CSNS-II Low Intensity Proton Beam Test Stations

(极弱质子束实验终端)

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CEPC Day

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Introduction

- CSNS (most probably) will have an upgrade starting year 2022. After the upgrade, it can also deliver a muon beam, high / low intensity proton beams, maybe a pion beam in the future, to test stations.
- Prof Jingyu Tang, who is leading this project, invited us to join the design of the low intensity proton beam experiment stations.
- This will be a great aid to the CEPC detector R&D program. We are more than happy to contribute.
- As veteran users, we all have our own preferences, tricks and special needs. These will help making this facility more user friendly.
- Junguang Lv had a design ~2 years ago. Some of the ideas were kept.
- Many thanks to everyone who chipped in, either detector info or requests. Local members who joined discussions and design:

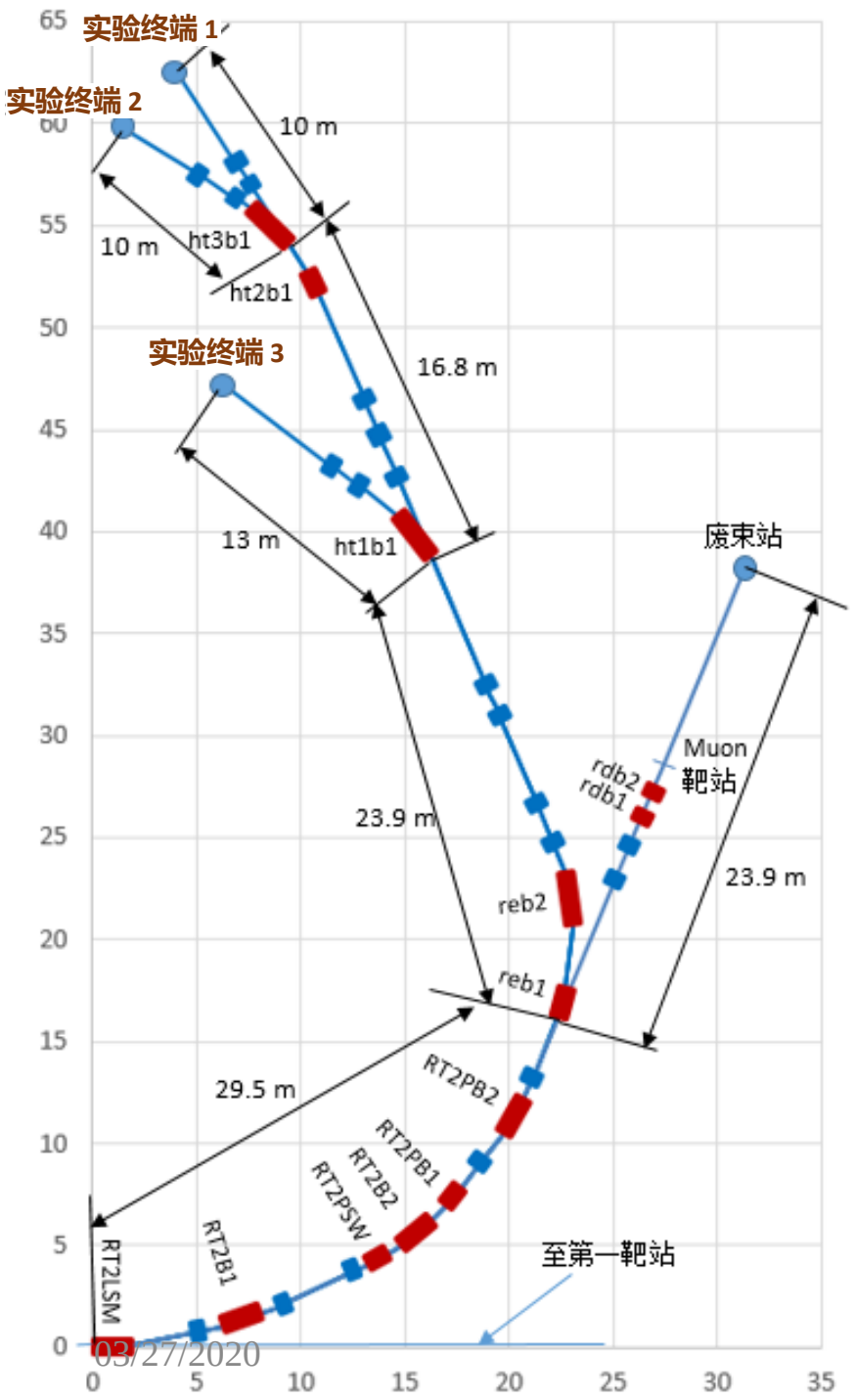
Jing Dong, Mingyi Dong, Zhijun Liang, Peilian Liu, Yong Liu, Yunpeng Lu, Junguang Lv, Huirong Qi, Xin Shi, Jianchun Wang, Hongbo Zhu

