



中国科学院高能物理研究所

Institute of High Energy Physics, Chinese Academy of Sciences

Lithium vapour

Wakefield  
acceleration

# Plasma Test Facility at IHEP

Plasma electrons

Ion channel

Pulse electrons

Dr. Dazhang Li  
Institute of High Energy Physics  
On behalf of on IHEP-THU-BNU Team

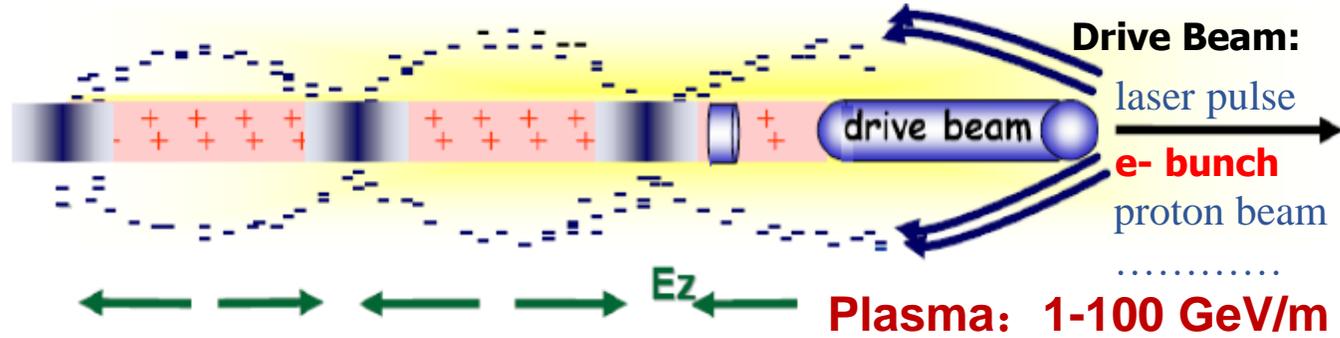


# Outlines

- **PWFA and CEPC plasma injector (CPI)**
- **Current status of IHEP PBA TF**
- **Summaries and prospects**

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

RF cavity:  $< 100\text{MeV/m}$

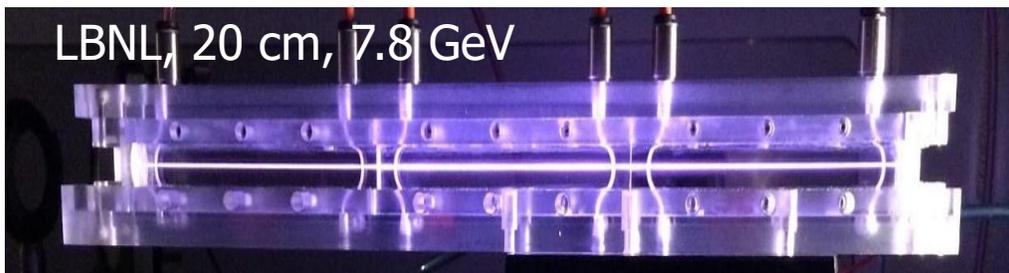


Plasma:  $1-100\text{ GeV/m}$

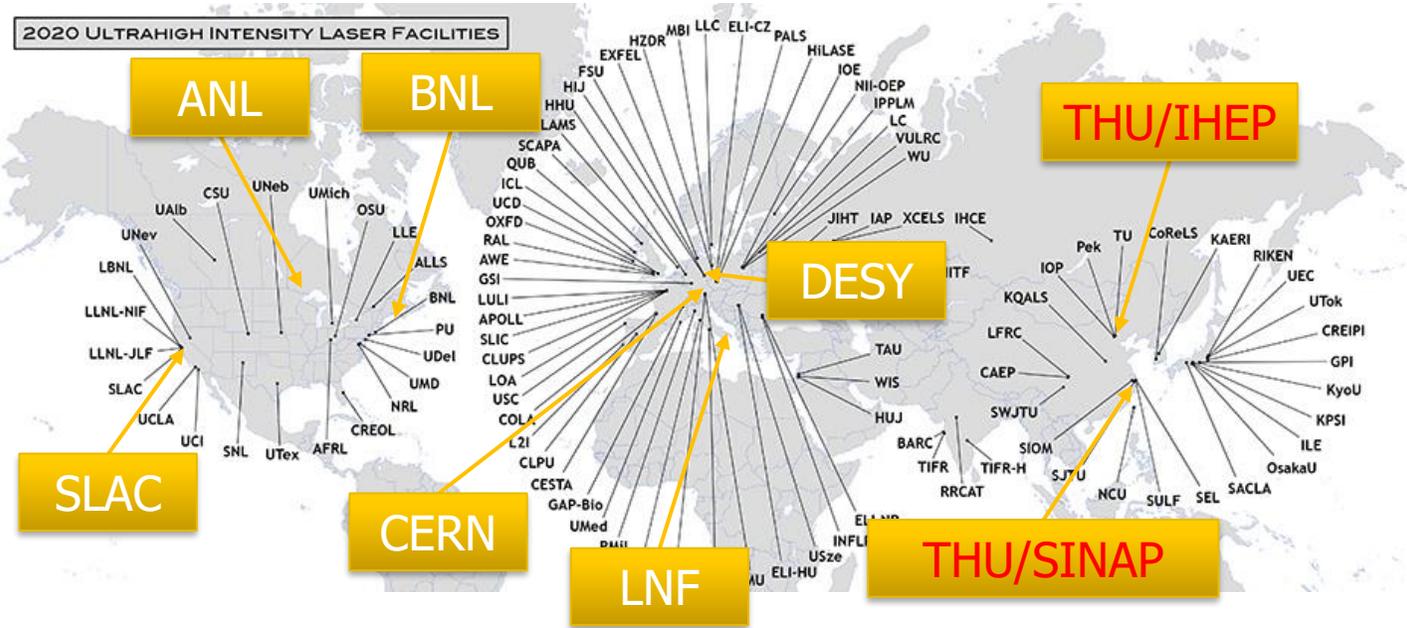
- Table-top X/γ sources
- High Energy colliders
- HEDP platforms



