XFEL Operator Training
Start-Up Procedure

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MXL

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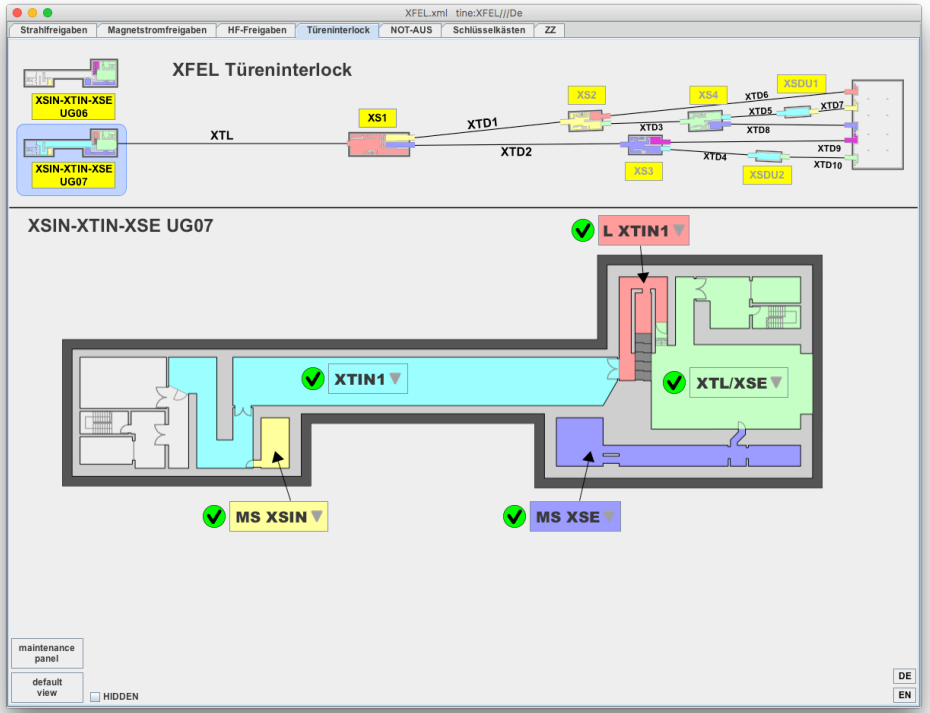
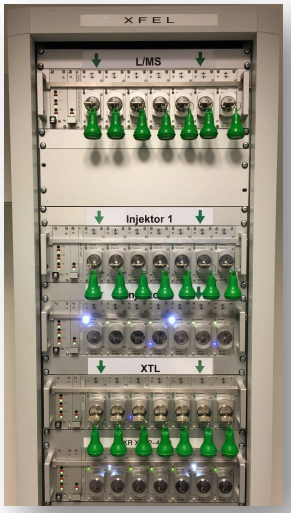
What is the aim of this operator training?

- You will learn how to restart the XFEL after maintenance day and how to ensure safely machine operation.
- That includes:
  - What is necessary for tunnel search
  - Granting magnet current and beam permission
  - Using the sequencer
  - Ensuring proper magnet and RF settings
  - Ensuring proper beam parameters
  - Trouble shooting
  - …

Tunnel search

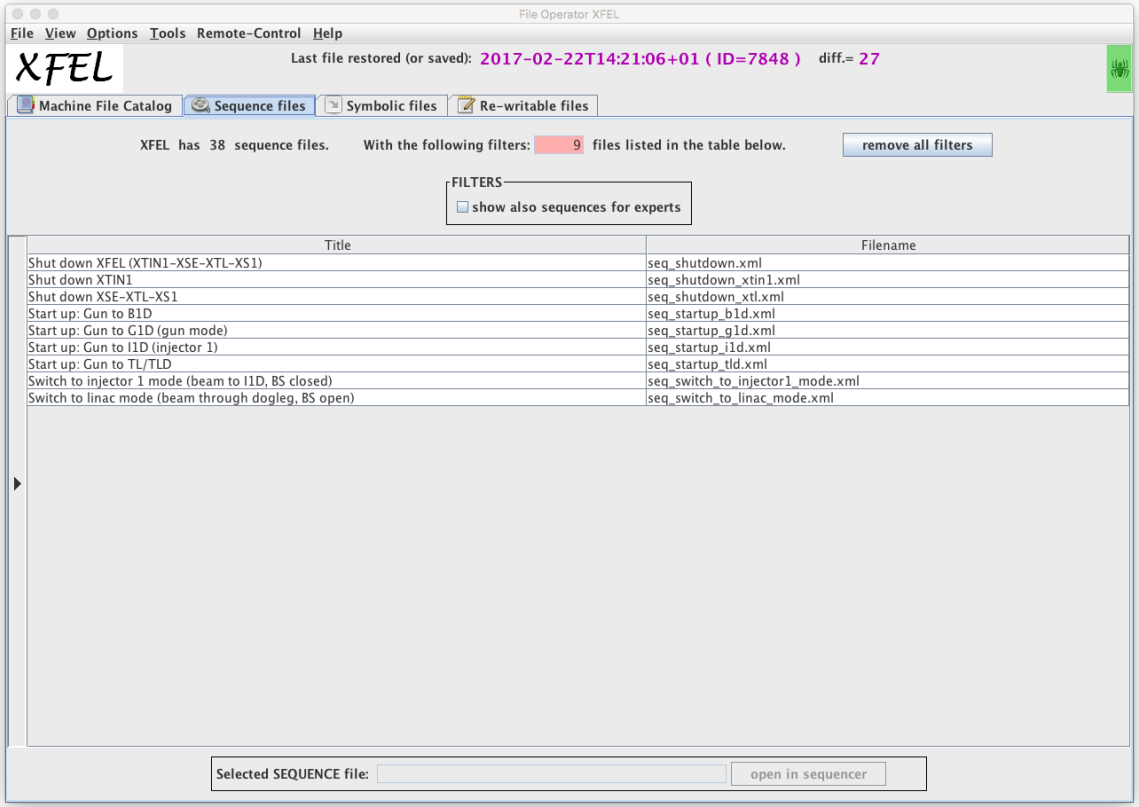
- So far, we have in total 7 interlock areas that have to be set for beam operation in the XTL:
  - Injector 1
  - Labyrinths 1 and 2
  - XTL/XSE and XTL/XS1
  - MS ZSIN and MS XSE
- Each of these areas has to be searched by two trained operators. A third operator can participate as trainee.
- You need the following for tunnel search:
  - Safety shoes
  - Helmet
  - Flashlight
  - Oxy-Box
  - Tunnel search instruction
  - Interlock key from BKR.





BKR interlock keys for labyrinths and media shafts (L/MS), Injector 1 and XTL

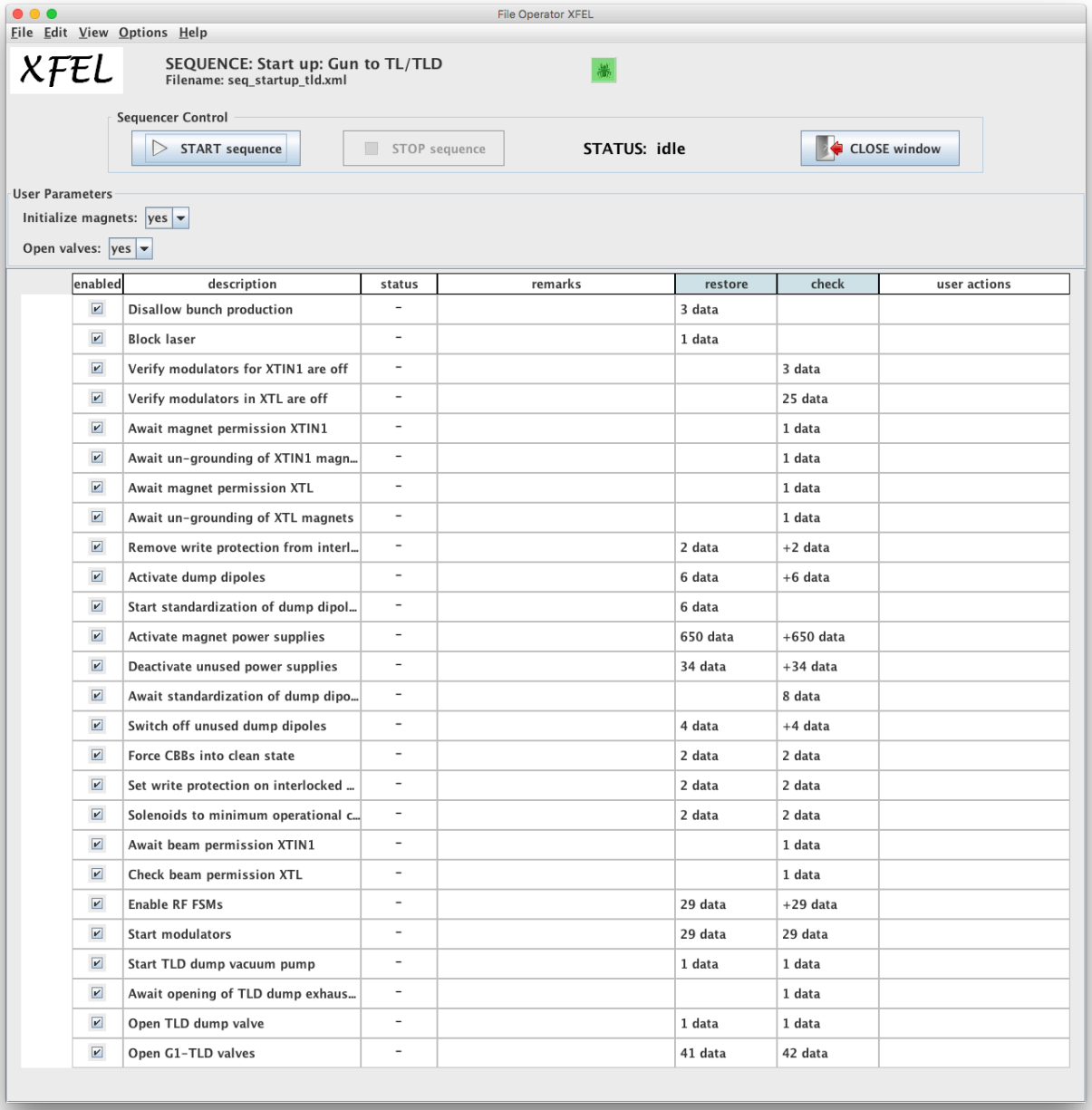
Sequencer files



- Open the sequencer (Main Taskbar, Operations Procedures, Sequencer)
- Select the start-up sequence suitable for the planed machine operation.
  For example ‘Start up: Gun to TL/TLD’.
- Press the ‘open sequence’-button appearing on the bottom right of the panel.

