
VARIAN
medical systems

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

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

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Particle Therapy GmbH
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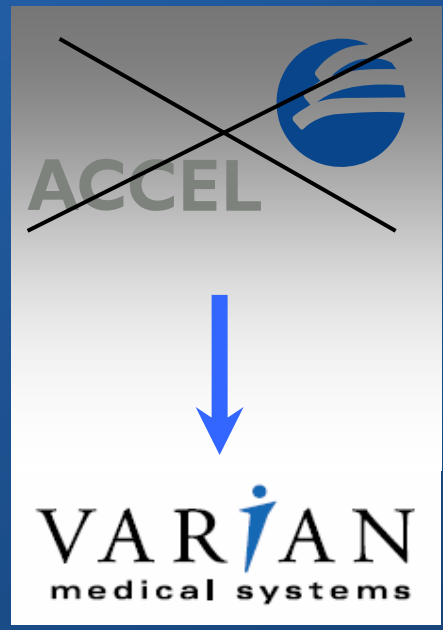
VARIAN PT ?

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)

➢ **Beam**	- Energy	250 MeV
	- Extracted current (max)	800 nA
	- Emittance of extracted beam	< 3 / 5 π mm mrad (2σ)
	- Momentum spread $\Delta p/p$	±0.04% (i.e. 200keV @ 250MeV)
	- Number of turns	650
	- Extraction efficiency (multi-turn extraction mode)	~80%
	- Dynamic range for intensity modulation	1:800
	- Fast intensity modulation	via electrostatic deflector, >10% in 100 μs
➢ **Iron Yoke**	- Outer diameter	3.1 m
	- Height	1.6 m
	- Weight	<90 t
➢ **SC Magnet**	- Stored energy	2.5 MJ
	- Central field	2.4 T
	- Max. field at the coil	<4 T
	- Operating current	160 A
	- Rated power of cryocoolers	40 kW
➢**RF System**	- Frequency	72.8 MHz (2nd harmonic)
	- Voltage source to puller / @ extraction radius	80 kV / 130 kV
	- RF power	⩽115 kW

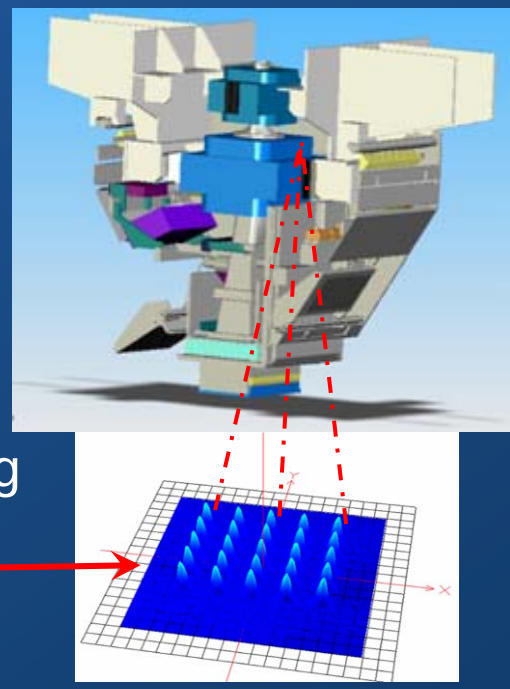
Operating VARIAN PT Cyclotrons #1 and #2

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 :

PATIENT TREATMENT STARTED MARCH 16th, 2009

TREATMENT REPORTS ARE AVAILABLE

STATUS REPORTS AND MEDICAL CASE STUDIES ARE AVAILABLE

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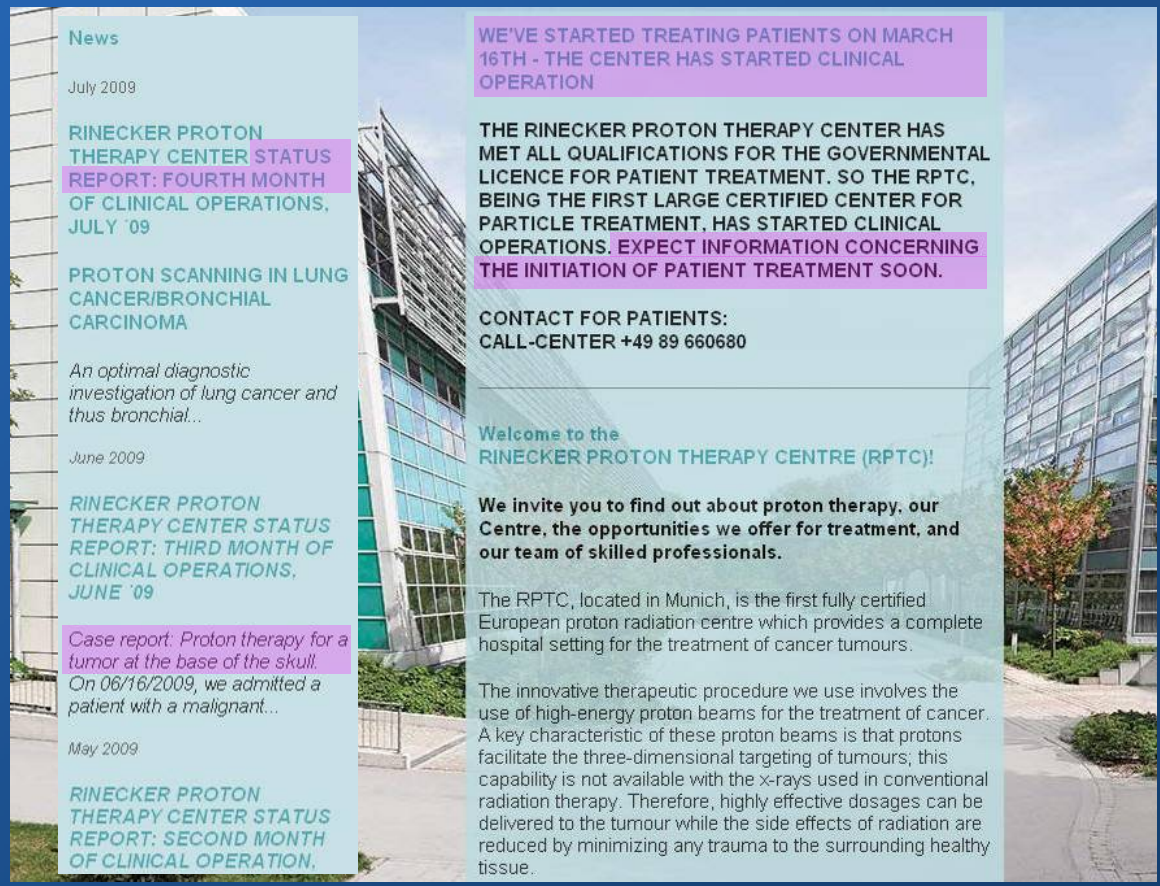
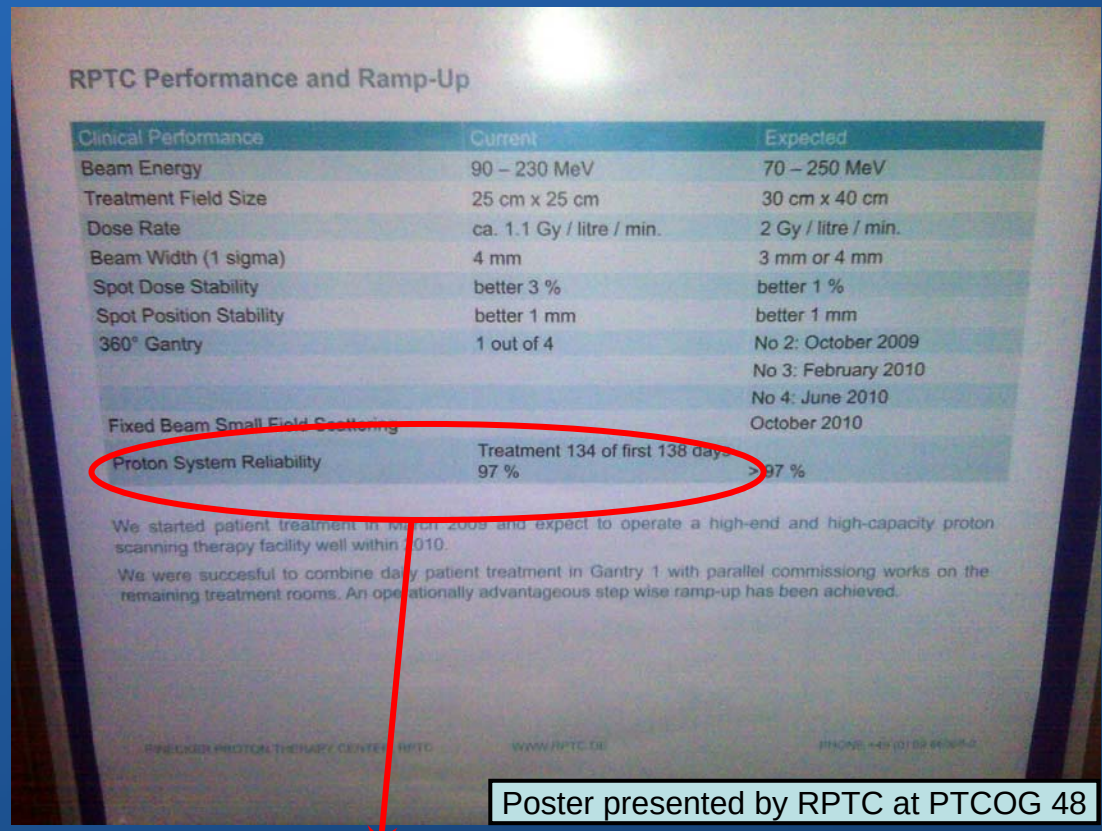


