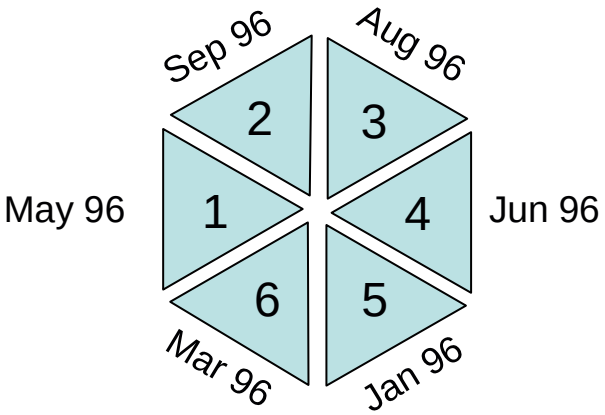
Forward EM Calorimeter
Status and Outlook

C. Smith, UVa



Issues for Forward EC and CLAS12

- **Integration with pre-shower calorimeter (PCAL)**
  - Common calibration, monitoring and data analysis scheme

- **New trigger and readout electronics**
  - Flash ADCs for both PCAL and FCAL
    - Deadtimeless, massive buffering, no delay cables
    - Opens possibilities for more sophisticated trigger (better e^- ID)
    - Eliminate or augment analog summing amplifiers ?
  - MIP energy calibration (FADC charge sensitivity, noise issues)

- **Longevity of FEC for CLAS12**
  - Oldest sector (5) in use since Jan. 1996
  - PMT and scintillator aging, radiation damage

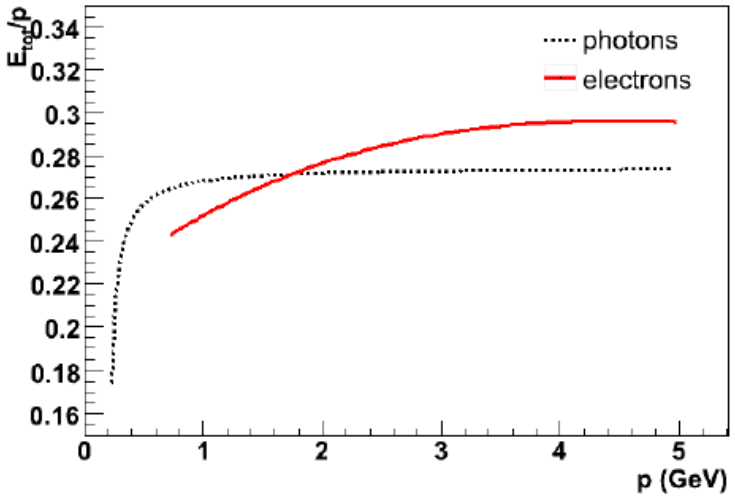
Status - Hardware

- **EC HV mainframes**
  - Replacement rate excessive
  - Frequent trips and failures during running (radiation ? cooling ? firmware?)

- **Noisy ADC pedestals**
  - Specs: 0.7 channel RMS Measured: 2 - 6 channels
  - Increases event size
  - Affects accuracy of cosmic or MIP calibration
    - MIP is only 100 channels above pedestal
  - Future solution to noisy peds
    - Cable routing should be less vulnerable to disturbance
    - Reduce ground loops
    - AC coupled inputs

- **Photomultipliers**
  - HV divider replacement rate ~ 6 yr^{-1}
  - Mostly capacitor and FET failures…lots of spares.
  - XP2262 PMT still available from Photonis

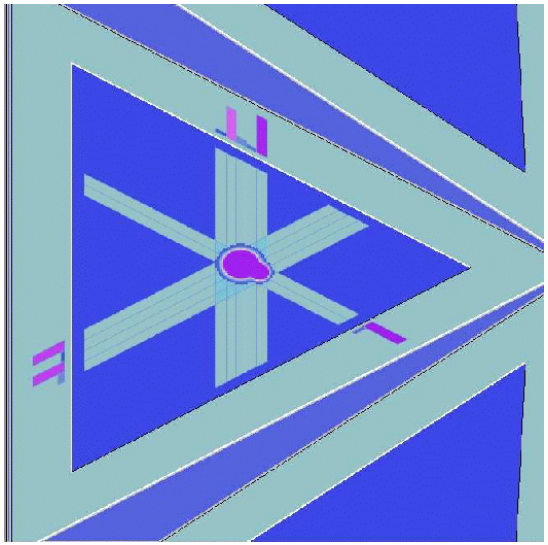
Recent EC Studies

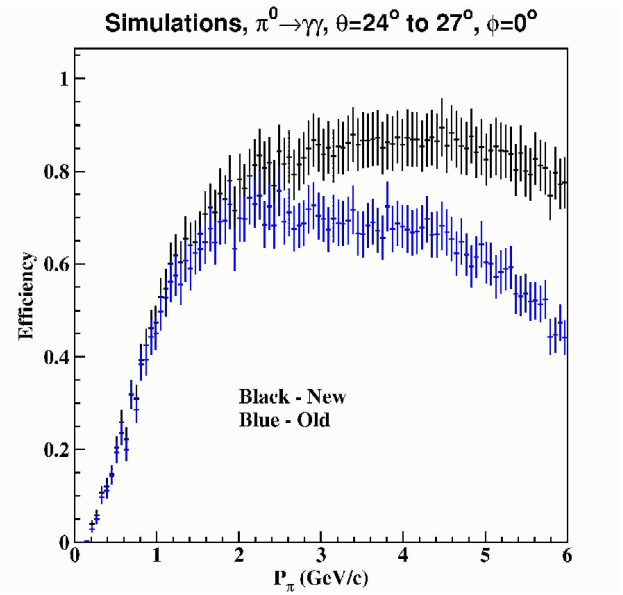


Photon energy corrections in EC from data

R. De Masi et al., CLAS NOTE 2006-015

Longstanding question: Why is sampling fraction of photons and electron different ?





Improved reconstruction algorithm…

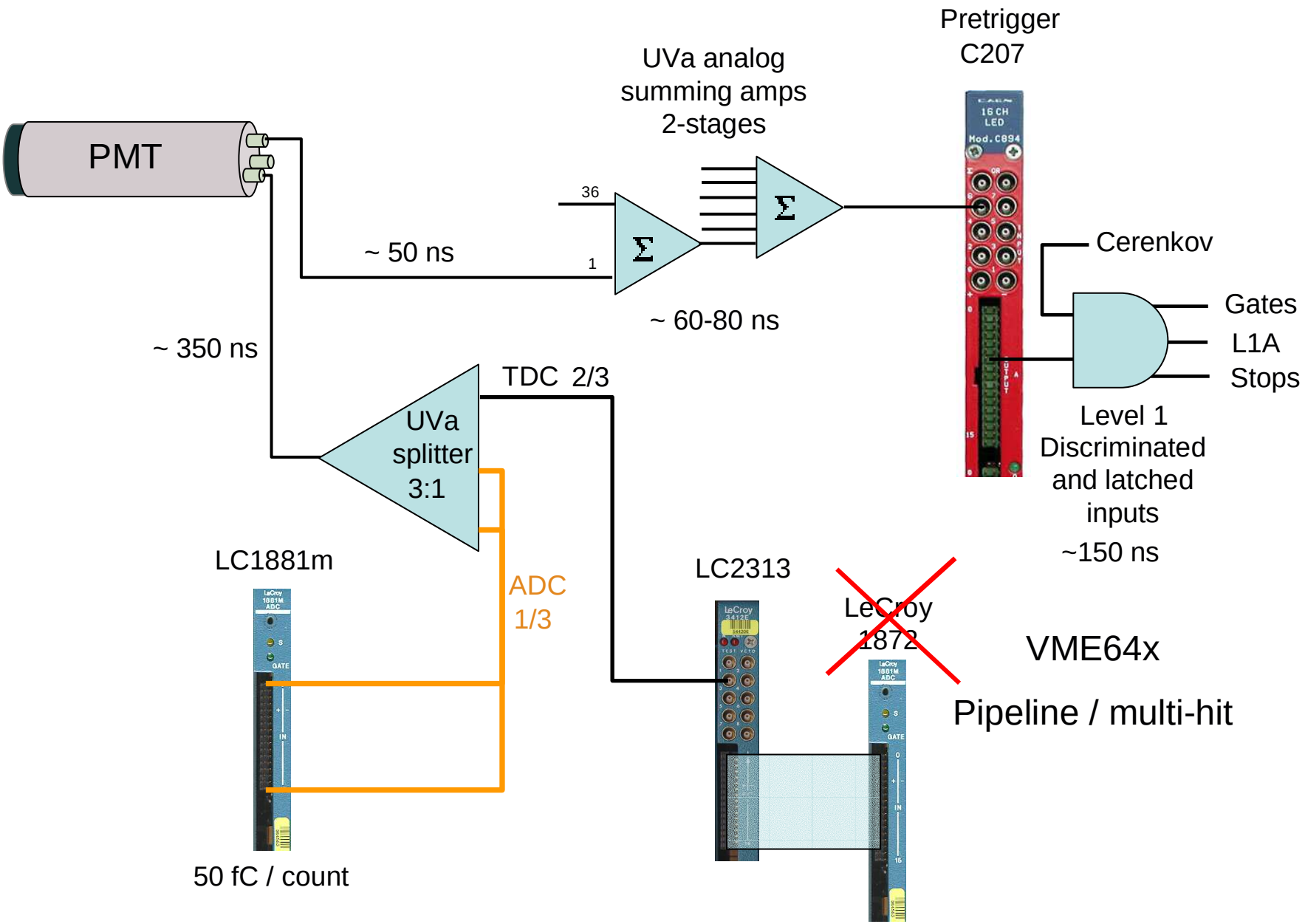
Natasha Dashyan (Yerphi)

Stepan Stepanyan (JLAB)

CLAS NOTE 2006-16

New cluster recognition better separates 2-photon hits for π^0 reconstruction

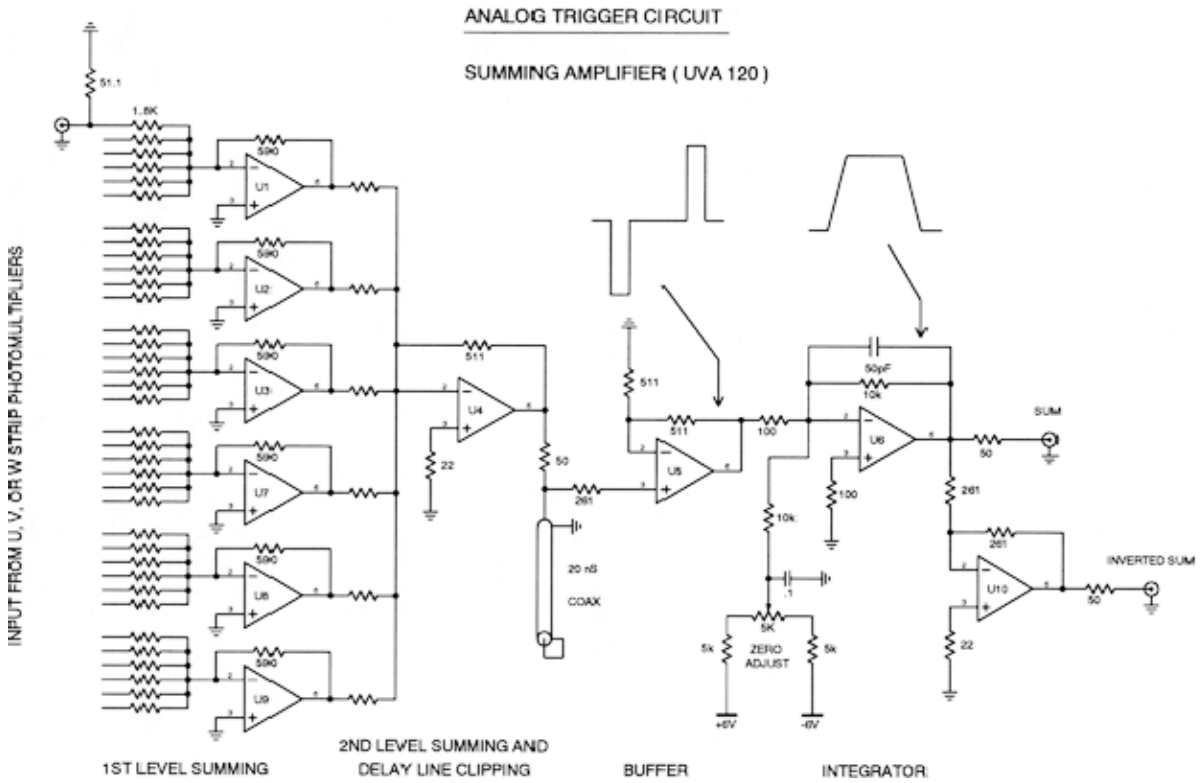
Present trigger relatively unsophisticated – requires long delays



CLAS Level 1 PreTrigger - EC Summing Amplifiers

Trigger: Total energy deposited in the FEC + Cerenkov

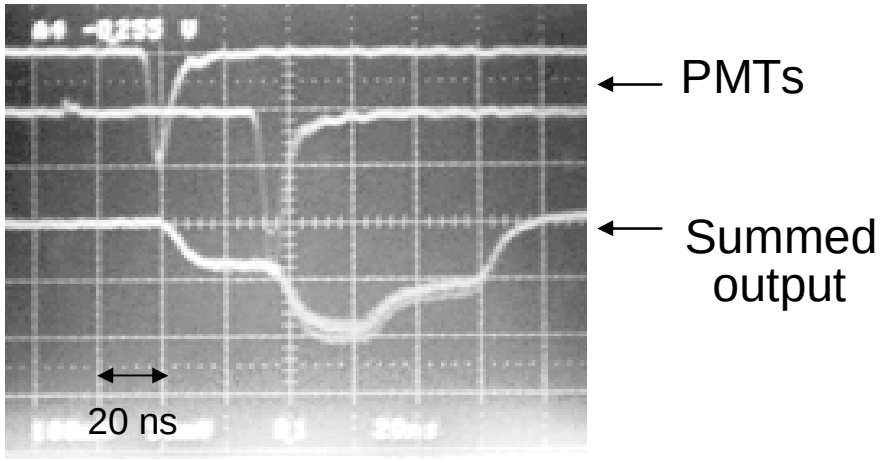
At high energies electron ID is very inefficient due to hadronic interactions



• 1st level summing: 36 PMT signals from each U,V,W view summed in groups of 6 to minimize noise.

• EC triangular geometry: dispersion in PMT pulse arrival times requires slow integration.

