FROM RESEARCH TO INDUSTRY

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LINAC2022
LIVERPOOL

SARAF COMMISSIONING: INJECTOR, MEBT AND CHOPPER

OUTLINE

1. INTRODUCTION

2. INSTALLATION STATUS

3. SARAF FAST CHOPPER (SNRC)

4. CONTROL SYSTEM (INJECTOR+MEBT)

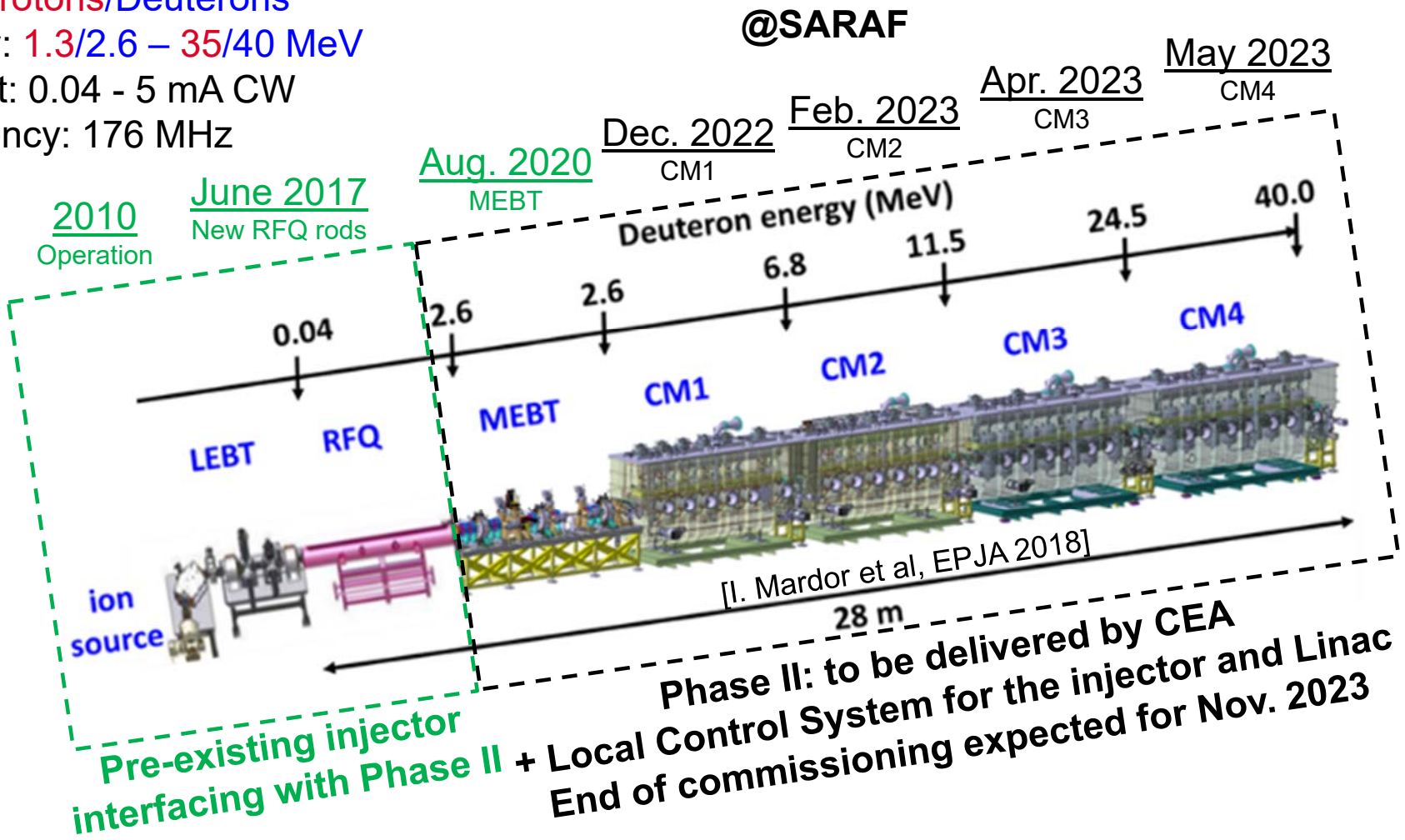
5. INJECTOR AND MEBT BEAM COMMISSIONING STATUS

Jonathan Dumas on behalf of the Saraf-linac project teams

SEPTEMBER 2, 2022

SARAF accelerator for neutron production

Ions: Protons/Deuterons
Energy: 1.3/2.6 – 35/40 MeV
Current: 0.04 - 5 mA CW
Frequency: 176 MHz



MEBT COMMISSIONING SETUP

SARAF accelerator for neutron production

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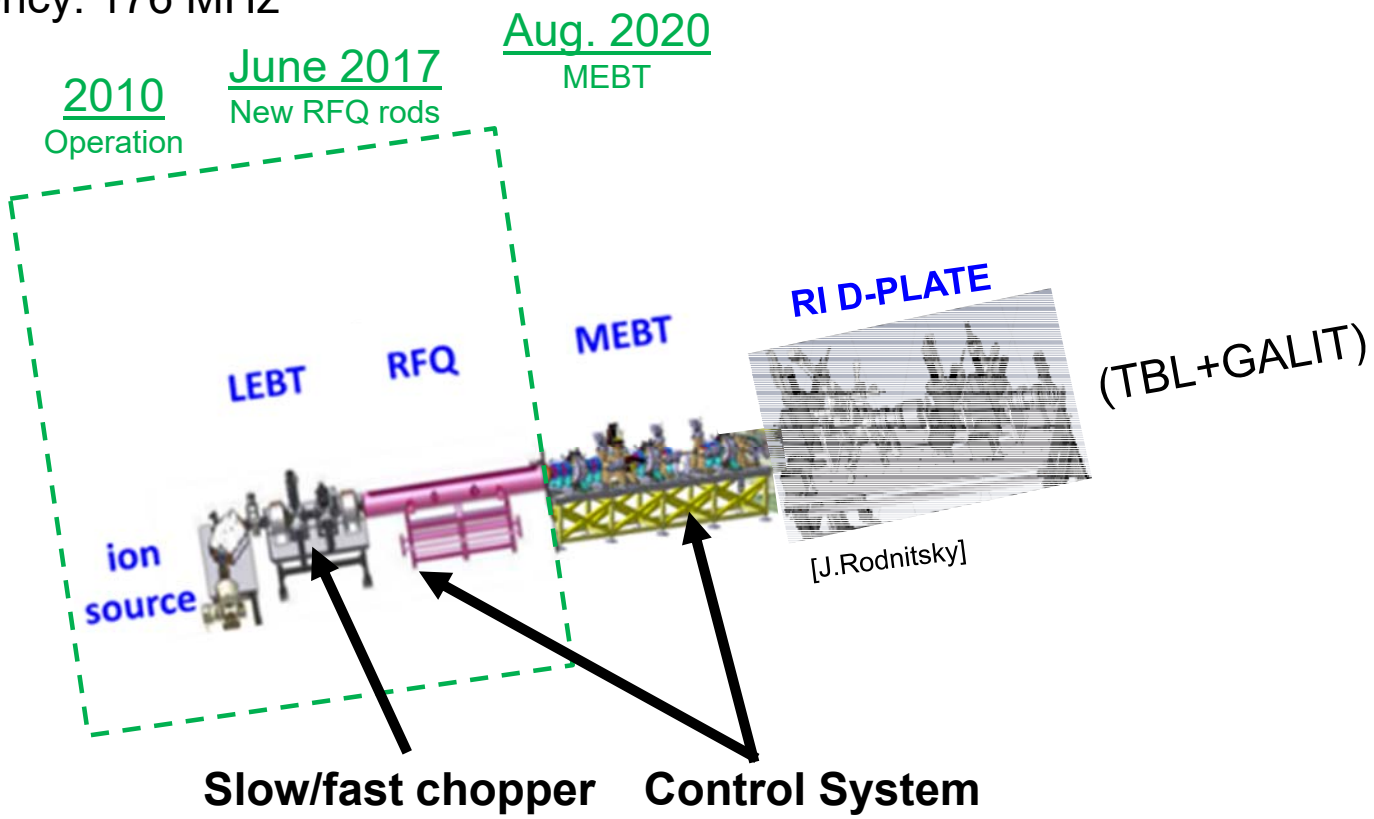
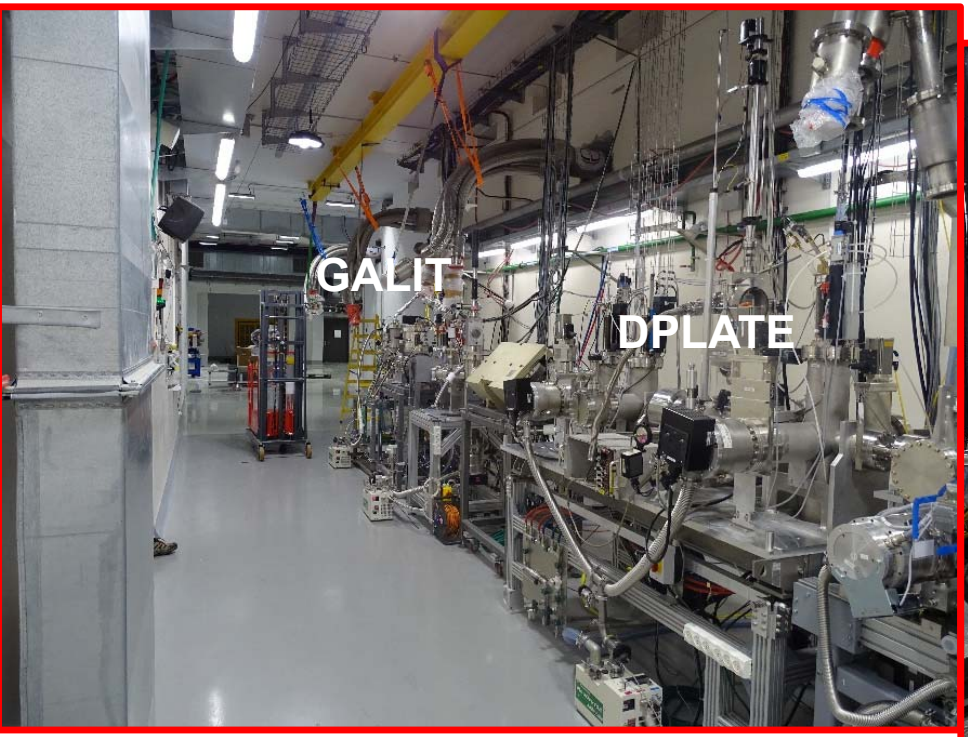
Energy: 1.3/2.6 – 35/40 MeV

