

The background of the top section is a detailed, close-up photograph of a large, complex medical device, likely a linear accelerator, featuring teal-colored curved components and intricate metallic structures.

# ECPPM 2012

Paul Scherrer Institut

Switzerland

May 9-12, 2012

PAUL SCHERRER INSTITUT



# VAR*i*AN

**medical systems**

# Commissioning and Testing of Varian's 250 MeV Superconducting ProBeam™ Cyclotrons for Proton Therapy

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**VARIAN Medical Systems**

**Particle Therapy GmbH**

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GERMANY



# OUTLINE

- ProBeam™ Machine Key Data
- What have we told you so far?
  - ECPM 2009
  - CYCLOTRONS 2010
- Current Status of Varian's ProBeam™ Systems
- Factory Comm. & Testing of Cyclotron #3
  - RF Commissioning Results
  - Digital LLRF Control System
- First Internal / External Beam, Extraction Efficiency
- Transport to the USA, First Beam On Site
- Production of Further ProBeam™ Systems
  - Status of ProBeam™ Cyclotrons #4 & #5
- Conclusion

# VARIAN ProBeam™ SC Cyclotron Key Data

(Engineering Goals)

➤ Beam	<ul style="list-style-type: none"> <li>- Energy and particles</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>	250 MeV protons 800 nA $< 3 / 5 \pi$ mm mrad ( $2\sigma$ ) $\pm 0.04\%$ (i.e. 200keV @ 250MeV) 650 $\sim 80\%$ 1:800 via electrostatic deflector, $>10\%$ in 100 $\mu$ s
➤ Iron Yoke	<ul style="list-style-type: none"> <li>- Outer diameter</li> <li>- Height</li> <li>- Weight</li> </ul>	3.1 m 1.6 m $< 90$ t
➤ 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>	2.5 MJ 2.4 T $< 4$ T 160 A 40 kW
➤ RF System	<ul style="list-style-type: none"> <li>- Frequency</li> <li>- Voltage source to puller / @ extraction radius</li> <li>- RF power</li> </ul>	72.8 MHz (2 <sup>nd</sup> harmonic) 80 kV / 105 kV $\leq 115$ kW



# What have we told you so far?

## ECPM 2009:

- Patient treatment started at RPTC Munich, all scanning proton therapy treatment equipment provided by Varian



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.

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- Uptime = 97% for first 138 clinical days

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.CH      PHONE: +49 (0) 69 86588-2



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## ECPM 2009:

- Patient treatment started at RPTC Munich, all scanning proton therapy treatment equipment provided by Varian
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- Development of Solid State RF Amplifier started (Power Transistor Modules)



Supplied by  
Cryoelectra GmbH

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- ProBeam™ Cyclotron #3 was being assembled





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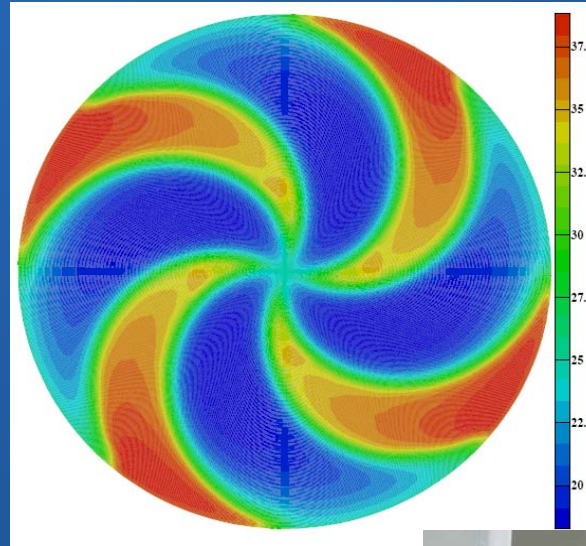
- RPTC Munich: 3 gantries were in clinical operation, the last one was about to be handed over
- ProBeam™ Cyclotron #3 was completely assembled and under commissioning



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- Field mapping and quench test had passed and demonstrated a stable, quench proof and quench tolerant system





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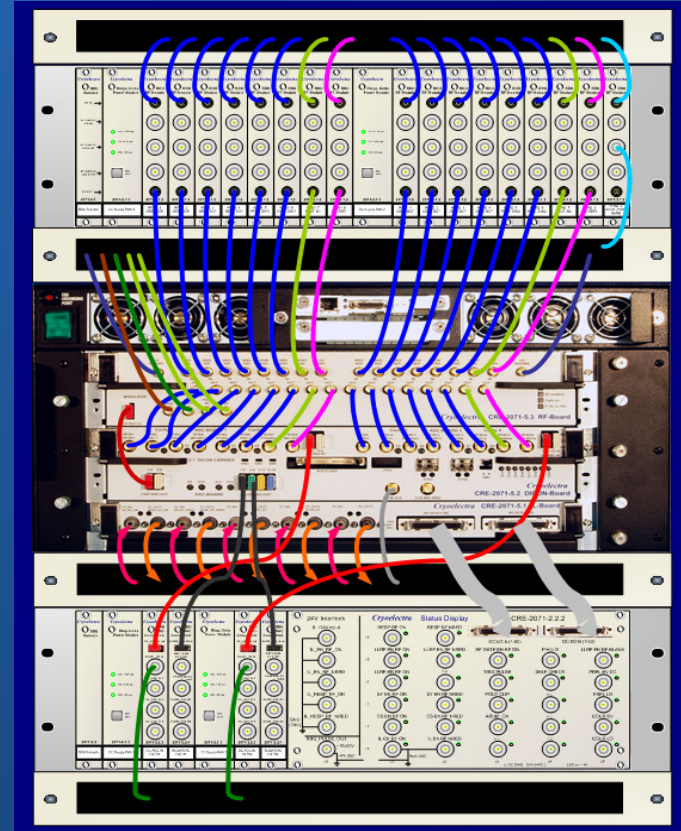
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- New full power RF amplifier with 120 modules was assembled and ready to use



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- Digital LLRF was ready to use





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- Digital LLRF was ready to use
- Factory Test Cell was ready for operation





# Current Status of Varian's ProBeam™ Systems

- RPTC Munich: All 4 gantries are clinical  
>1000 patients have been treated with a scanned proton pencil beam  
functionality is continuously being upgraded  
cyclotron is in continuous operation
- Cyclotron #3 RF conditioning is performed very efficiently  
using transistor amplifier and digital LLRF
- Cyclotron #3 was beam tested in the factory test cell
- Cyclotron and all other ProBeam™ PT equipment is shipped  
and installed at Scripps PTC in San Diego / USA
- First beam in April!
- Cyclotron #4 is under assembly  
coil is ready  
cryostat is ready and passed LN cold test  
complete machine will go into test cell in summer
- Cyclotron #5 coil is ready and electrically tested  
cryostat has to be completed

