



中国散裂中子源  
Chinese Spallation Neutron Source



高能质子束实验终端  
High-energy Proton Experiment Station

# Design of the Detector Systems in HPES Test Beam Terminals

*Presentation on the BTTB-13 workshop.  
19-23, May, 2025. Valencia, Spain.*



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**Date:**

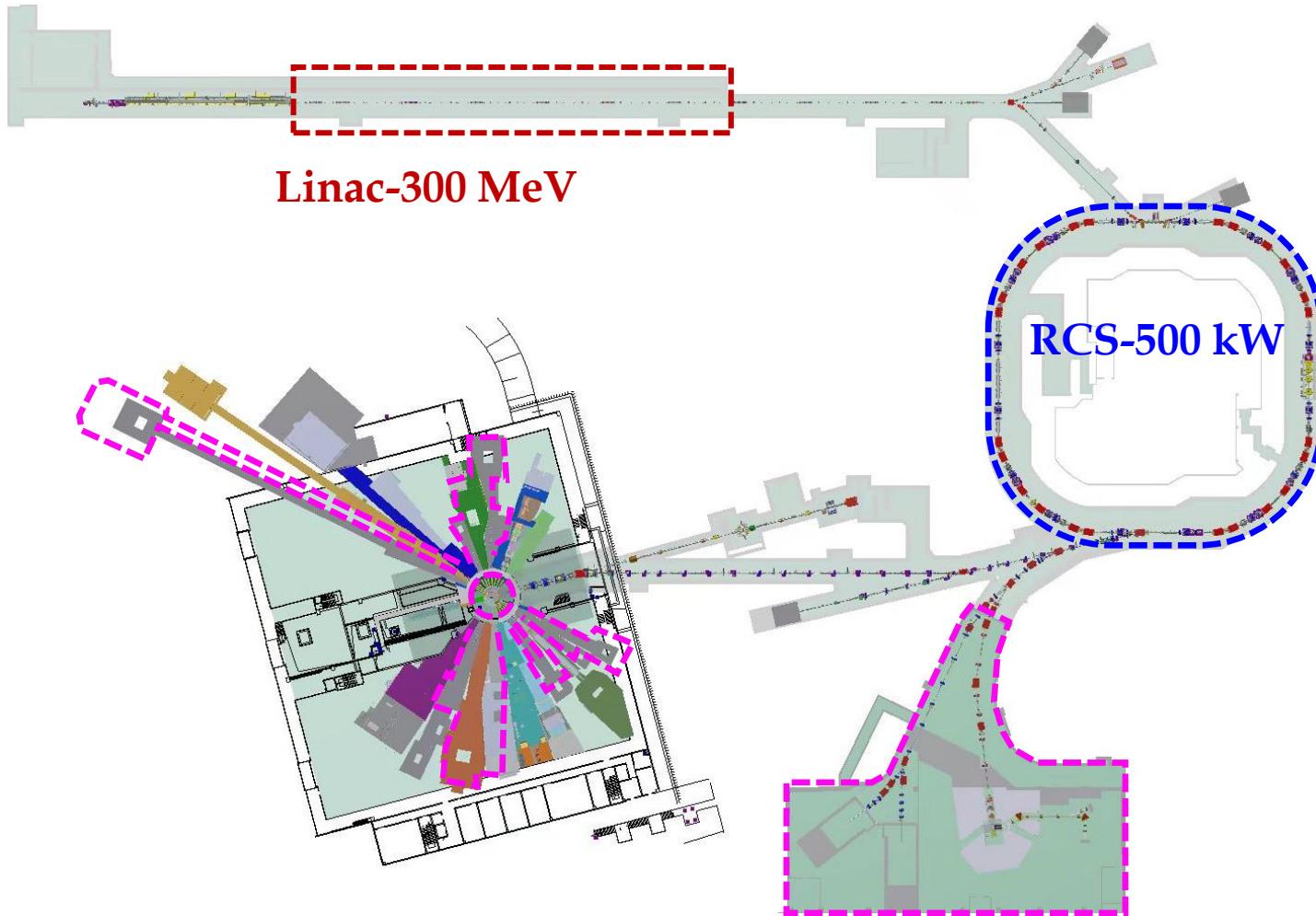
2025/05/20

# 目 录

CONTENT

1. Introduction to HPES
2. Detector System of HPES
  - 2.1 Proton Beam Telescope
  - 2.2 Proton Energy Measure Device
  - 2.3 Trigger System
  - 2.4 Beam State Monitors
3. Summary

# 1.1 CSNS-II project



Linac-300 MeV

RCS-500 kW

Neutron spectrometers and terminals-11 to be build

- China Spallation Neutron Source, CSNS
- ~0.8 Billion Dollars Investment
- Linac particle energy → 300 MeV
- Beam power → 500 kW
- Neutron flux@14m →  $1 \times 10^8 \text{n/cm}^2/\text{s}$
- 11 new beam lines will be build
- Including:
  - One 1.6 GeV proton test beam (HPES)
  - One surface muon source (MELODY)

## High-energy Proton Experiment Station (HPES)

- ▣ First GeV proton test beam in China.
- ▣ Under civil. First beam @ 2029.
- ▣ Proton extracted by a diamond proton scatter.
- ▣ Weak and Strong beam can be provided according to the requirement.

