Progress of HEPS project

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IHEP

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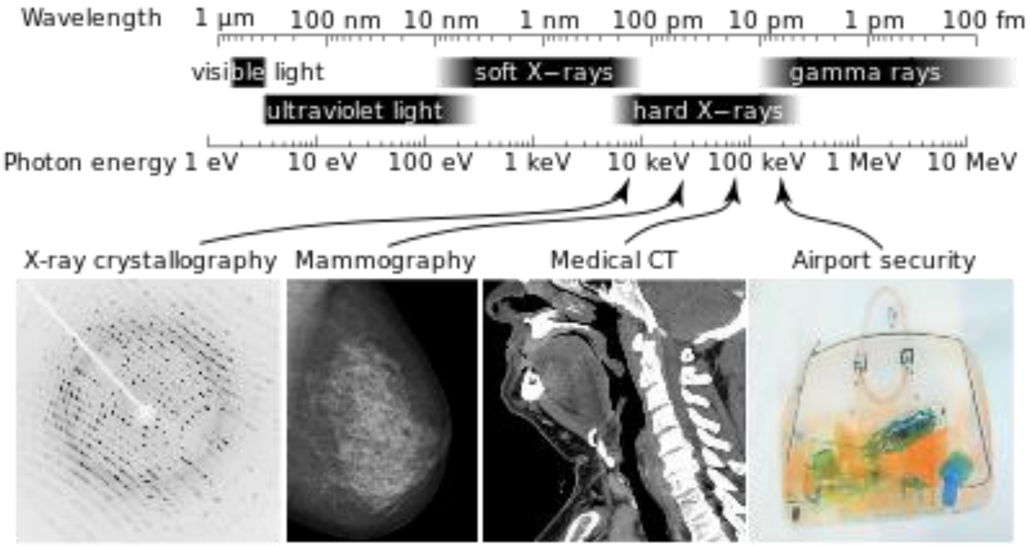
Outline

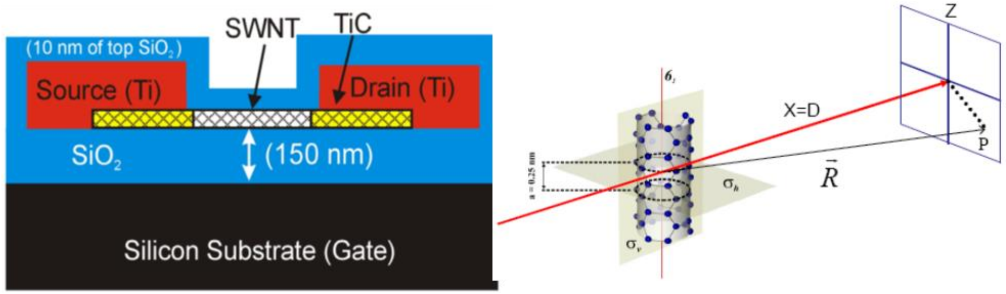
- Brief introduction on HEPS
- Main progresses from last IAC meeting
- Schedule, cost & manpower
- Organization of the project
- Risks and mitigation
- Possible international collaborations

1. Brief introduction on HEPS

Powerful light sources –

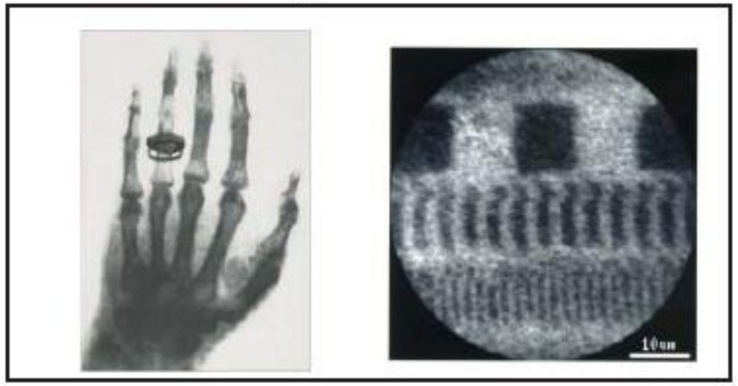
required with widely tunable frequency range from Infrared to X-rays !



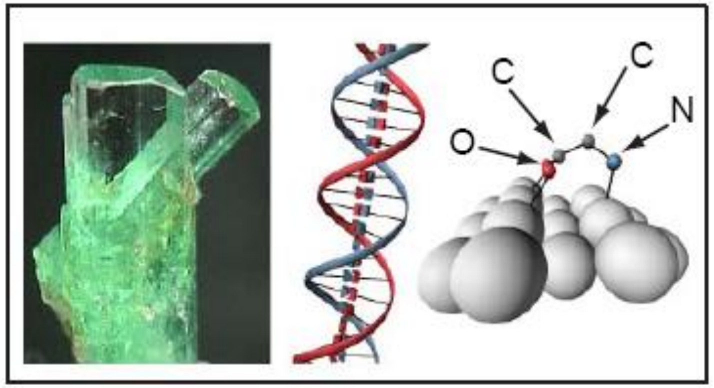


Diffraction of nano-tube

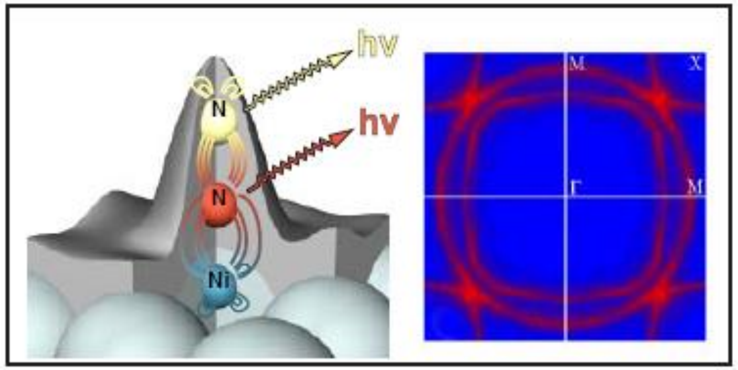
Seeing the invisible



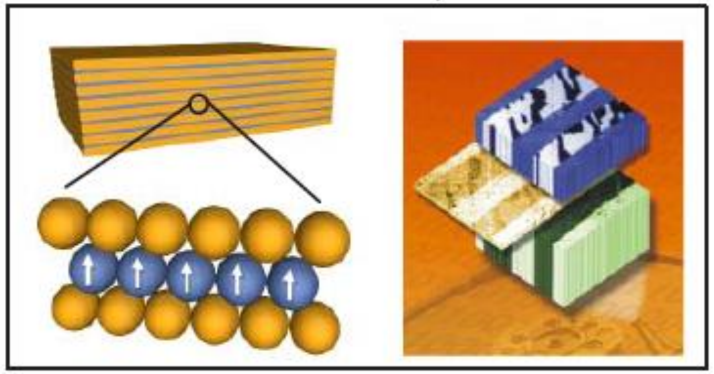
Where are the atoms?



Where are the electrons?

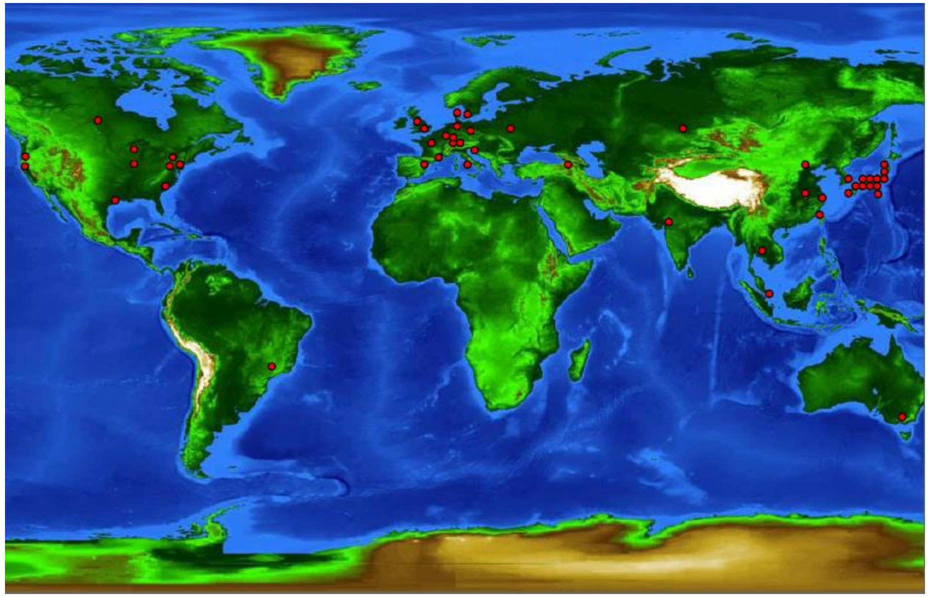


Where are the spins?



Synchrotron radiation light sources

- Most popular and successful photon science research platform worldwide &
- More than 50 facilities around the world!



Beijing Synchrotron Radiation Facility

Hefei Light source

Shanghai Synchrotron Radiation Facility

Towards the new light source

- High Energy Photon Source (HEPS) project
  - One of the 10 large scientific facilities in the 13th 5-year plan of the National Development and Reform Commission of China in mid-2016.
  - Officially approved in Dec. 2017, the construction was scheduled to start at the end of 2018, and completed in 2024. The whole project will be finished in mid-2025 after commissioning.
  - Accelerator Physics design and required key technologies were the goals of HEPS-TF, the R&D project of the HEPS project.

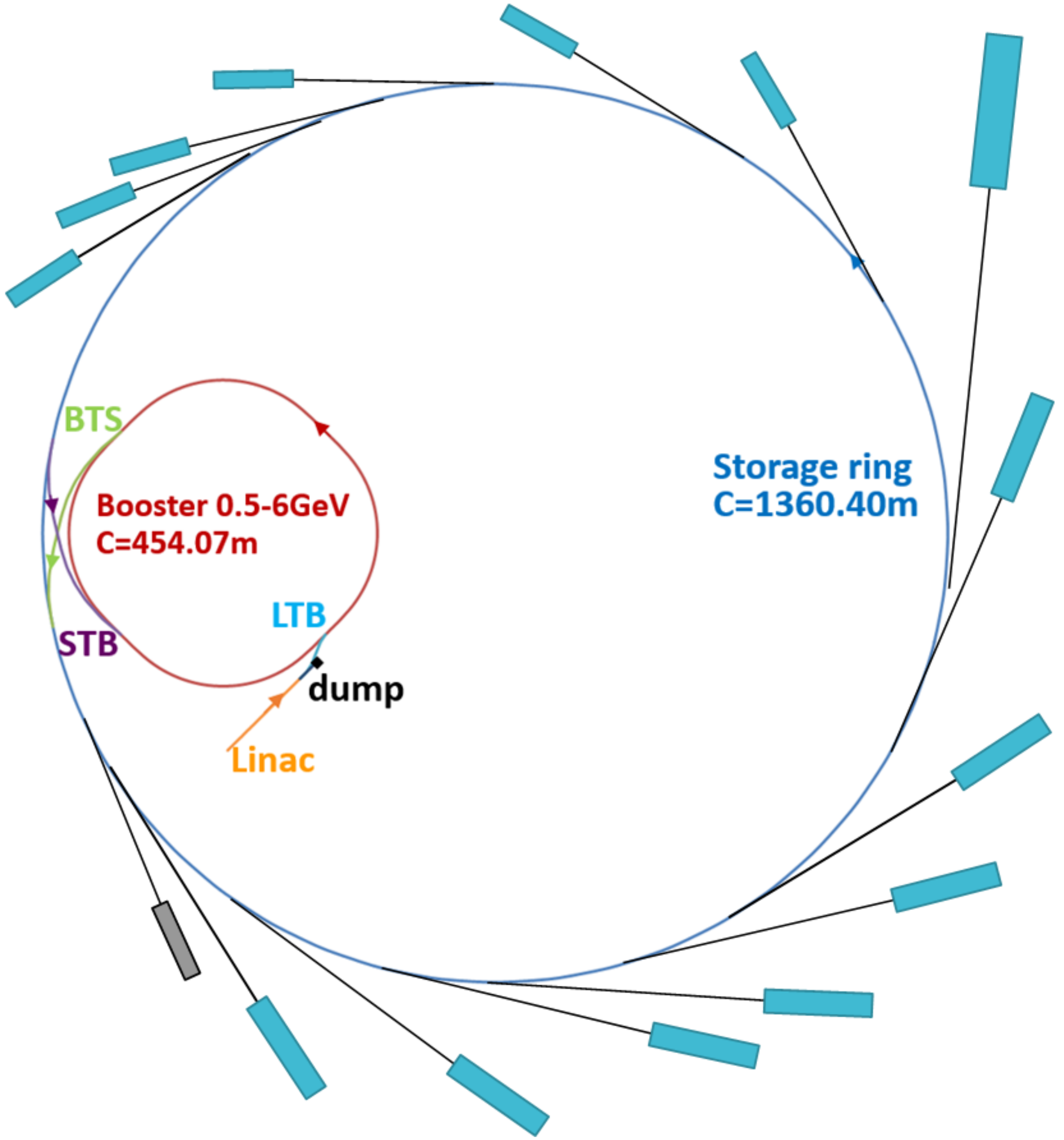
- HEPS-TF project – R&D of HEPS
  - One of the 16 large scientific facilities in the list of National Development and Reform Commission in the 12th 5-year plan.
  - It was officially started in April 2016, and had been completed in Sept. 2018.
  - Total budget: 321.6 M RMB (~42 M Euro, manpower excluded).

Milestones of HEPS project

- 01/2016, Conceptual Design Report study finished
- 02/2017, Project Proposal Report completed & submitted to CAS
- 03/2017, internal review of Project Proposal Report (PPR)
- 26/06/2017, national review of PPR
- 15/12/2017, PPR approved by government
- 01/2018, Feasibility Study Report submitted to CAS
- 11/06/2018, national review of Feasibility Study Report
- 31/08/2018, national review of Preliminary Design Report
- 28/12/2018, Feasibility Study Report approved by government
- 22/05/2019, final budget approved, total amount: 4.761 B RMB (~621 M Euro, w/o manpower)
- 29/06/2019, groundbreaking, and the project will be completed in 6.5 years

Design goals of HEPS

Main parameters	Unit	Value
Beam energy	GeV	6
Circumference	m	1360.4
Emittance	pm·rad	< 60
Brightness	phs/s/mm²/mrad²/0.1%BW	$>1\text{x}10^{22}$
Beam current	mA	200
Injection		Top-up

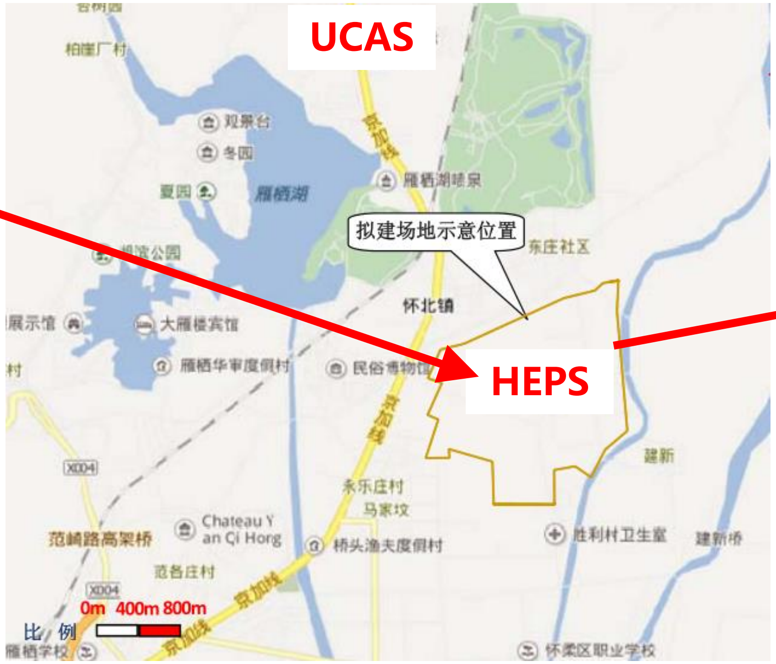


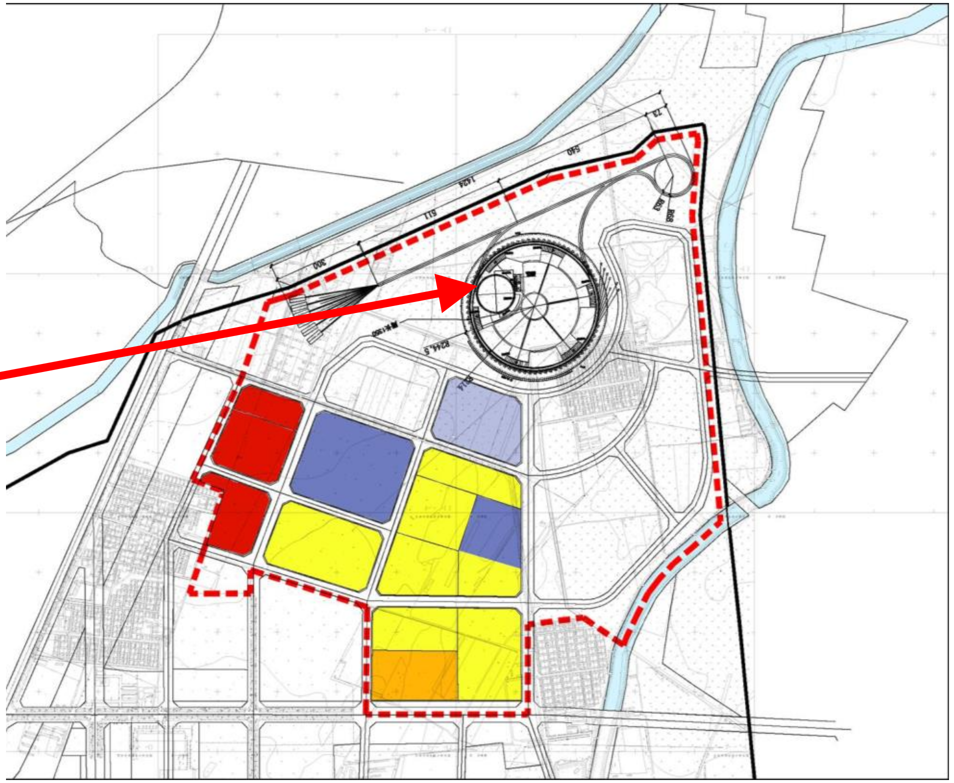
The site of HEPS

BASIC (Huairou Science Campus): An area of 233 acres, including:

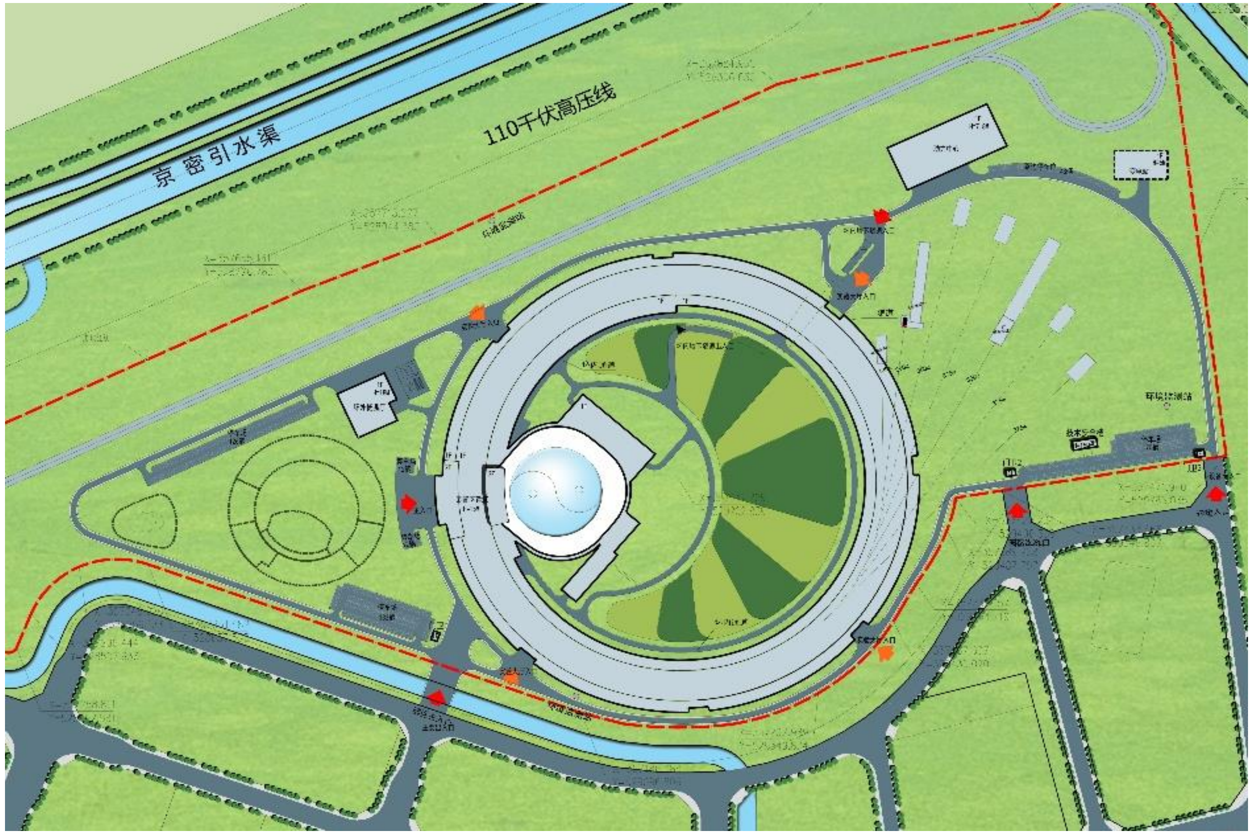
- HEPS
- SECUF (Synergized Extreme Condition User Facility)
- Simulation Facility for the Earth
- Series research platforms in energy, environment, biology, materials, etc.

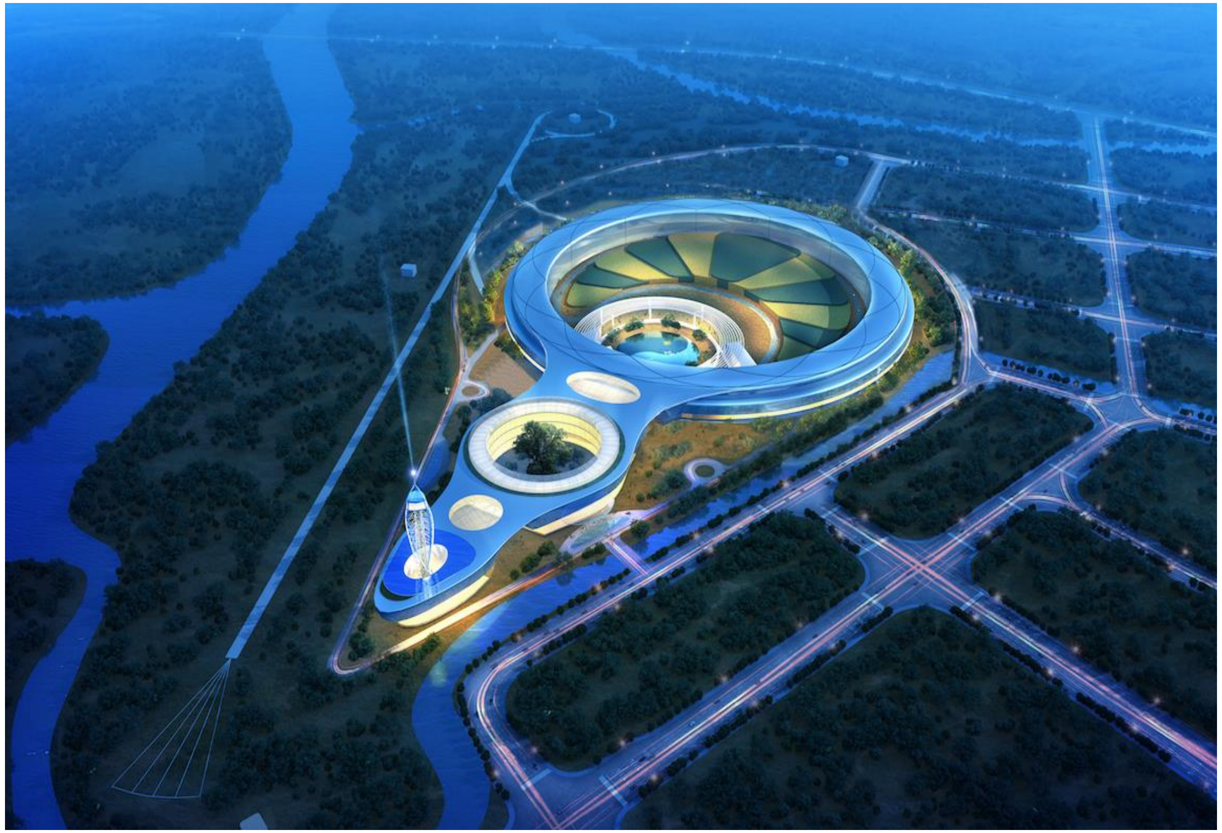
- Huairou District, Beijing area, ~80 km northeast to IHEP





Outline of buildings & utilities





Outcomes of IAC 2018

Recommendations from IAC	Responses
Timeline: As the project goes from design into construction phase, it is crucial that a detailed resource-loaded time plan is prepared, including the remaining R&D activities. This could be the topic of a dedicated review to be held before the next IAC meeting.	Not fully done, but emphasized from top management and the Project Management Body of Knowledge with EMV/WBS/Project is adopted.
A detailed risk analysis should be made for the project including the operations phase.	All kinds of Risk analysis are being applied to all the systems, but need more iterations and to watch any modifications.
System integration: Tight system integration is a critical success factor and proper communication channels amongst the different work packages as well as clear design choice decision paths are needed.	On going.
Staffing: A total of ~200 people are currently involved with the HEPS project (not full time). Given the overall strategy of in-house development, the IAC feels that these numbers need to increase significantly over the next years. A staff ramp-up plan should be established.	~275 FTE now. Staff plan per year is analyzed and given in detail.
Infrastructure: The performance of fourth generation sorage rings such as HEPS is critically dependend on high-performance infrastructure. Proper attention needs to be given to incorporting lessons learned from the R&D phase into the buidling infra-structure design.	It is very concerned, and strongly supported by the Beijing local government. Lessons from CSNS and other projects constructed by IHEP are seriously considered.