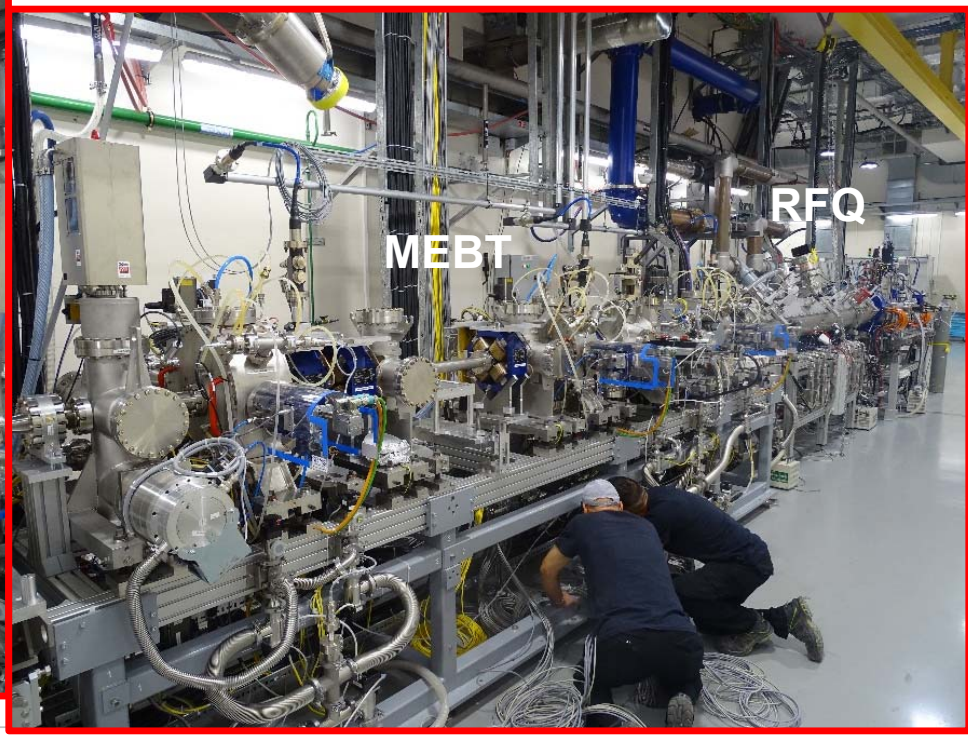
Current: 0.04 - 5 mA CW

Frequency: 176 MHz



INSTALLATION STATUS





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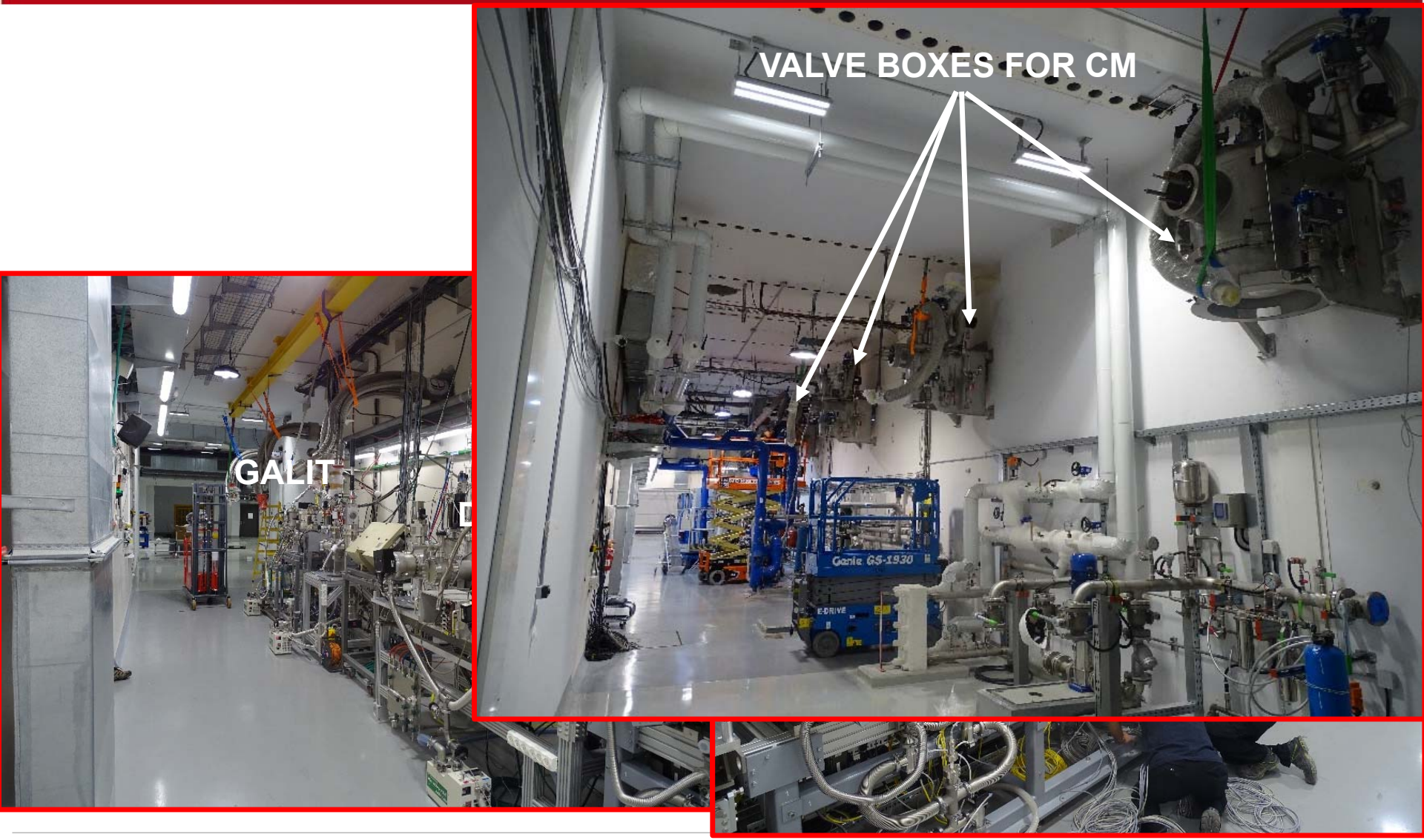

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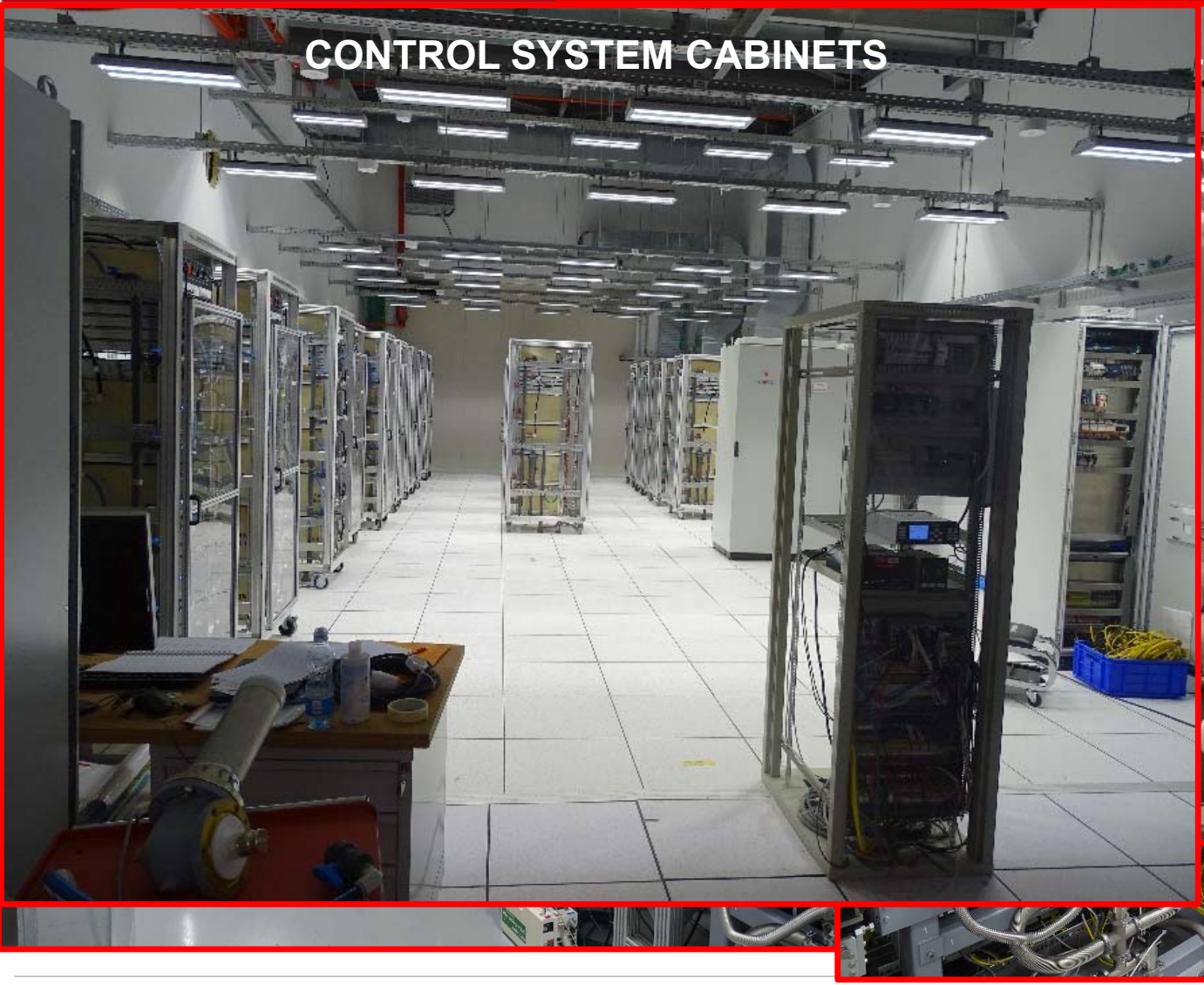
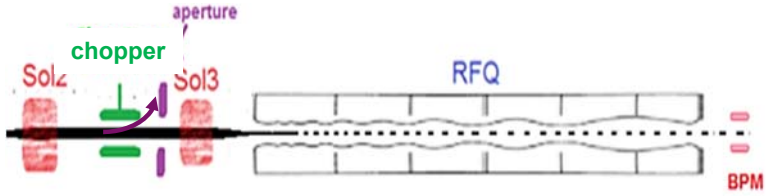


SARAF FAST CHOPPER IN THE LEBT

Slow chopper mode:

Deflection of beam in LEBT

Shortest chopping time ~ 180 ns

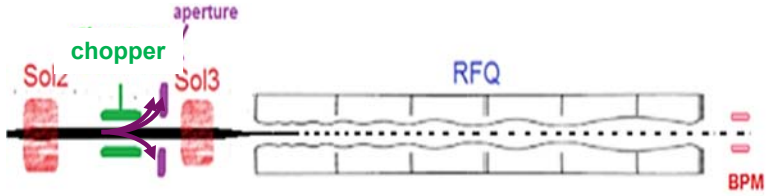


Fast chopper mode:

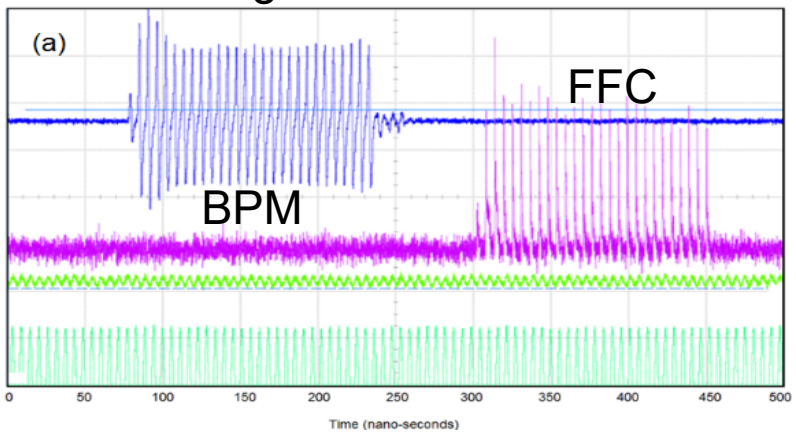
Sweep of beam in LEBT

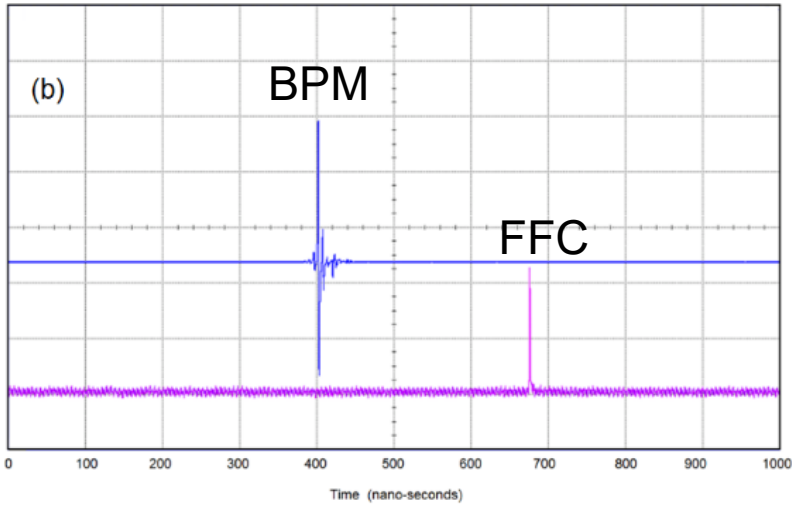
Sweep voltage synchronized with RF

Pseudo single bunch is formed in RFQ



Signals after RFQ





Courtesy of L. Weissman (SNRC)

