中国科学院高能物理研究所
Institute of High Energy Physics, Chinese Academy of Sciences

The strategic planning for the PBA-TF and the corresponding team

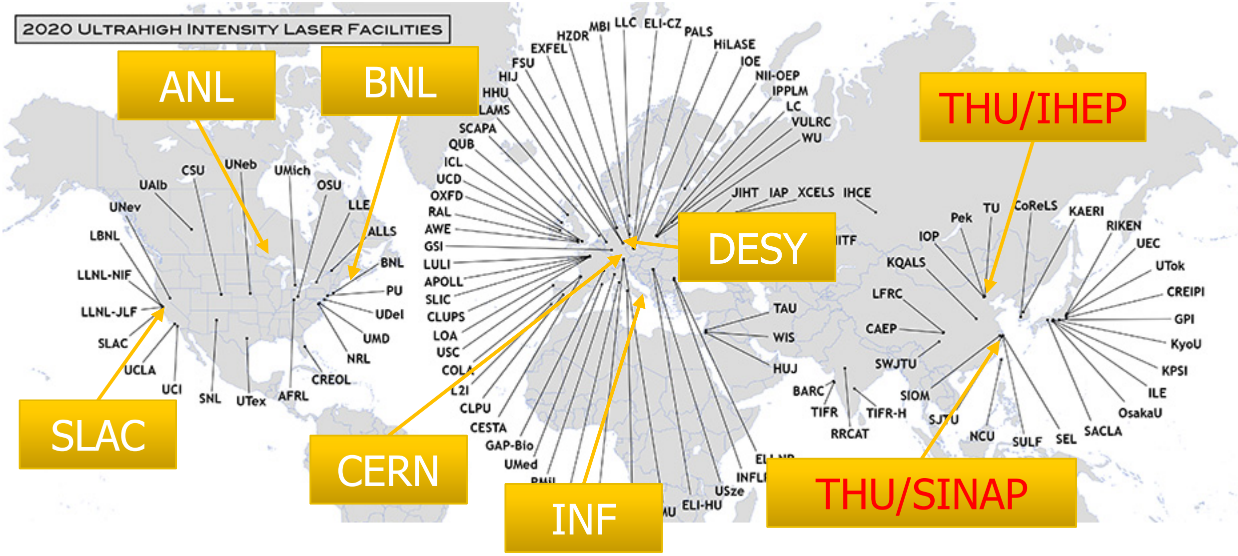
Dr. Dazhang Li, et al.

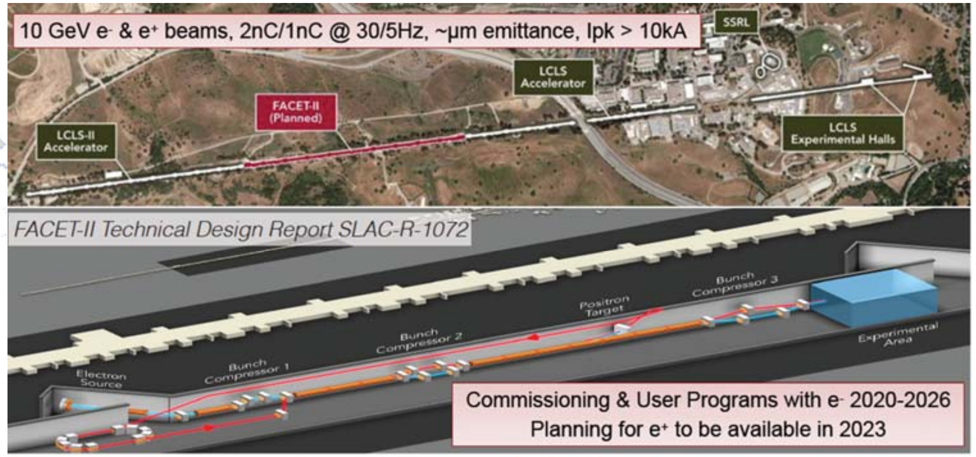
On behalf of the CEPC Plasma Injector team

Outlines

- Motivations and goals
- Current status and timetable
- Preliminary progress and growing team

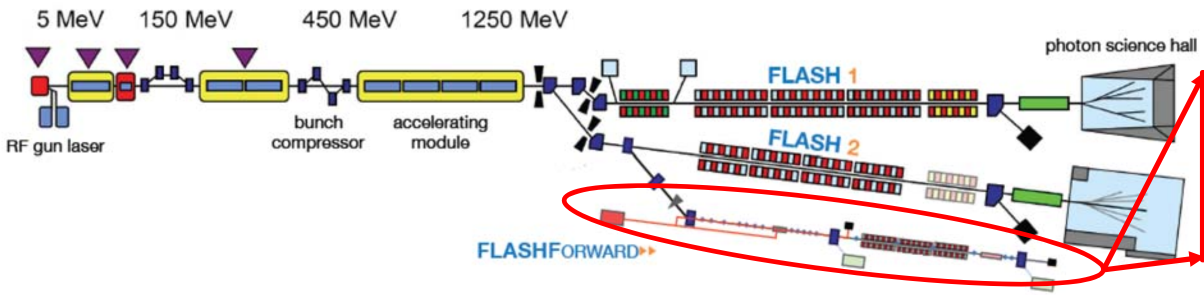
PWFA TF: for FEL and for Future Collider

