SESAME synchrotron status & development

Maher Attal

M. Attal, ESLS28 Meeting, ESRF (Teleconference Meeting), Dec 16-17, 2020

Outlines

- Overview of SESAME machine and beamlines.
- Machine performance
- Machine operation in the COVID-19 pandemic
- SESAME injector
    - Status of microtron refurbishment
    - Accommodation of 100MeV Linac

Overview of SESAME machine and beamlines

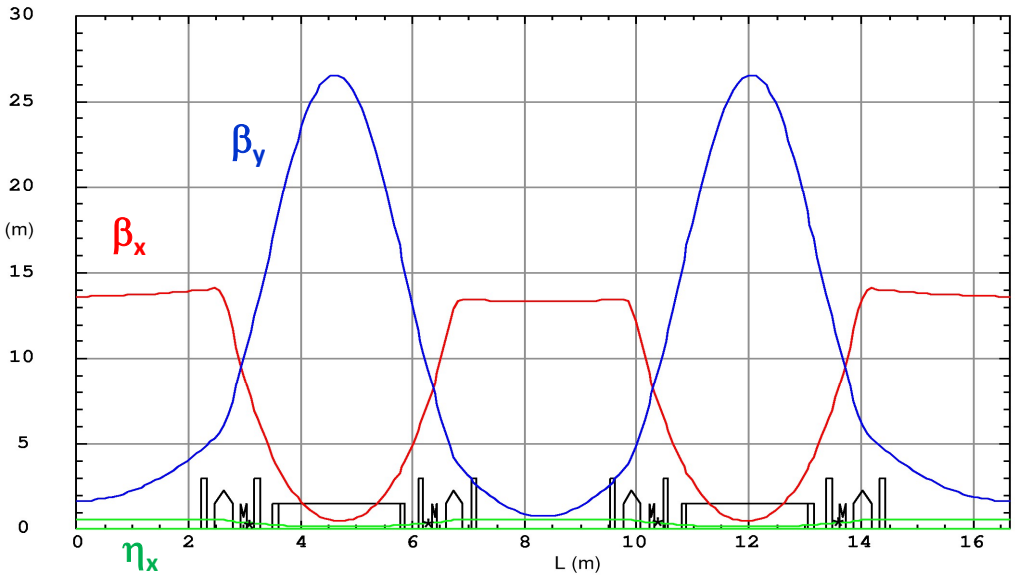
SESAME machine structure

- **20MeV classical microtron** (BESSY I microtron): *output current = 8-12 mA, pulse length = 2μs*.
  Needs refurbishment for more reliability.

- **800MeV booster** (BESSY I booster): output current = *up to 12 mA, pulse length = 110 ns.*
  In a better shape than the microtron, however its pulsed elements need some refurbishment.

- **2.5GeV storage ring** (completely new): *simple DBA lattice (2 families of quadrupoles and sextupoles) with dispersive sections.*

Parameter	Value
Circumference (m)	133.2
ε_x (nm.rad)	26
Q_x , Q_z	7.23, 6.19
U_0 (keV)	603
Operation, design current (mA)	250, 400
α	0.00833
σ_ε (%)	0.1087
No. of straight sections	16 (8x4.4m + 8x2.4m)
Bending magnet: B_0(T), g(T/m)	1.455, -2.79



SESAME beamlines

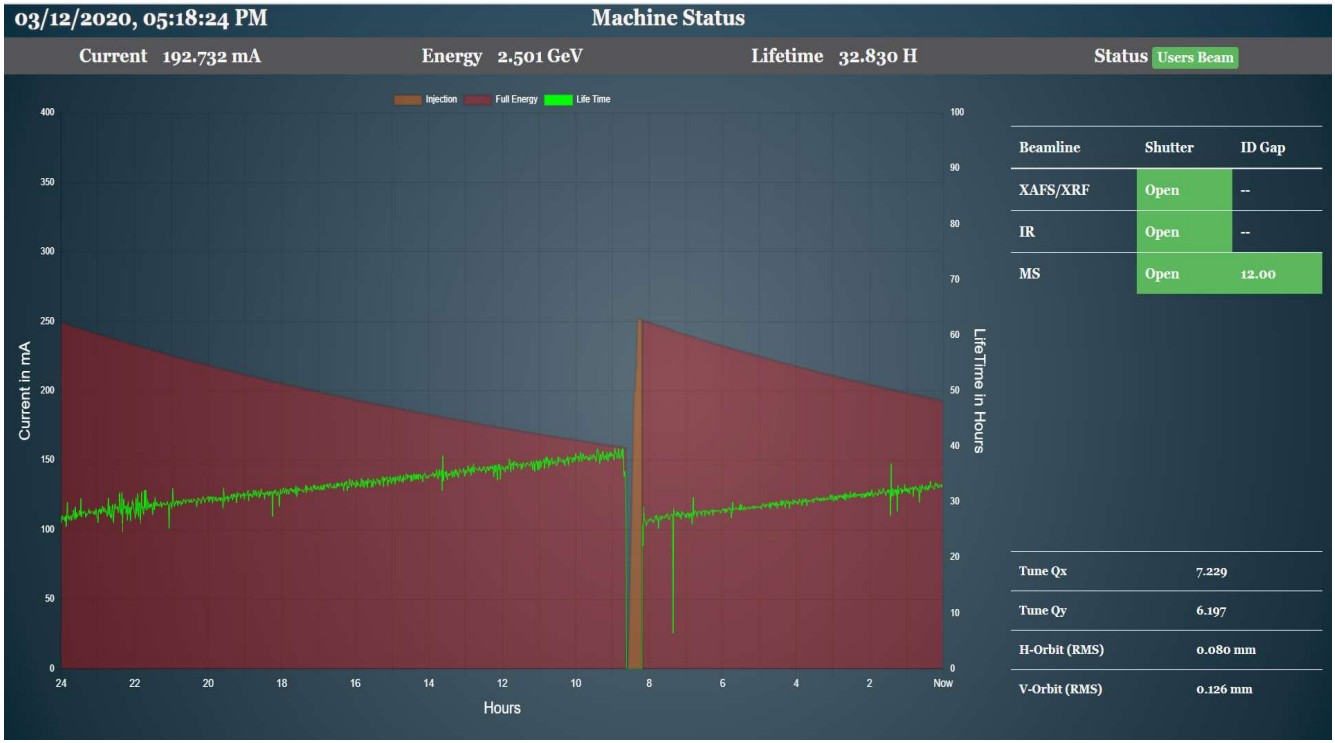
- SESAME is a user facility since June 2018.

- Three existing beamlines:

  - **XAFS/XRF beamline**:
    - a user beamline
    - donation from HZDR/ESRF.

  - **IR beamline**:
    - a user beamline
    - designed in collaboration with SOLEIL and financed by SESAME.

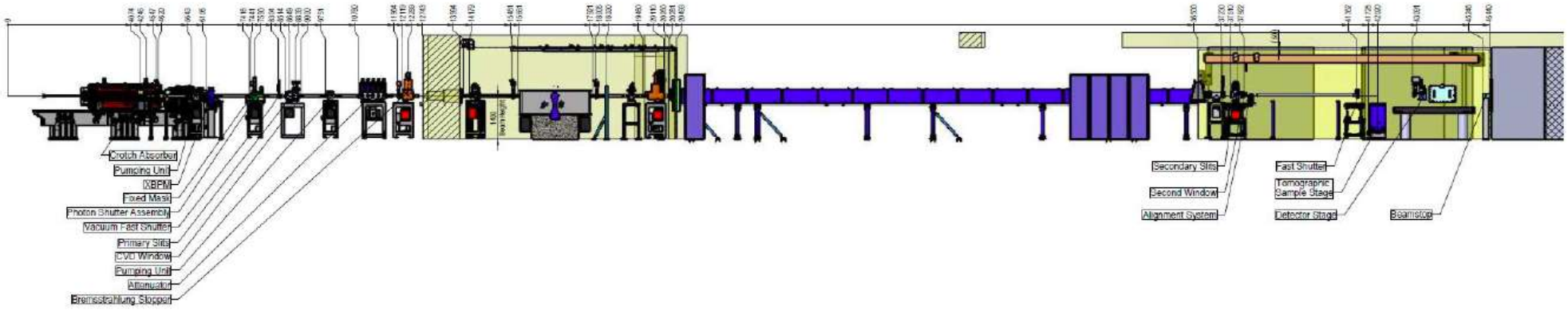
  - **MS beamline**:
    - has been commissioned, ready to receive users in 2021.
    - donation (with its wiggler source) from SLS.



SESAME beamlines

- **BEATS** (**BEA**mline for **T**omography at **S**ESAME) **beamline:**
  - Funded by the **EU's H2020** framework program under grant agreement n°822535
  - Source (3T three-pole wiggler) call for tender closed.
  - Front-end and Hutches call for tender launched. Building modification started.
  - The project is done in collaboration with many facilities:

  - Expected to be ready for users by end 2022.