A. Shor et al., Phys. Rev. Accel. Beams 22, 020403 (2019)

EPICS environment

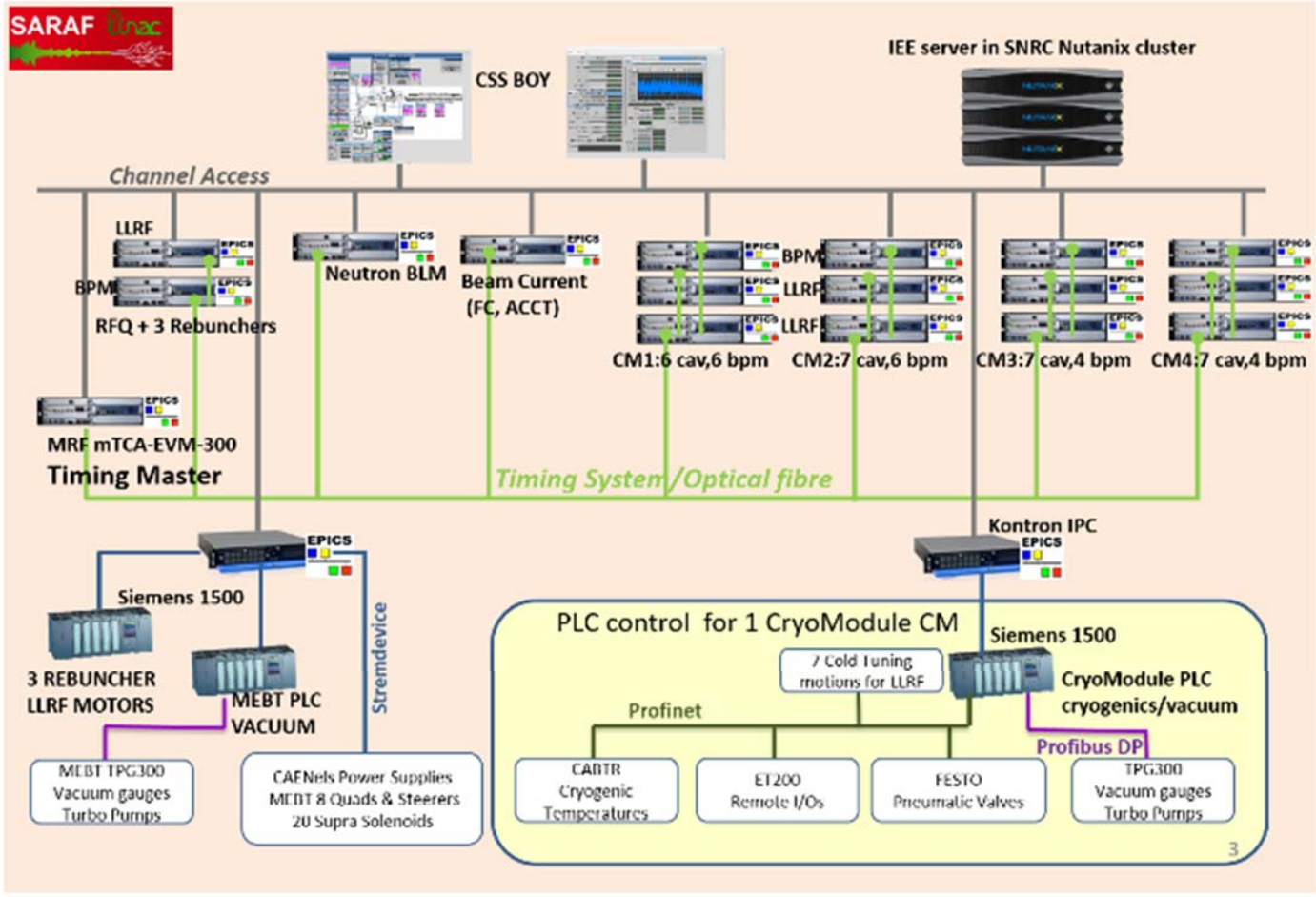
Common platform to control:

- Injector local control system (LCS)
- MEBT LCS
- SCL LCS

Hardware
MTCA.4
Siemens 1500 PLC
Industrial PC

MRF for timing system

IOxOS boards for fast acquisition for current measurement and beam loss monitors



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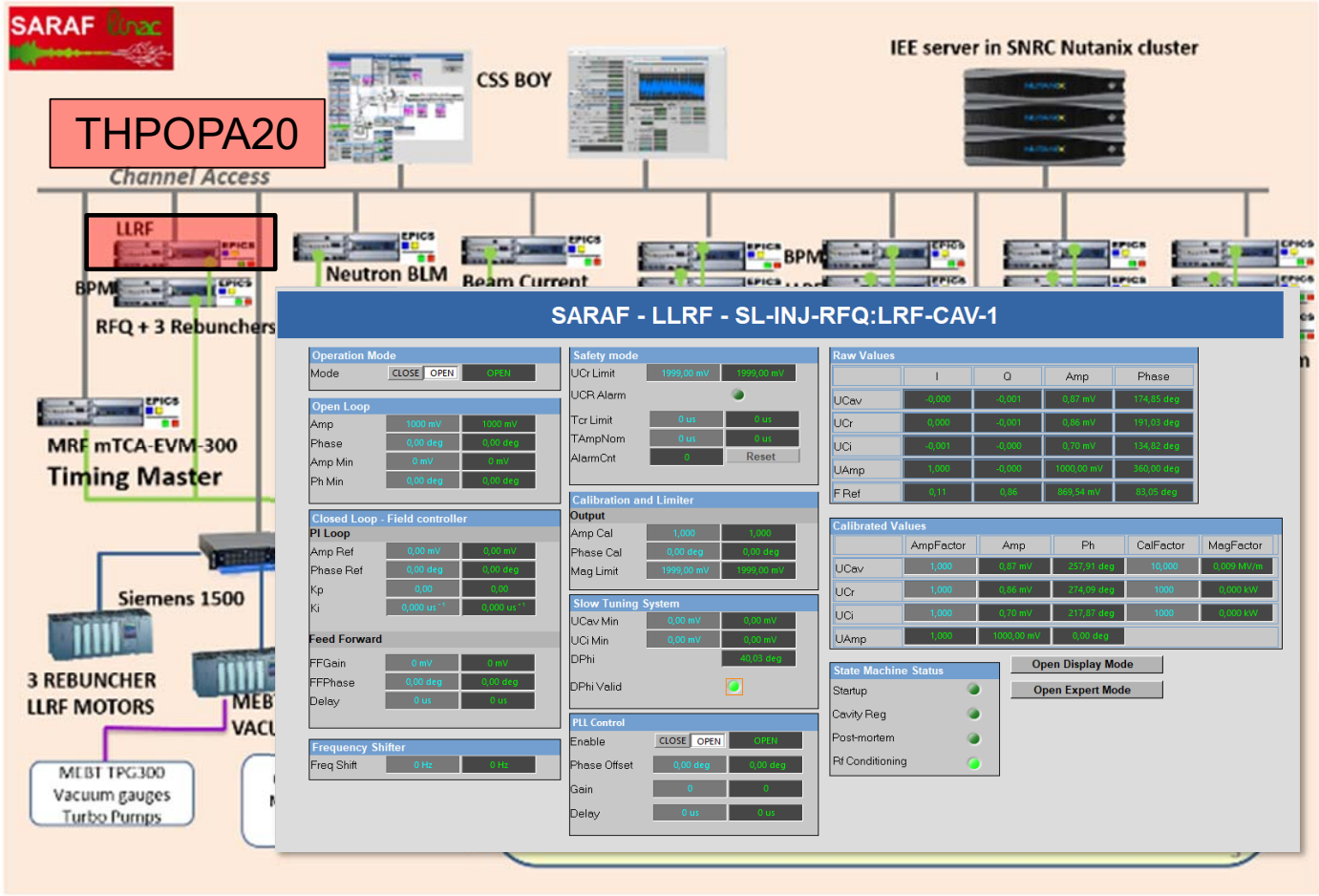
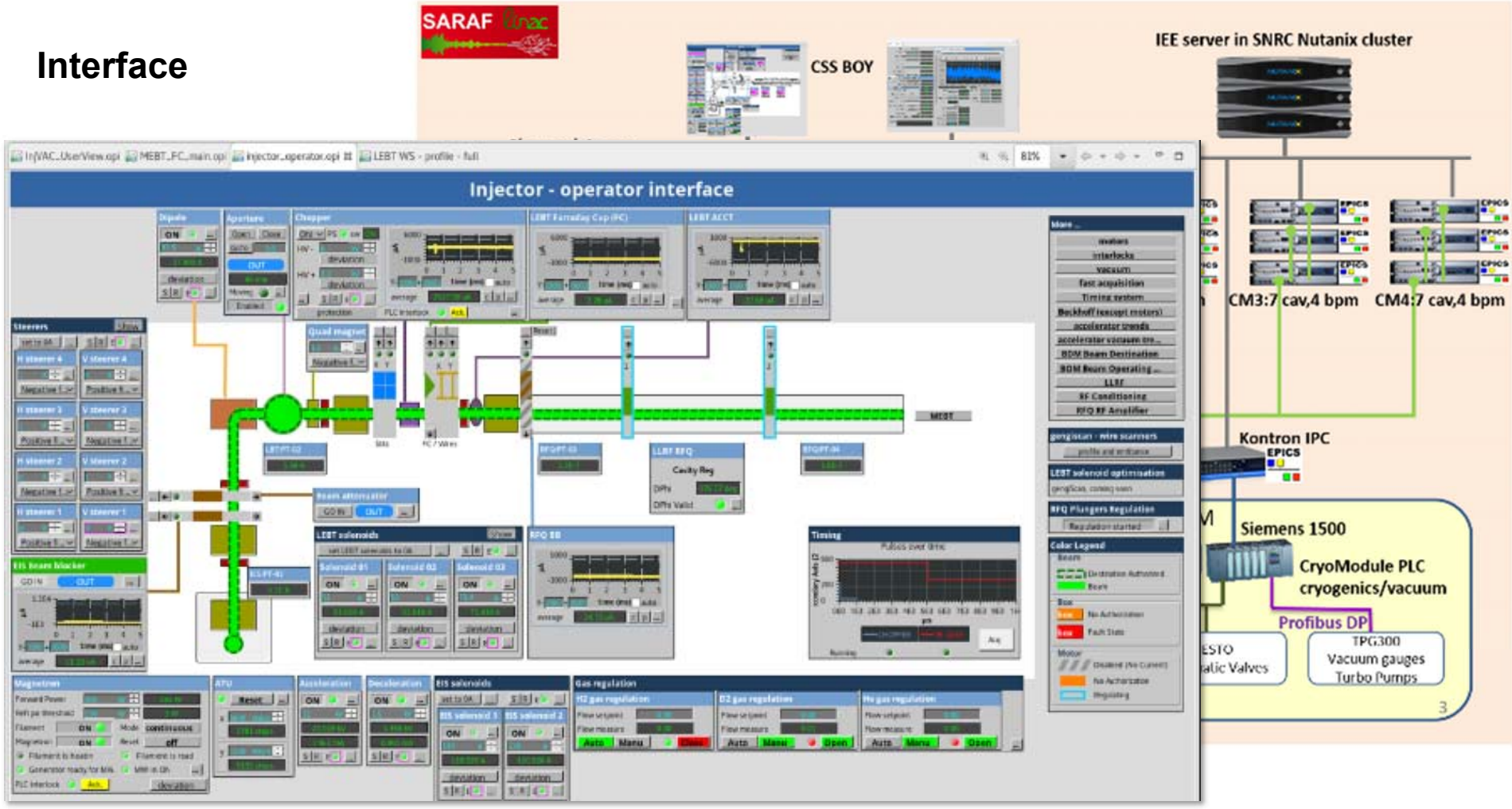
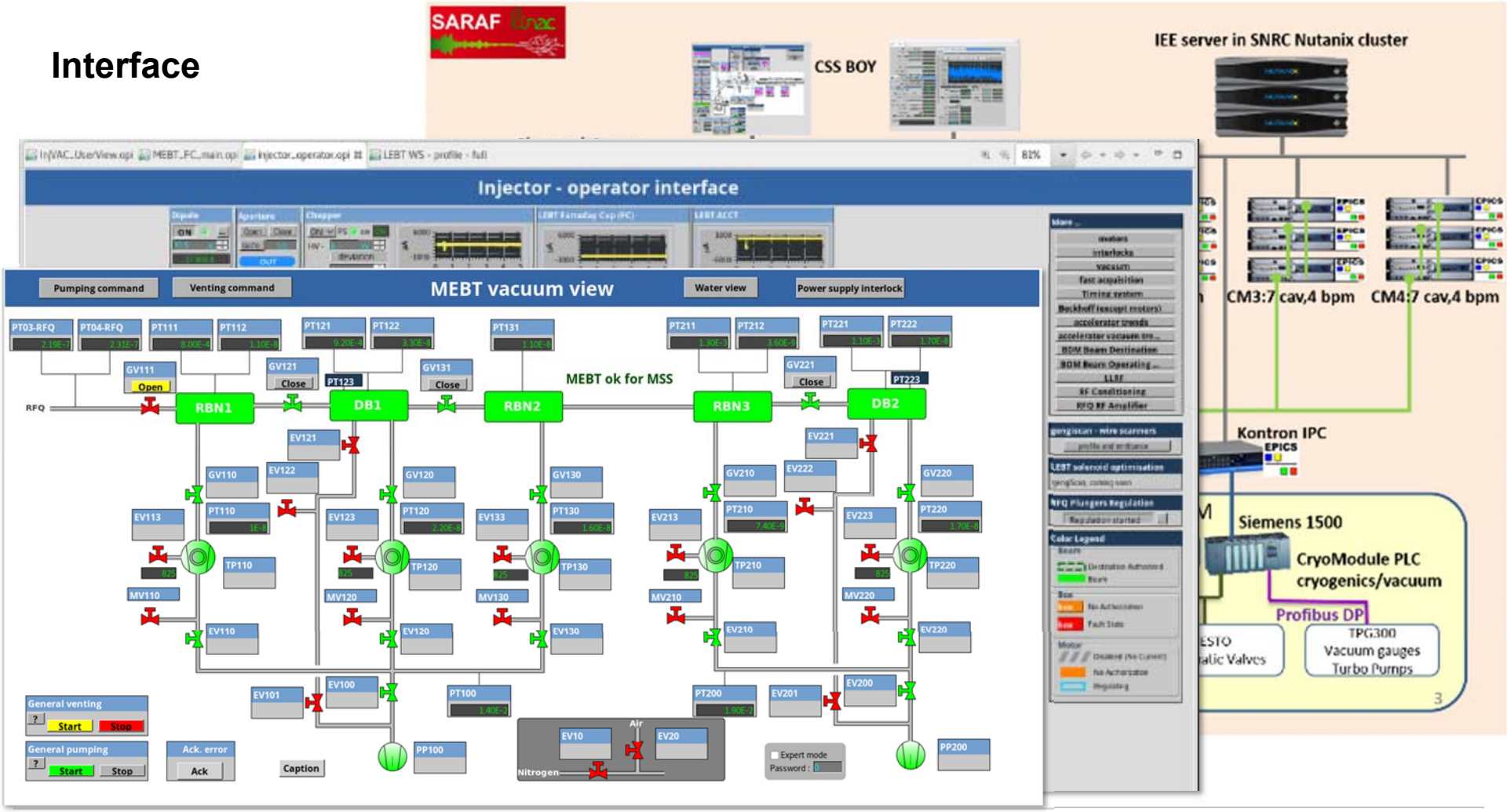


