PETIROC2A, a 32-channel readout ASIC for accurate time resolution and charge measurements

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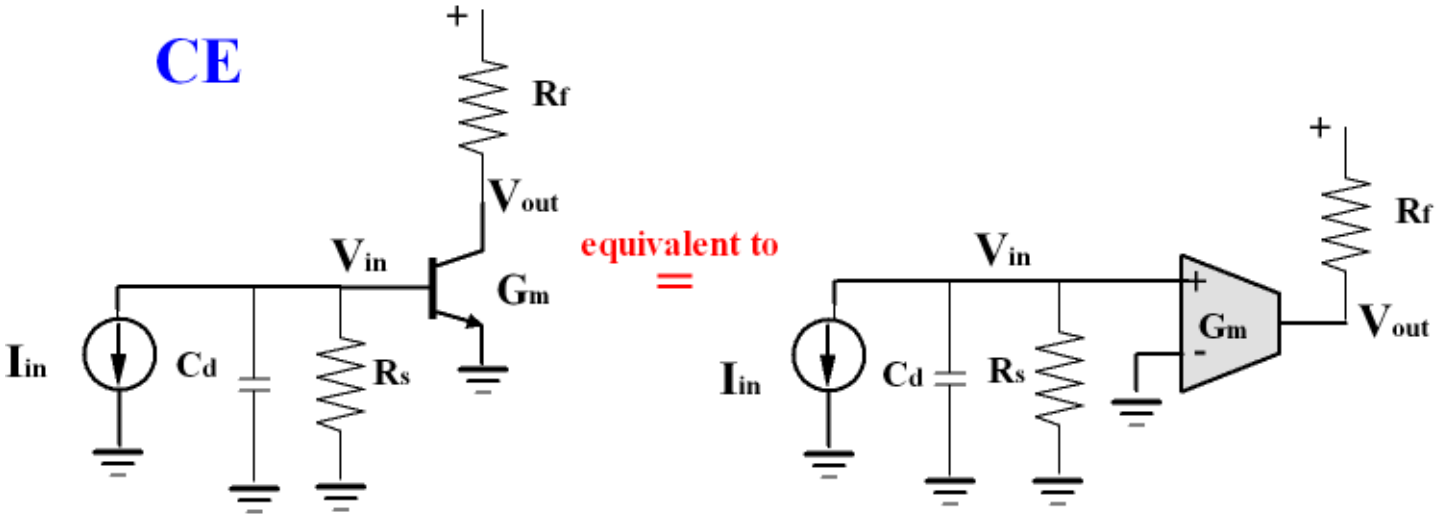
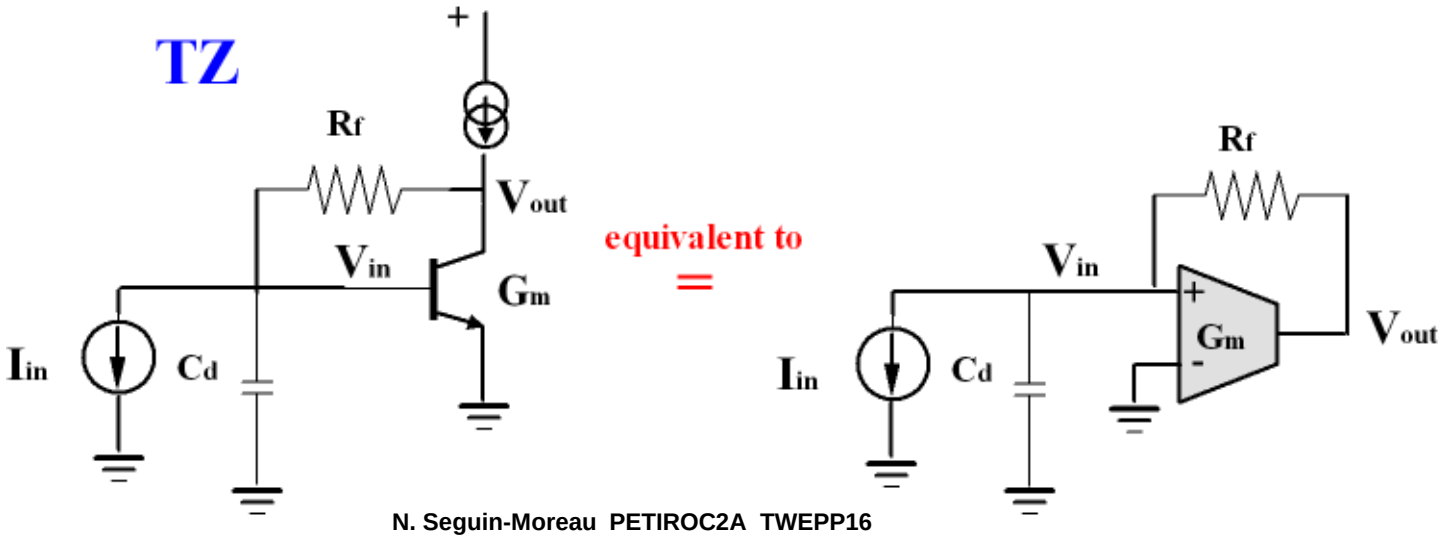
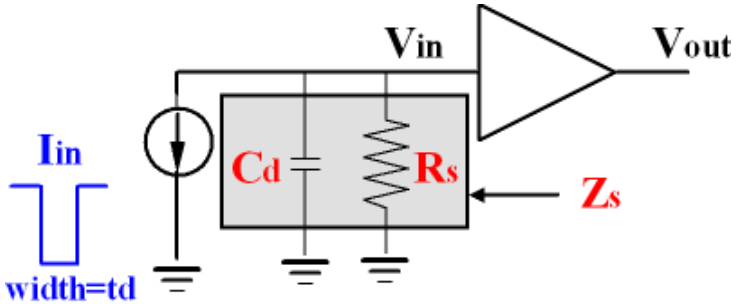


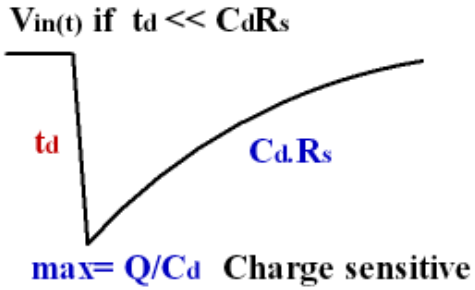
Similar response at very high Frequency $V_{OUT} = -g_m R_f \frac{Q_{IN}}{C_d}$

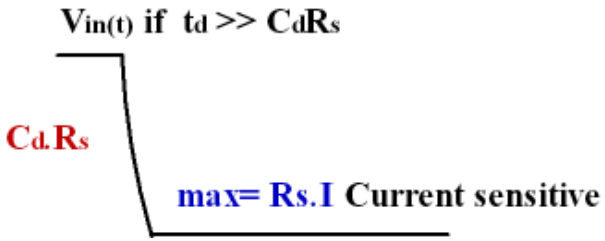


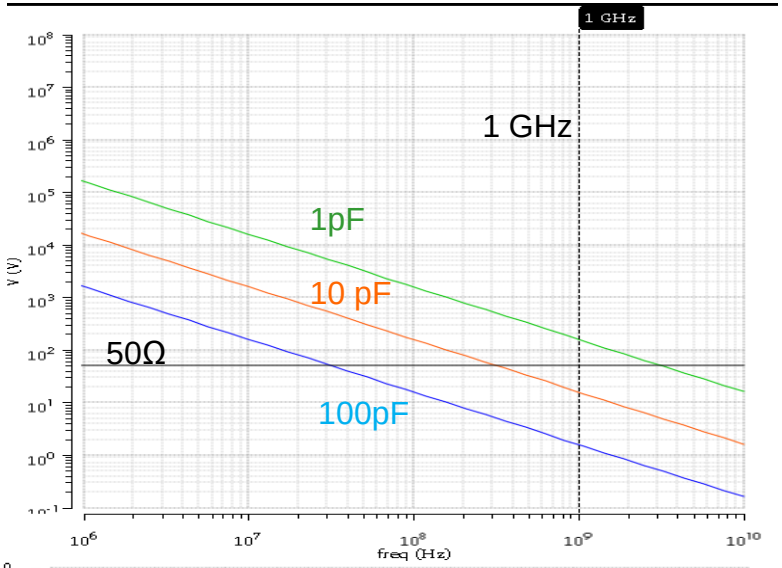
Detector impedance and input voltage

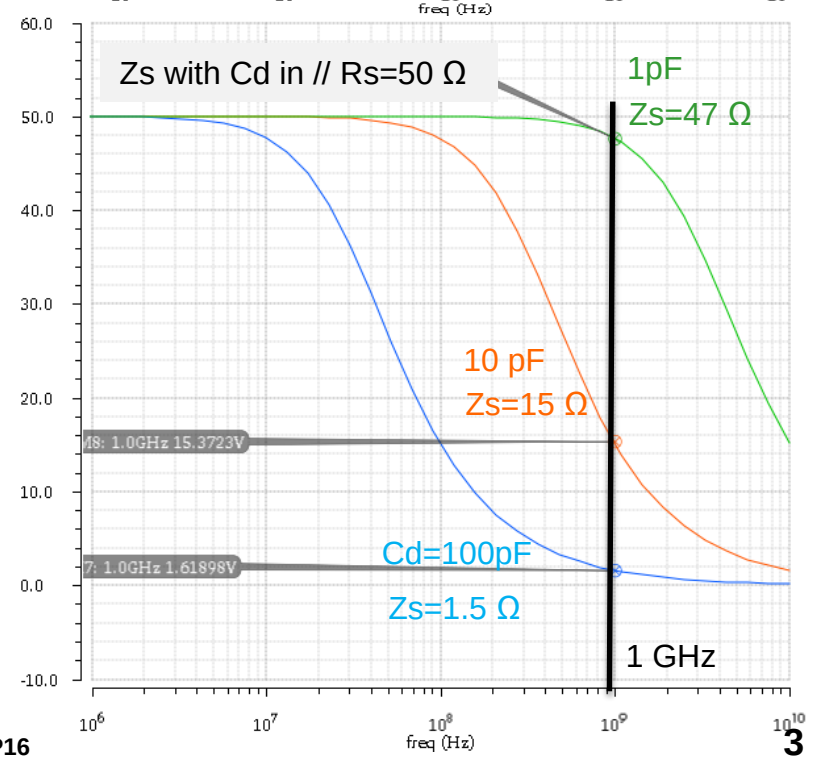
- 1 GHz, Cd=few tens of pF, input signal <1ns
- Cd>1 pF, Zs@1GHz dominated by Cd
- Rise time: tr= td when td<<CdRs and tr=CdRs when td>>CdRs







