



ITHPP Visit @ CERN

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Electrical Power Converter group activities

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Today's menu

The EPC group

Powering specificities

Pulsed power equipment examples

EPC group in a nutshell

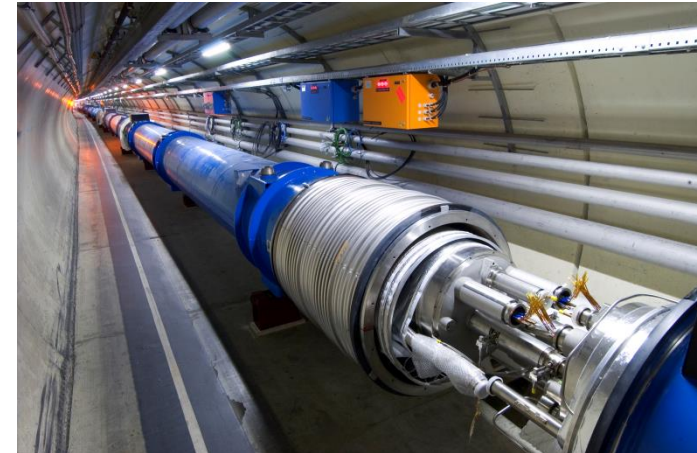
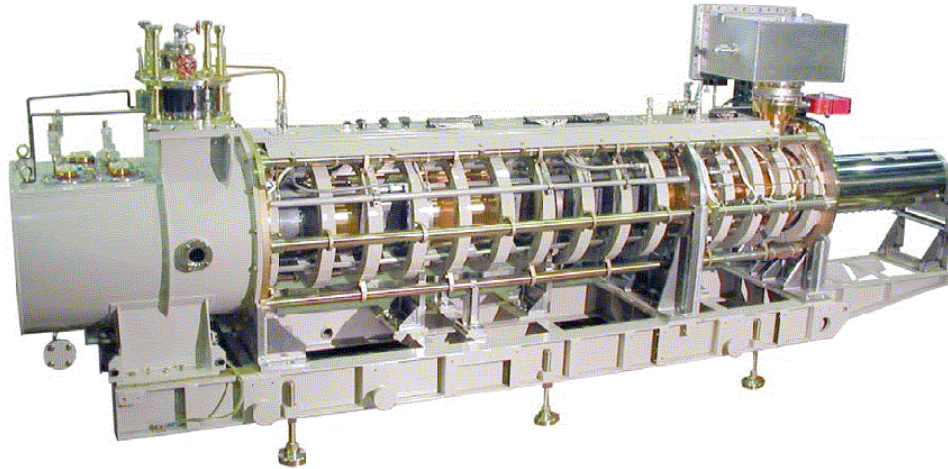
- ~ 100 people – ~70 staffs and ~30 Fellows / students / associates
- **Group organised in 8 sections**
 - 4 power sections (low, medium & high Power + Fast pulse converters)
 - 2 controls section (Hardware & software)
 - 1 High precision section
 - 1 Operation, Maintenance & methods section
- **Mandate**
 - Design/development, procurement, installation, operation and maintenance of electrical power converter systems for all accelerators, experimental areas & test facilities at CERN
- **Expertise**
 - Power electronics
 - Power quality
 - Analog & digital electronics
 - High precision current and voltage measurements
 - Radiation effects on electronics & mitigation techniques
 - Advanced control systems
 - Real-time computing & embedded software

What are we supplying?

Supply of several accelerator's equipment:

- Normal conducting and superconducting magnets
- Electronic tubes for RF production (klystrons, tetrodes, etc.)
- Particles sources (protons, electrons, ions)
- All auxiliary / standard DC supplies
(measurements, control electronics, etc.)

} ~6000 dedicated
converters at
CERN



Range of powers

From few 100W to 10s of MWs – From few volts to 170 kV / few Amps to tens of kA



CERN's power converters specificities

- **High precision: e.g. LHC main magnets at 1 ppm**

- Specific measurements
- Reduced EMI

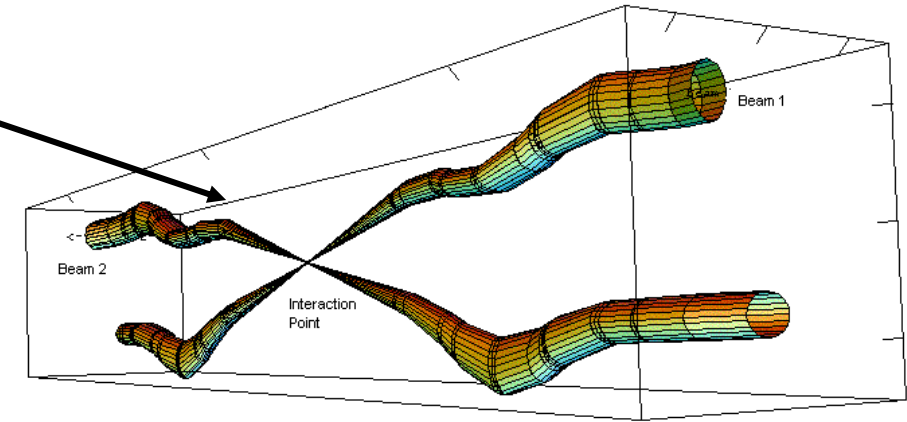
- **Accelerator availability**

- Reliability & Modularity (redundance)
- Repairability (MTTR)
- On call service 24/24 – 7/7

- **Radiation tolerant electronics**

- **Special current/voltage specs**

- High current at low voltage (superconducting magnets)
- High voltage & very low current (sources)



