



中国计量科学研究院  
National Institute of Metrology, China



Digital electronics for the RMO SIRTIs, 8 June, 2022

# The existing developments and application experience of digital electronics at NIM

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# 1. The existing developments at NIM

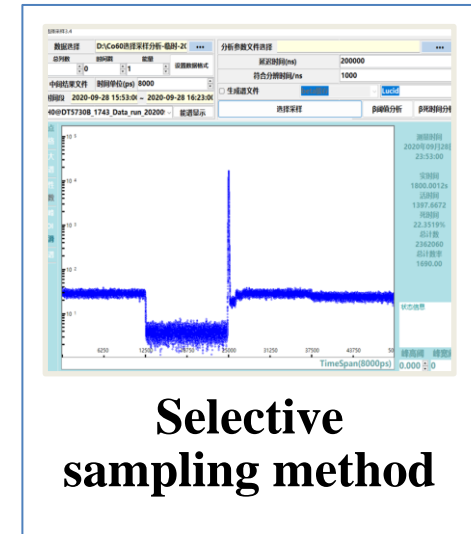
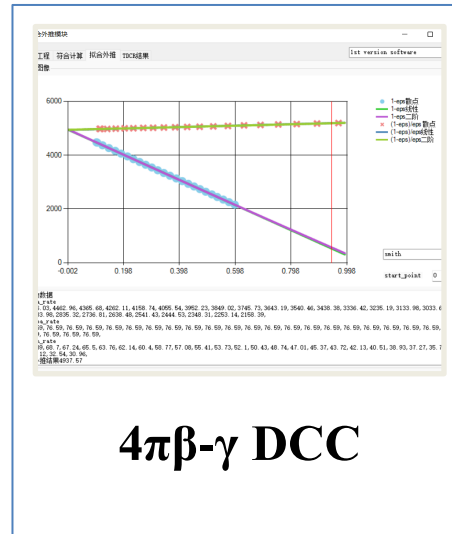
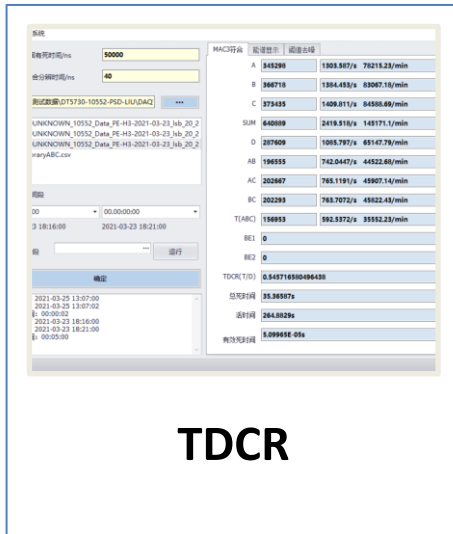
## Digitizer used for radionuclide metrology

- Data acquisition(DAQ)- **CAEN digitizer**



**730S Digitizer Family**  
 14-bit @ 500 MS/s  
 8 / 16 Channels

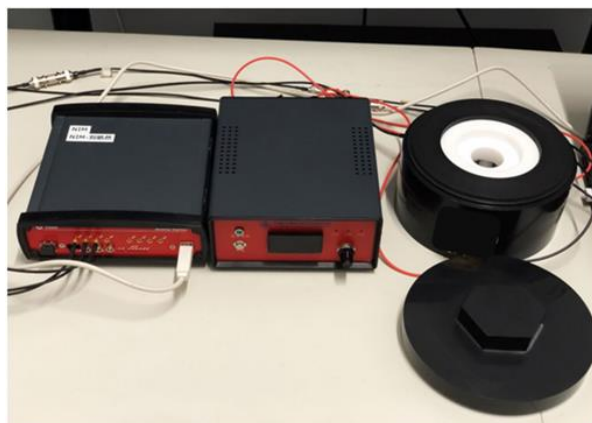
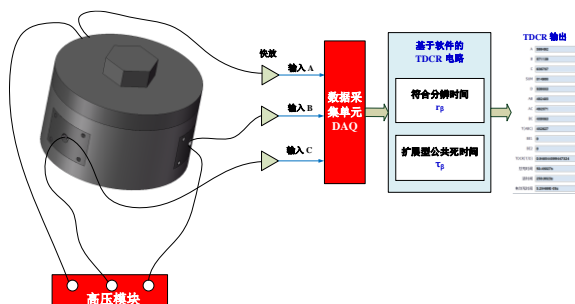
- Associated software-**Software based circuits & Analysis software**



# 1. The existing developments at NIM

## Digitizer used for radionuclide metrology

### TDCR application



MAC3符合系统V9.3.0

固有死时间/ns: 50000  
符合分辨时间/ns: 200

F:\【10】测试数据\DT5730-10552-PSD-LIU\DAQ\N\

CH0@UNKNOWN\_10552\_Data\_PE-C14-2021-03-23\_Isb\_22\_30\_  
 CH1@UNKNOWN\_10552\_Data\_PE-C14-2021-03-23\_Isb\_22\_30\_  
 CH2@UNKNOWN\_10552\_Data\_PE-C14-2021-03-23\_Isb\_22\_30\_

划分时间段  
00.00:00:00 - 00.00:00:00  
2021-03-23 15:41:03 - 2021-03-23 15:53:02  
 自定义分段时间  
 均等分段时间(ms): 60000 运行

确定

开始时间: 2021-03-25 13:07:00  
结束时间: 2021-03-25 13:07:02  
总测量时间: 00:00:02  
开始时间: 2021-03-23 15:41:03  
结束时间: 2021-03-23 15:53:02  
总测量时间: 00:11:59