# Factory Testing of Cyclotron #3

- Cyclotron #3 was moved into factory test cell





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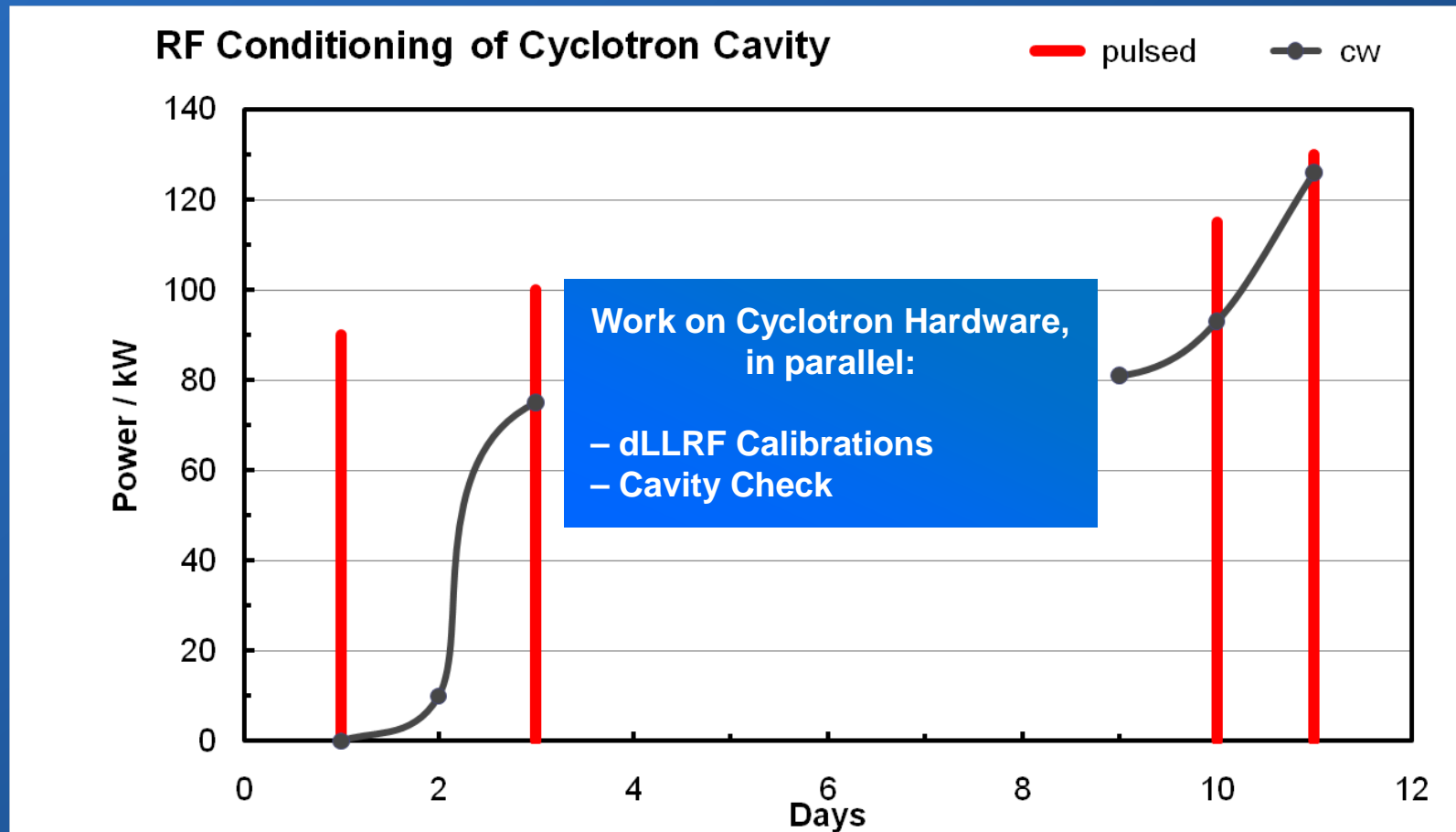