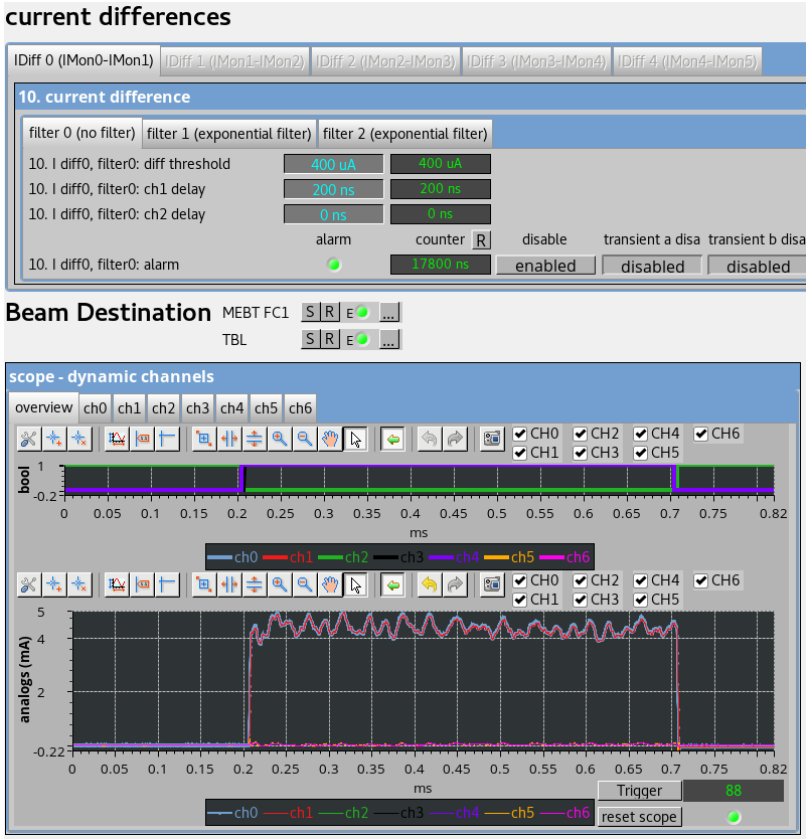
Interface


SARAF linac
CSS BOY
IEE server in SNRC Nutanix cluster
Injector - operator interface
CM3:7 cav,4 bpm
CM4:7 cav,4 bpm
Kontron IPC
EPICS
Siemens 1500
CryoModule PLC
cryogenics/vacuum
Profibus DP
TPG300
Vacuum gauges
Turbo Pumps

Interface

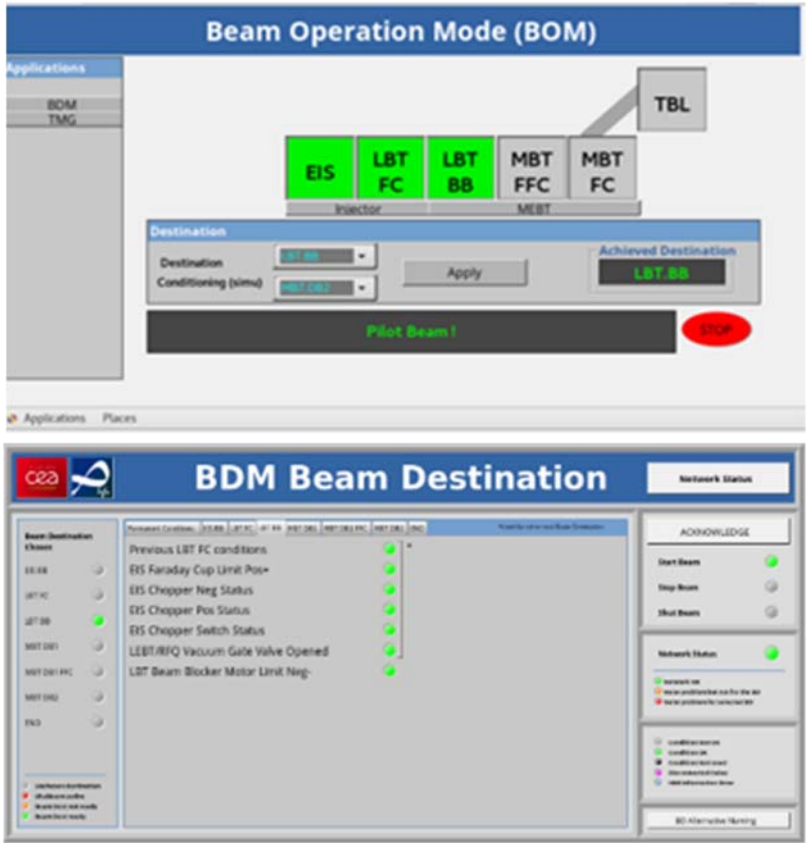

SARAF linac
CSS BOY
IEE server in SNRC Nutanix cluster
Injector - operator interface
Pumping command
Venting command
MEBT vacuum view
Water view
Power supply interlock
MEBT ok for MSS
RBN1
DB1
RBN2
RBN3
DB2
RFQ
CM3:7 cav,4 bpm
CM4:7 cav,4 bpm
Kontron IPC
Siemens 1500
CryoModule PLC
cryogenics/vacuum
Profibus DP
TPG300
Vacuum gauges
Turbo Pumps
General venting
General pumping
Start
Stop
Ack. error
Ack
Caption
Nitrogen
Air
Expert mode
Password :

Section Beam Current Transmission



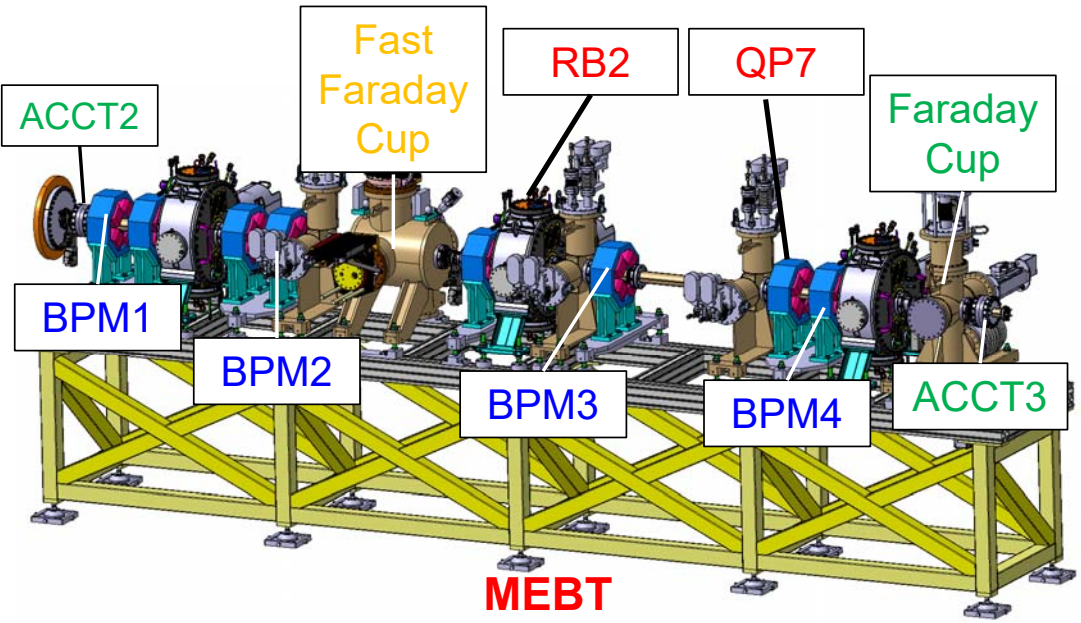
Monitors current difference between 2 ACCT to prevent harmful losses.