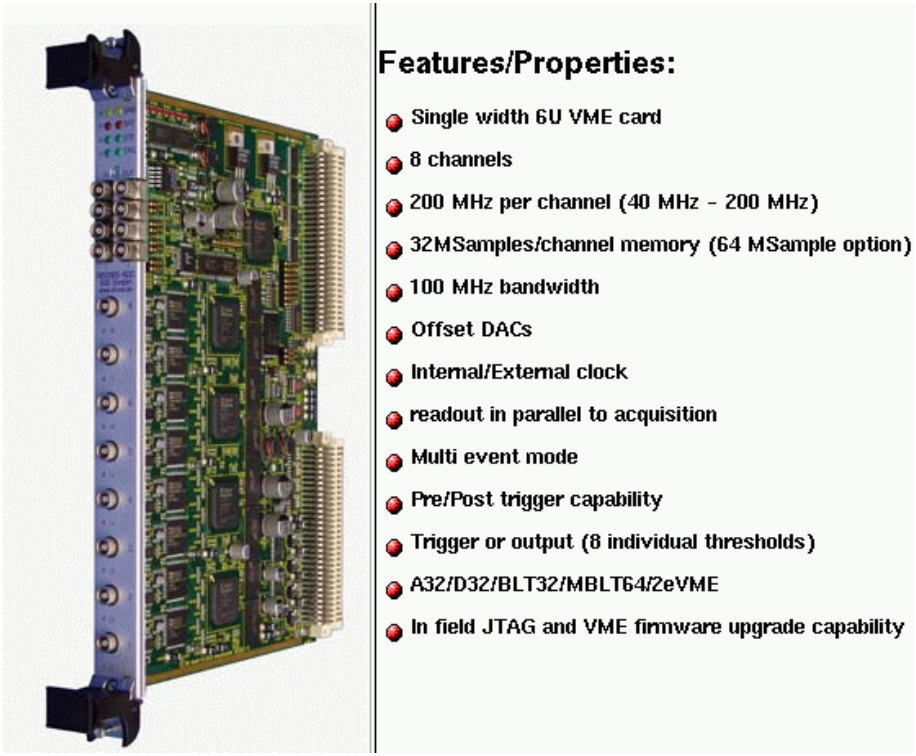
•For CLAS12 more restrictive energy selection may be performed in software by combining info from Flash ADCs, multihit TDCs and other detector components.



Flash ADC test setup – EC cosmics

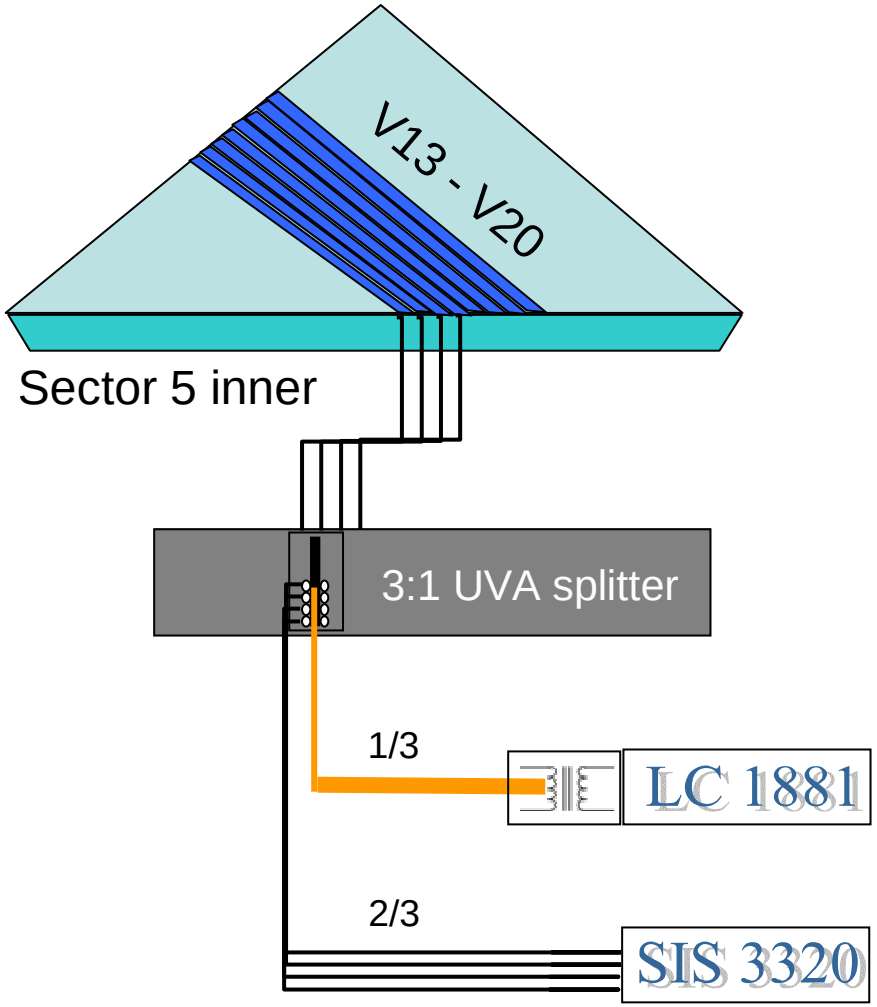
SIS3320 8 Channel 200 MHz

12-bit ADC / Wave Form Digitizer



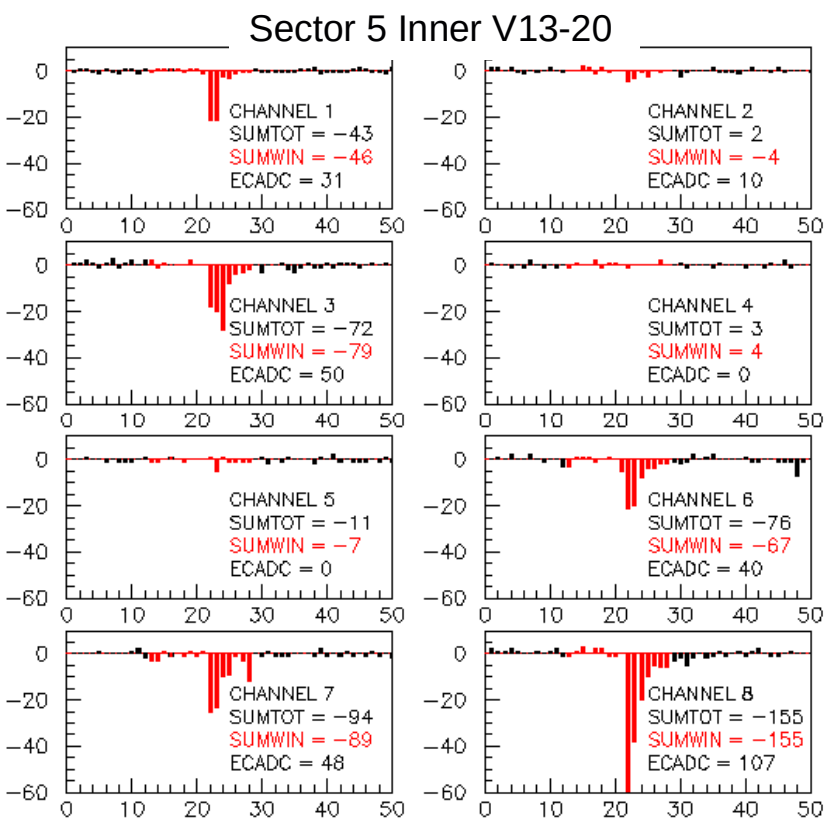
Features/Properties:

- Single width 6U VME card
- 8 channels
- 200 MHz per channel (40 MHz - 200 MHz)
- 32MSamples/channel memory (64 MSample option)
- 100 MHz bandwidth
- Offset DACs
- Internal/External clock
- readout in parallel to acquisition
- Multi event mode
- Pre/Post trigger capability
- Trigger or output (8 individual thresholds)
- A32/D32/BLT32/MBLT64/2eVME
- In field JTAG and VME firmware upgrade capability

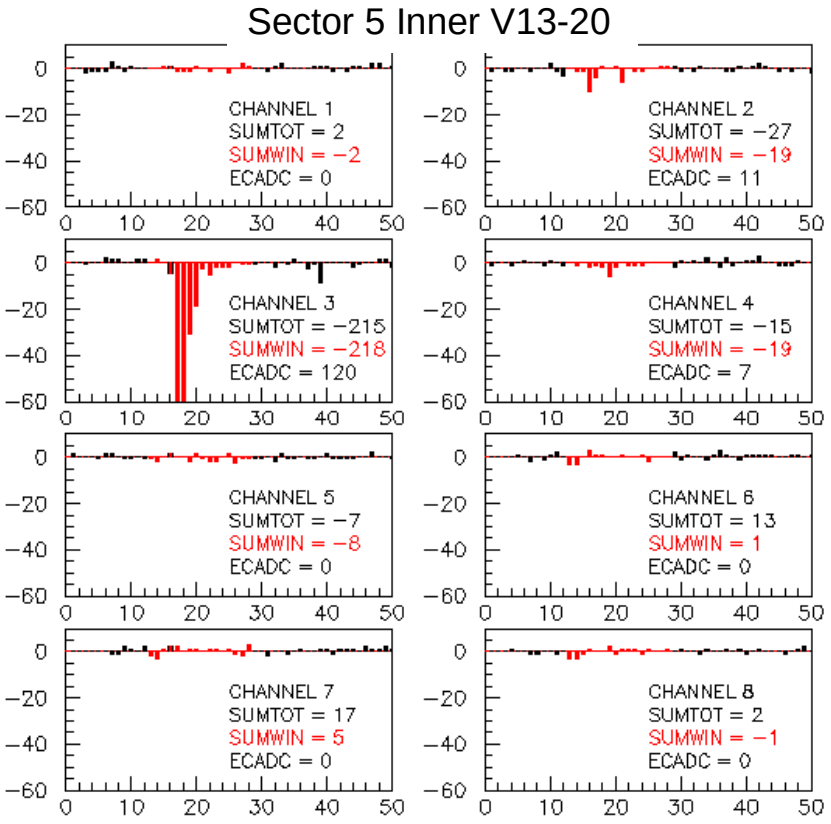


Serguei Pozdniakov, CLAS NOTE 2006-023

Typical FADC waveform captures of cosmic triggers



Cosmic shower spread over several strips



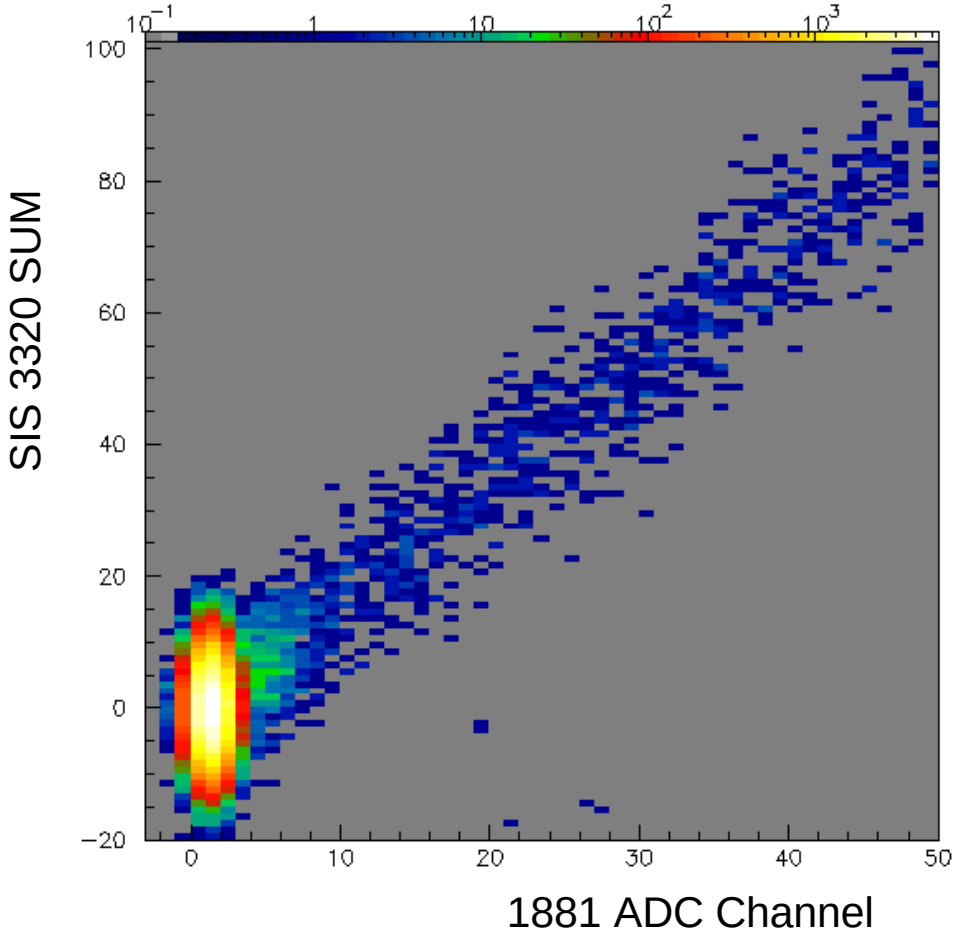
Direct hit on single pixel

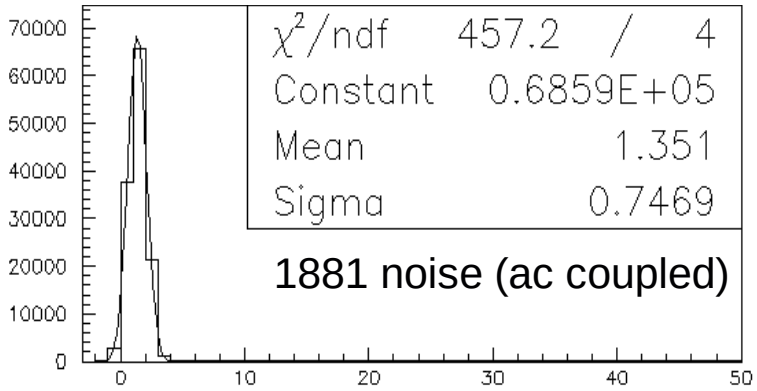
FADC : ~ 1 mV / count

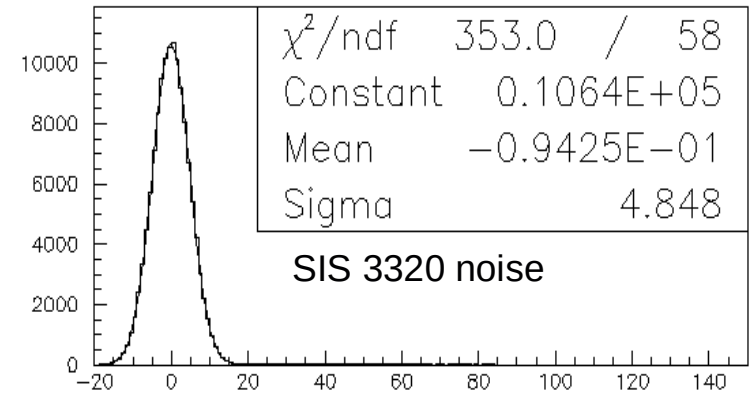
1881M: 50 fC / count

Baseline (pedestal) subtracted on event-by-event basis. Still need to find summing algorithm which optimizes signal/noise.

