MEG II実験陽電子タイミングカウンターのコミッショニング2017 -性能評価-

Commissioning of Positron Timing Counter for MEG II Experiment in 2017 -Performance Evaluation-

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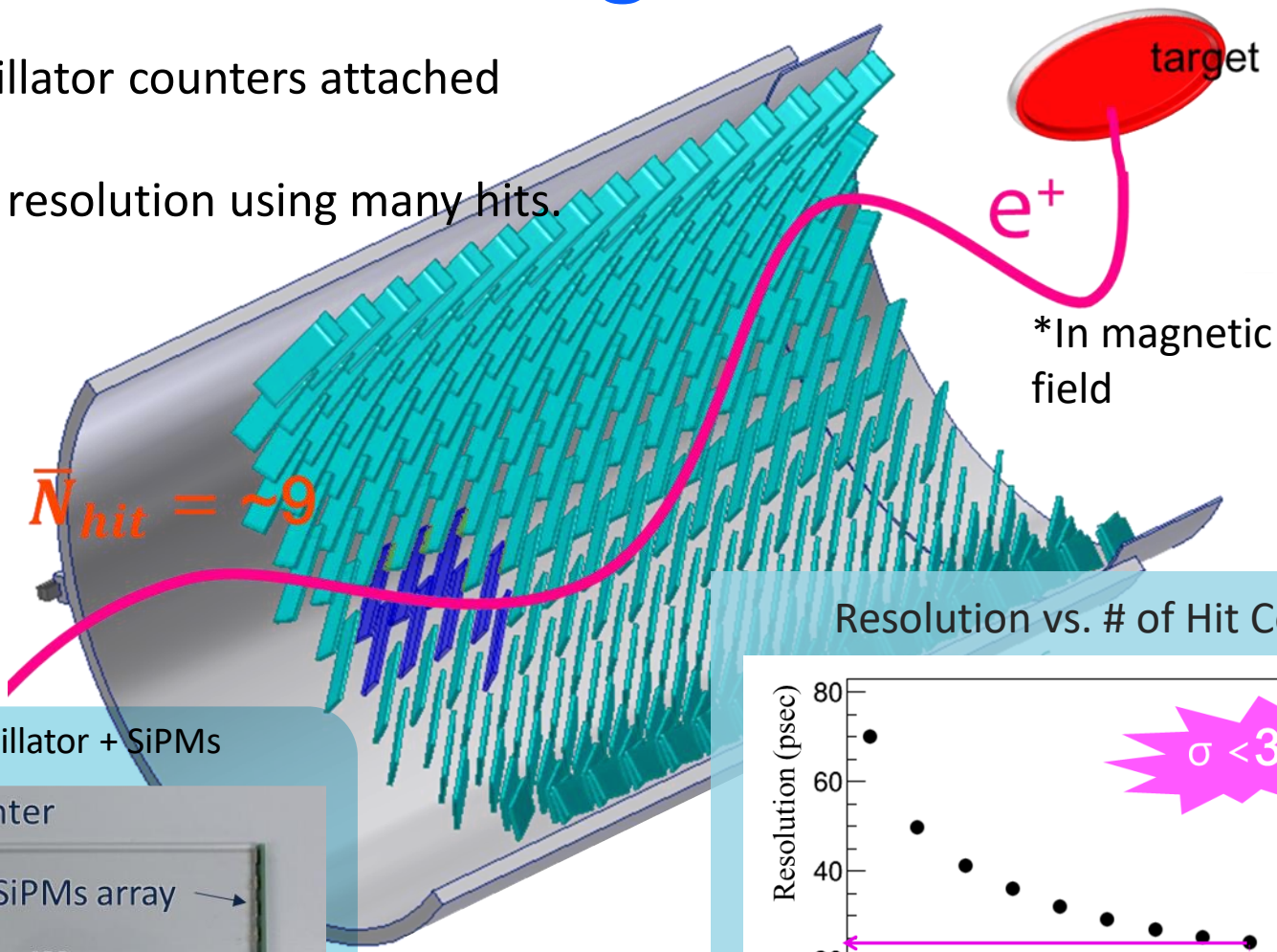
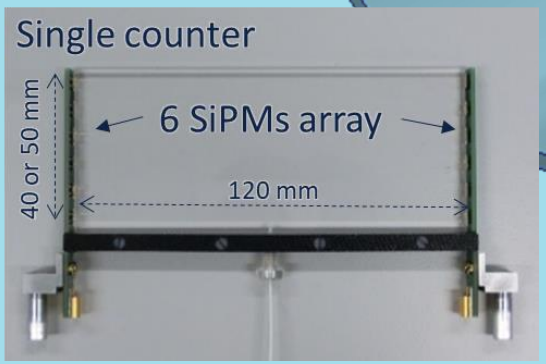
日本物理学会 第73回年次大会（2018年）
東京理科大学（野田キャンパス）

Overview of Timing Counter

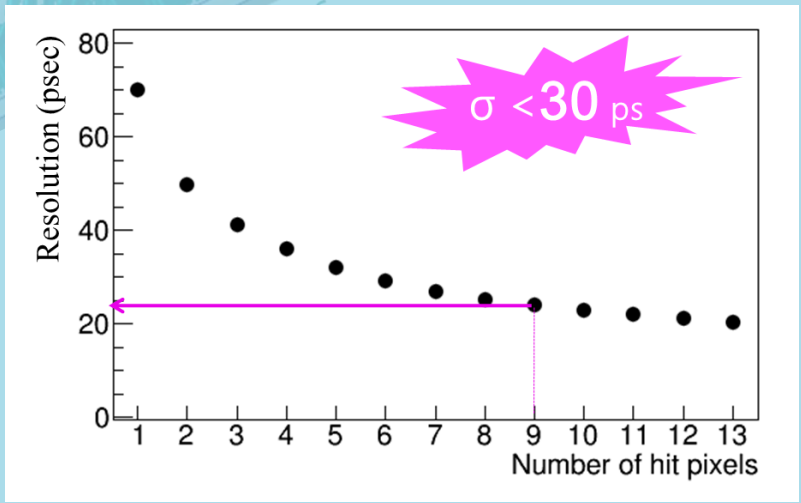
512 scintillator counters attached SiPMs.
Excellent resolution using many hits.



