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

IHEP plasma accelerator test facility development status

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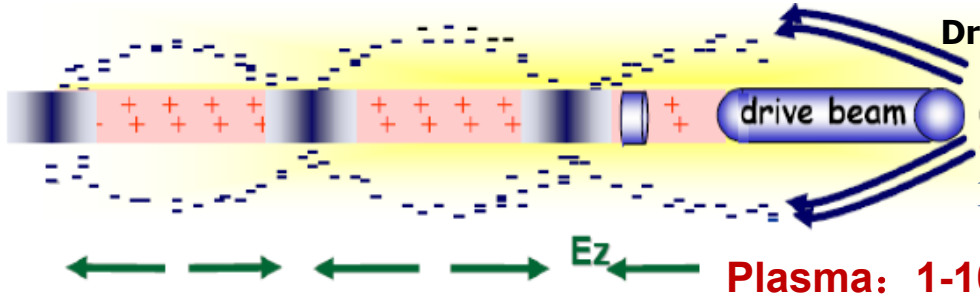
On behalf of on IHEP-THU-BNU Team

Outlines

- **Motivation**
- **PBA TF based on BEPCII linac**
- **Proposed experiments in the near future**
- **Summaries and prospects**

Plasma Based Acceleration (PBA): > 1000 $E_{acc.}$

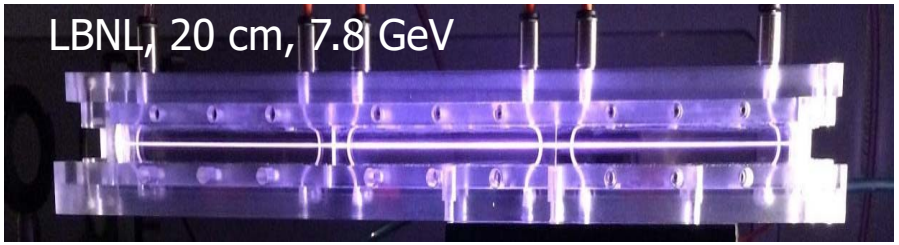
RF cavity：< 100MeV/m

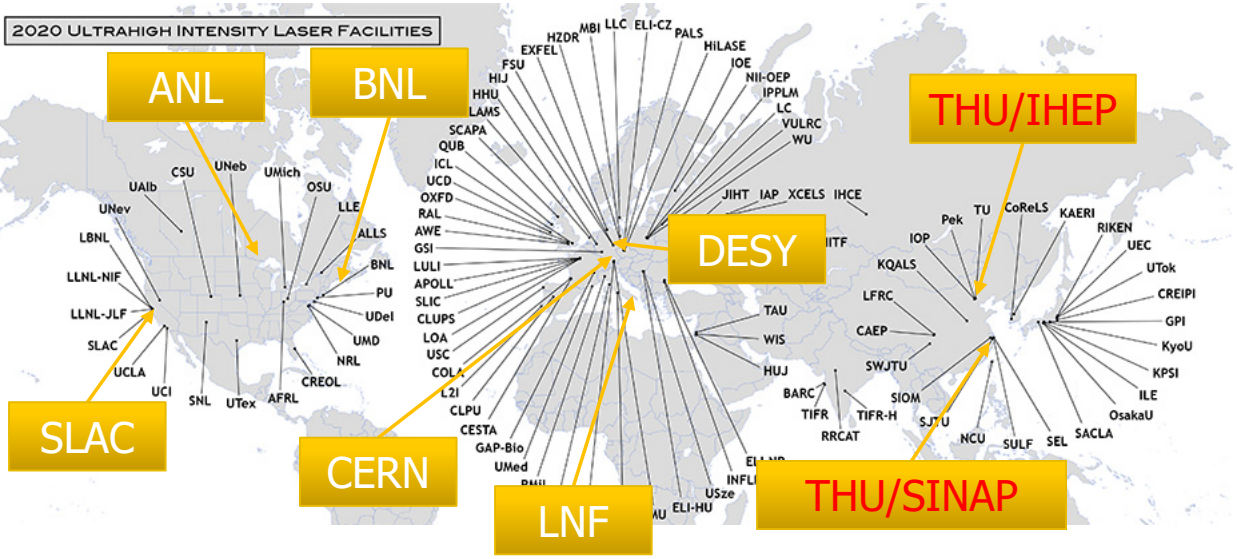


Drive Beam:
laser pulse
e- bunch
proton beam
.....

Plasma：1-100 GeV/m

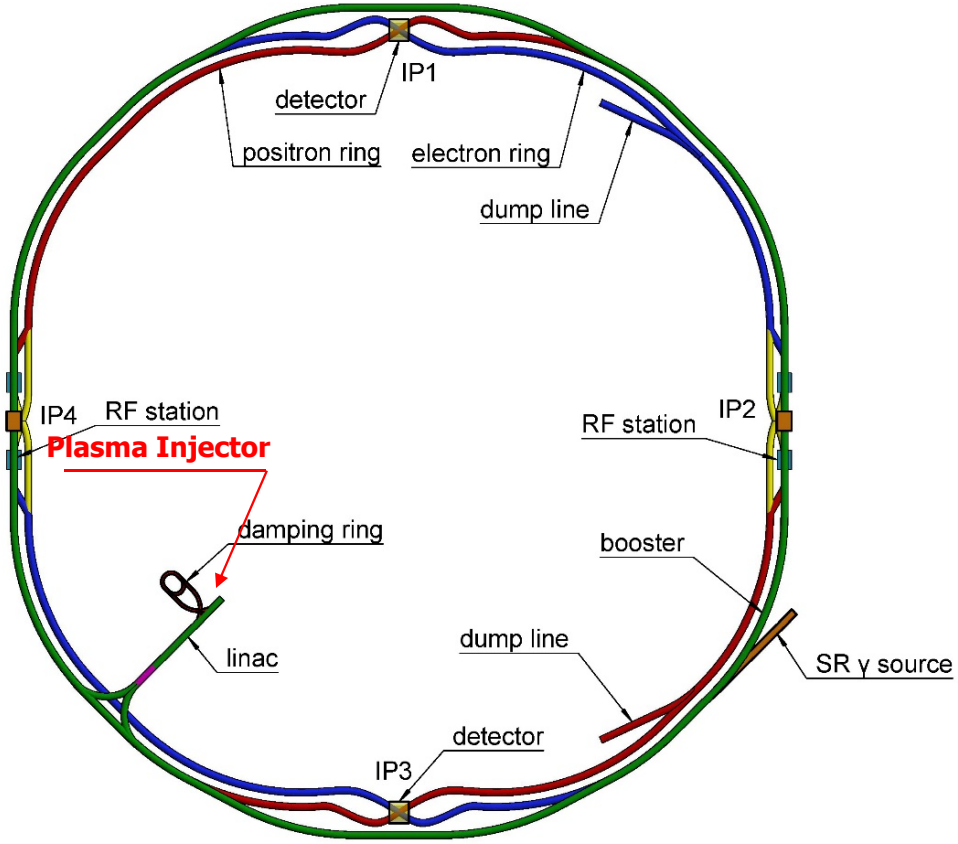
- Table-top X/γ sources
- High Energy colliders
- HEDP platforms





Affiliations/institutes on PWFA Study

CEPC Plasma Injector (CPI)



10 GeV e-/e+ beam in a 100 km ring

- Minimum magnetic field = 28 Gs
- Field error < 28 Gs*0.1% = 0.028 Gs
- Field reproducibility < 29 Gs*0.05% = 0.014 Gs
- The Earth field ~ 0.2-0.5 Gs, the remnant field of silicon steel lamination ~ 4-6 Gs.

