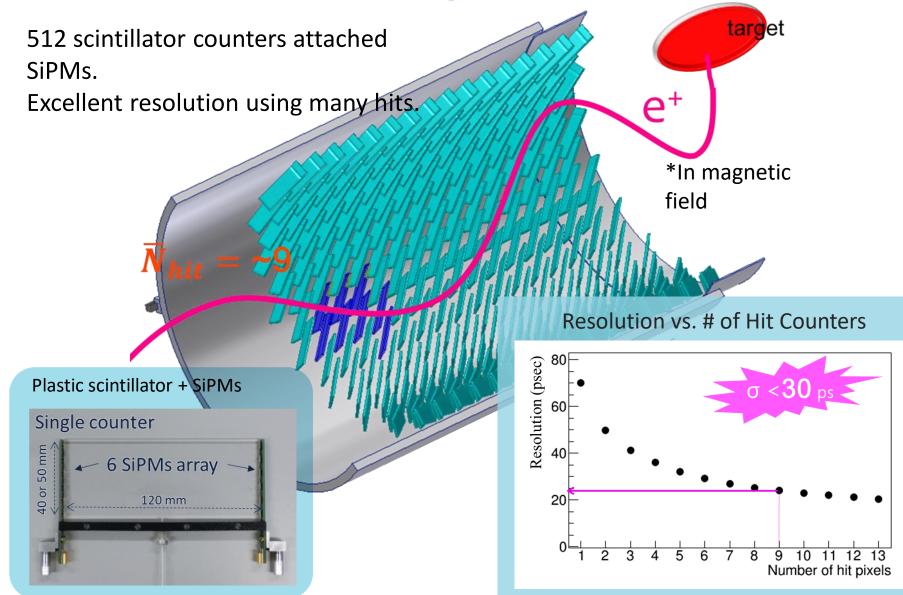
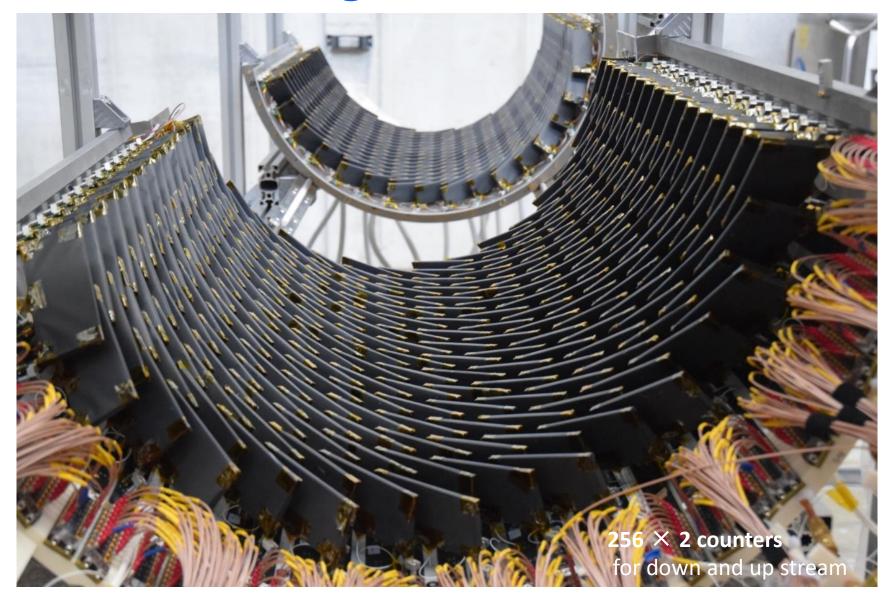
#### MEG II実験陽電子タイミングカウンターの コミッショニング2017 - 性能評価-

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

西村美紀(東大) 他 MEGIIコラボレーション 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** 



# 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<br>(128 in DS) |
| Lasers          | ALL (432)                 | Partially                |
| Synchronization | Final version             | External input           |
| DAQ channels    | Half (512)                | 256                      |
| Slow control    | HV,<br><b>Temperature</b> | HV                       |

