SKIROC2 measurements

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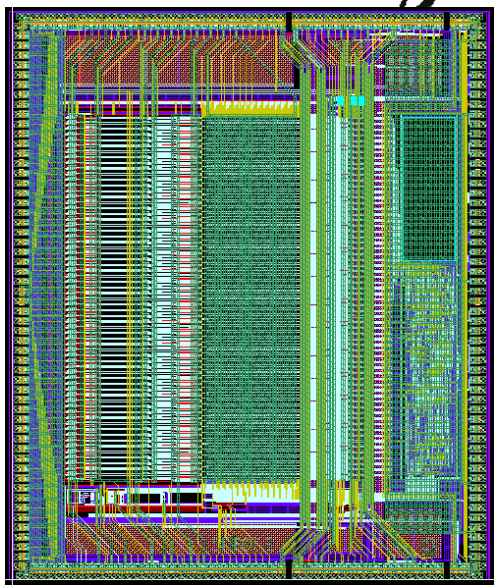
Orsay MicroElectronics Group Associated

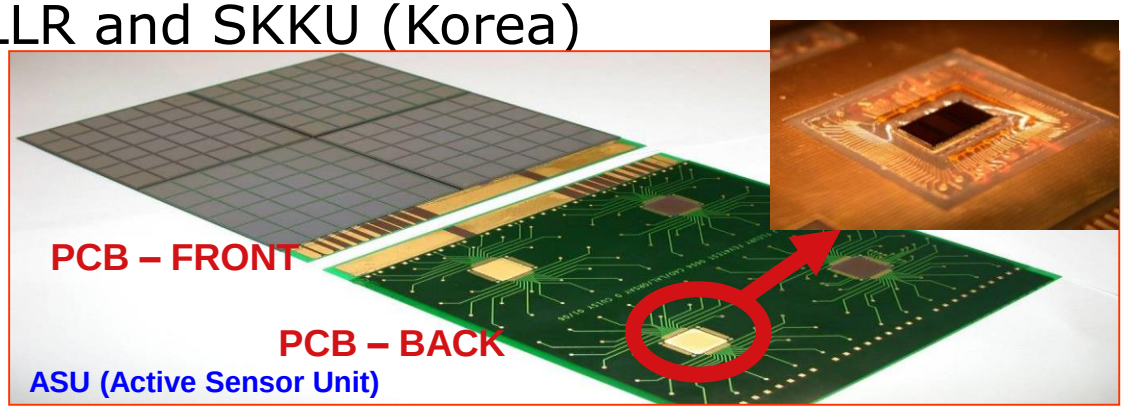
SKIROC : ECAL readout

- SKIROC2 : Silicon Kalorimeter Integrated Read-Out Chip
  - 64 channels, AMS SiGe 0.35 µm, 70 mm^2
  - **Very large dynamic range**:
    - HG for 0.5-150 MIP, LG for 150-2500 MIP
  - Auto-trigger, Analog storage, Digitization & Token-ring ReadOut
  - Testability at wafer level

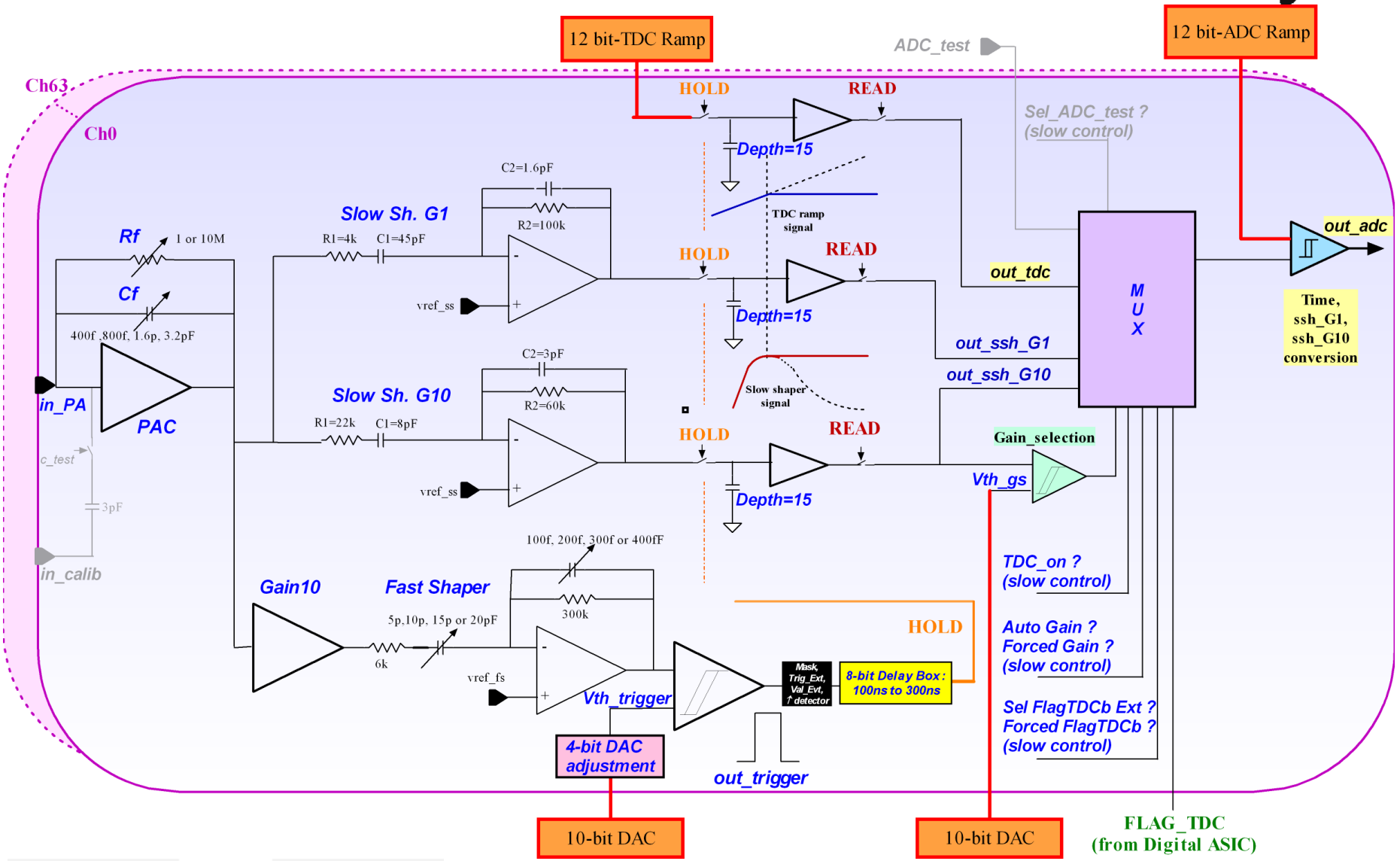


- Front End boards crucial element
  - Collaboration with LLR and SKKU (Korea)

C detector with PCB ≈ 20 pF

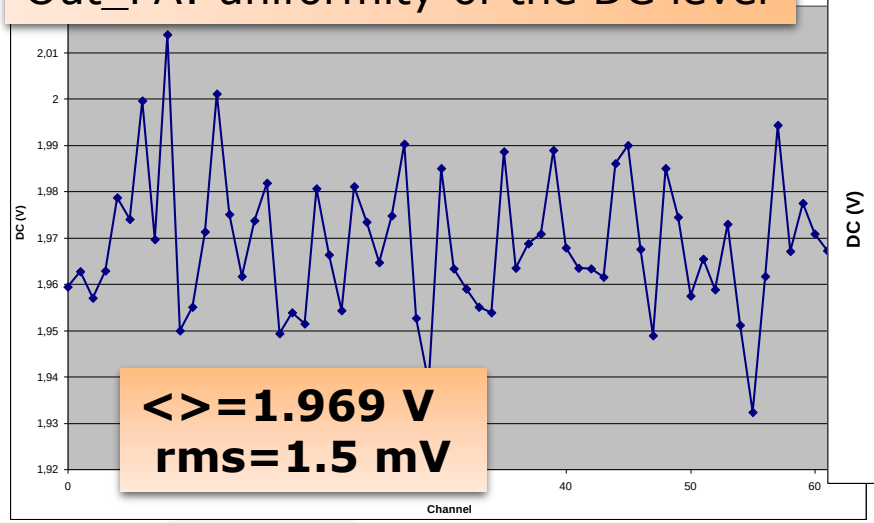


SKIROC2 Analogue core



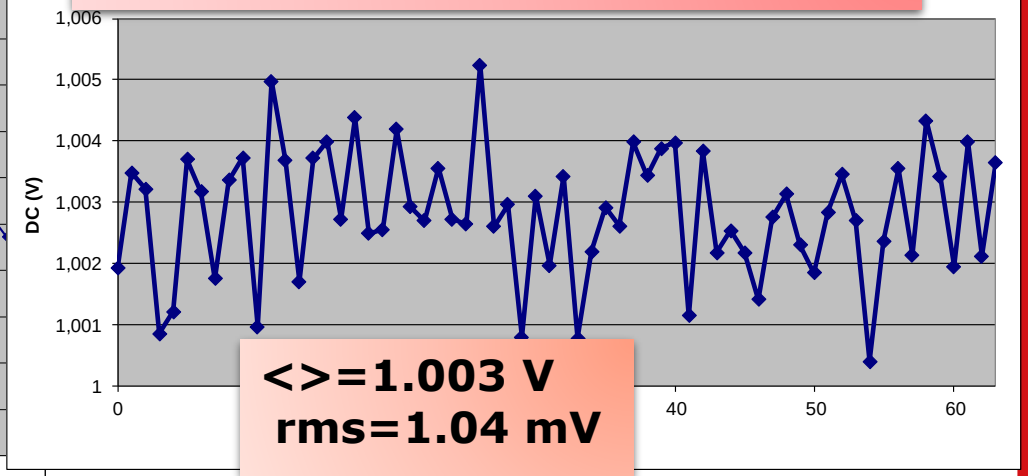
SKIROC2: DC PreAmp, Fast and Slow Shapers

