APIC Documentation & User Manual APIC V4.x

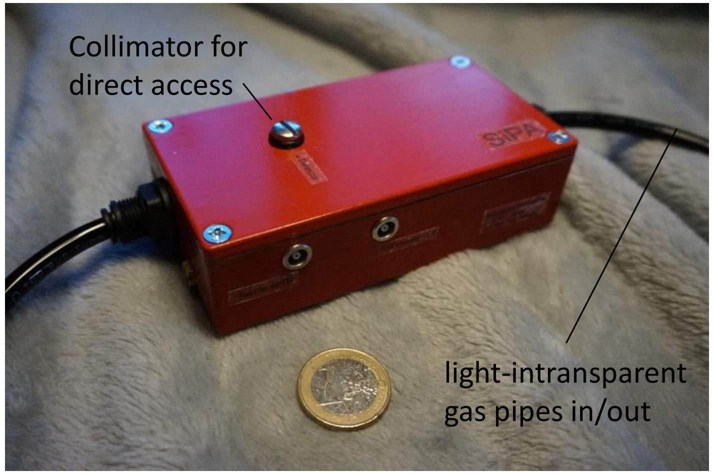
APIC is a pre-amplifier, dual shaper and dual polarity trigger discriminator in a 0.8 kg handheld metal box with up to 24h battery autonomy. The APIC functionalities compare to NIM modules in a bulky NIM crate [1] .

The spark protected pre-amplifier is optimized for low-capacitance MPGD detectors. External preamplifiers, like low-noise CSAs for large-capacitance Si diodes can be connected as external preamplifier boxes like SiPA. The 1st HV Bias Plugin options eliminates the need for external HV power supplies for most Si detector Diodes, and more planned HV plugins target HV generation required for operation of MPGD detectors.

APIC applications range from MPGD gas detectors, over solid-state Si detectors to Photodetectors.

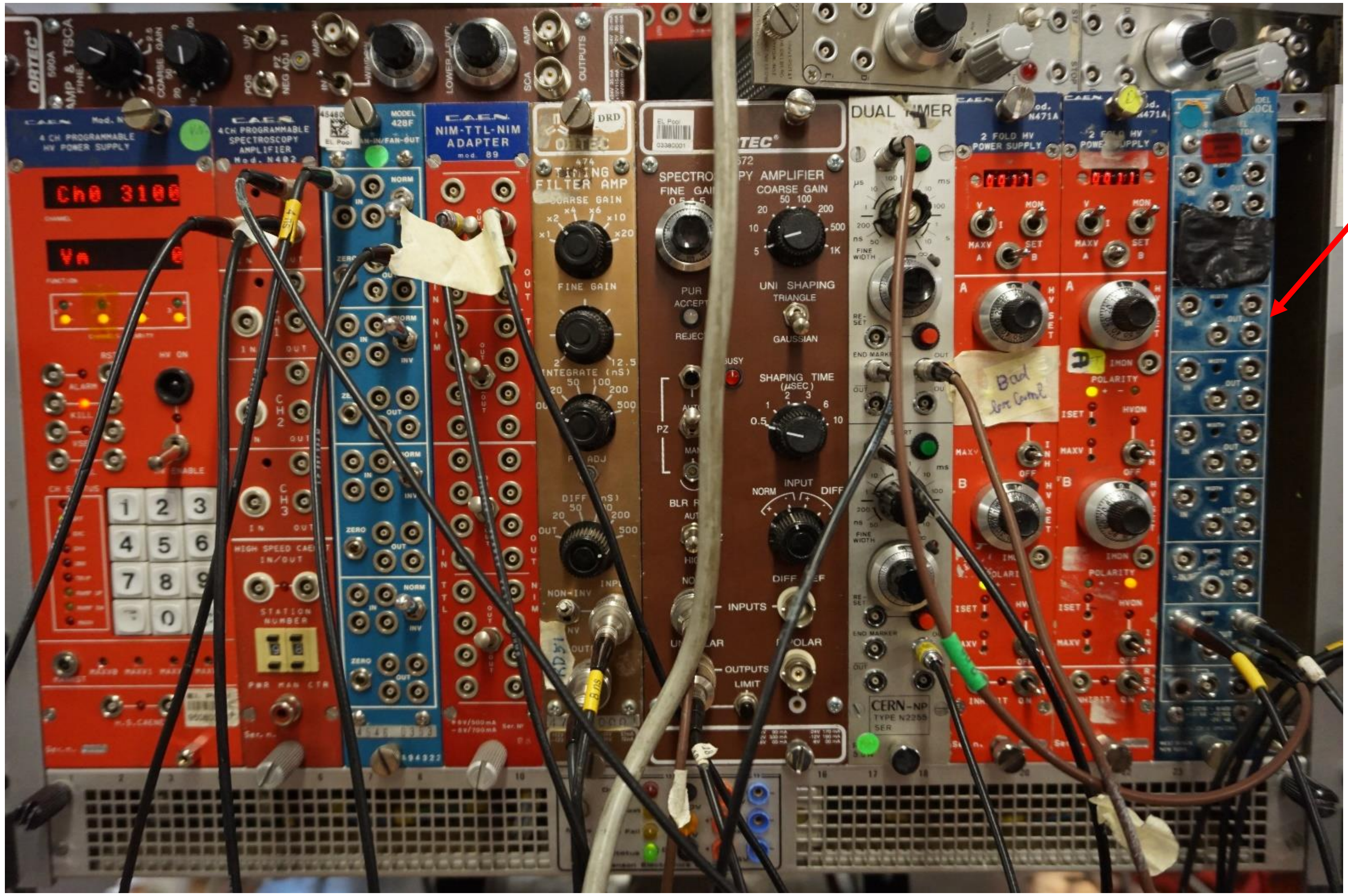
APIC $_{V4}$ 2018

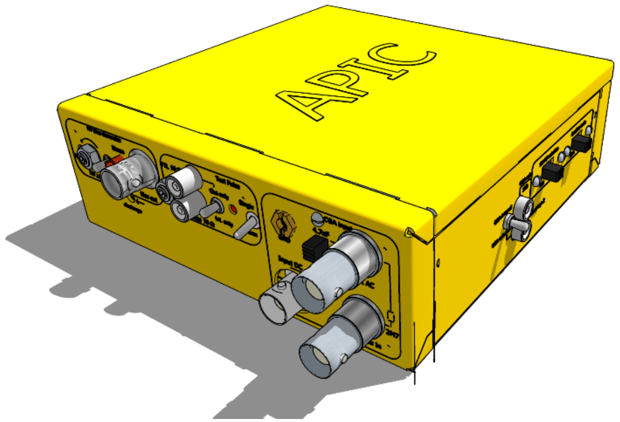
SiPA
External CSA option: a gas-tight CSA pre-amplifier for Pin Diodes, placed inside powered via the APIC.



APIC
Pre-amplifier-shaper-trigger-pulse-generator-bias voltage generator for gas detectors,
Powered by an AC adapter and a solar-chargeable battery.

Classical approach : NIM crate





APIC V4.x contains the essential subset of a bunch of NIM modules

plus an external an CSA pre-amplifer

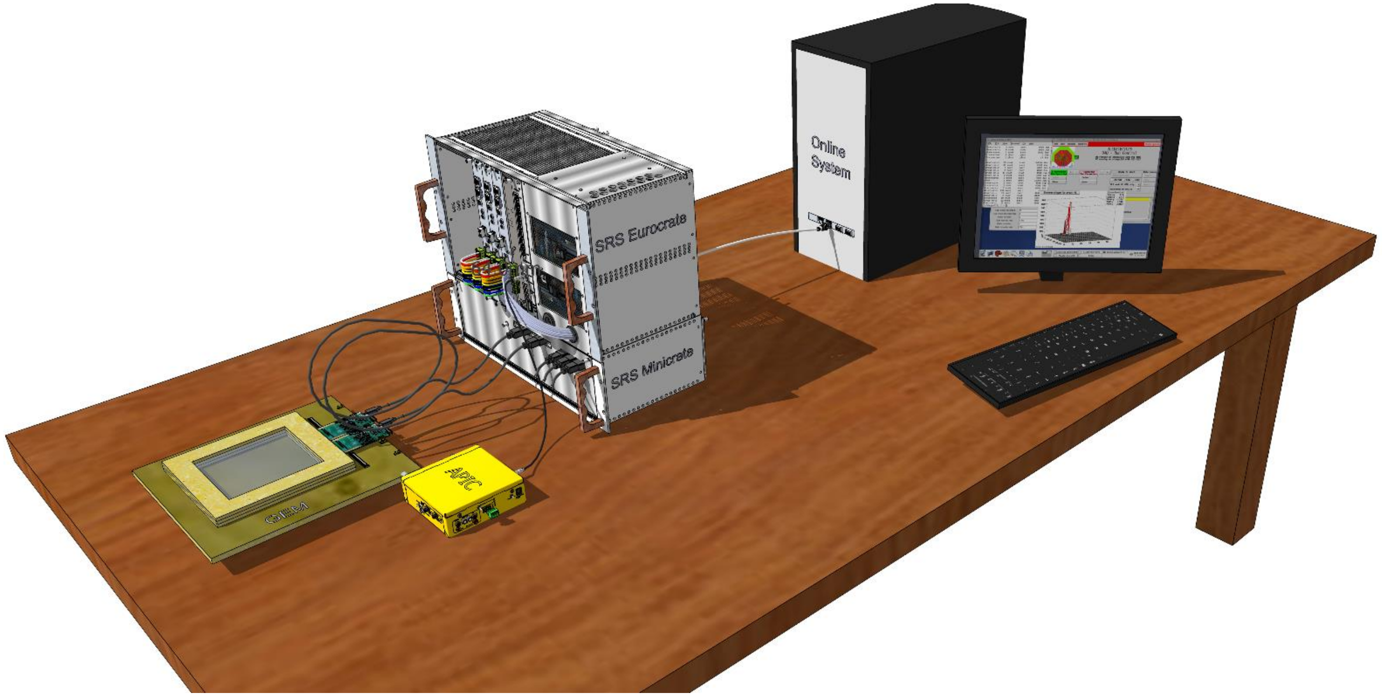
+

plus autonomous power from a Lithium Battery

+

plus a charge controller for small solar panels

APIC and SRS



SRS is a multichannel readout system for MPGD gas detectors, scalable from a few channels to tens of thousand of channels.

In order to trigger the SRS readout on passage of particles though an MPGD detector, the APIC can serve as mesh pickup trigger generator. The NIM trigger signal of the APIC can be directly connected to SRS.

Shown is a small table-top SRS system with a GEM detector, an APIC and an SRS crate, read out by PC or Laptop running Analysis software.

Application targets

MPGD* gas detectors (APIC only):

generic: particle spectroscopy, high rate particle trigger, rate and charge counting ...

specific: research, particle detectors, large-scale muon tomography, material science, calorimetry , tracking

Solid state ** detectors (APIC + preamplifier like SiPA):

generic: electromagnetic spectroscopy, dosimetry, beam monitoring, calorimetry, alpha detectors ..

specific: research, particle detectors, body scanners, calorimetry

Photomultipliers* (APIC only)**

generic: spectroscopy, high rate single particle trigger, coincidence triggers, picosecond timing ..

specific: research, particle detectors, body scanners, light amplifiers, cargo detectors, homeland security

- *Multipattern Gas Detectors like GEM, THGEM, MicroMega, etc.
- ** SiPM, MPPD, APD, Pin Diodes, photodiodes, CV diamond, direct or attached to scintillators
- *** Small and large PM's attached to scintillators

APIC feature summary

1x built-in CSA preamplifier with spark protection
- default trimmer set to 1mV/fC, 1us decay
- triple-spark-filter << 1nA leak

3x AC/DC input coupling modes
- direct DC, AC up 4 kV via slide switch: 360pF /4.7nF

1x detector Bias plug to detector
- LRC filtered via SHV connector to AC input

1x direct CSA output
- direct CSA output up +/- 1.1V 1MΩ, +/- 2.2V **50** Ω
- output polarity = input charge
- internal Pole-Z trimmer (pre-adjusted)

1x input for an external CSA preamplifier (SIPA)
- internal CSA disabled, adjust internal Pole-Z trimmer
- Signal input 50 Ohm Lemo-00, power cable Jack

1x testpulse generator 50 Ω LVTTL / NIM , 1M TLL
- permanent or single toggle with LED
- variable rate 1Hz..1 kHz via 15-turn potentiometer

1x test charge injector testpulse
- 200ps neg / 700ps pos. int. test pulse 1.4V via 0.125pF

2x shapers
- slide switches: 2 shapers, baseline zero/variable
- Gamma-2 shape, default: $t_{p,fast}$= 30ns, $t_{p,slow}$ =350ns

1x variable gain amplifier
- CSA -> shaper gain 0 – 20 via 15-turn potentiometer
- Gain Monitor Voltage plug (2mm Banana)

2x shaper outputs
- complementary up +/- 1V 50 Ω , +/- 2V 1MΩ
- 150 mV variable baseline +/-

1x dual polarity discriminator -> trigger generator
- Trigger via 15- turn discriminator over +/-CSA polarity
- TOT and TBT threshold over CSA signal slope

4 x Trigger LEDs: charge polarity and discriminator lock
- red/blue : +/- input signal polarity level in range
- orange/green: +/- TOT or TBT trigger locked

1x complementary 50 Ω NIM trigger output
- TOT time-over-threshold (prompt, short) NIM signal
- TBT time below threshold (prompt, short) NIM signal

1x 50 Ω NIM trigger pulse stretcher output*
- 50ns-500ns out via 15- turn trimmer

1 x classic audible beep
- audible beep from stretched NIM triggers

1 x 50 Ω -input for 3 selectable output functions (NIM 50 Ω)
- Input pulse stretching only*
- input gated with TOT trigger, stretched
- input gated with TBT trigger, stretched

1x optional HV bias generator (for Si Diodes)
- 10V-100V low noise , temp. stable via 15 turn pot.

* stretch prompt TOT/TBT triggers by connecting an external coax cable to input

APIC history

APIC technology was developed in discrete logic during 2015-2017 in the CERN GDD lab, initially targeting a simple integrated and portable pickup pre-amplifier for MPGD gas detectors. Quickly it became clear that a complete CSA-shaper chain with shaper and trigger logic would be more preferred for the laboratory practice of RD51 users.

The APIC development was performed within the RD51 Collaboration at CERN and sponsored by the EU AIDA 2020 project. APIC is one of several electronics projects of the RD51 collaboration for readout and operation of MPGD gas detectors in a variety of fields of research and industrial applications and as such, APIC sales are licenced by the CERN KT technology transfer.

The CERN inhouse development of 8 initial "blue box" APIC prototypes, all with slightly different experimental features, resulted early 2017 in a pre-series production of APIC V3 " yellow boxes". In Sept. 2017, additional functionalities have been added to APIC V4, allowing for pulse gating with external gating logic and to generate external NIM and TTL test pulses. After initial use of discrete CSA preamplifiers [5] we have adopted a commercial FET based amplifier as opposed to low-noise CMOS technologies [9] in view of lower noise and better Spark immunity for avalanche gas detectors. For high-rate gamma counting with detector capacitances < 150pF the fast shaper selection was chosen as 30 ns peaking time. For standard MPGD's with capacitances above 150 pF, the preferred slow shaping time selection choice was 350 ns .

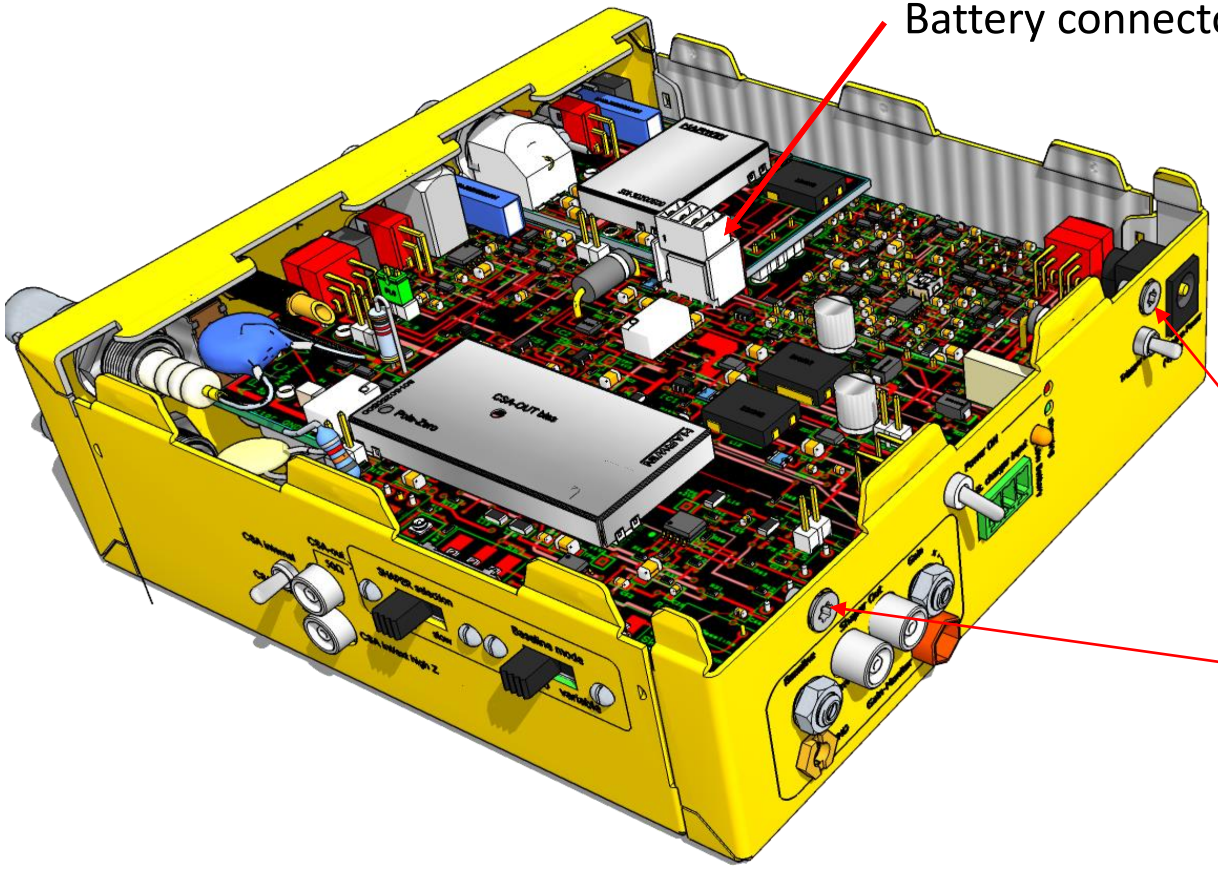
As from V4.x, APIC technology reached the maturity level required for commercial volume reproduction and includes almost all features requested by RD51 users.

An initial technical difficulty was power-autonomy for 12-24 hours operation, calling for very low power electronics techniques without compromise in performance. With 2 charging option, either 12V AC adapter or solar panel, the use of APICs is not restricted to laboratory infrastructures. Another main user request called for trigger signals for the RD51-standard SRS readout electronics [10] picked up from the mesh planes of MPGD gas detectors, in particular in fields of applications where scintillators and NIM crates are much too bulky. This feature was successfully tested on large surface MPGDs, calling however for large shaping times. A further request for high rates gamma recording beyond 1 MHz rate with very short shaping times was successfully implemented. APICs were also tested for alpha particle histogramming with Pin Diodes, confirming the need for large shaping times and preamplifiers optimized for large detector capacitance at low noise. The default APICs with shaping time selections 30ns / 350ns cover best all default MPGD applications and became the default. Due to its 2nd order shaper filter implementation with discrete components, different shaping times for large MPGDs or Si-detectors can be readily implemented on request. Aware that the built-in CSA will not be the best match for all applications, the possibility to connect external CSA's was added. SiPa is the first external preamplifier for Alpha spectroscopy with gas flow measurements. Other external CSA's for dedicated detectors are planned or can be provided on request in short time. The addition of an internal test pulse for the built-in CSA was obvious from the beginning but quite complex in practice. For best performance, a bipolar charge injector circuit with a 200ps SRD diode [7] fall-time was implemented, driven by a variable rate pulse generator. The test pulse mode can be selected for internal or external mode, the latter allowing to drive external charge generating devices like UV LEDs, from NIM, TTL or LTTL output signals. In the internal mode, every pulse transition injects 185 fC charge to the CSA input via 0.125pF coupling capacitor. An internal pole-zero trimmer is preselected to adjust the signal shapes of the internal or external CSA for return to zero. The internal CSA input is triple spark protected and adds 25 OHM to the default 75 OHM input impedance of the CSA. The default CSA gain is trimmed to 1 mV/fC, for very high charge input and larger dynamic range the CSA gain can be internally trimmed down to 0.3 mV/fC. The default linear dynamic range is +/- 2.2 pC in the linear range and +/- 4 pC at maximum. The effective input capacitance of 5.6nF allows for very high charge sharing with detectors up to 1 nF detector capacity. The CSA output signal is directly available as serially terminated 50 OHM output of same polarity as the input charge. The externally available CSA risetime, depending on detector capacity is t_{out}/ C_{det} = 0.153 ns/pF + 2.3 ns. When terminated with 1MΩ the extrenal CSA charge gain amplitude is =1mV/fC , when terminated with 50 Ohm it is 0.5mV/fC. The shapers are implemented as 2nd order Bessel filters which reduce the noise spectrum of the CSA to ENC_{slow} = 47.3 e- x C_d + 3015 e- for the slow shaper setting. The shaper outputs are complementary, semi-gaussian output signals with 2 selectable peaking times and variable gain/attenuation between (0…20) relative to the direct CSA signal, terminated with 1MΩ. The shaper envelope can best be fitted with Gamma-2 time functions with the selected peaking time, which is twice the shaping time. The shaper outputs are 50Ω complementary outputs allowing to connect instruments with positive and negative inputs, either terminated with 50Ω for best timing resolution, or with 1M for maximum amplitudes up to 2.5V. The shaper baseline is temperature-compensated and can be switched to zero, or varied between +/-150mV. The shaper gain can be monitored via a voltage test point, with a gain relative to the CSA 1MΩ output signal. Detectors can be connected via a direct, low noise DC input or, via two AC coupling options (4.7nF and 360pF) with insulation up to 4 kV electrode Voltage. Detector which are connected to the AC input can be biased via the HV bias SHV input which includes LRC noise filters. With APIC optional Bias generator plugin, an external Bias cable can be used to bias the AC input signal via the SHV bias input. The first Bias generator plugin is optimized for Si diodes, featuring very low noise 14mV p-p over a very wide frequency spectrum at 1% stability over the full temperature range (-10C..+50C). Further Bias plugins are planned for the generation of HV fields of opposite polarity as required for MicoMega detectors. The bipolar Trigger unit is a standard APIC feature. It generates prompt TOT (time over threshold) or TBT (time below threshold) NIM triggers from the slope of the CSA signal. For all practical cases, a pulse stretcher circuit is available as part of an independent coincidence/gate logic, allowing to stretch trigger signals between 50 to 500 ns NIM level. An audible beep can be enabled for acoustic triggers in particular at slow counting rates. The prompt TOT/TBT triggers have very low latency relative to the input charge signal and have negative or positive pulse-widths of order 50ns. By connecting the TOT or TBT outputs to the NIM trigger input of the pulse stretcher unit via a short coax cable. In this way, the prompt and short the TOT/TBT triggers can be stretched to match with the min.100 ns requirements of SRS triggers. A coloured, 4-level LED array facilitates the TOT/TBT discriminator settings for positive and negative input charge selection.

Further add-in options, extensions and improvements continue to be driven by user feedback.

H.Muller and colleagues of the CERN /RD51 lab, Jan. 2018

Unpacking APIC V4.x
Cover removal, screwdriver, Battery connector



Battery connector (polarized): remove for transport

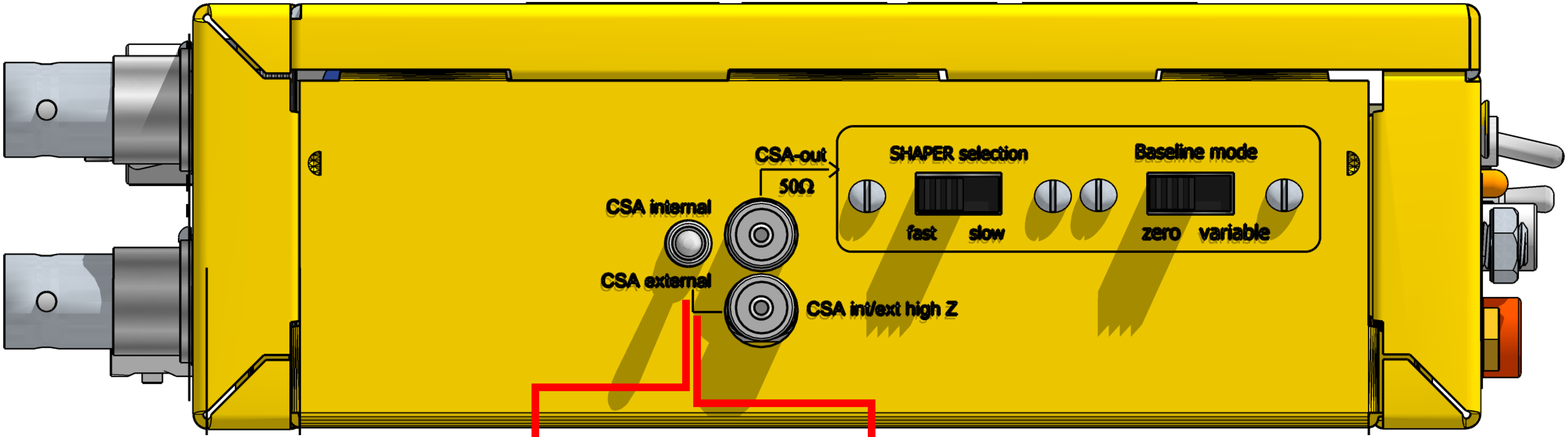
3 x interconnected PCB modules inside
1 x 12V Lithium Battery below PCB

use a mx 2.5 mm dia screwdriver for all APIC potentiometers

Cover removal:
-remove 2 x cover screws
-lift up cover from this side

APIC: CSA pre-amplifier input/output

CSA = Charge Sensitive Amplifier



CSA internal: int. CSA signal connected via pole-zero circuits to the shapers. The CSA out buffer (50Ω/ 1M) drives the CSA signal at same polarity as the input charge at gain = 1 for 1M and gain ½ for 50Ω termination (both polarities). The CSA peak amplitude at 50Ω termination is proportional to the input charge $U_p \sim ½ \Delta Q_{in}$ x CSA-gain (default CSA-gain value 1mV/fC)

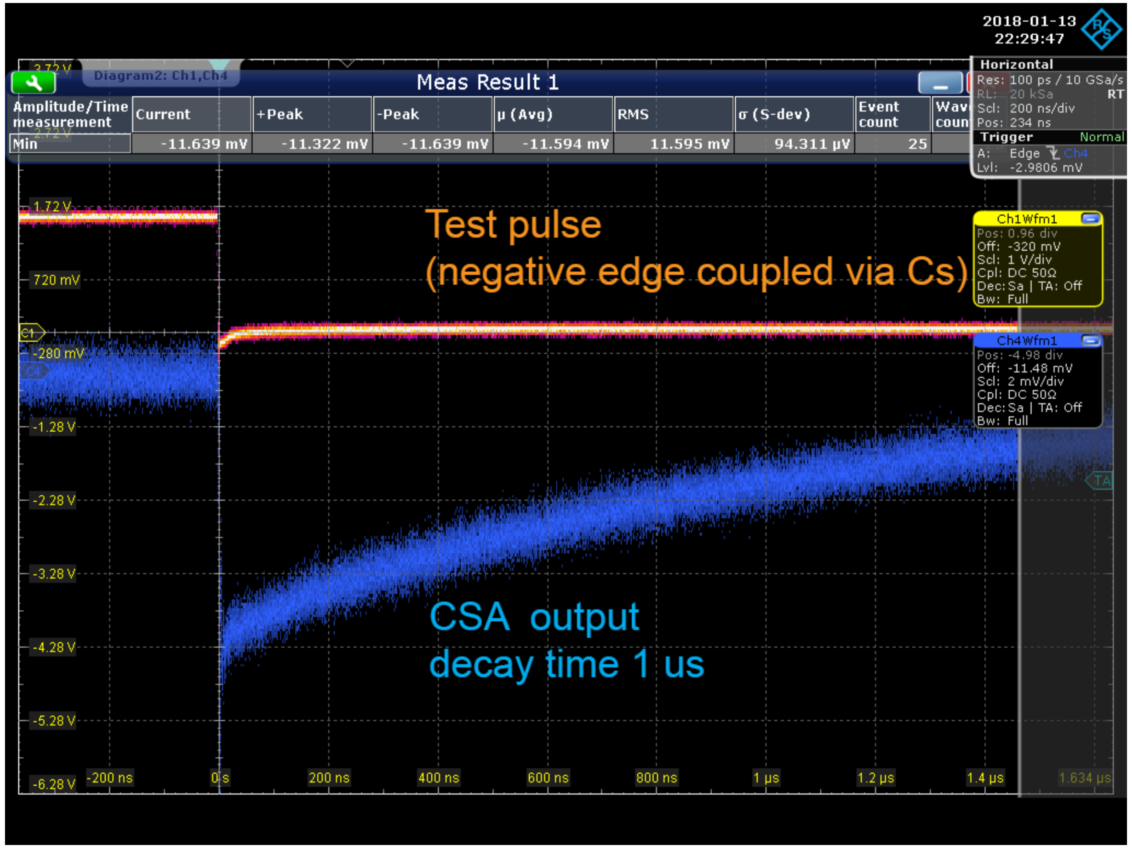
CSA external: Input for external CSA's like SiPa. Their signal gets connected via pole-zero circuit to the APIC shapers. The internal CSA is disabled. The internal Pole-Zero trimmer POT3 is to be adjusted, the signal can be monitored at the CSA-out buffer (50Ω / 1MΩ)

CSA properties

- CSA output signal, 2ns max. risetime, 1us decay buffer/driver gain =1, +/- 1.1V on 50 Ohm, +/-2.2V on 1M termination [page 11]
- CSA gain : 1 mV/fC t.b. calibrated via internal charge injection 200ps [page 12, 13, 14]
- CSA charge loss as function of added detector capacitance C_{det} 4%/100pF [page 15]
- CSA signal response to test charge : 1.5 ns with shaper latency 25ns intrinsic + 30ns peaking time [page 16]
- CSA dynamic range linear up +/- 2.2 pC, non linear up +/-3.5pC [page 17,18]
- CSA effective input capacitance 5.6 nF for spectral frequencies below 6 MHz [page 19]
- CSA charge sharing with detector 2% @ Cdet = 100pF [page 20]
- CSA risetime t_{out}/ C_{det} = 0.153 ns/pF + 1.3 ns [page 21]
- CSA response to non –matched input signals [page 22]
- CSA input impedance $R_{input} = R_{spark} + R_{in} = 25 + 75\Omega$ for default gain 1mV/fC [page 23,24], [page 30]
- CSA electronic noise ENC_{csa} = [126.4 e-/pF]* C + 19830 e- [page 25, 26] , lower ENC noise after shaper [page 49]
- Test pulse charge injection ΔU =1.51V, C_T =0.125 pF , ΔQ_T= 189 fC [page 28]
- CSA inputs: DC or AC 360pF / 4.7 nF , AC can be disabled via PL8 internal slide switch for reduced pickup for DC-only mode [page 29]
- Triple spark input protection, series resistivity 15 Ohm, 1 pF effective, max. leakage current < 1nA [page 30]

CSA output signal (50Ω/1M)

Test pulse on “internal”: charge injection to CSA.



Shown: neg. charge injection <1ns over C_s =0.125 pF via Test pulse “Internal”

CSA output signal polarity on “CSA out” : same as input charge !

Decay time (auto-discharge) by default: 1us

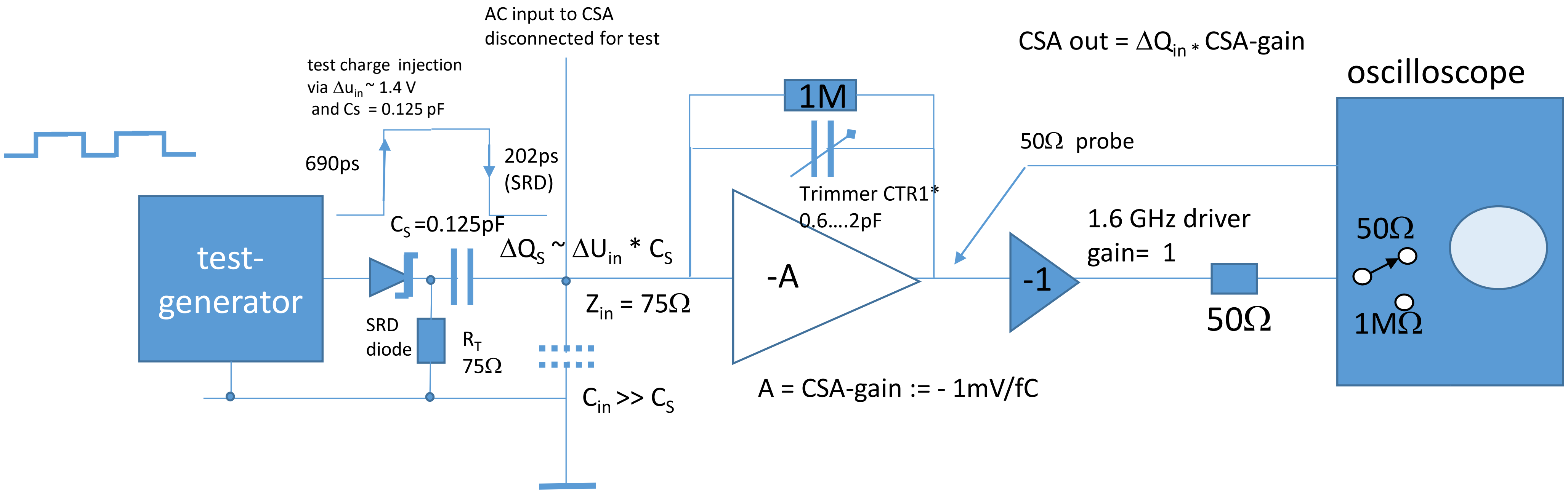
Note: statistical pile-up events on top of 1us decay result in perfect shaper outputs, unless average rates do not exceed 1 MHz

The CSA baseline is pre-adjusted (int. POT2) to zero [page 100]

Note: the CSA output is independent of the APIC shaper gain or shaping time settings

CSA gain determination/calibration

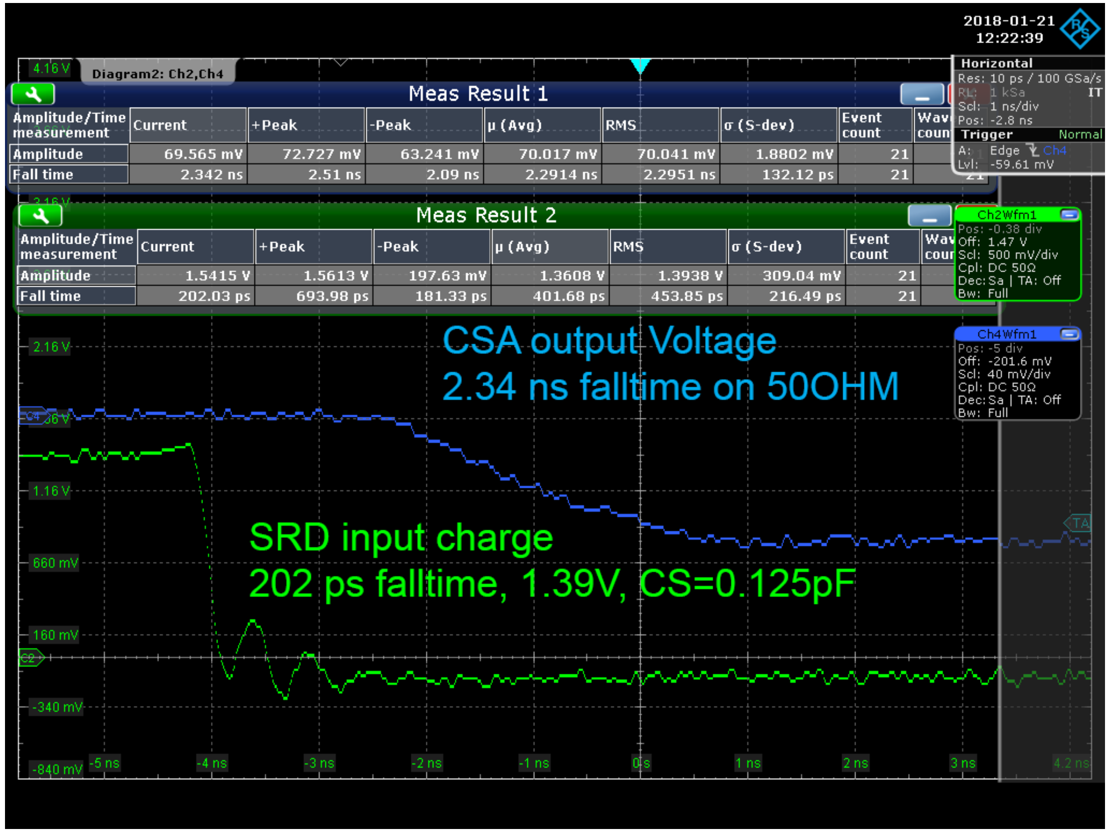
Method: negative/positive charge injection from the test voltage step ($\Delta t < 1ns$) of the built-in, rectangular (bipolar) test pulse generator over a coupling capacitor C_s =0.125pF with impedance matched coupling (R_T =75 Ω) to the CSA input impedance (75 Ω). [page 28]
The fast negative injected falltime (~200ps) is generated by a SRD diode used for charge injection.
The positive test pulse risetime is of order (~ 600ps)

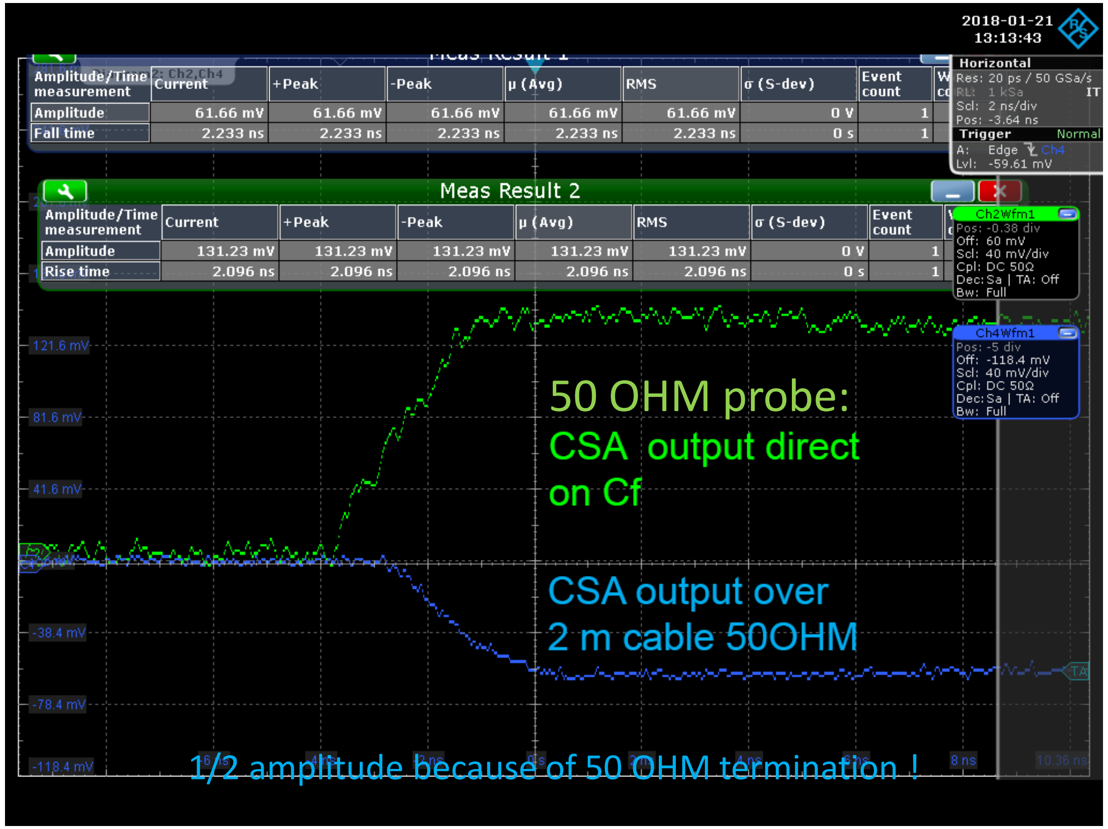


- Note: the CSA gain is pre-calibrated using a special tool (Johanson 4192) for CTR1

CSA time response to neg. charge

test signal neg. Q -> CSA (2m, 50Ω coax) compared to CSA direct probe





Attention: when measuring CSA amplitudes with 50Ω cable termination: due to series termination with an internal 50Ω resistor, the CSA amplitude gets divided by 2 and the cable length may add further attenuation, in this case (50Ω , 2 m cable) the internal CSA amplitude is 131.1mV and the external one is 61.66 mV (factor 2.12). For precise amplitude measurement use short cables and 1M termination.

