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HIE-ISOLDE Beam Properties and Beam Commissioning

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on behalf of BE-OP-ISO and the
HIE-ISOLDE project team

Outline:

- Introduction
- Beam Properties
- Beam Commissioning
- First Beam to Users
- Users/Machine Interface
- Summary

Introduction:

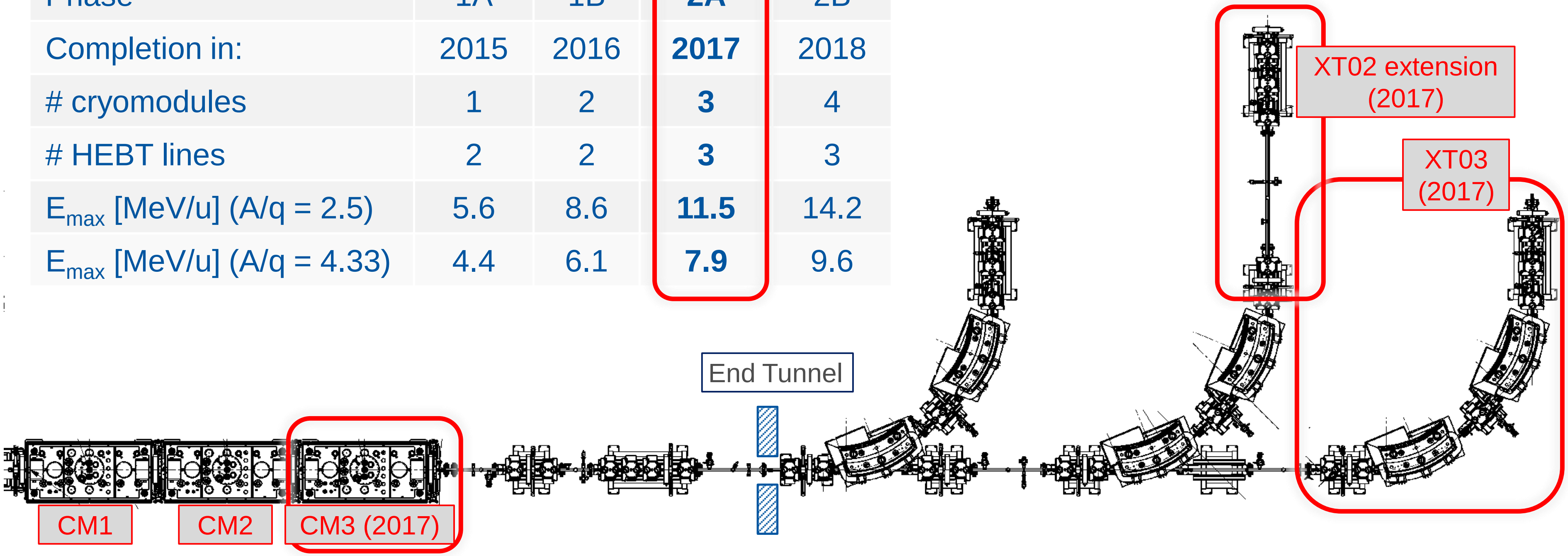
Phase 2A HIE-ISOLDE project:

- Additional cryomodule (CM3)
- Additional HEBT line (XT03)
- Modification of the XT02 HEBT line

Phases of the HIE-ISOLDE project

Phase	1A	1B	**2A**	2B
Completion in:	2015	2016	**2017**	2018
# cryomodules	1	2	**3**	4
# HEBT lines	2	2	**3**	3
E_{max} [MeV/u] (A/q = 2.5)	5.6	8.6	**11.5**	14.2
E_{max} [MeV/u] (A/q = 4.33)	4.4	6.1	**7.9**	9.6

Layout after Phase 2A



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Beam Properties: A/q

Before 2016:

- Nominal minimum: A/q > 2.5
- Nominal maximum: A/q < 4.5

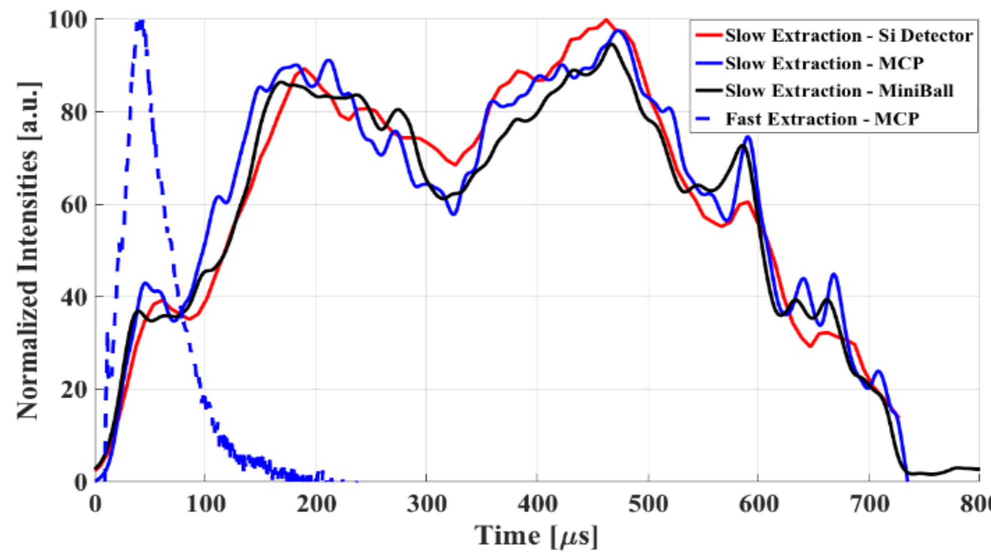
Since 2016:

- Nominal minimum: A/q > 2.5
- Nominal maximum: A/q < 4.33
- Several REX amplifiers not reliable at the power levels needed for beams with A/q = 4.5
- Impact of the change in specs is limited (needs to be analyzed case by case):
  - Some light beams are not possible (ex: $^{9}Li^{2+}$)
  - Charge breeding efficiency for some heavy beams could become lower (by a factor 2-4)

Beam Properties: Time Structure

In 2016:

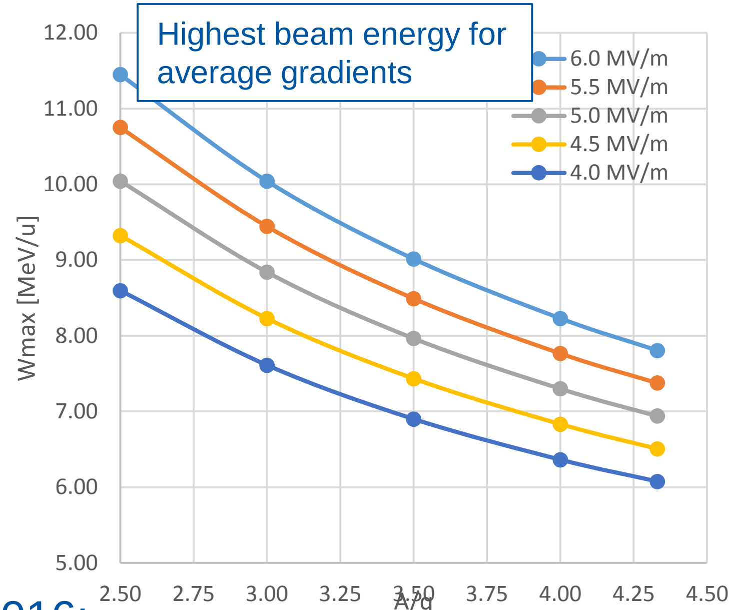
- Repetition rate: up to 50 Hz
- RF Pulse length: up to 1 ms → Beam Pulse Length ~ 0.7 ms (with slow extraction)
- Average power in 9gap < 2.5 kW

