EUROPEAN SPALLATION SOURCE

BCM Beam Physics Requirements and Use Cases

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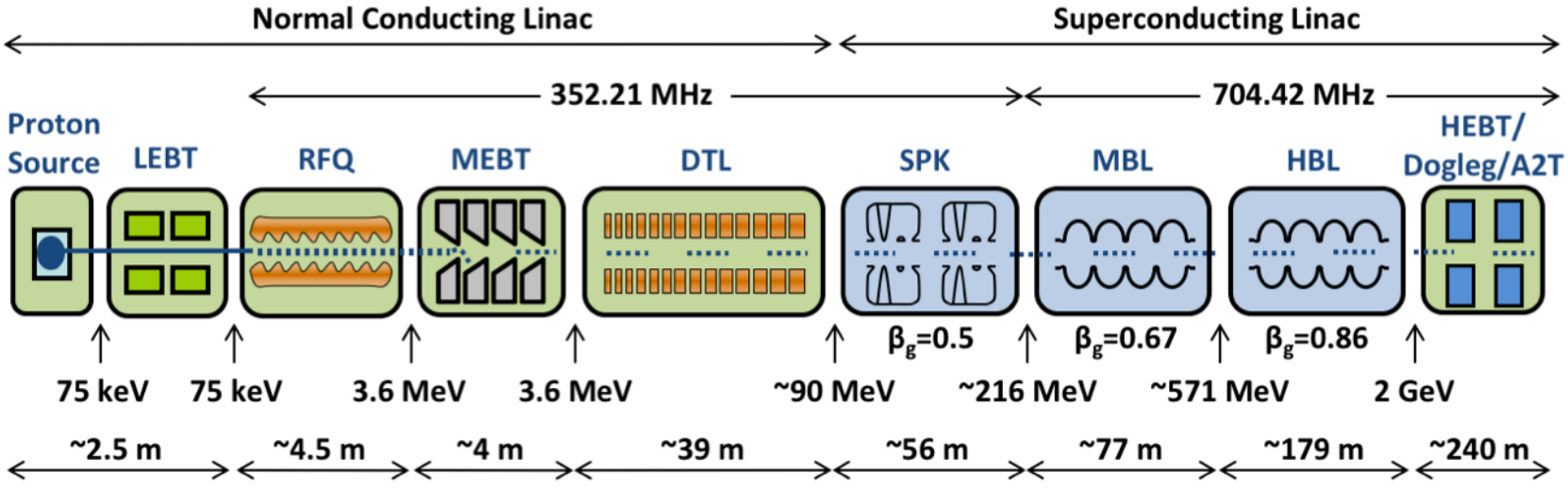
CDR of BCM Electronics
June 12-13th, 2017

BCM Beam Physics Needs

ESS Baseline Layout



Parameter	Value	Unit
Maximum Beam Energy	2	GeV
Average Beam Power	5	MW
Peak Beam Current	62.5	mA
Beam Pulse Length	2.86	ms
Beam Pulse Repetition Rate	14	Hz
Duty Cycle	4	%
RF Frequency	352.21/704.42	MHz
Machine Availability	95	%

Baseline Beam Modes

Type	Destination	Main Usage	Peak Current [mA]	Pulse Length [µs]	Rep. Rate [Hz]
Probe	- Any Beam Stop	- Initial Check - Beam Threading	6	≤ 5	≤ 1
Fast Tuning	- Any Beam Stop	- RF Setting	6 – 62.5	≤ 5	≤ 14
Slow Tuning	- Any Beam Stop	- Invasive Measurem. - LLRF Setting	6 – 62.5	≤ 50	≤ 1
Long Pulse	- Tuning Dump - Target	- Beam Loss Check - Lorentz Detuning Check	6 – 62.5	≤ 2860	≤ 1/30
Production	- Target	Neutron Production	6 – 62.5	≤ 2860	≤ 14

Beam Stops:

- FCs located in the LEBT, MEBT, DTL, SPK and MBL.

Tuning Beam Dump:

- 12.5 kW, can take the full pulse length at lower rep. rate.

