AGATA
Front-end electronics of the central contact

1. **Charge Sensitive Preamplifier**

   (Low Noise, Fast, Single & Dual Gain)

2. **Programmable Spectroscopic Pulser**

   (as a tool for self-calibrating)

3. **Updated frequency compensations in adverse cryostat wiring and reduced crosstalk in the transmission line**

G. Pascovici, A. Pullia, F. Zocca, D. Bazzacco; FREEDAC Meeting, Ljubljana, 28 Mai, 2008

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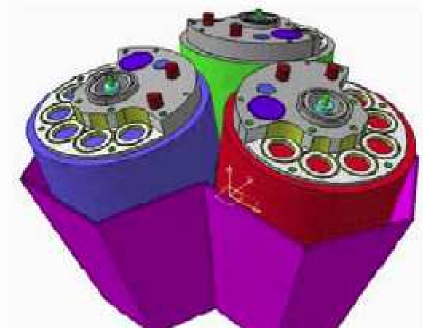
   (Low Noise, Fast, Single & Dual Gain)
2. ***Programmable Spectroscopic Pulser*** *(as a tool for self-calibrating)*

Front-end electronics with wide dynamic range (~ 100dB) divided in four sub-ranges and two modes of operations:

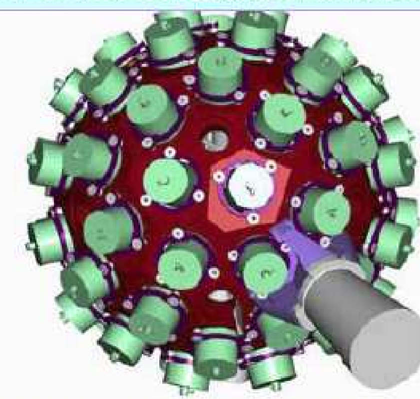
a) Amplitude and b) TOT (FZ)

AGATA 36_fold segmented, encapsulated HP-Ge Detector



AGATA Triple Cryostat
111 spectroscopic channels

AGATA Demonstrator [5 x TC]
(555 spectroscopic channels)



AGATA, the first complete 4pi gamma-ray spectrometer

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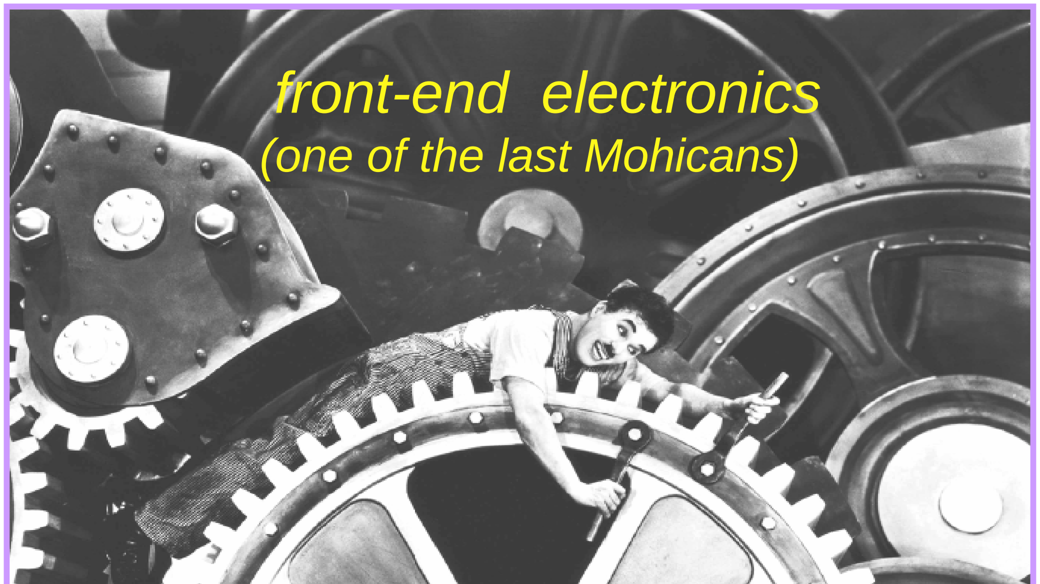

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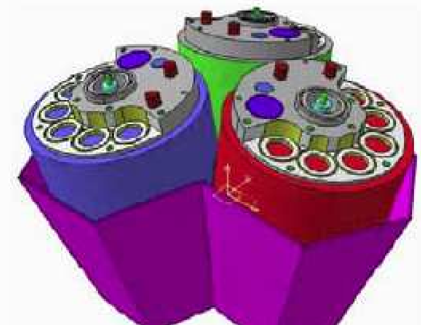

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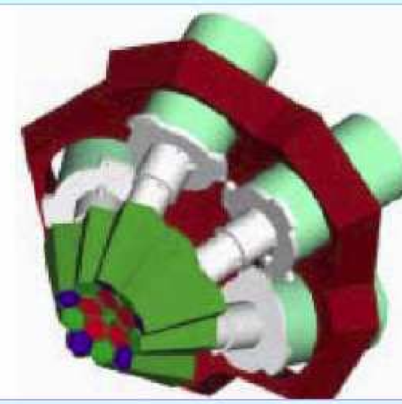

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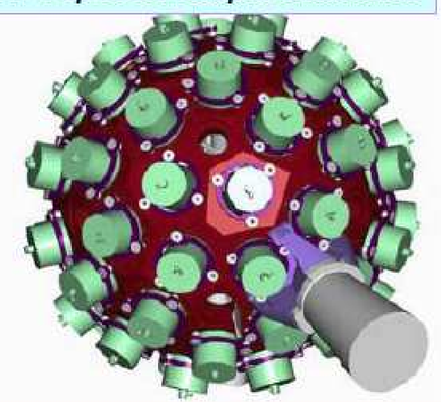

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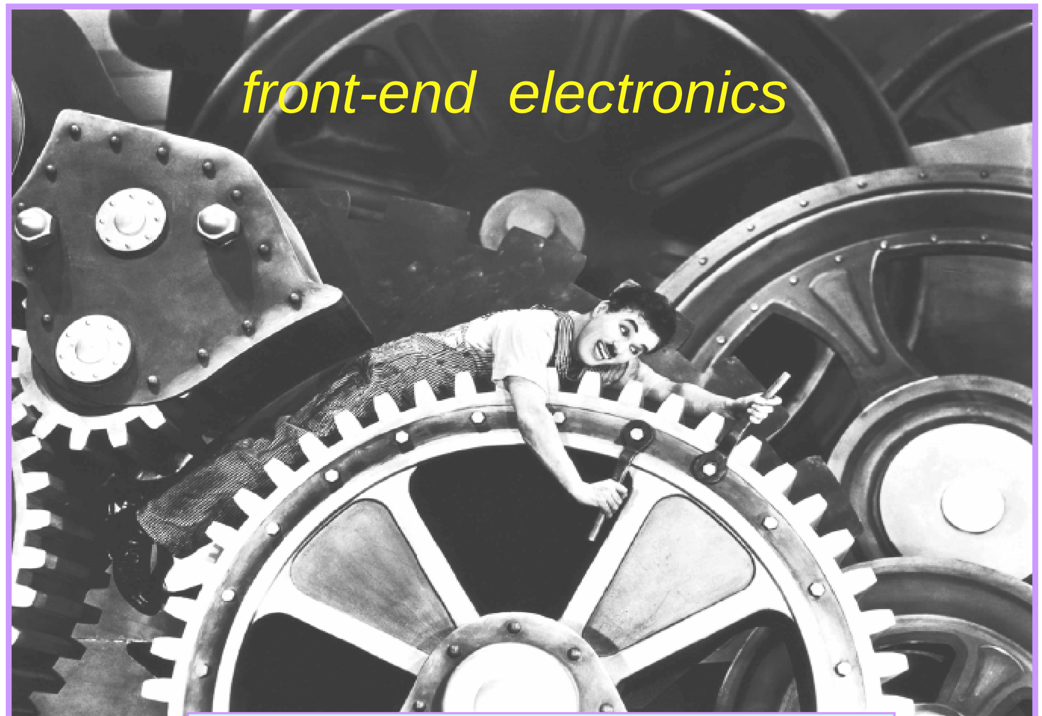
3. ***Updated frequency compensations in adverse cryostat wiring and reduced crosstalk in the transmission line***
   - ***crosstalk between participants:***
     - ***segments, electronic channels***
     - ***single dummy & detector , single cryostats, triple-cryostats…***



C. Chaplin, Modern Times (1936)

Specs	Prerequisite
Sensitivity (mV / MeV)	**~ 100 mV/MeV** (differential output)*
Resolution (Cd= 0pF; cold FET)	~ **600 eV**
Slope (+ eV/ pF) [Cd]	**< 10 eV / pF** (cold FET)
Rise time *) (Cd= 0pF);	**< 12 ns** (warm FET)
Slope (+ ns/ pF) [Cd]	**~ 0.25 ns** (~ 23 ns / 45 pF)
U (out) @ [100 Ohm] / **Power** [mW]	**~ 2.0V*/ ~290 mW** (i.e. 1V/term. @ FADC)*
Saturation of the 1st stage @	**> 50 MeV** (Active reset 2. stage)*
Open Loop Gain	**> 20,000**

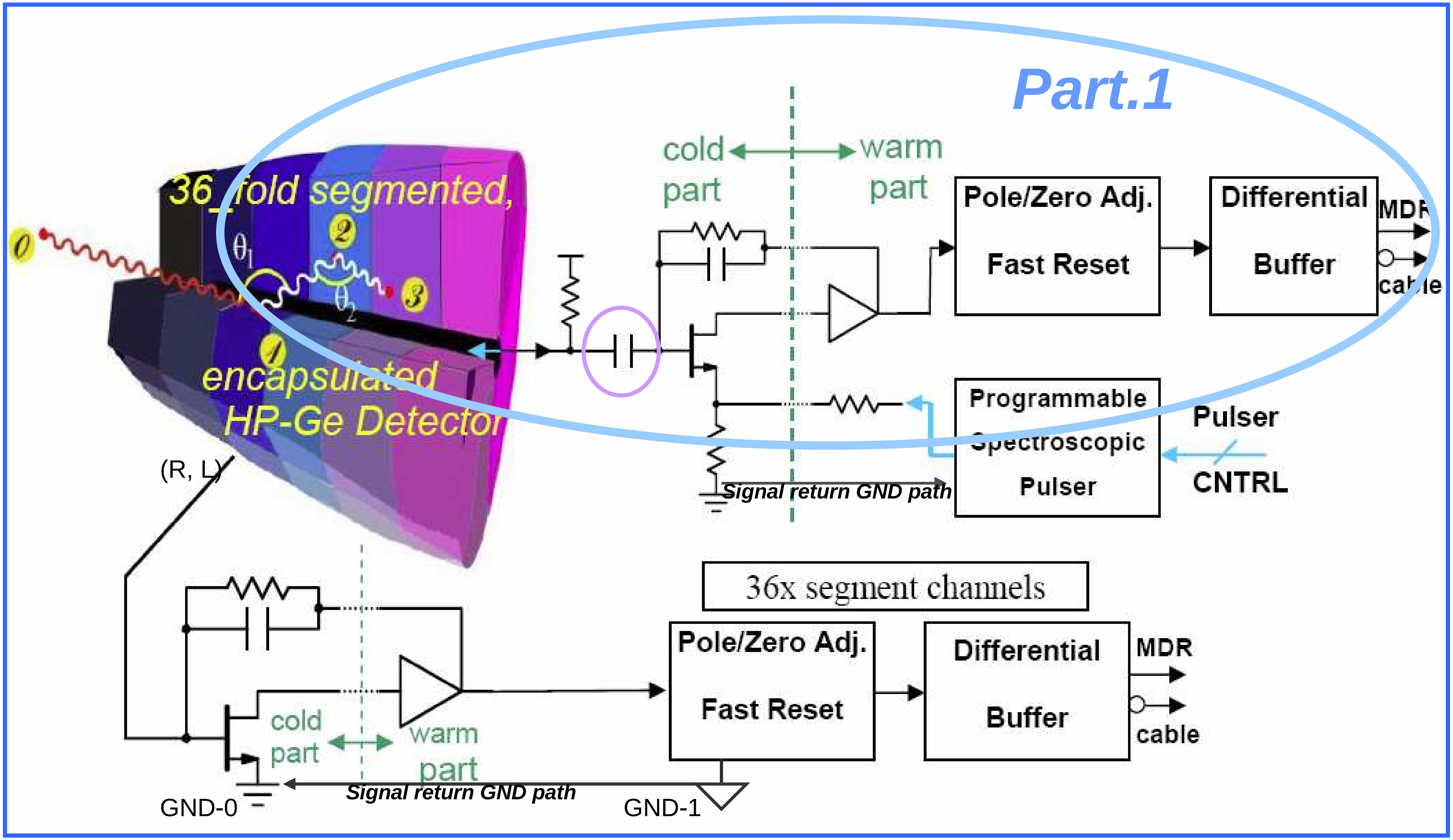
AGATA Core-Pulser Suggested Specifications

@ AGATA Week Padova, Sept. 2002

Crosstalk requirements

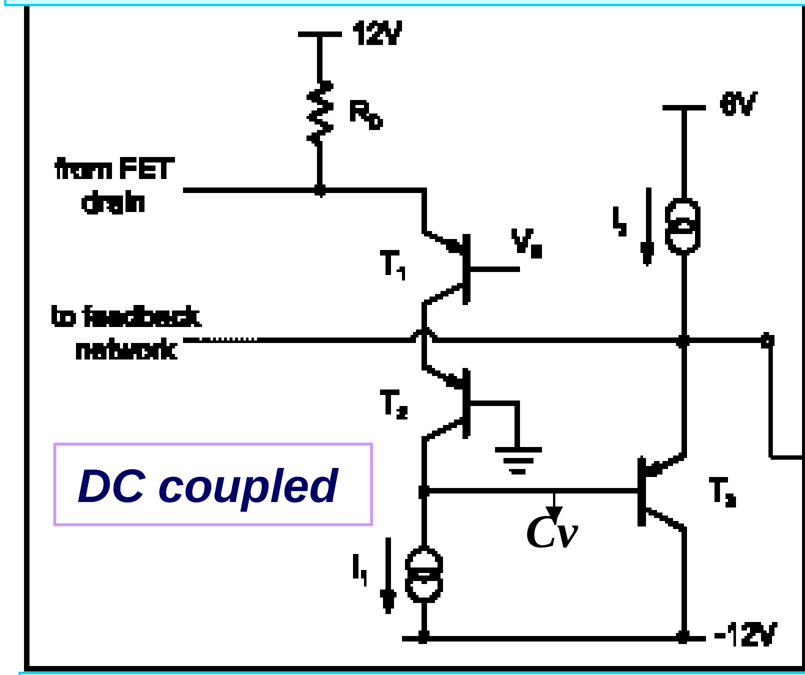
- less then ~ 0.1% core-segment

Block diagram of the AGATA front end-electronic



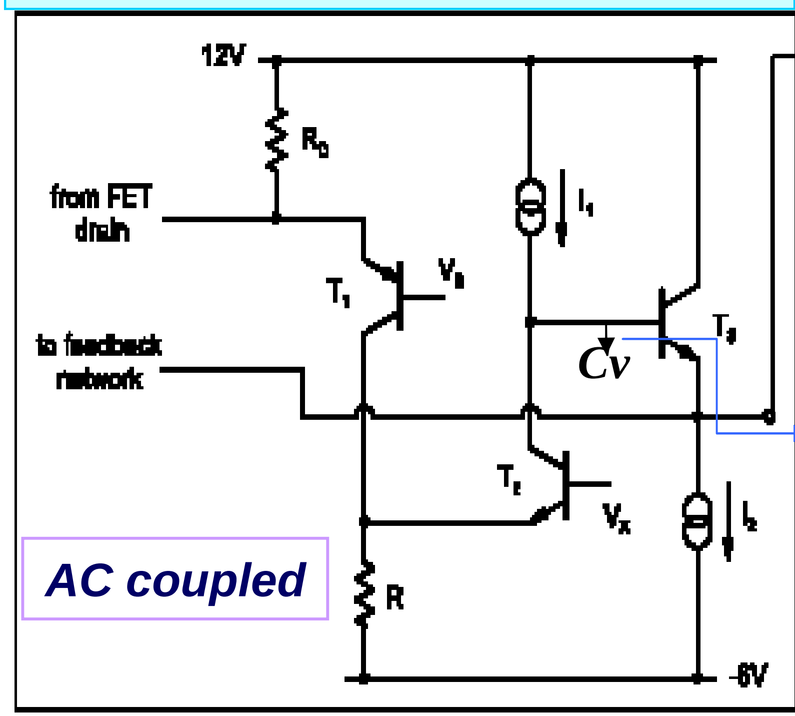
AGATA CSPs – the versions with large open loop gain (Milan – Cologne)

Segment CSP ⇔ Negative Output



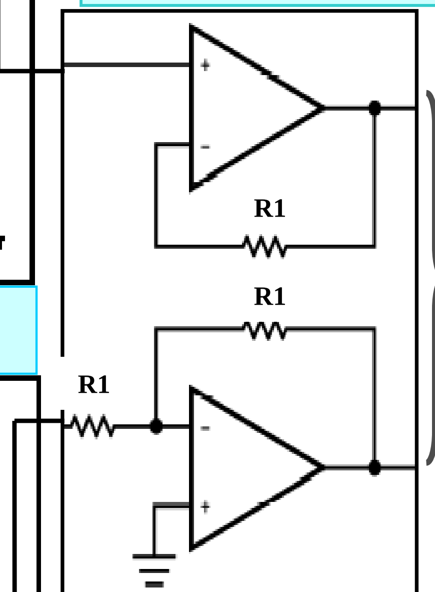
DC coupled

Core CSP ⇔ Positive Output



AC coupled

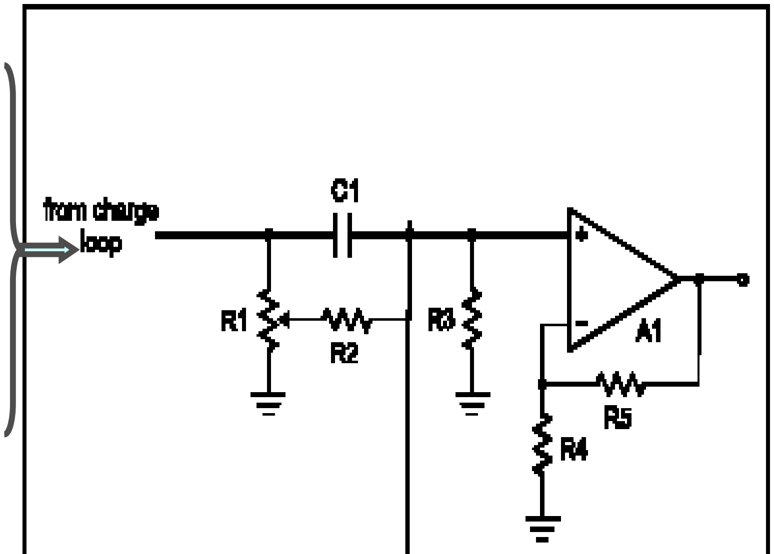
Segment Non-Inverting

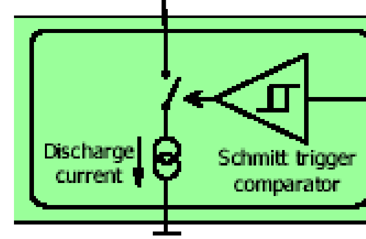


Core Inverting

* (Cv) stability adj.