Comparison of LC1881 and SIS3320







Main issue for calibration purposes is noise relative
to mip peak at 10 MeV (channel 100 for 1881)

ENERGY RECONSTRUCTION

$$E_{tot} = \sum_{i,o} \sum_{u,v,w} \sum_{n} E_n / f_s$$

$$E_n = g_n (A_n^{sig} - A_n^{ped}) / \exp(-x_{uvw} / \lambda_n)$$

E_n = energy deposited in scintillator stack

f_s = sampling fraction [~ 0.27]

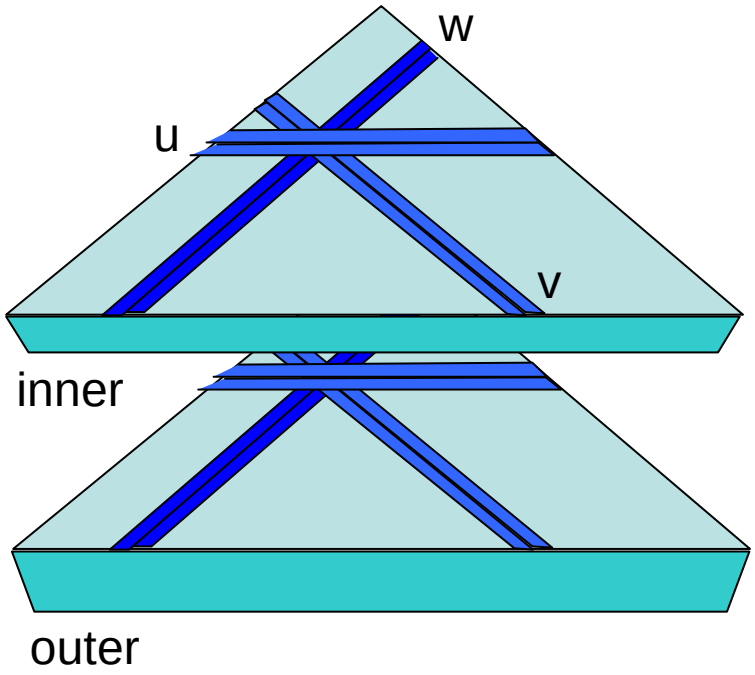
g_n = ADC calibration [~0.1 MeV/channel]

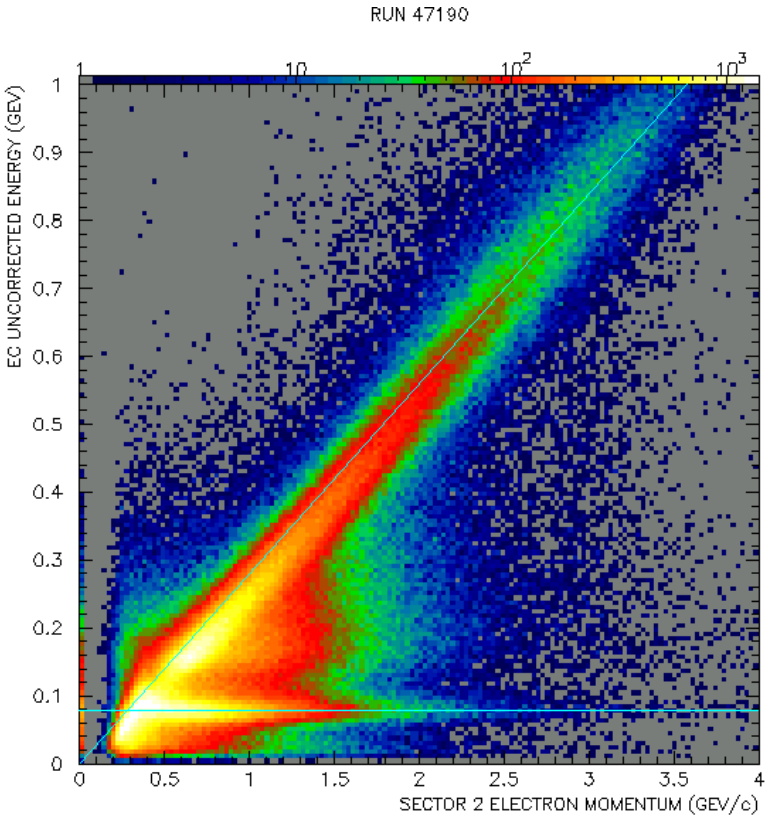
A_n^{sig} = ADC channel

A_n^{ped} = ADC pedestal

x_{uvw} = distance from PMT to reconstructed hit

λ_n = effective attenuation length of stack





History of calibration runs since Sept 1997…

- ~ 180 pedestal runs
  - Accumulate 1000-2000 events
  - PEDMAN used to analyze
  - Data stored in $CLON_PARMS/pedman/Tfiles

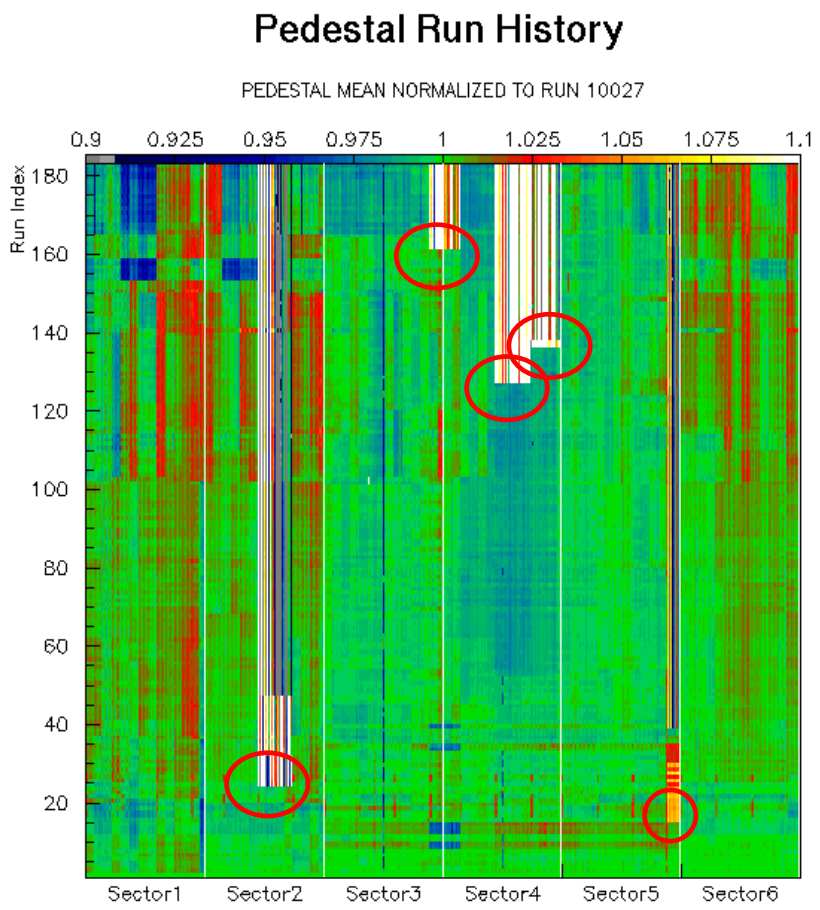
- ~ 120 cosmic ray runs
  - 50-100 million triggers at 2 kHz (~ 12 hour runs)
  - Single pixel event filter
  - No event recorder – data histogrammed directly from ET

- EC PMT HV adjusted ~ 20 times
  - Usually just prior to each run period if needed

What do 10 years tell us?

Time Dependence of Pedestals

http://www.jlab.org/Hall-B – Forward Calorimeters



ADC swaps

MEAN	RAW	NORM
RMS	RAW	NORM

Run Index	Run	Run Index	Run	Run Index	Run	Run Index	Run
1	10027	49	19531	97	24295	145	37636
2	11218	50	20014	98	24452	146	38533
3	11268	51	20060	99	24478	147	38754
4	11383	52	20163	100	24499	148	39679
5	11479	53	20178	101	25395	149	39733
6	11601	54	20447	102	25405	150	40495
7	11968	55	20563	103	25550	151	40764
8	12731	56	20778	104	25741	152	41223
9	12778	57	21012	105	25943	153	41575
10	13193	58	21032	106	25990	154	41851
11	13196	59	21098	107	26030	155	42251
12	13221	60	21119	108	26083	156	42365
13	13231	61	21396	109	26202	157	42682
14	13238	62	21639	110	26852	158	42862
15	13636	63	21688	111	27050	159	43426
16	13734	64	21705	112	27091	160	43660
17	13736	65	21730	113	27221	161	43661
18	13738	66	21732	114	28350	162	43779
19	13739	67	21752	115	28581	163	43780
20	13742	68	21768	116	28790	164	44100
21	13746	69	21811	117	29116	165	45383
22	13845	70	22005	118	29446	166	45838
23	13847	71	22037	119	29603	167	45967
24	13888	72	22165	120	29872	168	46319
25	13996	73	22199	121	30120	169	46322
26	14010	74	22342	122	30288	170	46325
27	14058	75	22364	123	30389	171	46387
28	14062	76	22689	124	30573	172	46500
29	14162	77	22691	125	30578	173	46502
30	14715	78	22868	126	30642	174	46515
31	14910	79	22964	127	30776	175	46764
32	15266	80	23292	128	31161	176	46950
33	15817	81	23426	129	31198	177	47173
34	15819	82	23536	130	31529	178	47243
35	15968	83	23705	131	31530	179	49079
36	16082	84	23745	132	31531	180	50664
37	17211	85	23790	133	31543		
38	17581	86	23860	134	31559		
39	17619	87	23930	135	31755		
40	17827	88	24034	136	31772		
41	17841	89	24078	137	31777		
42	18076	90	24116	138	31778		
43	18081	91	24125	139	32950		
44	18527	92	24197	140	34376		
45	18722	93	24213	141	34468		
46	18791	94	24264	142	35812		
47	19484	95	24277	143	36457		
48	19529	96	24293	144	37595		

Red indicates entries in Hardware Log (below)

Hardware Log

LeCroy 1881 ADC

RUN	COMMENTS	ELOG
13636	EC1 slot 04 noisy	No Entry
13888	EC2 slot 20 replaced	Entry 2810
14069	EC1 slot 04 noisy	Entry 2863
15266	EC2 slot 20 replaced	Entry 3430
17619	EC1 slot 04 replaced	Entry 4634
19531	EC2 slot 20 replaced	Entry 5558
30776	EC1 slot 09 replaced	Entry 12251
31778	EC1 slot 08 replaced	Entry 13308
43661	EC1 slot 11 replaced	Entry 17900

LeCroy 1872 TDC

RUN	COMMENTS	ELOG
13448	EC1 slot 4 slot 22 replaced	Entry 2847
13888	ADC 1881 EC2 slot 20 replaced	Entry 2810
14069	ADC 1881 EC1 slot 4 noisy	Entry 2863
15266	ADC 1881 EC2 slot 20 replaced	Entry 3430
19531	ADC 1881 EC2 slot 20 replaced	Entry 5558
30776	ADC 1881 EC1 slot 9 replaced	Entry 12251
31778	ADC 1881 EC1 slot 8 replaced	Entry 13308
43661	ADC 1881 EC1 slot 11 replaced	Entry 17900

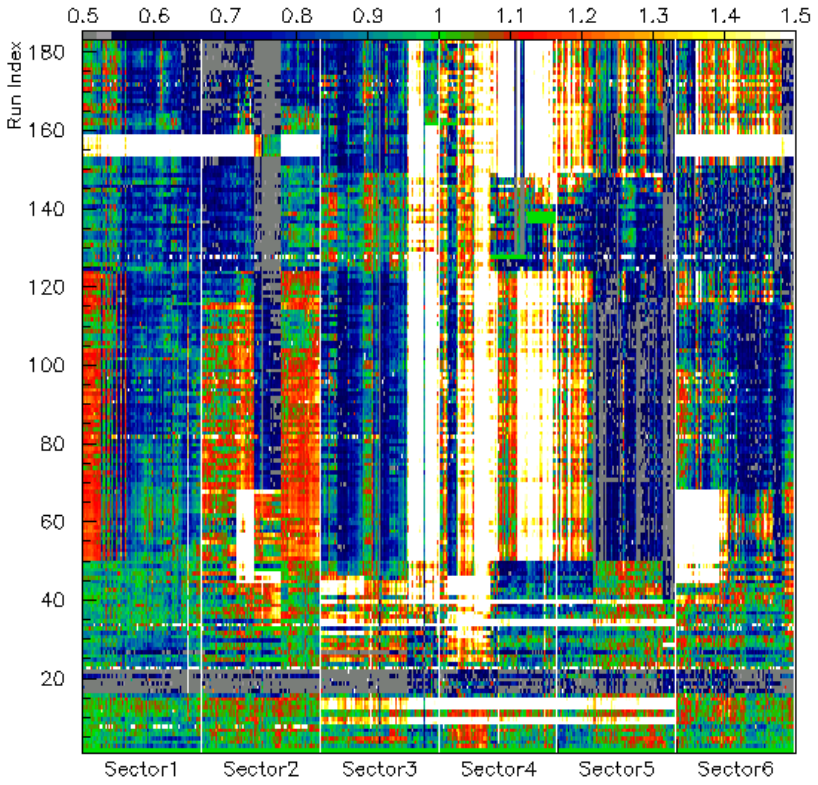
http://www.jlab.org/Hall-B – Forward Calorimeters

Time Dependence of Pedestal Noise

http://www.jlab.org/Hall-B - Forward Calorimeters

Pedestal Run History

PEDESTAL RMS NORMALIZED TO RUN 10027



MEAN	RAW	NORM
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Run Index	Run	Run Index	Run	Run Index	Run	Run Index	Run
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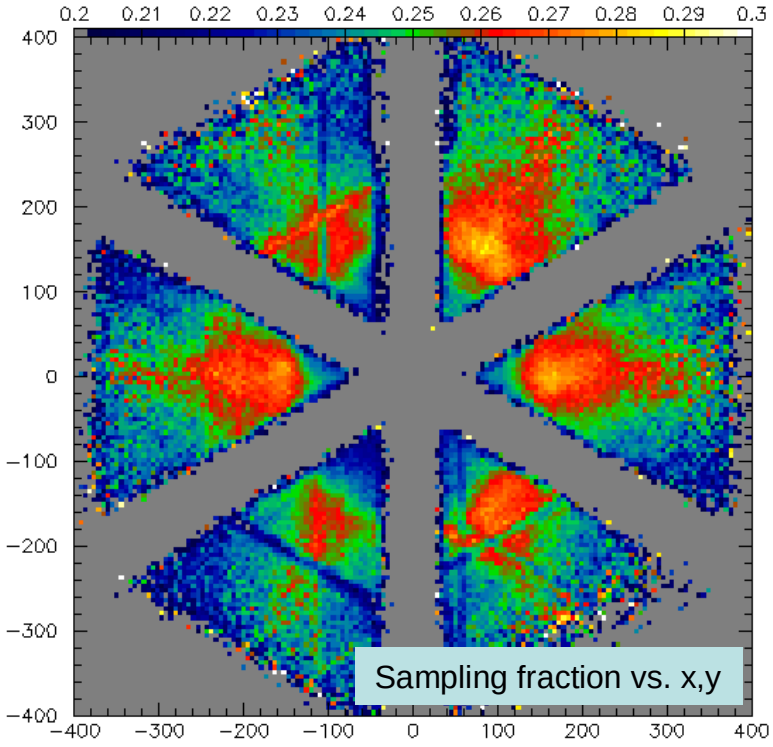
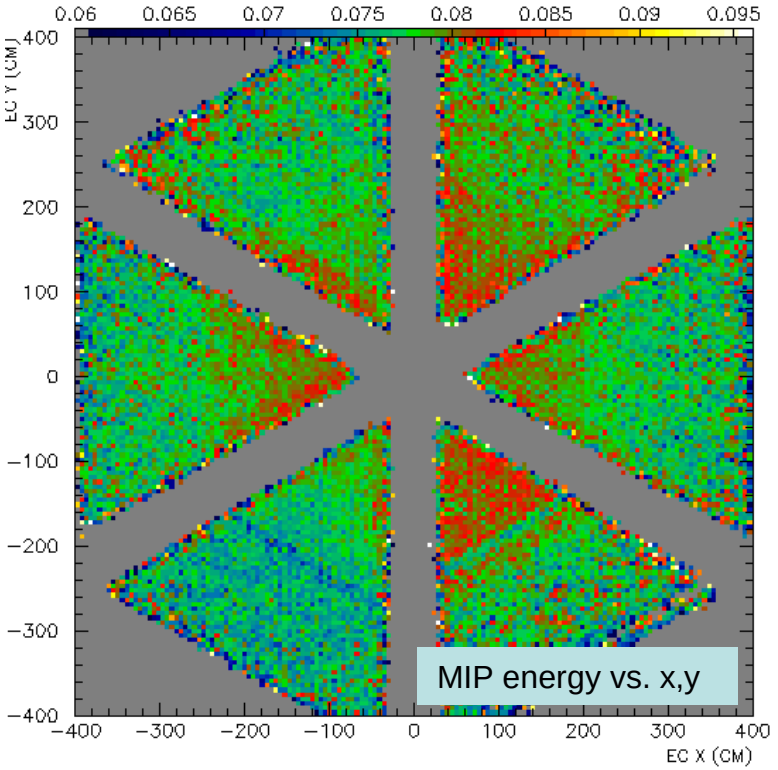
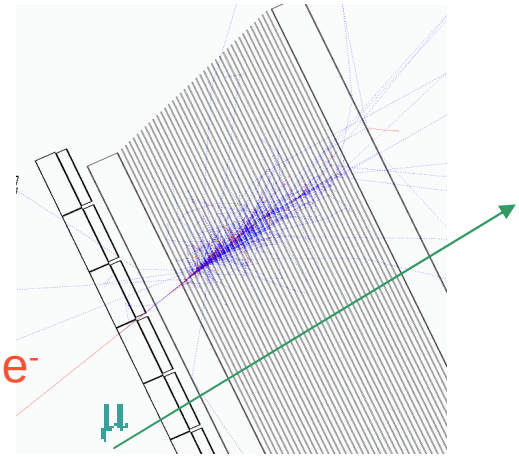
47	19484	95	24277	143	36457		
48	19529	96	24293	144	37595		

