Control system of Neutral Particle Analyzer in energy sweeping mode.

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Outline

- Introduction

  a)The neutral particle analyzer (NPA) in Uragan-3M (U-3M)

  b) The energy-sweeping mode of NPA operation

  c) Fast operations with high inductive load

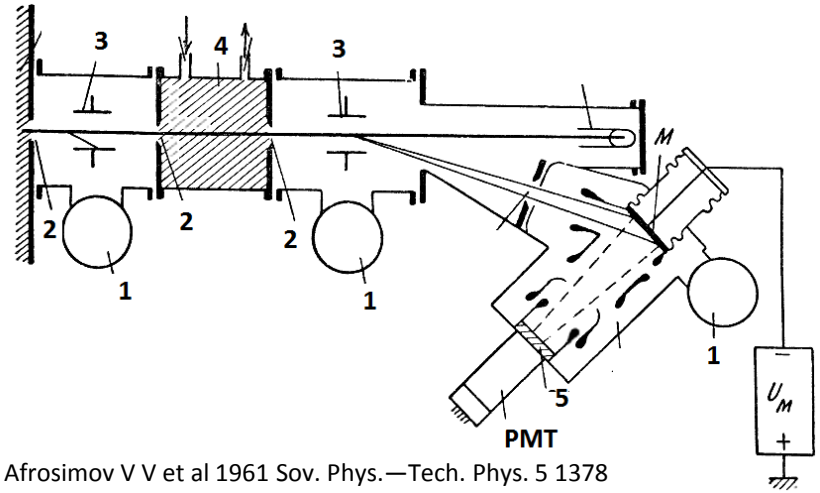
- Features of the energy-sweeping mode electronics

- Example of the NPA operation

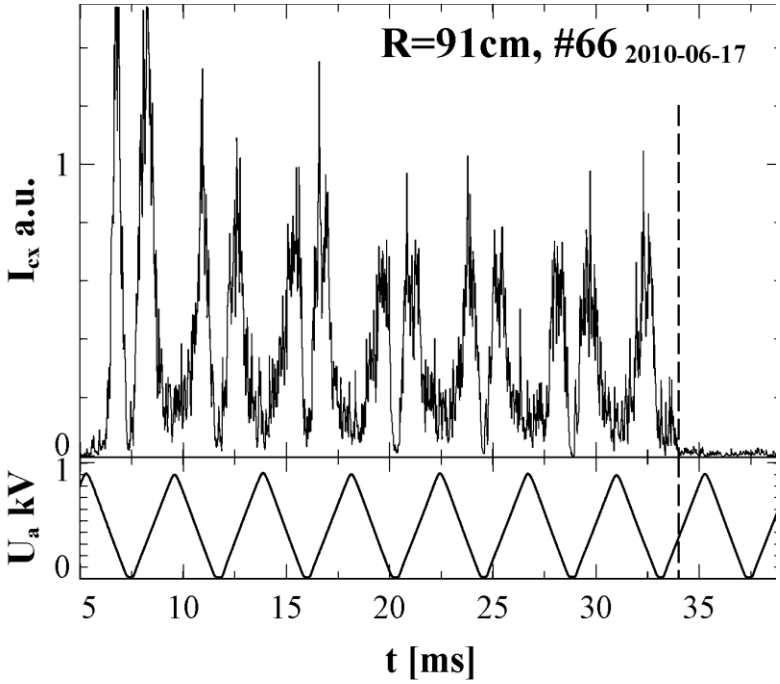
- Summary

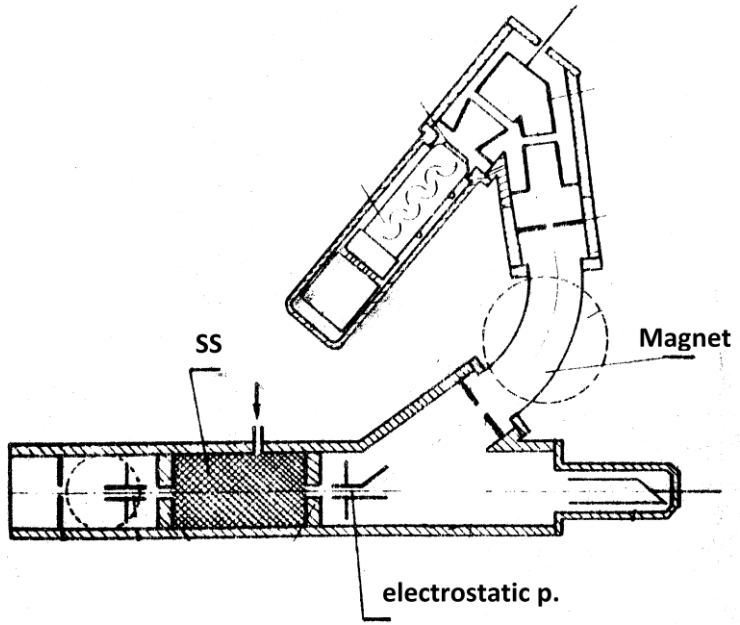
Introduction

NPA in U-3M – old design, single channel, passive.



