



TEST OF THE ALGORITHM EMPLOYED IN  
THE 1<sup>ST</sup> TRIGGER LEVEL OF THE JEM-EUSO  
EXPERIMENT

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# The JEM-EUSO experiment



JEM-EUSO (Extreme Universe Space Observatory on Japanese Experiment Module) is a new type observatory to detect extreme-energy cosmic rays (EECR) and neutrinos as its main objective of exploration.

To measure the cosmic rays energy spectrum ( $10^{19.5} \text{ eV} < E < 10^{21} \text{ eV}$ ) ●

Orbit at the altitude  $\sim 400 \text{ km}$  ●

Super-wide FoV ( $\pm 30^\circ$ ) ●

Viewing at night atmosphere in  $> 1.4 \times 10^5 \text{ km}^2$  area ●

One orbit is every 90 minutes ●



# JEM-EUSO

## Flight Segment



TDRS



HTV

EECR



H-IIB

UV photons

Fluorescence

Cherenkov

Air Shower

Ground Support Equipment

## Ground Segment



LIDAR station

## Ground Based Calibration System



Xe Flasher

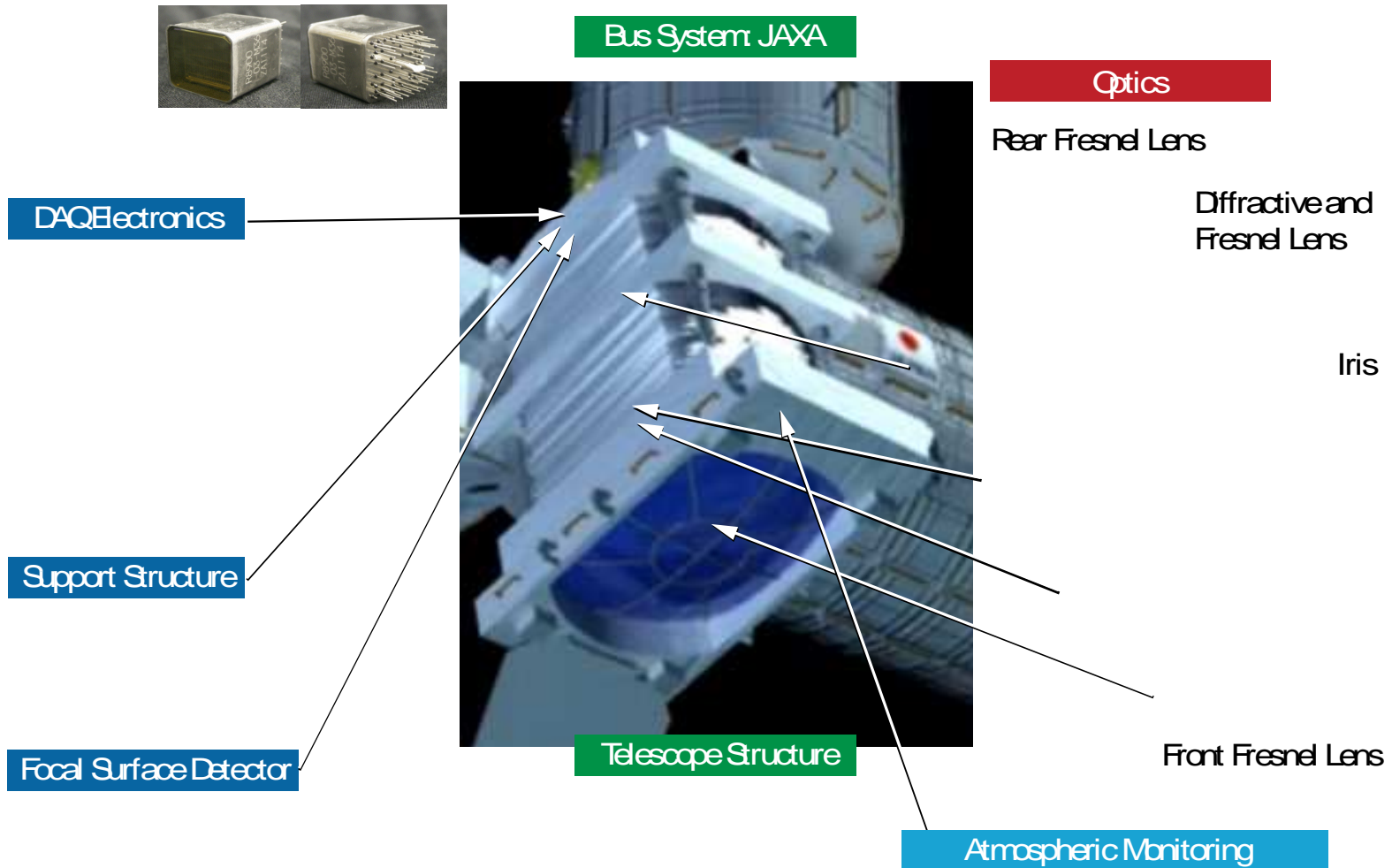


Data Center

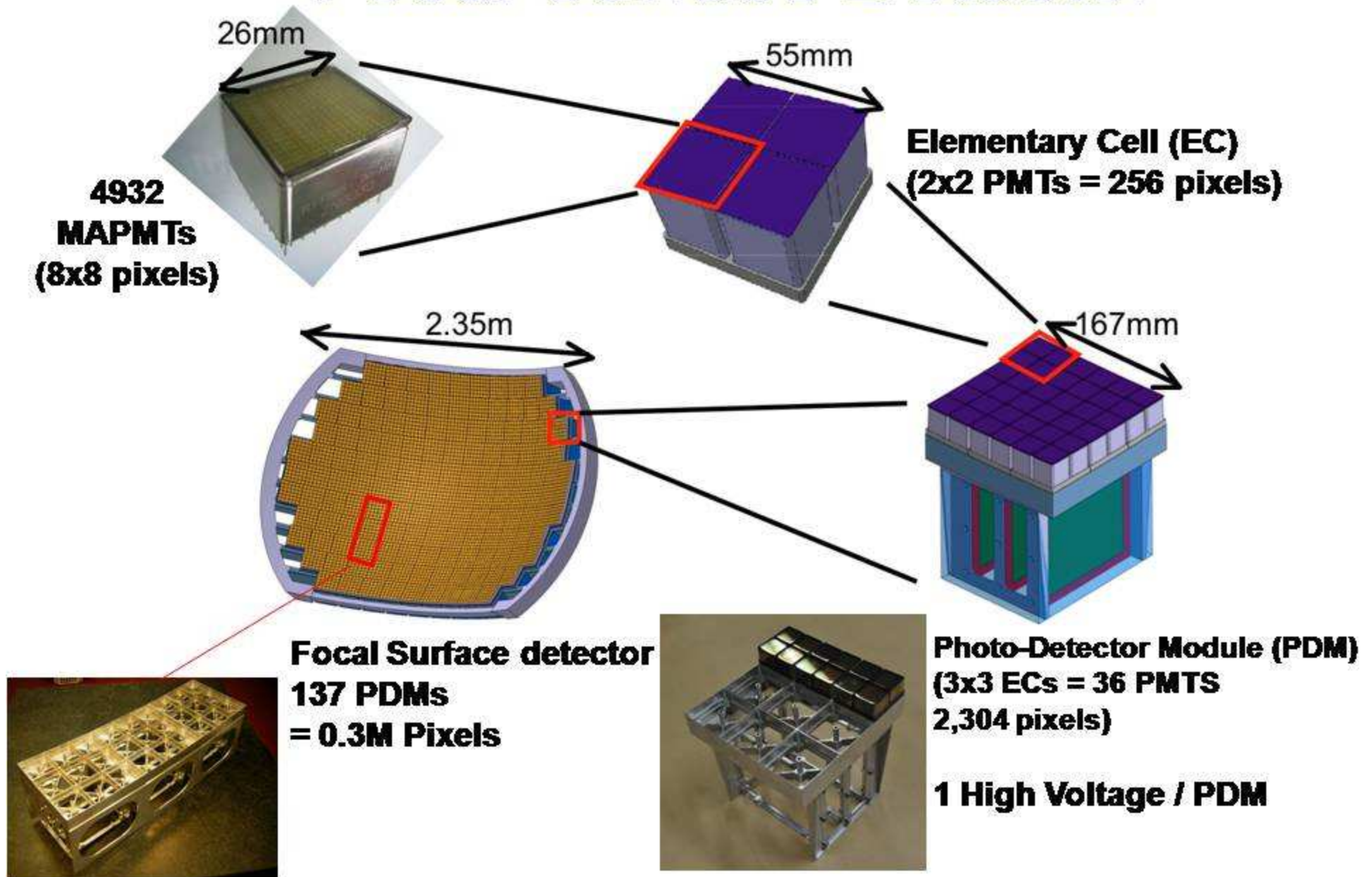


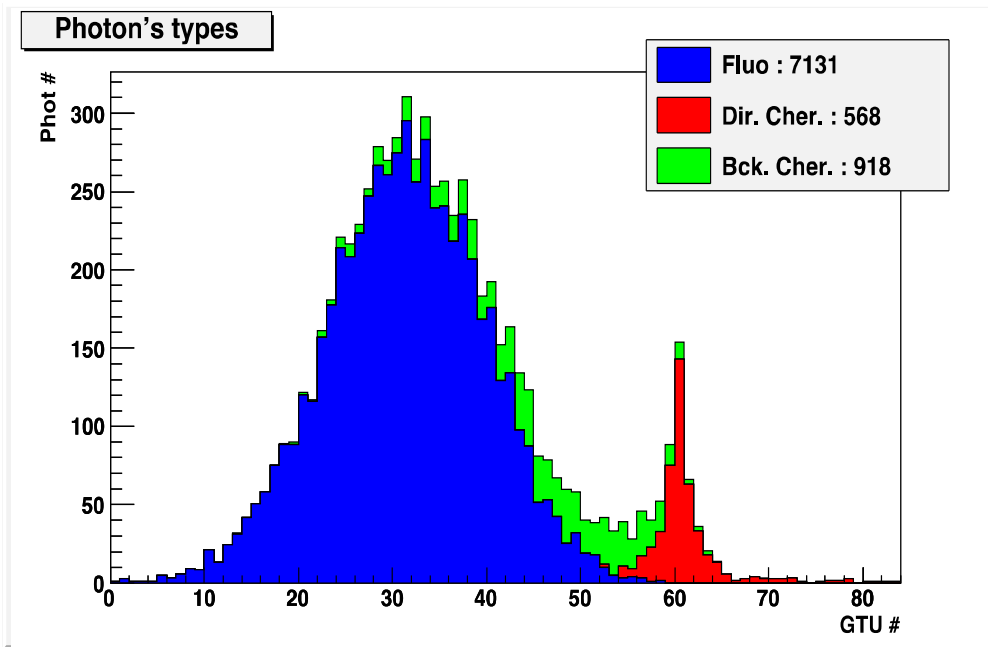
Mission Operation Control

# JEM-EUSO Telescope



# Focal Surface Detector





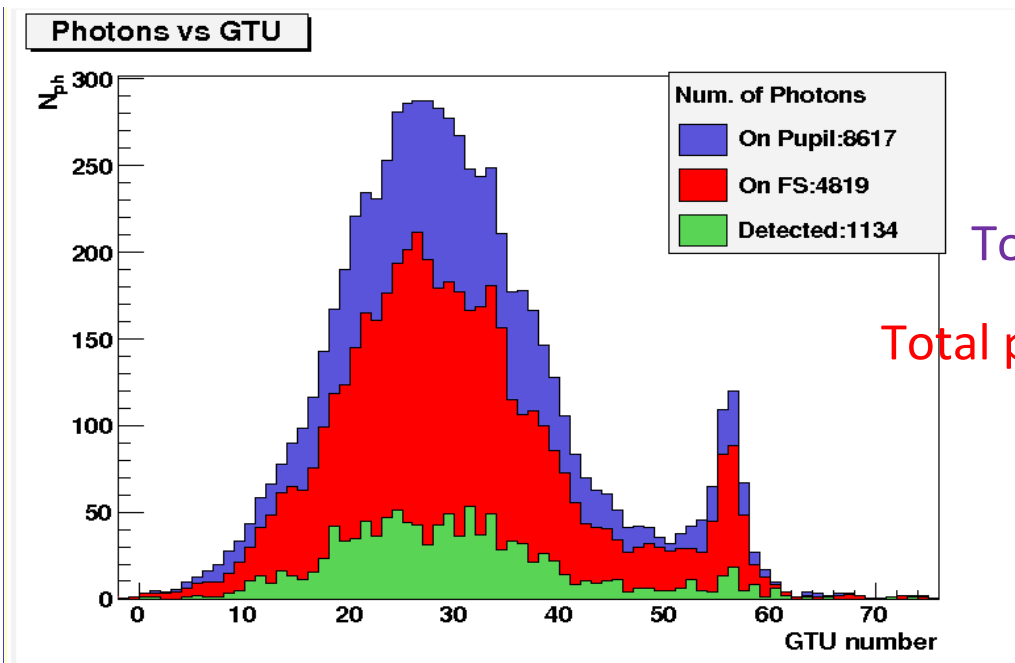
Fluorescence

Scattered Cherenkov

Diffusively reflected Cherenkov



1 Gate Time Unit ( $GTU$ ) =  $2.5 \mu sec$



Total photon enter on telescope

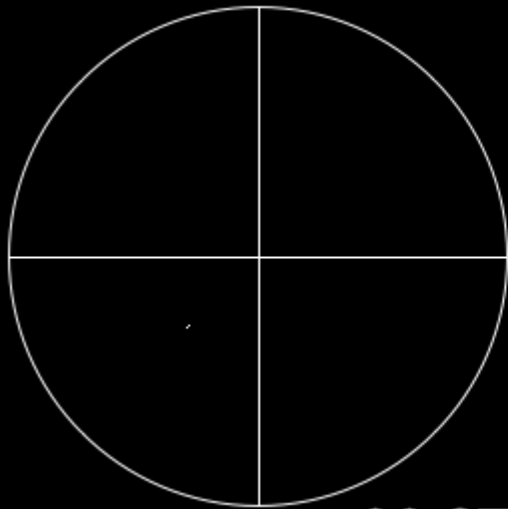
Total photon enter the Focal Surface

Total photon detected

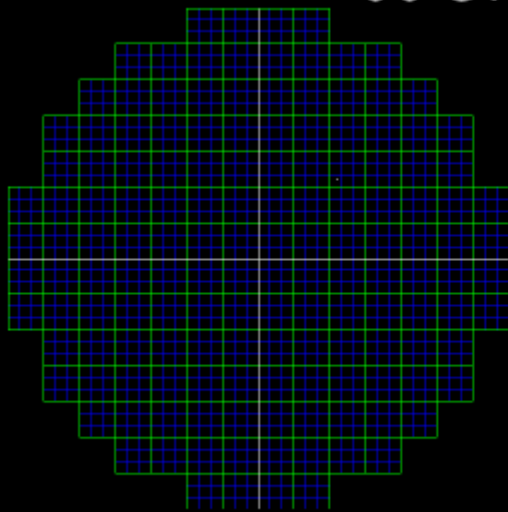


# The JEM-EUSO observe cosmic rays

Air Shower

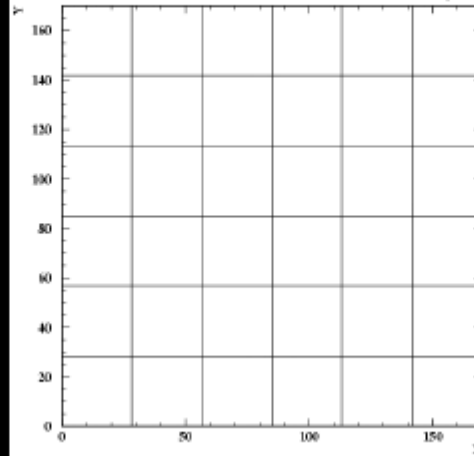


00 GTU

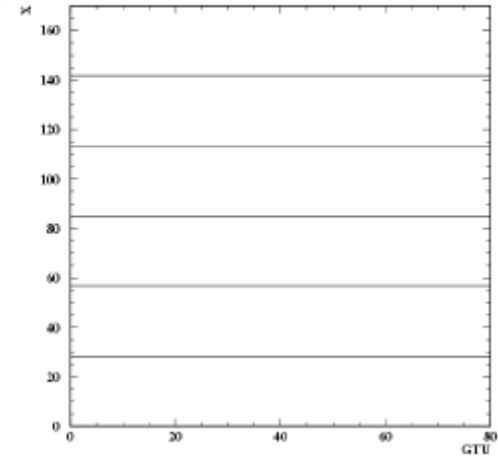


EUSO Focal Surface

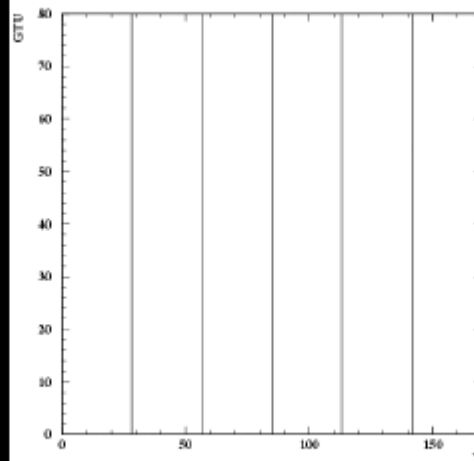
Photo Detector Module (3,3)



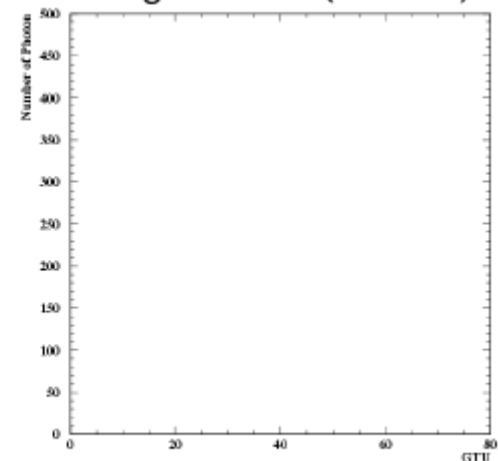
X-Time



Y-Time



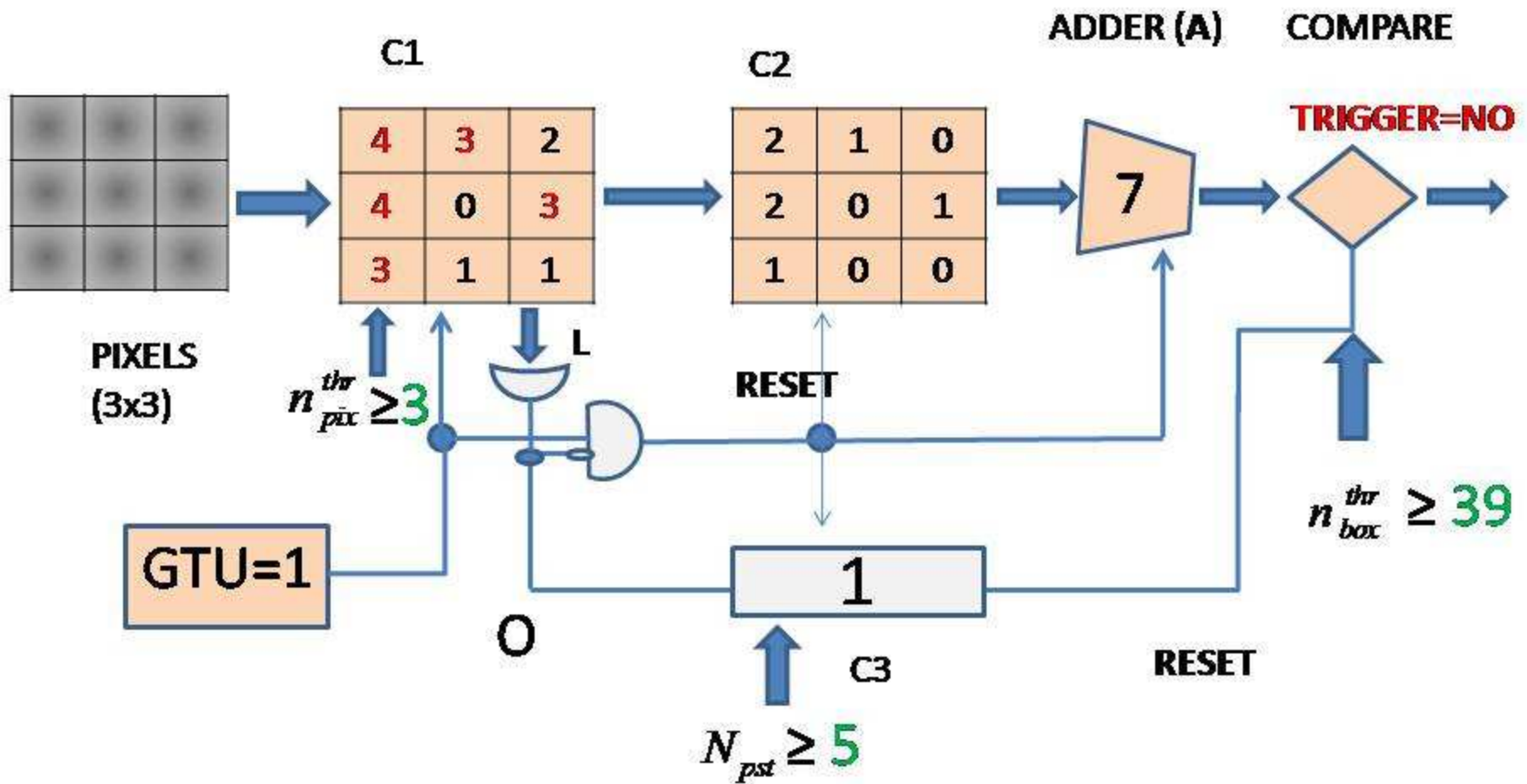
Light Curve (Photon)



