Future Chinese Large Scientific Facility based on Accelerator and Sustainability

3rd Workshop

Energy for Sustainable Science

at Research Infrastructures

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Institute of High Energy Physics

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Brief Introduction of IHEP

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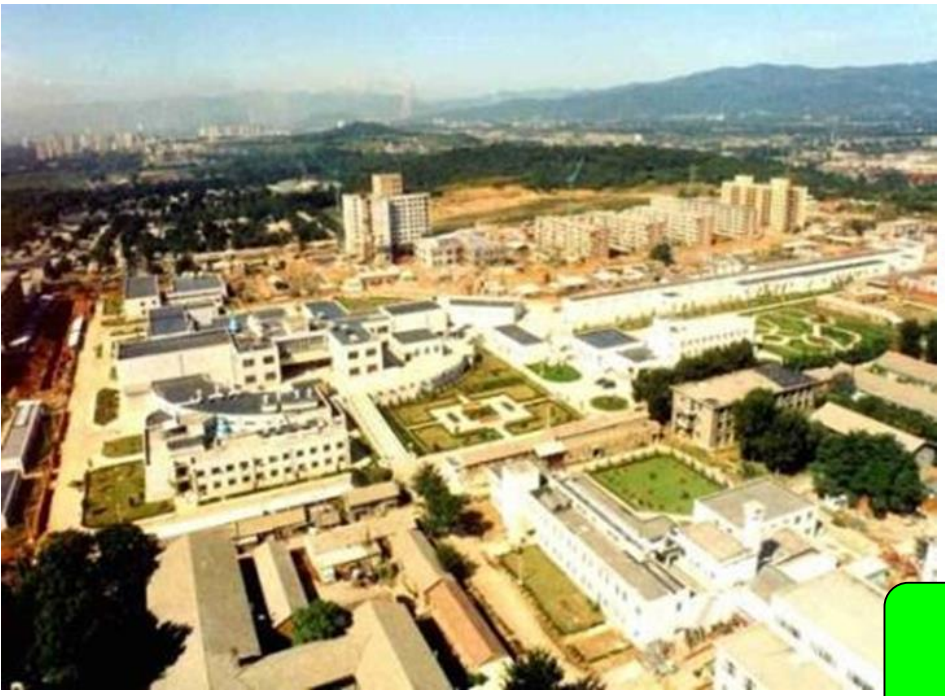
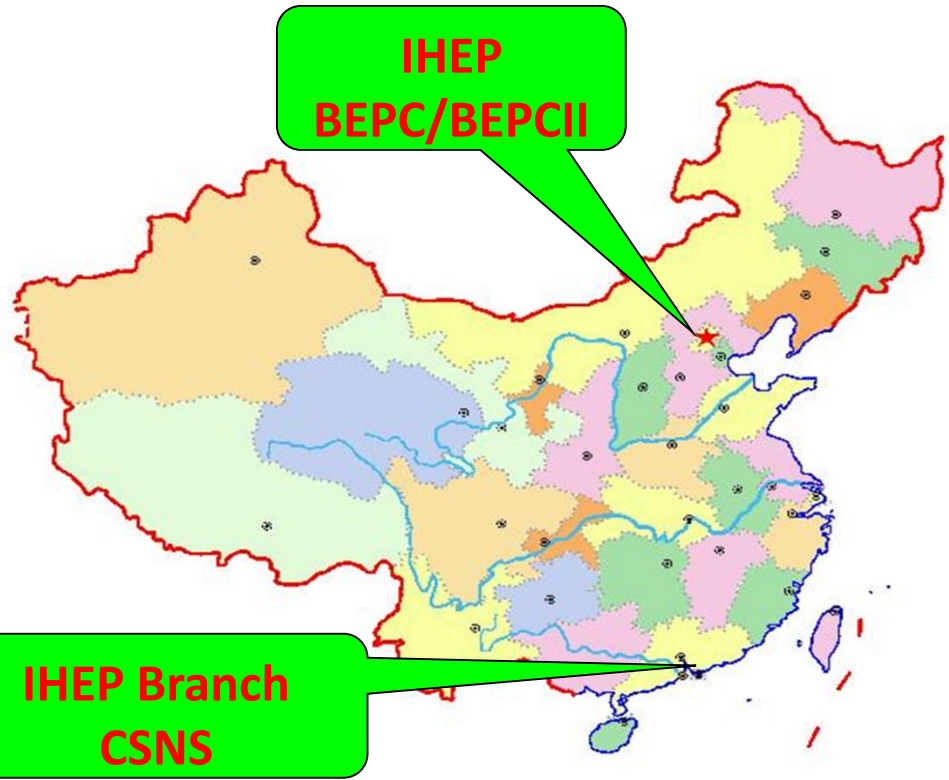
Institute of High Energy Physics

Brief Introduction of IHEP

May,1950	Institute of Modern Physics
October,1953	Institute of Physics
July ,1958	Institute of Atomic Energy
February ,1973	**Institute of High Energy Physics**





IHEP Main Research Disciplines

Particle Physics

- HEP Exp. Based on Accelerators
- Particle Astrophysics & Neutrino Exp.
- Particle Detection and Electronics
- Particle Physics Theory

Accelerator Physics and Technologies

- High Luminosity Electron Accelerator
- High Intensity Proton Accelerator
- Applied Research and Technology Transfer

Radiation Technologies and Applications

- Synchrotron Radiation Techniques & Applications
- Neutron Scattering Techniques & Applications
- Nuclear Analytical Techniques & Applications

→ Science

→ Technology

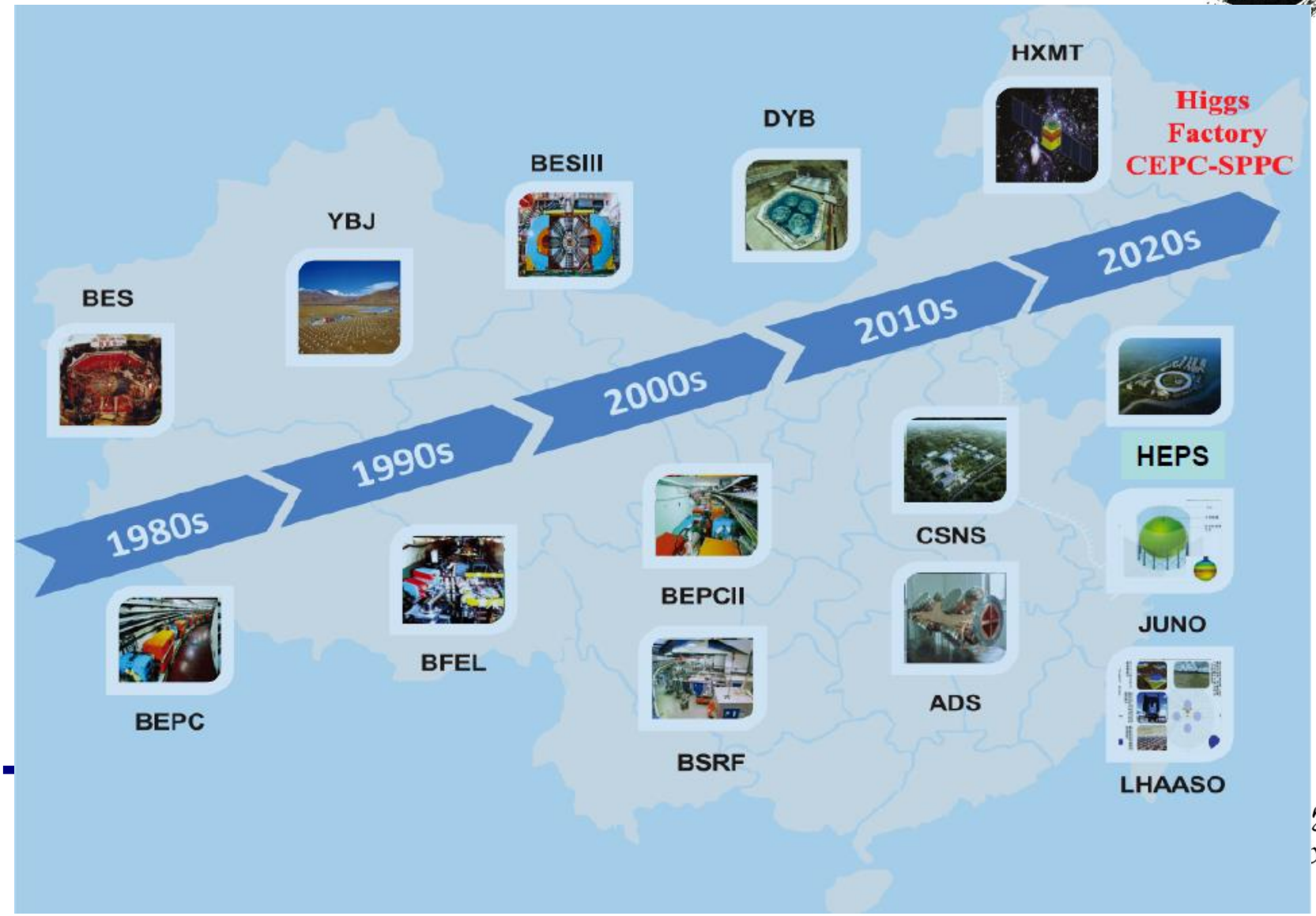
→ Scientific infrastructure for multi-disciplinary studies

