Presentation on Si-Ge needs for high quality amplifier

Roberto Cardarelli – INFN Roma Tor Vergata

Why SiGe?

Due to booming market for computer and wireless communication systems, there is a need of a single transistor technology simultaneously capable of delivering:

- Low Power
- High Linearity
- Ultra Low Noise
- High speed of operation for RF, analog, memory and digital circuits
- Low cost

“One technology fits all”

Moreover, this technology has:

- High Reliability
- Radiation hardness
- Easy integration
- An active developers community

All these are the main requirements for present and future high energy and nuclear physics instrumentation!

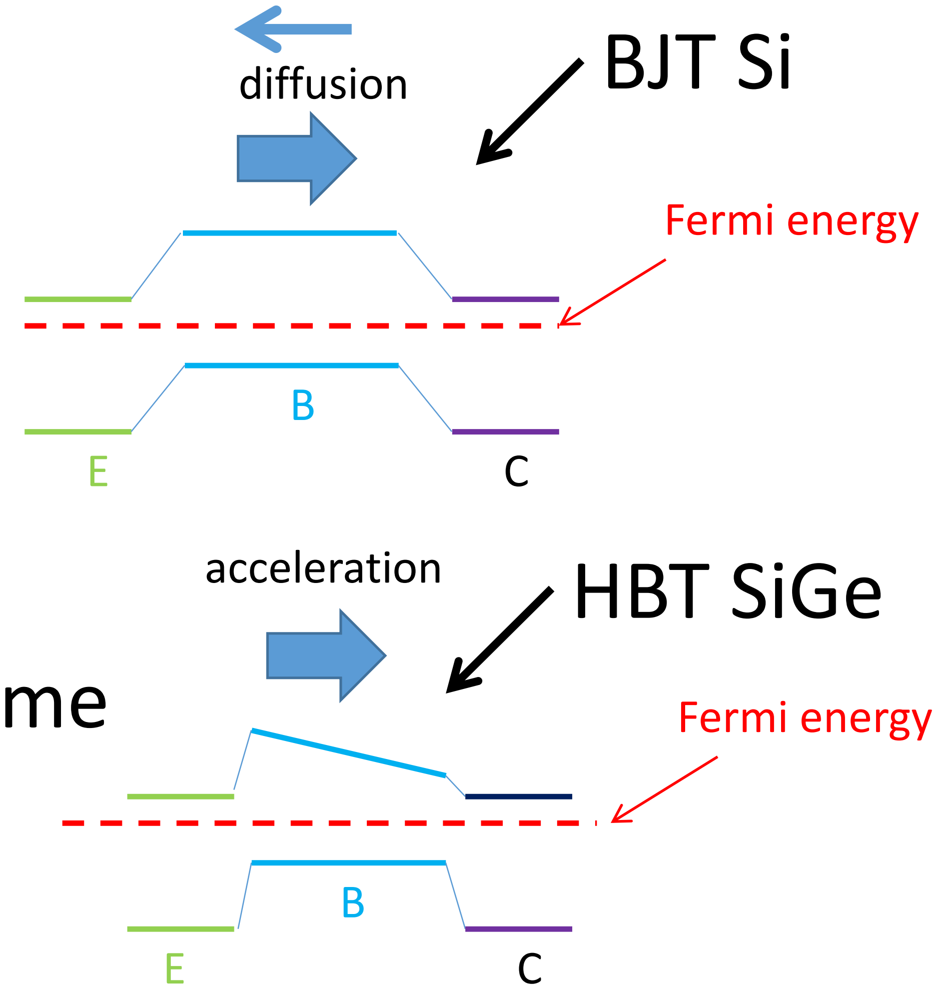
Si BJT vs SiGe HBT

- B JT performances
  - $\beta = \tau_c / \tau_t$
  - $f_t = 1/\tau_t$
  - $N = K^* \tau_t$