P/Z cancellation

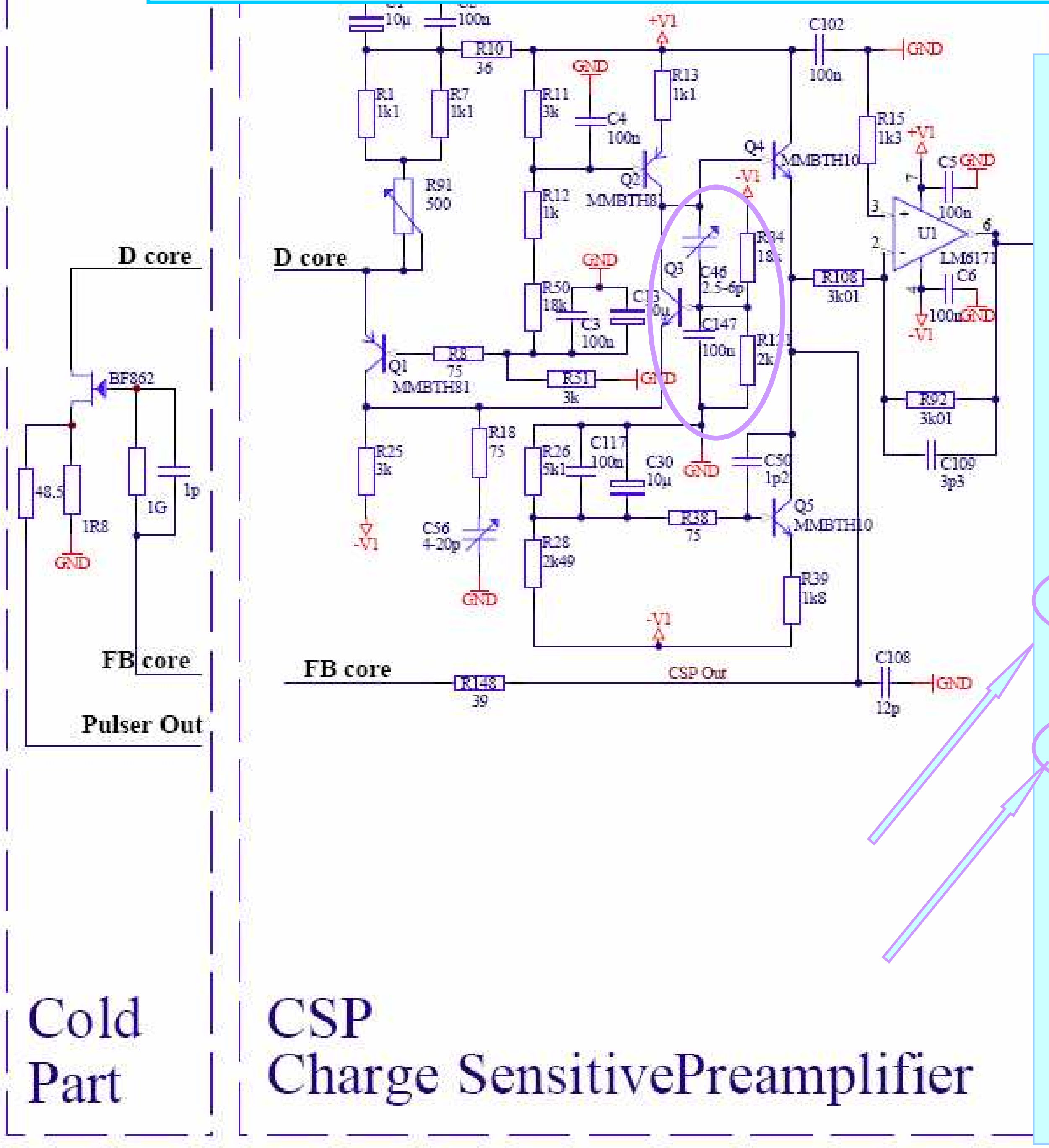




from Active Reset

- why **large Ao > 100,000 ?** ⇔ frequency compensation, slope & crosstalk

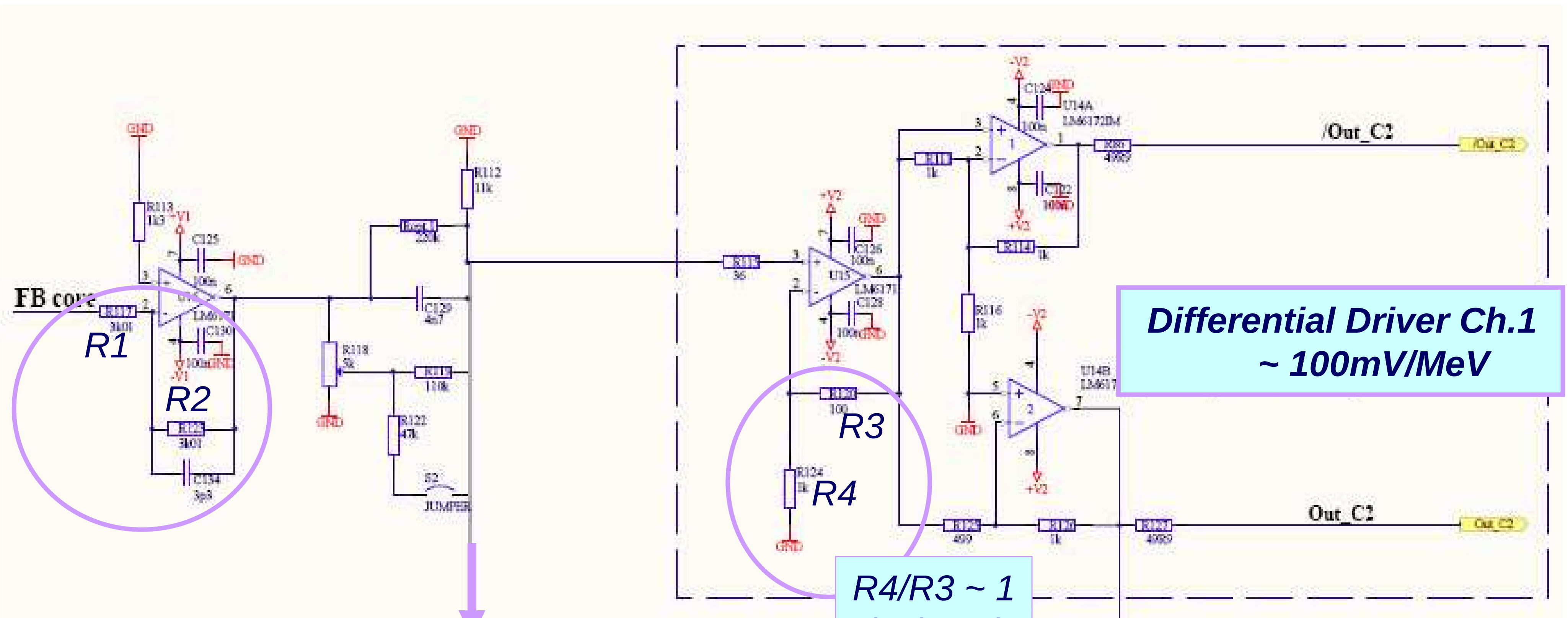
AGATA Core Preamplifier - Charge Sensitive Part



AGATA LVDS-Dual Core Preamplifier (Final design) with up-graded frequency compensations:

- ***Large Open loop-gain (~ 100,000)***
- ***Fast Rise Time***
  tr ~ 15 ns @ 45 pF
- ***Large dynamic range***
  ~ 180 MeV @ Cf~1pF
- ***Multiple frequency compensations:***
  - *minimum Miller effect*
  - *lead compensation*
  - *lead-lag compensation*
  - *dominant pole compensation*

AGATA Single Core Preamplifier
- 2. stage
- P/Z and Fast Reset
- 3. stage and Differential Driver

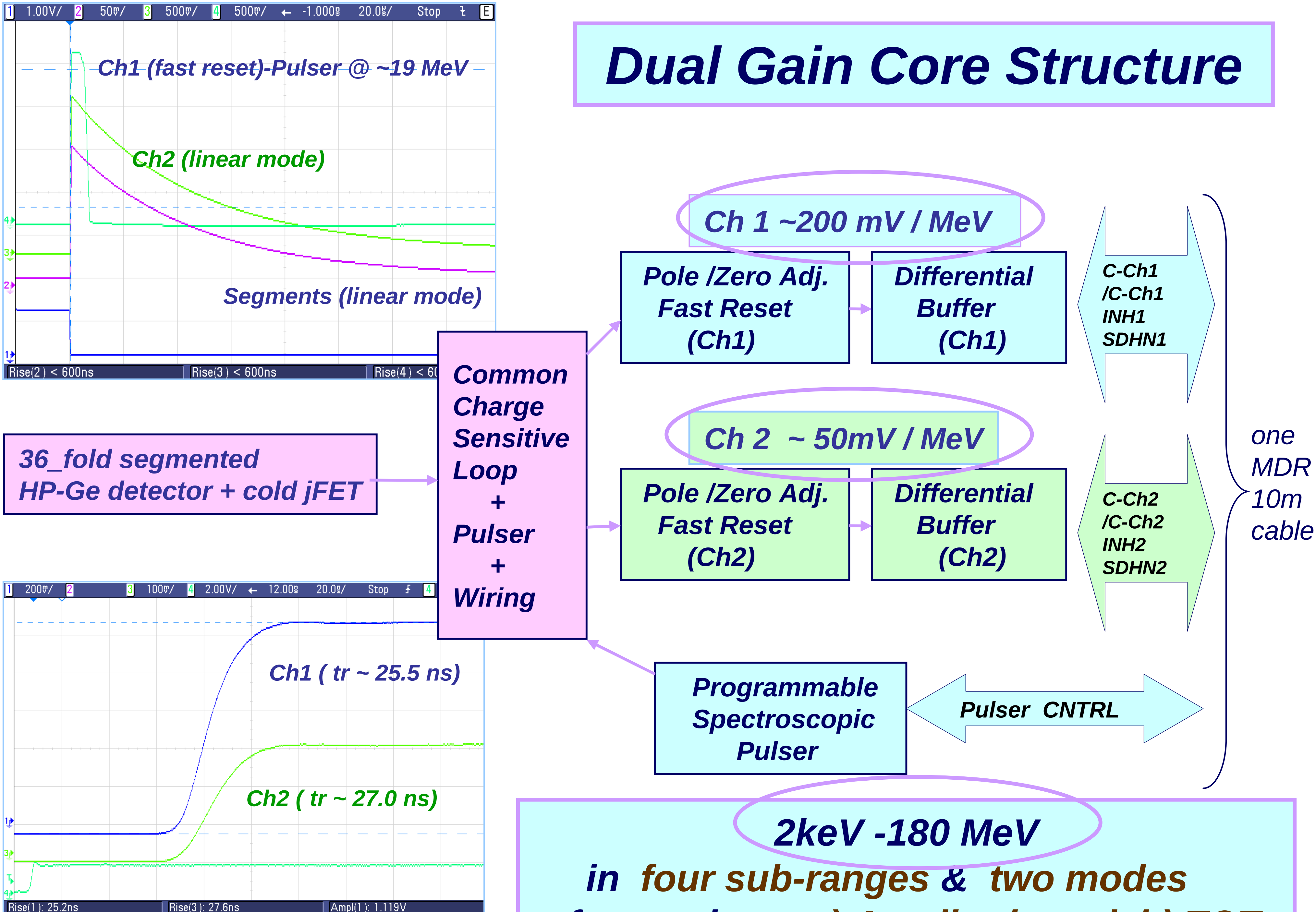


Differential Driver Ch.1 ~ 100mV/MeV

R4/R3 ~ 1 (gain ~2)

to Fast Reset (TOT technique) (Francesca's talk)

Dual Gain Core Structure

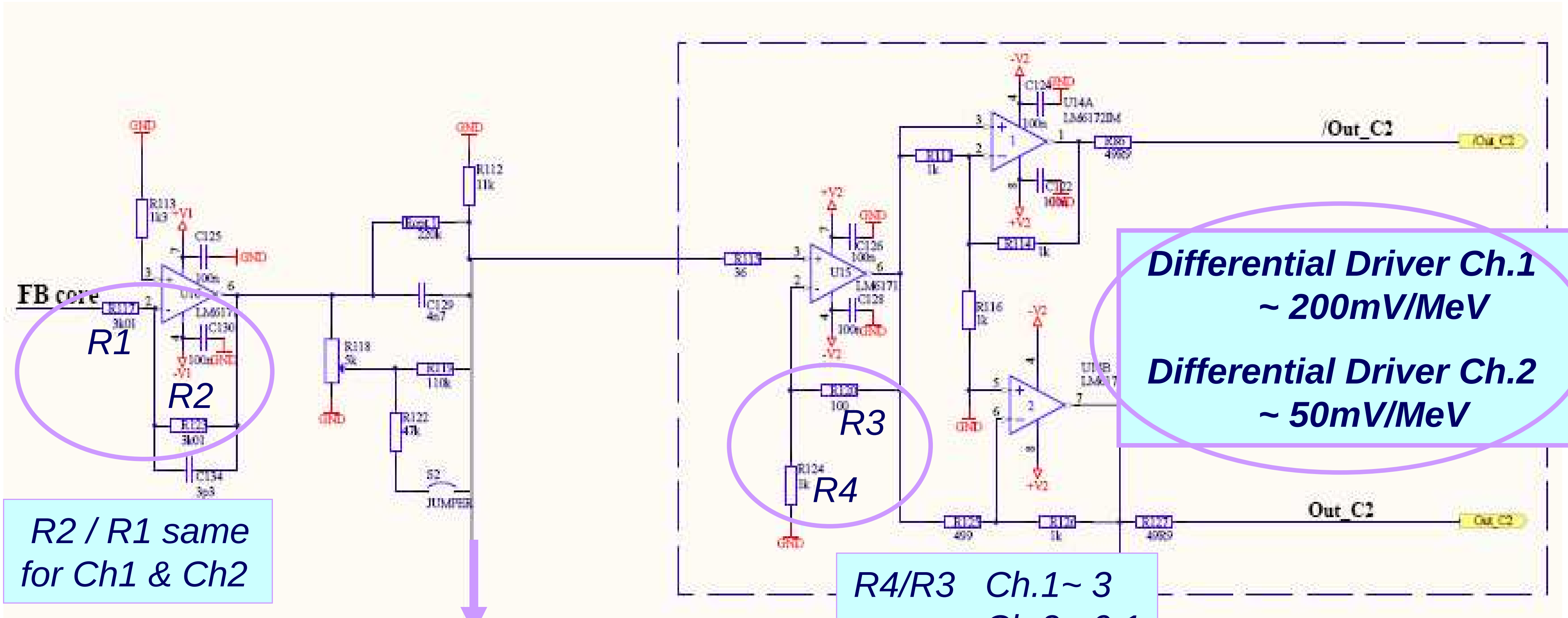


2keV -180 MeV

in four sub-ranges & two modes of operations: a) Amplitude and b) TOT

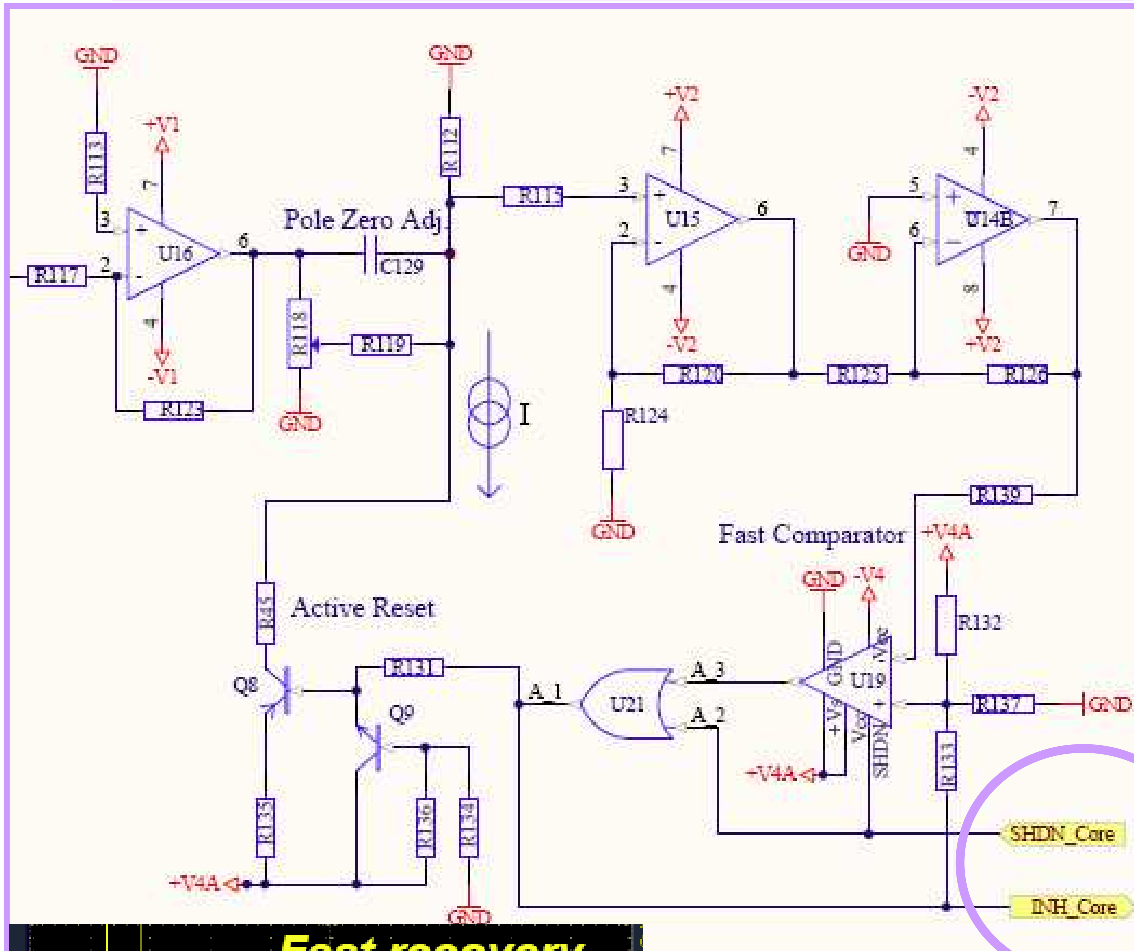
AGATA Dual Core Preamplifier

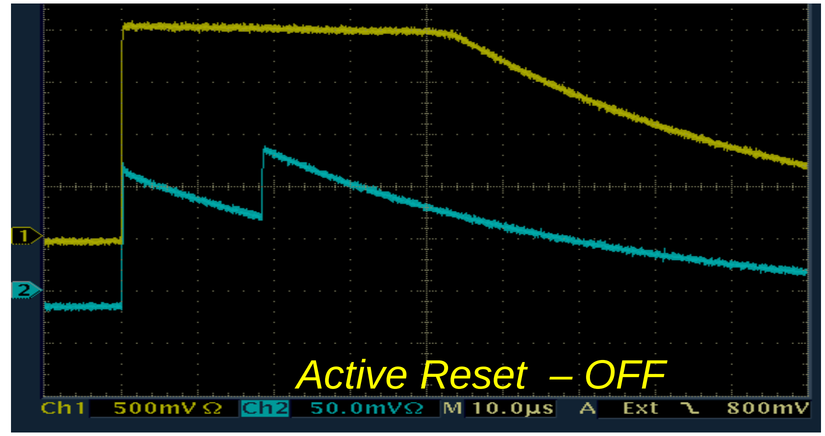
- 2. stage
- P/Z and Fast Reset
- 3. stage and Differential Driver

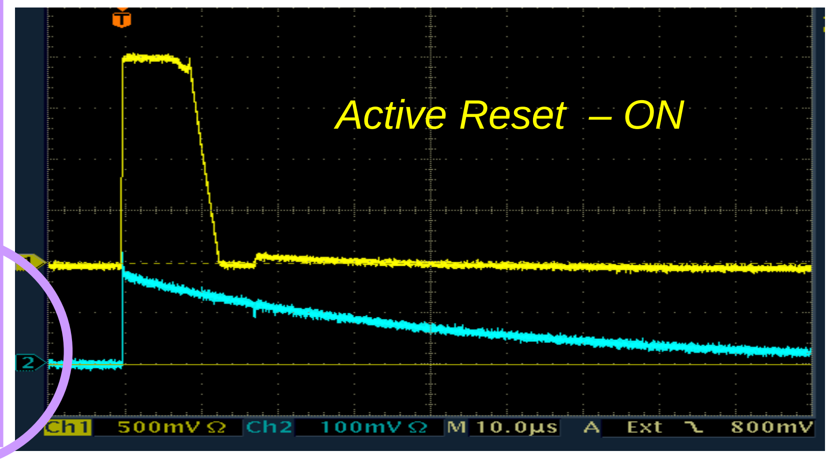


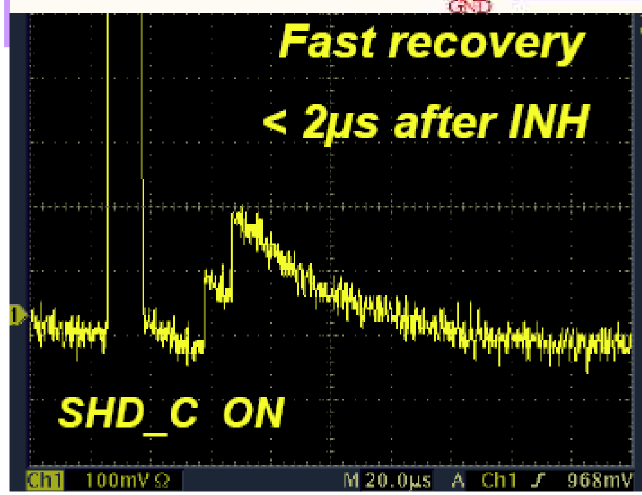
to Fast Reset (TOT technique)
(Francesca's talk)

