Crab Cavity RF Control

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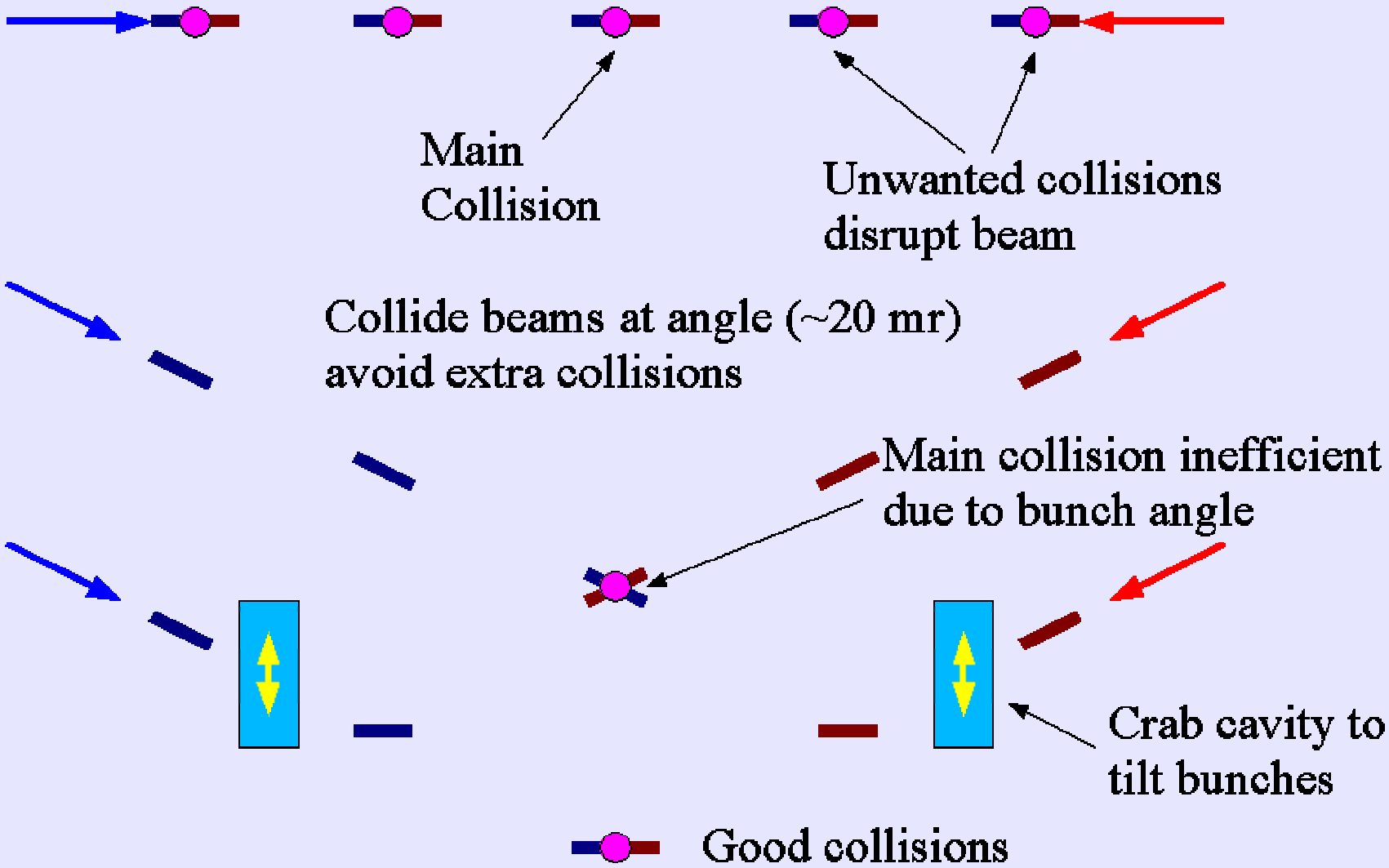
What is a Crab Cavity



RF Phase error will mis-steer beam

Requirements

- Differential phase errors most important.
  - Tolerance ~.05° S-Band (2856 MHz)
- Amplitude and common mode phase not at all critical (similar to other RF requirements)
- Drive power < 1 S-band klystron

How hard is this?

- Best SLAC Klystrons have ~0.1 degree jitter.
- Tough, but not ridiculous

How to measure cavity phase

- Direct RF measurements
  - Good for short term, but has long term drift
- Beam trajectory
  - No beam deflection at correct phase
  - Use Beam / Beam deflection for measurement
- Induced field
  - Use asymmetric crab cavity with energy gain off phase?
  - NO: This is asking for wakefield problems!