CSA gain calibration

measurement [page 13]

Measurement* of injected input charge ΔQ_{in}

Use negative going fall time (SRD diode):

3GHz 50Ω probe over RT resistor
t_f = 220 ps, ΔU_{in} = (1.39 V)
coupling capacitor C_s = 0.125pF
ΔQ_{in} = ΔU_{in} x C_s = **173 fC** +/- 10%

Measurement of Δu_{out}

best precision directly at CSA out testpoint

- depends on precision of C_s and ΔU_{in} measurement,
- assume +/- 15%

Determination / Calibration of CSA gain:

The CSA gain calibration to the nominal 1mV/fC setting can be effectuated via the C_f trimmer capacitor CTR1 (0.6..2 pF) [page 100]

$Gain_{CSA}$: = 1/C_f [mV/fC] nominal value

$\Delta U_{out,\ measured} = \Delta Q_{in} \times Gain_{CSA}$

measured $Gain_{CSA} = \frac{\Delta U_{out,\ peak}}{\Delta Q_{in}} = \frac{131.2mV}{173fC}$ = **0.76 mV/fC** +/- 15%

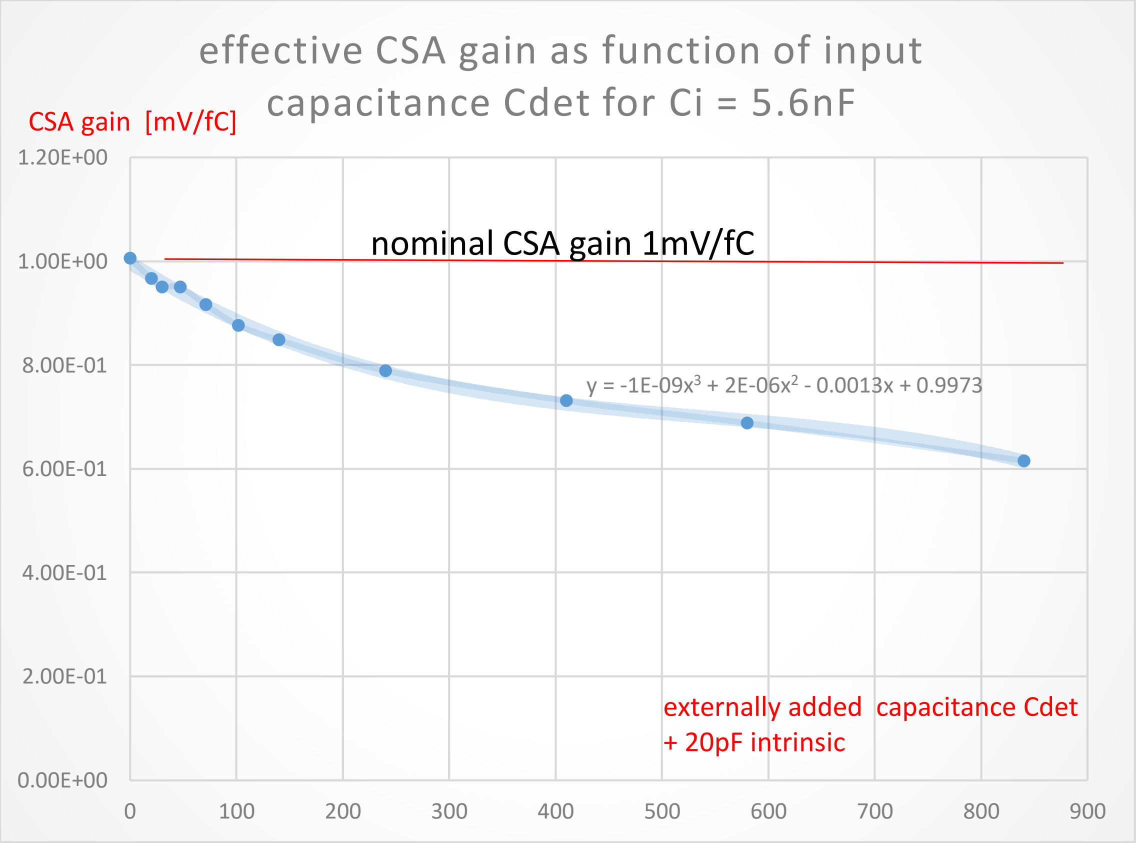
⇒ Measurement corresponds to an effective C_f = 1.32pF
⇒ For effective 1mV/fC , decrease C_f trimmer

$Gain_{CSA}$ is defined by the effective feedback C_{eff}

C_{eff} := 1pF = CTR1 [$C_{f\text{-}real}$] + 0.32 pF [$C_{parasitic}$]
=> set CTR1 to 0. 68pF (minimum = 0.6)

Charge loss

effectively reduced CSA gain by added input capacitance C_{det}



*capacitances added by cabling to the detector
Coax: RG58/U ~ 82pF/m, RG316/U ~ 95pF/m

The CSA gain is defined by the feedback capacitance C_f as
$Gain_{CSA} := 1/\mathbf{C_f}$ [mV/fC] with

$$U_{CSA,out} = Gain_{CSA} * Q_i = 1/C_f * Q_i$$

However, the total generated detector charge $Q = Q_{det}+Q_i$ is shared between the detector capactity C_{det} and the parallel input Capacity C_i.
With the Kirchhoff rule that the Voltages over parallel capacities are equal

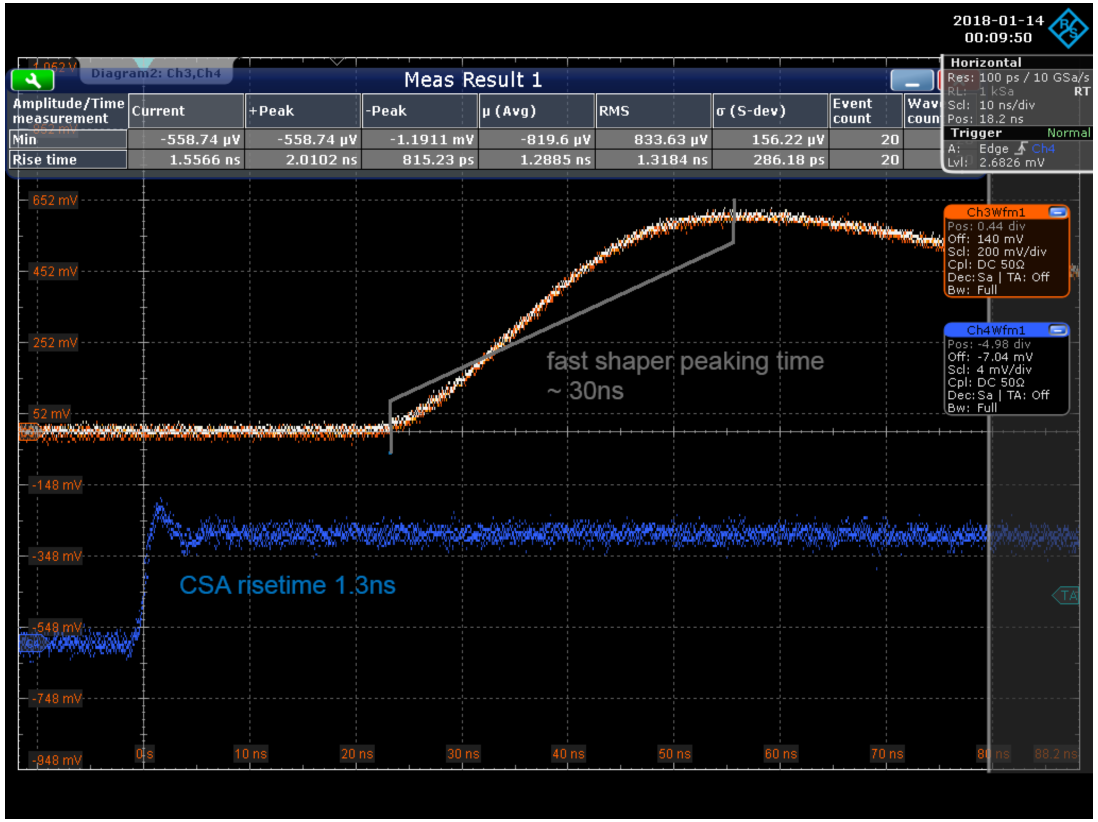
$$Qi = \frac{Q}{1+Cdet/Ci}$$

$$U_{CSA,out} = 1/C_f * \frac{Q}{1+Cdet/Ci}$$

Due to the effective charge loss due to the ratio of C_{det}/C_i an effectively lower CSA gain applies and corresponds to a $C_{parasitic}$ capacity in parallel to the feedback capacitor C_f.
As shown on [page 14] the nominal $Gain_{CSA}$ of 1mV/fC is effectively reduced to 0.76mV/fC corresponding to $C_{parasitic}$ = 0.3 pF in parallel to C_f

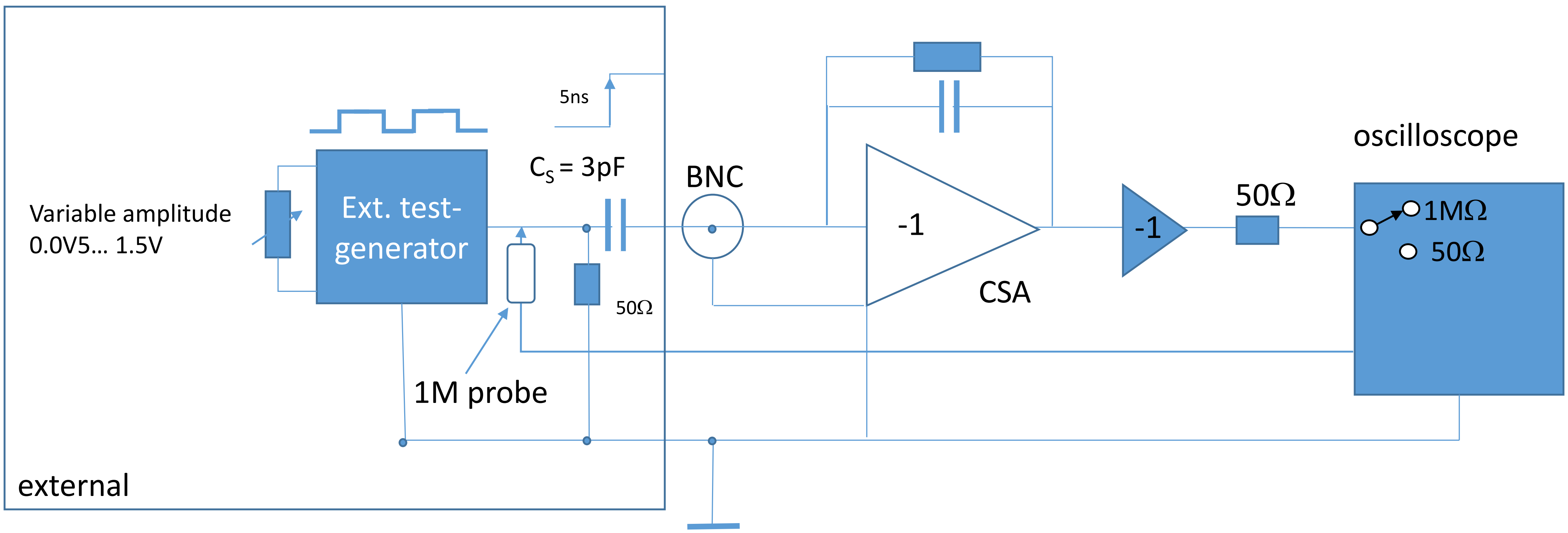
The relative APIC CSA charge gain shown here is calculated with an effective Cin = 5.6 nF [page 19] as $Gain_{CSA} \sim 1 - 0.0004 \times C_{det}$[pF] (polynominal fit see plot)
Note : capacitances of cables and connectors* must be included in C_{det}

Latency CSA signal -> Shaper signal

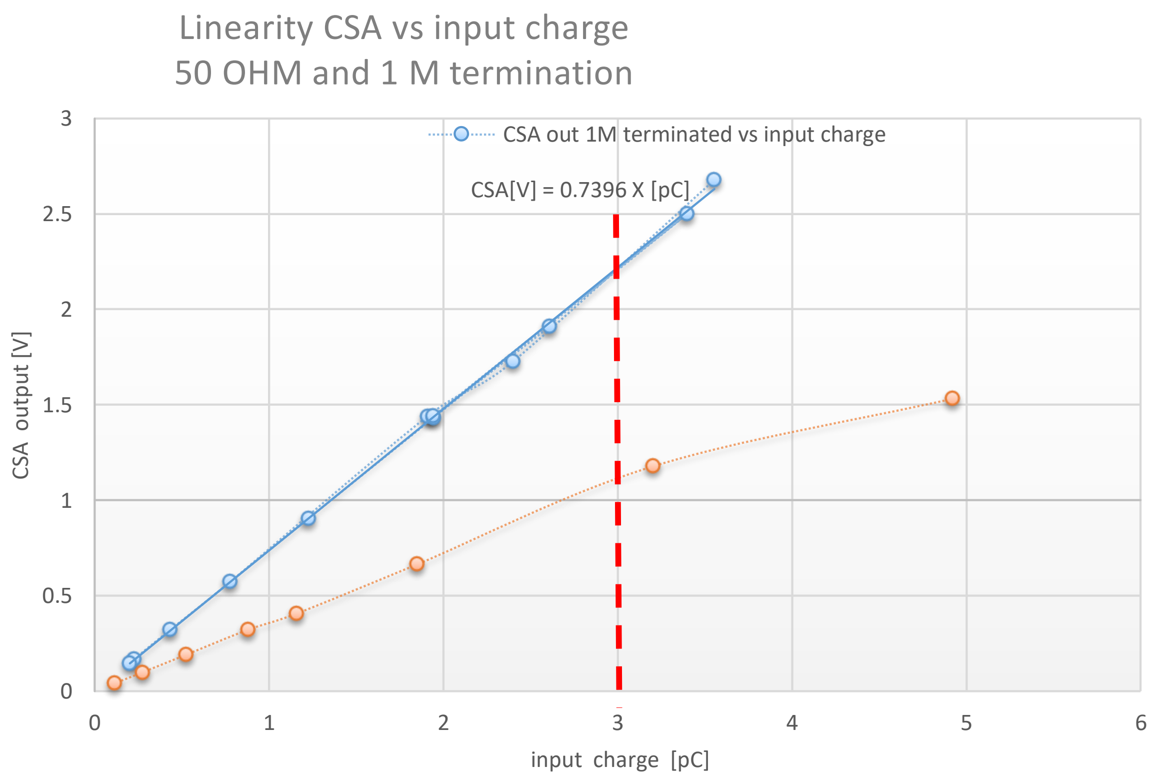


The internal CSA has an intrinsic risetime of 1.3 ns when using the internal testpulse with risetimes well below 1 ns.
With externally connected detector capacitance Cdet the risetime increases with 0.15ns/pF [page 21] The fast shaper response follows after 25 ns delay with a peaking time of 30ns.

CSA dynamic range test setup



Dynamic range CSA vs. Input charge



CSA dyn. Range ~ +/-3pC for gain 0.75mV/fC as hown above
+/- 2.25 pC for calibrated gain 1mV/fC

the nominal CSA gain 1mV/fC does not apply here for purpose of demonstration: without gain calibration [page 14] the effective CSA gain is here 0.75mV/fC.

1.) 1M cable termination: saturation > 2.2 V

$$CSA[V] = 0.7396 * Q_{in}\ [pC]$$

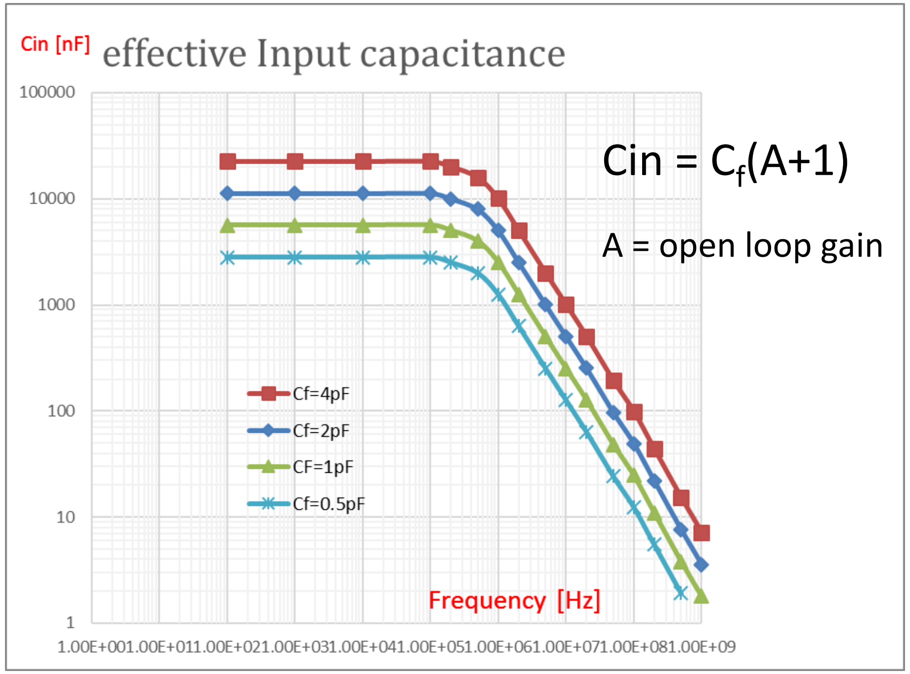
compare to value of
$Gain_{CSA}$ = 0.75mV/fC on [page 14]

2.) 50Ω cable termination: saturation > 1.1 V

Note:
For attenuation of input charges above 2pC, external methods (smaller AC coupling capacitor, capacitive cable less detector gain, etc.) have to be used.

CSA input capacity

(no detector connected)

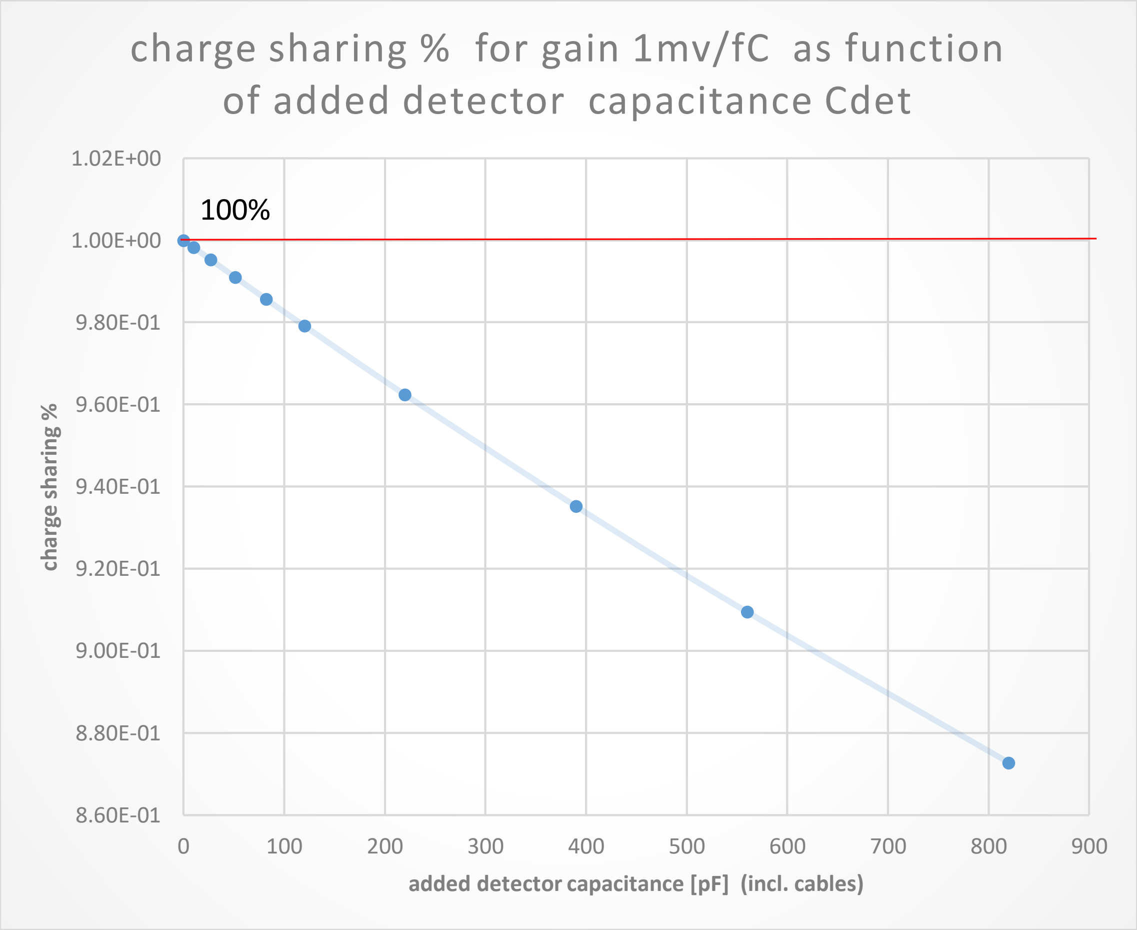


The effective input capacity of CSA amplifiers is high since the “Miller effect” multiplies the feedback capacitor C_f with open loop gain $A(\omega)$ of the amplifier [4]. As the amplifier gain is frequency dependent the input capacity is also frequency dependent.

Cin ~ 5.6 nF up 100kHz	CSA with C_f = 1pF (nominal value)
Cin ~ 2.5 nF @ 1MHz	Charge gain = 1mV/fC
Cin ~ 250pF 10 MHz	Input impedance R_{in} ~ 75 Ω
Cin ~ 25pF @100 MHz	Discharge time contant $\tau = 1\ \mu s$

Note: Due to the relatively high C_{in} of powered CSA’s, their spark immunity is relatively high due to lower input voltages ($U = Q/C$) as compared to non-powered CSA’s which are correspondingly more sensitive to spark damage.

Charge sharing
detector and CSA amplifier



The measured input charge Q_{in} is a share of the intrinsic detector charge Q which divides up on the detector capacity C_{det} and the CSA input capacity C_{in} as $Qi = \frac{Q}{1+Cdet/\,Ci}$, see [page 15]
The charge sharing measures in % how much of the total generated charge Q is measured by the preamplifier as Qi.

For C_{in}>> C_{det} the charge sharing is close to 100%, for example at C_{det} =100pF the charge loss is 2% and for C_{det}= C_{in}[5.6 nF] it decreases to 50%.

The effective CSA input capacity for a nominal CSA gain 1mV/fC is C_{in} ~ 5.6 nF [page 19]

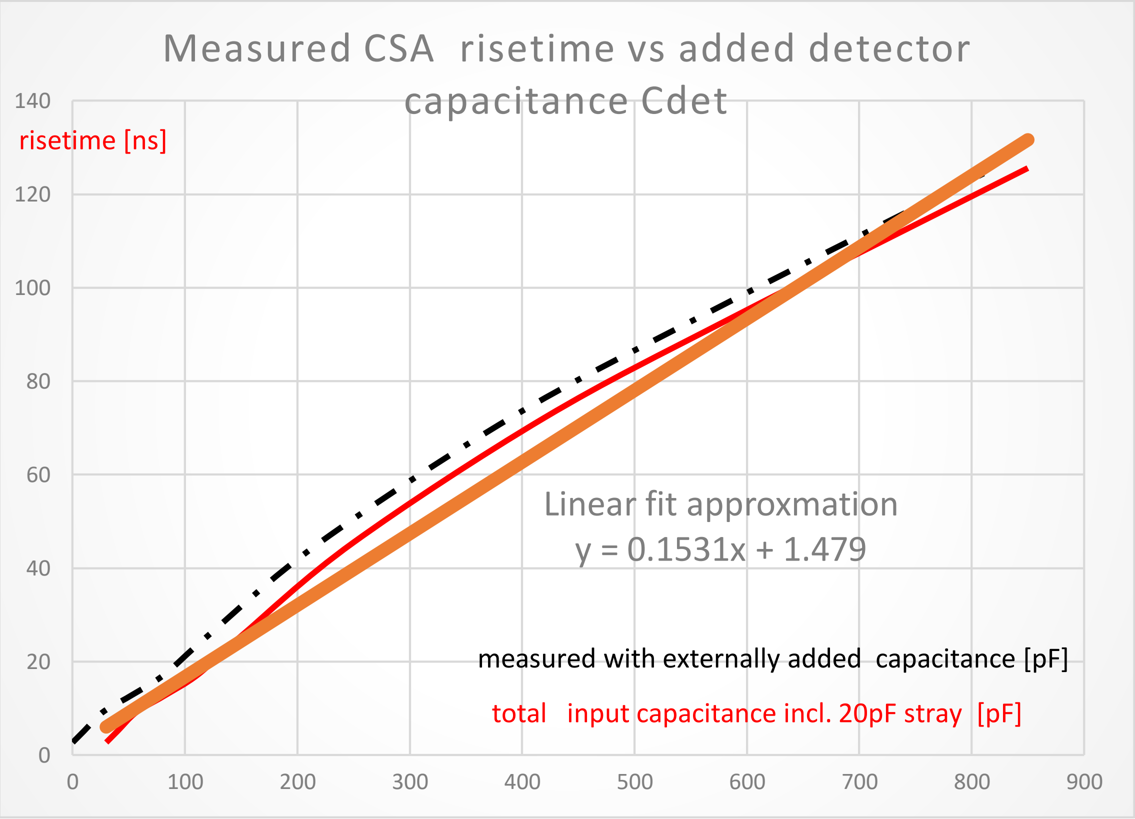
CSA output signal risetime t_{out}
as function of detector capacity C_{det}

theoretical $t_{out}/C_{det} = \frac{1}{\omega_0 \, Cf}$ =0.1ns/pF

measured t_{out}/C_{det} = 0.153 ns/pF + 1.48 ns

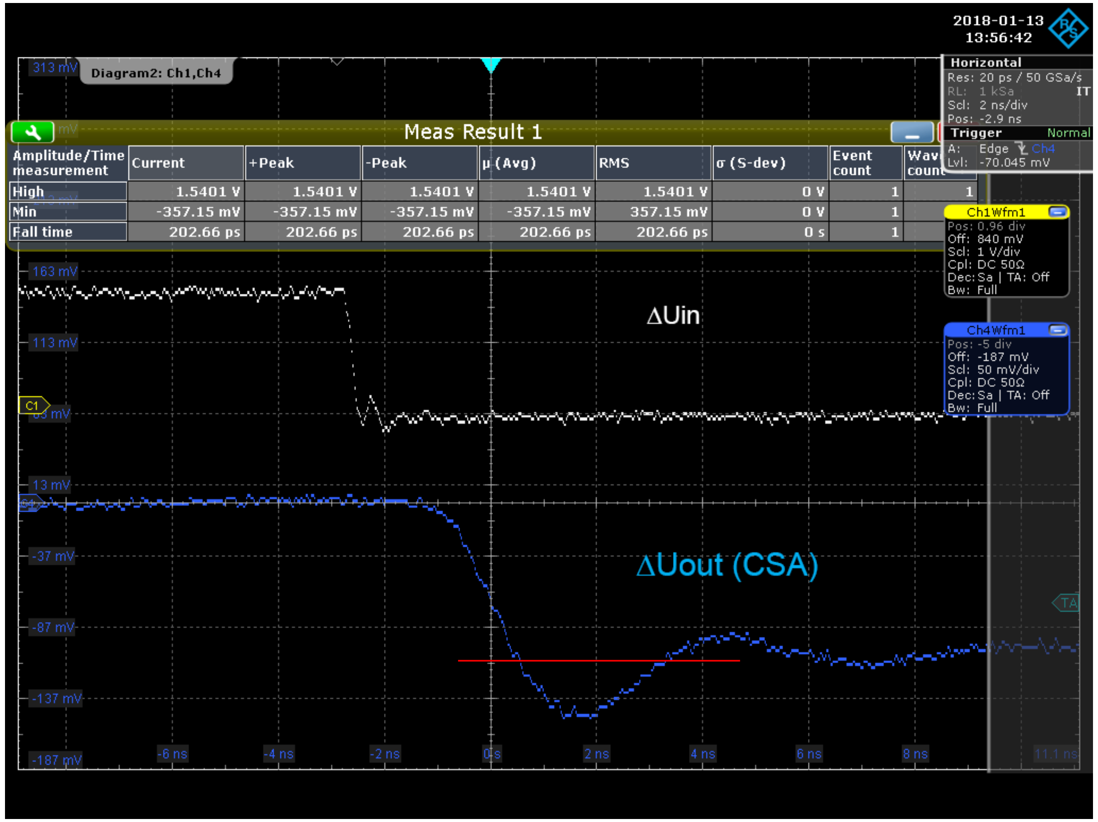
Added C_{Det} *	CSA risetime
10 pF	3 ns
20 pF	4.5 ns
50 pF	9.1 ns
100pF	16.7 ns
200pF	32 ns

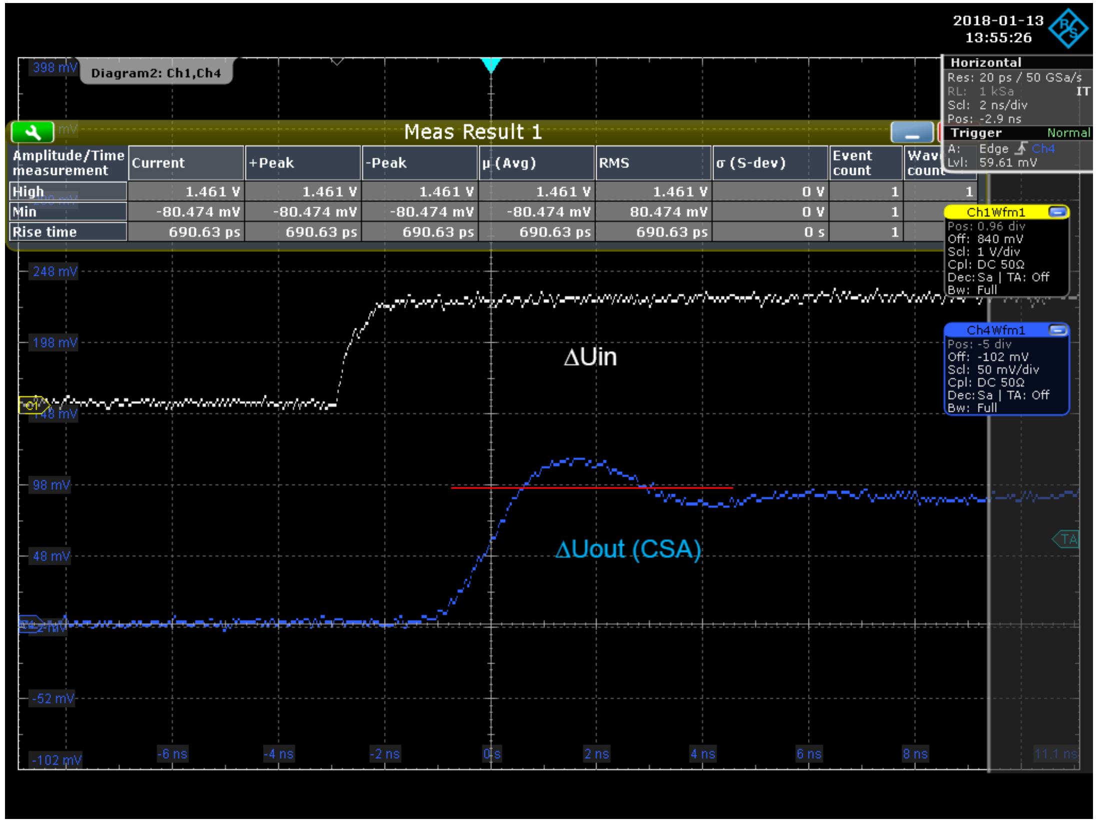
Note: the CSA risetime must be less than the shaping time of the following shaper, hence the APIC fast shaper with τ_s=1/2 τ_p = 15 ns should be used only up to added C_{det} < 100 ns



*including cables

CSA response to non-matched input signals





The CSA output step shows over- or undershoot in the input signals are badly matched with the CSA input Impedance (nominal 75Ω + 25Ω spark protection) see also [page 24]

CSA input Impedance

a.) from GBP Gain-Bandwidth Product [4]

Input impedance $R_{in} = Z_{in} = \frac{1}{2\pi * GBP * Cf}$ hence with GBP* =1.6 GHz

CSA input Impedances $\mathbf{Z_{in} = R_{in}}$ depending on feedback capacitor C_f

C_f	$Z_{in} = R_{in}$
4 pf	25 Ω
2pF	50 Ω
1pF	100 Ω (theoretical Zin for nominal feedback capacitor Cf)
0.5pF	200 Ω

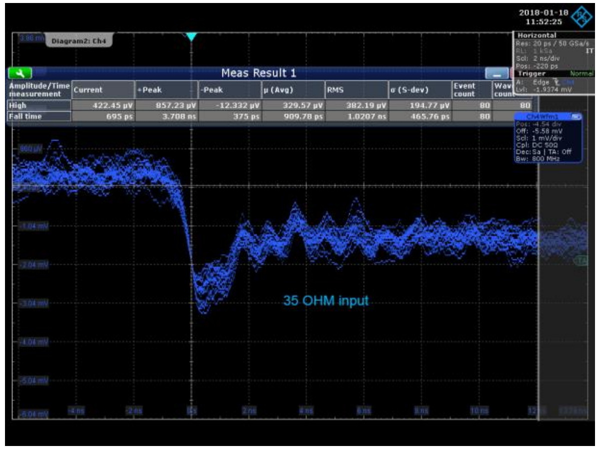
Note: The CSA input impedance has a real value (like a coax cable) and makes a time-constant with the AC input coupling capacitors. Charge coupling between neighboring gas detector strips, i.e. cluster size, gets less with smaller input impedance !

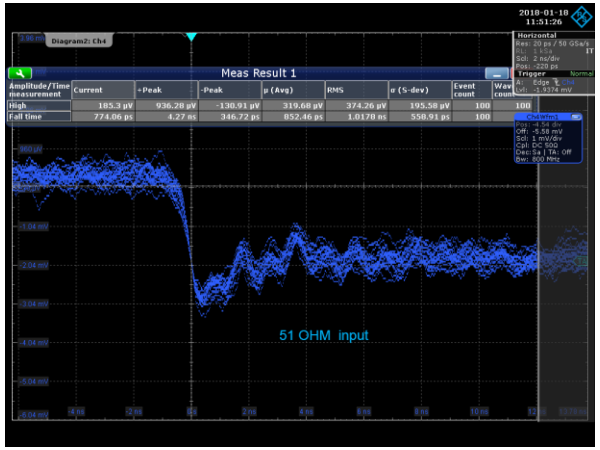
- GBP = gain of an amplifier as function of frequency becomes = 1 at ω_o = GBP. The amplifier used in the APIC V4.x GBP =1.6GHz. Future APIC versions V5 may have higher GBP and hence smaller input impedance

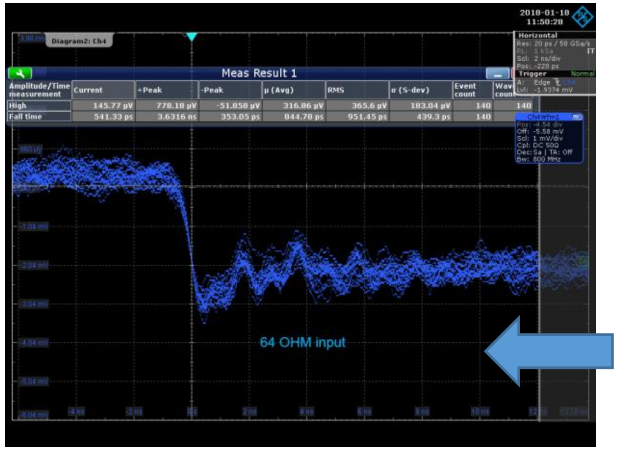
CSA input Impedance

2.) 75Ω via reflections versus input signal impedance

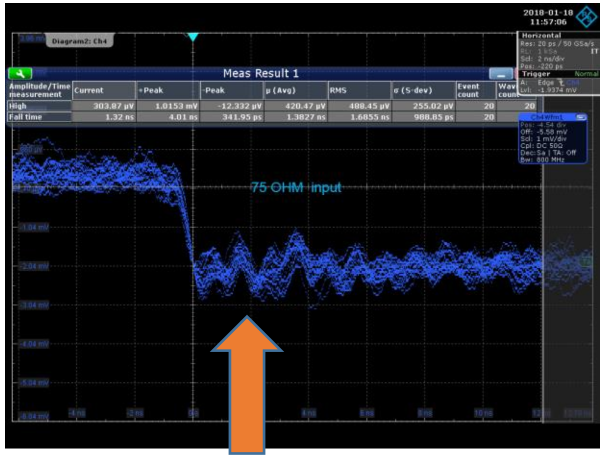
The total APIC V4 external input impedance R_{input} must include 25Ω series resistance of the spark protection [page 30] hence R_{input} = 100Ω



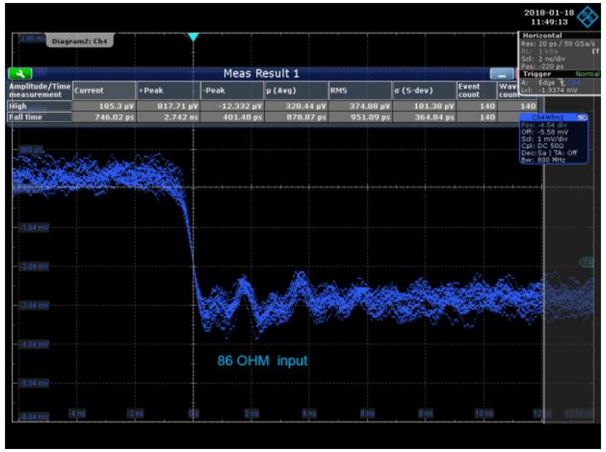


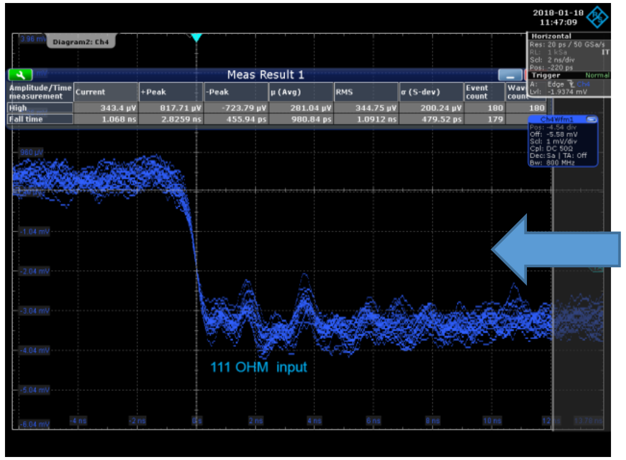


negative reflections superimposed: signal tail smaller than peak (R < Zin)



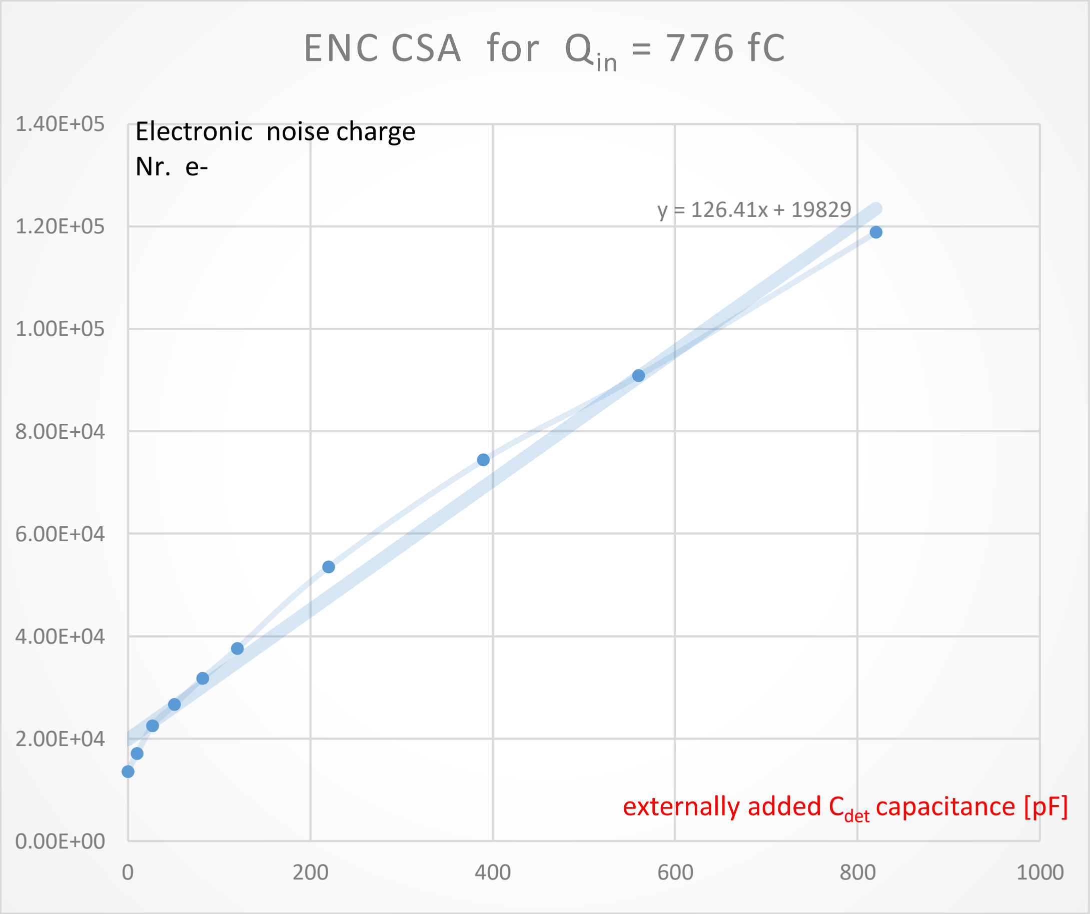
75 OHM: peak equal to tail , minimum reflections





positive Reflections Superimposed: signal tail bigger than peak (R > Zin)

ENC electronics noise of CSA preamplifier



$$ENC^* = \frac{U_{rms}}{e-} / \frac{2 * U_{peak}}{\Delta Q_s} = \frac{U_s \; Cs}{e-} * \frac{U_{rms}}{2 * U_{peak}}$$

U_{rms} is the RMS noise without ΔQ_s charge signal, U_{peak} the RMS peak for a a constant injected test charge signal ΔQ_s = $U_s C_s$ where U_s is the test Voltage amplitude and Cs the test coupling capacitor.

