

**VAR****IAN**  
**medical systems**

# The VARIAN 250 MeV Superconducting Compact Proton Cyclotrons: Medical Operation of the 2<sup>nd</sup> Machine, Production and Commissioning Status of Machines No. 3 to 7

H. Röcken, M. Abdel-Bary, E. Akcöltekin, P. Budz, T. Stephani, J. Wittschen



**VARIAN Medical Systems**

Particle Therapy GmbH

Friedrich-Ebert-Str. 1

D-51429 BERGISCH GLADBACH

GERMANY

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# VARIAN PT ?

Former ACCEL Instruments ...

... was acquired in 2007 by

VARIAN Medical Systems ...

... and became in 2009

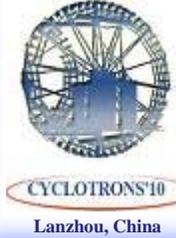


## Varian Medical Systems Particle Therapy GmbH

Further split-ups: > RI Research Instruments GmbH

> BASC Bruker Advanced Supercon GmbH

# OUTLINE



- Introduction
- Operating Cyclotrons #1 and #2  
Patient Treatment / Uptime Statistics
- Cyclotrons under Commissioning  
#3 Assembly, SC Magnet Ramping, Test Quench, Magnetic Field Mapping
- Examples for New Components  
Solid State Amplifier, Digital Low Level RF
- Cyclotron Production Site
- Production of Next Machines  
#4, #5, #6, #7
- Cyclotron and Scanning Nozzle Test Cell
- Conclusion

# VARIAN PT Cyclotron System Parameters

(Engineering Goals)



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Lanzhou, China

➤ Beam	<ul style="list-style-type: none"><li>- Energy</li><li>- Extracted current (max)</li><li>- Emittance of extracted beam</li><li>- Momentum spread <math>\Delta p/p</math></li><li>- Number of turns</li><li>- Extraction efficiency (multi-turn extraction mode)</li><li>- Dynamic range for intensity modulation</li><li>- Fast intensity modulation</li></ul>	<p>250 MeV</p> <p>800 nA</p> <p><math>&lt; 3 / 5 \pi</math> mm mrad (<math>2\sigma</math>)</p> <p><math>\pm 0.04\%</math> (i.e. 200keV @ 250MeV)</p> <p>650</p> <p>~80%</p> <p>1:800</p> <p>via electrostatic deflector, <math>&gt;10\%</math> in 100 <math>\mu</math>s</p>
➤ Iron Yoke	<ul style="list-style-type: none"><li>- Outer diameter</li><li>- Height</li><li>- Weight</li></ul>	<p>3.1 m</p> <p>1.6 m</p> <p><math>&lt;90</math> t</p>
➤ SC Magnet	<ul style="list-style-type: none"><li>- Stored energy</li><li>- Central field</li><li>- Max. field at the coil</li><li>- Operating current</li><li>- Rated power of cryocoolers</li></ul>	<p>2.5 MJ</p> <p>2.4 T</p> <p><math>&lt;4</math> T</p> <p>160 A</p> <p>40 kW</p>
➤ RF System	<ul style="list-style-type: none"><li>- Frequency</li><li>- Voltage source to puller / @ extraction radius</li><li>- RF power</li></ul>	<p>72.8 MHz (2<sup>nd</sup> harmonic)</p> <p>80 kV / 130 kV</p> <p><math>\leq 115</math> kW</p>

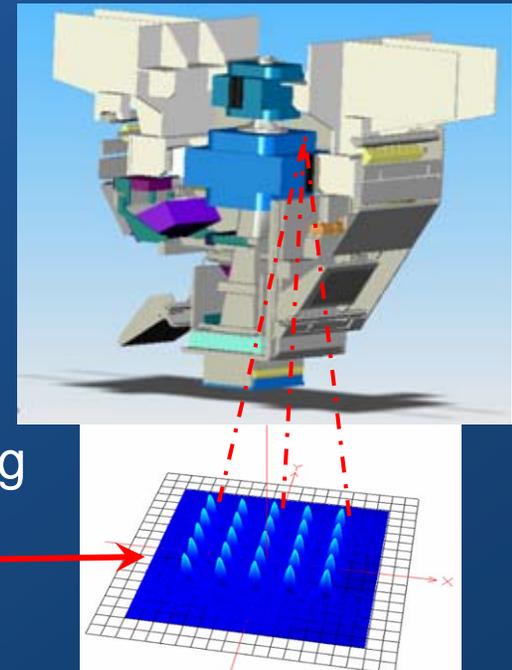
# Operating VARIAN PT Cyclotrons #1 and #2



1. Paul Scherrer Institut PSI (CH), treating patients since beginning of 2007.
2. Rinecker Proton Therapy Center RPTC (D) treating patients since beginning of 2009!

This facility is widely equipped with VARIAN technology, like

- superconducting compact 250 MeV proton cyclotron
- degrader for energy adjustment
- energy selection system for energy filtering
- beam line for beam transportation
- 4 rotational isocentric gantries for 360° irradiation
- + 1 fixed beam for head / neck treatments
- delivery nozzles providing pencil beam spot scanning
- safety systems
- treatment control software
- ...



# Patient Treatment at RPTC



On website

[www.rptc.de](http://www.rptc.de) :

PATIENT TREATMENT  
STARTED MARCH 16<sup>th</sup>, 2009

TREATMENT REPORTS ARE  
AVAILABLE

STATUS REPORTS AND  
MEDICAL CASE STUDIES  
ARE AVAILABLE



**RINECKER  
PROTON  
THERAPY  
CENTER**

**WE'VE STARTED TREATING PATIENTS ON MARCH 16TH - THE CENTER HAS STARTED CLINICAL OPERATION**

**THE RINECKER PROTON THERAPY CENTER HAS MET ALL QUALIFICATIONS FOR THE GOVERNMENTAL LICENCE FOR PATIENT TREATMENT. SO THE RPTC, BEING THE FIRST LARGE CERTIFIED CENTER FOR PARTICLE TREATMENT, HAS STARTED CLINICAL OPERATIONS. EXPECT INFORMATION CONCERNING THE INITIATION OF PATIENT TREATMENT SOON.**

**CONTACT FOR PATIENTS:  
CALL-CENTER +49 89 660680**

**Welcome to the  
RINECKER PROTON THERAPY CENTRE (RPTC)!**

**We invite you to find out about proton therapy, our Centre, the opportunities we offer for treatment, and our team of skilled professionals.**

The RPTC, located in Munich, is the first fully certified European proton radiation centre which provides a complete hospital setting for the treatment of cancer tumours.

The innovative therapeutic procedure we use involves the use of high-energy proton beams for the treatment of cancer. A key characteristic of these proton beams is that protons facilitate the three-dimensional targeting of tumours; this capability is not available with the x-rays used in conventional radiation therapy. Therefore, highly effective dosages can be delivered to the tumour while the side effects of radiation are reduced by minimizing any trauma to the surrounding healthy tissue.