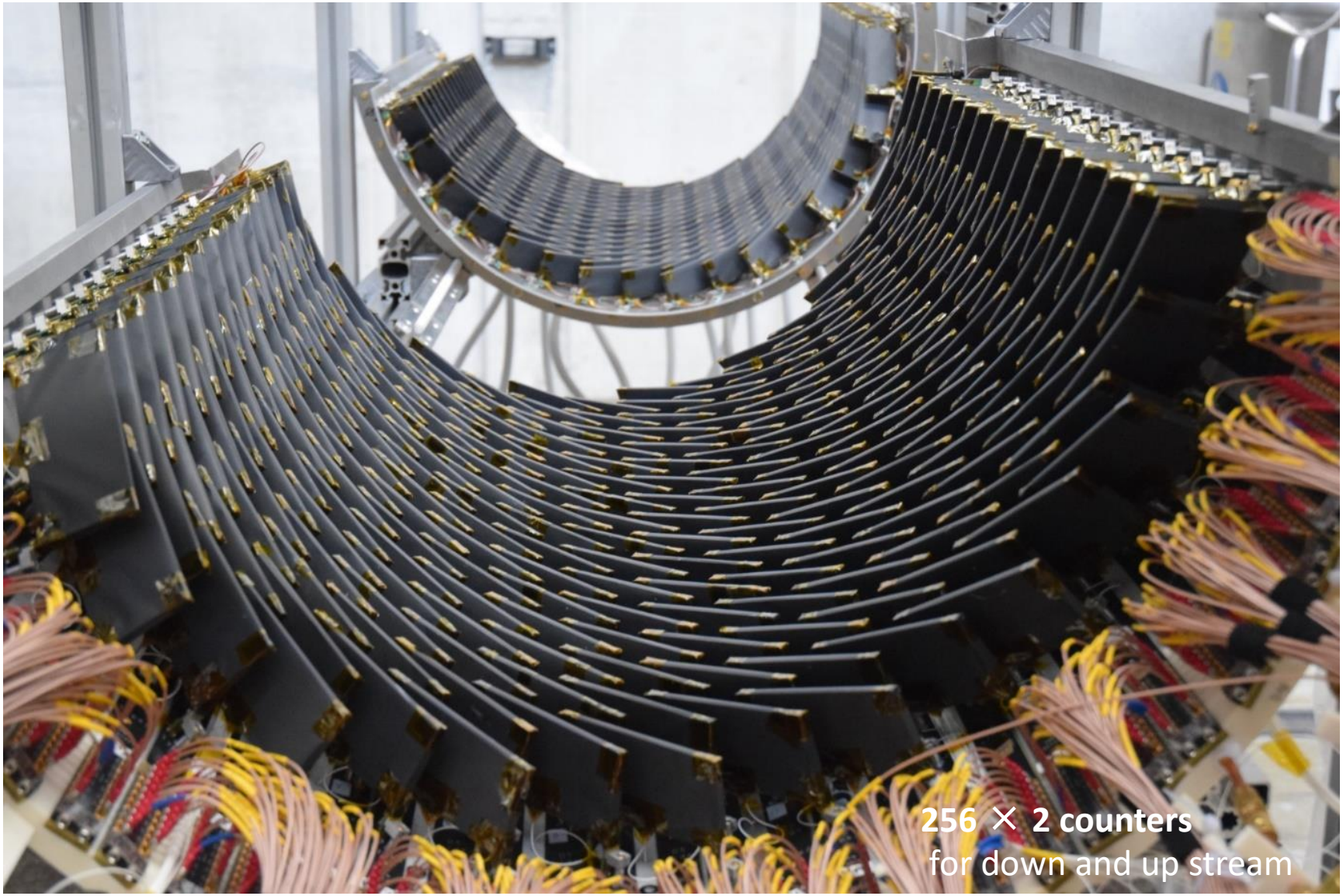
Plastic scintillator + SiPMs



Resolution vs. # of Hit Counters



Commissioning in 2017



Commissioning in 2017

- We had commissioning partially in 2015 and 2016.
- However almost **all apparatus** are prepared in 2017.
  - Especially we never had the data in US in previous runs.

Goals

① Hardware:
- Operate all the counters
- Operate slow control system
- Confirm stability

② Calibration:
- Confirm calibration systems
- Confirm stability

③ Performance:
- Confirm the performance
- Understand background behavior

	2017	Previous Runs
Counters	**ALL (512)**	Partially (128 in DS)
Lasers	**ALL (432)**	Partially
Synchronization	**Final version**	External input
DAQ channels	Half (512)	256
Slow control	HV, **Temperature**	HV

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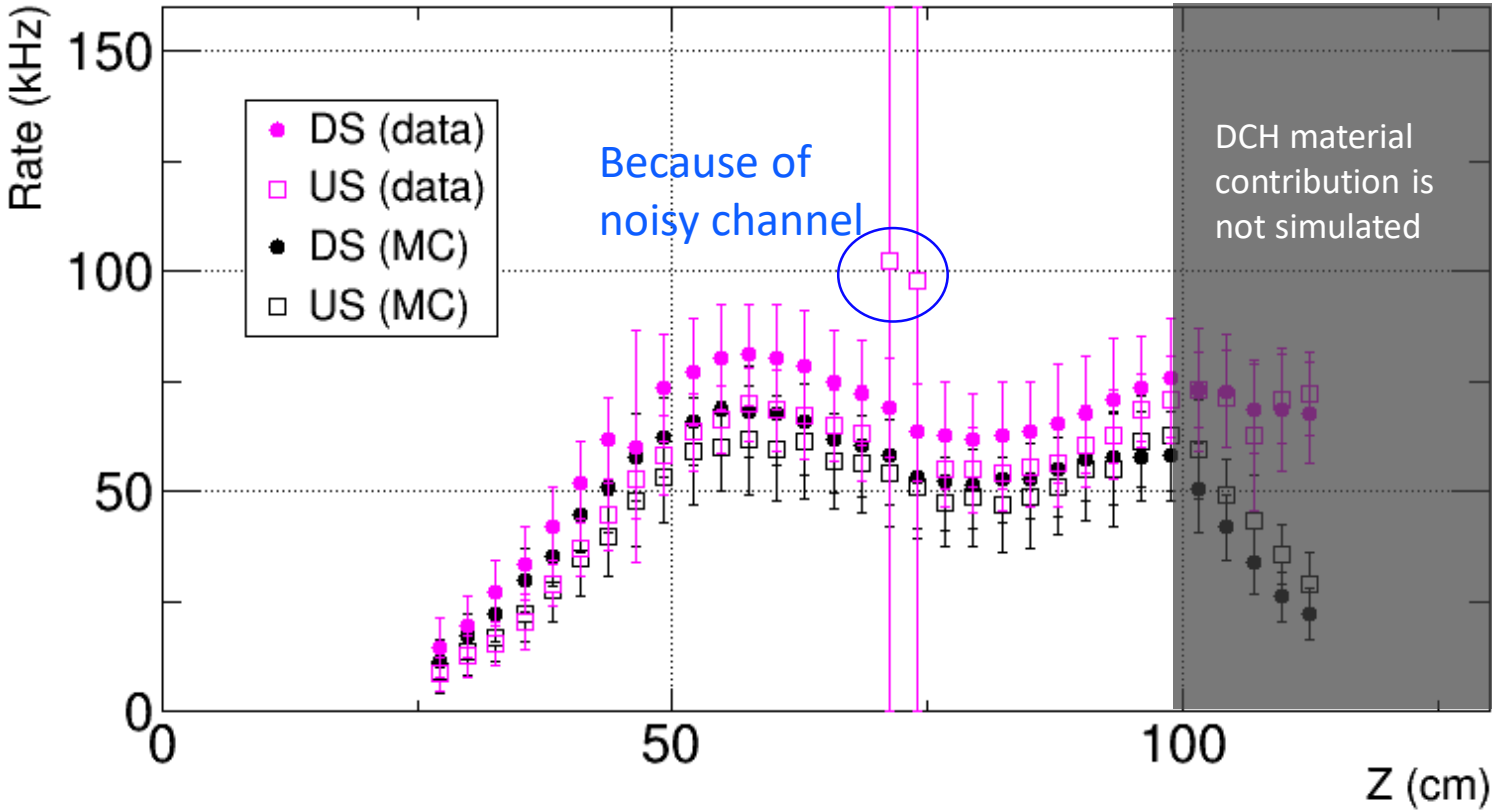
Hit Rate

Hit rate is calculated out of trigger region.