# RF Commissioning Results

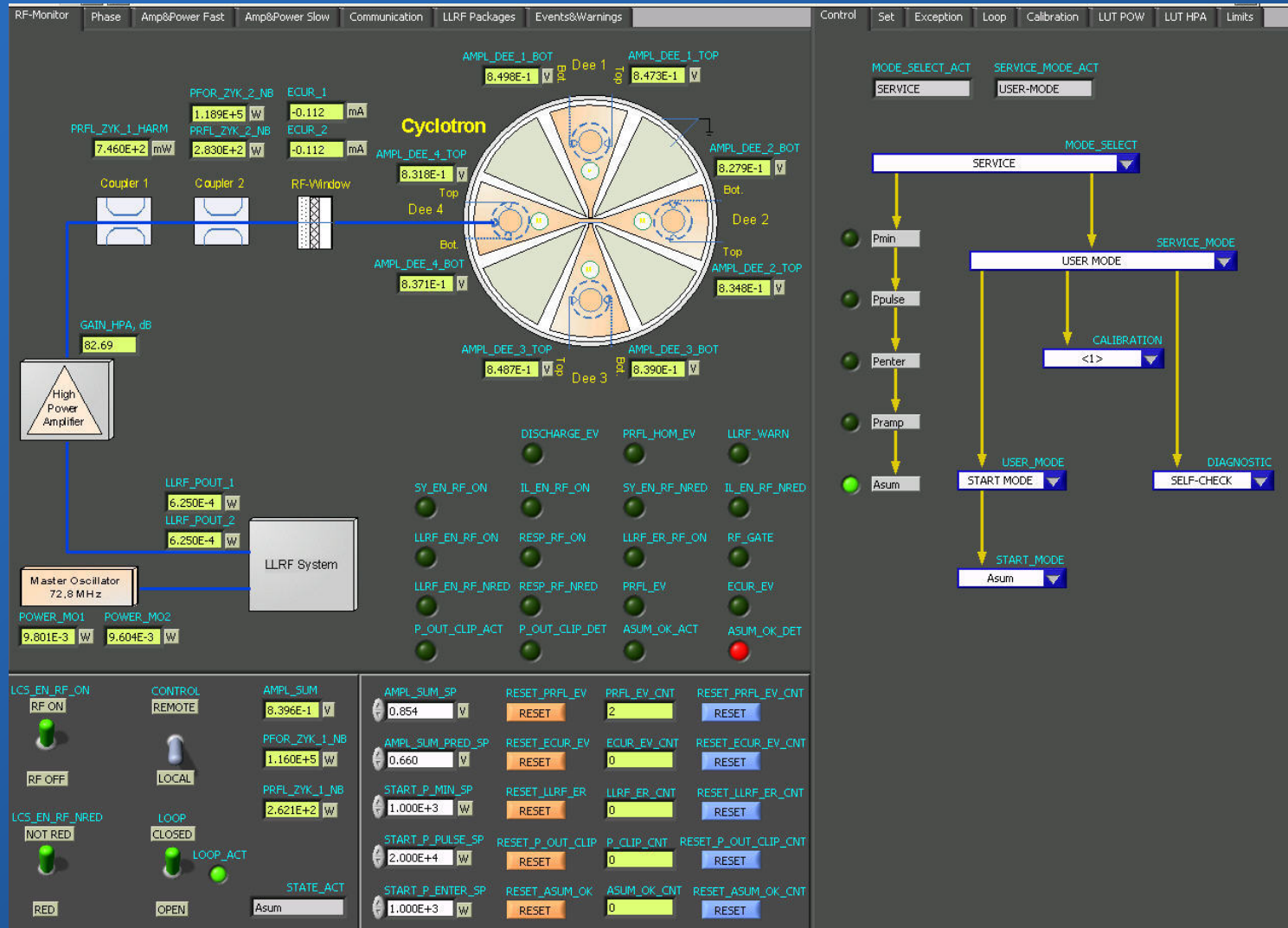
Solid State Amplifier  
& Digital LLRF



Very Fast RF Conditioning in Pulsed Mode  
(5% - 20% duty cycle)