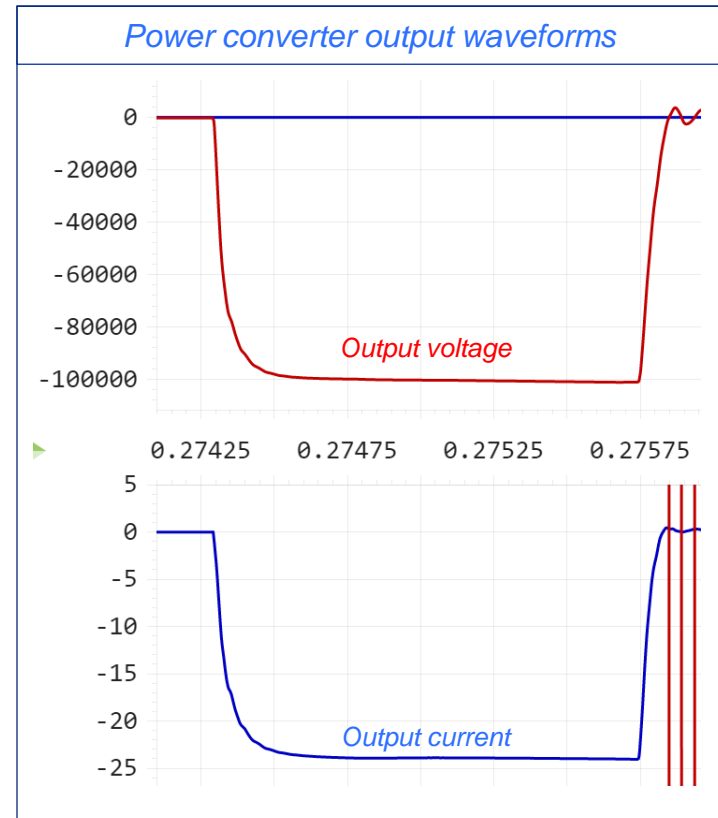
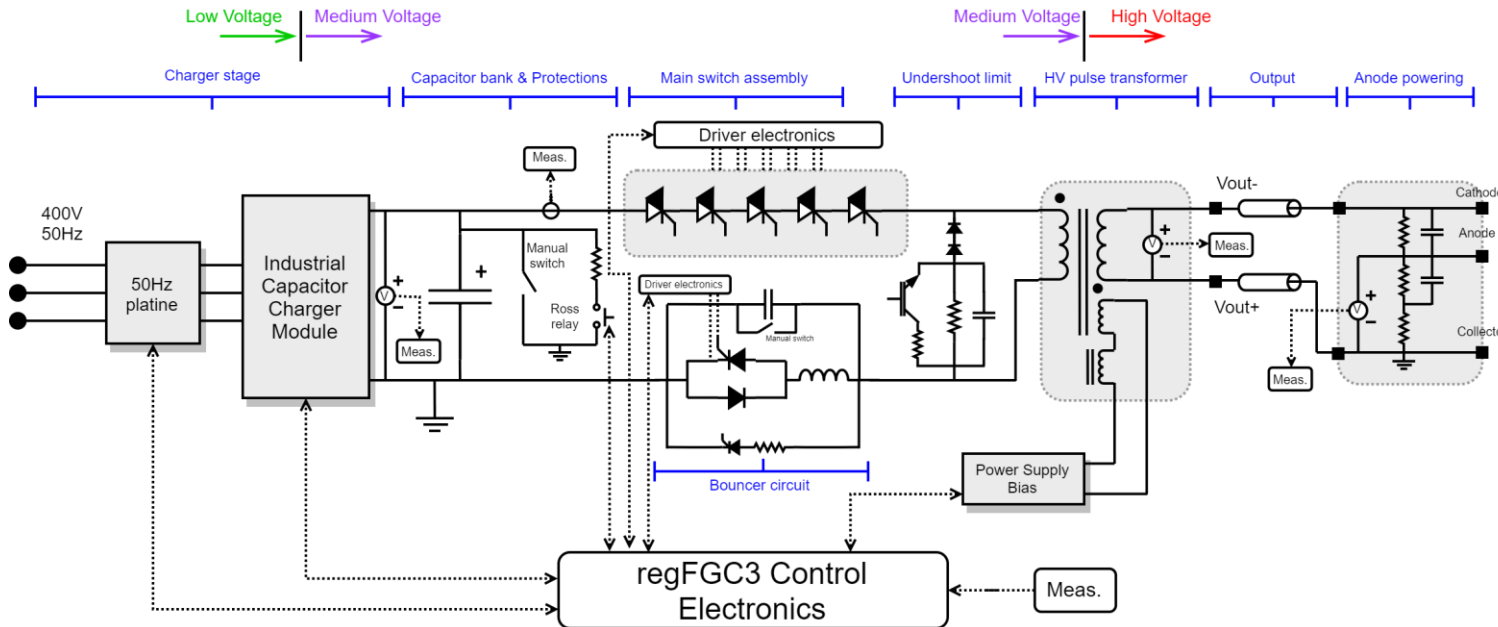
Relative beam sizes around IP1 (Atlas) in collision



