Test-beam facility at IHEP CAS

An Guangpeng

On behalf of the TBF group

1st workshop on applications of high energy Circular Electron-Positron Collider（CEPC） synchrotron radiation source

IHEP 2017-12-6

Outline

- The world test beam facilities
- Beijing Test Beam Facility (BTBF)
- Other Beam lines in china for experiments
- Laser Compton backscattering (LCS) γ-ray source at IHEP
- Summary

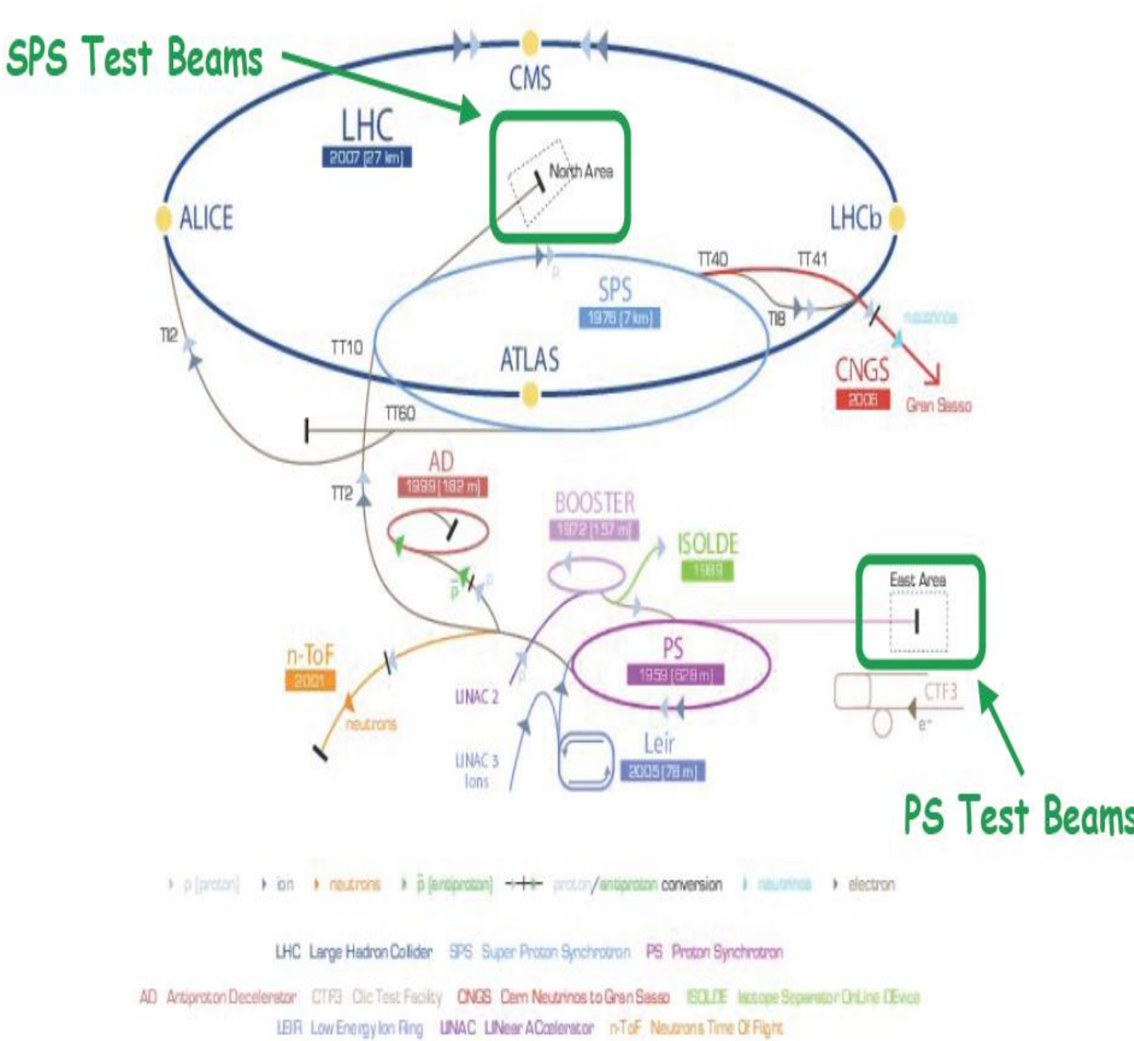
The most world test beam facilities

- There are many of test beams at most of accelerator laboratories.
- Base on the accelerator, the test beam can provide beam in a multitude of particle types and a range of energies.
- The goal of the Test Beam Program is to provide flexible, equal, and open access to test beams for all detector tests and detector R&D.
  - Vertex detector technologies: SOI, MAPS, 3D, CPCCD, FPCCD, DEPFET, …
  - EM Calorimetry: Silicon-Tungsten based fine pixels
  - HAD Calorimetry: analogue/digital with RPC, GEM, MicroMegas, Scintillator readout
  - Forward Calorimetry: BeamCal and LumCal
  - TPC: Gas amplification systems, GEM, Micromegas and readout
  - Muon Detection: MRPC readout
- More applications like irradiation experiments.

Comparison of the most test beams

Laboratory	Energy (GeV)	Particles	Rep. rate (Hz)	ΔP/P	Detectors
CERN-PS CERN-SPS	1-15 10-400	e,h,**μ**			Cherenkov, TOF, MWPC
DESY	1-7	e	12.5	1%	Pixels
Fermilab	1-120	e,π, ,K,P		1%,>10GeV	Cherenkov, TOF, MWPC, Si-Strips,Pixels
Frascati	25-750MeV	e			
IHEP Beijing	1.5-2.5GeV 0.1-1.2GeV	e, e,π,P	5-50 1-4	0.5% 0.5%	Cerenkov,TOF, MWPC,Si-Strips
IHEP Protvino	1-45	e,π,μ,K,P			Cerenkov., TOF, MWPC, Drif.
KEK Fuji, J-Parc	0.5-3.4 —	e ——	100 ——	0.4% ——	
LBNL	1.5, <55MeV <30MeV	e P n	1		Pixel Telescope
SLAC	28.5 , 1-20	e e,π,P	10	0.2%	

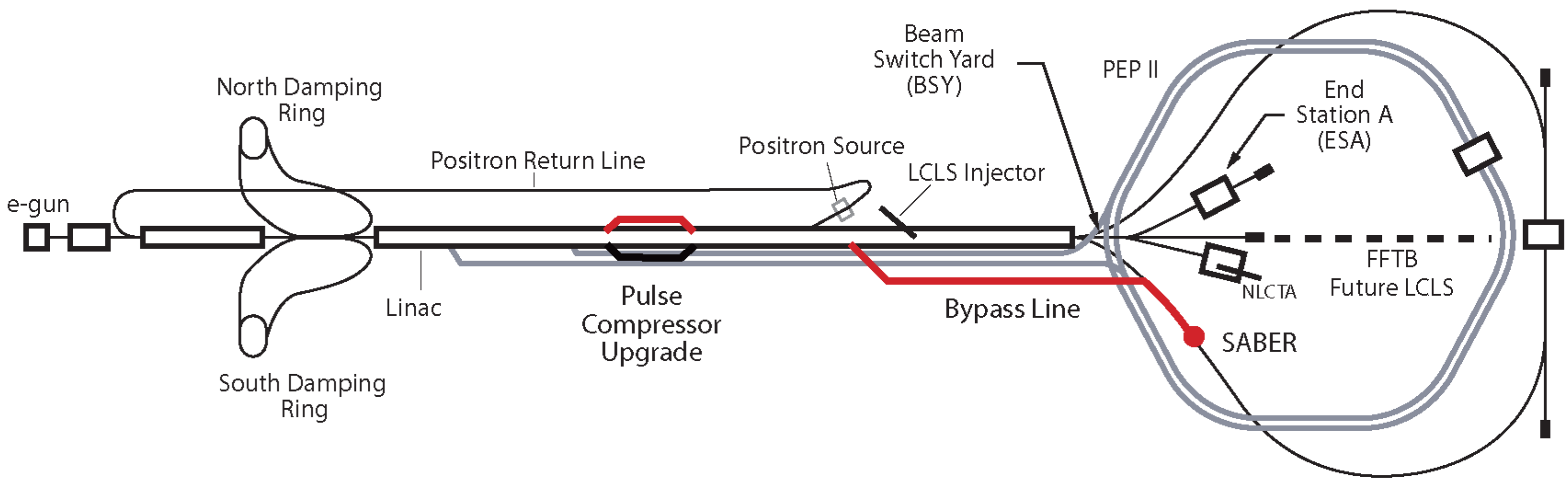
Test Beams at CERN



SPS Beamlines	
Momentum Range	10 - 400 GeV (H2) 10 - 400 GeV (H4) 10 - 400 GeV (H8) 10 - 205 GeV (H6)
Spill Duration	4.8 – 9.8 s
Duty Cycle	1 spill / 14 – 40 s
Particle Type	electrons hadrons muons
Intensity	~ 10^8 part./spill

PS Beamlines	
Momentum Range	1 - 3.6 GeV (T11) 1 - 7 GeV (T10) 1 - 10 GeV (T7) 1 - 15 GeV (T9)
Spill Duration	400 ms
Duty Cycle	2 spills / 16.8 s
Particle Type	electrons hadrons muons
Intensity	1 - 2 10^6 part. /spill

Test Beams at SLAC



SLAC Final Focus Test Beam

SLAC test beam line -- FFTB

There are three possible modes of operation. All provide beam pulses ~ 6ps long at 1 - 30 Hz depending on the accelerator program:

a) Low intensity electron or positron

Typical momentum range 5 - 20 GeV.

Up to a few x 10^3 particles per pulse, depending on momentum.

Space presently available ~1 m to south of beam line, ~2 m to north, ~1 m above and below, ~2m along beam line.

SLAC FFTB (cont.)

b) High intensity electron or positron. Available for very thin materials in vacuum or in some cases in air.

Momentum = 28.5 GeV

10^9 to 2×10^{10} per pulse (down to 10^7 under development).