Item	Parameters
Energy	<b>0.8-1.6 GeV</b>
Frequency	<b>24 Hz</b>
Strong Flux	<b><math>10^6</math>-<math>10^9</math> p/s</b>
Weak Flux	<b><math>10^3</math>-<math>10^4</math> p/s</b>

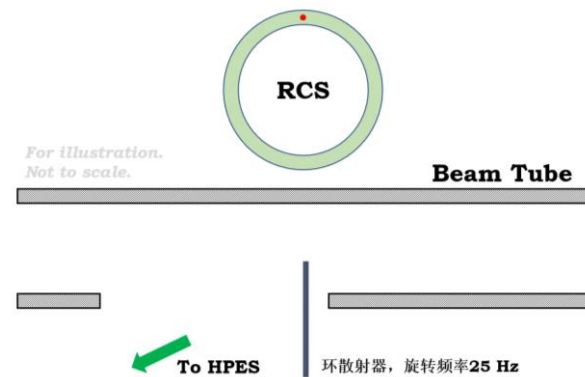
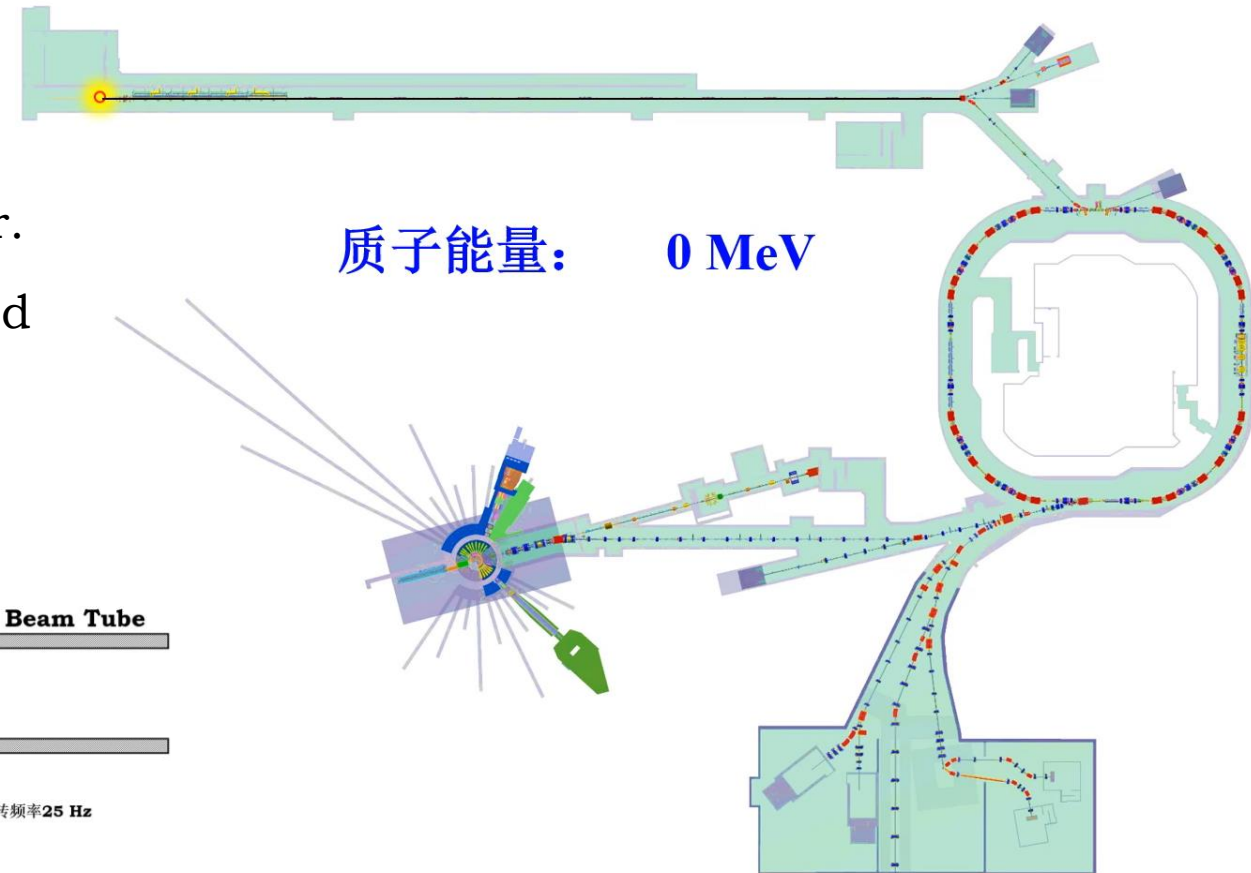
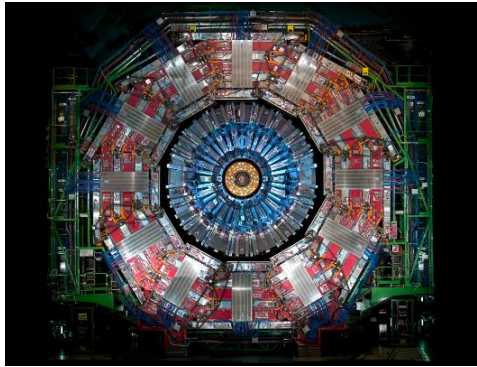


Diagram of the Proton scatter

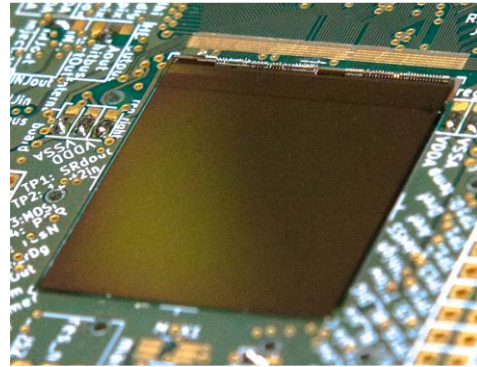


# 1.3 Applications of 1.6 GeV proton beam



## Calib. to Calorimeter

- ▣ 800~1600 MeV proton
- ▣ Hadron Collider Calorimeter calibration.