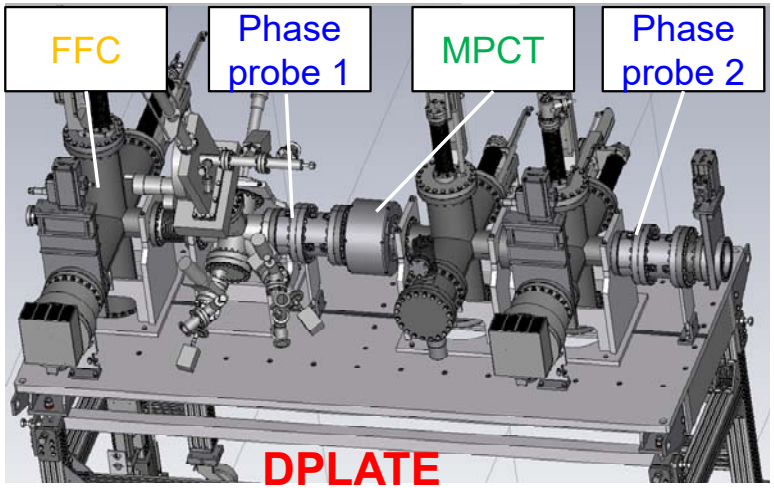
BOM for beam destination request



BDM for accepting beam destination request

BEAM COMMISSIONNING
DEC. 2021 AND APR.-JULY 2022



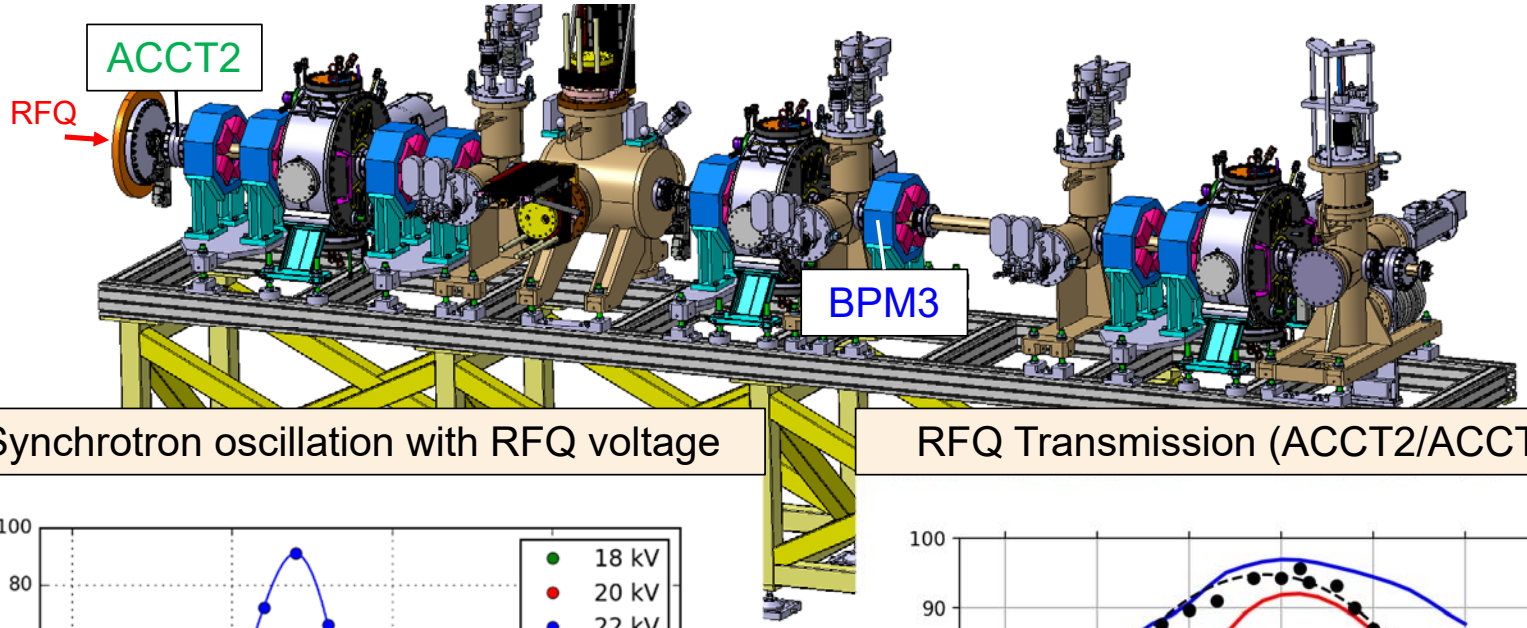


Goals for a low power proton beam (low DC, 5mA peak, 1.28 MeV)

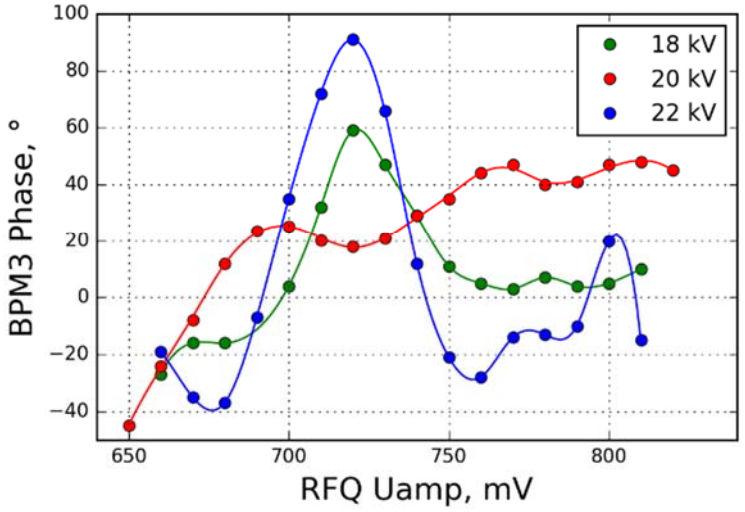
- Using available diagnostics in beam conditions ✔
- Measure RFQ/MEBT transmission using nominal transverse optics ✔
- Rebunchers calibration (beam phase/energy, rebuncher phase/amplitude) ✔
- Longitudinal beam characterization (bunch length, emittance) ✔

ION SOURCE EXTRACTION TUNING

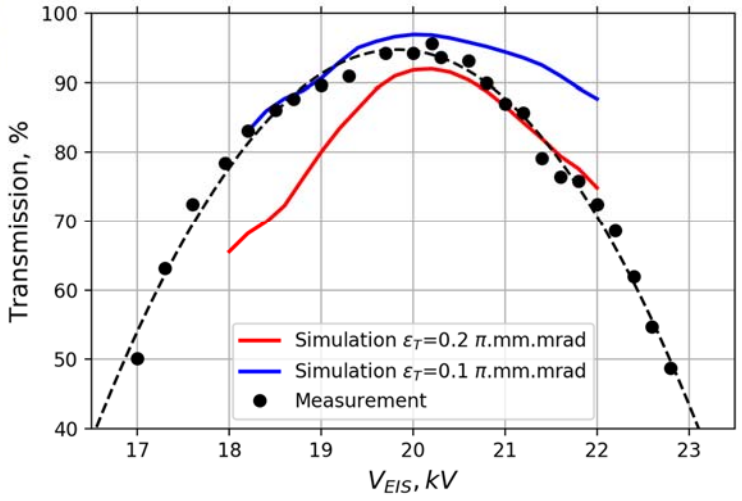
Nominal transverse optics from simulations



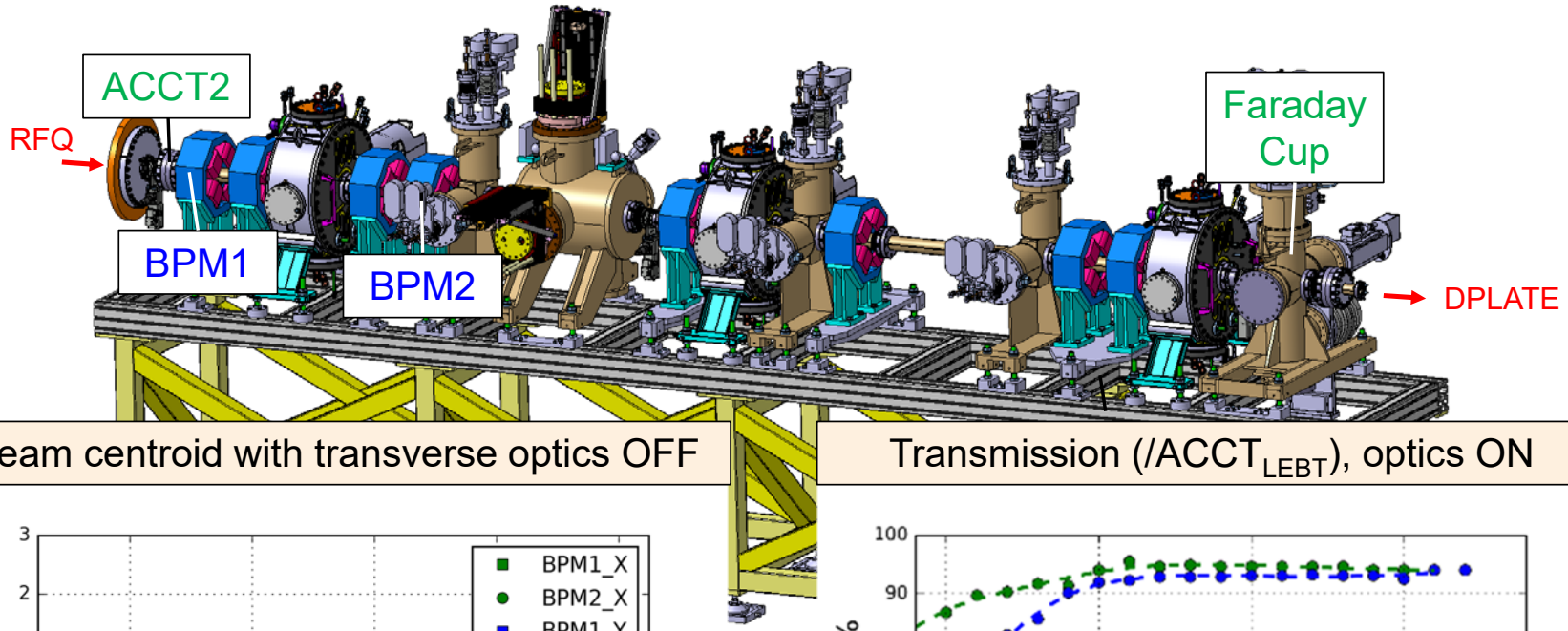
Synchrotron oscillation with RFQ voltage