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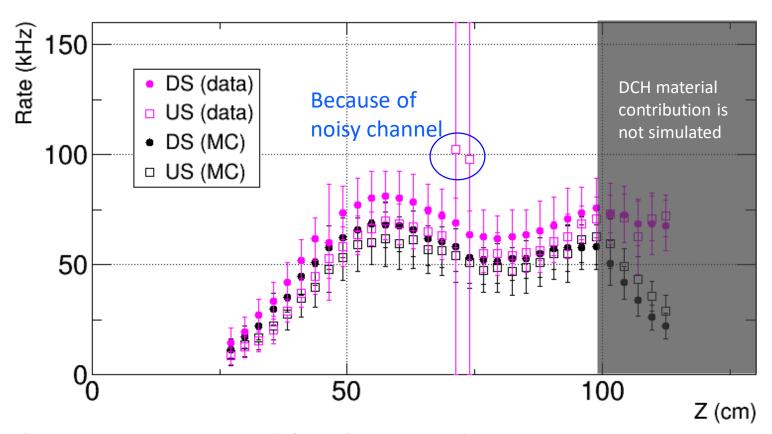
#### **Goals**

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#### Hit Rate

Hit rate is calculated out of trigger region.



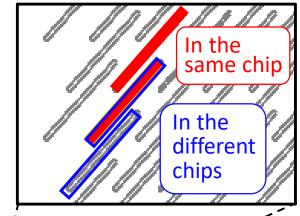
No large unexpected background.

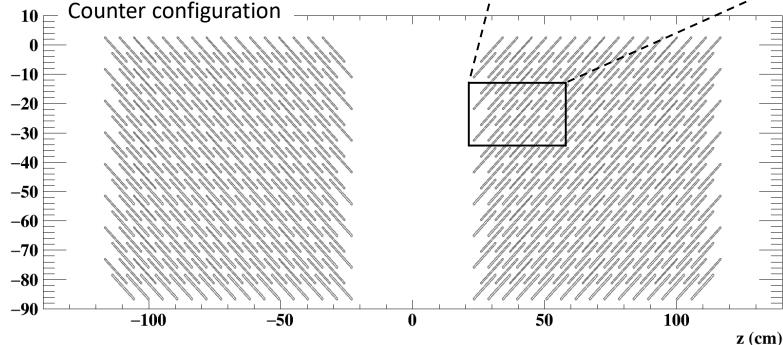
#### Two hits resolution

Check the resolutions with adjacent two counters,

sigma of  $(T_i - T_j)/2$ 

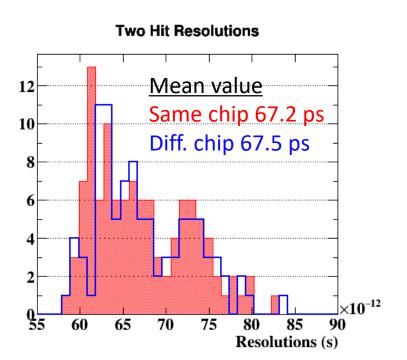
- Check the synchronization effect among chips.
  - Channels of some two counters are assigned over different chips.

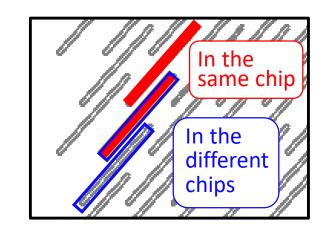




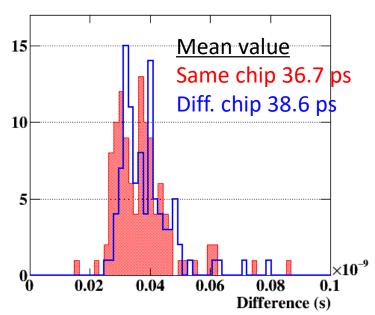
#### Two hits resolution

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



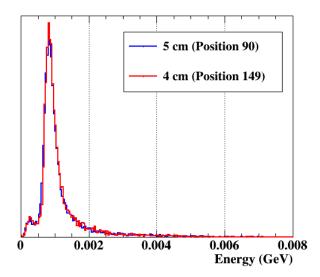


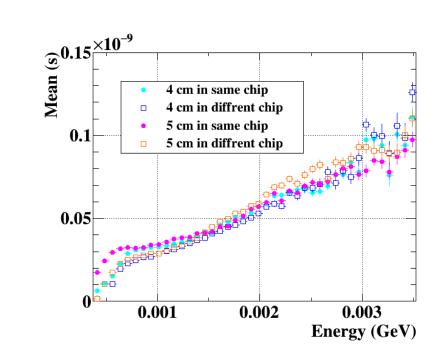
**Difference from Expected Resolution** 

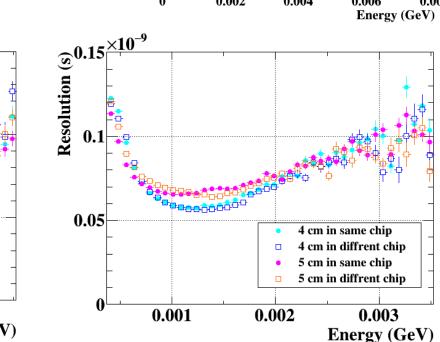


# Energy dependence

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







# **Overall Performance**

# N hits analysis

In the pilot run, TC independent data is taken.