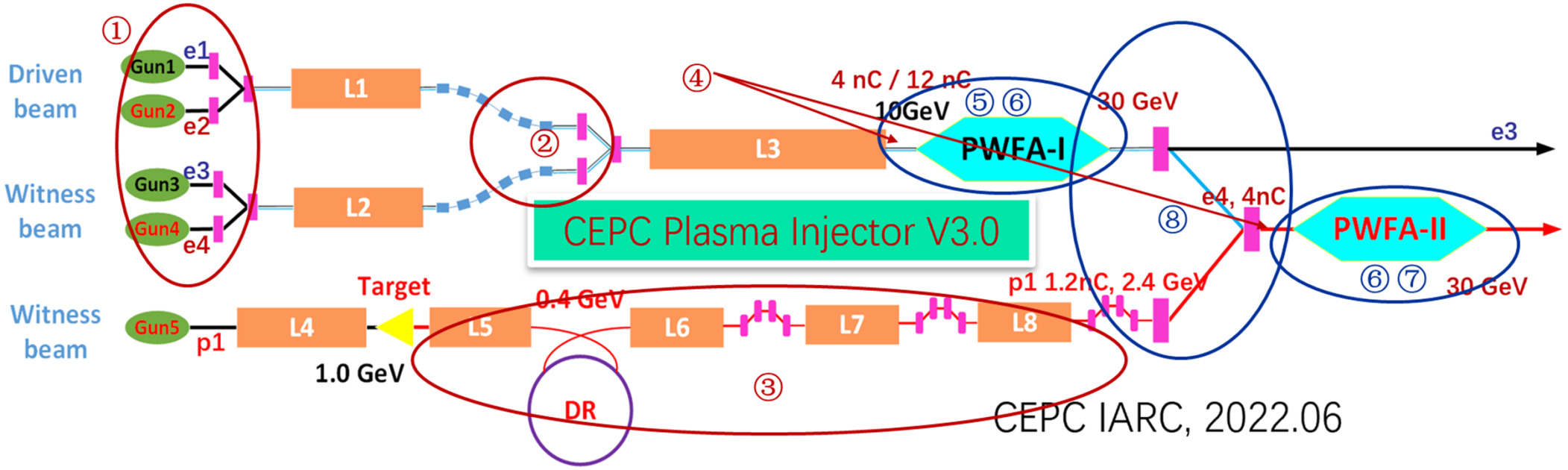
10 GeV Linac → **100 km Booster** → **Collider Rings**

10 GeV linac + CT coil magnet, or 30 GeV linac + iron-core magnet ? Both lead to significant cost rise ~ 1 B RMB

IHEP-THU-BNU Collaborated team on CPI (since 2017)

Proposed by Prof. Gao and Prof. Lu on 2017.01
First collaborated group meeting on 2017. 03
Till now, 20+ staffs, 5 postdocs, 20+ PhD students

CPI design V3.0 and key issues for CPI



Key issues for conventional accelerator:

① High charge longitudinal shaped bunch;

② High current beams combination;

③ Low emittance e+ beamline

④ Final focus system design and optimization

Key issues for plasma wakefield accelerator:

⑤ High TR e- PWFA and hosing instability;

⑥ High repetition rate stable plasma sources

⑦ High quality and high efficiency e+ PWFA

⑧ Staging / Cascaded acceleration

Progress on key issues of CIP

Key issues		Preliminary study/ Conceptual design	Detailed and convincing simulations / designs	Experiment test / Prototype
e- PWFA	HTR	√	√	×
	Beam quality preservation	√	√	×
	Error analysis	√	×	×
Conv. acc. physics and techniques	Beam merging	√	×	×
	Instrumentation	√	×	×
	Timing synchronization	√	×	×
	Positron beamline	√	√	×
Plasms source and beam manipulation	Plasma dechirper	√	√	√
	Plasma lens	×	×	×
	Plasma sources	√	√	×
	Staging	√	×	×

Biggest uncertainty: lack of experimental test

Need a dedicated PWFA test facility for CPI!

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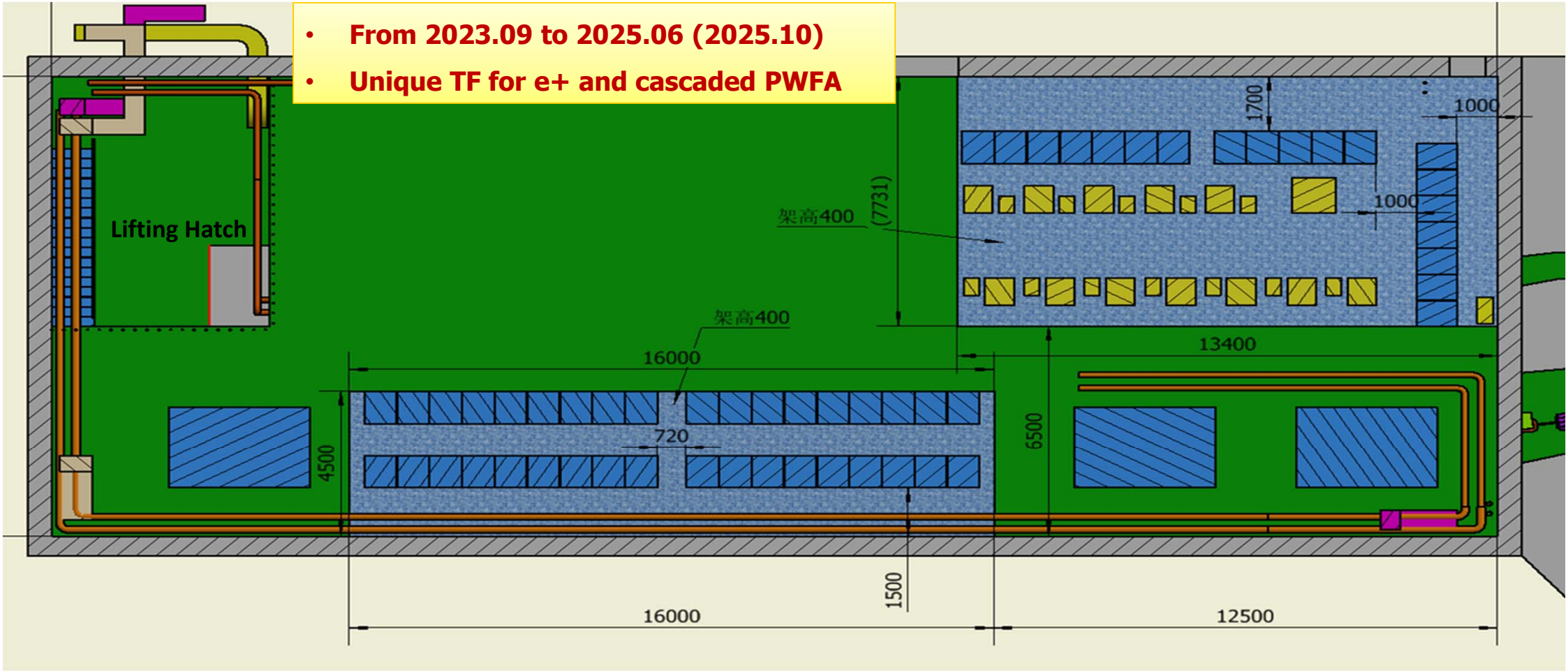
Hall #10 @ IHEP was used for detector calibration

