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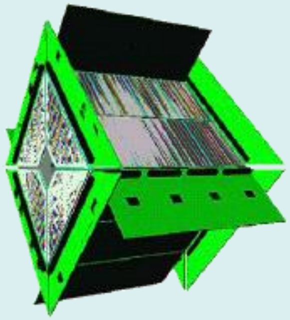
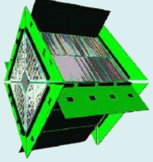


# Latest results in ASIC developments for TRACE and other detectors for nuclear physics research

Stefano Capra

"PhD Workshop 2013" **Oct. 14, 2013**

# Outline



- Context and goal of the research
- TRACE detectors & required specs for charge preamps
- From "Fast – Reset" preamplifier to "Fast – Reset" multichannel
- Non linear pole – zero compensation technique
- Micro – probe preamplifier: a completely new concept of preamplifier
- Conclusions

# Context and goal

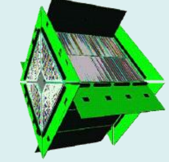
## *Context*

- New generation of nuclear-physics experiments with secondary radioactive beams.
- A technical advance for the FEE applied to the new highly segmentated telescopic silicon detector is required.

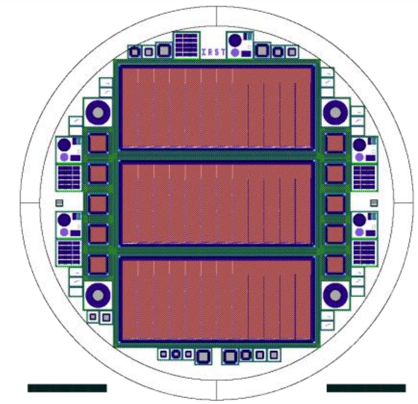
## *Goal of the research*

- High-resolution spectroscopy of charged particles implementing a FEE based on a dedicated ASIC multichannel CSP

# Highly segmentated Si detectors



High-resolution particle spectroscopy : investigation of nuclear structure approaching the two extreme regions of proton and neutron drip lines

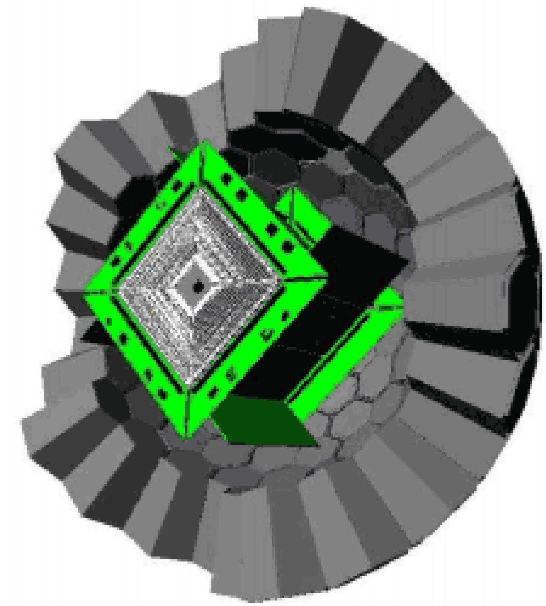


***Silicon PAD detectors - main features:***

- Operated at **room temperature** (no need for cryogenic temperatures)
- Detector thickness: E pad **1.5mm**, ΔE pad **200μm**
- Single pad capacitance value: ~ from **2 pF** to **15 pF**
- Energy dynamics for detected particles: ~ **100 MeV** for α – particles, **25 MeV** for protons
- Intrinsic energy resolution**: 40 keV @ 5.5 MeV** for α – particles in 200 **μm** detector
- Segmentation: **~ 4x4 mm** geometry (also 8x8mm)

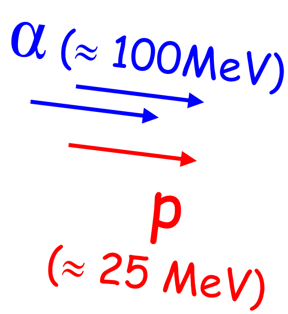
# TRACE detector

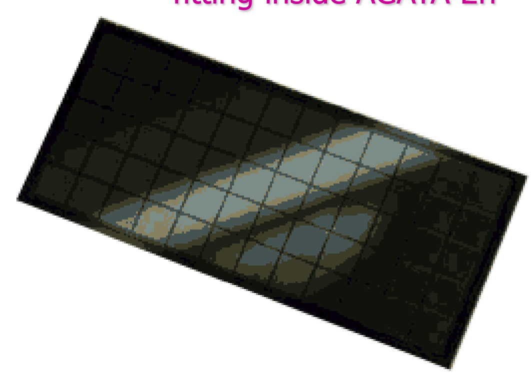
- Fit inside a sphere of 24 cm of diameter
- All the FEE electronics must fit inside the same volume
- Rise time of ~ 25 ns for 200 μm thick ΔE layer
- Transparent to γ radiation: coupled with γ spectrometer
- ~ 10000 output channels
- 4π configuration
- 4x4 mm and 8x8 mm segmentation
- Detection of light charged particles, neutron, heavy ions
- Particle discrimination and gamma doppler correction
- Decay spectroscopy



