Summary: Increasing beam current, gradient, energy

Frank Gerigk, 9 Nov 2016

contributions

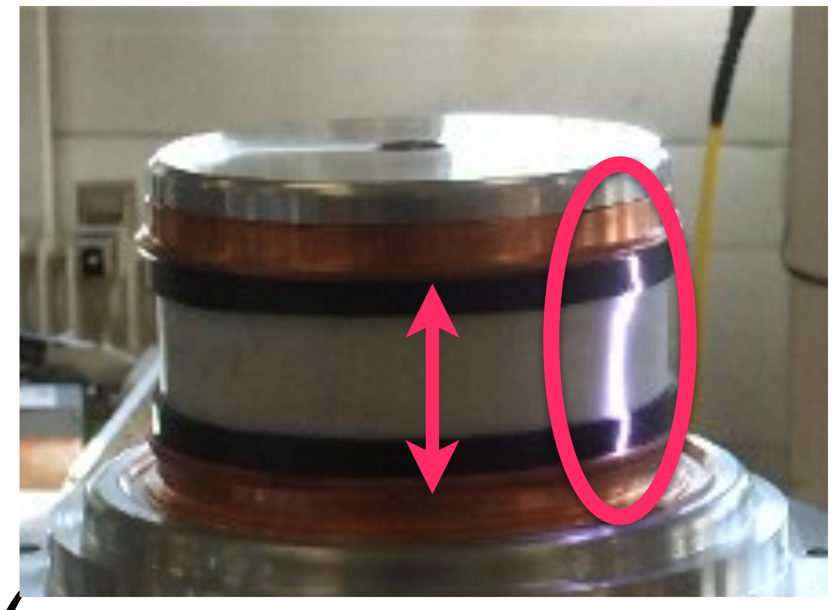
Table 1

speaker	title
Frank Gerigk	Introduction: Potential for gradient, current, or energy increase
Tomofumi Maruta	Power upgrade plan of J-PARC Linac and loss estimation
Franck Peauger	Gradient limitation in pulsed SC cavities, imposed by power couplers, RF systems, Lorentz force detuning compensation
Marc Doleans	Gradient increase in SC cavities via plasma processing
Ciprian Plostinar	Linac upgrade scenarios for the RAL neutron source
Mark Middendorf	Upgrades to the Spallation Neutron Source (SNS) Linac to support the Second Target Station (STS)

Frank Gerigk (CERN): Introduction: Potential for gradient, current, or energy increase

Example of ESSnuSB: upgrading the ESS linac to provide 5 MW of protons for neutrons plus 5 MW of H- to inject into accumulator for neutrino physics.

	baseline	ESSnuSB #1	ESSnuSB #2
beam power	5 MW	5 + 5 MW	5 + 5 MW
beam energy	2.0 GeV	2.5 GeV	2.5 GeV
beam current	62.5 mA	50 mA	50 mA
repetition rate	14 Hz	28 Hz	56 Hz
pulse length	2.86 ms	2.86 + 2.86 ms	2.86 + 3 x 0.95ms
particles	protons	protons + H^-	protons + H^-
accumulator	-	3 rings	1 ring



- Upgrade options often limited by coupler peak power limits (—> current, gradients), more margin on average power (—> duty cycle).

- Upgrade paths depend strongly on the margins of your RF systems, cooling systems, cryogenics, HVAC, … Some margins you will only know once the machine is in operation.

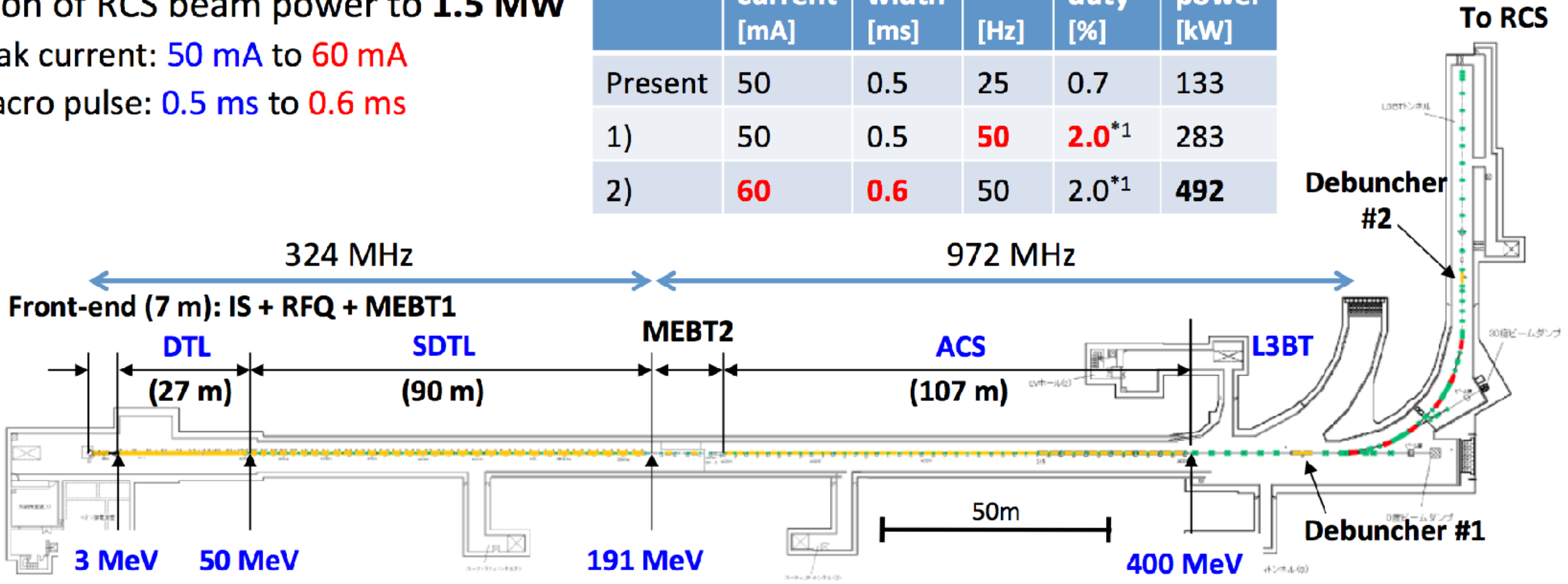
- For ESSnuSB, the duty cycle was doubled and in order to decrease the needed upgrades of the existing RF system, cooling, etc. the current was lowered (65 —> 50 mA) and the energy was increased. Resulting in modest upgrades of an existing installation combined with new installation of additional CMs and RF systems.