SACLA, 750 m, 8 GeV



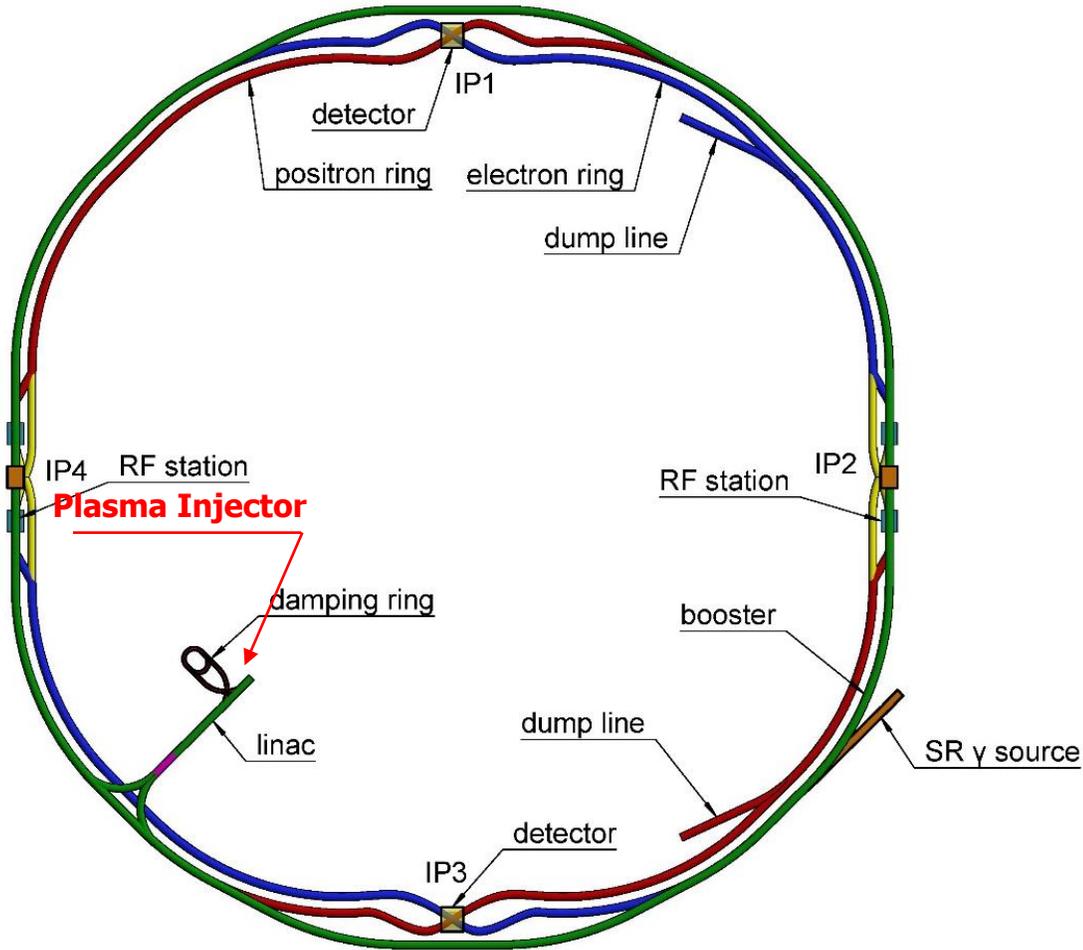
LBNL, 20 cm, 7.8 GeV



Affiliations/institutes on PWFA Study



# CEPC Plasma Injector (CPI) since 2017



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

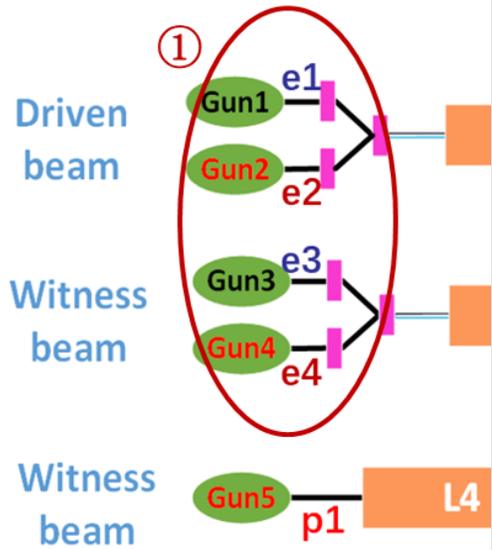
- Minimum magnetic field = 28 Gs
- Field error  $< 28 \text{ Gs} * 0.1\% = 0.028 \text{ Gs}$
- Field reproducibility  $< 29 \text{ Gs} * 0.05\% = 0.014 \text{ Gs}$
- The **Earth field**  $\sim 0.2-0.5 \text{ Gs}$ , the **remnant field** of silicon steel lamination  $\sim 4-6 \text{ Gs}$ .



10 GeV linac + CT coil magnet, or 30 GeV linac + iron-core magnet ? Both lead to significant cost rise  $\sim 1 \text{ B RMB}$



# CPI design V3.0 and key issues for CPI



## Key issues for conventional

- ① High charge loss
- ② High current beam
- ③ Low emittance
- ④ Final focus system

IHEP-CEPC-DR-2023-01

IHEP-AC-2023-01

## CEPC

### Technical Design Report

Accelerator

The CEPC Study Group

December 2023

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# CAS program on PWFA (approved in sept. 2023, ¥ 90M)

## 中国科学院

2023.10-2028.09

### 中国科学院关于基础与交叉前沿科研先导专项 “束流驱动新加速原理与应用研究” 立项的通知

中国科学院高能物理研究所:

经 2023 年第 8 次院长办公会议审议通过，院基础与交叉前沿科研先导专项“束流驱动新加速原理与应用研究”正式立项。现将有关事项通知如下。

#### 一、专项名称和依托单位

专项名称为“束流驱动新加速原理与应用研究”，依托单位为中国科学院高能物理研究所。

#### 二、首席科学家

专项首席科学家为中国科学院高能物理研究所鲁巍研究员。

#### 三、专项实施周期和经费概算

专项实施周期为 2023 年 10 月至 2028 年 9 月。经费概算共 9000 万元，全部由院财政支持。

¥ 90M → ¥ 88.32M

#### 四、相关要求

你单位要认真贯彻落实《中国科学院战略性先导科技专项管理办法》及其实施细则，全面履行依托单位法人责任，认真履行任务书合同条款，建立健全内部管理制度，做好专项组织实施和支撑保障工作。在专项实施过程中，要切实发挥首席科学家作用，加强专项各任务的衔接与协调；既要注重“导出”国家重大科技任务，也要进一步加强与重点实验室体系重组、人才培养等重要改革举措的衔接，注重形成合力，推动科研布局调整优化，促进出成果、出人才；要立足专项特点，建立健全有利于领军人才和青年人才成长的举措和机制，激发创新人才活力；要做好资金管理使用工作，确保资金专款专用，提高资金使用效益；要加强知识产权和成果管理，履行科研诚信建设主体责任，强化专项科研绩效管理，确保专项按期高质量实现预期目标。

附件：基础与交叉前沿科研先导专项“束流驱动新加速原理与应用研究”专项（项目）清单



（此件依申请公开）

抄送：办公厅、前沿科学与基础研究局（筹）、财务与资产管理局（筹）、人事人才局（筹）、科技基础能力局（筹）、监督审计局。

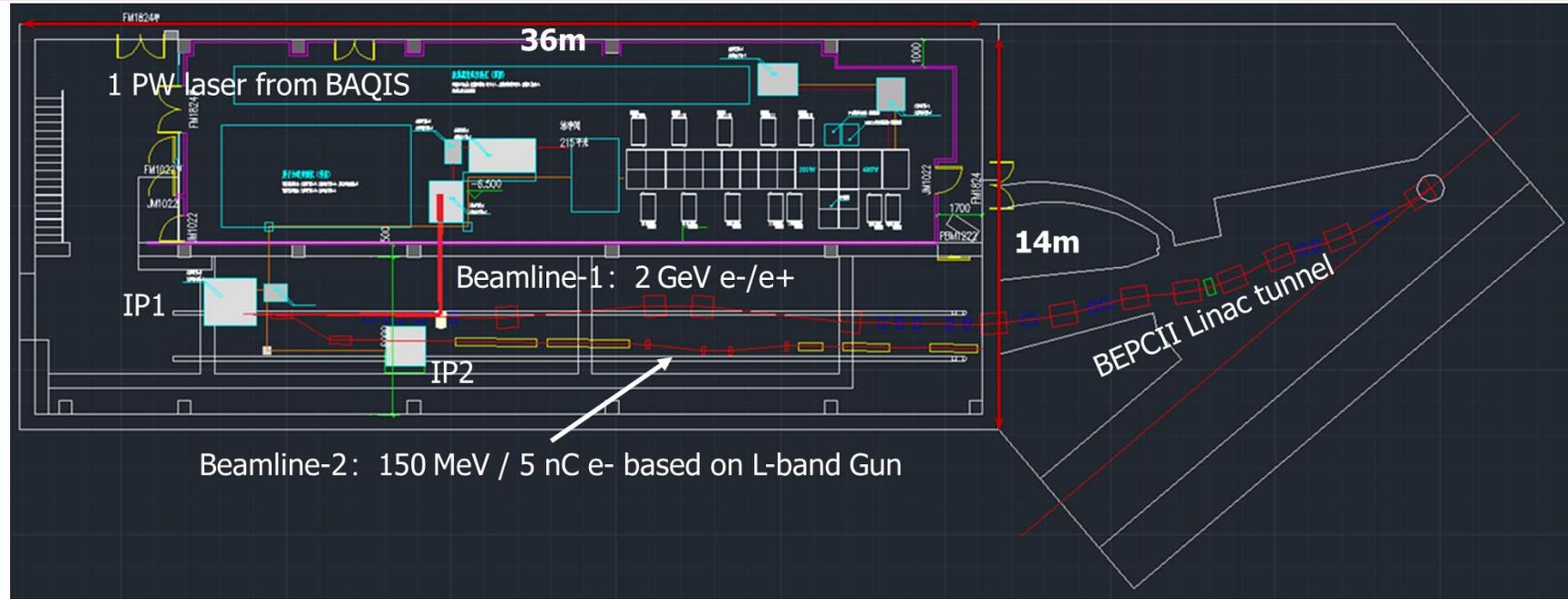
2023.9.20

专项概预算通过条  
财局组织的第三方  
机构预算评审

2023.9.28

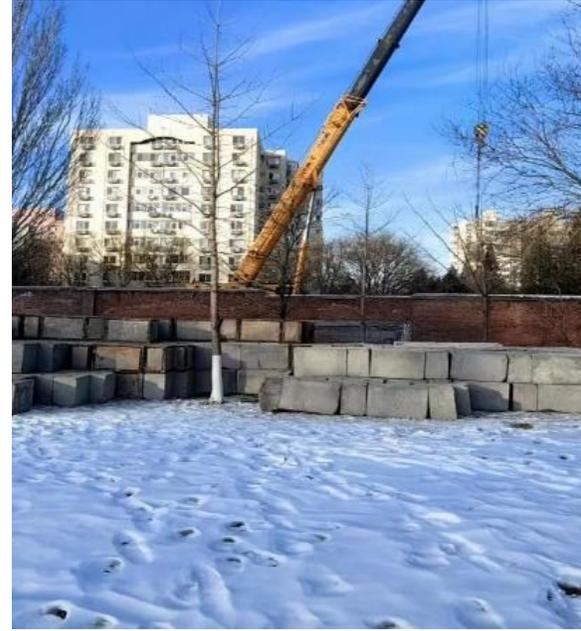
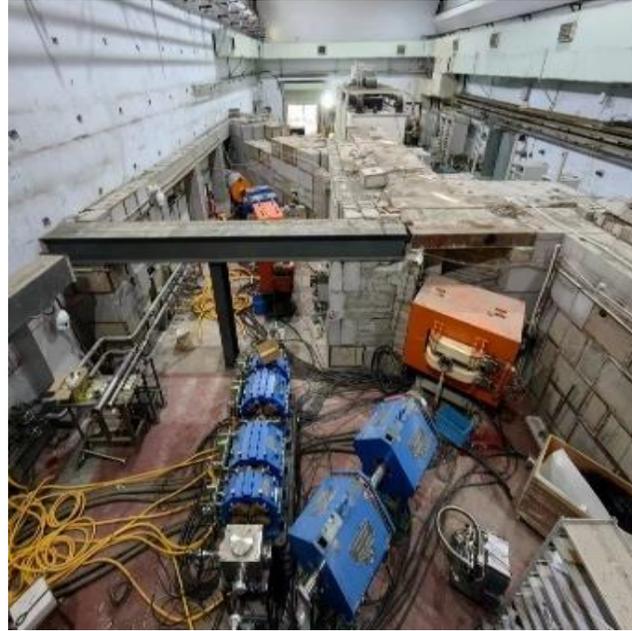
2023年第8次“院  
长办公会”审议通过