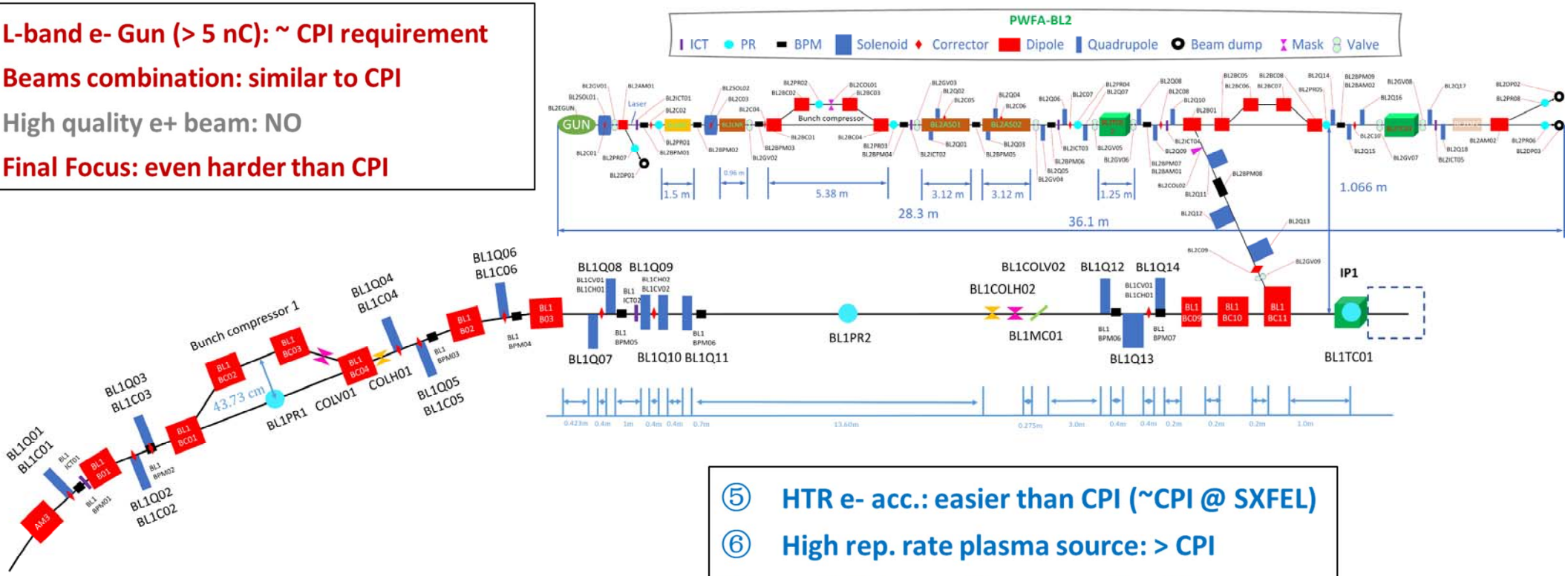
PBA TF proposal based on BEPCII linac

- From 2023.09 to 2025.06 (2025.10)
- Unique TF for e+ and cascaded PWFA



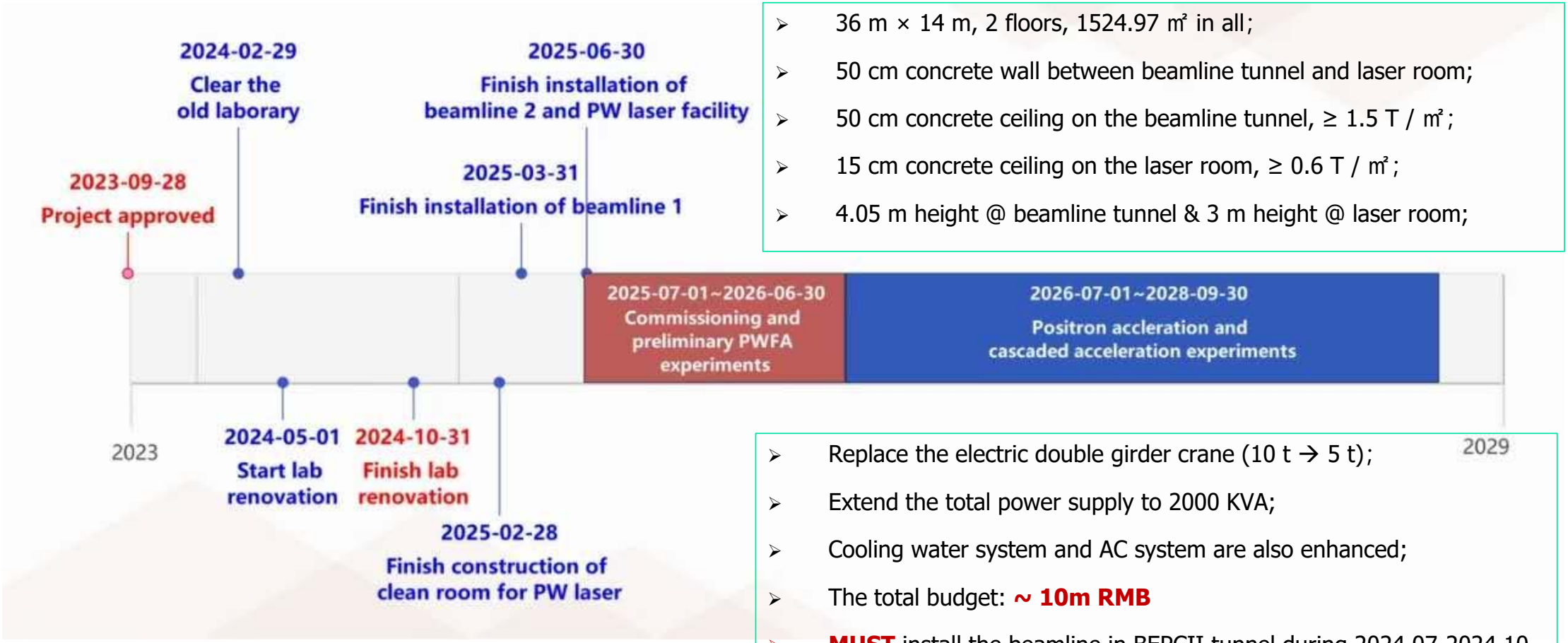
Detailed beamline design & key issues could be addressed

① L-band e- Gun (> 5 nC): ~ CPI requirement
② Beams combination: similar to CPI
③ High quality e+ beam: NO
④ Final Focus: even harder than CPI



⑤ HTR e- acc.: easier than CPI (~CPI @ SXFEL)
⑥ High rep. rate plasma source: > CPI
⑦ e+ PWFA acc.: 1st exp. result, < CPI
⑧ Cascaded/staging: 1st exp. result, < CPI

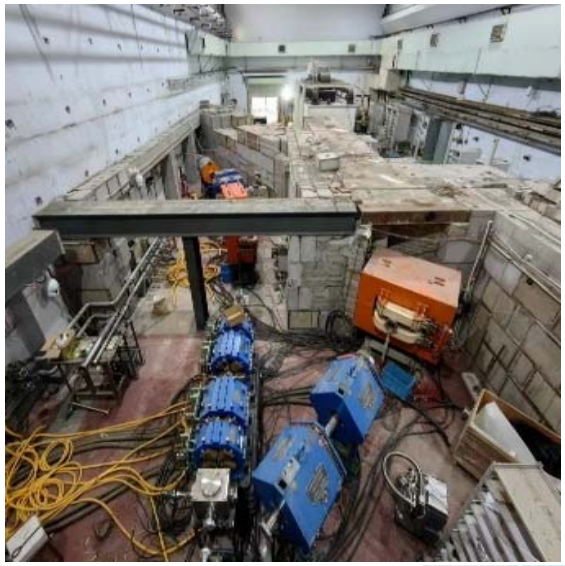
Timetable and the overall information

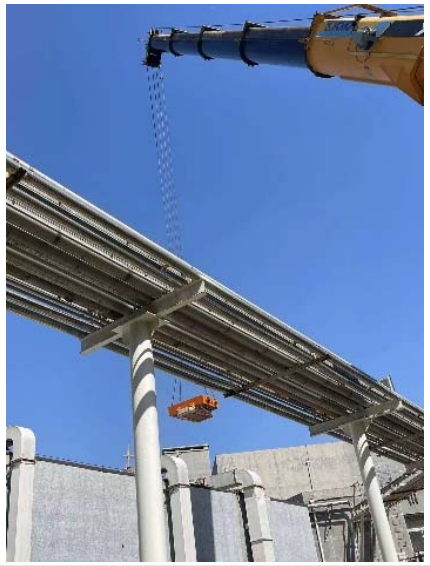


- 36 m × 14 m, 2 floors, 1524.97 ㎡ in all;
- 50 cm concrete wall between beamline tunnel and laser room;
- 50 cm concrete ceiling on the beamline tunnel, ≥ 1.5 T / ㎡;
- 15 cm concrete ceiling on the laser room, ≥ 0.6 T / ㎡;
- 4.05 m height @ beamline tunnel & 3 m height @ laser room;