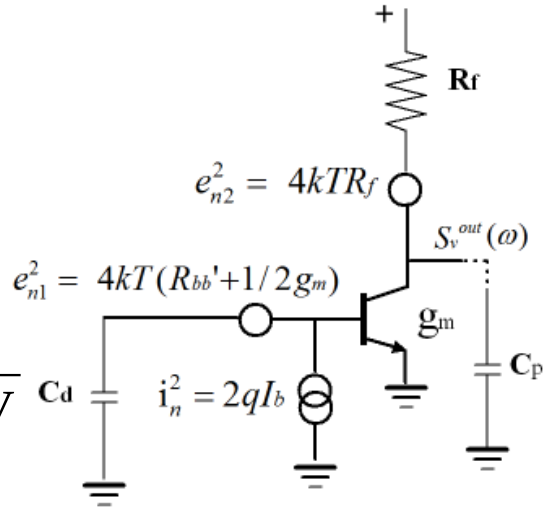




NOISE TZ and CE

- Similar noise for CE and TZ

$$S_v^{out}{}_{MOS}(\omega) = \left(g_m R_f\right)^2 \left(4kTR_{GG'} + \frac{4kT\Gamma}{g_m} \right) + 4kTR_f + k\frac{I_D}{f}$$



- rms noise v_n depends on the √BW
- Noise is independent of Cd

$$N = v_n \approx R_f \sqrt{2kTg_m BW}$$

- Signal scales with 1/ Cd

$$V_{OUT} = -g_m R_f \frac{Q_{IN}}{\mathbf{C_d}}$$

- S/N depends on Cd and BW

$$\frac{S}{N} \approx \frac{\alpha Q\sqrt{g_m}}{C_d\sqrt{BW}} \approx \alpha \frac{Q\sqrt{g_m}\sqrt{t_{r_ampli}}}{C_d}$$

- Jitter :

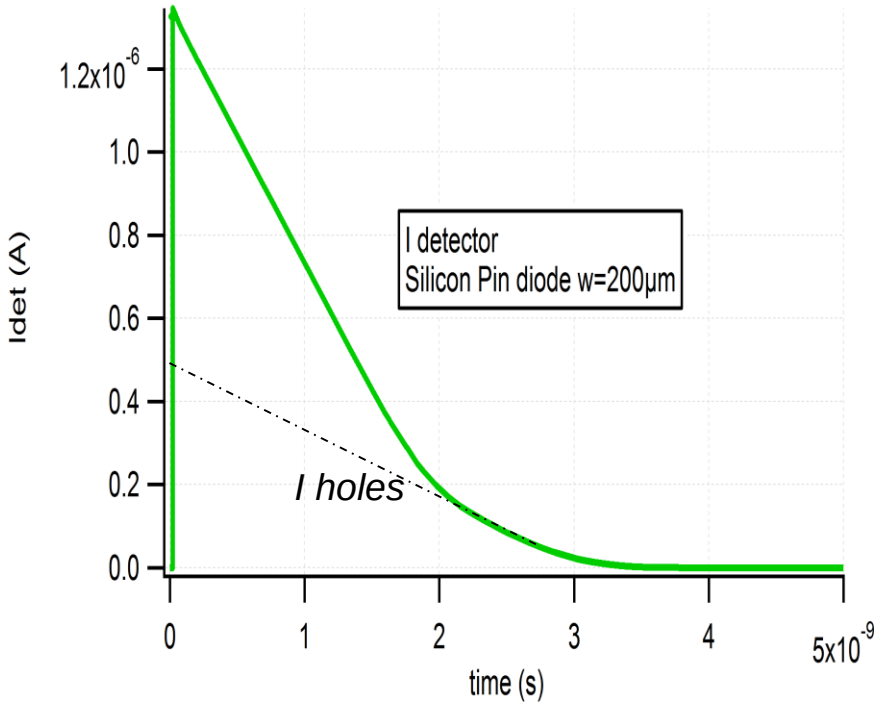
$$\sigma_t^{\ J} = \frac{N}{dV/dt} = \frac{\sqrt{t_{r_a}^2 + t_d^2}}{S/N} = \alpha \frac{C_d}{Q\sqrt{g_m}} \frac{\sqrt{t_{r_a}^2 + t_d^2}}{\sqrt{t_{r_a}}}$$

Optimum value: $t_{r_a} = t_d$ (current duration)

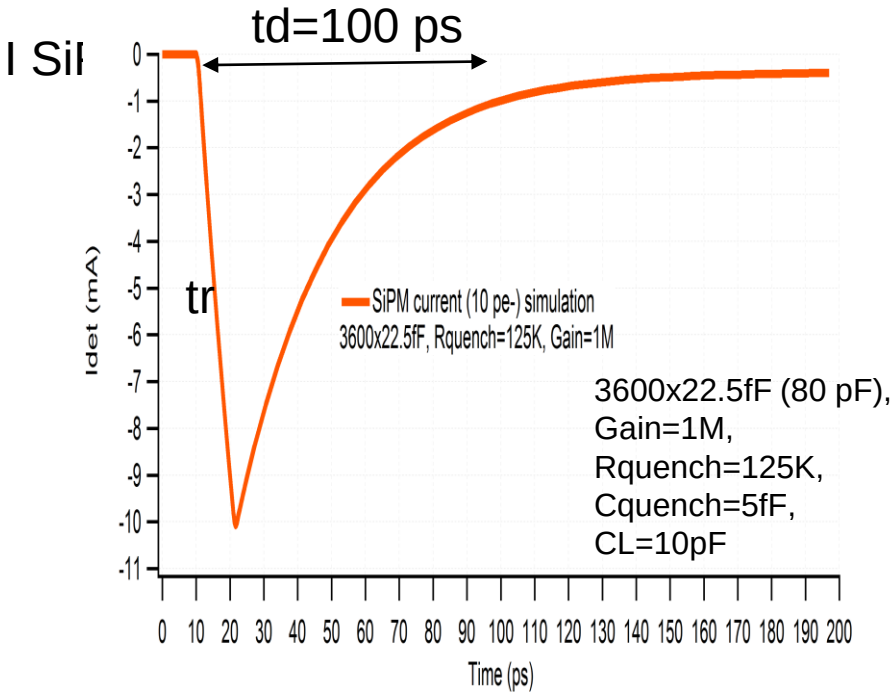
$$\sigma_t^{\ J} \approx \alpha . \frac{C_d}{Q} \sqrt{\frac{t_d}{g_m}}$$

Detector current

- PIN diode w =200µm
- Very short rise time : tr~10ps
- Relatively long «drift time» : td~2ns



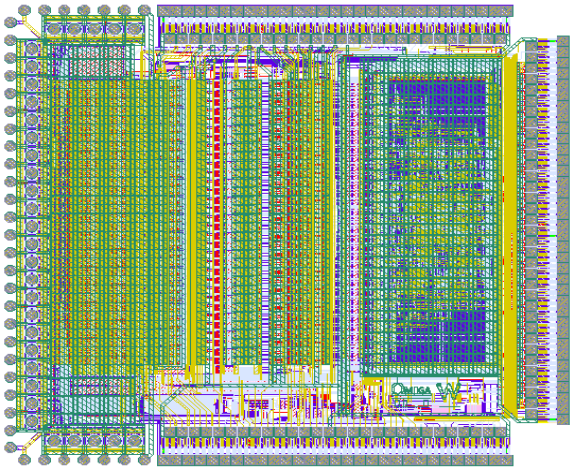
- SiPM detector (10pe-)
- very short rise time : tr~10 ps
- Short duration : td~100ps),



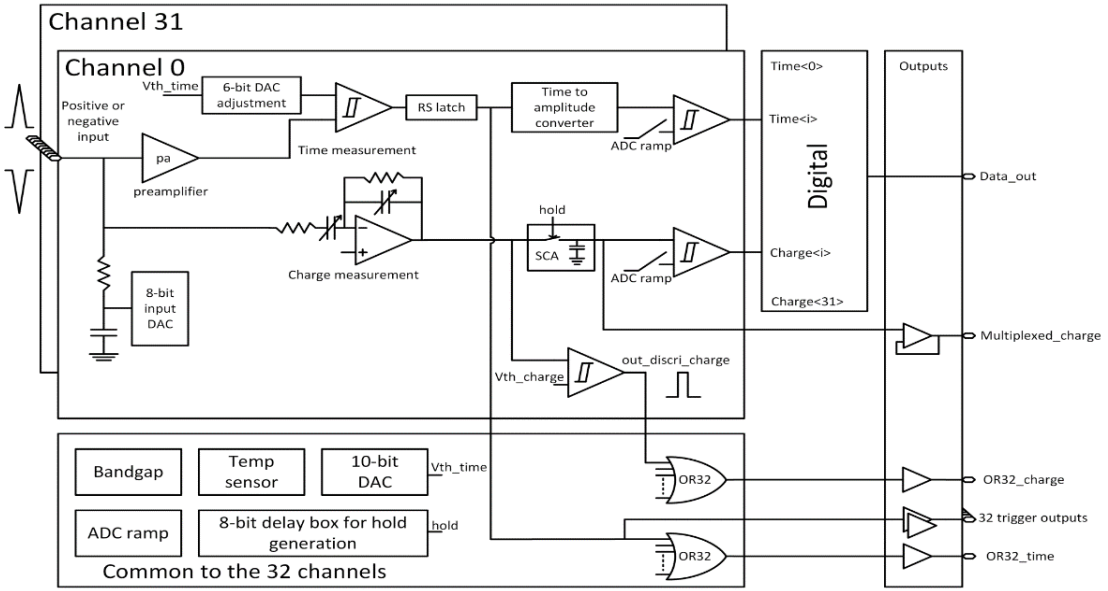
PETIROC2 DESCRIPTION

- Time of Flight read-out chip with embedded TDC (25 ps bin) and ADC
- Dynamic range: 160 fC up to 400 pC
- 32 channels (negative input)
  - 32 trigger outputs
  - NOR32_chrage
  - NOR32 time
  - Charge measurement over 10 bits
  - Time measurement over 10 bits
  - One multiplexed charge output
- Common trigger threshold adjustment and 6bit-dac/channel for individual adjustment
- Variable shaping time of the charge shaper
- 32 8bit-input dac for SiPM HV adjustment
- Power consumption 6 mW/ch
- Front-end
  - Broad Band SiGe fast amplifier
  - Fast SiGe discriminator
  - 1 GHz overall bandwidth, gain = 25