Various possible experimental stations, all with substantial space constraints.

c) Bremsstrahlung beam

Peak energy 28.5 GeV

Radiator up to 0.02 X_o for 10^{10} /pulse electron beam

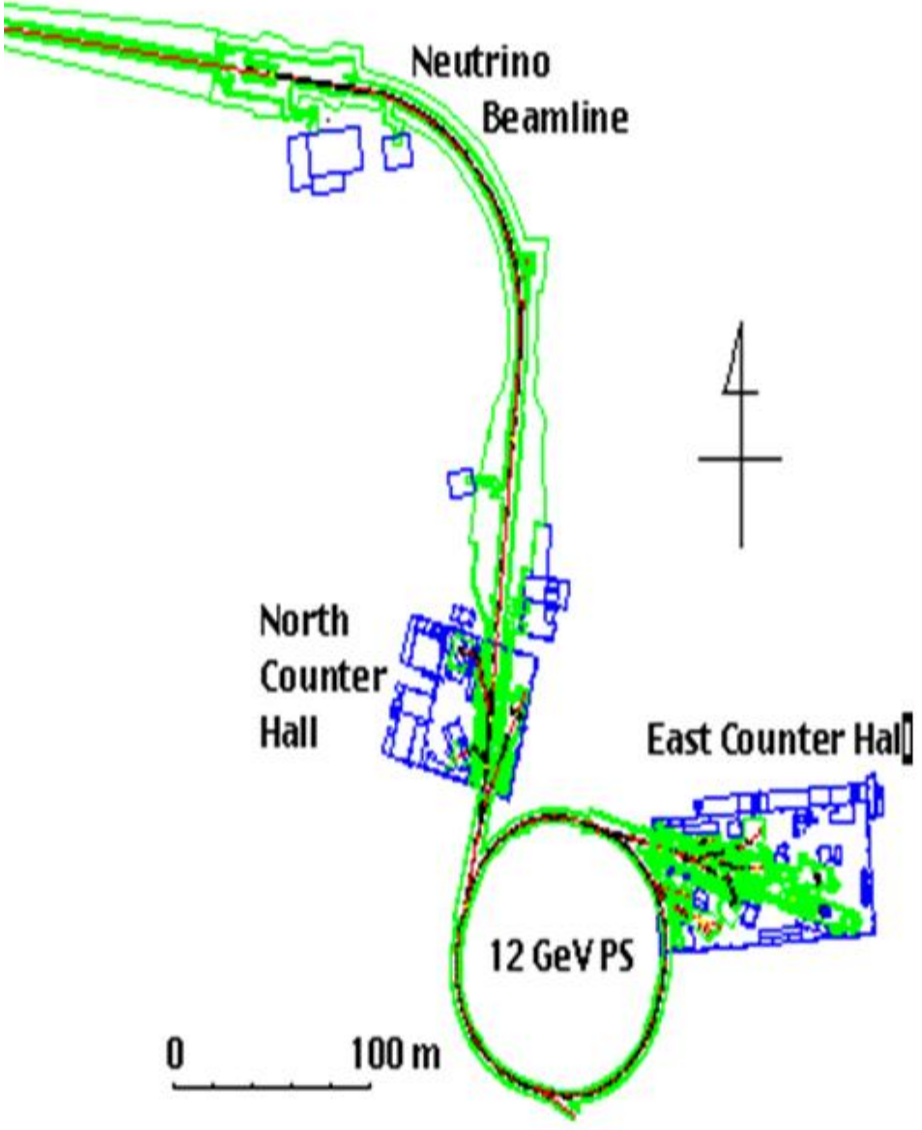
Electron beam pipe passes 30-35 cm below the gamma ray beam at the experimental station.

KEK Test Beams

KEK 12GeV-PS has two beamlines for beam tests:

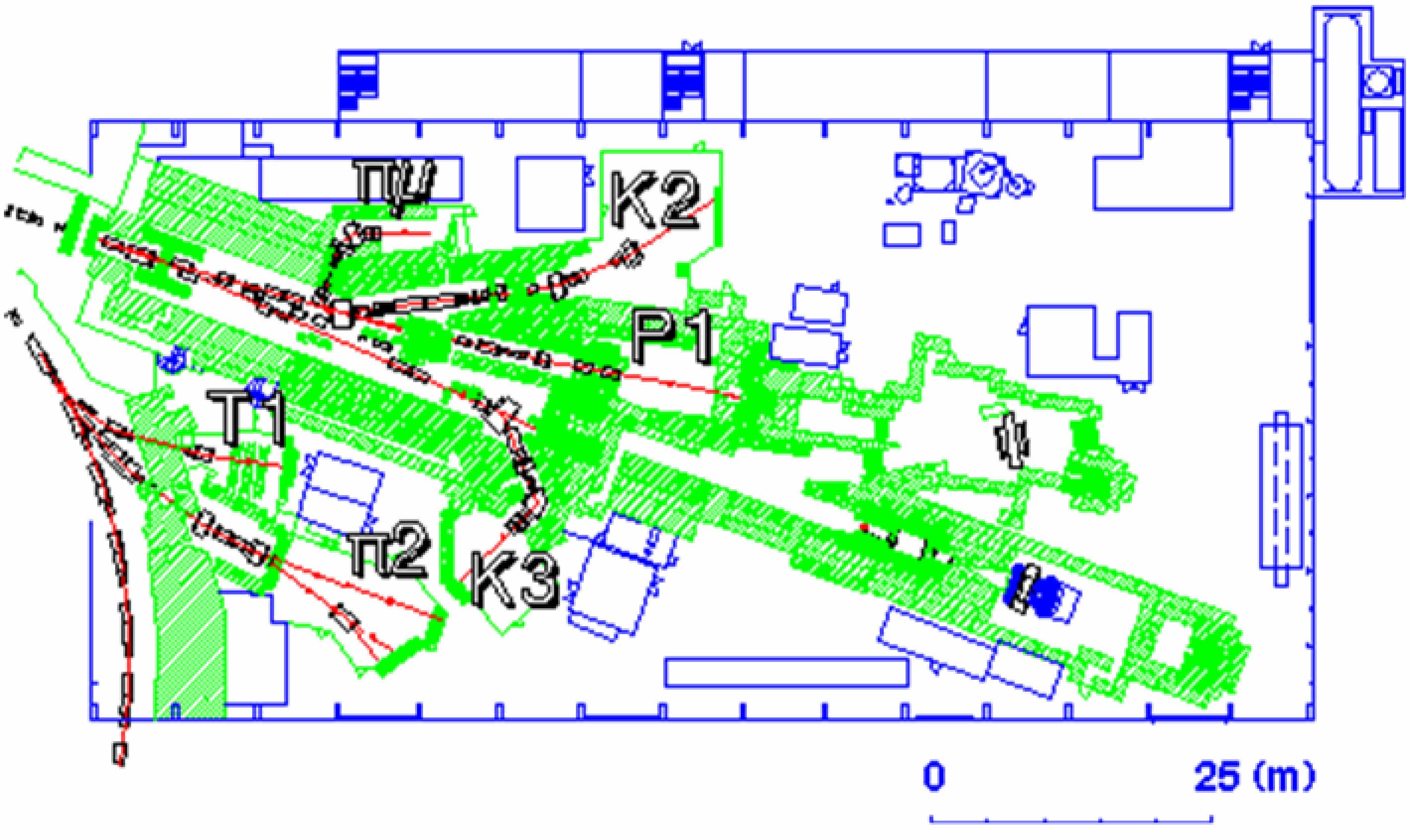
#1 π2 (up to 4GeV) #2 T1 (up to 2GeV)

- Unseparated beams: $\Delta p/p$ ~ 1%(FWHM).
- Cherenkov counters exist for e/π separation.
- π2 has an additional momentum-analyzing magnet,
- while T1 does not.

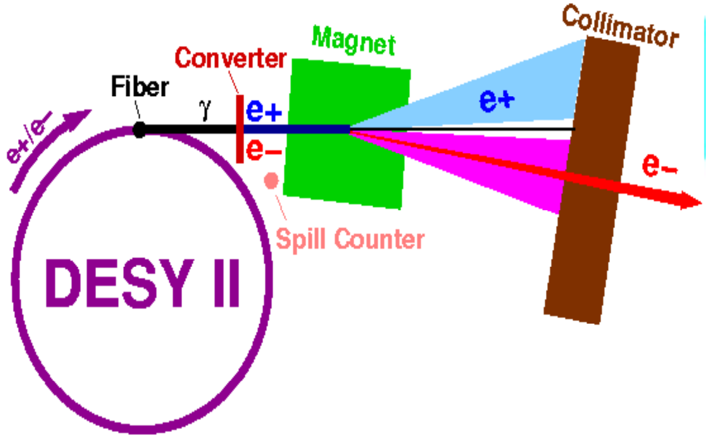


KEK East Counter Hall

(Gene Fisk, yoshiaki.fujii@heh.jp)