Large Science Facilities @ IHEP

IHEP serves as the backbone of China's large science facilities

- **In operation**
  - Beijing Electron Positron Collider (BEPCII)
  - Beijing Spectrometer (BESIII)
  - Beijing Synchrotron Radiation Facility (BSRF)
  - Yangbajing Cosmic Ray Observatory: ASγ & ARGO
  - Daya Bay Neutrino Experiment
- **Under construction**
  - China Spallation Neutron Source (CSNS)
  - Hard X-ray Modulation Telescope(HXMT)
  - Accelerator-driven Sub-critical System (ADS)
  - Jiangmen Neutrino Underground Observatory (JUNO)
- **Under planning**
  - BAPS, LHAASO, XTP, HERD, …

Way to the Future



Running Large Scientific Facilities Based on Accelerator in China

- Beijing Electron Positron Collider(BEPC/BEPCII)
- Heavy Ion Research Facility in Lanzhou(HIRFL)
- Shanghai Synchrotron Radiation Facility(SSRF)

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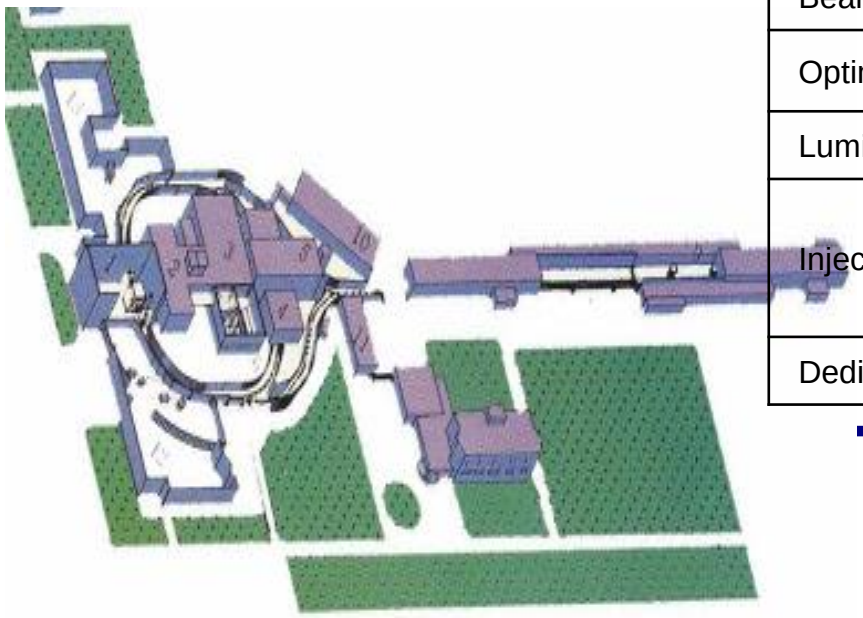
Beijing Electron Positron Collider(BEPC/BEPCII)

- Beijing Electron Positron Collider :
  - Constructed: 1984-1988
  - BESI: run from 1989-1998
  - BESII: run from 1999-2004
- Upgraded (BEPCII):
  - 2004-2008
  - BESIII: run from 2008



BEPCII:

High Luminosity Double Ring e- e+ Collider

Design Goals:

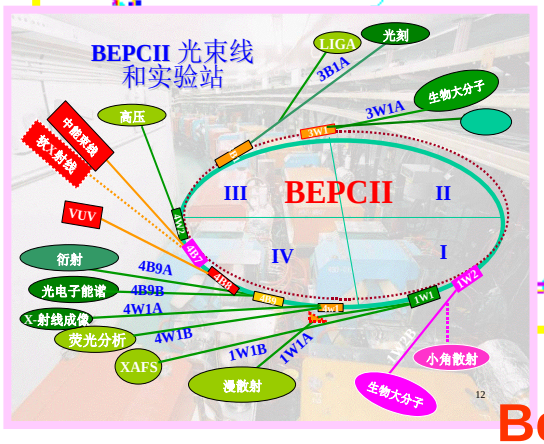
τ charm energy region world best collider

Keep Collider and Light source operation

Beam energy range	1–2.3 GeV
Optimized beam energy region	1.89GeV
Luminosity @ 1.89 GeV	1×10 33 cm-2s-1
Injection from linac	Full energy injection: Einj=1.55-1.89GeV Positron injection rate > 50 mA/min
Dedicated SR operation	250 mA @ 2.5 GeV

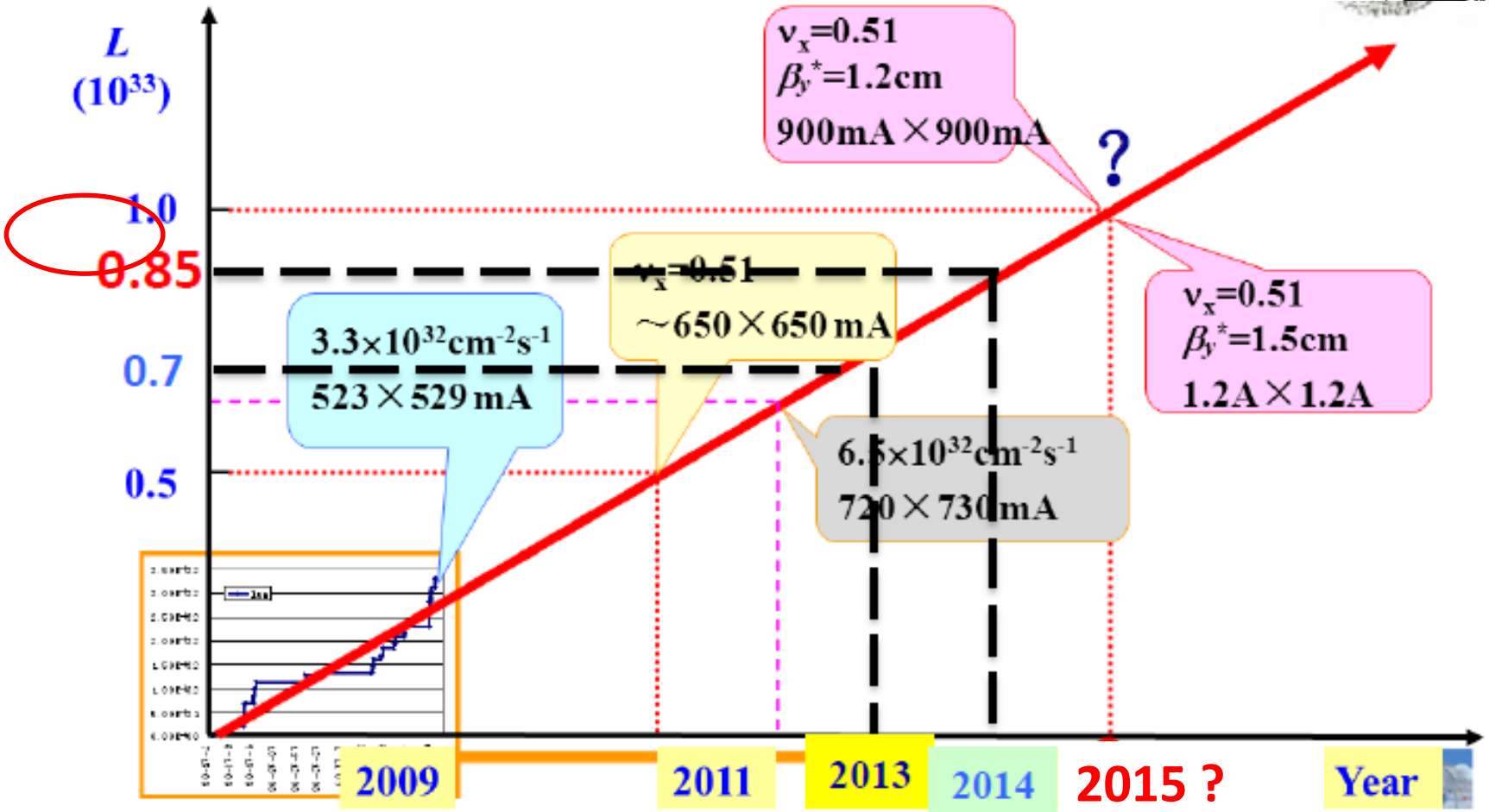
BEPCII: High Luminosity Double Ring e- e+ Collider

BESIII



Beam Lines

BEPCII Luminosity Roadmap



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Heavy Ion Research Facility in Lanzhou(HIRFL)

SSC (K=450)

100 AMeV (H.I.), 110 MeV (p)

SFC (K=69)

10 AMeV (H.I.), 17~35 MeV (p)

RIBLL1

RIBs at tens of AMeV

CSRe

RIBLL2

RIBs at hundreds of AMeV

CSR(Cooling Storage Ring)

CSRm

1000 AMeV (H.I.), ≤ 2.8 GeV (p)

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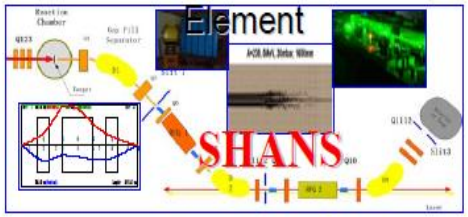
Heavy Ion Research Facility in Lanzhou(HIRFL)

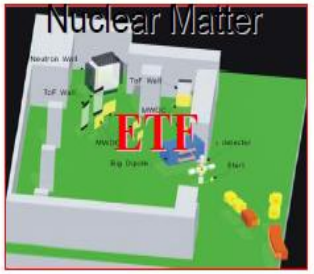
Main Exp. Setups for NP @ HIRFL

Nuclei Synth.