建设方案 – 新建缪子束线和高能质子束应用终端

- **质子束制备和传输**
  - 从RCS环寄生引出极弱质子束
  - 从RTBT分离脉冲束及弱束
- **高能质子束应用区**
- **实验型缪子源（EMuS）**
  - 束流功率25kW，重复频率2.5Hz
  - 1条缪子束线
- **质子束应用终端**
  - 极弱质子束：10^4 -10^7 pps，能量 0.5-1.6 GeV
  - 低重复频率强流质子束：单脉冲 10^{13}，<0.01 Hz

唐靖宇 提供

Proton Beam

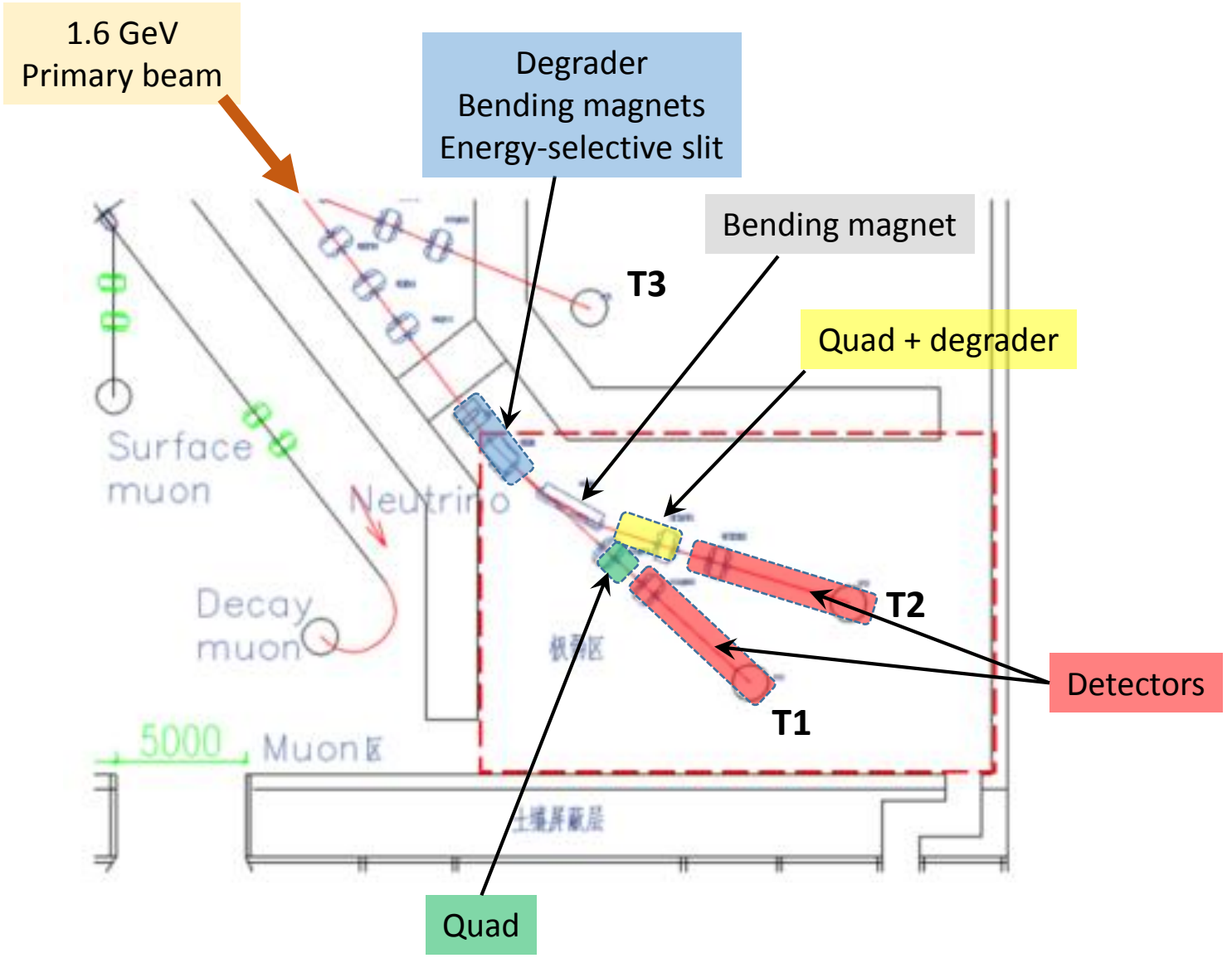


- Stations 1 & 2 are for low intensity proton beam experiments.
- Primary beam parameters:
  - Kinetic energy: 1.6 GeV
  - Intensity: 10^4 -10^7 pps (safe range).
  - Time structure: (spill) / batch / bucket

    bucket 2.44 MHz (~410 ns), length ~ 60 ns

    batch 25 Hz (40 ms), length ~ 1.5-2 ms
  - 10^7 pps, 2 ms⇒ 82 particles / bucket.
  - 1 particle / bucket ⇒ 1.22 ×10^5 pps
- Use energy degrader for 0.5-1.6 GeV beam, 1 degrader + bending magnets + energy selective slit for both stations. The efficiency is ~ 10^{-5}. A 2nd degrader is placed for station 2 without energy selection.
- Change beam optical parameters for different beam spot sizes, typically ~ 2×2 cm^2. A larger size is possible.

Floor Plan of The Proton Test Stations



Beamline Components

