Developmental status of read-out circuit for Straw Tube Tracker

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Introduction

μ-e conversion

$$\mu^- + N \rightarrow e^- + N$$

Standard Model

impossible to detect : Br<10^{-54}

Theory beyond standard model

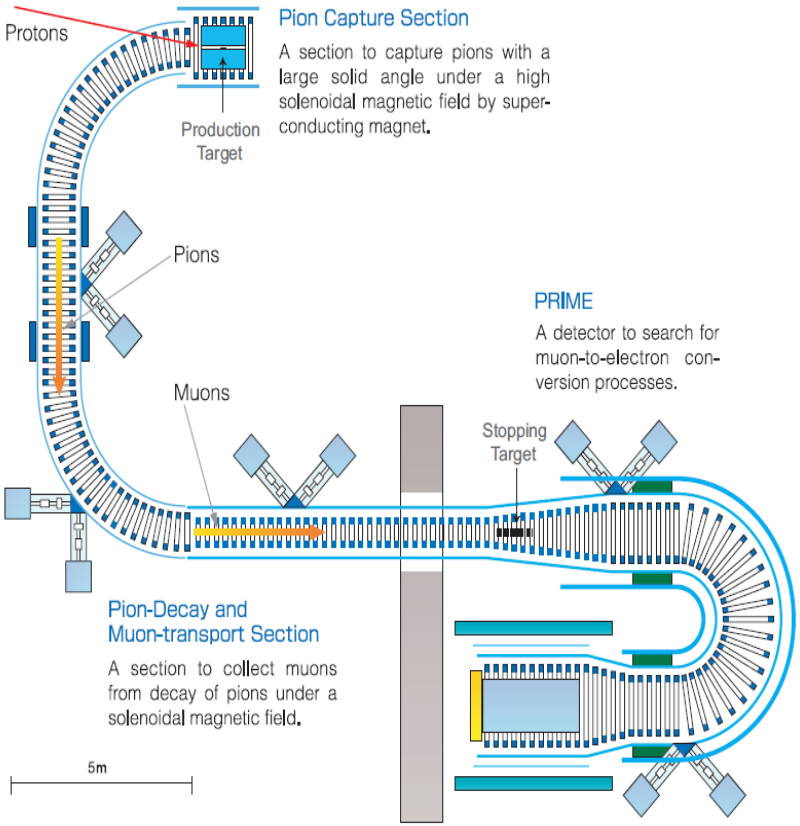
（ex:supersymmetry theory）

possible to detect : Br≦ 10^{-16}

⇓

If μ-e conversion are discovered, the discovery indicates new physics

Layout of COMET experiment instrument



COMET experiment : Exploration of μ-e conversion

- detect only electron around 105MeV/c from μ-e conversion
- aim at the experiment for the sensitivity that is better than 10^{-16}

