Front End Electronics (FEE) solutions for large arrays of segmented detectors

- *FEE for large array with segmented HP-Ge detectors*
- *Specific case: AGATA FEE*
- *FEE for other segmented detectors (DSSSD, SC etc.)*

Symposium on: "Application of Germanium Detector in fundamental research"
Beijing, P.R. China, 23.- 29. March 2011

G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

a) First arrays with segmented HPGe Detectors

(Miniball; Sega-NSCL; Tigress; Rising etc.

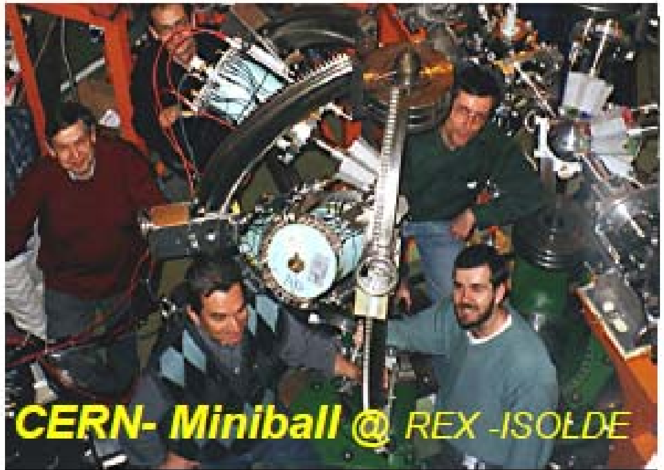
*- even **GERDA** det. characterization phase)*

b) AGATA - FEE

- ***Dual Gain CSP** - **for the central contact***
- ***ToT method** (combined dynamic range ⬄ ~100 dB)*
- ***Programmable Spectroscopic Pulser***

****c) DSSSD arrays of detector** (LUSIA, LYCCA, SC-matrix)*

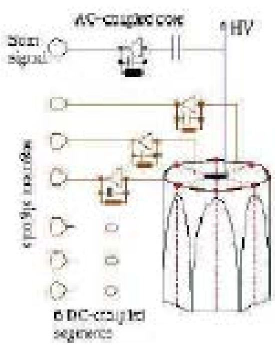
MINIBALL
Spectroscopy
with
radioactive
beams

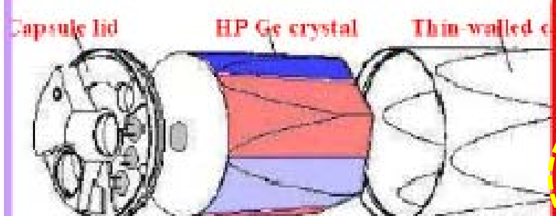


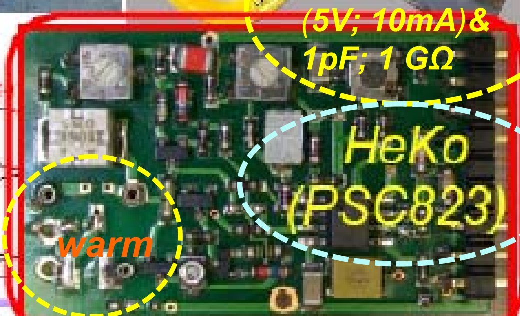
The 6-fold segmented, encapsulated Miniball detector

t_r ~ 30-40 ns Ch.1 @ 800 mV

- no over & under_shoot





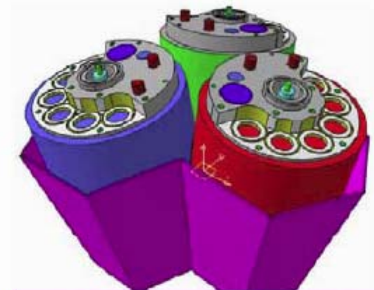


G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

1. ***Charge Sensitive Preamplifier***
   (Low Noise, Fast; Single & Dual Gain; ~ 100 dB extended range with ToT)

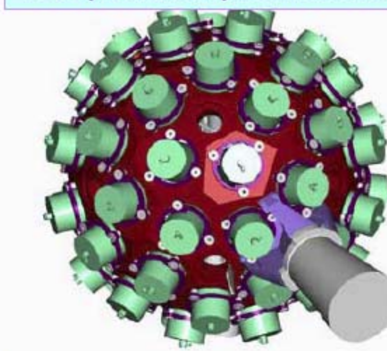
2. ***Programmable Spectroscopic Pulser*** *(as a tool for self-calibrating)*

AGATA 36_fold segmented, encapsulated HP-Ge Detector

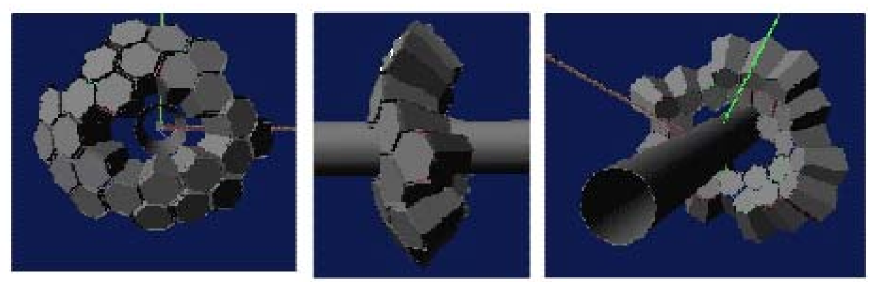


AGATA Triple Cryostat 111 spectroscopic channels

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



AGATA, the first complete 4pi gamma-ray spectrometer



8 Clusters (Hole 11.5cm, beam line 11cm)

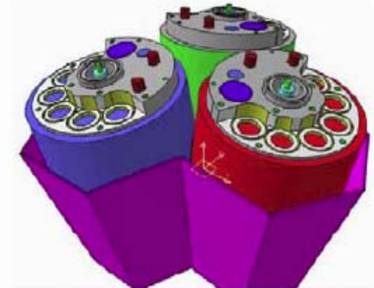
G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

1. Charge Sensitive Preamplifier
(Low Noise, Fast, Single & Dual Gain
~ 100 dB extended range with ToT)

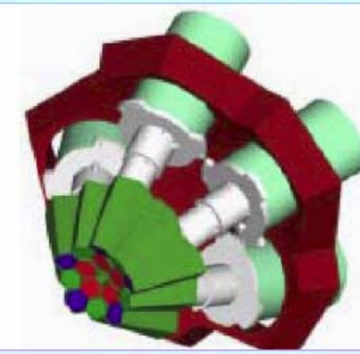
2. Programmable Spectroscopic Pulser
(as a tool for self-calibrating)

3. Updated frequency compensations to reduce the crosstalk between participants (**- from adverse cryostat wiring and up to - electronic crosstalk in the transm. line**)

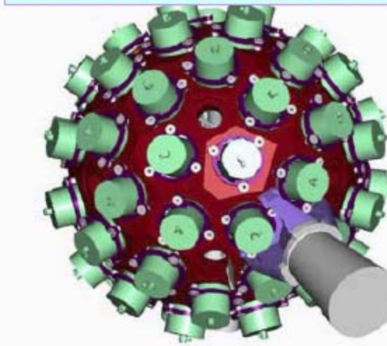
AGATA 36_fold segmented, encapsulated HP-Ge Detector



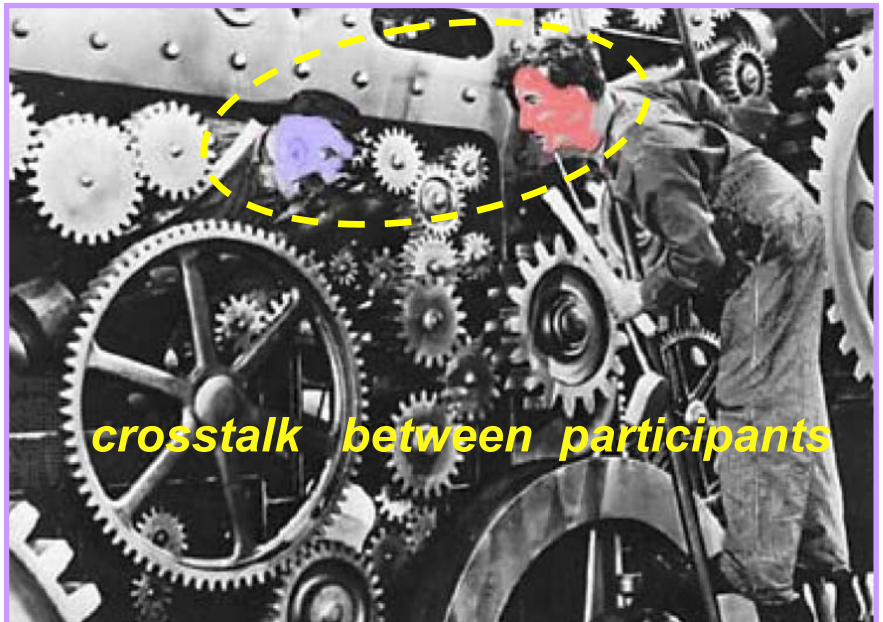
AGATA Triple Cryostat 111 spectroscopic channels

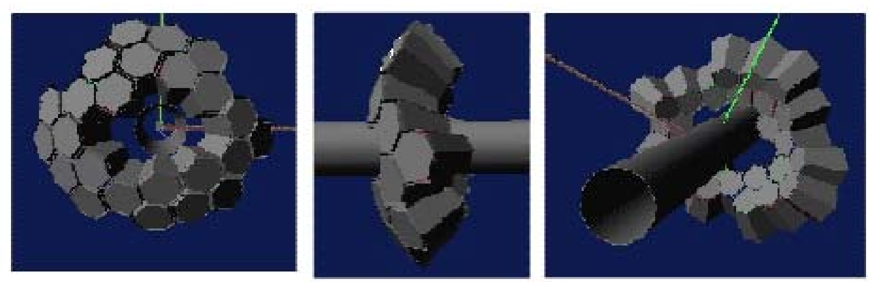


AGATA Demonstrator [5 x TC] (555 spectroscopic channels)



