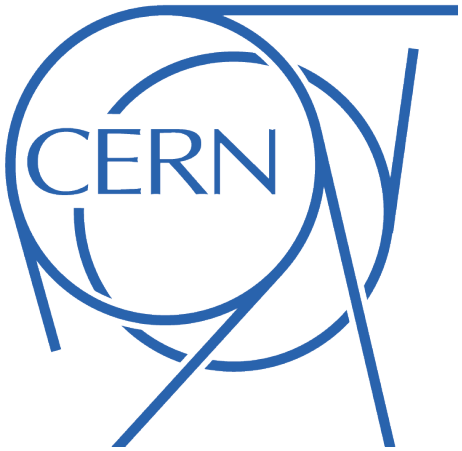


VMM1

An ASIC for Micropattern Detectors

- Preliminary Results -

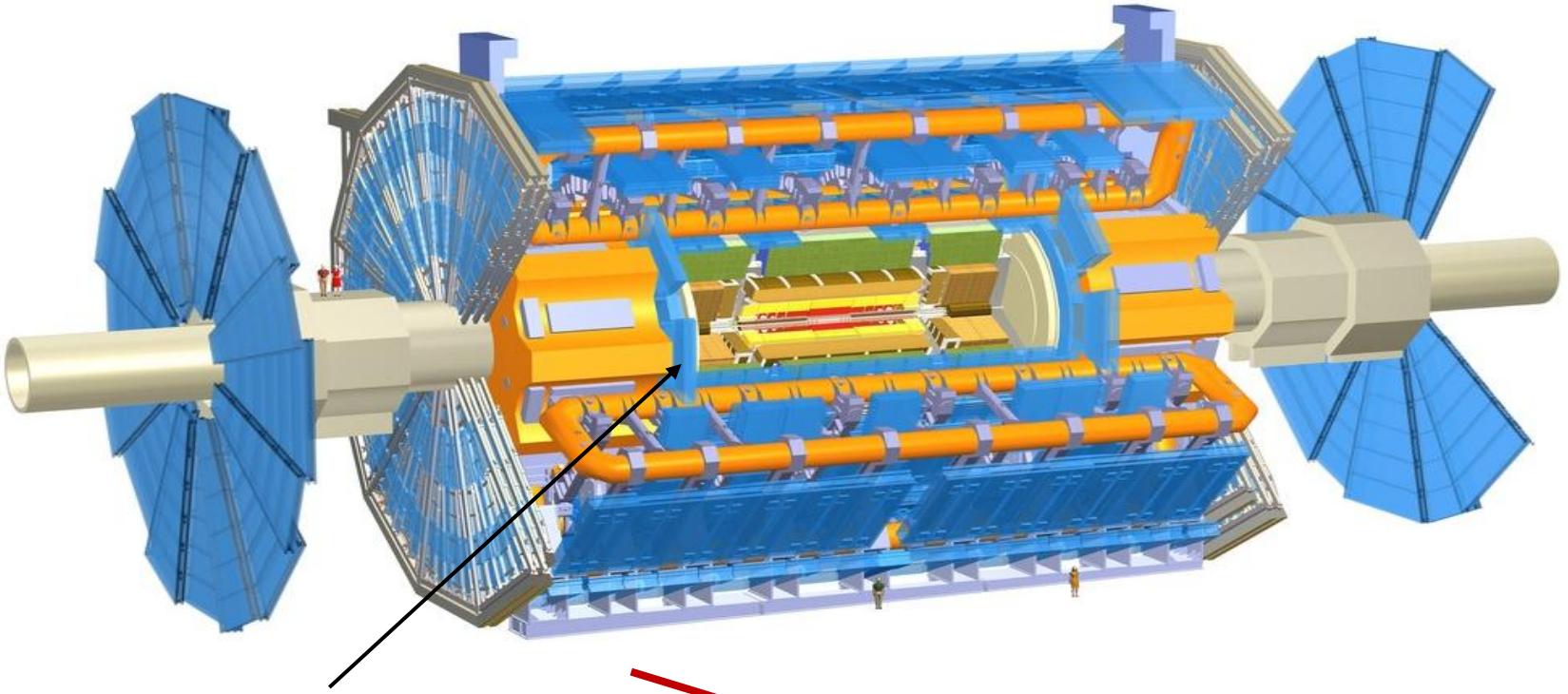
Gianluigi De Geronimo **, *Jack Fried, Shaorui Li, Jessica Metcalfe**

Neena Nambiar, Emerson Vernon, and Venetios Polychronakos

*Brookhaven National Laboratory - *CERN*

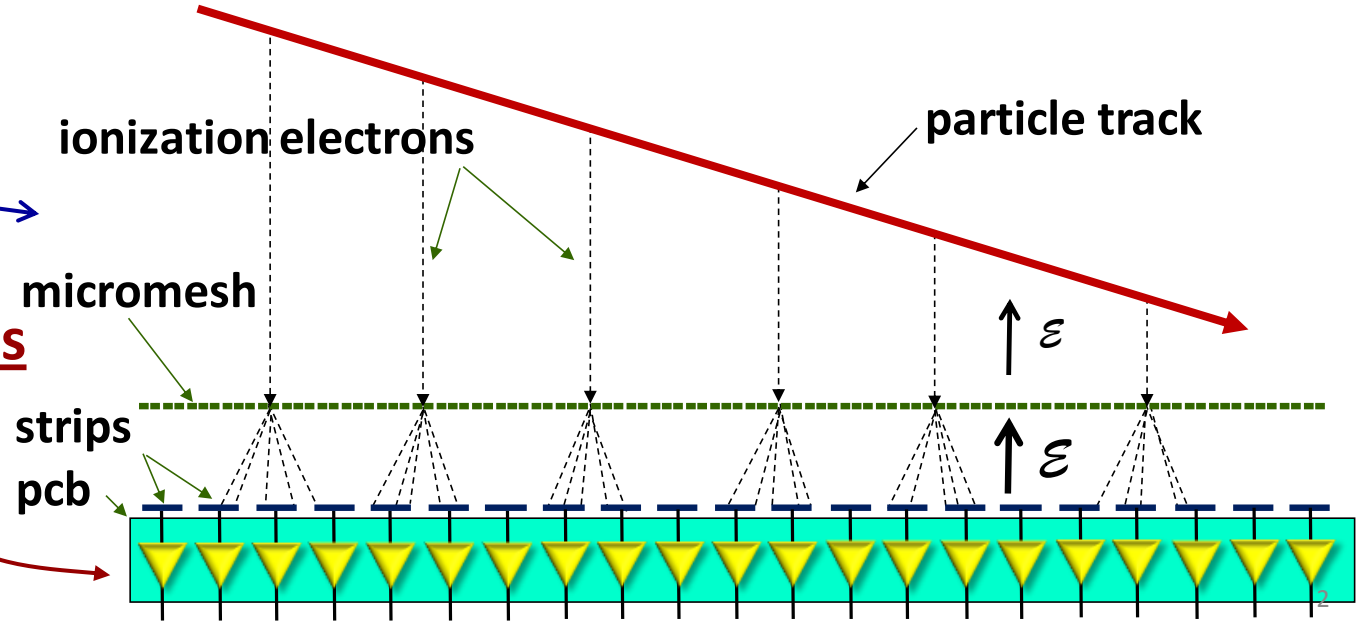
RD51 - SUNY - October 2012

ATLAS Muon Spectrometer upgrade



New Small Wheel

- **TGC** *Thin Gap Chamber*
- **MICROMEGAS**
  MICROMEsh GAs Structure



Front-end electronics

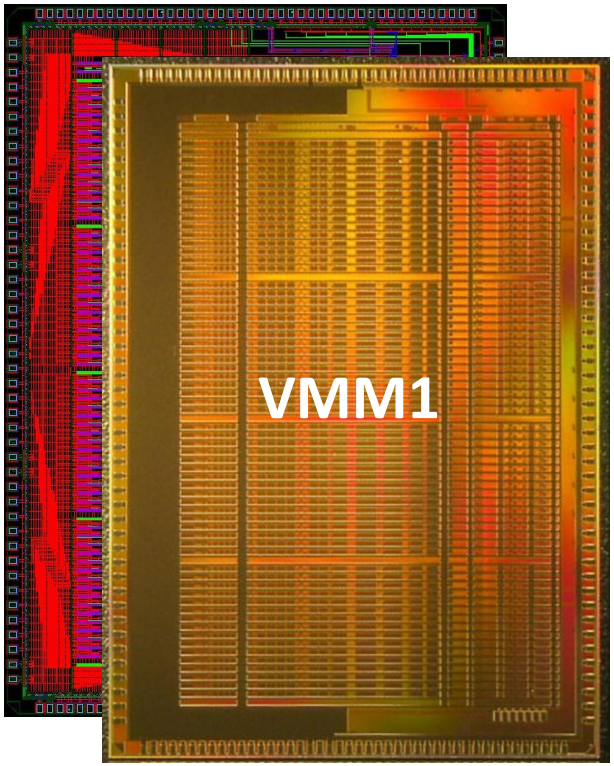
- 10-200 pF
- 2 pC @ < 1 fC rms
- 100 ns @ < 1ns rms
- > 2M channels

