A MWDC array for the external target experiment at HIRFL-CSR

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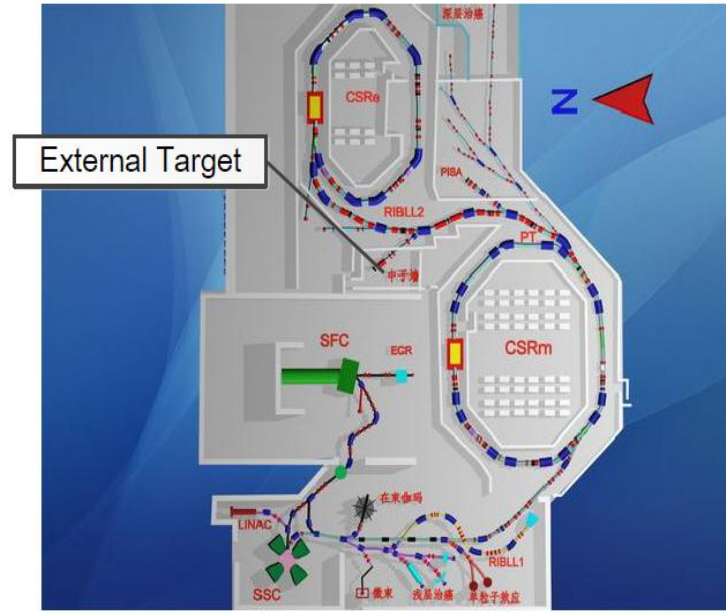
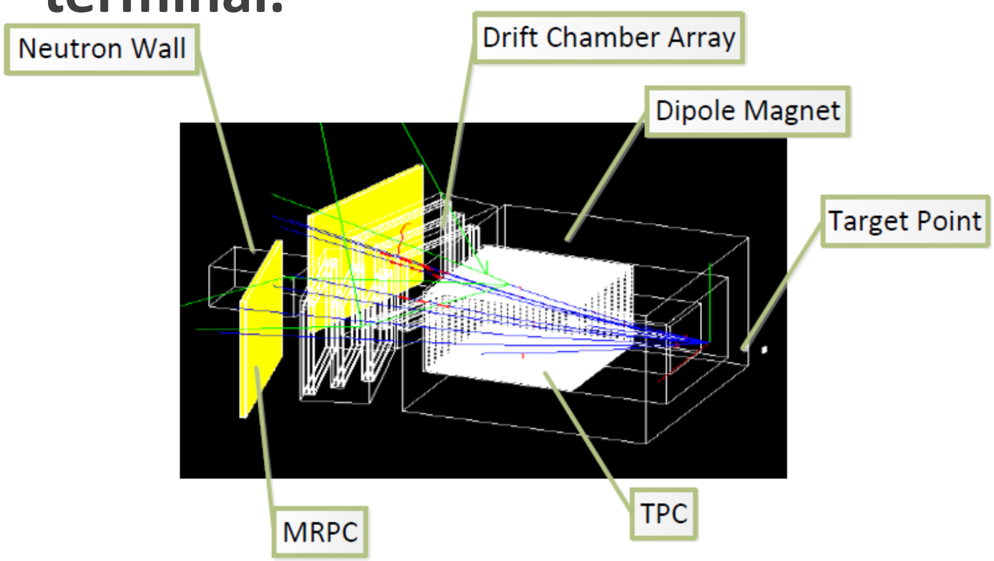
CONTENTS

Research of high energy physics in China



CSR External Target Experiment:

Based on the HIRFL-CSR, a high performance spectrometer system is proposed to be built at the HIRFL-CSR external target experiment terminal.

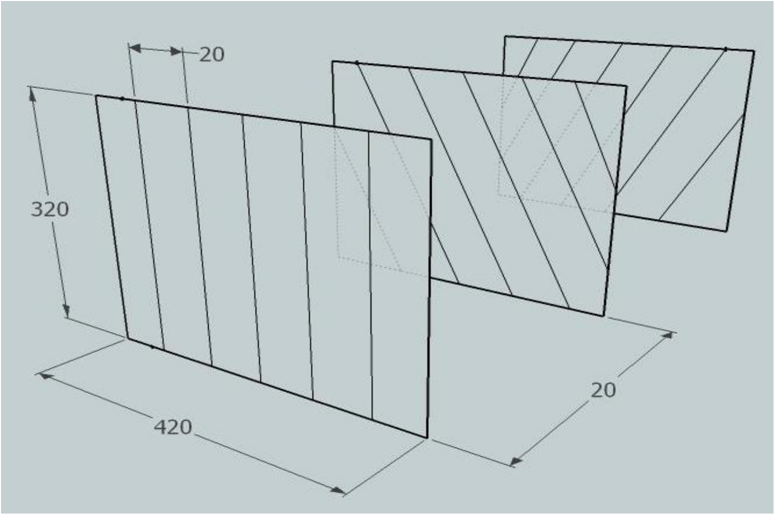


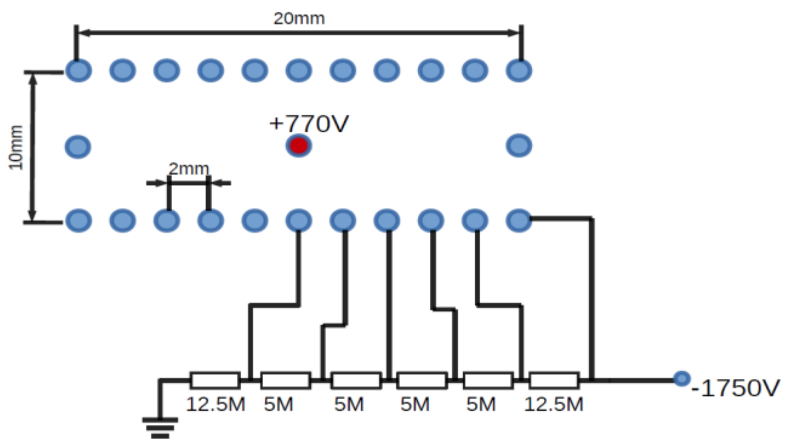
subsystem：

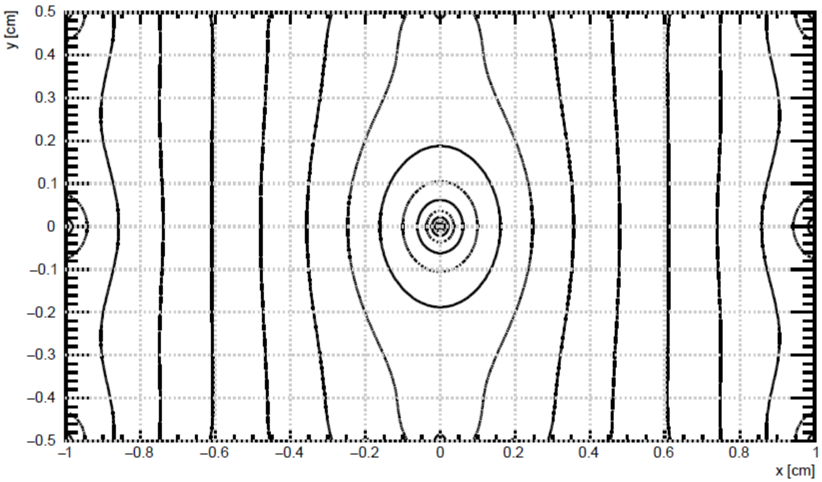
1） silicon detector at target point
2） TPC
3） TOF (MRPC)
4） forward tracker (MWDC)
5） hadron calorimeter (neutron wall)

