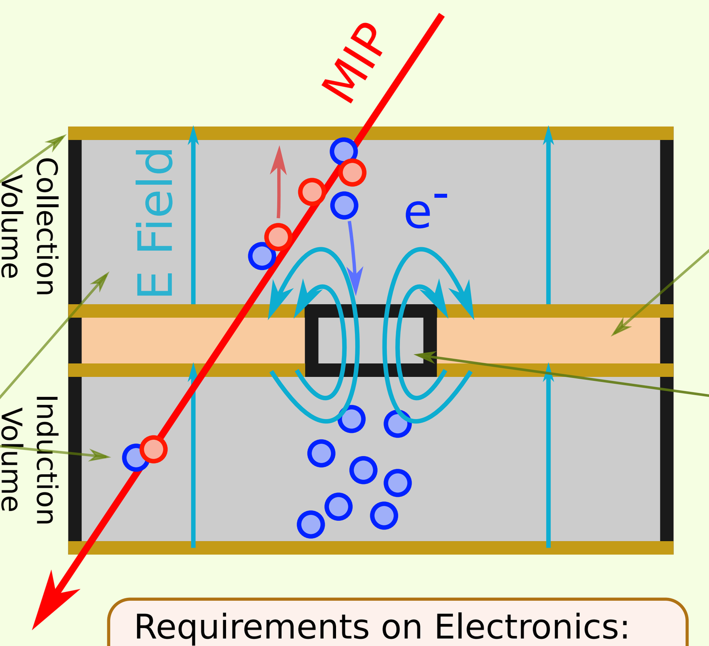
Electronics for GEM Detectors - Recent Developments

C. Honisch[1], K. Flöthner, C. Tezel, M. Lupberger, B. Ketzer   1: honisch@hiskp.uni-bonn.de
HISKP University of Bonn, Nussallee 14-16 53229 Bonn

Introduction: Gas Electron Multiplier



Copper Foils
- 2-3µm thick
- high voltage applied
- defining electric fields inside the detector

Gas Volume
- e.g. $Ar{:}CO_2$

GEM Foil
- 50µm thick polyimide foil
- plated with 2-3µm copper
- mircoscopic holes, 140µm pitch

Micro Hole
- ~70µm diameter
- high electric field
- → avalanche multiplication in detector gas

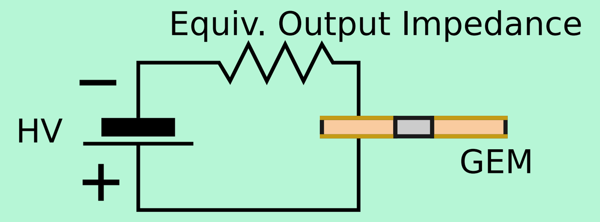
Principle of Operation
- a MIP creates free electrons
- collection field: electrons move to GEM
- GEM: high field in holes → avalanche multiplication
  - usually several GEMs are cascaded
- induction field: electrons induce signal in readout plane

Requirements on Electronics:
- cascaded high voltage supply (~kV)
- sensitive readout (signal: ~10^5 e^-)

Typical Detector
- sensitive volume: 3mm height → ~30e^- per MIP
- triple stack of GEM foils → total gain 10^4
- segmented readout: → pixels / strips

I) High Voltage Supply for a Triple GEM Detector

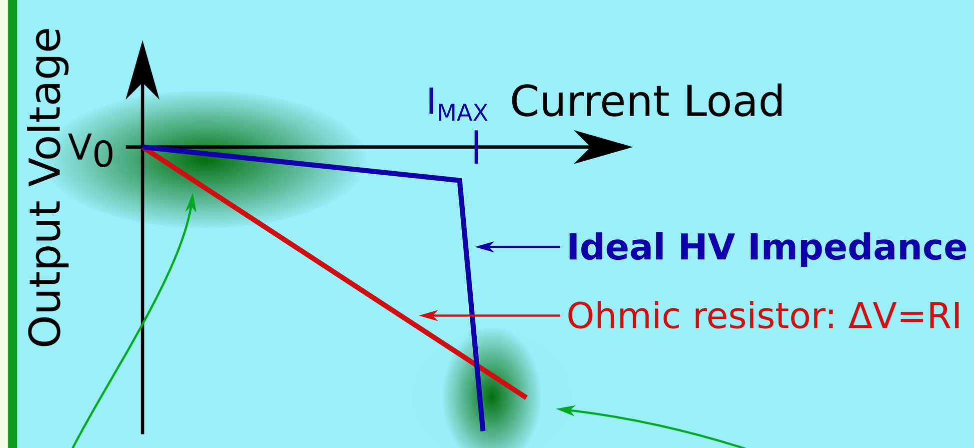
Example: Supply for a **single GEM**



Good Output Impedance?
- Current limitation needed in case of discharges
- Common Practice: Increase impedance using loading resistor = 10 MΩ
- However, $V_{GEM}=V_0-R_{HV}I_{AVG}$
  - → Decreased GEM Voltage V_{GEM}, due to average signal current I_{AVG}
  - → I_{AVG} depends on beam conditions!
  - → Low R_{HV} needed for stable V_{GEM}