Pulsed power – ms range

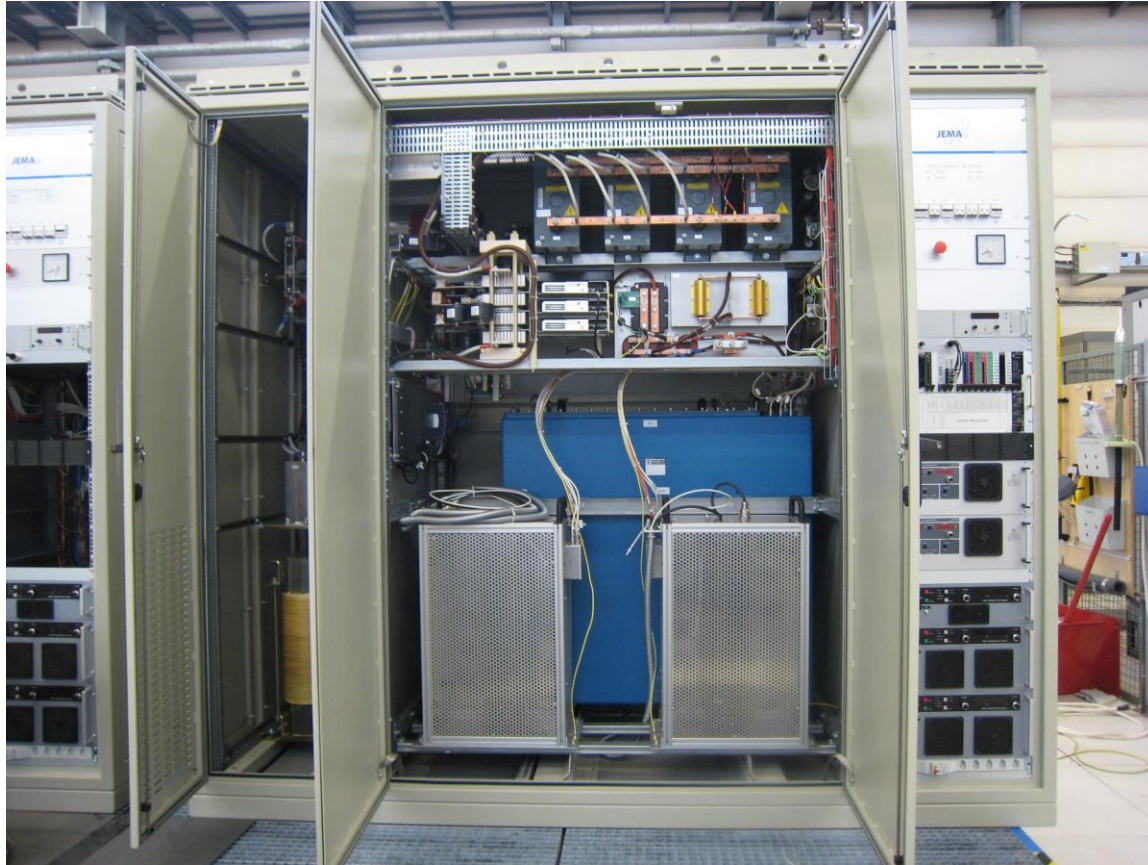
L4 Modulator - Power converter overview

- Topology: Capacitor discharge, HV pulse transformer, voltage droop correction with bouncer circuit
- Output voltage/current: 110kV / 50A, pulsed at 2Hz
- Voltage droop: 0.5%
- Voltage precision: $\pm 0.5\%$
- Load pulse length: 1.4ms
- Load: 2 x klystron 2.8MW



Pulsed power – *ms* range

L4 Modulator - Power converter & klystron photos



Power converter with exposed internal parts

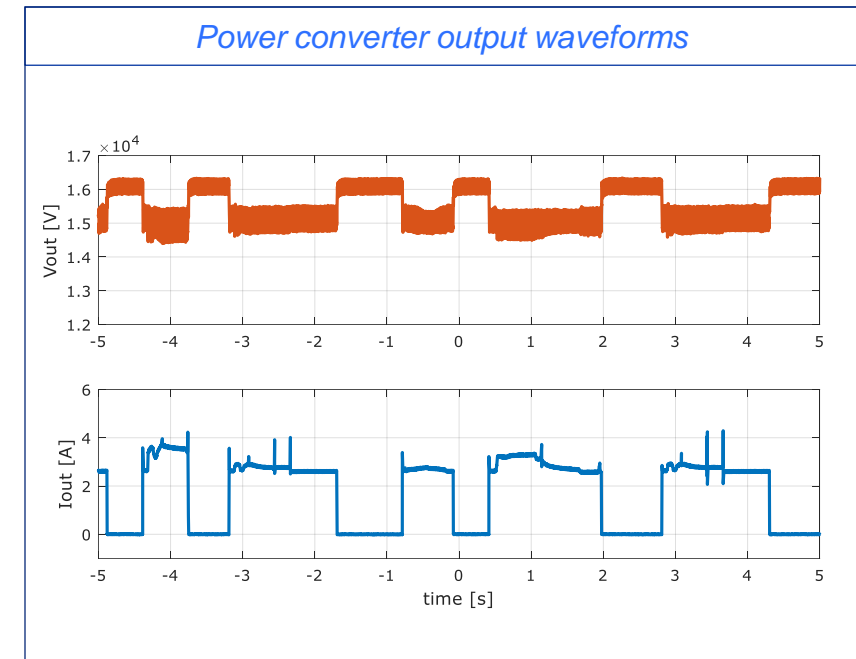
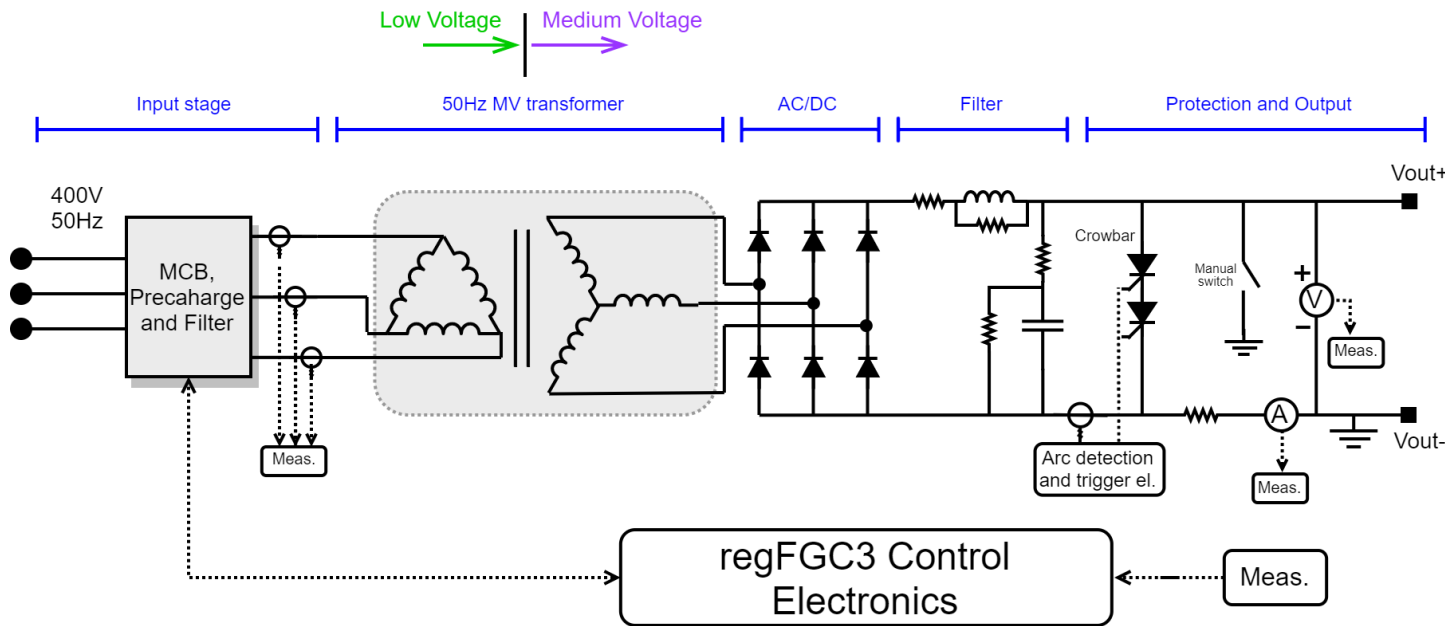


*Klystron with oil tank and electrical terminals
(anode power in oil tank)*

Pulsed power – *ms* range

PS RF final amplifier 10MHz - Power converter overview

- Topology: Single quadrant, HV diode rectifier, MV 50Hz transformer
- Output voltage/current: 15kV / 10A, DC
- Voltage precision: Unregulated
- Load: Tetrode, 10MHz and 20MHz, 70kW