RPTC Uptime during Patient Treatment

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
Fixed Beam Small Field Scattering		October 2010
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 succesful to combine daily patient treatment in Gantry 1 with parallel commissiong works on the remaining treatment rooms. An operationally advantageous step wise ramp-up has been achieved.

Poster presented by RPTC at PTCOG 48

Proton System Reliability — Treatment 134 of first 138 days 97 %

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.

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VARIAN PT Cyclotrons under Commissioning

#3 SC Magnet Ramping and Test Quench

CYCLOTRONS'10
Lanzhou, China

- 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

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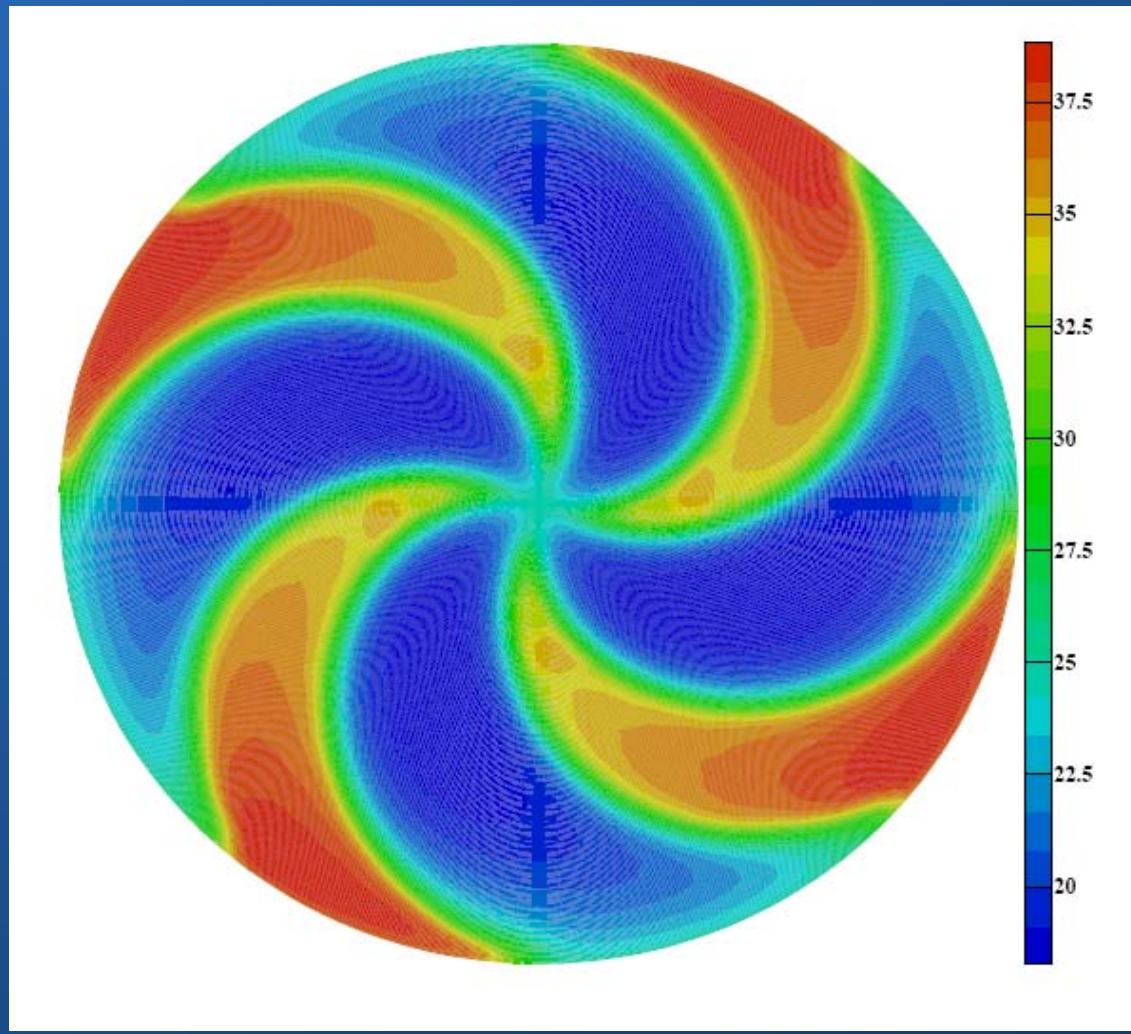
#3 Magnetic Field Mapping

