

Silicon timing detector in IHEP test beam

梁志均

Zhijun Liang,
on behalf of IHEP HGTD team

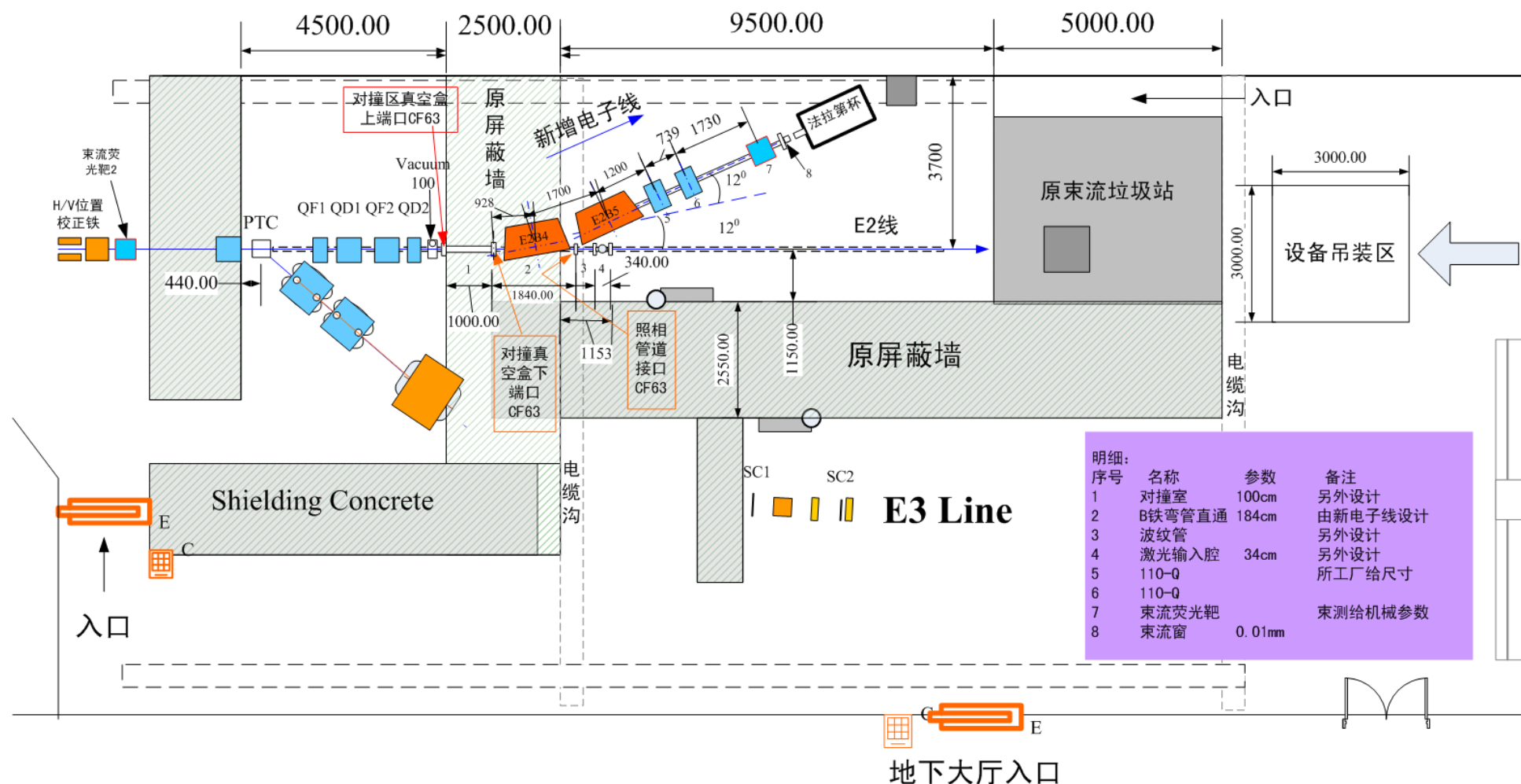
Beijing TestBeam 2020



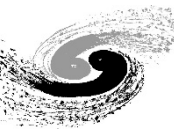
➤ E3 Beam line : Secondary particle beam

➤ Mixed with proton/pion ..