Structure of MWDC

planar structure:
wires angle: 0°, ±30°
sensitive area: 320mm*420mm
distance between anode wires: 20mm
distance between field wires : 20mm
anode wires: 20μm gold-plated tungsten wire
field wires: 100μm Be-plated copper wire
working gas: Ar/CO2 = 85/15

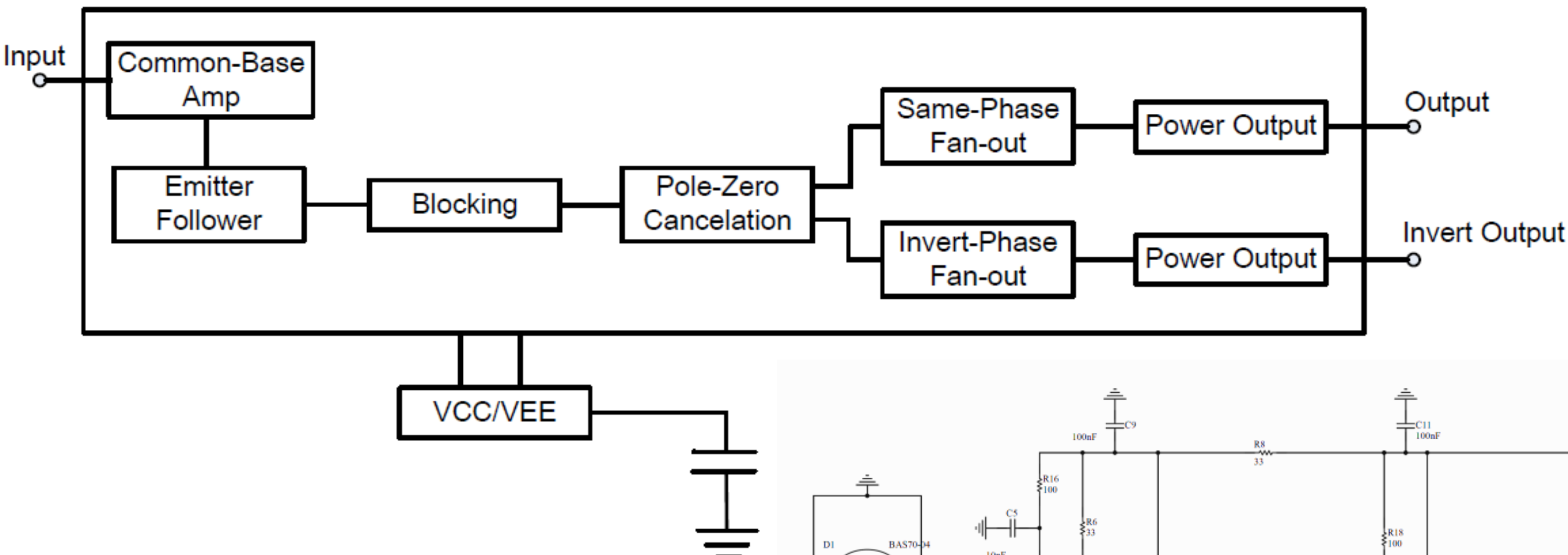


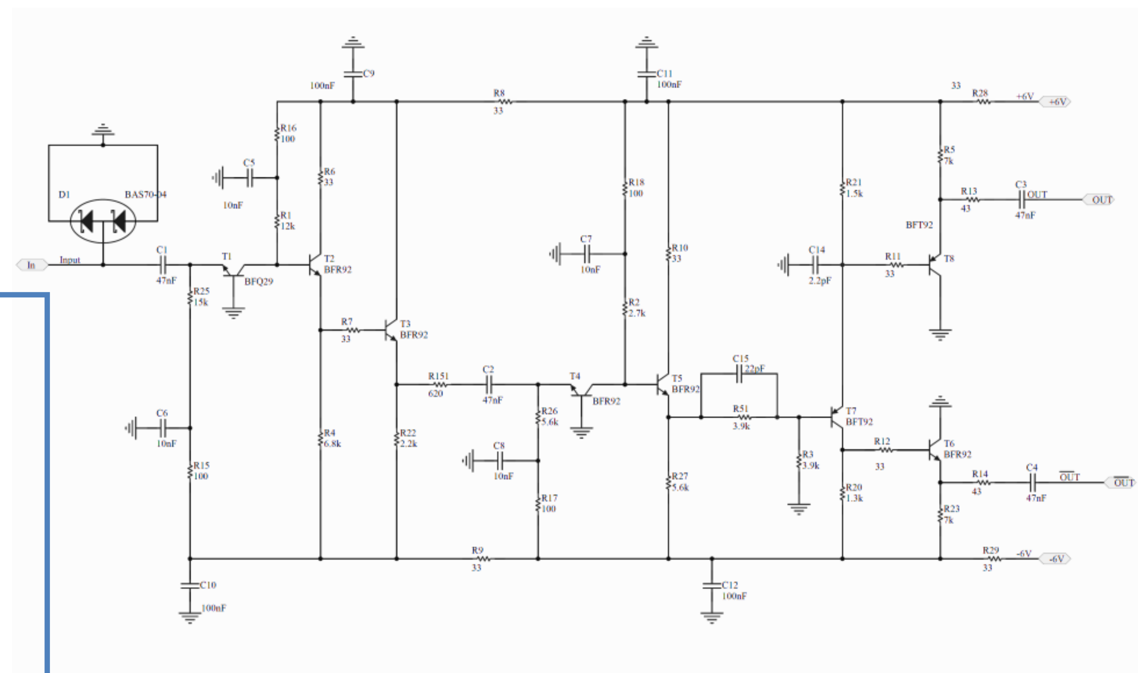




Equipotential lines distribution simulated by Garfield ++.

Pre-Amplifier





Design of Pre-Amplifier：

1） low power dissipation

2） high gain and wide bandwidth

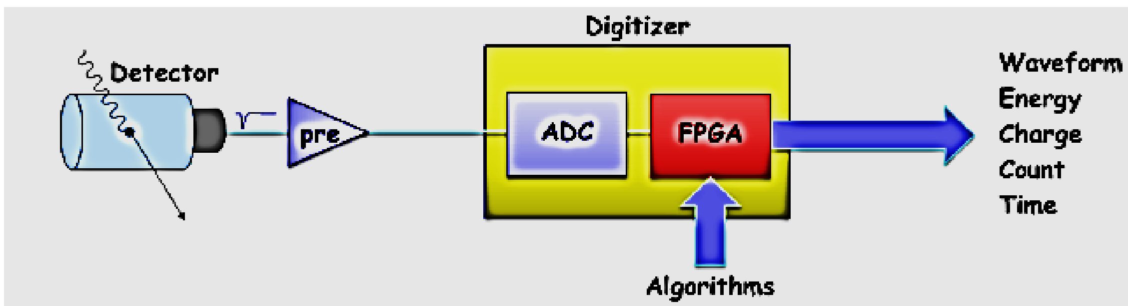
3） high time resolution

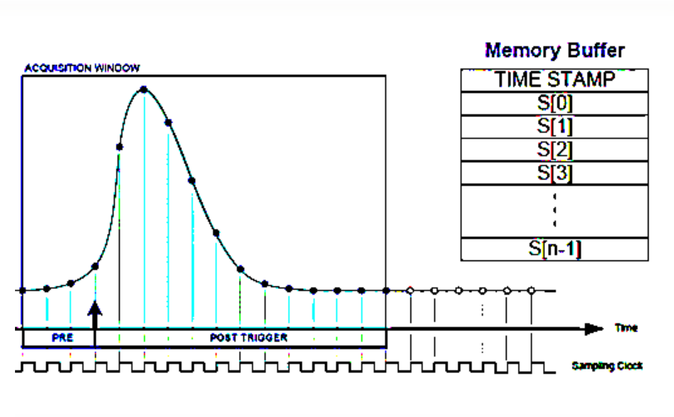
4） high energy resolution

5） high signal noise ratio

Flash-ADC Data Acquisition system (DAQ)