**THE GTU  
COLLECTED FOR AN  
EVENT OF  
 $1 \cdot 10^{20}$  eV**

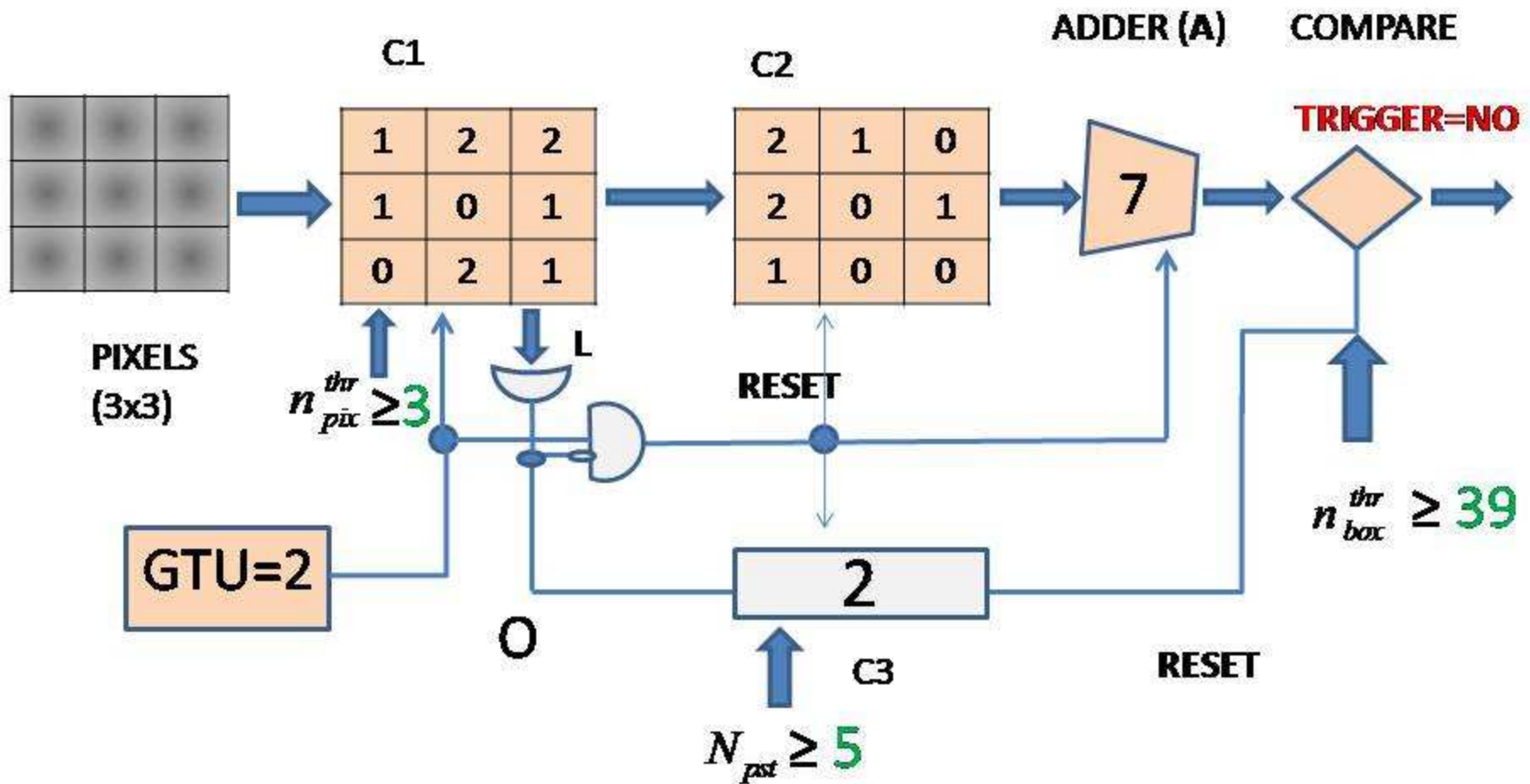


# EXAMPLE: TRIGGER IS NOT ISSUED



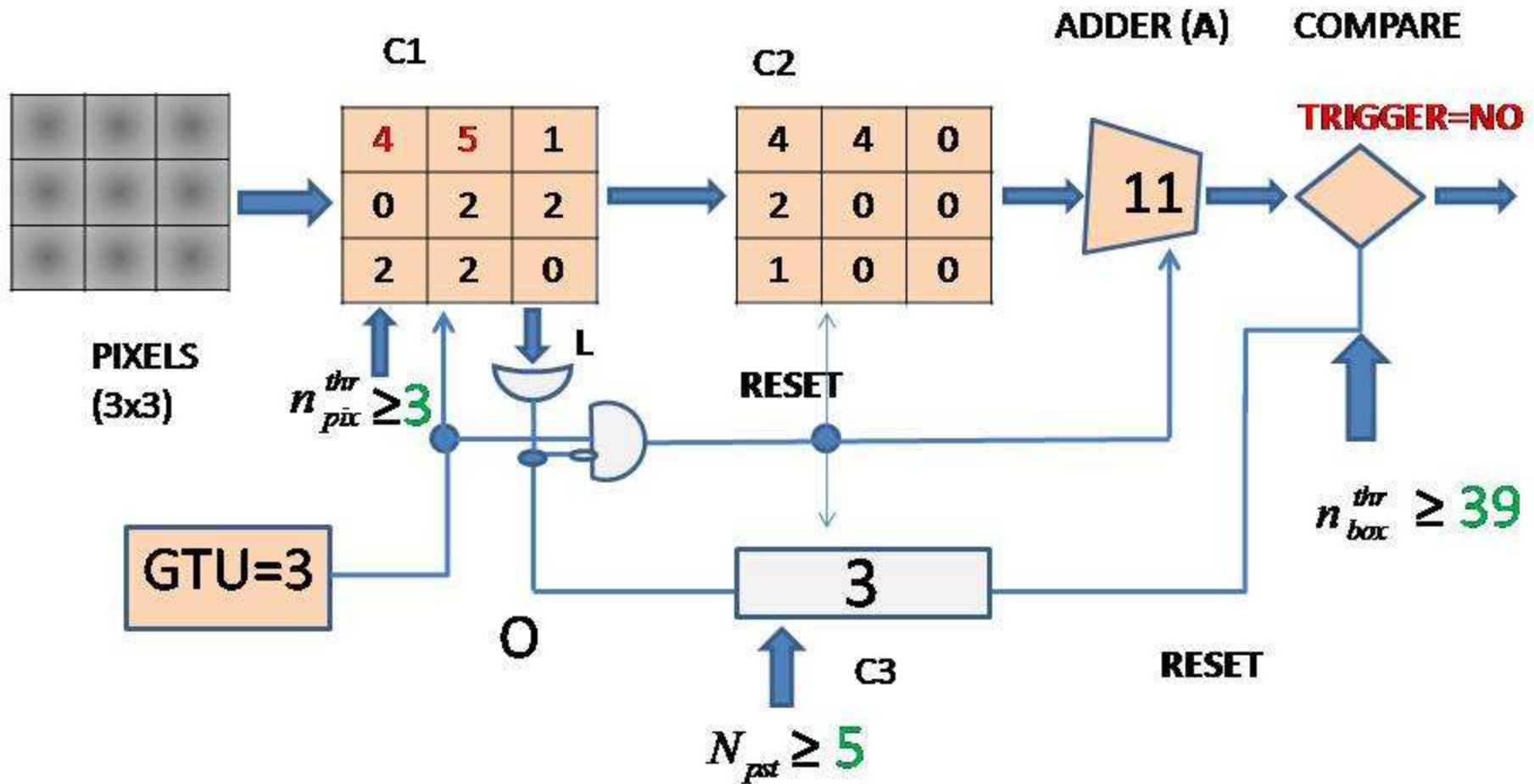
$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