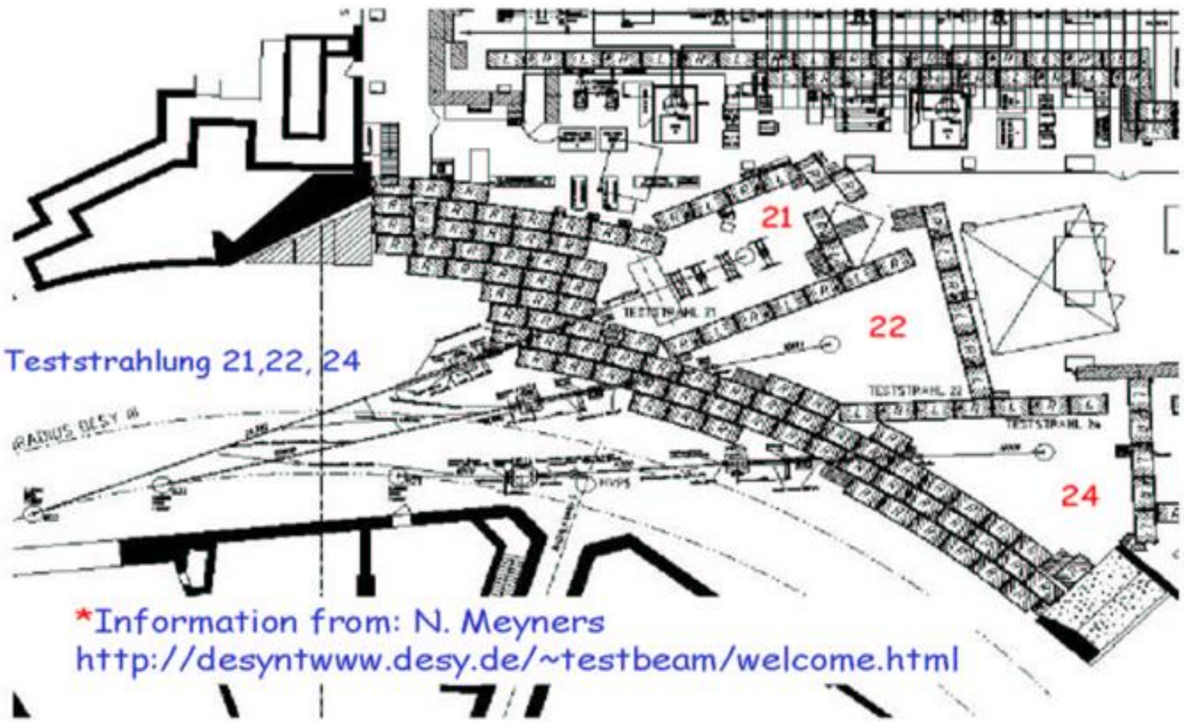
DESY Test Beams 21, 22, 24



Bremsstrahlung derived from in a carbon fiber in DESY II is converted to e+e- pairs in Cu, Al of thickness 1 – 10mm.

e+, e- momentum selection range: 1 – 6 GeV/c.

Intensity: max is ~ 1 kHz/cm^2 (avg)



Fermilab Test Beams

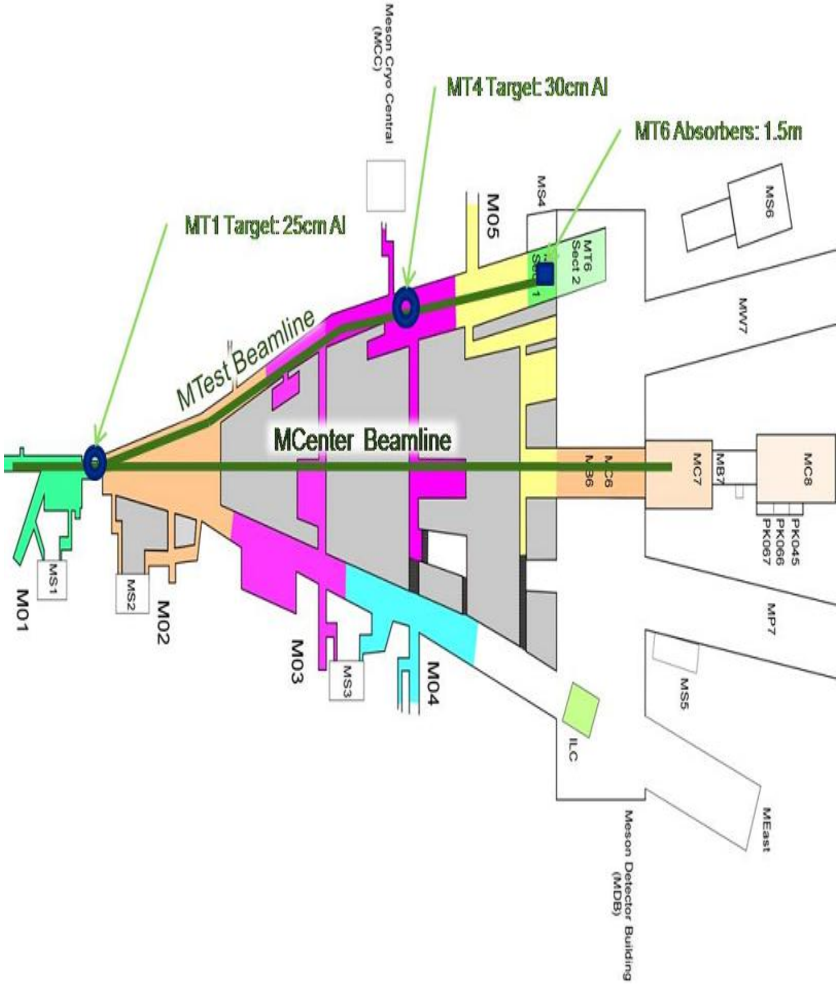
• The facility uses two versatile beamlines (MTest and MCenter) to provide beam in a multitude of particle types and a range of energies.

MTest

•The MT6 areas are the most commonly used. They have all of the features in Facility Infrastructure, and all of the Instrumentation available to them. The primary beam consists of high energy protons (120 GeV) at moderate intensities (~1-300 kHz). This beam can also be targeted to create secondary particle beams of energies down to about 1 GeV, consisting of pions, muons, and/or electrons.

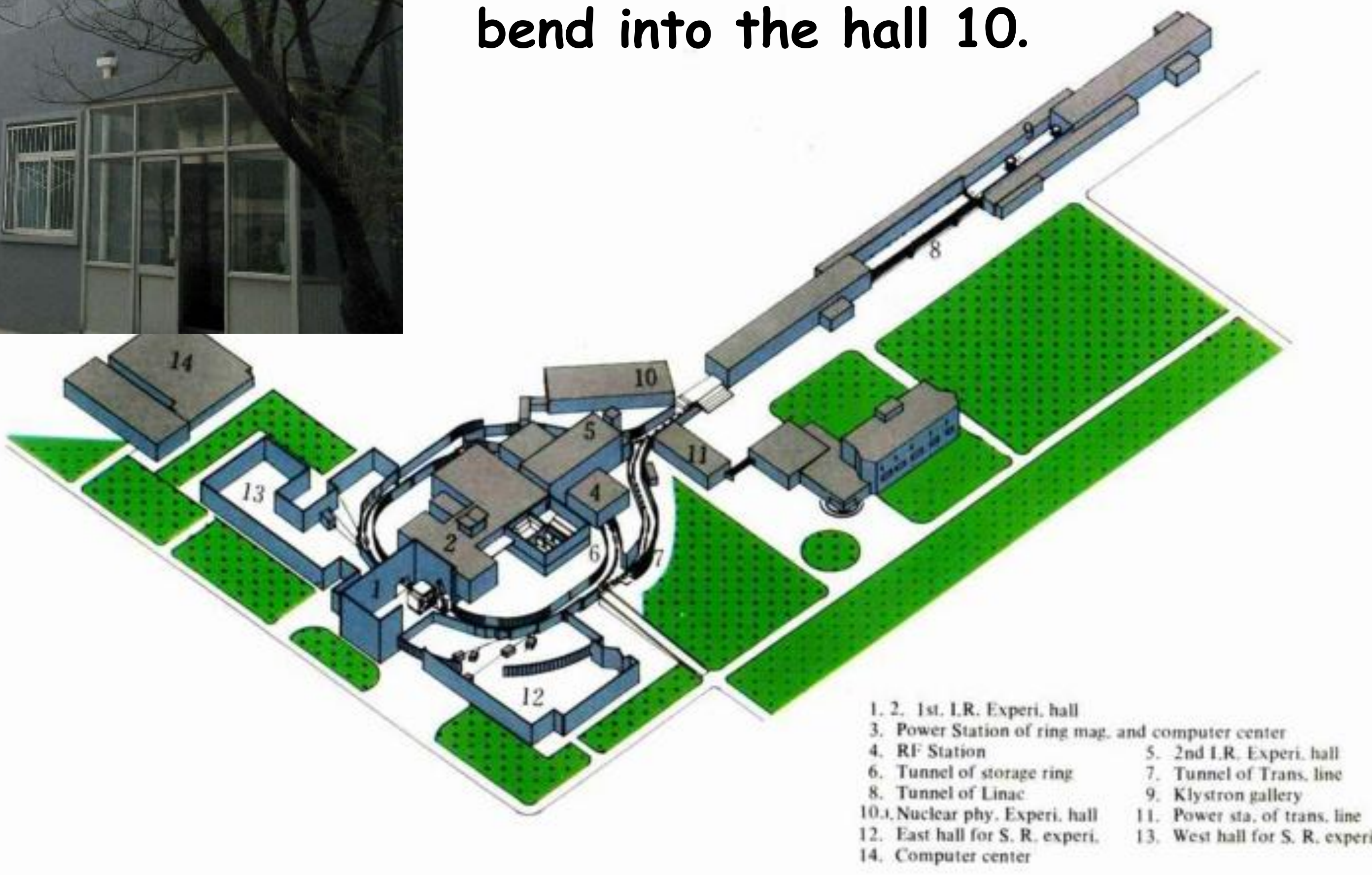
MCenter

•The MC7 areas are purposed more towards long-term experiments with a turn over rate of months or even years. This beamline has the same secondary particle beams as MTest, but has the added capability of a third beam line, which can produce pions and/ or protons down to energies of 200 MeV. Most of the same infrastructure and instrumentation are available.