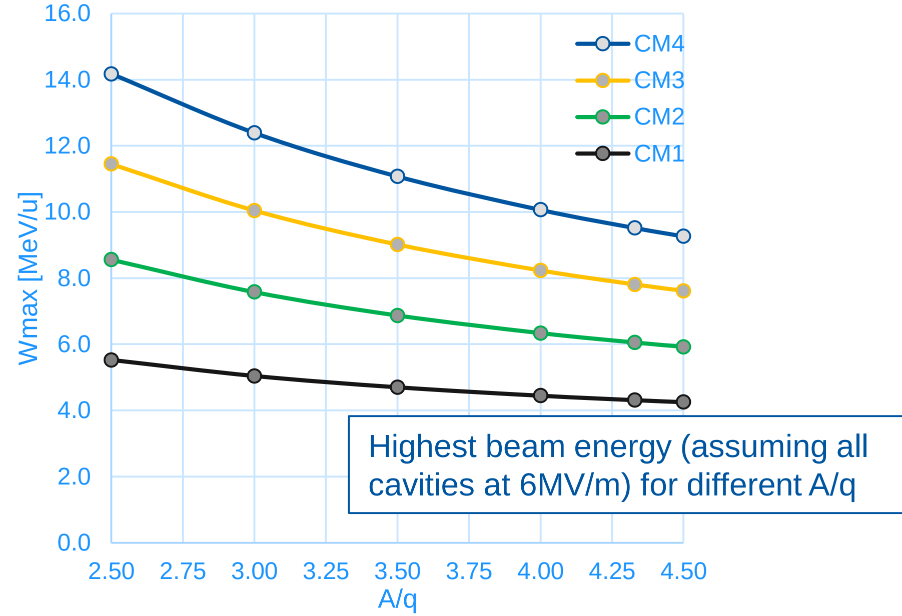


Expected for 2017:

- Repetition rate: up to 50 Hz
- RF Pulse length 2 ms → Beam Pulse Length ~ 1.7 ms
  - Heat exchangers installed during the technical stop
  - Bertronix was at CERN on wk. 7 and make the necessary modifications
- Average power in 9gap < 2.5 kW
- Spokesperson should inform OP if slow extraction is needed in advance (typically, a couple of hours are needed to set it up)

Beam Properties: Energy and Energy Spread



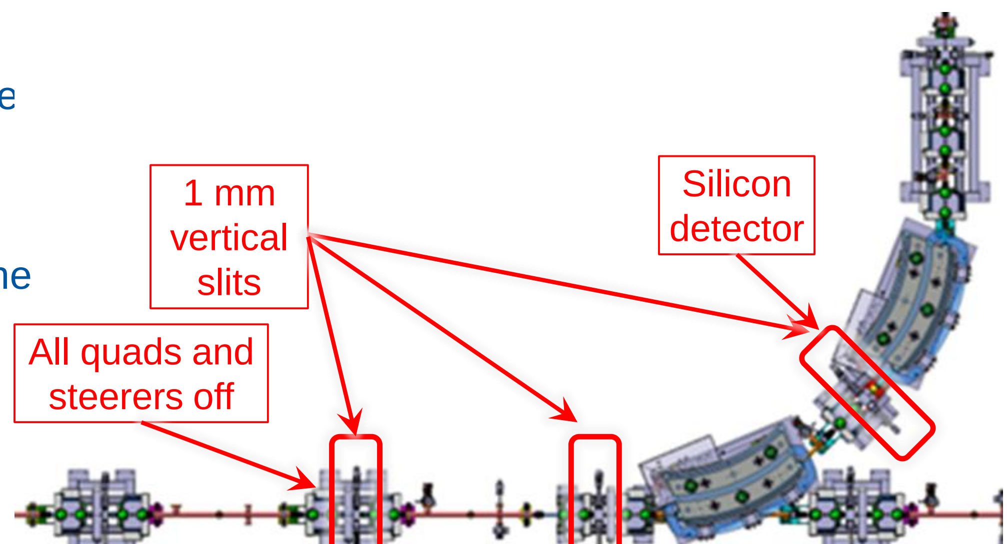


In 2016:

- Two cryomodules installed
- Dedicated energy measurement (~ 4 hours nee

In 2017:

- Three cryomodules installed
- A new timing class for the time information of the Si detectors has been developed and commissioned
- Dedicated energy measurement (~ 1 hour needed)
- Energy spread optimization may be possible (needs to be requested in advance)



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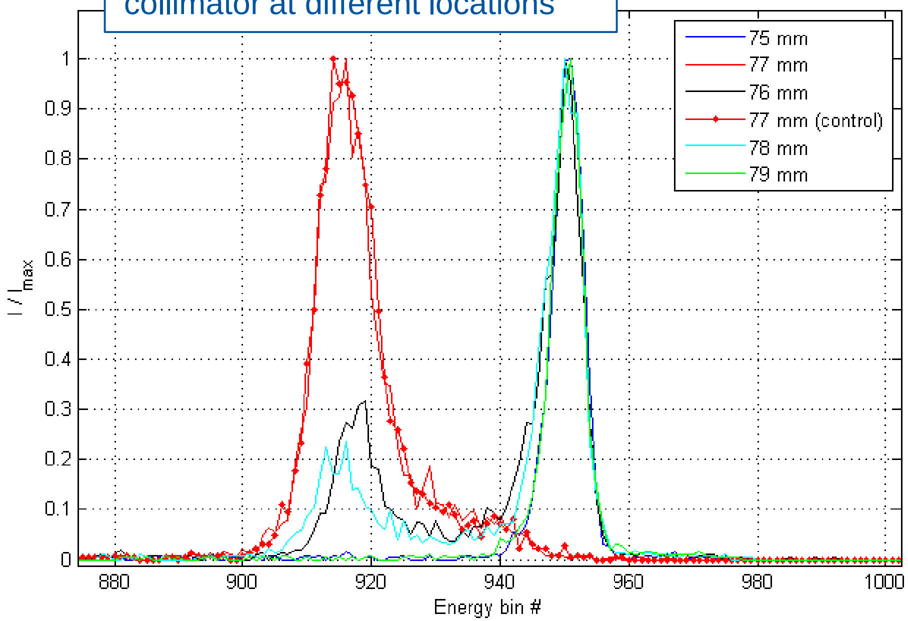
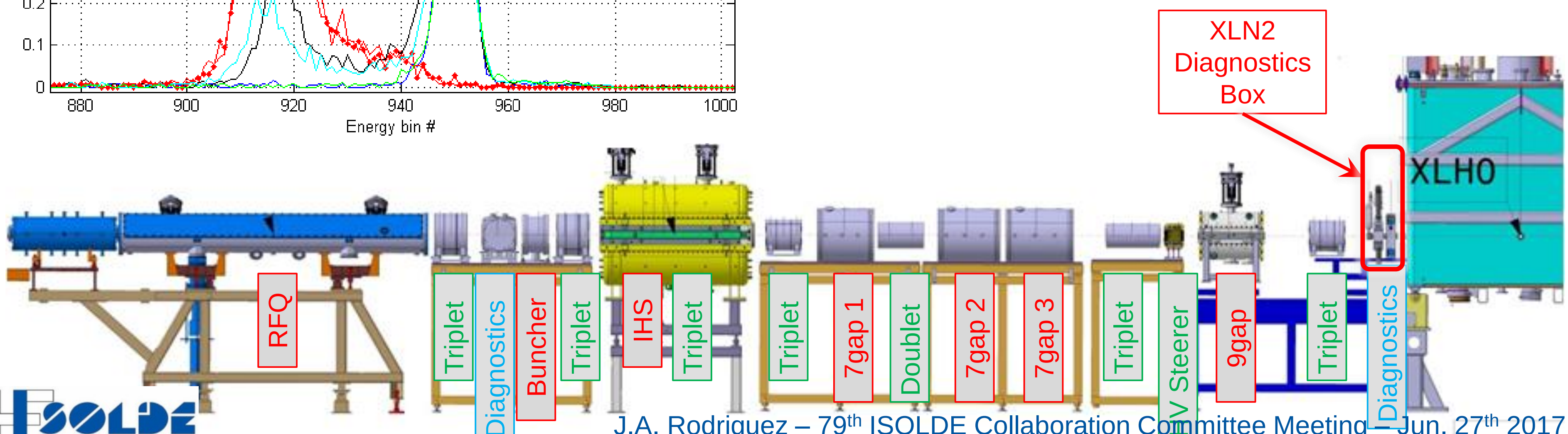
Beam Commissioning: Si detector at XLN2