Afrosimov V V et al 1961 Sov. Phys.—Tech. Phys. 5 1378





Energy sweeping mode:

- New live of old single-channel NPA
- Simplicity
- Better energy resolution

1kV corresponds to 4.5keV energy of CX neutrals

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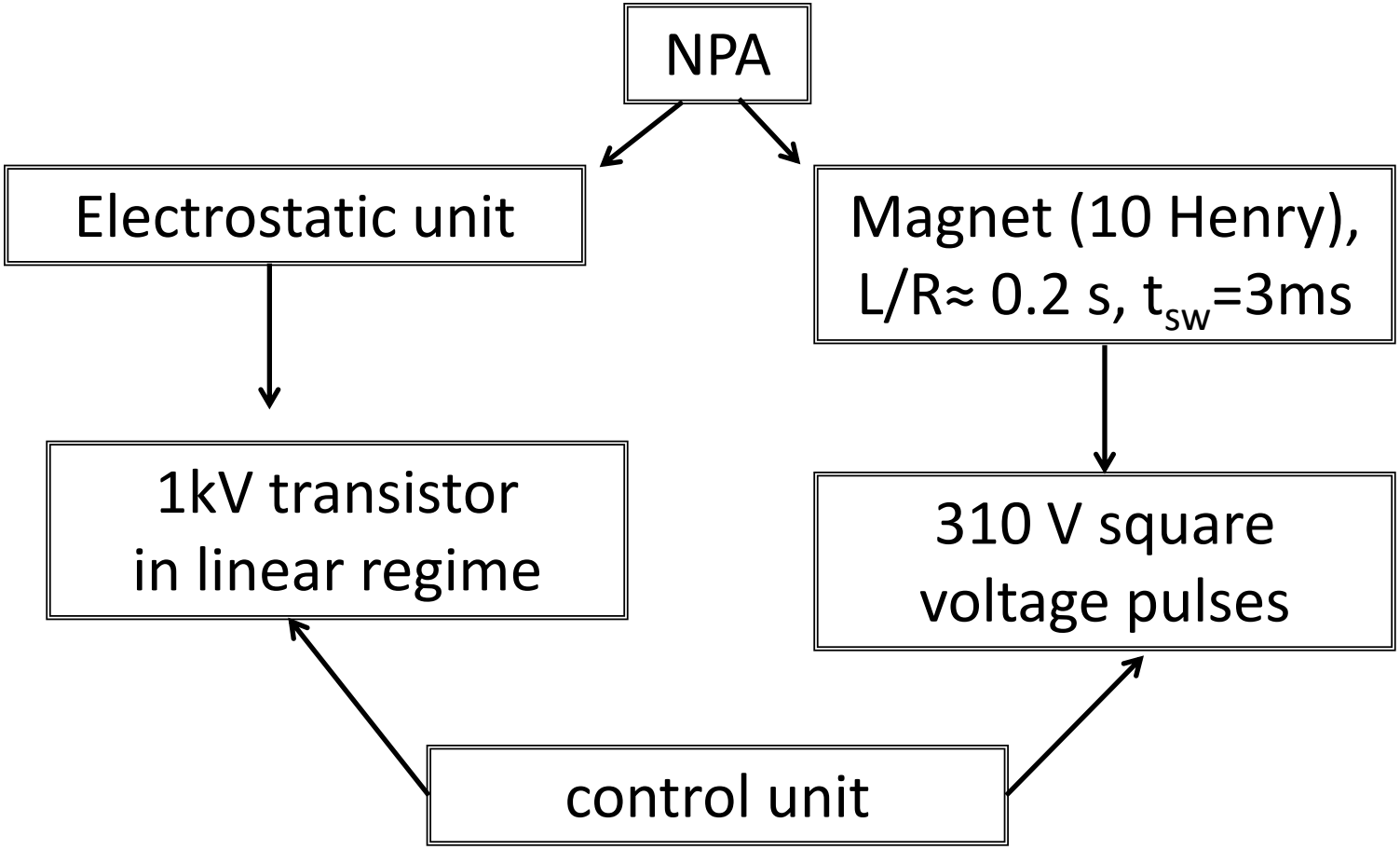
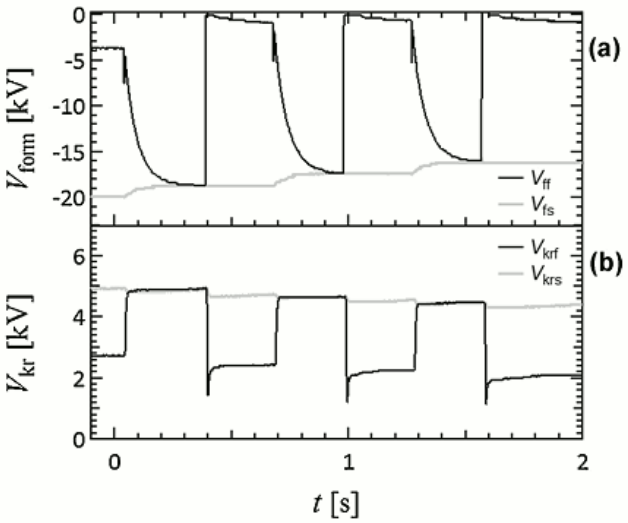
The energy sweeping electronics



