EUROPEAN
SPALLATION
SOURCE

Proton Driver Considerations

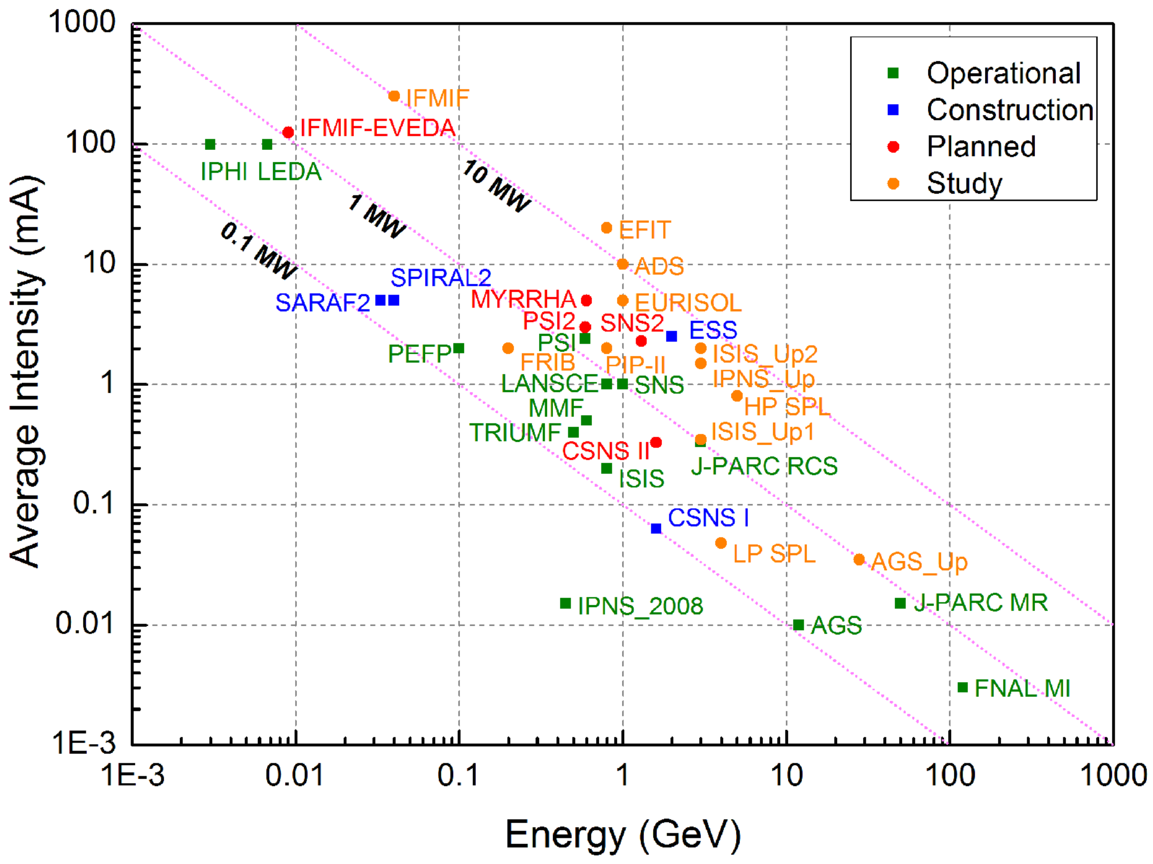
Muon Collider Collaboration Meeting

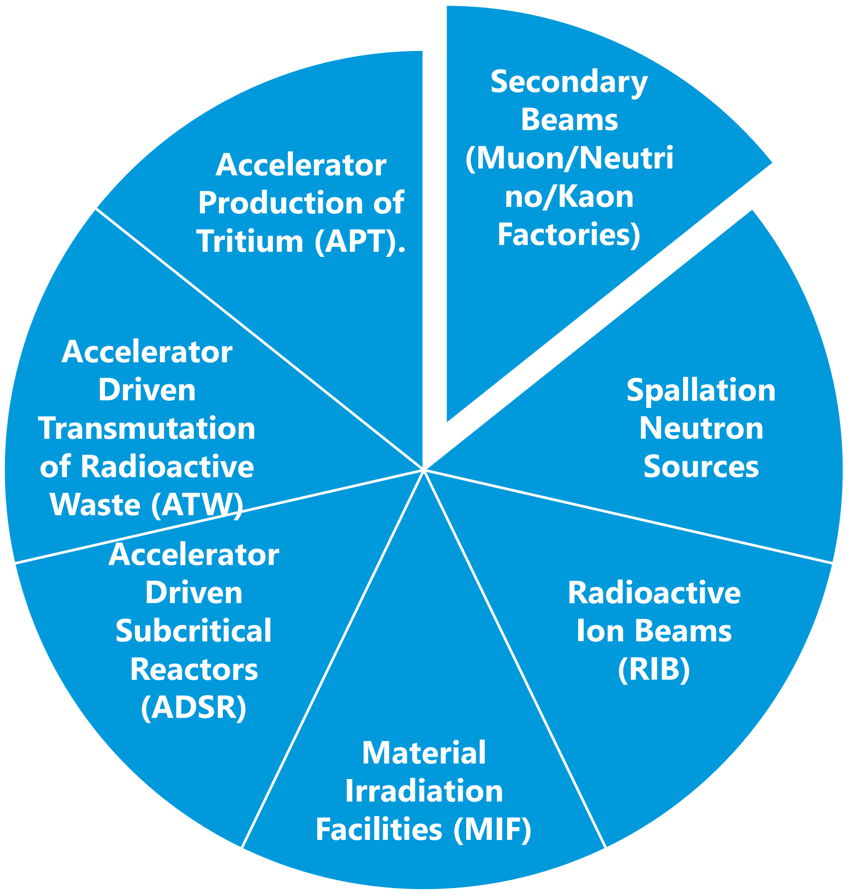
PRESENTED BY CIPRIAN PLOSTINAR

2022-10-17

Demand for High Power Beams

Global Picture





Proton Driver Requirements Context

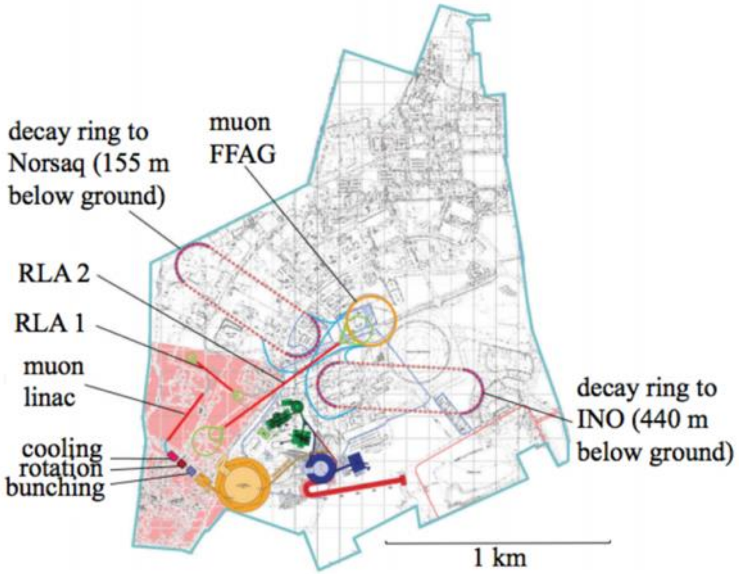
Some 30 Years History

- Joint effort in developing proposals for the development of Neutrino Factories (NF) and Muon Colliders (MC)
- Significant overlap for proton driver requirements for the NF and MC
- **Neutrino Factories:**
  - EUROnu Study []
  - **ISS-NF**: International Scoping Study of a Future Neutrino Factory and Superbeam Facility []
    - Accelerator Working Group (AWG) []
  - **IDS-NF**: The International Design Study for the Neutrino Factory
    - Expand the previous findings to develo baseline concepts for each part of the facility.
- **Muon Colliders**
  - Muon Accelerator Program (MAP)
- **Outcome of Studies:**
  - Baselines defined
  - Requirements for a proton driver analysed:
    - Beam Power, Optimum Beam Energy, Repetition Rate, Bunch Length, Etc.
    - Preferred hardware configuration (linac, synchrotron, FFAs)
- **Broad requirements today:**
  - ~2 MW beam power, low repetiotion rate (5 Hz), very short bunches (1-3 ns), 10 GeV energy range.