Fast Reset as tool to implement the "TOT" method

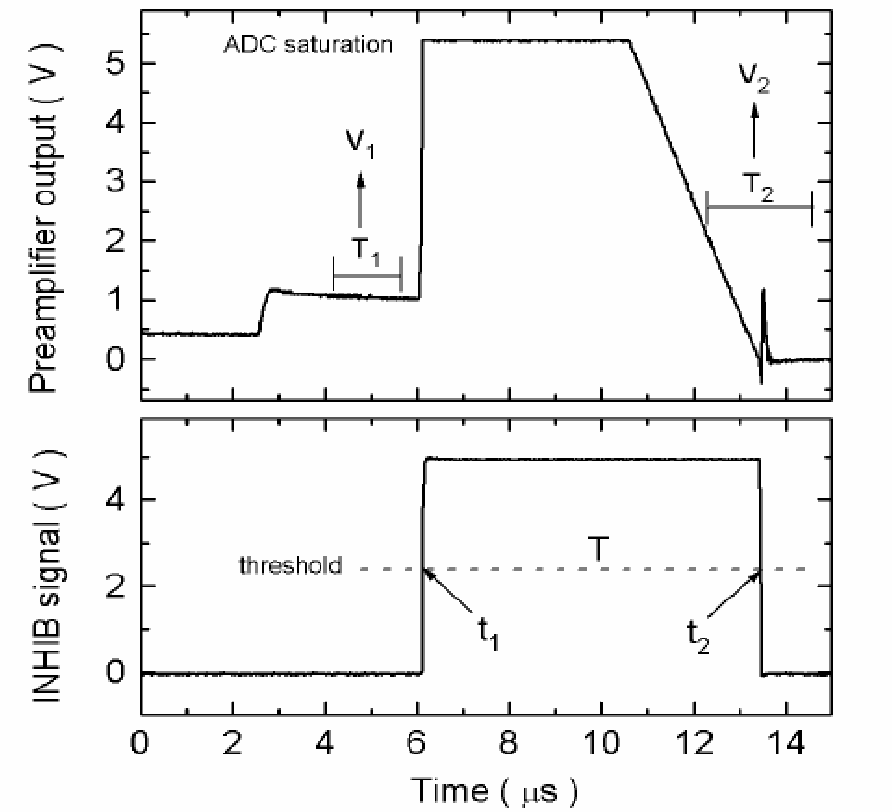


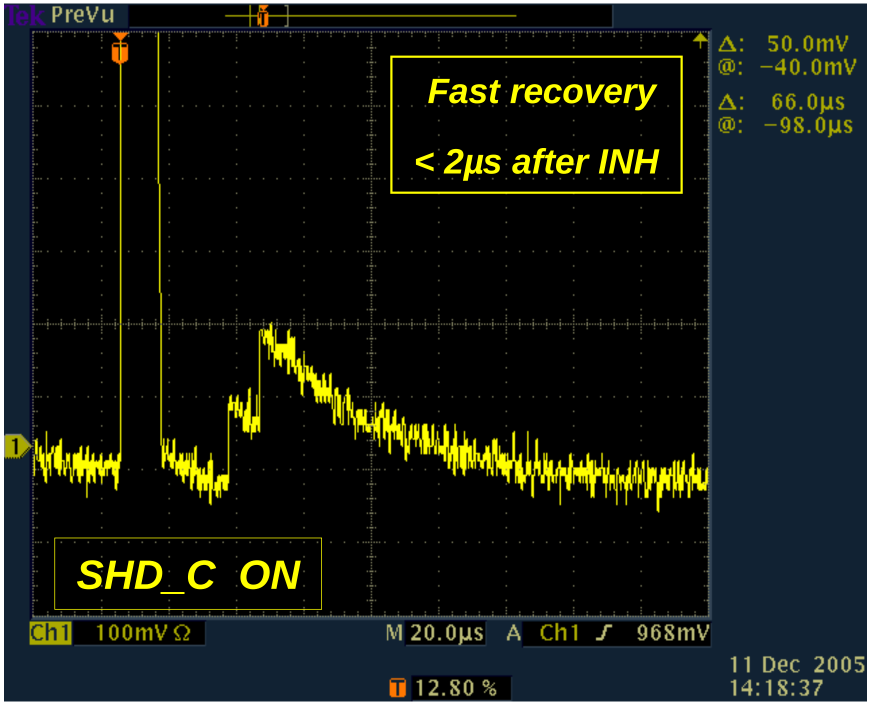




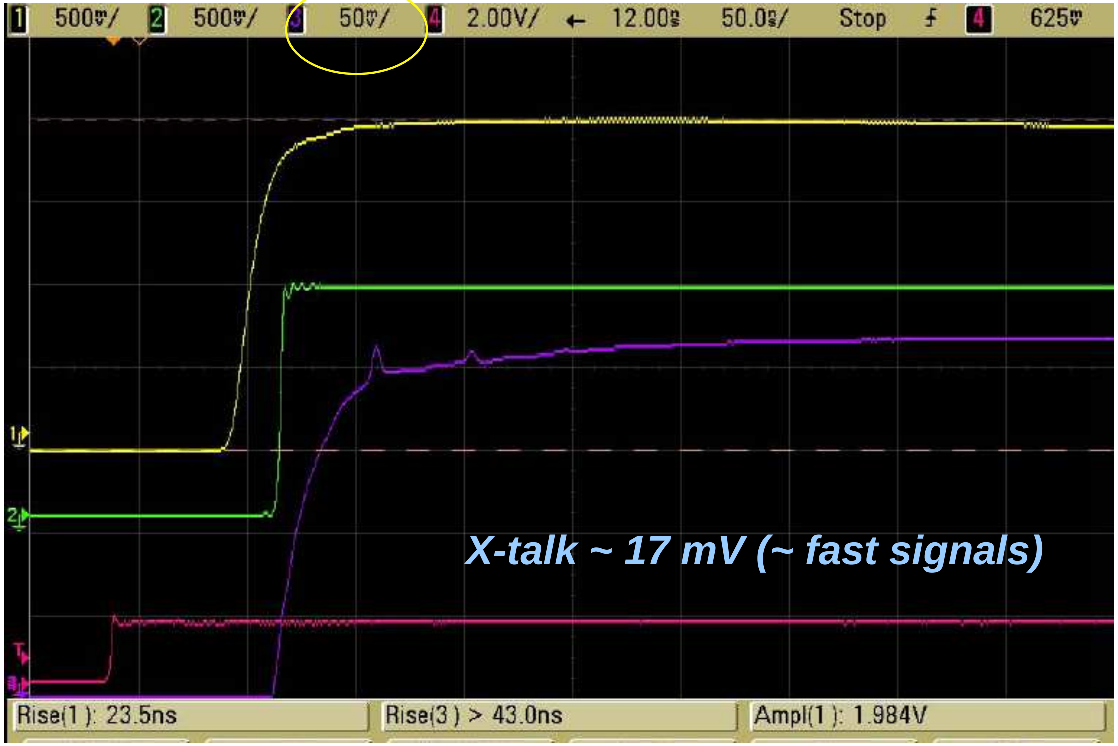


- *very fast recovery from TOT mode of operation*
- *fast comparator LT1719 (+/- 6V)*
- *factory adj. threshold + zero crossing*
- *LV-CMOS (opt)*
- *LVDS by default* ***Francesca's talk!***





Francesca's talk!



some new X-talk problems…

…if LV-CMOS transmission line

Advantage:

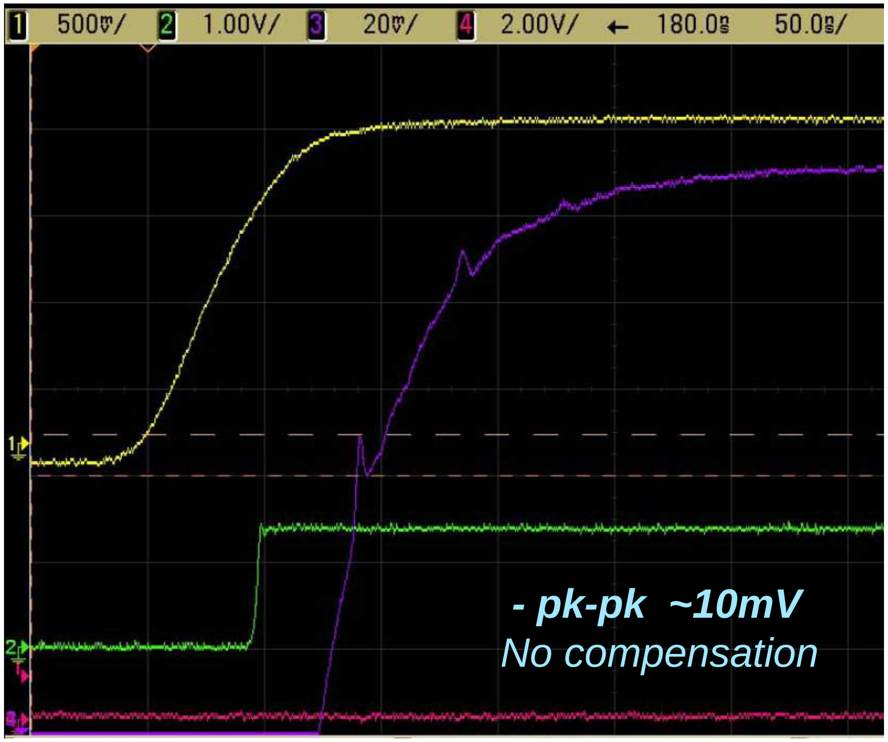
- ***simple upgrade of the single gain core***

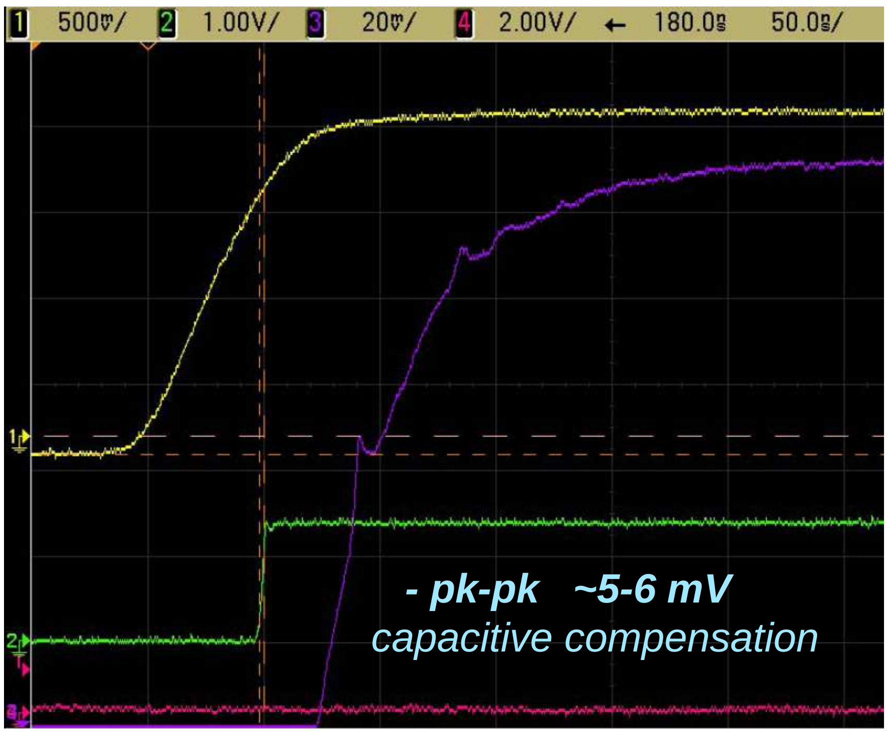
Disadvantage:

- ***relative large crosstalk between digital and analog opposite signal, namely:***

  INH-C1 ⇔ Core_Ch2

  INH-C2 ⇔ Core _Ch.1 *(sat)*





Observed transmission line crosstalk between

INH-Ch1 ⇔ Analog Signal Ch2

on the MDR-LVDS transmission line

- ***threshold dependent***
- ***difficult to compensate …***

Proposal for LVDS transmission for the INH_Core C1 and Pulser_In Signals

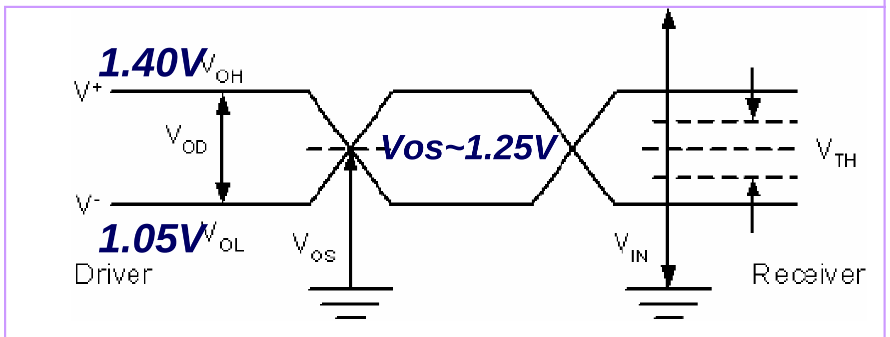
Advantage:

- *reduced crosstalk between INH-C1 and Core_Ch2 (from* ***~10 mV*** *down to* ***~1mV****)*
- ***terminated*** *digital signals INH and Pulser_In ⬄* ***accurate transmission*** *of INH_C1 (requested by TOT method) with tr;tf ~ 1.5 - 2.5 ns and smaller jitter*

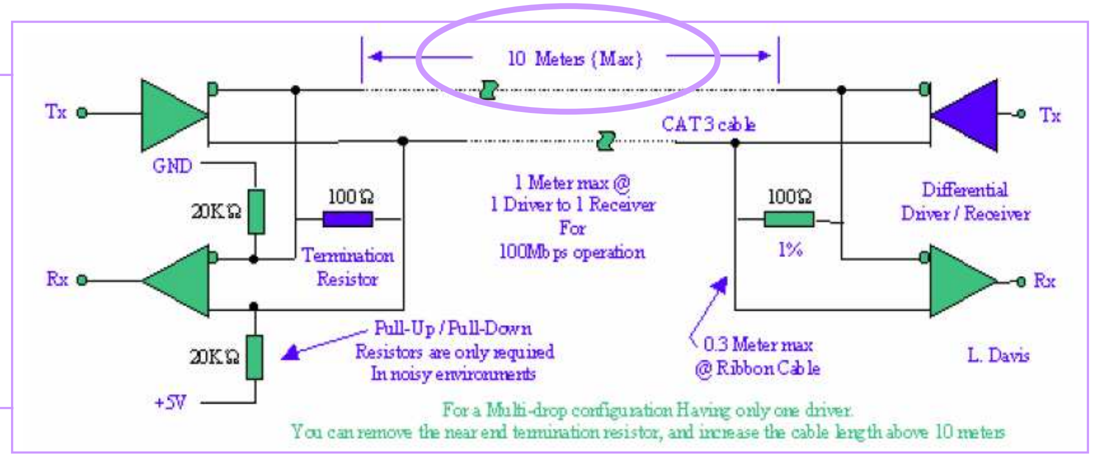
Disadvantage:

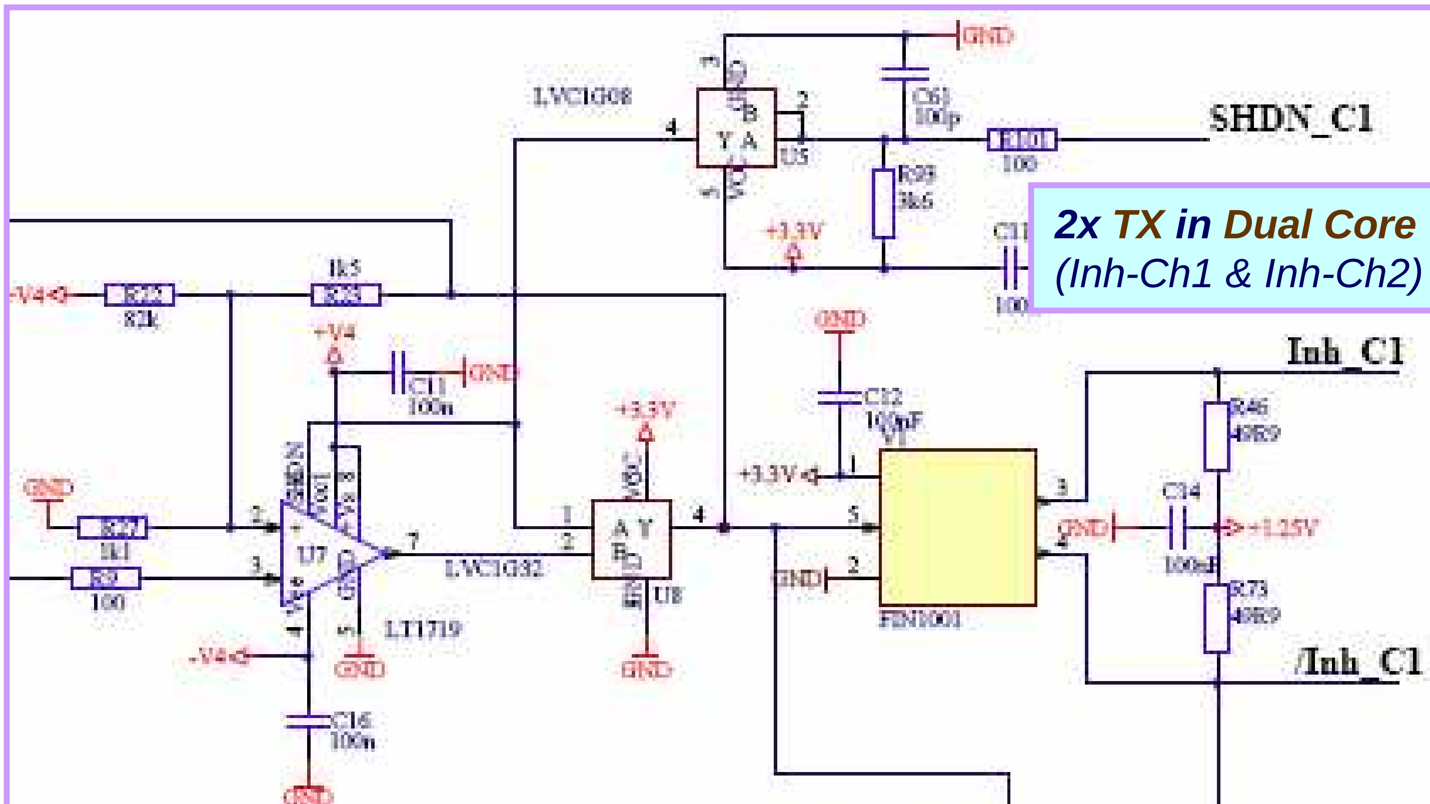
- *additional time needed for the PCB rework of both Dual-Gain Core Preamplifier and FADC*
- *LVDS transmission line*

LVDS transmission for the INH_Core C1 and INH_Core C2



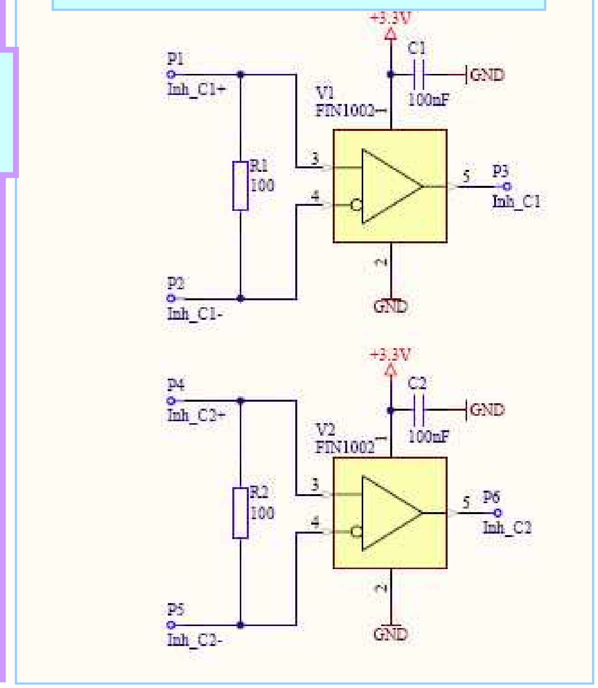
LVDS transmission





2x TX in Dual Core
(Inh-Ch1 & Inh-Ch2)