SESAME beamlines

HESEB Helmholtz-SESAME Soft X-Ray Beamline für SESAME

- Funded by **Helmholtz Gemeinschaft** institution**.**
- SESAME will provide the infrastructure.
- Source (APPLE II-type undulator) refurbishment in progress. Delivery expected June 2021.
- Construction of beamline and front-end started. Delivery expected October 2021.
- The project is done in collaboration with Helmholtz facilities:

DESY. JÜLICH FORSCHUNGSZENTRUM HZB Helmholtz Zentrum Berlin HZDR KIT

- Expected to be ready for users by end 2022.

Machine performance

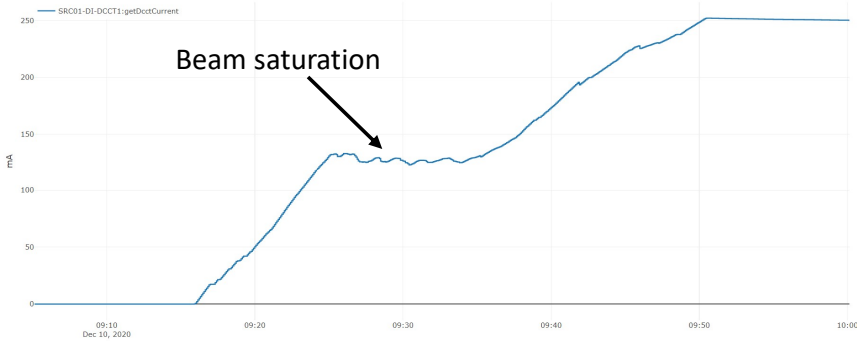
Injection scheme in storage ring

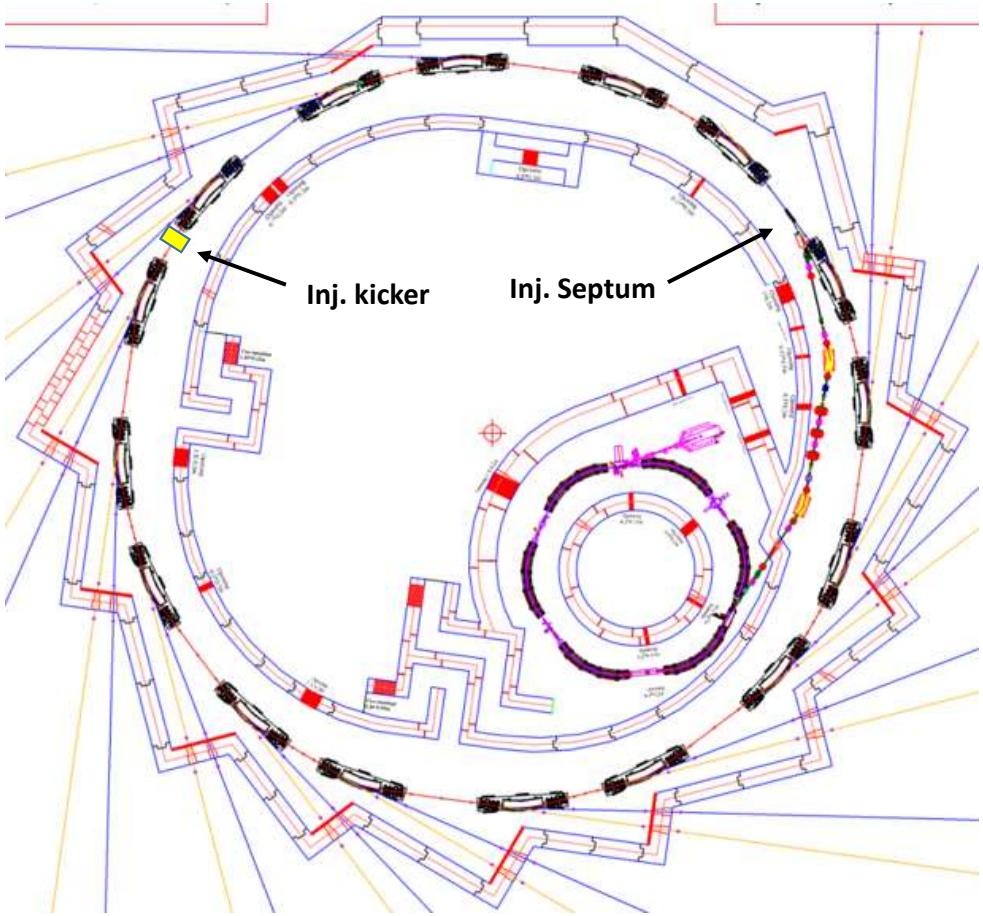
- **A single dipolar kicker injection scheme**: *kicker pulse is 0.84µs half sine one*.

- Stored beam is kicked together with the injected beam using a compromised kicker strength.

- HOMs in RF cavities are always there at injection energy (800 MeV).

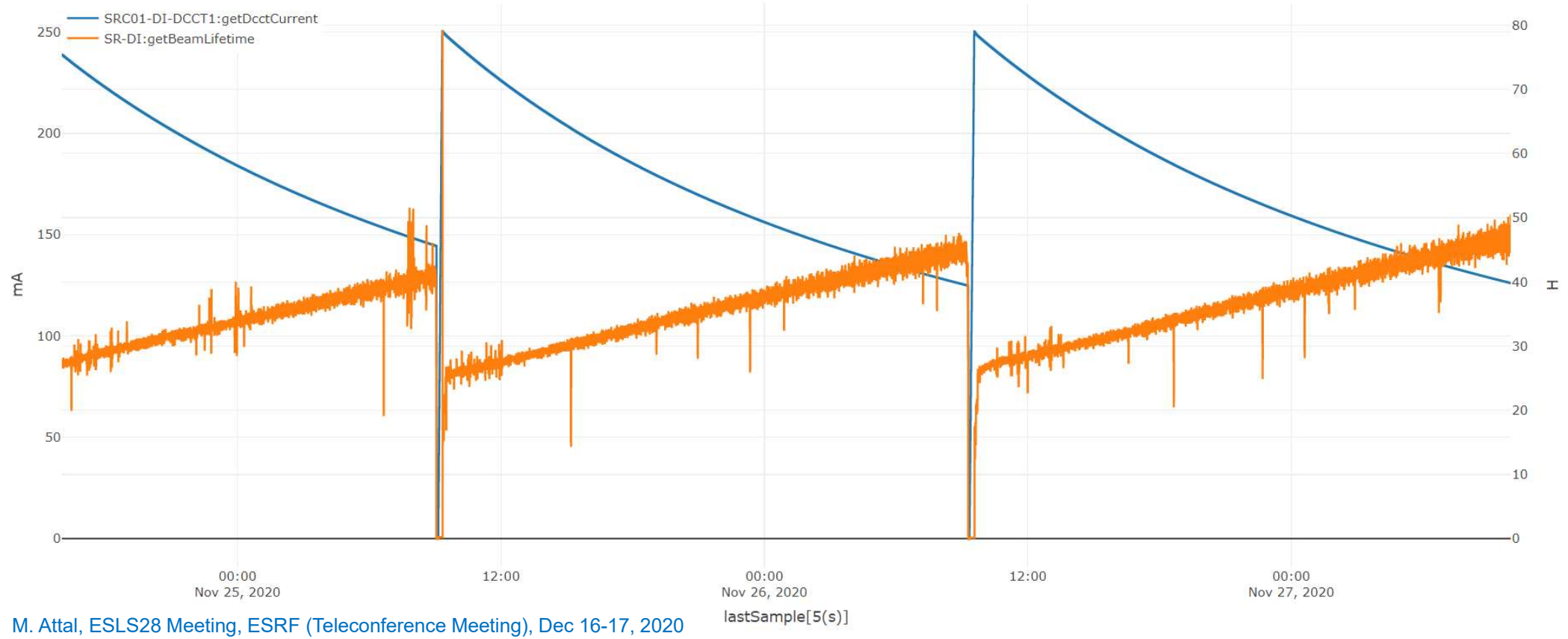
Beam saturation is seen during injection from time to time due to CBI.