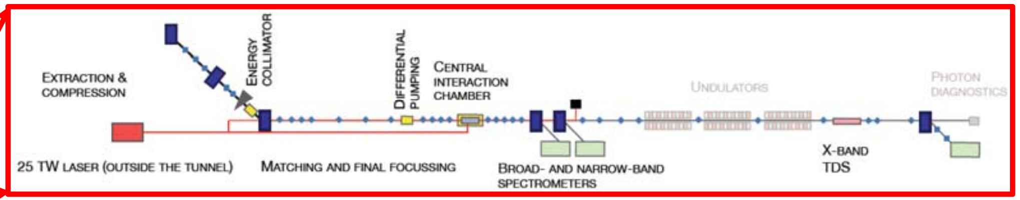




Electron Beam Parameter	Baseline Design	Operational Ranges	Positron Beam Parameter	Baseline Design	Operational Ranges
Final Energy [GeV]	10	4.0-13.5	Final Energy [GeV]	10	4.0-13.5
Charge per pulse [nC]	2	0.7-5	Charge per pulse [nC]	1	0.7-2
Repetition Rate [Hz]	30	1-30	Repetition Rate [Hz]	5	1-5
Norm. Emittance $\gamma\varepsilon_{x,y}$ at S19 [μm]	4.4, 3.2	3-6	Norm. Emittance $\gamma\varepsilon_{x,y}$ at S19	10, 10	6-20
Spot Size at IP $\sigma_{x,y}$ [μm]	18, 12	5-20	Spot Size at IP $\sigma_{x,y}$ [μm]	16, 16	5-20
Min. Bunch Length σ_z (rms) [μm]	1.8	0.7-20	Min. Bunch Length σ_z (rms)	16	8
Max. Peak current I_{pk} [kA]	72	10-200	Max. Peak current I_{pk} [kA]	6	12

Affiliations/institutes on PWFA Study





CPI TF: not only for PBA, but also for conv. acc.

Key issues		Preliminary study/ Conceptual design	Detailed and convincing simulations / designs	Experiment test / Prototype
e- PWFA	HTR	√	√	×
	Beam quality preservation	√	√	×
	Error analysis	√	×	×
e+ PWFA	High quality practical scheme	√	√	×
	More schemes, HTR etc.	√	×	×
	High efficiency	√	×	×
Conv. acc. physics and techniques	High charge L-band RF Gun	√	×	×
	Beam profile preservation	√	×	×
	Beam merging	√	×	×
	Instrumentation	√	×	×
	Timing synchronization	√	×	×
	Positron beamline	√	√	×
Plasms source and beam manipulation	Plasma dechirper	√	√	√
	Plasma lens	×	×	×
	Plasma sources	√	√	×
	Staging	√	×	×

Principles of CPI TF: unique and cost-effective

Beam Parameters of FACET-II

Electron Beam Parameter	Baseline Design	Operational Ranges	Positron Beam Parameter	Baseline Design	Operational Ranges
Final Energy [GeV]	10	4.0-13.5	Final Energy [GeV]	10	4.0-13.5
Charge per pulse [nC]	2	0.7-5	Charge per pulse [nC]	1	0.7-2
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Beam Parameters of FLASHForward

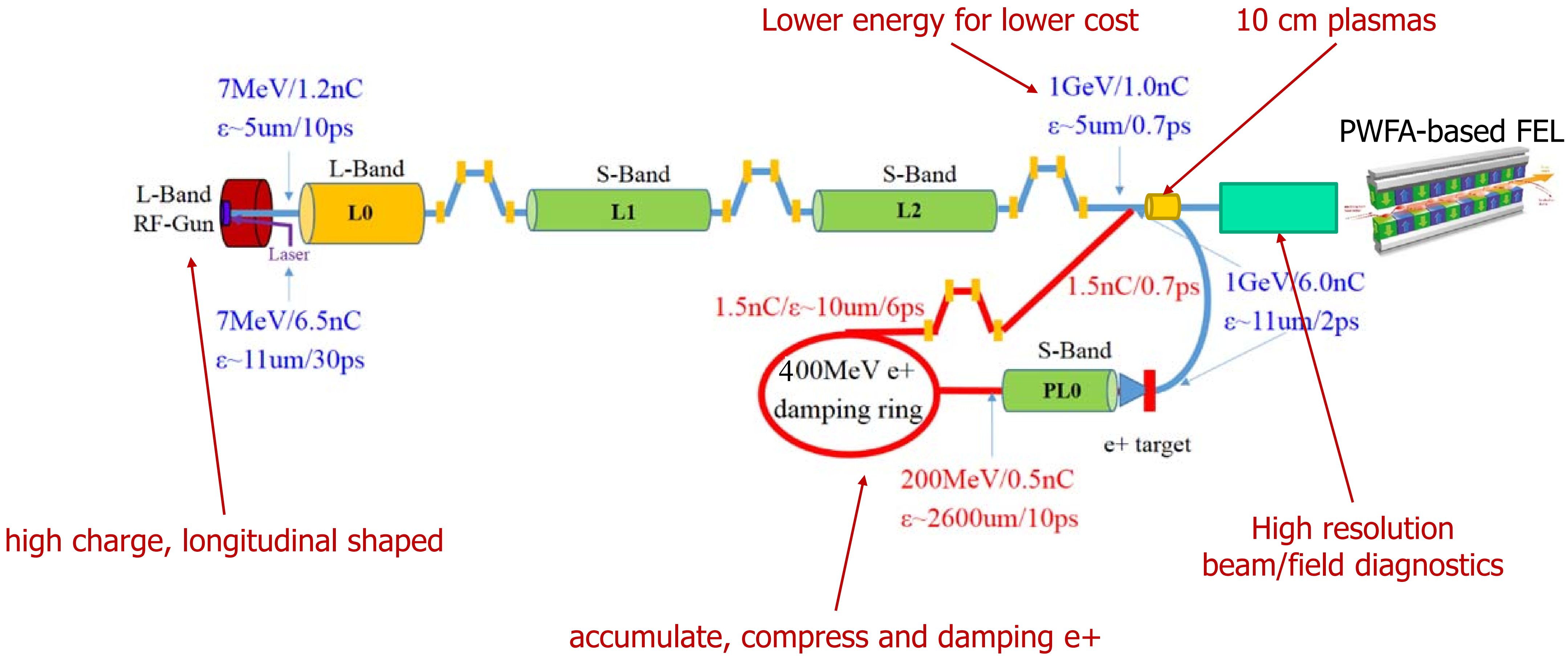
Beam type	e- only
Beam energy	1.25 GeV
Transverse emittance (nor.)	2 mm·mrad
Peak current	2.5 kA
Bunch charge	0.1~3 nC
Focal spot	~ 7μm
Energy spread	0.1%

Principles of CPI TF

1. **MUST including e+ beamline**
2. **High charge L-band RF needed**
3. **Staging of different types of accelerators**
4. **As low energy as possible**
5. **PWFA-based FEL studies included**
6. **Scheme 1: based on BEPC-II linac**
7. **Scheme 2: a new dedicated TF based on a SC linac for high rep. rate and high average power EUV source studies**
8. **$I_{peak} \geq 3$kA; $n_b \geq n_p (10^{16} cm^{-3})$ →**