Proton Driver Requirements Context

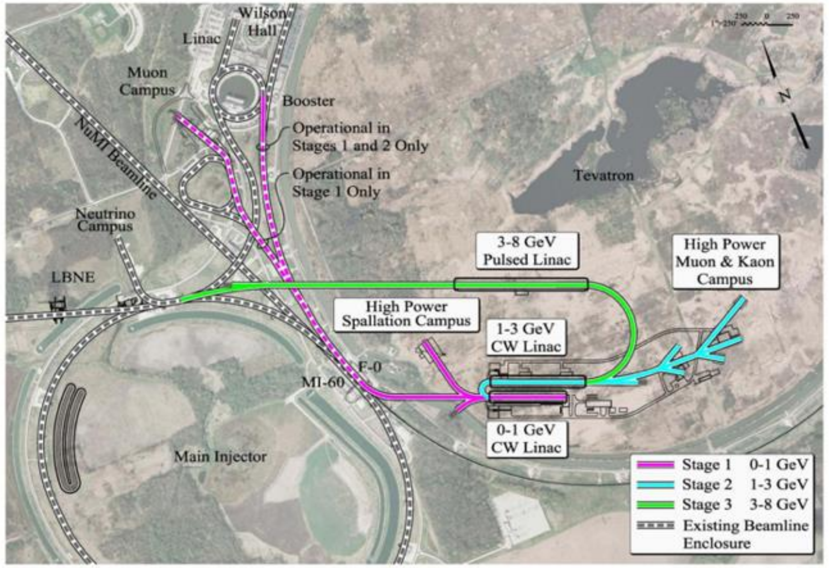
Some 30 Years History

@RAL



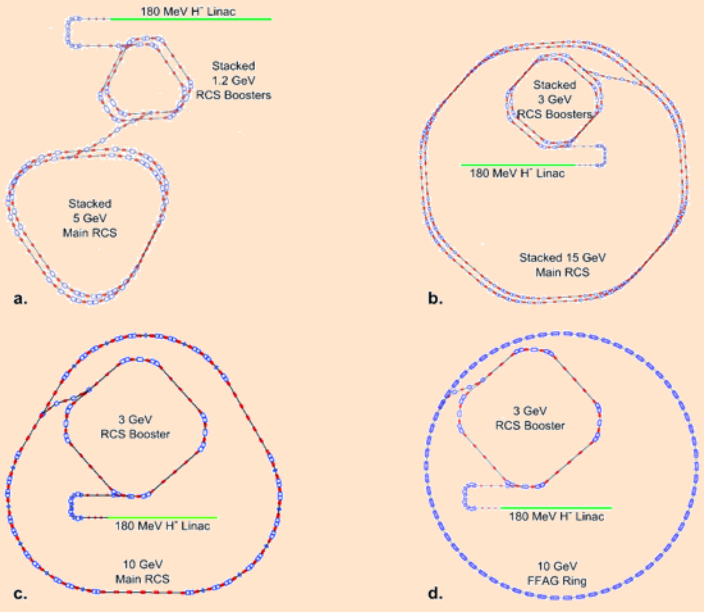
@CERN

@Fermilab

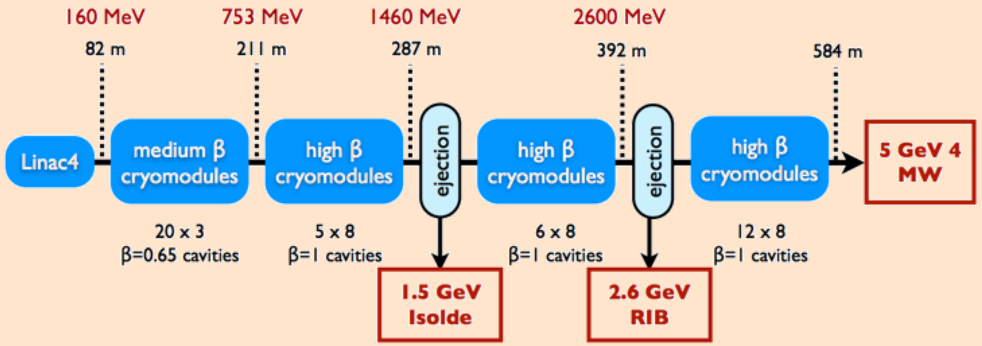


Past Proton Driver Proposals

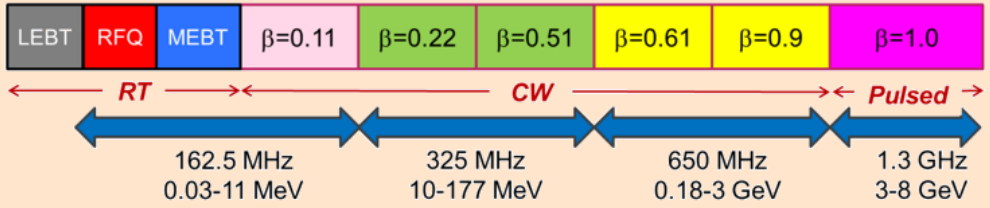
But never built



At RAL, multi-MW machines were proposed as proton drivers that would also serve as a driver for the ISIS Spallation Neutron Source.



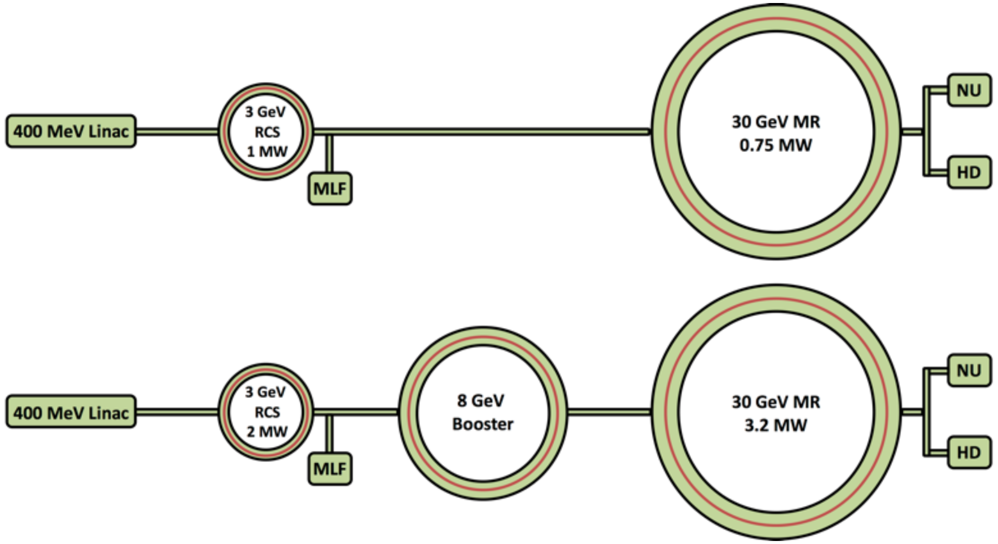
At CERN, a superconducting proton linac (SPL) was studied, with an energy of 5 GeV and a beam power of 4 MW.

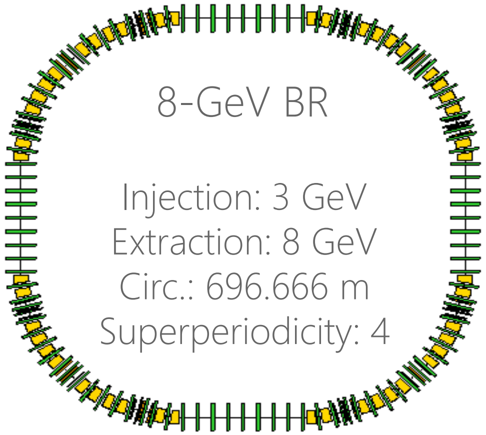


ProjectX at Fermilab aimed to deliver beam powers up to 3 MW using a CW linac driver with the option for future staged upgrades.

