Updates on SESAME Machine

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On behalf of SESAME team

Outlines

- Introduction to SESAME
- Commissioning milestones
- Status

SESAME Machine

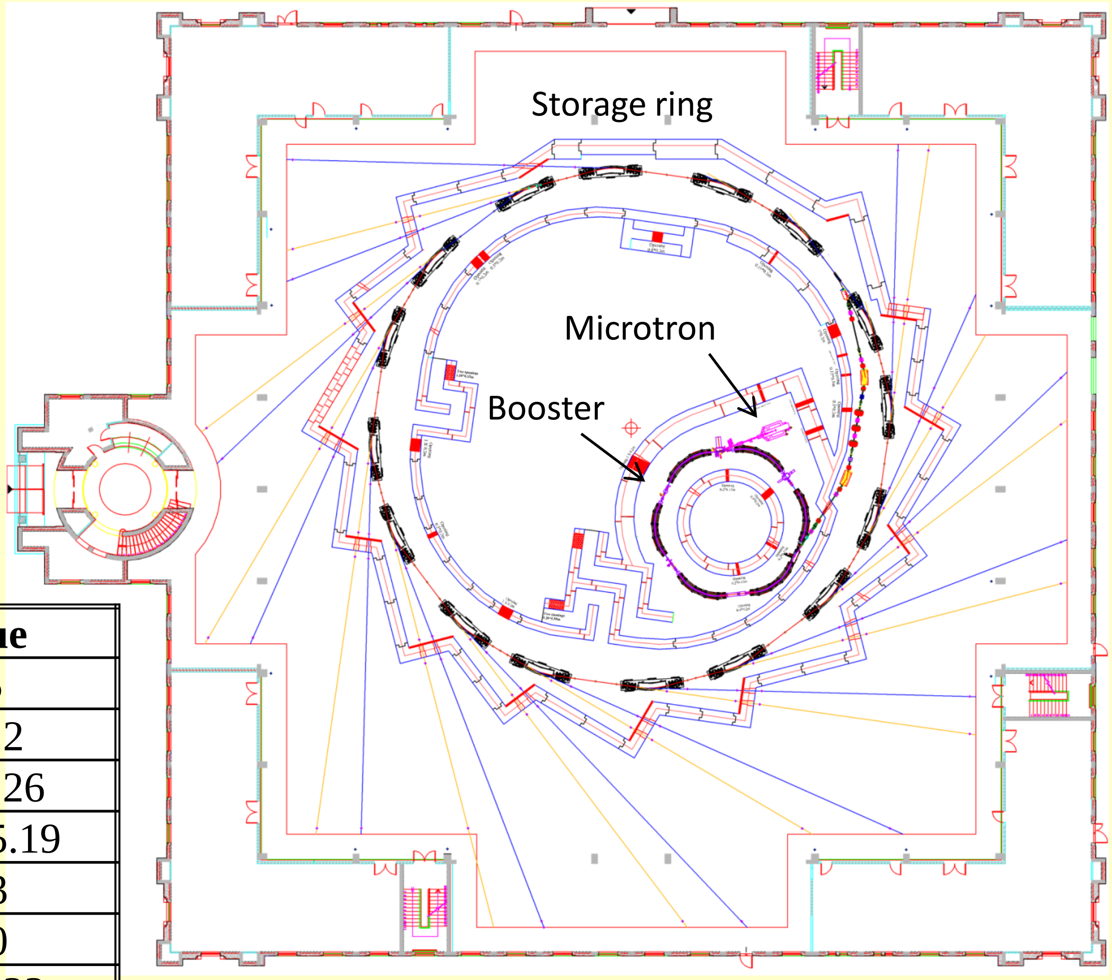
SESAME Injector:

- BESSY I 20MeV classical Microtron:

  output I = 8-12 mA, pulse length = 2μs.

- BESSY I 800MeV Booster:

  I(@800MeV) = up to 12 mA.
  Extracted pulse length = 100ns



Parameter	Unit	Value
Energy	GeV	2.5
Circumference	m	133.2
Emittance ε_x ,ε_z	nm.rad	26, 0.26
design Q_x , Q_z		7.23, 5.19
Energy Loss / turn	keV	603
Target Beam current	mA	400
Mom. Com. Factor α	nm.rad	0.00833
Relative energy spread	%	0.1087
∑(str. section length) /circumference	%	41.1

SESAME Phase I Beamlines

No.	Beamline	Energy Range	Photon Source	Research Area	Donation
1	Protein Crystallography	4 – 14 keV	In-vacuum Und.	Structural Molecular Biology	---
2	XAFS / XRF	5 – 30 keV	Bending Magnet	Material Science, Environment	HZDR Institute
3	Infra-Red (IR) Spectromicroscopy	0.01 – 1 eV	Bending Magnet	Environmental, Materials and Archaeological Science	---
4	Powder Diffraction	5 – 25 keV	Wiggler	Material Science	SLS (with source)
5	Soft X-ray, Vacuum Ultraviolet (VUV)	0.05 – 2 keV	Elliptically Polarizing Undulator	Atomic, Molecular and Condenced Matter Physics	---
6	SAXS / WAXS	8 – 12 keV	Bending Magnet	Structural Molecular Biology, Material Science	Daresbury
7	Extreme Ultraviolet (EUV) Spectroscopy	10 – 200 eV	Bending Magnet	Atomic and Molecular Physics	LURE

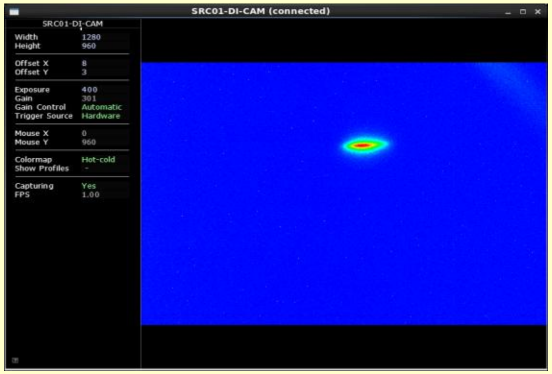
“Day-one” beamlines

Milestones in Storage Ring Commissioning

✓ *Full turn beam* ***(Jan 11, 2017).***

-Fine-tuning inject. *angles, dipoles.*

- Vertical correctors in cell 5 & 14.

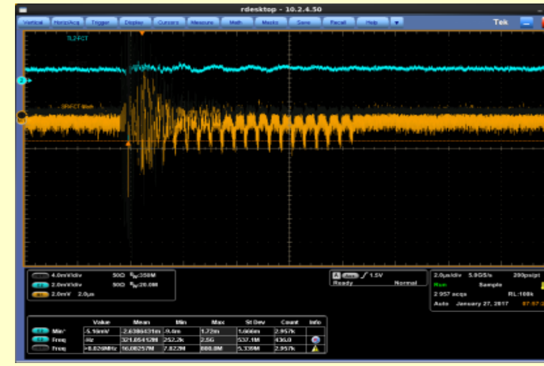


✓ *Multi-turns* ***(Jan 26, 2017).***

-TL2-storage ring optical matching.

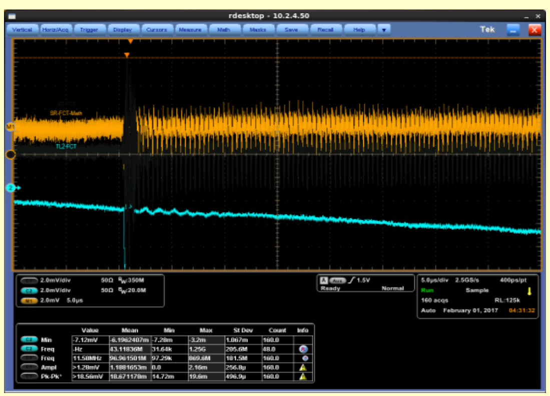
- Reversing kicker polarity.

- Reducing Q_x below half-integer.



✓ *Hundreds of turns* ***(Jan 31, 2017).***

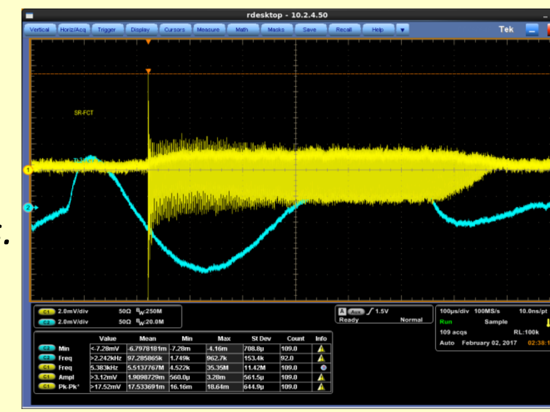
- Fine-tuning vertical correctors, *kicker strength & timing, quadrupole strengths.*



✓ *Thousands turns* ***(Jan 31 -Feb. 6)***

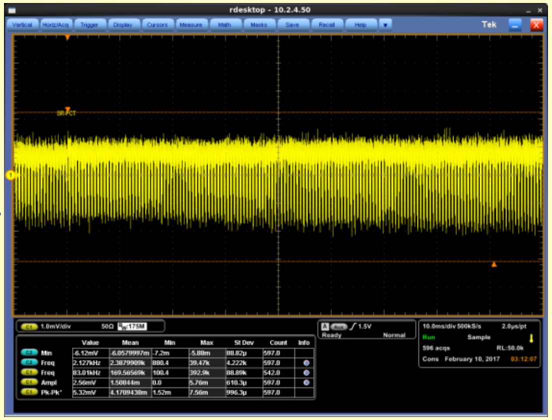
-Turn on sextupoles.

- Fine-tuning of quadrupole strengths.



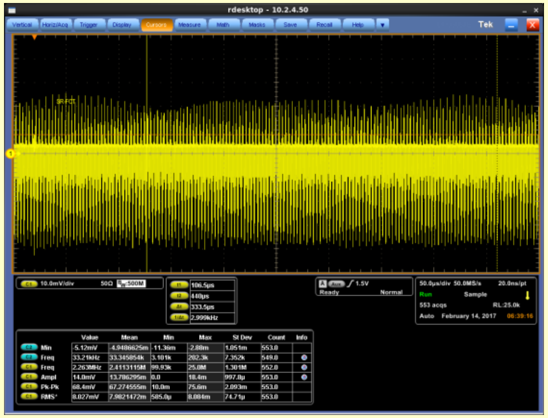
✓ *Stored beam with RF **(Feb. 9).***

-Correcting (Q_x , Q_y) from (7.12, 5.7-6) to (7.23, 5.17)
-Scanning RF phase & *frequency.*
- *Using horizontal correctors.*



✓ *3mA accumulated **(Feb. 13, 2017).***

-Going up with Q_x to 7.45.
(single-kicker inject. Scheme which preferred $Q_x = 0.45$ over $Q_x = 0.23$)



✓ *Accumulated 30 mA current at 800 MeV (**by Feb. 21.2017**).*

✓ *Ramping up to 2.3GeV only (**Feb. 23**) due to:*

- *limitation on RF power (2 cavities were operational with total voltage 700 kV).*
- *saturation in some vertical correctors (strong A1 component in dipoles).*

✓ *Ramping to 2.5GeV (**April 2017**):*

- *RF power was increased to > 1.2 MV using 3 RF cavities.*
- *12 vertical corrector were relaxed by factors 6-10 when 6 dipole were shifted vertically by 0.5 – 0.6 mm.*

Vertical Displacements in 6 Dipoles (March 16)

- *It is not possible to inject without vertical orbit correction.*
- *Vertical correctors saturation before 2.5 GeV restricted ramping to full energy.*
- *Skew dipole components (A1) in dipoles are the source of such restriction.*