- 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 ~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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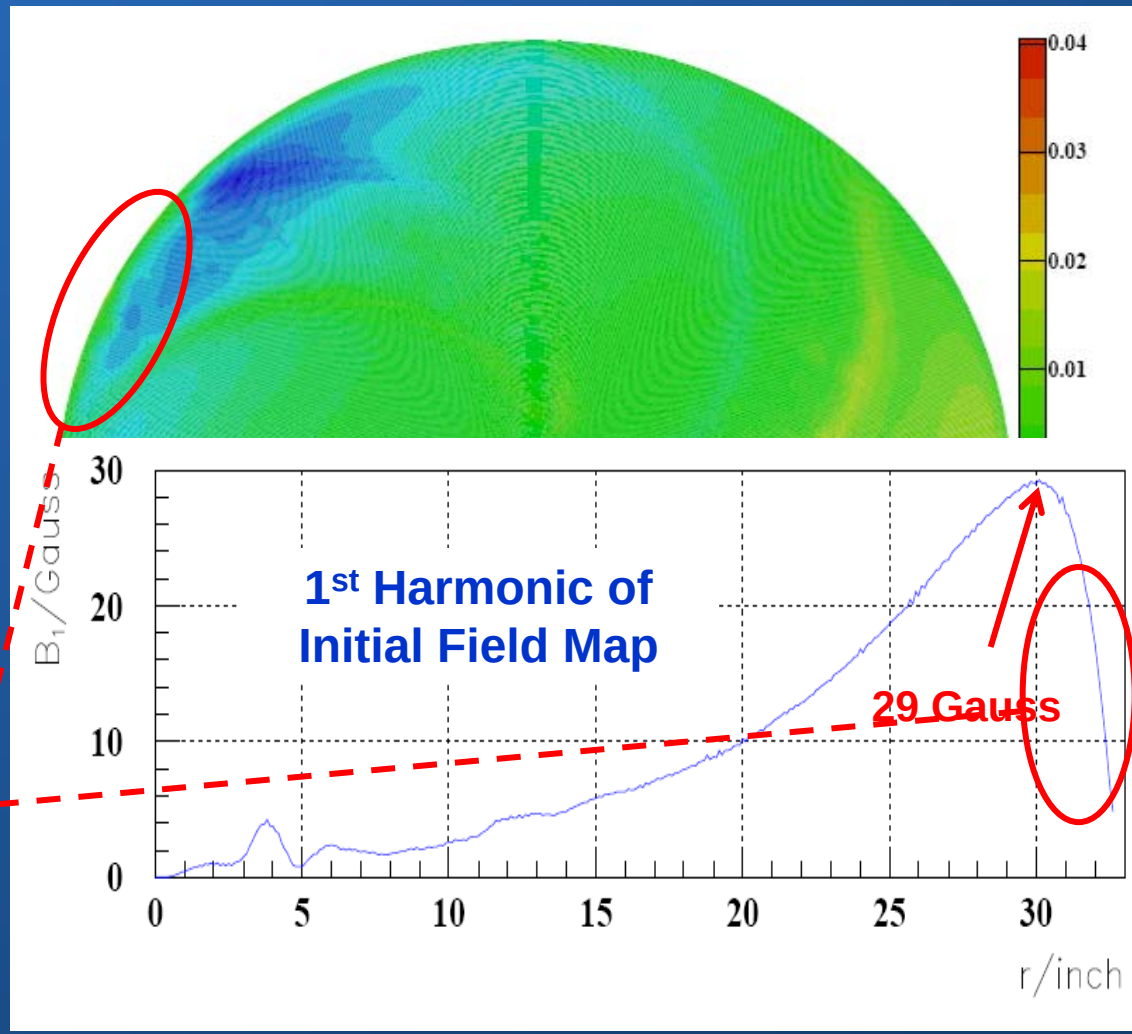

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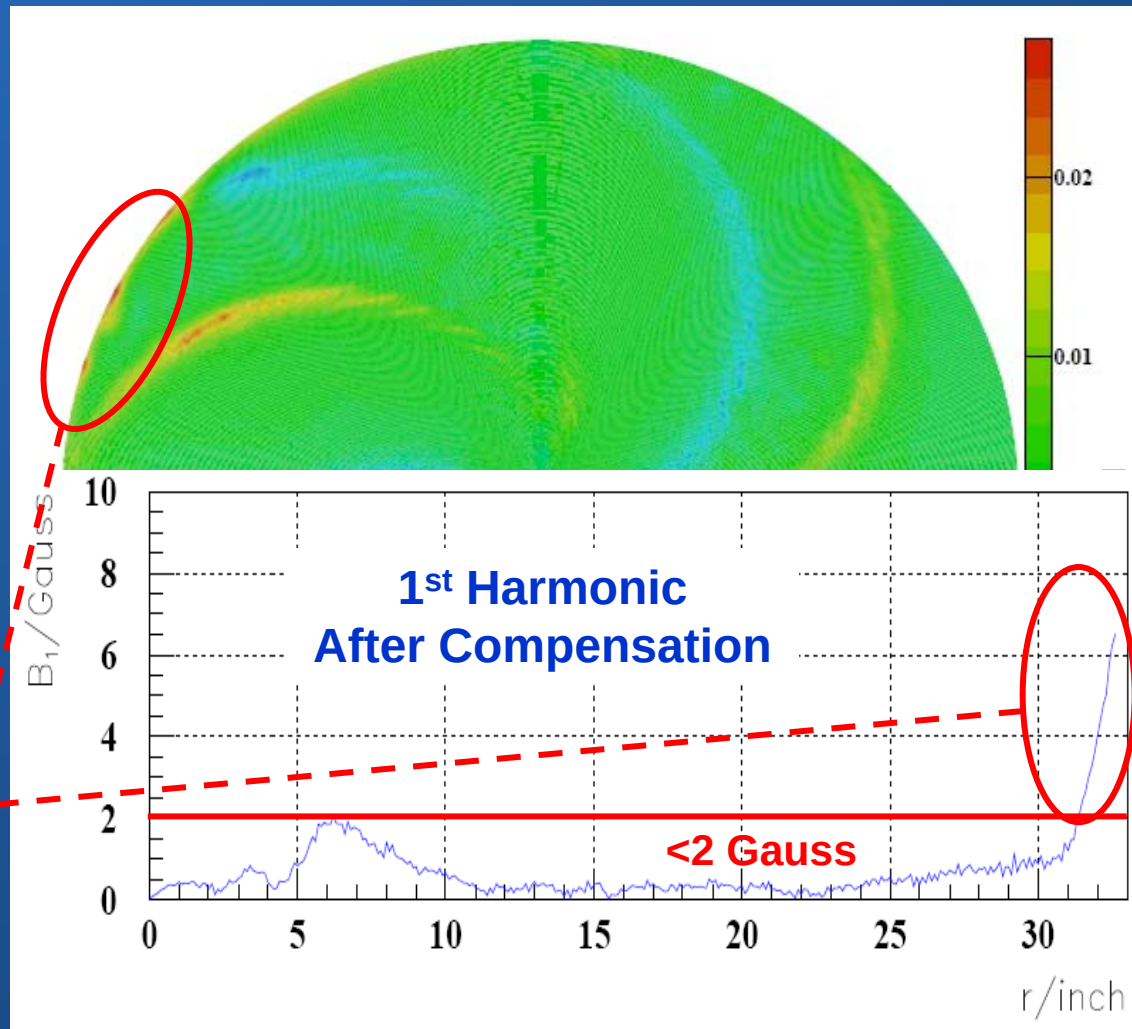
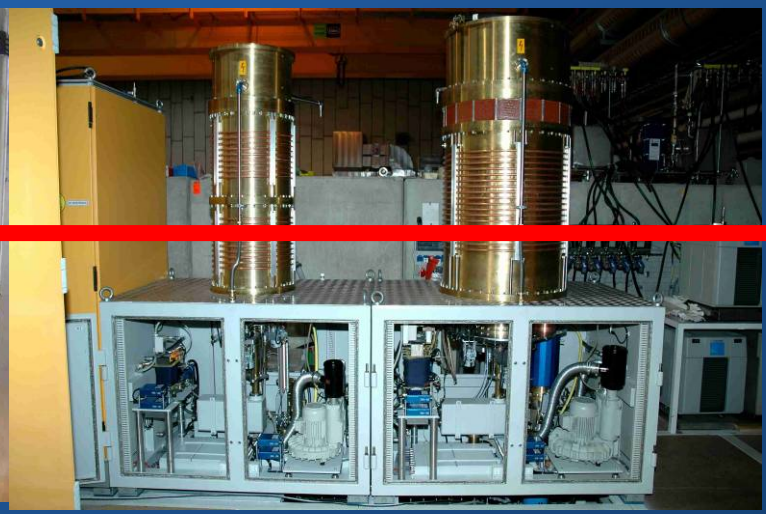