BCM Requirements Considerations

- Beam current and charge measurements vs time at various locations along the accelerator
  - Beam current waveform over the macro pulse (pulse profile)
  - Average beam current over the pulse flat top
  - Per pulse and cumulative beam charge
  - Pulse rising/falling edges

- Modes:
  - Absolute
  - Differential
    - Beam loss detection

- Beam presence signal
  - Verify that no beam is present downstream of a beam stop.
  - Verify that no beam is present in-between intended pulses.

- Pulse amplitude/frequency/width measurements
  - Verify that beam parameters are consistent with the beam mode intended
  - Errant beam
  - Allows beam power estimation

BCM Requirements Considerations

- Differential mode needs BCMs at several locations along the linac
  - Uses BCM pairs
  - Allows measurements at entrance/exit of each section of the linac
  - Needs fast response time for MPS
- BCM system will be critical for commissioning
  - Has to work for inferior/non-standard conditions
    - Short pulse, low current, etc.
- Beam Interlock System
  - BCMs will provide a fast input to the machine protection system to shut the beam off
    - critical
    - high and sudden beam loss
      - Loss exceeds some user-defined level
    - pulse with wrong width/rate
    - Complimentary to BLMs/Redundancy (areas where BLMs cannot easily detect loss)
    - Component protection

BCM Requirements Considerations

- BCMs in the MEBT require special attention

- MEBT hosts a fast chopper
  - Cuts up to ~20 µs of unwanted beam
  - Pulse rise/fall time of ~10 ns
  - BCMs are the only way to measure the chopper performance
    - Low efficiency, beam partially chopped, etc.

- MEBT needs FCTs
  - Measurement bandwidth significantly larger than baseline BCMs (ACCTs)

BCMs Specifications

Beam current range	From 0 to 80 mA*
Pulse width range	5 µs – 6 ms**
Pulse repetition rate range	Possible for all modes (1/30 – 14 Hz)
Absolute accuracy	Better than +/- 1% (0.8 mA)***
Absolute resolution	Better than 1% of the peak current***
Differential resolution	Better than 2% of the peak current***
Time resolution	Better than 1 µs****
MPS detection threshold	10% beam current loss over 10 µs

* - 80 mA is probably excessive beyond MEBT, but OK if it comes for free.
** - Might not need 6 ms after the LEBT.
** - Can we measure pulses shorter than 5 µs? In theory we can produce them
*** - Definitions?
**** - Definitions again.

H. Hassanzadegan - Beam Current Monitor System Design Report
S. Varnasseri - BCM: Preliminary Design Review

NC Linac: LEBT, RFQ, MEBT, DTL

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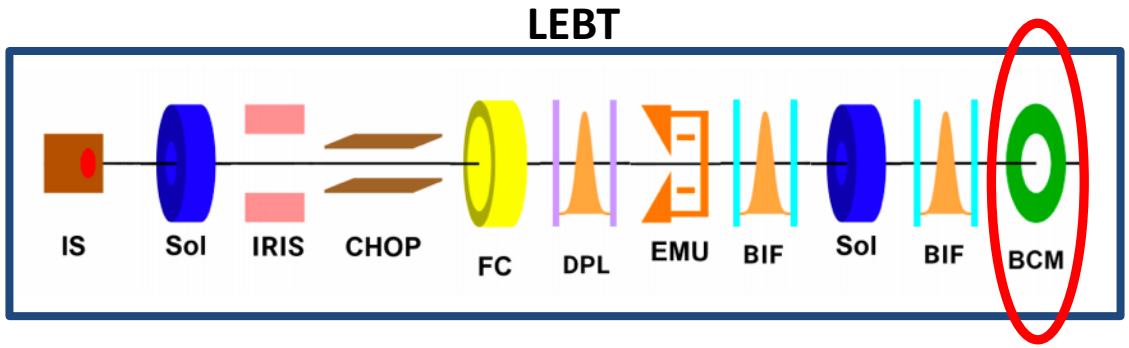