Red indicates entries in Hardware Log (below)

Energy Calibration: EM shower vs. MIP





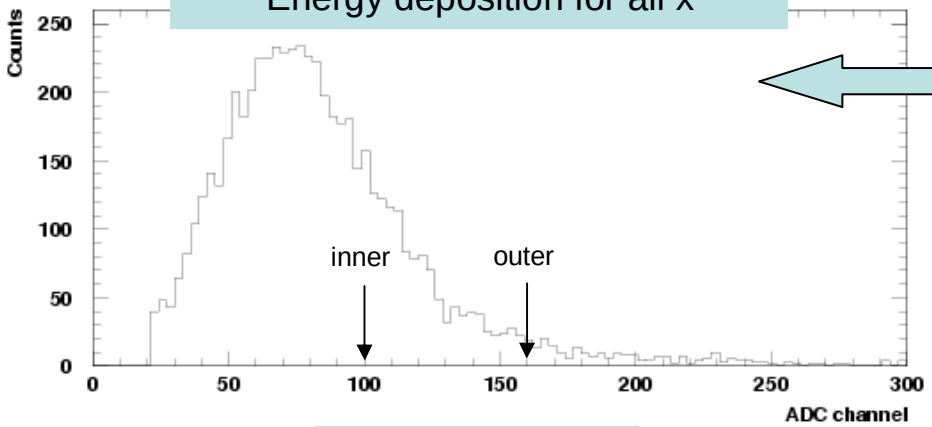


EM shower: Energy deposition non-uniform function of position and depth. Difficult to define calibration benchmark.

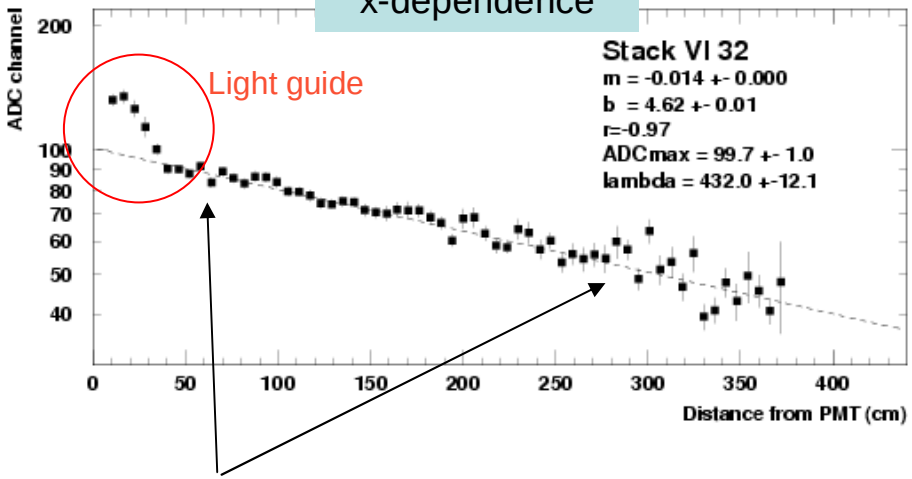
Minimum ionizing muon: Uniform and localizable energy deposition profile (~2 MeV / cm).

Cosmic ray runs

Energy deposition for all x



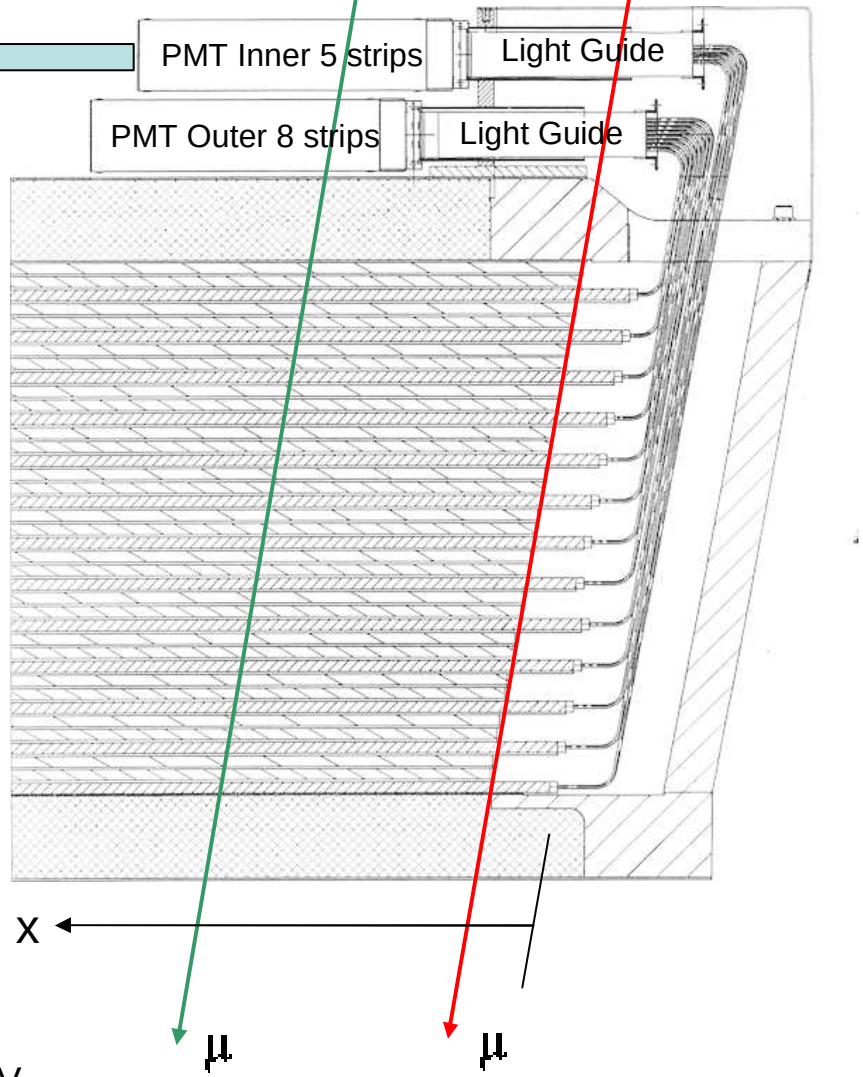
x-dependence



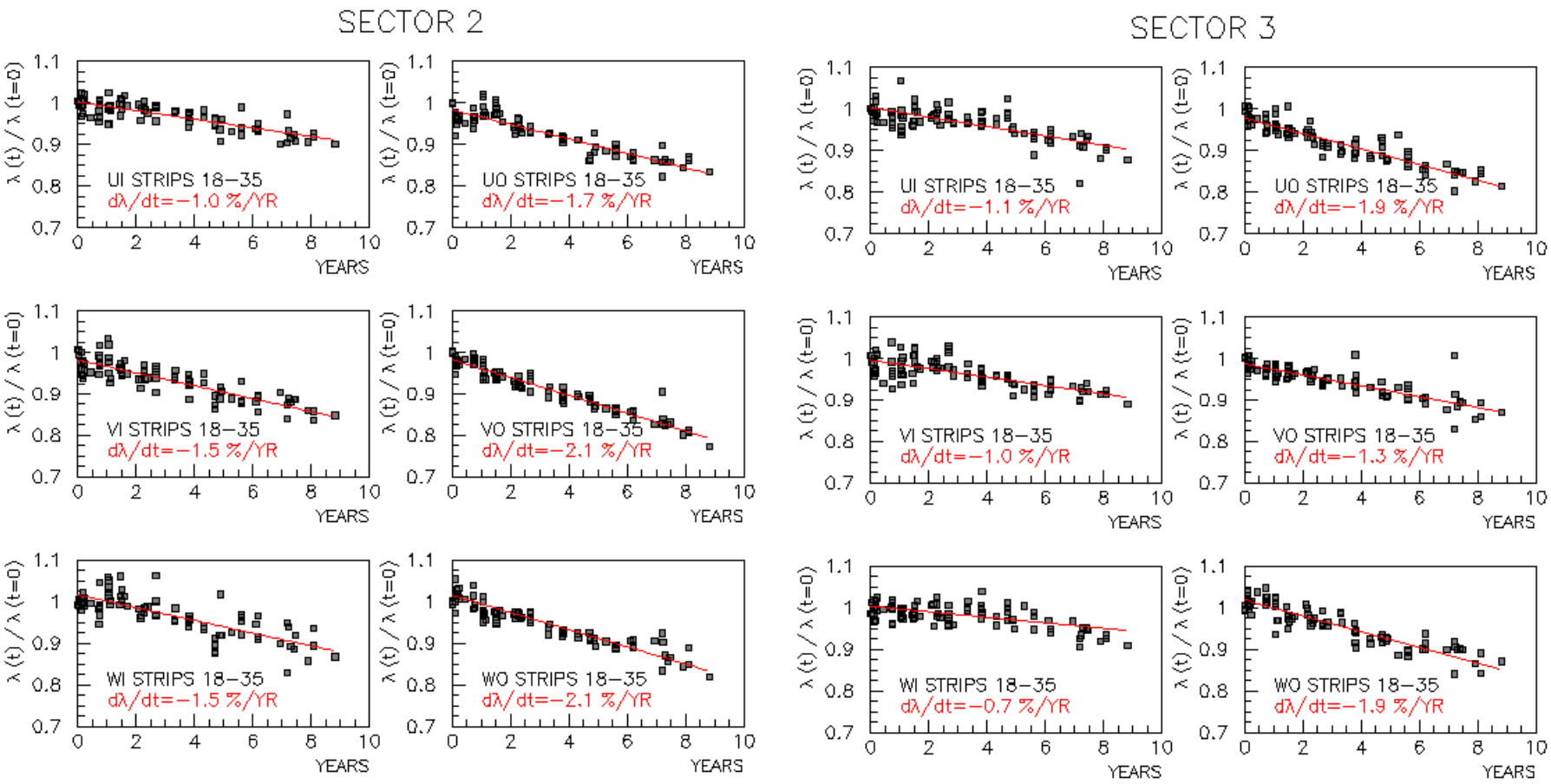
Fit linear portion of ADC(x) to extract ADC(0) and attentuation length λ

Adjust HV to obtain ADC calibration = 10 channels / MeV

MIP deposit ~ 2 MeV / strip



Time Dependence of Attenuation Lengths



- Attenuation lengths have decreased 10-20 % in sectors 1-4 over last 10 years of running.

- About ½ this effect seen in sectors 5-6.

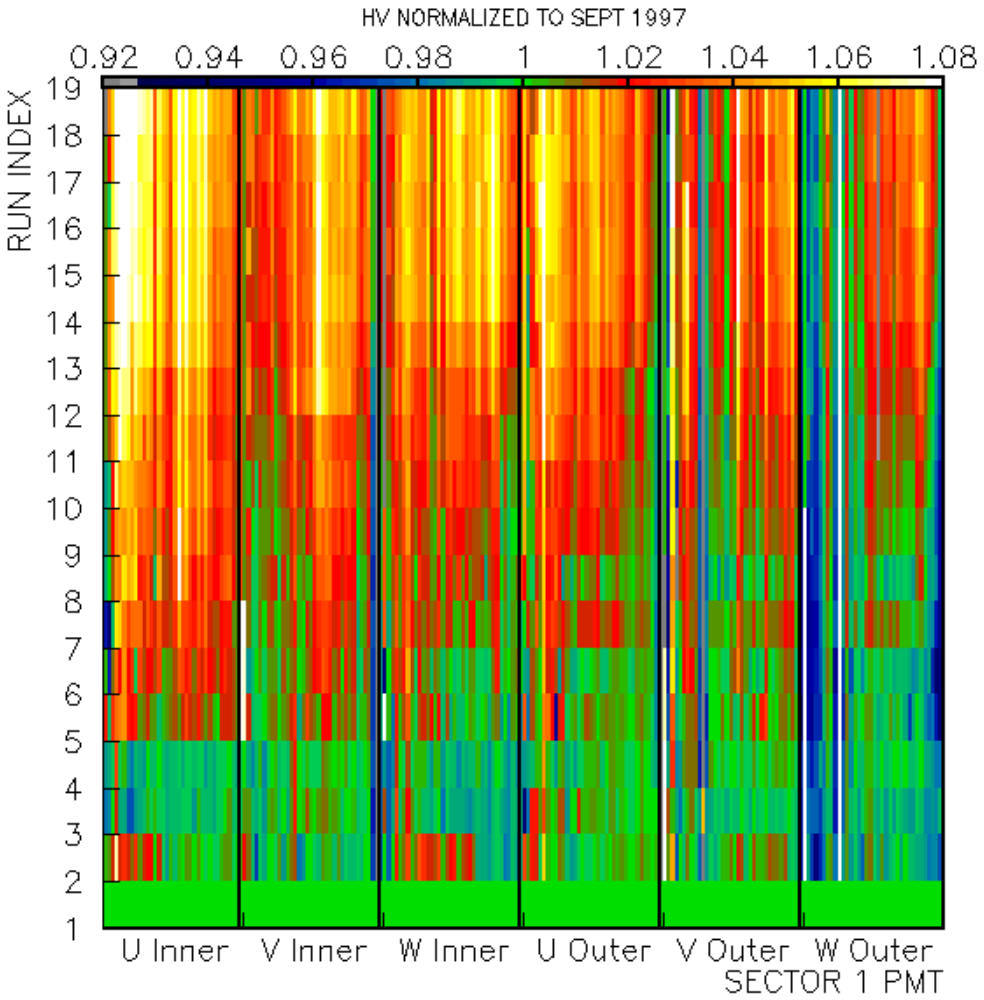
- Origin?
  - Possible scintillator surface degradation due to weight of overlaying layers and lead (minimized in vertical CLAS configuration).

