Status of the Soreq Applied Research Accelerator Facility

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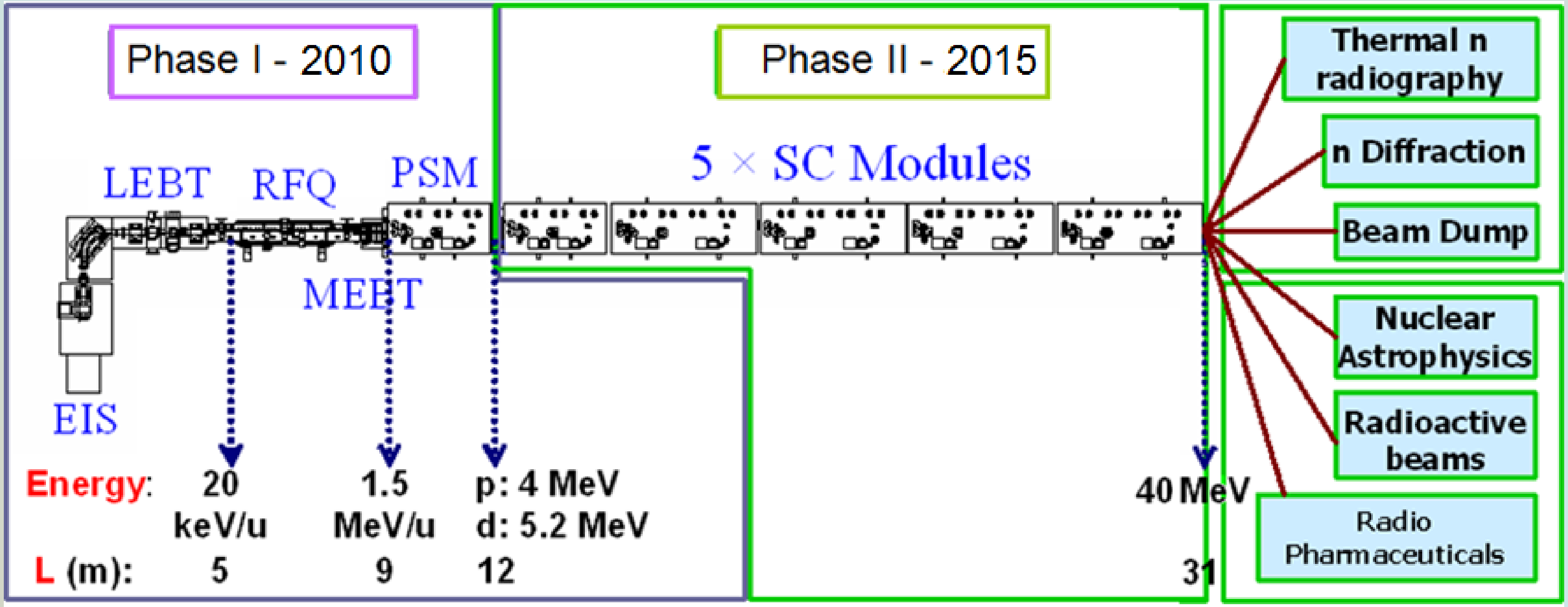
Topics of the Talk

- Brief overview of SARAF
- The specialty of SARAF
- Beam characterization and Phase I applications plan and its execution
- Summary and Conclusions

SARAF Layout

Parameter	Value	Comment
Ion Species	Protons/Deuterons	M/q ≤ 2
Energy Range	5 – 40 MeV	
Current Range	0.04 – 2 mA	Upgradeable to 4 mA
Operation	6000 hours/year	
Reliability	90%	
Maintenance	Hands-On	Very low beam loss



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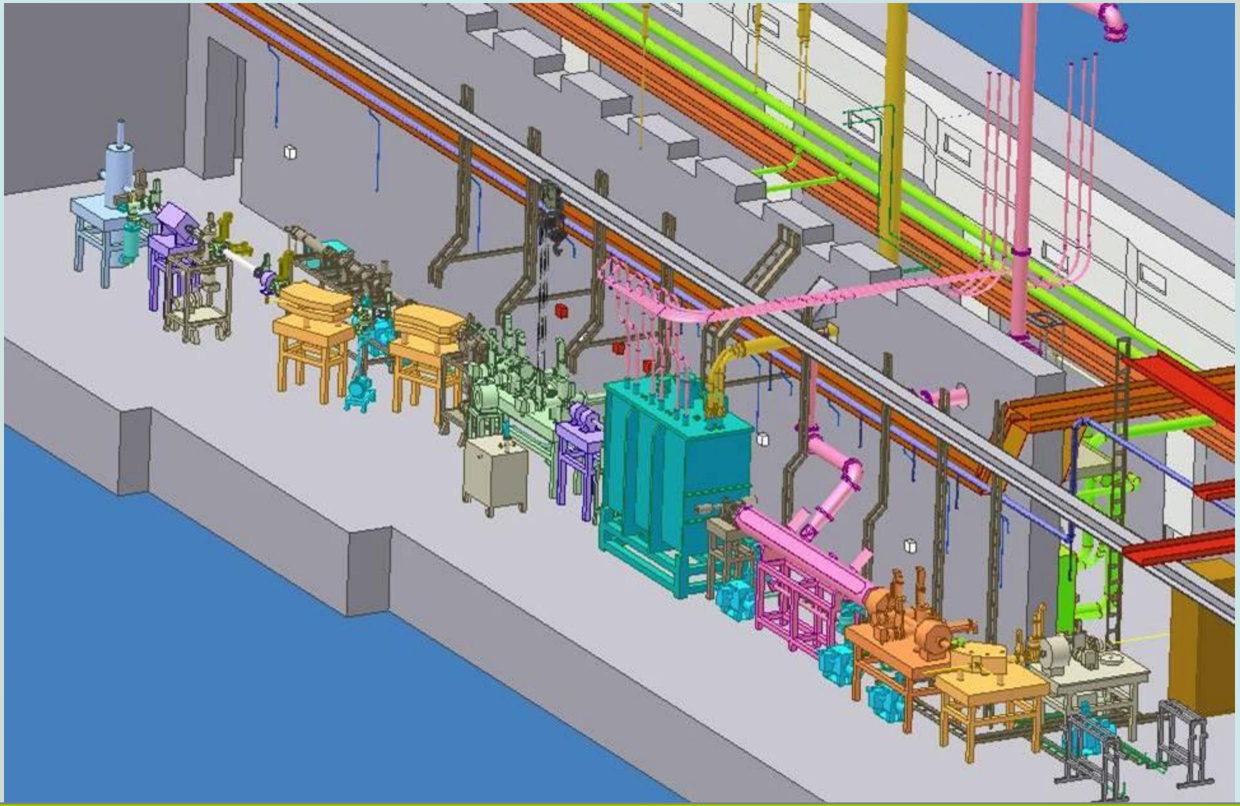
SARAF Phase I – Detailed Design (2010)

Extracted from a 3D model of SARAF developed under “Inventor 3D” (CAD application)



3D model was crucial for:

• The detailed design of infrastructure interfaces

• Installation of all accelerator components

SARAF Phase I – As installed (2010) View Towards Downstream

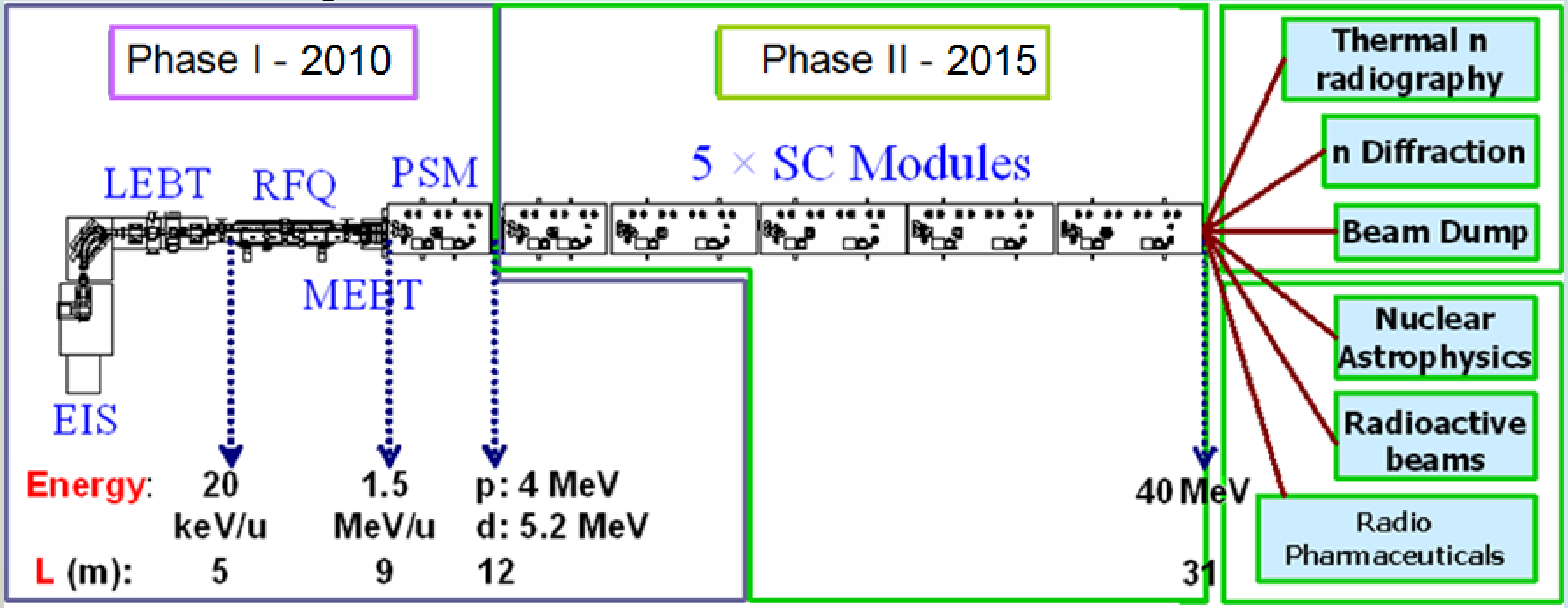
SARAF Phase I – As installed (2010) View Towards Upstream

SARAF Phase I – Beam line segments before installation (2010)

SARAF Phase I – Liquid Li Target (LiLiT) under tests (2010)

The specialty of SARAF (1)

- 0.04 - 2 mA of protons and deuterons, CW, at energies 5 - 40 MeV, with hands-on maintenance
- Flexible, independently phased design
- Very low beam loss required (1 nA/meter)
- Beam dynamics calculations focused on beam loss



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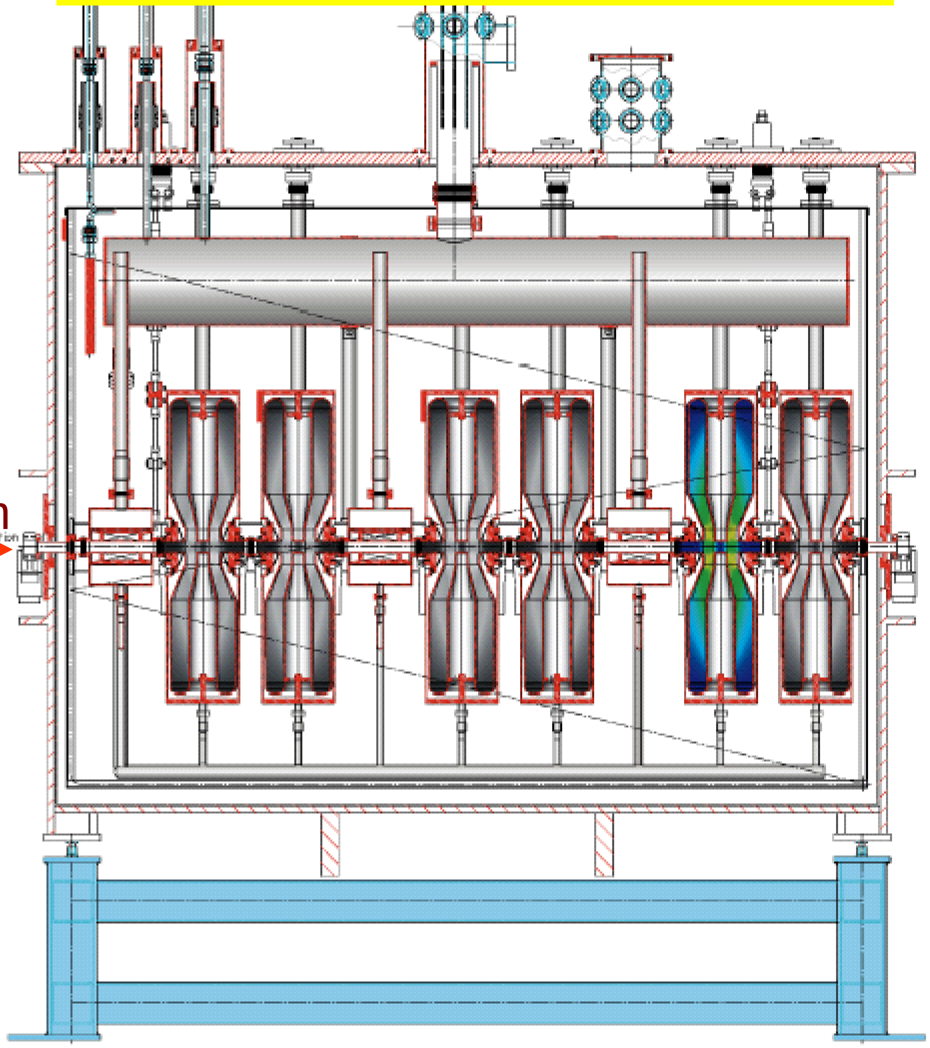
The specialty of SARAF (2)

Novel design

- Superconducting acceleration starting at 1.5 MeV/u
- SC Linac based on Half Wave Resonators (HWR)
- Separation of vacuum between beam line and cryostat
- 4-Rod RFQ with a heat flux of more than 60 kW/m

Prototype Superconducting Module (PSM)

Beam



Pekeler et el., LINAC 2006

The Specialty of SARAF (3)

Construction and Commissioning of a **(Beyond-)State-of-the-Art accelerator** within an **international business collaboration**

- Accelerator – Accel Instruments (RI) (Germany)
- Cryogenics – Linde Kryotechnik (Switzerland)
- Building and Infrastructure – U. Doron (Israel)
- Beam Lines and Applications - Soreq

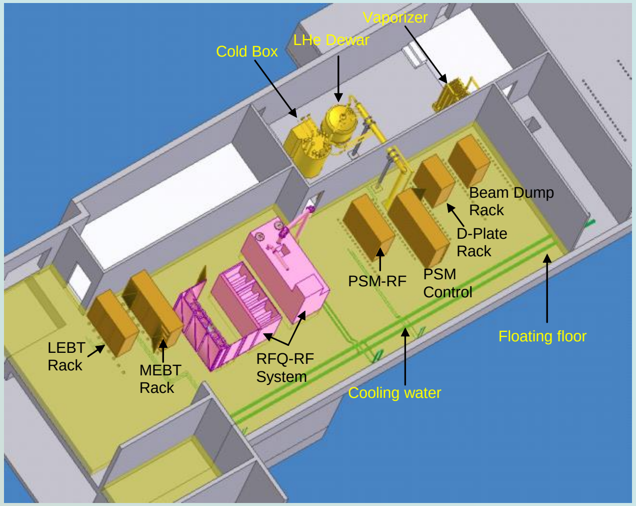
Overall Integration – Soreq

The Operation, Construction and Commissioning Group

- SARAF engineering group members - Soreq
  - **Head of Engineering Group (**Facility Management, Site Engineering**,** Control Systems, Electrical and Electronics Systems, Infrastructure)
  - **Electrical Engineer** (RF)
  - **Mechanical Engineer** (Cryogenics, Vacuum)
  - **Physicist** (Accelerator, Diagnostics, Beam lines)
  - **Industrial Engineer** (Maintenance and Technical Office Management)
  - **Safety Specialist** (“online” safety, procedures for present and future)
  - **Software Development Advisor** (NI Labview Applications Development, SARAF DB Development, Operational tools development (Tickets System, E-logbook))
  - **RF Advisor** (Design and Development of new RF equipment, Maintenance and Upgrade of an existing equipment)