Current Global Landscape

Japan – J-PARC

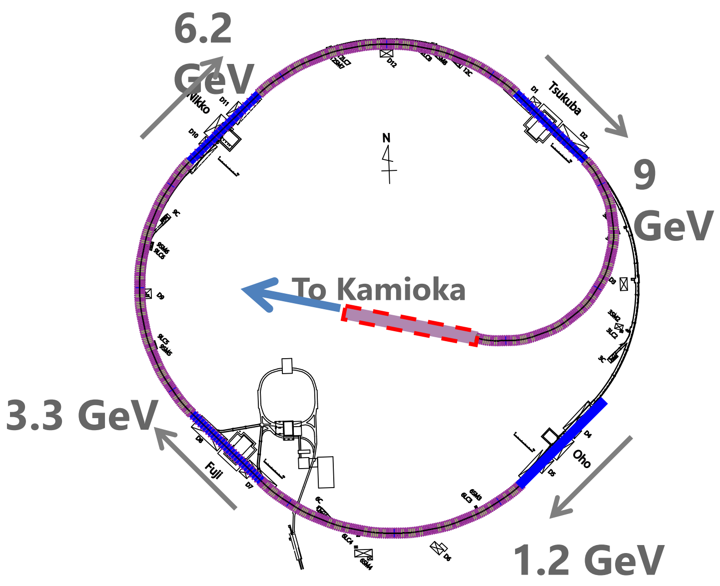


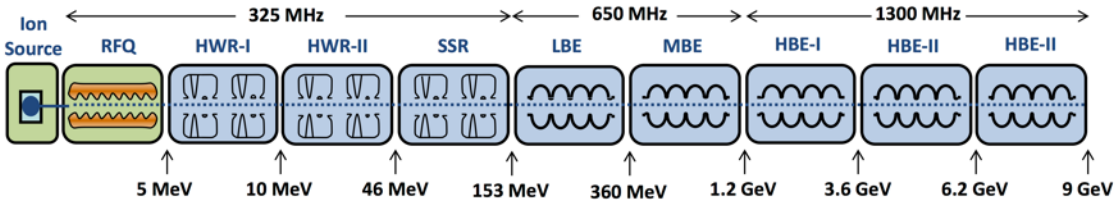


- In the RCS, 800 kW is now routinely delivered for user operation while operation at 1.0 MW (equivalent) was also demonstrated.
- Plans for incremental upgrades up to 1.5 MW are being made in preparation for the addition of a second neutron target station.
- In the MR, stable operation at 500 kW was also achieved, with a 2.48 s cycle time and an intensity of 2.5e14 ppp. Upgrade to 1.3 MW is planned. It includes upgrade of the magnet PS, RF, ring collimators, injection and fast extraction systems, etc. This will allow fast cycling (1.16 s) and higher intensity (3.3e14 ppp).
- Long term upgrades include adding an 8 GeV ring between the RCS and the MR.

Current Global Landscape

Japan - KEK

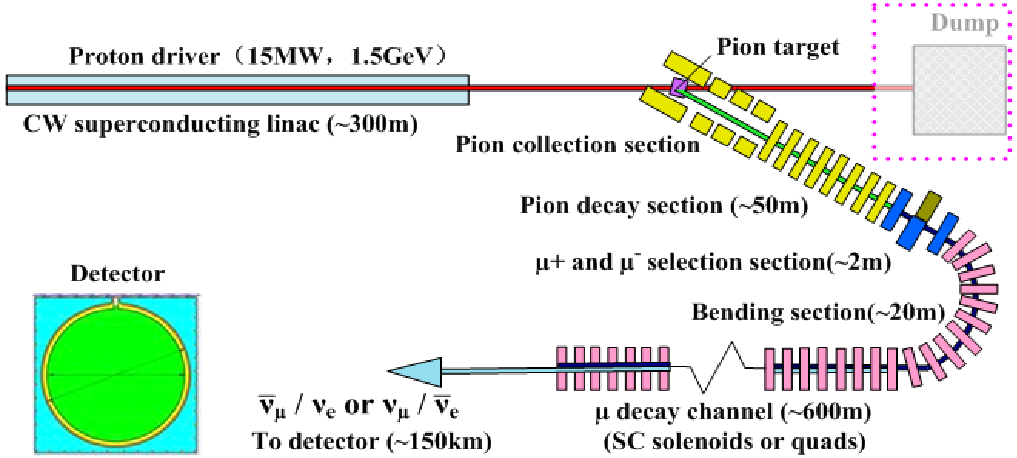


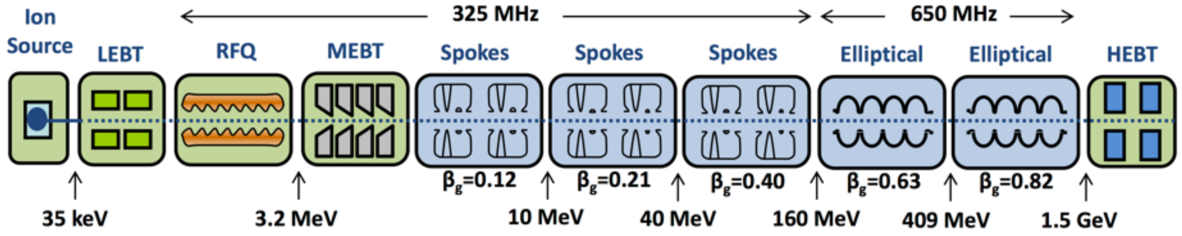


- Proposal to utilise the KEKB tunnel to build a 9 GeV proton linac after SuperKEKB will come to the end of its planned operational life.
- The new linac will be employing SC cavities and making use of the technology already developed for the ILC. The tunnel has a fourfold configuration with four straight sections and four arc sections.
- The accelerating structures will be placed in the straight sections, with the energy ramping to 1.2, 3.3, 6.2 and finally 9 GeV as illustrated.
- Operating at 100 mA and 1% duty cycle, the new machine could provide 9 MW beams for neutrino experiments at