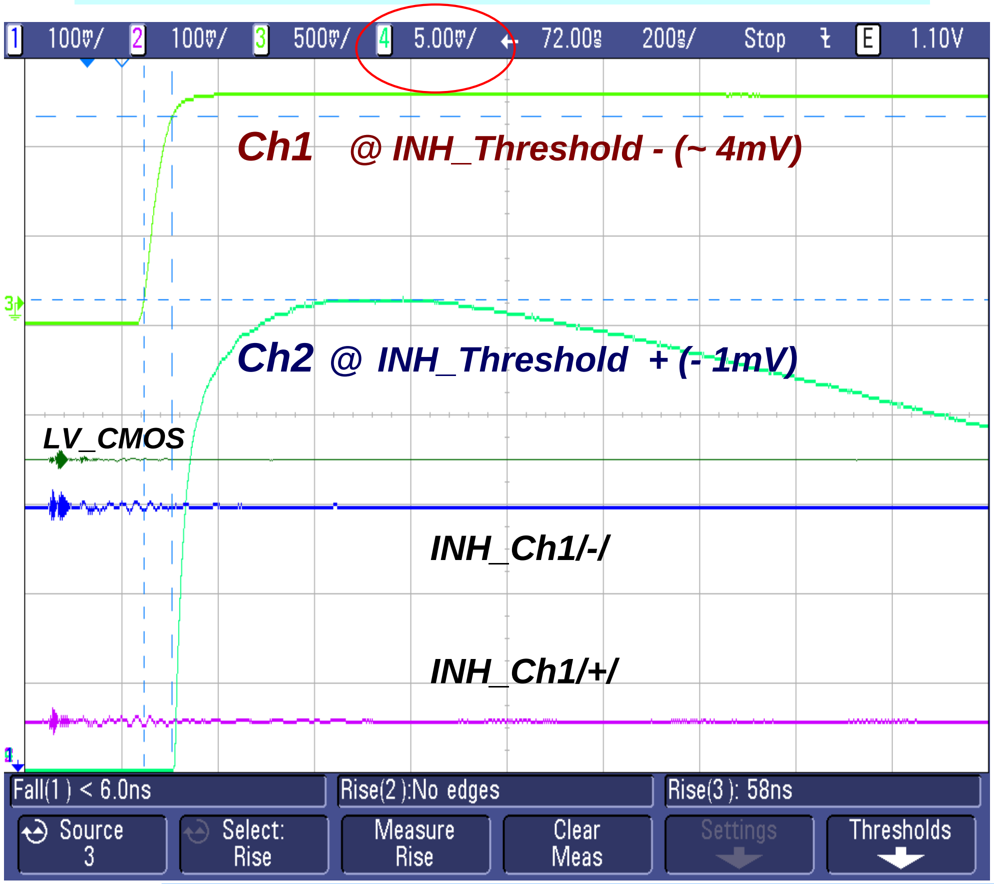
2x RX in FADC
(Inh-Ch1 and Inh-Ch2)



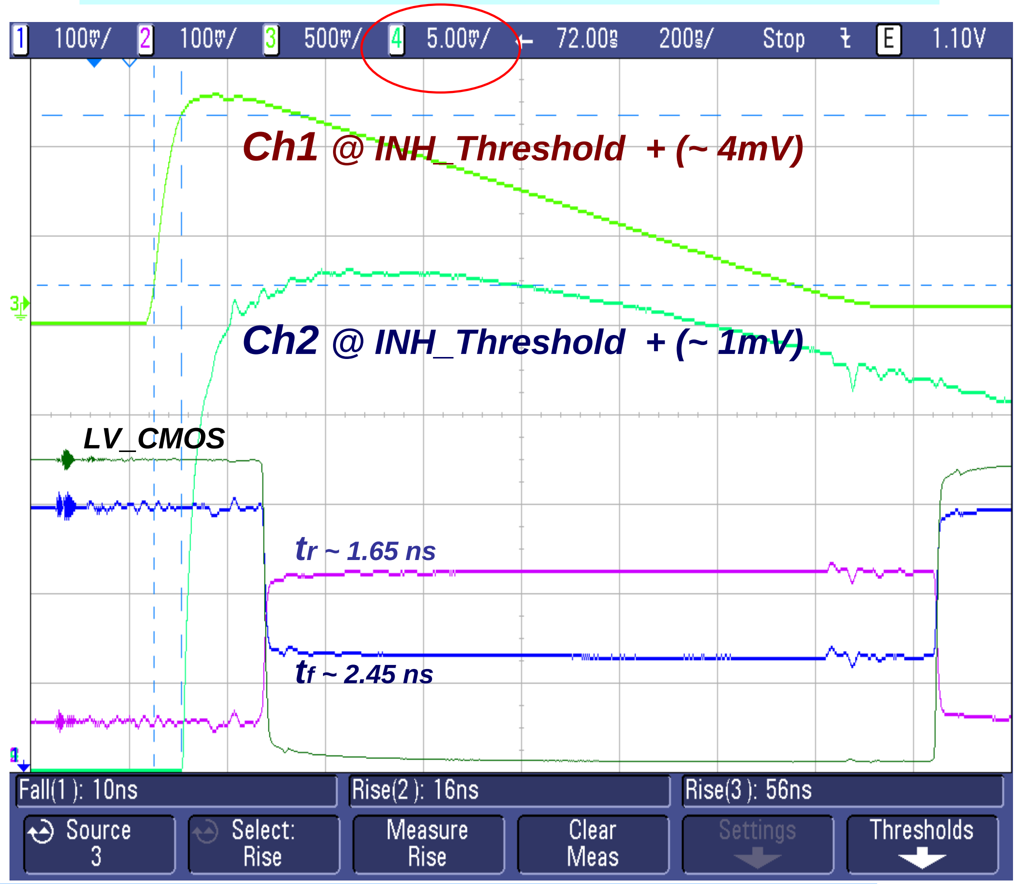
AGATA Dual_Core LVDS transmission of digital INH and Pulser_In signals

AGATA Dual Core crosstalk test measurements
Ch2 (analog signal) vs. LVDS-INH-C1 (bellow & above threshold)

Core amplitude just below the INH threshold



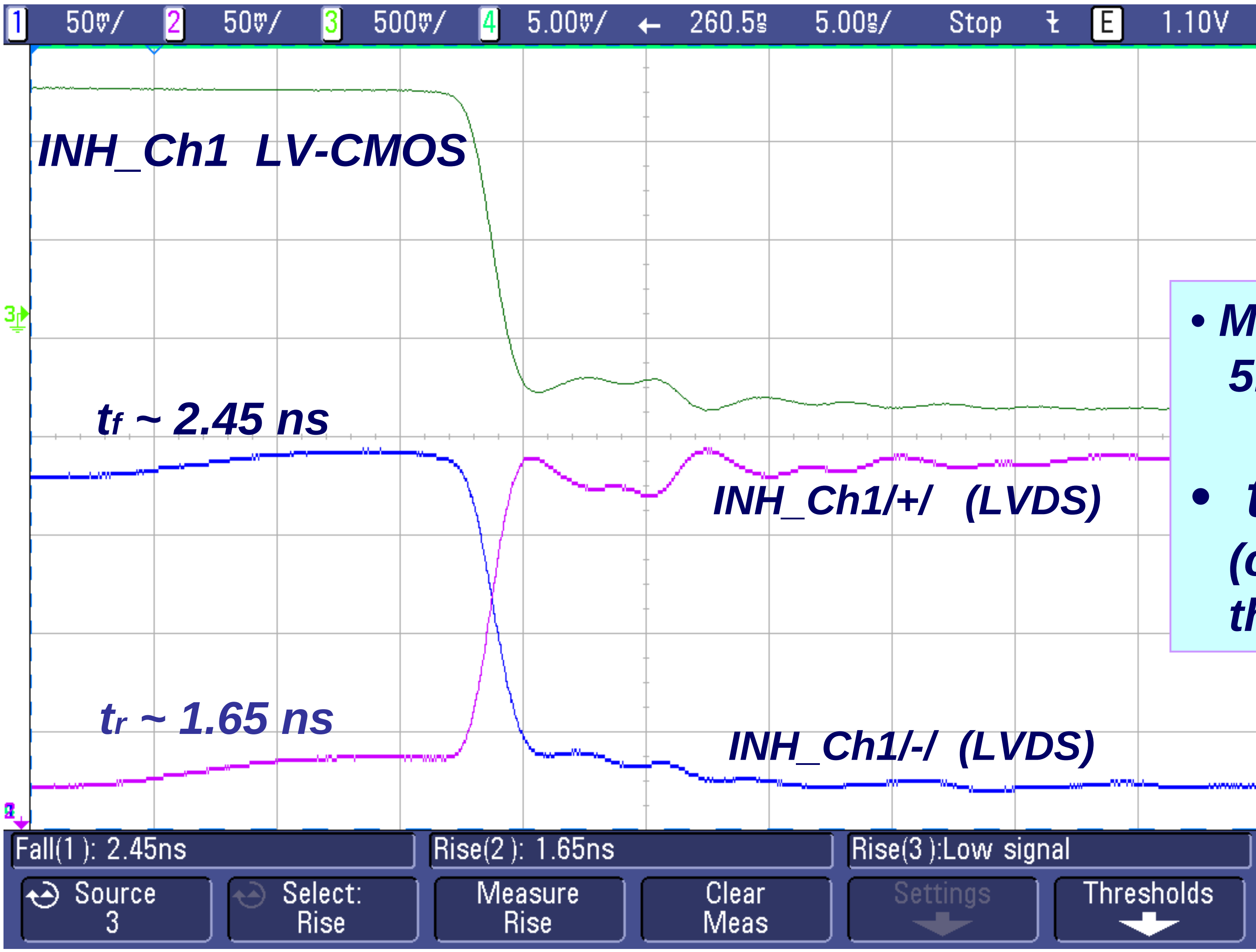
Core amplitude just above the INH threshold



(1) Core_Ch1, (2) Core_Ch2, (3) INH_Ch1(LVDS/-/, (4) INH_Ch1(LVDS/+/)

G.Pascovici, Dual_Core IReS Test Box, warm jFET, Feb.23, 2008

AGATA Dual_Core LVDS transmission of digital INH and Pulser_In signals



- *MDR connector and 5m cable assembly*
- t_r, t_f *~ 1.7-2.5ns (clean enough for the TOT technique)*

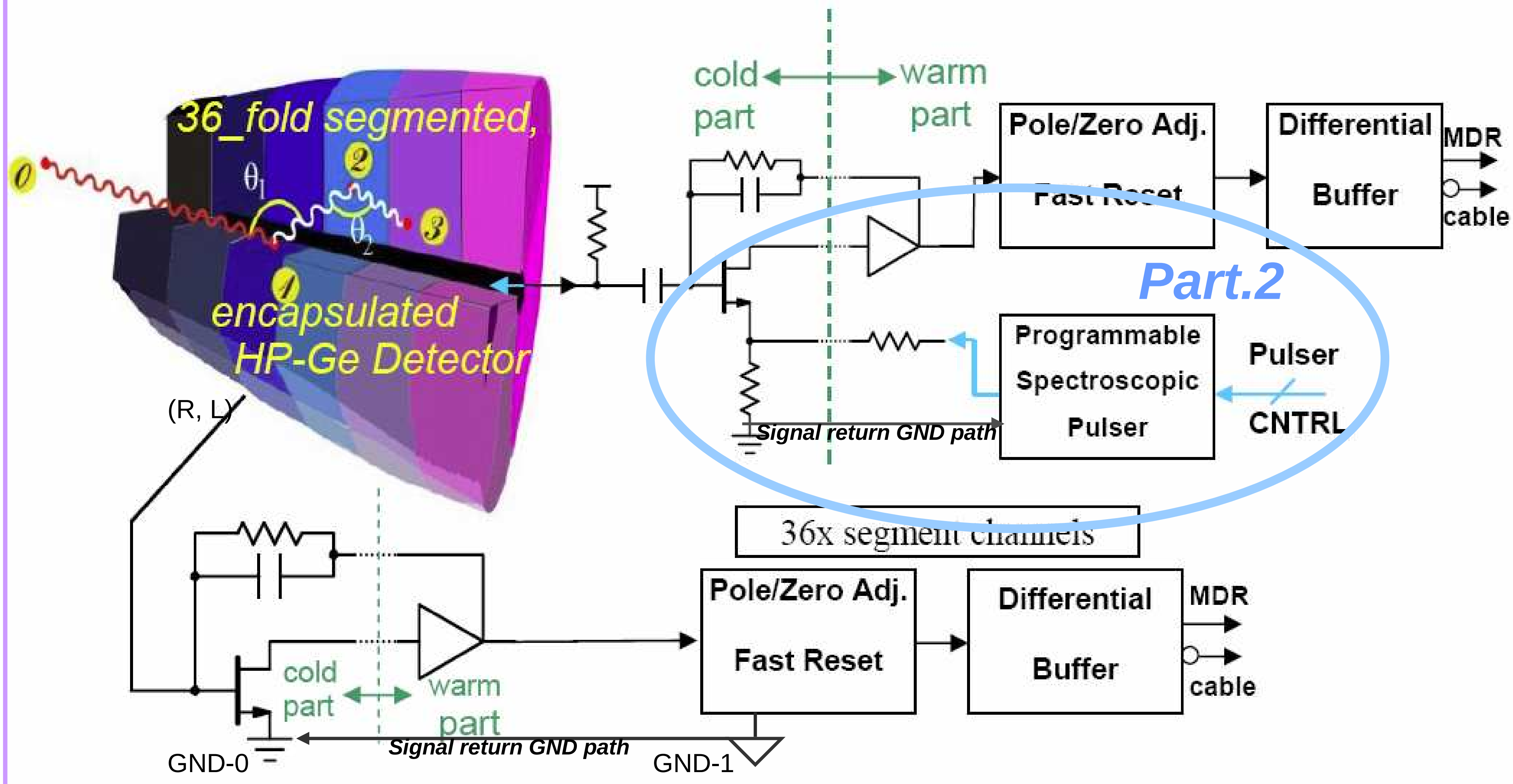
AGATA Dual Core Final specs.

Property	value	tolerance
Conversion gain for segments and single core	100 mV / MeV (terminated)	±10 mV
Conversion gain for dual core	200 mV/ MeV (Ch 1) 50 mV/ MeV (Ch 2)	±20 mV ±5 mV
Noise	0.6 keV fwhm (0 pF; 150K)	
Noise slope	8 eV / pF	±2 eV
Rise time	12 ns (0 pF)	±2 ns
Rise-time slope	~0.2 ns / pF	
Decay time	50 µs	±2 µs
Integral non linearity	< 0.025% (D=3.5V)	
Output polarity	differential, Z=100W	
Fast reset speed	~10 MeV / µs	
Inhibit output	TTL/CMOS ⇔ LVDS	
Power supply	±6.5V, ±12.5V	±0.5V
Power consumption jFET	< 20 mW	
Power consumption (except diff. buffer)	< 280 mW Single Core <500mv Dual Core	
Mechanical dimension	(62 x 45 x 8) mm - Single Core (70 x 45 x 8) mm - Dual Core	

Comments:

- comparison with the tentative AGATA Specs Padova 2002
- Front end electronics was not an issue of the AMB only detector& cryostat R&D…. ☺

Block diagram of the AGATA front end-electronic

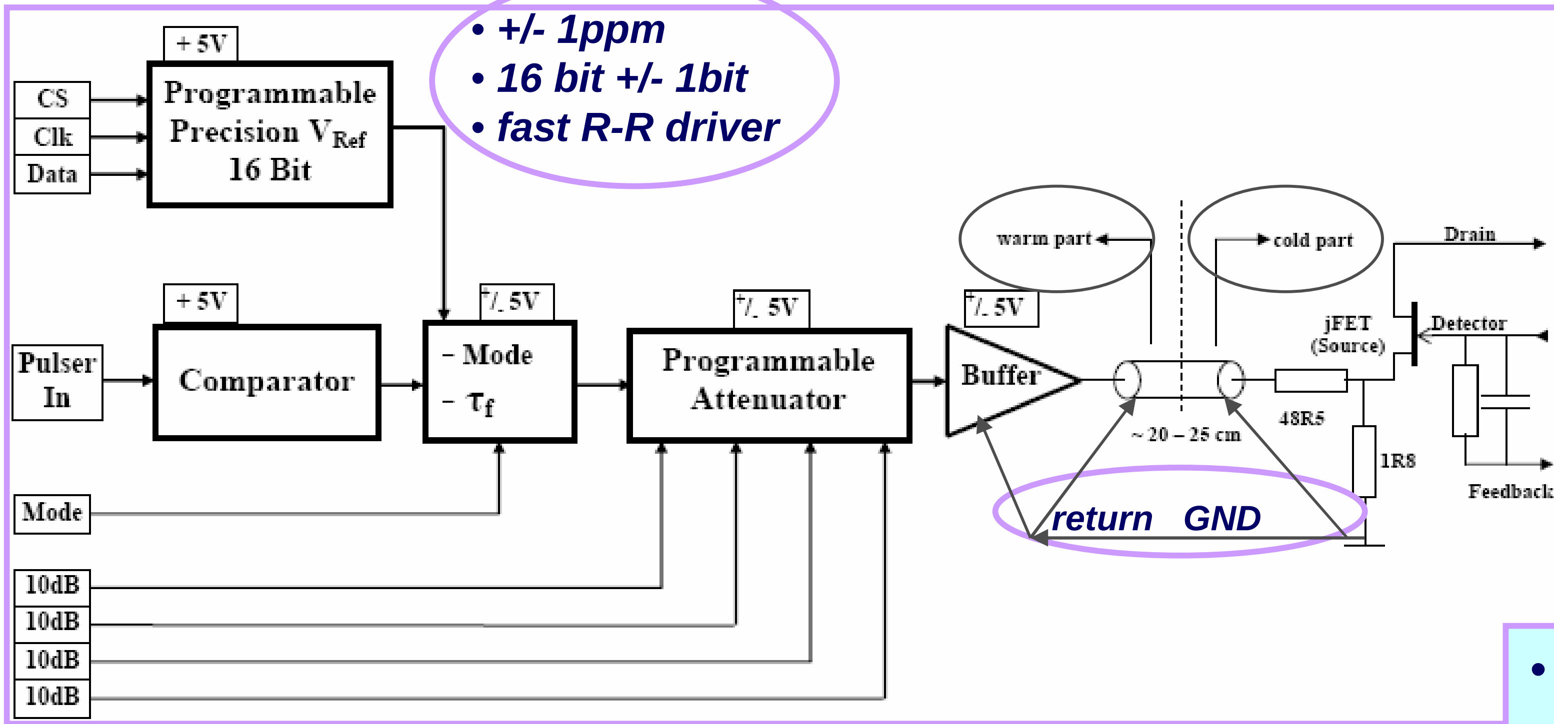


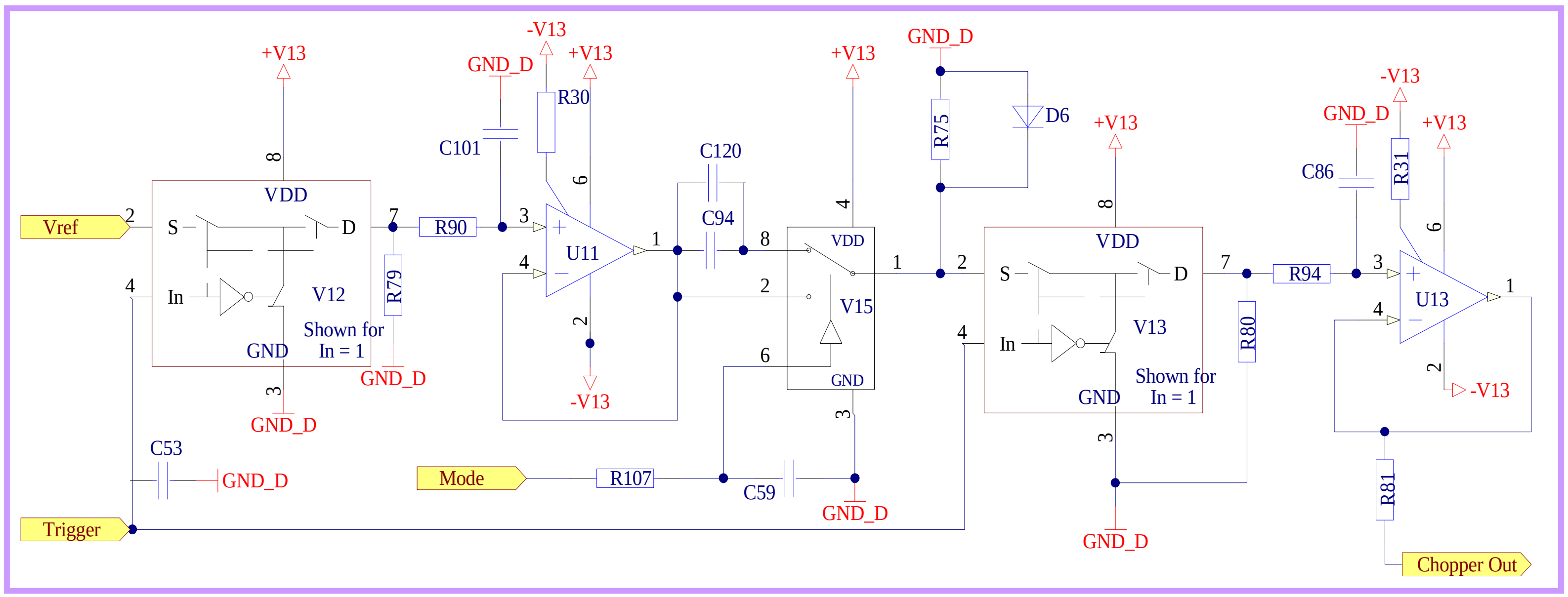
- ***Programmable Spectroscopic Pulser***

- ***why is needed? ⇔ self-calibration purposes***
- ***brief description …***
- ***Specs and measurements …***