BROOKHAVEN NATIONAL LABORATORY
Instrumentation Division

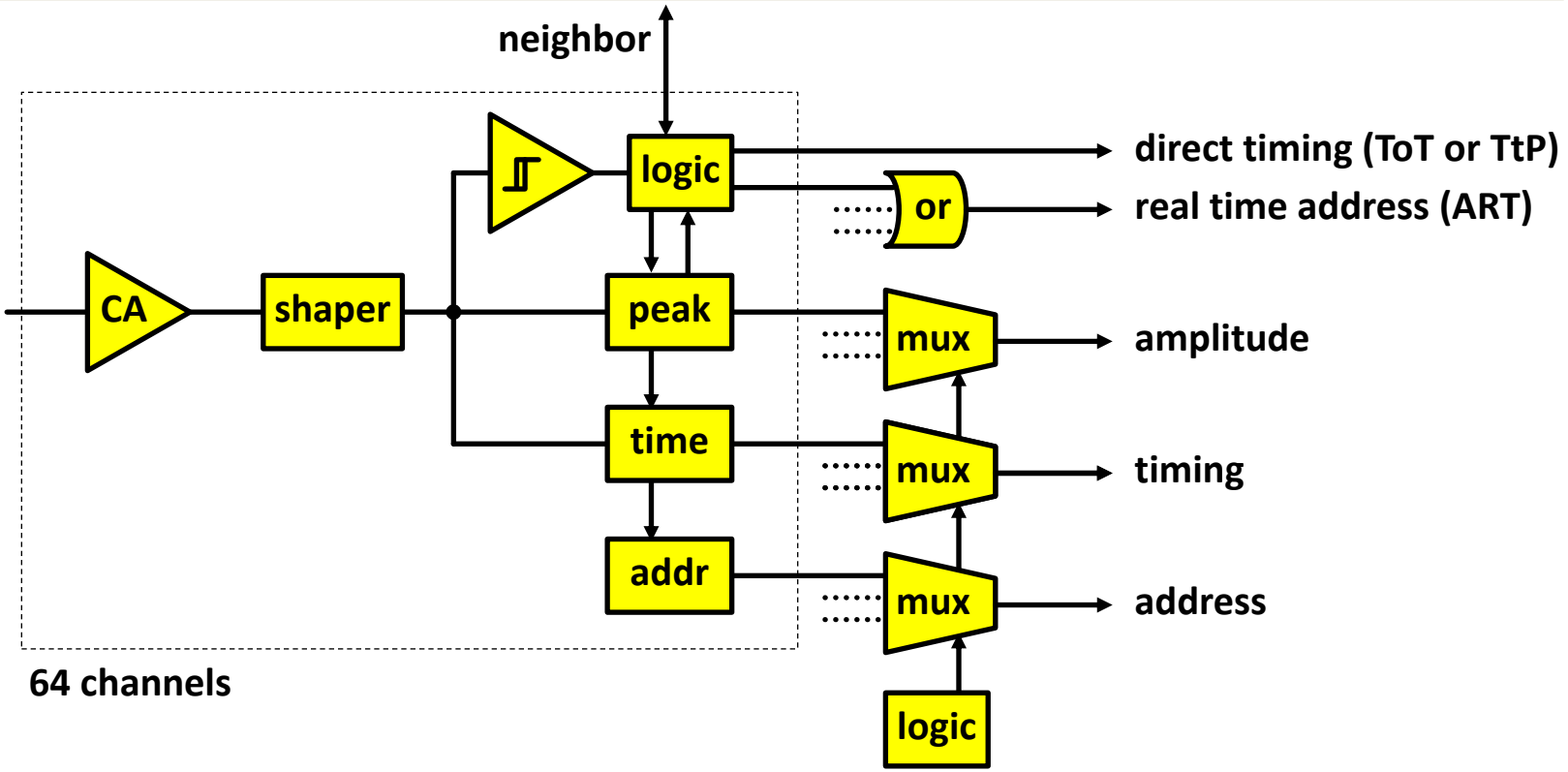
VMM ASIC family

VMM - ASIC family for ATLAS Muon Spectrometer upgrade ***MICROMEGAS and TGC***

- **VMM1 - architecture and results**
- **VMM2 - plans**



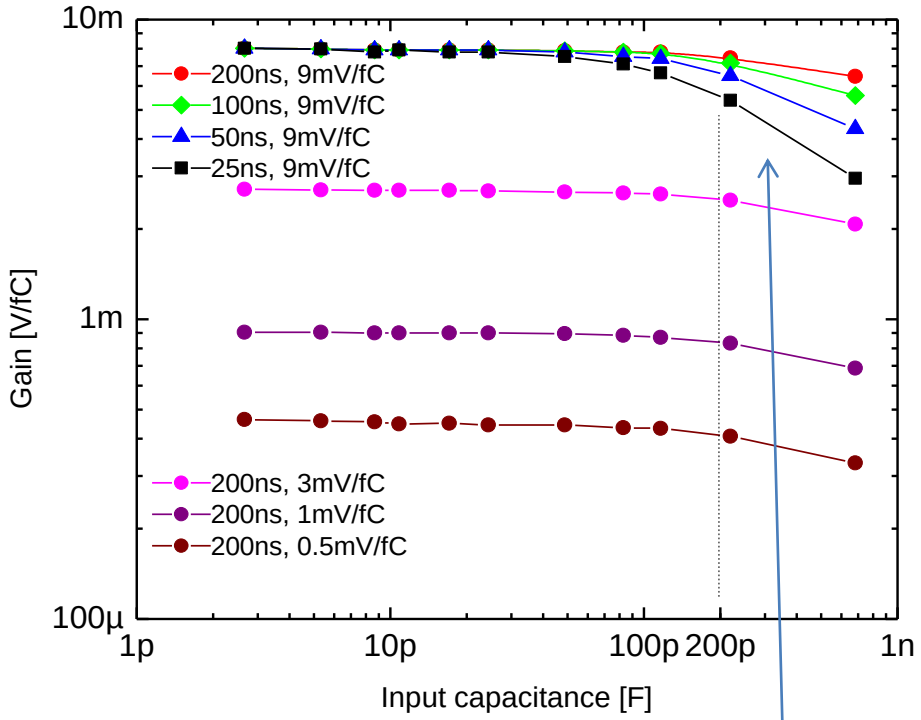
Architecture



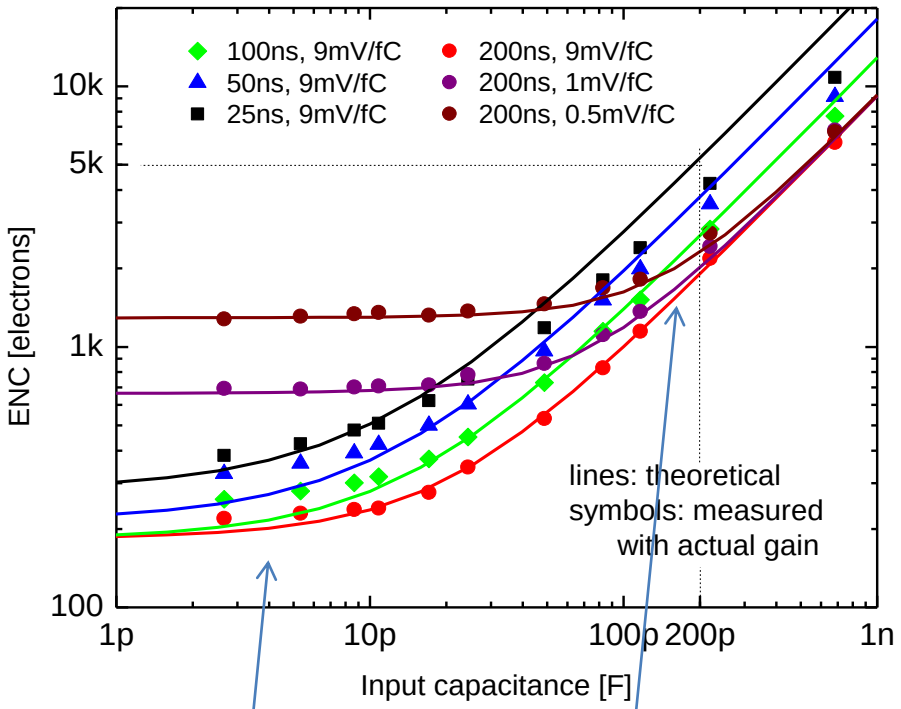
- 200pF (few pF to nF), dual polarity, adj. gain (0.11 to 2 pC), adj. peaktime (25-200 ns), DDF
- discriminator with sub-hysteresis and neighboring (channel and chip)
- address of first event in real time at dedicated output (ART)
- direct timing outputs: time-over-threshold or time-to-peak (*for TGC*)
- multi-phase peak and time detector
- multiplexing with sparse readout and smart token passing (channel and chip)
- threshold and pulse generators, analog monitors, channel mask, temperature sensor, 600mV BGR, 600mV LVDS
- power 4.5 mW/ch, size 6 x 8.4 mm², process IBM CMOS 130nm 1.2V