One injection per day due to the good beam lifetime

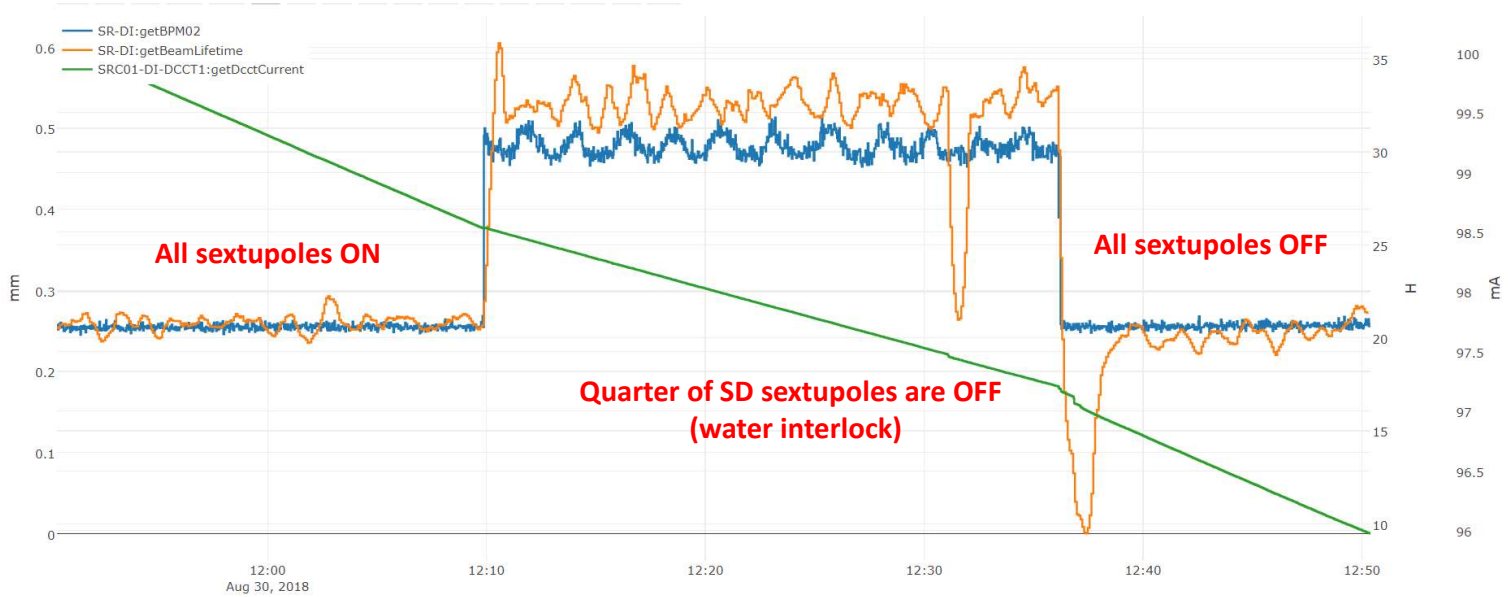
- <beam current*lifetime> = 6200 mA.h, using coupling ≈ 1%.
- Integrated beam dose now = 960 A.h.



Electron beam stability

- Operational chromaticities used are $\xi_x = 6$ and $\xi_y = 7$ respectively. This is sufficient to get a stable beam at high current values (up to 250mA). No feedback systems are used yet.

- At low current values ($\leq$ 100mA) sextupoles seem not required any more !

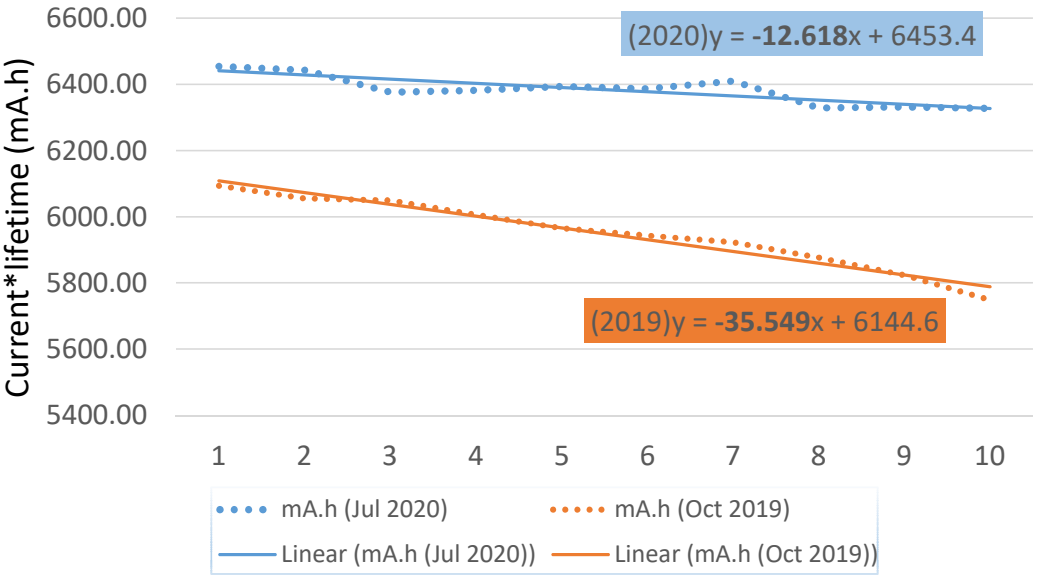


- The main beam instability, that is coming from RF cavities' HOMs, is suppressed by fine-tuning cavities' temperature.

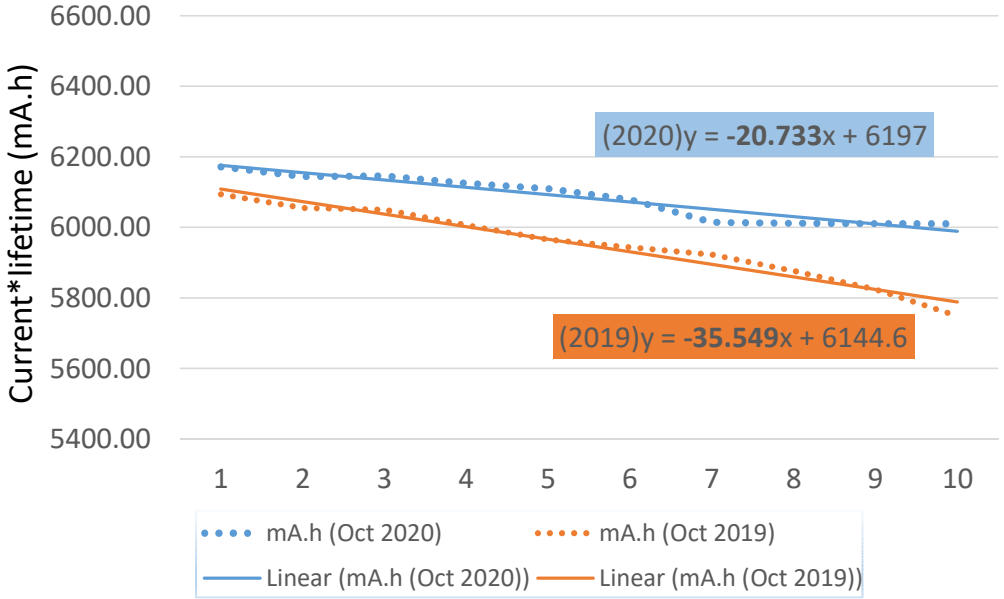
Beam lifetime and vacuum breakdown incident

- Vacuum breakdown (July 29, 2020) in cells 13, 14 & long section of cell 15, due to damage in view port glass window.
- The vacuum chamber exposed to air was not baked out due to technical difficulties.
- More than 96% of the beam lifetime has been recovered.

(July 29, 2020 before incident) vs (Oct 14, 2019)



(Oct 14, 2020) vs (Oct 14, 2019)

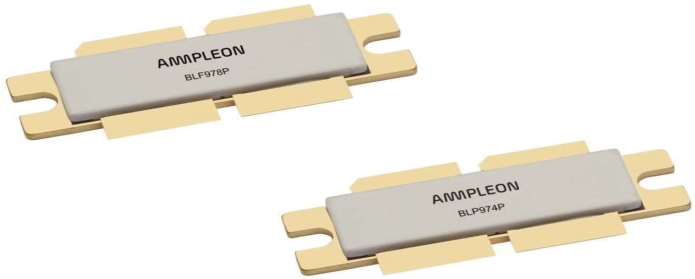


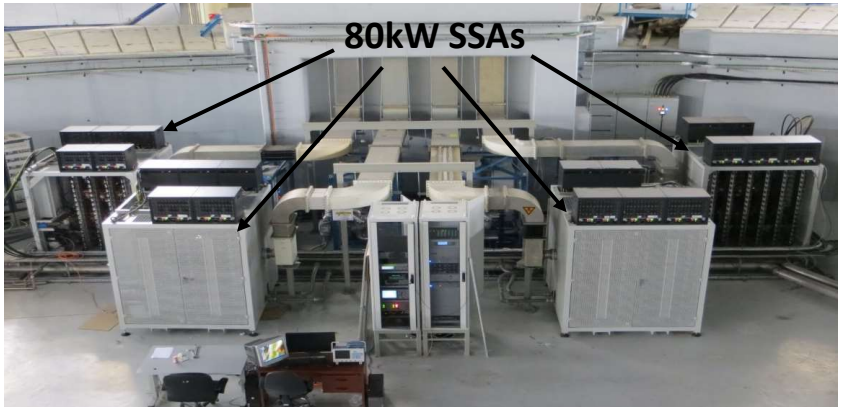
RF system: migration to new transistors

- The solid-state amplifiers are working smoothly with no major issues.
- The transistors **BLF578** in use are getting obsolete and a new type **BLF978P** is being produced.