Out_PA: uniformity of the DC level



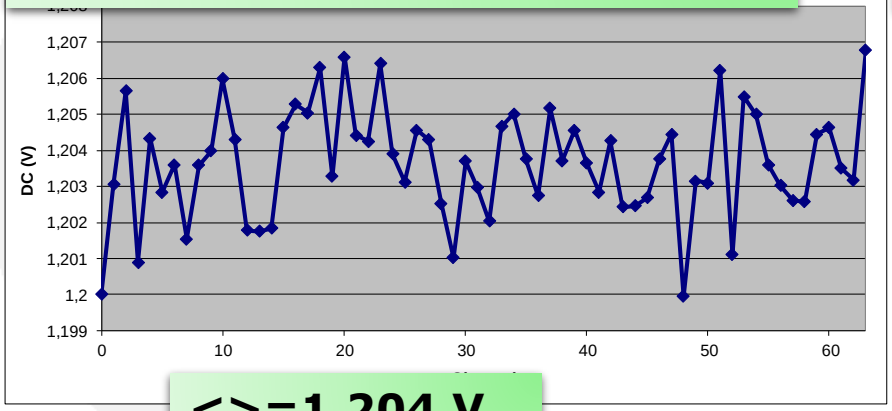
<>=1.969 V
rms=1.5 mV

Out_SS10: uniformity of the DC level



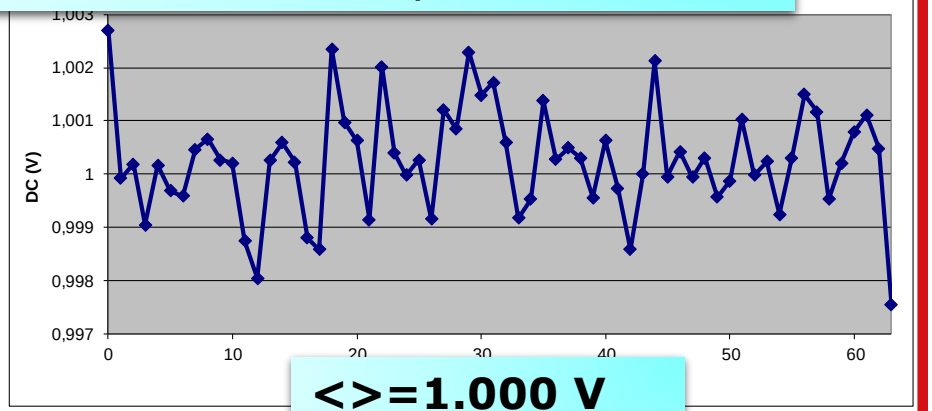
<>=1.003 V
rms=1.04 mV

Out_FS: uniformity of the DC level



<>=1.204 V
rms=1.5 mV

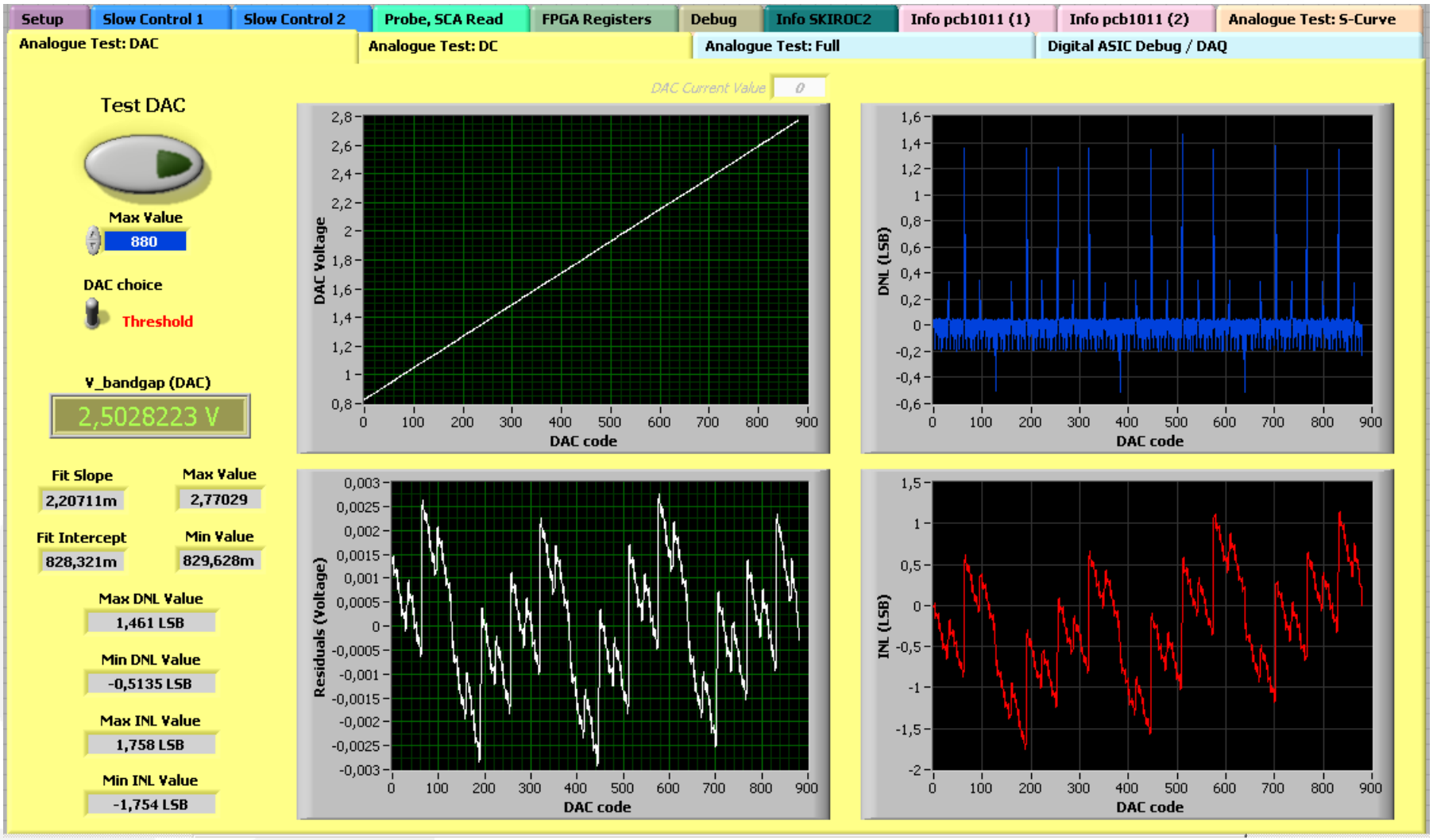
Out_SS1: uniformity of the DC level



<>=1.000 V
rms=1.00 mV

DAC Threshold Linearity

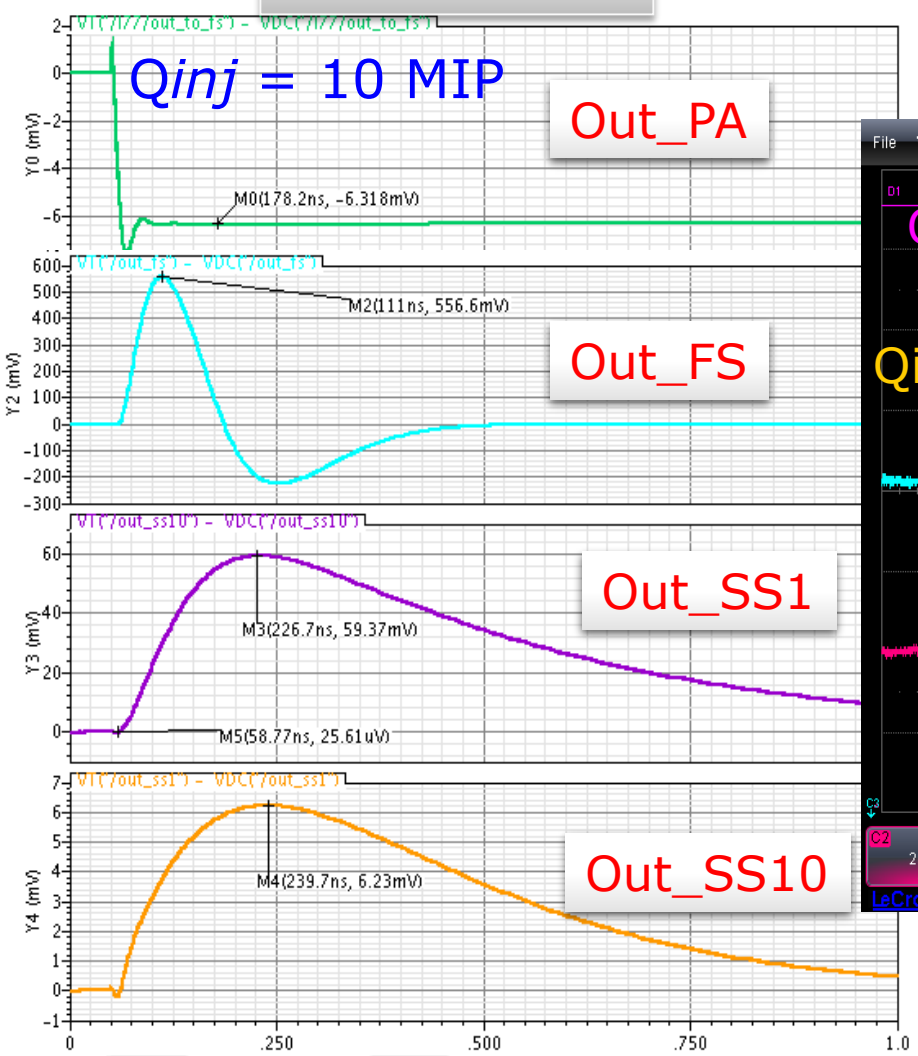
Slope 2.2 mV/DAC Unit, DNL ±1LSB INL= ±1.7LSB



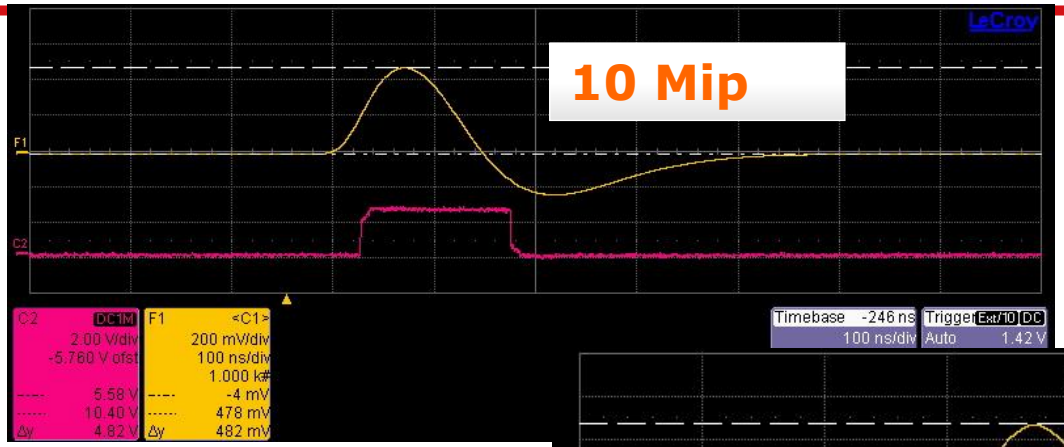
SKIROC2 Analogue Simulations/Measurements

