



# CERN ISOLDE facility



## CATHI Final Review Meeting

### BARCELONA - SPAIN

## High Voltage and Front End

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*CERN*

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2) Lisbon Superior Engineering Institute (ISEL) and Nuclear Physics Center from Lisbon University (CFNUL)





## OUTLINE



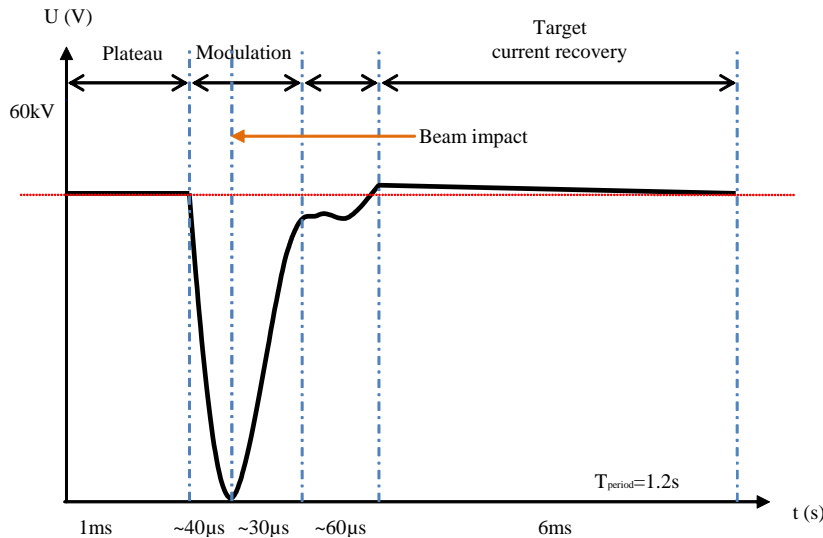
- Why modulate the target at ISOLDE ?
- Existing HV modulation characteristics
- Existing HV modulator
- Upgrade of existing modulator
- Reasons for modulator upgrade
- The Marx generator, the C modulator
- Behlke test bench
- MD's and MEDICIS project
- Charge pump modulator
- Conclusion



## WHY MODULATE THE TARGET?



- Ionisation around the target in air during and immediately after beam impact discharges the effective target capacitance which in turn reduces the target voltage level
- To ensure extraction of short life-time isotopes this voltage is required to recover to its stable value within 10ms
- Because of the limited power output of the high precision power supply the recovery time cannot always be respected



## Basics

- The modulation system uses the action in which the charge on the effective target capacitance is resonantly transferred to a buffer capacitor during the heaviest ionisation period (during beam impact) and re-established  $\sim 200\mu\text{s}$  later on the target capacitance

## Specifications:

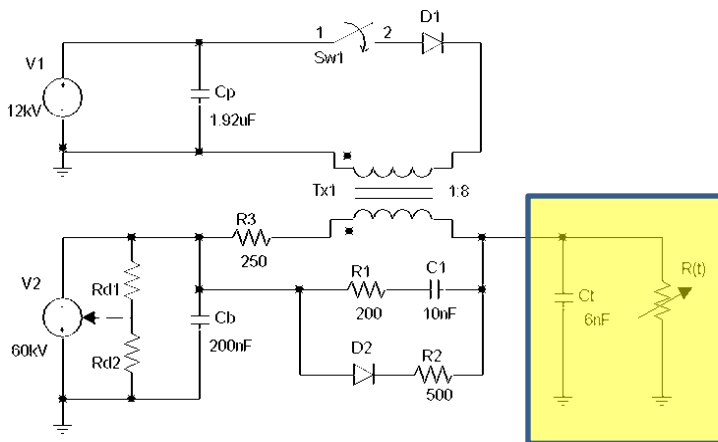
- Fast recovery from modulation
- $10^{-5}$  DC voltage stability
- Circuit losses requires the power supply to provide current for a further 6ms before full stable target voltage is obtained ( $\pm 0.6\text{V}$ )

## H/W requirements:

- High precision HV power supply

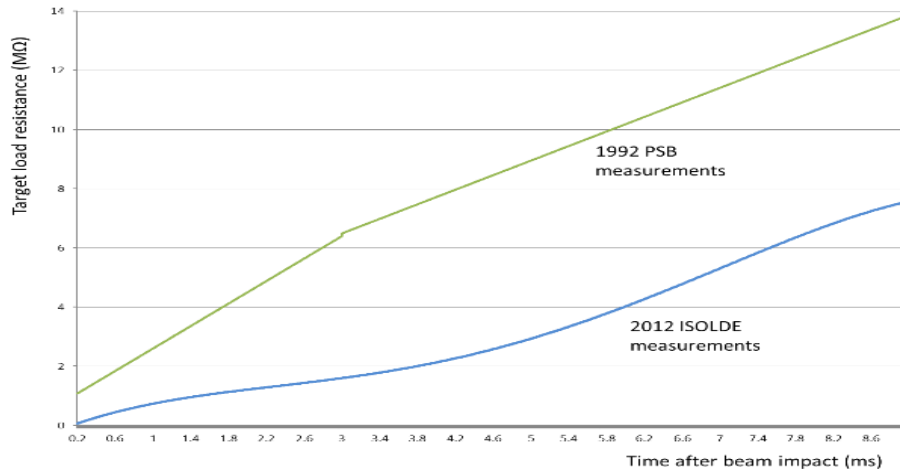
## Advantages of modulation:

- Prevent HV breakdown
- HV recovery time shortened





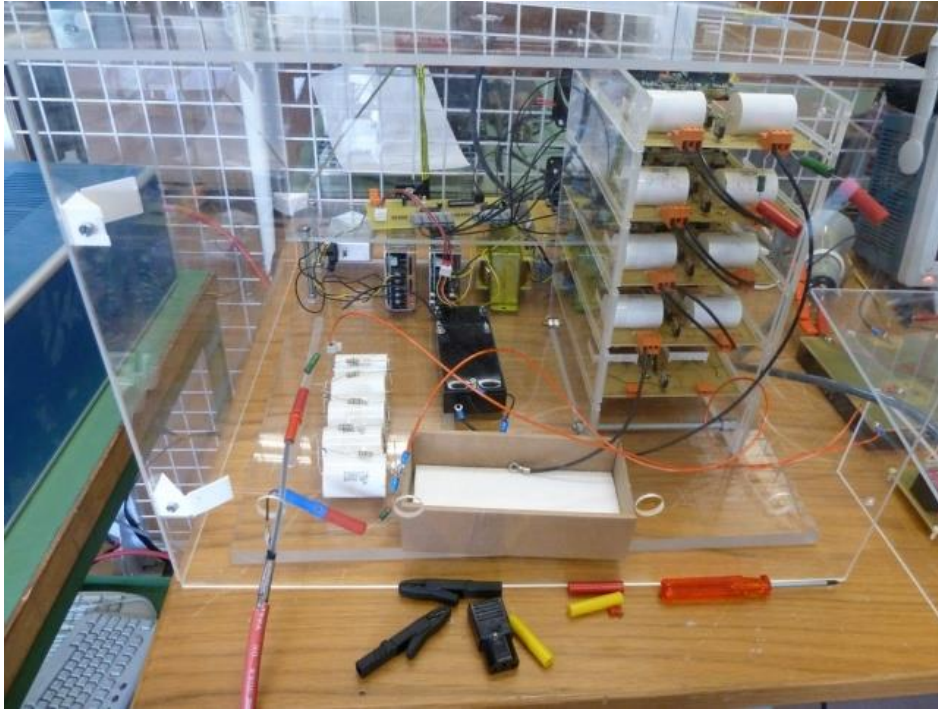
- Increasing ionisation due to new target materials and neutron converters has stretched the limits on the voltage recovery time, >10ms



- The existing 60kV ASTEC power supplies have a current output limited to 5mA d.c., with a short transient capacity of 50mA.
- These power supplies are increasingly more difficult to maintain and repair, these are no longer manufactured and other modulator components are aging
- HIE-ISOLDE intensities (2Gev) will add further stress onto ionisation impact

# Proposed modulator variants:

## 1. THE MARX GENERATOR MODULATOR



Marx generator prototype circuit developed in collaboration with Lisbon University, 10kV system. Tested at 3kV only.

### ADVANTAGES

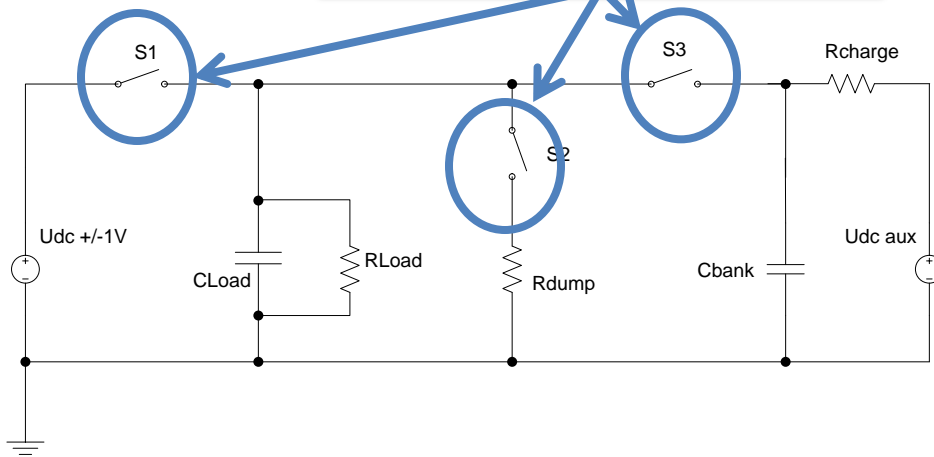
- Reduced voltages across individual devices
- A good recovery time with a standard R-C load. Dynamic ionization effects are ignored
- Control of fall and rise times possible to reduce risk of HV breakdown

### DISADVANTAGES

- Many devices, troubleshooting difficult
- PS high current
- Reliability
- Trigger system complex
- Expensive system