The ENC was measured for a range of externally added capacitances, giving

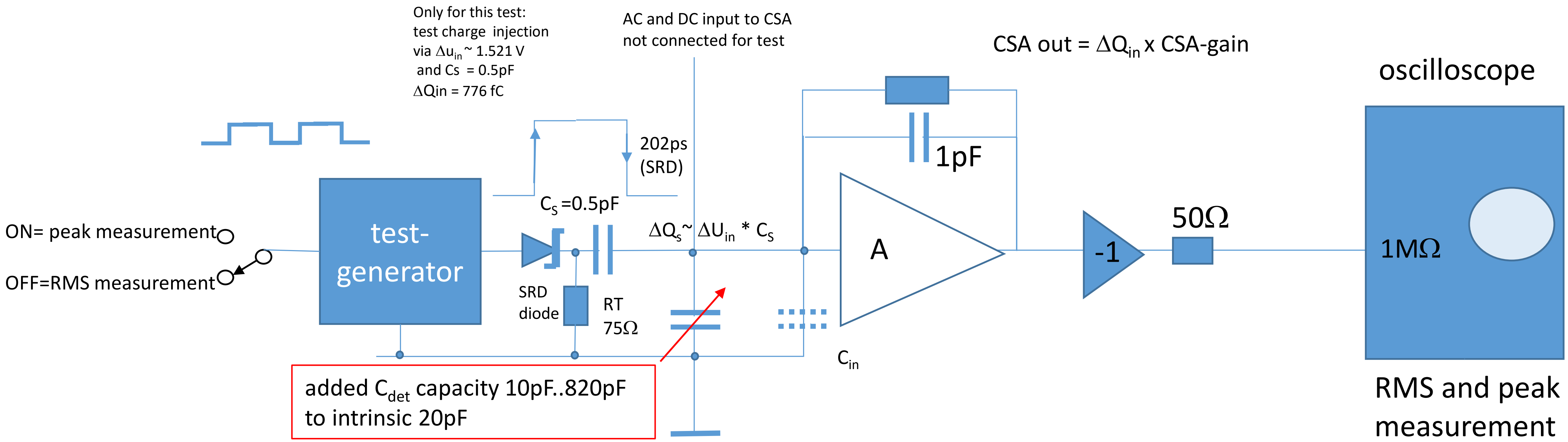
a quasi linear fit :

ENC_{csa} = [126.4 e-/pF]* C + 19830 e-

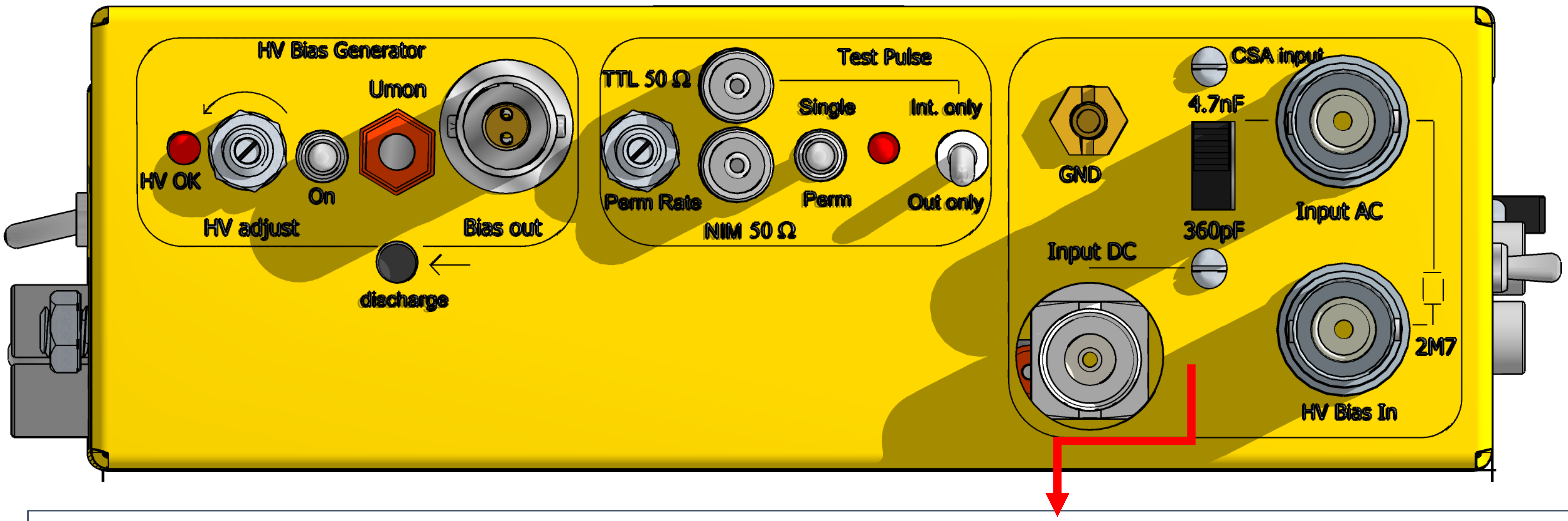
Note: the ENC noise of the same signal after the shapers is significantly lower [page 48]

* Ref [11]

Test setup ENC measurement



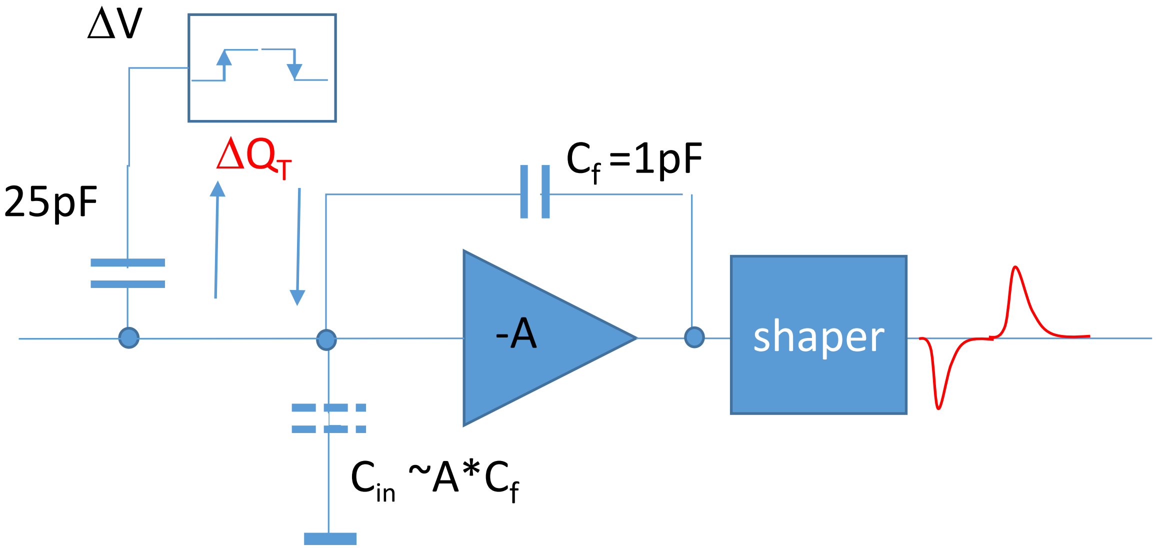
APIC: Detector inputs to CSA preamplifier



Input +/- DC : direct input to CSA preamplifier (can be disconnected from AC inputs via internal PCB switch)
BNC connection to detector as short as possible, BNC Ground is detector Ground , GND is chassis GND
Input +/- AC : from (non-grounded strips, meshes, Diodes etc.) with AC coupling selected as 4.7nF/360pF
HV bias : Detector bias input max 4kV, provides LRC filtered bias field to the detector via the Input AC line

Test charge Q_T injection CSA input

ΔV amplitude = 1.51V see measurement [page 22]



$$\Delta Q^*_T = \frac{C_T}{1+\frac{C_T}{C_{in}}} \Delta V \sim C_T\left[1-\frac{C_T}{C_{in}}\right]\Delta V$$

$\frac{C_T}{C_{in}} << 1$ $C_T = 0.125$ pF

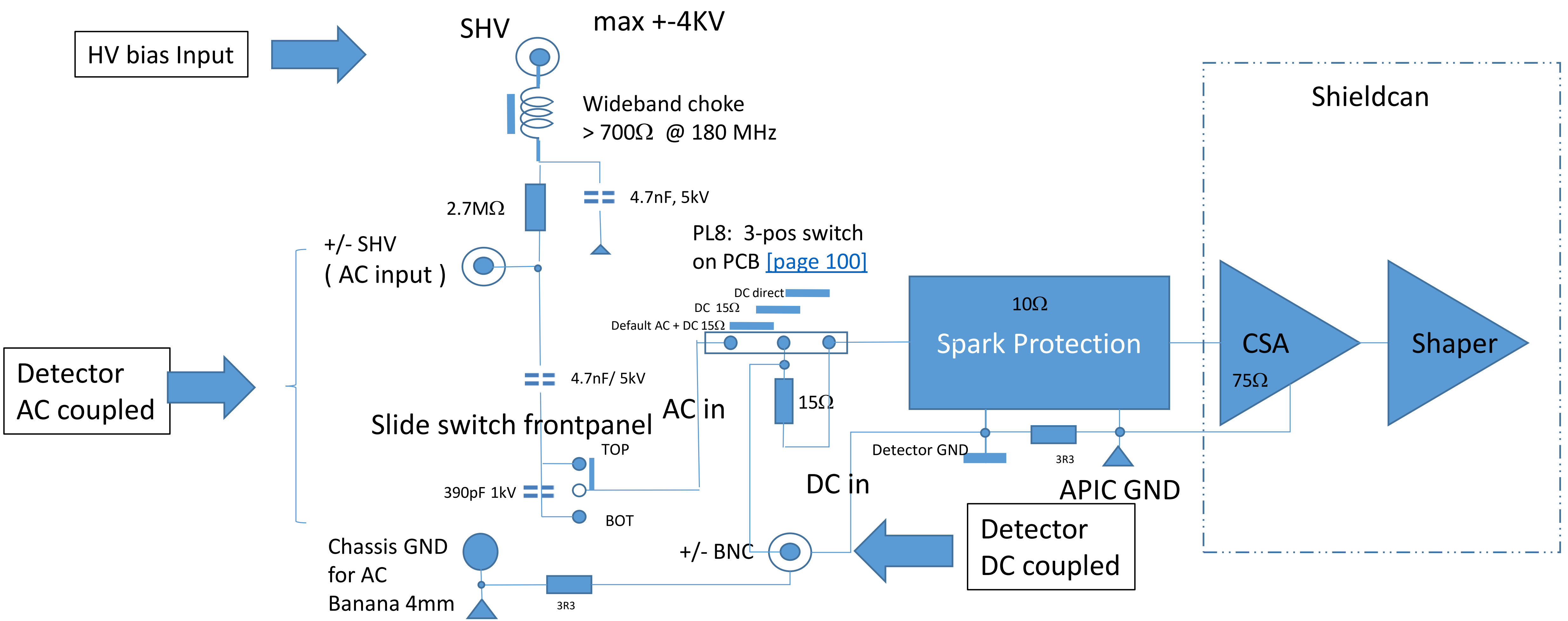
$C_{in} = 5600$ pF

$$\Delta Q_T \sim C_T * \Delta V = 189 \text{ fC}$$

Valid for standard APIC configuration

* Ref [4]

APIC Input AC-DC signal connectivity

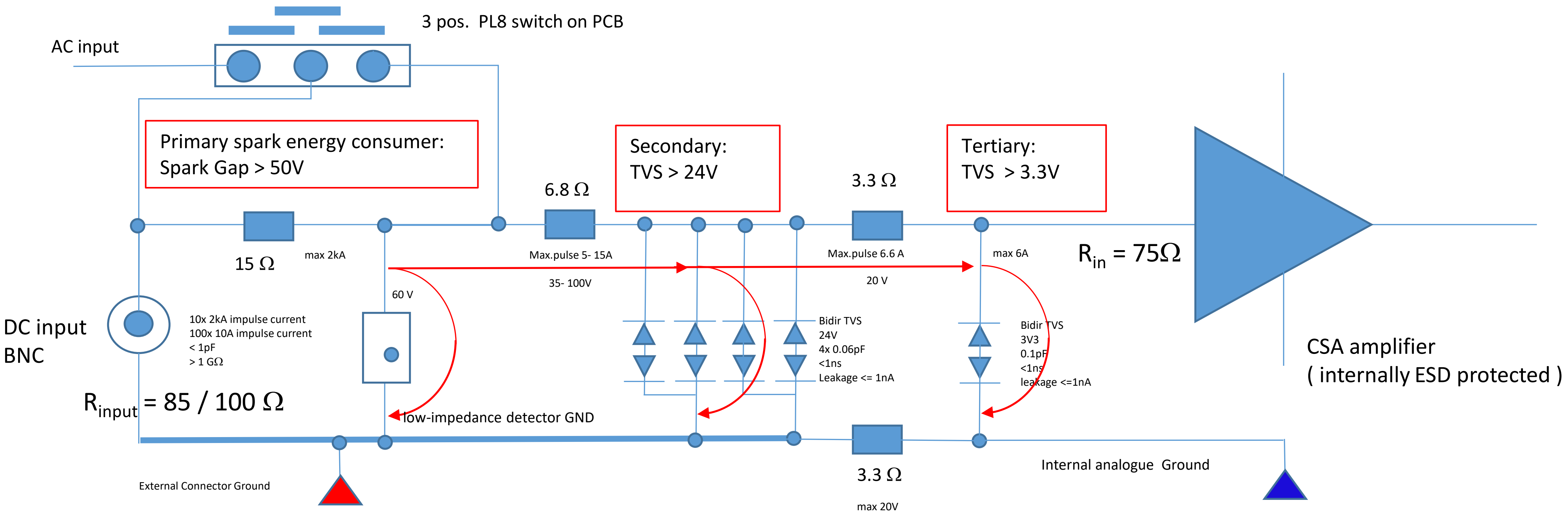


Spark protection

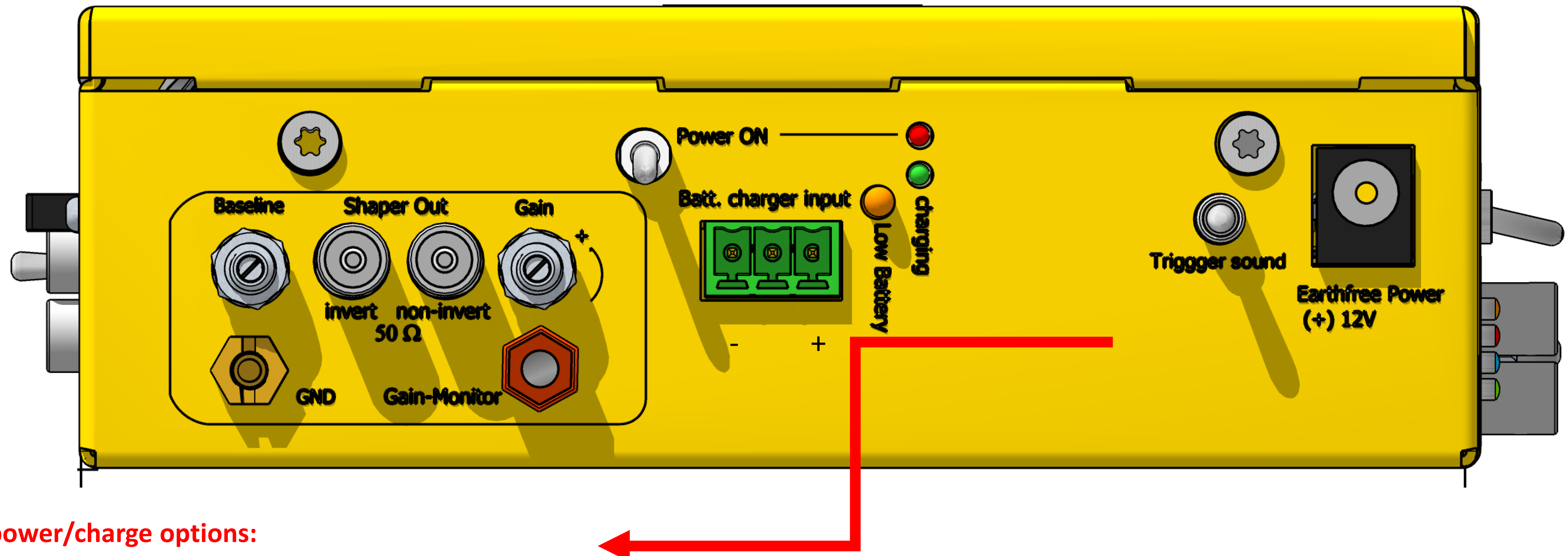
APIC triple spark protection scheme:

$\Delta U_{in} >> 50V$: 1 ns -> $\Delta U_{out\ max} = 3V$

$C_{parallel} = 1pF$, $R_{series} = 25\Omega$, $I_{leak} <= 1nA$



APIC: **Power and charging**



2 power/charge options:

- Battery charger input: Solar panel or any Voltage source 14V .. 40V, charge during operation possible, up. 96% max. Battery capacity
- Direct Power: DC power plug from standard +12V AC/DC adapter (5mm dia, earthfree plug): prompt power promptly available even if
- battery is empty, charge up capability 90%

Note: Connect power when the orange "low battery" LED is blinking, the green charger LED lights up when charging is active

Direct charging

The simplest way to operate & charge APICs
is via state-of-art + 12V AC-DC adapter >= 250mA

Only use ground –free and short-circuit proof adapters with internal DC-DC technology and Voltage tolerances +/- 10%. The Maximum Voltage must be less than 12.5V @ 200mA

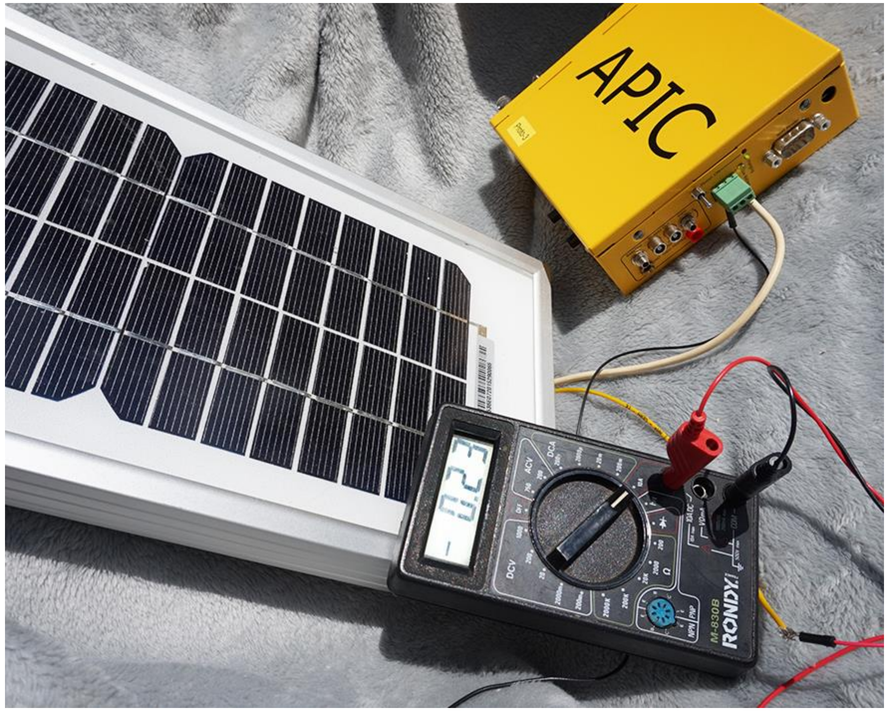
The 5mm diameter round plug shell (+ on middle pin) must not get in contact with the chassis.

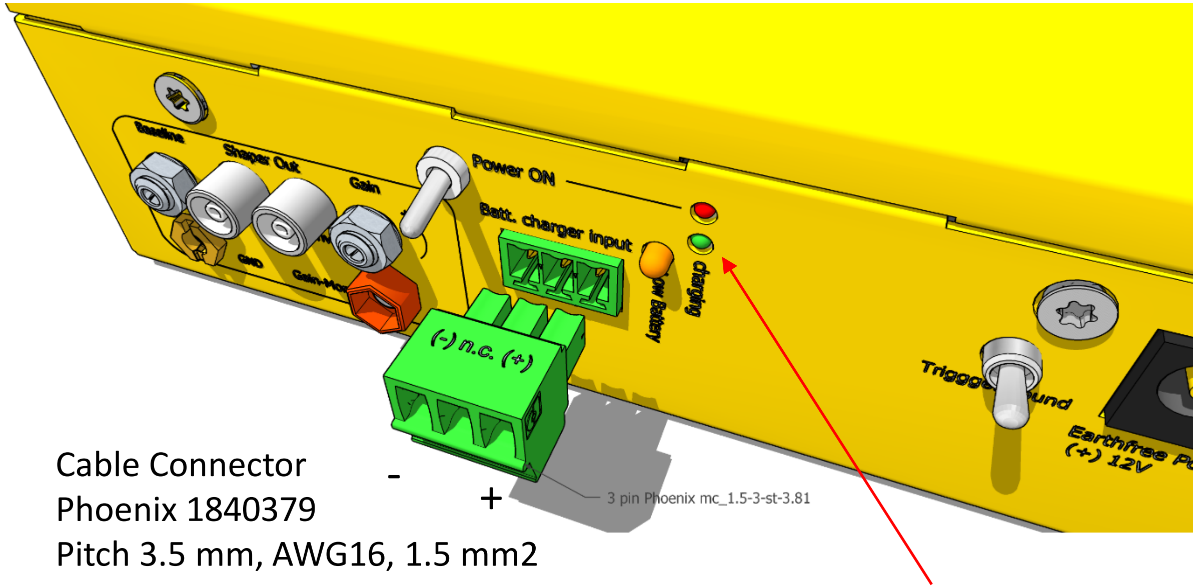
Some recommended adapter models:

STONTRONICS P/N T3624ST 12V=1A
XP-Power VEL05US120-EU-JA 12V=420mA

Note1: the RS232 charge option has been removed
on APIV V4.1+ due to ground loop problems

Solar / full charging





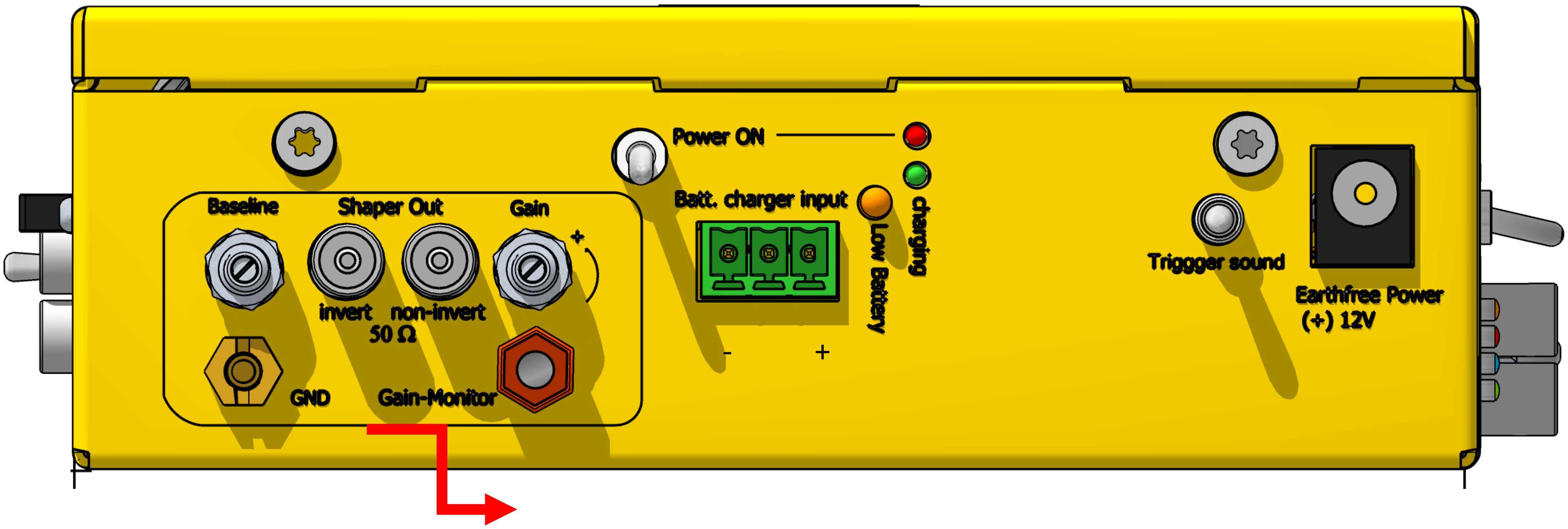
Cable Connector
Phoenix 1840379
Pitch 3.5 mm, AWG16, 1.5 mm2

- +

green charging LED
auto-extinct @ 12.4V battery (98% max.)

Full charging of APIC proto via 5W Solar panel (0.23 A @ 15V when sky is part. cloudy)
alternatively any Voltage source between 12V and 48V, set current limit to 250mA

APIC: Shaper gain control and monitoring

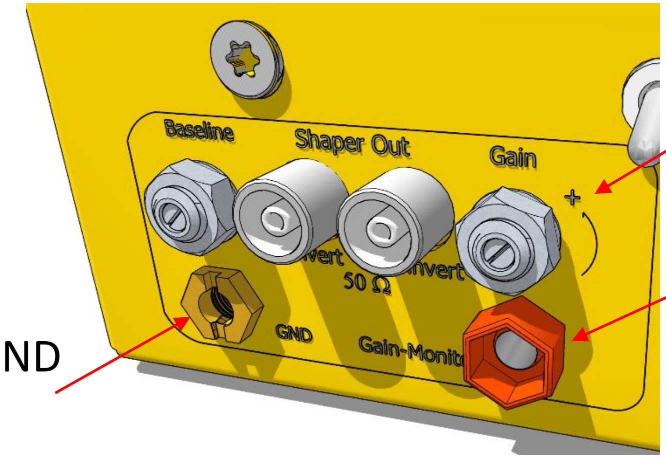


Shaper output (NIM 50 OHM) is available with 2 selectable peaking times. The “invert” and “non-invert” outputs deliver complementary signals, “invert” means opposite polarity than input signal polarity and vice versa.
The baseline can be selected “zero” or “variable”. The variable baseline can be shifted by +/- 150m V via the 15-turn baseline potentiometer. The shaper gain can be trimmed from 0… 20 relative to the CSA preamplifier peak signal. The signal gain relative to the peak CSA signal can be measured via the Gain-Monitor voltage .

Shaper properties

- Shaper gain via 15-turn potentiometer and gain monitor Voltage gain = 0.0375 e $^{4.4156*|Vmon[V]}$ relative to CSA 1MΩ output [page 36,37]
- Shaper complementary output signals at 50Ω termination saturates at 1V, and at 1 MΩ termination, saturates at 2V [page 38,39]
- Shaper linear dynamic range +/- 2.2pC [page 40,41]
- Shaper peaking time selection, fast: = 30ns (shaping time 17.5ns) slow: 350 ns (shaping time 175 ns) [page 42]
- Shaper output shapes and amplitudes have opposite polarities on the 2 complementary outputs [page 43]
- Shaper relative amplitudes +/-10% (tunable +/- 2%) [page 44]
- Shapers, constant peak time over variable input signal amplitudes [page 45]
- semi-Gaussian shaper CR2RC with timing output that can be fitted with Gamma-2(t) timing functions [page 46]
- Relation between shaping-time, peaking-time and rise-time [page 47]
- pole-zero cancellation for asymptotic return-to-zero of subsequent signals [page 48]
- ENC noise of shapers as function of detector capacity ENC_{slow} = 47.3 e- x C_d + 3015 e- [page 49]
- RMS noise measurements slow shaper 3…50 mV in range Cdet = 10pF -1000pF [page 50]
- Noise versus shaping time detector dependent, for 10x10 GEM optimal peaking time around 400 ns [page 51, 52]
- Baseline variable or fixed to zero via slide switch, variable output range +/- 150mV [page 54,55]

APIC: shaper gain monitor



GND

Shaper gain potentiometer 15 turn

V_{mon} voltage pickup (-1.5V .. + 0.07 V)

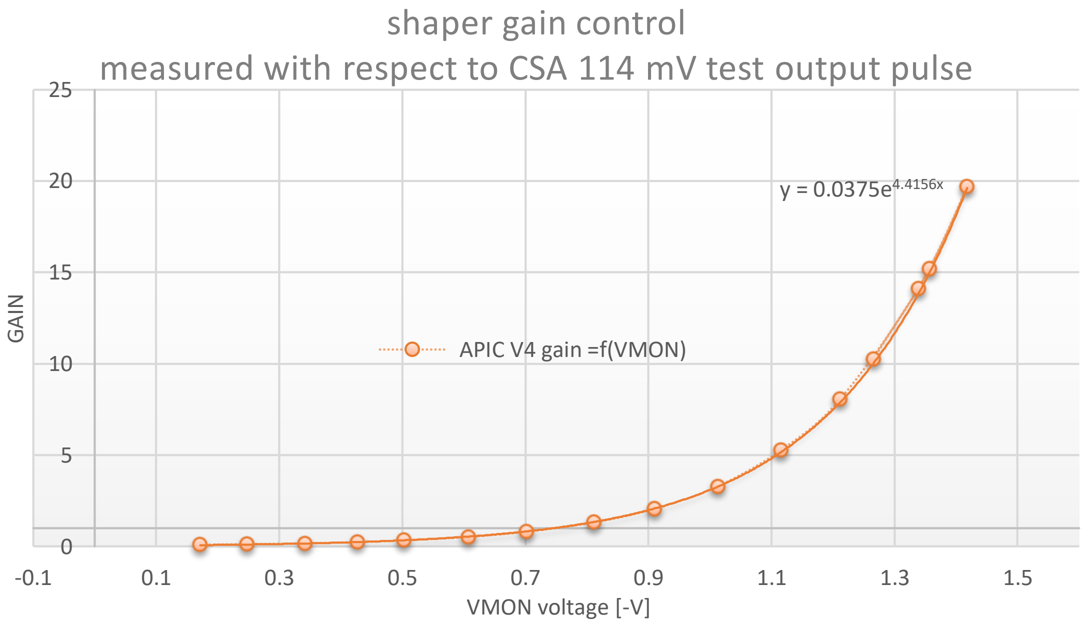
Gain = 0.0375 e $^{4.4156*|Vmon[V]|}$

Gain = 0.1 @ V_{mon} = -0.222V

Gain = 1 @ V_{mon} = - 0.744V

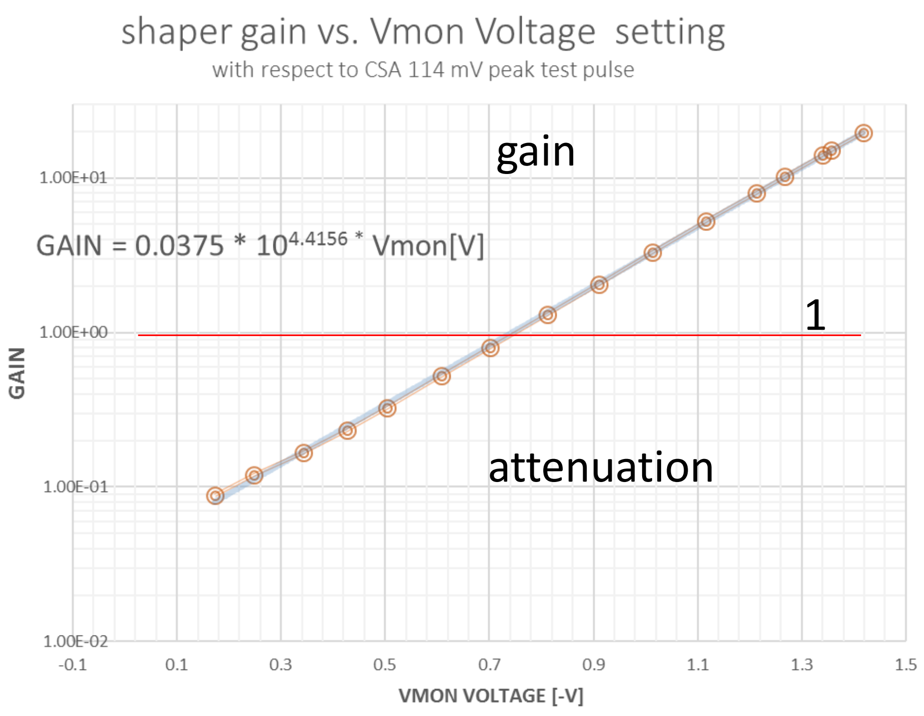
Gain =10 @ V_{mon} = - 1.265V

Gain = 20 @ V_{mon} = - 1.42V

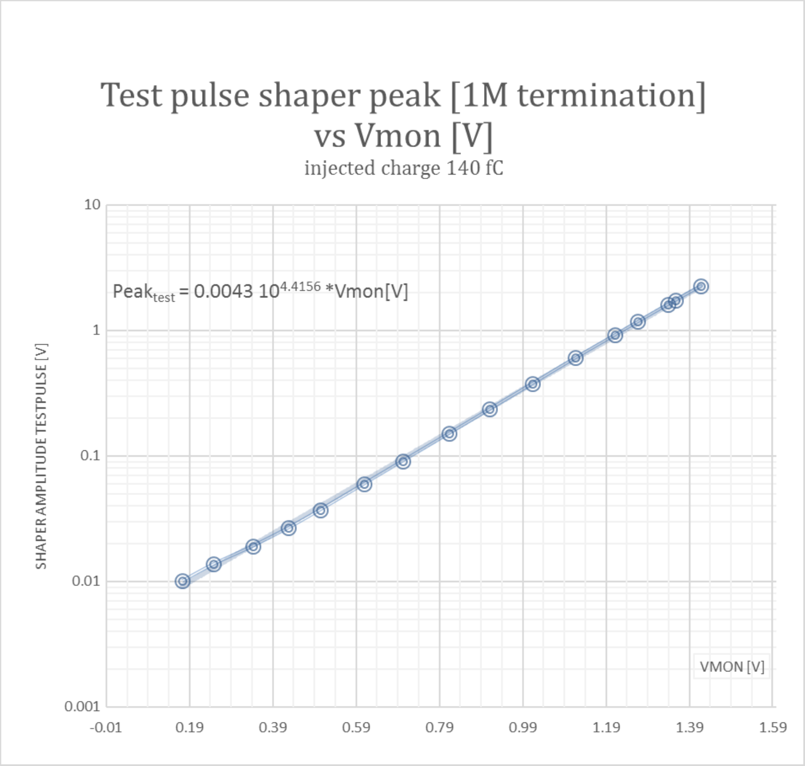


Note: Vmon range is measured as negative Voltage, a small positive range (0.0 …+ 0.07V) is required zeroing the output .

Shaper gain and attenuation



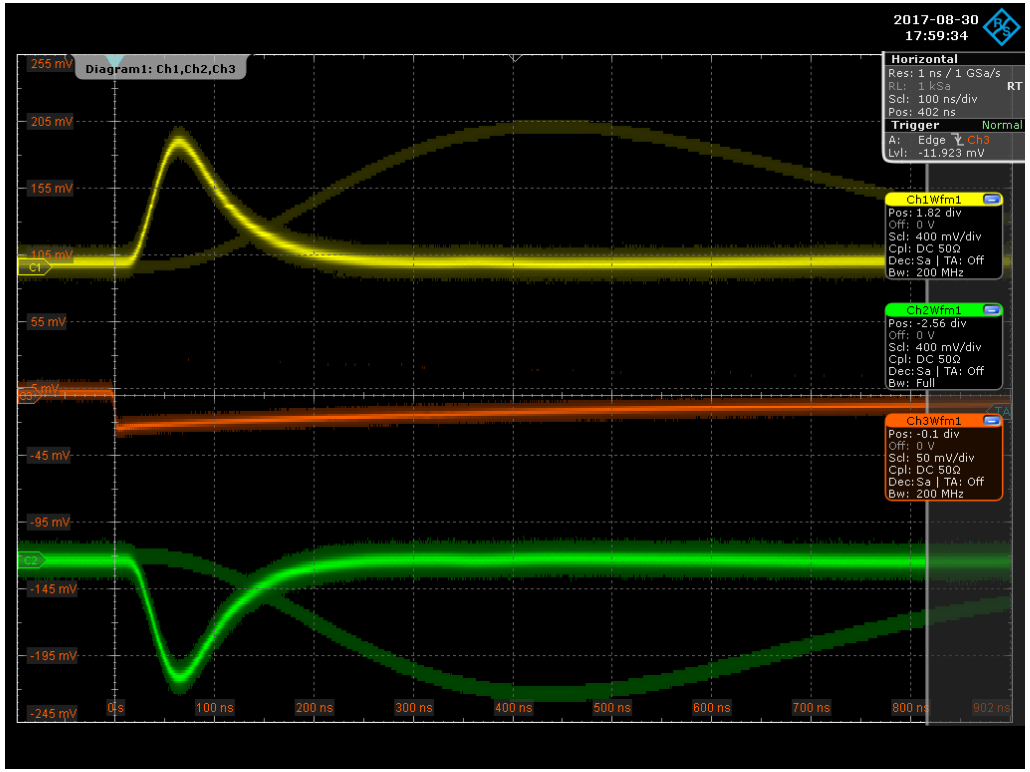
Relative gain relative to CSA



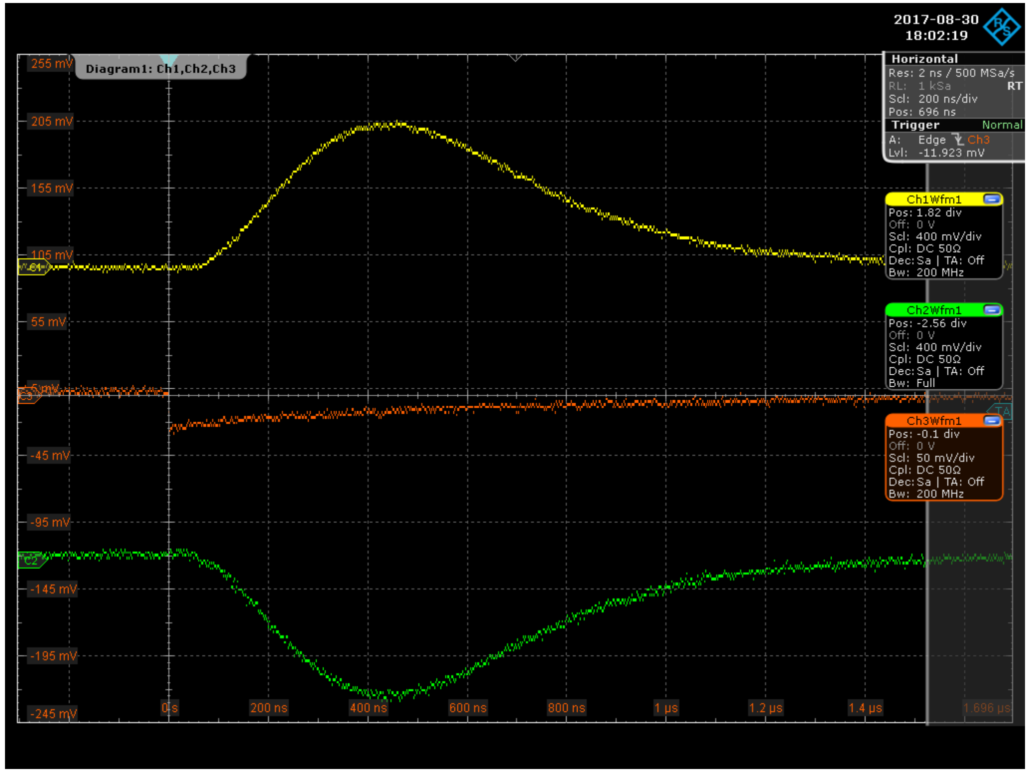
Absolute Voltage from Testpulse

Shaper complementary signals

Dynamic range both positive and negative, complementary outputs with coaxial termination.
Saturation @ 50 Ω: +/– 0.9V max / @ 1MΩ: +/– 1.8V max see shaper dynamic range [page 41]



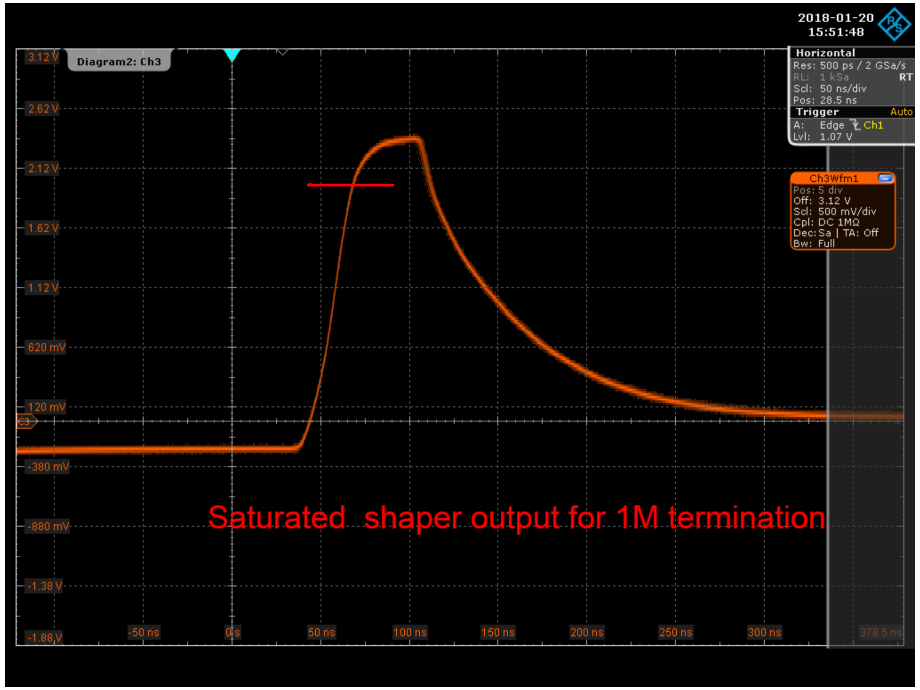
Fast shaper (30ns) selection

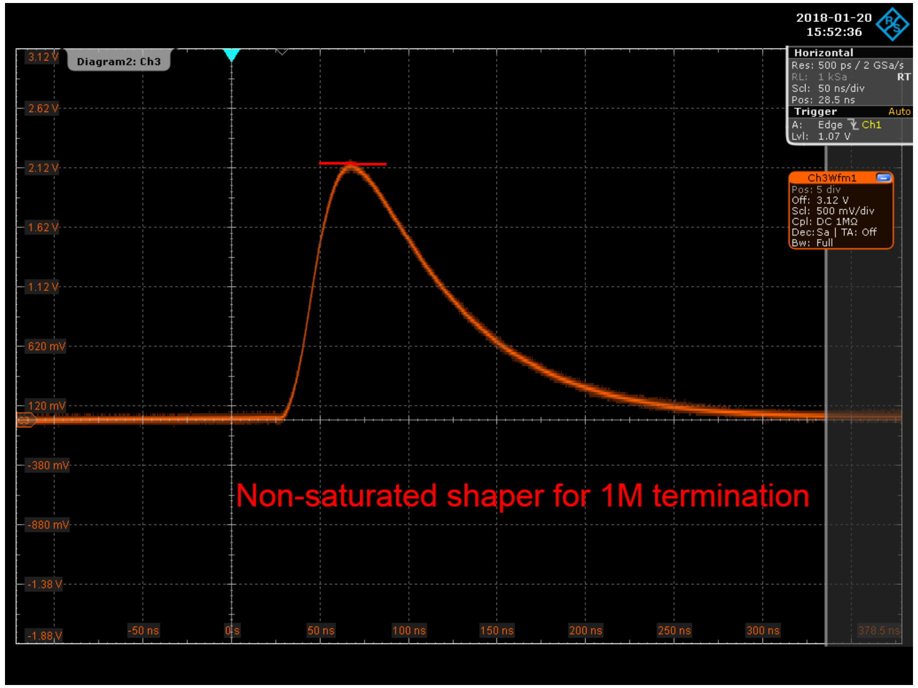


Slow shaper (400 ns) selection

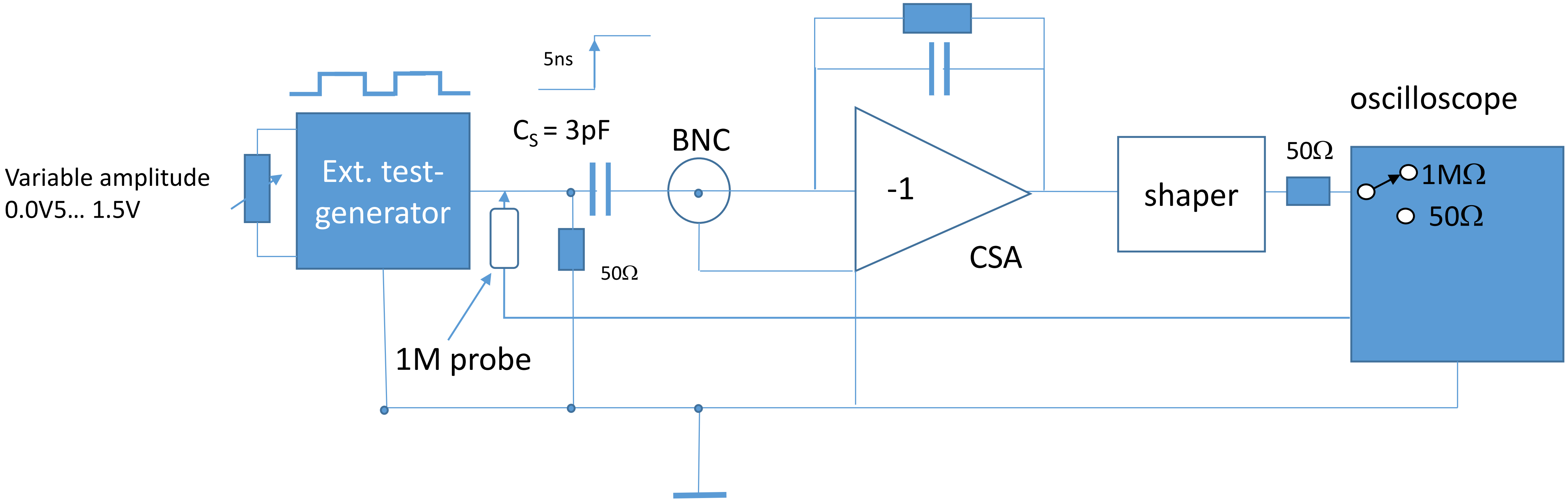
Shaper output termination/saturation

The shaper gain is variable via the 15 turn gain potentiometer
adjust the gain for max. amplitude at 80-90% below saturation
Saturation for 1M termination starts +/- 2V (shown below)
Saturation for 50 Ω termination +/- 1.1V (not shown)