# Hall #10 @ IHEP was used for detector calibration

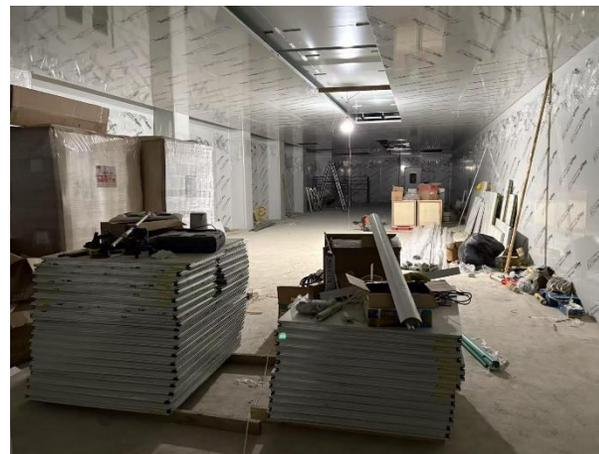
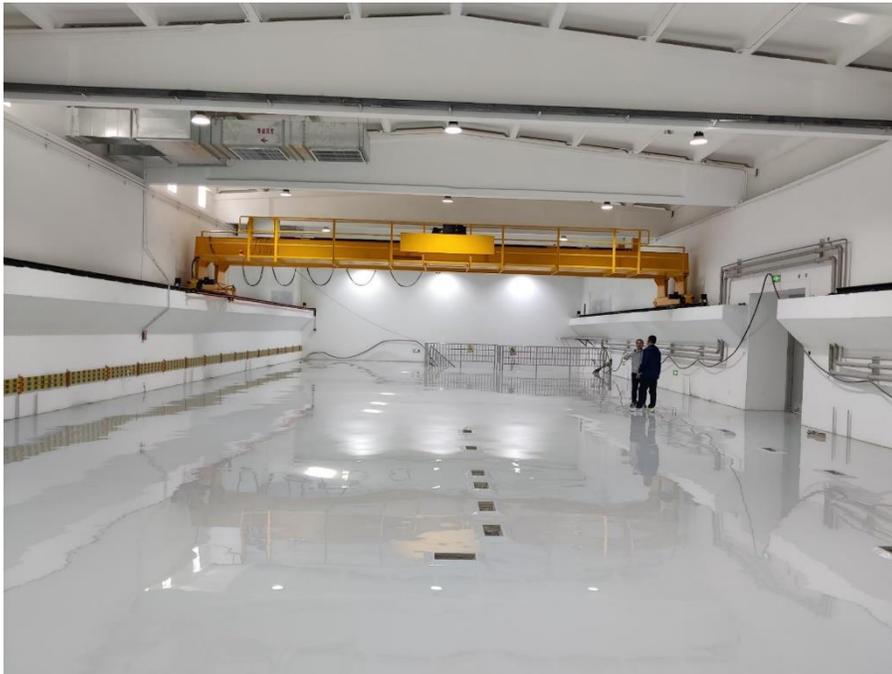
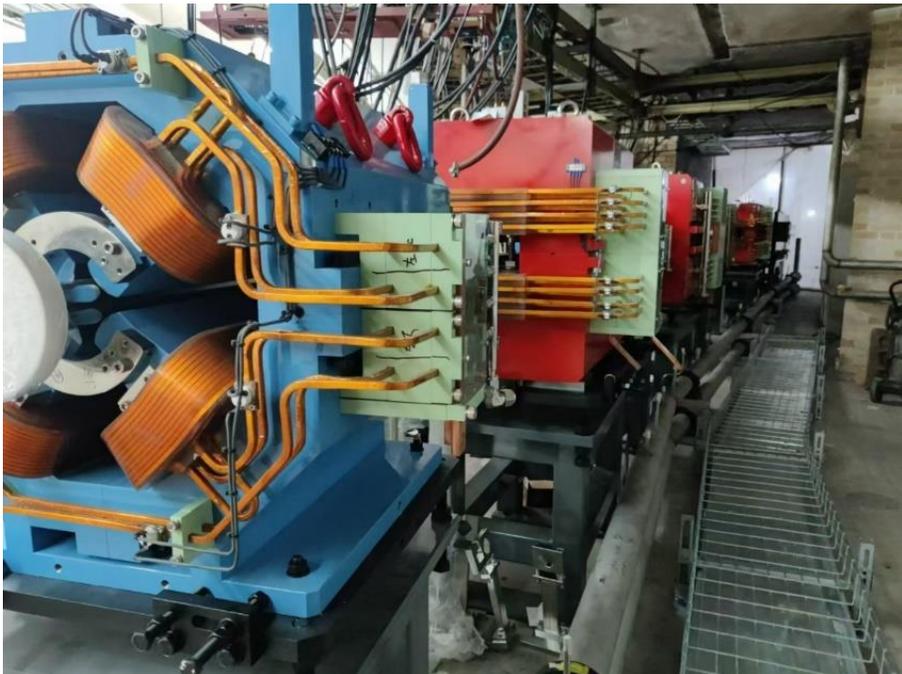