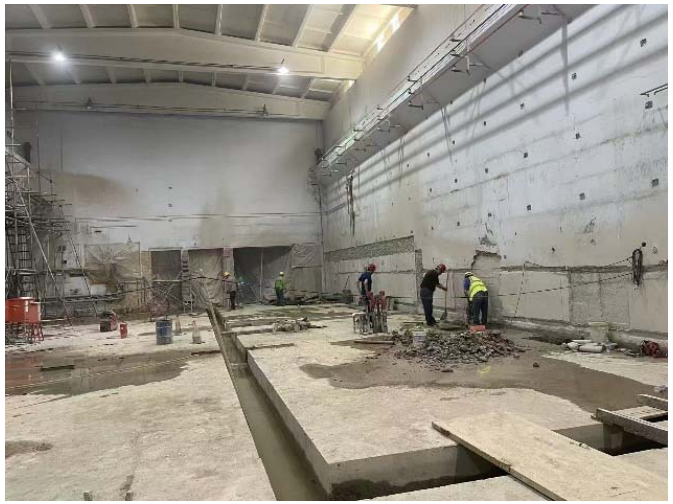
- Replace the electric double girder crane (10 t → 5 t);
- Extend the total power supply to 2000 KVA;
- Cooling water system and AC system are also enhanced;
- The total budget: **~ 10m RMB**
- **MUST** install the beamline in BEPCII tunnel during 2024.07-2024.10

PBA TF progress ---- clear the lab (2023.11-2024.03)



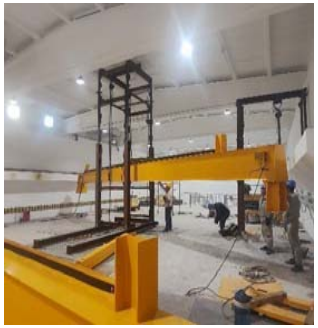


PBA TF progress ---- re-construction (2024.05-2024.09)

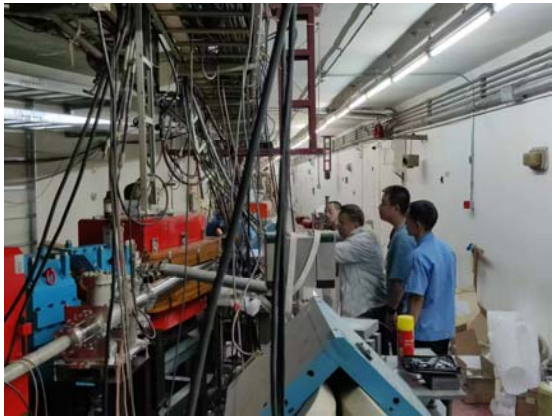





PBA TF progress ---- replace the double girder crane



PBA TF progress ---- beamline installation in B2 tunnel



PBA TF progress ---- utility renovation (since 2024.11)

PBA TF progress ---- utility renovation (2024.11-2025.06)

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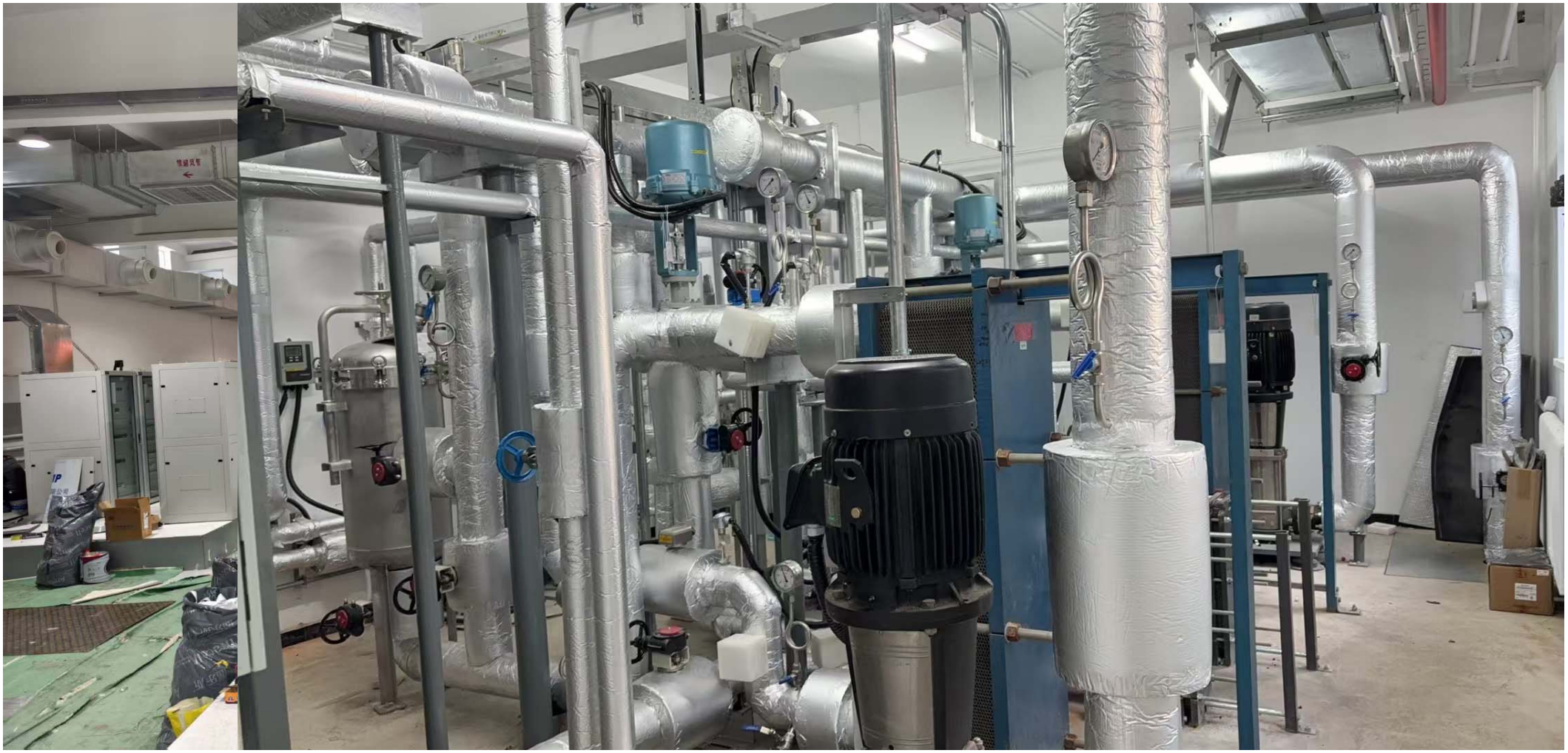
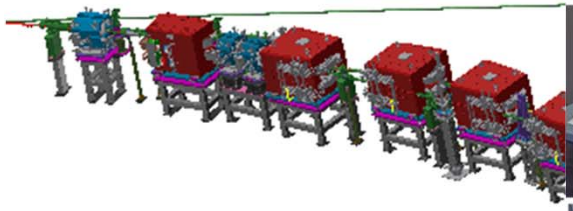
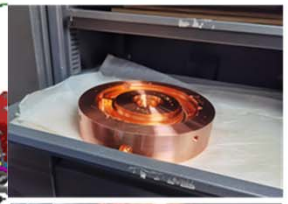
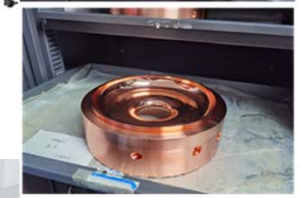


