RF Summary
SLHIPP – 1

o. brunner BE-RF

Program

- RF sources and beam dynamics:
  - Magnetrons (Amos Dexter Lancaster Univ.)
  - LLRF for the SPL SC cavities (Wolfgang HOFLE)
  - SPL beam dynamics (Piero Antonio POSOCCO)
  - ESS Beam dynamics (Mohammad ESHRAQ -ESS)

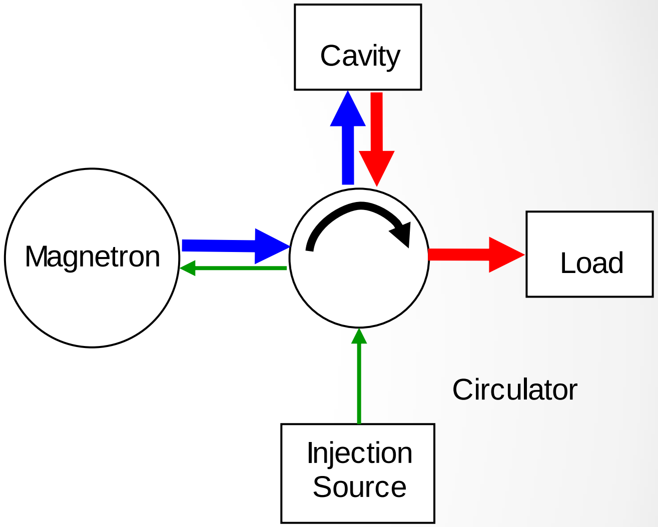
yesterday

- SC cavity tests
  - Results on cavity simulations and measurements (Szabina MIKULAS)
  - Diagnostics for SPL cavities (Kitty LIAO)
  - Dumbbell measurements (Nikolai SCHWERG)
  - Bead pull bench & multipacting of HOM couplers (Rob AINSWORTH _RHUL))
  - Various approaches to electromagnetics field simulations for RF cavities (Cong LIU-TU Darmstadt)

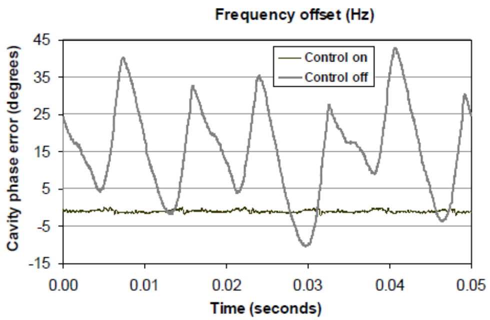
  - Updated info on SPL test stand in SM18

A magnetron solution for proton drivers (Amos DEXTER) -1-

- Framework:
  - Lancaster Univ. is using Tech-X Vorpal code to simulate 704 MHz magnetron
  - Linacs require accurate phase control
  - Phase control requires an amplifier
  - In this scheme the magnetron is operated as reflection amplifier
  - Potential advantages: size, efficiency, cost