# Patient Treatment at RPTC



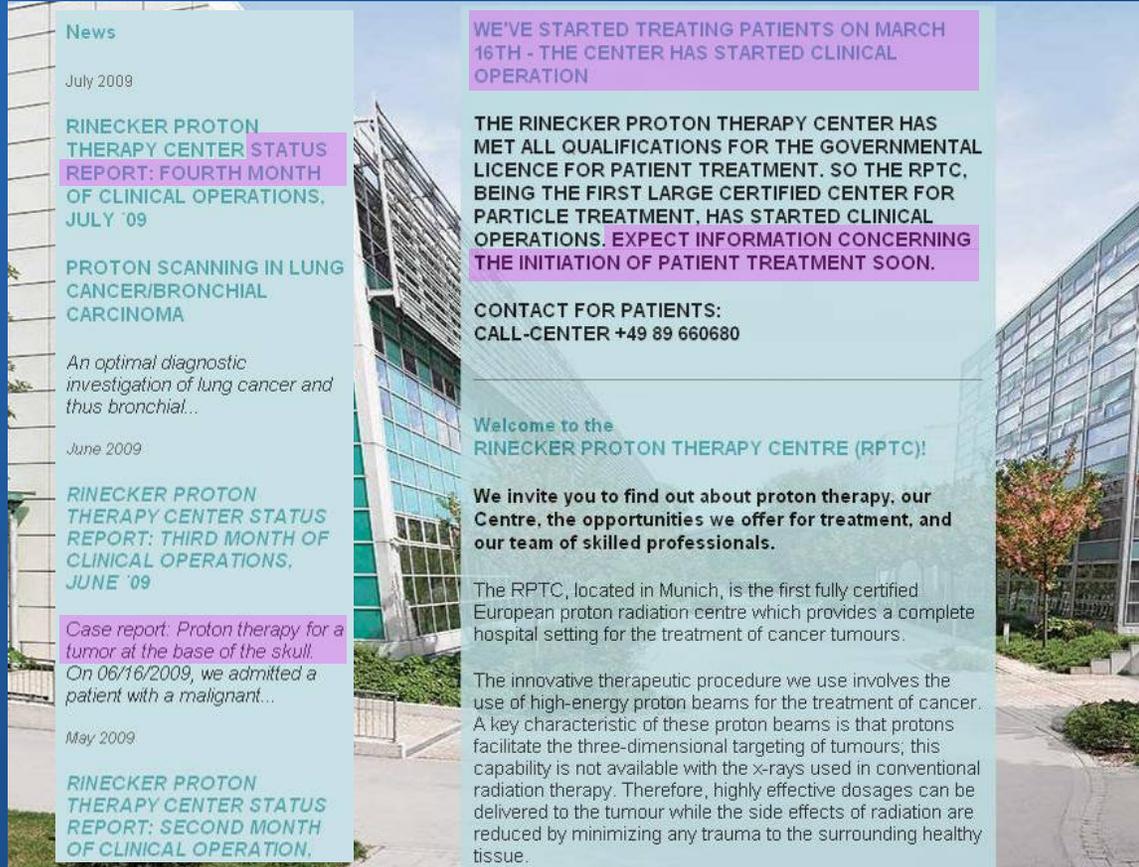
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A photograph of the Rinecker Proton Therapy Center (RPTC) building, a modern multi-story structure with a glass facade and a prominent staircase on the exterior.

**News**

July 2009

**RINECKER PROTON THERAPY CENTER STATUS REPORT: FOURTH MONTH OF CLINICAL OPERATIONS, JULY '09**

**PROTON SCANNING IN LUNG CANCER/BRONCHIAL CARCINOMA**

*An optimal diagnostic investigation of lung cancer and thus bronchial...*

June 2009

**RINECKER PROTON THERAPY CENTER STATUS REPORT: THIRD MONTH OF CLINICAL OPERATIONS, JUNE '09**

*Case report: Proton therapy for a tumor at the base of the skull. On 06/16/2009, we admitted a patient with a malignant...*

May 2009

**RINECKER PROTON THERAPY CENTER STATUS REPORT: SECOND MONTH OF CLINICAL OPERATION.**

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Lanzhou, China

# RPTC Uptime during Patient Treatment

RPTC presentation on PTCOG 48 conference (specialized particle therapy event)

6 months after start of operation:

RPTC Performance and Ramp-Up

Clinical Performance	Current	Expected
Beam Energy	90 – 230 MeV	70 – 250 MeV
Treatment Field Size	25 cm x 25 cm	30 cm x 40 cm
Dose Rate	ca. 1.1 Gy / litre / min.	2 Gy / litre / min.
Beam Width (1 sigma)	4 mm	3 mm or 4 mm
Spot Dose Stability	better 3 %	better 1 %
Spot Position Stability	better 1 mm	better 1 mm
360° Gantry	1 out of 4	No 2: October 2009 No 3: February 2010 No 4: June 2010 October 2010
Fixed Beam Small Field Scattering		
Proton System Reliability	Treatment 134 of first 138 days 97 %	> 97 %

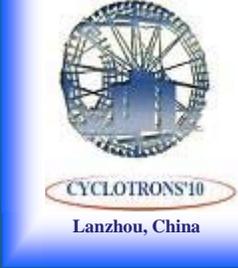
We started patient treatment in March 2009 and expect to operate a high-end and high-capacity proton scanning therapy facility well within 2010.  
We were successful to combine daily patient treatment in Gantry 1 with parallel commissioning works on the remaining treatment rooms. An operationally advantageous step wise ramp-up has been achieved.

FRANKFURT PROTON THERAPY CENTER RPTC      WWW.RPTC.DE      PHONE: +49 (0) 69 86369-0

Poster presented by RPTC at PTCOG 48

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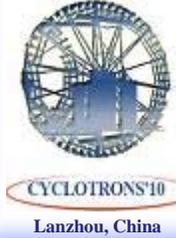
# RPTC Operating Time / Facility Uptime



- User treats patients 6 days/week, 8-10 hrs/day (8hrs officially scheduled)
- Commissioning of gantries / scanning nozzles is continued during nights and weekends, current status:
  - 3 gantries are handed over to the customer,
  - the last one will be handed over within these days
- Treatment facility including cyclotron is operated 24hrs on 6-7 days/week
- Service is performed every Sunday
- The RPTC uptime of 97% for the complete treatment facility since startup was determined by the user for daily patient treatment
- Cyclotron contributes only little to downtime

# VARIAN PT Cyclotrons under Commissioning

## Cyclotron #3 Assembly and FAT

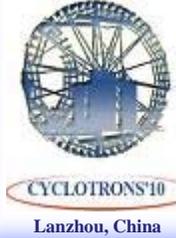


- Cyclotron #3 will be widely pre-assembled, tested (with beam!) in the factory, and shipped to its destination in 2 large lots (upper / lower part).
- It is currently in the final stage of assembly and is undergoing FATs in parallel.



# VARIAN PT Cyclotrons under Commissioning

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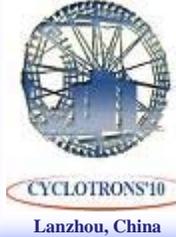


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# VARIAN PT Cyclotrons under Commissioning

## #3 SC Magnet Ramping and Test Quench



- First excitation of the superconducting magnet took place on May 18, 2010 on the first attempt.
- The obligatory test quench could not be forced by fast ramping and had to be triggered by the dedicated quench heaters.
- After cool down (5 hrs) all forces on the support links as well as the magnetic field map remained unchanged:  
⇒ stable, quench proof and quench tolerant system