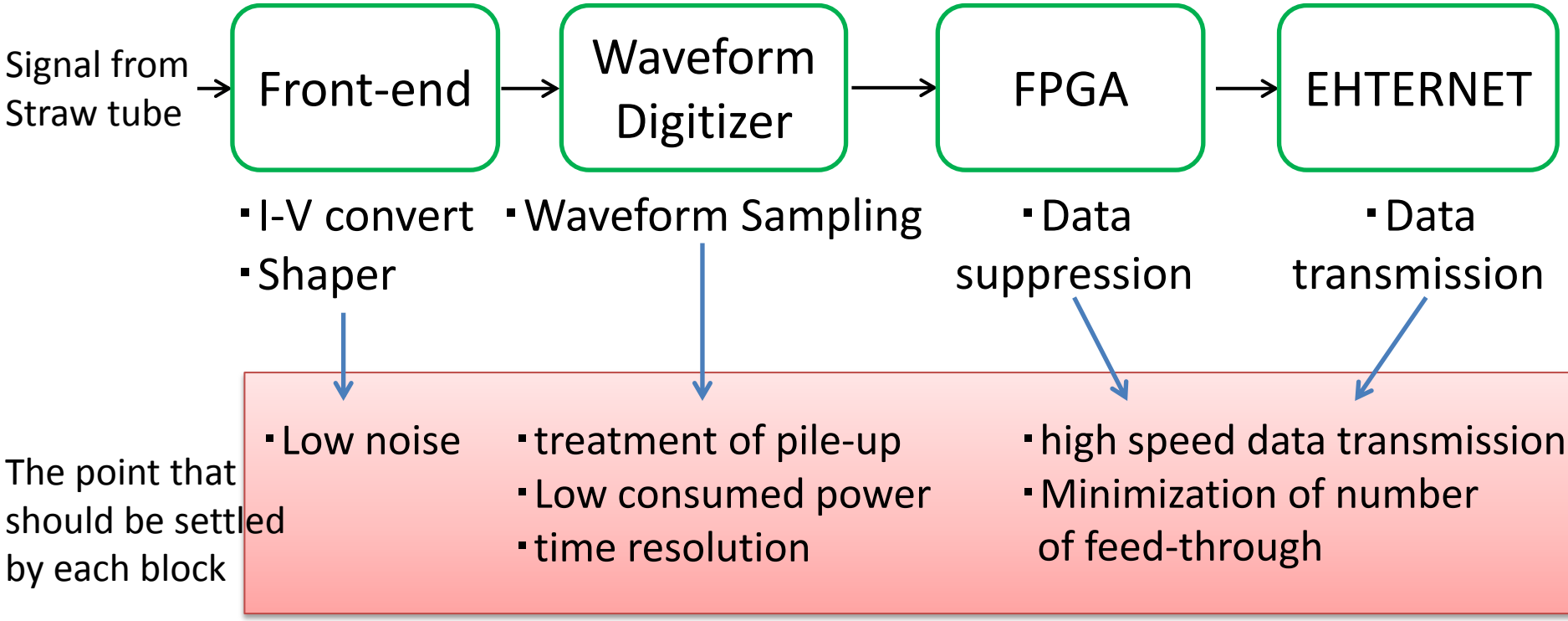
Demand to Board

Experiment specifications	To Board
• High rate measurement(3.6KHz/ch)	Treatment of pile-up
• Many channels(4160ch)	Low consumed power
• Behavior in vacuum	Minimization of number of feed-through
• Position resolution(~100 μm)	Time resolution(~1ns)
• Low quantity of charge	Charge Amplification (I-V convert)

ROESTI（Read-Out Electronics for Straw Tube Instrument）

As read-out circuit for straw tube tracker,
we decide to use Waveform Digitizer

Block diagram



Description of functions

Front-end

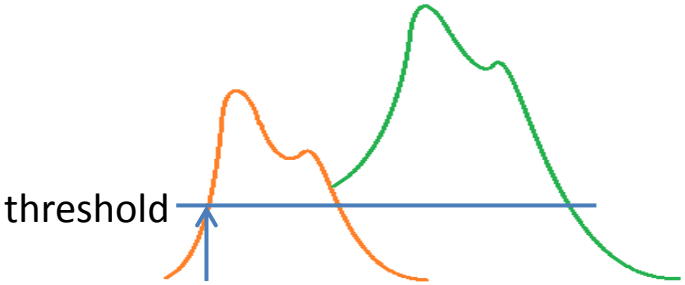
- Low noise ⇒ Satisfaction to implement AMP/Shaper

Waveform Digitizer

Sampling waveform

If waveform data are left,
we can treat pile-up by offline analysis

Signal when pile-up happen



We can't distinguish whether pile-up happen or not.