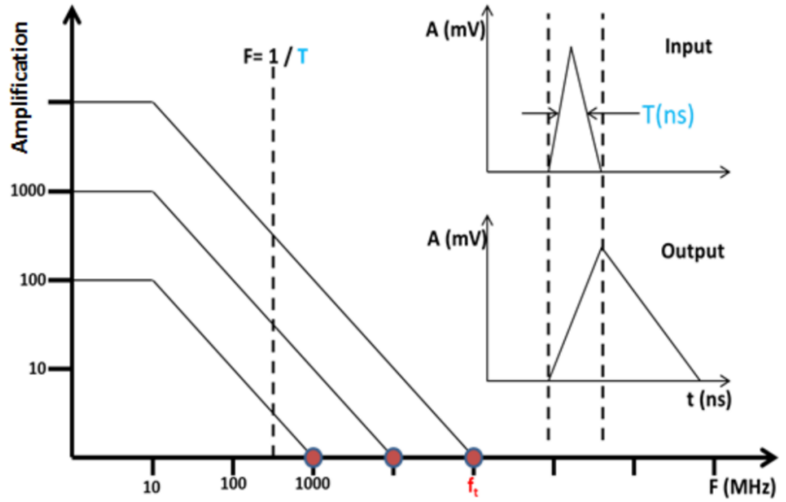
τ_c = base life time

τ_t = base transient time

τ_t (Si) >> τ_t (SiGe)

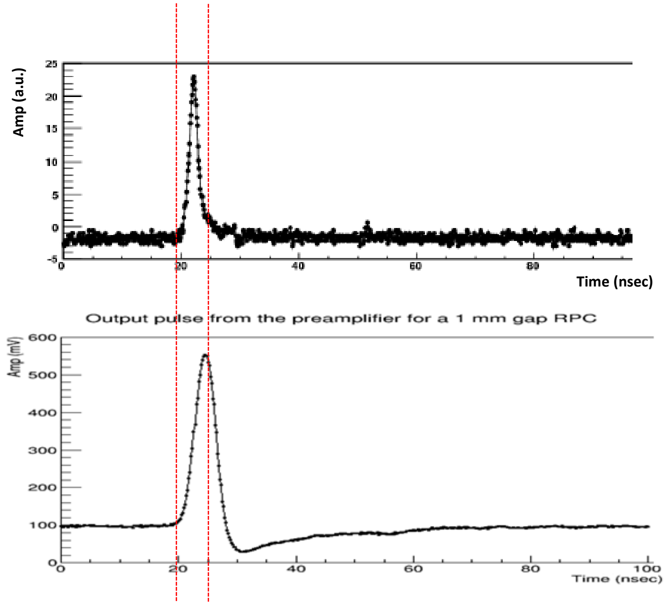


Strategy for the new front-end (SiGe)

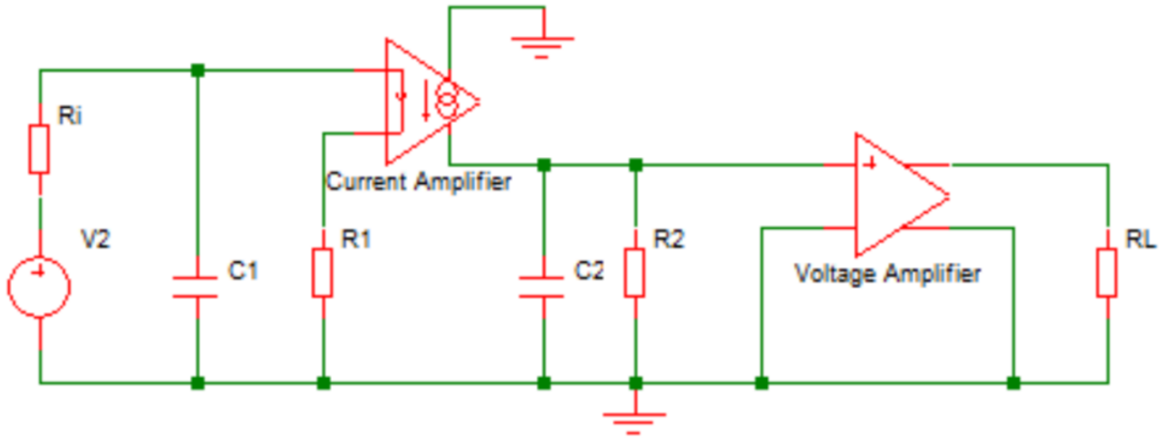


Working strategy

Actual result for the RPC signal



The block diagram of the preamplifier



The same scheme can be used for both Silicon and SiGe technology for a comparison.