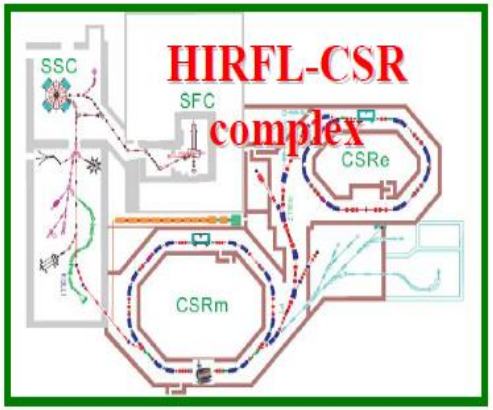
Super-heavy Element



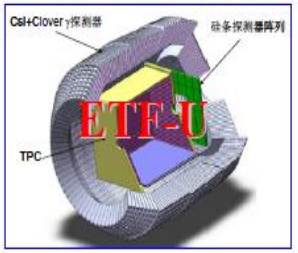
Exotic Nuclei and Nuclear Matter



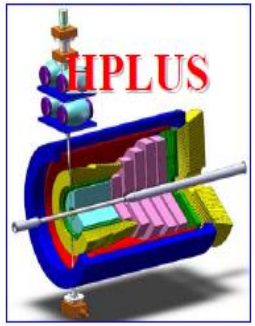
Exotic Nuclei



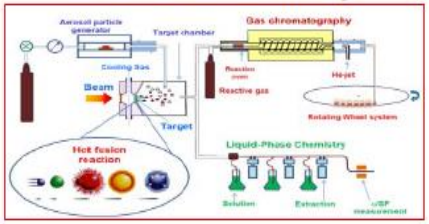
Nuclear Matter



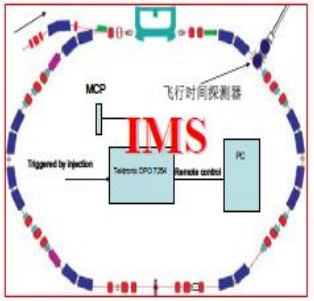
Hadron Physics



Nuclear Chemistry



Mass Measuring



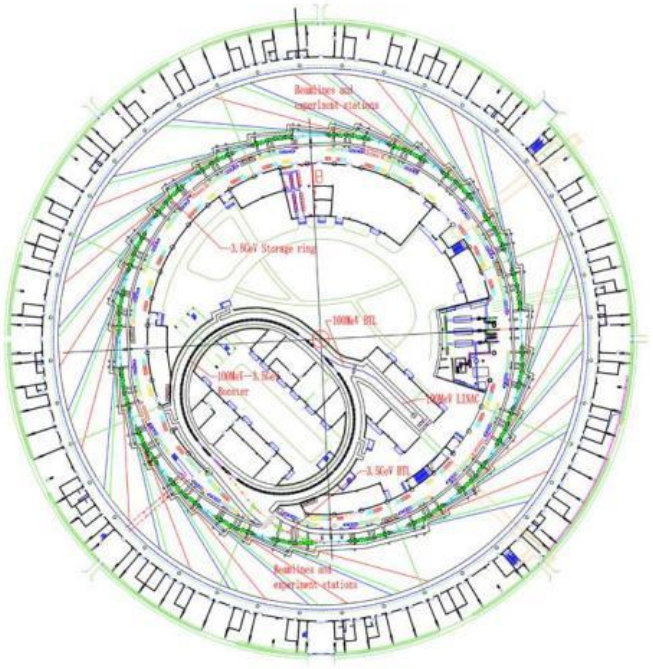
Typical beams provided by in recent years

Ion Beams	E (MeV/A)			Intensity (eμA)
	SFC	SSC	CSR	
$^{9}Be^{4+}$	7			0.008
$^{12}C^{4+}$	7.0			10-15
$^{16}O^{6+}$	7.99			7-12
$^{20}Ne^{7+}$	7.2			10-12
$^{26}Mg^{8+}$	6.54			2.0
$^{40}Ar^{8+}$	2.35			8-15
$^{40}Ca^{12+}$	5.8			1.0
$^{78}Kr^{19+}$	4.0		4~487	7-350
$^{129}Xe^{27+}$	3.0			6.0-7.0
$^{208}Pb^{27+}$	1.1			0.8-1.0
$^{238}U^{26+}$	0.81			0.33
$^{12}C^{4+\sim6+}$	7.0~8.2	80.5~100	7~1000	0.2-10000
$^{22}Ne^{7+/10+}$	6.17	70		0.2-0.5
$^{26}Mg^{8+/12+}$	6.17	70		0.3-0.4
$^{32}S^{11+/16+}$	7.1	82		0.2-0.3
$^{36}Ar^{8+/18+}$	2.07	22	22~1000	2.5-3.5
$^{40}Ar^{12+/17+}$	7.1	82		0.1-0.3
$^{58}Ni^{13+/22+}$	4.5	50		0.1-0.2
$^{129}Xe^{27+}$	1.8	19.5	200	0.6-500
$^{209}Bi^{31+/36+}$	0.88	9.8	170	0.08-60

Shanghai Synchrotron Radiation Facility(SSRF)

Medium Energy 3rd Generation Light Source, running from 2009

- 150 MeV Linac
- Full energy booster
- 3.5 GeV Storage Ring
- 7 Beam Line +



Under Construction Large Scientific Facilities Based on Accelerator in China

- China Spallation Neutron Source (CSNS)

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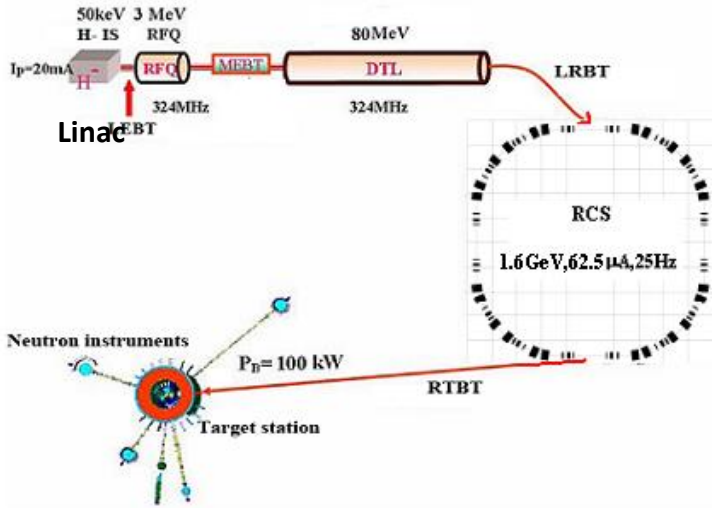
China Spallation Neutron Source (CSNS)