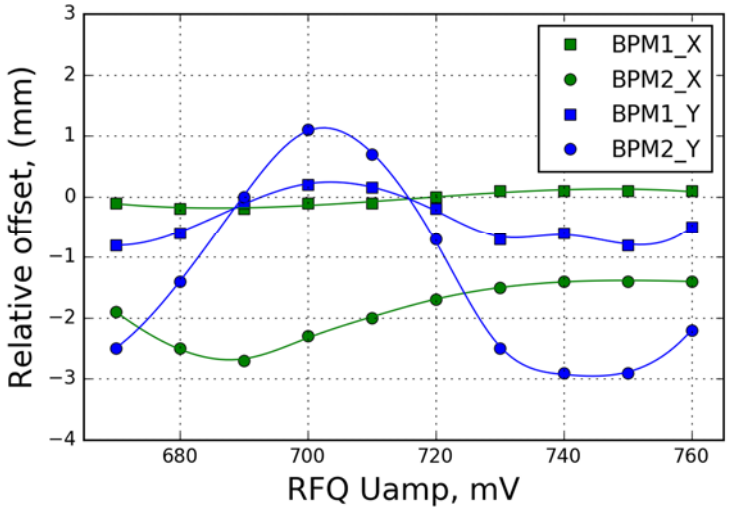
RFQ Transmission (ACCT2/ACCT$_{LEBT}$)



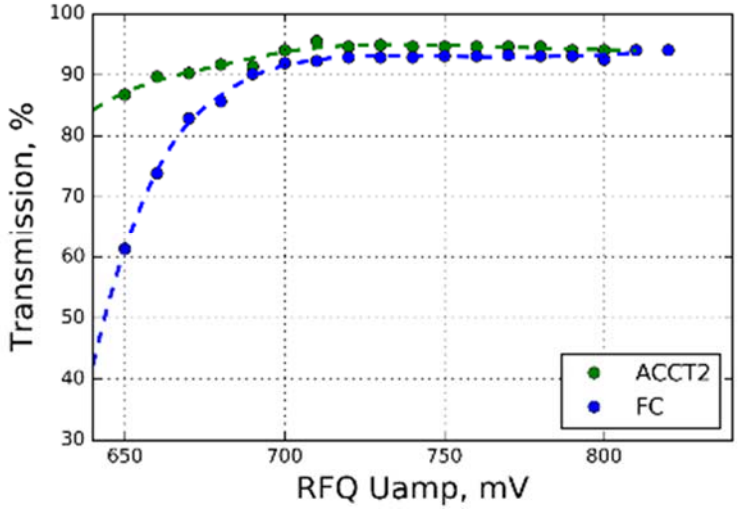
RFQ TUNING AND IMPACT ON CENTROID



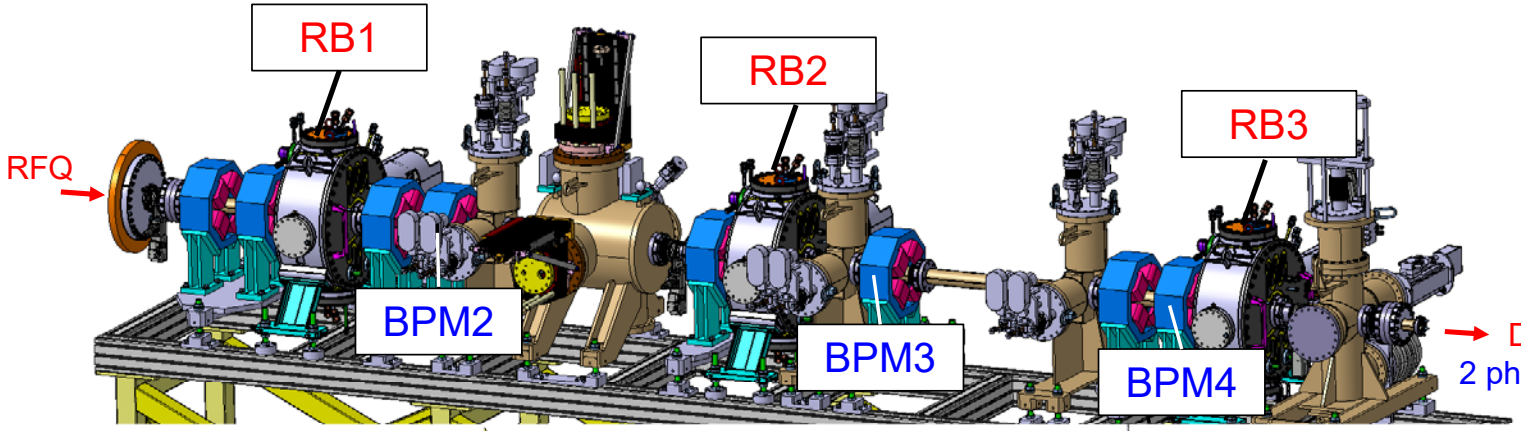
Beam centroid with transverse optics OFF

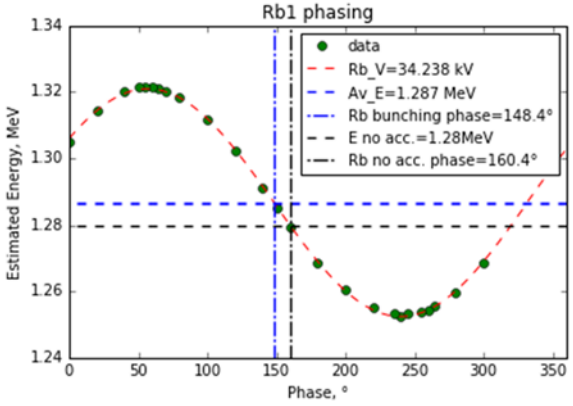


Transmission (/$ACCT_{LEBT}$), optics ON

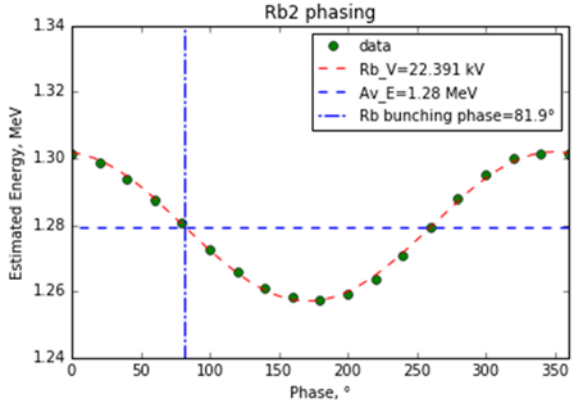


PHASING OF REBUNCHERS: SIGNATURE MATCHING

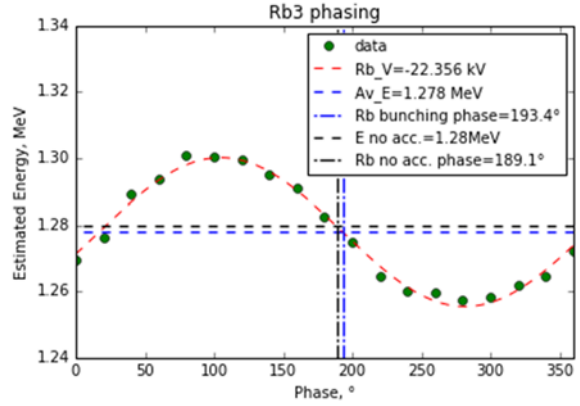




Using BPM2-BPM3



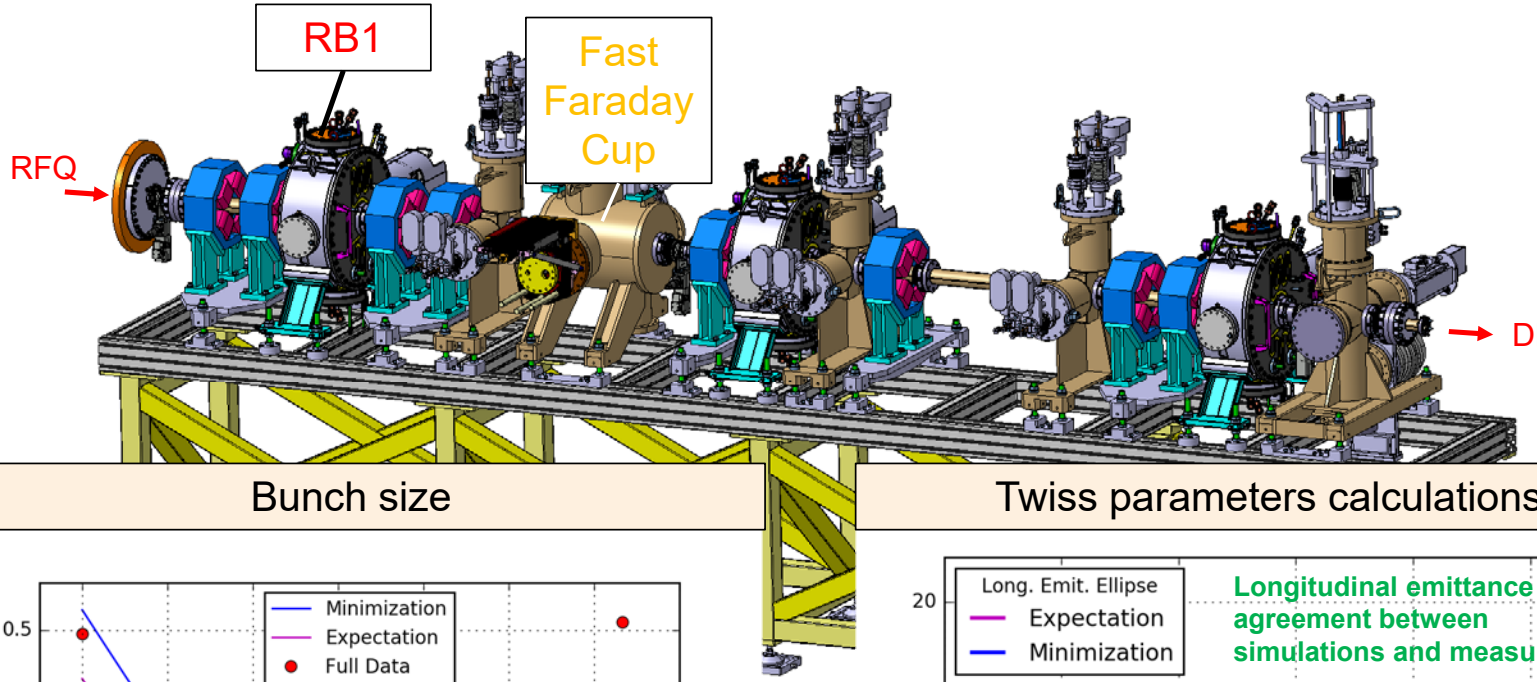
Using BPM3-BPM4



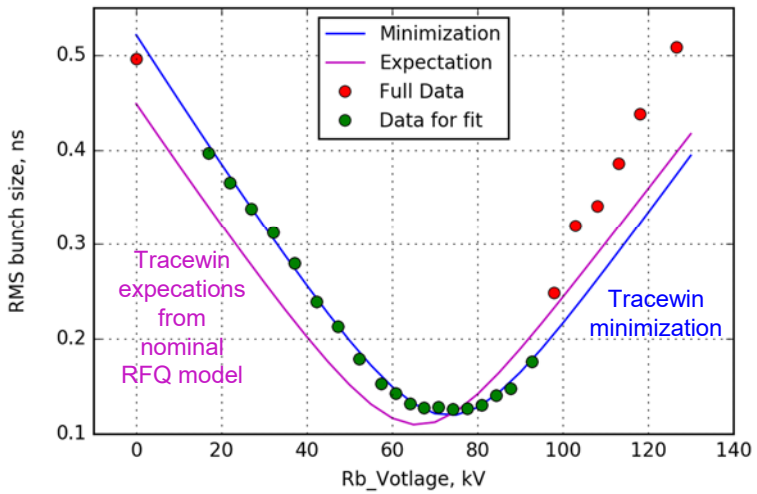
Using DPLATE Phase probes

- BPM phase measurement very stable
- Calibration of RB voltage vs LLRF voltage setpoint (Ucav=150mV)
- Calibration of Rebunching phase vs LLRF phase setpoint