SIMULATIONS

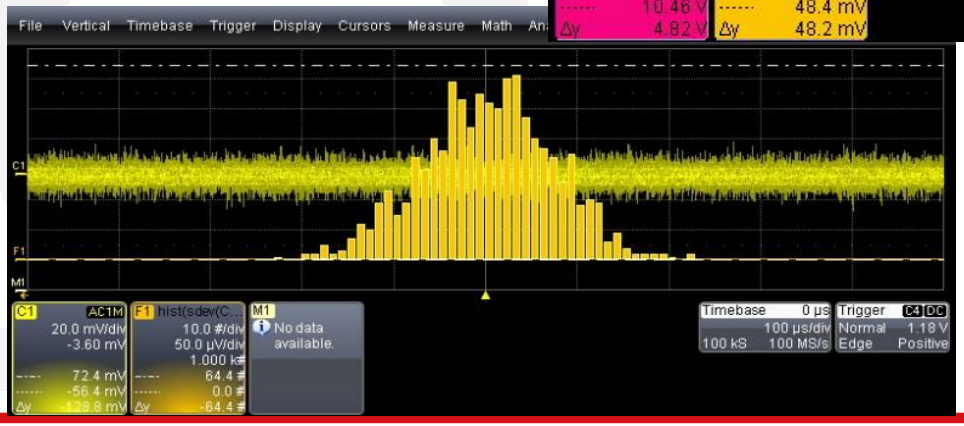
MEASUREMENTS



SKIROC2: Fast Shaper noise

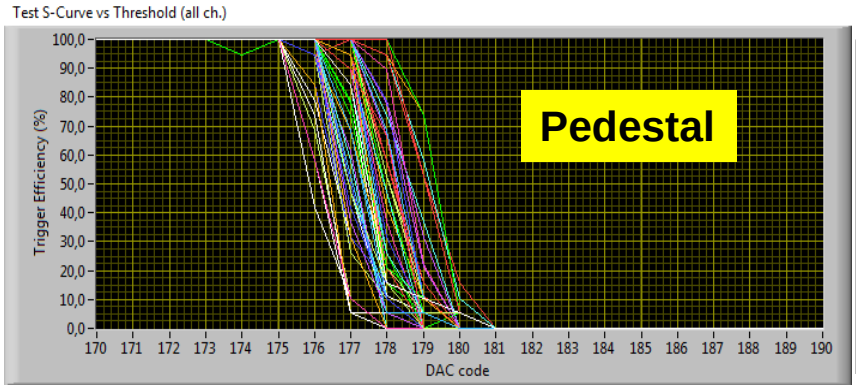


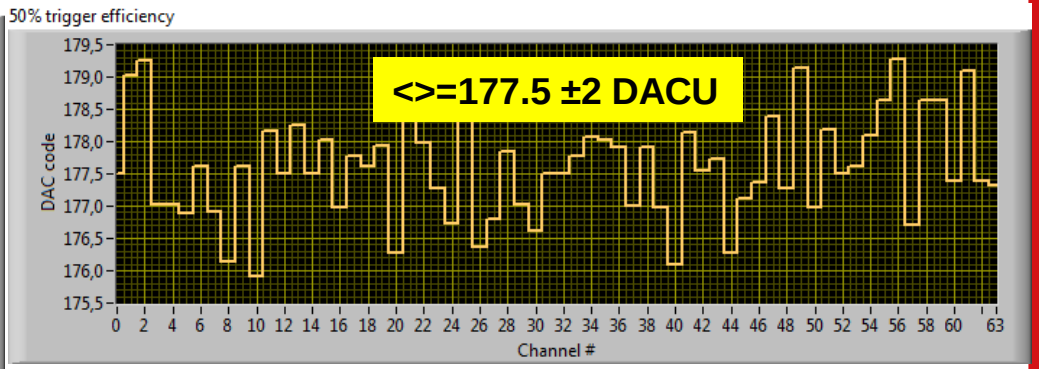
Fast Shaper ~ 48mV/Mip

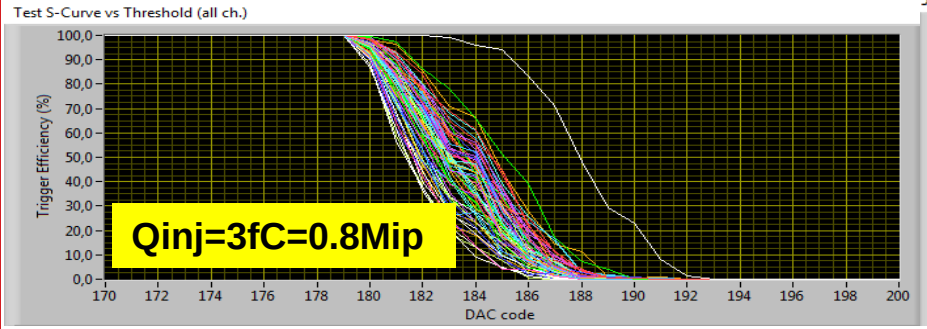


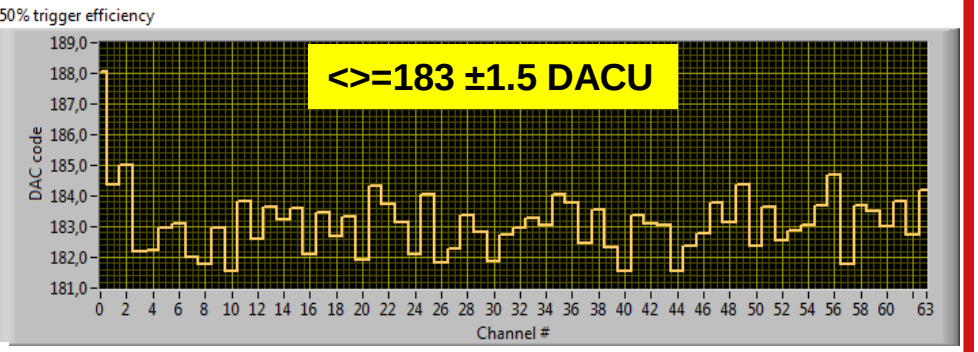
rms noise= 5.3 mV ie 1/9 MIP S/N=9

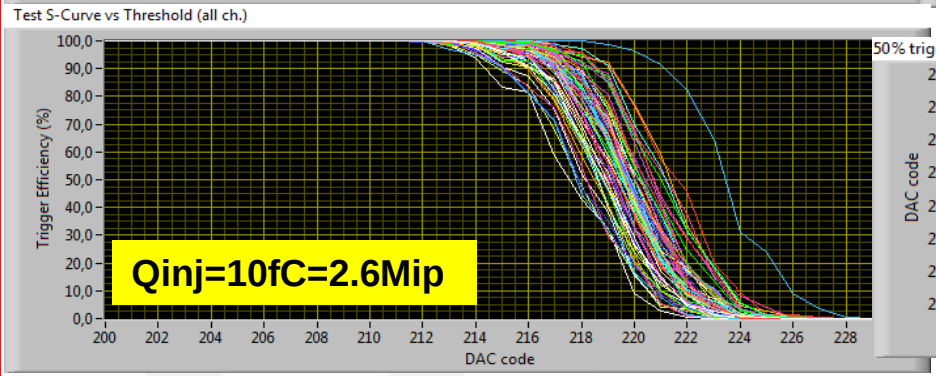
Trigger efficiency (1)

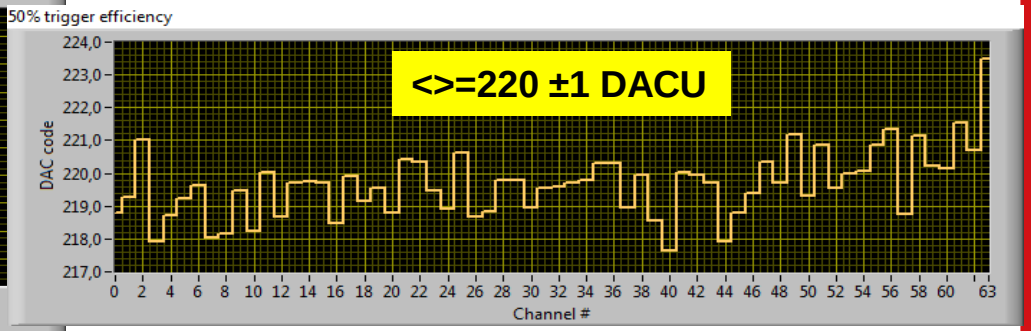




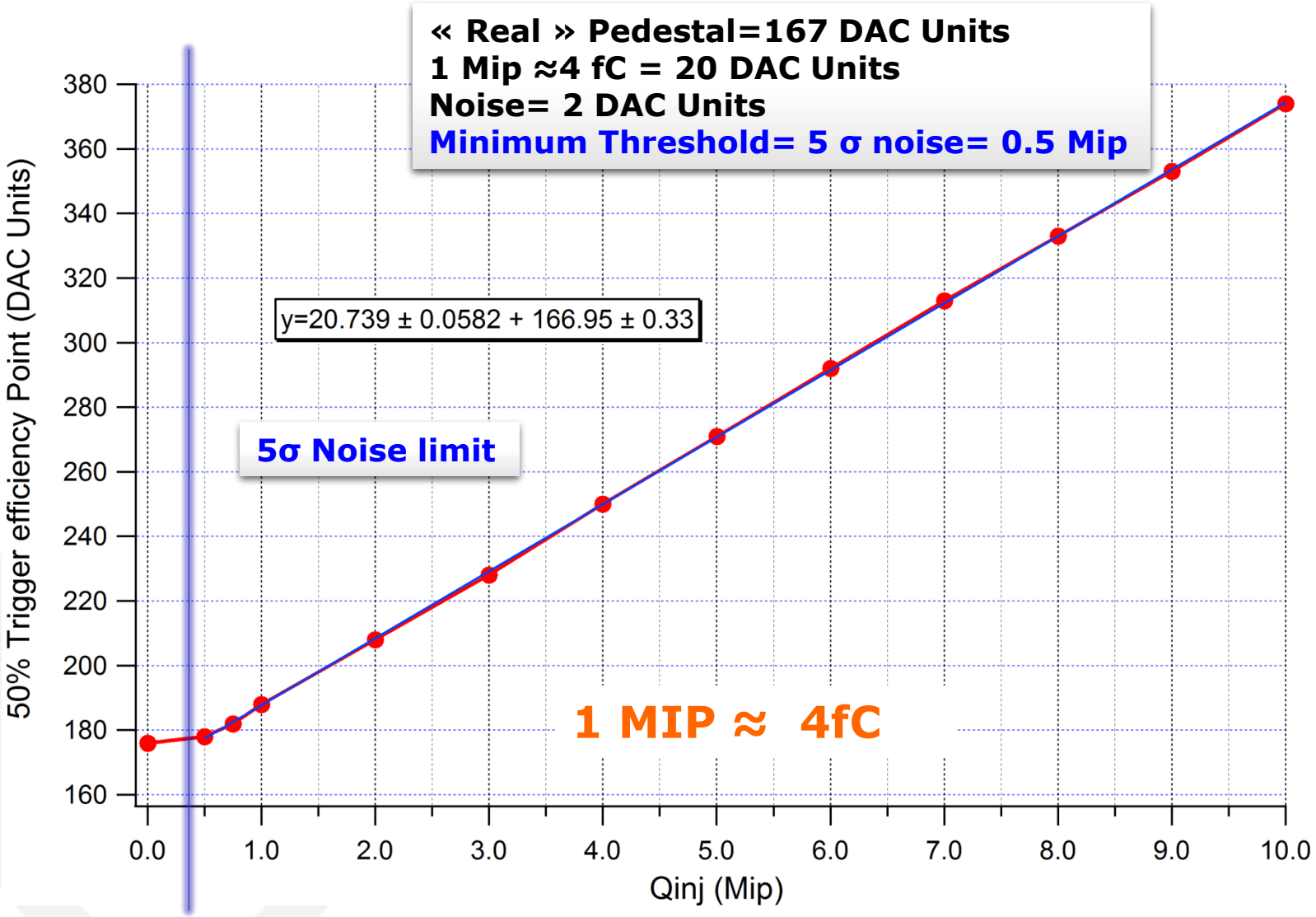








Trigger efficiency (2)



