Project News

G-AVD GEM Voltage Divider
TPIC Mesh trigger pickup
Femto-Meter

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- these and more electronics projects progress in the GDD lab at CERN depending on availability of resources and students

G-AVD
Active Voltage Divider for GEMs

3 month 2015 sponsored by ALICE TPC upgrade project
looking for another 3 month

RD51/CERN works since 2013 on active voltage divider technology for GEMs as a general solution

1.) eliminate load inefficiencies of resistive dividers

2.) quench and mitigate sparks

3.) decouple load and spark effects between sectors

4.) precision monitoring of U and I

5.) analogue current failure monitor/detector

6.) fast reaction to trip and safe tripping power off procedure

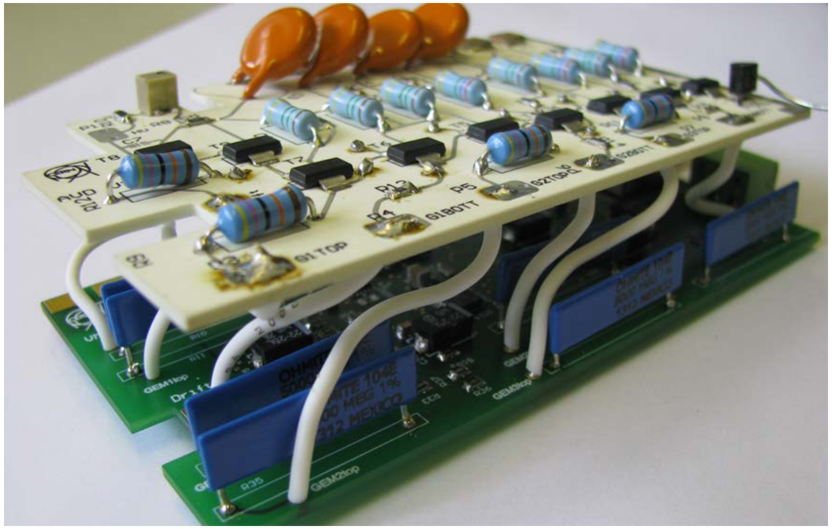
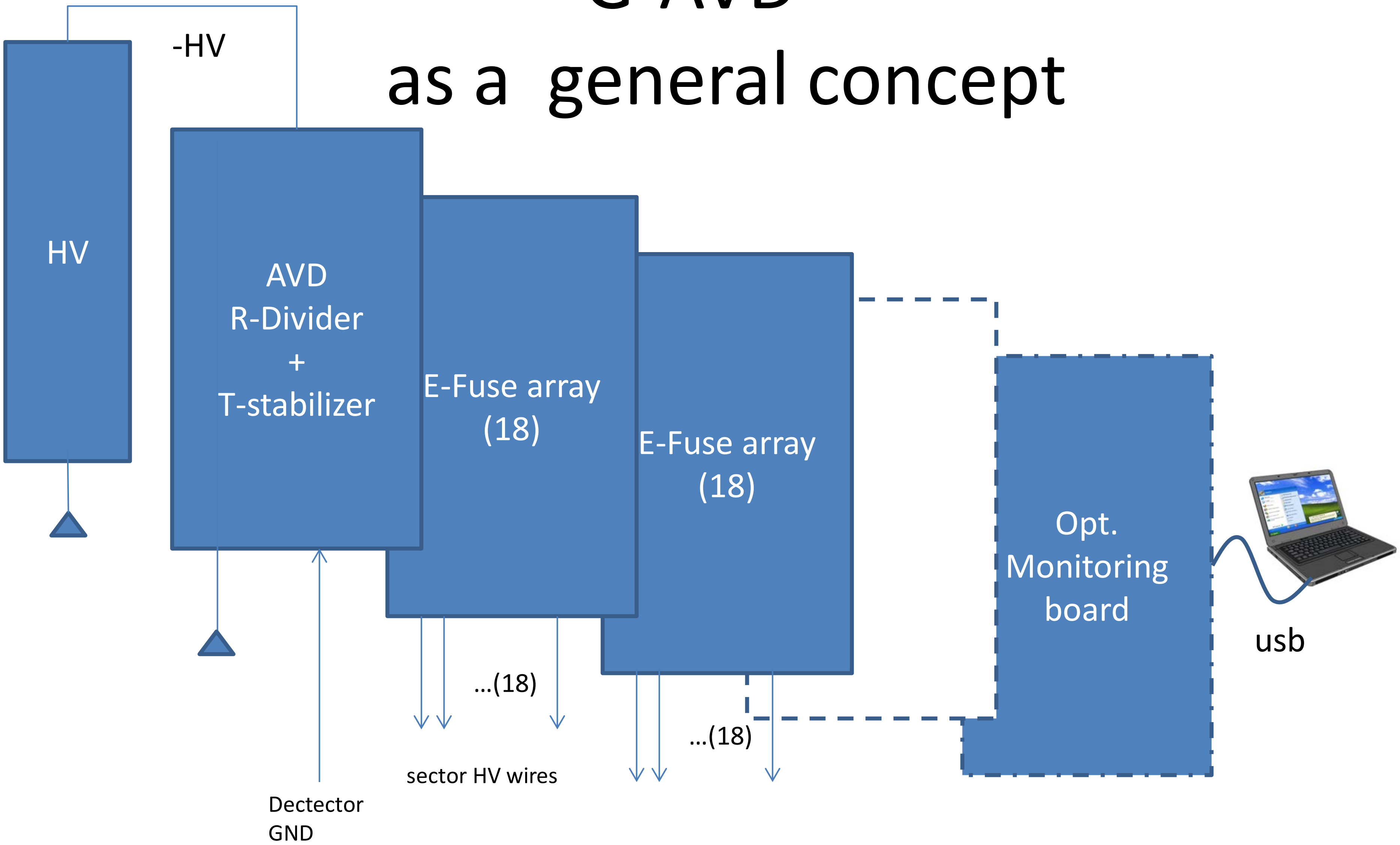
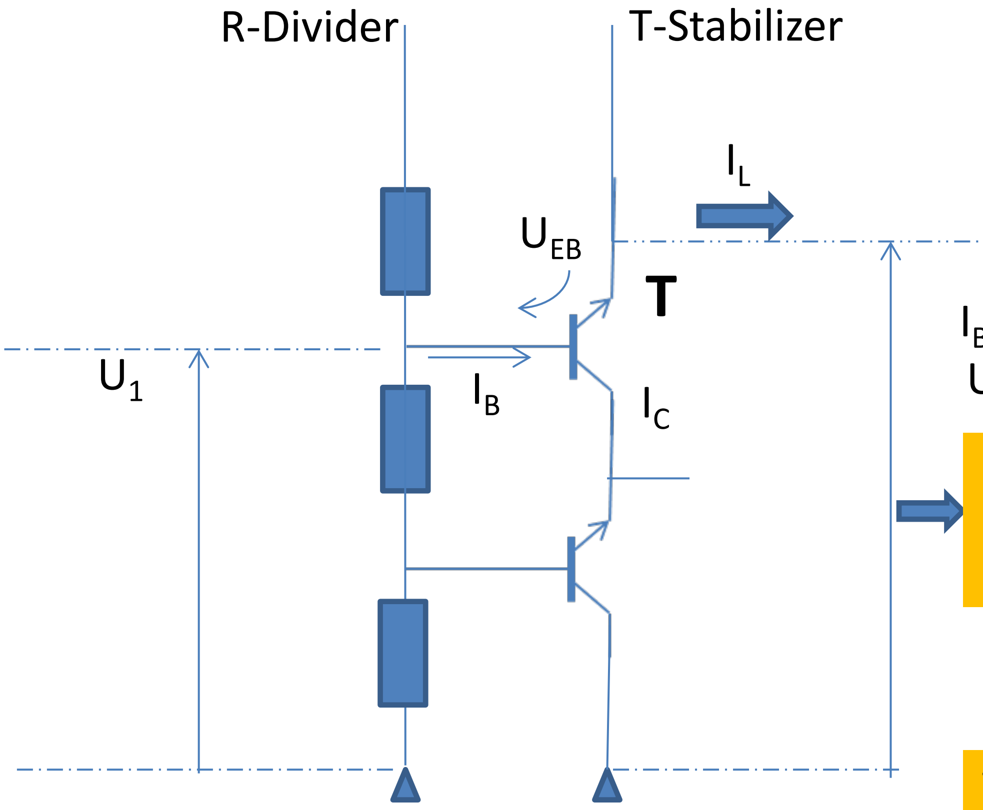


Photo : 2014 AVD proto for triple GEM with Voltage monitoring and readout board

G-AVD
as a general concept



T-stabilizer



$U_2 = U_1 + U_{EB}$

$I_B = O(5uA)$

$U_{EB} = O(0.5V) \sim const \cdot \ln(I_B)$

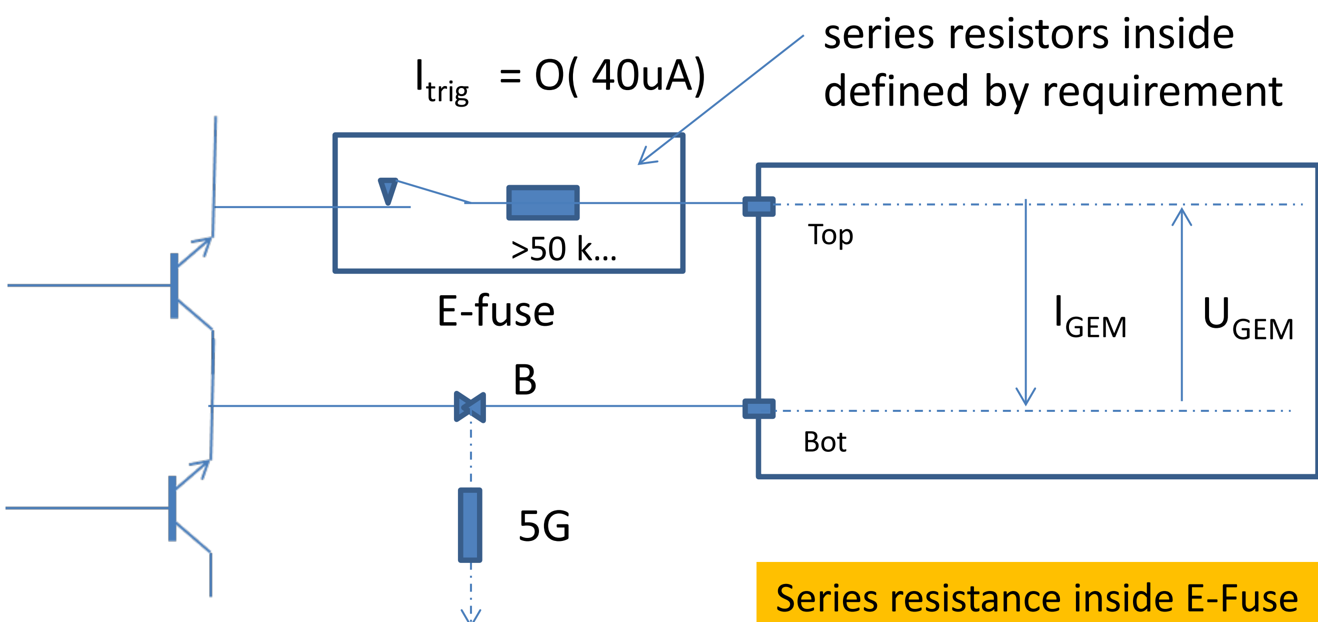
Output Voltage of T follows very closely the Voltage of the resistor divider at an almost constant 0.6V offset.

$I_B = I_C / \beta \sim I_C / 50$

The load current I_L is provided by >90% from the power supply and < 10% from the resistor divider.