  - Effect of maximal loading (90 g/cm^2) was studied using prototype stacks - < 5% effect.

  - JLAB prototype studies by Carl Zorn with ^{60}Co source showed 16 % decrease in attenuation length after 160 Gy dose. Not likely that EC has sustained such a dose in 10 yr.

- For CLAS12 not a problem but may want to rely more on *in-situ* measurements rather than using pre-installation database values for scintilator attenuation as is current practice.

History of PMT HV Changes – Sector 1

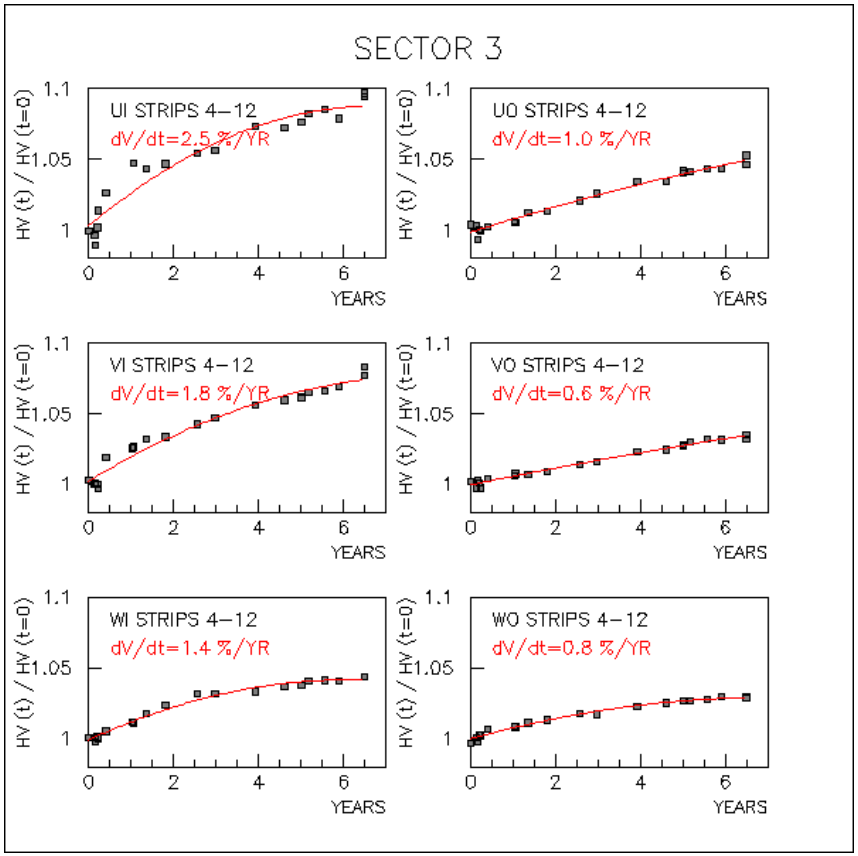


RUN INDEX	DATE	SNAP FILE
1	Sep 11 1997	ec1_w874010950.snap
2	Nov 1 1997	ec1_w878395759.snap
3	Nov 8 1997	ec1_w879011090.snap
4	Nov 25 1997	ec1_w880452678.snap
5	Feb 8 1998	ec1_w886868177.snap
6	Sep 22 1998	ec1_w906488944.snap
7	Sep 24 1998	ec1_w906665322.snap
8	Jan 16 1999	ec1_w907086528.snap
9	Jan 17 1999	ec1_w916485417.snap
10	Jan 18 1999	ec1_w916600542.snap
11	Jul 4 1999	ec1_w931113234.snap
12	Apr 4 2000	ec1_w954878477.snap
13	Sep 1 2000	ec1_w967823390.snap
14	Aug 15 2001	ec1_w997898485.snap
15	Sep 15 2002	ec1_w1032108044.snap
16	Sep 16 2002	ec1_w1032189991.snap
17	Nov 14 2002	ec1_w1037289467.snap
18	Aug 7 2003	ec1_w1060229848.snap
19	Mar 9 2004	ec1_w1078839272.snap

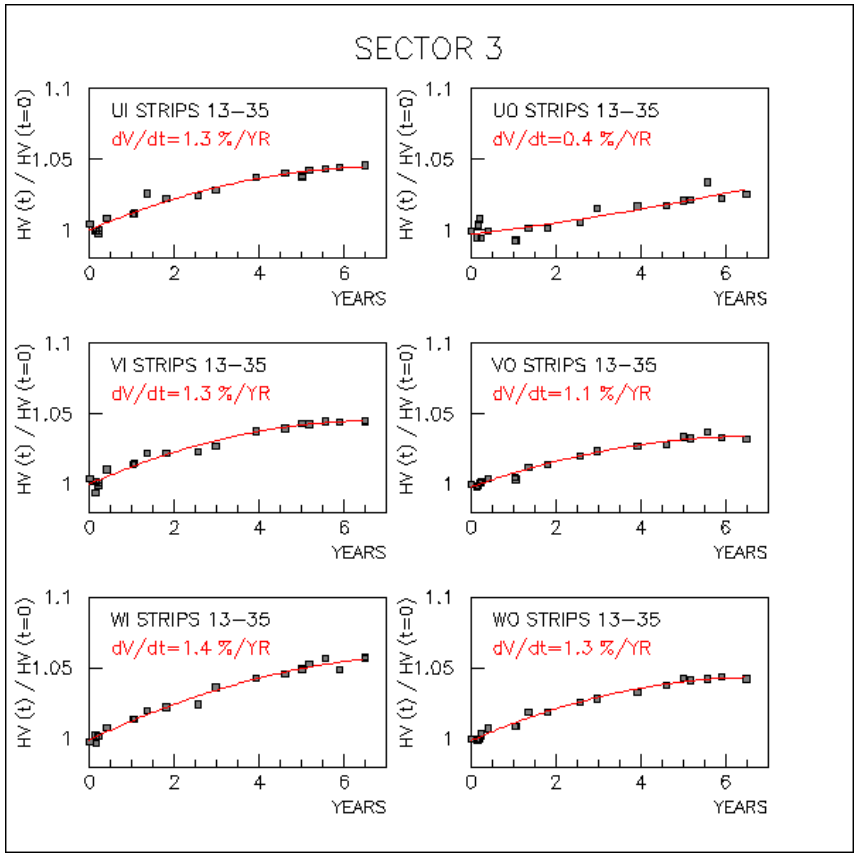
- HV were adjusted as needed after cosmic runs to maintain constant PMT gain
- Run index covers Sept. 1997-Mar. 2004
- During this period HV have increased 3-10%
- Largest voltage increase seen for U inner strips at small theta.

Time Dependence of PMT HV – Sector 3

Fractional increase in HV vs time

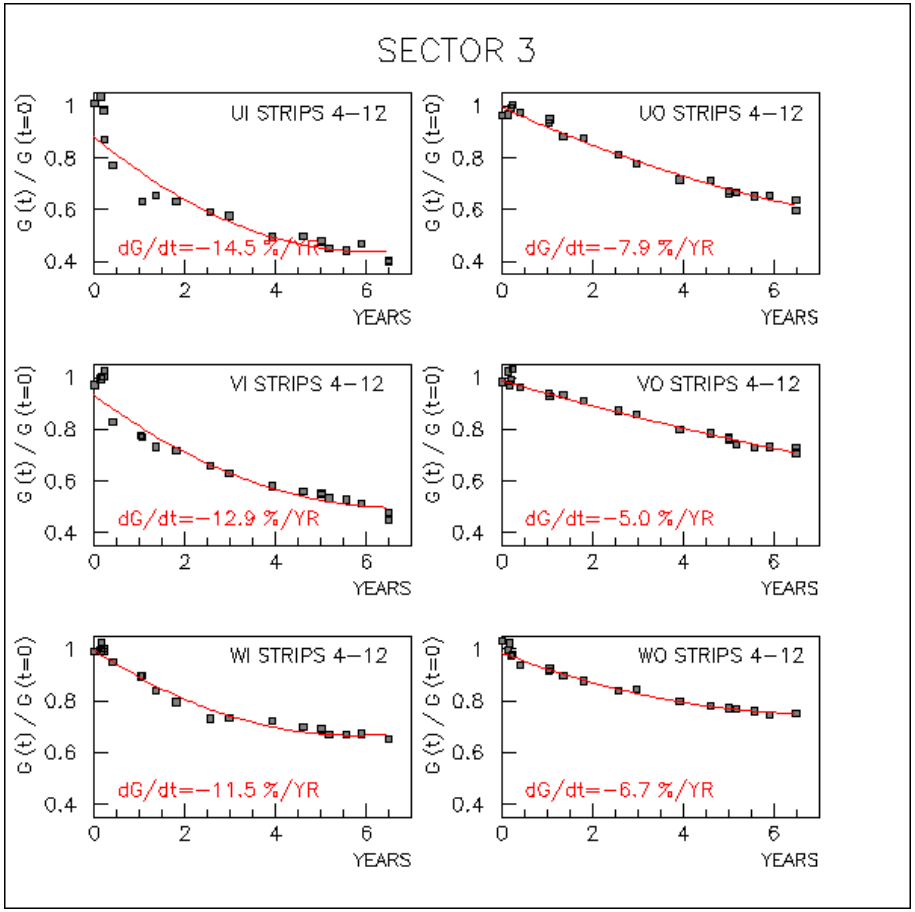


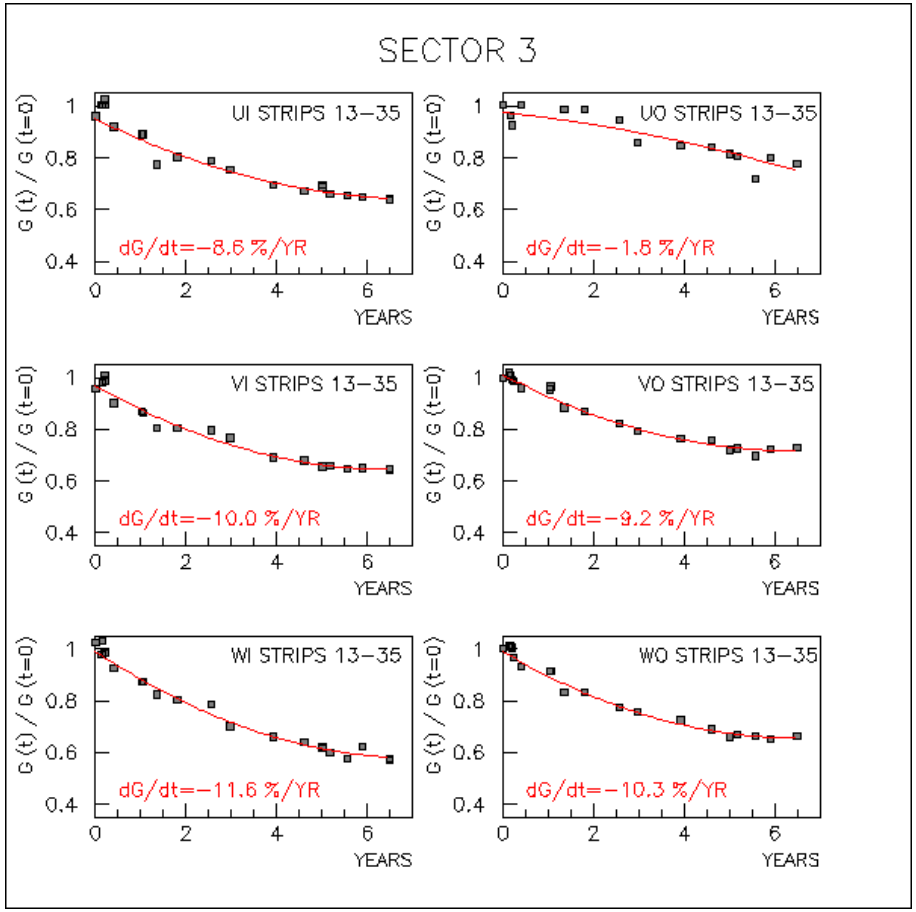
Shorter strips



Longer strips

Time Dependence of PMT Gains – Sector 3





$$\log G = n \log V$$

$$\Delta G / G = \left(\Delta V / V\right)^n$$

Empirically for 12-stage XP2262: n = 9-10

PMT Gains – Summary and Observation

- Strongest gain decrease (up to 15% / year) seen for short (small angle) U inner PMTs
- Gain decrease for inner PMTs larger than for outer
- Smaller overall gain decrease for sectors 5 and 6

Question: Is 50% gain decrease over 6 years reasonable ?

From Phillips PMT Handbook: 50% decrease in anode sensitivity expected after 300-1000 C charge collected.

$300\ \text{C} / 6\ \text{years} / 0.5\ \text{data taking} / 3\text{x}10^{7}\ \text{s}\ \text{y}^{-1} \sim 3.3\ \mu\text{A}$

This current is equivalent to energy deposition rate (per PMT) ~ 500 kHz MeV^{-1}

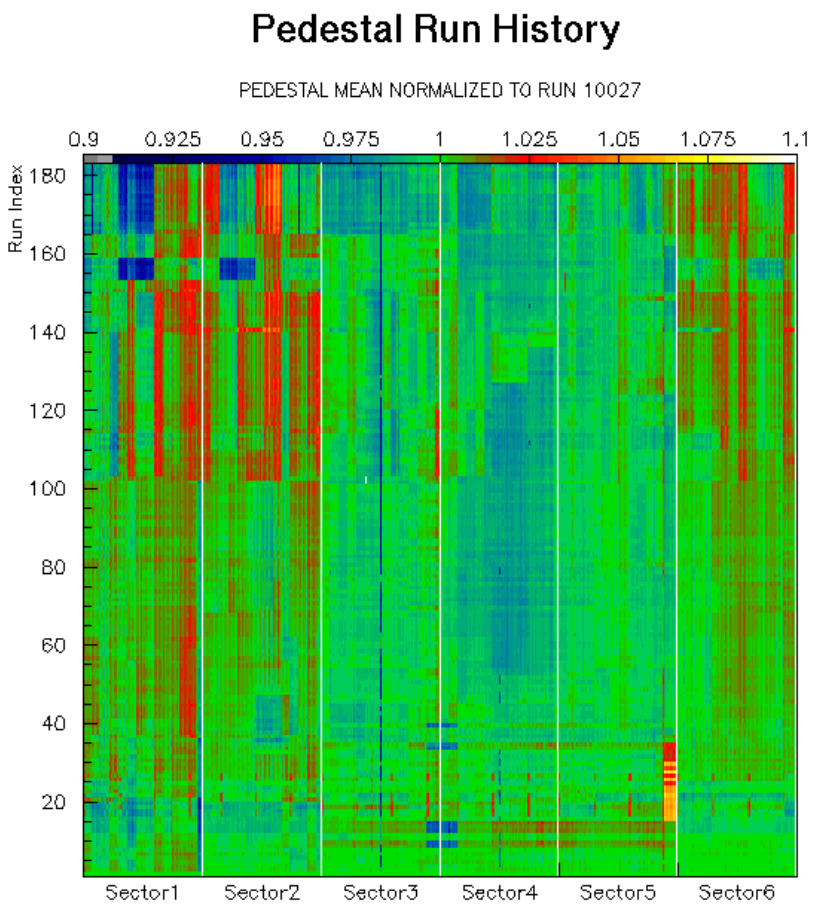
PMT Gains – Recommendations

- Need to independently confirm PMT gain decrease
- Check if implied energy deposition rate is consistent with soft photon and hadronic rates
- Make *in-situ* measurement of PMT anode current during electron beam running. Note 3 uA is still only 1% of anode string current so HV power supply current monitor may not reveal anything.
- Restore operation of laser system and use to monitor further gain decrease. Comparison to laser runs of 4 years ago may yield some information.
- Implications for running at 10x luminosity for CLAS12 ?