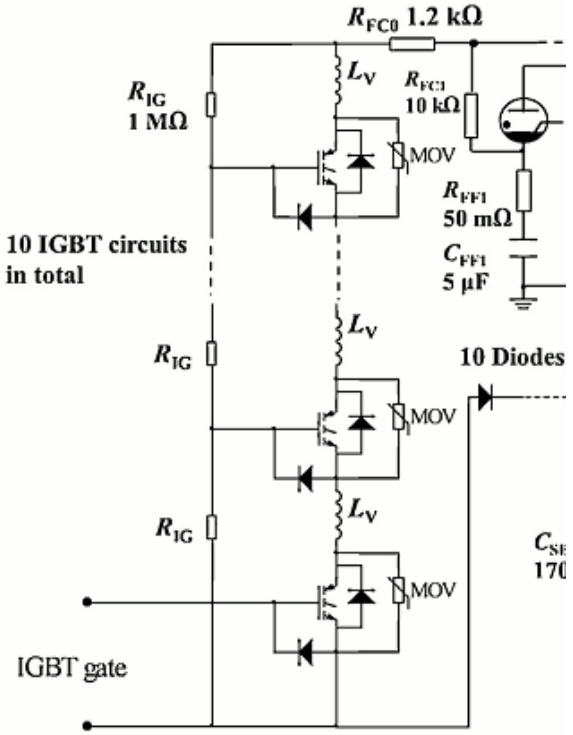
Philosophy: current waveform evolution is “self-defined” (by voltage, inductance and pulse duration), corresponding voltage evolution is predefined by feed-forward method in order to obtain required dependence from current.

Intro. philosophy: “self-defined” waveforms

- If the speed is the key factor
- To high power and/or voltage for PWM control
- To high inductance for PWM control

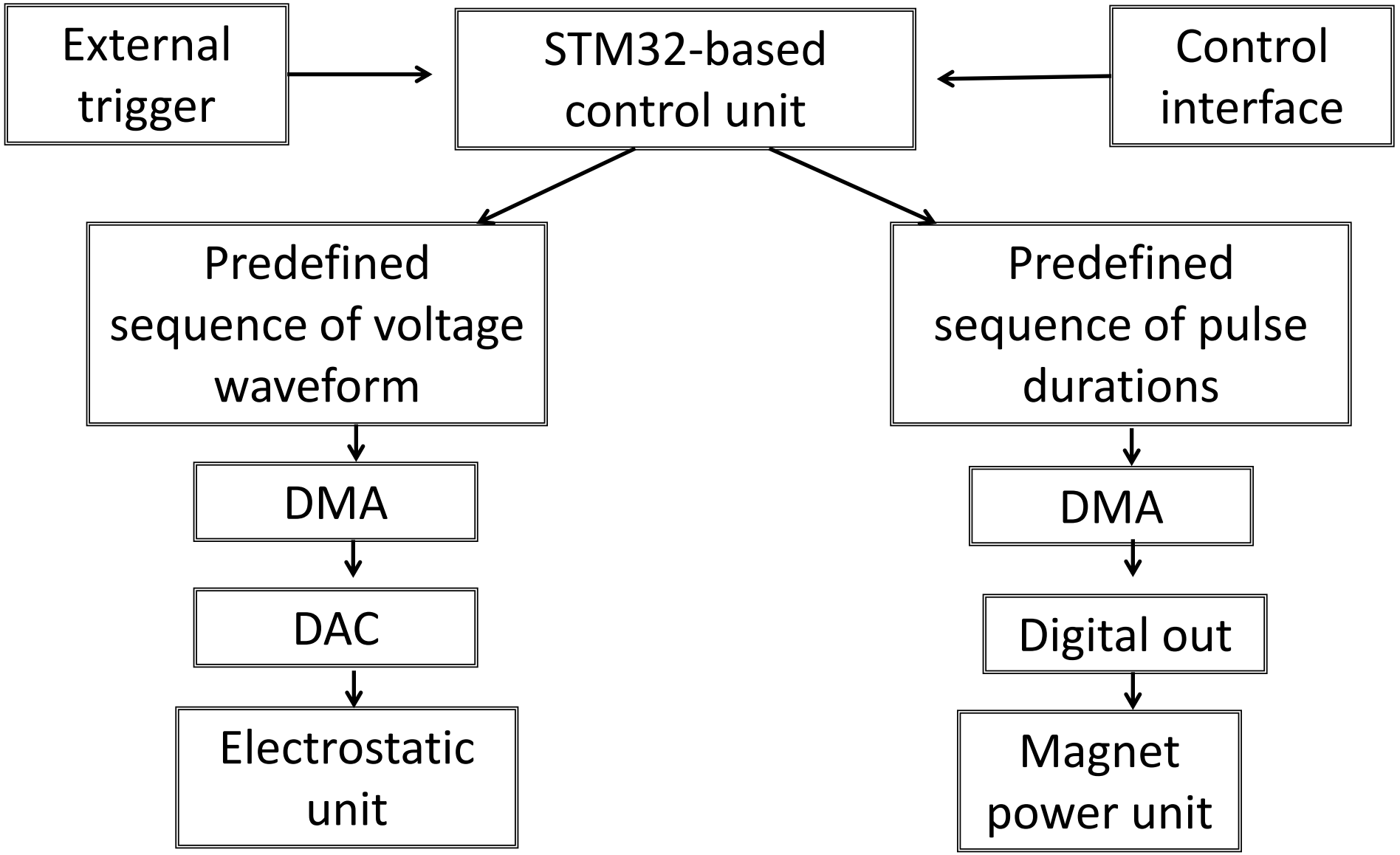


Voltages at the fast bank (black) and the slow bank (gray) in the ignitor circuit using a krytron.