Current Global Landscape

China

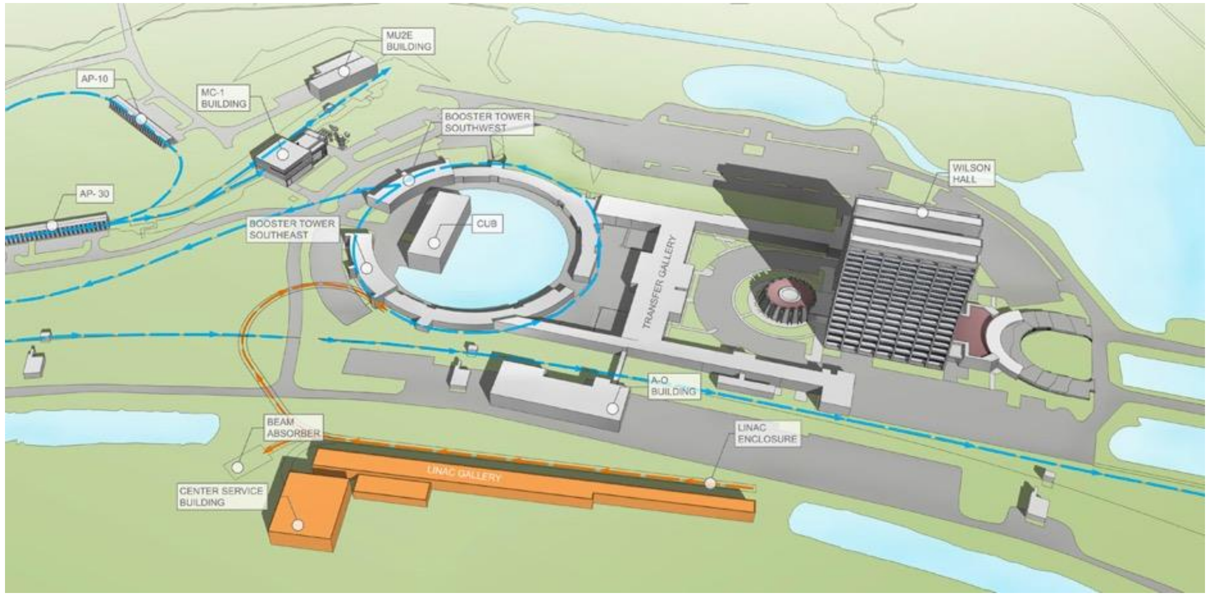


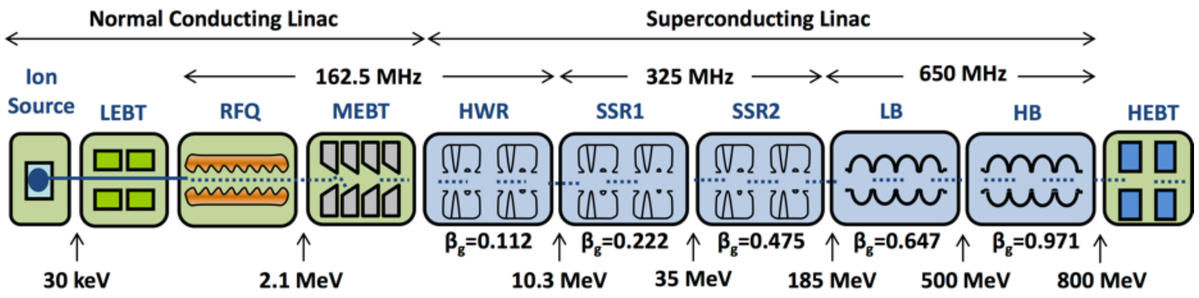


- MuOn-decay MEdium baseline NeuTrino beam facility (MOMENT)
  - Perhaps the most ambitious proposal. It aims to produce muon-decayed neutrinos.
  - The machine proposed is a CW SC linac, with a nominal design energy of 1.5 GeV and beam current of 10 mA, delivering a beam power of 15 MW
  - The linac will adopt the machine configuration currently under development as part of the China ADS programme (CADS), thus benefiting from the large ongoing R&D efforts.
- CSNS (China Spallation Neutron Source)
  - One proposal is the addition of a post-acceleration system to CSNS for a Superbeam facility. By using 10% of the CSNS beam, a system with a 20 GeV booster ring, followed by an accumulator ring and a 128 GeV main ring, could deliver beams in the 4 MW range