  Migration to the new type of transistors is mandatory.

- The new transistors requires some modifications on the RF modules.
- Testing the new transistors has been started in collaboration with SOLEIL.

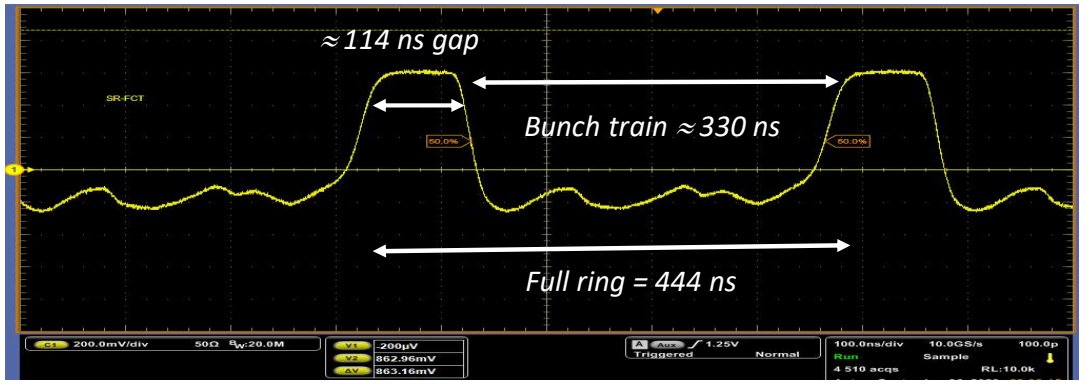




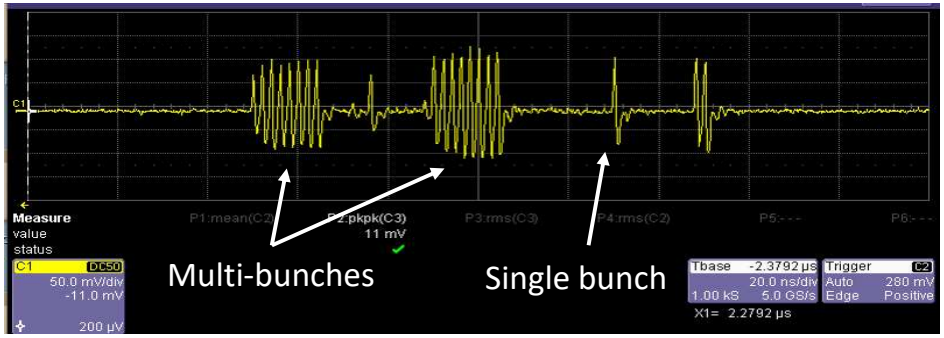
Different filling patterns in storage ring

- Only one filling pattern is available in SESAME storage ring:

  3/4 of the ring filled with electrons, and
  1/4 is kept empty as ion cleaning gap.

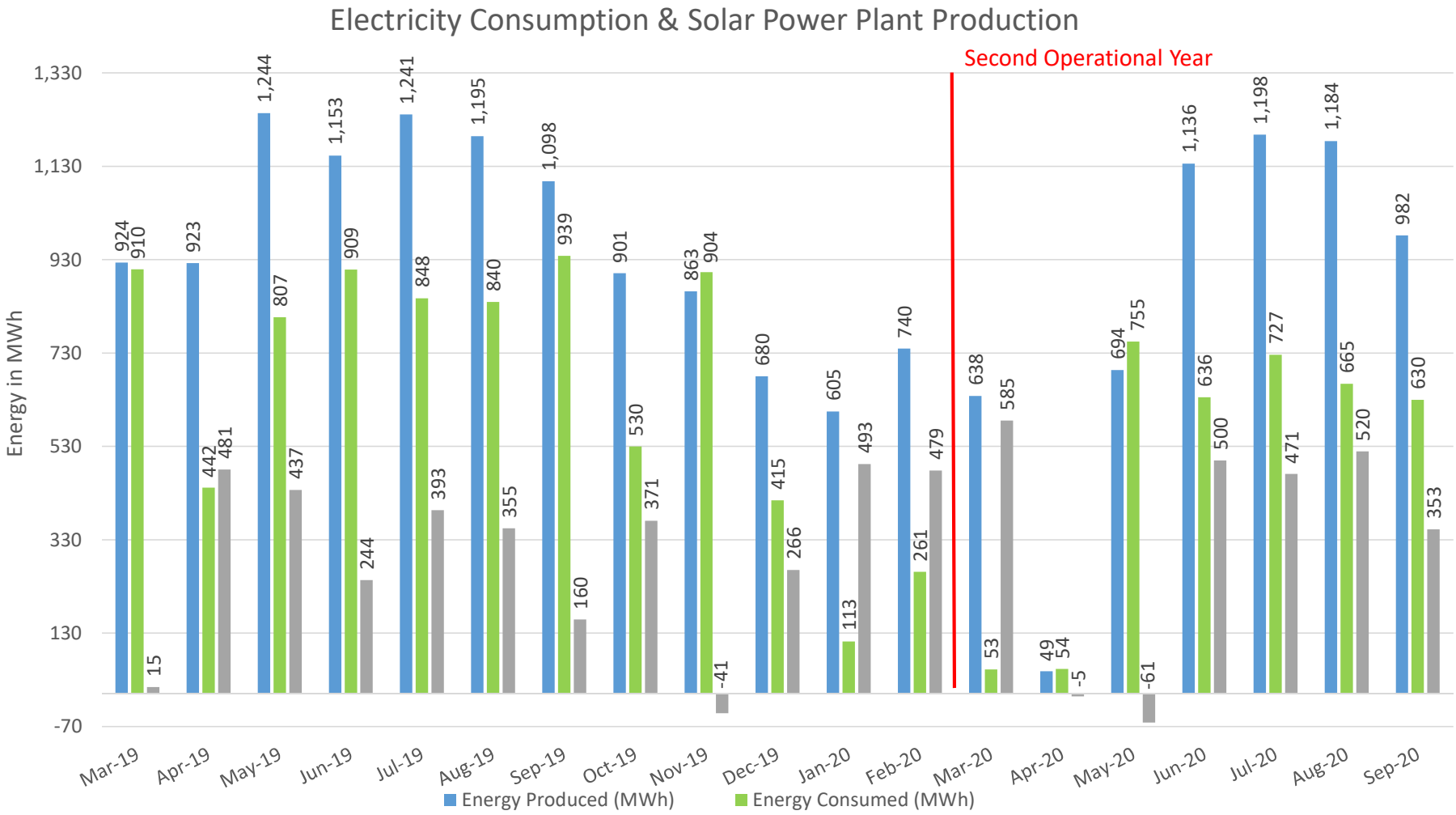


- Trials started in order to offer more filling patterns in the ring (*single bunch, hybrid modes*) using the '*bunch cleaning*' method.
- Bunch cleaning is done at 800MeV energy.
- **An issue**: a small current (~ 1 mA) is left in the remaining single bunch (*under investigation ?*).