Outcomes of IAC 2018 (cont.)

Recommendations from IAC	Responses
Injection schemes: Even though the IAC supports the choice of swap-out on-axis injection as the baseline option, straight section space should be kept to allow for future use of longitudinal injection schemes.	Yes. Two injection schemes are compatible. Compared to the swap-out on-axis injection, long. Injection only needs shorter rise time for the power supply of kicker.
Now that the key technical issues have been addressed by HEPS-TF, the next round of more detailed engineering design work still lies ahead. A timeline that identifies the tasks as well as their relative priorities with targeted goals needs to be developed. An intermediate stage review should be held as soon as the plan is developed and ASAP	Reviewed in general by the domestic Science & Technology Committee. Each system of hardware had review meeting for technical design before manufacture and mass production.
Risk management (the presented material shows a good start)–Define branch dates in case components do not fulfil requirements (e.g., 166.6 MHz superconducting cavities), include spare parts necessary for reliable operation, additional diagnostics (2 DCCTs, photon BPMs before front ends, beam loss monitoring).	See Risk analyses in the presentations of each system.
Keep the option for a more traditional top-up injection scheme with accumulation in the storage ring with a triple RF-system (i.e. reserve the required straight sections for the implementation of the second harmonic cavities and the corresponding cryogenic plant capacity).	Yes, this option is kept.
Test the proposed commissioning approach on a storage ring with state-of-the-art shot-by-shot BPM electronics.	1 set of digital electronics of BPM is being used at the BEPCII storage ring, and 19 sets used at the linac now for routine operation.

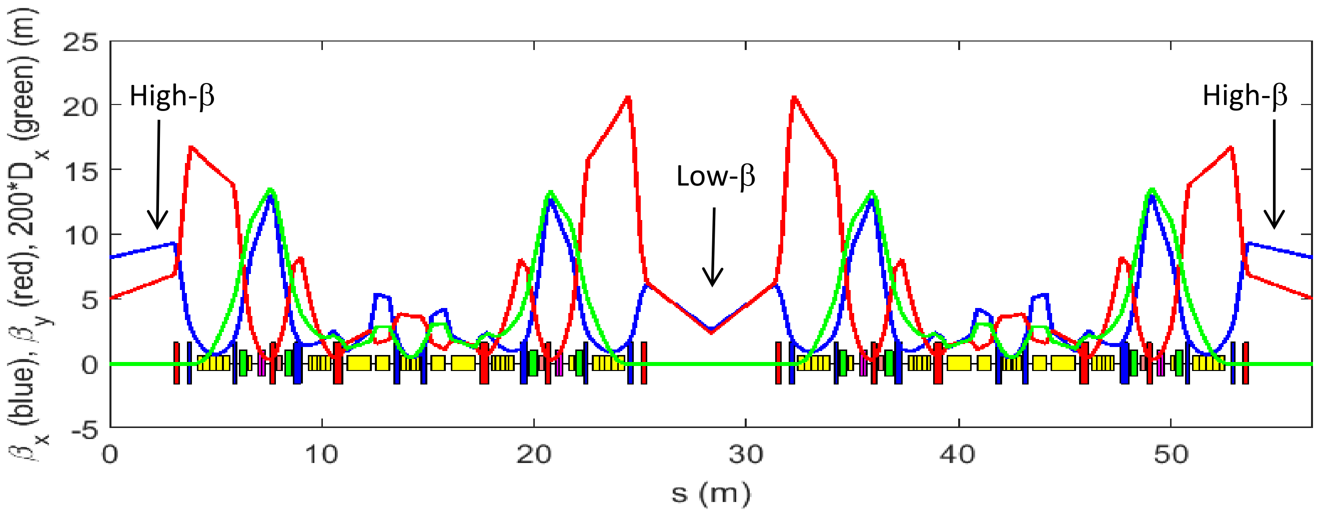
2. Main progresses from last IAC meeting

- Accelerator design

Main parameter	Design	Goal@12/2025 for test
Beam energy	6 GeV	6 GeV
Beam current	200 mA	100 mA
Circumference of SR	1360.4 m	
Circumference of booster	454.5 m	
Hori. Natural emittance	<0.06 nm·rad	0.1
Brightness	$>1\text{x}10^{22}$ phs/s/mm^2/mrad^2/0.1%BW	$2\text{x}10^{21}$ phs/s/mm^2/mrad^2/0.1%BW

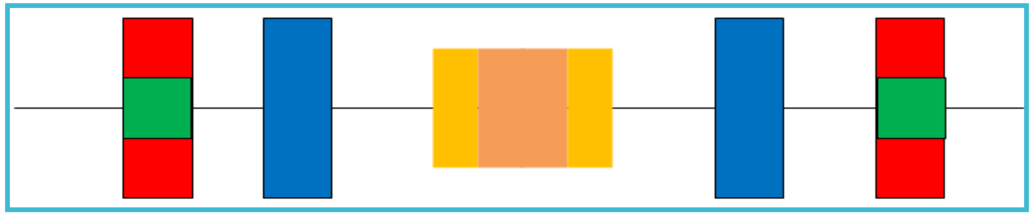
The current lattice design

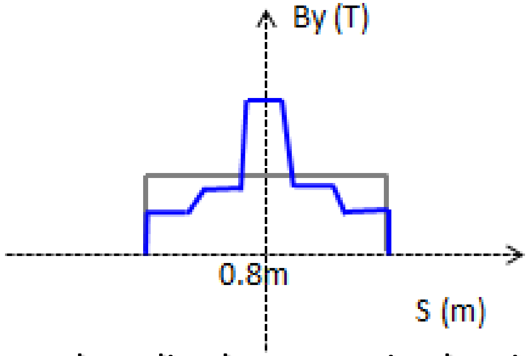
- C=1360.4 m, 48 hybrid 7BAs with AB/BLG cell, 24 super-periods



Combination of AB and BLG in one cell promises lowest possible emittance [1-3].

Emittance reduced from ~45 pm ($\varepsilon/\varepsilon_{TME}$ ~ 3.8) if with 48 hybrid 7BAs to **34.8 pm** ($\varepsilon/\varepsilon_{TME}$ ~ 2.9).

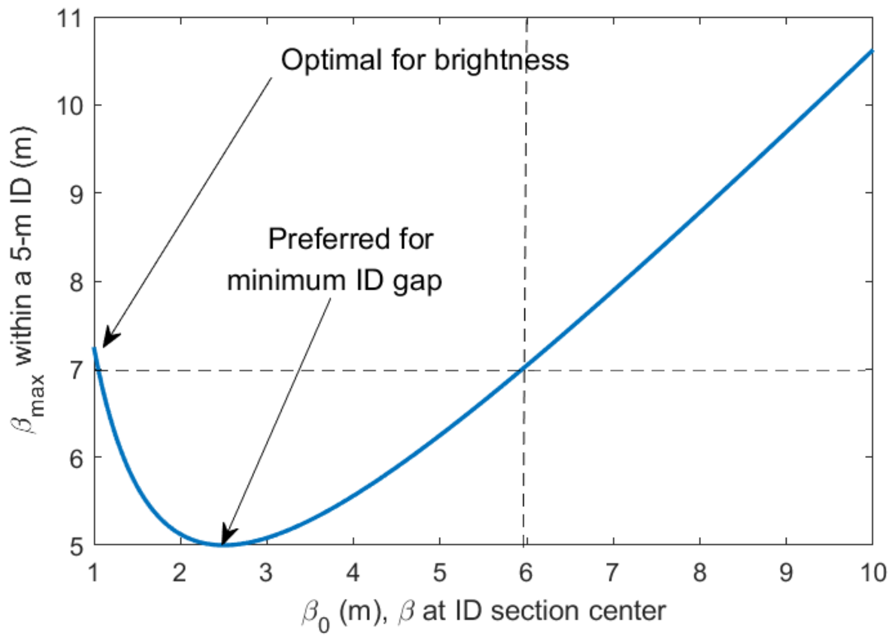




Peak field (T)	Critical photon energy (keV)	Peak power density (W/mrad²)
0.5T	12.0	702
0.85T	20.3	1194
1T	23.9	1405
1.5T	35.9	2107
2T	47.9	2810
3T	71.8	4215
3PW(1.6T)	38.3	2349

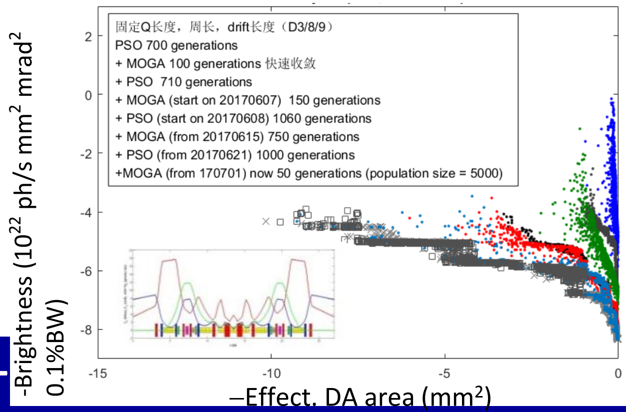
Central slice of BLG used for bending magnet beam line, will not install any other dipole source in the ring

[1] A. Streun, A. Wrulich, NIM-A 770, 98 (2015). *[2] Y. Jiao, X.Y. Li, G. Xu, IPAC2018, TUPMF054.*
[3] B. Riemann, A. Streun, PR-AB 22, 021601 (2019).

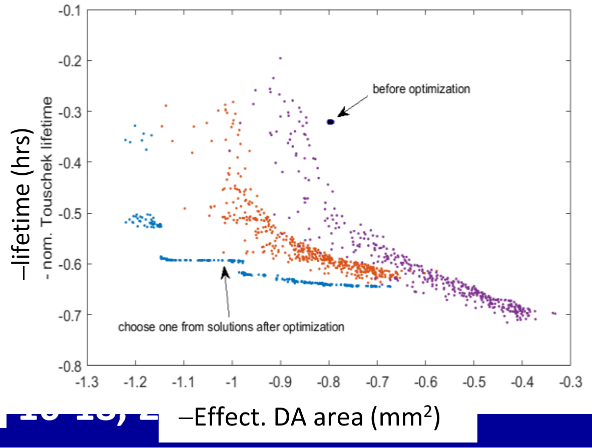


Parameters	High-brightness mode, 200 mA	High-bunch-charge mode, 200 mA [1]	Units
Beam energy	6	6	GeV
Number of bunches	680	63	
Bunch Duration (rms)	106	160	ps
Bunch spacing	6	72	ns
Emittance ratio ($\varepsilon_y/\varepsilon_x$) [2]	0.1	0.1	
Horizontal emittance	27.5	33	pm·rad
Vertical emittance	2.75	3.3	pm·rad
Horizontal beam size (rms) (high-/low-β section)	14.3/8.5	15.6/9.3	μm
Vertical beam size (rms) (high-/low-β section)	4.4/2.3	4.8/2.5	μm
Lifetime	~4	~1	hrs
Time between two refills	~30	~8	s

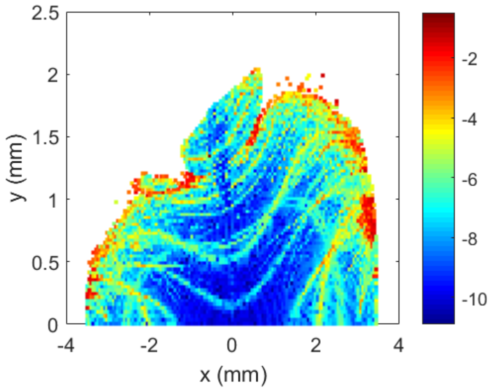
- Simultaneously optimize brightness and DA with PSO/MOGA

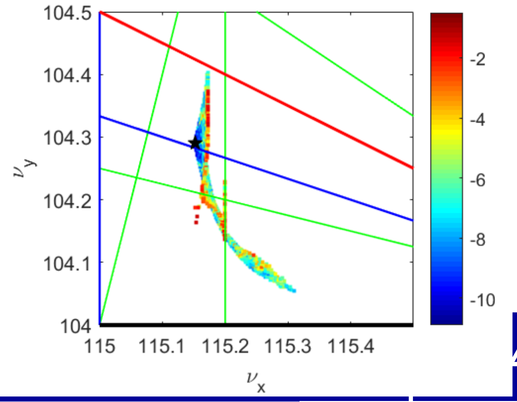


- Touschek lifetime also optimized



- Dynamic aperture (H/V): 3.5/1.9 mm w/o error but w/ physical aperture(@high-β)

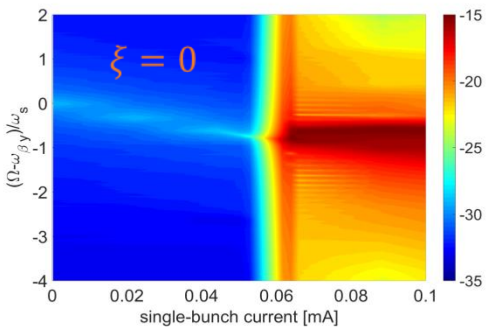


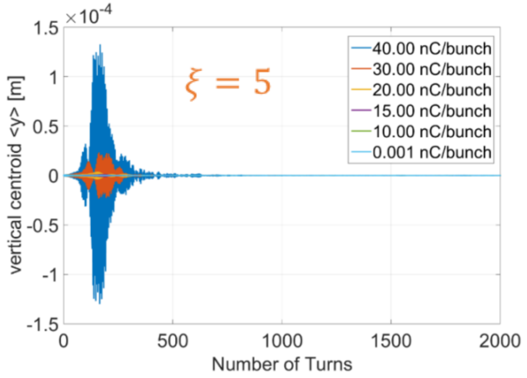


Collective Effects

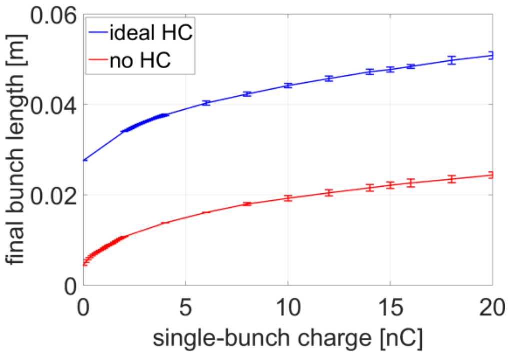
- Impedance modeling
  - Dominant impedance contributions are included.
  - Impedance optimization are performed based on iteration with hardware designs.
- Single bunch instability

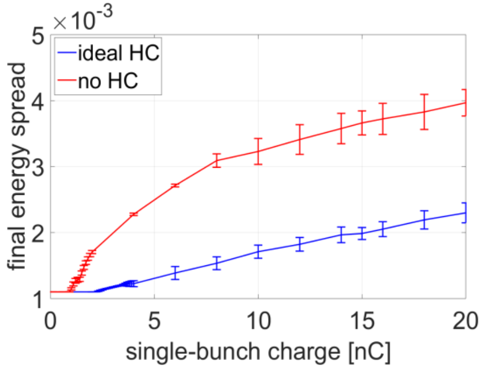
Transverse mode coupling instability I_{th}> 30 nC.
—With a large positive chromaticity (+5)





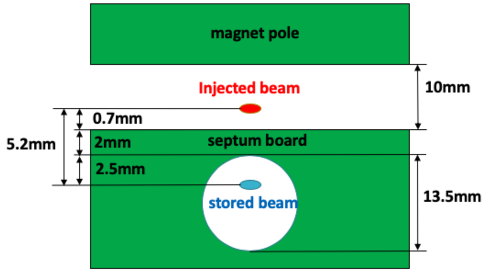
Microwave instability threshold ~2.2 nC.
Brightness degradation expected for high-bunch-charge mode (14.4 nC)

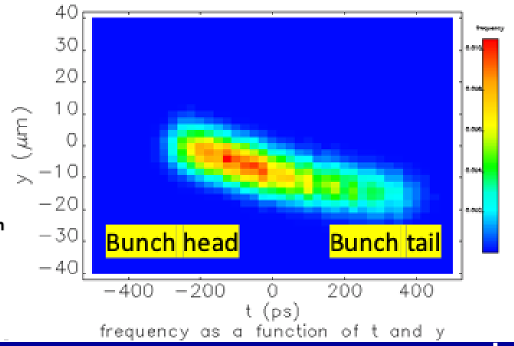




Emittance degradation due to asymmetry structures

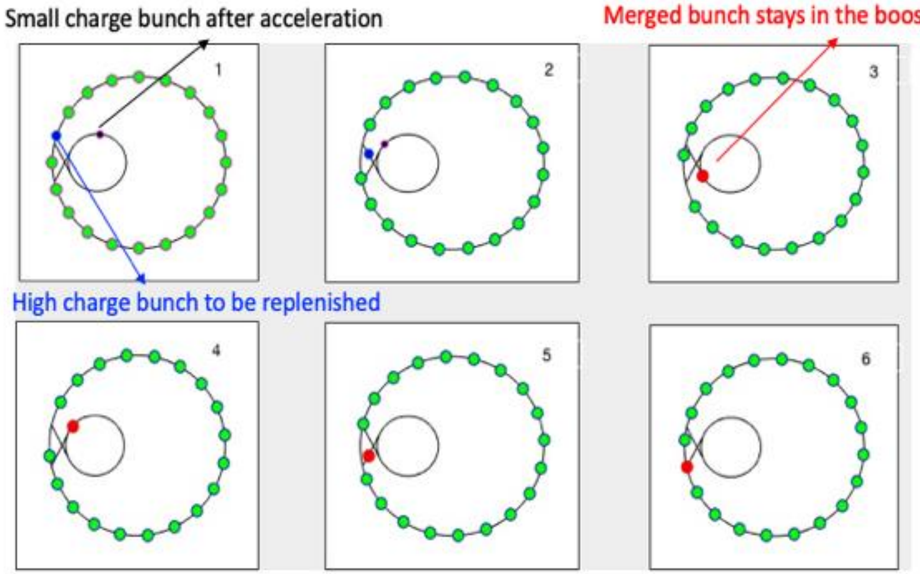
- ➢ Vertical monopole wake leads to static vertical tilt of the bunch tail.
- ➢ The vertical phase advance between the extraction Lambertson and the injection Lambertson is close to (2n+1)π, the increase in the projected emittance is quite localized.

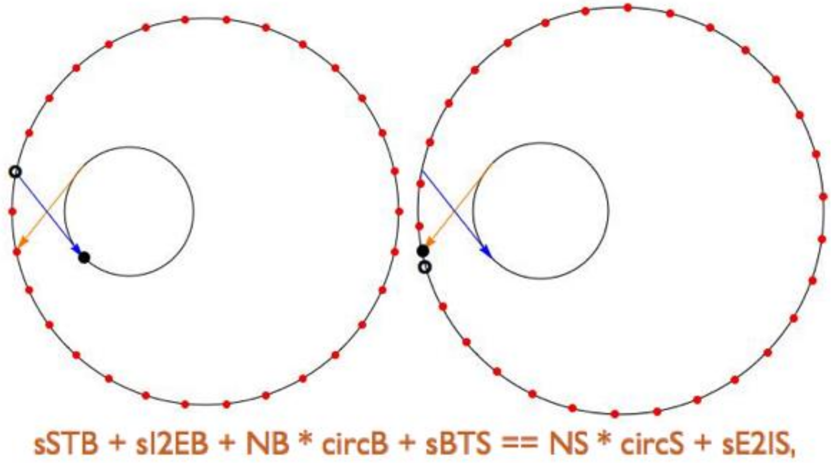


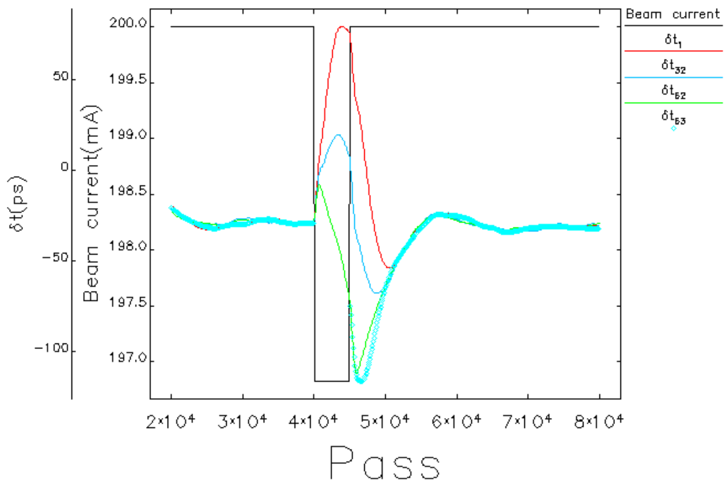


Injection — Swap-out + High-energy accumulation [1]

- Challenge of "swap-out" injection: a full charge injector : "Charge accumulation" in the booster @ 6 GeV
- The replaced bunch is transported back to the booster and merged with an accelerated small-charge bunch, after ~20 ms damping, the bunch is re-injected into the empty bucket in the storage ring.
- Synchronization requires booster/SR harmonic number: 757/756, and proper lengths of two transport lines.
- Injection transient: one missing bunch in SR for about 20 ms, leads to a small brightness drop, and some variations in longitudinal dimensions for the high charge mode, acceptable for most users.





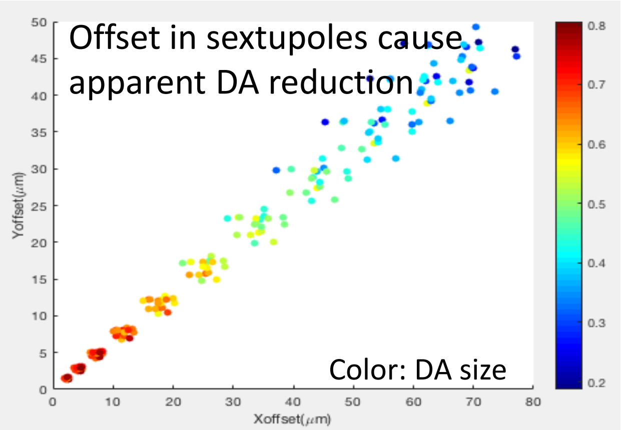


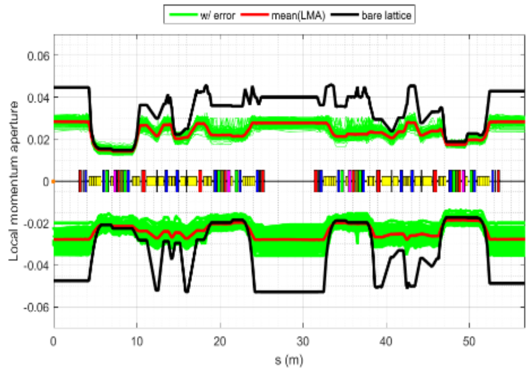
[1] Z. Duan et al., IPAC2018, THPMF052.

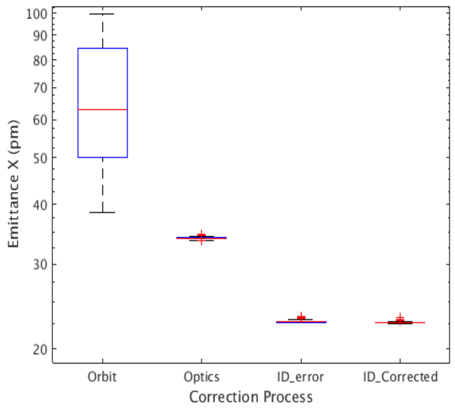
Lattice Calibration

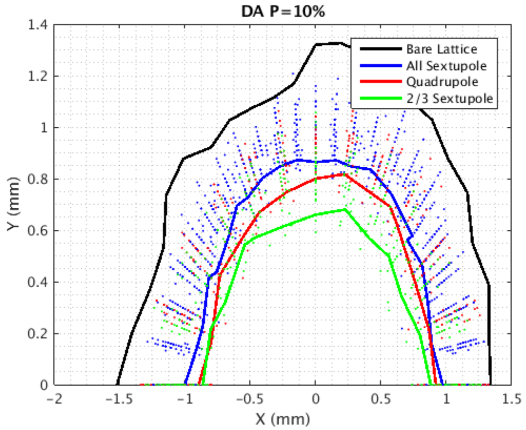
- Detailed lattice calibration simulation has been done.
- Requirement on alignment, magnetic field errors, etc. are specified.
- Number and locations of BPMs and correctors in the ring are optimized and fixed.
- First turn accumulation strategy developed.