Current Global Landscape

North America

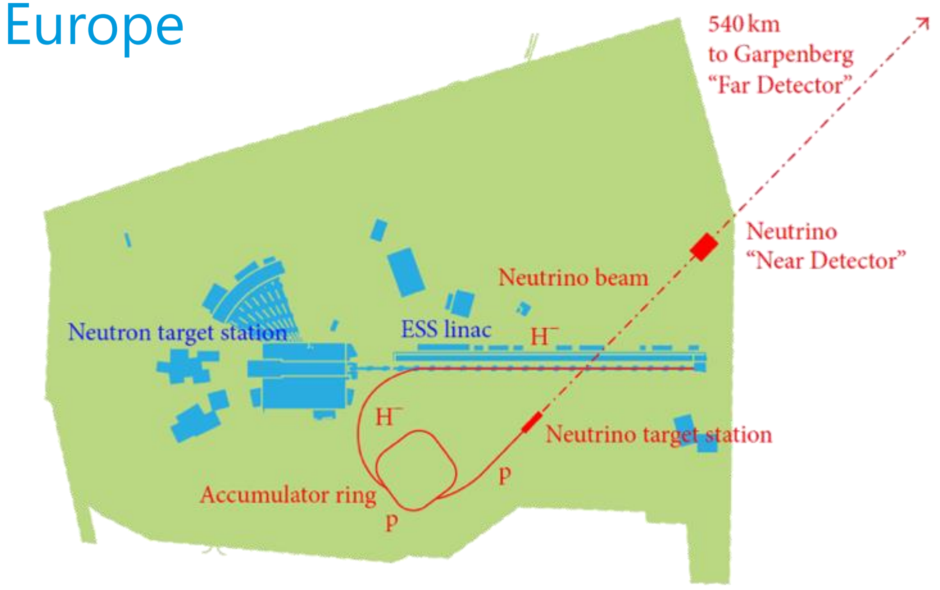


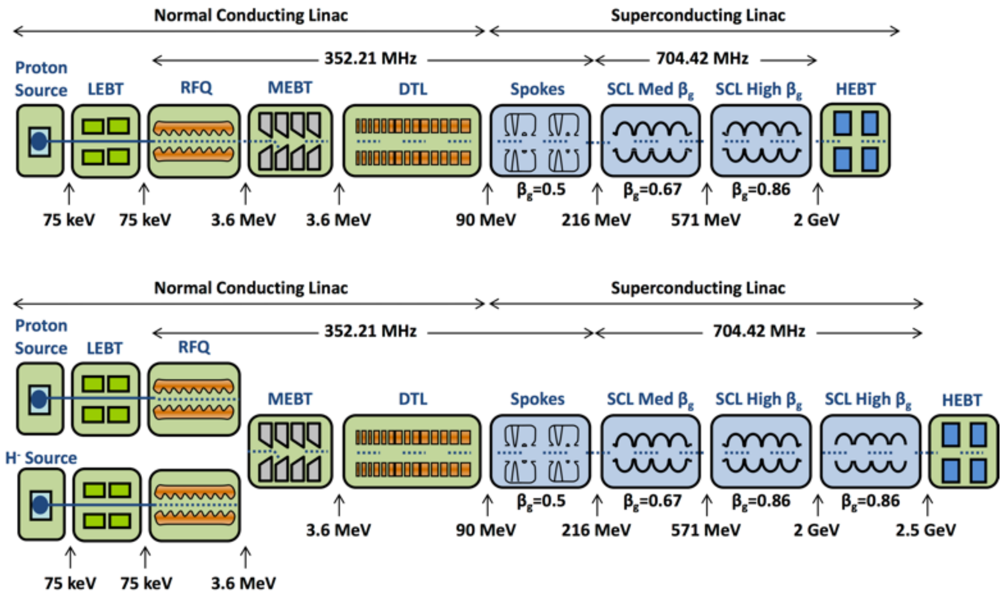


- SNS machine delivering 1.4 MW
- The Proton Improvement Plan II (PIP-II)
  - Plans for providing high power proton beams are closely connected with the upgrade strategy for Fermilab.
  - The main aim is to increase the Main Injector (MI) power from 700 kW currently available for the NuMI/NOvA programme to 1.2 MW at 120 GeV for the start of LBNF/DUNE operation.
  - The main development of PIP-II is a new 800 MeV, 2 mA SC H− linac. It will be operating in pulsed mode, but capable of CW operation for potential future upgrades. This will replace the current 400 MeV injector.
  - Further upgrades of the acceleration chain would allow beam powers of 2.4 MW.

Current Global Landscape

Europe





- ESS Neutrino Superbeam project (ESSnuSB)
  - ESS is currently under construction in Lund, Sweden. When completed, it will deliver a 5 MW proton beam at 2 GeV.
  - The ESSnuSB project is studying the possibility to add an accumulator ring and a neutrino target that would be using the ESS linac as the injector.
  - To avoid reducing the beam power to the neutron users, the proposal is to double the power in the linac to 10 MW, by accelerating both protons and H−, with the proton beam to be sent to the neutron target, while the H− beam to be injected in the accumulator ring via charge-exchange injection.
- nuSTORM
  - Also at CERN the feasibility of using the existing CERN infrastructure for a nuSTORM facility is being studied

Some Considerations

Proton Driver

- **Accelerator technology for the proton driver is now more mature to reduce the overall technical risk of a future facility.**
  - While significant technical challenges remain in meeting the MC requirements, in terms of beam power several facilities now delivering MW level beams
    - We have the experience of SNS and J-PARC.
  - Others facilities under construction are pushing that limit
  - Multiple R&D programmes (closed or ongoing)
  - Several technical options are being considered
  - ESS – J-PARC workshop remark: “At J-PARC the accelerator was not the biggest challenge!”
    - What is the biggest challenge for the MC?