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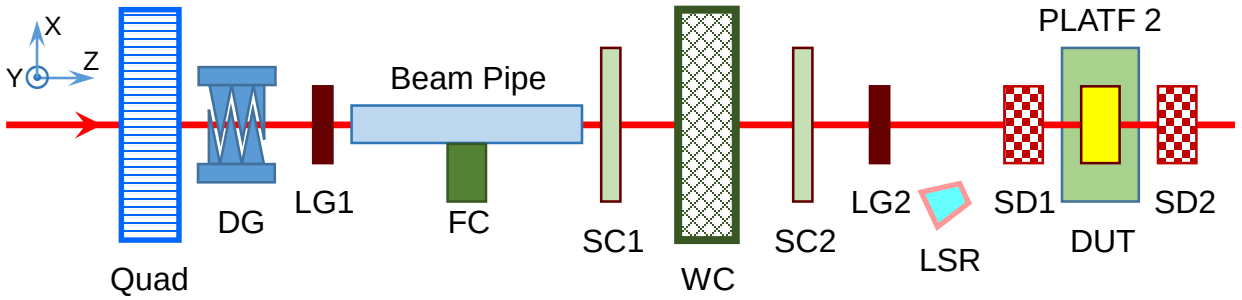

Element	Description
Quad	The last beam lens. A typical beam spot size at DUT ~ 2×2 cm^2.
DG	Energy degrader, combining with collimator to obtain wide band lower energy beam.
LG	LGAD detectors of size 2×2 cm^2, pixel size 1×1 mm^2; measurements σ_t ~ 25 ps, $\sigma_{x/y}$ ~ 350 μm. Provides particle timing, trigger signal and particle counting, ToF and hence the kinetic energy.
FC	Faraday cup (not shown), to measure the beam intensity, sensitive in ~10^7 pps range.
SC	Scintillator detectors of size 12×12 cm^2, provide trigger for wide low intensity beam.
WC	Wire chamber of size 12×12 cm^2. To measure beam intensity and its profile.
LSR	Laser crosshair for visual alignment in X & Y directions separately.
SD	Silicon pixel detectors of size ~2×2 cm^2, pixel size 20×20 μm^2, $\sigma_{x/y}$ ~ 6 μm; to provide precision projection on DUT. Detectors can slide along Z direction.
DUT	Detector under test.
PLATF	A small platform with XY stage and Y rotation for a small DUT, a large platform with horizontal translation for a large DUT.