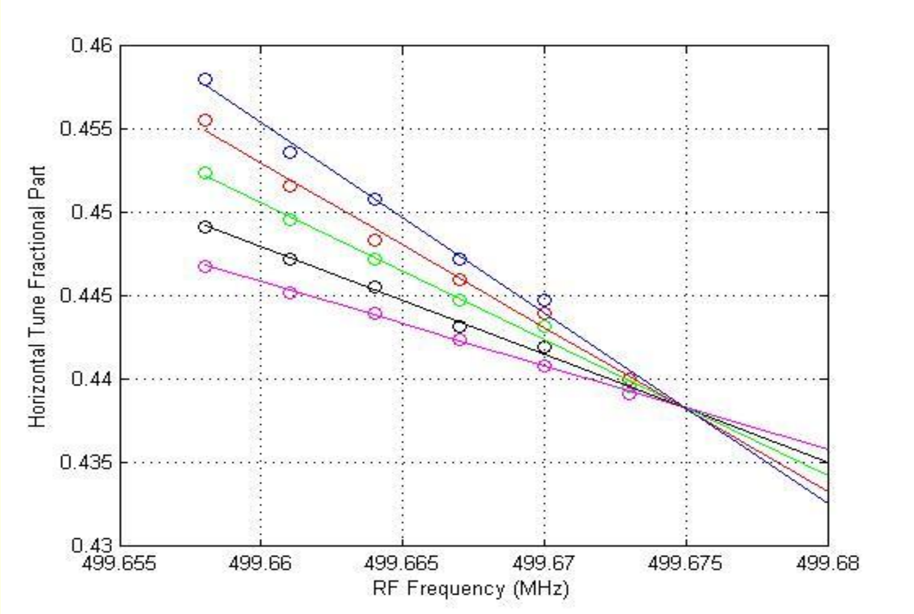
Cell #	**Dipole #**	**VC1 (A)**	**VC2 (A)**	**Source of orbit dist.**	**Due dy (mm)**	**Displacement**
3	17	1.7	6.6	-A1 component	0.64	0.5
5	14	3.6	5.1	-A1 component	0.67	0.5
6	16	4.95	3.6	-A1 component	0.66	0.5
7	15	4.3	4.2	-A1 component	0.65	0.5
10	1	-6	-4	+A1 component	-0.77	-0.6
12	13	5.8	2.8	-A1 component	0.66	0.5

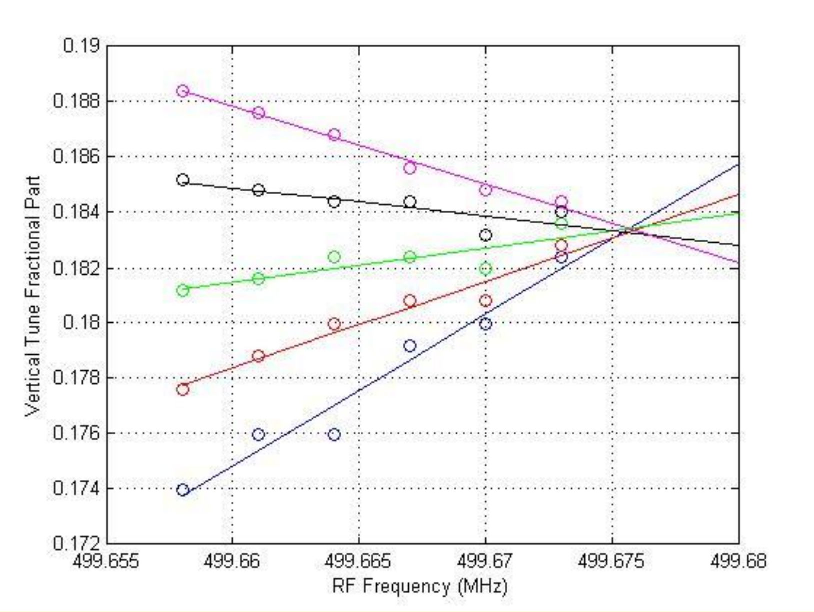
Vertical corrector values @ 2 GeV (max. corrector current = 10 A)

- *The vertical dipole displacements reduced correctors currents by factors 6-10, nevertheless it is still not possible to inject and ramp without vertical correctors.*

Measured Central Frequency in SR at 800 MeV

- *The measured central frequency is **499.675 MHz***
  The design one is 499.654 MHz
  *The one calculated from the dipole prototype magnetic measurement is **499.67488 MHz**.*

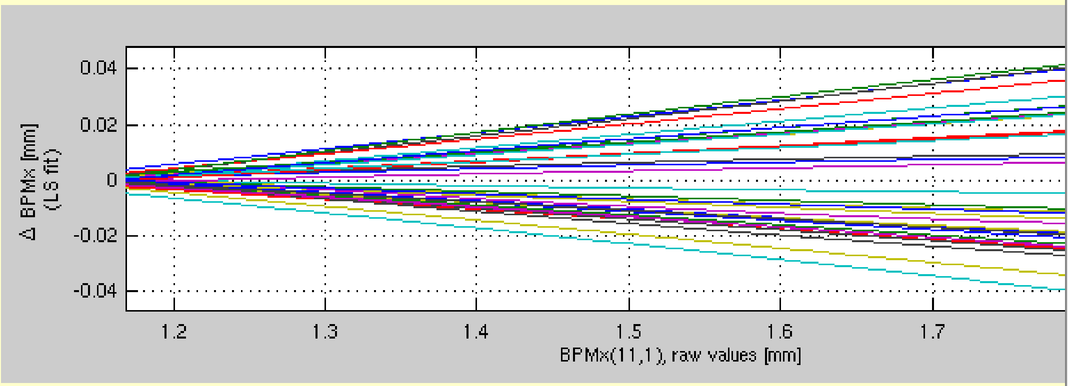


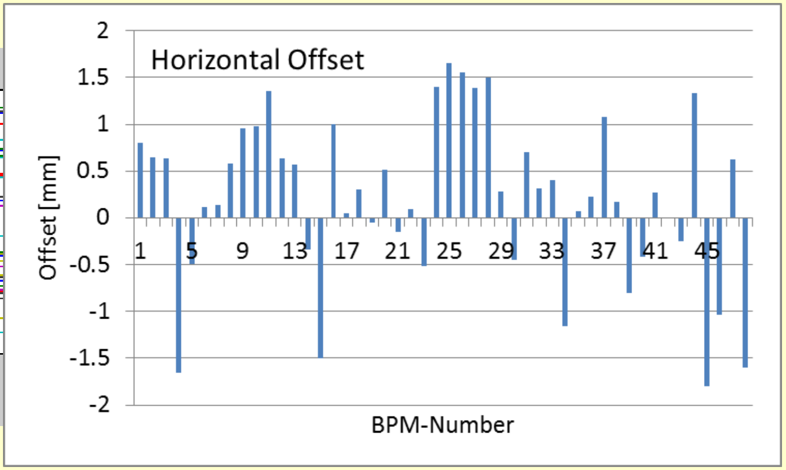


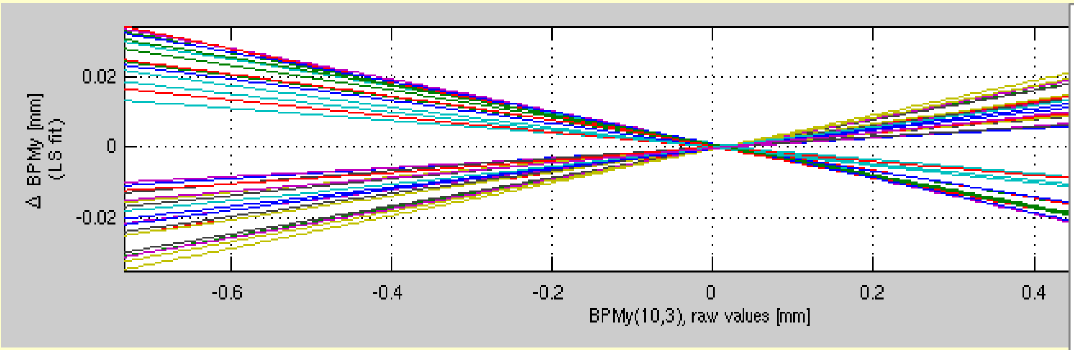
SF sextupole is fixed to 18.79A, while SD is varied: 24.9A (blue), 25.9A (red), 26.9A (green), 27.9A (black), and 28.9A (pink).

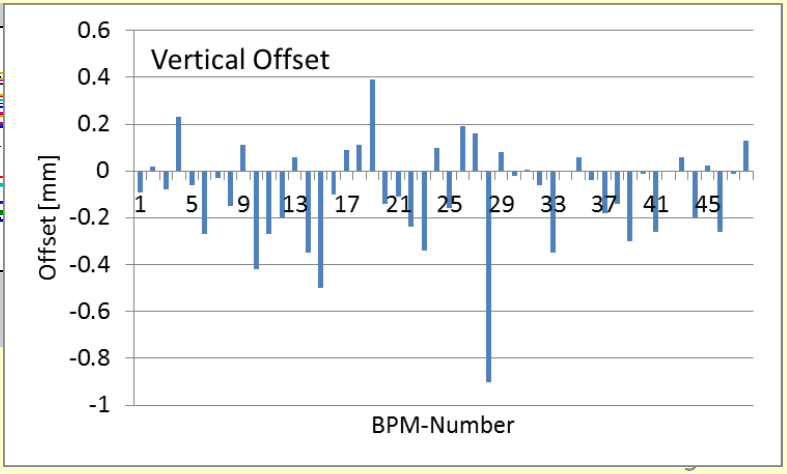
Beam Based Alignment @ 800 MeV ≈ @ 2.5 GeV

- Beam position moved in Quadrupole by the most effective corrector.
- Quadrupole strength varied for each position.
- Minimal Orbit-deviation for QP strength variation defines BPM offset







