Development of the TOF detector

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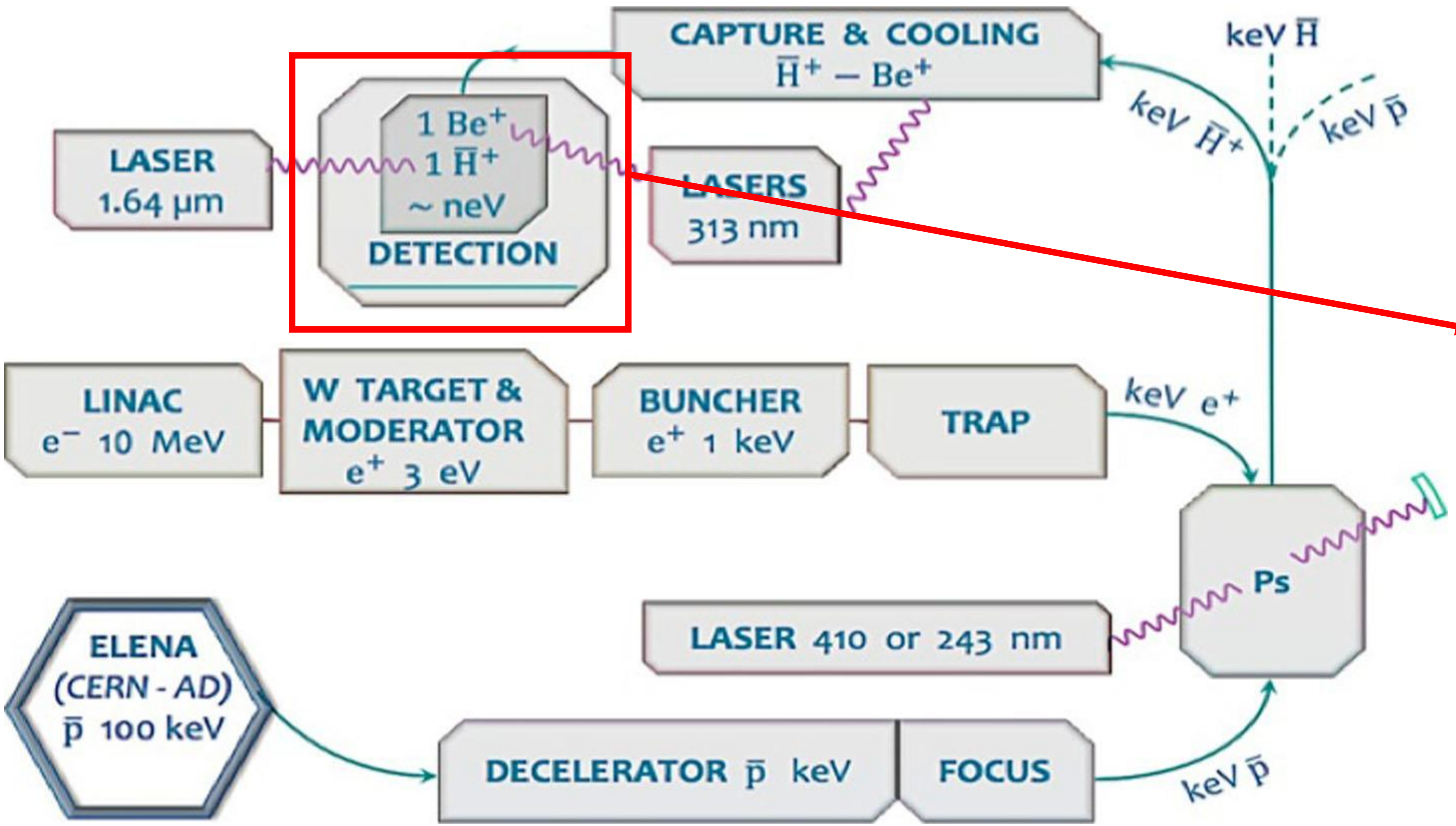
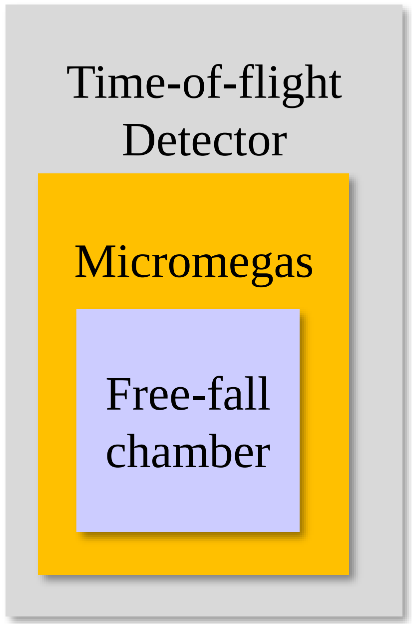
The GBAR experiment





TOF detector description

Time-Of-Flight(TOF) detector

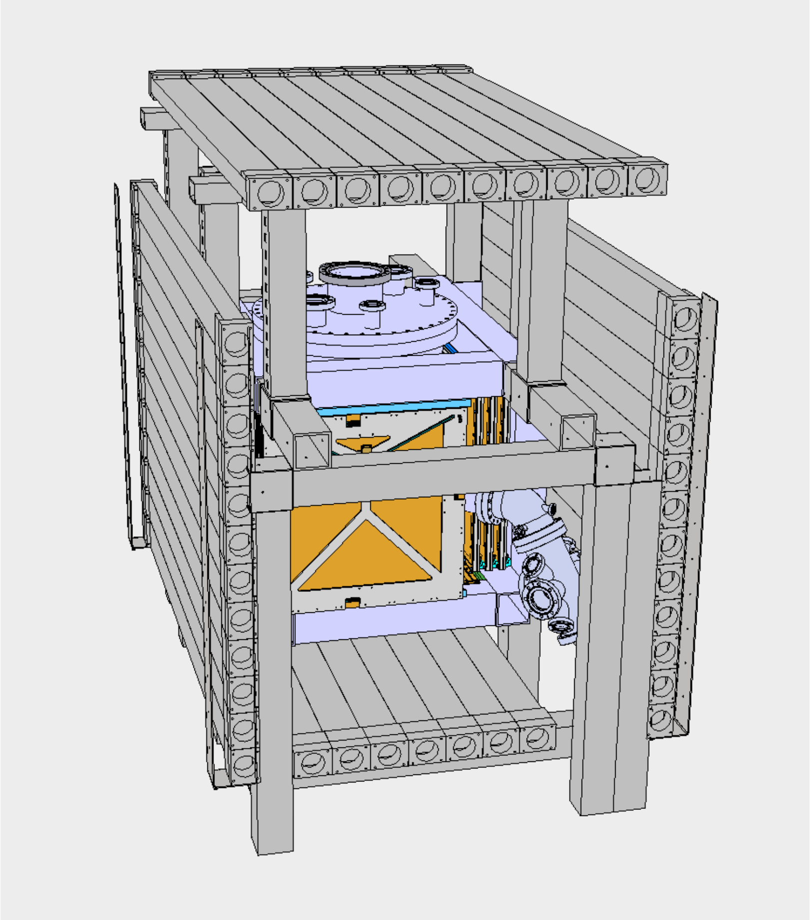
An array of plastic scintillation bars
with four walls – top, bottom, left, right

