List of things to do:

Installation of the chopper:

- First install the chopper into the casemate
- Chopper requires alignment with the beamline
- Start construction of the setup piece by piece from upstream to downstream with a laser placed in front of the casemate.

Assembly of the cubes:

- Requires crane to drop each cube and vacuum chambers into the pit
- While the cubes are being dropped into the pit and aligned, the vacuum chambers and electrode stacks can be preassembled, ready to be installed.
- Each cube needs to be connected via the corner pins. To hold them together aluminum plates are bolted to item profiles on the edges of each cube (only on the inside to avoid conflict with the mu-metal panels). Then once all cubes are connected, they can be aligned to the beamline.
- As the first two cubes are installed, the vacuum chambers with electrodes can be mounted. This avoids having to dismount a section of the z coil and awkwardly angle the chambers into position. The chambers should have the electrode stacks preassembled with grounding connections fitted. They can then be aligned with respect to the beamline after the cubes are aligned.
- The magnetic field coils can then be connected. Check resistance of the coils!
- The SENSEY fluxgates can then be installed and cables connected. The cables for the fluxgates enter upstream of the experiment!
- The Faxion coil should also now be installed!
- The SF, guiding field coils, and apertures can also now be installed.

Setup of the electrodes

- As the cubes are being assembled, vacuum chambers are also installed. They are aligned after the cubes are aligned to the beamline.
- The electrode stacks will need to be connected, as this is done the electrical connection of the electrodes and rings need to be check!

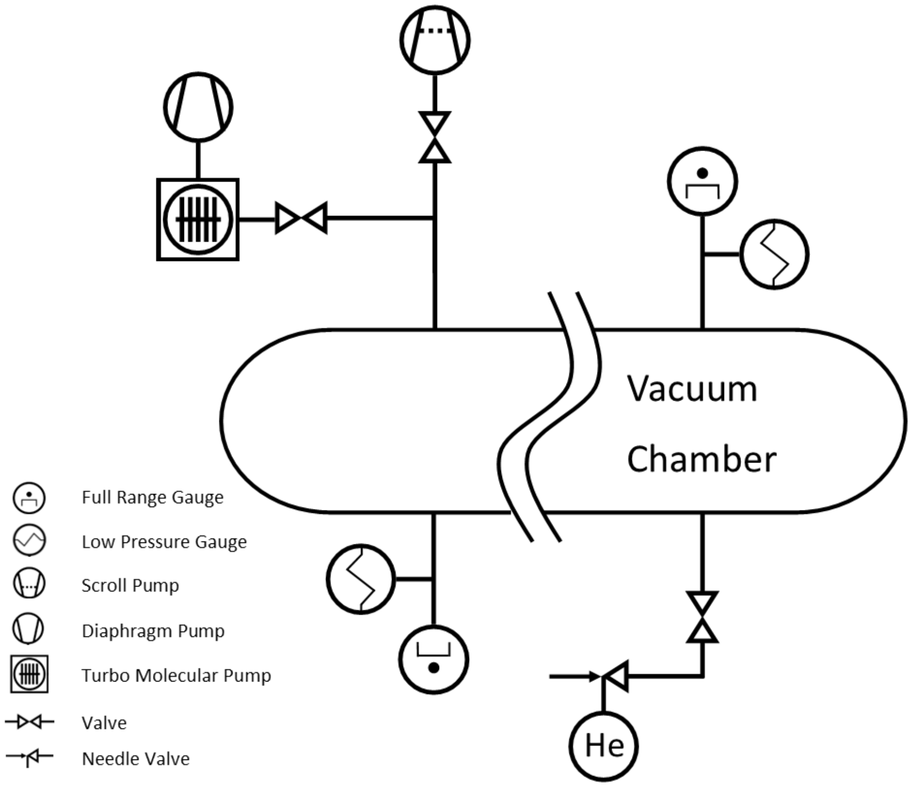
Setup of the vacuum chambers

- Connecting the 1 m long aluminum KF50-KF50 tubes for the 4 KF50 flanges at the ends of the vacuum chambers. Need to make sure the tubes will protrude from the mu-metal plates.
- The ISO 160 connector with the HV feedthrough, without cable, can also be added. Then this connected to the HV electrode and electrical connection checked.
- At this point the end caps of the vacuum chambers can be put on

Installation of the mu-metal

- Requires use of the crane to lower the plates down
- The inside connector pieces of mu-metal should all be installed before any plates are mounted.