TRACE detector (including electronics) fitting inside AGATA 2π

extremely hostile background of highly energetic charge particles in next-generation nuclear physics experiments with high-intensity beams



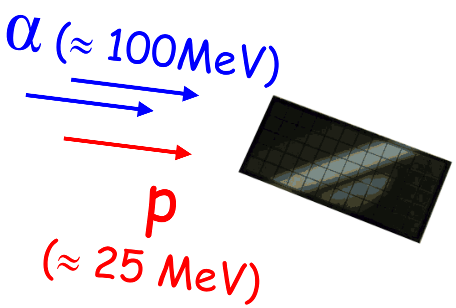
# Charge-preamplifier specifications

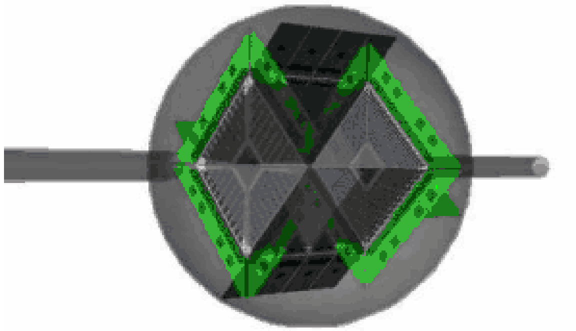
- low noise (no more broadening than the intrinsic one)
- Few mW of single - channel power consumption
- excellent stability of the gain and of the shape of the preamplifier response (loop gain~$10^3$)
- wide bandwidth: rise time of ~ 10 ns  (pulse shape analysis)
- low power consumption (large number of channels operated in vacuum)
- <u>**LARGE DYNAMIC RANGE**</u>:

  - at least ~$10^5$ : from a few keV to 100-200 MeV (or above)

  - minimization of the dead time in a larger energy range up to some hundreds of MeV

extremely hostile background of highly energetic charge particles in next-generation nuclear physics experiments with high-intensity beams

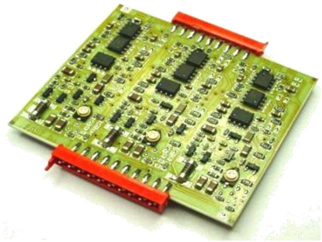


TRACE detector (including electronics) fitting inside a reaction chamber with a radius of 24 cm

# The issue of a wide dynamic range

## Old-style solution: hybrid DISCRETE preamplifiers

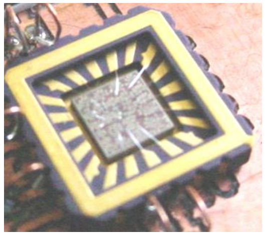


- high flexibility in the design
- use of high voltage power supply (ex: +/- 12 V)
- Absolutely unusable in this context

## Modern CMOS integrated solutions: a mandatory task

The high segmentation of the detectors yields a higher and higher count of read-out channels ($7k - 10k$)

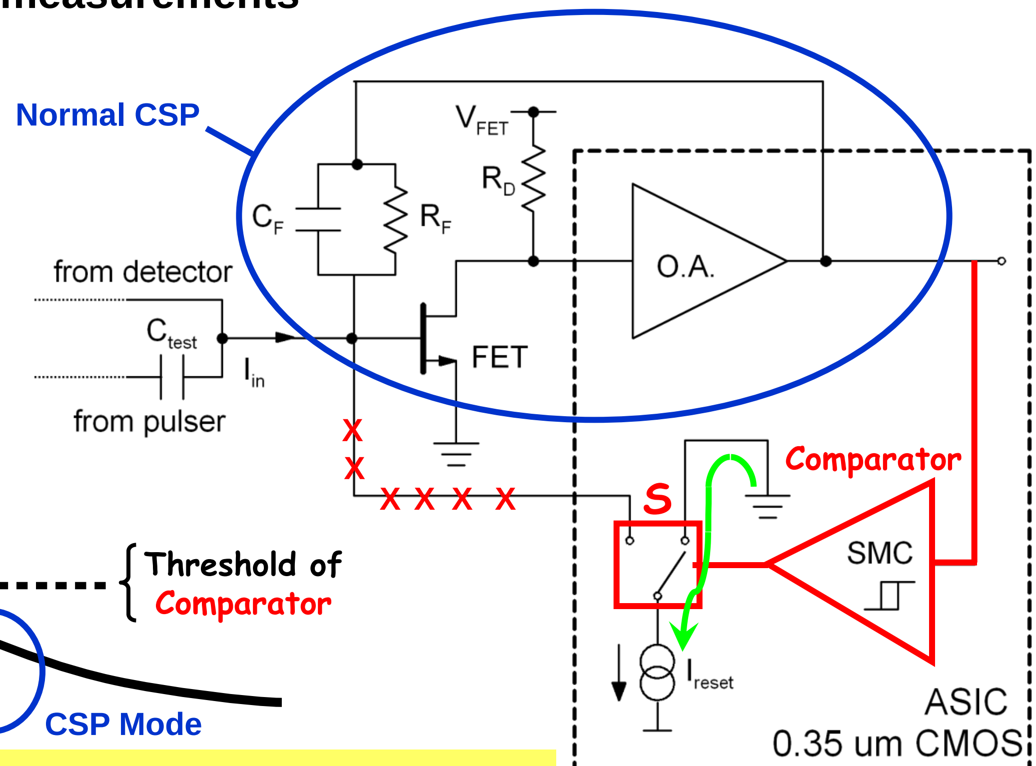
- small dimensions (very little space is available for FEE)
- radio-purity
- Low power consumption (operated in vacuum)
- Voltage power supply limited to +/- 2.6 V (limited dynamic range)
- Need for a multichannel ASIC solution