DA at injection (low-β) straight center
— ~1.5/1.4 mm (w/o error)
— ~1.2/1.2 mm (w/ error & correction)
Satisfies injection requirement
— ~0.8/0.45 mm in x and y

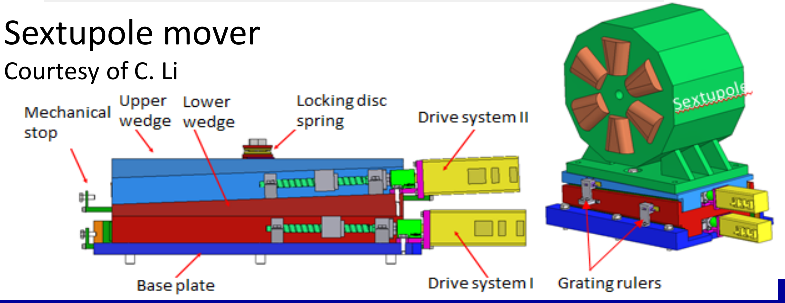








Sextupole mover
Courtesy of C. Li

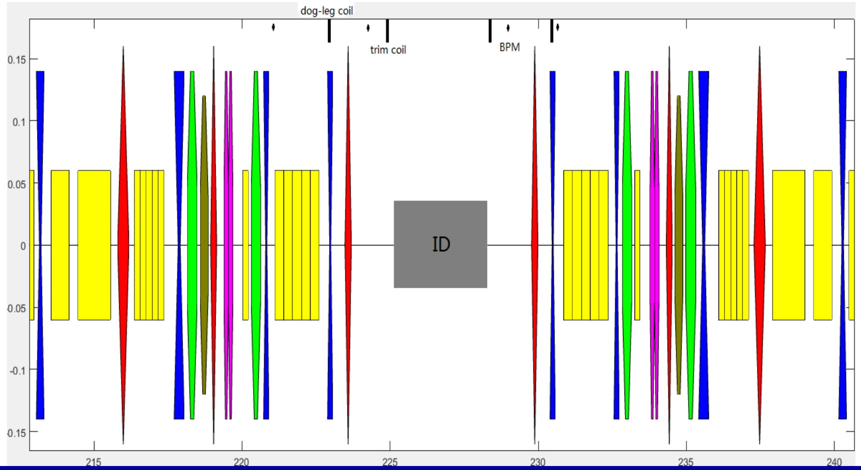


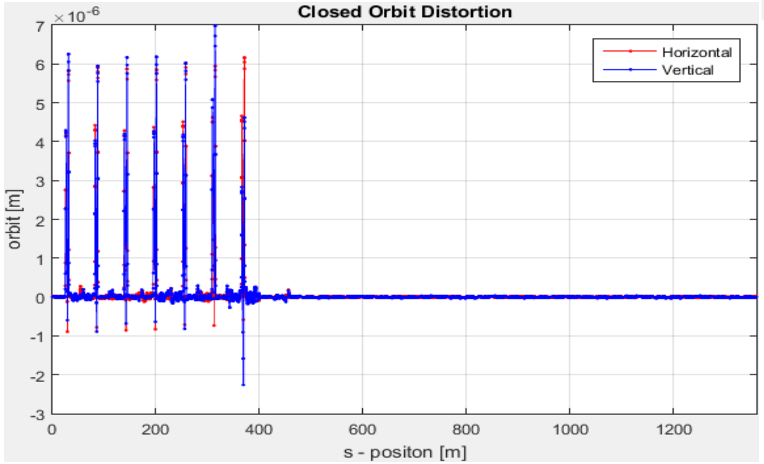
DA improved using sext. movers in lattice calibration

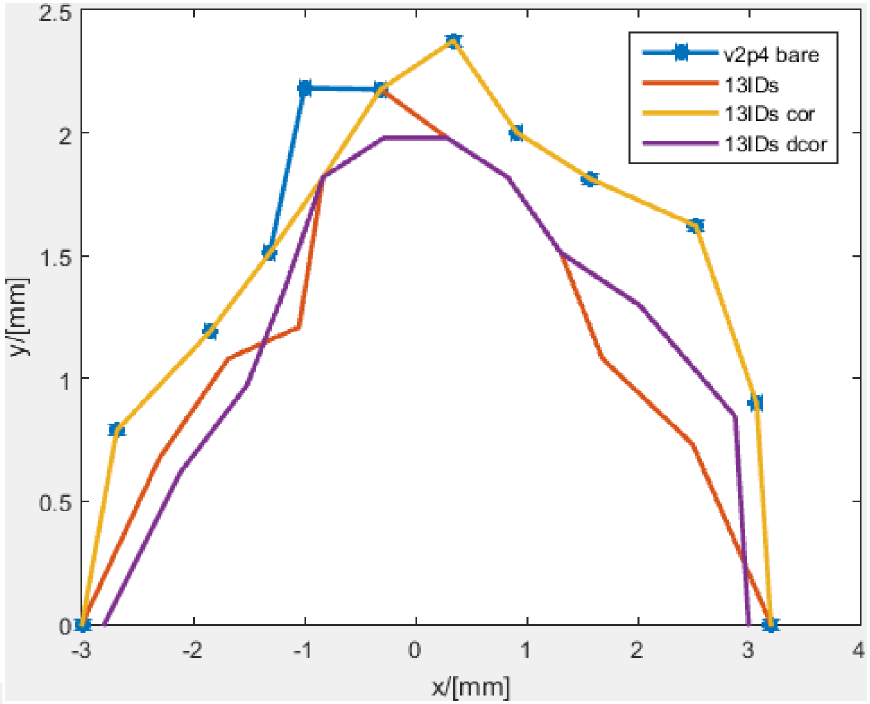
Optics correction	w/o Mover	w/ Mover
sextupole rms H/V offset (μm)	100 / 80	20 / 50
rms H/V β-beat after correction	1.7% / 1.6%	0.7% / 1.1%
rms Horizontal dispersion error (mm)	7.3 / 2	1.59 / 1.49
Emittance (pm)	43 / 1.63	34.96 / 0.81

ID Effects

- Dynamic multipole effects on beam optics
  - Seven quadrupoles on both sides of each ID to correct the tune shift, beta beating and dispersion generated by IDs.
  - The remain beta beating due to IDs is less than 1‰ in the horizontal direction and less than 2‰ in the vertical direction.
  - The horizontal dispersion at the midpoint of the straight section after correction is less than 0.2mm.
- ID integral error effects on C.O.D.
  - Trimming coils and dog-leg coils are used to correct the position of the photon beam produced by ID, while ensuring the close orbit distortion does not leak to the arc section



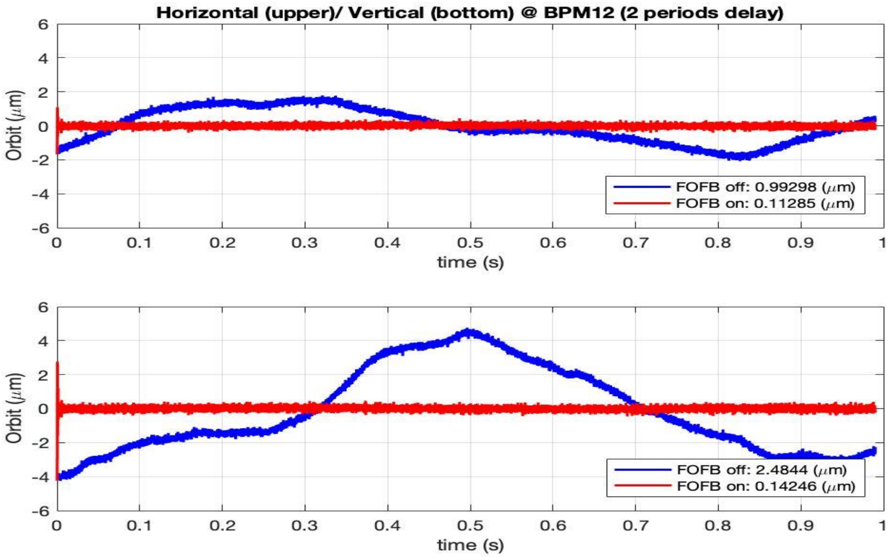




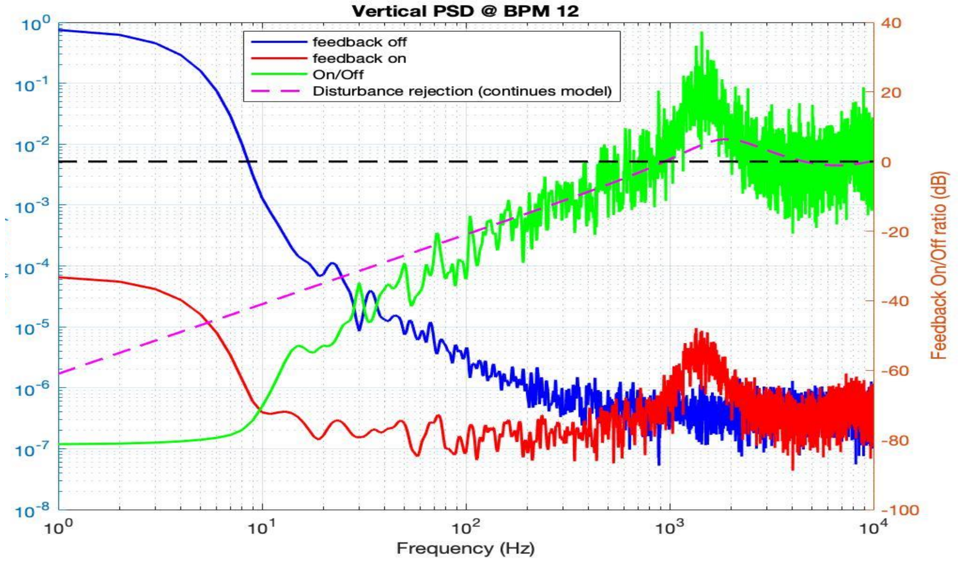
Comparison of DA :
- blue line: bare lattice
- orange line: IDs without correction
- yellow line: IDs with tune shift and beta beating correction
- purple line: IDs with tune shift, beta beating and dispersion correction

Beam Stability

- Beam stability requirement is extremely critical in the vertical plane
- Different type of feedback implementation and algorithm are under comparison
  - FOFB only (SLS, etc.)
  - FOFB + slow correctors (NSLS-II, etc.)
  - FOFB + SOFB (ALS, APS-U, etc.)
- Preliminary simulations on FOFB shows that the bandwidth is around 800-1000Hz



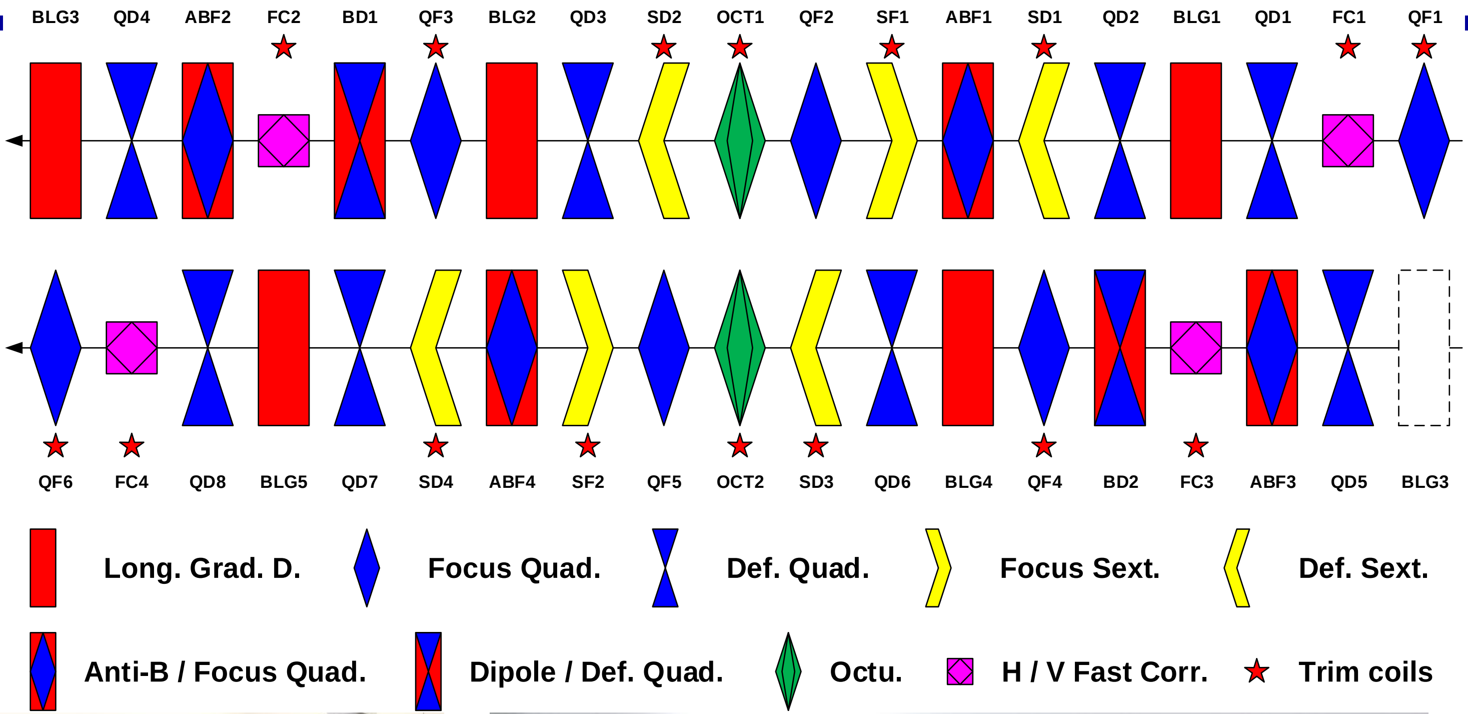
Variation of the orbit at the ends of the straight section with FOFB off/on (blue/red)

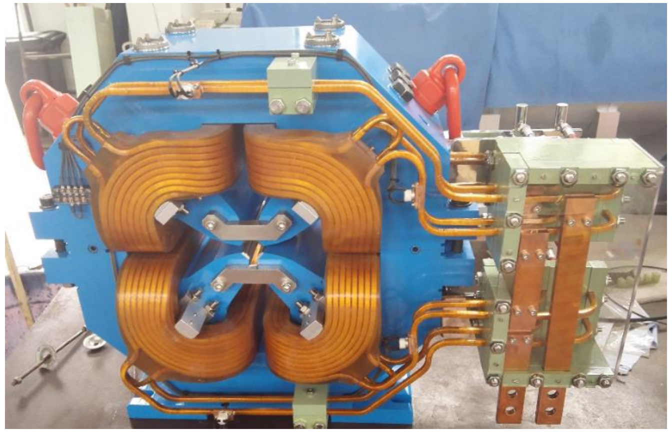


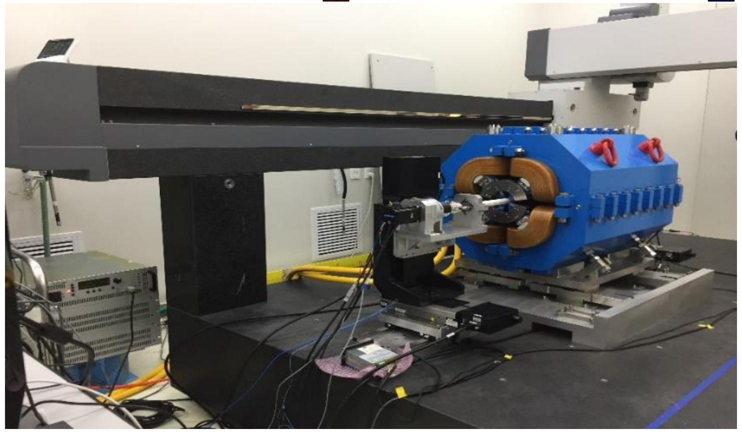
Vertical beam motion PSD with FOFB off/on (blue/red), and the ratio between the two (green: simulation, magenta: analytical)

Hardware of storage ring

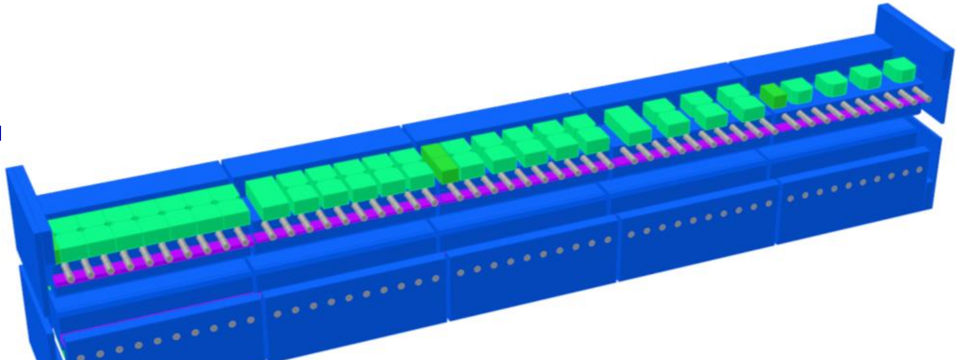
- Magnets
  - 37 magnets in one 7BA cell
  - BLG 0.11 – 1 T
  - Quad 82 T/m
  - BD 66 T/m
  - Sext 6082 T/m^2
  - Oct 512600 T/m^3
  - Fast Corr 0.08 T



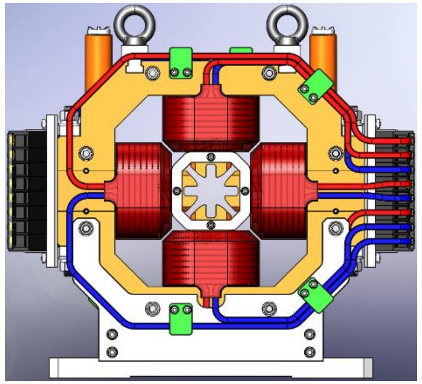


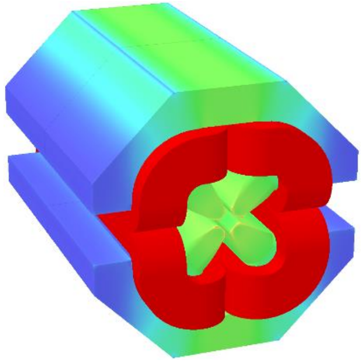


- Physical design of the magnet is almost finished
  - Longitudinal gradient dipoles (permanent magnet), anti-bend quadrupoles, quadrupoles, sextupoles and octupoles → Done
  - Dipole/quadrupole combined magnets → Done
- Fast corrector prototype is under development
  - Skew quadrupole type with slot on the pole
  - 0.15mm thickness lamination

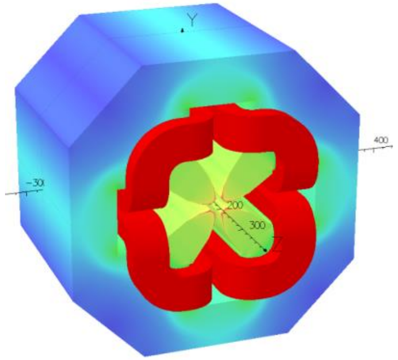


Longitudinal gradient dipole BLG1/5

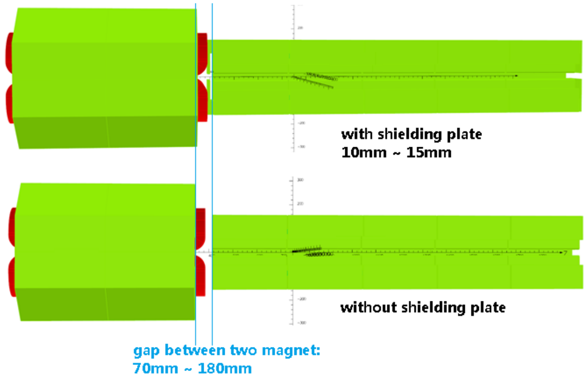


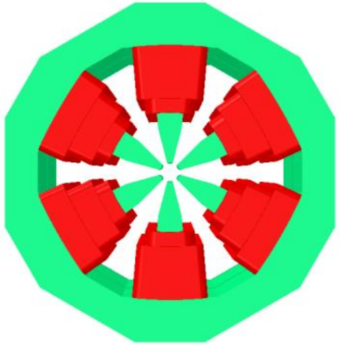


Anti-bend quadrupole ABF2/3

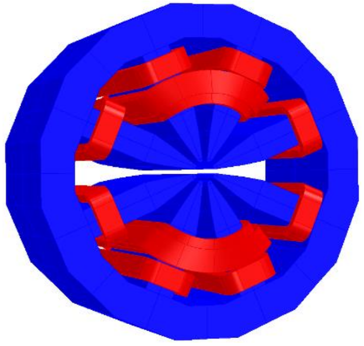


Quadrupole QF3/4





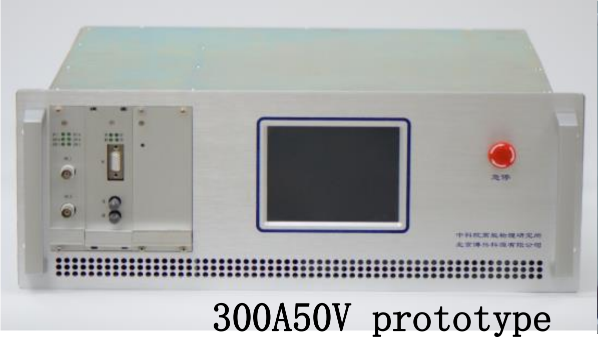
Sextupole SD2/3

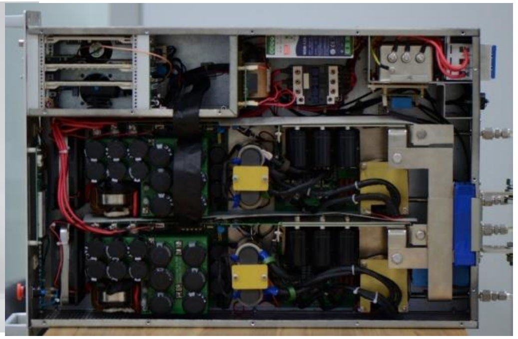


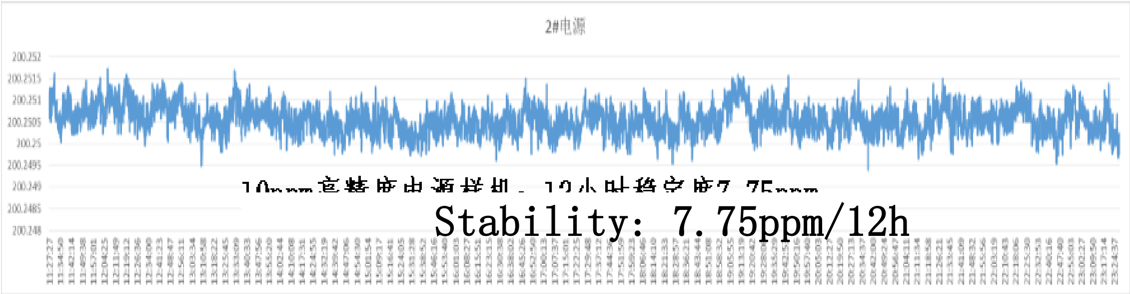
Octupole OCT1/2

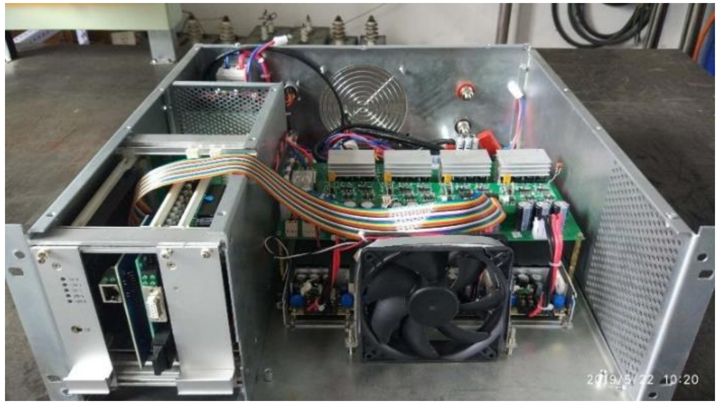
- Power supplies for magnet
  - Finished the design of DPSCMII
  - High precision PS developed, designed and tested
  - Home-developed DCCT
    - ➢ 20A for correctors
    - ➢ 300A for SR main magnet power supplies
  - Fast corrector power supply prototype
    - ➢ 10kHz bandwidth
    - ➢ 20ppm current ripple

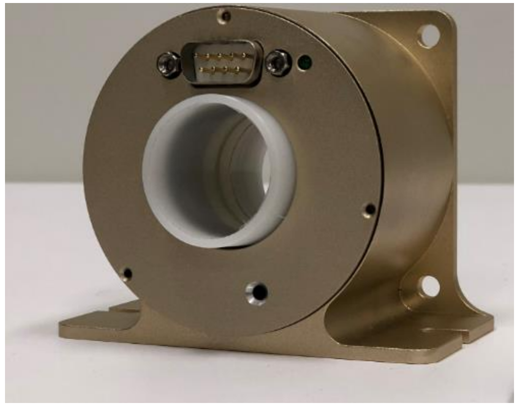
FPGA-based main board of Digital Power Supply Control Module