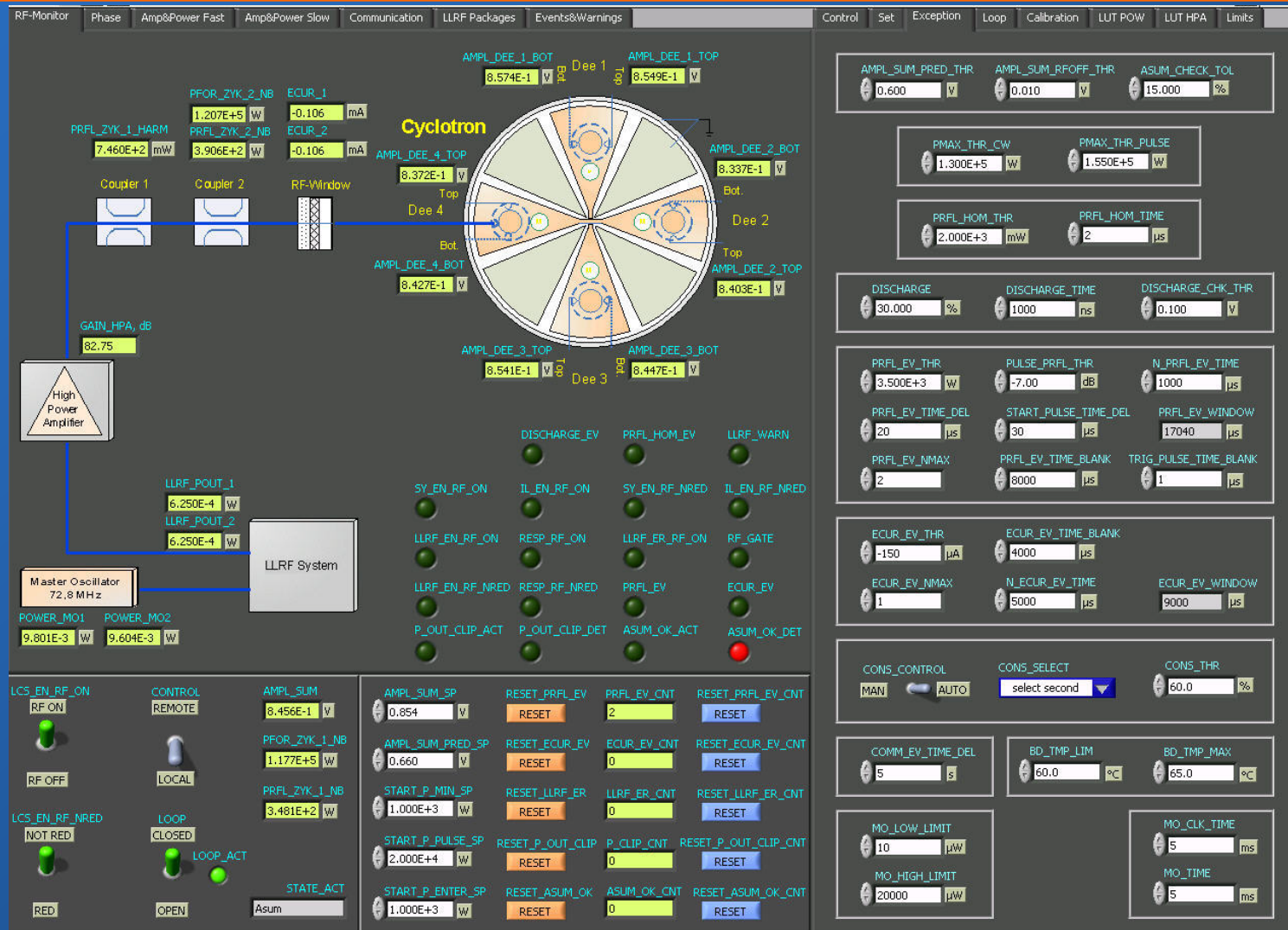


# Digital LLRF Control System

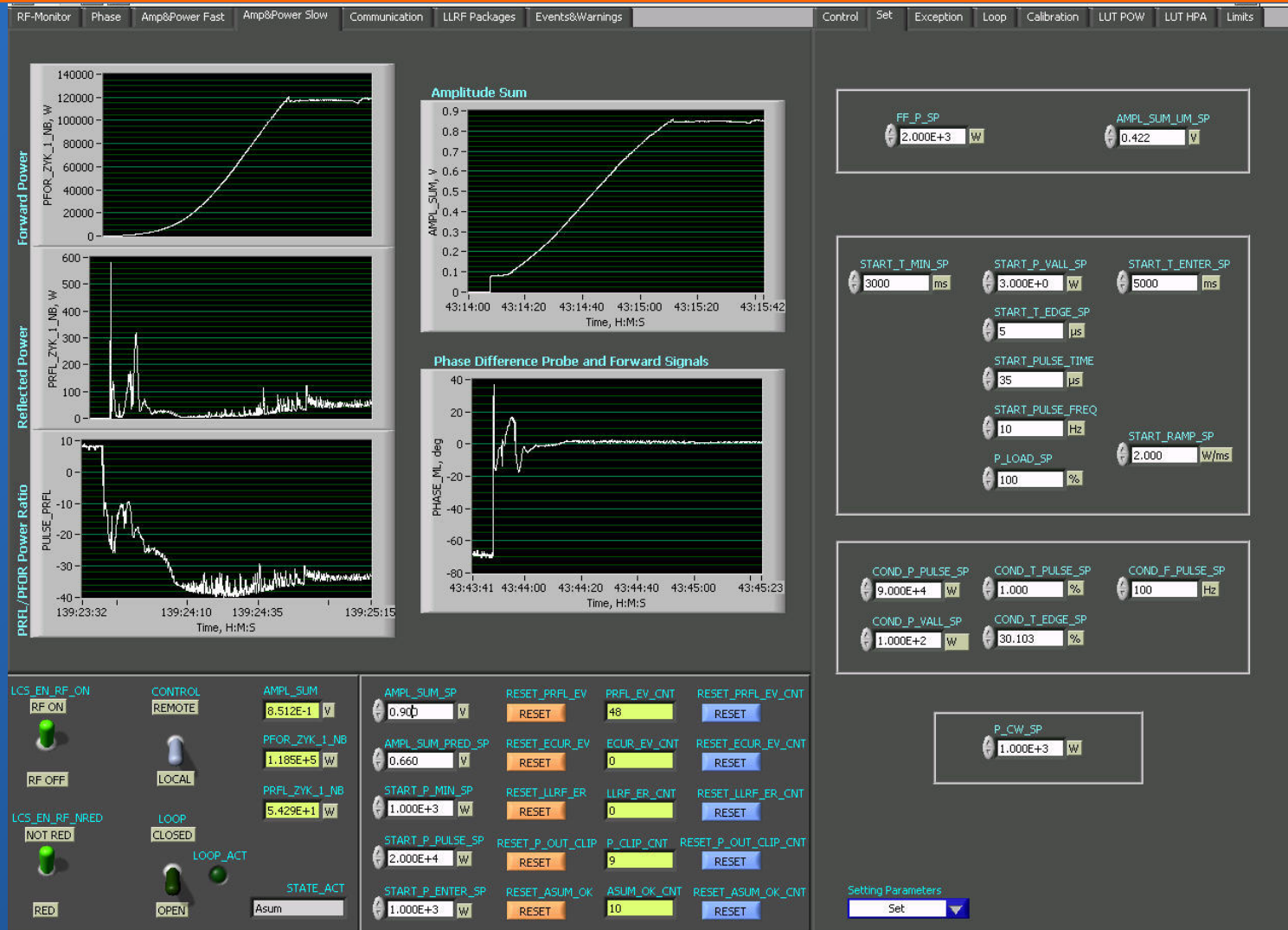




# Digital LLRF Control System



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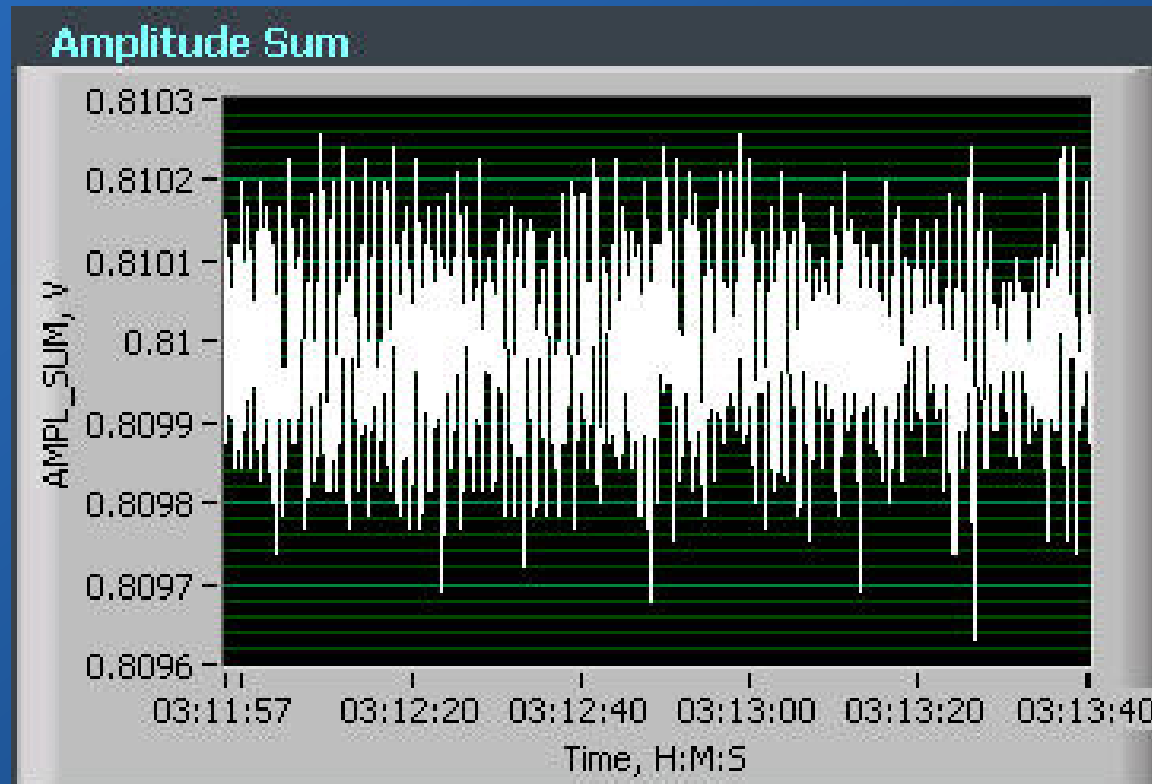