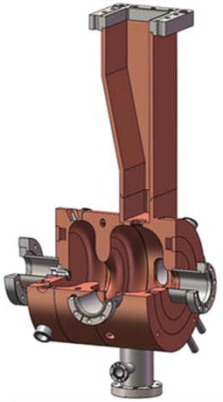
PBA TF progress ---- utility renovation (2024.11-2025.06)

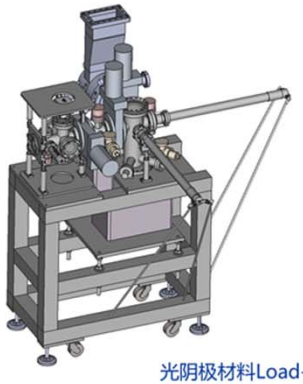
PBA TF progress ---- equipment manufacture



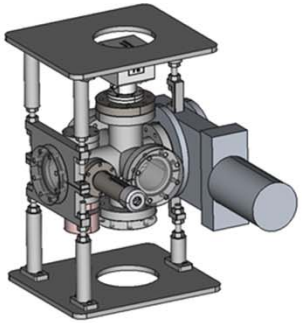




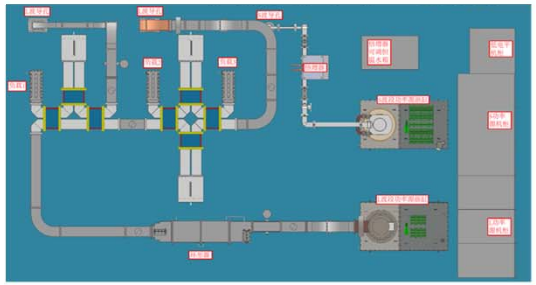




光阴极材料Load-Lock装置

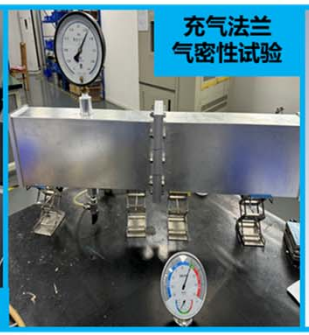


光阴极Suitcase

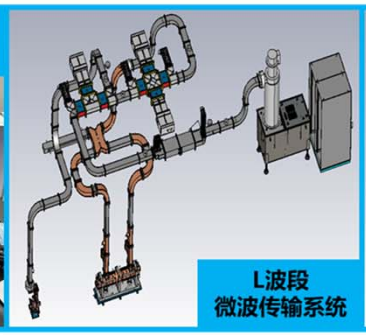


正在开展的半精加工

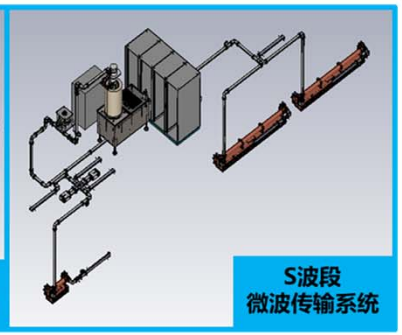
真空法兰试验件检漏



充气法兰
气密性试验



L波段
微波传输系统



S波段
微波传输系统

Outlines

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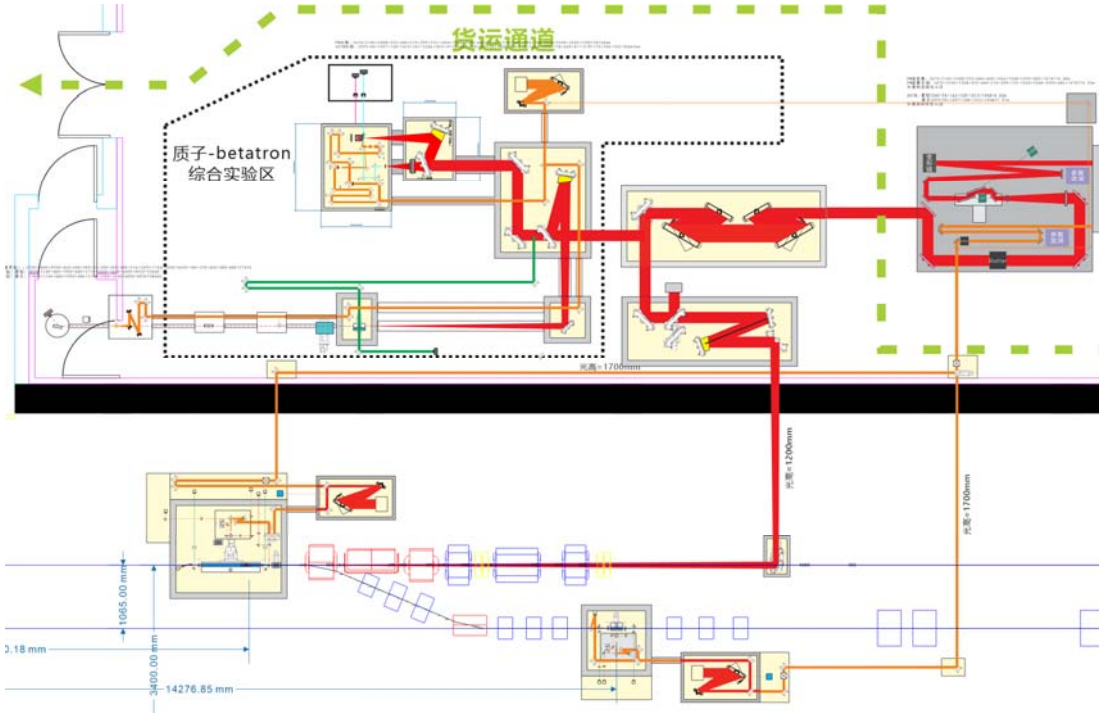
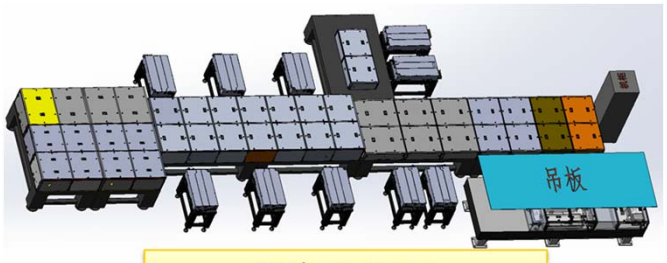
Light path design of the PBA TF and beam quality @ IPs