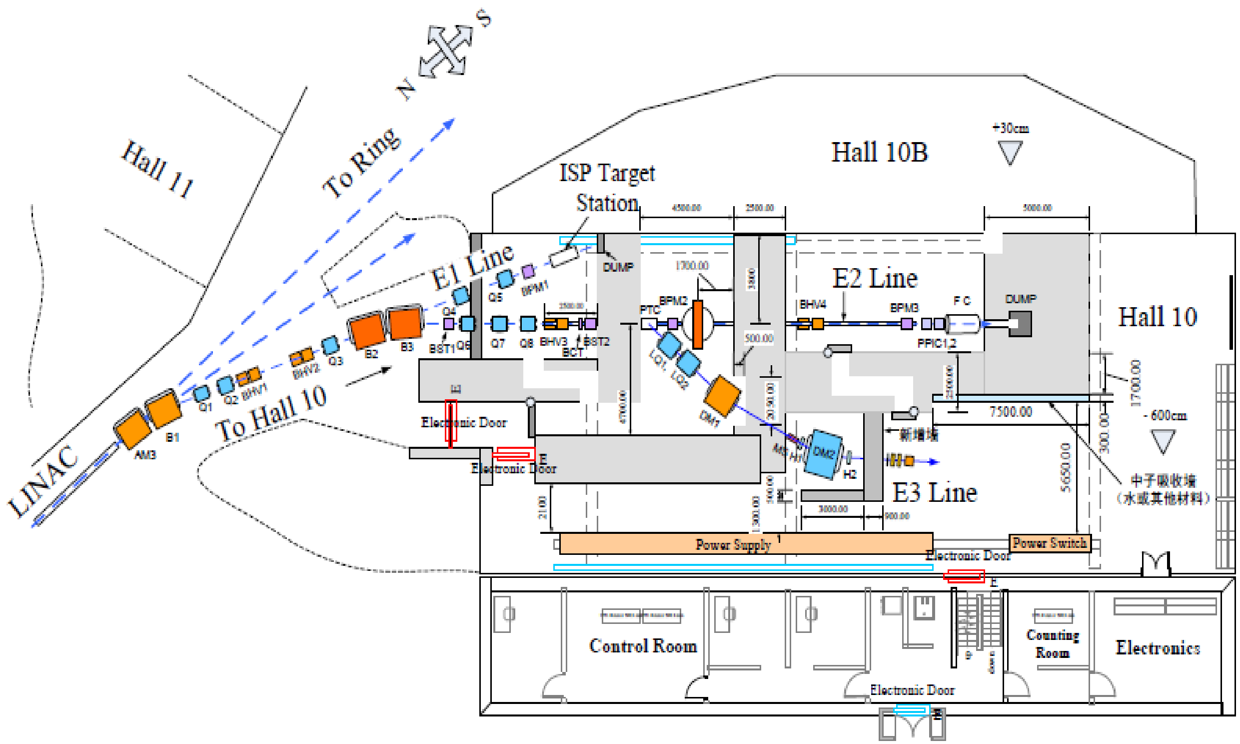
The Beijing Test Beam Facility

The Beijing Test Beam Facility is Located at the hall 10 of the BEPC, when collider work at Synchrotron radiation pattern, after the storage ring injections, the $e^{\pm}$ beam can be bend into the hall 10.

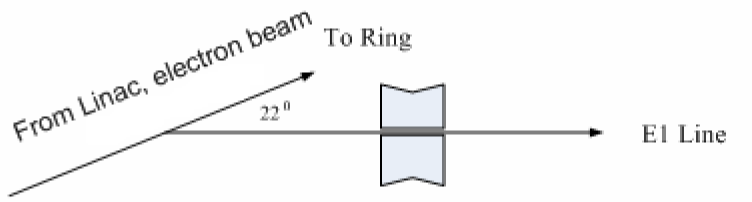


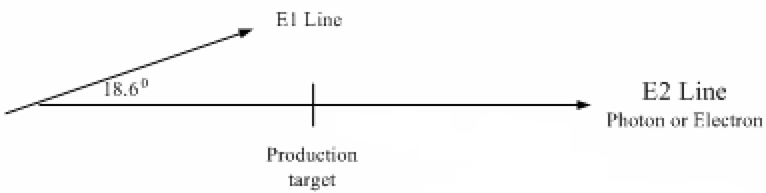
●The facility is in Hall 10 there is an area of 540m^2, and with a crane has a capability of 10 Tons.

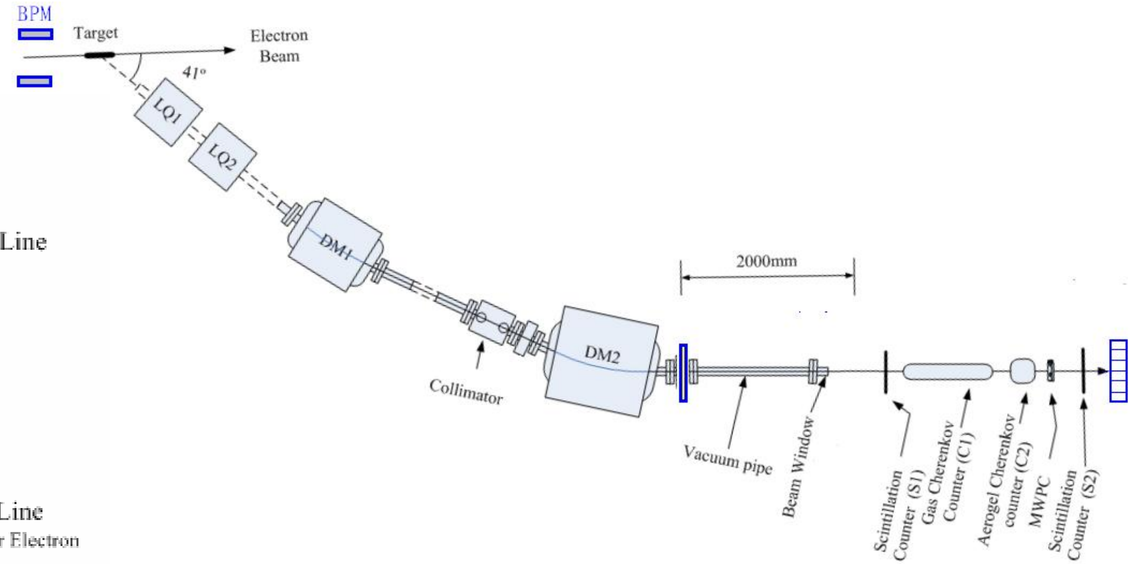
●As shown in the figure, the E1 and E2 electron beam line which is 20m and 29m long respectively. The E3 line provided with a spectrometer and that is 17m long.



The Configuration of Beijing-BTF Upgrade at Hall 10







□The Linac beam which has a bend of 22° into the Hall 10. As the left fig. that is an E1 Line, is used for Slow positron Facility specially.

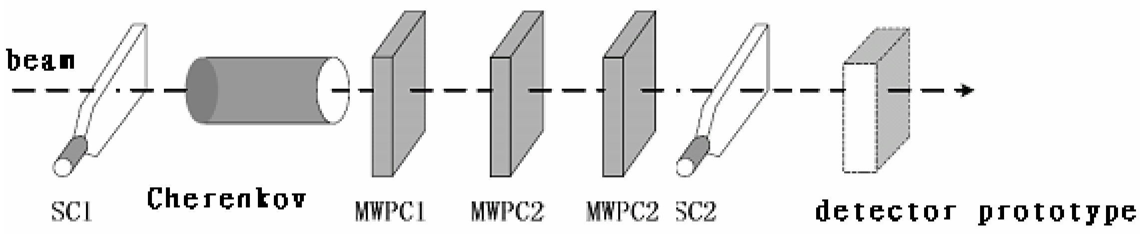
□Two dipole magnets were inserted to the E1 line that beam was bend 18.6° again, and then come into the E2 line as a primary beam line.

□The E3 line is a secondary beam line which is produced by electron impinging a target. Particles that are at fixed angular 41° enter a spectrometer and are transported to beam test area.

Spectrometer

The magnetic spectrometer on E3 line which has a structure of 2Q2D, its momentum resolution is 1% and has two running modes to detect both negatively and positively charged particles. In the spectrometer the detectors contain a Cherenkov counter, TOF counters and MWPC.

The detectors on E3 beam line



Detectors	Specification	Functions
Scintillator	$50*50*5mm^3$	TOF measure ,identify particles
CO2 Cherenkov counter	barrel，L=1330mm Φ=220mm	identify π/*e*
MWPC	stripe width is 4.2mm. The position resolution is less than 300micro-m.	Determine the position of the income particles
Silicon strip	Strip width：60um Active area：$120*100mm^2$	Determine the position of the income particles
BGO crystal calorimeter	25 pieces of $200*200*20mm^3$的 BGO crystals	Distinguish single particle and multi-particles
Silica aerogel Cherenkov	Sensitive volume： $100*100*117.5mm^3$	identify π/*e*
Plastic scintillating fiber hodoscope	With 4 layer of fibers(D:1mm) Active area：$60*60mm^2$	Determine the position of the income particles

Beam test on the BTBF：

➢BESIII sub-detectors： MDC、TOF、Muon detector（RPC）、EMC（CSI）and its electronics system；

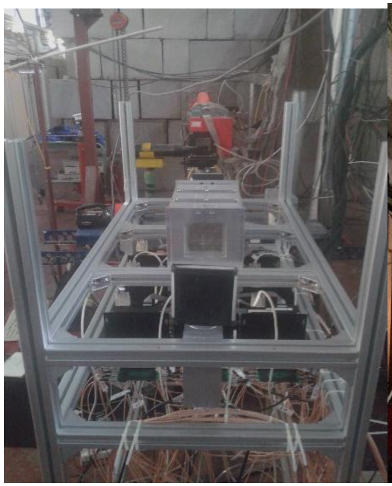
➢Some detectors of Particle Astrophysics: HXTM、 YAC、 POLAR、GRM HERD etc.