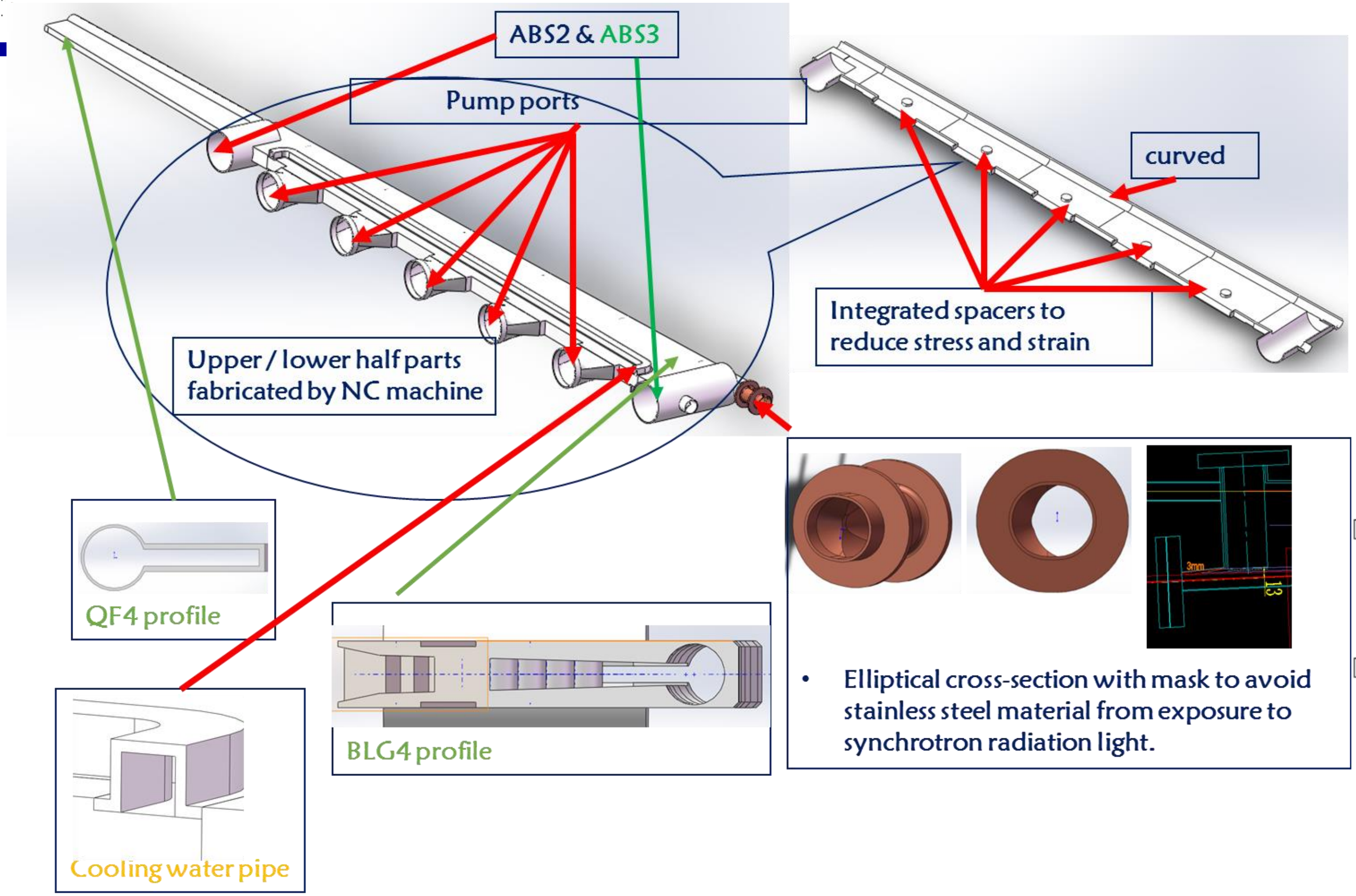


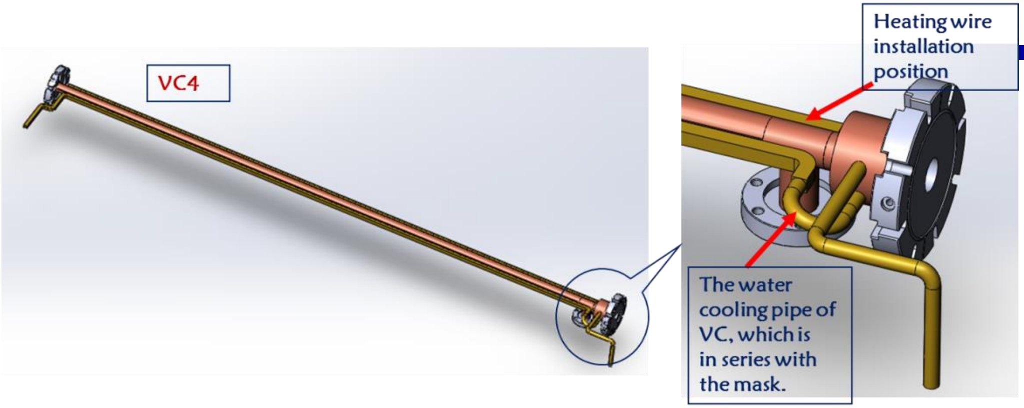


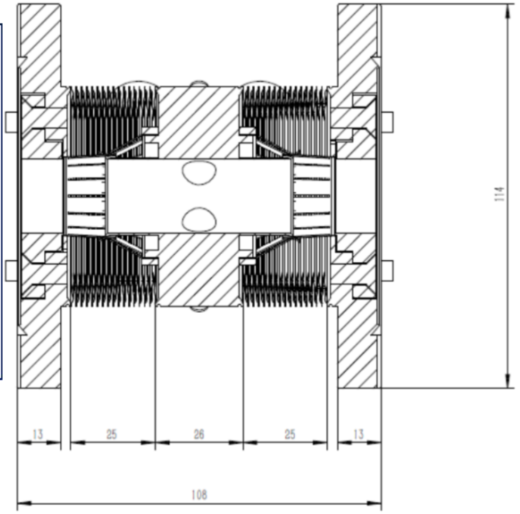




•Vacuum chambers, RF bellows and Photon absorbers







Total length/mm	108
Axial Stroke	-16~+4
Radial Offset/mm	±2
Bend angle/°	±1
Be-Cu strip thickness/mm	0.2
Contact pressure/g	125±15
Permeability of stainless steel	<1.02

- Silver-bearing (0.085%) oxygen-free copper (OFS-C10700) or Cu-Cr-Zr (C18150) will be chosen as the main chambers material.
- Inconel material will be used for fast corrector chambers.
- Stainless steel will be adopted for the BLG chambers and coated with copper inside.

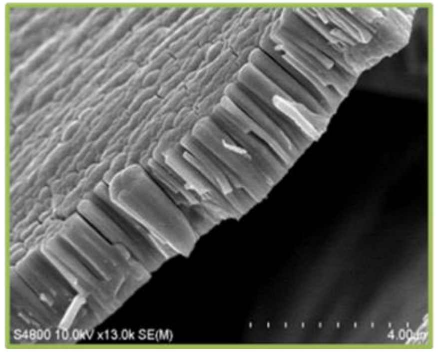
GlidCop-AL15 and CuCrZr photon absorbers

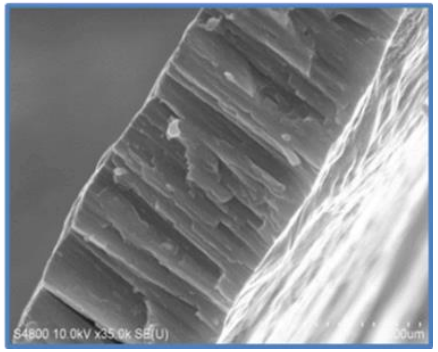
• NEG Coating devices setup

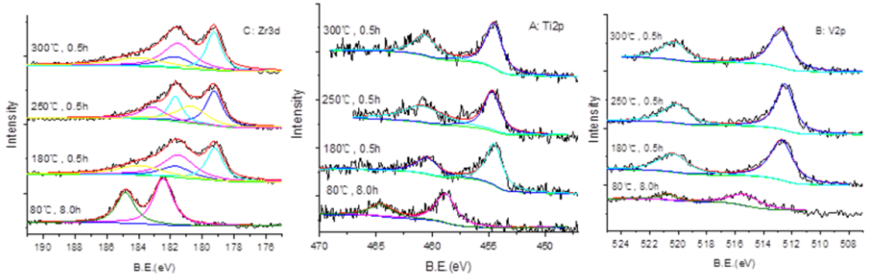
Two sets of NEG coating equipment have been built and have capability to coat up to **1.5** m long chambers with a diameter of **0.5** m.

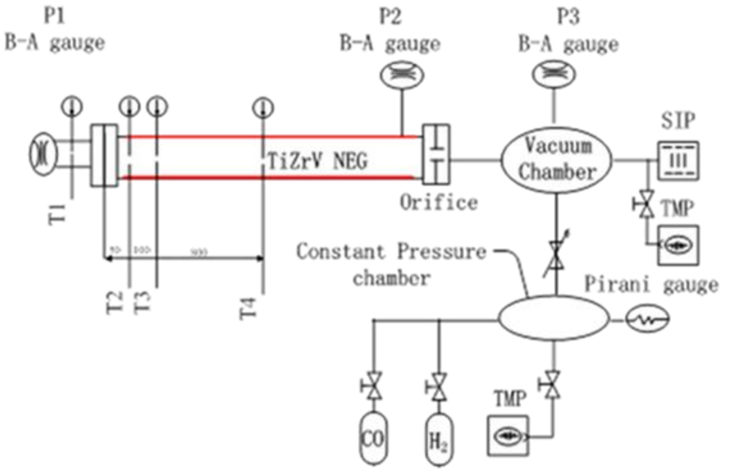
Columnar film for high pumping speed

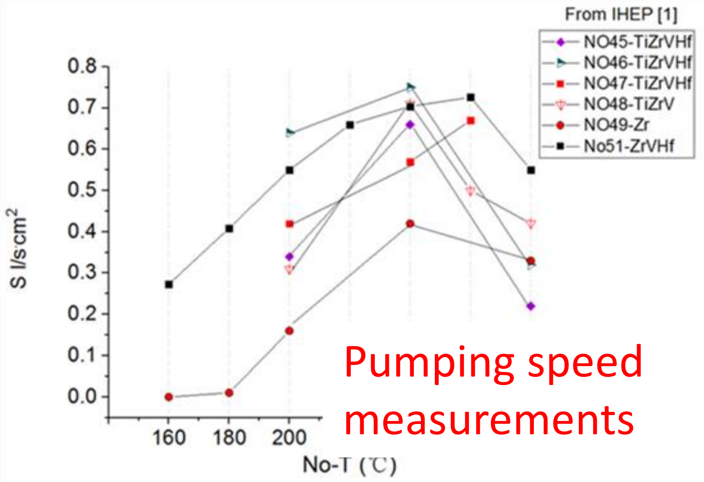
Dense film for low impedance







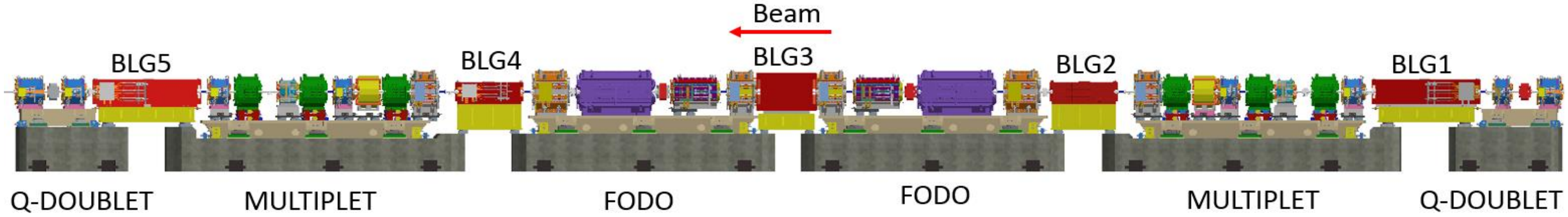




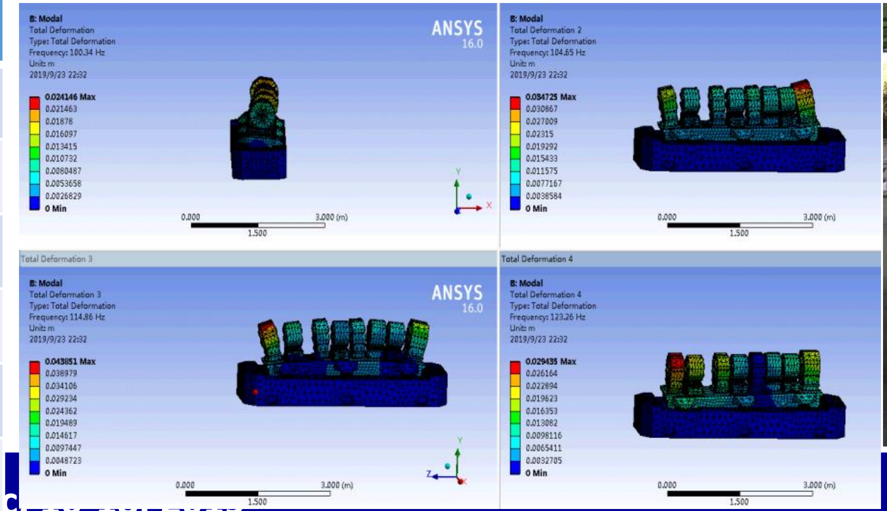
[1]. 20 Hours Heating Temperature for Different Times 160℃ is 48 hours and 180 ℃is 22h heating

• Mechanical support

- Optimize stability, alignment, transportation, cost, etc.
- FEA modal used for simulation of evaluating the effect of different structure parameters.
- Manufacture and construction process test of the plinth was performed

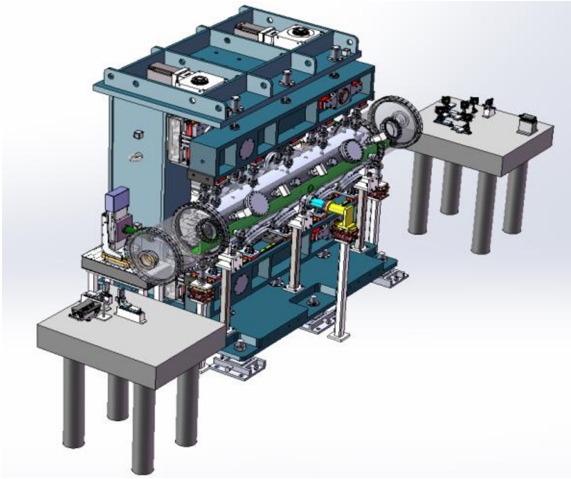


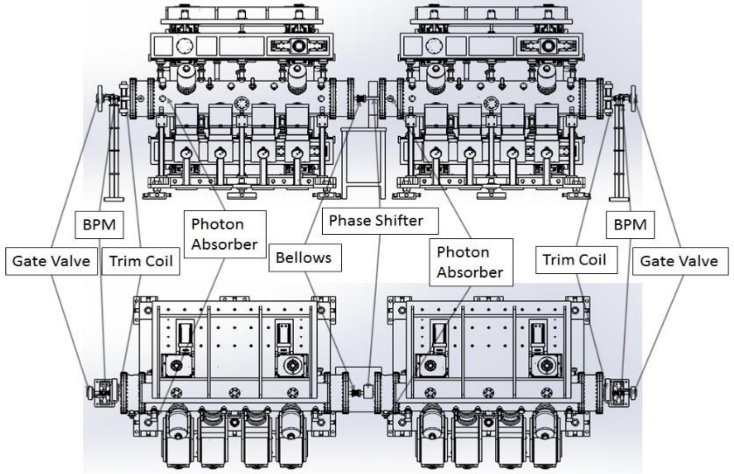
Requirements of girder design		
Resolution	Transverse	≤5μm
	Vertical	≤5μm
	Longitudinal	≤15μm
Adjusting range	Horizontal	±5mm
	Vertical	±9mm
Eigen frequency		≥54Hz

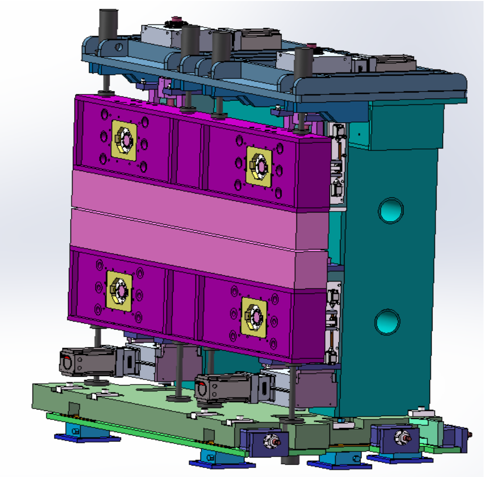


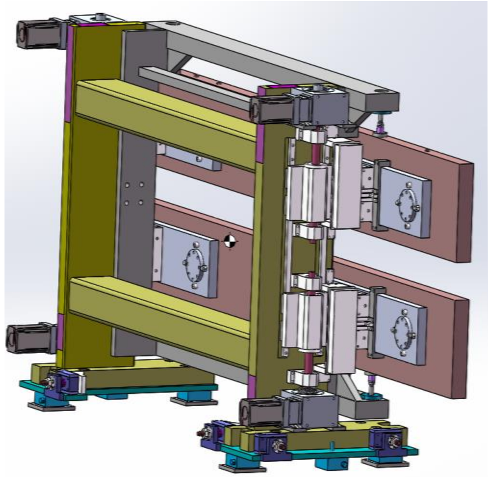
Plinths for testing

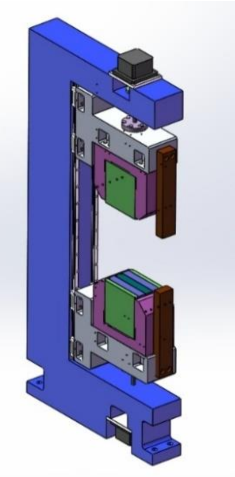
- Insertion devices
  - Mass production, large amount, many types, in limited time
  - 3m-CPMU, 4m-IVU (first time for HEPS), APPLE-KNOT (new design of 4 magnet arrays)
  - CPMUs are main IDs, working at liquid nitrogen temperature, optimization still needed
  - Specifications of 4 IAU Beamlines are confirmed.
  - Preliminary mechanical design of IAU, IAW and phase shifter is done.

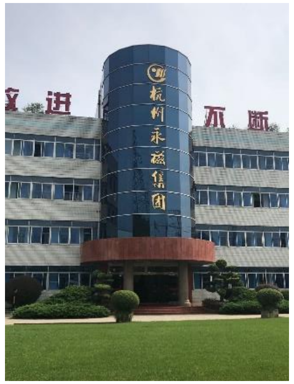


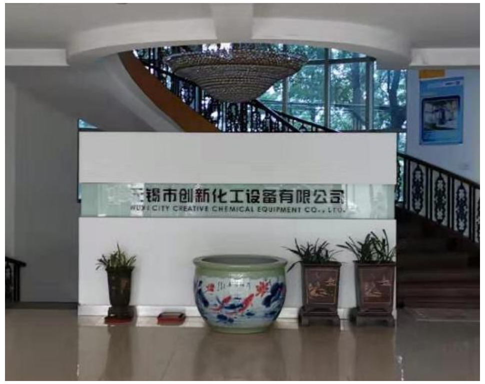




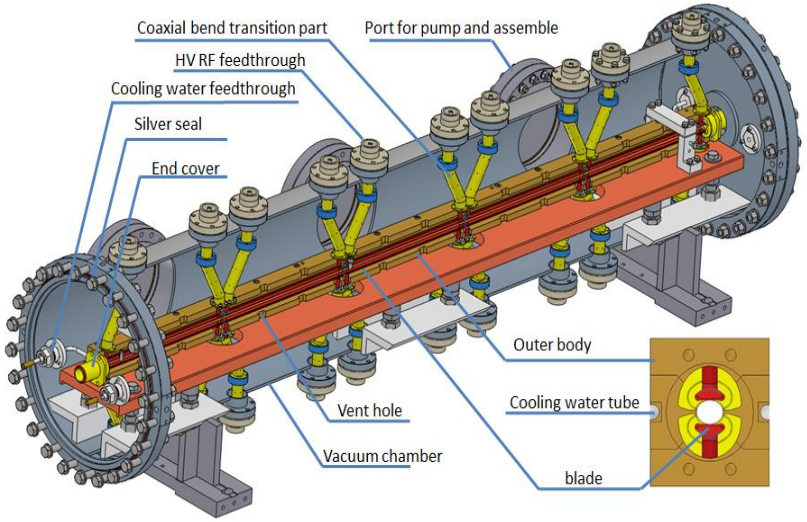




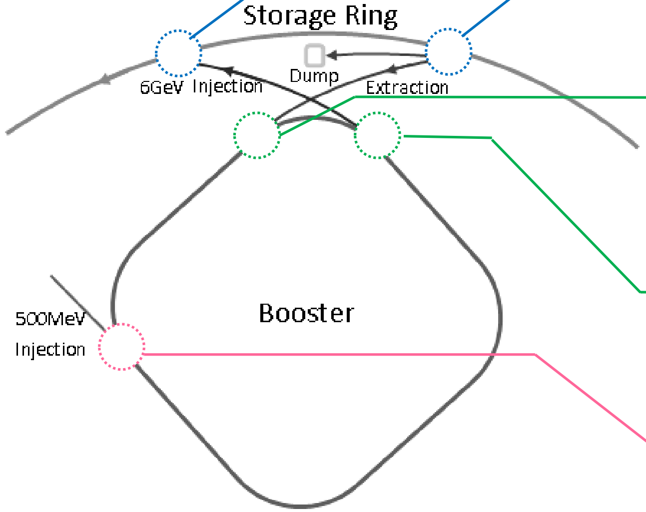




Injection & extraction



5 300mm-stripline kicker in one single module



- BTS: SR 6GeV injection system
- STB: SR 6GeV extraction system

(Bunch by bunch/on-axis swap out injection)

- STB: Booster 6GeV injection system

(Pulsed local bump injection)

- BTS: Booster 6GeV extraction system

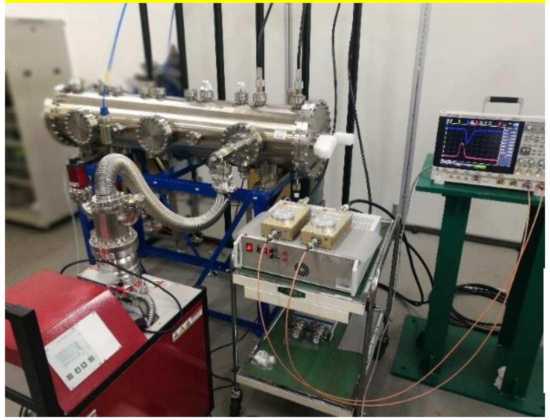
(Bunch by bunch/fast extraction assisted by slow bumpers)

- LTB: Booster 0.5GeV injection system

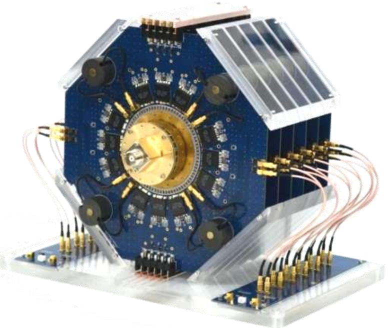
(Bunch by bunch/one turn/on-axis injection)