Auxiliary systems

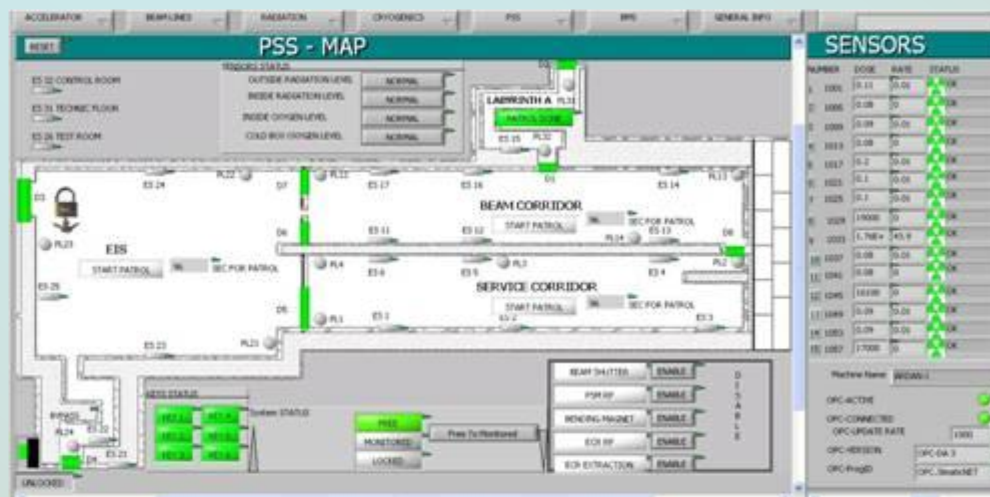
- All auxiliary systems were installed and accepted (RF, Magnets power supplies, PLCs, Cryogenic Plant) and currently are under optimization and matching to system requirements



Personal Safety System (PSS)

Controlled entry to the accelerator area

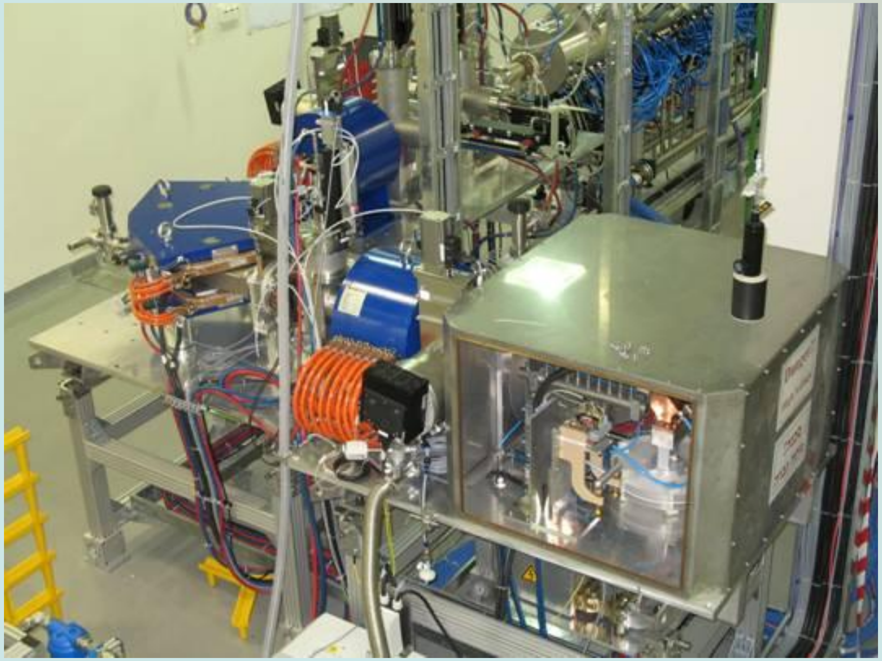
PSS Station at the Main Control Room



PSS HMI

Status of Ion Source and LEBT

- The EIS has passed SAT and is under routine usage for proton and deuteron operation



Status of RFQ (1)

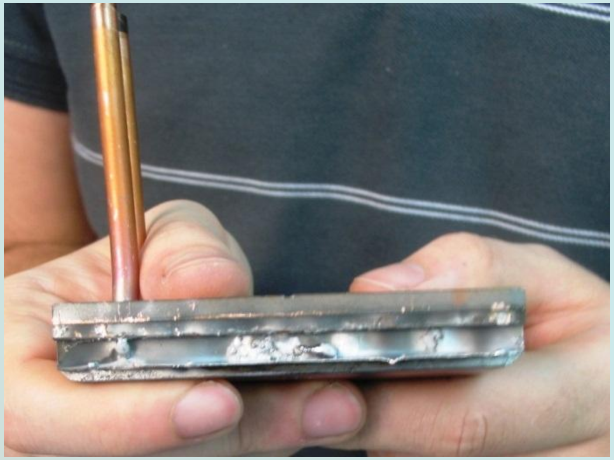
- Fully conditioned RFQ for proton operation

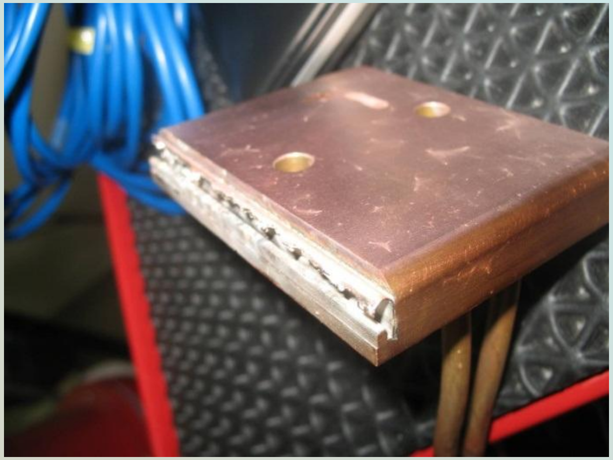
Parameter	Value
frequency f_0 [MHz]	176
input energy W_{in} [keV/u]	20
output energy W_{out} [keV/u]	1500
max. mass to charge ratio A/q	2
inter electrode voltage V_{el} [kV]	65
electrode length [cm]	390
duty factor [%]	100
thermal load [kW/m]	62.5

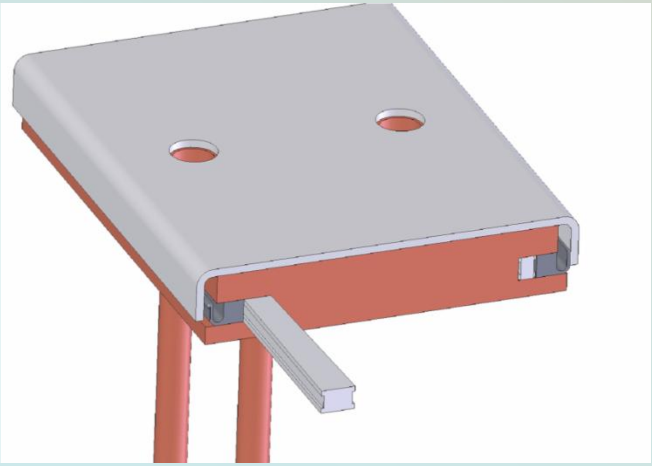
The RFQ as installed in beam corridor

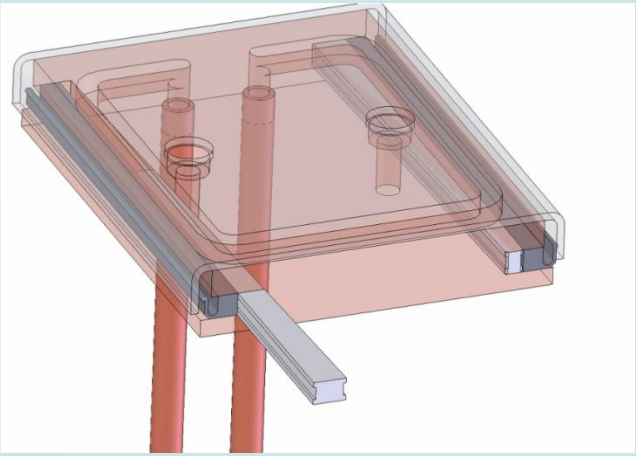
The RFQ during assembly

Status of RFQ (2)