Sampling the whole wave forms of detectors to get the time an energy information and analysis events with complex ware forms.





DAQ architecture

CAEN-V1720 module

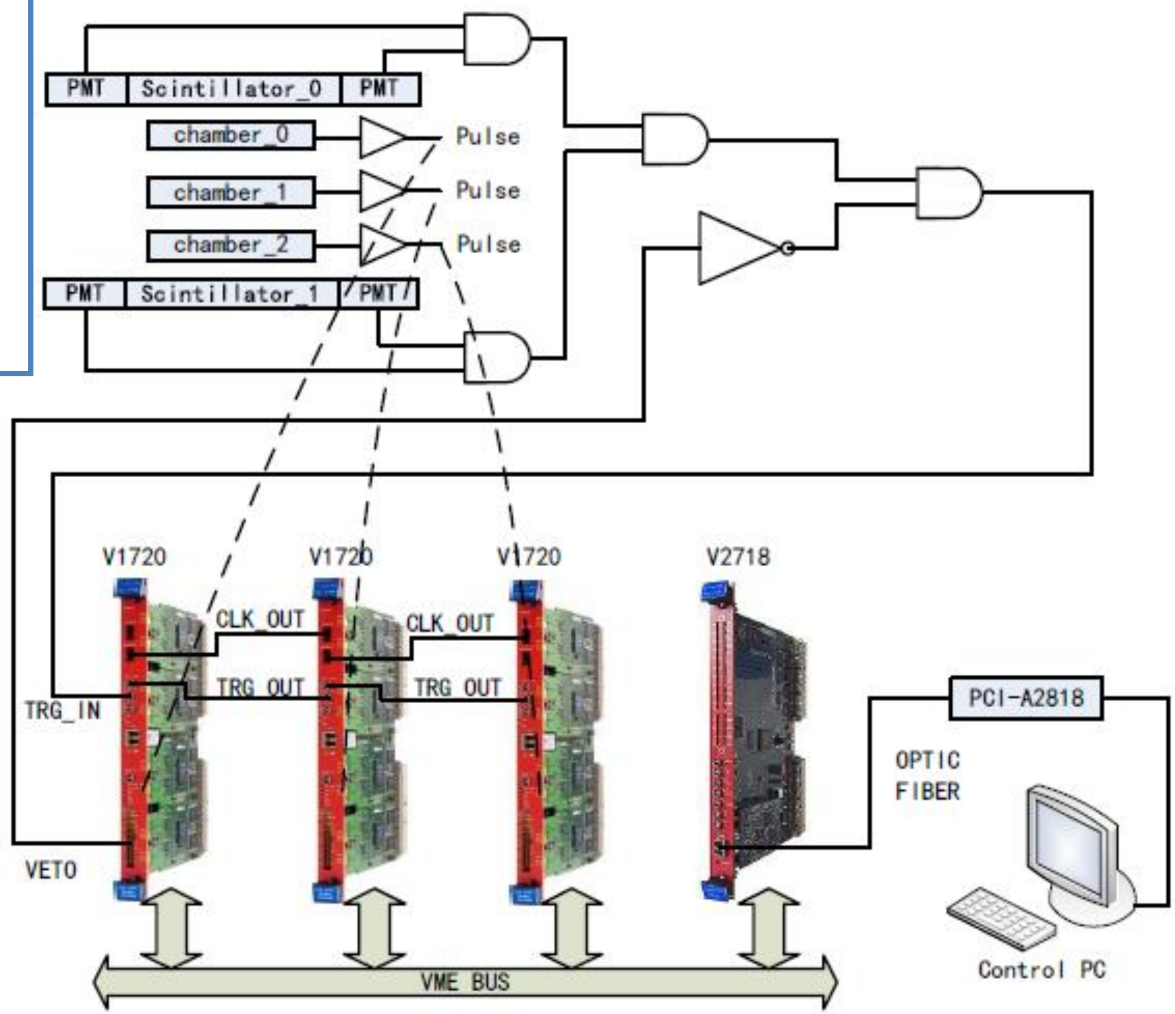
ADC： 12bit

Dynamic range： 2Vpp

DC offset： ±1V

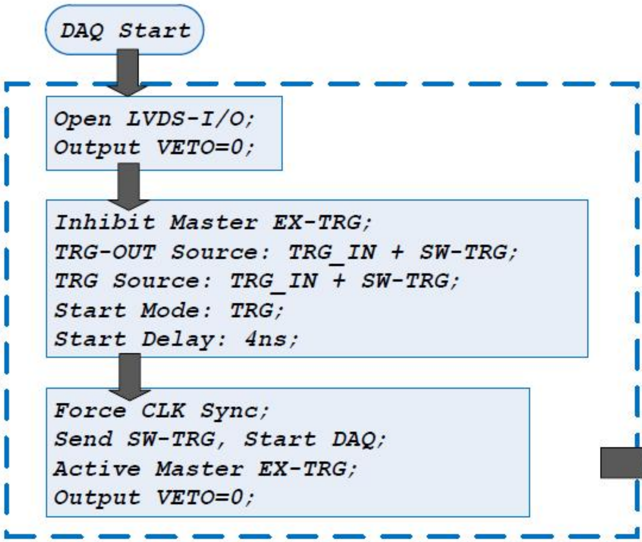
Sampling frequency： 250MHz

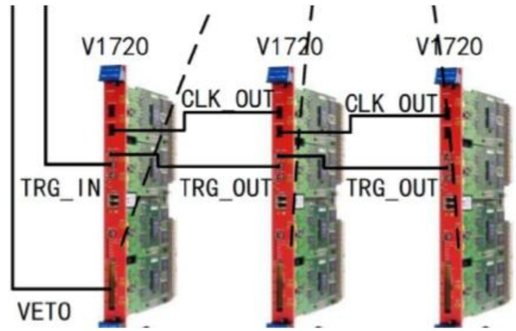
Data transmission： 80MB/s



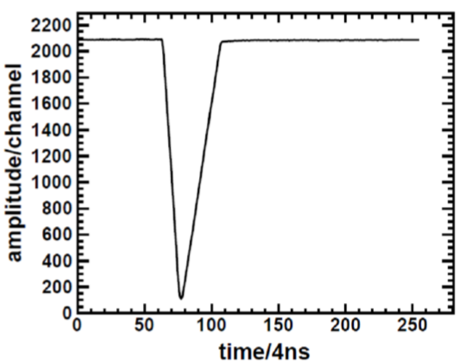
Clock signal is generated by the master and transmitted to the slaves. Trigger signal is the coincidence of the four PMTs and transmitted to the slaves through the daisy chain.