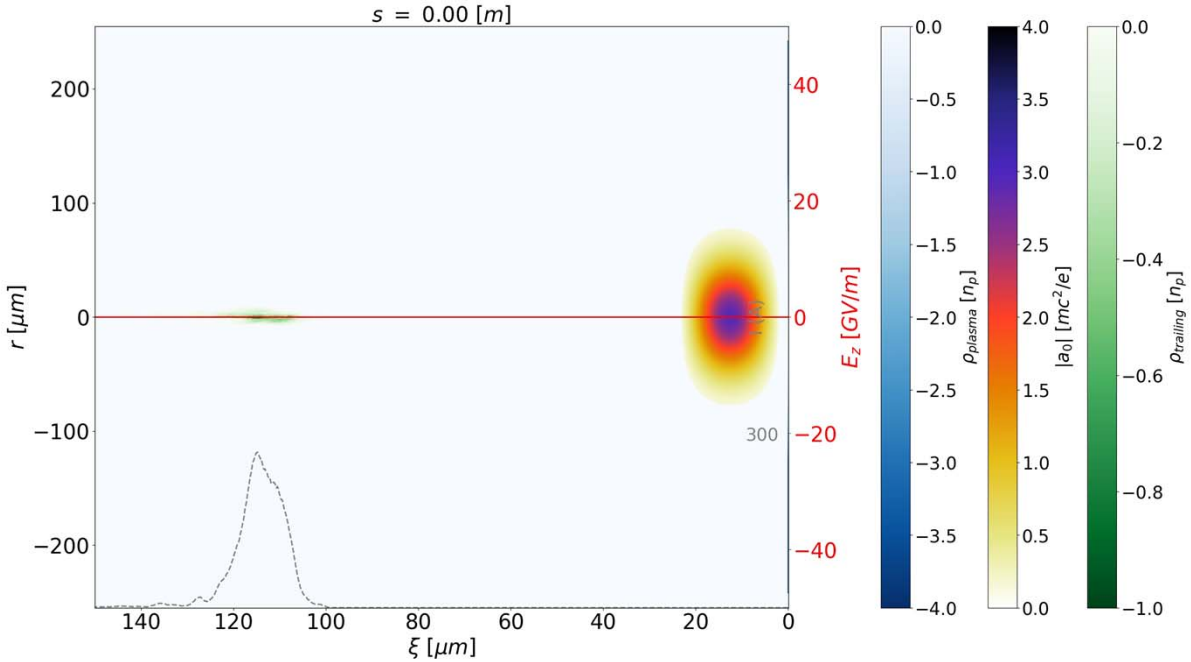


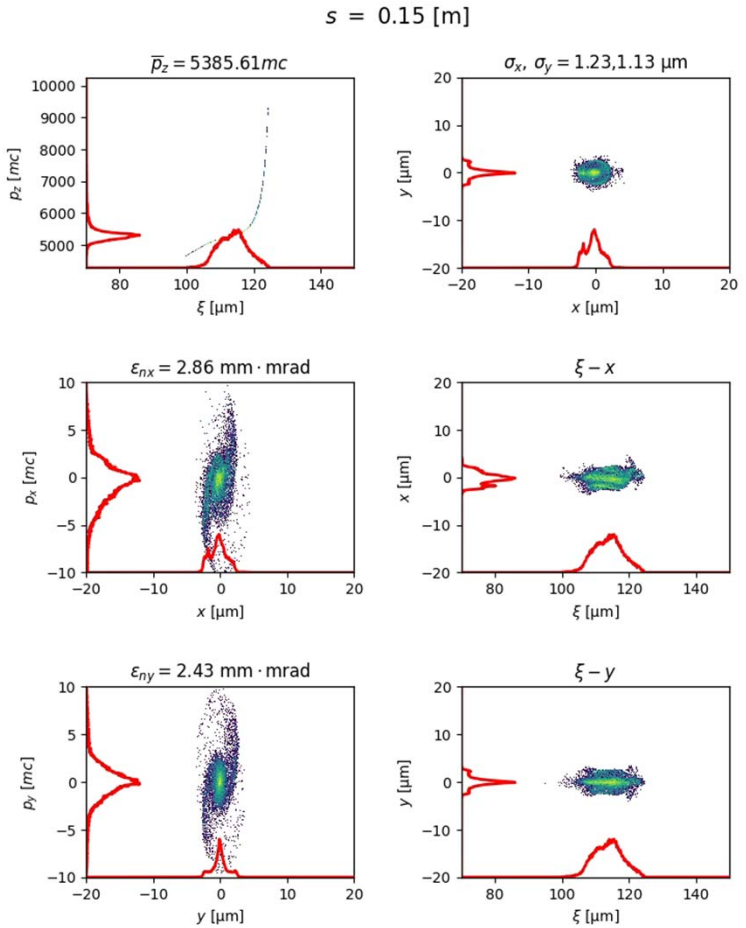
PW laser system

drive laser of L-band e- gun (4 m × 1.5 m)

Parameters	Unit	BL-I e- (AM3)	BL-I e- (IP1)	BL-I e+ (AM3)	BL-I e+ (IP1)	BL-I e- (IP1, block)	BL-I e+ (IP1, block)	BL-II e- (IP2)	BL-II e- (IP1)
Energy	GeV	2	2	2	2	2	2	0.15	0.15
Charge	pC	2000	2000	100	100	9.4	0.2	5000	1000
bunch length	ps	10	1	10	1	~1	~1	0.7	1
Geo. emittance	mm·mrad	0.1/0.1	0.1/0.1	0.4/0.4	0.4/0.4	0.011/0.005	0.04/0.02		
RMS beam size	μm	-	150/150	-	300/300	30/40	54/76	35/22	100/50