# of bars	(10)	(10)	(12)	(12)

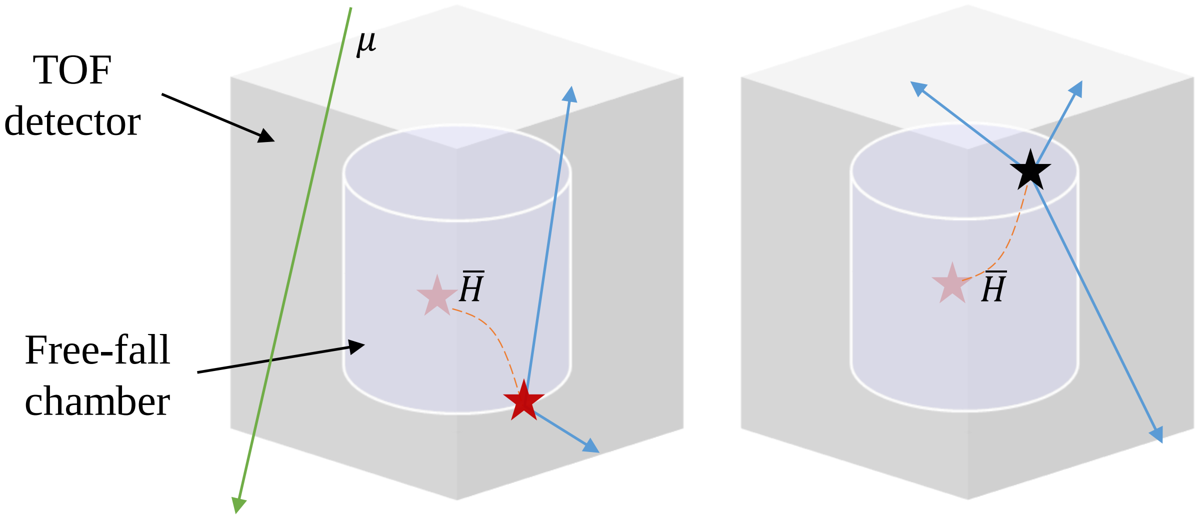
consists of 44bars and 88PMTs

a bar = $10*5*170\ cm^3$

an array ~ $120*170*1250\ cm^3$



TOF detector description

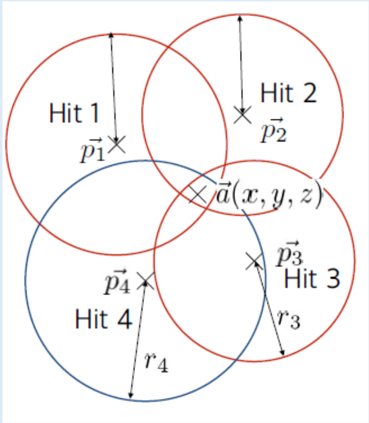


T_1 = time to bottom of TOF
T_2 = time to top of TOF
$dT = T_1 - T_2$

1. Free-fall time
   fastest one among 2nd particle signals

2. Annihilation position
   $dT < 0$ for chamber-bottom-annihilation
   > 0 top

Annihilation vertex reconstruction

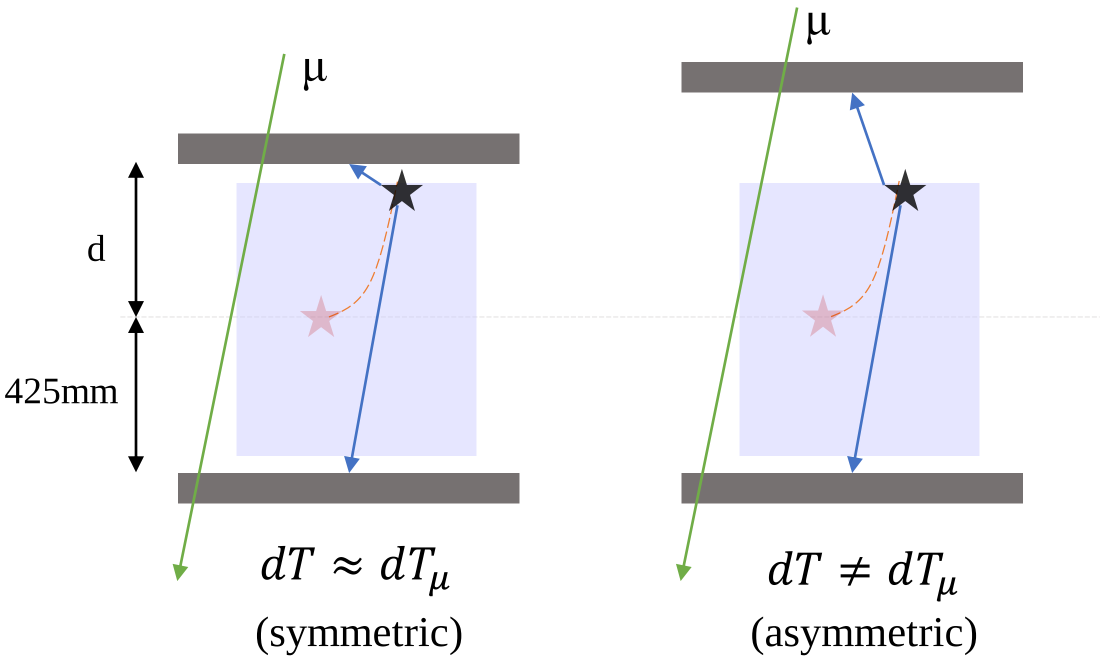


to minimize the error
(Trilateration)

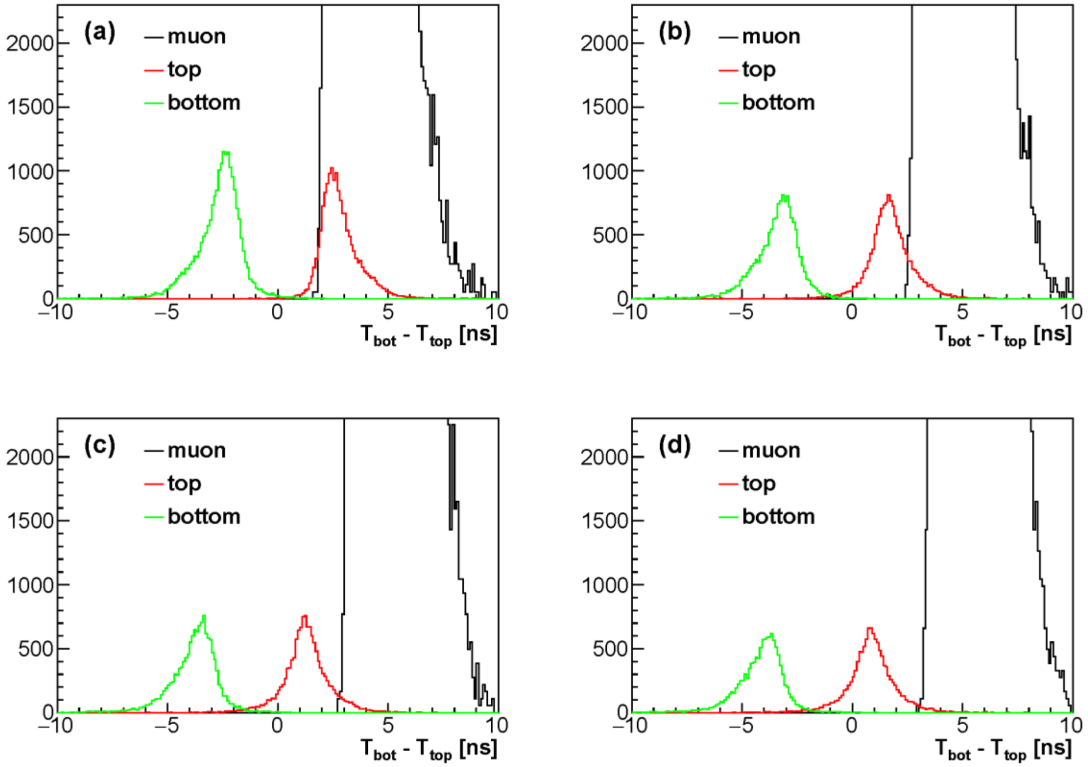
$$\Delta r_i = |\vec{p_i} - \vec{a}| - r_i$$