## Calib. to Pixel Detector

- ▣ 1.6 GeV proton in MIP state
- ▣ Positioning Performance calibration in 10  $\mu\text{m}$



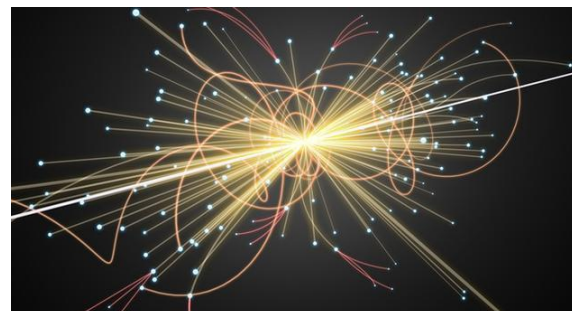
## Aerospace related Study

- ▣ 1.6 GeV proton, close to Cosmic ray.
- ▣ Performance test to the aerospace devices.



## Proton Imaging

- ▣ Provide a test platform for proton imaging technique development.



## Particle Physics

- ▣ Important properties of mesons in detector.

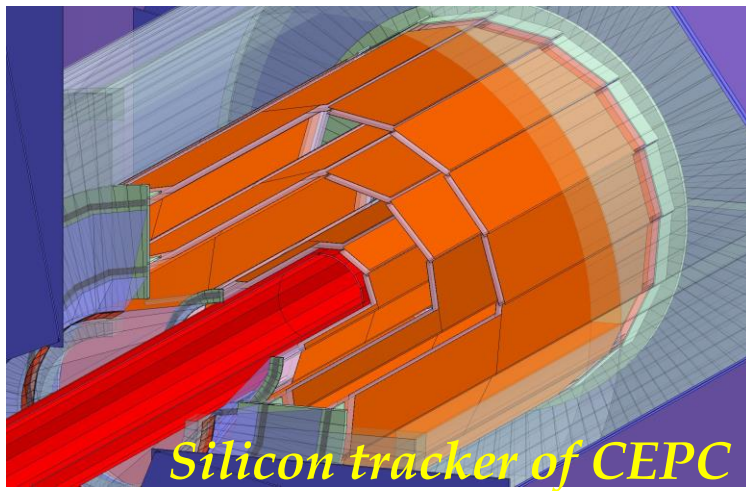
# 2. Detector System of HPES



- Primary purpose of HPES: provide a detector test platform for CEPC.
- HPES is equipped with 6 detector systems :
  - Proton Event Detectors: Measure the local information of proton particle.
  - Beam State Monitors: Measure the general information of the proton beam.

Devices		Quantity	Techniques	Key paramters
Proton Event Detector	LEMS	Energy	LGAD	Energy res. < 1%
	Telescope	Track	Pixel Detector	Position res. < 10 $\mu\text{m}$
	FLASH	Time	Scintillator Fiber	Timing res. < 1 ns
Beam State Monitor	PROUD	Beam Intensity	Plastic Scintillator	Dynamic Range 1~10 <sup>8</sup> p/s
	BMOS	Beam Stability	SiC	Intensity < 1E5 p/s
	PALET	Beam Profile	Micromegas	Position res. < 150 $\mu\text{m}$

# 2.1.1 Calibration to Pixel Detector



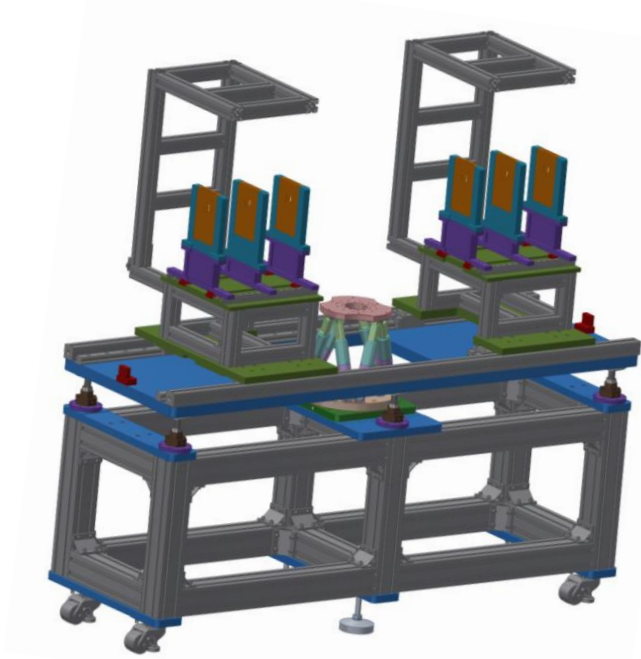
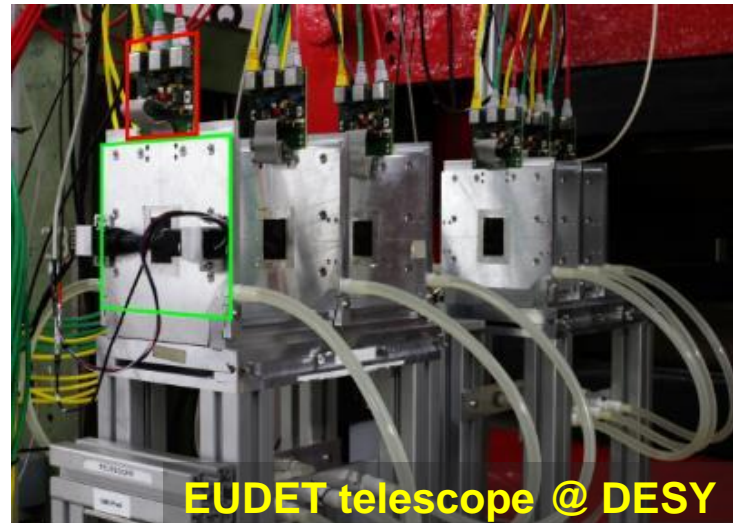
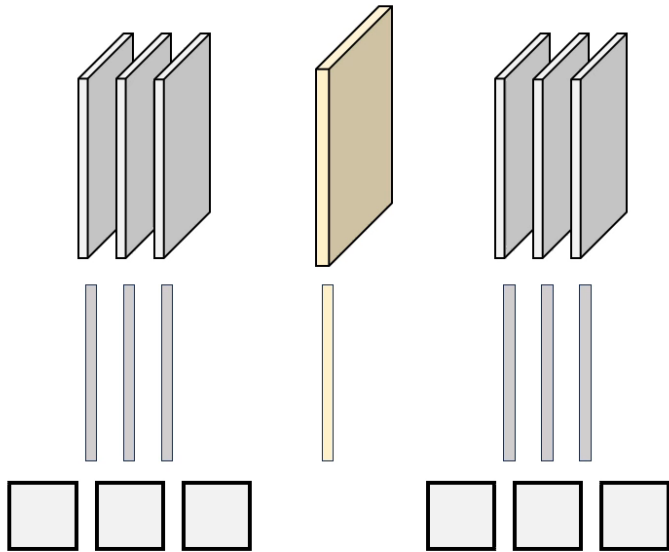
- Pixel Detector **TaichuPix** and **JadePix** are potential options for CEPC trackers.
- Pos. Res. of CEPC ITK is required  $< 10 \mu\text{m}$ .
- Tens of thousands of pixel detectors in CEPC. Need plenty of beam resources to test.
- 1.6 GeV proton beam will contribute to the performance test of the CEPC tracking detectors.

