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中国有色集团成员企业

OTIC超导铌材和射频超导腔加工及 产业化

OTIC Niobium and SCRF activity and industrialization

宁夏东方钽业股份有限公司
Ningxia Orient Tantalum Industrial Co.,Ltd.
2022

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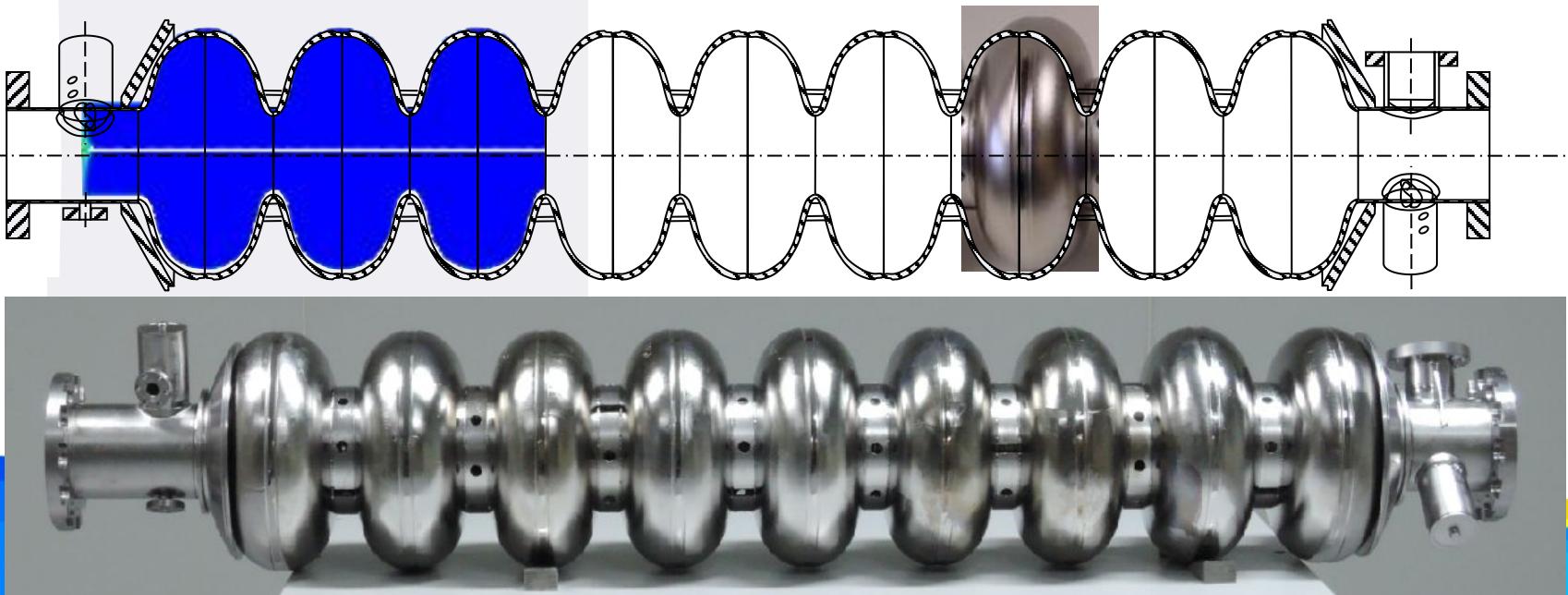
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1. 粒子和SCRF加速器 Particles and SCRF accelerator

SRF腔主要由高纯铌材制成，用于粒子加速器。SRF腔在4.2K液氦温度下工作，达到超导状态。在高频电场的作用下，对内部真空室的电子、质子和重离子加速。

The SRF cavity is mainly made of high purity niobium and used in particle accelerator. The SRF cavity operates below 4.2K liquid helium temperature and reaches superconducting state. Under the action of high frequency electric field, the electron, proton and heavy ion passing through the internal vacuum chamber are accelerated.



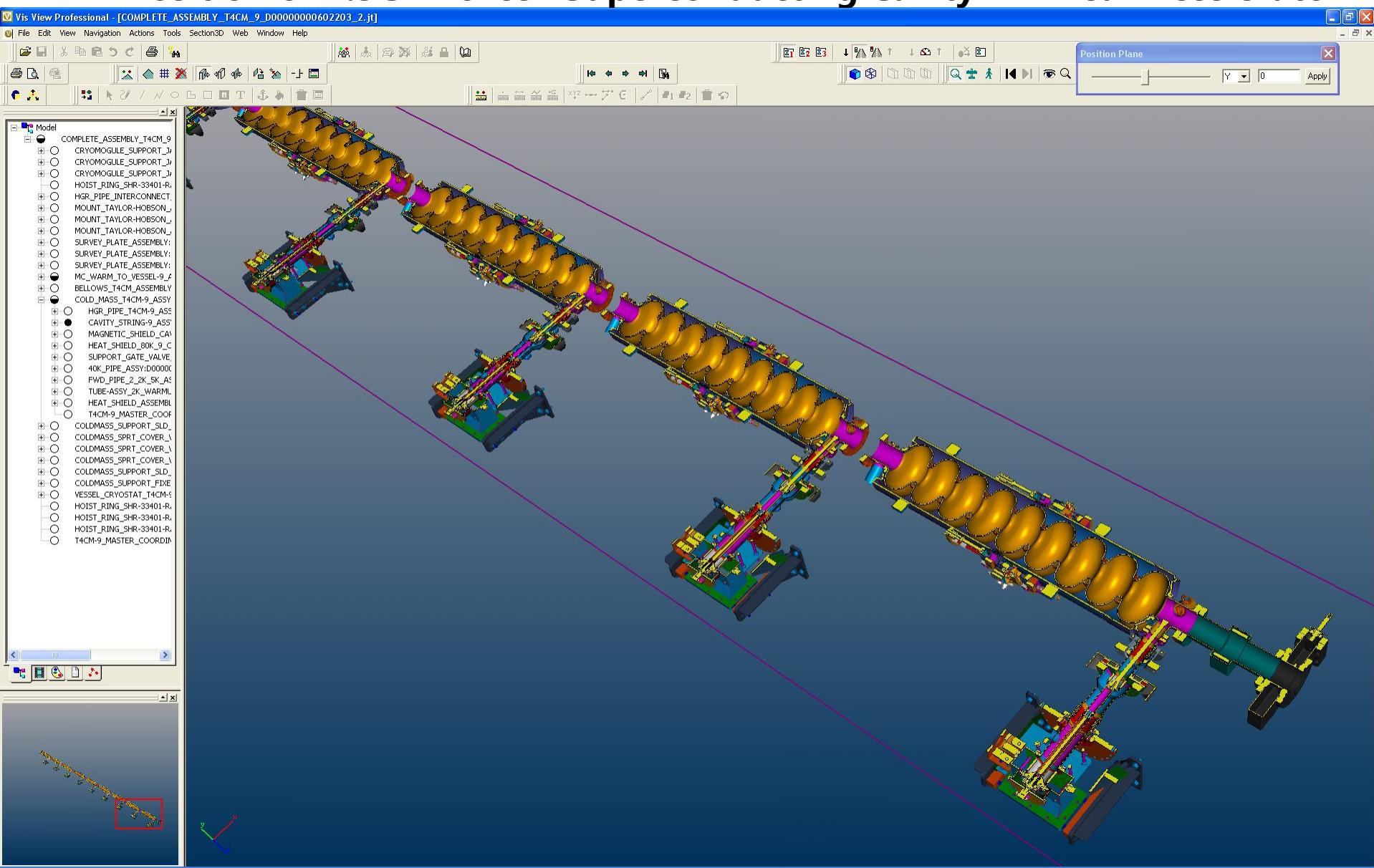
1.粒子和SCRF加速器Particles and SCRF accelerator

1.3GHz 9单元超导腔在直线加速器中的位置研究

Position of 1.3GHz 9-cell Superconducting Cavity in Linear Accelerator



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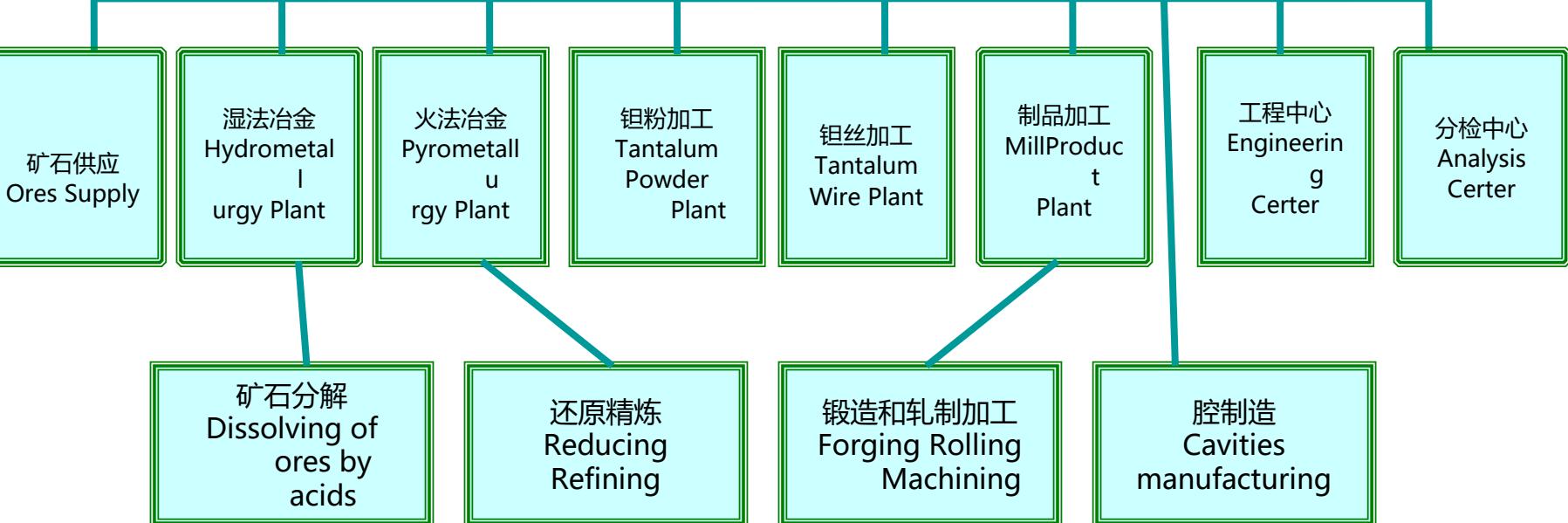
2. OTIC简介 Brief Introduction of OTIC



宁夏东方钽业股份有限公司
Ningxia Orient Tantalum Industry Co., Ltd
(OTIC)

宁夏有色金属进出口公司
Ningxia Nonferrous Imp. &
Exp. Corp.