AMS 0,35µm SiGe

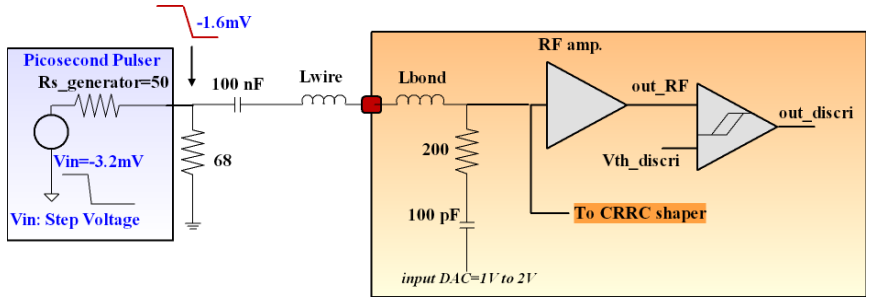


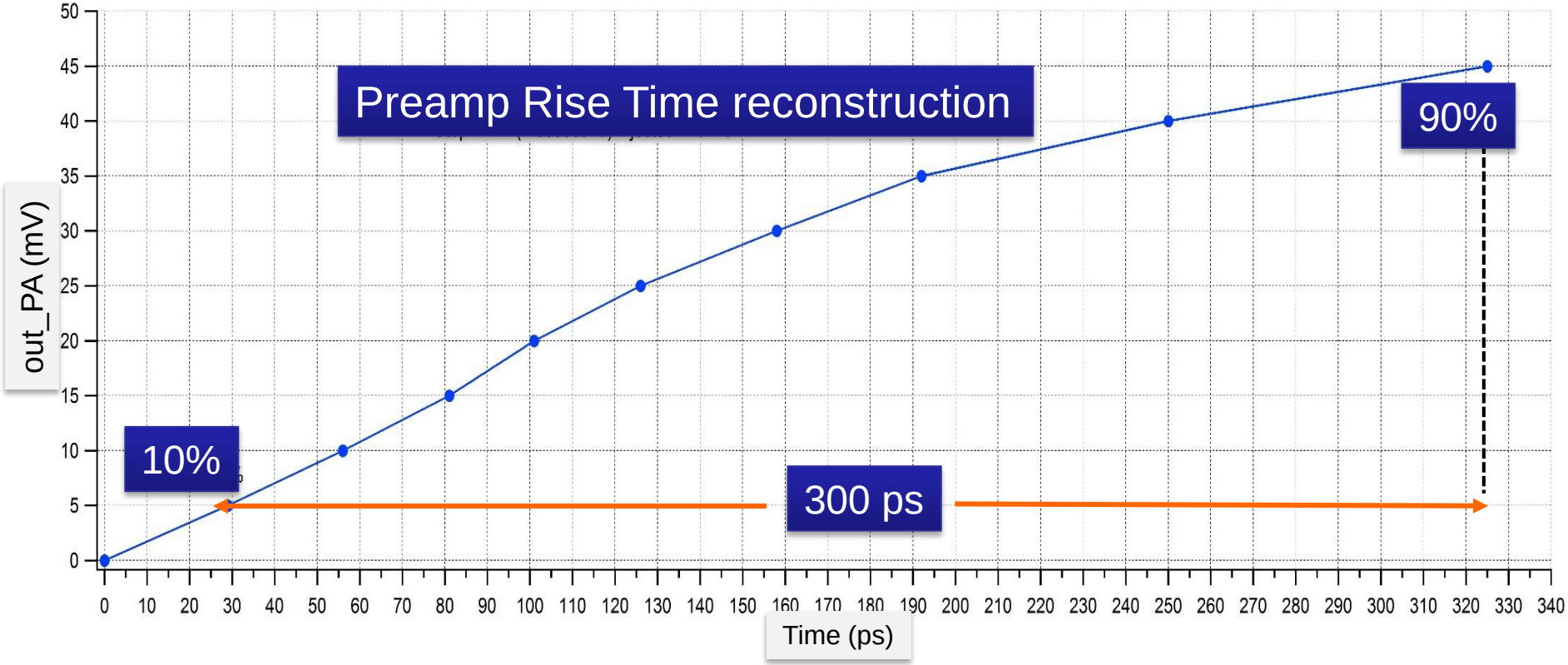
weeroc



PETIROC2A: Rise Time of the PA+discri

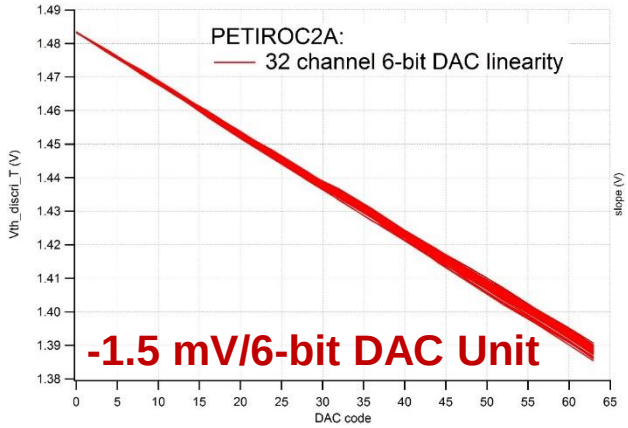
- Injection of a step of 2 mV in ch20,
- reconstruction of pulse by discriminator
- **tr 10%-90% = 300 ps,**
- **BW = 0.35 / tr ~ 0.9 GHz**
- **can also use BW = 0.1 / ($t_{50\%}$ - $t_{10\%}$)**

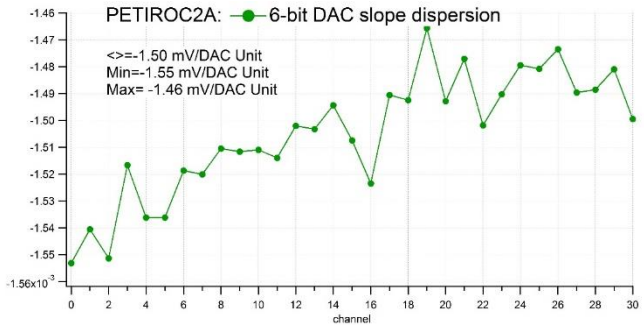


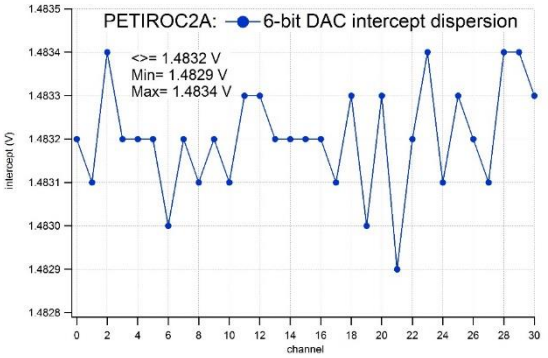


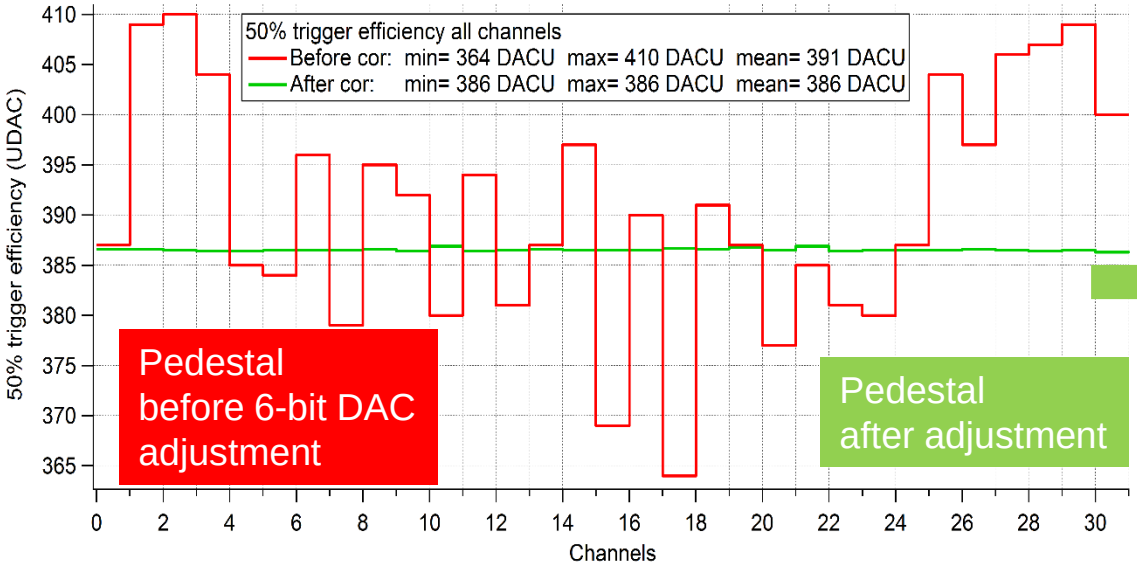
6bit-DAC for pedestal adjustment

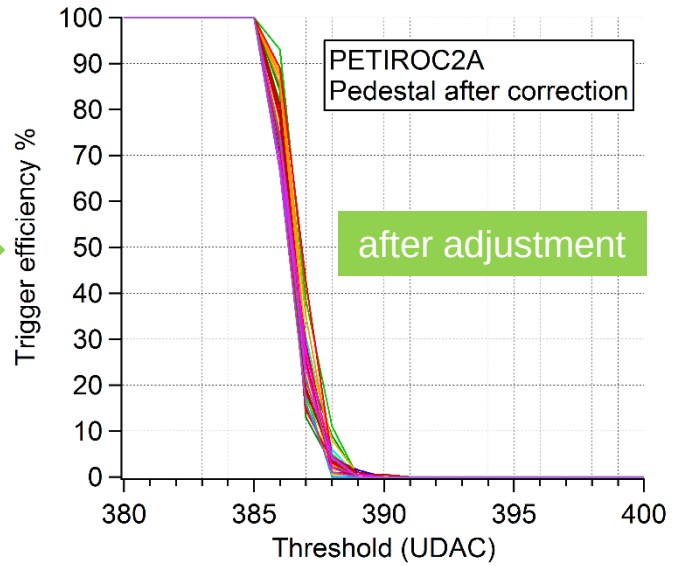
- Preamp: Open loop => dispersion of the pedestal
- 6 bit dac/channel for pedestal uniformization