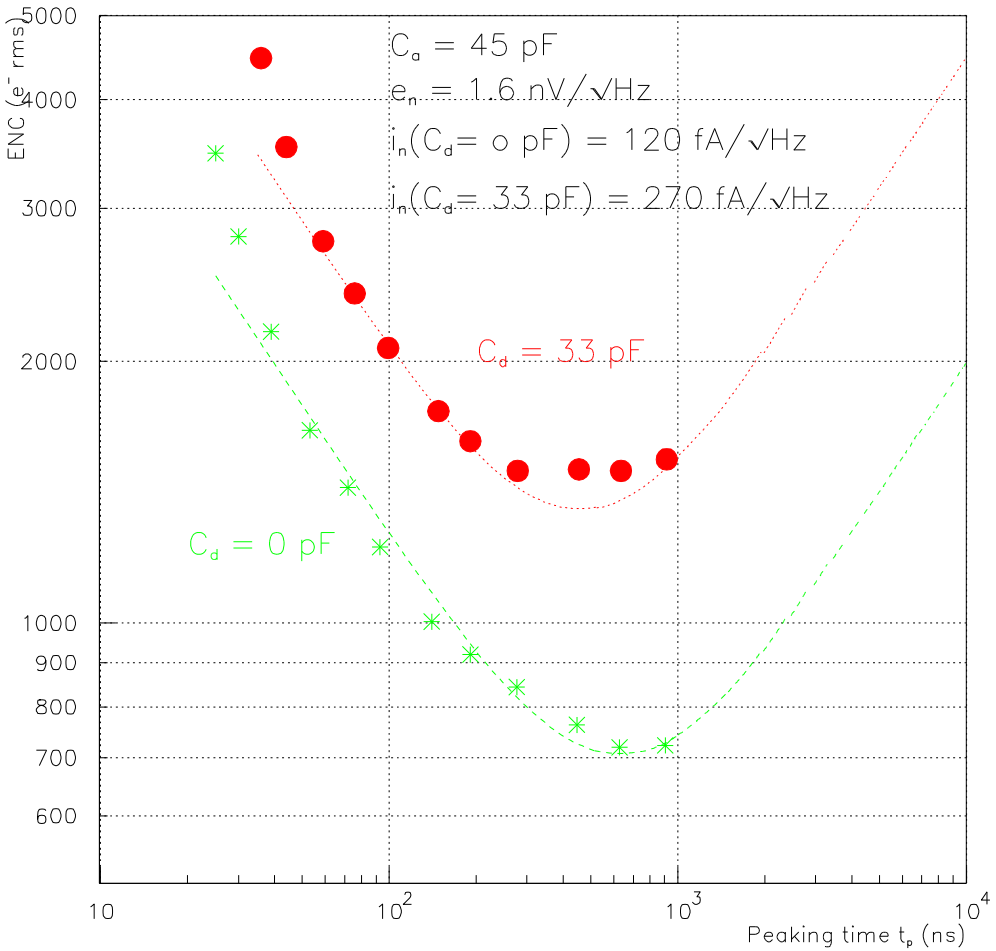
SKIROC2 : PreAmplifier ENC

SKIROC2

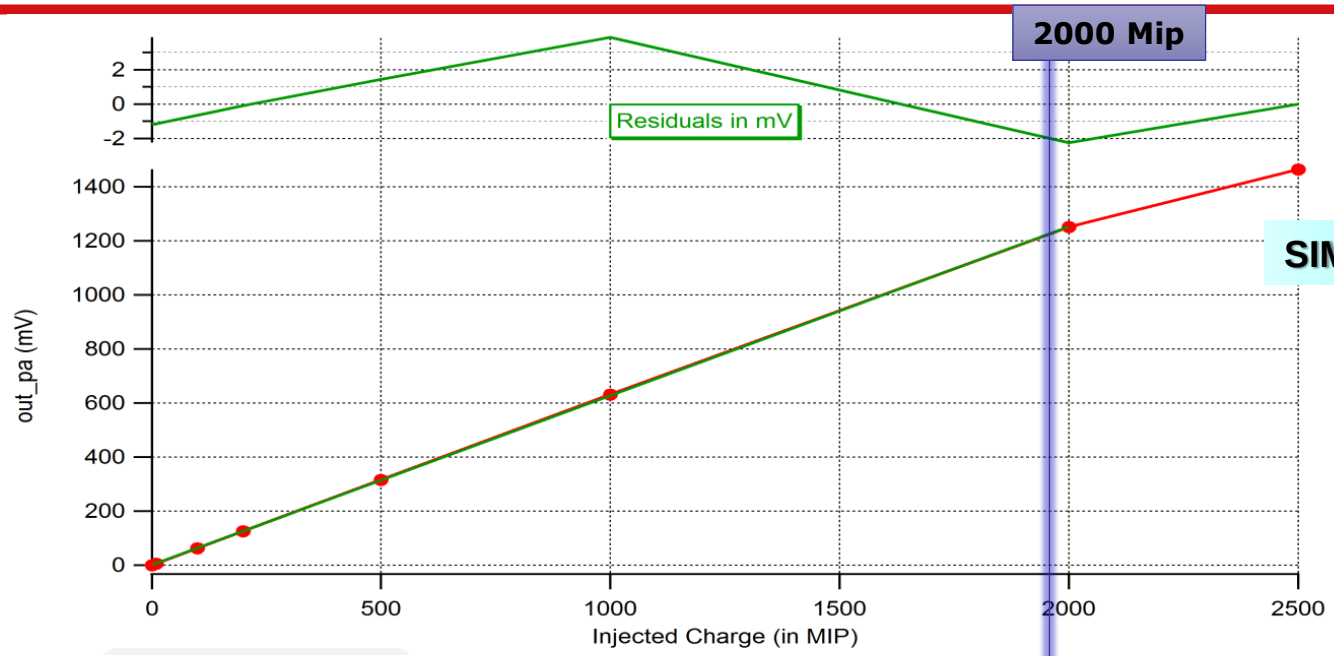
Cf=6pF, Qinj=2510^6 e-
CRRC2 x 100

C_d (pF)	A	A*181.5	B	C	e_n x C_t
0	0.4	72.6	664700	0	72.6
33	0.7	127.05	1400000	0	127.05

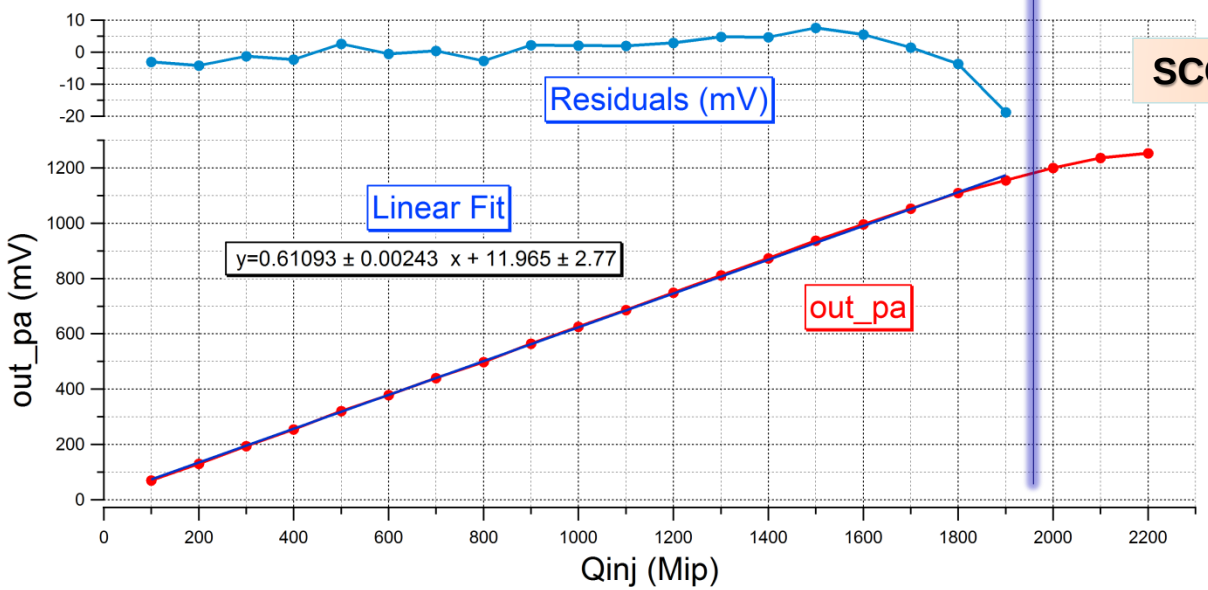
e_n nV/sqrt(Hz)	i_n fA/sqrt(Hz) (Cd= 0pF)	i_n fA/sqrt(Hz) (Cd= 33pF)	Ca pF
1,6	120	270	45



