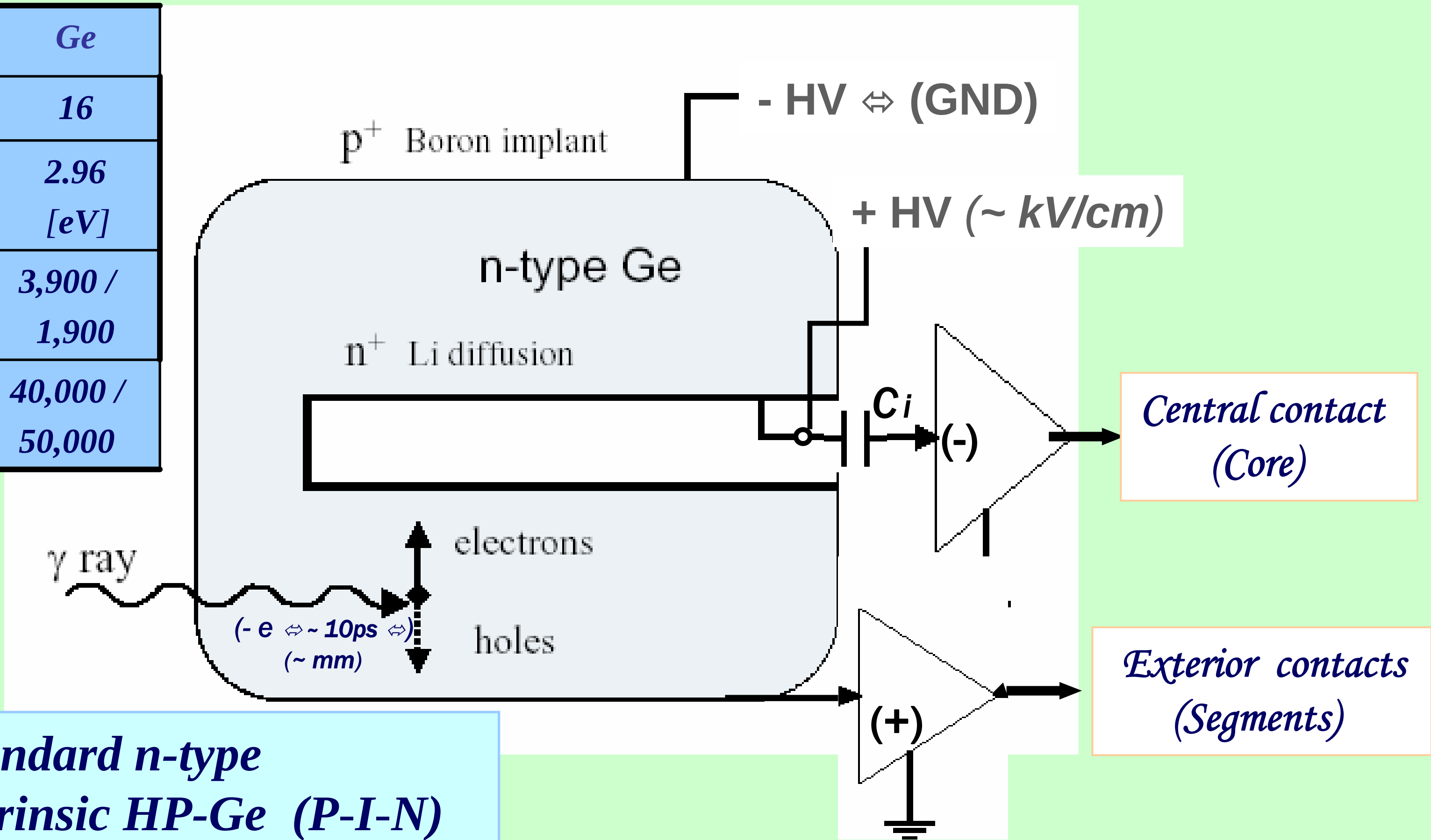
• *Charge Sensitive Preamplifiers (CSP)*
for the MINIBALL Array of Detectors

- *Core & Segments CSPs for 6-fold and 12-fold segmented and encapsulated detectors;*
- *Principle of operation, schematics, PCBs;*
- *Adjustments, troubleshooting, maintenance.*

A typical structure of a symmetric HP-Ge Detector

Parameter	Ge
Dielectric	16
Electron-hole pair E	2.96 [eV]
Mobility e / hole(+)	3,900 / 1,900
e / hole(+) [cm ^{2}/Vs]	40,000 / 50,000



- Standard n-type
- Intrinsic HP-Ge (P-I-N)
- Closed end
- Co-axial structure
- I(o) ~ < 10 [pA]

- C_{det} ~ 35 pF
- Collection time ~ 100 - 1000 ns

Semiconductors Detectors HP-Ge

Parameter	Ge	
Dielectric constant ε_o	16	e (-) ⇔ 38,500 [100]/[111]
Electron-hole pair E $\mathcal{E}_n$ [eV]	2.96 [eV]	Hole (+) ⇔ 61,500 [100]/[111]
Mobility e / hole(+)	3,900 / 1,900	@ [~ 300^oK]
e / hole(+) [cm^2/Vs]	40,000 / > 50,000	@ [~ 80^oK]

Analog Nuclear Electronics

- *Detector Signal collection*
- *Electronic Signal Processing*
- *Front-End : Preamplifier & Shaper*
- *Considerations on Detector Signal Processing*

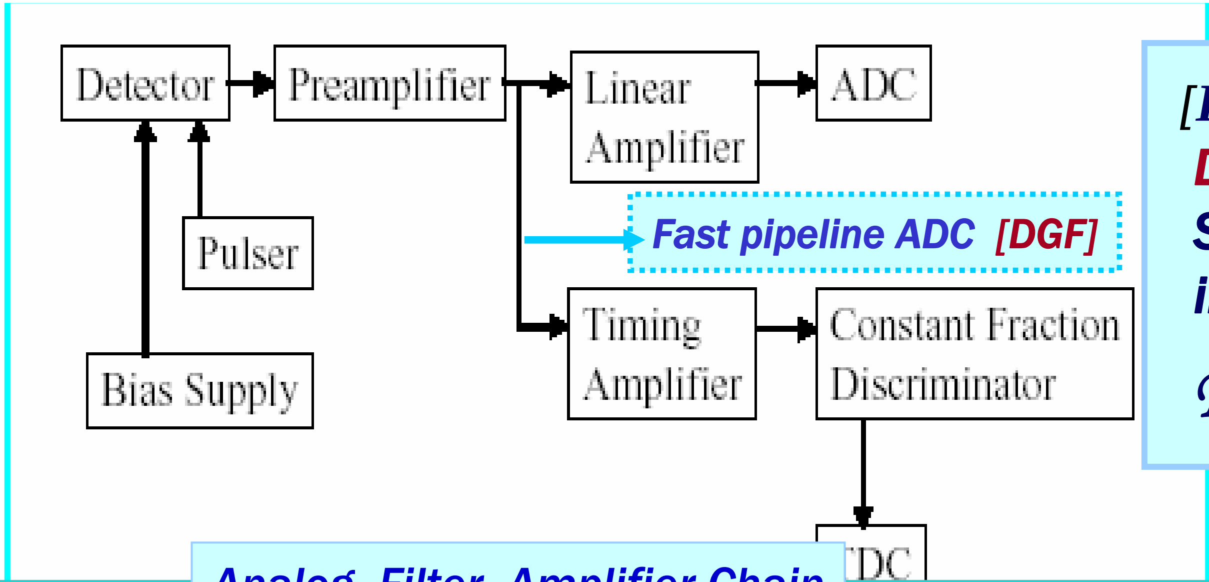
- *Specific issues about signal processing in gamma spectroscopy: a) pulses (delta, step, ~ Gaussian form)*
  b) they are statistically distributed (BLR)