Tomofumi Maruta (JPARC): Power upgrade plan of J-PARC Linac and loss estimation

J-PARC linac is under considering two-step beam power upgrade.

1) Supply to TEF (Transmutation Experimental Facility) in parallel with 3 GeV RCS.
   - Repetition rate: 25 Hz to 50 Hz
2) Extension of RCS beam power to **1.5 MW**
   - Peak current: 50 mA to 60 mA
   - Macro pulse: 0.5 ms to 0.6 ms

	Peak current [mA]	Pulse width [ms]	Rep. [Hz]	Beam duty [%]	Beam power [kW]
Present	50	0.5	25	0.7	133
1)	50	0.5	**50**	**2.0***1	283
2)	**60**	**0.6**	50	2.0*1	**492**

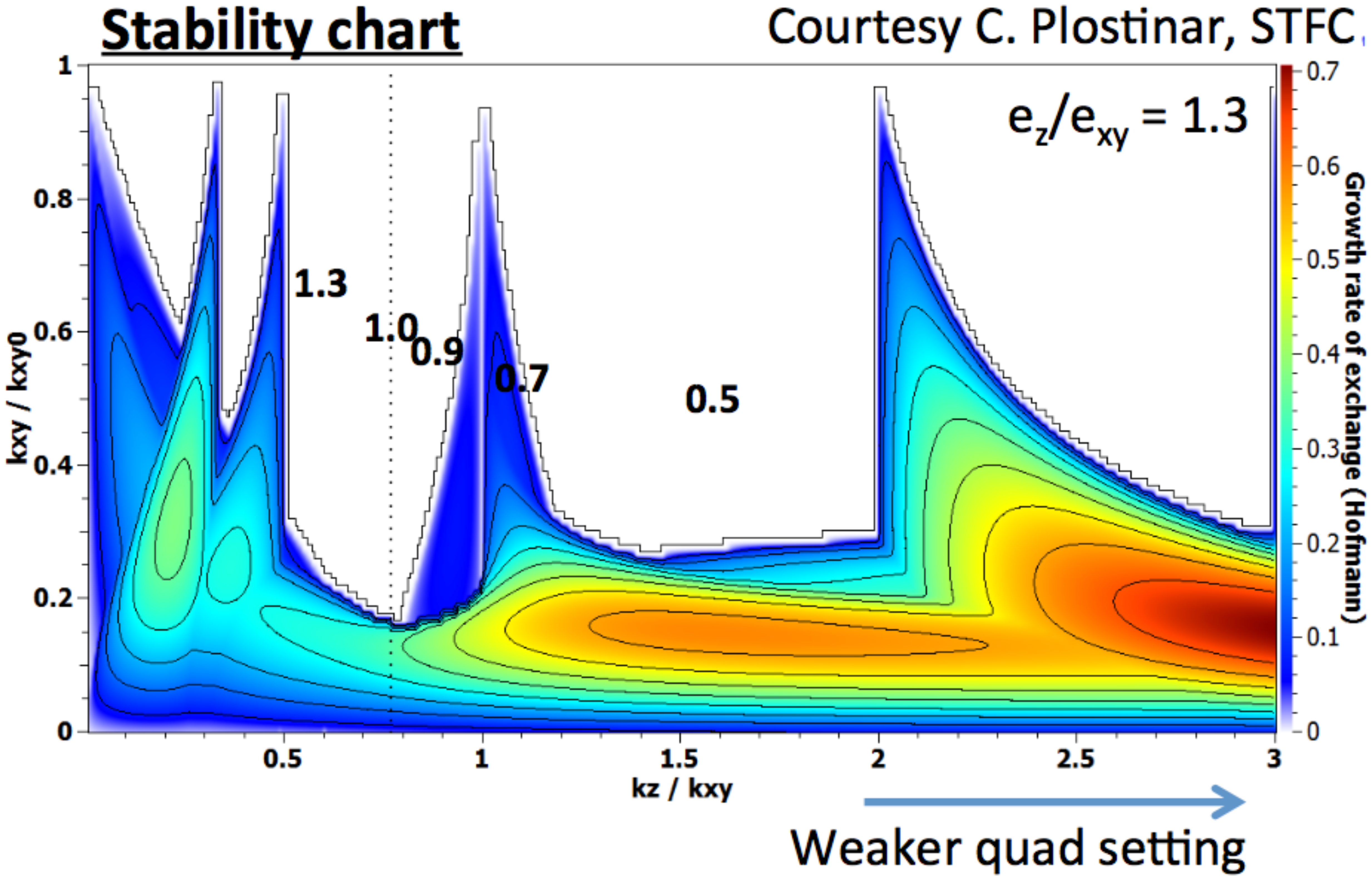


- High losses observed in ACS section.

- Intrabeam stripping identified as main loss mechanism because of the squeezed beam in the ACS.

- Trying to relax beam conditions by moving away from strict equipartitioning. New working point of 0.7 considered.

- IBS losses in arc should be acceptable after upgrade



Franck Peauger (CEA): Gradient limitation in pulsed SC cavities, imposed by power couplers, RF systems, Lorentz force detuning compensation