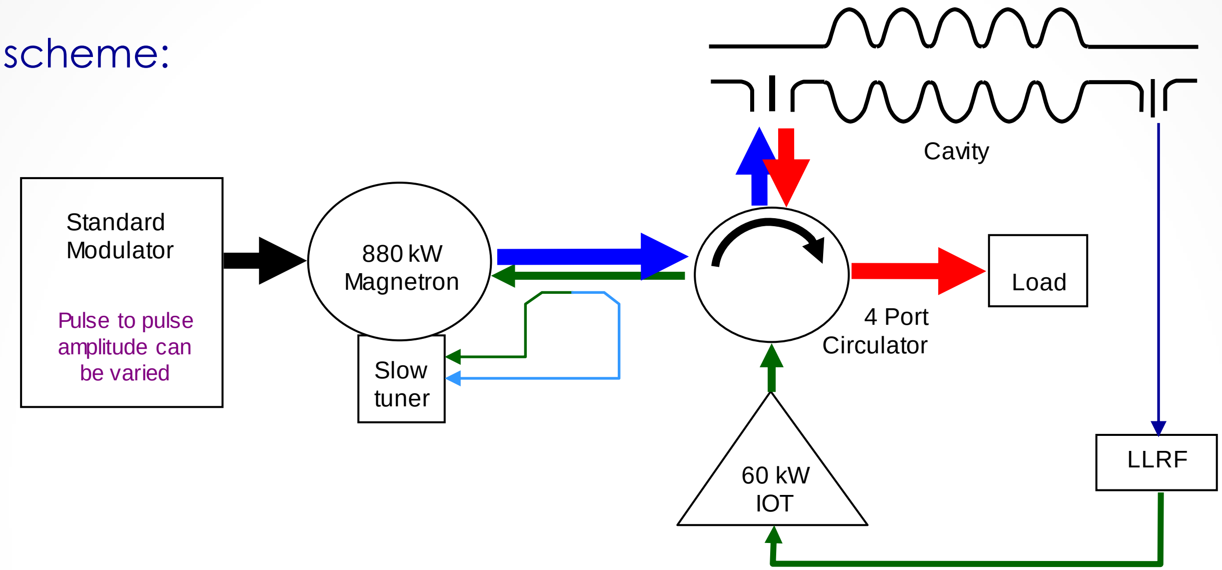
- Proof of principle demonstrated by Jlab:



- Next Steps:
  - Demonstrate at high power 704 MHz magnetron (aim at 95% efficiency)
  - Procure modulator and television IOT as driver
    - Need collaboration to be established

A magnetron solution for proton drivers (Amos DEXTER) -2-

- Proposed scheme:

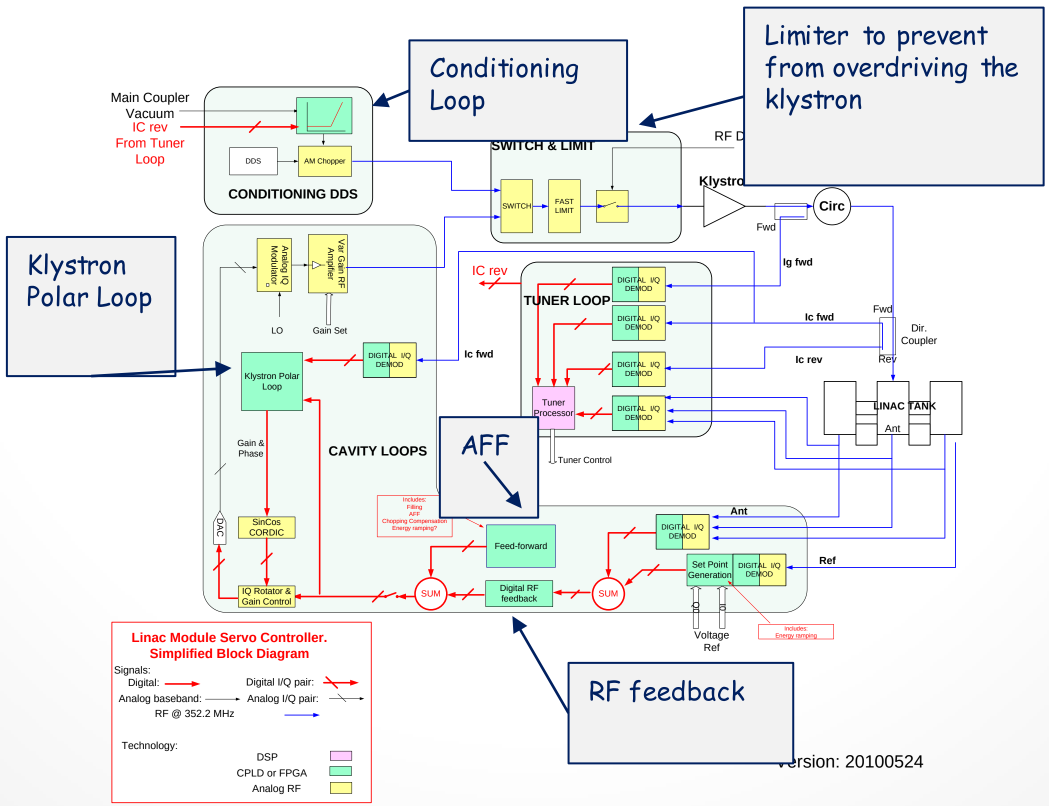


Could fill cavity with IOT then pulse magnetron when beam arrives

- Reflection amplifier controllability has also been studied:
  - Difficulty is that the magnetron frequency and output vary with several parameters: magnetic field, anode current,…
- Specs of initial device and operating range have been presented:
  - 704 MHz
  - 200 kW – 1 MW (100kW average power)
  - Efficiency > 90%
  - Simulations in progress

LLRF for SPL (Wolfgang Hofle) -1-

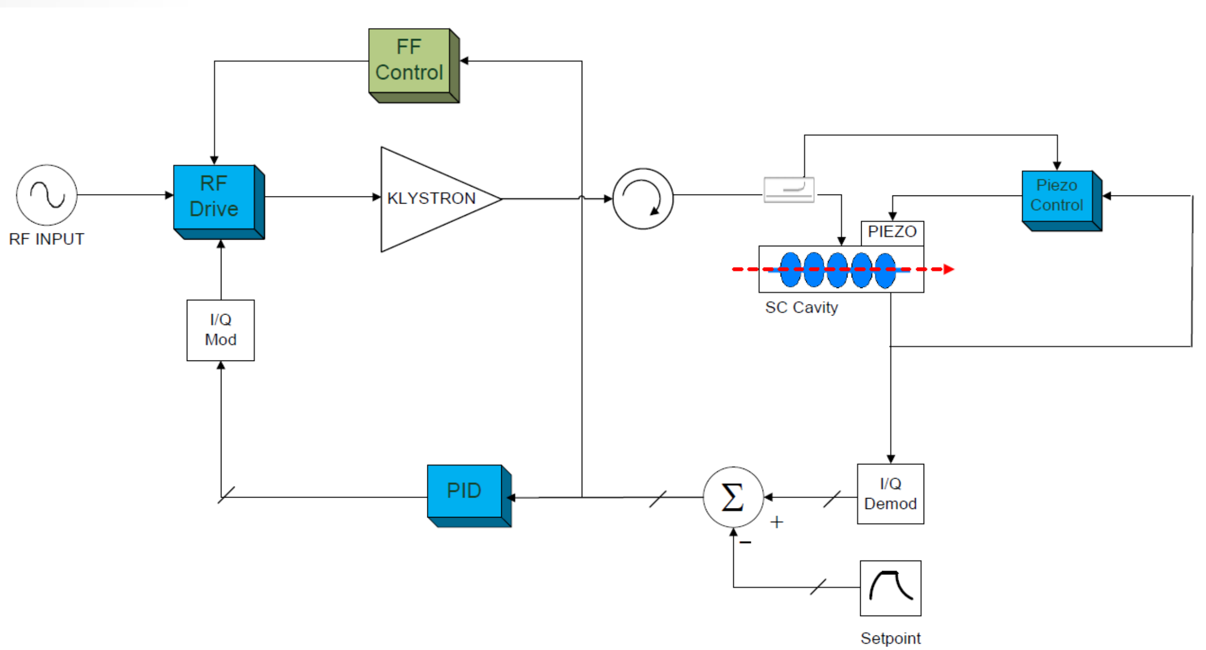
- SPL architecture: an evolution from the Linac4 LLRF system
- Differences:
  - SC cavities: => subject to Lorentz force detuning -> sophisticated control piezo control required.
  - Duty cycle: 50 Hz vs 2 Hz
  - Large number of cavities: => interest for compact LLRF system



LINAC4 cavity controller block diagram

LLRF for SPL (Wolfgang Hofle) -2-

- A new analog RF front end has been developed for SM18 (D. Valuch)
  - Based on successful tests done with LHC LLRF board (at Saclay?)
  - Includes piezo control
  - Board still to be tested
- Upgrade of simulations for cavity voltage control:
  => now includes the new klystron and modulator characteristics