## Cyclotron C3

First Excitation of Superconducting Magnet

**MAY 18, 2010**

**VARIAN**  
medical systems

A partner for **life**

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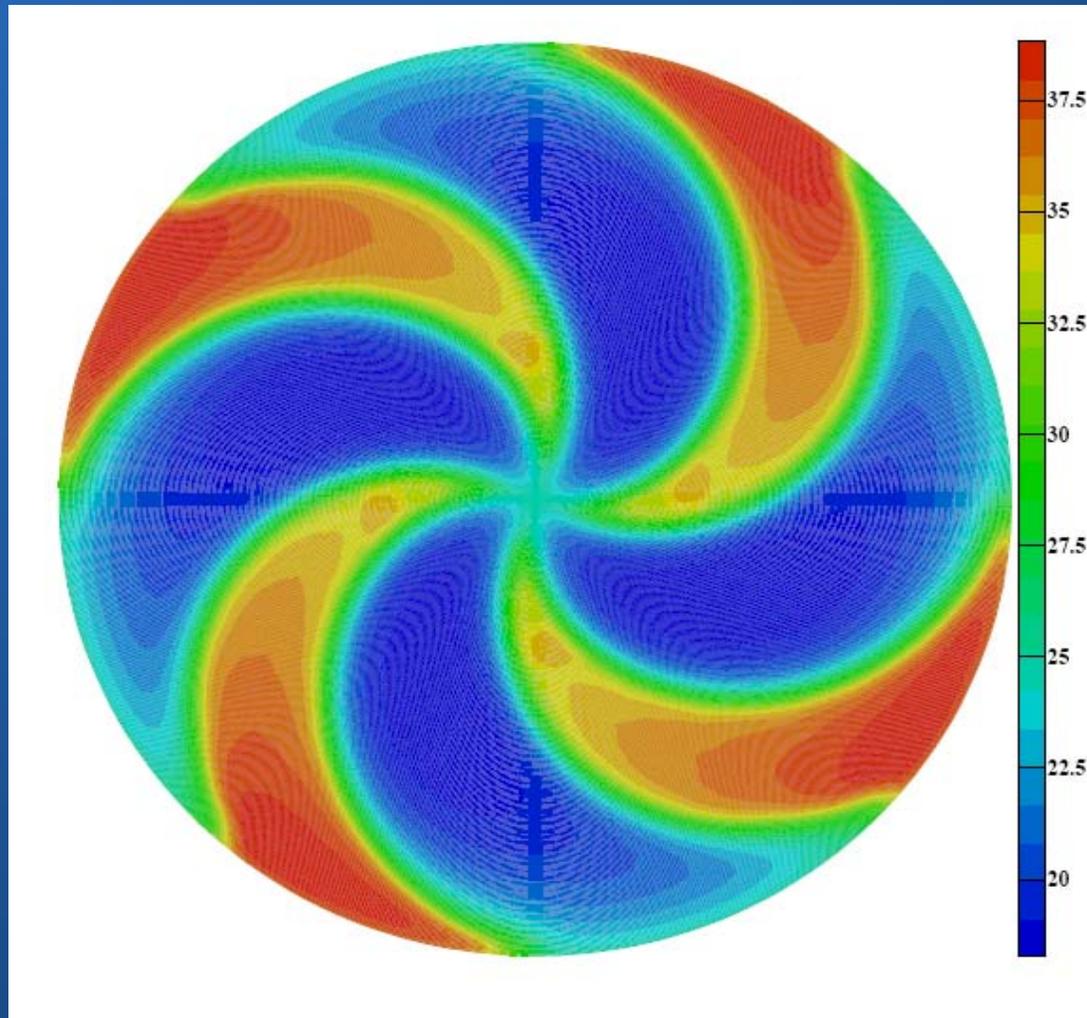


# VARIAN PT Cyclotrons under Commissioning

## #3 Magnetic Field Mapping



- A measured field map ...  
...is compared to its symmetrized form to reveal deviations from perfect 4-fold symmetry.
- Initially the field showed a first harmonic of  $\sim 29$  Gauss.
- This could be compensated down to  $< 2$  Gauss by a simple lateral adjustment of the sc coil.
- Some remaining deviations on the extraction radius must be shimmed locally.

