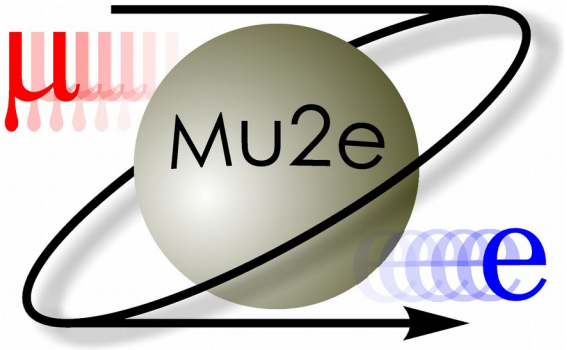


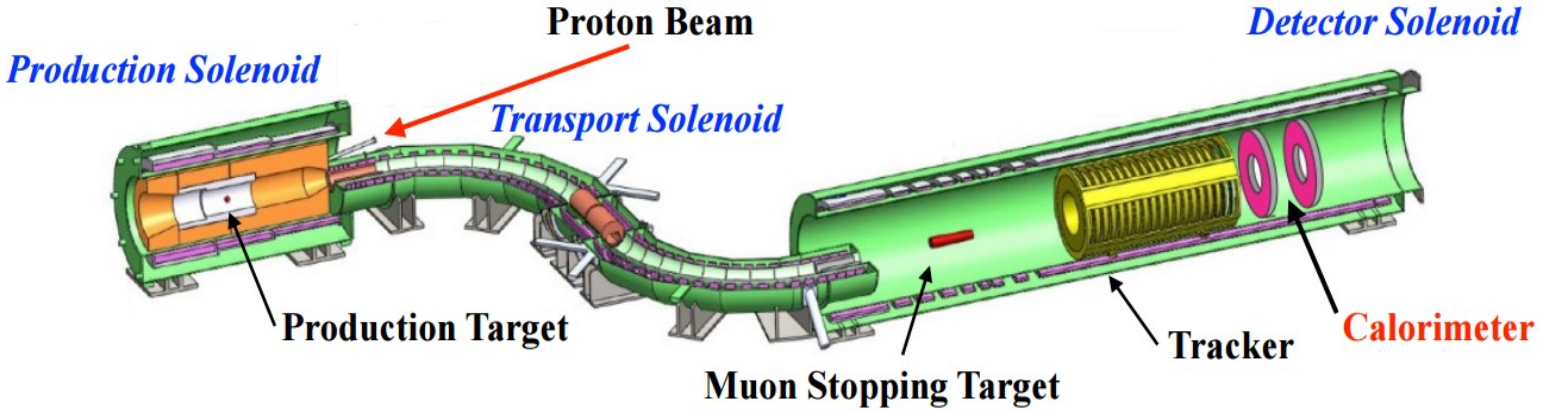

# The front-end electronics of the Mu2e electromagnetic calorimeter

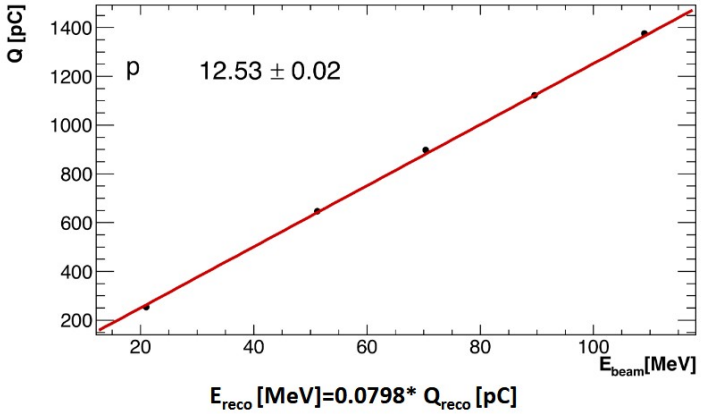
N.Atanov, JINR,Dubna
on behalf of Mu2e calorimeter group

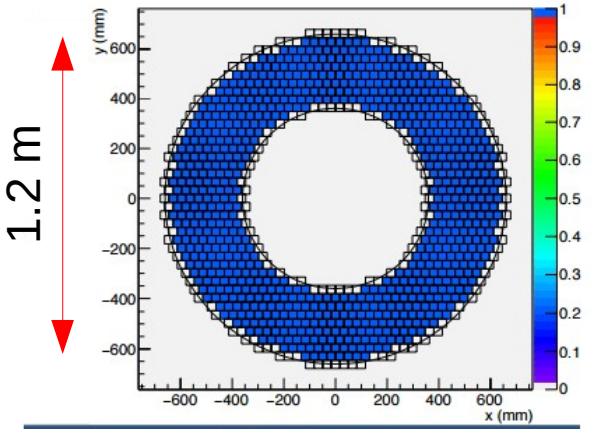


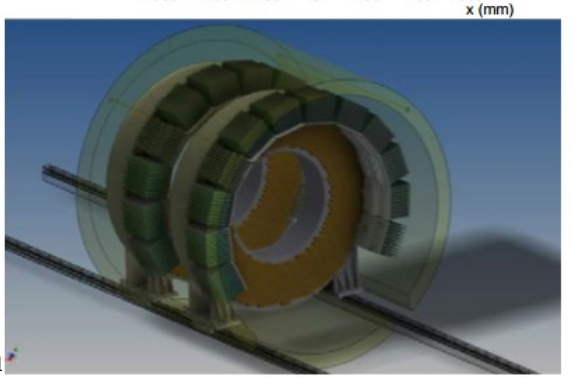
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

# Mu2e electromagnetic calorimeter



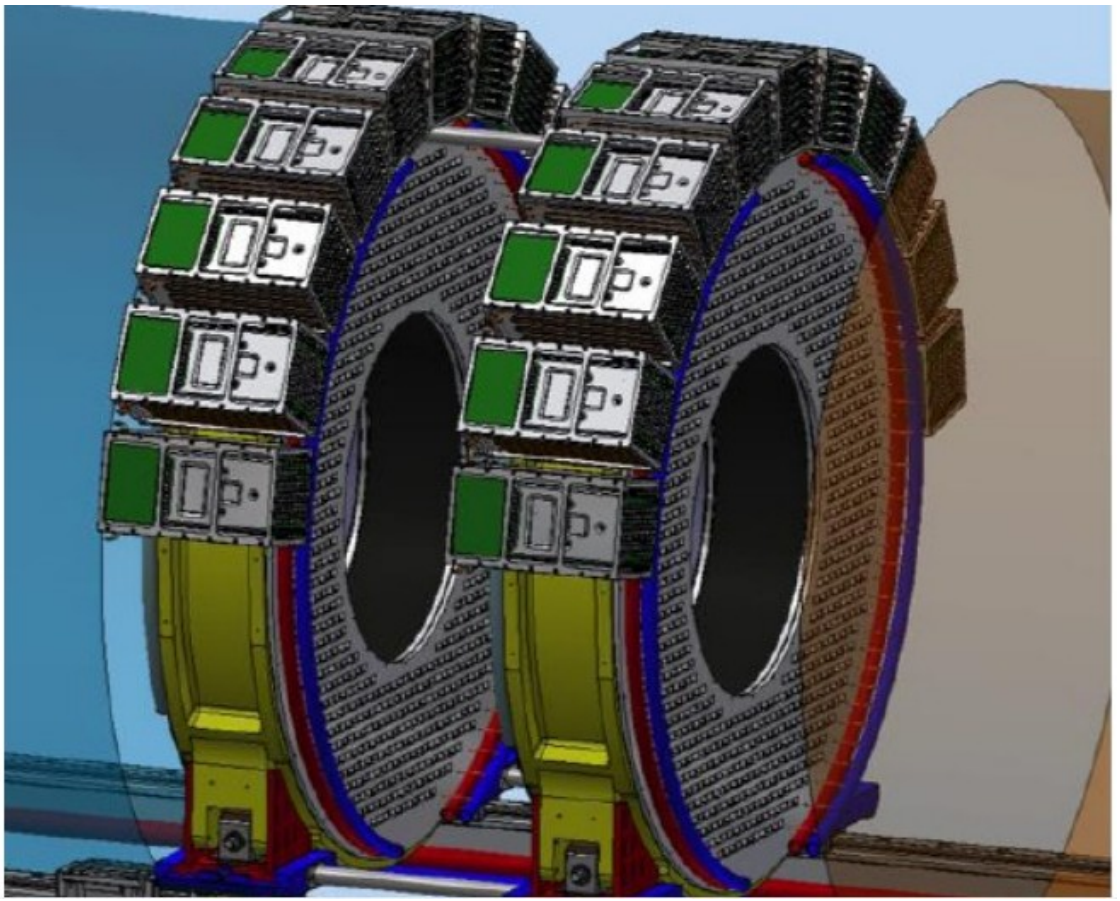



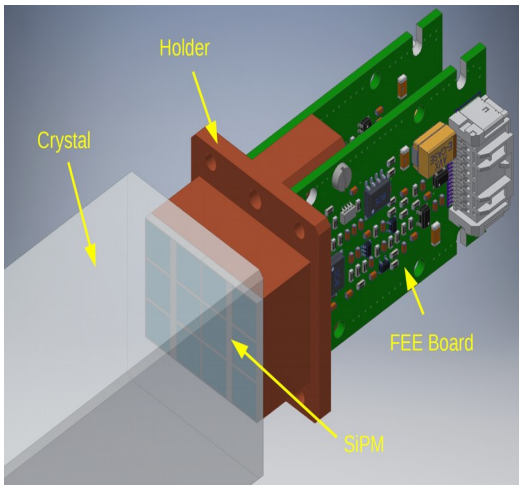



- Two disks with inner radius 35.1 cm and outer radius 66 cm
- 674 CsI crystals per disk
- Square crystals (34x34x200 mm3)