➤ 500MeV ~ 1GeV



Ultra-fast silicon sensor R & D



➤ Low gain avalanche diode(LGAD)

- Radiation hard, **Medium gain**, High S/B, **fast timing**, **no self-triggering**

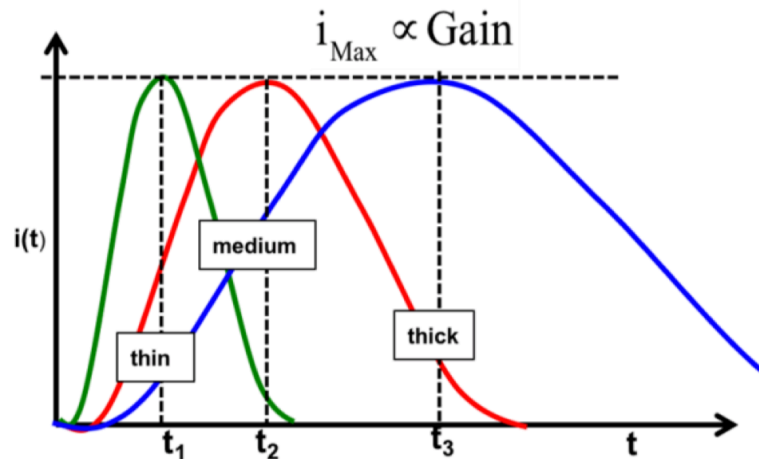
$$\sigma_t^2 = \sigma_{TimeWalk}^2 + \sigma_{LandauNoise}^2 + \sigma_{Distortion}^2 + \sigma_{Jitter}^2 + \sigma_{TDC}^2$$

➤ Landau Noise term

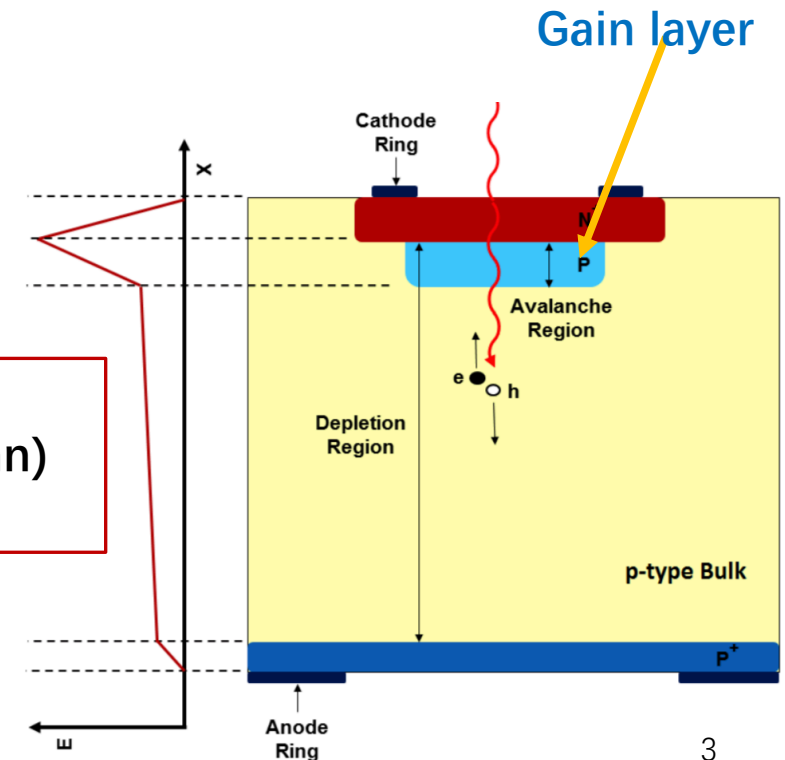
- Signal fluctuation due to non-uniform charge deposition
- Minimized by reducing thickness of sensor to **50μm**

➤ Jitter term

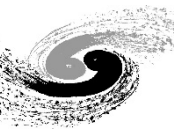
- Need **gain layer** to increase S/N
- Thin detector to decrease rise time