PBA experiment proposals —— LWFA e- external injection

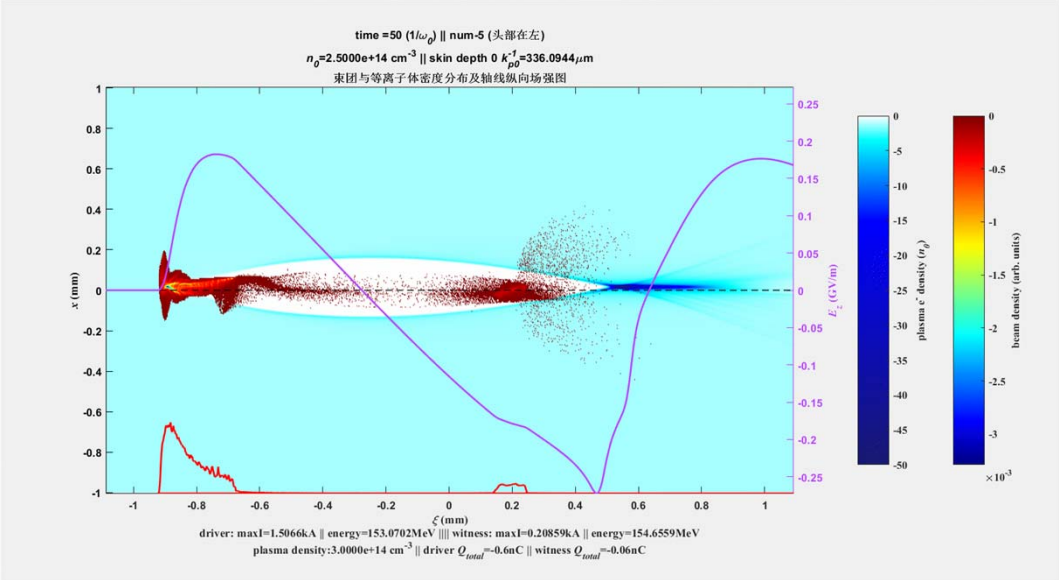


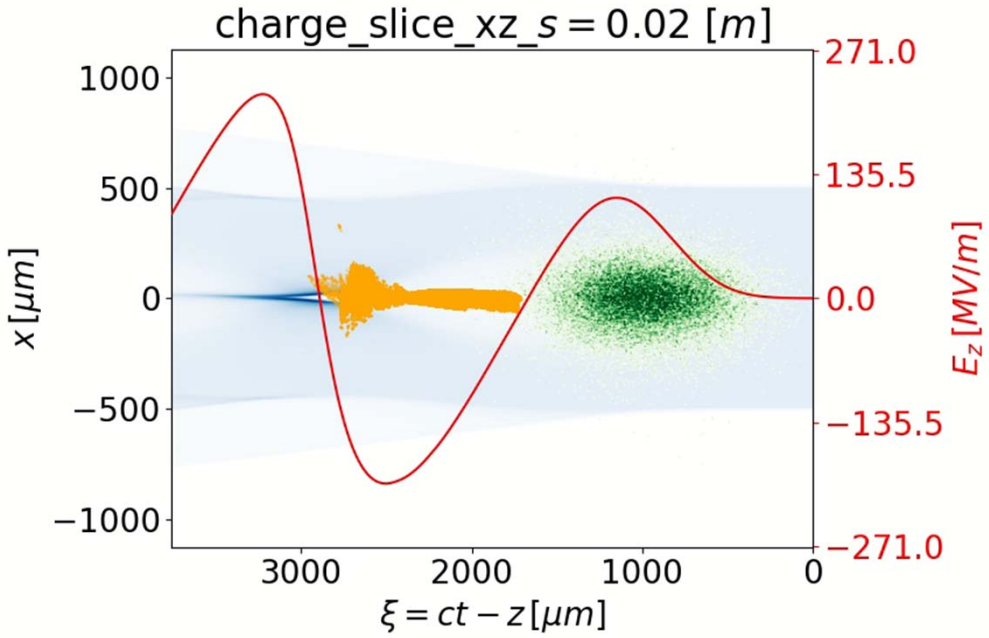


PW Laser + BL2 e- (9.45 pC)

E~16.6 GeV, rms energy spread ~ 7.7%

PBA experiment proposals —— cascaded acceleration





Stage 1: PWFA @ IP2

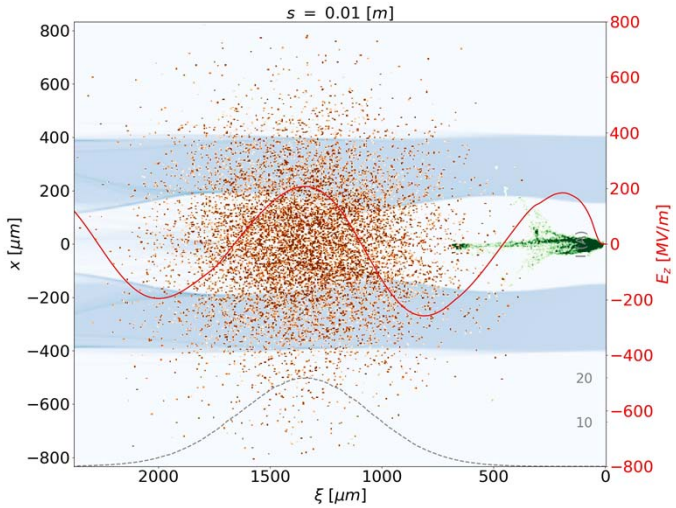
L-band e- gun generate 2 bunches
Trailer is accelerated from 150 MeV to 170MeV

Stage 2: PWFA @ IP1

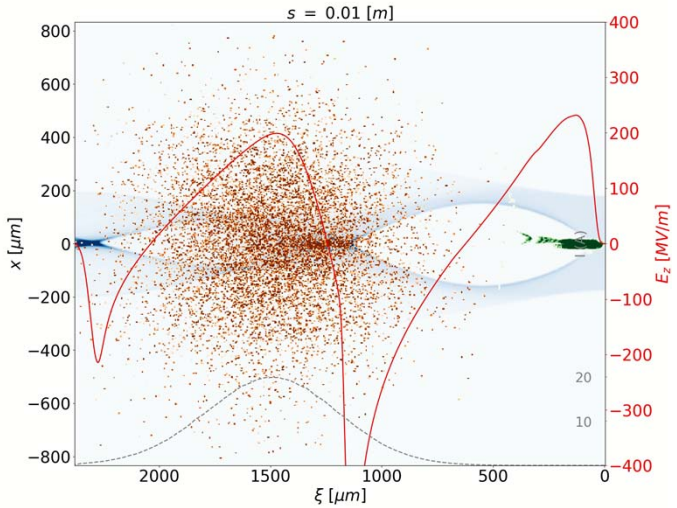
Use 2 GeV e- bunch from BEPCII linac as driver
Trailer is accelerated from 170 MeV to 310 MeV

PBA experiment proposals —— PWFA e+ acceleration

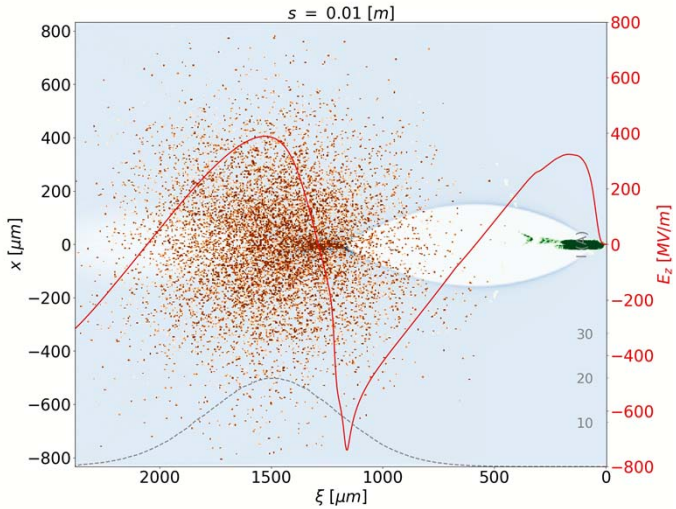
hollow channel plasma



finite-width channel



uniform plasma

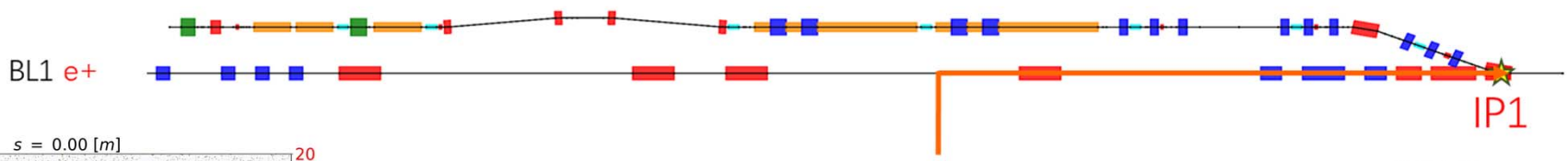


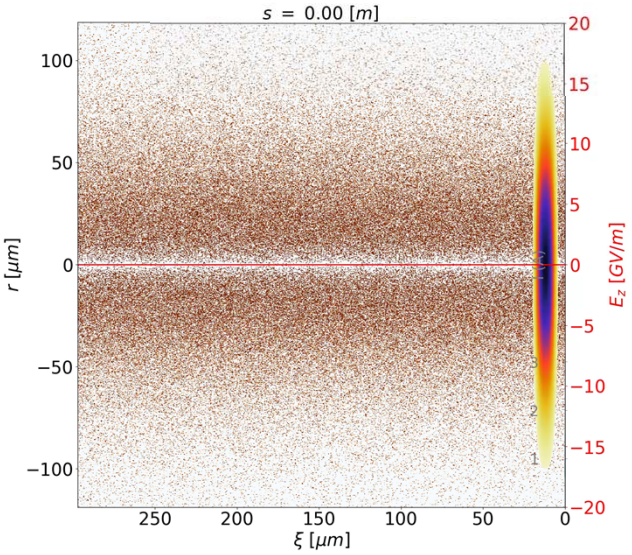
Use BL2 e- as driver, and e+ from BL1 as trailer