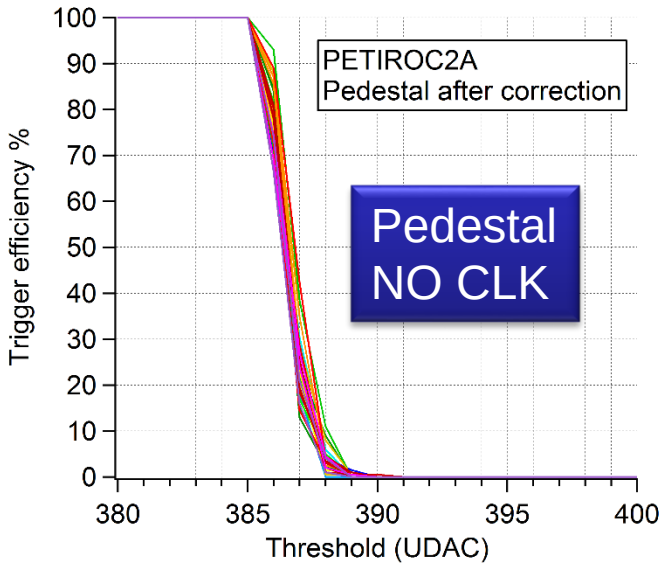


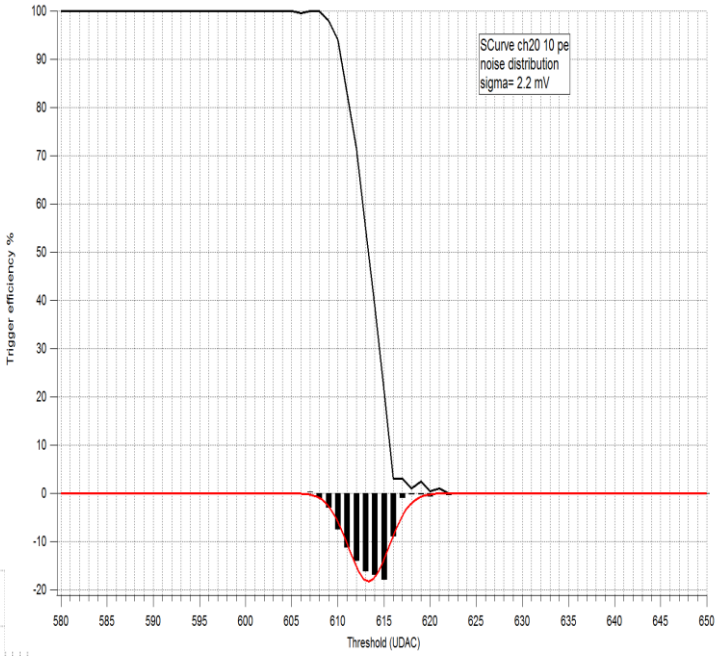


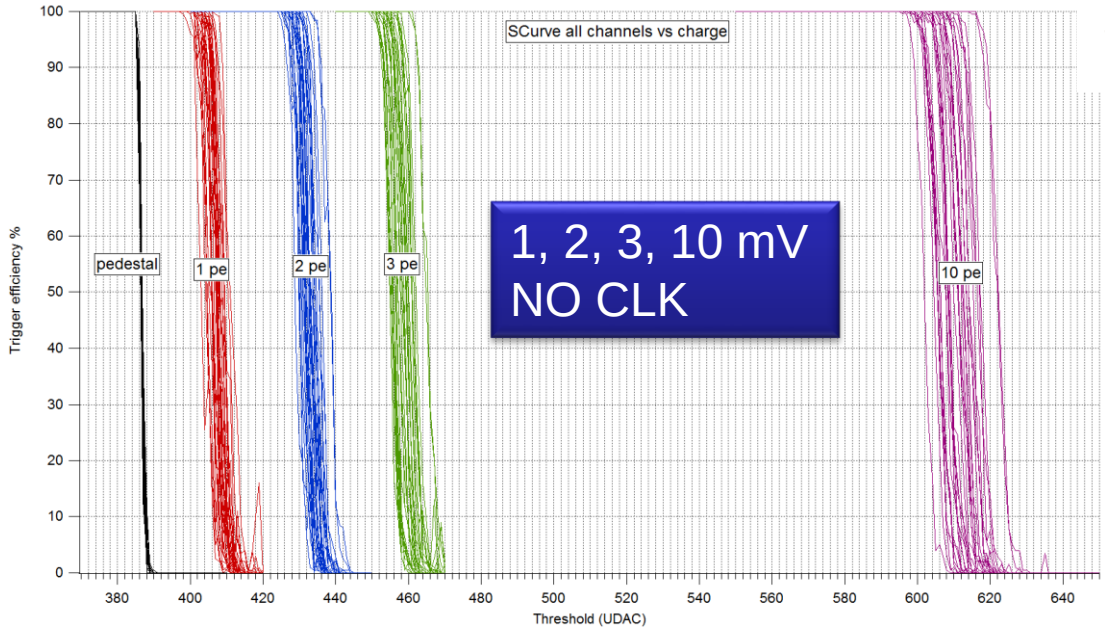




TRIGGER EFFICIENCY MEASUREMENTS

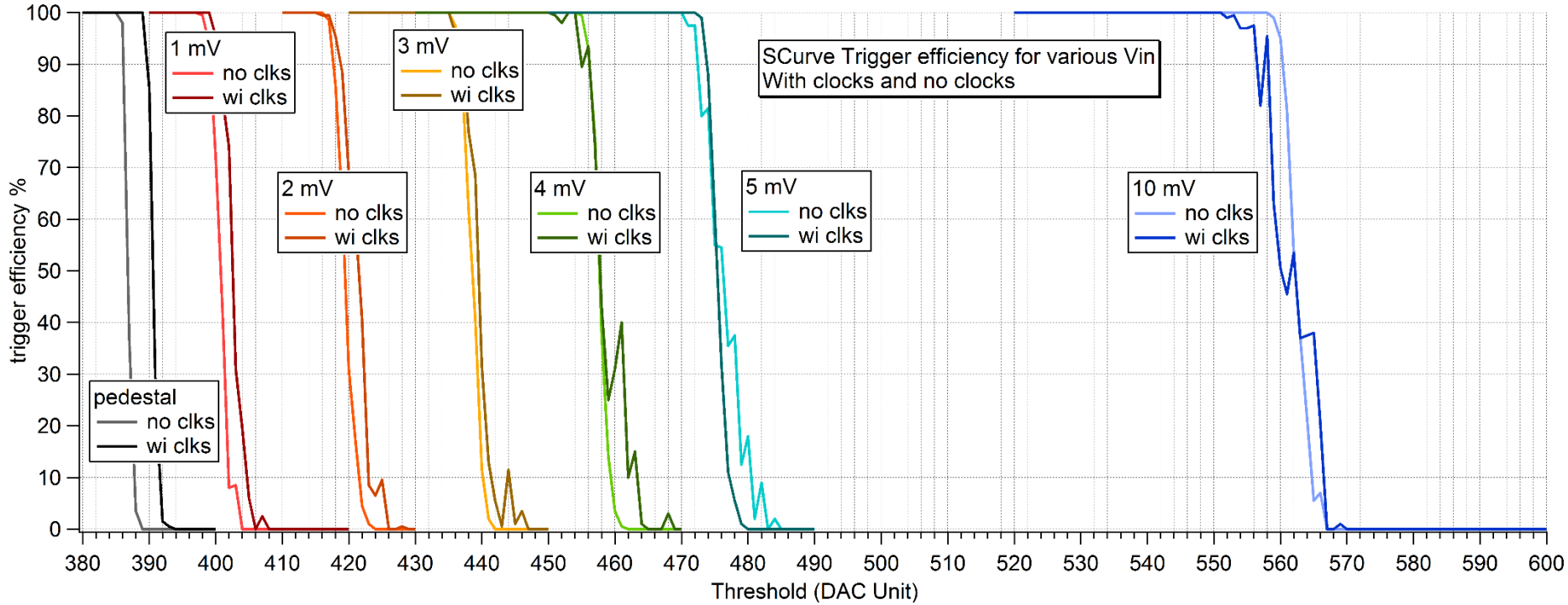


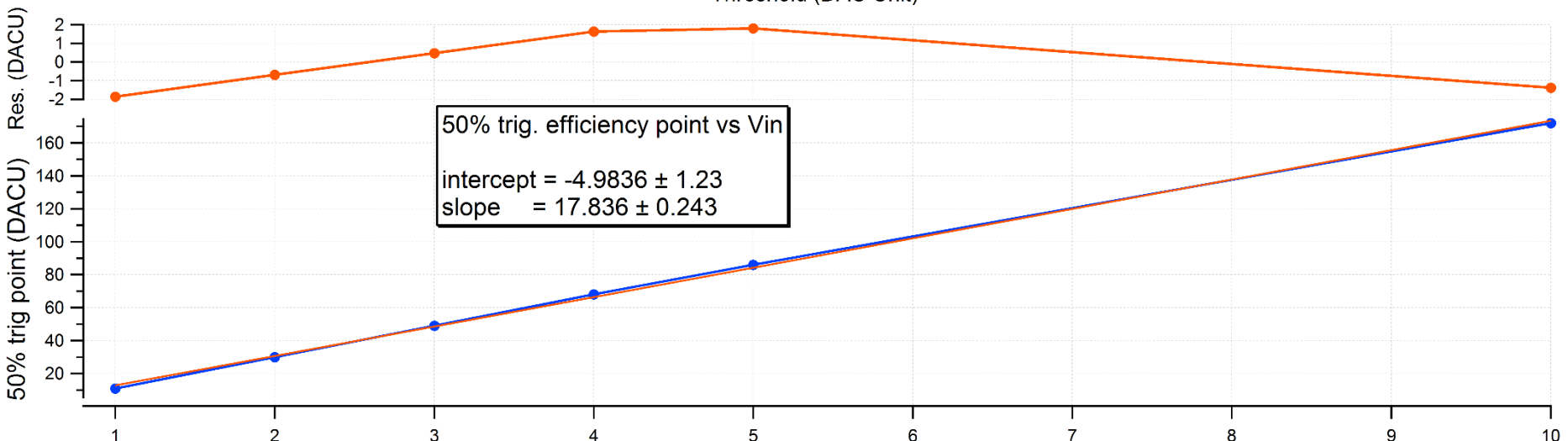




SCURVES with and w/o clock

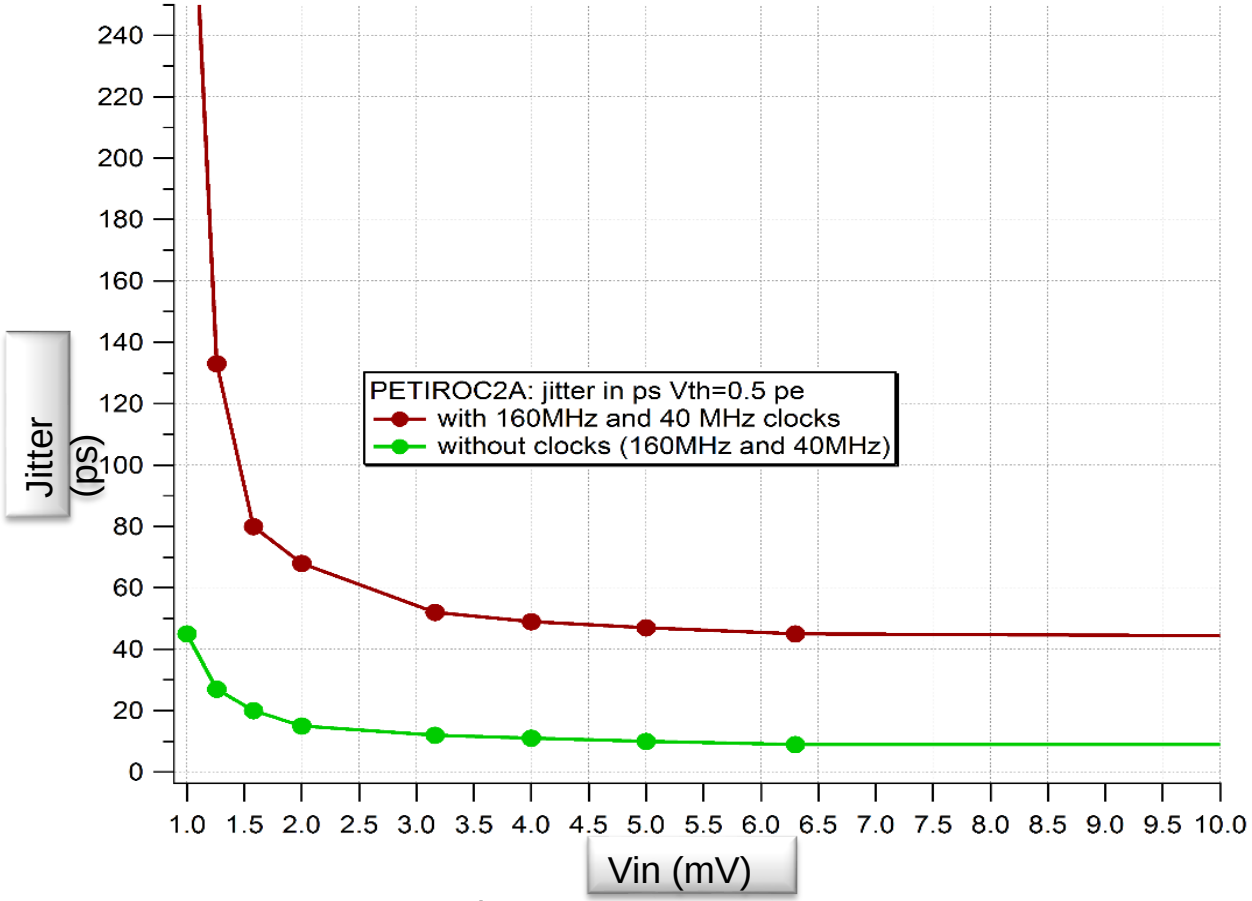
- Injection of a step (1mV, 2mV, 3mV, 4mV, 5mV and 10mV)