3kA @ 10μm×10μm

Preliminary design for a plasma acceleration TF



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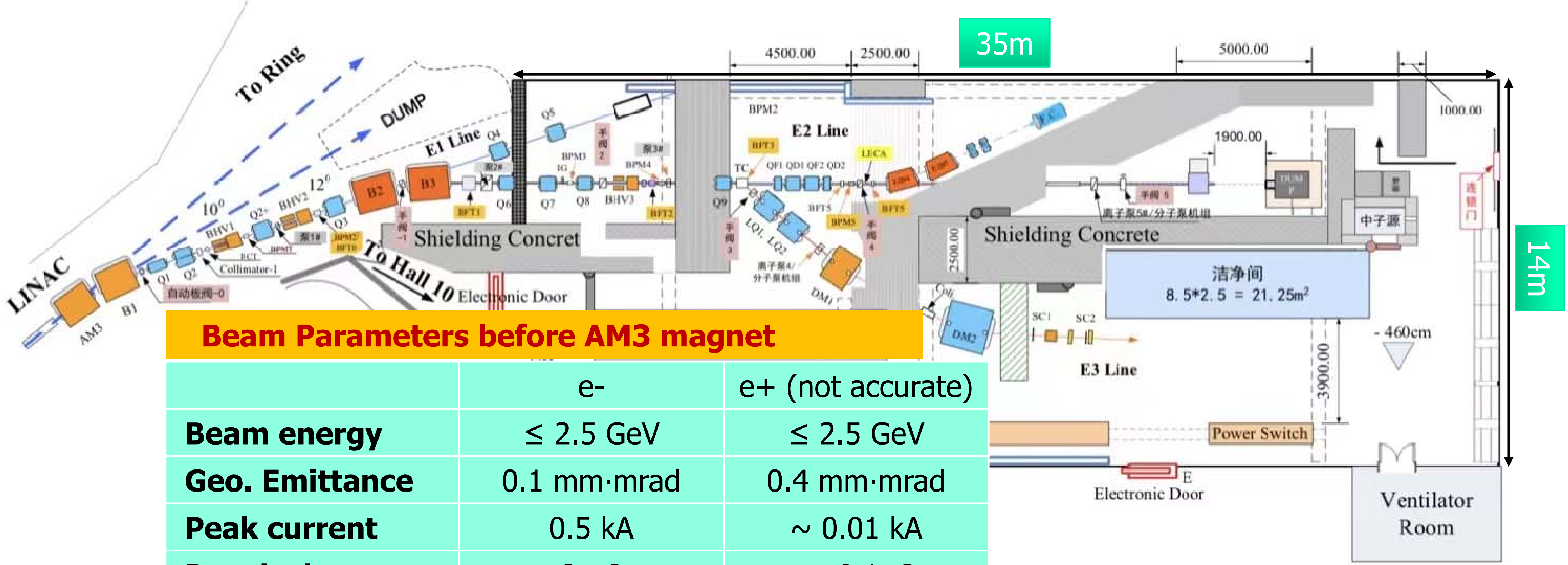
BEPC-II linac and Hall 10



Beam Parameters before AM3 magnet

	e-	e+ (not accurate)
Beam energy	≤ 2.5 GeV	≤ 2.5 GeV
Geo. Emittance	0.1 mm·mrad	0.4 mm·mrad
Peak current	0.5 kA	~ 0.01 kA
Bunch charge	2 nC	< 0.1nC
Focal spot	1.1mm×1.1mm	2mm×2mm
Energy spread	0.5%	0.5%

Hall 10 upgrade proposals and beam qualities

- **Phase I (1-2 years):**
  - ➢ Overall lattice and light path design
  - ➢ New transport beamline installation & commissioning
  - ➢ Final Focus installation in Hall 10
  - ➢ Clean room + laser system installation
  - ➢ L-band RF gun design
- **Phase II (3-5 years):**
  - ➢ L-band RF gun fabrication and test
  - ➢ Instrumentation installation
  - ➢ Laser system and beamline combination
- **Phase III (~ 5 years):**
  - ➢ L-band RF installation and BEPC-II linac upgrade
  - ➢ e+ beamline installation
  - ➢ PBA based FEL studies

Phase I	e0	e1	p1	eL
Energy	≤ 2.5 GeV	/	≤ 2.5 GeV	≤ 0.5 GeV
Peak current	0.5 kA	~ 2 kA	~ 0.1 kA	≥ 5kA
Bunch charge	2 nC	2nC	< 0.1nC	0.2nC
Focal spot	1.1mm	50μm	50μm	1μm
Energy spread	0.5%	0.5%	0.5%	< 5%
Profile	Gaussian	Gaussian	Gaussian	Gaussian

Phase II & III	e1	e2	p2	eL
Energy	/	≤ 2.5 GeV	0.4~0.6 GeV	≤ 0.5 GeV
Peak current	~ 2 kA	≥ 6 kA	~ 3 kA	≥ 5kA
Bunch charge	2nC	10 nC	~ 1nC	0.2nC
Focal spot	50μm	< 10μm	50μm	1μm
Energy spread	0.5%	/	/	< 5%
Profile	Gaussian	triangle	Gaussian	Gaussian

Beam requirement for different studies

Research		driver	trailer
e- PWFA	① blowout acc.	e1 or eL	
	③ HTR acc.	e2	e1 or eL
e+ PWFA	① acc. structure	e1	/
	① preliminary acc.	eL	p1
	③ High quality acc.	e2	p2
Conv. acc. physics and techniques	② L-band RF gun test	/	/
	③ Beam profile	e2	/
	① Beam merging	e1/eL	
	② Instrumentation	eL	/
	② Synchronization	eL	e1/e2
	③ e+ beamline	p2	/
Plasms source and beam manipulation	① Dechirper	e1/eL	/
	② Plasma lens	/	/
	① Plasma sources	/	/
	③ Staging	e1, e2, eL	

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Focal spot	50μm	< 10μm	50μm	1μm
Energy spread	0.5%	/	/	< 5%
Profile	Gaussian	triangle	Gaussian	Gaussian