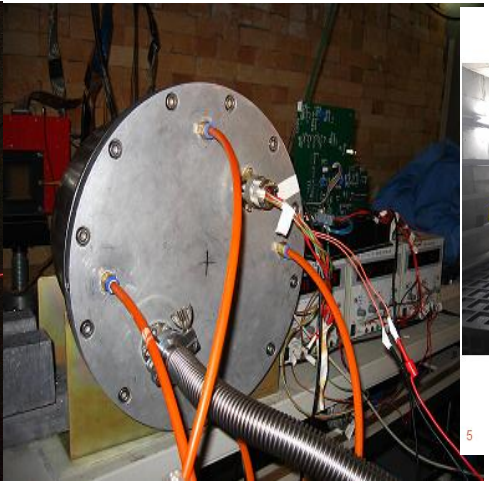
➢Irradiation experiments for crops

● Institute of Genetics and Developmental Biology; CAS

● Institute of Crop Sciences (ICS, CAAS)

➢Some electronic components and material (magnetic material) irradiation experiments。

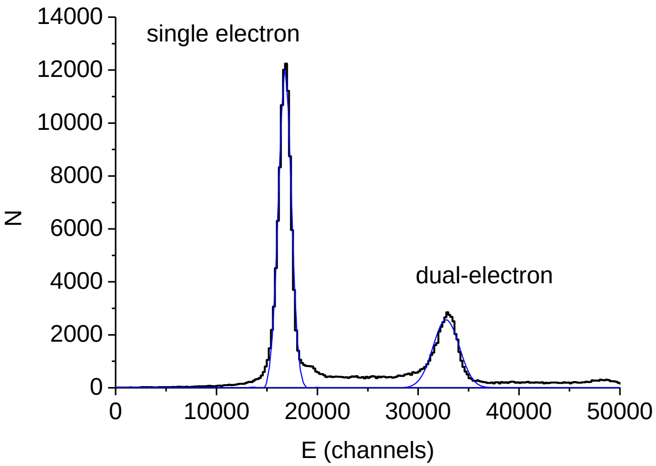


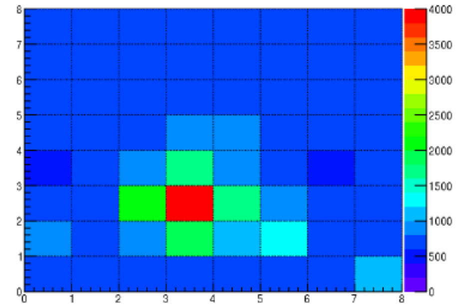


Beam Test for BESIII-EMC
EMC spectrum with 0.8GeV electron
Rawdata: 190000;
Single electron events : 46%

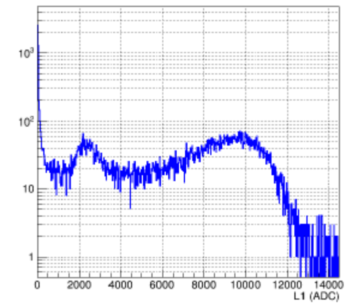
LYSO晶体颗粒量能器

E3初步结果

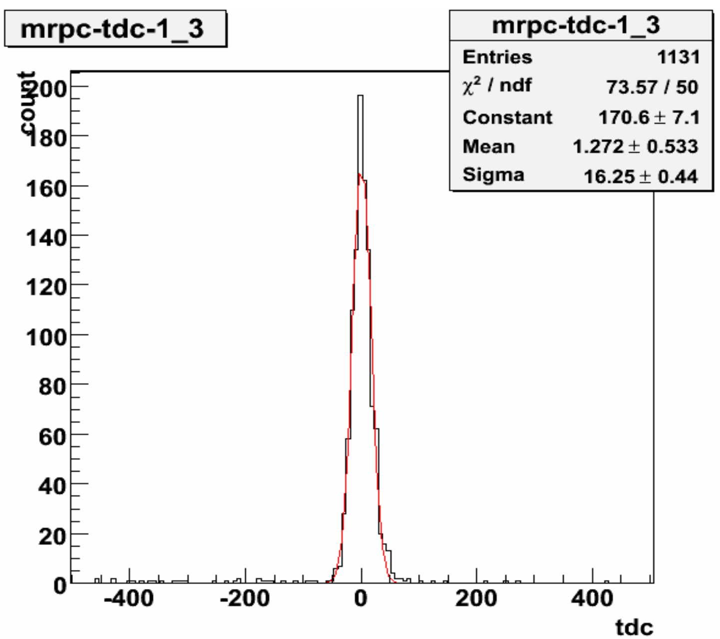


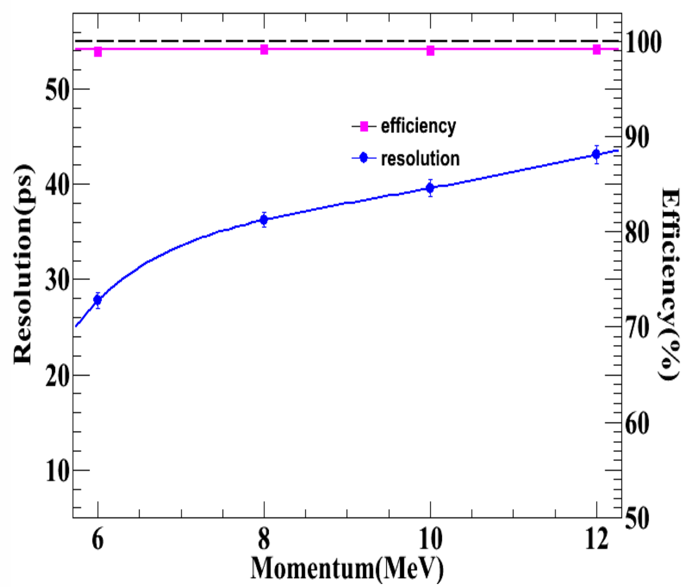


64通道定位系统(5*5 mm2/通道)的一个典型事例，其中沉积能量最大的部分为束流击中点，四周次高的响应由击中通道的串扰引起



700MeV/c入射，单路LYSO晶体的响应，前一个峰为pion+ 的MIP响应；后一个峰为质子的电离能损响应



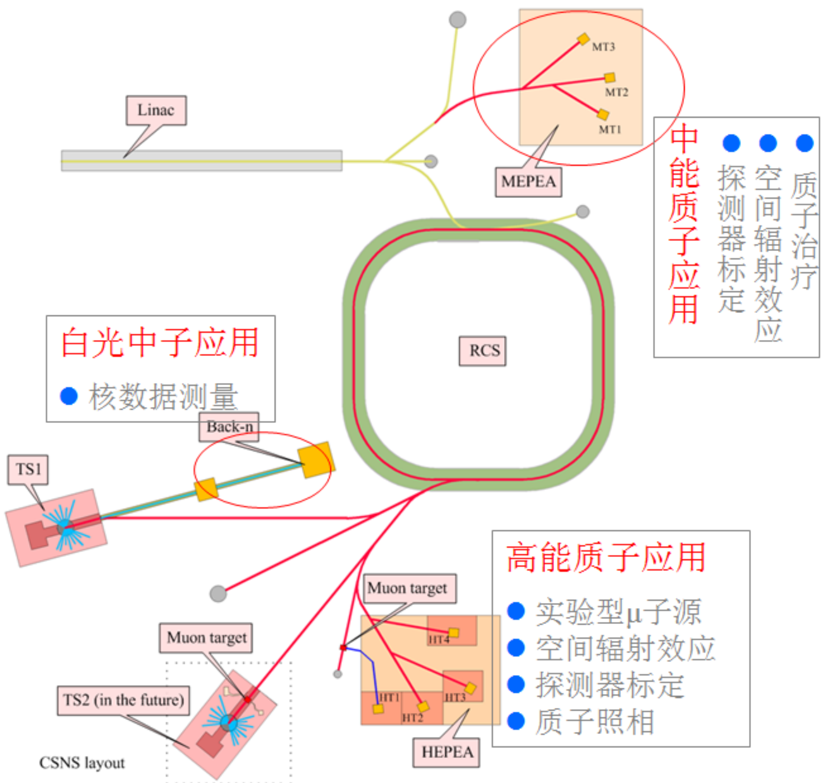


E-TOF upgrade

t_Res=sqrt(16.3*16.3-9.8*9.8)*3.015ps =39.2ps

Other Beam lines in china for experiments

IMP:HIRFL-CSR, proton 10-100MeV
CIAE: HI-13(Tandem accelerator), proton 3-26MeV(100MeV)
CSNS(will deliver a beam at 2017: LE proton 2-80MeV(250MeV).
HE proton 400-1600MeV(1-10^4 ppp)



NSRF & SSRF: Synchrotron radiation

Other low energy e-; proton; neutron can be achieved at NSSC/NINT/CAST and some reactors for some irradiation experiments.