VARIAN PT Cyclotrons under Commissioning

Solid State Amplifier

CYCLOTRONS'10
Lanzhou, China

- 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.

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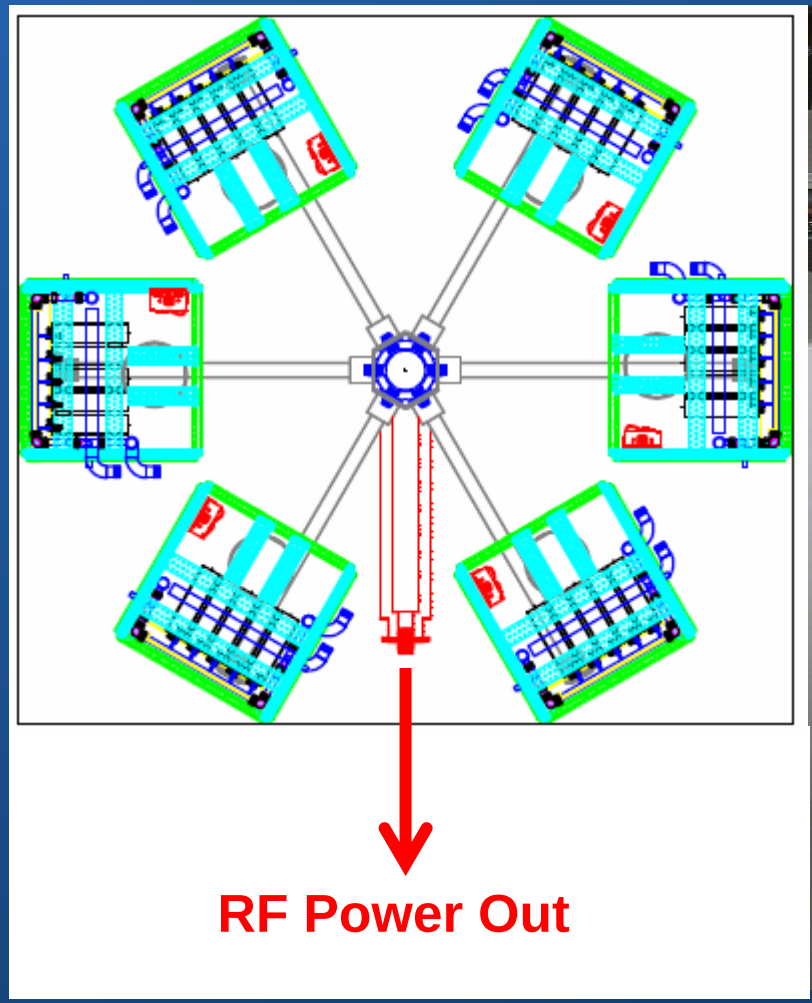

VARIAN PT Cyclotrons under Commissioning

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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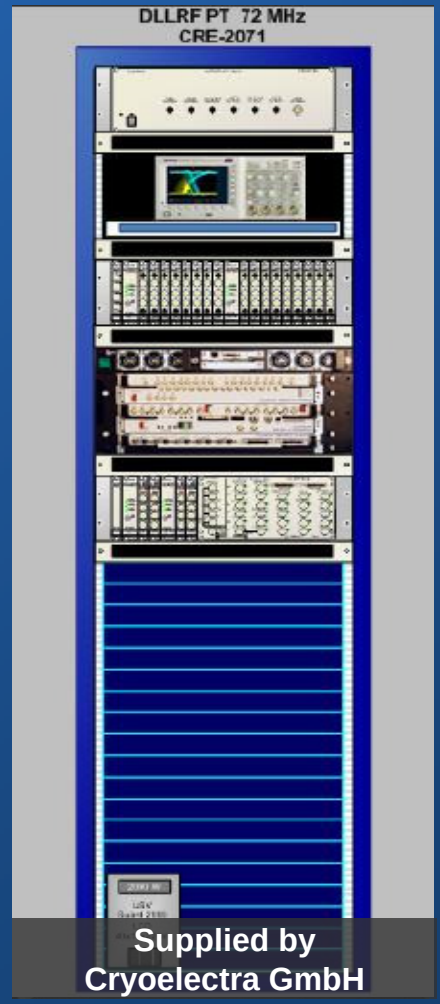

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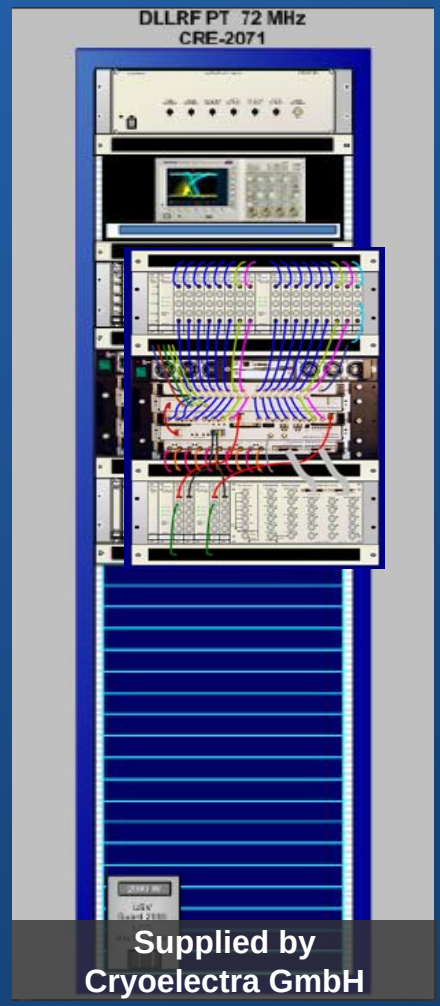