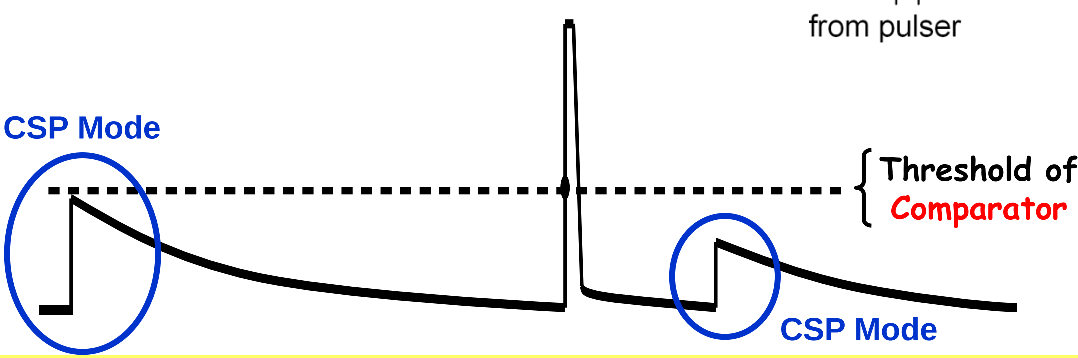


## Charge-Sensitive Preamplifier (CSP) Mode

- For "normal" amplitude signals (up to a few MeV) the **comparator** keeps switch **"S"** in the right position
- The circuit is a Low-Noise Charge-sensitive preamplifier
- Allows for **high-resolution energy measurements**