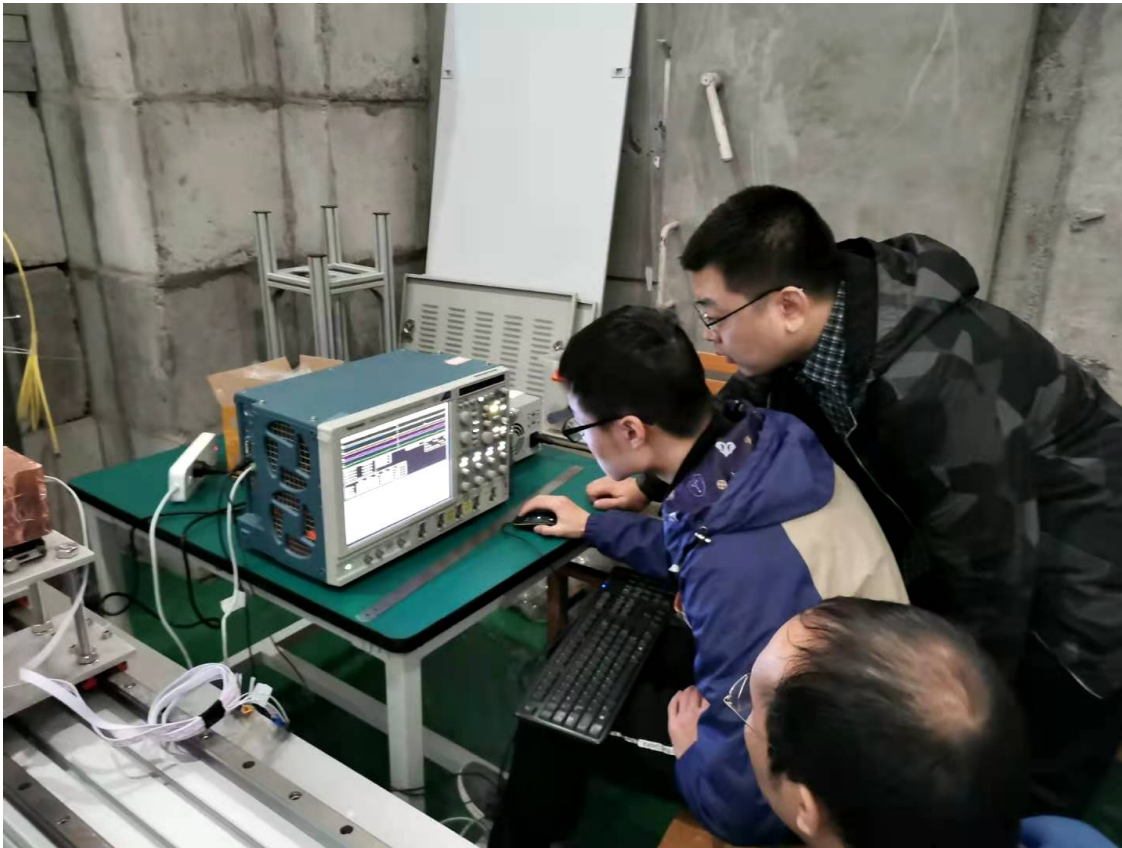
Manufacturers of LGAD
CNM (Spain), HPK (Japan)
FBK (Italy), NDL (China)



Silicon timing detector team



- 3 postdocs and 4 students participated testing
 - Postdoc : Bo Liu, Xuan Yang, Yunyun Fan 樊云云
 - 学生 : MengZhao Li 、 Shuqi Li, Chengjun Yu, Han Cui



Test beam at IHEP 2020

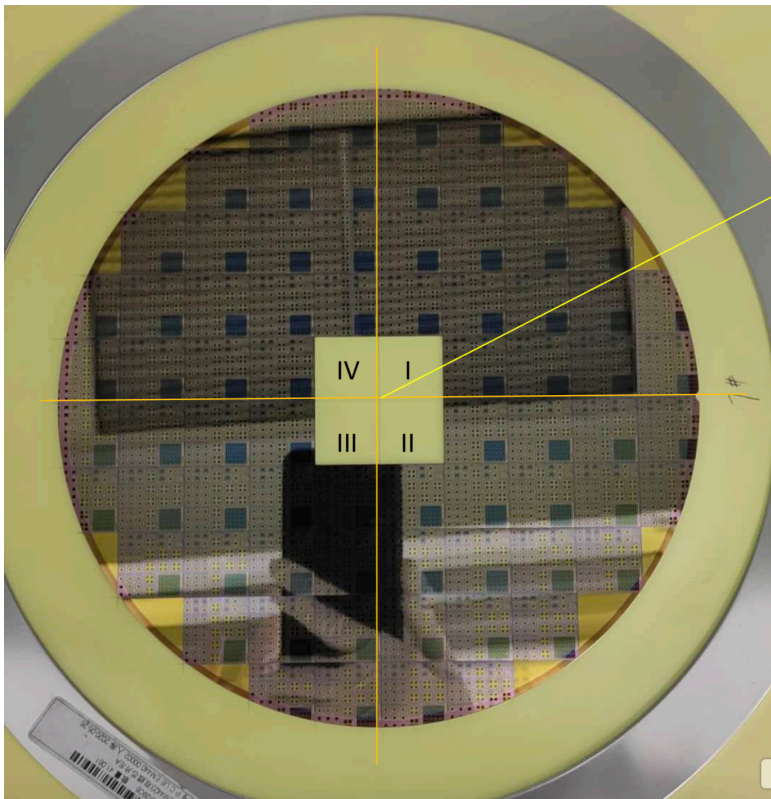
4 layer of silicon timing sensors

- IHEP-IME LGAD (3mm*3mm) $\sigma_t=39\text{ ps}$
- CH2 : HPK type 3.1(6.5mm*6.5mm) $\sigma_t= 63\text{ ps}$
- CH4 : HPK type 3.1 (6.5mm*6.5mm) $\sigma_t= 77\text{ps=}$