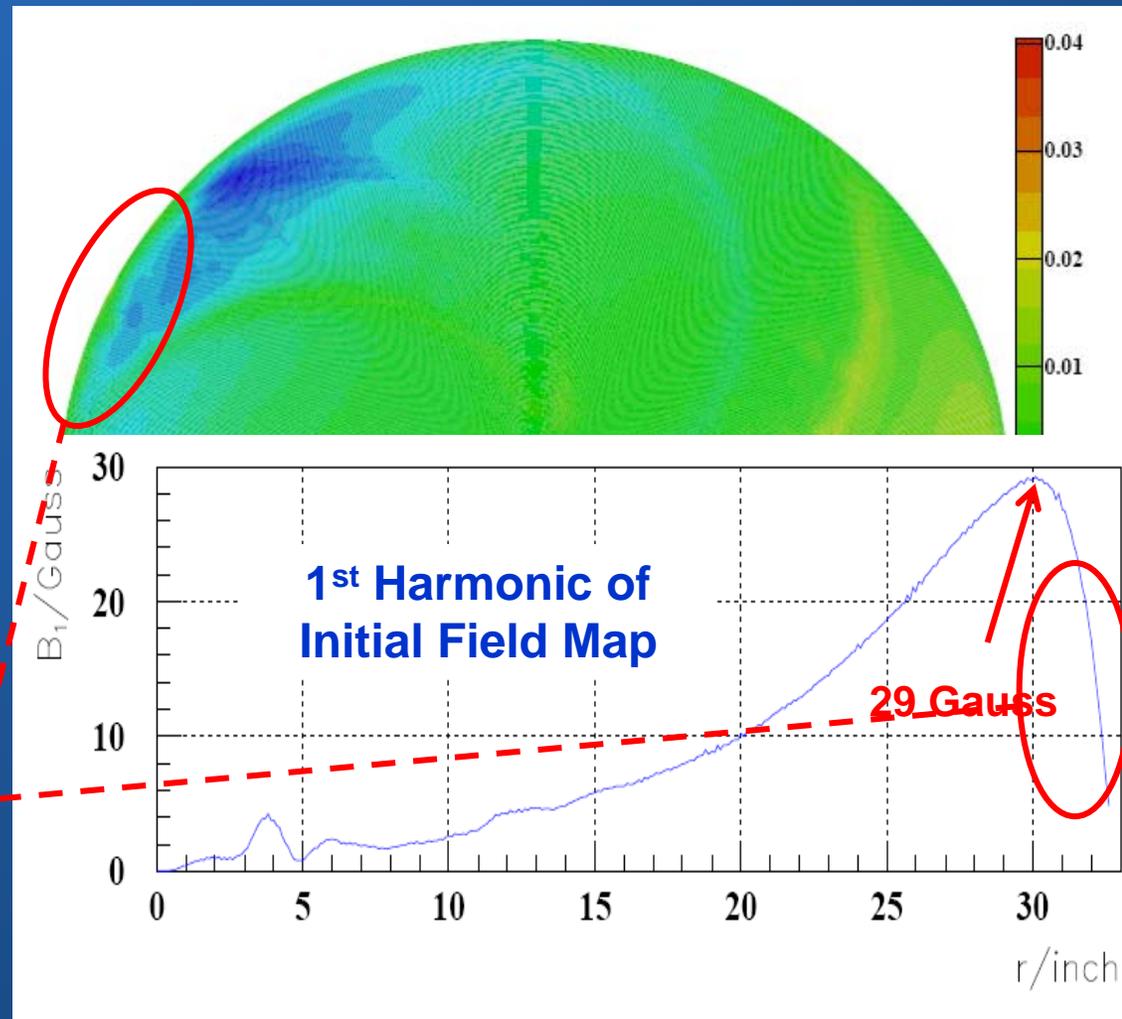


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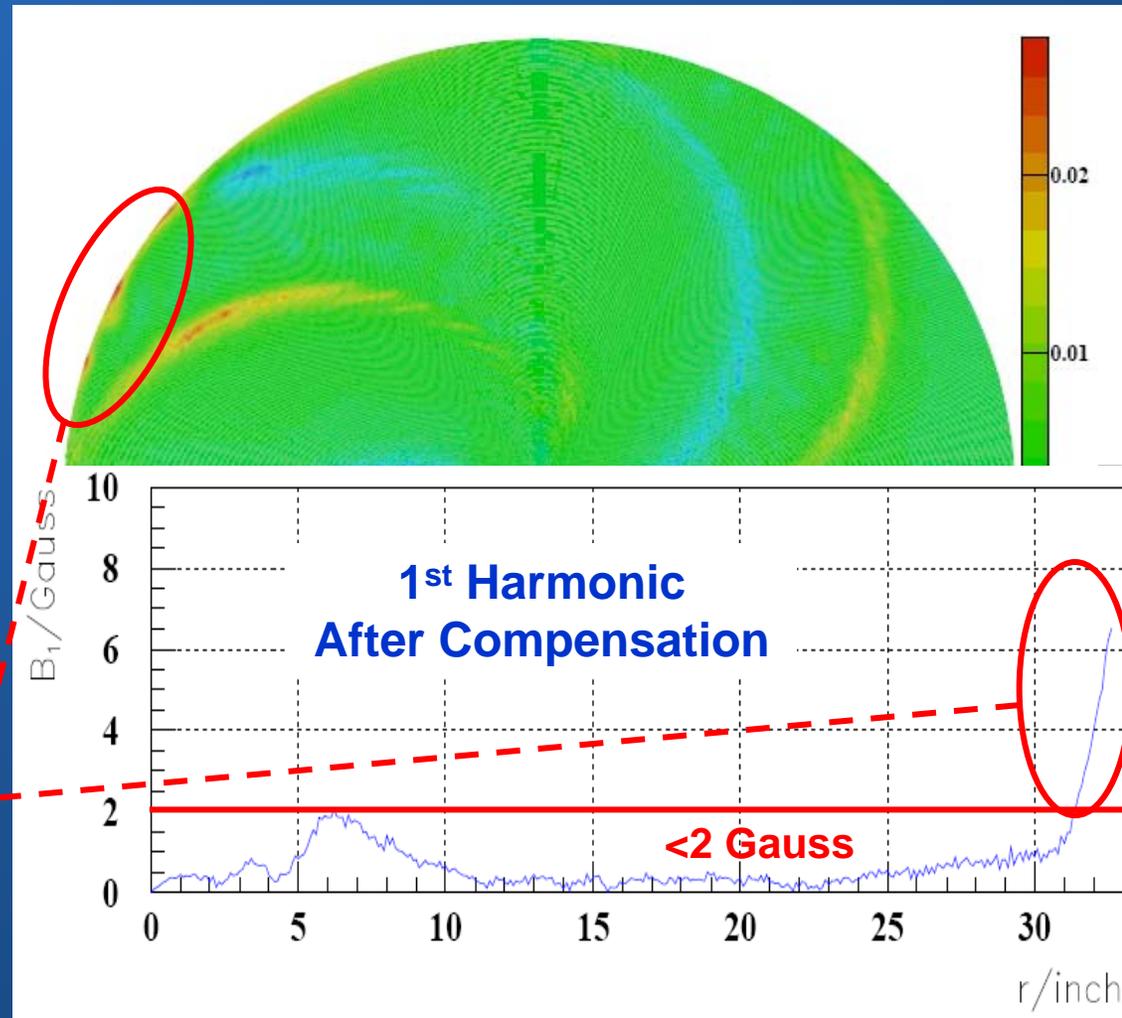


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# VARIAN PT Cyclotrons under Commissioning

## Solid State Amplifier



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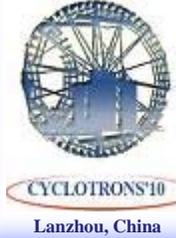
- RF power amplifiers used at PSI and RPTC:  
*3-stage tetrode tube based, several electrical cabinets for power transformers and high voltage supplies*
- New design is tested:  
*transistor based, 20 parallel working RF power modules*
- Test setup completed a >1000h test with 25kW,  
allowed reflected power limit >15%



Supplied by  
Cryoelectra GmbH

# VARIAN PT Cyclotrons under Commissioning

## Solid State Amplifier



- Currently the final setup consisting of 6 cabinets with a total of 120 power modules is under test in the factory.
- Via its redundancy, the design features a higher
  - availability,
  - maintainability,
  - cost reduction, ...
- The digitally controlled modularized system provides extended diagnostics capabilities.



# VARIAN PT Cyclotrons under Commissioning

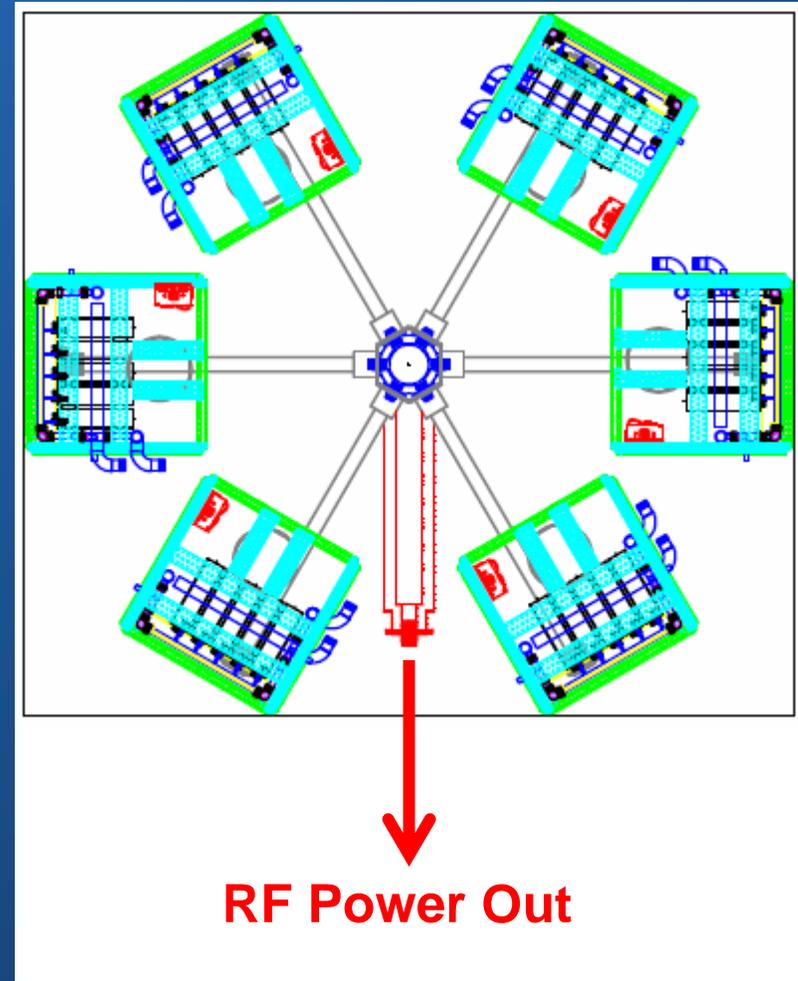
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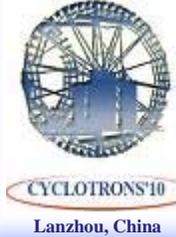
Lanzhou, China

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## Digital Low Level RF

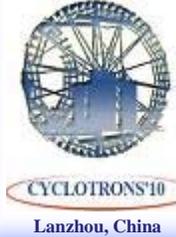


- VARIAN will use a digital LLRF with its future systems.
- The dLLRF has already passed performance tests at the supplier and will be delivered in September to the VARIAN factory for system integration tests.
- Like the SSamp, the dLLRF is designed for high redundancy. This yields a high fault tolerance and increases system uptime.
- The dLLRF is faster than the previously used system and provides much more diagnostic signals and functionality.