就绪

CDT\_符合 IDT\_符合 阈值去噪 能谱显示 时间分布谱 延迟时间谱

延迟时间/ns: 0 符合

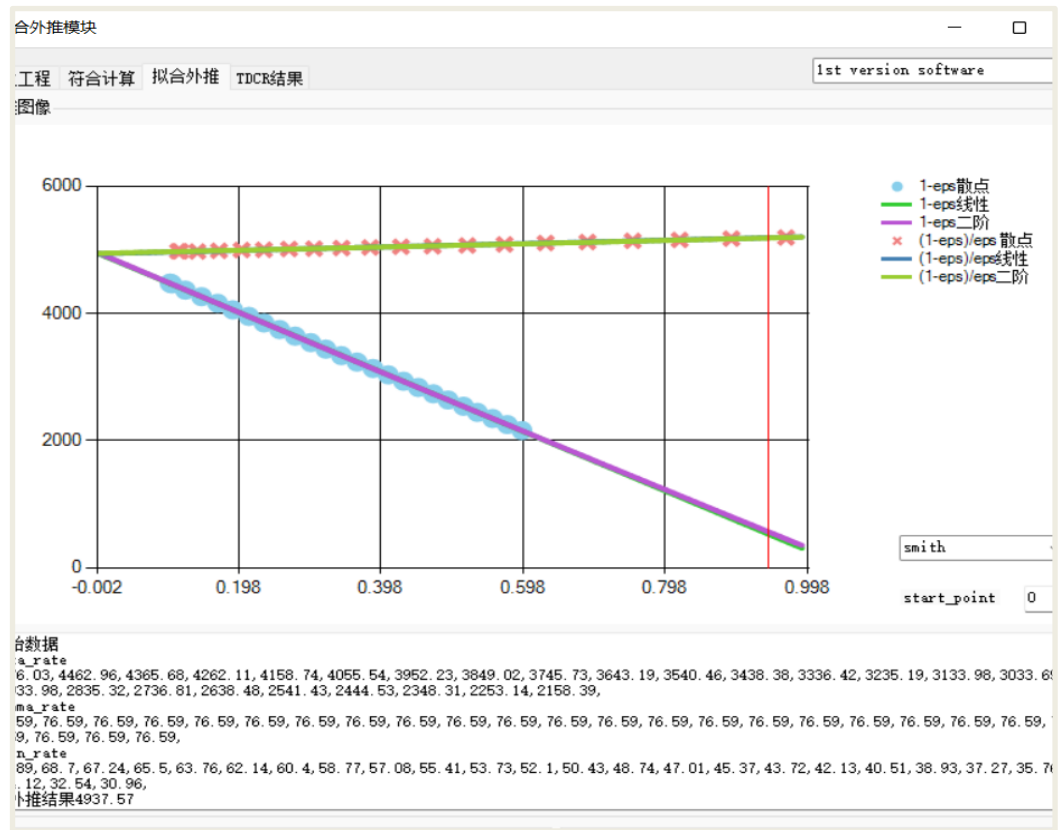
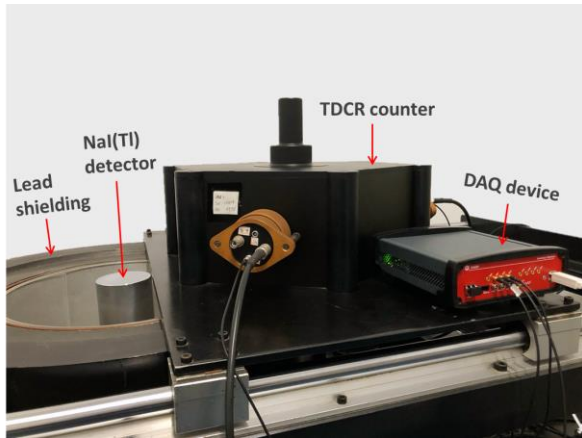
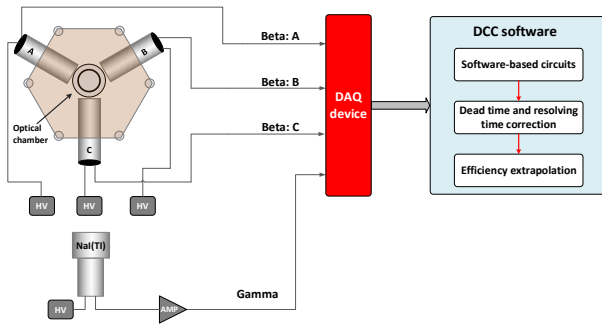
符合参数分析

A	1426026	2482.969/s	148978.1/min
B	1526626	2658.131/s	159487.9/min
C	1478086	2573.614/s	154416.9/min
SUM	2131897	3712.017/s	222721/min
D	1177653	2050.506/s	123030.4/min
AB	1138602	1982.511/s	118950.7/min
AC	1139742	1984.496/s	119069.8/min
BC	1141685	1987.88/s	119272.8/min
T(ABC)	1121188	1952.191/s	117131.4/min
BE1	0		
BE2	0		
TDCR(T/D)	0.952052939193464		
总死时间	133.9447s		
活时间	574.3231s		
有效死时间	5.28775E-05s		