# EXAMPLE: TRIGGER IS NOT ISSUED



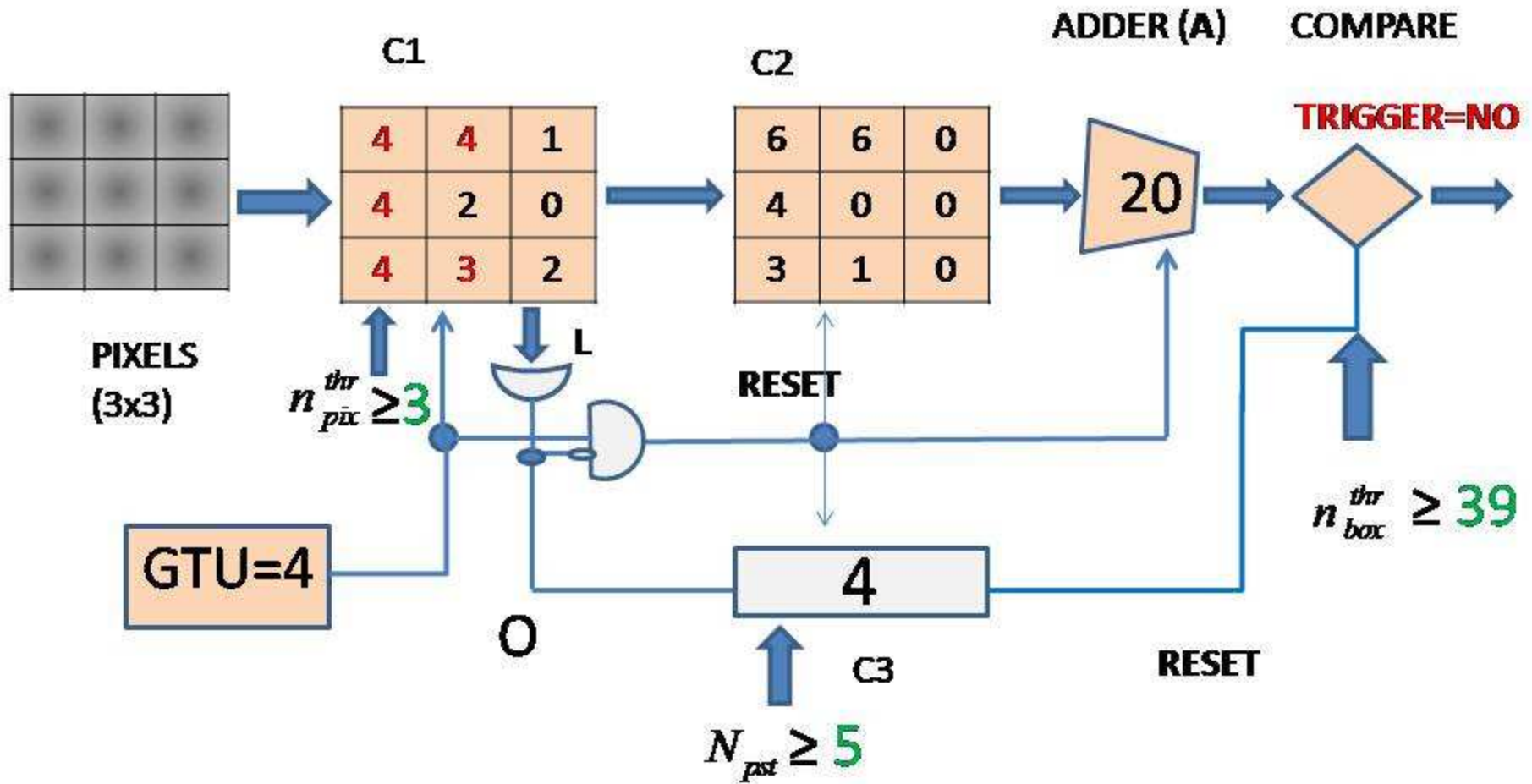
$$N_{C2} = N_{C1} - n_{thr_{pix}} + 1$$

## EXAMPLE: TRIGGER IS NOT ISSUED



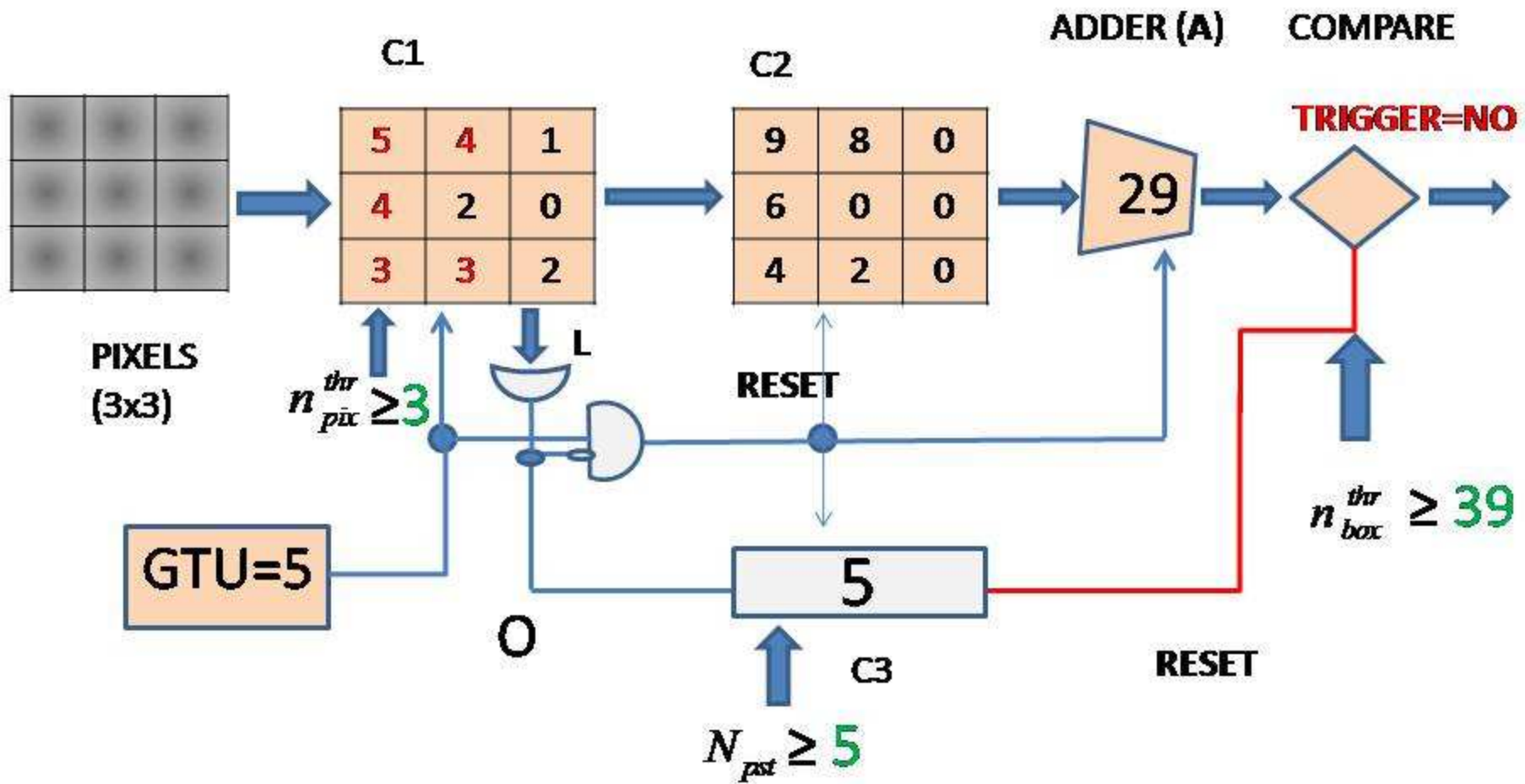
$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

# EXAMPLE: TRIGGER IS NOT ISSUED



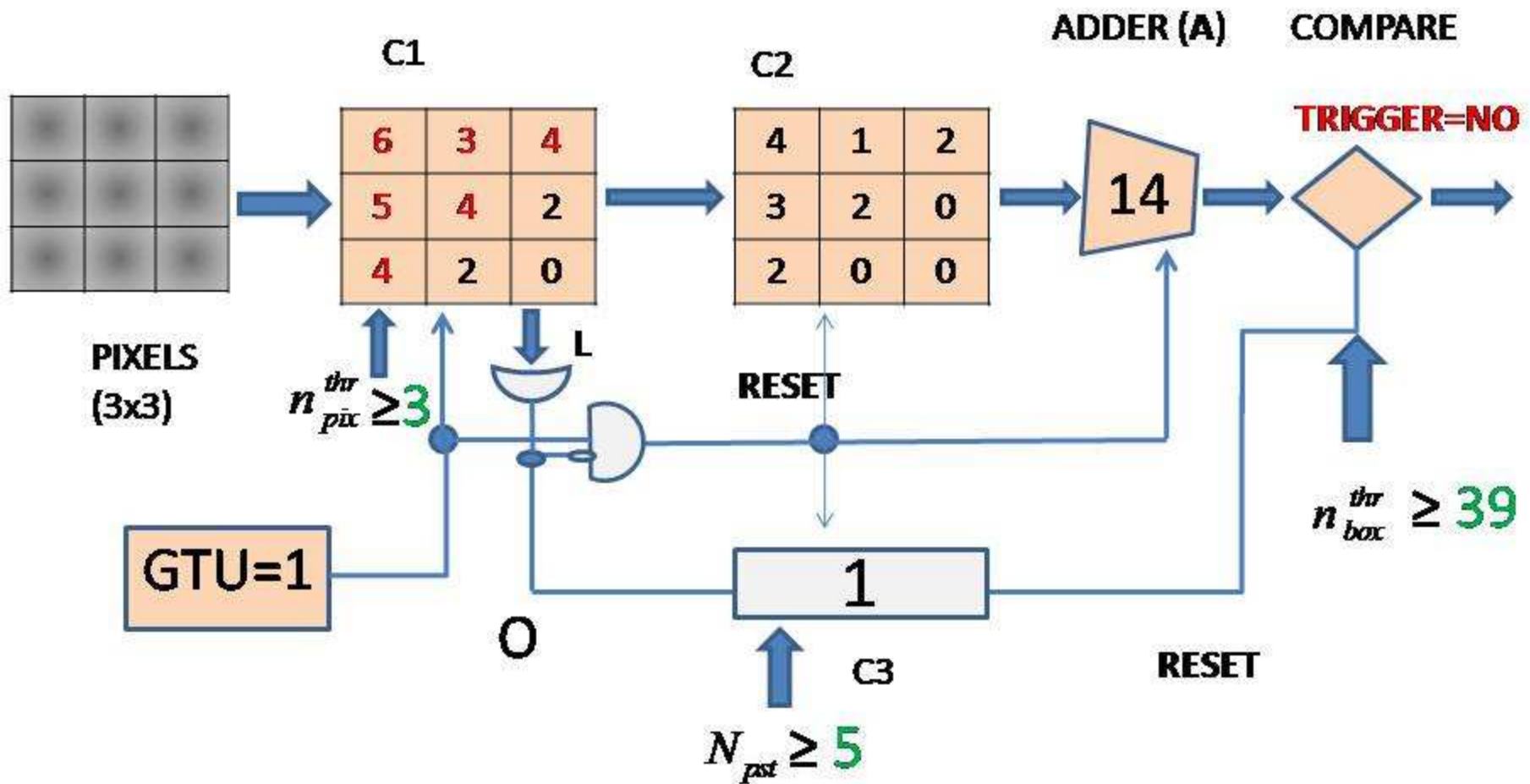
$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

## EXAMPLE: TRIGGER IS NOT ISSUED



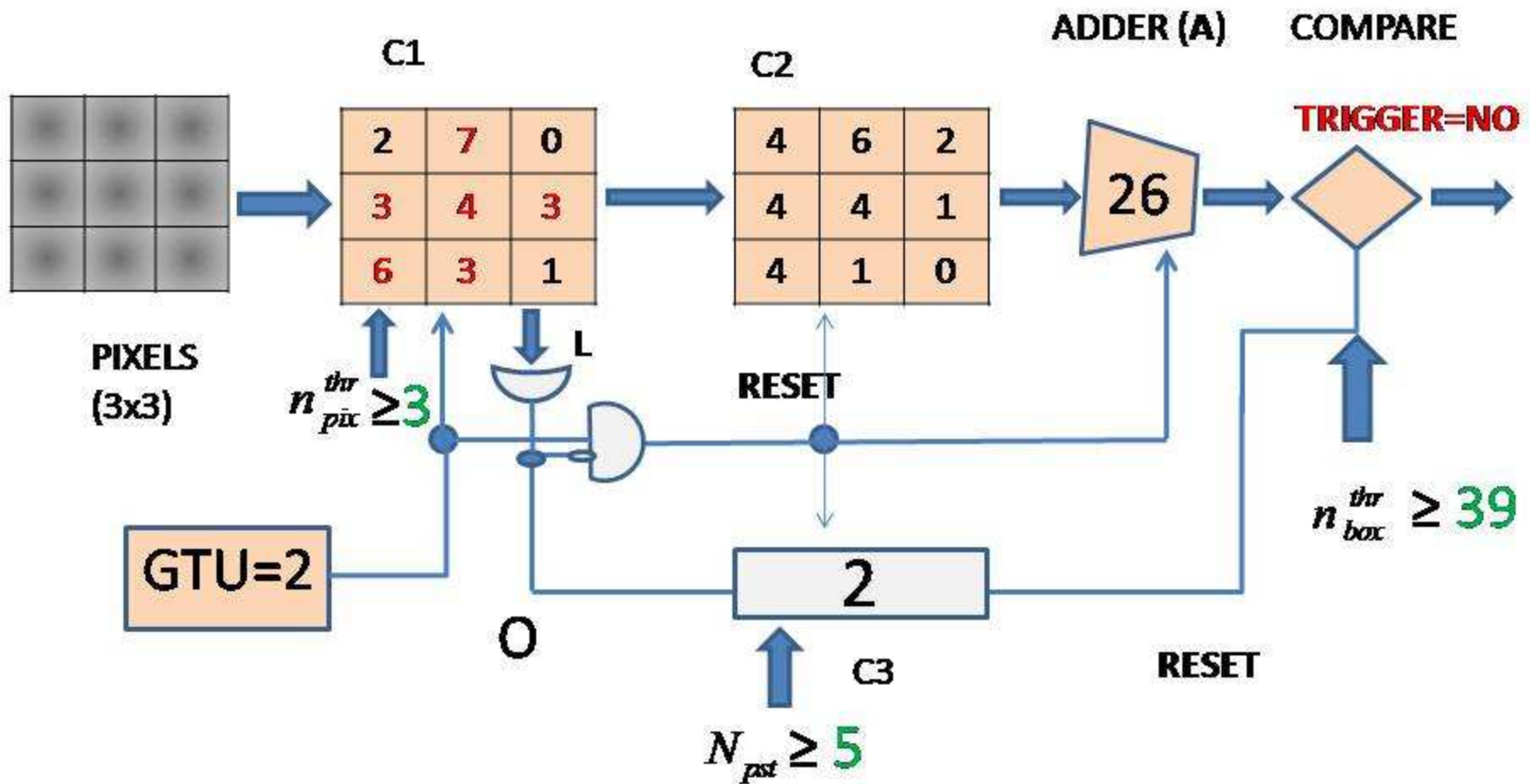
$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