E-fuse*

Without E-fuse, a GEM foil short circuit over a 50k series resistor would draw O(10 mA). With E-fuse, the current limit of a short is O(40 uA)



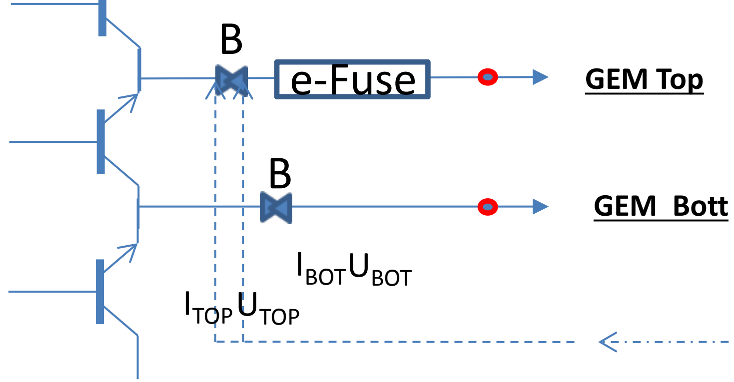
To: optional monitoring board for (U,I) measurement, 14 bit ADCs and USB port

Series resistance inside E-Fuse 50 --100k: GEM current of I_{GEM} = 10 uA result in GEM Voltage drop of 0.5-1V

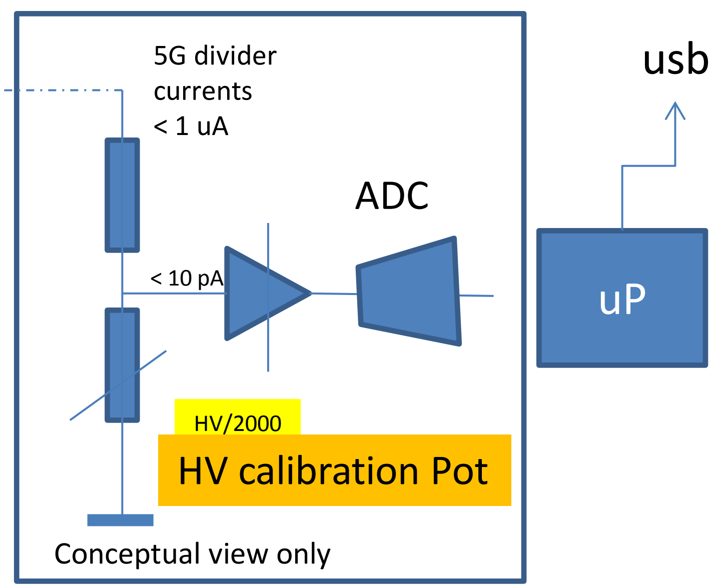
*E-fuse technology was developed by RD51/CERN

GEM voltage and current measurement (optional use of Probe Points B*)

Measure I_{BOT} and U_{TOP1}
With Rs (inside F) => U_{TOP2}



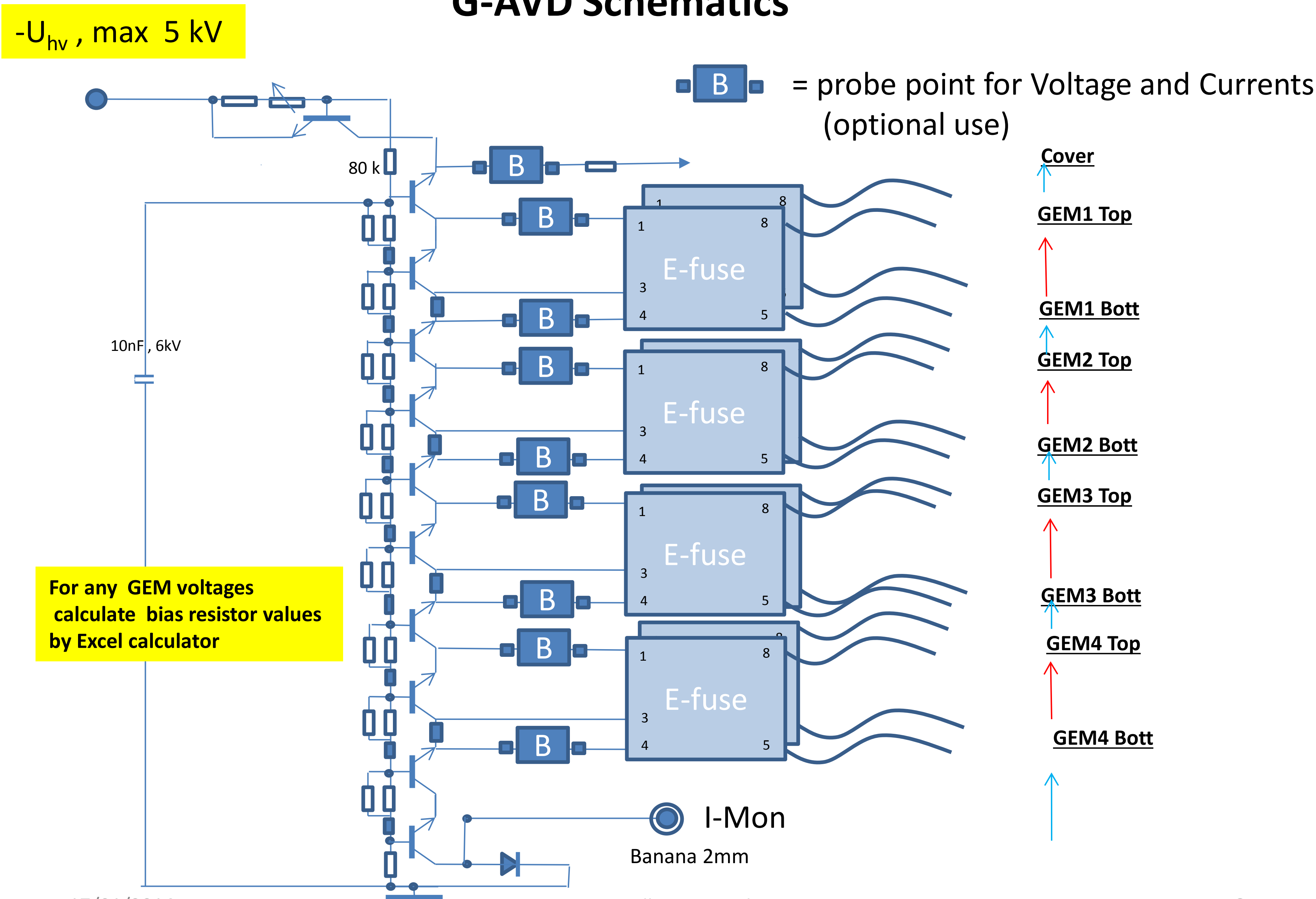
3-stack GEM: 7 measuring lines
4 stack GEM: 9 measuring points



Bias Currents O (1uA) of GOHM divider is constant and compensated by T-stabilizer

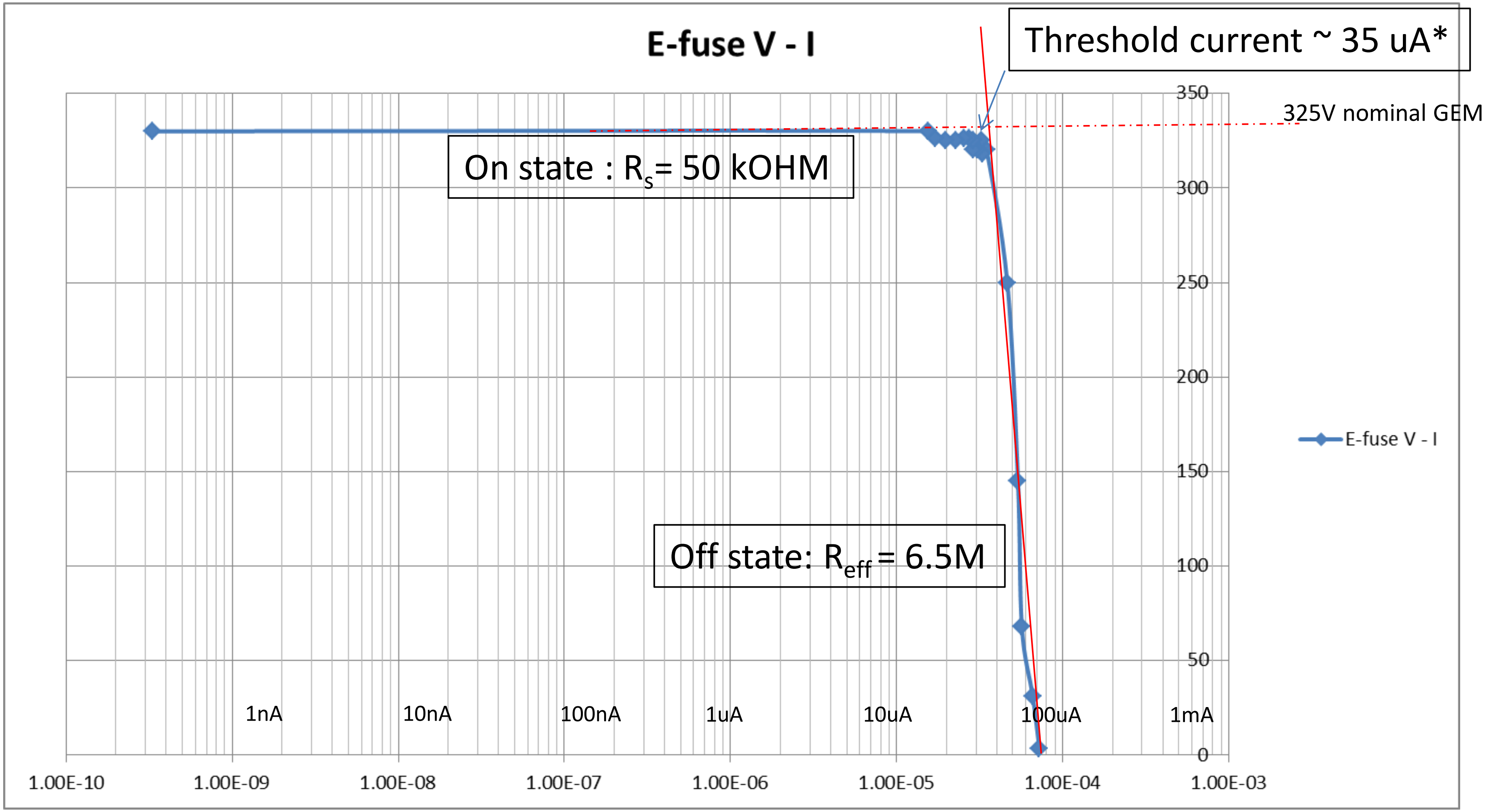
*Probe B is a bidirectional, very low impedance component

G-AVD Schematics



E-Fuse characteristics

Measured after E-Fuse at GEM4 @ 320V and 5nF , R_s = 50 kOHM



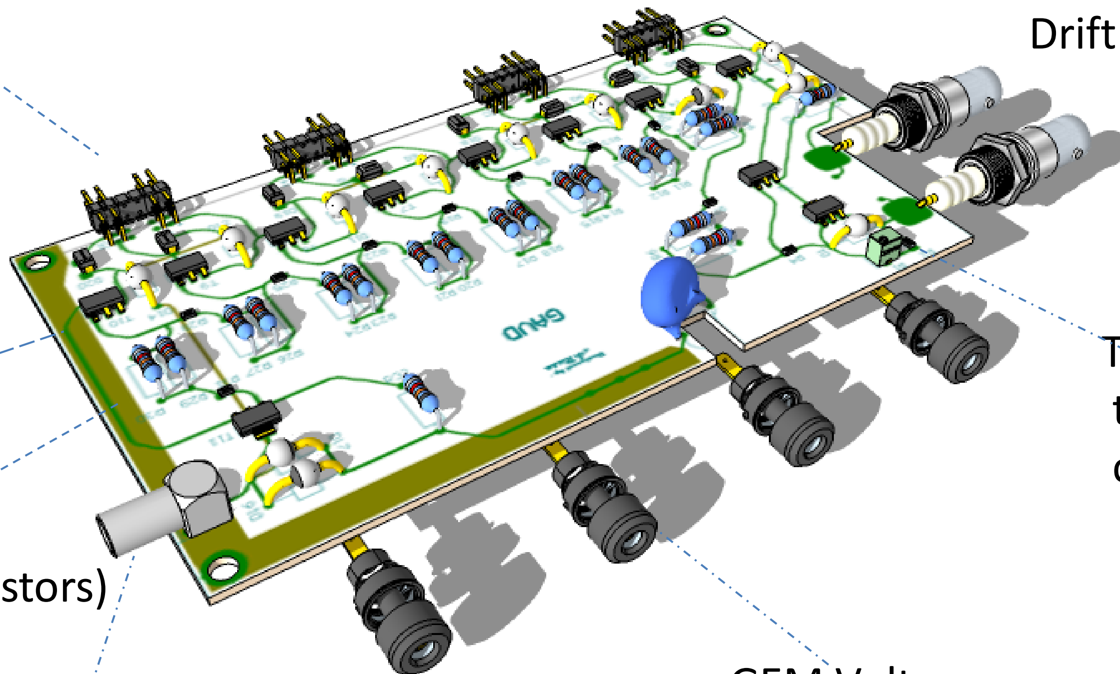
*different threshold currents defined by resistor