HV semiconductor switch type Behlke



### ADVANTAGES

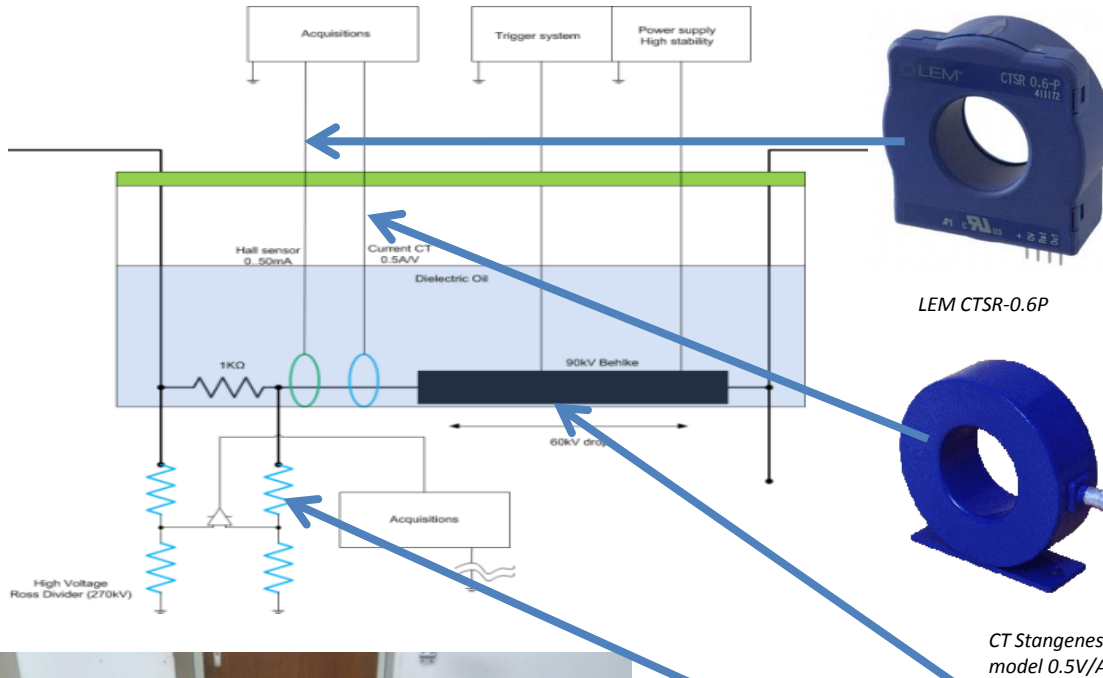
- Simpler circuit
- Monolithic HV semiconductor-based switch commercially available
- Rapid recovery time
- Flexible modulation time
- Compact
- Re-uses many passive components of present modulator tank

### DISADVANTAGES

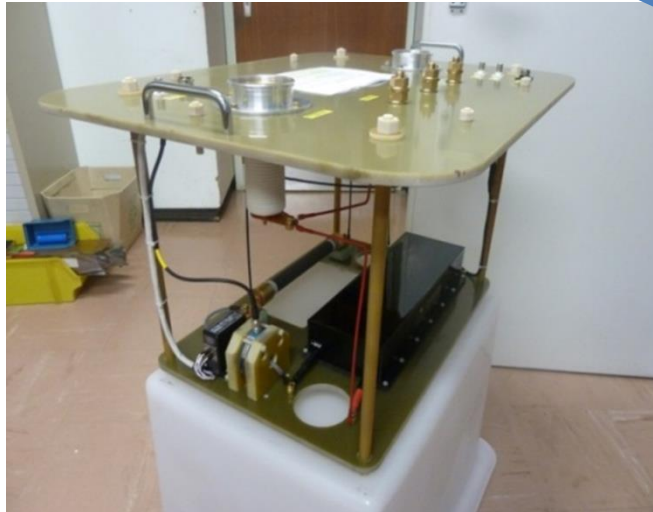
- Semiconductor switch is not a proven, mature technology however recent MD's have demonstrated robustness of the technology
- Fast rise time may increase probability of HV breakdown



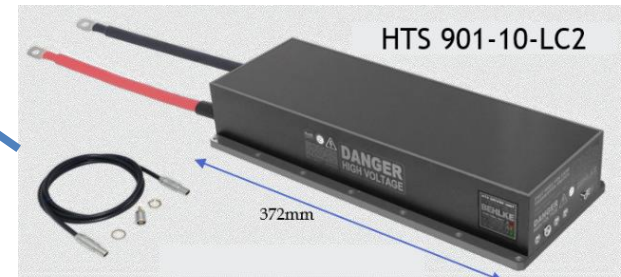
# TEST BENCH FOR A BELHKE SWITCH



- High current measurement
- Low current measurement
- Switch voltage drop
- Series resistor voltage drop
- High precision voltage measurement
- R 'ON' studies
- Di/Dt's behaviors

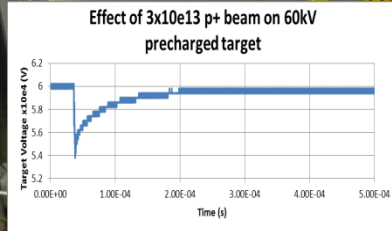
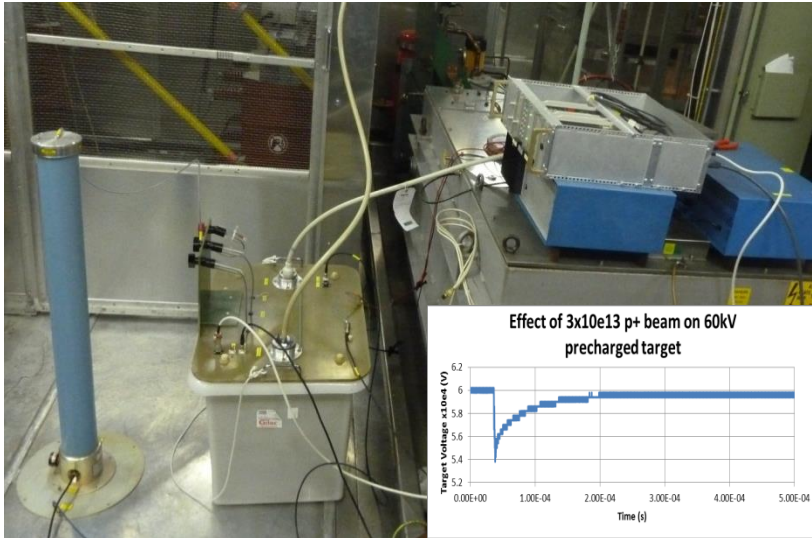