Linearity of the Charge Preamp



SIMULATION

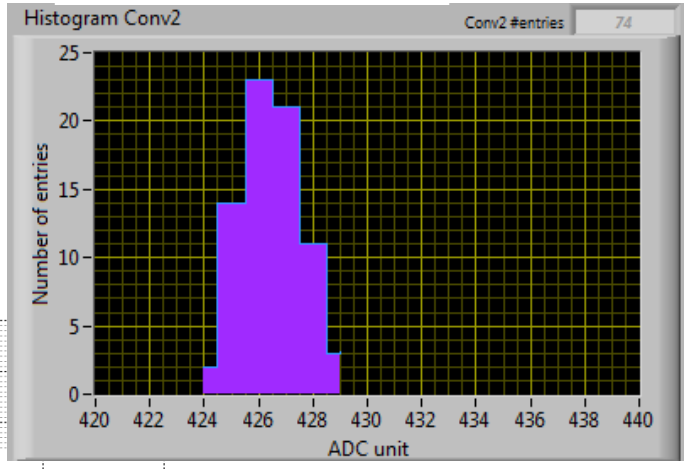


SCOPE MEASUREMENTS

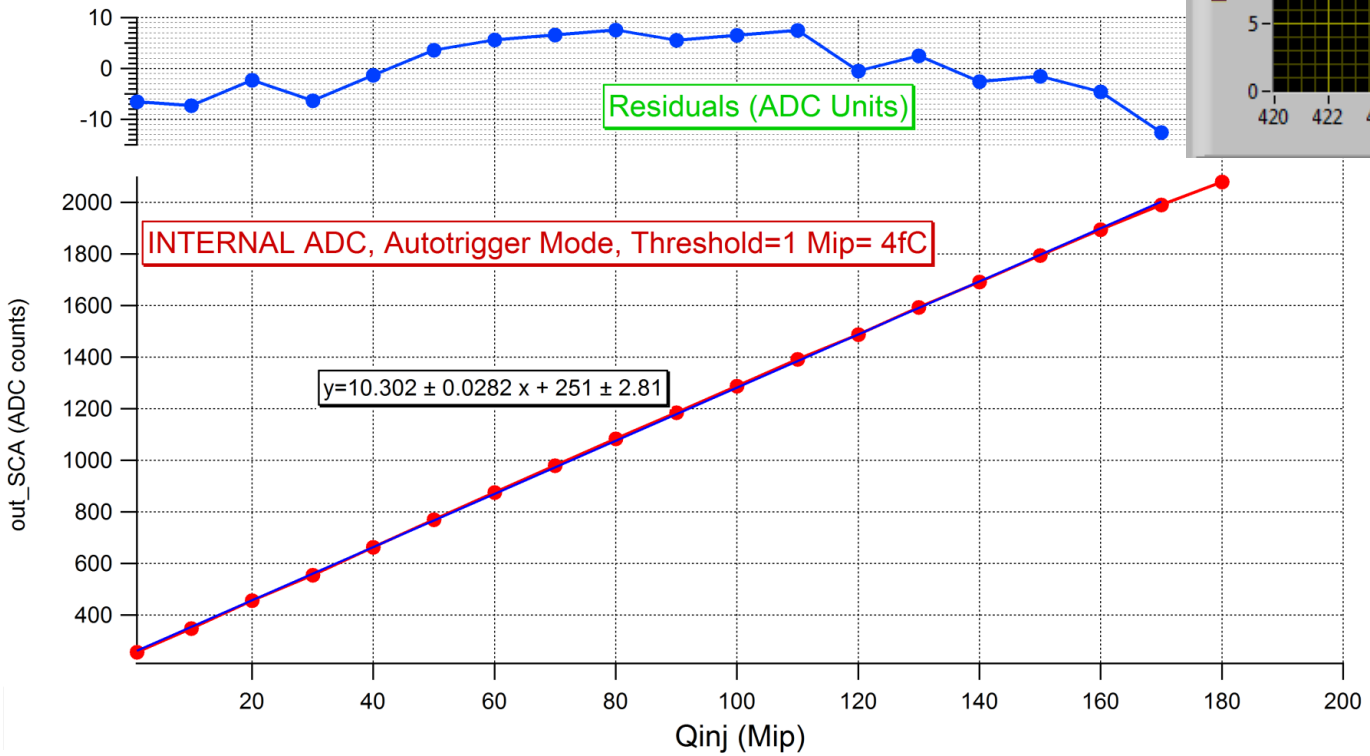
Linearity of High Gain Shaper

Noise = 630 µV
1 Mip gives 5.7 mV
S/N=9

SS10@20 MIP
Rms =1.16 ADC
U=600µV

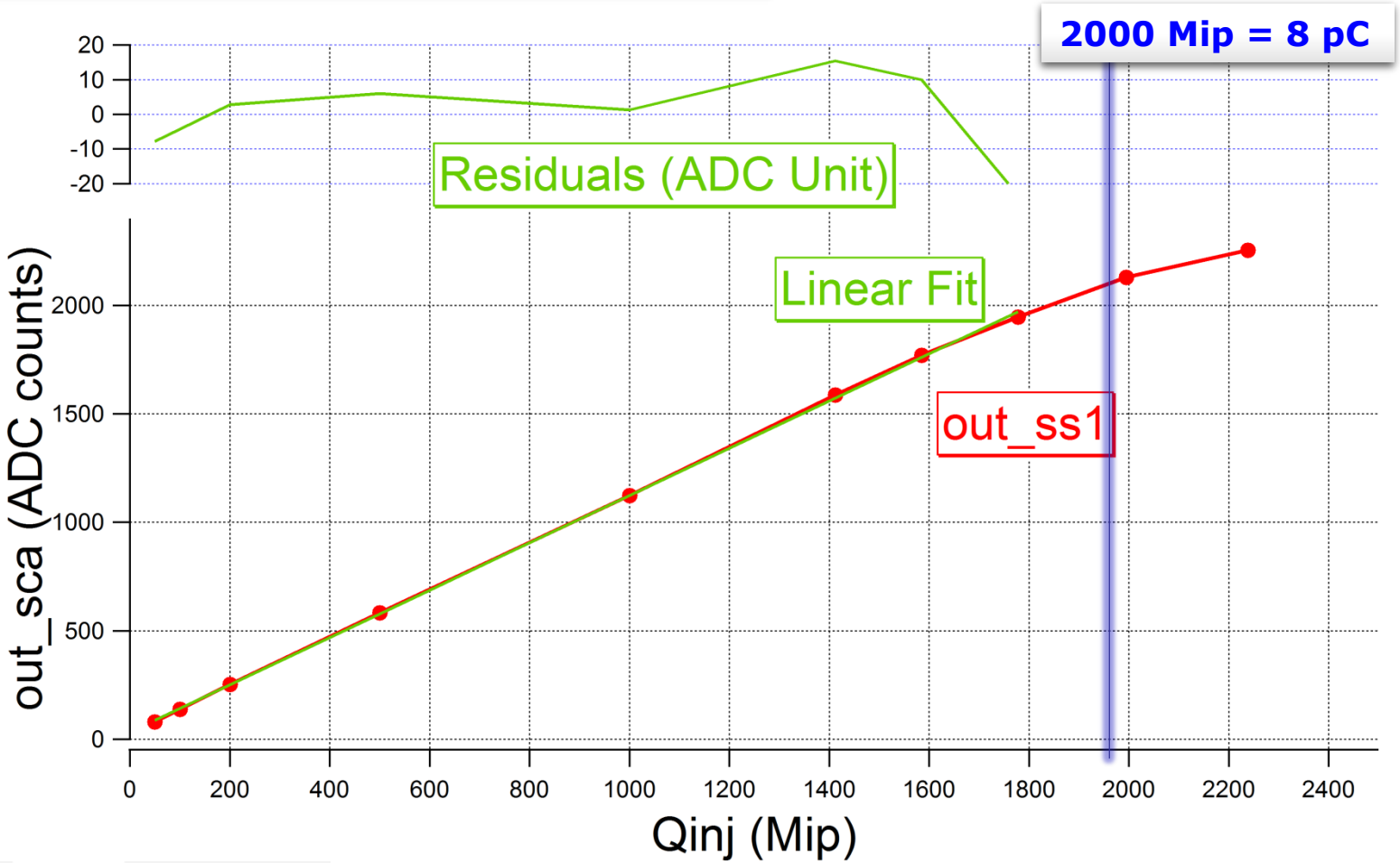


MEASUREMENTS using SCA and internal ADC
Autotrigger mode
1 MIP (4fC) threshold

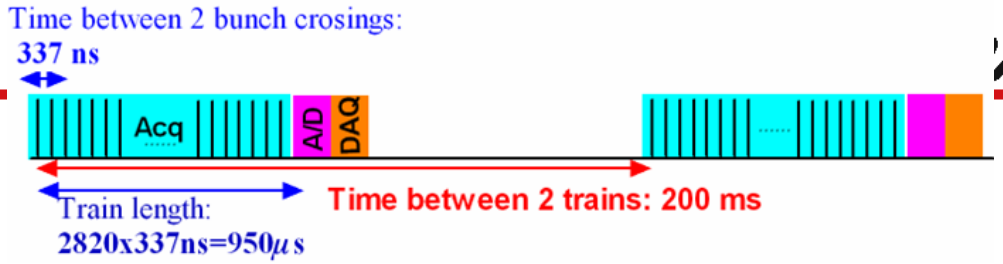


Linearity of the Low Gain Shaper

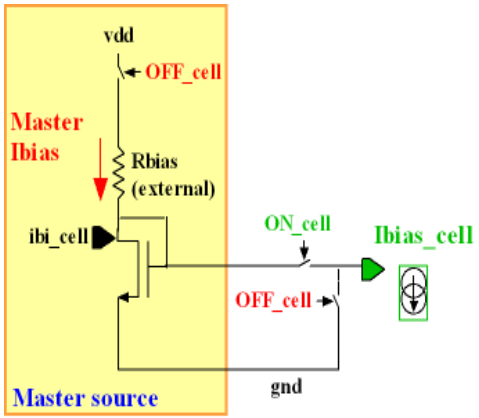
MEASUREMENTS using SCA and internal ADC
Autotrigger mode
1 MIP (4fC) threshold



POWER PULSING



- **Requirement:**
  - **25 μW/ch with 0.5% duty cycle**
  - **500 μA for the entire chip**



- **Power pulsing:**
  - Bandgap + ref Voltages + master I: switched ON/OFF
  - **Shut down bias currents with vdd always ON**
- **SK2 power consumption measurement:**
  - 123 mA x 3.3V ≈ 40 mW => **0.6 mW/ch**

- **4 Power pulsing lines** : analog, conversion, dac, digital
- Each chip can be forced **on/off by slow control**

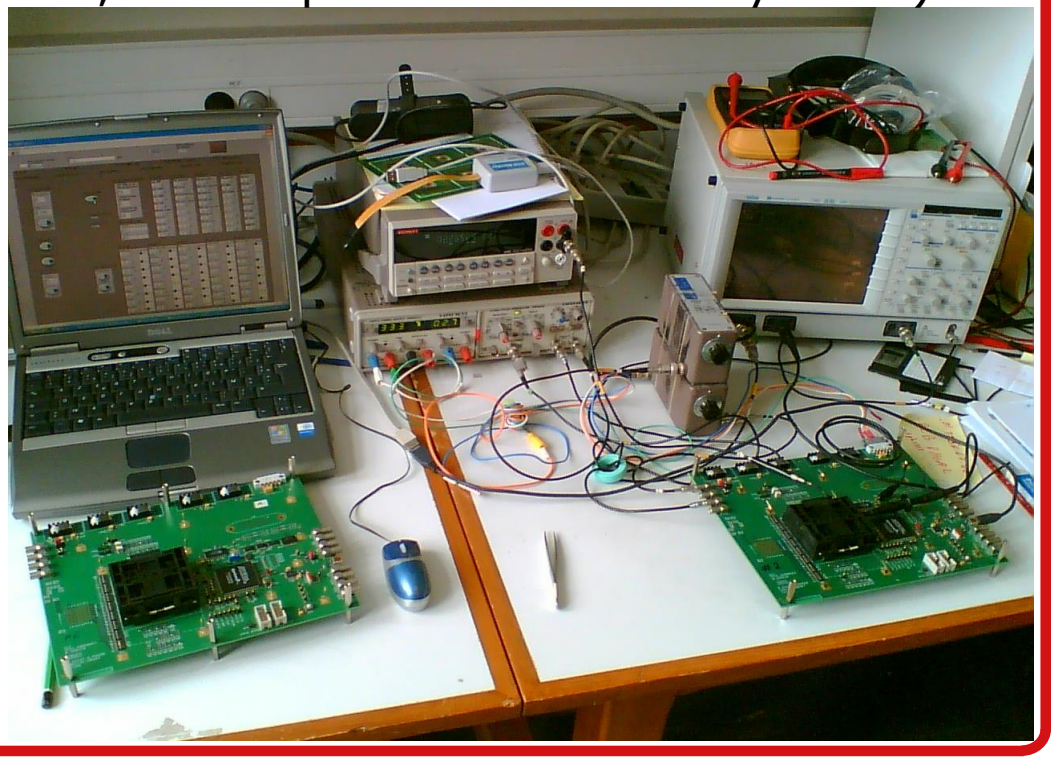
Measurements

Acquisition	88 mA , 290 mW	Duty Cycle =0.5%, 1.45 mW
Conversion	27.3 mA, 90 mW	Duty Cycle =0.25%, 0.225 mW
Readout	8.0 mA, 26.4 mW	Duty Cycle =0.25%, 0.066 mW

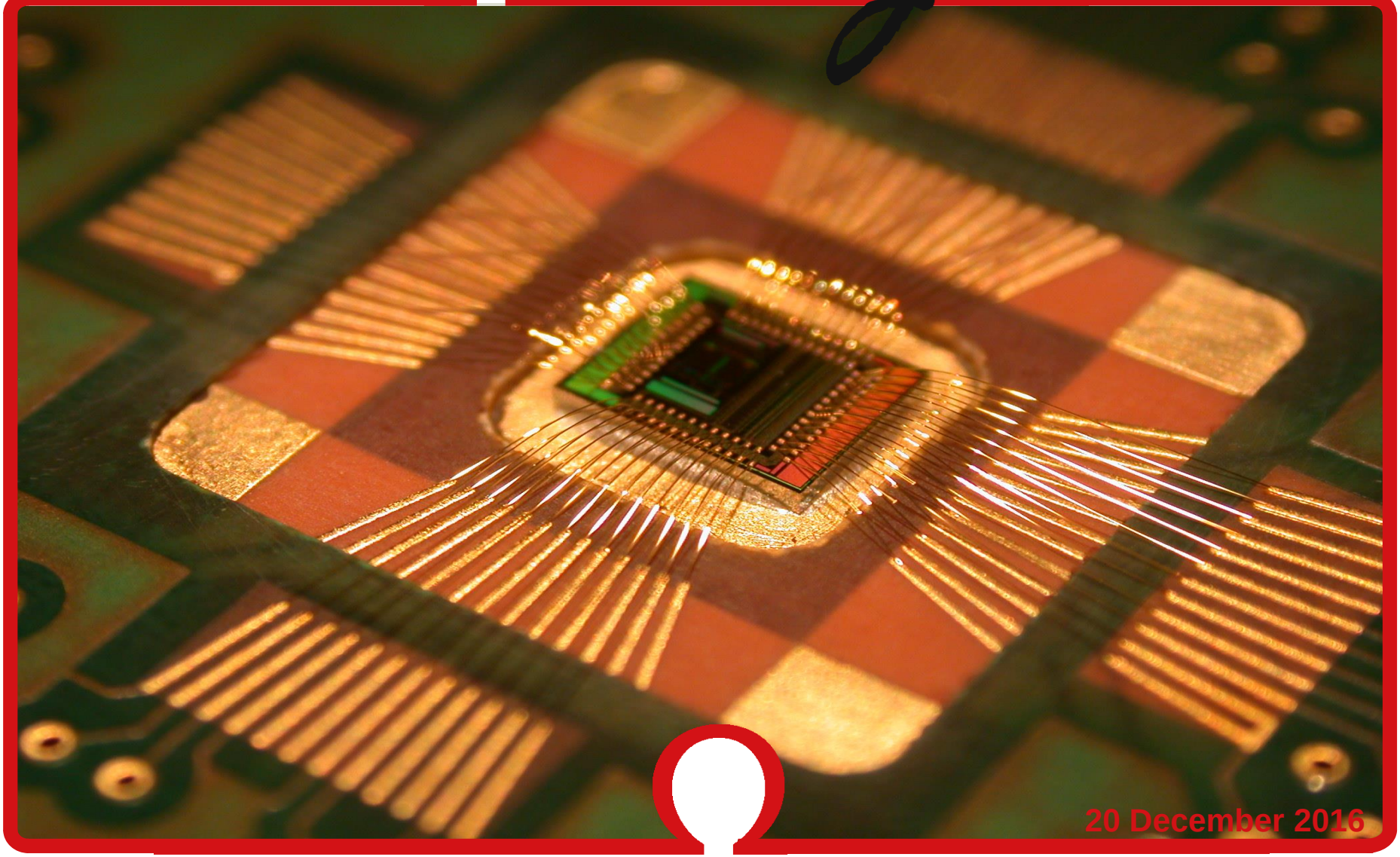
Skiroc2 power consumption with Power pulsing: 1.7 mW ie 27 μW/ch

SKIROC2 Summary

- Good performance of SKIROC2:
  - 0.5 Mip (2 fC) up to 2000 Mip (8 pC) dynamic range
  - 0.1Mip noise (0.4 fC ie 2500 electrons), minimum threshold 0.5 Mip, autotrigger mode
- 300 SKIROC2 will be packaged
  - For FEV8-CIP (design complete, PCB expected end January 2012)
- Test with FEV and sensors to be done at system level (power pulsing, DAQ)
- 4 Test Board
  - 2 OMEGA, 1 LLR, 1 SKKU