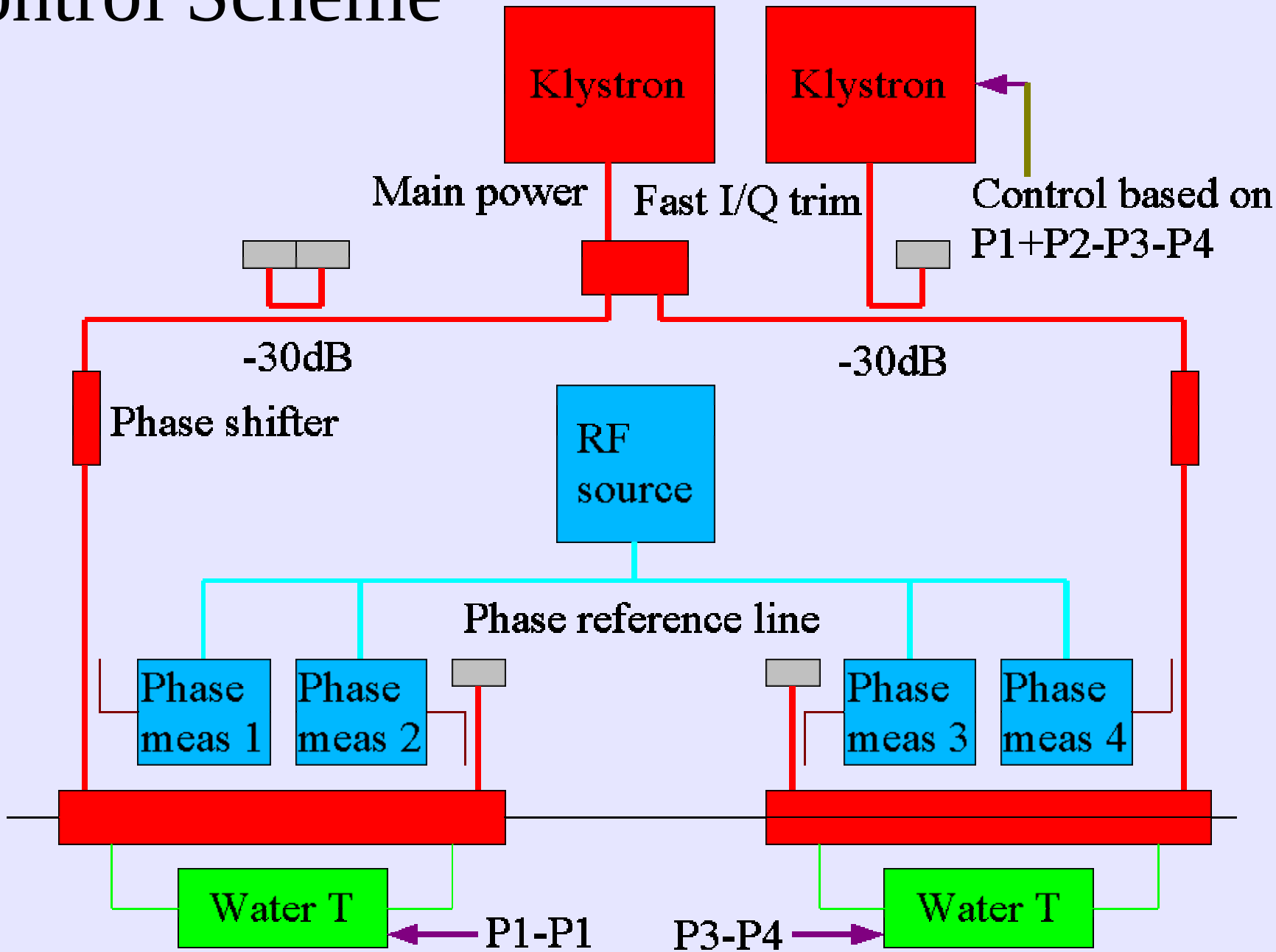
How Hard is a 0.05° Phase Measurement?

- Absolute phase number is not scary
  - Have done .003° at 357MHz without any heroics
- Mixer measurement: Typically get ~1mV/degree
  - .05 degree is a 50uV measurement
  - 1 MHz bandwidth -> 50nV/$Hz^{1/2}$. (35dB noise figure)
  - Not scary
- Signal levels are constant
  - Don't need to worry about amplitude to phase conversion.

Phase Control

- Using a single Klystron, with a hybrid splitter
  - Match waveguide lengths
  - Phase jitter will be equal for 2 cavities
- Use slow mechanical phase adjust to correct for thermal errors
- Use second klystron weakly coupled to one cavity for fast control.
  - Fast response (can use AWG to control within pulse)
  - Expensive – but only need one.

Control Scheme



Phase Reference Line Stability

- This is a short line: 30M, not 30 KM.
- Need stability of ~5×10^{-7} Relative Length
  - 15 microns: OK for ground motion / vibration
  - Copper temperature stability of .02° C.
    - SLAC water is stable to 0.1° C long term.
    - Only need this very short term (between beam measurements)
    - Easy
- Fundamental RF noise.
  - Thermal noise 10^{-20}W/Hz.
  - Assume 1 mW transmission power, 1 MHz bandwidth
  - 10^{-4} Degree thermal noise: Easy

Cavity Stability

- High cavity Q (few thousand) will cause large phase shifts from vibration and temperature
- Temperature: Expect ~100° RF / °C
- Appear to need .01°C stability
- But: Measure phase in and out of cavity – correct average phase inside cavity.
- Also, only need stability for short times
- Cavity Matching?
  - Different frequency and Q will turn phase noise into beam motion
  - Phase noise already almost OK without matching

Overall Conclusions / Comments

- Parameters don't look particularly difficult.
- May find some unexpected effect.
- Prototype would be nice, but probably much lower priority than other systems.