GAVD board

Edge connectors towards e-fuse board

Drift out

-HV in



T-stabilizer chain

R- divider
(with adjustment resistors)

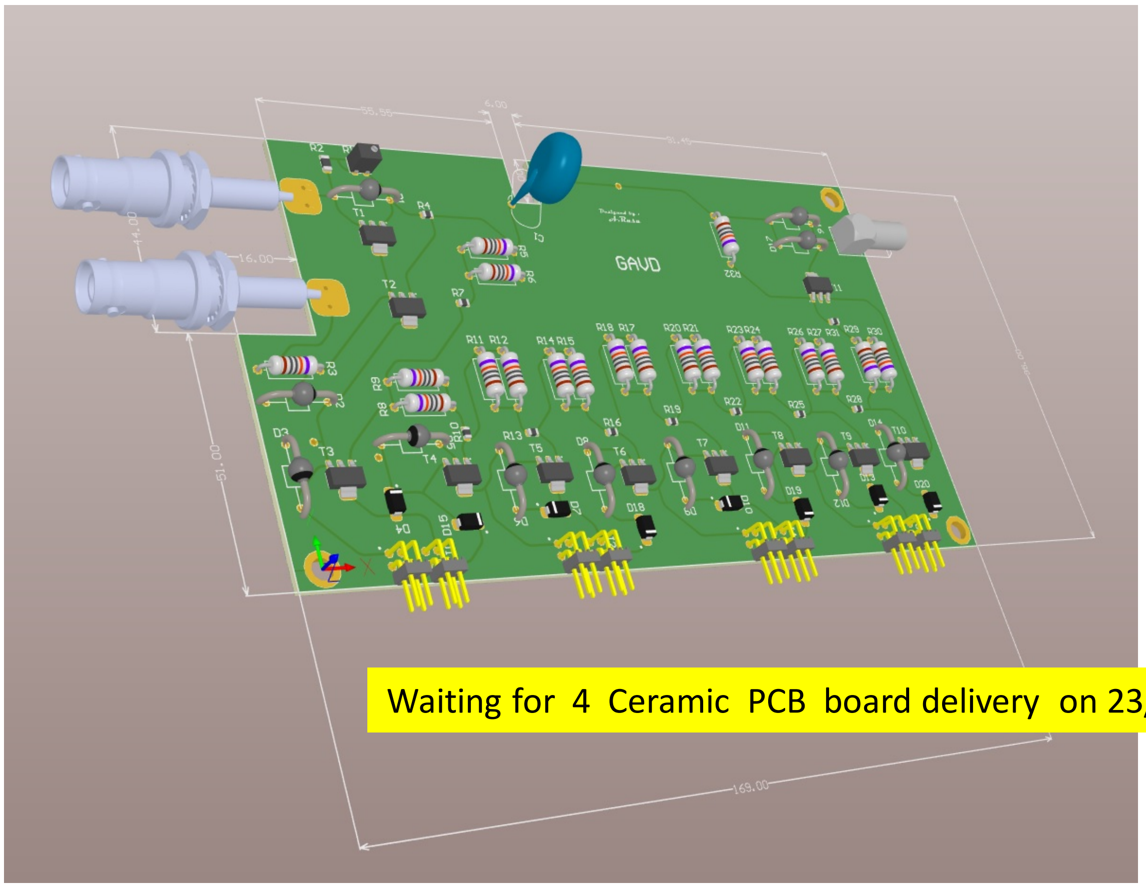
Trimmer
transistor chain
current limit

GEM Voltages measuring points
1/1000

Analogue current monitoring output

GAVD and e-fuse Altium design*

1st GAVD board /box to be delivered to ALICE TPC by end march



Waiting for 4 Ceramic PCB board delivery on 23/03

* Alexandru Rusu

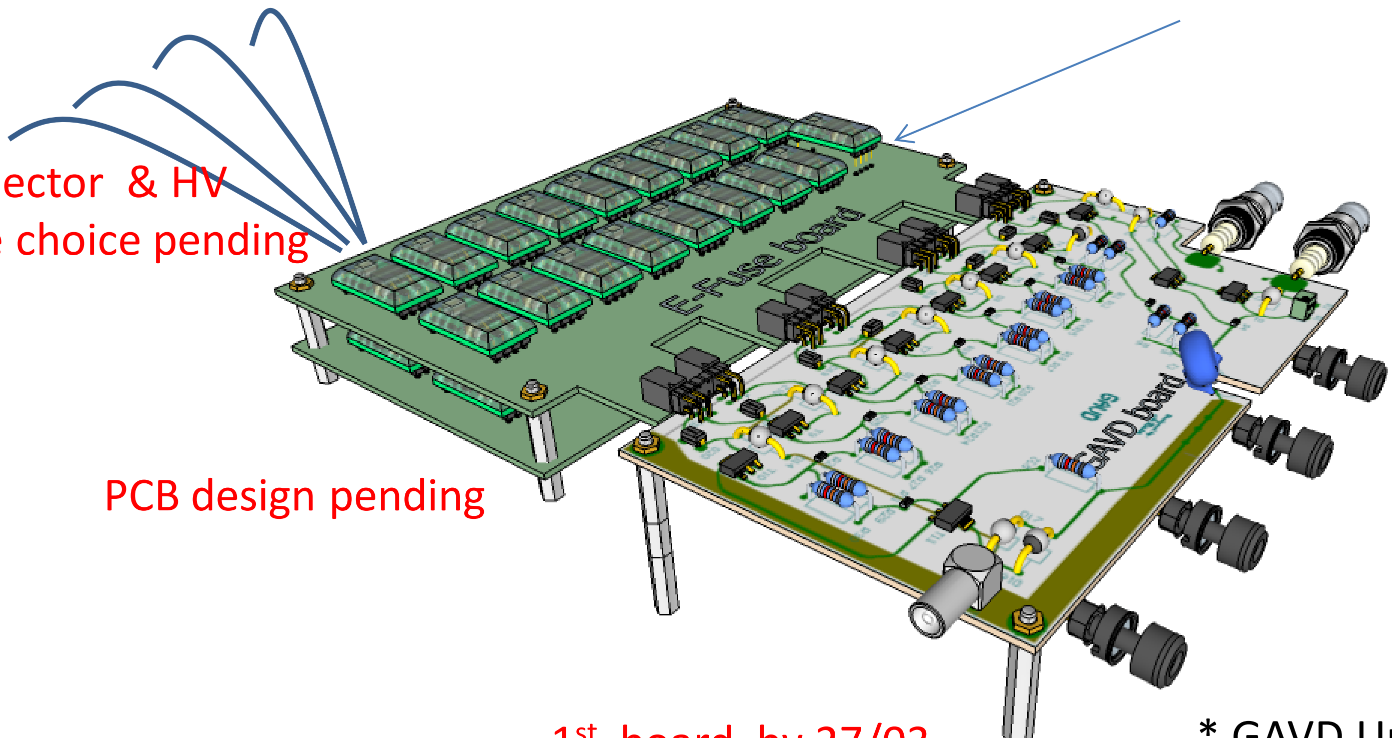
GAVD board and E-fuse board

36 ..54 e-fused sectors per G-AVD Unit*

1 Carrier for 18 e-fuses

18 HV wires to GEM sectors/board

2..3 stacked E-fuse boards



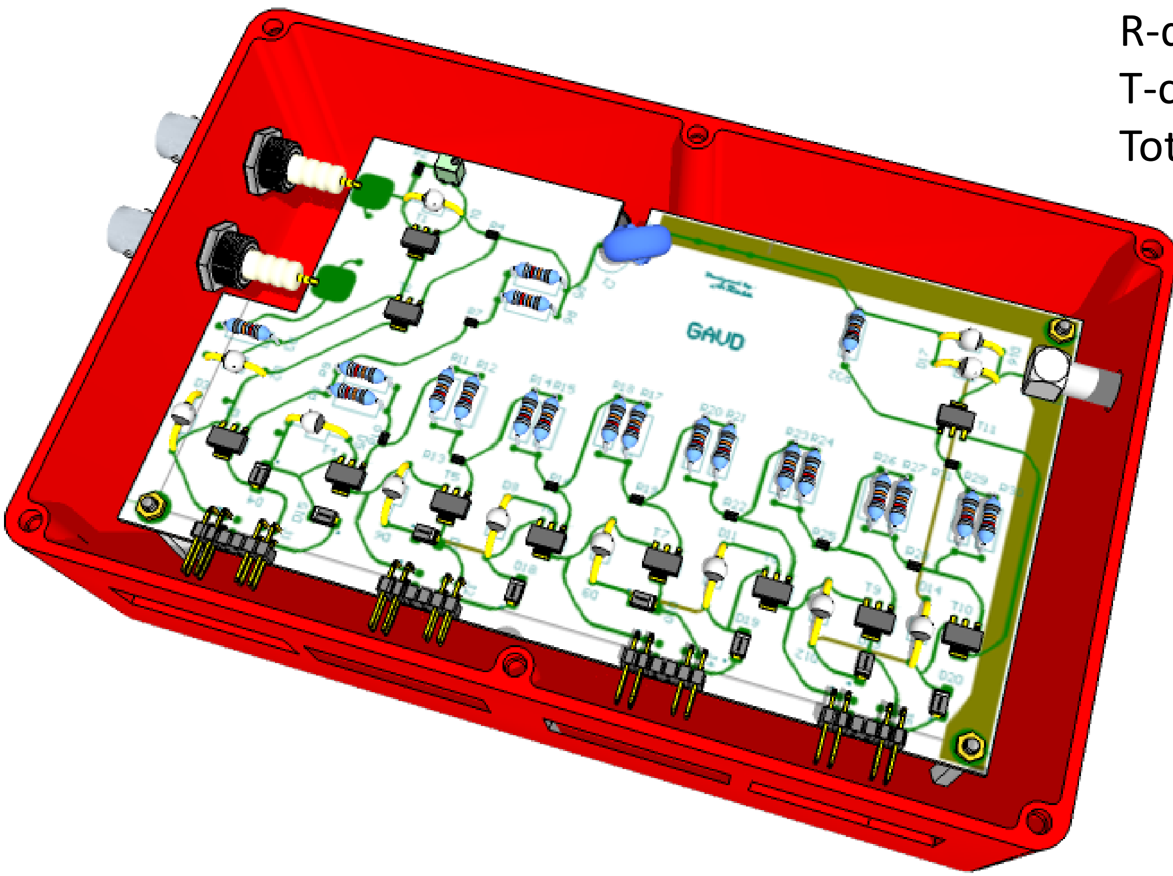
Connector & HV
cable choice pending

PCB design pending

1st board by 27/03

* GAVD Unit=
1 GAVD + 1 E-fuse stack

GAVD heat dissipation*



Typical GAVD Wattage @ 3 kV

R-divider (0.5mA*) = 1.56 W

T-cascade (0.5mA) = 1.56 W

Total current = 1mA @ 3.12kV

$\Sigma_{standard}$ = 3.1 Watt

Some applications may require T-cascade currents up to 2 mA

Σ_{max} = 10 Watt

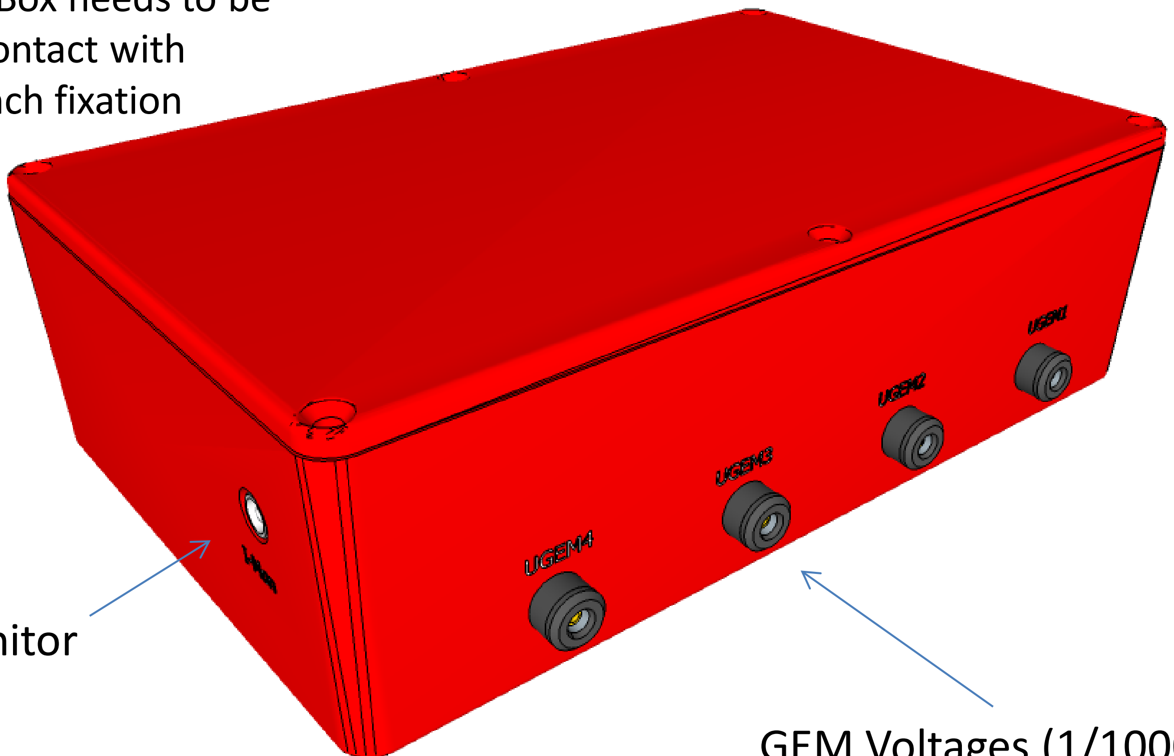
Only passive cooling possible inside B-fields