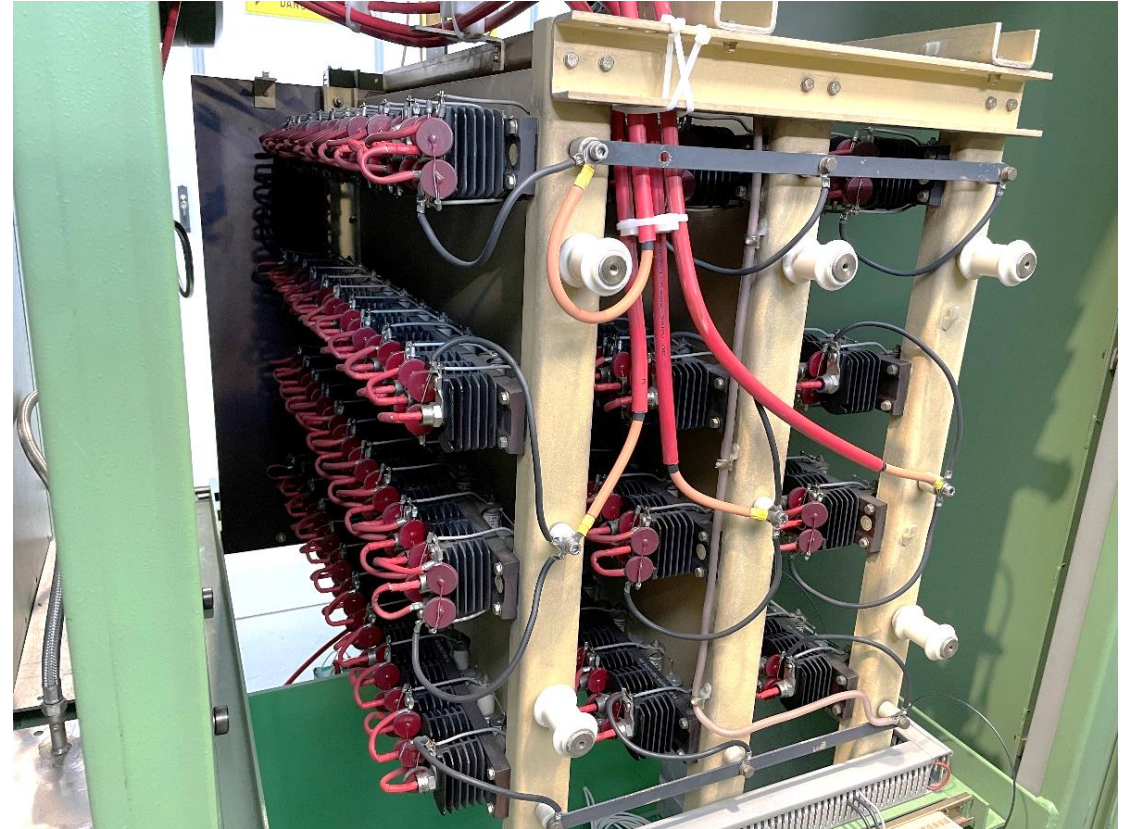


Pulsed power – *ms* range

PS RF final amplifier 10MHz - Power converter photos



Converter exposed rack with MV transformer on the left

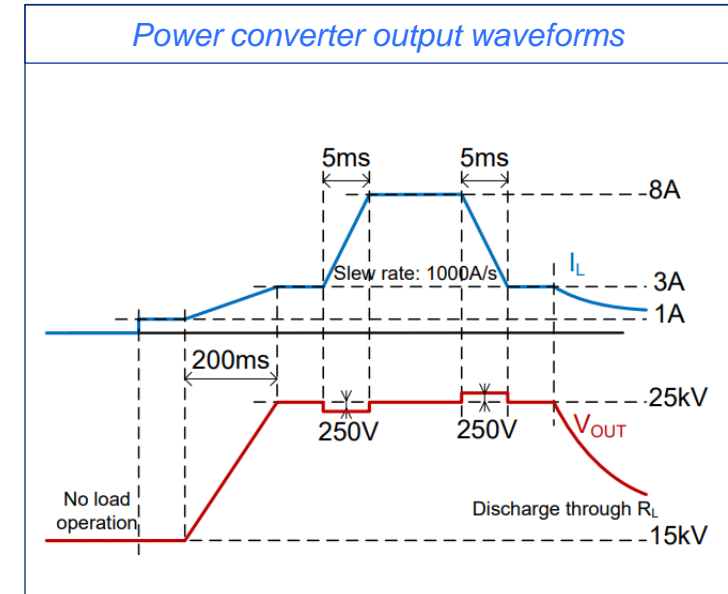
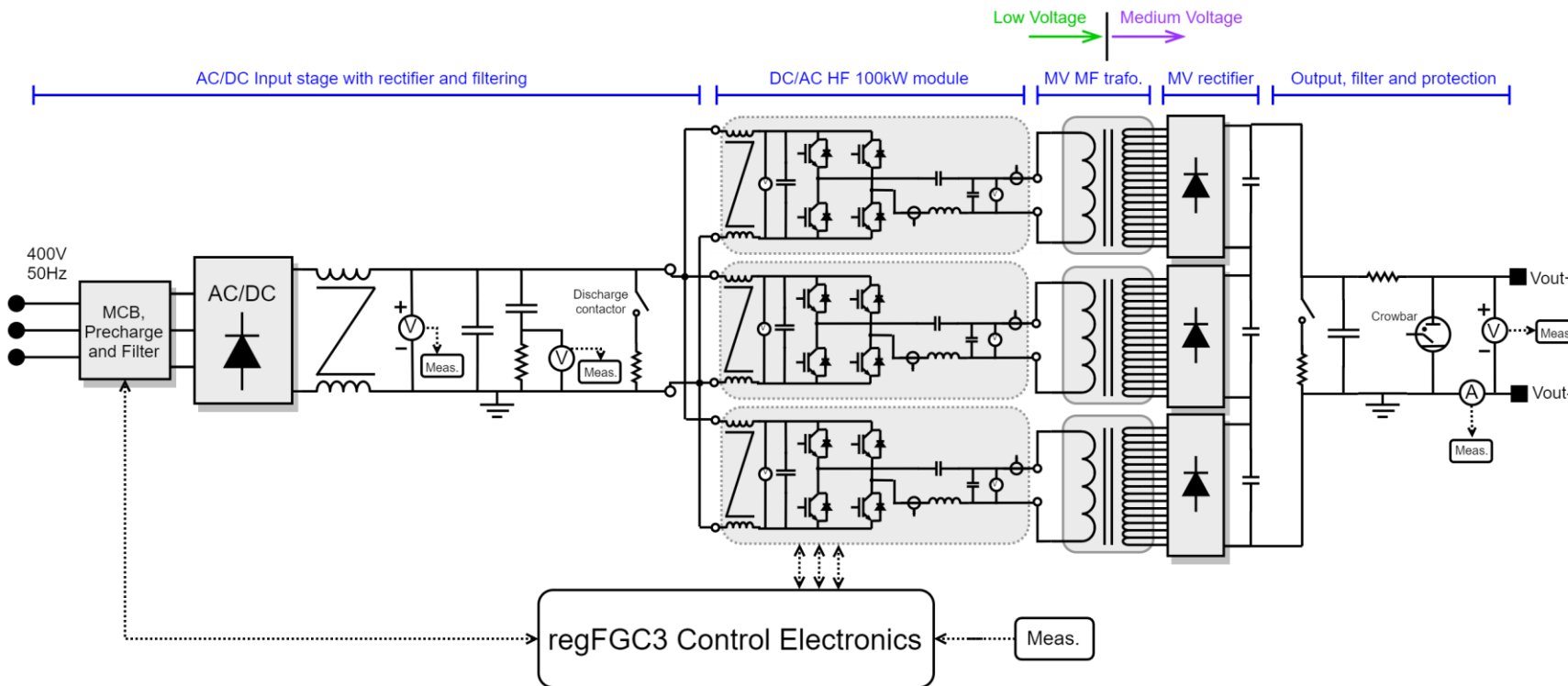