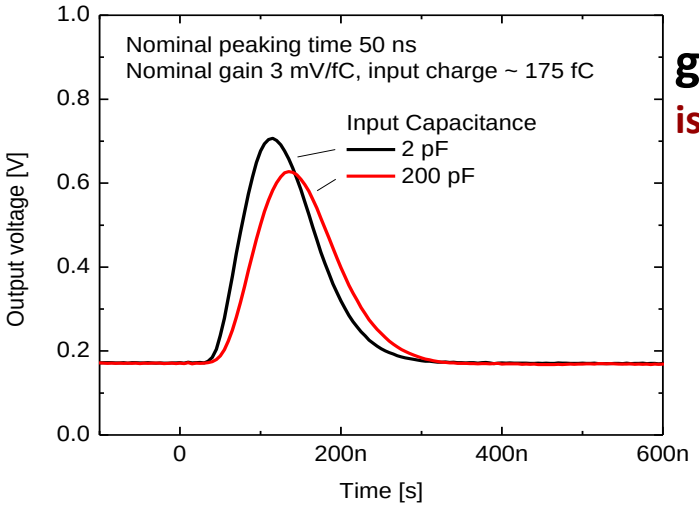
Gain and energy resolution

Gain vs input capacitance



ENC vs input capacitance





gain drop

issue with compensation

disagreement due to increased peaking time

issue with compensation

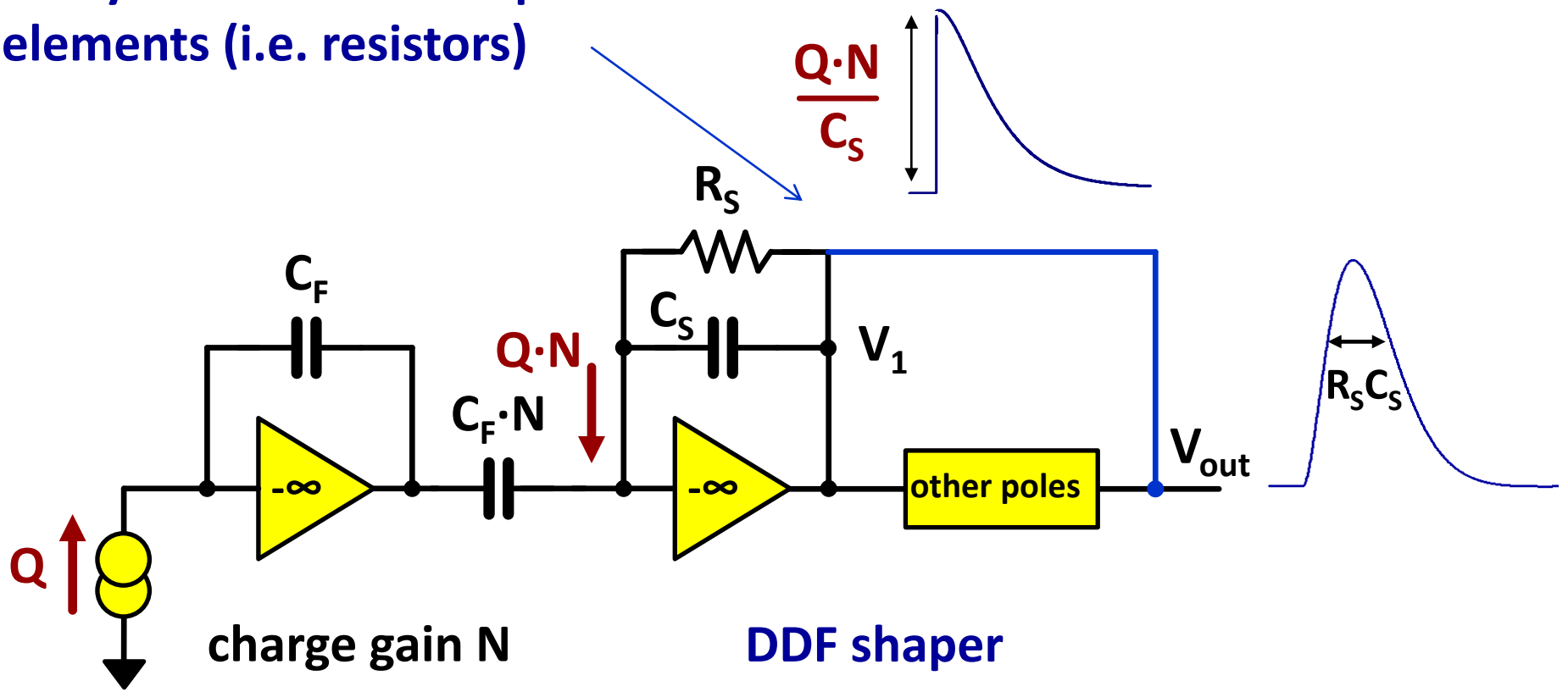
disagreement part due leakage

issue with ESD protection

analog dynamic range Q_{max}/ENC exceeds 12,000

Delayed Dissipative Feedback (DFF)

Delay feedback of dissipative elements (i.e. resistors)



charge gain N

DDF shaper

1) set Q_{max} with N,C_S
2) get ENC_S from R_S

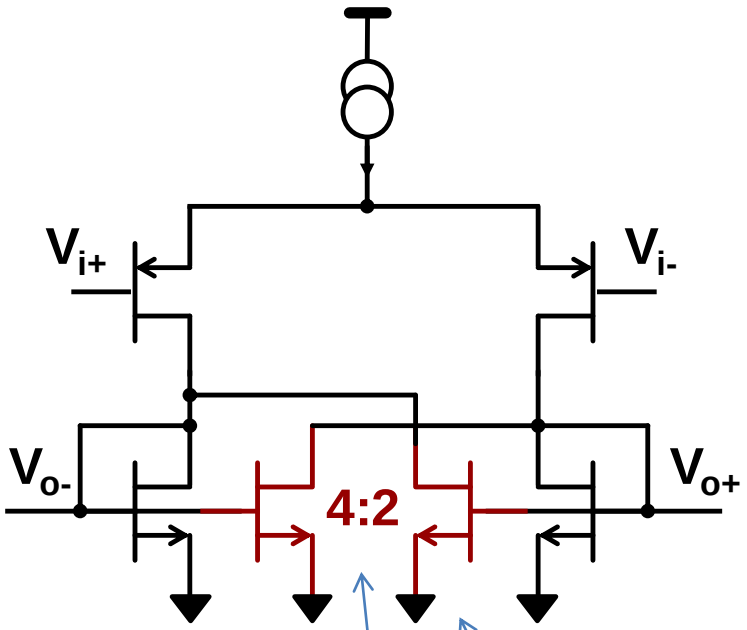
$$DR_a = \frac{Q_{max}}{\sqrt{ENC_{CA}^2 + ENC_S^2}}$$