- Silicon detector at XLN2 used during the beam commissioning campaigns in 2016 and 2017
- A 1 mm diameter collimator normally used in combination with the Si detector
- Measurements with the collimator masking different areas of the detector carried out

Energy and energy spread with collimator at different locations

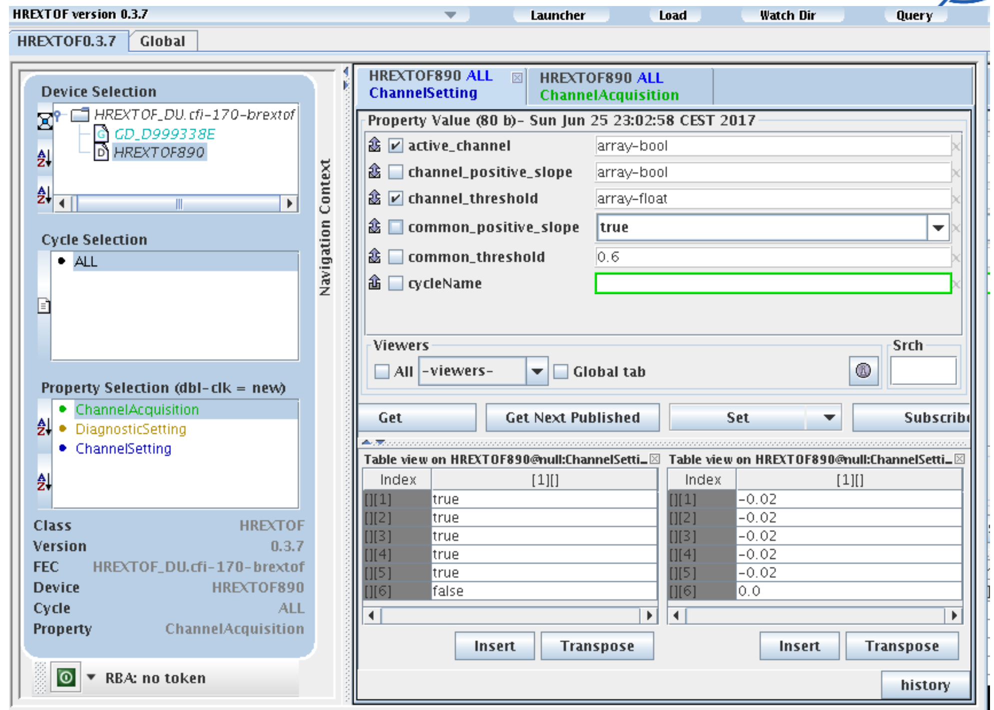


- Signs of degradation of the Silicon detector at XLN2 observed:
  - Energy spread artificially increased
  - Offset in absolute energy measurement

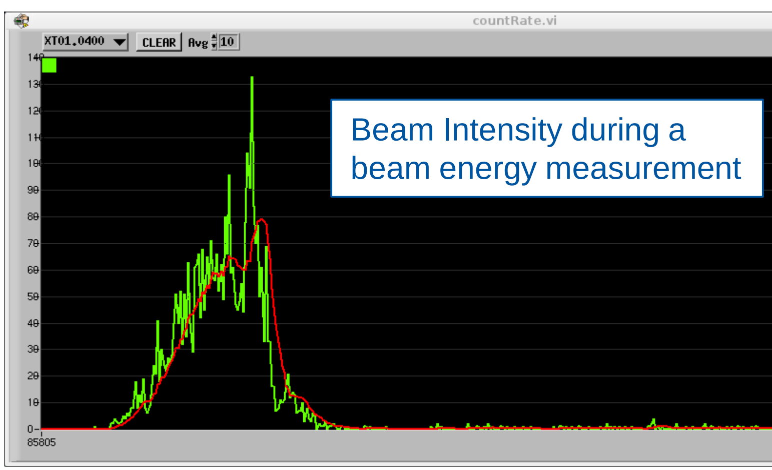


Beam Commissioning: Count Rate

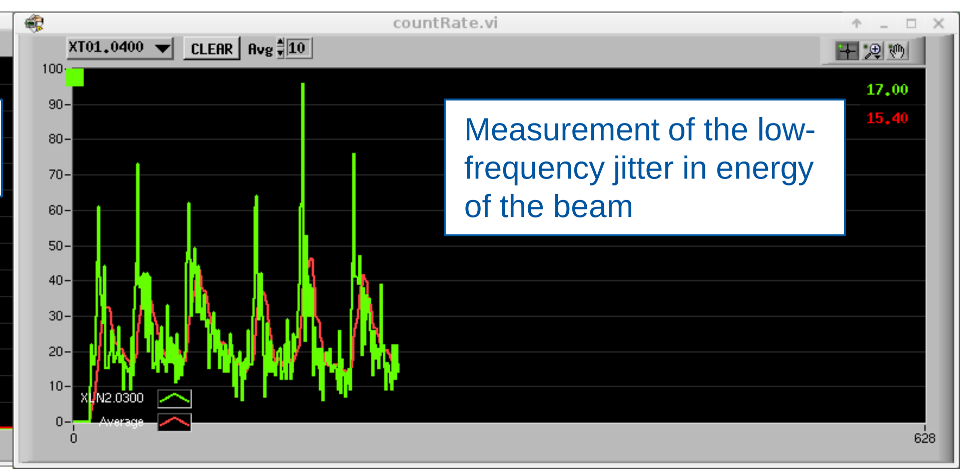
- New low-level controls (FESA class) Time Of Flight partially commissioned (channel settings and particle count rate)
- Commissioning of the bunch time structure still pending



- High-level application to use the Si detectors as very low current FC commissioned