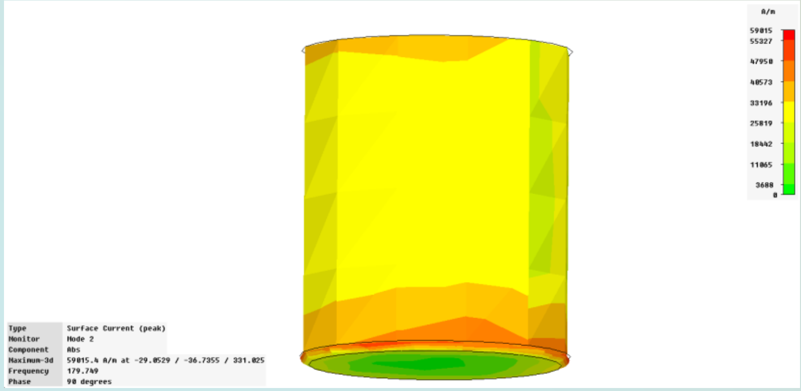


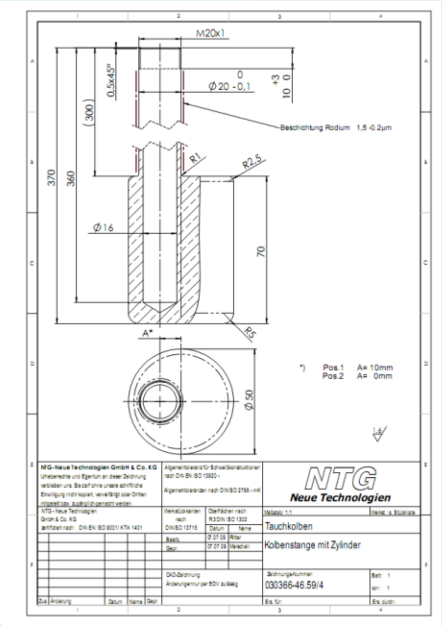




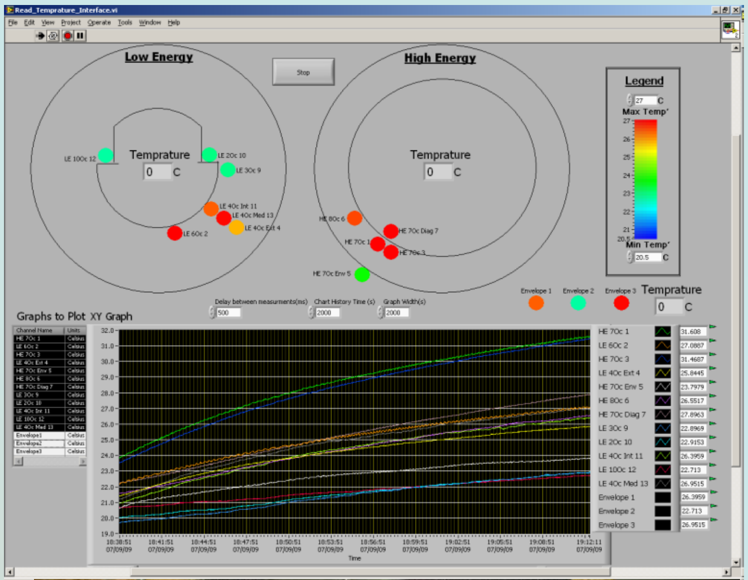


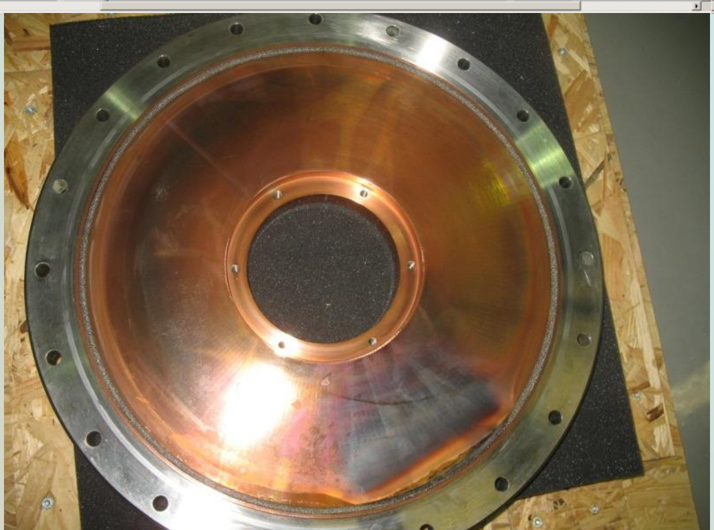
Status of RFQ (3)

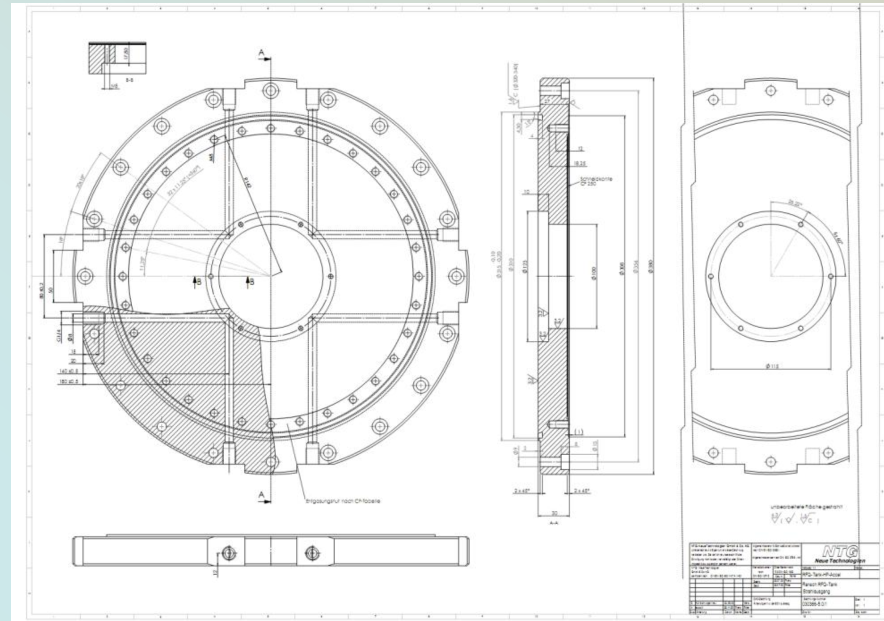


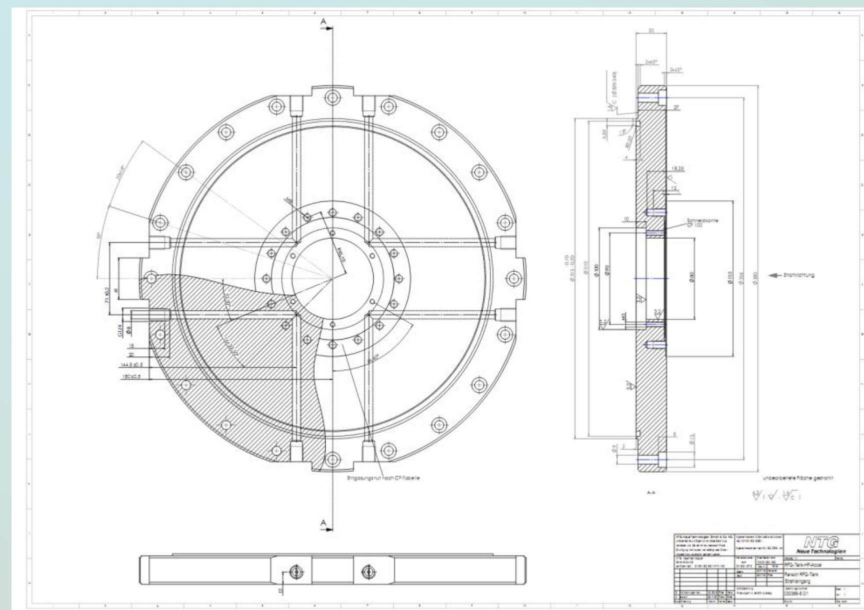


Status of RFQ (4)