Start-up sequence

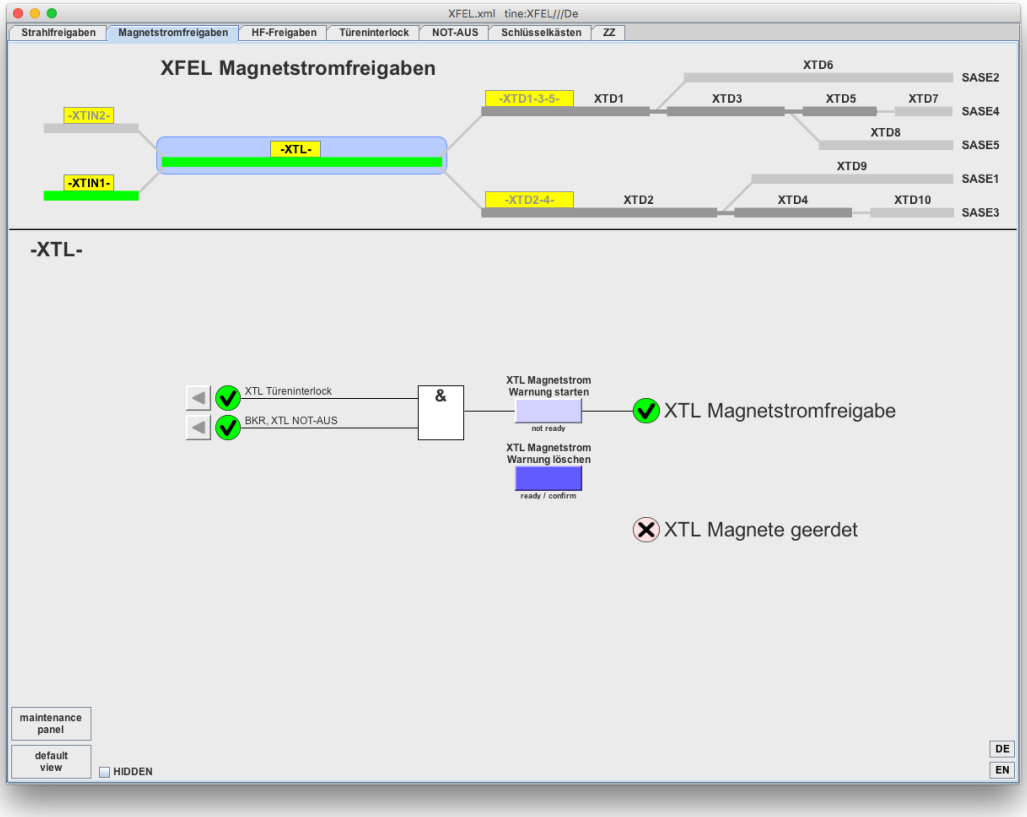
- Start the sequence
- It will take care of all steps necessary to get beam in the XTL.
- The sequence will stop at the following lines:
  - Await magnet permission
  - Await un-grounding
  - Await beam permission
- Magnet and beam permission have to be granted at the interlock console.
- Un-grounding of the magnets has to be done by MKK shift crew.



enabled	description	status	remarks	restore	check	user actions
☑	Disallow bunch production	-		3 data		
☑	Block laser	-		1 data		
☑	Verify modulators for XTIN1 are off	-			3 data	
☑	Verify modulators in XTL are off	-			25 data	
☑	Await magnet permission XTIN1	-			1 data	
☑	Await un-grounding of XTIN1 magn...	-			1 data	
☑	Await magnet permission XTL	-			1 data	
☑	Await un-grounding of XTL magnets	-			1 data	
☑	Remove write protection from interl...	-		2 data	+2 data	
☑	Activate dump dipoles	-		6 data	+6 data	
☑	Start standardization of dump dipol...	-		6 data		
☑	Activate magnet power supplies	-		650 data	+650 data	
☑	Deactivate unused power supplies	-		34 data	+34 data	
☑	Await standardization of dump dipo...	-			8 data	
☑	Switch off unused dump dipoles	-		4 data	+4 data	
☑	Force CBBs into clean state	-		2 data	2 data	
☑	Set write protection on interlocked ...	-		2 data	2 data	
☑	Solenoids to minimum operational c...	-		2 data	2 data	
☑	Await beam permission XTIN1	-			1 data	
☑	Check beam permission XTL	-			1 data	
☑	Enable RF FSMs	-		29 data	+29 data	
☑	Start modulators	-		29 data	29 data	
☑	Start TLD dump vacuum pump	-		1 data	1 data	
☑	Await opening of TLD dump exhaus...	-			1 data	
☑	Open TLD dump valve	-		1 data	1 data	
☑	Open G1-TLD valves	-		41 data	42 data	

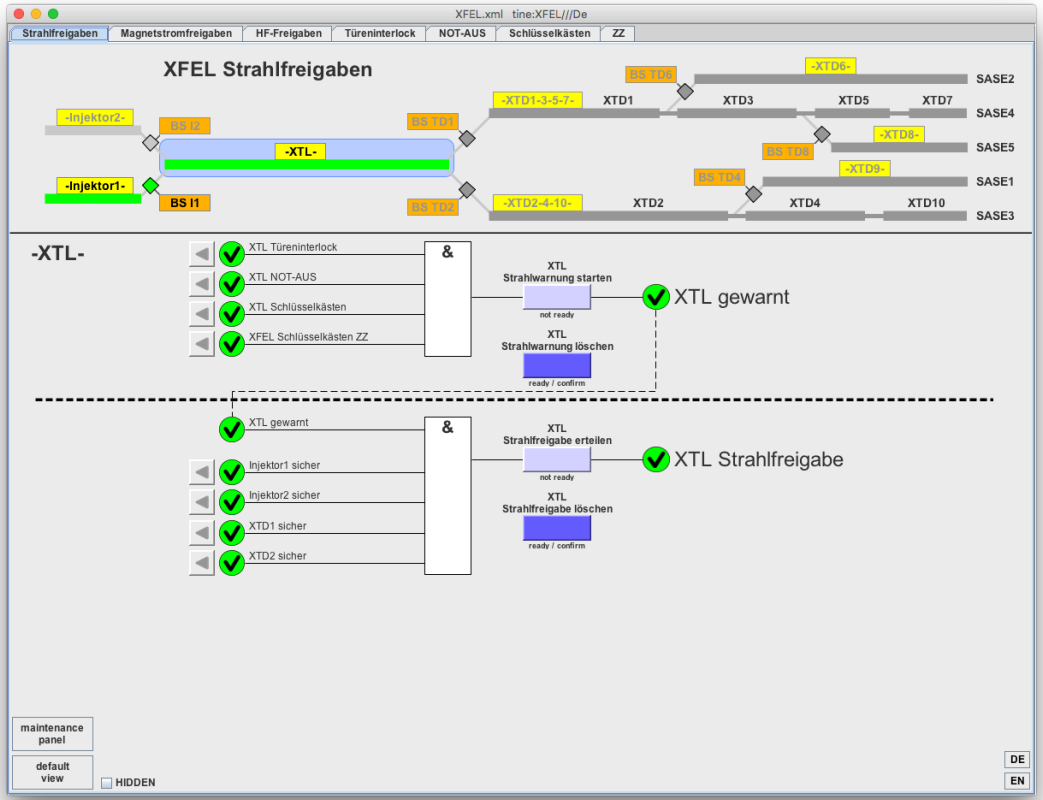
Magnet current permission

If you are interested in the magnet current permission status in the single areas, open the following panel: Main Taskbar, Operations and Procedures, Personnel Interlock, Magnetstromfreigaben