Ross VD-270 matched pair HV dividers



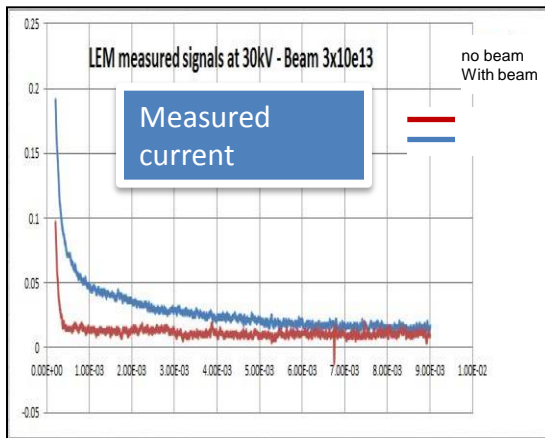
HTS 901-10-LC2 HV switch



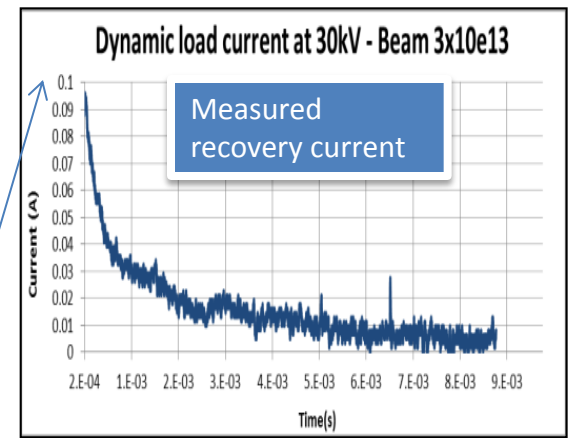
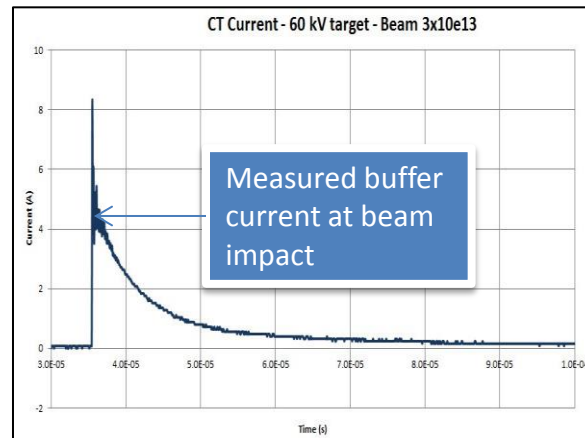


Behlke test bench setup at ISOLDE on the HRS target on HT1 slot, Use of worst case target, Uranium Carbide Target + Neutron converter (Tungsten)

- Aim to measure real target current and test robustness of Behlke switch.
- Tested at 2 intensities levels ( $1 \times 10^{13} p+$  &  $3 \times 10^{13} p+$ )
- 'Cold' and 'Hot' target measurements
- Extraction Electrodes in/out position
- Dynamic electrical load studies (with beam/no beam)
- Target charging voltage
- Dynamic load impedance of target
- Mainly 30kV studies due to the hall effect current transducer saturating
- The MD measurements showed that a 'cold' target or 'heated' target shows no difference in the dynamic loading of the modulator.
- The extraction electrodes position, completely 'out' or 'in' gives no change in the dynamic loading i.e. the ion beam seems to have no effect on the loading of the HT sources.