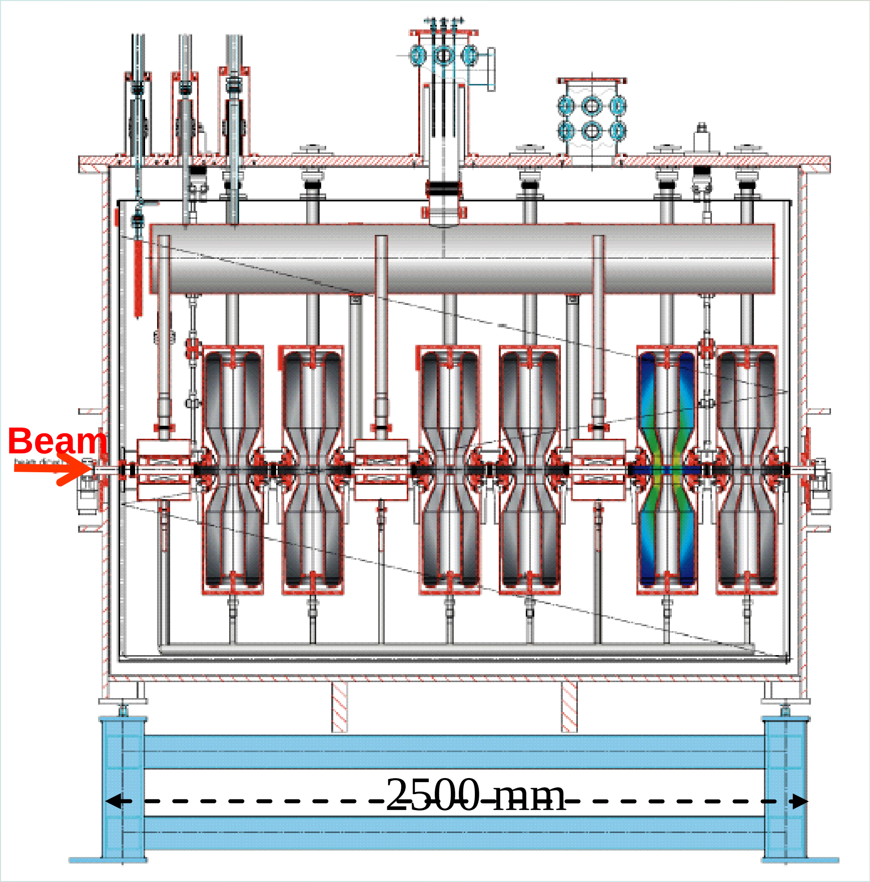




Prototype SC Module (PSM)

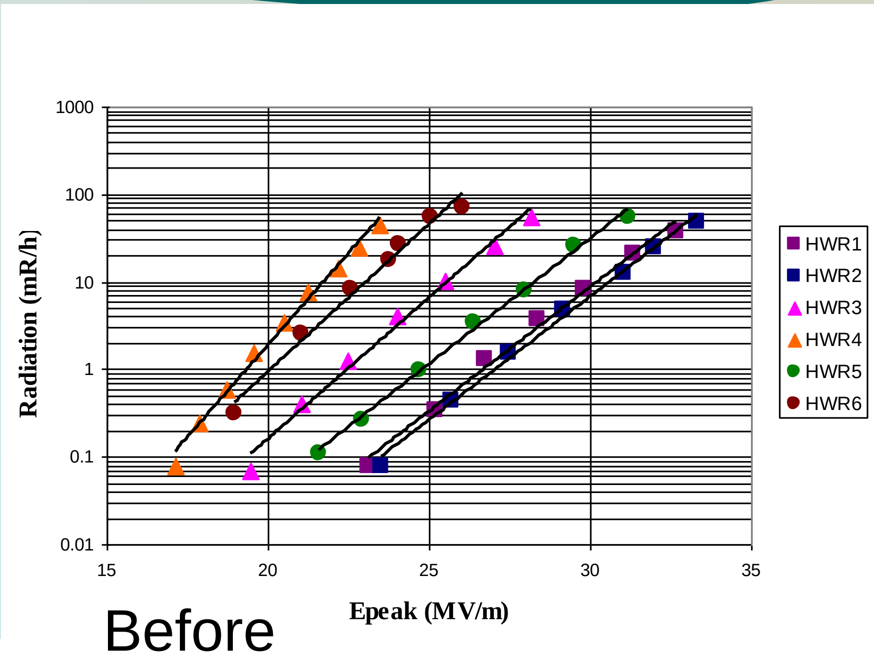
General Design:

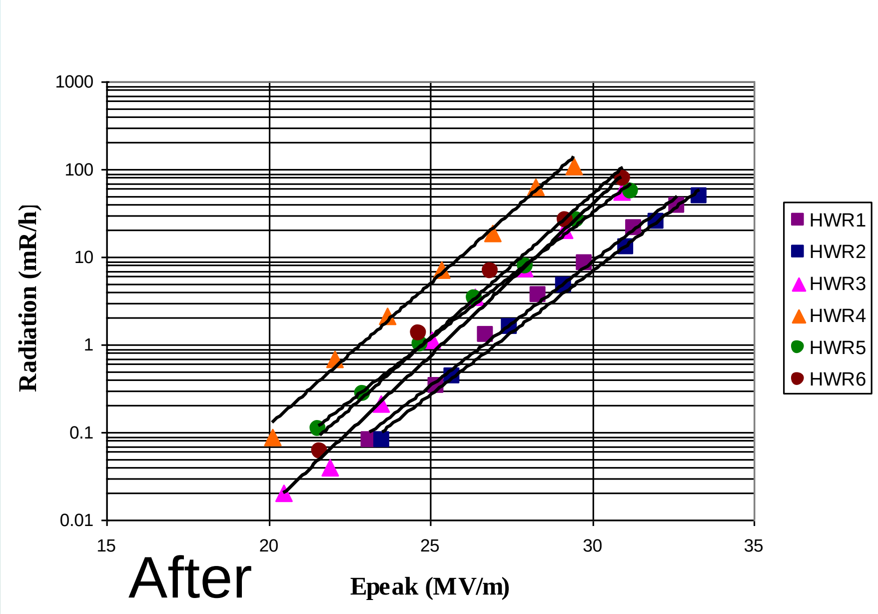
- Houses 6 176 MHz HWRs and 3 SC solenoids
- Accelerates protons and deuterons from 1.5 MeV/u
- Very compact design in longitudinal direction
- Cavity vacuum and insulation vacuum separated



PSM commissioning

- Helium processing reduced field emission from the cavities and allowed stable operation at higher fields