AGATA, the first complete 4pi gamma-ray spectrometer

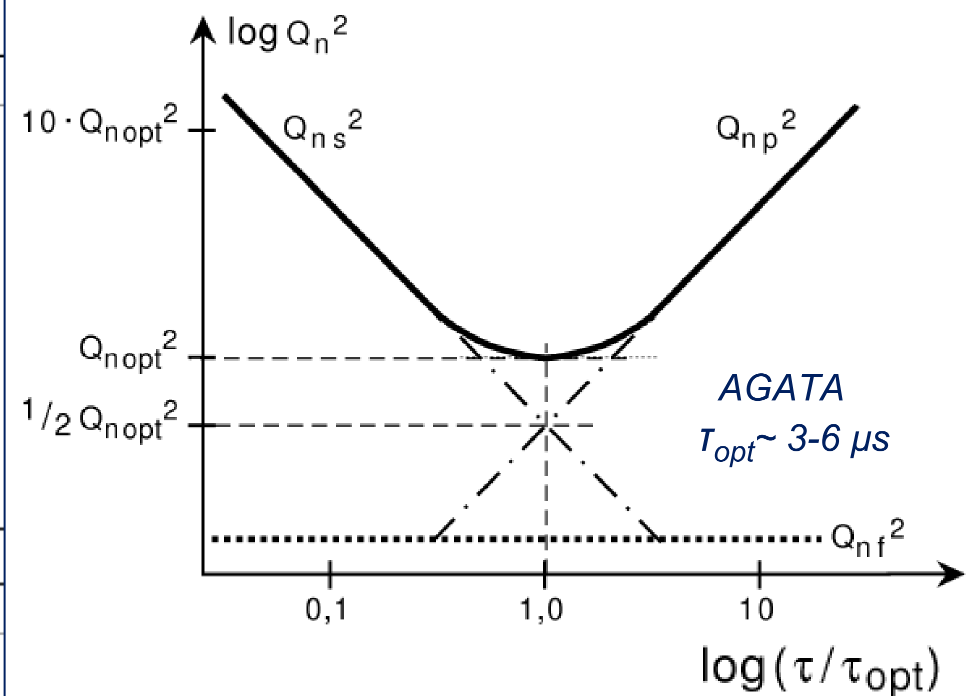




8 Clusters (Hole 11.5cm, beam line 11cm)

G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

SOURCE	PARALLEL NOISE A^2/Hz	SERIES NOISE V^2/Hz
	white	white
Detector	$q M^2 I_{db}(1+v_M)$	
Bias resistor	$2kT/R_b$	
Feedback resistor	$2kT/R_f$	
J-FET:		
gate current	$q I_G$	
channel thermal noise		$\frac{2kT}{g_m} \cdot \frac{2}{3}$
induced gate noise		$\frac{2kT}{g_m} \cdot \frac{1}{4}\left(C_{GS}/C_t\right)^2$
SUB-TOTAL	b	a
	violet	pink
J-FET		$c/\lvert\omega\rvert$
Dielectrics	$d \cdot \lvert\omega\rvert$	
TOTAL	$i_{np}^2 = b + d\lvert\omega\rvert \approx b$	$v_{ns}^2 = a + \frac{c}{\lvert\omega\rvert}$



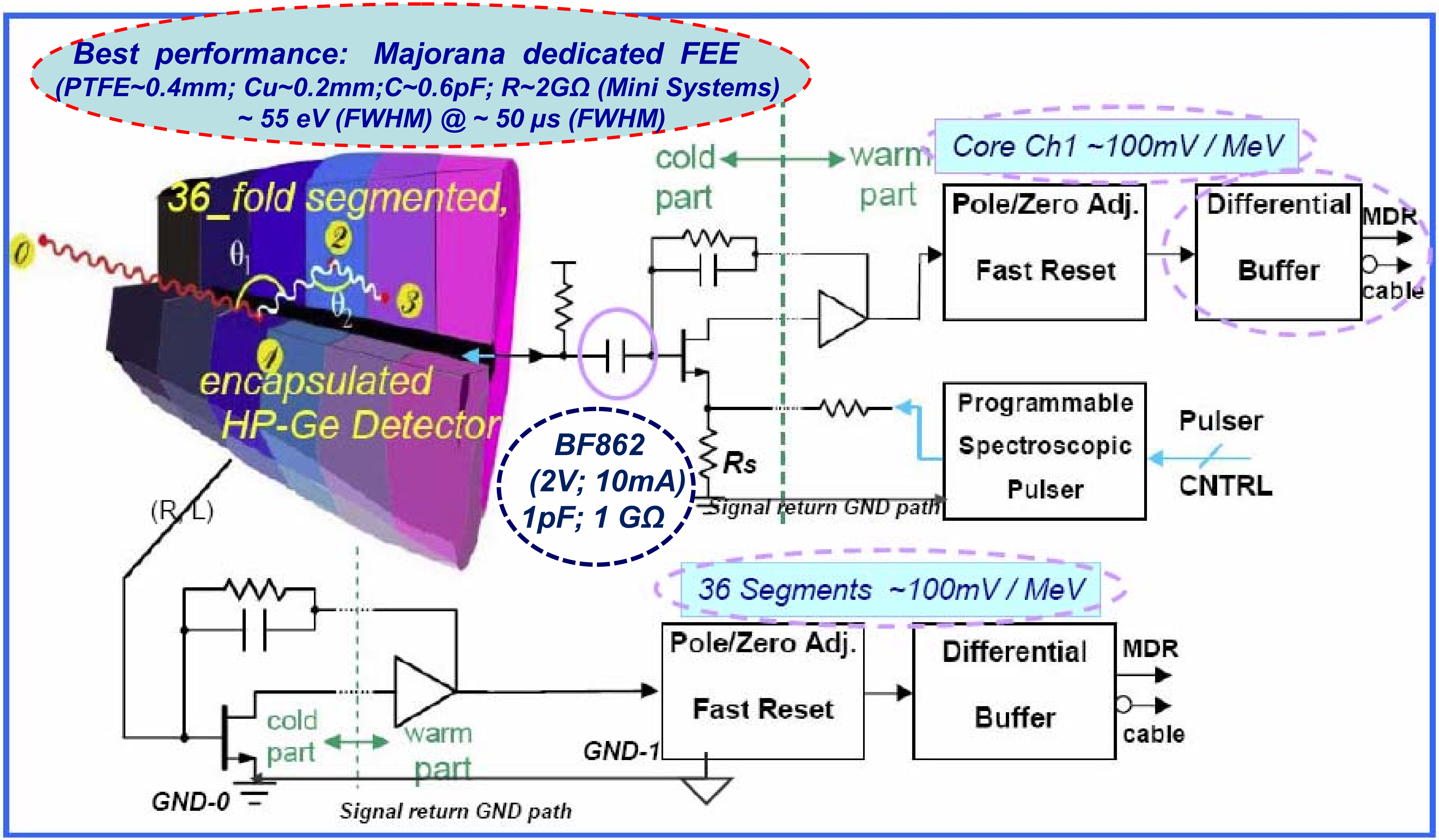
J.-F. Loude, IPHE 2000-22

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

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

- ***the equivalent noise charges Q_n assumes a minimum when the current and voltage contributions are equal***
- ***current noise ~ (RC)***
- ***voltage noise ~ 1/(RC)***
  ~ C_d^2
- ***1 / f noise ~ C_d^2***

