02/08 Questions from Akira

Please confirm that the quad alignment requirements are:
- +/- 0.2 or 0.3 mm static and
- +/- 100 nm in vibration,

The quad axis should be aligned to the cryomodule axis to < 200 microns while the cavities should be aligned to this axis to < 500 microns.

The 100 nm rms vibration tolerance refers specifically to the uncorrelated (quad to quad) part of the motion that is above ~ 0.1 Hz in frequency

A third requirement is that the quads do not move than a few microns relative to their neighbors day-to-day (not much larger than natural ATL motion).

How much effect do temperature changes have on alignment. Do we need to provide dynamic adjustment or is beam steering enough?

Temperature changes cause slow quad motion in at least three ways:

1) When the beam is turned on/off, the cryomodule 40-80 K shield temperature will change and cause the quads (whose support are tied to the shield) to move by up to 6 um, but this should be mostly correlated quad-to-quad except at cryo-unit boundaries.

2) Cryomodules will move vertically about 20 um per degC of air temperature change due to expansion of the cryomodule supports – this should also be mostly correlated quad to quad.

3) The centers of the cryomodules will bow by about 160 um per degC variation of the cryostat top-to-bottom differential temperature, so supporting the quad at the center is not good in this regard. To prevent such differentials, we need to control heat leaks from service tunnel into the beam tunnel and cool/insulate the waveguide system. Note this could be a big problem with one tunnel design where the klystrons, which dissipate the most heat, are located near cryomodules.

In these cases, beam based alignment can be used offset the temperature related motions, although this may require frequent application if the changes are fast (i.e. if there is uncorrelated micron level motions in less than a hour).

It seems easier to align a super-ferric magnet because of the easier reference from the iron-pole. In the case of cos-2-theta design, how do we fix the reference point to be aligned. How should we align the cos-2-theta magnet which does not have a clear mechanical reference.

To limit the length of the quads to ~ 0.6 m with the baseline 90 mm aperture, we need to use a cos-2-theta design in downstream two-thirds of linac. If we reduce aperture to 35 mm, can use a superferric design throughout linac.

However, the main advantage of superferric design is that its magnetic center is likely to move less when the field is changed, not that it is easier to align.

Both the superferric and cos-2-theta designs can likely be fuducialized to < 200 um level required for ILC. For example, run them warm in their He vessels at ~ 1 amp and measure the field center and orientation with a rotating coil, then mount tooling balls on He vessel to 'mark' this alignment. These fixtures would then be used to align the bpm to the quad to < 100 um (it should be bolted to the quad He vessel if possible).

Note also that the quad rotation needs to be set to the 300 urad level – this is 90 um across the 300 mm quad He vessel – again the tooling balls on the He vessel would be used.

How can we position/orient the quadrupole package at the axial center of the cryomodule within the requested tolerance ?

While the quad can be well aligned on the gas return pipe during initial assembly, it is not clear that alignment will be preserved when the cryomodule is assembled and transported. Having the quad near the end of the cryomodule would allow this be more easily checked after the cryomodule is installed in the tunnel. With the quad located at the center of the cryomodule, we may have to install windows in the cryomodule to verify both the position and orientation (the motion of the quad during cooldown could also be studied).

Do we really need to provide a dynamic adjustment/alignment system for the quadrupole alignment during the operation ?  If necessary, how much span range? and how much control accuracy ?  what response time?  Are the beam steering magnets not sufficient ?

At minimum, we should make the cryomodule horizontal and vertical position manually adjustable (i.e. this would require an access into the beam tunnel instead of using remote movers). The adjustability would be used to:

1) offset large (several mm) changes in tunnel straightness that can occur over years (the corrector magnets can only handle a few mm). Such 'local' changes are seen in the LEP/LHC tunnel at CERN.

2) keep the beam centered in quad/bpms to the few hundred um level so systematic bpm errors are less than the 1 um bpm resolution.

The system should have a cm-level range and a 50 um or better positioning accuracy.

Although we can likely live with this, a more desirable (but more expensive) option is to have remote movers on the cryomodules, and even better yet, is to have micron precision remote movers on the quads only, which would eliminate the need for corrector magnets.

Please provide quantitative requirements for the beam position monitors and comment on availability of the technology.

Basic requirements include

1) ~ 1 micron resolution with 2e10 electrons/bunch. S-band and higher frequency cavity bpms have achieved this, but L-band (1.5 GHz) versions with a > 70 mm aperture have not.

2) ability to measure individual bunches at this resolution, so want signal decay time to be < 300 ns bunch separation

3) geometry such that the interior of the cavity can be made very clean

4) readout system such that measured position is stable to 1 um on a time scale of a day for a fixed beam offset up to 1 mm.

Do we really need to provide tunability of the coupler or can we expect to simplify the coupler design without tunability for cost saving ? If we need it, how much tunability? If we eliminate the tunability, what will be the problem ?

Qext needs to be adjustable in the +/- 30 % range or we will be forced to run all 26 cavities in an rf unit at a gradient near the lowest sustainable cavity gradient, which will lower the average gradient by about 20% compared to that if all cavities run near their sustainable gradient.

Qext can be adjusted using matching section in the warm waveguide outside of the cryomodule but this adds cost and further enhances the field in the coupler, which is already increased to deal with the cavity gradient variability.

In your understanding, which plug-compatibility is required, and which kind of tests need to be made to verify the compatibility, for example:

- interface between coupler and cavity,
- between coupler and RF distribution system
- between quadrupole/BPM and cryomodule component.

Currently, the KEK couplers will only work with the KEK TESLA-like cavities, and the DESY TTF3 couplers will only work with the TESLA cavities. This is because the coaxial connections to the cavities differ (one is 40 mm diameter and one is 60 mm) and one cannot simply add a conversion section between them. Also, I suspect the coupler mounting holes and supports on the cryostats are distinct in these cases. Finally, if the length of the couplers differ, how they mate to the rf distribution waveguide would have to change as well. In these respects, it would be better to have the plug compatibility at the cryomodule level.

For the quad/corrector/bpm, the mounting to the gas return pipe could probably easily be made to be common, but the layout for cooling the leads and for bringing out signals would require more effort to be compatible.

The components you mention are modular and function independently, so except for testing the mating flanges, I do not foresee having to do full system tests with various combinations of components.