HV Supply Requirements
- Ladder of 7 voltages, steps of 300...800V
- Stable output voltage (avalanche gain depends on E field)

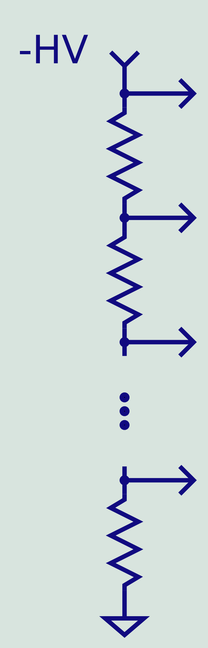
HV Output Impedance: Low **and** High!
Use component with non-linear characteristics
- low impedance at low currents
- high impedance at higher currents



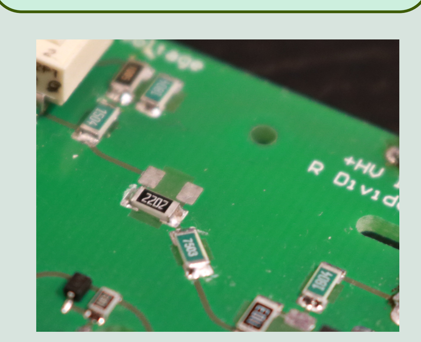
Outperforms Ohmic Resistor:
+ **lower voltage drop** for signal current load
+ **lower maximum current** in case of short circuit

Technical Details

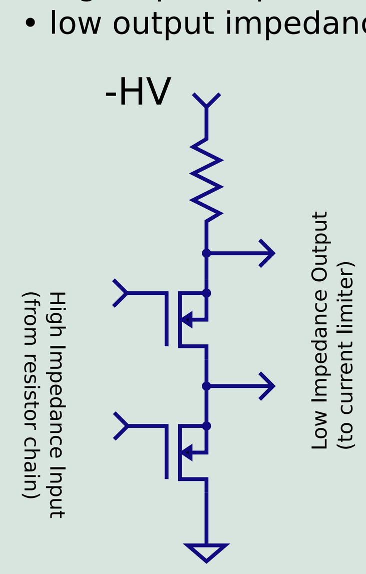
1) Generate Voltage Levels:
External HV + Multi-Tiered Voltage Divider

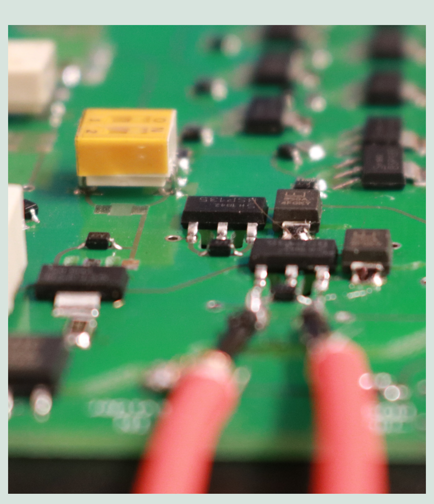


Resistors:
- Rated for high voltage
- Low temp. coefficient!!
  - → stability voltages vs ambient temp



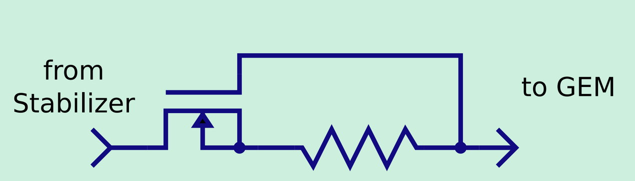
2) Stabilization vs Load Current
Impedance converting amplifier:
- high input impedance
- low output impedance