AC/DC MV diode rectifier stack

Pulsed power – ms range

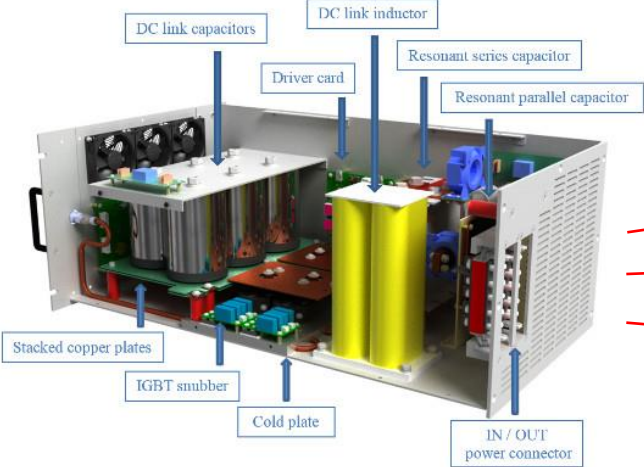
PS RF 40&80MHz- Power converter overview

- Topology: Single quadrant, MV MF transformer isolated, LCC resonant H-bridge
- Output voltage/current: 25kV / 8A, DC
- Voltage precision: 1000ppm, regulated
- Load: Tetrode, 40&80MHz, 4MW