- The top and bottom plates can be installed first. The use of the crane means that the top plates can be lowered on to the cubes easily. However, the bottom ones need to be lowered in and carried underneath the cubes by hand, requires about 3-4 people to do this safely.
- The side panels can now be installed, mu-metal covers should be removed for the panels with feedthroughs.
- Once all the panels are installed the outer cover plates that goes between the panels should be added.
- With everything assembled on the cubes the mu-metal tubulations are then added.
- Now the vacuum system components (HV cable, gas handling, pumping, gauges) external to the cubes are added, shown in the following diagram:



Begin pump down of the system

- Require to be <10-5 mbar, which should take about 2-3 days.
- Everything that's already connected should be checked that it functions, like the gauges before moving on to the next step.

Installation of equipment

- The installing of all the racks, severs, power supplies, monitoring equipment, etc.
- This should also now be connected to their respective devices in order to check that everything works.

Systematic equipment checks

- Go device by device to check everything is setup correctly and outputs what is expected, i.e. running the chopper and it spins at the correct frequency in MIDAS. All devices should be checked in MIDAS!

- Install the HV-safely interlock, then HV can be run at this point to check the target field can be reached and maintained.
- Once every device its working, run everything in MIDAS and check it can receive and record data.
- Test sequencers, ODB, Elog, analyzer, everything to make sure it's all ready

Chopper characterization

- Chopper vibration test/measurement to be performed before neutrons.
- As the beamline comes online, the flux with the chopper open and closed needs to be measured for radiation safely. Then will determine if we need to add shutters to lower the flux or if we are only allowed to operate with a pulsed beam. This could take a day for these safely checks. At the same time the detector can be checked to see if it works and the circuit blow out that occurred has not damaged it.
- The neutron background rate with the chopper in the closed position needs measuring. Needed to check how effective the chopper blocks the beam. This will determine the background rate of the detector.
- The opening window of the chopper needs to be measured. A scan from -5 to +5 degrees, with zero being the beam direction, with steps of 0.02 degrees needs to be performed. This will characterize the absorption of the wafers and the shape of the spectrum.
- Next the ToF spectrum needs to be measured at different frequencies between 4 – 16 Hz with steps of 2/4 Hz. This is complementary to the previous measurements. The idea with changing the frequency is that it will select only the faster neutrons while slower ones get absorbed, narrowing the peak of the ToF spectrum. This measurement would also determine the frequency to avoid frame overlap. The measurement would be repeated in the opposite direction as a check for any discrepancy, no time-offset.

Detector checks

- Before measurement of the detectors, i.e. once installed, a 24-hour flush with ArC02 gas needs to be performed.
- Possible measurements that could be perform are a HV and/or CPiX scan. This would involve adding shades over given CPiX on the detector in order to measure the different quarters of the detector to check the background reference.
- If the detector behaves as expected, then this time period can be used to measure the stability over a 24-hour period only in pulse mode, could try with white beam if the radiation safely check means we can operate with such a large flux.

Beamspot characterization

- Scan the angle of the polarizer to define the beamspots on the detector, the detector position may need to be moved in order to better define the beamspot.
- The analyzer power needs to be optimized; this can be done with changing the guiding field as well as the angle of the polarizer.

Rabi technique

- In pulsed beam mode and magnetic field direction to the vertical (y-axis)
- This requires only one SF at a time; scanning the frequency and amplitude to find the resonance for both SF.

Ramsey technique

- Now both SF are locked with sinusoidal field.
- The frequency for the Rabi technique for each SF is then used to compute an average.
- Using this average, we fine scan around it, find the optimal frequency.
- Then once found switch back to Rabi to check the amplitude with this frequency, expect the amplitude to be that same as before.
- Perform a classic Ramsey

vxE measurement

- Magnetic field is set to the x direction (transversal axis), 100 uT.
- Characterize SF in the transversal axis, find frequency/amplitude of both.
- Both SF are set for non-modulation with amplitude/frequency the same as that found in the Rabi technique.
- Then perform a classic Ramsey
- The vxE measurement is required as a systematic check to make sure that the E field that's applied is what we expect.
- Measurement of applied HV, i.e. 0,+20,-20,+40,-40, +60,-60,+80,-80 kV, sequence to be defined.