# RF Amplitude Stability

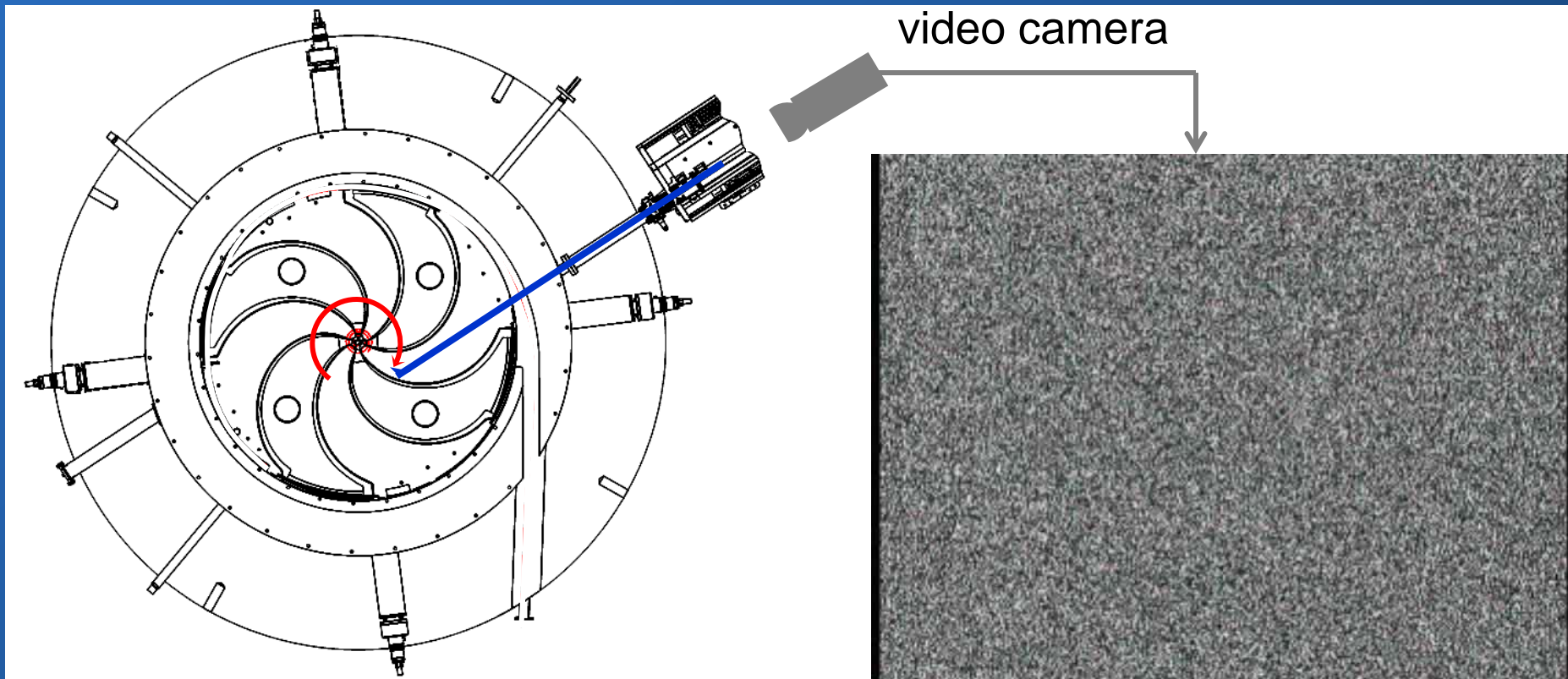
$$\Delta V/V \approx 2 \times 10^{-4} (1\sigma)$$

$$\Delta V/V \approx 6 \times 10^{-4} (\text{pp})$$



# First Internal Beam, June 8, 2011

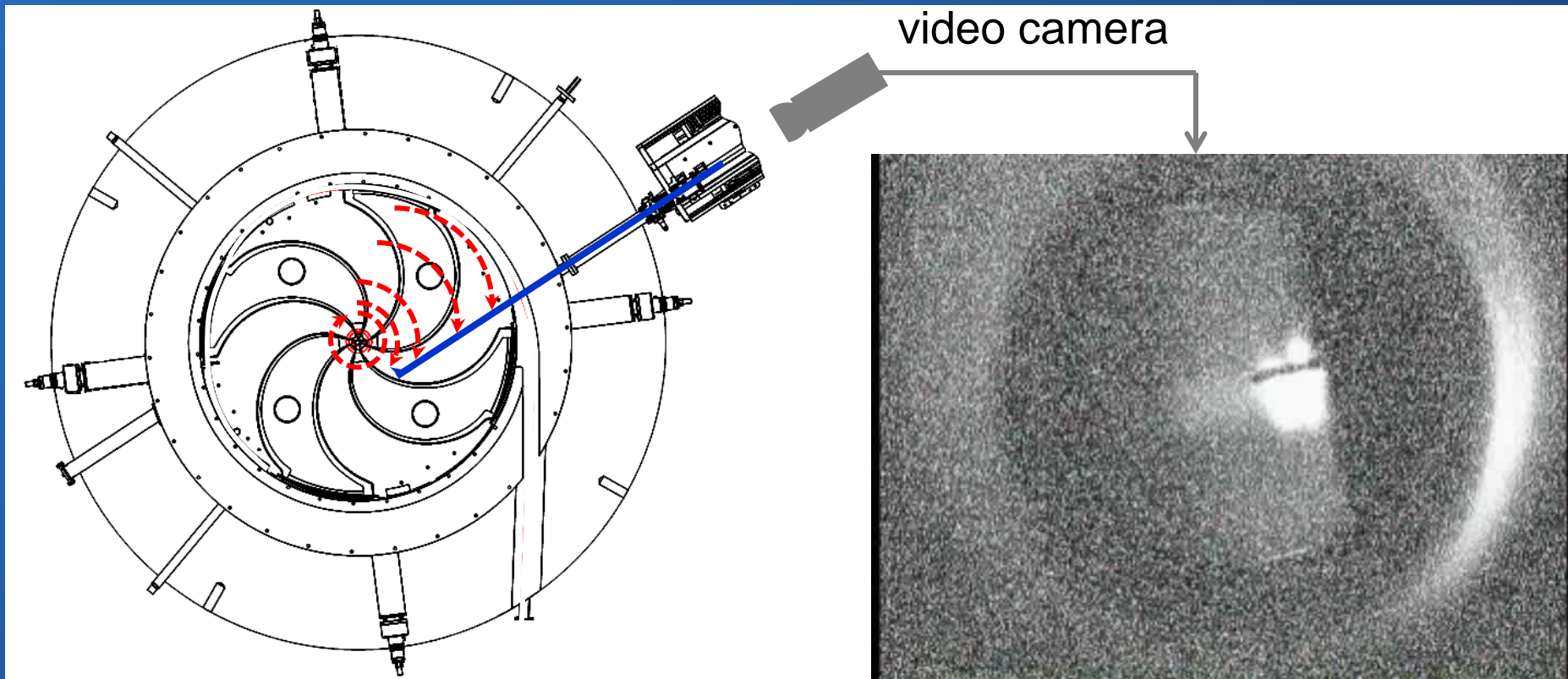
- System prepared (magnet & RF ramped up, viewer probe with video camera installed near cyclotron center)
- First switch-on of ion source