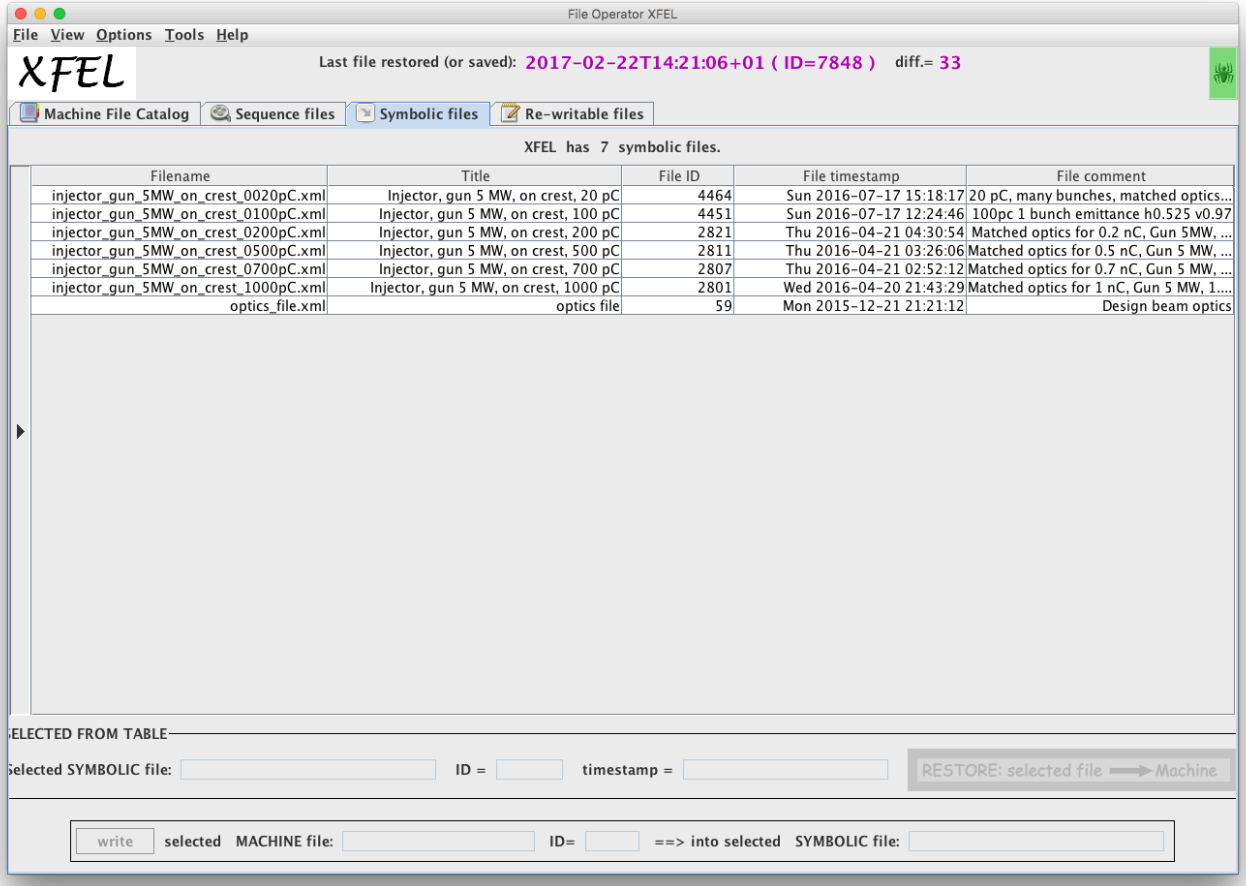
Beam permission

If you are interested in the beam permission status in the single areas, open the following panel: Main Taskbar, Operations and Procedures, Personnel Interlock, Strahlfreigaben



Symbolic files in the sequencer

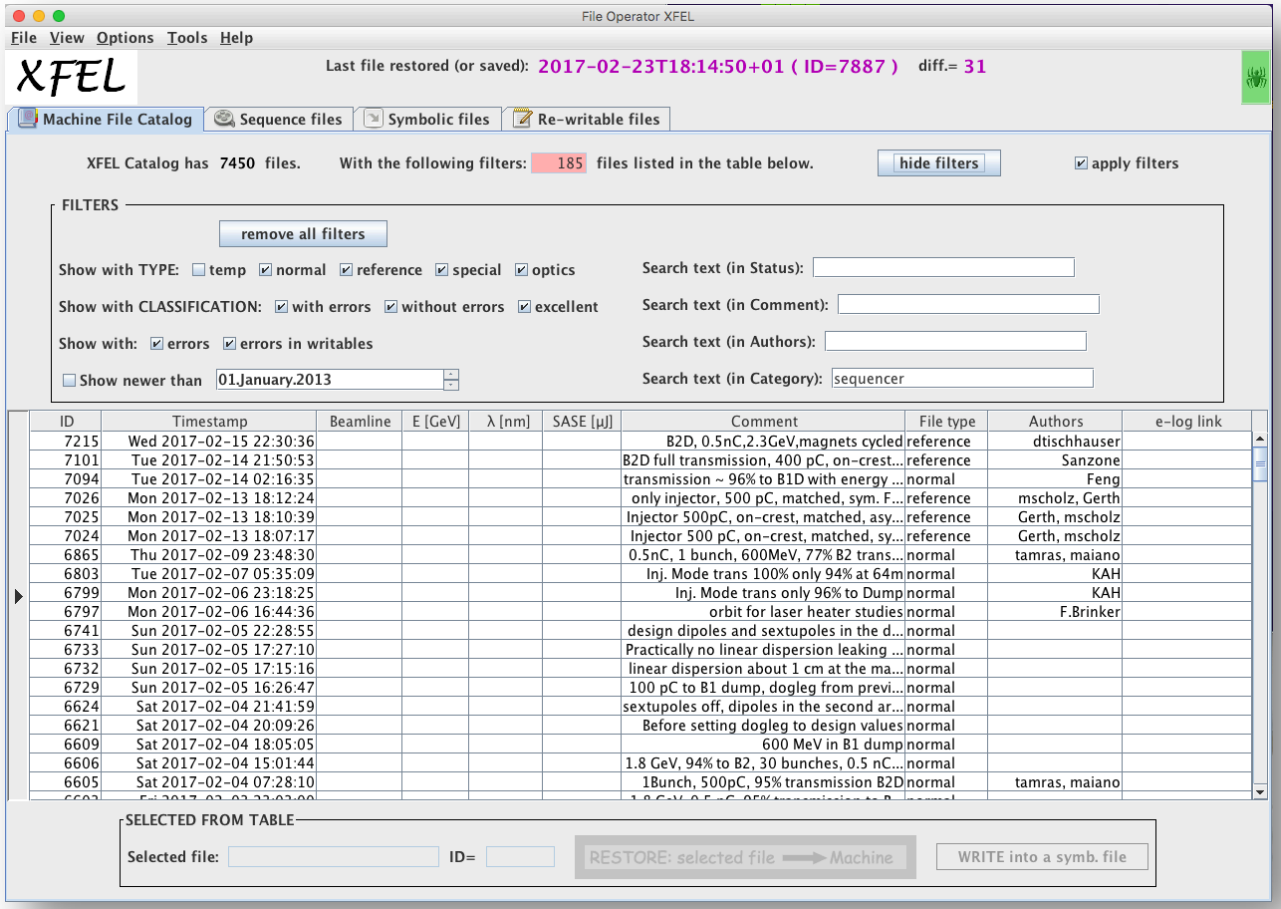
- The sequence run before can not (yet) load a file including magnets strengths, RF settings as well as diagnostics parameters.
- This has to be done in the next step.



- Select a symbolic file according to the machine setup plans. Restore the file using the button on the bottom right of the panel.
- Typically the run coordinator will tell you which file to use.
- There will be additional symbolic files soon.

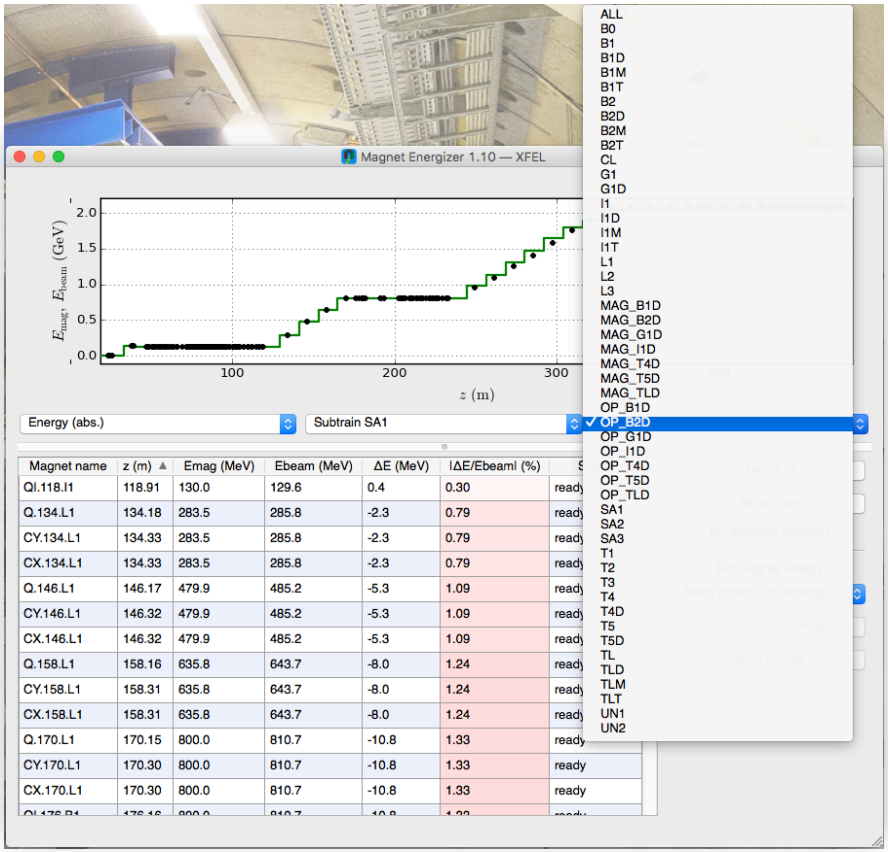
File catalog

- In case there is no symbolic file matching the machine operation requirements, load one of the files in the file catalog.
- The run coordinator should tell you which one to chose.
- The provided filters may help you to find your file in the catalog.



Magnet energizer

- The sequencer writes kick strengths to the magnets, not currents. The magnet ML server calculates the correct current from the kick strengths and from the momentum setpoint of the magnets.
- The momentum setpoint of the magnets can be easily changed using the magnet energizer.