- *Time ⇔ frequency domain signal, circuit representation,*

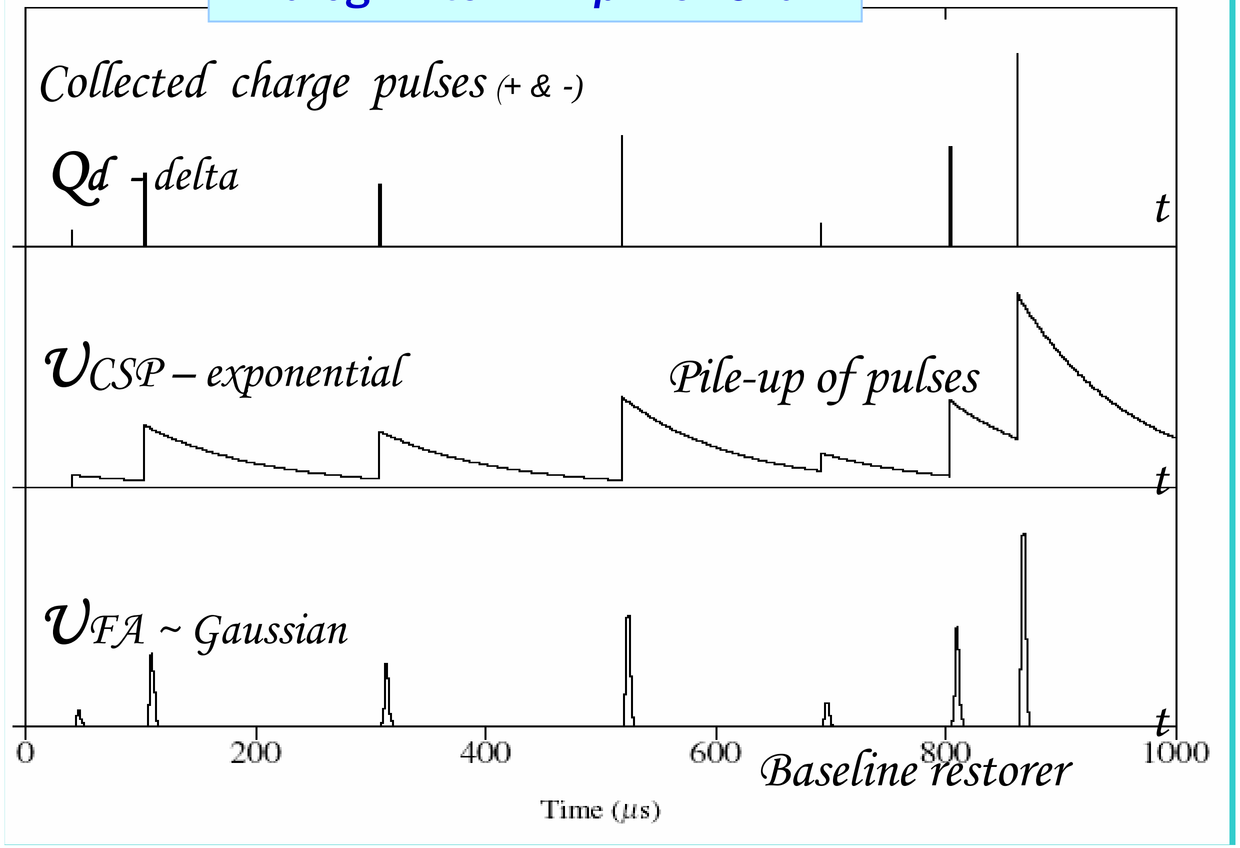
- *A typical analog "front-end" electronics, namely a detector and charge sensitive preamplifier assembly*

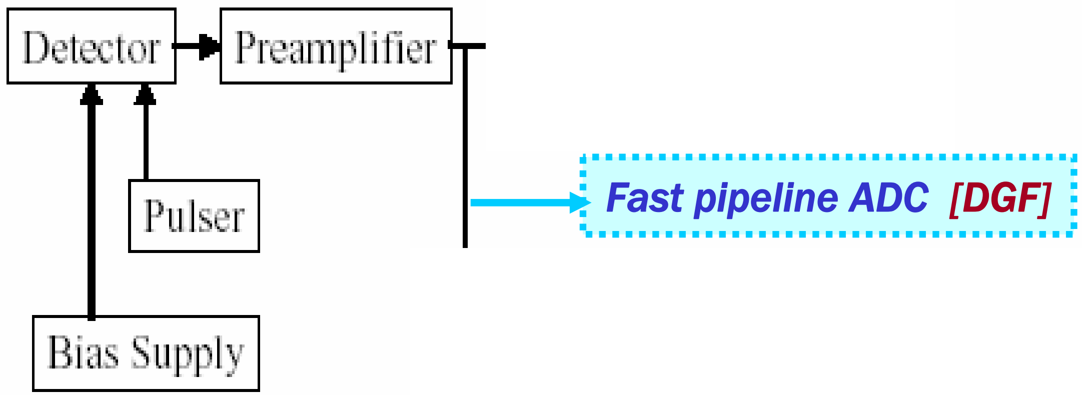
[HP-Ge+CSP] + an ***Analog*** *or* ***Digital Nuclear Electronics Spectroscopic Chain is used in order to extract the:***

E, t,



Analog Filter Amplifier Chain

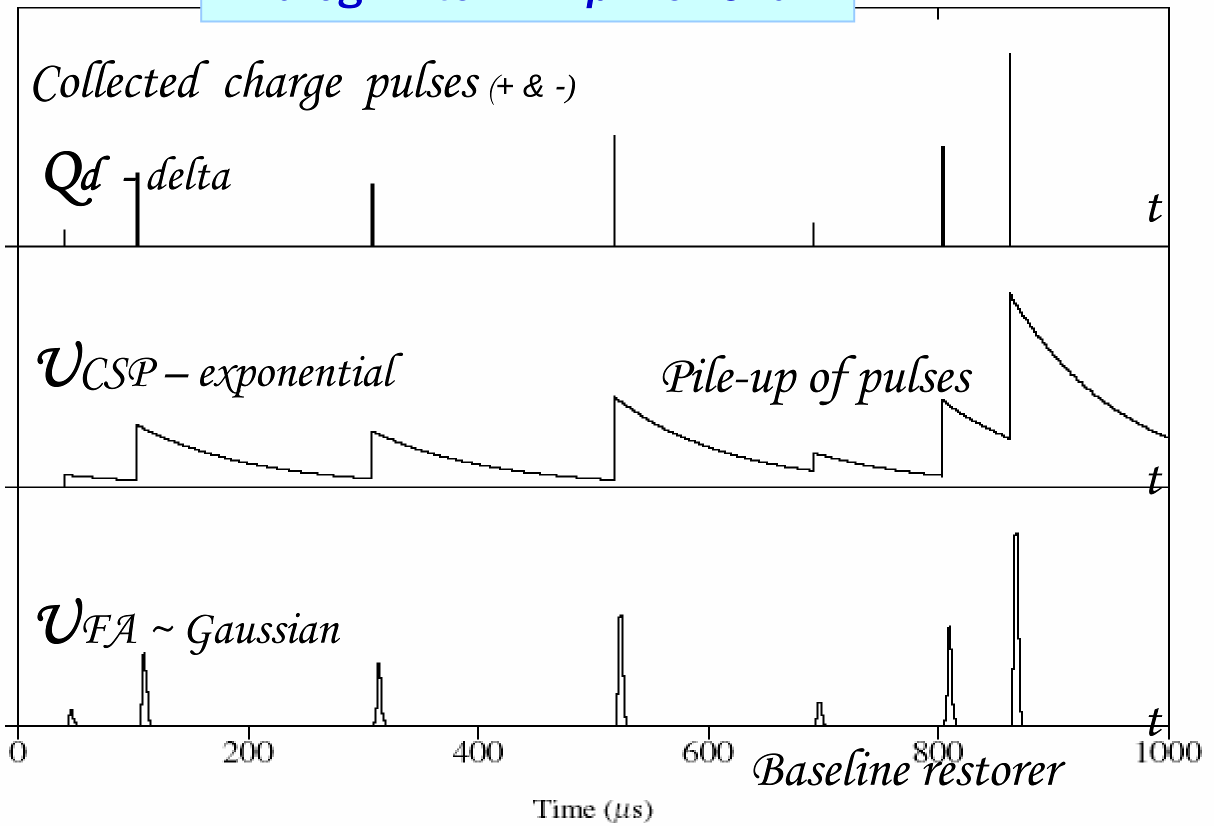




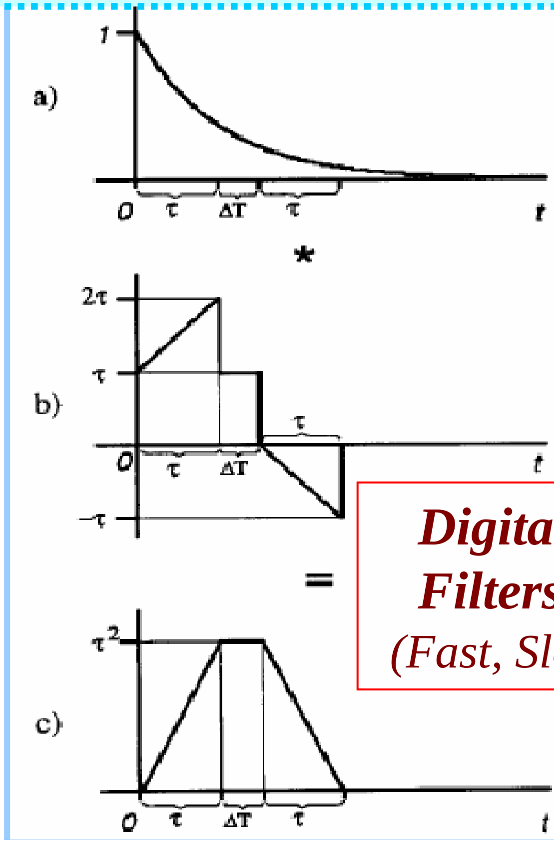
[HP-Ge+CSP] + an ***Analog*** *or* ***Digital Nuclear Electronics Spectroscopic Chain is used in order to extract the:***

E, t, position (r, azimuth)