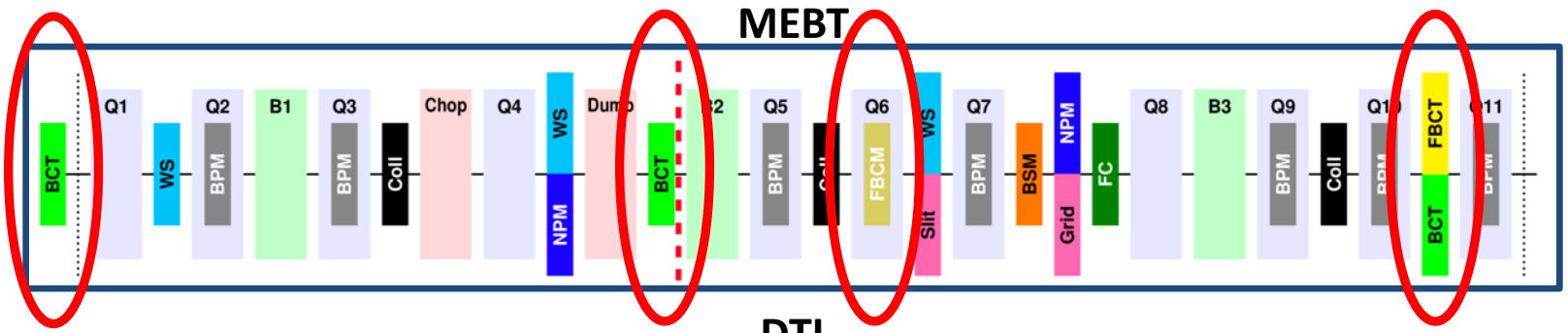

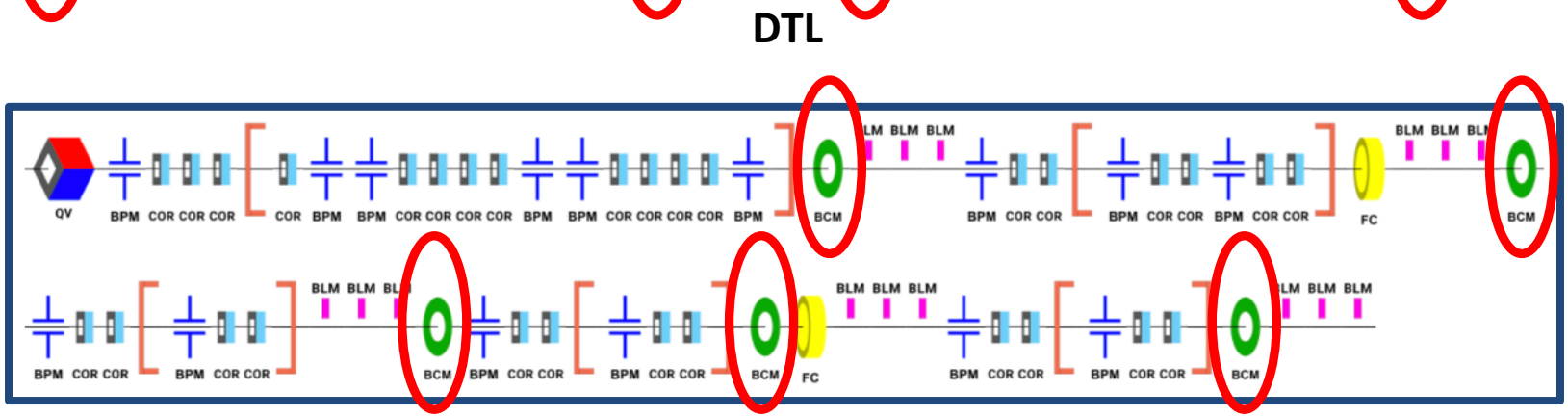

SC Linac: SPK, MBL, HBL

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