Name	Matrix	Pixel Size/ $\mu\text{m}^2$	Application	Type
<b>JadePix3</b>	<b>512×192</b>	<b>16×23</b>	<b>CEPC</b>	<b>Monolithic</b>
<b>TaichuPix-2</b>	<b>192×64</b>	<b>25×25</b>	<b>CEPC</b>	<b>Monolithic</b>

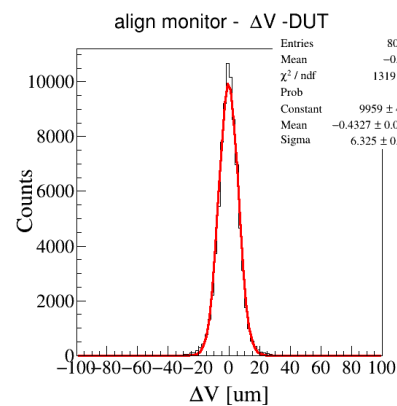
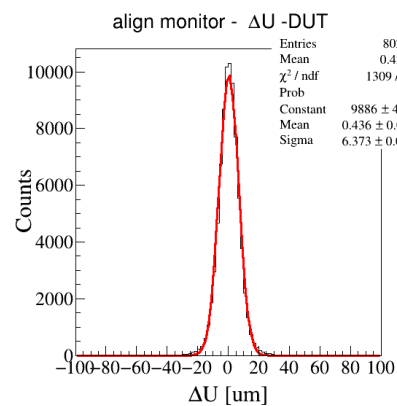
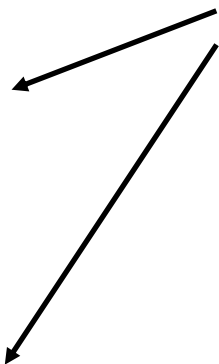
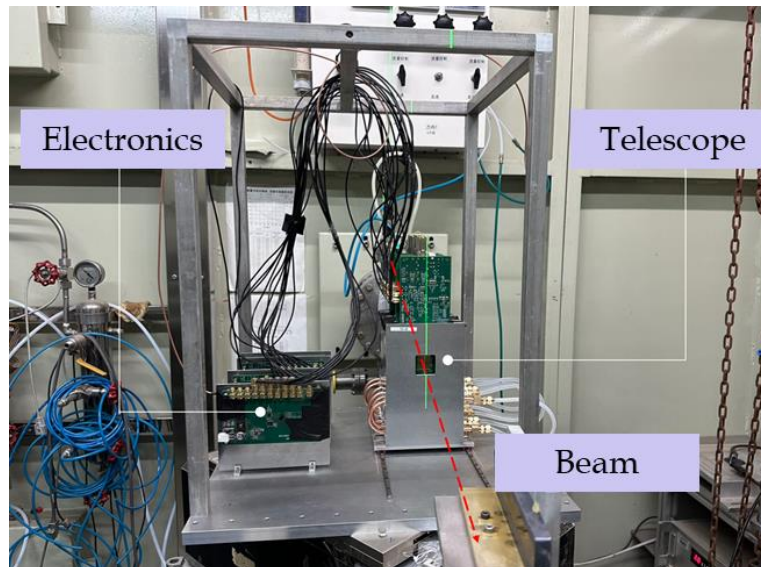
# 2.1.2 Proton Beam Telescope



- Beam Telescope would be equipped in HPES.
- 6 MIMOSA28 → a EUDET type telescope.
- The DUT resolution is designed to reach  $< 10 \mu\text{m}$
- In the future, the telescope will be updated based on JadePix/TaichuPix.



# 2.1.2 Proton Beam Telescope



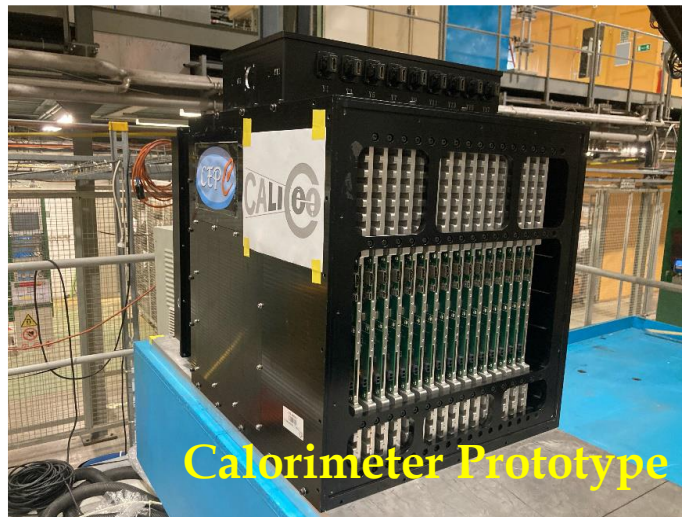
- Recent test on 1.3 GeV electron beam shows the DUT resolution is  $\sim 6.37 \mu\text{m}$ .
- Efficiency is  $> 99\%$ .

