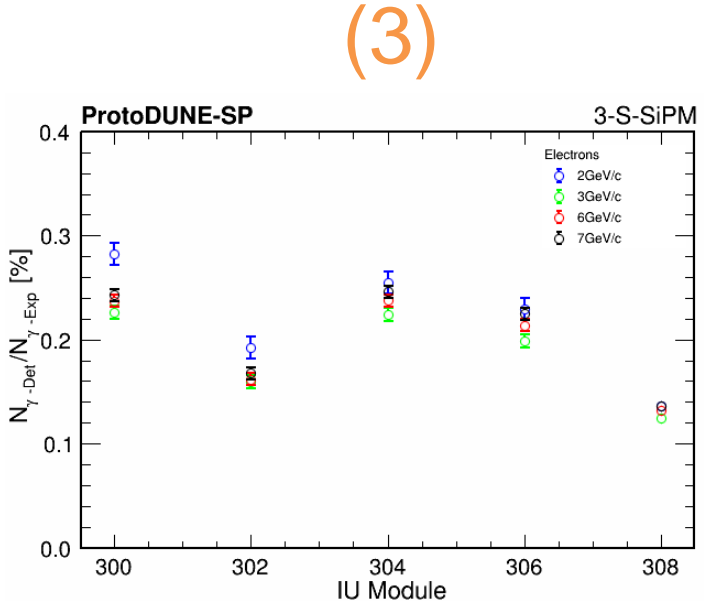
Electrons	7GeV		
Ch	<Photons>	<Photons>_corr	err
63	10908.8	5902.141481	70.1614
64	11476	6209.021673	78.105
65	11780	6373.499069	78.9847
66	10574.2	5721.108137	74.0663
67	9075.07	4910.01275	59.507
68	7189.35	3889.755138	47.2345
69	5225.02	2826.966053	32.7902
70	3419.09	1849.878347	21.2776
71	33280	18005.94644	142.765
72	48009.1	25975.03855	225.766
73	58487.5	31644.31467	291.584



# First Look at UNcorrected Efficiency Results- Function(p)

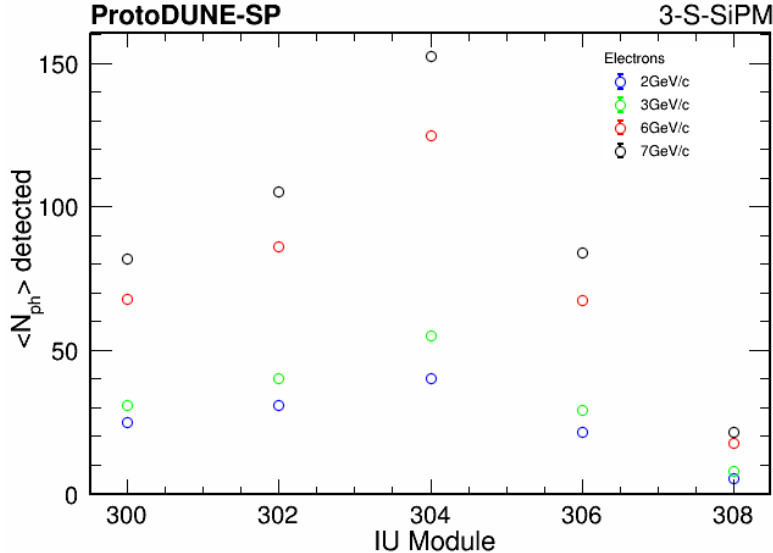


=

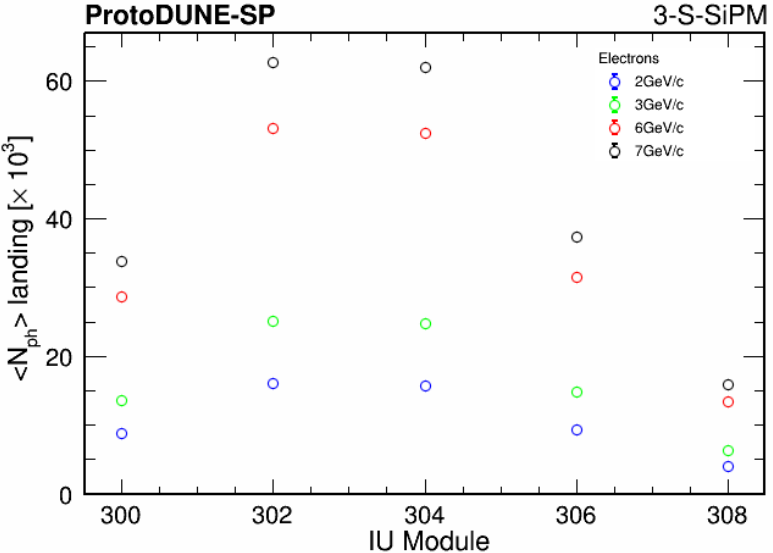


# IU Modules UNcorrected Efficiency Results: APA 3

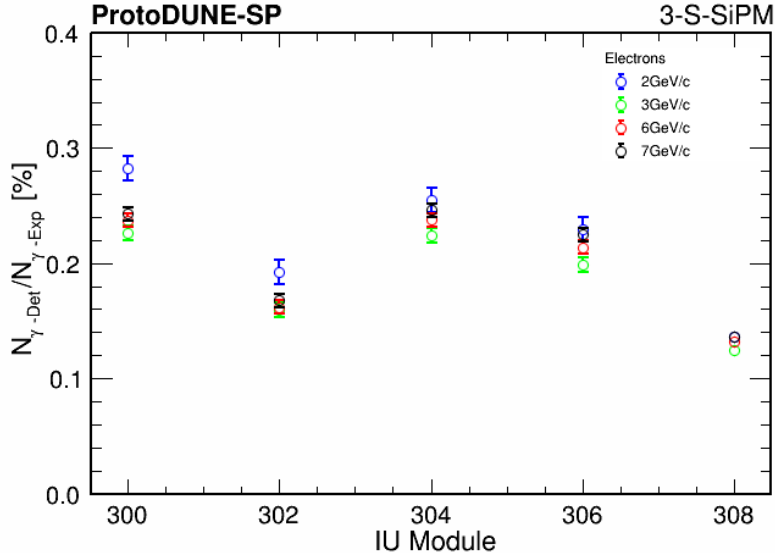
(1)



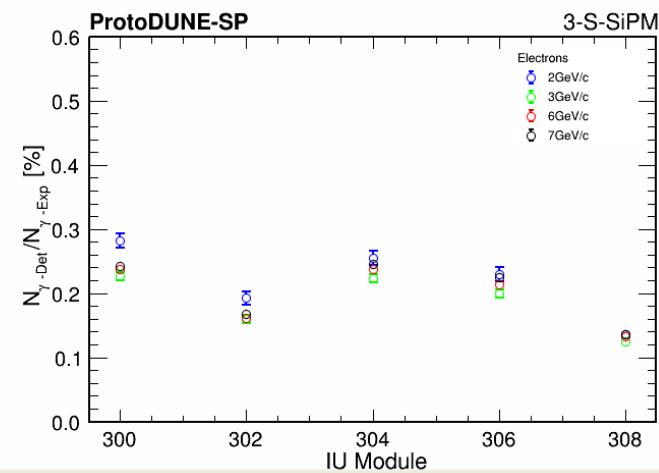
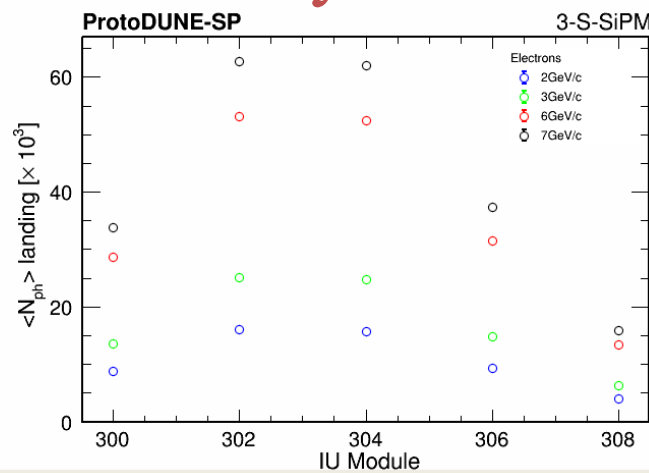
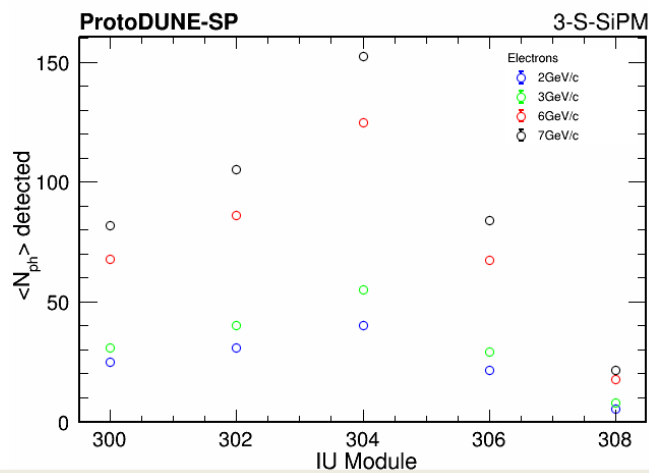
(2)



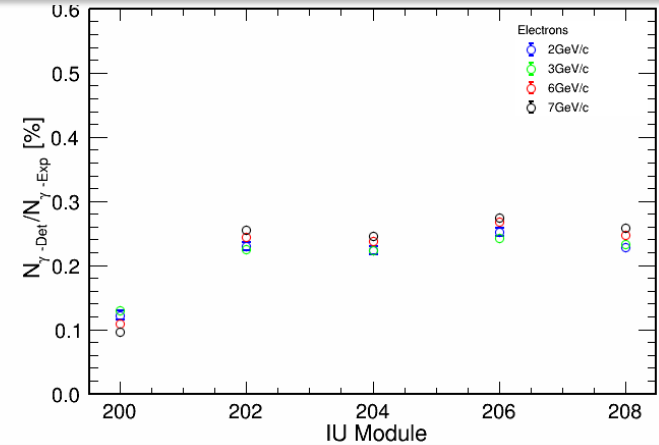
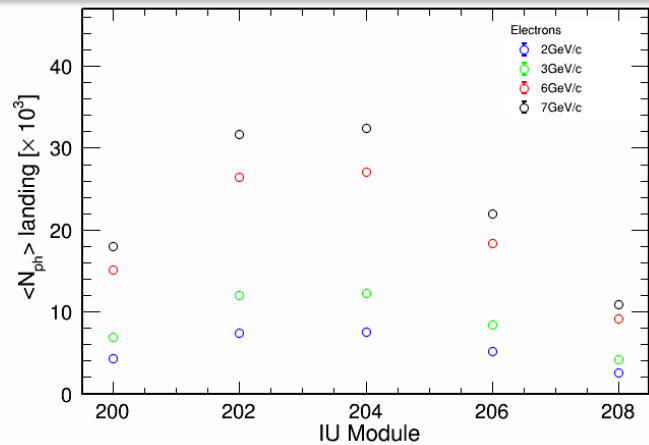
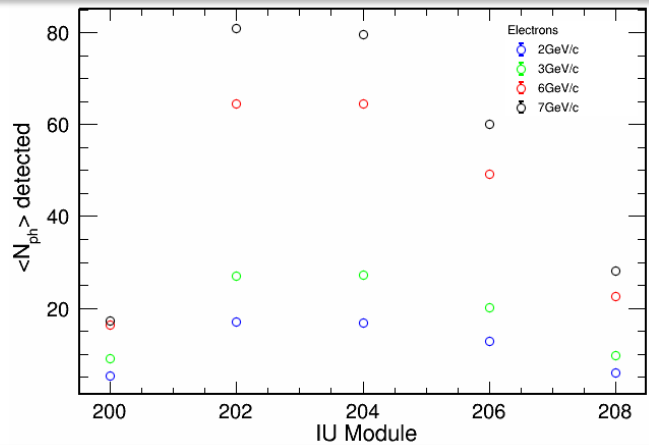
(3)