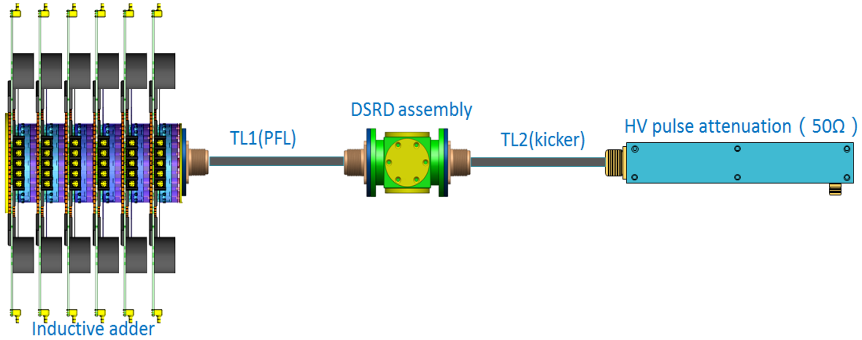
TDR measurement

HV pulse testing at ± 20kV

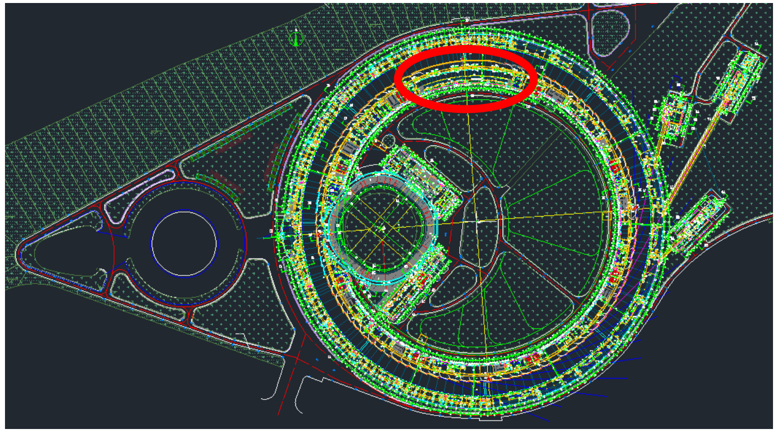


Fast pulser based on DSRDs driven by 6 stage inductive adder; pulse width=10ns

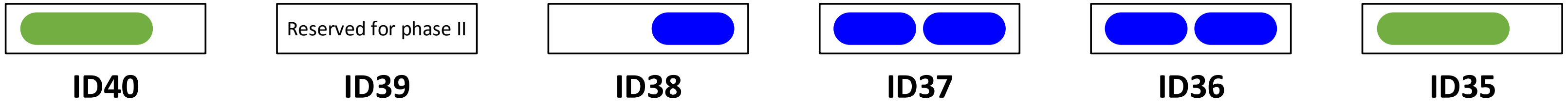




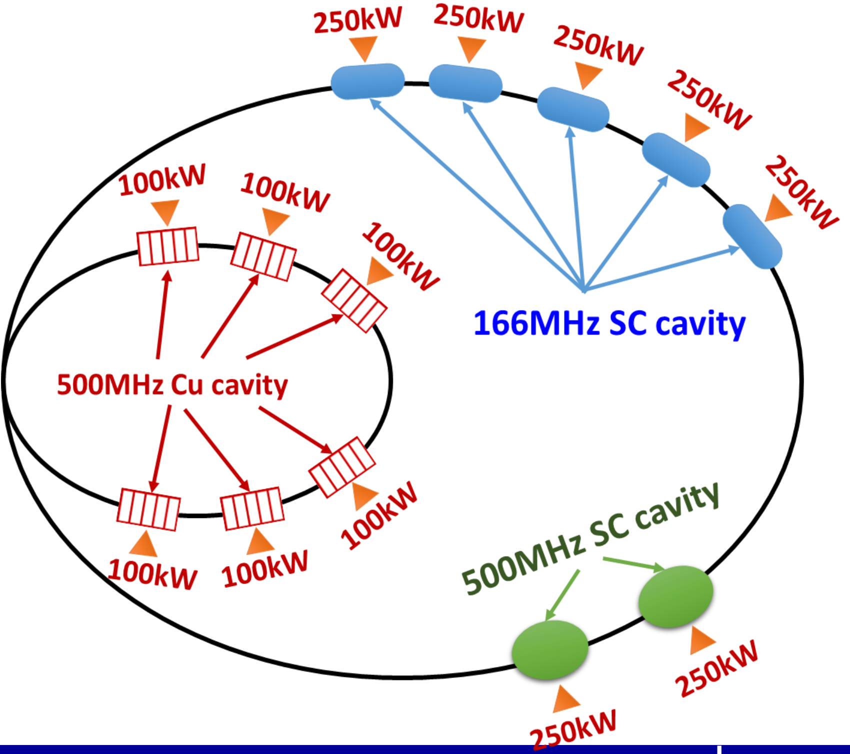
RF system

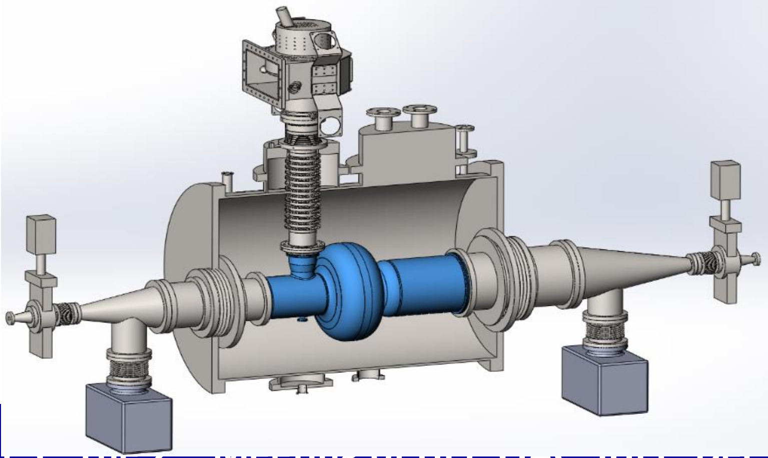


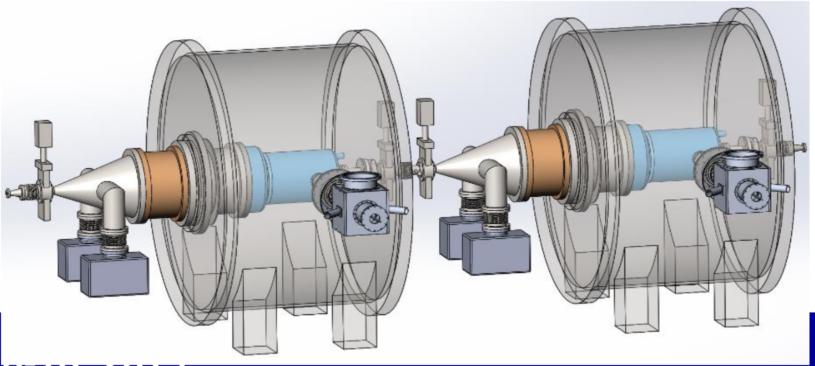
- Number of linear sections for RF: 6 (48 in total)
- Frequency: 166.6MHz (fund.) + 499.8MHz (3rd harm.)
- Technology choice: SRF cavity + solid state amplifier + digital LLRF



- Energy loss per turn: 4.4MV (14 IDs)
- Total RF voltage: 5.4MV
- Beam power: ~900kW
- Number of RF cavities: 5 fund. + 2 HHC



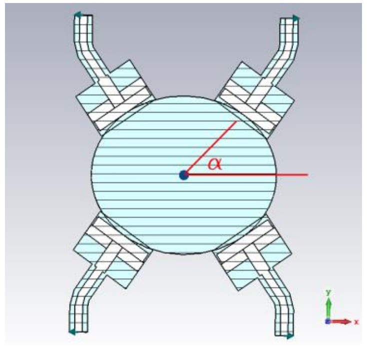




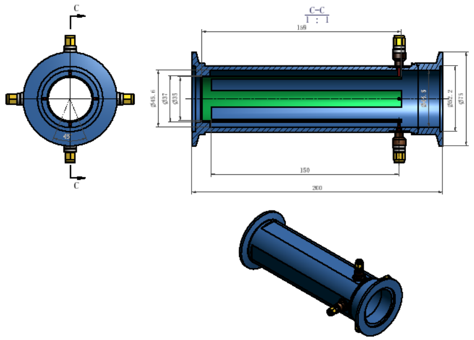
Beam instrumentation (injectors included)

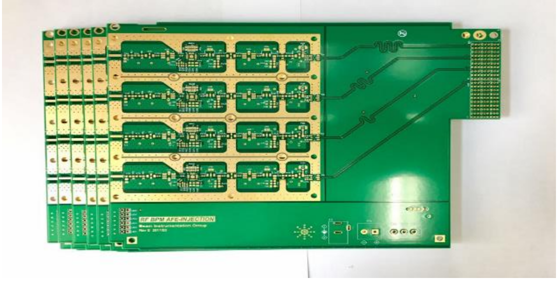
		LINAC	LTB	Booster	BTS	SR	STB
Position	Button BPM	7	8	80	11	48*10+3	11
	Stripline BPM	1					
	ID Button BPM					48*2	
Current	ICT	7	2		2		2
	DCCT			1		1	
	BCM			1		1	
Profile	OTR/YAG	7	2		2		2
	X-Ray Diagnostics beamline					2	
	VSLM Diagnostics beamline			2		1	
BLM	Pin Diode					1	
	Fiber BLM			4			
other	Pilot Tune			1		1	
	Direct Diode Detection			1		1	
	Beam length	1		1		1	
	Slits	1					
	Emittance	2					
	Energy analysis	2					
	BxB Feedback (H & V& L)					1	


ICT

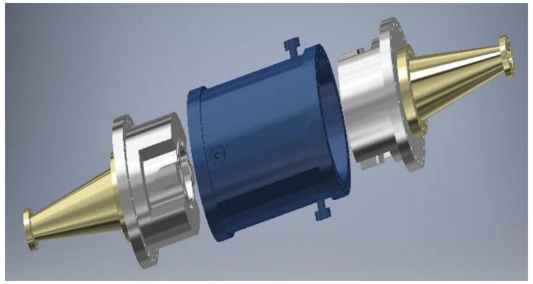


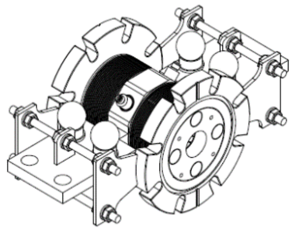
Booster BPM

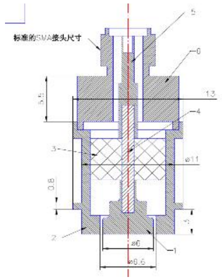

Linac stripline BPM


Digital BPM electronics

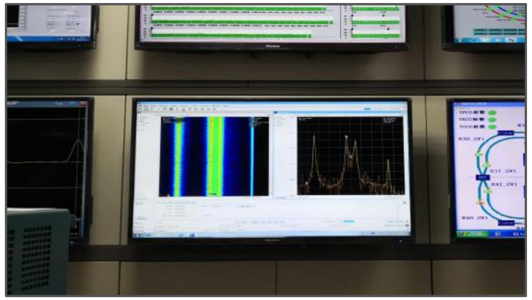

Transverse kicker


Longitudinal kicker


Storage ring BPM


Feedthrough


Feedback system


3D tune measurement with FB

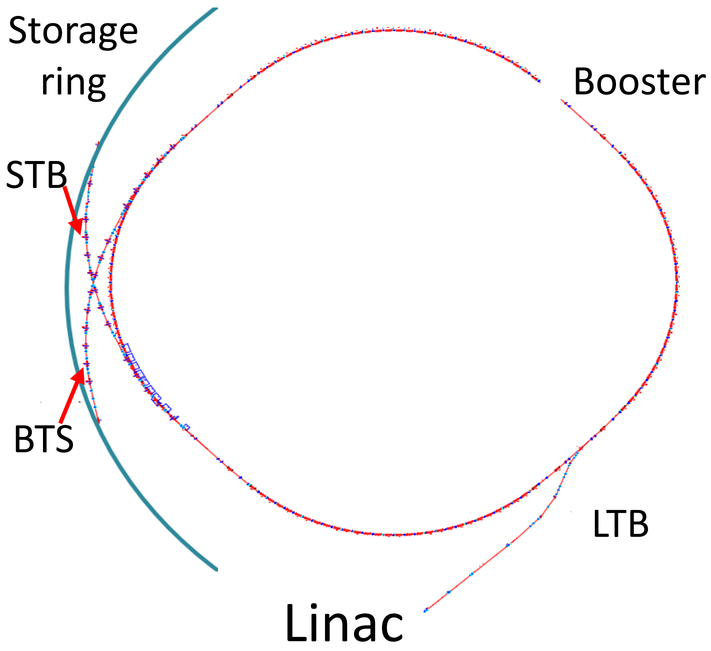
Accelerator physics design of booster

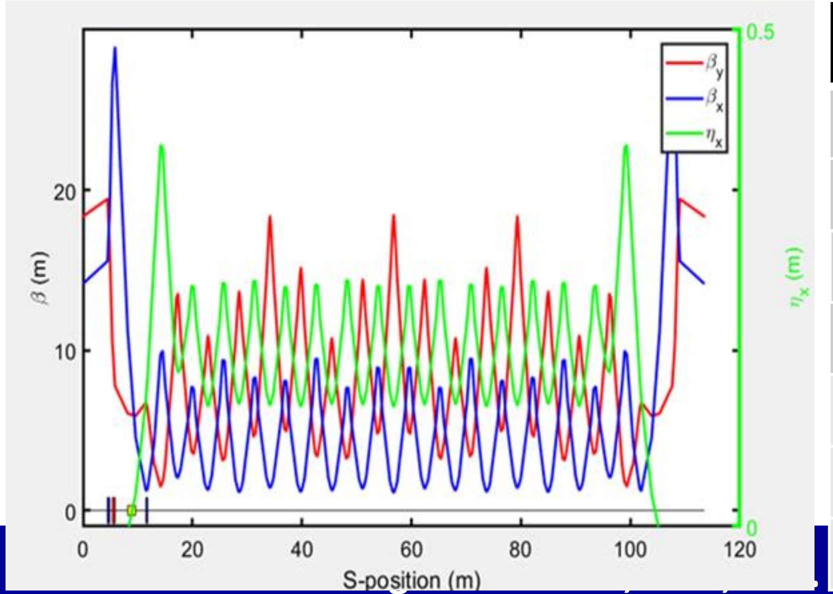
Requirements from storage ring (SR)

- Emittance less than 20nm
- 15nC for high bunch charge mode
- Setting in a separate tunnel

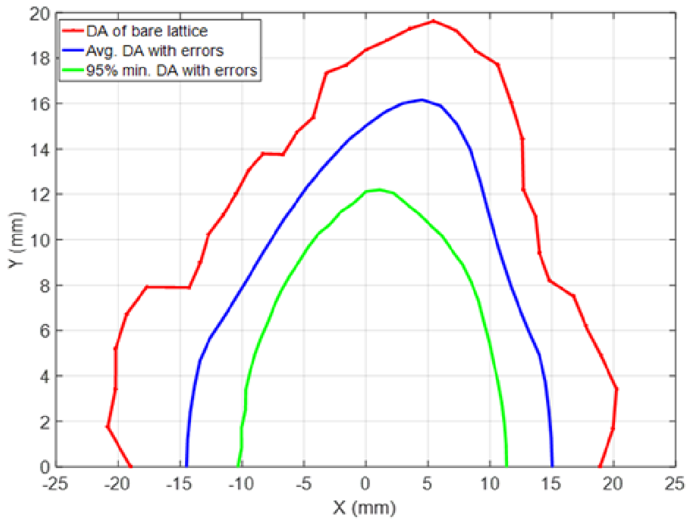
Design consideration

- "High energy accumulation" to reduce the affect of TMCI @500MeV
- The emittance as lower as better , with α_c>2E-3 (requirement from TMCI)
- π section for 2 kicker re-injection

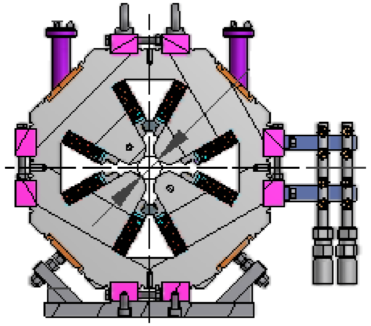


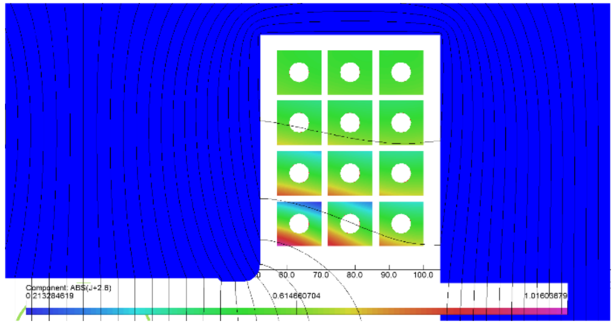


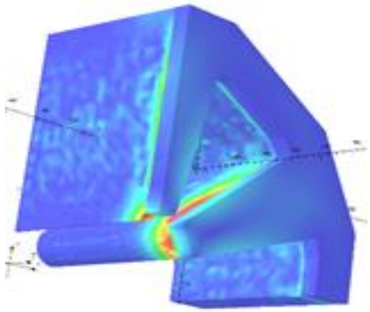
parameters	Value
Circumference	454.0665 m
Tune	21.30/10.19
Mom. compaction α_c	2.2E-3
Average βy	8.6m
Emittance@6GeV	16 nm
Energy loss per turn	3.89MeV
Energy spread	9.5E-4

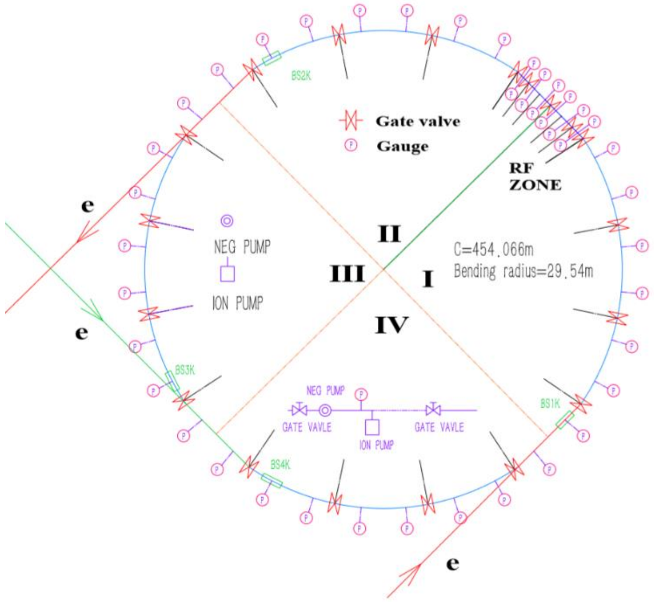


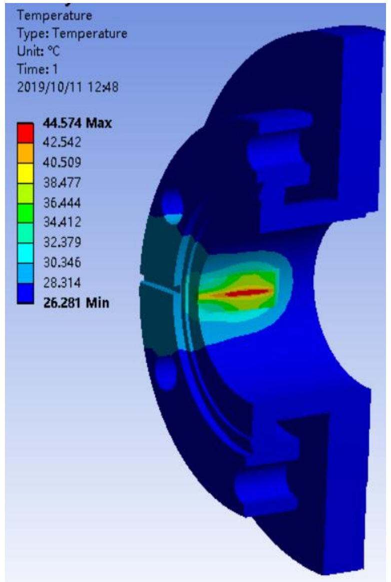
Hardware of booster

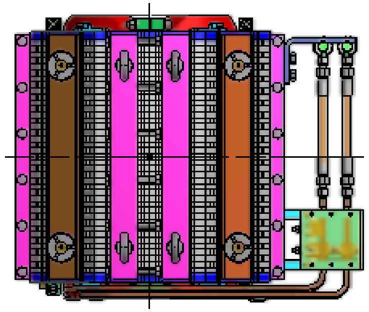


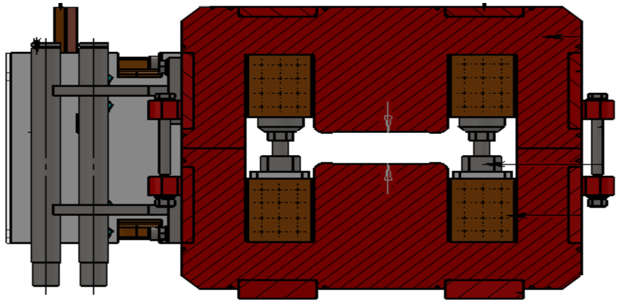


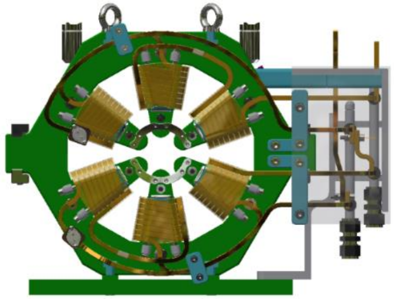


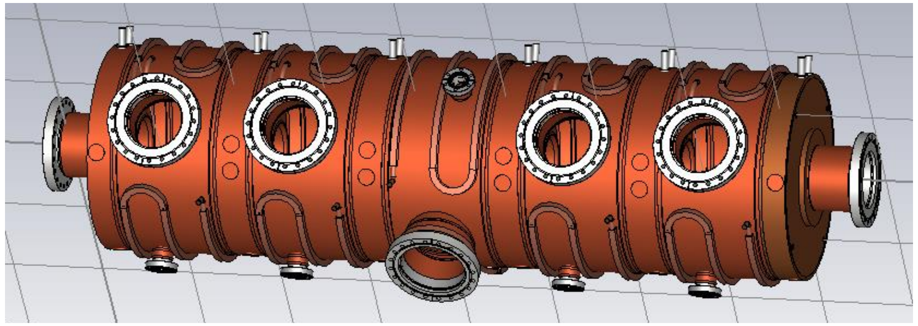


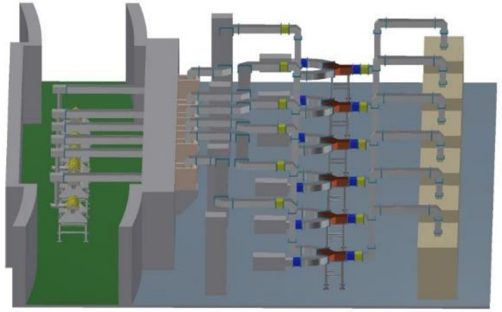


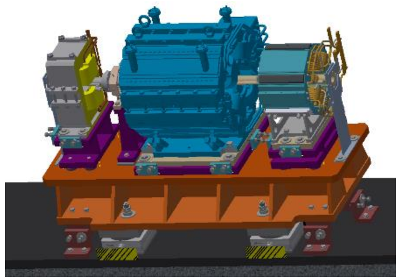




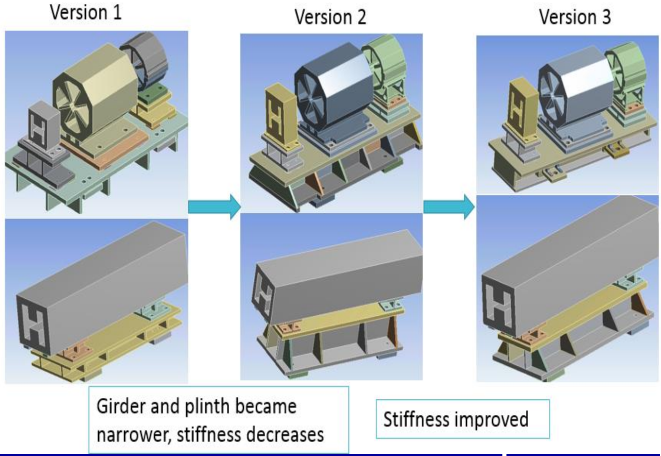








- Evolution of structure—to reduce size and cost, to improve stiffness.

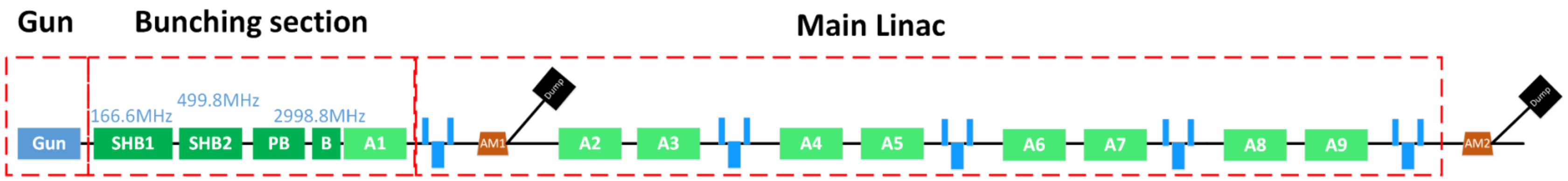


Linac and Transport Lines

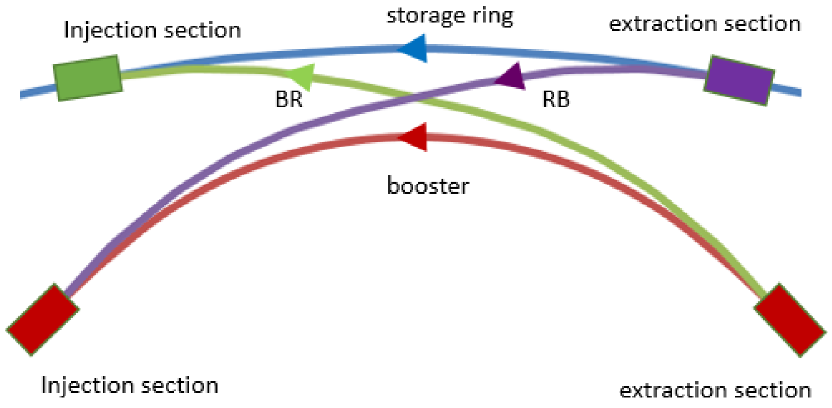
Linac

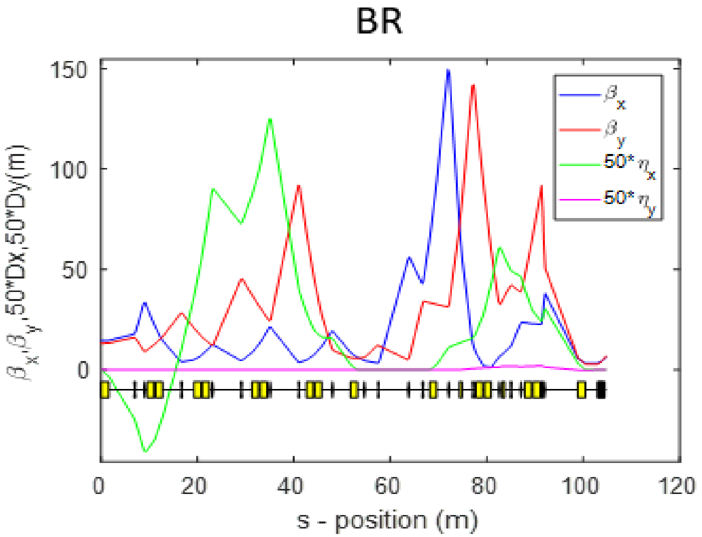
- Linac is designed to meet the requirement from the booster.
- Two sub-harmonic bunchers are introduced for the high bunch charge.