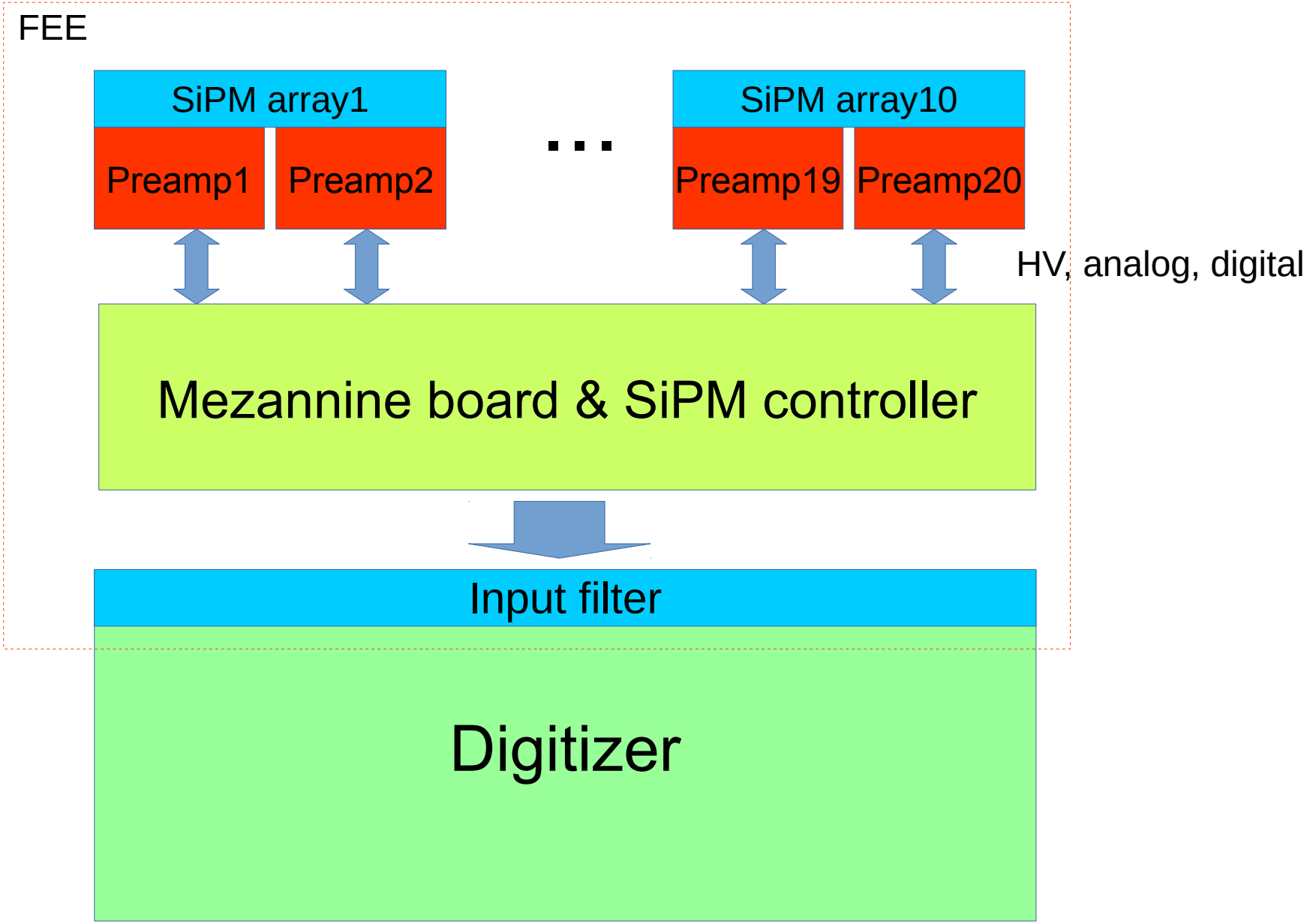
# Mu2e electromagnetic calorimeter



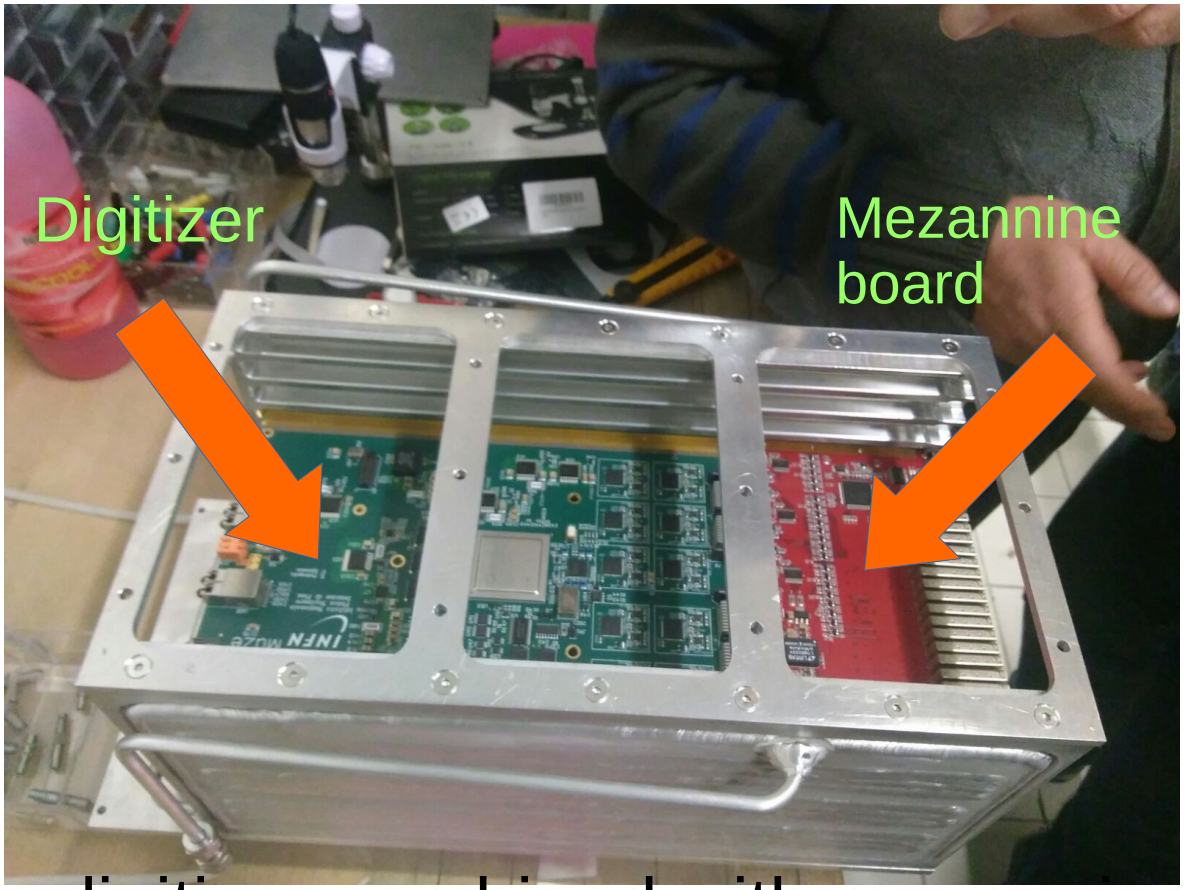



- Each crystall is read out with 6-SiPM array, which is read out with 2 FEE preamplifier modules
- We need 1348 preamplifiers per one disk