# PBA Lab @ 2023.10~2024.04



# PBA Lab @ 2024.10~2025.01



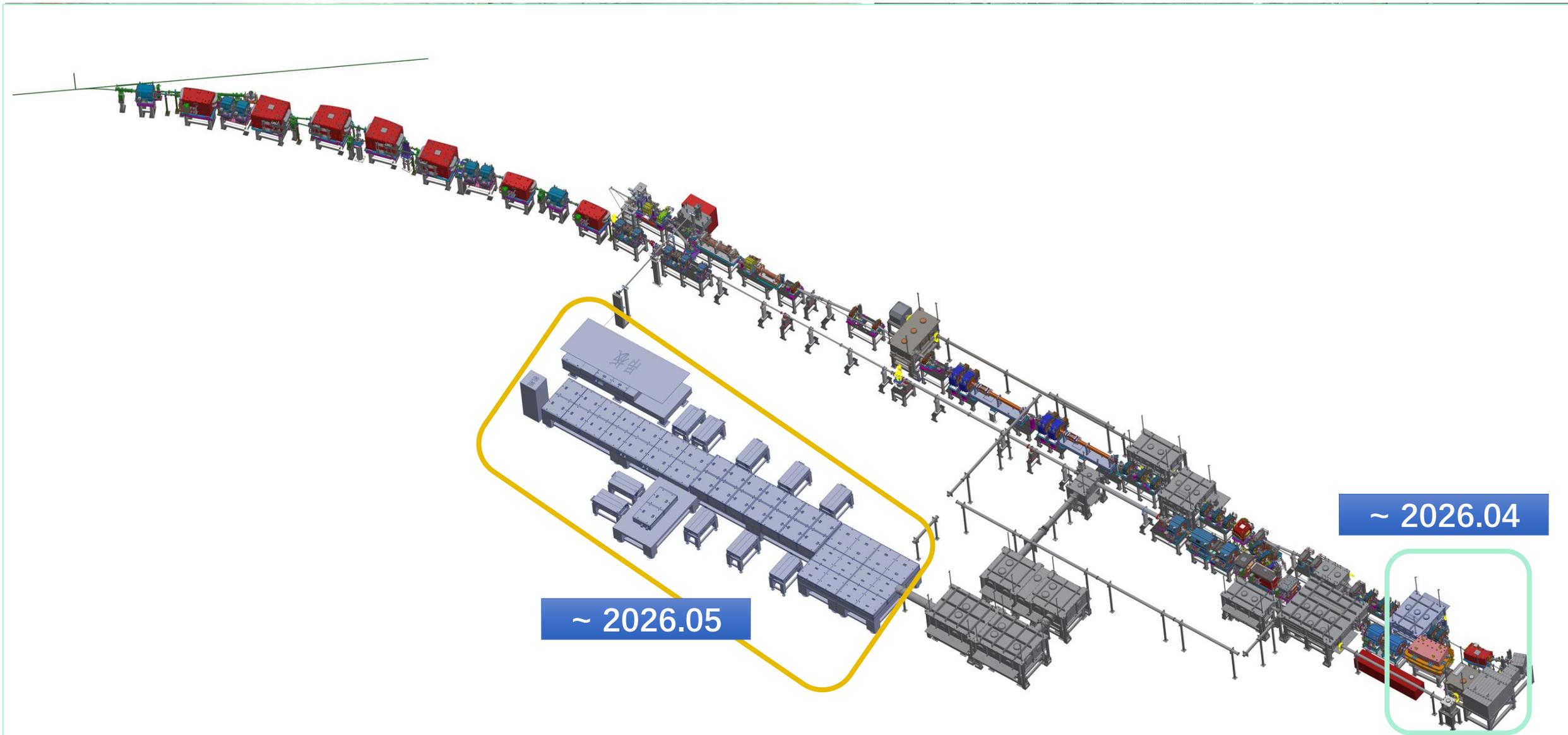


# PBA Lab @ 2025.05~2025.08



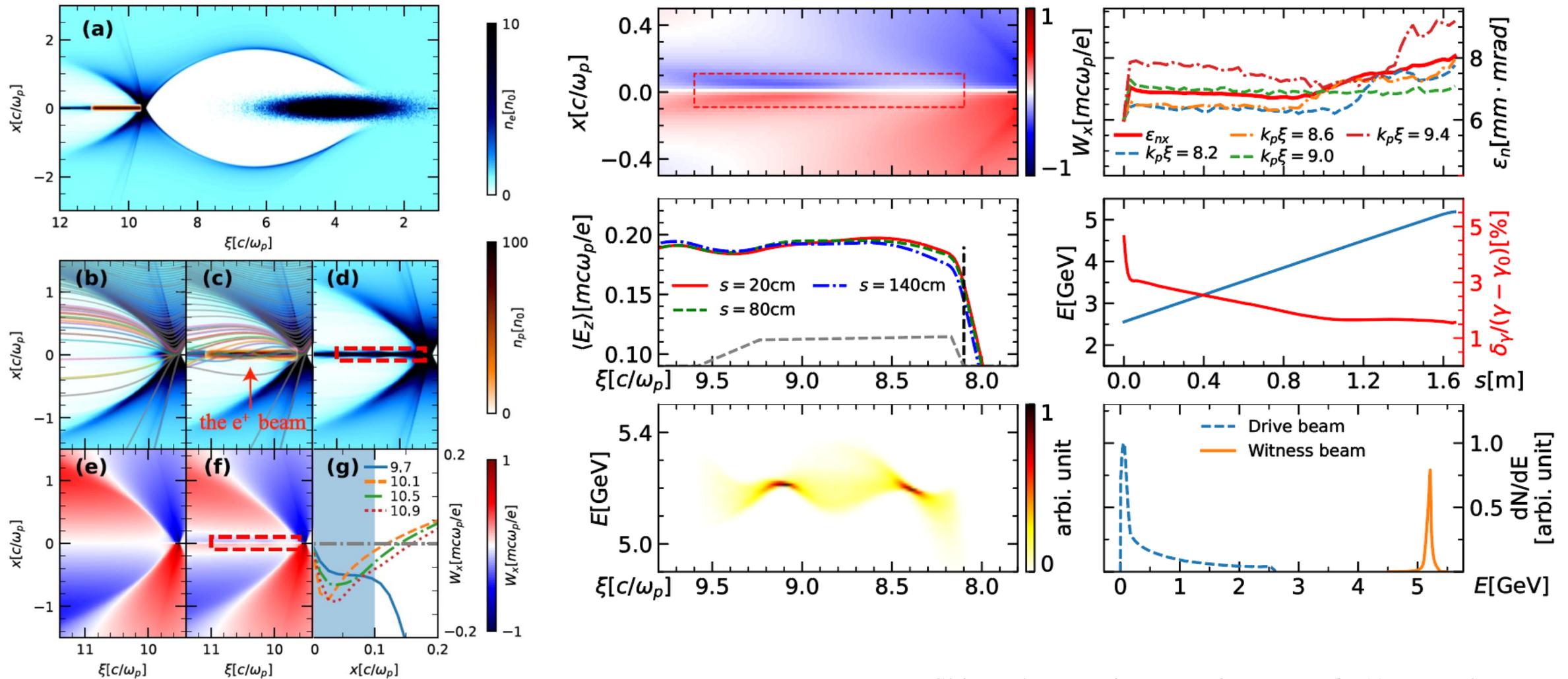


# PBA Lab right now: start beam commissioning ~ 2026.06





# Recent progress on IHEP PBA studies – e+ acc. scheme

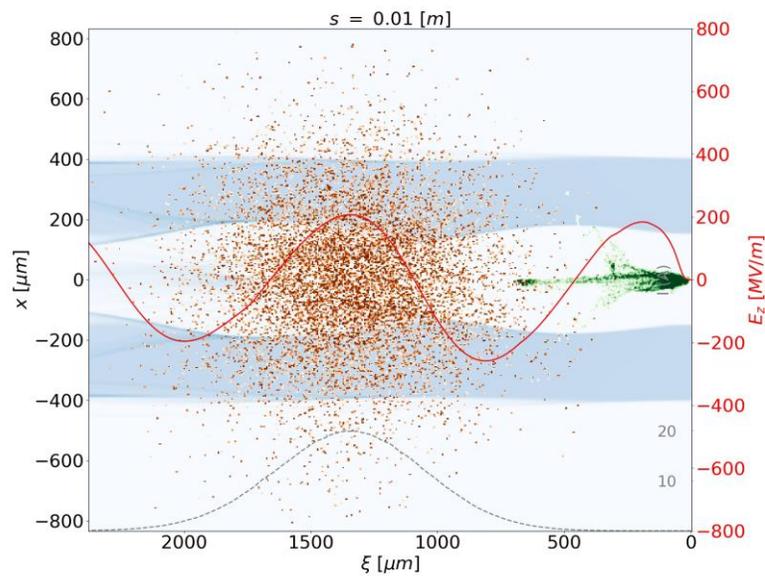


Shiyu Zhou, Wei Lu, *et al.*, *Research*. (Accepted)