Analog Filter Amplifier Chain

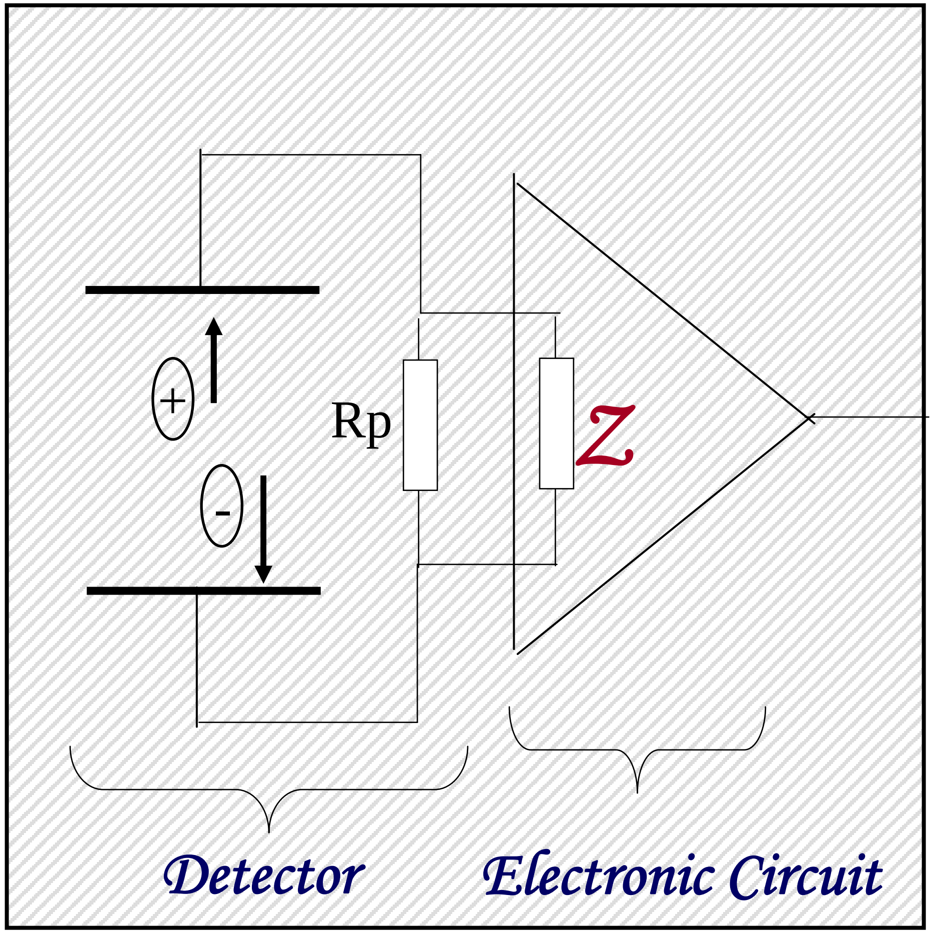


Fast pipeline ADC & [DGF]



Digital Filters
(Fast, Slow)

Detector Signal Collection



- ***a gamma ray crossing the Ge detector***

  generates electron-hole pairs

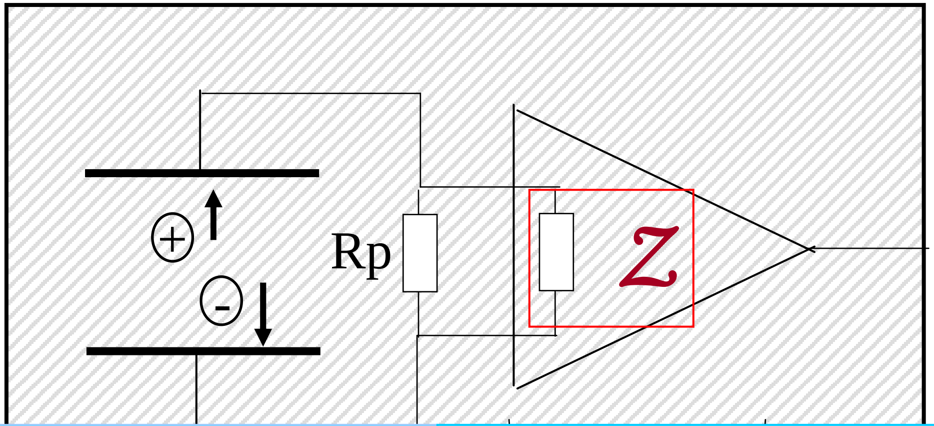
- ***charges are collected on electrode plates (as a capacitor) ⇔ building up***

  a voltage or a current pulse

Final objectives:

- ***amplitude measurement*** (E)
- ***time measurement*** (t)
- ***position*** (radius, azimuth)

Detector Signal Collection



if Z is high,

- ***charge is kept on capacitor nodes and a voltage builds up (until capacitor is discharged)***
- ***Advantages:***
  - *excellent energy resolution*
  - *friendly pulse shape analysis ⇔ position*
- ***Disadvantages:***
  - *channel-to-channel crosstalk*
  - *pile up above 40 k c.p.s.*
  - *larger sensitivity to EMI*

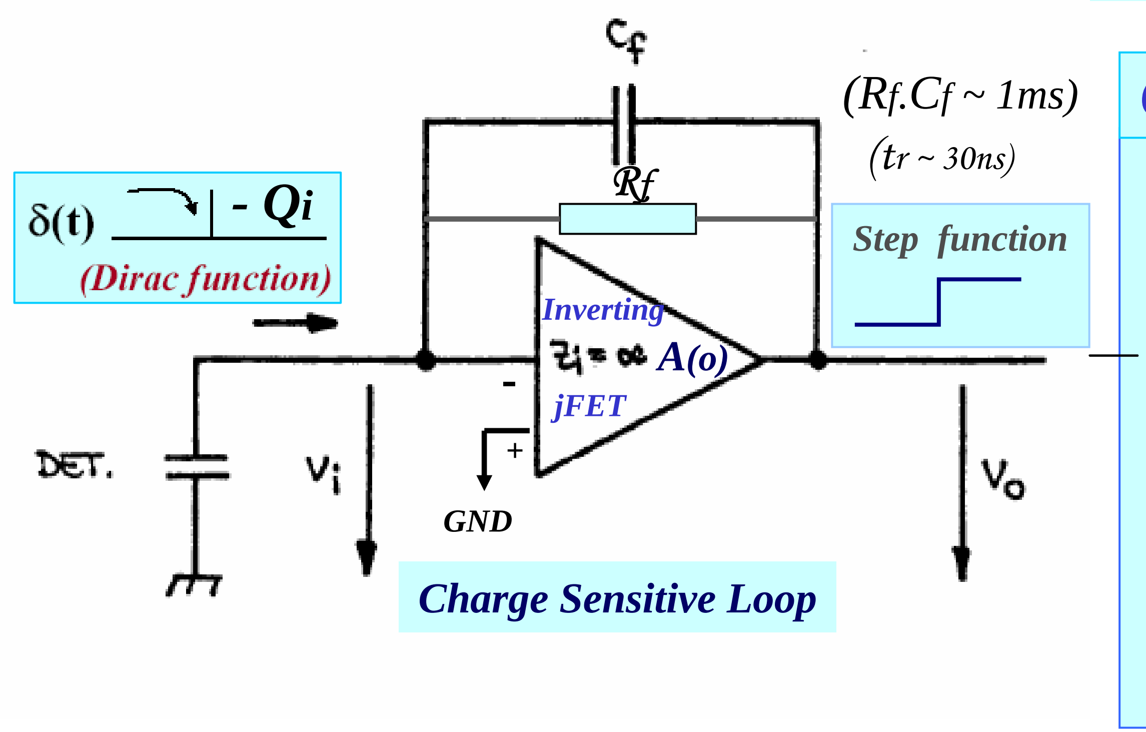
if Z is low,

- ***charge flows as a current through the impedance in a short time.***
- ***Advantages:***
  - *limited signal pile up (easy BLR)*
  - *limited channel-to-channel crosstalk*
  - *low sensitivity to EMI*
  - *good time resolution*
- ***Disadvantages:***
  - *signal / noise ratio to low ⇔ worse resolution*

Charge Sensitive Preamplifier

Active Integrator ("Charge Sensitive Preamplifier" - CSP)

- Input impedance very high (i.e. ~ no signal current flows into amplifier),
- Cf /Rf feedback capacitor /resistor between output and input,
- very large equivalent dynamic capacitance,
- sensitivity A(q) ~ - Qi / Cf,
- large open loop gain Ao ~ 15,000 - 150,000
- clean transfer function (no ringing, no over shoots, no under shoots)