# Front-end electronics overview

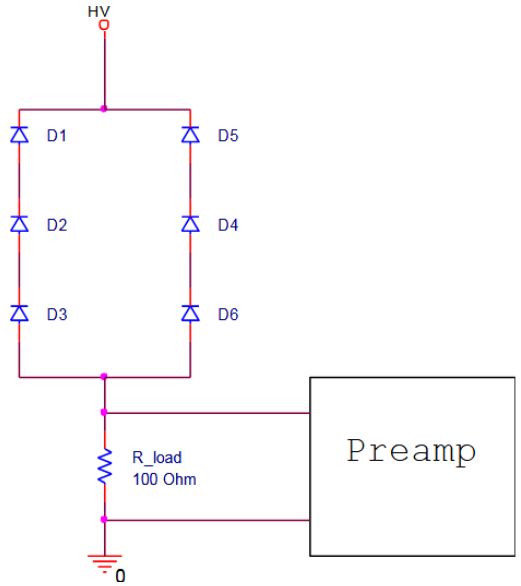


# Waveform digitizer with mezannine board




Waveform digitizer combined with mezannine board in crate

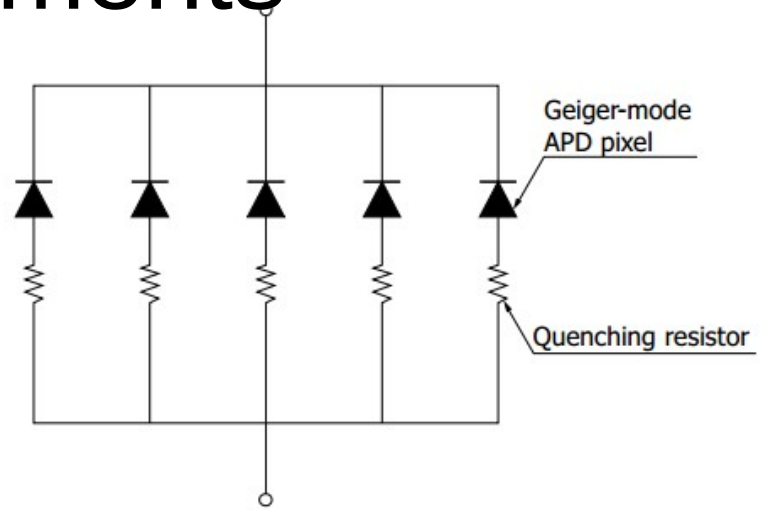
# FEE requirements




SiPM array for one crystall readout

For each crystal one need to read signal from 2 arrays of three 6x6 mm2  Hammamtsu SiPMs:

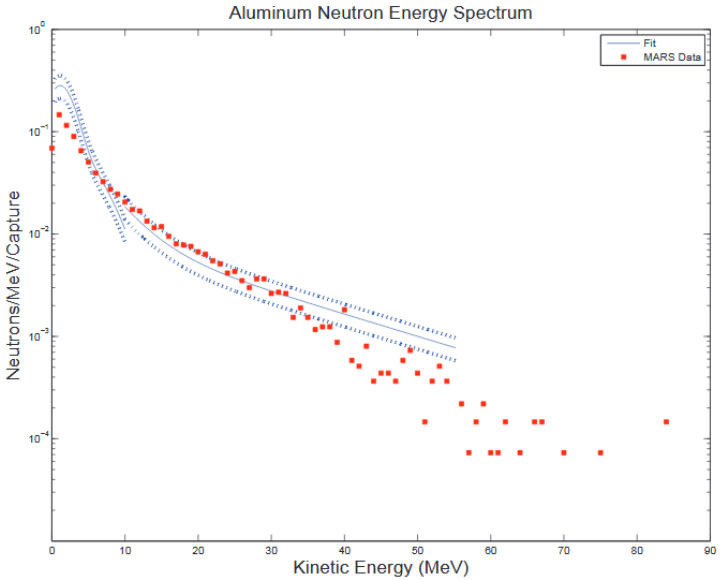
- 50 μm pitch, Rq=150 kOhm
- Total capacity Ct=860 pF



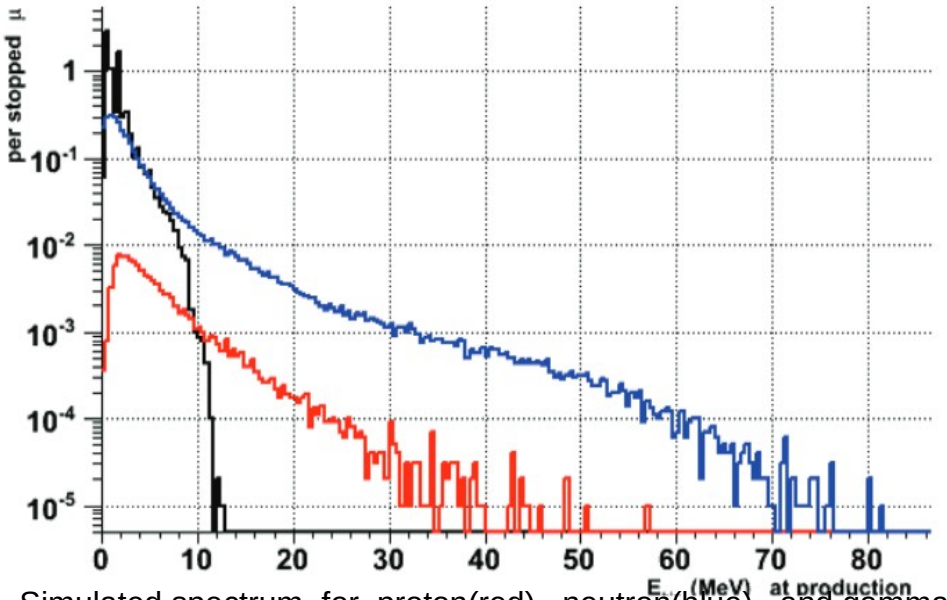

Several SiPM cells

# FEE requirements

- Radiation hardness. Maximum dose ~ 100kRad & strong neutron integrated flux at the level of $10^{12}$ n/cm2 for 3 years
- Heat efficiency because of a $10^{-4}$ Torr vacuum
- Constant 1T axial magnetic field strength
- Linearity in wide input current range from 2uA to 2mA
- Stable DC/DC conversion in the LDO regulator for all current range