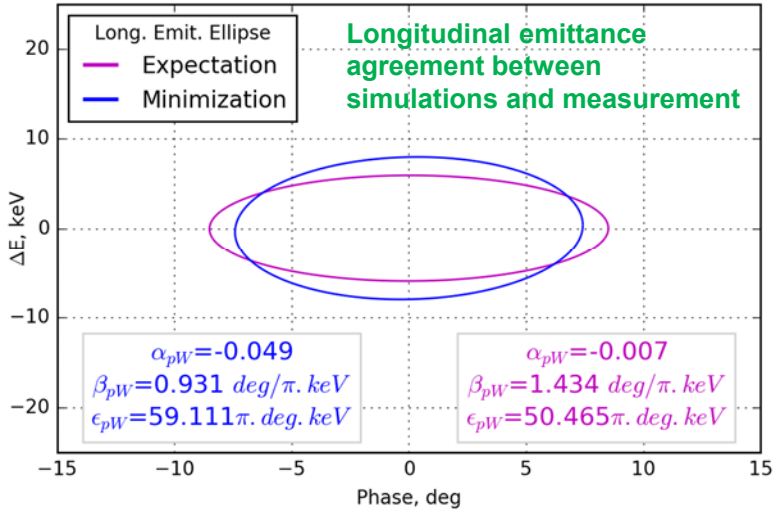
LONGITUDINAL EMITTANCE : 3 GRADIENT VARIATION



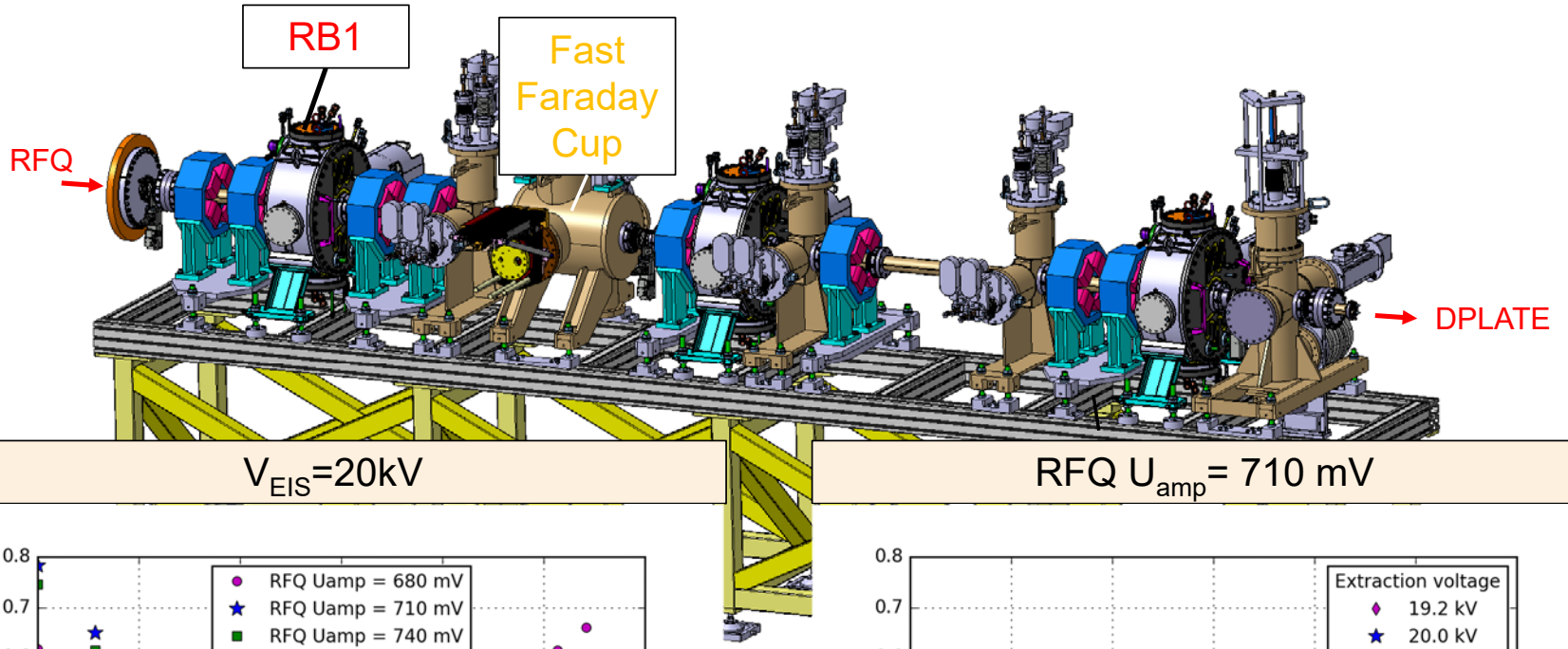
Bunch size



Twiss parameters calculations

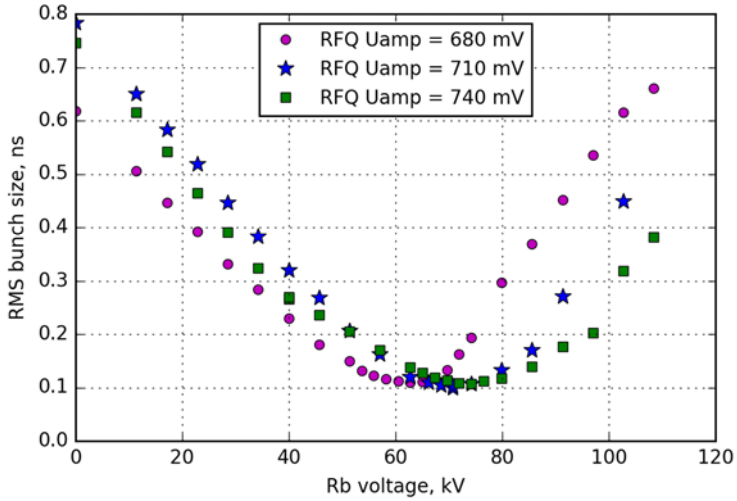


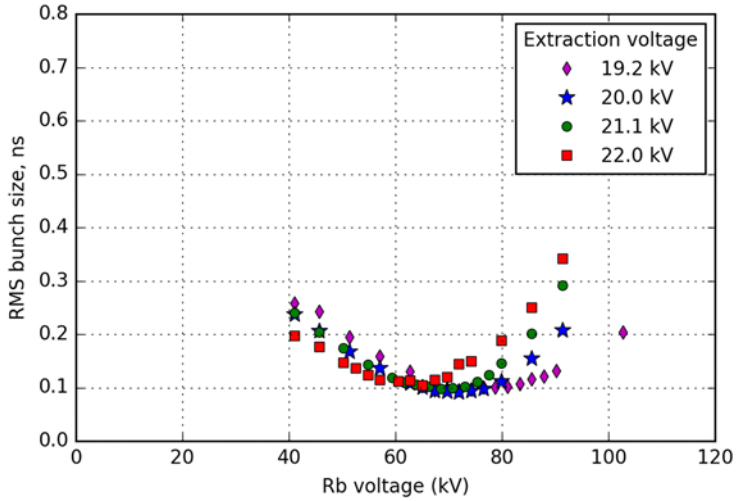
LONGITUDINAL EMITTANCE VARIATIONS: SOURCE EXTRACTION AND RFQ VOLTAGE



V_{EIS}=20kV

RFQ U_{amp}= 710 mV





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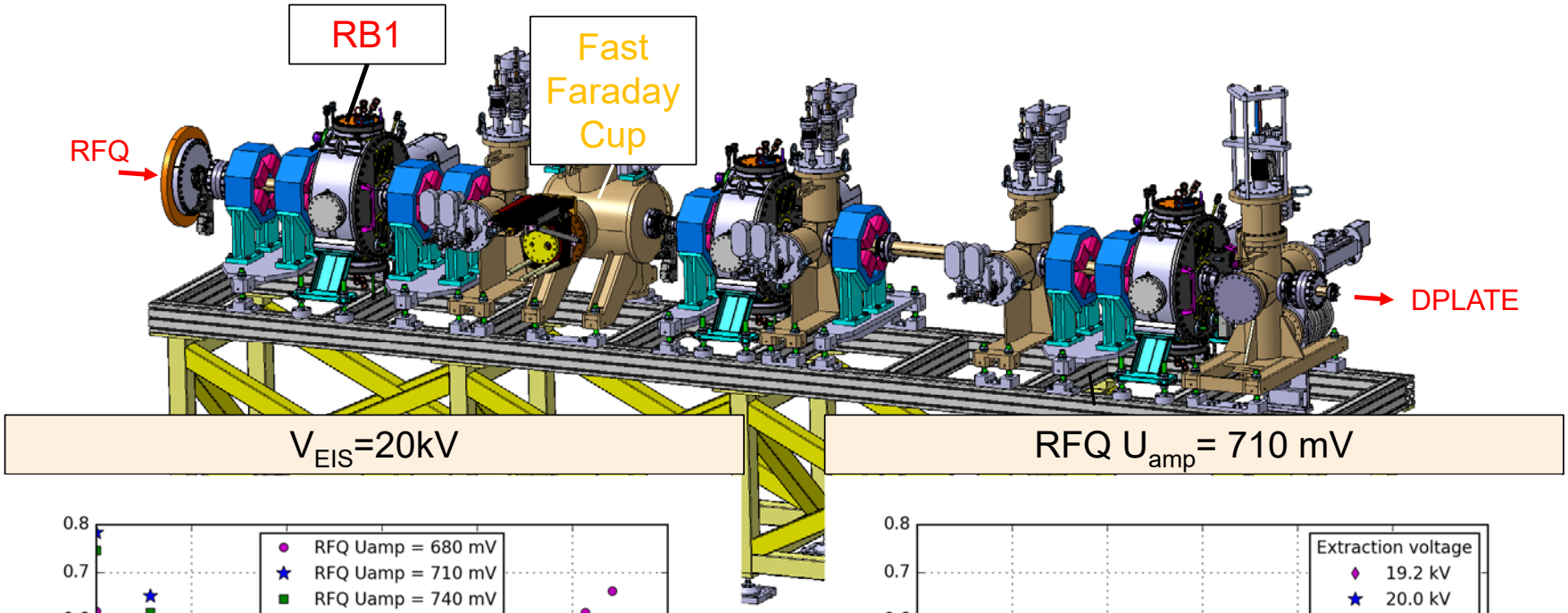


V_{EIS}=20kV

RFQ U_{amp}= 710 mV

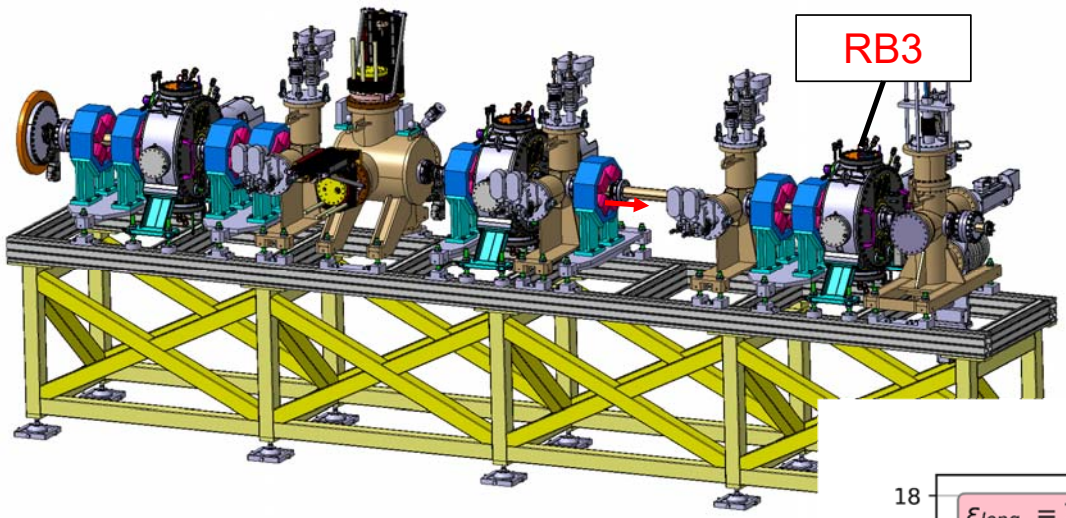
SAME MEASUREMENT, 40% discrepancy in the emittance « minimization »