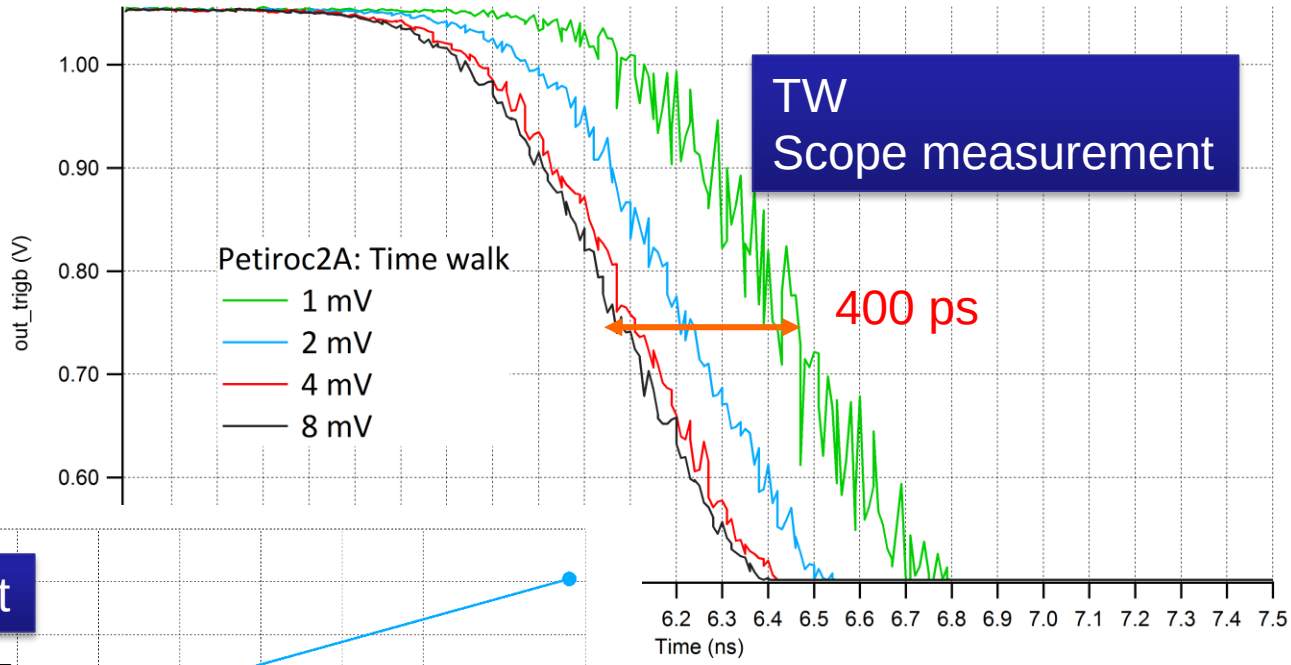


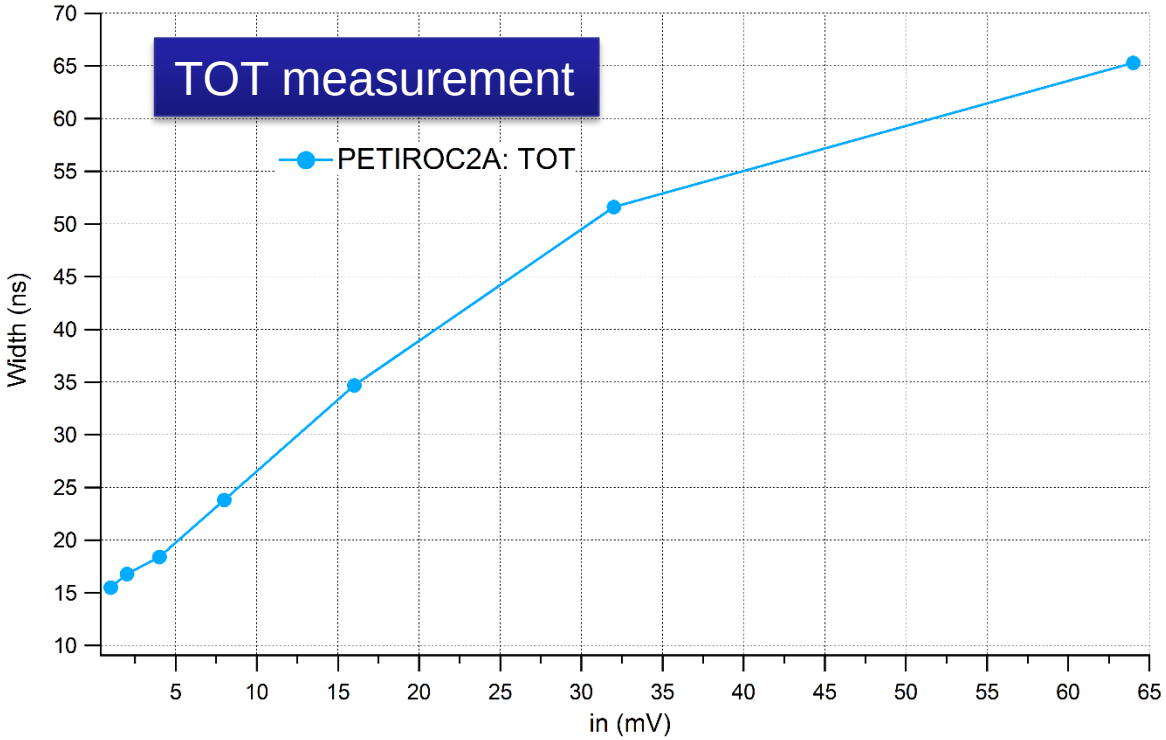
JITTER MEASUREMENT

- Jitter vs threshold & injection, Jitter improves with signal
- Clock couplings: through substrate, better results expected with technologies that offer triple well trans (TSMC 130nm)
- Jitter < 40 ps for input pulse > 1mV