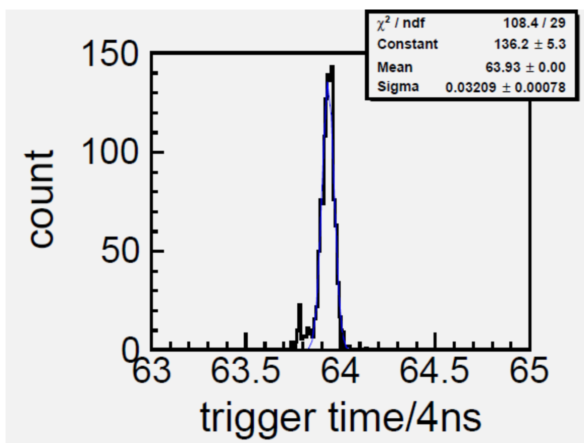
DAQ clock synchronization



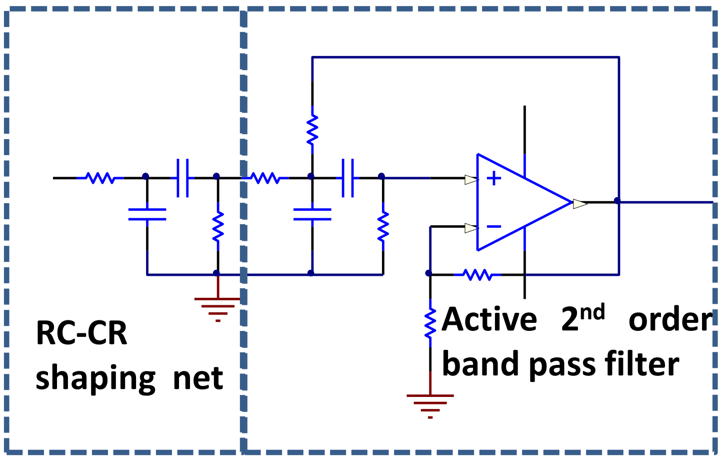


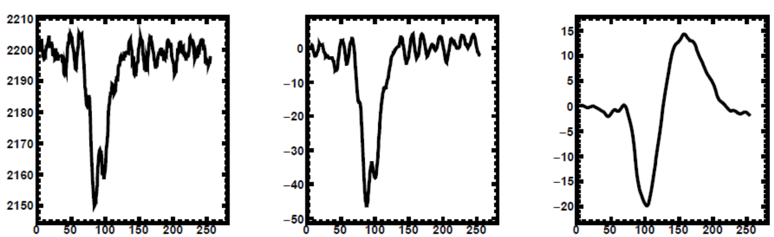
Test the time walking between different boards using a test pules. The sigma of the time walking distribution is 128ps.





Digital filter algorithm





Derive the digital filter algorithm according to the transfer function:

1) **RC-CR shaping net;**
2) **digital active 2nd band pass filter.**

Digital RC-CR shaping net recursive algorithm:

$$y(k) = \frac{A\tau_2}{\tau_2 - \tau_1}\left[\frac{\tau_1}{T}\left(1 - e^{-T/\tau_1}\right)y_1(k) - \frac{\tau_2}{T}\left(1 - e^{-T/\tau_2}\right)y_2(k)\right]$$

$$y_i(k) = \frac{T}{\tau_i}x(k) + e^{-T/\tau_i}y_i(k-1),\quad y_i(0) = \frac{T}{\tau_i}\cdot\frac{x(0)}{1 - e^{-T/\tau_i}}$$

Digital band pass filter:

1) transfer function of analog filter:

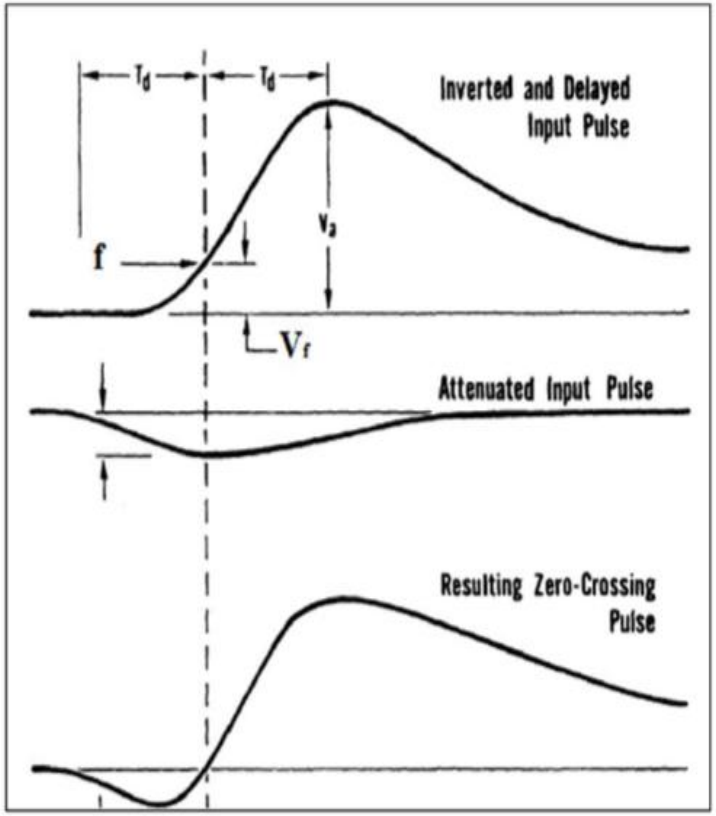
$$H(s) = \frac{A\,s/\omega}{1 + \frac{s/\omega}{Q} + (s/\omega)^2}$$

2) transfer function of digital filter:

$$H(z) = A\omega T\,\frac{1 - e^{-\alpha\omega T}\left(\cos\beta\omega T + \frac{\alpha}{\beta}\sin\beta\omega T\right)z^{-1}}{1 - 2e^{-\alpha\omega T}(\cos\beta\omega T)z^{-1} + e^{-2\alpha\omega T}z^{-2}}$$

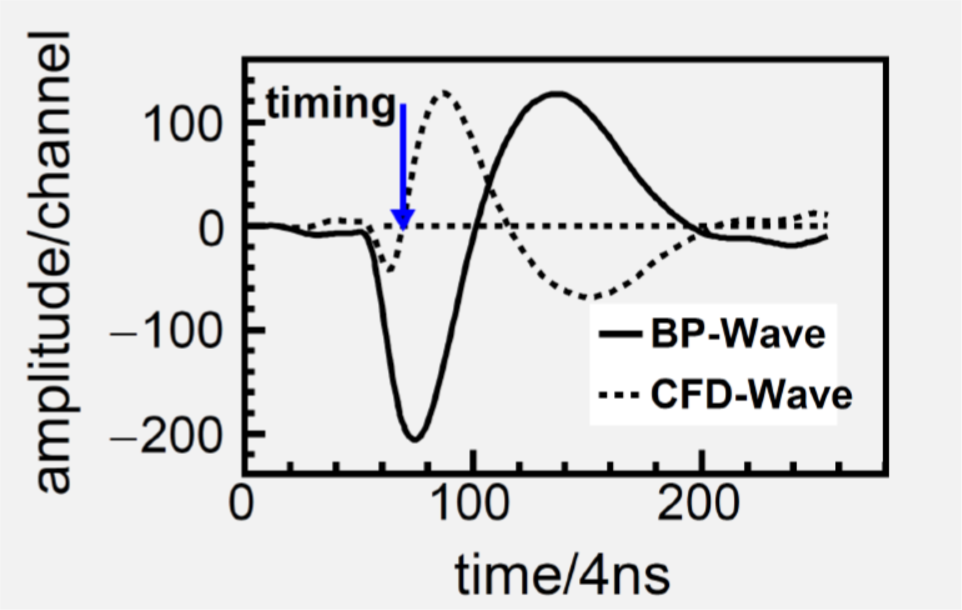
Deduce the energy and time information with the filter output waveform.