- Optimize capability of read-out circuit by 500MSPS～1GSPS sampling speed
  clear demand for time resolution
- By combination use of analog memory and ADC, low consumed power
  Analog memory : sampling waveform （quickly sampling）
  ADC : digitalize sampling data （slowly readout）

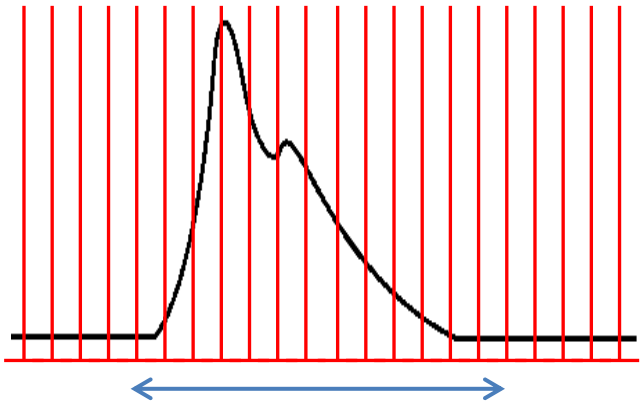
Description of functions

FPGA

- Many quantification of data due to digitalizing waveform ⇒ Need to suppress data

（ex：In 500MSPS sampling and 8bit ADC resolution , data rate is 0.5GByte/sec）

Example



Limit region of read out

GbE

- high speed data transmission by use of Giga bit Ether(1Gbit/sec)

Read-out circuit prototype

Front-end

Waveform Digitizer

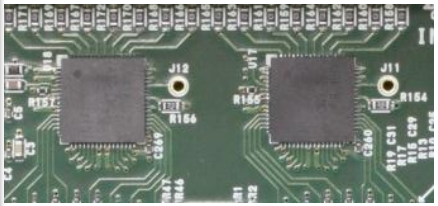
FPGA

EHTER NET

ASD（Amplifier Shaped Discriminator）

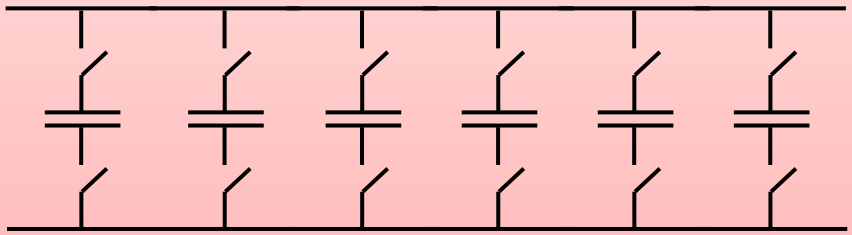
- Gain：1pC → 1.1V

ASD



Analog memory：DRS4

- 1024 switched capacitor are connected in parallel



- Sampling speed　700MSPS～5GSPS

ADC：12bit resolution

DRS4

Read-out circuit prototype

Front-end

Waveform Digitizer

FPGA

EHTER NET

Firmware
- Control the whole board
  - Initialize
  - Control timing
  - Data suppression
  - Connect to Ether Net