*External discrete components:*
*BF862 Si JFET, $R_F$=1G$\Omega$, $C_F$=1pF*



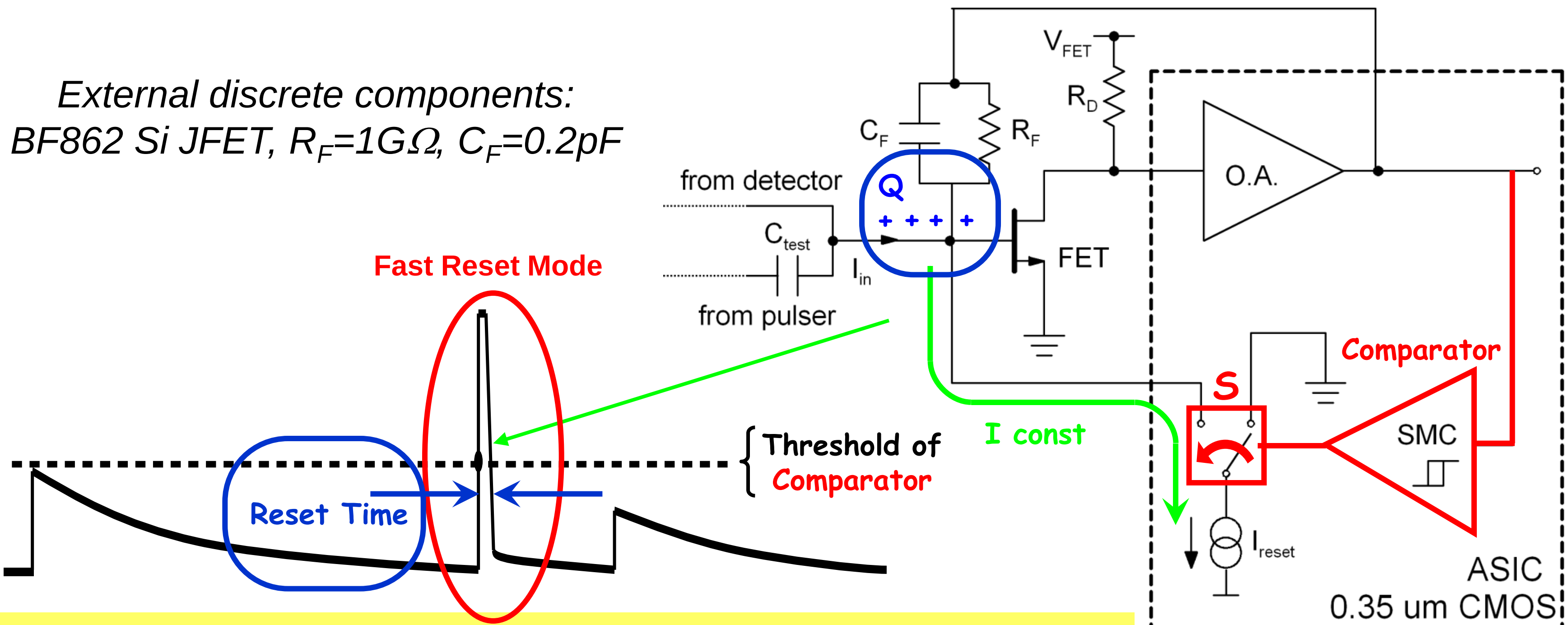

*see also Radeka, Overload Recovery Circuit for Charge Amplifiers, IEEE Trans. Nucl. Sci., vol. 17, no. 1, p. 269, 1970

# From "Fast Reset" preamplifier To "Fast Reset Multichannel"

## Fast-Reset Mode

- Minimizes the preamplifier **dead time** and prevents from the paralysis of the acquisition system in the case of extremely high background counting rates
- Allows for **charge information** even in the saturation condition
- Allows for **high-resolution energy measurements** ➔ extending the dynamic range of photons/particles spectroscopy

*External discrete components:*
*BF862 Si JFET, $R_F$=1G$\Omega$, $C_F$=0.2pF*

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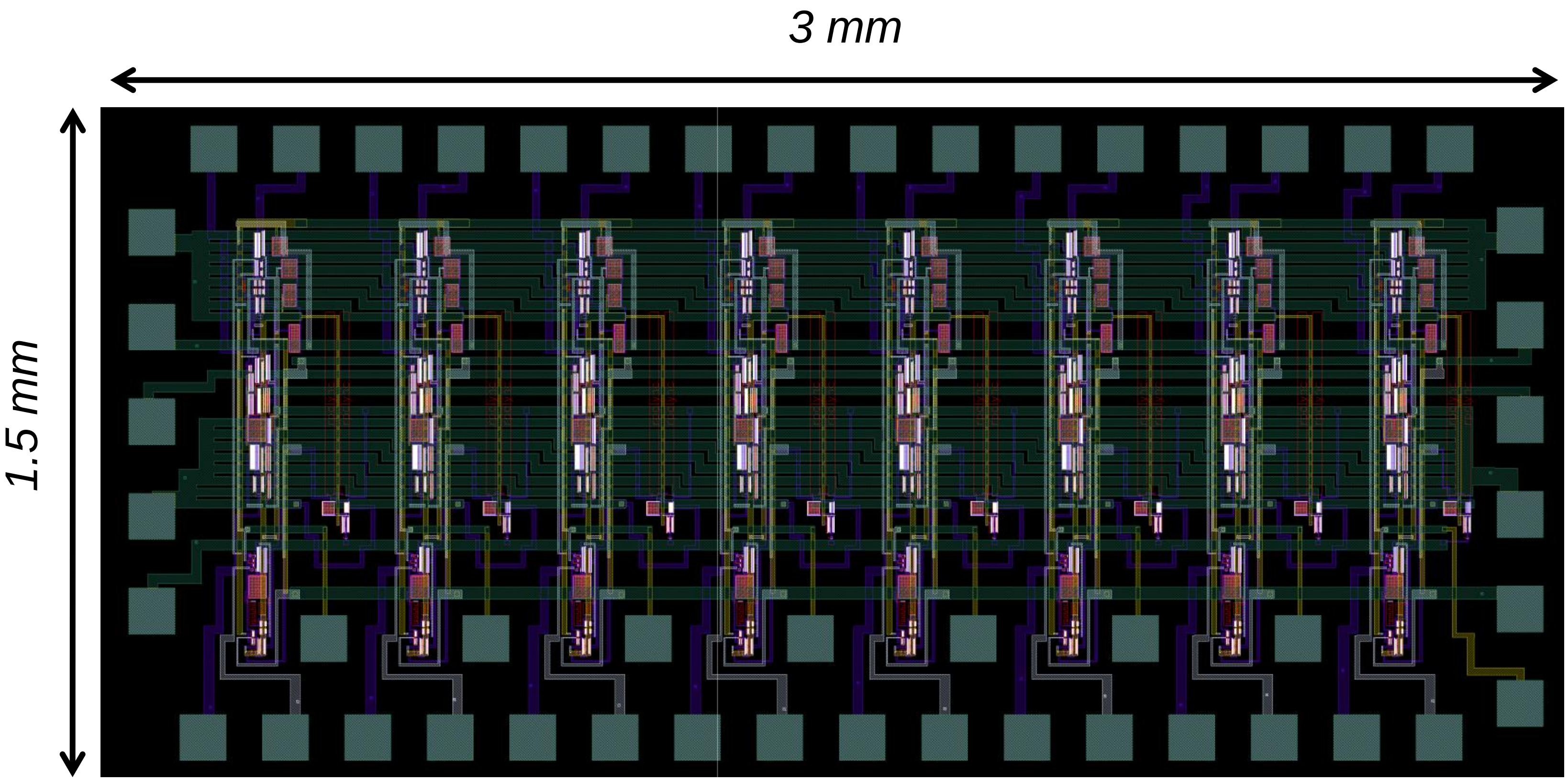
# Multichannel device