Silicon technology

Voltage supply	3–5 Volt
Sensitivity	2–4 mV/fC
Noise (independent from detector)	4000 e^- RMS
Input impedance	100–50 Ohm
B.W.	10–100 MHz
Power consumption	10 mW/ch
Rise time $\delta(t)$ input	300–600 ps
Radiation hardness	1 Mrad, 10^{13} n cm^{-2}

SiGe technology

Voltage supply	2–3 Volt
Sensitivity	2–6 mV/fC
Noise (independent from detector)	500 e^- RMS
Input impedance	50–200 Ohm
B.W.	30–100 MHz
Power consumption	2 mW/ch
Rise time $\delta(t)$ input	100–300 ps
Radiation hardness [4]	50 Mrad, 10^{15} n cm^{-2}

Problems solved by this amplifier

- Signal **pile up** at high rate → **small integration time** (10 ns) with low noise (500e^- RMS).
- Uncorrelated **background** → suppressed through **fast rise time** (100 ps).
- Detectors with large **pick-up capacitance** → the noise of the preamplifier is **500 e^- RMS up to 1 nF**.
- **Thickness reduction** for Silicon and Diamond detectors. → **Small noise** (down to 200 e^-) for small collected charge.

Problems solved by this amplifier

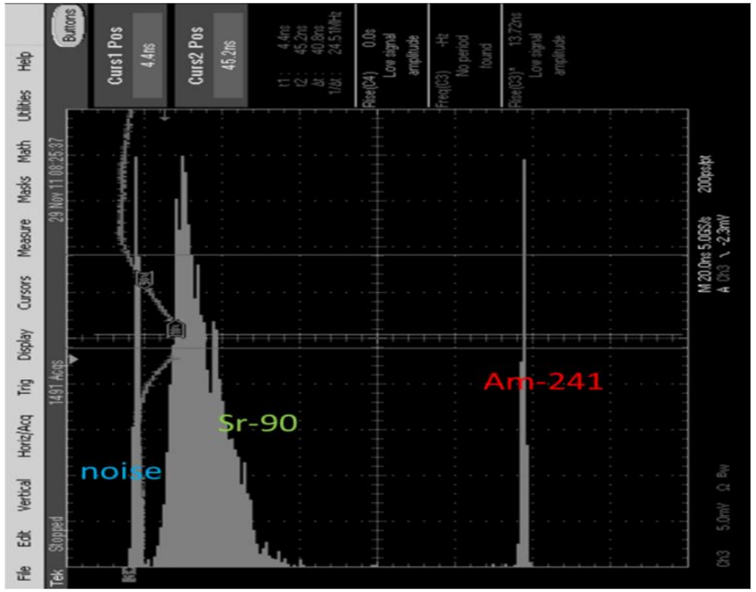
- **High density** of read out channels → **Low power consumption** (down to 1.5 V power supply).

- Fluctuations of **picked-up charge** → **large dynamics** (ex: space resolution with charge centroid).

- **Rate capability** and **ageing** of the detectors → amplification transferred **from the detector to the front end electronics**.

- Radiation and temperature **damage to the electronics** → possibility to **interconnect the preamplifier to the detector via a coaxial cable** (up to 50 m). (Tokamak, nuclear reactors and accelerators).

Preliminary results with SiGe amplifier on a diamond detector.

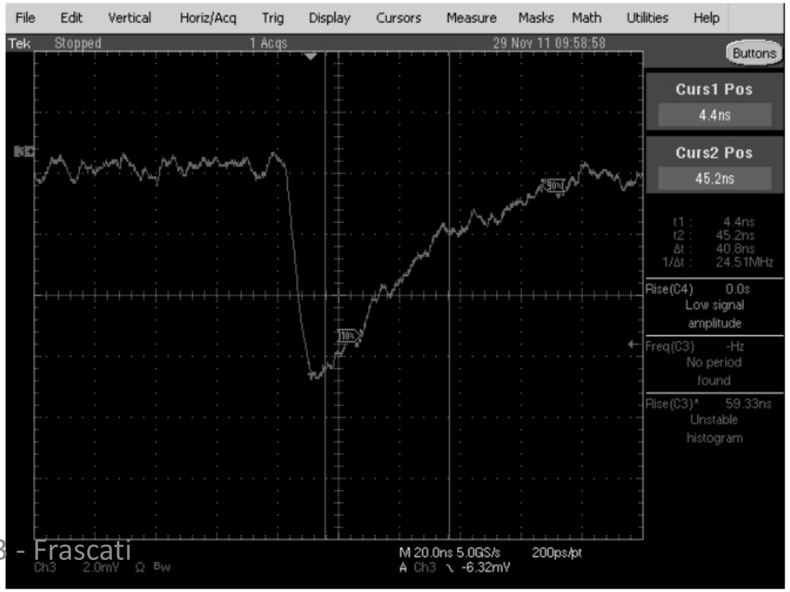


Histogram with:

- Noise of the SiGe amplifier
- Spectrum of a beta source (^{90}Sr)
- Spectrum of an alpha source (^{241}Am)

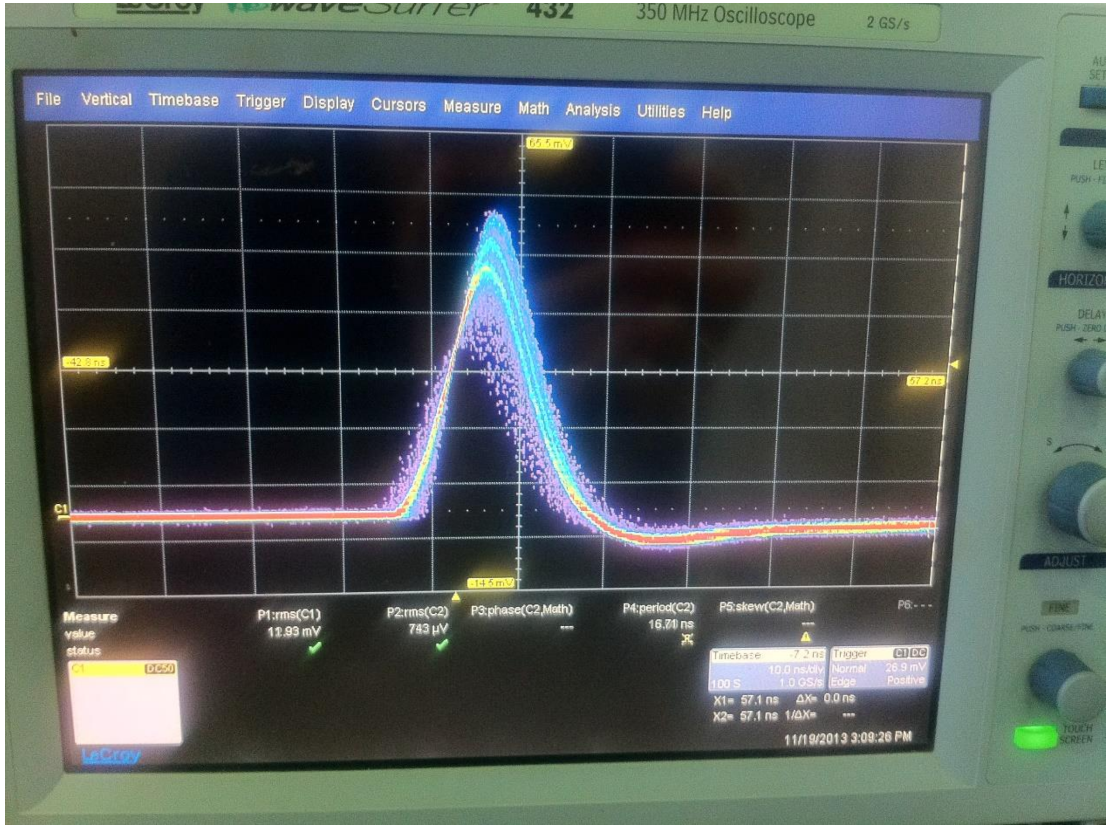
Detected by a CVD (0.5mm thicnkess)