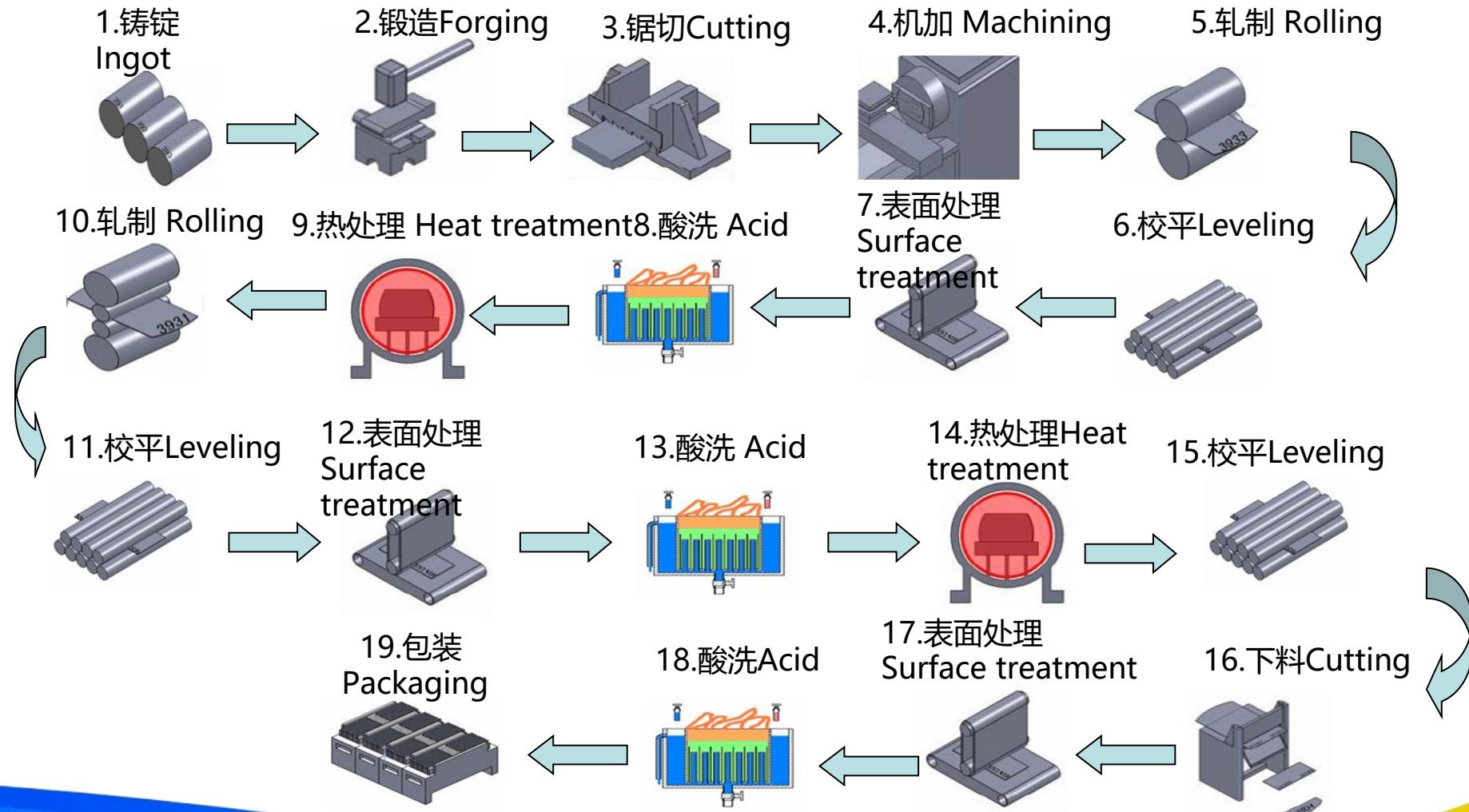
宁夏东方超导体科技有限公司
Ningxia Orient Superconductor
Technology Co.,Ltd.



2. OTIC简介 Brief Introduction of OTIC



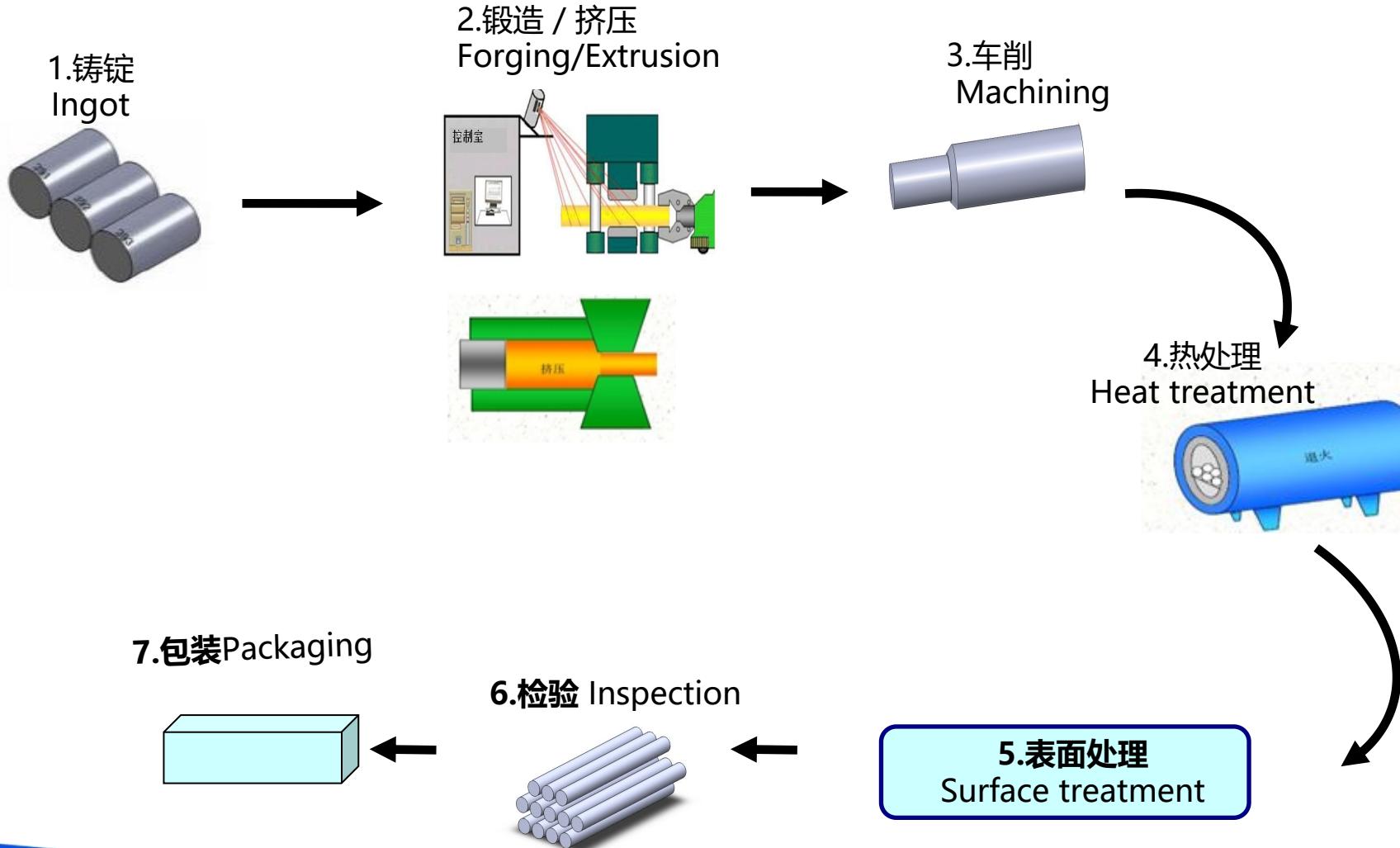
铌板加工流程 Process Flow of Nb-sheet



2. OTIC简介 Brief Introduction of OTIC



铌管、棒加工流程 Process Flow of Nb-tube/rod



2. OTIC简介 Brief Introduction of OTIC



10000吨液压机设备
10000T hydraulic press equipment

通过对锻造工艺的研究：可以将RRR300高纯铌的晶粒尺寸控制在两级波动范围内。

Through the research of forging technology: the grain size of RRR300 high purity niobium could be controlled to fluctuate within two stages.

控制锻造过程中的温度变化:保证铌的RRR值大于300。

Control the temperature change in forging process: ensure that the RRR value of niobium is more than 300.