# 2.2.1 Calibration to Calorimeter

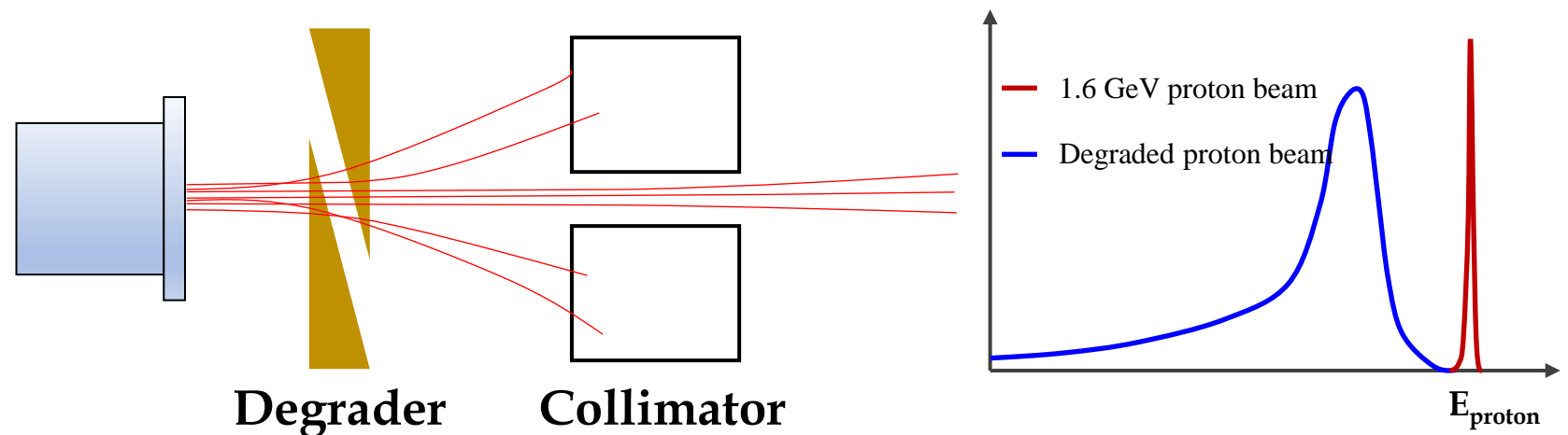


ECAL of CEPC

- ECAL/HCAL, two types of Calorimeter in CEPC.
- Energy Res. of the CEPC calorimeter is required  $< 3\%$ .
- BGO/Glass + SiPM, under prototype test.
- Recent test work are carried out on CERN and DESY.
- Protons in HEPS can be degraded to 0.8~1.6 GeV, and are good option for the test for CEPC calorimeter.



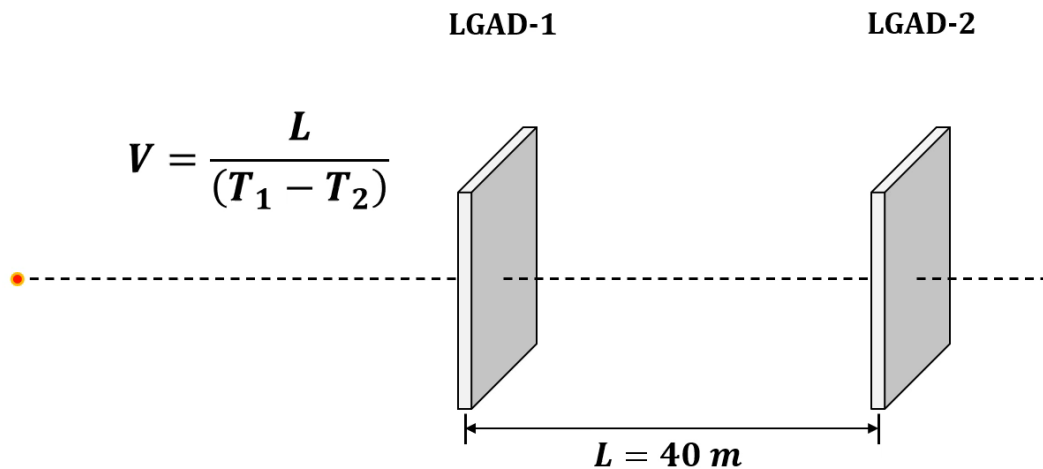
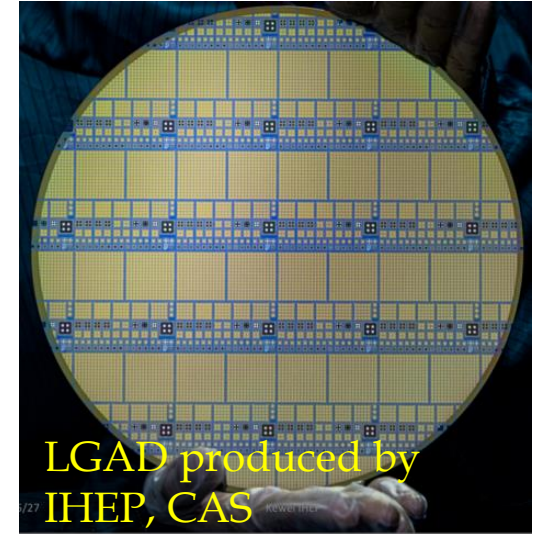
Calorimeter Prototype