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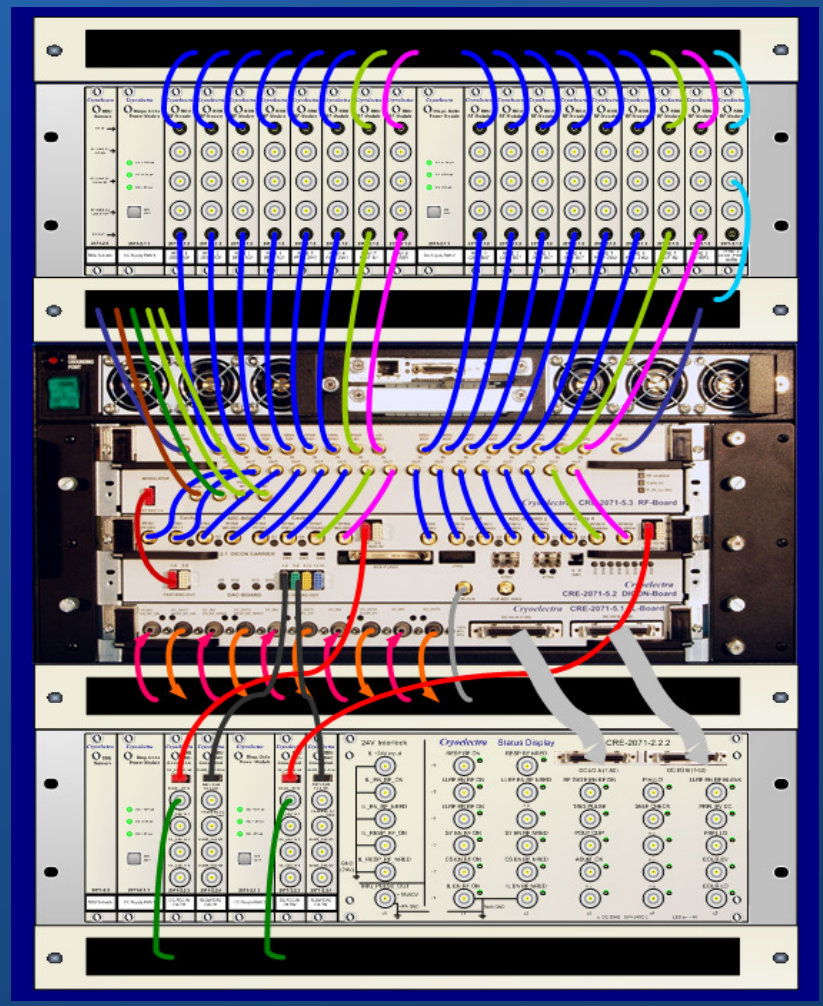

VARIAN PT Cyclotron Production Site
Overview

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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Assembly Stands

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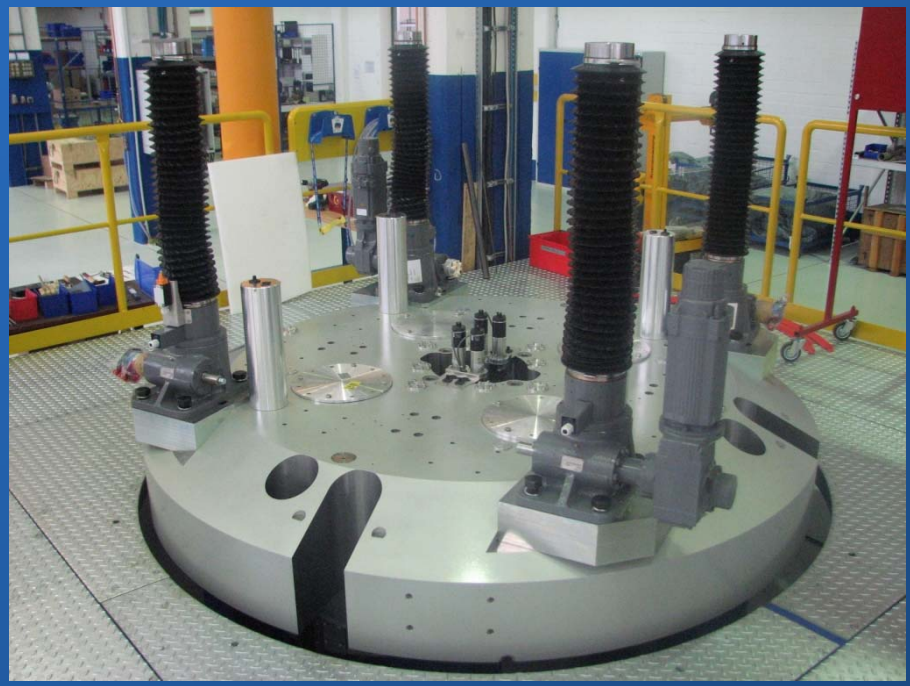
Assembly Stands



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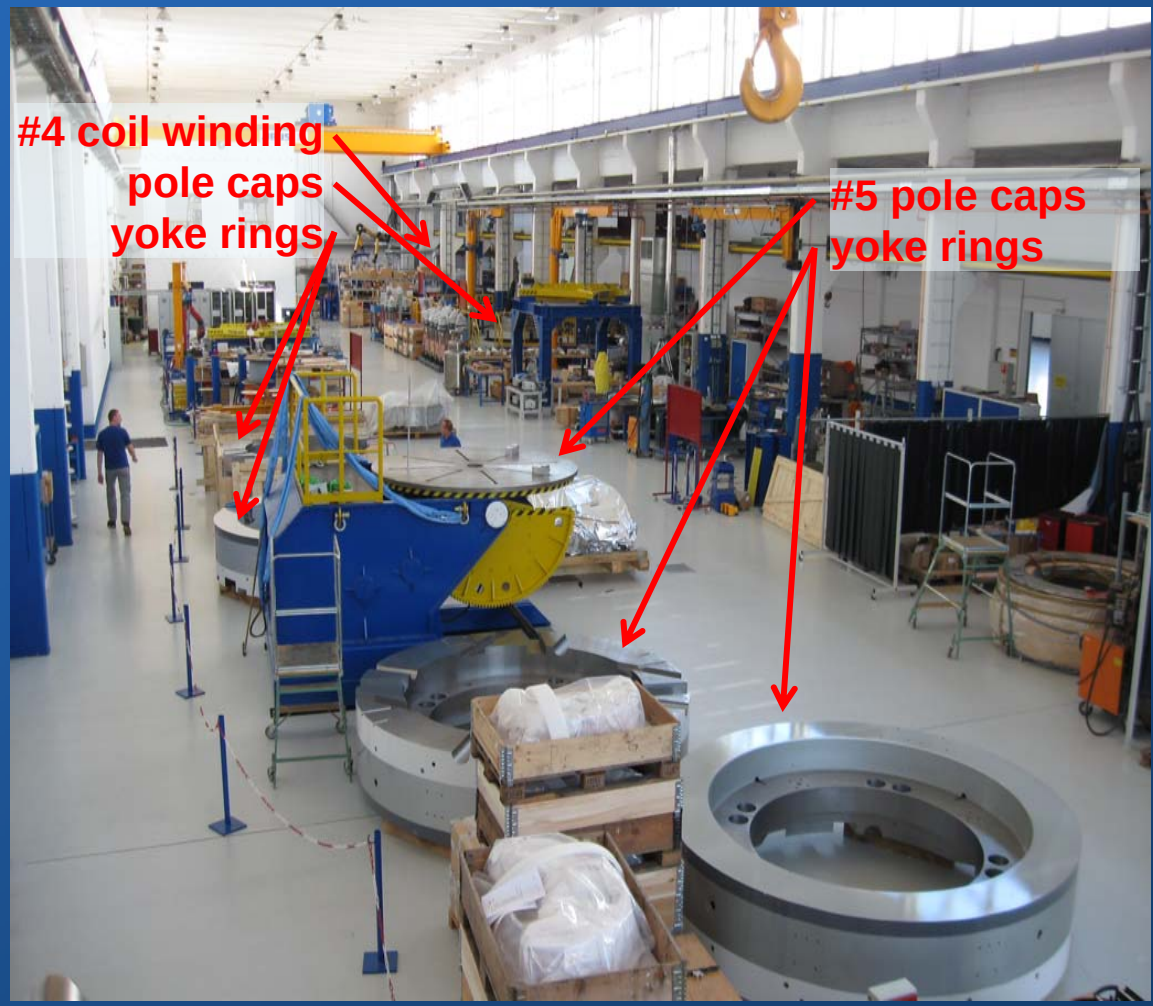
Assembly Stands