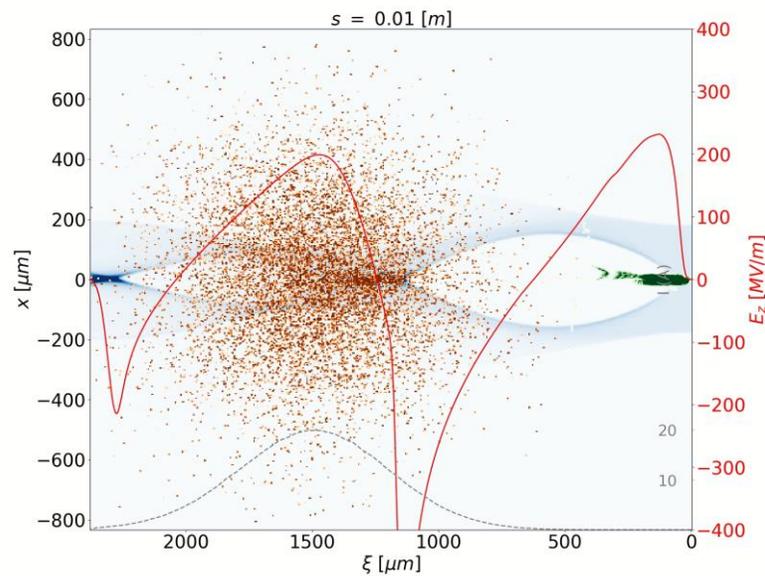


# Recent progress on IHEP PBA studies – e+ acc. @ TF

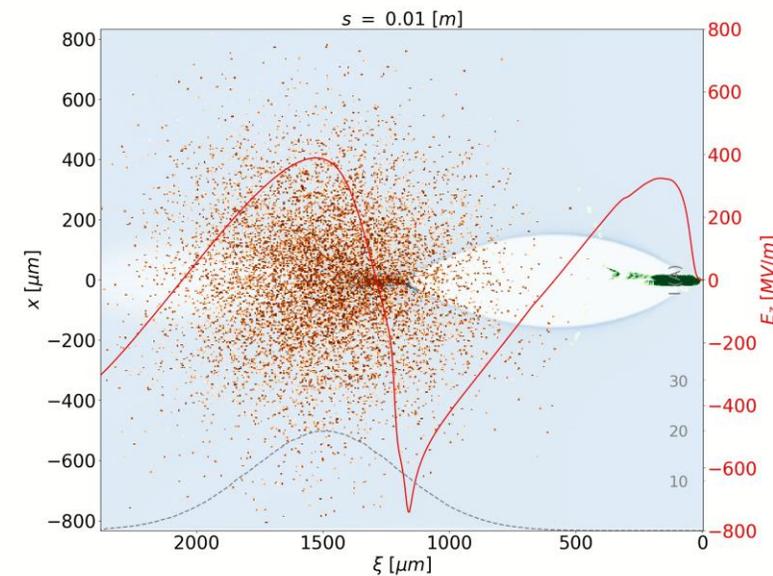
hollow channel plasma



finite-width channel



uniform plasma

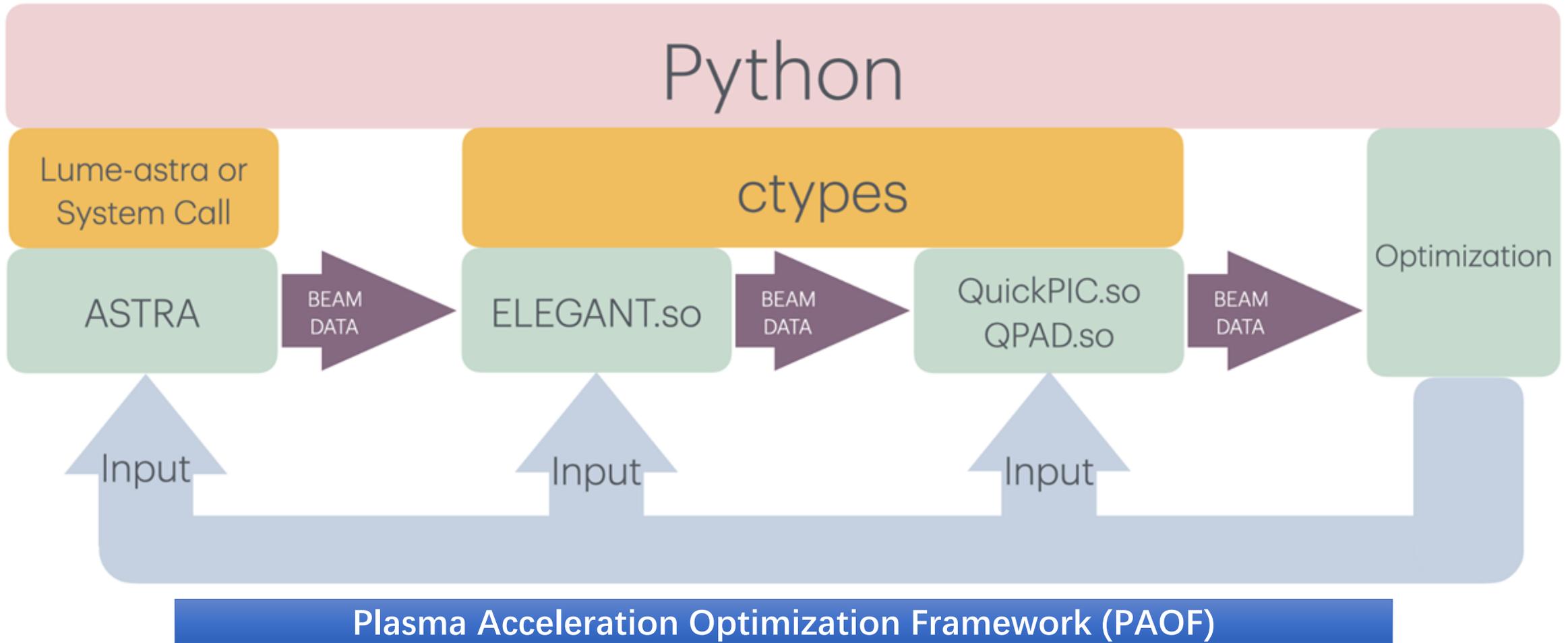


**Use BL2 e- as driver, and e+ from BL1 as trailer**

**Try different schemes for better capture efficiency and beam quality**



# Recent progress on IHEP PBA studies – Start-to-end Sim.





# Recent progress on IHEP PBA studies – Start-to-end Sim.

PWFA 1.3 / PAOF

## PAOF is the Plasma based Accelerator Optimization Framework.

### Step for setting ASTRA

1. Configure Python library function lume-astra  
Anaconda installation required  
URL:[lume-astra](#)

### Steps for compiling elegant

1. Set shell variable PAOF being the path to PAOF: export PAOF=...
2. cd \$PAOF/src/elegant/ANL/epics/base && make
3. cd \$PAOF/src/elegant/ANL/epics/extensions/src/SDDS && make The error "\*\*\*\* No rule to make target '././././././lib/linux-x86\_64/libpng.a', needed by 'sddsplot'" can be ignored.
4. source \$PAOF/src/elegant/env\_make.sh
5. cd \$PAOF/src/elegant/ANL/oag/apps/src/elegant && make

Before runing elegant: source \$PAOF/src/elegant/env\_run.sh

### Steps for compiling quickpic

1. Install Necessary Libraries  
You need to install the following libraries: MPI, HDF5, and JSON-Fortran. You can search for the corresponding libraries in your browser or use the libraries we provided in /PAOF/src/QuickPIC/lib\_need/. Installation tutorials are included in the Word document in /PAOF/src/QuickPIC/quickpic\_lib\_install.txt or quickpic\_linux\_install.docx.
2. Modify Your `make.GF_OPENMPI`  
Update your `make.GF_OPENMPI` file as follows:

Project information

- 50 Commits
- 1 Branch
- 0 Tags
- 124.6 MiB Project Storage

README

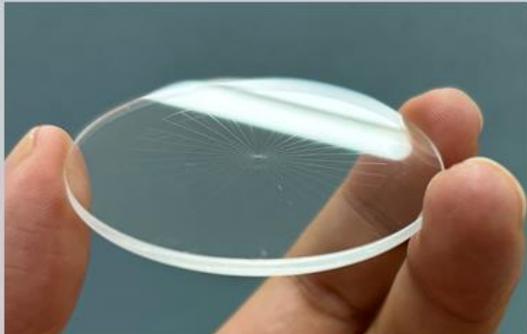
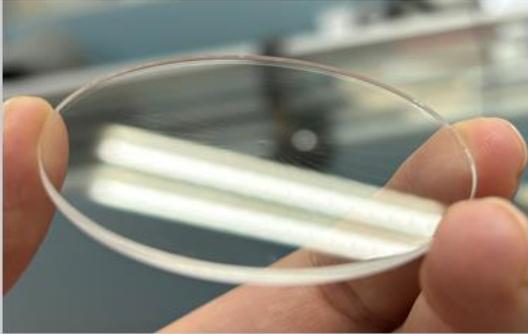
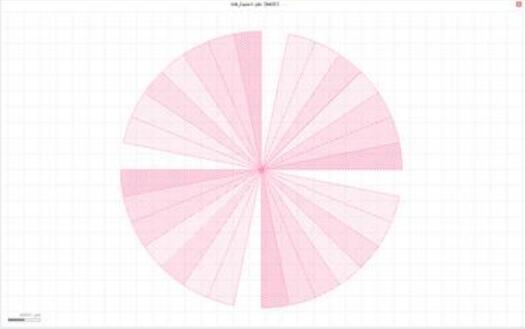
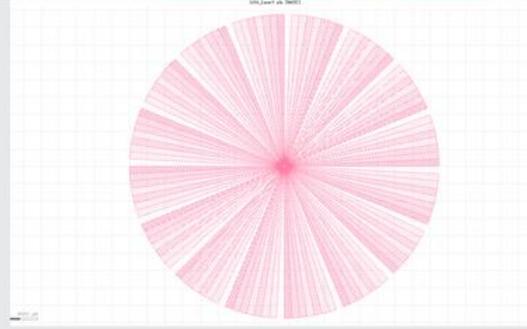
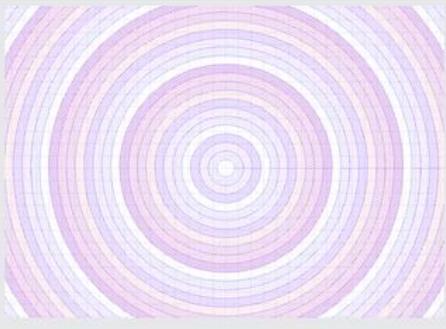
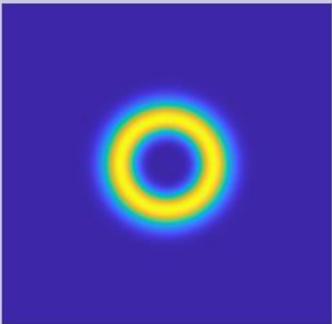
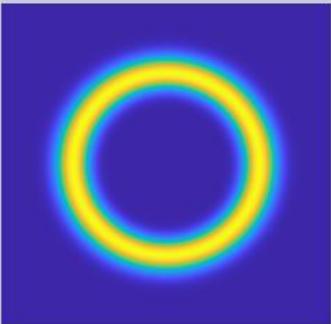
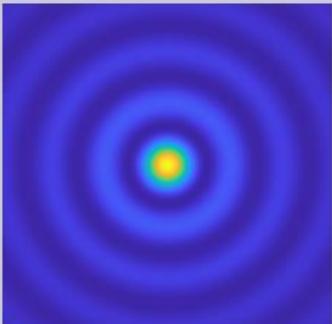
- + Add LICENSE
- + Add CHANGELOG
- + Add CONTRIBUTING
- + Enable Auto DevOps
- + Add Kubernetes cluster
- + Set up CI/CD
- + Add Wiki
- + Configure Integrations

Created on  
September 30, 2024

Git repository for PAOF already on [code.ihep.ac.cn](https://code.ihep.ac.cn)