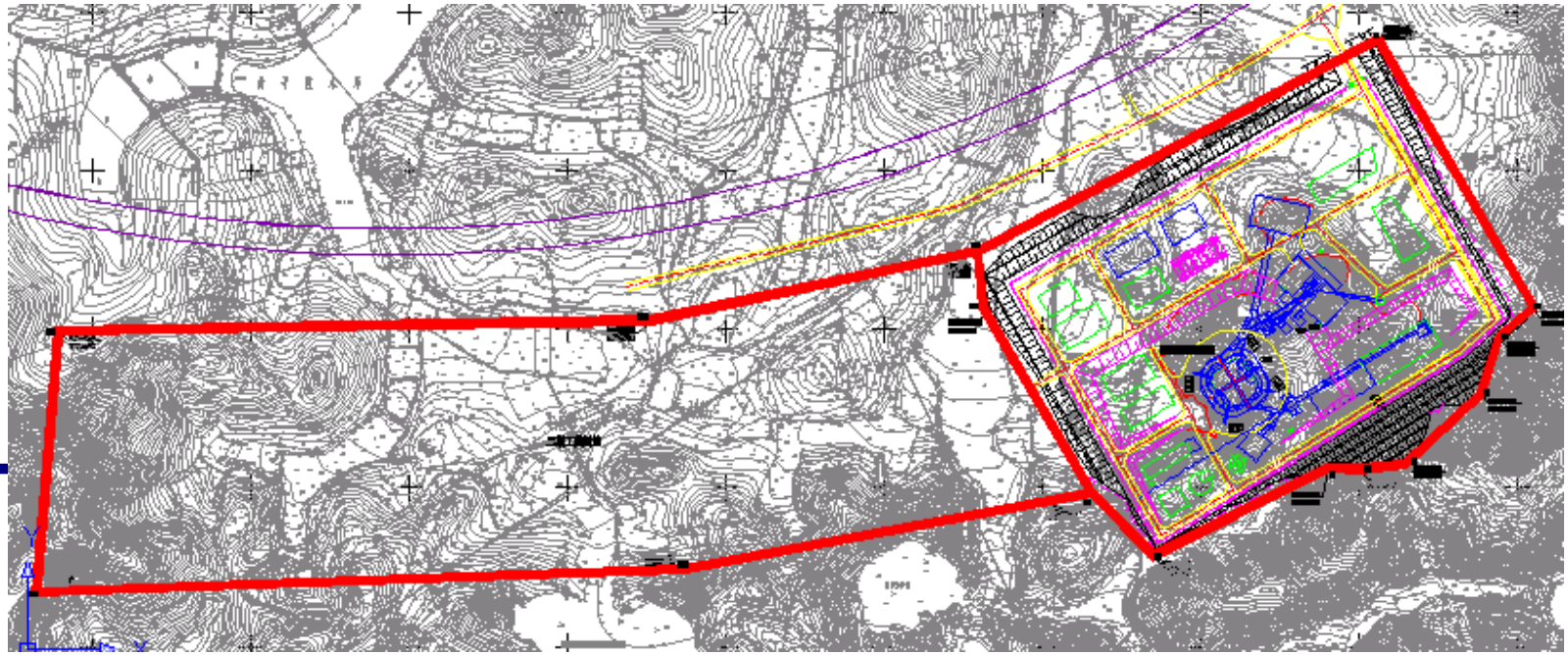
- The phase-I CSNS facility consists of an 80-MeV H^- linac, a 1.6-GeV RCS, beam transport lines, a target station, and 3 instruments.

Project Phase	I	II
Beam Power on target [kW]	100	500
Proton energy [GeV]	1.6	1.6
Average beam current [μA]	62.5	312.5
Pulse repetition rate [Hz]	25	25
Linac energy [MeV]	80	250
Linac type	DTL	+Spoke
Linac RF frequency [MHz]	324	324
Macropulse. ave current [mA]	15	40
Macropulse duty factor	1.0	1.7
RCS circumference [m]	228	228
RCS harmonic number	2	2
RCS Acceptance [πmm-mrad]	540	540
Target Material	Tungsten	Tungsten



CSNS Civil Design

- Total long-term construction site area is about 0.67km^2.
- 0.27km^2 has been occupied for phase-I construction.
- The remaining land is planned for future expansion for new project.

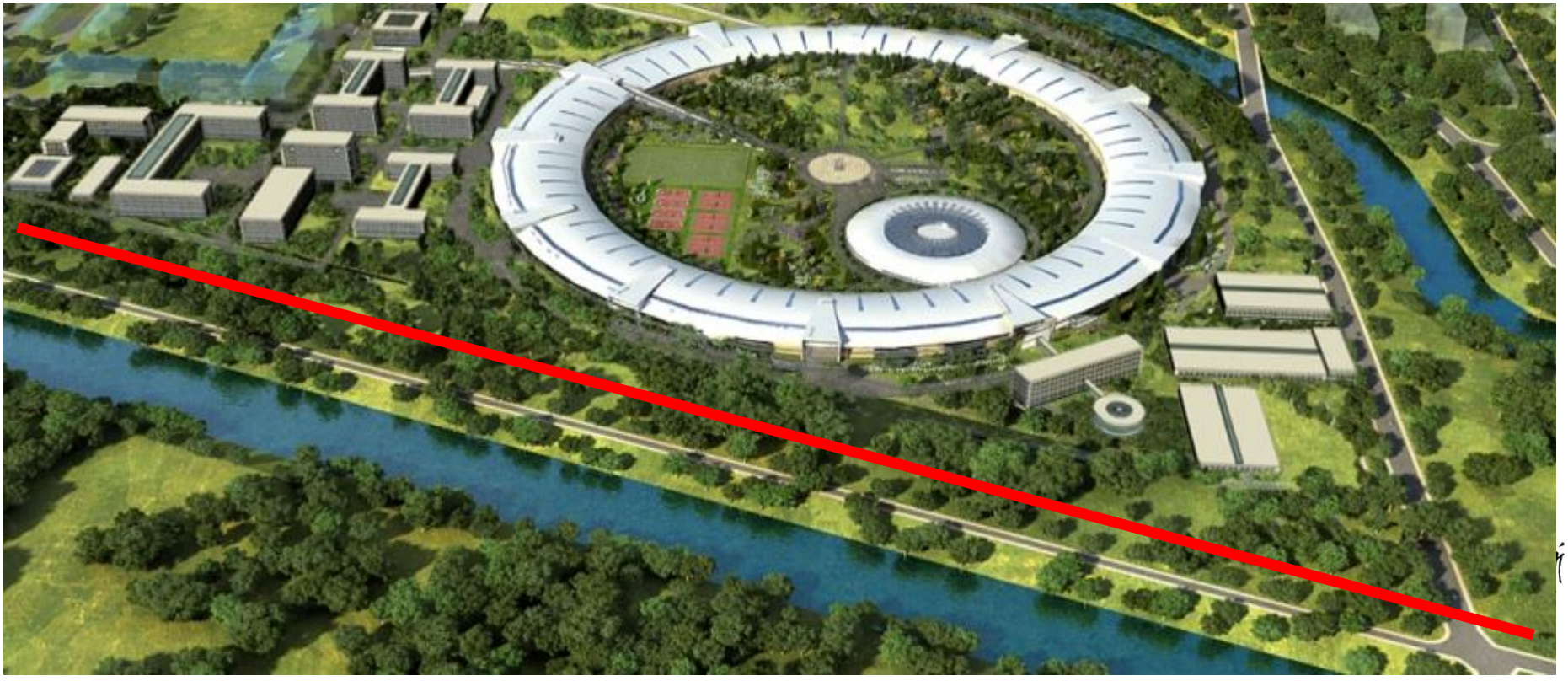


Future Chinese Large Scientific Facilities Based on Accelerator in China

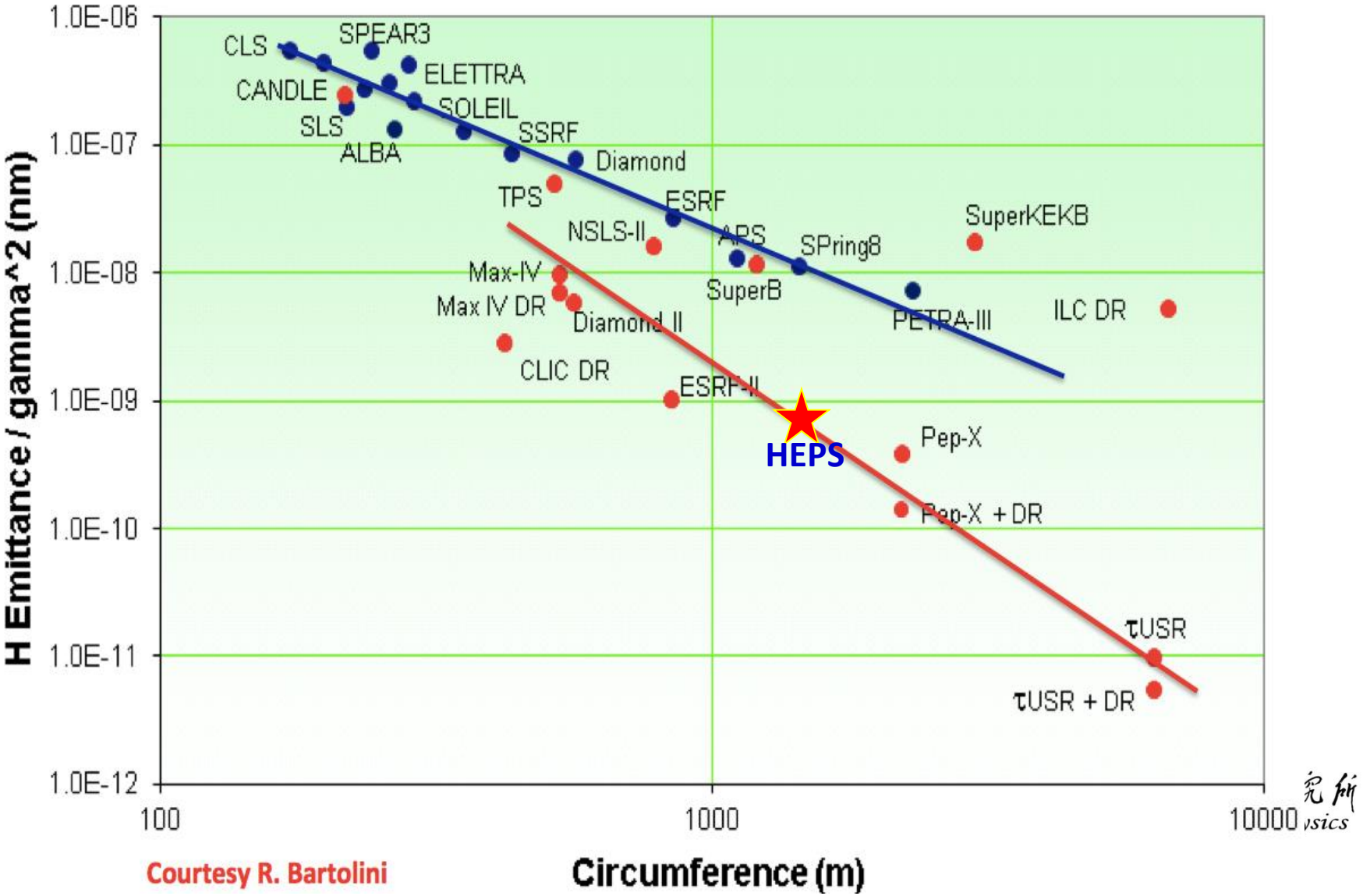
- High Energy Photon Source (HEPS)
- Accelerator Driven System (ADS) in China & China Initiative ADS (CIADS) , Accelerator Driven Advanced Nuclear Energy (ADANES)
- Heavy Ion Accelerator Facility (HIAF)
- Circular Electron Positron Collider (CEPC) & Supper Proton Proton Collider (SppC)