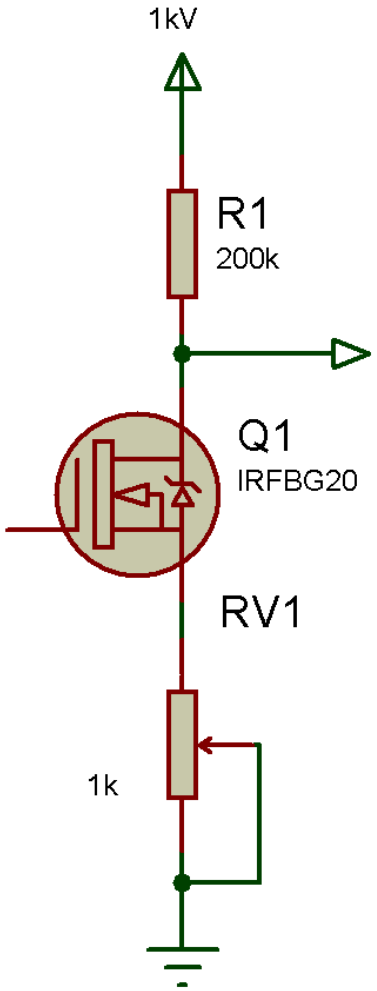
T. Onchi et al. / Fusion Engineering and Design 89 (2014) 2559–2565
Onchi T et al 2016 IEEE Transactions on Plasma Science, Vol. 44 No. 2, 195

STM32-based control unit



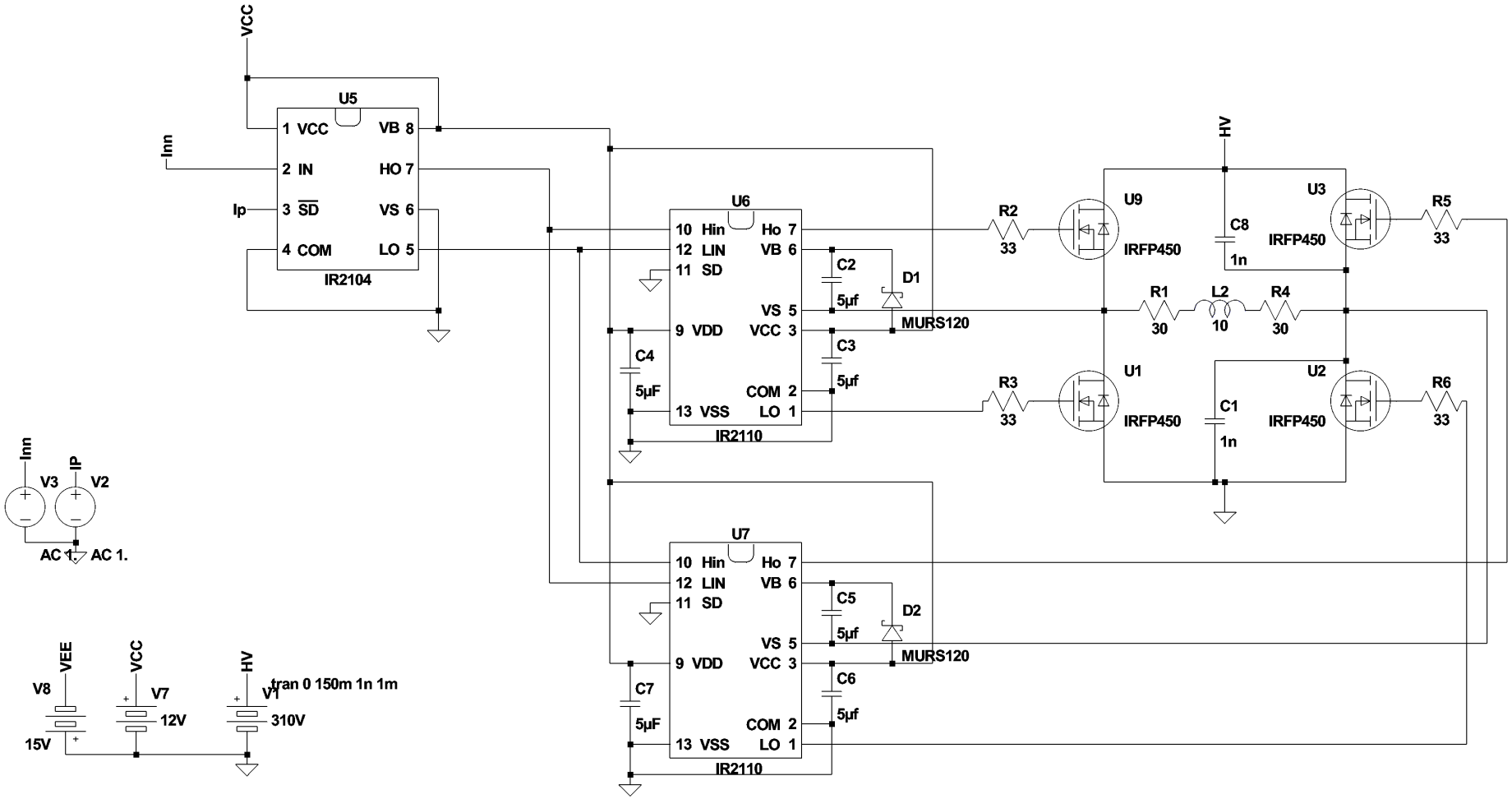
Electrostatic power part

- Most of modern high voltage IGBT and MOSFET can be operated in the linear mode, in spite of the original designs for switching mode
- Very low current consumed by the electrostatic unit simplify design
- By simple adjustment of two resistors R1 and RV1 transistors can be tuned for linear mode .

