Superconductivity in the BEPCII Performance

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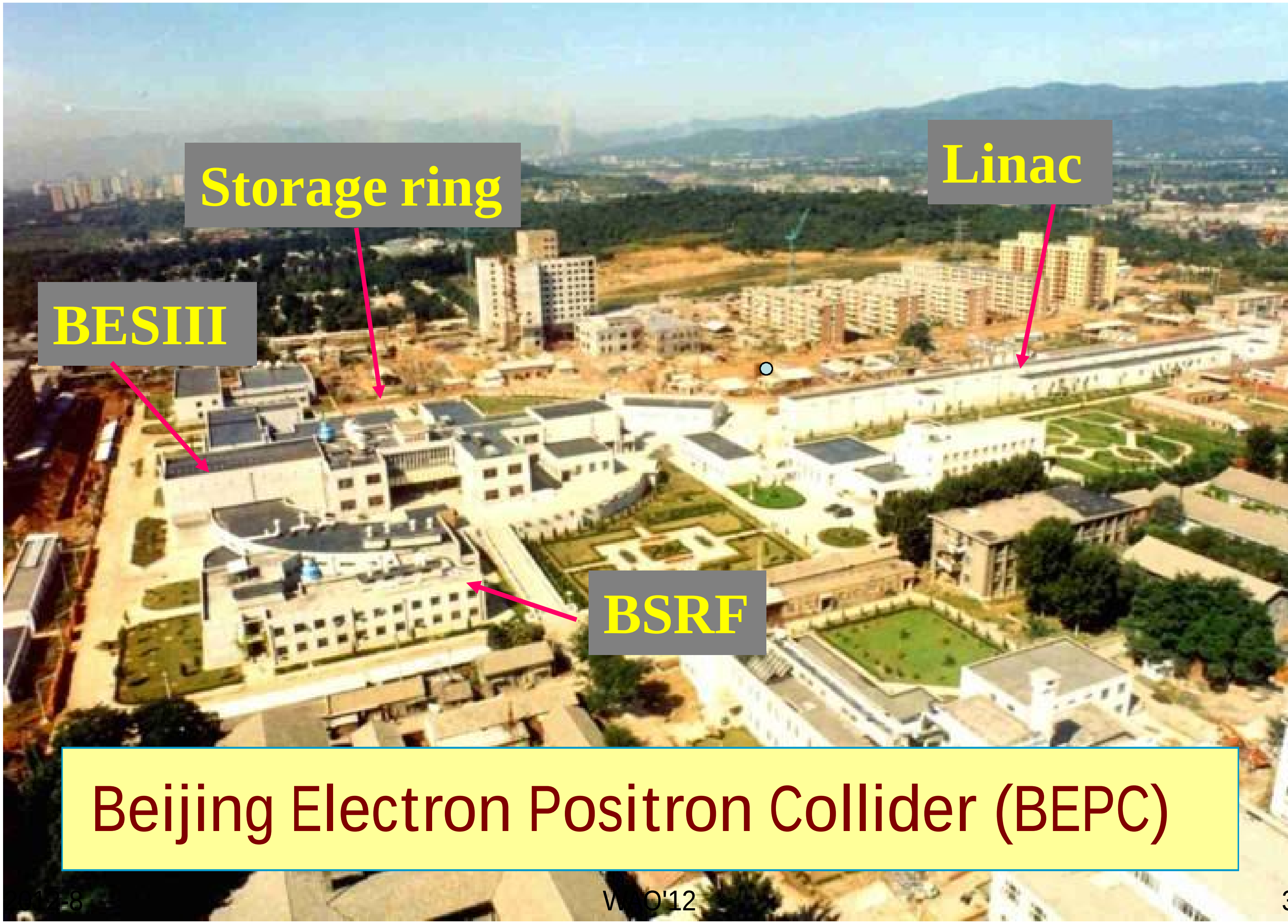
Outline

- Introduction on the BEPCII
- Why we chose superconducting stuffs
- How superconducting affects operation
- What we benefit from superconducting
- Summary



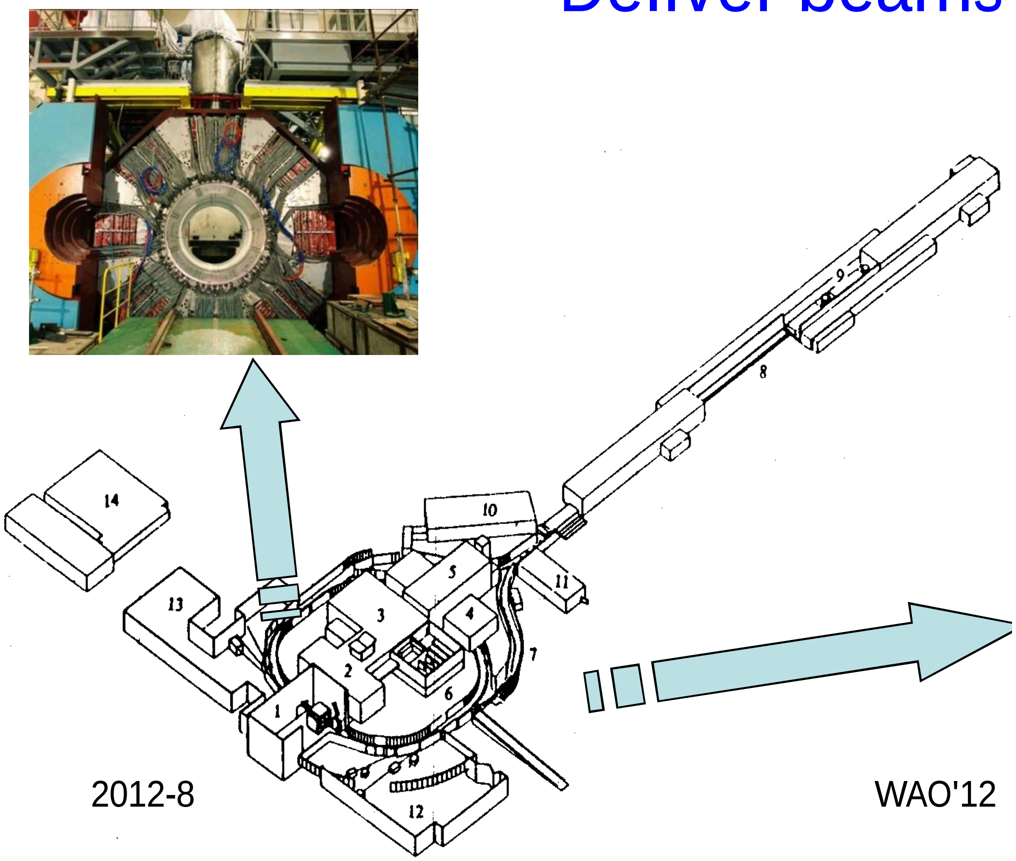
Beijing Electron Positron Collider (BEPC)

