IPHI RFQ
Beam loading measurements

O. PIQUET, M.DESMONS

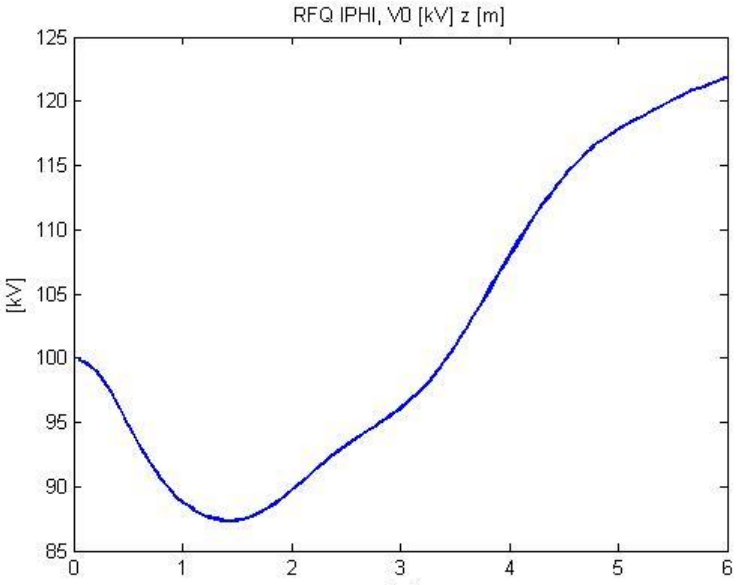
- RFQ parameters
- Water cooling and Static thermal detuning
- LLRF overview
- Transient responses with/without beam loading

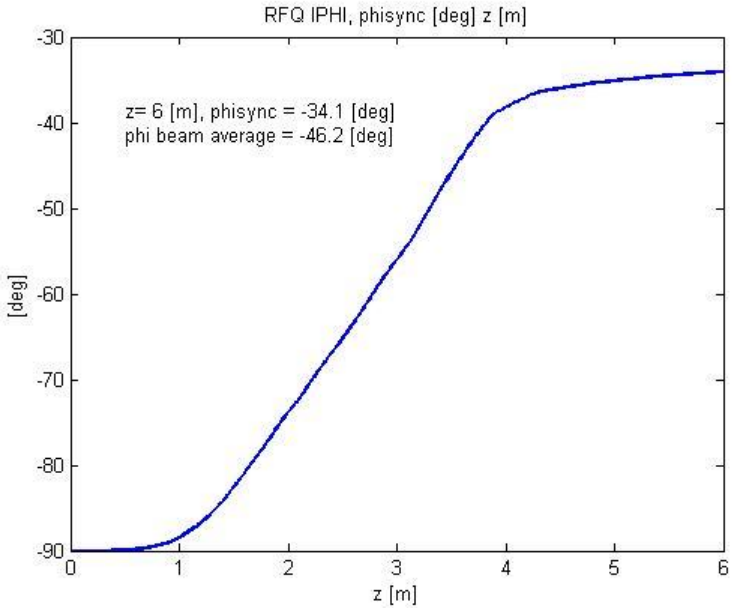
IPHI RFQ parameters (1)

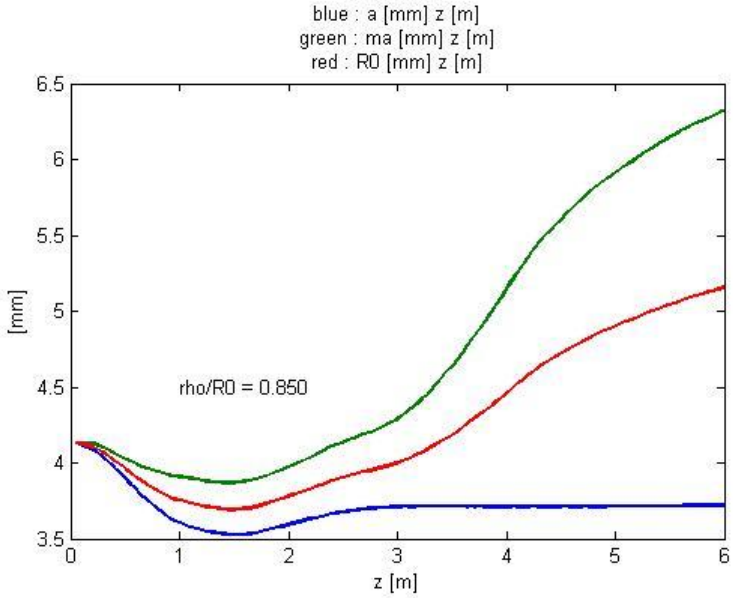
4 vanes segmented RFQ
RFQ length : 6m
6 x 1meter long modules grouped in 3 x 2meters long segments (capacitively coupled) for larger mode separation