- **2022.12: Phase I conceptual design (physics)**
- **2023.02: Phase I technical design (engineering drawing) and Phase II and III conceptual design (physics)**
- **2022.04: Phase II and III technical design (engineering drawing)**

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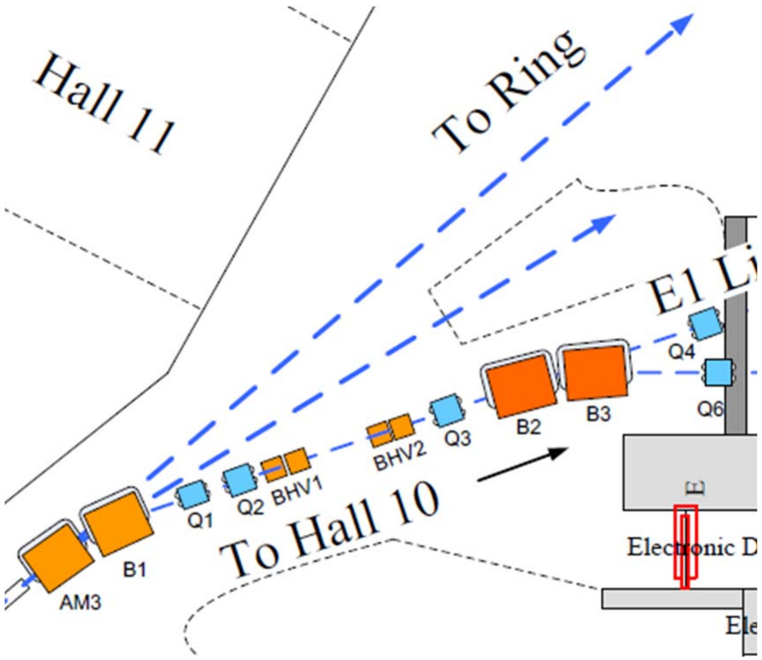
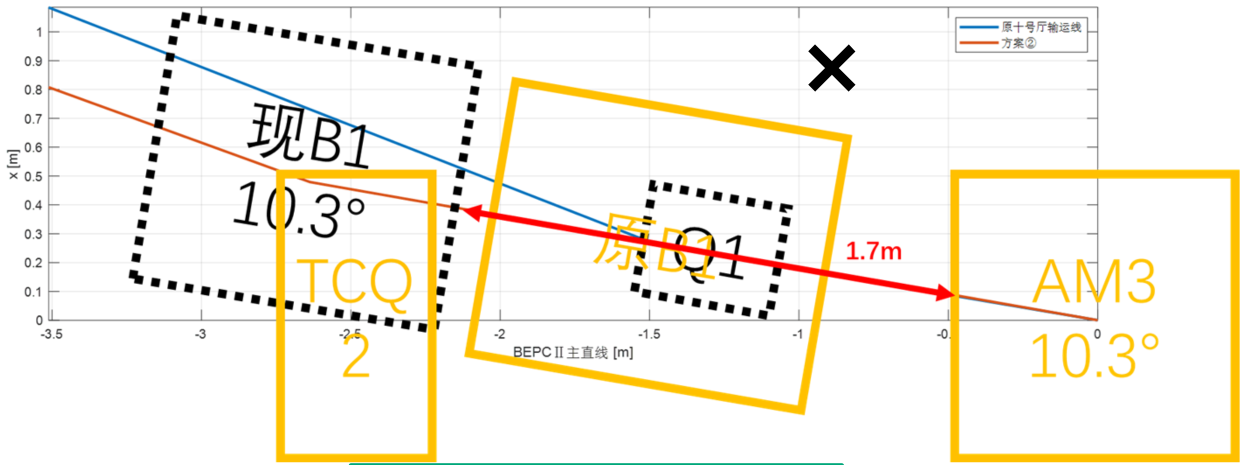
Transport Line from AM3 to Hall 10

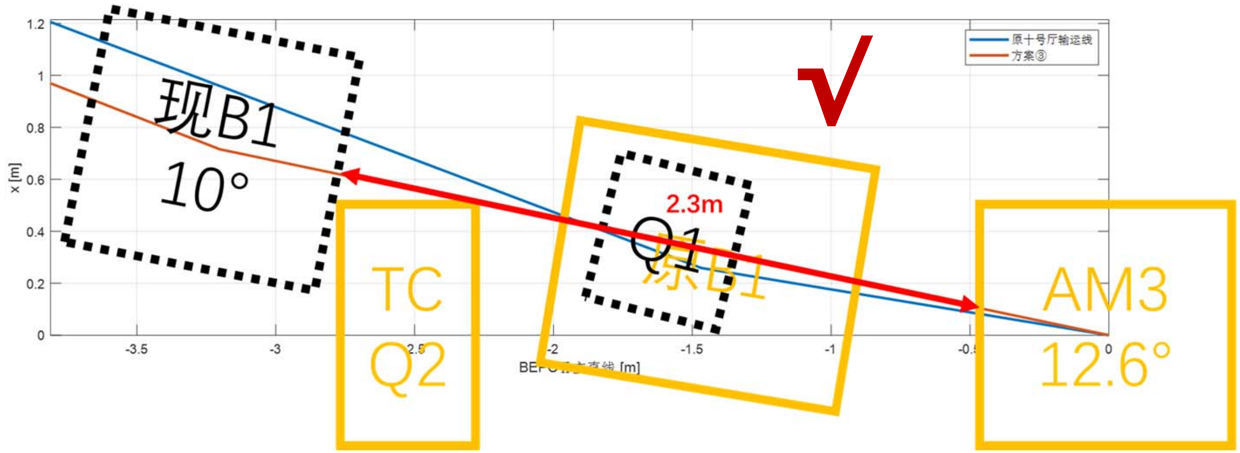


- **Main function of the new transport line:**
  - ➢ Dispersion correction (since the energy spread is large)
  - ➢ Bunch length compression from 1.2mm to ≤0.3mm
  - ➢ Similar twiss parameters before AM3 and after B3
- **Boundary condition:**
  - ➢ Space limit, especially around AM3, B1
  - ➢ Same deflect angle for AM3, B1 and B2, B3
  - ➢ AM3 to Hall 10: ~ 18-20 meters
  - ➢ Quadruple ≤ 30 T/m， Dipole ≤ 1.4 T (for large beam pipe)
  - ➢ Gap between magnets should be larger than 30cm
- **Basic method:**
  - ➢ Local dispersion correction (B+Q+B)
  - ➢ Add chicane for bunch length compression