Difference of The Two Stations

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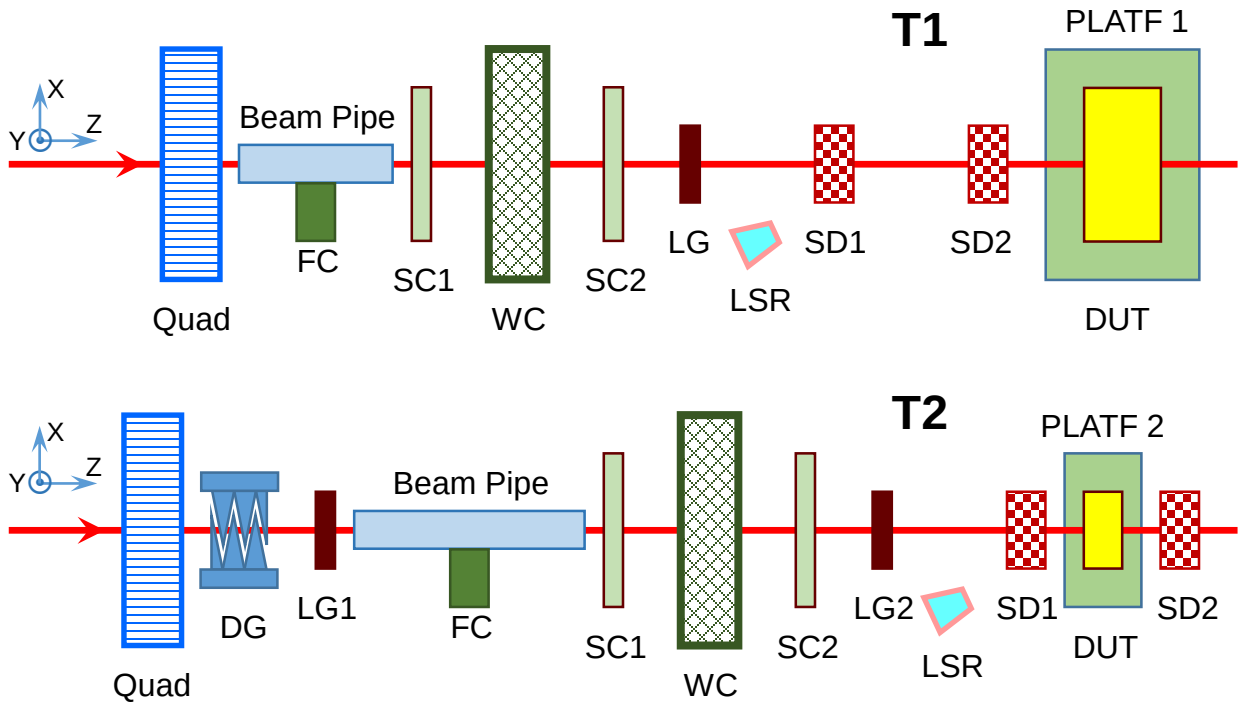
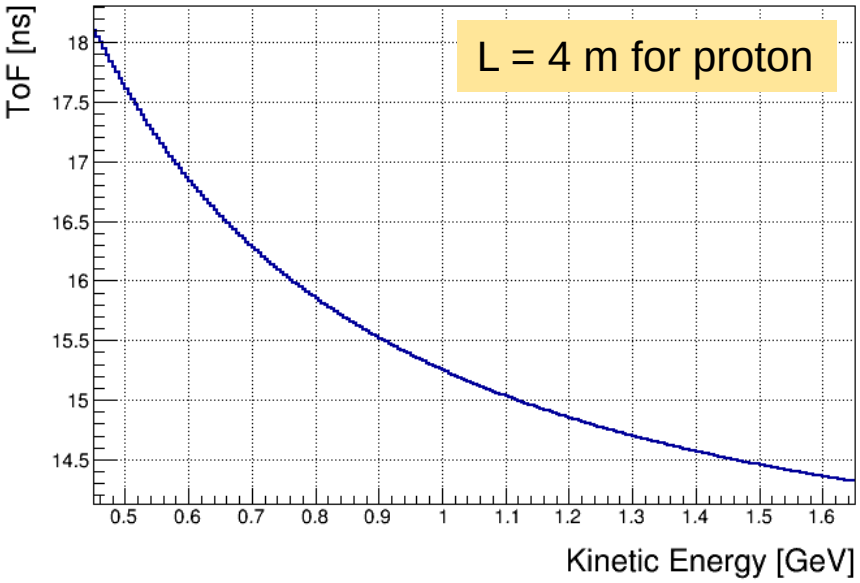
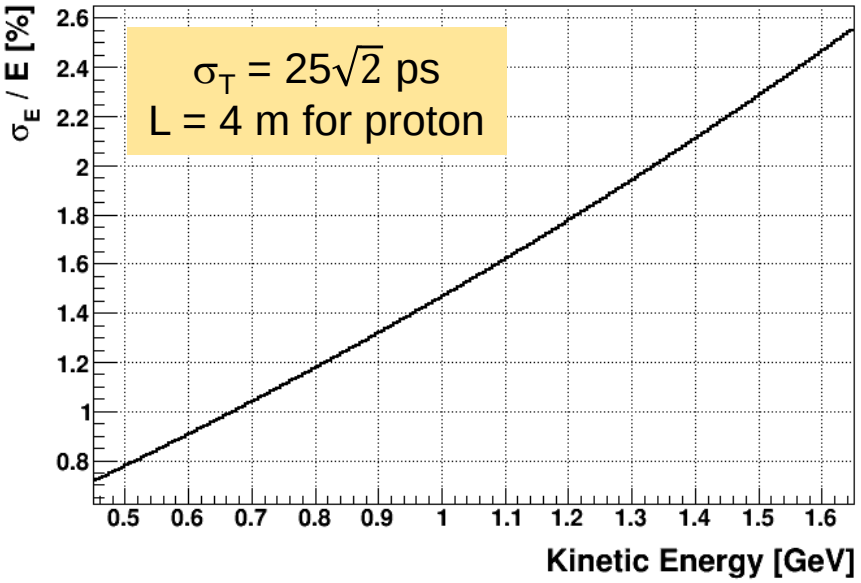