Crymodule upgrade

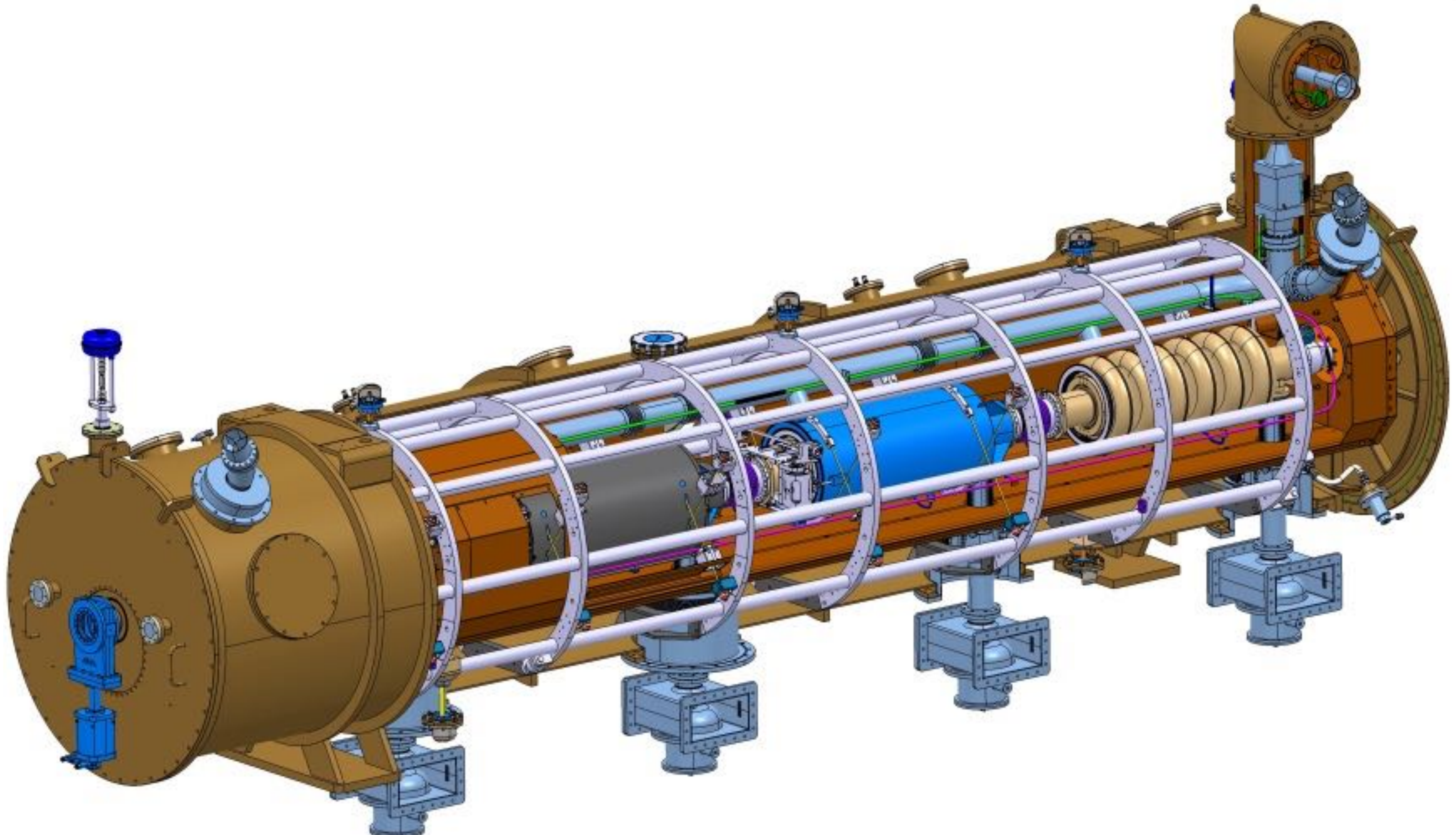
Without disassembly 1

With disassembly
- Cavity string back in clean room

Same design 2
- New surface treatment

New design 3

Cost and schedule increase



- Power coupler: tested up to 1.2 MW peak limited only by available RF power,
    - Upgrade options: use of SF6 instead of air next to the window or complete re-design.
- Elliptical cavities: specs reached in vertical tests,
    - Upgrade options: Flash BCP at low temperature, 120 C baking, Electropolishing, thermal exchange with helium bath, N2 doping