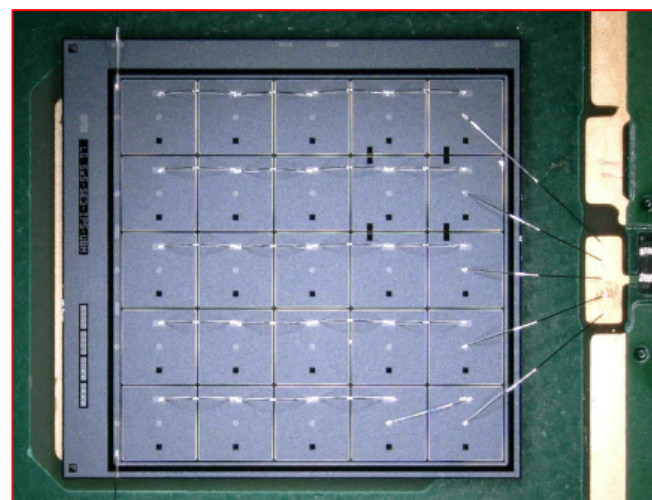
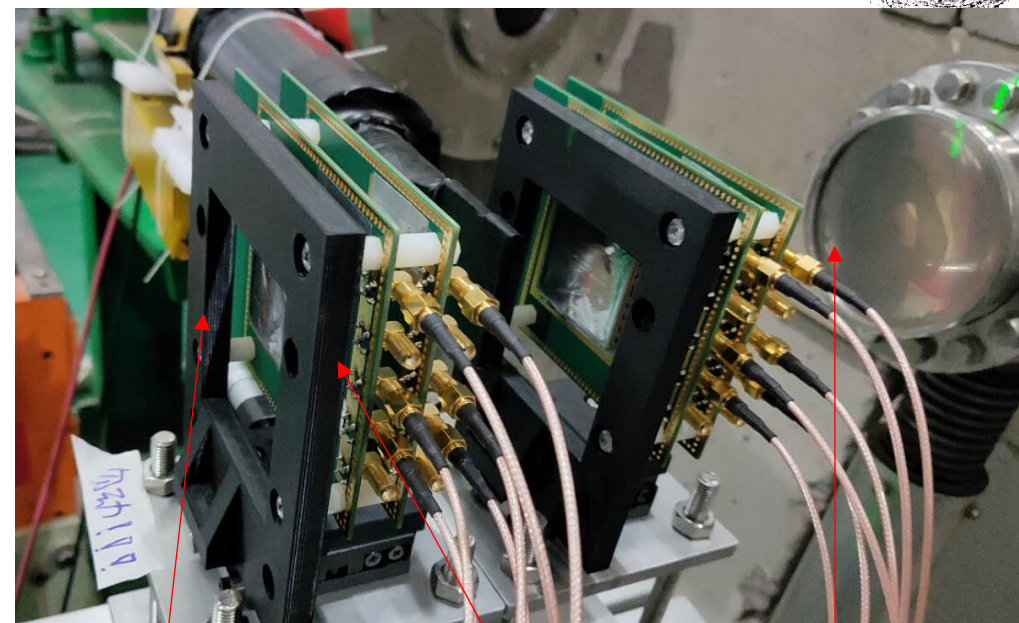
IHEP-IME LGAD:

IHEP team design(赵梅, 杨涛, 吴科伟)

39ps time resolution (in beta tests)