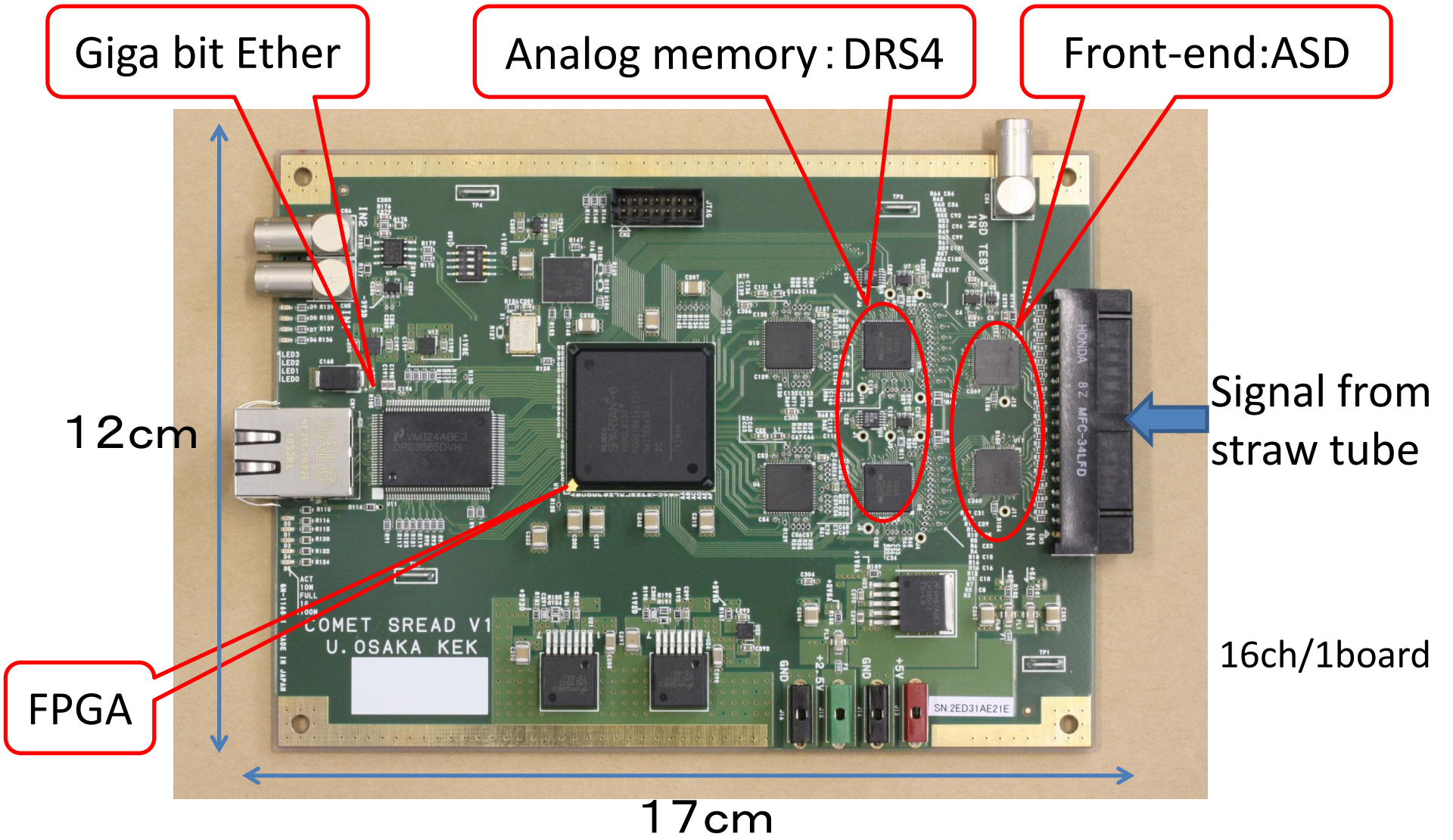
Giga bit Ether Net chip
Use of SiTCP

FPGA

GbE チップ

Developmental status of ROESTI prototype

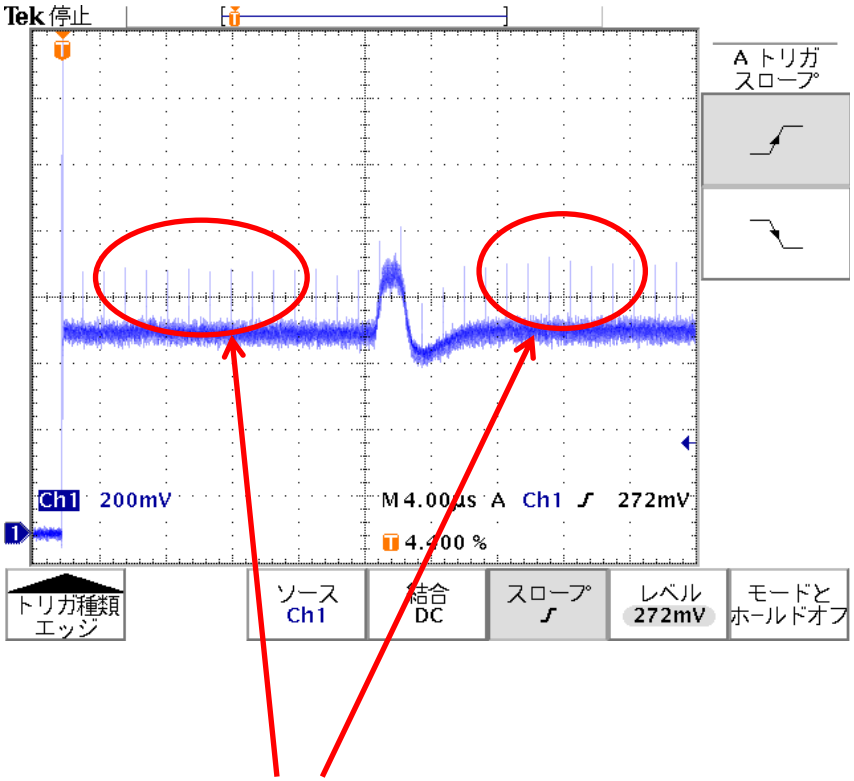
Now I am debugging



Developmental status of ROESTI prototype

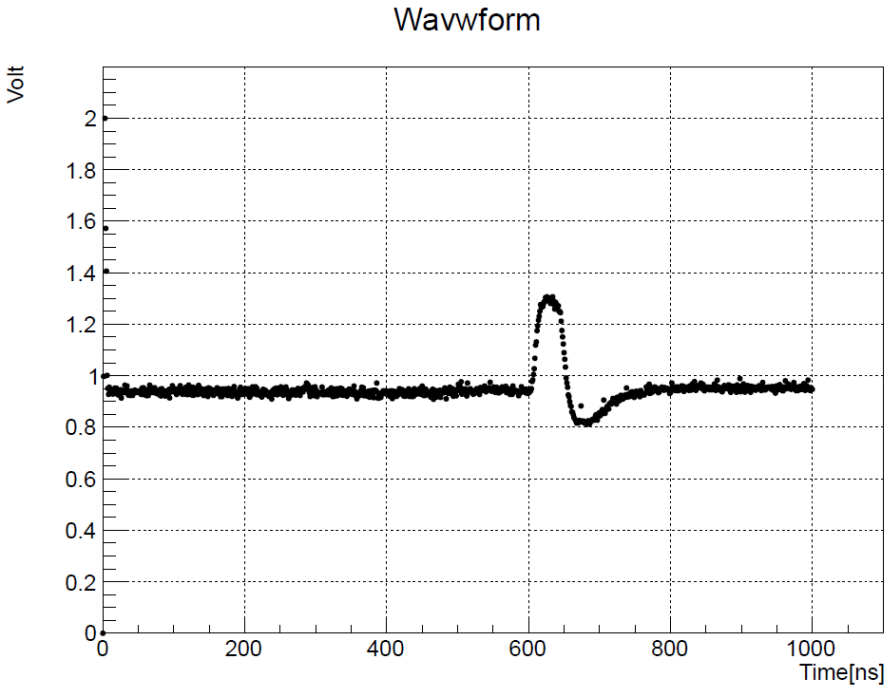