*nominal currents
R-divider : depends on R-divider resistor choice
T-cascade: depends on current source setting

GAVD box

10 Watt heat conduction via ceramic PCB in thermal contact to box via 4 standoffs . Box needs to be in good thermal contact with environment : flanch fixation

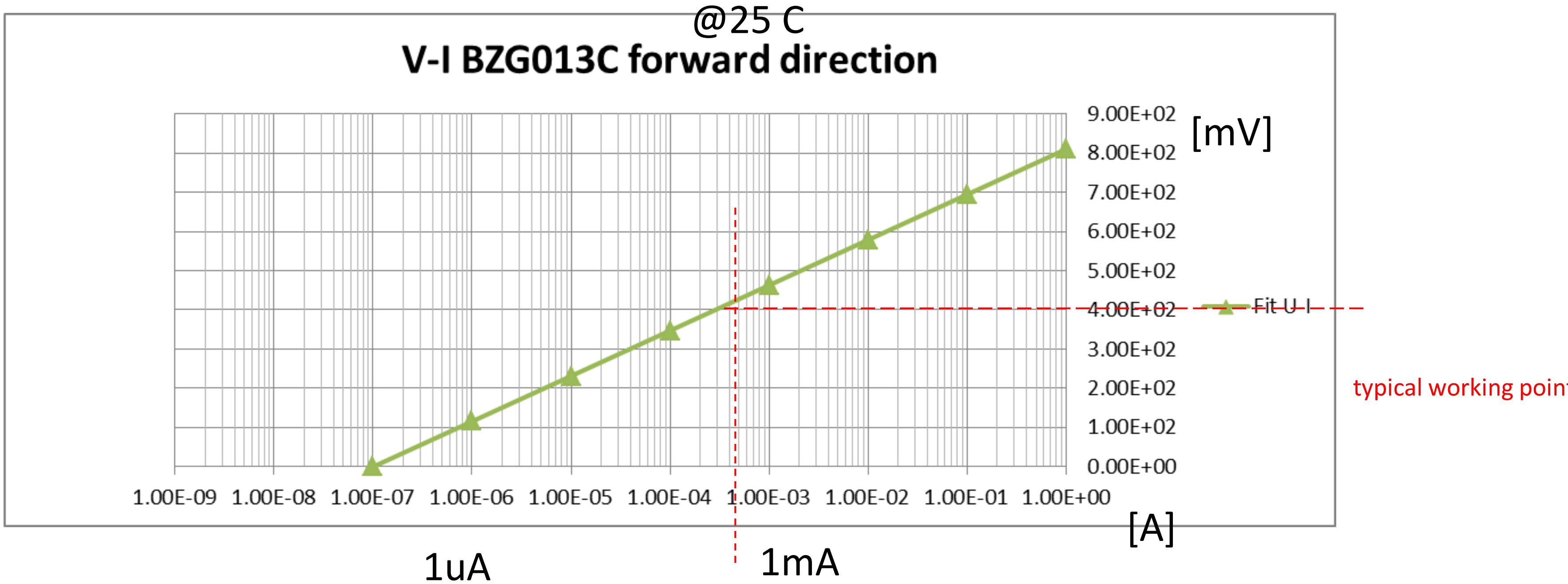
Die-cast Hammond 1590D
119.5 x 56 x 51 mm

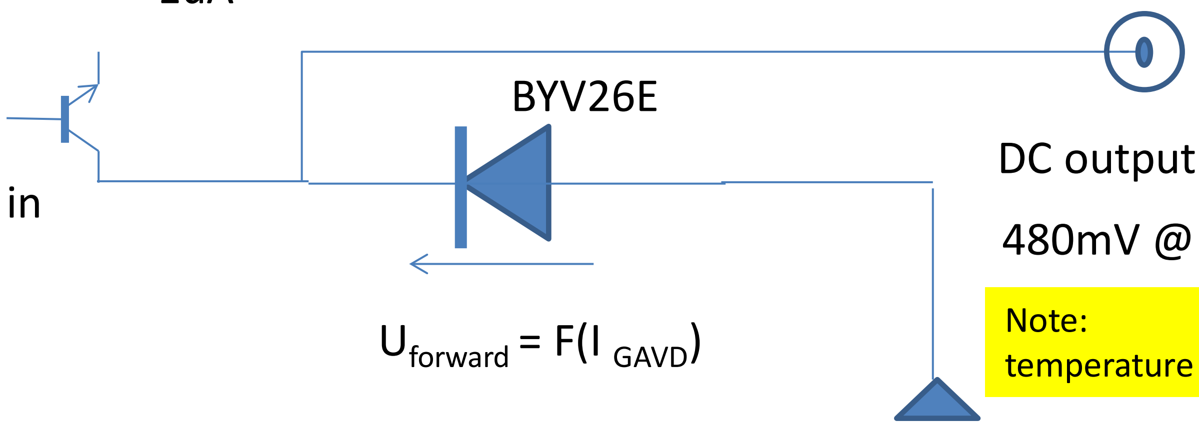


Current monitor (LEMO)

GEM Voltages (1/1000)