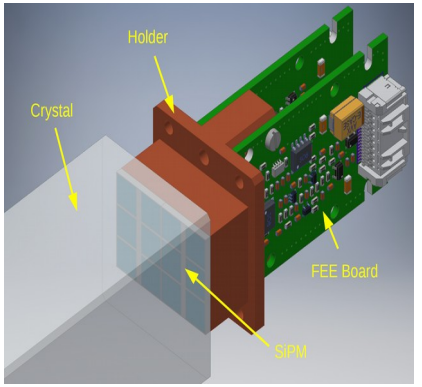



Simulated spectrum for neutrons emission after μ capture on Al

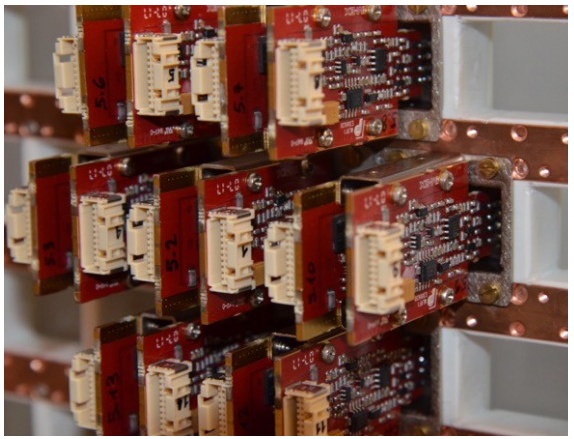


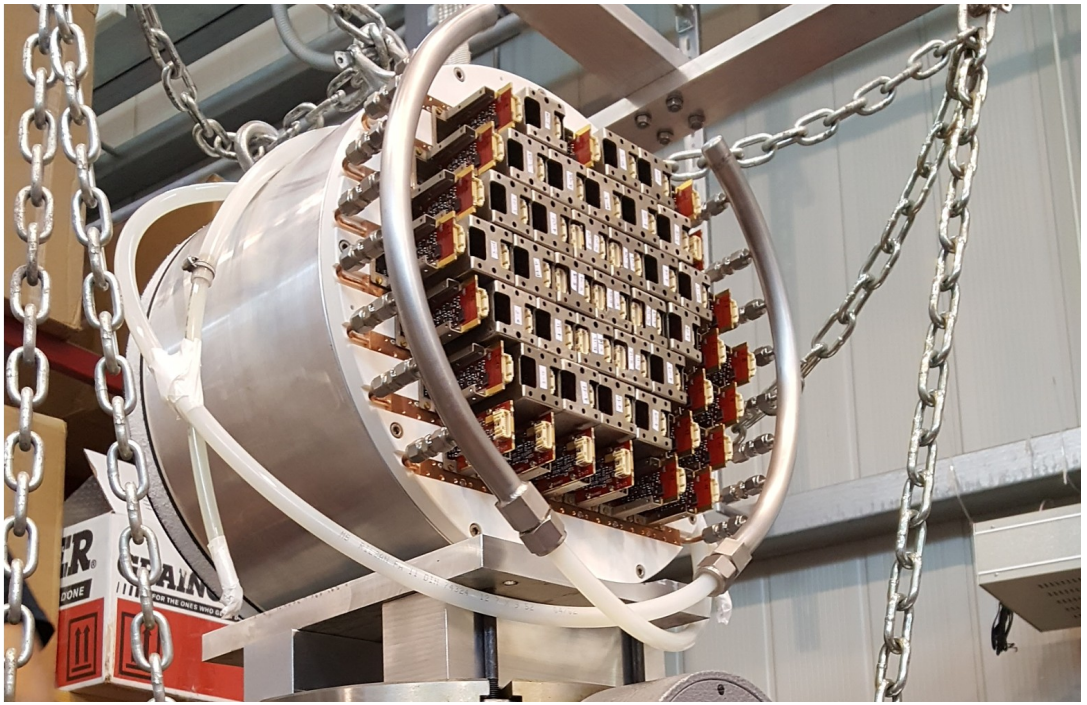

Simulated spectrum for proton(red), neutron(blue), and gamma(black) emission per μ stop after μ capture on Al

# FEE preamplifiers



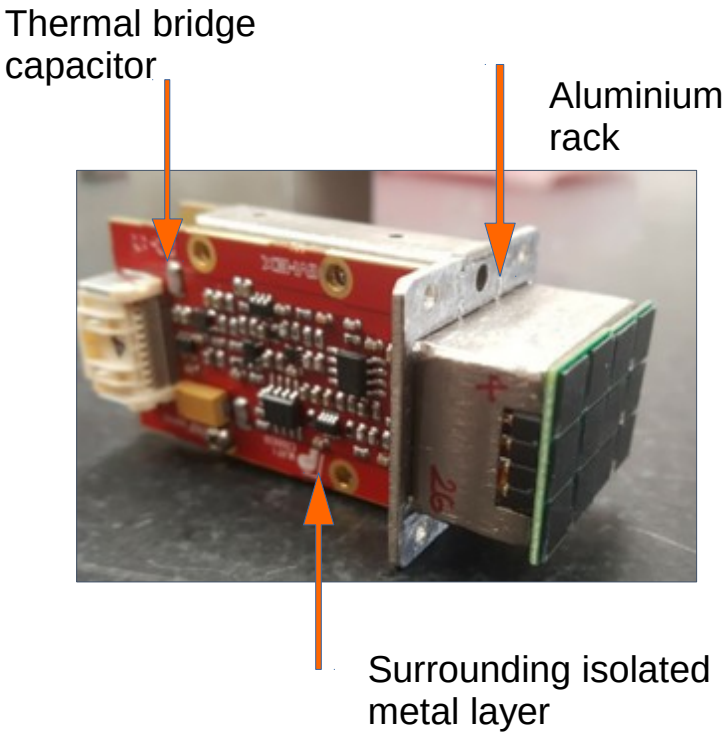

Single SiPM array with 2 preamps

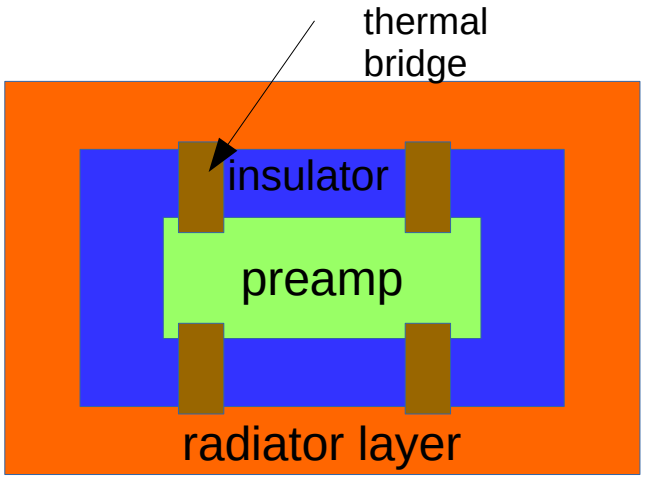




Electromagnetic calorimeter prototype Module0 with preamps installed

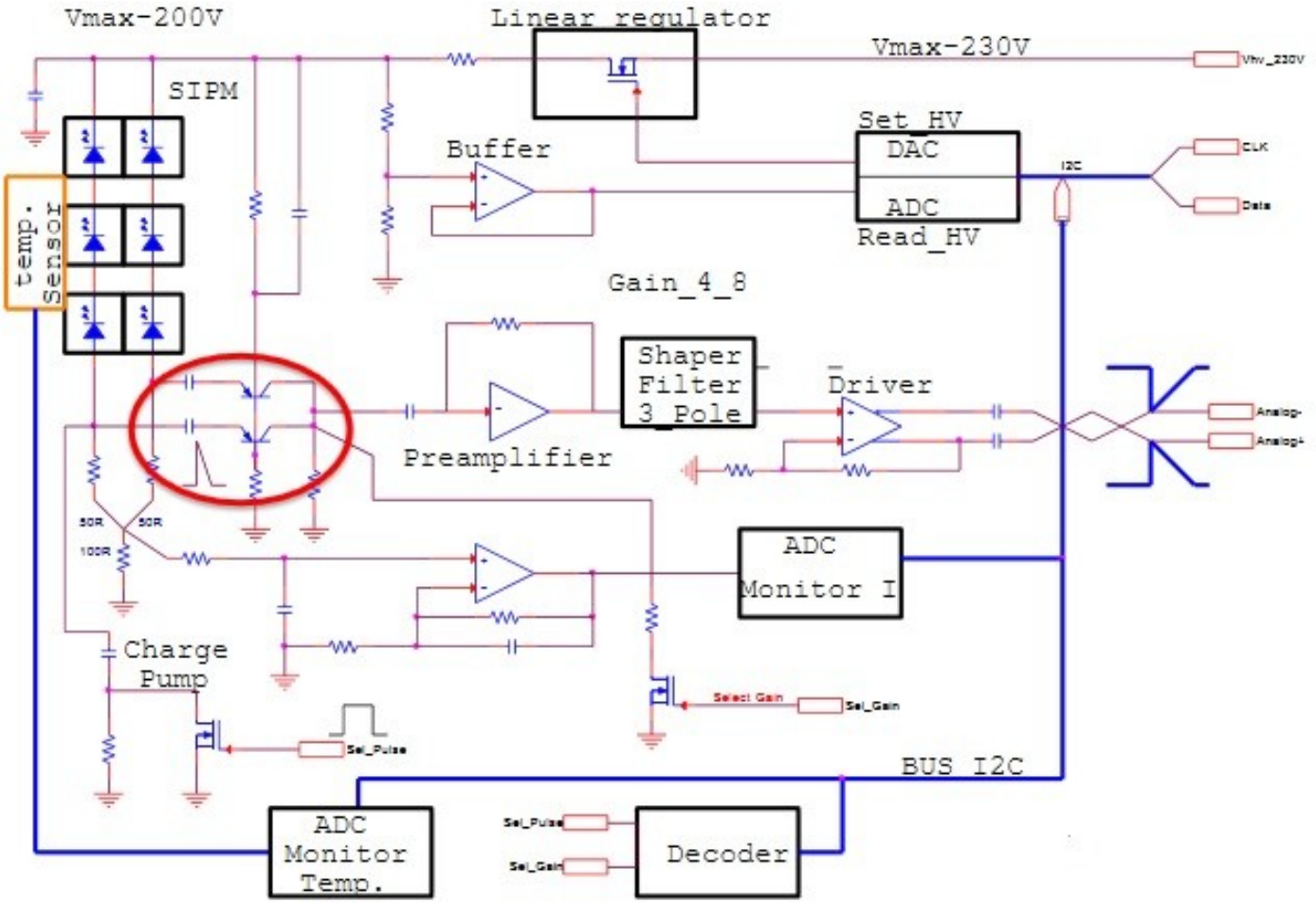
# FEE preamplifier. Thermal efficency




All front-end electronics is placed in vacuum vessel. To avoid overheating only direct connection to rack and radiator is allowed. For this main PCB layer of preamplifier is surrounded with electrically insulated metal layer that is connected to rack