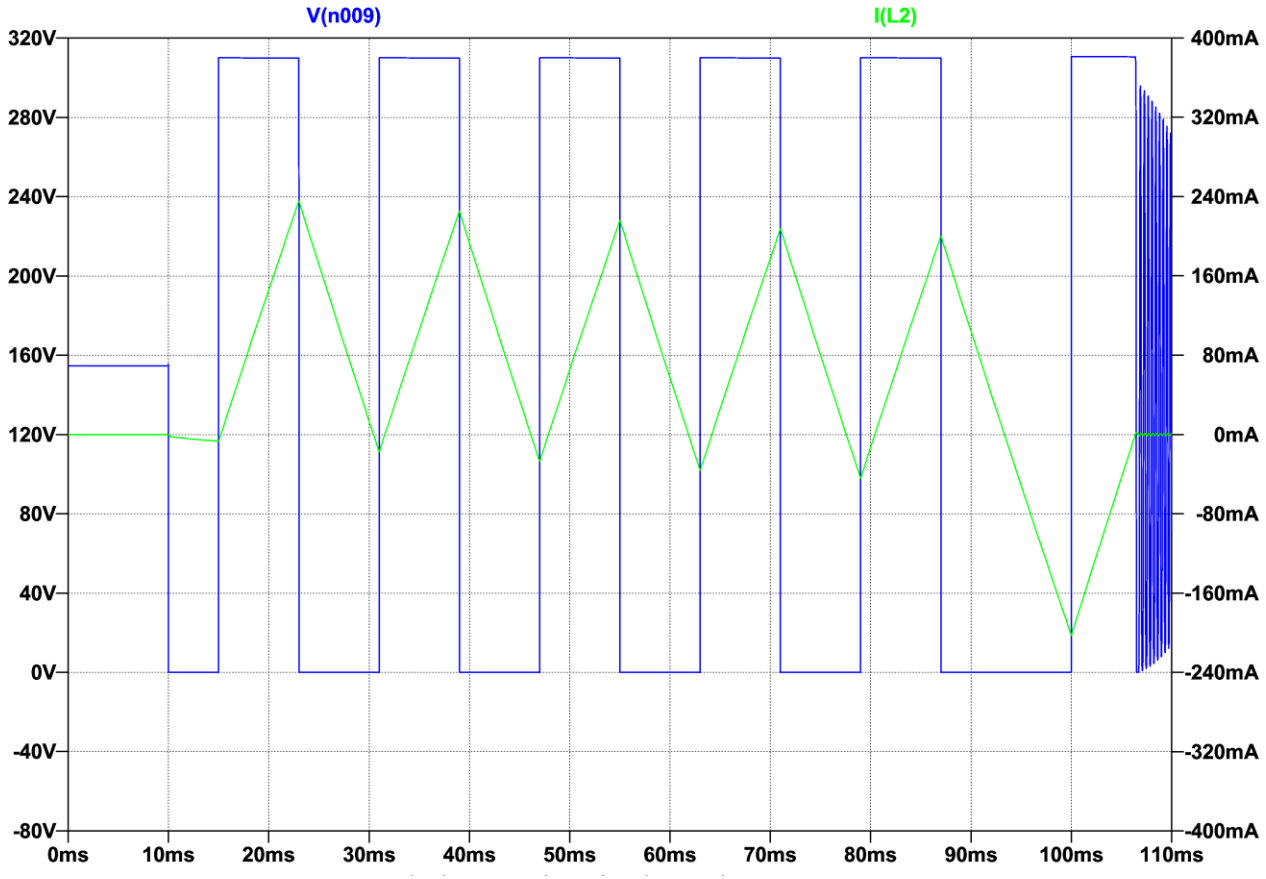


Magnet power part

One pair of the bridge is used at the current rise stage; another pair is applied reverse voltage for fast decay of the MS magnet current.