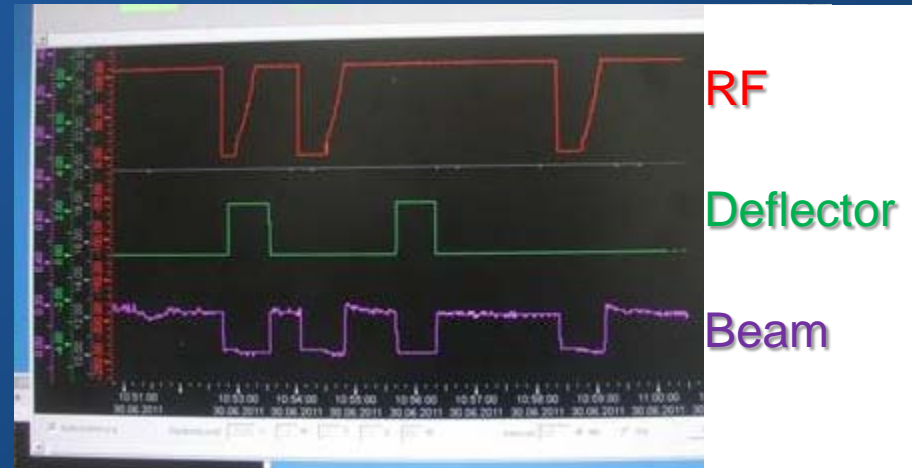
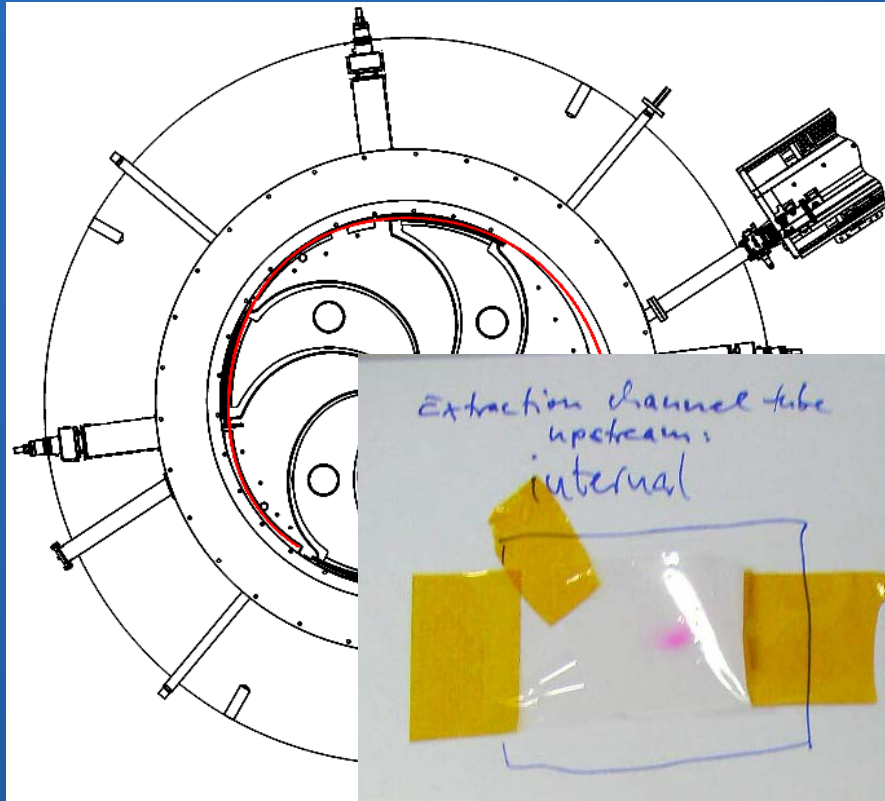
# Beam Development, June 9, 2011

- Already on the next day it was possible to bring the beam close to extraction radius