Backup Slides

Time Dependence of Pedestals

http://www.jlab.org/Hall-B – Forward Calorimeters

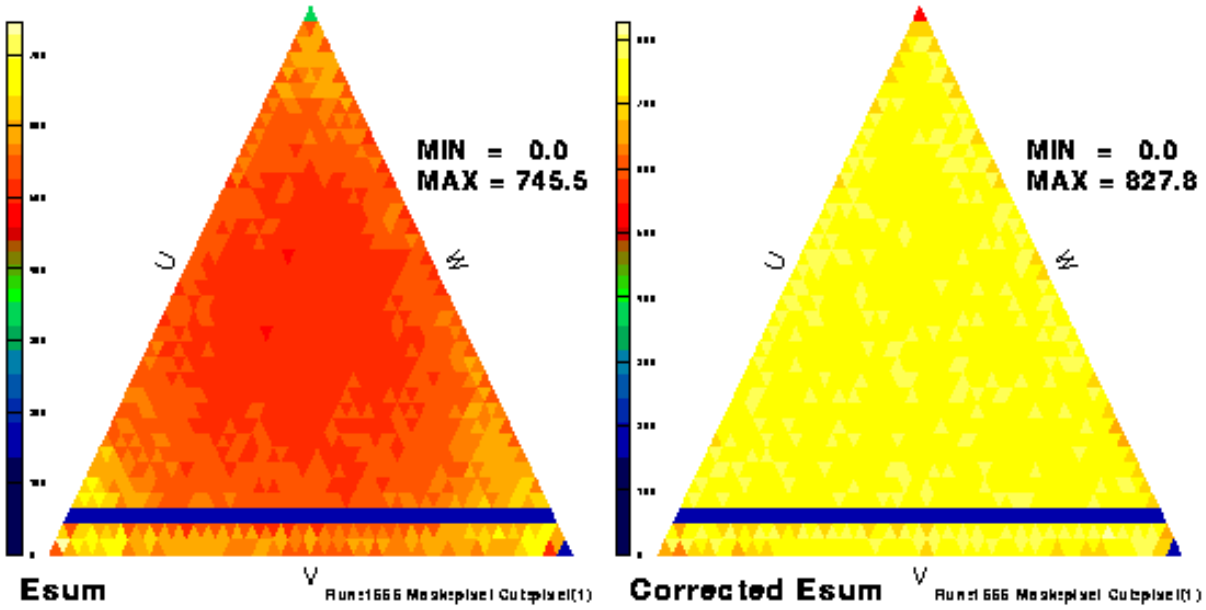


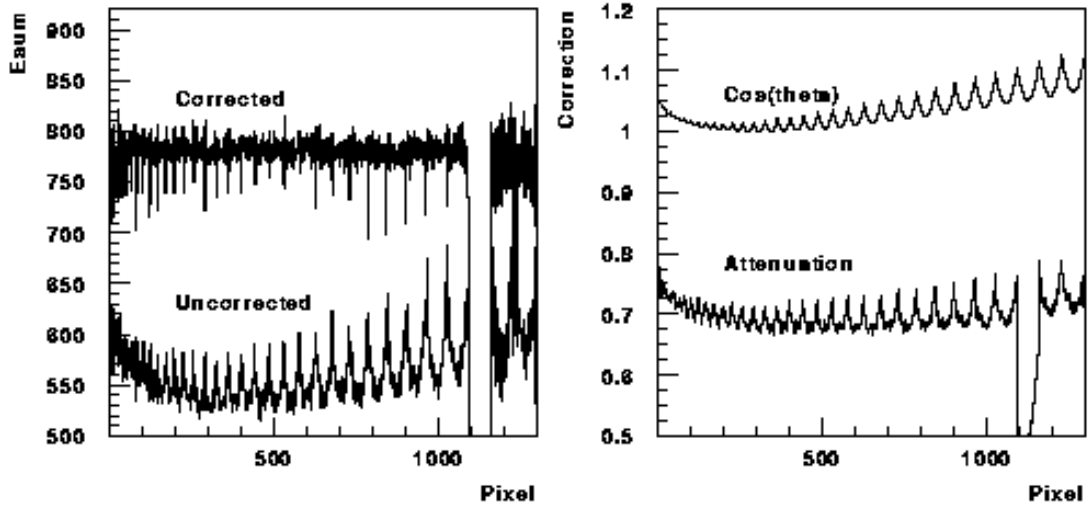
MEAN	RAW	NORM
RMS	RAW	NORM

Run Index	Run	Run Index	Run	Run Index	Run	Run Index	Run
1	10027	49	19531	97	24295	145	37636
2	11218	50	20014	98	24452	146	38533
3	11268	51	20060	99	24478	147	38754
4	11383	52	20163	100	24499	148	39679
5	11479	53	20178	101	25395	149	39733
6	11601	54	20447	102	25405	150	40495
7	11968	55	20563	103	25550	151	40764
8	12731	56	20778	104	25741	152	41223
9	12778	57	21012	105	25943	153	41575
10	13193	58	21032	106	25990	154	41851
11	13196	59	21098	107	26030	155	42251
12	13221	60	21119	108	26083	156	42365
13	13231	61	21396	109	26202	157	42682
14	13238	62	21639	110	26852	158	42862
15	13636	63	21688	111	27050	159	43426
16	13734	64	21705	112	27091	160	43660
17	13736	65	21730	113	27221	161	43661
18	13738	66	21732	114	28350	162	43779
19	13739	67	21752	115	28581	163	43780
20	13742	68	21768	116	28790	164	44100
21	13746	69	21811	117	29116	165	45383
22	13845	70	22005	118	29446	166	45838
23	13847	71	22037	119	29603	167	45967
24	13888	72	22165	120	29872	168	46319
25	13996	73	22199	121	30120	169	46322
26	14010	74	22342	122	30288	170	46325
27	14058	75	22364	123	30389	171	46387
28	14062	76	22689	124	30573	172	46500
29	14162	77	22691	125	30578	173	46502
30	14715	78	22868	126	30642	174	46515
31	14910	79	22964	127	30776	175	46764
32	15266	80	23292	128	31161	176	46950
33	15817	81	23426	129	31198	177	47173
34	15819	82	23536	130	31529	178	47243
35	15968	83	23705	131	31530	179	49079
36	16082	84	23745	132	31531	180	50664
37	17211	85	23790	133	31543		
38	17581	86	23860	134	31559		
39	17619	87	23930	135	31755		
40	17827	88	24034	136	31772		
41	17841	89	24078	137	31777		
42	18076	90	24116	138	31778		
43	18081	91	24125	139	32950		
44	18527	92	24197	140	34376		
45	18722	93	24213	141	34468		
46	18791	94	24264	142	35812		
47	19484	95	24277	143	36457		
48	19529	96	24293	144	37595		

Red indicates entries in Hardware Log (below)

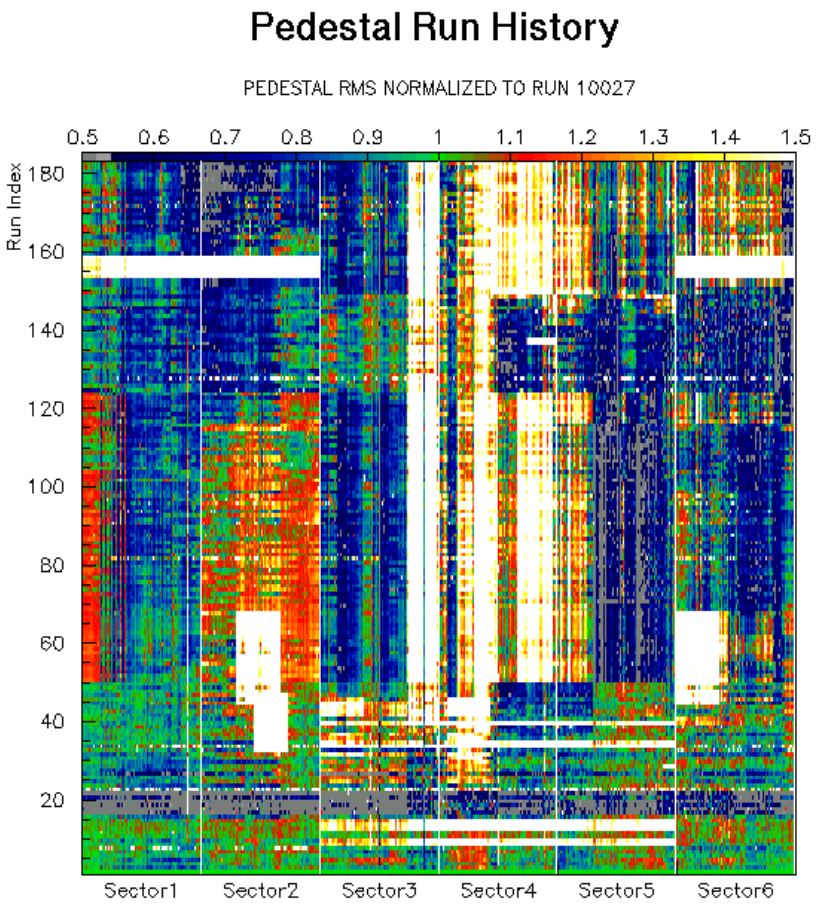
Uniformity of MIP response





Time Dependence of Pedestal Noise

http://www.jlab.org/Hall-B – Forward Calorimeters



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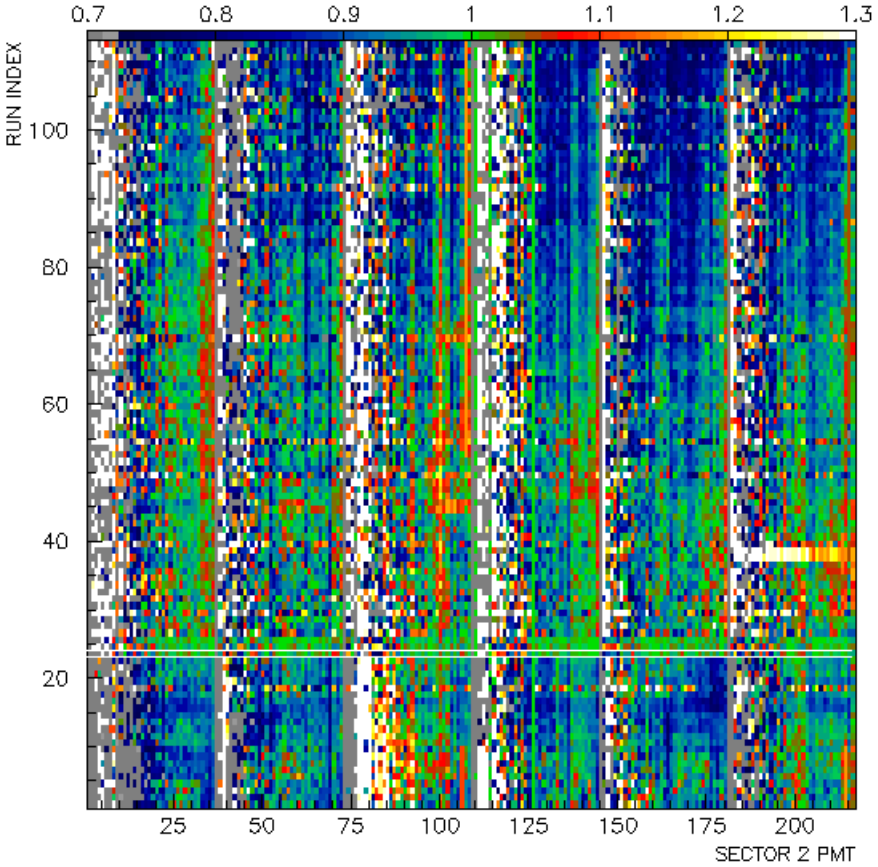
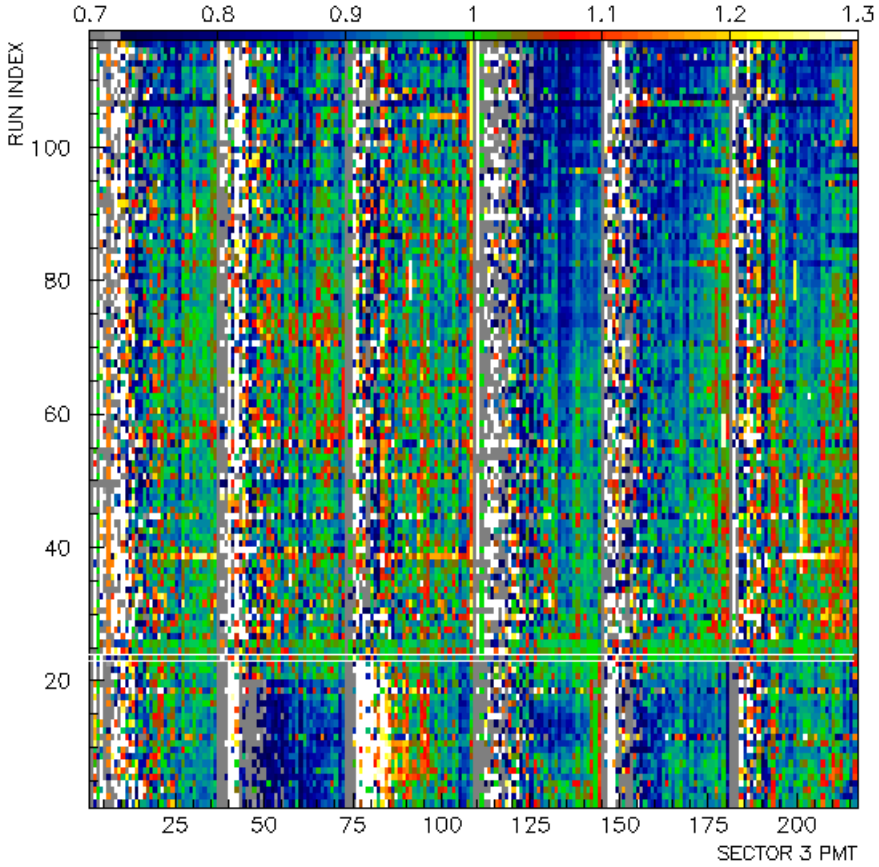
47	19484	95	24277	143	36457		
48	19529	96	24293	144	37595		

Red indicates entries in Hardware Log (below)