2. OTIC简介 Brief Introduction of OTIC



轧机和真空热处理设备 Rolling and vacuum annealing



二辊轧机
twin rolling mill

优化了轧制工艺，保证了RRR300铌材料的力学性能满足工艺要求。
有效去除加工应力，提高材料力学性能。

The rolling process is optimized to ensure the mechanical properties of RRR300 niobium materials meet the processing requirements.
Effective removal of processing stress, improve the mechanical properties of materials.



四辊轧机
4-rolling mill



真空退火炉
vacuum annealing
furnace

2. OTIC简介 Brief Introduction of OTIC



主要检测设备 Main inspection instruments

	分析项 Analysis items	分析方法 Analysis Method	RRR300 铌板 RRR300 Nb sheet	OTIC实测值 OTIC typical value
化学分析 Chemical analysis	C、S	高频加热红外吸收法 The high frequency heating infrared absorption method	≤10	≤10
	O、N	脉冲加热红外吸收法 The pulse heating infrared absorption method	≤10	≤10
	H	脉冲加热红外吸收法 The pulse heating infrared absorption method	≤2	≤2
	杂质 Impurity	电感耦合等离子体发射光谱法 Inductively coupled plasma emission spectrometry	Ta≤500, W≤70, Ti≤50, Fe≤30, Mo≤50, Si≤30	Ta≤100, W≤10, Ti≤5, Fe≤5, Mo≤10, Si≤10
剩余电阻比 RRR	RRR	四线法 4-point measurement method	RRR≥300	RRR≥300
机械性能 Mechanical properties	硬度 Hardness test	ASTM E - 384 or E92	HV≤60	HV < 60
	平均晶粒度 Average grain size	ASTM E - 112	ASTM 4-6#	ASTM 4-6#
	拉伸测试 Tensile test	ASTM E - 8	Elongation ≥30%	Elongation ≥50%

2. OTIC简介 Brief Introduction of OTIC

主要检测设备 Main inspection instruments



碳-硫测量仪 CS-600 carbon-sulphur analyzer



氧-氮量仪 TC-600 oxygen-nitrogen analyzer



全谱直读光谱仪 ICP full spectrum direct reading spectrometer



光谱仪 ICP-AES spectrometer

2. OTIC简介 Brief Introduction of OTIC



生产能力 Capacity

产品 Products	产量 Annual capacity	种类 Spec.
铌板 RRR Nb sheet	30吨 30 Tons	RRR40, RRR250, RRR300
铌管 RRR Nb tube	5吨 5 Tons	RRR40, RRR250, RRR300
铌棒 RRR Nb rod	10吨 10 Tons	RRR40, RRR250, RRR300

2. OTIC简介 Brief Introduction of OTIC



供货经验 Achievements

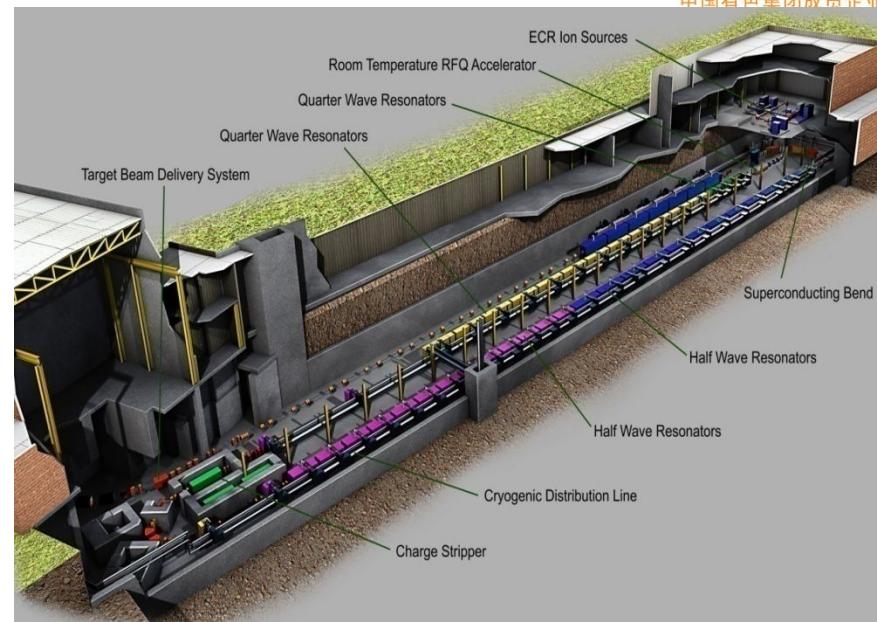
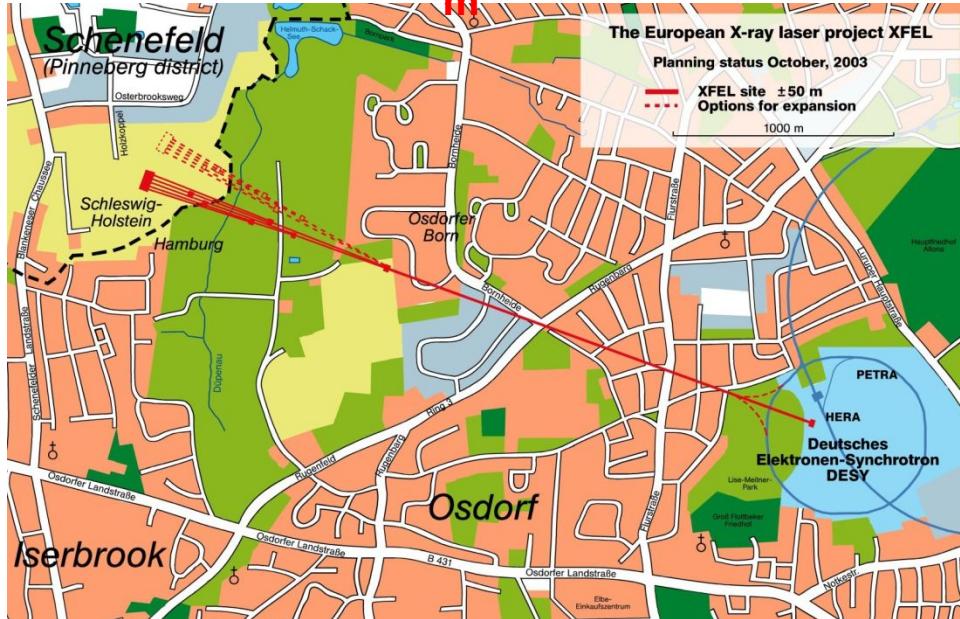


INFN公司现场检查 On-site inspection by INFN



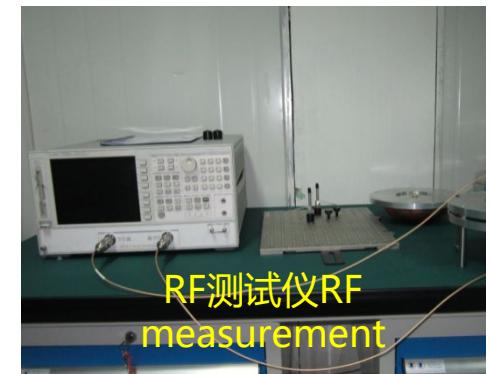
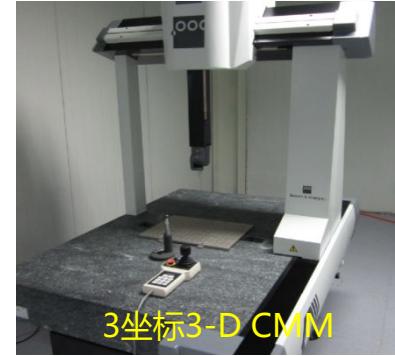
SHINE公司现场检查 On-site inspection by SHINE

2. OTIC简介 Brief Introduction of OTIC



- 2011 DESY – XFEL: 8吨RRR300铌板, 占项目总量的30%。
2011 DESY – XFEL: 8 tons RRR300 Nb sheets, 30% of the project
- 2012 MSU-FRIB: 8.5吨RRR250铌板, 占项目总量的70%。
2012 Michigan State University – FRIB: 8.5 tons RRR250 Nb sheets, 70% of the project
- 2014 Fermilab - LCLS II: 5吨RRR250铌板, 占项目总量的50%。
2014 Fermilab - LCLS II: 5 tons RRR300 Nb sheets, 50% of the project
- 2017 INFN & STFC – ESS: 10吨 RRR300铌板, 占项目总量的100%
2017 INFN & STFC – ESS: 10 tons RRR300 Nb sheets, 100% of the project
- 5、我们与许多大客户建立了业务关系, 如DESY、MSU、Fermilab、JLAB、INFN、STFC、CERN、TRIUMF、RI、E.ZANON、RRCAT等等。

3. SCRF研究和制造 Study and manufacture for SCRF



3. SCRF研究和制造 Study and manufacture for SCRF



BCP



HPR



EP for single-cell cavity



Vacuum furnace



Annealing

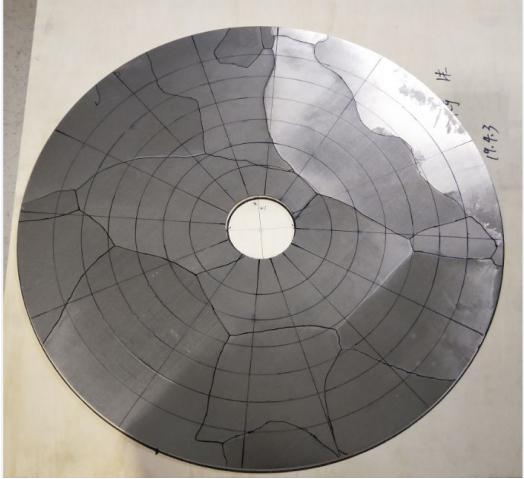
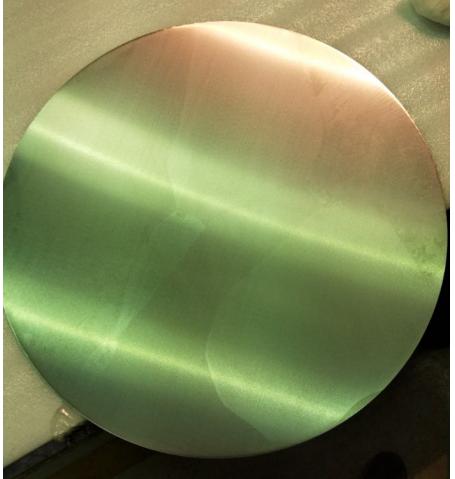