## EXAMPLE: TRIGGER IS ISSUED



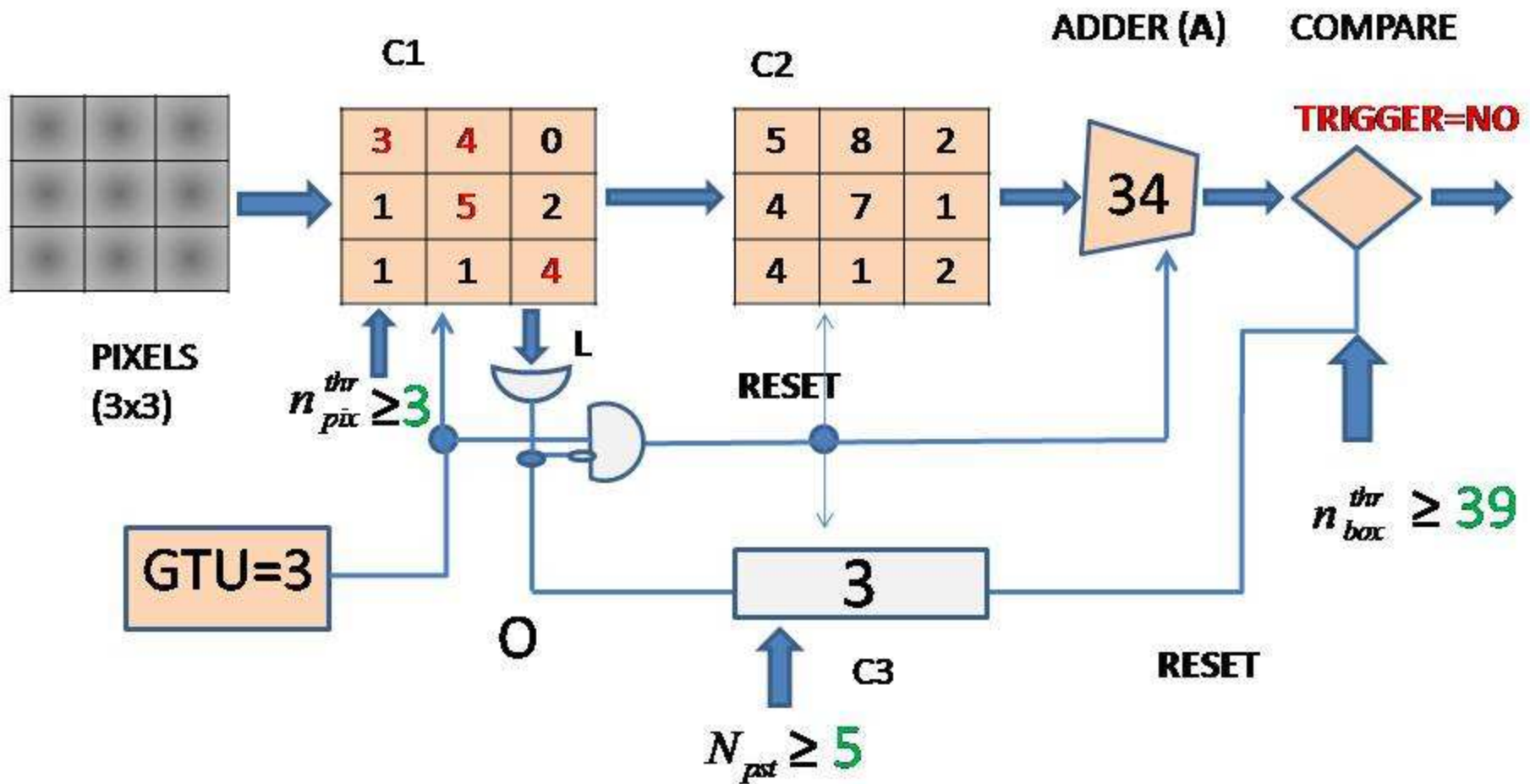
$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