Potential use of SPP for self-calibrating

Parameter		Potential Use / Applications
• Pulse amplitude	⇔	Energy, Calibration, Stability
• Pulse Form (rise time, fall time, structure)	⇔	Transfer Function in time domain, ringing ⇔ (PSA)
• Detector Bulk Capacities (also for Dummy Capacities)	⇔	Crosstalk input data (Detector characterization)
• Pulse Form	⇔	TOT Method ⇔ (PSA)
• Repetition Rate (c.p.s.) (with periodical or statistical distribution)	⇔	Dead Time (Efficiency meas.)
• Time alignment	⇔	Correlated time spectra
• Segments calibration points	⇔	Low energy calibration points





- **Analog Switches:**
  - t on / t off ,
  - Qi,
  - dynamic range (+/- 5V)
- **Op Amp:**
  - ~ R to R
  - bandwidth
- **Coarse attenuation** (4x 10 dB) (z_0~150 Ohm)
- **transmission line to S_ jFET and its return GND!**

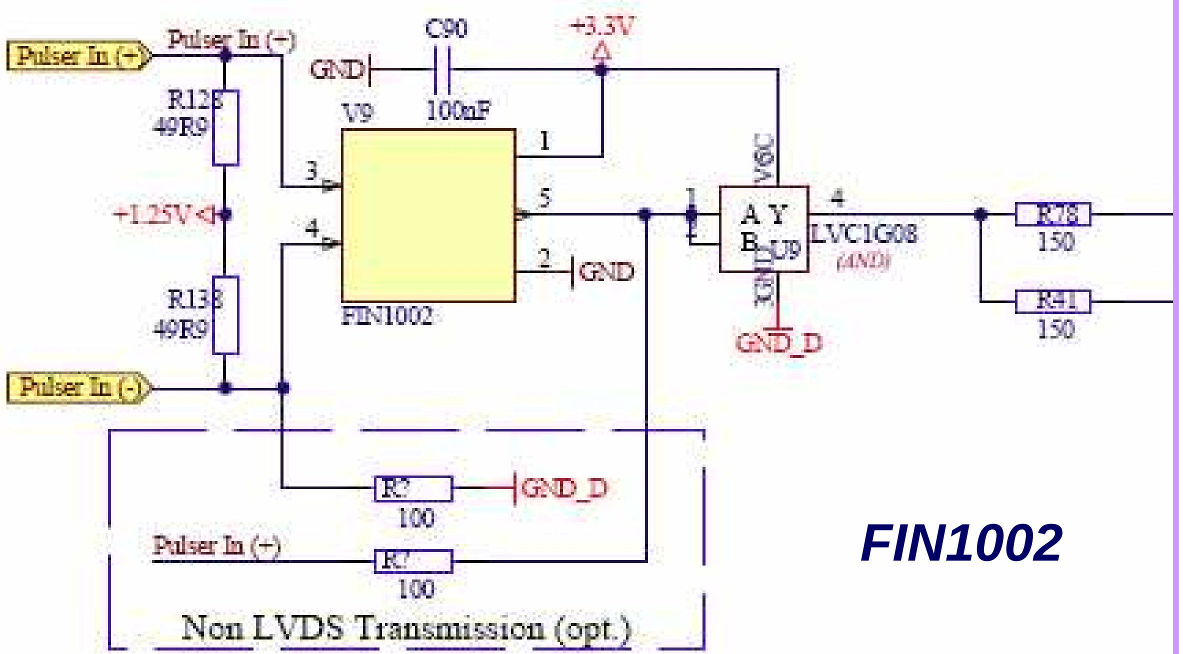
AGATA Dual_Core LVDS transmission of the digital Pulser_In signals

Two additional PS are needed on the preamplifier board:

V_{cc} ~ + 3.3 V

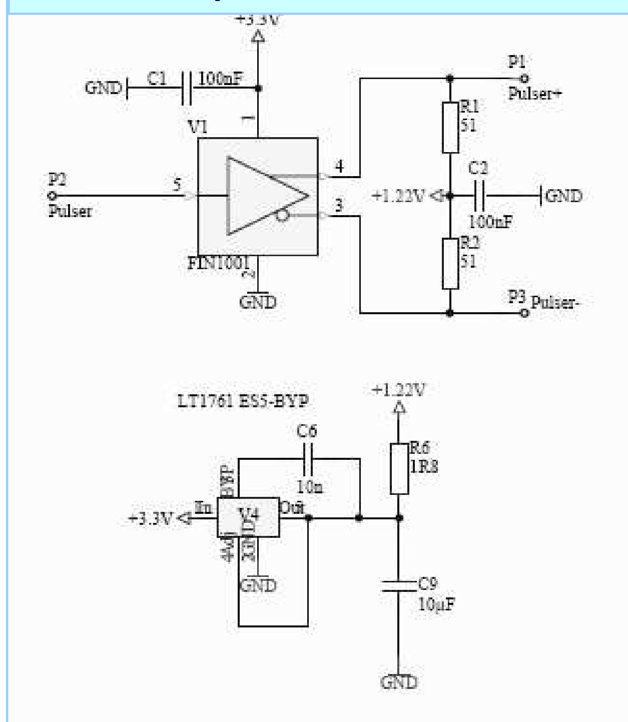
V_{os} ~ + 1.25 V (opt)

Pulser signal
(RX in Pulser Dual Core)



FIN1002

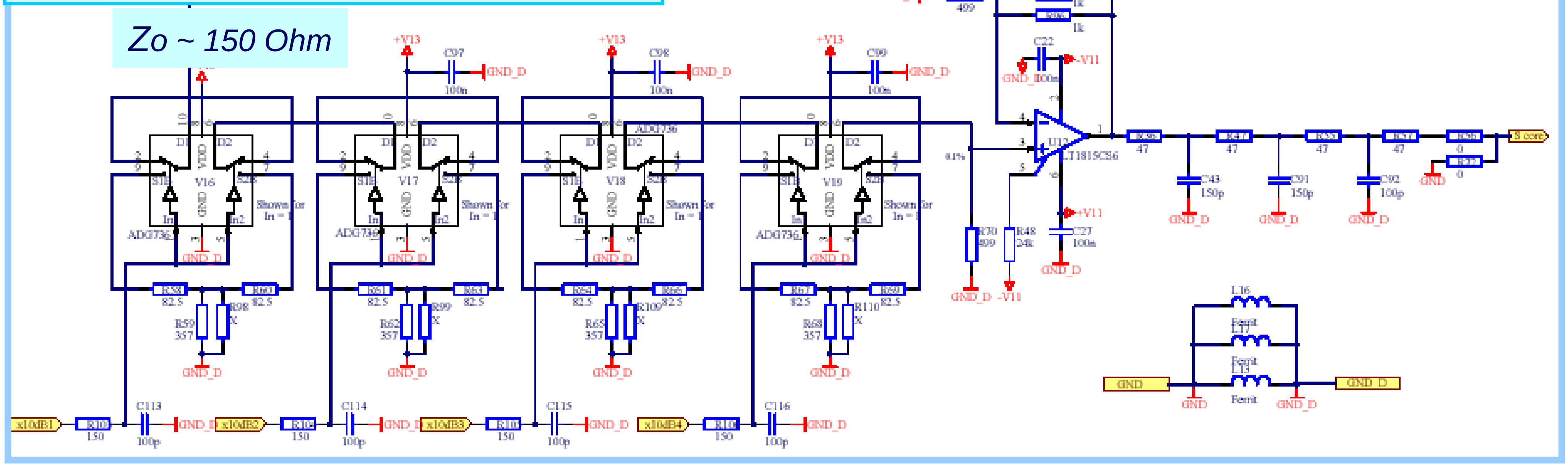
TX in FADC
(Pulser signal)



Programmable Pulser (3)

from Chopper / Linear Gate Stage

Zo ~ 150 Ohm



Programmable attenuator 4x 10 dB

Issues:

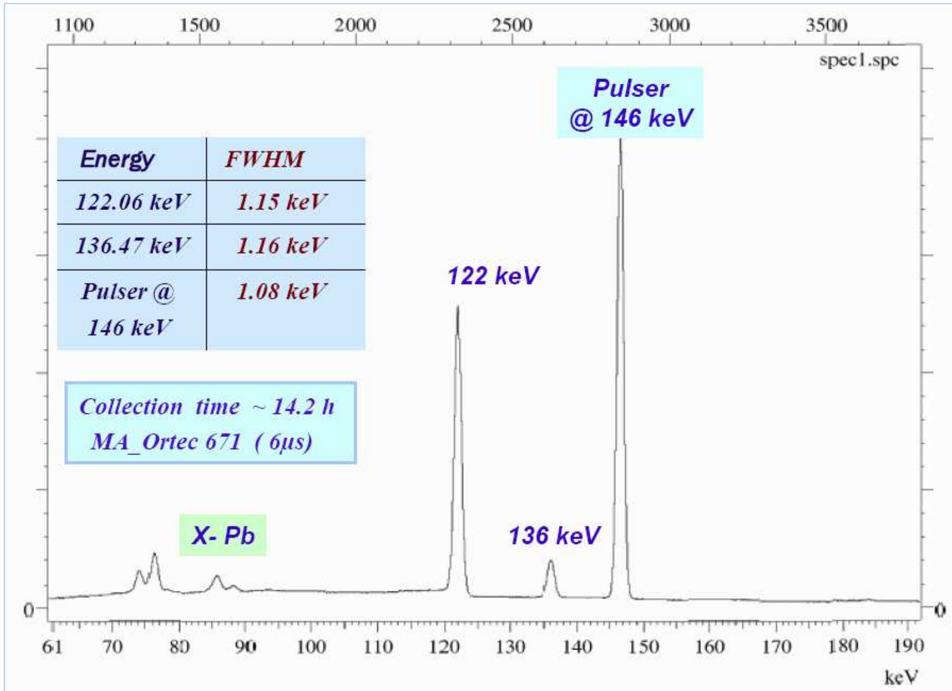
- *Bandwidth (tr) vs. Noise*
- *Pulser pulse shape vs. gamma*
- *Pulser return GND ⇔ core noise*

Selection Mode of operation

Exponential	Rectangular
Good DC Level	Same P/Z ⇔ good PSA
Disadvantage: - Different P/Z for Signal & Pulser ⇔ PSA! - Bipolar Signals (+ & -)	**Advantage/Disadvantage** Base line OK (good P/Z), but DC level ~ pulser level (50%)

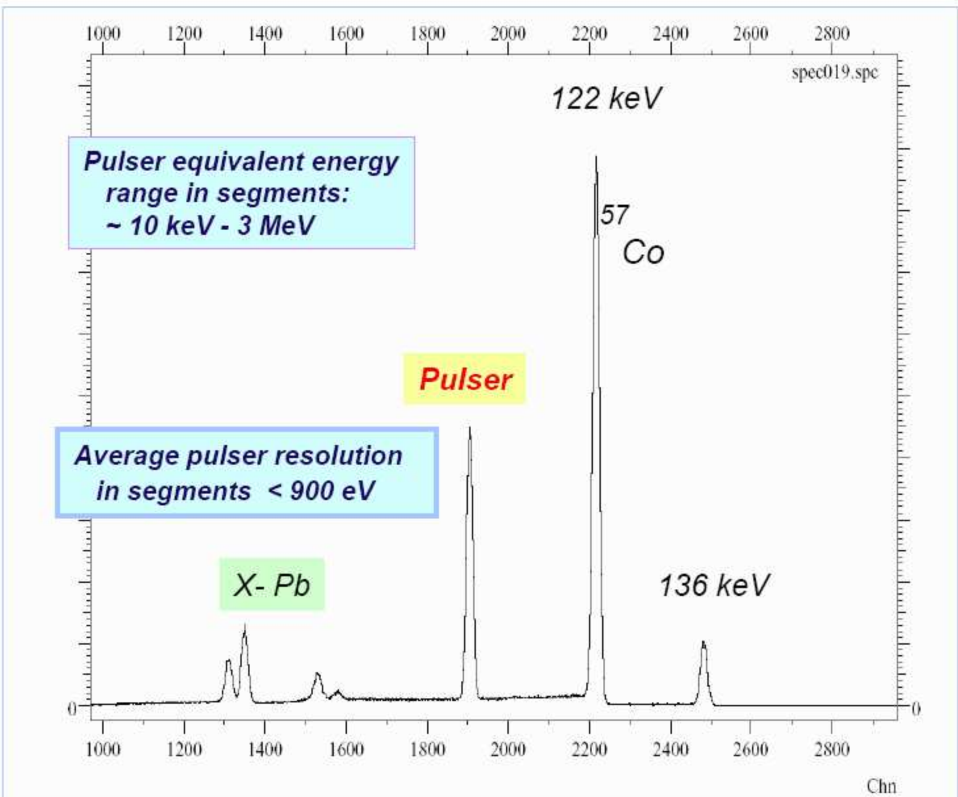
Pulser Specs and Measurements

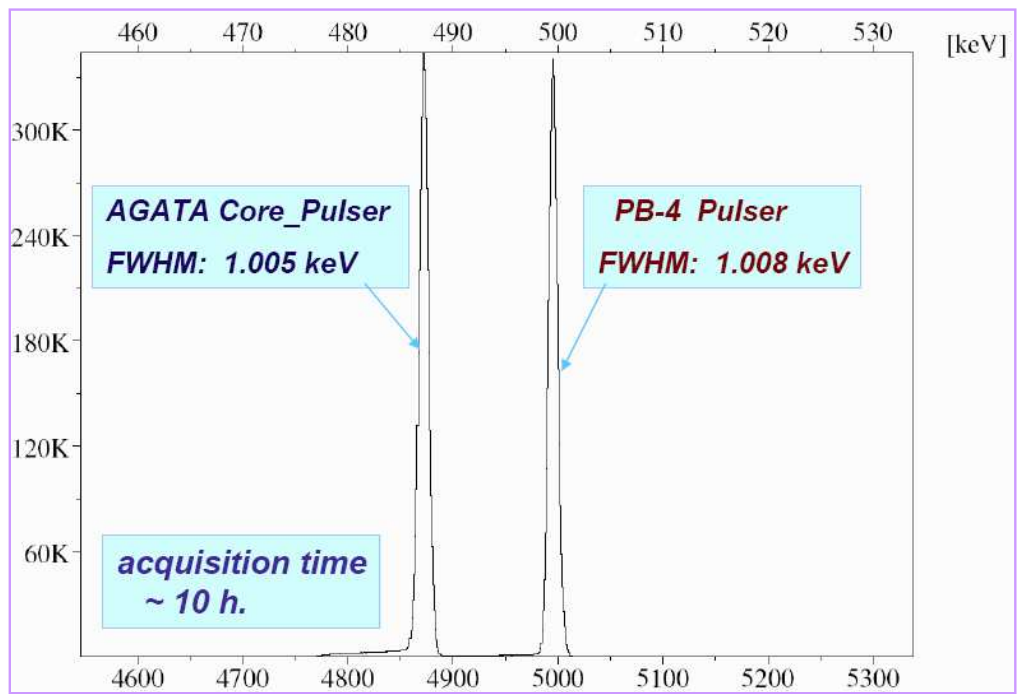
- Dynamic range:
  - Core 0 to ~ 180 MeV (opt. ~ 90 MeV)
  - Segments 0 to ~3 MeV (opt. ~ 1 MeV)
- Rise Time Range: 20 ns - 60 ns (by default ~45 ns)
- Fall Time Range: 100 µs - 1000 µs (by default ~150 ns)
- Long Term Stability: $< 10^{-4}$ / 24 h



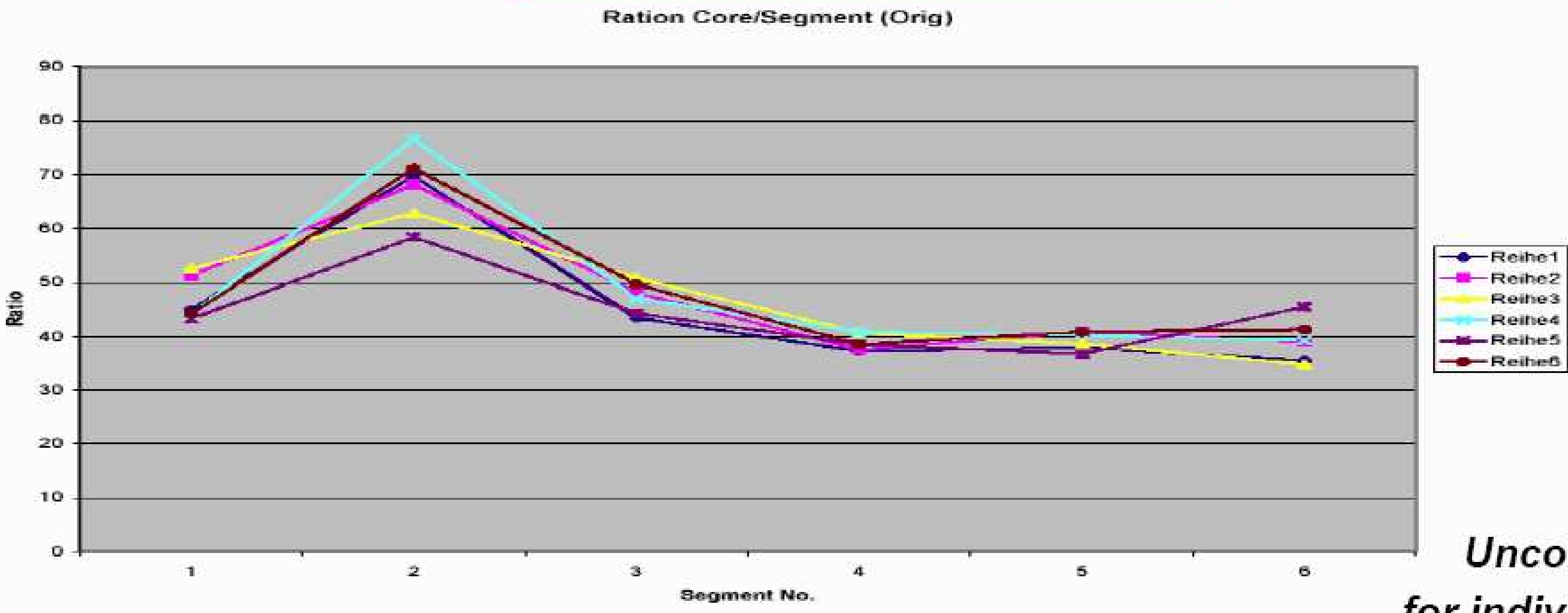
Measurements:

- GSI Single Cryostat (Detector S001)
- Portable 16k channels MCA (IKP)
- Resolution (acquisition time 12-14h):
  - core 1.08 Pulser (Detector)
  - cold dummy (V3): 0.850 keV
  - segment Pulser: < 0.90 keV
  - core @ 59.5 keV: 1.10 keV
  - core @ 122.06 keV: 1.15 keV

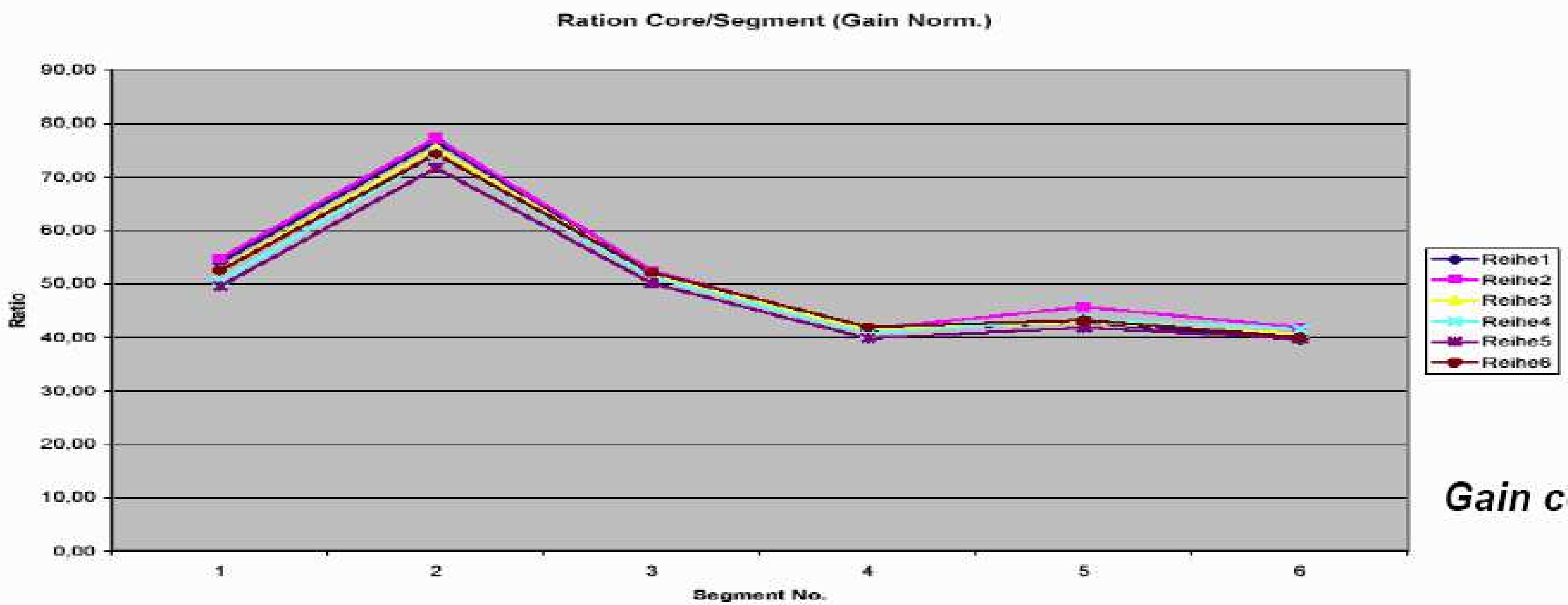




Pulser Ratio Core /Segments



Uncorrected for individual Gain



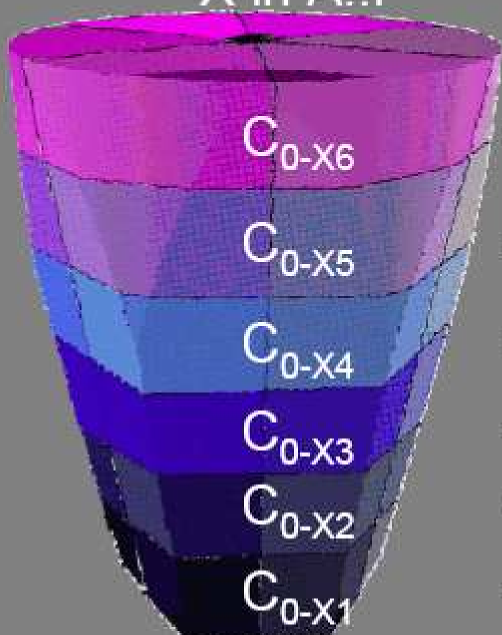
Gain corrected

Core to Segment Capacities

- Pulser signal in segments: Inverse proportional to core-segment capacity.
- Capacities normalized to total capacity of crystal (46pF cfr. Eurisys)