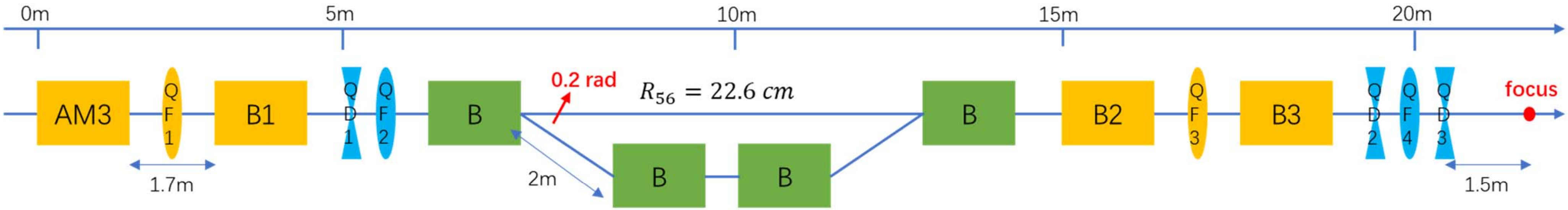
Space limit: AM3, B1 and Q1



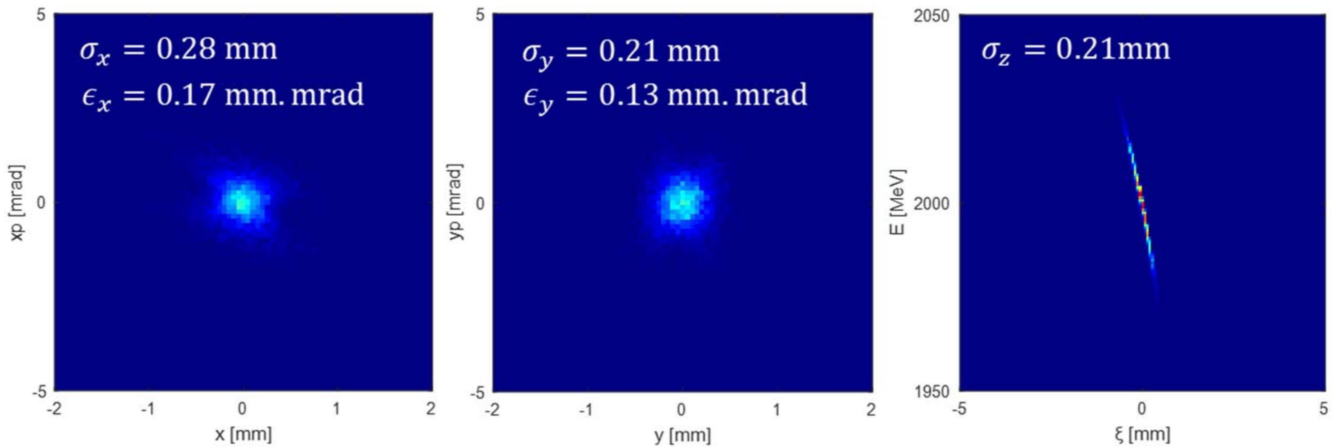
Need Check the space



Preliminary optimization results

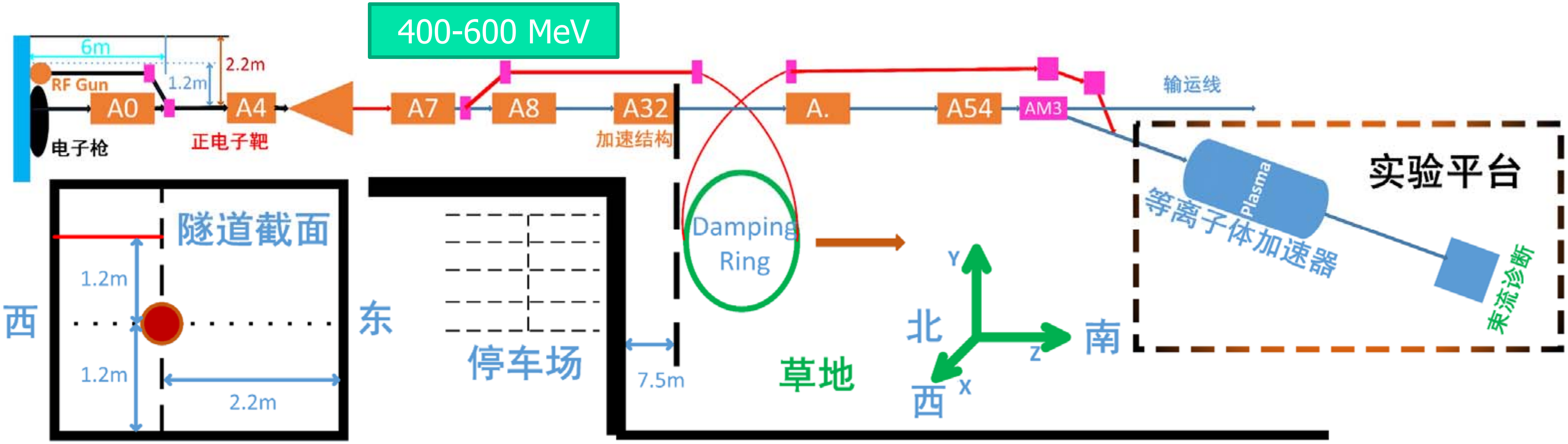


磁铁参数	AM3/B1/B2/B3	B	QF1	QD1	QF2	QF3	QD2/QD3	QF4
Length[m]	0.98	1.1	0.5					
Strength	1.22 T	1.2 T	23 T/m	12 T/m	11 T/m	23 T/m	21.4 T/m	23 T/m