Block diagram of the AGATA front end-electronic



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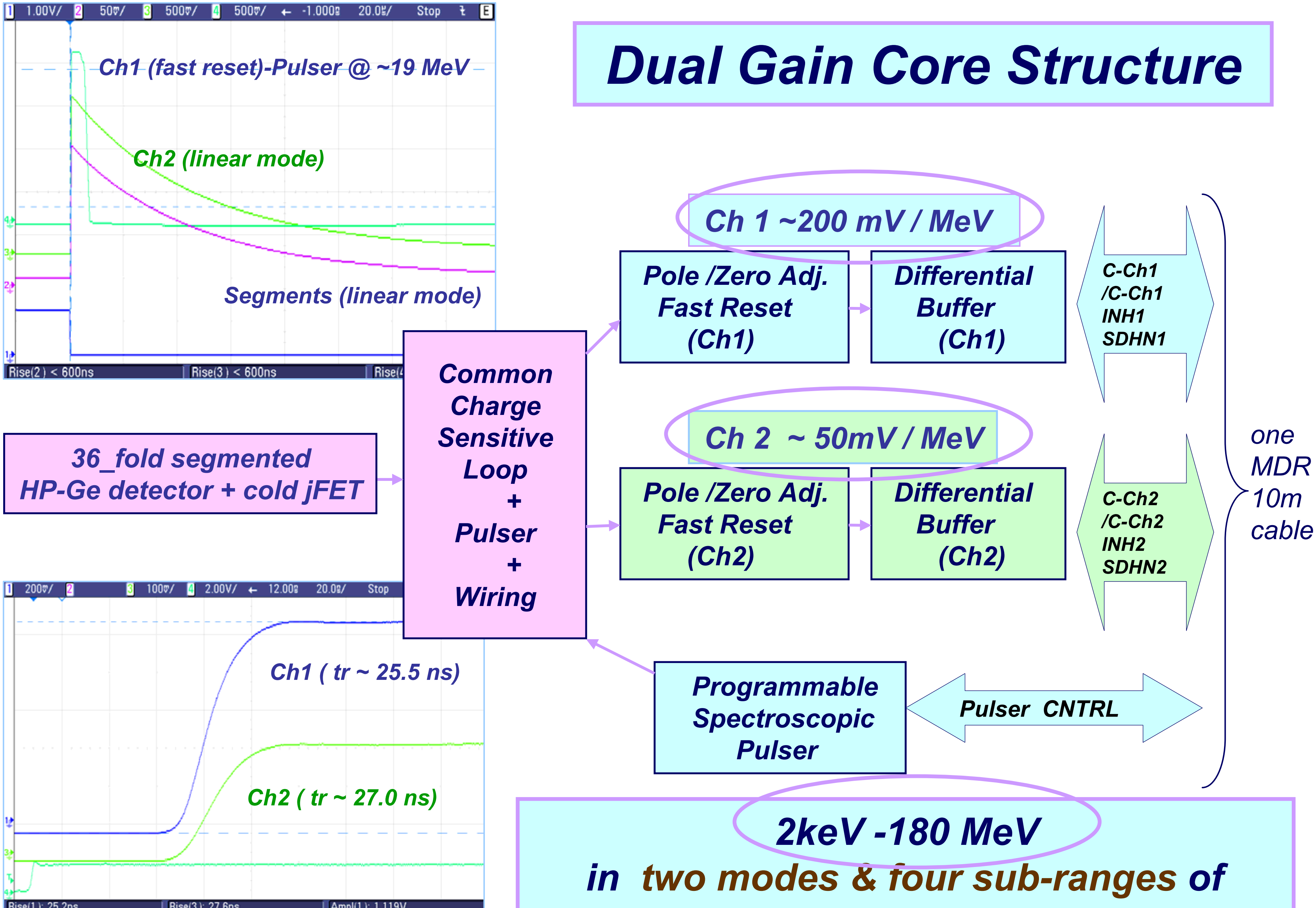
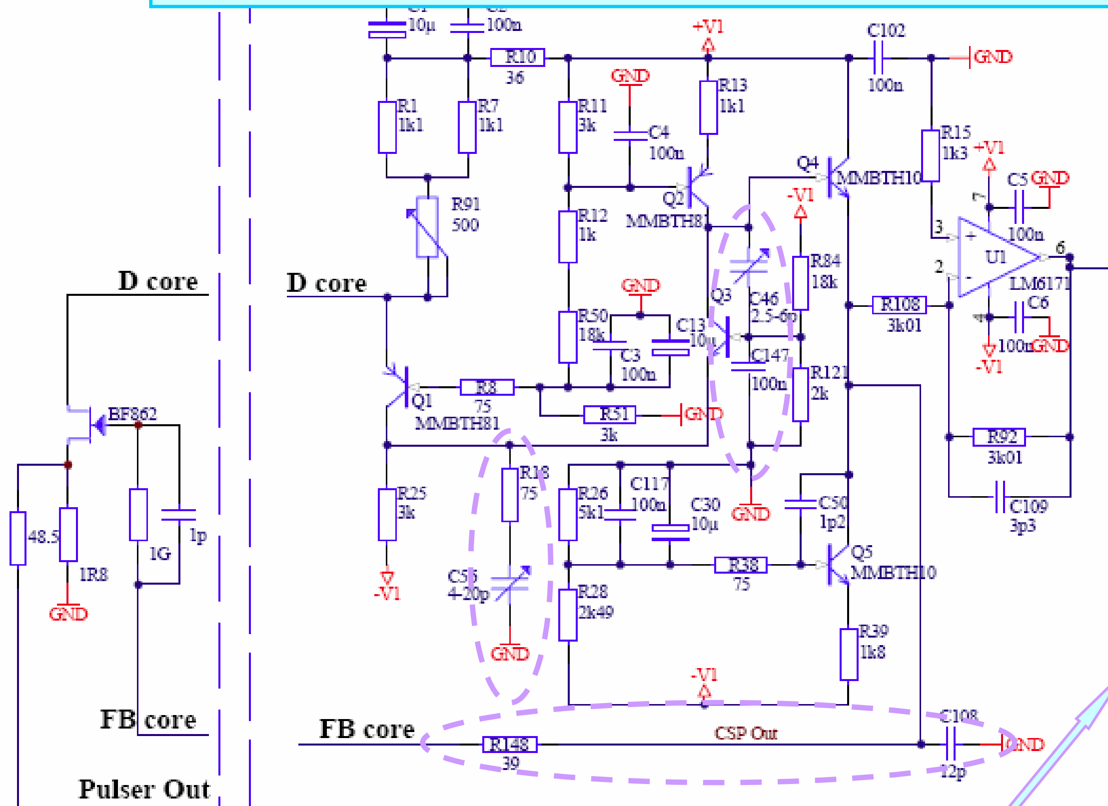
Dual Gain Core Structure



2keV -180 MeV

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

AGATA Core Preamplifier - Charge Sensitive Part



- *large dynamic range in the first CSP*
- *large open loop gain*
- *frequency compensations for optimum transfer function*

Cold Part

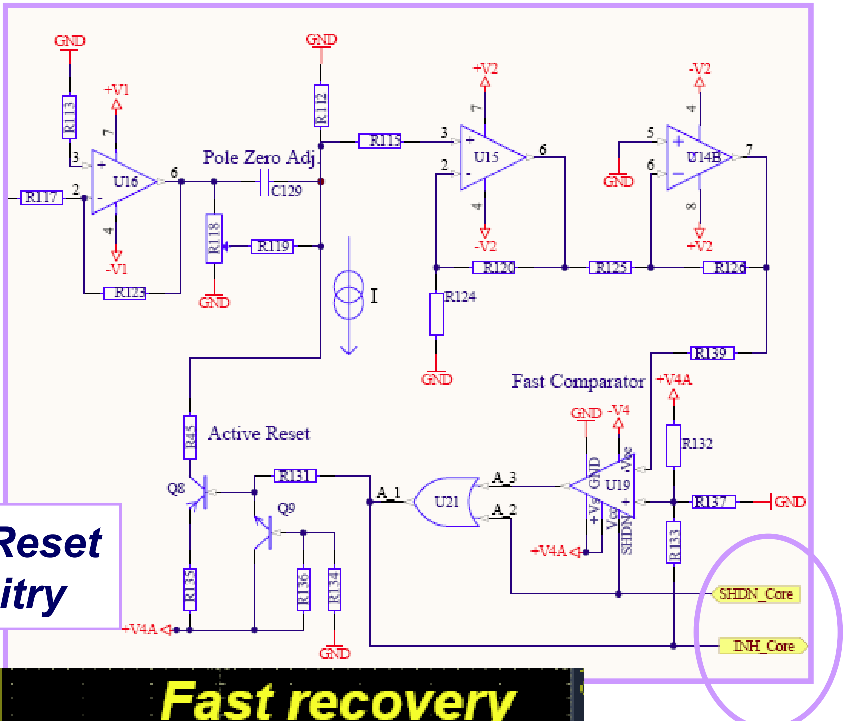
CSP
Charge SensitivePreamplifier

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

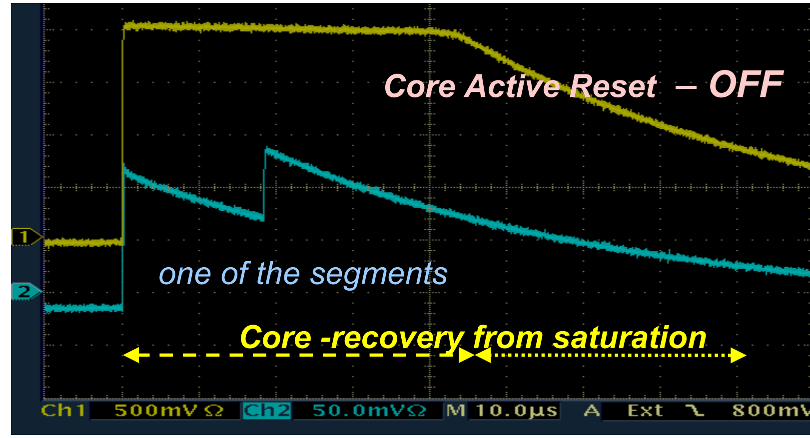
- ***Large Open loop-gain*** *(~ 100,000)*
- ***Fast Rise Time*** *tr ~ 15 ns @ 45 pF*
- ***Large dynamic range*** *~ 180 MeV @ Cf~1pF*
- ***Multiple frequency compensations:***
  - *- minimum Miller effect*
  - *- lead compensation*
  - *- lead-lag compensation*
  - *- dominant pole compensation*

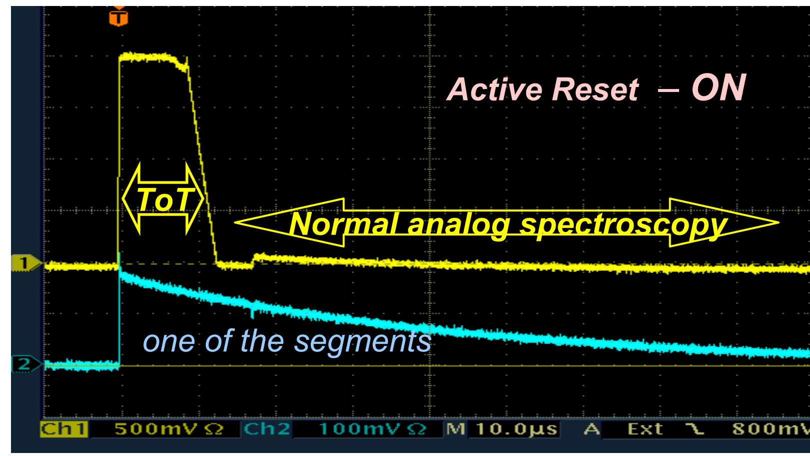
G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

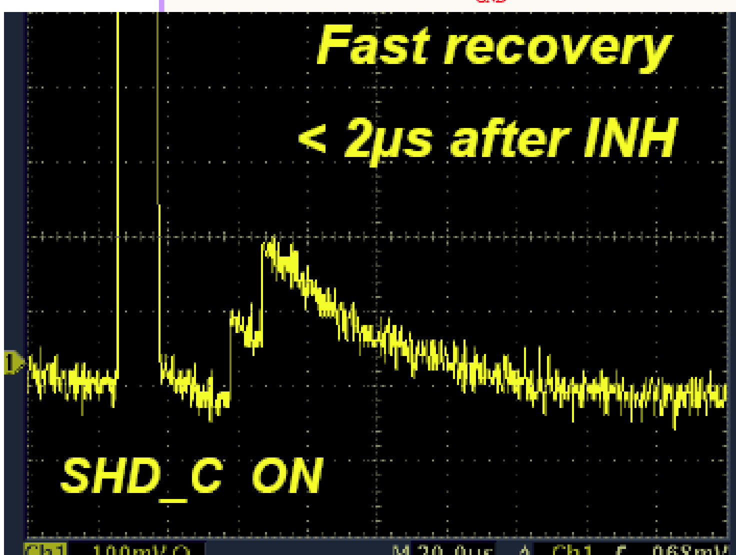
Fast Reset as tool to implement the “TOT” method