Scan of the modulated signal

- Perform Ramsey technique with phase scan
- Scan with t0 (point at which the exponential decay of the modulated signal should begin), p=1 (power of the exponential) with the right amp/ ToF factor so basically determining when the modulation should start within the limitation of the spectrum for single SF
- Above should be done for each SF individually.
- Check that t0_SF1 is compatible with t0_SF2 (critical point)
- Define the zone of interest (ToF range)
- Now combining everything for both SF (f, amp1, amp2, t0_SF1, t0_SF2) and scan p around 1 to optimize the zone of interest.
- Then compare the optimal p value with the sinusoidal signal

Magnetic field scan using Ramsey technique

- Using the Ramsey measurement with the modulated signal, varying the magnetic field for off-resonance spin flip
- This would be a systematic check to make sure we understand the field in the setup

Stability check

- Before starting an EDM sequence, it would be prudent to do a 24-hour run, full setup, modulated spin flipper, pulsed beam, HV = off, etc… This would check to make sure we record data correctly and ensure everything is ready for 17 days of data taking.
- During this measurement, the stability of the magnetic field can be check so we know the polarity reversal cycle we want to use on the HV.

EDM measurement

- Shift plan starts, take data for at least 17 days.
- This is under the assumption of the following:

$$\sigma_{d_n} = \frac{2\hbar}{\alpha E T\sqrt{N}},$$

- where α = 0.75, E = 100 kV/cm, T = 10 ms, N = 1 MHz. This gives us 9.8 E-24 ecm per day, in order to match 3 E-24 this would take 11 days, so include extra 6 days to consider any deadtime, total minimum measurement period of 17 days.

Begin axion setup

- The first thing is to allow the chopper to cooldown to be accessed in order to switch out the apertures.
- If the neutron background rate is low then decrease the x resolution of the detector, to save memory.
- In the meantime, setup of the waveform generator to set the signal for the faxion coils
- Spin flippers in sinusoidal mode and phase at working point
- No magnetic field stabilization
- Switch over to faster magnetic field read-out, as the time stamp on the measurement needs to be very accurate and faster then for EDM measurement, the readout of the magnetic field also must be faster. Normally this generates very large data files and for the main experiment it would be too much for unnecessary data.
- Enable more accurate timing of the data files on the detector, requires a waveform generator
- Chopper set to permanently open position (white beam)

Faxion measurement

- Perform measurement for longer period compared to BOA
- If time available, possible faxion measurement with a pulsed beam/or in sweep mode.
- More frequencies in the low range < 10 Hz
- 1 day for measurement

Axion measurement

- Switch off the faxion signal
- Enable electric field, with cycling of each polarity including zero with equal lengths, one day each (dependent on the stability of the HV which is measured before during the EDM measurement)
- Check monitor desync of the measurement
- Bigger time bins (2 ms), therefore, longer duty cycle
- Apart from this, setup is the same as faxion measurement

Chopper cooldown

- Once axion measurement complete, the chopper needs time to cooldown before removal at the end of beam time
- Can take about 2-3 days before it can be removed

Beamtime complete

- Disassembly of the apparatus begins
- First the equipment should be packed up and sealed away, cables, connectors, racks, servers, etc. included.

- The guiding field coils and ASF can now be removed.
- The detector and analyzer dismounted and pack away.
- The vacuum and gas handling system next, so that the mu-metal plates can be removed easily. This involves removal of the mu-metal tubulations to get to the aluminum tubing which connects to the gas, gauges, HV feedthrough, and pumping system.
- With everything apart from the cubes with mu-metal cleared, the panels can be dismounted and craned out of the pit.
- Then the downstream cube can be removed.
- The SF1 & SF2 can be taken out
- With the back cube out, the vacuum chambers can be removed one by one and taken out of the pit
- After the vacuum chambers are removed, each cube can be separated and taken out of the pit
- At this point the chopper should be cooldown enough to be removed from the casemate.