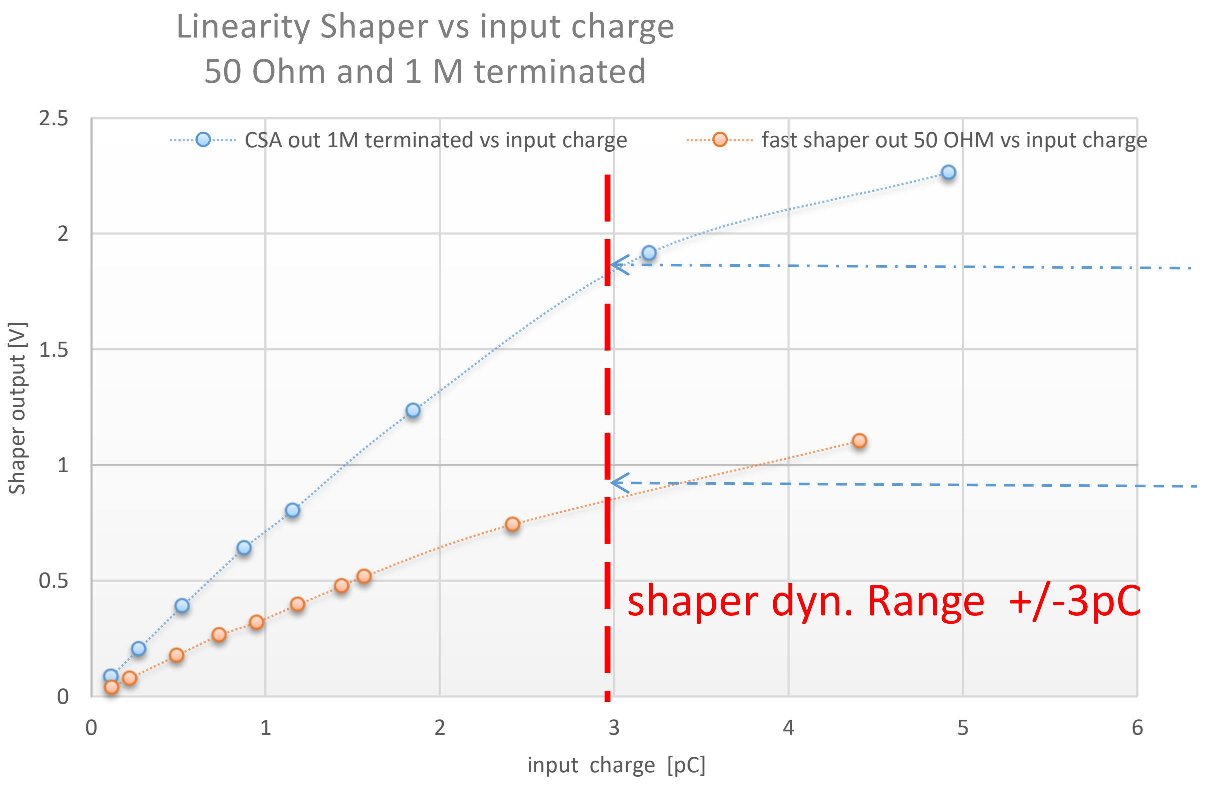




Shaper dynamic range test setup



Shaper Dynamic range vs. input charge



Due to internal 50 Ω series termination of the shaper outputs the amplitude gets divided by 2 when terminating with 50 Ω

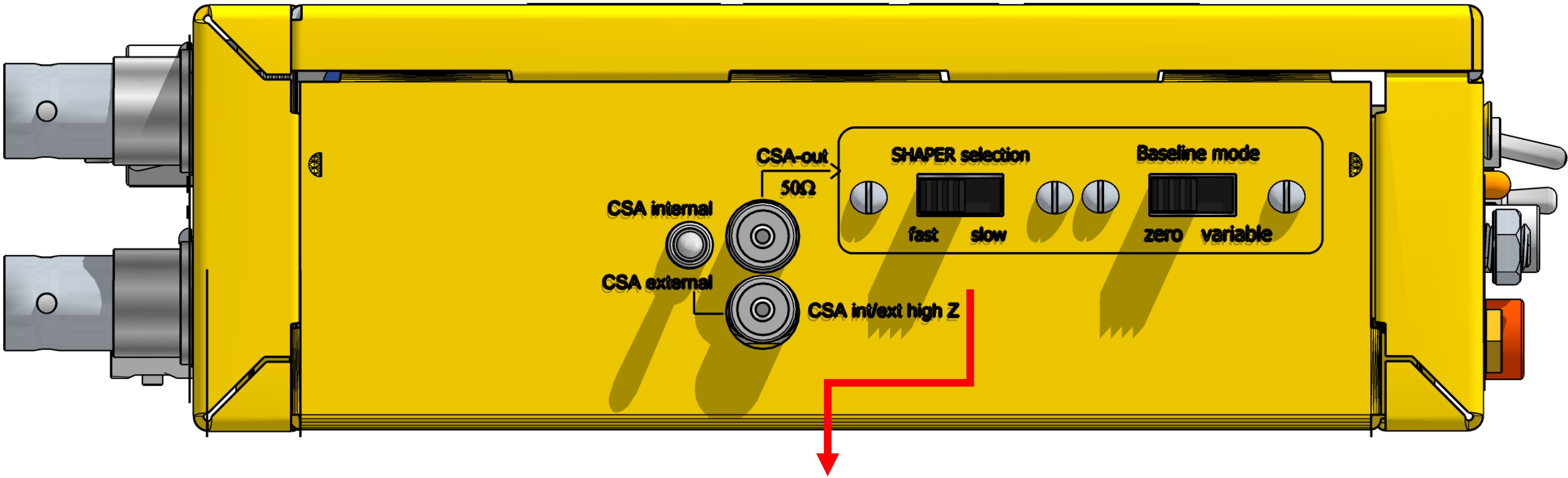
Shaper saturation (1M term.) for > 1.8 V

Shaper saturation 50Ω term.) for > 0.9 V

50Ω termination = 1/2 amplitude , best for timing
1MΩ termination =1/1 amplitude, best for precision

Note: compare dynamic range of CSA preamplifier on [page 18]

APIC: **Shaper selections**



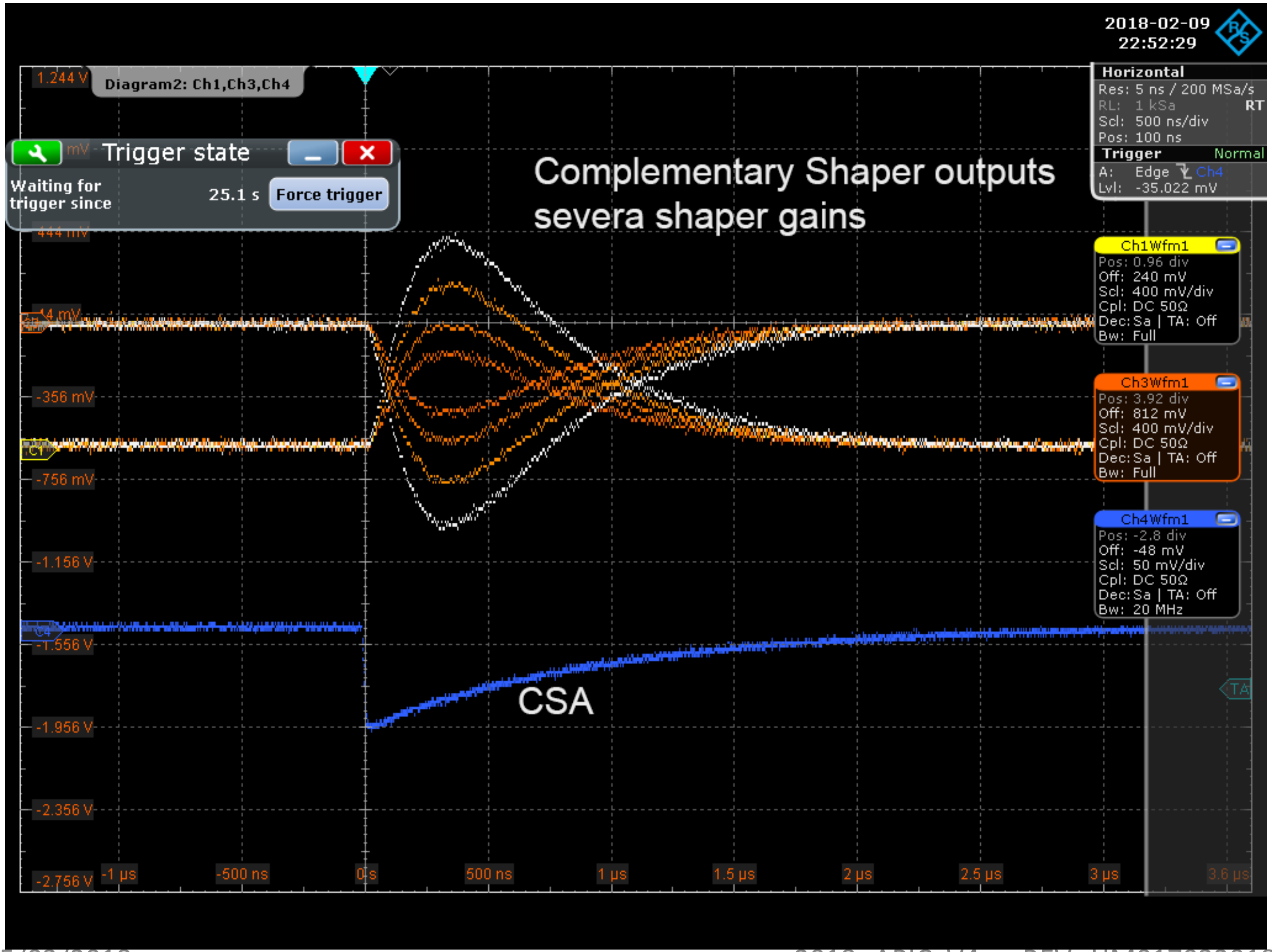
shaper shaping time selection (peaking time = 2x shaping time)

Default configuration

<u>fast:</u> peaking time = 30ns (shaping time 17.5ns)

<u>slow:</u> peaking time 350 ns (shaping time 175 ns)

Complementary shaper outputs

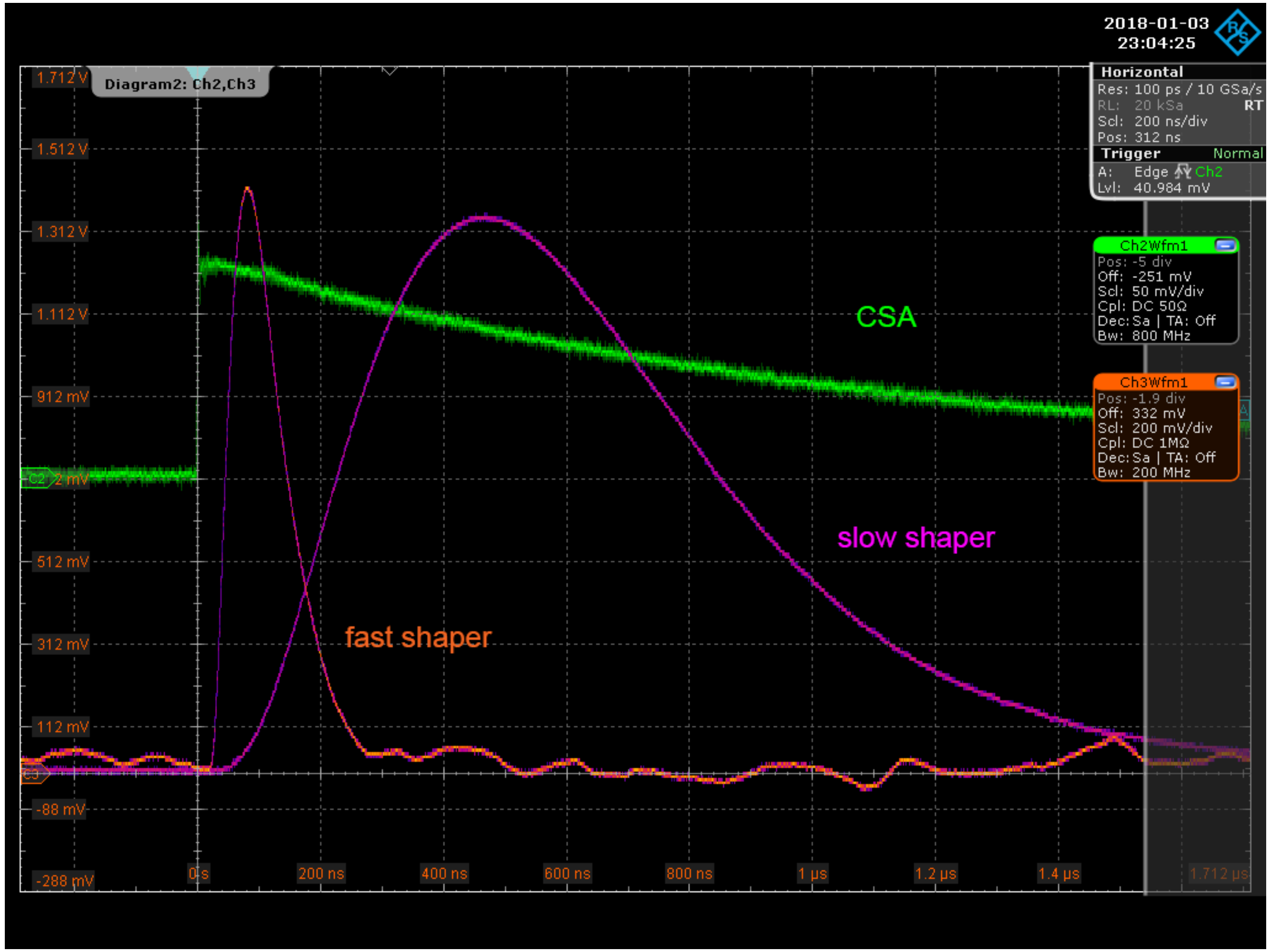


The 2 shaper outputs are complementary with a common gain control.

The non-inverted output has the same polarity as the input charge.

Also the CSA output has the same polarity as the input charge.

Relative shaper CSA amplitudes



The slide-switch selections (fast/slow) result in fast or slow peaking times (default 30 ns/350ns) of approximately equal amplitudes*.

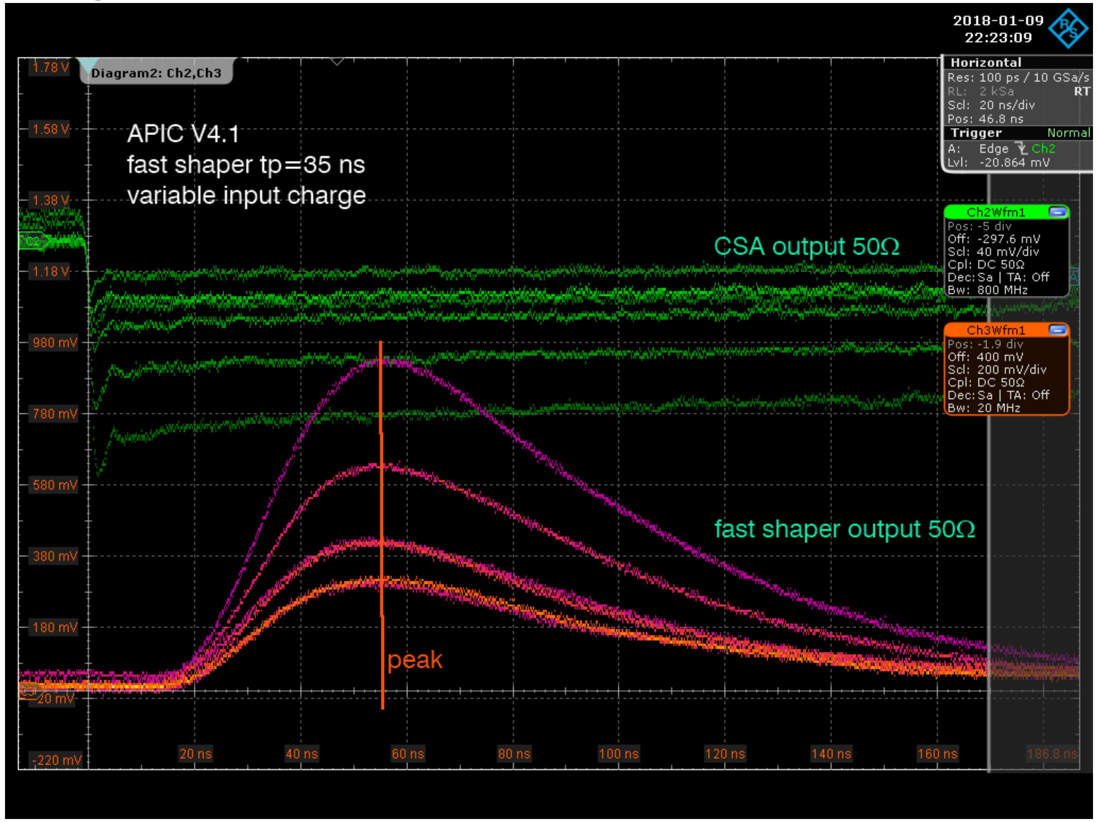
The fast shaper selection applies to high-rate, low capacitance detectors with average rates up to 1 MHz.

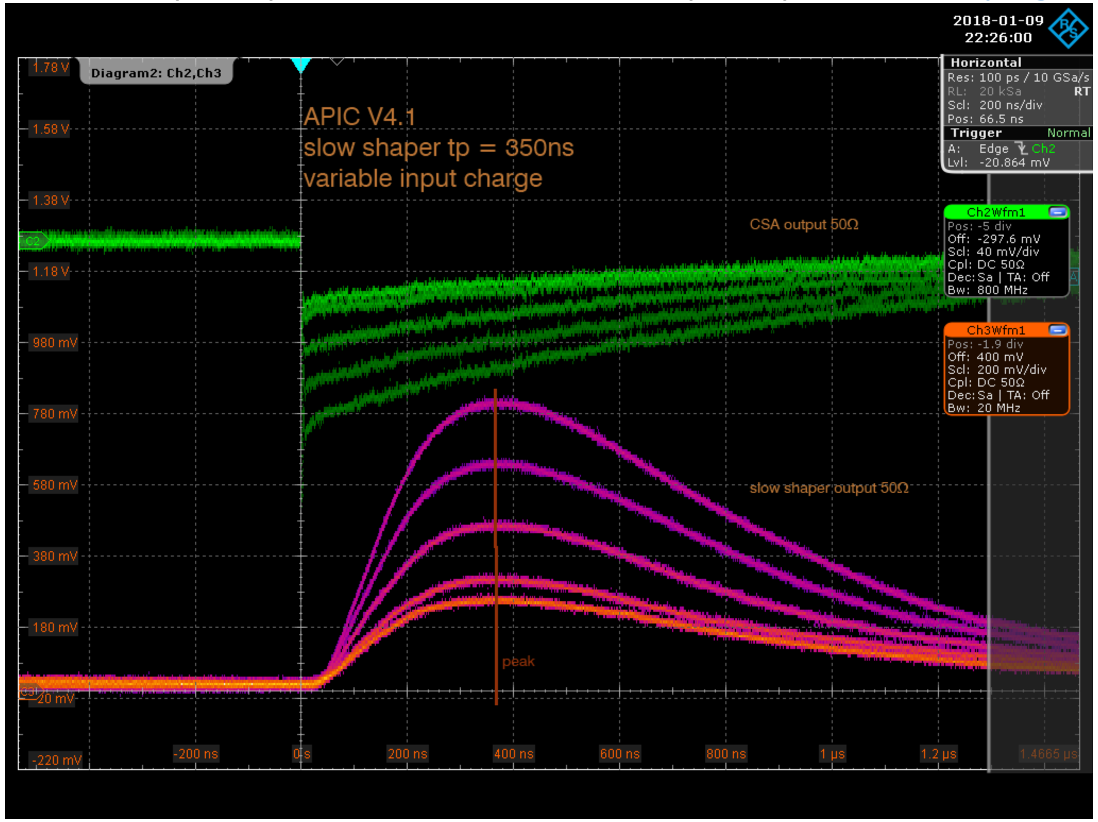
The slow shaper selection applies to low noise measurements of detectors up to C_{det} ~ 1 nF

* Can be tuned on request to +/-2% equality

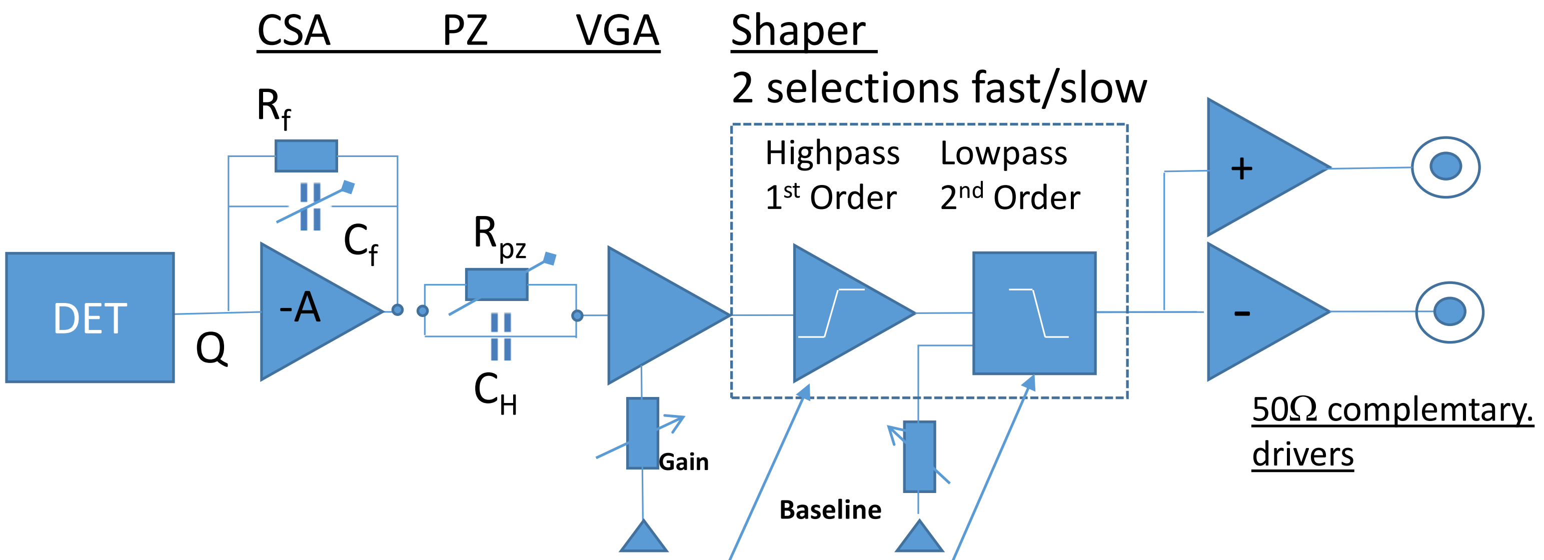
Fast/Slow Shaper output
for variable amplitude input charge

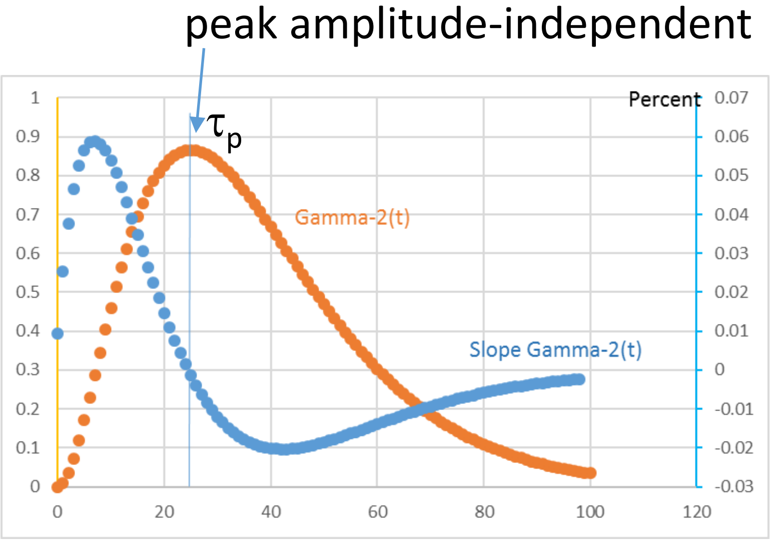
Digitized waveforms can be fitted with Gamma-2(t), for fast shaper tp ~ 30ns, for slow shaper tp ~350ns [page 46]



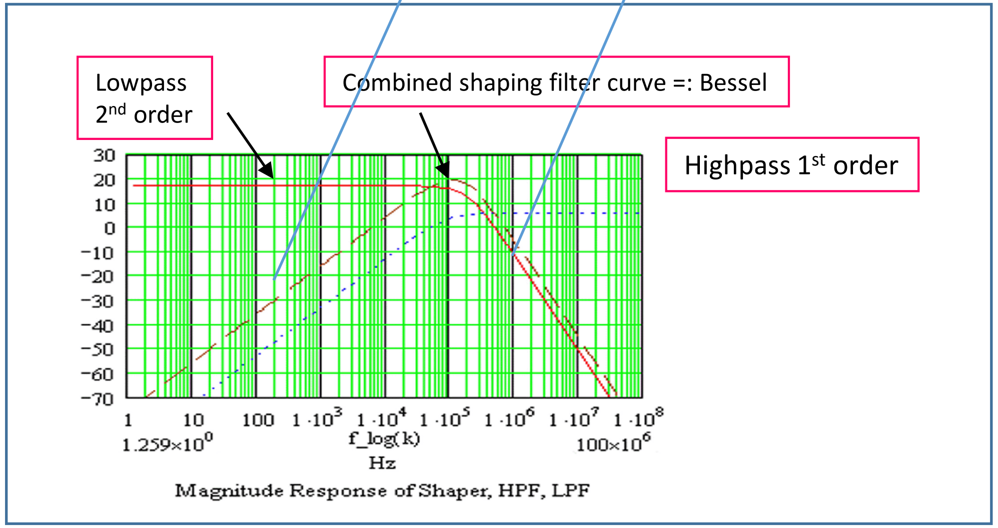


APIC Shapers [3]





2nd order filter charactristics of an APIC shaper



Gamma-2(t) shaper output:

$$V(t) = \left[\frac{2Q \cdot A^2}{C_f}\right] \cdot \left[\frac{t}{\tau_p}\right]^2 \cdot e^{-2\frac{t}{\tau_p}}$$

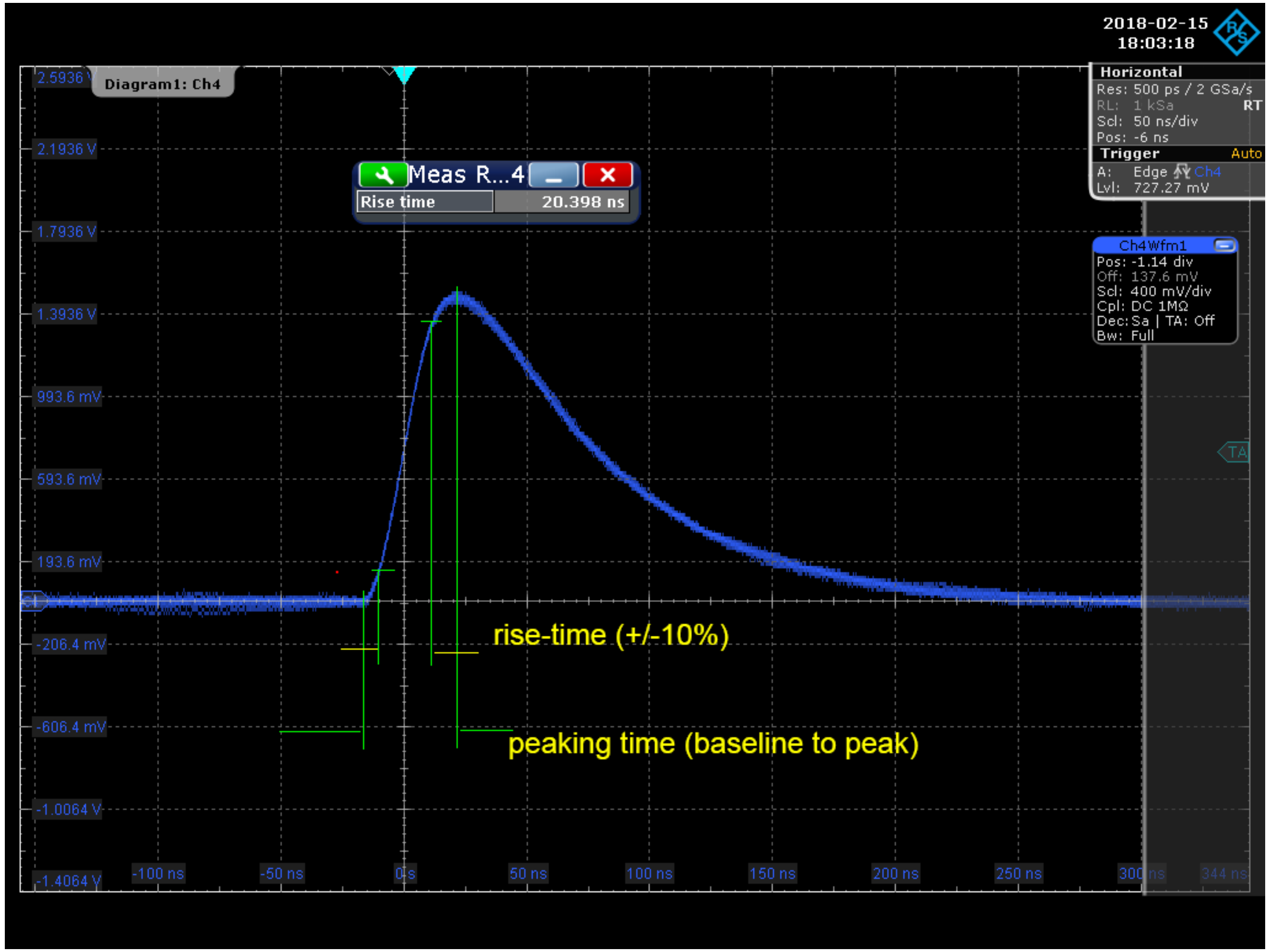
A: CSA Amplifier open loop gain

C_f: CSA feedback capacitor

Q: Input charge to CSA

τ_p: peaking time (2 x shaping time) and assumed shaper gain =1

Shaping-time , peaking-time, rise-time



The analytically important shaper figure is the peaking time $\mathbf{t_p}$ which in case of the 2nd order shaper is related with the shaping time ts as

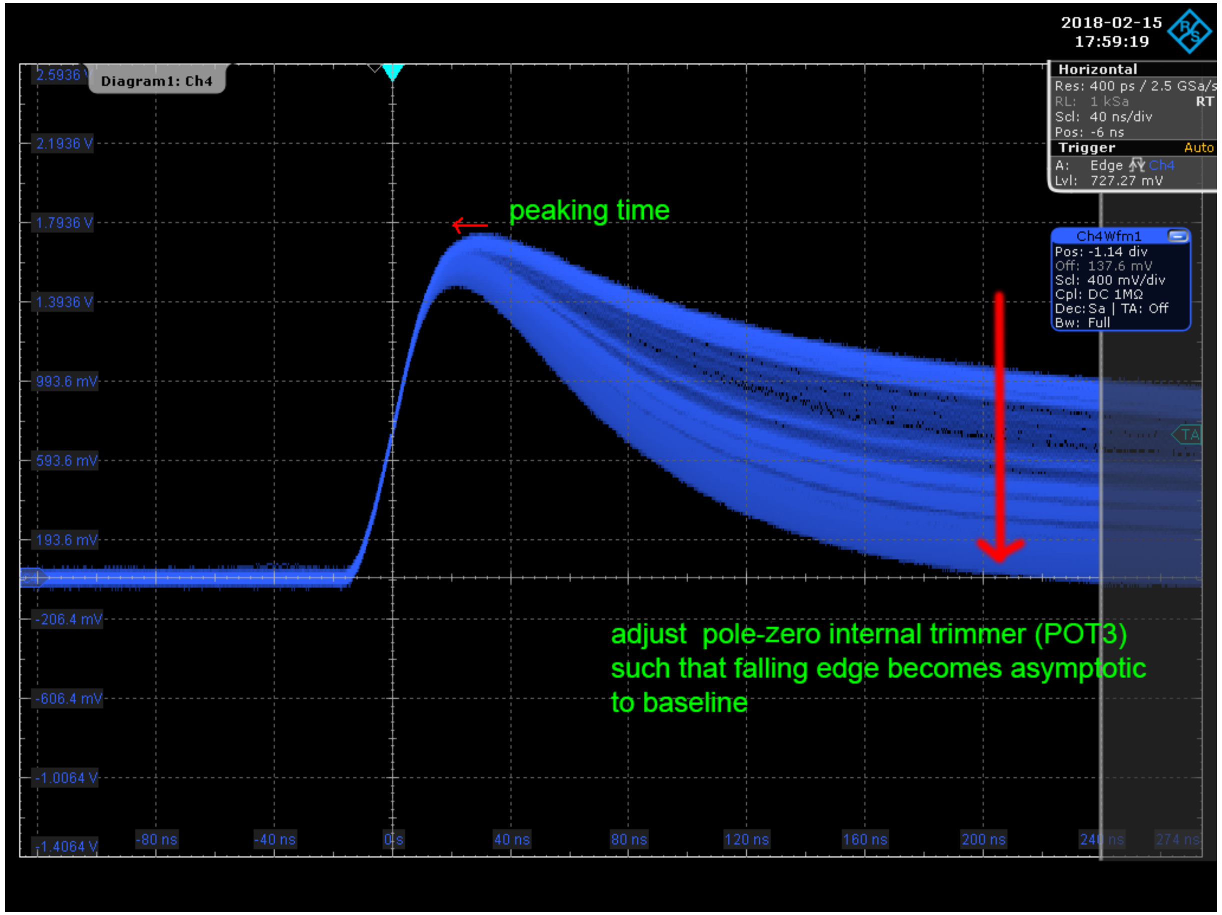
$t_p = 2 * t_s$

The shaping time relates with the -3dB cutoff frequency f_c of the shaper filter as

$t_s = \frac{1}{2\pi f c}$ [page 46]

Note that the risetime t_r as measured by oscilloscopes is measuring from 10% above baseline and below peak is therefore about 30% smaller than t_p

Pole-zero adjustment

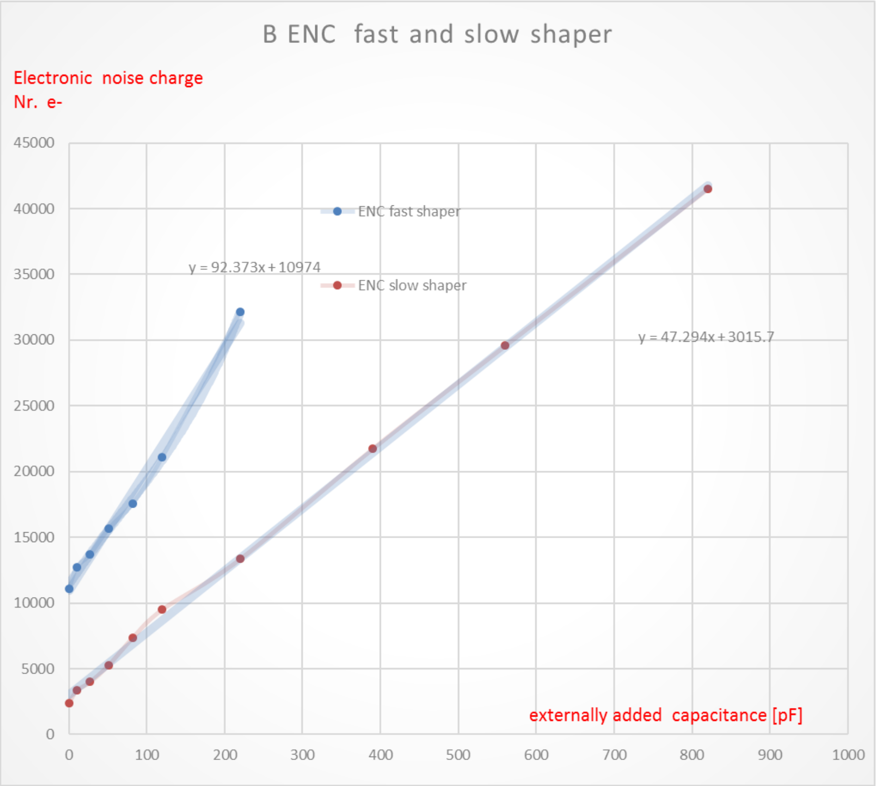


The pole-zero calibration is by default done, but may have to be changed when an external CSA like SiPA is connected.

The calibration via the internal trimmer POT3 (close to CSA in/ext switch) is important and must be done with care. As can be seen in the picture the falling slope must become asymptotic without undershoot to the baseline.
Also the shaper peaking times depend on correct pole-zero calibration.

ENC noise of Shapers

as function of externally added detector capacitance Cd*



The ENC noise of the fast shaper is higher than the slow shaper (the fast shaper should only be used for Cd < 150pF when CSA risetime starts to be less the fast shaping time [page 21]

$$ENC^{**} = \frac{U_{rms}}{e-} / \frac{2{*}U_{peak}}{\Delta Q_s} = \frac{\Delta Q_s}{e-}\frac{U_{rms}}{2{*}\,U_{peak}} = \frac{U_{test}\ Cs}{e-}\frac{U_{rms}}{2{*}U_{peak}}$$

Same method as for CSA on [page 25]

Due to the 2nd order filter of the shaper [page 46] the ENC is significantly smaller compared to direct CSA signal outputs [page 25]

ENC_{fast} = 92.37e- * C_d + 10974 e- for C_d <150 pF

ENC_{slow} = 47.3 e- x C_d + 3015 e-

- Capacitance from cables must be included : RG58/U ~ 82pF/m, RG316/U ~ 95pF/m

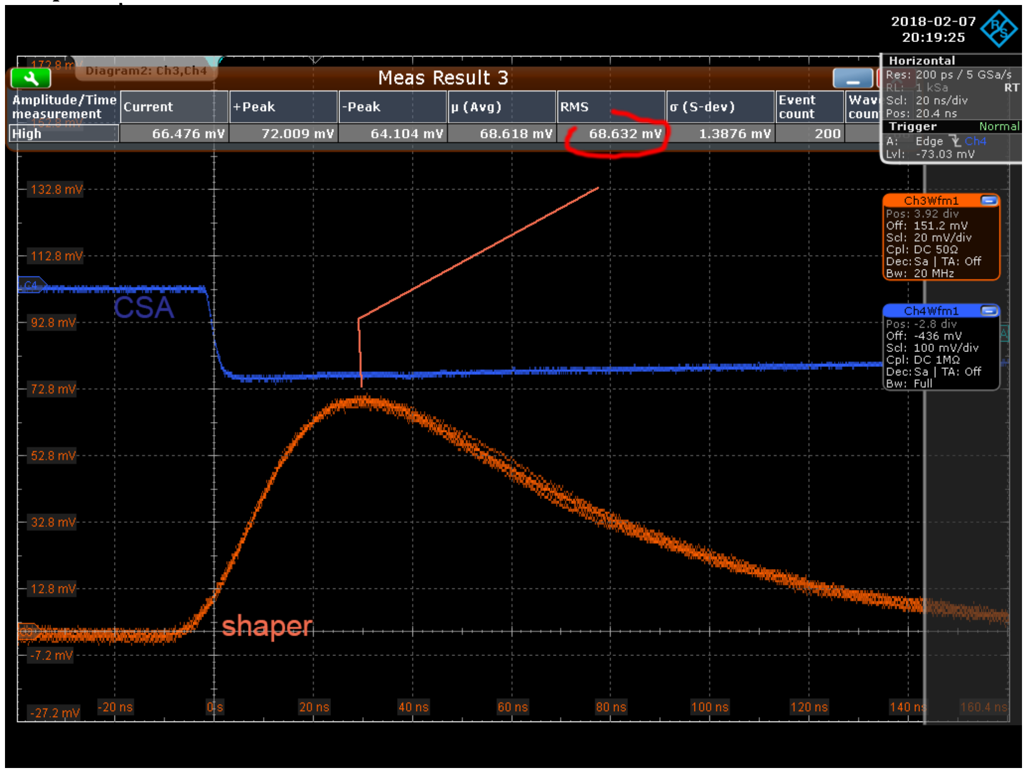
** the injected test charge ΔQs was 380 fC @ t_{rise} = 200ps

Oscilloscope rms noise measurements

do this for a range of added detector capacitances Cdet

Noise(amplitude)
$U_{amplitude,rms}$ without test signal

Peak(high)
U_{peak_rms} with test pulse



ENC Noise Minimum vs shaping time

- The ENC noise sources are 1/f noise, white noise and shot noise. Sometimes also dielectric noise D is considered, calling for low-loss PCB material for CSA's. The equivalent noise voltages and noise currents at the CSA input add up quadratically. For a CSA one considers the detector leakage current $id^2 = 2qI_0$ and the dominant equivalent input noise voltage $U_{ni}^2 = 8/3(kT/g_m) + K_{tech}$.

  I_0 is the sum of detector and bias leakage currents, gm =s the forward conductance of the input JFET transistor, $8/3(kT/g_m$ is the thermal noise in the input transistor and K_{tech} its technology coefficients like the 1/f noise coefficient.