- Lorentz force detuning: pop done, not yet tested on ESS cavity
    - Upgrade options: accessible from the outside of the cryo module, can be exchanged if needed for higher duty cycle operation, R&D on reliability needed.
- RF power: 1.6 MW available from available klystrons (1.2 MW needed). Modulator development progressing successfully
    - Upgrade options: Modulators upgradable, higher power klystrons (peak and average power) are feasible.

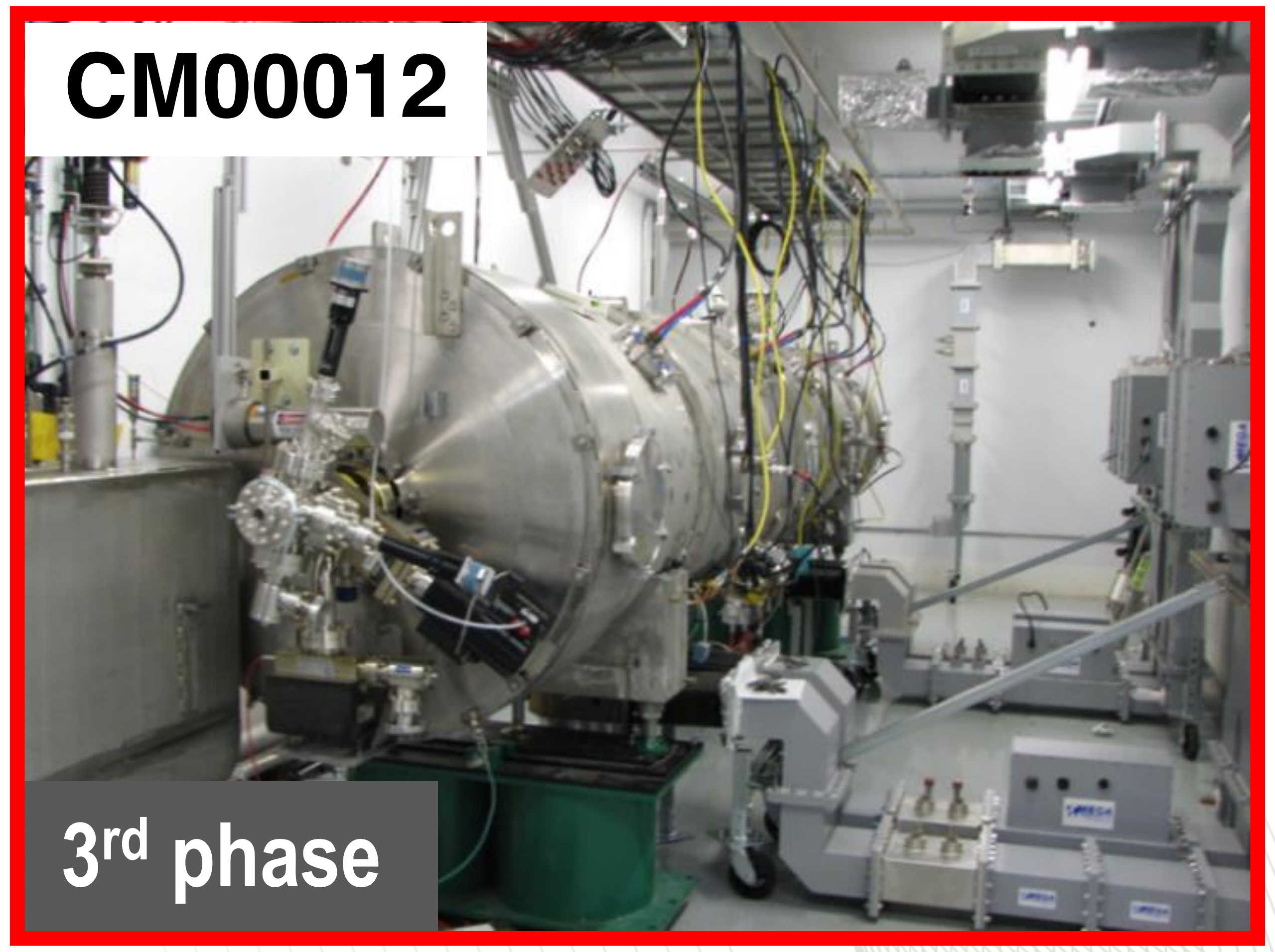
Marc Doleans (SNS): Plasma Processing to Improve the Performance of the SNS Superconducting Linac