$$(\Delta r)^2 = \sum_{i=1}^{4} (\Delta r_i)^2$$

3. Cosmic ray rejection
   - need to be asymmetric along z-axis



3-pi decay events, 4 different height
(a) d=425mm (b) 625mm (c) 725mm (d) 825mm

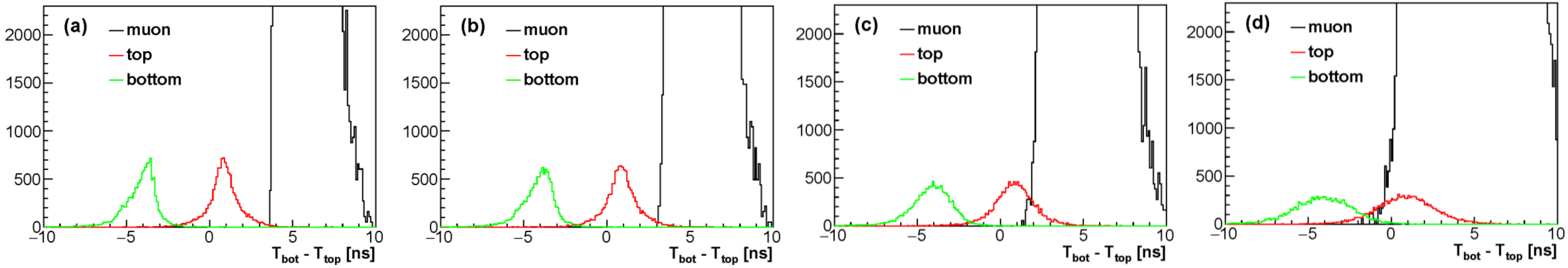


TOF detector description

3. Cosmic ray rejection

- need the time resolution smaller than 0.2ns

3-pi decay events, 825mm height, 4 different t-resolution
(normalized pion:muon = 1:5500)

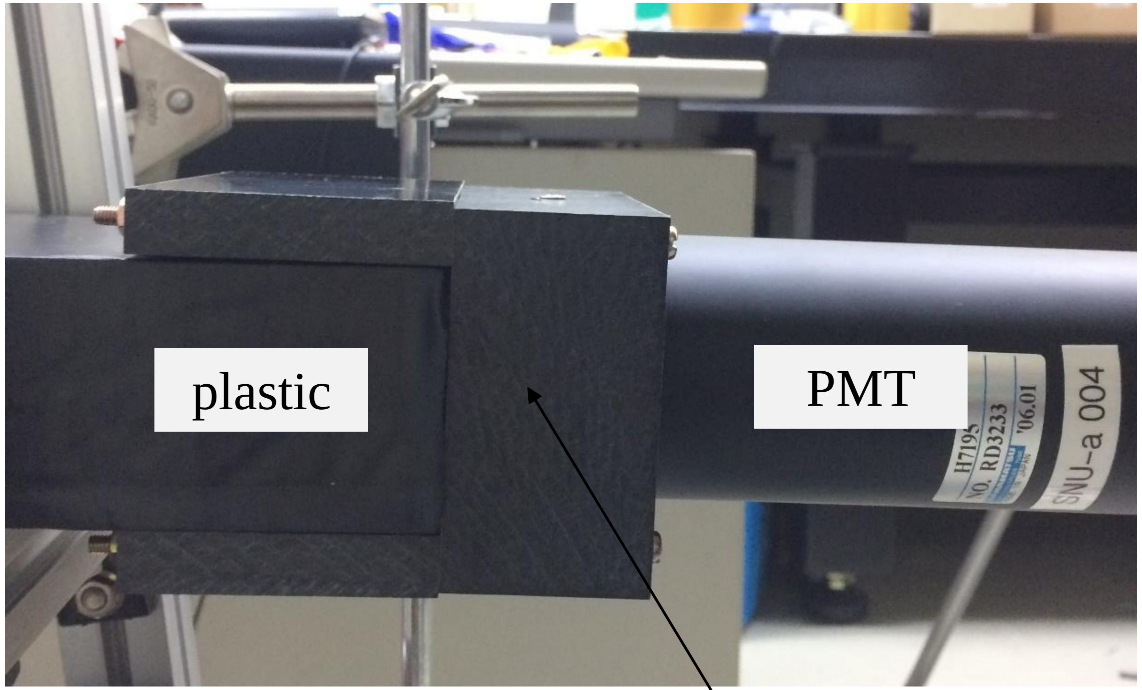


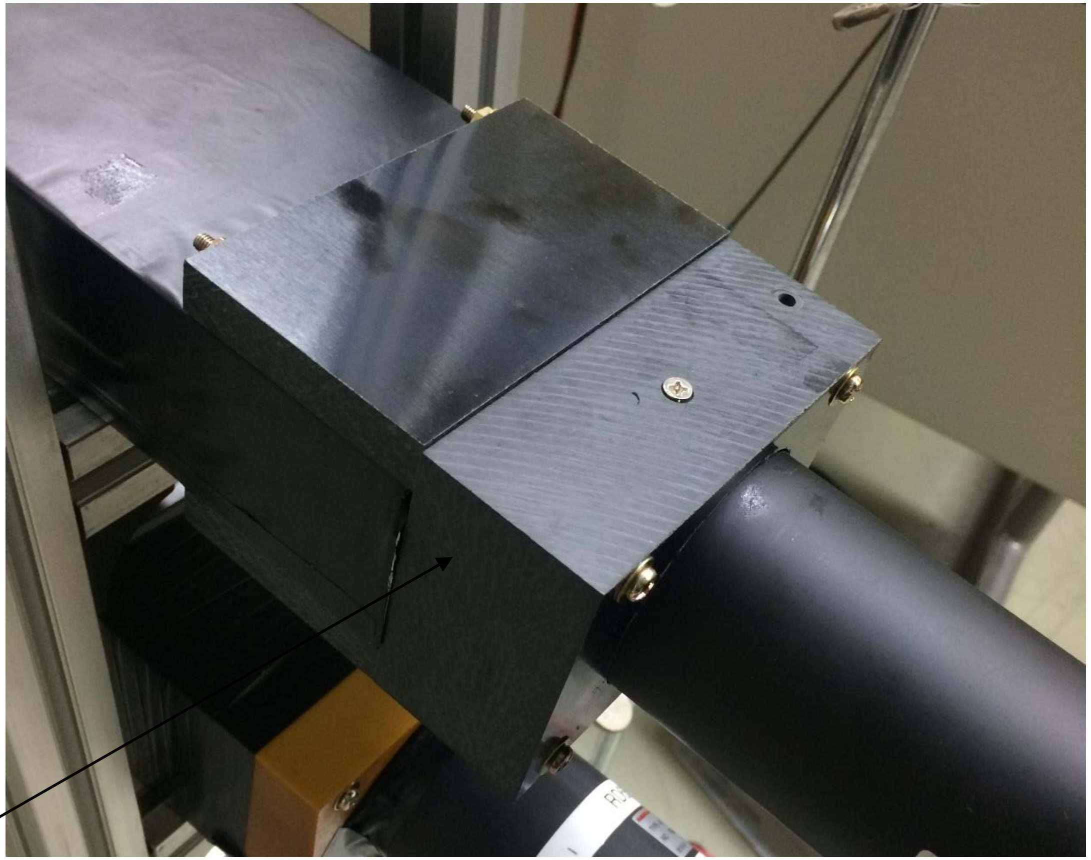
(a) 0.1 ns (b) 0.2 ns (c) 0.5 ns (d) 1.0 ns

Distinguishable !