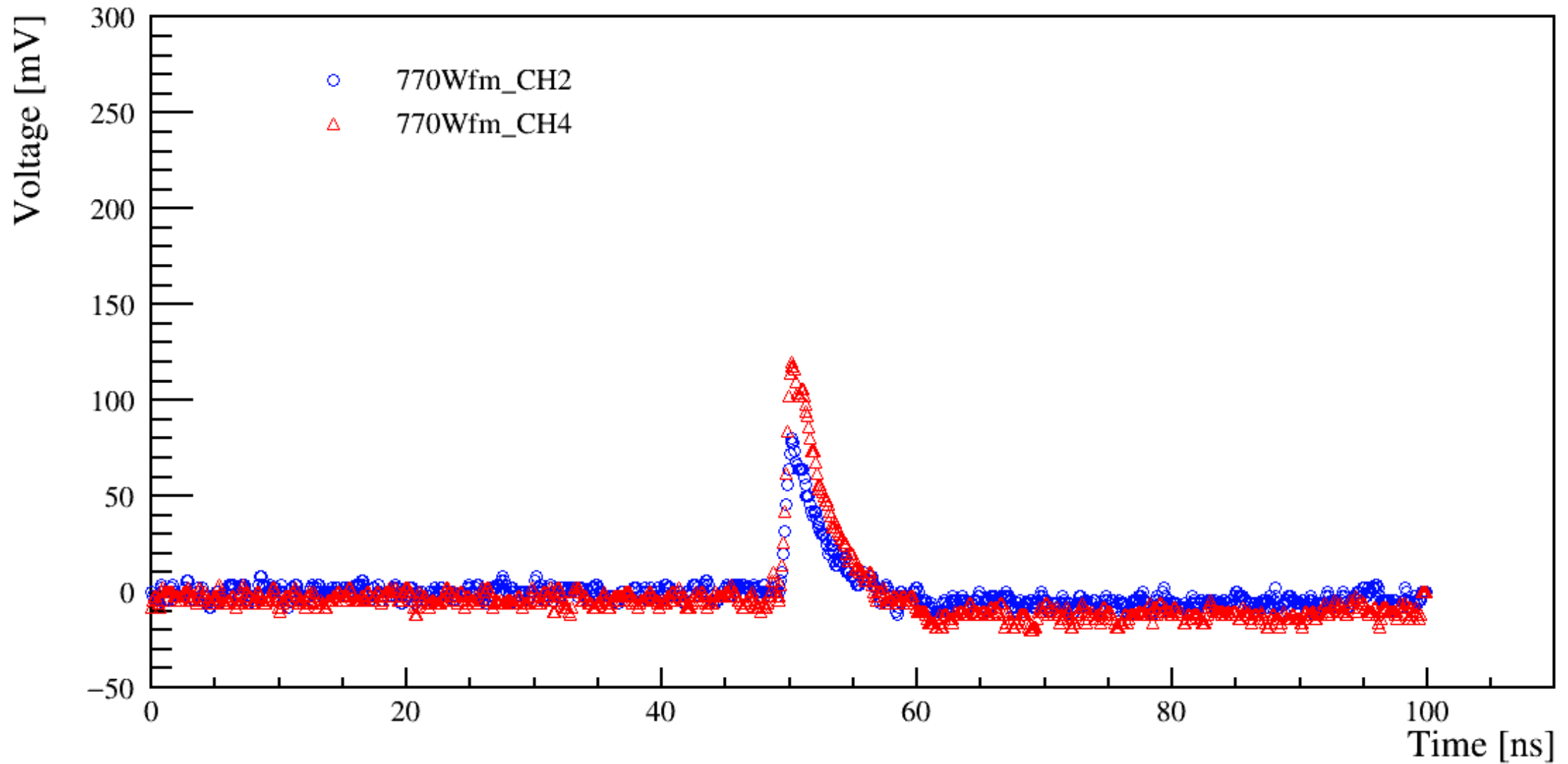
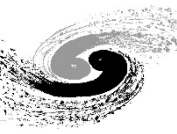
HPK sensors
5*5 array
Single channel readout

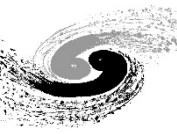


Distance L

Beam exit

Typical signal events for silicon timing detector





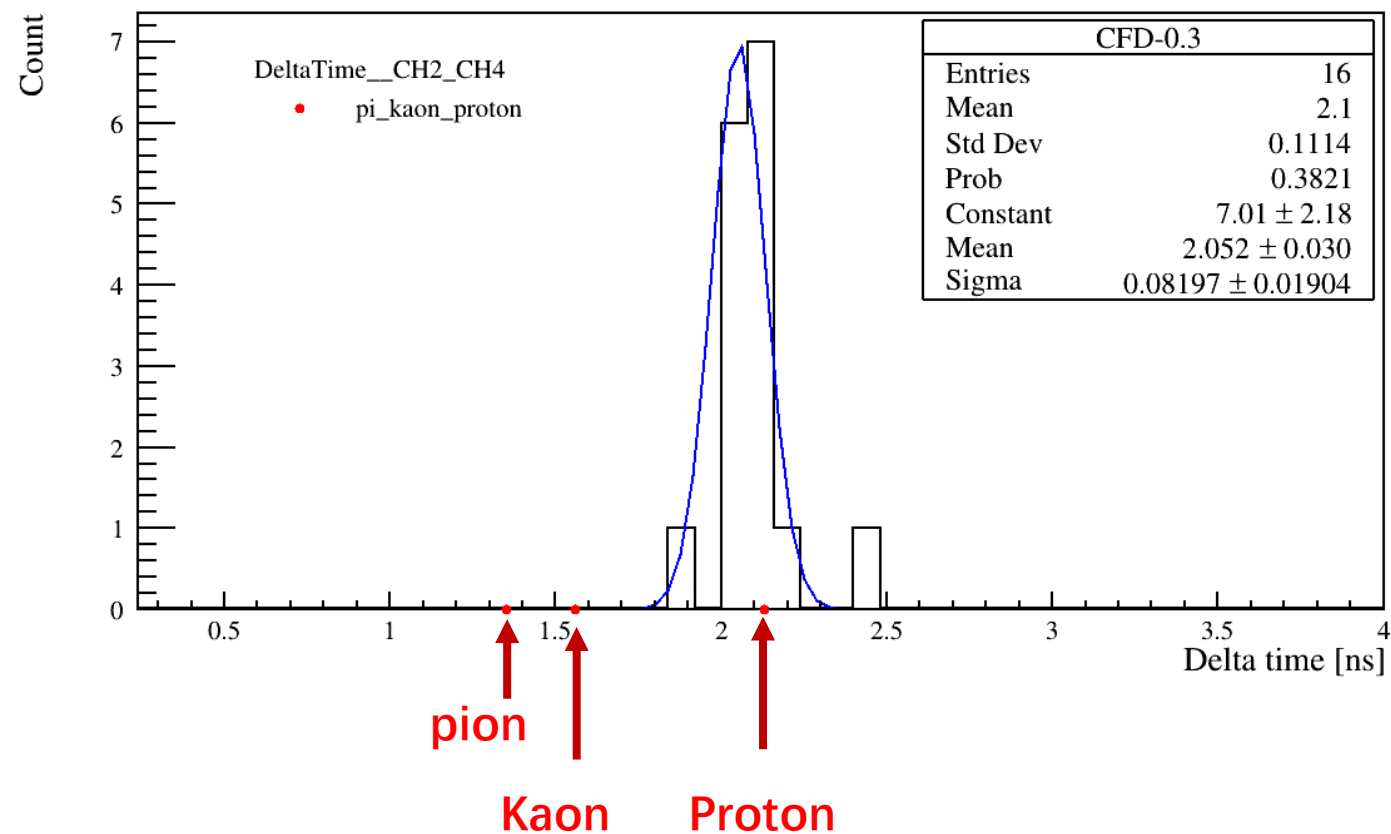
Period I : Distance between sensors (L=400mm)