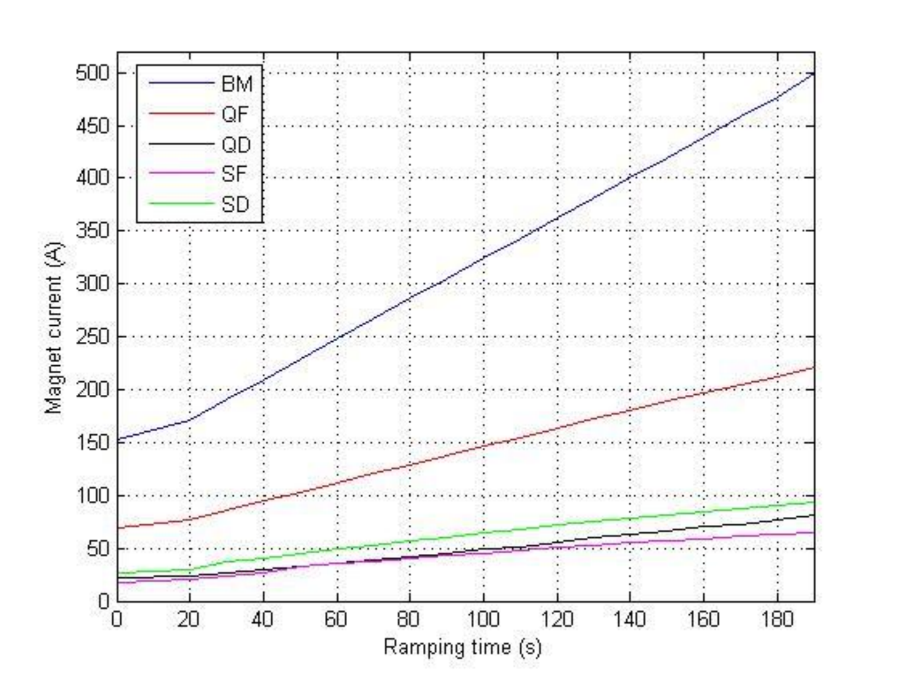


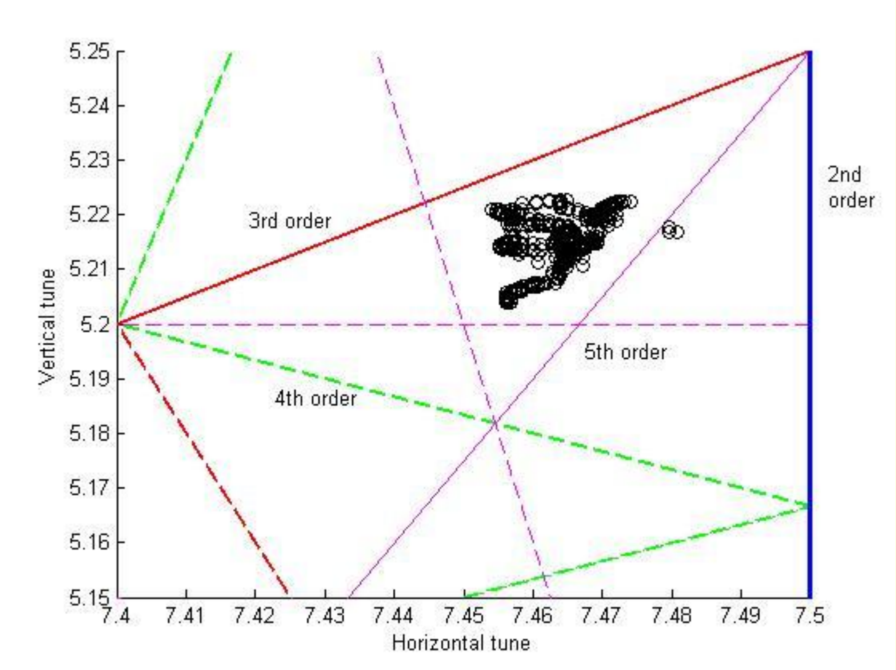
Energy Ramping from 800 MeV to 2.5 GeV

- ✓ *Ramping time = 190 s.*

- ✓ Vertical *orbit correction is mandatory over the ramping (more dipole vertical shifts can be done).*
- ✓ Only *1% beam current loss is achieved (for the best cases) during ramping*

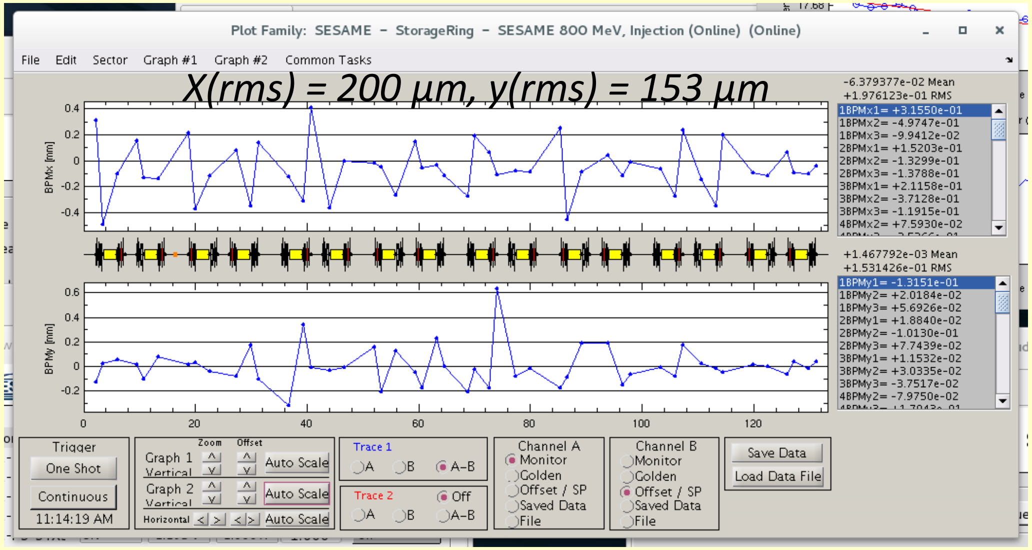
- ✓ *RF is linearly ramped from 80 kV/ cavity to 450 kV/cavity (out of 600kV).*



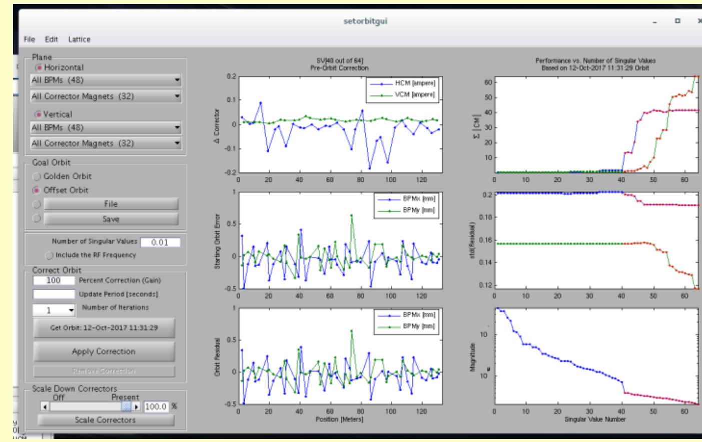


Closed Orbit Correction at Top Energy

✓ *Orbit correction is done using SVD (32 Corrector * 48 BPMs (out of 64) in each plane).*



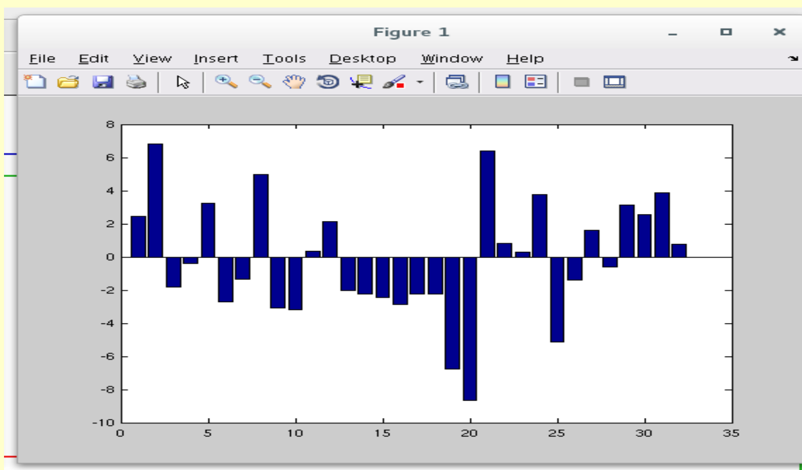
40 Singular Values are used

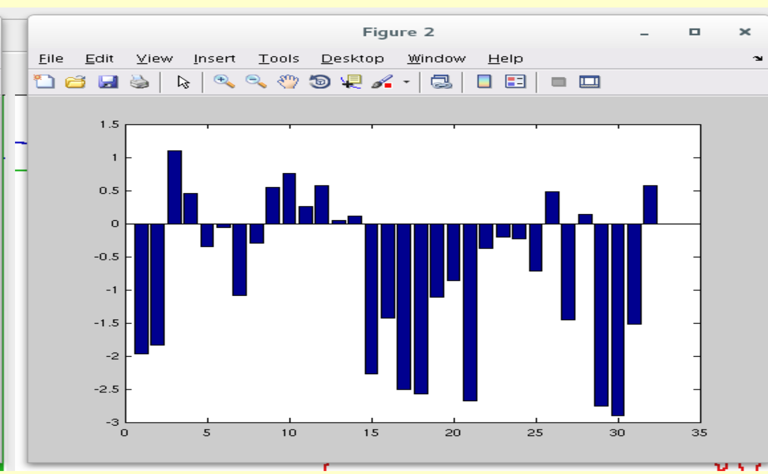


Horizontal correctors (need to be relaxed)