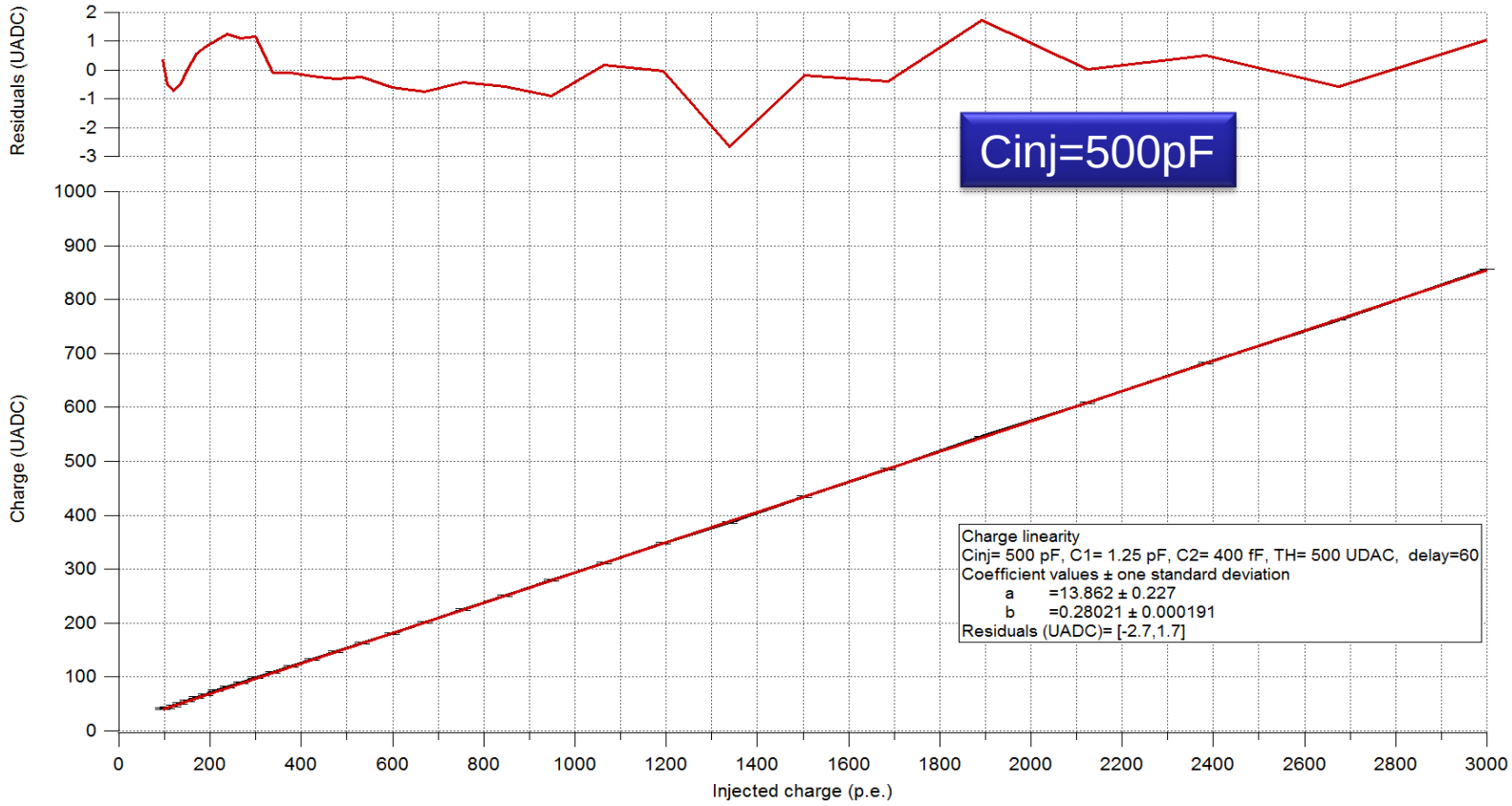
Time Walk and TOT measurements





CHARGE MEASUREMENT

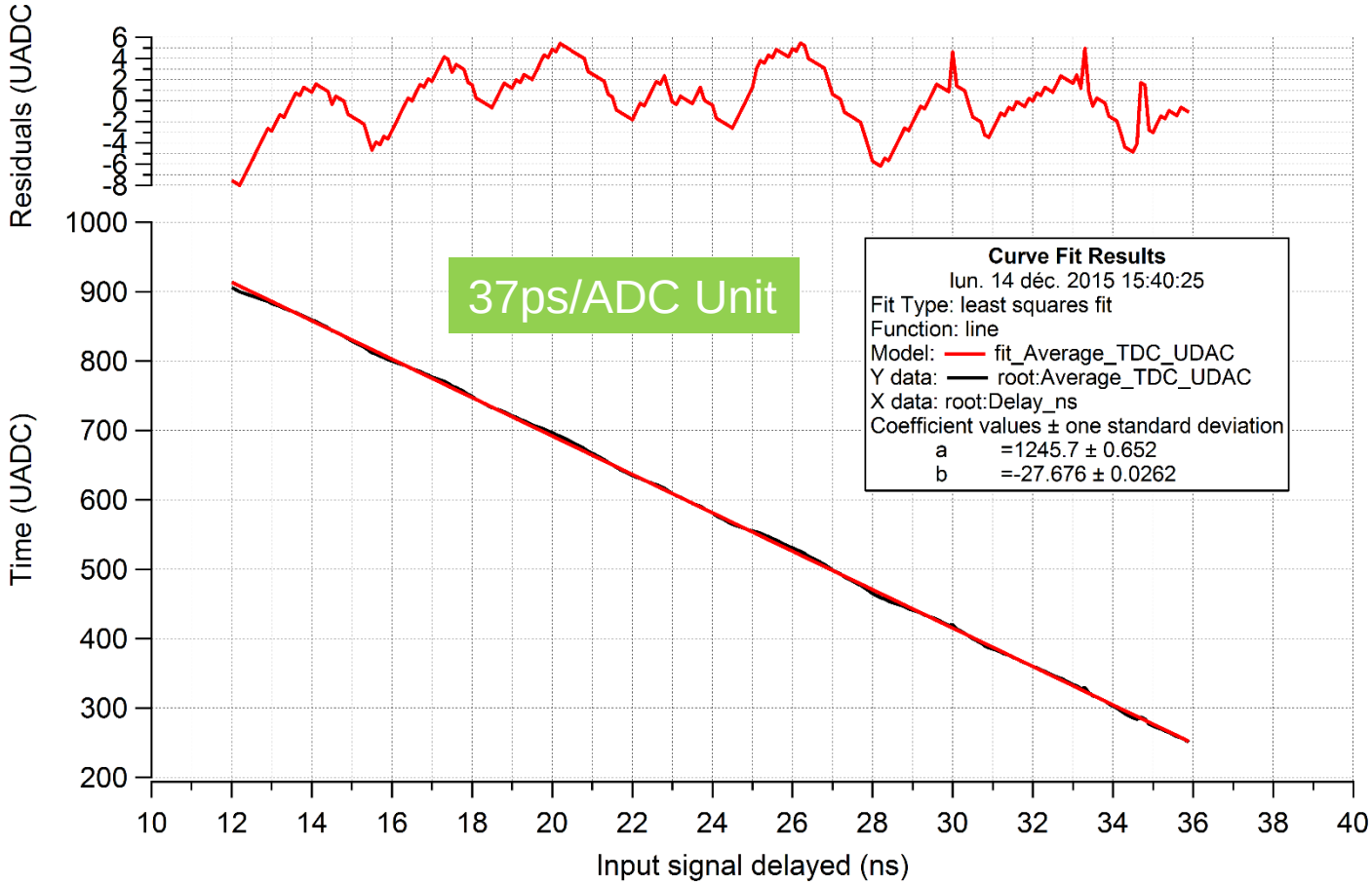
- Linearity within ±3 UADC up to 3000 p.e. (500 pC)
- Using the internal ADC, C1=1.25pF, C2=400 fF
- measurements made with Cinj = 500 pF



Time to Amplitude Convertor measurement

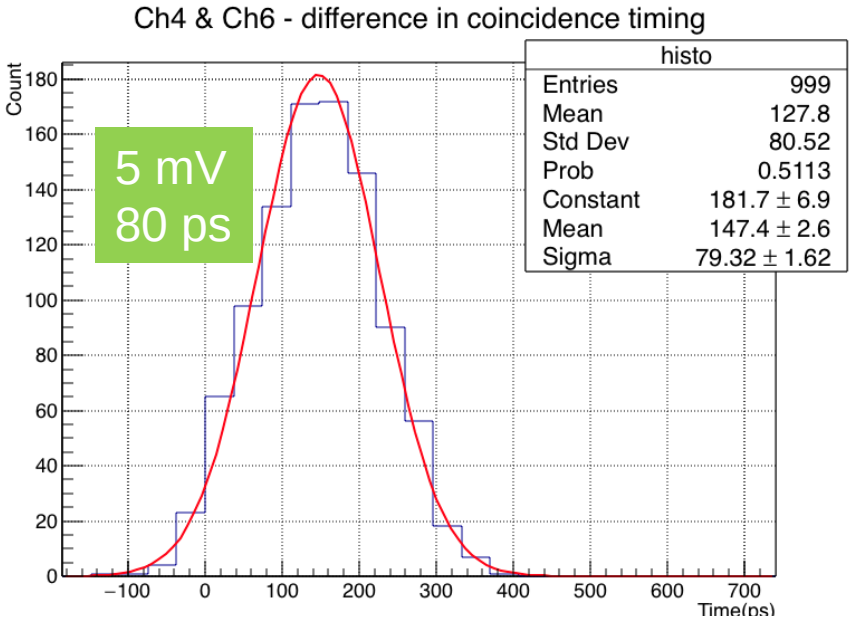
- 160 MHz clock seen on the TDC (residuals)
- *rms* of the residuals: 2.6 ADC Unit

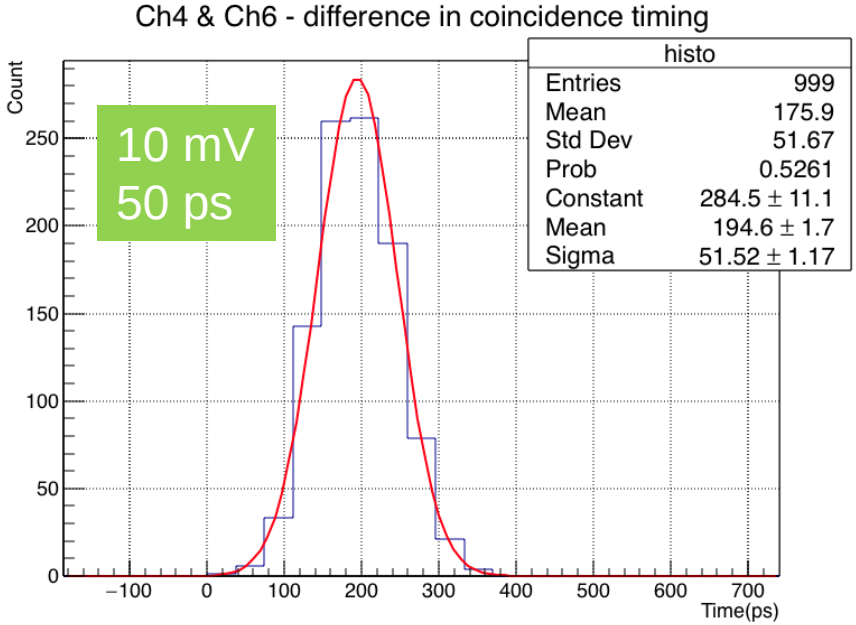
⇒ Time resolution: 2.6x37ps (step)= 100 ps

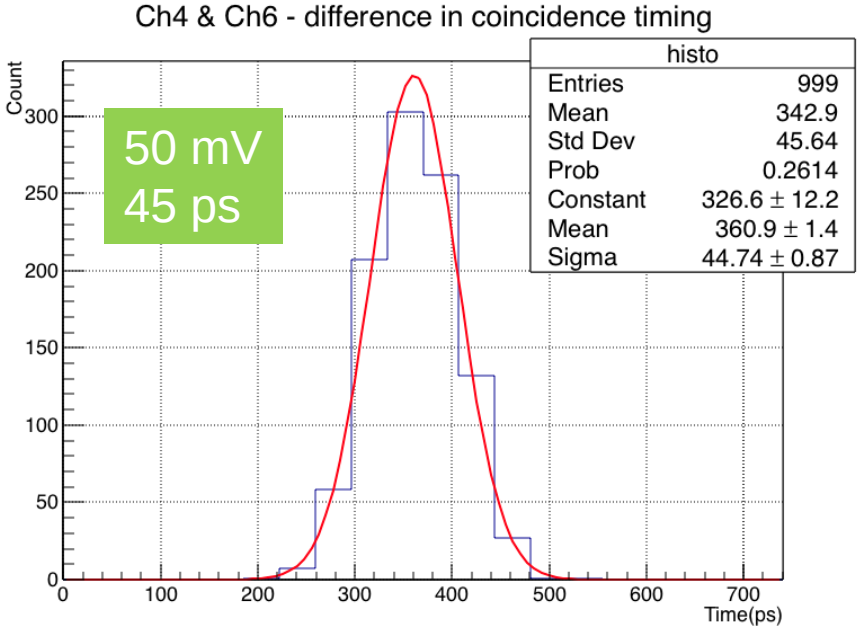


COINCIDENCE with Synchronous CK

- Jitter measurement with innternal TDC
- Synchronous pulse injection
- Remove TDC non linearity
- Constant term : ~50 ps

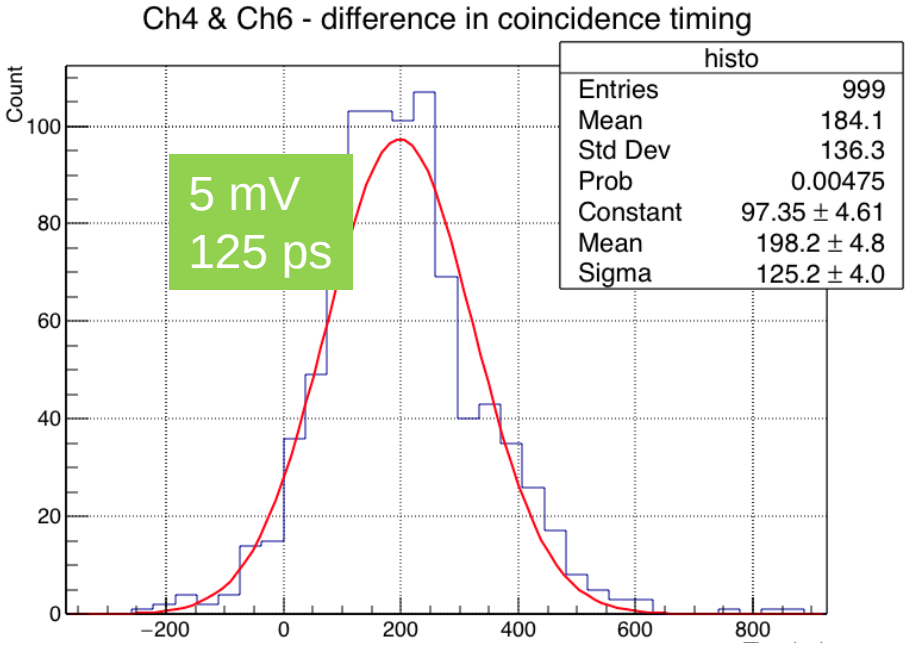


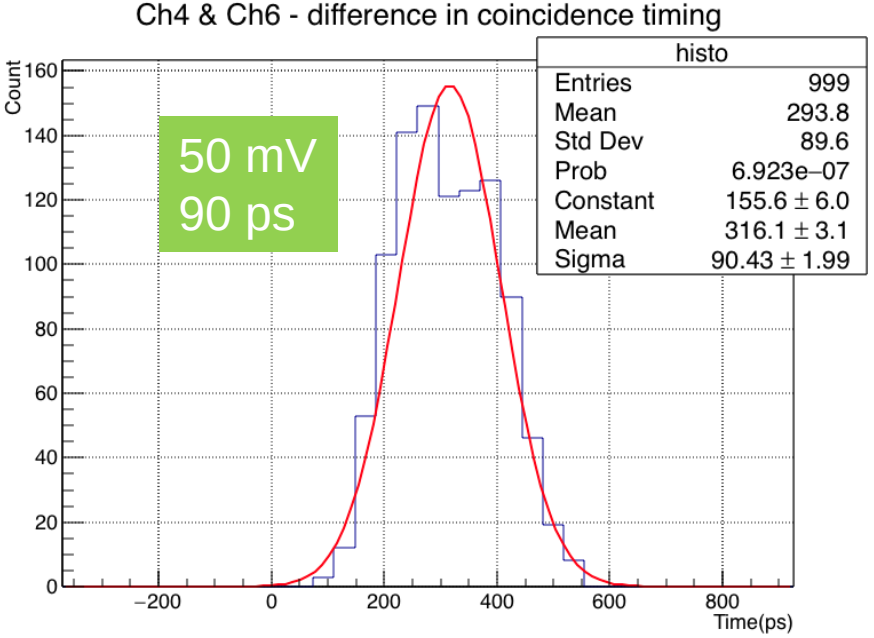




COINCIDENCE with Asynchronous CK

- Jitter measurement with innternal TDC
- Asynchronous pulse injection
- Suffers from TDC non linearity
- Constant term : ~90 ps