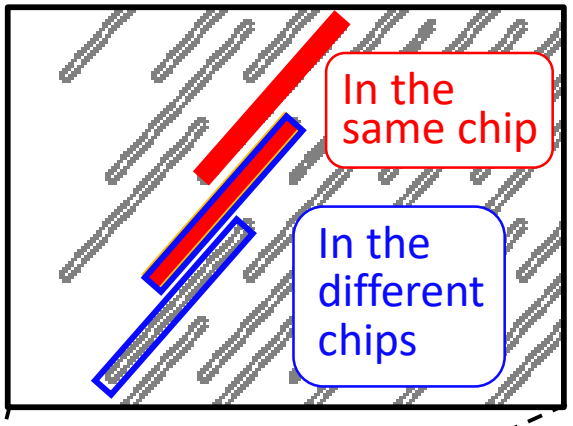
No large unexpected background.

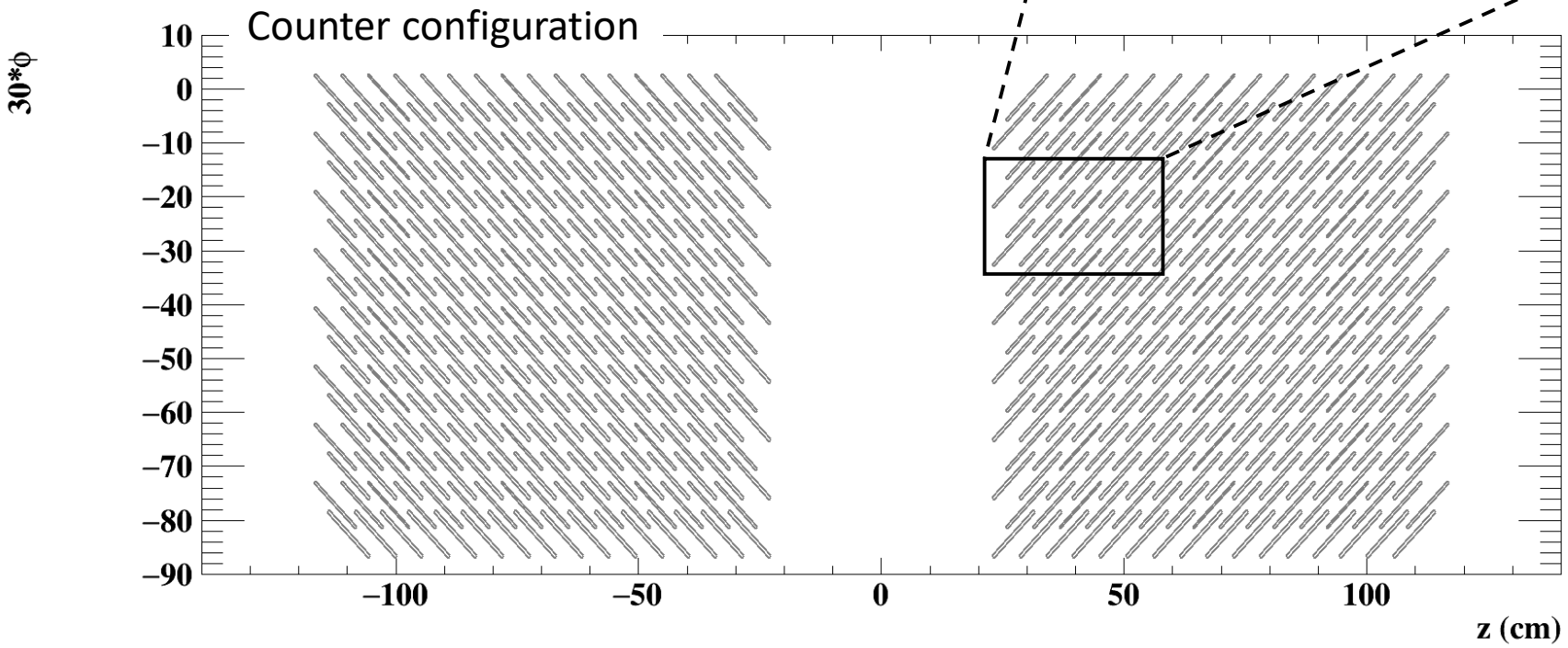
Two hits resolution

- Check the resolutions with adjacent two counters,

  sigma of $(T_i - T_j)/2$

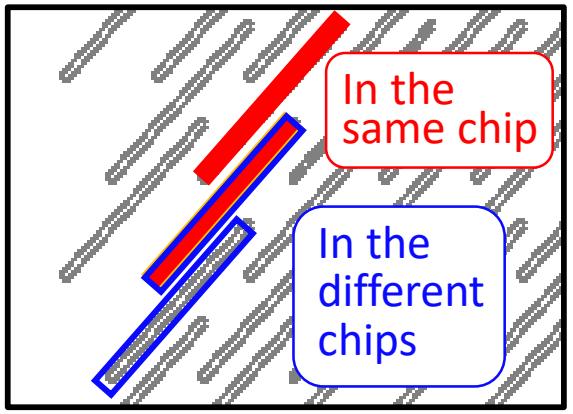
- Check the synchronization effect among chips.
  - Channels of some two counters are assigned over different chips.