High Energy Photon Source(HEPS)

- High energy: 6GeV
- Low emmitance: <0.1nm·rad, can be improved to 0.01nm·rad
- Brilliance: >10^{22}phs/s/mm^2/mrad^2/0.1%BW
- The site has the possibility to build XFEL



Comparing with other facilities



Courtesy R. Bartolini

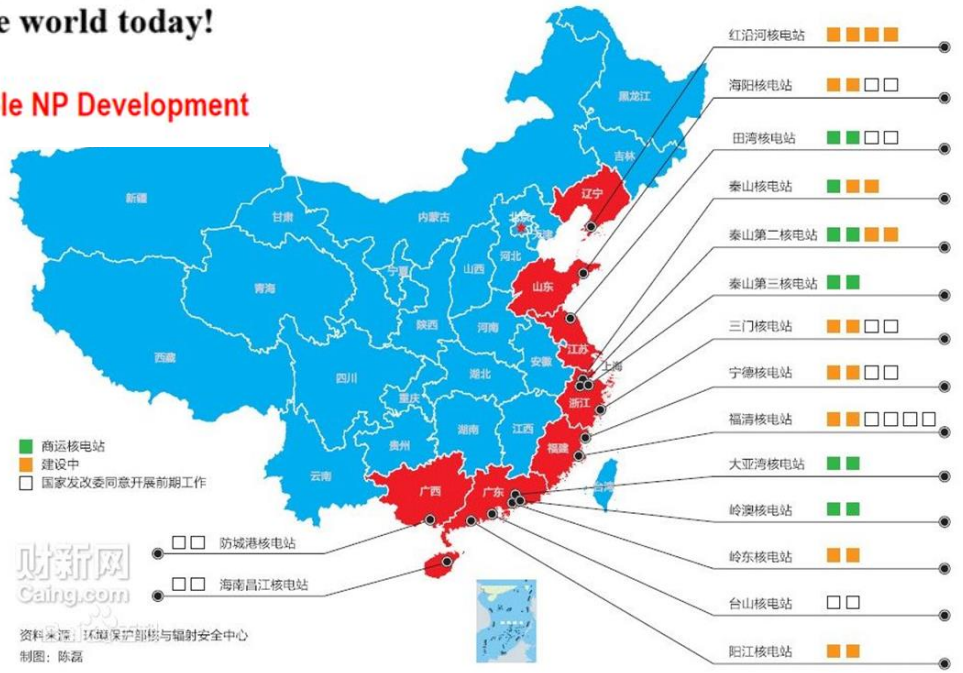
The schedule of HEPS construction

- The preliminary research was supported by IHEP.
- HEPS-TF (High Energy Photon Source Test Facility) project was approved in Feb. 2015 (323.5M RMB)
- HEPS
- Construction will start in 2018.
- Commissioning in 2023.

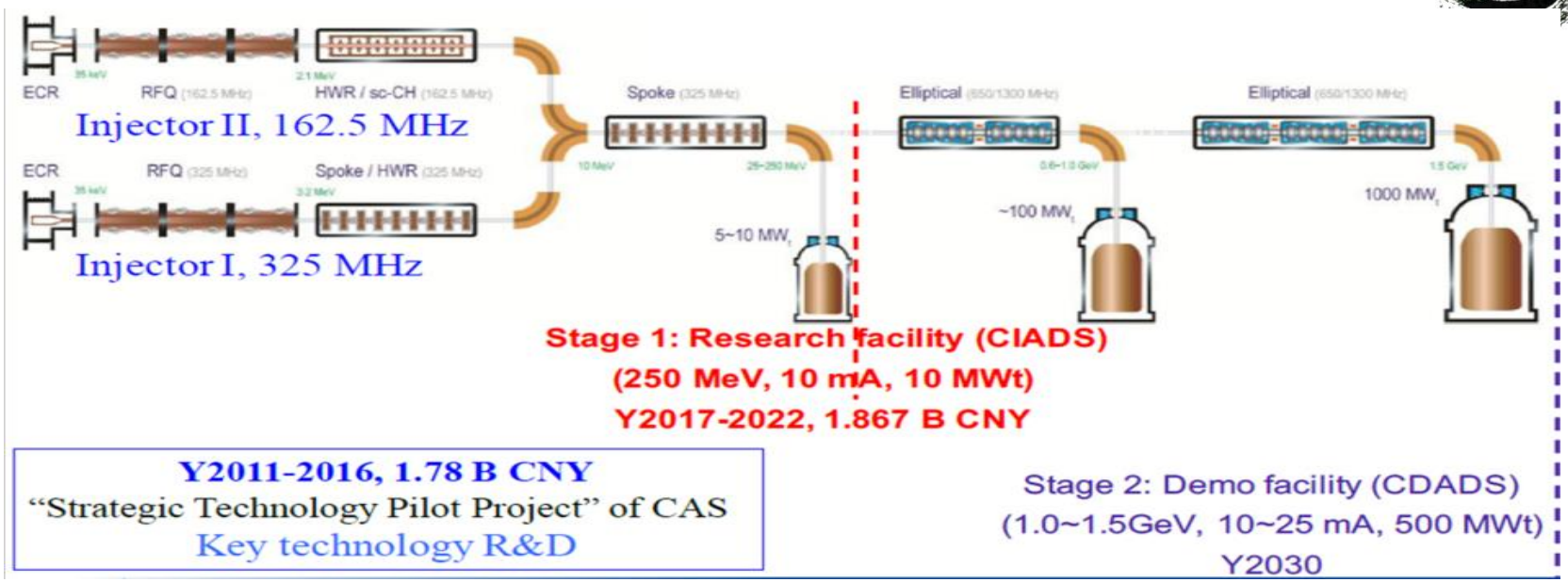
Accelerator Driven System (ADS) in China

- **To July 2013** (http://www.iaea.org/NuclearPower/Systems-and-Databases/index.html)
  - 18 reactors in operation, 13.860GW$_e$; (6th in the world)
  - 28 reactors under construction, 27.790GW$_e$; (1st in the world)
- **Estimation for the future (slow down after 2011.3)**
  - **2020**: ~58 GW$_e$ NPP in operation
  - **2030**: ~10% of NP to total power capacity
  - **2050**: 350~400 GW$_e$, ~20% of NP to total power capacity
    → **almost same as the scale of the total in the world today!**

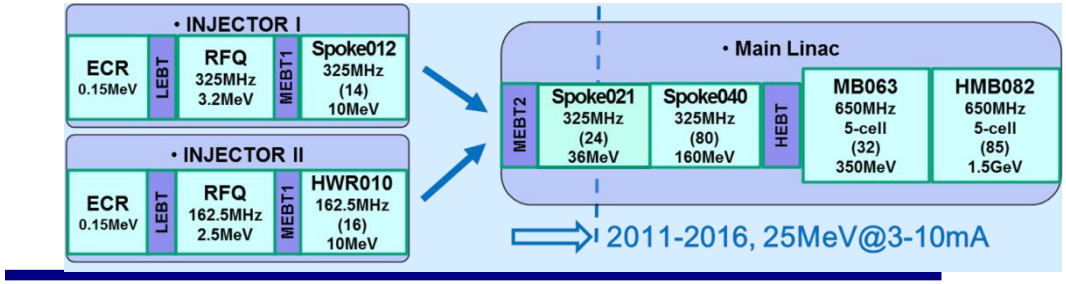
Nuclear Waste Management is a serious Issues for Sustainable NP Development