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.

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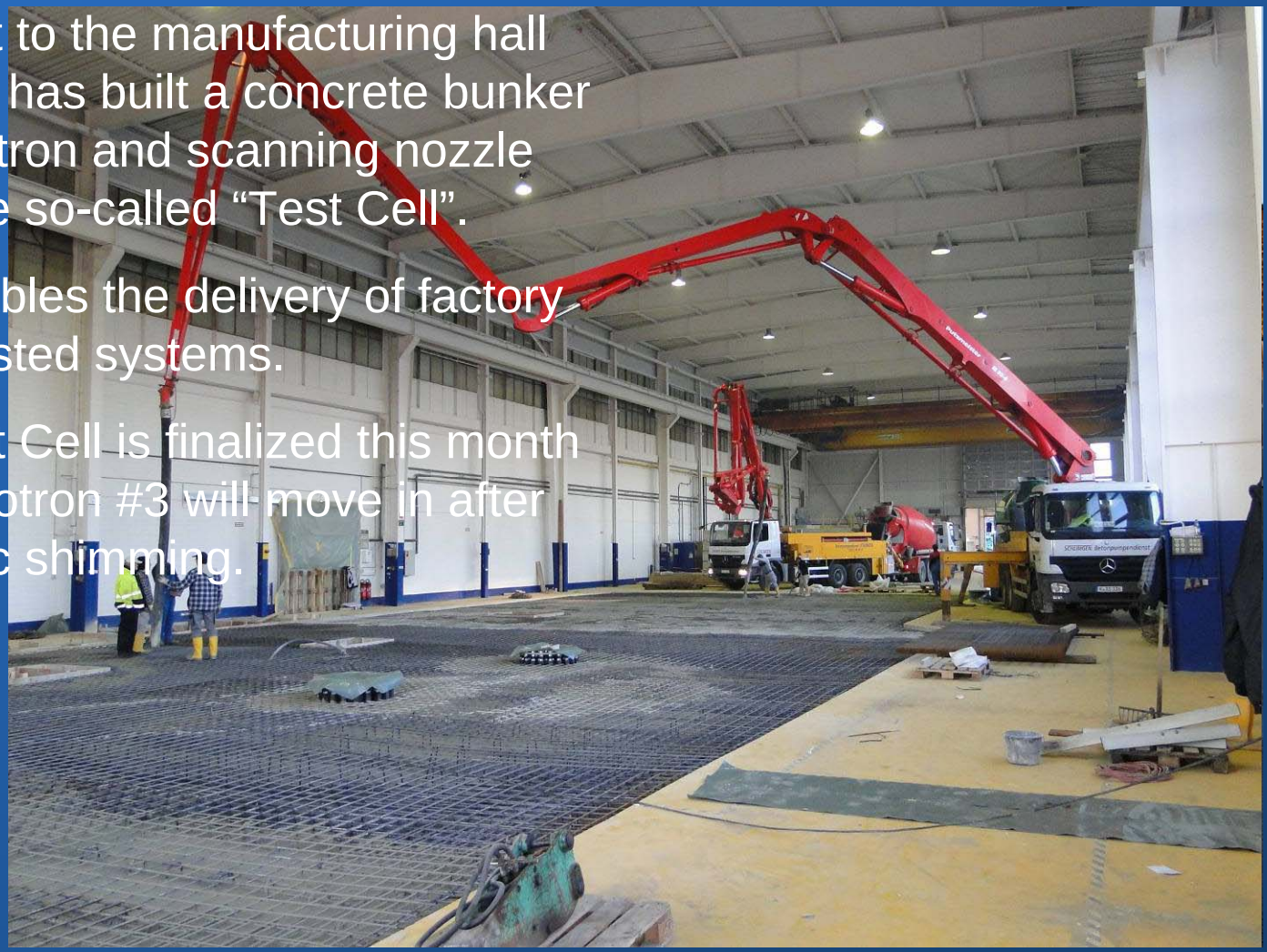