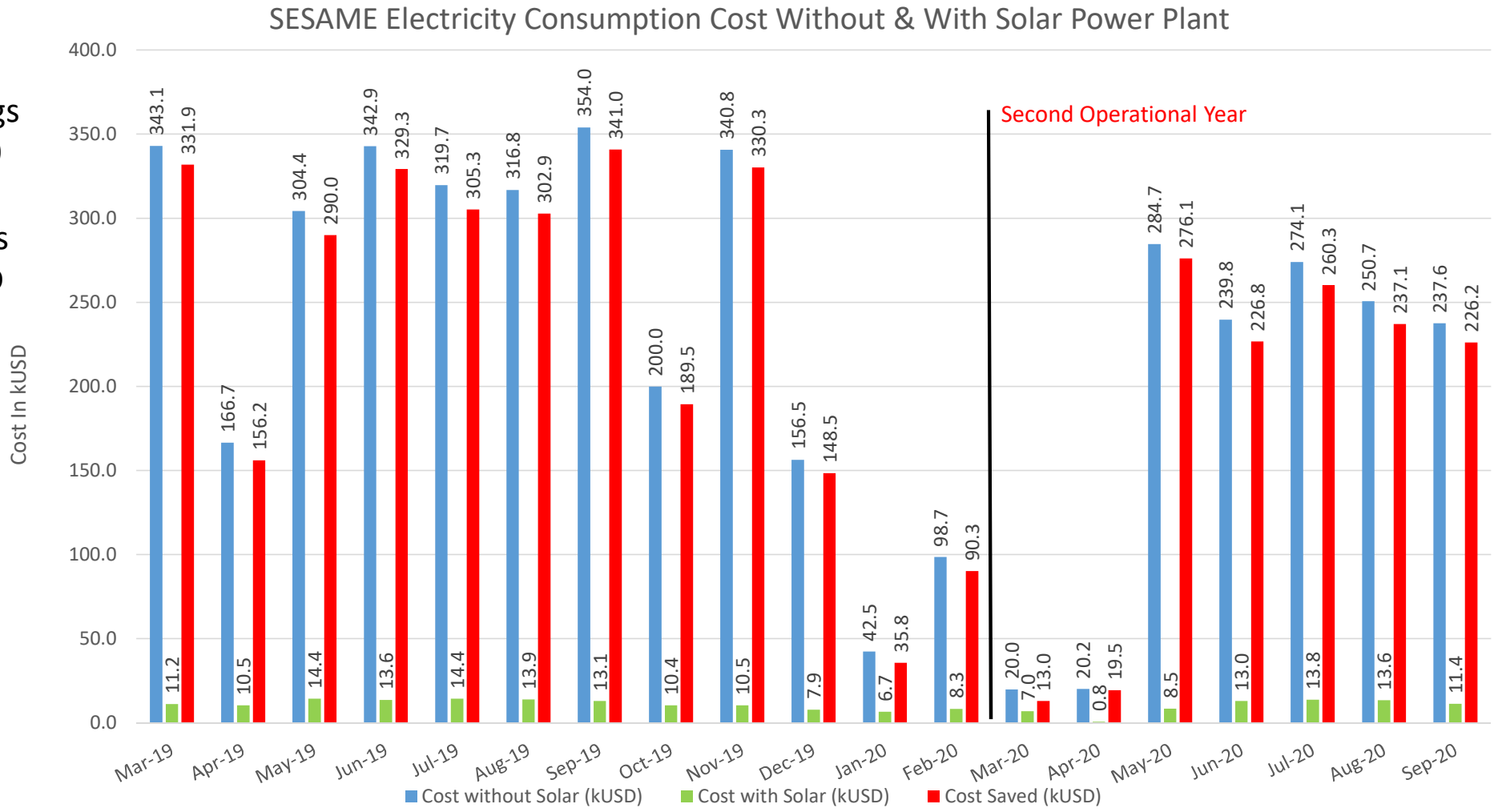
- More practice and experience are still needed.

SESAME is powered by Sun



SESAME is powered by Sun

Total savings over the 19 months of operation is **4,110**k USD



SESAME is powered by Sun

No.	Item	Value
1	a. Energy Produced in 2019 b. Energy Consumed in 2019 c. Extra Energy in 2019 d. Energy Credited to 2020 (10% of consumed energy) *	9,542 MWh 7,127 MWh 2,415 MWh 713 MWh*
2	a. Total Energy Produced in 2020 (Until Oct. 2020) b. Total Energy Consumed in 2020 (Until Oct. 2020) c. Extra Energy in 2020 (Until Oct. 2020)	7,907 MWh 4,306 MWh 3,601 MWh
3	Total Extra Energy (1 d + 2 c) (Until Oct. 2020)	**4,314 MWh**

* *According to Jordanian Regulation, Not More than 10% of the consumed energy will be credited to the next year.*

SESAME

Machine Operation in the COVID-19 Pandemic

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Safety instructions and procedures

- **Basic safety procedures**:

  Wearing masks + safe distance + cleaning hands + checking temperature at facility entrance + one person/ office.

- **Follow-up for suspected cases**:

  - **suffering from any respiratory symptoms**: not allowed to enter SESAME unless a full assessment is conducted by Safety Officer.
  - **a suspected case in his family or close people**: inform safety officer and his sector director, and wait for some days watching himself before coming to SESAME.
  - **a confirmed case in his family or close people:** inform safety officer and his sector director, and wait for up to 14 days watching himself before coming to SESAME (in case he had symptoms a COVID-19 test is needed).

- **Isolation zone:**

  all rooms in the old guest house ground floor are specified as isolation zone for suspected cases inside SESAME.

- **Users:**

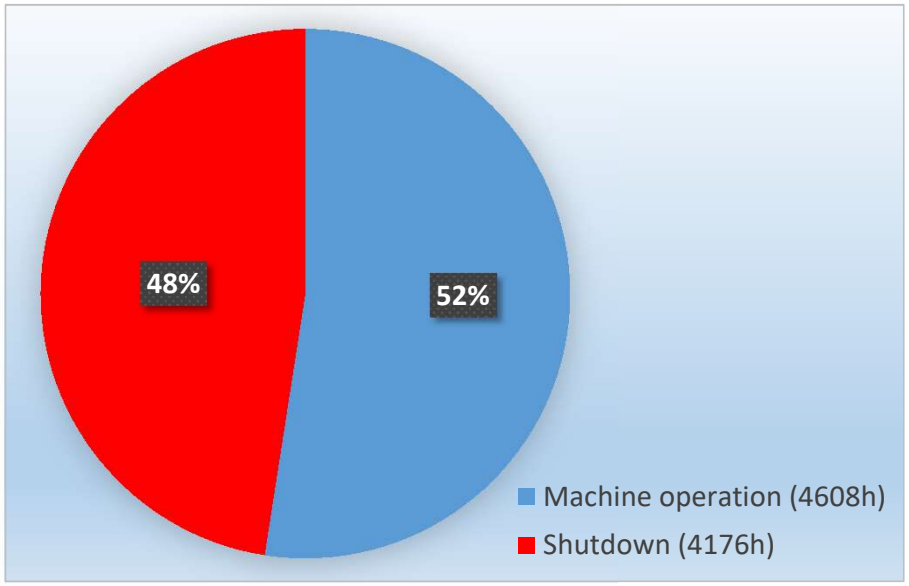
  mail-in samples method used. Local users could conduct some of their experiments under high safety restrictions.

Machine operation with minimum staff

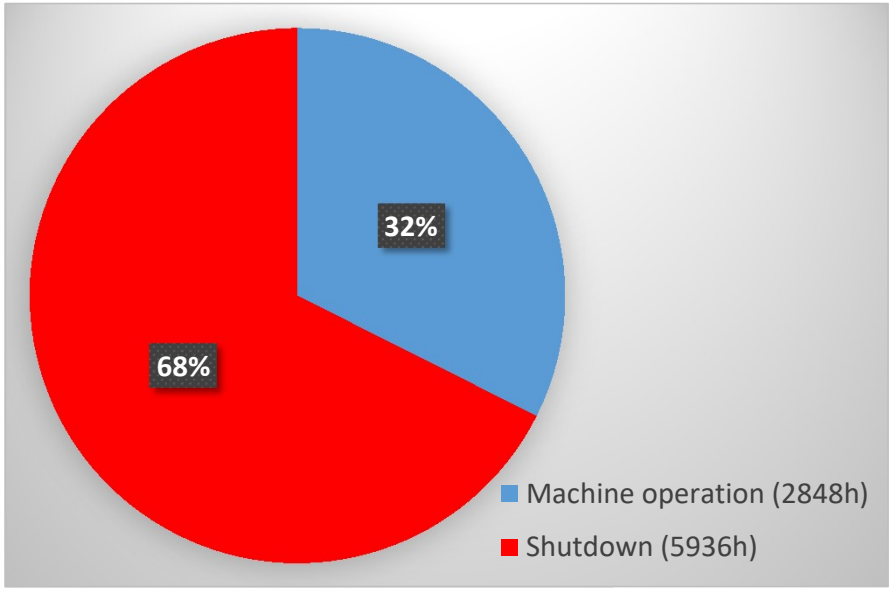
- The machine is operated to comply with the plan using ≤ 50% of the technical staff on site.
- The staff work schedules are planned on a bi-weekly basis taking into account the ability of some staff to work remotely from home, and the need for others to work on site.
- However, these schedules are frequently revisited due to COVID-19 related developments.
- The machine is manned in the period 8:00 - 22:00 (two shifts / day) during the user time:
    - one operator in the day shift.
    - two operators in evening shift.