## EXAMPLE: TRIGGER IS ISSUED



$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

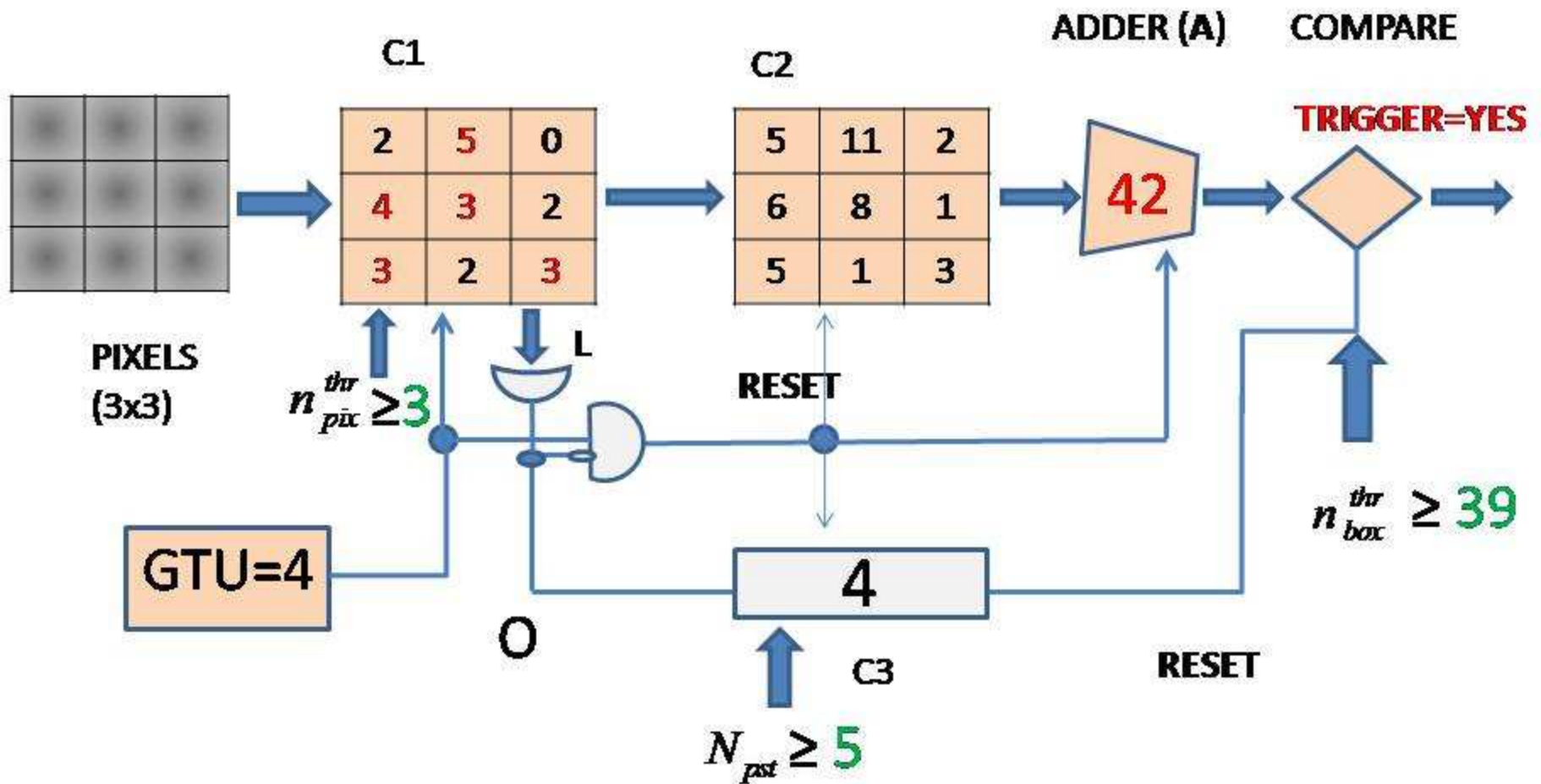
## EXAMPLE: TRIGGER IS ISSUED



$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

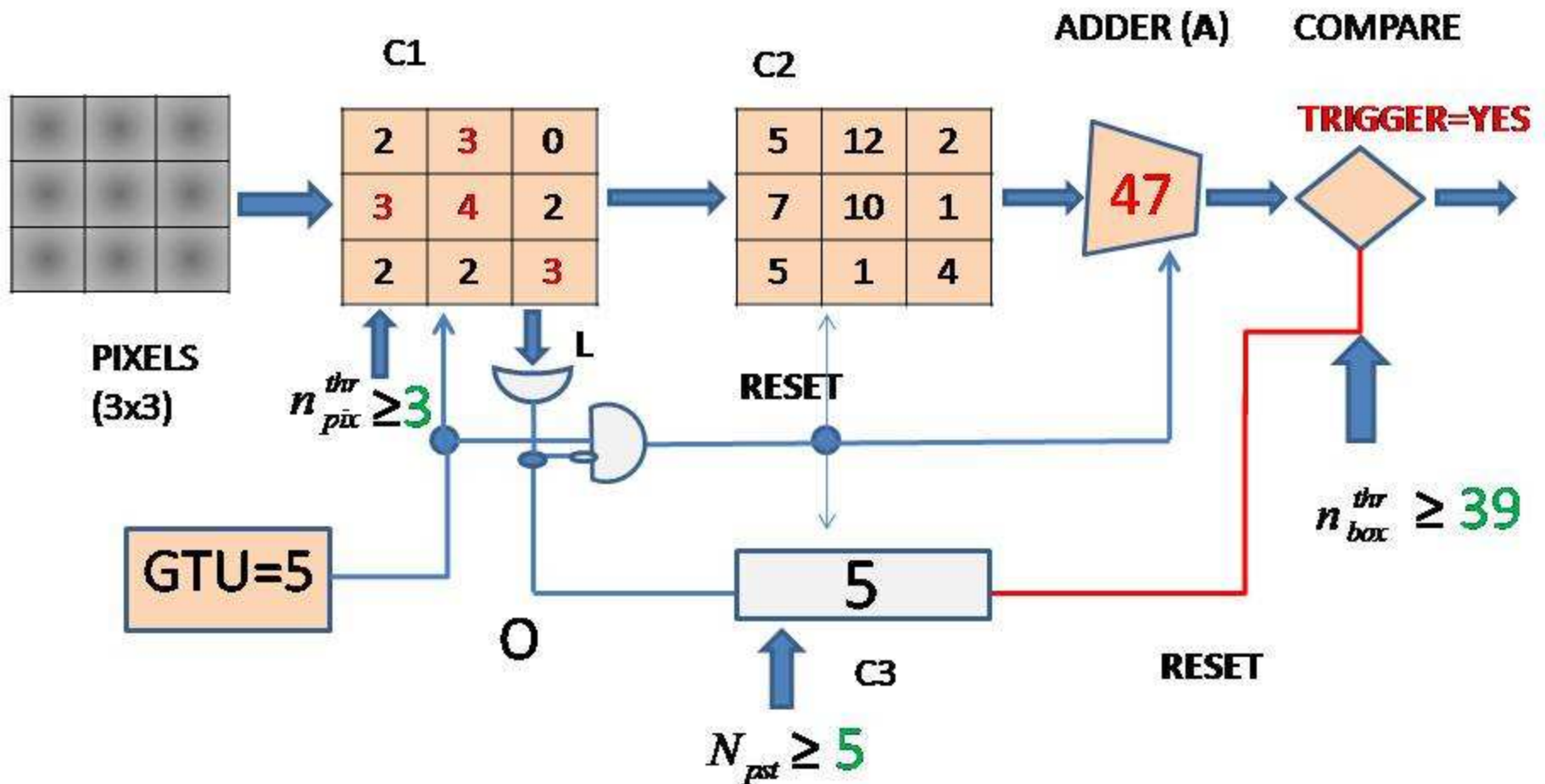


## EXAMPLE: TRIGGER IS ISSUED



$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

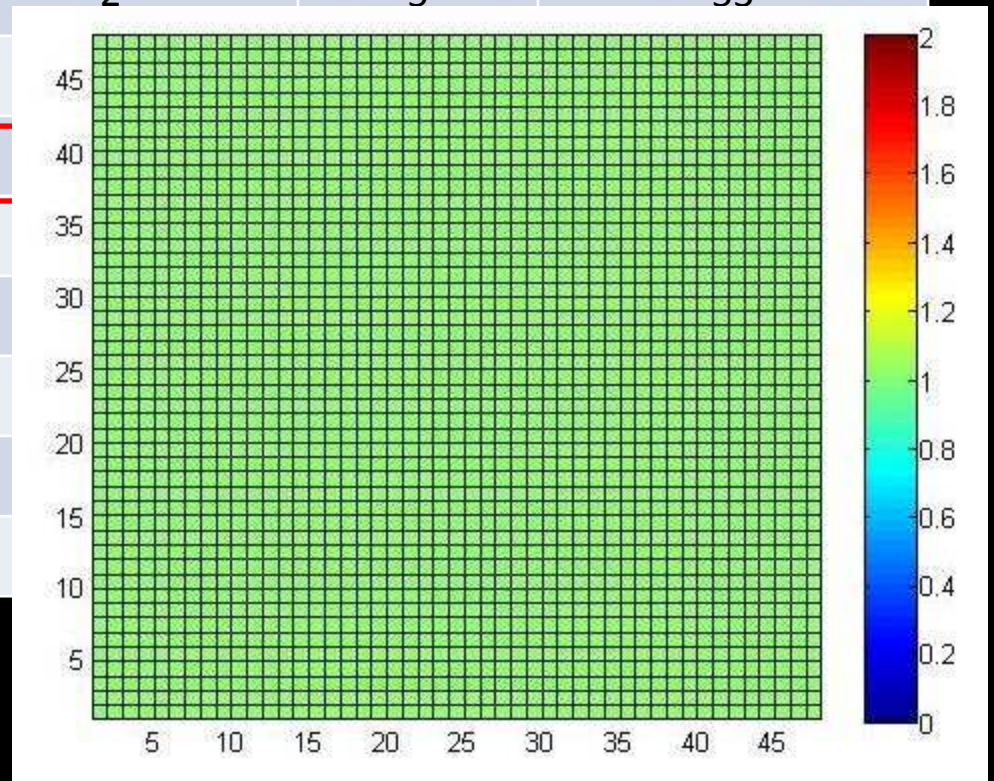
## EXAMPLE: TRIGGER IS ISSUED



$$N_{C2} = N_{C1} - n_{pix}^{thr} + 1$$

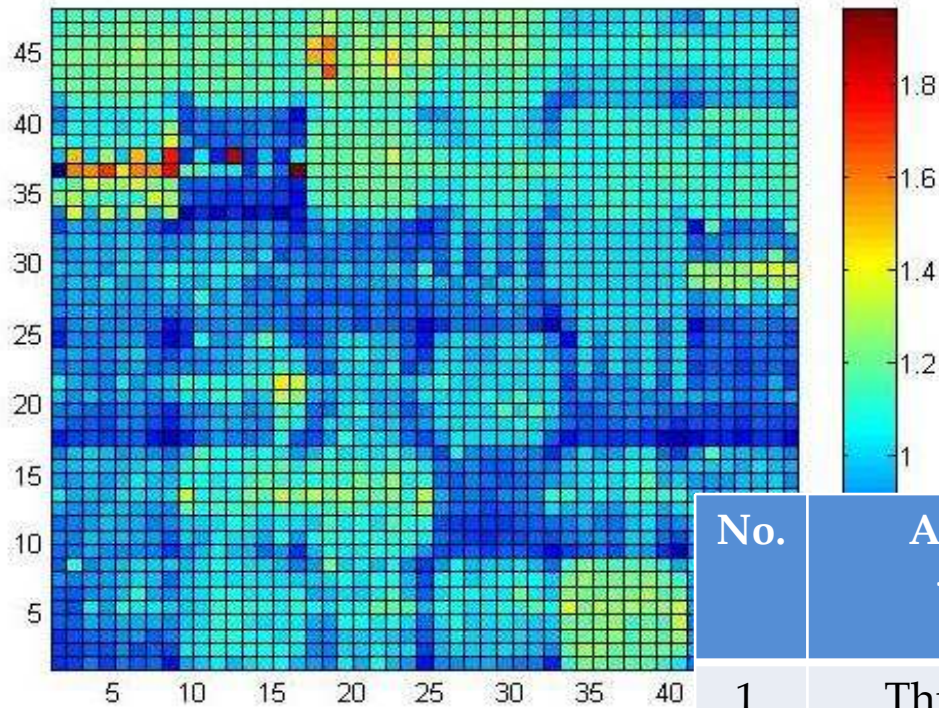
# List of threshold

No.	Average Background (photoelectron/pixel/GTU)	$n_{pix}^{thr}$ (photoelectron)	$N_{pst}$ (GTU)	$n_{box}^{thr}$ (photoelectron)
1.	0.1	0	5	18
...	...	...	...	...
18.	1.8	2	5	53
19.	1.9			
20.	2.0			
21.	2.1			
22.	2.2			
23.	2.3			
...	...			
63.	6.3			



Map of uniform PDM

# My stage work



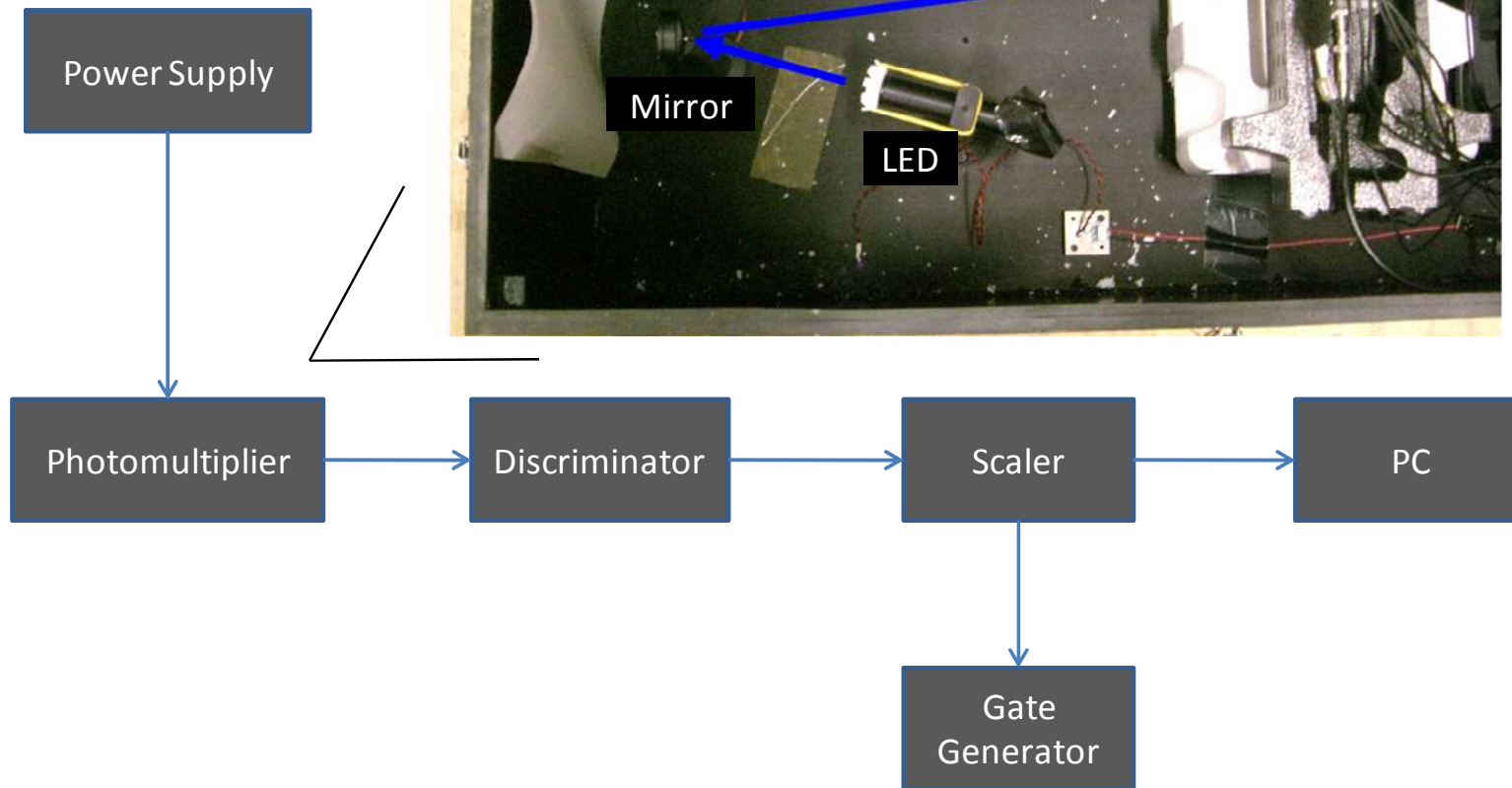
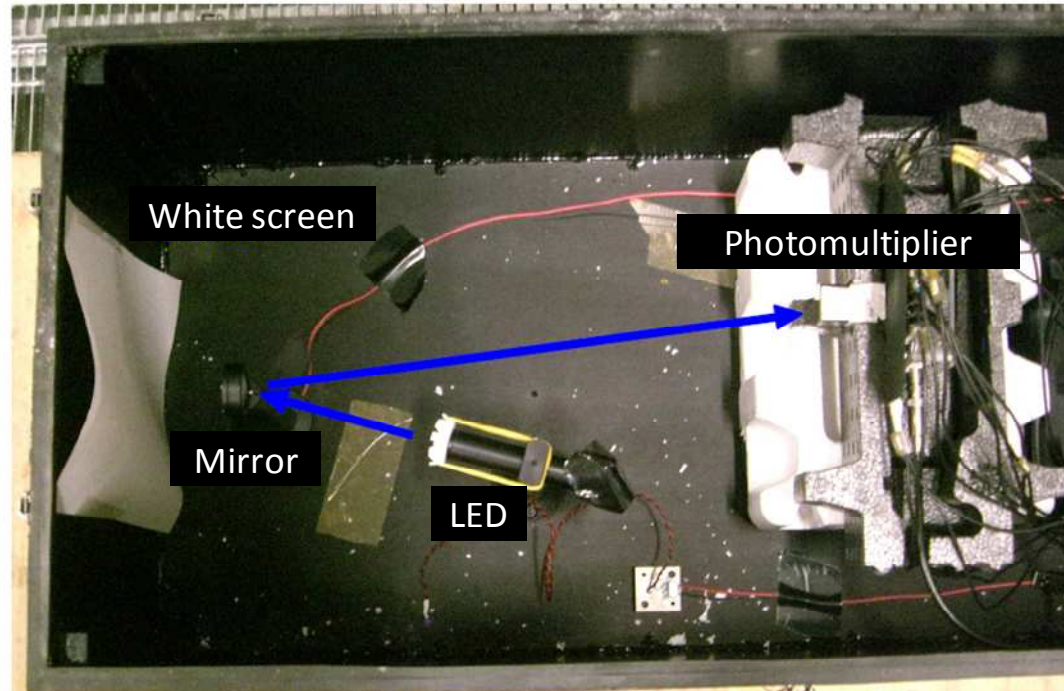
Map Efficiency of PDM