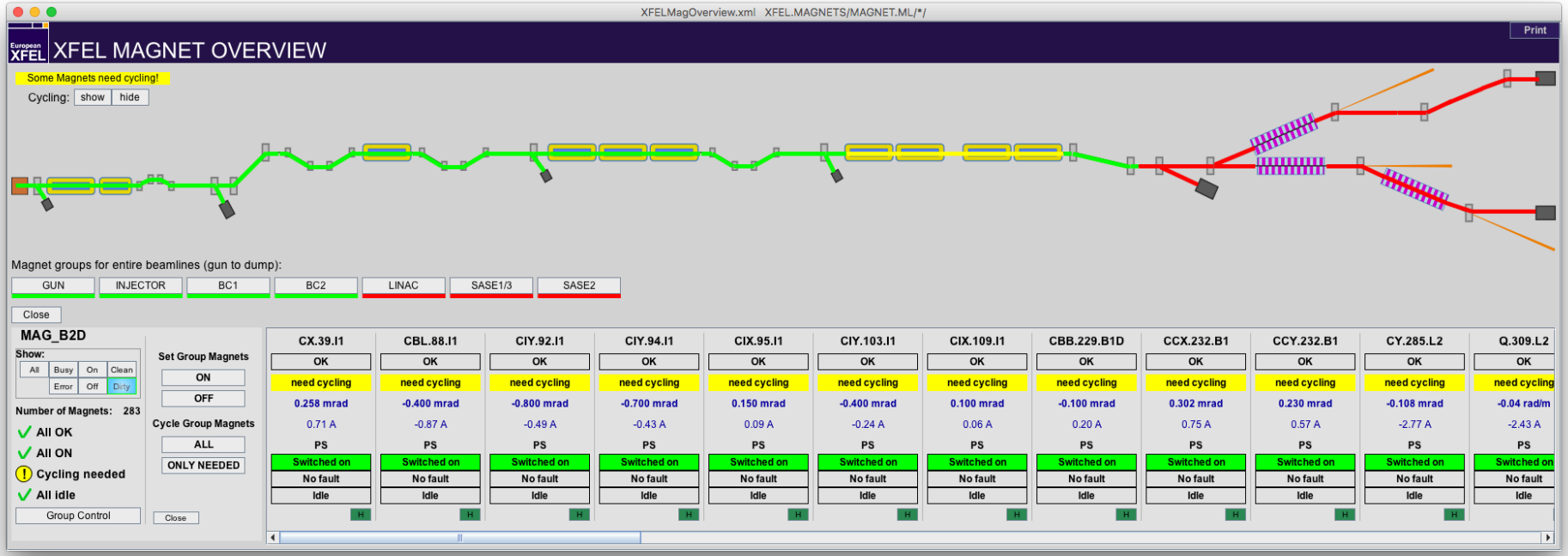


Magnet name	z (m)	Emag (MeV)	Ebeam (MeV)	ΔE (MeV)	|ΔE/Ebeam| (%)	S
QI.118.I1	118.91	130.0	129.6	0.4	0.30	ready
Q.134.L1	134.18	283.5	285.8	-2.3	0.79	ready
CY.134.L1	134.33	283.5	285.8	-2.3	0.79	ready
CX.134.L1	134.33	283.5	285.8	-2.3	0.79	ready
Q.146.L1	146.17	479.9	485.2	-5.3	1.09	ready
CY.146.L1	146.32	479.9	485.2	-5.3	1.09	ready
CX.146.L1	146.32	479.9	485.2	-5.3	1.09	ready
Q.158.L1	158.16	635.8	643.7	-8.0	1.24	ready
CY.158.L1	158.31	635.8	643.7	-8.0	1.24	ready
CX.158.L1	158.31	635.8	643.7	-8.0	1.24	ready
Q.170.L1	170.15	800.0	810.7	-10.8	1.33	ready
CY.170.L1	170.30	800.0	810.7	-10.8	1.33	ready
CX.170.L1	170.30	800.0	810.7	-10.8	1.33	ready

- You can find the energizer here: Main Panel, Magnets, Magnet Energizer
- Select the beamline in the third dropdown menu. The beamlines starting with OP_ include all magnets from the gun to the named dump.
- The momentum setpoints have to be in agreement with the beam energy at each position in the beamline.
- If that is not the case, select ‘keep strength (scaling)’ and press the ‘set to beam energy’ button. This relies (yet) on properly calibrated RF stations.

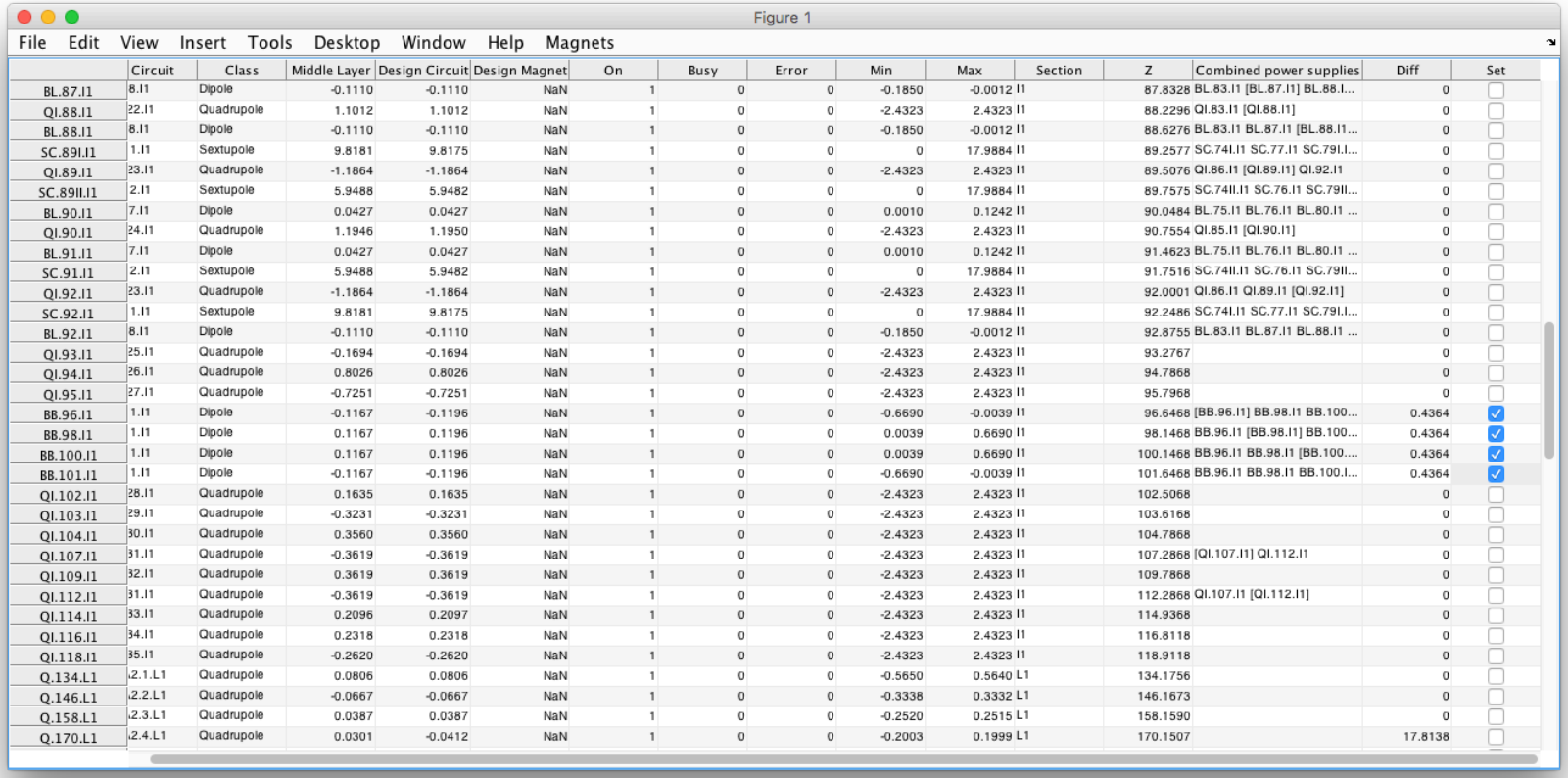
Magnet overview

- Open the magnet overview here: Main Panel, Magnets, Magnet Overview.
- Select the correct beamline and check for magnets that are off or in an error state.
- Filter only the dirty magnets, open group control and cycle only the magnets that need cycling.
- Filter the busy magnets (SP and RBV are different). Refresh the filter by clicking on ‘busy’ from time to time. The number of shown magnets should become less and less.
- Wait until no magnets are busy any more.
- Check one more time for magnets that are off or in an error state.



Design beam optics

- Open the tool here: Main Panel, Beam Dynamics, Design Kick Control
- This is the best tool we have so far to compare the magnets settings in the machine with the design values.
- You can select the magnets with the check boxes and write the design values to the machine. To do that, click on ‘Magnets’ in the menu bar of the window.