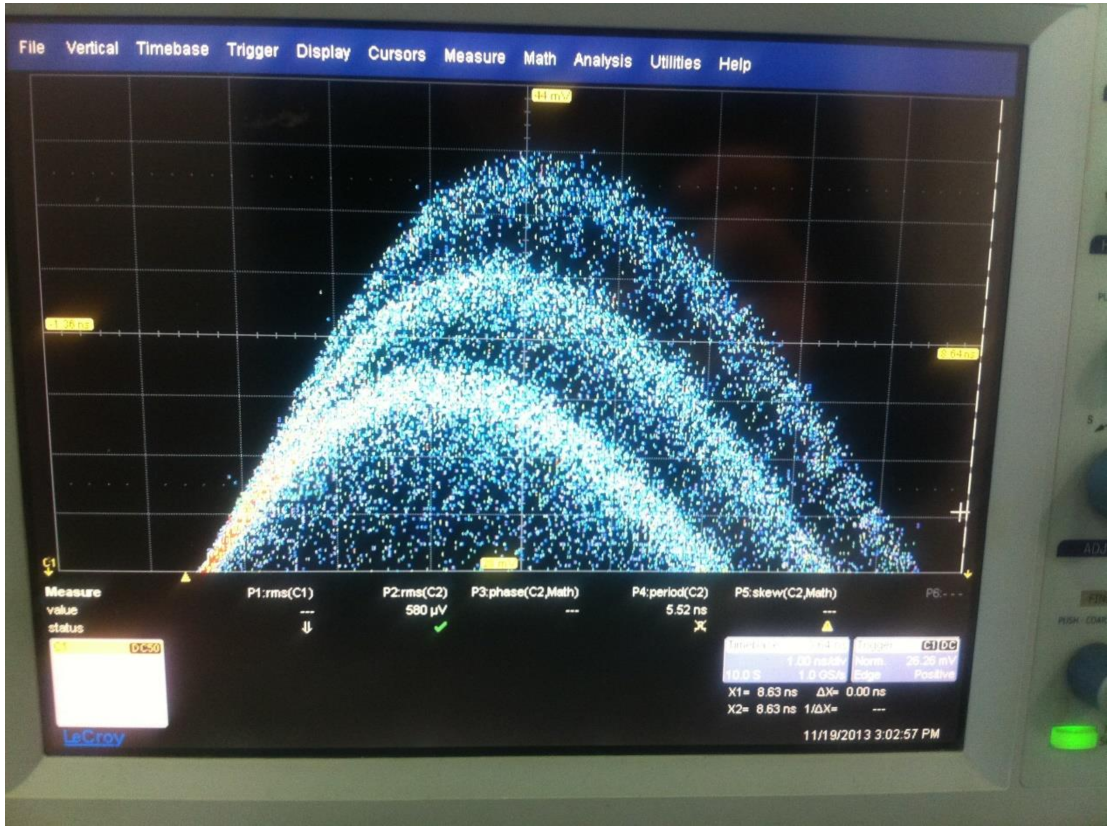
Example of pulse from a minimum ionizing particle on a CVD (0.5mm thickness).
$\sim 8000\ e^{-}$ input to the amplifier



Preliminary results with SiGe amplifier on a diamond detector.

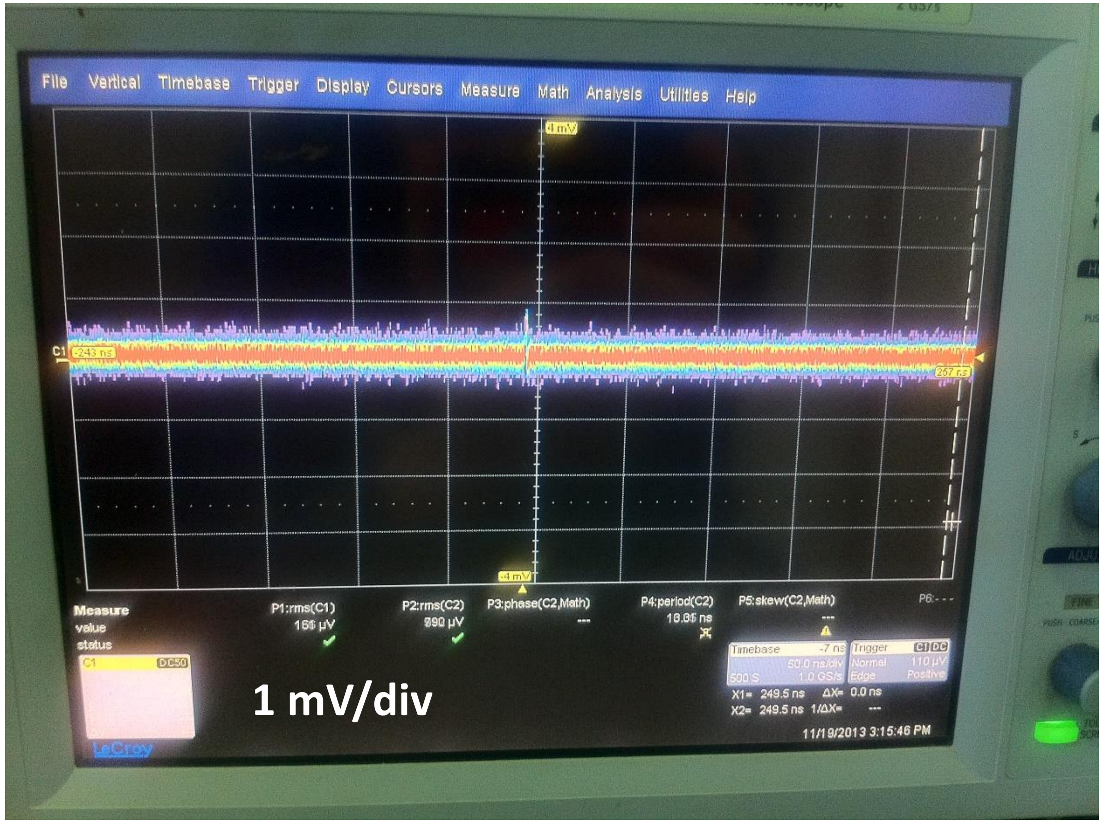
Signals from a Mixed Nuclides alpha source