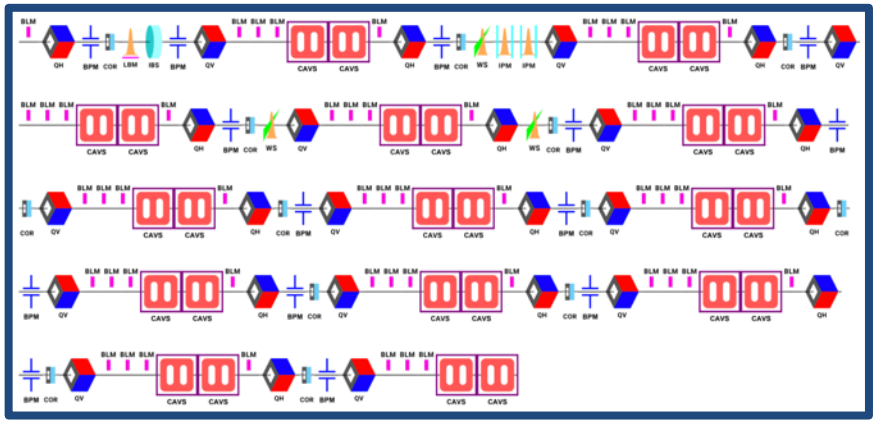
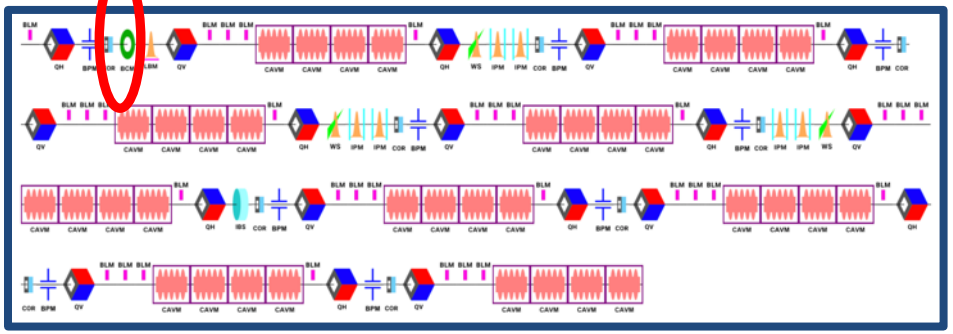
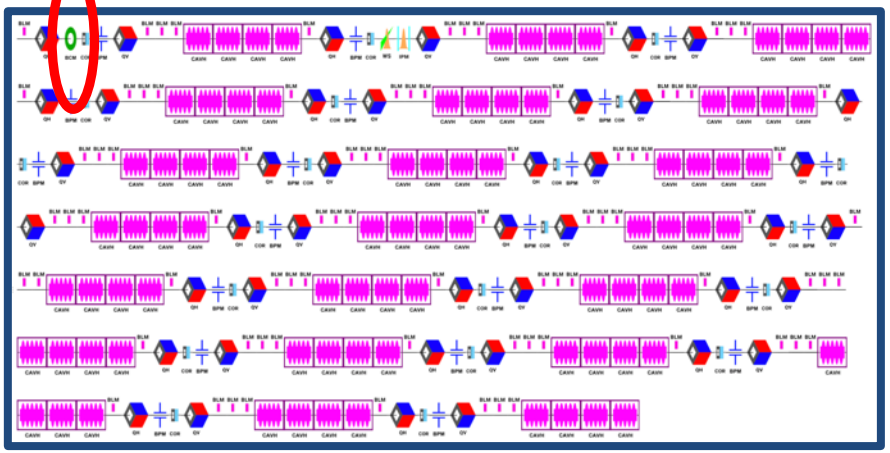
SPK