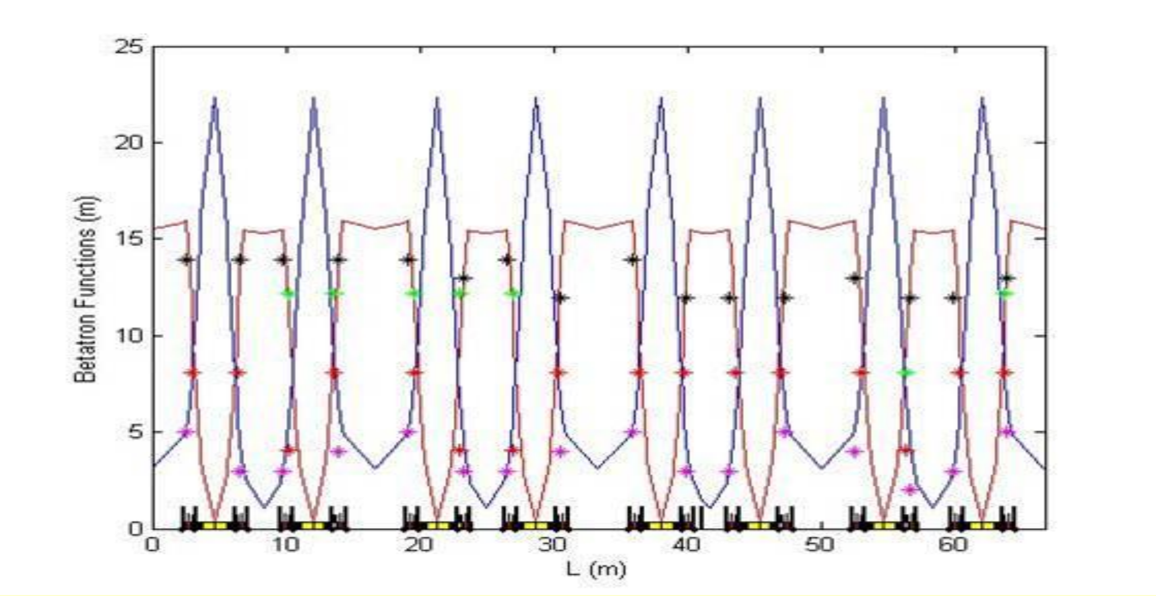
Vertical correctors

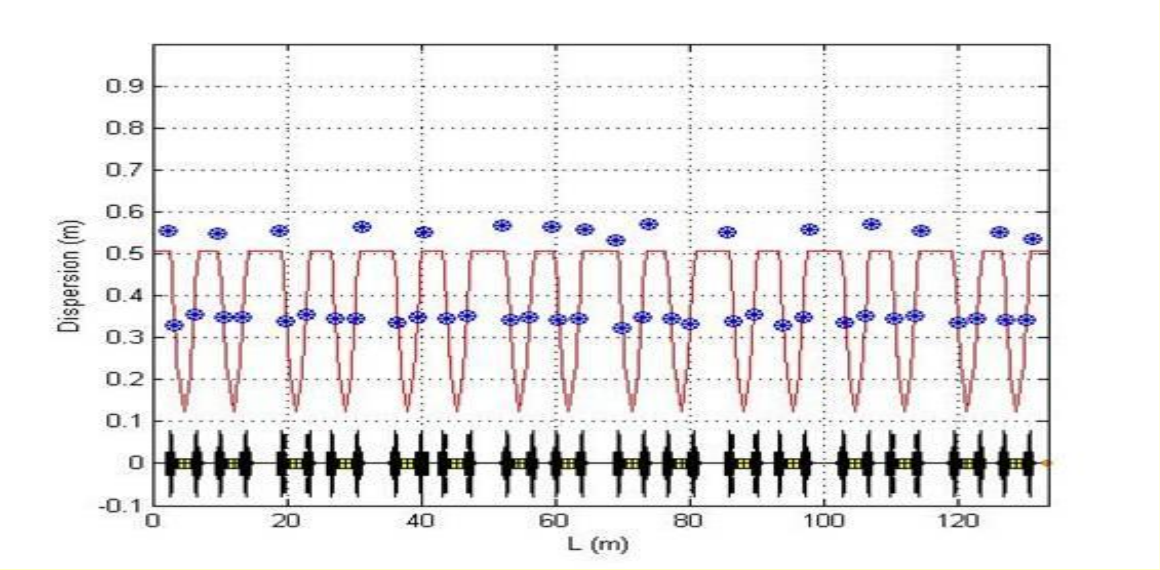
Maximum corrector I = 10A



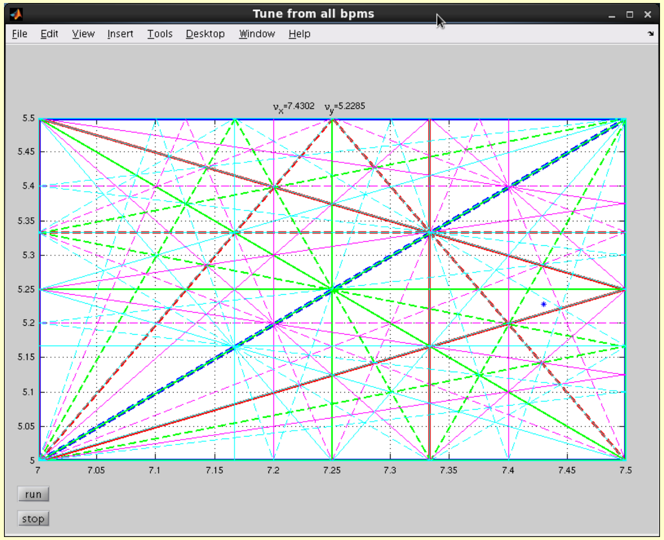


Measured Optics at Top Energy





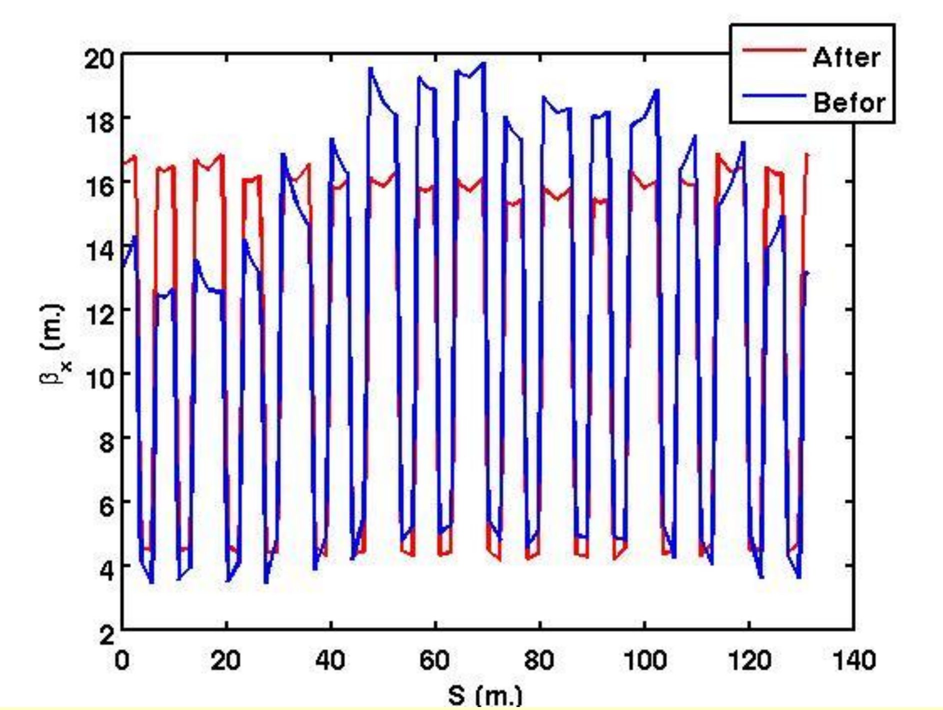
$Q_x = 7.43$, $Q_y = 5.23$

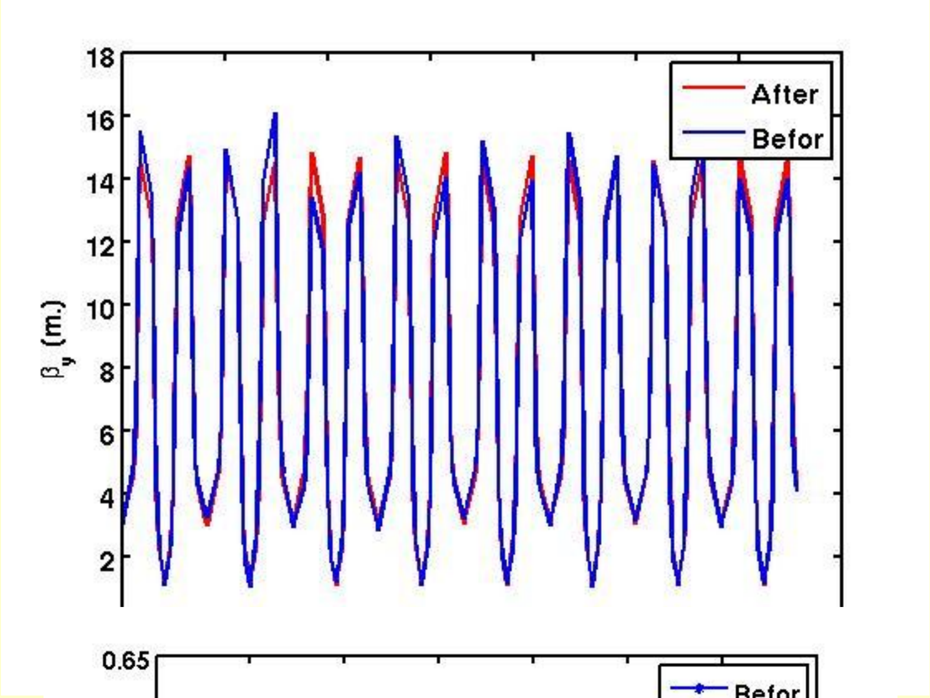


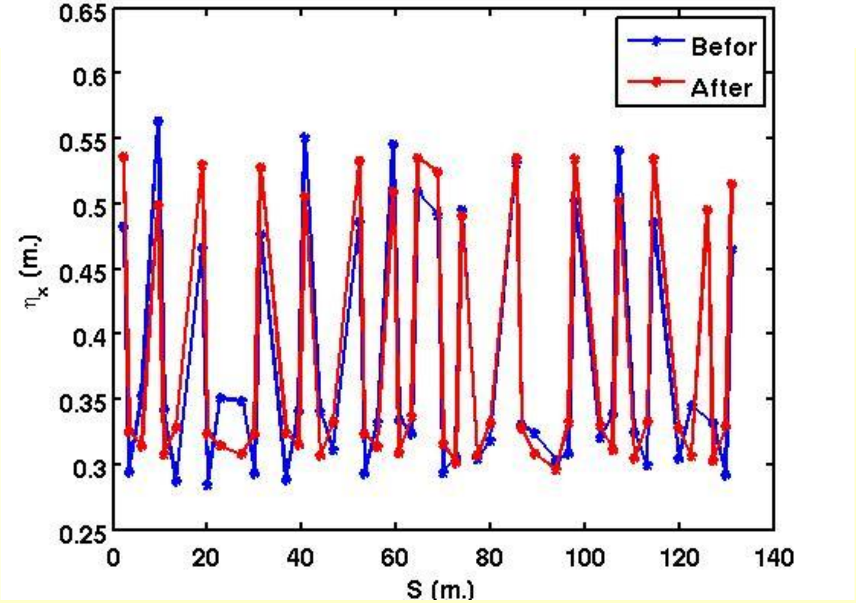
Optical symmetry needs optimization

M. Attal, XXV ESLS workshop, 21-22 Nov. 2017, Dortmund Univ.

More symmetric Optics with LOCO