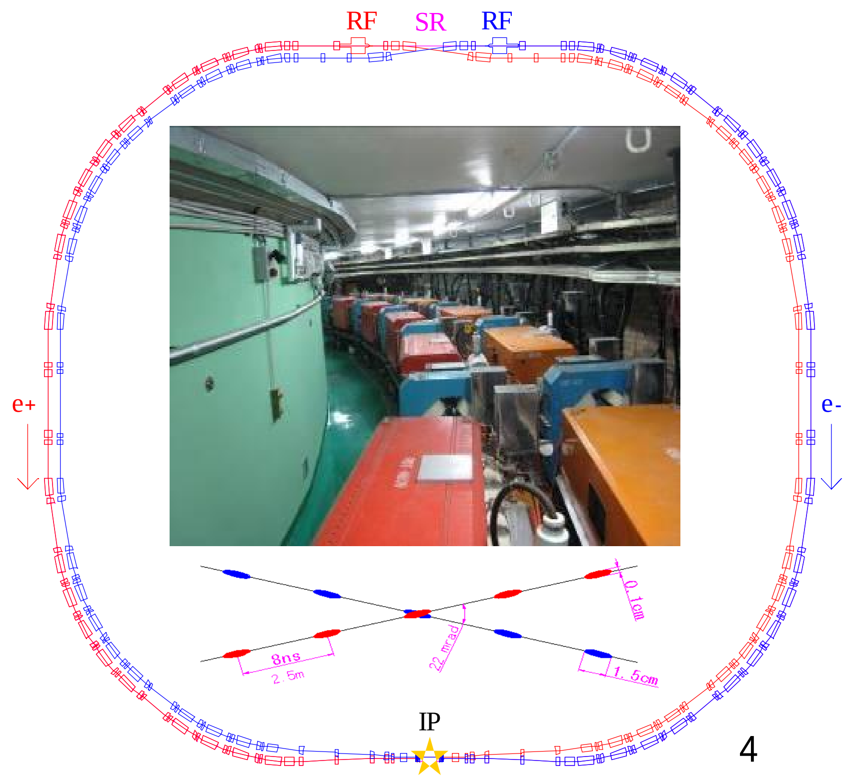
1. Introduction on BEPCII

BEPCII — An upgrade project of BEPC

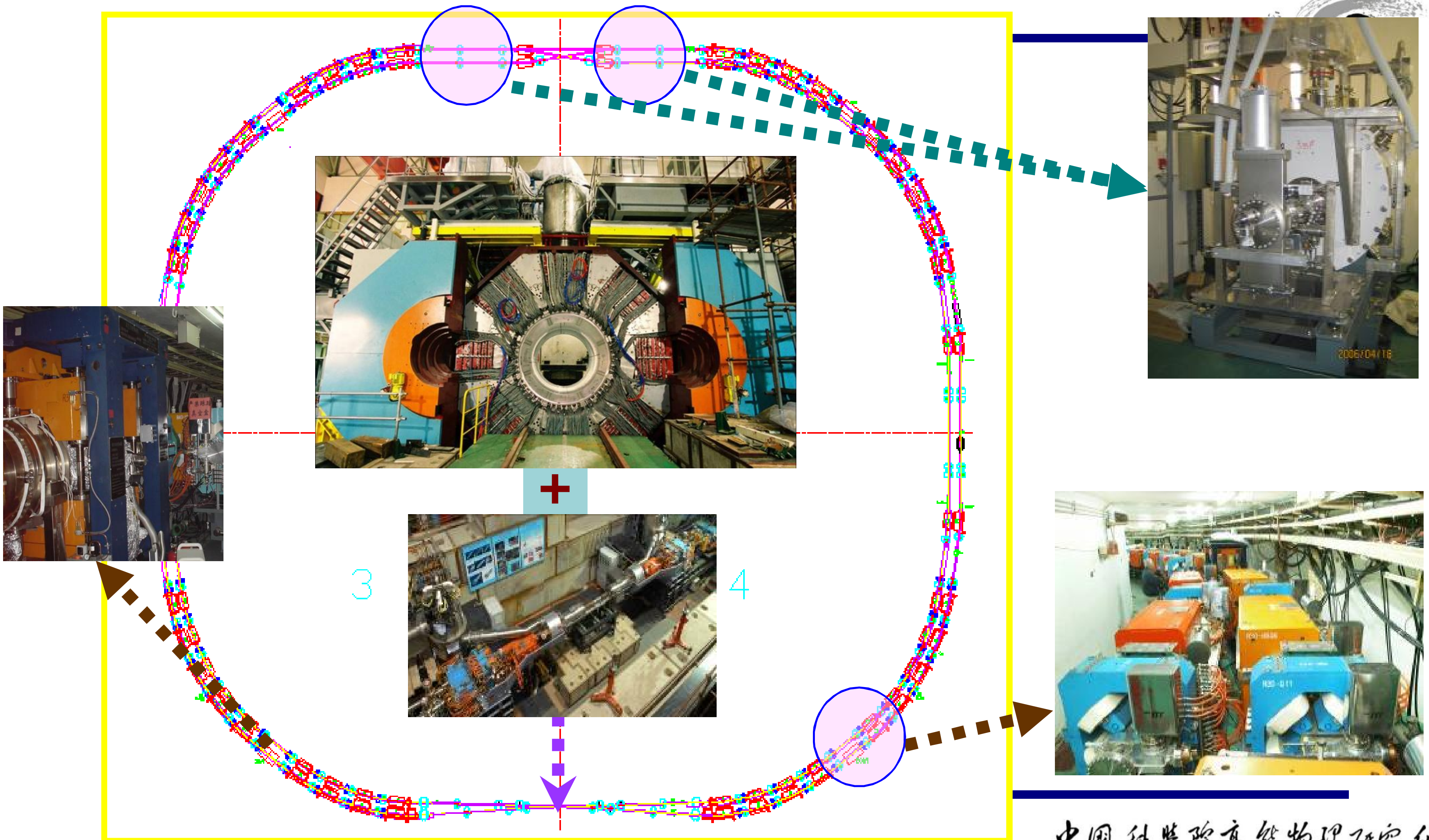
— A double-ring factory-like machine

— Deliver beams to both HEP & SR





3-ring structure



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Design Goals of BEPCII

Collision

- Beam energy range — 1-2.1 GeV
- Optimized beam energy — 1.89 GeV
- Luminosity — 1×10^{33} $cm^{-2}s^{-1}$ @1.89 GeV
- Full energy injection — 1-1.89 GeV

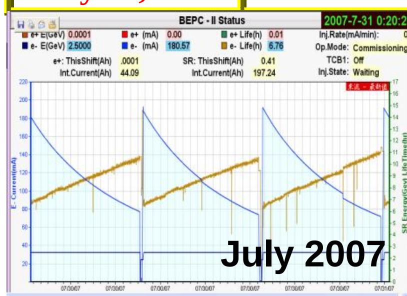
Synchrotron radiation

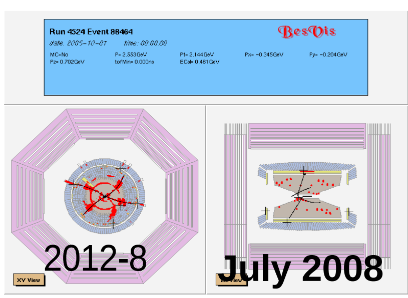
- Beam energy — 2.5 GeV
- Beam current — 250 mA
- Keep the existing beam lines unchanged

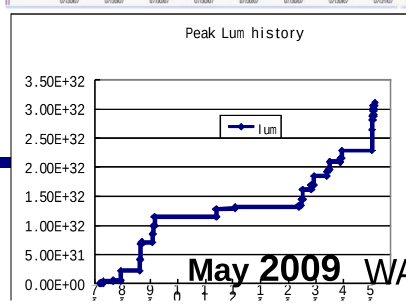
BEPCII: One-machine, Two-purpose (HEP, SR)

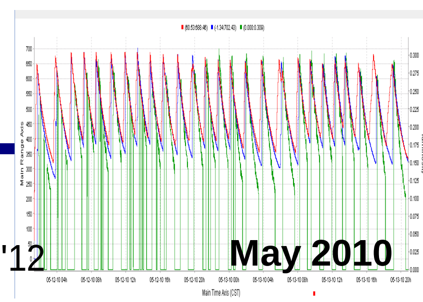
The Milestones

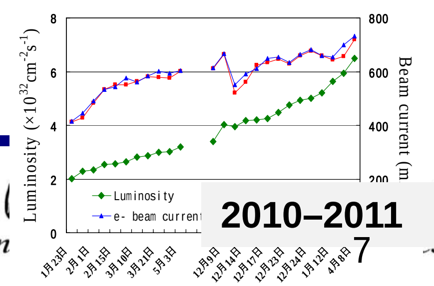
January 2004	Construction started
May. 4, 2004	Dismount of 8 linac sections started
Dec. 1, 2004	Linac delivered e⁻ beams for BEPC
July 4, 2005	BEPC ring dismount started
Mar. 2, 2006	BEPCII ring installation started
Nov. 13, 2006	Phase 1 commissioning started
Aug. 3, 2007	Shutdown for installation of IR-SCQ's
Oct. 24, 2007	Phase 2 commissioning started
Mar.28, 2008	Shutdown for installation of detector
June 24, 2008	Phase 3 commissioning started
July 19, 2008	First hadron event observed
May 19, 2009	Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$