MBL



HBL



HEBT, A2T, Dump Line

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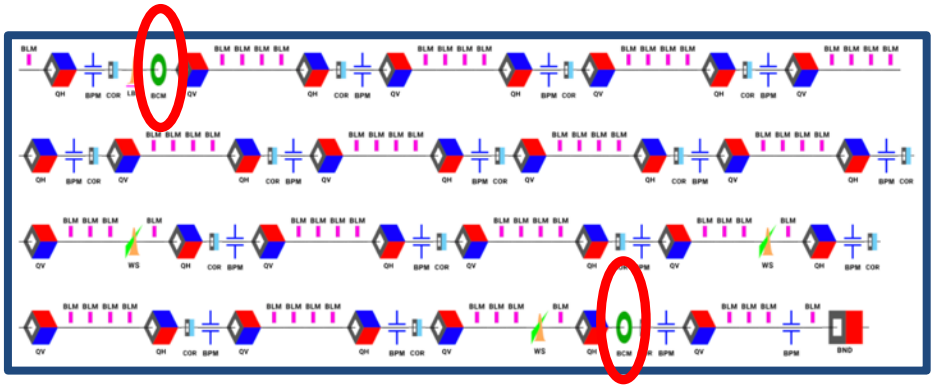
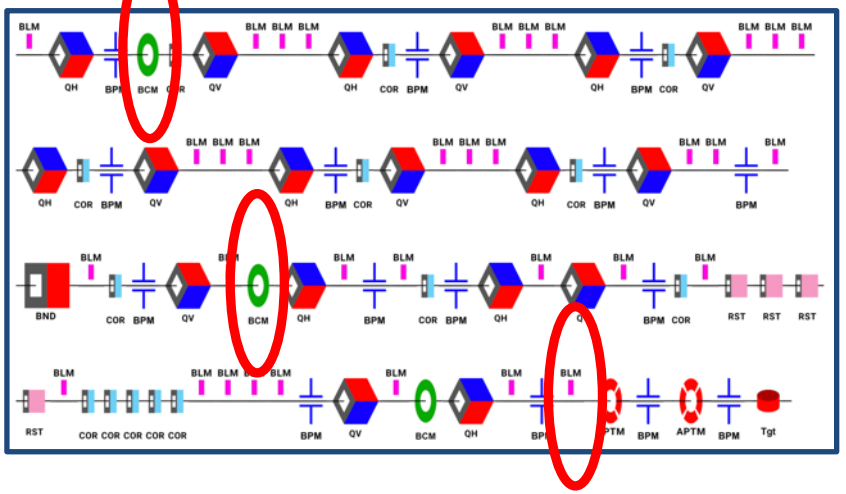
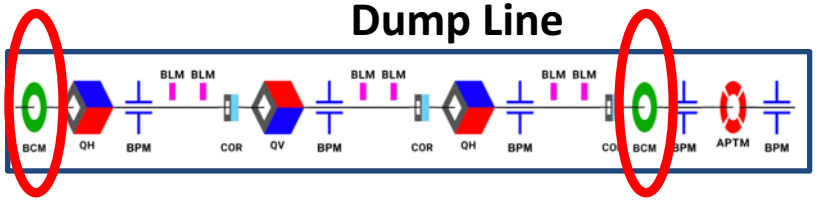
HEBT