Fast Reset circuitry

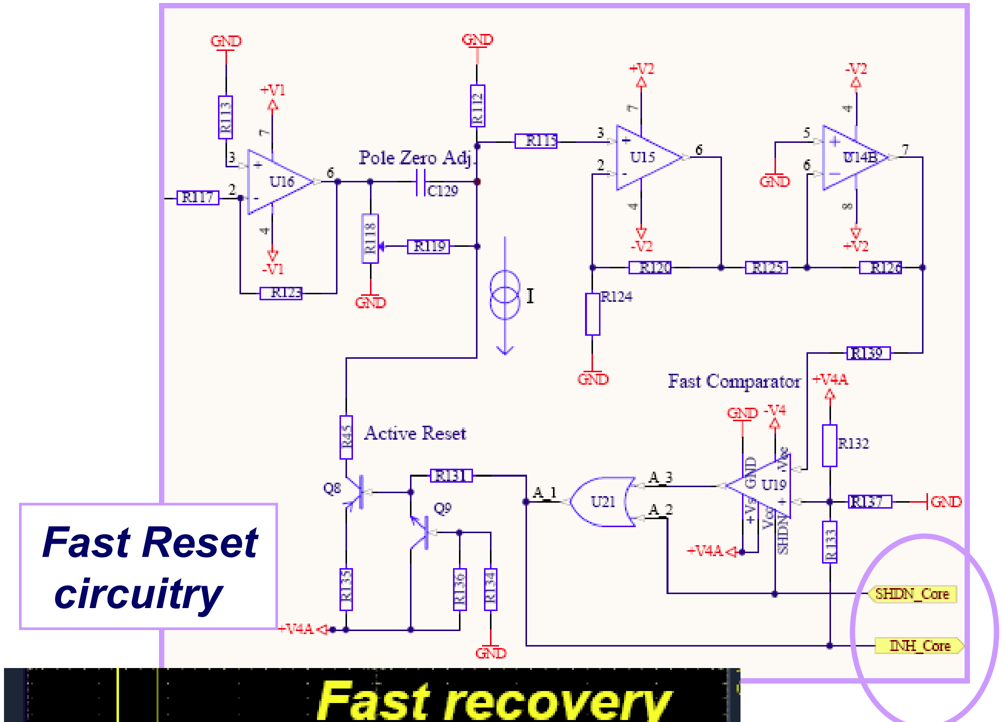


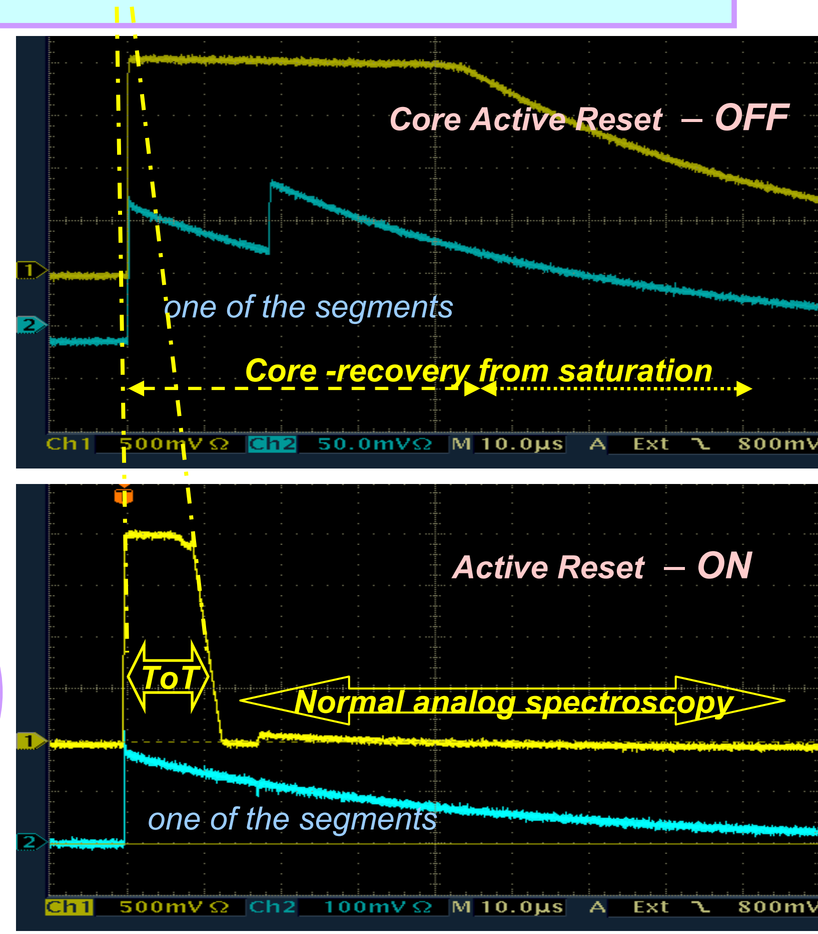


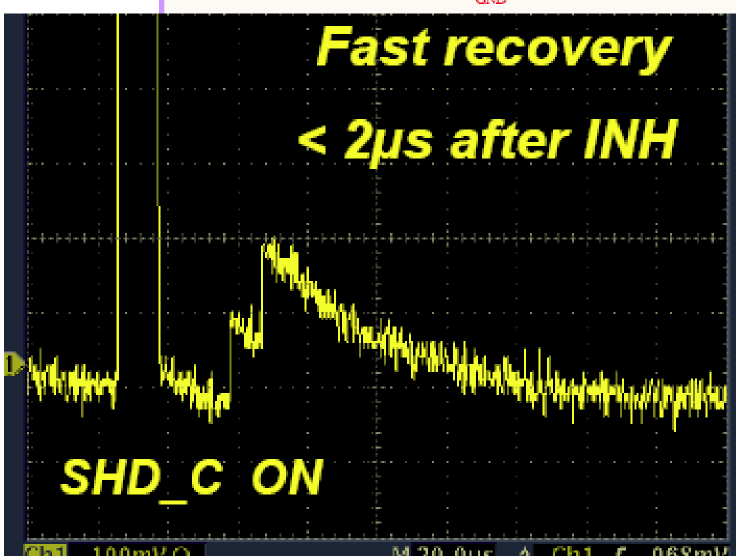


- *very fast recovery from TOT mode of operation*
- *fast comparator LT1719 (+/- 6V)*
- *factory adj. threshold + zero crossing*
- *LV-CMOS (opt)*
- *LVDS by default*

Fast Reset as tool to implement the "TOT" method



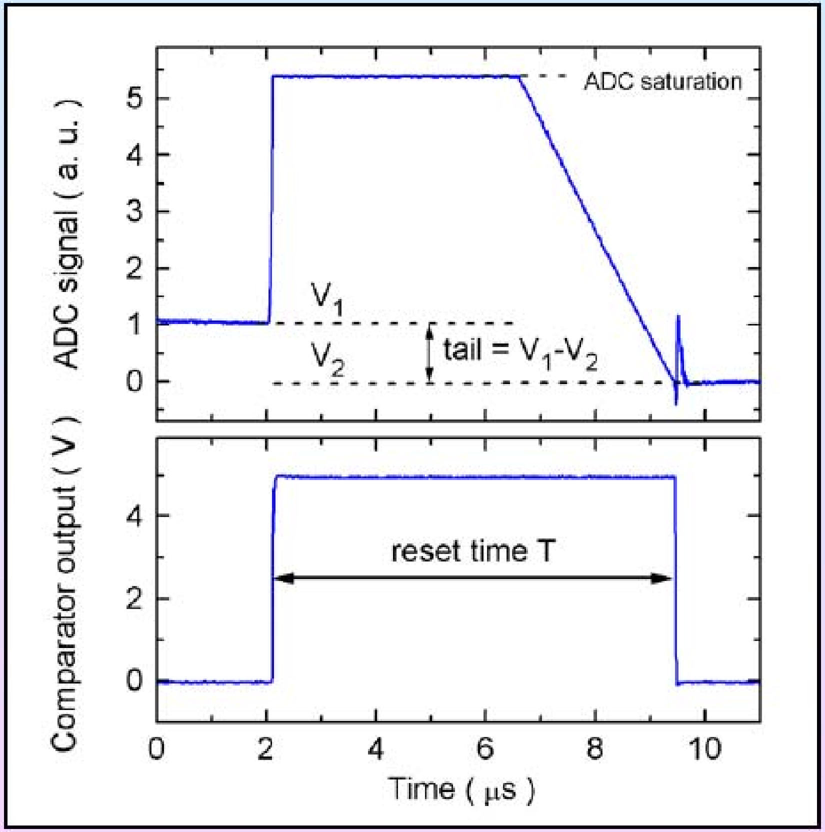




- very fast recovery from TOT mode of operation
- fast comparator LT1719 (+/- 6V)
- factory adj. threshold + zero crossing
- LV-CMOS (opt)
- LVDS by default