The first realization of the ASIC implements a discrete input stage (BF862) and discrete feedback loop (capacitor and discharge resistance)




*Layout 0.35$\mu$m 5V mid-oxide CMOS*

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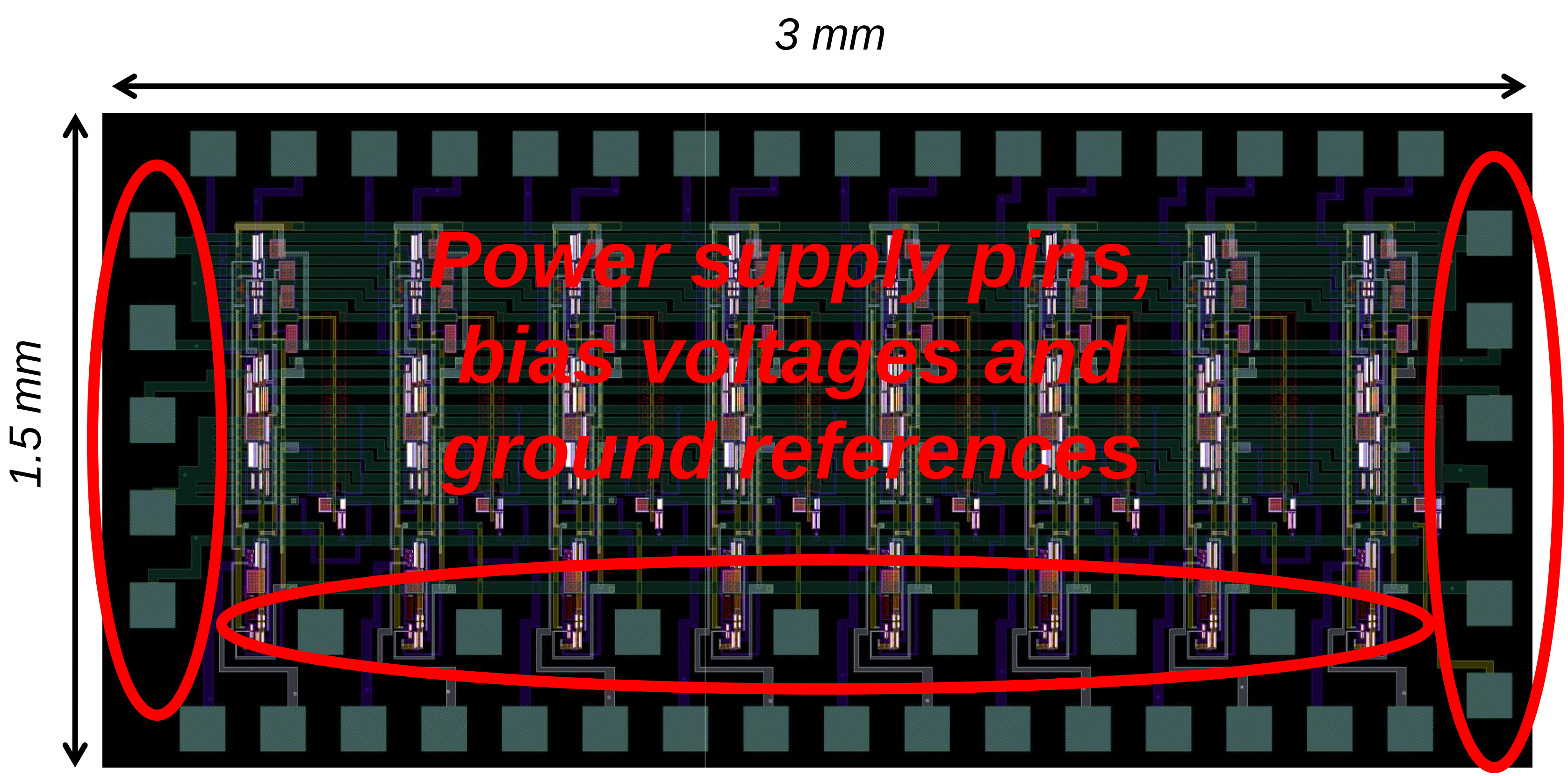