Impact of COVID-19: reduced machine operation time

Planned machine calendar 2020

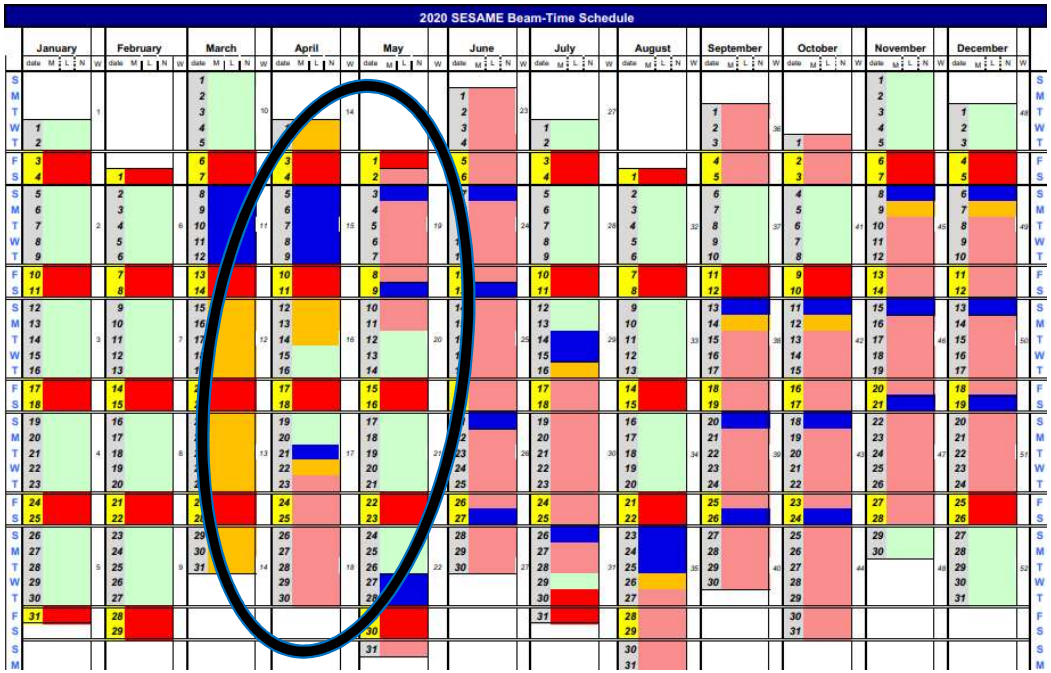


Achieved calendar due to COVID-19

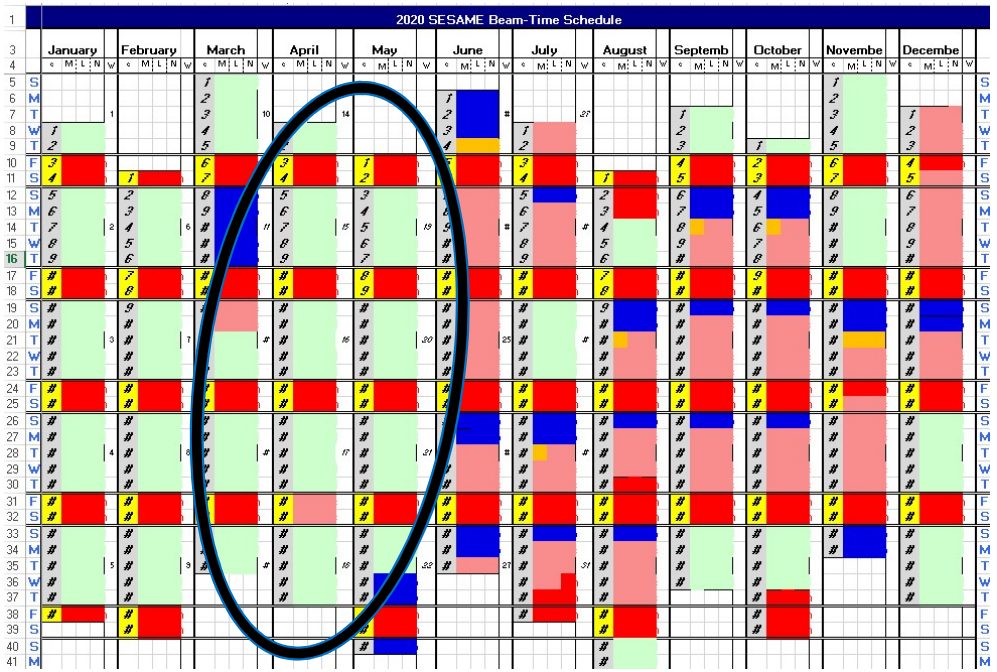


Impact of COVID-19: changes on machine calendar 2020

Planned machine calendar 2020



Achieved calendar due to COVID-19



- The time lost due to lockdown (March 17 – May 25) modified later to be a shutdown period.
- The machine operation changed to be 5 days / week (*absence of users, curfews during weekends*).

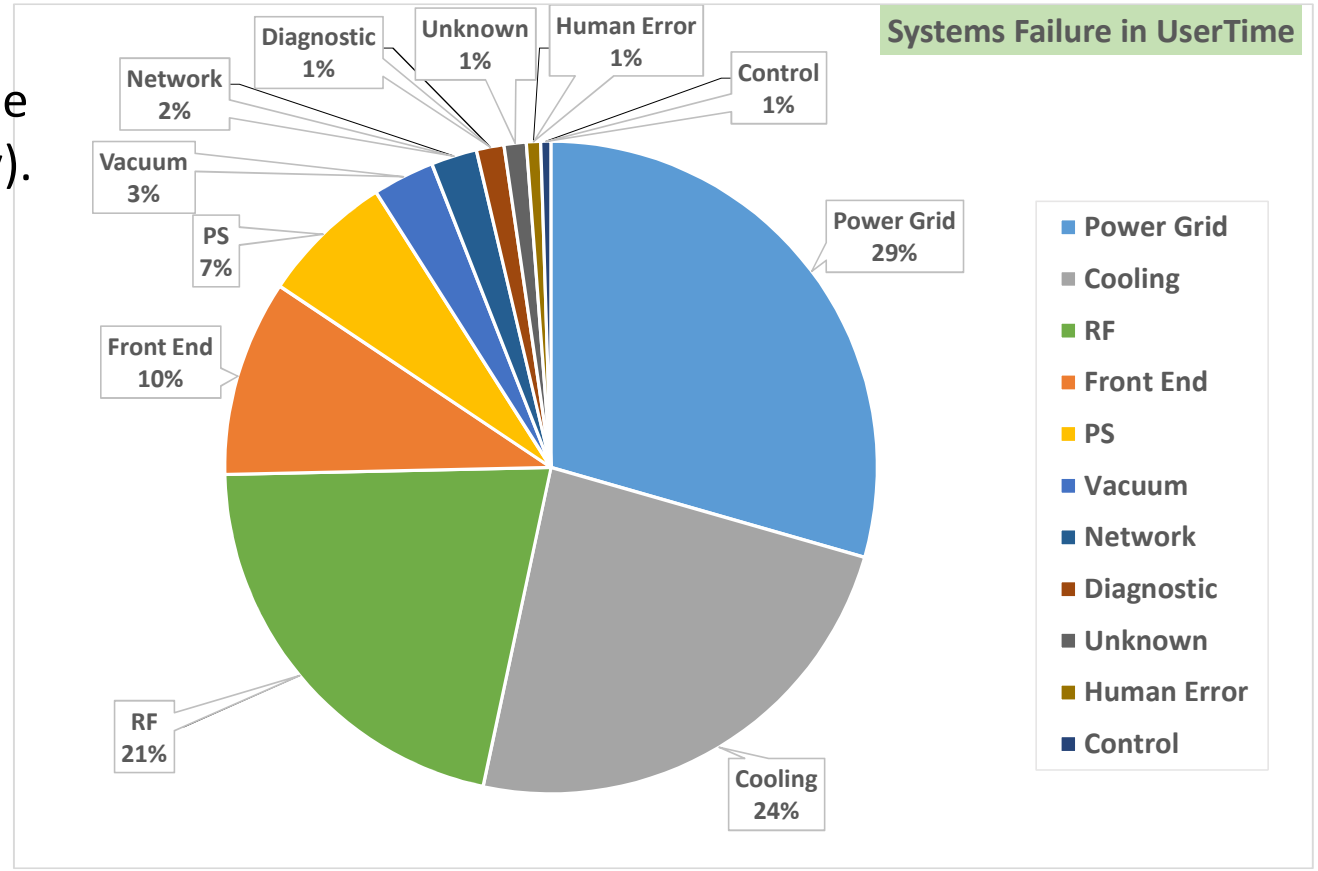
Impact of COVID-19: increased machine failure time

- The failures considered only in the user time (injection + top energy).