G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

Time-Over-Threshold (TOT) technique



second-order time-energy relation

offset term

$$E = b_1 T + b_2 T^2 - k_1 (V_1 - V_2) + E_O$$

contribution of the tail due to previous events

***E* = energy of the large signal**

***T* = reset time**

V_1, V_2 = *pre-pulse and post-pulse baselines*

b_1, b_2, k_1, E_0 = *fitting parameters*

Francesca Zocca, INFN, Milan

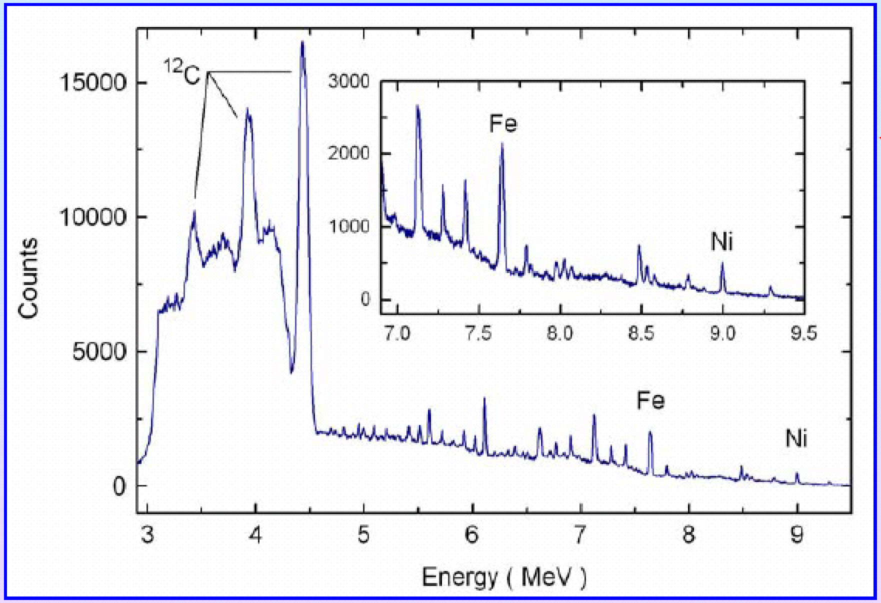
see Francesca Zocca et al, INFN, Milan

Within ADC range → standard "pulse-height mode" spectroscopy

Beyond ADC range → new "reset mode" spectroscopy

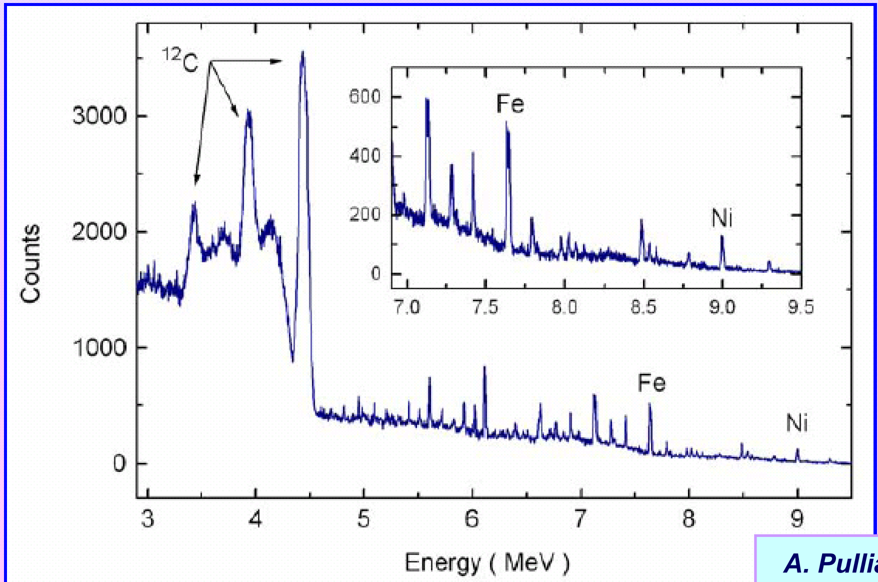
G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

Comparison between "reset" mode (ToT) vs. "pulse-height" mode (ADC)



"reset" mode
(by TOT technique)

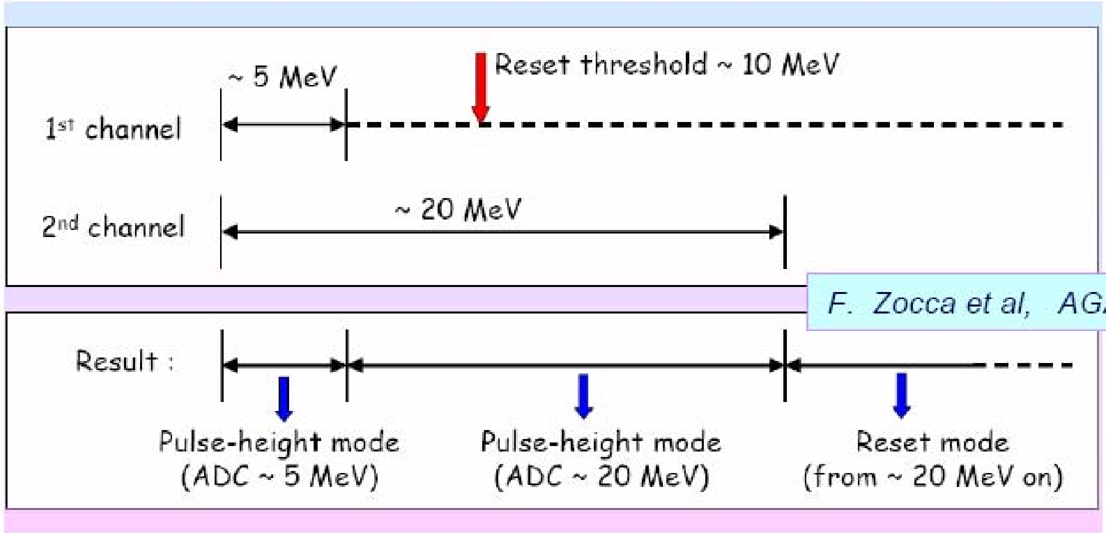
Energy	Resolution (fwhm) in pulse-height mode		Resolution (fwhm) in reset mode	
4.440 MeV (^{12}C)	104 keV	2.34 %	104 keV	2.34 %
~5.6 MeV	10.5 keV	0.14 %	18.8 keV	0.34 %
~6.1 MeV	15.1 keV	0.17 %	17.1 keV	0.28 %
7.6312 MeV (Fe)	11 keV	0.14 %	18.8 keV (29.4 keV for the double-peak)	0.25 % (0.38 % for the double-peak)
7.6456 MeV (Fe)	11 keV	0.14 %		
8.9984 MeV (Ni)	15 keV	0.17 %	18.9 keV	0.21 %



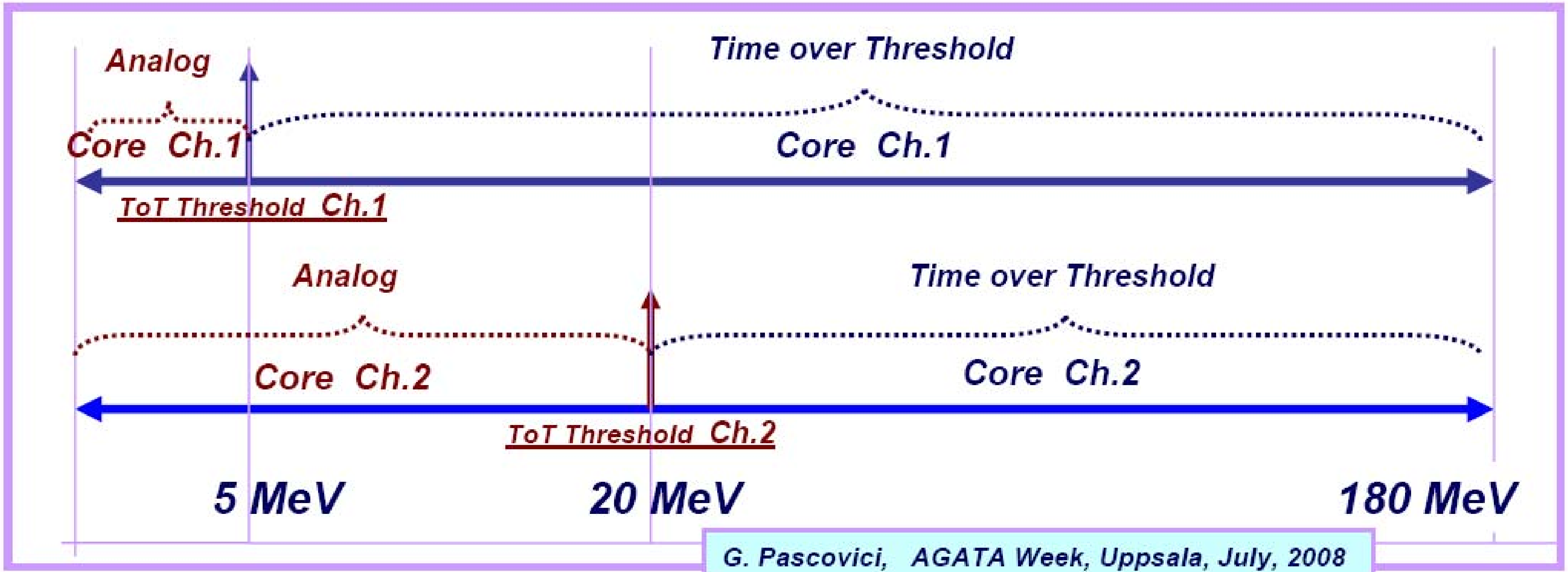
"pulse-height" mode
(by ADC)

A. Pullia at al, Extending the dynamic range of nuclear pulse spectrometers, Rev. Sci. Instr. 79, 036105 (2008)

AGATA-Dual Gain Core - Time over Threshold ranges



F. Zocca et al, AGATA Week, Padova, 2007



G. Pascovici, AGATA Week, Uppsala, July, 2008

AGATA
Dual Gain 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	

- **Summary active reset:**
  - active reset @ 2nd stage
  - active reset @ 1st stage with advantages vs. disadv.