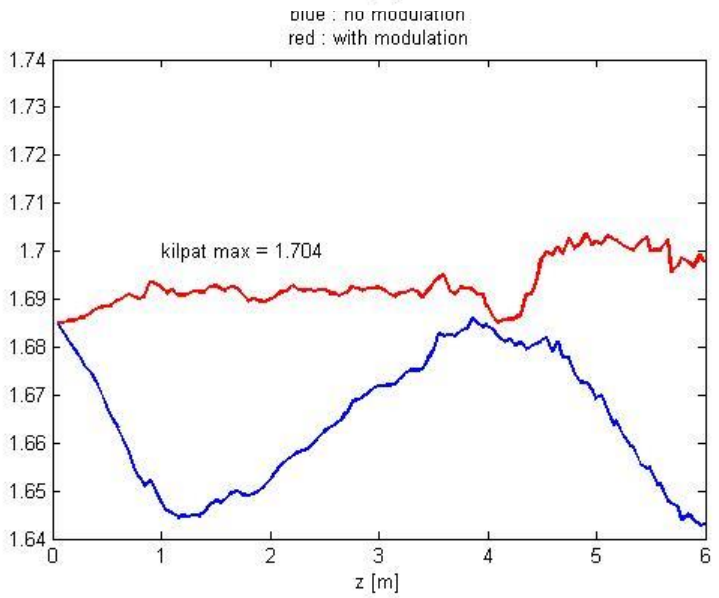
Operation : CW
frequency : 352.2 MHz
Particle : protons
Input energy : 95 keV
Output energy : 3 MeV
Design beam Current : 100 mA
Output beam synchronous phase : -34.1 deg
Average beam phase : -46.2 deg
Stored energy : 3.622 Joules
RF losses : 1180 kW
Q0 : 6790
Total coupling factor (4 RF feeders) : 1.1982 achieved (0.2797+0.2979+0.3218+0.2988) @ 1.254 ideal value
QL : 3089 (Half bandwidth = 57 kHz)
Beam loading detuning : -7 kHz @ 100mA

IPHI RFQ parameters (2)