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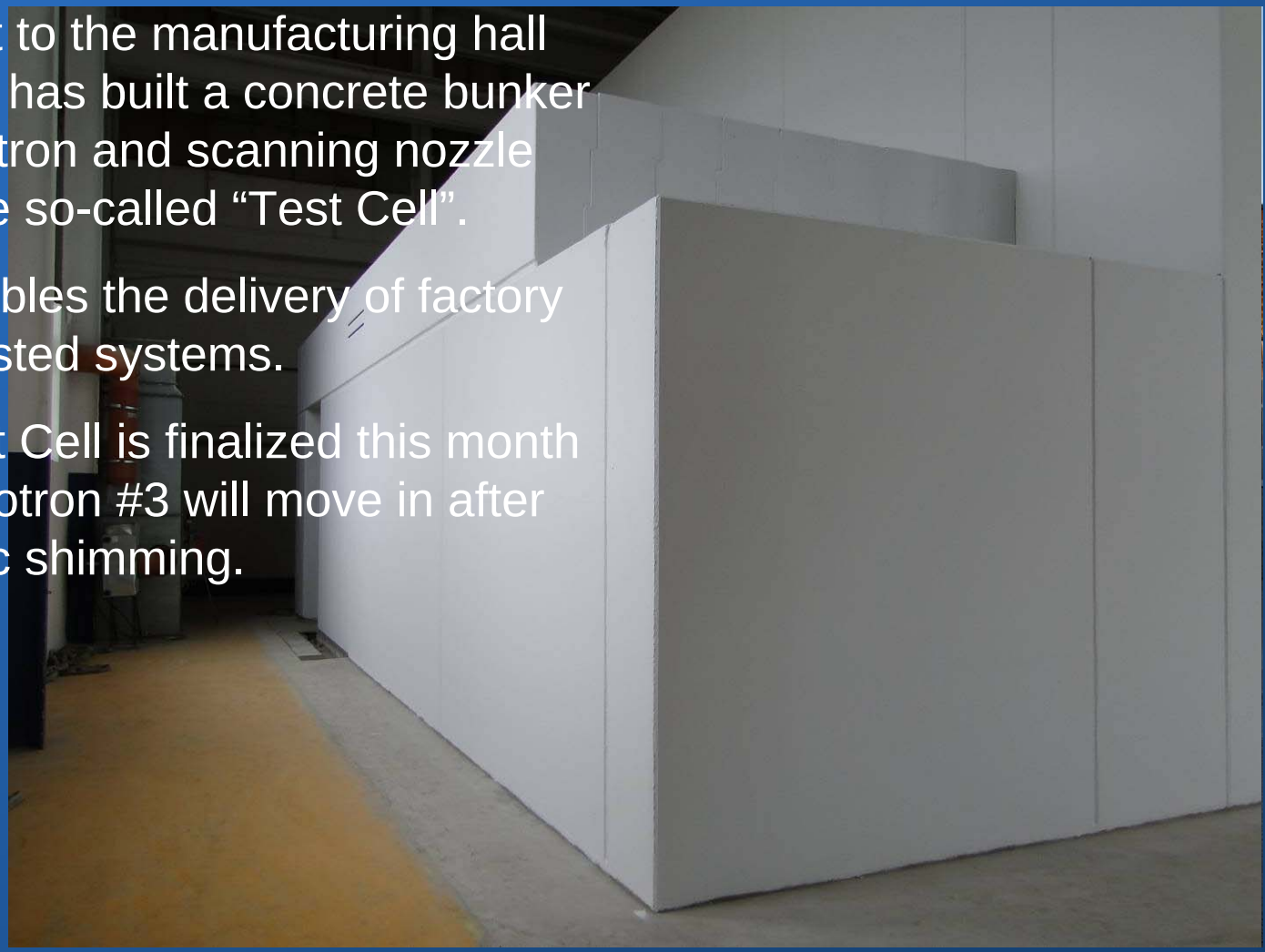

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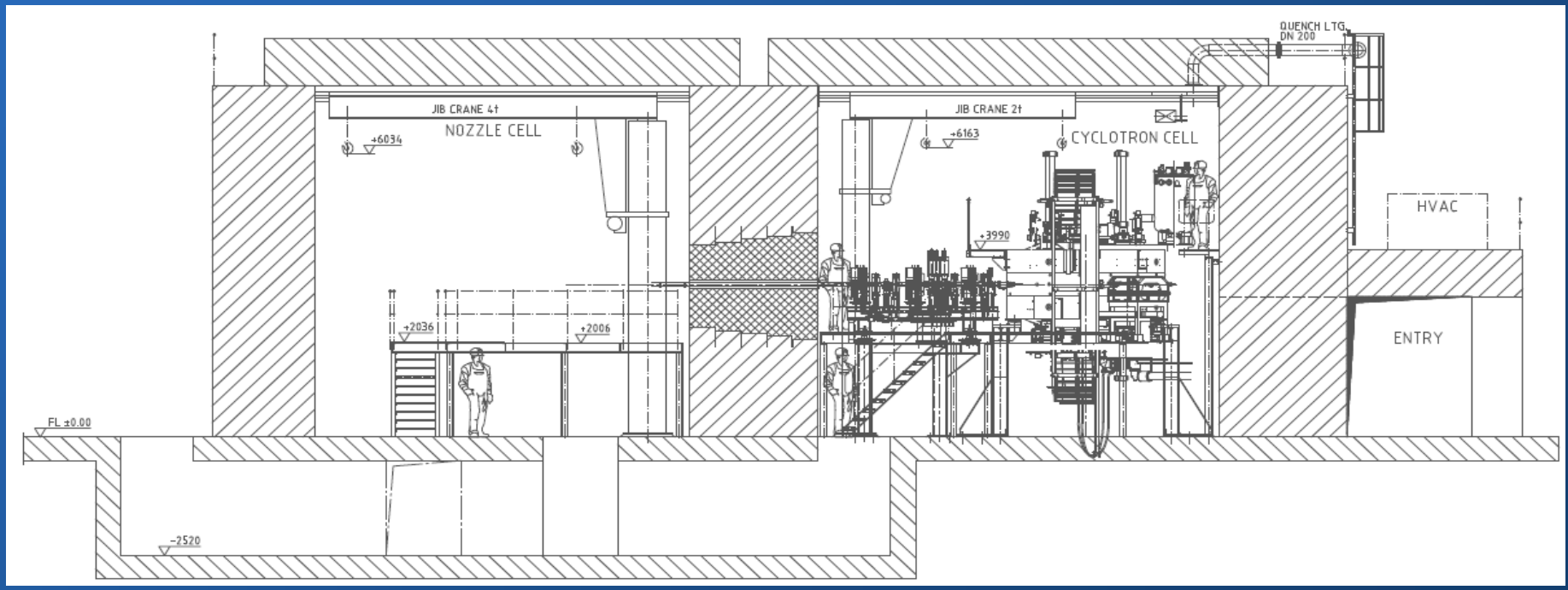

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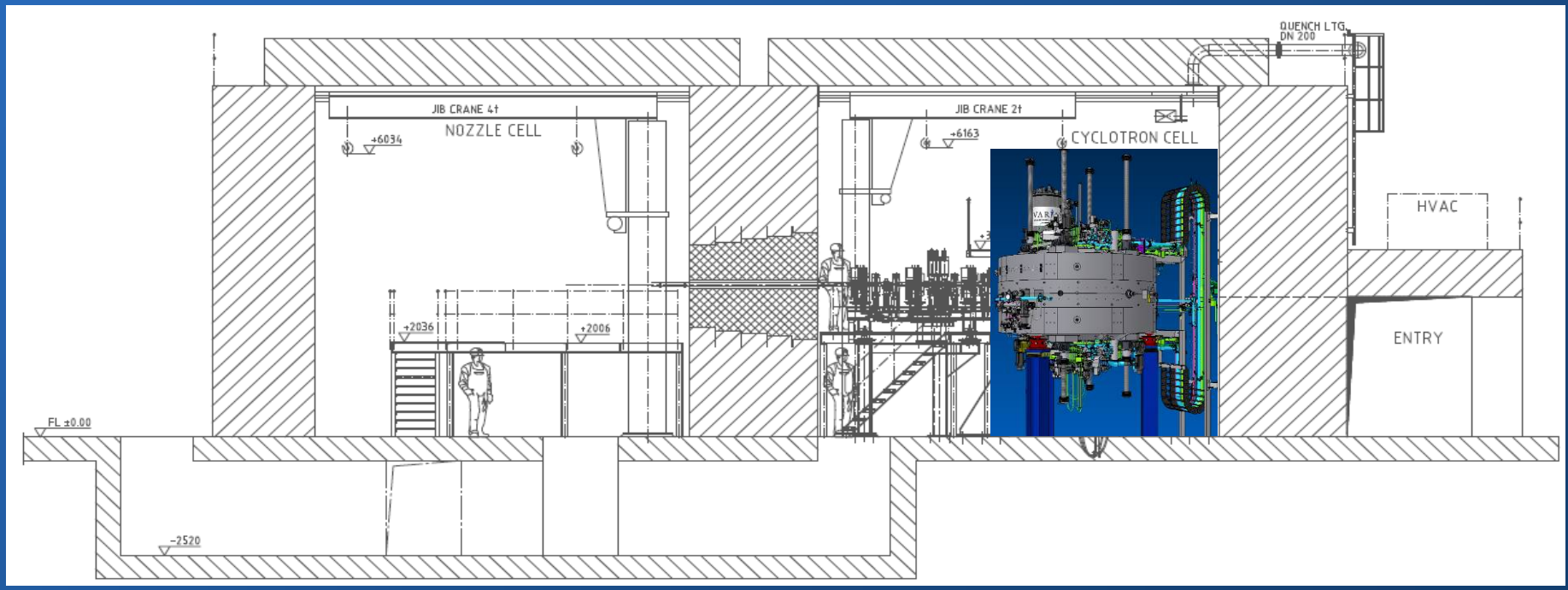