One channel result

DRS(Analog memory) output



This noise is unknown

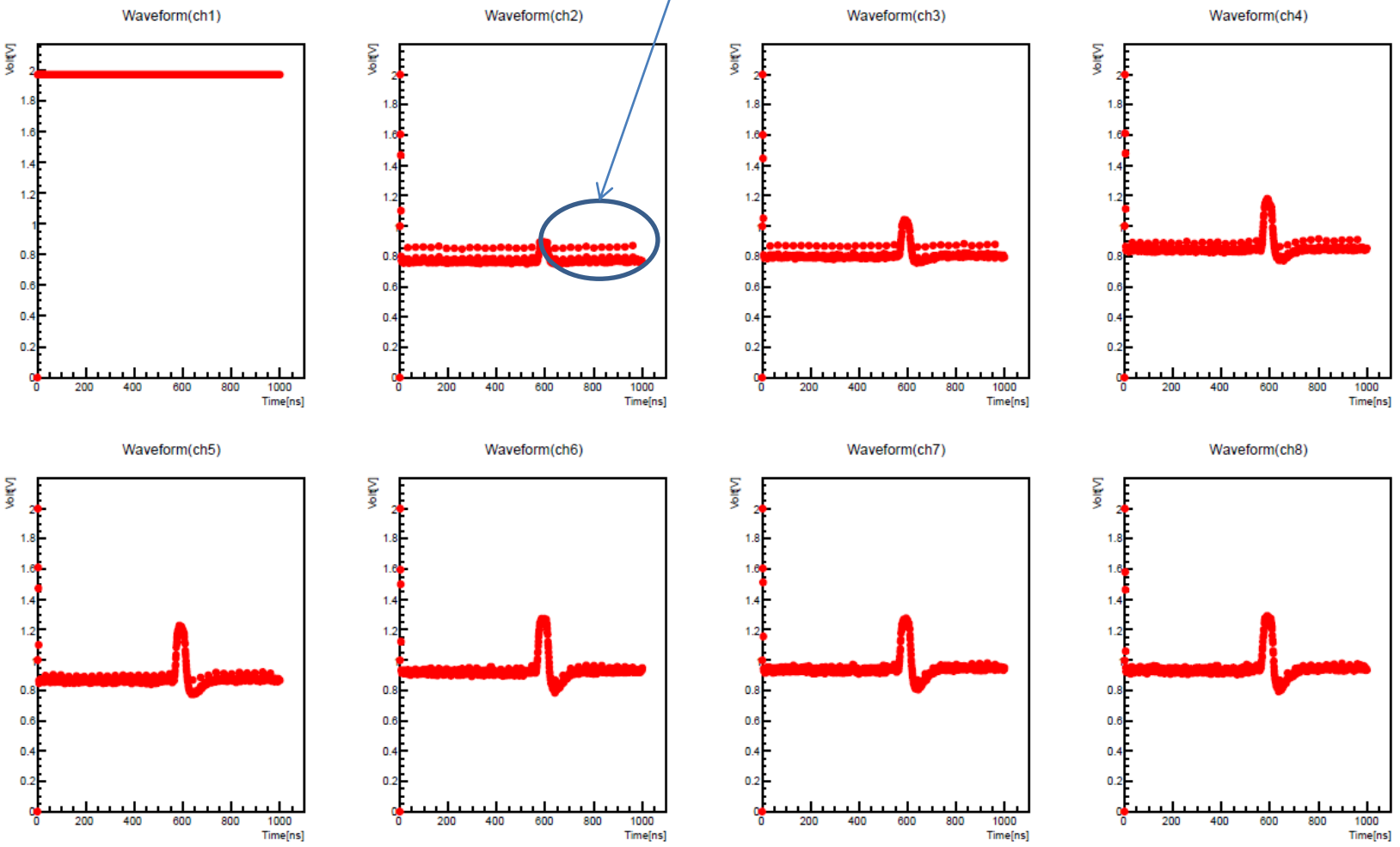
ADC Data



Developmental status of ROESTI prototype

Eight channels result

DRS noise appear



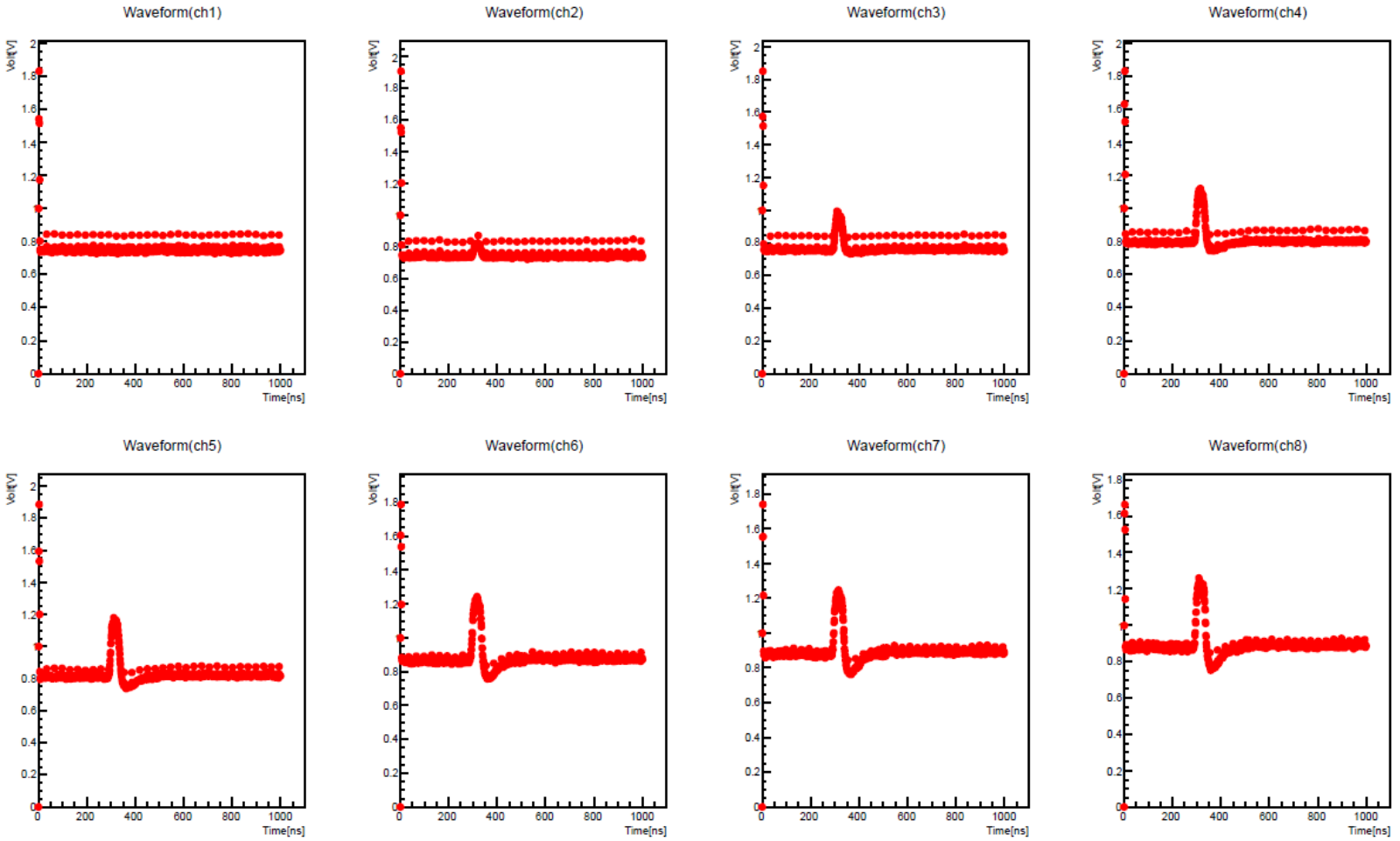
Each channel output is different <- because of ASD gain