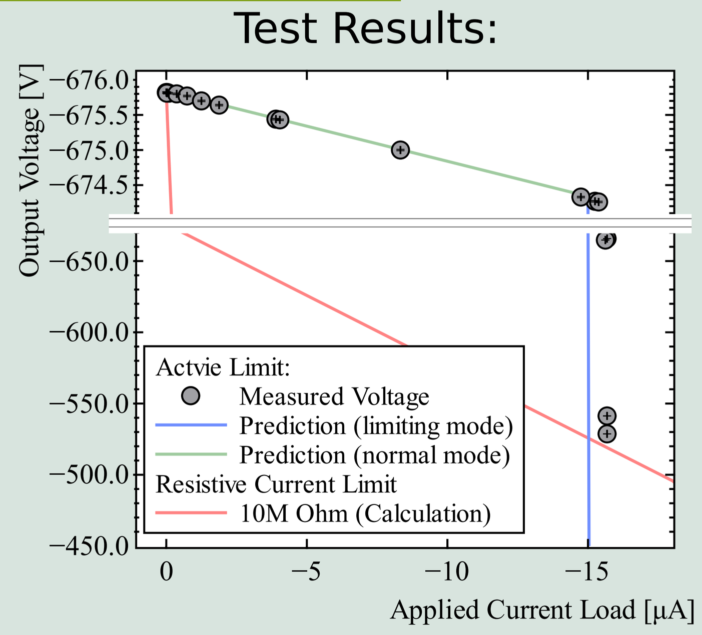
3) Protection: Active Impedance

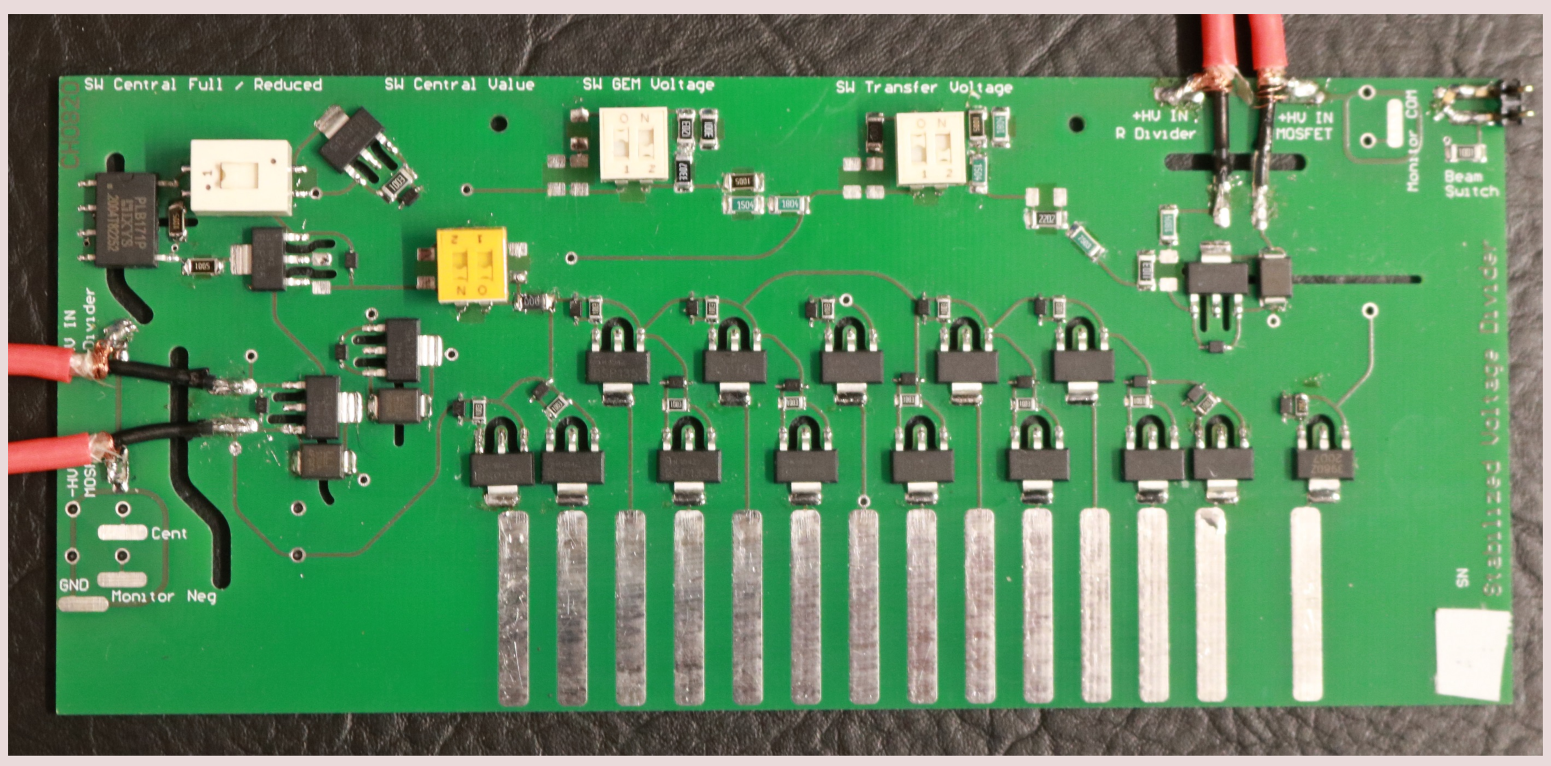
Using Depletion Mode MOSFET:



Consider current through R:
→ Generates voltage drop on R
→ Gate voltage
Transistor: turned off by gate voltage
→ limitation of current

Test Results:





II) High Voltage Protection Circuit

Deal with Sparks in the Detector
- Signal ~ 10^5 e^-
- Spark ~ 10^{12} e^-

If the signal is a glass of water, the spark is an olympic swimming pool!

→ Can damage the detector
→ Can damage the electronics

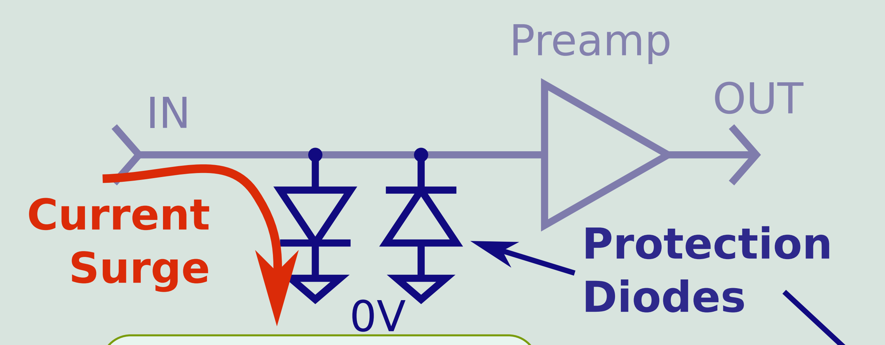
Signal:

x10^7 →

Spark:

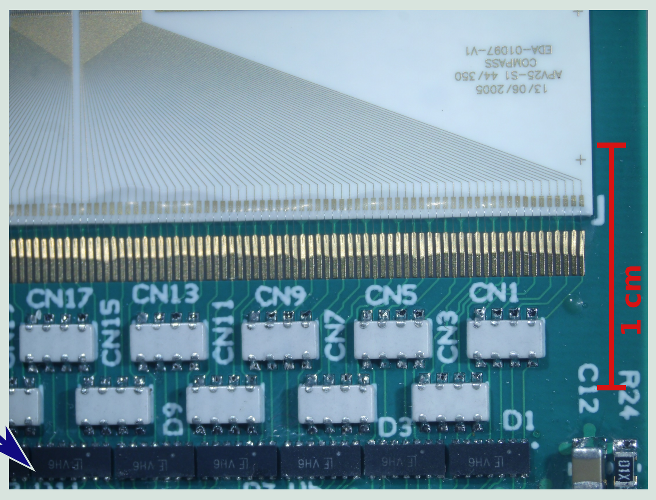
Photo by www.localfitness.com.au

Classical Approach: Diode



Input signals with $|V|>V_{Diode}$ get drained to ground

SP3012

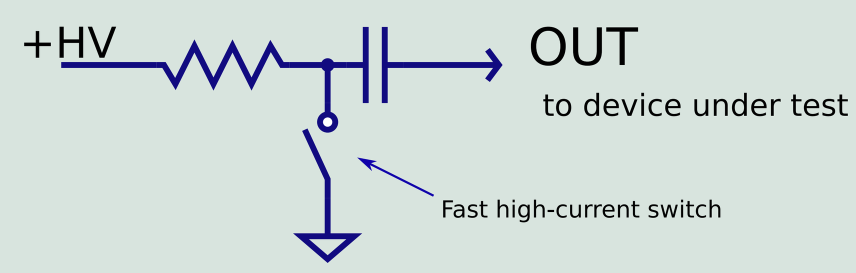


Conflicting Requirements:
1) The diodes need to handle discharge
   → high currents 1...100A
   AND
2) Diodes have a parasitic capacitance
   → Contributes to preamplifier noise level!