R&D with Nb samples and offline cavities

✓

Processing of 6-cell cavity in HTA*

✓



Processing of cryomodule in test cave

✓

In-situ processing in linac tunnel

On-going
FY16
FY17

*HTA: Horizontal Test Apparatus

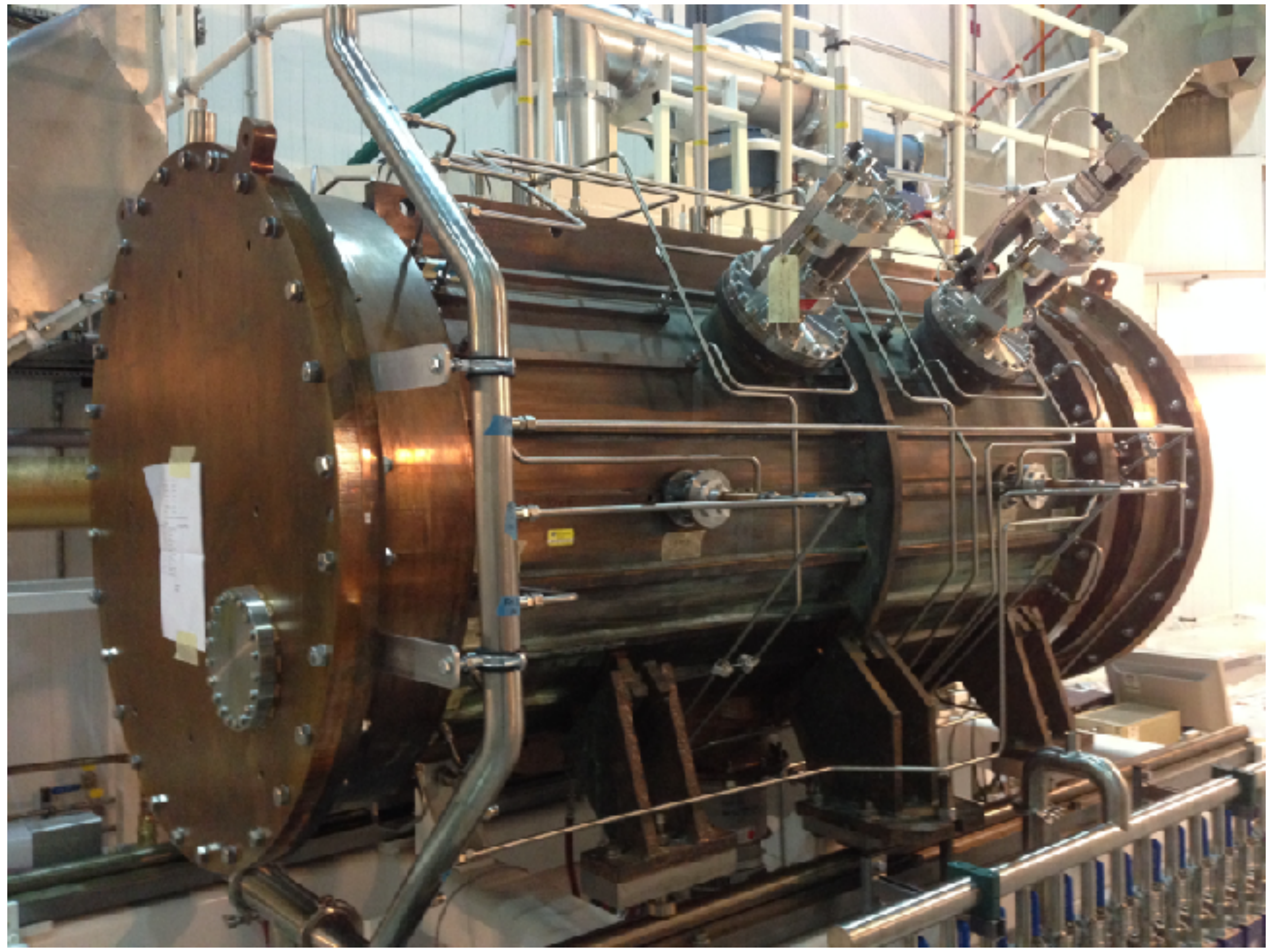
- Remove present gradient limitations by field emission. Average cavity gradient today: ~12/13 MeV/m.

- SNS developed in-situ plasma processing to remove hydrocarbon contamination on the cavity surfaces (some monolayers).

- Cleaning of one CM with several cleaning cycles takes ~2 weeks. First CM cleaning in test stand yielded a 25% improvement of cavity gradients.