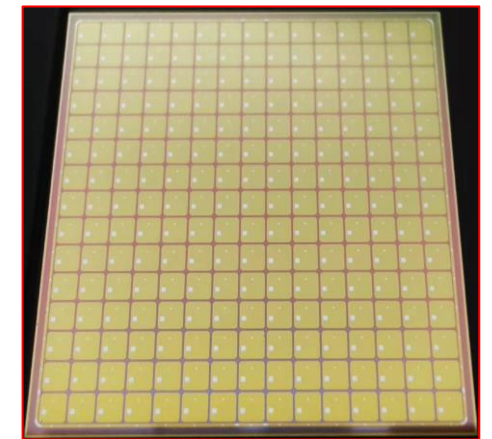
# 2.2.2 Proton Energy Measurement Device



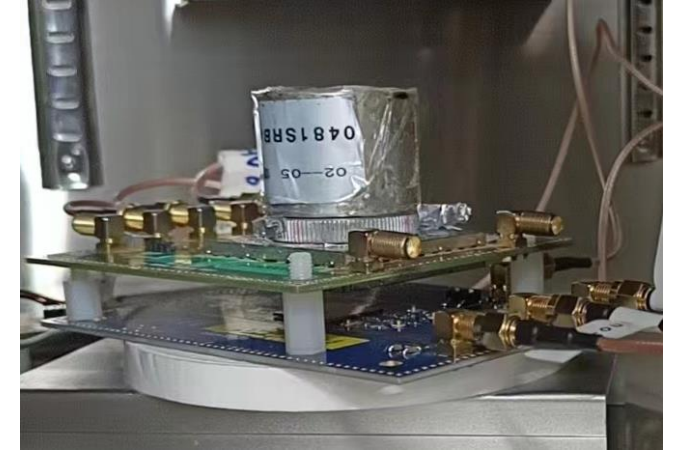
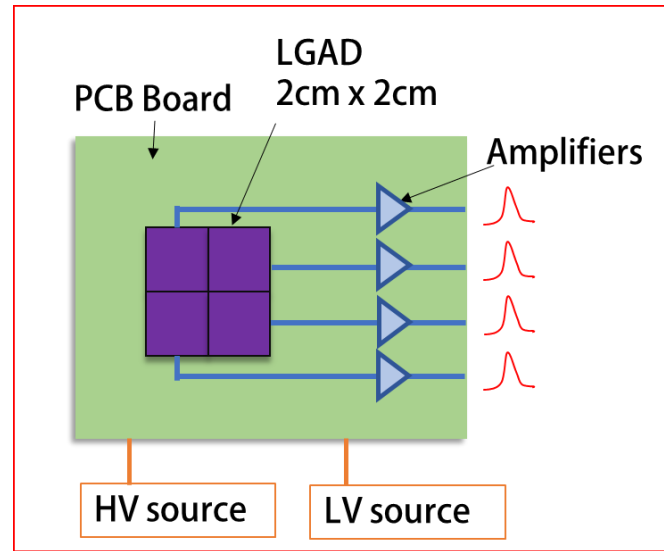
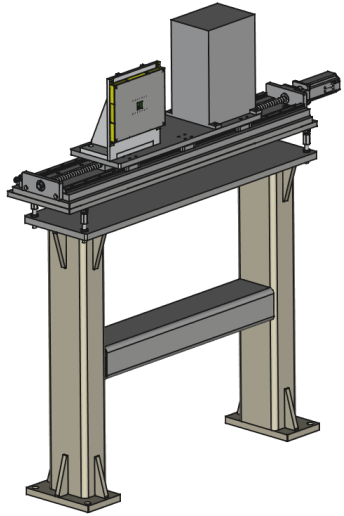
- LGAD is utilized to measure energy.
- LGAD is fast  $\rightarrow$  TOF of proton  $\rightarrow$  energy.
- Measure the energy of proton with res.  $< 1\%$  @ 1.6 GeV.
- Two LGAD in 40 m.
- Timing resolution  $\sim 100$  ps.



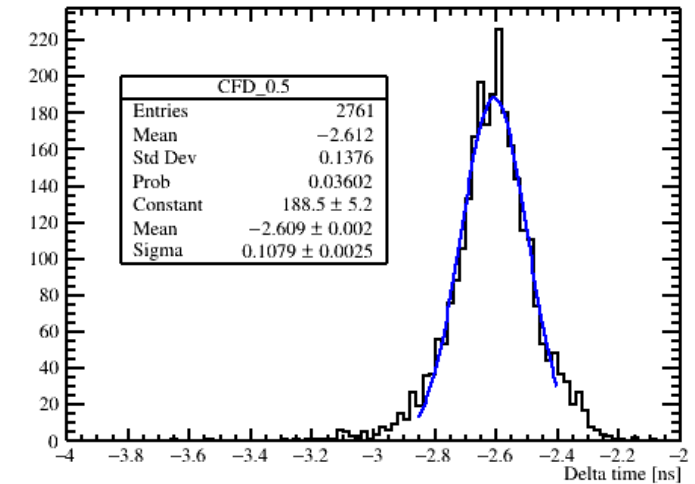
Parameters	Requirements
Energy Res.	1% @ 1.6 GeV
TOF Res.	140 ps @ 40 m
Timing Res. of LGAD	<b>100 ps</b>