Beam Intensity during a beam energy measurement

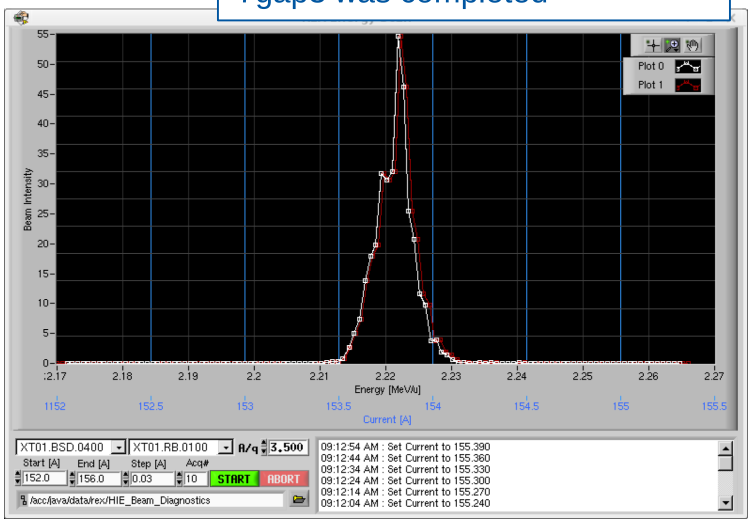


Measurement of the low-frequency jitter in energy of the beam

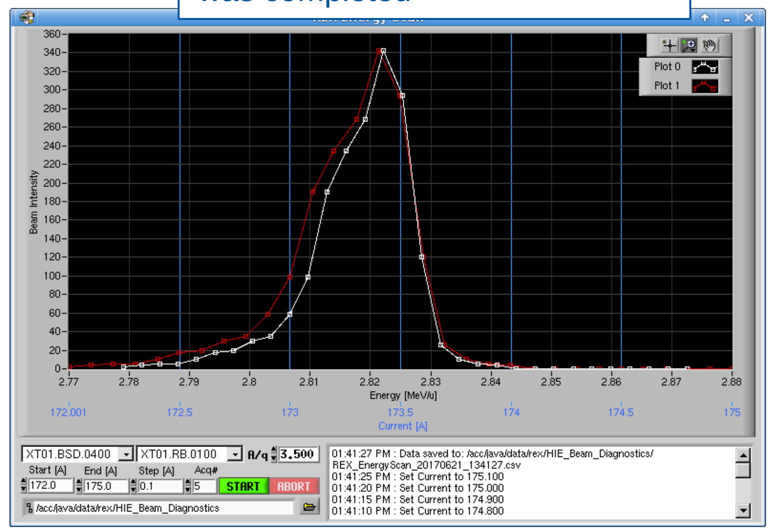
Beam Commissioning: Energy Scan

- Energy and energy spread of the beam can be carried out using the count rate measured at the Silicon detector at XT01.0400 after the first dipole magnet

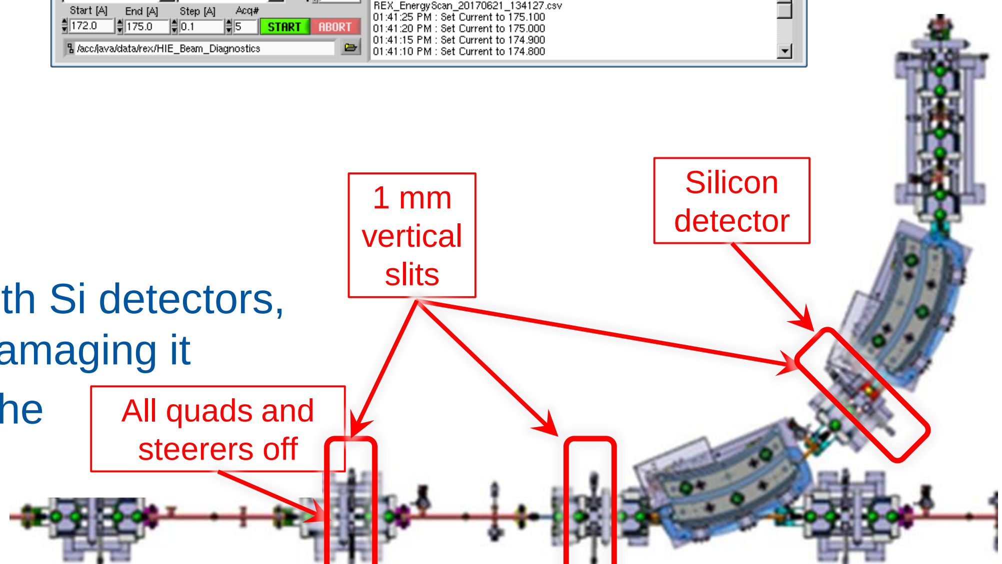
Energy Scan after set-up of 7gap3 was completed



Energy Scan after set-up of 9gap was completed



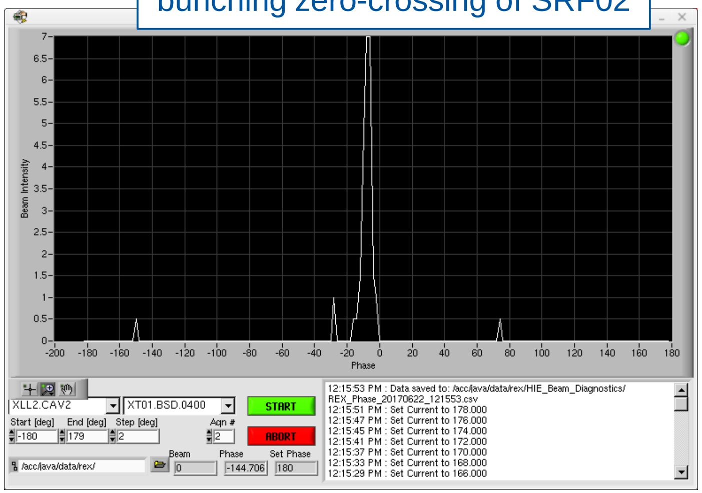
- The method works very well
  - Can be used for low-intensity beams
  - Can be completed in ~ 1 hour
  - However, as with all measurements with Si detectors, special attention is required to avoid damaging it
- We will need to consider installing them in the other two HEBT lines next year



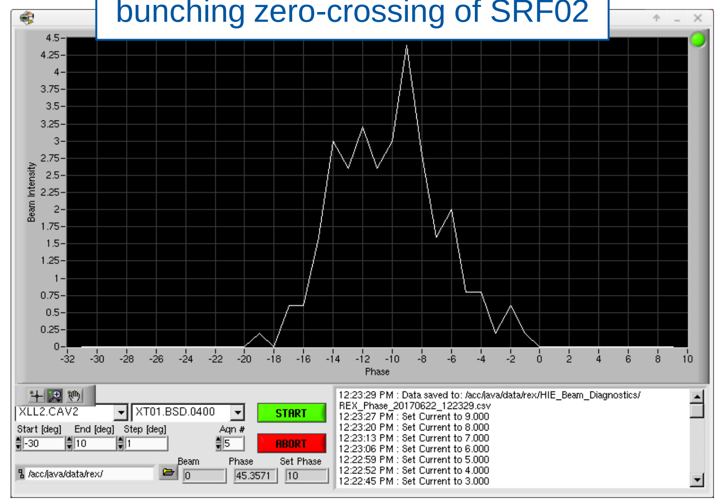
Beam Commissioning: Phase Scan

- Phase Scan can be carried out using the count rate measured at the Silicon detector at XT01.0400 after the first dipole magnet