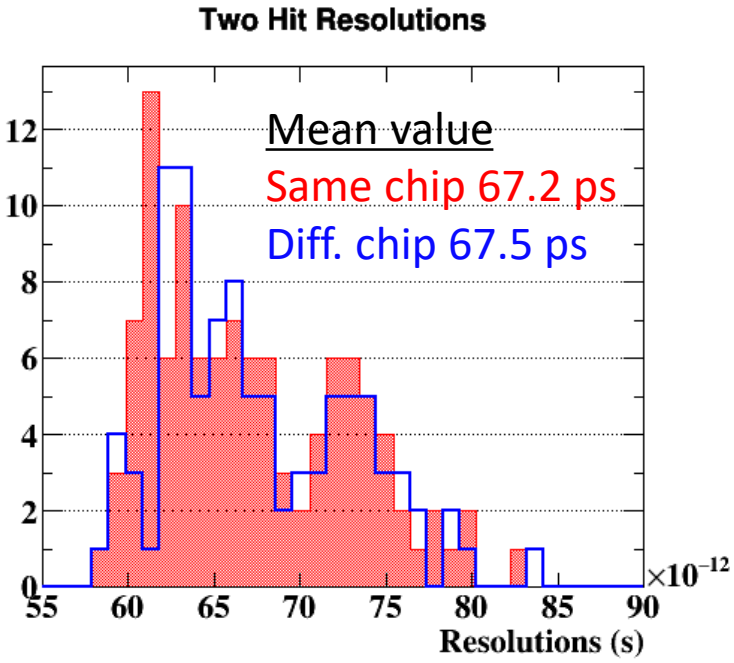


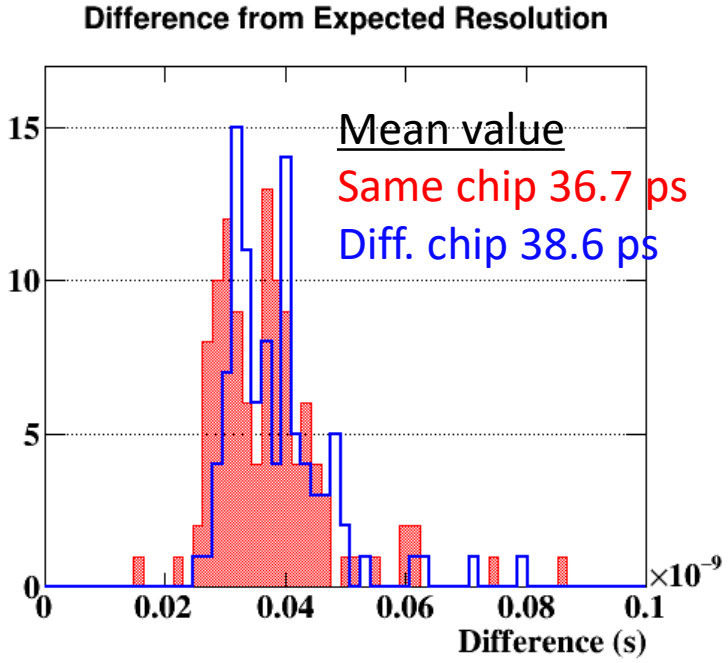


Two hits resolution

- Two hit resolution is ~67 ps
  - It is worse than the expectation from mass test with ^{90}Sr source. (reported in JPS 2015 autumn)
- Synchronization among chips works well.

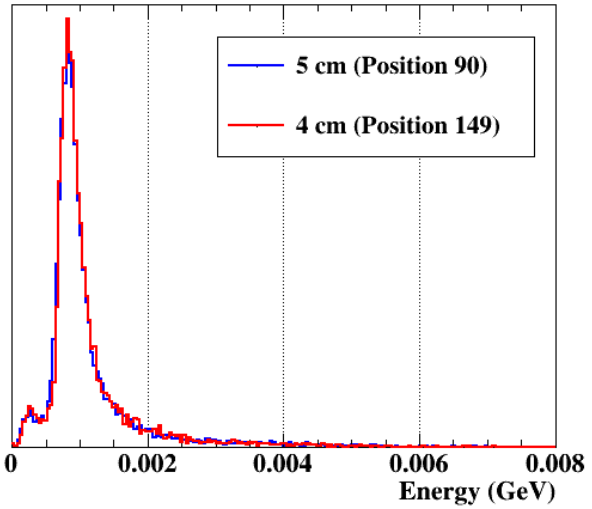


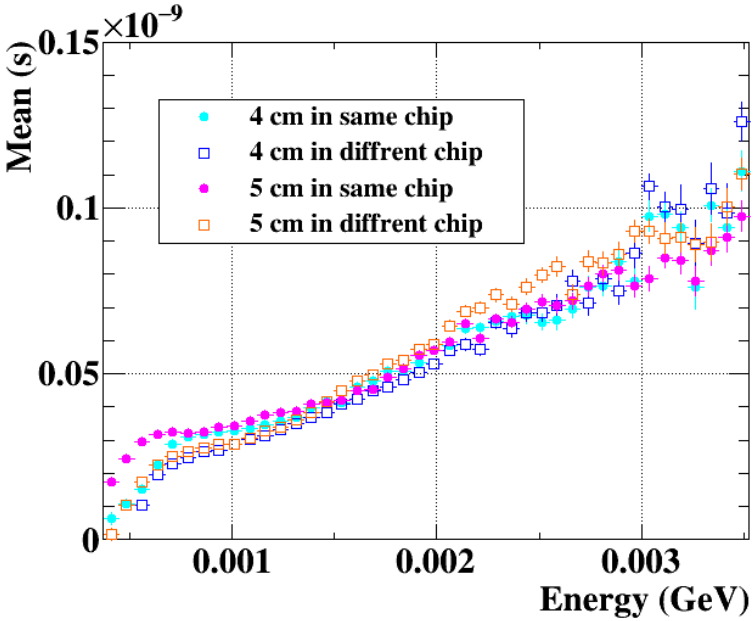


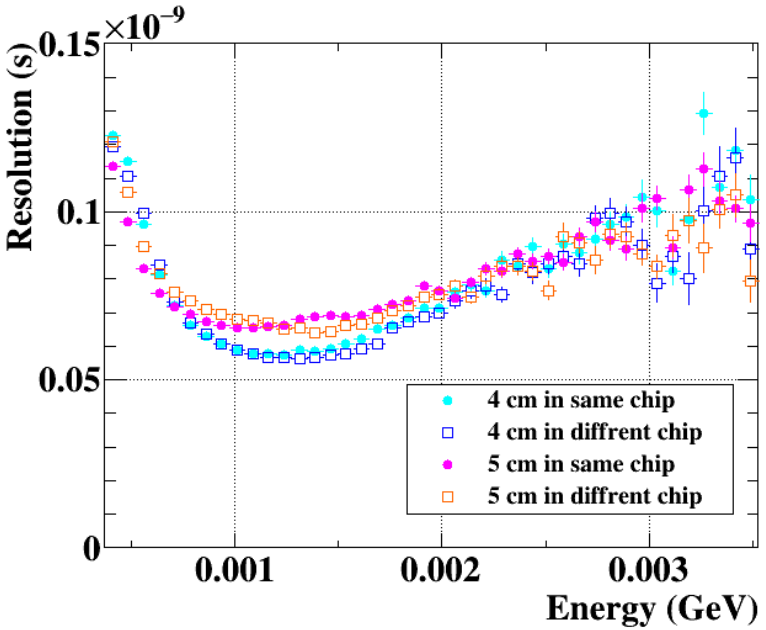


Energy dependence

- Clear dependence on deposit energy
- Measured time also has dependence on energy deposit
  - It is small in main energy region <1.5 MeV







Overall Performance

N hits analysis

In the pilot run, TC independent data is taken.

- No DCH. ×**No track information**

⇒ Fix the counter combination from geometrical point of view

- No coincidence data with photon detector. ×**No time reference**

⇒ Even-odd analysis

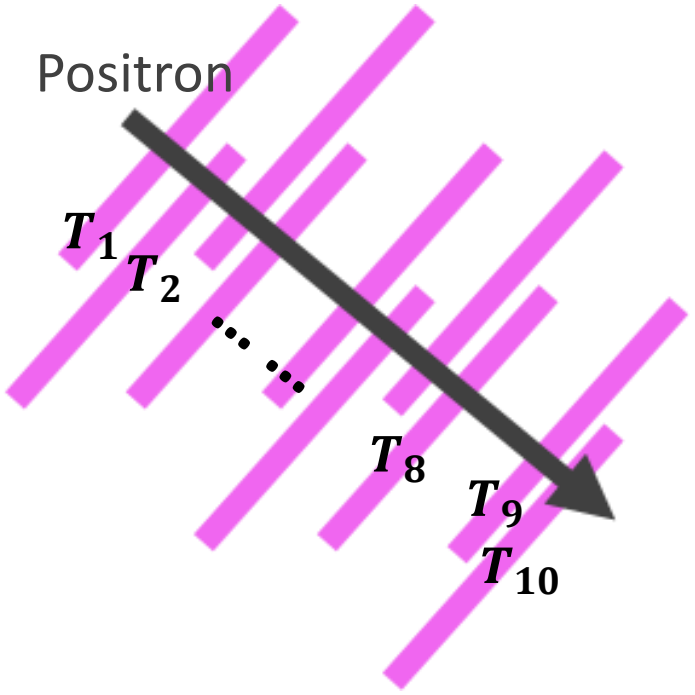
Real reconstruction in MEG II

- $(\sum_i^N T_i)/N$ (N: number of hits)

Even-Odd analysis

- $(\sum_i^{N/2} T_{2\times i})/N - (\sum_i^{N/2} T_{2\times i+1})/N$

Resolution should be **the same** if no correlation with each other is observed.