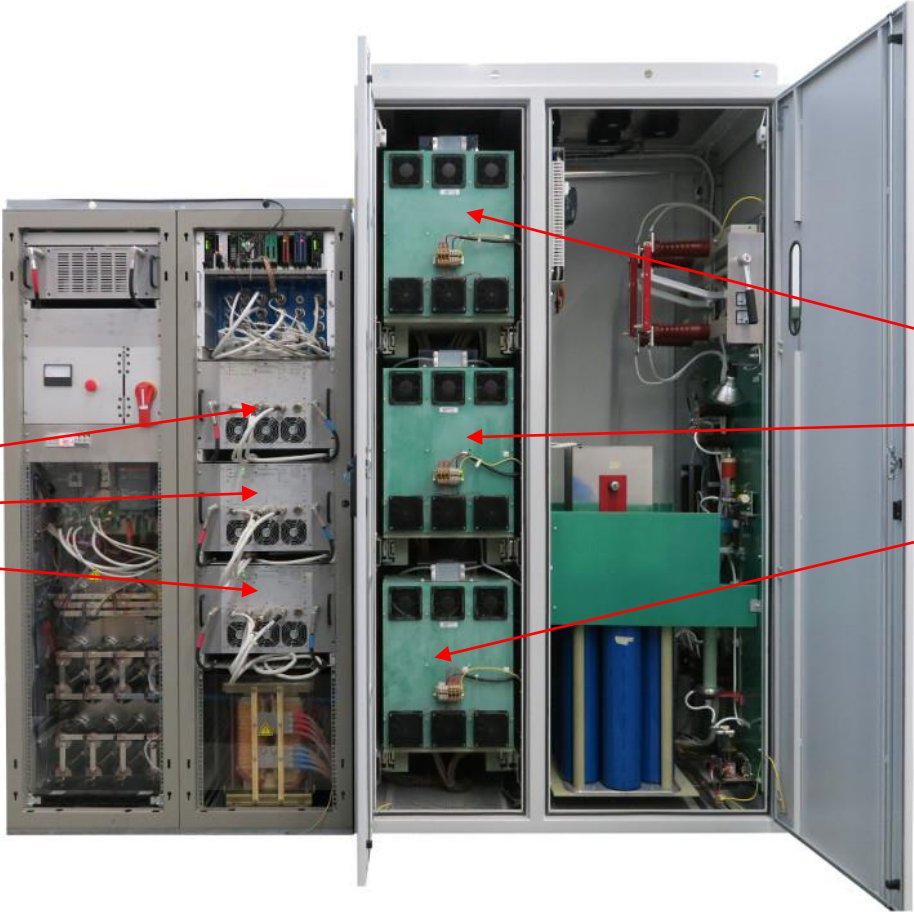


Pulsed power – *ms* range

PS RF 40MHz- Power converter photos



DC/AC 100kW power module



Power converter exposed racks

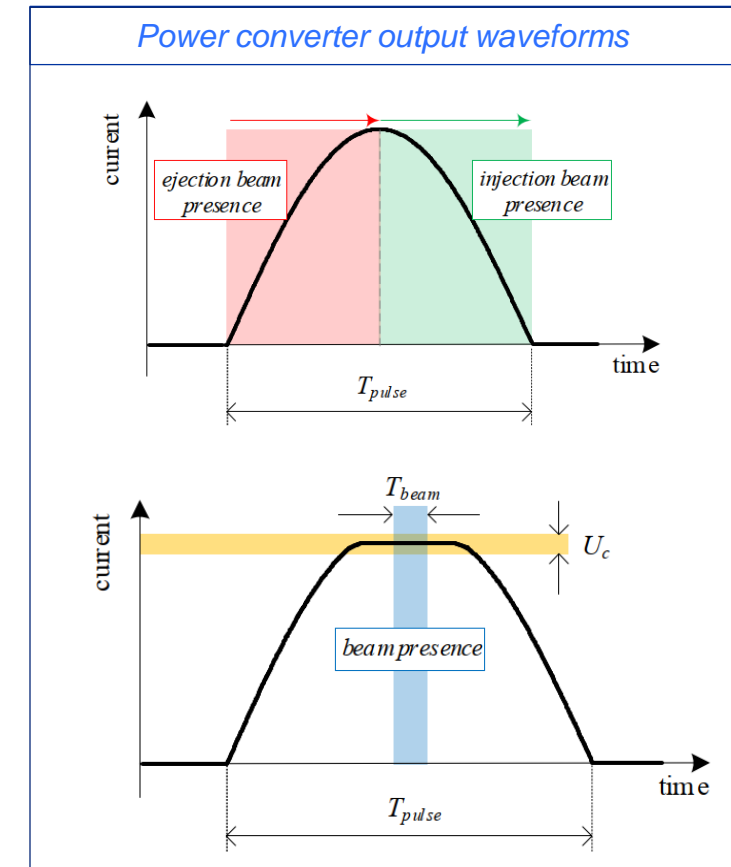
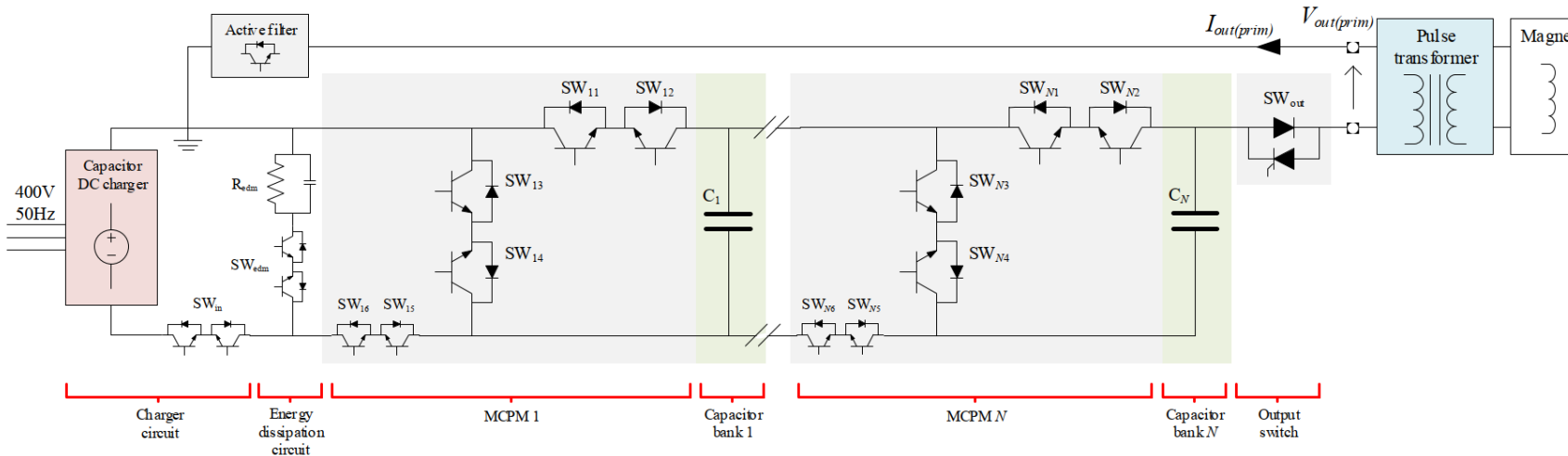


MV MF transformer

Pulsed power – ms range

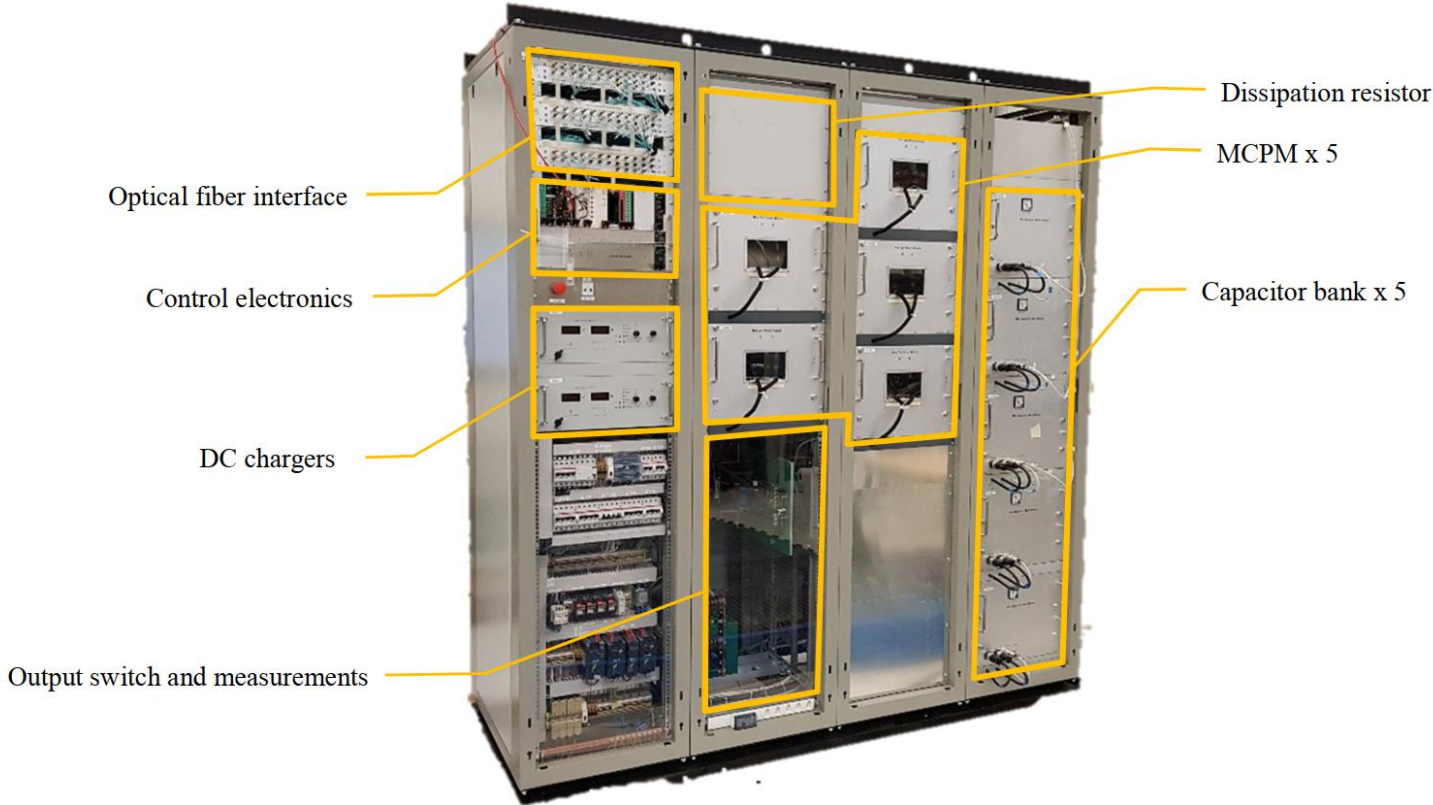
Adapted MarX topology for modular pulsed power (on magnets!)