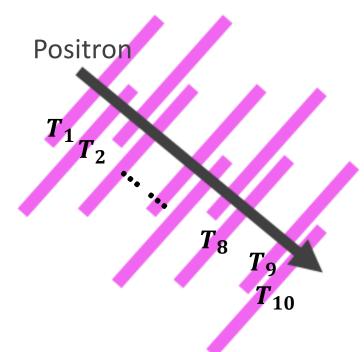
- No DCH. × No track information
- ⇒ Fix the counter combination from geometrical point of view
- No coincidence data with photon detector. X No time reference
- ⇒ Even-odd analysis

#### 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.
- Accumulate all normalized fit Gaussian.
  - Inter counter jitter is included. Calibration effect also can be seen.

496 4:0 4: 4 448 432 416 400 384 368 352 336 320 304 288 272 2:56
4.3 7 4: 14.5 449 433 417 401 385 369 353 337 321 305 2:0 2:0 2:0
4.8 42 466 450 434 418 402 386 370 354 338 322 306 2:0 274 255
4.9 48: 467 451 435 419 403 387 371 355 339 323 3:0 291 275 259
500 484 468 452 436 420 404 388 372 356 340 324 308 292 276 260
501 485 469 453 437 421 405 389 373 357 341 325 309 2 3 277 261
502 486 470 454 438 422 406 390 374 358 342 326 310 294 278 262
503 487 471 455 439 423 407 391 375 359 343 327 311 2 5 279 263
504 488 472 456 440 424 408 392 376 360 344 328 312 296 280 264
505 489 473 457 441 425 409 393 377 361 345 329 313 2 7 281 265
506 490 474 458 442 426 410 394 378 362 346 330 314 298 82 266
507 491 475 459 443 427 411 395 379 363 347 331 315 299 283 267
508 492 476 440 444 428 412 396 380 364 348 332 316 300 224 28
509 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299
500 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299
500 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299
50 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299
50 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299
50 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299
50 4 3 4 7 4 1 445 429 413 397 381 365 349 333 37 31 225 299

DS 18 32 48 64 86 96 112 128 144 166 176 172 298 224 246

2 16 4 \$6 68 2 98 114 130 146 162 178 194 210 126 241

3 19 35 4 67 83 99 115 131 147 163 179 195 211 127 143

4 20 36 \$2 68 84 160 116 132 148 164 180 196 212 228 244

5 21 37 3 69 85 161 117 133 149 165 181 197 213 229 245

6 22 31 \$4 76 86 162 118 134 150 166 182 198 214 230 246

7 23 39 \$ 71 87 163 119 135 151 167 183 199 215 231 247

8 24 4 \$6 72 88 164 120 136 152 168 184 200 216 232 248

9 25 41 7 73 89 165 121 137 153 169 185 201 217 233 249

16 26 4 \$8 74 96 166 122 138 154 170 186 202 218 234 250

11 27 43 \$9 75 91 167 123 139 155 171 187 263 219 235 251

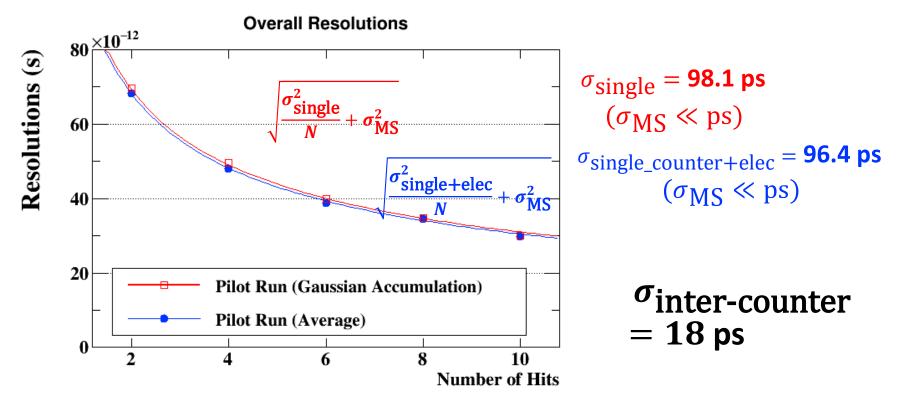
14 34 66 76 92 168 124 140 156 172 188 264 270 236 252

15 31 47 53 79 95 141 127 143 159 175 191 207 223 239 15

(Notice that counters are used twice or more.)