AGATA measured capacities using pulser :

X in A..F



averaged values S001: ← σ = 3%

Capacity	TC	GSI cryo	
C_{0-X6} =	1.27 pF	1.52 pF	← ????
C_{0-X5} =	1.50 pF	1.43 pF	
C_{0-X4} =	1.54 pF	1.50 pF	
C_{0-X3} =	1.27 pF	1.20 pF	
C_{0-X2} =	0.86 pF	0.83 pF	← Low effective volume
C_{0-X1} =	1.22 pF	1.18 pF	

Structure of Core Resolution in Coincidence with Segments Rings

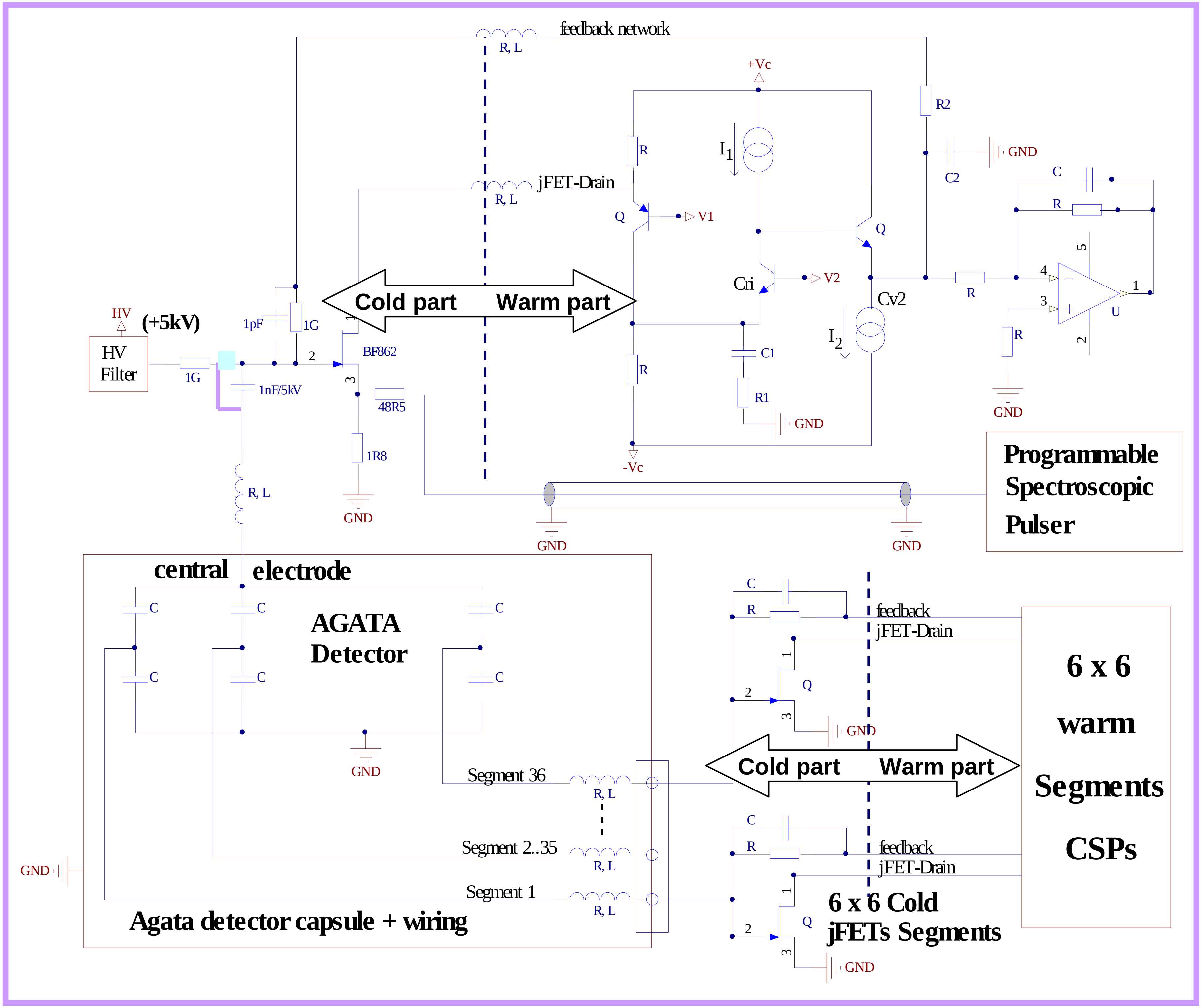
Ring ⬄	1	2	3	4	5	6
Peak Position (1332,...) keV	.285 keV	.166 keV	.353 keV	.535 keV	.543 keV	.495 keV
Resolution FWHM (keV)	2.37	2.38	2.27	2.22	2.24	2.34 passivation problems

Nigel Warr, "AGATA core resolution wit gate on segment

Part.3

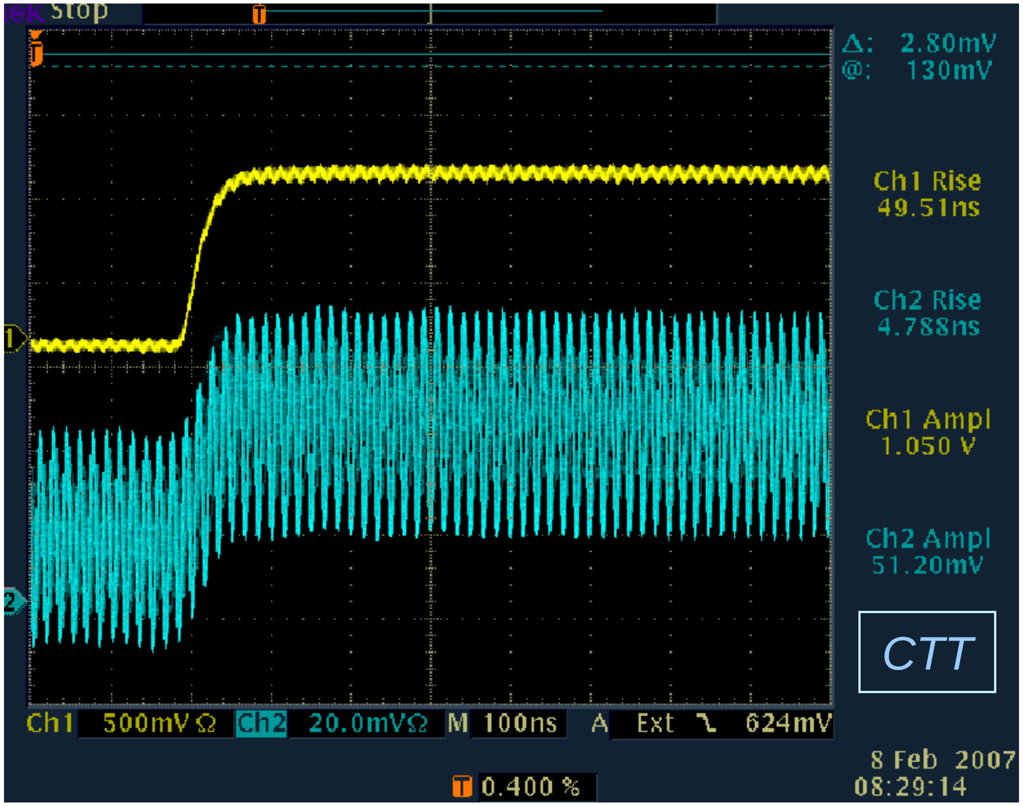
Transfer Function & X-talk

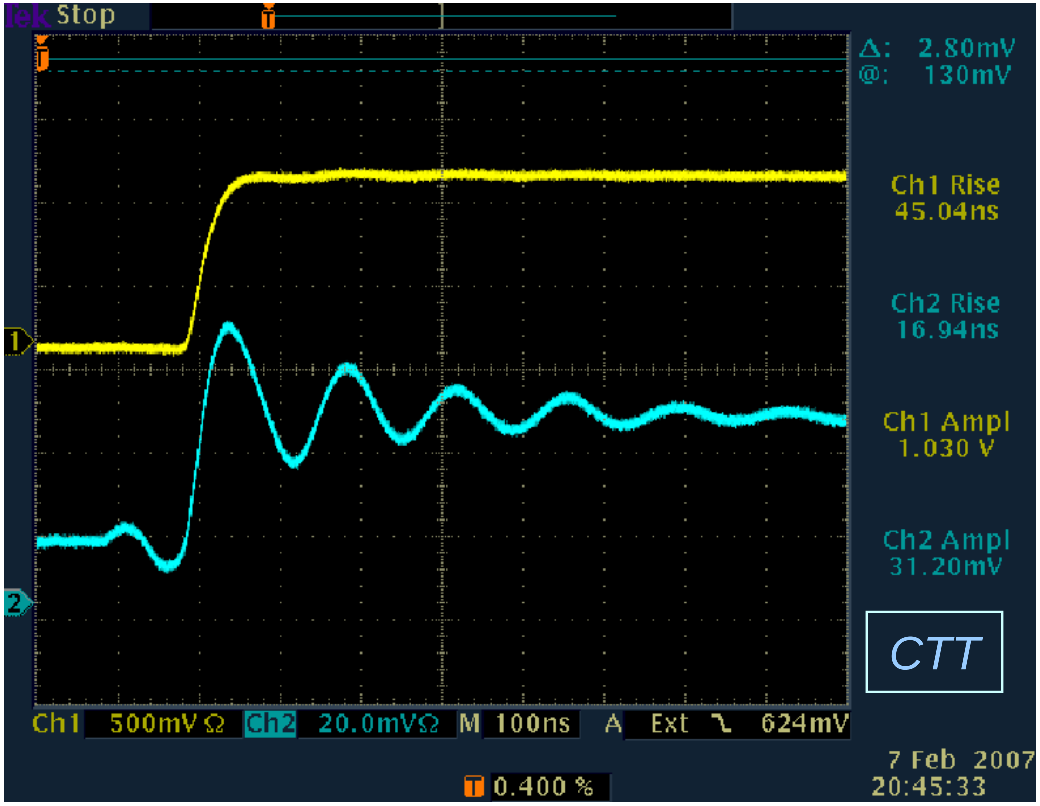
- Stand alone transfer function (bench tests... 2004++)
- Wiring influence - detector wiring & cryostat wiring
  - Dummy Detectors (2D ⇔V2; 3D ⇔V3)
- Solution for frequency compensation to find
  - stability criteria for - oscillations,
    - peaking & ringing
  - methods of compensation depending on:
    - op amp type (or equivalent op amp when distributed)
    - feedback, source and load networks
- Updated version of compensation and measurements



feedback network
R, L
+Vc
R2
R
I1
GND
C2
jFET-Drain
C
Q
V1
Q
Cri
V2
Cv2
R
4
5
1
3
2
U
HV
(+5kV)
1pF
1G
Cold part
Warm part
HV Filter
2
BF862
I2
C1
1G
1nF/5kV
3
48R5
R1
GND
1R8
-Vc
R, L
GND
GND
GND
Programmable Spectroscopic Pulser
central electrode
AGATA Detector
C
feedback
jFET-Drain
6 x 6 warm Segments CSPs
Q
GND
Segment 36
Cold part
Warm part
Segment 2..35
Segment 1
6 x 6 Cold jFETs Segments
Agata detector capsule + wiring

TC_Warm with Slow Core and Segment A_ S1 with common or separated cold grounding GND_0 + GND_1

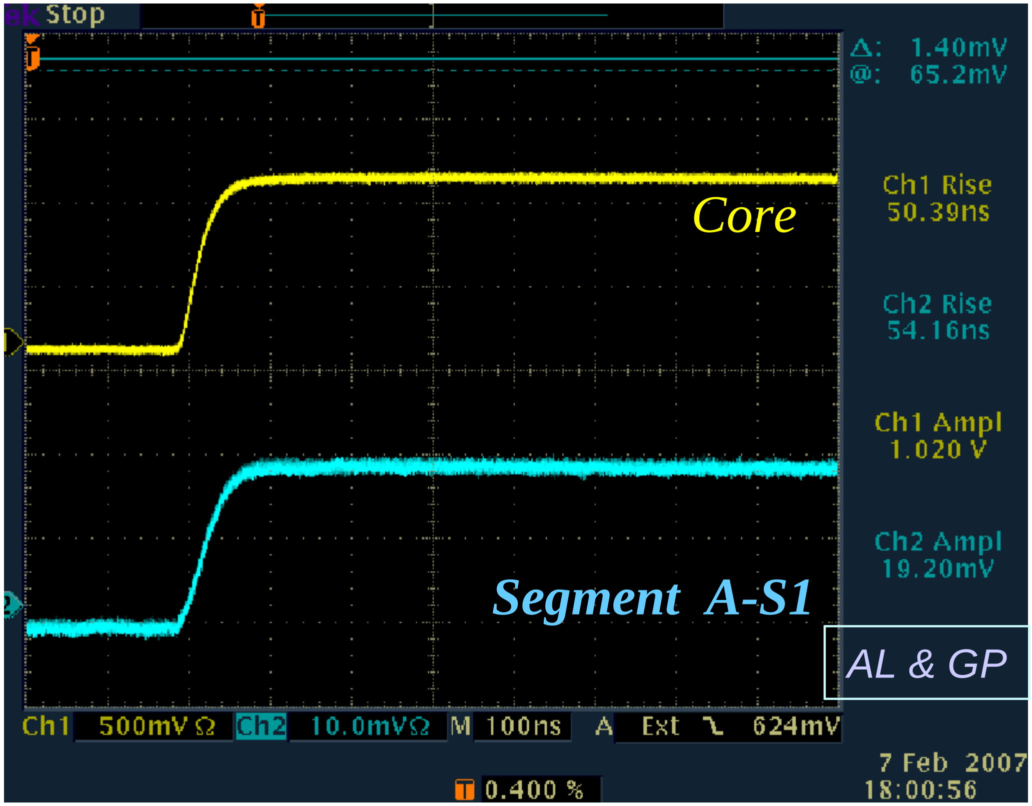


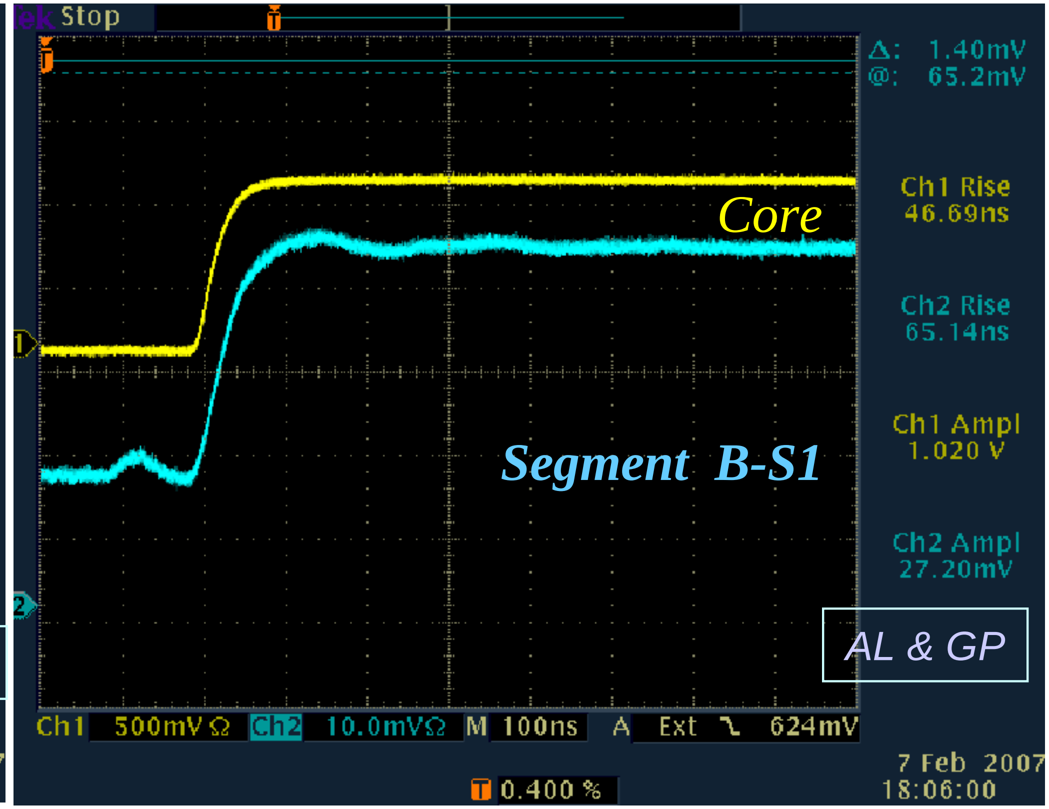


Common cold grounding
GND_0 (Cryostat Cu_Al)
GND_1 (Cold CSPs)

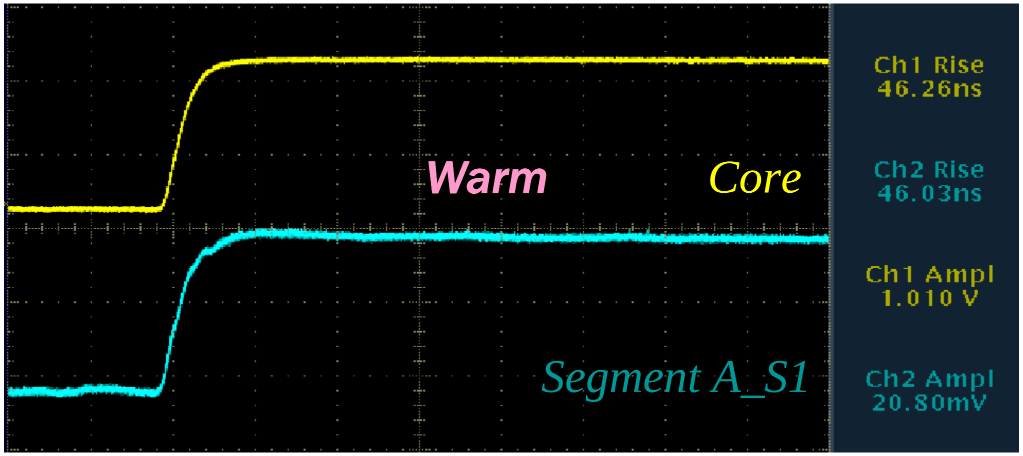
Separated cold grounding
GND_0 (Cryostat Cu_Al)
GND_1 (Cold CSPs)
(end cup opened)