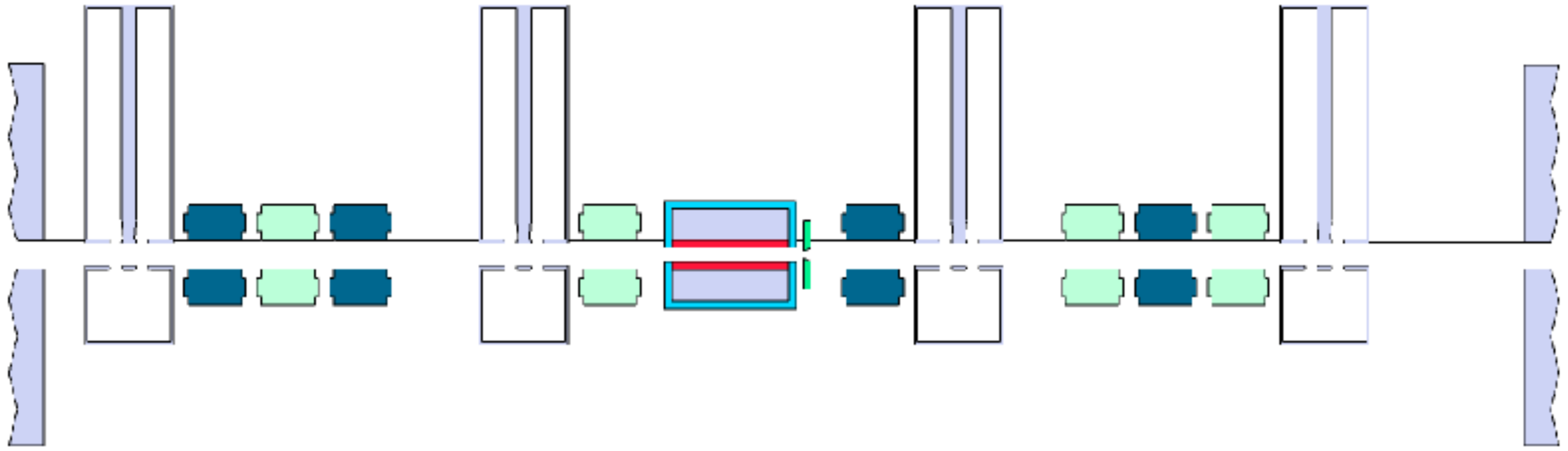
- Deployment in tunnel on 2 CM done with a 21% increase of cavity gradients.

Ciprian Plostinar (RAL): Linac upgrade scenarios for the RAL neutron source



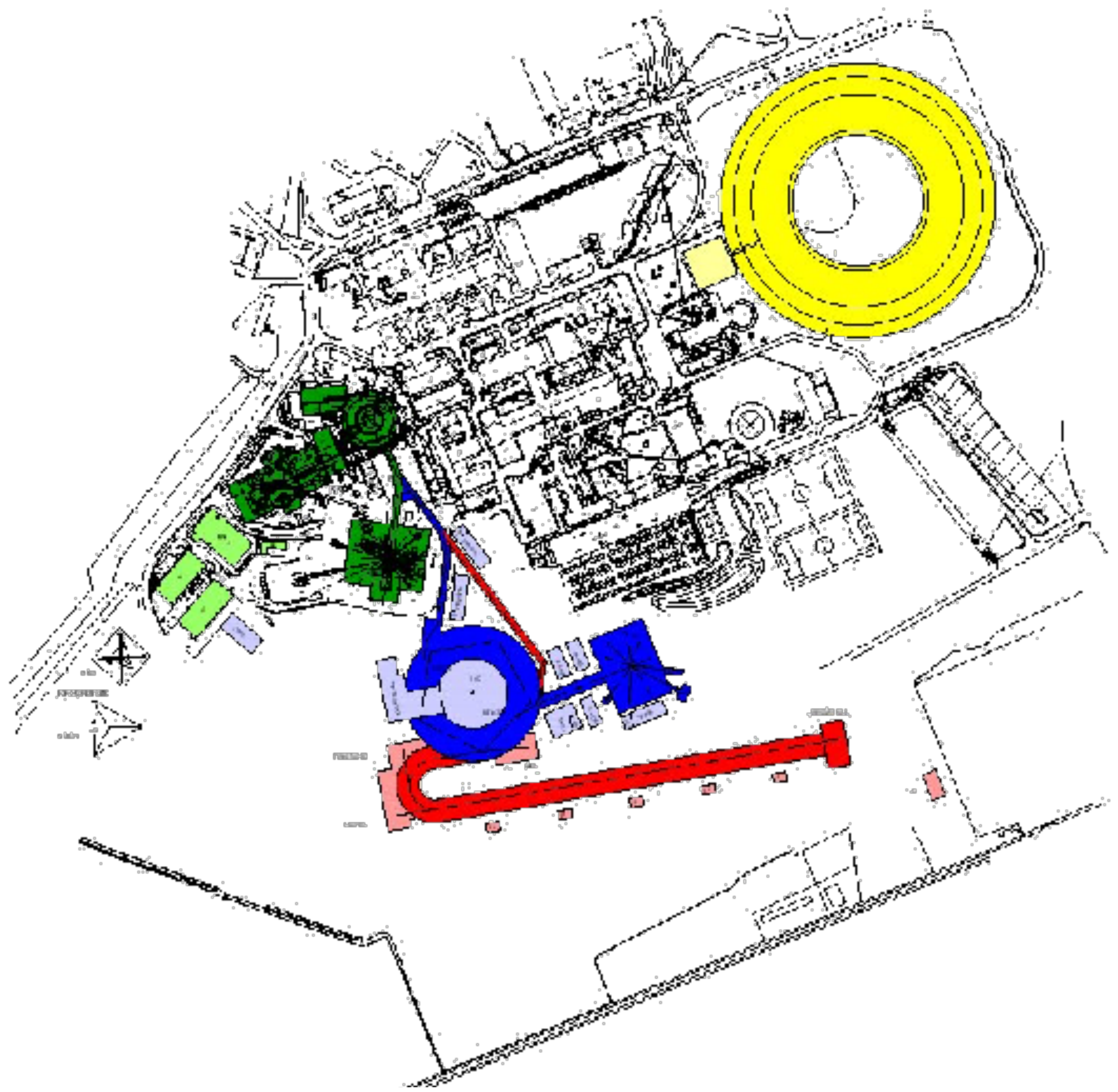
- Replacement of 4th DTL tank, which is at risk of becoming unsustainable. Redesign with same gradient but improved efficiency.