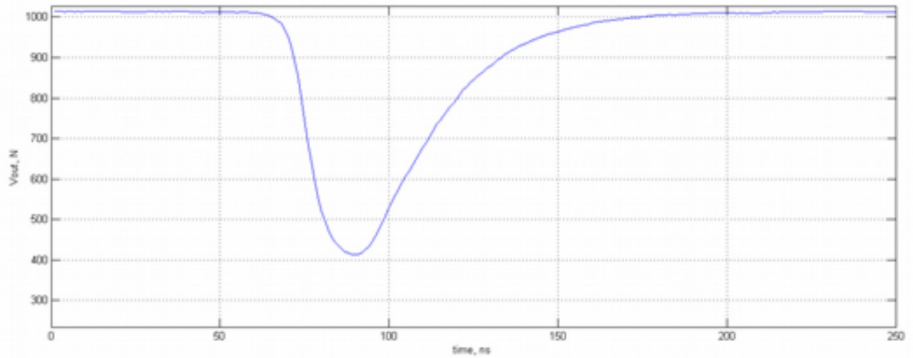
# FEE preamplifier. Simplified schematic



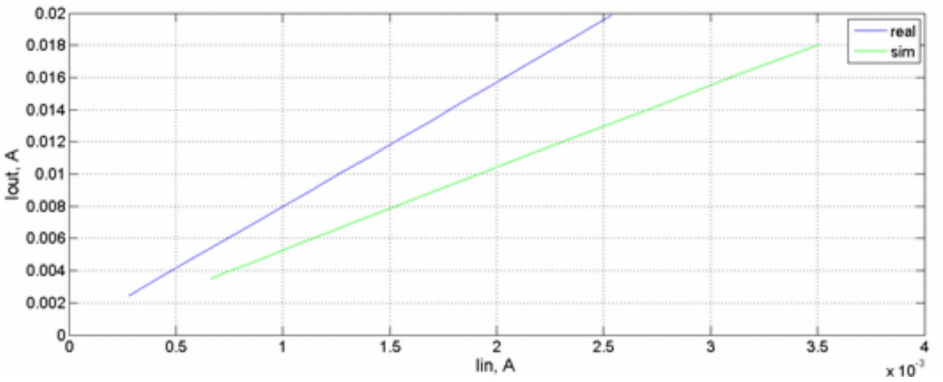

Preamplifier simplified schematic. Base blocks are

- Input transistor cascade
- Pulse shaper
- Linear regulator (LDO) for SiPM array
- Gain switch
- Current monitor
- Charge pump for test pulses
- Temperature sensor

# FEE preamplifier




Preamplifer output signal



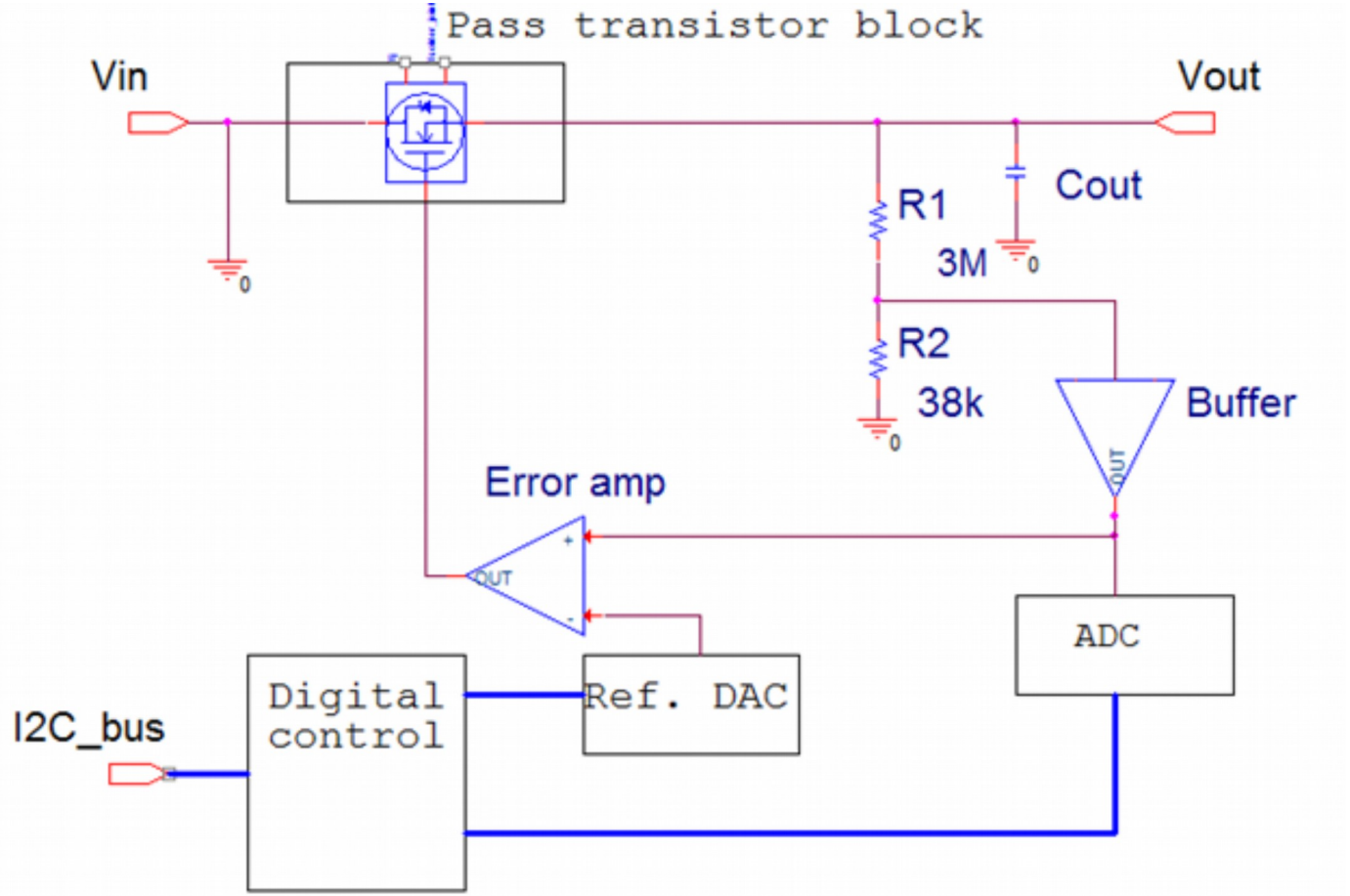

Preamp gain &
linearity measurement

Main features:

- Input resistance 33 Ohm
- Output resistance 100 Ohm
- Diff. output range 2V
- Gain for current 4-8

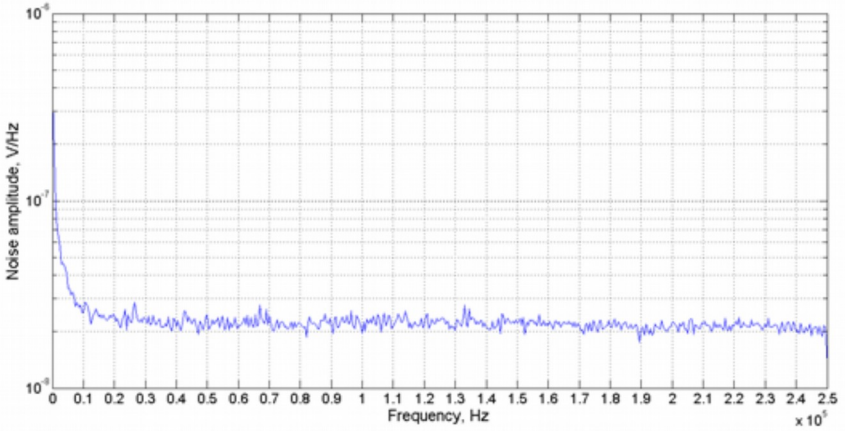
- Bandwidth 40MHz
- Noise 2nV/√Hz
- Power supply +8V
- Power consumption 45mW
- Rise time 25ns
- Fall time <120ns