Omega



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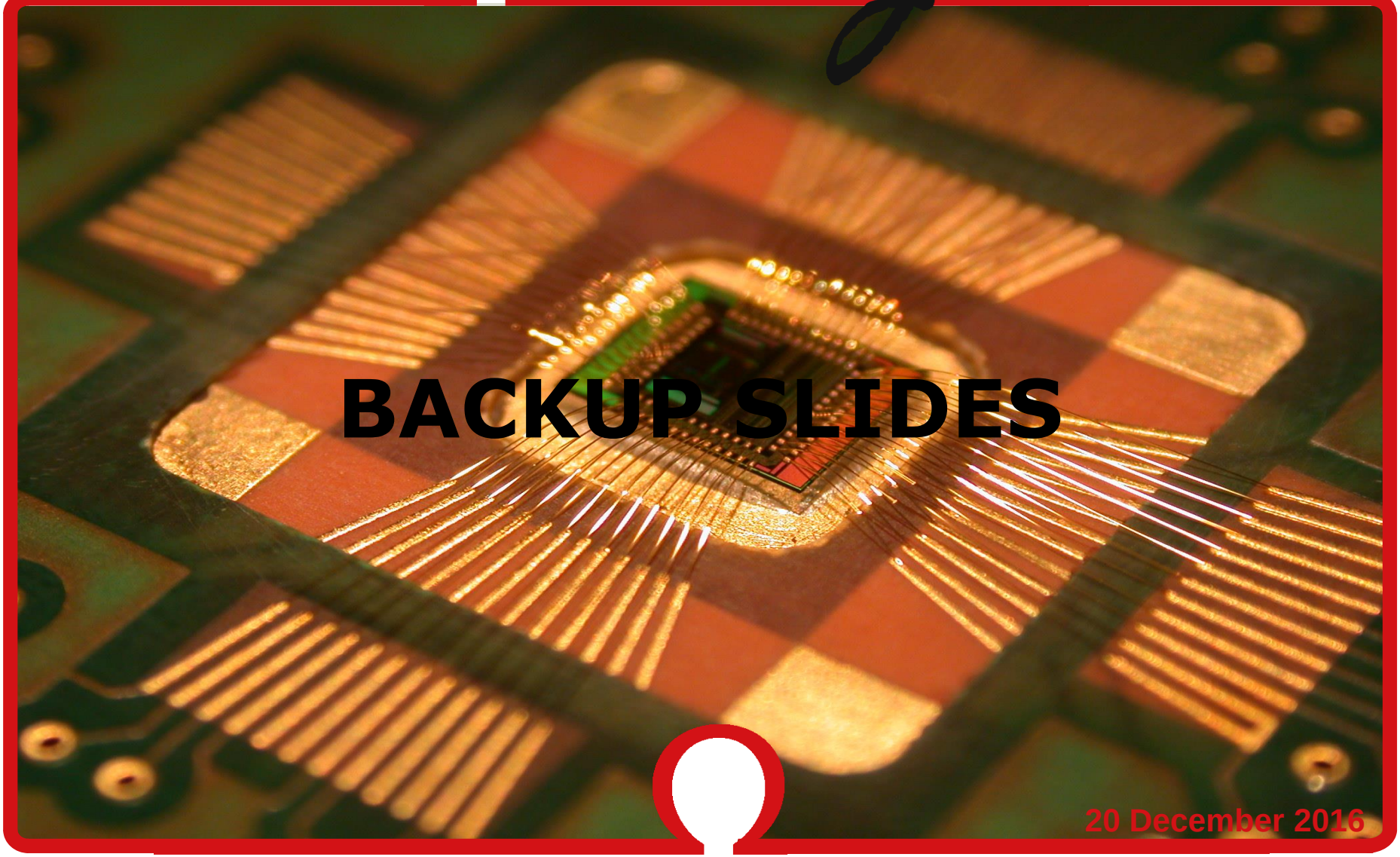
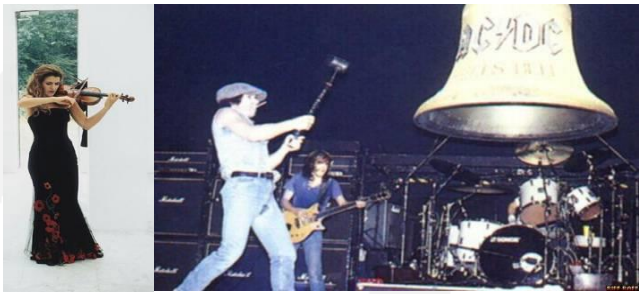

BACKUP SLIDES
20 December 2016

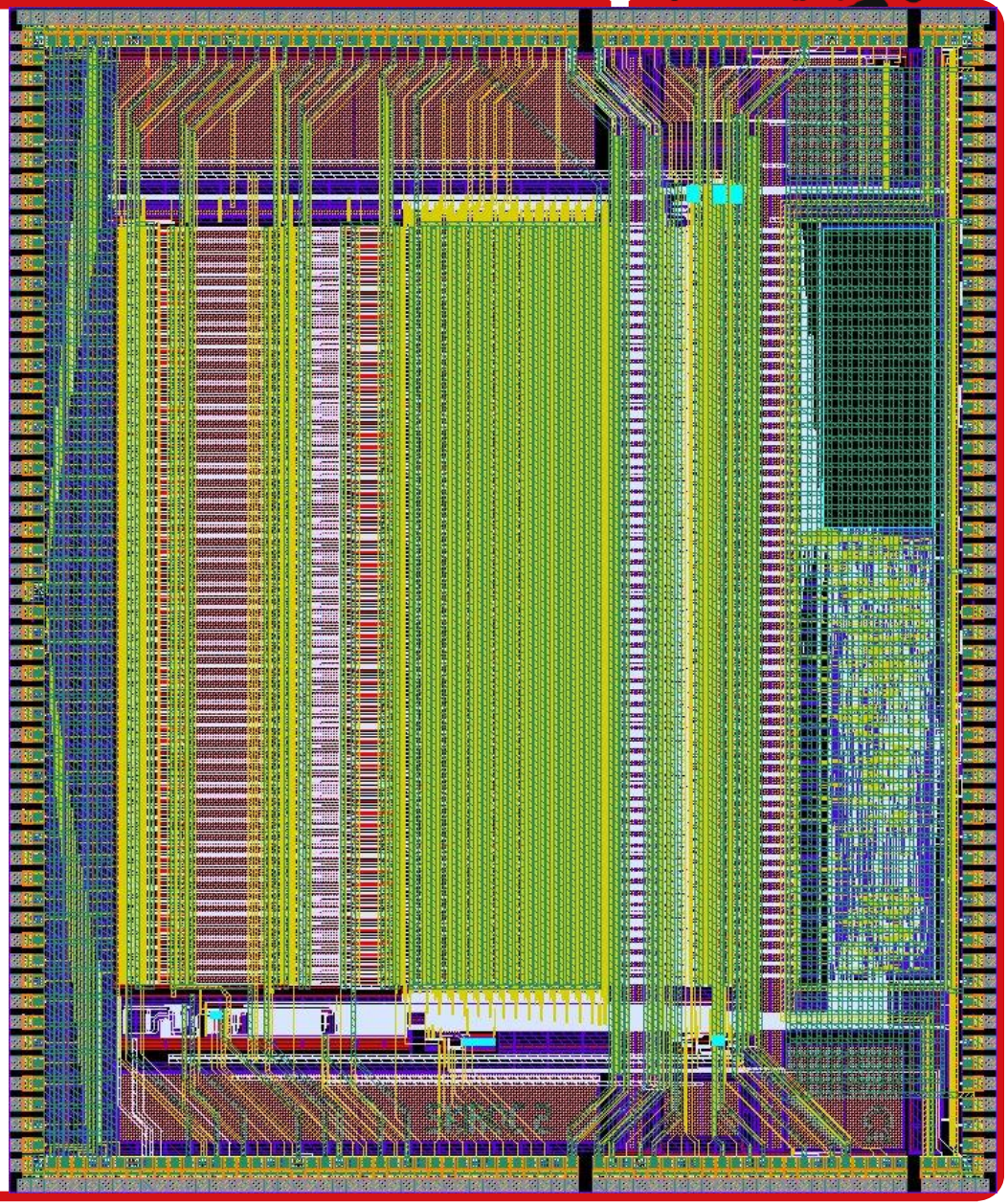
SKIROC2 overview

S*ilikon*
K*alorimeter*
I*ntegrated*
R*ead*
O*ut*
C*hip*

- 64 Channels
  - Difficult layout : 1MIP =4fC, with digital activity !



- 250 pads
  - **17 for test purpose only**
- Die size
  - 7229 µm x 8650 µm



SKIROC2 Requirements

SILICON SENSORS (WAFERS) :

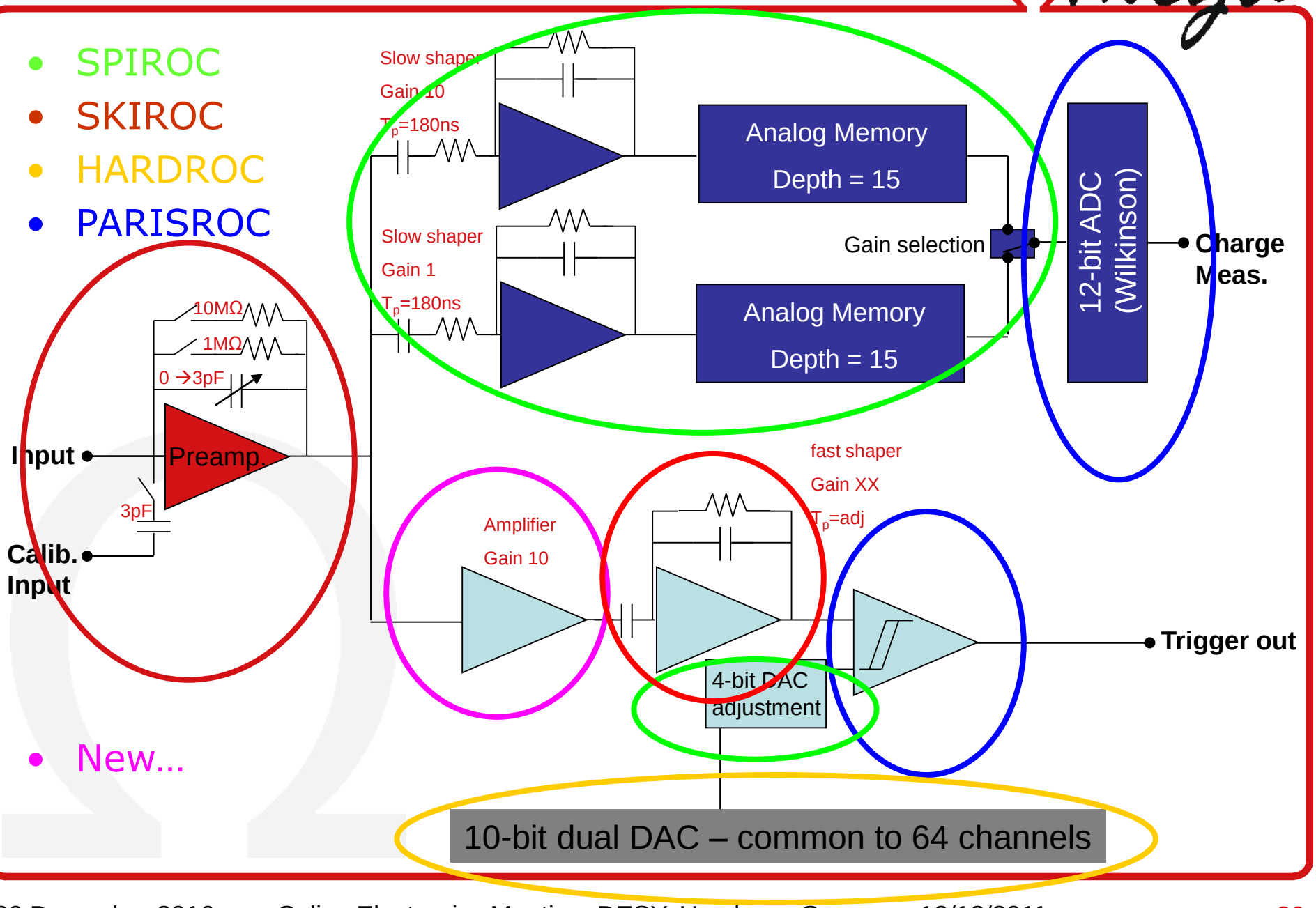
- Using 325µm thick Silicon Wafers => 26000e^-/MIP
- $C_{detector}$ estimated 9pF
  - Add also 10pF due to PCB pads' capacitance
- PIN diode leakage up to 10nA / channel
  - Chip has leakage current capability