Digital CFD

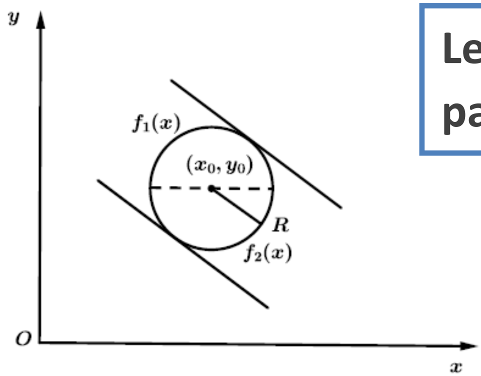


The CFD waveform is the sum of the delayed waveform and the inverted and attenuated waveform:

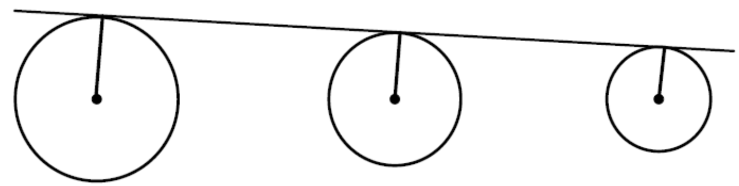
$$y(k) = x(k-d) - \gamma x(k)$$



Track finding algorithm-Legendre transformation



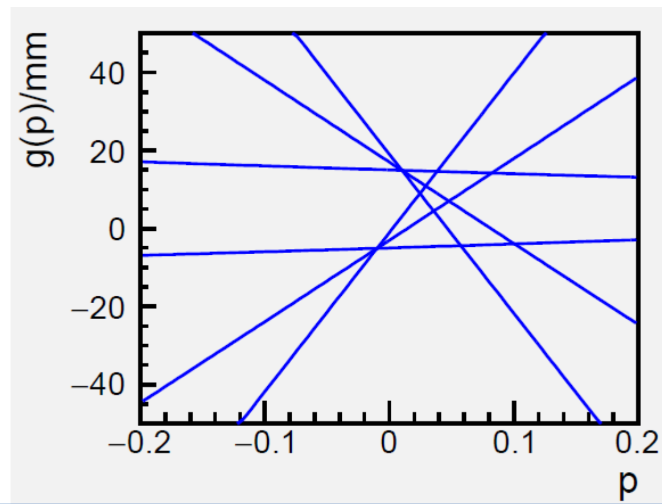
Legendre transformation of the upper-half and lower-half part of a circle.



$$f(x) = \begin{cases} f_1(x) = y_0 + \sqrt{R^2 - (x - x_0)^2} \\ f_2(x) = y_0 - \sqrt{R^2 - (x - x_0)^2} \end{cases}$$

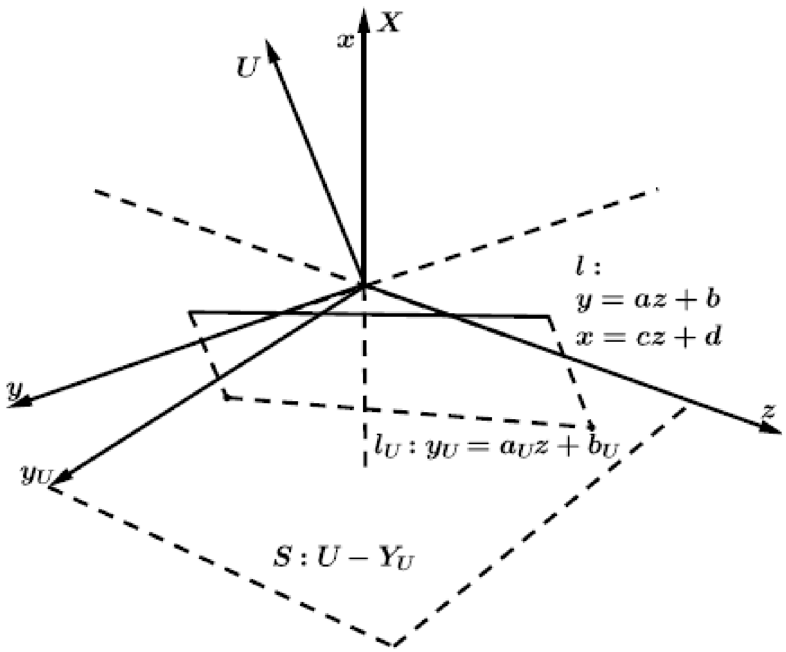
$$\begin{aligned} g_1(p) &= f_1(x_0) - px_0 \\ &= y_0 - px_0 + \frac{R}{sqrtp^2 + 1} + \frac{p^2 R}{\sqrt{p^2 + 1}} \\ &= y_0 - px_0 + R\sqrt{p^2 + 1} \end{aligned}$$

$$\begin{aligned} g_2(p) &= f_2(x_0) - px_0 \\ &= y_0 - px_0 - R\sqrt{p^2 + 1} \end{aligned}$$



Find the common point in the Legendre space to get the common tangent line in the x-y space.

Analytical solution for track reconstruction



Use Least Square method to reconstruct the track in the projection space.

$$\chi^2 = \sum_i \left(r_i - \frac{k_i z_i + b_i - y_i}{\sqrt{1+k_i^2}}\right)^2$$