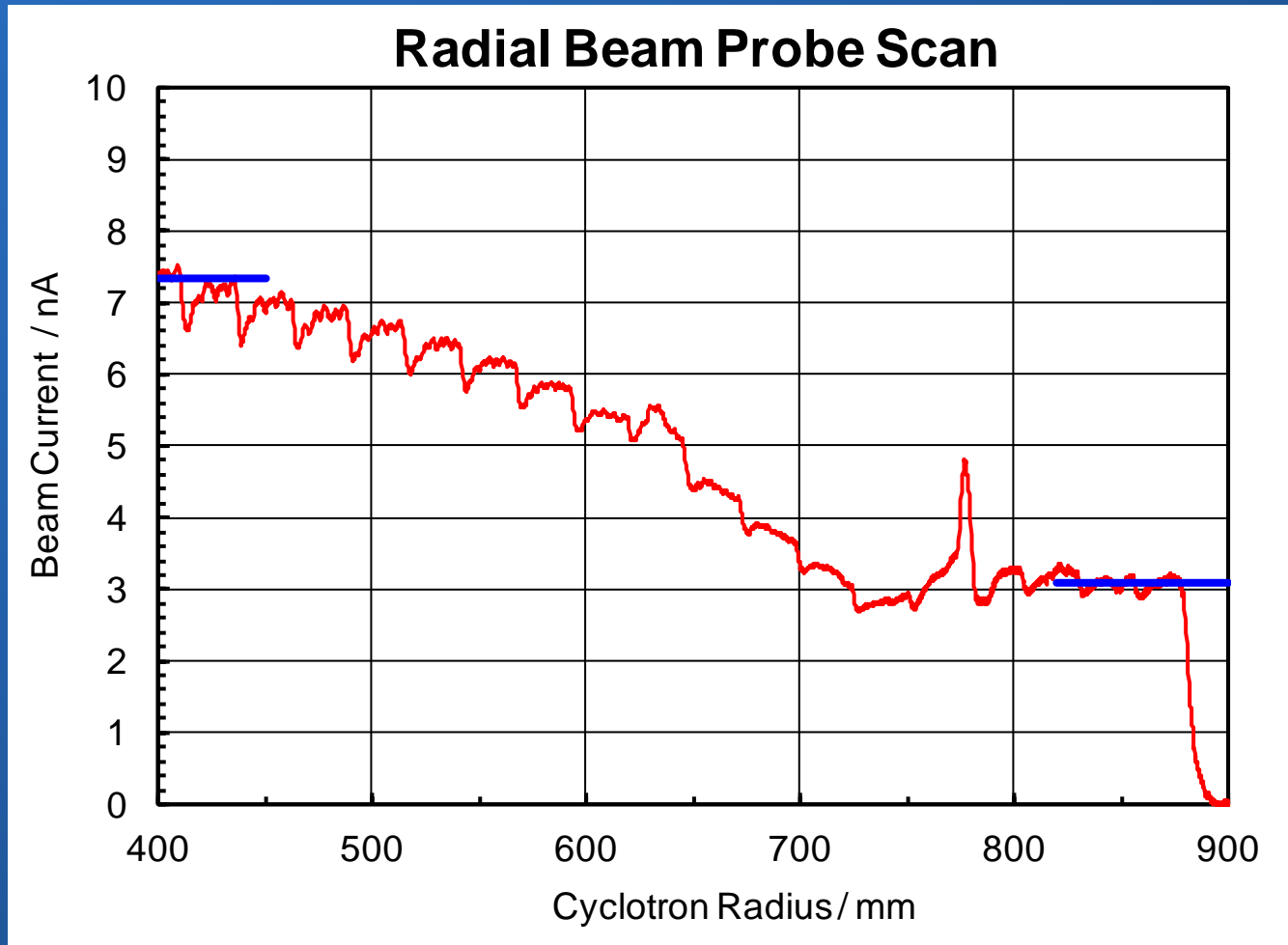
# First Extracted Beam, June 29, 2011

- 1<sup>st</sup> extracted beam:





# Extraction Efficiency ~40%, July 15, 2011



# Transport to the USA, 2011

- Disassembly and packaging end of July



# Transport to the USA, 2011

- Disassembly and packaging end of July
- Shipping August to September





# Transport to the USA, 2011

- Disassembly and packaging end of July
- Shipping August to September
- Installation into building October



# Transport to the USA, 2011

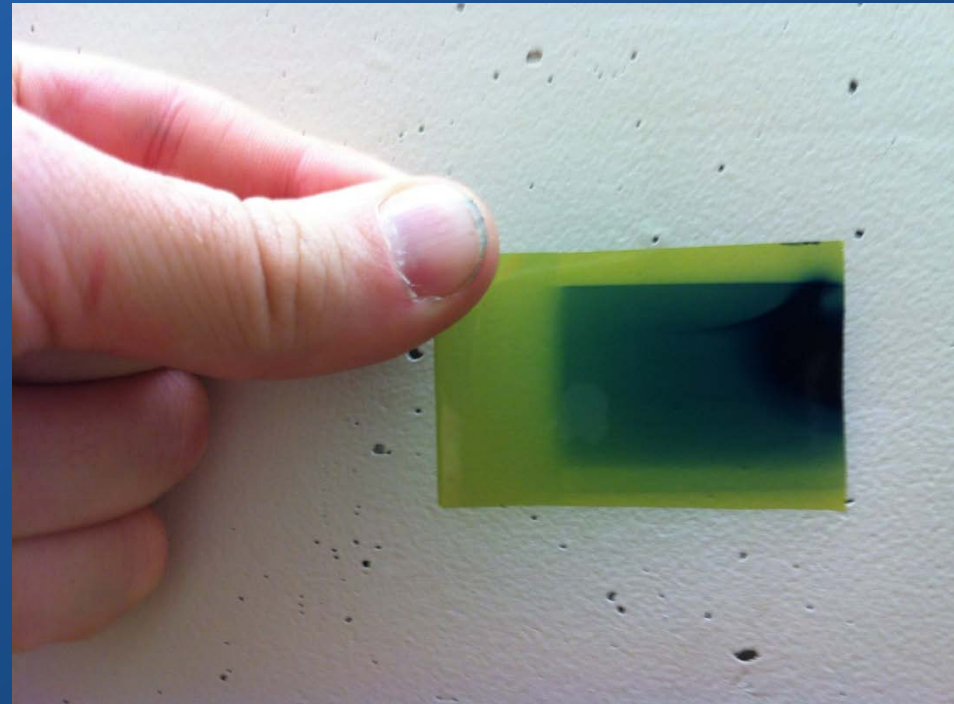
- Disassembly and packaging end of July
- Shipping August to September
- Installation into building October



# First Beam On Site, 2012

- November to December 2011: Cabling, installation of beamline
- January 2012: Cyclotron powered and cooled down
- February: On site magnetic field verification after transport
- March: RF re-conditioning
- April 18: First beam on site!

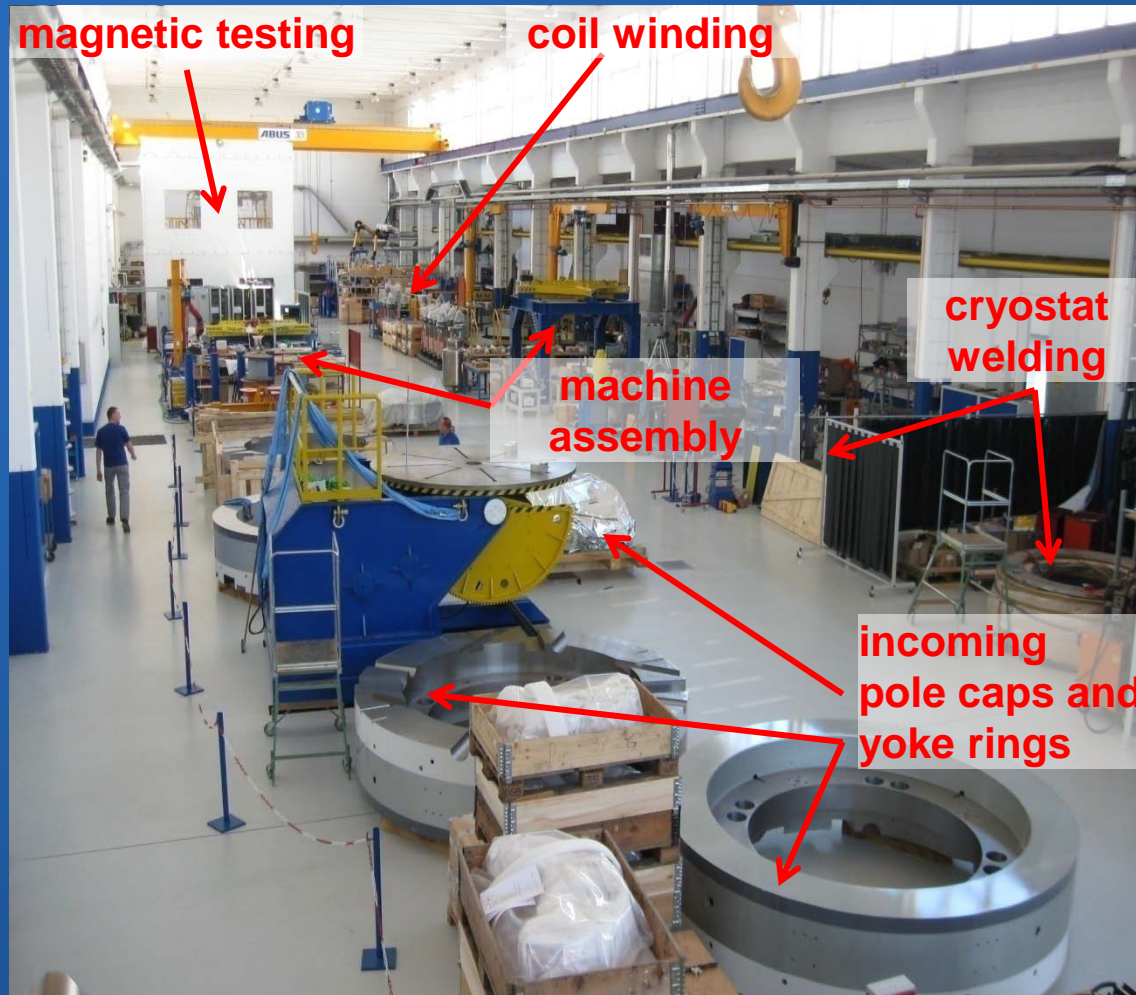
Without any re-tuning,  
all parameters known from  
the factory testing.