A2T



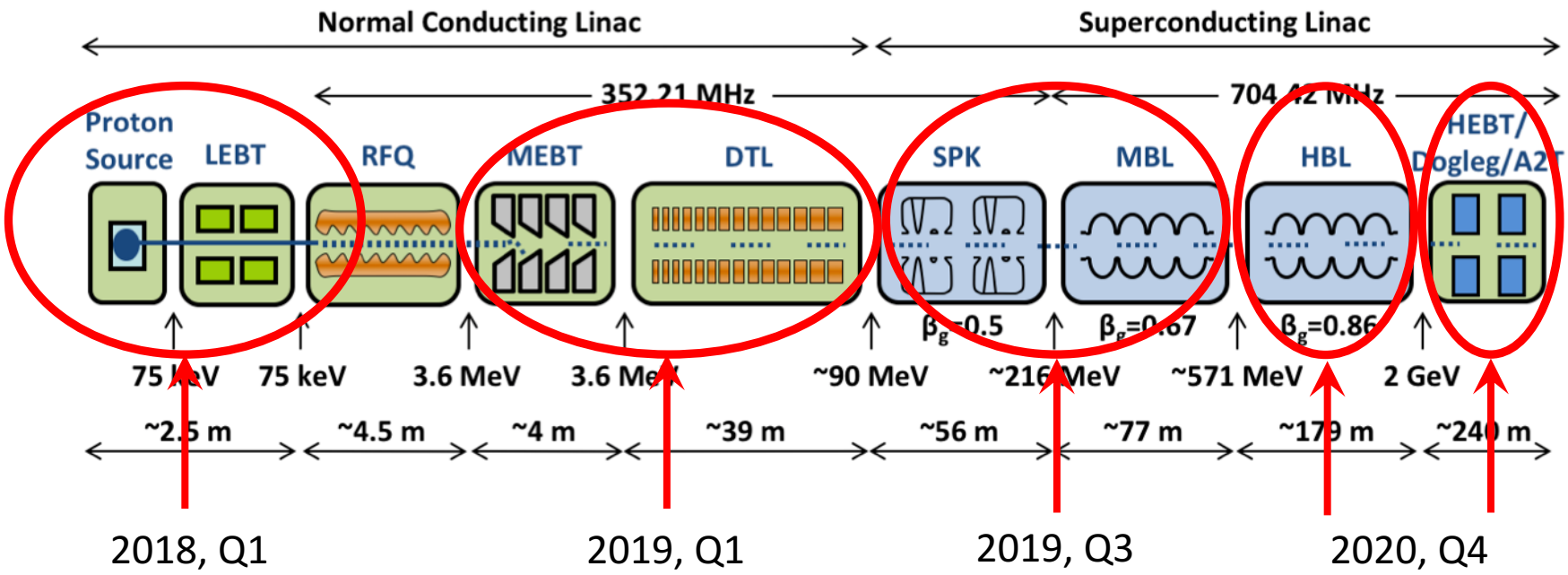
Dump Line



BCMs Needed

Location	Quantity	Type
LEBT	1	ACCT
RFQ	1	ACCT
MEBT	4	ACCT/FCT
DTL	5	ACCT
SPK	0	-
MBL	1	ACCT
HBL	1	ACCT
HEBT	2	ACCT
A2T	3	ACCT
Dump Line	2	ACCT
Total	**20**	**ACCT/FCT**