Current monitoring





bottom transistor in cascade

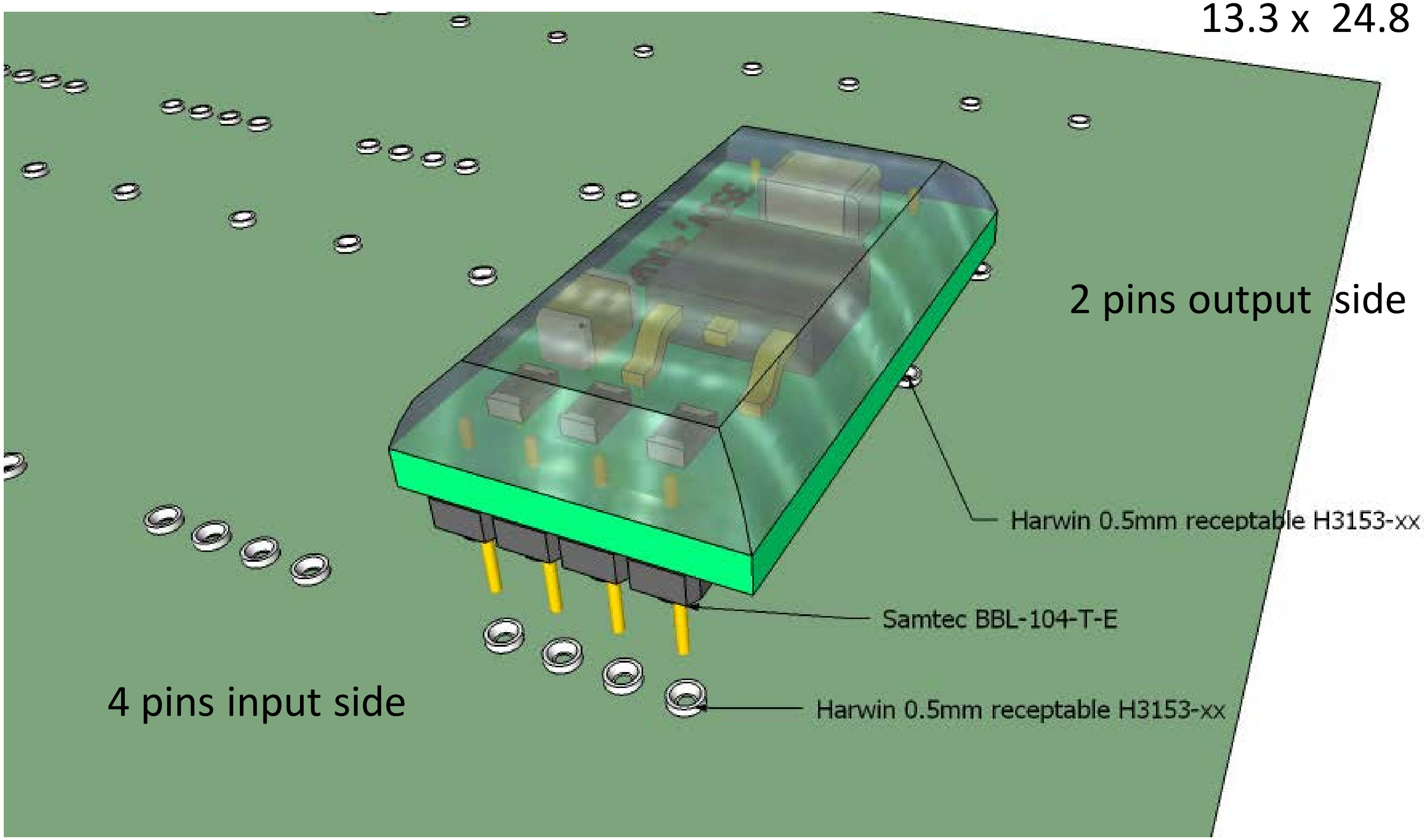
DC output LEMO

480mV @ 1mA

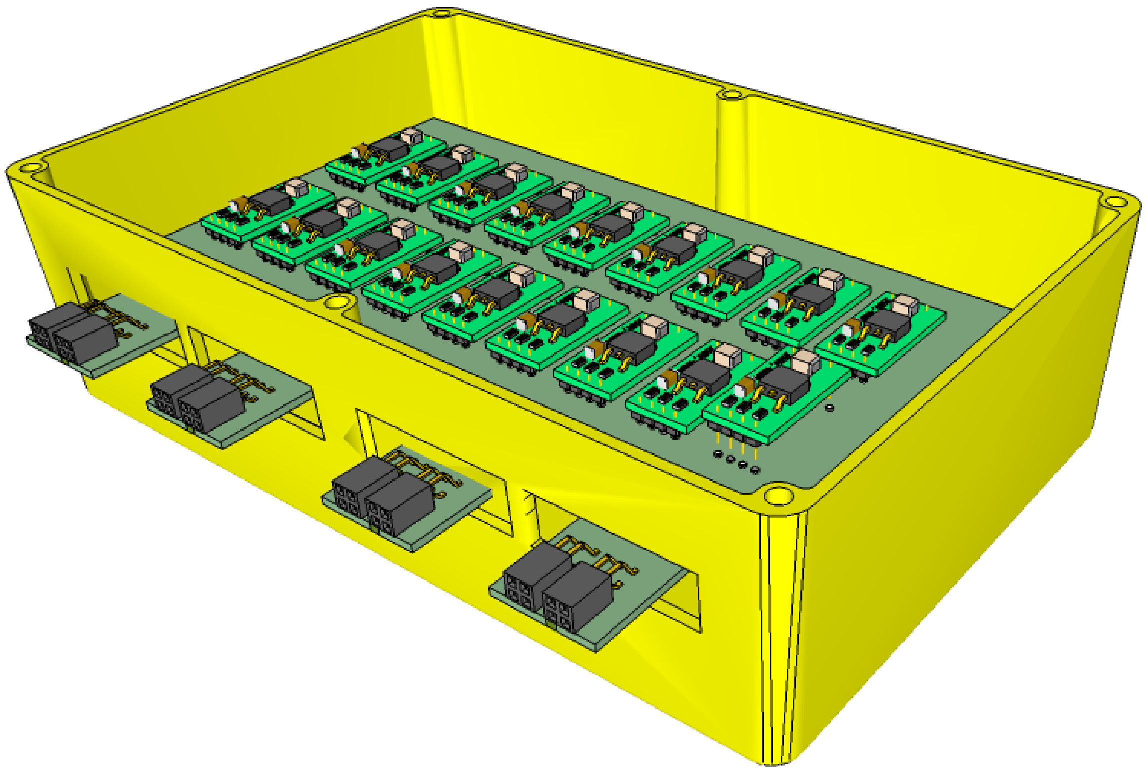
Note:
temperature coefficient -2mV/C

E-fuse hybrids

Plugin
13.3 x 24.8 mm2



E-fuse box



G-AVD conclusion

- 3 slices: R-Divider, Active stabilizer and E-fuses
- R-divider defines raw-HV voltges for GEMs
- Active stabilizer decouples Voltages from Currents
- E-fuses decouple individual GEM segments from each other
- Overcurrent > I_{th} makes e-fuse output Voltage drop to zero
- Within the ON-state of the e-fuse, the GEM dropoff voltage as function of GEM current is according OHMs law: $U_d = I_{GEM} \times R_s$. Example with Rs=50k , at 10 uA the voltage drop is 500mV.
- G-AVD works with a single HV supply
- GEM voltages are proportionally coupled like R-Divider Voltages
- During ramp- up and ramp-down , all GEM voltages are scaled in proportion
- The current through R-divider I_R is constant
- The current through Active stabilizer I_A is dynamic
- The total HV supply current is $I_R + I_A$
- Monitoring of I_A over a diode gives prompt feedback on current changes due to high load, sparcs etc

APIC –TPIC

Analogue Pickup
Trigger Pickup

Orders for > 10 APIC's are pending

Need ~ 1 month resources for finalization (new PCB)

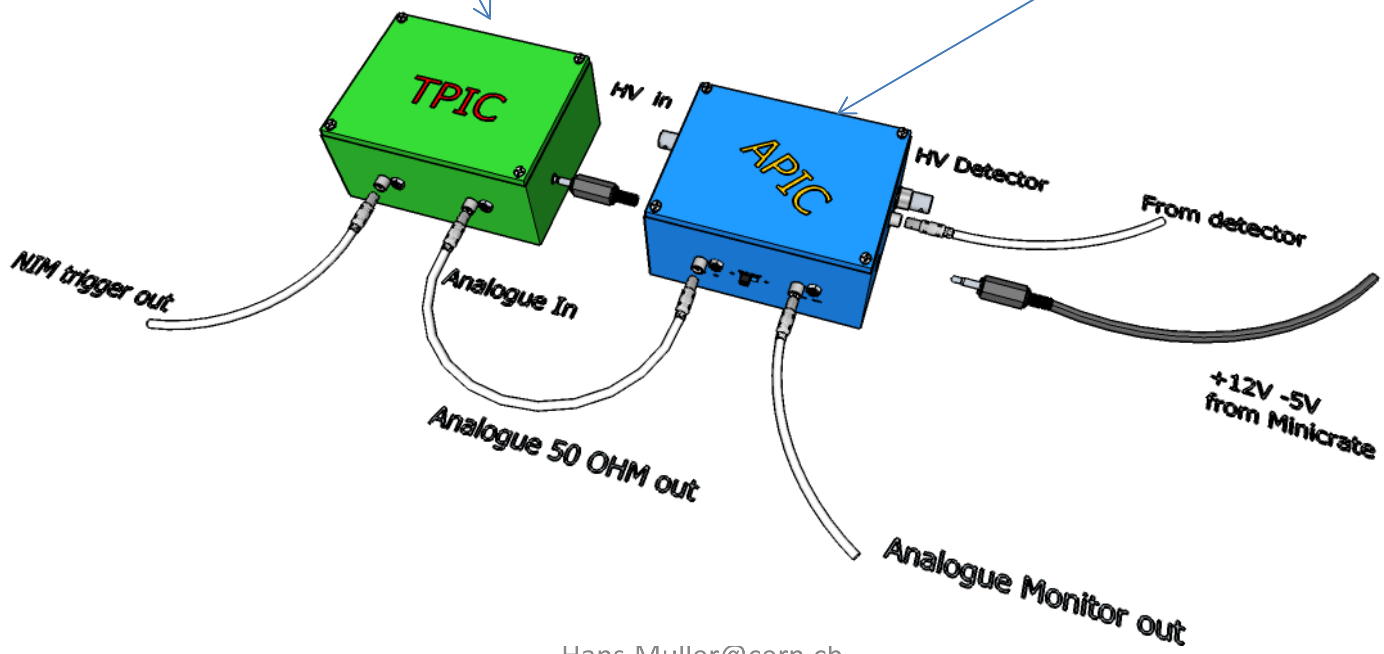
TPIC boxes require 1-2 month new PCB design and proto tests

APIC
Analogue Pickup box

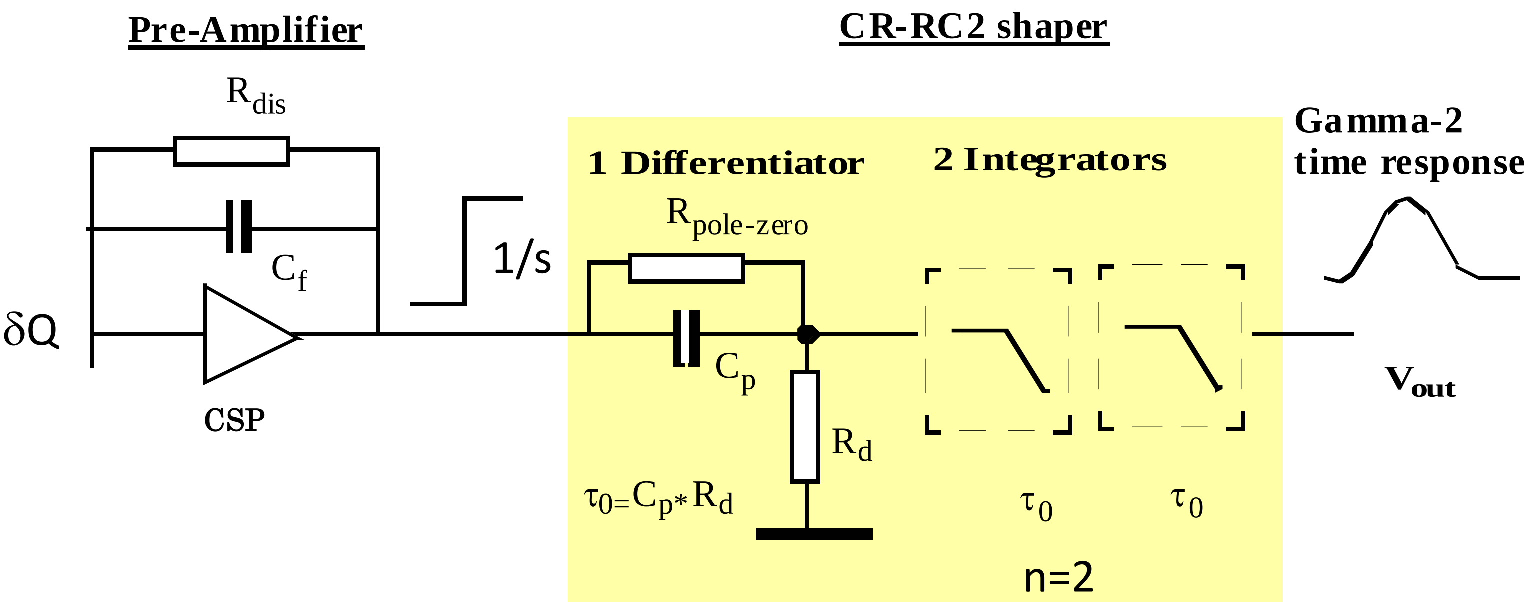
APIC box

CSA preamplifier
dual polarity 100 ns shaper
Variable gain max . 900mV
Calibration 10 kHz 50 fC

TPIC Trigger



APIC principle



Laplace analysis of the chain is composed in several operators, including CSA

Pole zero cancellation

$$H_{shaper}(s) = \frac{1}{s}\left[\frac{s\tau_0}{1+s\tau_0}\right] \times \left[\frac{q/C_f}{1+1/(R_{dis}\cdot C_f)}\right]\left[1+1/(R_{dis}\cdot C_f)\right]\left[\frac{A}{1+s\tau_0}\right]^n$$

step function | differentiator | CSPdischarge | pole-zero | RC integrator n-th order

Gamma-n shaper

$$H_{shaper}(s) \;=\; \frac{Q}{C_f}\left[\frac{\tau_0}{1+s\tau_0}\right]\left[\frac{A}{1+s\tau_0}\right]^n$$

Inverse to Laplace => V(t) signal in time:

$$U_n(t) =\left[\frac{n^n\ Q\ A^n}{C_f\ n!}\right]\left[\frac{t}{\tau p}\right]^n e^{-n\frac{t}{\tau p}}$$

Gamma (t) function of order n with τp peaking time

With 2 integrators we have order n=2

$U_n(t)$ ~ $Q/C\ [t/\tau_p]^2 \exp\{2\ [t/\tau_p]\}$

Peak proportional to charge Q

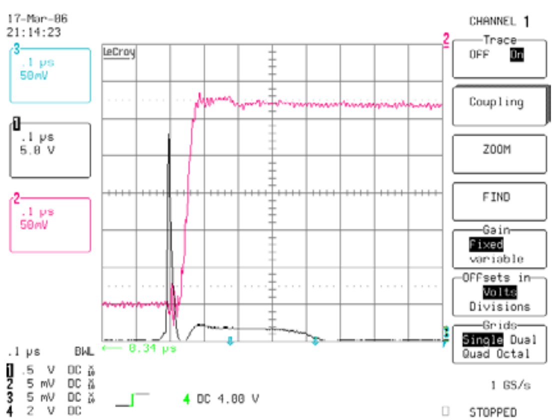
First derivative = 0

Relation between peaking and shaping time

$$\tau_{peak} \;=\; n \cdot \tau_0 \;=\; 2\tau_0$$

CSA Charge Sensitve Amplifier

- Discrete, JFET CSA developed in 2006-2012 by my students* for 14 bit dyn range of the ALICE EMCal.
- In 2013, revised layout by S.Martoiu
- ENC = 200 e + 3.2 e /pF * Cin(pF) --- Risetime 15 ns
- In 2014 , slightly modified for APIC - TPIC