High-Level Diagram of Single Cavity + Control System

$f_{RF} = 704.4\ \text{MHz}$

$I_{b,DC} = 40\ \text{mA}$

$\phi_s = 15^\circ\ \text{(LINAC)}$

$P_b = V_{acc} \times I_{b,DC} \times \cos(\phi_s) = 1.0277\ \text{MW}$

$\frac{R}{Q} = 570\ \Omega\ \text{(LINAC)}$

$Q_L = \frac{V_{acc}}{\frac{R}{Q} \times I_{b,DC} \times \cos(\phi_s)} = 1.2078 \times 10^6$

$\tau_{beampulse} = 0.4\ \text{ms}$

$\text{rep period} = 20\ \text{ms}$

$R_L = 690\ \text{M}\Omega$

$I_g = \frac{V_{acc}}{R_L} + I_{b,DC}\cos(\phi_s) = 77.3\ \text{mA}$

$\tau_{fill} = \frac{2Q_L}{\omega_{RF}} = 0.5458\ \text{ms}$

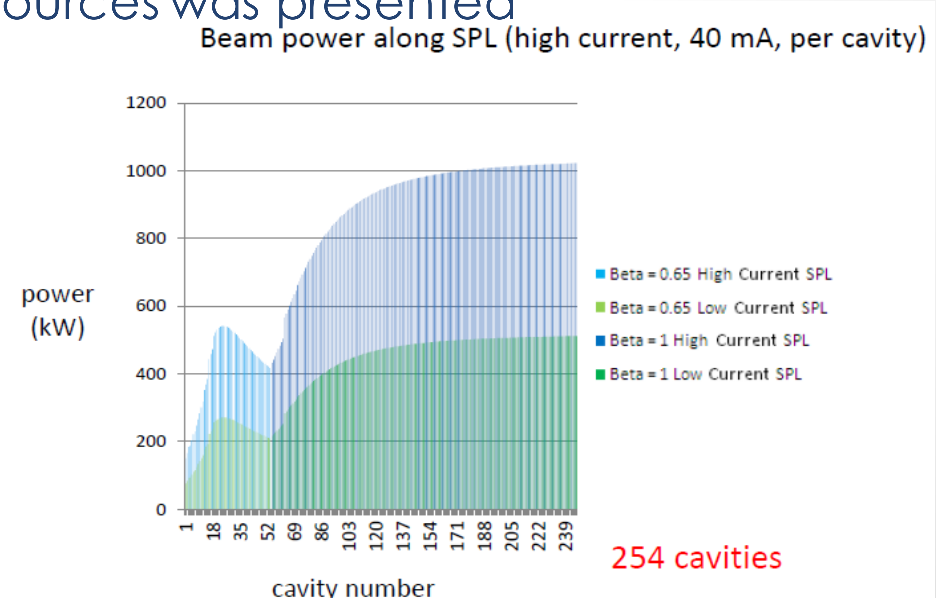
$\alpha = \frac{I_g}{I_{b,DC}\cos(\phi_s)} = 2$

$t_{inj} = \tau_{fill}\ln(\alpha) = 0.3783\ \text{ms}$

LLRF for SPL (Wolfgang Hofle) -3-

- As a result:
  - Even with feedback ON, the cavity voltage is drifting during the beam pulse
  - Feed-forward is necessary: it corrects for the residual error in the cavity voltage from pulse to pulse.
  - Good piezo compensation is essential, but compatible with 2 or 4 cavities per klystron