EP for 1.3GHZ-9cell cavity

3. SCRF研究和制造 Study and manufacture for SCRF



3. SCRF研究和制造 Study and manufacture for SCRF



大晶粒Nb盘和腔的制造

Large grain Nb disc and cavity manufacture

可将大晶粒RRR300 Nb盘片的最大直径加工至Φ540mm，满足CEPC 650MHz超导腔的制造要求。

目前，正在向上海硬x射线大科学基地供应大晶粒的大型Nb材料。

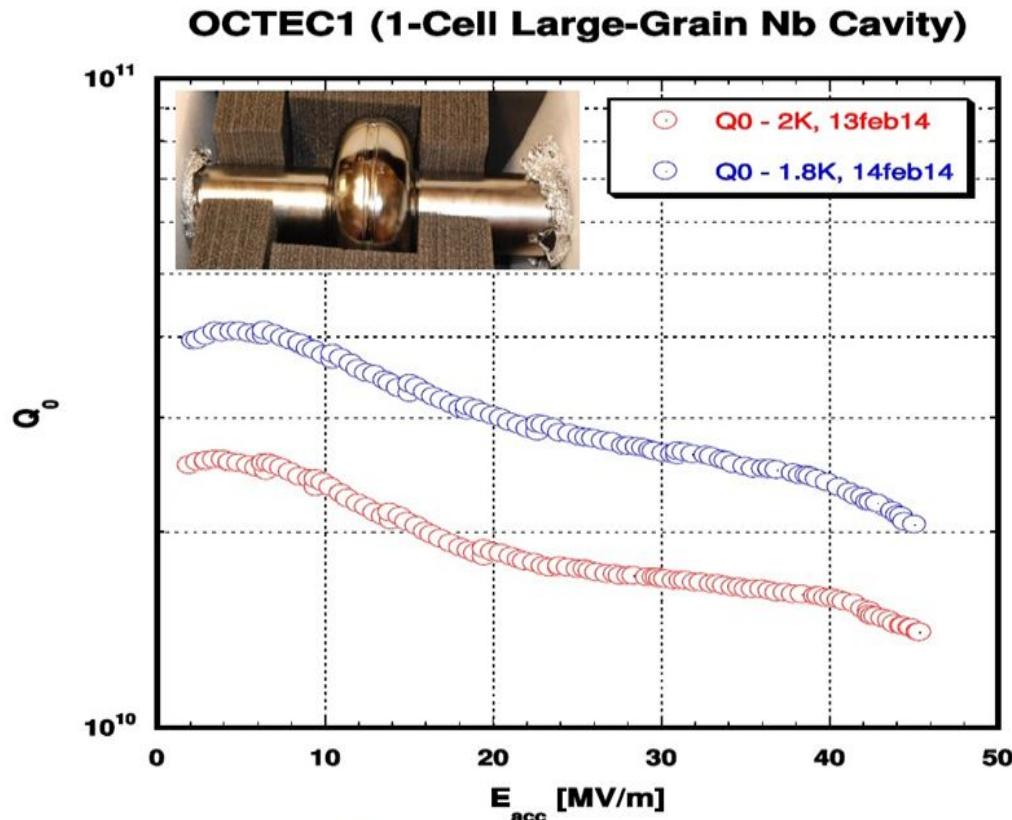
The maximum diameter of RRR300 Nb disc with large grain at OTIC can be machined to $\Phi 540\text{mm}$, which can meet the manufacturing requirement of CEPC 650MHz superconducting cavity.

At present, large-scale Nb material with large grain is being supplied to Shanghai Hard X-ray Big Science Facility.

3. SCRF研究和制造 Study and manufacture for SCRF

十四届二系四次会议

First superconducting niobium cavity built by OSTEC. Maximum gradient 46 MV/m with excellent Q0



Prior history since last test on November 4, 2013:

electropolishing for 30 micron removal followed by baking at 120 degree Celsius for 18 hours

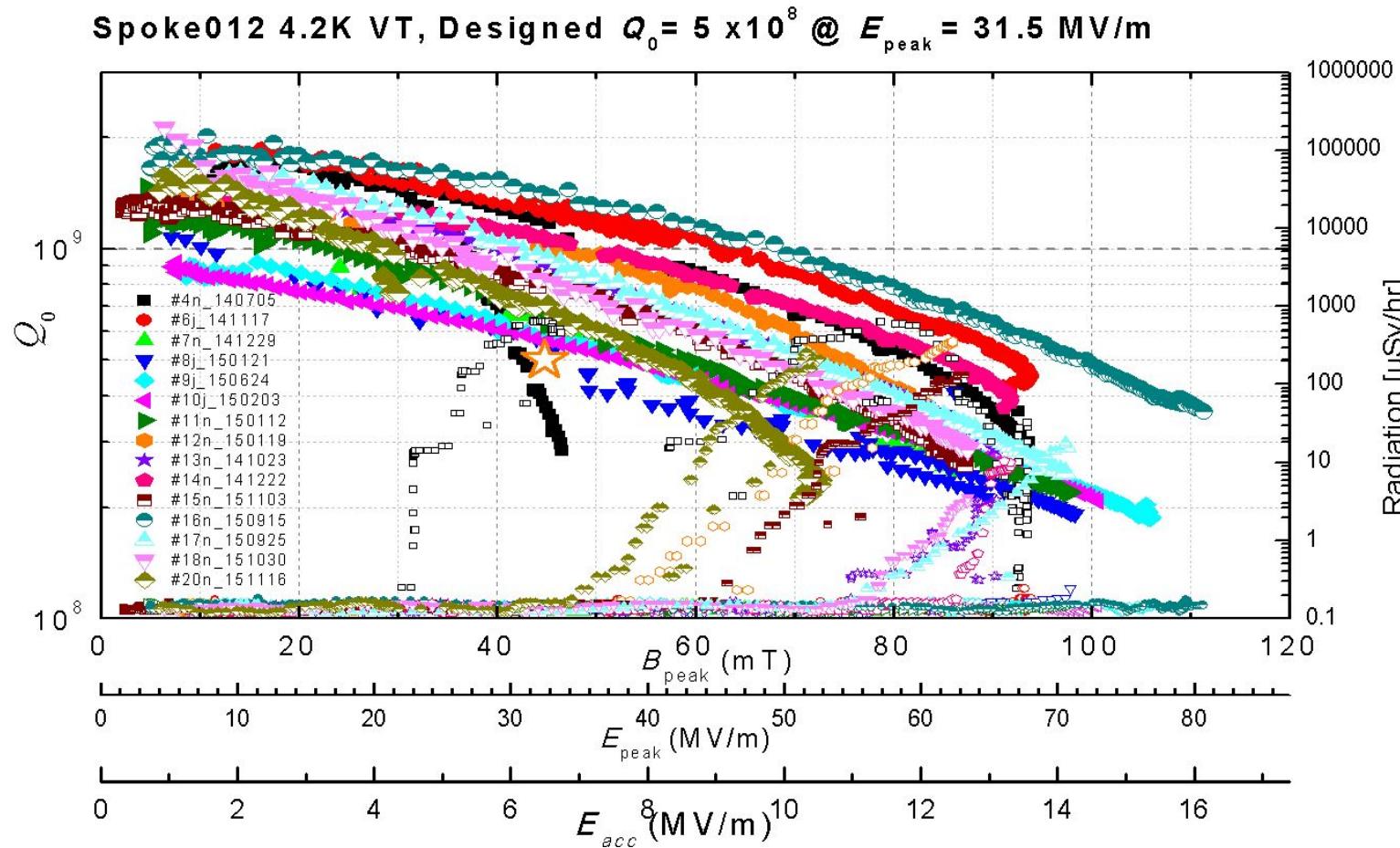
1.5GHz大晶粒单Cell超导铌腔，其最大加速度梯度达到46MV/m。这是2013年在OTIC上制造的第一个Nb腔

1.5GHz large grain single cell superconducting Nb cavity, its maximum acceleration gradient reached 46MV/m. It was the first Nb cavity which was manufactured in OTIC in 2013.

