General Notes:

The 4 and 8 pack development is R+D. The LLRF system must be designed to allow flexibility in operational parameters, number of channels, etc.

RF Control: Each Klystron must have independent phase and amplitude (or I/Q, or digital IF) control. The control requirements are:

8 and 4 Pack overall requirements:

- LLRF output power >10dBm at exit of LLFR module.
- Adjustable X-band frequency control +/- 30MHz is required for some tests.
- Analog IQ modulation inputs must be provided for external arbitrary waveform control.

4-Pack: 3 Klystrons to be controlled.

1. The signals to the 3 TWTs require independent slow (1 second time constant) phase and amplitude control. Stability ~5 degrees X-band. Accuracy: no tight requirements - will be controlled by measuring the output. This functionality may be included in the arbitrary I/Q control.

2. The phase of the LLRF signal to the 3 TWTs must be switched by 180 degrees with a switching time of less than 10ns (settle to 10 degree phase).

3. The output from the LLRF system must be switched in pulses with 10ns rise and fall times (to 10% power) and 50ns to 4 microsecond length. Eight pulses are required, with the last pulse starting at the time of the phase switch. This is to allow operation with shorter RF pulse lengths.

4. Note: the 4-pack functionality is a subset of the 8-pack functionality.

8-Pack: 8 Klystrons to be controlled.

1. The signals to the 8 TWTs require phase and amplitude control in 8 steps of ~400nsec each. I/Q steps should settle to ~1% in ~10ns. Stability should be 8 bit.

2. An additional ~8 phase and amplitude ramps, each 50ns, may need to be applied to all of the drive signals to compensate for the turn-on of the modulator. This signal would be the same for all klystrons.
Note that 1 and 2 could be achieved with a 20MHz, 8 bit (true) DAC driving each of the Is and Qs for modulating the RF.

3. The output from the LLRF system must be switched in pulses with 10ns rise and fall times (to 1% power) and 50ns to 4 microsecond length. 8 pulses (of identical length) are required, spaced by ~400ns. This is to allow operation with shorter RF pulse lengths. This switching is the same for the two (SLEDII) tubes, but may be different for the third tube.

RF Diagnostics:

Note: It should be possible to measure timing difference between the rising and falling edges of “related” RF signals (e.g.: structure in / structure out) to <1ns. This may have implications for IF frequencies, and for whether the IFs need to be locked to the master oscillator.

Diagnostic Types:

1. **Calibration / Special Purpose Diagnostics:** must be switchable to look at any RF signals. Real time readout is not required. Digital IF processing with >100MHz bandwidth to 8 bits (6 effective) is required. Digitization should occur on all pulses, with ability to store on a “breakdown” pulse. This can be performed with a >1Gs/s scope. Any pair of signals should be available for measurement.

   Calibration: The system must allow for calibration of selected channels to 0.2dB absolute, 0.1dB stability. Note that additional equipment may be used to provide calibration of these selected channels.

2. **Waveform Diagnostics:** 100MS/s, 8 bit digitization of I / Q signals for a selected number of channels. Bandwidth > 50MHz. These signals should be recorded on every pulse, and read out on “breakdown” pulses. All Waveform signals should also have Single Pulse Diagnostics.

   TDC and GADC like measurements can be performed by processing the digitized data. This processing will be done in the EPICS IOC, with the resulting values available through channel access.

   “Raw” RF signals (for digitized channels) must be available for measurement with oscilloscopes, spectrum analyzers, etc. Providing X-band, IF or IQ signals with >50MHz bandwidth is sufficient.

3. **Single Pulse Diagnostics:** Peak RF power is measured on these channels on every pulse. The peak detector requires 3% accuracy for a 20ns FWHM pulse. Note: this specification can be met by an *Analog Modules #611-20 Peak Detector* digitized by a *VMIVME 3122* digitizer.
4-Pack Signal Counts:

Total RF Signals: 40 (All go to pulse ADCs)
Signals to 100Ms/s I and Q Digitizers: 15 (30 Digitizer channels = 4 digitizers).

8-Pack Signal Counts: Including 6 structures (rough estimate)
Total RF Signals: 100 (All go to pulse ADCs)
Signals to I and Q digitizers: 50 (100 digitizer channels = 12 digitizers)
4-Pack Layout / channel count - Klystrons

- LLRF
- TWT
- Klystron
- Load

Circular guide
- Pulse Monitor (diode - peak detector)
- I/Q monitor (100Ms/s I, 100Ms/s Q, + Peak detector)
  Also mux to Fast (>1Gs/s digitizer)

LLRF drive
4-Pack channel count - Super Hybrid and DLDS

Circular Guide

Super Hybrid

Mode converter / test device

Note: no power expected to these loads

Loads have built-in forward / reverse detection.

- Pulse Monitor (diode -peak detector)

- I/Q monitor (100Ms/s I, 100Ms/s Q, + Peak detector)
  Also mux to Fast (>1Gs/s digitizer)