$$\chi^2 = (R - \lambda - Aq)^T (R - \lambda - Aq)$$

$$q = (A^T A)^{-1} A^T (R - \lambda)$$

$$\begin{cases} y = az + b \\ x = cz + d \end{cases}$$

$$d_i = \frac{k_i z_i + b_i - y_i}{\sqrt{1+k^2}}$$

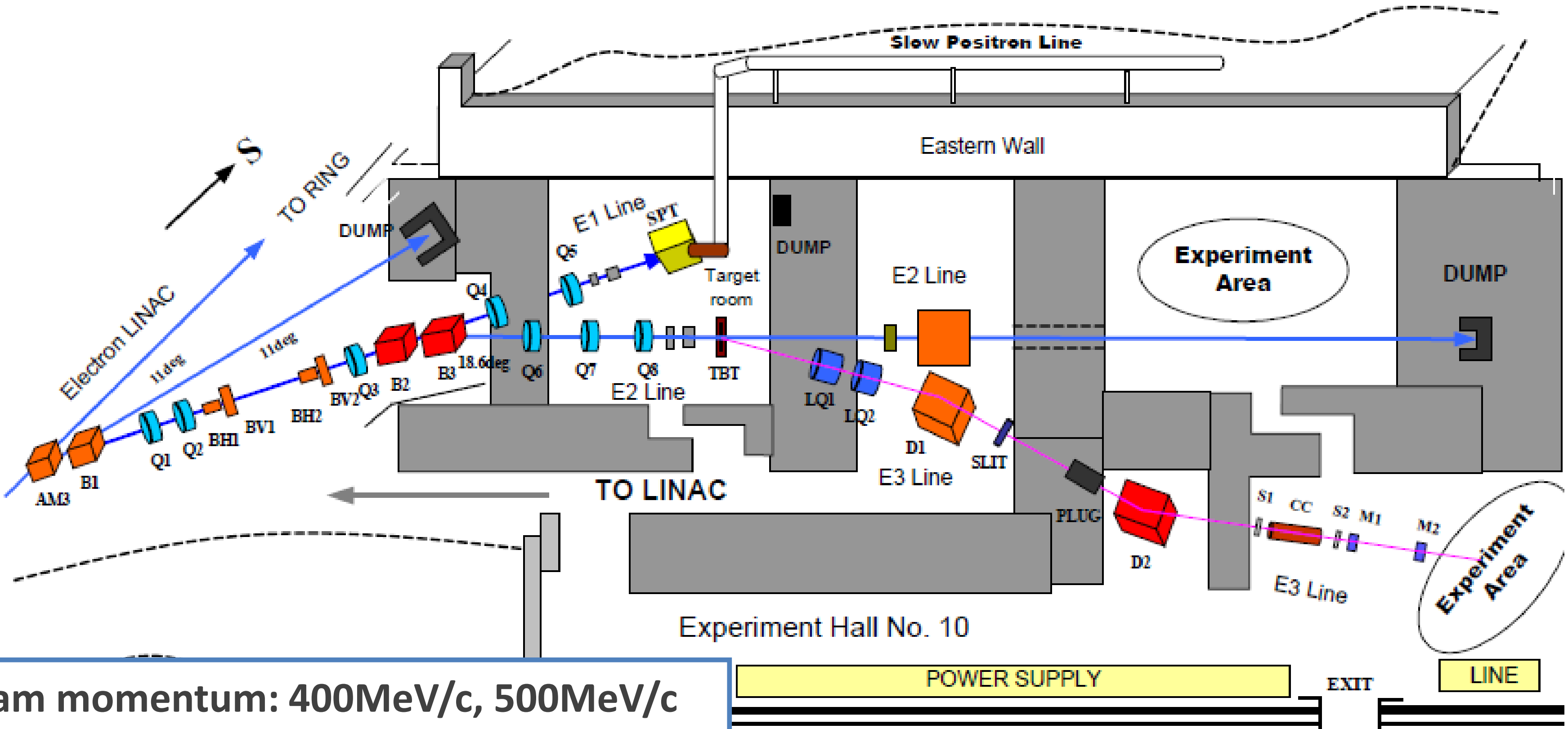
$$k_i = a \sin\theta_i + c \sin\theta_i$$

$$b_i = b \cos\theta_i + d \sin\theta_i$$

$$y_i = (a\cos\theta_i + c\sin\theta_i) z + (b\cos\theta_i + d\sin\theta_i)$$

Beam test

Beam test is done at the E3 Test Line at IHEP. The beam is guided to the test hall through the E3 line.