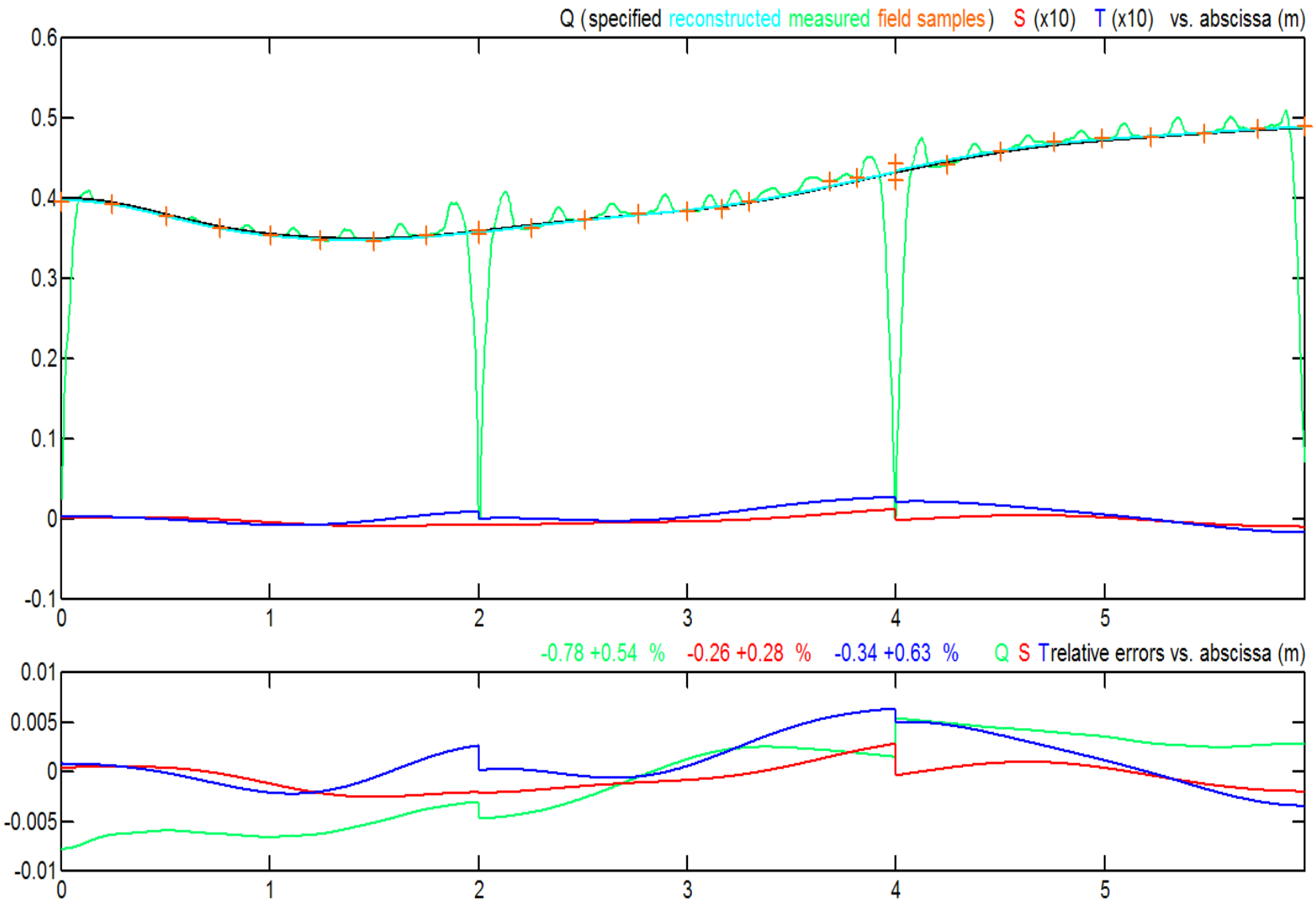






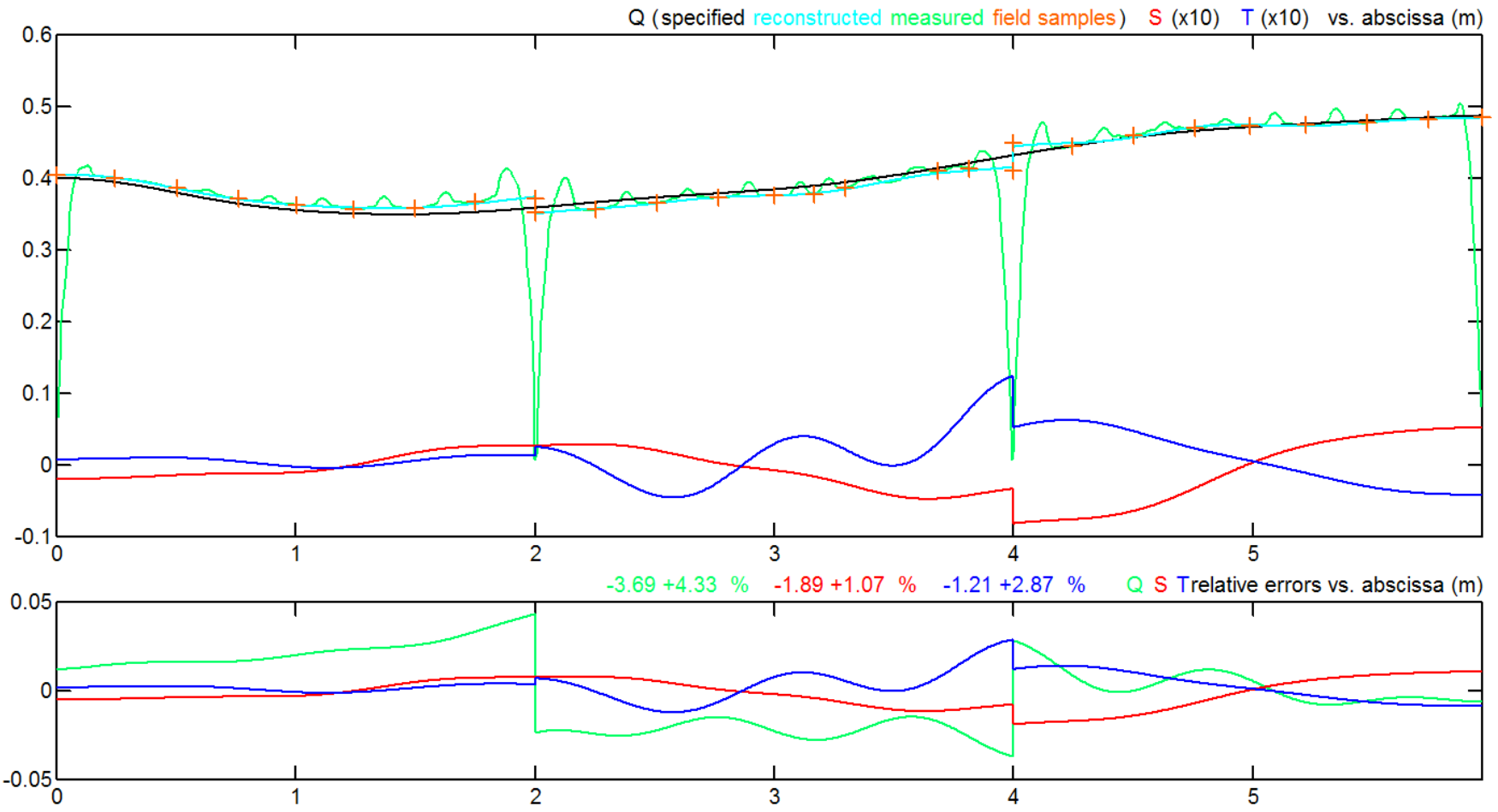


IPHI RFQ
Achieved Voltage after tuning

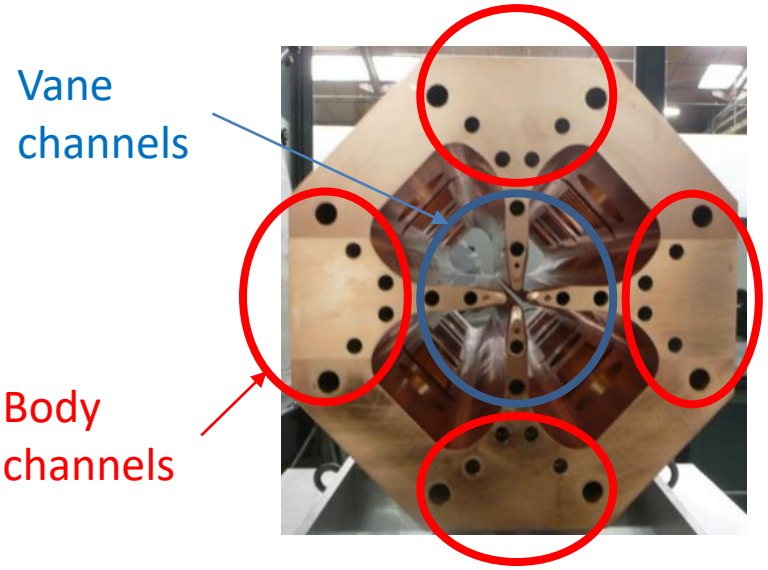


IPHI RFQ
Final Voltage Law

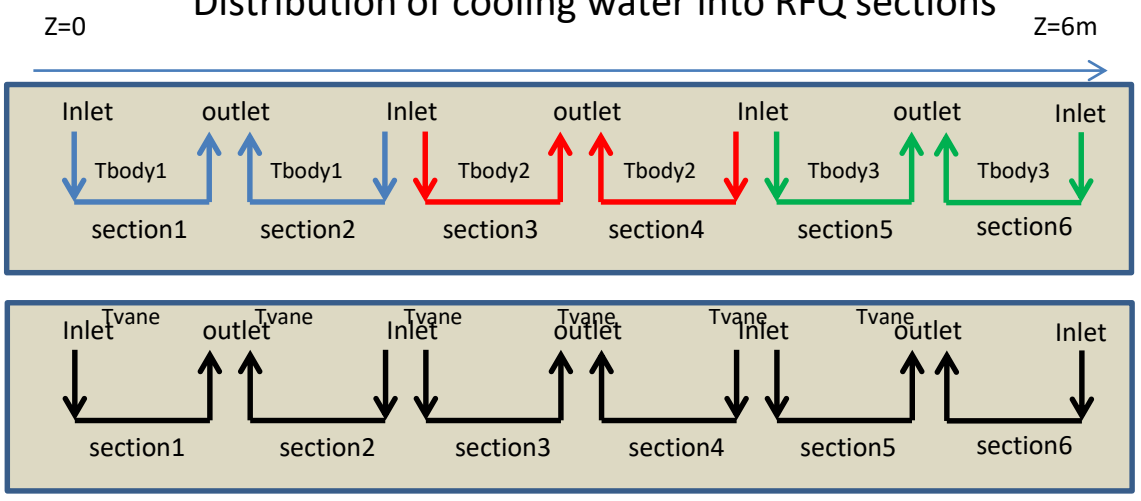