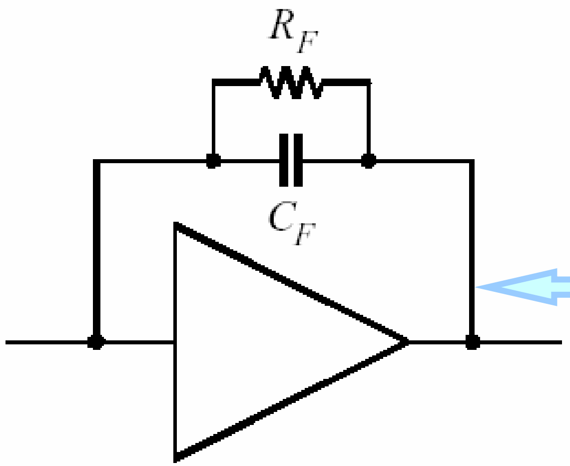
Ci ~ "dynamic" input capacitance

$$C_i = \frac{Q_i}{v_i} = C_f(A+1)$$

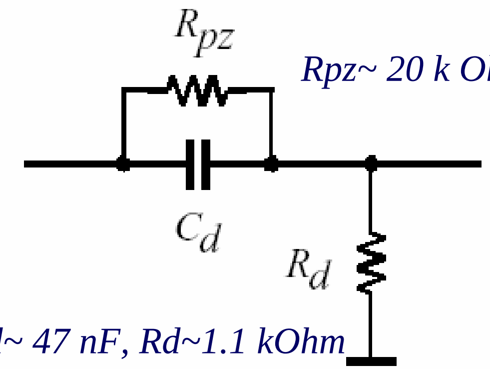
⇔ Ci ~ 10 - 20,000 pF

$$A_Q = \frac{dV_o}{dQ_i} \approx \frac{1}{C_f}$$

Pole - Zero cancellation technique



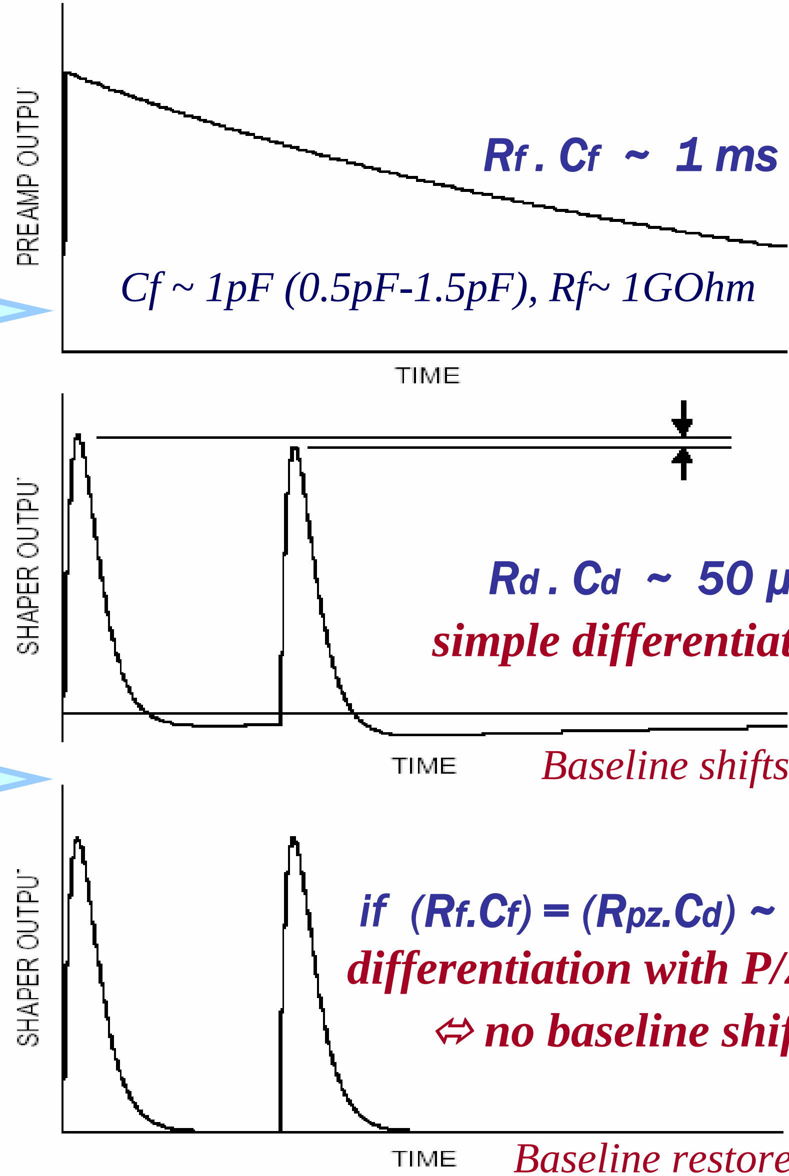
Add R_{pz} to differentiator:



Rpz~ 20 k Ohm

Cd~ 47 nF, Rd~1.1 kOhm

"zero" cancels "pole" of preamp when $R_F C_F = R_{pz} C_d$



Rf . Cf ~ 1 ms

Cf ~ 1pF (0.5pF-1.5pF), Rf~ 1GOhm

Rd . Cd ~ 50 µs

simple differentiation

Baseline shifts

if (Rf.Cf) = (Rpz.Cd) ~ 50 µs

differentiation with P/Z adj.

⇔ no baseline shifts

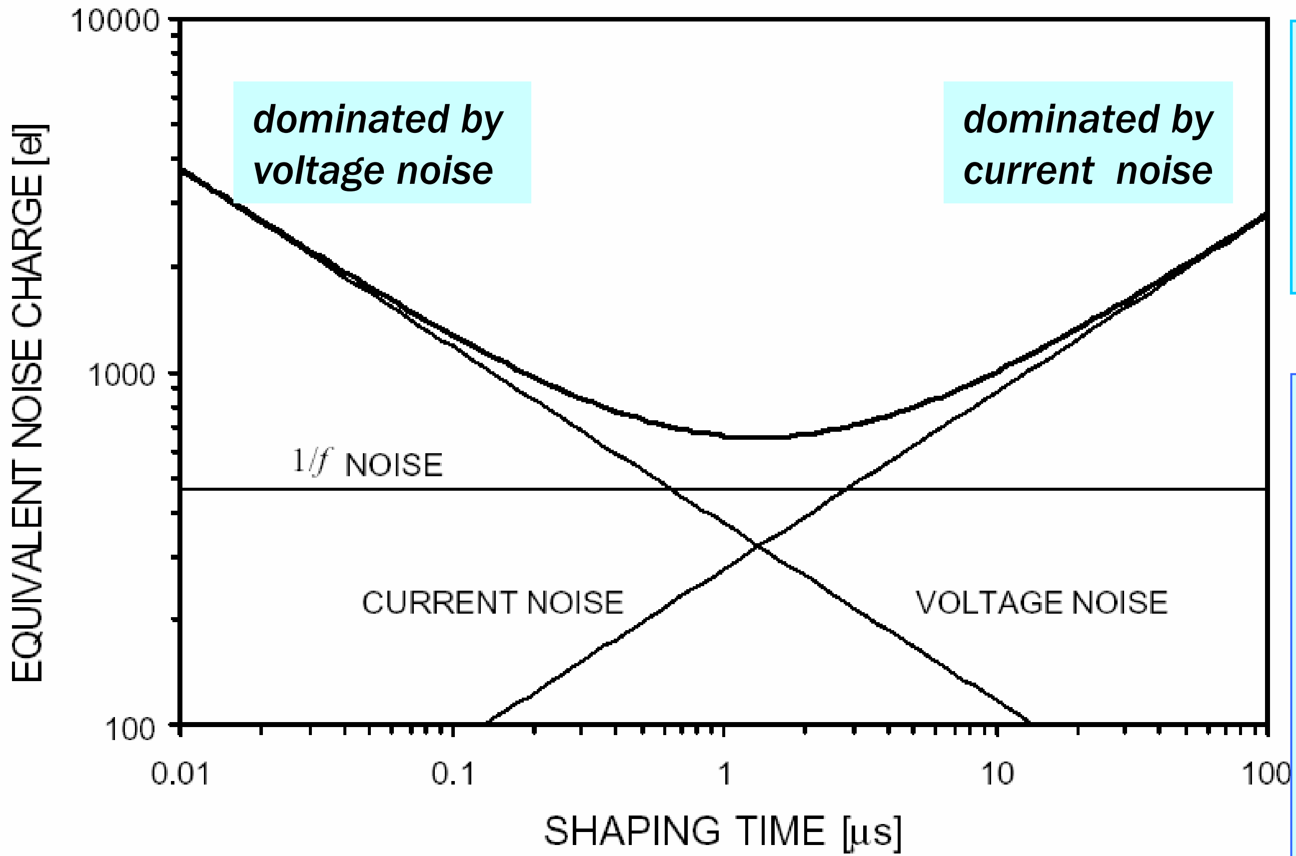
Baseline restored

MINIBALL
Charge Sensitive Preamplifier Specifications

Parameter	IKP-Cologne (Miniball – jFET IF1320)
Sensitivity (mV / MeV)	~ 175 mV/MeV (single ended)
Resolution (Cd= 0pF; cold FET)	~ 600 eV
Slope (+ eV/ pF) [Cd]	< 10 eV / pF (cold FET)
Rise time (Cd= 0pF);	~ 15 ns (cold FET)
Slope (+ ns/ pF) [Cd]	~ 0.3 ns (~ 25 ns / 33 pF)
U(out) @ [50 Ohm] / Power [mW]	~ 4.5V /~ 450 mW (+/- 12V ⇔ Op.Amp.LM-6172)
Saturation of the 1st stage @	equiv. ~100 MeV (@ ~60mW_jFET)
Open Loop Gain	~ 20,000

- *By design optimized* ***Transfer Function***
- *Crosstalk requirements less then* 10^{-3} *core-segment*

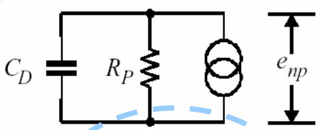
Noise Bandwidth vs. Signal Bandwidth



- the equivalent noise charges Q_n assumes a minimum when the current and voltage contributions are equal