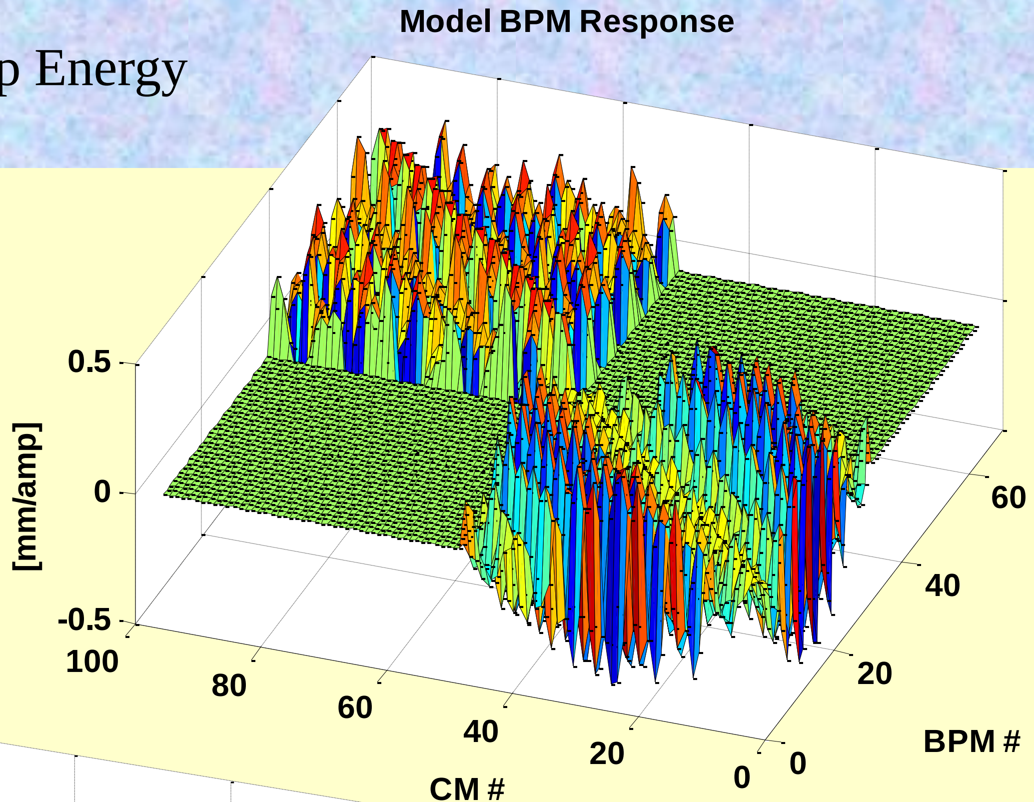




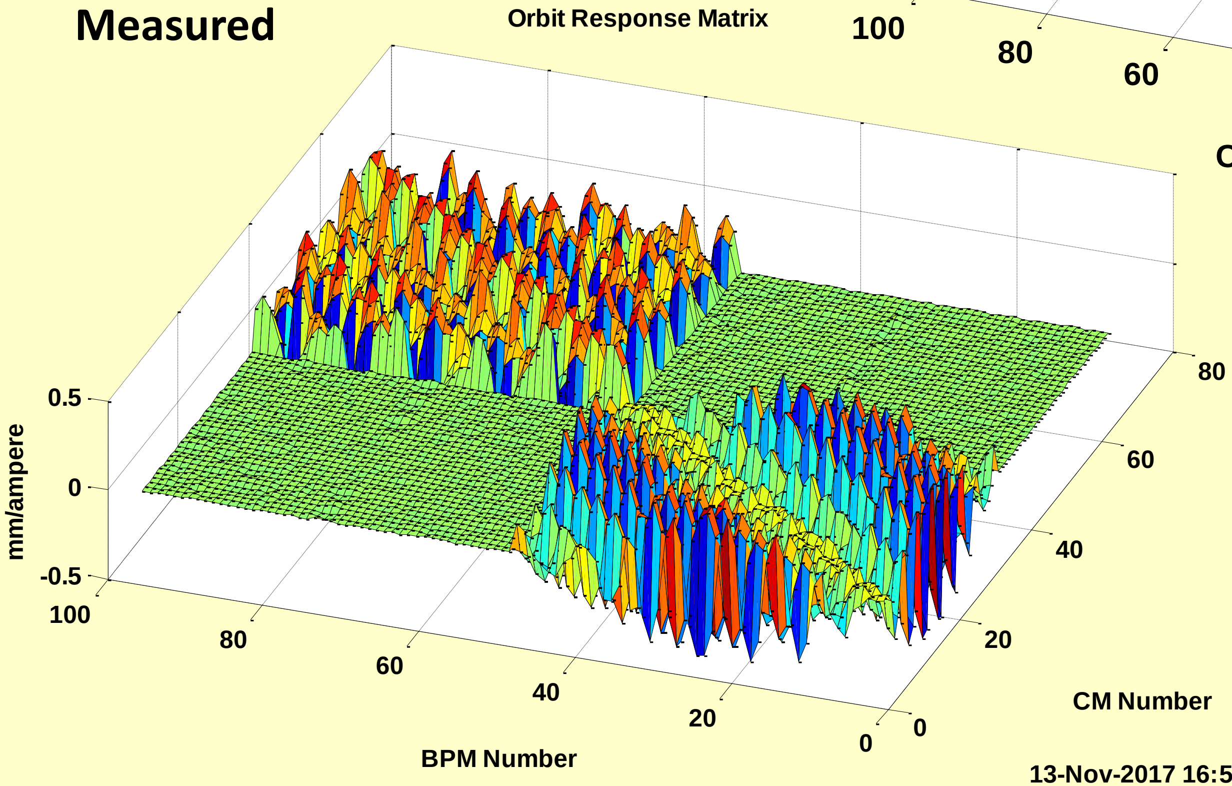
The model-measured response matrices are fitted using quadrupole strengths only.

Response Matrix at Top Energy

Model

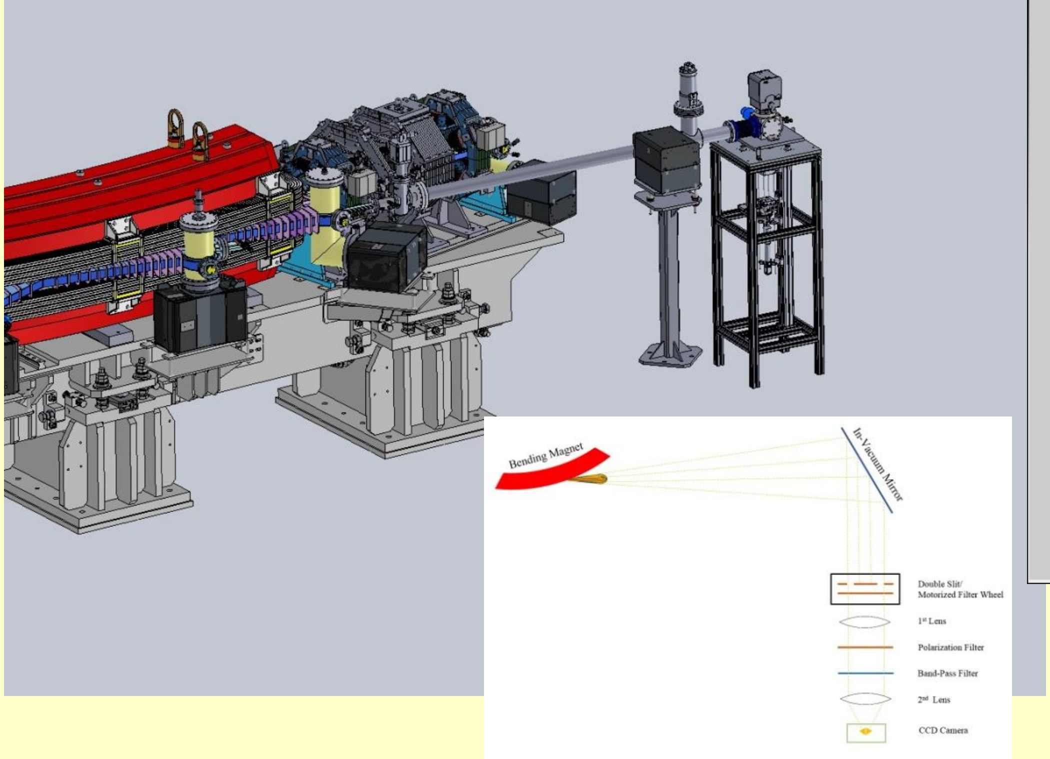


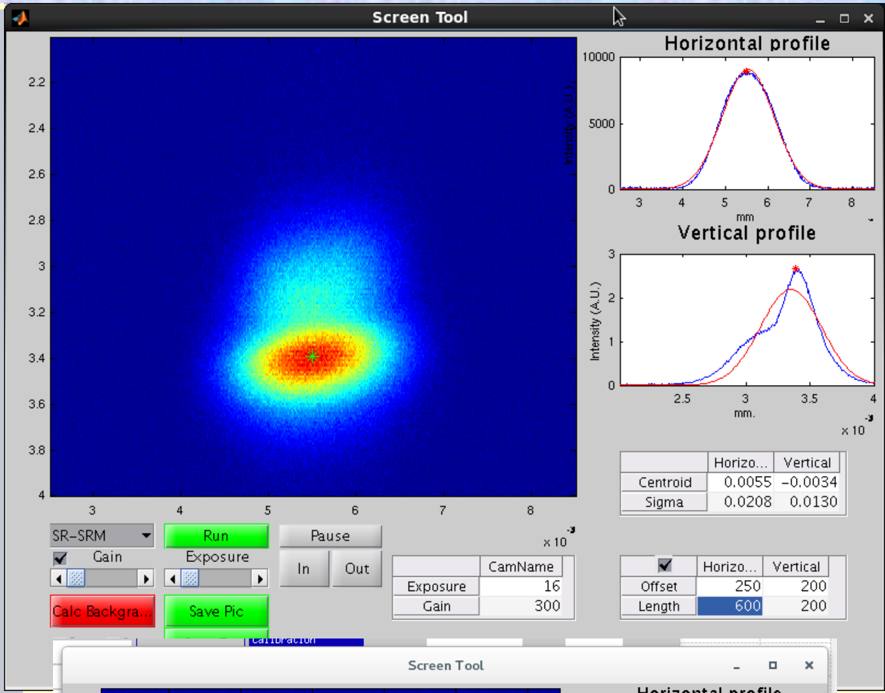
Measured

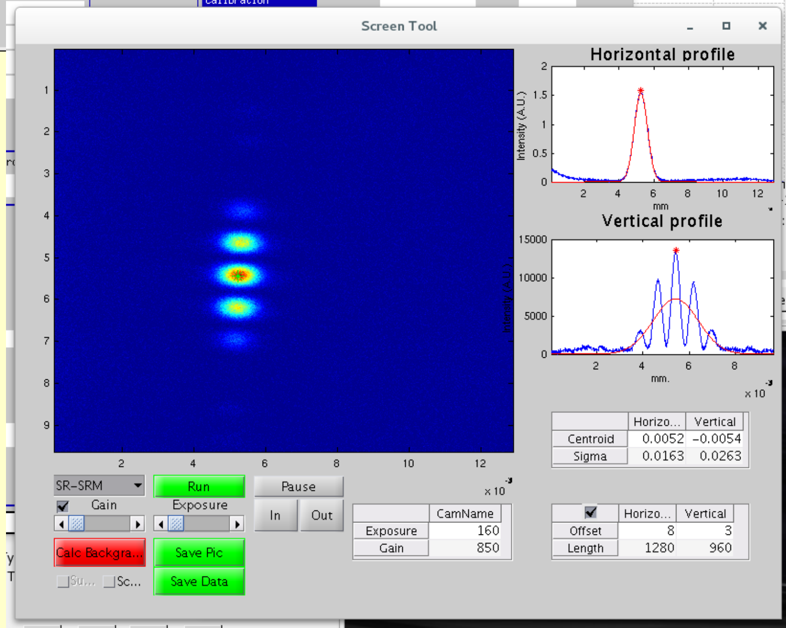


Beam Image from VLD beam line (September, 2017)

Visible Light Diagnostic Beamline



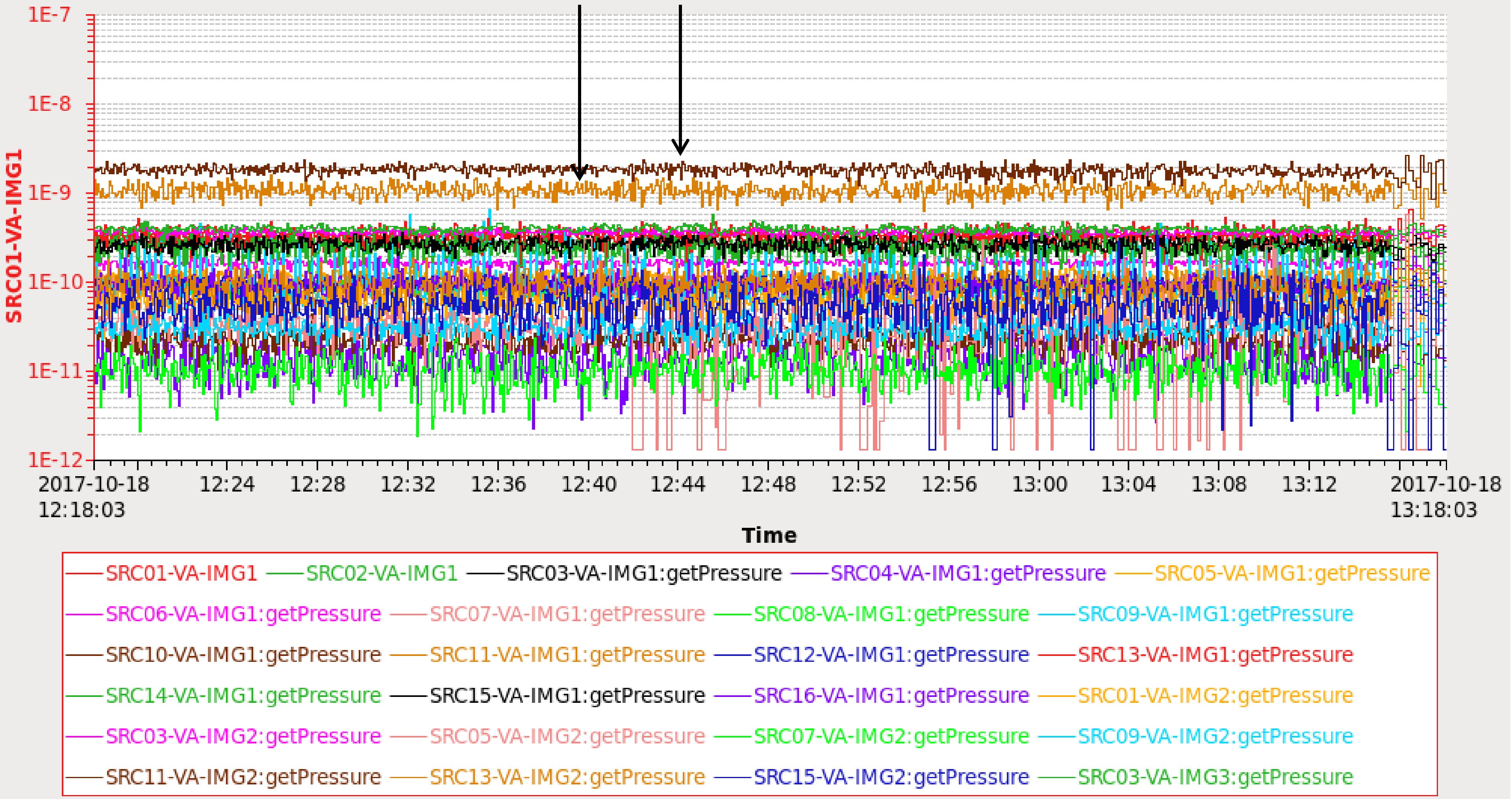




3mm-distant slits are introduced recently for the first time.