  Total failure time = 65.8 h

  Power grid failure time = 19.4 h

- *Power grid instability due to COVID-19 related conditions.*



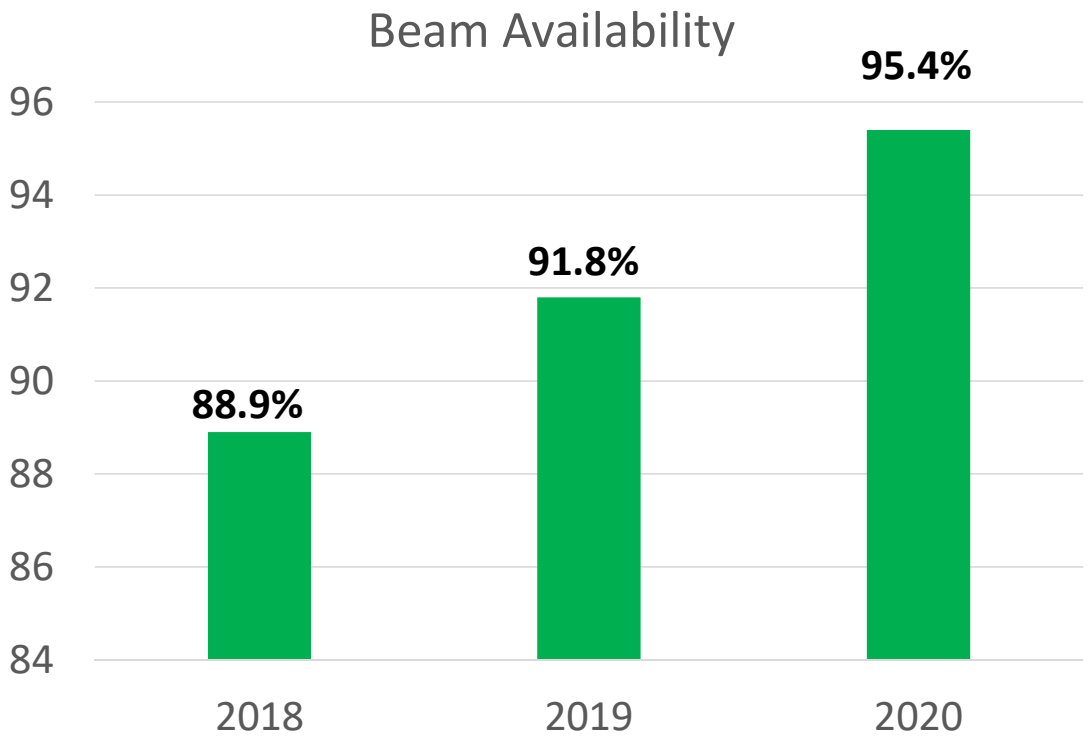
Impact of COVID-19: reduced beam availability

- Criterion: *the time delay in injection is considered a failure time* (*reference injection time = 30 min*)

- Beam availability for users = **95.4 %**
- **MTBF** (Mean Time Between Failure) = **19.5 h**
- **MTTR** (Mean Time To Repair) = **0.85 h**

By including the power grid failures (Impact of COVID-19)

- Beam availability for users = **93.7 %**
- **MTBF = 17.9 h**
- **MTTR = 1.1 h**



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SESAME injector

The plan foreseen for SESAME injector

- **Short term solution**

  Refurbishment of the existing microtron to improve machine reliability and move away from the risk of single point of failure.

- **Medium and long term solution**

  Work on having a 100 MeV Linac for:
  - better reliability
  - getting flexibility in storage ring filling patterns.
  - faster filling for the storage ring, hence reduction in the injection time.
  - the 1st step towards full energy injector.

Status of Microtron refurbishment

Microtron with aged subsystems

Auxiliary Gun PS

- No spare units existing.
- Some of its parts are obsolete.

Highly critical
Should be replaced as soon as possible.

On-going

Modulator

- Its LL electronics, PFN are problematic.
- Its interlock signals are highly problematic.

Highly critical
Should be replaced as soon as possible.

On-going

Central Control Rack

- Most of its wires are disconnected.
- But it is still a central connection interface for many signals.

Critical
Should be removed From the control path.

Done

Actuating Motors and Accessories

- DC motors with high loose and non-reproducible positioning.
- Old and problematic encoders.
- Aged and obsolete electric accessories.

Gun motors

Magnetron motor

Normal
Should be changed but with less priority.

Didn't start yet

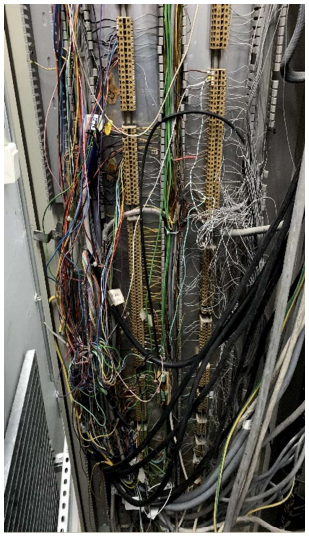
The old control rack replaced by a new one

- The old central control rack has been replaced by a new one that is:
  - well organized and well wired (*more reliable)*.
  - well documented wiring diagrams (*signals can be easily tracked within a short time)*.

- The old power and control cables have been replaced by new ones.

Old control rack

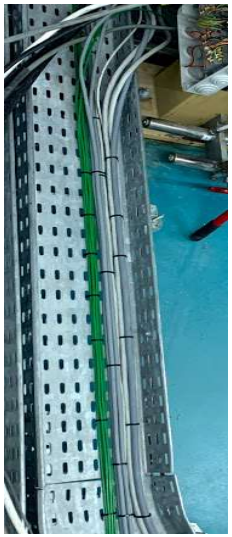
Old control rack



New control rack

New control rack

New cables



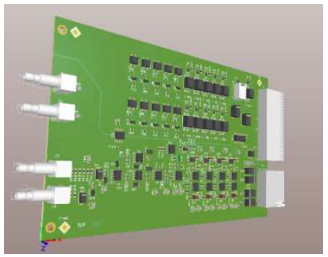
Building a new auxiliary gun power supply

- AGPS is composed of:
  - two commercial (customized) power supplies
  - control modules designed by SESAME

- The power supplies have been purchased and their stability has been tested at SESAME. They showed a high performance.

- Functionality of the AGPS system has been demonstrated using a test bench installed in the lab. It behaved as expected.

- Design of control modules is in “review phase”, and the PCB boards to be ordered very soon.



SESAME

Accommodation of 100MeV Linac

Accommodation of 100MeV Linac

- **Option 1**:

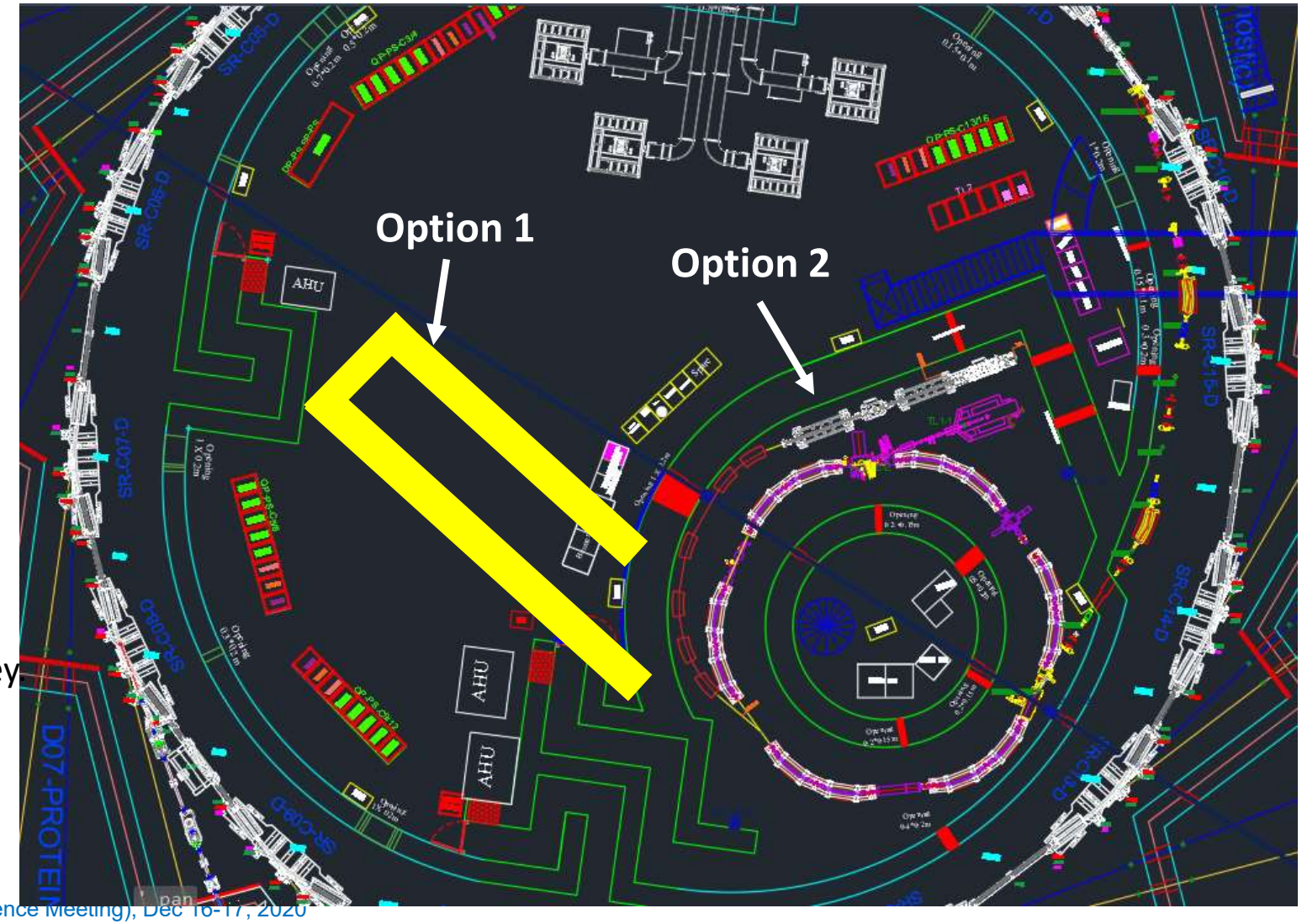
- space, effort and money consuming.