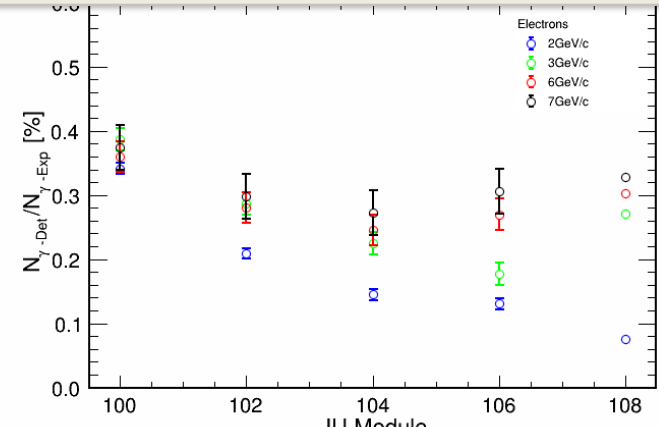
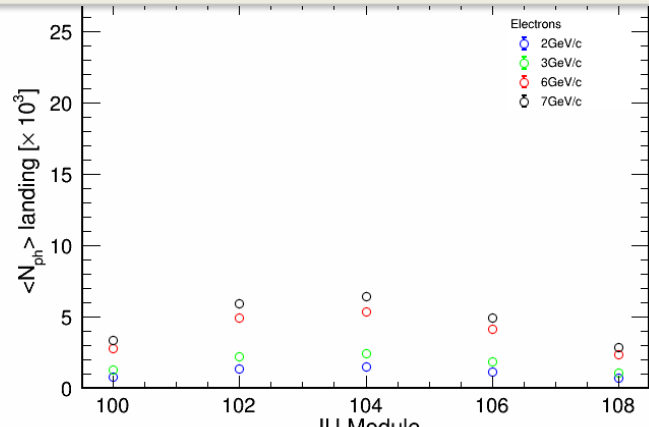
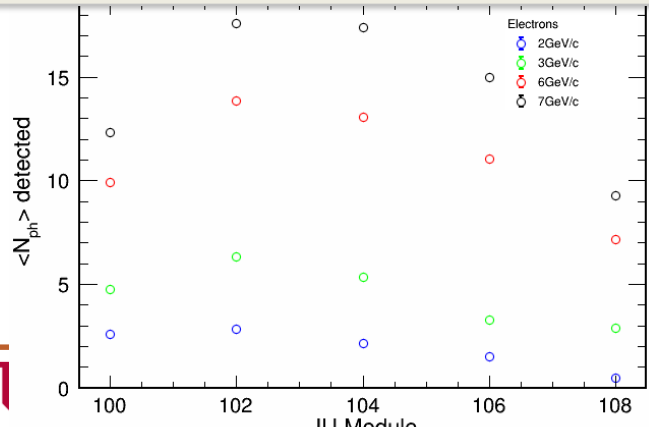
# IU Modules UNcorrected Efficiency Results: APAs 1-3



APA 3



APA 2



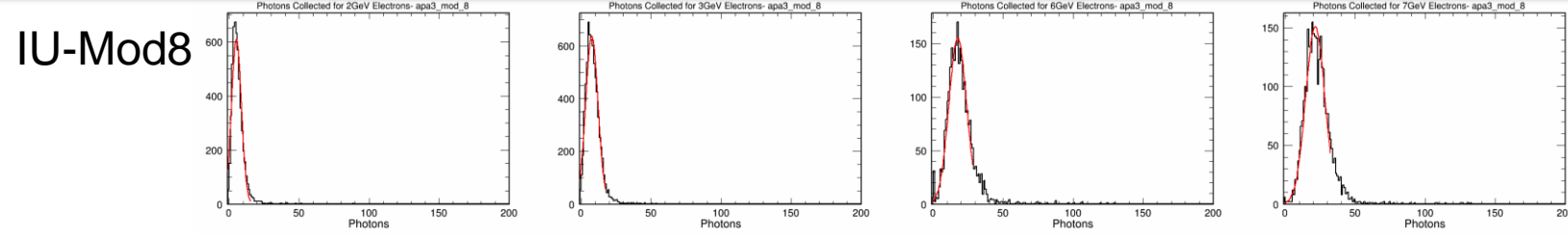
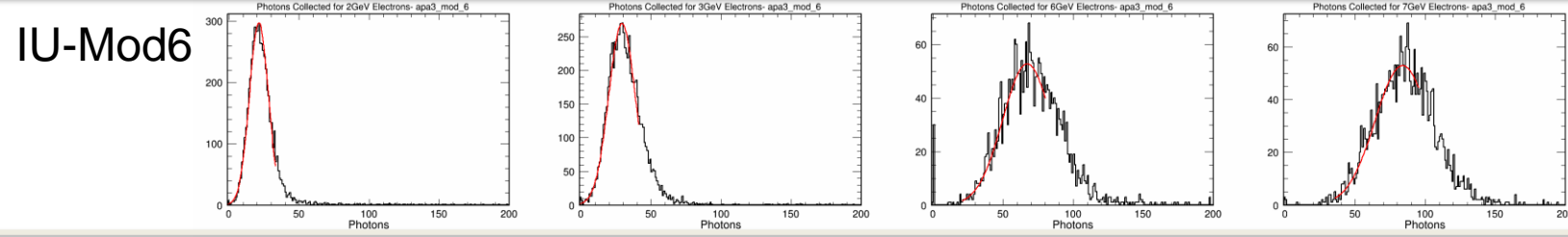
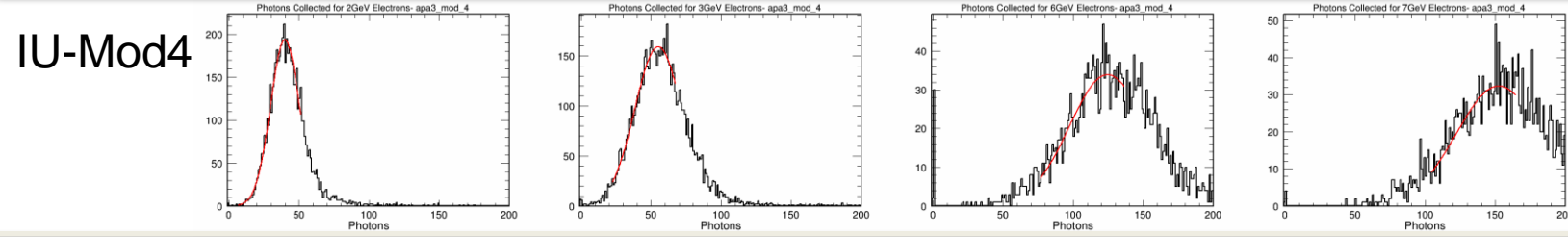
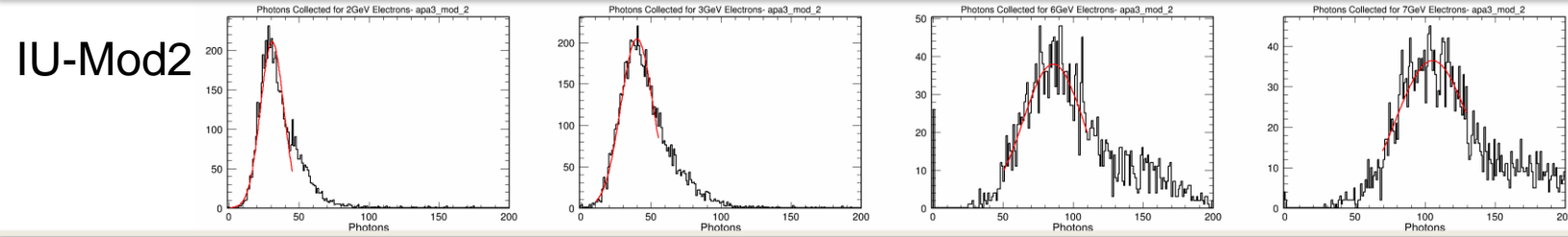
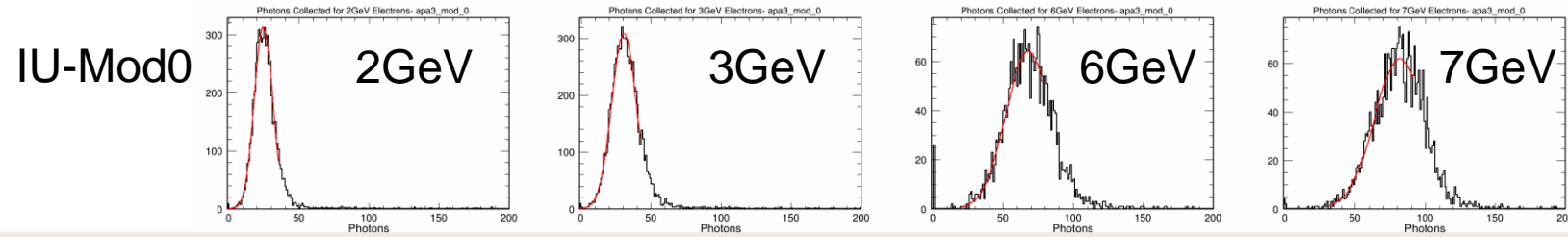
APA 1