VARIAN PT Superconducting Proton Cyclotrons

Future Developments

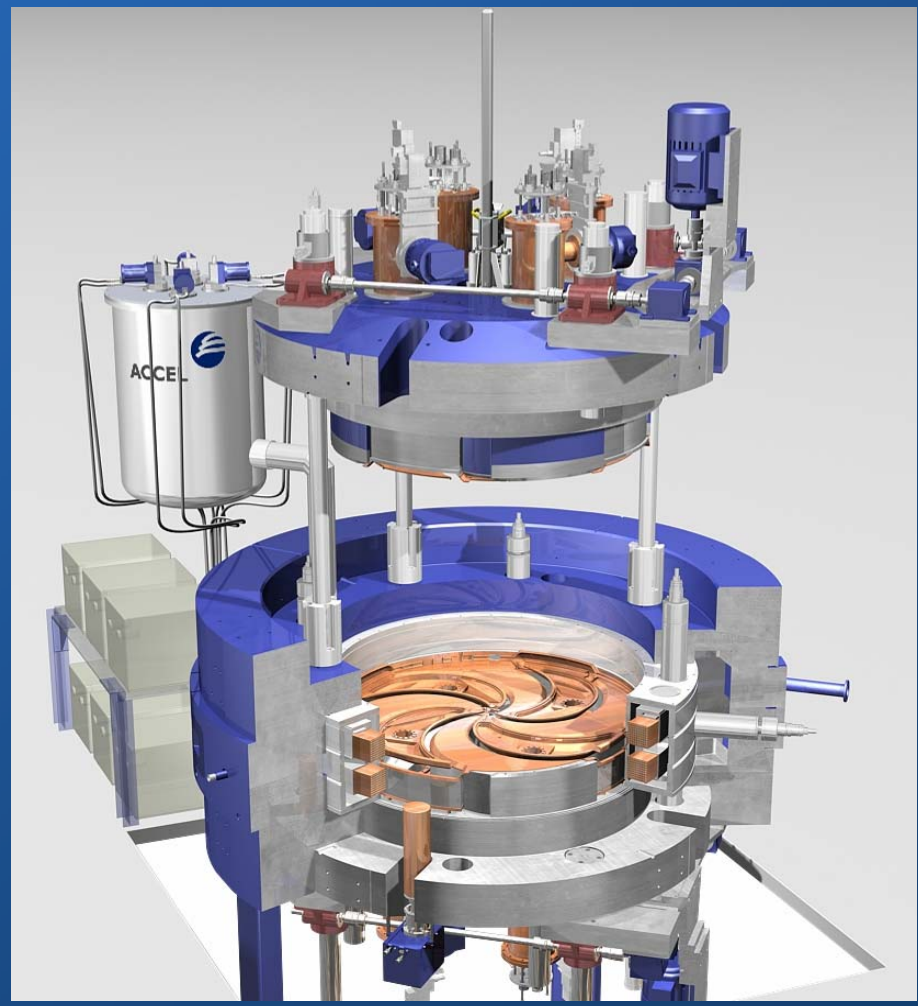
The proven design …

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 ...



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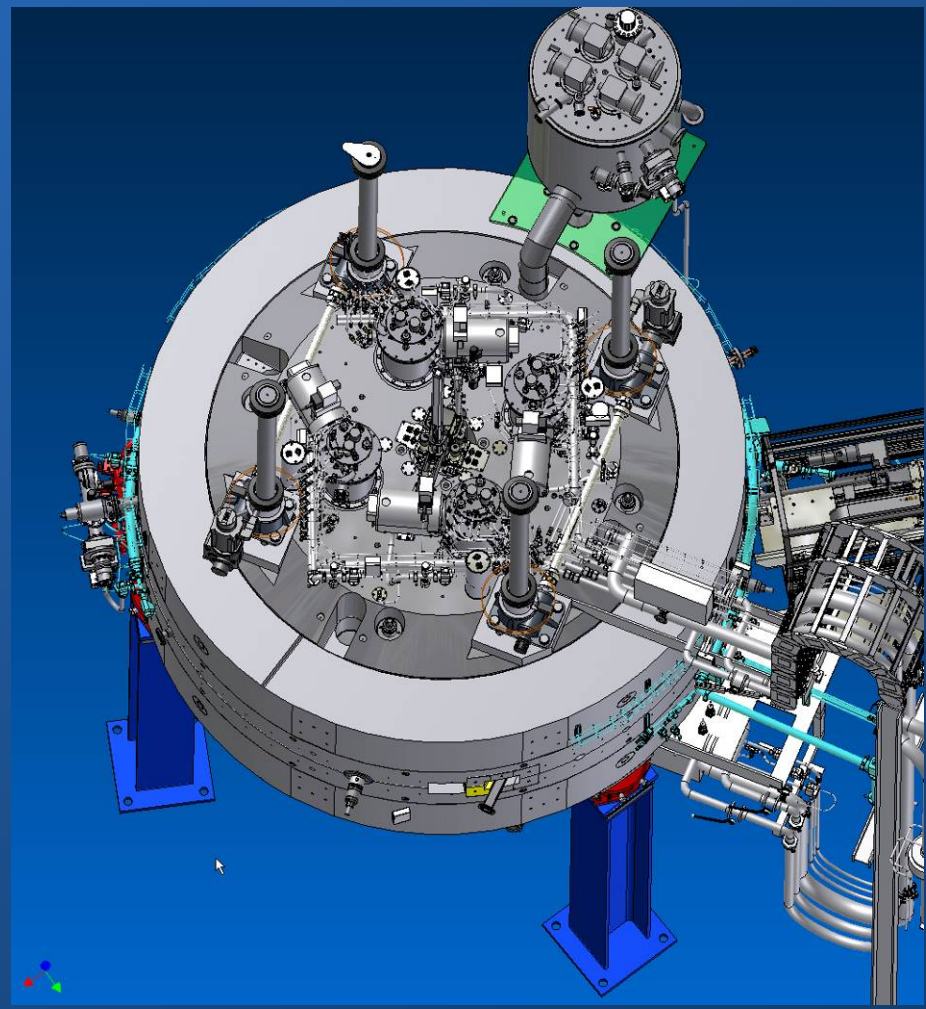

Conclusion

Operating & Future VARIAN PT Cyclotrons

* 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

CYCLOTRONS'10
Lanzhou, China

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

Thank you!