# 1. The existing developments at NIM

## Digitizer used for radionuclide metrology

### 4 $\pi\beta$ (LS)- $\gamma$ DCC application



# 1. The existing developments at NIM

## Digitizer used for radionuclide metrology

### Selective sampling method application

选择采样 3.4

**数据选择** D:\Co60选择采样分析-临时-2C

总页数: 3 | 时间戳: 0 | 能量: 1 | 设置数据格式

中间结果文件 | 时间单位(ps): 8000

时间段: 2020-09-28 15:53:00 ~ 2020-09-28 16:23:00

CH0@DT5730B\_1743\_Data\_run\_20200928 | 能谱显示

**分析参数文件选择**

延迟时间(ns): 200000

符合分辨时间/ns: 1000

生成谱文 | beta保存 | Lucid

选择采样 | **β阈值分析** | β死时间分析

**β参数** | γ参数

CH0@DT5730B\_1743\_Data\_run\_20200928\_Co-60\_F1

CH1@DT5730B\_1743\_Data\_run\_20200928\_Co-60\_F1

阈值: 0 ~ 16000

死时间类型: 固定死时间

死时间(ns): 5000

开始时间: 2020-09-28 15:53:00

结束时间: 2020-09-28 16:23:00

总测量时间: 00:30:00

散点 | 网格 | 放大 | 全谱 | 线性 | 对数 | 寻峰 | ROI | 平滑 | 截谱

测量时间: 2020年09月28日 23:53:00

实时间: 1800.0012s

活时间

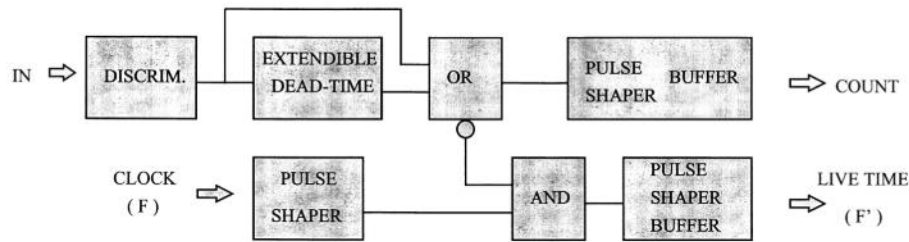
状态信息

峰高阈: 0.000 | 峰宽阈: 0

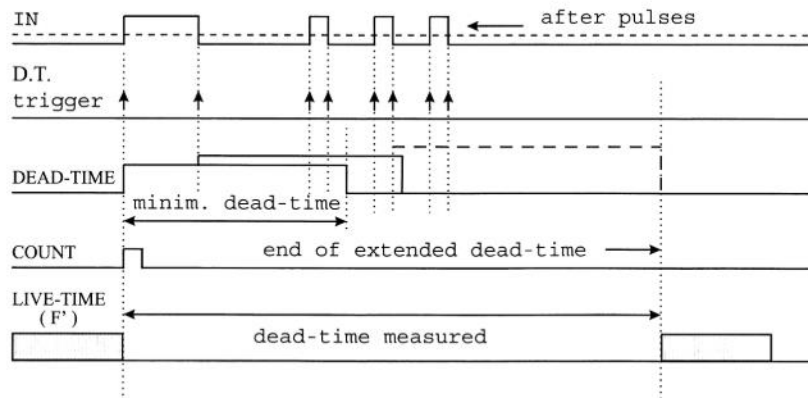
## 2. Some considerations about digital electronics for SIRT

### 2.1 Dead-time processing

#### MTR2: Extendible dead-time & live-time method



An external clock-pulse generator is only required



Extendible dead-time

$$\rho = R / \left( \frac{C/T}{f} - Rdt \right)$$

Live-time method

## 2. Some considerations about digital electronics for SIRTI

### 2.1 Dead-time processing

#### MTR2: Special features

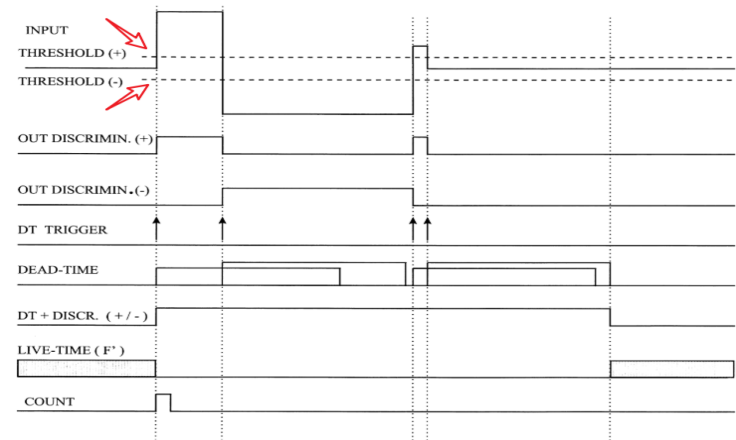
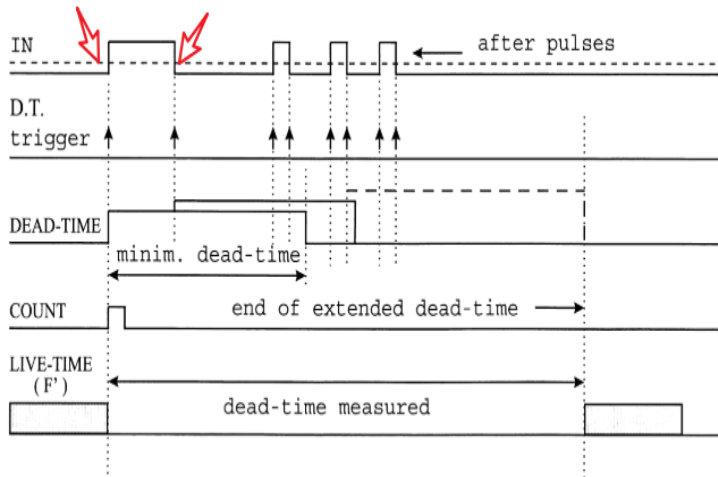


Fig. 5. Double threshold system to process the positive and negative parts of the input signal.

- dead-time is not only triggered by the **leading edge** but also by the **trailing edge** of the incoming pulse

- A **double threshold system** has been implemented

## 2. Some considerations about digital electronics for SIRT

### 2.1 Dead-time processing

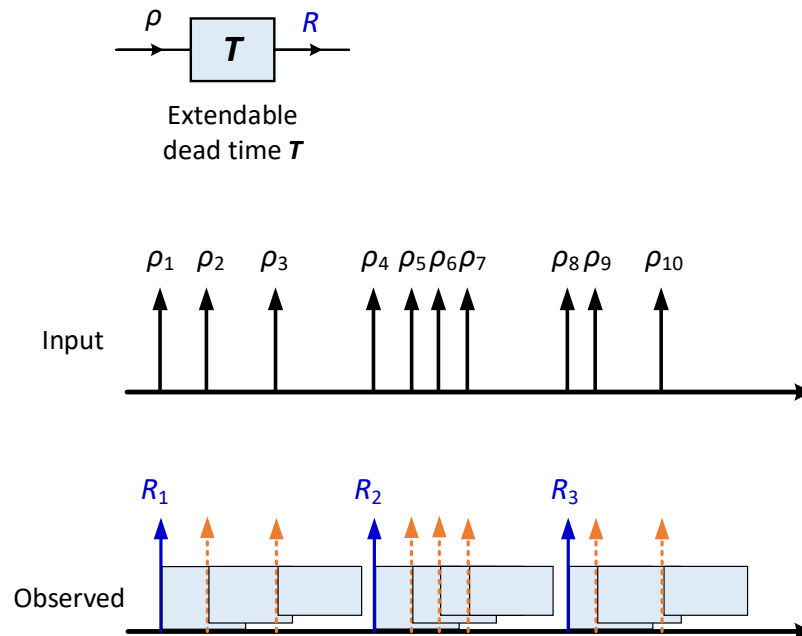
#### CAEN digitizer: list mode data & software processing

```

BOARD;CHANNEL;TIMETAG;ENERGY;ENERGYSHORT;FLAGS
0;0;2406303749;4095;0;0x4080
0;0;43922782374;1;0;0x4000
0;0;166038797312;0;0;0x4000
0;0;596359591374;4;4;0x4000
0;0;607616806067;41;37;0x4000
0;0;651180316577;0;0;0x4000
0;0;883314405663;16;15;0x4000
0;0;1040260911678;24;23;0x4000
0;0;1096681713029;4095;2047;0x4080
0;0;1159758417662;4095;2047;0x4080
0;0;1166575378370;0;0;0x4000
0;0;1178534583515;4095;2047;0x4080
0;0;1482371707523;0;0;0x4000
0;0;1714611480273;4095;2047;0x4080
0;0;1747076108155;38;37;0x4000
0;0;1794617725576;0;0;0x4000
0;0;2034473937529;4095;2047;0x4080
    
```

list mode data file

timestamps



Extendible dead-time processing logic



## 2. Some considerations about digital electronics for SIRTl

### 2.2 Pile-up management

- **SIRTl:** No pile-up rejector in amplifier (ORTEC 590A)