Some Considerations

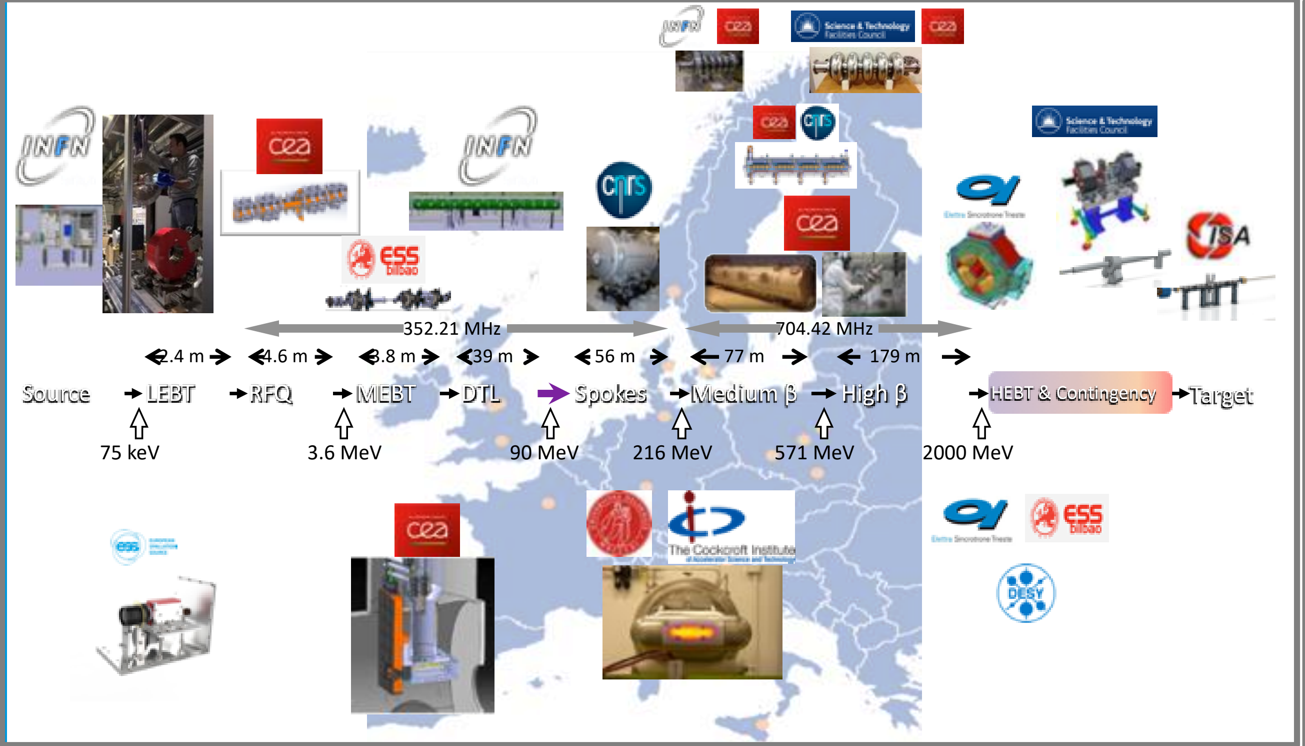
Proton Driver

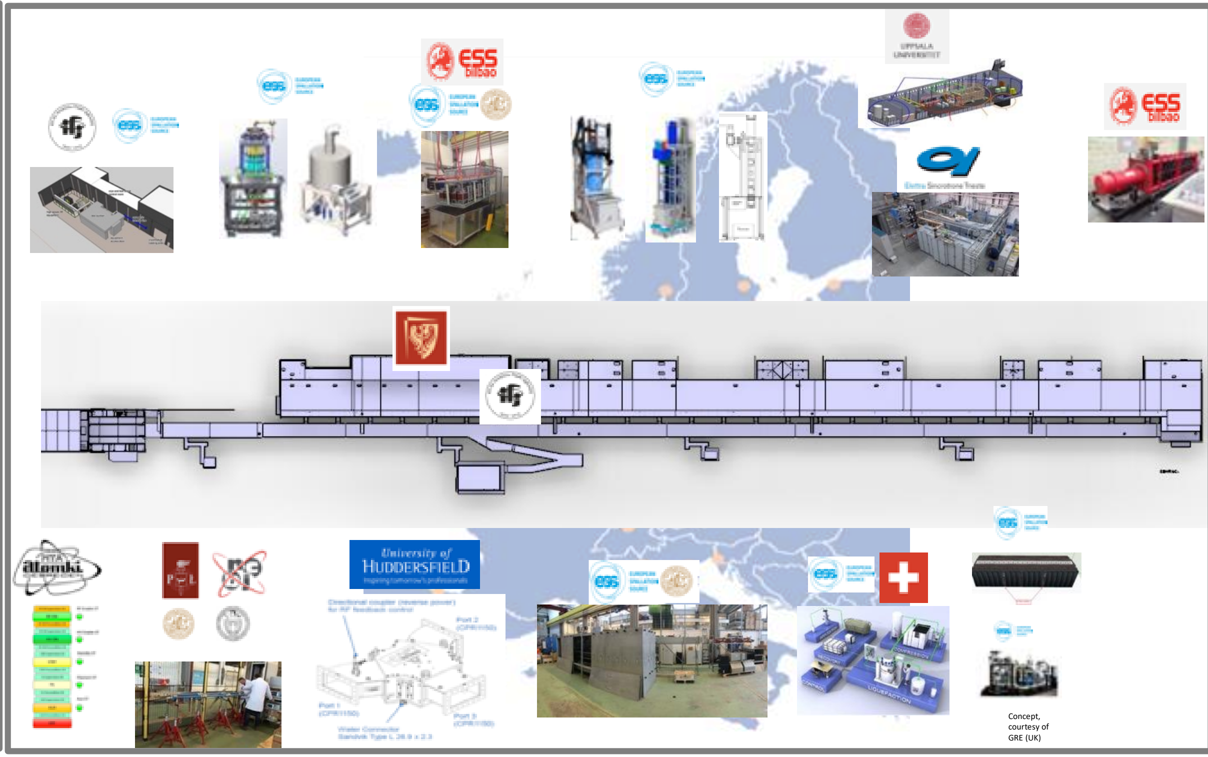
- **Greenfield site vs Upgrading existing facility**
  - Advantages and disadvantages for both
  - Greenfield has offers more design freedom, opportunities for optimisations, fewer boundaries conditions and no disruption to a running machine. However, lacking the support infrastructure can be challenging and so is setting up strong teams, processes, etc. Sometimes need to “reinvent the wheel”.
  - “Greenfield” shouldn't be a “greyfield”.