- current noise ~ $(RC)^2$
- voltage noise ~ $1/(RC)^2$ ~ C_d
- $1/f$ noise ~ C_d

$$Q_n^2 = \left(\frac{e^2}{8}\right)\left[\left(2q_e I_D + \frac{4kT}{R_P} + i_{na}^2\right)\cdot\tau + \left(4kTR_S + e_{na}^2\right)\cdot\frac{C_D^2}{\tau} + 4A_f C_D^2\right]$$



$$i_{np}^2 = \frac{4kT}{R_P}$$

current noise $\propto \tau$ independent of C_D

voltage noise $\propto 1/\tau$ $\propto C_D^2$

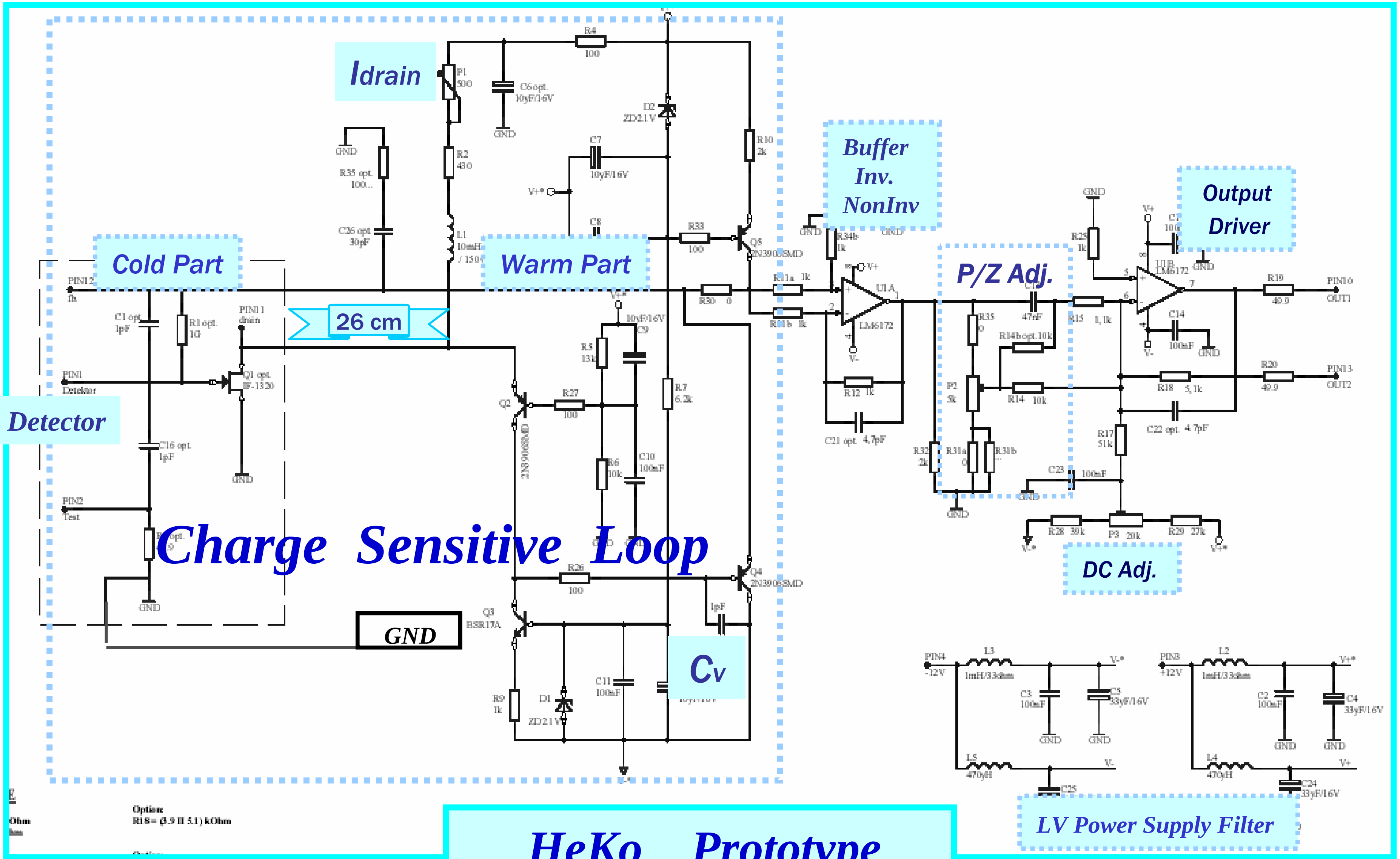
$1/f$ noise independent of τ $\propto C_D^2$

$$e_{na}^2 = e_{nw}^2 + \frac{A_f}{f}$$

"white noise"

$1/f$ noise (can also originate in external components)