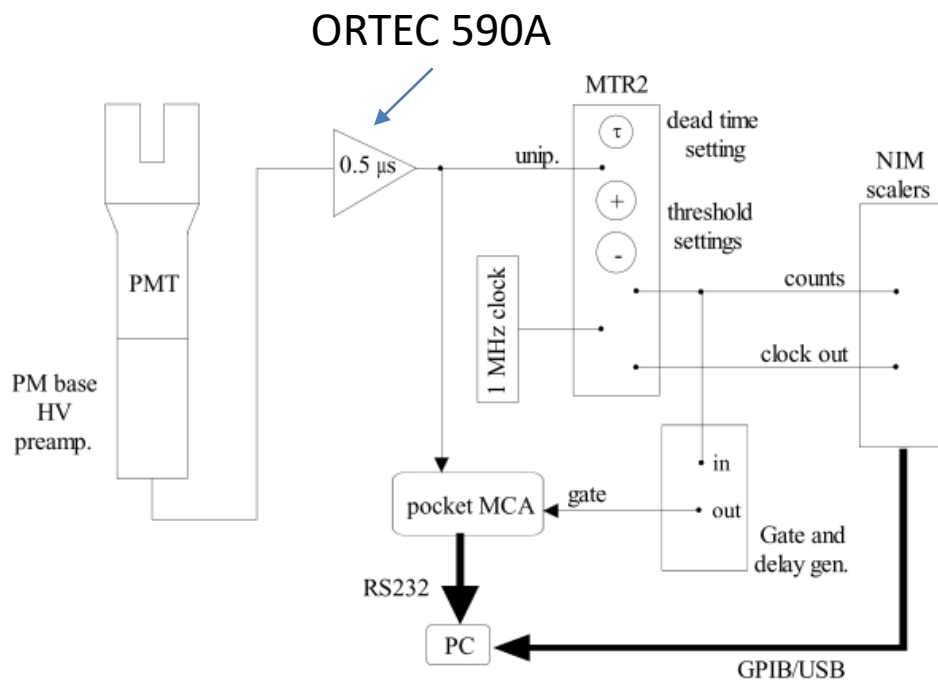


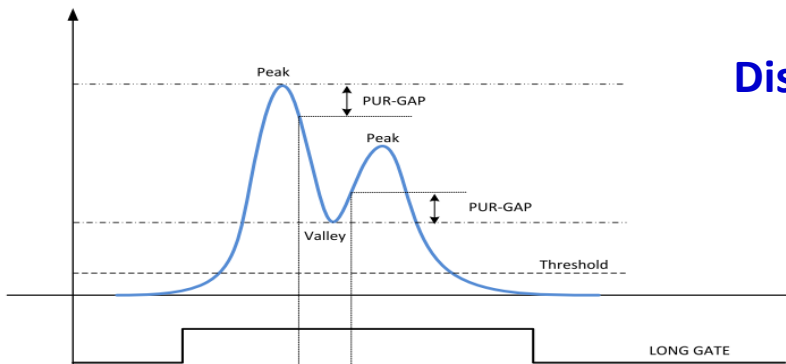
Figure 4: Block diagram of the SIRTl.

Pile-up rejector is incorporated in the amplifier to suppress the spectral distortion, which is caused by pulses piling up on each other at high counting rates

## 2. Some considerations about digital electronics for SIRTI

### □ 2.2 Pile-up management

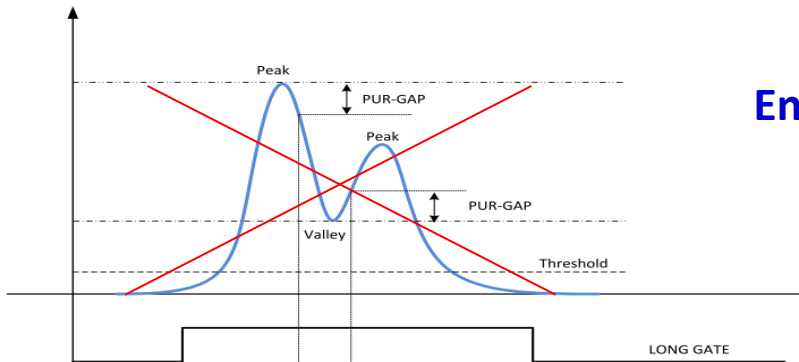
#### ● CAEN digitizer: optional



Disable

⇒ Good for counting

- Considered as a single “event”, and flags that event as “pile-up”
- The pile-up events can be rejected at software level