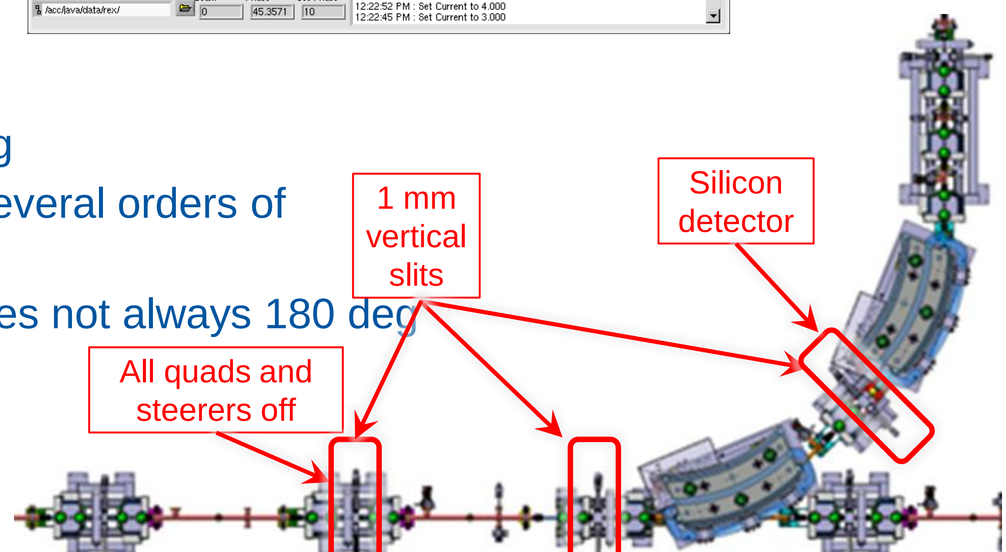
Rough Phase Scan to find the bunching zero-crossing of SRF02



Fine Phase Scan to find the bunching zero-crossing of SRF02



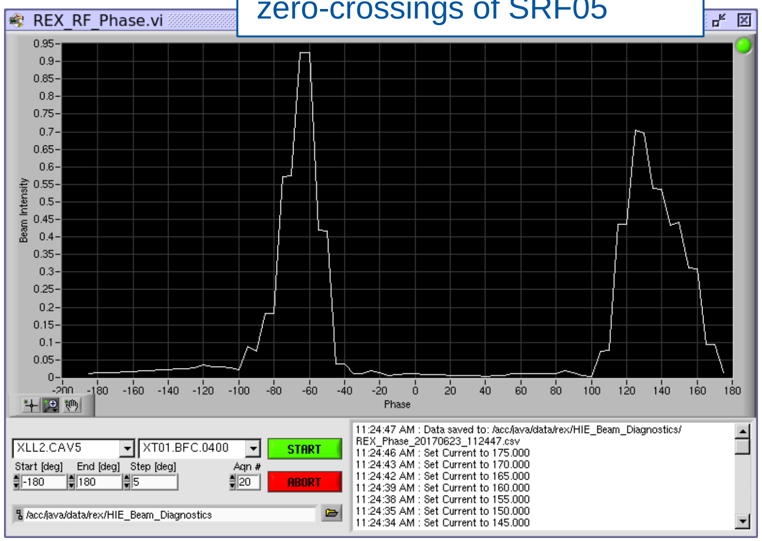
- Unexpected behaviour observed:
  - Occasionally not second zero-crossing
  - Needed beam attenuation varies by several orders of magnitude from cavity to cavity
  - Distance between zero-crossing phases not always 180 deg
- Additional work needed to understand the sources of the issues observed



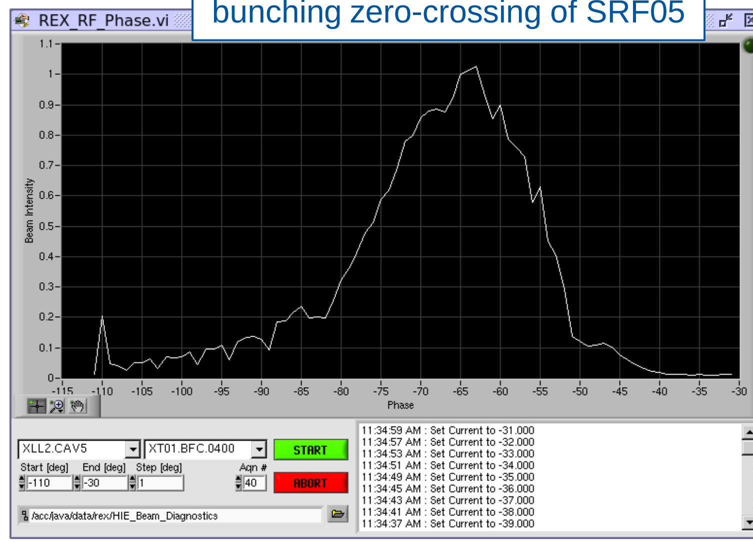
Beam Commissioning: Phase Scan

- Phase Scan can also be carried out using the XT01.0400 FC after the first dipole magnet
  - Due to the beam low current, focussing elements cannot be turned off and only one slit (10 mm) before the FC can be used
  - Injection to the dipole on axis is not guaranteed

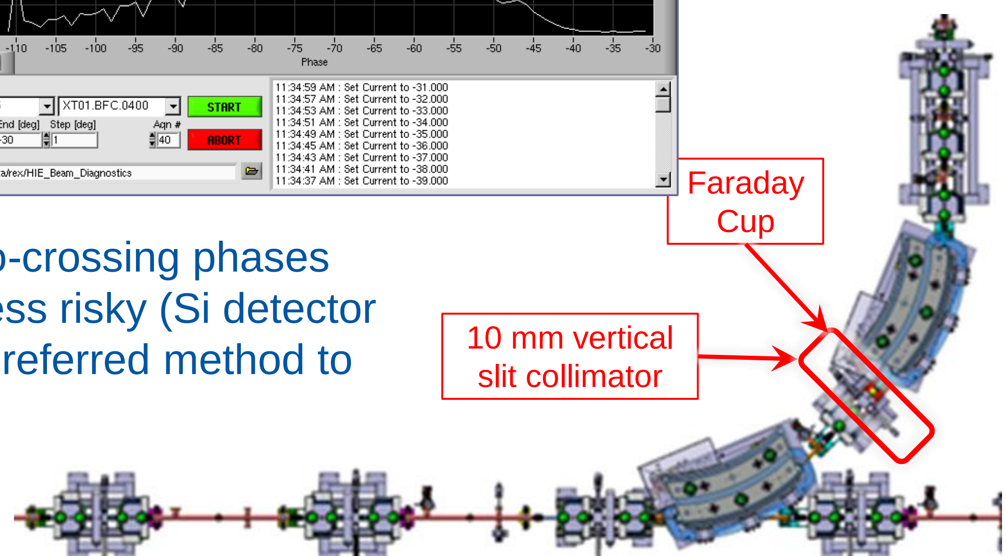
Rough Phase Scan to find the zero-crossings of SRF05



Fine Phase Scan to find the bunching zero-crossing of SRF05



- Even though the measurements of the zero-crossing phases are less precise, they are a lot faster and less risky (Si detector can be damaged) → At this point, it is the preferred method to phase the cavities



Beam Commissioning: Low Energy Beams

- Tunes for beams with A/q = 3.5 to the end of XT01 after each REX RF structure was set-up
- Precise energy measurement using the dipole for each tune
- Transverse beam profiles at each diagnostics box measured (data not yet analysed)