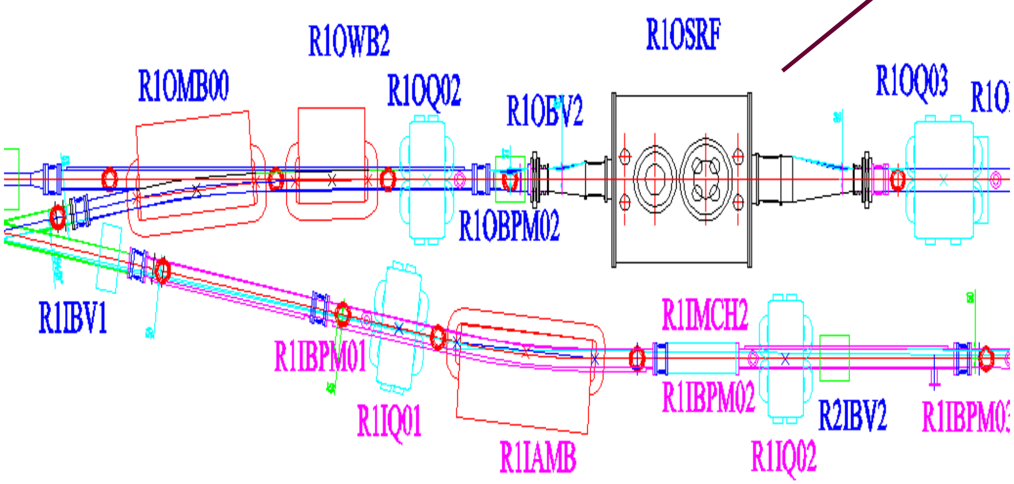


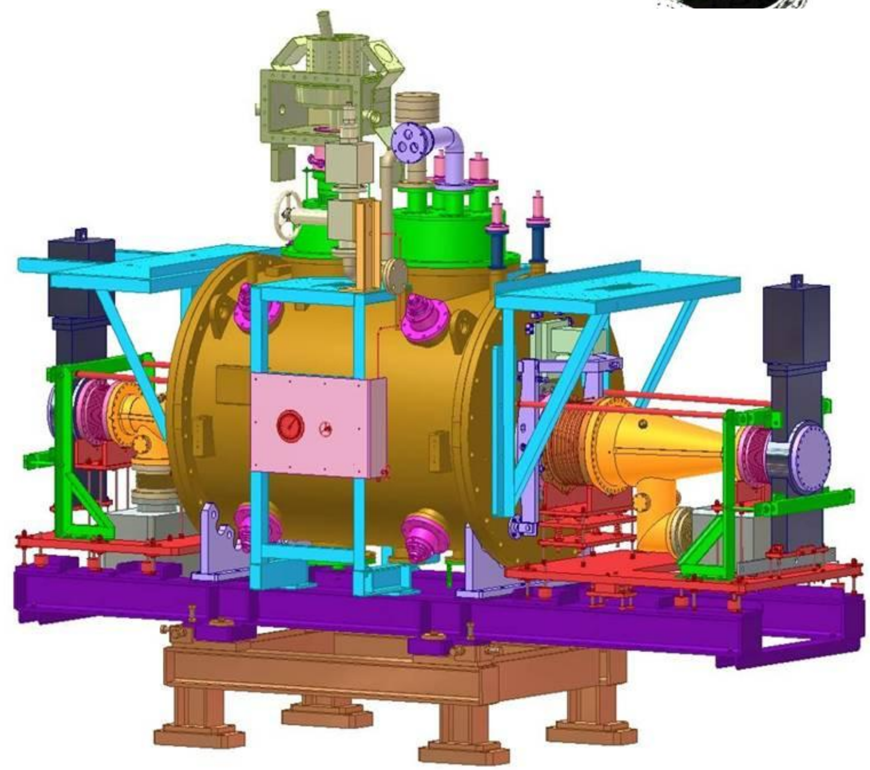
2. Why we chose superconducting items

In the BEPCII, there are

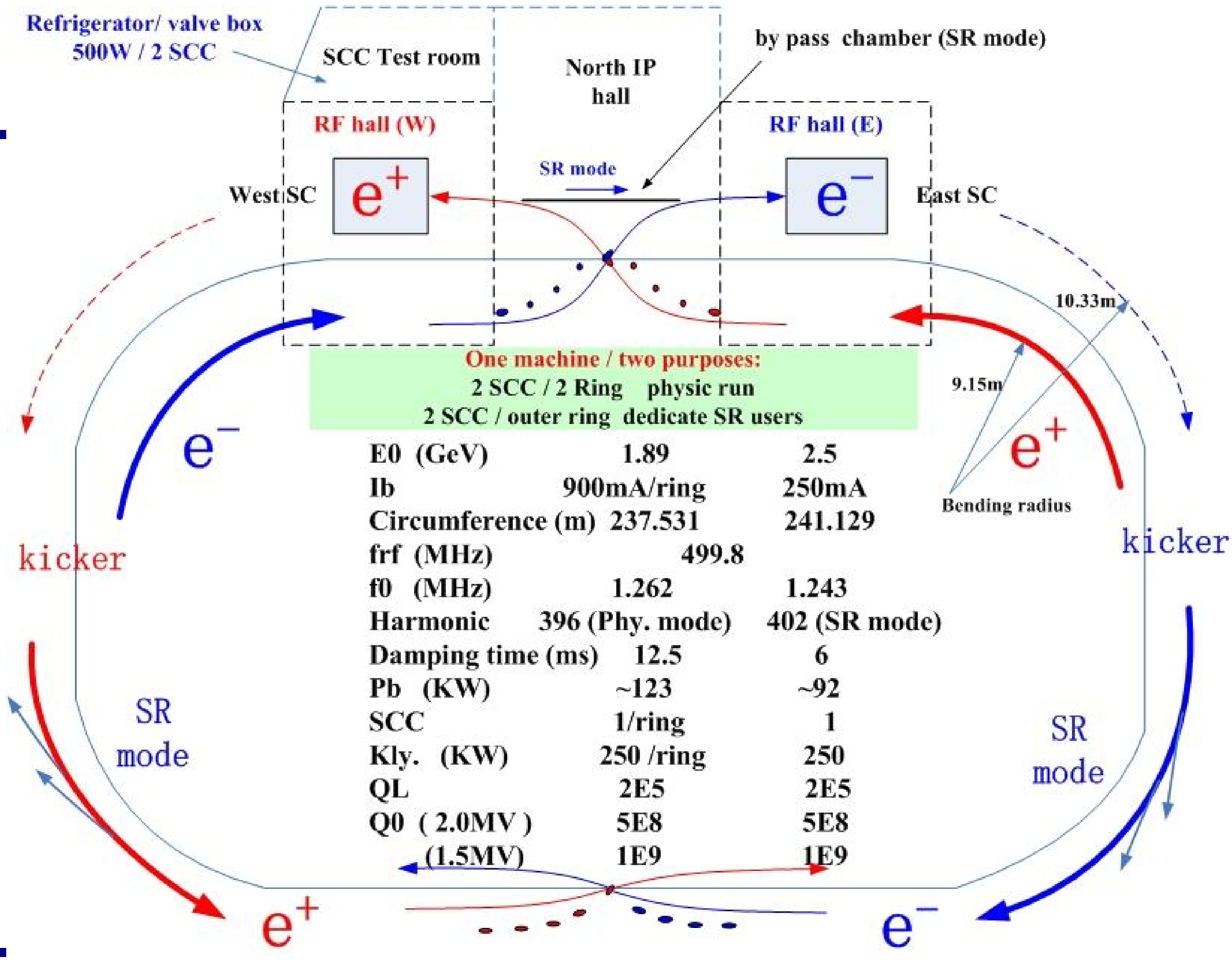
- Two SC RF cavities (SRF)

— one cavity/ring





- SC RF



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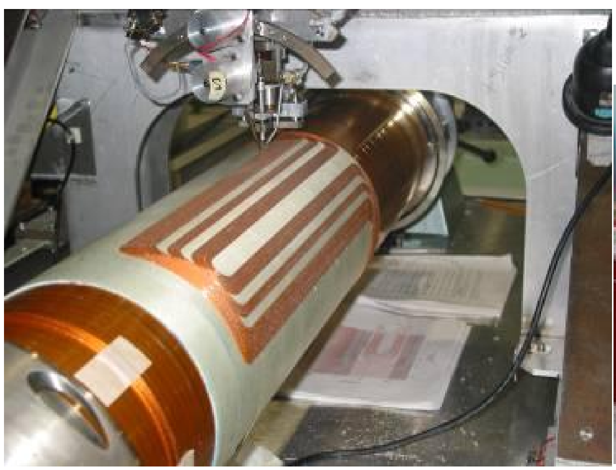
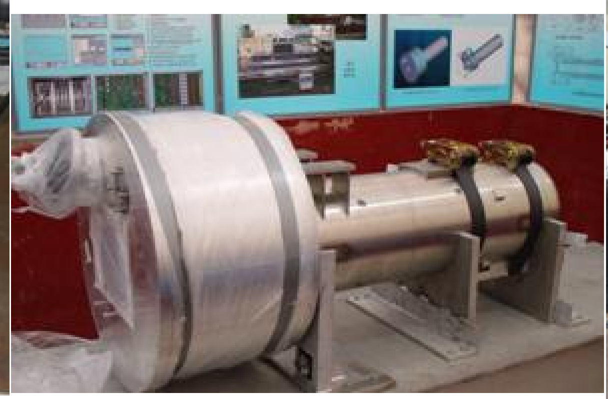
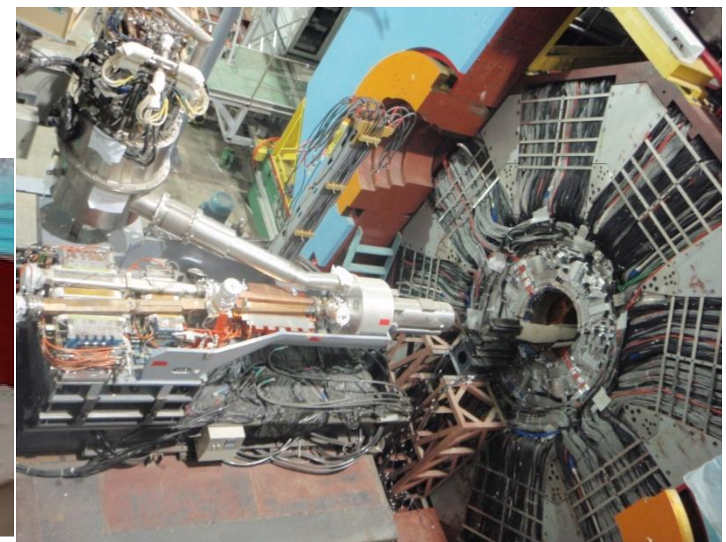
- In the CD0, 3 NC RF cavities were used instead of 1 SRF each ring, providing energy to beams with a reasonable bunch lengthening.
- To save the longitudinal space of each ring, and develop the technology of SC RF, we decided to use SC RF cavity in the BEPCII