Developmental status of ROESTI prototype

To Do List

- 16ch readout
- Search DRS noise
- ASD gain study

BackUp


Waveform(ch1)
Waveform(ch2)
Waveform(ch3)
Waveform(ch4)
Waveform(ch5)
Waveform(ch6)
Waveform(ch7)
Waveform(ch8)
Volt[V]
Time[ns]

Artifice of COMET experiment

- Large intensity pulse beam

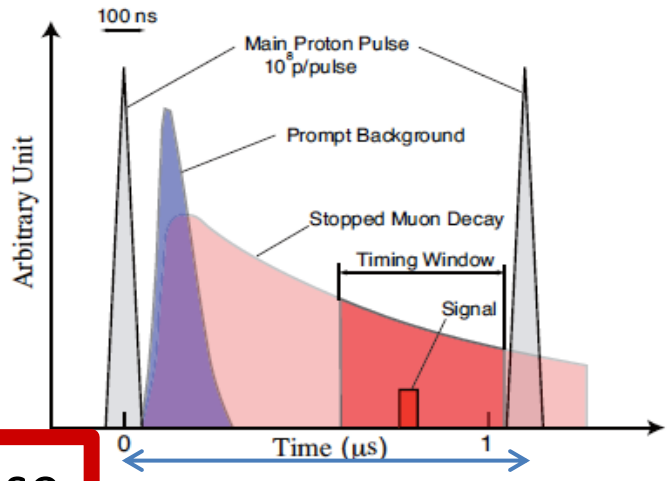
Lifetime of muon in muonic atom

～1μsec

By looking at only delay component,

suppress prompt background

Beam profile



1.3μs～1.9μs

It is useful to prevent pile-up and to increase event number.(But pile-up happen in fact.)