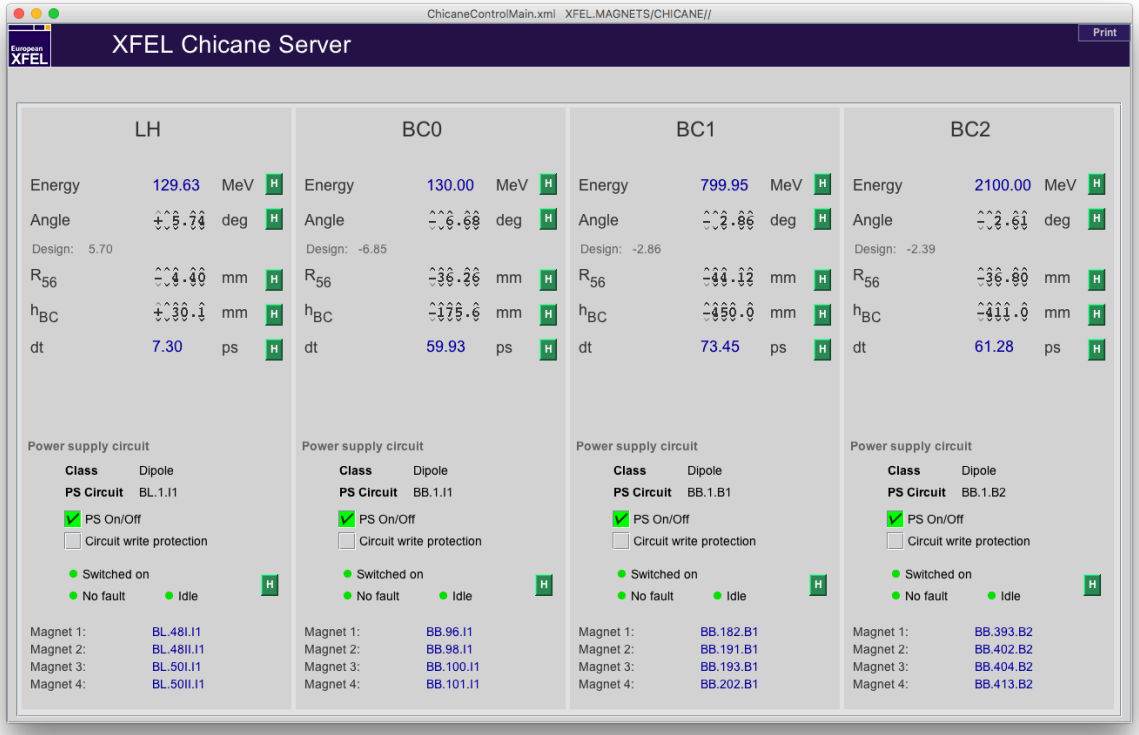


	Circuit	Class	Middle Layer	Design Circuit	Design Magnet	On	Busy	Error	Min	Max	Section	Z	Combined power supplies	Diff	Set
BL.87.I1	8.I1	Dipole	-0.1110	-0.1110	NaN	1	0	0	-0.1850	-0.0012	I1	87.8328	BL.83.I1 [BL.87.I1] BL.88.I...	0	
QI.88.I1	22.I1	Quadrupole	1.1012	1.1012	NaN	1	0	0	-2.4323	2.4323	I1	88.2296	QI.83.I1 [QI.88.I1]	0	
BL.88.I1	8.I1	Dipole	-0.1110	-0.1110	NaN	1	0	0	-0.1850	-0.0012	I1	88.6276	BL.83.I1 BL.87.I1 [BL.88.I1...	0	
SC.89I.I1	1.I1	Sextupole	9.8181	9.8175	NaN	1	0	0	0	17.9884	I1	89.2577	SC.74I.I1 SC.77.I1 SC.79I.I...	0	
QI.89.I1	23.I1	Quadrupole	-1.1864	-1.1864	NaN	1	0	0	-2.4323	2.4323	I1	89.5076	QI.86.I1 [QI.89.I1] QI.92.I1	0	
SC.89II.I1	2.I1	Sextupole	5.9488	5.9482	NaN	1	0	0	0	17.9884	I1	89.7575	SC.74II.I1 SC.76.I1 SC.79II...	0	
BL.90.I1	7.I1	Dipole	0.0427	0.0427	NaN	1	0	0	0.0010	0.1242	I1	90.0484	BL.75.I1 BL.76.I1 BL.80.I1 ...	0	
QI.90.I1	24.I1	Quadrupole	1.1946	1.1950	NaN	1	0	0	-2.4323	2.4323	I1	90.7554	QI.85.I1 [QI.90.I1]	0	
BL.91.I1	7.I1	Dipole	0.0427	0.0427	NaN	1	0	0	0.0010	0.1242	I1	91.4623	BL.75.I1 BL.76.I1 BL.80.I1 ...	0	
SC.91.I1	2.I1	Sextupole	5.9488	5.9482	NaN	1	0	0	0	17.9884	I1	91.7516	SC.74II.I1 SC.76.I1 SC.79II...	0	
QI.92.I1	23.I1	Quadrupole	-1.1864	-1.1864	NaN	1	0	0	-2.4323	2.4323	I1	92.0001	QI.86.I1 QI.89.I1 [QI.92.I1]	0	
SC.92.I1	1.I1	Sextupole	9.8181	9.8175	NaN	1	0	0	0	17.9884	I1	92.2486	SC.74I.I1 SC.77.I1 SC.79I.I...	0	
BL.92.I1	8.I1	Dipole	-0.1110	-0.1110	NaN	1	0	0	-0.1850	-0.0012	I1	92.8755	BL.83.I1 BL.87.I1 BL.88.I1 ...	0	
QI.93.I1	25.I1	Quadrupole	-0.1694	-0.1694	NaN	1	0	0	-2.4323	2.4323	I1	93.2767		0	
QI.94.I1	26.I1	Quadrupole	0.8026	0.8026	NaN	1	0	0	-2.4323	2.4323	I1	94.7868		0	
QI.95.I1	27.I1	Quadrupole	-0.7251	-0.7251	NaN	1	0	0	-2.4323	2.4323	I1	95.7968		0	
BB.96.I1	1.I1	Dipole	-0.1167	-0.1196	NaN	1	0	0	-0.6690	-0.0039	I1	96.6468	[BB.96.I1] BB.98.I1 BB.100...	0.4364	☑
BB.98.I1	1.I1	Dipole	0.1167	0.1196	NaN	1	0	0	0.0039	0.6690	I1	98.1468	BB.96.I1 [BB.98.I1] BB.100...	0.4364	☑
BB.100.I1	1.I1	Dipole	0.1167	0.1196	NaN	1	0	0	0.0039	0.6690	I1	100.1468	BB.96.I1 BB.98.I1 [BB.100....	0.4364	☑
BB.101.I1	1.I1	Dipole	-0.1167	-0.1196	NaN	1	0	0	-0.6690	-0.0039	I1	101.6468	BB.96.I1 BB.98.I1 BB.100.I...	0.4364	☑
QI.102.I1	28.I1	Quadrupole	0.1635	0.1635	NaN	1	0	0	-2.4323	2.4323	I1	102.5068		0	
QI.103.I1	29.I1	Quadrupole	-0.3231	-0.3231	NaN	1	0	0	-2.4323	2.4323	I1	103.6168		0	
QI.104.I1	30.I1	Quadrupole	0.3560	0.3560	NaN	1	0	0	-2.4323	2.4323	I1	104.7868		0	
QI.107.I1	31.I1	Quadrupole	-0.3619	-0.3619	NaN	1	0	0	-2.4323	2.4323	I1	107.2868	[QI.107.I1] QI.112.I1	0	
QI.109.I1	32.I1	Quadrupole	0.3619	0.3619	NaN	1	0	0	-2.4323	2.4323	I1	109.7868		0	
QI.112.I1	31.I1	Quadrupole	-0.3619	-0.3619	NaN	1	0	0	-2.4323	2.4323	I1	112.2868	QI.107.I1 [QI.112.I1]	0	
QI.114.I1	33.I1	Quadrupole	0.2096	0.2097	NaN	1	0	0	-2.4323	2.4323	I1	114.9368		0	
QI.116.I1	34.I1	Quadrupole	0.2318	0.2318	NaN	1	0	0	-2.4323	2.4323	I1	116.8118		0	
QI.118.I1	35.I1	Quadrupole	-0.2620	-0.2620	NaN	1	0	0	-2.4323	2.4323	I1	118.9118		0	
Q.134.L1	2.1.L1	Quadrupole	0.0806	0.0806	NaN	1	0	0	-0.5650	0.5640	L1	134.1756		0	
Q.146.L1	2.2.L1	Quadrupole	-0.0667	-0.0667	NaN	1	0	0	-0.3338	0.3332	L1	146.1673		0	
Q.158.L1	2.3.L1	Quadrupole	0.0387	0.0387	NaN	1	0	0	-0.2520	0.2515	L1	158.1590		0	
Q.170.L1	2.4.L1	Quadrupole	0.0301	-0.0412	NaN	1	0	0	-0.2003	0.1999	L1	170.1507		17.8138	

Chicane server

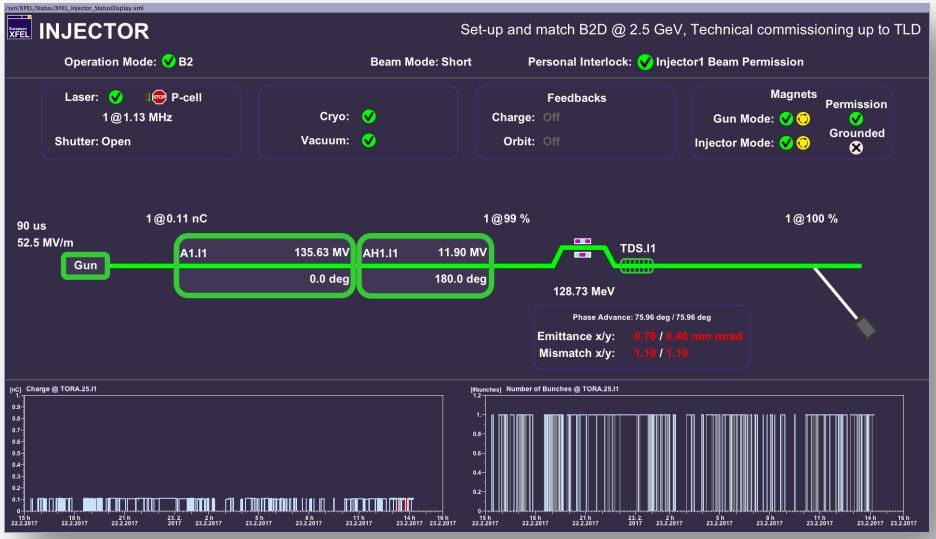
- Open the tool here: Main Panel, Magnets, Chicane Server