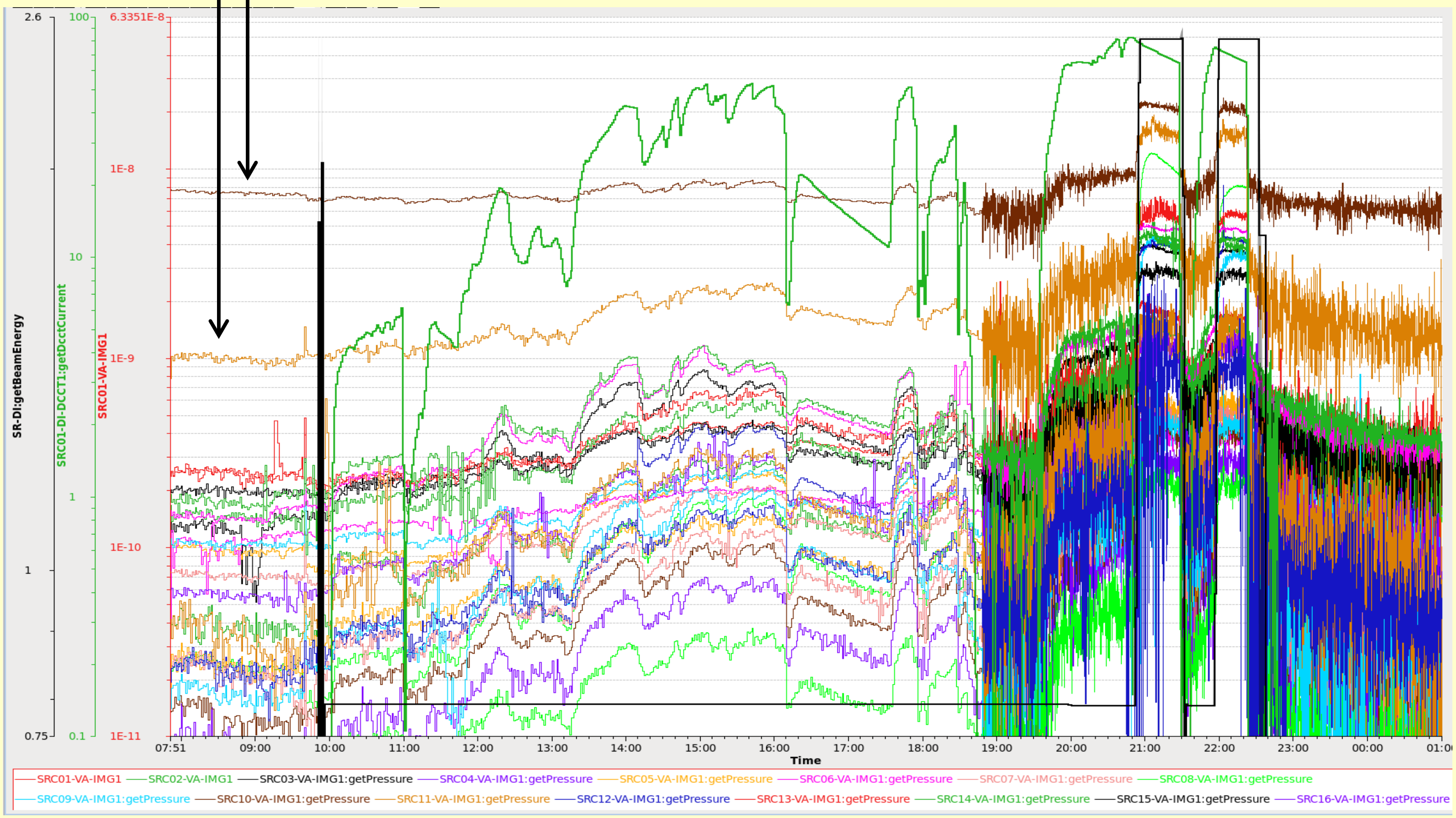
Pressure Profile in the Ring When There is no Beam

- ✓ *Gas pressure in cell 11 is always higher than other locations.*



Pressure Profile and Beam Lifetime

- ✓ The higher *gas pressure in cell 11 is a source of current limitation.*
- ✓ ***Vertical misalignment 1-3 mm found in the crotch absorber.***

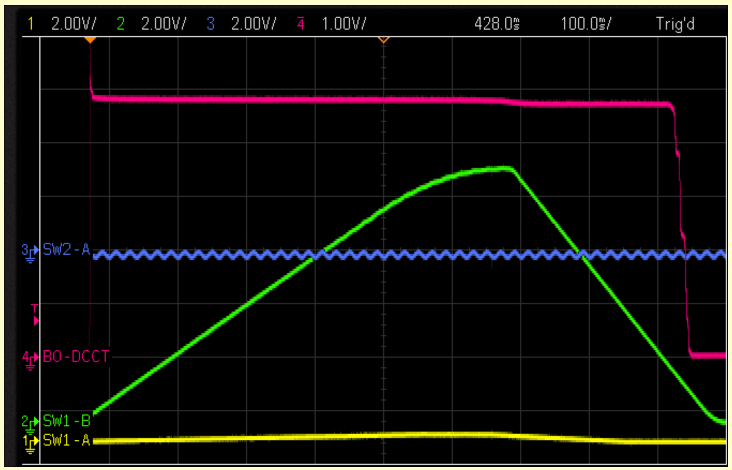


- ✓ *The accumulated current achieved is 26 A.h.*
- ✓ *The beam lifetime @ 70mA, 2.5GeV, 1.8 MV (out of 2.4 MV) = 5 h*

Poor Injection Efficiency

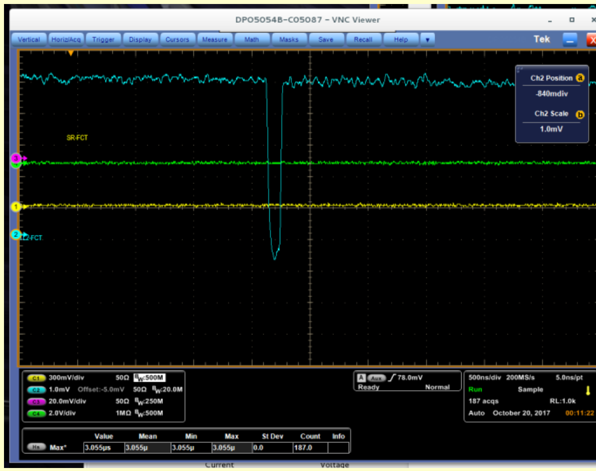
✓ *Maximum injection efficiency obtained≈20%*

Booster current at the extraction ≈9.5 mA



Extraction + transmission efficiency < 30%

FCT of TL2≈2.3 mA

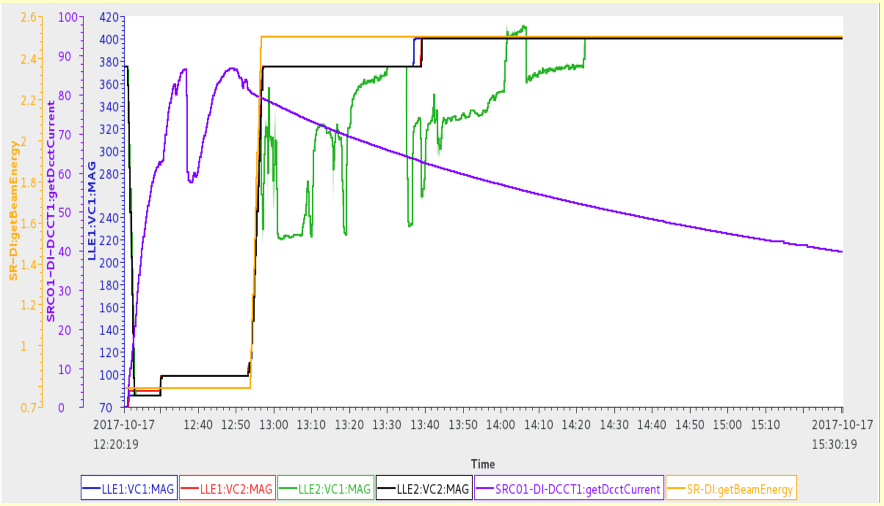


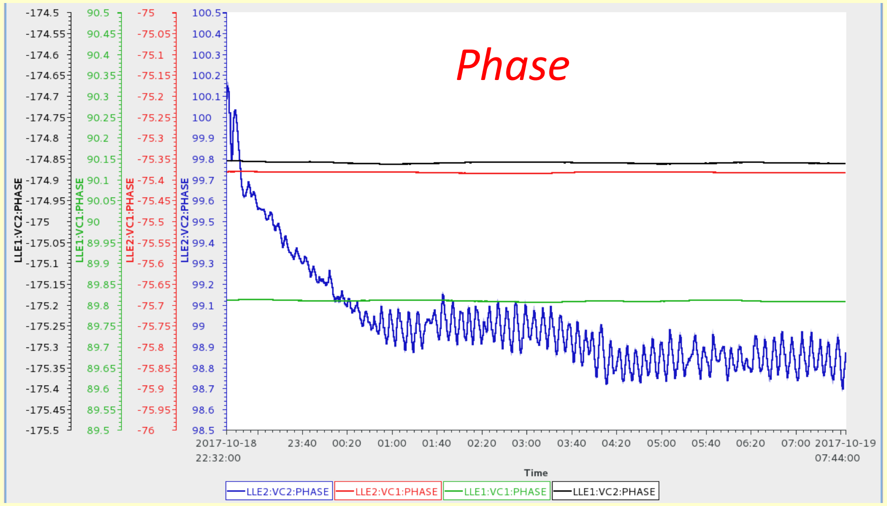
✓ Sources of poor injection efficiency:

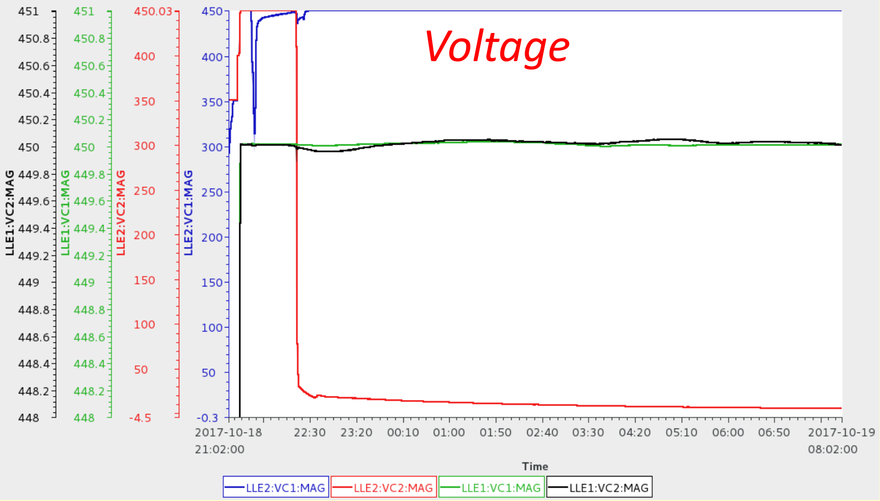
- Shortage in extraction kicker strength ??? (the main source).
- Misalignments in some elements of TL2.
- Some mismatching between TL2 and SR optics ??