# Production of Further ProBeam™ Systems

## ■ Cyclotron Production Hall



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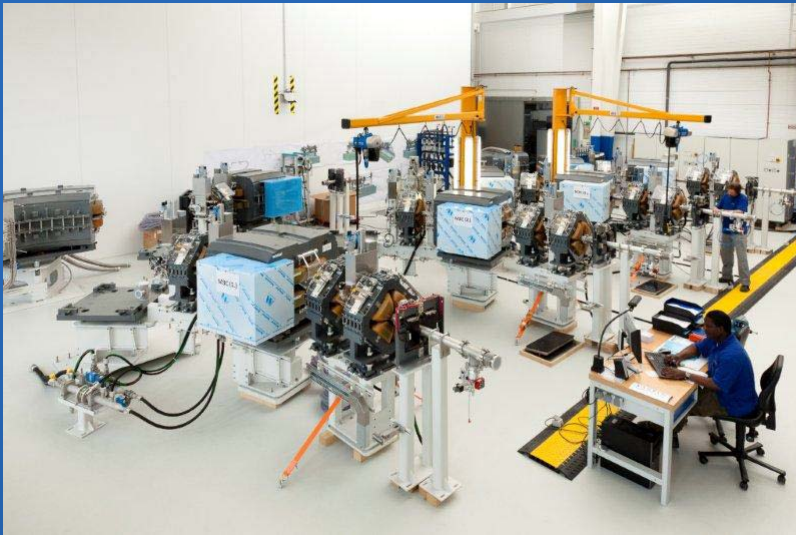
## ■ Cyclotron Production Hall





# Production of Further ProBeam™ Systems

- Other production areas:
  - Beamline modules



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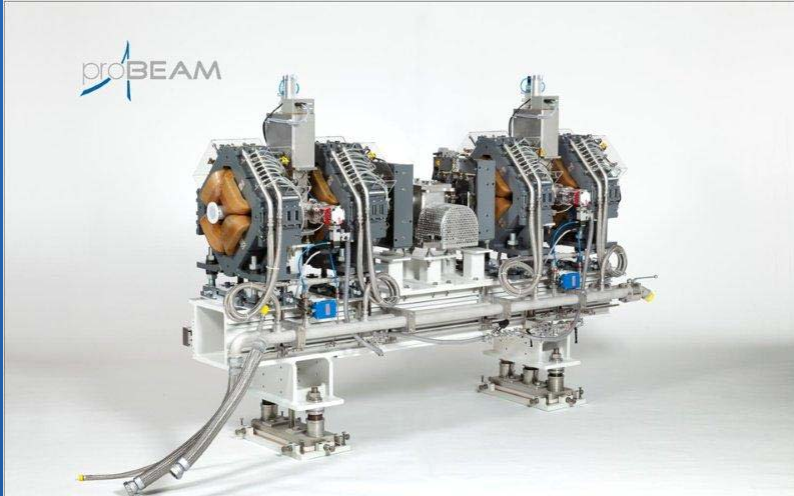
- Other production areas:
  - Beamline modules
  - Scanning nozzles





# Production of Further ProBeam™ Systems

- Other production areas:
  - Beamline modules
  - Scanning nozzles
  - SW test center





# Status of ProBeam™ Cyclotrons #4 & #5

## ■ Cyclotron #4

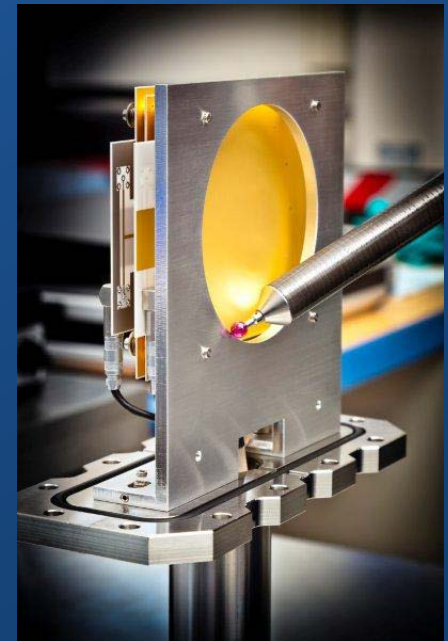
- Pole caps and yoke rings are being equipped with components
- All media get connected
- Cryostat is completed and passed electrical and LN2 tests



# Status of ProBeam™ Cyclotrons #4 & #5

## ■ Cyclotron #5

- Coil is completed and passed electrical tests, cryostat welding will start soon
- Yoke rings and pole caps passed factory incoming inspection
- Assembly will continue in parallel to #4 testing





# Conclusion

- The VARIAN ProBeam™ Superconducting Compact Proton Cyclotrons feature superior properties that make them turn-key operational machines and predestine them for use in pencil beam scanning proton therapy.
  - 2 of such cyclotrons are already in clinical use.
  - #3 is currently being commissioned at customer's site, first beam was extracted in April 2012.
  - Several more machines are in production.
  - All cyclotrons will be factory tested with beam.
  - VARIAN is continuously developing its technology further and introducing new features.
  - Recent product enhancements include Transistor RF Power Amplifiers and Digital Low Level RF electronics.
- cw proton beam
  - high energy
  - high current
  - stable beam position
  - small footprint
  - high extraction efficiency
  - low activation
  - fast and easy access for maintenance
  - high uptime
  - operator-free operation
  - low power consumption



THANK YOU!