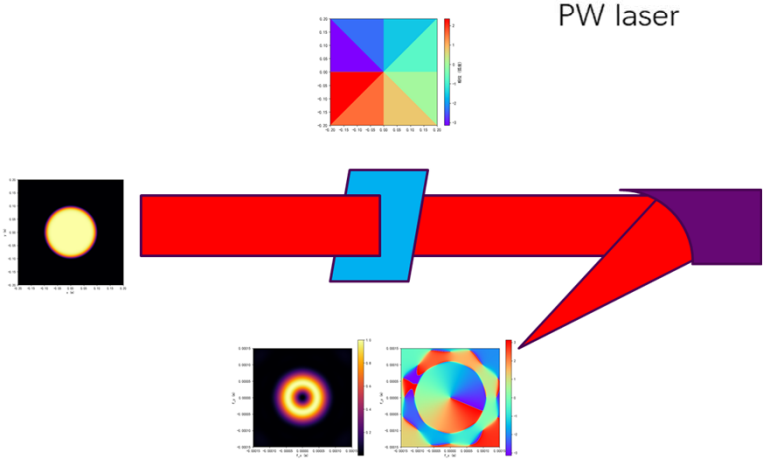
Try different schemes for better capture efficiency and beam quality

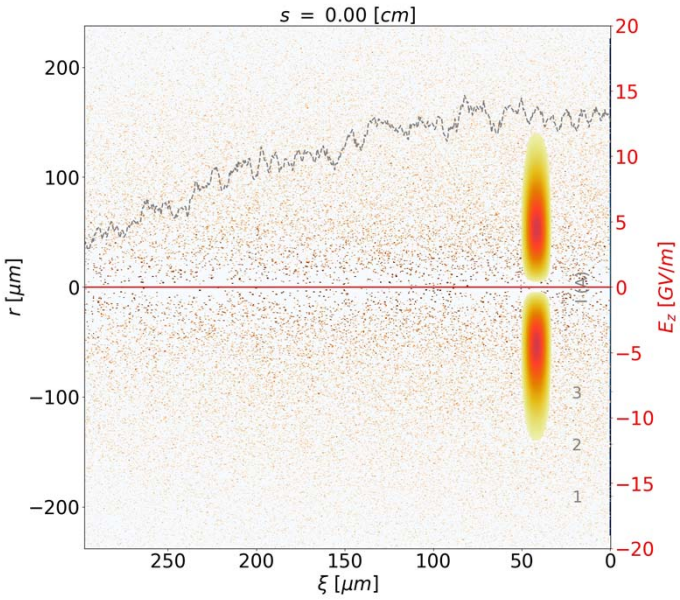
PBA experiment proposals —— LWFA e+ external injection

➢ PW laser + BL1 e+









Laser: 18J, a0=2.4, w0=60um, τ=25fs
e+: 50pC, 2GeV, $\boldsymbol{\sigma_r = 40um}$, $\boldsymbol{\sigma_z}$ ~ 1ps
Plasma: ~ 1e17cm-3

Both e+ energy gain > 1GeV

Laser: 19J, a0=1.1, w0=75 um, τ=30fs
e+: 7.5 pC, 2GeV, $\boldsymbol{\sigma_r = 40um}$, $\boldsymbol{\sigma_z}$ ~ 1ps
Plasma: ~ 5e16+2e16×(r(μm)/75)2

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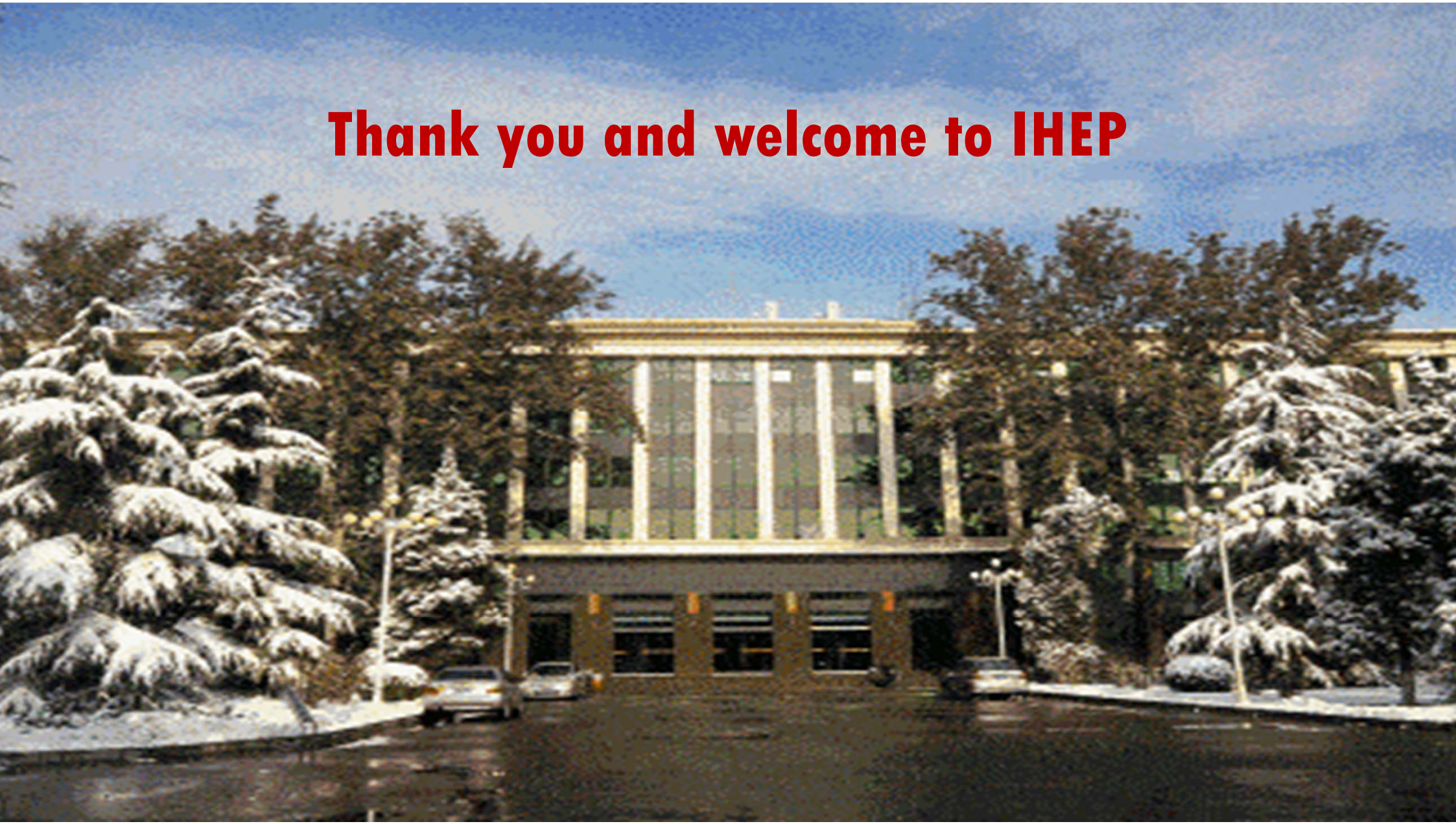
IHEP PBA study is advancing to a new stage

- Conceptual design of CPI has been carried out since 2017
- The PBA TF based on BEPCII will be ready for commissioning in several months
- The new TF is NOT only for PBA, but also for conventional accelerator R&D
- The new TF is NOT only for CPI, but also for a real plasma-based accelerators
- HOPE to address mainly technical concerns of CPI

① **L-band e- Gun (> 5 nC): ~ CPI requirement**
② **Beams combination: similar to CPI**
③ **High quality e+ beam: NO**
④ **Final Focus: even harder than CPI**

⑤ **HTR e- acc.: easier than CPI (~CPI @ SXFEL)**
⑥ **High rep. rate plasma source: > CPI**
⑦ e+ PWFA acc.: 1st exp. result, < CPI
⑧ Cascaded/staging: 1st exp. result, < CPI


Thank you and welcome to IHEP