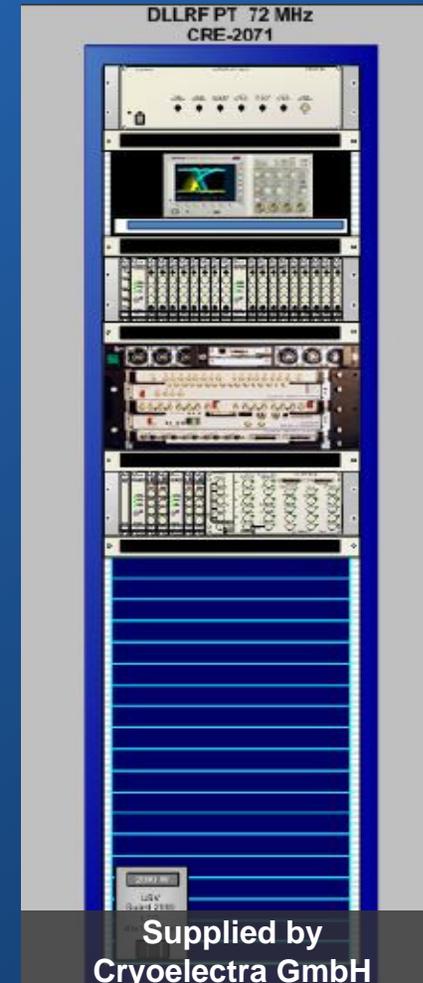


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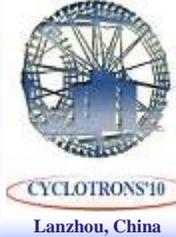


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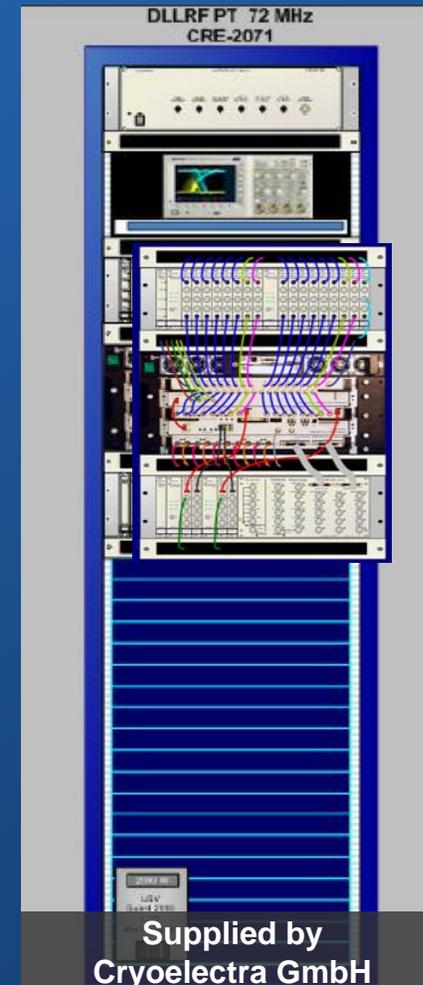


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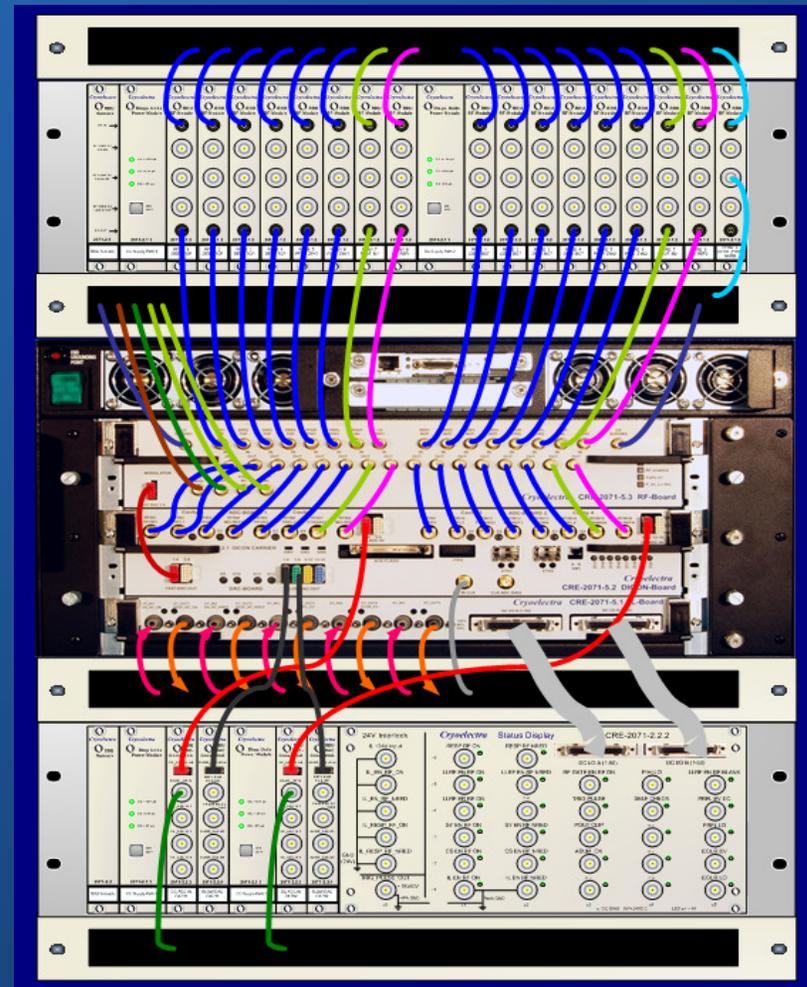
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Lanzhou, China

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# VARIAN PT Cyclotron Production Site Overview



Production site near  
Cologne / Germany

Allows assembly of  
up to 6 cyclotrons in  
parallel ...

and up to 8 - 12  
cyclotrons / year ...

# VARIAN PT Cyclotron Production Site Overview



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# VARIAN PT Cyclotron Production Site

## Assembly Stands



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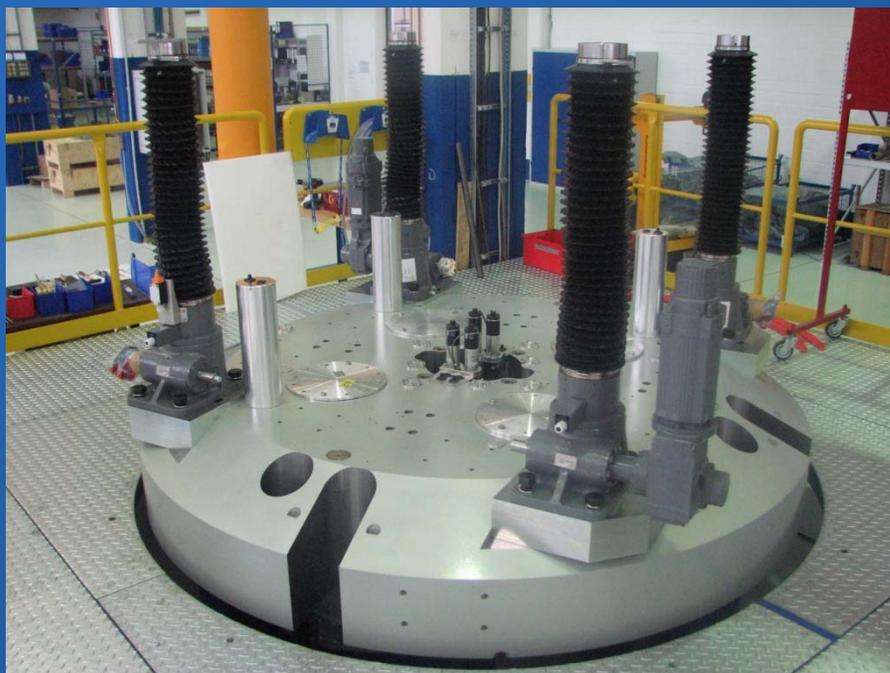
# VARIAN PT Cyclotron Production Site