- The total CSA noise spectrum for integrated CMOS circuits is quoted in the literature * as

$$u^2(s) = [\frac{C_d + Cf + CGS + CGD}{Cf}]^2 * U_{ni}^2 + [\frac{1}{sC_f}]^2 * i_d^2$$

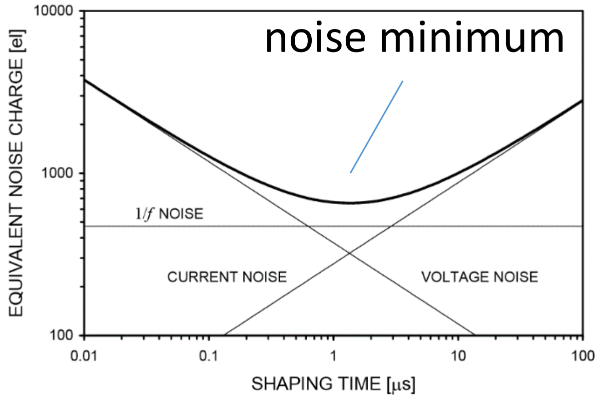
where C_{GS} and C_{GD} are transistor gate capacitances, the first term is the amplifier noise and the second the contribution from leakage currents

The equivalent noise charges ENC for 2nd order shaper (n=2) with $C_t = C_d + Cf + CG_S + CG_D$

- thermal voltage noise $\quad ENC_d^2 = \frac{8}{3} kT \frac{1}{g_m} Ct^2 \frac{0.78}{q^2 4\pi \tau_s} 13.64$ where τ_s is the shaping time
- 1/f noise $\quad ENC_f^2$ for JFET inputs is generally neglected and independent of τ_s
- leakage current noise $\quad ENC_o^2 = 2q I_0 \tau_s \frac{1.17}{q^2 4\pi} 13.64$

The total electronic noise of the CSA-shaper chain is $\quad ENC = \sqrt{ENC_d^2 + ENC_f^2 + ENC_o^2}$

Important: *With the 3 dependencies ($1/\tau_s$, τ_s , const) of ENC from the shaping time τ_s there is a noise minimum for τ_s depending on detector capacitance C_{det} and leakage currents. Generally due to C_t^2 , higher detector capacitances require higher shaping times in order to achieve low ENC noise. Note that for 2nd order shapers , $\tau_s = ½ \tau_p$*



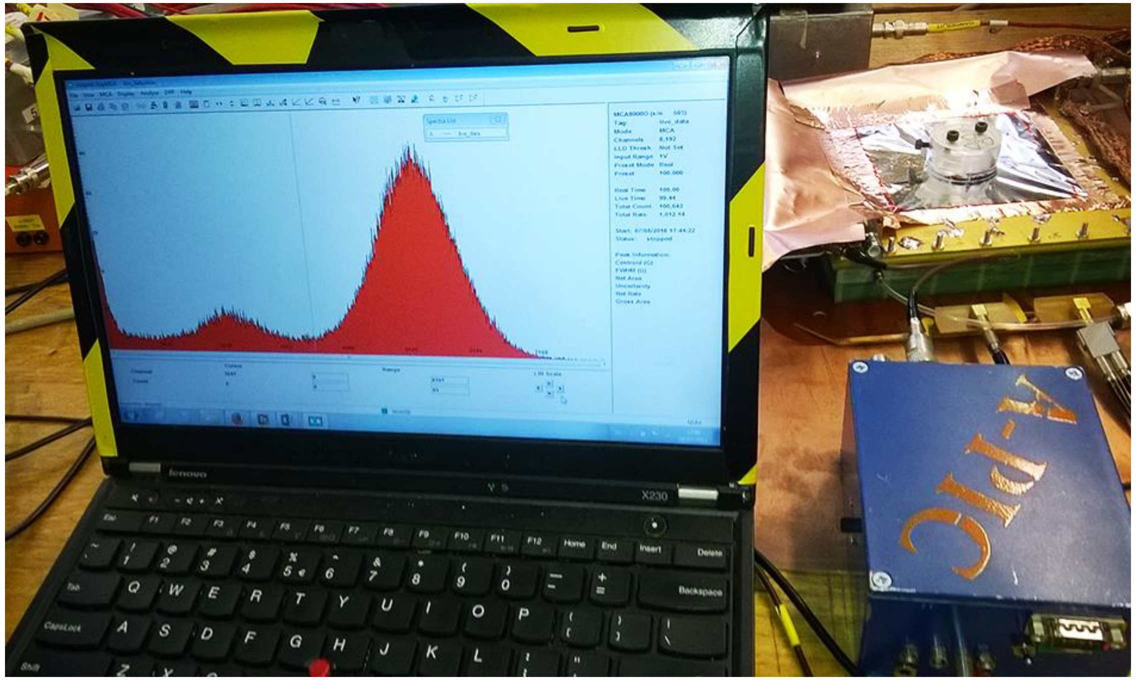
dominated by voltage noise current noise

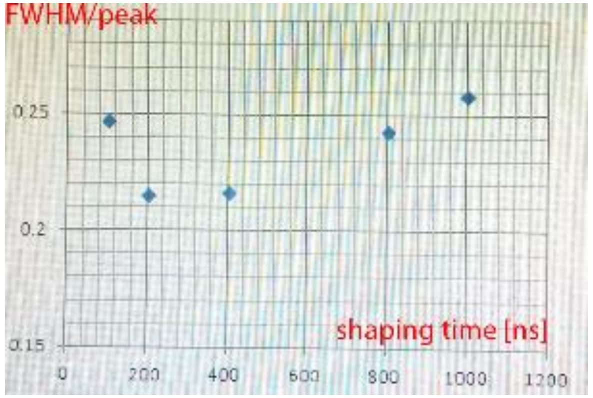
From: H.Spieler Solid state detectors and electronics

*W.M.C.Sansen IEEE Trans circuits and systems, Vol37, No11, 1990

GEM detector APIC 2016 prototypes

10x10 GEM with Fe55 source

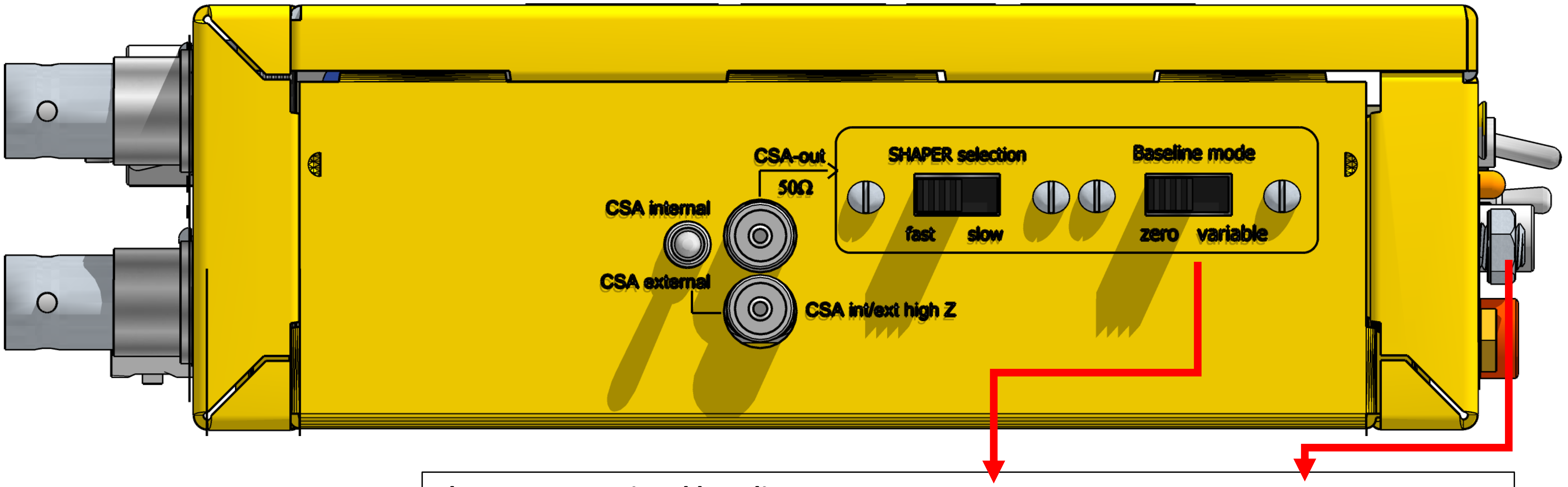




APIC peaking time for noise minimum of 10x10 GEM ~ 400 ns

Note: for this measurement 5 different APIC shaping times have been implemented in APIC test boxes.

APIC: Shaper baseline control



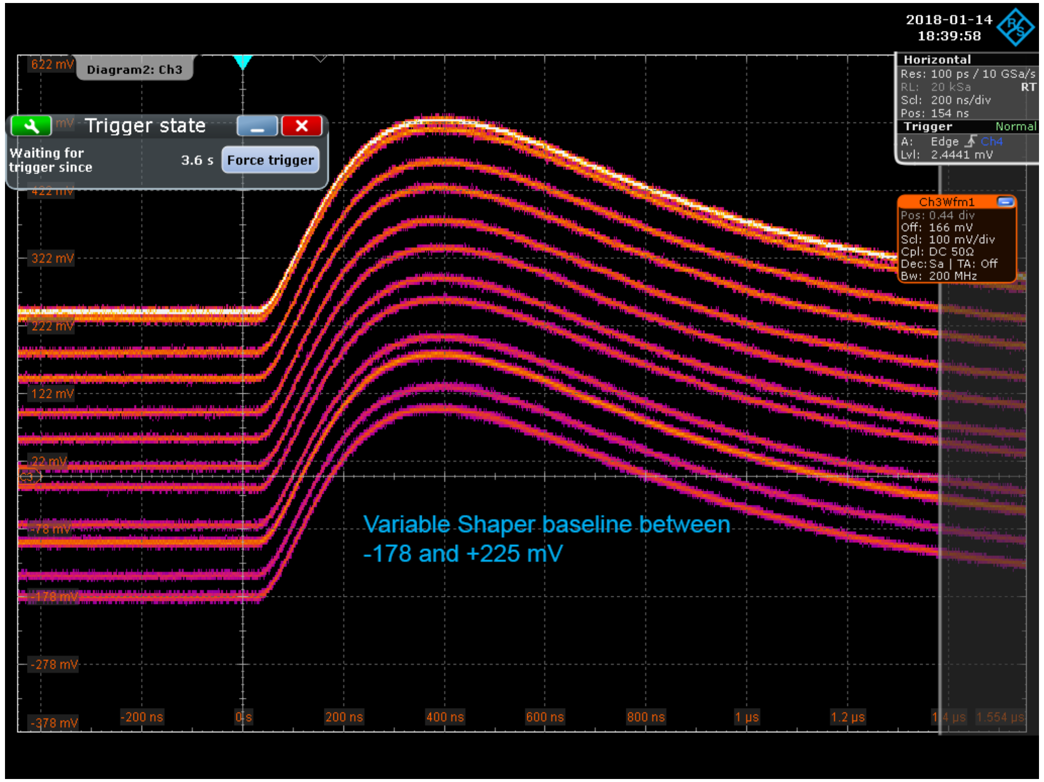
Shaper output signal baseline

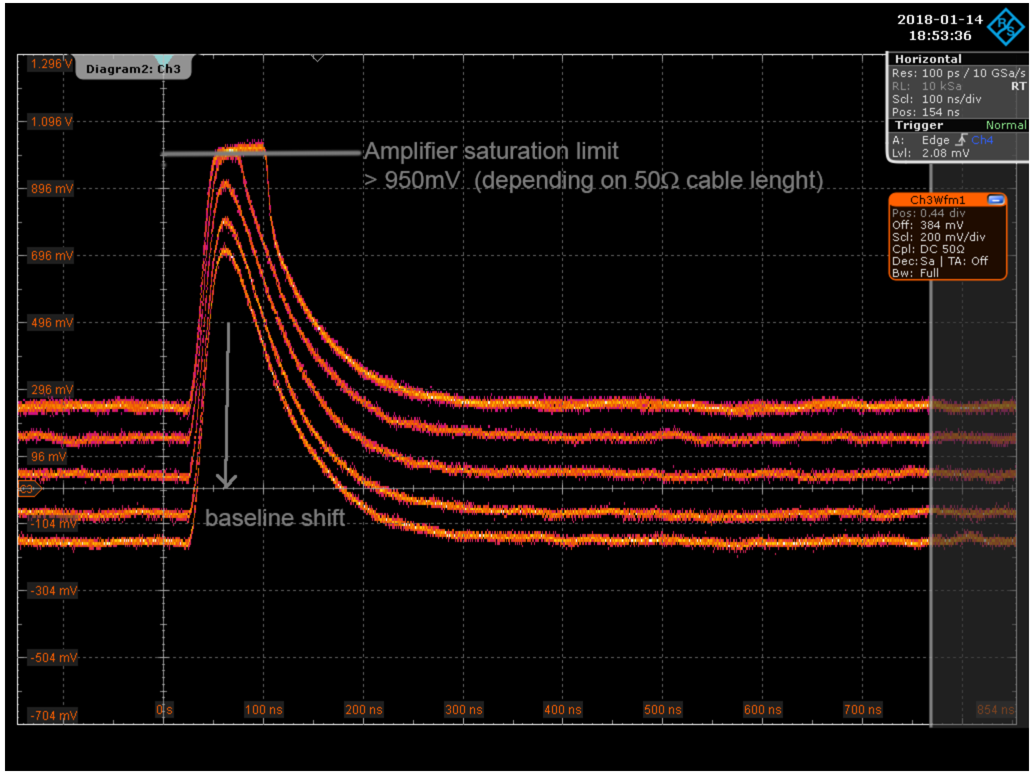
zero: shaper output baseline = 0V, complementary shaper output signals, baseline zero

Note: the baseline is temperature compensated

variable : +/- 150mV baseline shift via 15-turn potentiometer (on shaper output side)

Variable shaper baseline

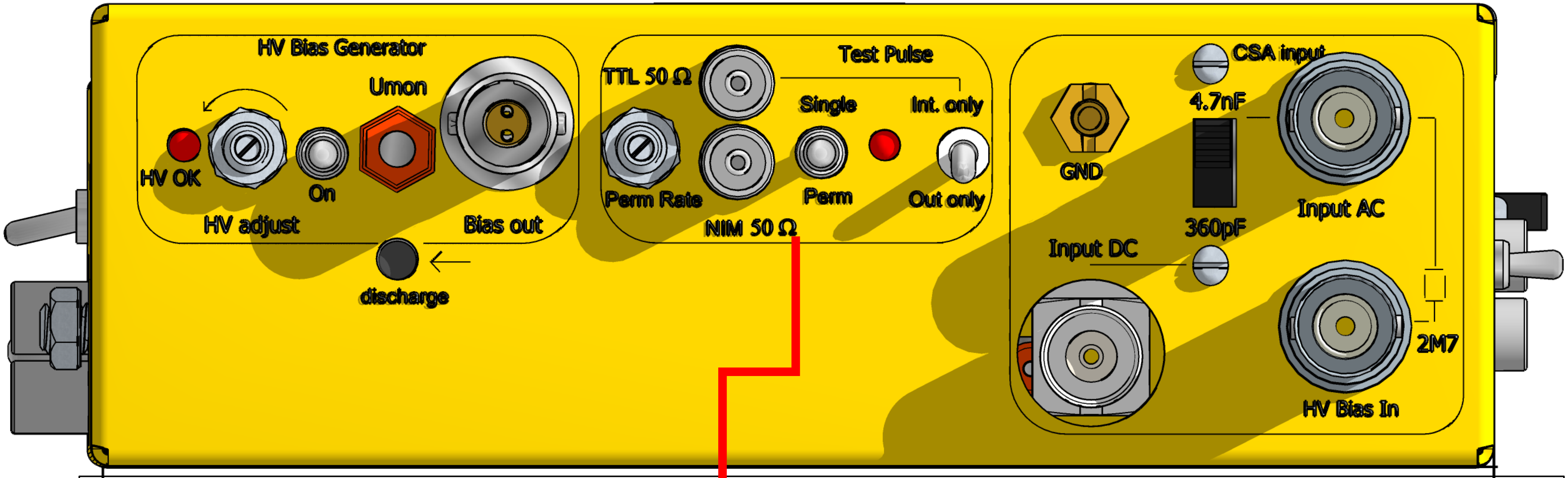




<u>With the slide switch in “variable” position, the shaper baseline can be varied in a range of +/- 150 mV.</u>

Saturation of the 50Ω terminated output signal occurs around +/- 950 mV (depending on the coax cable length) and can avoided a.) by reducing the shaper gain (recommended) b.) by shifting the baseline (special cases only)

APIC: Test pulse schemes



Square wave test pulse generator, pos. 4ns external rising edge, neg. on external 4ns falling edge.

Perm: 15- turn trimmer for continuous rate variation

Single: actuator switch for single square test pulse

Int. only: test pulses are only generated internally with charge injection to CSA input on both edges

Out only: test pulses are only generated externally either negative on output NIM 50Ω or positive on the TTL output: TTL for 1M termination, LVTTL for 50Ω (-> LED pulser etc.)

Test pulse features

- Internal test pulse generator 1kHz -600kHz square wave with pos / neg edges for charge injection to CSA via Cs = 0.125 pF [page 57]
- CSA response, negative edge ΔQ = 187 fC @ 202 ps positive edge ΔQ = 182 fC @ 690 ps [page 58]
- CSA risetimes for int. test pulse, measured on terminated coax 50Ω: negative charge 2.26ns, positive 3.37 ns [page 59]
- External test signals : NIM (50Ω), TTL (1MΩ) and LVTTL(50Ω) for external devices [page 60]
- NIM signal clippable* via external clip cable for generating short pulses from the edges of the square wave [page 61]

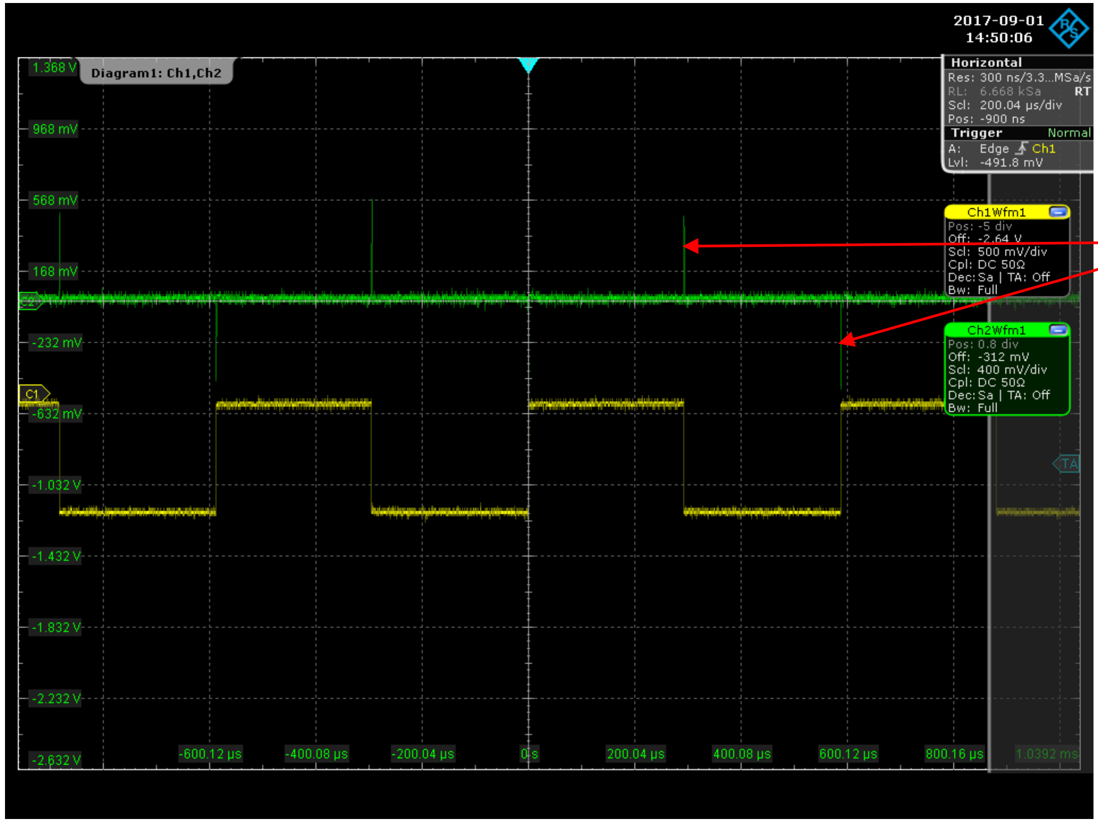
***Note:** do not forget to put test pulse in "Out.only" mode when measuring signals from external detectors in order to avoid interference with internally generated test pulses

- *coax cable with 0-Ω terminator, clip pulse length = 2 x cable delay*

Internal test pulse generator

CSA

TEST pulse



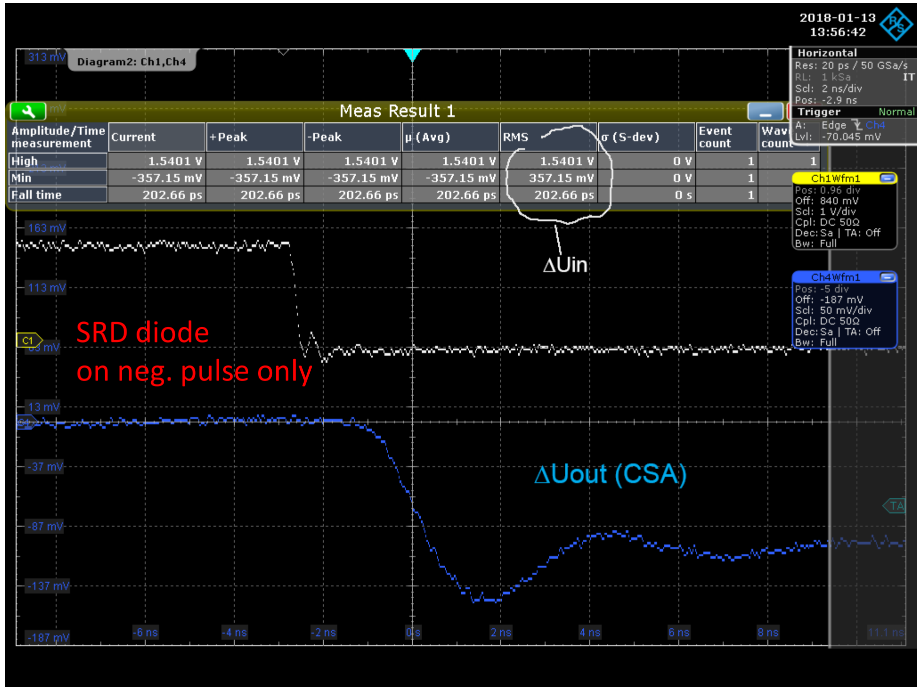
<u>Set Test pulse mode switch to "Int. only" = internal and actuator switch to "Perm."</u>

The test pulse generator generates rectangular pulse range between 1 kHz to 600 kHz. The rate can be changed via the "Perm Rate" frontpanel trimmer.
The CSA output responses follow the pulse transitions, corresponding to pos. and neg. input charge signals.
The negative pulse transition is faster than the positive due to the use of a 200ps SRD diode for the negative transition

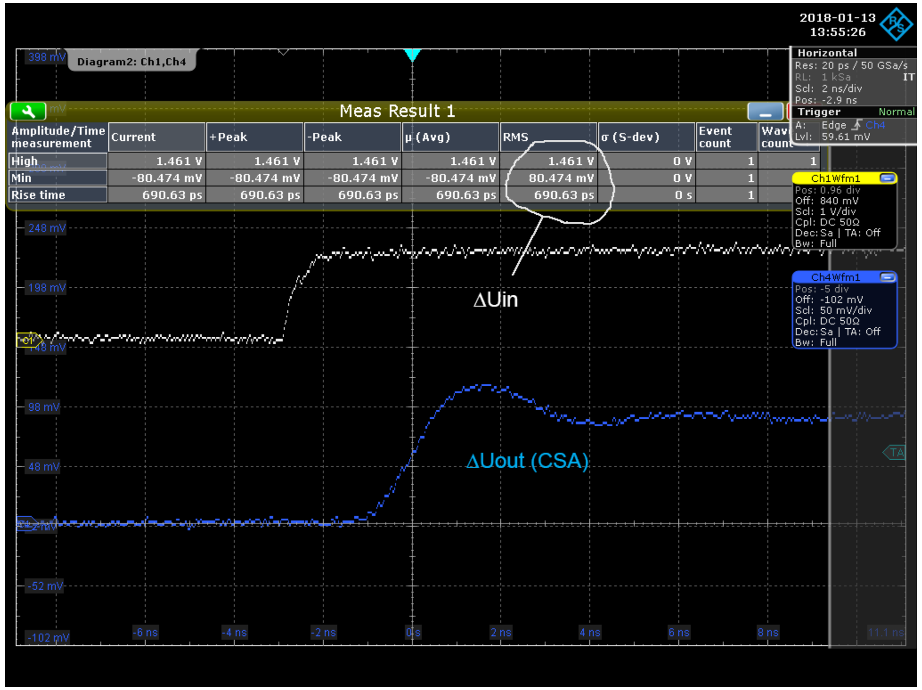
The testpulse is very loosely AC-coupled via a 0.125pF capacitor to the input of CSA.

CSA response to test pulse

Negative test pulse: ΔU_{in} =1.5V @ 202 ps
with C_c=0.125pF => ΔQ = 187 fC

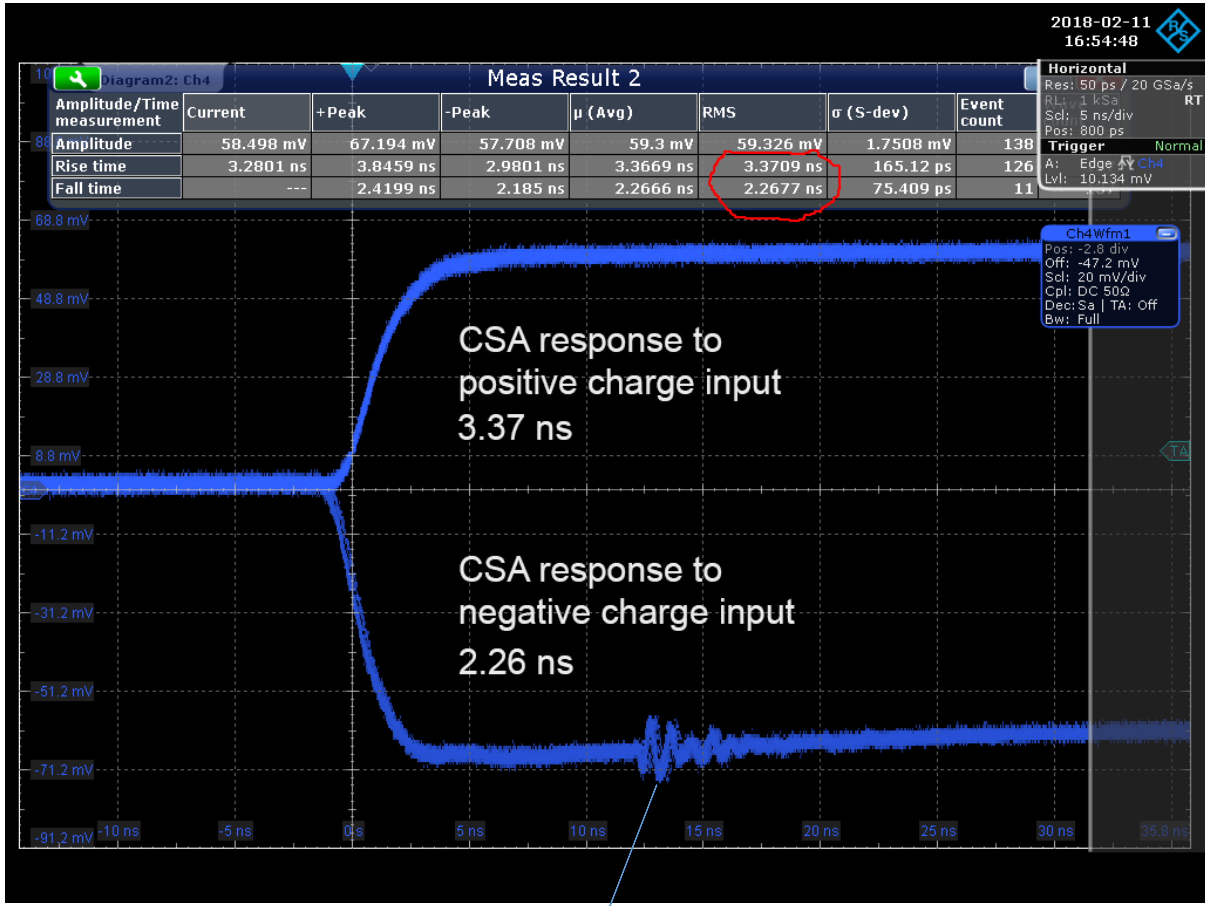


Positive test pulse: ΔU_{in} =1.46V @ 690 ps
with C_c=0.125pF => ΔQ = 182.5 fC



Note: the CSA overshoot was due to test setup with mismatch of signal impedance [page 24] , minimize the overshoot by connecting impedance matched input signals

CSA output risetime for testpulse



Note: the fast ringing superposition on the neg. CSA is due to the Trigger Unit in the Prototype and disappears when it gets switched off. The effect will be eliminated by shielding on the next revision.

The risetime of the CSA signal depends on (see [page 13])

-electronics risetime

-input signal risetime

-detector capacity C_{det}

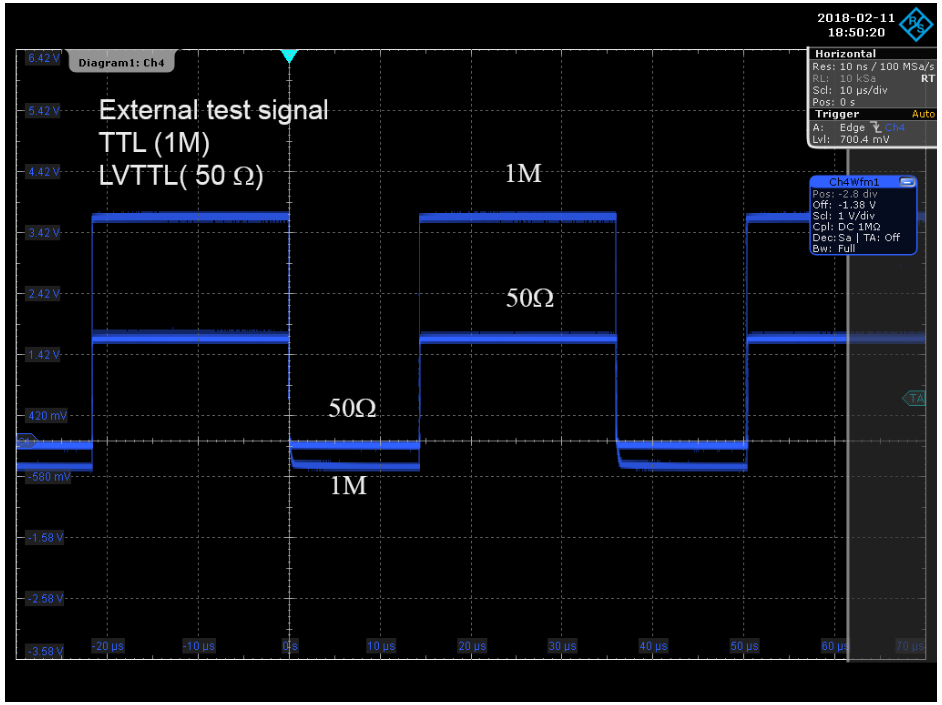
The risetimes of the 50Ω- terminated CSA output for the positive / negative testpulse edges are shown here for:

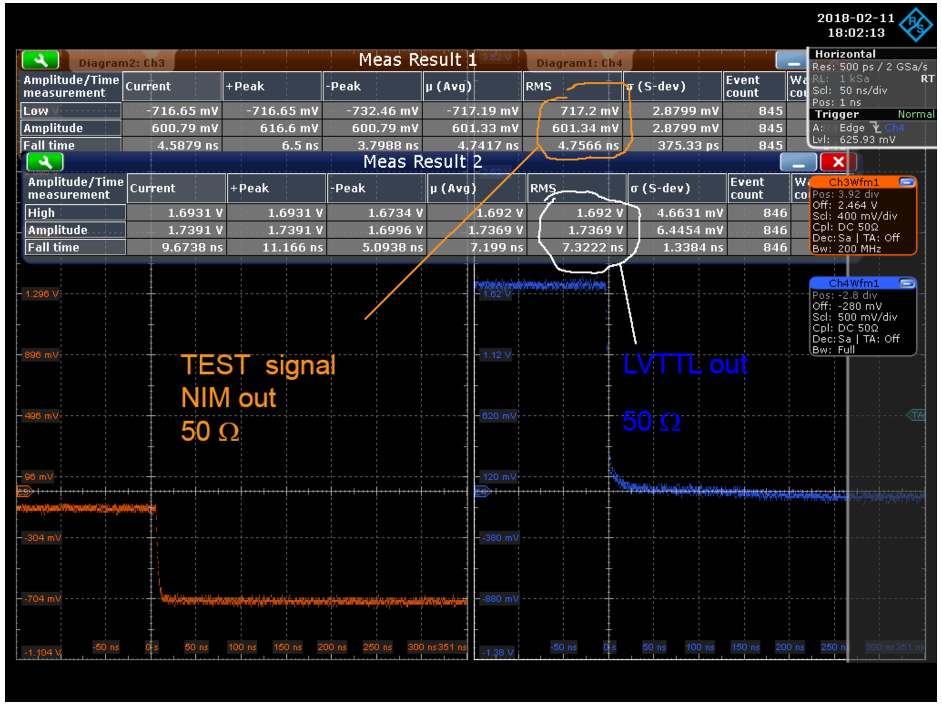
-CSA internal risetime O(1.3 ns) [page 16]
-signal risetime pos = 690ps, neg = 202 ps
-detector capacity C_{det} = 0 + intrinsic (20pF)
(AC input disabled via int. switch PB8)

AIDA 2020 Advanced European Infrastructures for Detectors at Accelerators

External test signals

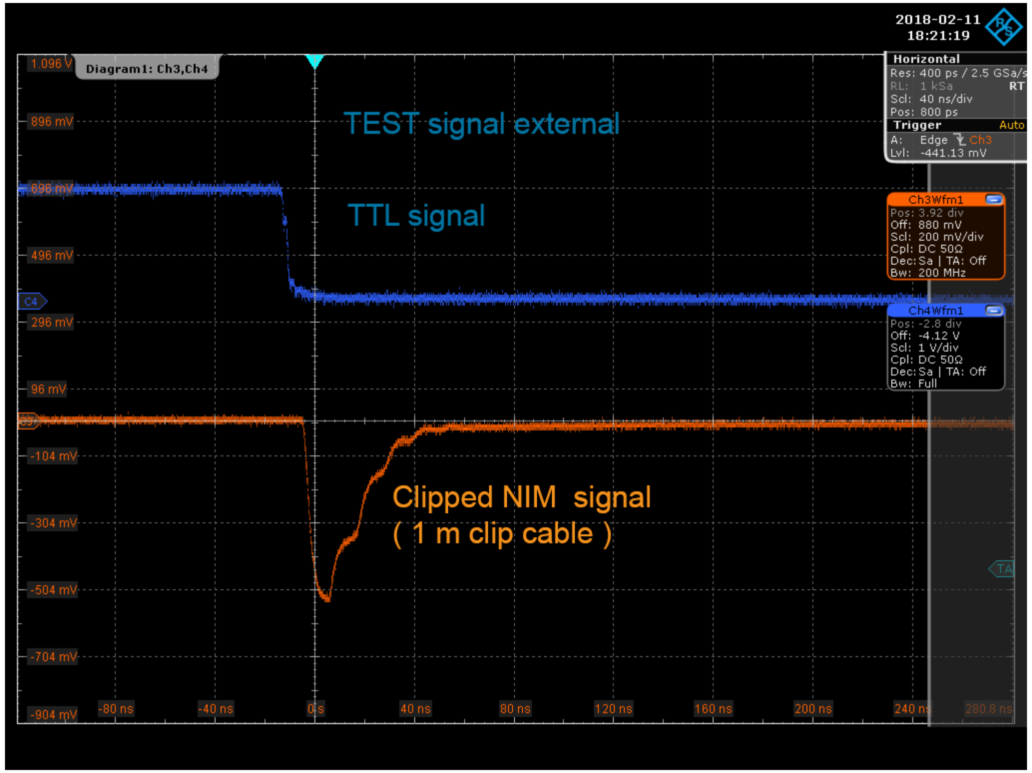
Set Test pulse mode switch to “Ext. only” = external:
the internal charge injection is disabled, allowing to use the NIM or LVTTL test pulse rate generator for charge injection to a detector via the external devices like LED pulsers.
The NIM signal must be terminated with 50Ω, and can be clipped via a clip cable.
The TTL signal can be terminated with 1M or 50Ω resulting in TTL or LVTTL levels (see below)





NIM signal clipping

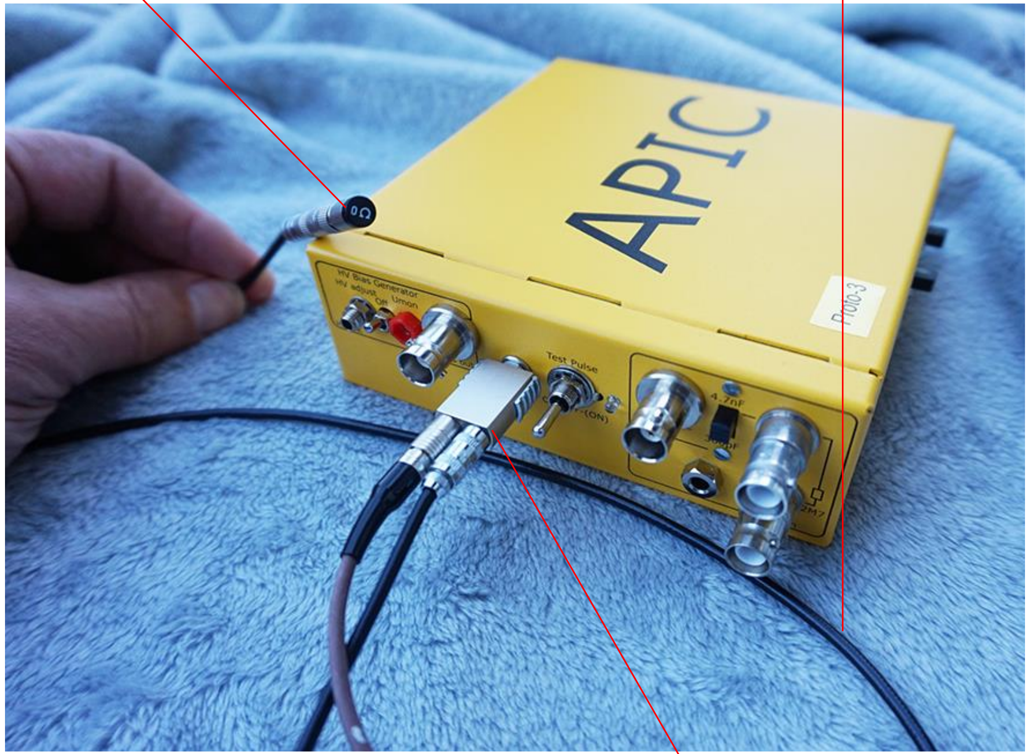
The edges of the square test signal can be clipped short edge pulses by the use of a clip coaxial cable.



Clipped signals should be refreshed by a discriminator

Zero-OHM terminator

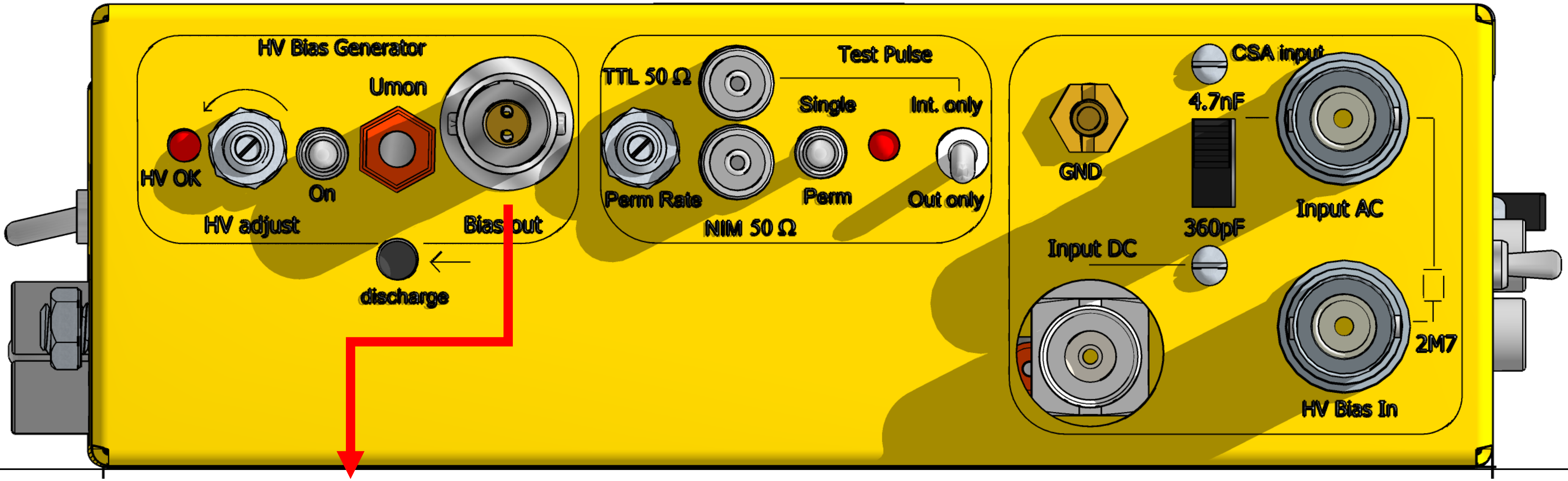
1m clip coaxial cable



pulse splitter on NIM output

APIC: HV bias generator
shown: Si Diode option

Advanced European Infrastructures for Detectors at Accelerators



Optional HV bias plugin, shown here   +5V…+ 110V Bias option for solid-state detectors*

Umon: direct bias voltage, unfiltered for DVM monitoring, relative to chassis GND

Bias out: BNC filtered low noise, high impedance (other options may have different connectors)

Note: the bias voltage requires internal charging of large capacitors hence the final bias voltage setting is stable only after 30 sec. Note: Other bias options may have different, bipolar connectors

Discharge: push with pen or needle to discharge the internal capacitor and reset the bias voltage

HV adjust: 15-turn potentiometer for full range

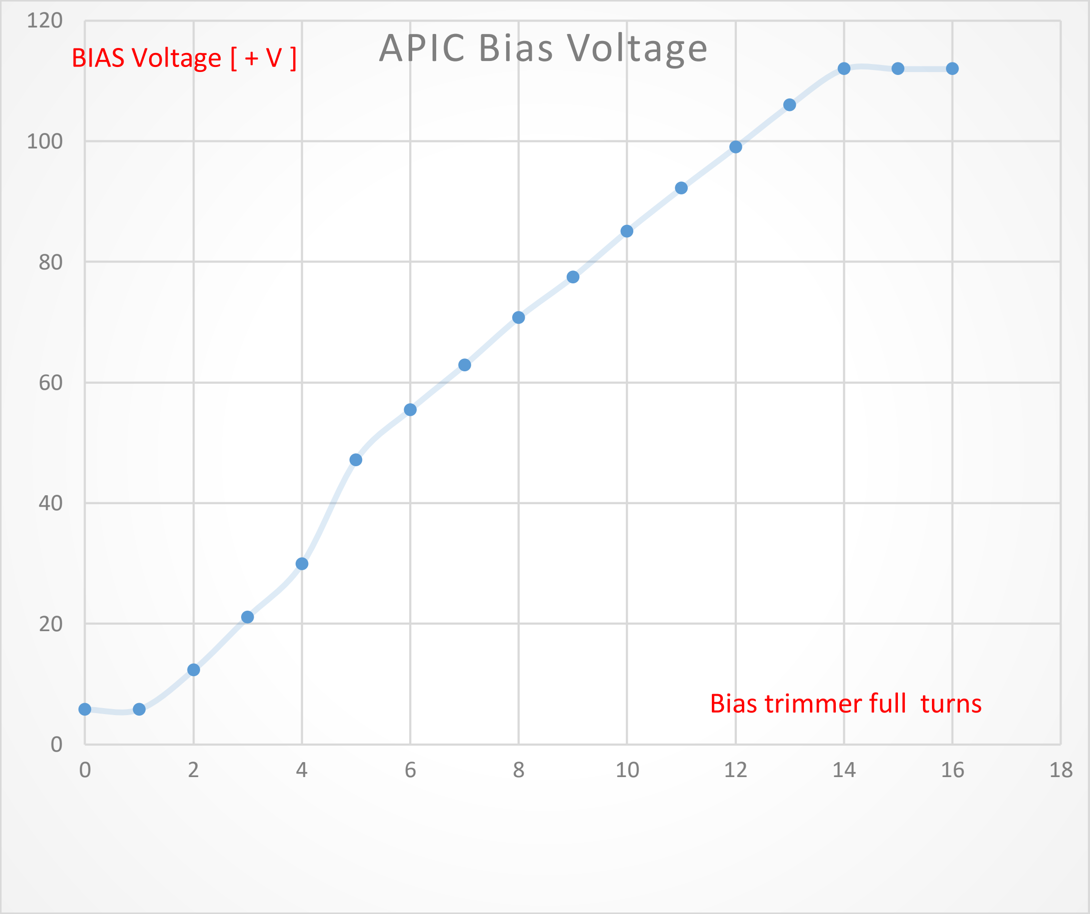
HV OK: LED lights up above +10V with increasing intensity

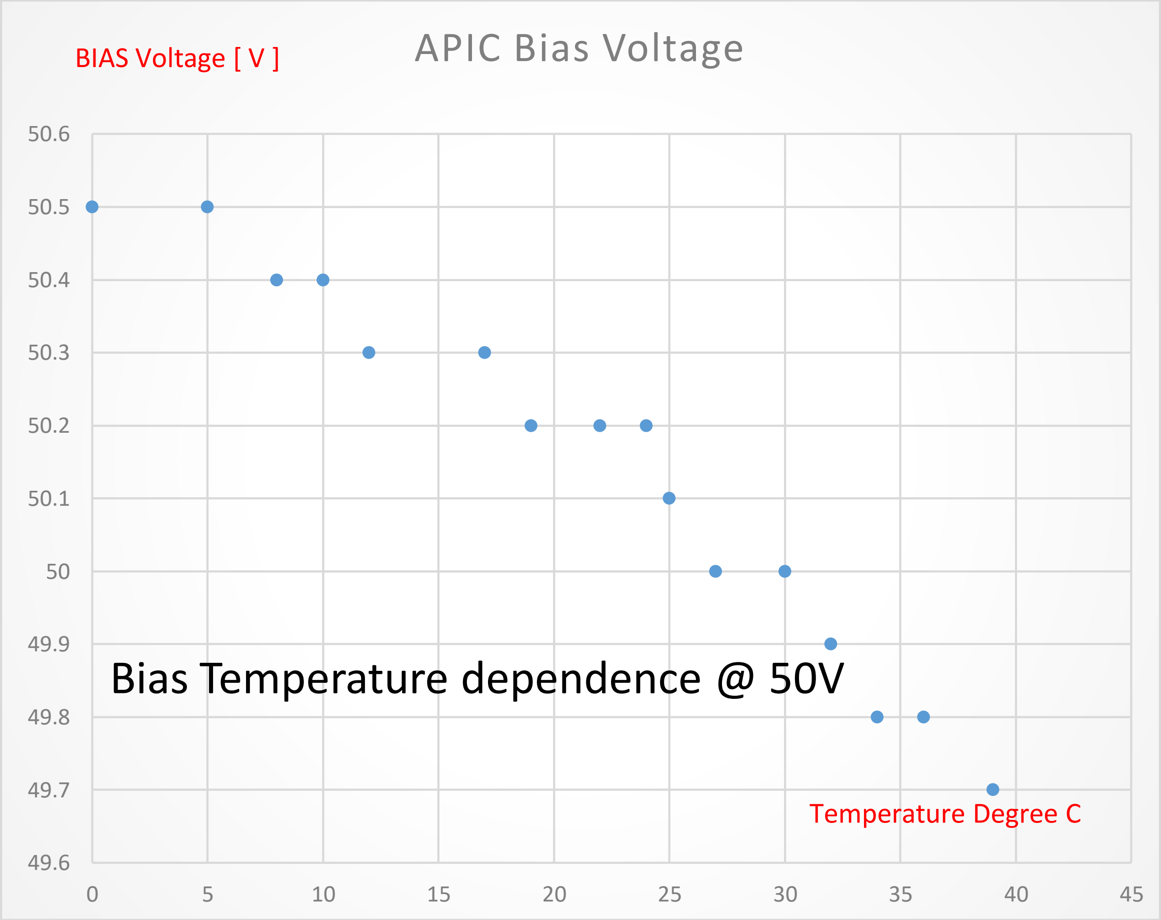
* Pin Diodes, MPPC, APD , Si PM, photodiodes, CVdiamond, etc)