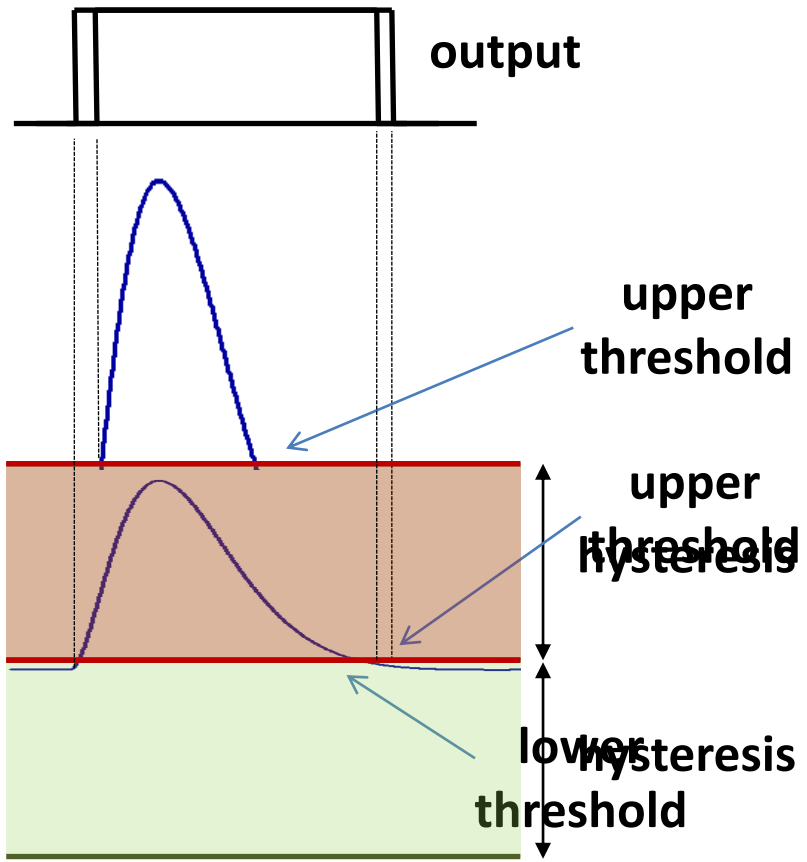
DDF - higher analog dynamic range

see G. De Geronimo and S. Li, TNS 58, Oct. 2011

Sub-hysteresis discrimination

Comparator input stage





Positive feedback

- high speed at low V_{i+}-V_{i-}
- hysteresis set NMOS ratio

sets minimum detectable

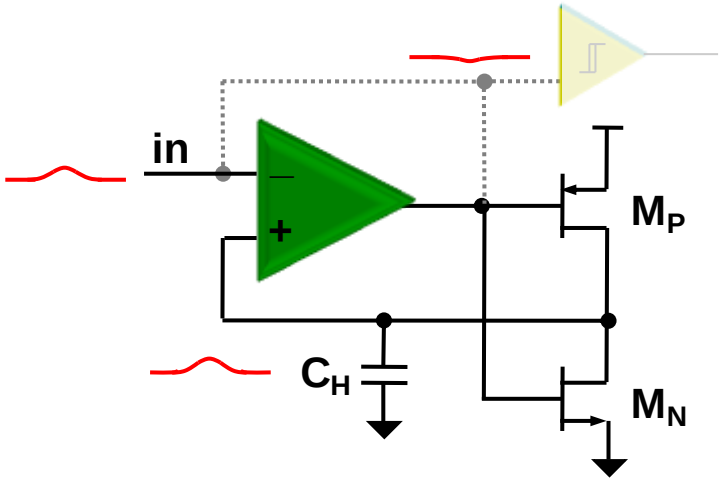
Sub hysteresis

1 - set window lower

2 - raise window after trigger switch NMOS ratio
hold until triggers back

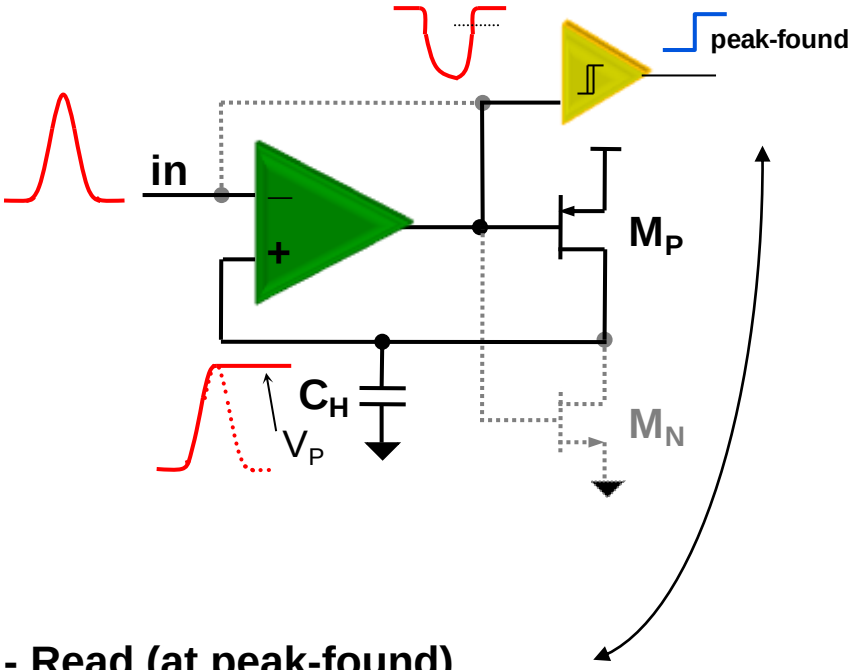
- *limit reduced to overlap*
- *no action on input or threshold signals*

Multi-phase peak detection



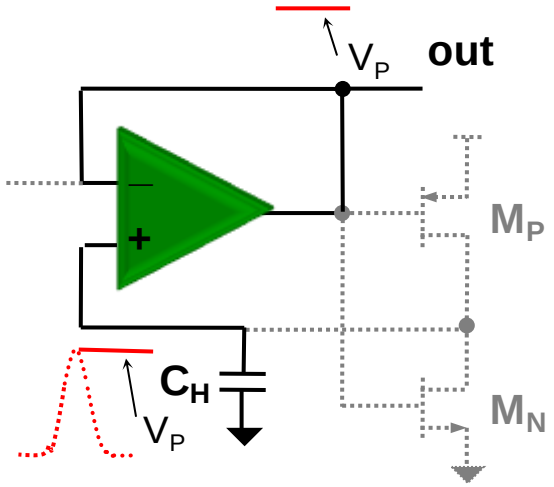
1 - Track (< threshold)

- M_P and M_N enabled
- pulse tracked at hold capacitor



2 - Peak-detect (> threshold)

- only M_P is enabled
- pulse tracked and peak held at capacitor
- peak-found from comparator (timing)

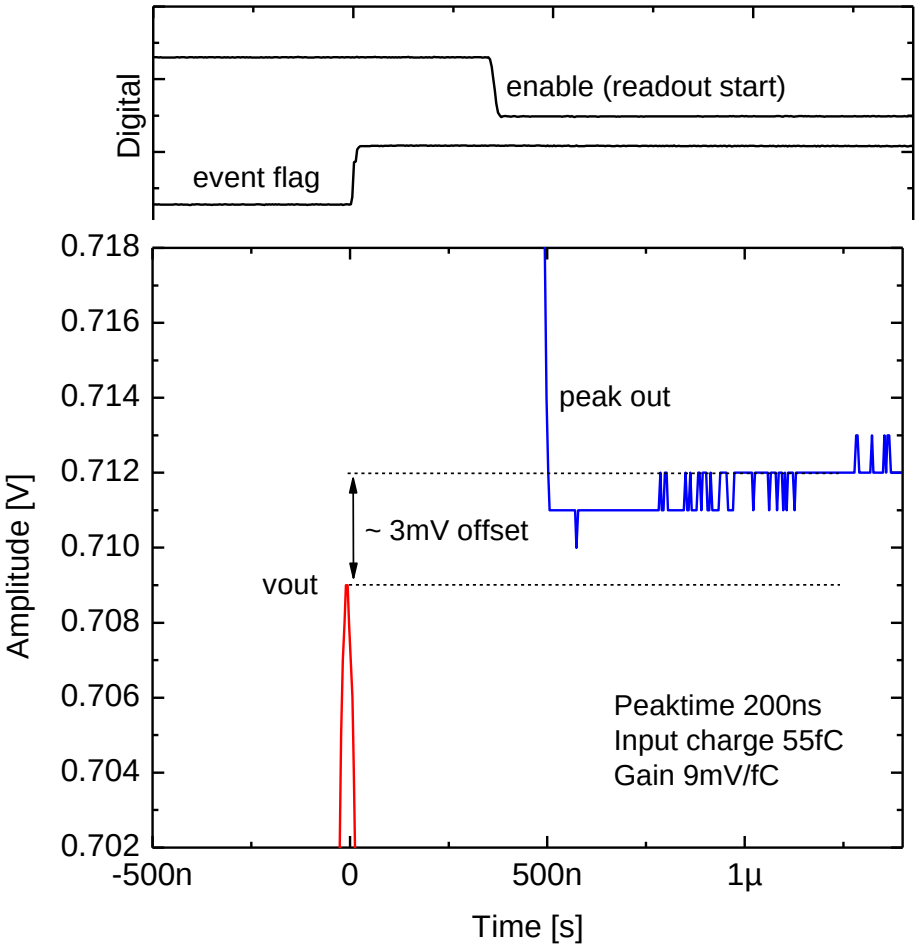


3 - Read (at peak-found)