MINIBALL Charge Sensitive Preamplifier

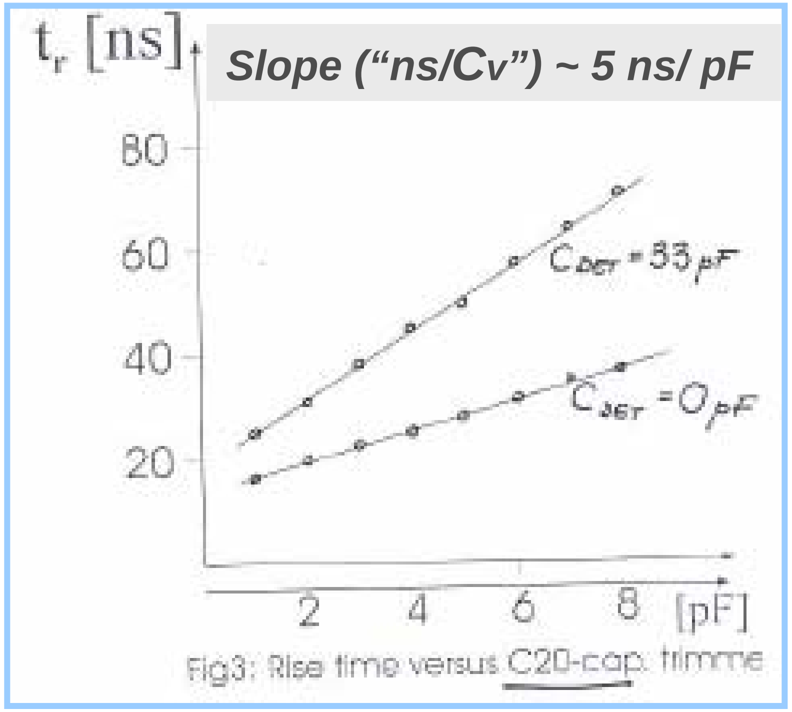


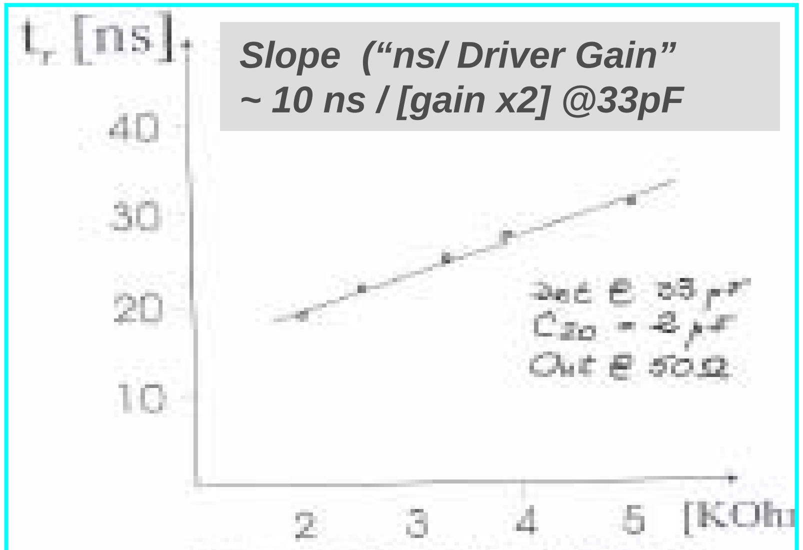
HeKo Prototype

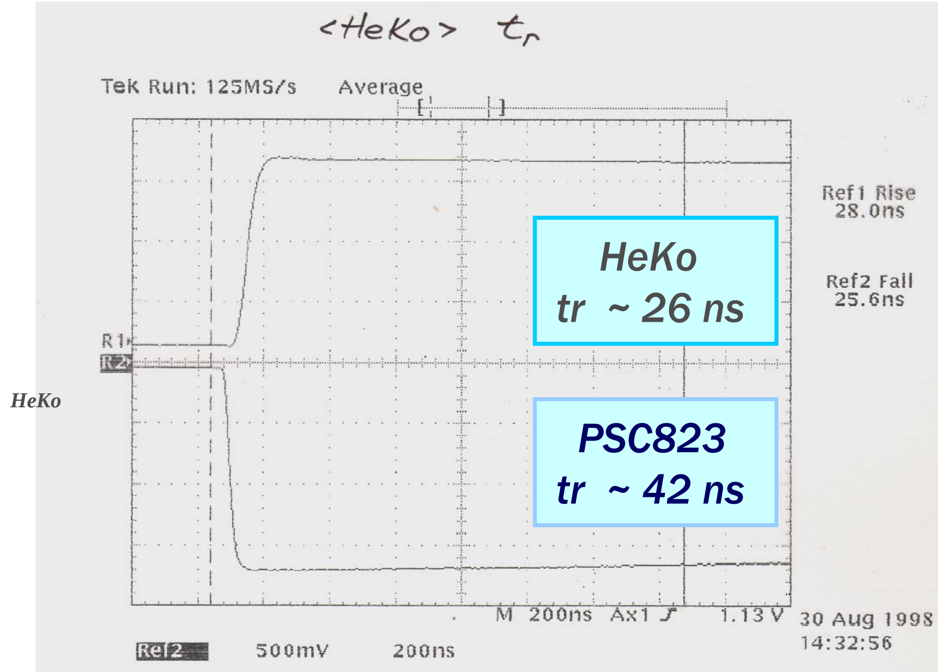
[HeKo] - Family of CSP

consequences of various adjustments

gain, rise time, slope, ringing

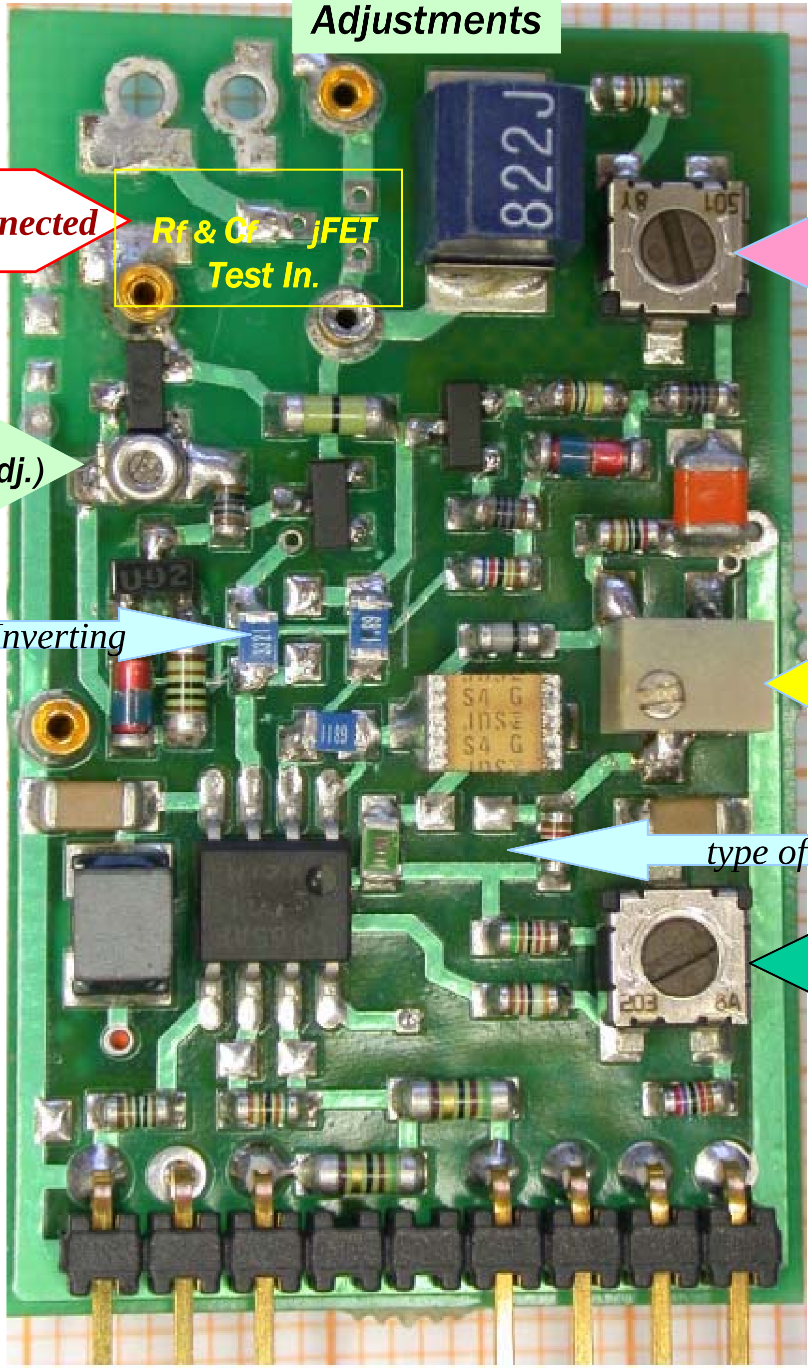






http://www.nsg.tsl.uu.se/agata/padova-sep2002/slides/Pascovici/Outlook_CSP(2).pdf

Miniball warm CSP type HeKo



NOT Connected

I Drain (JFET) (Step 1)

Cv - trimmer (bandwidth adj.)

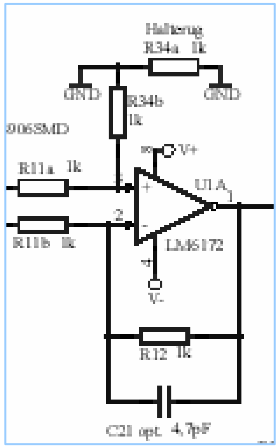
S1 + S3 Inverting / Non_Inverting

P/Z Adj. (Step 2)

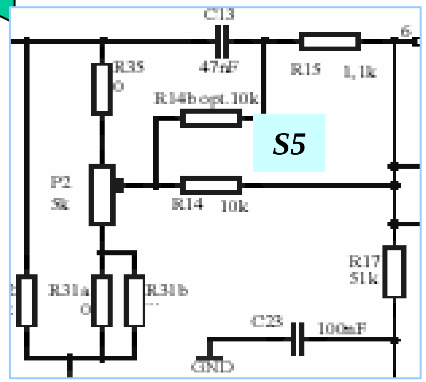
(Helitrim. 11 turns)

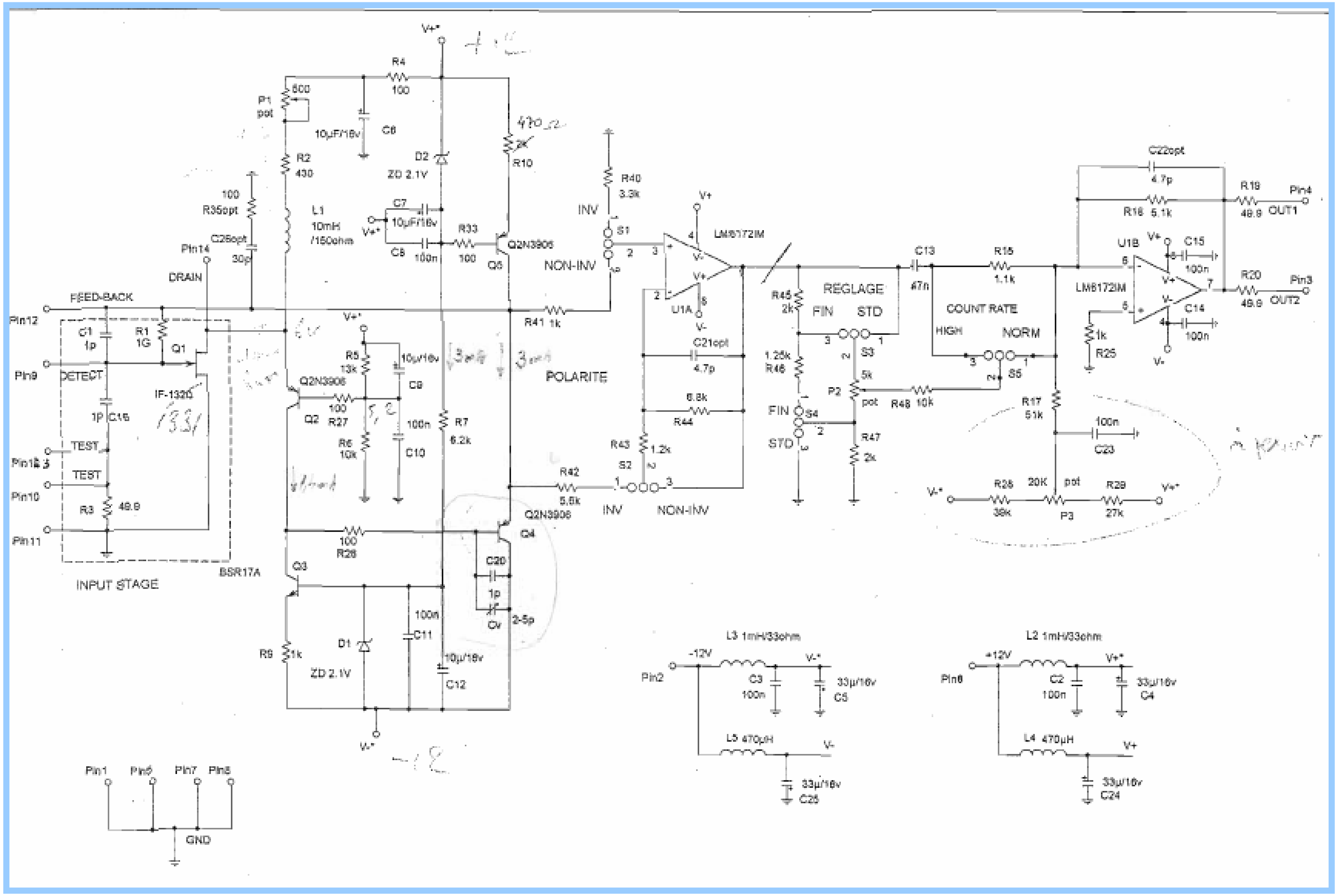
type of P/Z cancellation S5

DC Level Adj. (Step 3)