1.5GHz大晶粒单Cell超导体腔的研究结果
Results of 1.5GHz large grain single cell superconductor cavity

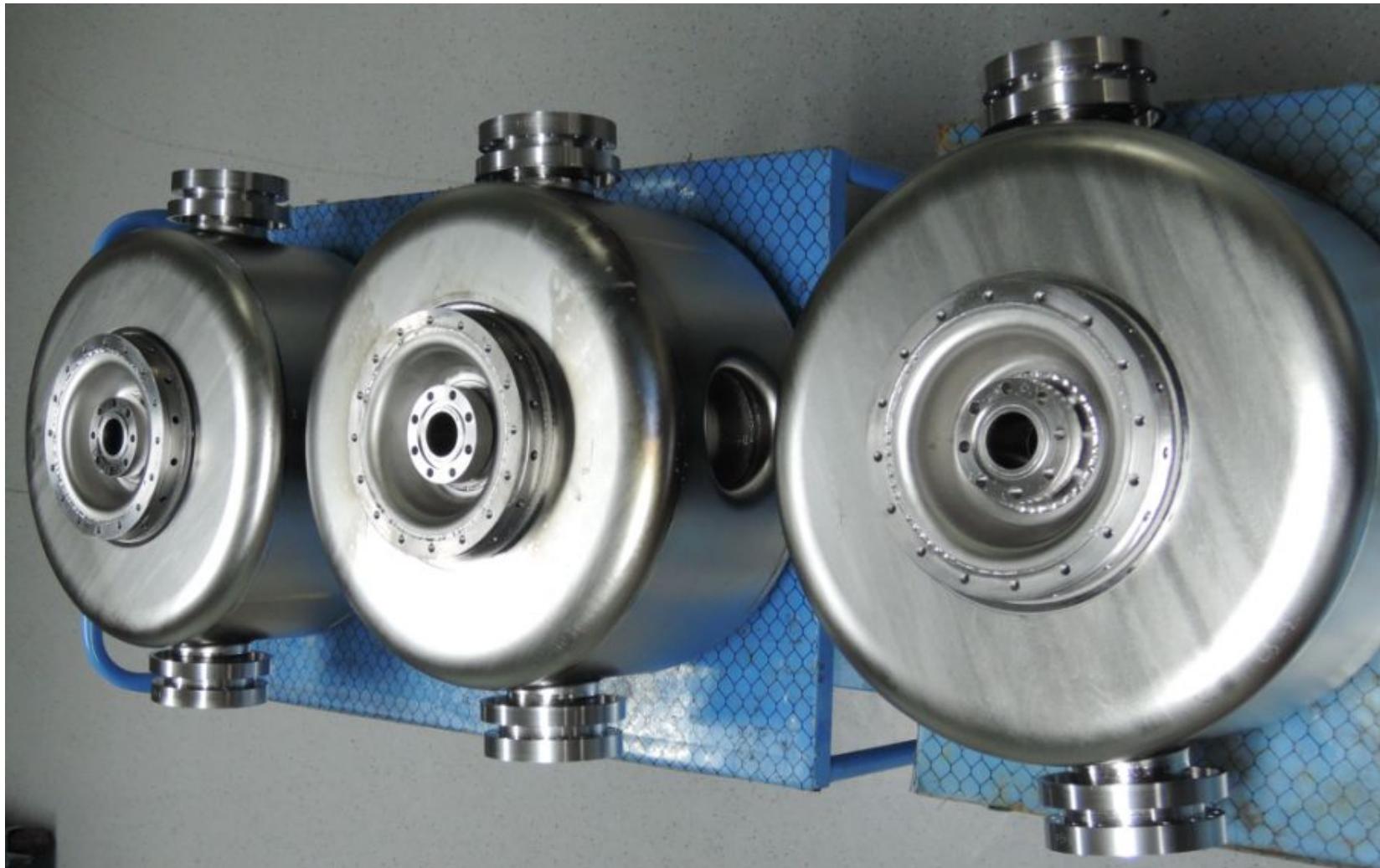
3. SCRF研究和制造 Study and manufacture for SCRF

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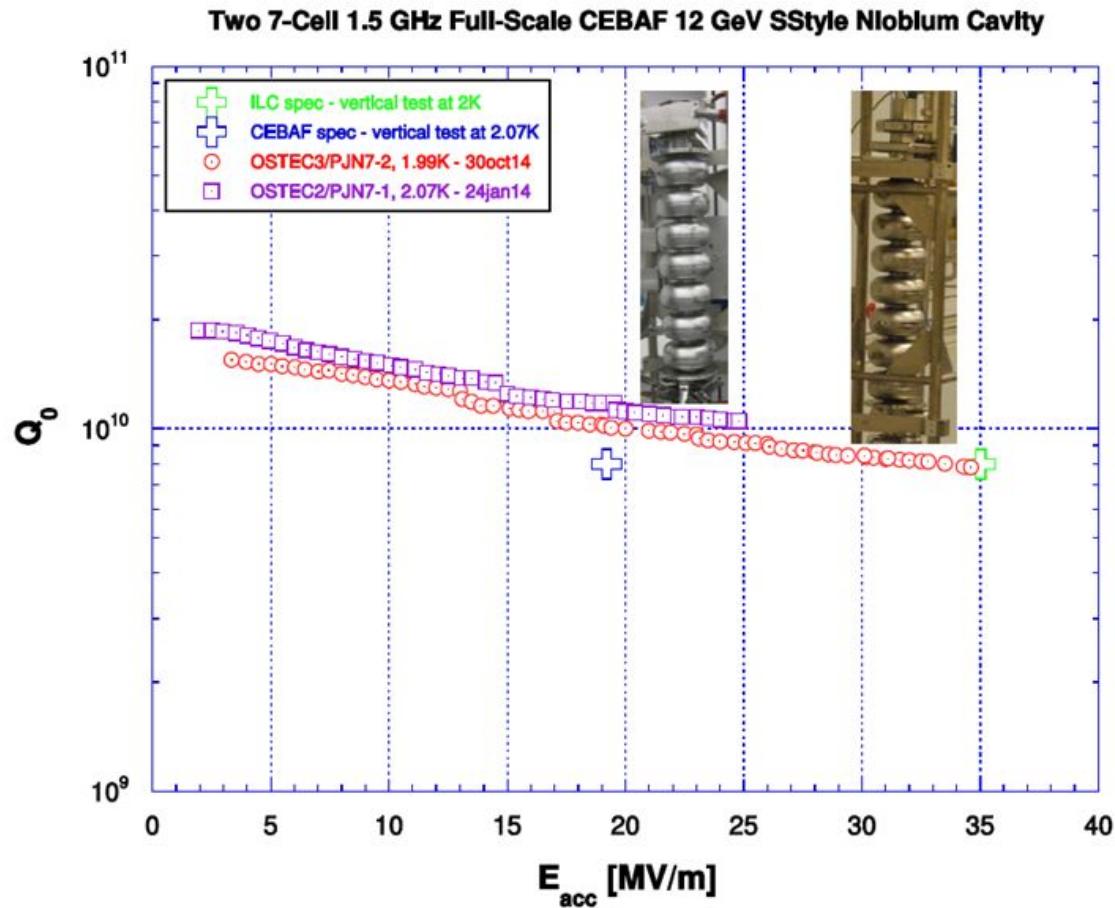


IHEP项目的21支SPOKE012 腔, 图中#14-#18由OTIC制造
21 SPOKE012 cavities for IHEP, #14-#18 were manufactured by OTIC.

3. SCRF研究和制造 Study and manufacture for SCRF



3. SCRF研究和制造 Study and manufacture for SCRF



2013年，公司首次与Jlab合作，研发了用于CEBAF升级的1.5GHz 7-cell超导腔。在2K低温条件下对超导腔进行了测试，加速度梯度达到36MV/m。这是OTIC首次具有超导腔的制造能力。

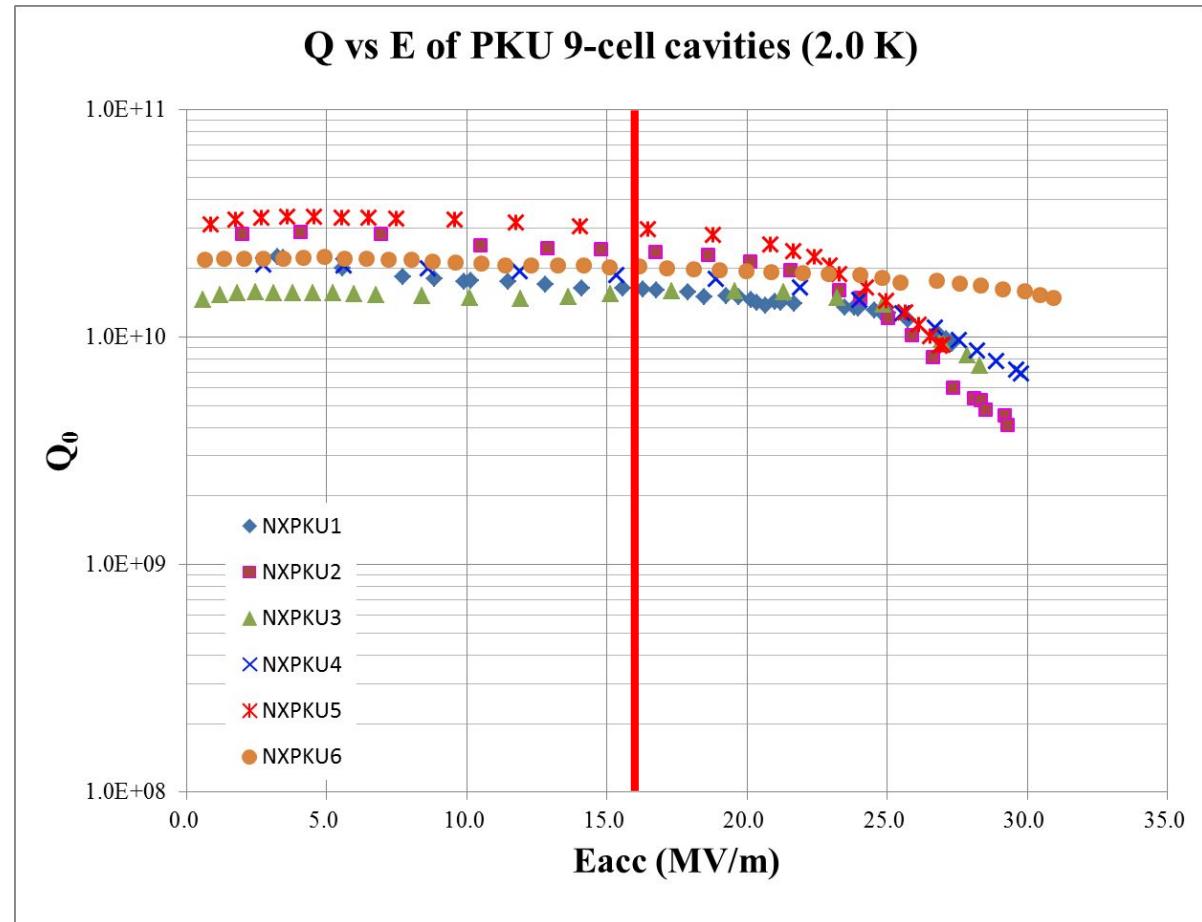
In 2013, OTIC cooperated with Jlab for the first time to develop a 1.5GHz 7-cell superconducting cavity for CEBAF upgrade. Superconducting cavity was tested at 2K low temperature and the acceleration gradient reached 36MV/m. It was the first time for OTIC to have the manufacturing capability of superconducting cavity.