	RF cavity	RFQ	Buncher	IH	7GP1	7GP2	7GP3	9GP	
	Energy [MeV/u]	**0.29**	**0.3**	**1.185**	**1.53**	**1.88**	**2.23**	**2.82**	
Transmission [%]	**XSEP.FC20**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	REX
	XLN2.BFC.0300	0.81	0.80	0.80	0.79	0.79	0.79	0.79	Long
	XLN3.BFC.0300	0.88	0.89	0.90	0.91	0.92	0.91	0.95	
	XLN4.BFC.0300	0.90	0.89	0.91	0.93	0.92	0.93	0.96	
	XLN5.BFC.0300	0.88	0.89	0.85	0.86	0.84	0.85	0.86	Short
	XT00.BFC.0700	0.88	0.89	0.84	0.86	0.85	0.87	0.84	
	XT00.BFC.1050	0.90	0.86	0.82	0.81	0.81	0.84	0.84	
	XT00.BFC.1300	0.81	0.80	0.81	0.81	0.80	0.81	0.80	
	XT01.BFC.0400	0.73	0.79	0.82	0.81	0.79	0.80	0.76	Long
	XT01.BFC.0900	**0.81**	**0.80**	**0.81**	**0.81**	**0.80**	**0.80**	**0.78**	

Conclusions:

- Low-energy beams can be transported without additional losses
- Beam losses in HIE-ISOLDE (ie. XLN2 to end of XT01) negligible or at the very least small
- Differences between different types of FC noticeable

Beam Commissioning: Plan

Week 26:

- Phasing of cavities in CM2 and CM3 with $^{14}N^{4+}$ (E_{final} = 6.6 MeV/u)
- Scaling to A/q = 3.67 and 4.0
- REX-TRAP and REX-EBIS synchronization with ^{39}K from the pilot ion source
- Scaling to A/q = 3.9

Week 27-28:

- Set-up for first RIB and Physics

Week 29:

- Scaling to A/q = 4.33

Week 30-32:

- Set-up and Physics

Week 33:

- First beam to XT03
- Commissioning of all diagnostics devices
- Commissioning of the stripping foils

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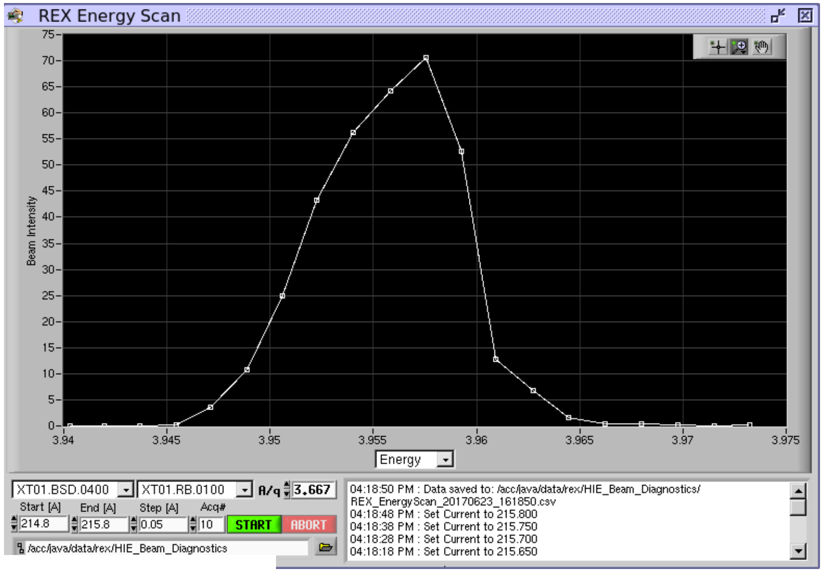
First Beam to Users:

- ^{22}Ne beam requested by Miniball users for testing and calibration last weekend

Ion	$^{22}Ne^{6+}$
A/q	3.667
HEBT	XT01
Transmission	~ 72 %
E	**3.955 MeV/u**
dE_{FWHM}	0.25 %
Length	~ 60 hours
Rep. rate	20 Hz



- Both REX and the SRF cavities quite stable (1.5 trip/shift)

RF structure	**REX**		**HIE**	
	RFQ	**7GP3**	**SRF02**	**SRF04**
# Trips	1	3	2	8
Downtime [mins]	15	0	10	40
Downtime [%]	0.4	0	0.3	1.1

- However, note that 40% extra power will be needed at REX for beams with A/q = 4.33 and that the gradient of the SRF cavities was not pushed to 6 MV/m

Cavity	**Pf [kW]**
RFQ	32.8
Buncher	1.45
IH	38.0
7GP1	51.0
7GP2	50.2
7GP3	46.2
9GP	61.5

Cavity	**E [MV/m]**
SRF01	4.14
SRF02	4.14
SRF03	4.14
SRF04	4.14
SRF05	3.22

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Users/Machine Interface:

Vacuum:

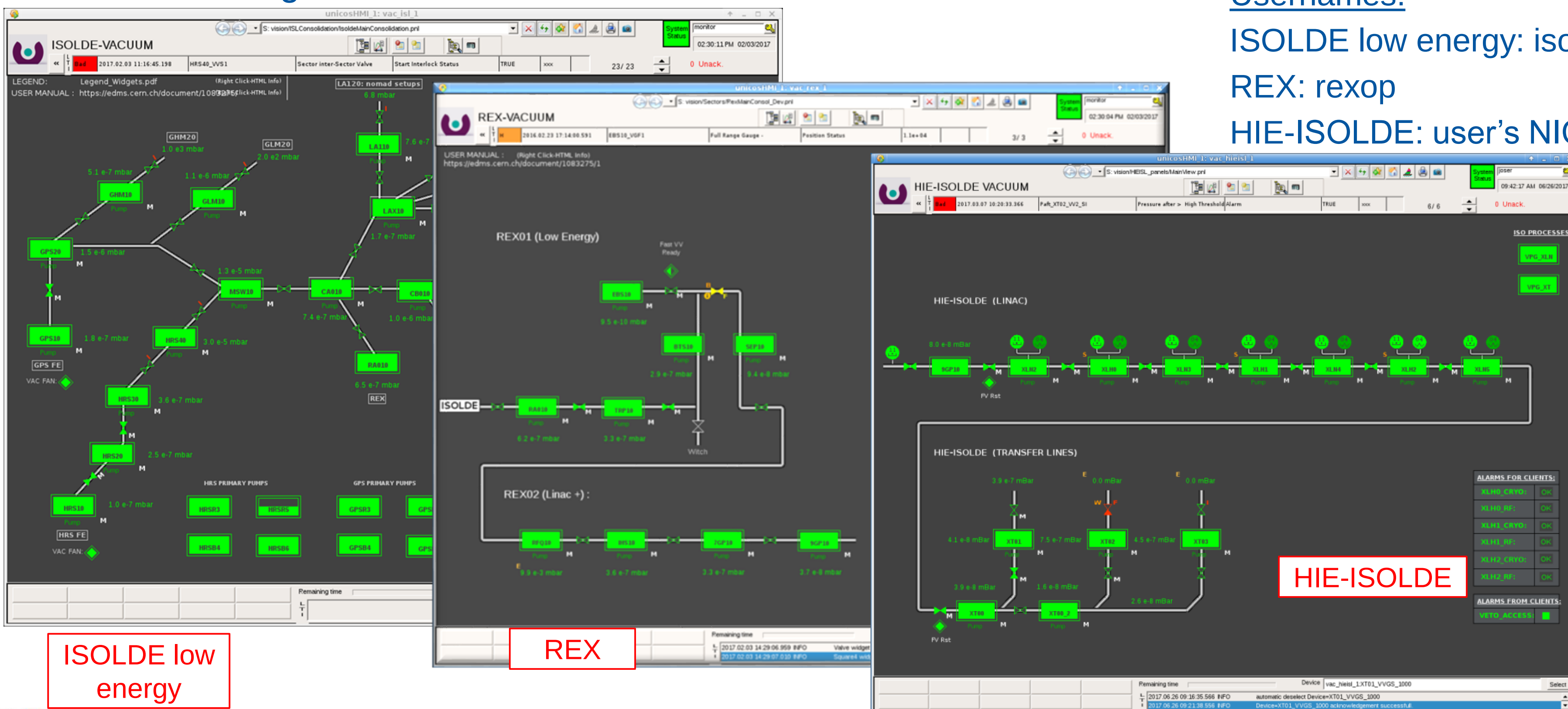
- Vacuum in experimental station of 10^{-6} mbar required before beam is delivered
- Valves between HEBT lines and the experimental station need to be closed before a mechanical intervention takes place on the experiment side
- Users need to be granted access to open/close last valve in the HEBT line (NICE usernames need to be provided at least a week in advance)
- Visual sign with the status of the valve needs to be checked