Enable

⇒ Good for energy spectrum

- The pile-up events are rejected at board level

720, 725, and 730 series with DPP-PSD firmware

## 2. Some considerations about digital electronics for SIRTI

### □ 2.2 Pile-up management

- CAEN digitizer: **optional**

➤ Possible solutions for both counting and energy spectrum

① Disable the pile-up rejection


② Filter events at the software level

for subsequent applications

- **For counting:** all events in the list-mode data file

- **For energy spectrum:** filter events without pile-up flags

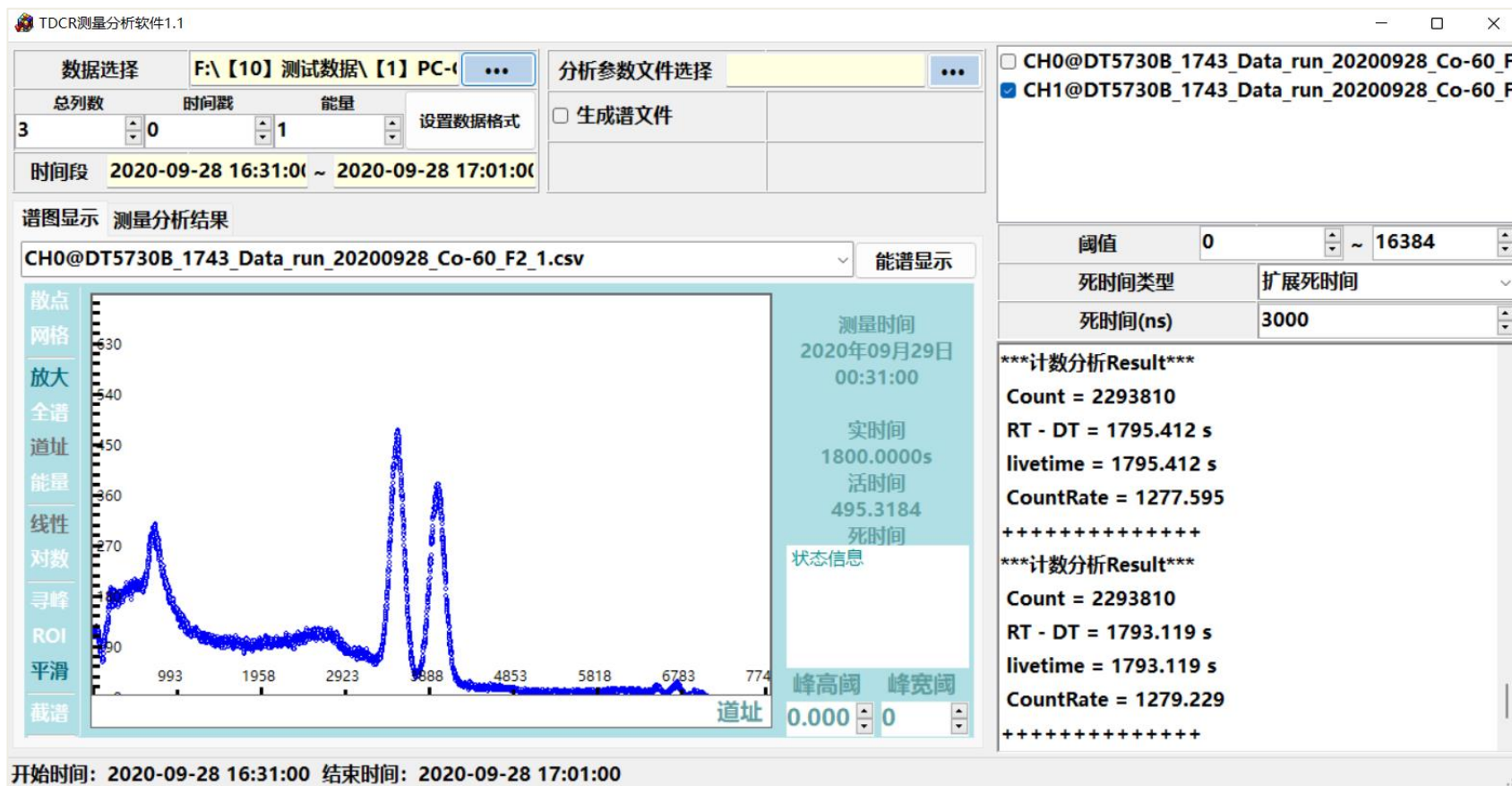
```
BOARD; CHANNEL; TIMETAG; ENERGY; ENERGYSHORT; FLAGS
0;0;2406303749;4095;0;0x4080
0;0;43922782374;1;0;0x4000
0;0;166038797312;0;0;0x4000
0;0;596359591374;4;4;0x4000
0;0;607616806067;41;37;0x8000
0;0;651180316577;0;0;0x4000
0;0;883314405663;16;15;0x4000
0;0;1040260911678;24;23;0x4000
0;0;1096681713029;4095;2047;0x4080
0;0;1159758417662;4095;2047;0x8000
0;0;1166575378370;0;0;0x4000
0;0;1178534583515;4095;2047;0x8000
0;0;1482371707523;0;0;0x4000
0;0;1714611480273;4095;2047;0x4080
0;0;1747076108155;38;37;0x4000
```



## 2.3 Examples-count rate correction

- Co-60 measured by NaI(Tl)

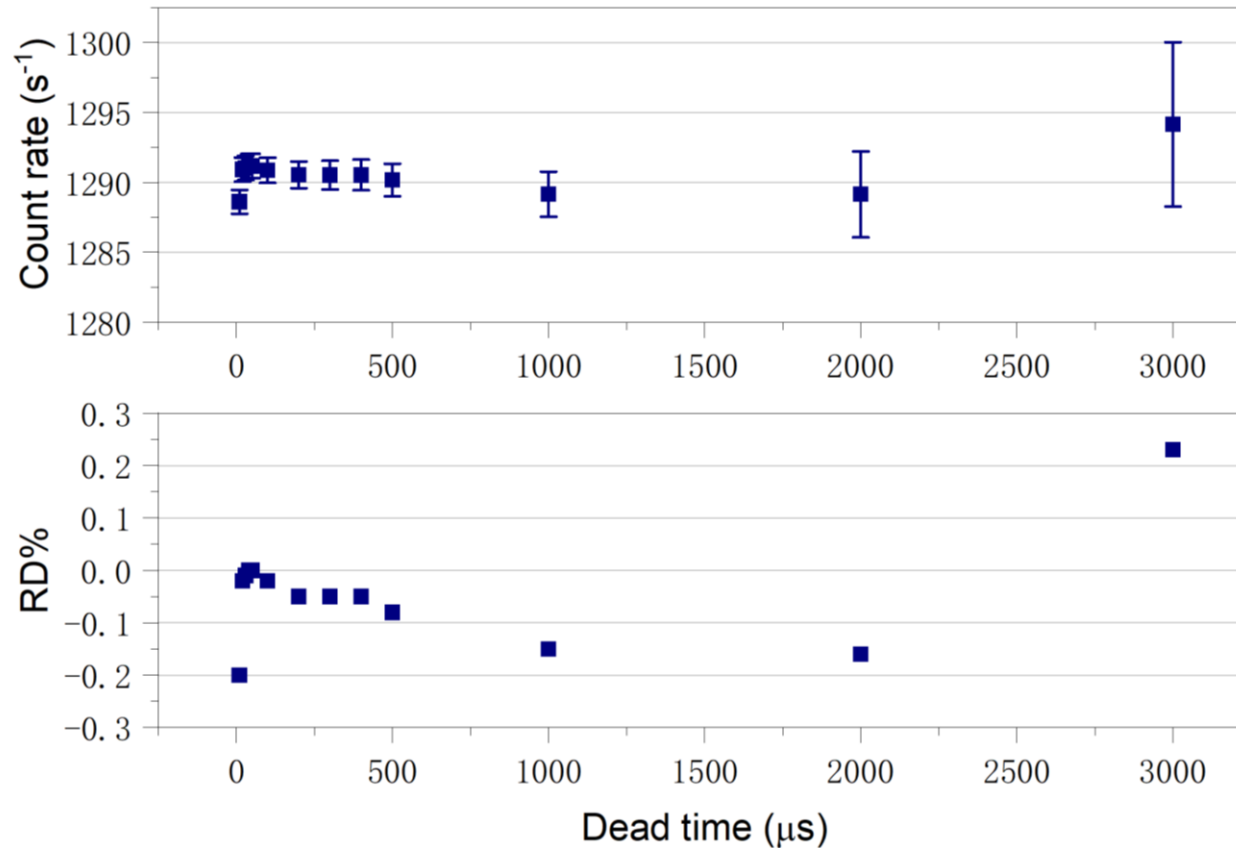
Digitizer + Dedicated software



## 2.3 Examples-count rate correction

● Co-60 measured by NaI(Tl)