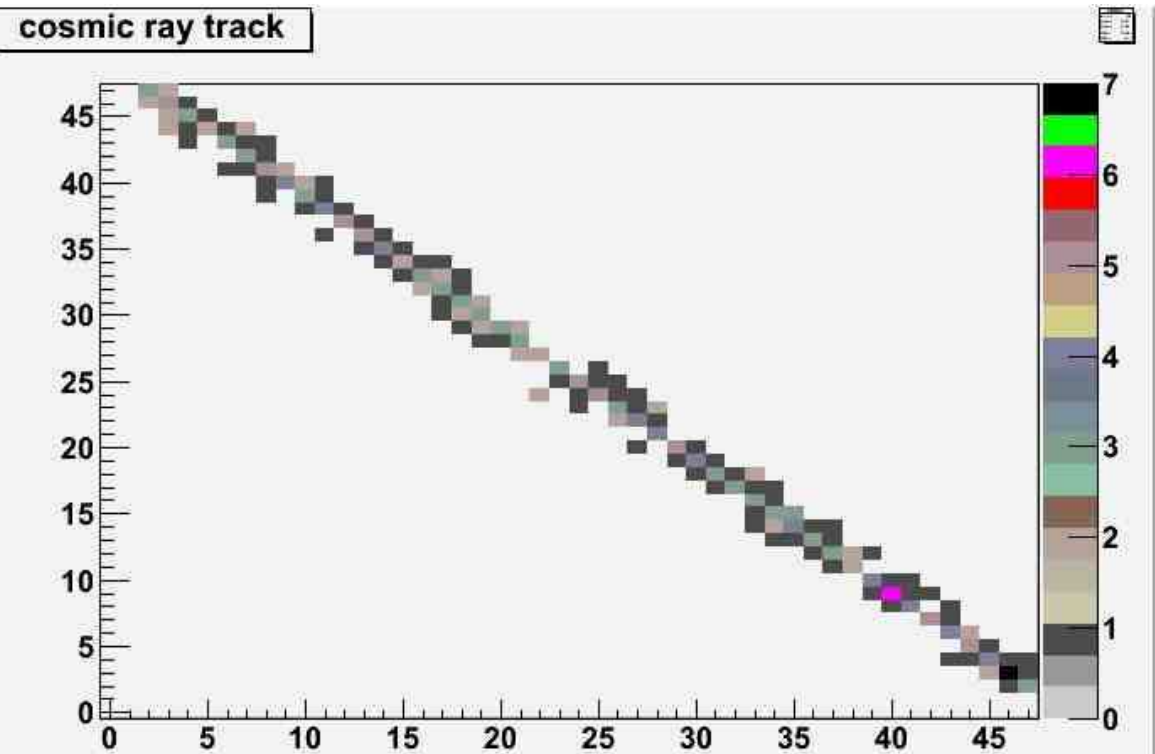
$$P_i(x, \lambda_i) = \frac{-e^{\lambda_i} \lambda_i^x}{x!}$$

Trigger rate for different threshold and background level

No.	Avg bck <phe>	Trigger rate (Hz/PDM)			
		0.5phe	1phe	1.5phe	2phe
1.	Thr(<phe>)	1656	1605	2985	8121
2.	Thr(<phe>+0.1)	128	644	1326	2449
3.	Thr(<phe>+0.2)	4	39	273	641
4.	Thr(<phe>+0.25)	0	2	130	323
5.	Thr(<phe>+0.3)	0	1	45	74
6.	Thr(<phe>+0.4)	0	0	4	19
7.	Thr(<phe>+0.45)	0	0	0	0

# Experimental Setup





# nd measurement

Pixel 2

h
Entries 1500000
Mean 1.228
RMS 1.107



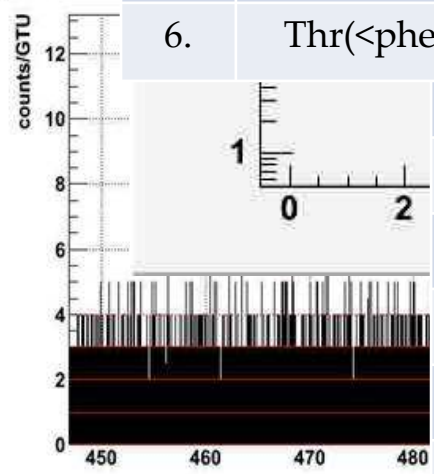
## Average background of first night measurement

		Pixel x1	Pixel x2	Pixel x3	Pixel x4	Pixel x5
Pixel y1	No.	Avg bck		Number of Triggers		Trigger rate (Hz/PDM)
Pixel y2	1.	Thr(<phe>)		35359		9426
Pixel y3	2.	Thr(<phe>+0.1)		14200		3787
Pixel y4	3.	Thr(<phe>+0.2)		1422		379
Pixel y5	4.	Thr(<phe>+0.3)		84		22.4
	5.	Thr(<phe>+0.4)		2		0.533
	6.	Thr(<phe>+0.5)		0		0

h
Entries 1500000
Mean 0.8684
RMS 0.9308

h
Entries 1500000
Mean 1.019
RMS 1.011

Pixel 13 Ti

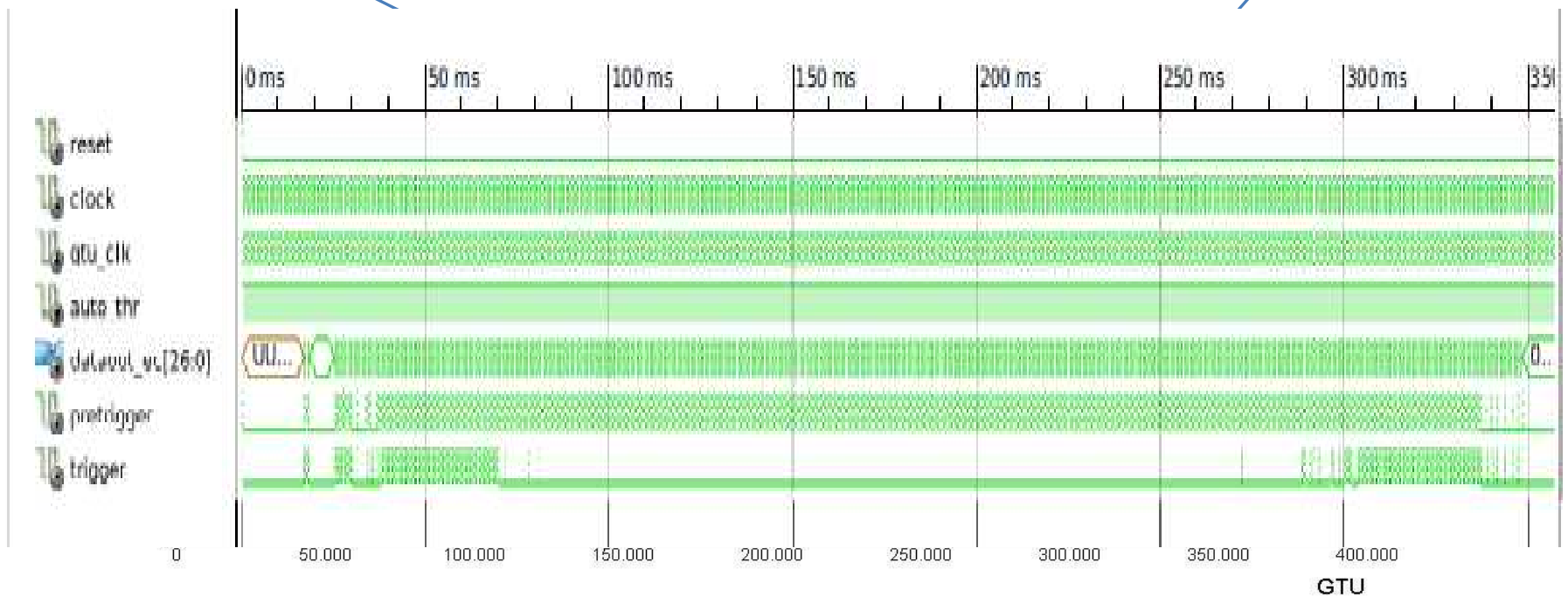
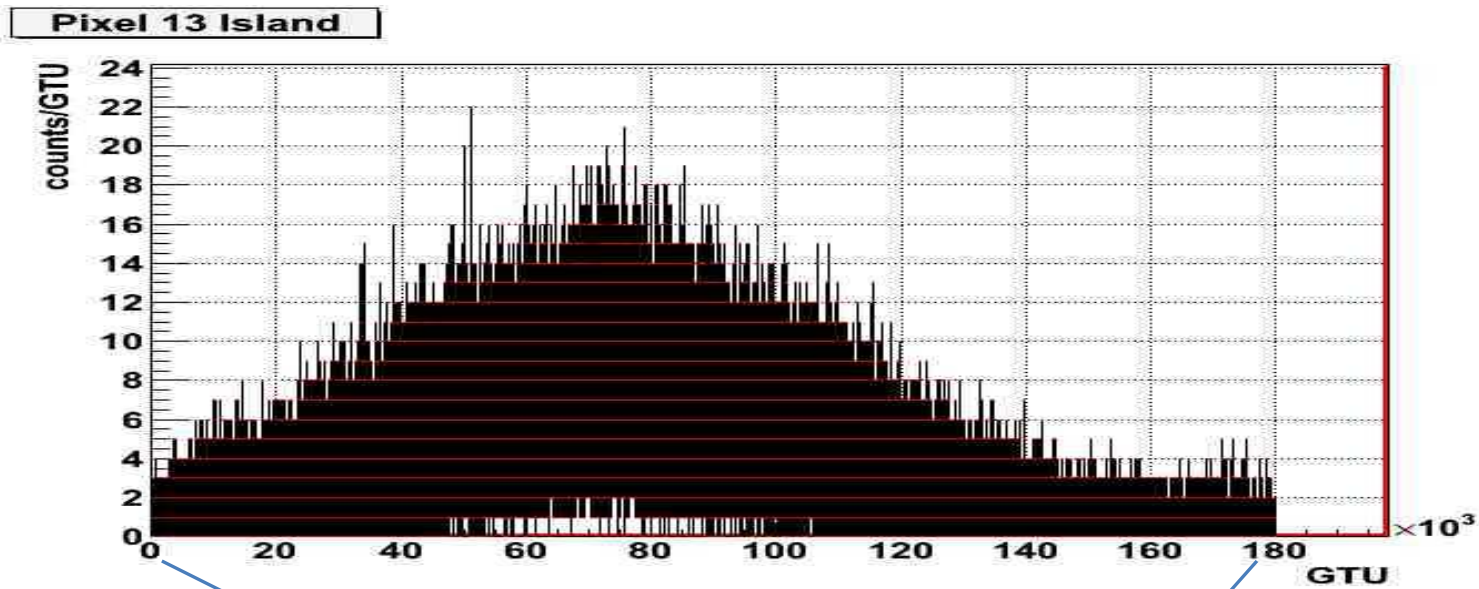


	Pixel x1	Pixel x2	Pixel x3	Pixel x4	Pixel x5
Pixel y1	0	1.228	1.208	1.203	0.784
Pixel y2	0.991	1.392	1.691	1.123	1.034
Pixel y3	1.102	0.630	0.868	1.218	0.875
Pixel y4	0.679	1.412	0.742	0.692	0.844
Pixel y5	0.688	0.967	0.898	1.019	0

nt

0 2 4 6 8 10 12 14

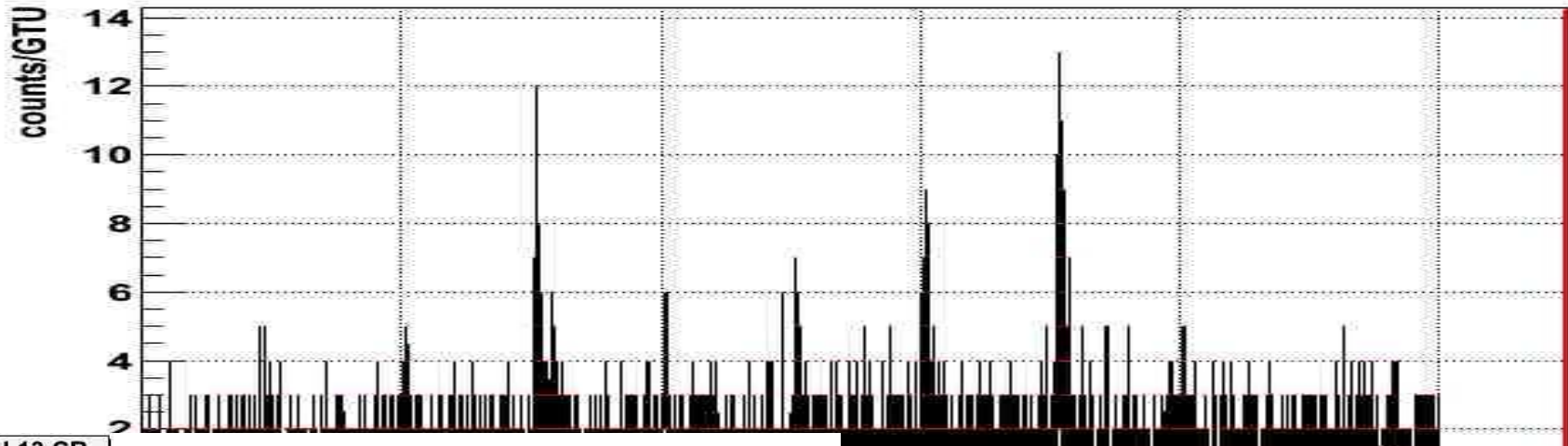
# Time profile of the amount of light by telescope when pass an island