# IU Modules- Function(p)

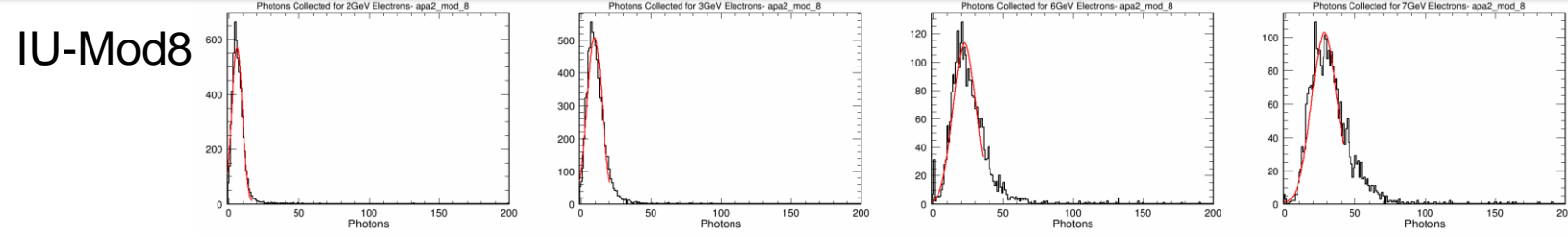
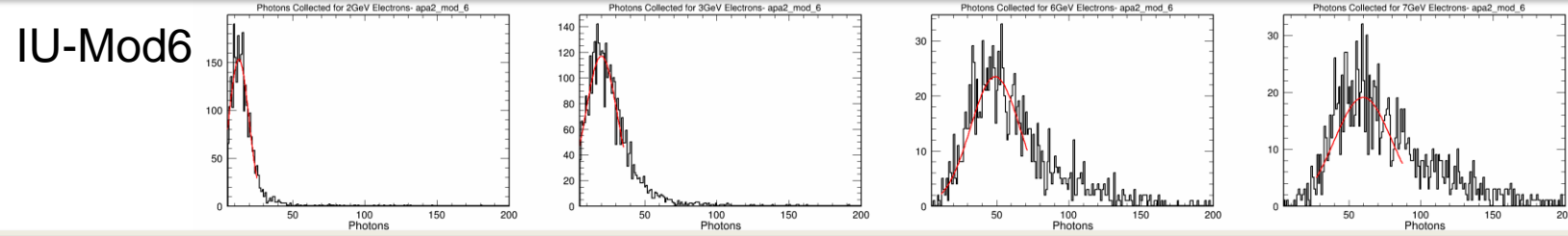
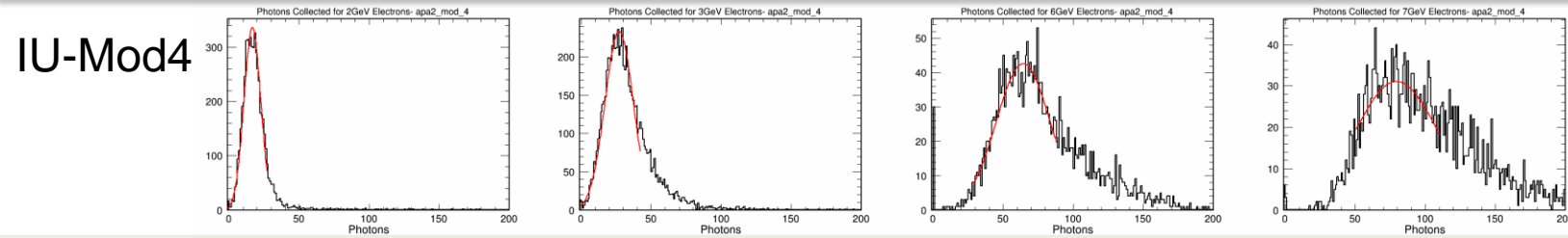
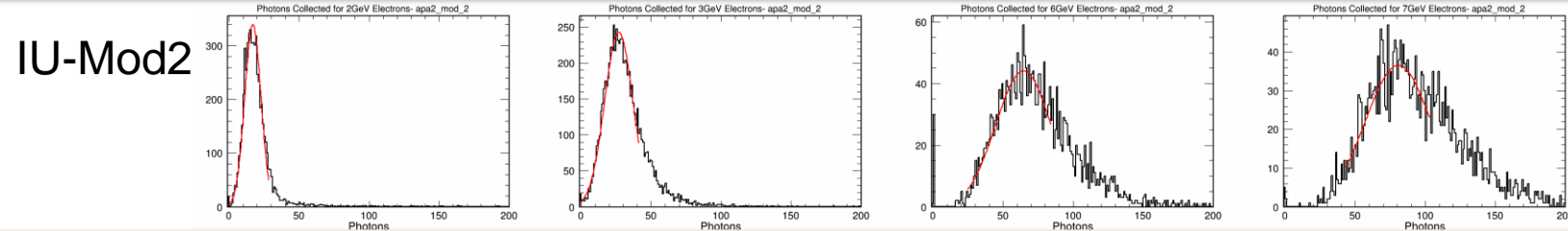
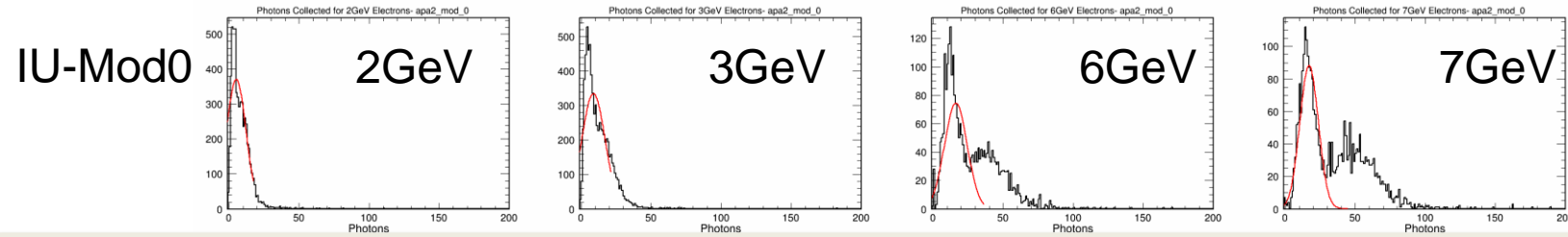
Top of APA 3



Bottom of APA 3

# IU Modules- Function(p)

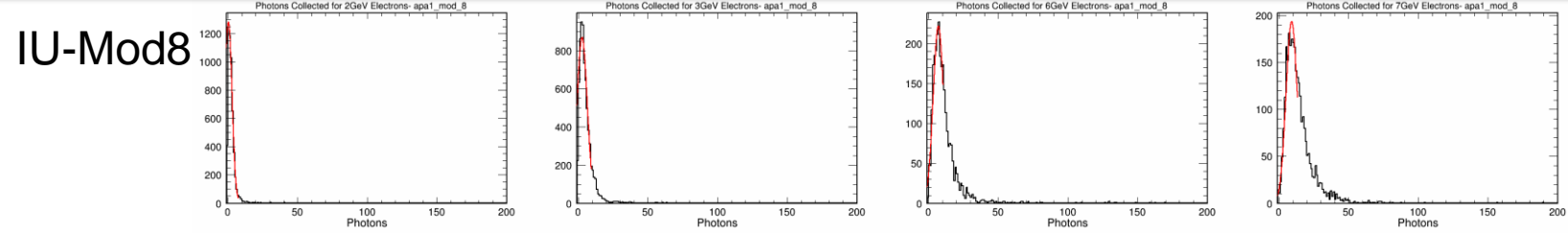
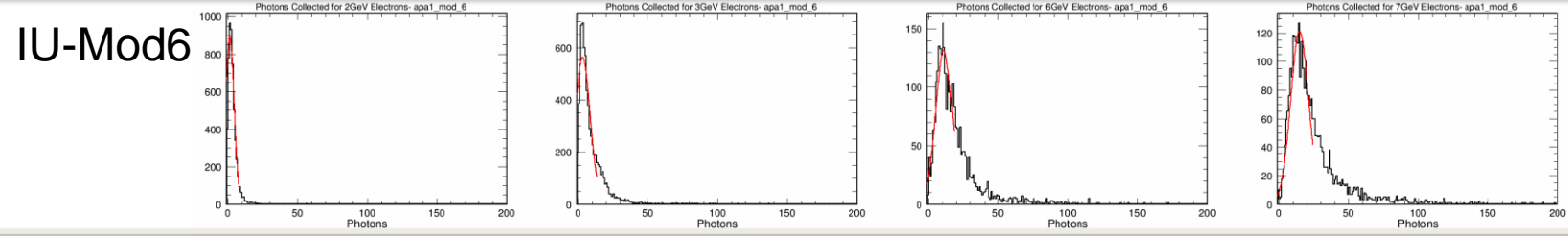
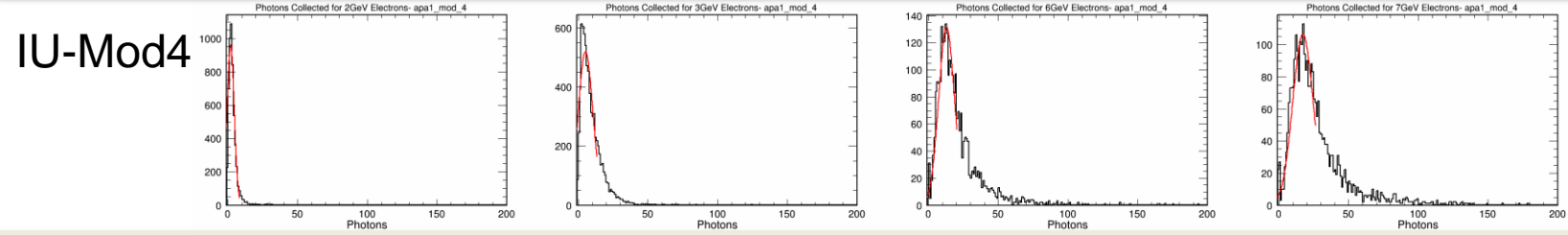
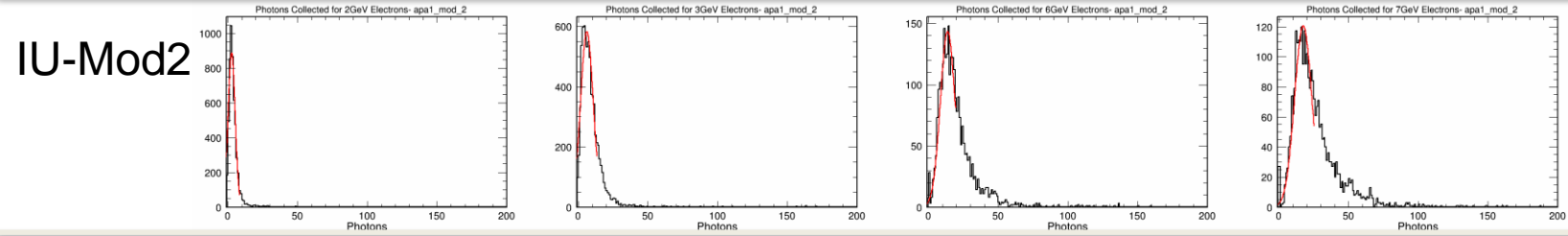
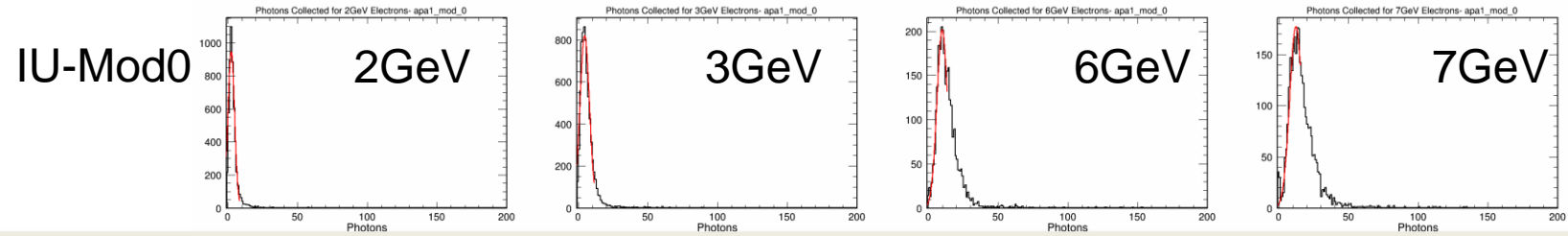
Top of APA 2