Some Considerations

Proton Driver

- **What delivery model is adopted**
  - Several project now being delivered with in-kind contributions (ESS, PIP-II, etc.)
  - See the ESS example



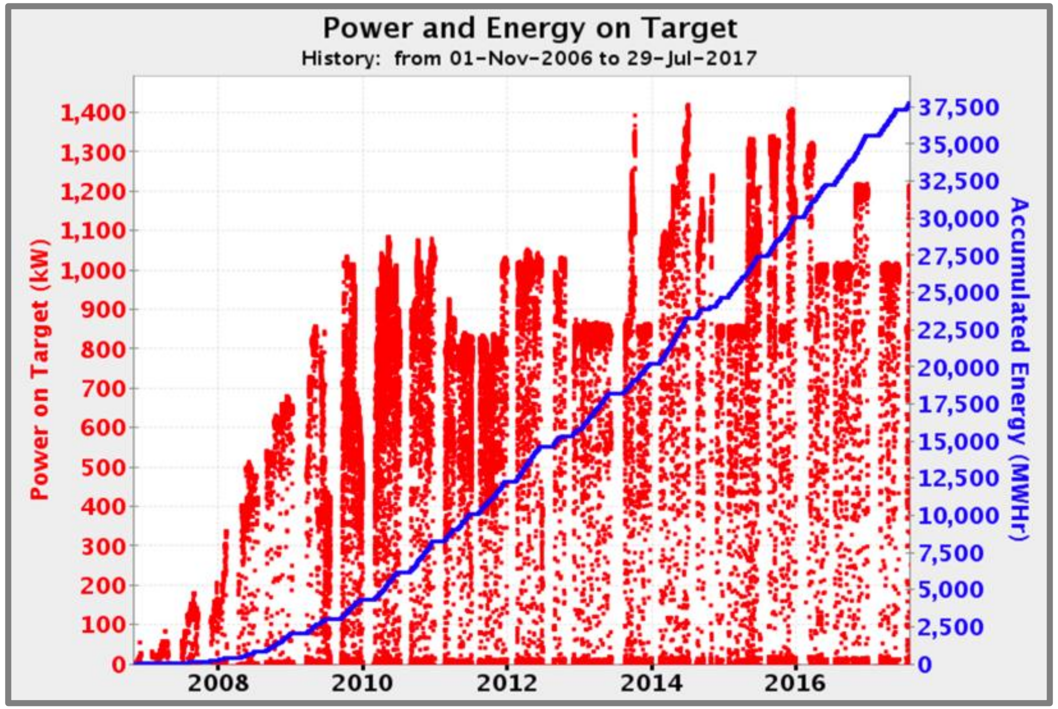


Some Considerations

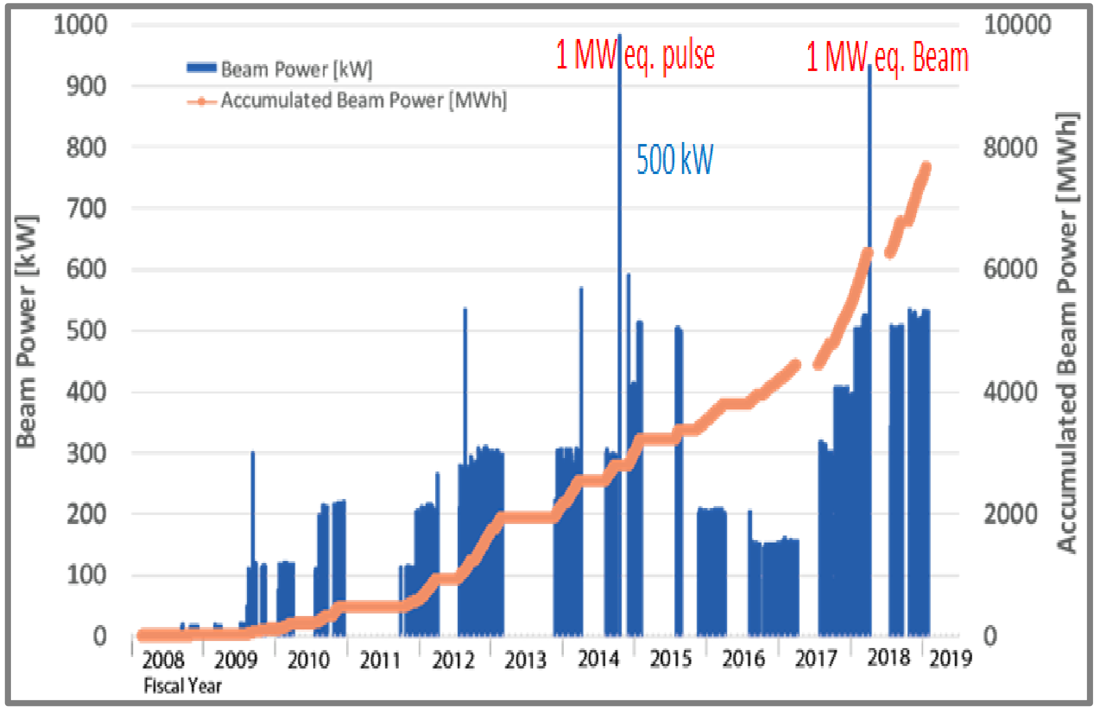
Proton Driver

- **Timeline for achieving design parameters**
  - Experience from MW level facilities

SNS



J-PARC



Summary

Proton Drivers

- **Demand for high power beams:**
  - Several facilities pushing the boundaries
  - Multiple R&D programmes
  - Multiple proposals
    - Japan, China, North America, Europe
    - Very valid technical solutions

- **Some considerations:**
  - Greenfield site vs Upgrading existing facility
  - What delivery model is adopted? In-kind?
  - Timeline for achieving design parameters

Discussion

2022-10-17

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