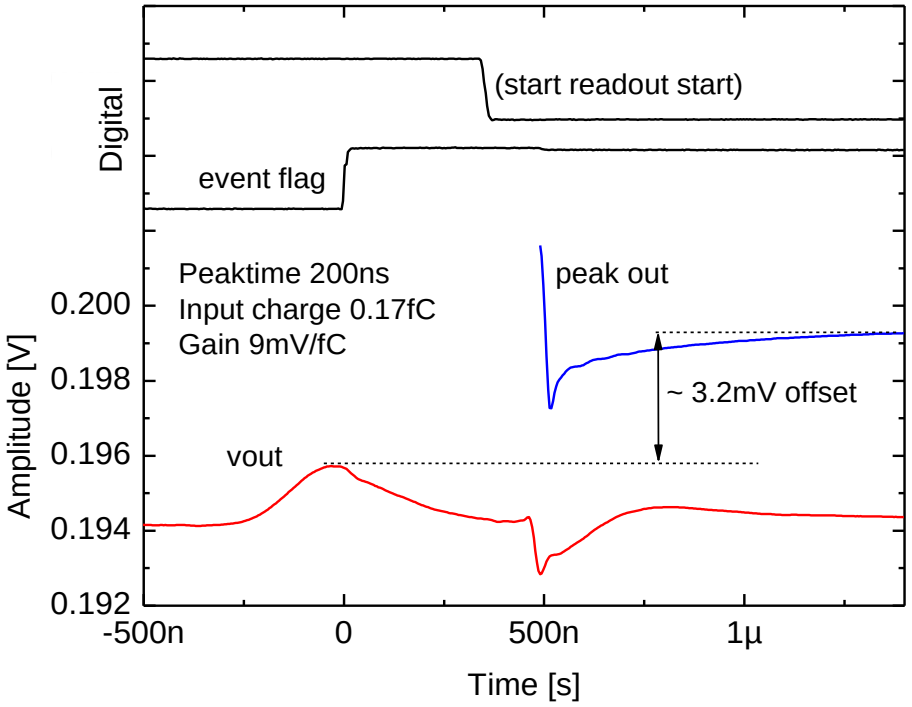
- amplifier reused as buffer, high drive capability
- amplifier offset canceled, rail-to-rail enabled
- some pile-up rejection

Peak measurements

Large amplitude



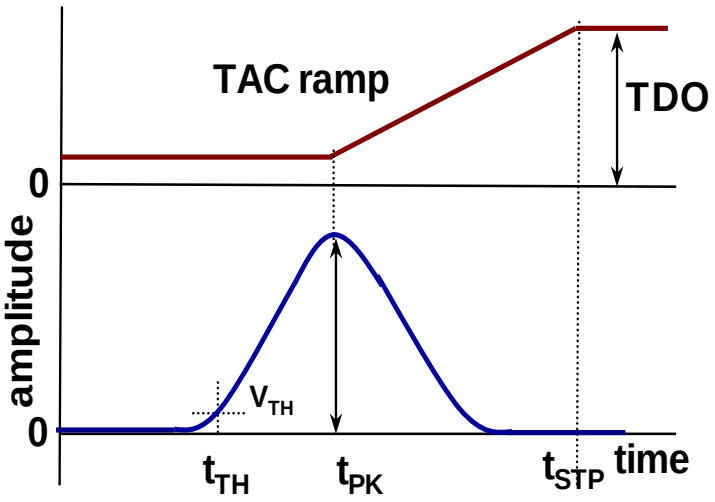
Small amplitude

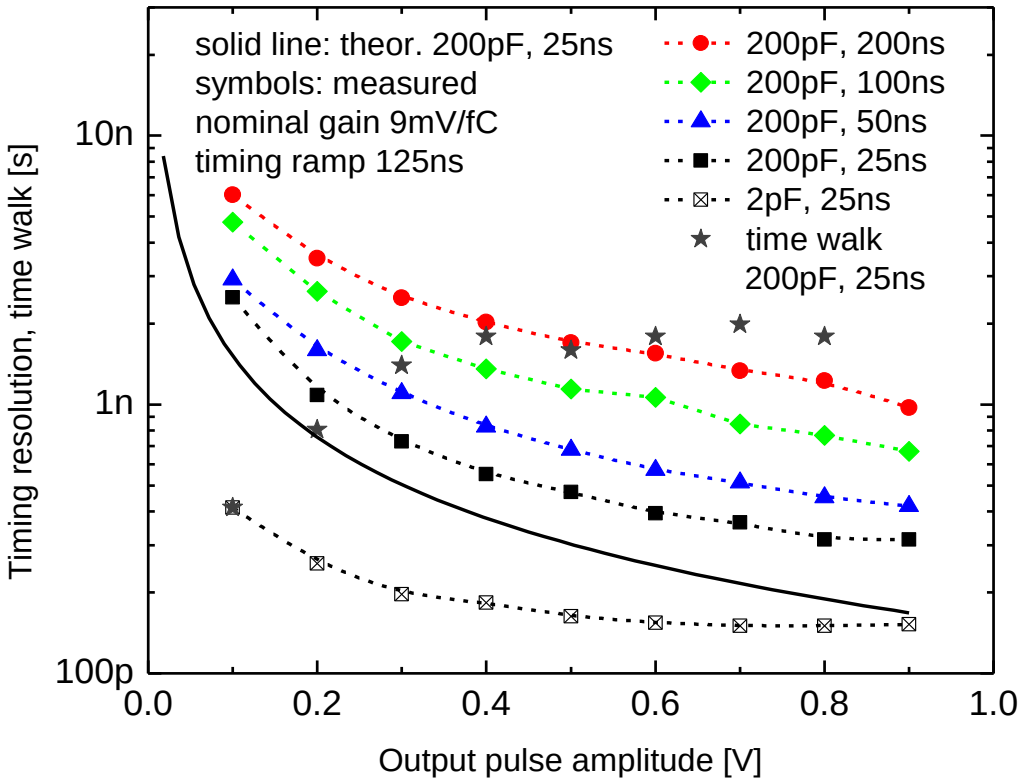


- **with sub-hysteresis**
  nominal hysteresis 20 mV
- **~3 mV offset**
  from external buffers

Timing measurements

Uses peak-found signal





- **very low time-walk**
- **high timing resolution**

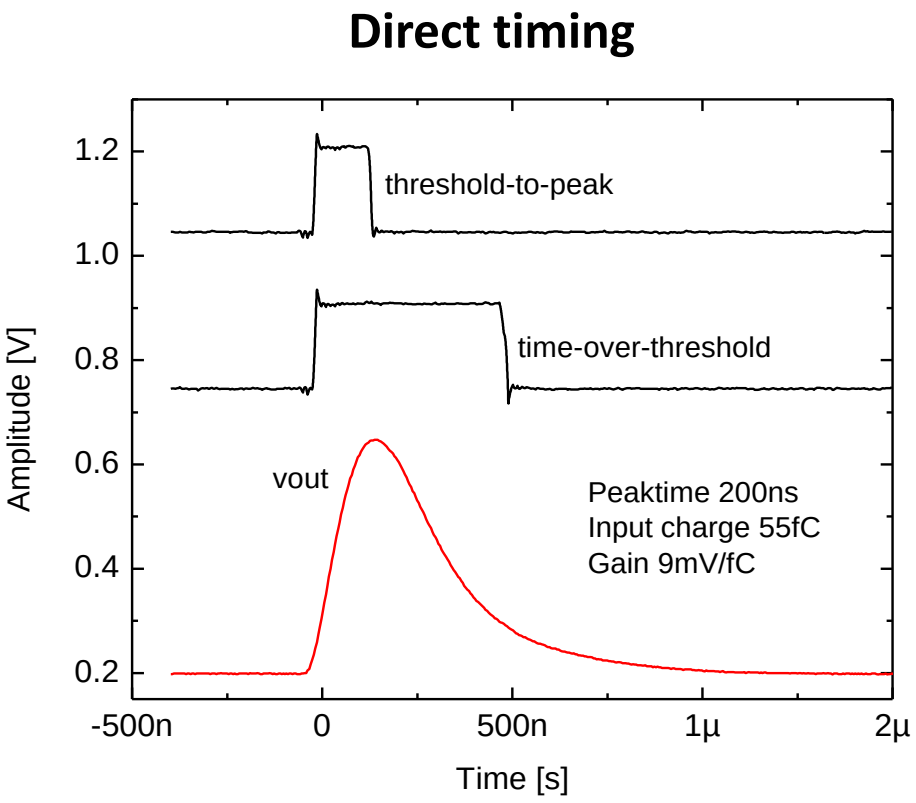
$$\sigma_t \approx \frac{ENC \cdot \tau_p}{Q} \frac{\lambda_p}{\rho_p} \qquad \frac{\lambda_p}{\rho_p} \approx 0.3 - 0.8$$