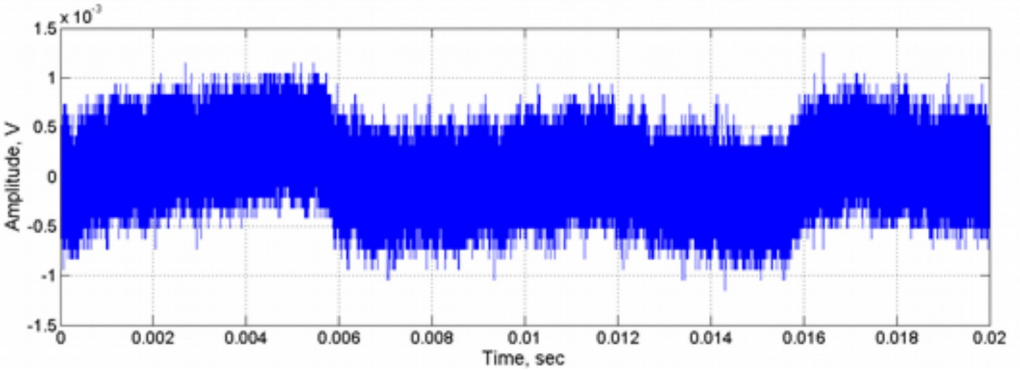
# FEE preamplifier. Linear regulator (LDO)



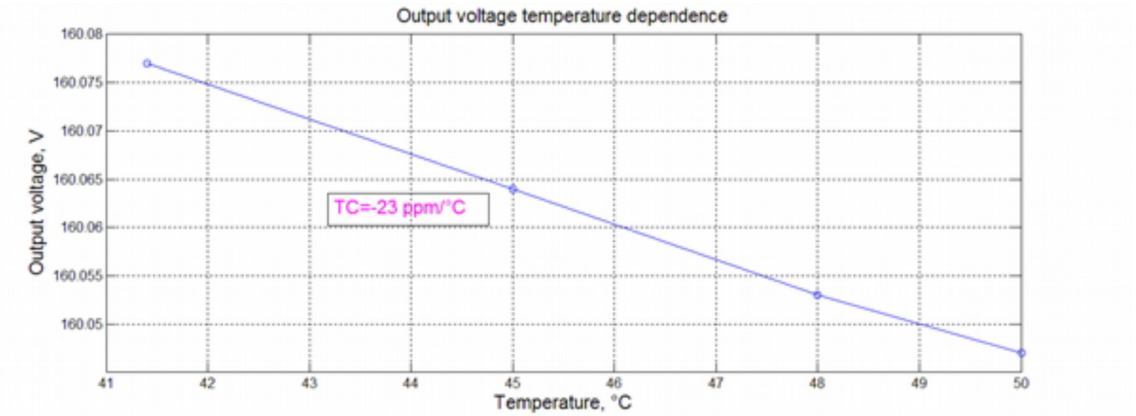

To provide HV to SiPM array LDO with analog and difgital feedback is used. Pass transistor block based on NMOS depletion-mode transistor. It is designed to provide stable DC output for load current from 2uA to 2mA

# FEE preamplifier. Linear regulator perfomance



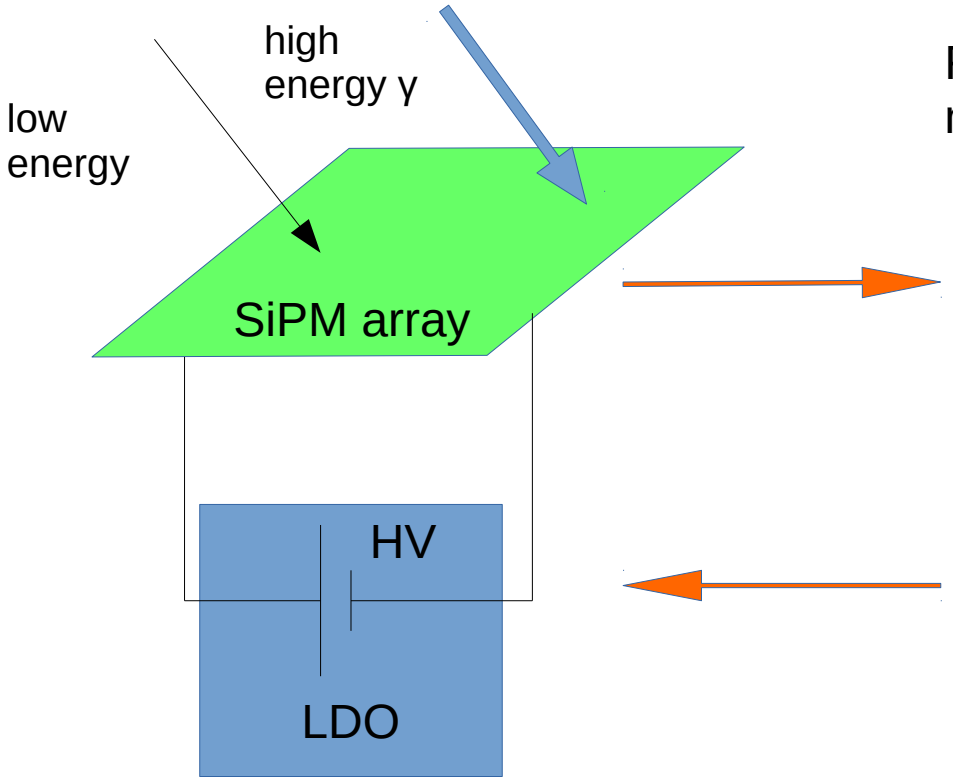

Output noise spectrum, high load current I_load = 2mA, Vin=200V, Vout=160 V



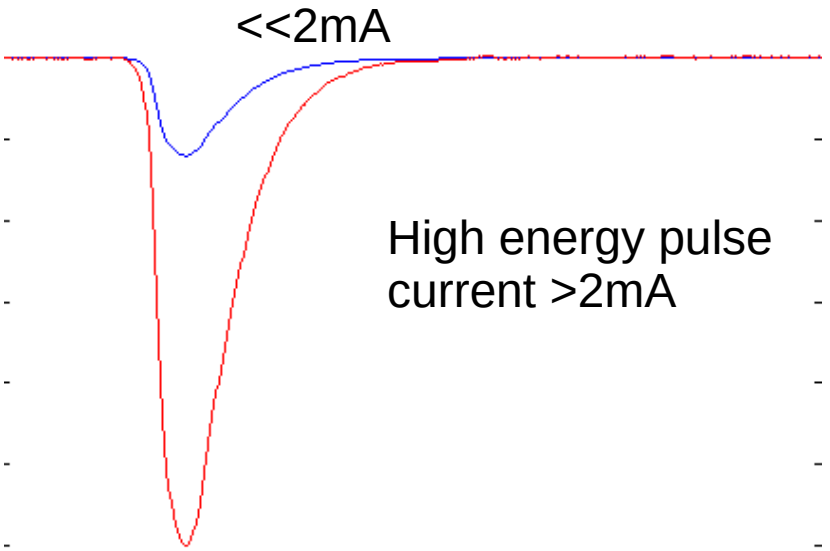

Output LDO voltage temperature dependence

Output noise is calculated for DC/DC conversion from Vin=200V to Vout=160 with a constant load current I_load=2mA (maximum). The total noize level for high current is less then 3 mV peak-to-peak.