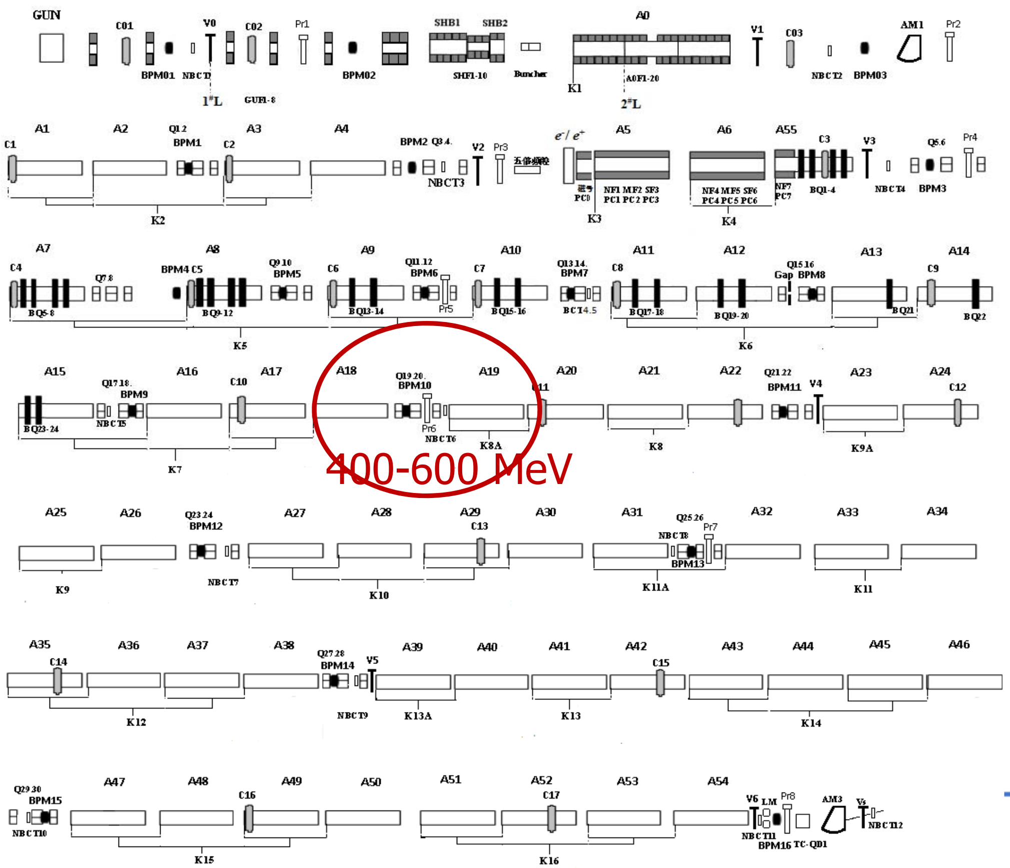
by Dr. Xueyan Shi, Haisheng Xu and Weibin Liu

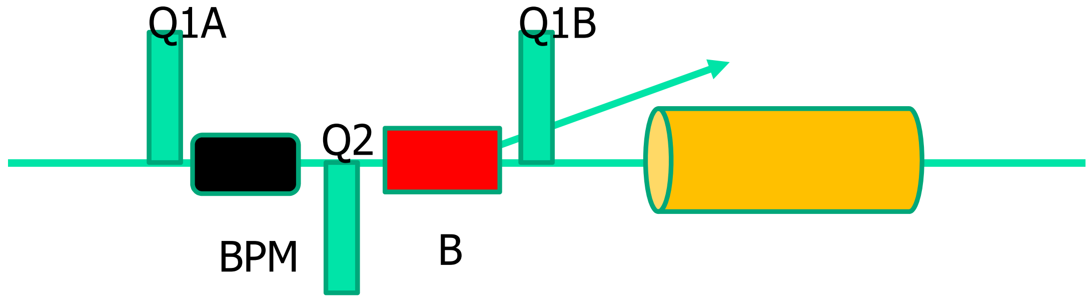
Conceptual design for BEPC-II main Linac upgrade



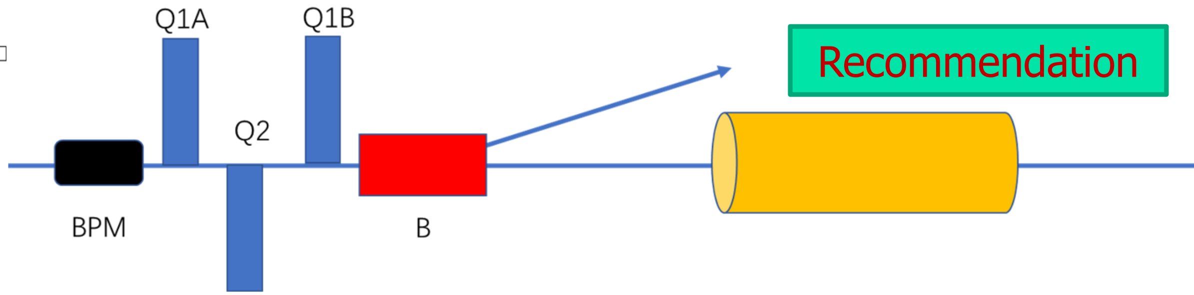
1. **e+ beamline**
2. **e- L-band RF gun**
3. **e- beam line (for RF gun)**