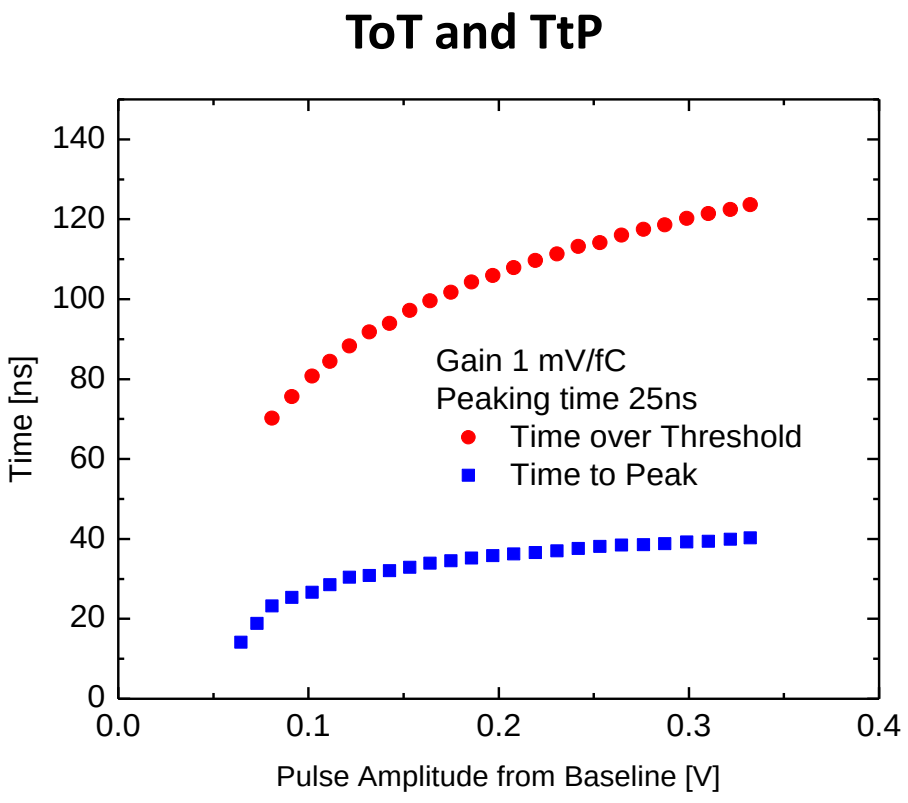
G. De Geronimo, in "Medical Imaging" by Iniewski

- **sub-ns timing**
- **ns time walk (can be calibrated)**

disagreement with theor. due to effective peaktime

Direct timing

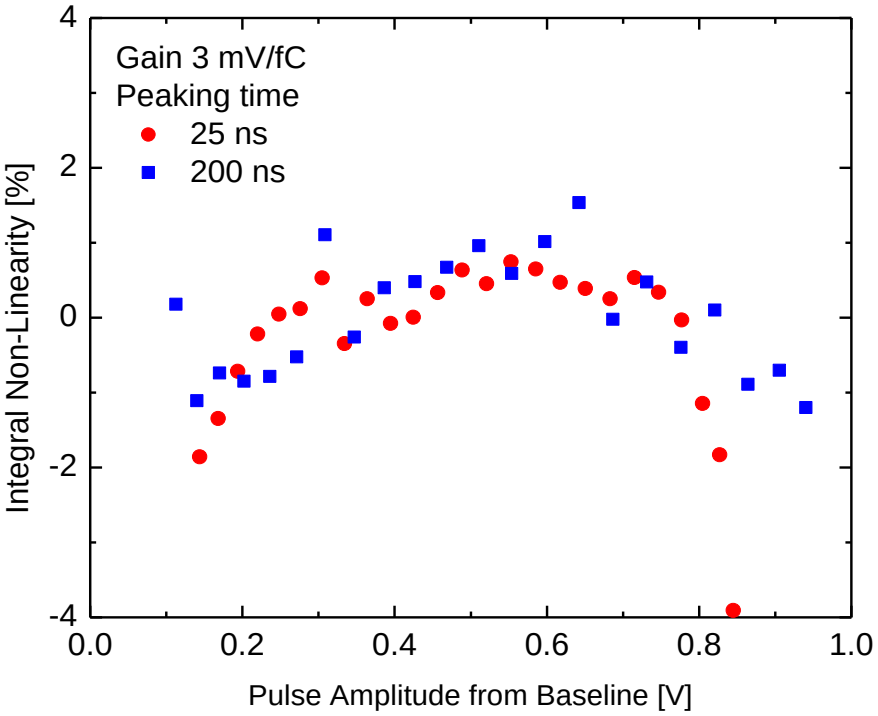




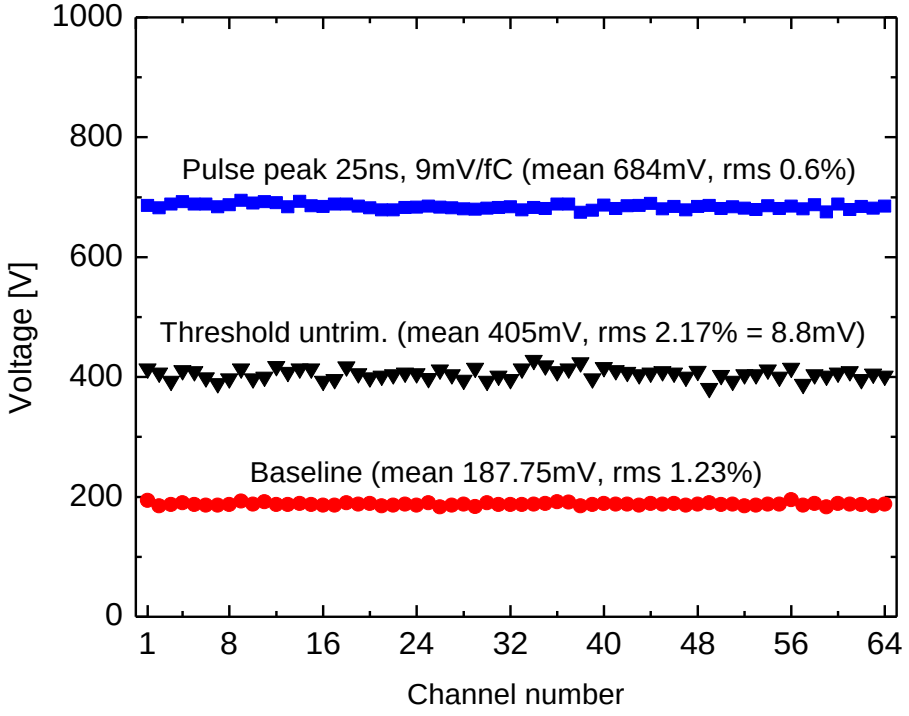
- **dedicated output for each channel**
- **available as ToT or TtP (time-to-peak)**

Amplitude measurements

Linearity



Channel uniformity



- **within 2% for ~ 1 V full swing**

- **peak dispersion includes baseline**
- **threshold dispersion 8.8 mV rms**

  requires improved matching and/or larger trimming range (currently 15 mV)