- other complications:
  - o closes Booster entrance
  - o closes service area

- **Option 2**:

- saves space, effort & money

- shorter Linac is needed.

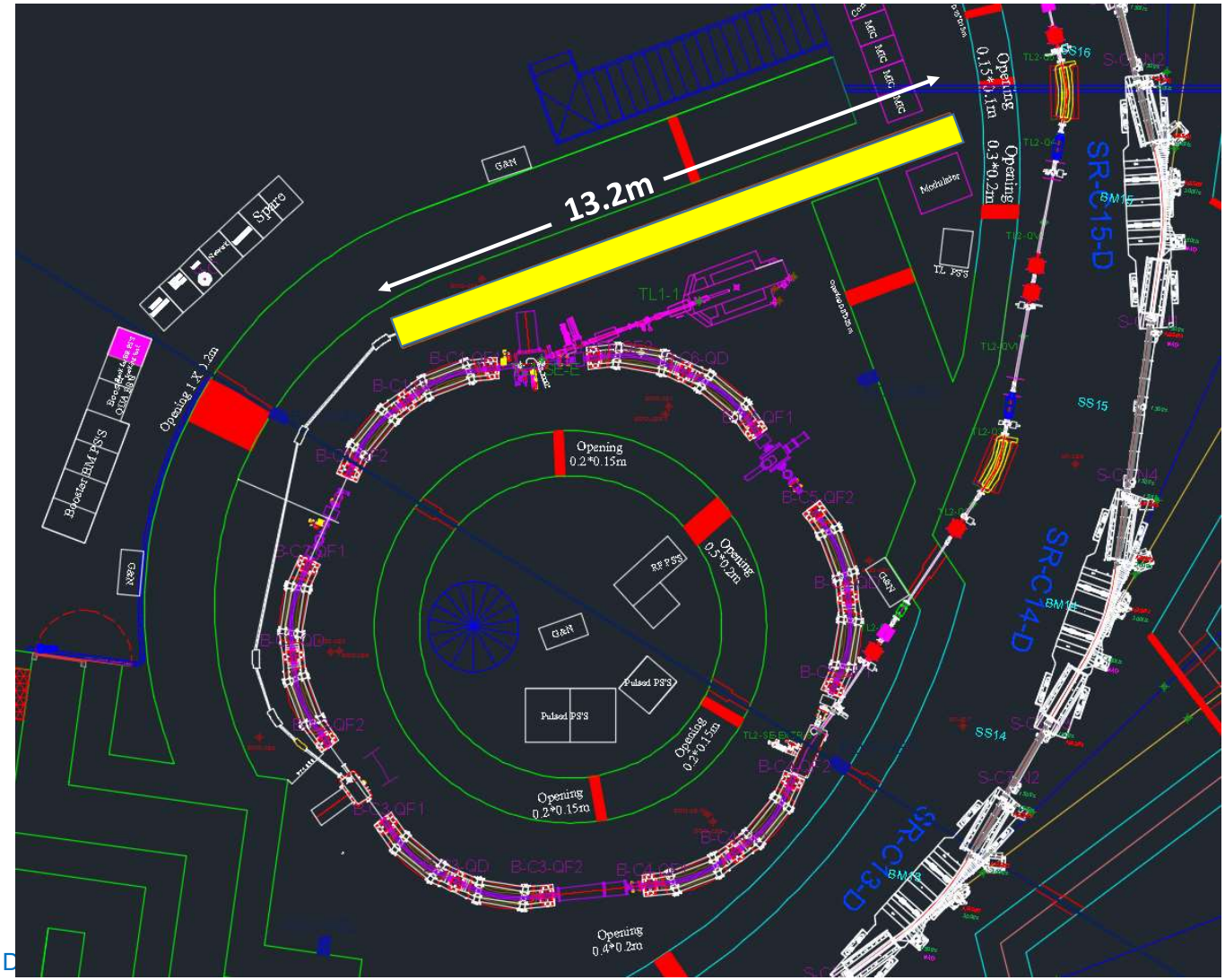


Accommodation of 100MeV Linac

- **Option 3**:

- an extension to option 2 where a traditional Linac (13 m) can be installed.
- Linac needs to penetrate the back shielding wall.
- The triangle-like area needs to be shielded.

Option 2 looks the most attractive one, hence we are working on it.



Proposed layout of Linac and Linac-Booster transfer tine

- A 9.5m length proposed for the 100MeV Linac in the booster tunnel.

Proposed transfer line layout

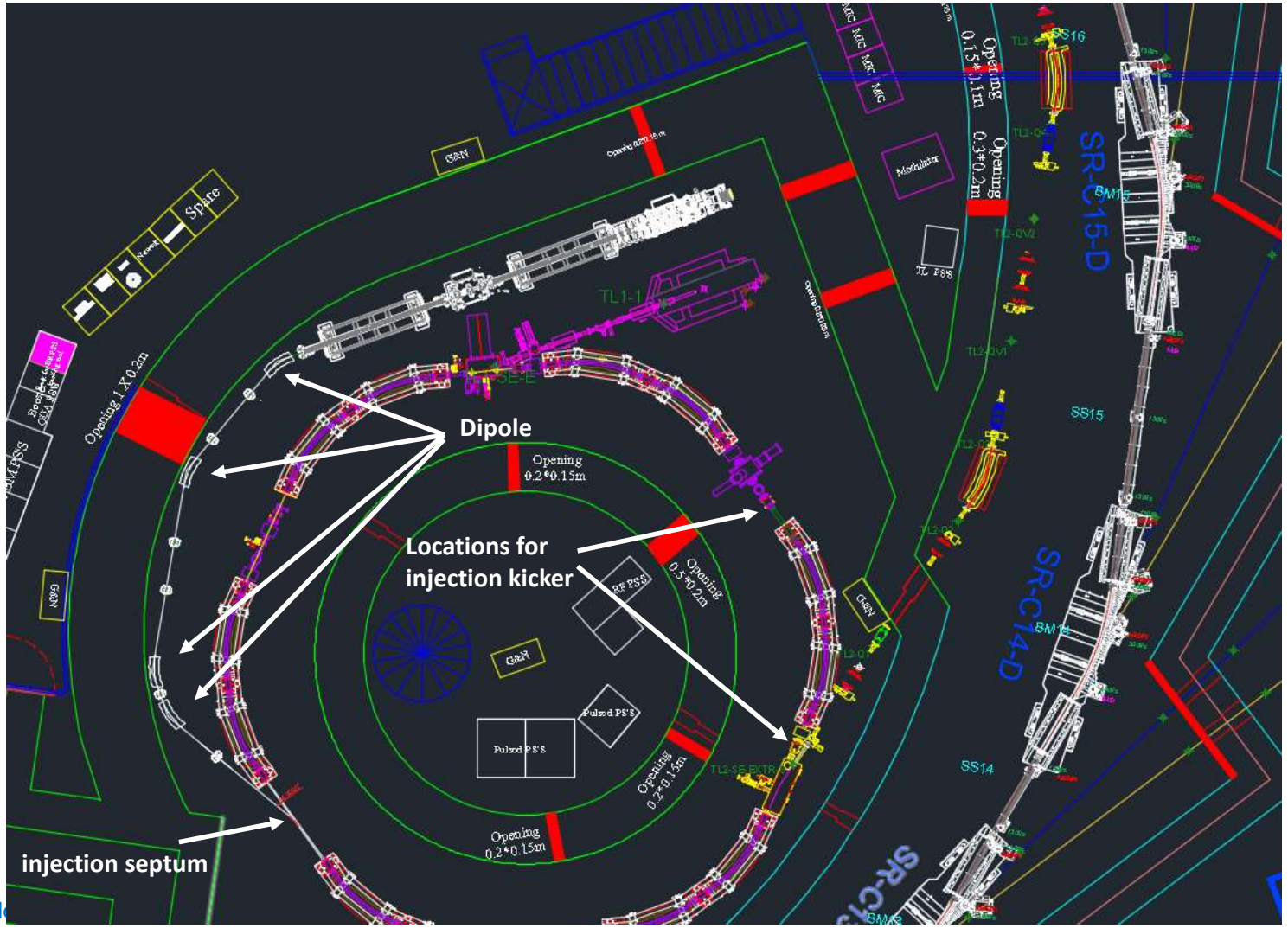
- Four equal dipoles:
  - **bending angle = 30°**
  - **B = 0.28 T, L = 62 cm**

Proposed injection into Booster

- 14.3° injection septum.

- Two possible locations for the injection kicker. A 30cm kicker fits easily there.

- ***The microtron will be kept as a backup injector***.



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Thank you