Accelerator Driven System(ADS)



Parameters	Value	Units
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
Frequency	162.5/325/650	MHz
Duty factor	100%	
Beam Loss	<1 (0.3)	W/m
Beam trips/year	<25000 <2500 <25	1s<t<10s 10s<t<5m t>5m



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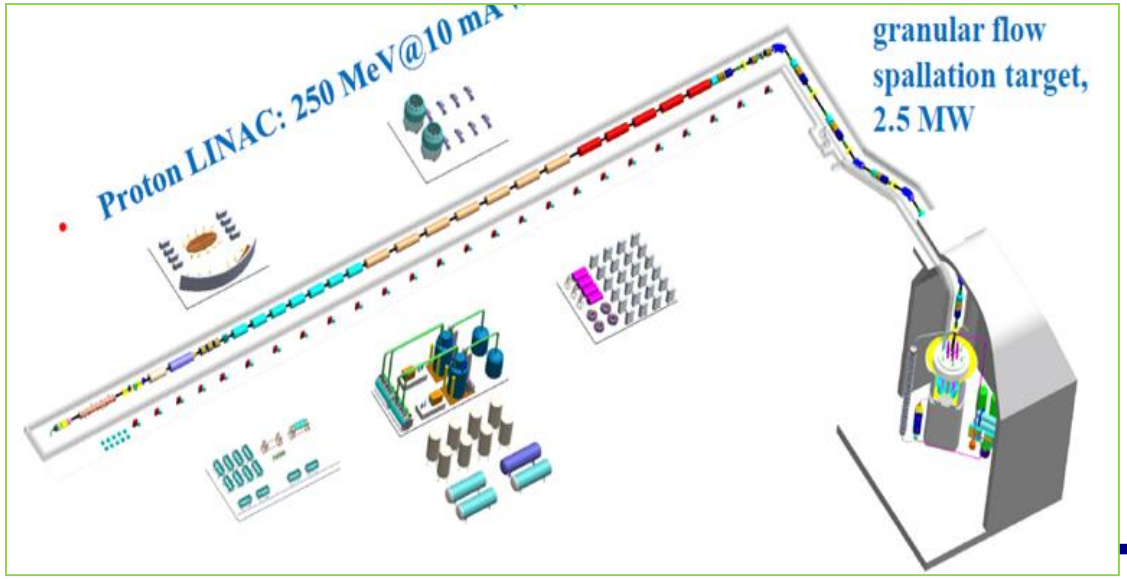
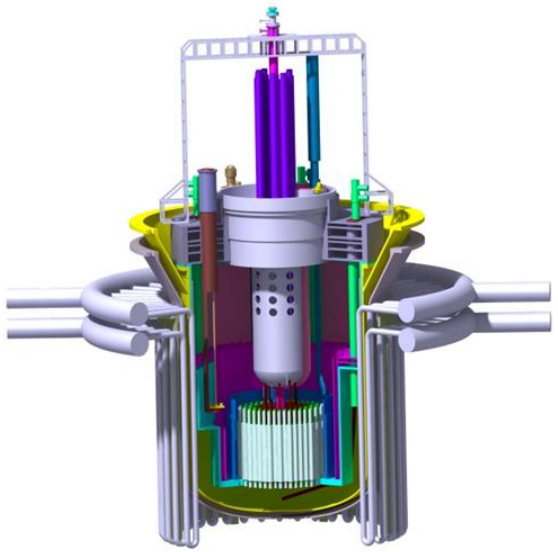
China Initiative ADS (CIADS)

Linac ： 250MeV@10mA with CW Proton Linac
Target ： Granular flow spallation target
Reactor ： 10MW Pb-Bi cooling subcritical reactor





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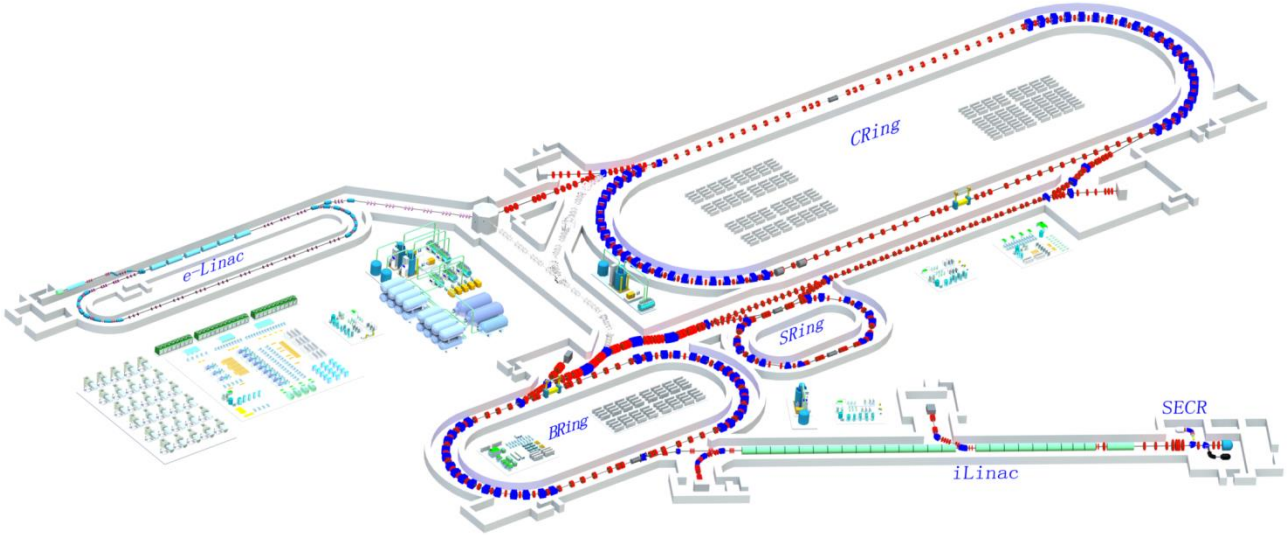
Heavy Ion Accelerator Facility(HIAF)



Motivations of HIAF

Basic Researches

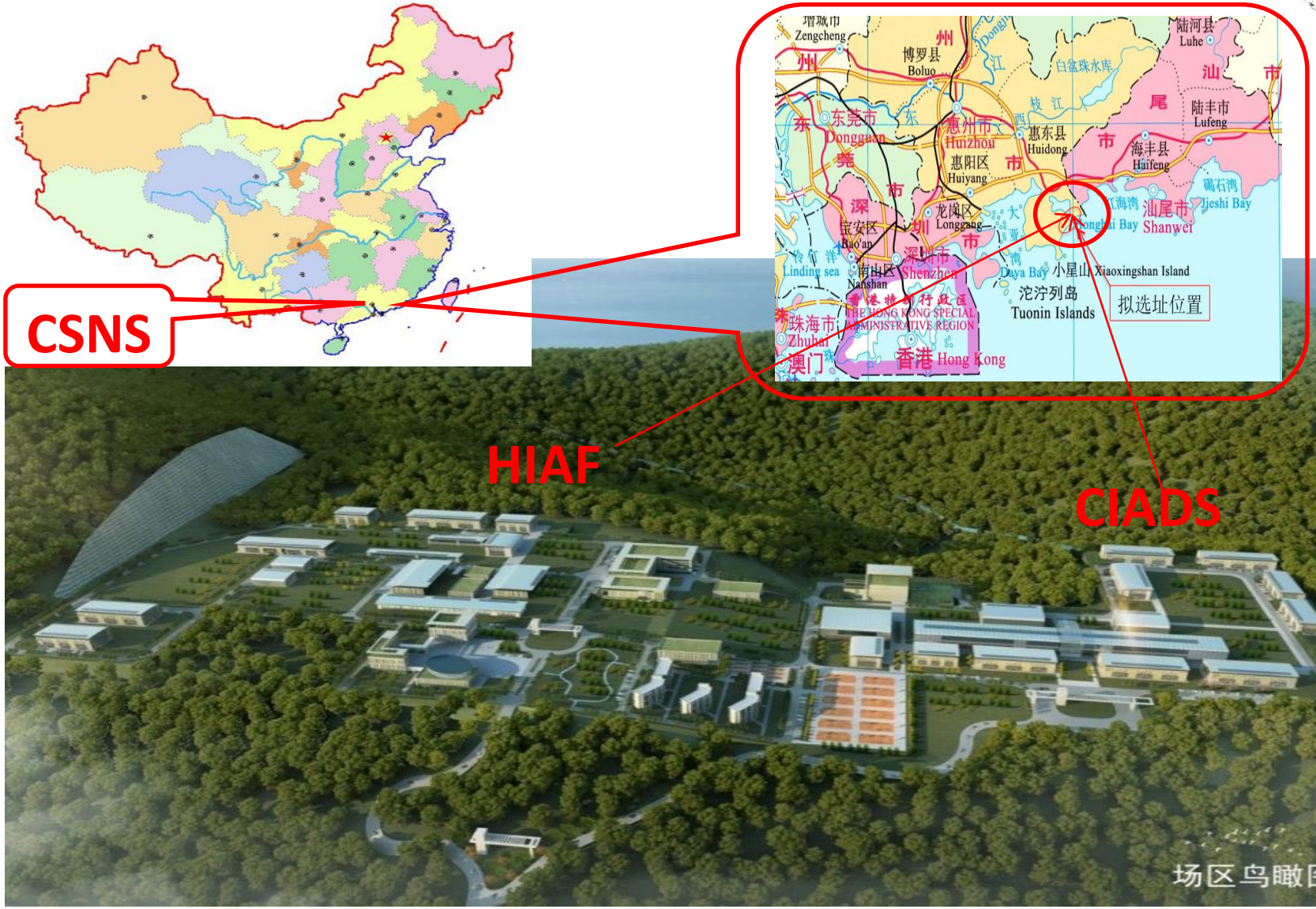
- Precise Mass Measuring
- Radioactive Physics and Super-heavy Element Synthesis
- High Energy Density Physics
- Non-perturbation Hadron Physics
- ....