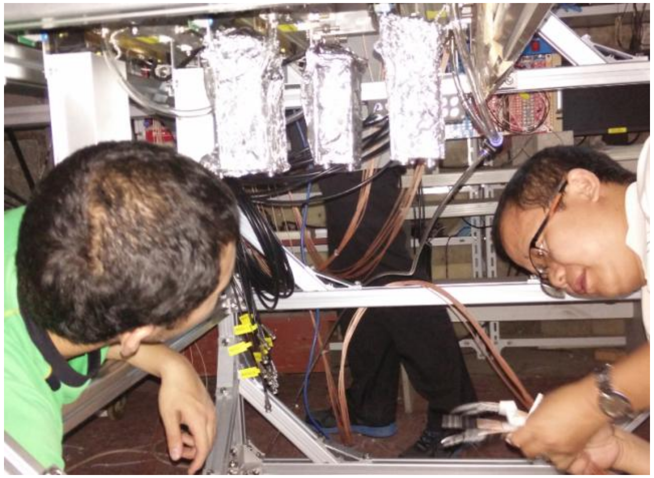
Beam momentum: 400MeV/c, 500MeV/c

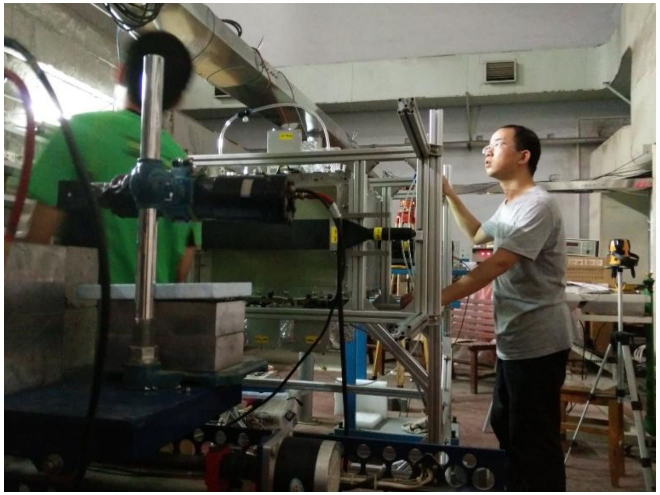
Particle: proton, pion

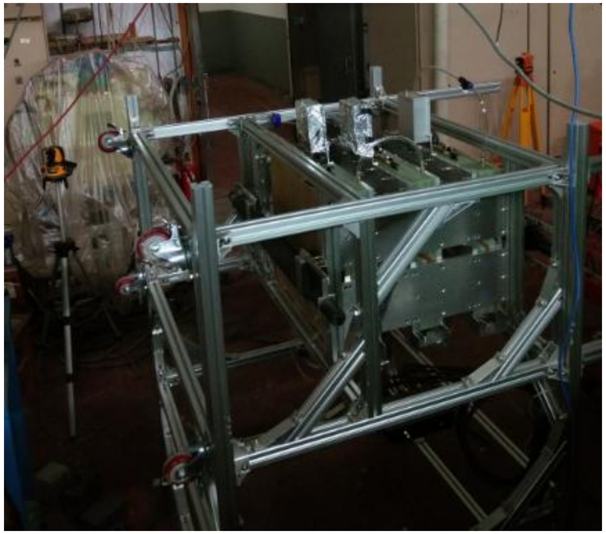
Count rate: ~100/min

Beam test

Working photos

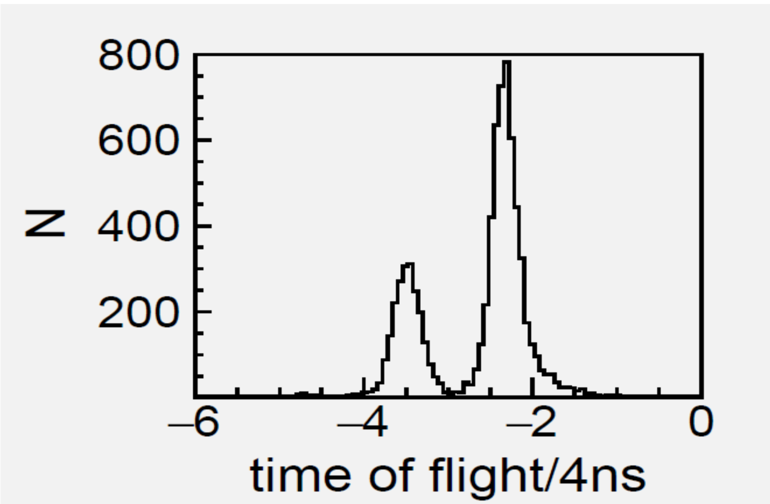


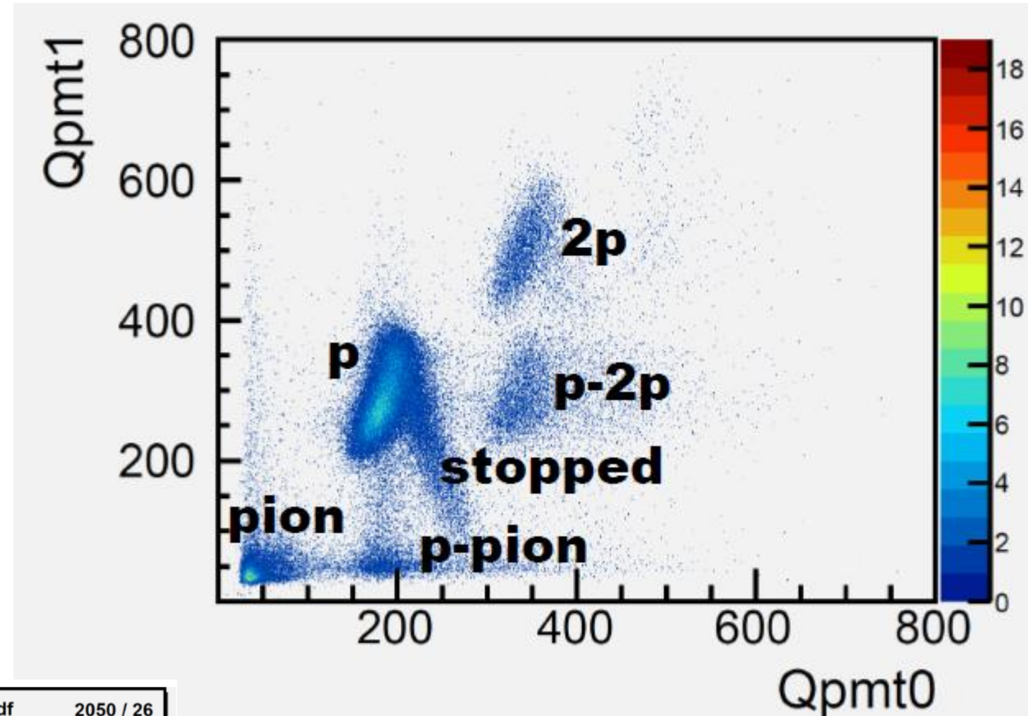


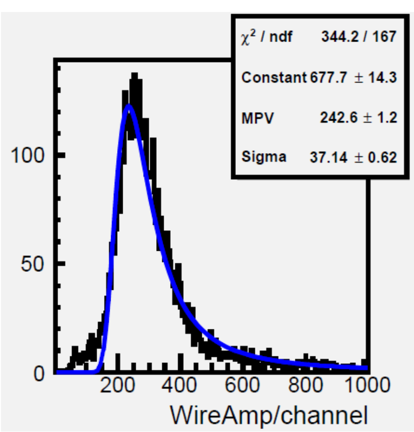


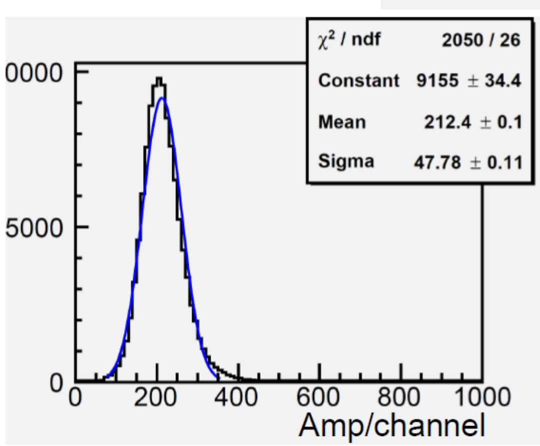
Data analysis

TOF has a time resolution of 600ps. Select single proton event to analysis.



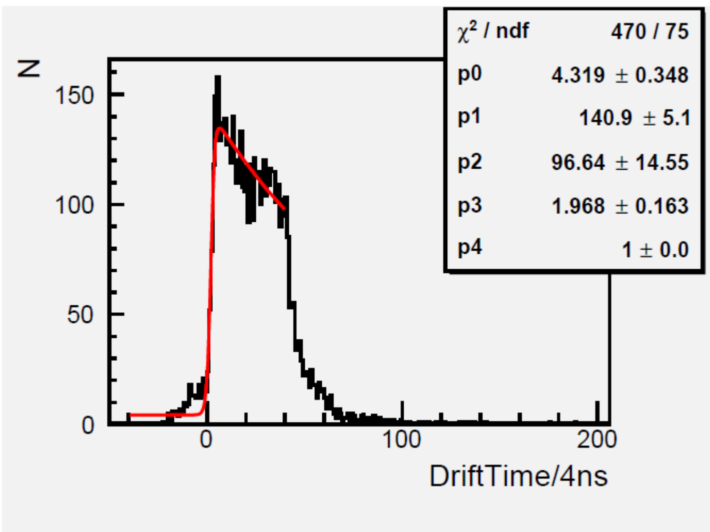






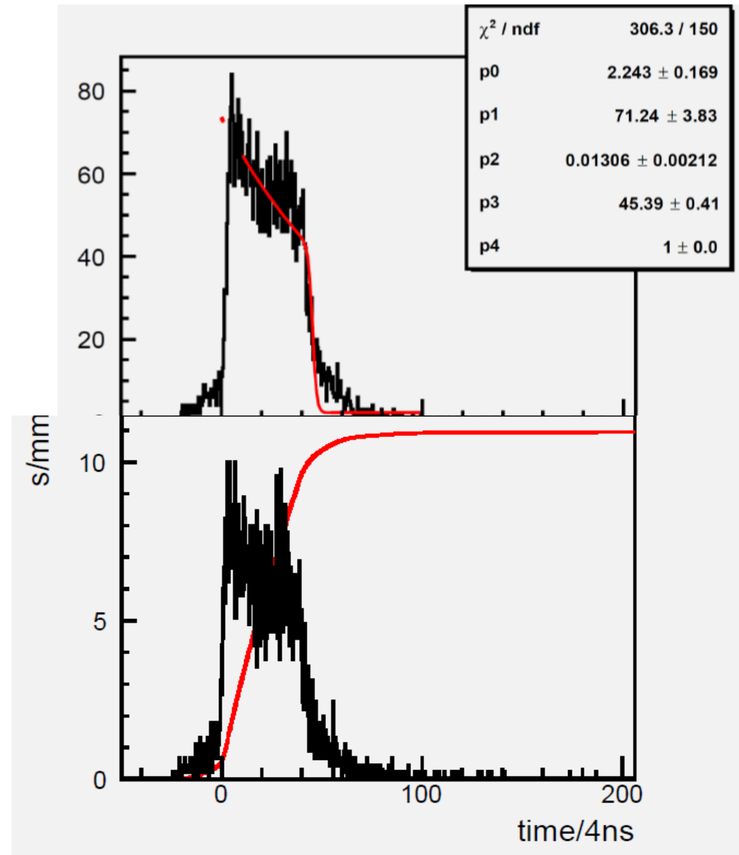
Use truncated mean method to get the energy resolution of the chamber. The relative energy resolution is 22.5%。