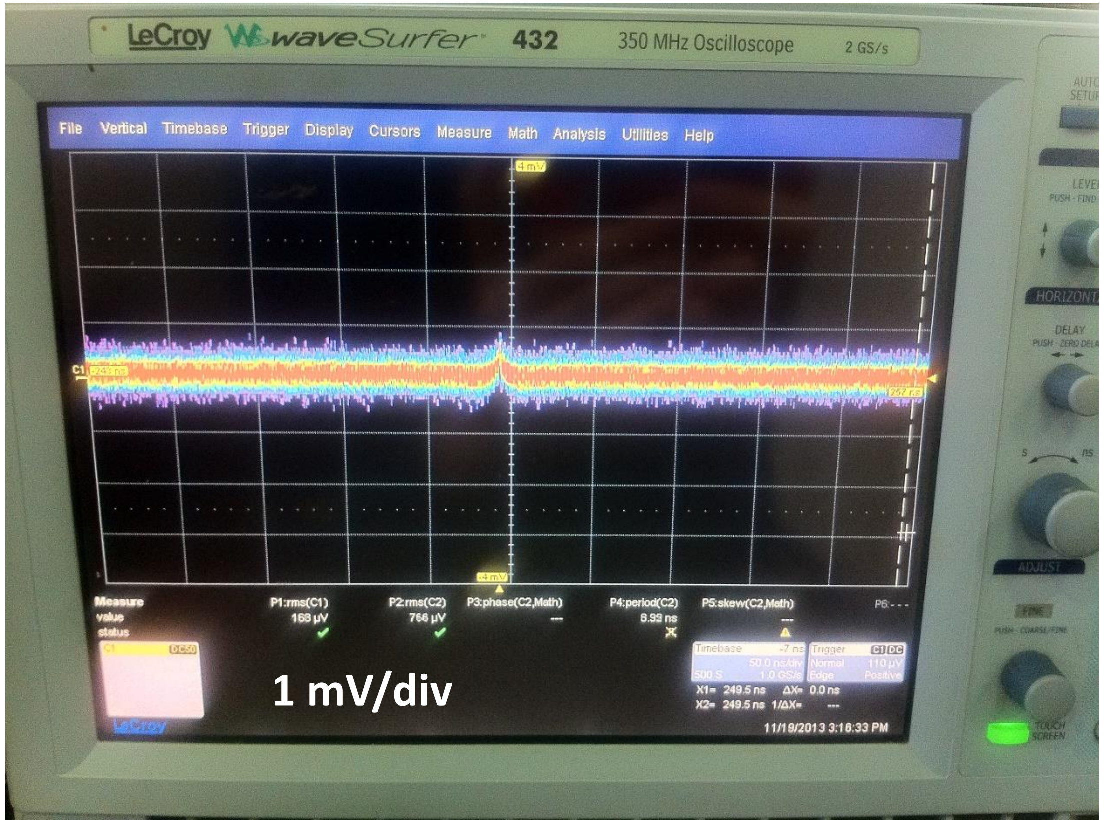


Preliminary results with SiGe amplifier on a diamond detector.