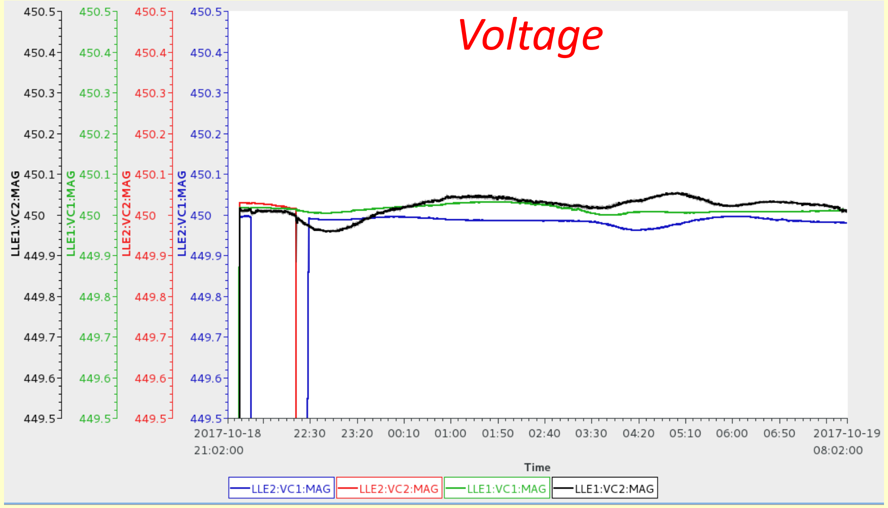
Optimization of RF System is Still Going On

✓ *Sudden disturbance in voltage and phase of some RF cavities ?*



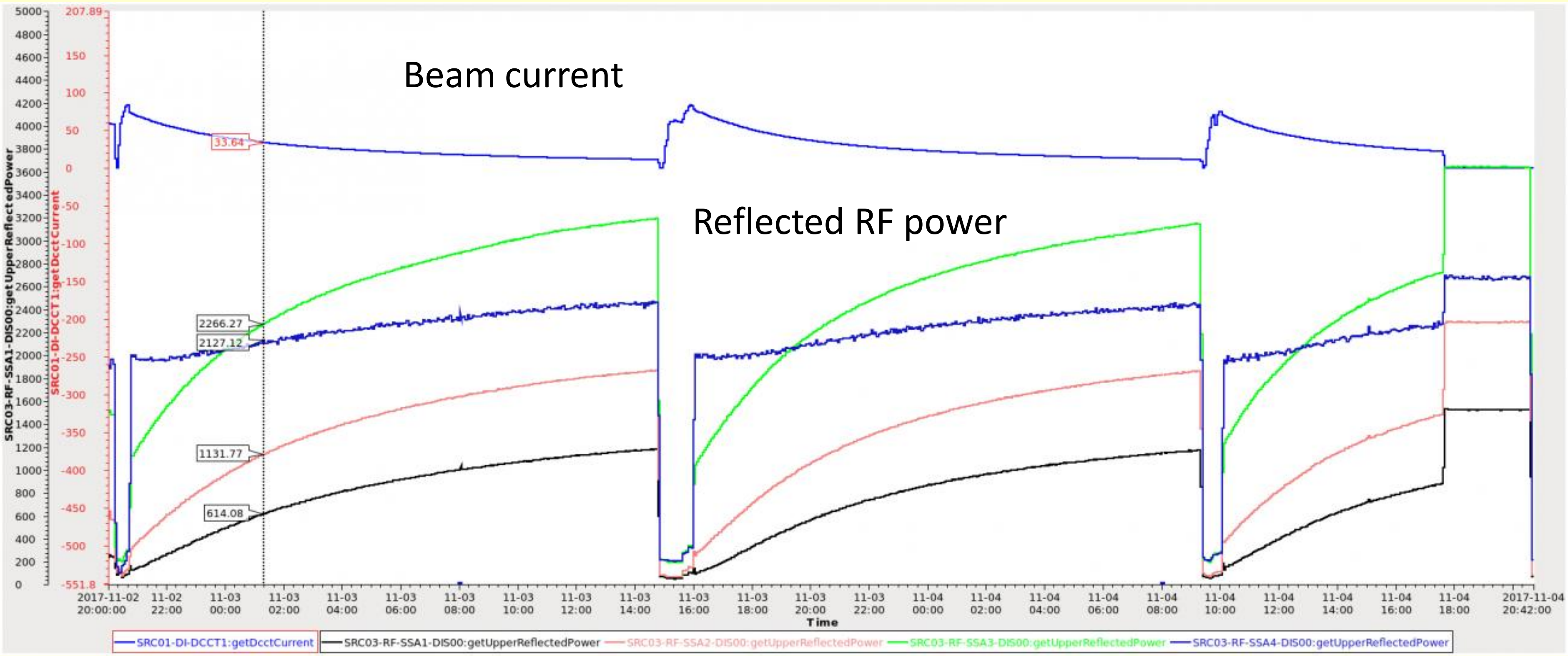






Optimization of RF System is Going On

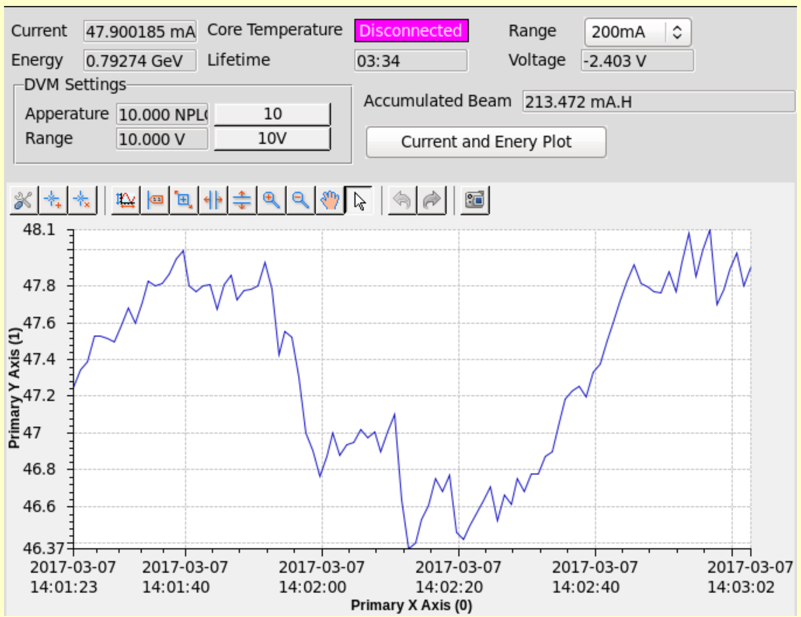
✓ *It shows a better performance now, nevertheless more calibration is still needed.*



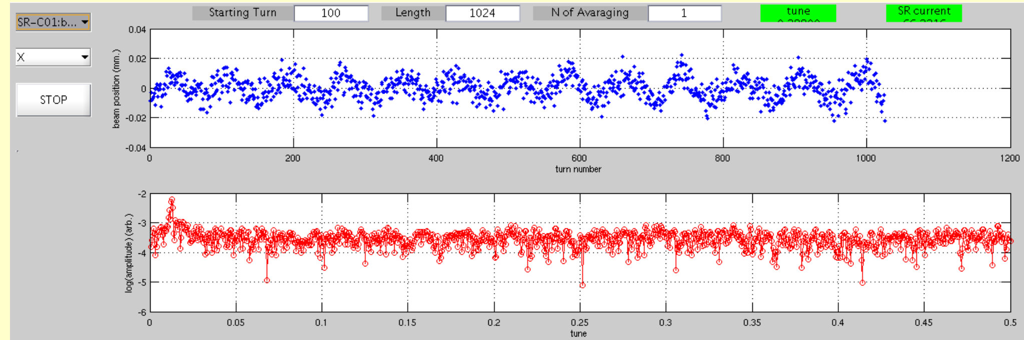
Beam Longitudinal Instability at Injection & Top Energies

- ✓ *Longitudinal HOMs in RF cavities (which are still under calibration).*

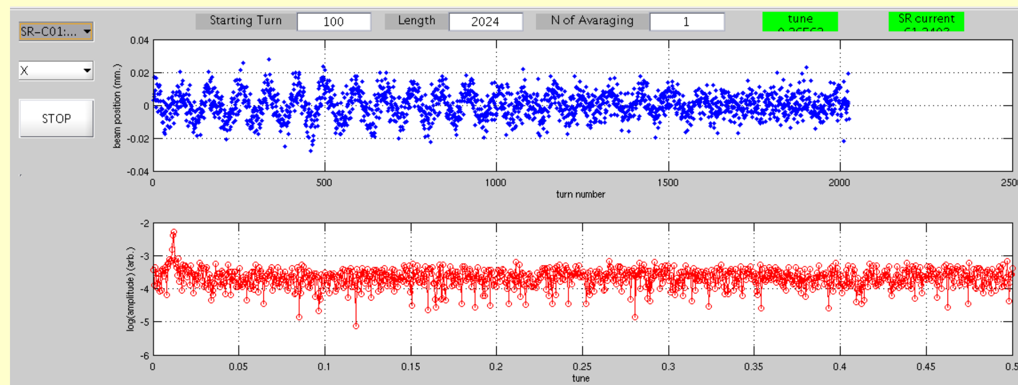
Current saturation during injection



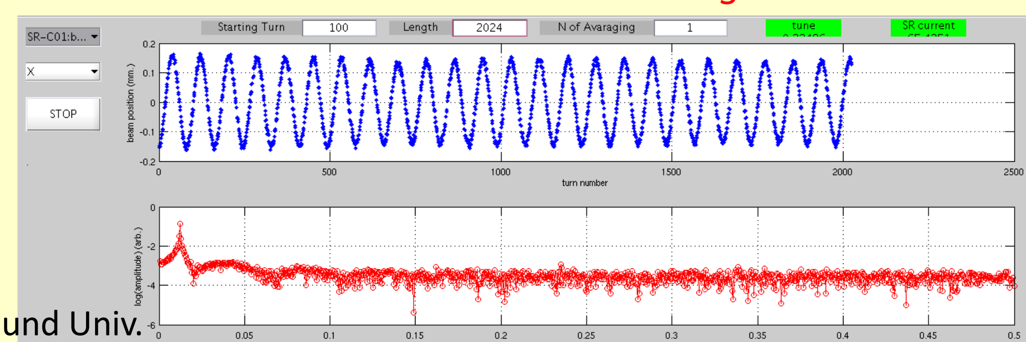
The residual case at top energy



More disturbance is seen from time to time.



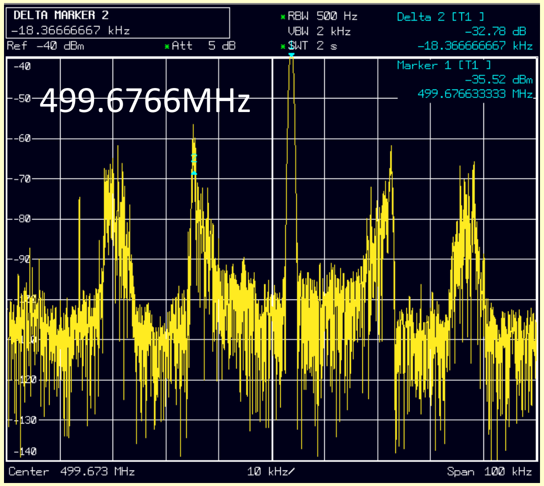
When disturbance become so strong sometimes.