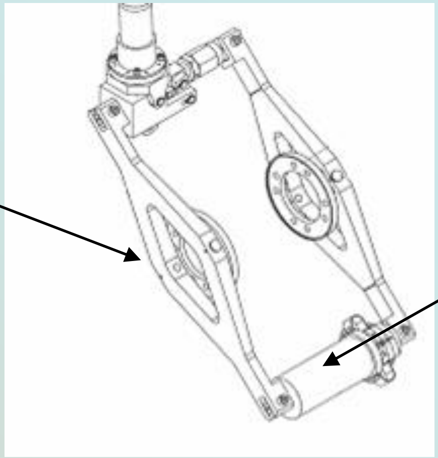


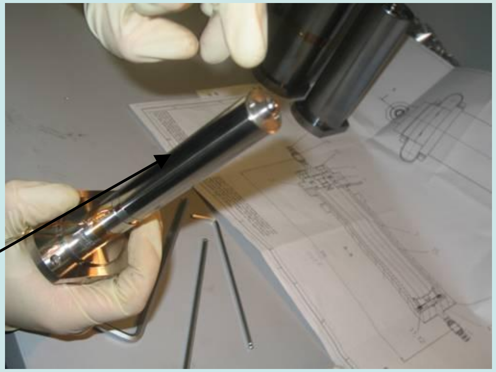


PSM commissioning

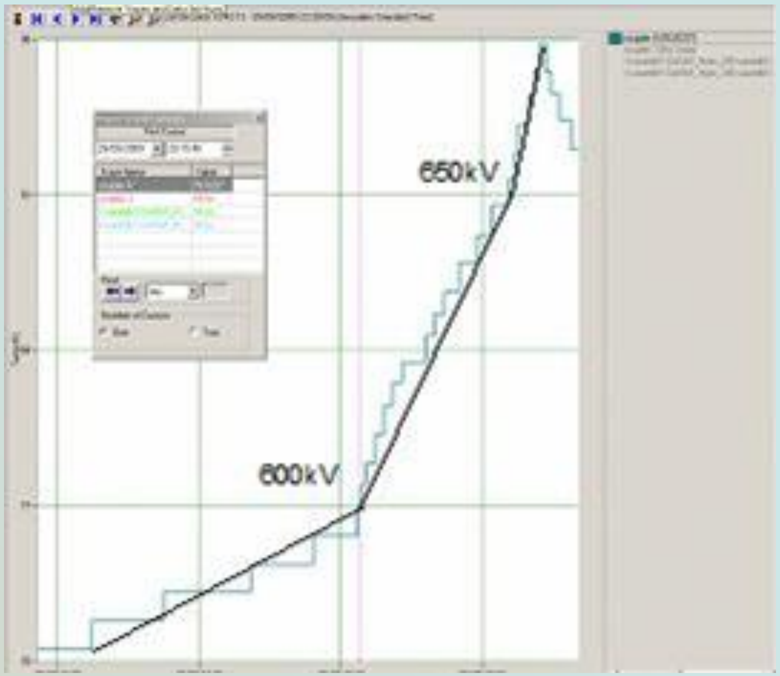
- Measurements of the piezoelectric tuner tuning range showed a reduction by a factor of 2.
- The Cryostat was opened and the piezoelectric actuators were exchanged. Analysis done by the manufacturer revealed a fault of electrical contact due to differential expansion.
- The tuning range of the new-piezos was measured and found to be higher. However, recent measurement indicate a reduction again.

Change the resonance frequency by expanding or compressing the cavity



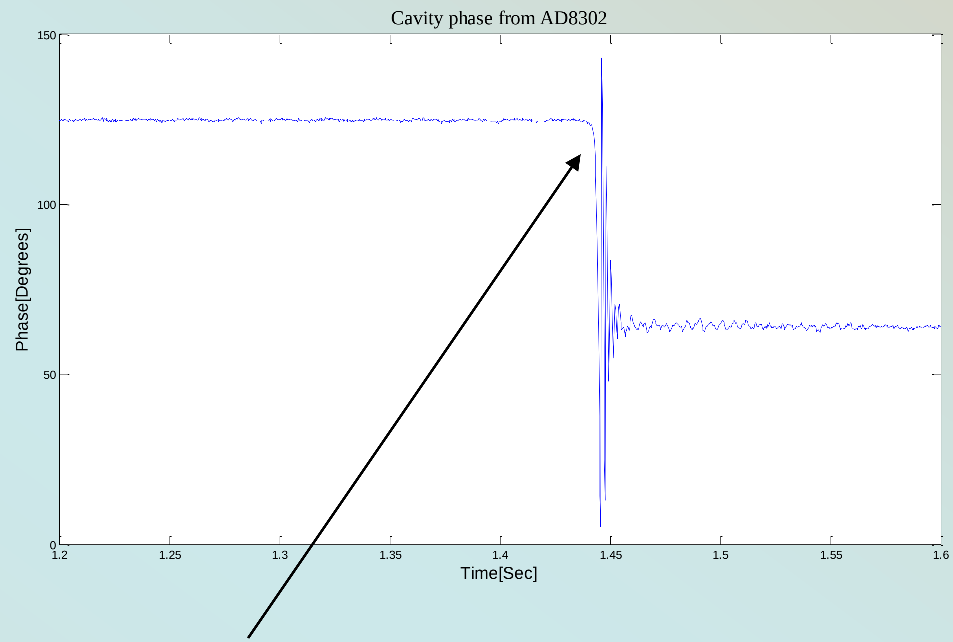


PSM - Issues under investigation



Coupler temperature increase during RF operation in HWR4

Probably insufficient heat removal



Cavity Trip

Stable operation at moderate gradients (EP~15MV/m, Vacc~500kV)

Frequent trips at higher gradients

2009 Beam operation (1)

June : Deuteron beam (beam DC 10^{-4}, 5mA LEBT current, RFQ only, RFQ DC 10-30%)

- optimum RFQ power (252 kW)
- transmission (57 %)
- transversal emittance (0.16 mm mrad)

August: Proton beam (beam DC 10^{-4}, 5mA LEBT current, RFQ +PSM, RFQ CW)

- acceleration to **3.7 MeV**
- instabilities in cavities and instabilities in cryogenics(fall every 15-20 min)
- transversal emittance (0.15 mm mrad)

September: Proton beam (beam DC 10^{-4}-10^{-2}, 5mA LEBT current, RFQ +PSM, RFQ CW)

- acceleration to 3.4 MeV
- increase of beam DC to **2 %**
- beam induced instabilities

I. Mardor, SRF2009

2009 Beam operation (2)

October : Proton beam (beam DC 10^{-4}-1, 0.1-2 mA LEBT current, RFQ +PSM, RFQ CW)

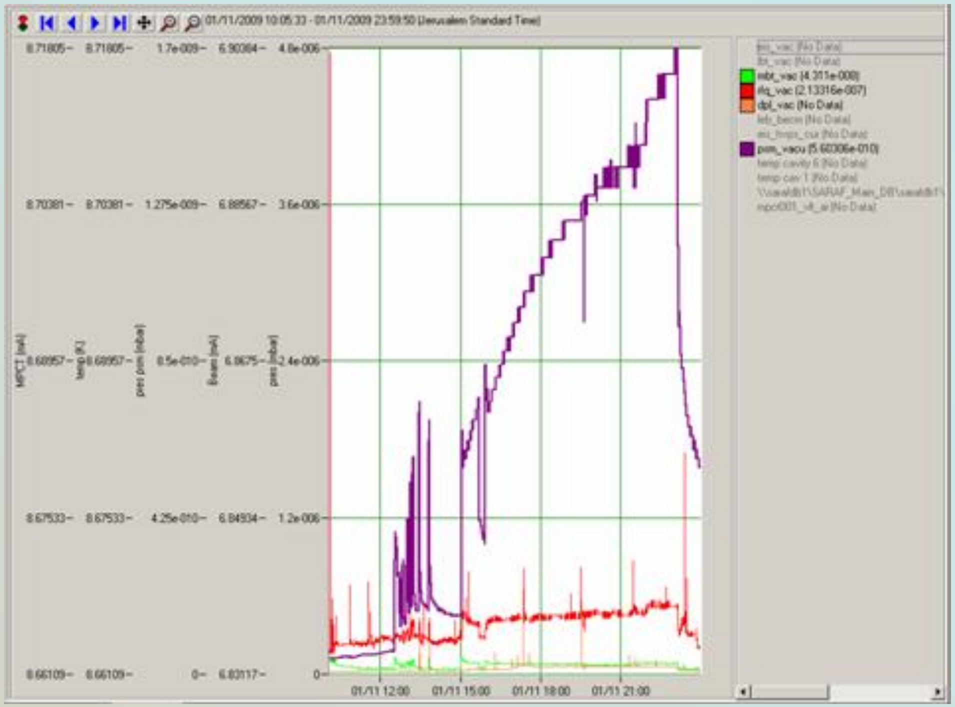
acceleration to 3.15 MeV
transmission 80-70 %
gradual increase of beam DC to **CW** for low current
gradual increase **CW** beam current to **1 mA**
stability tests