Bottom of APA 2

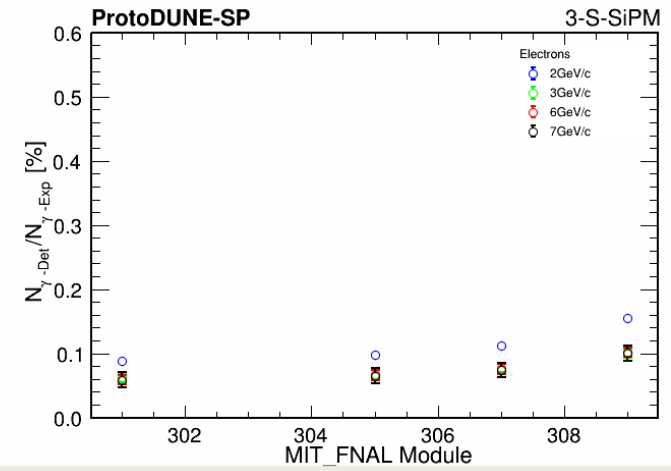
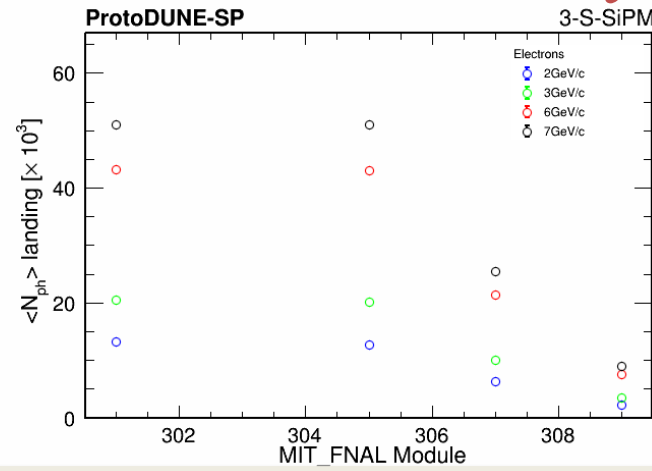
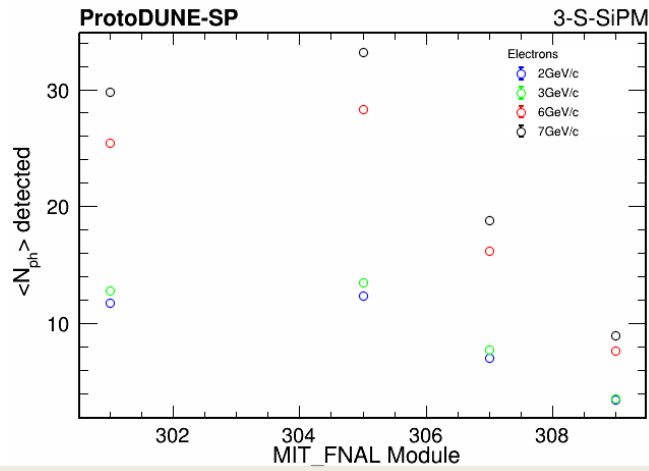
# IU Modules- Function(p)

Top of APA 1

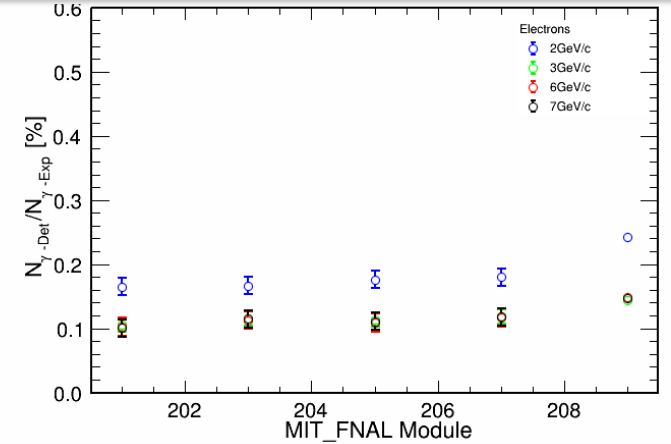
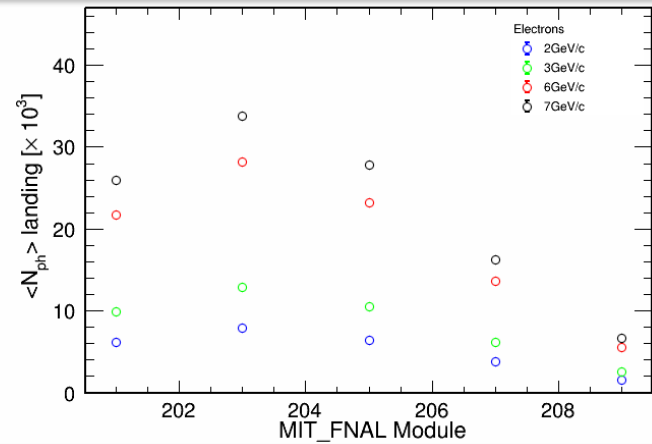
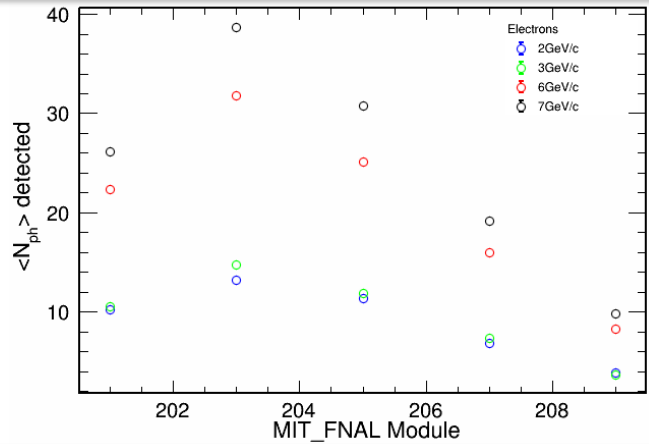


Bottom of APA 1

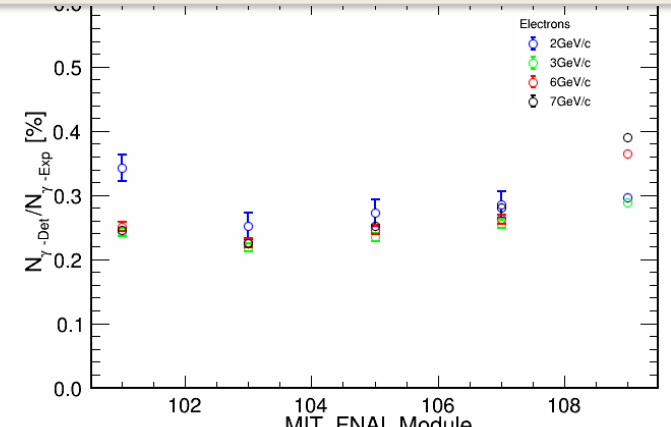
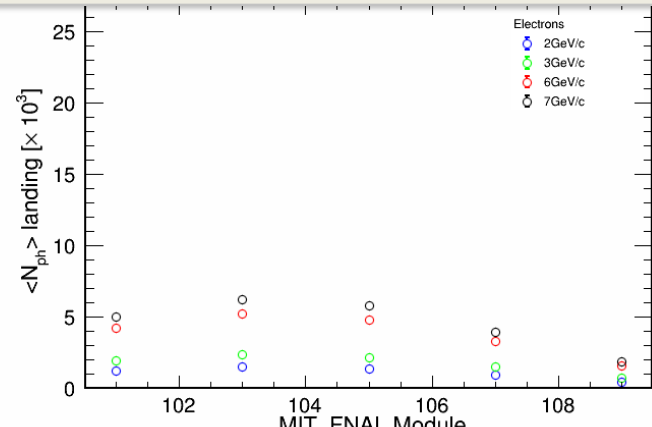
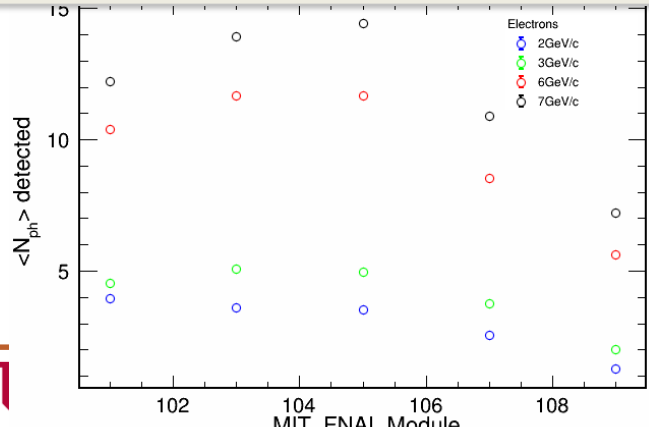
# MIT/FNAL Modules UNcorrected Efficiency Results: APAs 1-3