- Two SC quad/multipolar insertion magnets (SIM) near the interaction point

— one SIM/ring

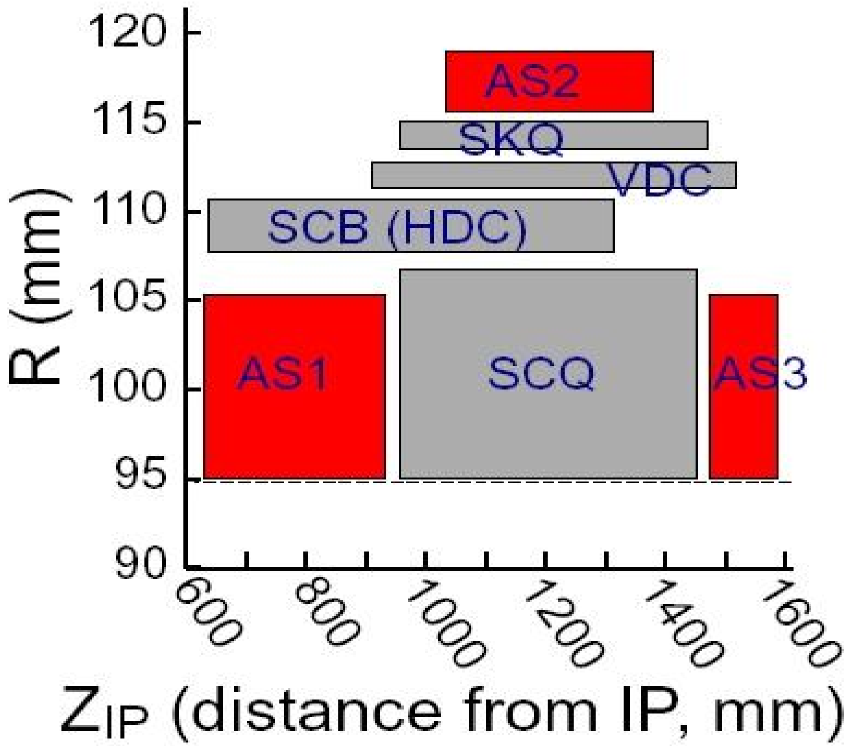




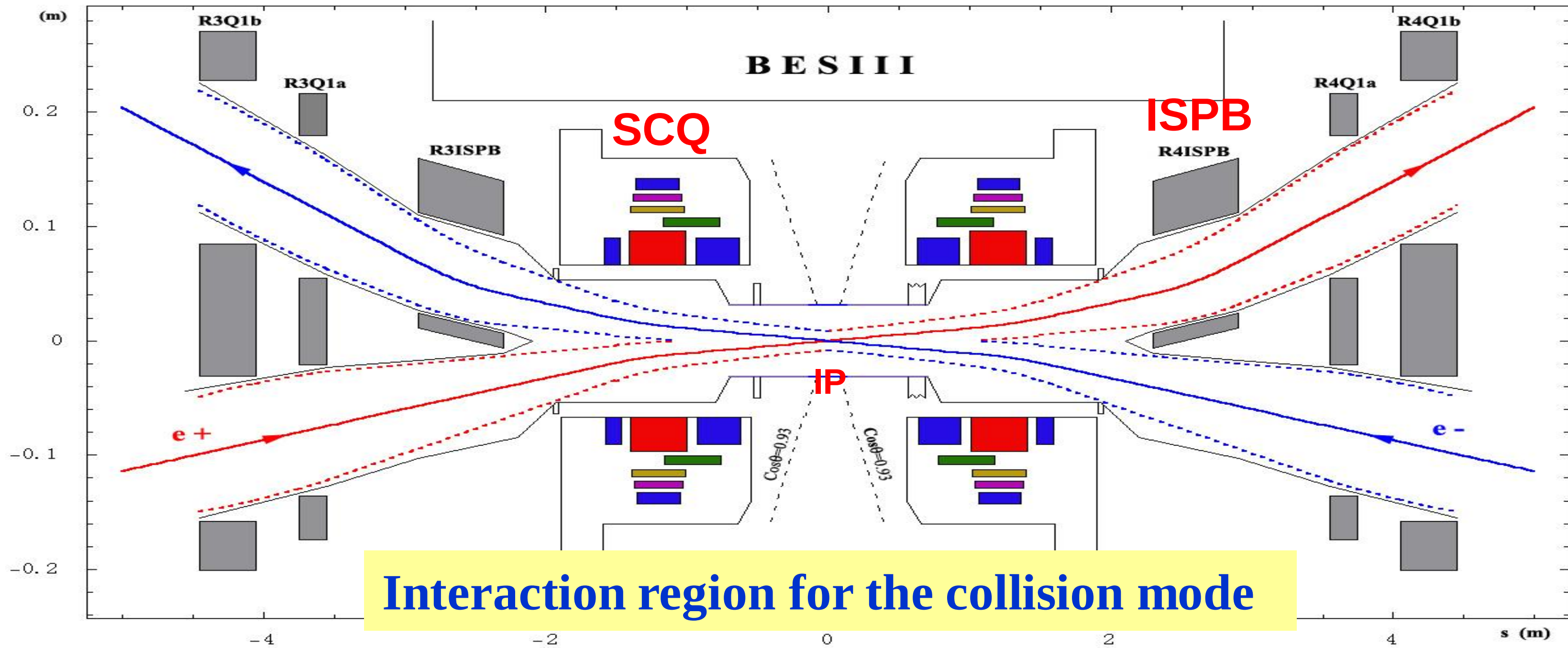


- A compact multipole-coil designed to squeeze β_y^*, compensate coupling caused by the detector solenoid, bend beam to outer ring in SR mode, tune orbit and coupling by corrector and skew quad coils.
- SIM used for above aim, saving the space in IR, increasing the strength of quad.
- A scheme of permanent squad near IP was also considered, but not as good as SC scheme.

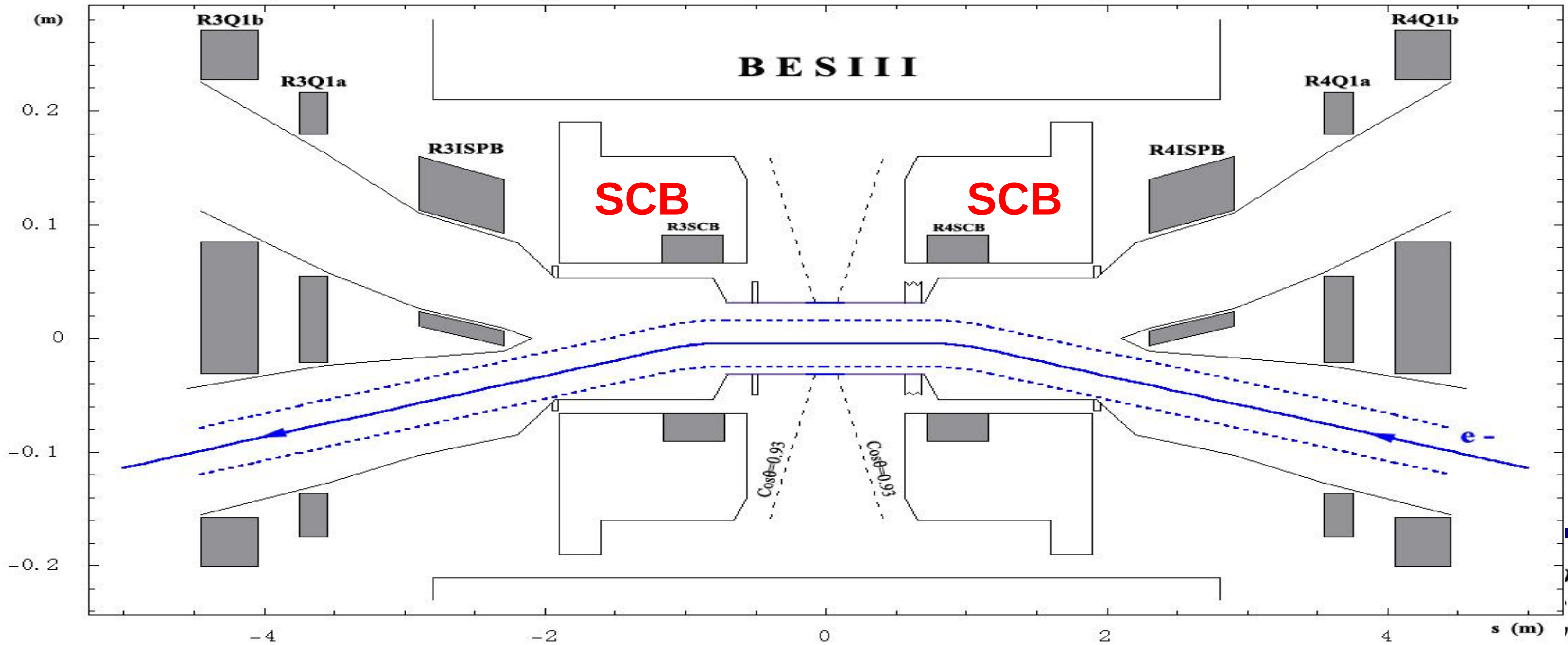
Coil winding layout of SC IR magnet (SIM)



Name	Layers	Conductor
SCQ	8	7 strand cable
SCB (HDC)	2	7 strand cable
VDC	2	1 strand wire
SKQ	2	1 strand wire
AS1	6	MRI wire
AS2	2	MRI wire
AS2	6	MRI wire



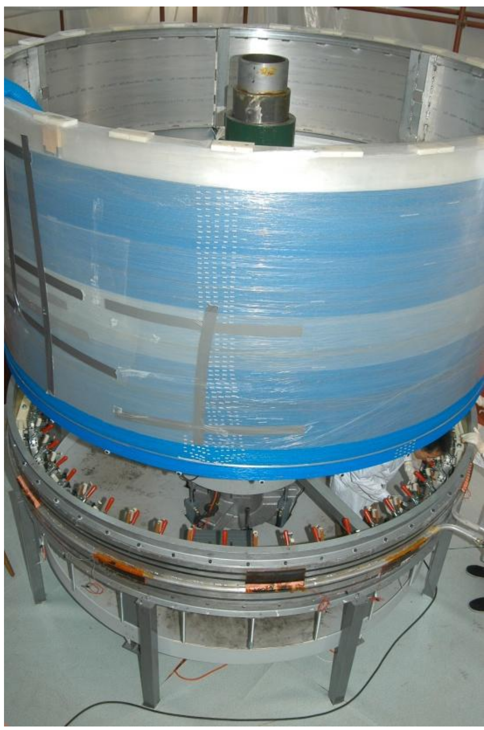
Interaction region for the collision mode