Chamber-top-annihilation signal is not distinguishable from cosmic ray signal

TOF detector description

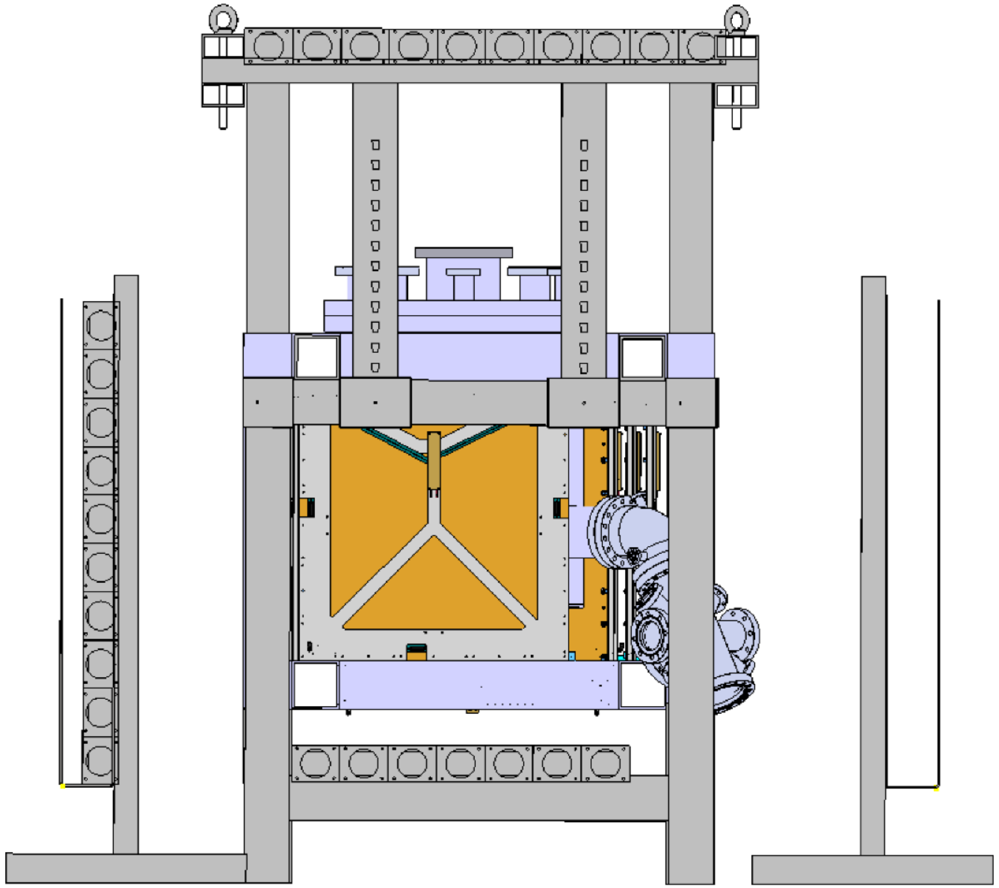




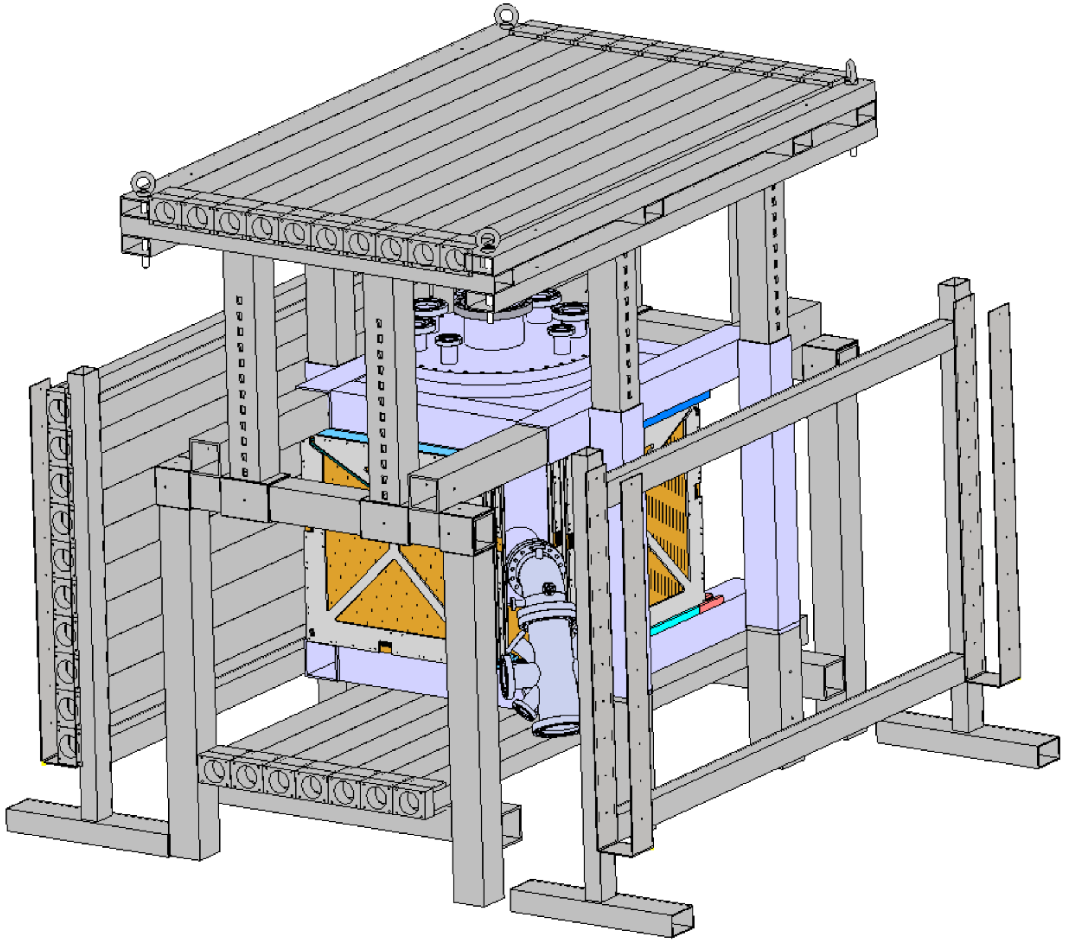
Bakelite guide

TOF detector description

[Front view]



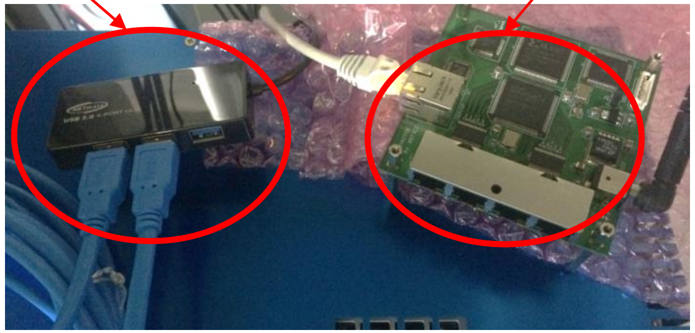
[Front-right view]