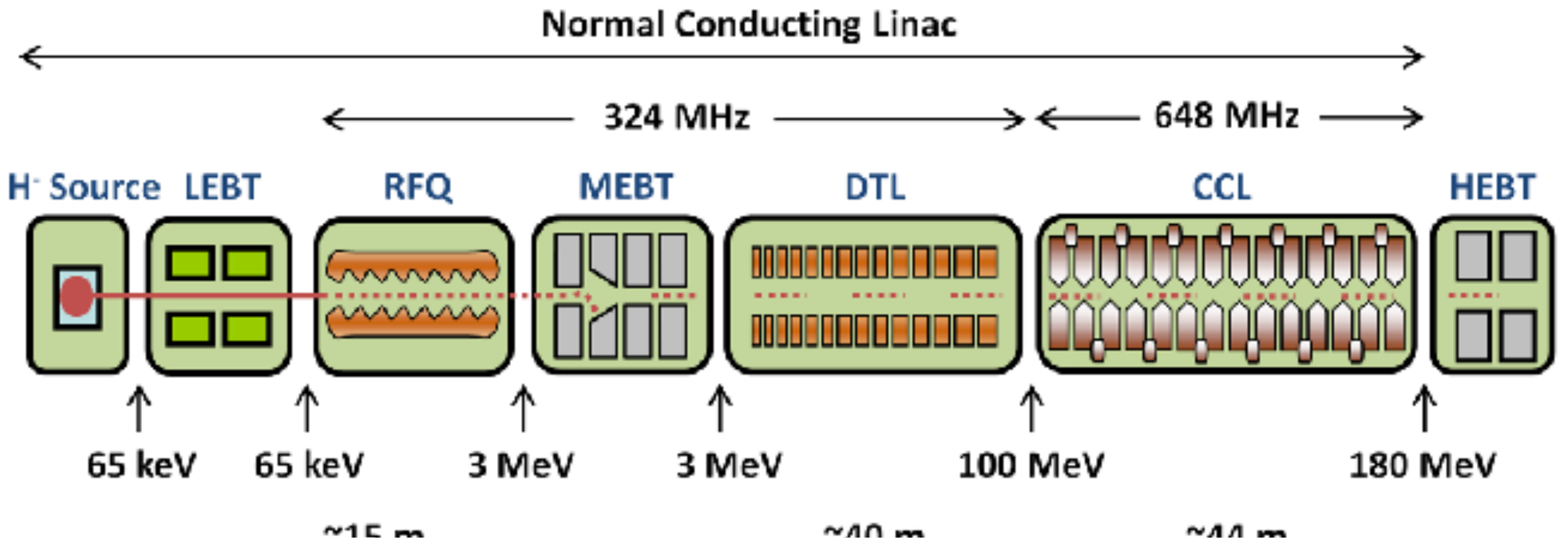
- Introduction of MEBT between RFQ and DTL to reduce the present 20% beam loss in tank 1