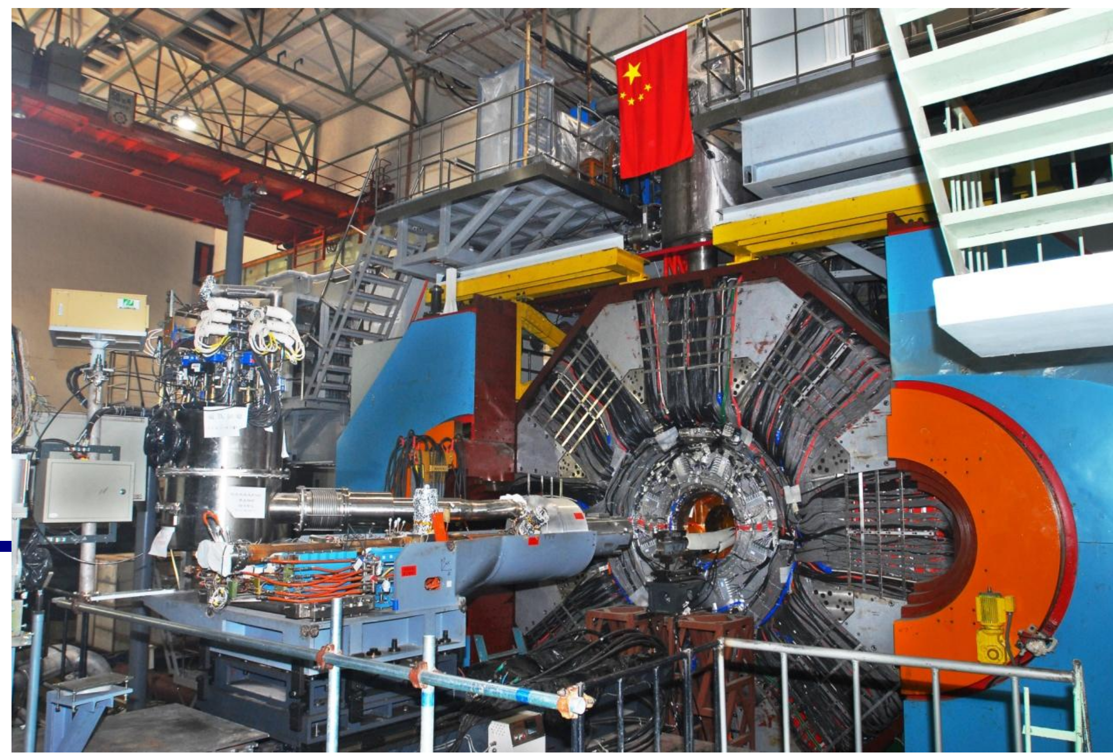


Interaction region for the dedicated SR mode

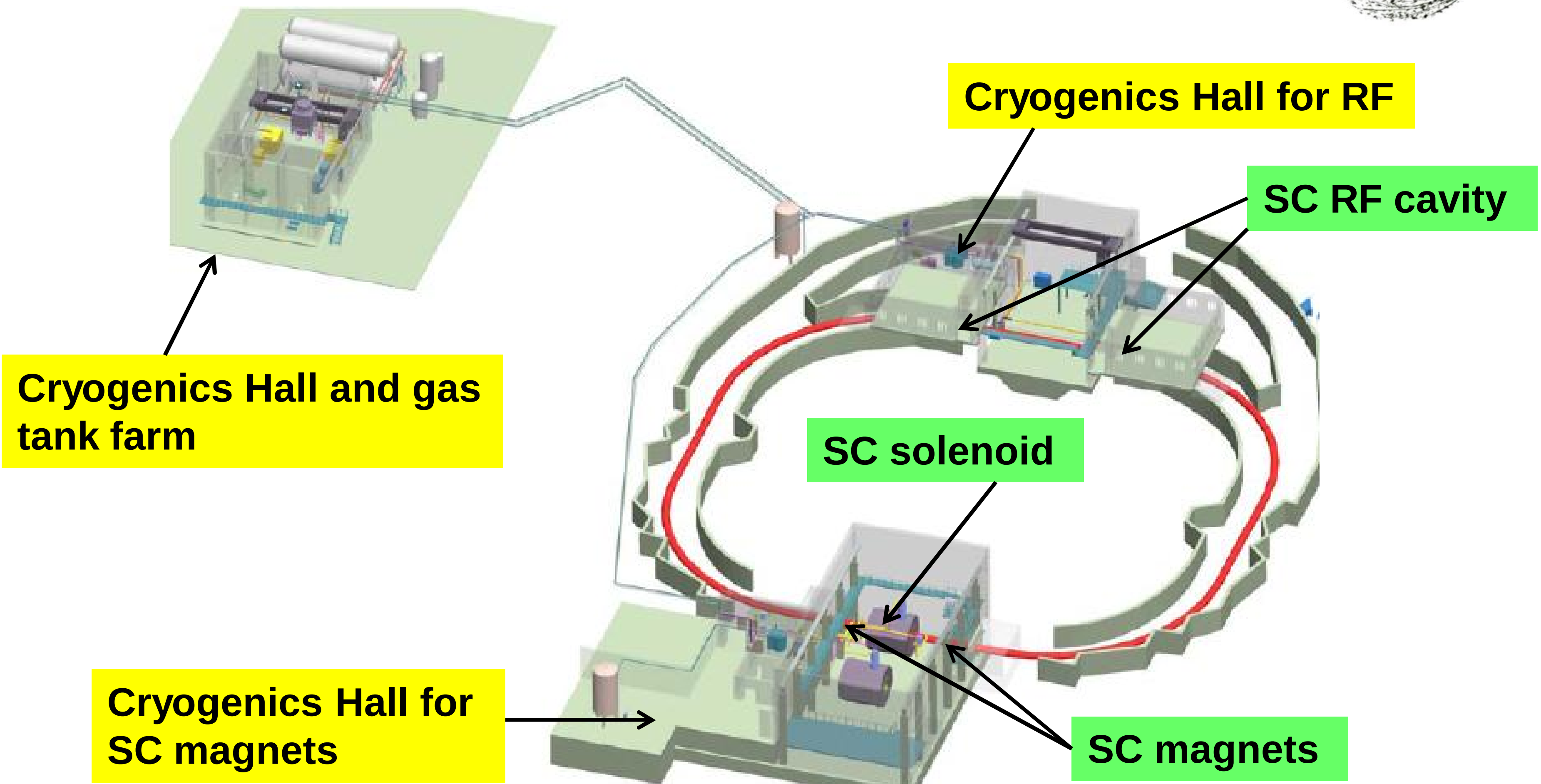
- One SC solenoid magnet (SSM) in the detector of BES III

— Higher solenoid field (1.0 Tesla) compared to BES I and BES II (0.4 Tesla), having better resolution.





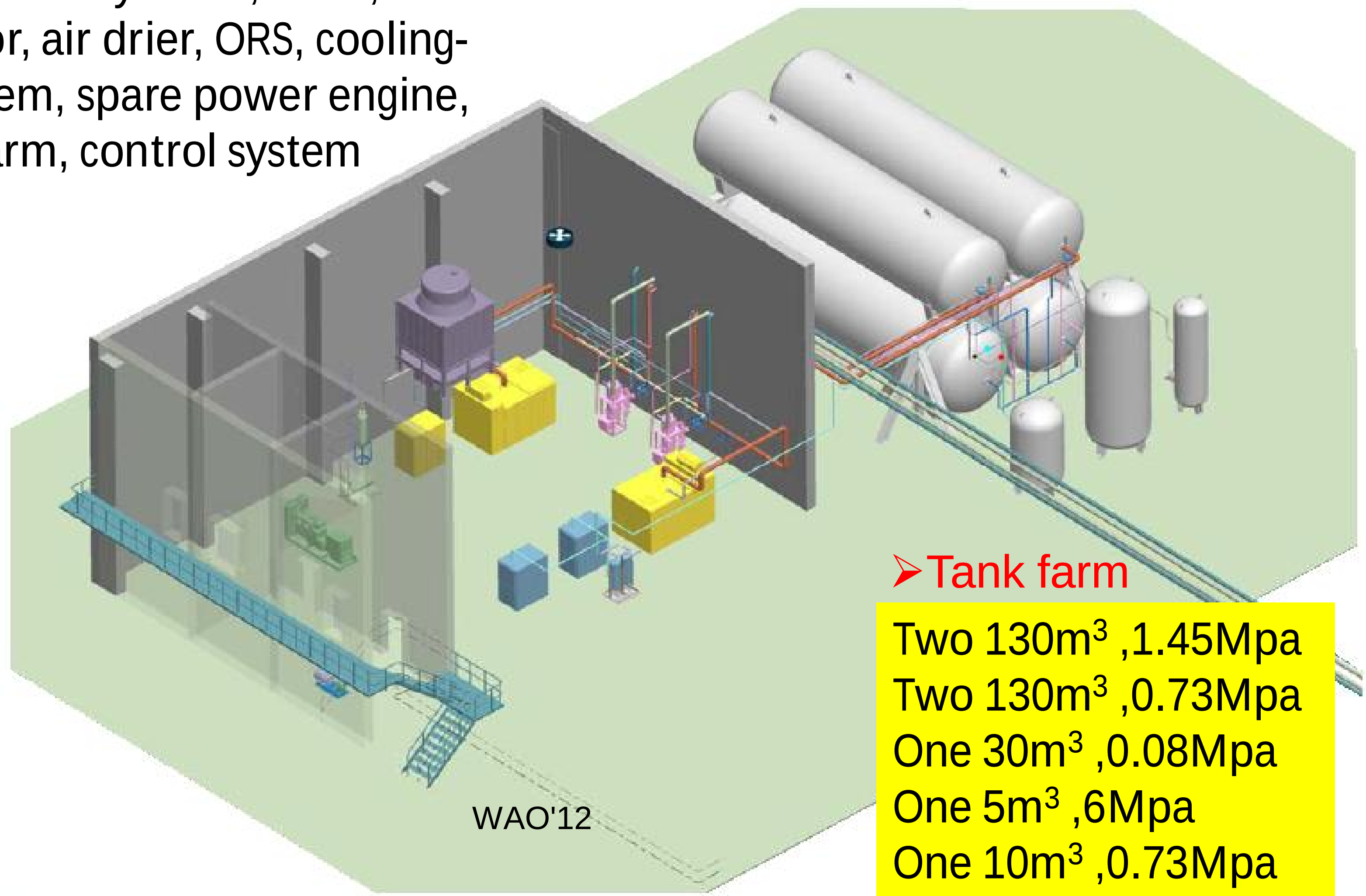
Cryogenic system of BEPCII



Cryogenic hall and gas tank farm

Contains:

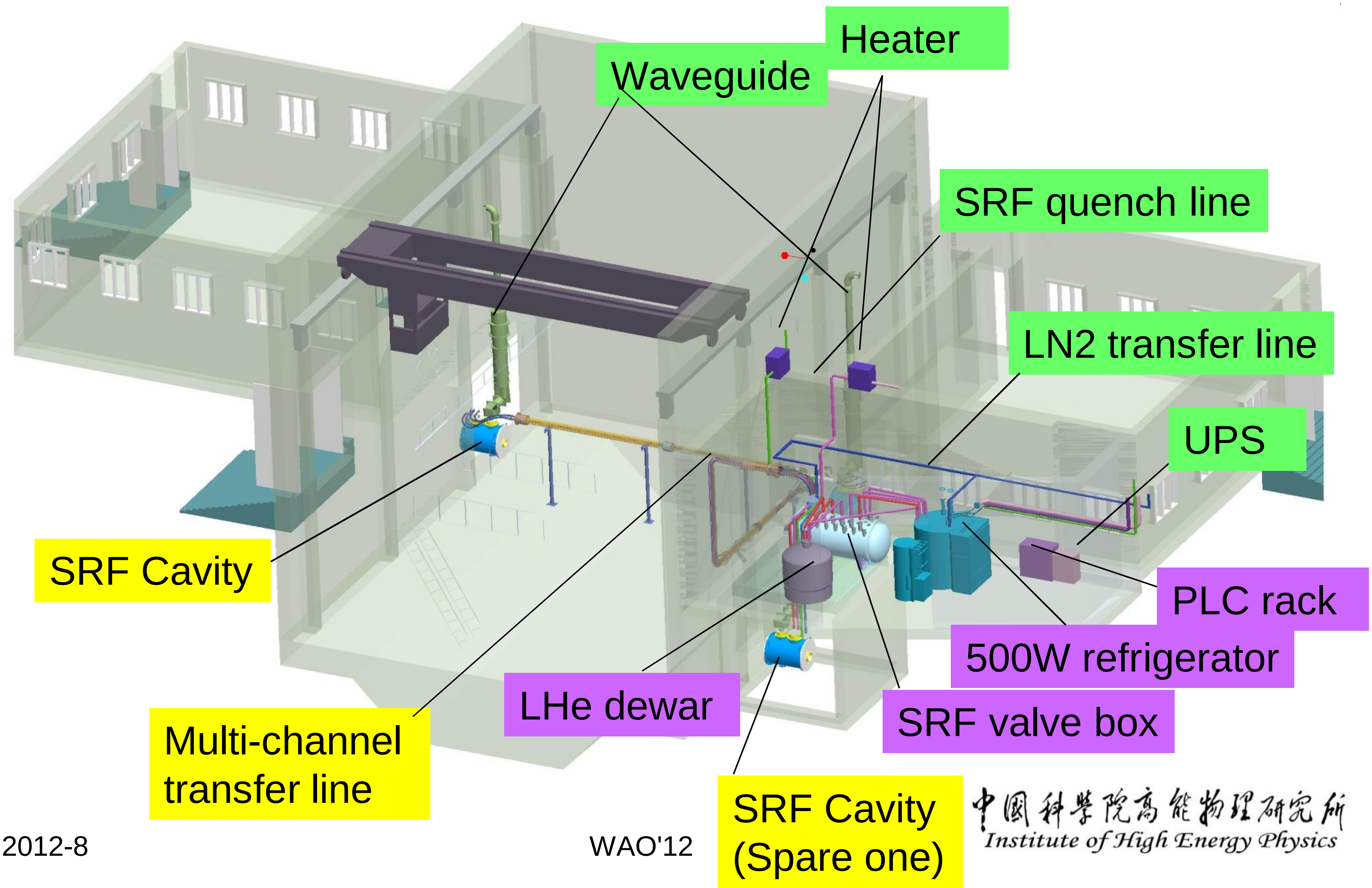
He compressor systems, VFDs, air compressor, air drier, ORS, cooling-water system, spare power engine, gas tank farm, control system



➢Tank farm

Two 130m^3 ,1.45Mpa
Two 130m^3 ,0.73Mpa
One 30m^3 ,0.08Mpa
One 5m^3 ,6Mpa
One 10m^3 ,0.73Mpa

BEPCII north crossing point region



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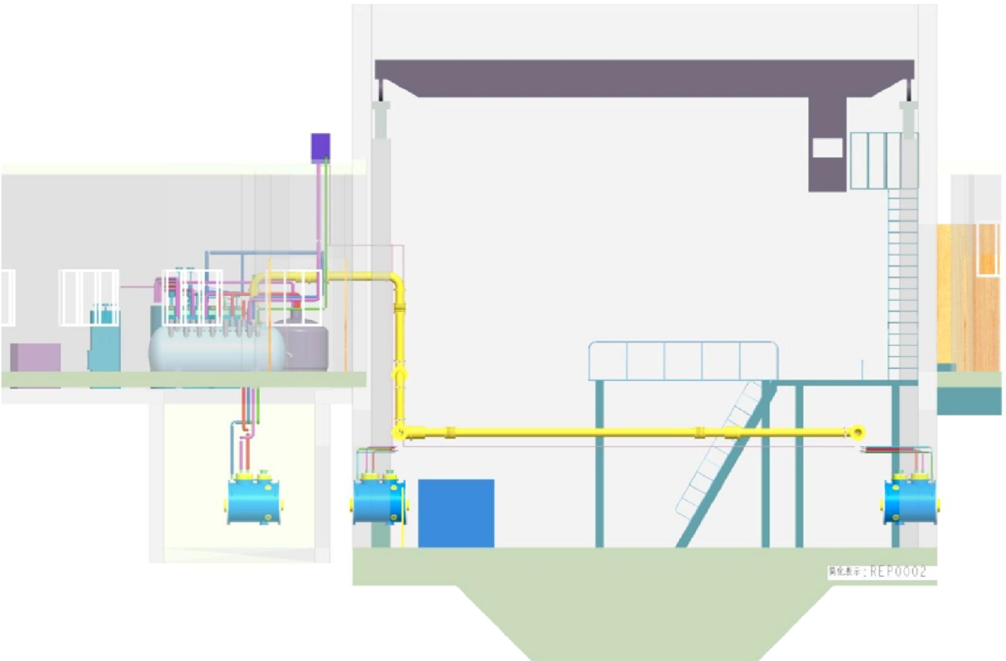
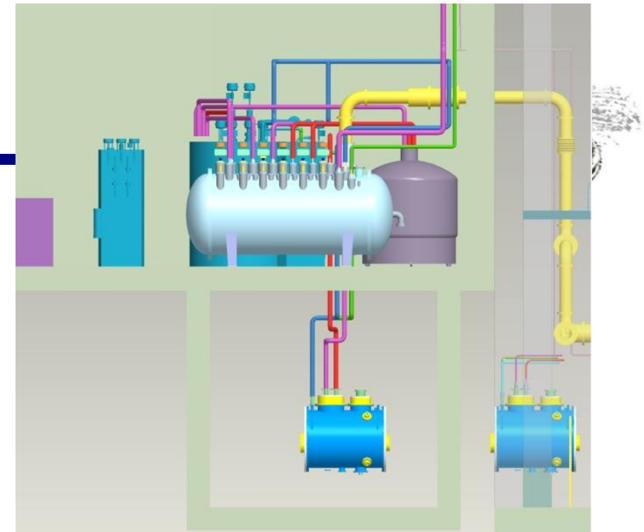
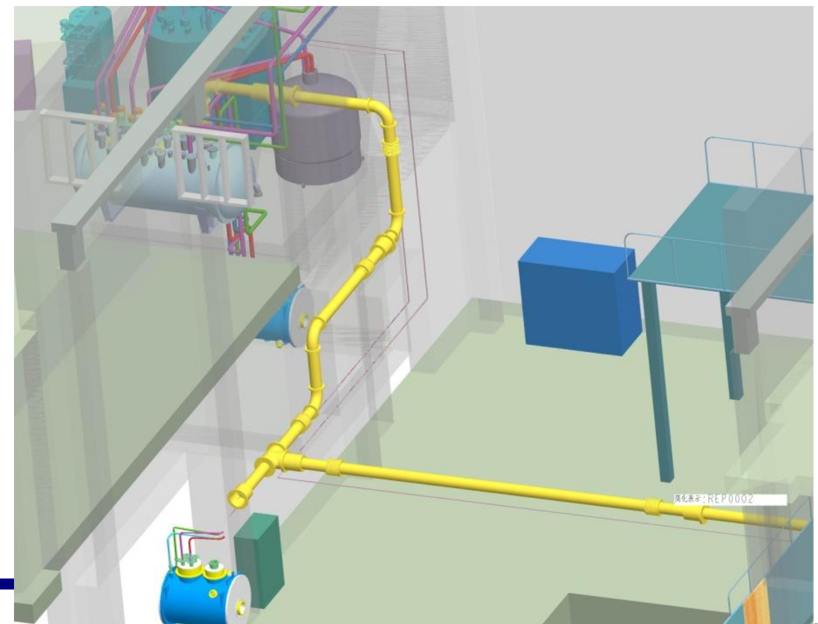
NCP hall and cryogenics facilities