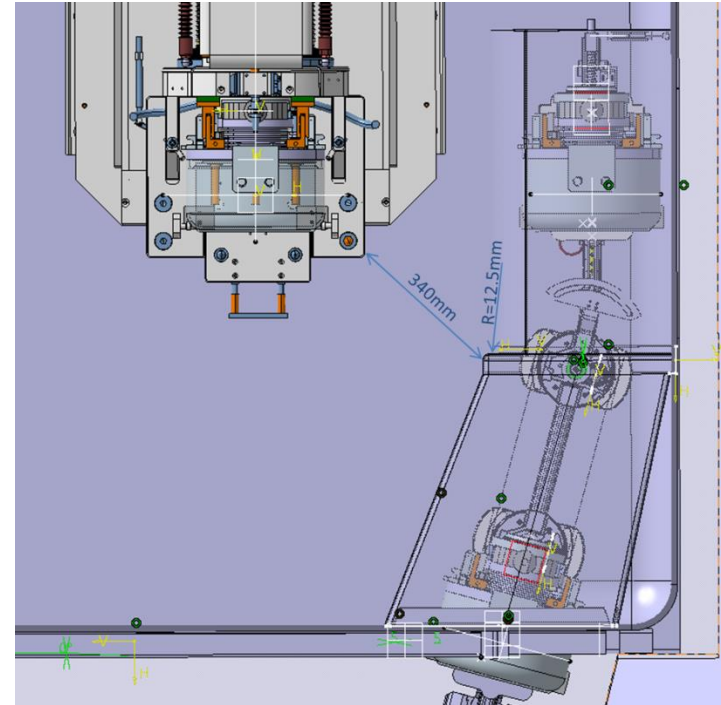
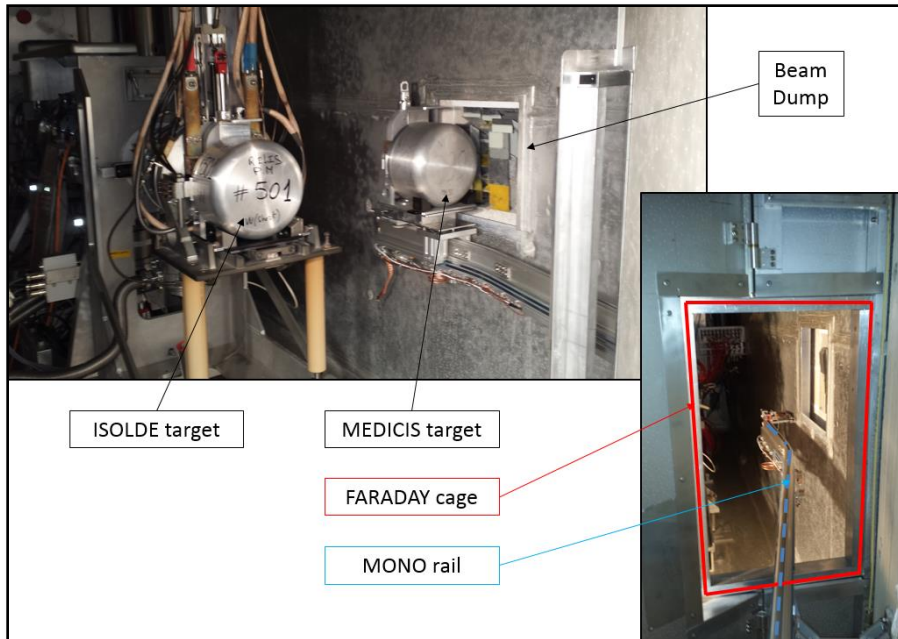
Recovery current difference with beam and no beam.



Target leakage current 200us after beam impact



The CERN MEDICIS, a research facility that will produce radioisotopes for medical applications. The facility will use a proton beam at ISOLDE to produce the isotopes, which are first destined for hospitals and research centers in Switzerland, and will progressively extend to a larger network of laboratories in Europe and beyond.



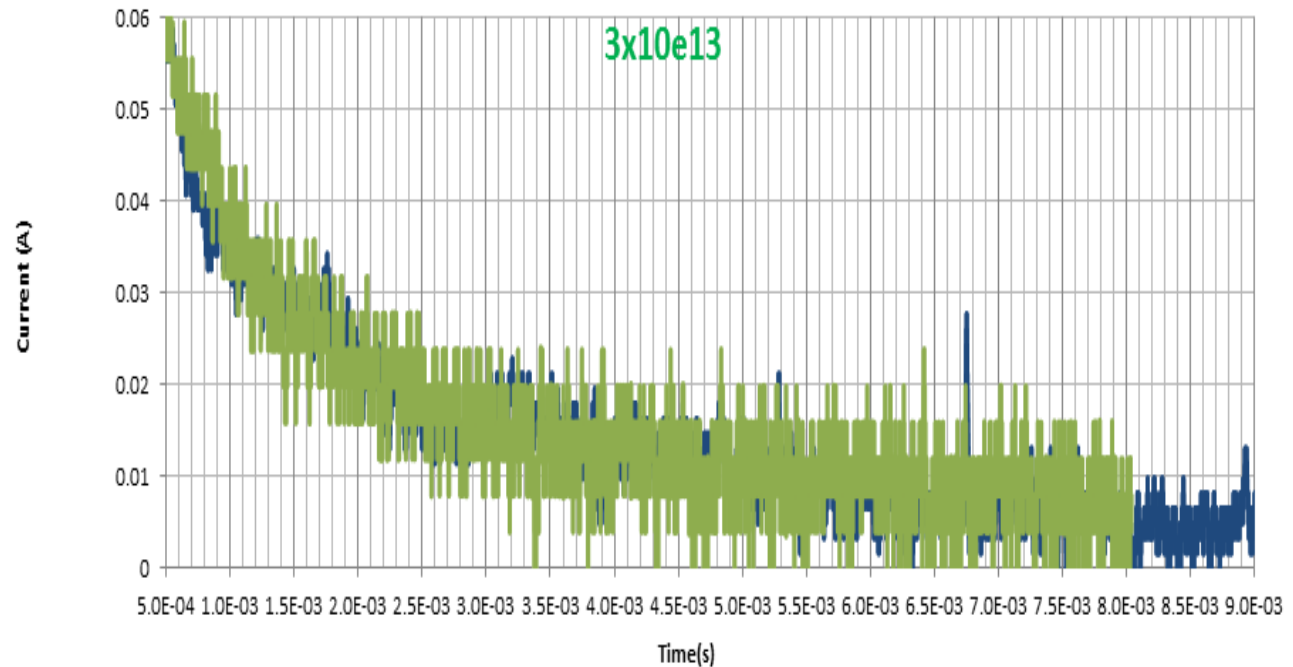
### MEDICIS MD, AUGUST 2014

The ISOLDE target area has received an adjacent secondary target named MEDICIS. It was thought that initially this might cause problems with the existing target such as greater ionisation, hence more stress incurred on the existing modulator. The MD for MEDICIS investigated the phenomenon and was used to measure new target currents and so forth.