Si Diode Bias Voltage features

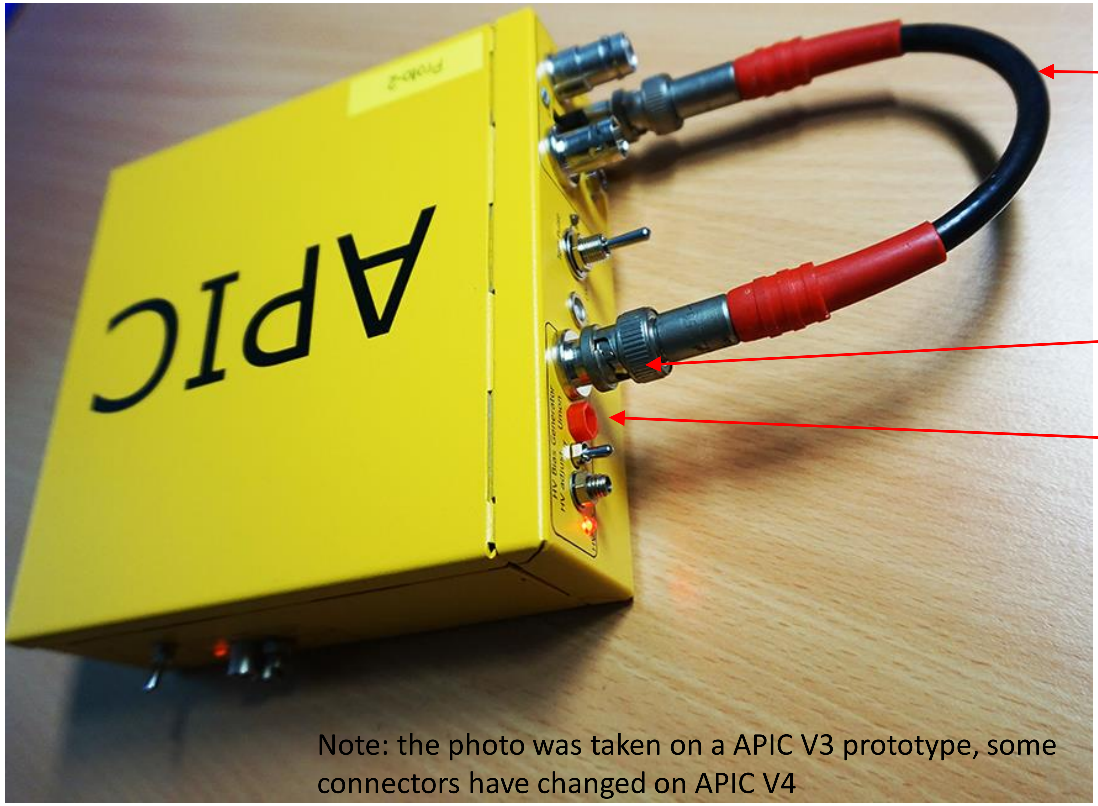
- Adjustable range 5V-110V, via 15 turn pot, temperature stability +/- 0.4 V over 40 ^{o}C range [page 64]
- HV Bias direct to detector AC input via external Cable to HV bias SHV input with LT=RC filter [page 65]
- Peak peak noise <15 mV [page 66]

Bias voltage plugin for S_i-Diodes





HV Bias connectivity



Note: the photo was taken on a APIC V3 prototype, some connectors have changed on APIC V4

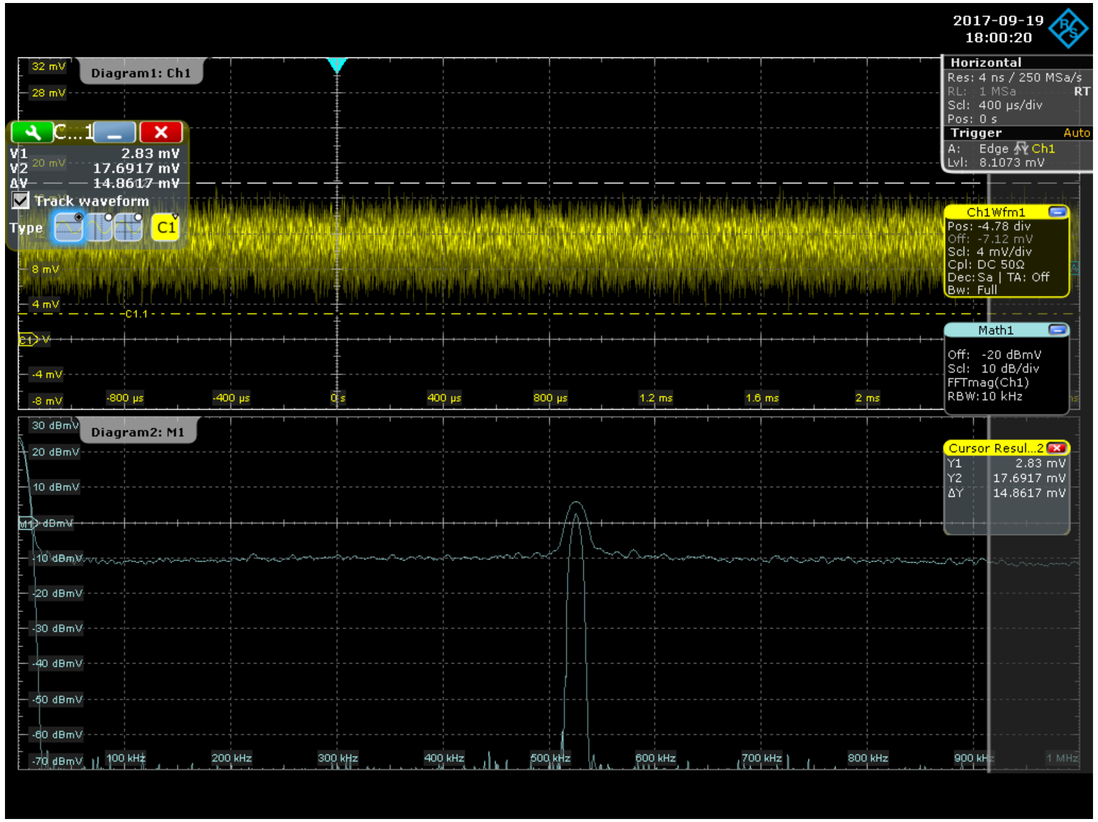
Special **BNC to SHV cable** connects Bias voltage to a detector (connected on the HV AC input)

+ HV Bias for Si Diodes on BNC connector

V_{mon} monitoring voltage to measure HV Bias

Noise of HV Bias generator

Noise spectrum (FFT picked up behind low noise filter)

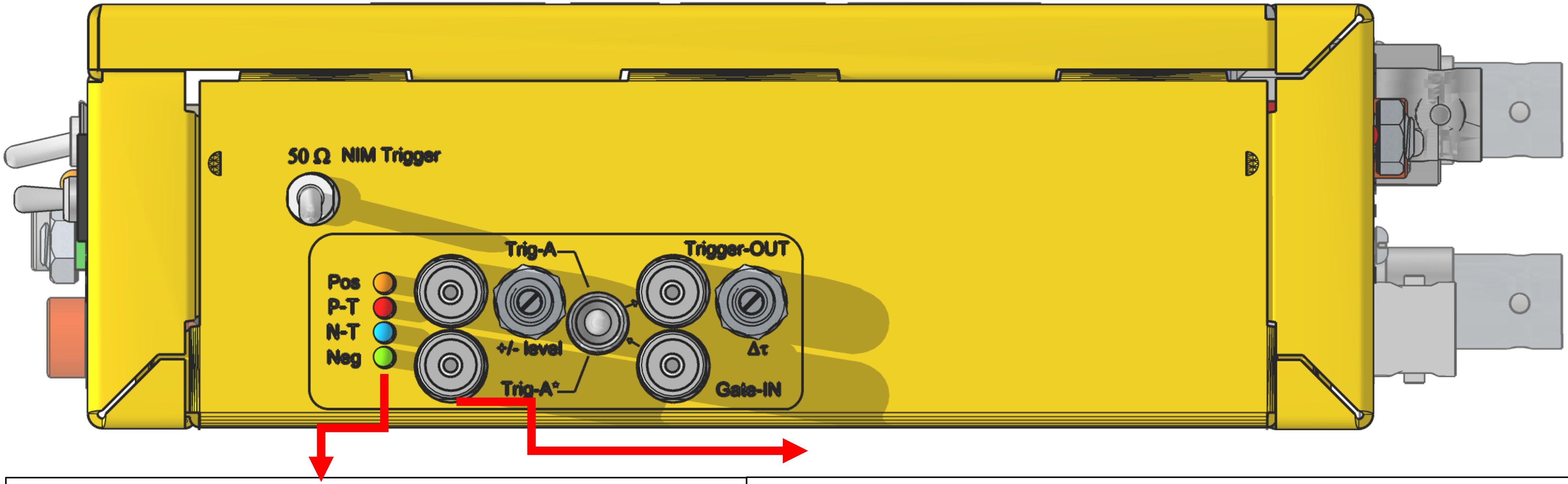


measured from direct CSA output
Ext. cable from Bias output to HV Input

ΔV (peak-peak) 14.8 mV

-10dB flat noise 50 Hz - 1 MHz
520 kHz switching noise down-filtered
from 20 dB to 0dB

APIC: NIM Trigger and external gating Unit



Pos positive signal above threshold present P-T positive signal over threshold triggered (**TOT**) N-T negative signal below threshold triggered (**TBT**) Neg negative signal below threshold present	+/- level: discriminator threshold on slope of +/- CSA input signal Complementary 50 Ω NIM outputs for TOT or TBT signals Note: middle +/- level around zero generates random triggers

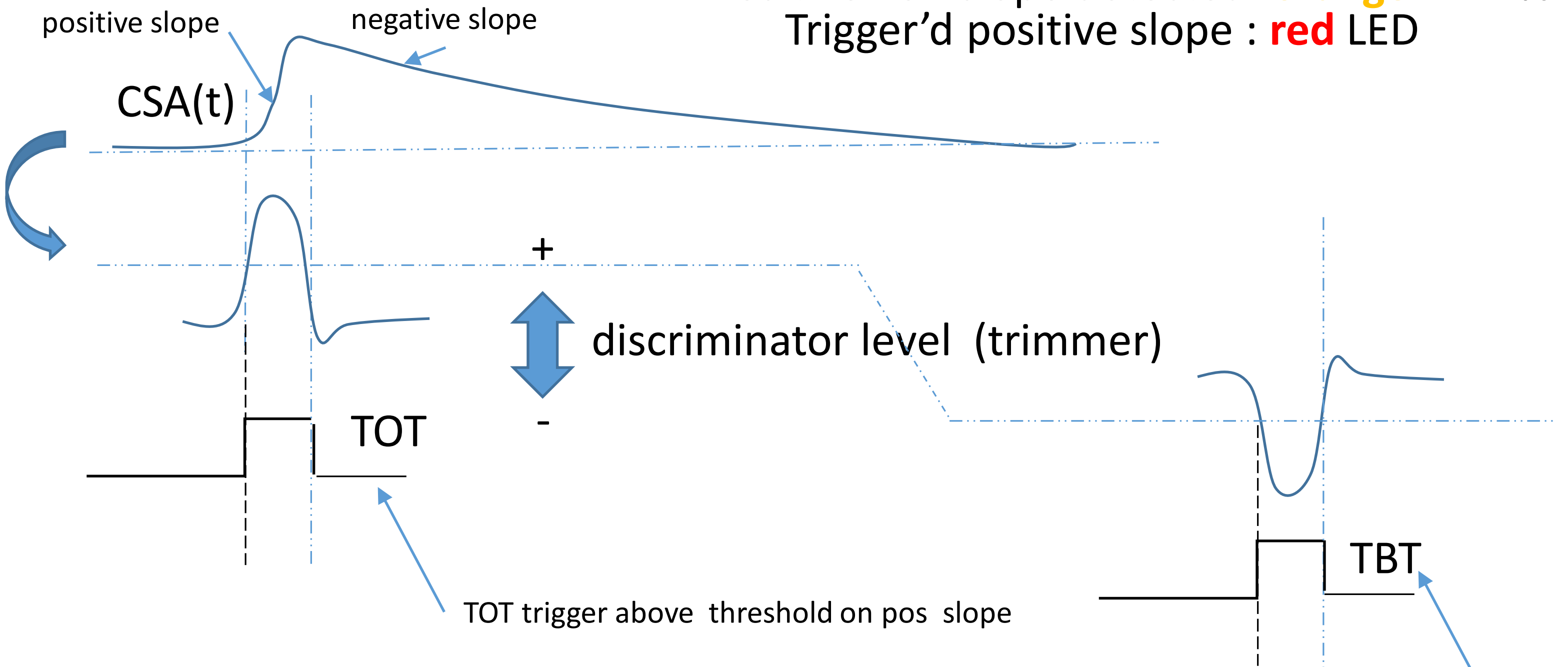
Trigger Unit properties

- Bipolar discriminator for prompt TOT and TBT triggers [page 69]
- Prompt trigger timing [page 70]
- Trigger polarities [page 71]
- Prompt trigger - stretched trigger [page 72]
- Trigger threshold levels [page 73]
- NIM pulse stretcher Unit [page 74]

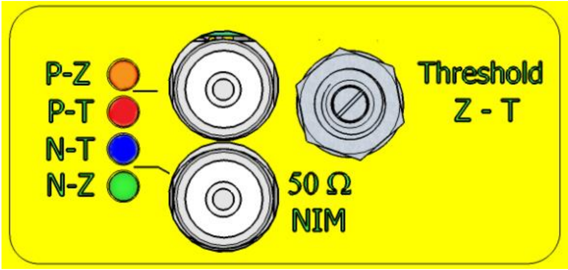
Bipolar discriminator
for prompt TOT and TBT triggers

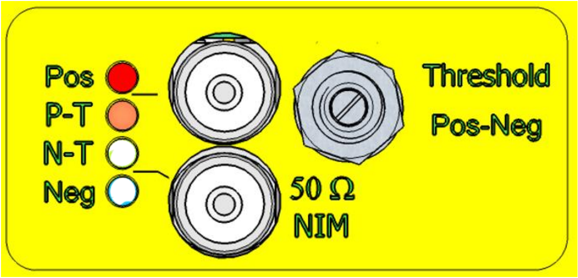
Positive CSA slope detected: orange LED
Trigger'd positive slope : red LED

Negative CSA slope detected: green LED
Trigger'd negative : blue LED

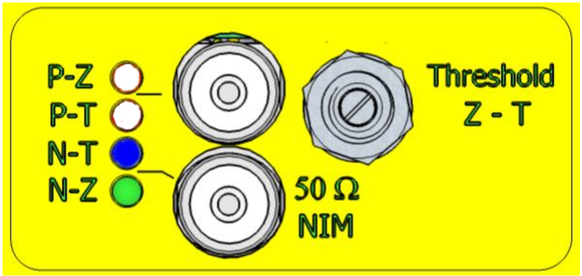


TBT trigger below threshold on neg slope





Pos. signal present and triggered

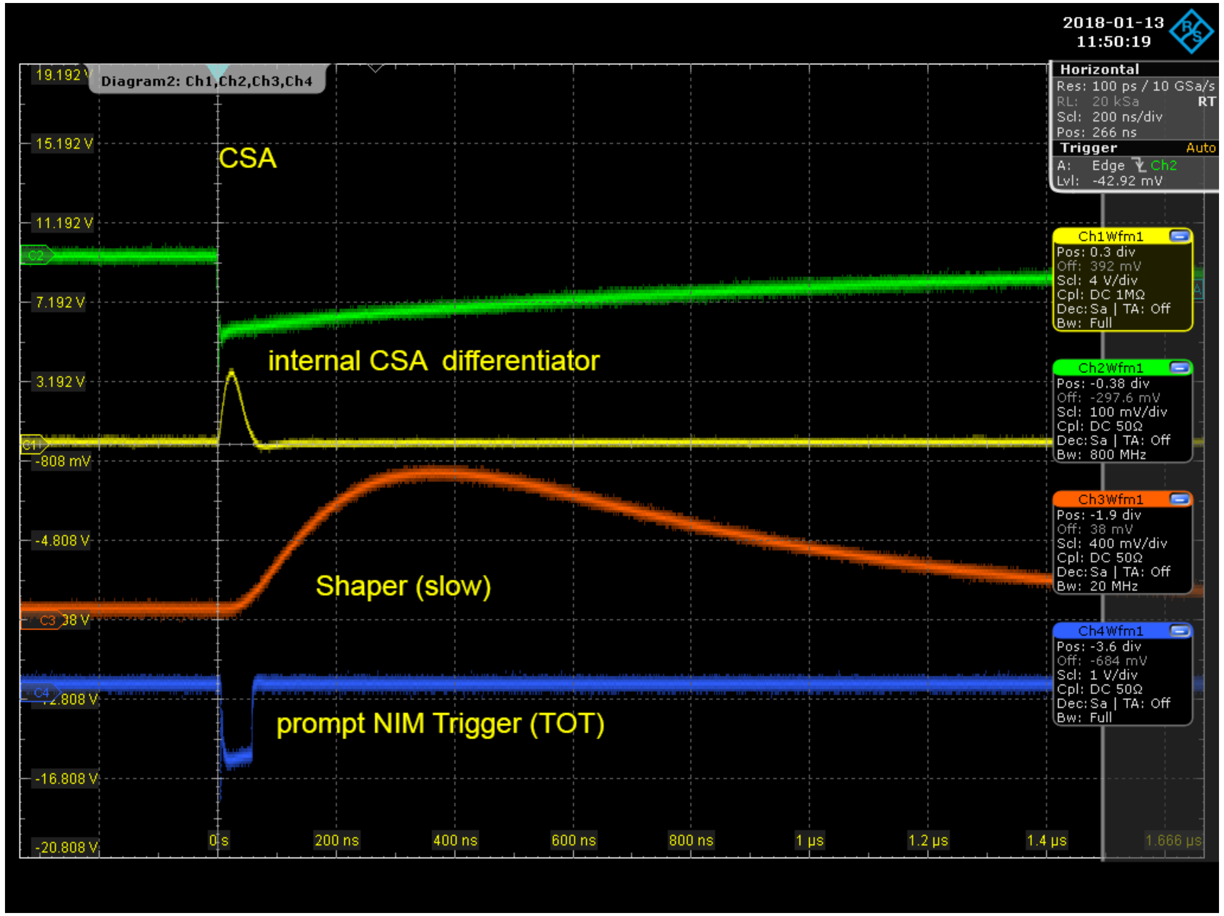


Neg signal present and triggered

Note: Random (ALL) triggered when discriminator ~ 0

Prompt trigger timing

CSA->Discriminator->trigger TOT/TBT



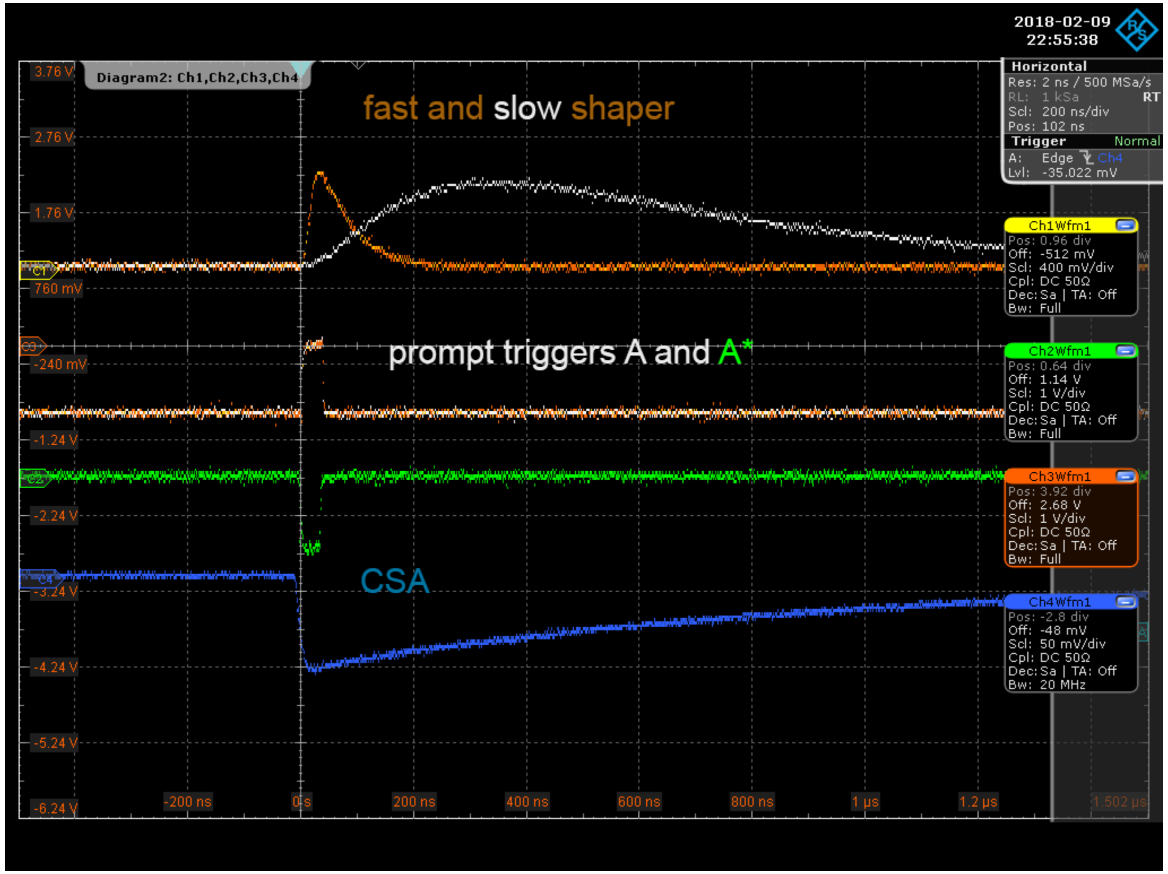
The APIC trigger latency can be important for time-dependent systems like SRS readout trigger, coincidence logic with other detectors etc.
The latencies shown below are approximate figures and do not include cable delays.

-Qin -> CSA out ~ 5 ns [page 13]

CSA->prompt NIM triggers TOT/TBT: 20 ns
to pulse start, the pulse length is O(50ns)
longer pulselength via the stretcher unit

CSA-> shaper baseline: 25-30ns
the peaking times have to be added

Trigger polarities



Shown for a negative charge input polarity (same as CSA) are the complementary TOT/TBT trigger polarities, relative to CSA and relative to fast or slow Shaper.

The shaper is of opposite (positive) polarity.

Negative charge input (LEDs: Neg and N-T)

Trig A output = TOT

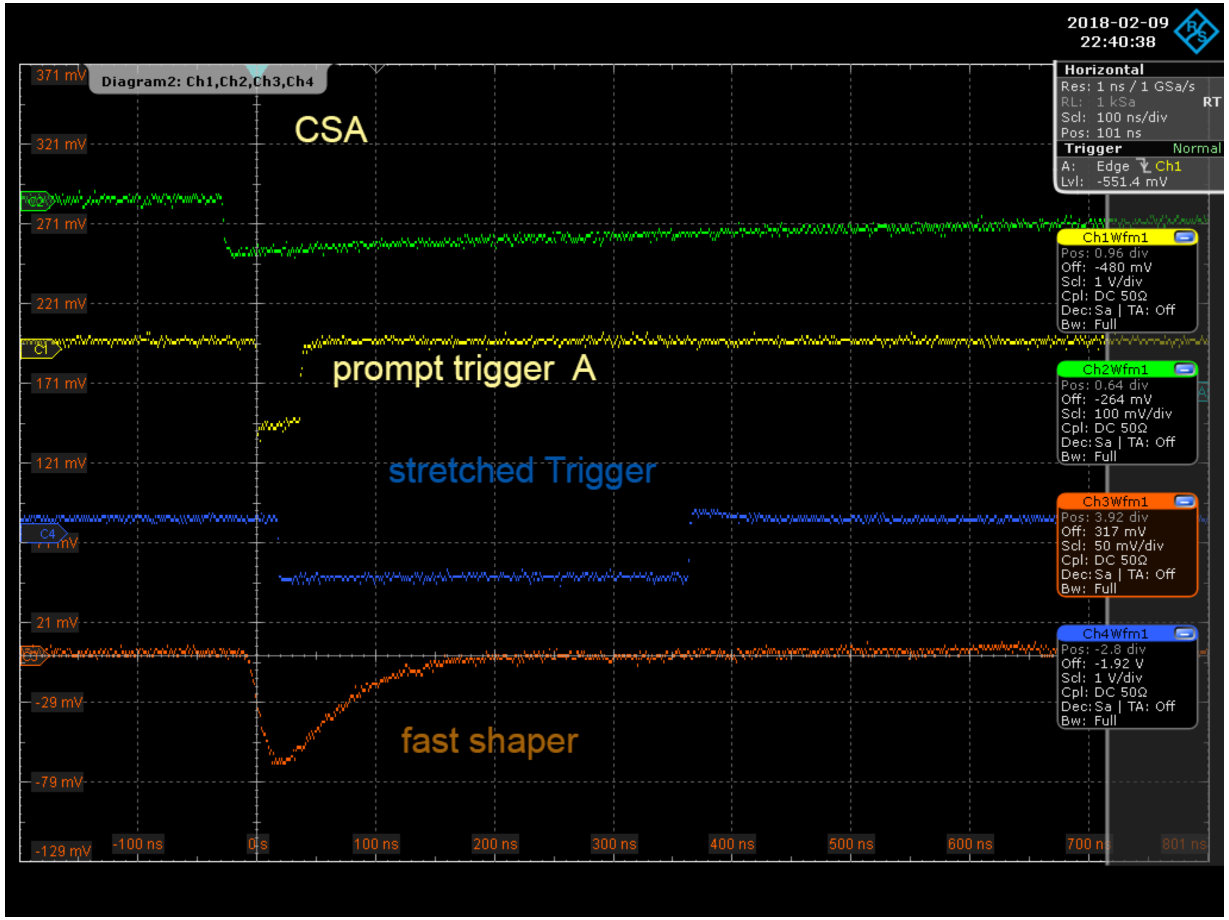
Trig A*output = TOT*

Positive charge input (Pos and P-T LEDs)

Trig A output = TBT

Trig A*output = TBT*

Prompt trigger - Stretched trigger



The short TOT /TBT triggers can be stretched by the APIC NIM pulse stretcher Unit. This requires a short coax cables from the negative going A or A* trigger output to the NIM input of the pulse Stretcher unit.

0.5 ns coax cable
from A
to NIM trigger input

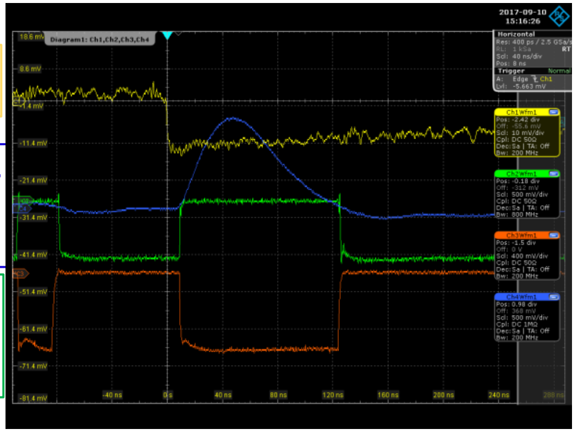
Trigger –threshold levels

Neg. CSA output

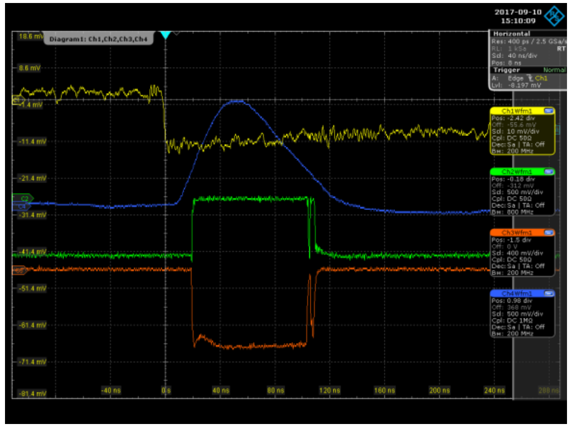
CSA differentiator (inverts polarity)

Complementary A and A* trigger

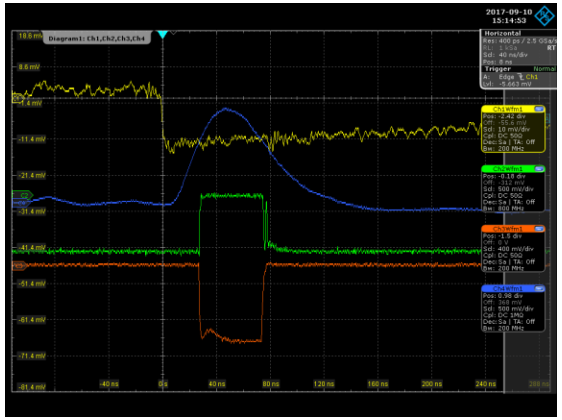
Threshold low, long TOT



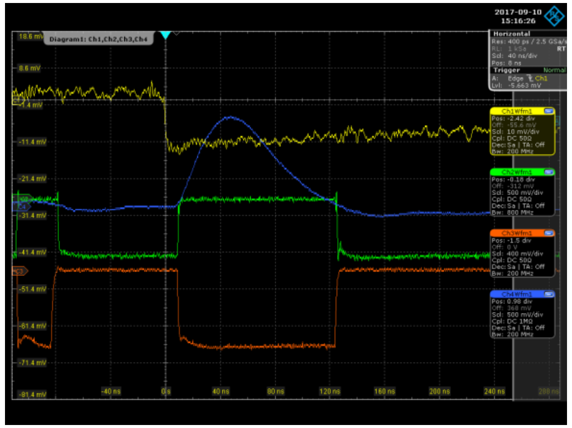
Threshold middle, shorter TOT



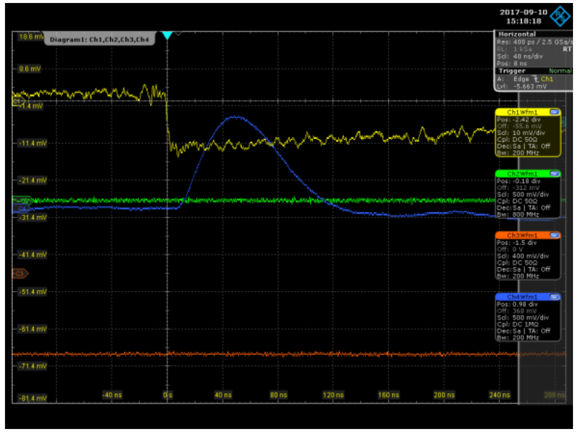
Threshold high, short TOT



Threshold close to zero: Random triggers

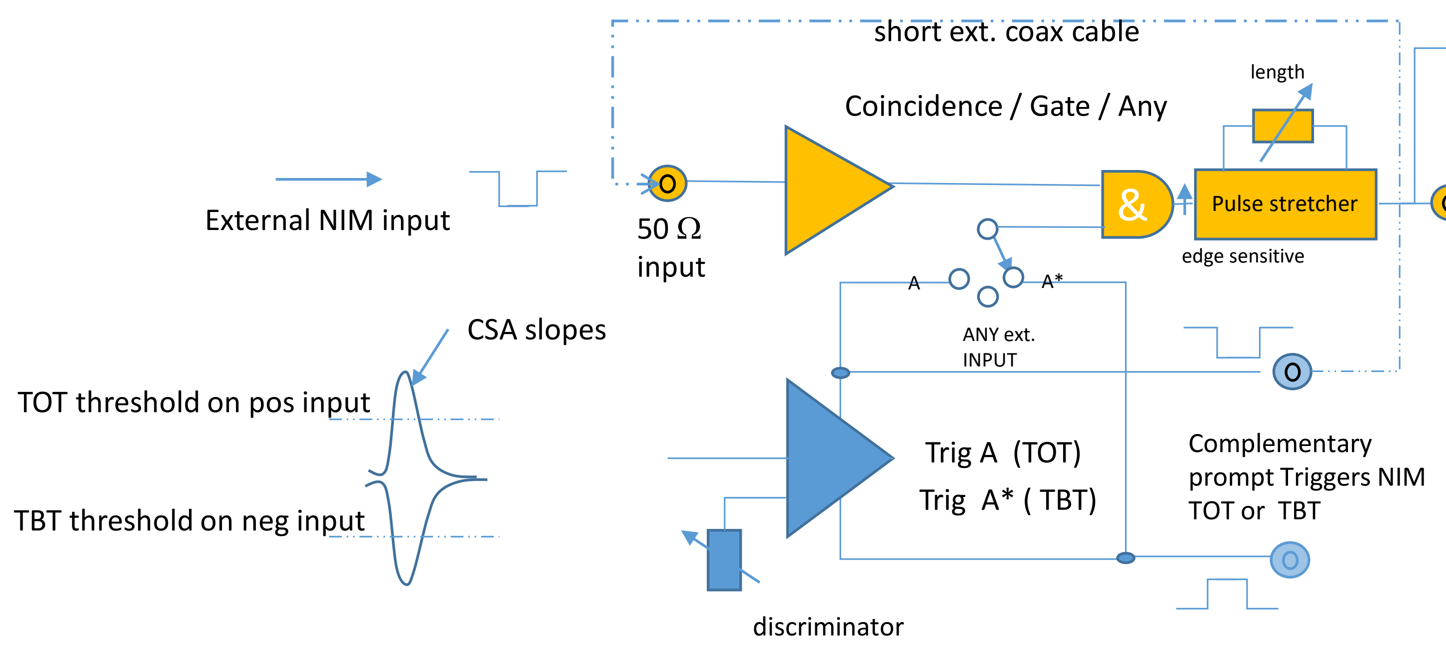


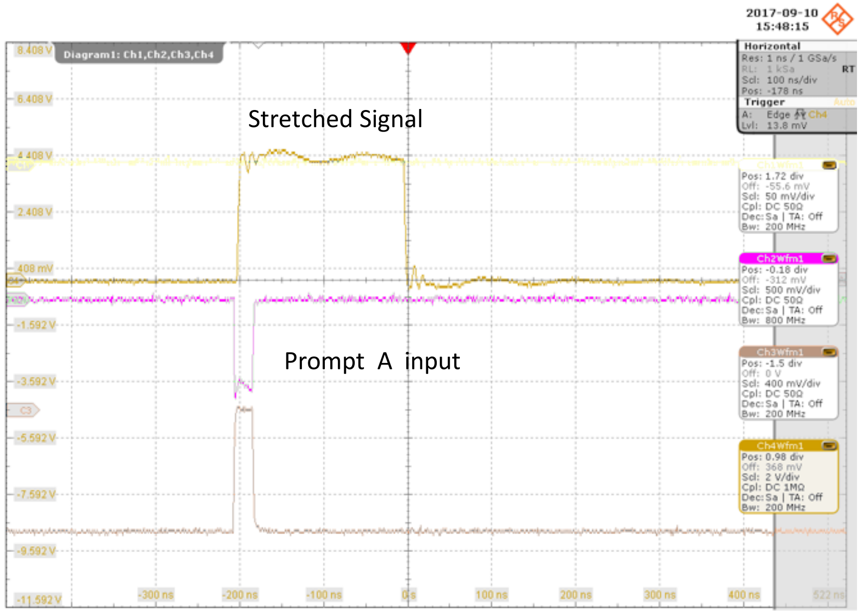
Threshold below zero: No trigger



The gain of the CSA differentiator amplitude can be set via an internal trimmer POT5, see [page 101]
This will
change the discriminator settings and prompt A /A* pulse lenght

NIM Pulse stretcher Unit

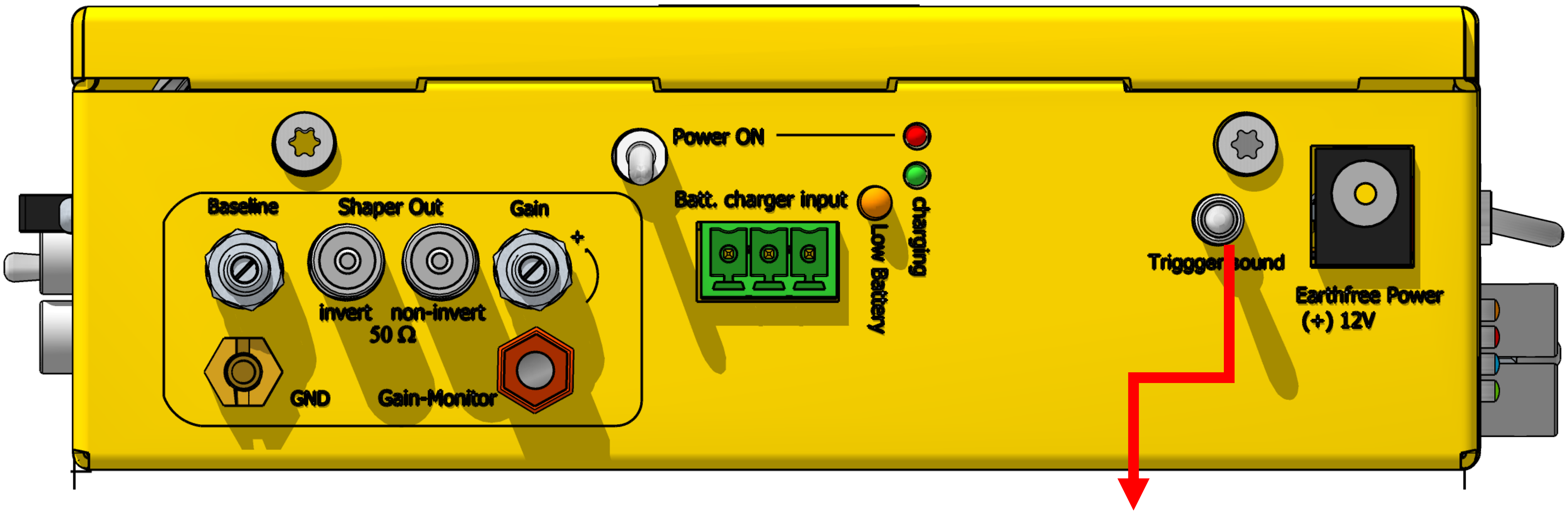




Stretcher Unit Modes:

1. Coincidence (ext. NIM signal) with direct triggers A or A*
2. Unconditional stretch for any external NIM signal
3. Stretched TOT or TBT trigger (coax cable to ext. NIM input)

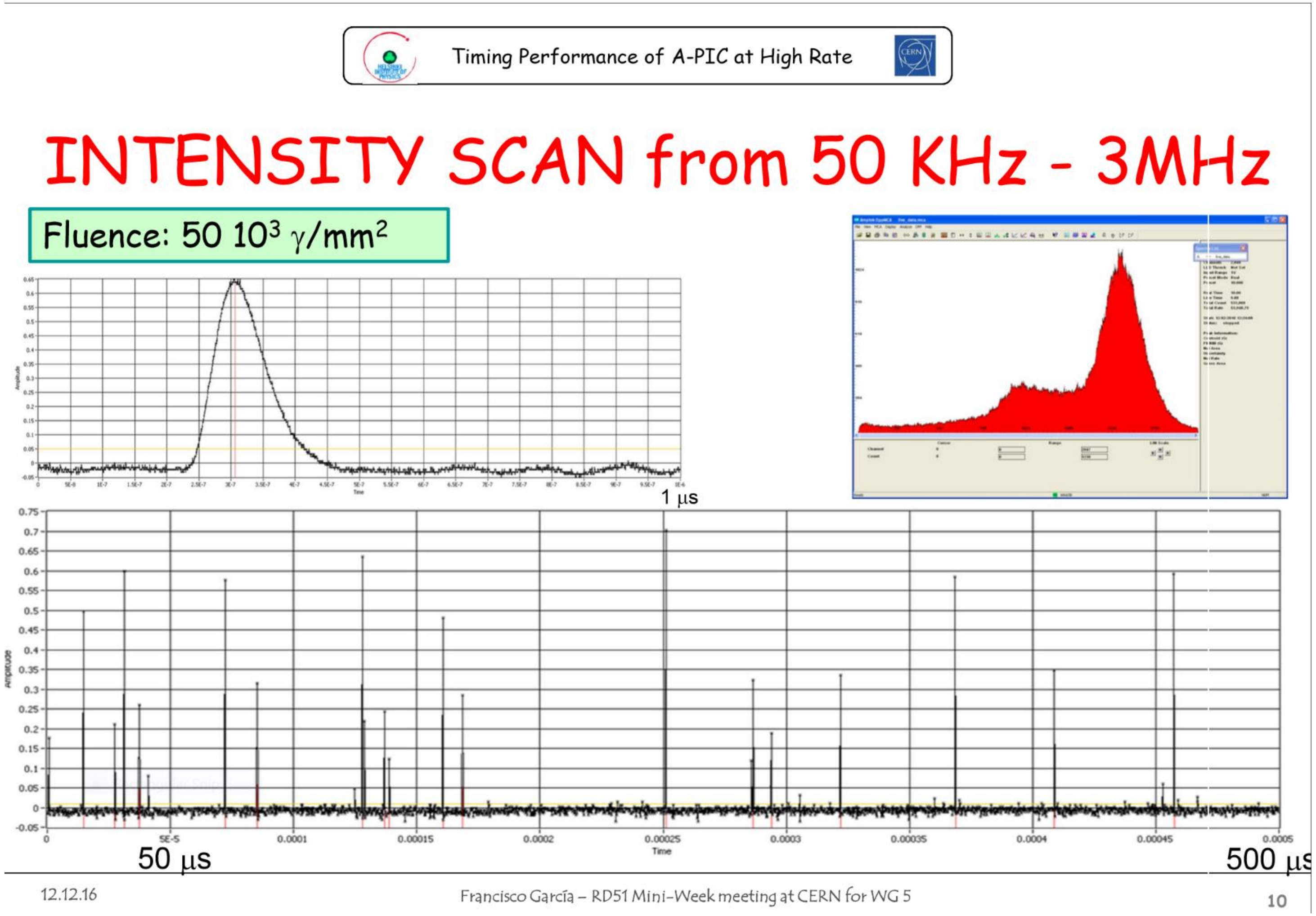
APIC: **Trigger Buzzer**



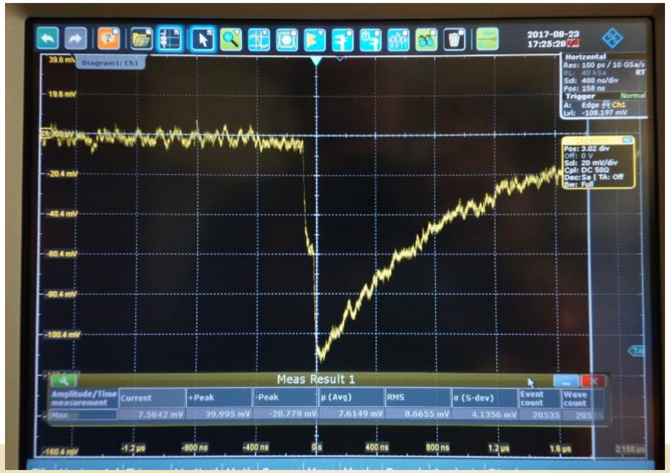
Trigger sound: Piezo buzzer, audible also for single triggers
The buzzer requires a stretched NIM output signal: Connect an short external coax cable between TOT or TBT trigger output to the trigger gate input (page 72)