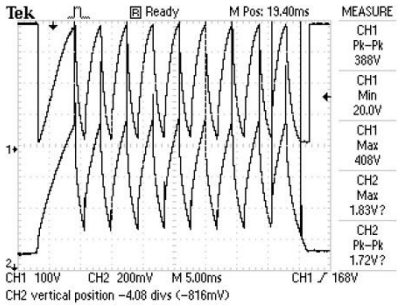


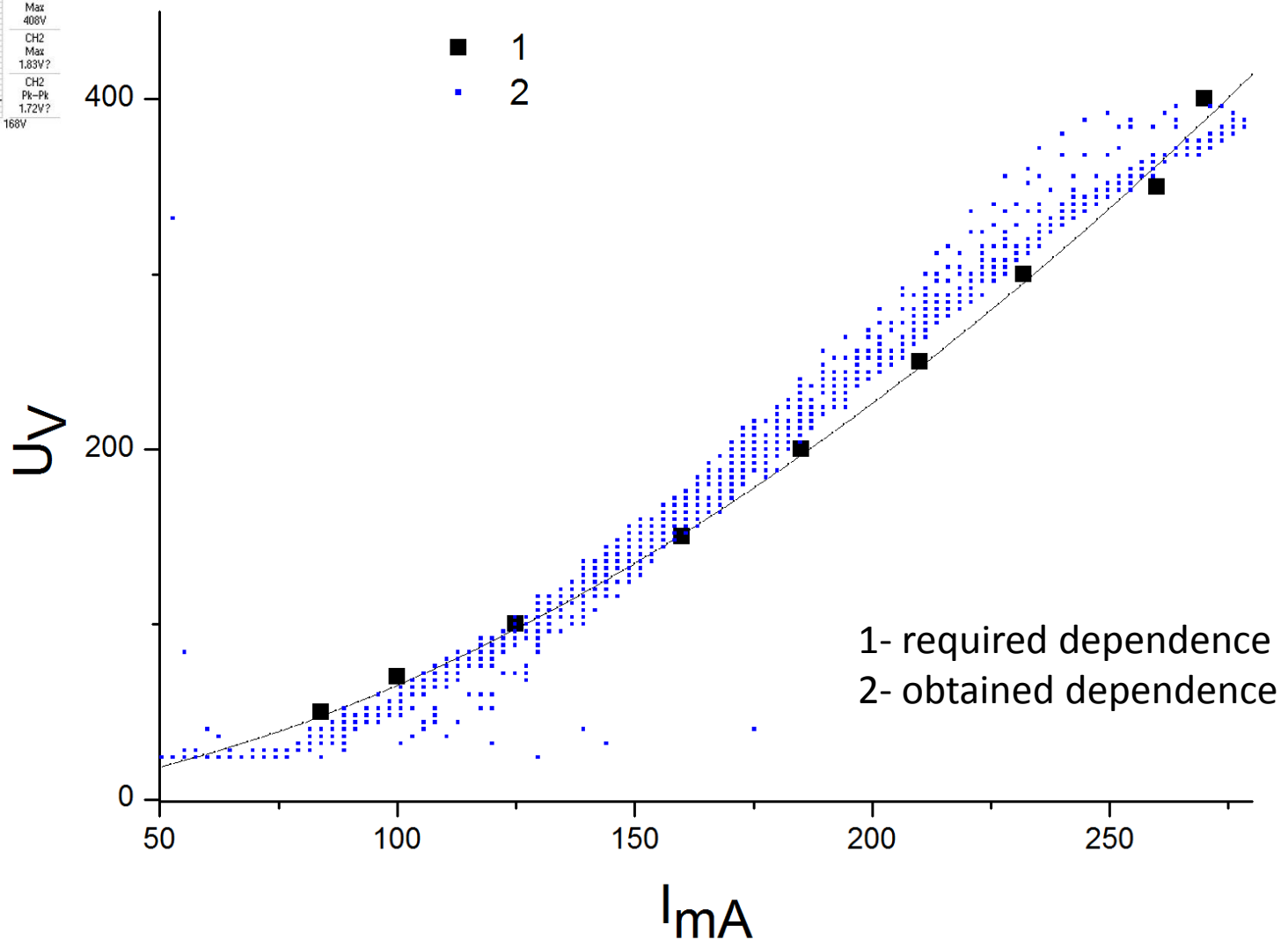
Magnet power part: LTspice simulation



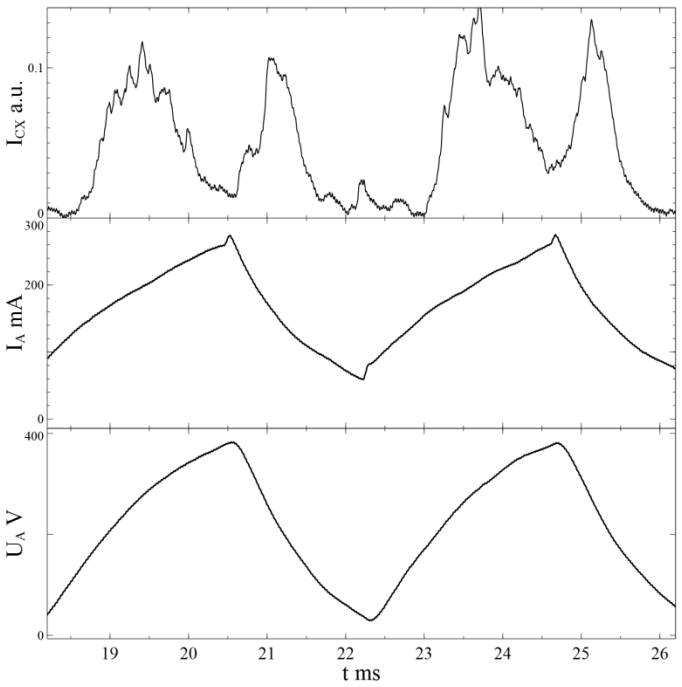
310 V is enough for 0.2-0.3A current variation during few ms. The sizing/falling time is in two orders of magnitude shorter than L/R time of the magnet.