Time Dependence of Attentuation Lengths

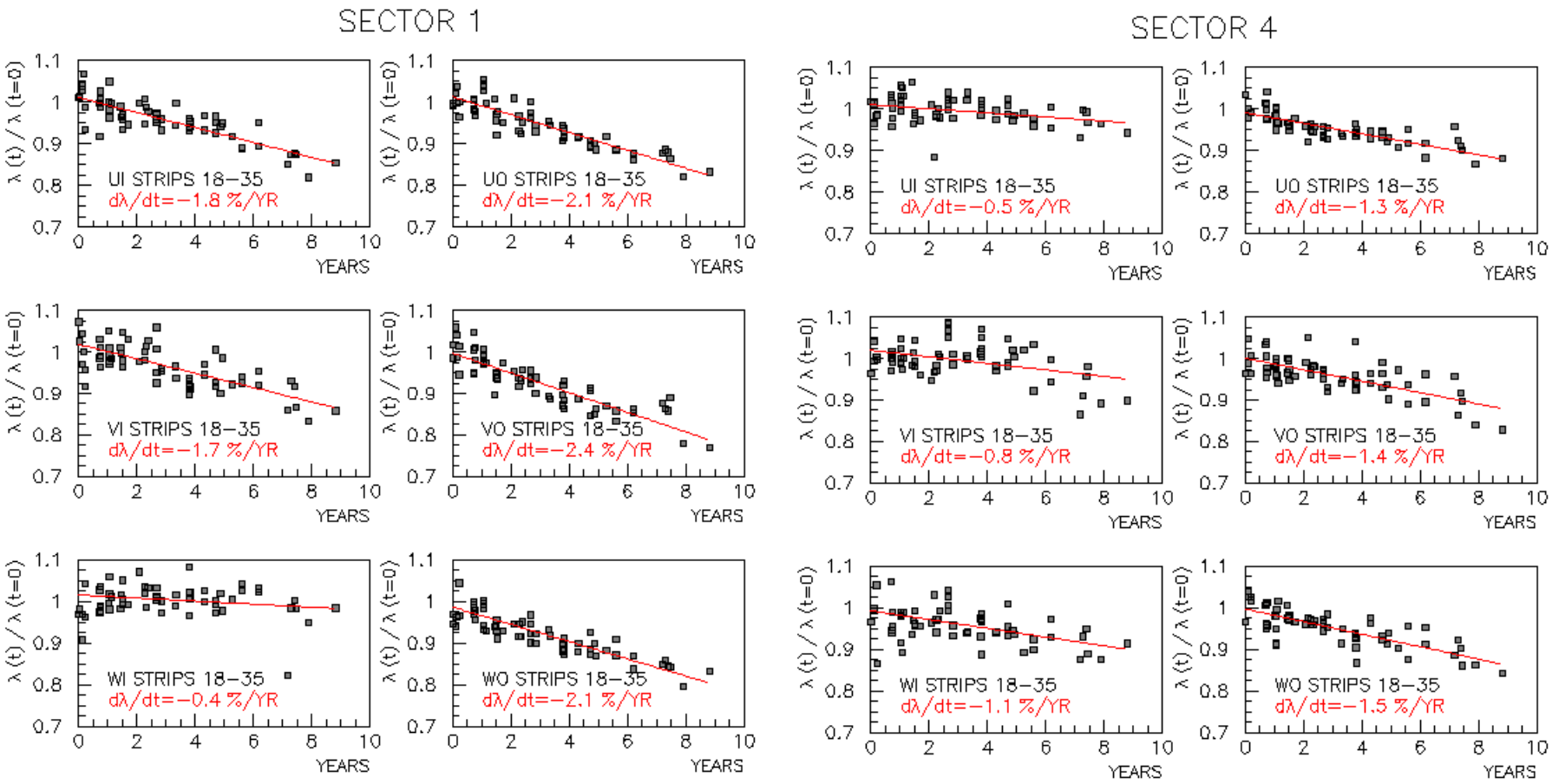


Sector 2

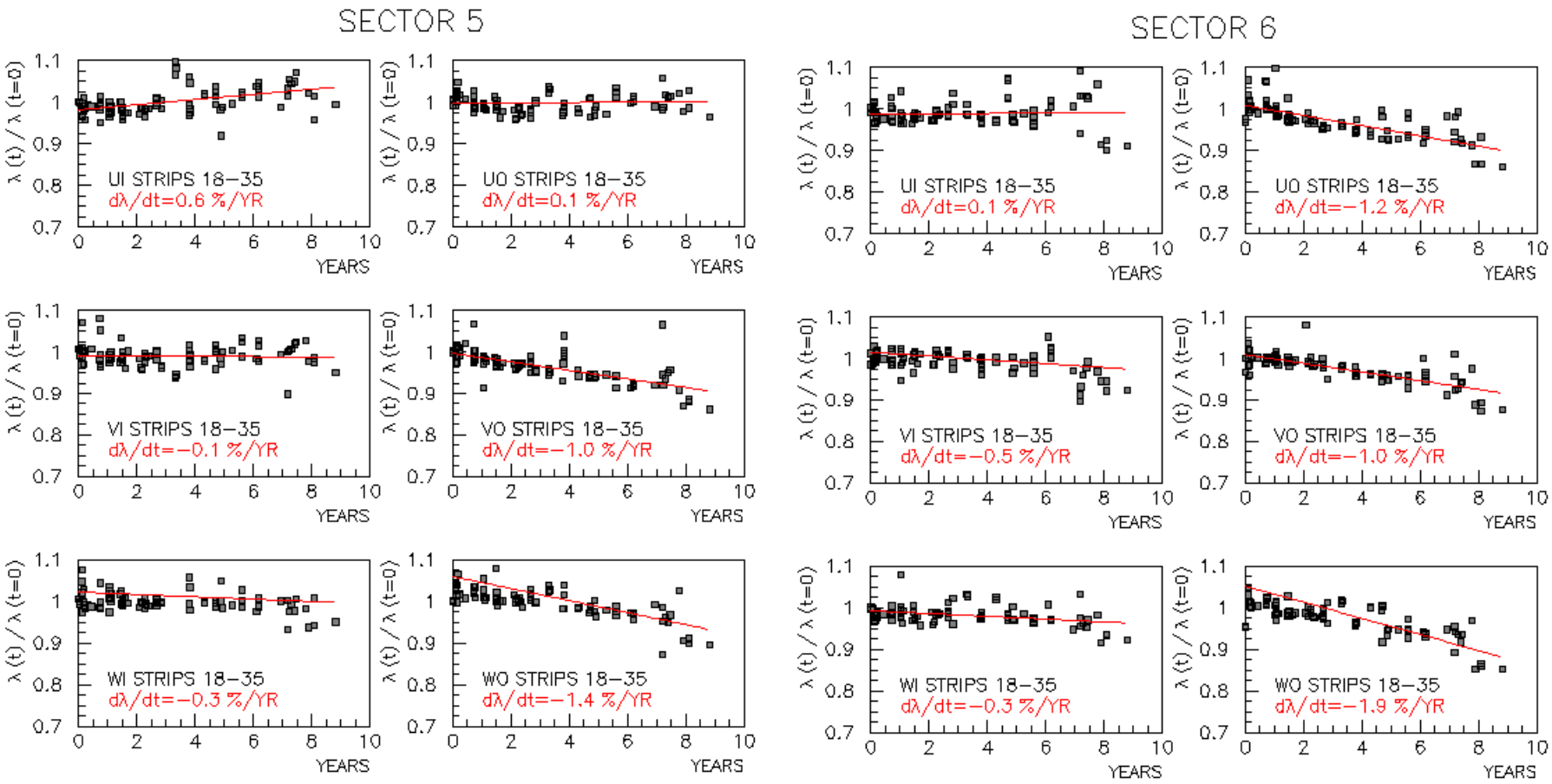


Sector 3

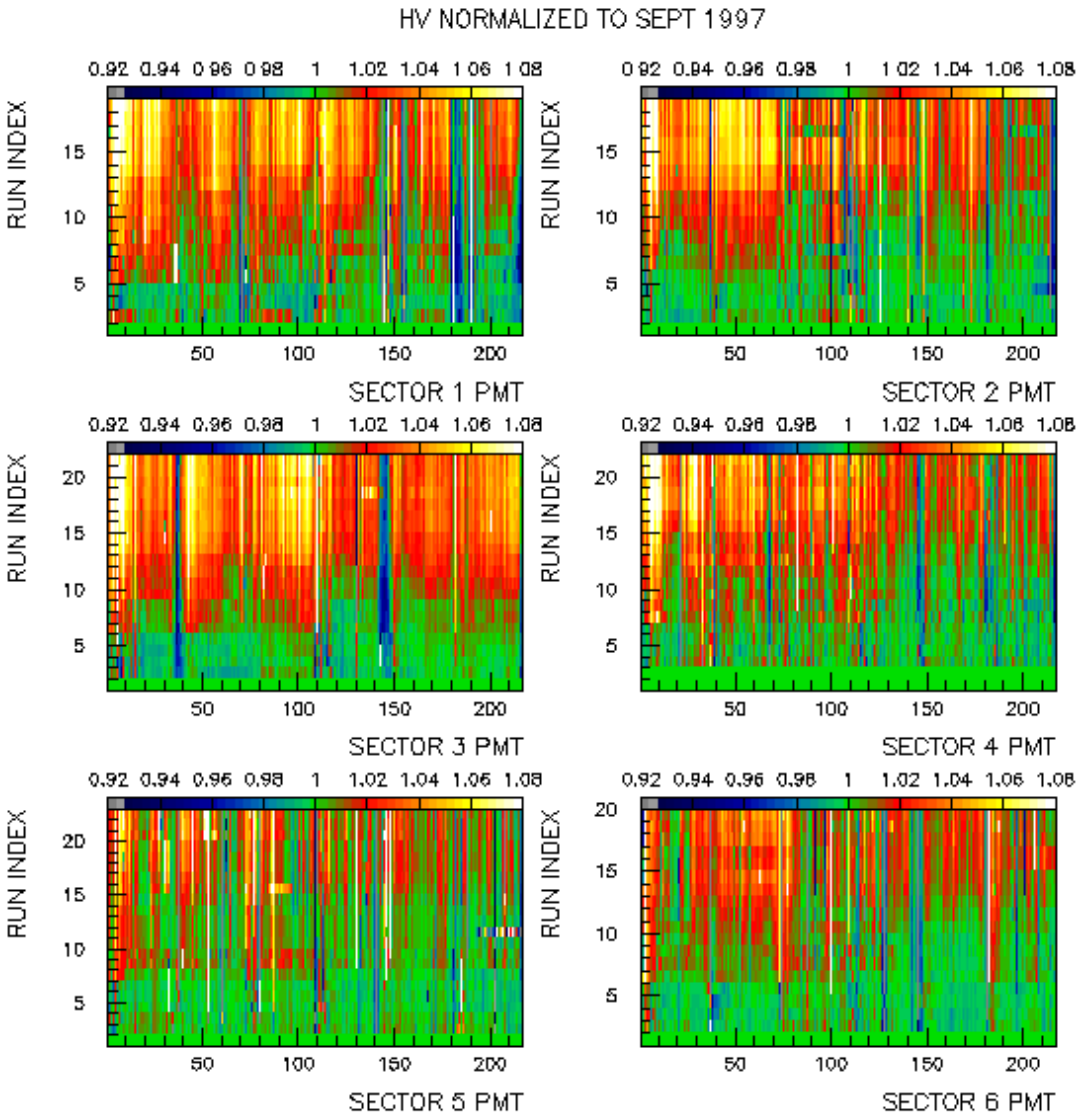
Time Dependence of Attenuation Lengths



Time Dependence of Attenuation Lengths

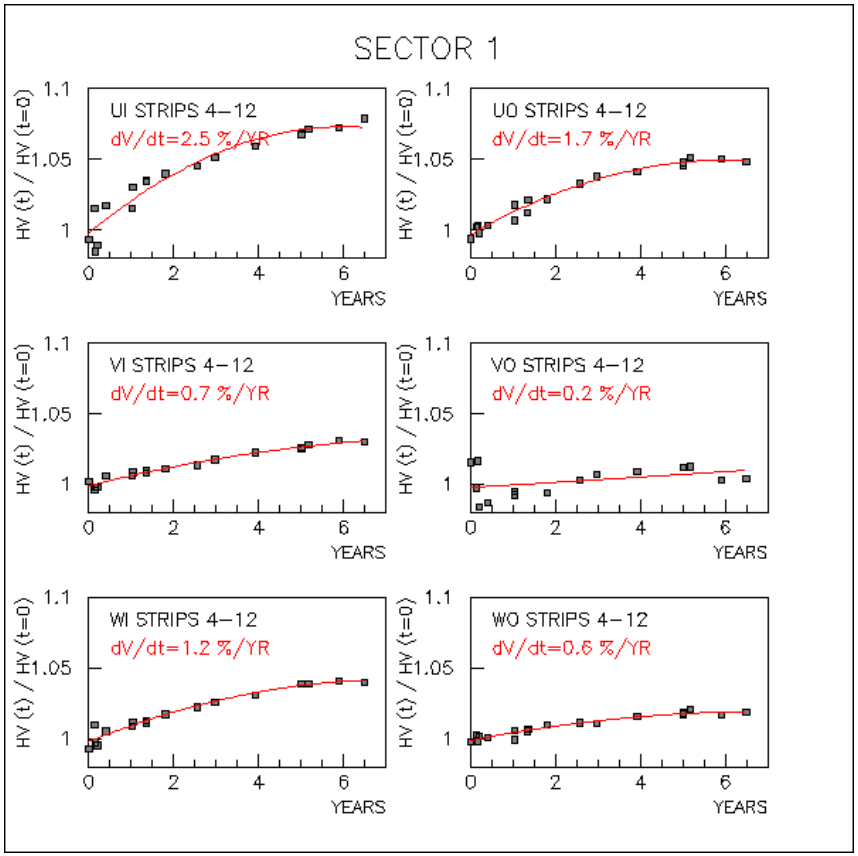


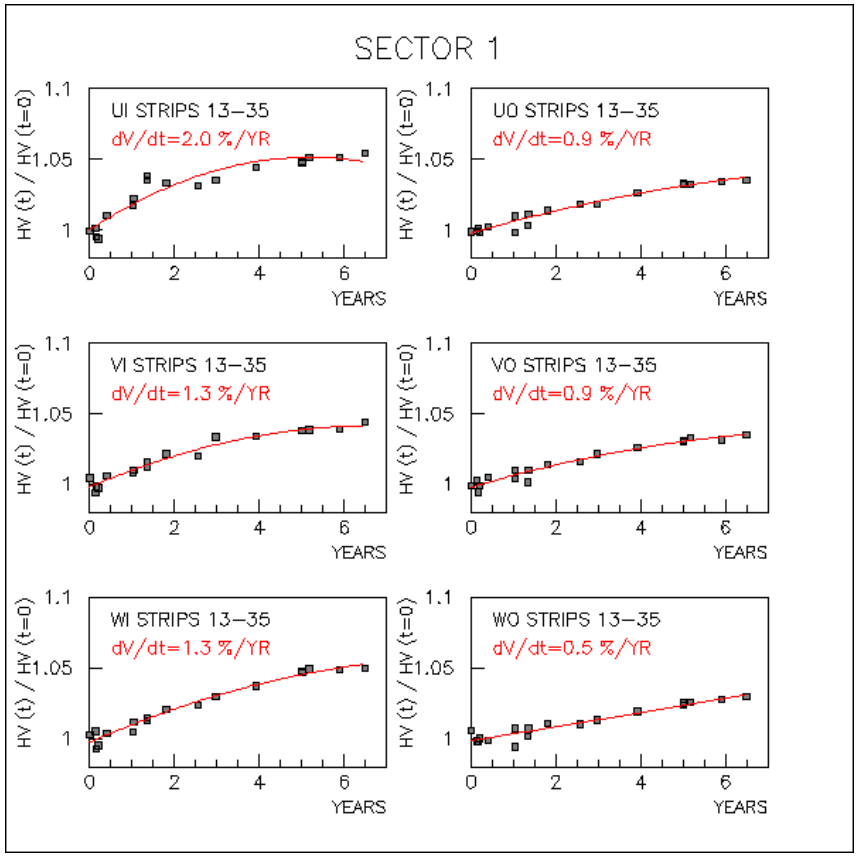
History of PMT HV Changes – Sectors 1-6



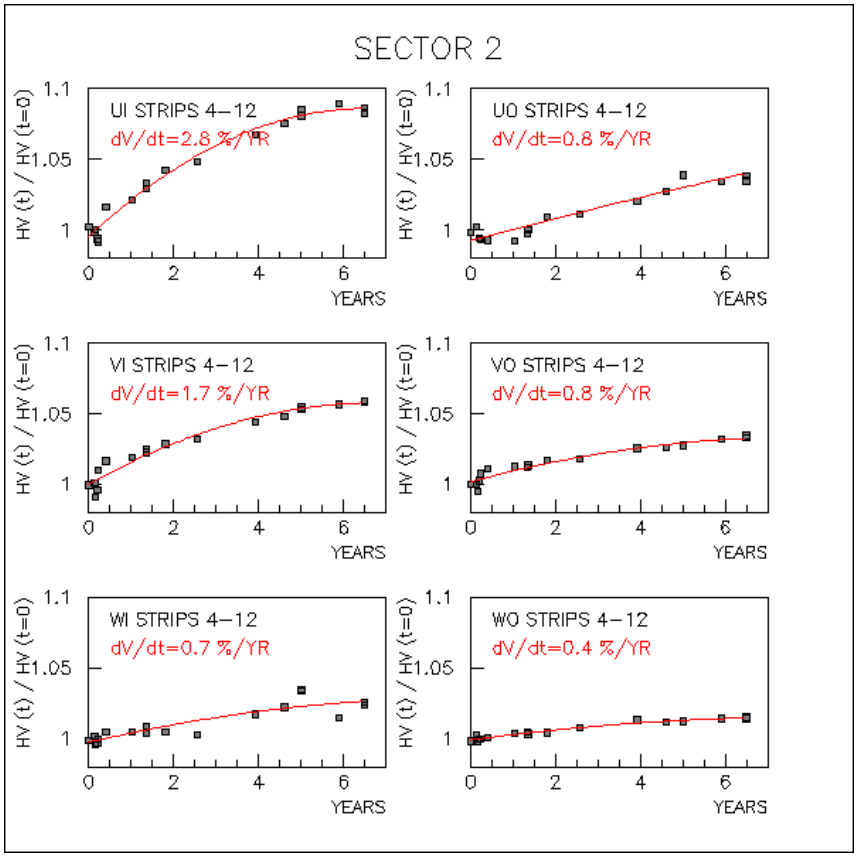
- Run index covers 1997-2004
- HV adjusted as needed after cosmic runs to maintain constant PMT gain