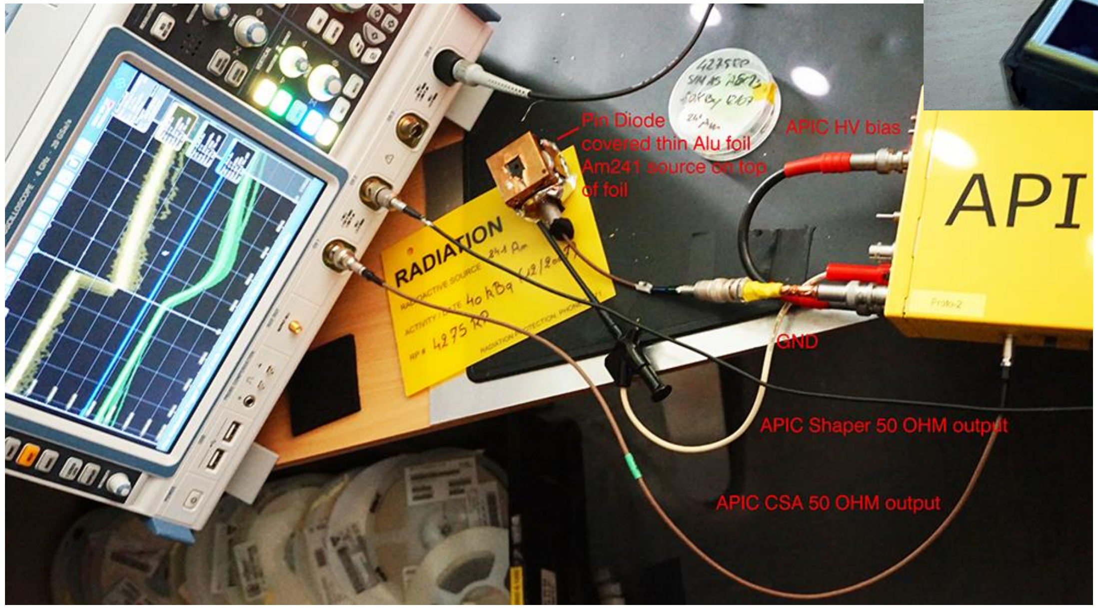
Examples APIC applications

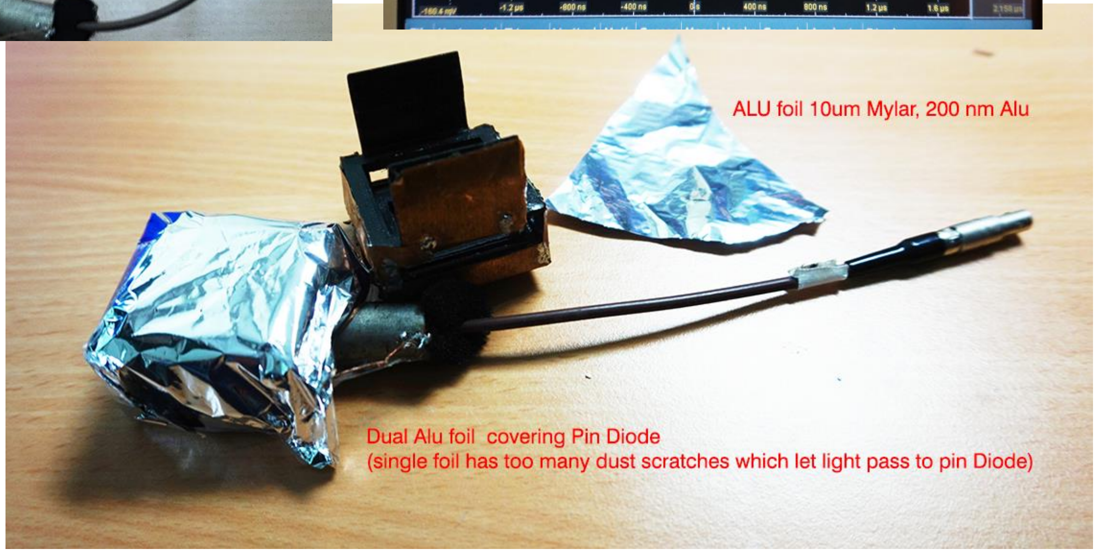
Triple GEM high rate Intensity Gamma



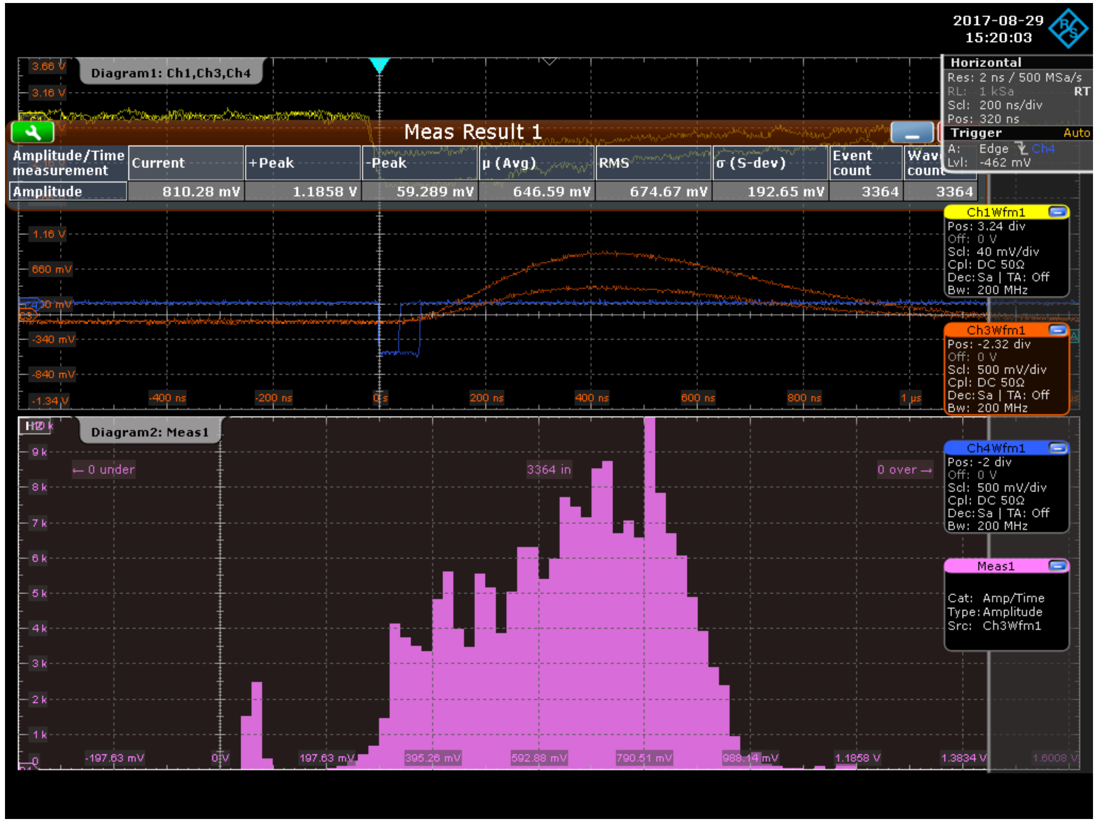
Pin Diode frontend : α spectra







α-spectrum bias voltage



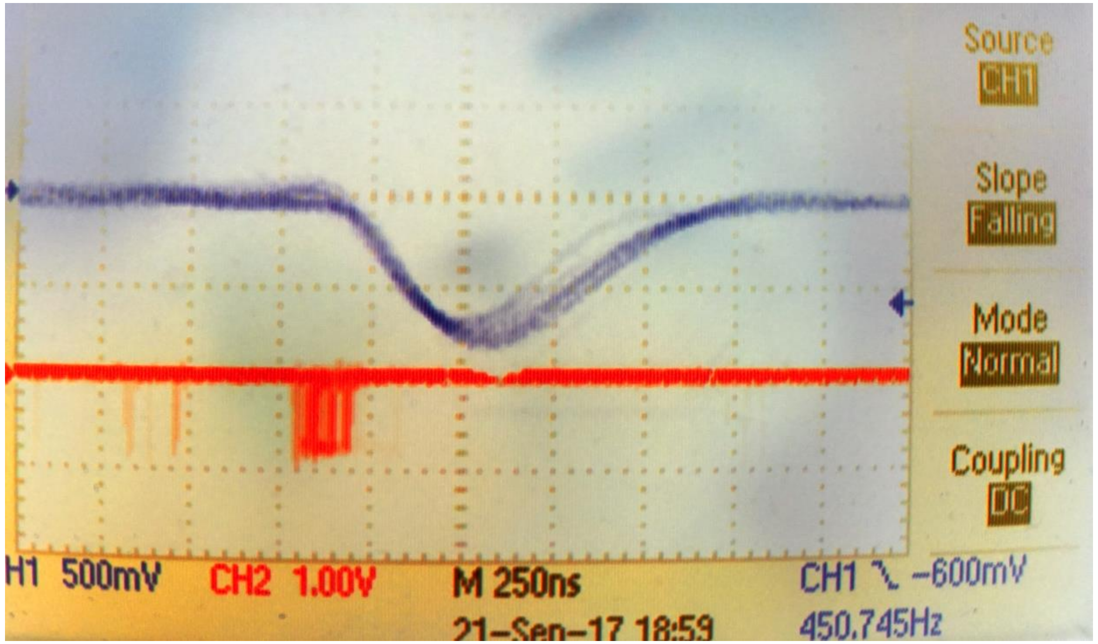
90V bias from APIC HV bias option

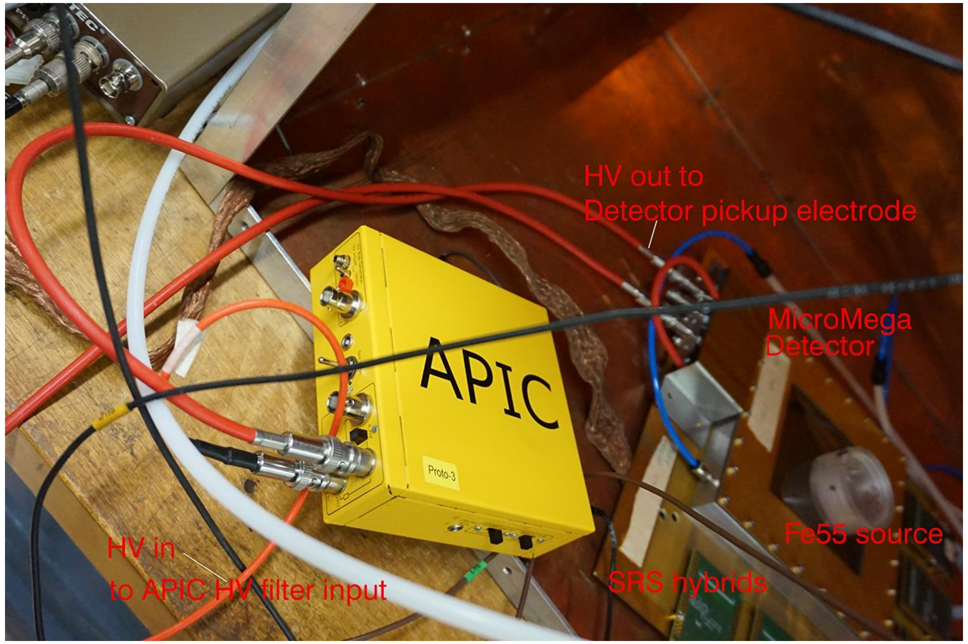
10V bias from APIC HV bias option

Signal and Trigger from Micromega mesh

APIC 300ns shaper

APIC NIM Trigger



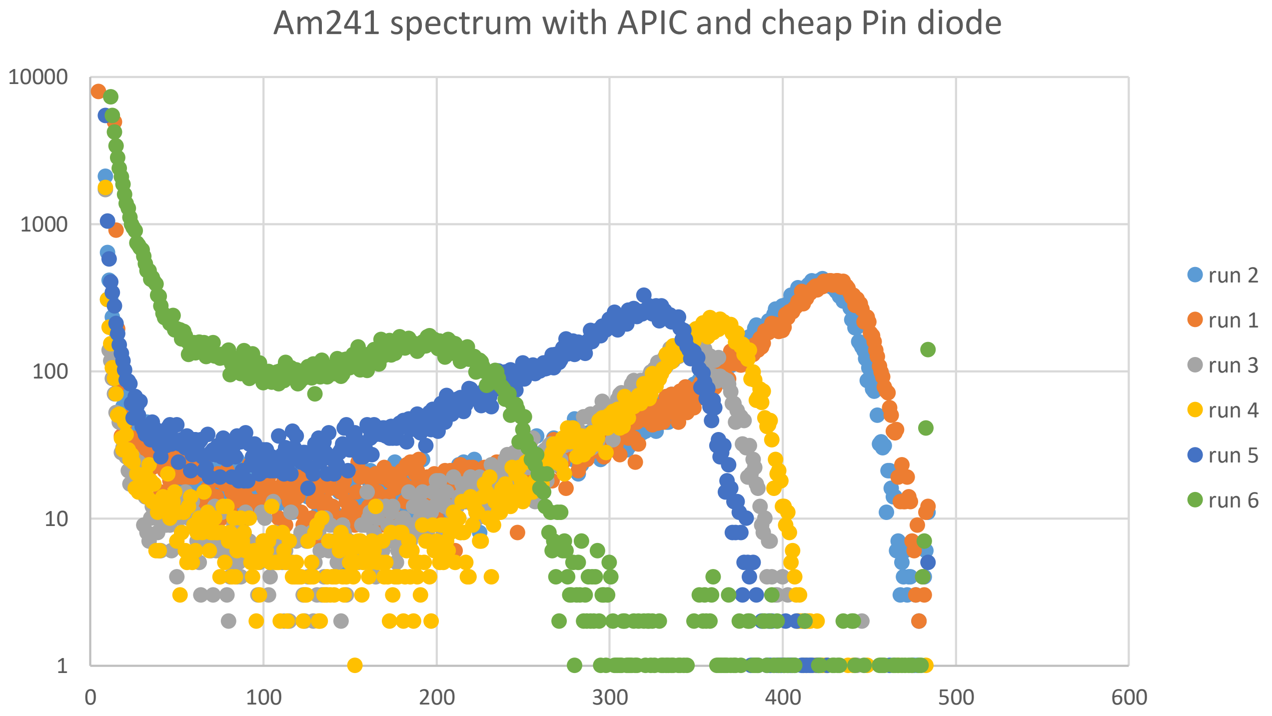


Alpha spectra with APIC and Pin photodiode

Test cover with Amaricium 241

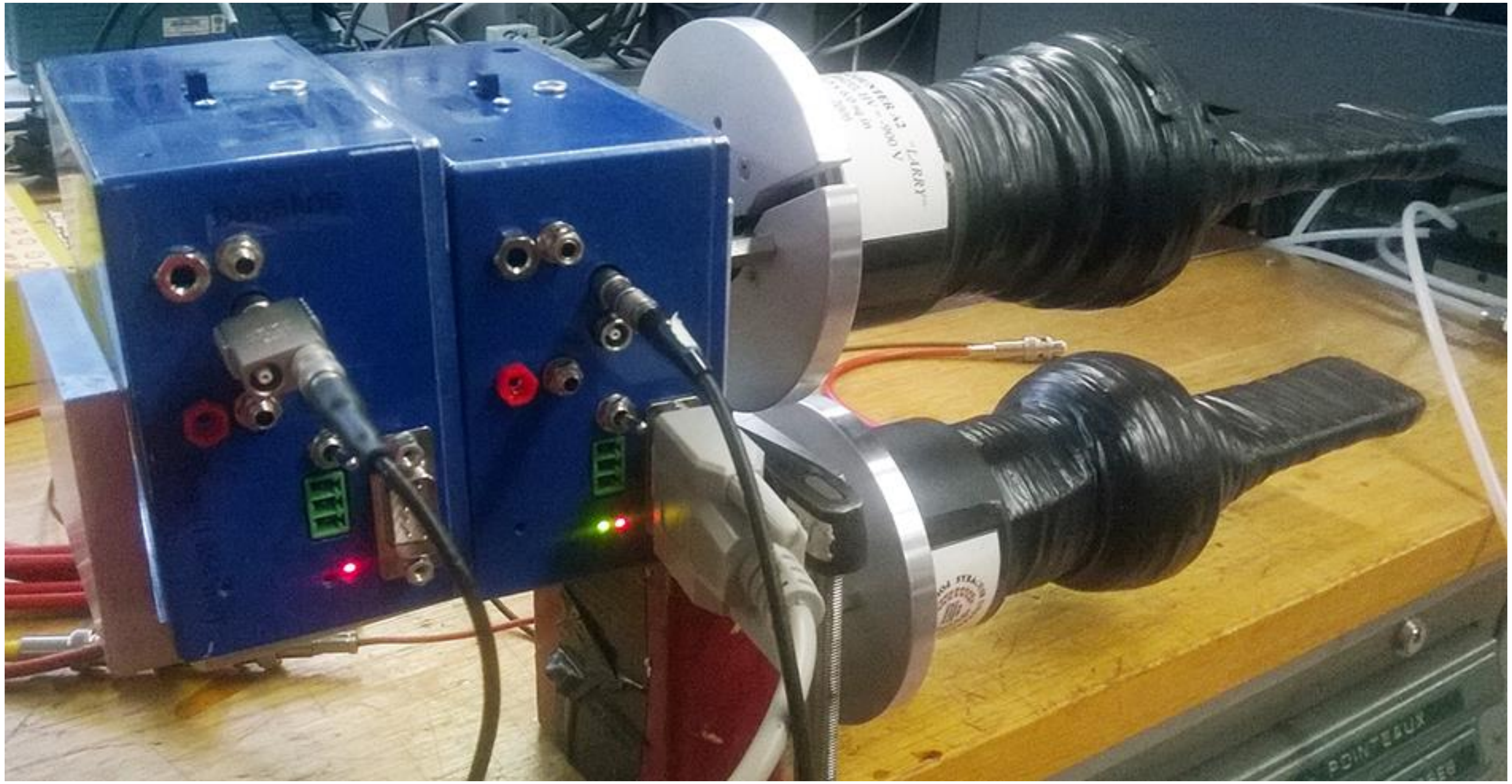
Photodiode

A cheap commercial photodiode was biased at variable APIC generated bias voltages and the APIC shaper output connected to an MCA

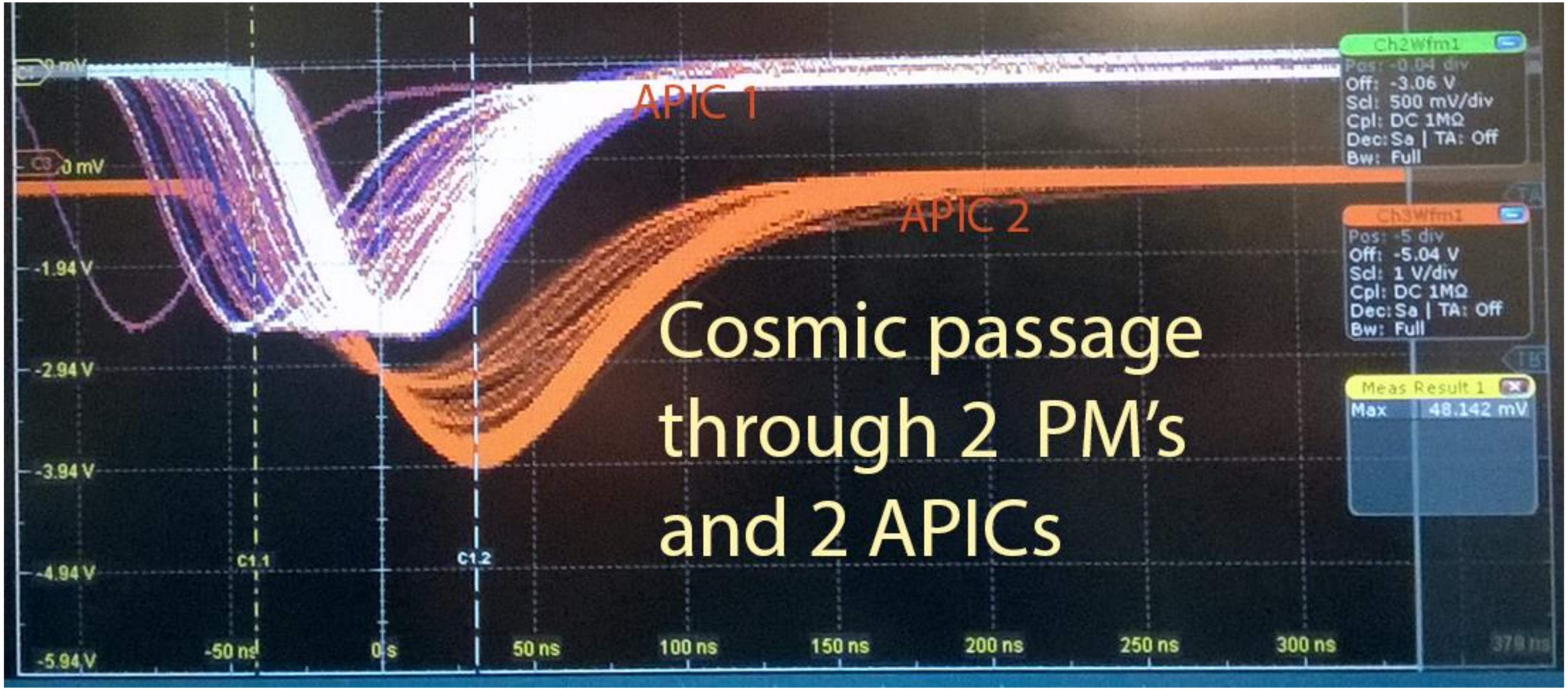


Run 1 with APIC internal Bias Voltage 20V , light shield around test box
Run 2 with 9V Battery Bias (~ noiseless crosscheck), light shield around test box
Run 3 and 4 like Run 1 with 4 and 5 mm wider separation, light shield around test box
Run 6 like Run 1 but lightshield replaced by 1 thin Alu foil 5uAlu+100u Mylar
Run 6 like Run 4 but 2 x Alu foil

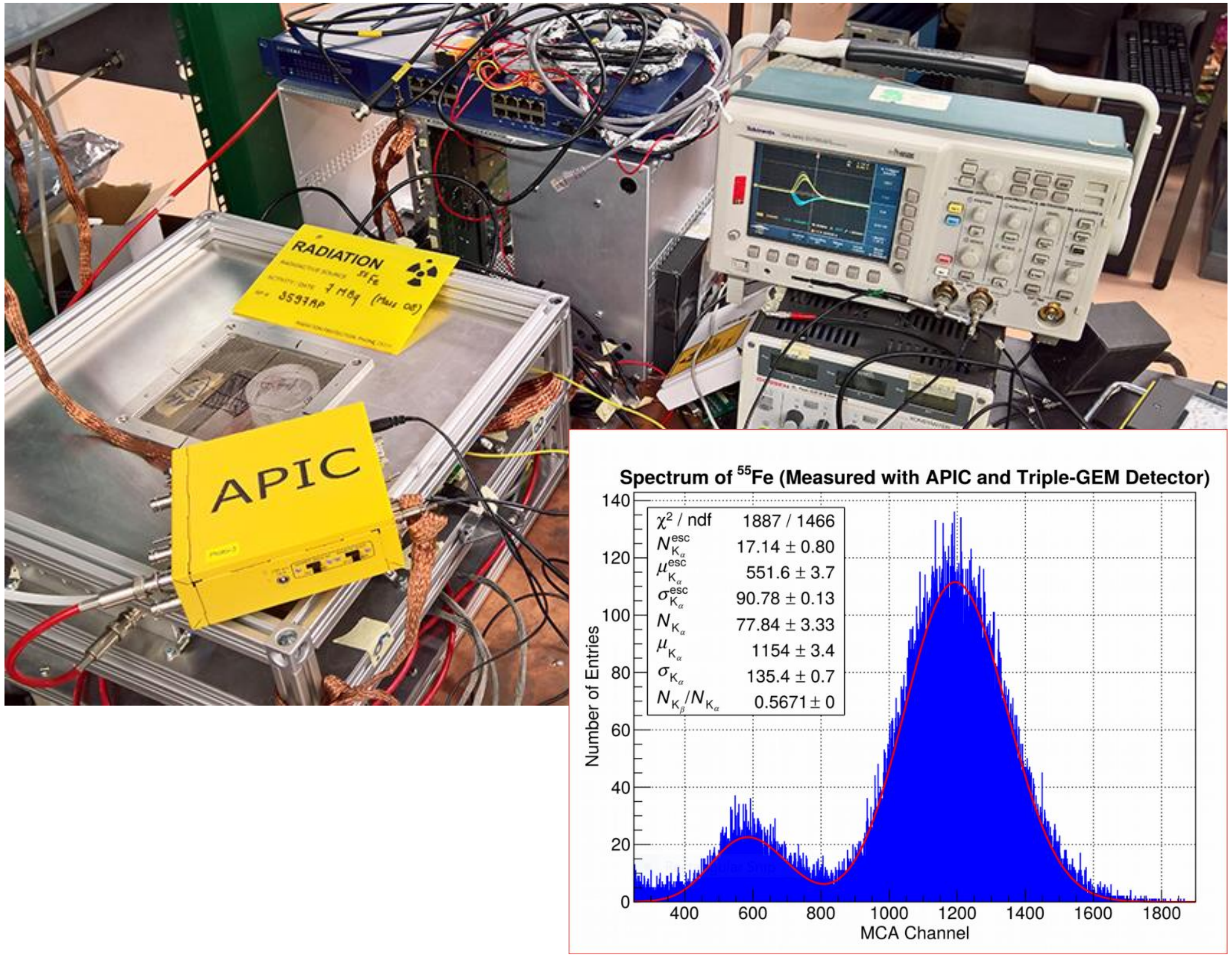
Photomultiplier telescope, 2 APICs (2016 prototypes)

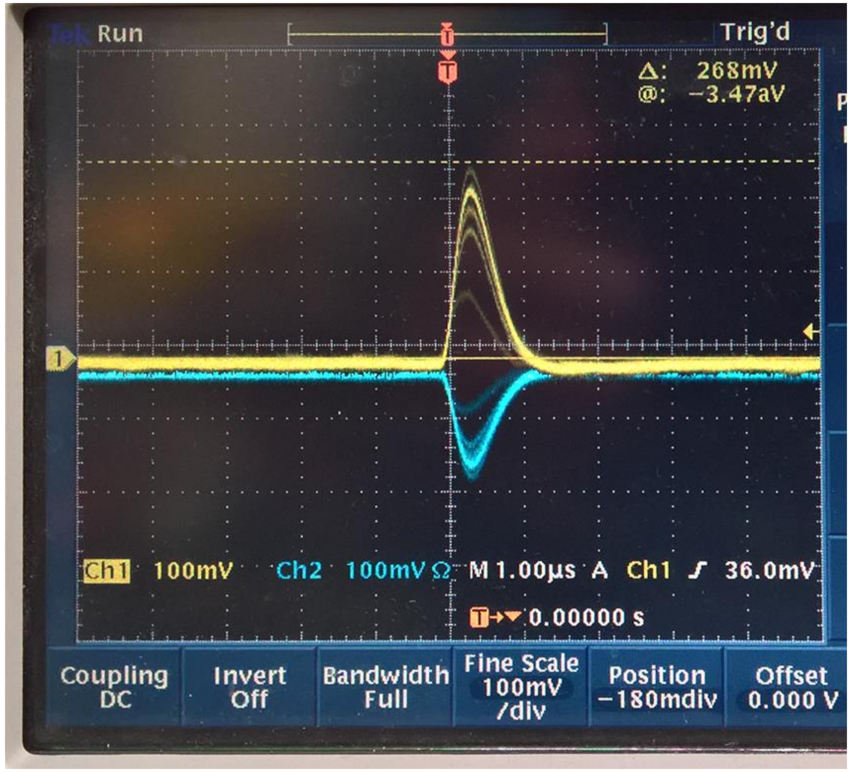


APIC with Photomultiplier

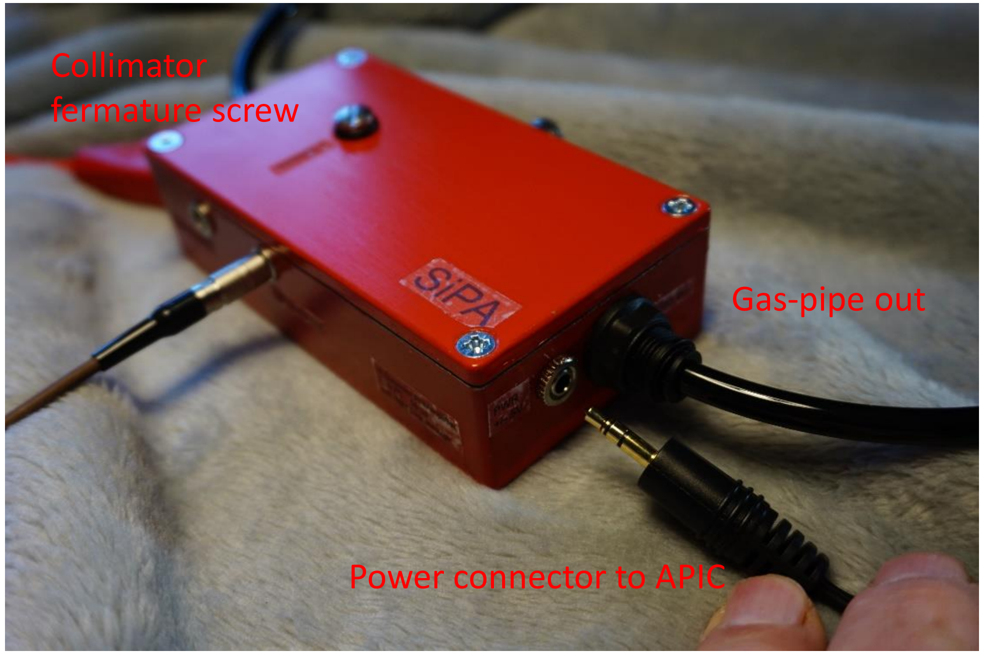


Bottom GEM signal pickup (2017 APIC V3)

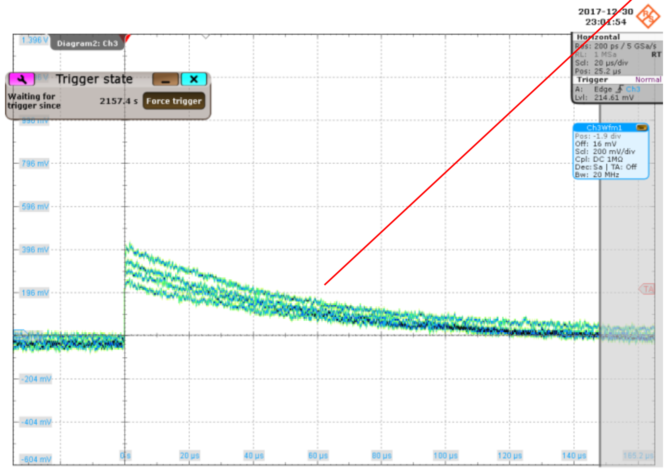


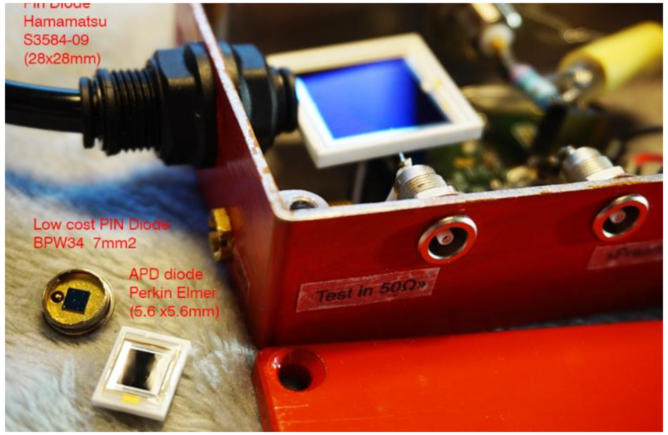


SiPA: external CSA for Si-Diodes



SiPa is an external preamplifier box for high capacity Si-Diodes. SiPa boxes can be connected and powered by APIC's from v4.1 on.





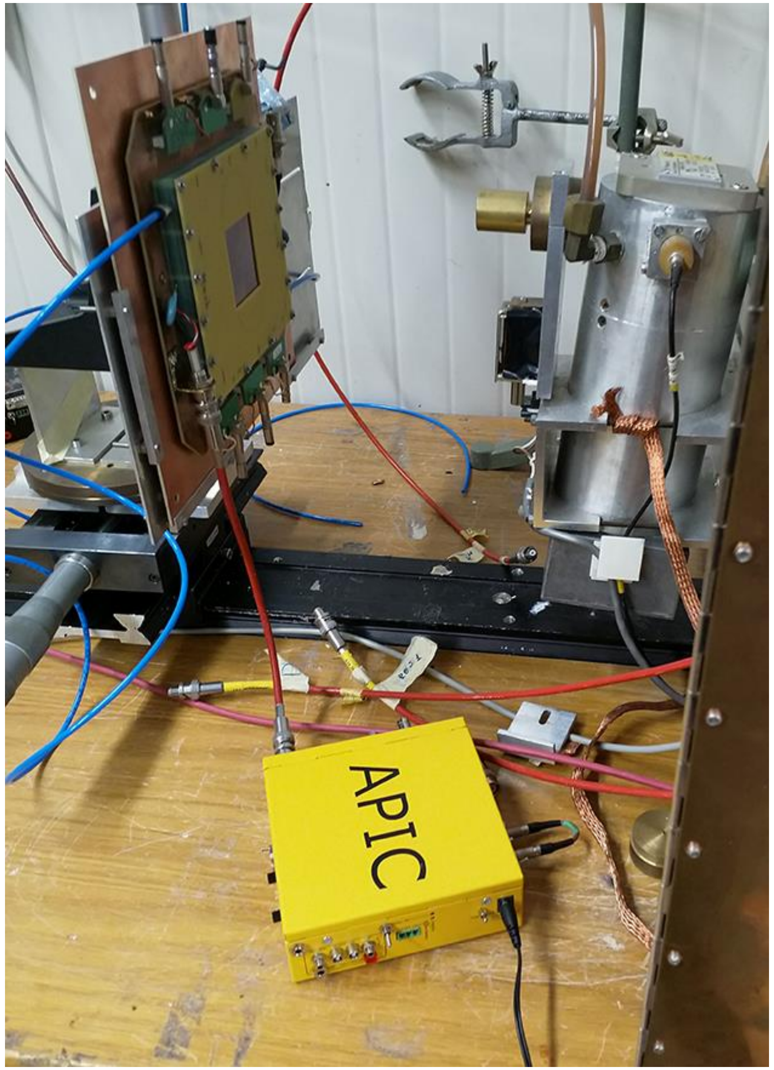
Direct SiPa response to rare , highly ionizing cosmics, recorded at a rate of 1/h by plugging a Hamamatsu S3584 PIN diode into the SiPa Socket.

The SiPa box is gas and light-tight and comes optionally with light-tight (black) gas inlets and outlets, allowing for Alpha detection contained in gas (i.e. Radon)

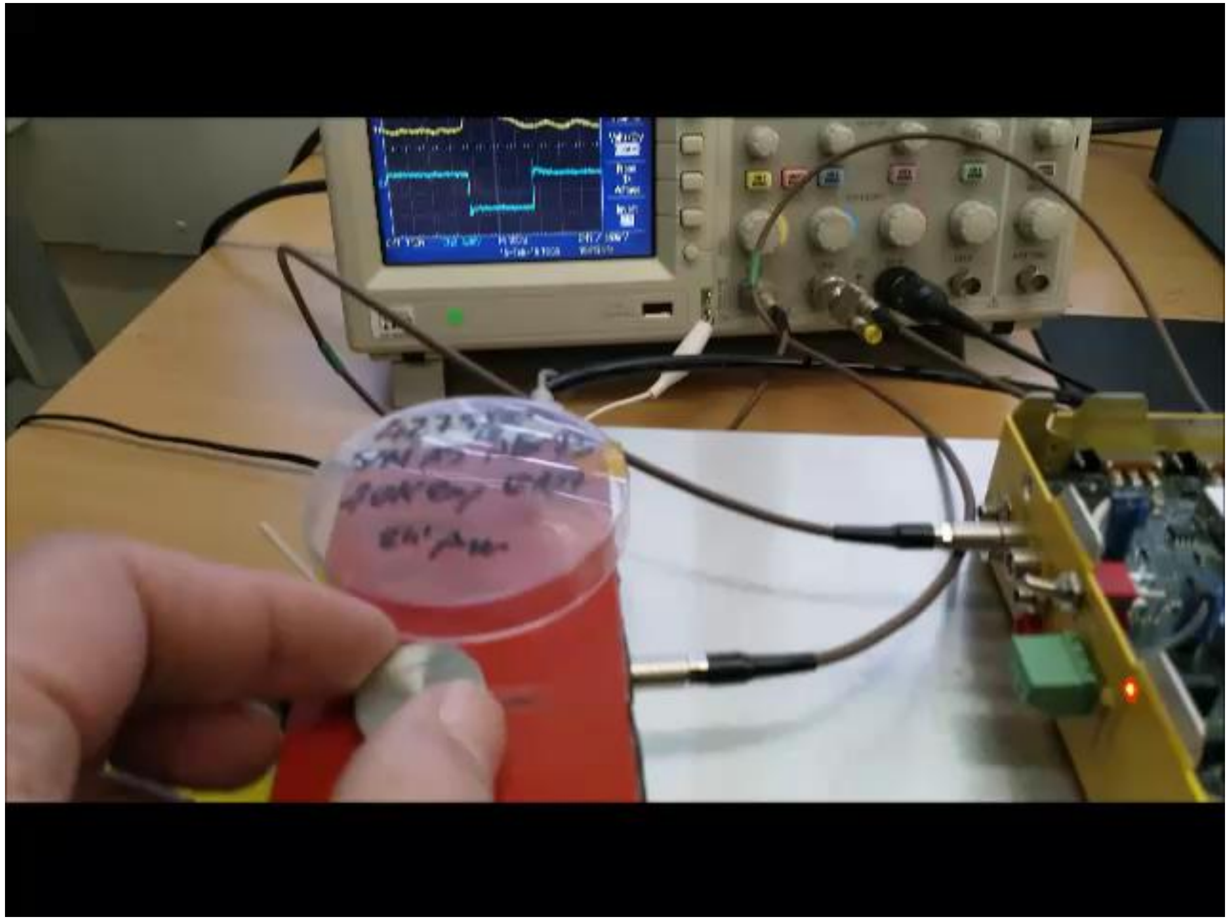
A collimator window can be opened for direct tests with Alpha sources (i.e. Amaricium 241)

Bias voltages for Pin, APD or Si-PM diodes can be connected from the APIC's 10- 100 V bias generator.