DETECTOR INTEGRATION

- Full power pulsing capability
  - 25 µW/ch => 24h operation of full slab with 2 AAA batteries !
- Dynamic Range : from ½ MIP up to 2500 MIP
- Auto-trigger, Analog storage, Digitization & Token-ring ReadOut

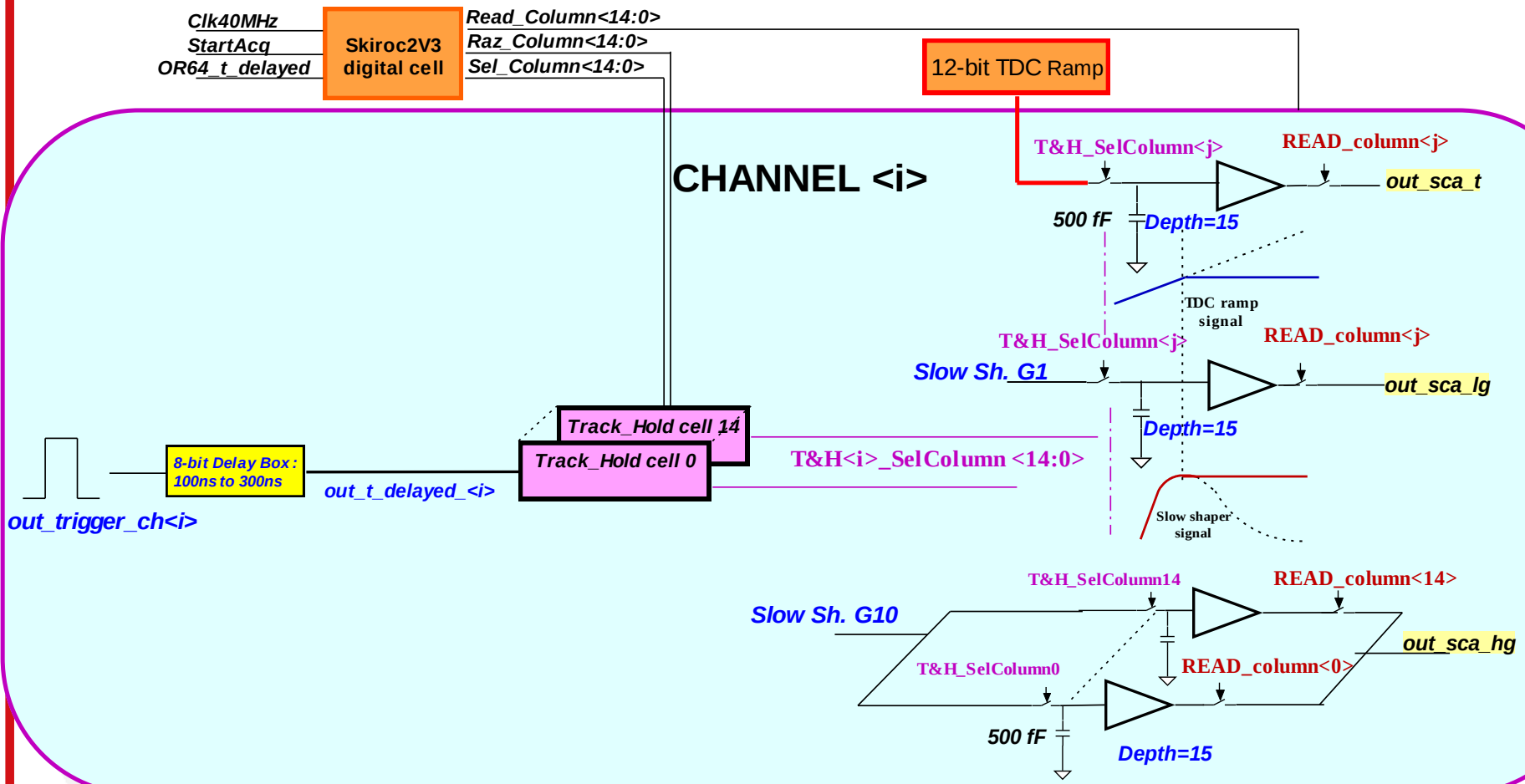
SKIROC2 One channel block scheme

- SPIROC
- SKIROC
- HARDROC
- PARISROC



- New…

SCA detail


Clk40MHz
StartAcq
OR64_t_delayed
Skiroc2V3 digital cell
Read_Column<14:0>
Raz_Column<14:0>
Sel_Column<14:0>
12-bit TDC Ramp
CHANNEL <i>
T&H_SelColumn<j>
READ_column<j>
out_sca_t
500 fF
Depth=15
TDC ramp signal
T&H_SelColumn<j>
READ_column<j>
Slow Sh. G1
out_sca_lg
Depth=15
Track_Hold cell 14
Track_Hold cell 0
T&H<i>_SelColumn <14:0>
8-bit Delay Box : 100ns to 300ns
out_t_delayed_<i>
out_trigger_ch<i>
Slow shaper signal
T&H_SelColumn14
READ_column<14>
Slow Sh. G10
out_sca_hg
T&H_SelColumn0
READ_column<0>
500 fF
Depth=15

SKIROC2 analogue features

- Bandgap (reference voltage from Hardroc2b)
- Dynamic Range : from ½ MIP up to 2500 MIP
  - With C*detector* = 20pF
- Analogue channel muting capability (PA can be shut down)
  - Common 4-bit adjustable gain
  - PIN diode leakage current swallow capability (up to 10nA)
- 180ns shaping time Slow Shapers for charge measurement
  - Optimized S/N
  - Antisaturation system in Gain 10 Slow Shaper
- Analogue signal-to-noise ratio : 17 (1500 e^- noise for 1 MIP)
- 2-bit shaping time adjustable Fast Shaper (50 to 100ns)
  - Antisaturation system in Fast Shaper
- Analogue Memory depth : up to 15 events can be stored

SKIROC2 mixed features

- 10-bit DAC for discriminator threshold
  - With improved 4-bit adjustment on each channel
- Trigger Discriminator for autotrigger on ½ MIP
  - Better performance
  - Mask on each channel
- External Triggers now follow same path as internal ones
- 8-bit adjustable delay for peaking maximum signal
- (10 or 12-bit) ADC Discriminator from Parisroc
- Digitization of either time and charge or of both charges

SKIROC2 digital features

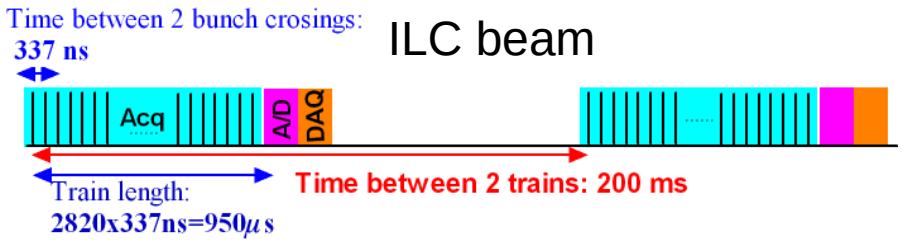
- Common features with Hardroc & Spiroc (compatibility with any CALICE DAQ system)
  - Open Collector token-ring ReadOut
  - Multiplexed Slow Control & Probe
  - Redundancy on Data Out & Transmit On signal lines
  - 2 switchable StartReadOut Inputs & EndReadOut Outputs :
    - to prevent chip failure
- Improved Slow Control/Probe
  - Default value for Slow Control (already done in Hardroc2B & Easiroc)
- Very Complex Digital Part (~10% of the Die)
  - Manage Acquisition, Conversion, 15 SCA control, RAM, I/Os…
  - new layout (easier interconnections with analogue part)
  - minor modifications concerning some timings (allowing more latency to analogue signal during conversion)

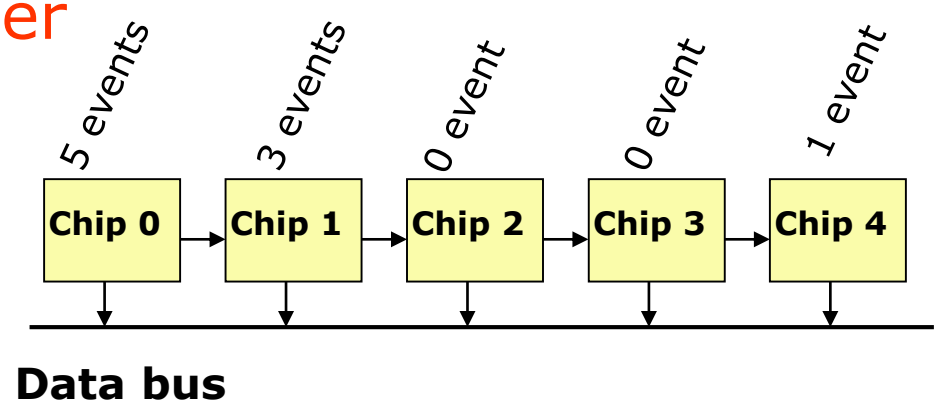
SKIROC2 extra features (free R&D !)

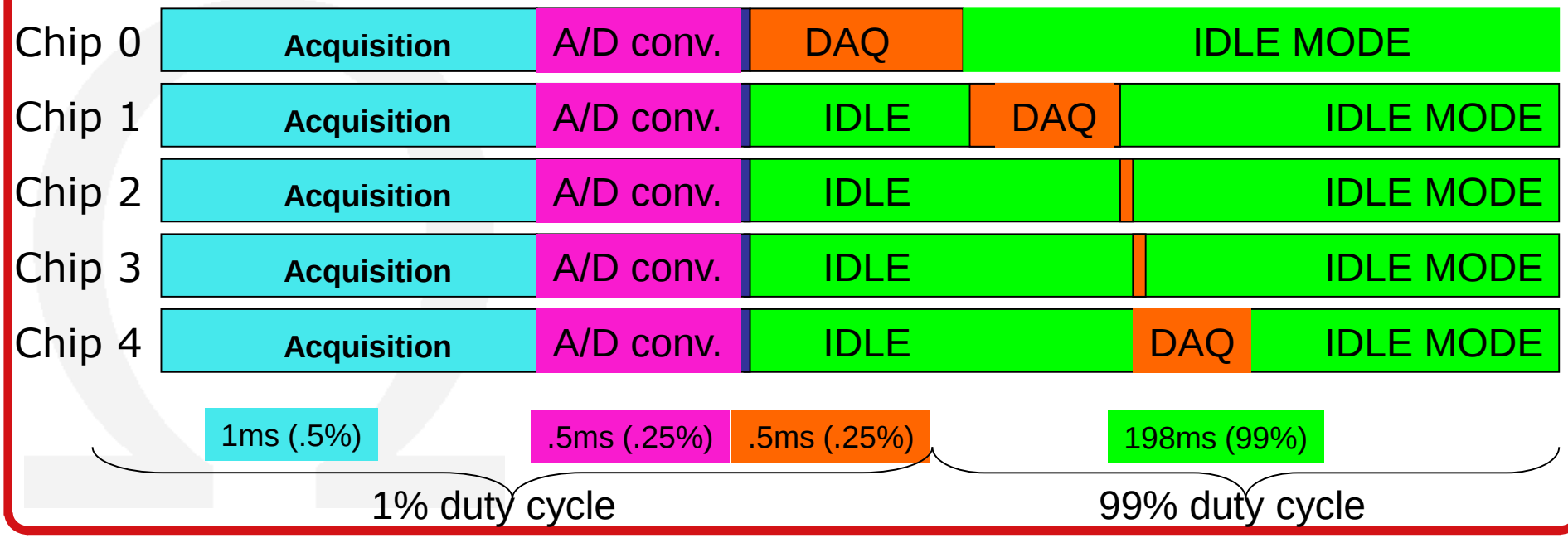
- 1 ns TDC capability
- TDC facility to operate in ILC mode or in test beam mode
  - 200ns for ILC / 5µs for test beam
- Power consumption optimized
  - Power-On-Digital included for LVDS receivers
  - Each stage can be totally disabled
- Analogue and Digital probe system
- Tri-state multiplexed Analogue output
- Test purpose : few pads required, single ended 40MHz needed, default slow control configuration, “only” Acquisition/Conversion/ReadOut Command necessary