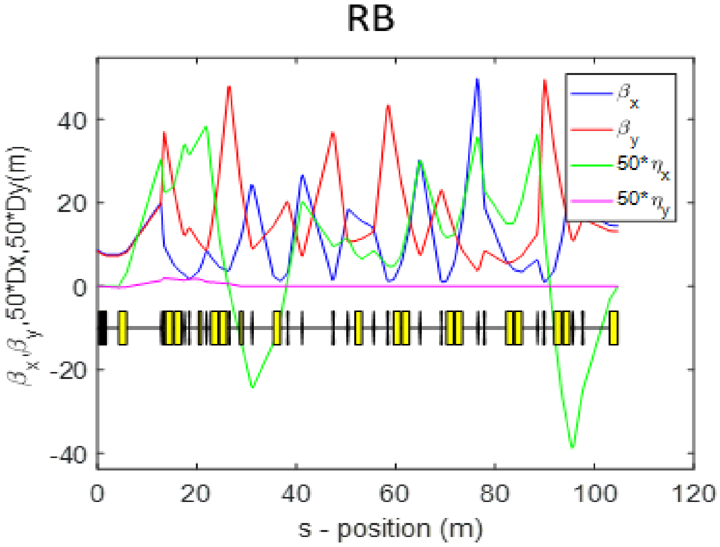
Parameter	Requirements		Unit
RF frequency	2998.8	2998.8	MHz
Pulse bunch charge	≥2.5	≥7	nC
Beam energy	≥500	≥500	MeV
Energy spread	≤0.5%(rms)	≤±1.5%(pp)	-
Repetition	50	50	Hz
Norm. emittance	40	70	mm·mrad



Transport lines

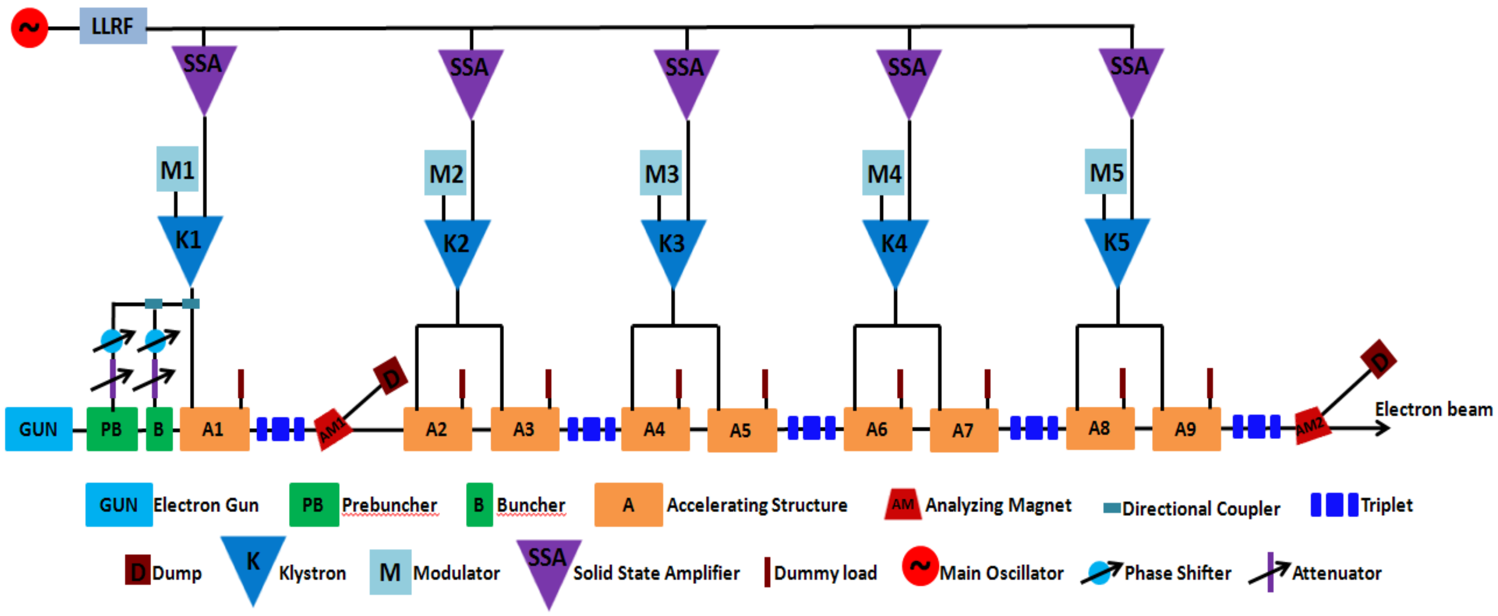


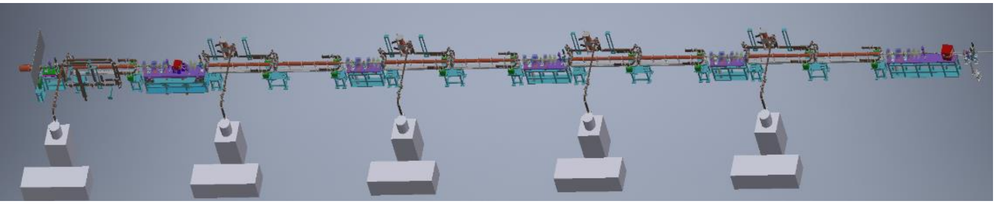


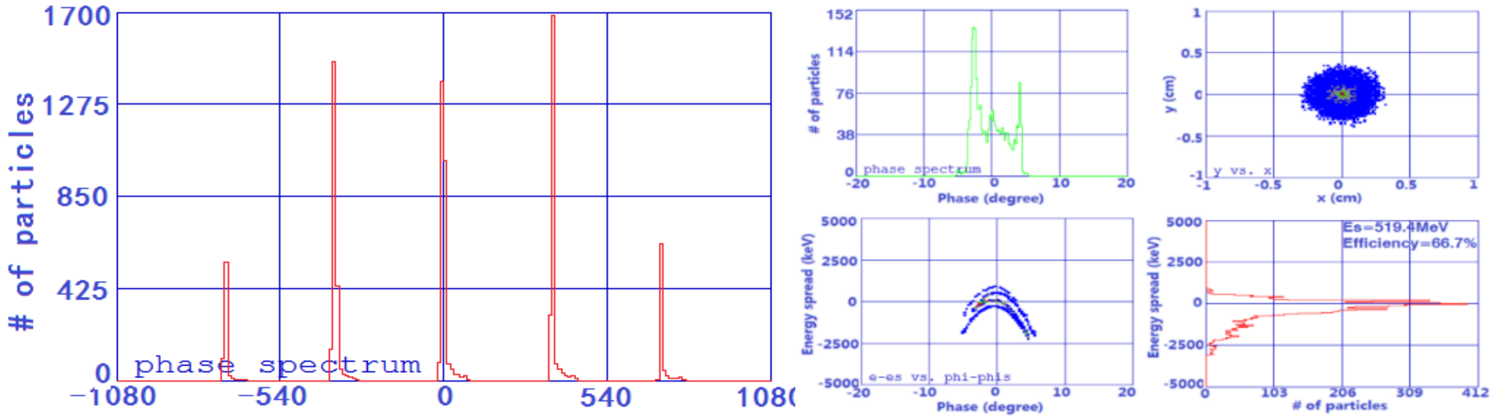


Linac design

Parameters	Value	Unit
Charge/pulse @ linac exit	≥2.5	nC
Bunch number per pulse	5	-
Pulse width	1.6	ns
Energy	≥500	MeV
Energy spread	≤0.5	%
Energy stability	±0.25	%
Repetition frequency	50	Hz
Un-normalized rms emittance	≤41	nm·rad
Normalized rms emittance	≤40	μm·rad







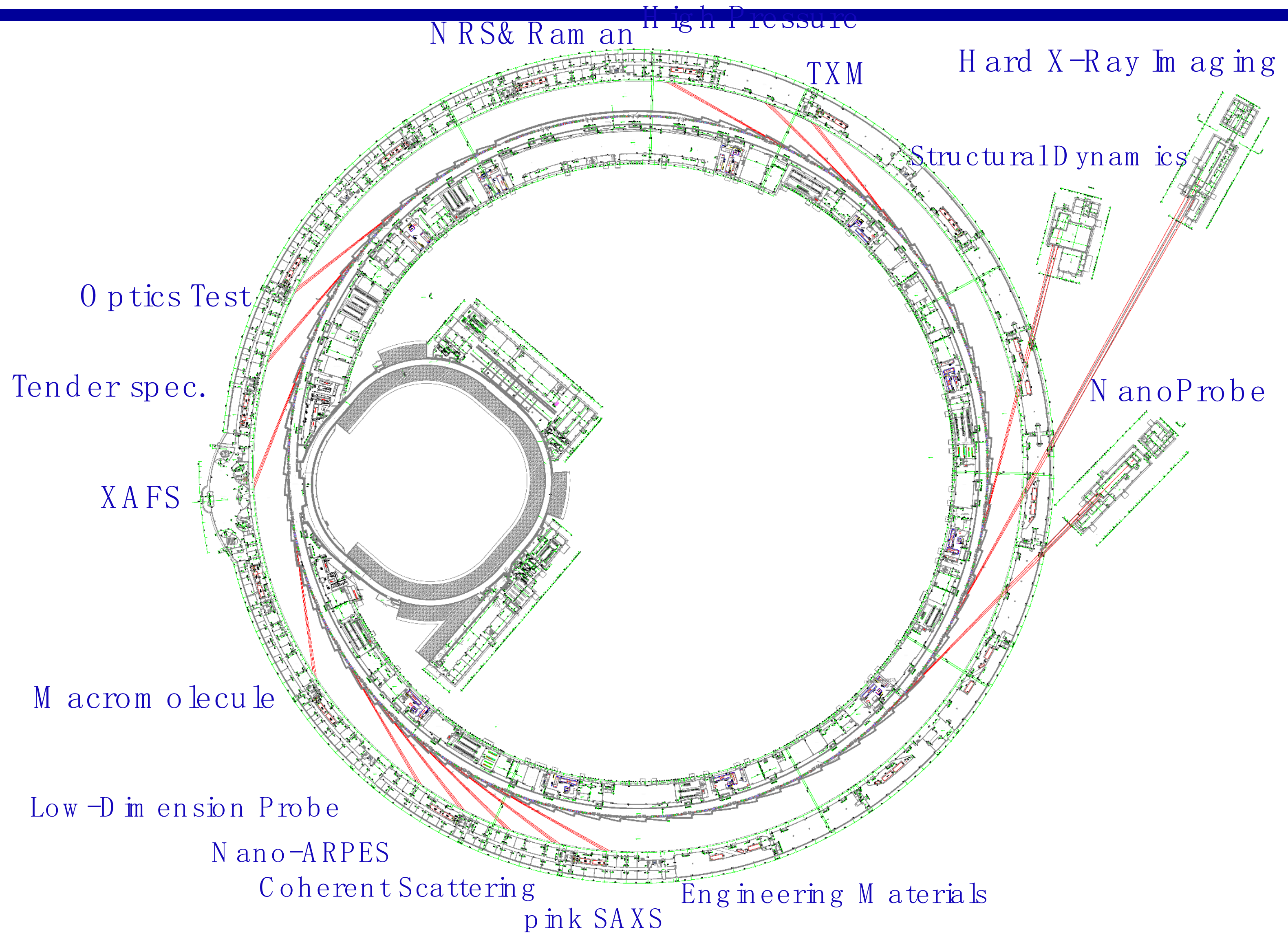
Beamlines design

- Layout of 15 beamlines
- 14 for users, 13 IDs (incl. 3 long beamlines) and 1 BM beamlines

  1 for optics test

Most of the beamlines were re-designed after the last IAC.

More details in Y.H. Dong's talk



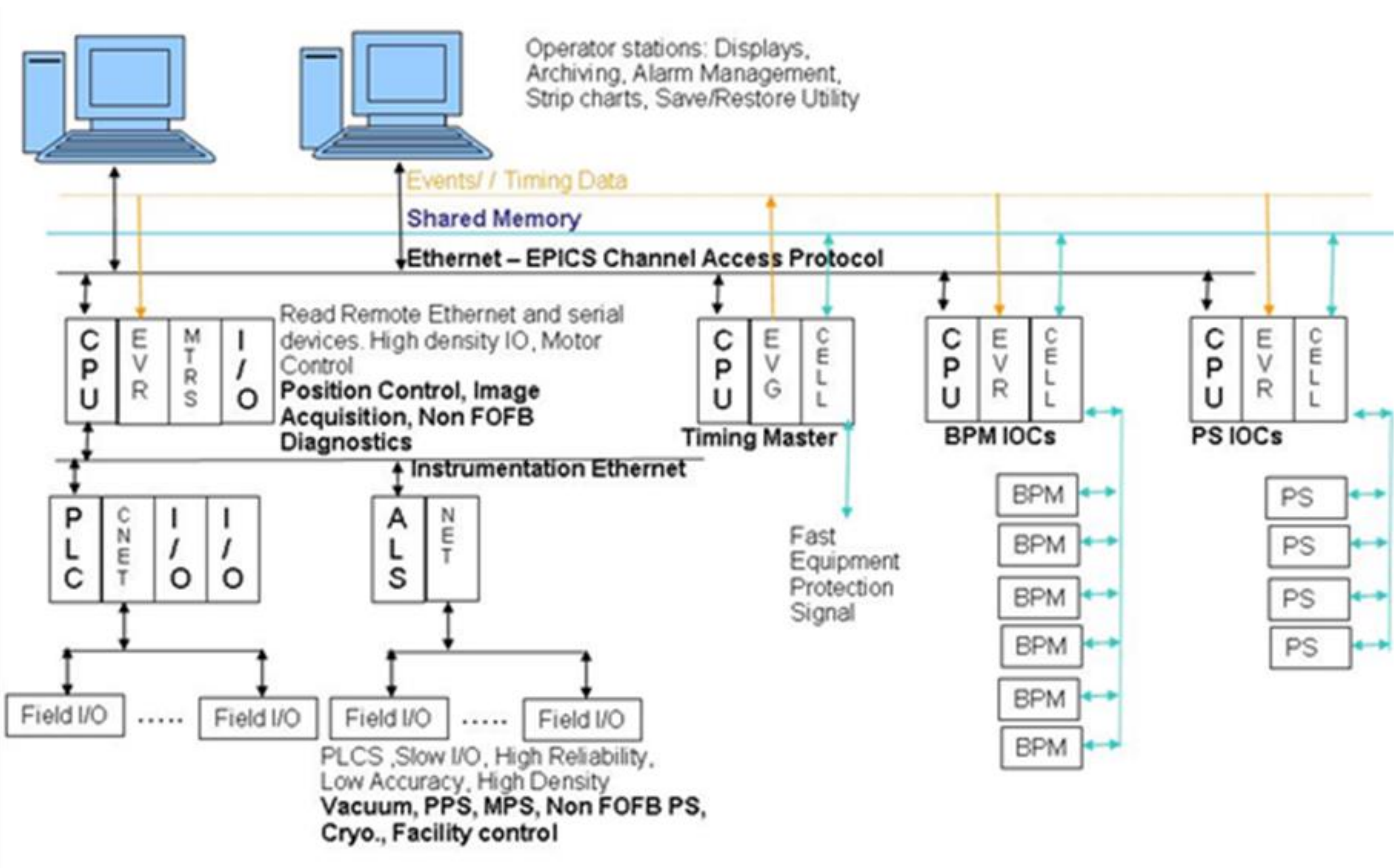
Beamlines description

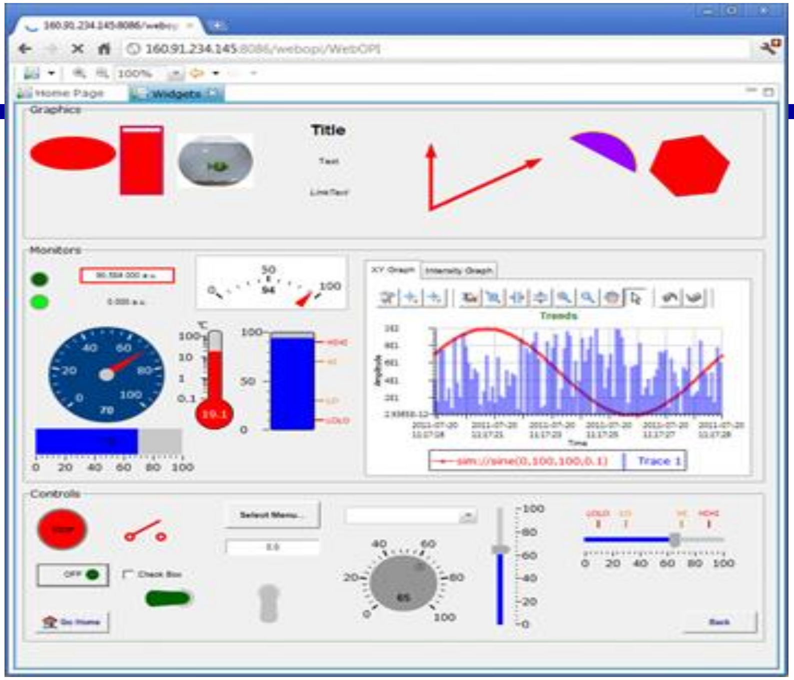
	Beamlines	Features
High Energy	Engineering Materials	50-170keV， XRD, SAXS, PDF
	Hard X-Ray Imaging	10-300keV, Phase and Diffraction contrast imaging, 200mm large spot, 350m long
High Brightness	NanoProbe	Small probe, <10nm; InSitu nanoprobe, <50nm; 180m long
	Structural Dynamics	15-60keV, single-shot diffraction and imaging; < 50nm projection imaging
	High Pressure	110nm focusing, diffraction and imaging
	Nano-ARPES	100-2000eV，100nm focusing, 5meV@200eV, APPLE-KONT undulator,
High Coherence	Hard X-ray Coherent Scattering	CDI(<5nm resolution), sub-μs XPCS
	Low-Dimension Probe	surface and interface scattering, surface XPCS

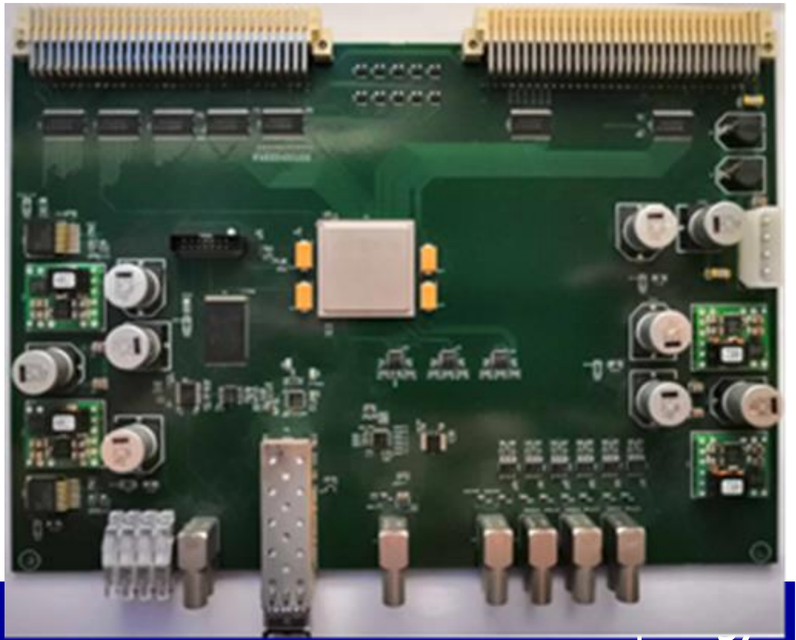
Beamlines description (cont.)

	Beamlines	Features
General beamlines	NRS&Raman	Nuclear Resonant Scattering and X-ray Raman spectroscopy
	XAFS	routine XAFS，plus 350nm spot and quick XAFS
	Tender spectroscopy	Bending magnet，2-7 keV spectroscopy
	μ-Macromolecule	1μm spot, standard and serial crystallography
	pink SAXS	pink beam, lest optics
	Transmission X-ray Microscope (TXM)	full field nano imaging and spectroscopy
Test beamlines	Optics Test	with undulator and wiggler source for optics measurement and R&D

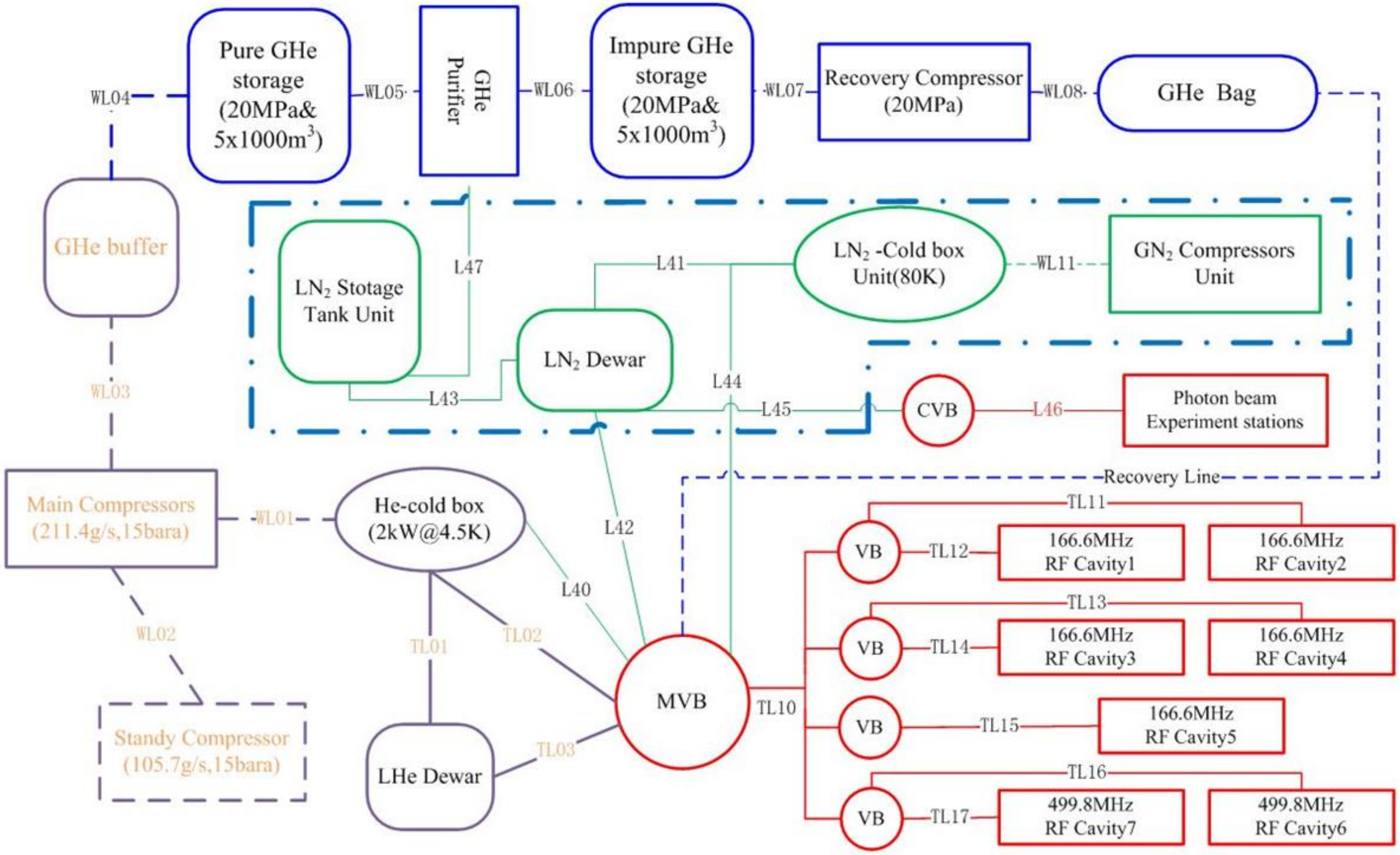
Control for accelerator & beamlines







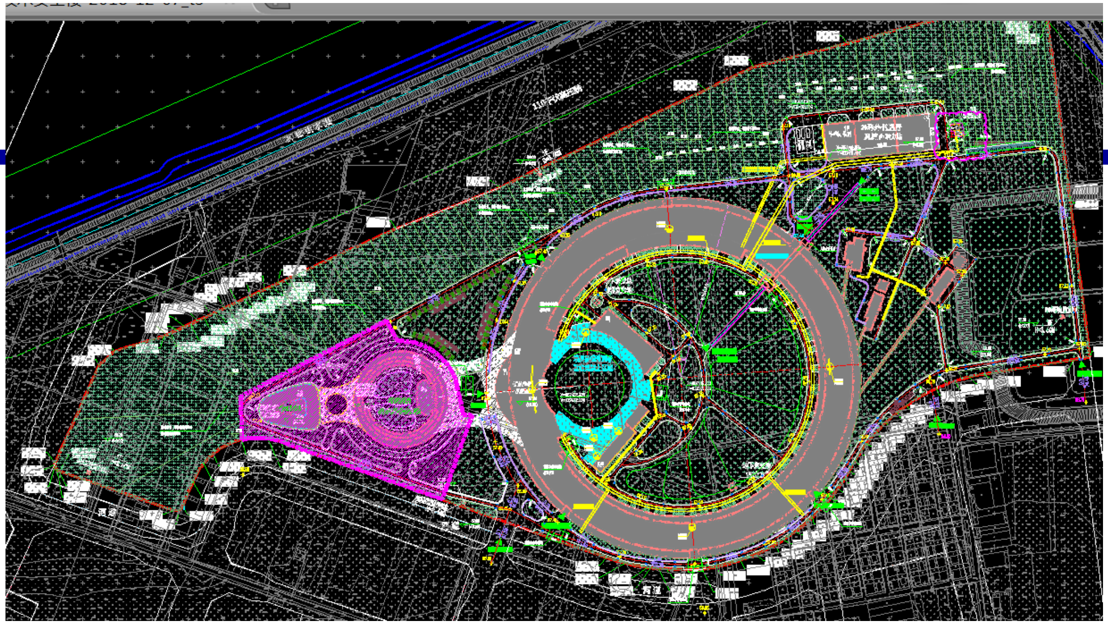
Cryogenic system

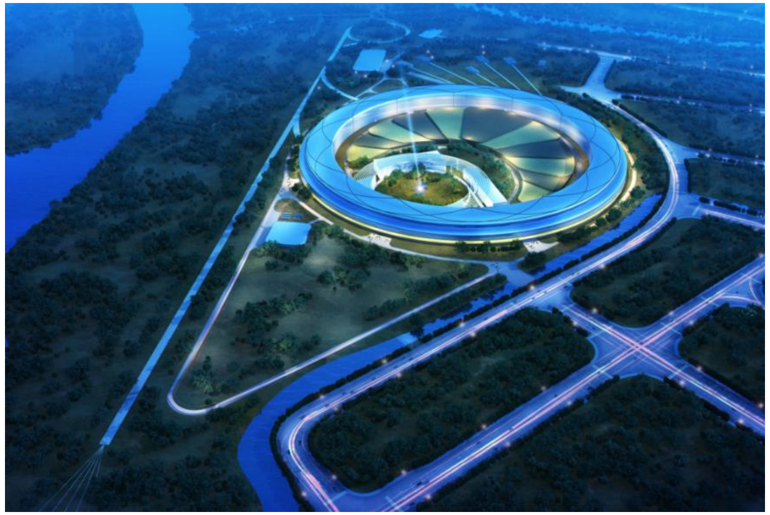


Constructions & infrastructure

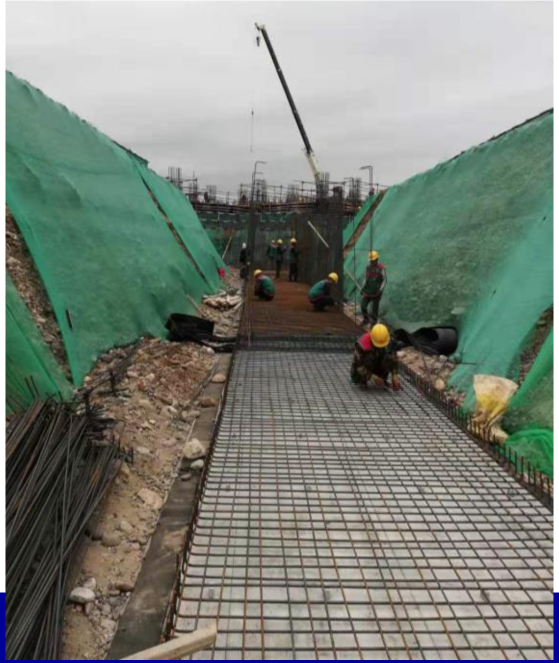
- Covering an area of 650,658 square meters, the main buildings of HEPS include accelerator relative building and SR experimental hall, refrigerator station, five environmental monitoring stations, etc.
- The gross area is 125,000 square meters and is expected to be finished in 2023.