APA 3



APA 2

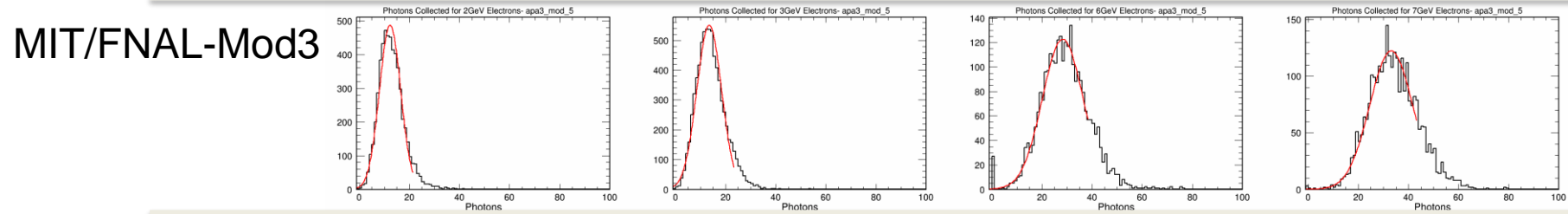
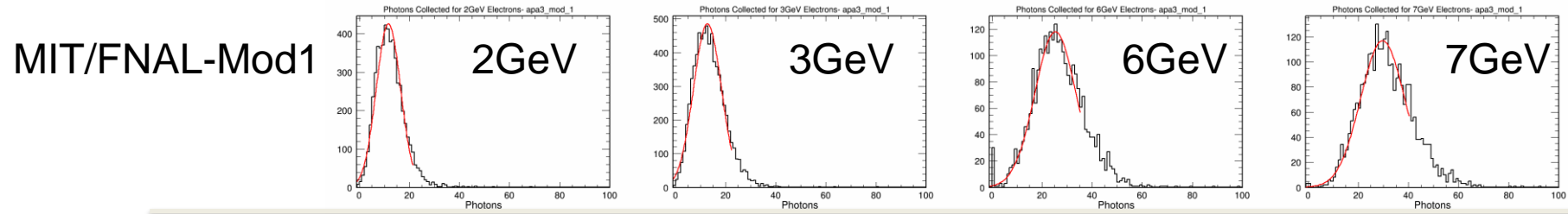


APA 1

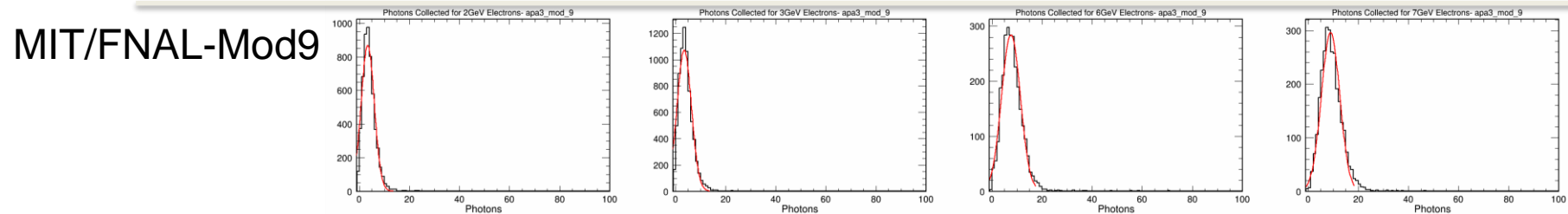
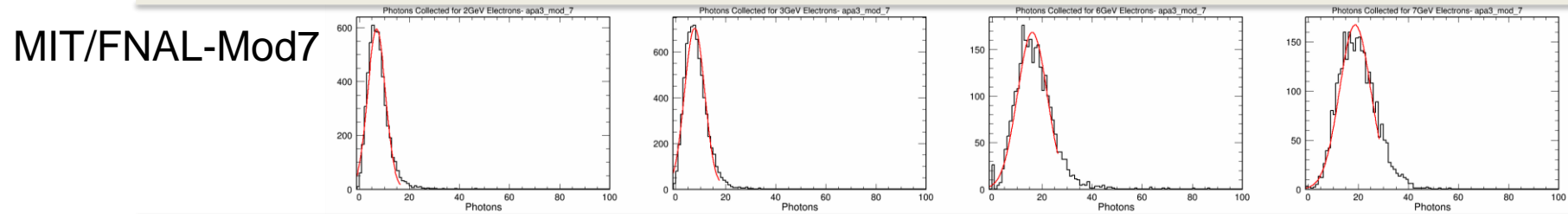


# MIT/FNAL Modules: Function(p) – APA3

Top of APA 3



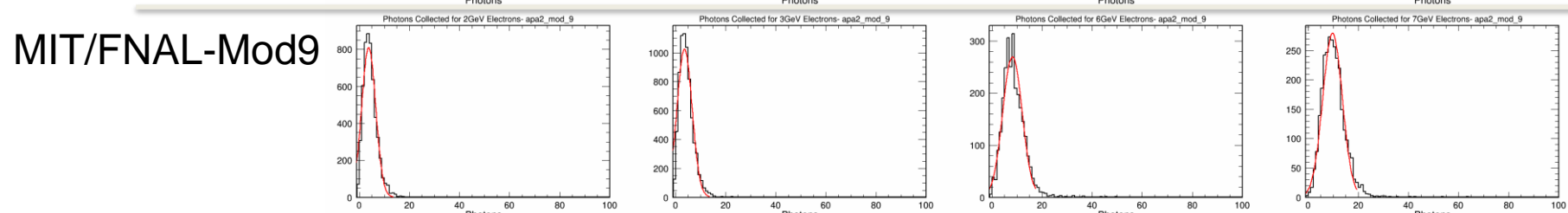
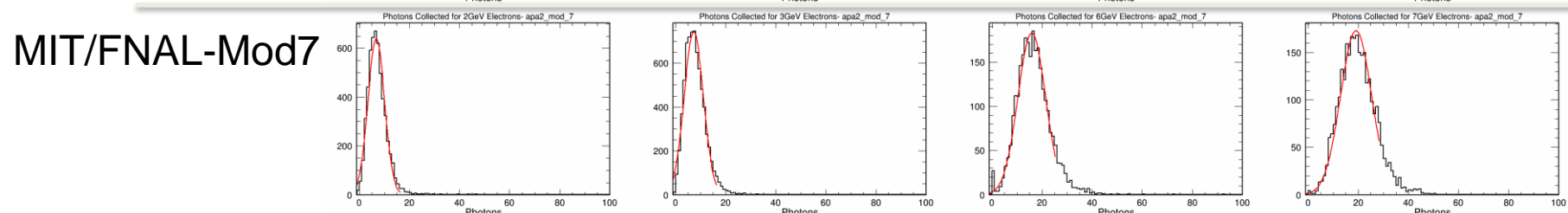
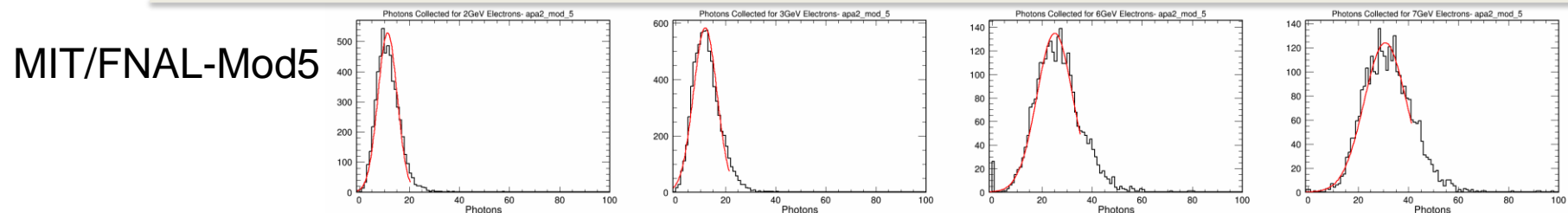
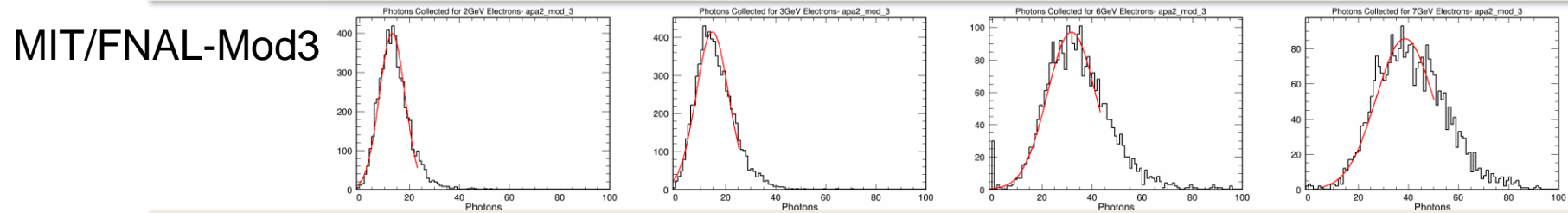
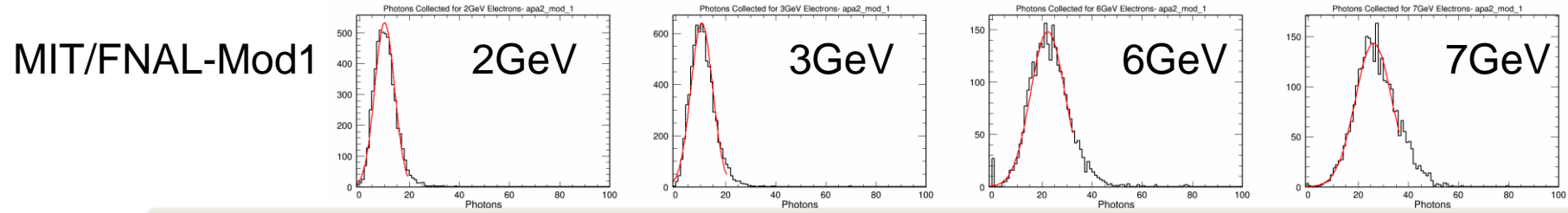
ARAPUCA