# 2.2.2 Proton Energy Measurement Device

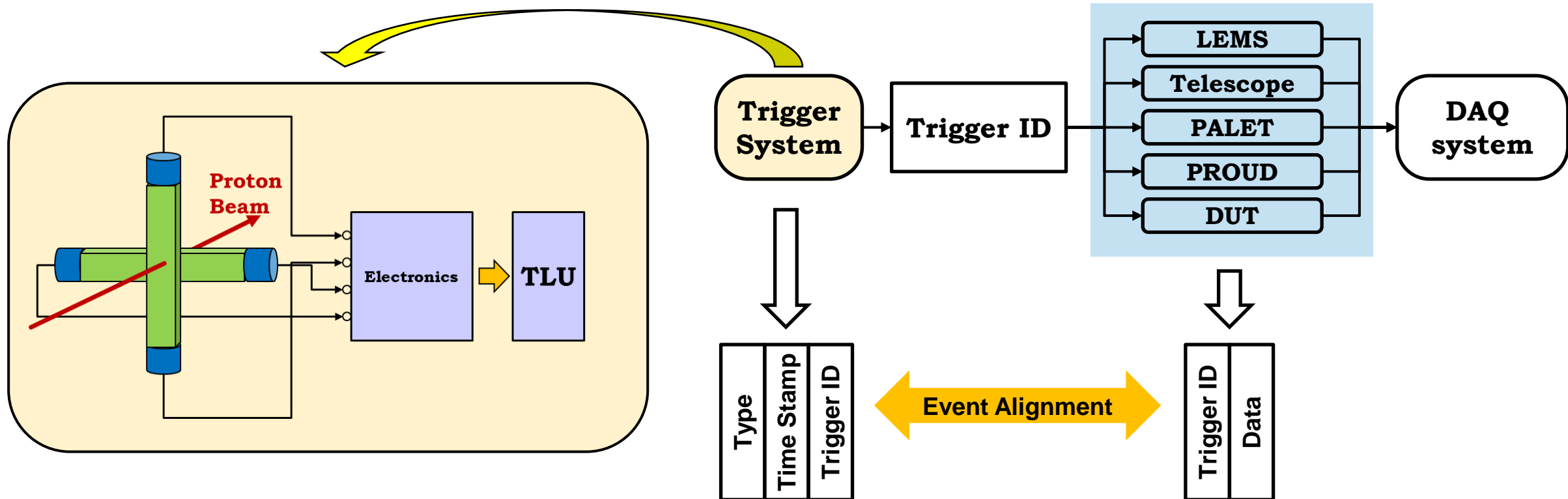


- One 15x15 LGAD matrix is divided into 4 portions.
- LGAD pixels in one portions are connected in parallel.
- Waveforms acquisition with 6.4 Gsps developed by the EVERACQ Tech. company.
- Recent test shows the timing res. is  $\sim 108$  ps.



# 2.3 Trigger System

- Data alignment in proton level is required in telescope and energy measurement.
- A trigger system is equipped to fan out **trigger ID** to each detectors.
- The trigger ID will be the handle to achieve the data alignment in proton level.

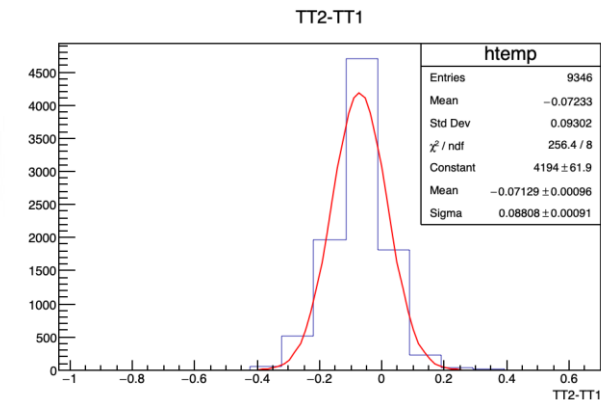
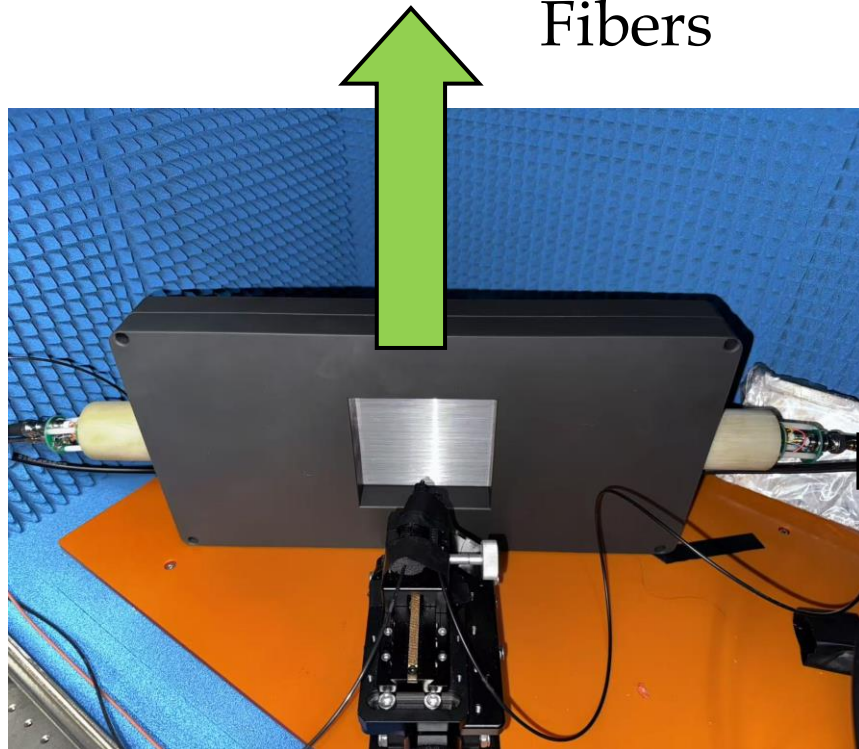


# 2.3.1 Trigger Detection System

- The scintillation fibers + NNVT FPMT
- EVERACQ used to produce basic triggers.
- Recent test shows a 88 ps trigger time jitter.