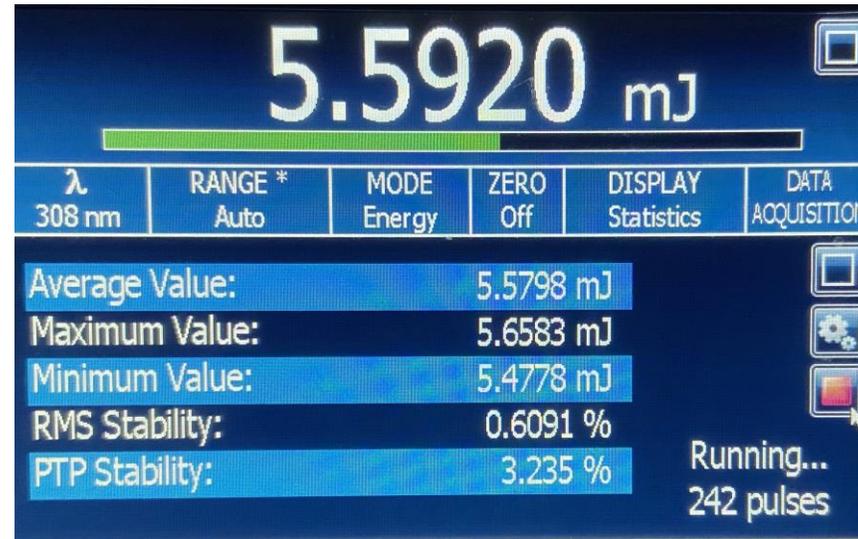
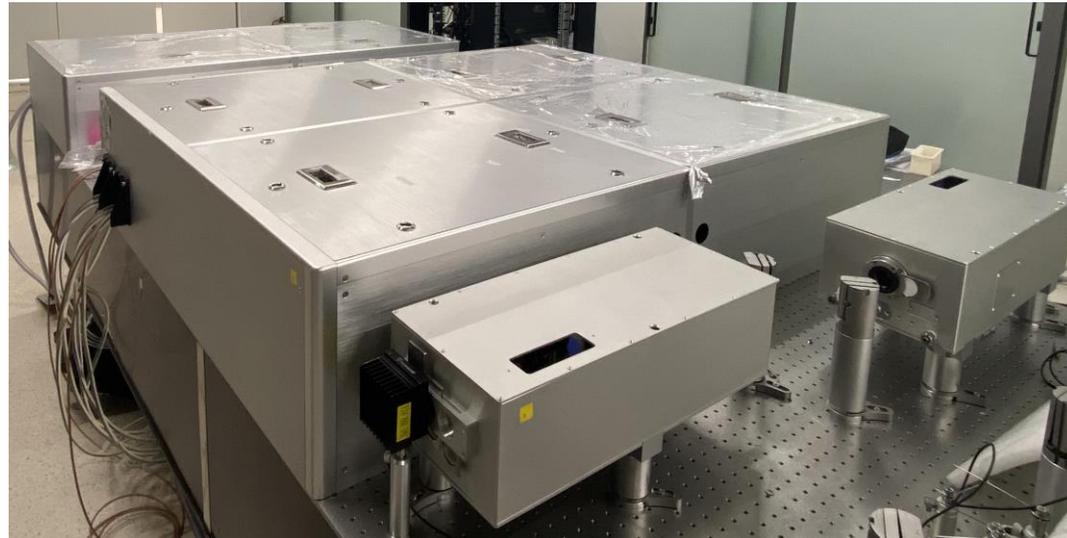
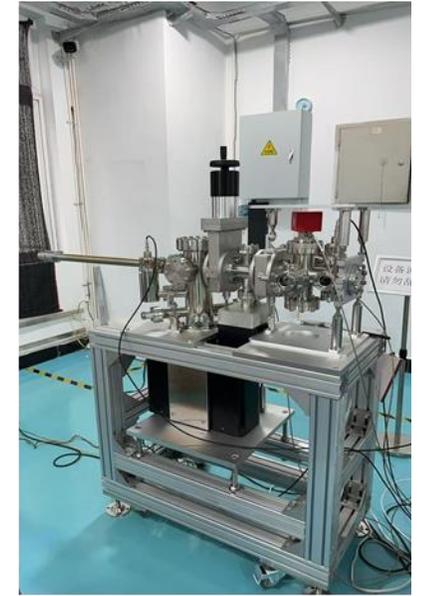
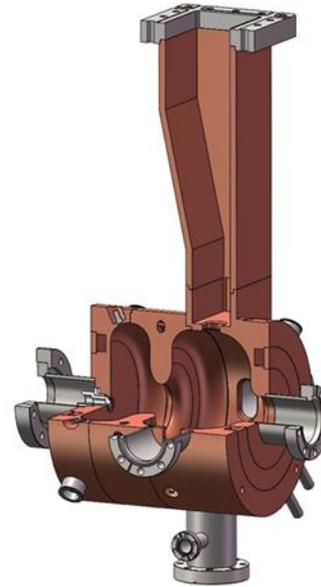
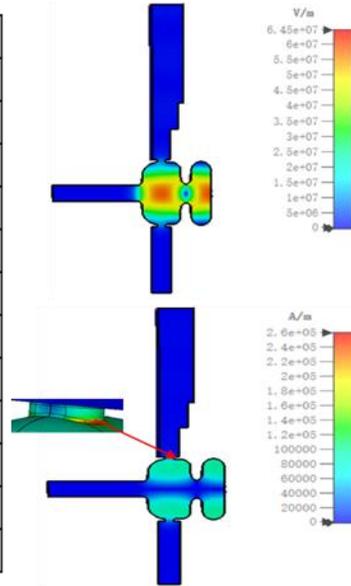


# Recent progress on IHEP PBA studies – plasma sources

名称	4阶拉盖尔高斯光	16阶拉盖尔高斯光	0阶贝塞尔光
实物			
图纸			
光强分布 (1mm*1mm区域内)			

# Recent progress on IHEP PBA studies – L-band RF Gun

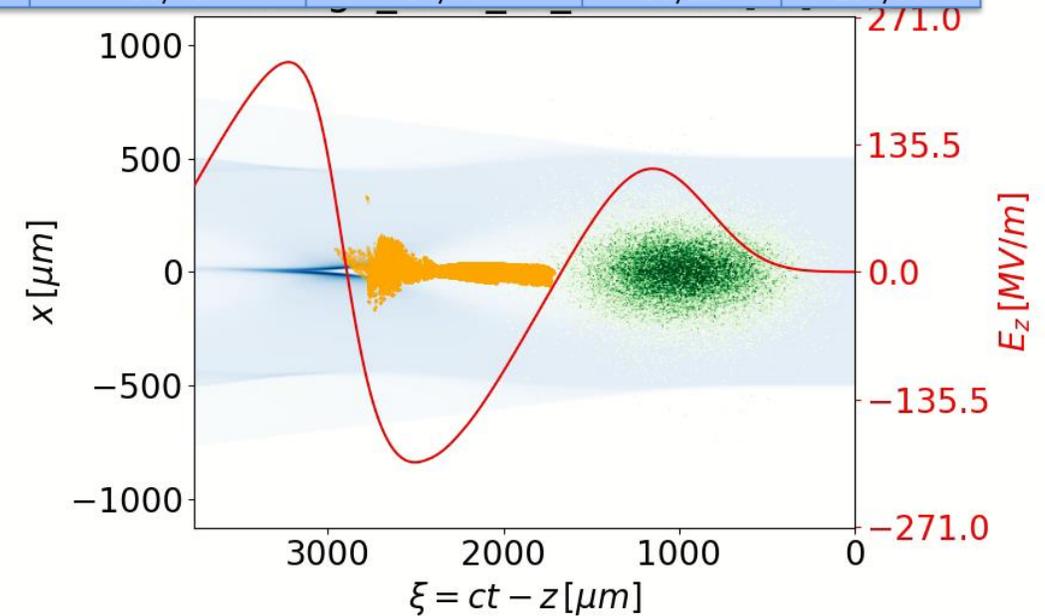
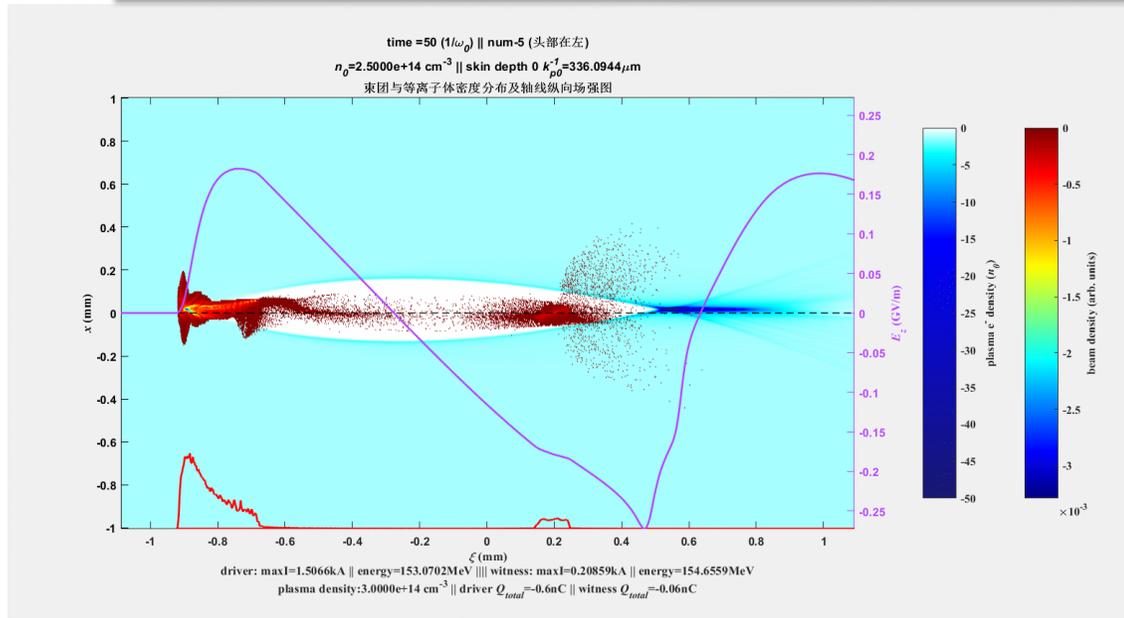
参数	设计值
频率(MHz)	1299.48
腔数	1.55
轴线归一化场平坦度	0.98
无载品质因数	24291
阴极表面加速梯度(MV/m)	60@6.3MW/稳态
模式间隔(MHz)	7.1
最大表面场强/阴极加速梯度	0.936(盘片处)
修正坡印廷矢量(W/um <sup>2</sup> )	0.65
脉冲加热(°C)	29
重复频率(Hz)	10
射频脉宽(us)	10
耦合系数	1.07





# Recent progress on IHEP PBA studies – cascaded acc.

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	$\mu\text{m}$	-	150/150	-	300/300	30/40	54/76	35/22	100/50