## Assembly Stands



CYCLOTRONS 10

Lanzhou, China



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CYCLOTRONS 10

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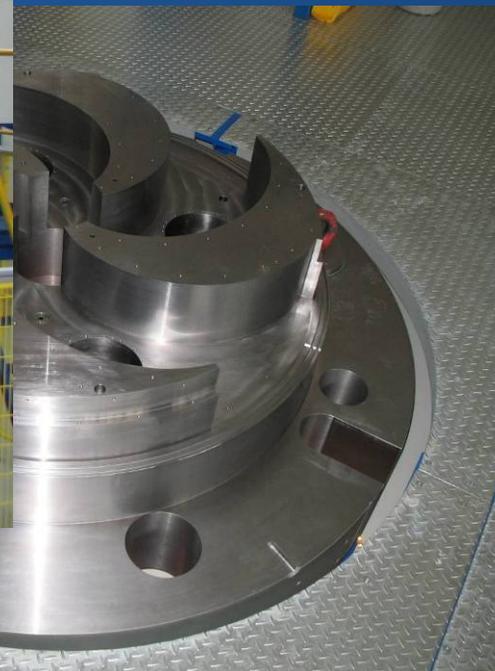
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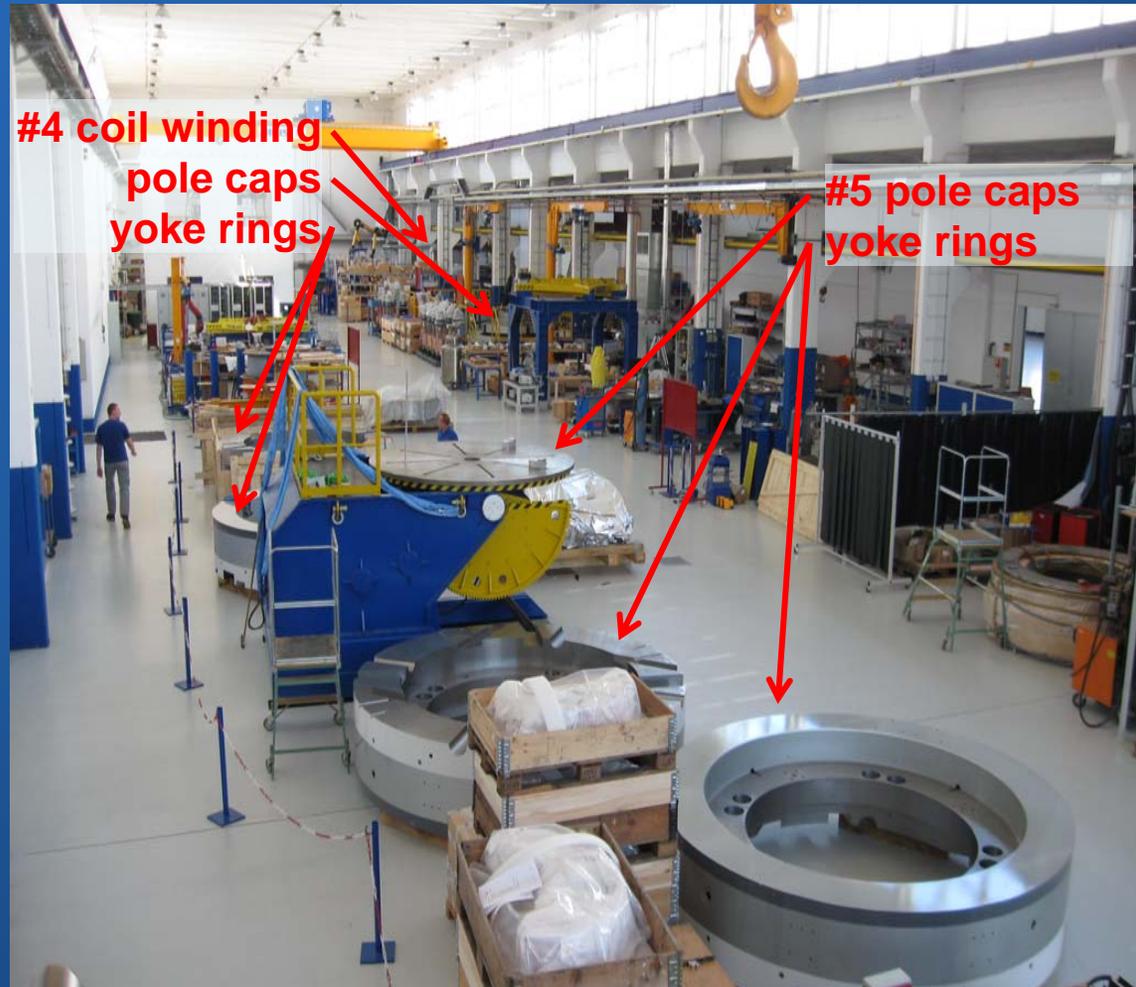
Lanzhou, China



# Production of Next Machines

#4, #5, #6, #7

- #4: All major components are ready, coil winding and assembly of pole caps is underway
- #5: Fine machined iron yoke and pole caps are in the factory under inspection
- #6, #7: Iron parts and long lead items are ordered (iron is casted and forged these days)
- Expected build sequence is ~2 cyclotrons per year at the moment



# Cyclotron and Scanning Nozzle Test Cell

## Factory Beam Test Plans



- Adjacent to the manufacturing hall VARIAN has built a concrete bunker for cyclotron and scanning nozzle tests, the so-called “Test Cell”
- This enables the delivery of factory beam tested systems.
- The Test Cell is finalized this month and cyclotron #3 will move in after magnetic shimming.



©bieling  
Großes Schild 600 x 360  
Wareneingang 150 x 90  
Besucher 150 x 120  
Besucher hinten an Mauer 150 x 120



CYCLOTRONS'10

Lanzhou, China

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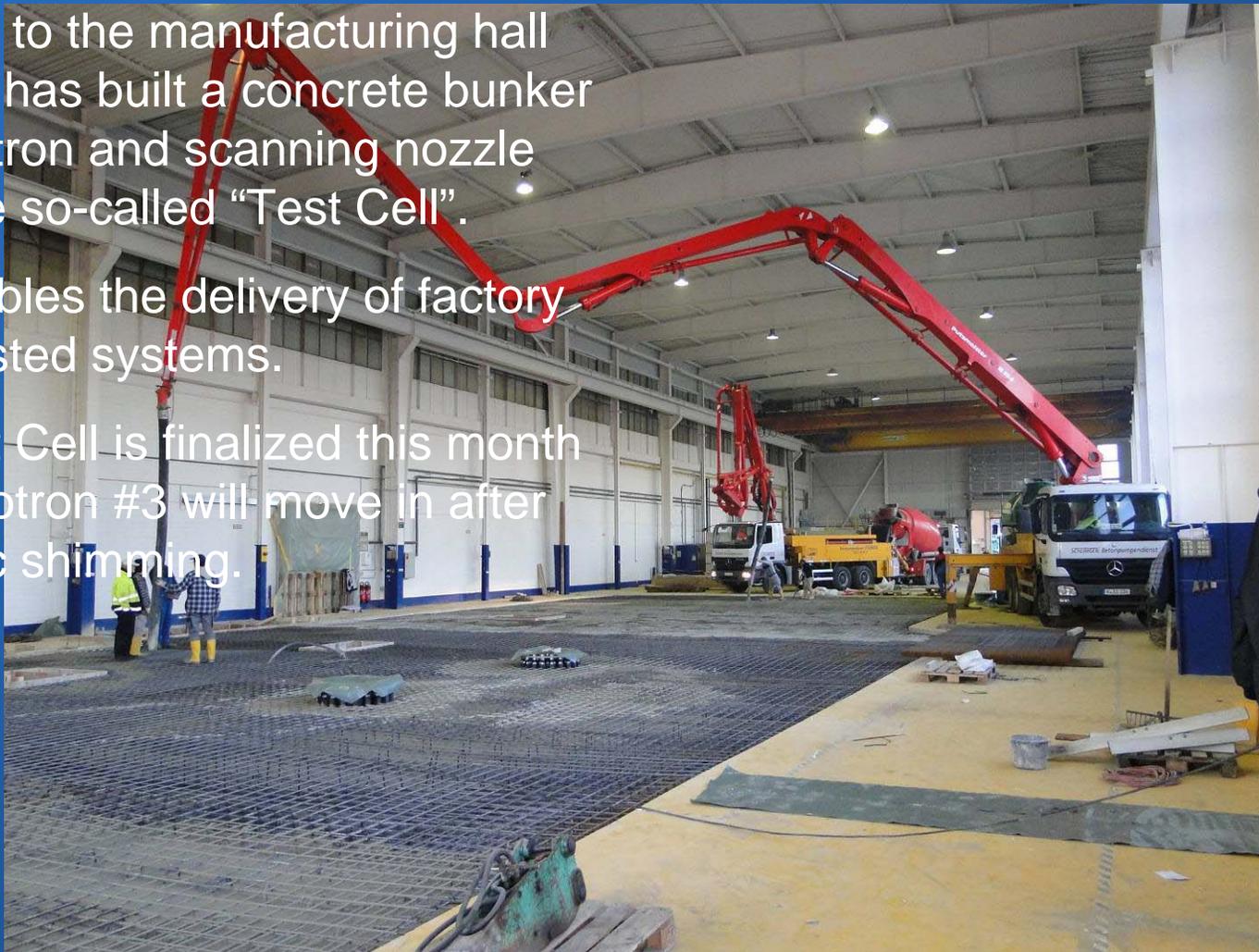