Bottom of APA 3

# MIT/FNAL Modules: Function(p) – APA3

Top of APA 2

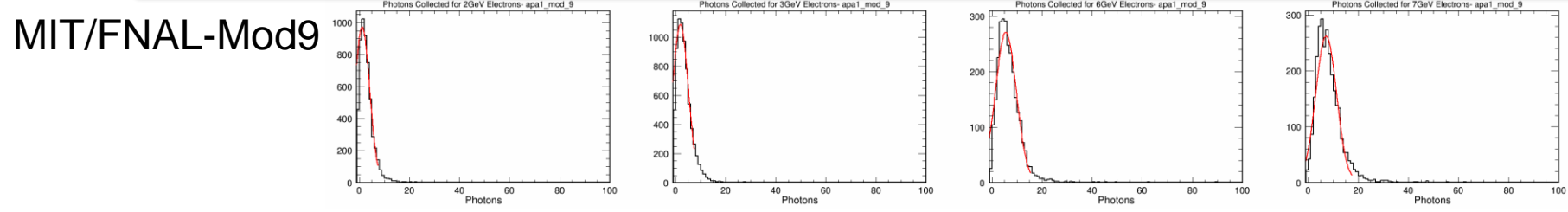
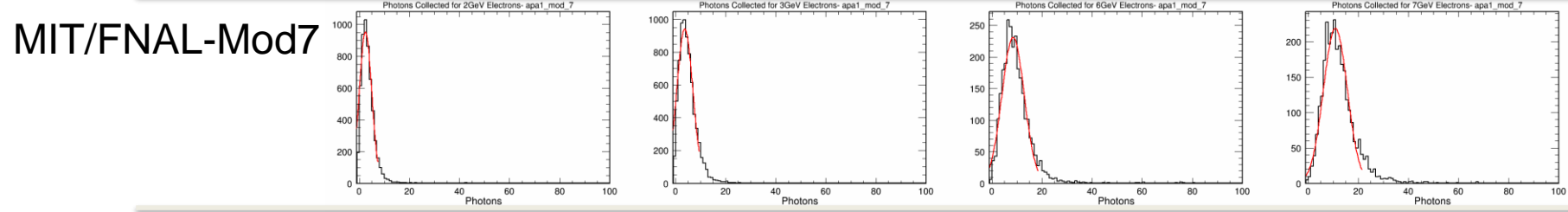
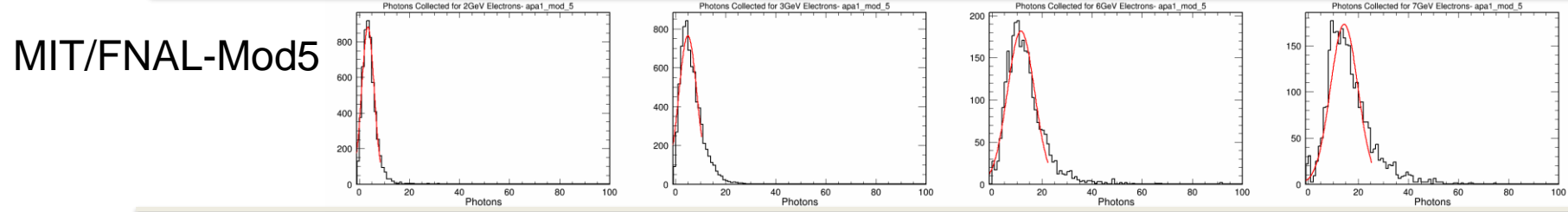
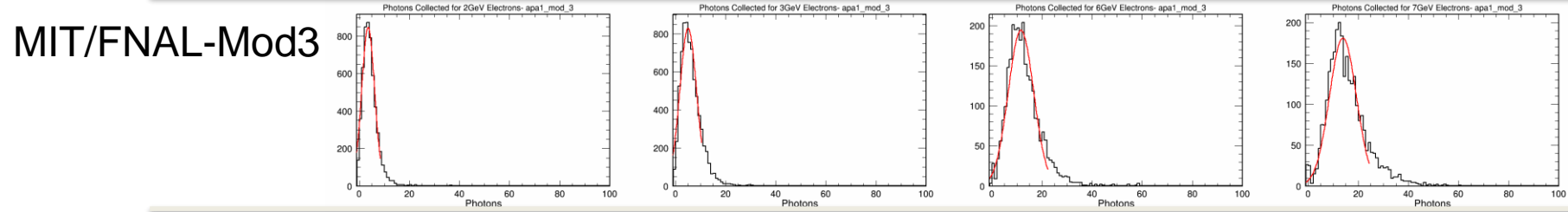
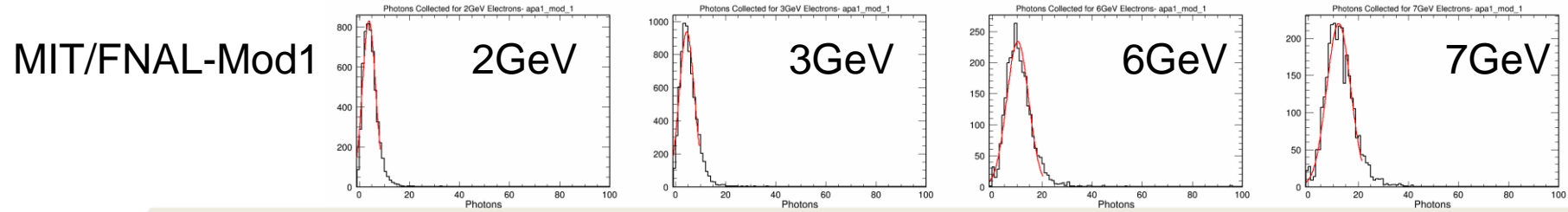


Bottom of APA 2



# MIT/FNAL Modules: Function(p) – APA3

Top of APA 1



Bottom of APA 1

# ProtoDUNE PD Channel Map



APA- Face A



APA- Face B

= Readout end

USDaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
002-0047-FL34	Hamamatsu	SSP503	0-3	216-219	41
002-0008-IU54	Hamamatsu	SSP503	4-7	220-223	43
002-0058-FL24	Hamamatsu	SSP503	8-11	224-227	45
002-0063-IU19	Hamamatsu	SSP504	0-3	228-231	47
003-0026-FL07*	SensL-C1	SSP501	0-3	192-195	49
002-0014-IU26	Hamamatsu	SSP504	4-7	232-235	51
003-0024-FL33	SensL-C1	SSP501	4-7	196-199	53
003-0004-IU48	SensL-C1	SSP501	8-11	200-203	55
002-0041-FL36	Hamamatsu	SSP504	8-11	236-239	57
002-0036-IU47	SensL-C1	SSP502	0-3	204-207	59

MSDaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
002-0002-FL22	Hamamatsu	SSP601	0-3	240-243	21
002-0054-IU22	Hamamatsu	SSP601	4-7	244-247	23
002-0059-FL08	Hamamatsu	SSP601	8-11	248-251	25
002-0020-IU09	Hamamatsu	SSP602	0-3	252-255	27
002-0060-FL39	Hamamatsu	SSP602	4-7	256-259	29
ARAPUCA-2	Hamamatsu	SSP603	0-3	264-267	31
		SSP603	4-7	268-271	
		SSP603	8-11	272-275	
002-0055-FL40	Hamamatsu	SSP602	8-11	260-263	33
002-0013-IU01	Hamamatsu	SSP604	0-3	276-279	35
002-0011-FL15	Hamamatsu	SSP604	4-7	280-283	37
002-0031-IU02	Hamamatsu	SSP604	8-11	284-287	39

DSDaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
001-0003-FL01	SensL-C1	SSP401	0-3	144-147	1
002-0044-IU50	SensL-C1	SSP401	4-7	148-151	3
002-0039-FL29	SensL-A1	SSP401	8-11	152-155	5
003-0002-IU27	SensL-C1	SSP402	0-3	156-159	7
002-0025-FL25	SensL-C1	SSP402	4-7	160-163	9
003-0011-IU37	SensL-C1	SSP402	8-11	164-167	11
003-0048-FL42	SensL-C1	SSP403	0-3	168-171	13
002-0023-IU53	SensL-C1	SSP403	4-7	172-175	15
002-0038-IU35	SensL-C1	SSP403	8-11	176-179	17
002-0040-FLP06*	SensL-C1	SSP404	0-3	180-183	19

USRaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
003-0031-IU20	SensL-A1	SSP301	0-3	96-99	40
002-0055-FL03	SensL-A1	SSP301	4-7	100-103	42
002-0020-IU31	SensL-A1	SSP301	8-11	104-107	44
ARAPUCA-1	Hamamatsu	SSP304	0-3	132-135	46
		SSP304	4-7	136-139	
		SSP304	8-11	140-143	
002-0042-IU52	SensL-A1	SSP302	0-3	108-111	48
002-0056-FL30	SensL-A1	SSP302	4-7	112-115	50
002-0047-IU17	SensL-A1	SSP302	8-11	116-119	52
002-0054-FL38	SensL-A1	SSP303	0-3	120-123	54
001-0039-IU51	SensL-A1	SSP303	4-7	124-127	56
003-0015-FL04	SensL-C1	SSP303	8-11	128-131	58

MSRaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
002-0049-IU16	SensL-A1	SSP201	0-3	48-51	20
001-0054-FL18	SensL-A1	SSP201	4-7	52-55	22
002-0035-IU13	SensL-A1	SSP201	8-11	56-59	24
002-0006-FL14	SensL-A1	SSP202	0-3	60-63	26
001-0044-IU18	SensL-A1	SSP202	4-7	64-67	28
002-0012-FL19	SensL-A1	SSP202	8-11	68-71	30
002-0027-IU12	SensL-A1	SSP203	0-3	72-75	32
002-0015-FL21	SensL-A1	SSP203	4-7	76-79	34
001-0052-IU14	SensL-A1	SSP203	8-11	80-83	36
003-0025-FL06	SensL-A1	SSP204	0-3	84-87	38

DSRaS					
PD Module	HB	SSP	SSPch	OpChannel	OptDet
403-003-0063-IU28	SensL-A1	SSP101	0-3	0-3	0
403-003-0041-FL9	SensL-A1	SSP101	4-7	4-7	2
403-002-0001-IU15	SensL-A1	SSP101	8-11	8-11	4
403-003-0054-FLP12	SensL-A1	SSP102	0-3	12-15	6
403-001-0006-IU49	SensL-A1	SSP102	4-7	16-19	8
403-003-0064-FLP13	SensL-A1	SSP102	8-11	20-23	10
403-001-0061-IU04	SensL-A1	SSP103	0-3	24-27	12
403-001-0042-FLP4	SensL-A1	SSP103	4-7	28-31	14
403-001-0025-IU21	SensL-A1	SSP103	8-11	32-35	16
403-003-0020-FL5	SensL-A1	SSP104	0-3	36-39	18