#### Resolutions with Number of Hits

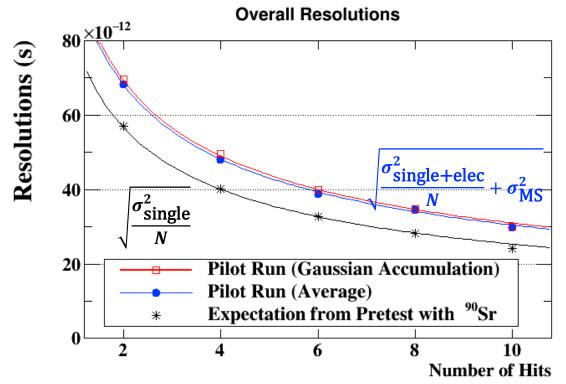
Overall resolution; 
$$\sqrt{\frac{\sigma_{\rm single}^2 + \sigma_{\rm MS}^2}{N}} + \sigma_{\rm single}^2 = \sigma_{\rm single\_counter}^2 + \sigma_{\rm inter-counter}^2 + \sigma_{\rm electronics}^2$$



The time calibration b/w counters works well.

# Comparing with Expectation

Overall resolution; 
$$\sqrt{\frac{\sigma_{\rm single}^2 + \sigma_{\rm MS}^2}{N}} + \sigma_{\rm single}^2 = \sigma_{\rm single\_counter}^2 + \frac{\sigma_{\rm inter-counter}^2}{\sigma_{\rm electronics}^2}$$



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

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

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

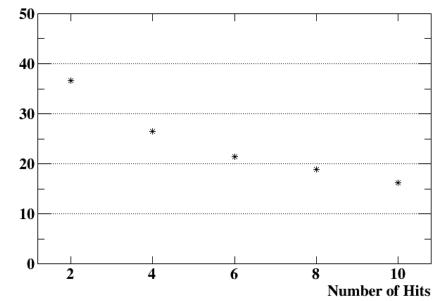


The difference is **53.6** ps.

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

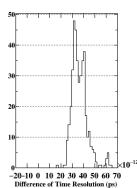
#### Resolution with Number of Hits

#### Difference between Pilot Run and expectation

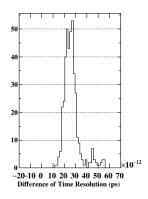


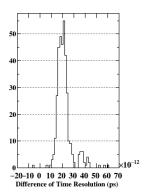
$$\sigma_{\rm total}^2(N_{\rm hit}) = \frac{\sigma_{\rm single}^2 + \sigma_{\rm inter-counter}^2 + \sigma_{\rm elec}^2}{N_{\rm hit}} + \sigma_{\rm MS}^2(N_{\rm hit}),$$

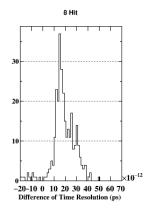
Even though the single resolutions are worse than the expectation, thanks to multiple hit scheme the degradation becomes small with  $\sqrt{N}$ .

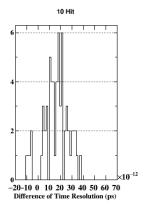


Difference (ps)





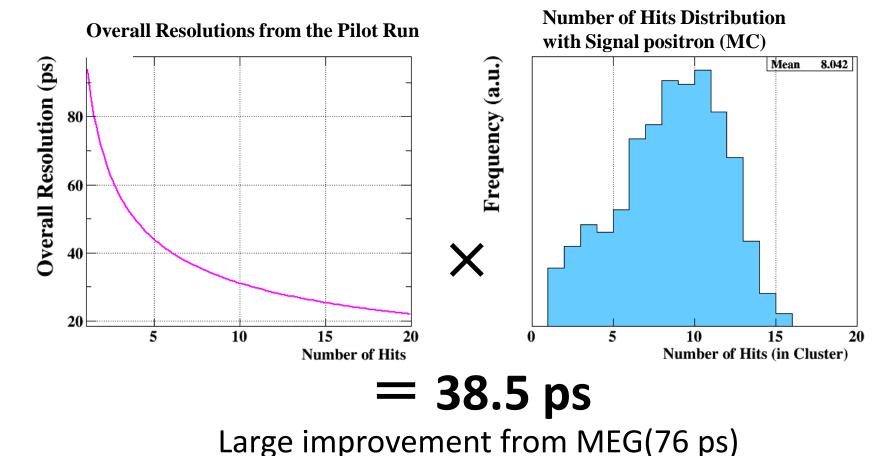




# Final Performance for Signal Positron

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,



#### **Overall Positron Time Resolution**

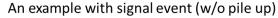
 Time on vertex is reconstructed by TC and DCH, that is overall positron timing resolution;