Scope noise



Amplifier+Scope noise



Calibrating with the sources: amplifier noise ~400 e^-

Preliminary results with SiGe amplifier on a diamond detector.

Time of flight between a CVD and a 1 mm gap RPC ($\sigma_t \cong 400ps$) with MIPs.

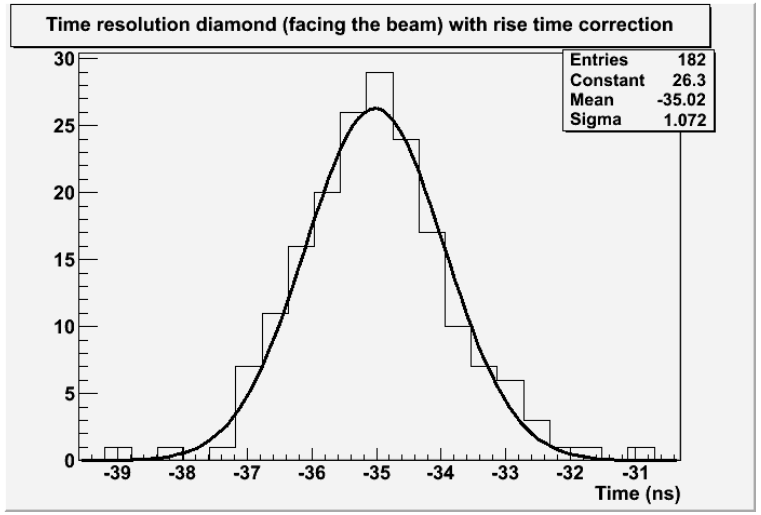
- Assuming $\sigma_{comb}^2 = \sigma_{Diam}^2 + \sigma_{RPC}^2$

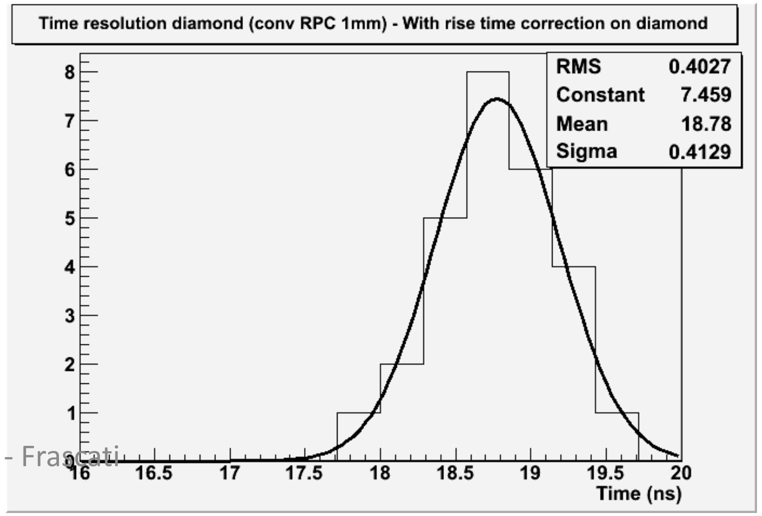
- For orthogonal orientation (diamond orthogonal to beam) the overall jitter is dominated by the diamond.

  $\sigma_{Comb} = 1$ ns

- For parallel orientation the jitter is dominated by the RPC.