# FEE preamplifier. Current monitor

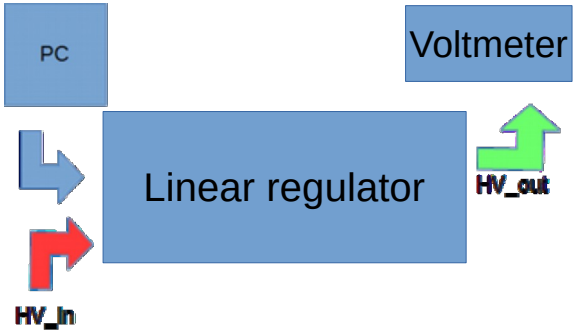


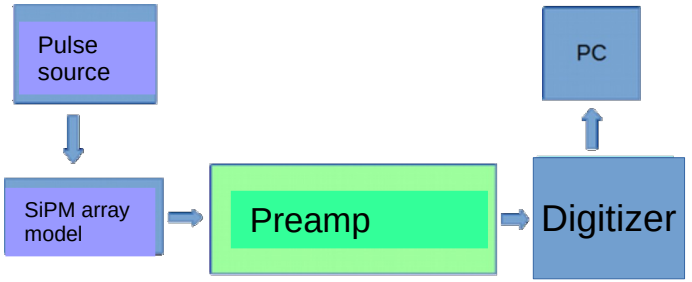

For 3 years neutron flux is ~10^12 n/cm2

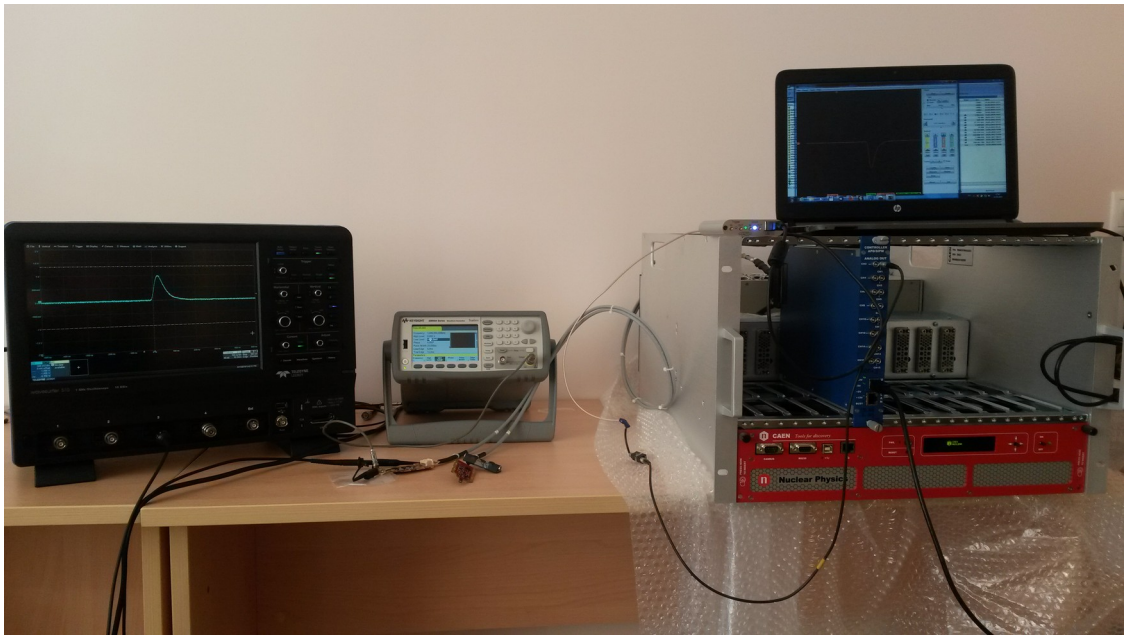



To avoid SiPM overheating & damaging when high-energy photons hit surface of detector, the SiPM supply voltage is decreased by digital loopback in linear regulator

# FEE preamplifier. Testbench

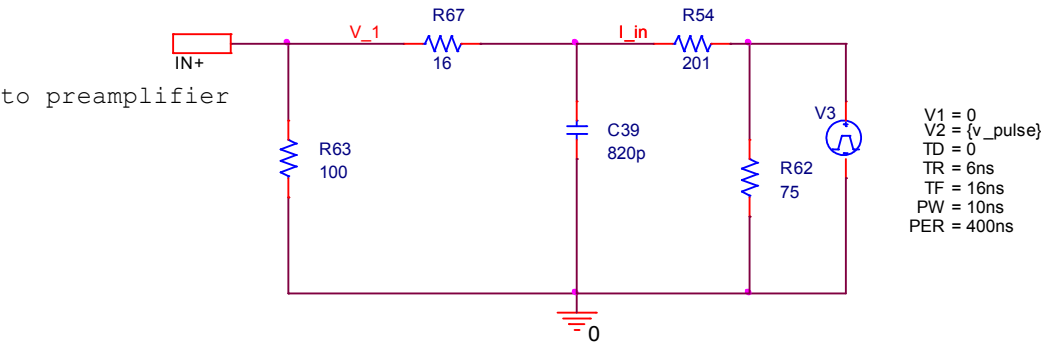


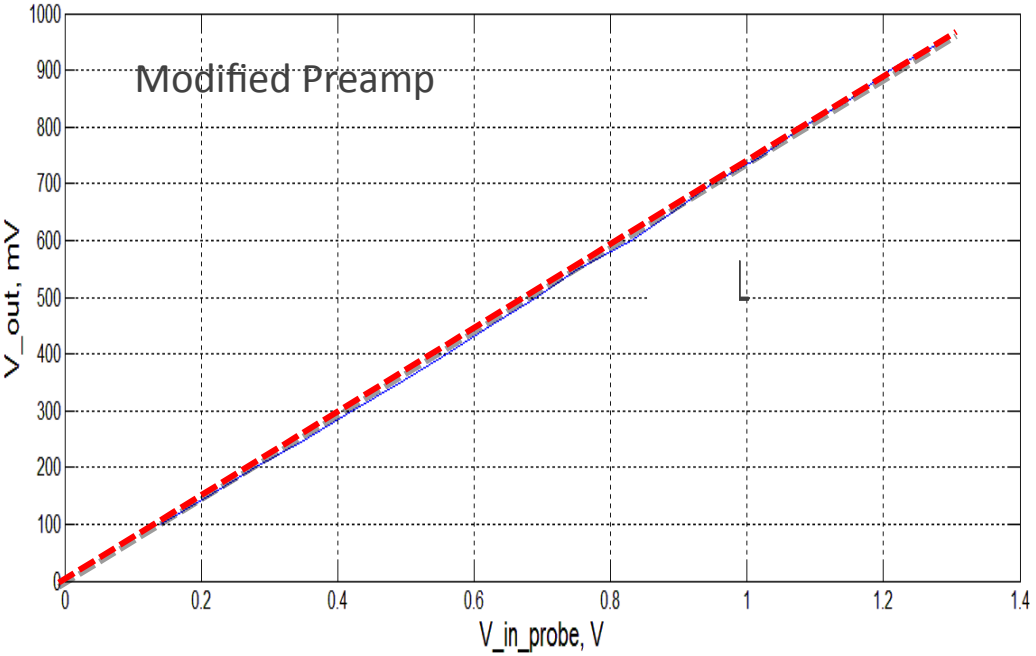



For QA of preamplifiers for the MU2E electromagnetic calorimeter in DLNP, JINR testbench for preamplifier linearity and LDO settings is created