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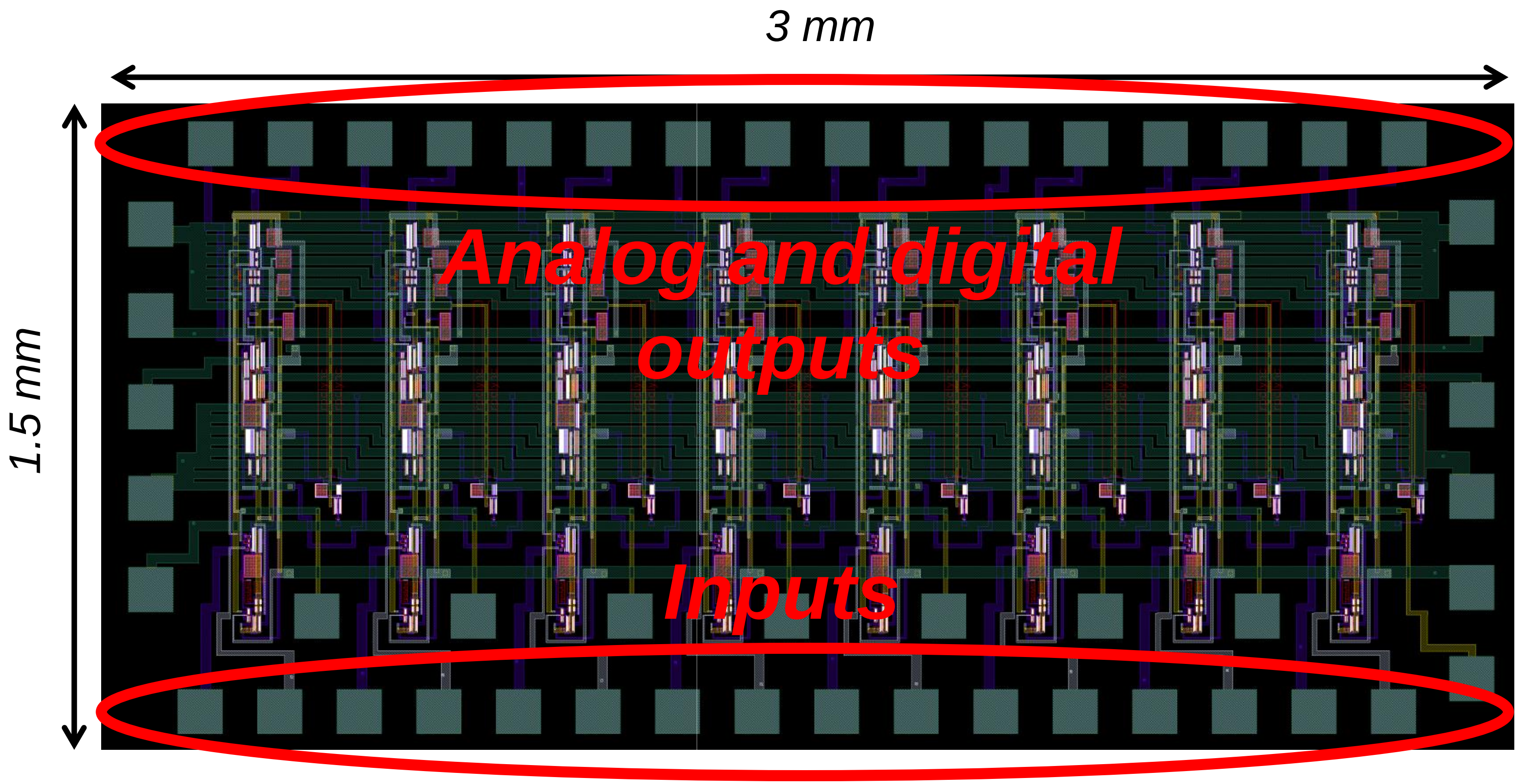



*Layout 0.35μm 5V mid-oxide CMOS*

# Integration of the discrete components

**In order to provide low ENC the feedback resistance must be as high as possible**

- Common choice for gamma-grade spectroscopy is 1GΩ
- It would occupy an area of $2mm^2$