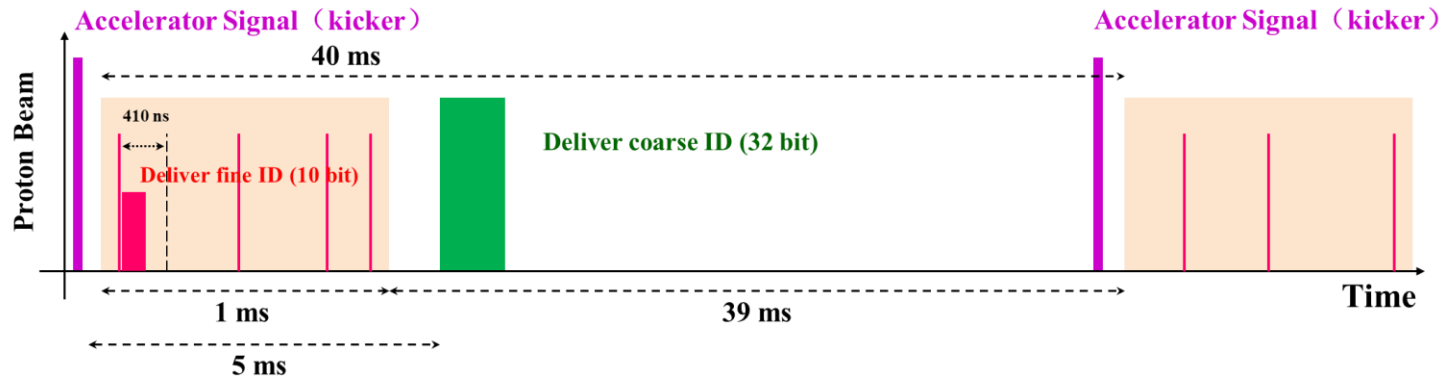
Fibers



# 2.3.2 Trigger Logic Unit



- Trigger Logic Unit (TLU) is developed based on the design of AIDA-2020.
- Trigger ID is split to fine ID and coarse ID, to reduce the signal transition time.
- The HPES-TLU is compatible with devices following AIDA trigger standard.



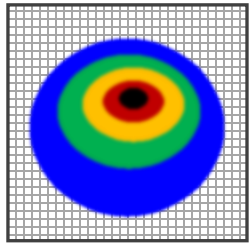
HDMI PIN	TLU SIGNAL	HDMI PIN	TLU SIGNAL
1	CLK	10	SPAR
2	GND	11	GND
3	$\overline{CLK}$	12	$\overline{SPAR}$
4	CTL	13	N.C.
5	GND	14	+3.3 V
6	$\overline{CTL}$	15	TRIG
7	BUSY	16	GND
8	GND	17	$\overline{TRIG}$
9	$\overline{BUSY}$	18	TAG
		19	$\overline{TAG}$

Parameters	AIDA-2020	HPES-TLU
Delivered Digit of ID	15	10 fineID + 32 coarseID
Time of signal trans.	~450 ns	375 ns
Supported TLU mode	eudet/aida	eudet/aida/hpes

# 2.4 Beam State Monitors of HPES



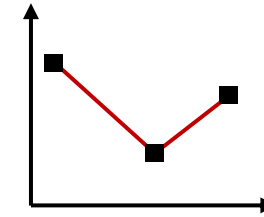
**Beam State Monitor: Measure the general information of proton beam**



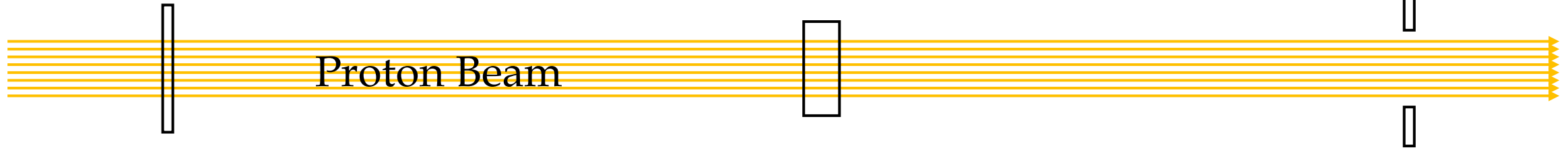
Profile Measurement  
*Micromegas*

$X$  p/s

Flux Measurement  
*Scintillator*



Online Flux Monitor  
*SiC*

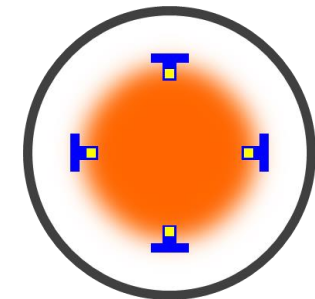


- Profile Distribution

Name	Value
Counting Rate	10 kHz
Sensitive Area	$10 \times 10 \text{ cm}^2$
Position Res.	150 $\mu\text{m}$

- Measure Absolute Flux
  - Beam Tuning.
  - Calibrate the flux every month and year.
- **Requirement: Large Dynamic range.**  
( $10^4 \sim 10^9$  p/s or 0.2~20000 MIP)

- Measure Relative flux
- Online the beam.



# 3. Summary



- A **1.6 GeV proton** test beam is under construction in China. **Beam supply will start from 2029.**
- Based on the running plan of CSNS, **more than 5000h** beam plan will be provided every year.
- HPES can provide **single particle proton** beam to test the performance of detectors.
- Several devices will be equipped to HPES:
  - Proton beam telescope
  - Proton energy measurement device
  - Trigger system
  - Beam State Monitors
- Any creative ideas and cooperation are welcomed.



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# 致谢



承蒙厚爱  
感谢倾听  
**Thanks!**