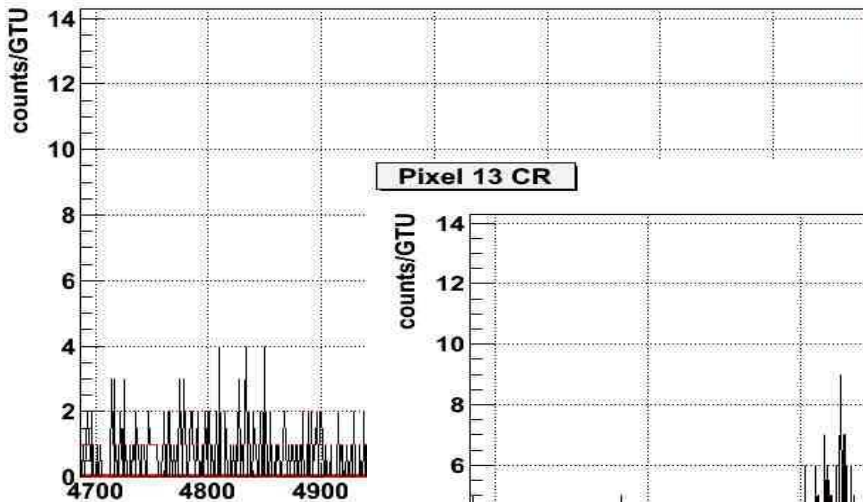


# Time profile of the amount of light by telescope when EAS happen

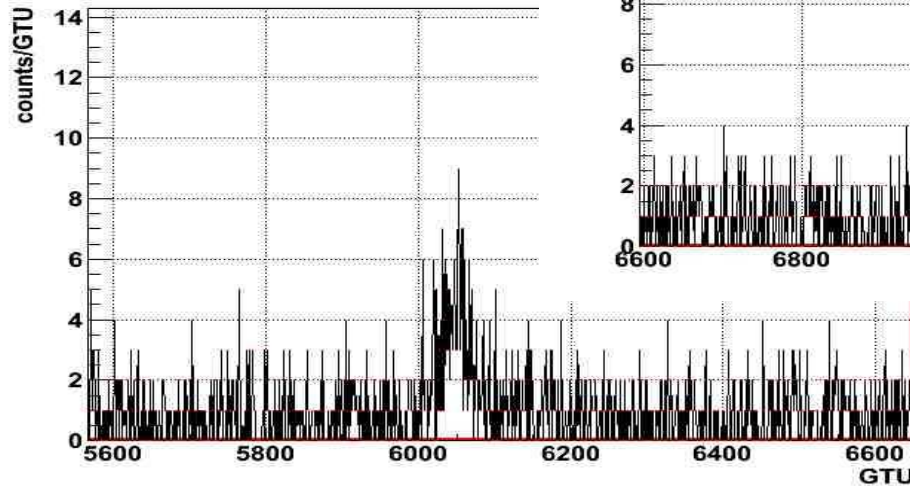
Pixel 13 CR



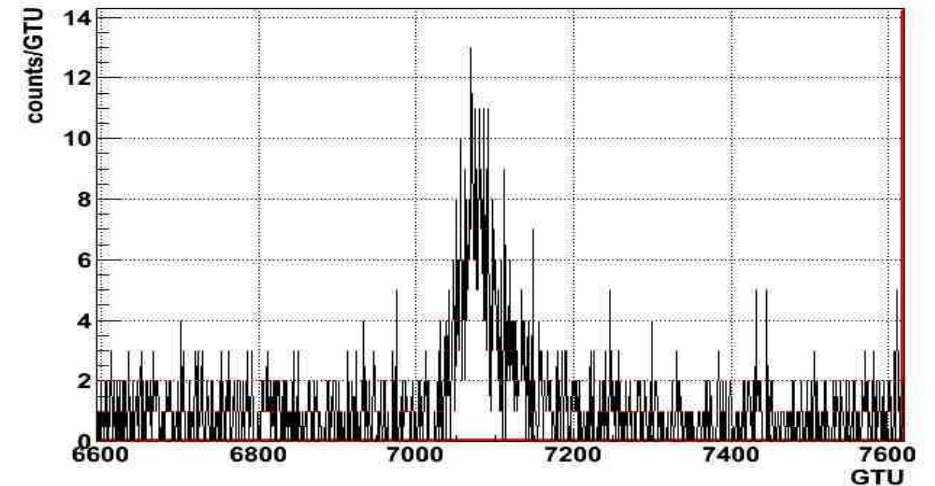
Pixel 13 CR



Pixel 13 CR



Pixel 13 CR



# CONCLUSION



The threshold should be increase ( $\sim 30\%$ ) compared to pure Poissonian fluctuation on a homogeneous layer of PMT



Cosmic rays events were succesfully triggered



It is important in future controle some transient in which the number of trigger becomes very high such as island type measurement



Backup slide

# Preparation of the data format for VHDL code implemented in the FPGA

c13 c12 c11 c10 c9 c8								c5 c4 c3 c2 c1 c0								D	
1 A								2 B								C	
7,0	6,0	5,0	4,0	3,0	2,0	1,0	0,0	7,0	6,0	5,0	4,0	3,0	2,0	1,0	0,0	r0	r0
8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	r1	r1
7,1	6,1	5,1	4,1	3,1	2,1	1,1	0,1	7,1	6,1	5,1	4,1	3,1	2,1	1,1	0,1	r2	r2
16	15	14	13	12	11	10	9	16	15	14	13	12	11	10	9	r3	r3
7,2	6,2	5,2	4,2	3,2	2,2	1,2	0,2	7,2	6,2	5,2	4,2	3,2	2,2	1,2	0,2	r4	r4
24	23	22	21	20	19	18	17	24	23	22	21	20	19	18	17	r5	r5
7,3	6,3	5,3	4,3	3,3	2,3	1,3	0,3	7,3	6,3	5,3	4,3	3,3	2,3	1,3	0,3	r6	r6
32	31	30	29	28	27	26	25	32	31	30	29	28	27	26	25	r7	r7
7,4	6,4	5,4	4,4	3,4	2,4	1,4	0,4	7,4	6,4	5,4	4,4	3,4	2,4	1,4	0,4	r8	r8
40	39	38	37	36	35	34	33	40	39	38	37	36	35	34	33	r9	r9
7,5	6,5	5,5	4,5	3,5	2,5	1,5	0,5	7,5	6,5	5,5	4,5	3,5	2,5	1,5	0,5	r10	r10
48	47	46	45	44	43	42	41	48	47	46	45	44	43	42	41	r11	r11
7,6	6,6	5,6	4,6	3,6	2,6	1,6	0,6	7,6	6,6	5,6	4,6	3,6	2,6	1,6	0,6	r12	r12
56	55	54	53	52	51	50	49	56	55	54	53	52	51	50	49	r13	r13
7,7	6,7	5,7	4,7	3,7	2,7	1,7	0,7	7,7	6,7	5,7	4,7	3,7	2,7	1,7	0,7	r14	r14
64	63	62	61	60	59	58	57	64	63	62	61	60	59	58	57	r15	r15

3 D								4 C									
7,0	6,0	5,0	4,0	3,0	2,0	1,0	0,0	7,0	6,0	5,0	4,0	3,0	2,0	1,0	0,0	r16	r16
8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	r17	r17
7,1	6,1	5,1	4,1	3,1	2,1	1,1	0,1	7,1	6,1	5,1	4,1	3,1	2,1	1,1	0,1	r18	r18
16	15	14	13	12	11	10	9	16	15	14	13	12	11	10	9	r19	r19
7,2	6,2	5,2	4,2	3,2	2,2	1,2	0,2	7,2	6,2	5,2	4,2	3,2	2,2	1,2	0,2	r20	r20
24	23	22	21	20	19	18	17	24	23	22	21	20	19	18	17	r21	r21
7,3	6,3	5,3	4,3	3,3	2,3	1,3	0,3	7,3	6,3	5,3	4,3	3,3	2,3	1,3	0,3	r22	r22
32	31	30	29	28	27	26	25	32	31	30	29	28	27	26	25	r23	r23
7,4	6,4	5,4	4,4	3,4	2,4	1,4	0,4	7,4	6,4	5,4	4,4	3,4	2,4	1,4	0,4	r24	r24
40	39	38	37	36	35	34	33	40	39	38	37	36	35	34	33	r25	r25
7,5	6,5	5,5	4,5	3,5	2,5	1,5	0,5	7,5	6,5	5,5	4,5	3,5	2,5	1,5	0,5	r26	r26
48	47	46	45	44	43	42	41	48	47	46	45	44	43	42	41	r27	r27
7,6	6,6	5,6	4,6	3,6	2,6	1,6	0,6	7,6	6,6	5,6	4,6	3,6	2,6	1,6	0,6	r28	r28
56	55	54	53	52	51	50	49	56	55	54	53	52	51	50	49	r29	r29
7,7	6,7	5,7	4,7	3,7	2,7	1,7	0,7	7,7	6,7	5,7	4,7	3,7	2,7	1,7	0,7	r30	r30
64	63	62	61	60	59	58	57	64	63	62	61	60	59	58	57	r31	r31

c8 c9 c10 c11 c12 c13								r7 r6 r5 r4 r3 r2 r1 r0								C	
B								A								D	
1	2	3	4	5	6	7	8	57	49	41	33	25	17	9	1	r16	r16
9	10	11	12	13	14	15	16	58	50	42	34	26	18	10	2	r17	r17
17	18	19	20	21	22	23	24	59	51	43	35	27	19	11	3	r18	r18
25	26	27	28	29	30	31	32	60	52	44	36	28	20	12	4	r19	r19
33	34	35	36	37	38	39	40	61	53	45	37	29	21	13	5	r20	r20
41	42	43	44	45	46	47	48	62	54	46	38	30	22	14	6	r21	r21
49	50	51	52	53	54	55	56	63	55	47	39	31	23	15	7	r22	r22
57	58	59	60	61	62	63	64	64	56	48	40	32	24	16	8	r23	r23
8	16	24	32	40	48	56	64	64	63	62	61	60	59	58	57	r24	r24
7	15	23	31	39	47	55	63	56	55	54	53	52	51	50	49	r25	r25
6	14	22	30	38	46	54	62	48	47	46	45	44	43	42	41	r26	r26
5	13	21	29	37	45	53	61	40	39	38	37	36	35	34	33	r27	r27
4	12	20	28	36	44	52	60	32	31	30	29	28	27	26	25	r28	r28
3	11	19	27	35	43	51	59	24	23	22	21	20	19	18	17	r29	r29
2	10	18	26	34	42	50	58	16	15	14	13	12	11	10	9	r30	r30
1	9	17	25	33	41	49	57	8	7	6	5	4	3	2	1	r31	r31