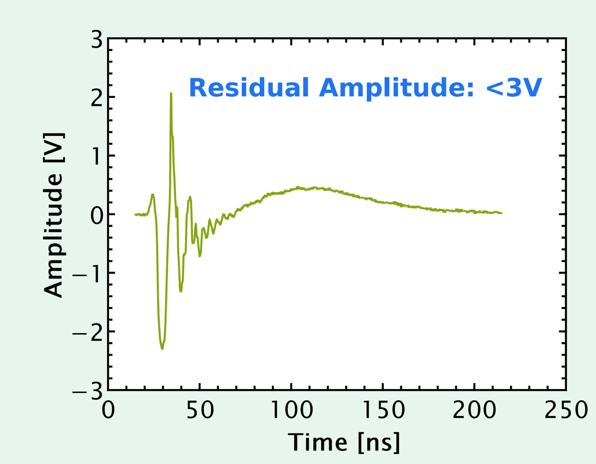
Commercial Solution: USB3 protection diodes.
- designed to protect commercial electronics against static discharge events
- C_{par} = 0.5 pF. For reference: $C_{Detector}$ = 30 pF

Testing the Protection Circuit

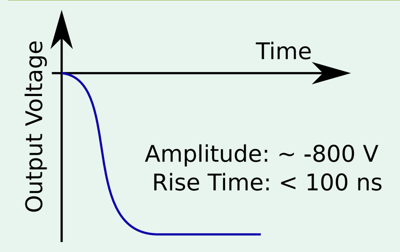
Useful for testing:
Setup that mimics discharges



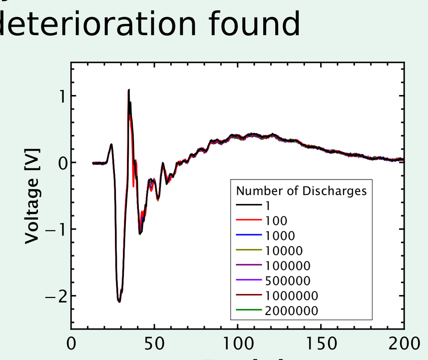
Effect of Protection Circuit

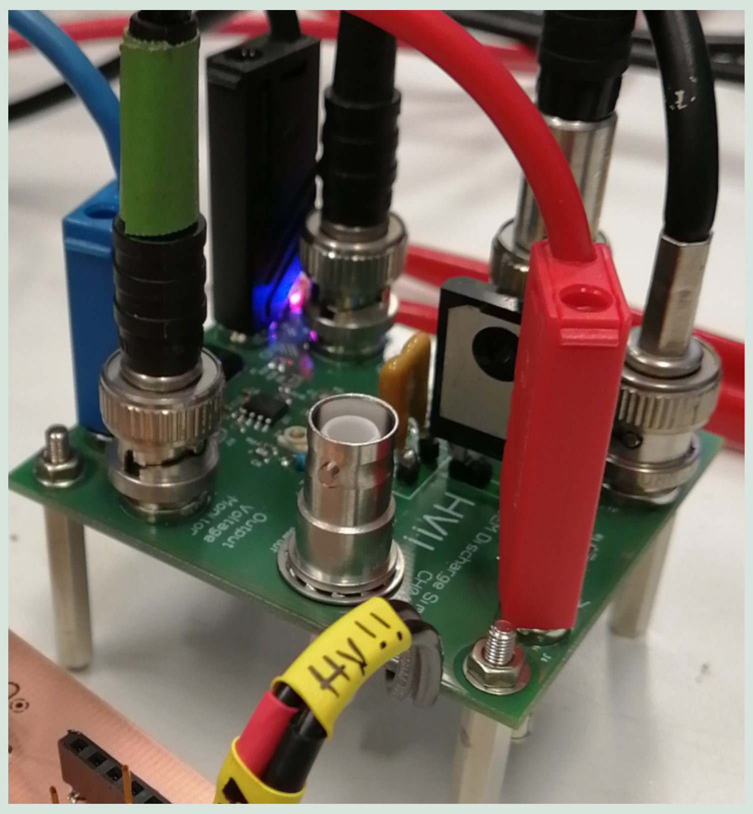


Simulated Spark:



Testing the Durability
- Apply lots of simulated discharges
→ no deterioration found





Outlook - Next Steps

1) Implement Voltage Monitoring
So far, voltages were measured in a dedicated test setup.
In the final setup, multiple voltages should be measureable remotely.
Supervise voltage supply, understand the detector performance in Beamtimes!

2) Test on live GEM detector
All measurements so far were done in dedicated test setups.
Next: Operate on GEM detector to prove performance under realistic conditions.

3) Determine radiation hardness
Electronis are in many experiments exposed to high levels of ionizing radiation.
Radiation hardness of commercial components varies.
The hardness of the compenents used here has to be determined.