Read Out: token ring

- Readout architecture common to all calorimeters
- Minimize data lines & power





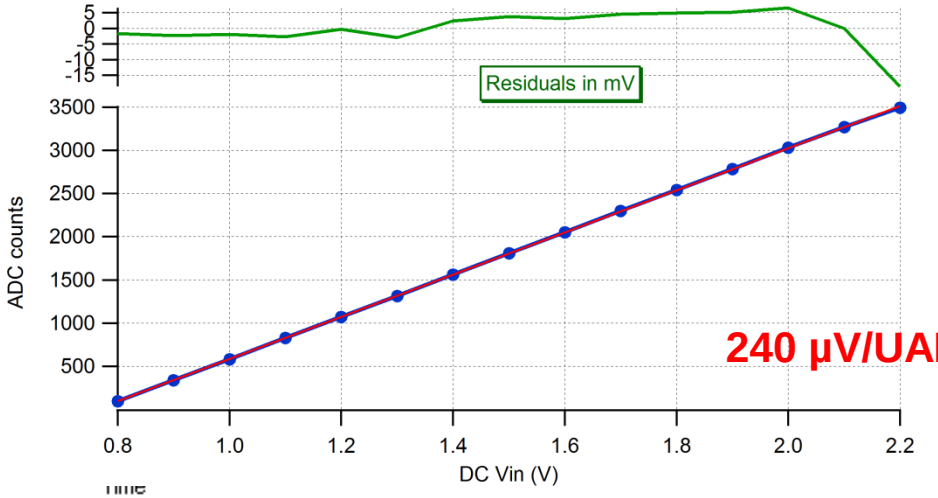


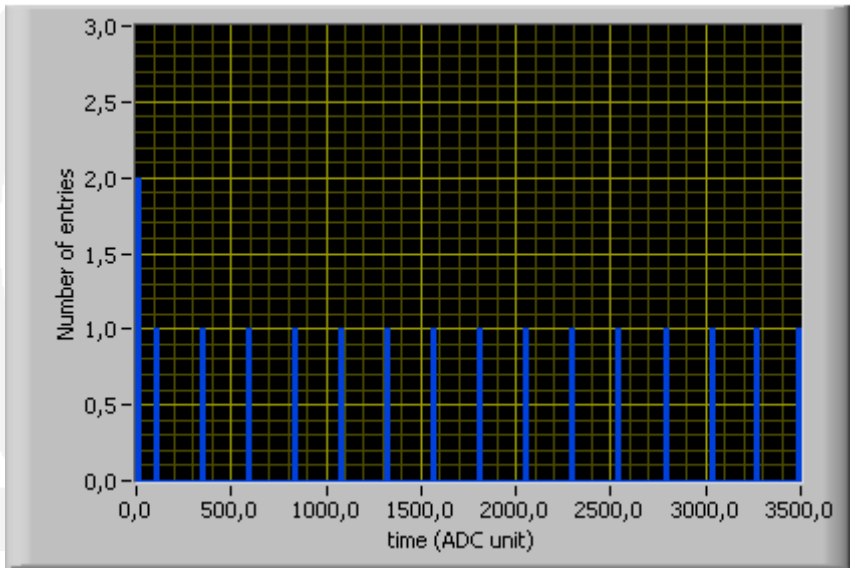
SKIROC2 Analogue Simulations

Q inj	Out_PA	Out_SS1	Out_SS10
1 MIP	639.6 µV	623.7µV	6.65 mV
10	6.32 mV	6.236mV	66.47 mV
100	63.2 mV	62.33 mV	664.1 mV
200	126.4mV	124.7 mV	1317 mV
500	315.9 mV	311.5 mV	Saturation to 1.5V
1000	631.6 mV	622.4 mV	
2000	1252 mV	1234 mV	
2500	1465 mV	1437 mV	

SKIROC2 ADC Test : Board 1

Using DC voltage as input and manual step-by-step acquisition system



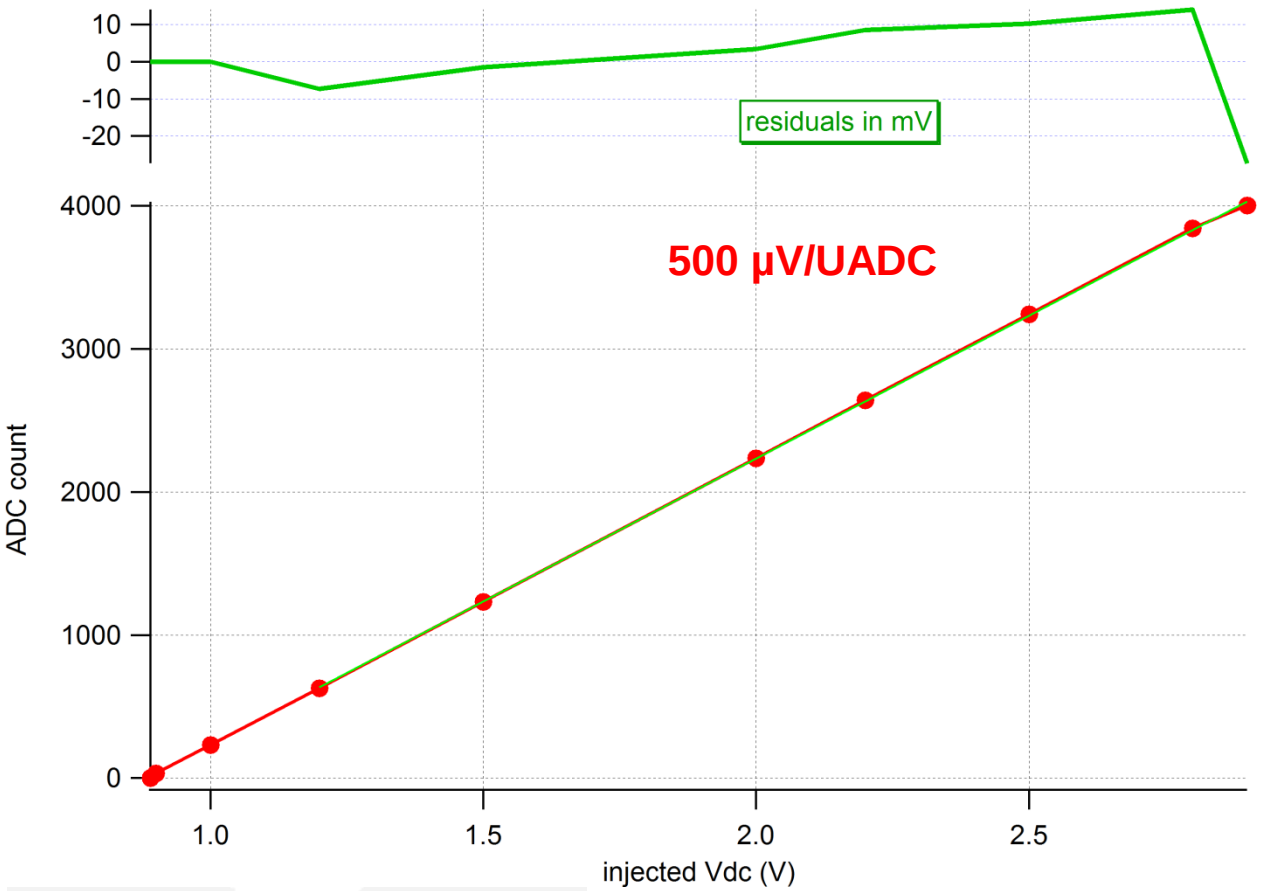


V DC	ADC count
0,6	5
0,7	5
0,8	99
0,9	342
1	586
1,1	829
1,2	1075
1,3	1316
1,4	1565
1,5	1810
1,6	2053
1,7	2298
1,8	2542
1,9	2786
2	3031
2,1	3268
2,2	3493
2,3	1

Underflow

Overflow

SKIROC2 ADC Test : Board 2



V DC	ADC count
0,89	10
0,9	36
1	235
1,2	630
1,5	1234
2	2236
2.2	2640
2,5	3240
2.8	3842
2.9	4000

SKIROC2 : Digital Data (Board 2)

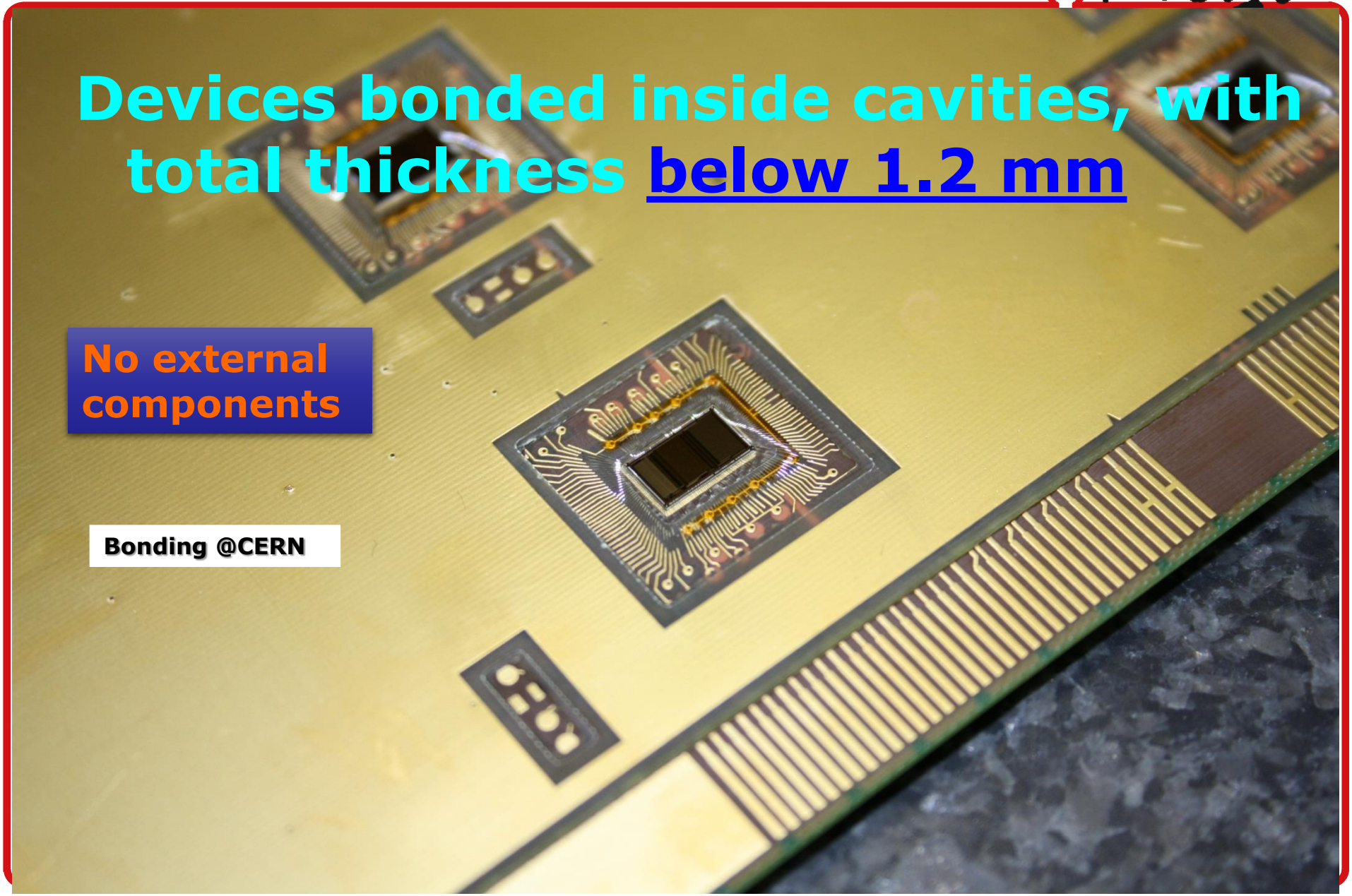
Input signal: 3.8V@20dB in 10 pF=1000 Mip

1350 UADC ie 1V+674 mV= 1.674 V Scope measurement 1.580 V

Input signal: 3.8V@40dB in 10 pF=100 Mip

340 UADC ie about 1.1V Scope measurement: 1.06V

FEV board


Devices bonded inside cavities, with total thickness below 1.2 mm
No external components
Bonding @CERN