Main Linac upgrade -- e+ beamline -- extraction

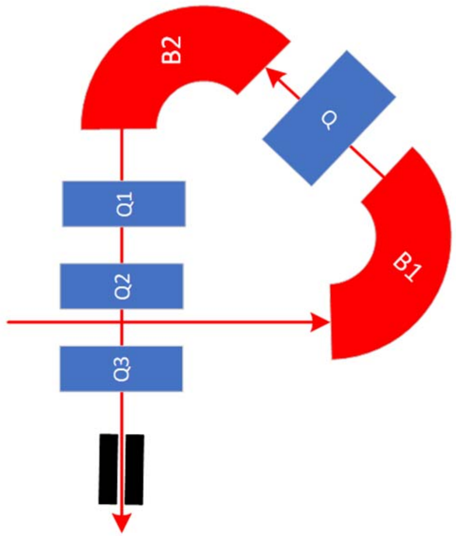




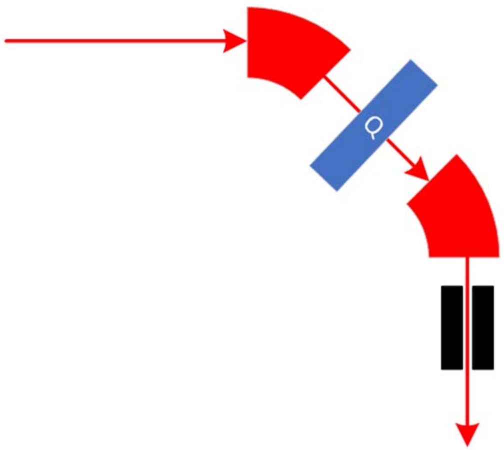
- 限制条件（需要实际查看）
  - 两个四极磁铁之间距离350mm，四极磁铁长度100/200mm，四极磁铁与下游加速结果长度307mm（可能有BCT？）
- **布局1**
  - 二极磁铁放在Q2与Q1B之间
  - 正电子400MeV→磁刚度1.334T-m
    - 偏转半径1.2m，磁场强度1.2T
  - 偏转角度13°
    - 在加速结构处，偏离约130mm，估计基本满足要求
    - **Q1B处孔径太大，需要重新设计**

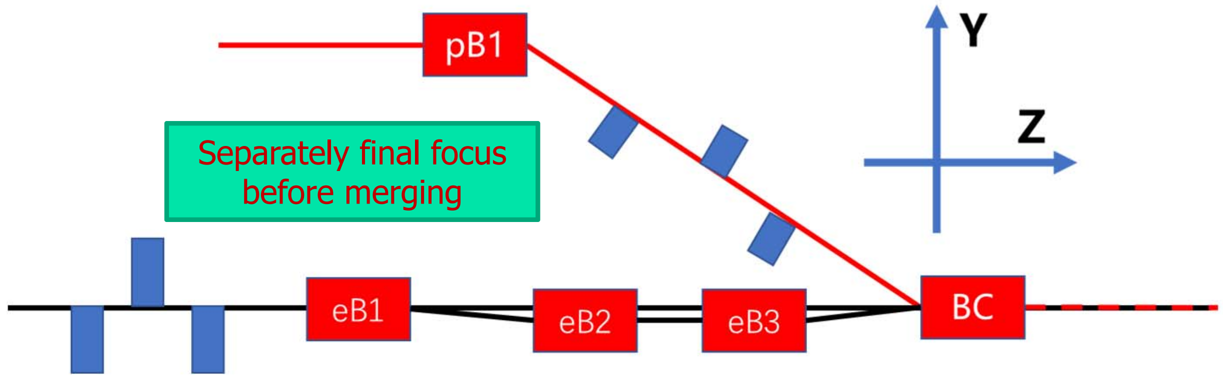


Main Linac upgrade -- e+ beamline -- through wall

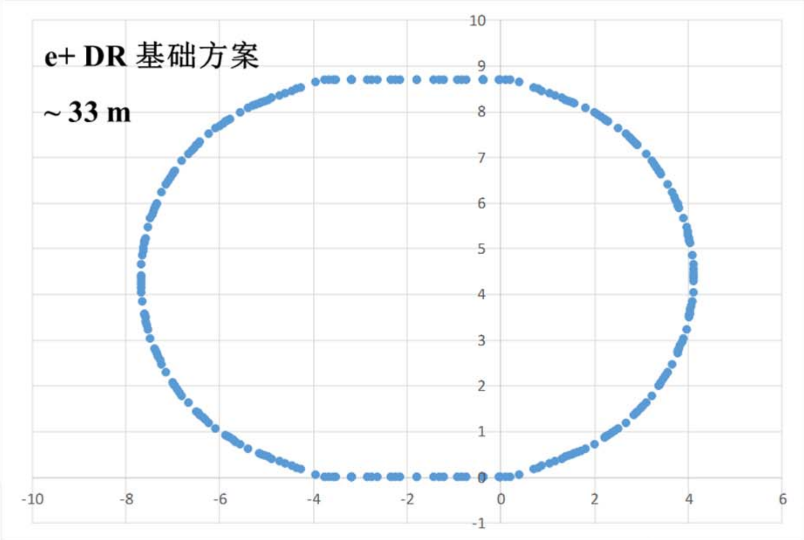


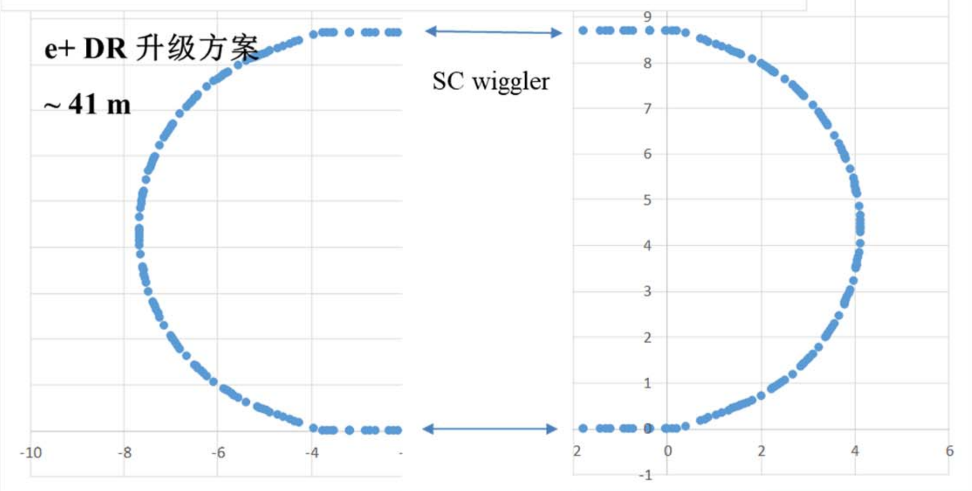
- 正电子束线过墙（需要明确过墙尺寸限制）
  - 要求过屏蔽墙只能小孔过，不能放四极磁铁
  - 需要在直线隧道内完成局部消色散
    - 方案1：采用~270°弯铁系统，两个~135°偏转铁+四极磁铁（×）
      - 【√】可以在过墙之前放置triplet，长漂移段
      - 【×】横向空间要求占用人行道侧大于2.4m,超过直线隧道横向空间
    - 方案2：采用<90°弯铁系统，比如两个35°偏转铁+四极磁铁
      - 横向空间要求$\rho\left(1-\cos\theta+\frac{1}{2\cos\theta}\right)+L\sin\theta$，占用内测空间，需要确认空间是否满足要求
      - 偏转系统之前放置四极磁铁