Fit zero point of drift time distribution and get the space-time relation



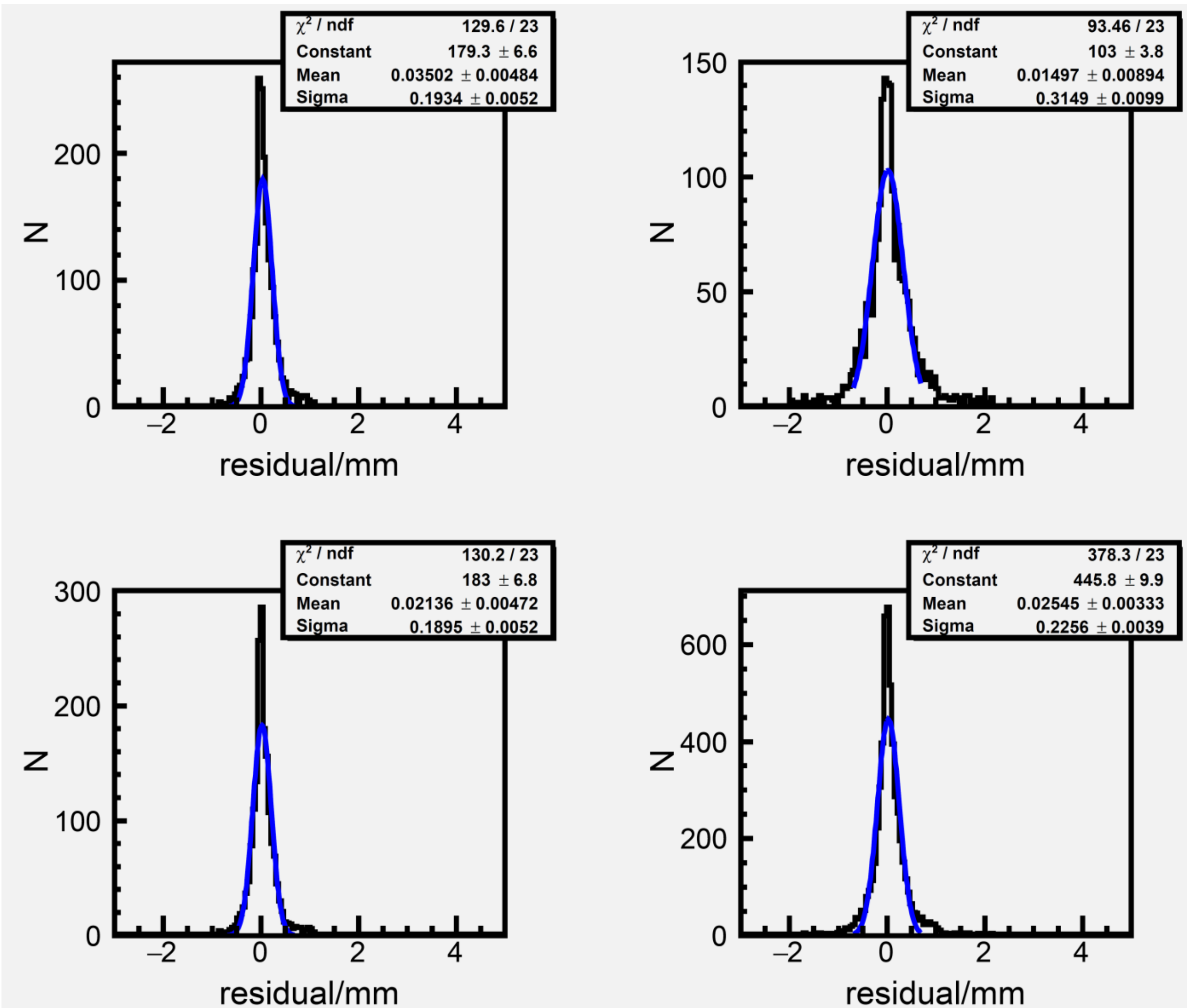
Function that used for fitting:

$$N = B + A\frac{e^{-t/\tau_1}}{1+e^{(t-T_0)/\tau_2}}$$



Get the space-time relation by integral the drift time distribution.

Tow dimension space resolution

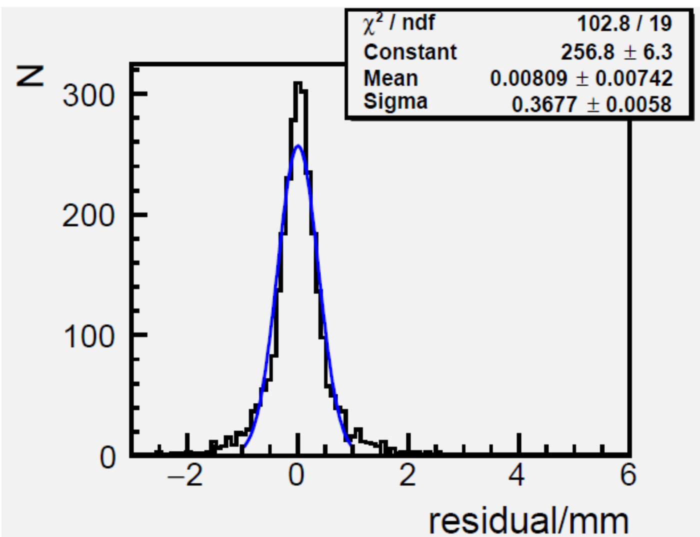


Do track reconstruction with data of wires in the one direction.

The tow dimension resolution is 226μm.

Three dimension space resolution

Do three dimension track reconstruction. The resolution is 368μm.



$$\sigma^2 = \sigma_{TOF}^2 + \sigma_{STR}^2 + \sigma_{T_0}^2 + \sigma_{Timing}^2 + \sigma_I^2 + \sigma_{Mech}^2 + \sigma_{DAQ}^2$$

System errors：

TOF error σ_{TOF}: 30μm

STP error σ_{STR}: 100μm

DAQ clock error σ_{DAQ} : 1.6μm

T0 error σ_{TOF}: 10μm

initial resolution σ_{TOF}: 100μm

mechanical error σ_{Mech}: 335μm

Timing error: 50μm

summary

- A MWDC array is built and tested.
- The Pre-Amplifier is designed.
- The DAQ is developed.
- Digital filter and track reconstruction algorithm is developed.
- The current space resolution is 368μm.

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Thank you !