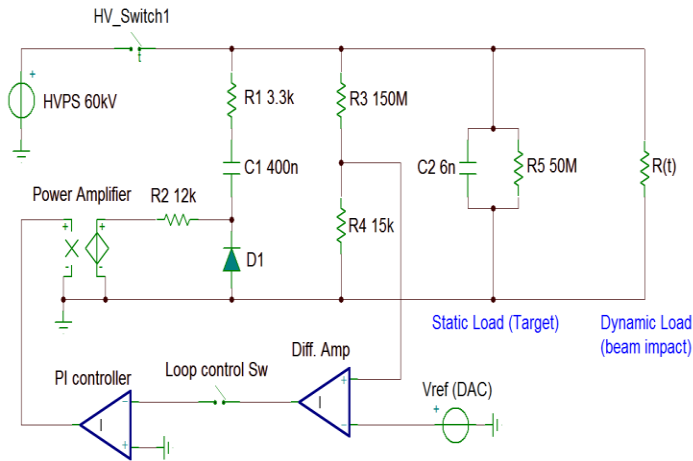


- The presence of the MEDICIS target does not cause aggravated sparking
- No alteration of voltage hold off on the primary target
- Ionisation current does not change
- These results help to further characterise the target model for the modulator R&D program
- **Post analysis does suggest suboptimal target steering and the MD is re-scheduled for further investigations**

Previous ionisation current without Medicis at 30kV - Beam  $3 \times 10^{13}$   
 Last ionisation current with Medicis at 30kV - Beam corrected to



To a first approximation the post impact leakage amplitude is proportional to  $\sqrt{N}$ , N is the burst intensity. Taking into account that the beam intensities are not the same (past MD + MEDICIS MD), a factor of  $\sqrt{2/3}$  is applied here.

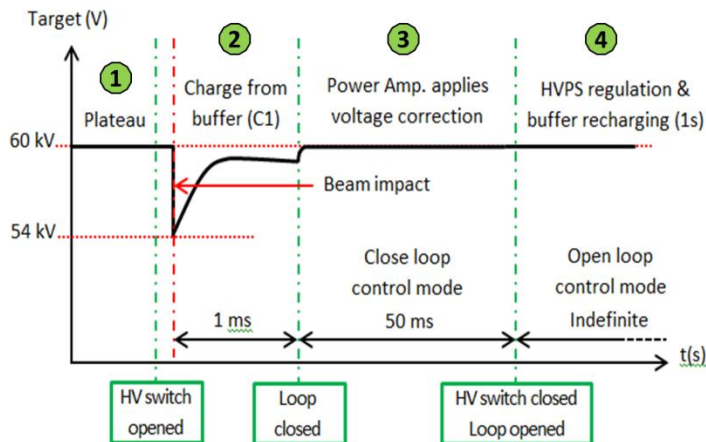


1) In this circuit a 400 nF buffer capacitor (C1) and the target capacitance (C2) are charged to 60 kV by a low power, high precision d.c. power supply (HVPS)

2) Immediately prior to beam impact the HVPS is disconnected from the target and the buffer capacitor using a 90 kV rated semiconductor switch (HV\_Switch1). During beam impact the target capacitance is rapidly discharged to 54 kV. Then the buffer capacitor begins to re-establish voltage on the target to 99,4% of its initial value.

3) After 1 ms a feedback loop controlling an auxiliary high voltage amplifier is switch on and increases the buffer capacitor potential. This additional voltage brings the target voltage back to the required +/- 0.6 V tolerance within 5 ms.

4) Finally, when the target has recovered to a sufficient high impedance, the feedback loop is opened and the HVPS is re-connected to the target to maintain the stable 60 kV voltage.



### Advantages

- **Modulation recovery time adjustable**
- **Requires a single low current high precision power supply (High power supply not necessary)**
- **A single HV switch is required (compared to C modulator which uses 3)**