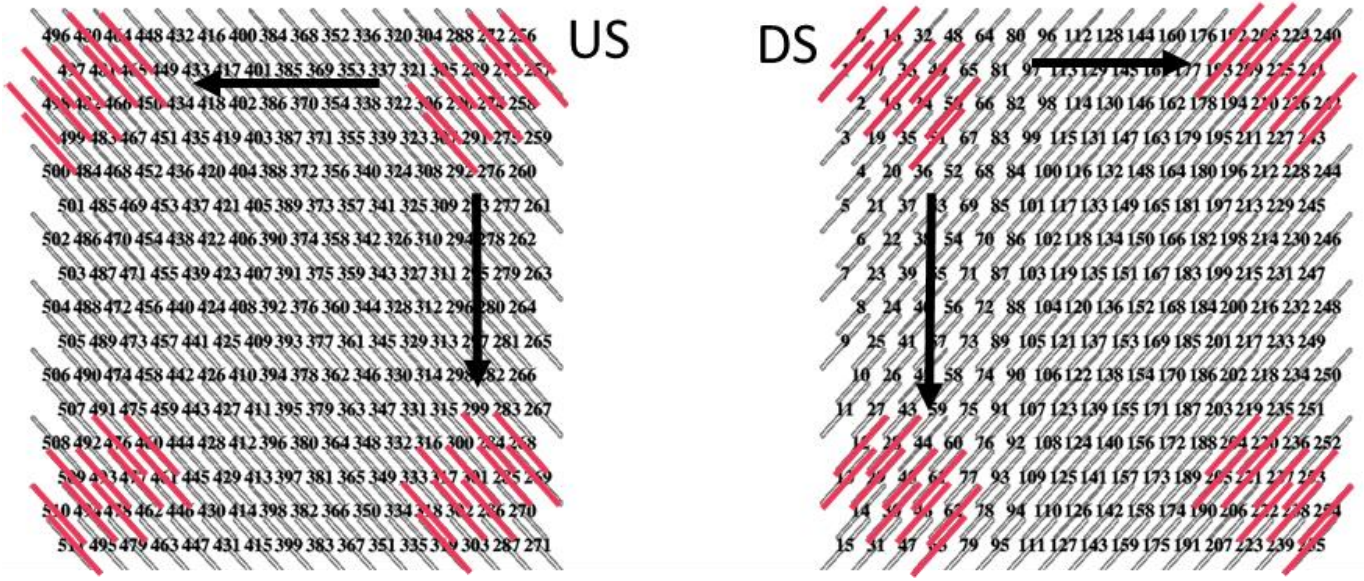


N hits analysis

Obtain the time distributions over every combination.

Then two way to check the resolutions.

1. Average over obtained time resolutions.
   - The fluctuation of measured time is not included.
2. Accumulate all normalized fit Gaussian.
   - Inter counter jitter is included. Calibration effect also can be seen.

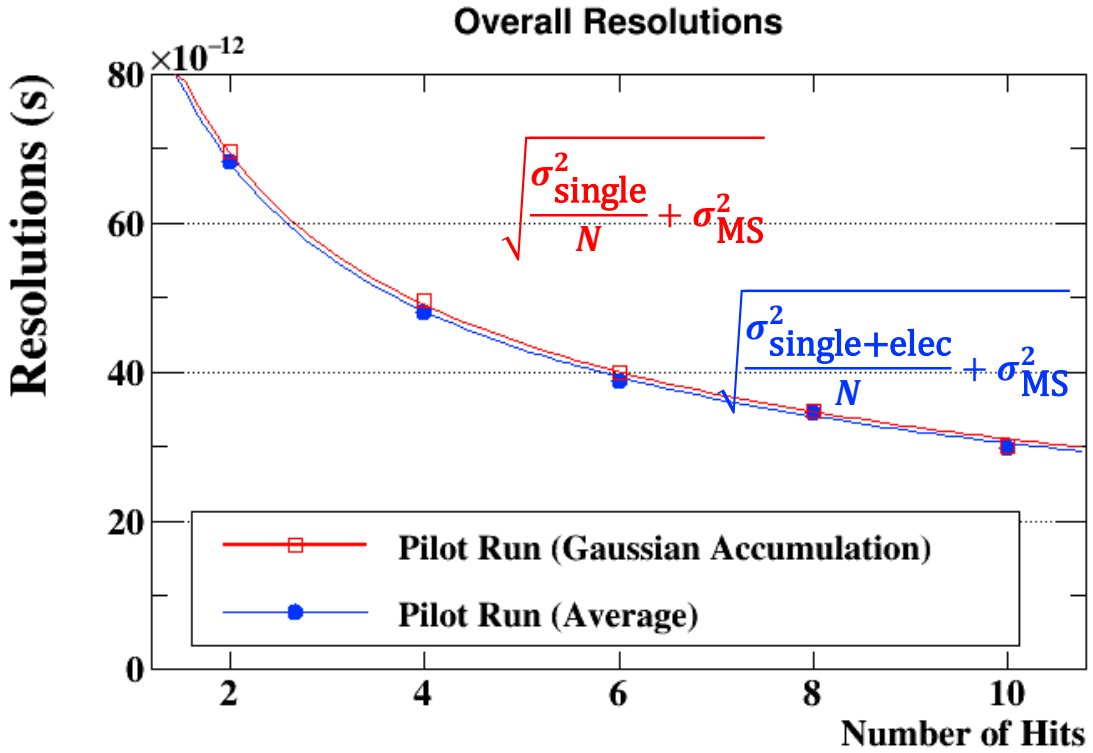


(Notice that counters are used twice or more.)

Resolutions with Number of Hits

Overall resolution; $\sqrt{\frac{\sigma^2_{\text{single}}}{N} + \sigma^2_{\text{MS}}}$

$$\sigma^2_{\text{single}} = \sigma^2_{\text{single\_counter}} + \boldsymbol{\sigma^2_{\text{inter-counter}}} + \sigma^2_{\text{electronics}}$$



$\sigma_{\text{single}} = \mathbf{98.1\ ps}$
$(\sigma_{\text{MS}} \ll \text{ps})$

$\sigma_{\text{single\_counter+elec}} = \mathbf{96.4\ ps}$
$(\sigma_{\text{MS}} \ll \text{ps})$

$\boldsymbol{\sigma_{\text{inter-counter}} = 18\ \text{ps}}$

The time calibration b/w counters works well.