G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

Incorporated Programmable Spectroscopic Pulser

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

G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

The use of PSP 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)
• Pulse C/S amplitude ratio (Detector Bulk Capacities)	⇔	Crosstalk input data (Detector characterization)
• Pulse Form	⇔	TOT Method ⇔ (PSA)
• Repetition Rate (c.p.s.) (with periodical or statistical distribution)	⇔	Dead Time ⇔ (Efficiency)
• Time alignment	⇔	Correlated time spectra
• Segments calibration	⇔	Low energy calibration
• Detector characterization	⇔	Impurity concentration, passivation

G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

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**

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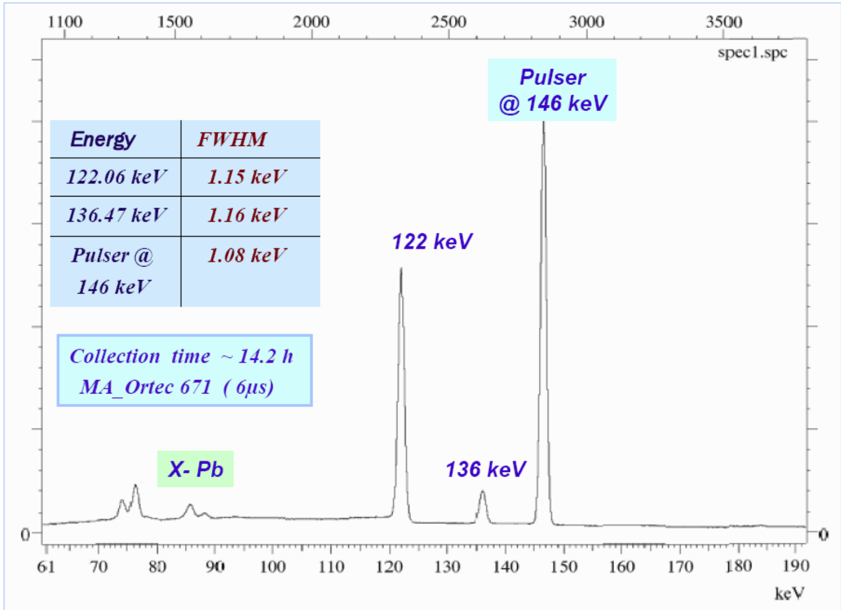
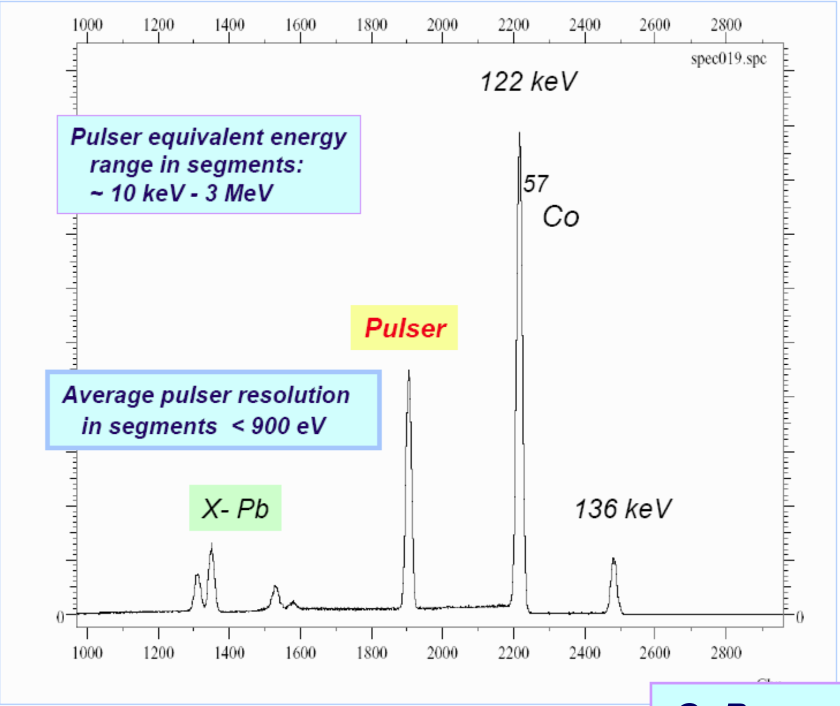
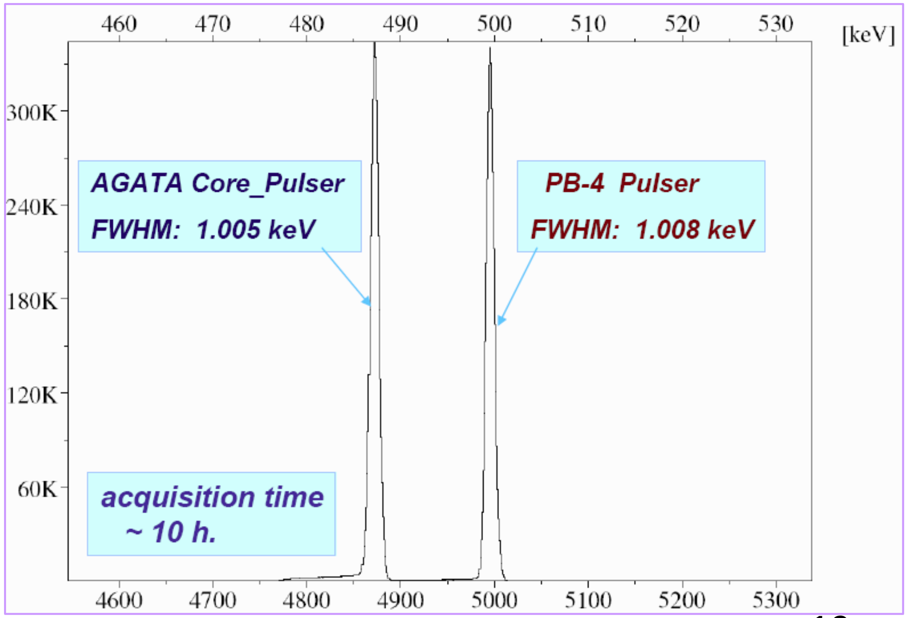


Energy	FWHM
122.06 keV	1.15 keV
136.47 keV	1.16 keV
Pulser @ 146 keV	1.08 keV

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



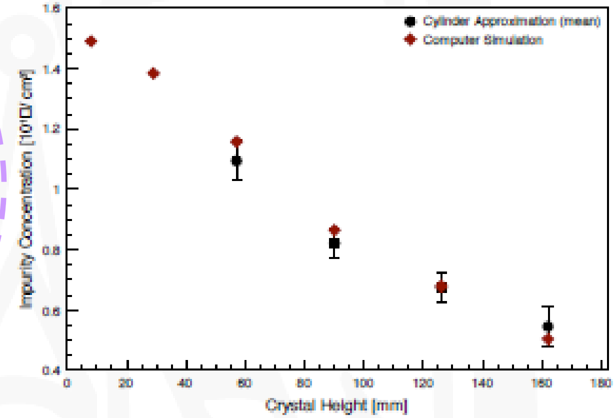


G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne

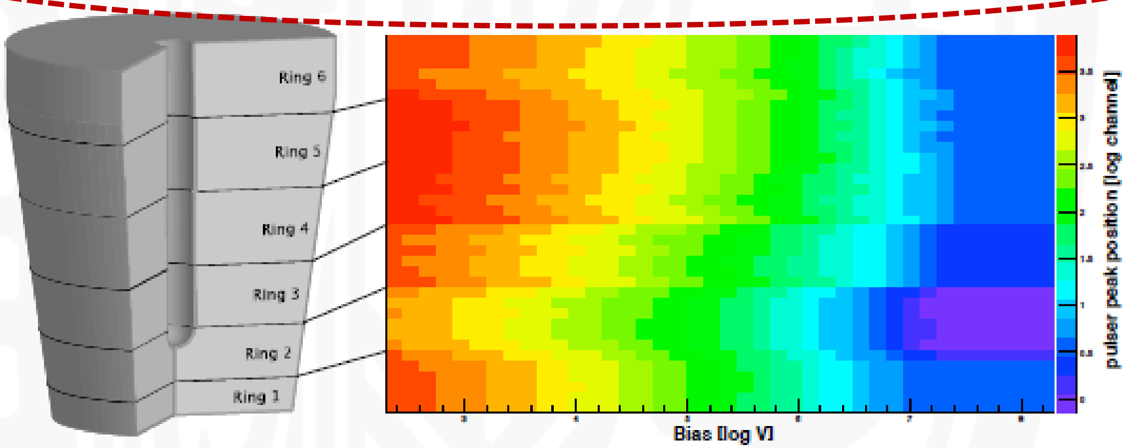
Impurity concentration of AGATA detectors

- New method to determine impurity concentration
- Based on capacitance voltage analysis
- Pulser of AGATA preamplifier used to measure capacitance of core and segments
- Fast reliable method
- Feasible with standard configuration
- Agreement with computer simulations in cylindrical segments
- Simulations needed for hexagonal part

Comparison of mean impurity concentration of AGATA detector S002



Pulser peak position for different voltages of detector C006

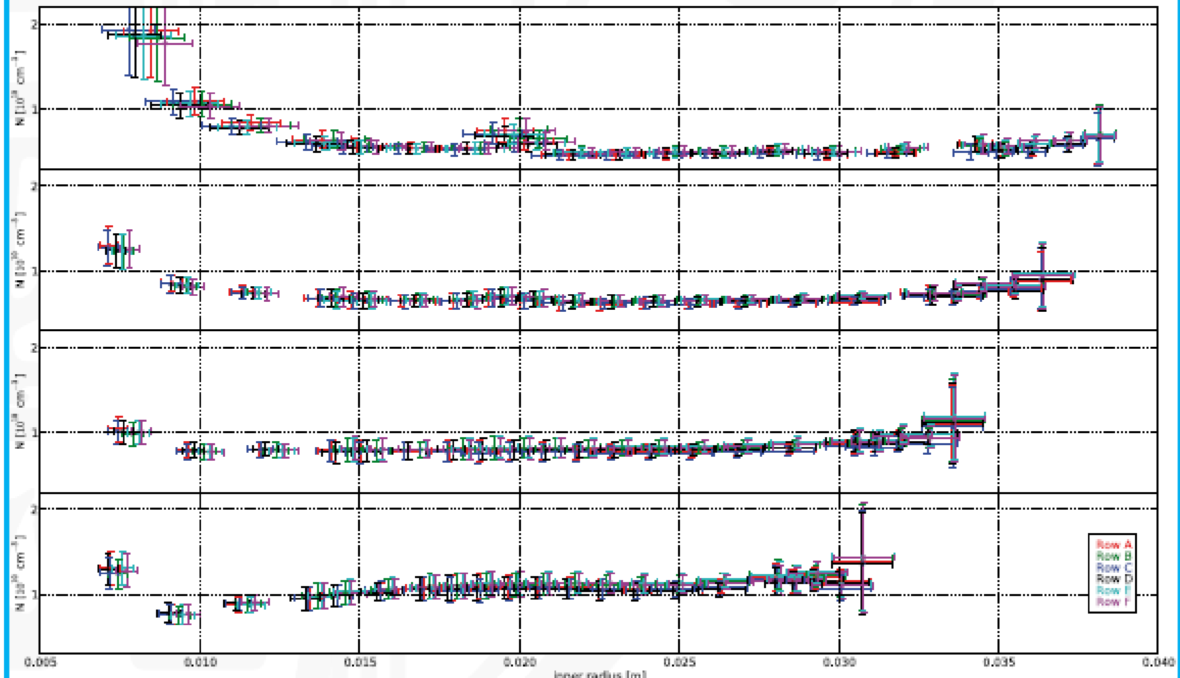


Characterisation of AGATA detectors

B. Birkenbach, B. Bruyneel, J. Eberth, H. Hess, D. Lersch, G. Pascovici, P. Reiter, A. Wiens

17th Euroschool on exotic beams 2010 - Santiago de Compostela, Spain

Impurity concentration of last four rings of AGATA detector S002 using a cylindrical approximation