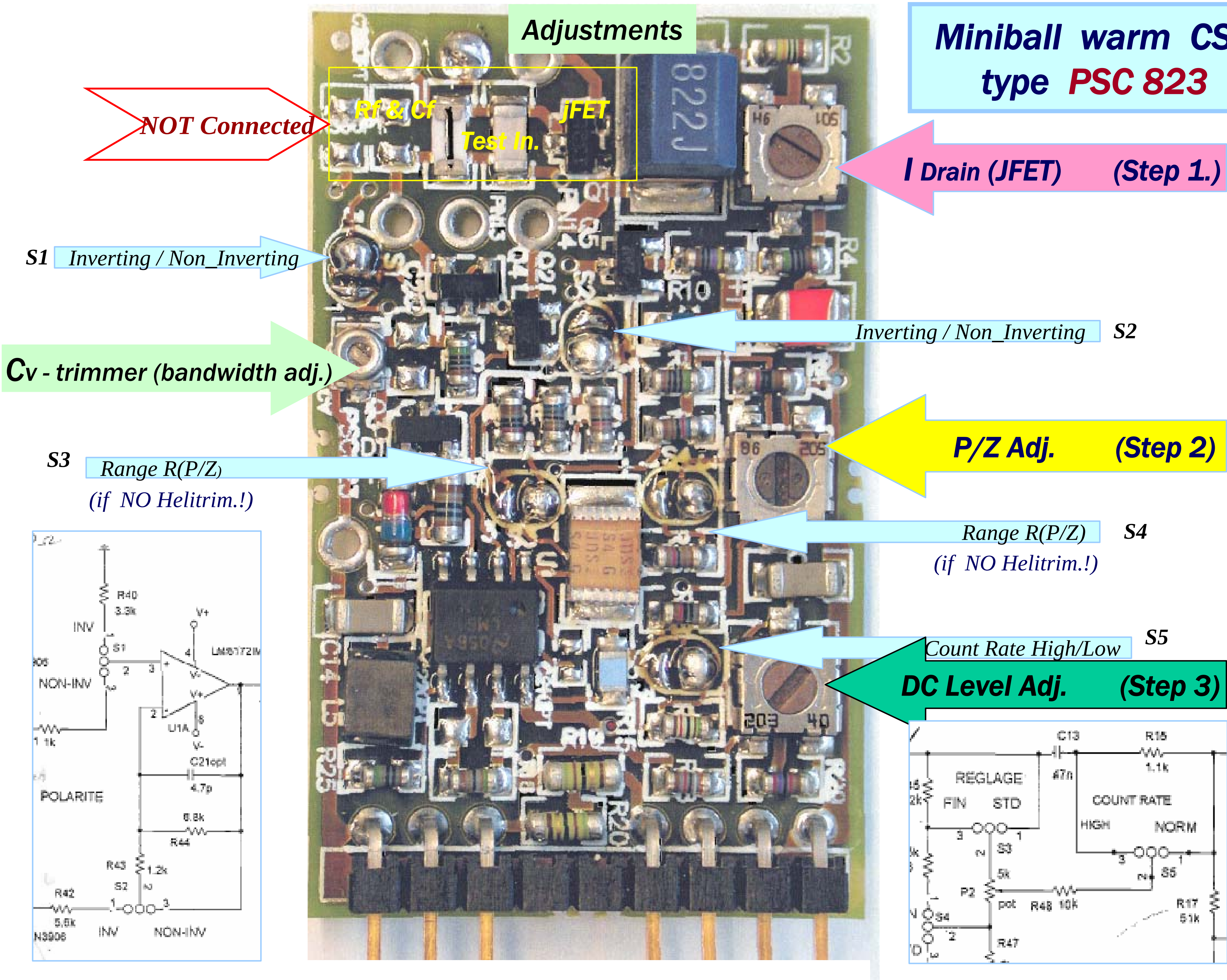
N.B. by default "Inverting"
(R11b and R34b – ON)

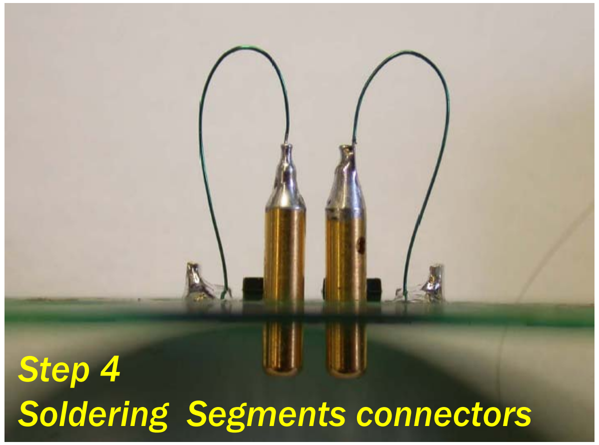


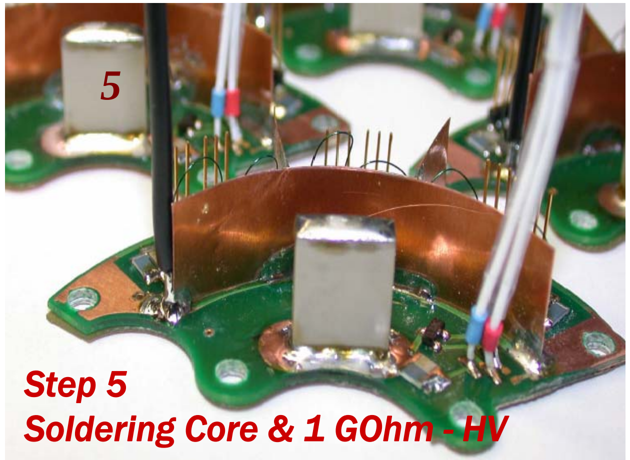


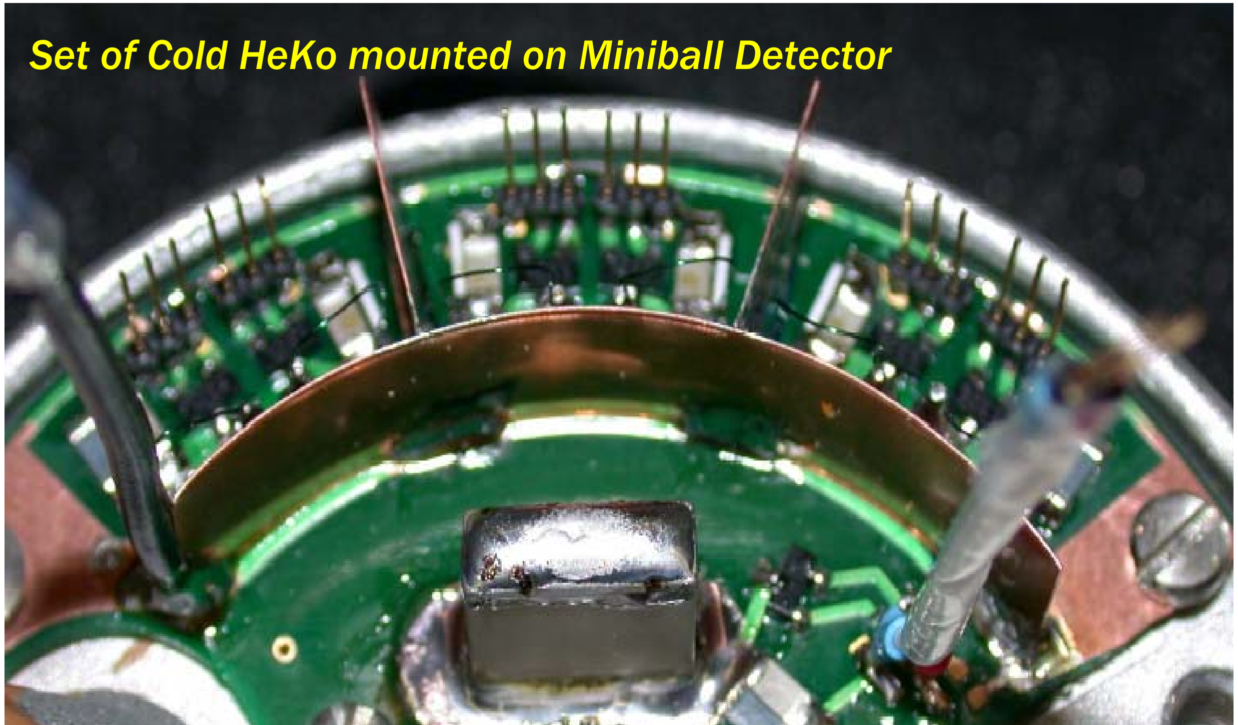
INPUT STAGE
BSR17A
FEED-BACK
DRAIN
DETECT
TEST
Pin12
Pin9
Pin10
Pin11
Pin14
IF-1320
Q1
Q2
Q3
Q4
Q5
Q2N3906
L1 10mH /150ohm
R4 100
P1 pot
R2 430
D2 ZD 2.1V
D1 ZD 2.1V
R10
R33 100
R7 6.2k
R41 1k
R42 5.6k
POLARITE
INV
NON-INV
S1
S2
S3
S4
S5
R40 3.3k
R43 1.2k
LM6172IM
U1A
U1B
C21opt 4.7p
6.8k R44
C13 47n
R15 1.1k
R16 5.1k
C22opt 4.7p
R19 49.9
R20 49.9
OUT1
OUT2
Pin4
Pin3
REGLAGE
FIN
STD
COUNT RATE
HIGH
NORM
R45 2k
1.25k R46
P2 5k pot
R47 2k
R48 10k
R17 51k
C23 100n
R28 39k
P3 20K pot
R29 27k
R25 1k
C14 100n
C15 100n
C20 1p
Cv 2-5p
C12 10µ/16v
C11 100n
R9 1k
R26 100
R27 100
R5 13k
R6 10k
C9
C10 100n
R3 49.9
R1 1G
C1 1p
C16 1p
R35opt 100
C26opt 30p
L3 1mH/33ohm
L2 1mH/33ohm
L5 470µH
L4 470µH
-12V
+12V
Pin2
Pin6
C3 100n
C2 100n
C5 33µ/16v
C4 33µ/16v
C25 33µ/16v
C24 33µ/16v
Pin1
Pin5
Pin7
Pin8
GND