More details in F. Yang's & G.P. Lin's talks



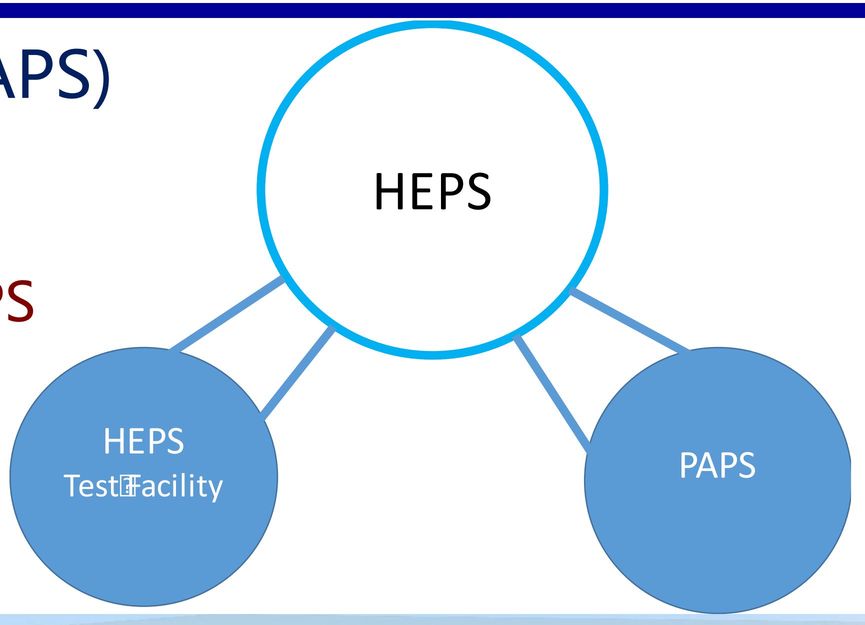


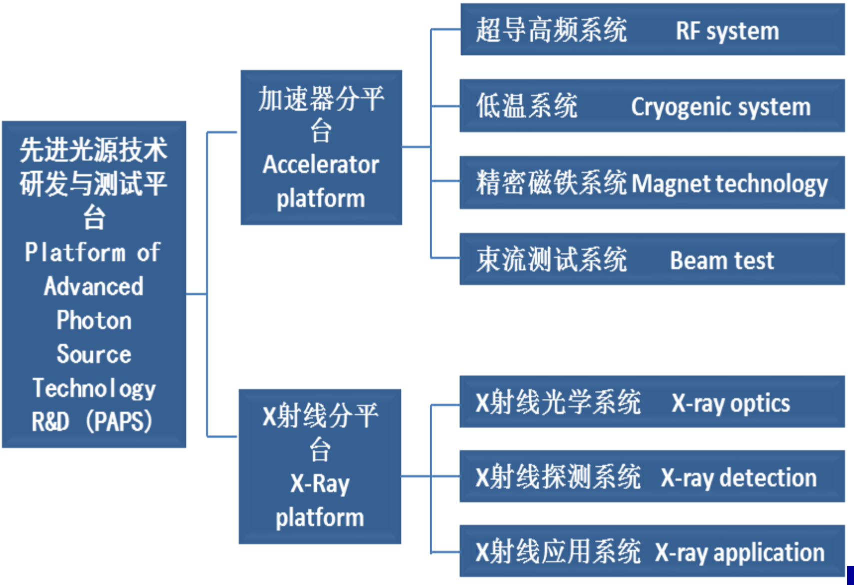
Kickoff on 29 June, 2019



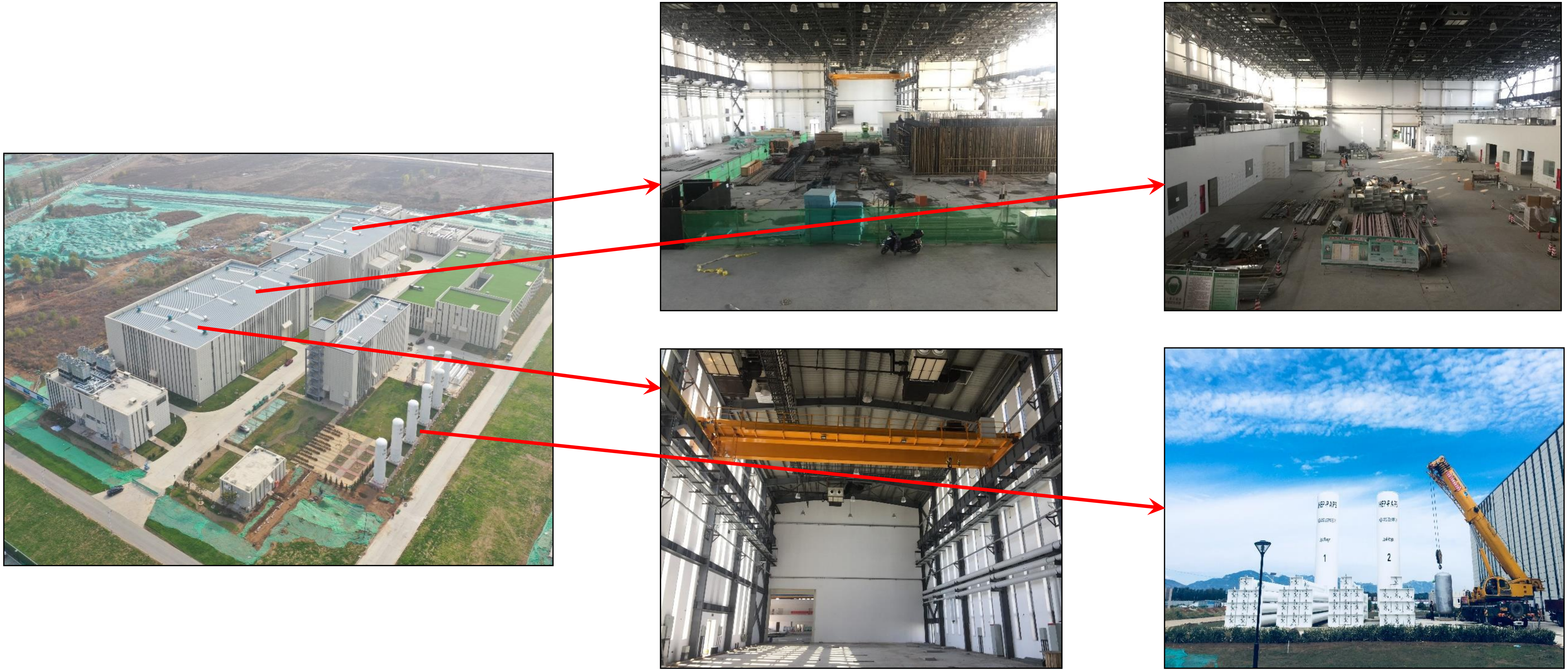
Other resources

- Platform of Advanced Photon Source Technology (PAPS)
  - Budget: ~78M Euro, funded by Beijing local government
  - Construction period: 2017.5-2020.6
  - Providing key technical support for the construction of HEPS
  - Platform of core technology development, verification and equipment testing
  - Output of new technologies of accelerator and X-ray applications



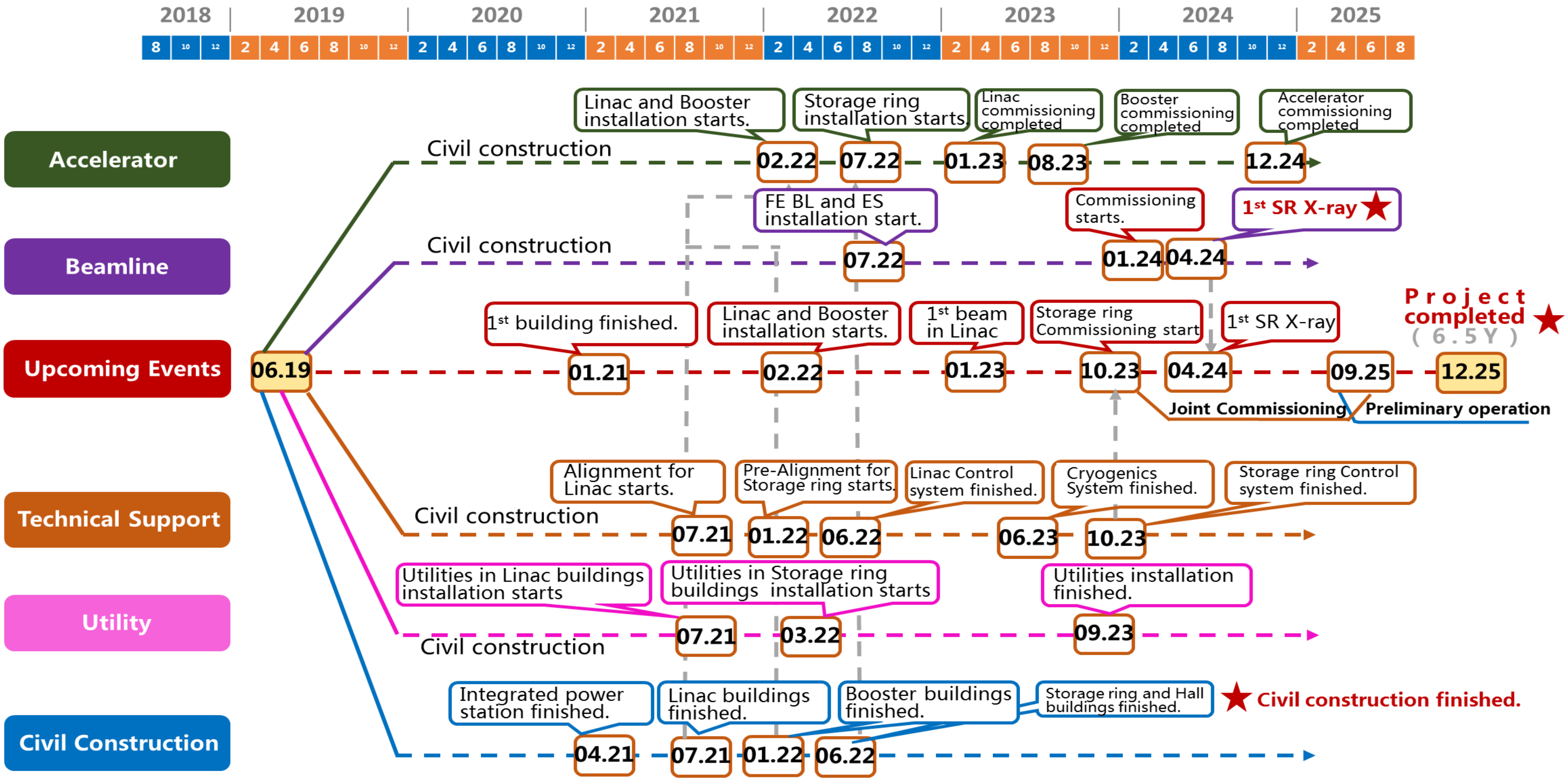


PAPS



2. Schedule, cost & manpower

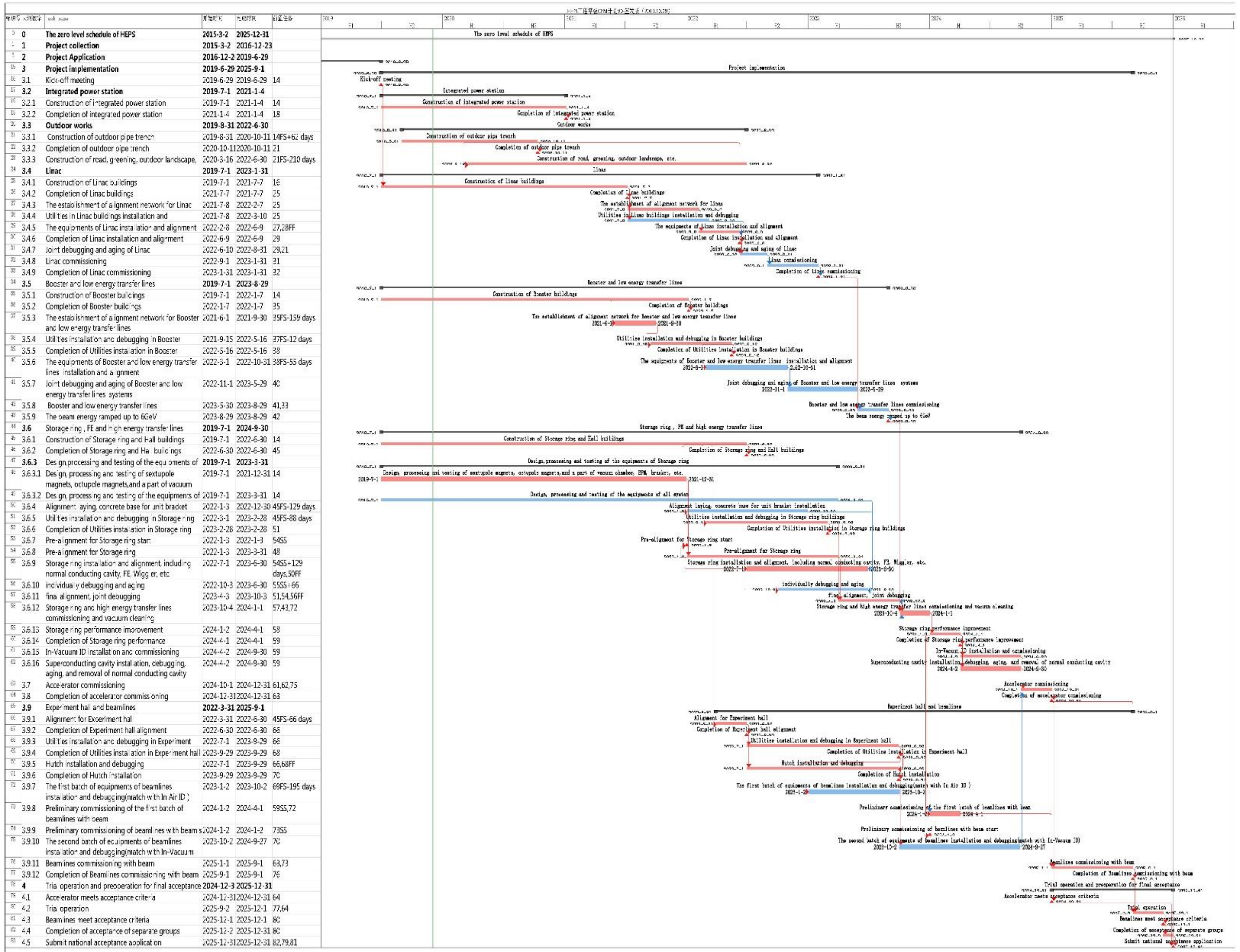
- Project Management Body of Knowledge
  - Take the management systems of DOE and CERN as references
  - Earned Value Method (EVM) is introduced w/ code PROJECT
  - Project management system just established, with the purpose of guaranteeing completion of HEPS project
  - WBS for each system of HEPS was setup
  - Applied to analyze/track the schedule, cost and manpower



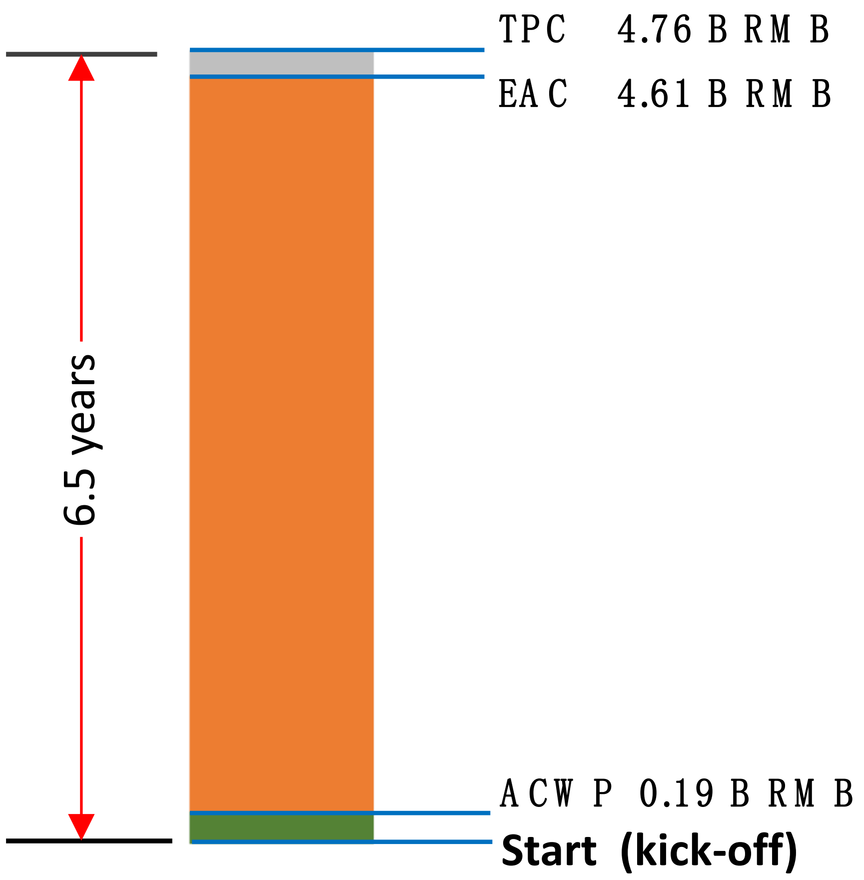
2018
2019
2020
2021
2022
2023
2024
2025
Accelerator
Beamline
Upcoming Events
Technical Support
Utility
Civil Construction
Civil construction
Linac and Booster installation starts.
Storage ring installation starts.
Linac commissioning completed
Booster commissioning completed
Accelerator commissioning completed
02.22
07.22
01.23
08.23
12.24
FE BL and ES installation start.
Commissioning starts.
1st SR X-ray
07.22
01.24
04.24
1st building finished.
Linac and Booster installation starts.
1st beam in Linac
Storage ring Commissioning start
1st SR X-ray
Project completed (6.5Y)
06.19
01.21
02.22
01.23
10.23
04.24
09.25
12.25
Joint Commissioning
Preliminary operation
Alignment for Linac starts.
Pre-Alignment for Storage ring starts.
Linac Control system finished.
Cryogenics System finished.
Storage ring Control system finished.
07.21
01.22
06.22
06.23
10.23
Utilities in Linac buildings installation starts
Utilities in Storage ring buildings installation starts
Utilities installation finished.
07.21
03.22
09.23
Integrated power station finished.
Linac buildings finished.
Booster buildings finished.
Storage ring and Hall buildings finished.
Civil construction finished.
04.21
07.21
01.22
06.22

- CPM

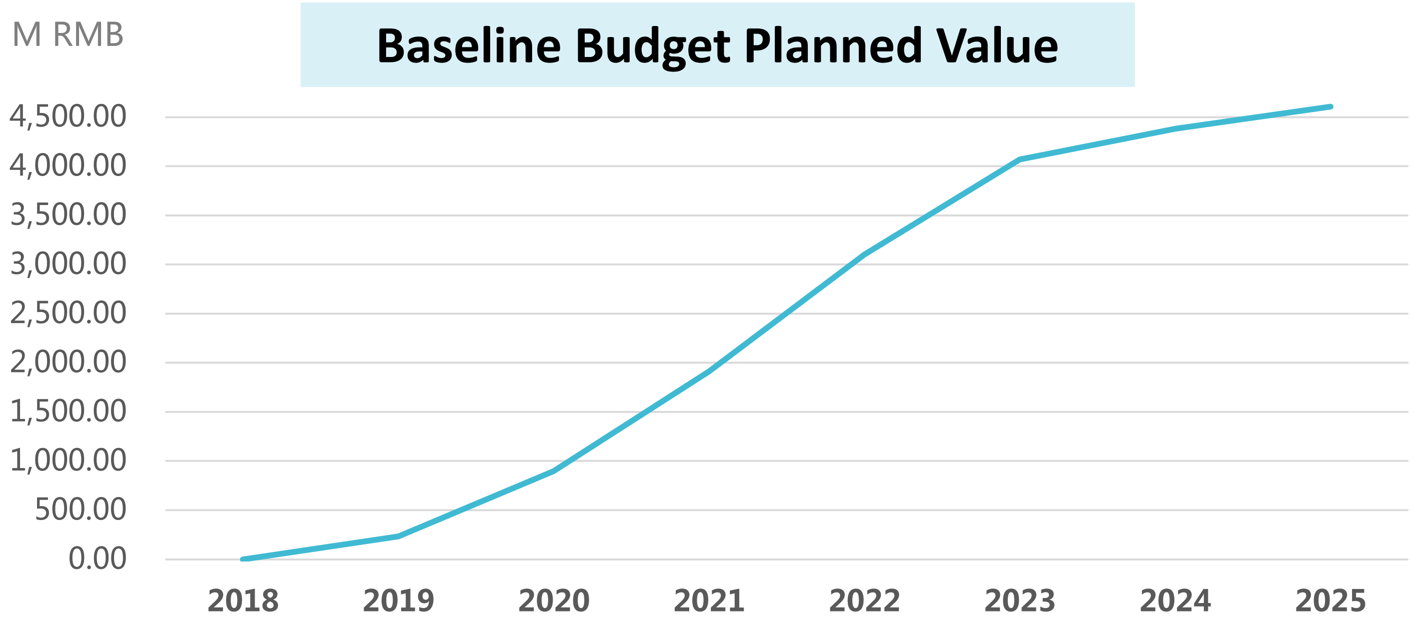
TASK NAME	DATE
Ground breaking ceremony	**2019-6-29**
Construction completion of facility power station	2021-1-4
Construction completion of outdoor pipe trench	2020-10-11
Construction completion of Linac buildings	2021-7-7
Completion of Linac installation and alignment	2022-6-9
Completion of Linac commissioning	2023-1-31
Construcion completion of Booster and LTB buildings	2022-1-7
Completion of utility installation and commissioning for Booster and LTB	2022-5-16
Beam ramped to 6GeV	**2023-8-29**
Construction completion of Storage ring, high energy transfer lines and Experiment Hall buildings	2022-6-30
Completion of Utilities installation in Storage ring and high energy transfer lines buildings	2023-2-28
Storage ring girder cell pre-alignment start	2022-1-3
Completion of Storage ring performance improvement	2024-4-1
Completion of accelerator commissioning	2024-12-31
Completion of Experiment hall alignment	2022-6-30
Completion of utilities installation in Experiment hall	2023-9-29
Completion of hutches installation	2023-9-29
Commissioning of the first batch of beamlines with beam start	2024-1-2
Completion of Beamlines commissioning	2025-9-1
Accelerator meets project minimum acceptance	**2024-12-31**
Beamlines meet project minimum acceptance	**2025-12-1**
National acceptance application Submitted	**2025-12-31**