RFQ U_{amp}, mV	$\varepsilon_{\phi.w}$, π.deg.keV	$\alpha_{\phi.w}$	$\beta_{\phi.w}$, deg/π.keV
680	77.39	0.69	1.84
710	76.43	0.86	1.03
740	61.49	0.24	0.86

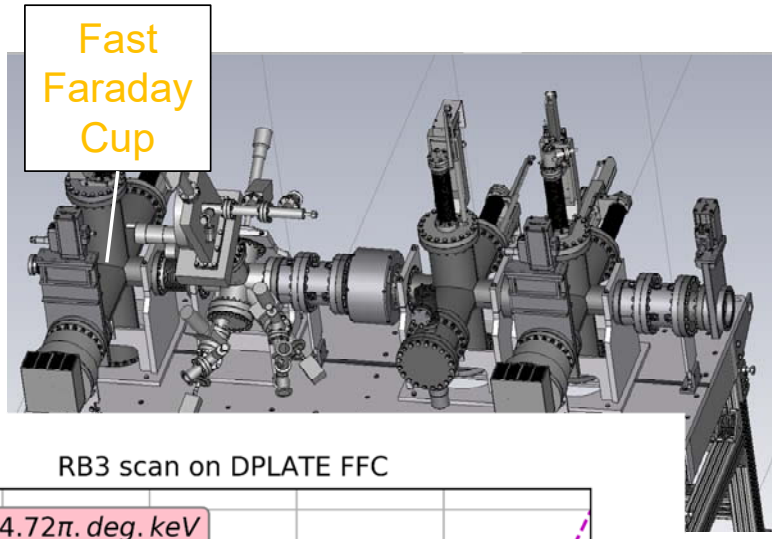
V_{EIS} (kV)	$\varepsilon_{\phi.w}$, π.deg.keV	$\alpha_{\phi.w}$	$\beta_{\phi.w}$, deg/π.keV
19.2	46.05	0.15	0.84
20.0	47.73	0.33	1.11
21.1	56.10	0.44	1.24
22.0	65.08	0.41	1.73

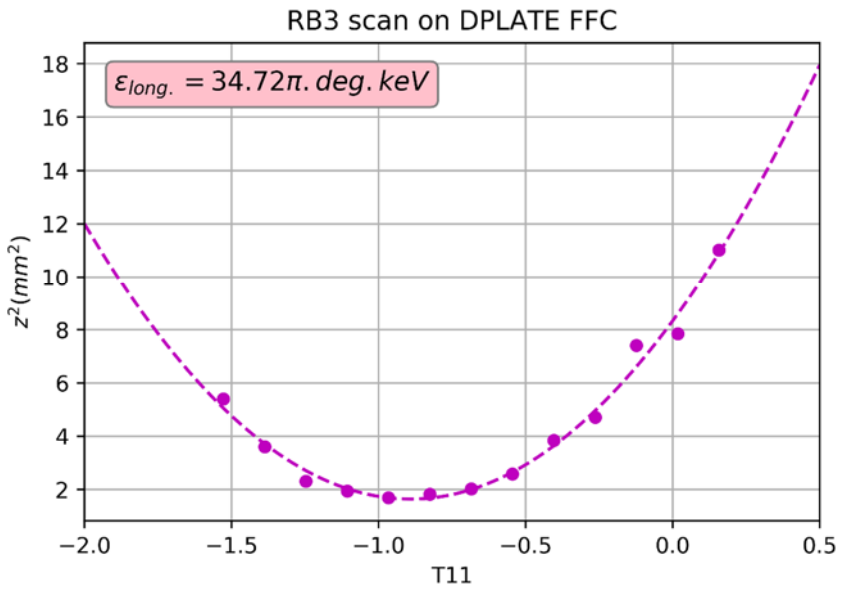
LONGITUDINAL EMITTANCE : 3 GRADIENT VARIATION WITH RB3

MEBT



DPLATE





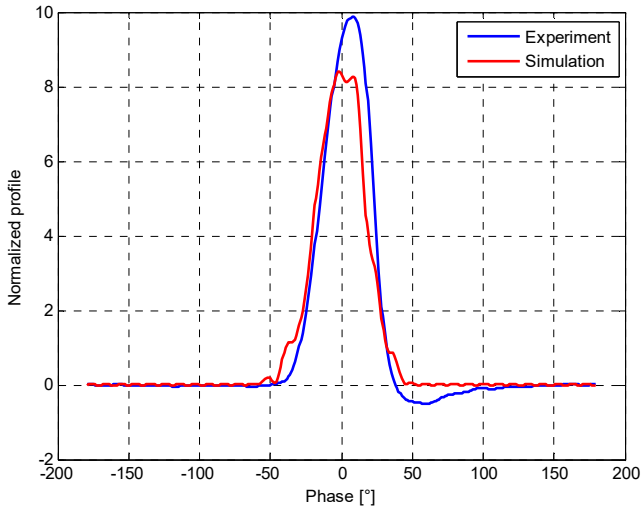
Nominal transverse and longitudinal setting
First order longitudinal emittance calculation

IMPROVING MODEL FOR EMITTANCE CALCULATION

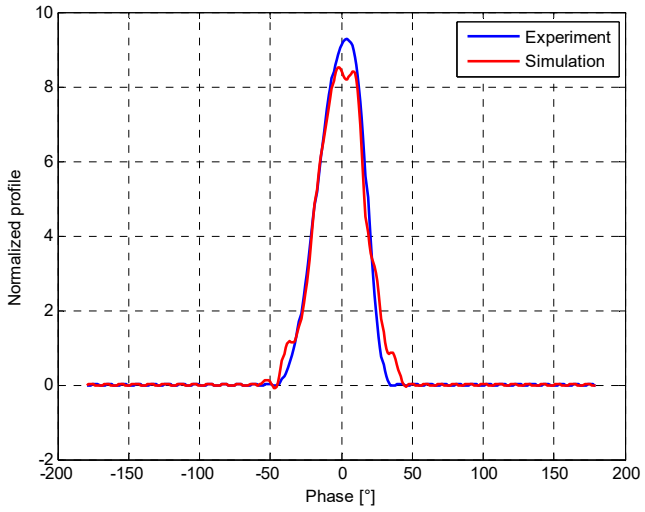
For improving the simulation model :

- FFC pinhole of 0.5mm radius
- Comparison of raw signal with bunch profile simulation (normalizing beam center and integral)
- The profiles are noisy and experimental profiles have negative “bounce”
- Simulating the scope bandwidth of 6Ghz

Before

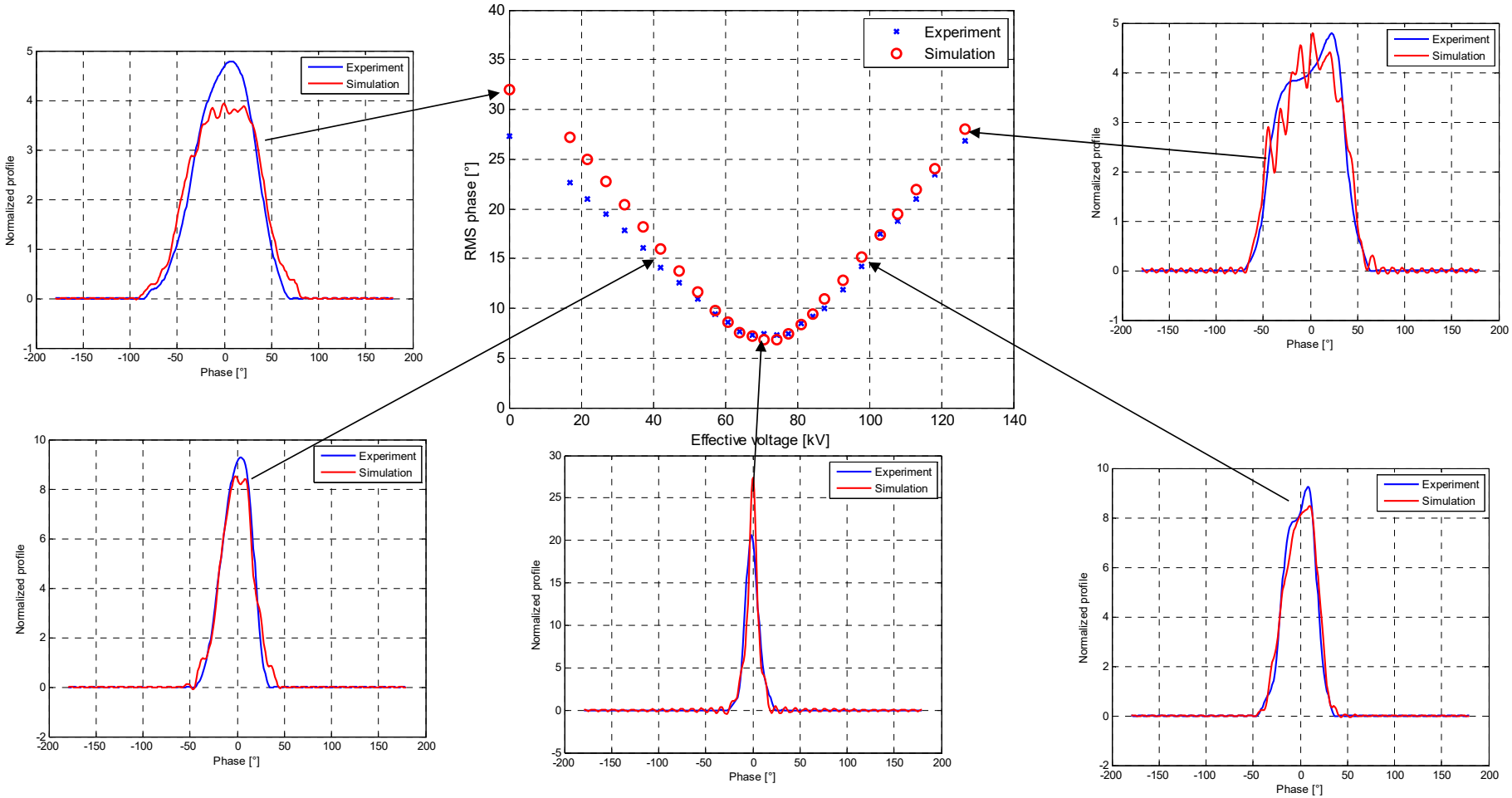


After



IMPROVING MODEL FOR EMITTANCE CALCULATION

- Remarkable agreement between simulations (TraceWin) and experiment
- Iterative process with new beam/beamline characterization (RFQ, transverse emittance…)



SUMMARY

Beam commissioning overall on tracks

Chopper slow->fast:

- ❑ SNRC successfully managed to single out bunch with fast chopper in LEBT

Control system:

- ❑ Many systems are developed and functional. Debugging as they are used in operation

Injector/ MEBT commissioning:

- ❑ High transmission in RFQ/MEBT (>90%)
- ❑ All rebunchers calibrated
- ❑ Beam longitudinal characterization reproducibility to be checked

Next for the MEBT commissioning until December 2022:

- ❑ Transverse characterization coming up next with the installation of a SEM Grid in September 2022.
- ❑ Switch to deuteron beam
- ❑ Max beam power (5mA peak, high DC: 13kW)