November: Deuteron beam (beam DC 10^{-4}, 0.5 mA LEBT current, RFQ +PSM, RFQ DC 1%)

acceleration **4.3** MeV
transversal emittance (0.15 mm mrad)
study long. emittance

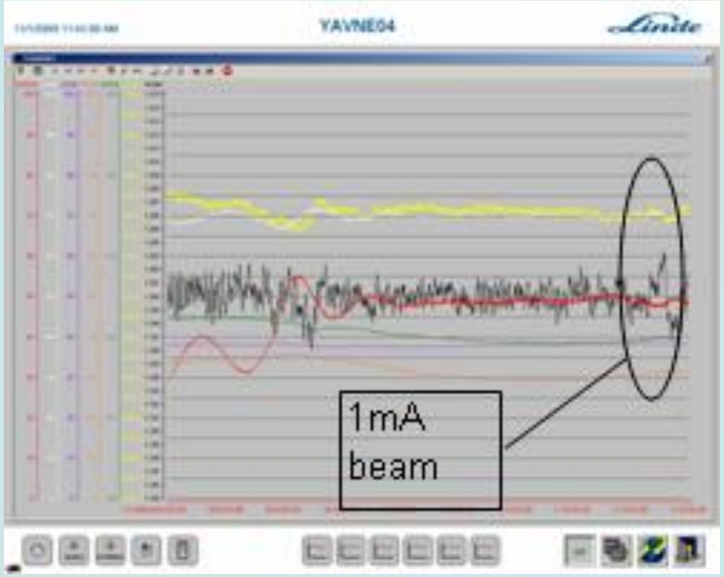
Beam operation (CW proton beam)

After phasing, gradually increased duty cycle and beam current
Long stability test : CW proton beam 0.7-0.8 mA, at energy 3.15 MeV kept for 8 hours



Two types of vacuum PSM effects:

1. sharp jumps with beam injection
2. gradual increase with time

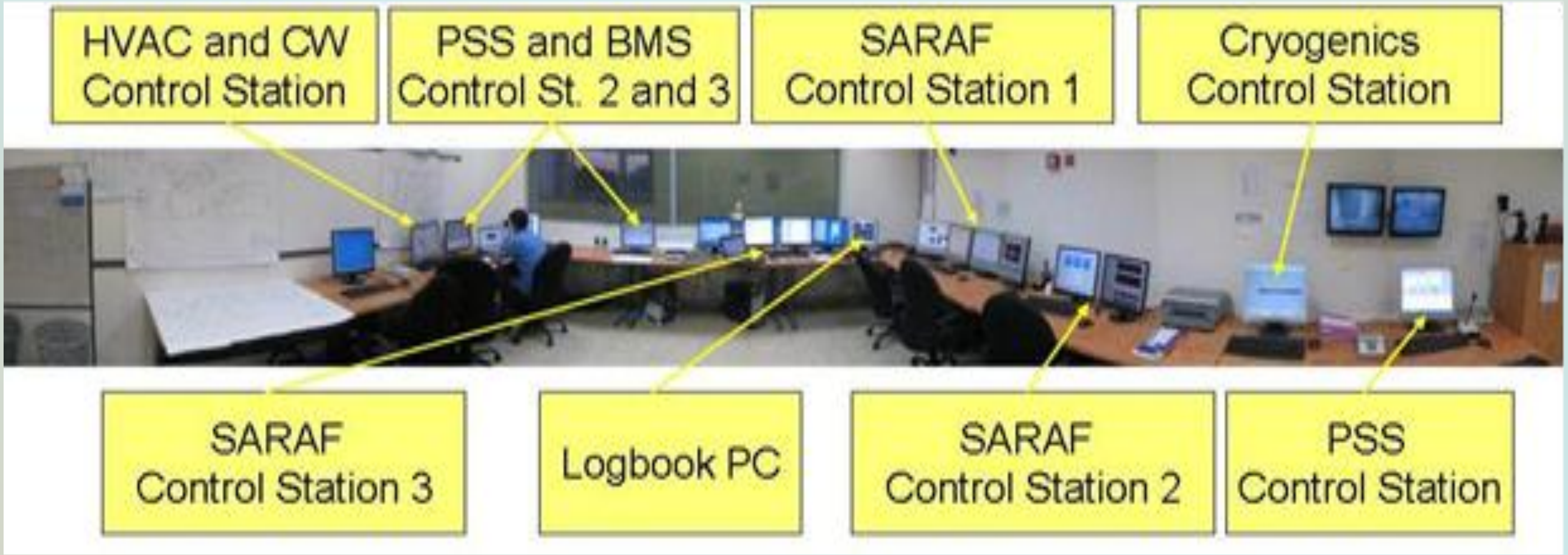


Further increase of current (up to 1.5 mA CW) lead to instability in cryogenics and cavity trips

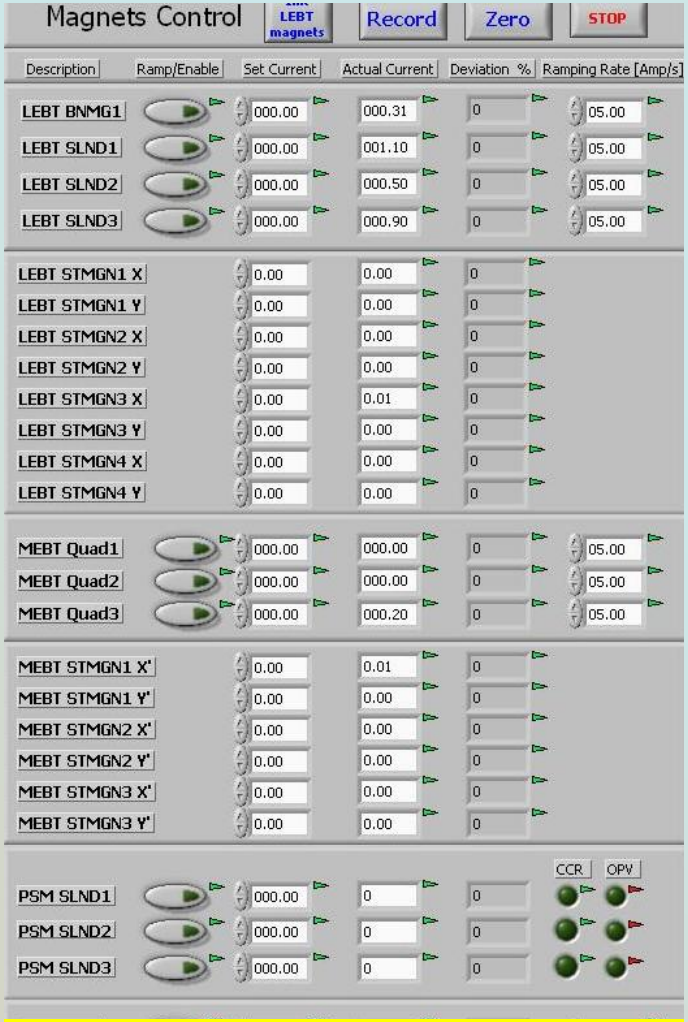
Status of the Control System (1)