- T1 provides single energy beam. T2 can provide wide energy band beam, thus needs the LGAD detectors to measure particle energy.
- Non-penetrating DUTs may be placed downstream of the two SD detectors for track extrapolation points.
- Each station has 1 small platform with XY movement + Y rotation. The large platform with horizontal movements can be used at either station.
- All detectors are synchronized to the same clock source.

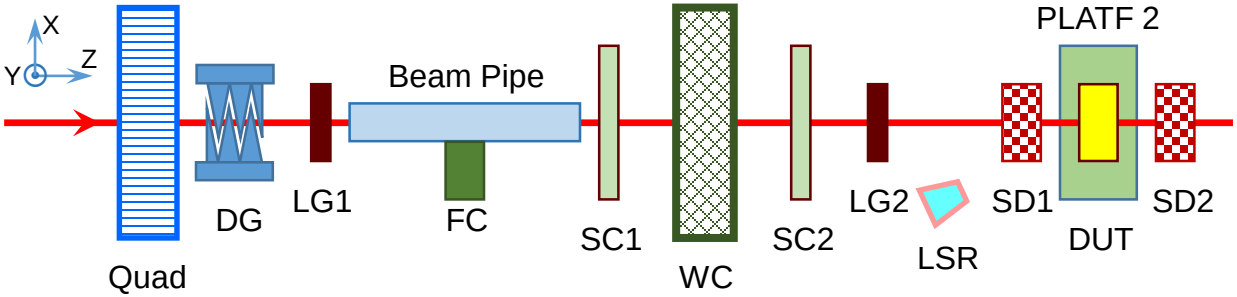
ToF For Energy Measurement

- One layer LGAD detector can provide 25 ps precision of timing, ~350 μm position resolution.
- If we use 2 single-layer LGAD detectors, and place them ~4 m apart, the proton energy resolutions are ~0.8% at 0.5 GeV and ~2.5% at 1.6 GeV





Different Operation Modes



Mode		Single Particle Beam			Low Intensity Beam	
		Mono-energy		Wide band	Mono-energy	Wide band
Energy	Goal [GeV]	1.6	0.5 - 1.6	0.5 - 1.6	1.6	0.5 - 1.6
	Spectrum	-	-	LG	-	LG
	Single Partile	-	Slit,LG	LG	-	-
Intensity	Goal [pps]	$<10^5$	$<10^2$	$<10^5$	10^4-10^7	10^4-10^7
	Measurement	LG (narrow), WC, SC			WC, LG (narrow), SC (Low Int.)	
Time Measurement		LG (narrow), SC (wide)			-	-
Trigger signal		LG (narrow), SC (wide)			-	-
Hit position on DUT		SD (narrow)			-	-

Summary

- The CSNS-II plans to deliver low intensity proton beams for detector and electronics R&D. The kinetic energy of the proton beam is 0.5 - 1.6 GeV or even lower, intensity from 10^7 pps to as low as single particles.

- We help design the experiment stations, especially the supporting detectors, and most probably will build them. The detectors provide beam intensity and profile, particle energy, time, and position info for the experiments. The initial budget is 6M CNY. More may be added later after the facility starts operating.

- Construction will likely start in year 2022, and finish in a couple of years. It will be a very useful facility to the CEPC detector R&D program.