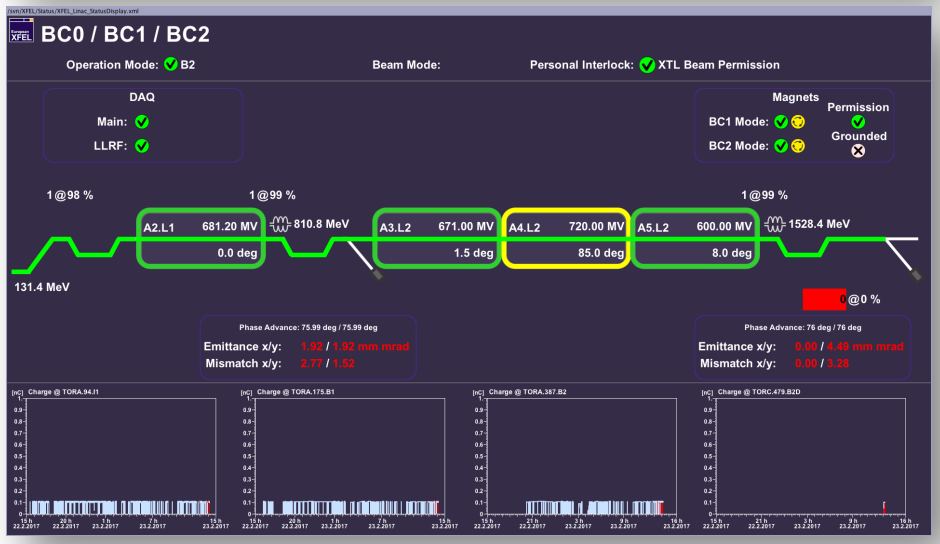
- This tool should be used to change the dipoles of the bunch compressor chicanes.
- You can either set the
  - deflection angle
  - the R56 transfer matrix element
  - or the beam offset in the chicane.
- The dipole currents are calculated by the magnet ML server.



Overview panels

- Any error messages from FSMs shown?
- Is the laser blocked by the MPS?
- Cryo and Vacuum ok?
- Are the slow feedbacks on/off?
- Is the DAQ ok?
- What is the status of the magnets?
- …



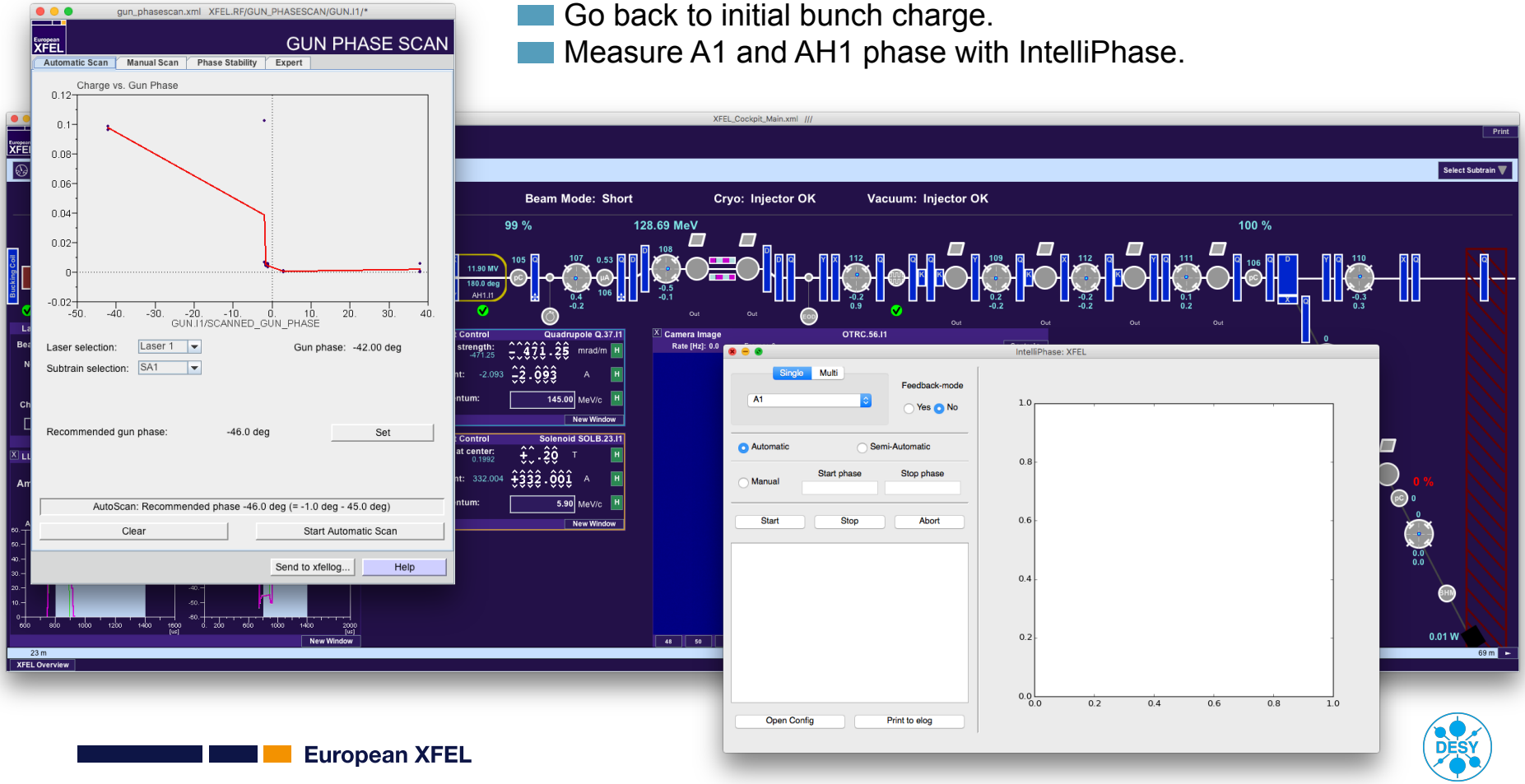


Cockpit panel

- This panel contains all important functionalities that you need to operate the machine!
- Information that is not present on the panel itself it typically linked. Either on the panel at good visible positions or in the drop down menu on the top left.
- This panel is professionally maintained.

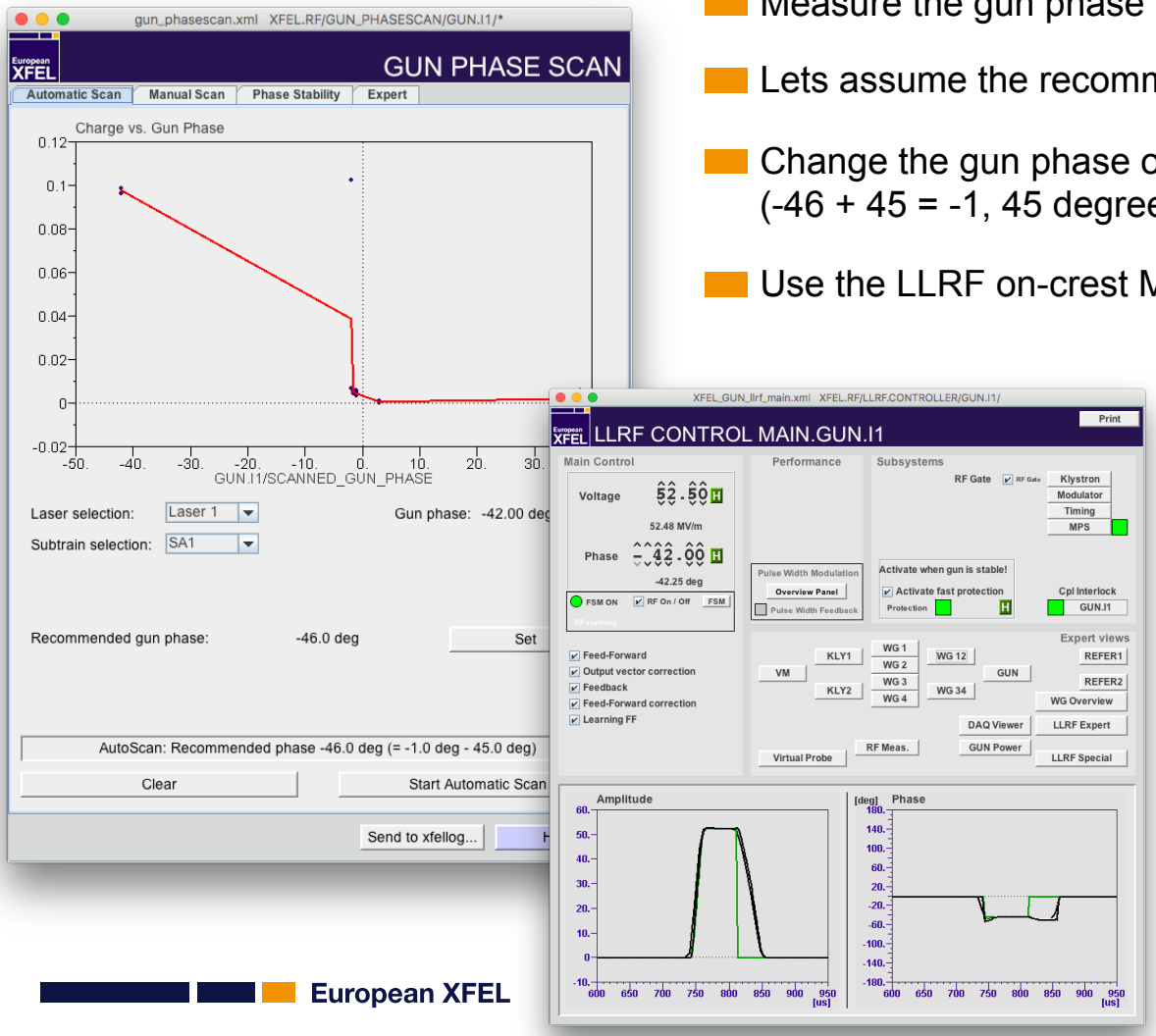
Cockpit panel, injector view

- RF phase measurements
  - Reduce the charge to 100 pC using the charge feedback.
  - Open the gun phase scan tool, which you can find on the main panel after pressing the ‘Injector’ tab.
  - Scan the gun phase.
  - More about the gun phase on the next slide.
  - Go back to initial bunch charge.
  - Measure A1 and AH1 phase with IntelliPhase.