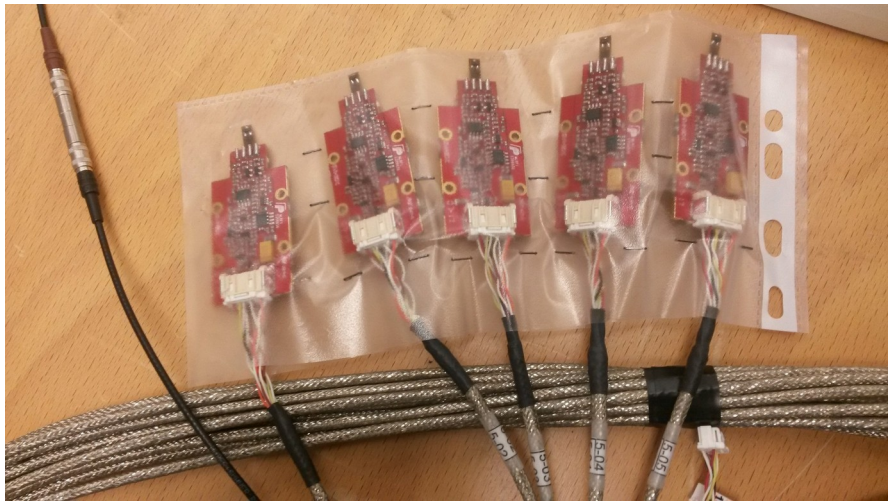
# Test of FEE preamplifier linearity




SiPM array model



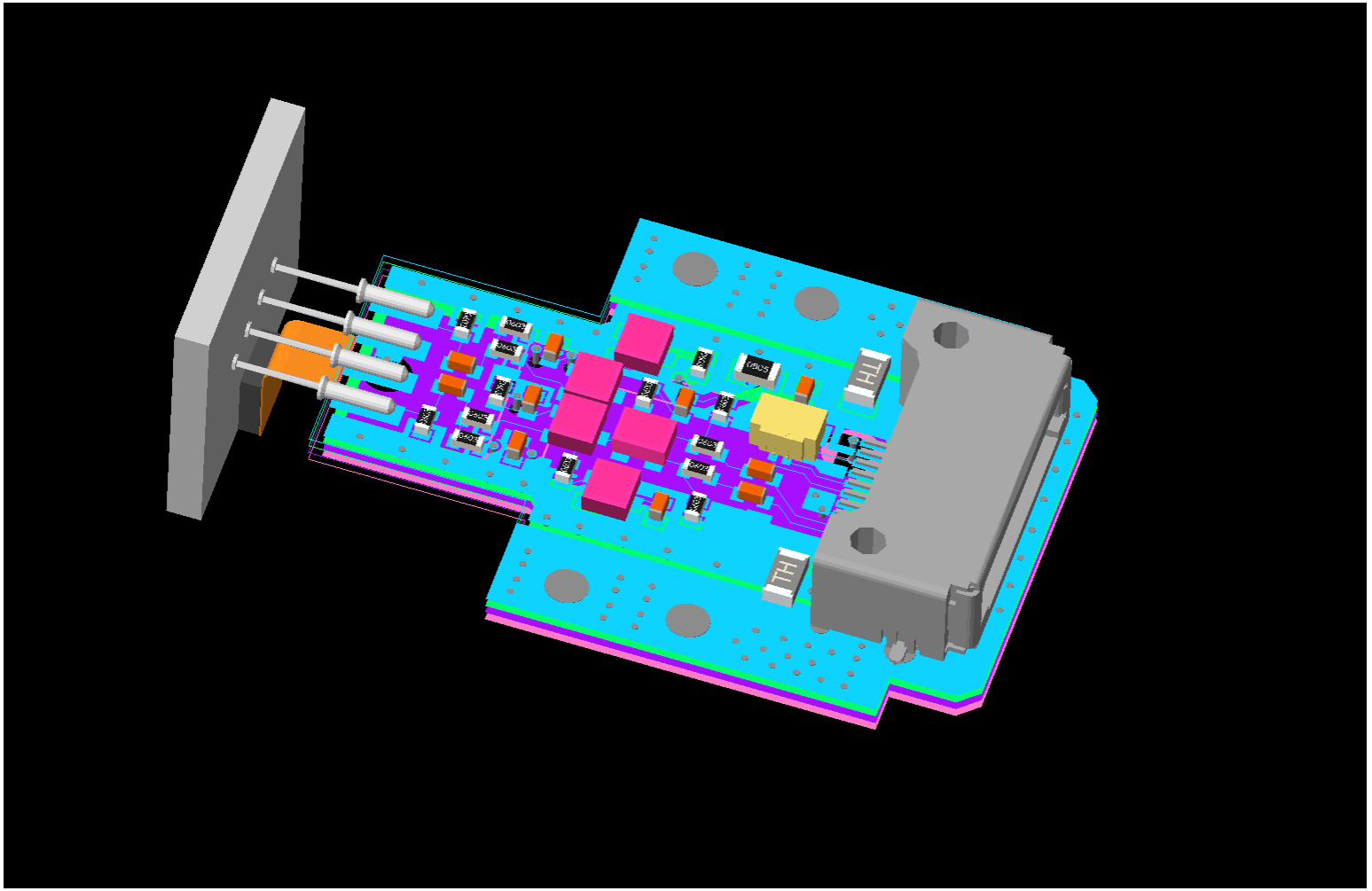

Linearity plot for preamplifier after processing



Set of amplifiers for testing

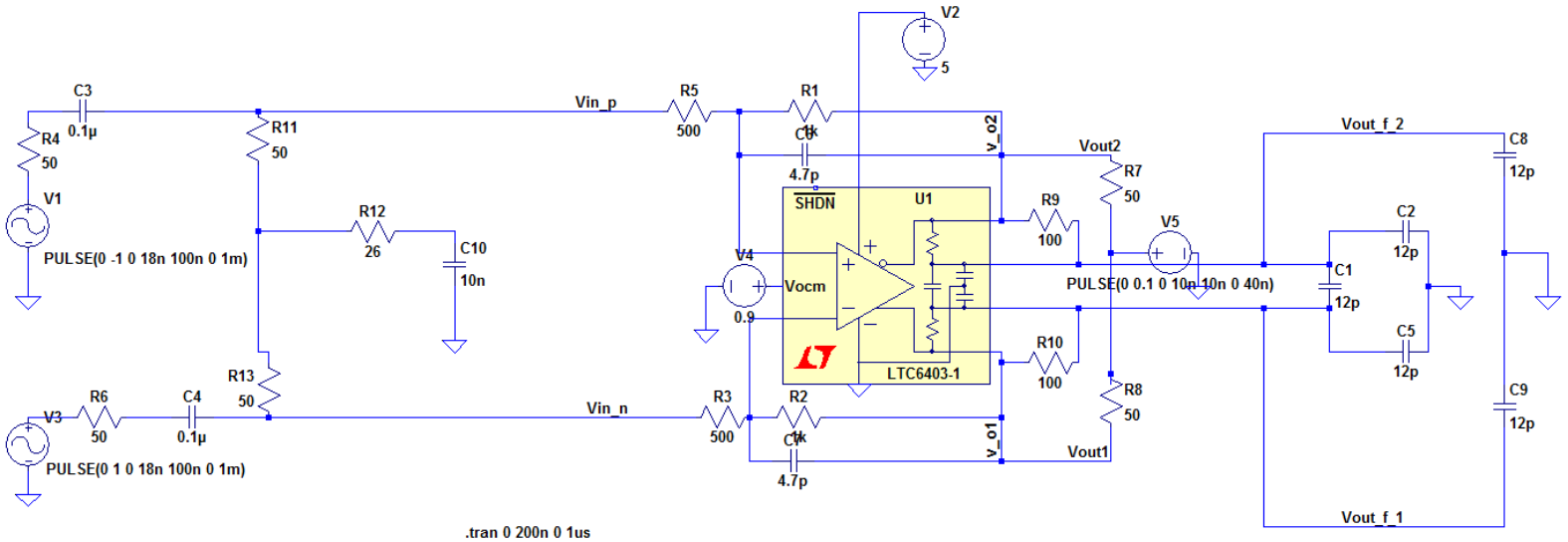
and first samples are proceeded

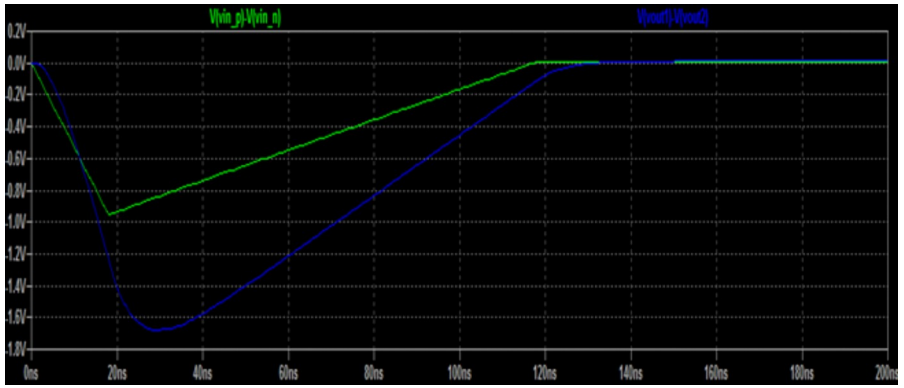
# Preamp version with improved radiation resistance

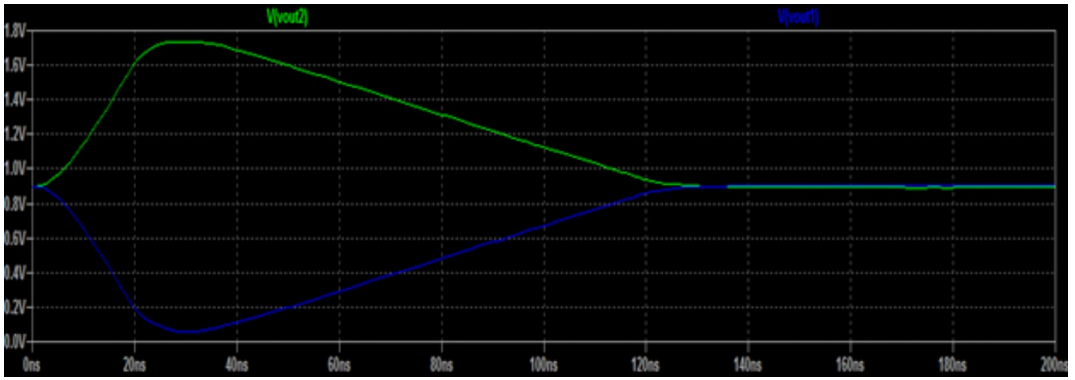


It is possible that during first Mu2e phase total dose will be over 100 kRad, so more protected topology of preamplifier may be needed. It is under developing at the moment

# WD receiver section




In order to shape pre-amplifier signal passed through transmission line for 200 MHz ADC and to regulate DC offset on receiver end it is proposed to use input differential amplifier with low-pass filtering circuit

# Conclusions

- FEE to meet MU2E experiment requirements is designed
- To complete design and start mass production dose tests should be passed
- Calorimeter prototype shows good resolution & linearity, so mass production & QA for all components should be prepared
- Test-bench for preamplifiers QA is installed in JINR

Thank you for your attention !