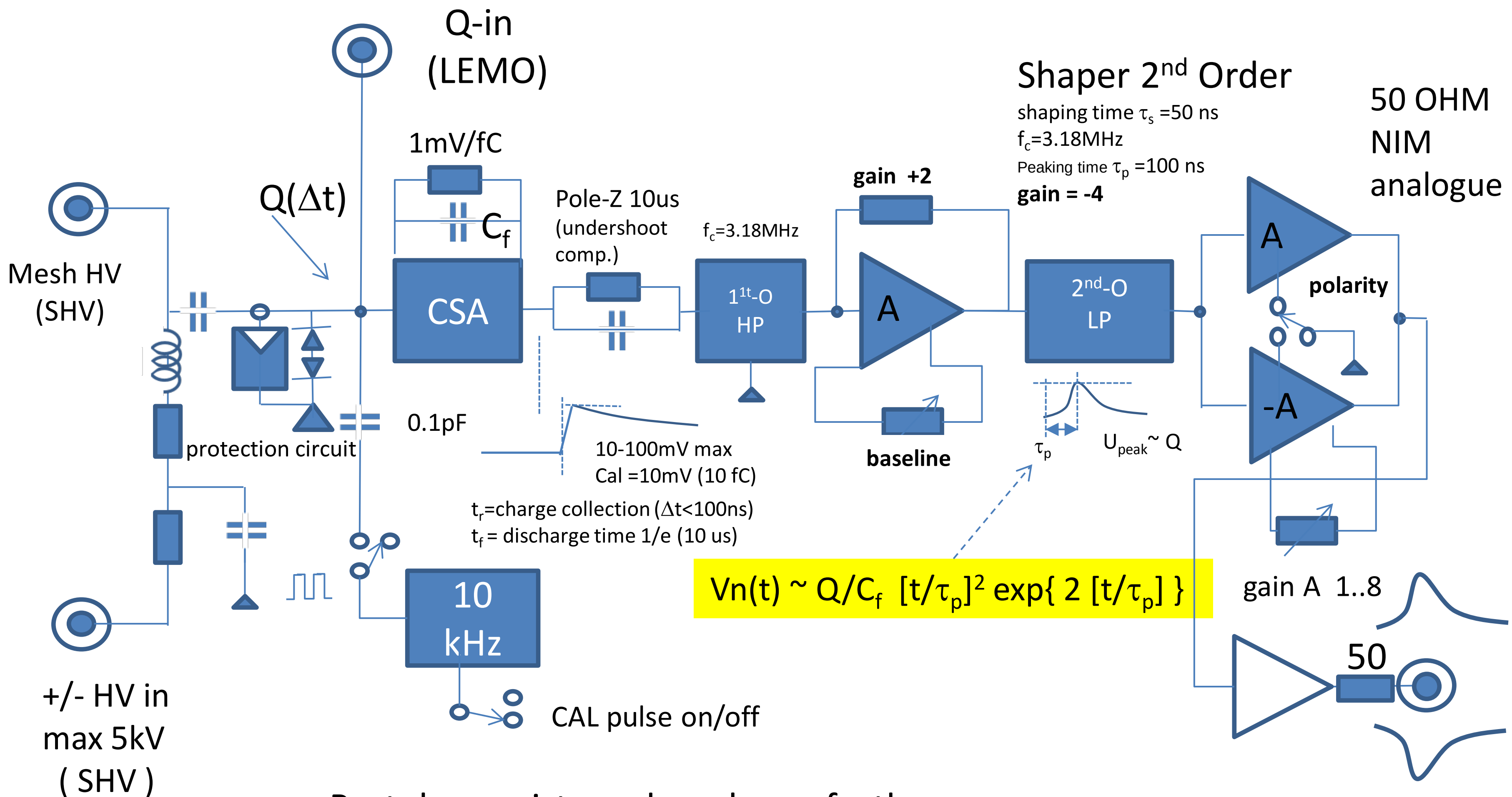


Step response to 1 ns LED pulse on APD

Charge/Voltage gain
1 mV/ fC

* Yaping Wang et al. NIM A 687 (2012) 75–81

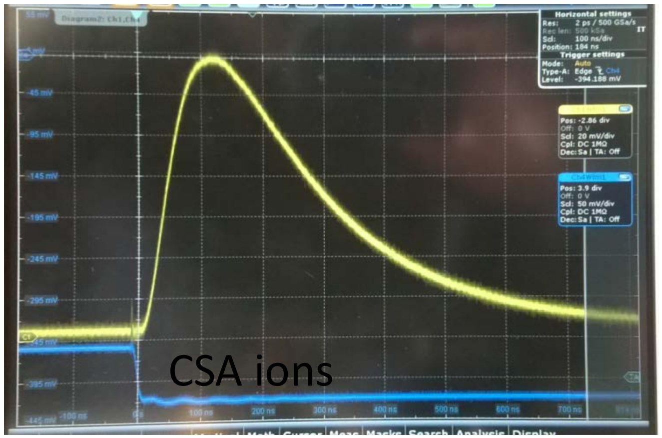
APIC box*



- Protobox exists and works perfectly
- PCB design for Quantity reproduction pending

APIC test results

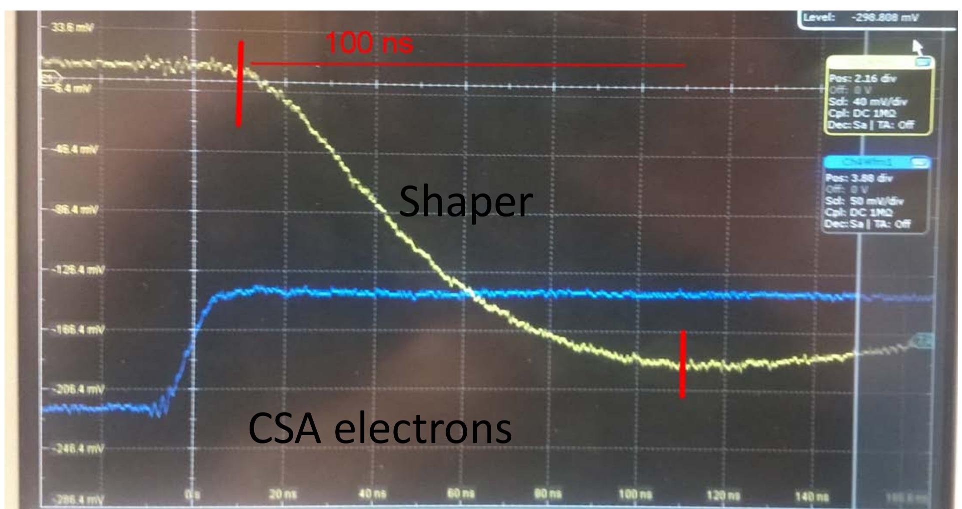
bipolar CSA-Shaper τ_p = 100ns



70fC CSA negative

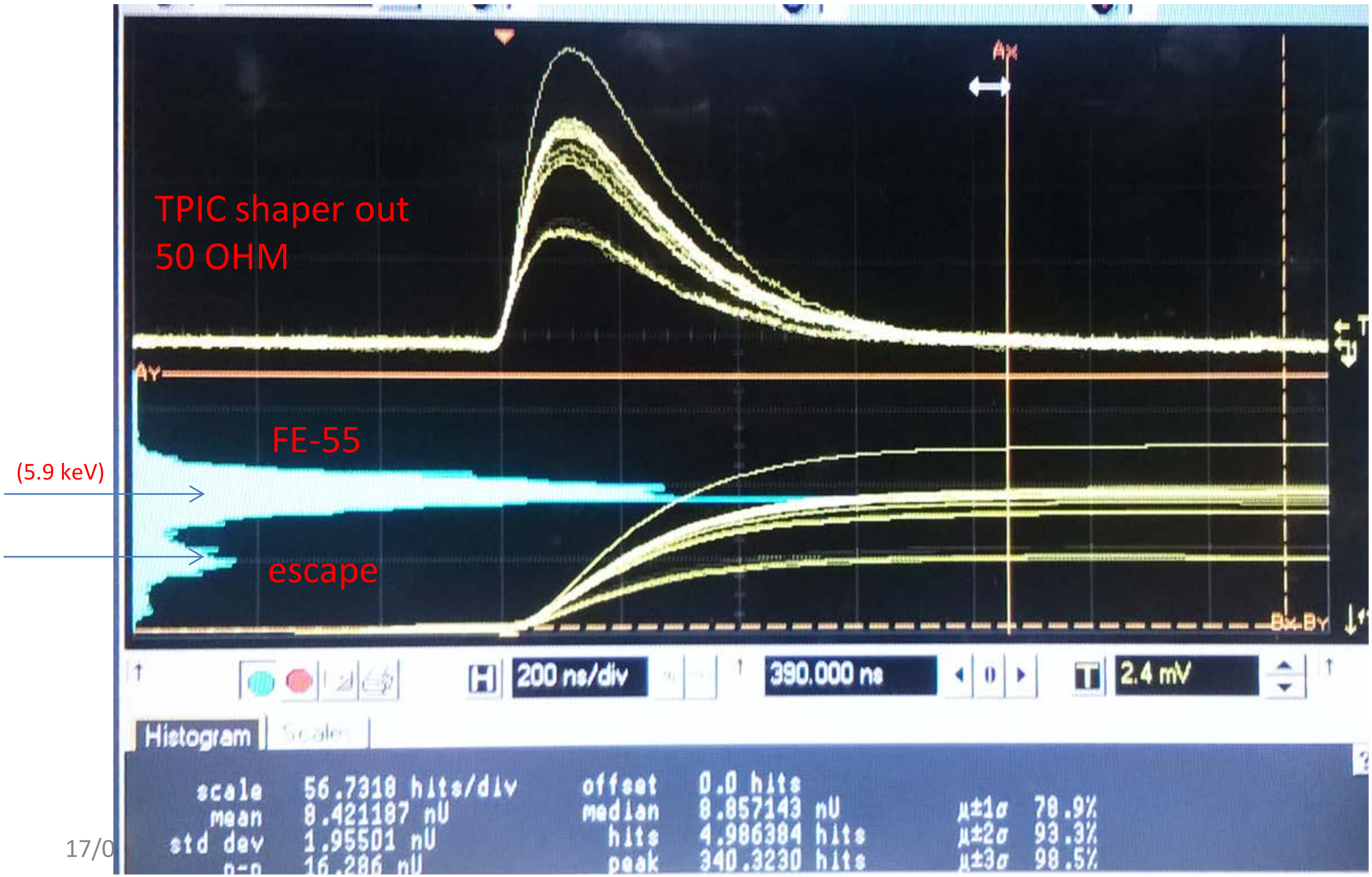
400fC CSA positive

Gamma-2 shape

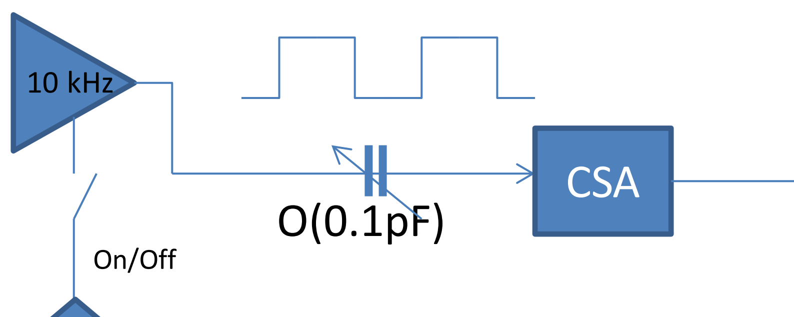


τ_{peak} = 100ns

FE-55 spectrum with APIC on GEM



50 fC Calibration pulser
(part of APIC)



Tuned to deliver 50 mV CSA = 50 fC

TPIC

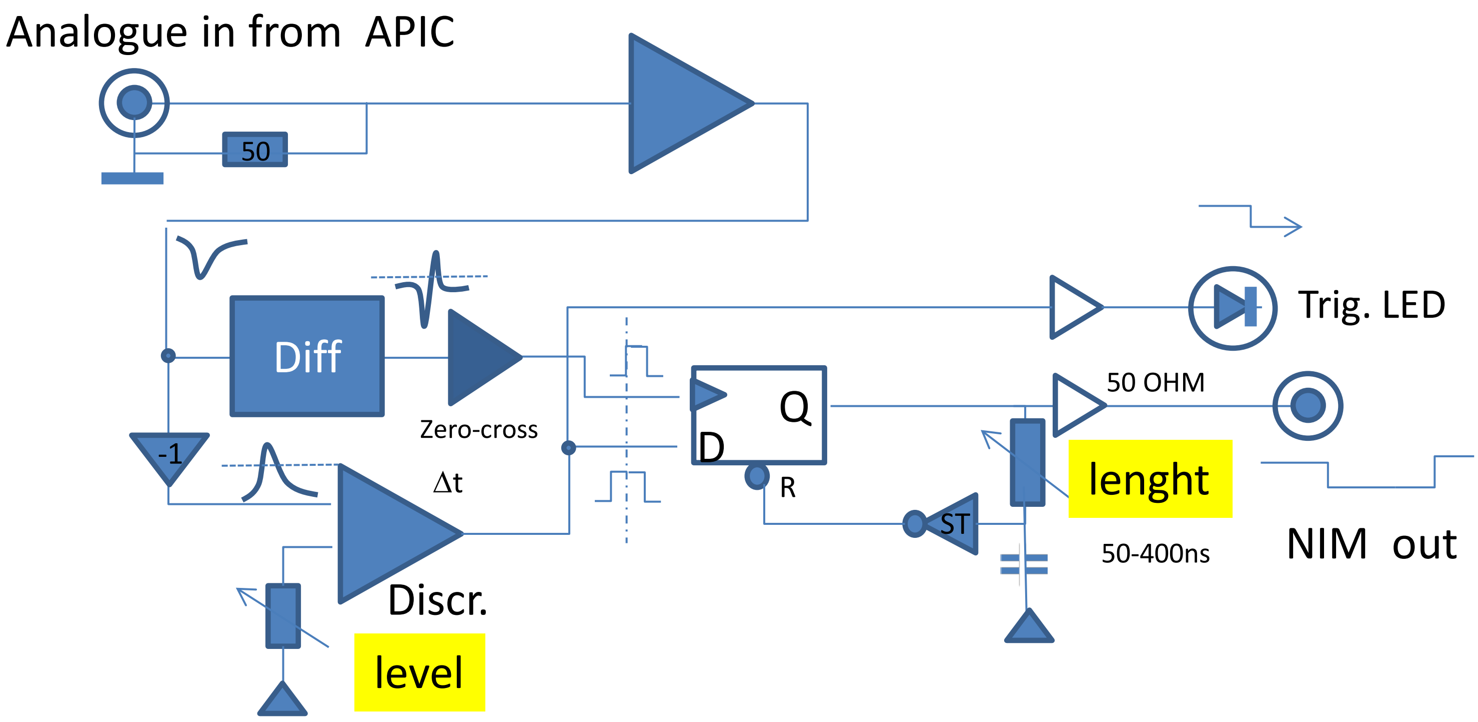
TPIC Trigger (separate box*)