TC_Warm with Slower Core

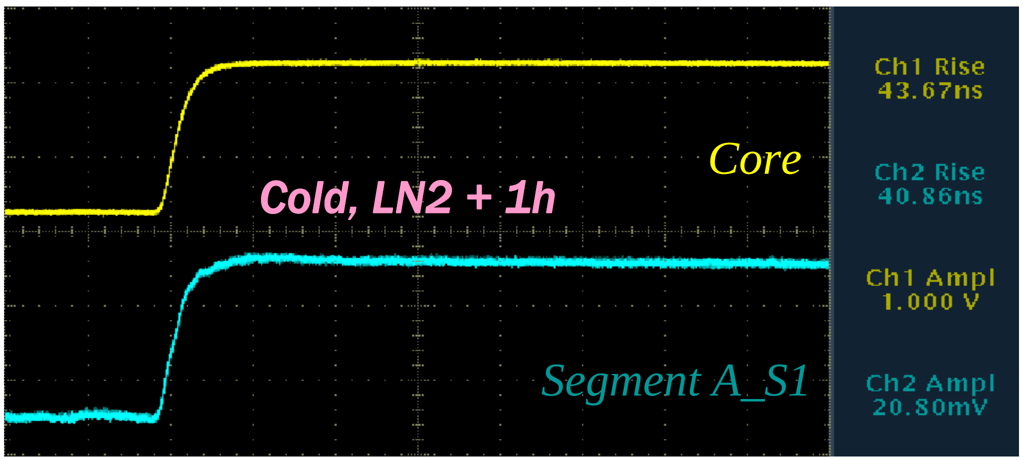


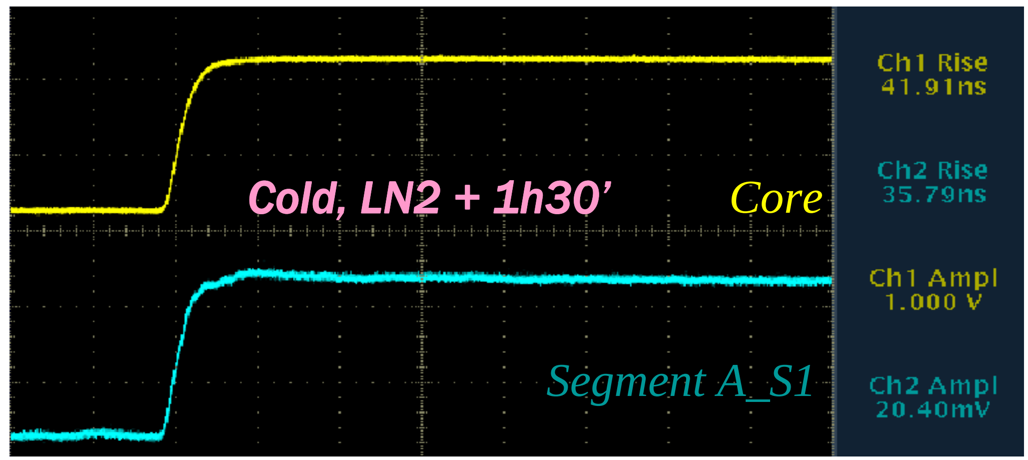


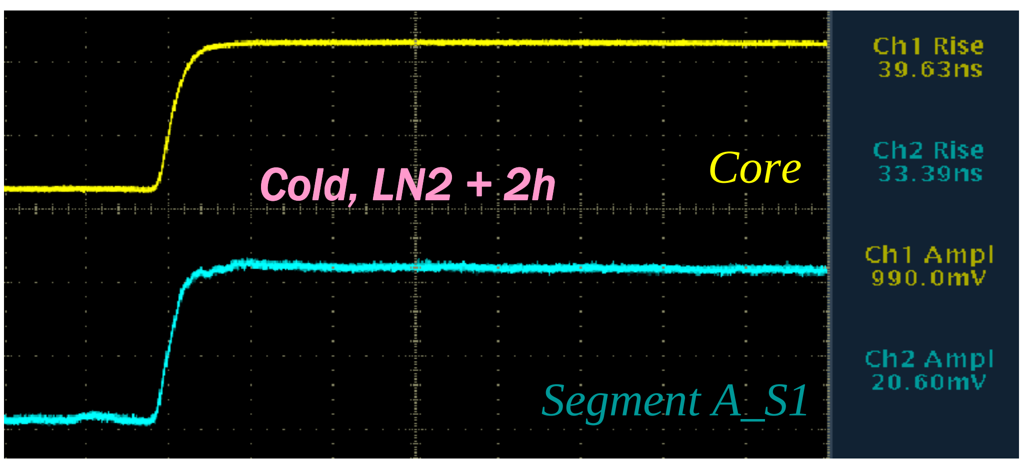
Transfer Function Temperature dependents

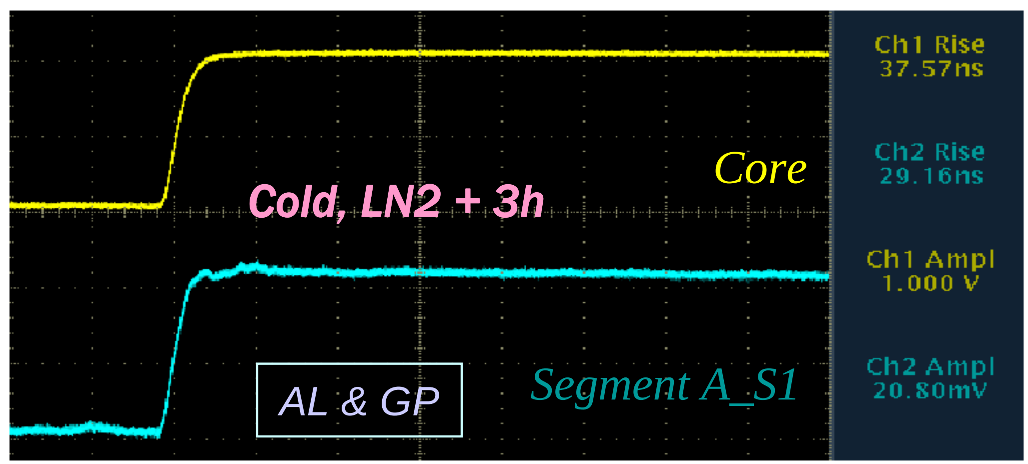


Transfer Function - Temperature dependents for Dummy_V3 Core and Segment A_S1 (best case) **mounted in TC - Symetric** (vers. 2005)

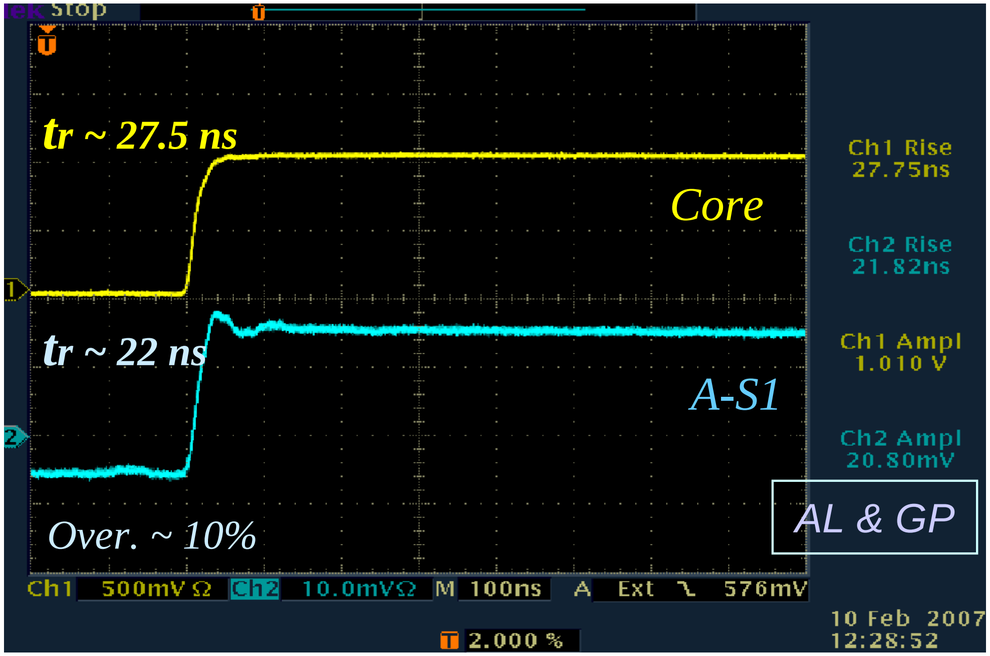


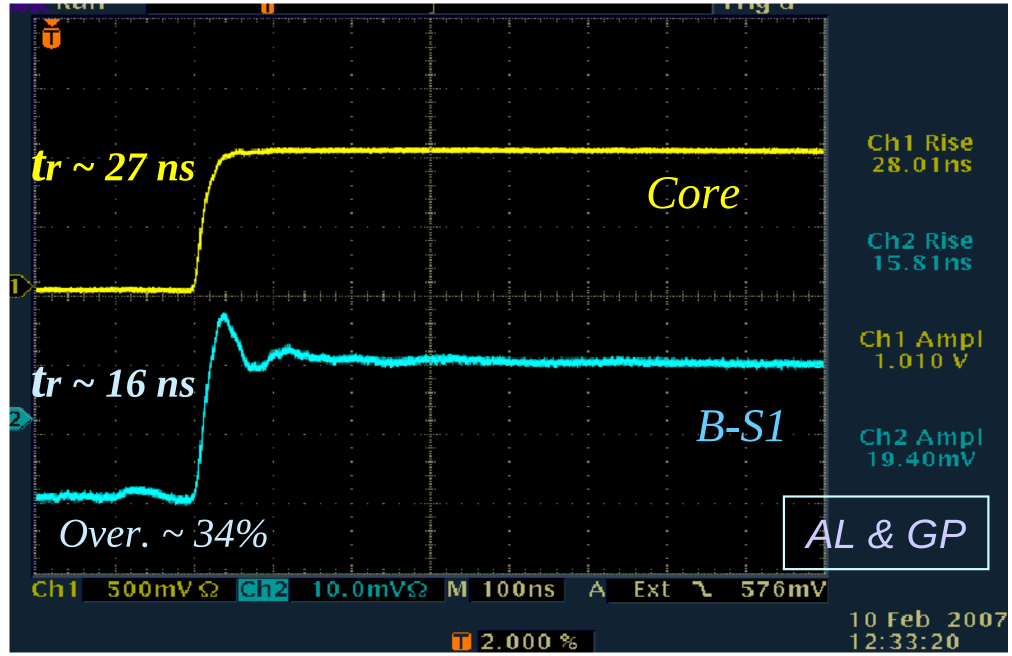






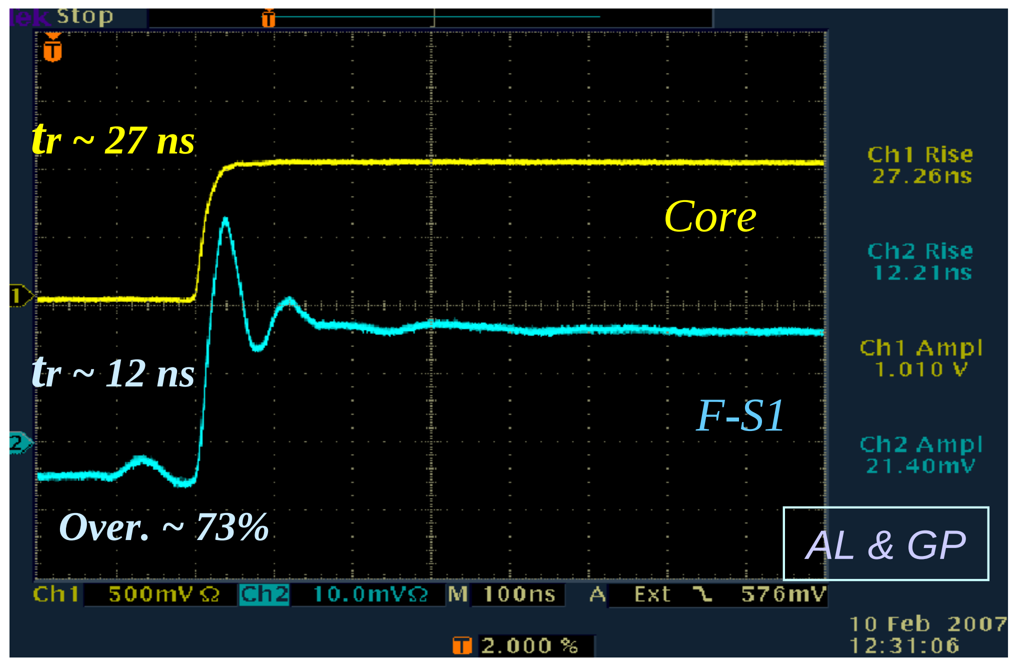
TC_Cold with Faster Core (Core warm ~ 32 ns, cold ~ 27.5ns)

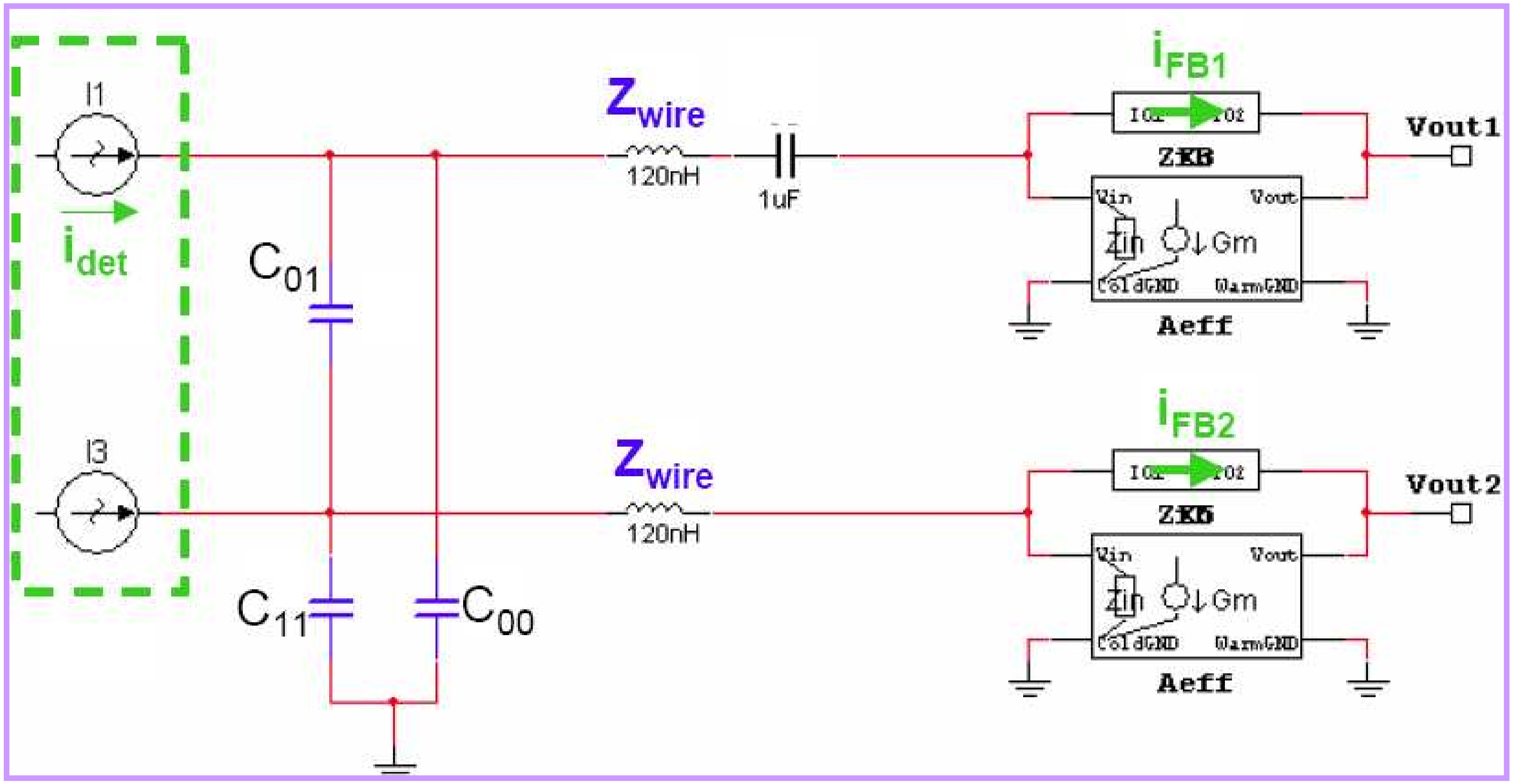




Note: - larger overshoot on segments (influence of the Core 1.stage + return GND core – segm.)

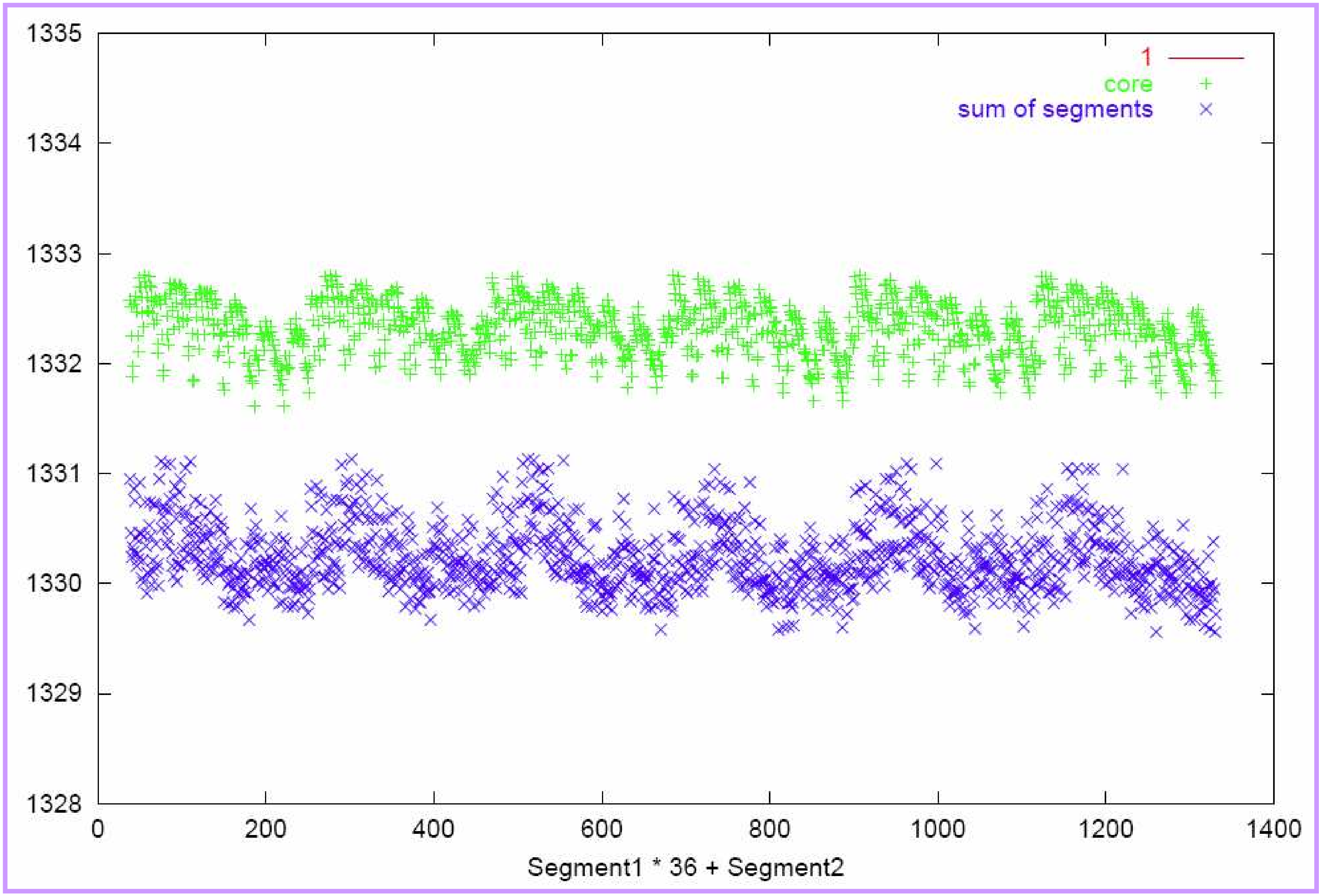
- tr core: - warm ~ 32 ns,
  - cold ~ 27.5ns
  (same Pulser)