- Topology: Single quadrant, MV MF transformer isolated, LCC resonant H-bridge
- Output voltage/current: 25kV / 8A, DC
- Voltage precision: 1000ppm, regulated
- Load: Tetrode, 40&80MHz, 4MW



Pulsed power – *ms* range

PS RF 40MHz- Power converter photos



Power module

Pulsed power – sub-*ms* range

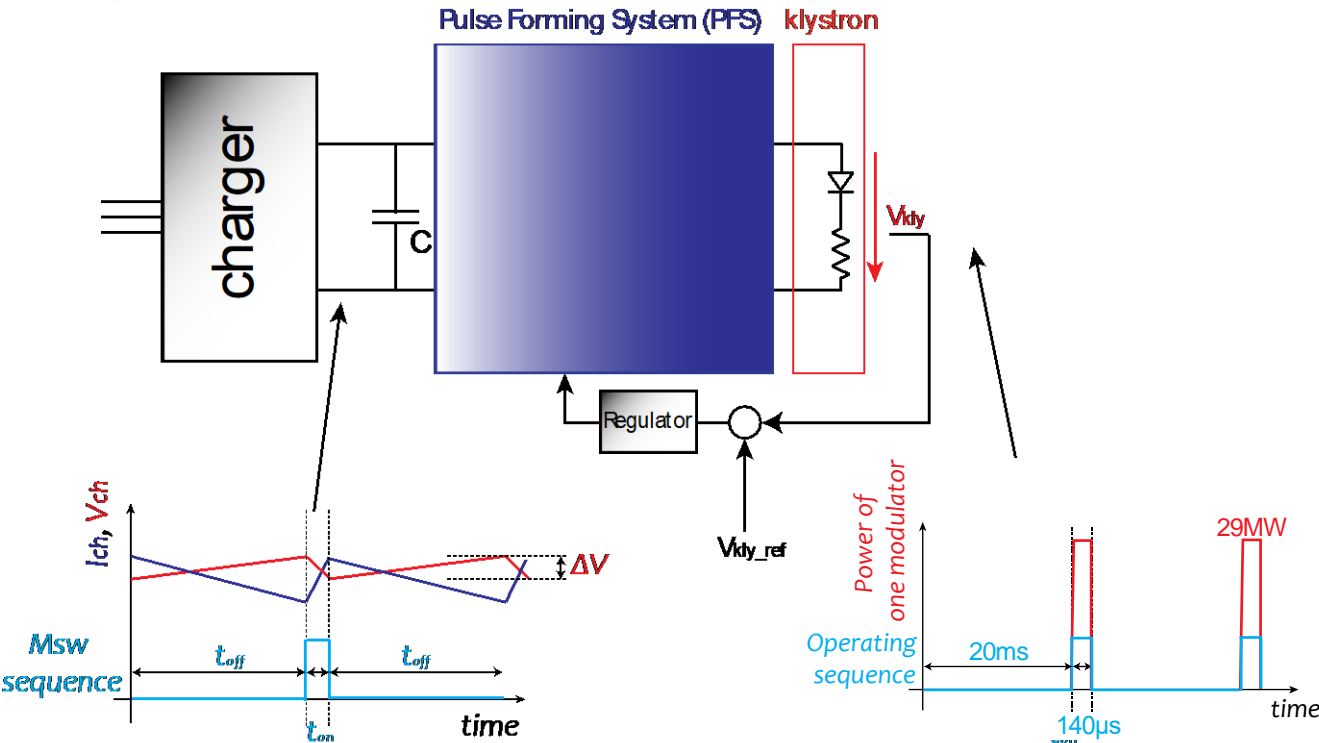
R&D for possible future accelerators

The Compact Linear Collider (CLIC) case study – Grid connection challenge

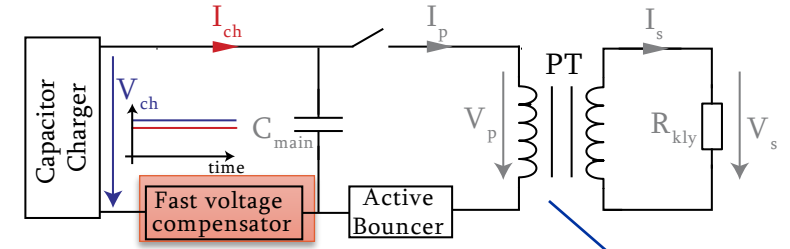
Simultaneous operation of all modulators

➔ 29 MW x 1300 klystrons = **38GW!**

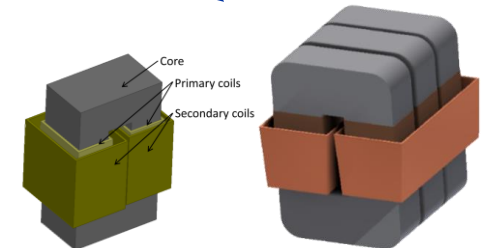
- Absorbed AC power from network must be constant to stabilize distribution voltage!
- Even with energy storage, a power fluctuation on the AC side exists. Active compensation necessary!