Computer simulations using AGATA Detector Library [6]

Depletion boundary and core electrode

Characterisation of AGATA detectors

B. Birkenbach, B. Bruyneel, J. Eberth, H. Hess, D. Lersch, G. Pascovici, P. Reiter, A. Wiens

Transfer Function & X-talk

- ***Stand alone transfer function (bench tests)***
- ***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***

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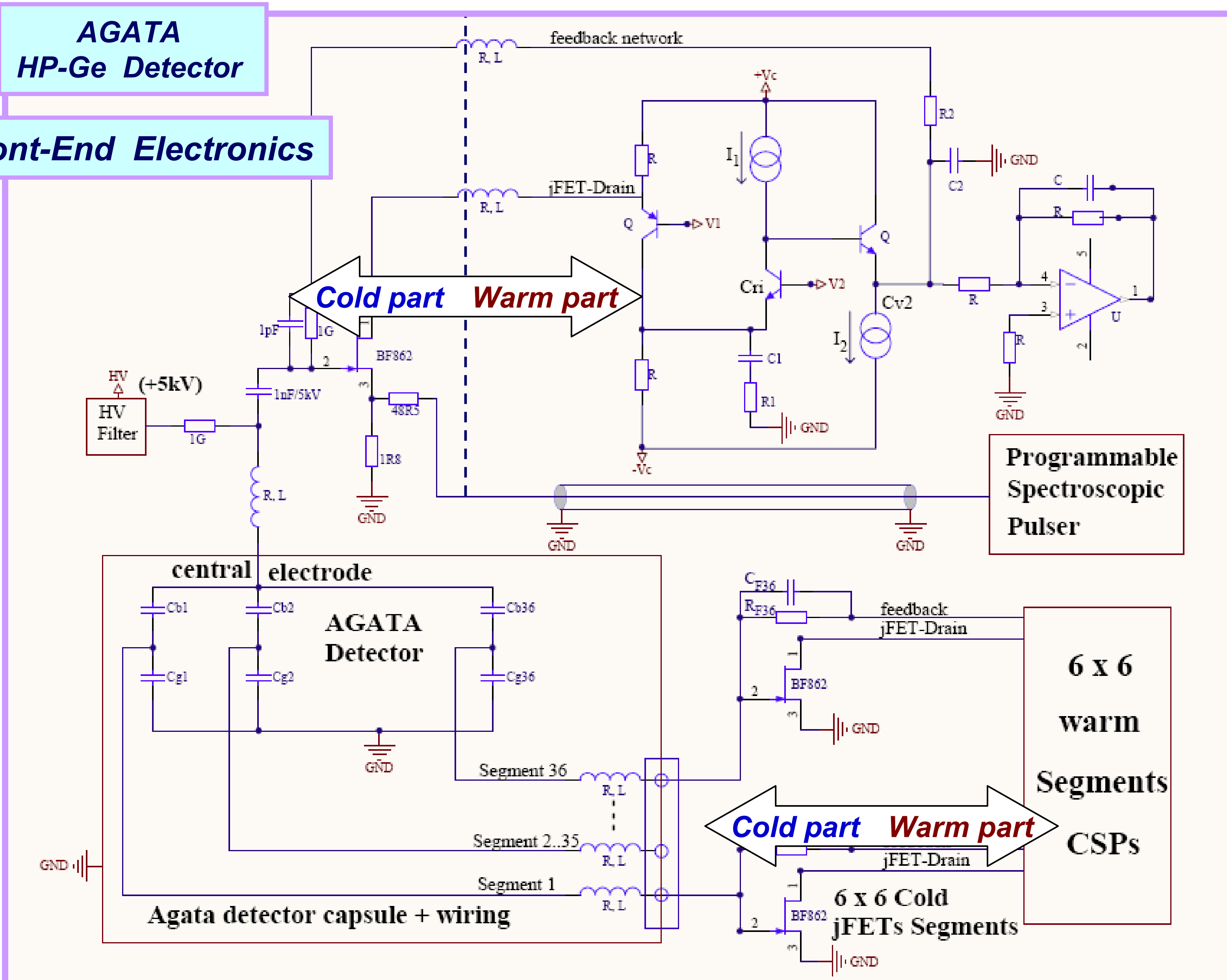
AGATA HP-Ge Detector

Front-End Electronics



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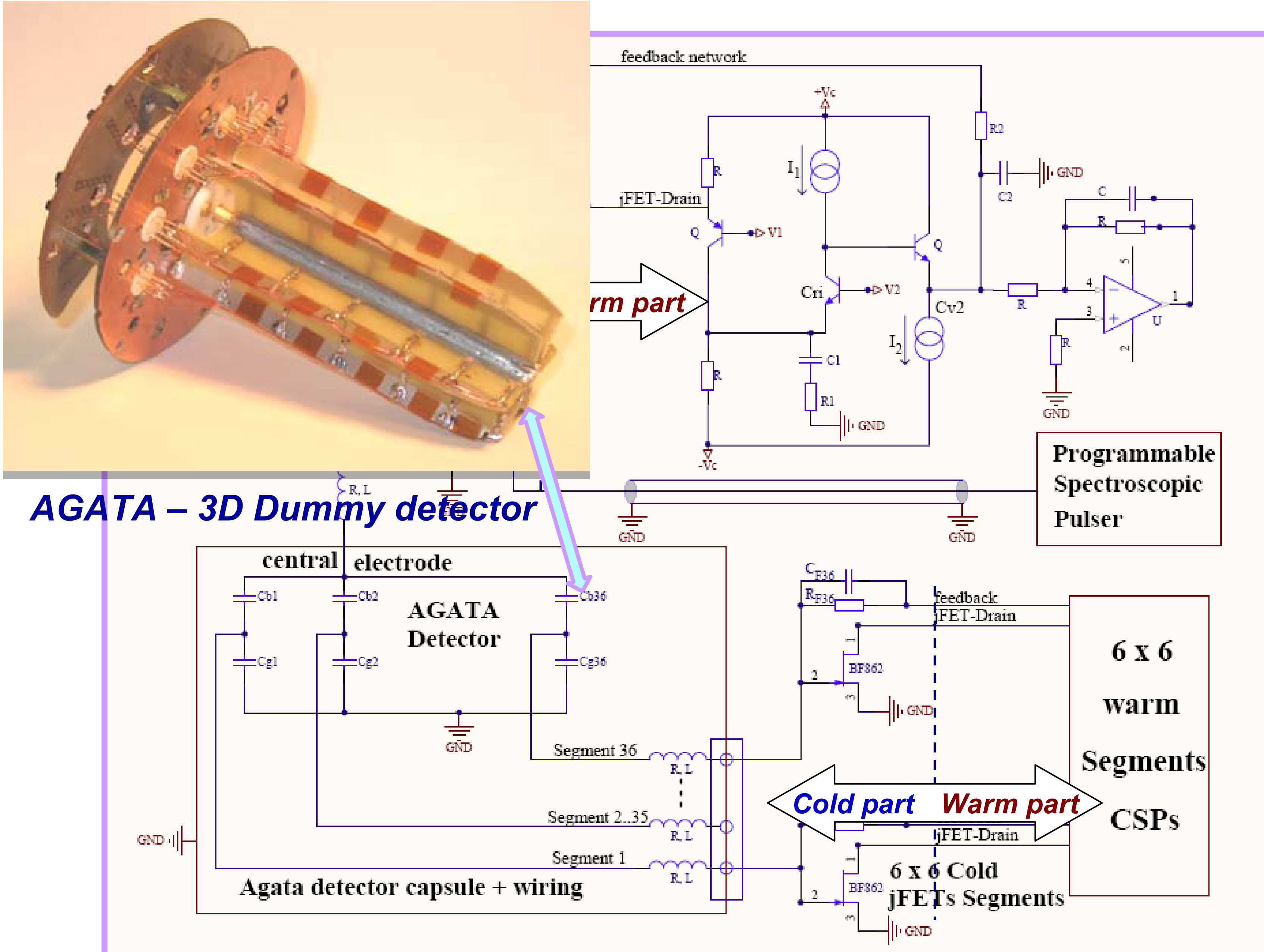
AGATA – 3D Dummy detector