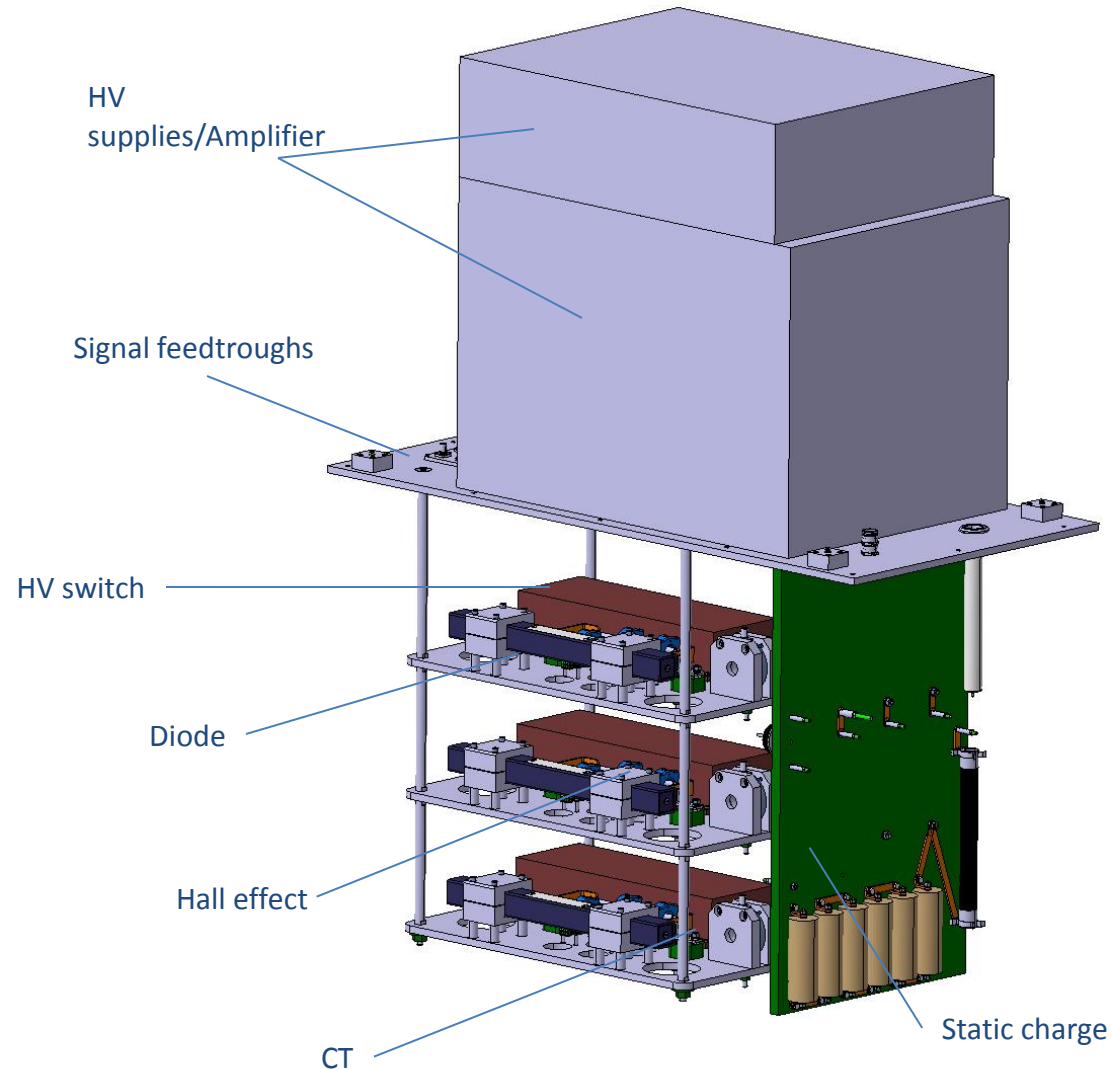


# 3. Charge pump modulator

## Hardware assembly

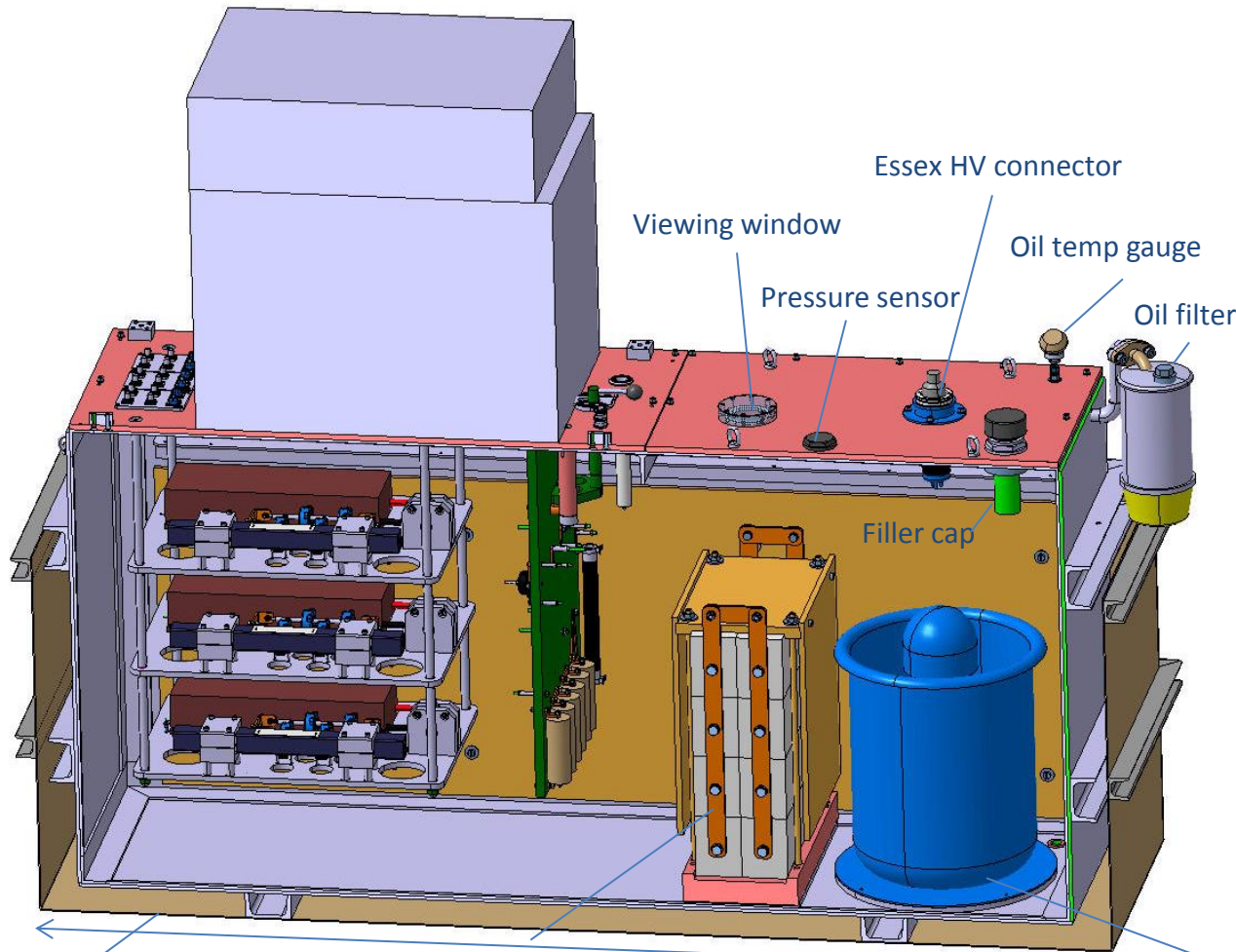


- C modulator topology / Charge pump topology (Reconfigurable prototype)
- Design can support up to 3 (90kV) Belkhe switches
- Structure all Vetronite
- Static charge for 'on-board' testing
- Compact design



# Charge pump modulator

## Assembly / Tank housing



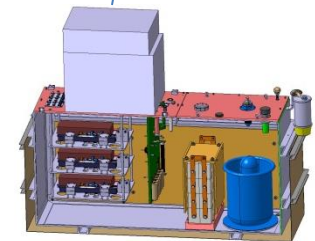
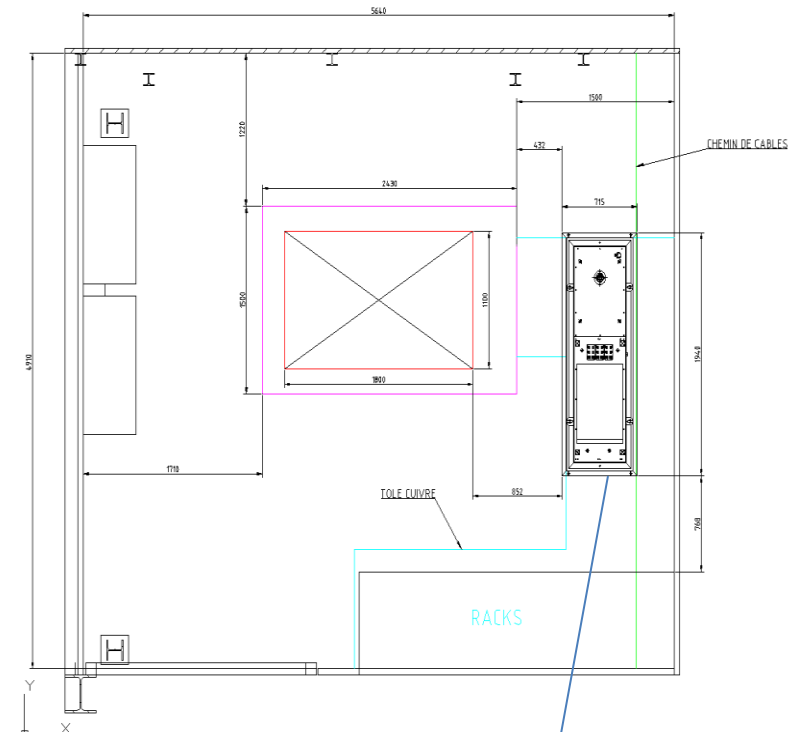
- Custom built tank enclosure
- Tank is filled with dielectric oil
- Has a second 'skin' for oil leak protection
- Contains the modulator system, buffer capacitor bank, HV precision divider, static and dynamic load

Tank housing

Capacitor bank  
0.05uF 75kVdc  
(hivoltcapacitors)

1800mm

75kVdc high precision divider  
VD75-20Y-BDSC-KC-BEA/PB/F  
(RossEngineering)



## Technical characteristics

- Modern HV test facility
- Safety access system
- Spacious (important for 60kV test)
- Overhead crane
- Static and dynamic load capability + Exiting modulator tests and maintenance





## CONCLUSIONS



- Target ionisation is becoming increasingly severe hence the need for a new type of modulator.
- A charge pump type modulator appears to be the best solution.
- The Behlke test bench has proven to be an invaluable asset in determining the next generation of ISOLDE/HIE-ISOLDE modulator design.
- Target 'discharge' time can be tailored to suit target types, a real 'advantage' compared to the actual modulator
- Serviceability and repair should be simpler with the new modulator technology.
- Prototype configuration and functionality still to be determined through R&D program!



THANK  
YOU