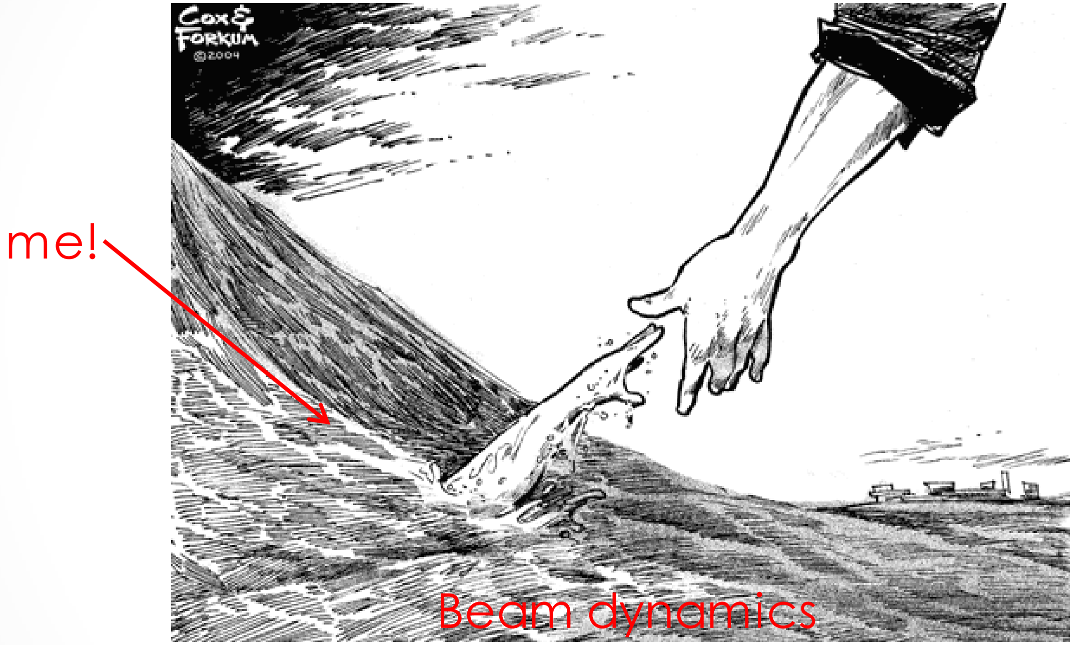
- Scenarios for optimizing the power sources was presented
  - 5 scenarios identified
    - high/low current options
    - one or several cavities per klystron



Most of these scenarios can be tested with the CERN ordered klystron and modulator without beam

SPL Beam Dynamics (P.A. POSOCCO, M. ESHRAQI) -1-

- Warning:



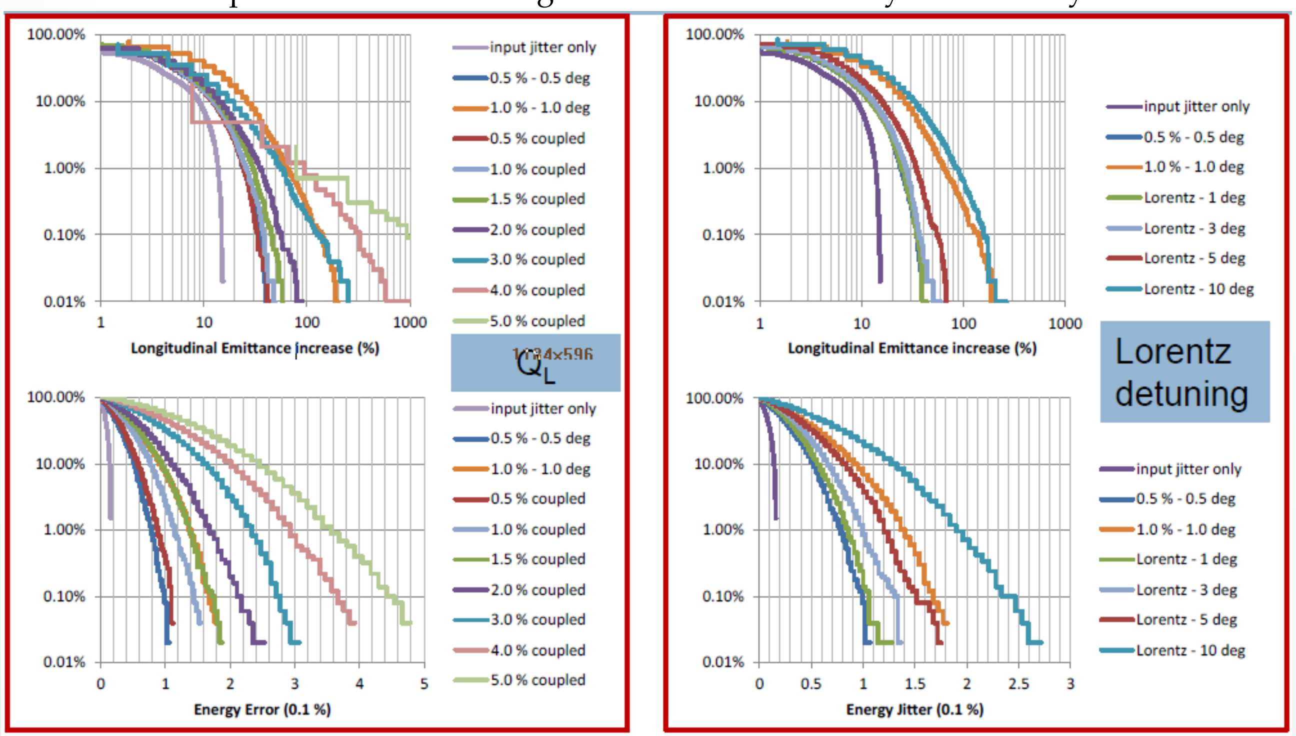
please be tolerant…

SPL Beam Dynamics (P.A. POSOCCO, M. ESHRAQI) -2-

- Latest beam dynamics results were presented
- Complete error analysis
  - Longitudinal errors
  - Transverse errors
  - Quadratic higher order components
  - <u>Quadrupole and cavity misalignment</u> (not an issue up to resp. 0.2mm and 2mm)

  - Example:

Coupled Errors for two high beta cavities driven by the same klystron



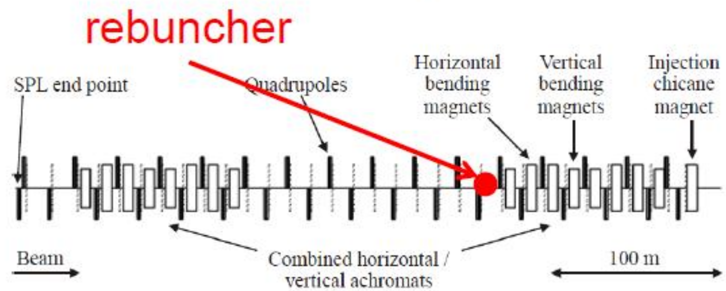
SPL Beam Dynamics (P.A. POSOCCO, M. ESHRAQI) -2-

- A detailed study of an example of transfer line was presented
  - SPL -> PS2, as proposed by BE/ATB
  - ≈ 400 m long
  - Equipped with rebuncher cavity to meet the energy spread requirements:
    - Neutrino factory, PS2: 0.1 %
    - Neutrino superbeam: 0.1 – 0.3 %
- Lot of work done to optimize the rebuncher cavity parameters (voltage, etc)

The TL on the CERN map

TL characteristics TE/ABT

- The TL has to overcome an altitude difference of 21 m over its length of ~400 m.
- The bending strength has to be limited to prevent Lorentz stripping of the H- beam.



SPL Beam Dynamics (P.A. POSOCCO, M. ESHRAQI) -3-

- "Main" outcome:
  - 0.5 deg phase – 0.5 % amplitude will allow for a broad range of applications for SPL
  - However, the 1:2 power scheme for the high beta section is only a suitable solution for fixed target experiments.
  - The specs for the transfer line rebuncher cavity strongly depends on the SPL "mandate" (i.e. accumulation, fixed target exp.,...)

Updated info on SPL test stand in SM18

- 1.5 MW klystron:
  - Ordered (Thales)
  - Design has started:
    - gun design well advanced
    - next step: focusing coil design
    - aim at 65 % efficiency
  - Planning:
    - March 2012: design report
    - monthly reports
    - delivery date: April 2013
- Circulators and RF loads
  - Specification documents finalized
  - Shall profit from MS make for Linac4 (DR approved)
  - Offer for the RF loads is expected soon
- WG distribution system
  - 3D Integration in bunker has started