400MeV e+ DR (600 MeV DR under consideration)

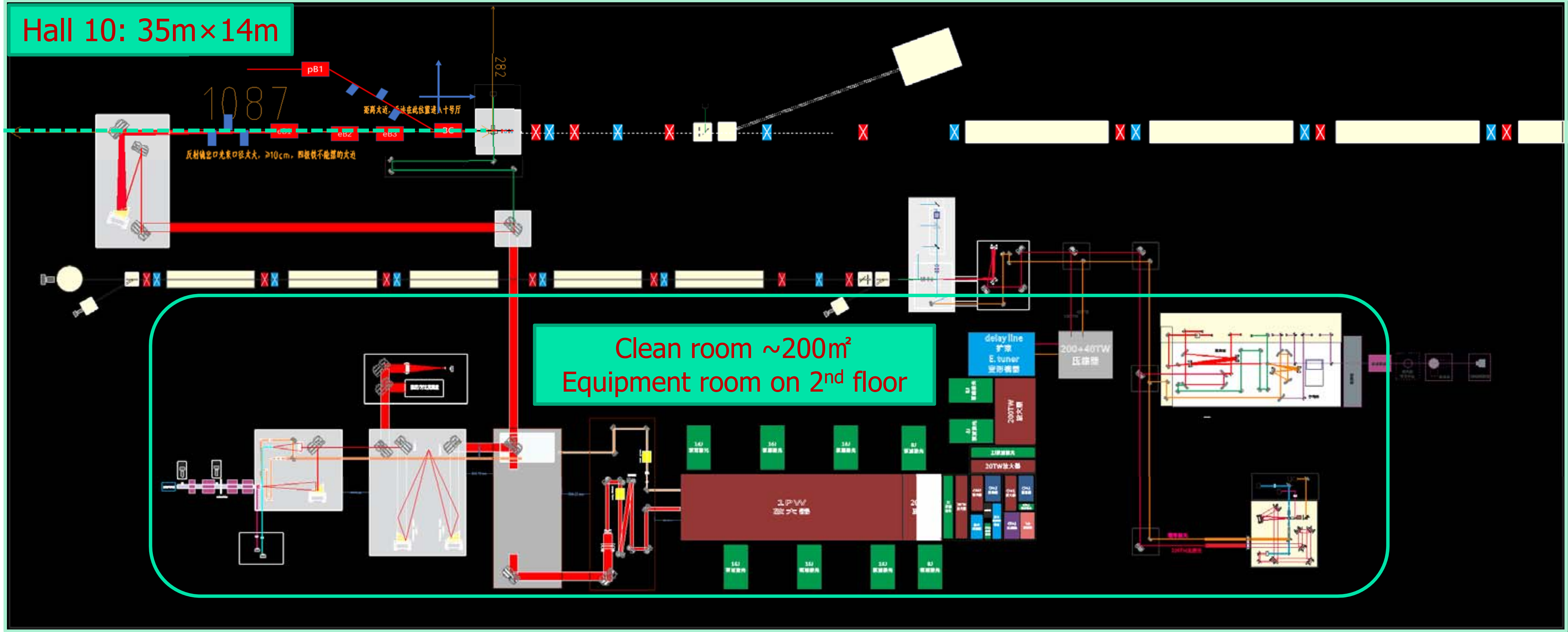




	DR
Energy (Mev)	400
Circumference (m)	33
Number of bunches	1
Bunch charge (nC)	1.0
Bending radius (m)	1.0
Dipole strength B_0 (T)	1.3
U_0 (kev/turn)	2.6
Damping time x/y/z (ms)	33.5/33.5/16.9
Phase/cell (degree)	60/60
Momentum compaction	0.088
Storage time (ms)	$\propto$?
δ_0 (%)	0.039
ε_0 (mm.mrad)	35
injection σ_z (mm)	3.1
Extract σ_z (mm)	2.65
ε_{inj} (mm.mrad)	2500
$\varepsilon_{ext\,x/y}$ (mm.mrad)	35/49
$\delta_{inj}/\delta_{ext}$ (%)	0.3%/0.039%
Energy acceptance by RF(%)	2.8
f_{RF} (MHz)	500
V_{RF} (MV)	2.4
Longitudinal tune	0.068

e+ DR 基础方案设计参数

Overall design for Hall 10 light path



Manpower distribution (IHEP team & THU team)

- **In charge: Prof. Yuhui Li and Prof. Wei Lu (take regular meeting fortnightly)**
- **Overall lattice design:**
  - Transport line: Weibin Liu, Xueyan Shi, Haisheng Xu;
  - Final Focus in Hall 10: Yiwei Wang, Cai Meng, Dou Wang; Zhi Song, Hengyuan Xiao
  - BEPC-II main Linac: Cai Meng, Xiaoping Li, Lei Du;
  - L-band RF Gun: Xiaoping Li, Guan Shu; Zhi Song
  - e+ beamline: Dou Wang, Lei Du, Xiaohao Cui, Zhe Duan (polarization)
  - Instrumentation: Huizhou Ma, Yanfeng Sui (may need more people)
  - Beam dump and radiation protection: Zhongjian Ma
  - FEL related: Yuhui Li
  - Other supporter from AC: Xiang He, Dayong He (AC-Linac); Jianli Wang (AC-Mechanical)……
- **Laser installation and optics path design:**
  - 40TW, 200TW and 1PW Laser system: Desheng Hong, Fei Li
  - Clean room and Hall 10 decoration: Dazhang Li, Jianfei Hua
  - Laser system and beamline combination: Dazhang Li, Caimeng; Jianfei Hua, Fei Li
  - Plasma source and fs e- probe: Fei Li, Shuang Liu