- Most applications are being developed and upgraded during commissioning

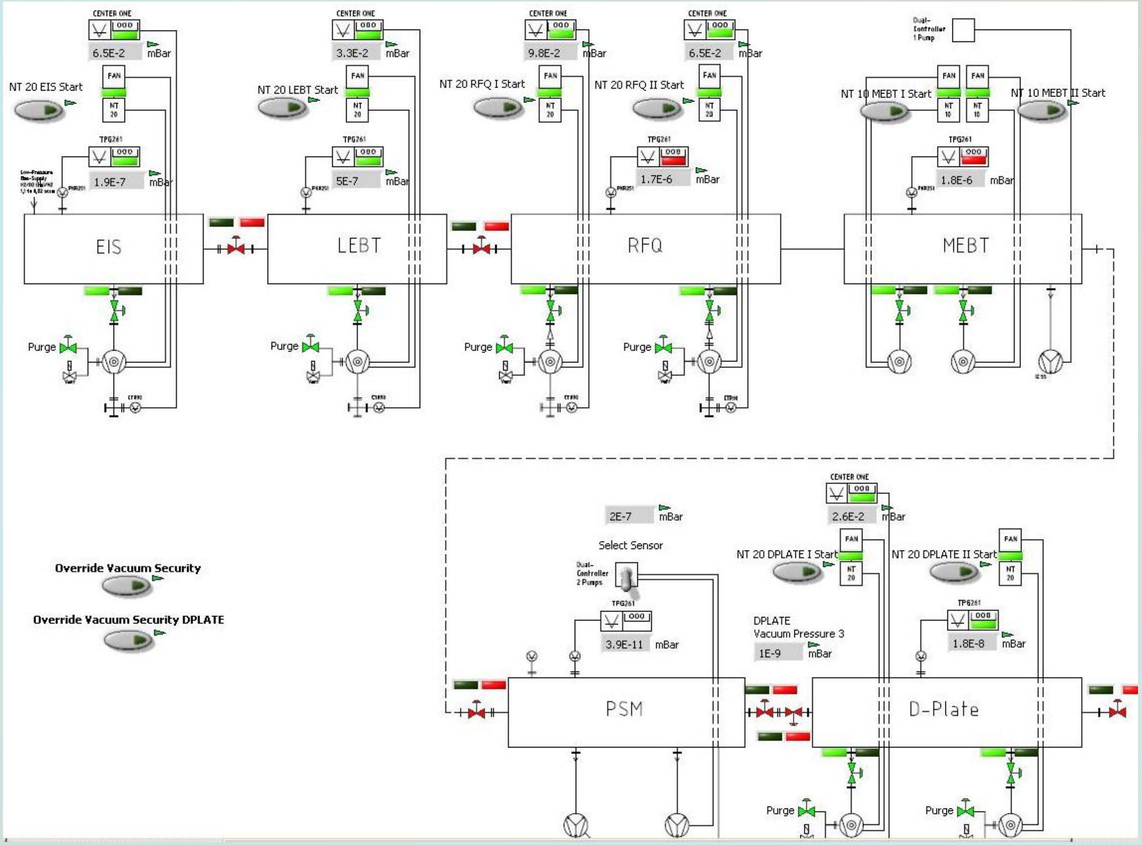
Overview of the SARAF Main Control Room



Status of the Control System (2)



Power Supplies Control Screen



LINAC Vacuum Control Screen

Summary of the project status

- During 2009, significant progress was achieved:
- a. First experience with proton/deuteron beam acceleration
- b. First experience with high duty cycle proton beam
- c. Several significant RFQ modifications
- d. Most importantly: accumulation of expertise by local staff

The SARAF International Steering Committee recommended for going forward with the second phase of the project

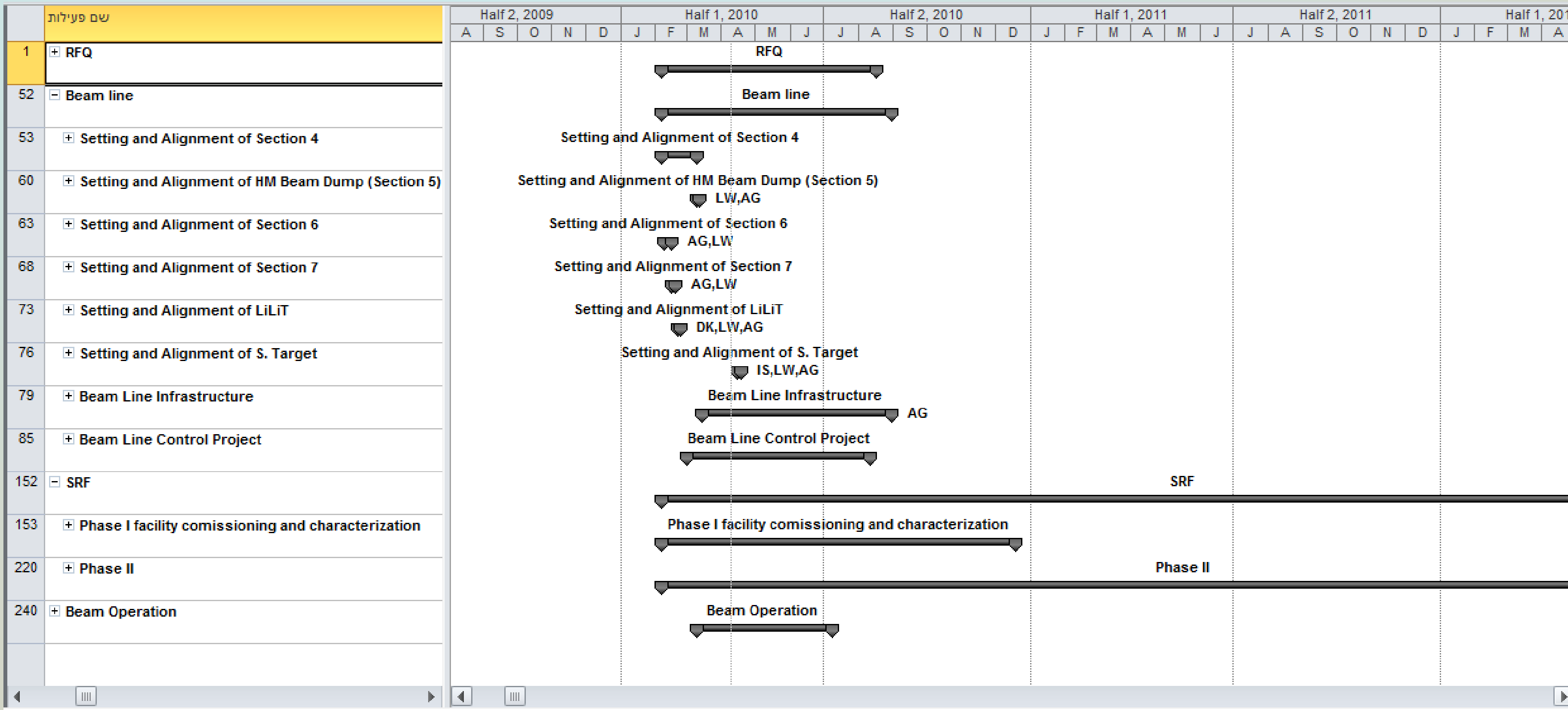
Nevertheless, there are still some challenges in bringing Phase I of the project to the required specifications till the end of 2010

- a. Modification and conditioning of RFQ up to the fields needed for CW deuteron beam (260 kW CW)
- b. Understanding of beam optics and higher current operation
- c. Optimization of SRF System
- d. Temporary Phase I Beam line construction and tests

Work Methods

- Establishment of 4 working independent workgroups:
  - RFQ
  - Beam Operation
  - SRF
  - Beam Lines
- Weekly workgroup meeting
- Weekly integration inter-group meeting
- Integrated Gantt chart development

Integrated Gantt



Work Methods – Challenges

- Main challenge is a resource sharing:
  - Beam Corridor
  - Human Resources
- Preventive and Predictive Maintenance Scheduling
- Breakdowns

Thank you