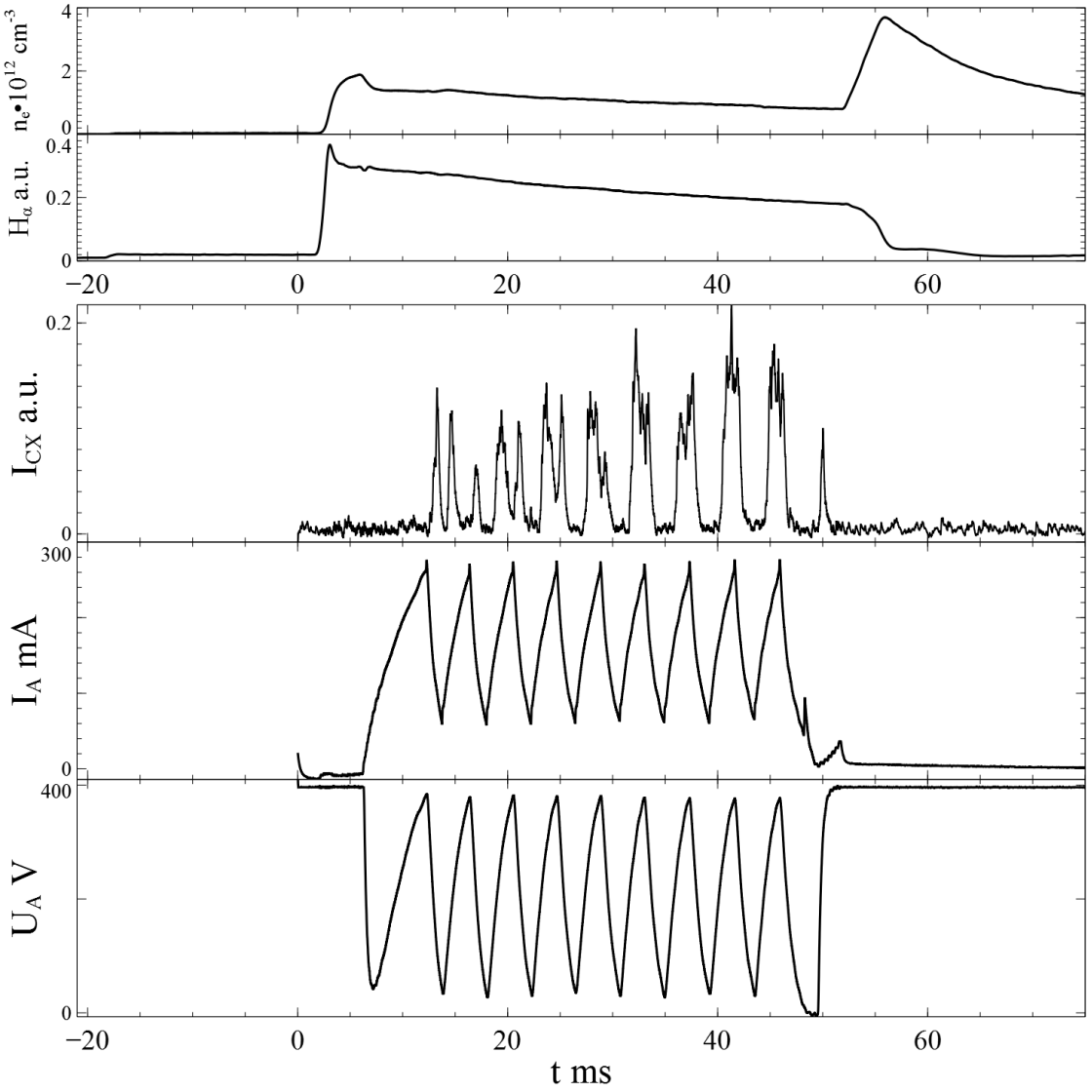
NPA calibration for hidrogen





U-3M : NPA signals





- 2-4ms duration of the NPA measurement during 50 ms of U-3M discharge.
- High CX flux from U-3M plasma allow NPA operation in analog mode of data collection.