Set gun phase

This is a temporary solution. Some steps will not be necessary any more in the future.

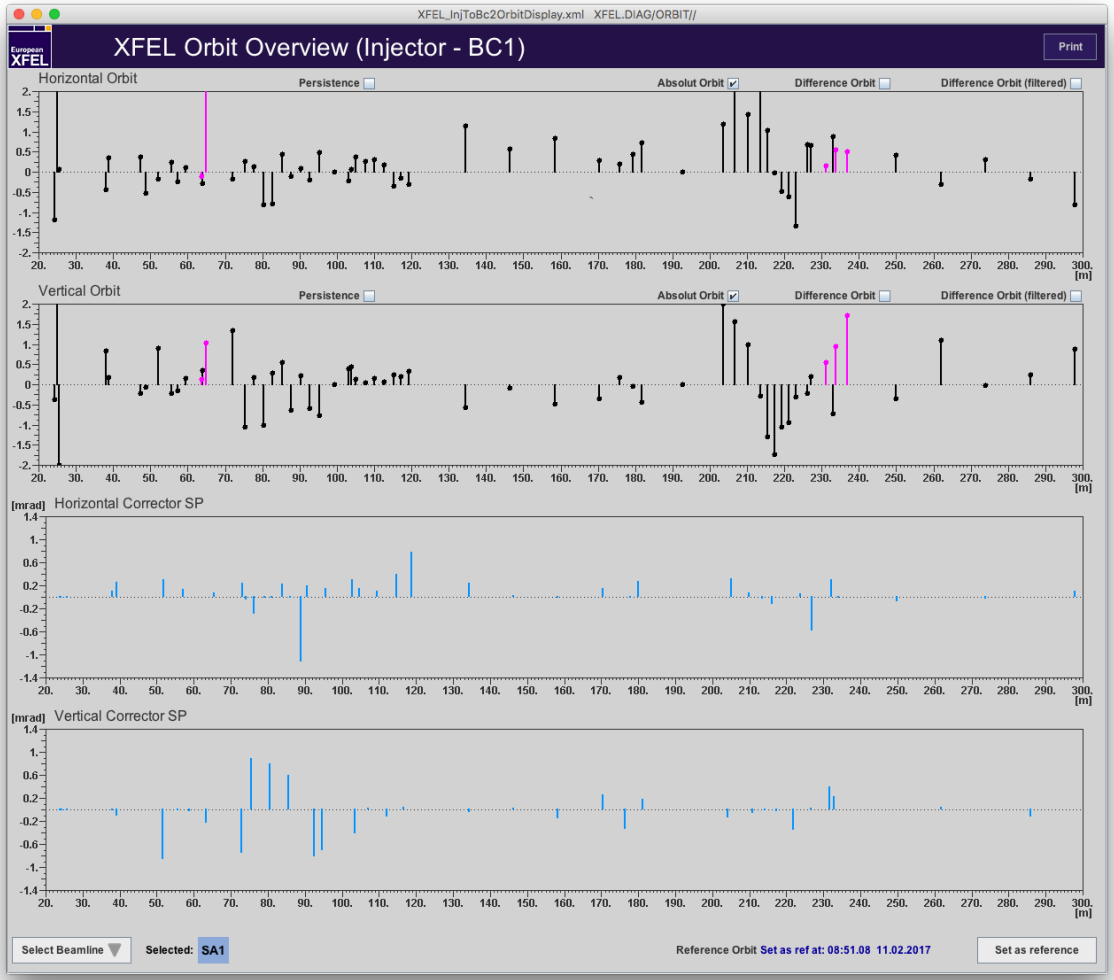


- Measure the gun phase using the provided tool.
- Lets assume the recommended gun phase is -46 degree.
- Change the gun phase on the gun LLRF panel to -1 degree (-46 + 45 = -1, 45 degree is the default gun phase).
- Use the LLRF on-crest Matlab tool to set the gun phase.

- Go back to -45 degree gun phase.
- You can find the tool on the Main Panel, RF, Set On-Crest Phase
- The on-crest server, that is linked below the Matlab tool is not yet capable to set the gun phase.

Orbit panel

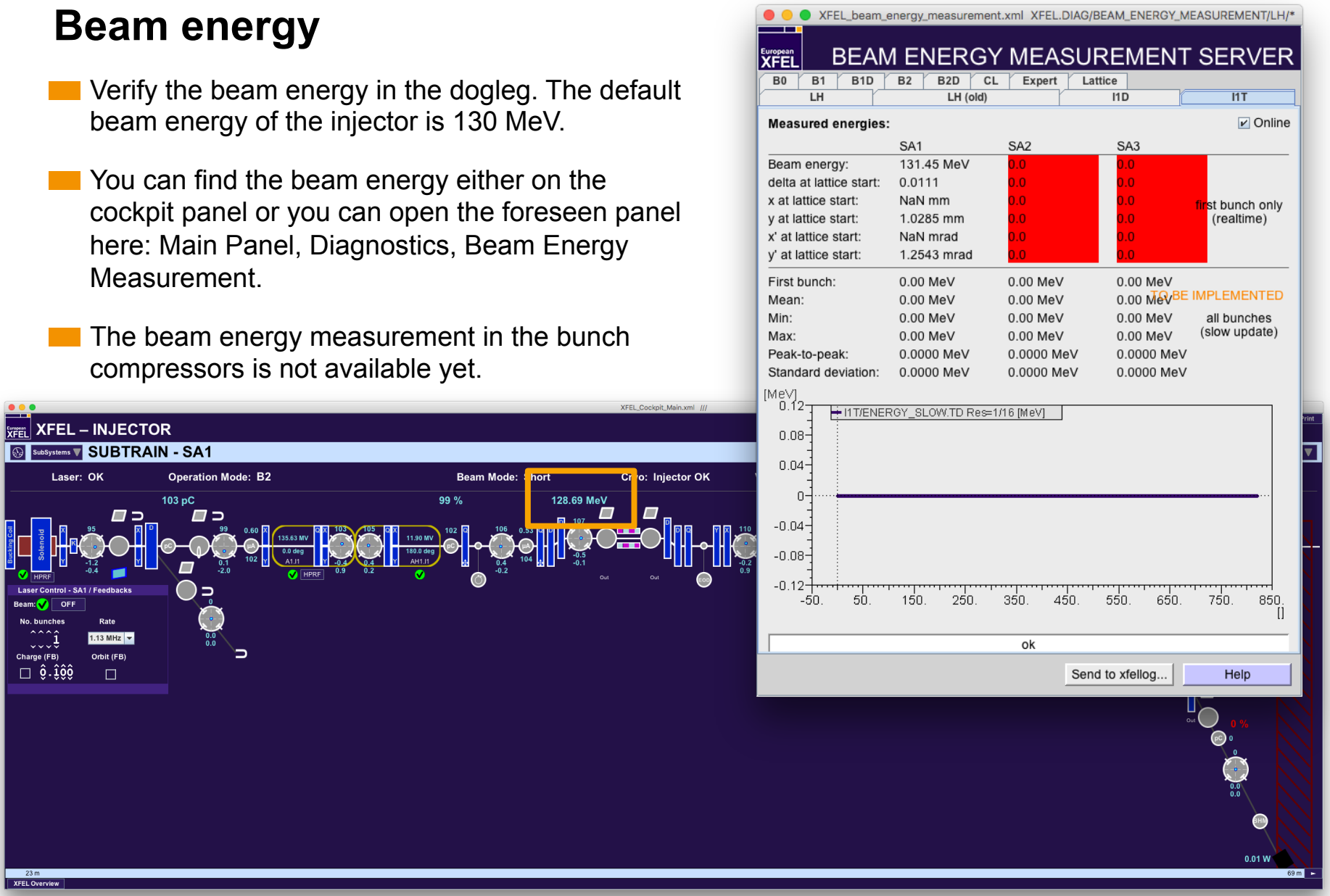
You can find the panel here: Main Panel, Orbit, Orbit (Inj-TLD)



- This panel provides both, beam orbit along the beamlines as well as steerer strengths.
- You can click on one of the steerers to open a magnet middle layer panel where you can change the kick setpoint.
- This is one of the panels, that should always be open!
- Unblock the beam and check the beam orbit along the machine.
- Use either the orbit feedback or the orbit correction tool to correct the beam orbit.
- Only minor corrections should be done with point to point steering.