after final assembly Tuners and Power couplers



Cooling system

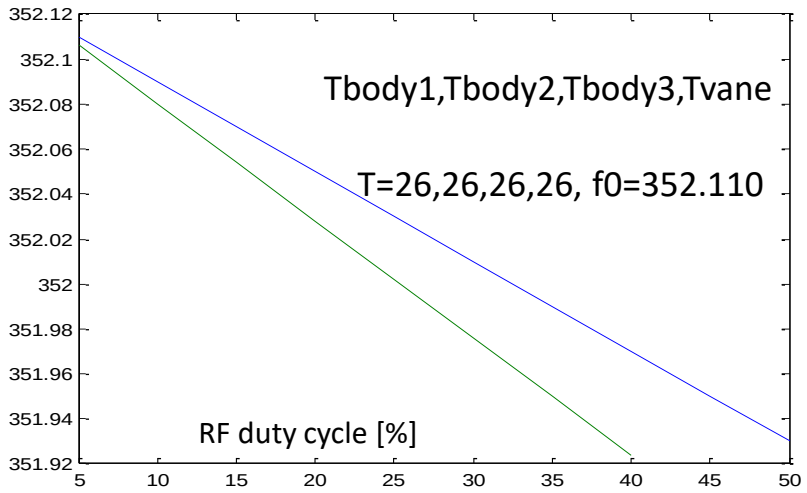


Distribution of cooling water into RFQ sections



RFQ voltage thermal stability (RFQ RF peak power = 1200kW)