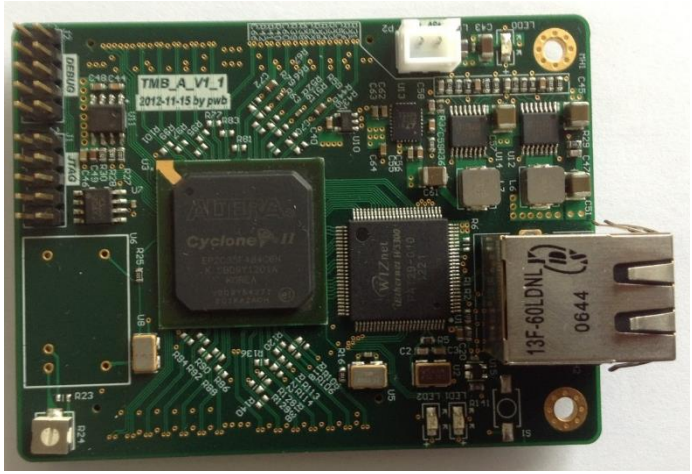


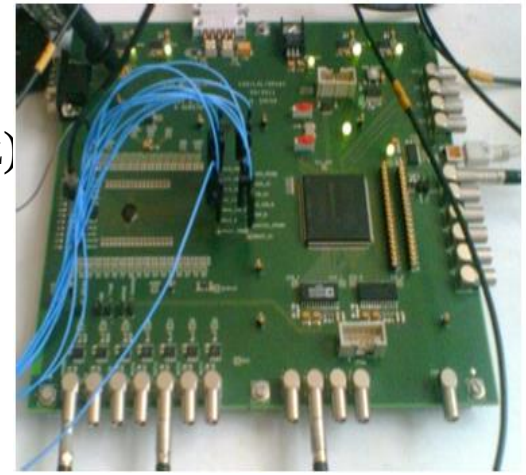


PETIROC2 for Multi-gap CMS-GRPC (1)

@ *I. Laktineh PNL Lyon*

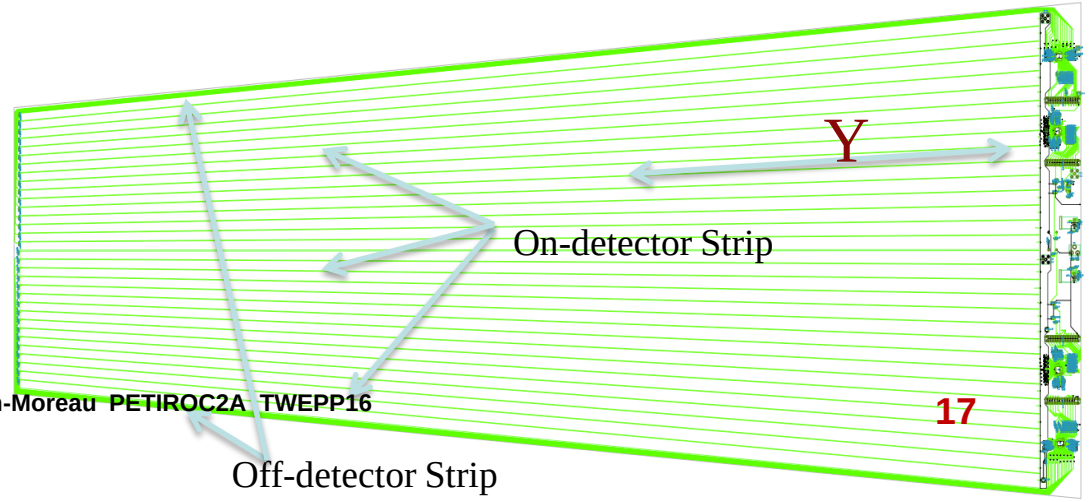
-PETIROC ASIC : 32-channel,
high bandwidth preamp (GBWP> 10 GHz)
<3 mW/ch, dual time and charge
measurement (160 fC-400 pC)
vey fast and low-**jitter < 25 ps rms**





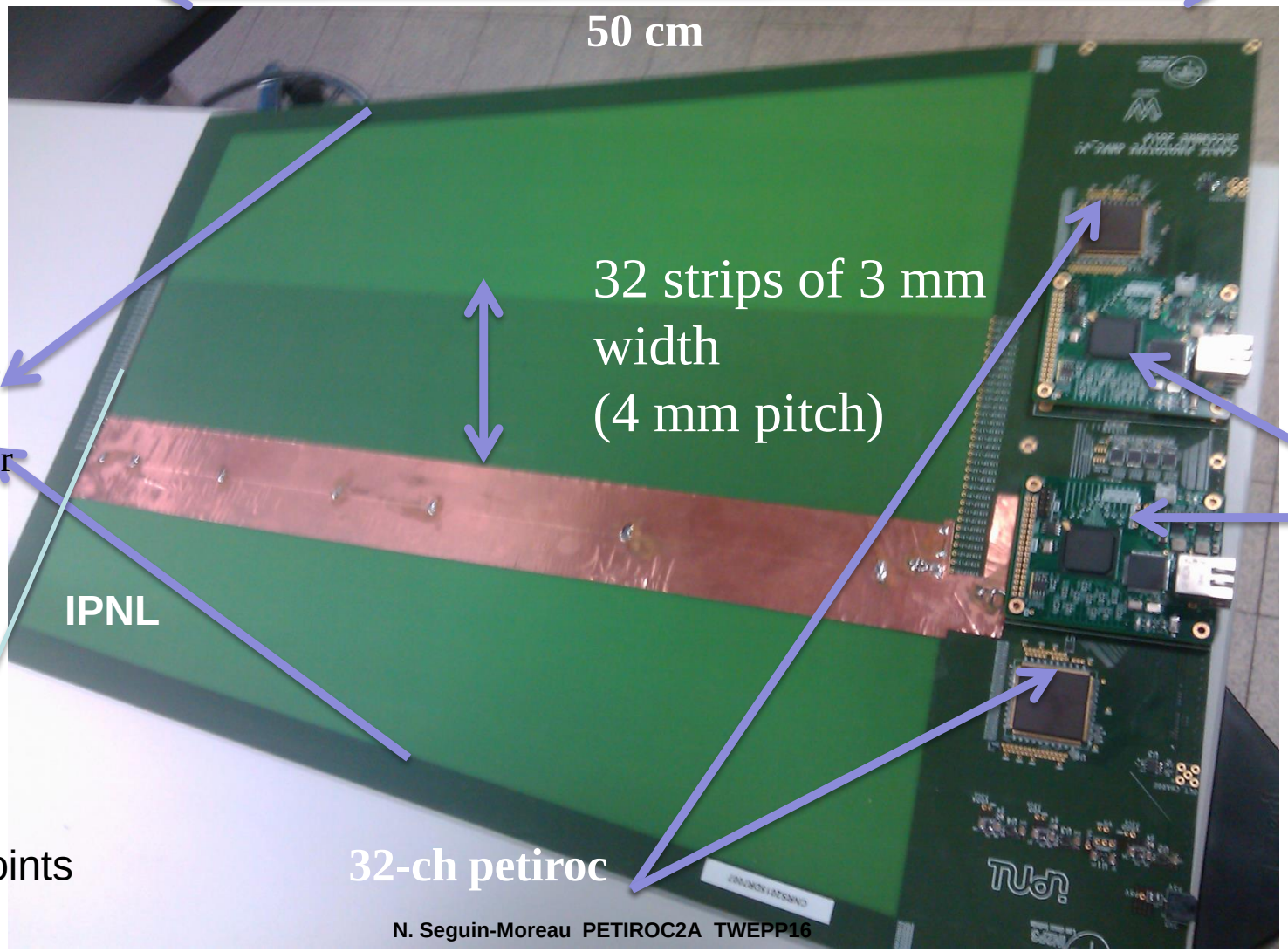
- 24-ch, TDC of 25 ps time resolution developed by the Tsinghua university will be used to demonstrate the RPC/MRPC time

-.New PCB with pick-up strips read from both sides is being designed information with the aim to achieve Y-position determination $\mathbf{Y= L/2-v*(t_2-t_1)/2}$.
Time resolution can be measured:
$\mathbf{(t_1+t_2)- L/v}$



PETIROC2 for Multi-gap CMS-GRPC (2)