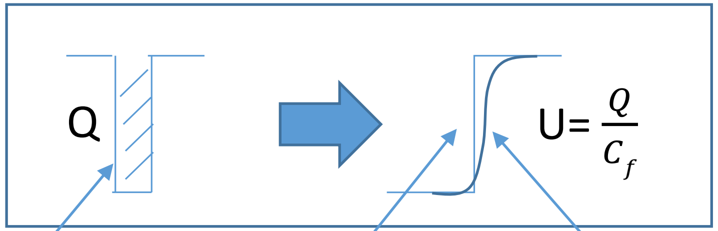
New

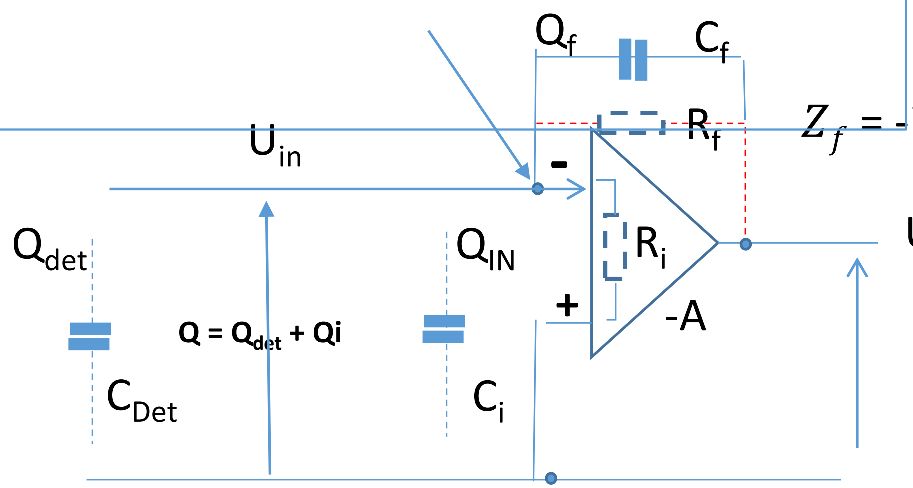


APIC "Geiger Buzzer" video



B1: CSA basics [4]





$Z_f = -i \frac{1}{\omega\, Cf}$

$U_{out} =: \frac{Q_{in}}{C_f}$

$= \int \frac{dQ_{in} dt}{C_f}$

$Z_{in} = \frac{Z_f}{(A+1)} \sim \frac{1}{\omega_0\, Cf} = R_{in}$ (real resistance)

Amplifier's Gain BW product: $\boldsymbol{\omega_0 = \omega(A=1)}$

<u>CSA features:</u>

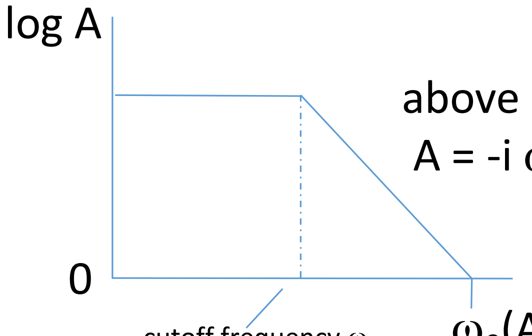
High: voltage/charge conversion gain = $1/C_f$

Example: $C_f = 2pF$ -> gain 0.5mV/fC

High: effective input capacitance $C_i = C_f\,(A+1)$ (Miller effect)

Low: input impedance $Z_{in} = R_{in} = \frac{1}{\omega_0\, C_f}$

High: response time $t_{out} = \frac{C_{Det}}{\omega_0\, Cf}$



above ω_c :

$A = -i\, \omega_0/\omega$

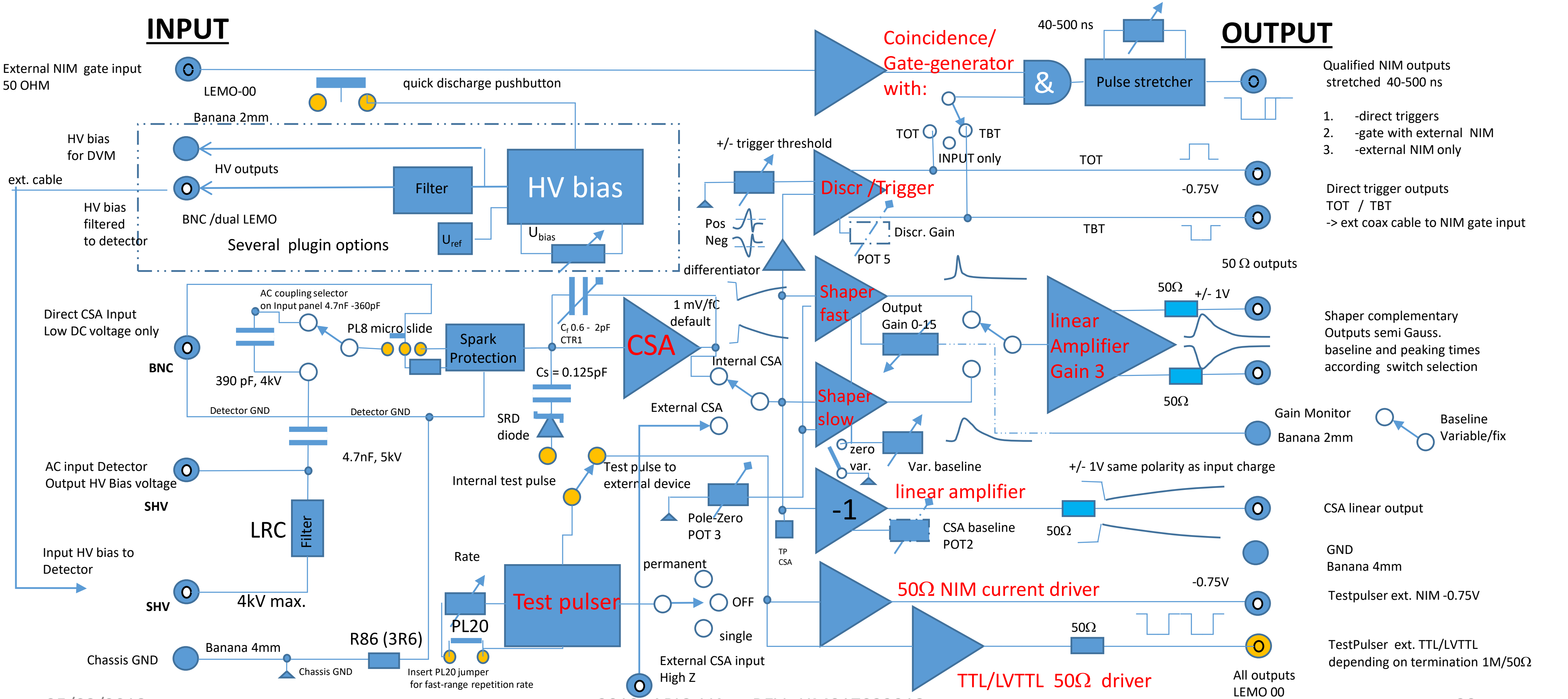
output risetime to step input: $t_{out} = 1/\omega_c$

Technical Appendix

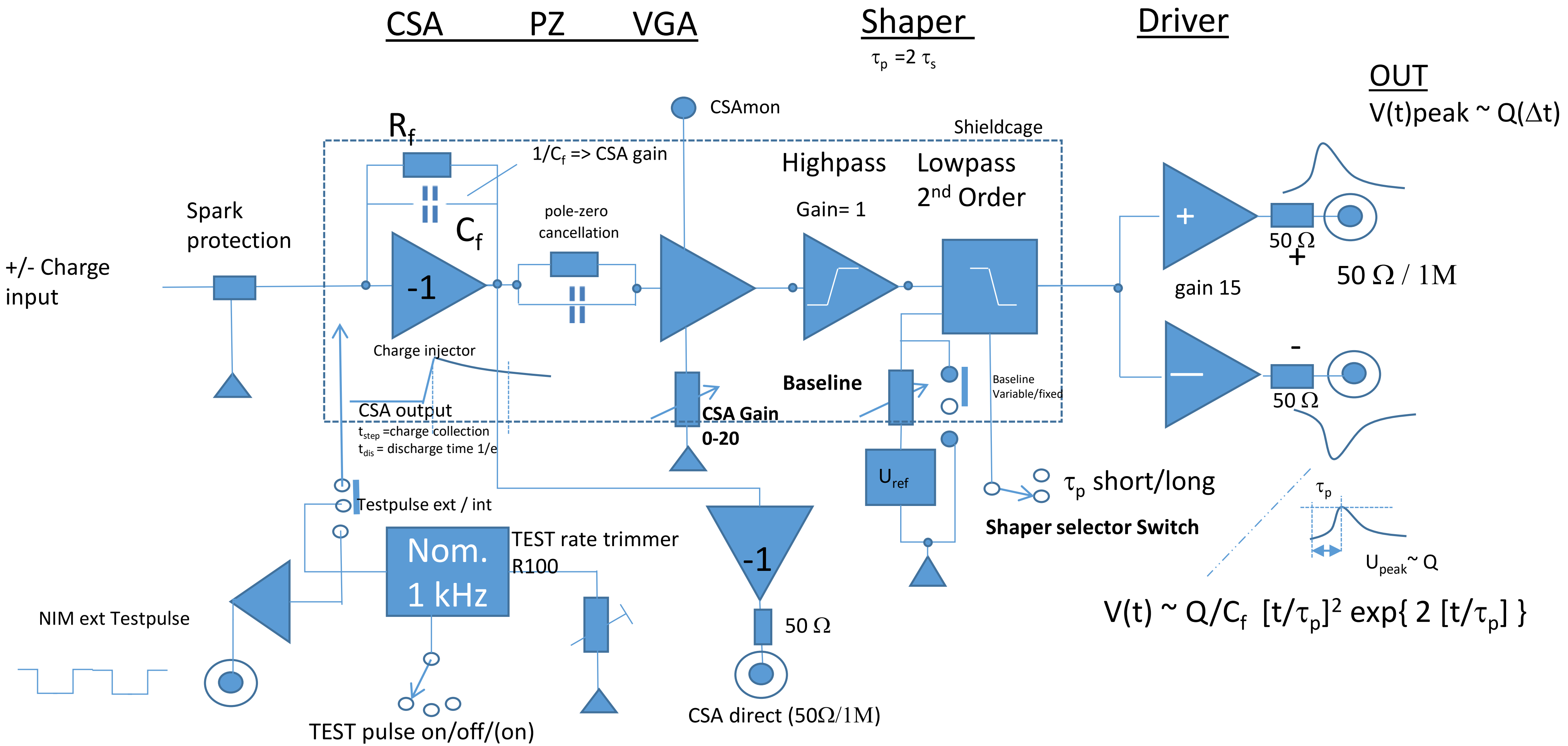
A1: APIC functions/configuration (V4.x)

External pots

Internal trimmers

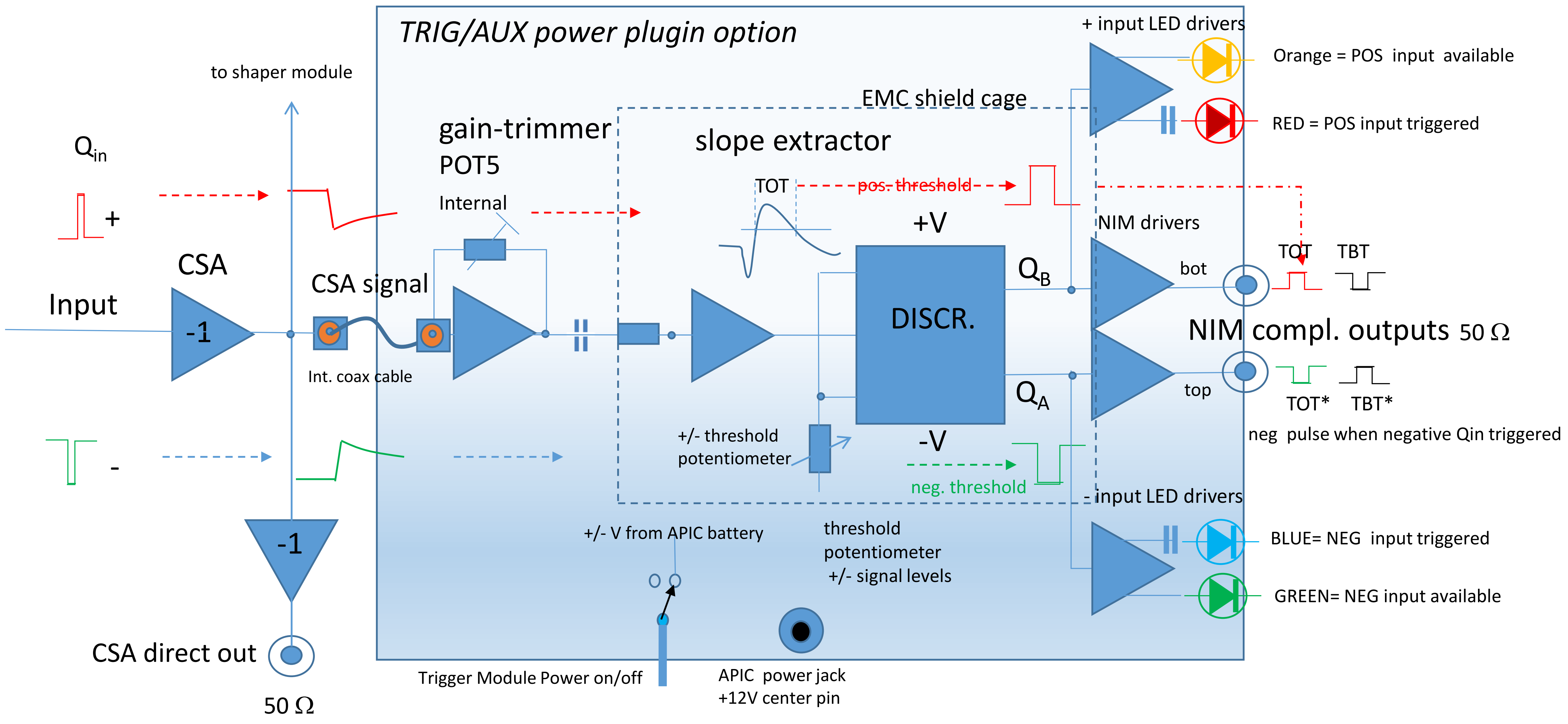


C1: CSA-shaper block diagram

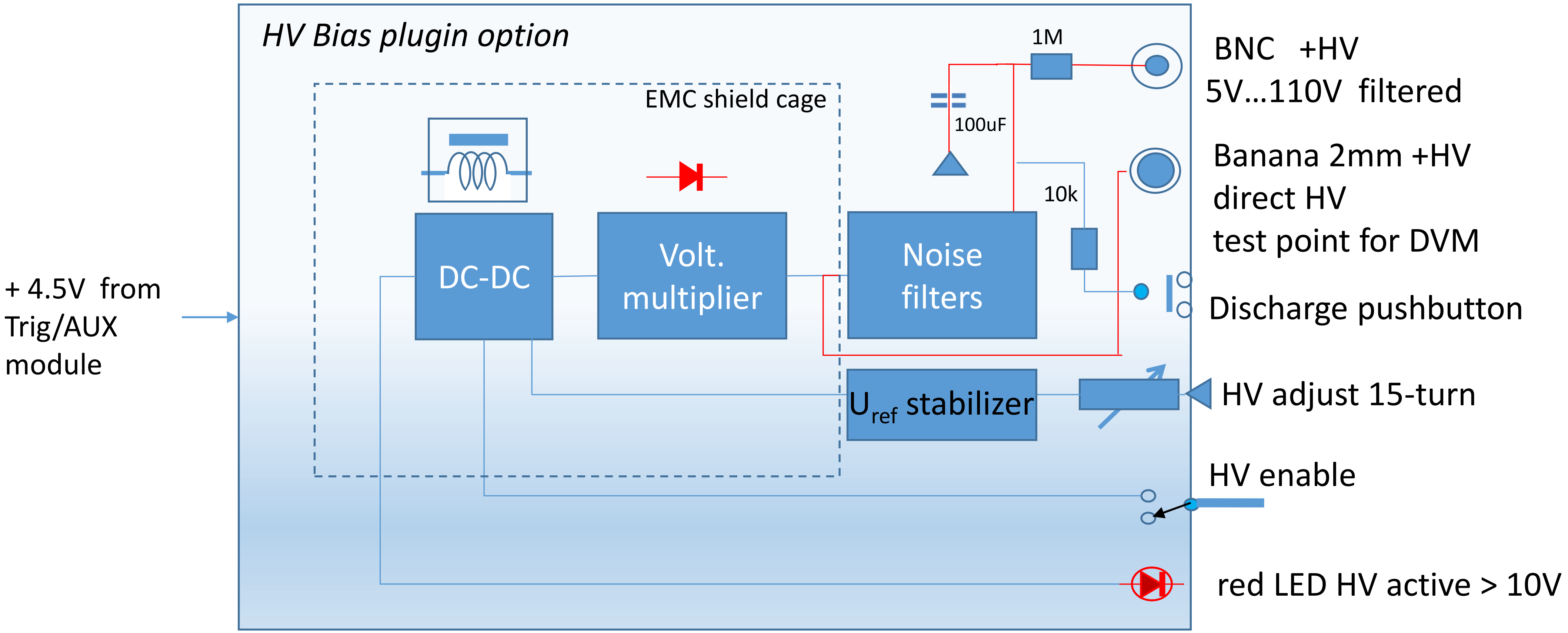


$$V(t) \sim Q/C_f \; [t/\tau_p]^2 \exp\{ 2 \, [t/\tau_p] \}$$

D1: Trigger / AUX power module

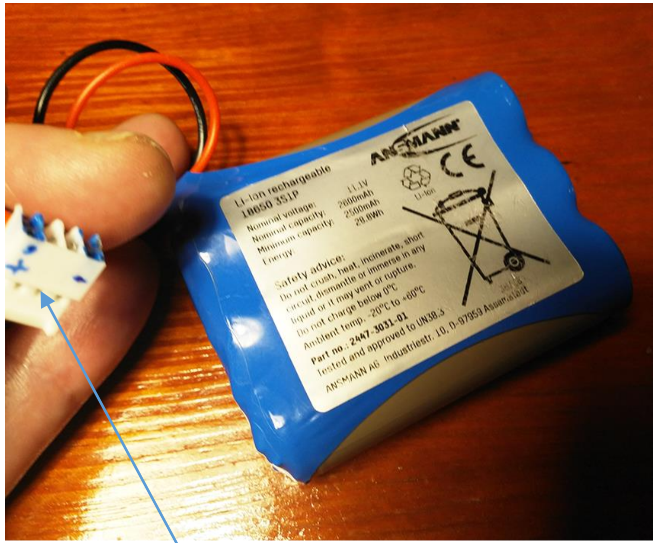


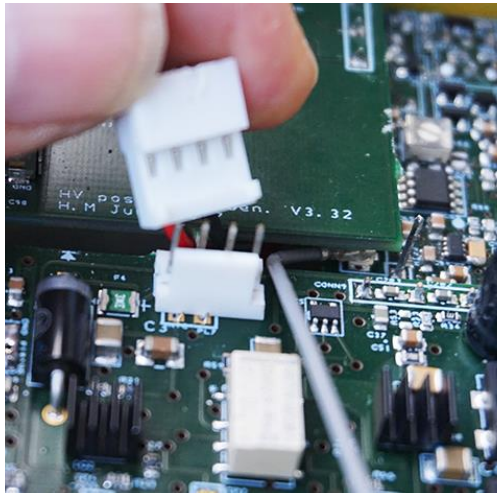
E1: HV bias plugin option for Si-Diodes



F1: Battery*

3-cell Li-Ion 11.1 V 9V… 12.6V, 2600 mAh (31 Wh ~110 kJoule !!)
An intelligent charger ASIC in the APIC regulates the charge current according temperature and charging status with max current of ~ 250 mA and limits the maximum battery voltage to 12.4 V (100% max. = 12.6V)
An NTC element adjusts charge current according battery temperature.
Electronic PTC fuses (200mA) protect Battery against short circuits APIC.
Full chargeup time 220 ca. 12 h.





CAUTION !!

DO NOT short-circuit the APIC battery
For any APIC shipment:
disconnect the 4-pin Battery plug (photo)
and protect the plug contacts via insulating tape.
Place APIC box in a humidity-tight,
non –inflammable bag.
Place APIC box in shock absorbing box
with min. 10 cm shock absorbing material

4 pin connector (not original)
TE connectivity 3-643814-4

*Ansmann 2447-3031

G1: APIC box and Power consumption

industry-style Alu instrumentation

compact 4-parts, 2 fixation screws

177 x 133 x 44 mm

Weight 0.8 kg

bottom-side rubber spacers

power consumption 1.2 – 1.8W*

max. stored Battery Energy 31 Wh

*depending on enabled functions

G2: APIC Power consumption

- Lithium battery 10.4V -- 12.4V
- Lithium charge current max. 220mA
- Int. regulated supply voltages A: +/- 4.24V
- Int. regulated supply voltages B: +/- 2.6 V
- APIC main Unit
  - -CSA(10mA) + Shapers (120mA)
  - -Test pulser 20 kHz active +(10 mA)
- Trigger Unit
  - - TOT / TBT triggered + (90 mA)
- HV Bias Unit
  - - stable Voltage (not ramping) +(5 mA)

Full stored Energy: **31 Wh**

Minimal functions enabled**: 130 mA**
CSA and Shapers no trigger: 1.5 Watt
=> max **20h** autonomy

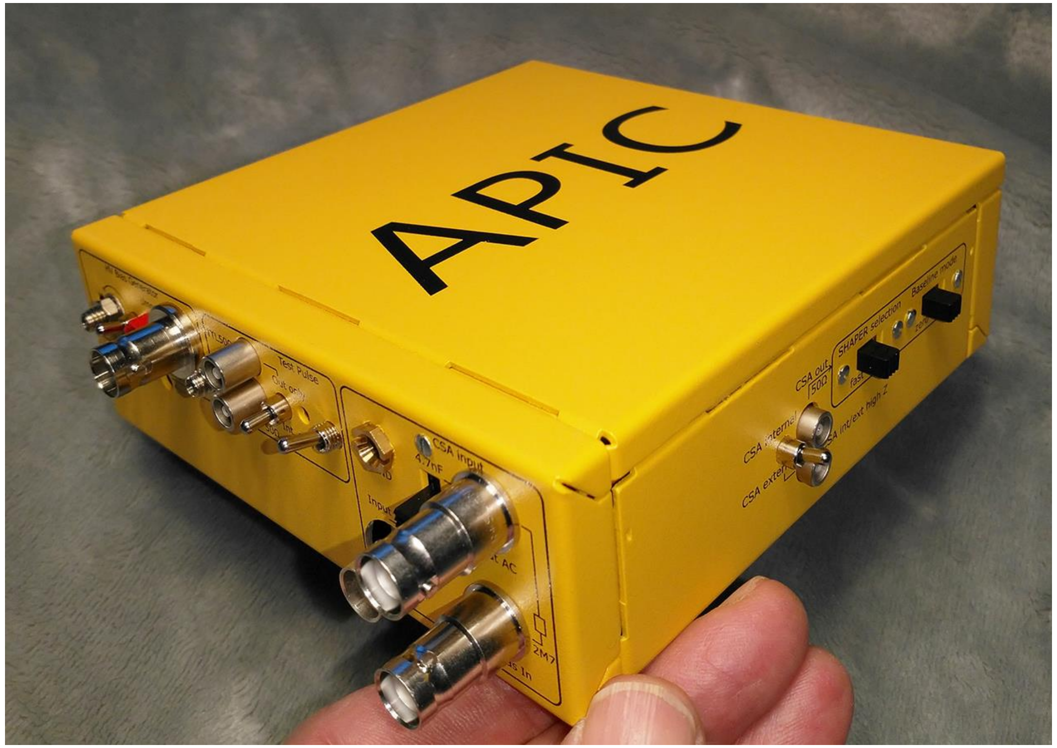
Maximalfunctions enabled**: 235 mA**
CSA shapers Trigger and HV bias: 2.6Watt
=> max **11.5h** autonomy

Note: a fully discharged APIC can be immediately used by plugging the direct AC +12 V supply.

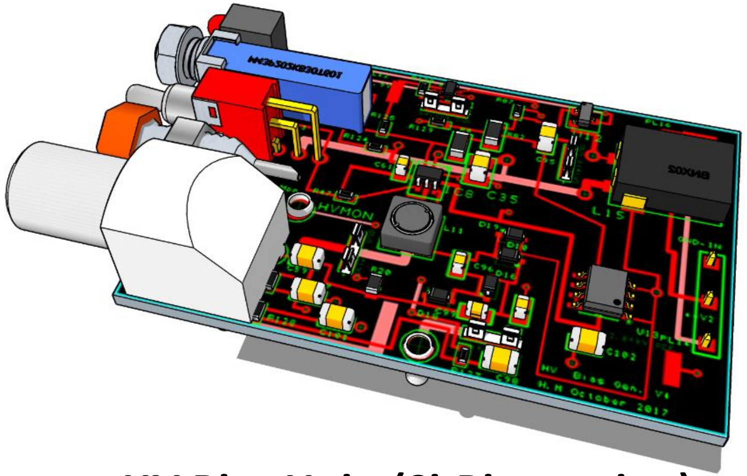
H1: Photos APIC V4 all sides

Shaper / power / buzzer - Trigger and stretcher unit

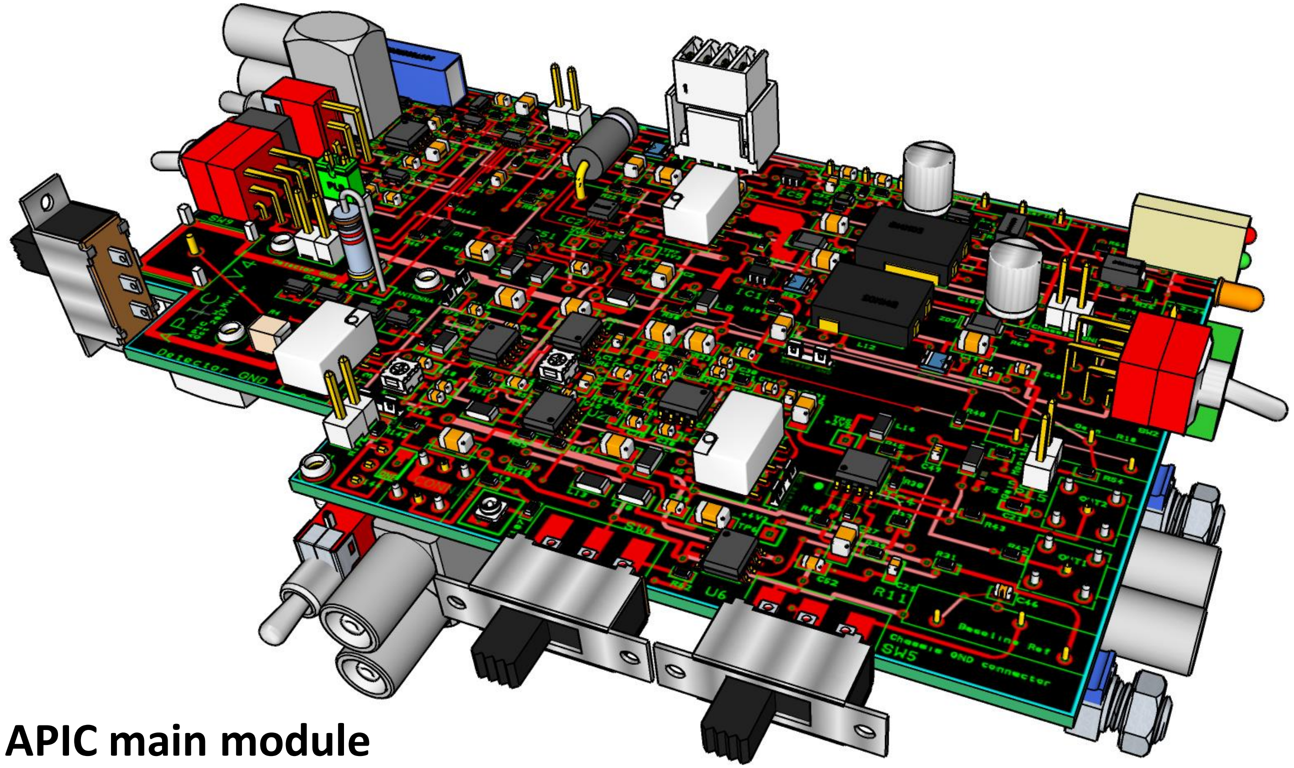
Bias HV, Test and Detector Input - CSA- and shaper selector



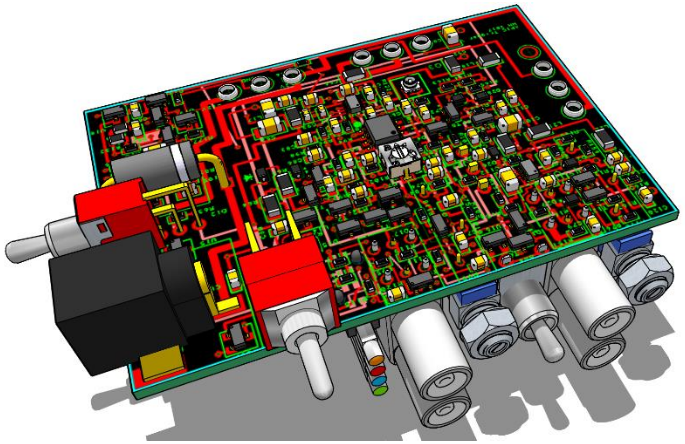
K1: APIC modules



HV Bias Unit (Si-Bias option)



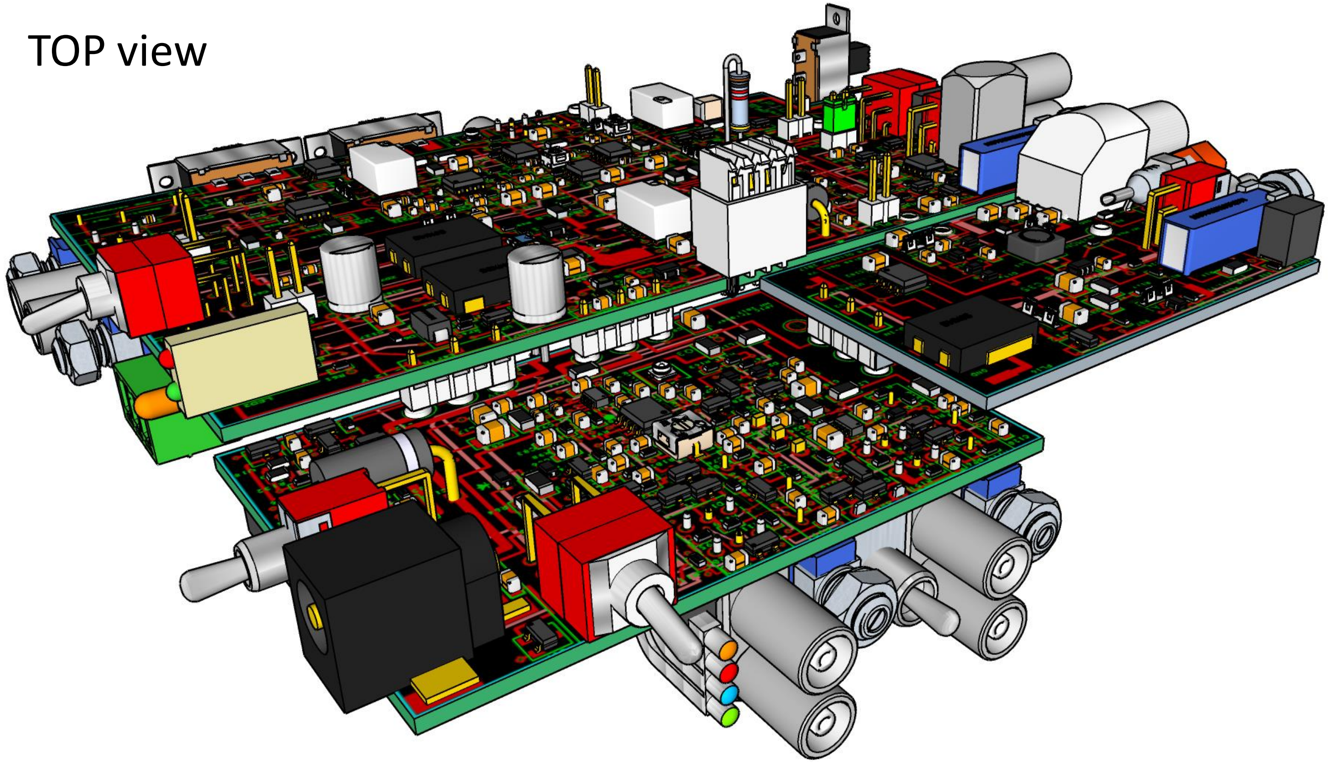
- **APIC main module**
  CSA – shaper- Power management –test pulser



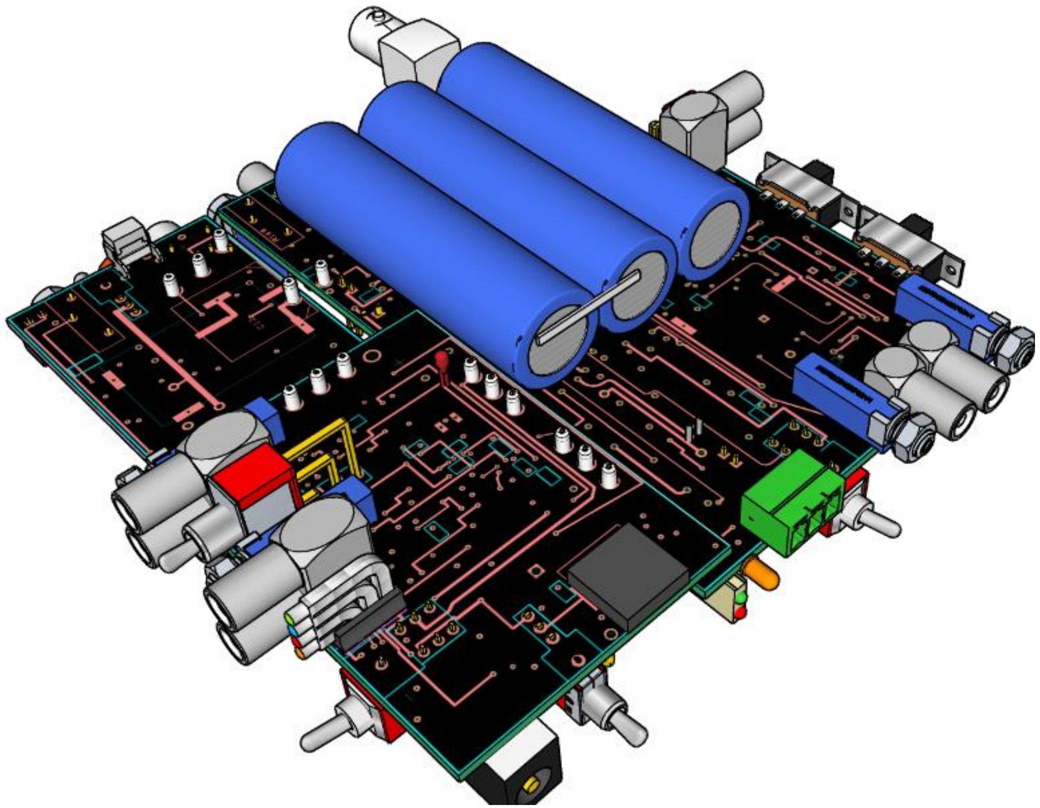
Discriminator/Trigger AUX power Unit

L2: APIC modules interconnected

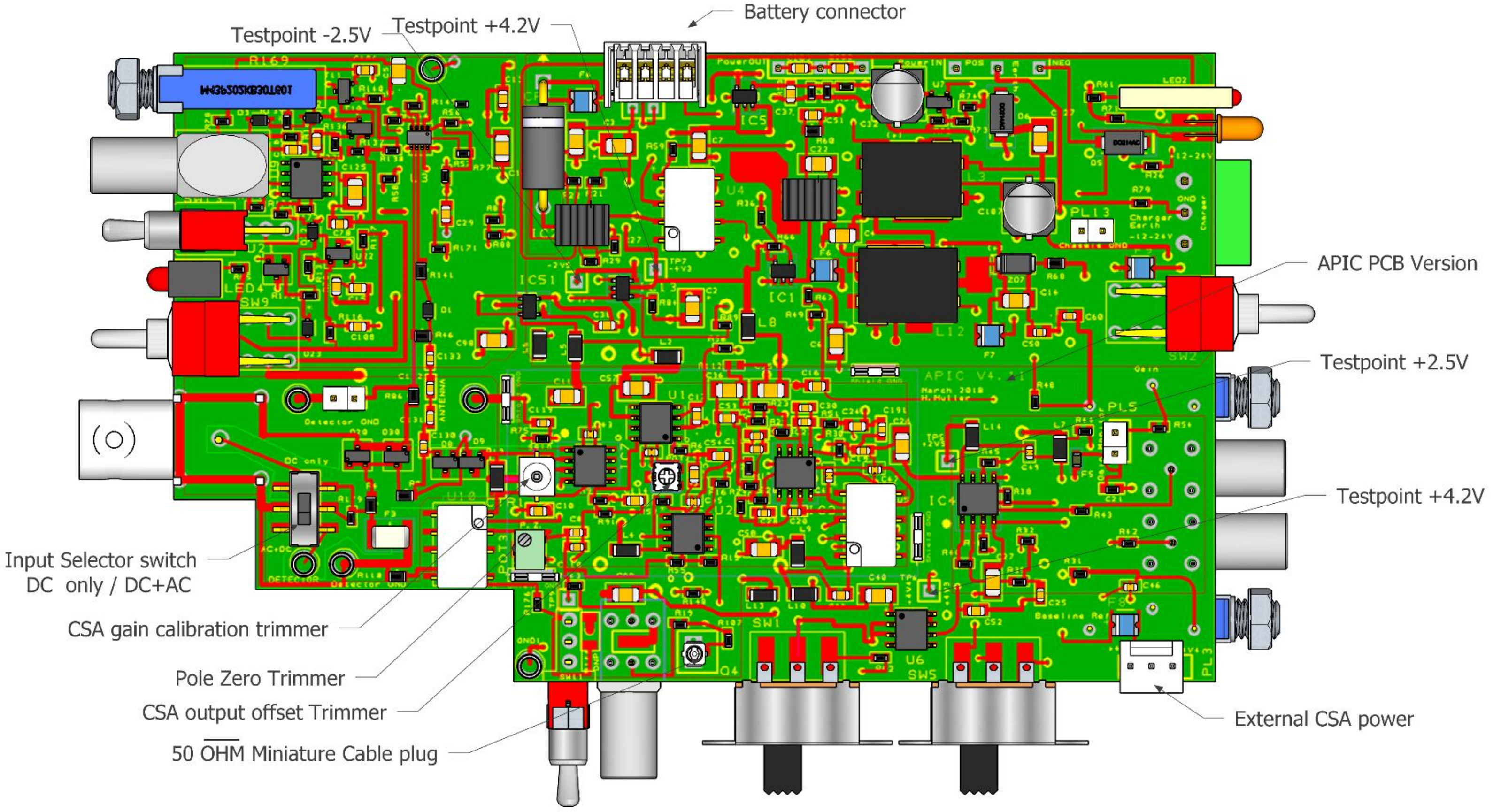
TOP view



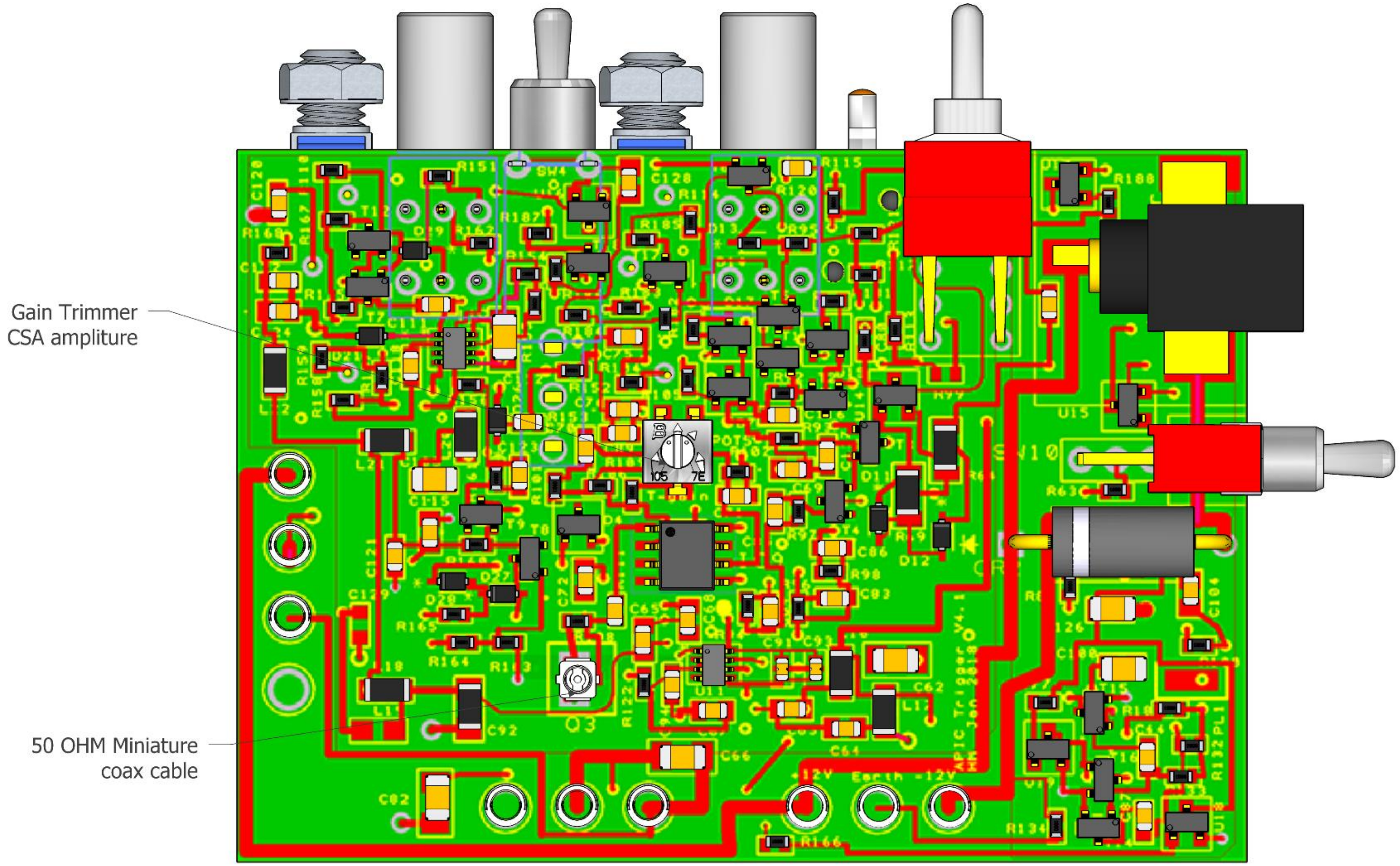
Bottom view



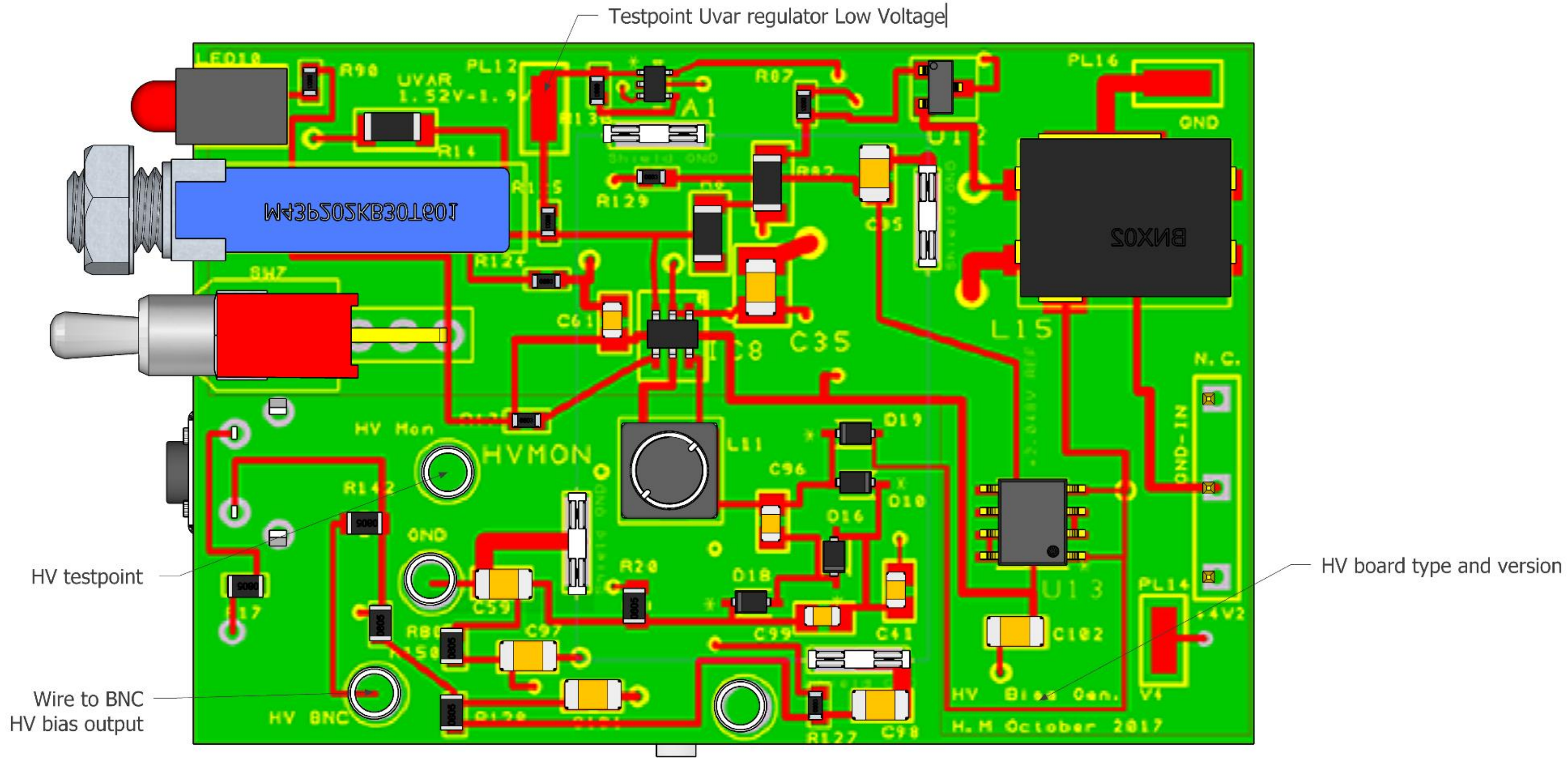
M1: Trimmers and Testpoint APIC main board



M2: Trimmer and access point Trigger Unit



M3: Testpoints HV Bias module



SiPa* feature summary

1x built-in CSA preamplifier
- default gain 2mV/fC, 50 us decay
- internal offset-zero trimmer
- 50Ω output to APIC via coax cable
-3 pos. receptable for Diode plugin(pitch 2.54 or 5.08 mm)

1x Test pulse input (from APIC)
- 50 OHM pos. or neg.

1x filtered detector Bias Voltage input
- SHV connector, requires SHV –SHV cable to APIC
- LRC filter (R=10M) to diode cathode

1x direct CSA output 50 Ω
- 50 Ω direct CSA output, polarity = - (input charge)
-direct monitoring on Oscilloscope

SiPa box
-Alu cast 112 x 98 x 30 mm without connectors
-gas tight connectors and cover/collimator joints

Collimator
-direct access of radioactive sources to Diode sensitive area
-gas tight M4 screw

1x gas inlet
- Festo quick tube connector for Legris black tubes 6mm dia
- direct stream on Si Diode emplacement

1x gas outlet
-- Festo quick tube connector for Legris black tubes 6mm dia

* external preamplifier (photo page 2)

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