Zero –Cross discriminator

Variable Threshold

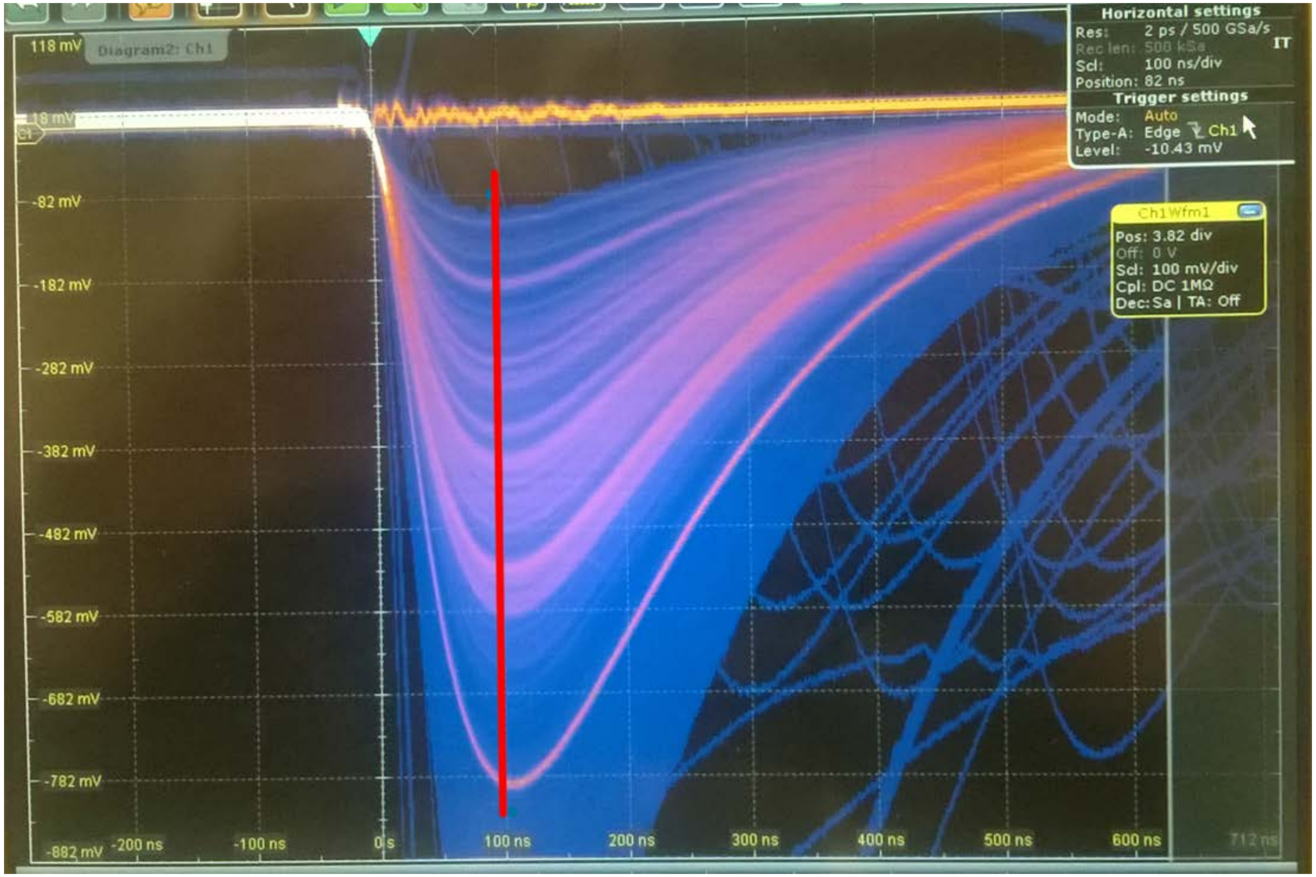
Variable NIM pulse lenght

Zero-cross Trigger box (latency 110 ns)



- Basic Circuits tested OK, component tuning required.
- PCB design required for test with APIC

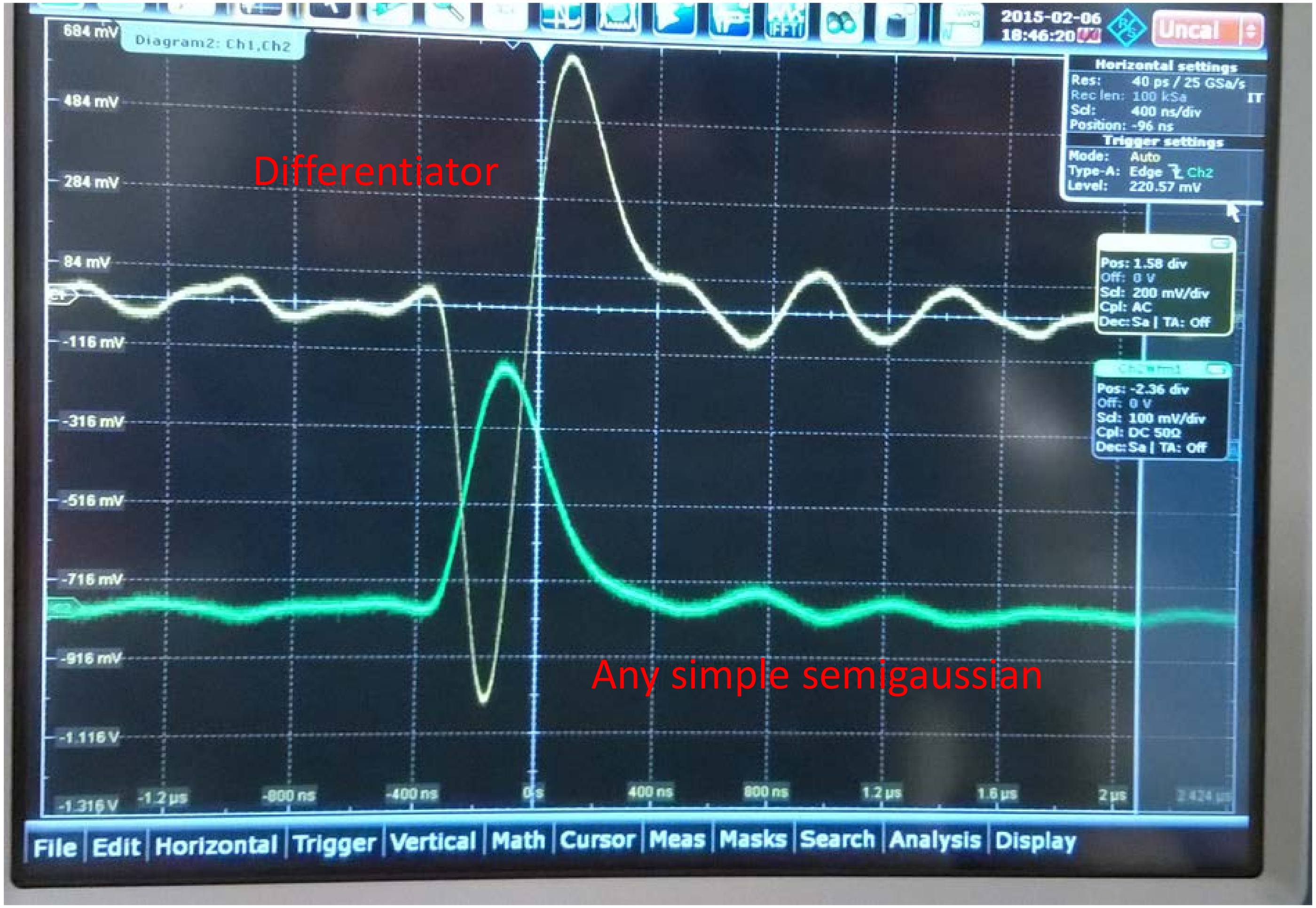
Peak position independence for Gamma-2 shapers in practise



Remaining “walk” of ca 10 ns will be tuned in final version

Zero-cross trigger

Zero-crossing => threshold independent Trigger point
use pos. slope electronically



APIC conclusion

- APIC for charge-monitoring on MPGD meshes (also APD or PIN diodes)
- Voltage charge gain variable up 64 mV/fC
- APIC calibration pulser 40 fC
- 2nd Order electronics results in perfect Gamma-2 time-function
- Default 100 ns peaking time (any other can be implemented)
- Very low noise level
- High charge resolution: Linearity, low noise, peak-amplitude invariance
- Charge Monitoring output for Oscilloscopes
- 50 OHM analogue shaper output max 900mV with selectable polarity
- Powered from SRS Minicrate optional power panel

TPIC conclusion

- Separate box to avoid X-coupling on input signals
- Peak- Zero-cross discriminator
- With APIC shaper input, peak-Z jitter tunable < 10 ns
- NIM output length variable 50 – 400 ns
- Discriminator levels from APIC 50-900 mV
- Powered from SRS Minicrate optional power panel

Femto-Meter

Started as Summer-Student project 2013

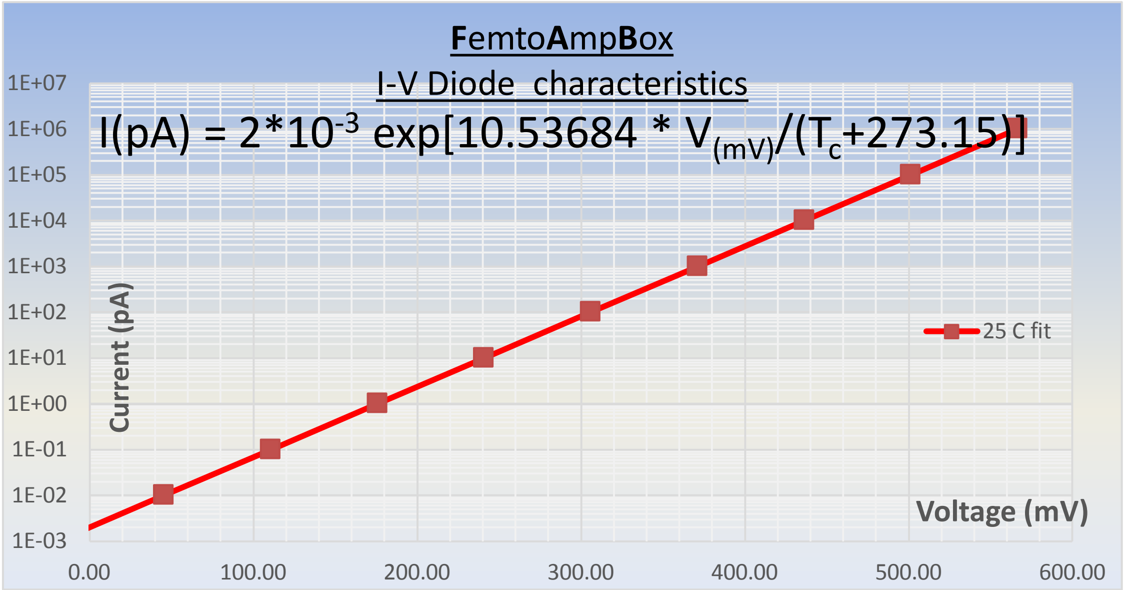
2 Femto-meters in use

Revison to include digital readout (New PCB)

Femtometer V 1.3

Principle

- Uses a temperature –compensated Si diode forward characteristics for conversion between Current and Voltage
- Dynamic range 11 decades (10 fA- 1 uA)



4 Modes of operation

-V/I (Femto-Ampere) current measurement based on the logarithmic linear V/I characteristics of a calibrated and temperature-compensated Si Diode

-V/Q (CSA) charge-sensitive feedback configuration, thus the output voltage corresponds to the input charge Q measured over 0.5pF, or 2mV per femto-Coulomb.