Digitizer + Dedicated software



Extendable dead-time imposed by software

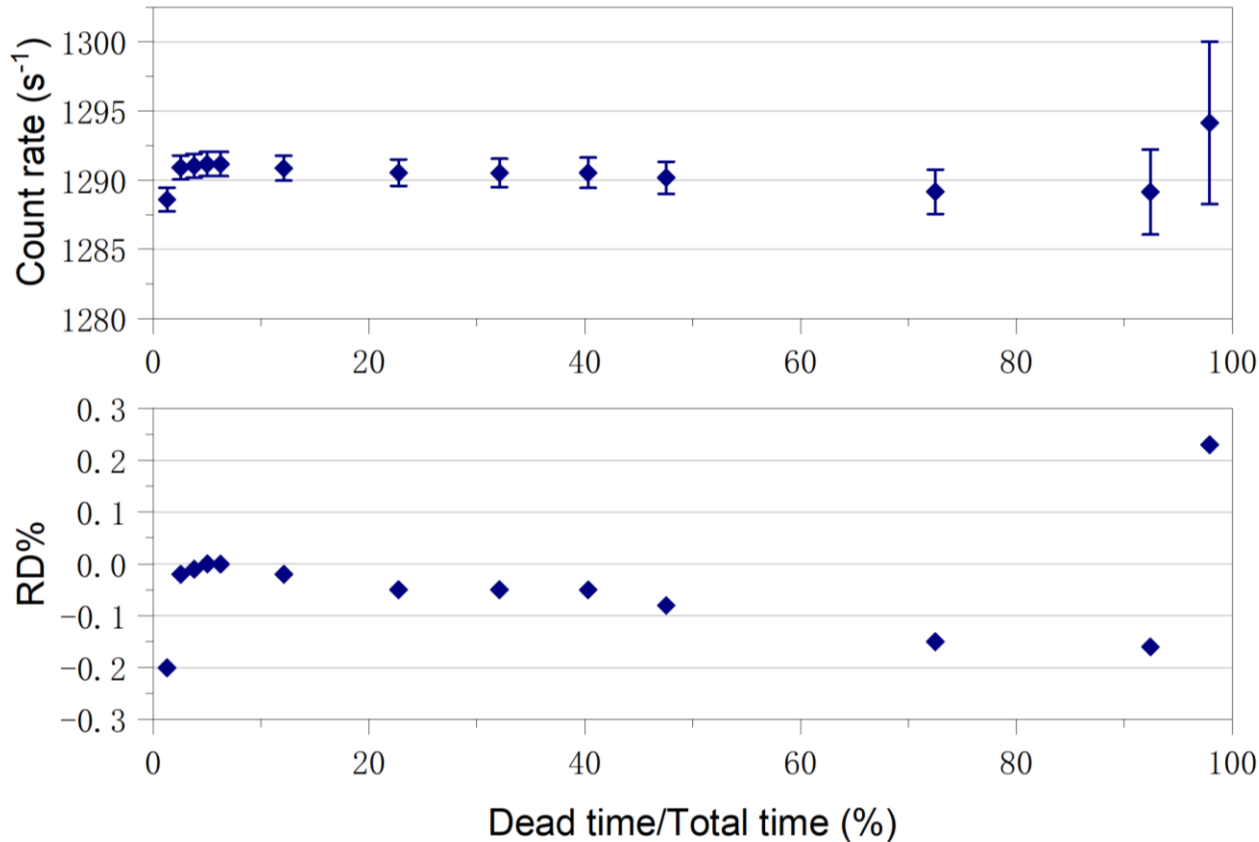
Dead time changed from 10  $\mu\text{s}$  to 3000  $\mu\text{s}$

For the calculation of the relative deviation, the reference point is 50  $\mu\text{s}$

## 2.3 Examples-count rate correction

● Co-60 measured by NaI(Tl)

Digitizer + Dedicated software



Extendable dead-time imposed by software

Dead time ratio changed from 0.6% to 98%

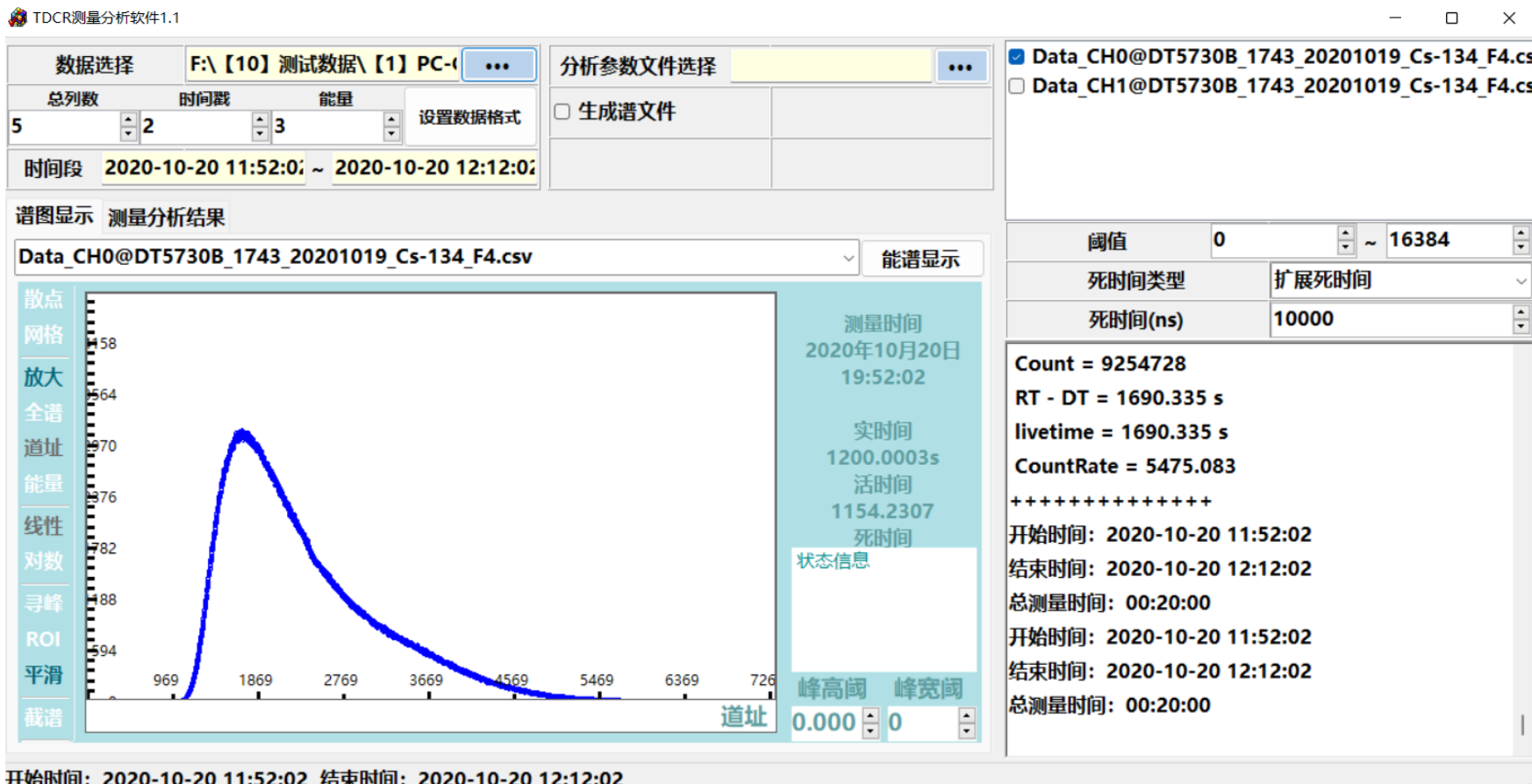
For the calculation of the relative deviation, the reference point is 50  $\mu$ s