Laser Compton backscattering (LCS) γ-ray source at IHEP

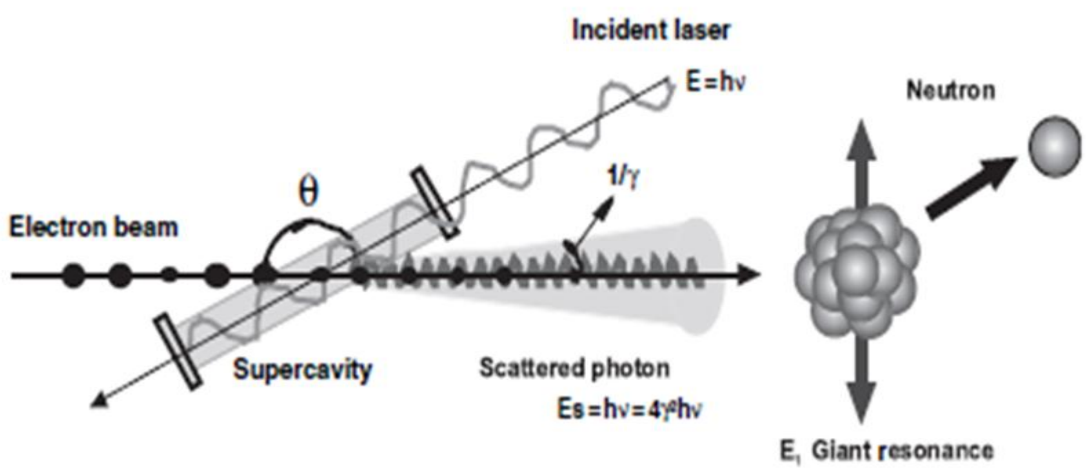
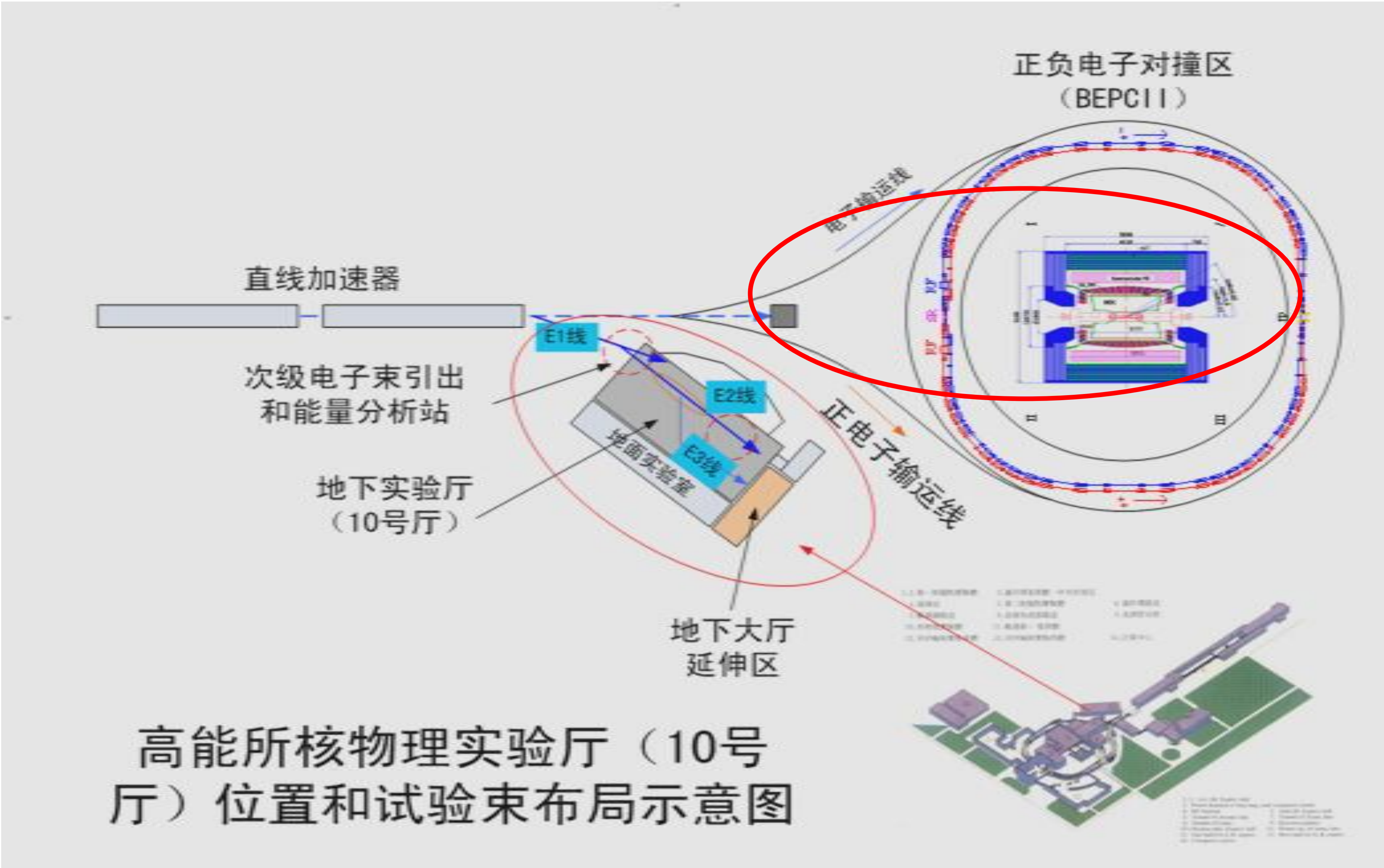


Fig. 10.1. Principles of this scheme

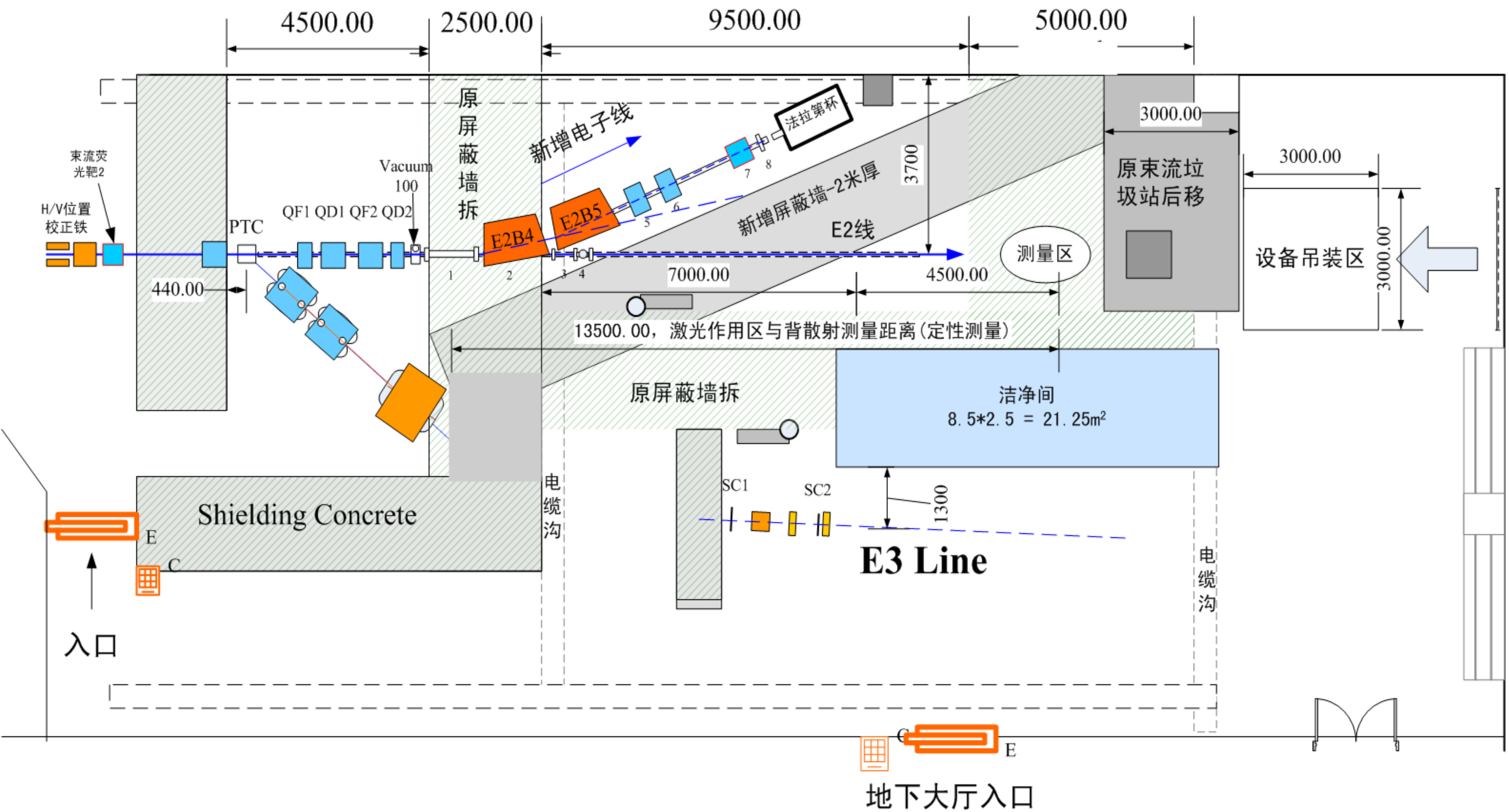
- High brightness
- The Small divergence angle: 1/γ
- tunable energy in the wide MeV-GeV energy range.
- Quasi-monoenergetic
- Highly polarized

- Applications：
- Gamma-nuclear physics：(γ,*) reactions
- Nuclear technique
- Calibration of γ-detectors

10 hall at IHEP



LCS at 10 hall E2 line



LCS parameters—energy:MeV-100MeV

- **Electron beams: 0.5GeV-2.5GeV,10ps, 1nC,12.5Hz**
- **Laser systems:**
- **CO2 laser: 10.6μm, 180ps,1J**
- **Solid laser:1053nm,5-10ps, 500mJ**

$$E_\gamma = E_e \frac{z}{1+z+x},$$
$$z = \frac{4E_eE_L}{(m_ec^2)\text{^}2}, x = (\theta\gamma_e)^2$$

θ: the angle between the γ-ray and the electron;γ_e: the relativistic factor of the electron

Head on collsion&$\theta = 0$	527nm （2.36eV）	1053nm (1.18eV)	10.6μm(0.117 eV)
0.5GeV	9MeV	4.5MeV	0.45MeV
1.0GeV	35MeV	18MeV	1.8MeV
2.5GeV	207MeV	108MeV	11MeV

The parameters of electron and laser beam

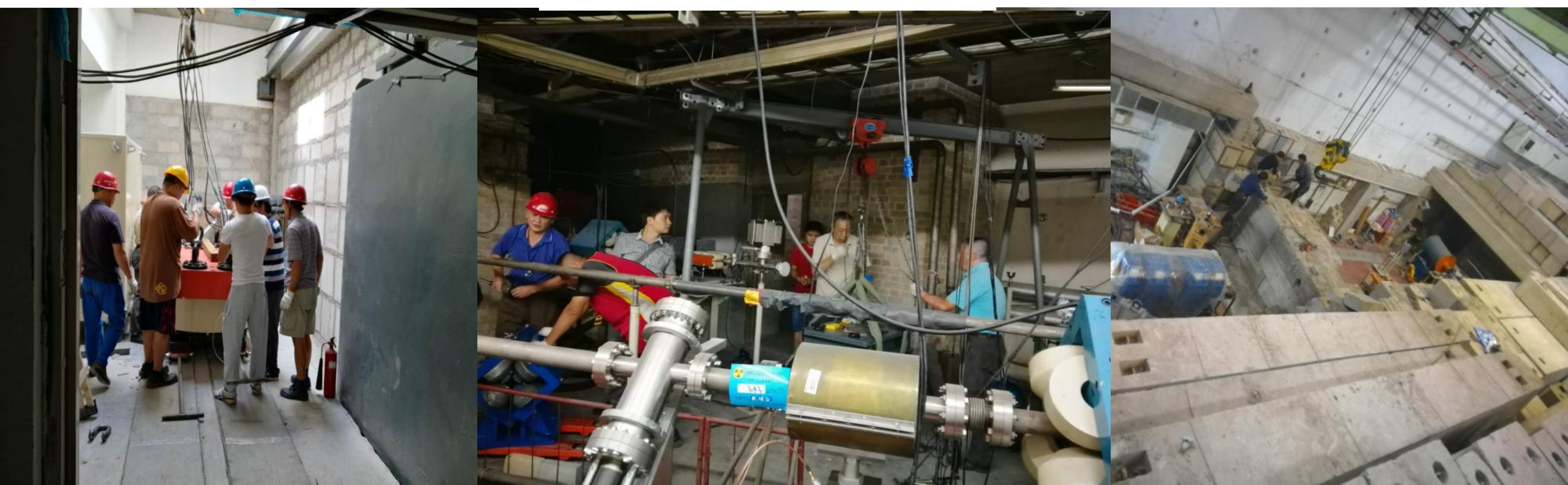
electron:

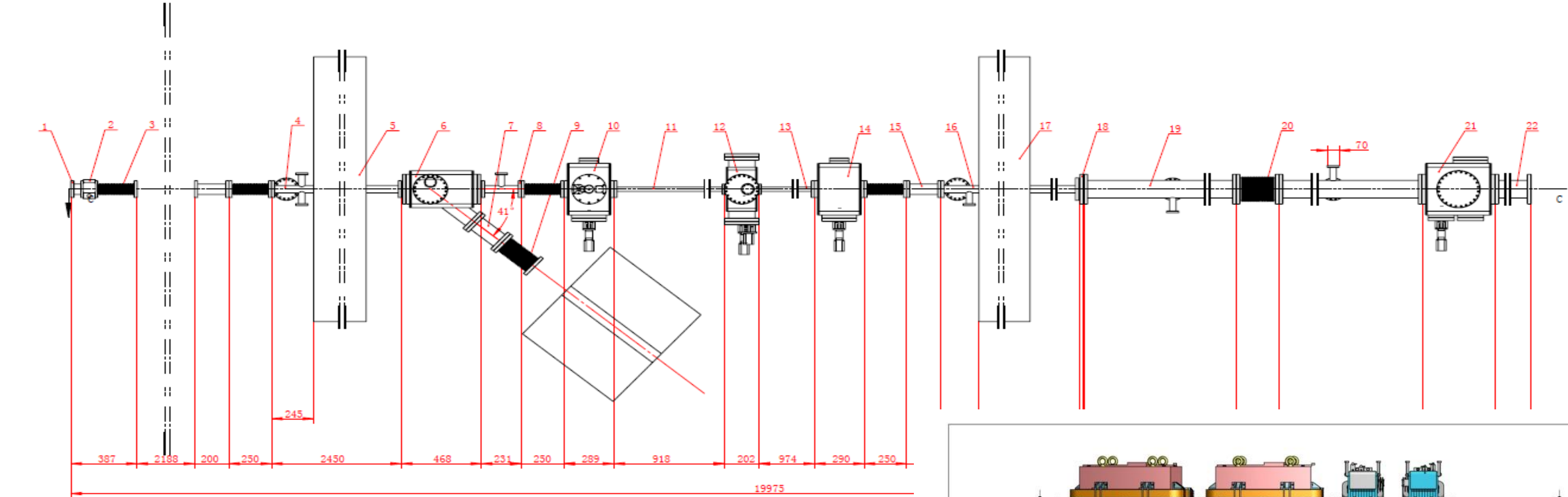
- 2.5GeV/c (1.1Gev /c for future giant resonance experiments)
- pulse width: 10ps
- Charge per bunch: 10nC
- σx,y=0.2mm， 0.6 mm

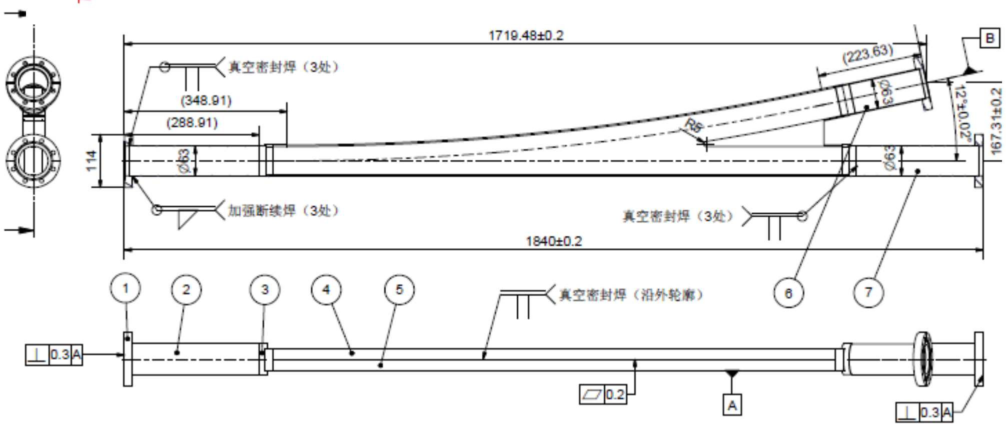
- Laser:
- Wavelength: 1064 nm
- Pulse width: 10ns.
- pulse energy: 2J
- Repetition frequency: 12.5 Hz
- saddle size: 0.4 mm, 0.8mm (focus).

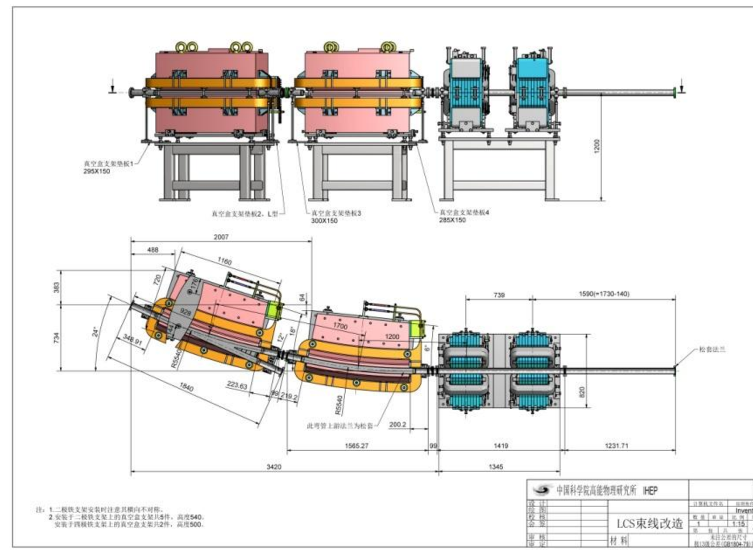
LCS Current status

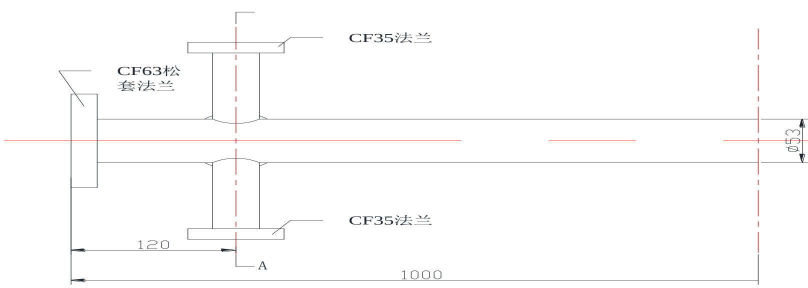
- Magnets(B4, B5,Q9,Q10):completed (on calibration)
- Shield structure and clean room: under construction
- Vacuum tube : completed
- Power supply and control system: under construction
- Beam detectors: under construction
- Maybe perform Collision before Feb. 2018

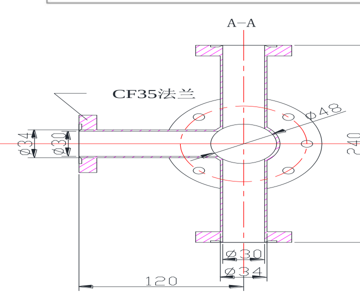












技术要求：

1. 主管道与支管道、主管道与松套法兰，支管道与刀口法兰之间都要有真封焊接，真空漏率小于4×10^{-9}Pa·L/s。
2. 松套法兰刀口端面垂直于主管道轴，垂直度高于0.2。
3. 未注公差尺寸按IJ14级精度加工。
4. 焊接后应保证主管道任意一处相对磁导率小于1.05。

零件名称	数量		
CF63松套法兰	2		
CF35法兰	6		
主管道	1		
支管道	6		
名称	对撞管		
图号	pipe03		
数量	1	比例	
共 3 张		第 3 张	