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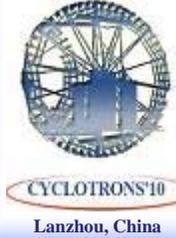
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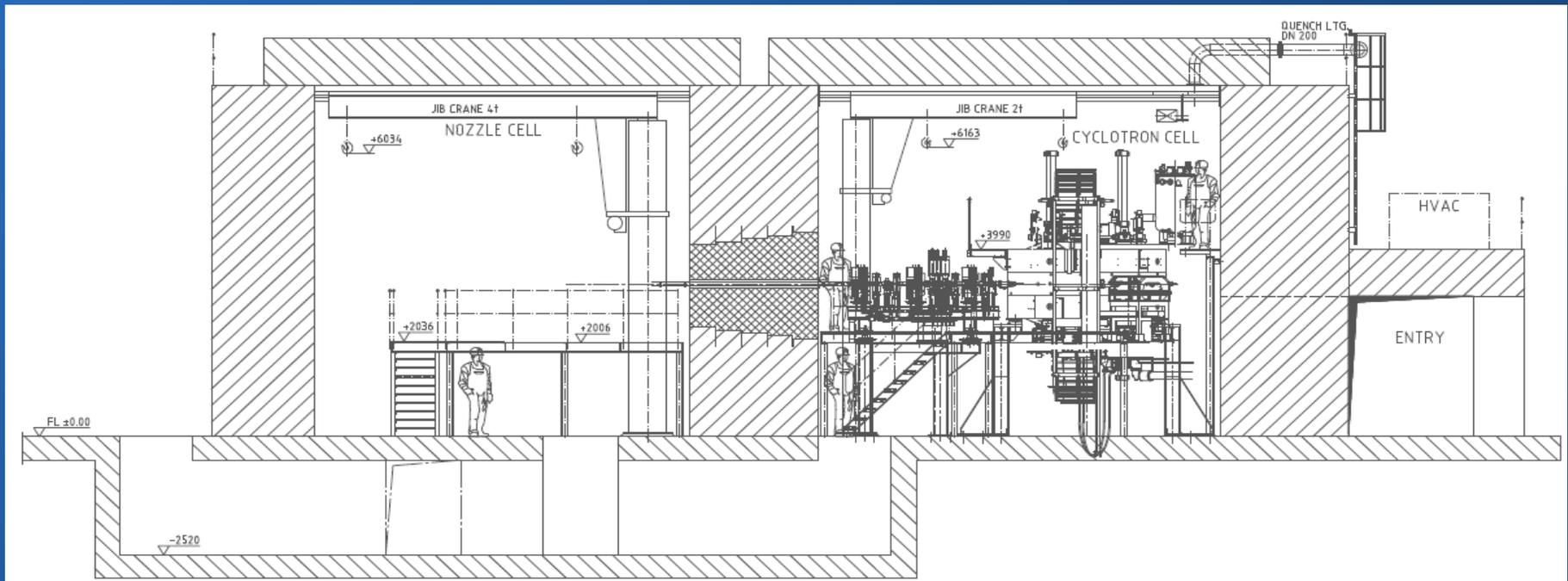


# Cyclotron and Scanning Nozzle Test Cell

## Factory Beam Test Plans



- We plan to test all RF components, ion source, slit systems, extractors, diagnostics, etc. during a system integration and FAT for cyclotron #3 in this year.



# Cyclotron and Scanning Nozzle Test Cell

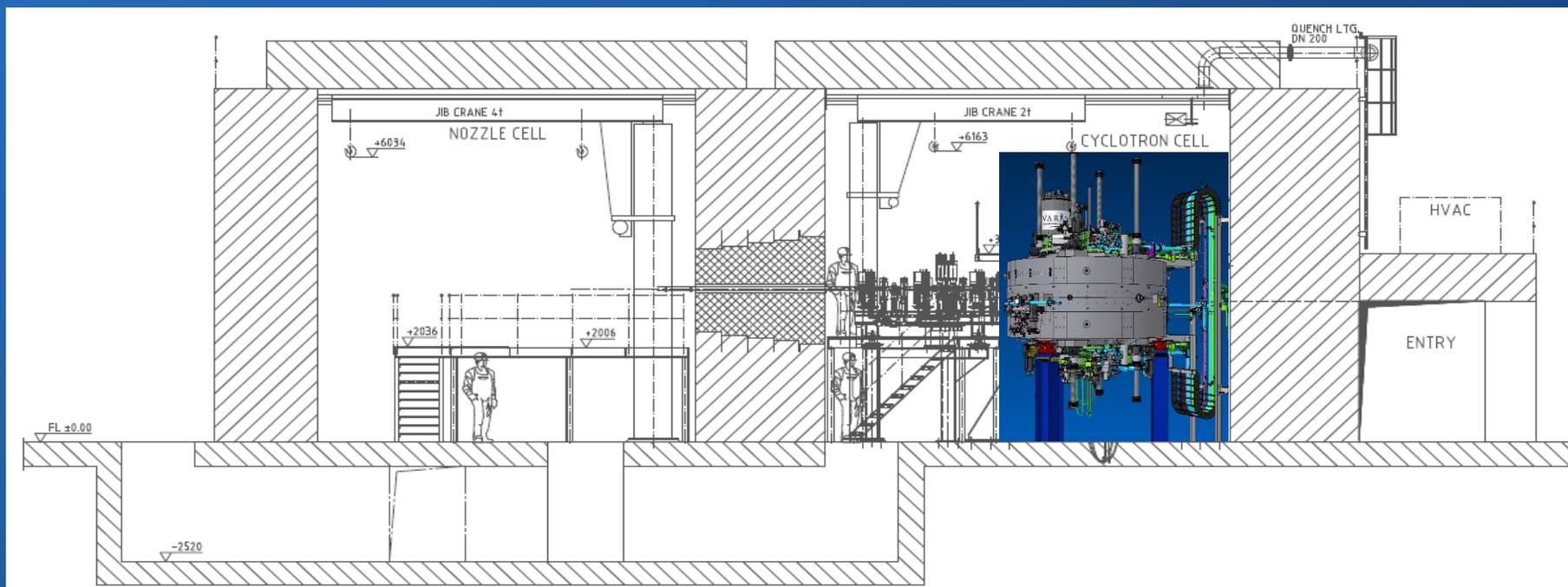
## Factory Beam Test Plans



CYCLOTRONS'10

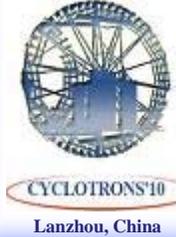
Lanzhou, China

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# VARIAN PT Superconducting Proton Cyclotrons