- Detecrtor

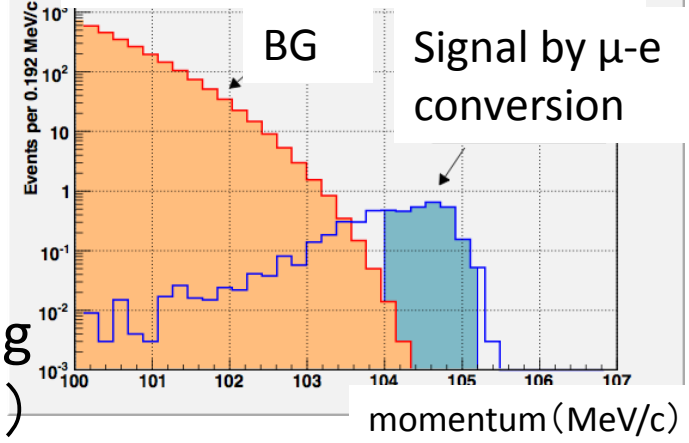
Measure electron around 105MeV/c with 1% energy resolution

⇓ As one countermeasure

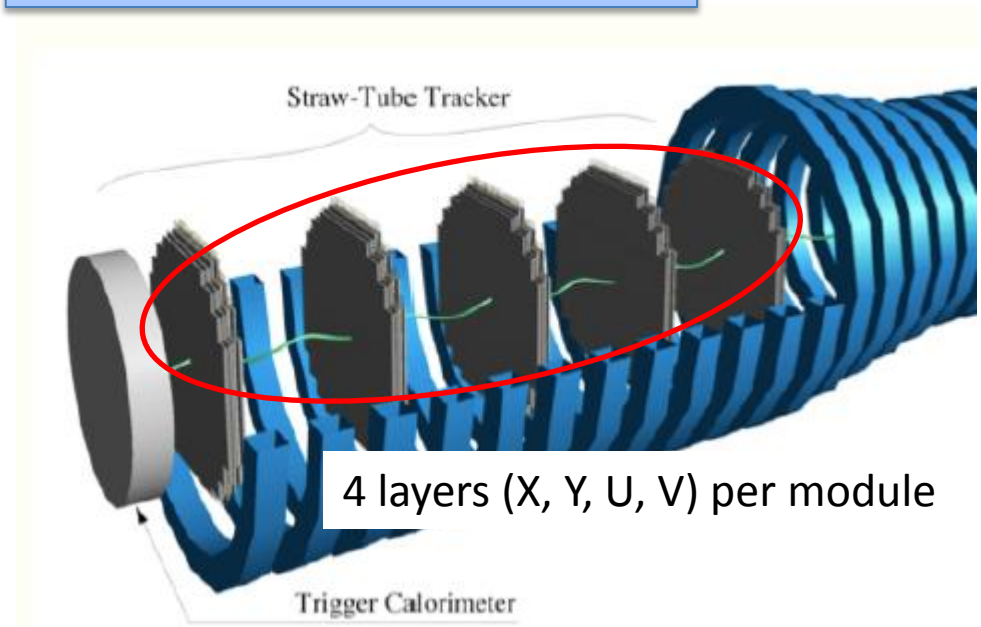
Scale back the influence of multiple scattering

（lessen amount of material, place in vacuum）

Histogram of momentum



Straw tube Tracker



4 layers (X, Y, U, V) per module

- Detector in vacuum
  It is very difficult to operate popular chamber in vacuum

Use of straw tube
（Small amount of material and operation in vacuum）

Main specification of straw tube

Diameter	5mm
Thickness	25μm
Number of channel	4160ch
Position resolution	100～200μm
Drift velocity（Ar/C_2H_6）	4.8cm/μsec
Assumed minimum charge	16fC

Low consumed power

Time resolution：2nsec

Amplifier