\*Modified SSP

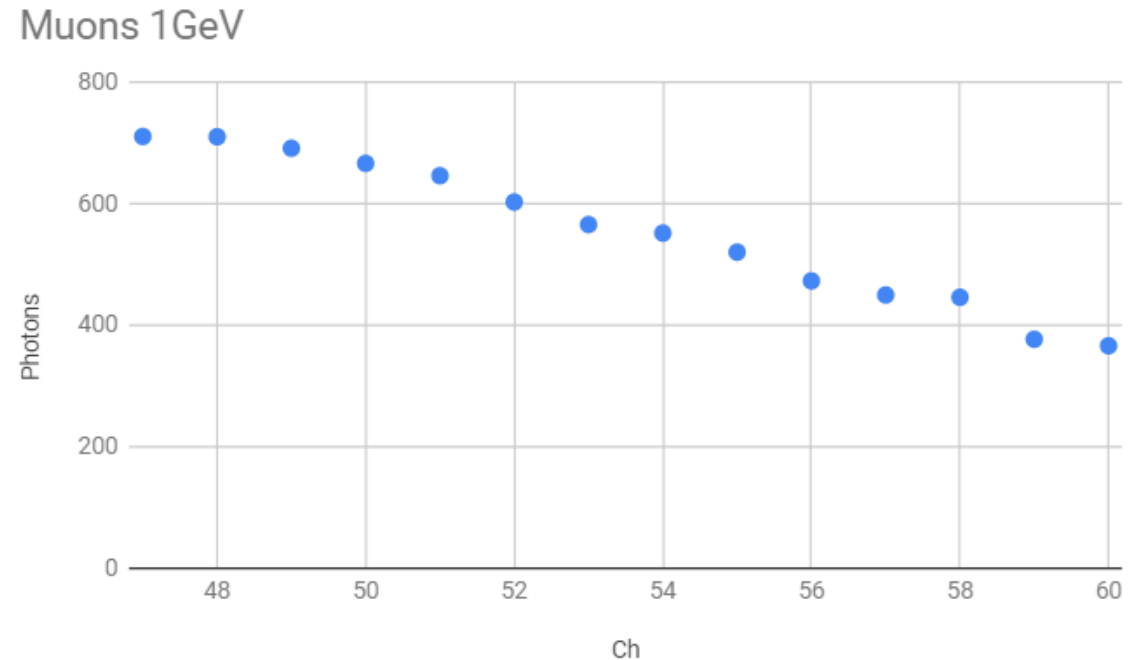
SSP_Serial#		
USDaS	MSDaS	DSDaS
127	131	120
125	130	119
132	129	118
121	128	117
123	113	109
116	112	108
115	111	107
114	102	106

SSP_IP#		
USRaS	MSRaS	DSRaS
504	604	404
503	603	403
502	602	402
501	601	401
304	204	104
303	203	103
302	202	102
301	201	101



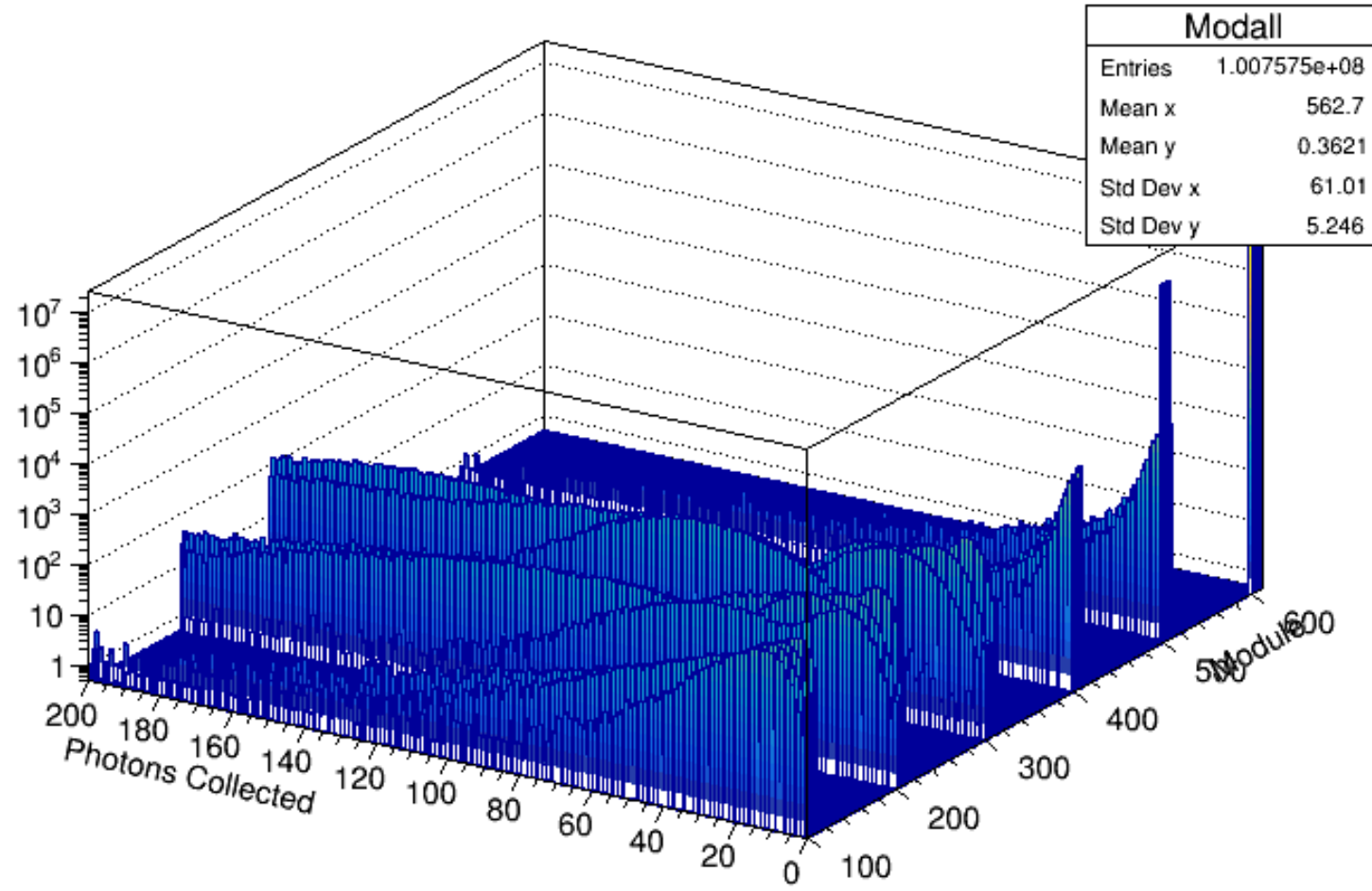
# Digging into Geometrical/Readout-end Effects

- Using ARAPUCA information from MC to predict bar geometrical/readout effect
  - Number of incident photons landing on each position along a bar.
- Fit an expected bar attenuation function to measure any variation
- Compare effect to bars
- Still in progress...