3. SCRF研究和制造 Study and manufacture for SCRF

1. E_{acc} of all 6 cavities
larger than 25 MV/m

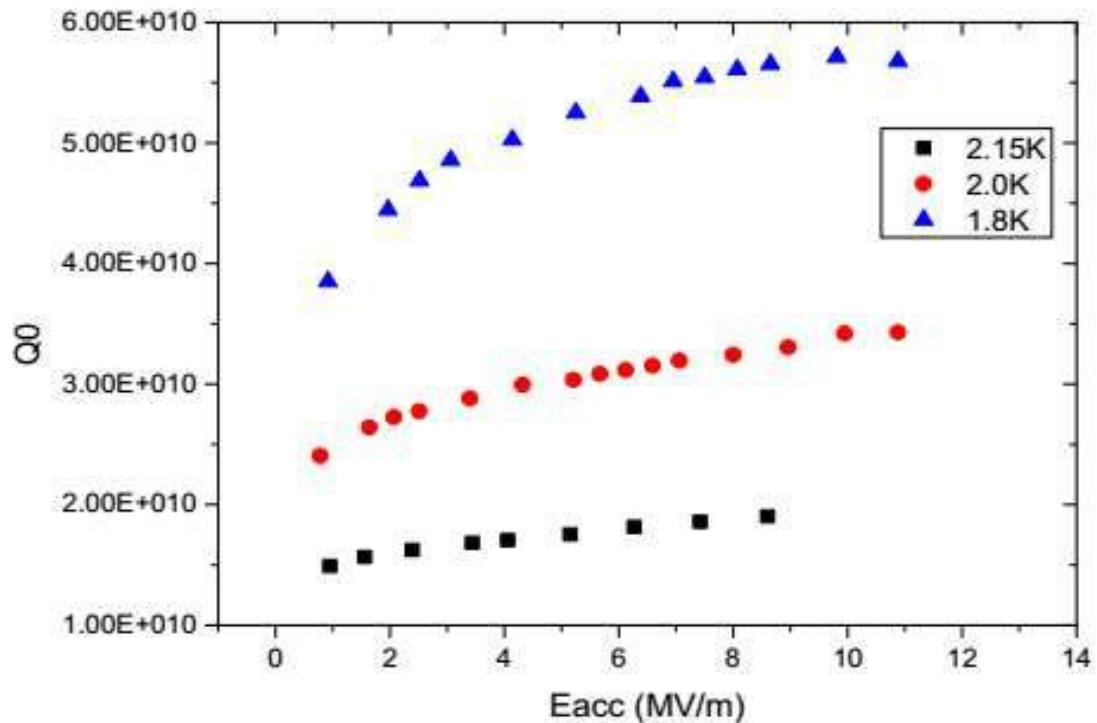
2. $Q_0 \sim 1.6\text{-}2.4 \times 10^{10}$ @ 16
MV/m

#3, 2nd test (Sept.
2017), with additional
BCP & HPR



VT result for 6 9-cell large grain cavities after BCP & HPR

3. SCRF研究和制造 Study and manufacture for SCRF

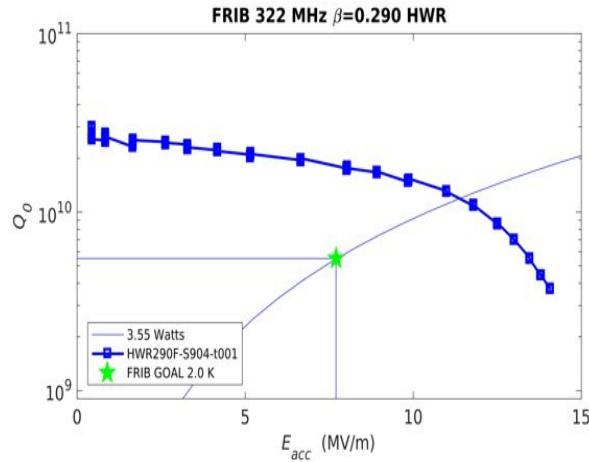
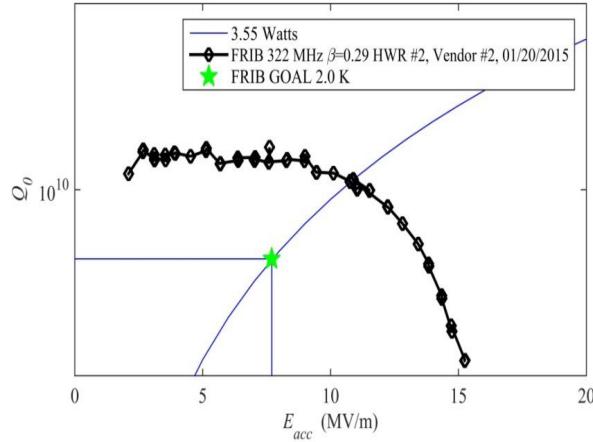


N掺杂在北京大学
1.3GHz大晶粒单cell腔中的应用
N-doping in Peking University
1.3GHz large grain single cell cavity

与IHEP和北京大学合作，在2019年上半年建立了BCP和HPR后处理设施，改进了氮掺杂工艺和EP设施，具备了超导空腔后处理能力。

In cooperation with IHEP and Peking University, OTIC established BCP and HPR post- processing facilities, improved nitrogen doping process and EP facilities, and possessed the capability of post-processing of superconducting cavity in the first half of 2019.

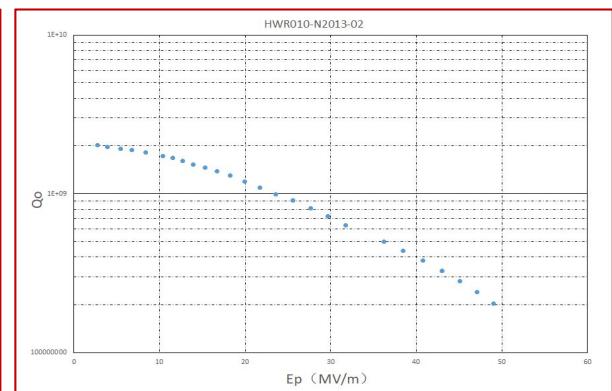
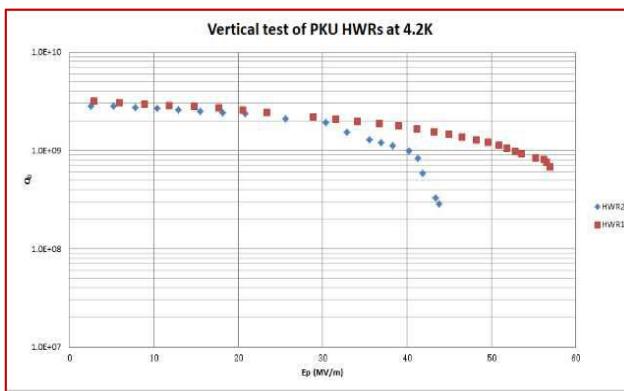
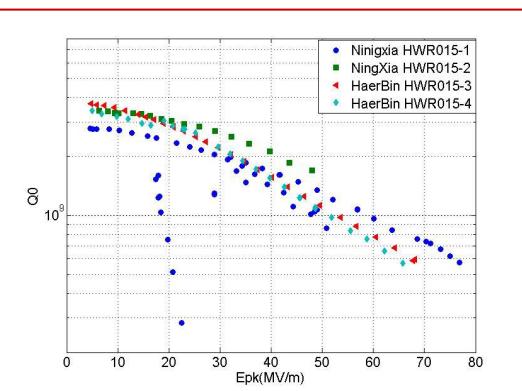
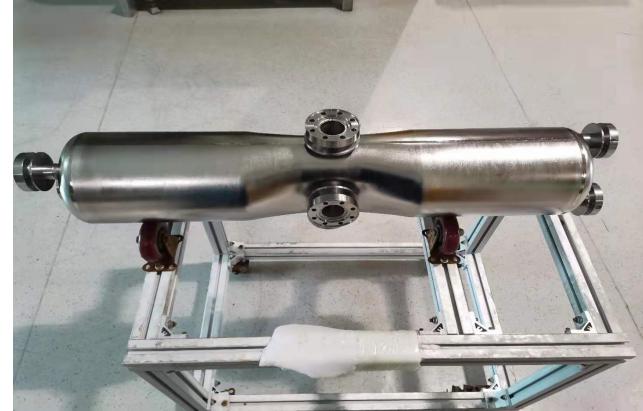
4.与主要机构的合作 Collaboration with main Agencies



用于FRIB项目的322MHz HWR029超导腔
 322MHz HWR029 superconducting cavity for FRIB project

参与美国MSU-FRIB项目
 $\text{beta}=0.29$ HWR超导腔
 和氦套的研制。
 在FRIB项目中安装了六个
 夹套焊接的腔体
 Participated in the
 development of
 $\text{beta}=0.29$ HWR
 superconducting cavity
 and helium jacket of
 MSU-FRIB project in
 the United States.
 Six cavities with jacket
 welding had been
 installed in FRIB project.