## Stage 1: PWFA @ IP2

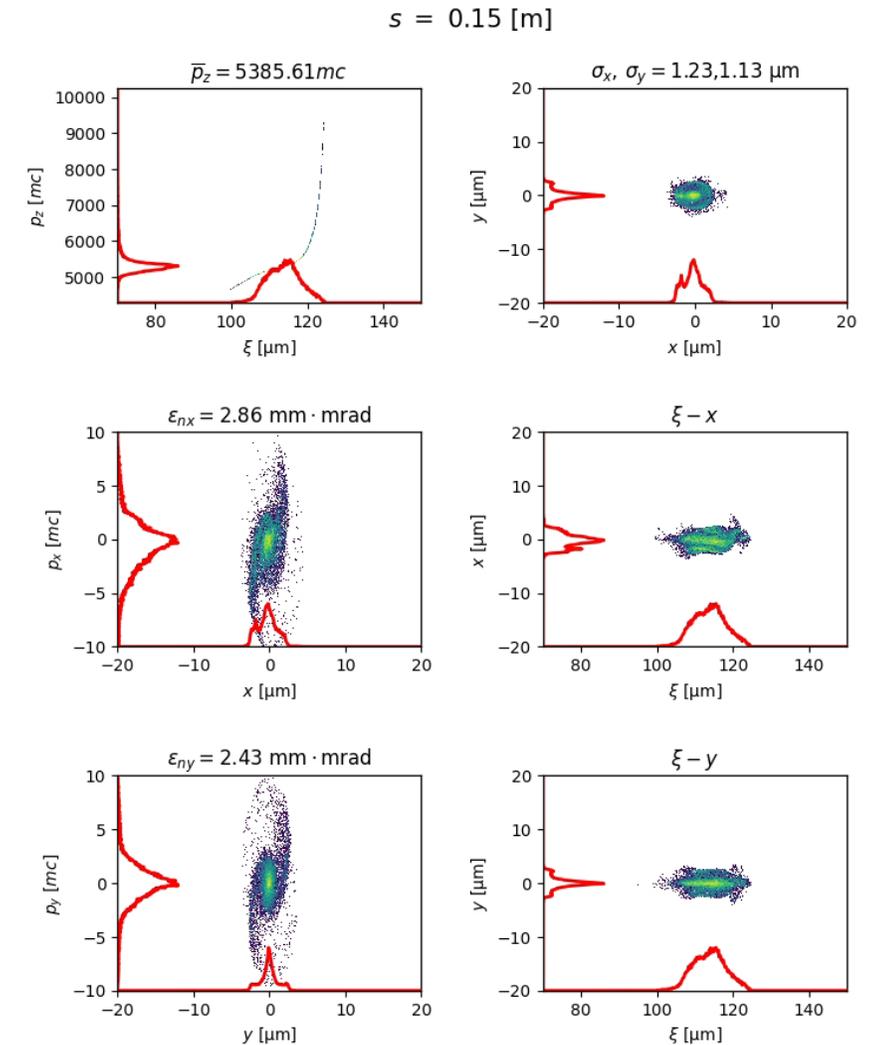
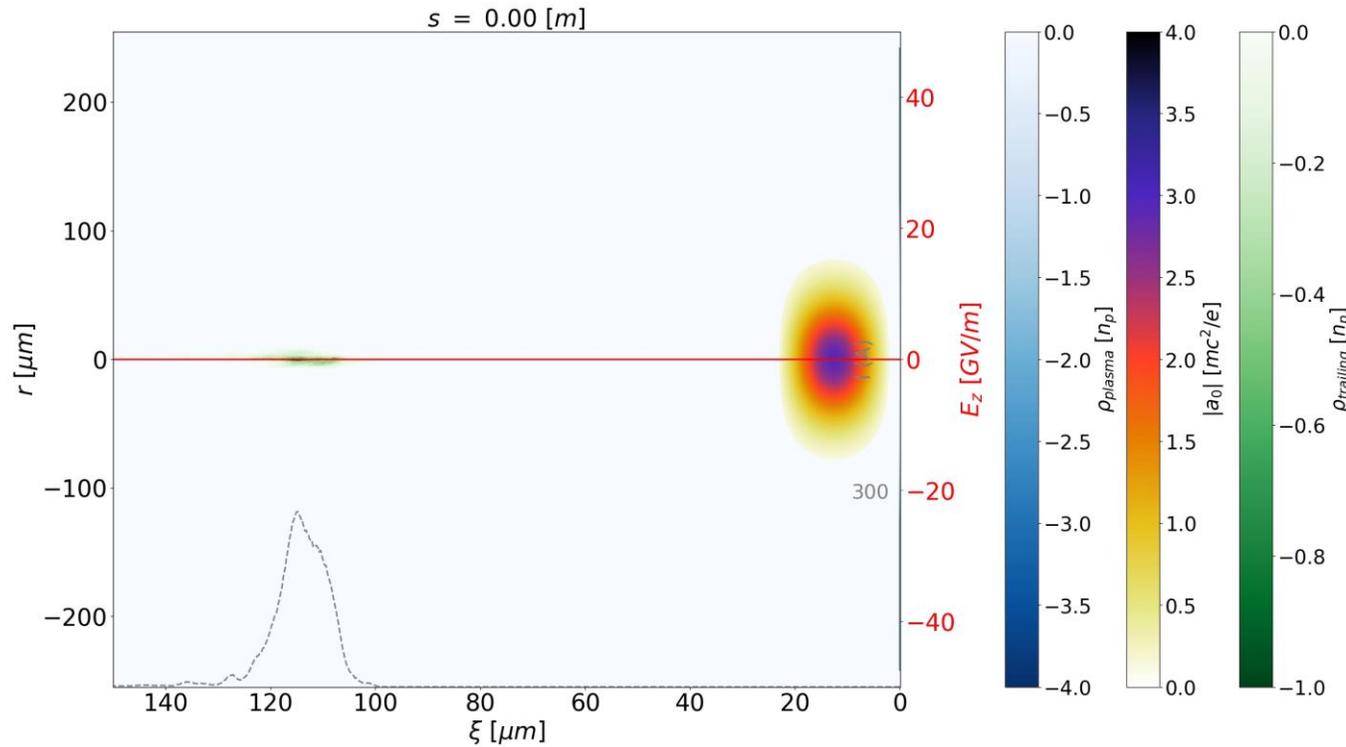
L-band e- gun generate 2 bunches  
Trailer is accelerated from 150 MeV to 170MeV

## Stage 2: PWFA @ IP1

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



# Recent progress on IHEP PBA studies – LWFA ext. inj.



**PW Laser + BL2 e- (9.45 pC)**

$E \sim 16.6 \text{ GeV}$ , rms energy spread  $\sim 7.7\%$



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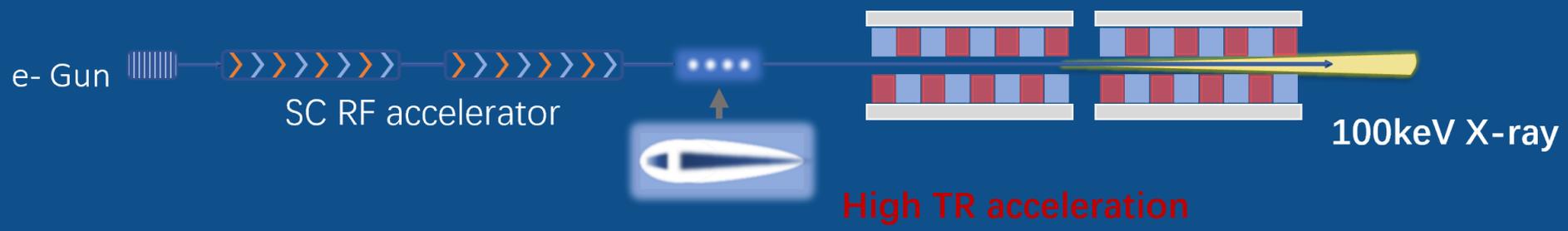
# PATH: Plasma Accelerator towards TeV Horizon

- PATH is a China initiated effort towards future light source and collider
- PBA TF is only the starting point for this effort.
  - The new TF is NOT only for PBA, but also for conventional accelerator R&D
  - The PATH is NOT only for CPI, but also for a real plasma-based accelerators
- Hope to start PBA experiments this year
- We'll focus on addressing the fundamental unsolved key issues, and clear the "path" of future plasma colliders