DAQ system

connect FADC to DAQ PC

MTCB



- System specification

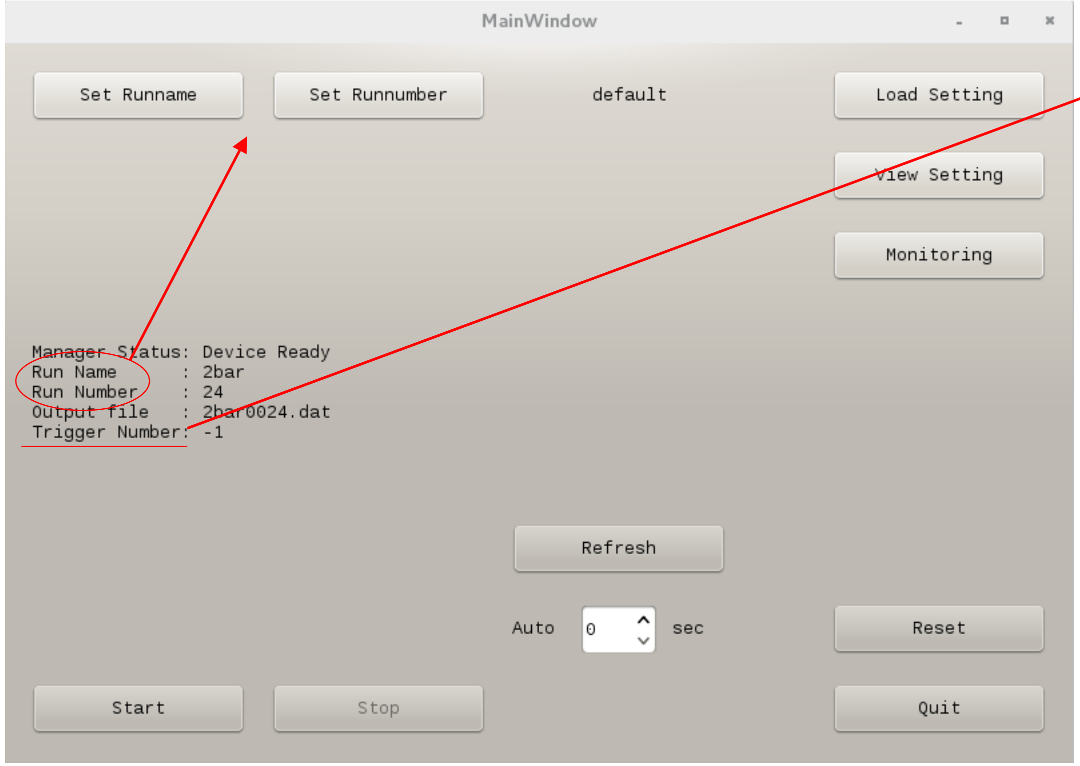
FADC(NOTICE, 500-IBS)
500MHz data sampling
2V/12bit dynamic range
4ch/mod * 2mod

DAQ PC(Intel Core i7-6500U)
2 cores, 8GB ram, 2.50GHz x 4
CentOs Linux7 installed
data collecting about 180MB/sec

MTCB – sync board
HV supplier(CAEN, SY1527LC)

- DAQ program

  fdaq – FADC daq program / fdaqg – fdaq with GUI



One block = data of each channel of a single event

randomly accumulated in the buffer

	Event1 From ch1	Event2 From ch1	Event1 From ch3	Event3 From ch2	…
Trig.num.	1	2	1	3	

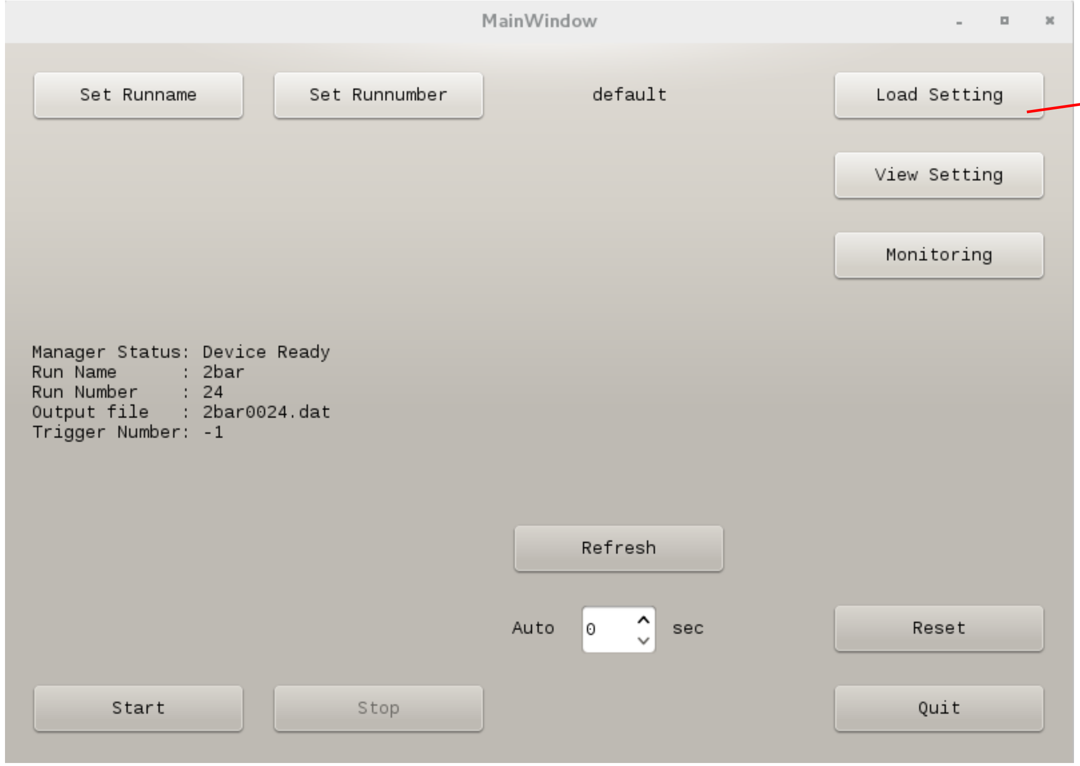
→ to order them, use "trigger number"

→ make entry based on trigger number, when converting into root file

DAQ system

- DAQ program

fdaq – FADC daq program / fdaqg – fdaq with GUI



Load setting option(.txt)