- During this period HV have increased 3-10%
- Largest HV increase for short U strips located at forward angles.

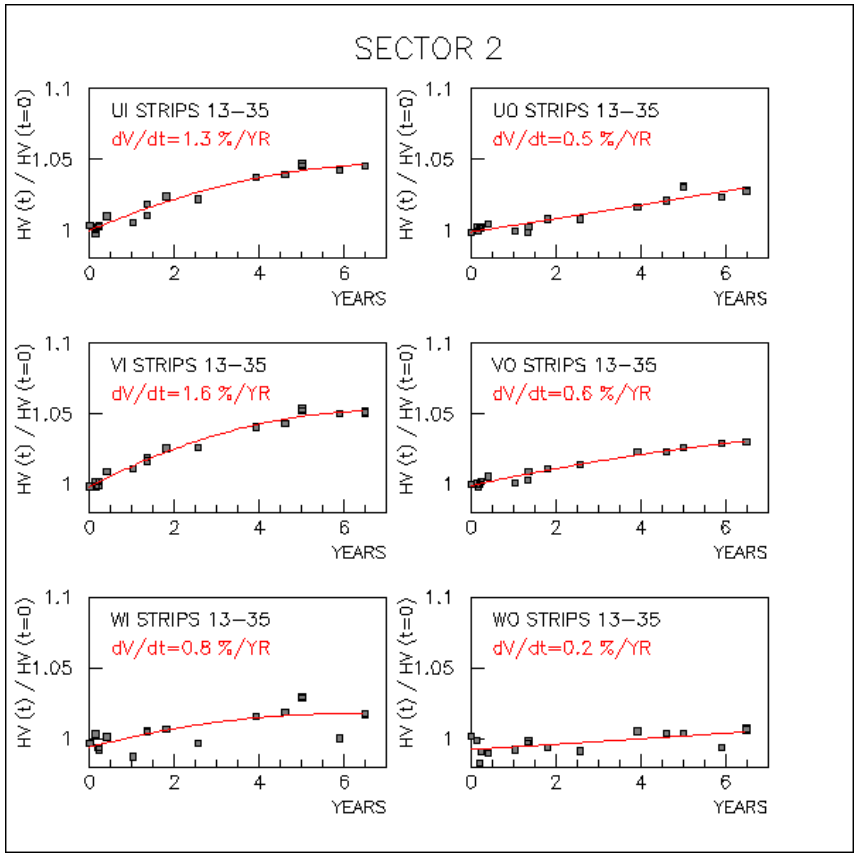
Time Dependence of PMT HV – Sector 1



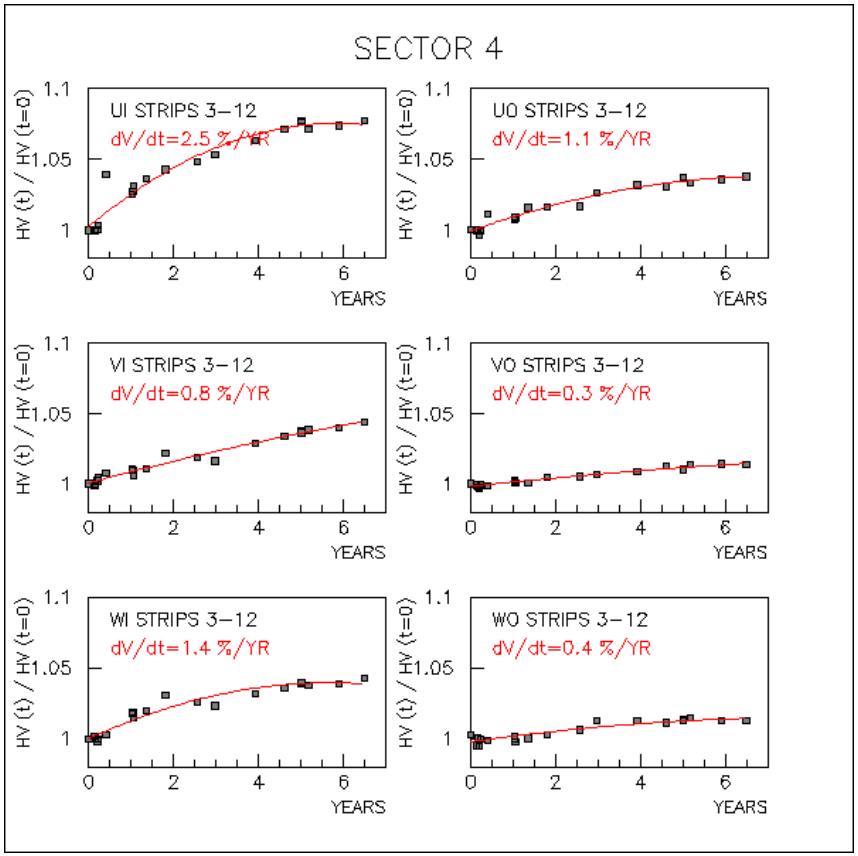


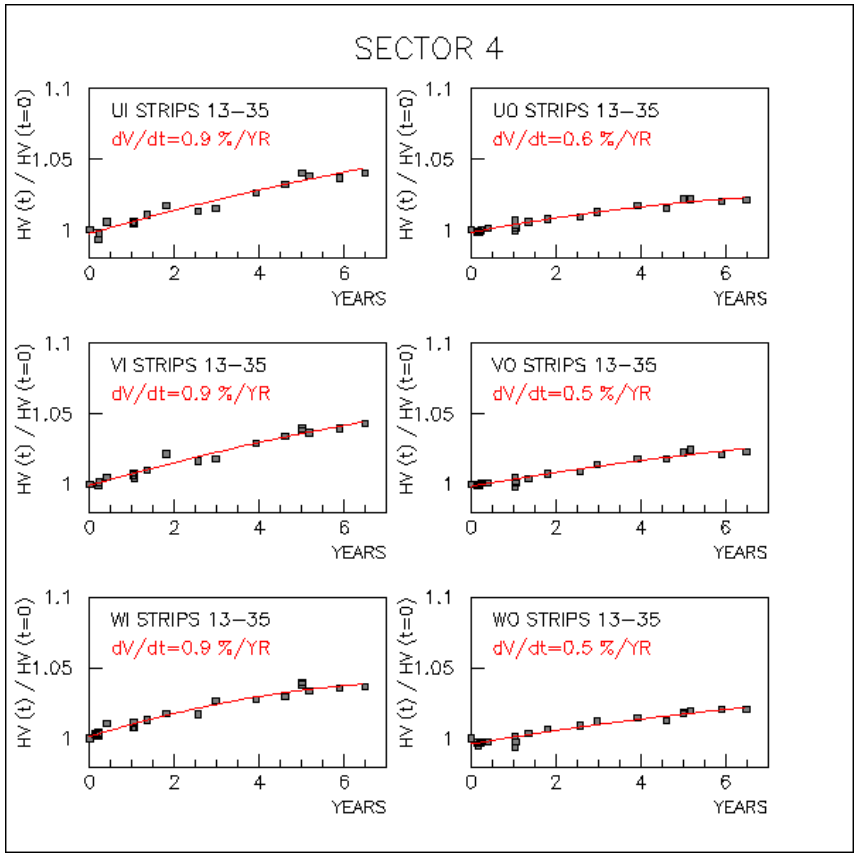
Time Dependence of PMT HV – Sector 2



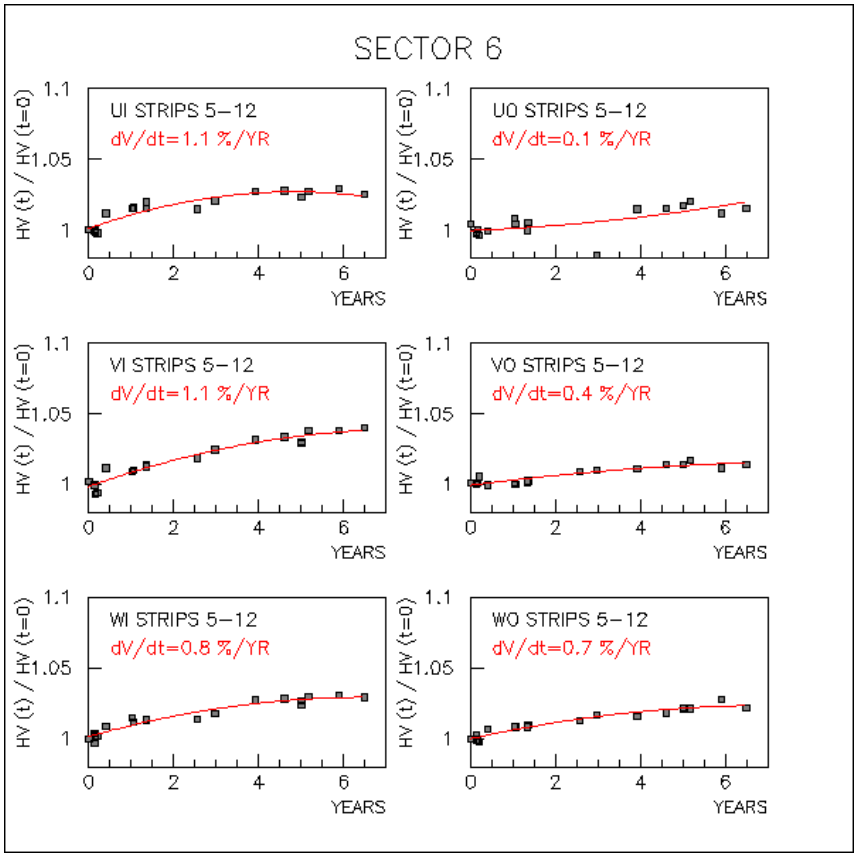


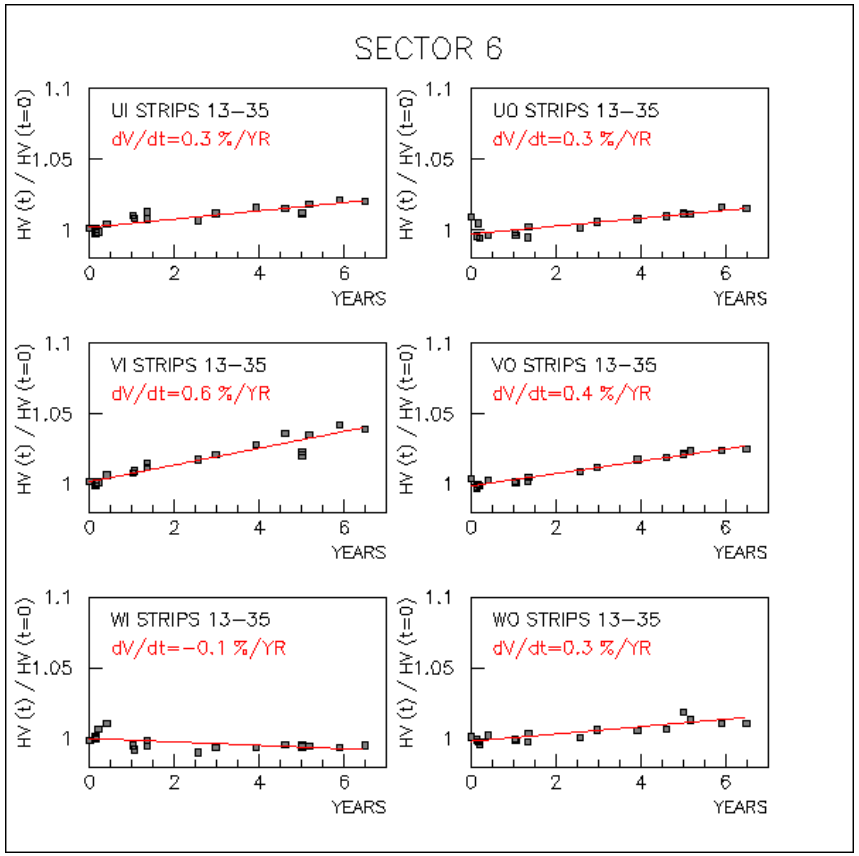
Time Dependence of PMT HV – Sector 4





Time Dependence of PMT HV – Sector 6





Time Dependence of PMT HV – Sector 5