Cryogenic transfer line

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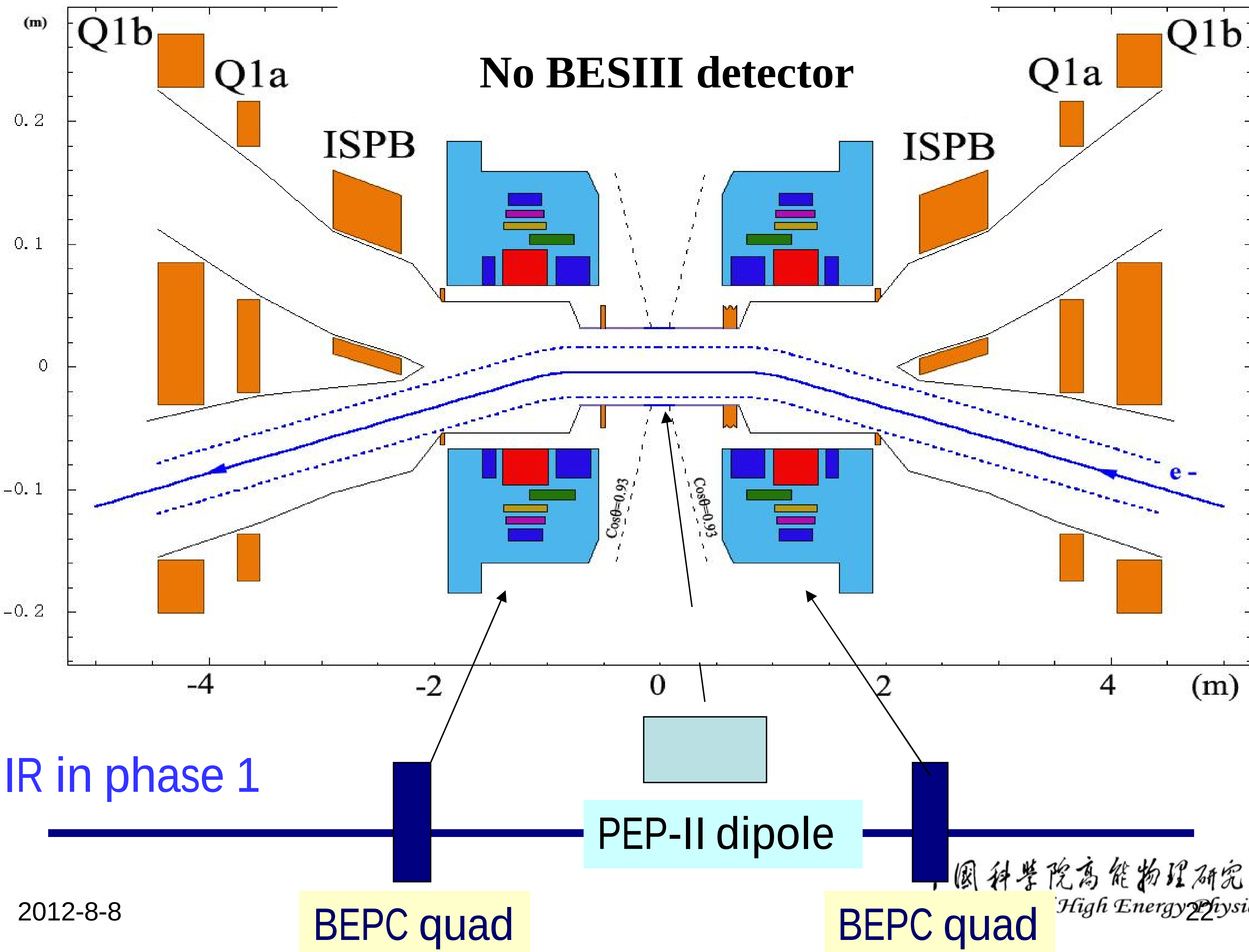
- The total cooling capacity of the cryogenic system of BEPCII is 1kW/4.5K, with the power supply requirement of 800kW.
- Two independent refrigerator systems, each with a cooling capacity of 500W/4.5K, are adopted to cool the SC magnets and SC RF cavities.
- Possible area to set up all the cryogenic system with He transport lines, is the base of adopting SC technology at the BEPCII

3. How superconducting affects operation

- Both superconducting and cryogenics system were new to us at the beginning of the commissioning in 2006.
- Vertical and horizontal tests of SC RF cavities were finished in May 2006, and ready for operation.
- SC magnets and solenoid were not ready, so a NC scheme was first adopted to run the machine, called phase 1.
- SIM was installed in 2007, and commissioned as phase 2. SSM and detector were rolled in IR in 2008, commissioned as phase 3.
- This helped us to get experiences of SC and cryogenic stuffs step by step during operation.

IR in phase 1



No BESIII detector
Q1b
Q1a
ISPB
Q1a
Q1b
ISPB
(m)
0.2
0.1
0
-0.1
-0.2
-4
-2
0
2
4
(m)
Cosθ=0.93
Cosθ=0.93
e -
PEP-II dipole
BEPC quad
BEPC quad

3-phase of BEPCII storage ring commissioning

Oct. 2006, Installation completed with NIM at IR

Nov 18, 2006 First beam stored

Mar 26, 2007 First collision

May 14, 2007 Luminosity reached that of BEPC

Phase 1

Oct. 2007, Installation completed with SIM at IR

Oct. 24, 2007 First beam stored

Nov. 18, 2007 First collision

Jan. 29, 2008 Luminosity > $1\times10^{32}cm^{-2}s^{-1}$

Phase 2

2008 June. Installation completed with BESIII in the IR

July 19, 2008 First hadron event got with BESIII

April 8, 2009 Luminosity reached $2.3\times10^{32}cm^{-2}s^{-1}$

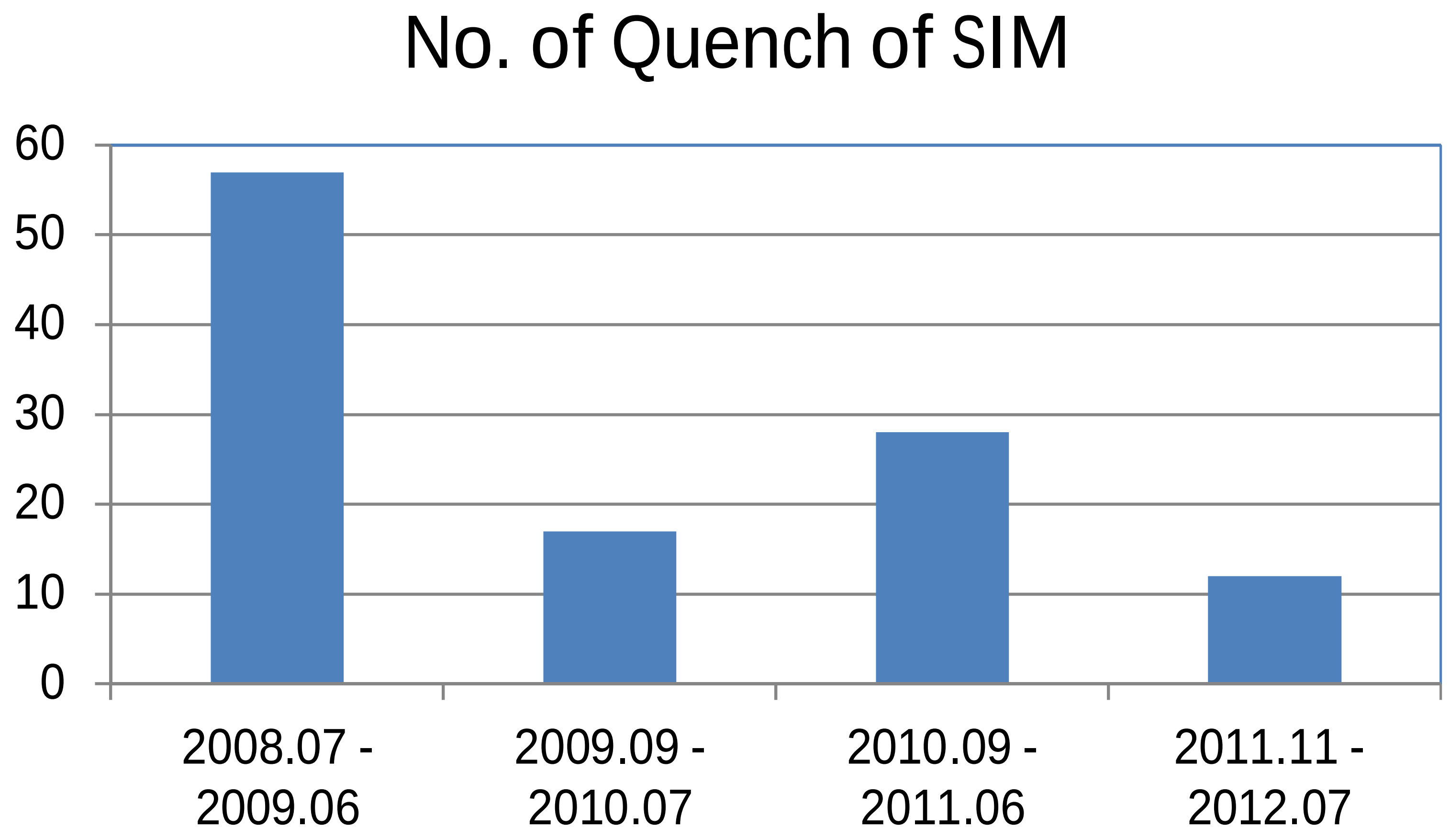
May19, 2009 Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$

Phase 3

Main problems we met

- Quench – SRF & SC magnets

- Quench protection systems were setup to analyze the reason of quench – SC items problem or due to cryogenic system problem, hardware or software problems, etc.
- Recover the SC devices carefully after getting the reason of quench in detail.
- Quench of SIM happened frequently at the beginning of commissioning, and now decreased gradually.
- Very few quench happened to SSM of detector.



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- Cryogenic system failures
- ➢ Abnormal data of control system
- ➢ The purification problem of He gas (should be better than 99.99%), which can cause the ability of refrigerator lower
- ➢ Electrical device failures, such as switcher, etc.
- ➢ Aging of main parts, such as turbo of refrigerator
- ➢ Other uncontrolled force, such electricity down or fluctuation, thunder storm, strong wind, etc.