RFQ detuning vs RF duty cycle

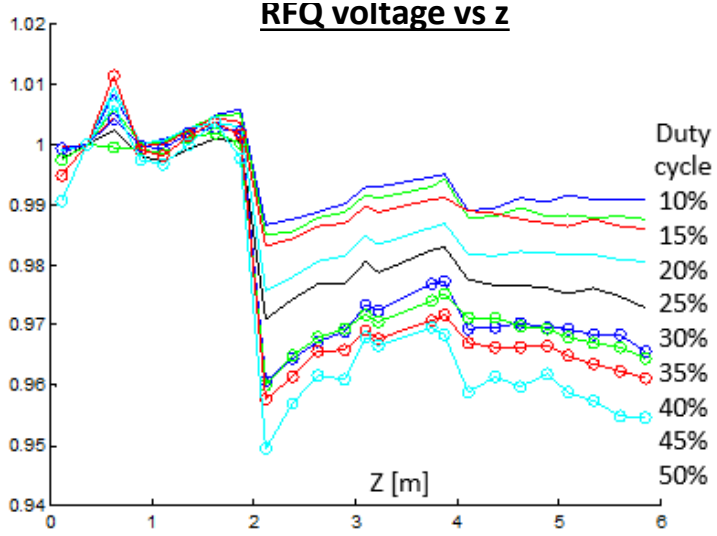


Water flow rate, detuning
Blue : 52 m3/h, -4,0 kHz/%
Green : 40 m3/h, -5,2 kHz/%

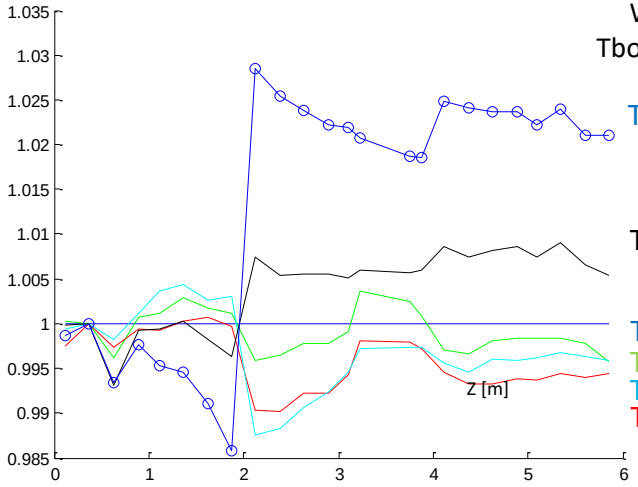
RFQ frequency decrease with increasing duty cycle but can be corrected by adjusting water inlet temperature into Vane channels for a given set of Body channels temperatures

Frequency sensitivity @ Tbody1=Tbody2=Tbody3=Tbody
F=f0+23kHz*(Tboby-T0)-29kHz(Tvane-T0)