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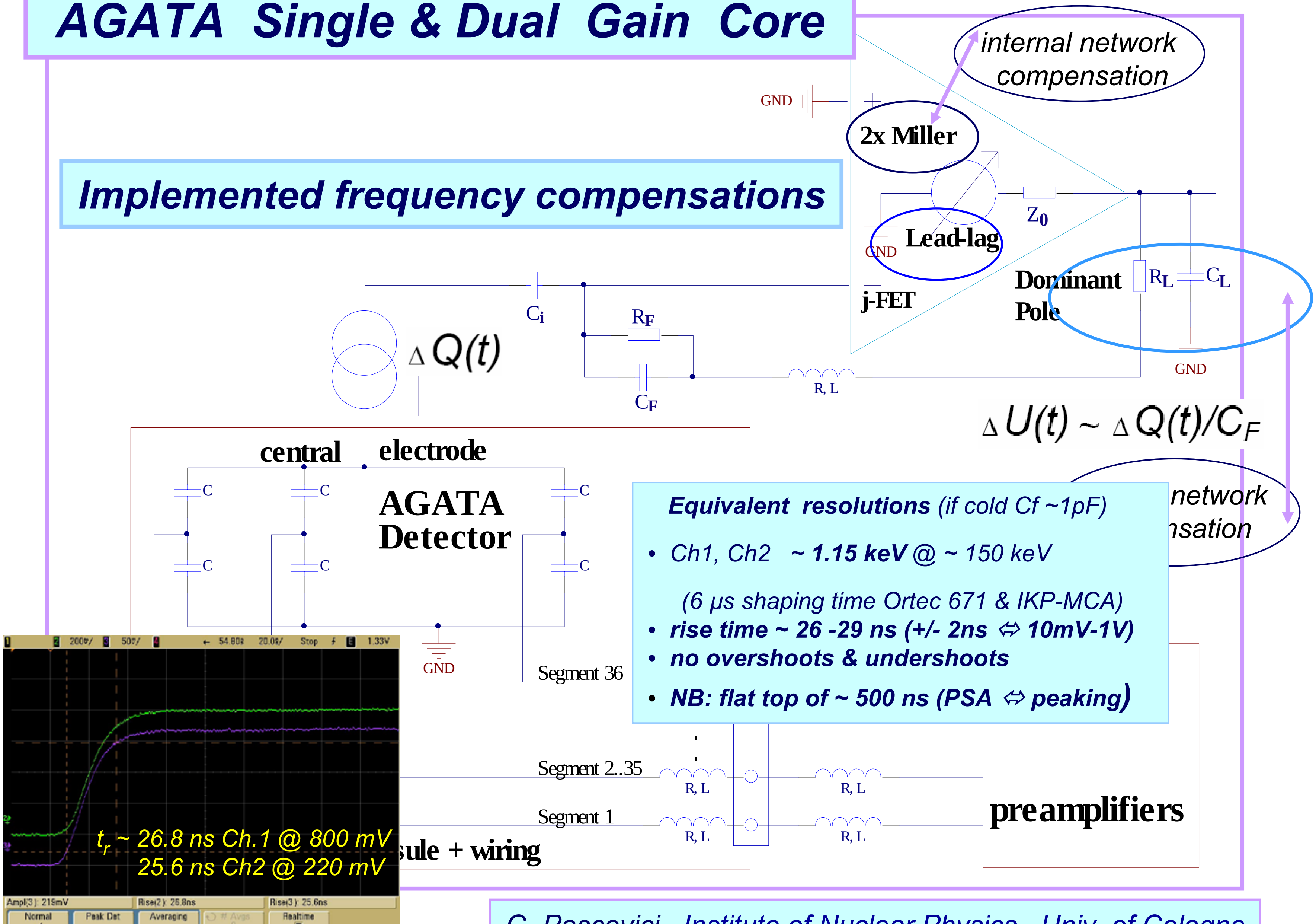
AGATA Single & Dual Gain Core

Implemented frequency compensations

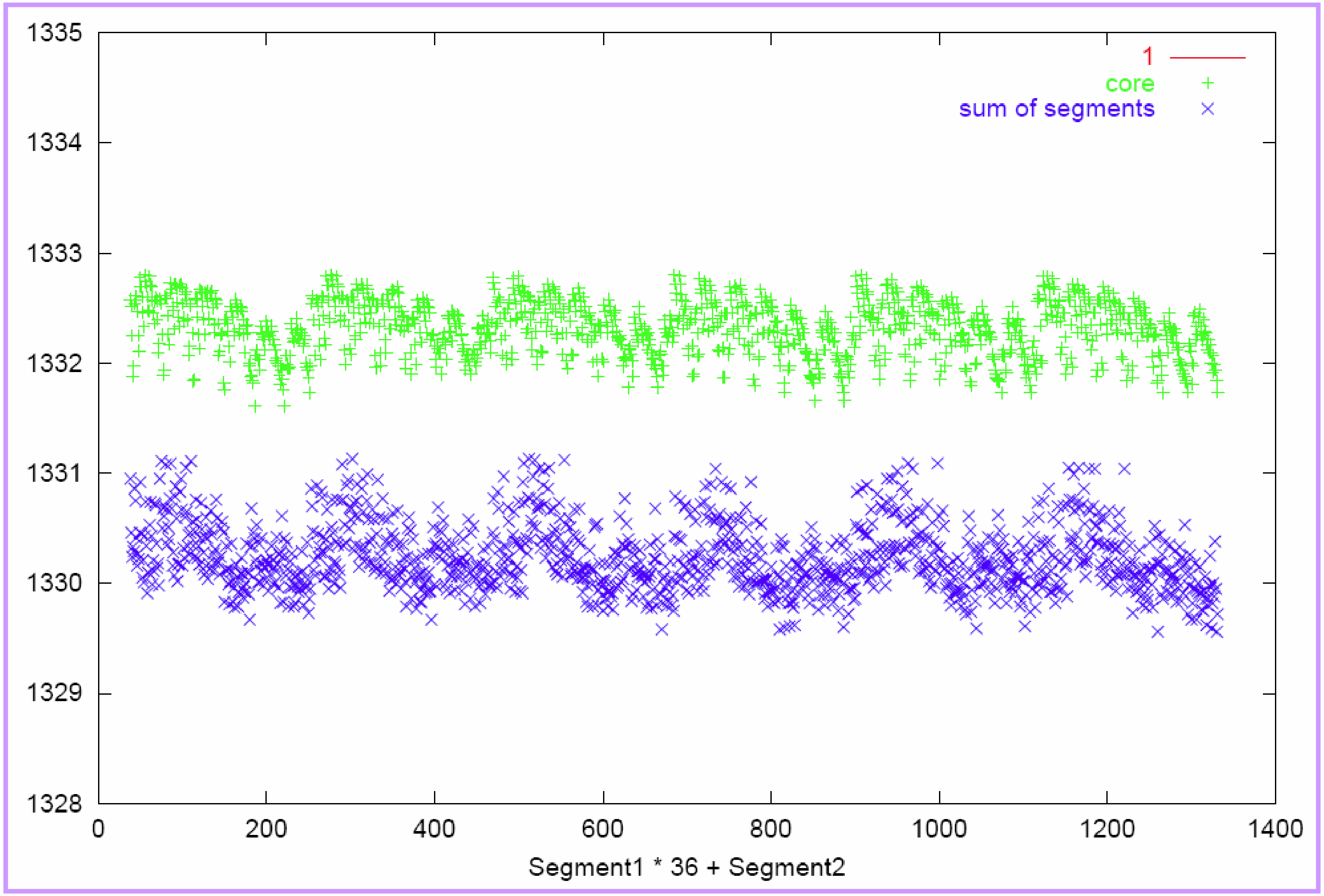


Equivalent resolutions *(if cold Cf ~1pF)*

- *Ch1, Ch2 ~* ***1.15 keV*** *@ ~ 150 keV*

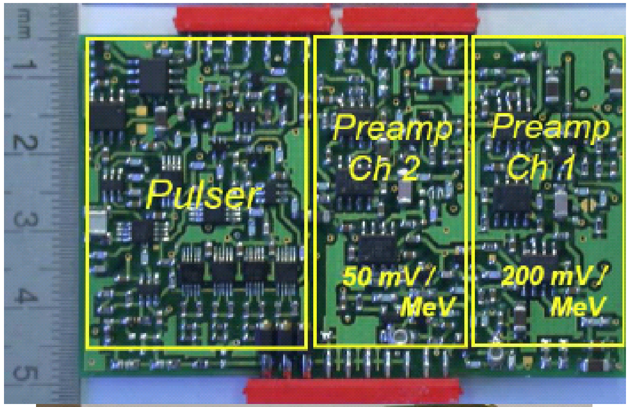
  (6 µs shaping time Ortec 671 & IKP-MCA)
- ***rise time ~ 26 -29 ns (+/- 2ns ⇔ 10mV-1V)***
- ***no overshoots & undershoots***
- ***NB: flat top of ~ 500 ns (PSA ⇔ peaking)***

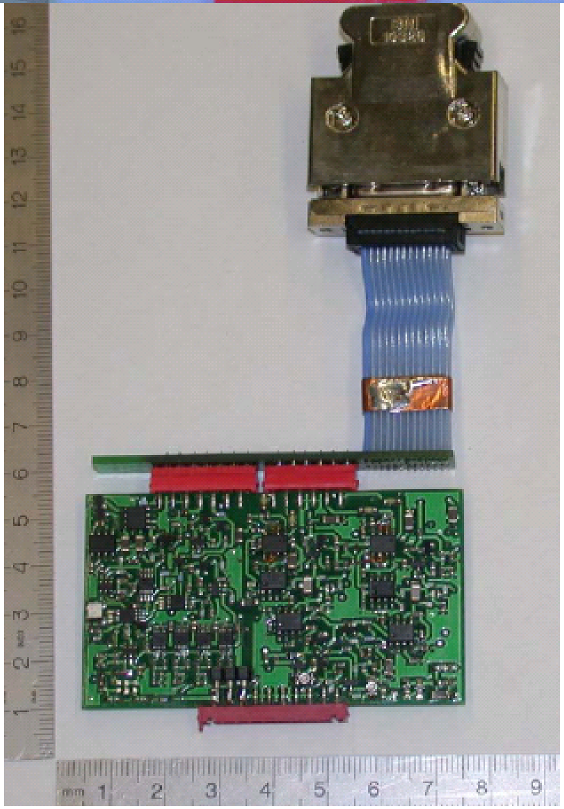
G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne


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

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 imple´mented in the AGATA –Core Front-end Electronics





G. Pascovici, Institute of Nuclear Physics, Univ. of Cologne