- Among all the fault time of cryogenic system, about 80% are abnormal data of control system and impure of He gas
- Features of cryogenic system:

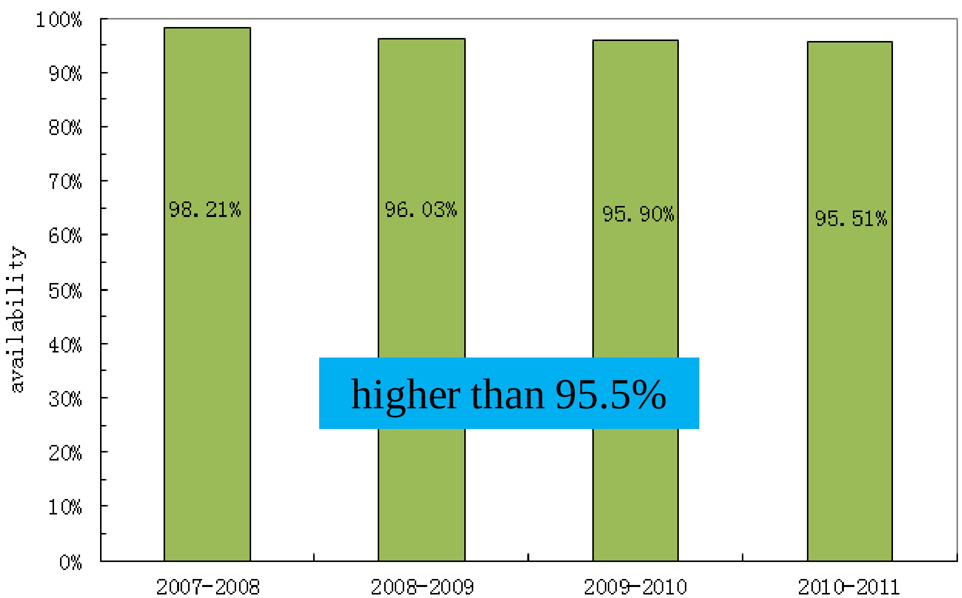
➢ Long time to recover SC status if failed due to any reason

➢ "Fragile" due to environment

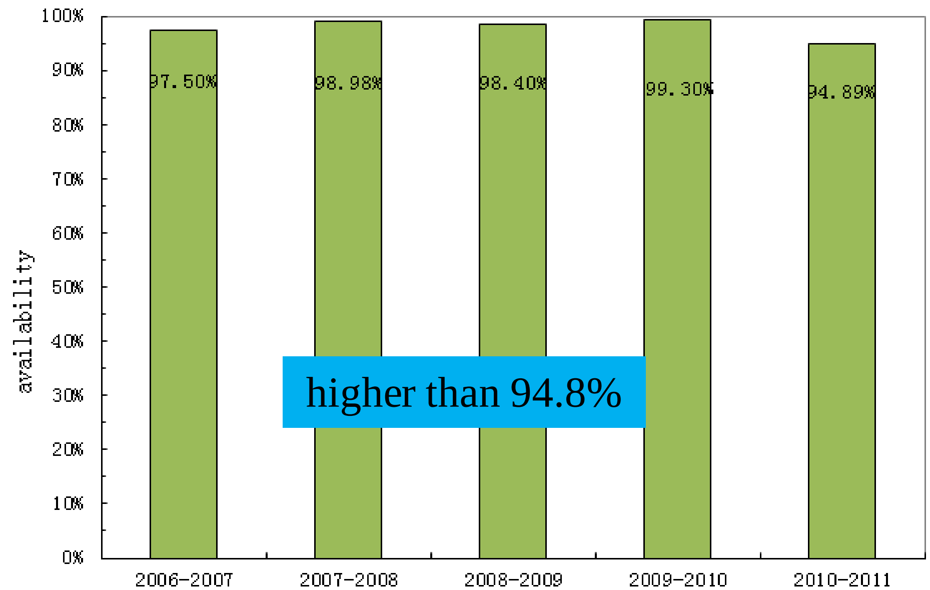
➢ A spare compressor was added last summer shutdown, and improved the performance this year.

Availability of BEPCII Cryogenics system

Availability of 1# cryogenic system
(for superconductive magnets)



Availability of 2# cryogenic system
(for superconductive cavity)



$$\text{Availability}(\%) = \frac{\text{TBF}}{\text{TBF+TTR}} \times 100\%$$

TBF: Time between failures

TTR: Time to repair and restoration system

4. What we benefit from superconducting

- Help the machine to get to its design goal in such a small ring tunnel
- Introduce SC to accelerator in main land China
- Master the accelerator related SC technology gradually
- Setup the first and biggest cryogenics system for large scientific facility in main land China
- Get experiences on SC and cryogenics performance, operation gets more and more smooth...

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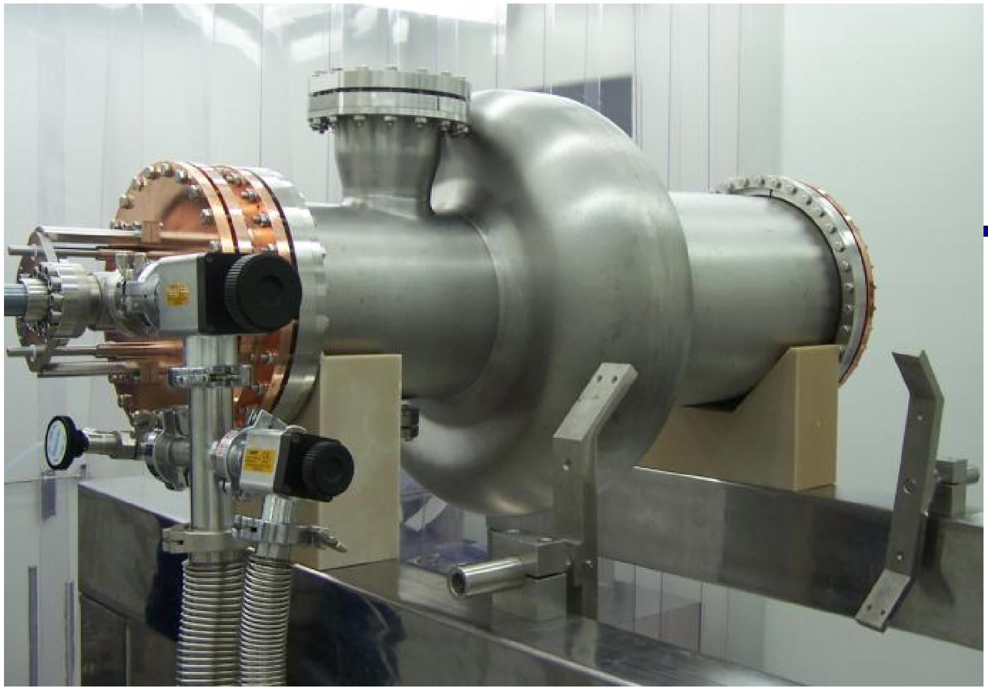
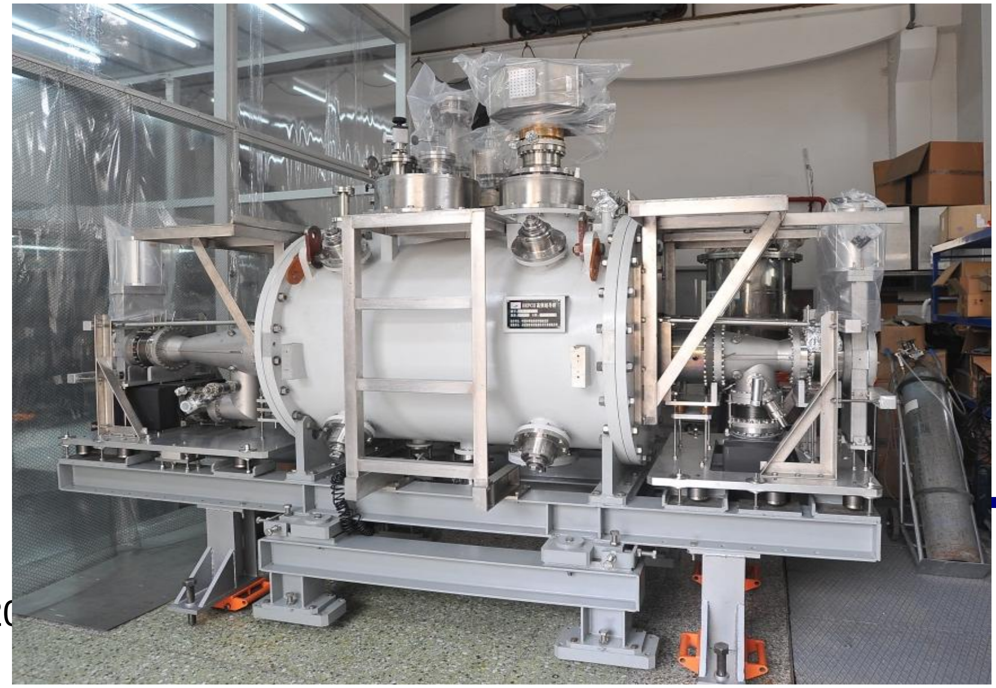
- From 2008, we started to study and manufacture the SC RF cavity, including cavity, HOM damper, high power coupler, cryo-module, etc., by ourselves.
- A spare SC RF cavity has been finished last year. Vertical and horizontal measurements were done in IHEP, and the main parameters are good enough. Now, it is on the tunnel site as a spare part.
- R&D of SC quad is being carried on in IHEP.





Summary

- SC technology used in BEPCII brought the SC application to accelerator in main land China.
- SRF and SC magnets run well in BEPCII, with design parameter of the hardware, and helped the whole machine to reach its design goal.
- Operation with SC and cryogenics is getting experienced, though they are sometimes vulnerable.
- SC benefits us not only on the machine itself, but the technology development.

Thanks for your attentions!