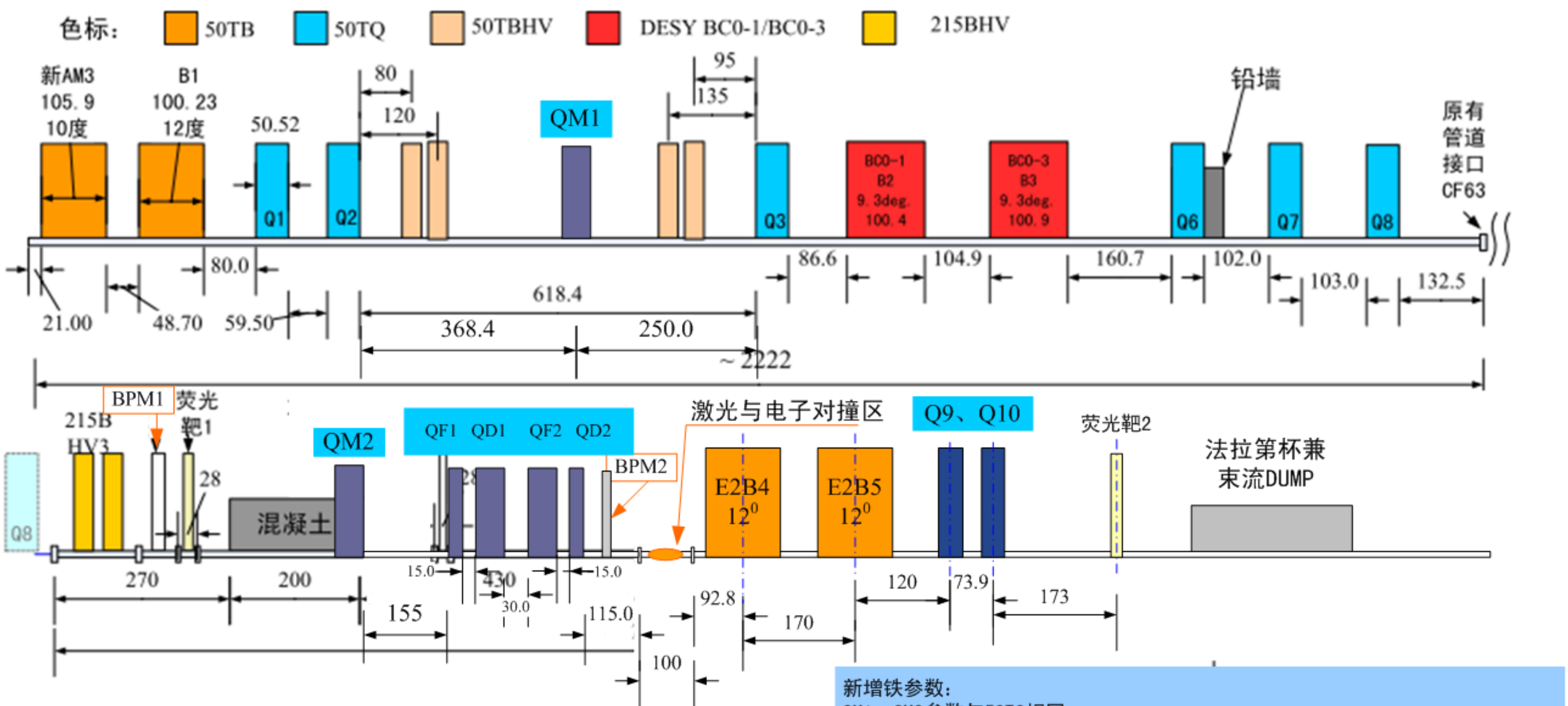
summary

- There are significant test beams lines at most of our laboratories.
- Detector R&D is critical to extract the physics from the machine.
- As hardware and software prototypes are developed, and test beam results will have a significant impact on the research tool we are building.
- Need a strong user support to keep the facility operational.
- High brightness Laser Compton backscattering (**LCS**) γ-ray will be a very useful tool for nuclear physics.

Thank for you attention !

Backup

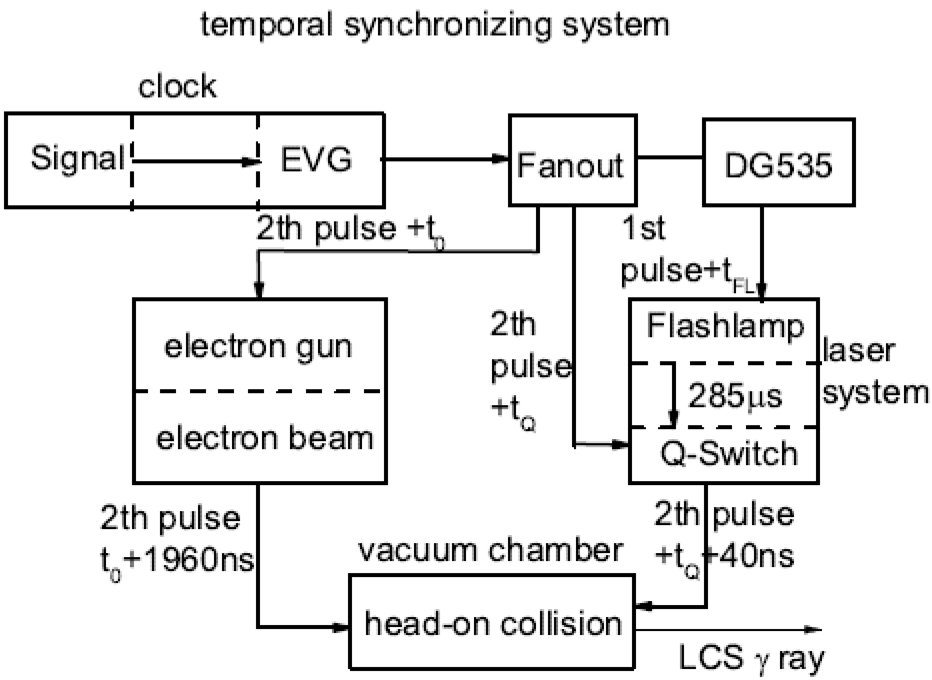
Transport Lines of the Beijing-TBF （E2 Line）

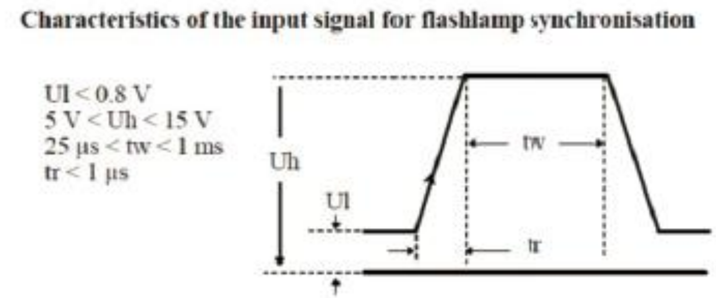


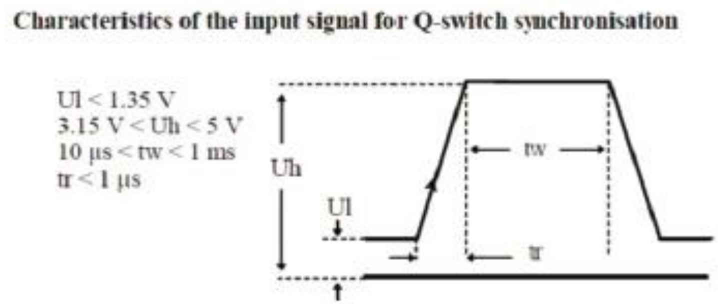
新增铁参数：
QM1，QM2参数与50TQ相同；
QF1，QD2铁长均为23.1cm，QD1，QF2铁长为41.1cm，梯度均为47T/m，孔径30cm；
Q9，Q10均为BEPC-110Q旧铁，L=40.4cm，梯度1100Gs/cm；
E2B4，E2B5新扇形铁，最大场强1.5T，$L_{有效}$=1.16m，Gap=5cm，好场宽（弧线）5cm

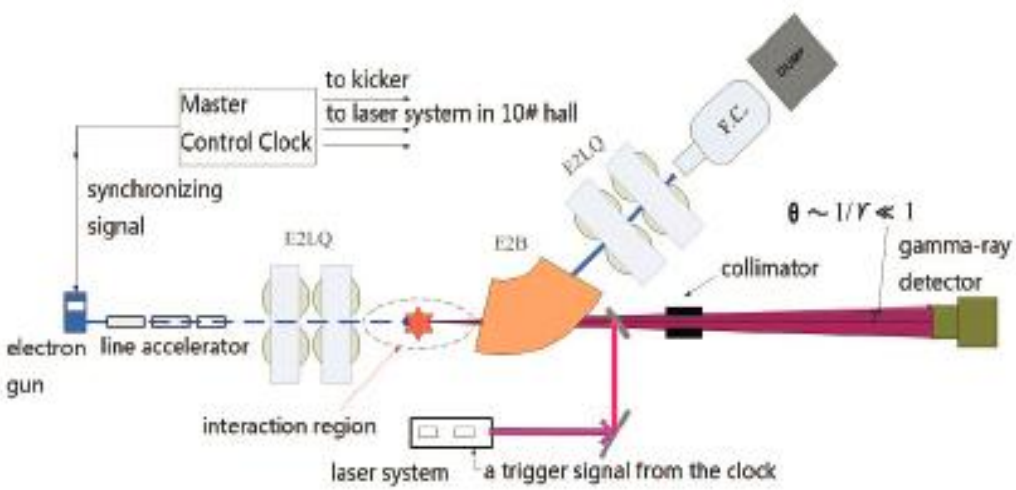
说明：
图中尺寸单位：厘米，矩形图上数字为磁铁的磁等效长度
和偏转角度，

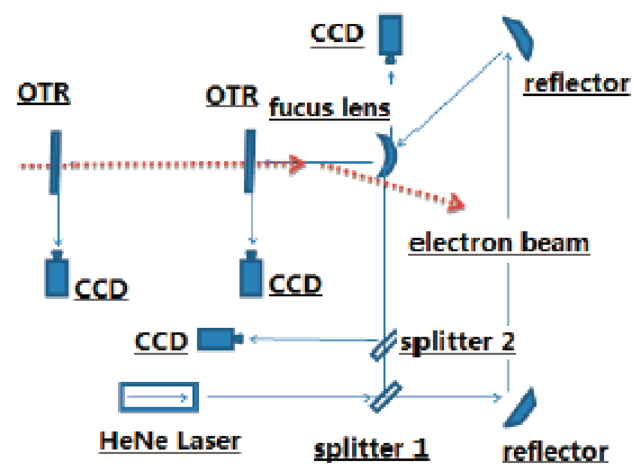
图1 — E2束流线结构与真空部件


temporal synchronizing system
clock
Signal
EVG
Fanout
DG535
2th pulse +t0
1st pulse+tFL
electron gun
electron beam
2th pulse +tQ
Flashlamp
285μs
Q-Switch
laser system
2th pulse t0+1960ns
2th pulse +tQ+40ns
vacuum chamber
head-on collision
LCS γ ray


Characteristics of the input signal for flashlamp synchronisation
Ul < 0.8 V
5 V < Uh < 15 V
25 μs < tw < 1 ms
tr < 1 μs
Uh
Ul
tw
tr


Characteristics of the input signal for Q-switch synchronisation
Ul < 1.35 V
3.15 V < Uh < 5 V
10 μs < tw < 1 ms
tr < 1 μs
Uh
Ul
tw
tr


Master Control Clock
to kicker
to laser system in 10# hall
synchronizing signal
E2LQ
E2B
E2LQ
F.C.
θ ~ 1/γ ≪ 1
collimator
gamma-ray detector
electron gun
line accelerator
interaction region
laser system
a trigger signal from the clock


CCD
reflector
OTR
OTR
fucus lens
electron beam
CCD
CCD
CCD
splitter 2
HeNe Laser
splitter 1
reflector