RFQ voltage vs z

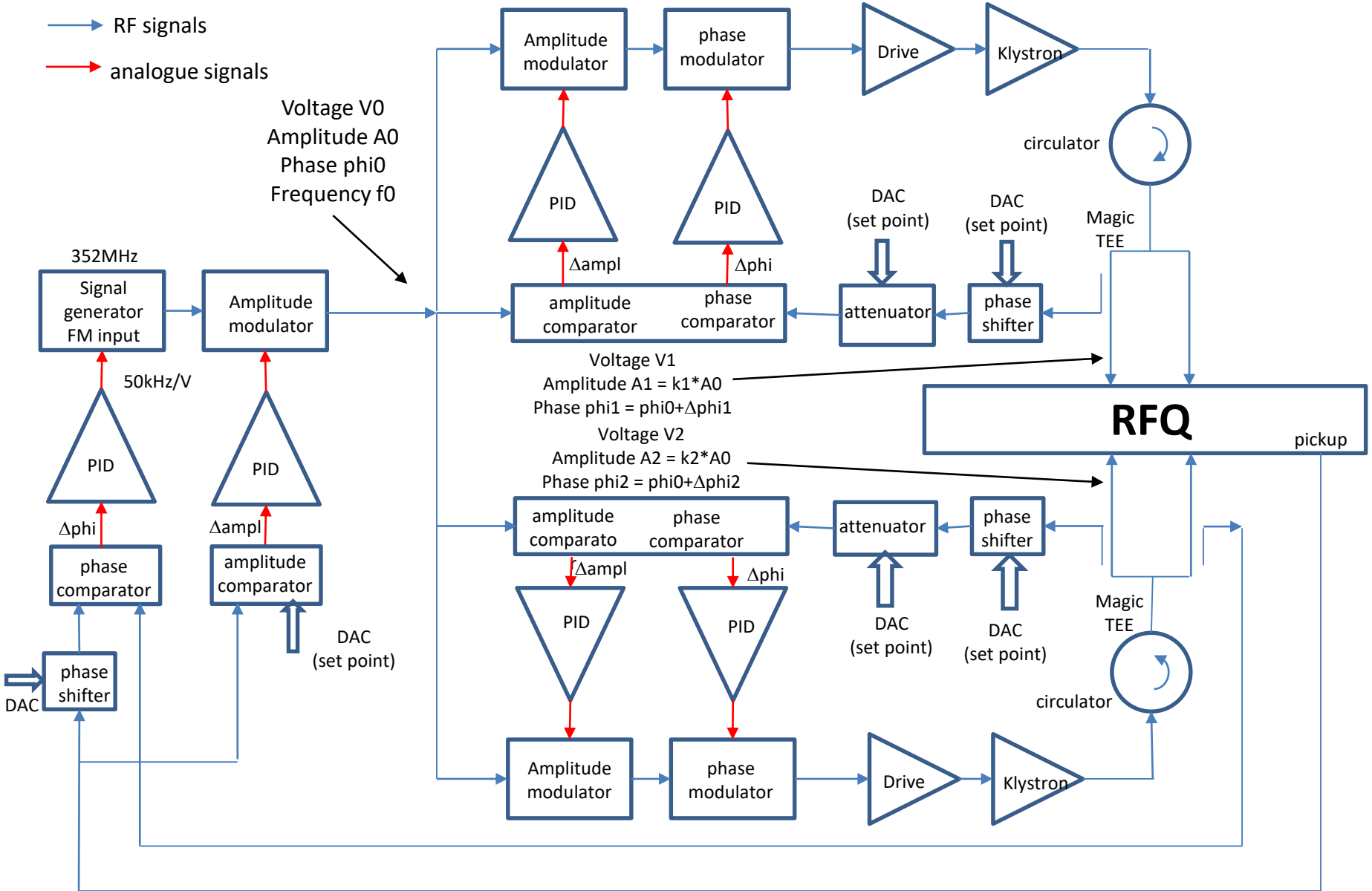


RFQ voltage vs z @40% RF duty cycle



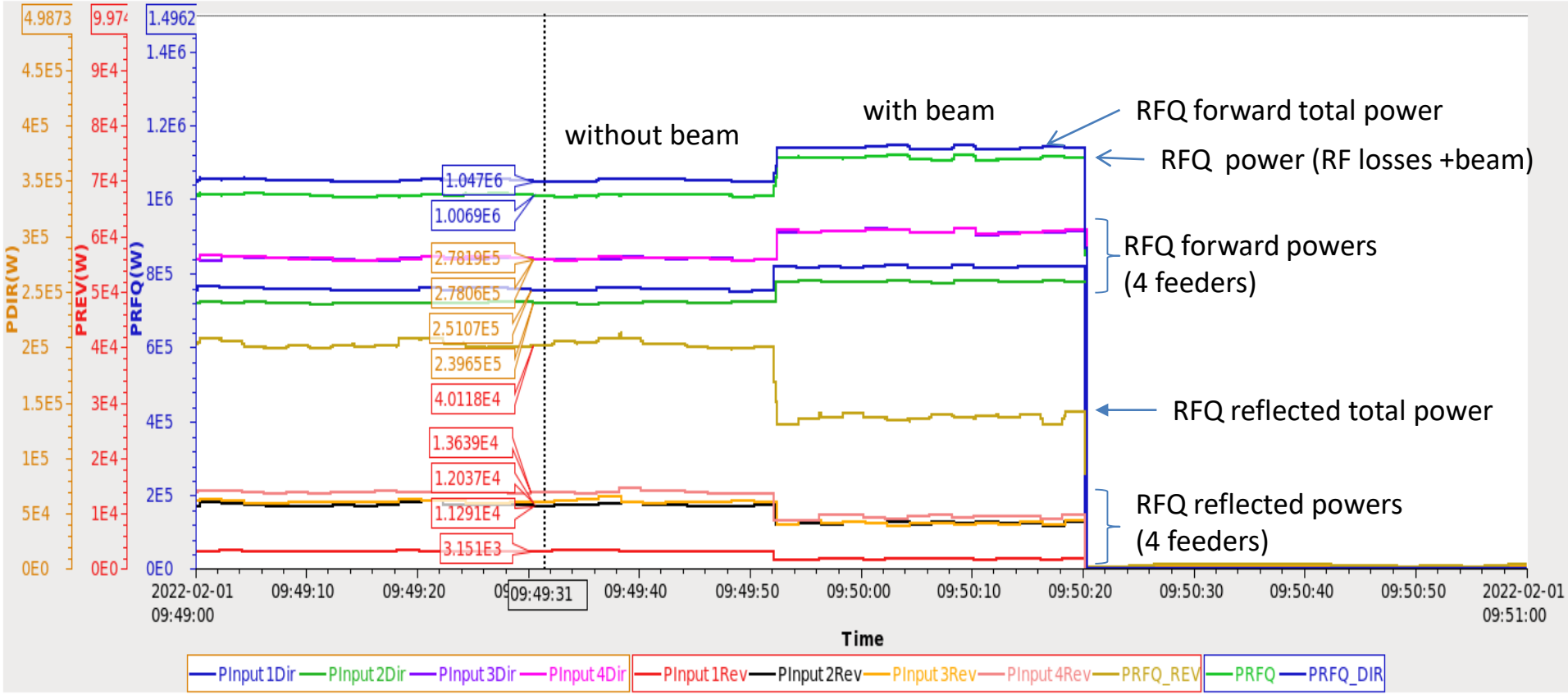
RFQ voltage profile is degraded with increasing duty cycle but can be corrected by adjusting water inlet temperature into Body channels