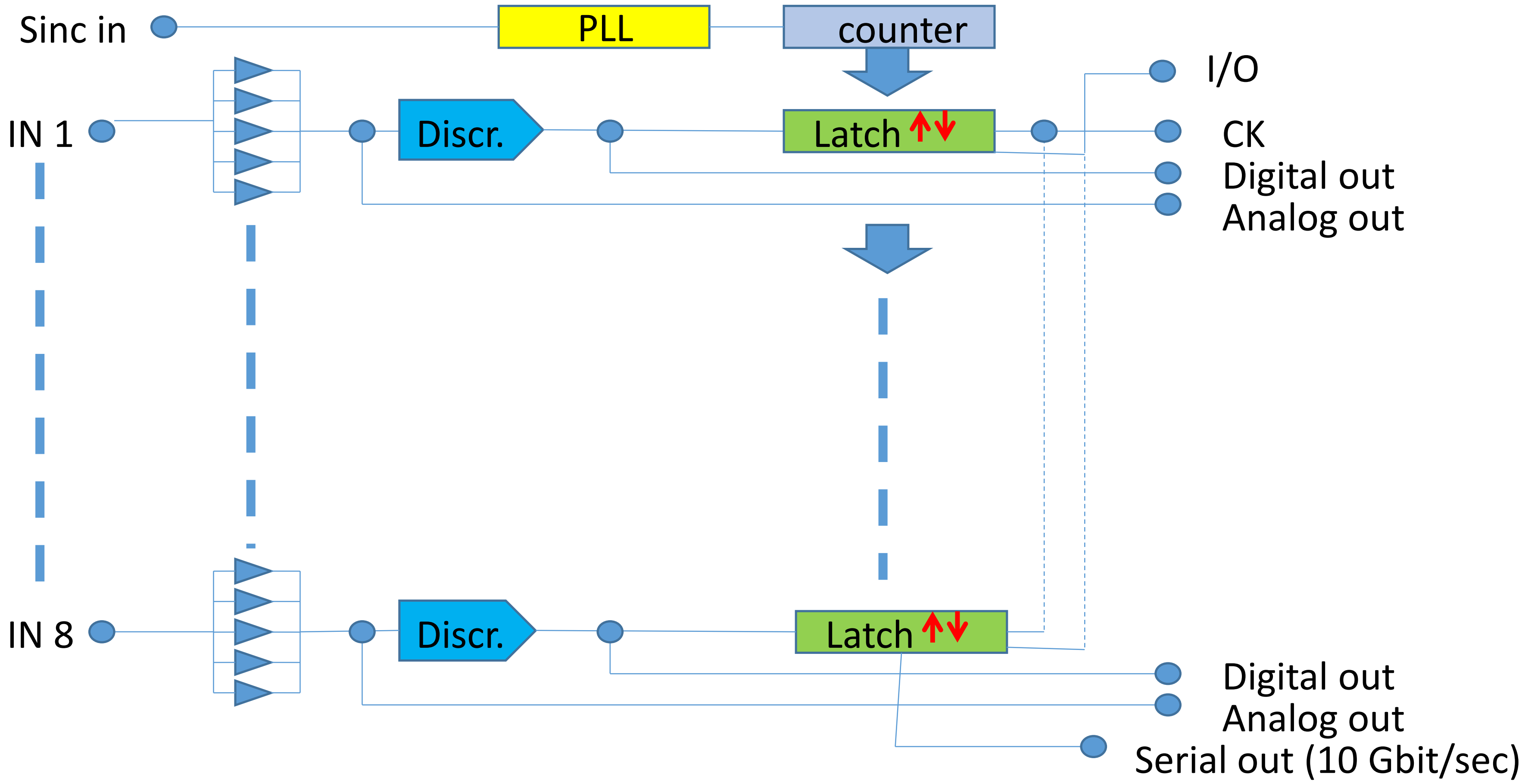
  $\sigma_{Comb} \approx \sigma_{RPC} = 0.41$ ns





Test beam done at the H8 beam facility at CERN.

Block diagram and performance of a new full custom front-end chip



SiGe requirements for the full custom chip

- Presently this transistor is designed for microwave applications ($> 2\ GHz$).

Optimization of the transistor for low frequency applications ($\sim 100\ MHz$).

- Sinusoidal signal.

Pulse signal.

- $^1/_f$ noise.

As low as possible.

SiGe requirements for the full custom chip

• Critic application for very high amplification (up to 1000).	➡	High stability.
• Protection from electrostatic discharges.	➡	Up to 2000 V for the gas detector applications.
• Full custom design	➡	Follow the design.

Conclusions

- The prototype of a new fast, ultra low noise preamplifier in SiGe technology has been developed.

- The project of the full custom front end chip is in progress.

- The preliminary tests of SiGe technology at low frequency (pulse signal) offered very promising results.

- On the side of experimental high energy physics, most of the challenges can be faced by introducing SiGe technology in the front end and instrumentation electronics.