One of the solutions proposed at CERN for CLIC:



R&D on HV pulse transformer design

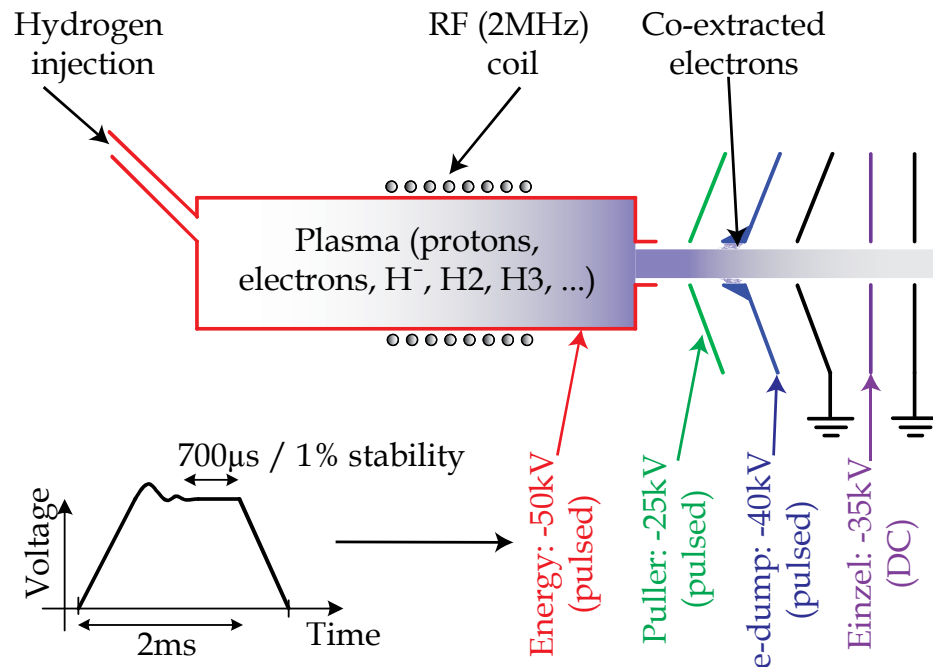


Pulsed power – *ms* range

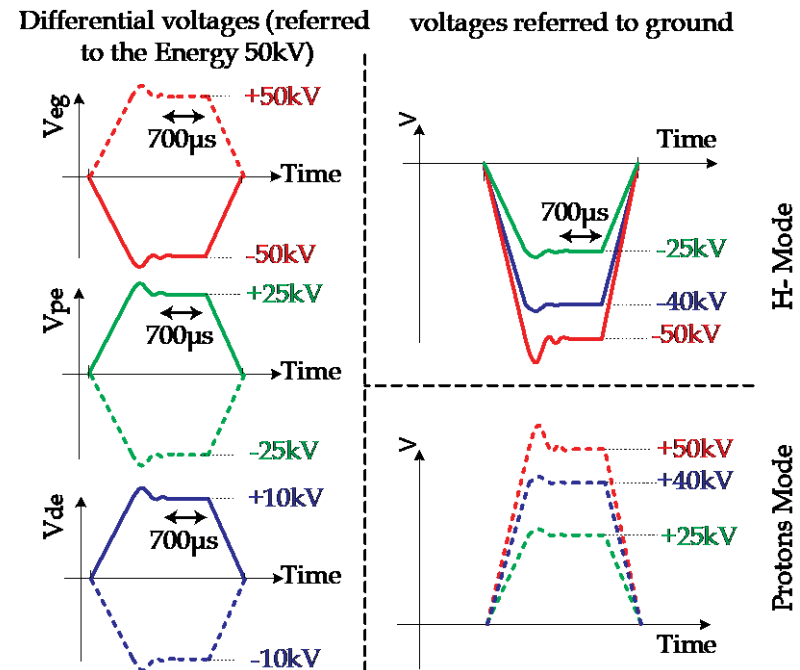
H⁻ ions source power supply

- A new linear accelerator in under construction (Linac4) to provide protons for the CERN complex
- Linac4 accelerates hydrogen ions from which electrons are then removed to produce protons.

Principle of H⁻ source



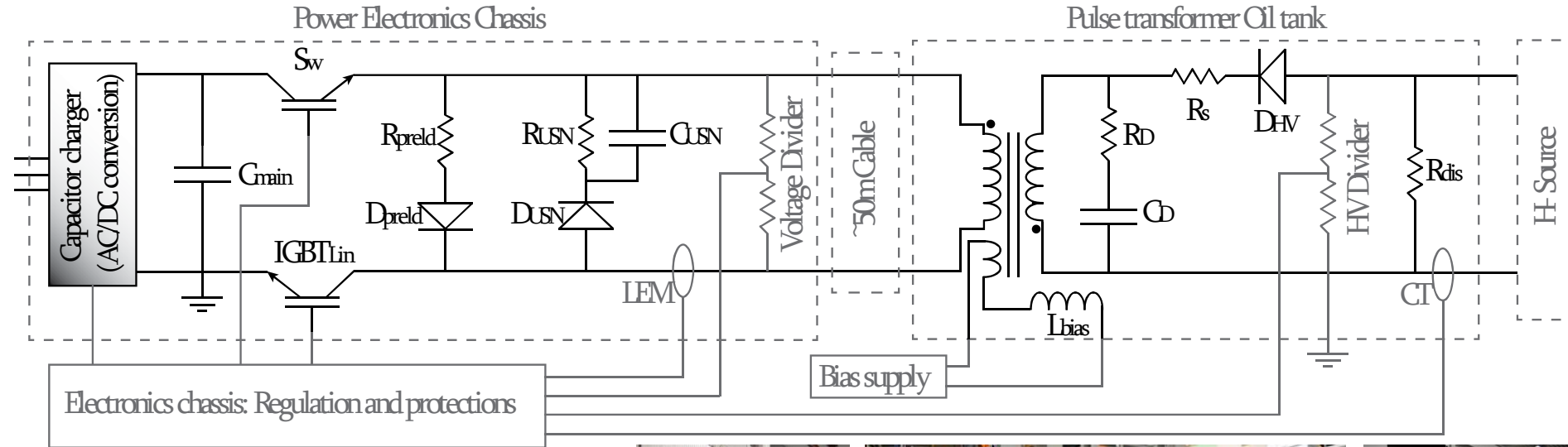
Voltage power supplies specification



Design examples

• H⁻ ions source power supply

Topology choice: simple (reliability), no ripple (IGBT in linear mode)



Quick access to the elements of the transformer for interventions in the tunnel – «custom».



Questions?

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