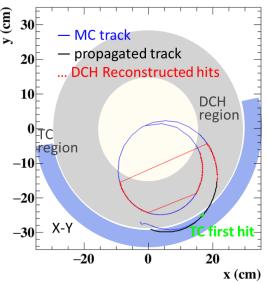
$$T_{e^{+}} = T_{TC} - L_{DCH}/c$$
38.5 ps  $\oplus$  14.8 ps (MC)
= 41.2 ps

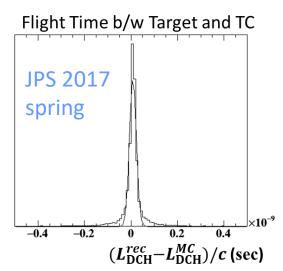
 More than twice better than MEG (108 ps)

• 
$$\sigma_{T_{e\gamma}}$$
 = 65 ps (as  $\sigma_{T_{\gamma}}$  = 50 ps)

• Backgrounds are reduced linearly.







### **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

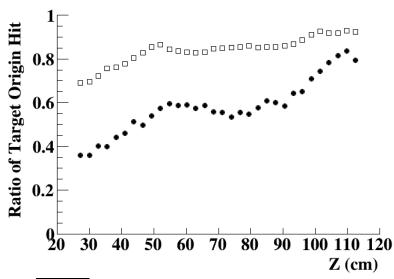
- Pilot run for TC with all counters is performed.
  - It is first time to install all the counter.
- We confirmed the energy dependence, effect of synchronization with two hits resolution.
- The resolution as a function of the number of hits is obtained with the final detector.
  - Though the difference 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.

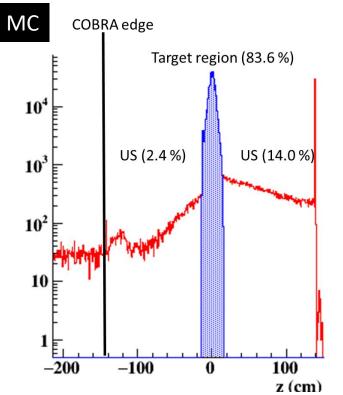
# Back Up

#### DS and US

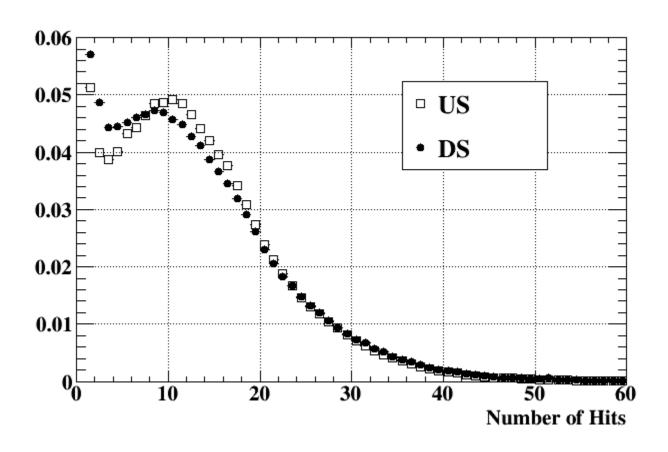
- It is the first time to install all the counters (512).
  - Tested only half of DS counters (128) in previous pilot runs.

 DS has more background from off-target decay

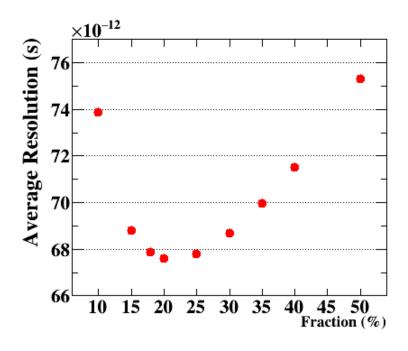




#### **Number of Hits**



# **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