LLRF Diagram



Beam loading measurement

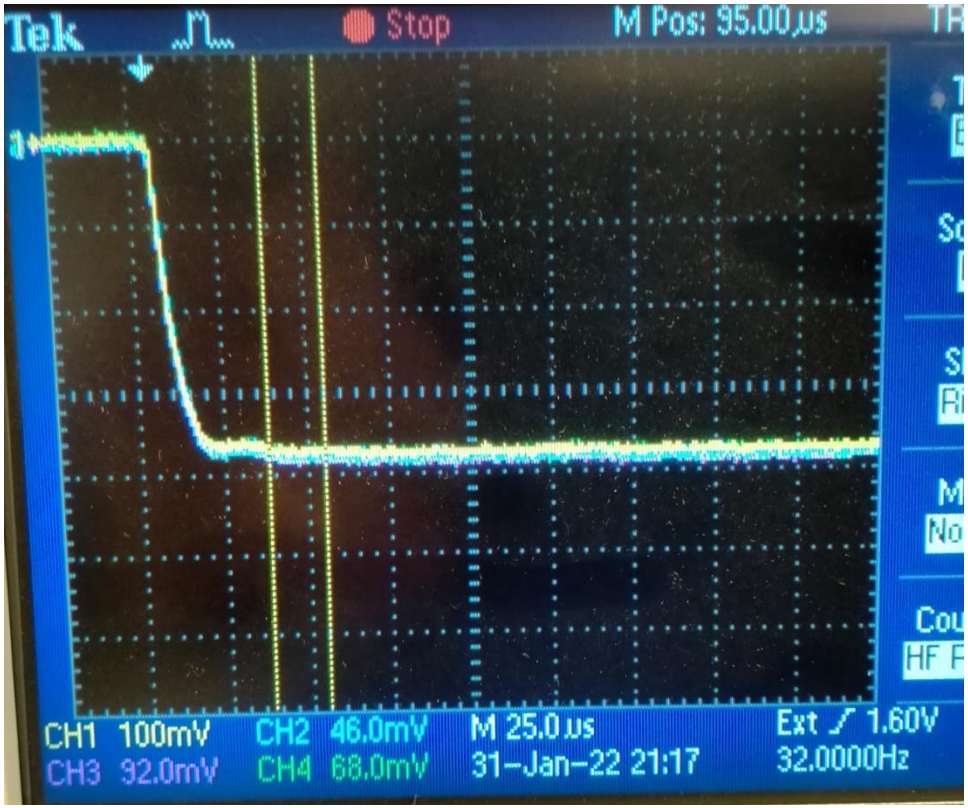
RF pulse : 10ms 32Hz
Beam=35mA



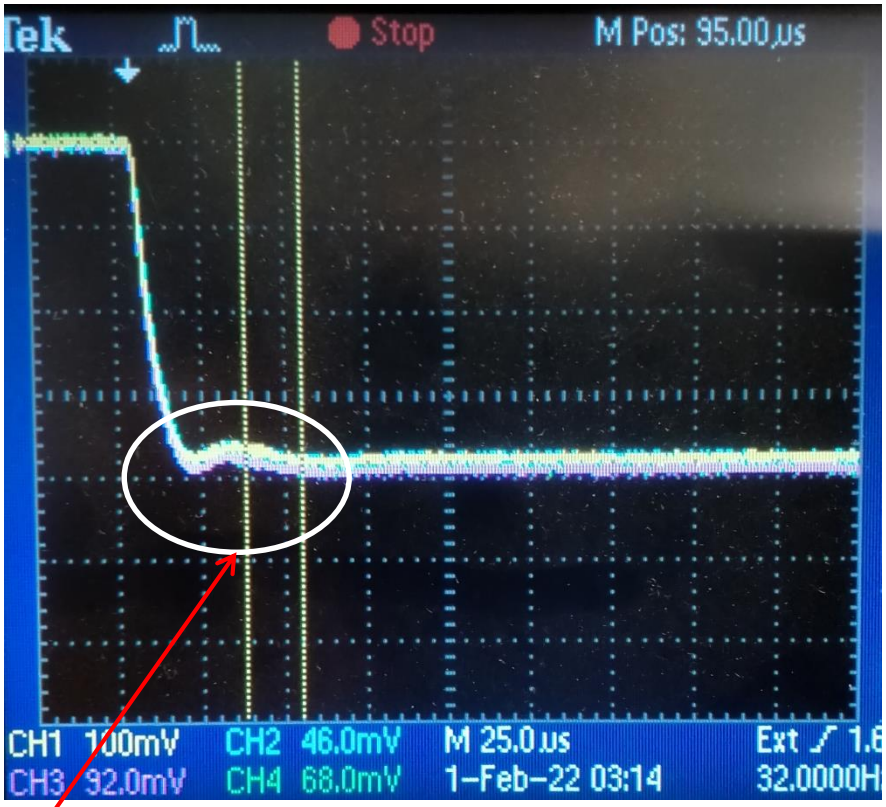
RFQ voltage transient response

Ion source pulse : 12ms 32Hz (starts 2 ms before RFQ pulse)
RFQ pulse : 10ms 32Hz
4 pickups amplitudes at z=0.25m
(negative output RF detectors)

with 30mA beam



without beam



Larger ringing without beam because larger open loop gain :
Higher gain of klystron at lower power
Higher gain of amplitude modulator at larger attenuation value

RFQ beam loading

RF pulse : 10ms 32Hz
Ion source is stopped 200us after RFQ pulse start