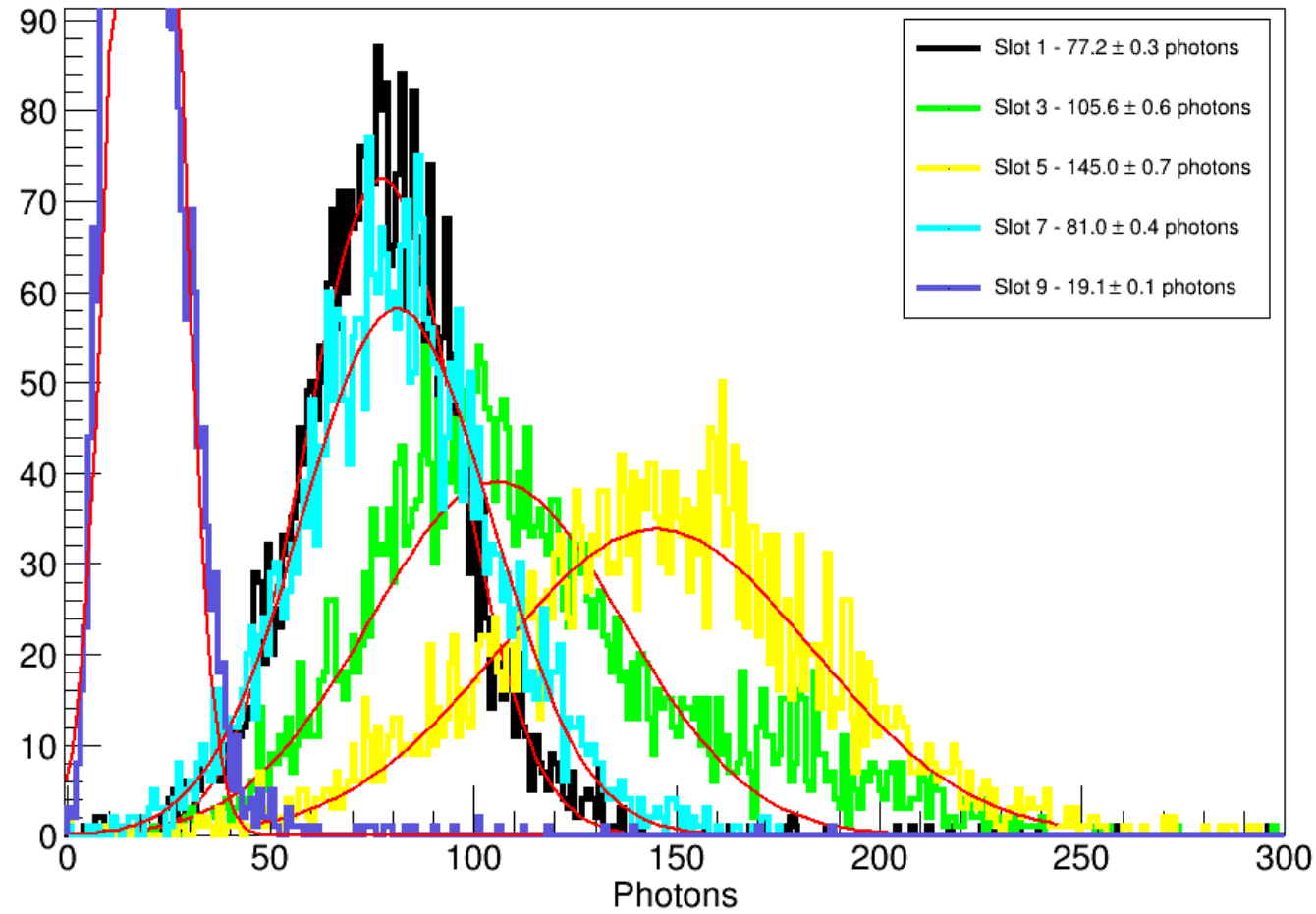


## Other Ways to Look at the Data

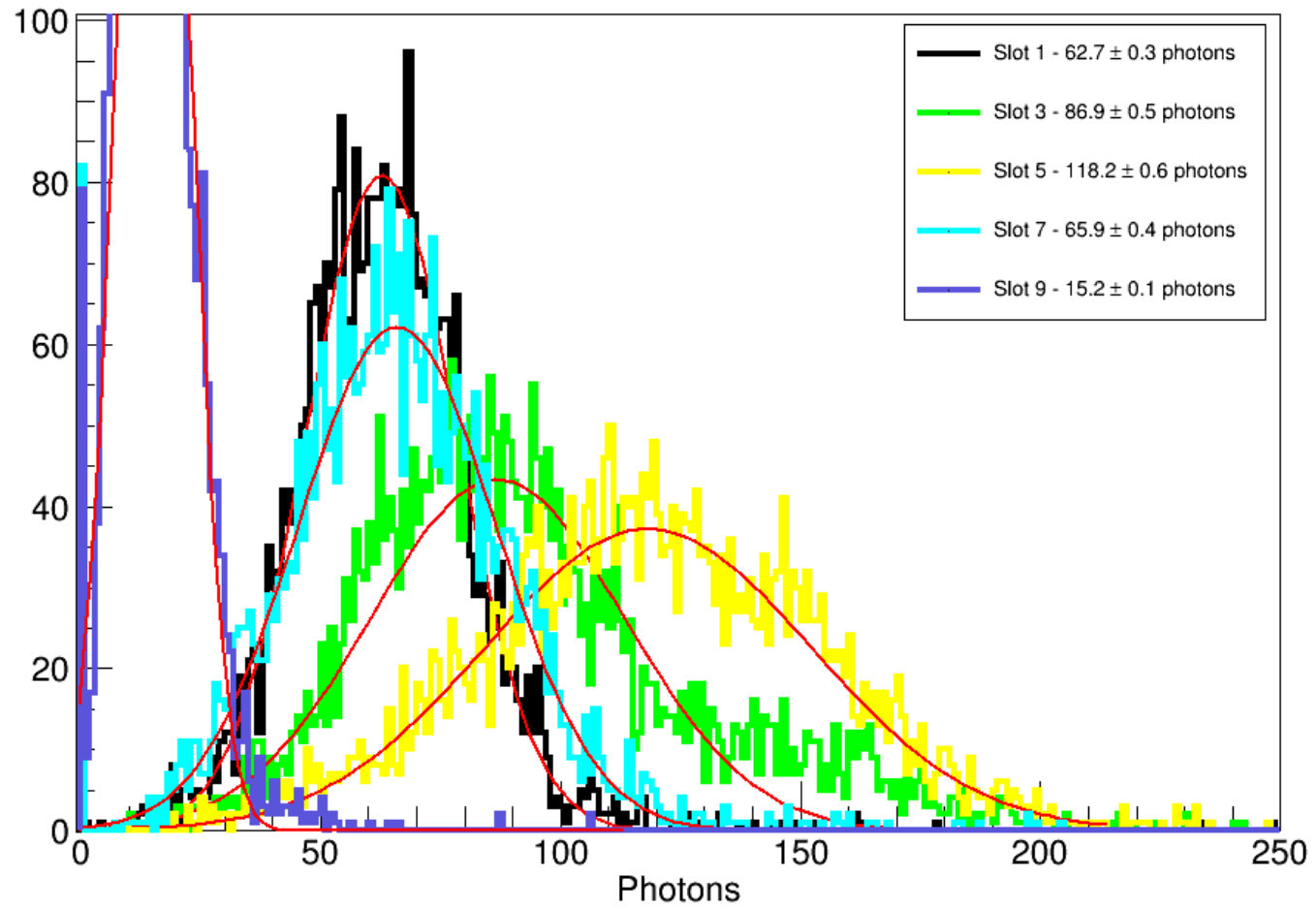
# Photons Collected for 7GeV Electrons



Photons per Module- 7GeV Electrons

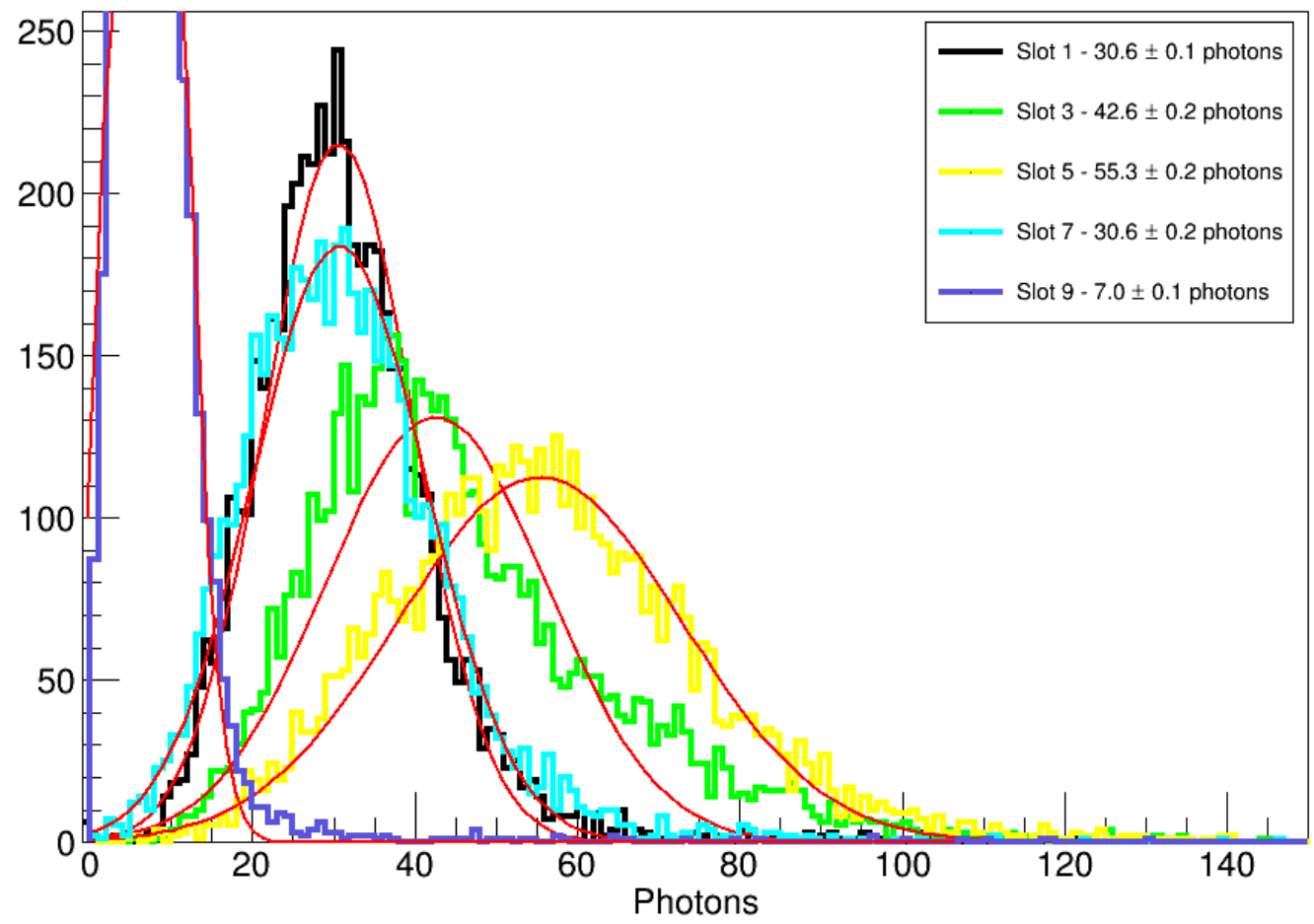


Photons per Module- 6GeV Electrons

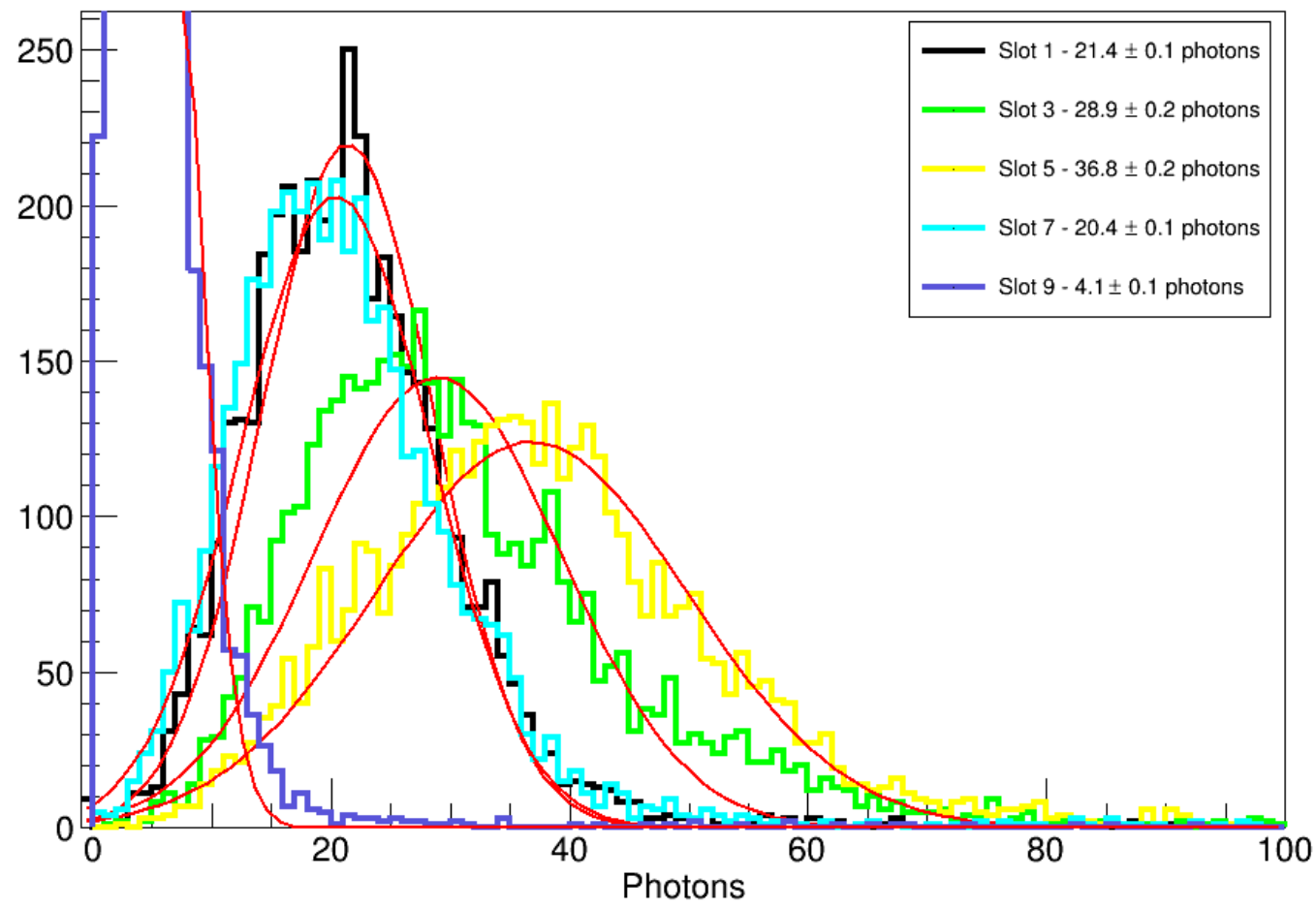




Photons per Module- 3GeV Electrons



Photons per Module- 2GeV Electrons



Photons per Module- 1GeV Electrons