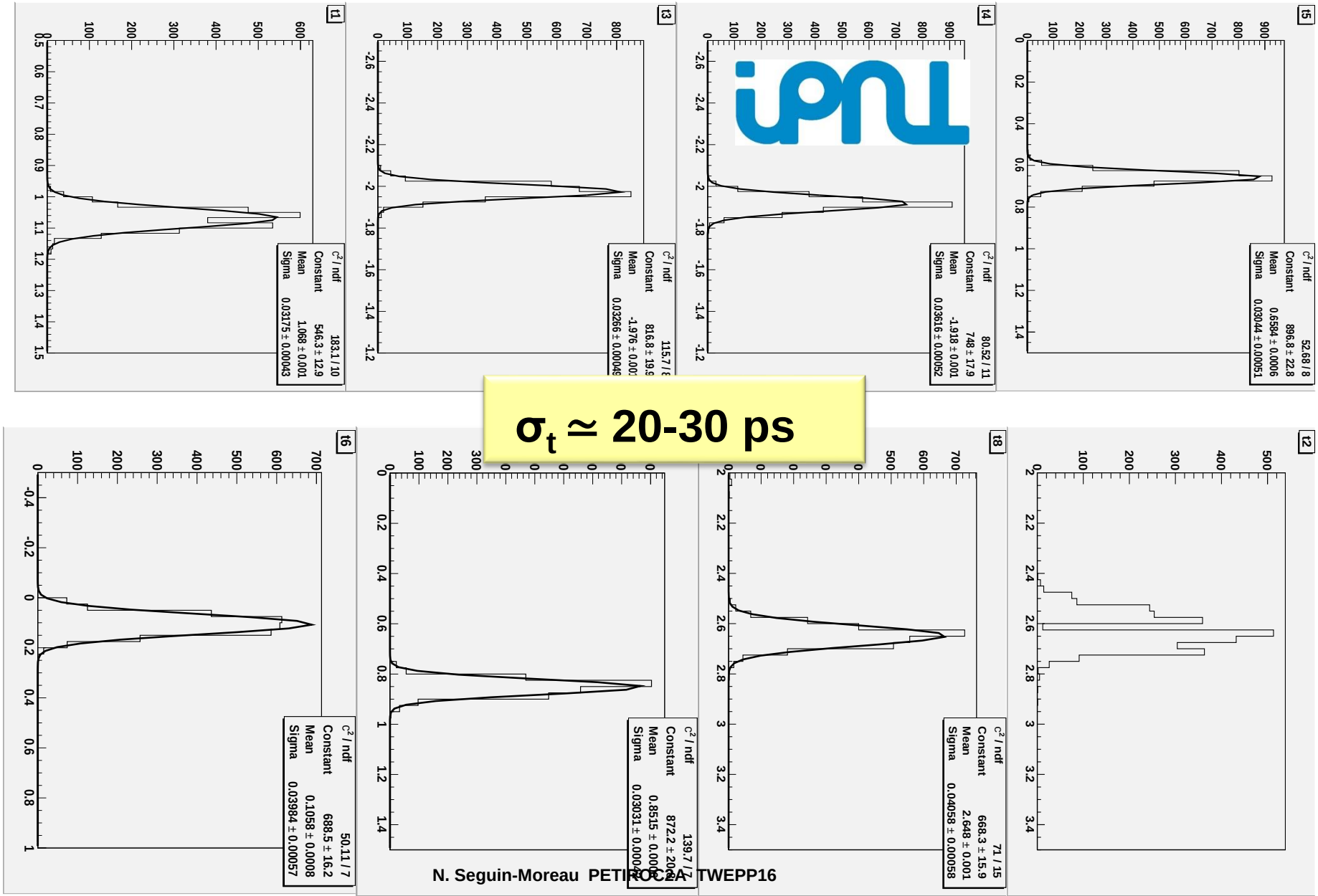
A PCB was conceived to host : Pickup strips, 2 PETIROC, 2 TDC
A DAQ system was developed. The PCB is intended to equip large chambers



PETIROC2 for Multi-gap CMS-GRPC (3)

Omega

Injecting charge on test points and then recording time difference $\Delta T=T_2-T_1$



$\sigma_t \simeq$ 20-30 ps

SUMMARY

- PETIROC2A features high speed time and charge measurement
  - 32 channels braodband amplifiers+discriminators
  - G = 25 BW = 0.9 GHz GBW = 20 GHz
  - Minimum Threshold <1 mV
  - Low power : 6 mW/ch
  - 10 ps jitter in analog operation (external TDC)
  - 50 – 90 ps with internal TDC (synchronous/asynchronous)

BACKUP

CE and TZ frequency response for Cd>>1pF

- **CE** using an OTA with gain G_m
  - $V_{OUT} = -G_m (Z_F // Z_L) V_{IN}$

With Z_L neglected and Z_s=C_d and Z_F=R_F

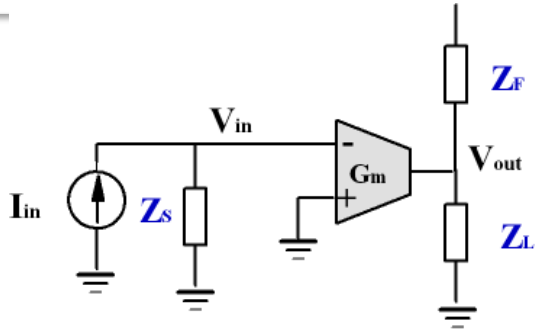
- $V_{IN} = Z_S I_{IN} = \frac{1}{j\omega C_d} I_{IN}$
- $V_{OUT} = -G_m Z_F V_{IN} = -\frac{G_m ZF}{j\omega C_d} I_{IN}$
- $\mathbf{V_{OUT} = -G_m R_F \frac{Q_{IN}}{C_d}}$
- $Z_{IN} = Zs \Rightarrow C_d$
- $Z_{OUT} = Z_F = R_F$

TZ using an OTA with gain G_m

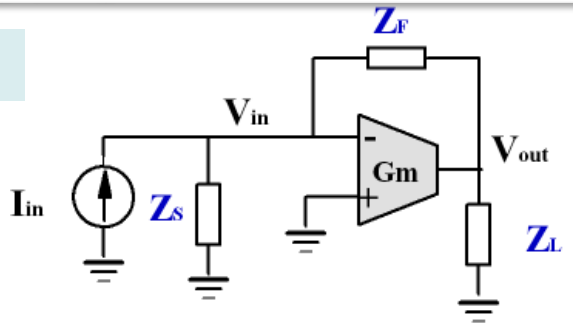
- $I_{OUT} = V_{OUT} / Z_L + (V_{OUT} - V_{IN}) / Z_F$
- $I_{IN} = V_{IN} / Z_S - (V_{OUT} - V_{IN}) / Z_F$
- $I_{OUT} = -G_m V_{IN}$

With Z_L neglected and Z_s= C_d and Z_F=R_F

- $I_{IN} = \frac{V_{in}}{Z_s} - I_{OUT}$
- $V_{IN} = \frac{I_{IN}}{(\frac{1}{Z_s} + G_m)} = \frac{\frac{1}{G_m}}{1+j\omega\frac{C_d}{G_m}} I_{IN}$
- $V_{OUT} = (1 - G_m Z_F) V_{IN}$
- $\mathbf{V_{OUT}} = \frac{\frac{1}{G_m} - R_F}{1+j\omega\frac{C_d}{G_m}} I_{IN} \approx -G_m R_F \frac{I_{IN}}{j\omega C_d} = \mathbf{-G_m R_F \frac{Q_{IN}}{C_d}}$
- $Z_{IN} = \frac{\frac{1}{G_m}}{1+j\omega\frac{C_d}{G_m}} \Rightarrow 1/G_m$ in // with C_d
- $Z_{OUT} = \frac{R_F}{1+G_m R_F} \sim \frac{1}{G_m}$

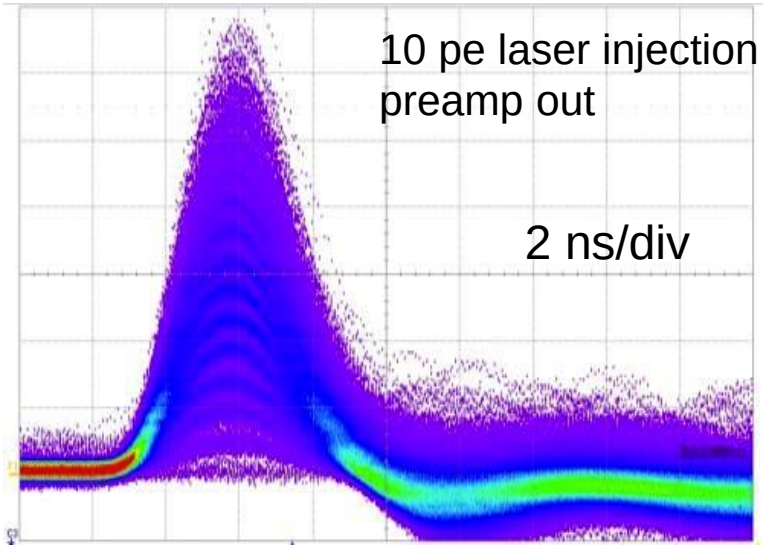
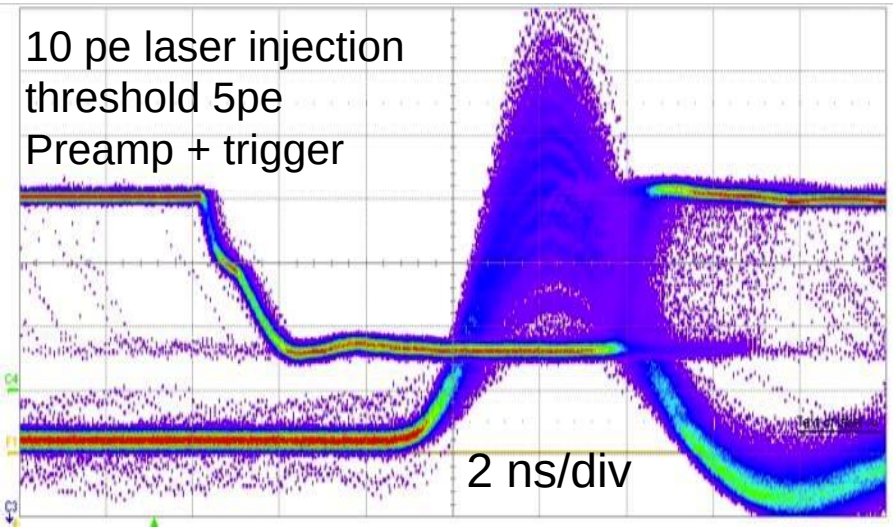
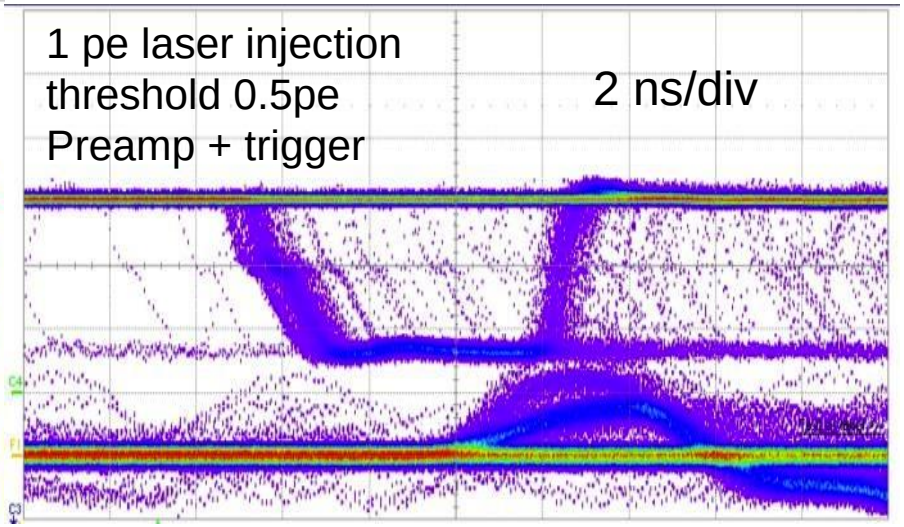


@Nathalie Seguin-Moreau



TRIGGER ON FIRST PHOTONS

- 1x1mm SiPM Hamamatsu
- Laser for low light injection
  - 405nm
  - Jitter : 28 ps FWMH
- Low trigger mandatory for good timing resolution
- Petiroc can trigger on first photoelectron
- Petiroc is low noise : single photon identification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