$$i_i = i_i^{Ramo} - \sum_{j \neq i} C_{i,j} \frac{\partial V_j}{\partial t}$$

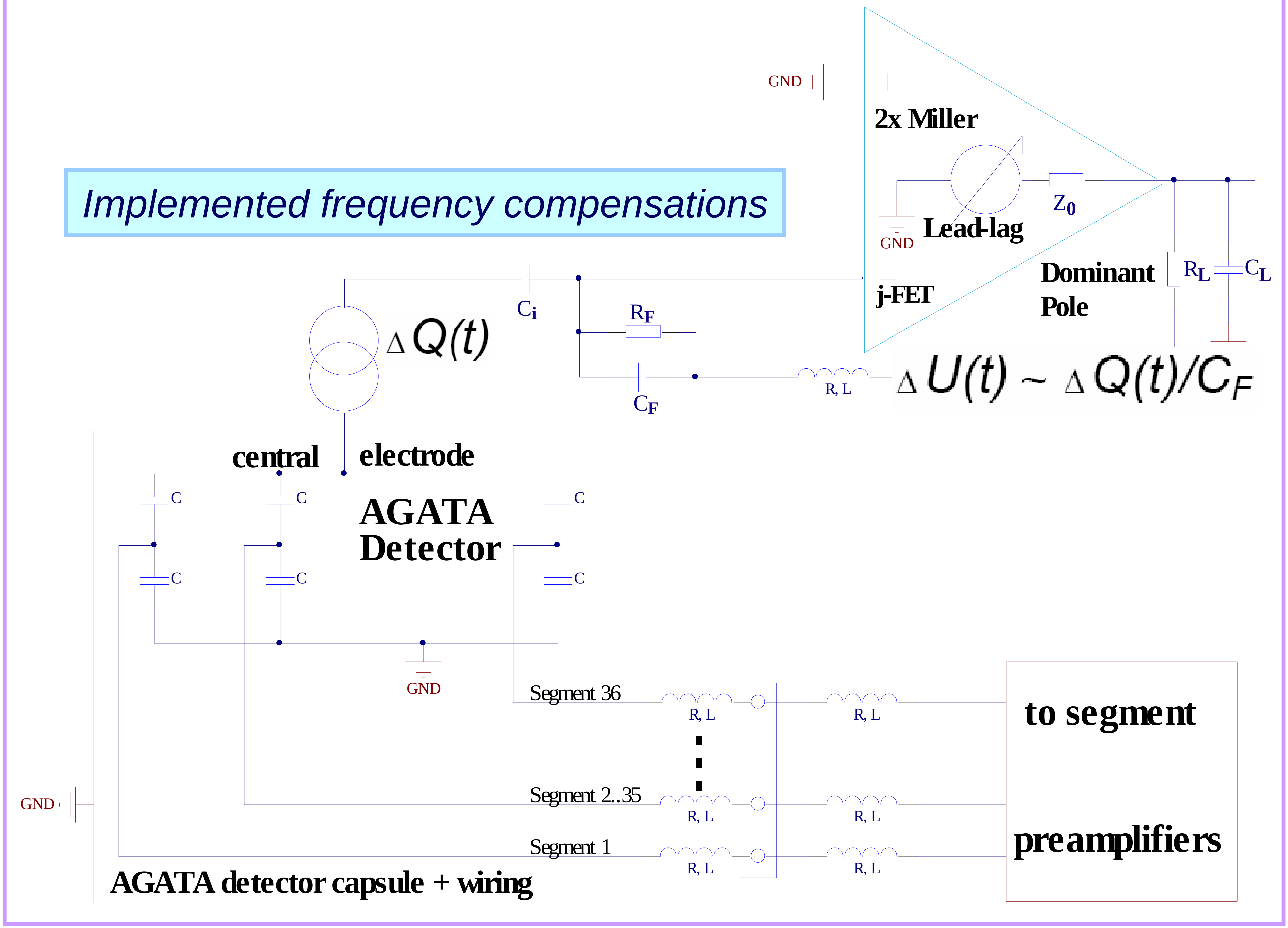
$$i_{Ramo} = \mathbf{Z}(f < 1\mathrm{Mhz})\, i_{FB} = \begin{pmatrix} 1+\Delta_{0,0} & \Delta_{0,1} \\ \Delta_{1,0} & 1+\Delta_{1,1} \end{pmatrix} i_{FB}$$



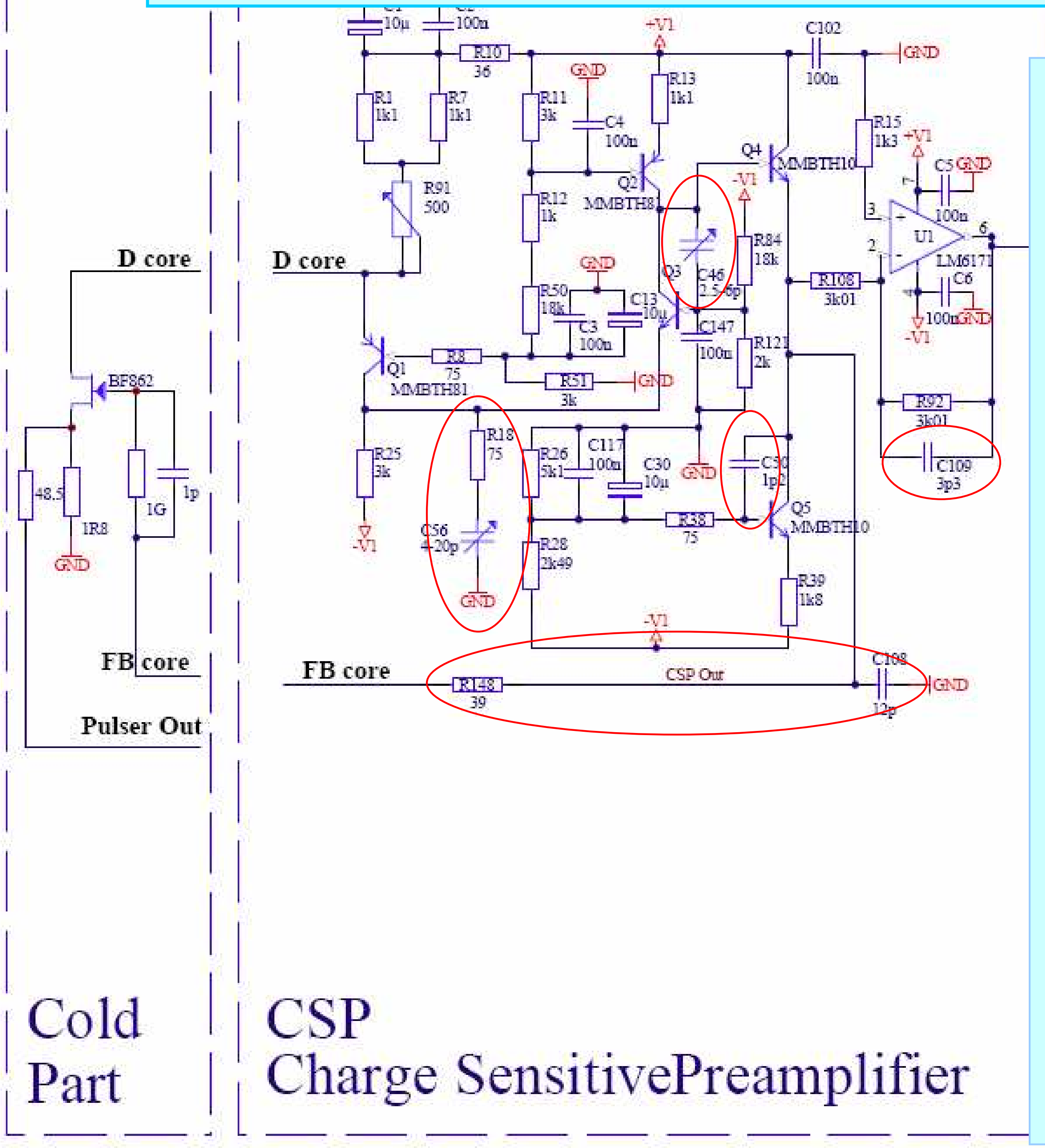
1335
1334
1333
1332
1331
1330
1329
1328
0
200
400
600
800
1000
1200
1400
Segment1 * 36 + Segment2
1
core
sum of segments

AGATA Core CSP

Implemented frequency compensations

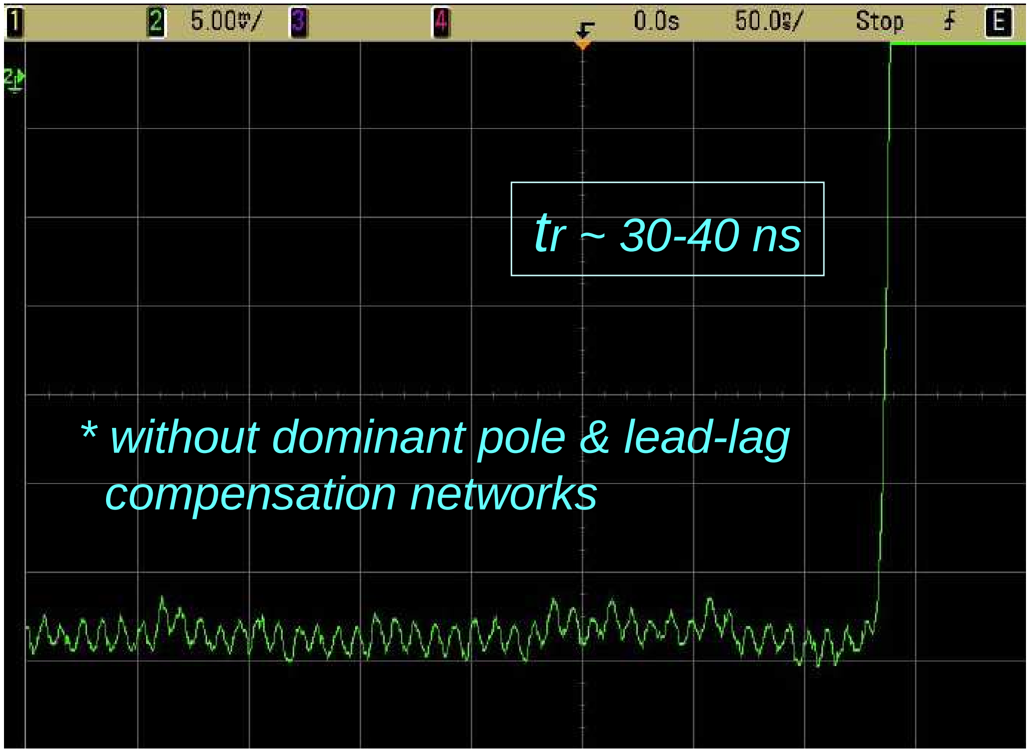


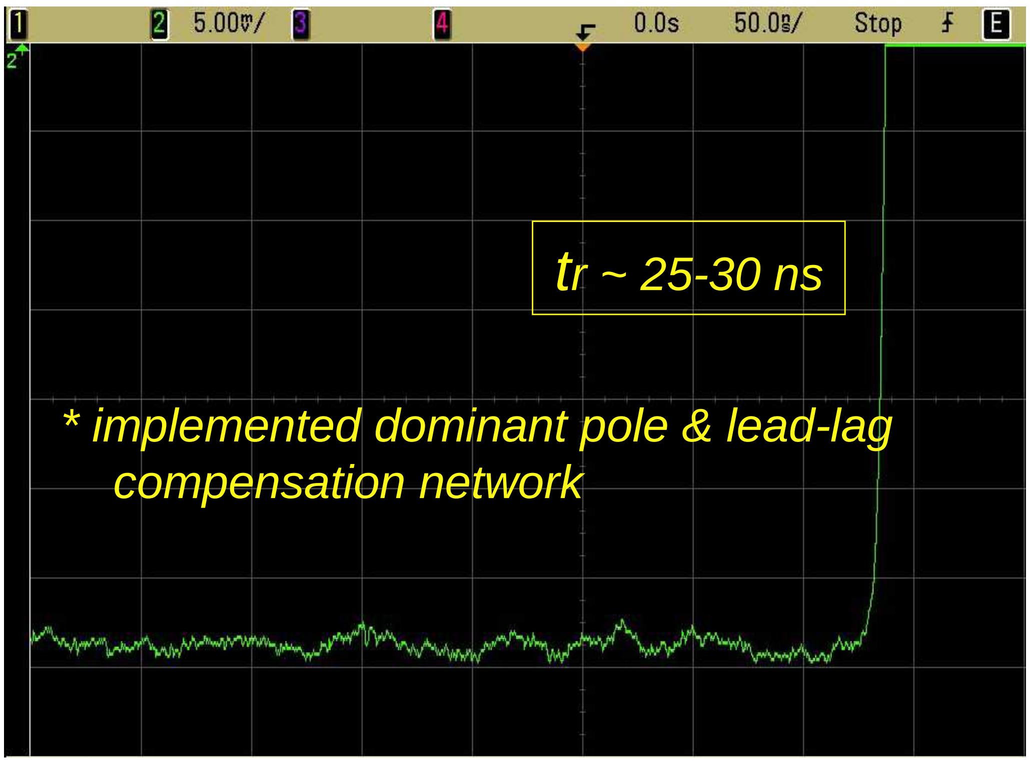
AGATA Core Preamplifier - Charge Sensitive Part



AGATA LVDS-Dual Core Preamplifier (Final design) with up-graded frequency compensations:

- Large Open loop-gain (~ 100,000)
- Fast Rise Time tr ~ 15 ns @ 45 pF
- Large dynamic range ~ 180 MeV
- Multiple frequency compensations:
  - minimum Miller effect
  - lead compensation
  - lead-lag compensation
  - dominant pole compensation





AGATA Single and Dual Core frequency compensations

Multiple frequency compensations:

- *minimum Miller effect*
- *lead compensation*
- *lead-lag compensation*
- *dominant pole compensation*

Comments:

- Stability criteria not only oscillations, rather it is circuit performance as exhibited by peaking and ringing

-the method of compensation depends on the equivalent op amp type and feedback, source and load networks

Dual Core in ‘GP - Cryostat’ (cold)

Dual Core** in **‘GP - Cryostat’ (cold)

- ***cryostat equipped with AGATA cold parts and wiring (only 1.8 Ohm, no 48.5 Ohm!)***

***Equivalent resolutions** (if cold Cf ~1pF)*

- *Ch1 ~ **1.15 keV** @ ~ 150 keV*

  *Ch2 ~ **1.31 keV** @ ~ 150 keV*

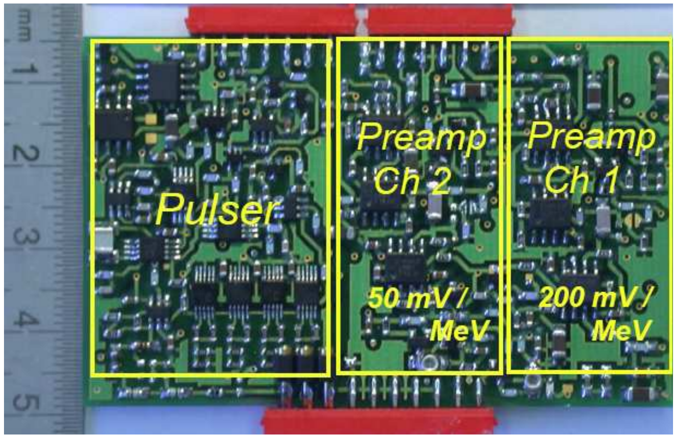
  (6 µs shaping time Ortec 671 & IKP-MCA)
- ***rise time ~ 26 -29 ns (+/- 2ns ⬄ 10mV-1V)***
- ***no overshoots & undershoots***
- ***NB: flat top of ~ 500 ns (PSA ⬄ peaking)***

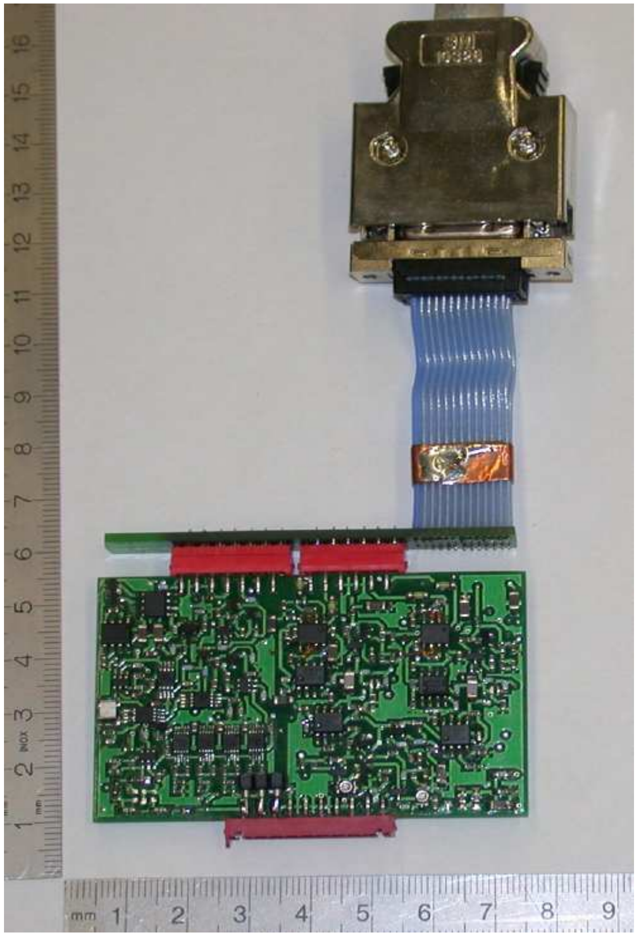
Outlook

- ***A very low noise, very wide dynamic range charge-sensitive pre-amplifier has been developed and tested to be used with a highly segmented and encapsulated HP-Ge AGATA Detector***
- ***Furthermore its wide spectroscopic range has been successfully extended by more than one order of magnitude, by switching (below the maximum of the ADC range) from the standard amplitude spectroscopic method to the new TOT technique***

(two modes of operations ⇔ four sub-ranges)

- ***A very clean transfer function at very high counting rates and adverse cryostat wiring (…useful set of Dummy - "detectors")***
- ***An accurate Programmable Spectroscopic Pulser has been developed and implemented in the AGATA front-end electronics***





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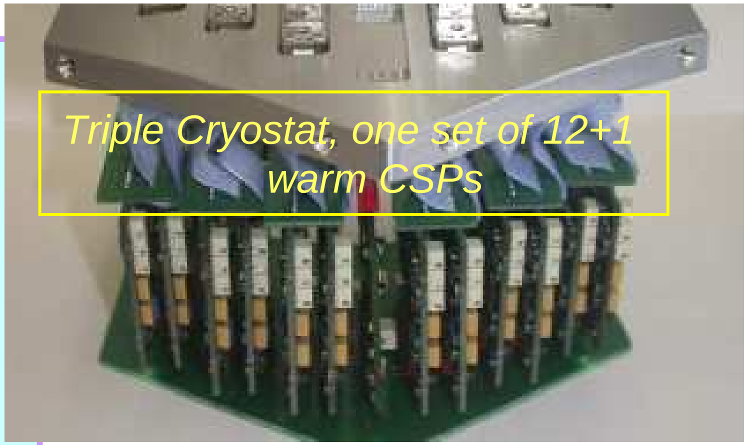

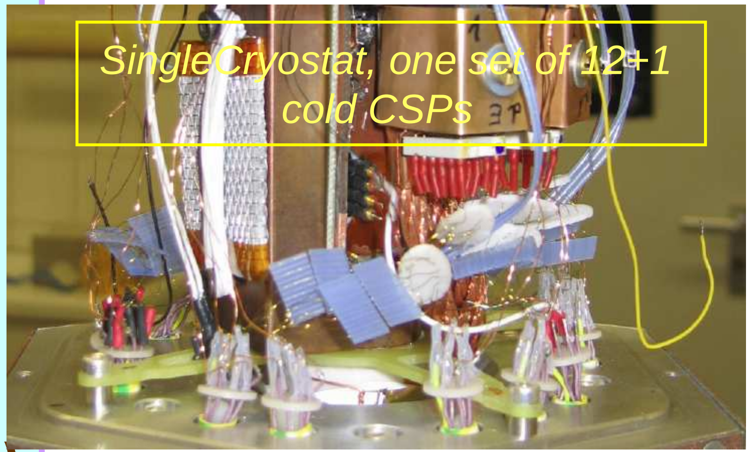

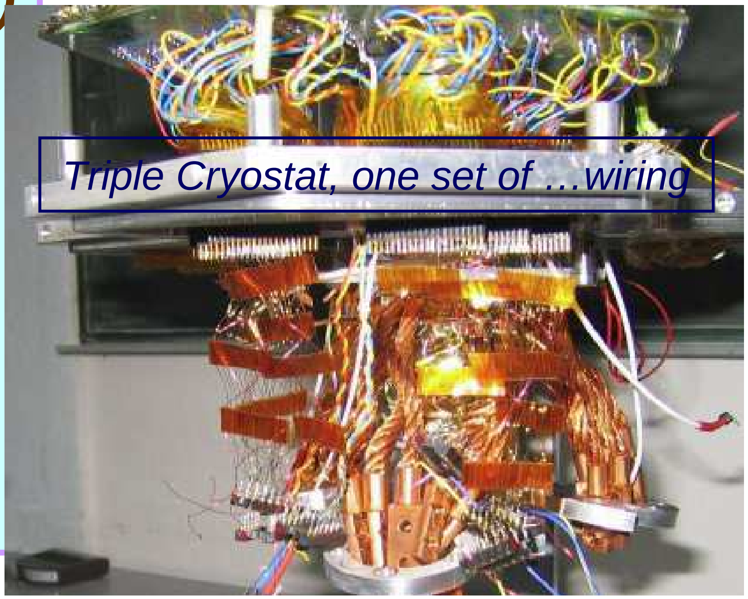

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