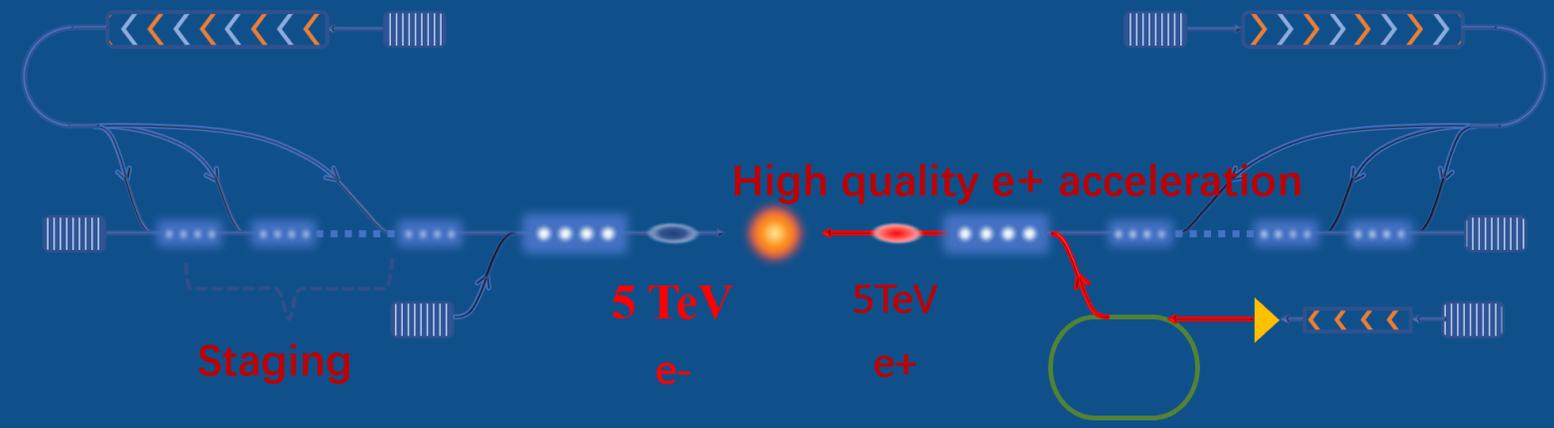


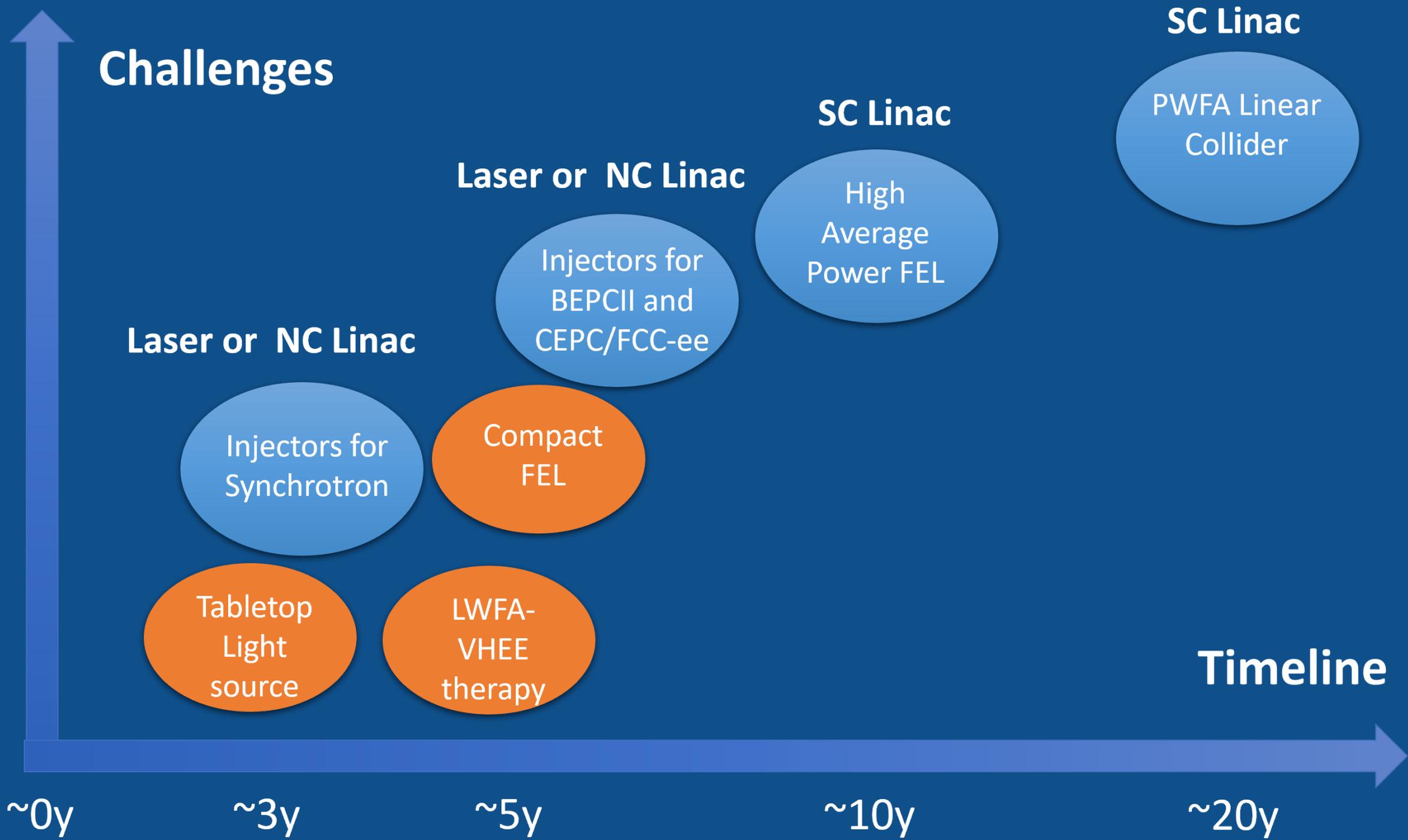
# Future high average power PWFA

100s keV X-ray FEL **5km** → **1km**



1-10 TeV e-/e+ Linear Collider **300km** → **20km**





**Challenges**

**SC Linac**

**SC Linac**

**Laser or NC Linac**

**Laser or NC Linac**

PWFA Linear Collider

High Average Power FEL

Injectors for BEPCII and CEPC/FCC-ee

Injectors for Synchrotron

Compact FEL

Tabletop Light source

LWFA-VHEE therapy

**Timeline**

~0y

~3y

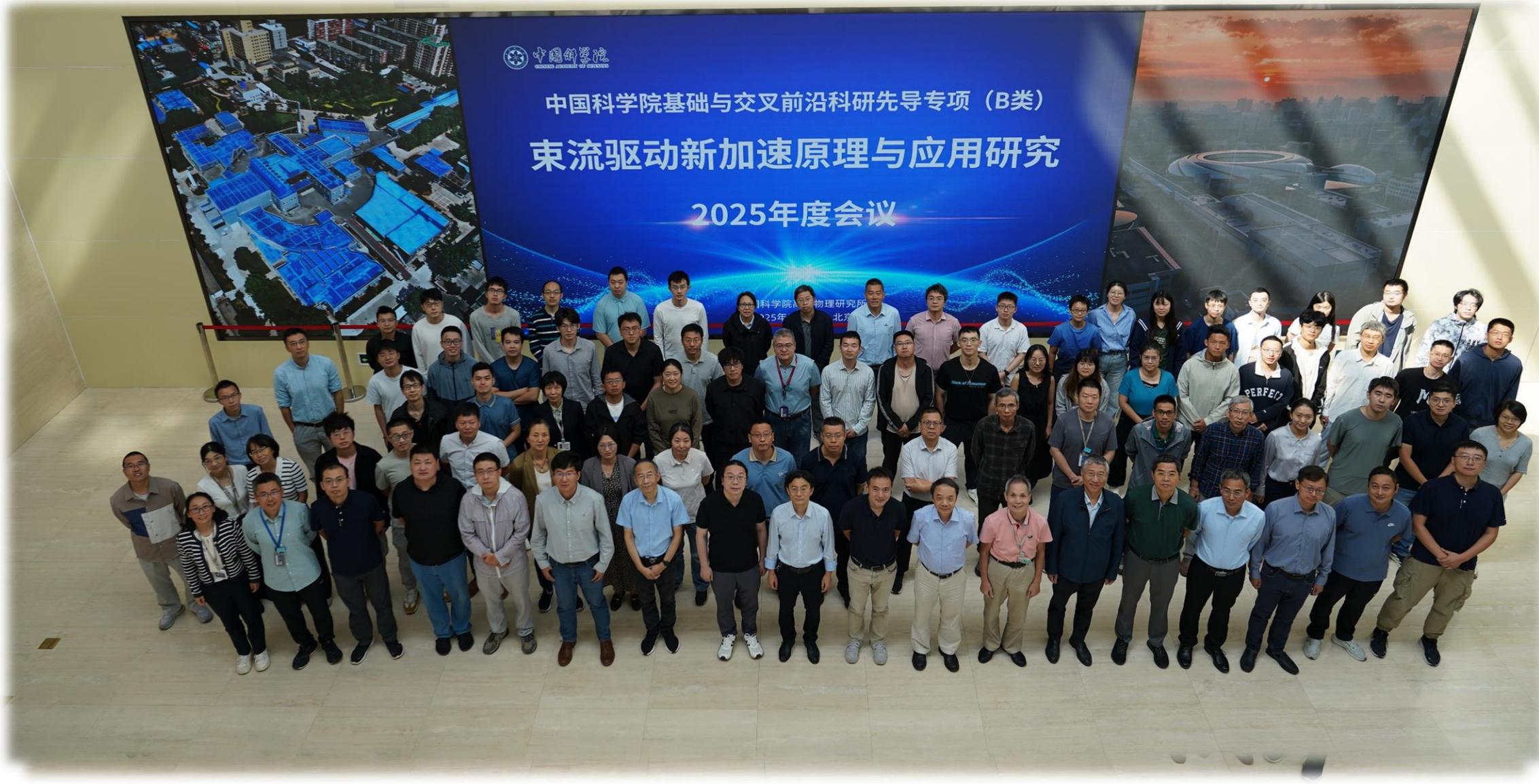
~5y

~10y

~20y



# Group photos at project annual meeting (2024 & 2025)



**Thank you and welcome to IHEP**