Usernames:

ISOLDE low energy: isoop

REX: rexop

HIE-ISOLDE: user's NICE

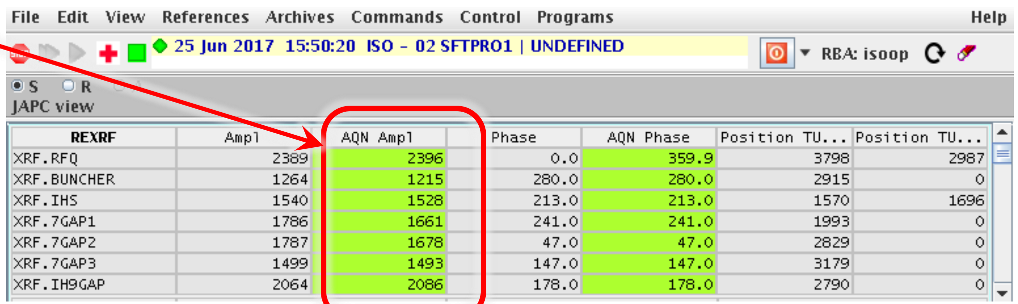


Users/Machine Interface:

REX RF:

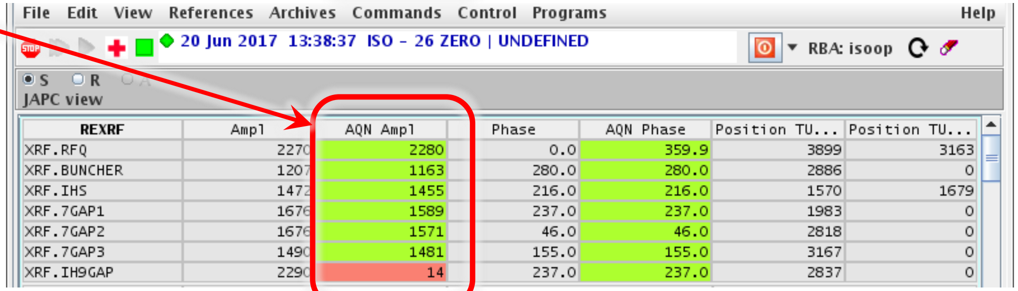
- All 7 RF Systems need to be working to reach energies higher than 2.8 MeV/u
- Working Set: REX/HIE LINAC > Linac: RF

All REX RF systems ok



REXRF	Ampl	AQN Ampl	Phase	AQN Phase	Position TU...	Position TU...
XRF.RFQ	2389	2396	0.0	359.9	3798	2987
XRF.BUNCHER	1264	1215	280.0	280.0	2915	0
XRF.IHS	1540	1528	213.0	213.0	1570	1696
XRF.7GAP1	1786	1661	241.0	241.0	1993	0
XRF.7GAP2	1787	1678	47.0	47.0	2829	0
XRF.7GAP3	1499	1493	147.0	147.0	3179	0
XRF.IH9GAP	2064	2086	178.0	178.0	2790	0

9GAP Structure down



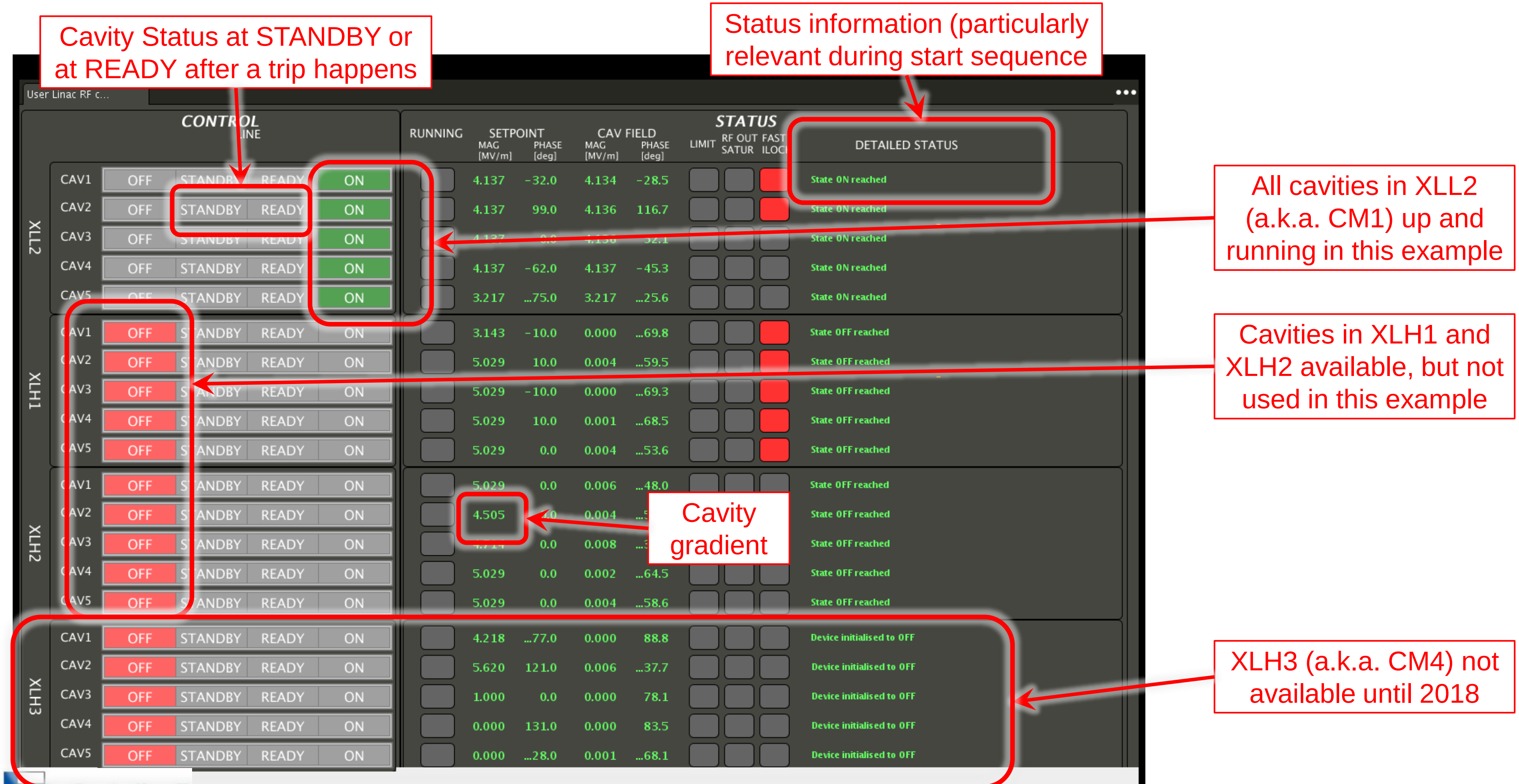
REXRF	Ampl	AQN Ampl	Phase	AQN Phase	Position TU...	Position TU...
XRF.RFQ	2270	2280	0.0	359.9	3899	3163
XRF.BUNCHER	1207	1163	280.0	280.0	2886	0
XRF.IHS	1472	1455	216.0	216.0	1570	1679
XRF.7GAP1	1676	1589	237.0	237.0	1983	0
XRF.7GAP2	1676	1571	46.0	46.0	2818	0
XRF.7GAP3	1490	1481	155.0	155.0	3167	0
XRF.IH9GAP	2290	14	237.0	237.0	2837	0