Miniball warm CSP type *PSC 823*

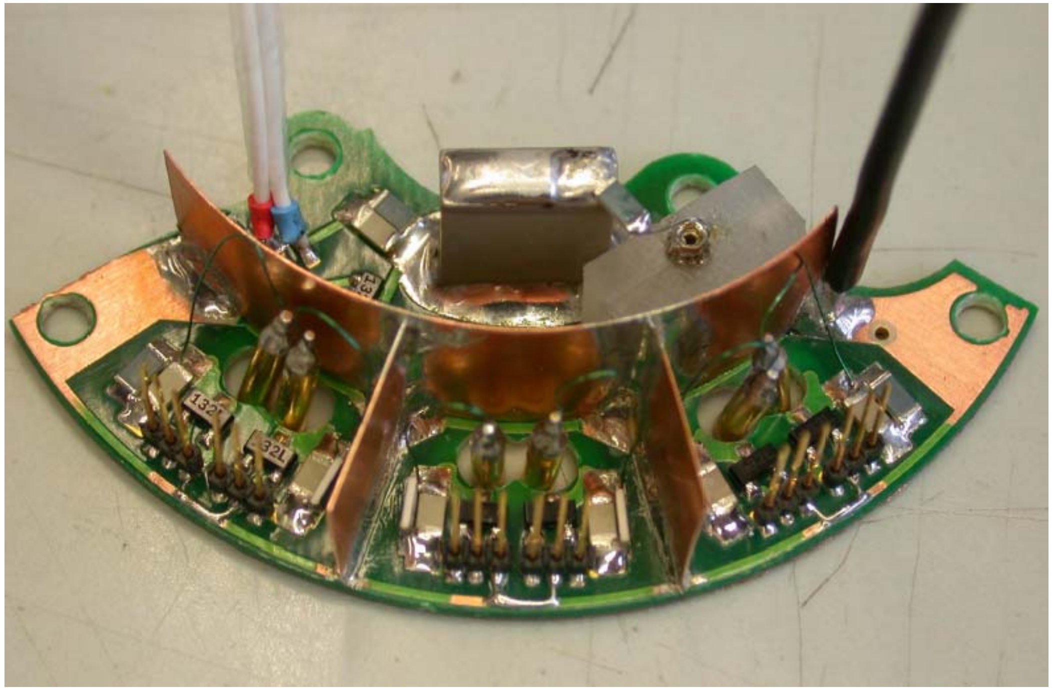






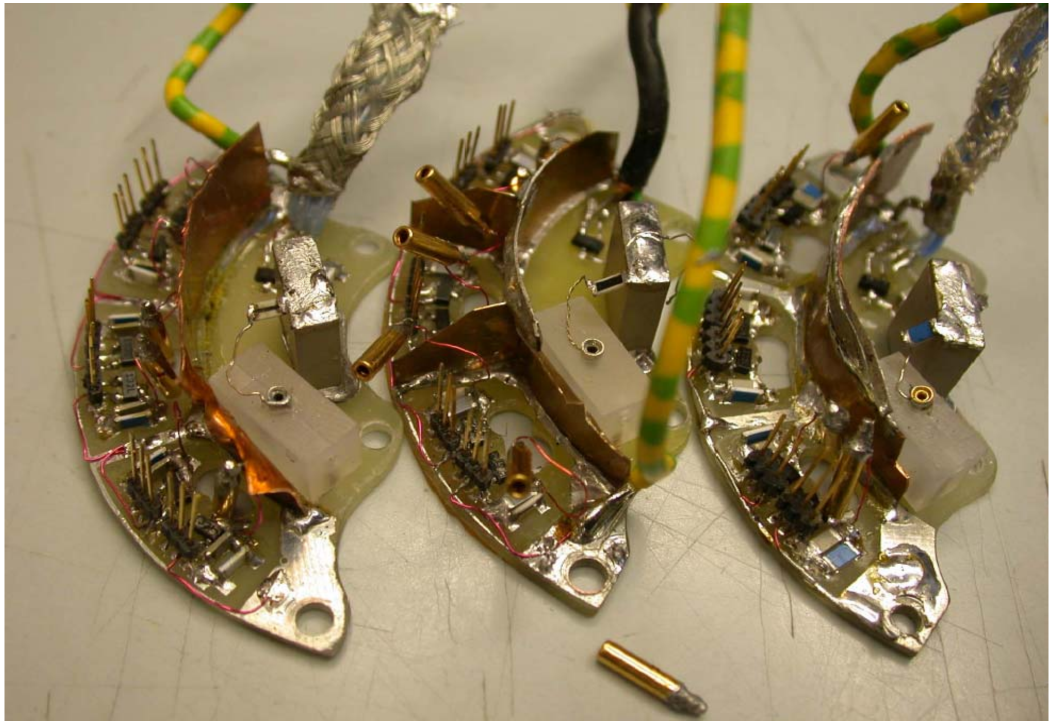


Technological steps in building - mounting a set of cold parts of CSPs on a 6_fold segmented encapsulated Miniball Detector



Miniball
cold preamplifier set

- ***new spare part (model) reworked at IKP-Köln (Jan. 2007)***



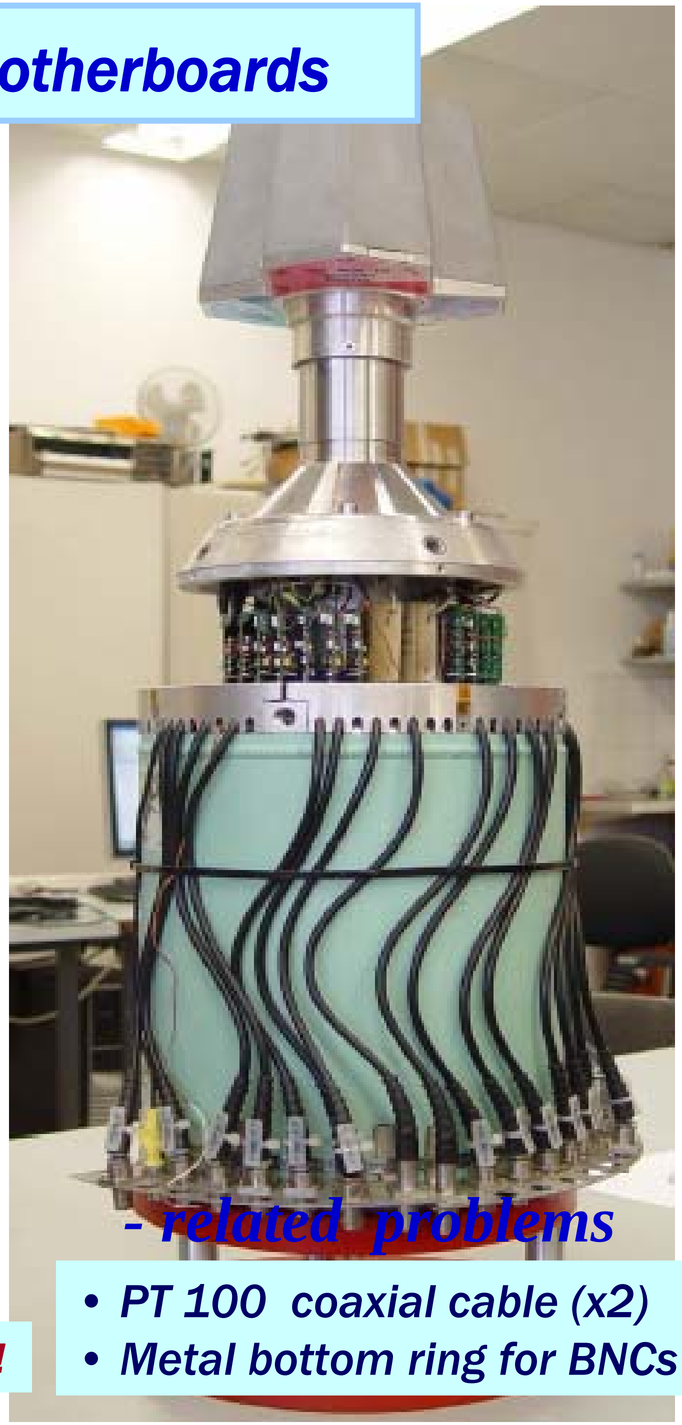
... and some still working cold parts but with:

- ***bad segments shielding,***
- ***some cold solder joints,***
- ***almost braking wires***

Miniball *Cryostat & warm motherboards*

D1 & D3 Motherboards with CSPs clockwise rotated ⇔ OK!

some D2 Motherboards with CSPs counterwise rotated ⇔ Wrong!



- related problems

- *PT 100 coaxial cable (x2)*
- *Metal bottom ring for BNCs*