Applications

- Space Simulation
- Irradiation Material
- Radiation Effects
- Trace Technology
- ....

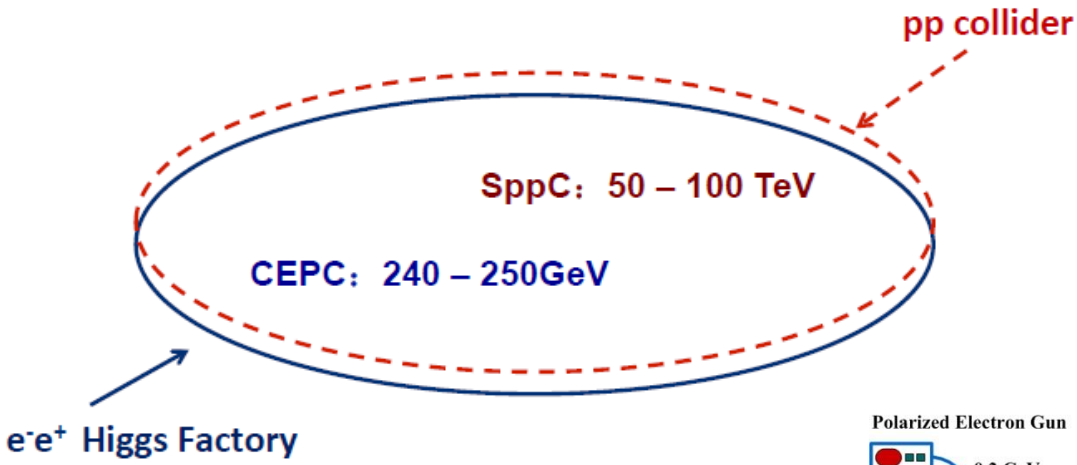
Accelerator		Ions	Energy	Intensity
Ion source	ECR	U^{34+}	14 keV/u	0.05 pmA
	H_2^+	H_2^+	14 keV/u	2.0 pmA
iLinac		U^{34+}	25 MeV/u	0.028 pmA
		H_2^+	54 MeV/u	1.0 pmA
BRing		U^{34+}	0.8 GeV/u	~3.3×10^{11} ppp
		p	9.5 GeV/u	~2.3×10^{12} ppp
CRing		U^{34+}	1.1 GeV/u	**~1.0×10^{12} ppp**
		U^{92+}	4.1 GeV/u	~2.0×10^{11} ppp
		p	12.0 GeV/u	~4.5×10^{12} ppp

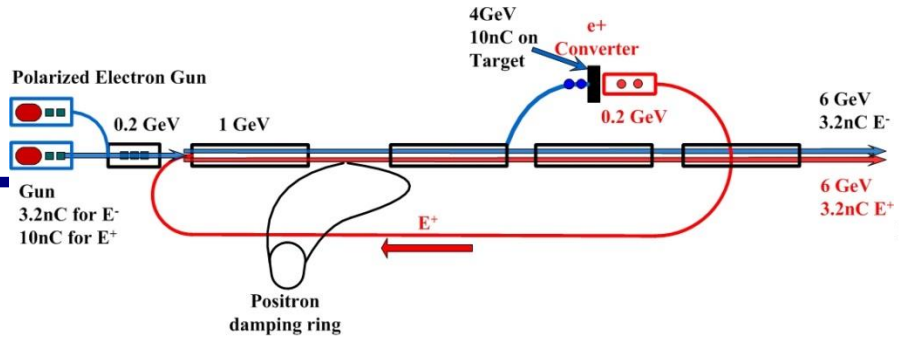
Site for CIADS & HIAF



CEPC & SppC

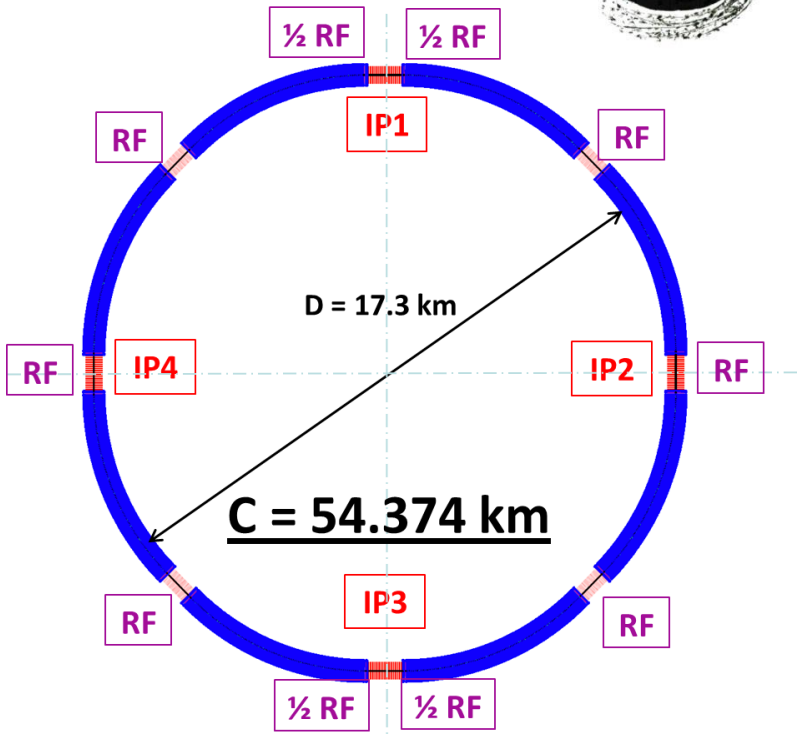
- Circular Electron Positron Collider (CEPC) is to study the Higgs boson
- Supper proton proton Collider (SppC)
- A CEPC (Phase I) + SppC (Phase II) was proposed in IHEP, Sept.2012





General info of CEPC

- **Critical parameters:**
  - **Beam energy: 120GeV**
  - **Circumference: ~54 km**
  - **SR power: 51.7 MW/beam**
  - **8*arcs**
  - **2*IPs**
  - **8 RF cavity sections**
  - **Filling factor of the ring: ~70%**

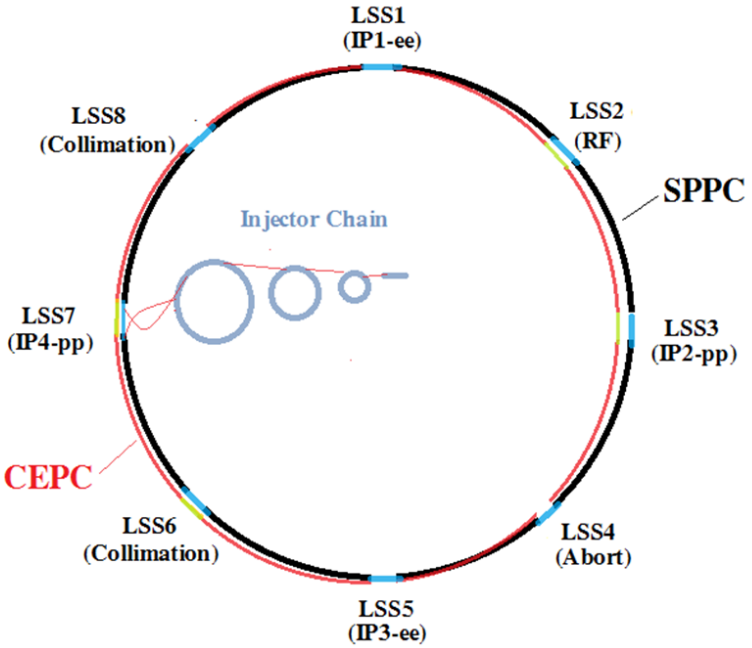


- **Length of the straight sections are compatible with SppC requirement**

General info of SppC

SPPC rings:

- 8 arcs (5.9 km) and long straight sections (850m*4+1038.4m*4)
- 2 IPs for pp (perhaps one at IR6 for e-p in the future)
- 2 IRs for e+e detectors (pp: injection, RF?)
- 2 IRs for collimation
- 2 IRs for RF and beam abort