Comparing with Expectation

Overall resolution; $\sqrt{\frac{\sigma^2_{\text{single}}}{N} + \sigma^2_{\text{MS}}}$

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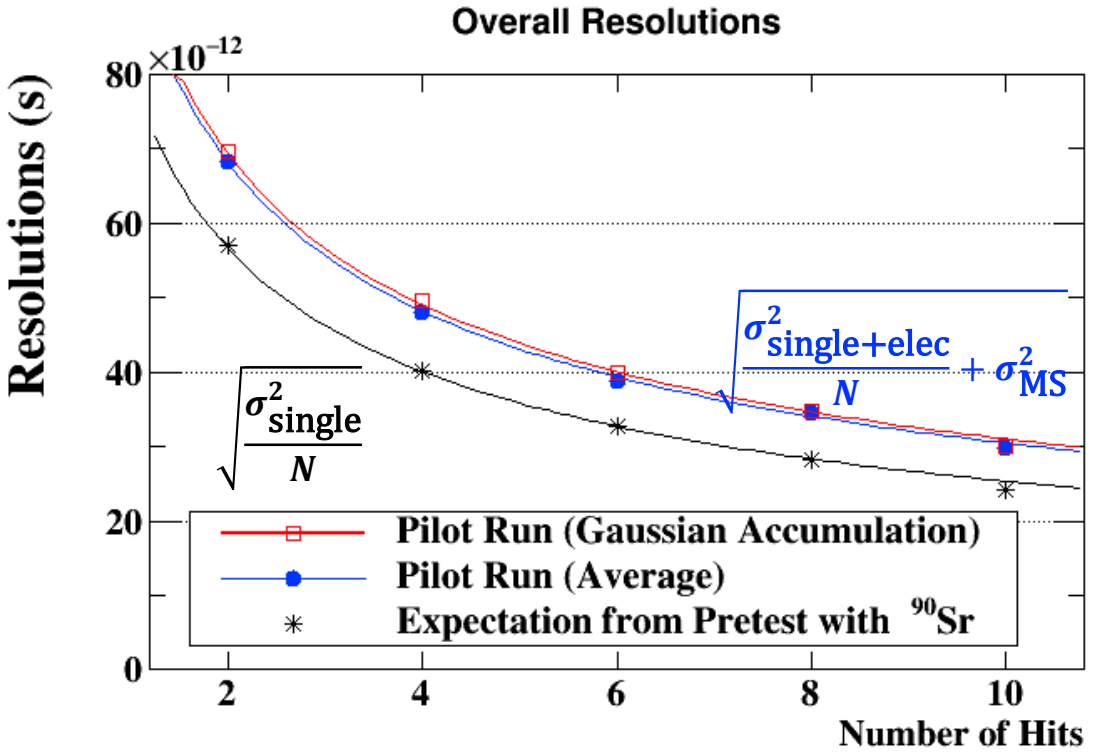


We had a pretest with Sr source for all single counters.

$\sigma_{\text{single\_counter+elec}} = \mathbf{96.4\ ps}$

$(\sigma_{\text{MS}} \ll \text{ps})$

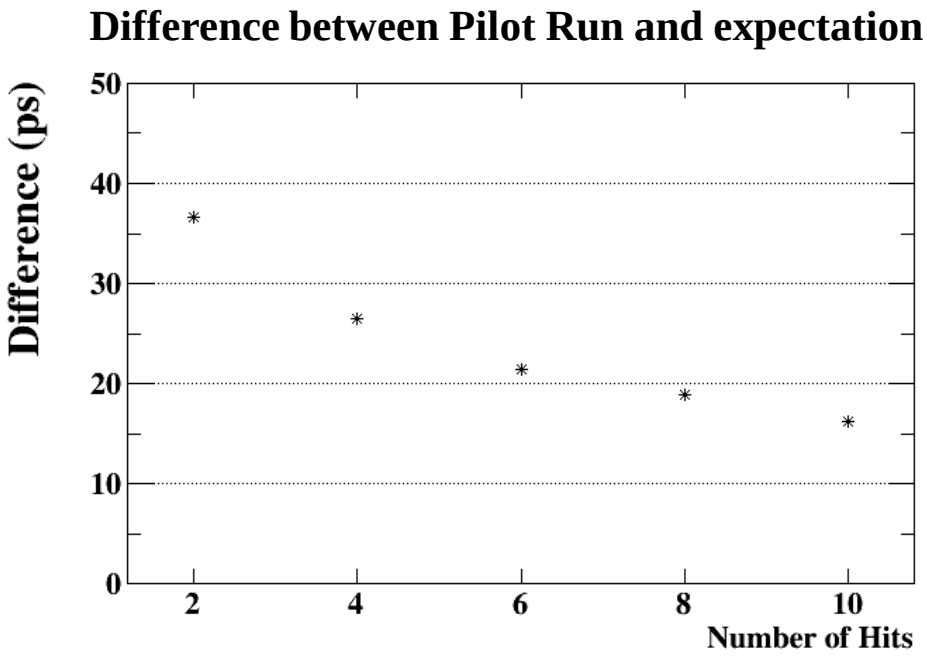
$\sigma_{\text{single\_counter}} = \mathbf{80.1\ ps}$

The difference is 53.6 ps.

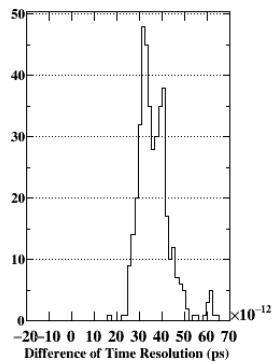
The contribution of electronics jitter and/or noise effect is large.

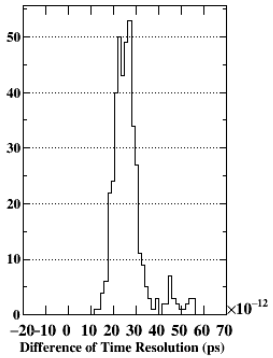
Resolution with Number of Hits

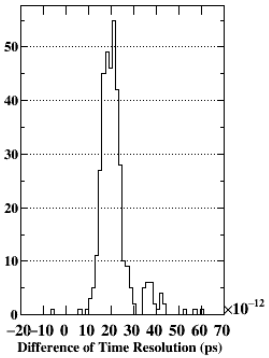
$$\sigma^2_{\text{total}}(N_{\text{hit}}) = \frac{\sigma^2_{\text{single}} + \sigma^2_{\text{inter-counter}} + \sigma^2_{\text{elec}}}{N_{\text{hit}}} + \sigma^2_{\text{MS}}(N_{\text{hit}}),$$

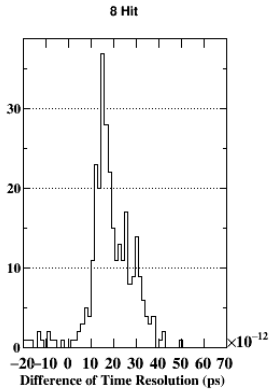


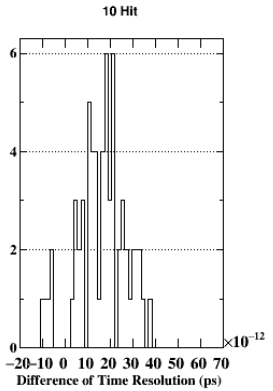
Even though the single resolutions are worse than the expectation, thanks to multiple hit scheme the degradation becomes small with $\sqrt{N}$.