## Future Developments



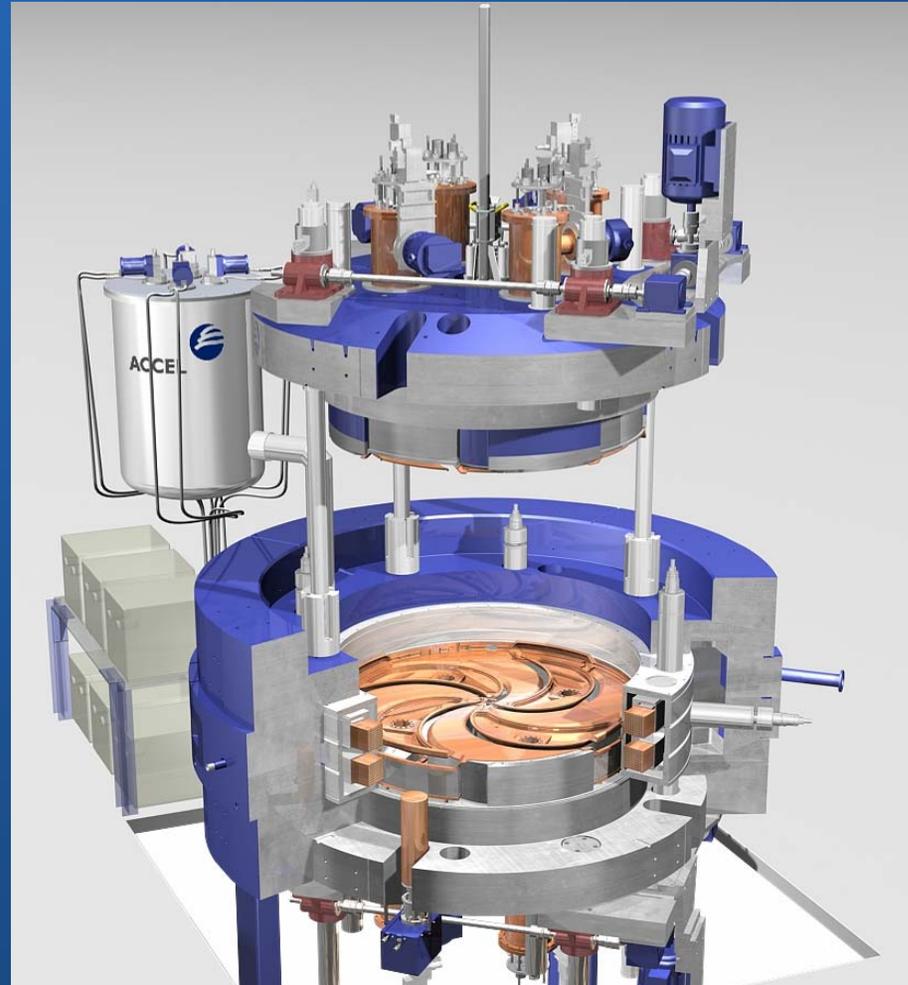
The proven design ...

which was built in the past ...

will be improved continuously for the VARIAN PT Cyclotron with regard to

- reliability
- maintainability
- performance upgrades
- cost reduction

Ion Source, Solid State Amplifier,  
Dee Noses, Digital LLRF, Simplified Media Supply,  
Iron, Cryosystem, Extraction System, and so on ...



# VARIAN PT Superconducting Proton Cyclotrons

## Future Developments



CYCLOTRONS'10

Lanzhou, China

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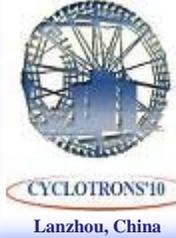
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# VARIAN PT Superconducting Proton Cyclotrons

## Future Developments



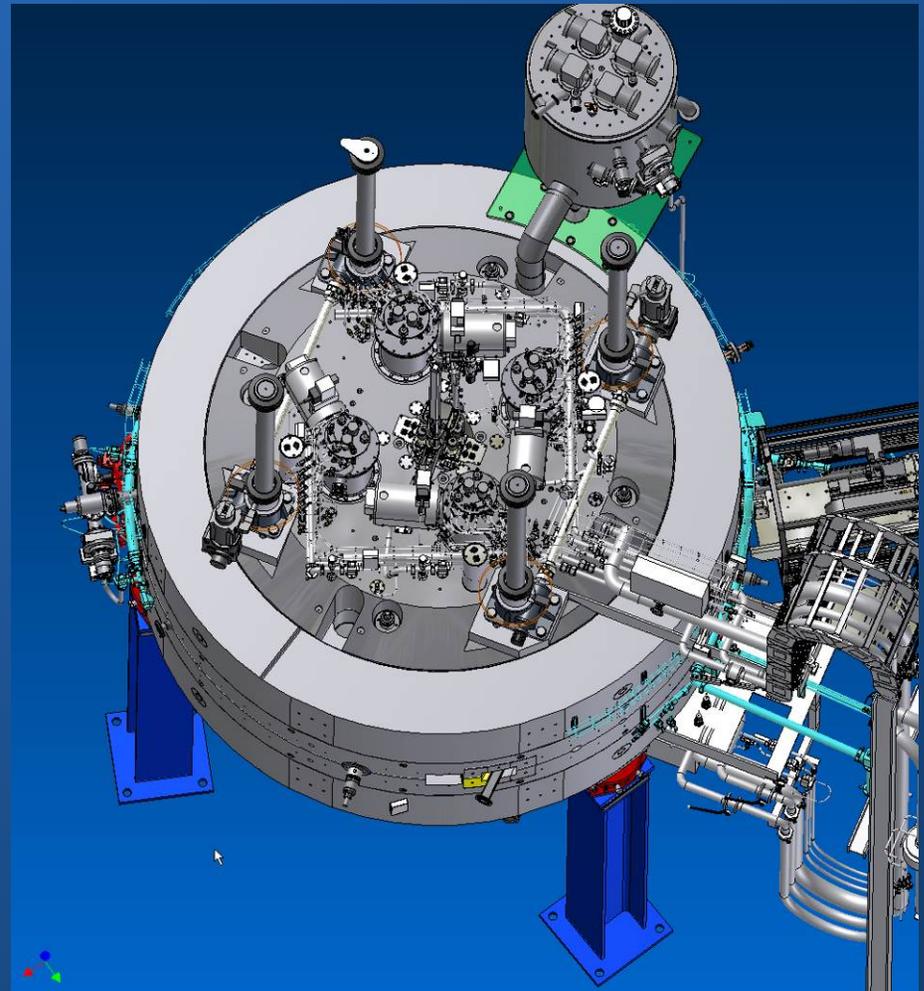
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# Conclusion

## Operating & Future VARIAN PT Cyclotrons



CYCLOTRONS'10

Lanzhou, China

- \* Paul Scherrer Institute (PSI), treating patients since beginning of 2007.
- \* Rinecker Proton Therapy Center (RPTC), treating patients since beginning of 2009. Gantry #4 @RPTC is handed over right now.
- \* A contract for the next complete PT installation with a customer from the USA has been signed.
  - \* There are more projects in Europe and the USA in the pipeline.
  - \* Cyclotron #3 is currently undergoing FATs.
  - \* Cyclotron #4 parts are currently assembled in the VARIAN factory.
  - \* Iron #5 is under inspection in the factory.
    - \* Irons #6 and #7 are currently being casted and forged ...

... more to come

# Team's Charity Run



...for the Children's Cancer Ward of the University Hospital in Cologne:



Thank you!