 # Common parameters
Coincidence width
Self /pedestal / soft ware trigger

 # Module parameters
Recording length (128ns ~ 32us)
Trigger set

 # Channel parameters
Offset value
Discrimination threshold
Pulse width(count) threshold
Pulse polarity
…

DAQ system

- Data structure

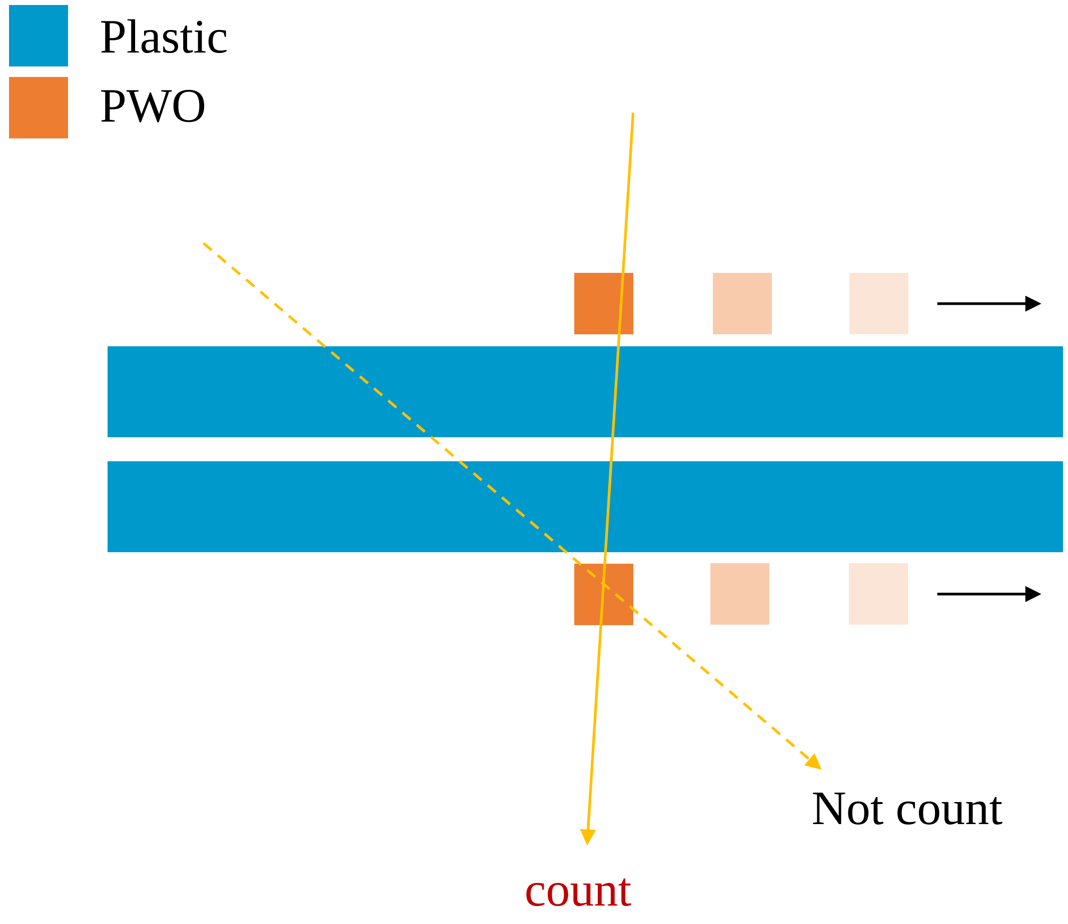
	4i-th Byte	(4i + 1)-th Byte	(4i + 2)-th Byte	(4i + 3)-th Byte
0 - 3	Data Length			
4 - 7	Run Number		Trigger Type Trigger Destination	
8 - 11	**Trigger Number (from 7th Byte)**			Trigger Fine Time
12 - 15	Trigger Coarse Time			Module ID
16 - 19	Channel ID	Local Trigger Number (to 20th Byte)		
20 - 24		Local Trigger Pattern		
25 - 29	Local Starting Fine Time	Local Starting Coarse Time		
32 -	ADC (12 bit * 4 points) / TDC Data (10 bit * 1 point) ······			

Raw data from FADC (.dat)

branch	name	
0~5	Information about data (id, length, type, …)	
6	Trig_num	Trigger number
7~8	Trig_time	Fine/coarse time
9~12	Local information	
13	Waveform	Raw signal volt
14	Waveformtime	Raw signal time
15~25	Analyzed quantities	

Converted data branch information(.root)