ART and Neighboring

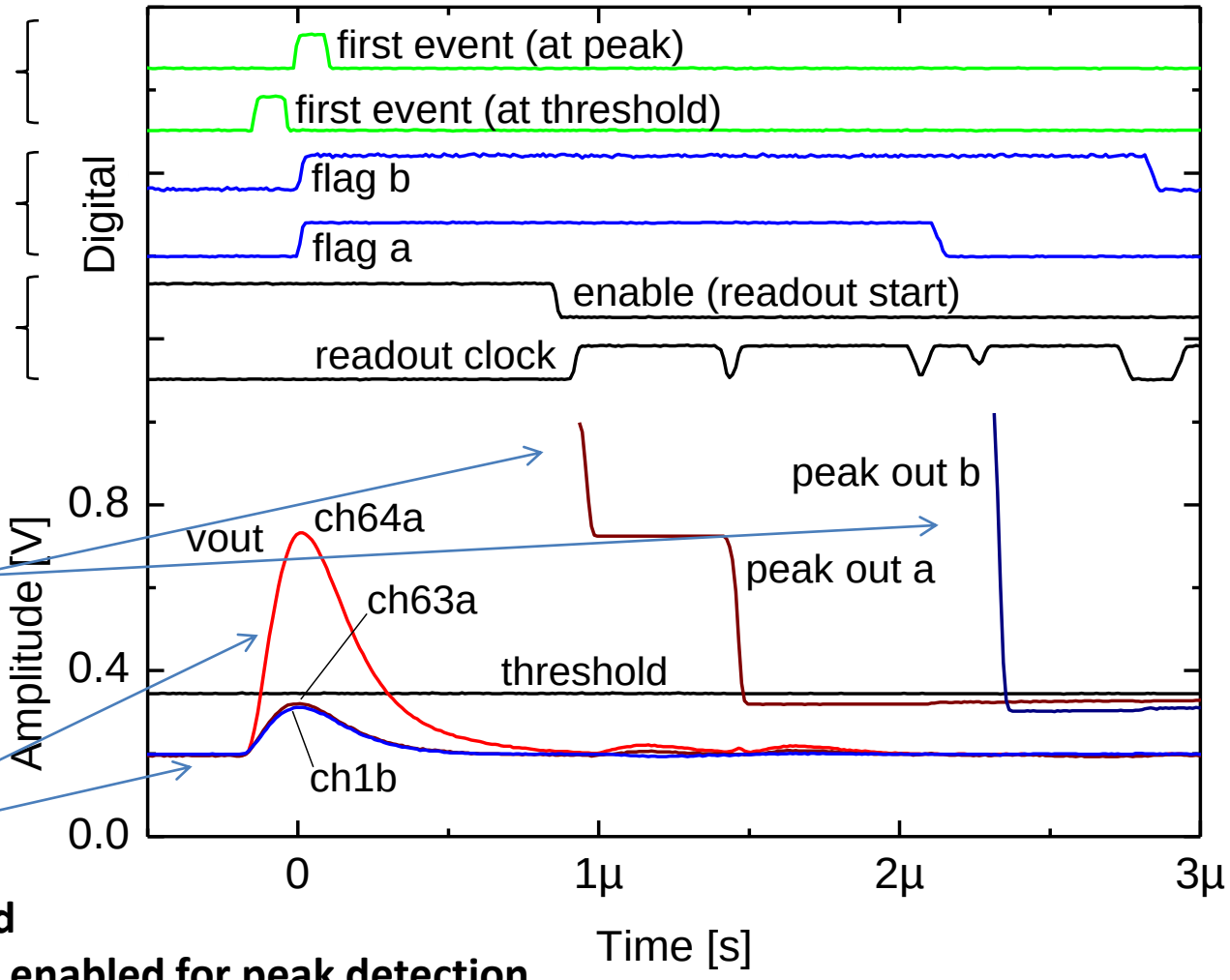
Two chips (a,b) and one channel exceeding threshold (64 in chip a)

ART
- **threshold or peak**
- **with address**

flags and readout

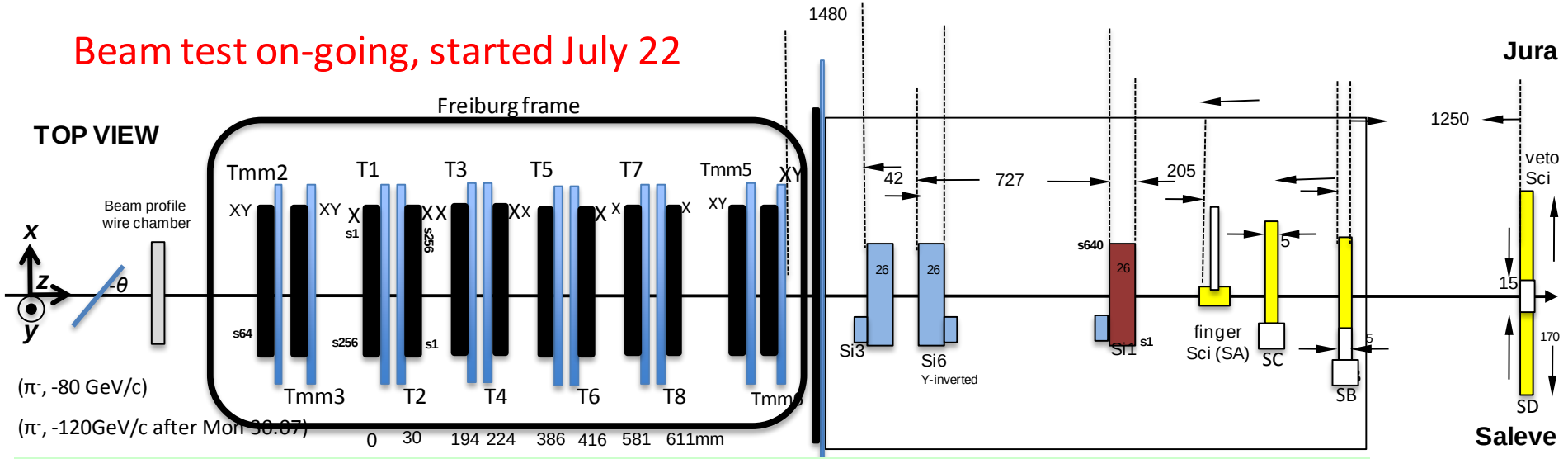
multiplexed sequential peak detect outputs

analog pulses
- **only one exceeds threshold**
- **neighbors (chan. and chip) enabled for peak detection**