4.与主要机构的合作 Collaboration with main Agencies



4.与主要机构的合作 Collaboration with main Agencies



用于CEPC项目的650MHz单cell腔(用于IHEP)
single cell cavity for CEPC project(with IHEP)

4.与主要机构的合作 Collaboration with main Agencies



国家自然科学基金项目1.3G 3 cell槽腔(用于IHEP)
1.3G 3-cell slot cavity for National Natural Science Foundation Project(with IHEP)

4.与主要机构的合作 Collaboration with main Agencies

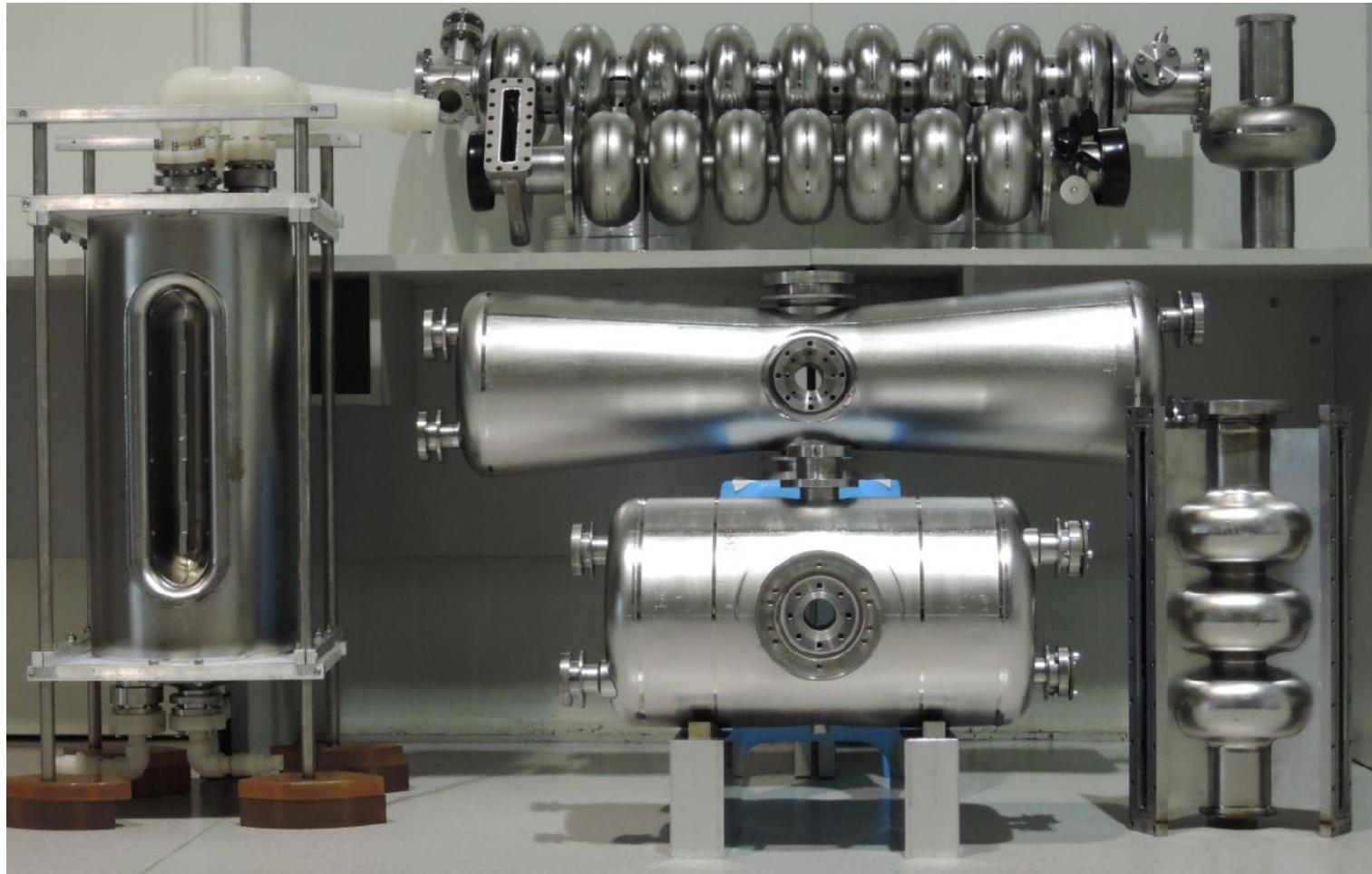


ILC型大晶粒1.3GHz 9 cell超导体腔(用于SHINE)
ILC type large grain 1.3GHz 9cell superconductor cavity(with SHINE)



162.5MHz锥形HWR 009超导体腔(用于PKU)
162.5MHz Taper type HWR 009 superconductor cavity(with PKU)

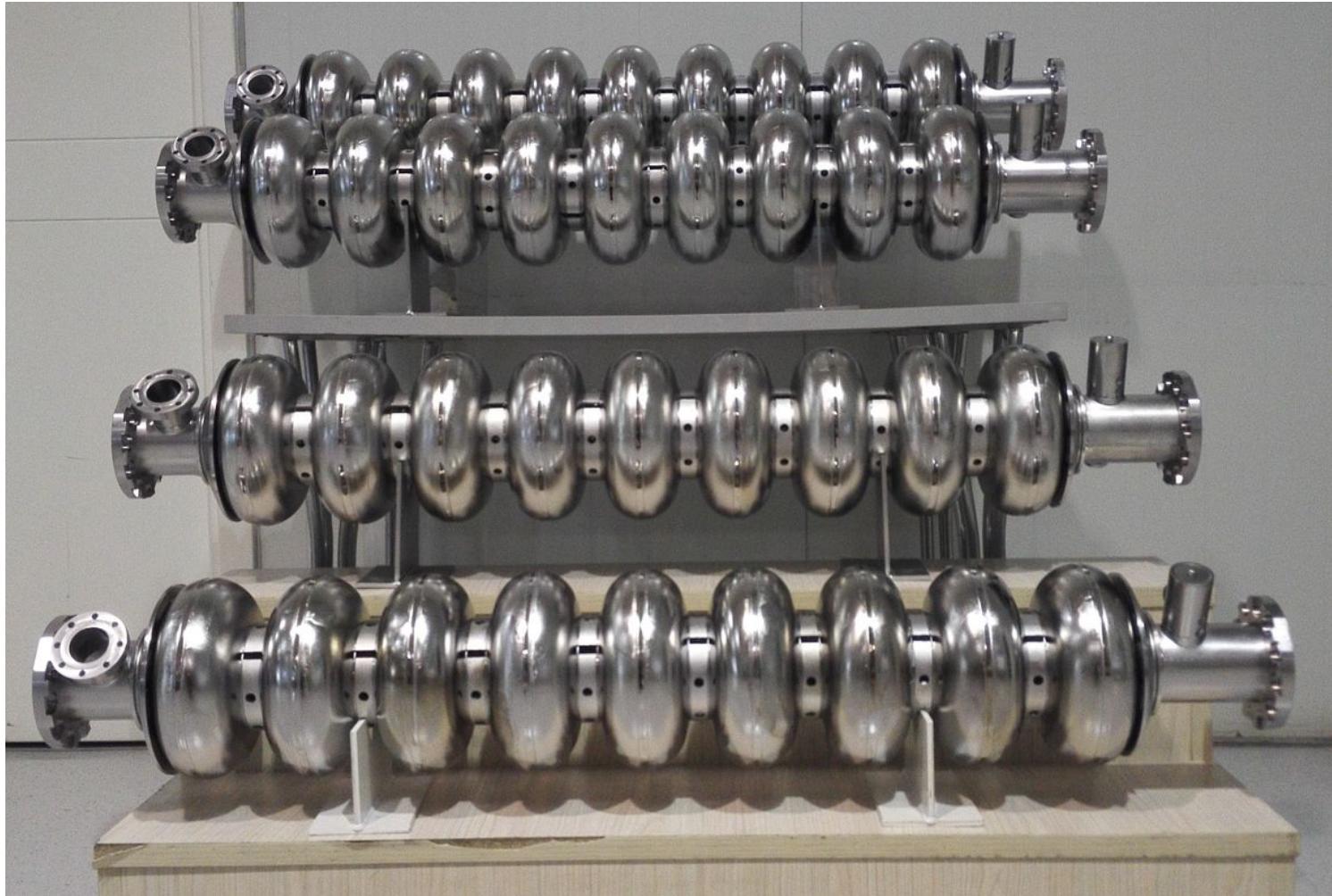
4.与主要机构的合作 Collaboration with main Agencies