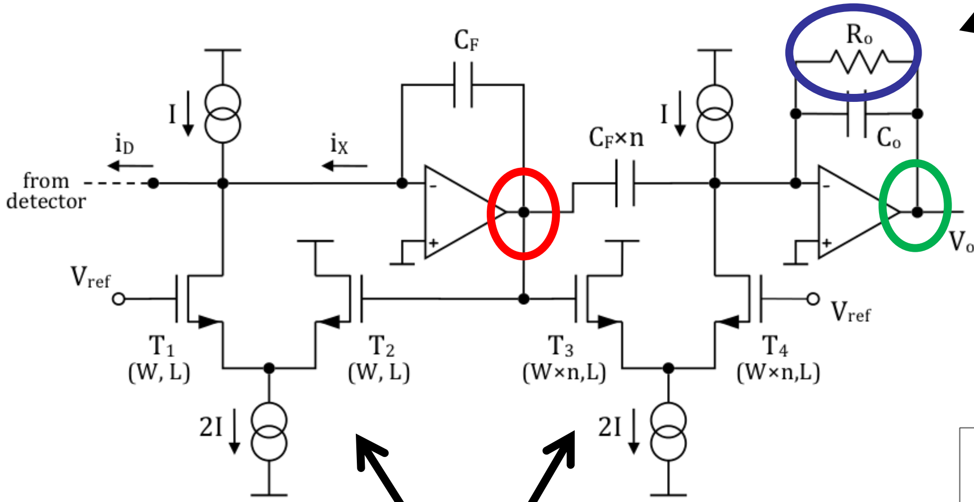

**Common methods for substituting the feedback resistor**

- High underthreshold CMOS structure (**NOISE OK** / **LINEARITY PROBLEMS**)
- Linear CMOS transconductor (**LINEARITY OK** / **NOISE PROBLEMS**)

Need for a new structure with provides both linearity and good noise performance, with limited area and power consumption

# Non linear pole – zero compensation technique

*Concept schematic*



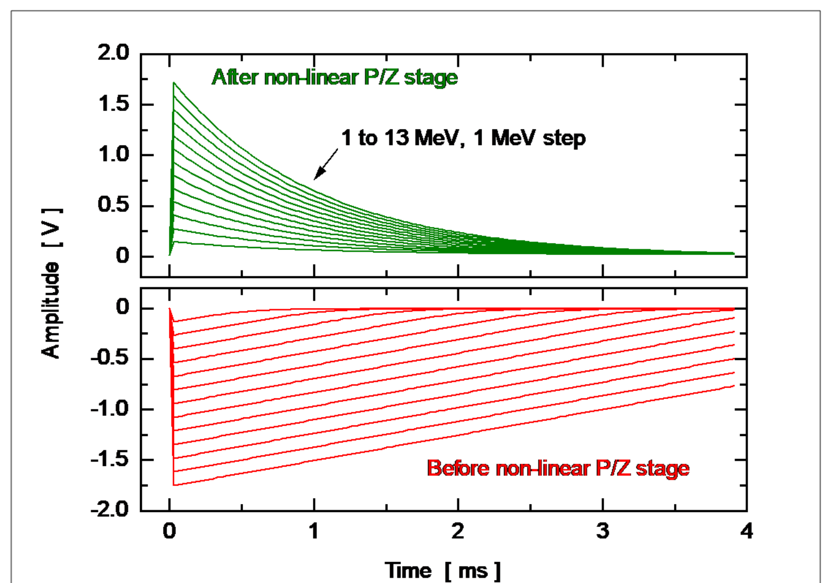

*10 MΩ resistor*

- *Reasonable area occupation*
- *Low capacitive coupling to bulk*
- *Good noise performance*