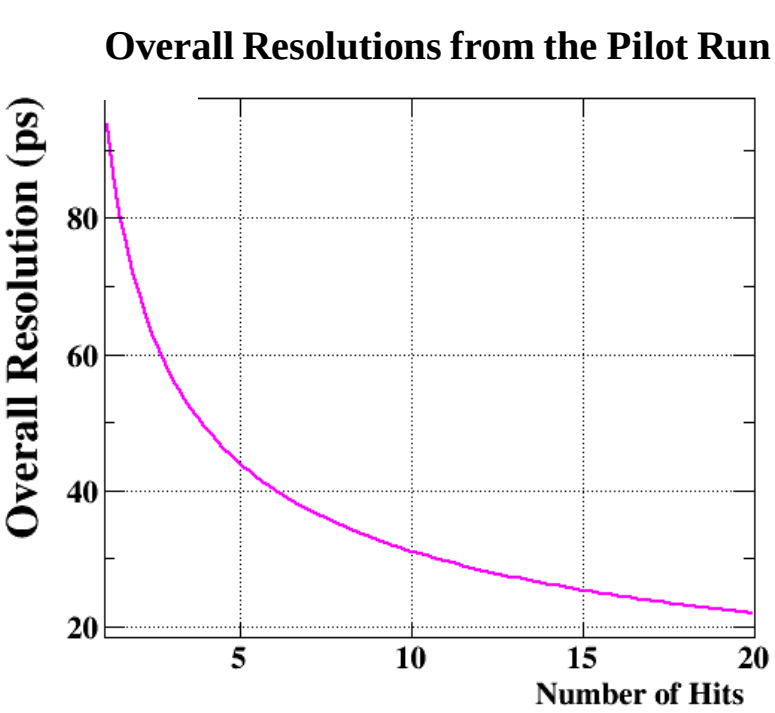






Final Performance for Signal Positron

Actually signal positrons hit several counters.
By multiplying the obtained function in pilot run by the ratio of the number of hits from signal positron (MC), the overall TC resolution is estimated as,



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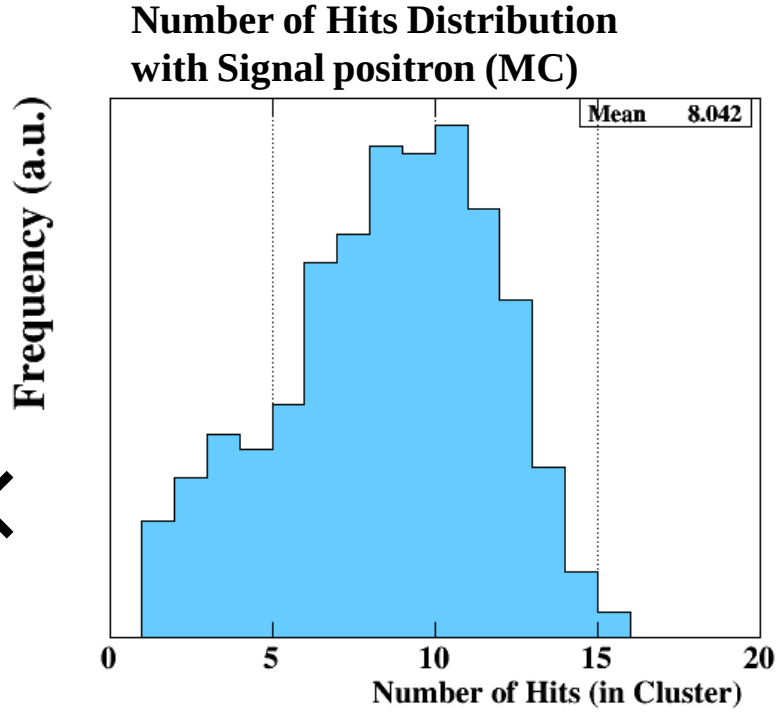


= 38.5 ps

Large improvement from MEG(76 ps)

Overall Positron Time Resolution

- Time on vertex is reconstructed by TC and DCH, that is **overall positron timing resolution**;

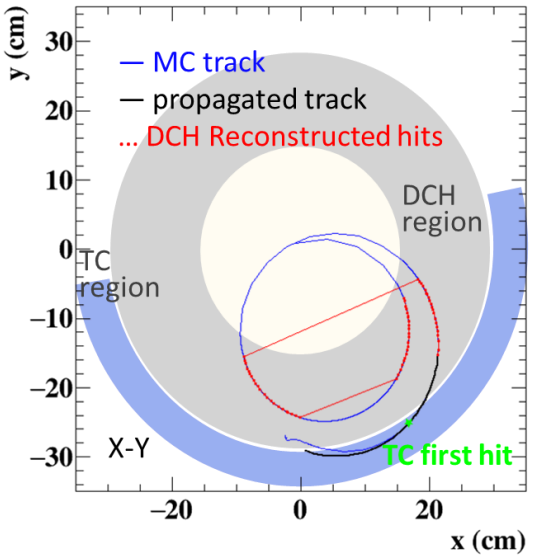
$$T_{e^+} = T_{\mathrm{TC}} - L_{\mathrm{DCH}}/c$$

38.5 ps $\oplus$ **14.8 ps** (MC)

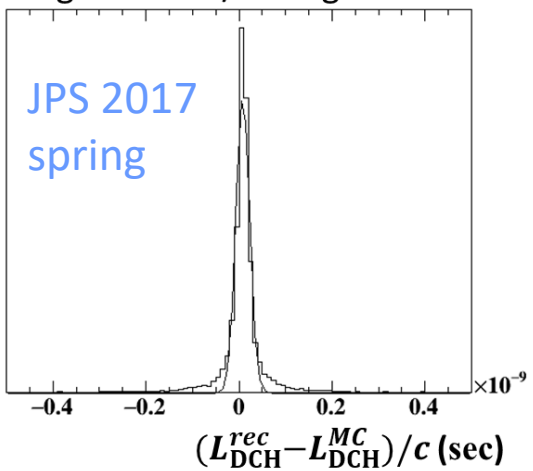
$$= 41.2 \text{ ps}$$

- More than twice better than MEG (108 ps)
- $\boldsymbol{\sigma_{T_{e\gamma}}}$ **= 65 ps** (as σ_{T_γ} = 50 ps)
  - Backgrounds are reduced linearly.

An example with signal event (w/o pile up)



Flight Time b/w Target and TC



Prospects

- Deep understanding of deterioration of the time resolution.

- Development and optimization of reconstruction algorithm.
  - Clustering optimization with MC
  - Tracking

- DCH will be installed in summer.
  - Contribution from the track reconstruction will be studied with real detector soon!