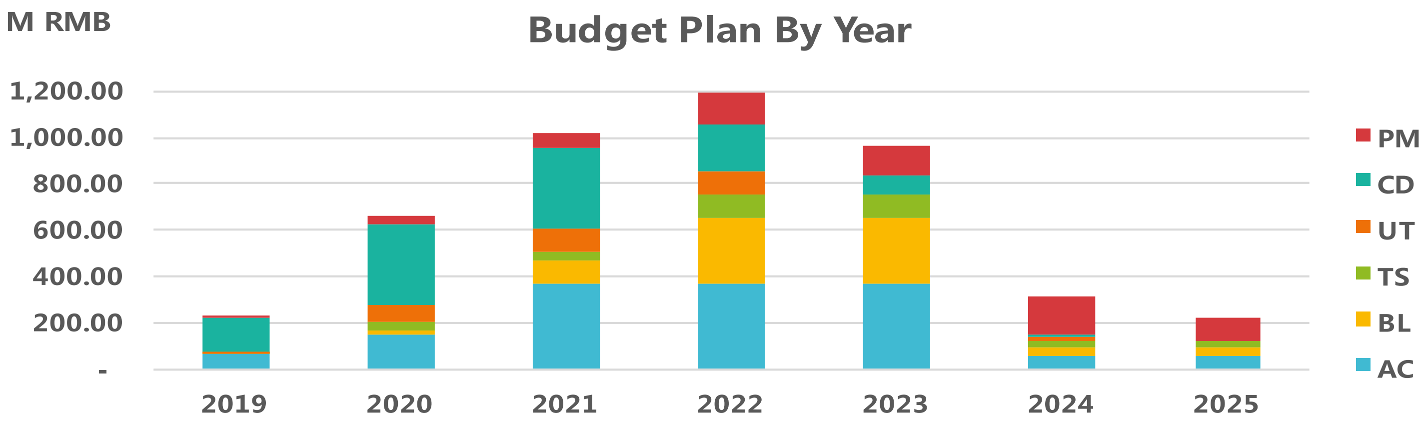


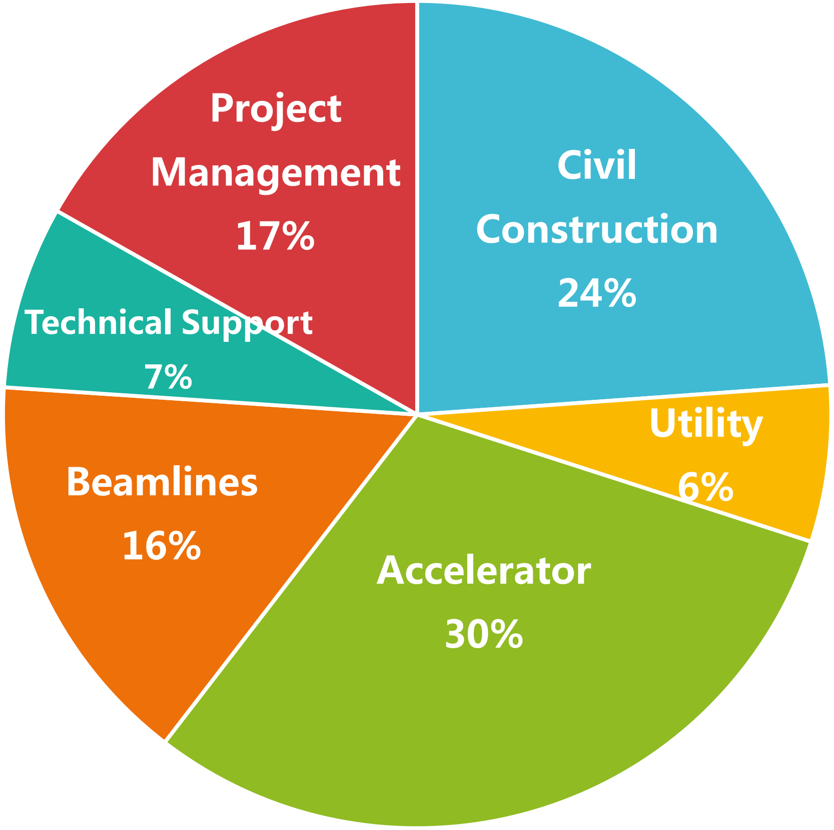
Budget



- TPC: **Total Project Cost**
  - Set at Budget to Preliminary Design of HEPS, cannot be exceeded.
  - TPC = 4.76139 B RMB
  - A total contingency of 3% of TPC is included in TPC
- EAC: **Estimate at Completion** to execute project scope
- C: **Cost Contingency**
  - C = TPC – EAC
  - Project Manager owns contingency
- EAC = ACWP + ETC
  - ACWP: **Actual Cost of Work Performed**
  - ETC: **Estimate to Complete**
    - ETC = EAC – ACWP

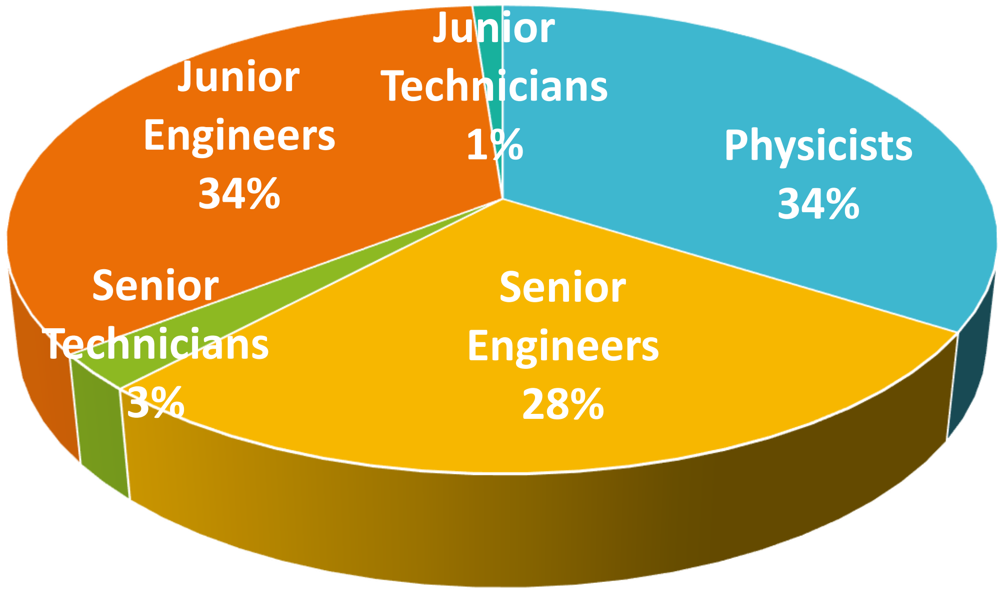






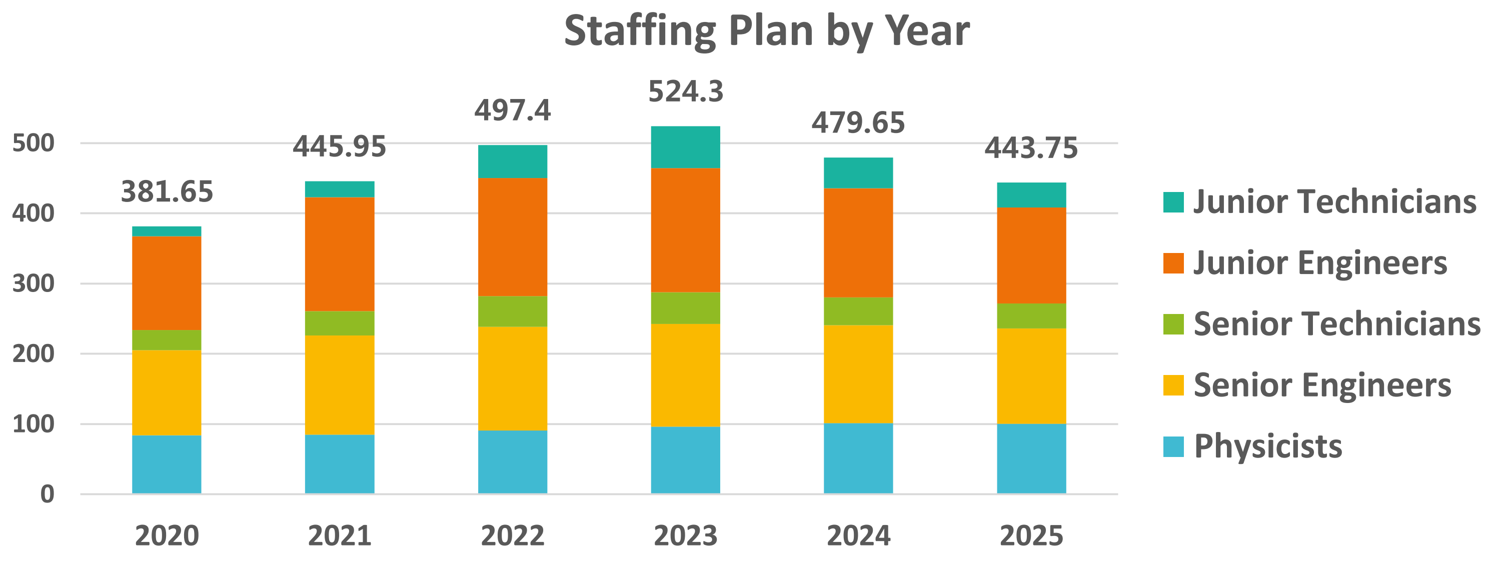
Project Management incl. design + contingency + all fare for admin process + collaboration, etc.

Manpower



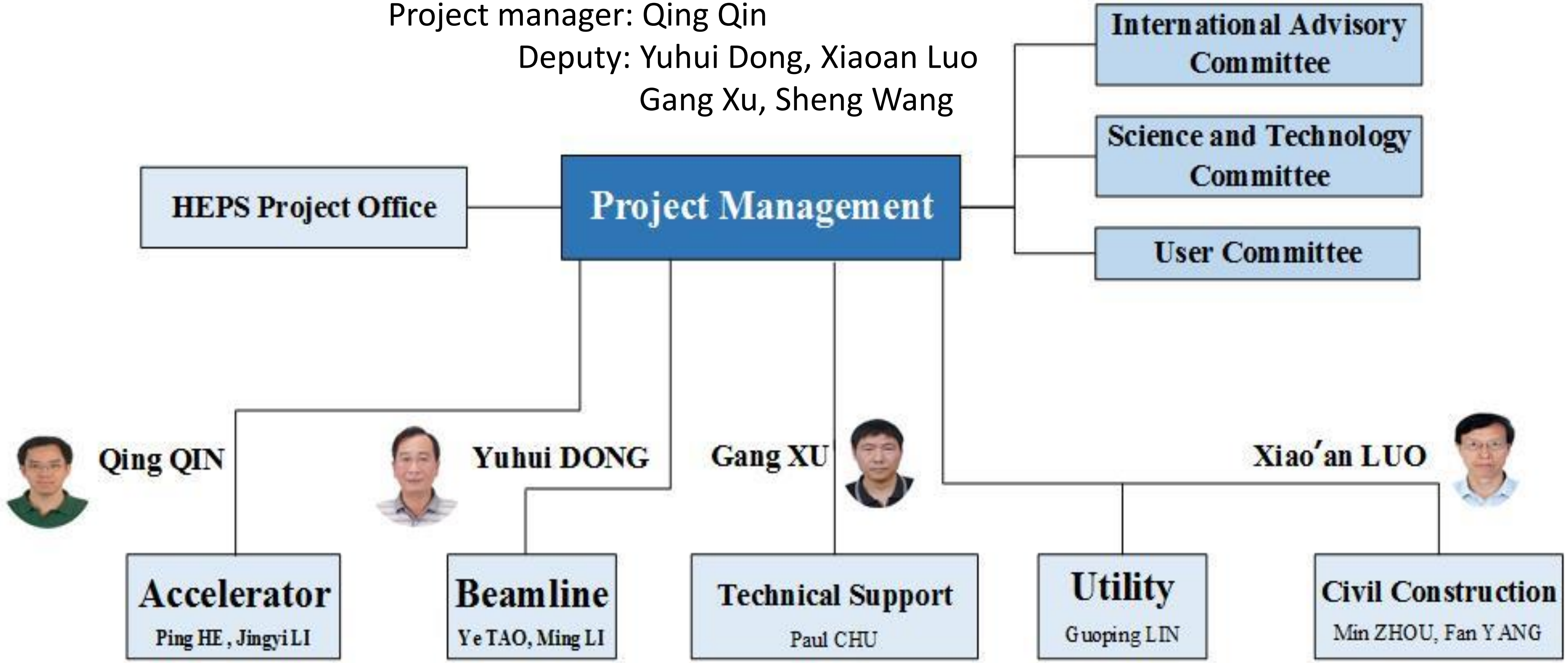
Project team was preliminarily formed.

- 275 full-time staff (physicsts-34%,engineers-62%, Technicians-4%)
- ~250 open positions (a 500-person team in 2023 expected)

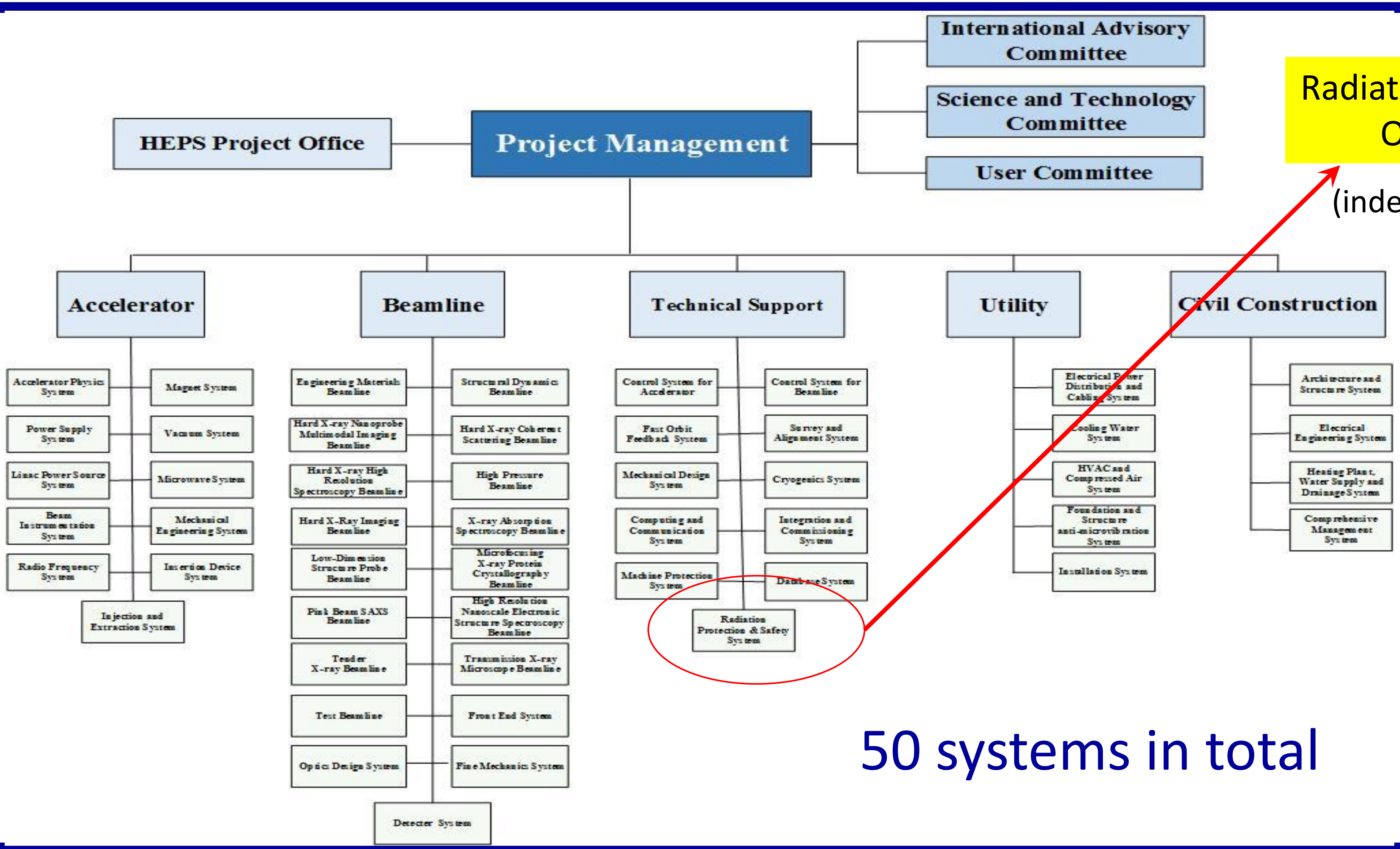


3. Organization & management

Project manager: Qing Qin
Deputy: Yuhui Dong, Xiaoan Luo
Gang Xu, Sheng Wang



Chief Engineer: Huamin Qu, General Technologist: Guoping Lin, CFO: Xiaoan Luo



Radiation Safety Office

(independent)

50 systems in total

5. Risk and mitigation

- A Risk is an uncertain event or condition that, if it occurs, has an effect on at least one project objective, or the effect of uncertainty on the achievement of objectives.
- Sources of project cost and schedule risk:
  - **Estimate Uncertainty (EU)**
    - For activities in the baseline scope
    - Depend on the activity definition maturity
  - **Identified Risk Events**
    - Known events that may or may not happen
    - Not included in baseline scope activities
  - **Unidentified Risk Events**
    - Unknown events that may or may not happen ("unknown unknowns")
    - Not captured in the AUP Risk Register
- We are trying to introduce the Risk Analysis Method in HEPS project
  - **Very preliminary now!**

Risk management

- Risk and probability
  - **Definition**: an uncertain event or condition that, if it occurs, has a positive or negative effect on the cost schedule, technical scope, quality, or some other aspect of Project.
  - **Management:** a forward-looking, continuous, and iterative process for managing threats and opportunities, in order to achieve the Project goals.
  - **Likelihood:** both in qualitative manner and numerical manner
  - **Impact**: Very low(0.05), Low(0.1), Medium(0.2), High(0.4), Very High(0.8).
  - **Various objectives**: Scope, Cost, Schedule, Quality

Likelihood		Description
Relative	**Numerical**	
Very Low	0.1	Highly unlikely to occur
Low	0.3	Will most Likely not occur
Moderate	0.5	Possible to occur
High	0.7	Likely to occur
Very High	0.9	Highly likely to occur

Objective	Relative/Numerical Scale				
	Very low 0.05	**Low 0.10**	**Medium 0.2**	**High 0.4**	**Very High 0.8**
Scope	Barely noticeable scope decrease	Minor areas affected	Major areas affected	Unacceptable decrease	Project end item effectively useless
Cost	Insignificant change in cost	< 10% increase	10%-20% increase	20%-40% increase	> 40% increase
Schedule	Insignificant change in schedule	< 5% delay	5%-10% delay	10%-20% delay	> 20% delay
Quality	Barely noticeable quality degradation	Quality reduction does not affect vital functionality	Quality reduction requires client approval	Unacceptable quality reduction	Project end item effectively useless

Probability and Impact Matrix

	Threats					Opportunities				
Very High 0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
High 0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
Medium 0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
Low 0.2	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
Very Low 0.1	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	Very Low 0.05	Low 0.10	Moderate 0.20	High 0.40	Very High 0.80	Very High 0.80	High 0.40	Moderate 0.20	Low 0.10	Very Low 0.05

High: Score > 0.18

Moderate: 0.07 < Score <= 0.18

Low: Score <= 0.07

Risk assessment

- The purpose of risk assessment is to provide evidence-based information and analysis to **make informed decisions** on how to treat particular risks and how to select between options.
- For HEPS Project:
  - Very little contingency of budget (3% included in the total budget)
    - Foreign currency rate increased compared to the approval time of the project
    - Unexpected inflation, especially the cost of some important materials
  - No any contingency of schedule
    - Civil construction needs more time than expected
    - Some advanced hardware/devices maybe delayed during manufacture or import
  - Manpower
  - Technical problems exist in all systems (work packages)
  - Other unknown risks

6. Possible international collaborations

- We hope to get more experiences and lessons from other light sources, ESRF-EBS, APS-U, PETRA III/4, Sirius, MAX IV, Spring-8, Diamond, SOLEIL, SSRF, SLS, TPS, etc.
- More collaborations on personal exchange, academic activity, technology development, are expected.

Charge of IAC'2019 and review on HEPS

- Project technical status and progress
  - Has the project identified the critical items of hardware and their schedule challenges?
  - Is the progress in each sub-system consistent with the schedule of the whole project?
  - Have the interfaces between different sub-systems been well incorporated into the engineering designs of the accelerators, beamlines and stations?
  - Are potential beam dynamics show-stoppers recognized and mitigations developed?
- Project steering and organization
  - Are the recommendations in the previous IAC meeting well understood and proper measures adopted accordingly?
  - Are the changes since the previous IAC meeting clearly identified and the reasons well explained?
  - Has the impact on scope, schedule and cost been understood and integrated in the project plan?
- Are the current design and science goals of beamlines improved according to the recommendations of previous IAC meeting and most of them expected to be competitive in the world by the time of the inauguration of HEPS?

Members of IAC

- Accelerator
  - Riccardo Bartolini (DLS)
  - Alex W. Chao (Stanford U. in emeritus)
  - Mark Boland (CLS)
  - Joel Chavanne (ESRF)
  - Hiroshi Sakai (KEK)
  - Peter Kuske (HZB)
  - Laurent Nadolski (SOLEIL)
  - Pedro F. Tavares (Chair, MAX IV)
  - Zhentang Zhao (SSRF)
- Beamline & Station
  - Joel Donald Brock (Cornell U.)
  - Andrew Harrison (Co-chair, DLS)
  - Reichert Harald (ESRF)
  - Tetsuya Ishikawa (Spring-8)
  - Brian N. Jensen (Max IV)
  - Tomas Lundqvist (RISE)
  - Kawal Sawhney (DLS)
  - Harry Westfahl Jr. (LNLS)

Meeting agenda

https://indico.ihep.ac.cn/event/11033/other-view?view=standard

Password: 20191216

2nd Meeting of International Advisory Committee for High Energy Photon Source (HEPS)

from Monday, December 16, 2019 at **08:00** to Wednesday, December 18, 2019 at **18:00** (Asia/Shanghai)
at **Kuangou Conference Center**
Kuangou Road No.1, Huairou District, Beijing

Support ***Email:*** sunxt@ihep.ac.cn ***Telephone:*** 88236507

Go to day

Monday, December 16, 2019

08:30 - 12:00 Plenary session

- 08:30 **IAC caucus, organization & charge (Executive session)** *30'*
- 09:00 **Welcome address** *5'*
- 09:05 **Progress on the HEPS project** *30'*
  Speaker: Prof. Qing Qin (秦庆)
- 09:35 **Progress in beamline systems** *30'*
  Speaker: Prof. Yuhui Dong(董宇辉)
  Material: **Slides**
- 10:05 **Group photo and coffee break** *20'*
- 10:30 **Site and building status** *30'*
  Speaker: Mr. Fan Yang(杨帆)
  Material: **Slides**
- 11:00 **Infrastructure and utilities** *30'*
  Speaker: Mr. Guoping Lin (林国平)
- 11:30 **Discussion** *30'*

13:30 - 18:30 Accelerator session(20' + 10')
Location: Courtyard No.3 Room 1

- 13:30 **Updates on accelerator physics studies** *30'*
  Speaker: Dr. Yi Jiao (焦毅)
  Material: **Slides**
- 14:00 **Updates on injector physics designs** *30'*
  Speaker: Dr. Yuemei Peng(彭月梅)
  Material: **Slides**
- 14:30 **Updates on impedance estimates and collective effects** *30'*
  Speaker: Dr. Na Wang (王娜)

…

  Speaker: Prof. Zhihong Li (李志宏)
  Material: **Slides**
- 11:50 **Transmission X-ray Microscope Beamline** *30'*
  Speaker: Dr. Qingxi Yuan (袁清习)
  Material: **Slides**
- 12:20 **Discussion** *20'*

14:00 - 18:40 Technical support session(20' + 10')
Location: Courtyard No.3 Room 1

- 14:00 **Radiation safety and Personnel Protection System** *30'*
  Speaker: Ms. Qiongyao Liu (刘琼瑶)
  Material: **Slides**
- 14:30 **Timing system status** *30'*
  Speaker: Ms. Fang Liu(刘芳)
  Material: **Slides**
- 15:00 **Updates on alignment** *30'*
  Speaker: Mr. Bo Li(李波)
  Material: **Slides**
- 15:30 **Coffee break** *20'*
- 15:50 **Ground vibration and measurements** *30'*
  Speaker: Dr. Fang Yan(闫芳)
- 16:20 **Status report of Stability Task Force** *30'*
  Speaker: Prof. Dapeng Jin(金大鹏)
  Material: **Slides**
- 16:50 **Discussion** *50'*
- 17:40 **Report writing / executive session** *1h0'*

Wednesday, December 18, 2019

08:30 - 15:30 Summary session
Location: Courtyard No.3 Room 1

- 08:30 **IAC final discussion (Executive session)** *1h0'*
- 09:30 **IAC discussion with HEPS team & managers** *1h0'*
- 10:30 **Coffee break** *20'*
- 10:50 **IAC close-out presentations** *1h20'*
- 13:30 **Tour of HEPS site and PAPS** *2h0'*

Thanks for your attention!