*Two transconductors*

*with 1:N scale*

*Computer simulations*



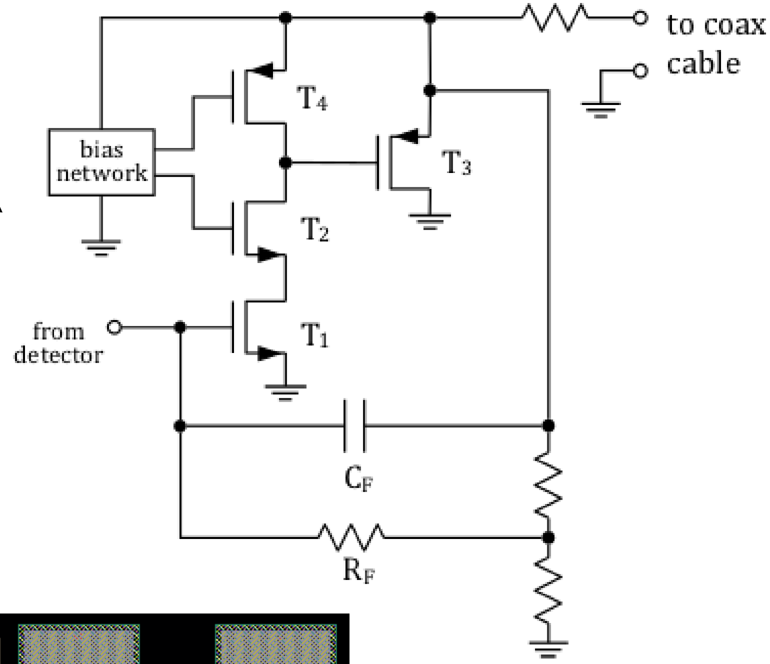

*Clear exponential signal at the output:*

*Needed by digital filtering to obtain best resolution results*

# Microprobe: a completely new concept of preamplifier

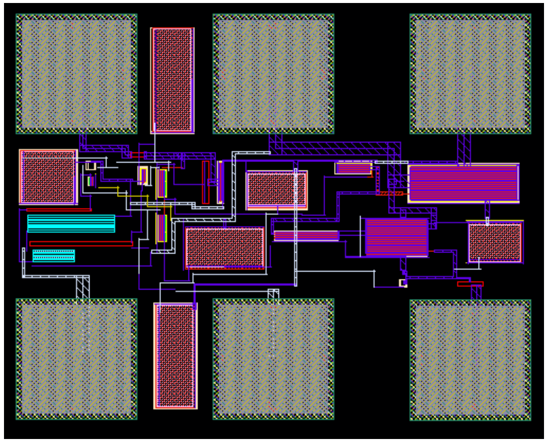
*The biasing network: key point of the whole circuit*

Concept schematic




## *Main features*

- *Only 1 connection with BEE*
- *No filtering capacitors for power supply*
- *Signal and power supply on a single node in the circuit*
- *Drives a 50Ω cable*
- *Ultra – fast risetime ( < 1 ns)*
- *Good dyamics*

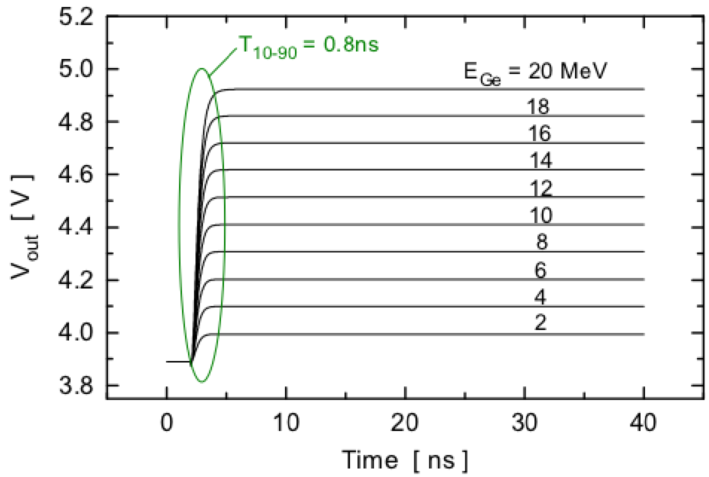


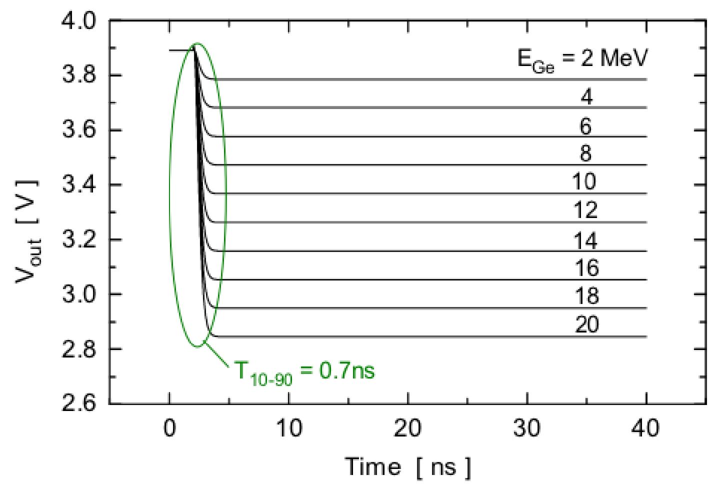
**Layout in C35B4C3 Technology (420 x 330 μm)**

# Microprobe: a completely new concept of preamplifier

*Both positive and negative dynamics above 20 MeV without appreciable distortion*

Computer simulations

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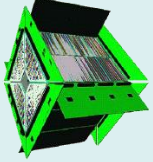

# Conclusions

- Design, layout & computer simulation of a JFET-CMOS multichannel preamplifier (0.35μm) for Si pad - detectors equipped with a fast reset device for charge sensing stage de-saturation

- Design & computer simulation of the innovative non linear pole – zero compensation technique, which is a great step forward to the total integration of the ASIC CSP.

- Design, layout & simulation of a non – conventional CSP device without power rails and a single power – signal connection to the BEE.

- Layout submission on 21th October 2013: experimental results on realized chips coming soon