Summary

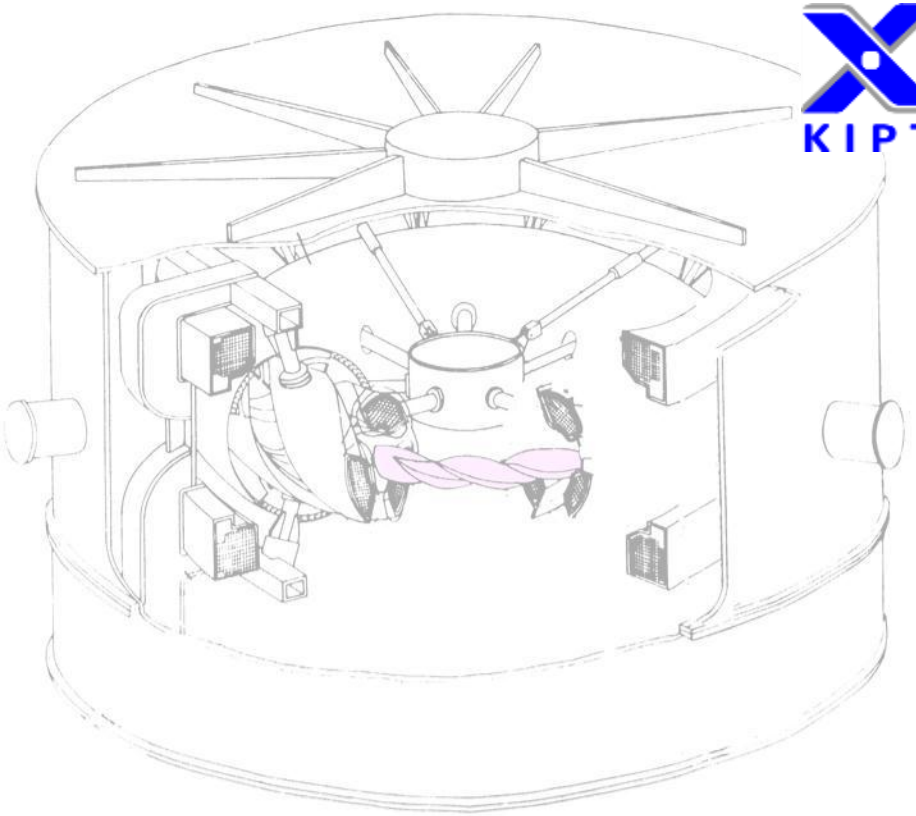
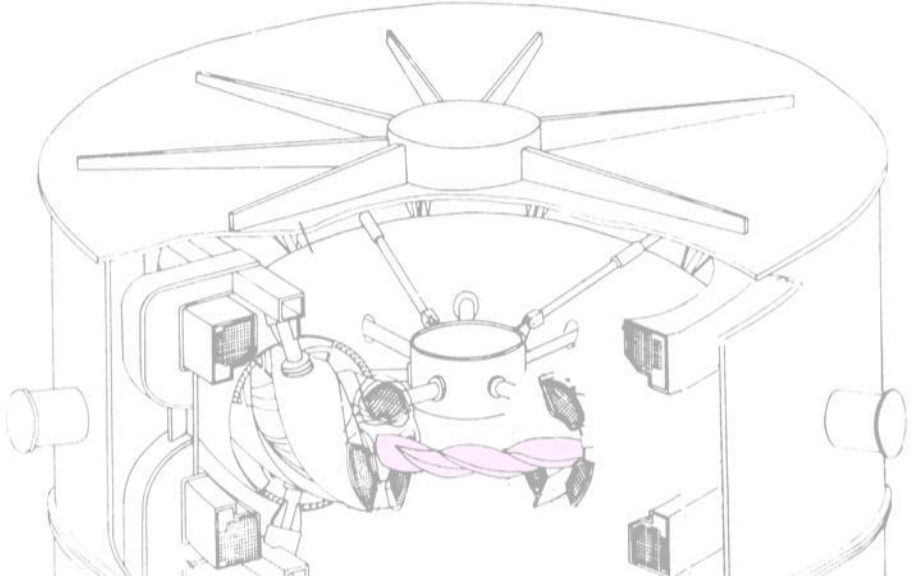
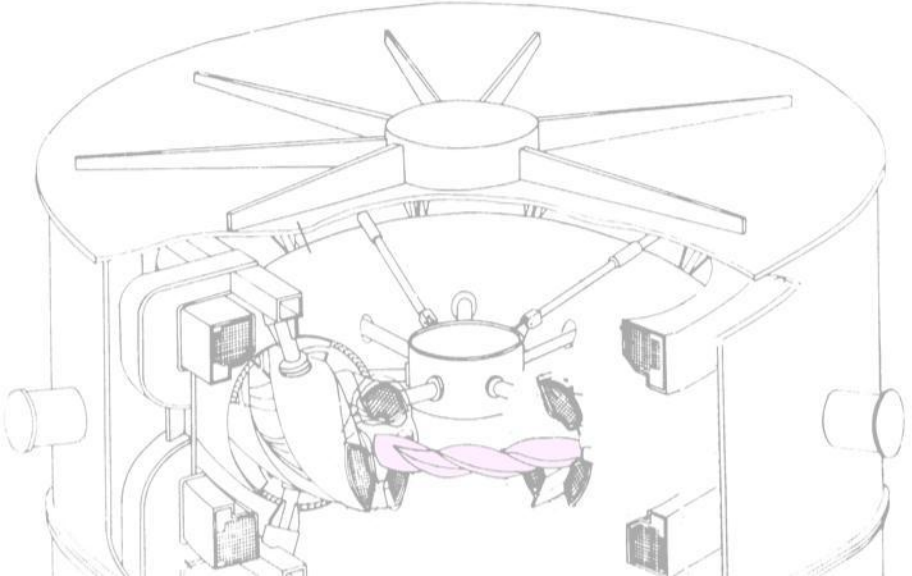
The energy-sweeping mode was recently used for measurement of the charge exchange flux energy distribution every 3-5ms via single-channel electrostatic neutral particle analyzer (NPA) in stellarator U-3M.

The MS magnets of about 10 Henry are used in our NPA diagnostics. The L/R time constant of the MS magnet is about 200 ms. A variation of current troughs MS magnet from zero to 0.3 A is required for energy-sweeping mode application in the energy range of 0-2keV.

We use STM32F100 microprocessor as a control unit. Square wave 310 V pulses of variable duration are used for control of MS magnet current. The IGBT bridge is used as a power unit of MS magnet. One pair of the bridge is used at the current rise stage; another pair is applied reverse voltage for fast decay of the MS magnet current. The digital to analog convertor unit of STM32F100 microprocessor is used for the electrostatic voltage formation.

Since parameters of MS magnet and electrostatic parts of NPA are fixed, no feedback is required in our system. The predefined set of durations for MS current control and waveform of electrostatic voltage are stored in the internal memory of the microprocessor.

The direct memory access unit of the STM32F100 microprocessor is used for synchronized output of two control signals.

Thank you