4.与主要机构的合作 Collaboration with main Agencies

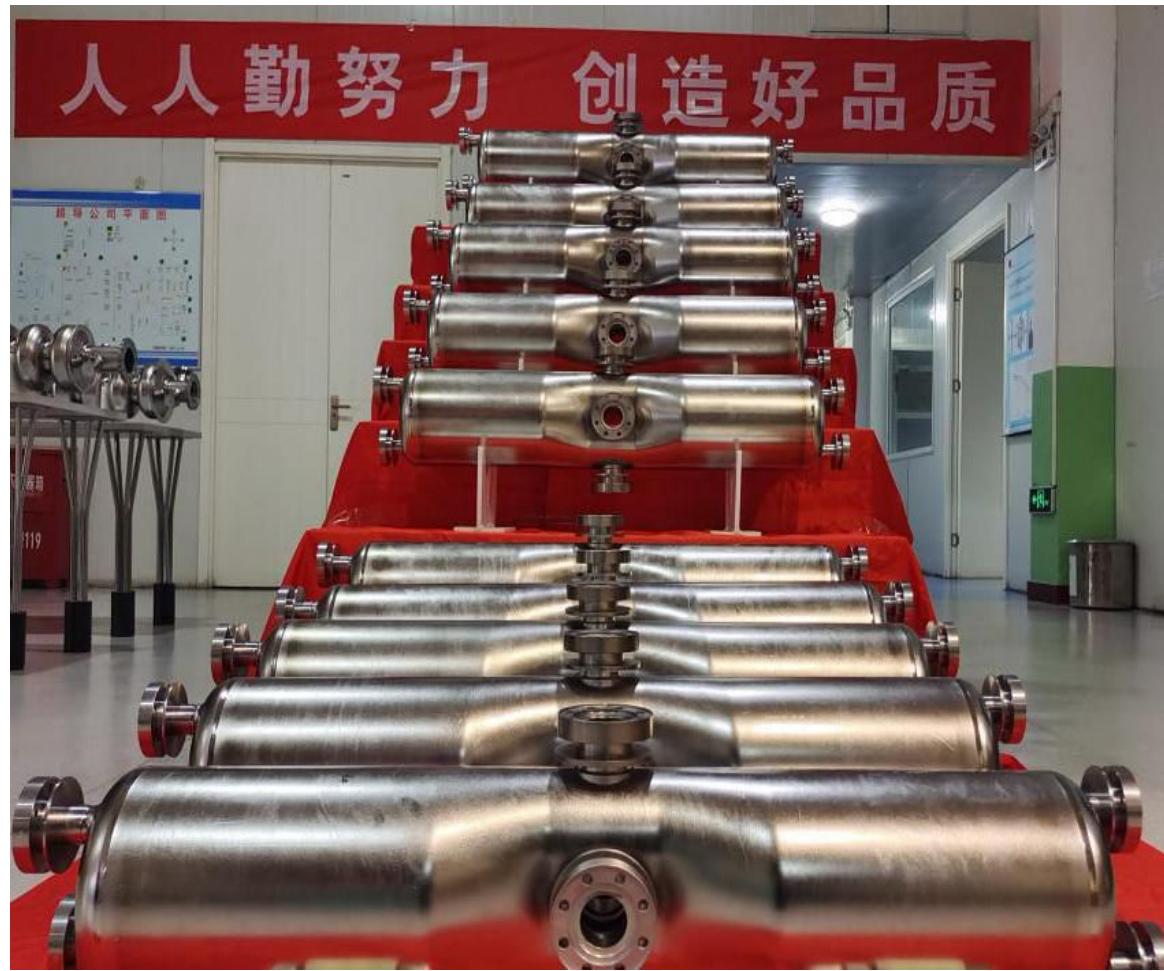


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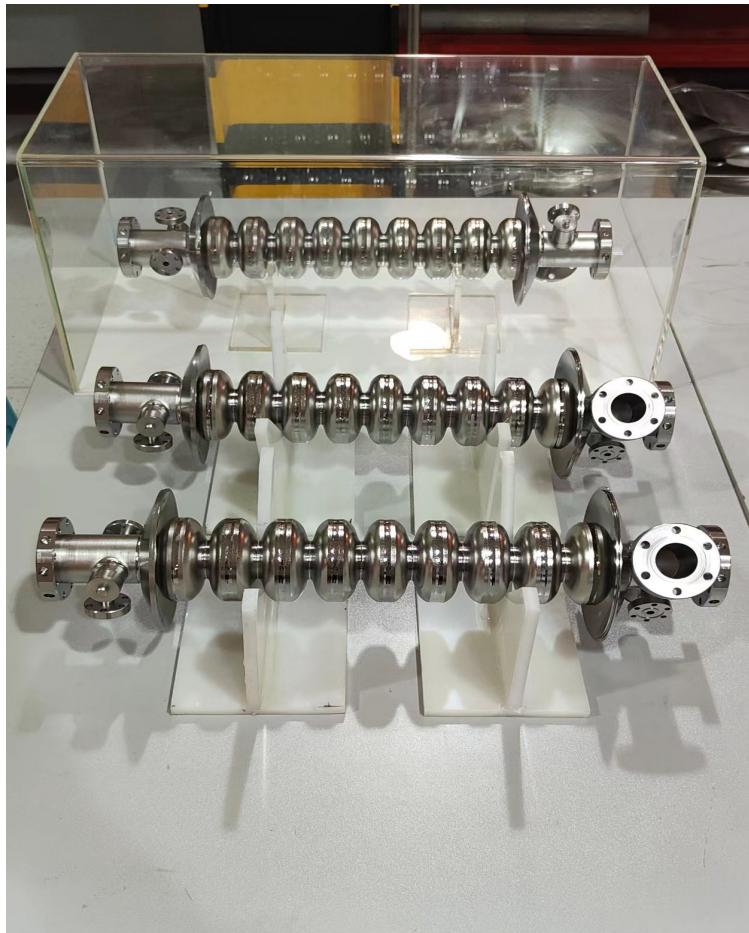
1.3GHz 9cell大晶粒超导体腔
1.3GHz 9cell large grain superconductor cavities

4.与主要机构的合作 Collaboration with main Agencies

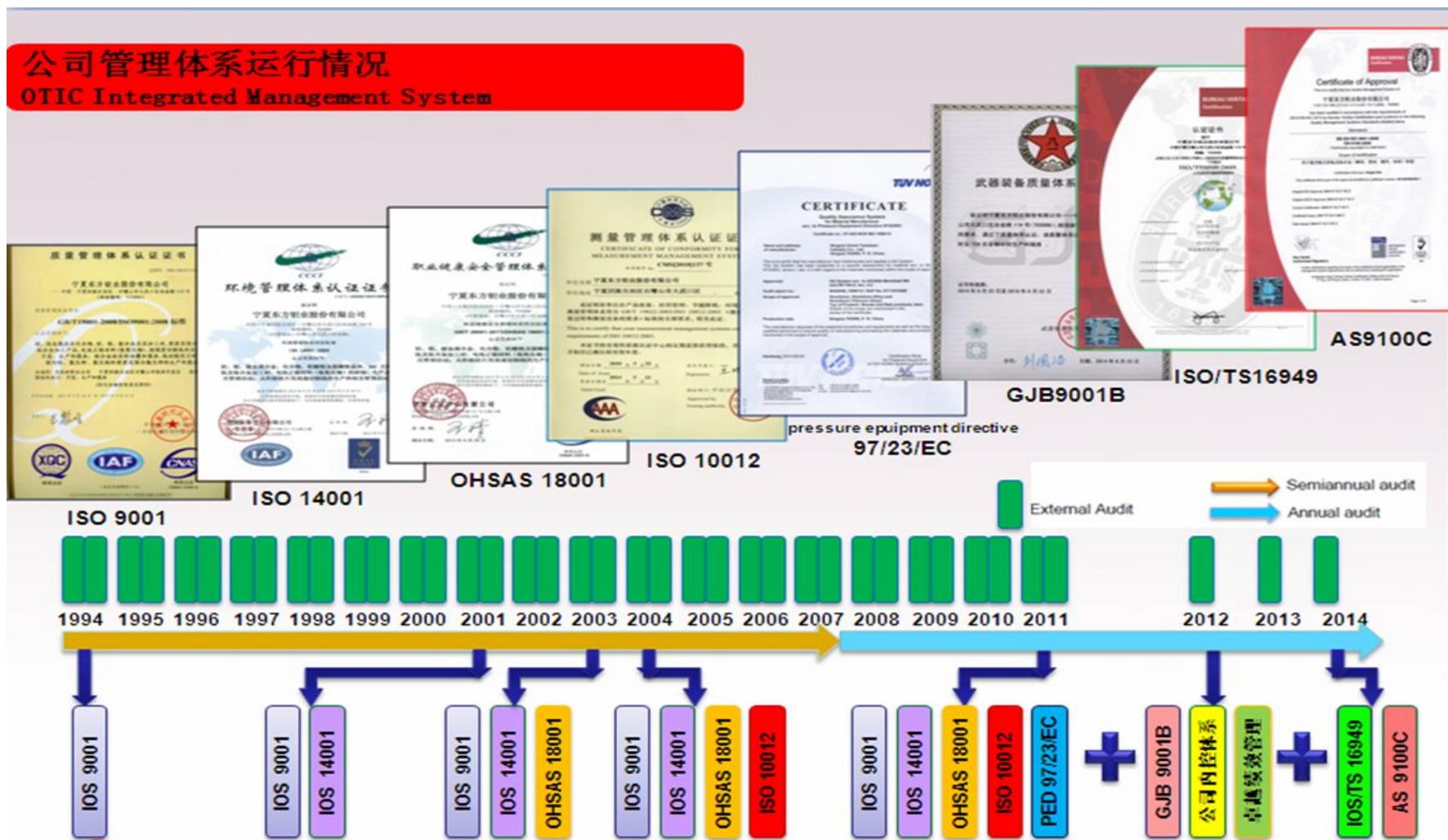


HWR010超导腔
HWR010 superconductor cavities

4.与主要机构的合作 Collaboration with main Agencies



3.9 GHz-9cell超导腔
3.9GHz-9Cell superconductor cavities



第十九届中国国际高新技术成果交易会
CHINA HI-TECH FAIR 2017



优秀产品奖证书

获奖单位： 宁夏东方钽业股份有限公司

获奖项目： 铌射频超导腔



荣誉证书
Certificate of honor

谢谢！

Thanks for your attention!

宁夏东方钽业股份有限公司
Ningxia Orient Tantalum Industrial Co., Ltd.

2022-8-29 宁夏

2022-8-29 NING XIA