## 2.3 Examples-count rate correction

- Cs-134 measured by Proportional counter

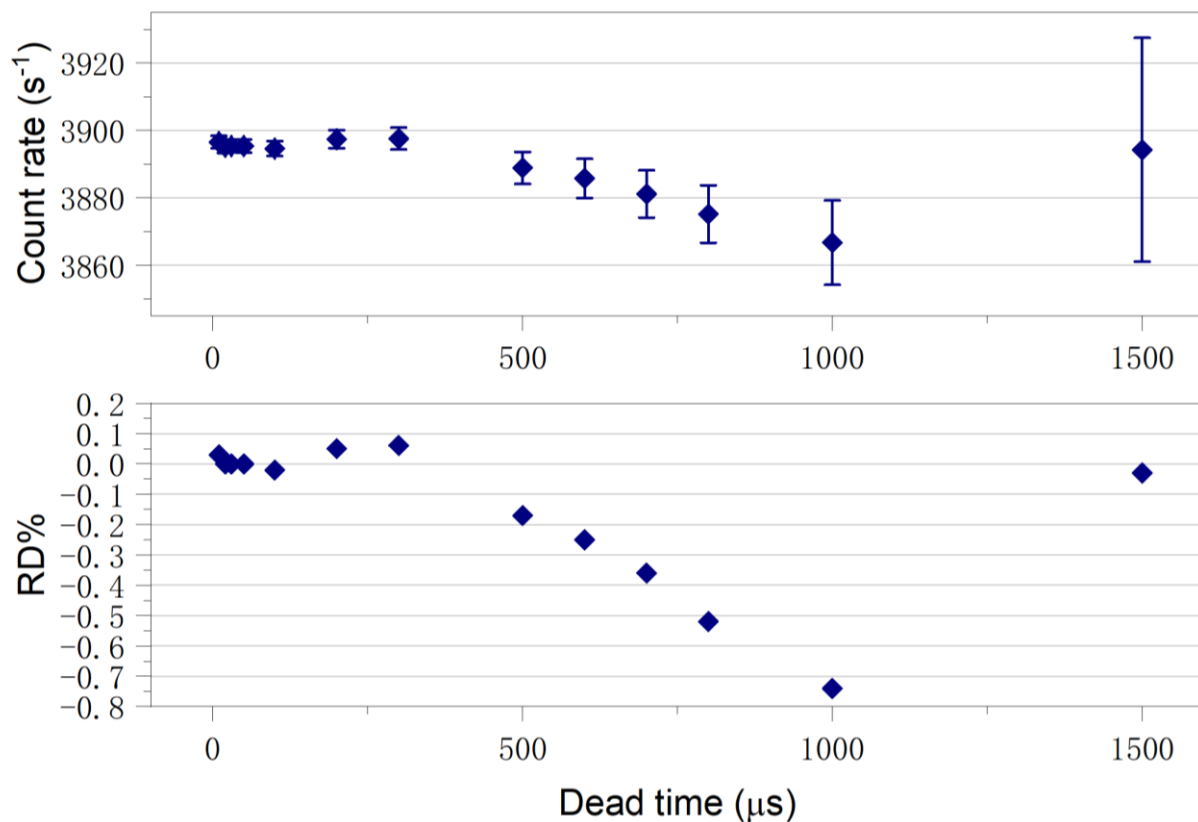
Digitizer + Dedicated software



## 2.3 Examples-count rate correction

- Cs-134 measured by Proportional counter

**Digitizer + Dedicated software**



Extendable dead-time imposed by software

Dead time changed from 10 μs to 1500 μs

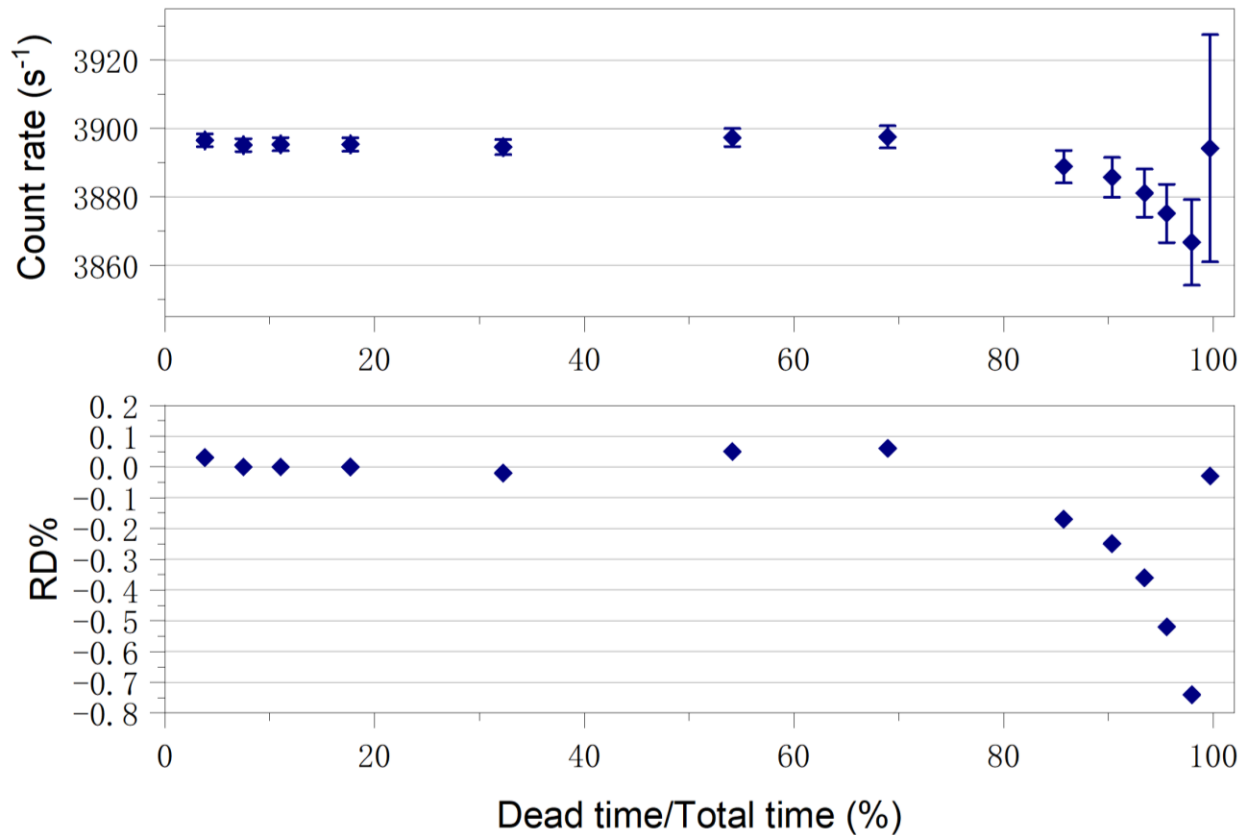
For the calculation of the relative deviation, the reference point is 50 μs



## 2.3 Examples-count rate correction

● Cs-134 measured by Proportional counter

Digitizer + Dedicated software



Extendable dead-time imposed by software

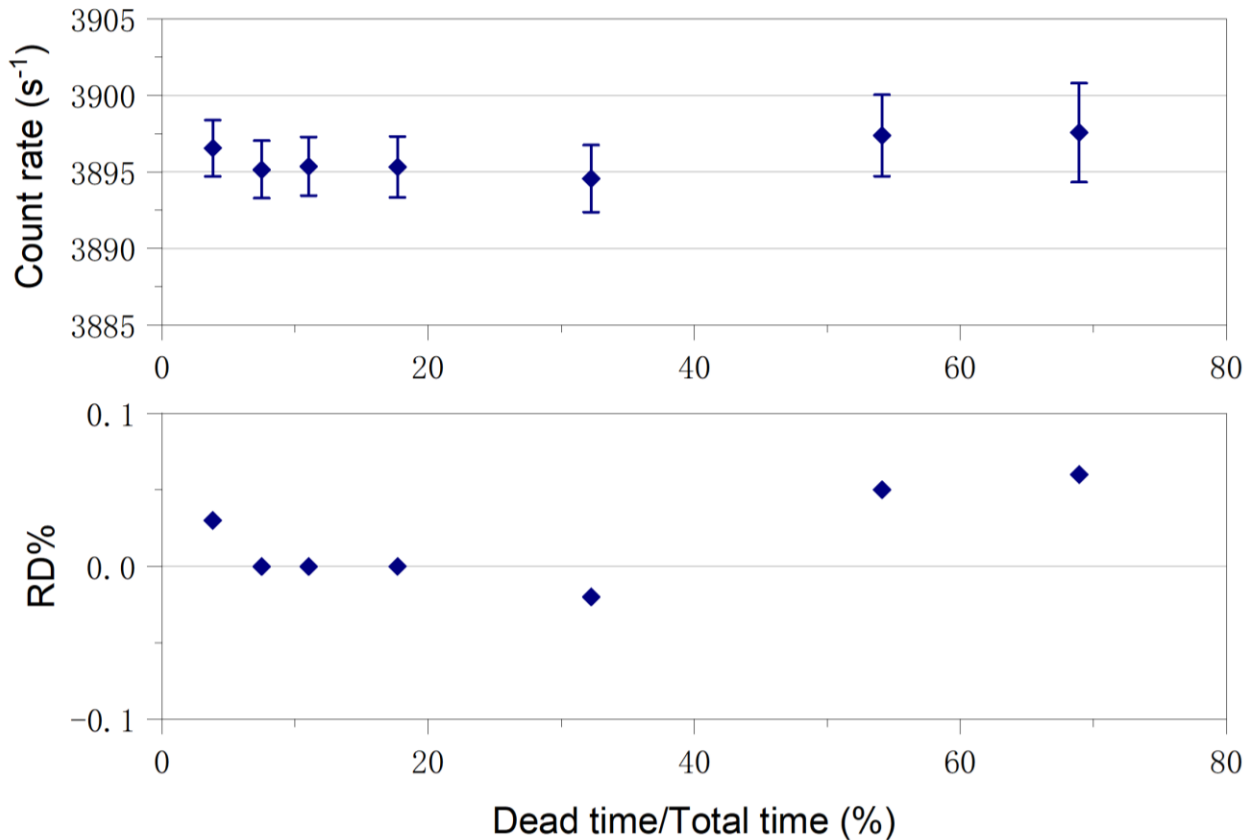
Dead time ratio changed from 3.8% to 99.7%

For the calculation of the relative deviation, the reference point is 50  $\mu$ s

## 2.3 Examples-count rate correction

● Digitizer + Dedicated software

Proportional counter for Cs-134



Extendable dead-time imposed by software

Dead time ratio changed from 3.8% to 80%

For the calculation of the relative deviation, the reference point is 50  $\mu$ s

## 2.3 Examples-count rate correction

- **Digitizer + Dedicated software**
- The current tests are not sufficient, high count rate tests need to be carried out.
- For example, measuring a strong  $^{99m}\text{Tc}$  source and looking for deviations from the exponential decay law.



Thanks for your attention