10.28 20:00 ~ 10.29 16:00

Distance **L=400mm** Energy **800MeV**, 16 events with double trigger

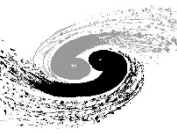
Most of beam particle are proton

$$L = 40cm$$



	0.5GeV	0.8GeV	1.0GeV
p(ns)	2.98142	2.13437	1.88562
pi(ns)	1.38461	1.3536	1.34634
kaon(ns)	1.87434	1.56705	1.48715

Expected flight time (ns)

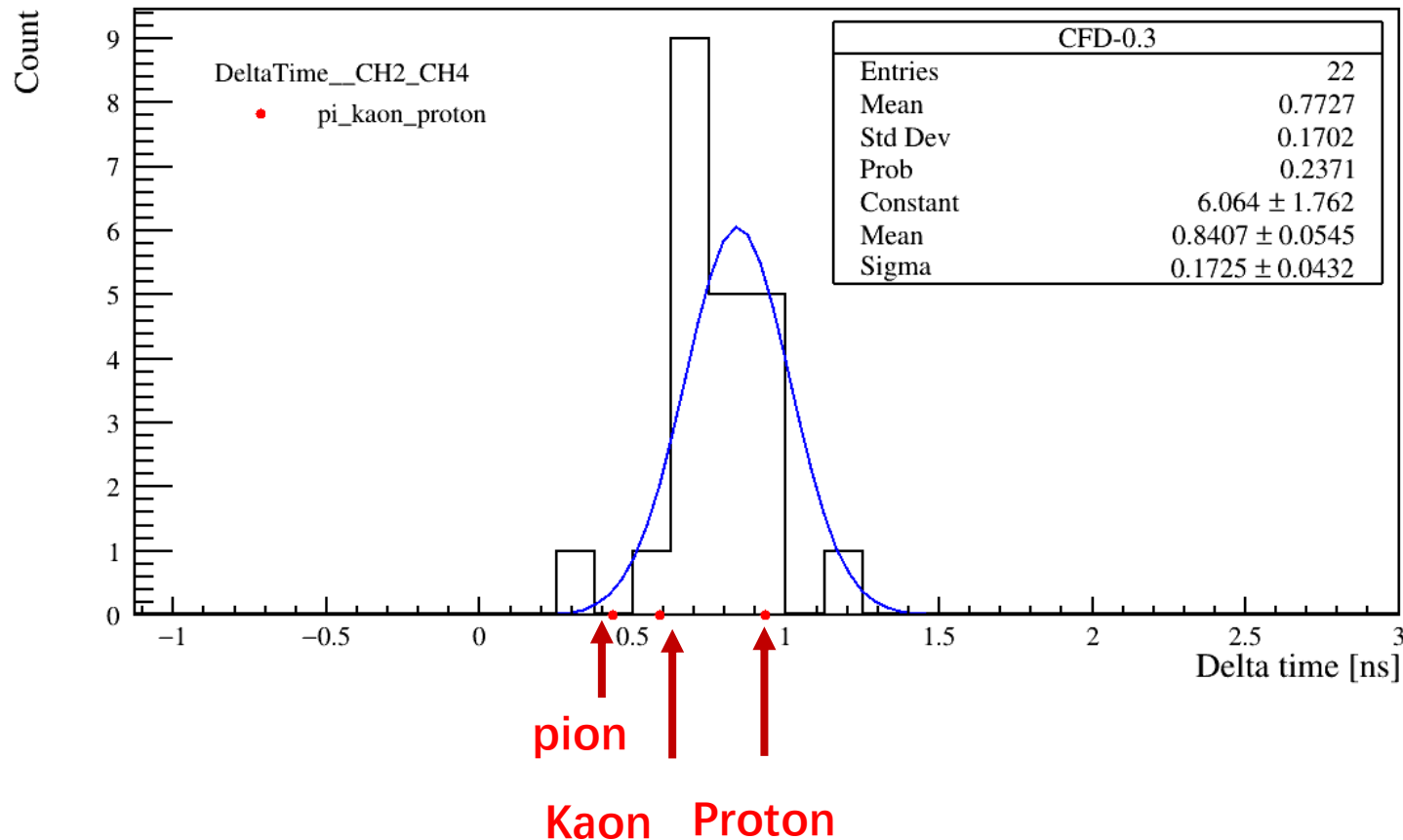


Period II : distance between sensors (L=125mm)