a. A prototype TOF detector

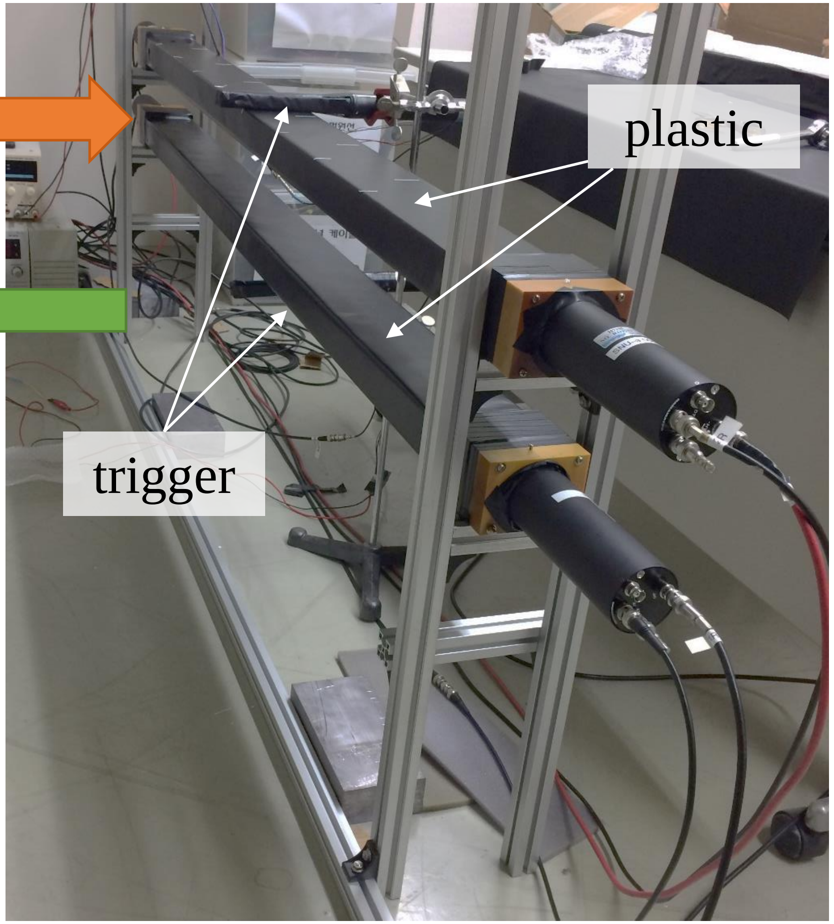


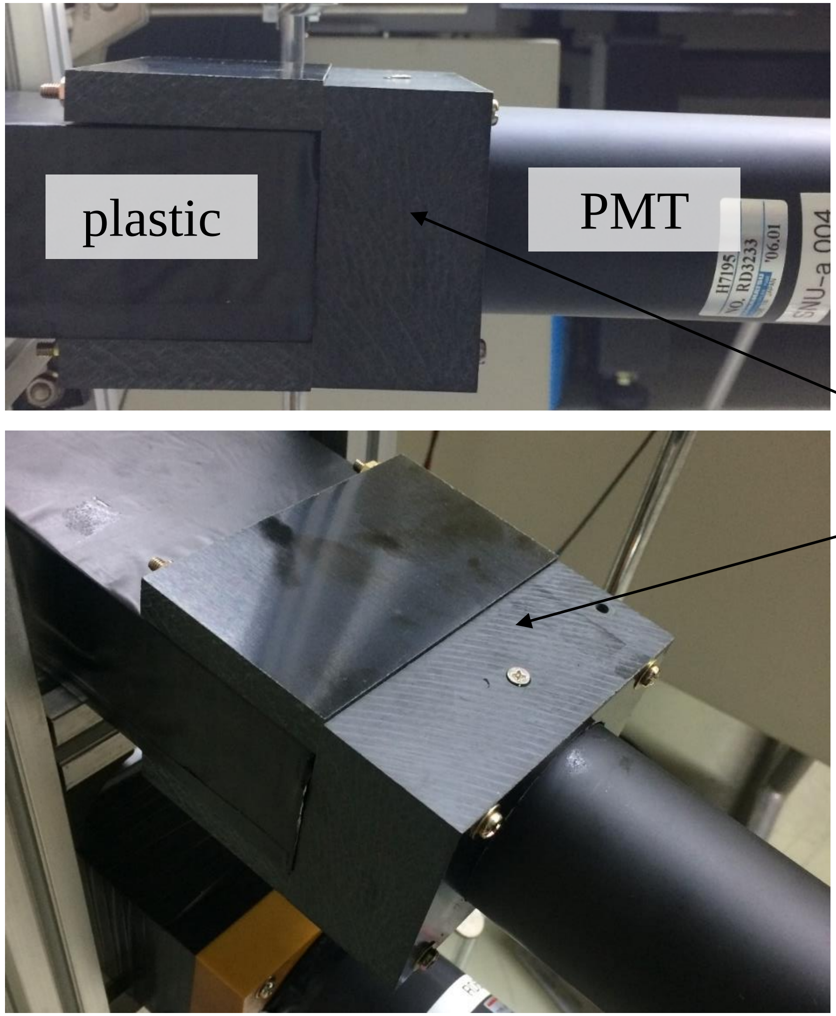
Without any source,
Cosmic rays go through scintillators and make signals.

Triggers are situated at center(0cm), 20cm, 40cm, 60cm, 77cm from center.

Taking only coincidence data of 6 PMTs,
we can measure the time resolutions,
find time – position conversion factor
and calibrate energy scale.

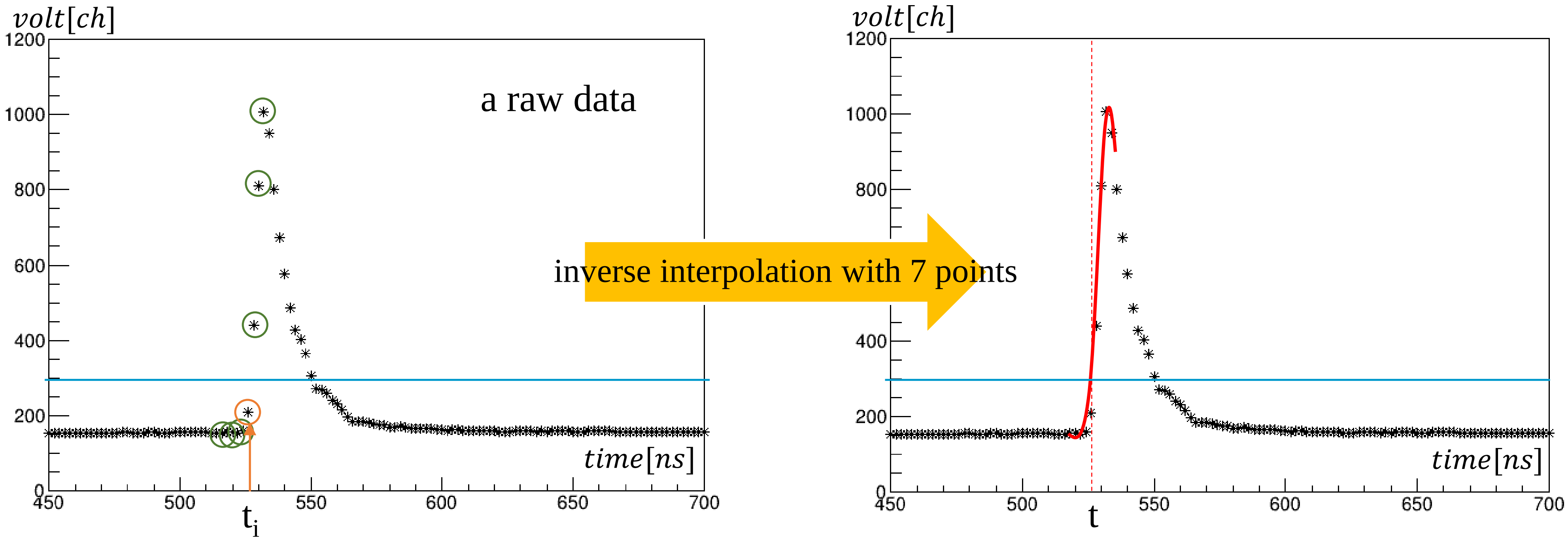
a. A prototype TOF detector





b. Analysis method

- Event time(t) : measured by inverse interpolation



t_i = the nearest point from 10% line

$f(\mathrm{t}) = 0.1 * (peak\ height)$

Computational Methods in Physics and Engineering, S.M.Wong

b. Analysis method

- Time difference : dtmean & dtfast

dtmean = (tmean_1) – (tmean_2)

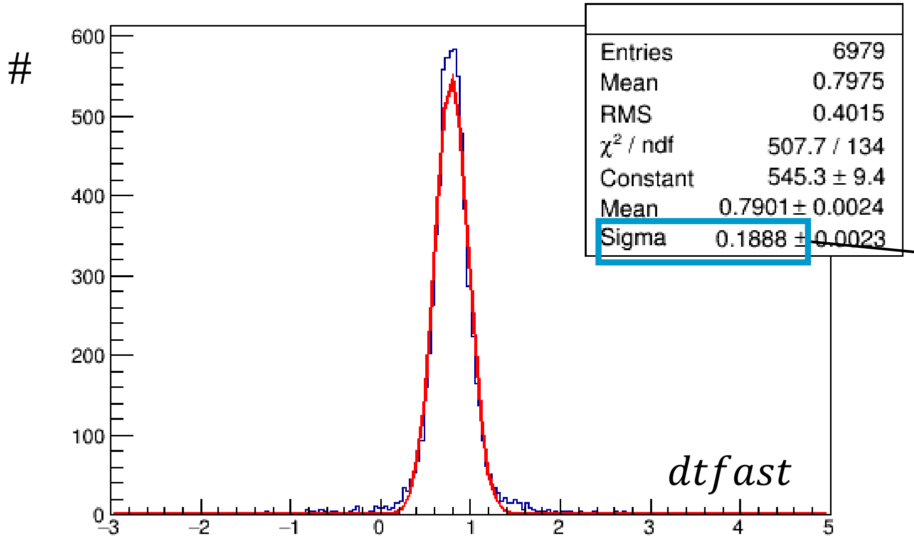
tmean_1 = $(t_0+t_1)/2$

tmean_2 = $(t_2+t_3)/2$

dtfast = (tfast_1) – (tfast_2)