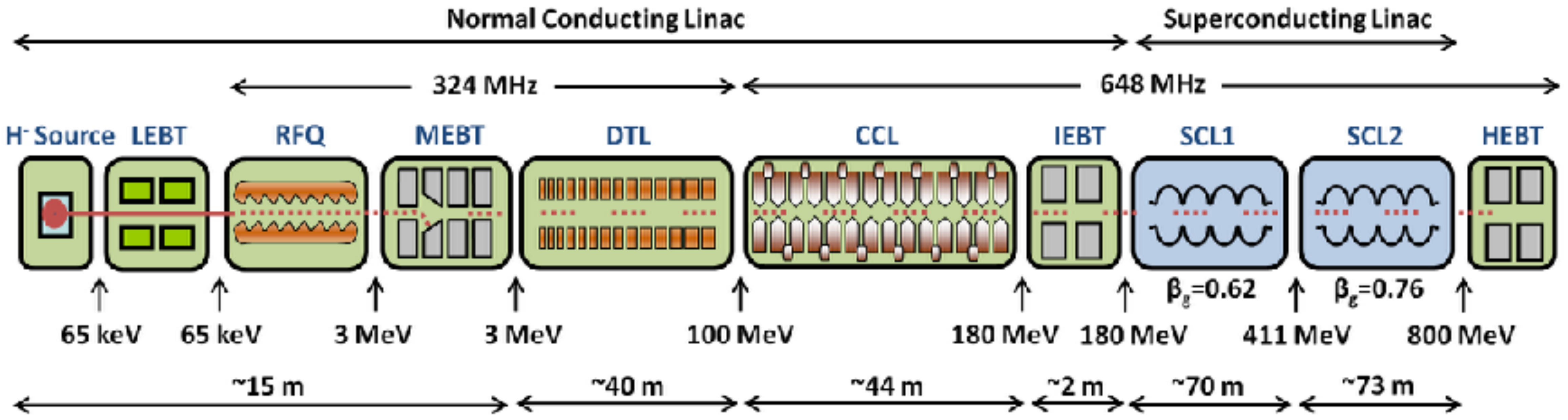


- MEBT upgrade has potential to increase beam current by 20%.

- Further upgrade options are a complete replacement of ISIS linac by a new 180 or even 800 MeV linac, which could be built without disturbing present operation.





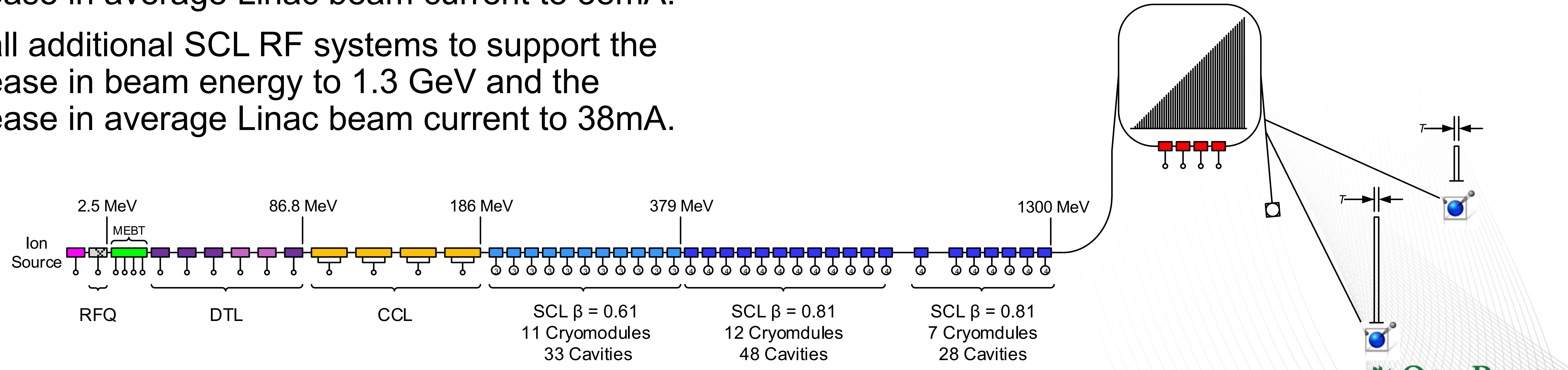


Mark Middendorf (SNS): Upgrades to the Spallation Neutron Source (SNS) Linac to Support the Second Target Station (STS)

PPU - Parameters

- Upgrades the SNS accelerator to provide sufficient RF to support proton beam-on-target capability of 2.8MW
  - Upgrades target to handle 2MW
  - Increases energy and current
- Installs all HPRF required for Second Target Station
  - Upgrades existing RF systems to support the increase in average Linac beam current to 38mA.
  - Install additional SCL RF systems to support the increase in beam energy to 1.3 GeV and the increase in average Linac beam current to 38mA.

	Routine Operation	PPU	FTS	STS
Kinetic Energy (GeV)	0.957	1.3	1.3	1.3
Beam Power (MW)	0.8-1.40	2	2	0.47
Energy per pulse (kJ)	13 - 23	33	40	47
Target Material	Hg	Hg	Hg	Tungsten
Repetition Rate (Hz)	60	60	50	10
RF Duty Factor (%)	7	7	7	7
Linac pulse length (msec)	0.975	0.975	0.975	0.975
Average Linac Current (mA)	27	30	38	38
SCL HVCMs	7	8	11	11
SRF Cavities	79-80	109	109	109



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- Consecutive linac upgrades until 2024: increase towards: 1.3 GeV (<1 GeV), 2.8 MW (1.4 MW), 38 mA (27 mA).
- Preparing for CD-1
- NCL: cooling system upgrades, some higher power transmitters,
- SCL: RF system has enough margin but needs upgrade of cooling system
- Reconfigure cabling and install 12 chase inserts
- New RF systems to supply added cryo modules.
- Improvements to modulators, LLRF, and controls.

Many thanks to all the speakers!

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