10.30 16:45 ~ 10.31 9:30

Distance **L=125mm** Energy **500MeV**, 22 events with double trigger

Most of beam particle are proton-like



$L = 12.5cm$

	0.5GeV	0.8GeV	1.0GeV
p(ns)	0.931695	0.666992	0.589256
pi(ns)	0.432692	0.422999	0.42073
kaon(ns)	0.585731	0.489704	0.464735

Period III : distance between sensors (L=17mm)



10.31 12:08 ~ 11.3 9:40

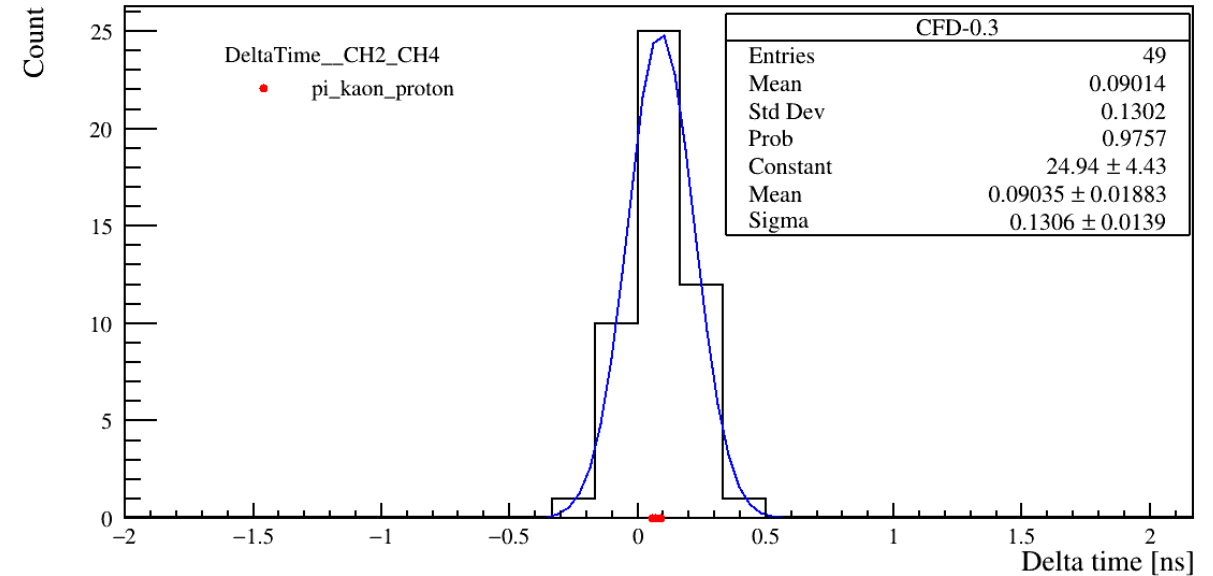
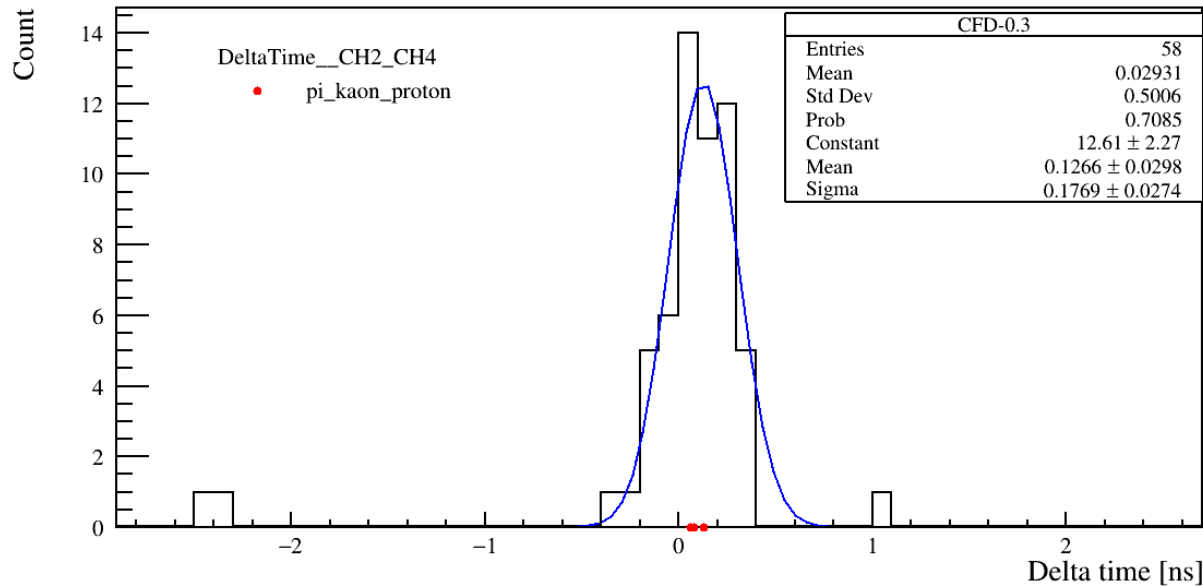
Distance L = 17mm