tfast_1 = faster time btw $t_0 \sim t_1$

tfast_2 = faster time btw $t_2 \sim t_3$



The resolution of histogram,

$$\sigma = 0.1888\ [ns]$$

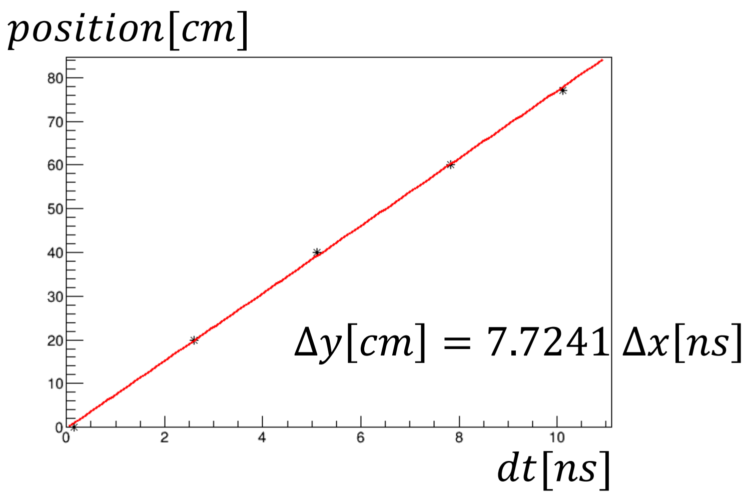
The resolution of plastic counter,

$$\sigma = \frac{0.1888}{\sqrt{2}}[ns] = 0.1335\ [ns]$$

c. Results

- Time and position resolution of scintillation bar

	sigma [ns]	sigma [cm]
dtmean	0.1119	0.86
dtfast	0.1335	1.03

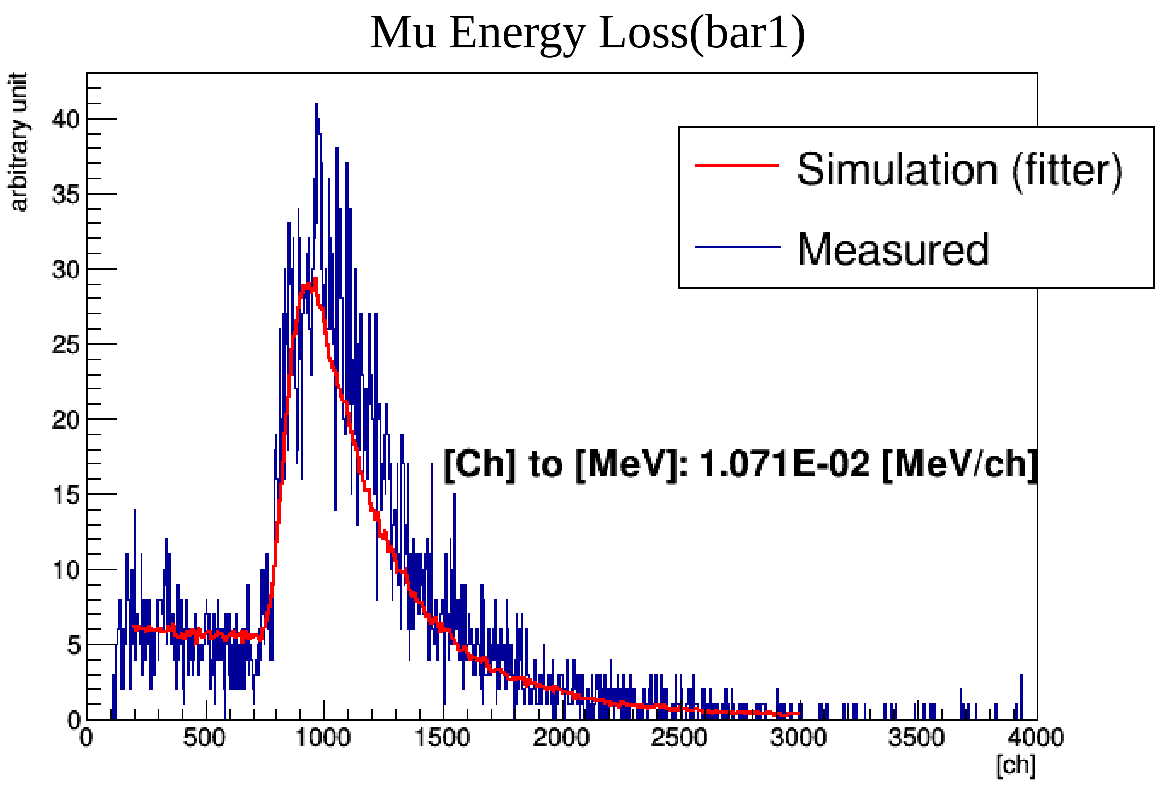


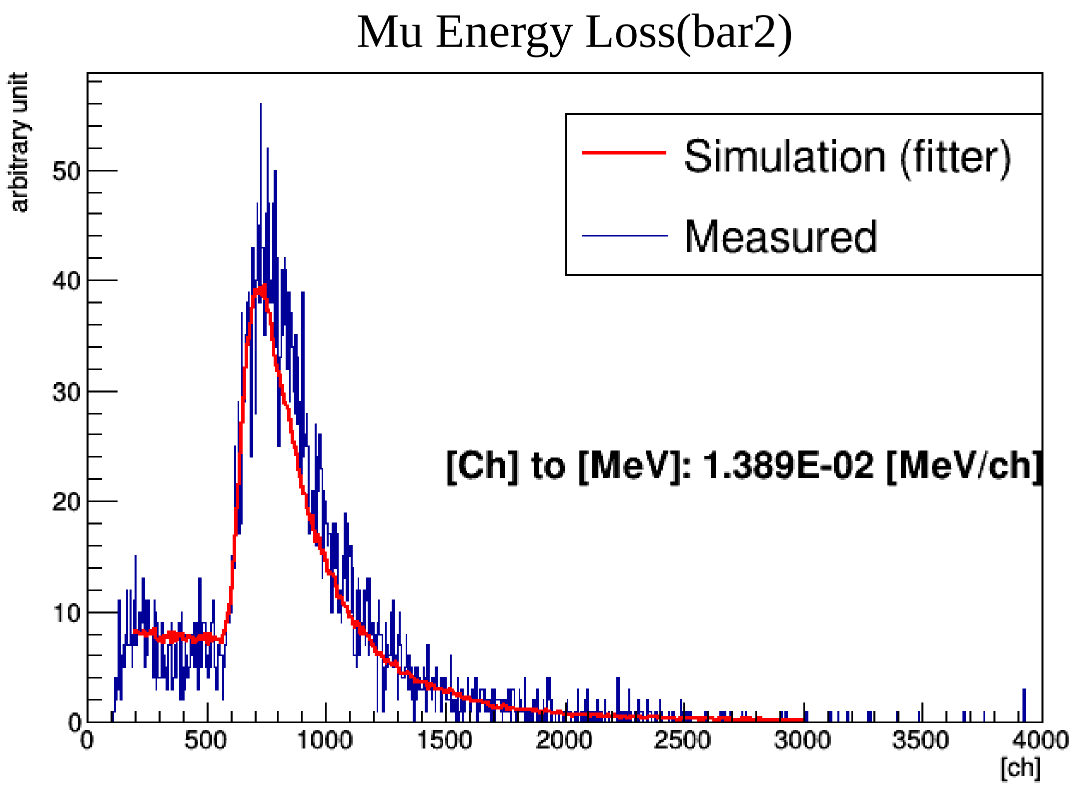
$$\sigma_{time} \sim 0.12\ ns, \qquad \sigma_{position} \sim 1\ cm$$

→ Enough to distinguish top & bottom annihilations and cosmic ray signal

c. Results

- Energy calibration (on 1600V)





c. Results

- Light efficiency

experimentally ~ 100 photoelectrons / MeV obtained

$$\sim 10{,}000 photons/MeV \; * \underline{0.2} \; * \underline{0.33} \; \approx 600 \; photoelectrons/MeV$$

Typical quantum efficiency of PMT

Scintillator area covered by PMT

$$\frac{photocathod\ area}{scintillator\ area} = \frac{23^2\pi\ [mm^2]}{50 * 100[mm^2]} \sim 0.33$$