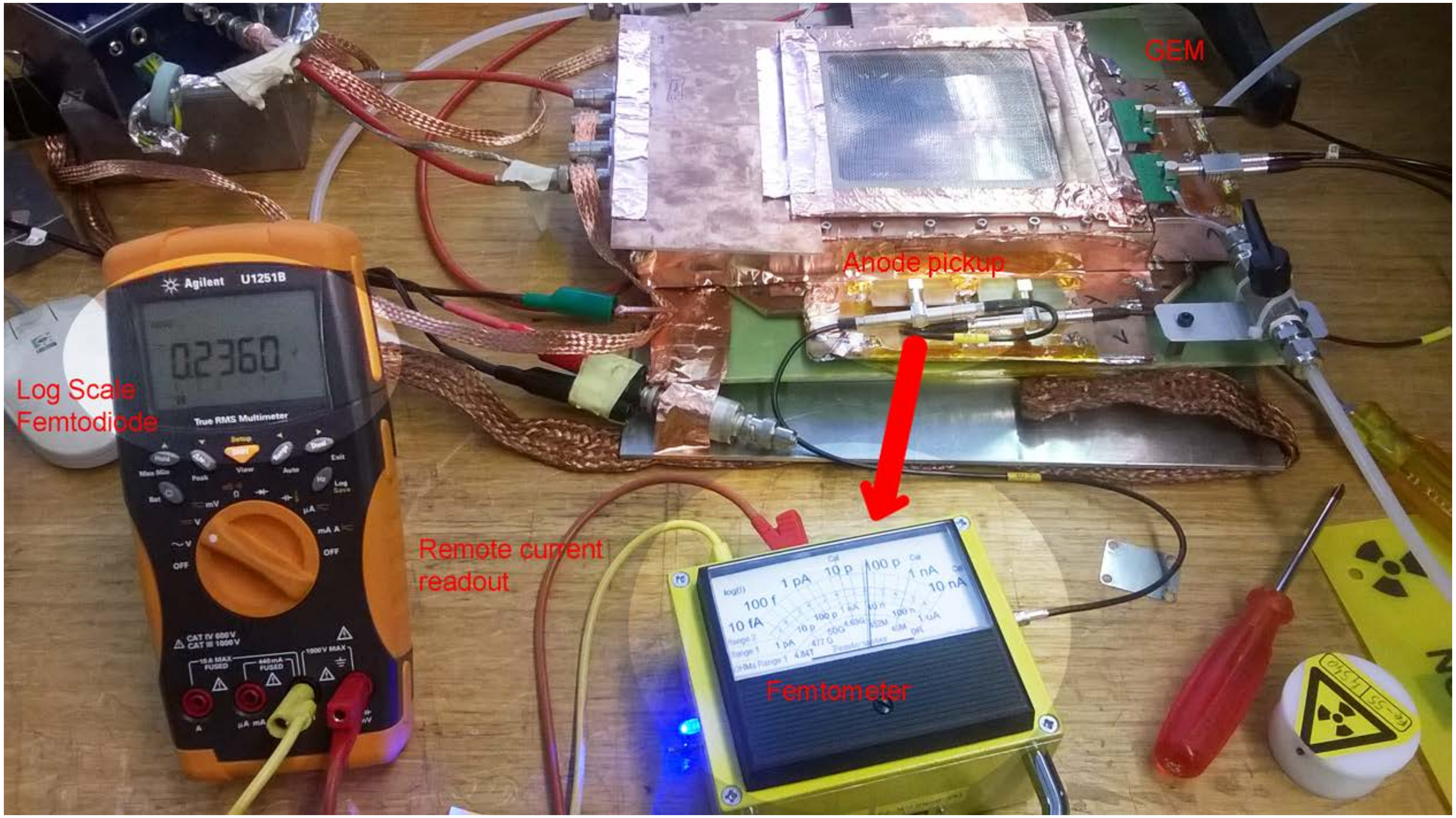
-V/V (electrometer) presents a very high impedance O(Tera-OHMS) at the input of a gain-1 amplifier and thus allows measurement of very high impedance voltage sources. The output voltage corresponds to the input charge measured over the input capacitance (incl. cable) i.e. very high impedance measurements may take a few seconds to charge up.

-V/I*R (Trans-Impedance TIA) represents measurement of small currents I over a user-defined resistor R in real time. The output voltage is V= I *R. The internal 5 GOHM resistor can be used to measure currents of the order 20 pA (100mV) and to monitor them in real time.

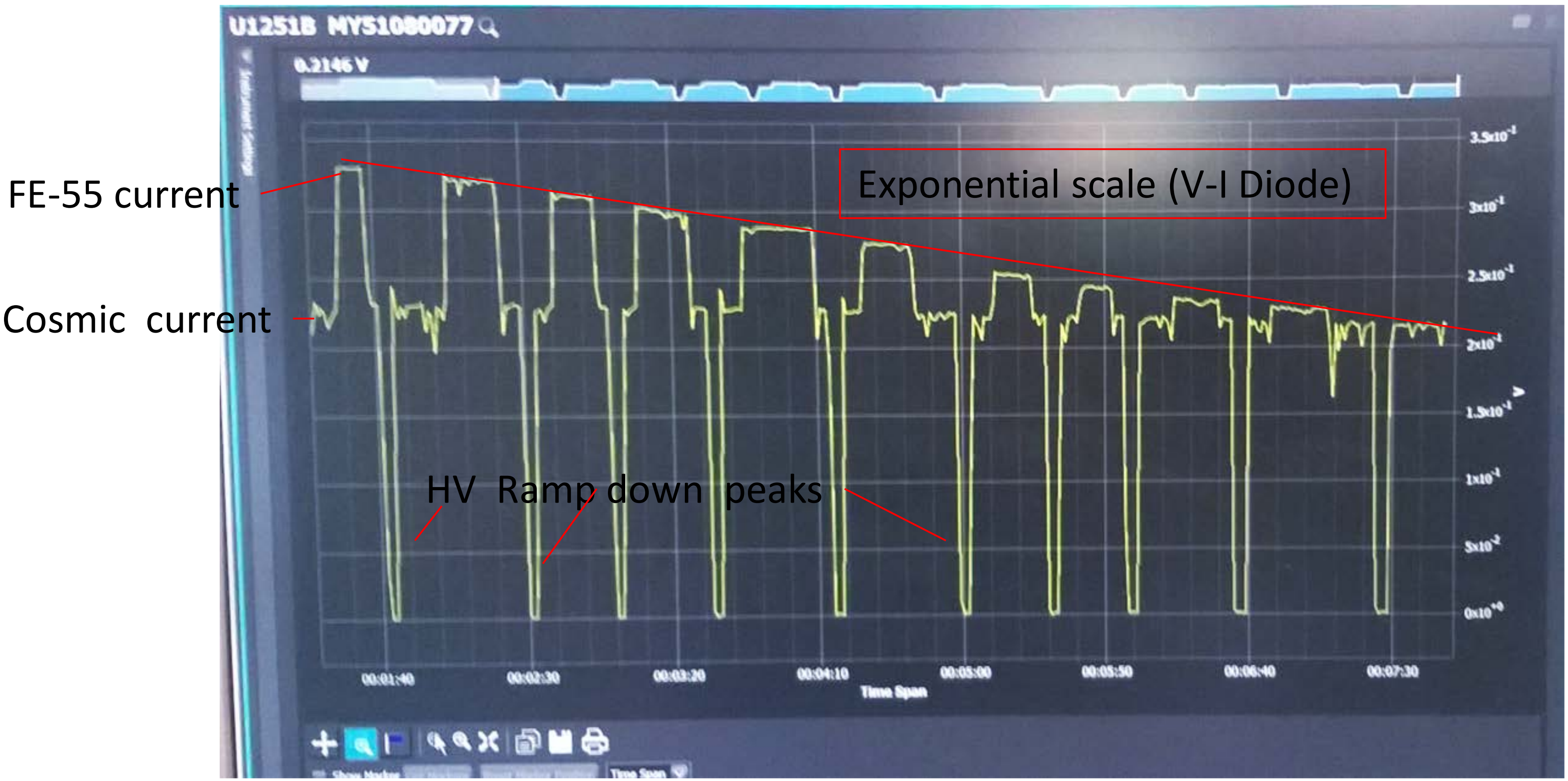
Features

- 4 conversion functions V/I, V/Q , V/V , V/R
- Portable, battery powered, sparc protected
- Dual range: 10fA- 10pA / 1pA- 1 uA
- Moving coil display
- Oscilloscope and filtered DVM outputs
- 2 Calibration points
- Temperature compensated
- Positive and negative inputs
- Giga.... Tera-OHM meter function

Application GEM Anode current



GEM Amplification Ramp-down*



O(2nA)

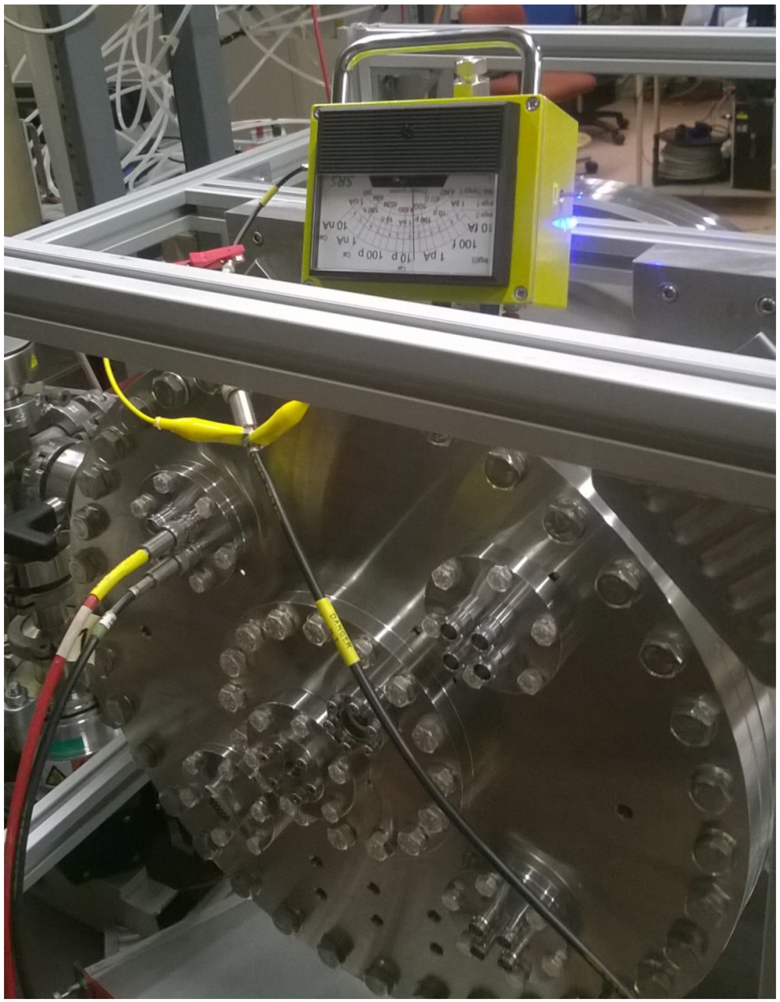
O(100pA)

O(10pA)

No more pulse detection

* Details E. Oliveri

Application GEM-foils resistivity in vacuum*



With increasing vacuum and externally applied HV field,
the GEM foil leakage current after some time indicates Orders > 50 GOHM

* Details F. Resnati

Summary

- We have a few interesting electronics projects
- The presented list is a subset
- In most cases, 90% of the R&D and prototyping is done
- We need resources/students for final characterization and production
- Volume production for RD51 is planned but requires more work and more resources
- Students with appropriate competences in electronics are welcome