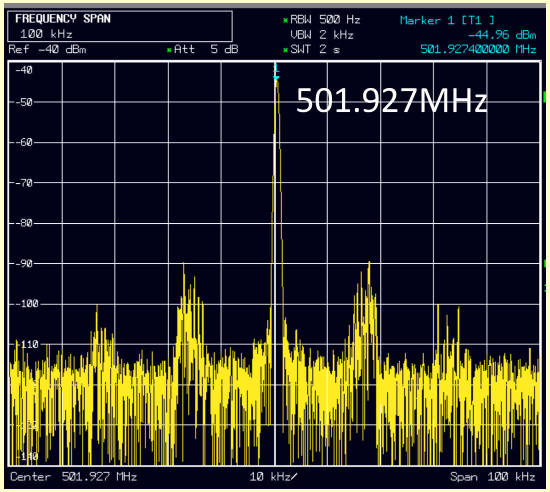


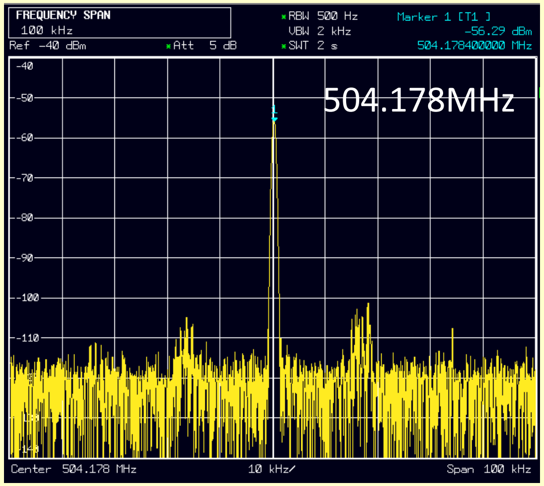
- ✓ *Cavities safe temperature windows need to be defined experimentally.*

Beam Longitudinal Instability at Injection & Top Energies

- *Beam spectrum was preliminar measured @ 800 MeV, RF = 499.6766MHz by connecting the spectrum analyzer to one button from the BPM.*







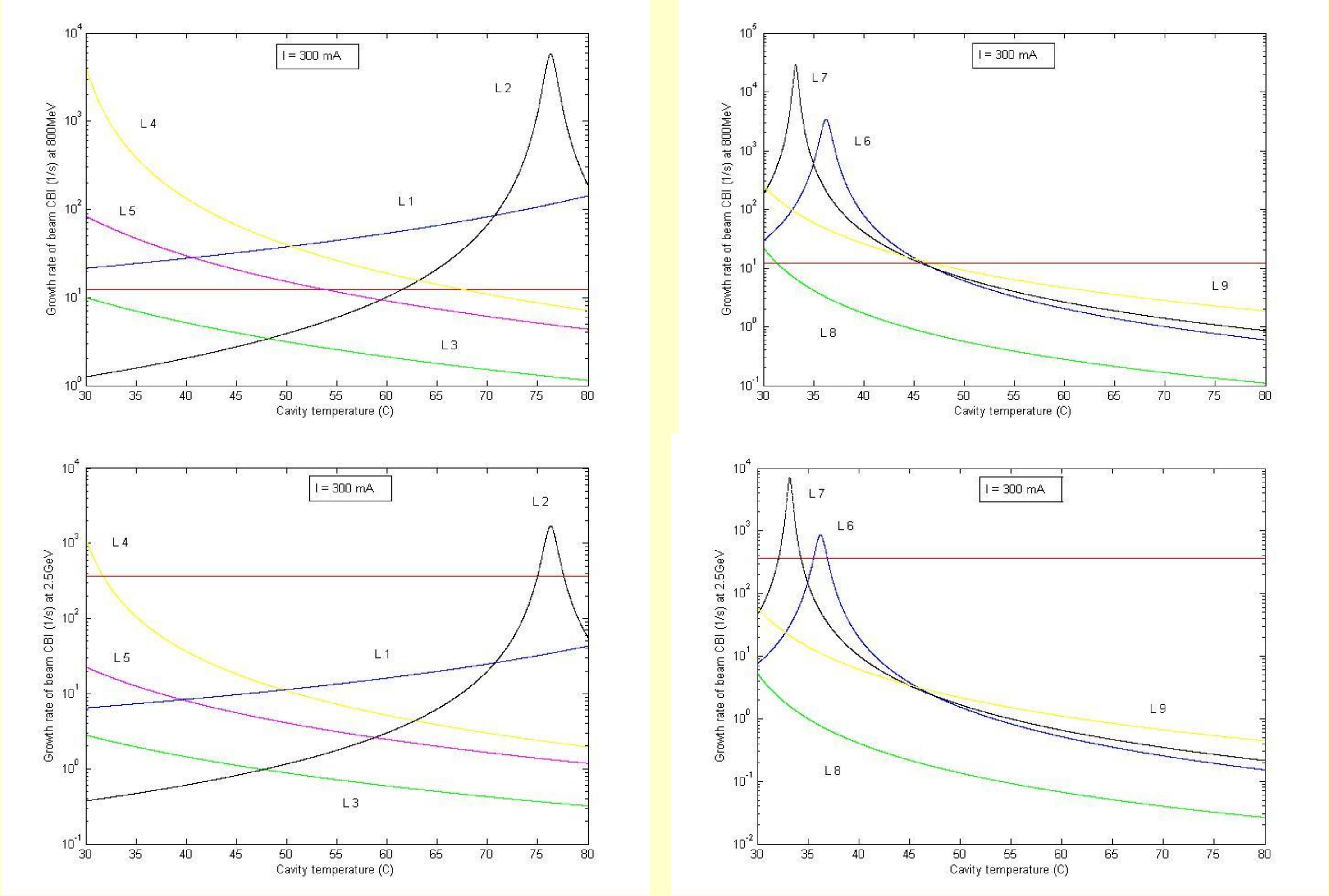
- *L4 HOM seems the main player but more detailed measurements are still needed.*

HOM	f_{HOM} (MHz)	CBM_{pn}	f_{CPMpn} (MHz)	$\Delta f_{HOM-CBM}$ (MHz)	HOM impact	CT (^{o}C)
L1	946.338	1, 198	945.323	1.015	**15689**	111.59
L2	1056.588	2, 25	1055.607	0.981	280	76.3
L3	1419.268	2, 187	1420.220	-0.952	**1230**	4.42
L4	1510.323	3, 5	1510.247	0.076	**650**	28.01
L5	1604.300	3, 47	1604.777	-0.477	**1300**	15.22
L6	1875.231	3, 167	1874.86	0.371	30	36.23
L7	1944.983	3, 198	1944.631	0.352	180	33.21
L8	2075.048	4, 34	2075.172	-0.124	2.7	26.30
L9	2117.687	4, 53	2117.935	-0.248	180	25.28

Cavity HOM-Free Temperature Windows

- CBM$_{pn}$ frequency $f_{pn} = (pN + n + mQ_s)\, f_0$, with N = 222 bunch, f_0 = 2.250694 MHz.

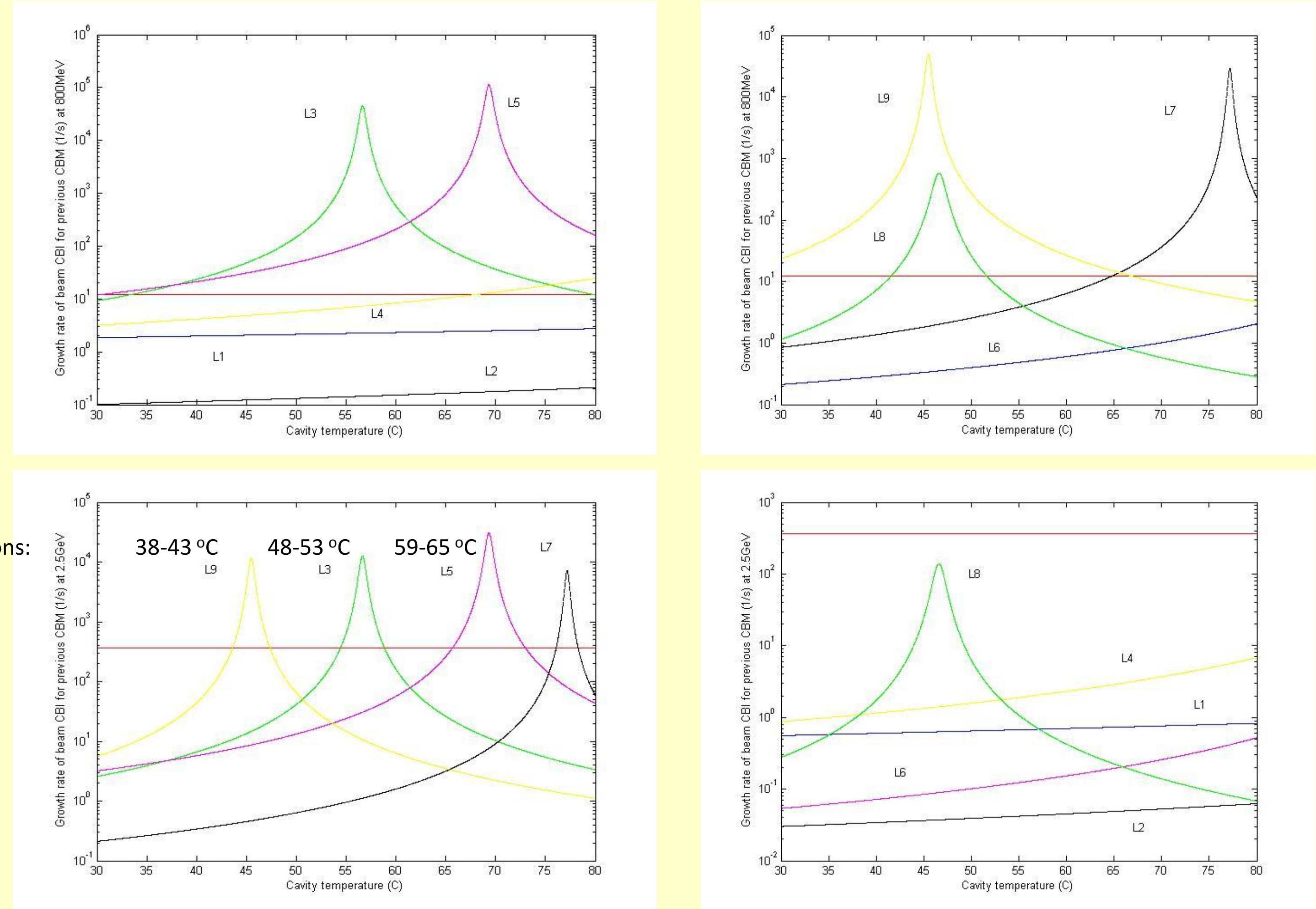
CBI growth rate @ 800MeV (top) and 2.5GeV (bottom) due to HOM-CBM$_{p,\,n}$ coupling



Cavity Temperature Windows

CBI growth rate @ 800MeV (top) and 2.5GeV (bottom) due to HOM-CBM$_{p,\ n-1}$ coupling

Safe operation regions:



HOMFS to be used at 800MeV to move out the most harmful HOM L1

Thank you