- REX RF amplifiers need to be restarted locally (amplifier room)
- Users trained to restart RFQ, 7GAP1, 7GAP2 and 7GAP3. Procedure can be found in RF amplifier room
- For the IHS, contact Engineer in Charge if standard procedure fails more than three times
- Procedure for the 9GAP not standard. Generally, the Engineer in Charge will need to be contacted

Users/Machine Interface:

HIE-ISOLDE RF:

- Generally not all SRF cavities will be used for a given experiment (OFF = not used)
- Those that trip (STANDBY or READY) need to be restarted by users (up to 3 times in a row)
- It takes a couple of minutes to complete the start sequence after the ON button is pressed
- Start sequence can be followed in Detail Status (message to logbook in restart not successful)



Users/Machine Interface:

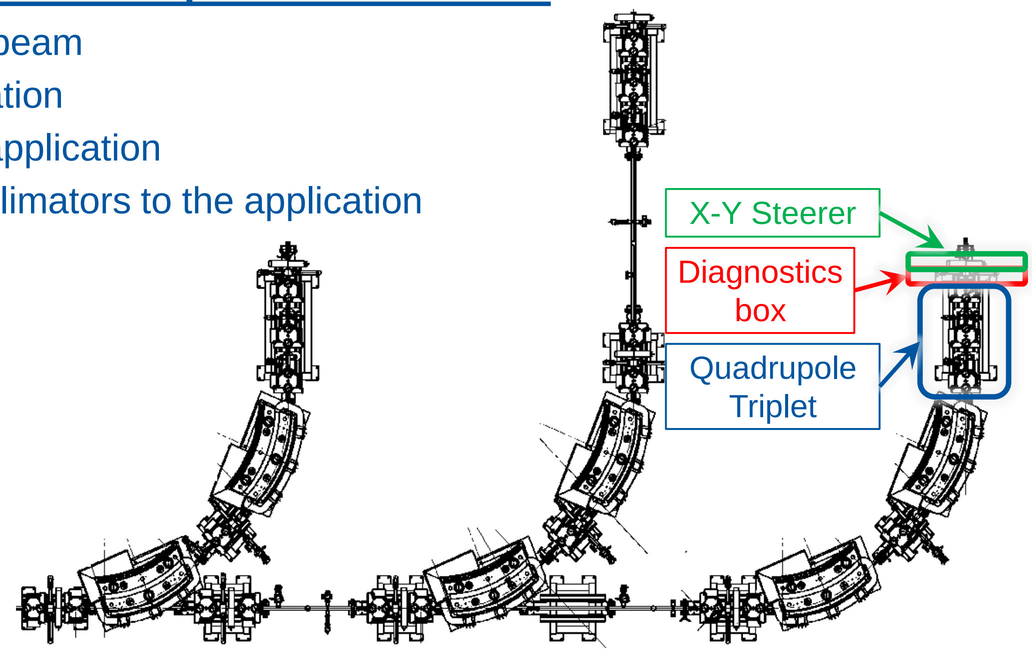
Injection into Experimental Station:

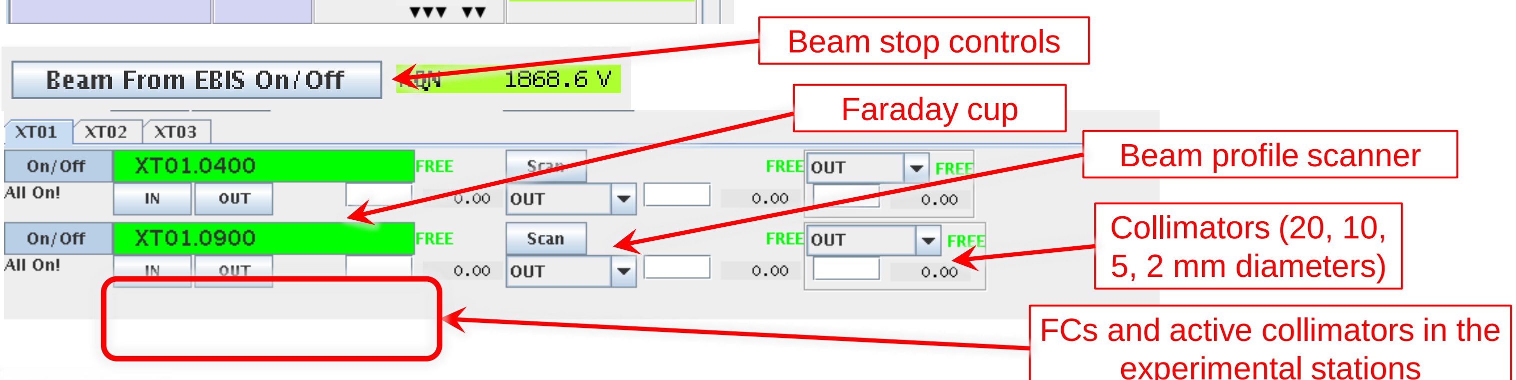
- Operations will **only deliver beam to the last diagnostics box of the HEBT line**
- **Users are responsible for injection into their experimental station**
  - Equipment array to steer and/or focus the beam
  - Version for users of the diagnostics application
  - Beam stop will be included in diagnostics application
  - Contact OP to add your FCs and active collimators to the application

170623_1709_ToXT01.0900_Aq3.67_3.955MeVu_74%_USERS.csv

/acc/java/data//iso/equiparray/rex/files/Setting_2017/2017_06_23_22Ne6p_4.0MeV

OB Name	Buffer	CCV Value	AQN Value
XT01.RQ.0600	34.23	CCV 21.23 A	AQN I: 21.23
XT01.RQ.0700	49.44	CCV 41.24 A	AQN I: 41.24
XT01.RQ.0800	34.23	CCV 29.23 A	AQN I: 29.23
XT01.RCH.0950	0.00	CCV -10.00 A	AQN I: -10.00
XT01.RCV.0950	0.00	CCV 4.00 A	AQN I: 4.00





Summary:

- Beam Properties:
  - 2.5 < A/q < 4.33
  - 0.1 ms < Pulse Length < 1.7 ms (needs to be requested in advance)
  - Repetition rate < 50 Hz
  - Energy and Energy Spread will be measured for each experiment

- Beam Commissioning:
  - Low energy tunes to the end of XT01 prepared (80% transmission)
  - Cavities in CM1 phased
  - New low and high level controls tested:
    - TOF FESA class
    - Count Rate application
    - Energy Scan application
    - Phase Scan application
  - Phasing of SRF cavities in CM2 and CM3 and scaling to A/q = 4 on-going
  - Commissioning of XT03 on week 33

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