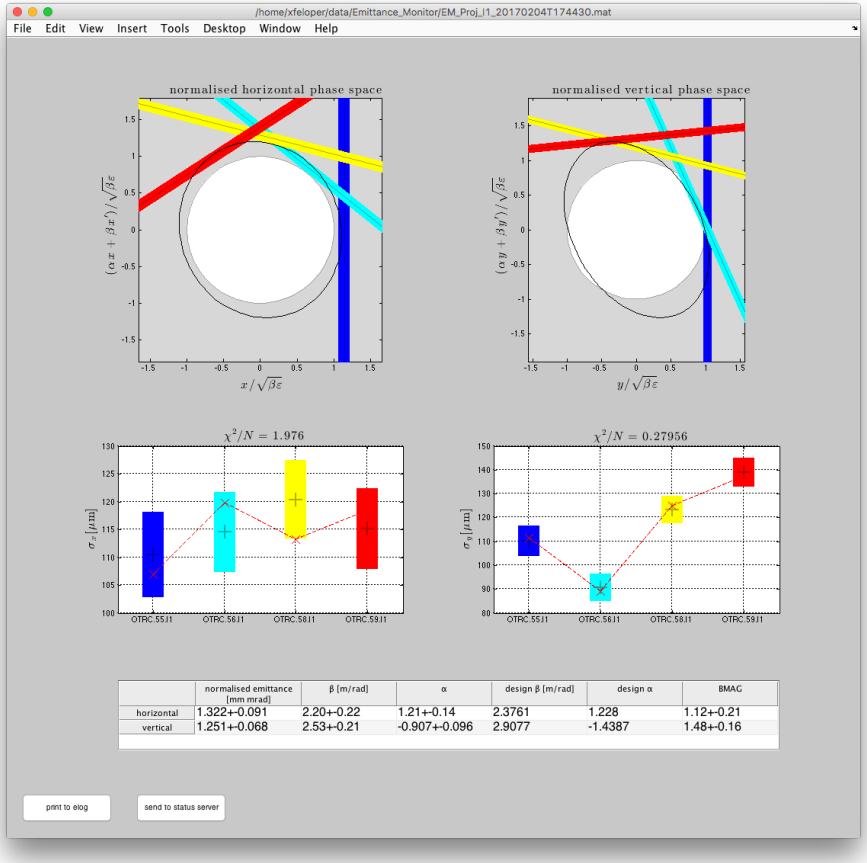
Beam energy

- Verify the beam energy in the dogleg. The default beam energy of the injector is 130 MeV.
- You can find the beam energy either on the cockpit panel or you can open the foreseen panel here: Main Panel, Diagnostics, Beam Energy Measurement.
- The beam energy measurement in the bunch compressors is not available yet.



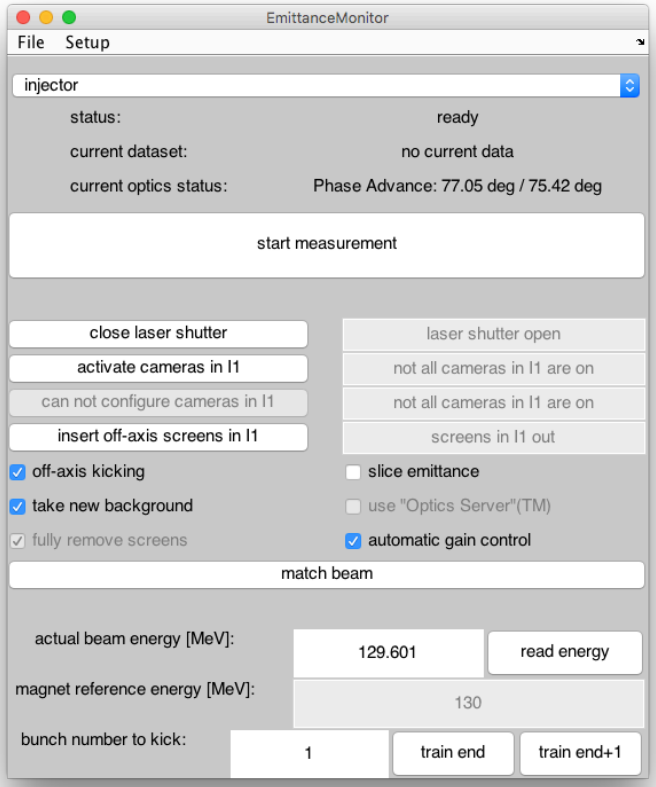
Measure emittances

You can find the emittance measurement tool here:
Main Panel, Beam Dynamics, Emittance Monitor



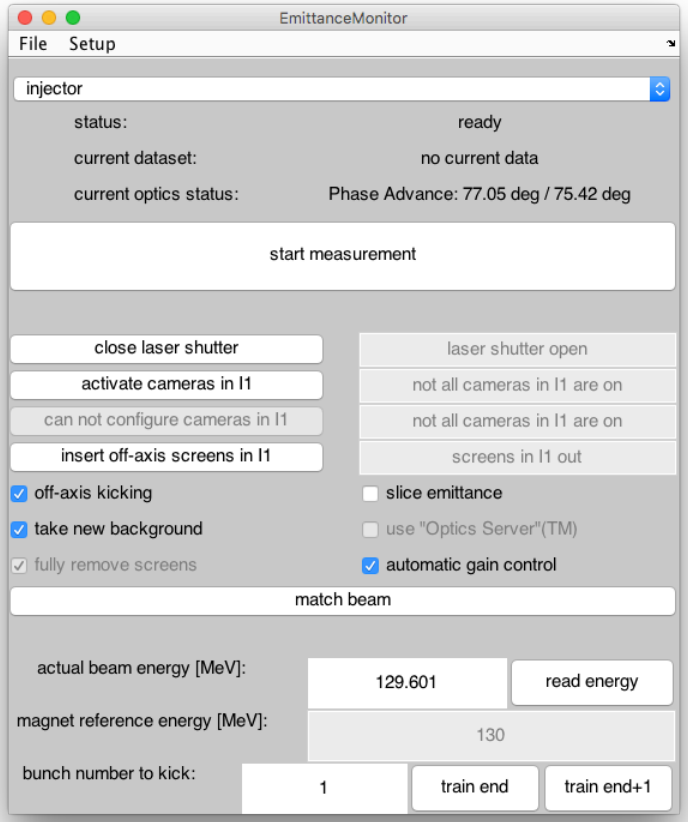
	normalised emittance [mm mrad]	β [m/rad]	α	design β [m/rad]	design α	BMAG
horizontal	1.322+-0.091	2.20+-0.22	1.21+-0.14	2.3761	1.228	1.12+-0.21
vertical	1.251+-0.068	2.53+-0.21	-0.907+-0.096	2.9077	-1.4387	1.48+-0.16

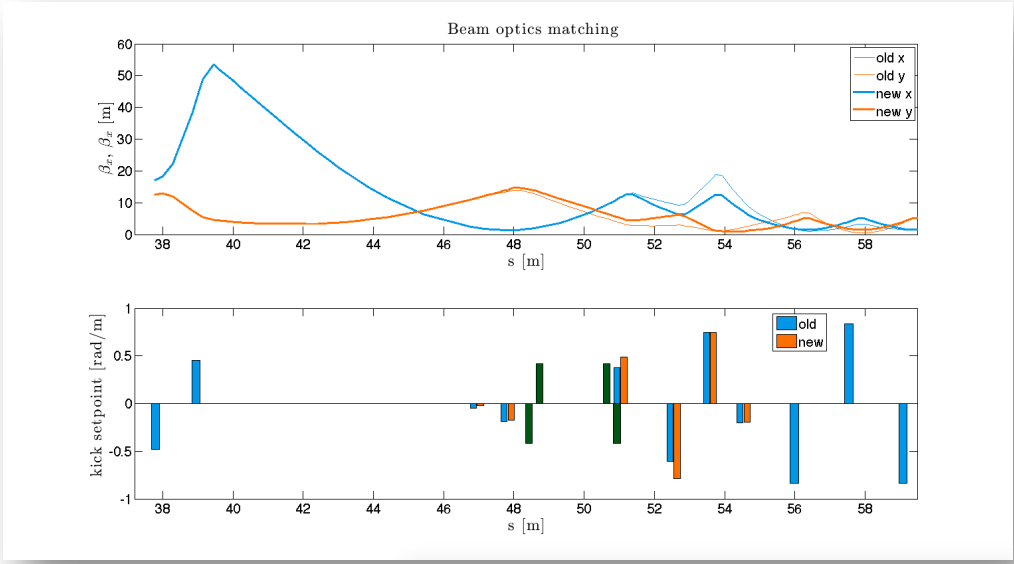
- Measure beam optics and emittances in the injector.
  - The emittances should be of the same size in both planes.
  - If this is not the case, you can change the main solenoid to get a better symmetry.
  - Consider, you can not believe the emittance measurement if the mismatch amplitude is about or larger than 2.



Match the beam

- You can/should match the beam after an emittance measurement by pressing the ‘match beam’ button on the emittance monitor panel.
- The mismatch amplitude in both planes should be smaller than 1.1 before you continue.
- The beam should be matched latest after 3-4 matching iterations.





Beam beyond the dogleg

- There should be already transmission to the B2D dump since you corrected the orbit.
- The injector delivers now a well defined beam to the linac.
- The next steps are:
  - Switch on the B1D dump dipole BB.229.B1D (-12 degree deflection angle) and measure the on-crest phase of A2 using IntelliPhase.
  - Set BB.229.B1D back to zero current (be careful, zero deflection angel is not possible) and correct the remanend filed using the dipole's correction coil CBB.229.B1D.
  - Do the same for L2 (A3, A4 and A5) while the beam goes to the B2D dump.
- In the near future, it will not be necessary to measure the on-crest phases of A2-A5 in the dump beamlines. But until the E-BPMs in the chicanes are in operation, we have to do it this way.
- Now you can start to optimize beam optics and emittancens in B1 and B2. Use the Emittance Monitor as described before (and as described in the particular operator training).
- After that, you can open the valve to L3 and set the B2D dump dipole to zero current.
- Futher steps will be discussed in future versions of this operator training.

Some ideas for trouble shooting

- Assuming there is no transmission through the beamline. What can it be that stops the beam?
  - A closed valve or a screen that was forgotten in the beamline.
  - A strong steerer that deflects the beam towards the vacuum chamber.
  - In general, a wrong magnet setup (kick set points or momentum set points).
  - There might be a collimator in the bunch compressor moved in too far for the aimed beam orbit.
  - If an RF station fails, the beam has not enough energy to pass through chicanes.

- Assuming there is no RF pulse in one of the modules/RF stations. What can you do?
  - Check the overview panel which RF station failed.
  - Open the FDM panel of the concerning station (Main Panel, RF, FSM -> select the station in the drop down menu on the top right).
  - If there is an error message, try to solve the underlying problem (if you can). Otherwise had over to the experts from MKK or to the expert on call from MHF-p (MIN in case of AH1 or TDS) or LLRF.