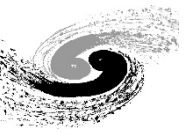
- Energy **500MeV** ~21h
- double triggered events : 55
- Time resolution: **176ps**

Distance 17mm

- Energy **800MeV** ~14h
- double triggered events: 49
- Time resolution: **130 ps**

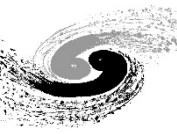
- Expected time resolution is about **100ps** (Measured by Beta source tests)
- The measured time resolution is **130~170ps, significantly larger than expected resolution**
- Due to contribution from **beam energy spread, estimated to be 15~20MeV (2%)**





Summary

- Verify silicon timing detector in test beam
- Most of particle identified by silicon timing detector is **proton**
- Time resolution with LGAD in test beam is worse than lab tests
 - Maybe due to beam energy spread
- Major issue:
 - Event rate in Beijing Test beam facility is low

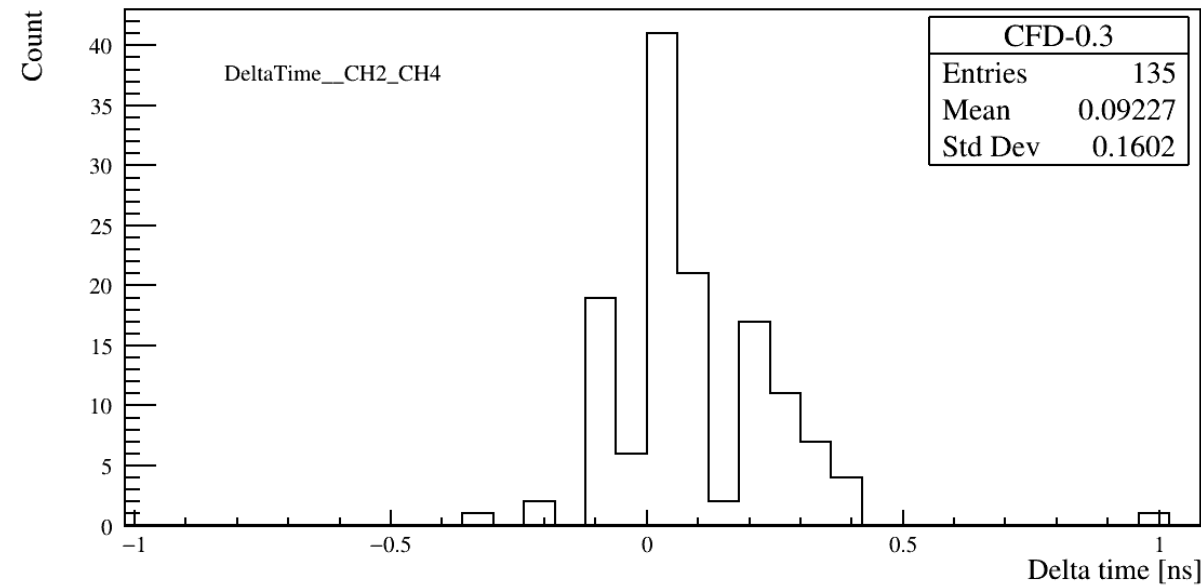


4. Delta time L =17mm

10.31 12:08 ~ 11.3 9:40

Distance L =17mm

- Energy 500MeV ~21h double triggered 55
- Energy 800MeV ~14h double triggered 49
- Energy 1000MeV ~9h double triggered 18

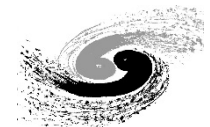


L = 17mm

	0.5GeV	0.8GeV	1.0GeV
p(ps)	126.711	90.7109	80.1388
pi(ps)	58.8461	57.5278	57.2193
kaon(ps)	79.6594	66.5998	63.2039

ToF of theoretical calculation

Silicon timing detector team



- 硅超快探测器参与束流测试(值班、调束、实验) 人员：
 - 博后：刘波，杨轩，樊云云
 - 学生：李梦朝、李淑琪，于承君，崔涵