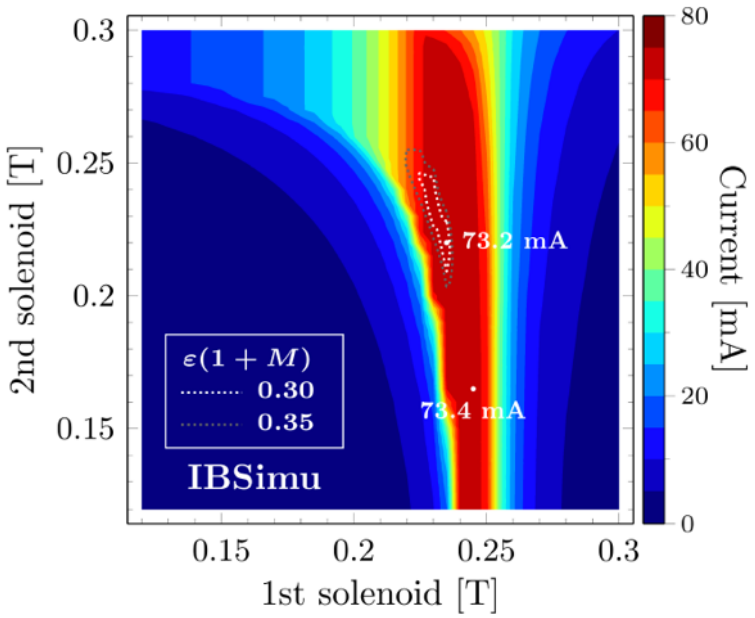
Scheduling – Commissioning Timeline

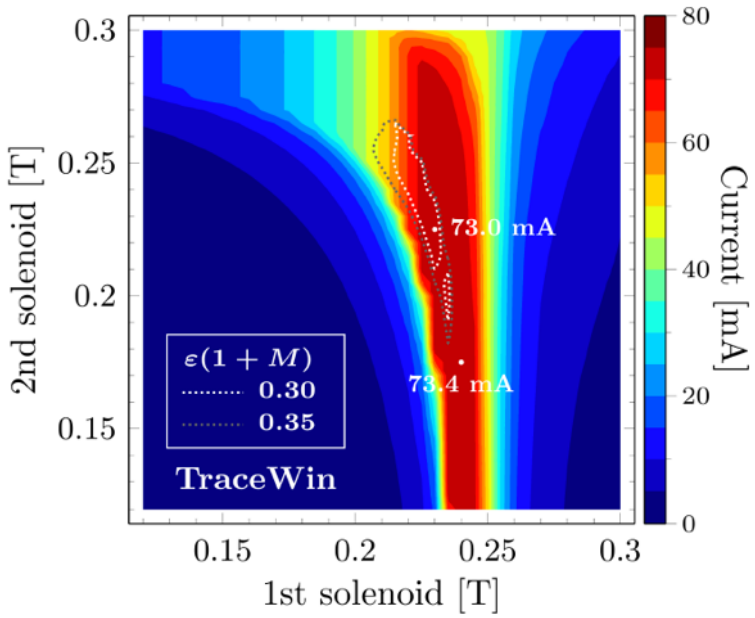


Scheduling – Commissioning Timeline

- NC linac commissioning starts in Q1 2018 (IS and LEBT)
  - LEBT BCM priority: solenoid scans for machine characterisation
- Initial beam parameters probably quite limited
  - BCM flexibility
- Commissioning of the NC linac to go in parallel with installation of the SC section.
- Beam loss detection up to DTL1 relies on BCMs
  - Critical
- When we send the beam to the tuning dump, we need BCMs in HBL, HEBT. In other words, though these sections are labelled as “2020, Q4”, BCMs there are already needed in 2019 Q3.
- Value engineering/ Deferral of scope
  - HBL installation up to 1.3 GeV to go ahead in 2020
  - Probably does not affect BCM delivery schedule
- Tuning dump limitations

Example of intended early usage (from simulation)





Ø. Midttun et al., THPVA013, IPAC'17

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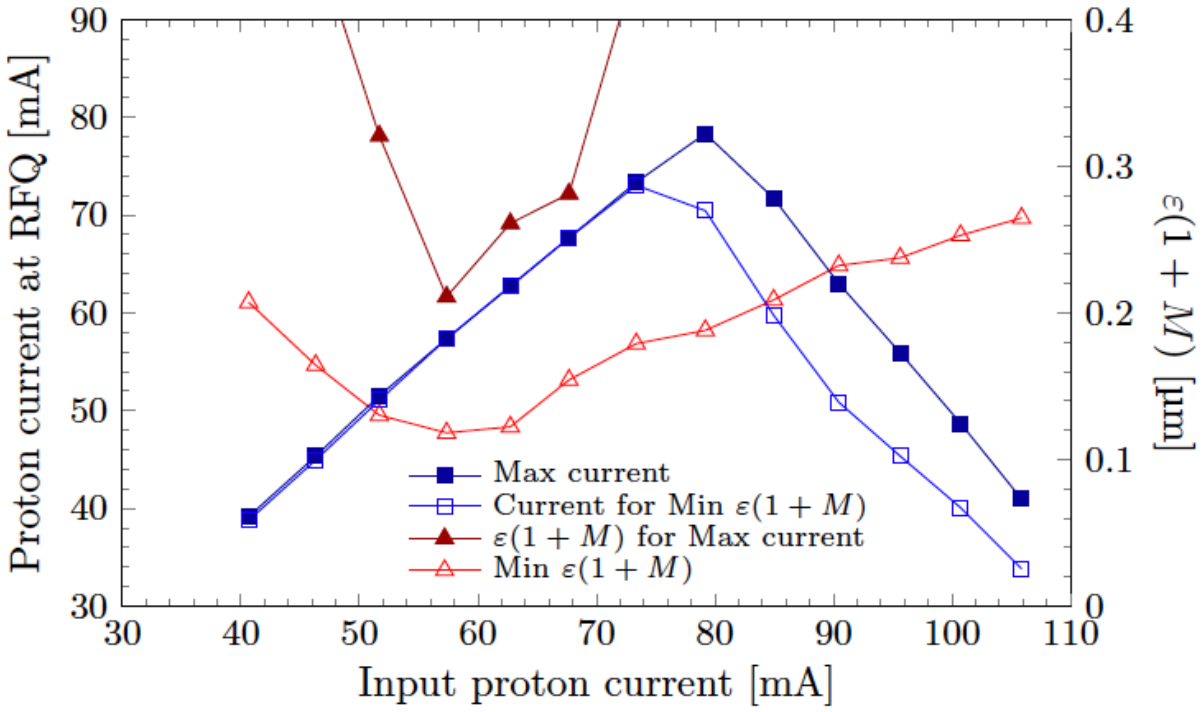

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Final remarks

- Do we speak the same language?
- Discussions between all groups involved on expectations
  - How is averaging, reporting, etc. done?
  - Applications.