4 RFQ pickups amplitudes at z=0.25m
(negative output RF detectors)

with 30mA beam

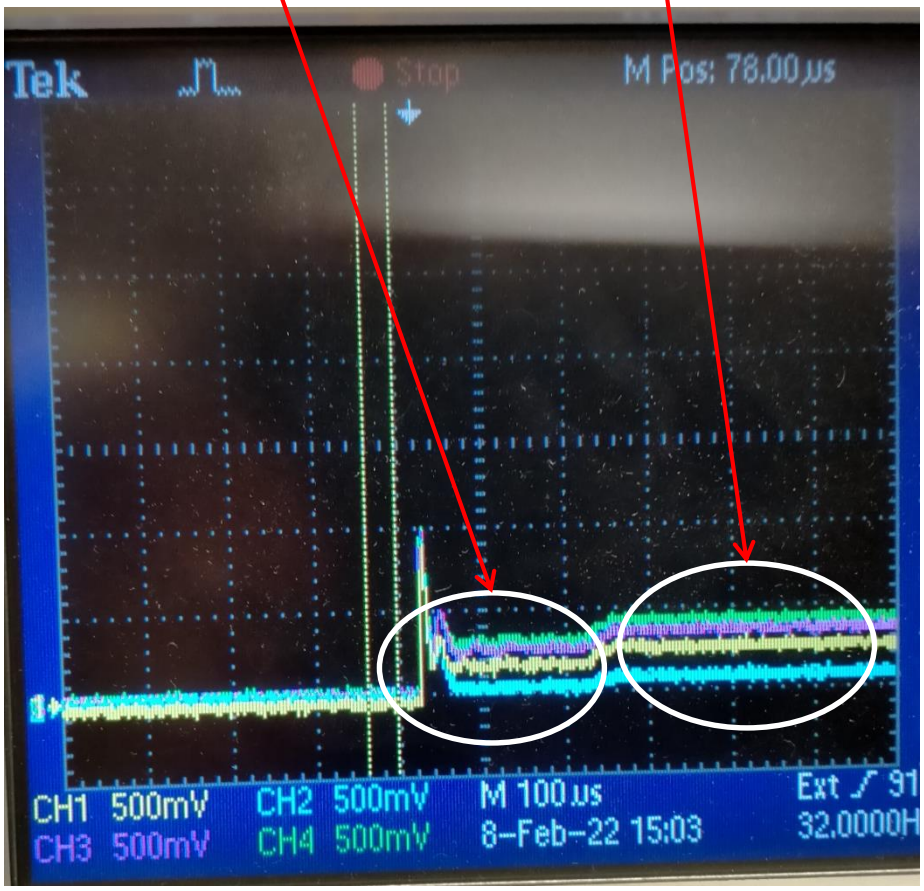
without beam

RFQ transient overvoltage

RFQ reflected power (4 feeders)

with 30mA beam

without beam



RFQ detuning

RF pulse : 10ms

Trace1 (Yellow) : RFQ pickup power (10dB/div)
Tace2 (Blue) : RFQ detuning (2.5kHz/div)
Trace3 (Purple) : amplitude modulator control voltage
(for RFQ voltage feedback control)

30mA Beam is stopped 200us after RF pulse start
Beam detuning : -1.5kHz/30mA

with beam

without beam

Thermal detuning : -1.5kHz/10ms