CEPC & SppC Time Schedule

CPEC

- Pre-study: 2013-15 ➔ End of 2014 Pre-CDR completed
- R&D: 2016-2020
- Engineering Design: 2015-2020
- Construction: 2021-2027
- Data taking: 2030-2036

SppC

- Pre-study: 2013-2020
- R&D: 2020-2030
- Engineering Design: 2030-2035
- Construction: 2036-2042
- Data taking: 2042 -

Possible site: Qinhuangdao, Hebei province

Time Schedule of Future Large Facilities

- **Most facilities construction & running during 2020~2040**

	Pre-Study	R&D	Engineering Design	Cons-truction	Commi-ssioning	Run
HEPS		2015-2018		**2018-2023**	2024	2024
CIADS		2011-2016		**2016-2022**		
HIAF				**2016-2022**	2013	2023
ADANES				**2023-2030**	2030	
CEPC	2013-2015	2016-2020	2016-2020	**2021-2027**	2027-2030	2030-2036
SppC	2013-2020	2020-2030	2030-2035	**2036-2042**		2042 -

Sustainability of Future Chinese Large Scientific Facility

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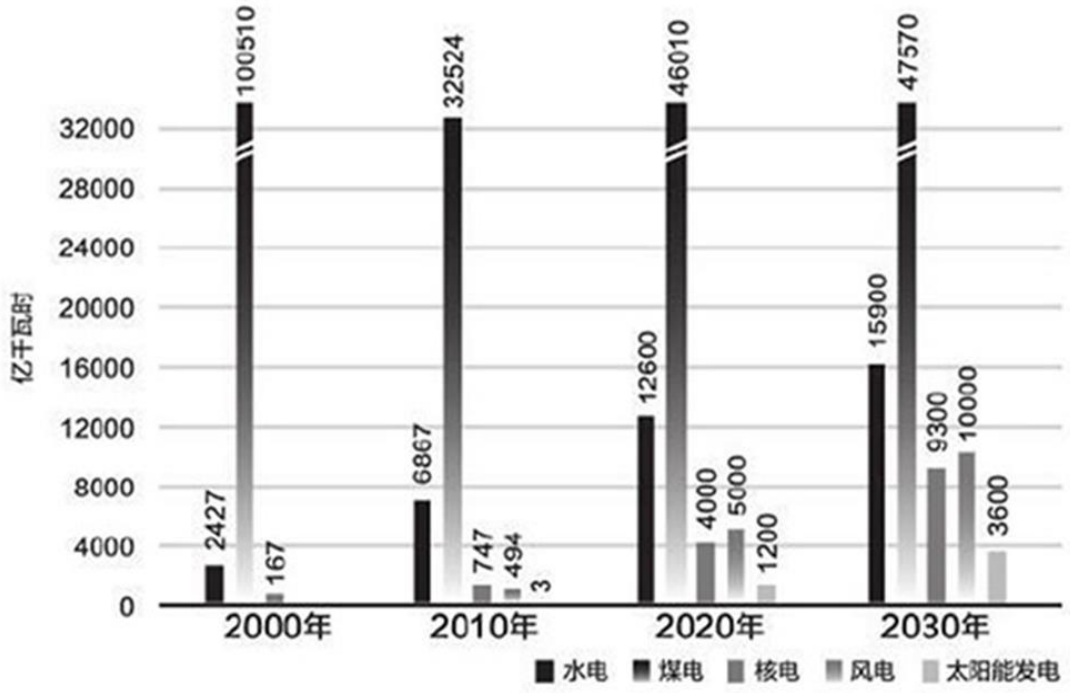
U.S.-China Joint Announcement on Climate Change

- Beijing, China,
- 12 November 2014

- Today, the Presidents of the United States and China announced their respective post-2020 actions on climate change, recognizing that these actions are part of the longer range effort to transition to low-carbon economies, mindful of the global temperature goal of 2℃.
- The United States intends to achieve an economy-wide target of reducing its emissions by 26%-28% below its 2005 level in 2025 and to make best efforts to reduce its emissions by 28%.
- China intends to achieve the peaking of CO2 emissions around 2030 and to make best efforts to peak early and intends to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030.

Non-fossil fuels in primary energy consumption to around 20% by 2030

- Wind power , Hydro power , Photovoltaic power significantly increased in 2030
- China has been the world's largest manufacturer of solar panels since 2008

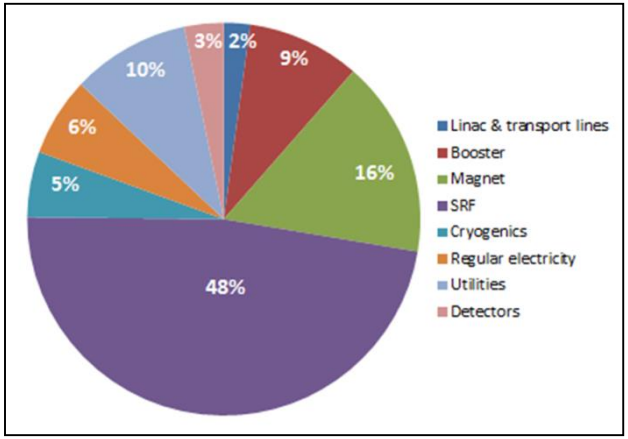


2000~2030 Electricity Production in China

Electricity Requirements of Large Facilities

Facility	Power Consumption MW	Operation hrs/Year	Electricity GWh/Year
BEPCII	~ 6	7000	42
HIRFL	~ 4	7000	28
SSRF	~ 6	7000	42
CSNS	~ 25	5000	125
CIADS	~ 5	5000	25
HEPS	~ 12	7000	84
HIAF		7000	
CEPC	~ 500	7000	3500
ADANES		5000	
SppC		7000	

CEPC Relative Power Consumption



900MW Qinshan NPP

Renewable energy for Future large facilities

- At present there are seldom considerations and experience for energy sustainable of Chinese large scientific facilities
- We Need to consider take advantage of Renewable energy for infrastructure of future large facilities
- Contribution to reduce CO2 Emission
- Need to organize expert team to develop energy sustainable technology for large scientific facilities

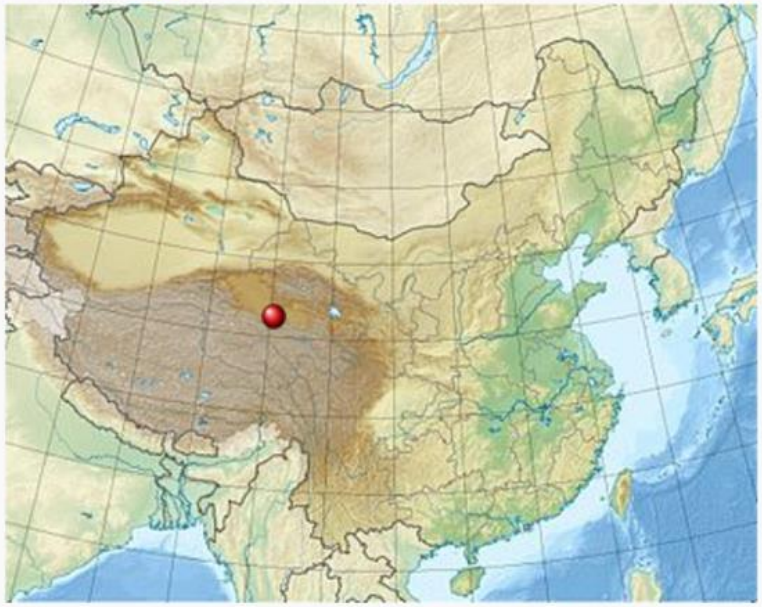
Renewable energy for Future large facilities

- Increase Component power efficiency,
  - like klystron,,,
- Energy recovery
  - Like CEPC 500MW power consumption, big heat from accelerator running, Recovery of waste heat is big energy saving
- Use green energy : Photovoltaic, wind,,,
  - Photovoltaic power is one of best renewable power for infrastructure, like CEPC big Campus, such as building and campus light, heat, etc.
  - ~ 6 km2 site can produce 200MW photovoltaic power

200 MW photovoltaic power station

Coordinates	36°24′00″N 95°07′30″E
Status	Operational
Construction began	20 August 2009
Commission date	29 October 2011
Construction cost	RMB3.26 billion
Owner(s)	Huanghe Hydropower
Solar farm	
Type	Flat-panel PV
Site area	5.64 km^2 (2.2 sq mi)
Power generation	
Nameplate capacity	200 MW_p
Annual generation	317 GWh

Qinghai Golmud Solar Park



Location of Qinghai Golmud Solar Park in China

Summary

- China running several large scientific facilities at present
- Proposed and submit to government to construct several large scientific facilities in future, some of them may approved and constructed by 2017-2030
- At present we are short of research activity at energy sustainable technology
- For the future large scientific facility we need to organize expert team to planning and Develope energy sustainable technology from initial stage of designing of facility
- We hope carry through the international collaboration in energy sustainable technologies for future facilities

Thanks for your attention !