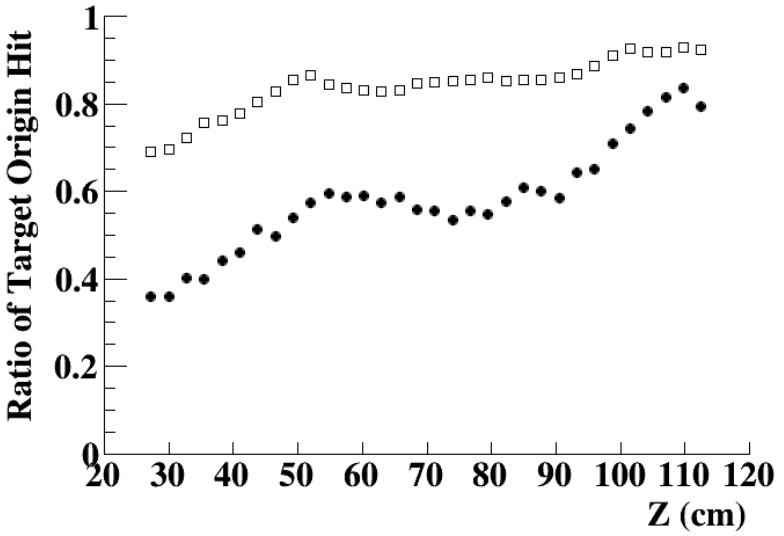
Summary

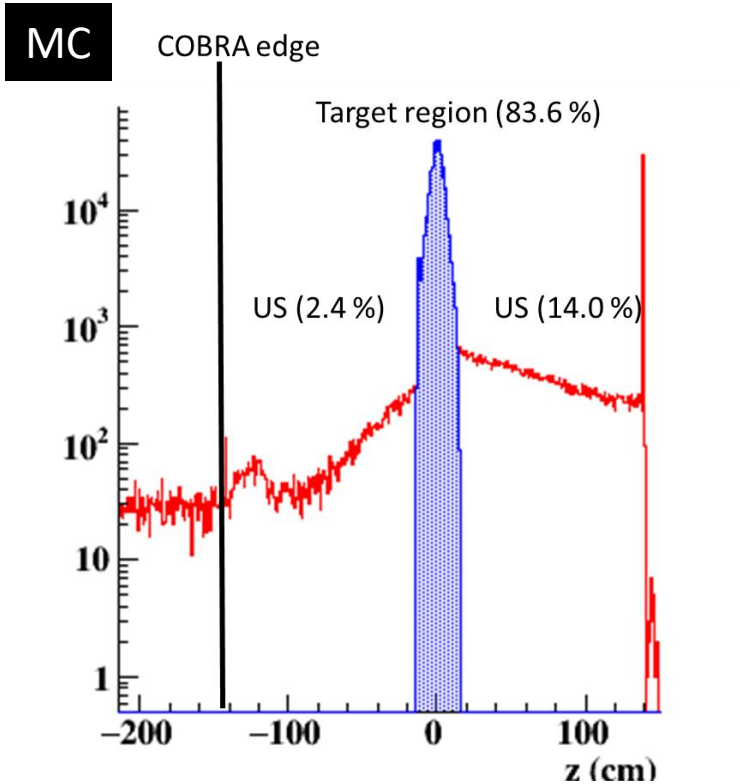
- Pilot run for TC with all counters is performed.
  - It is first time to install all the counter.
- We confirmed the energy dependence, effect of synchronization with two hits resolution.
- The resolution as a function of the number of hits is obtained with the final detector.
  - Though the difference from expectation of intrinsic single resolution is large, overall resolution becomes small with the number of hits increasing
  - For the signal positron overall resolution is 40 ps.

Back Up

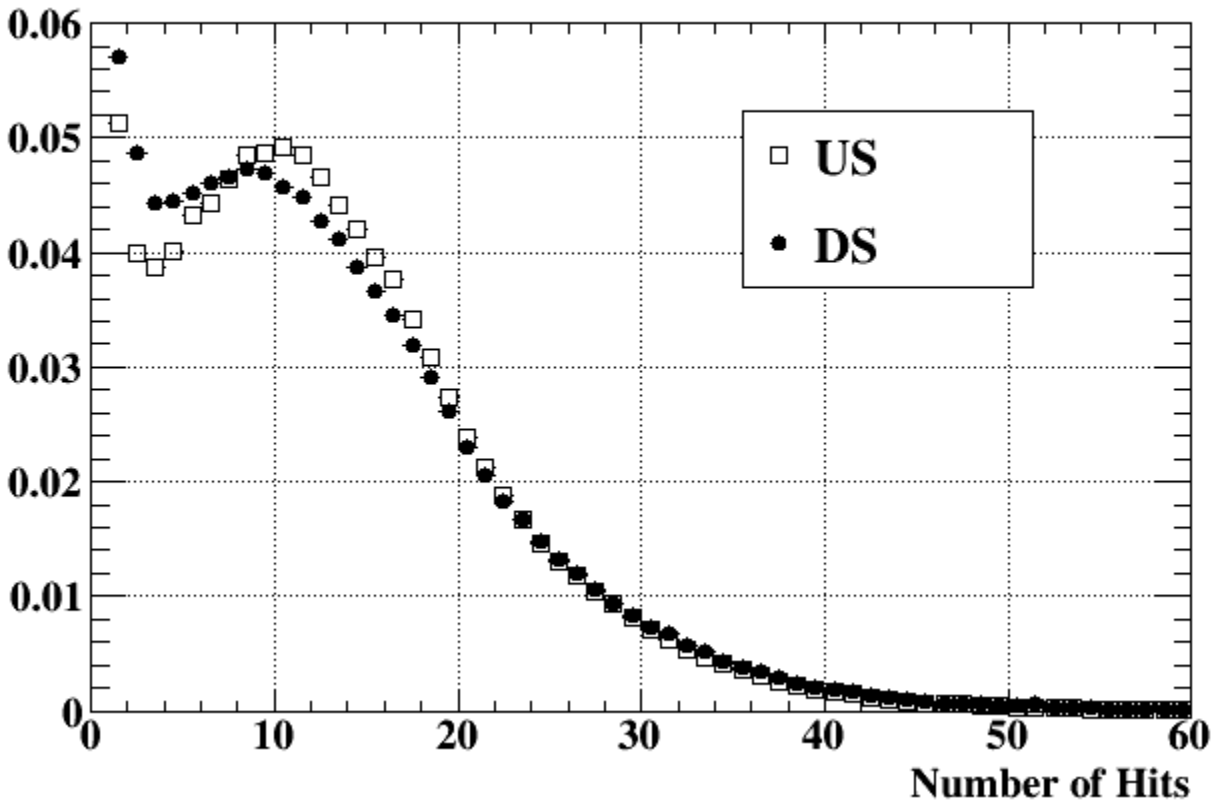
DS and US

- It is the first time to install all the counters (512).
  - Tested only half of DS counters (128) in previous pilot runs.
- DS has more background from off-target decay

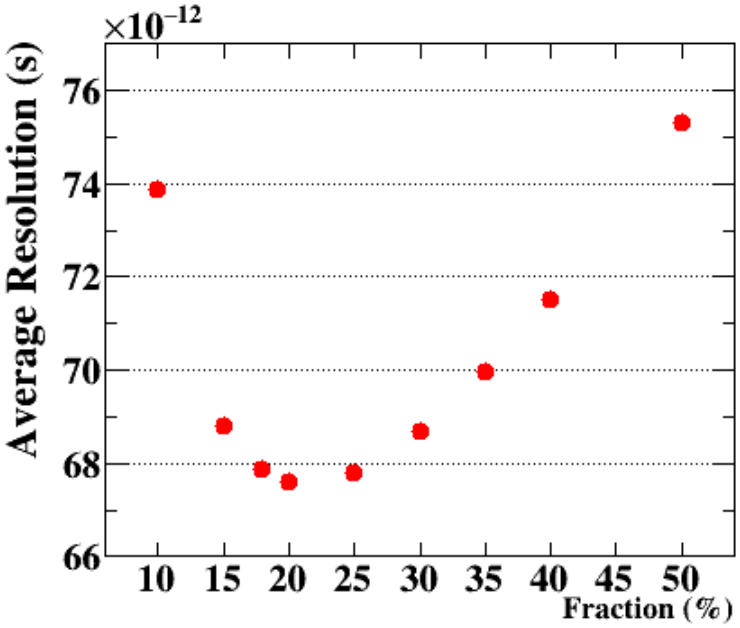




Number of Hits



Optimization Waveform Analysis



Fraction scanning (for DS) from 10 % to 50 %

Checking the two hit resolutions,

$$(T_{i+1} - T_i)/2$$

Average resolution,

$$\sum_{0}^{126} \sigma_j \,/126$$

* No signal in one channel, so number of the two hit combination is 127.

20 % is the optimal, though we used 30 % in the first analysis.

Average resolution is **67.7 ps**