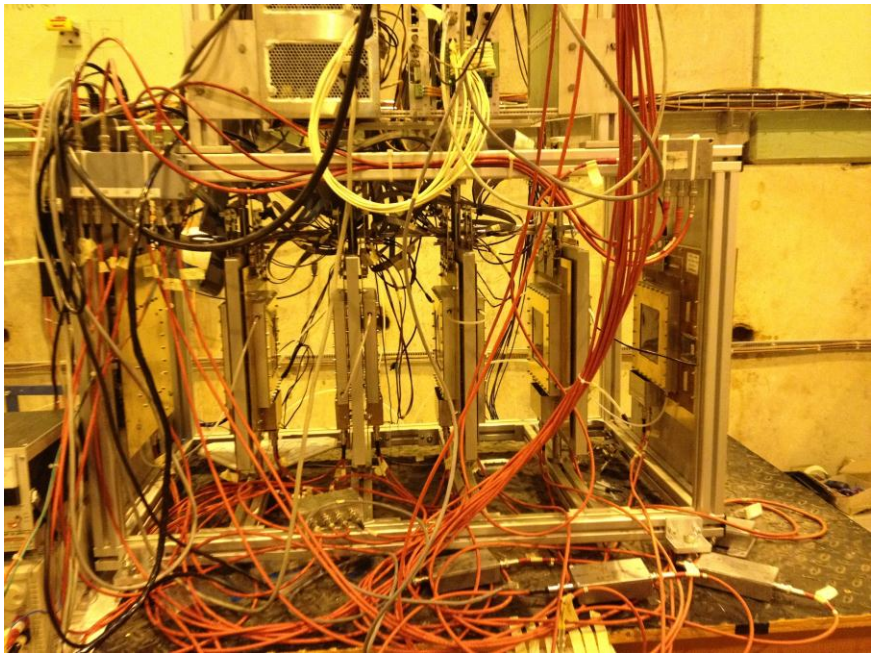


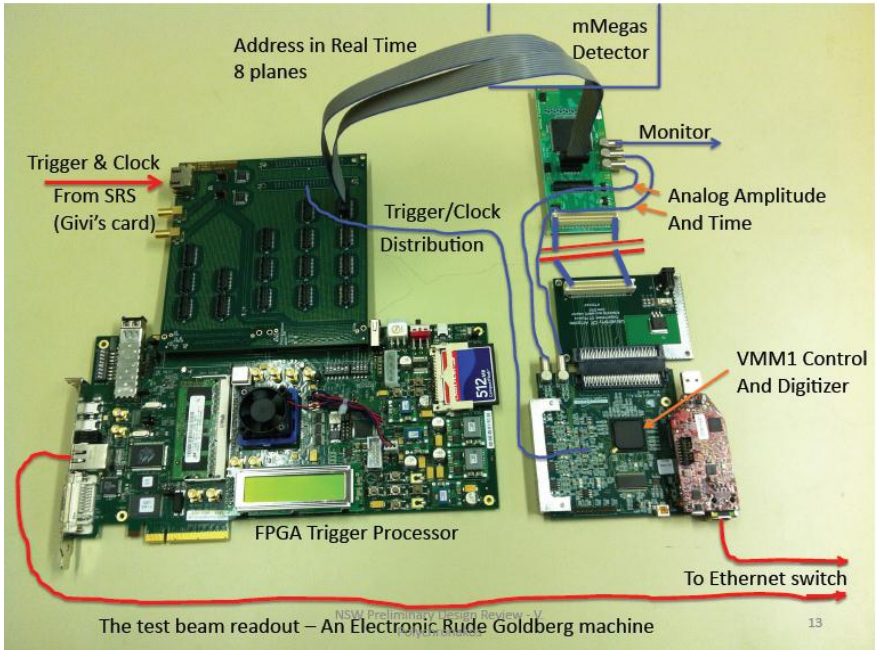
Beam tests at CERN - setup

Beam test on-going, started July 22



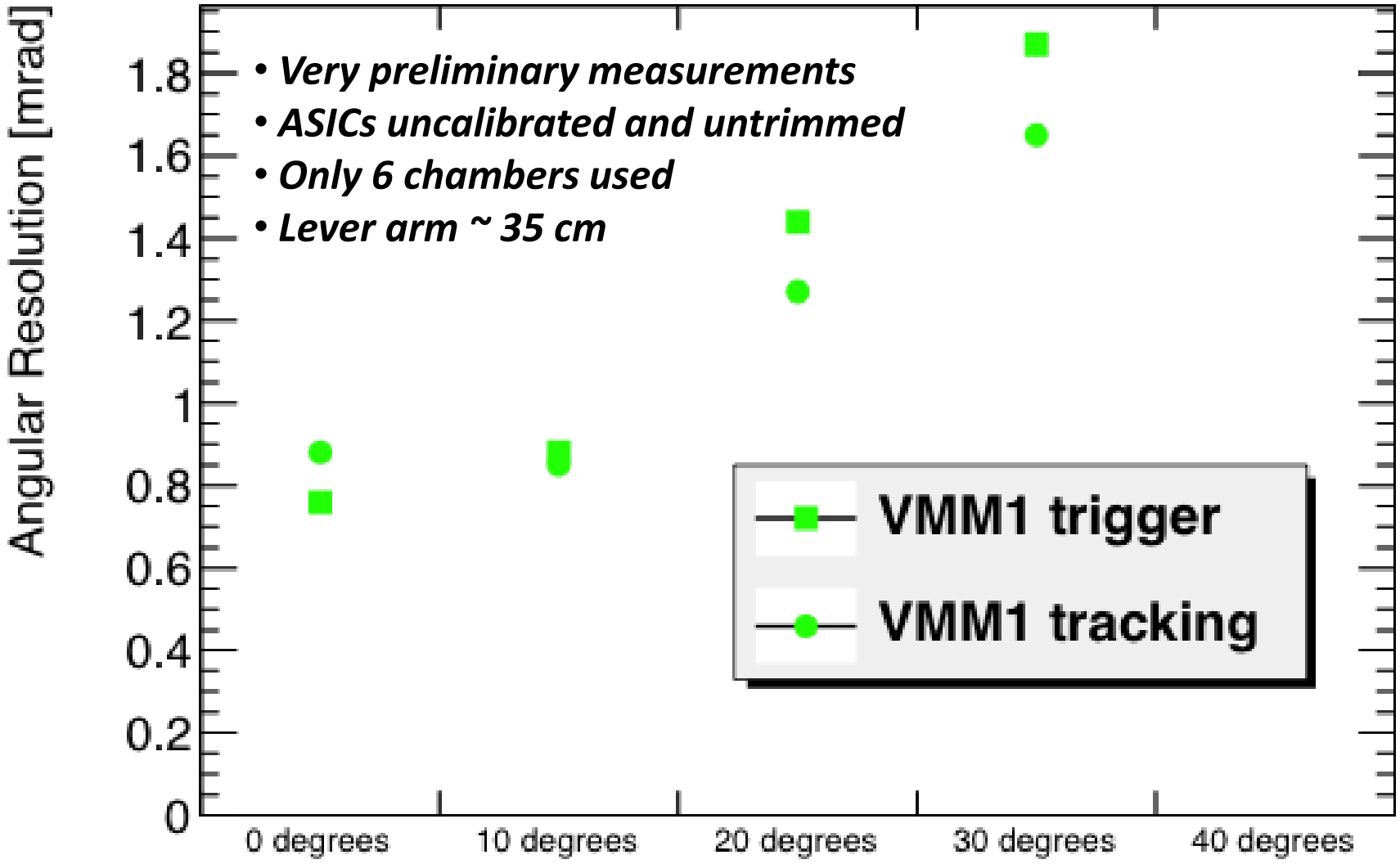
T1-8; S=10x10cm^2; p=0.4mm; dg=5mm; gG=10^4; Ar-CO_2 93-7; v_d=47um/ns; Elx=APV25; daq=SRS



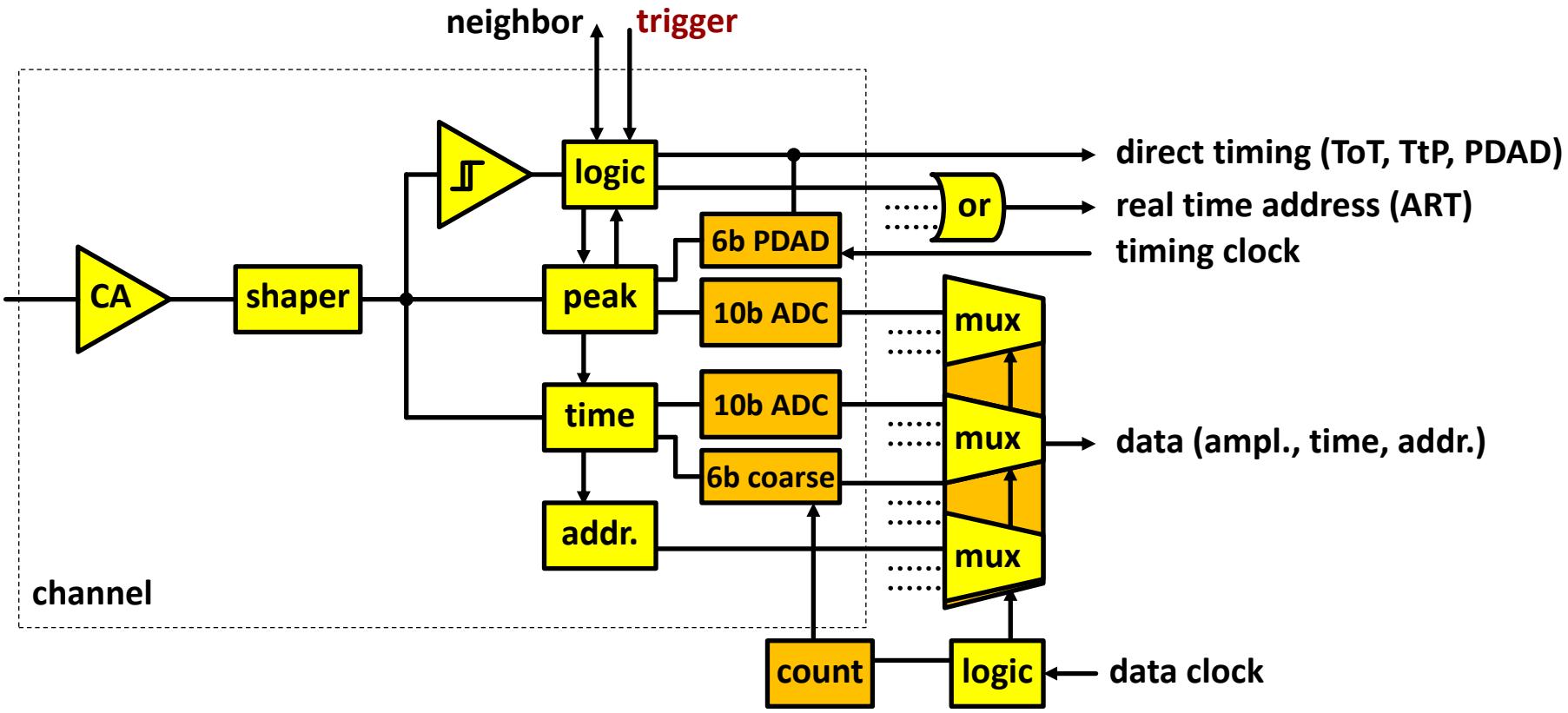


Beam tests at CERN - preliminary results

Track Slope Resolution as a function of angle



Plans for VMM2



- fixes, higher gain setting, lower gain setting (5pC)
- external trigger
- 6-bit peak detector and digitizer (PDAD) for direct timing
- 10-bit 5MS/s ADCs per channel and FIFO
  fully digital IOs, derandomization, simultaneous measurement and readout
- counter for coarse timing

Conclusions

- VMM is an ASIC family for the ATLAS Muon Spectrometer upgrade (MICROMEGAS AND TGC)
- VMM1 has been developed and tested, with results in good agreement with the design. Main issues are charge amplifier compensation and large leakage from ESD. Preliminary test beam results at CERN are promising
- VMM2 (in design) will integrate a number of improvements for simultaneous measurement and readout

Acknowledgment

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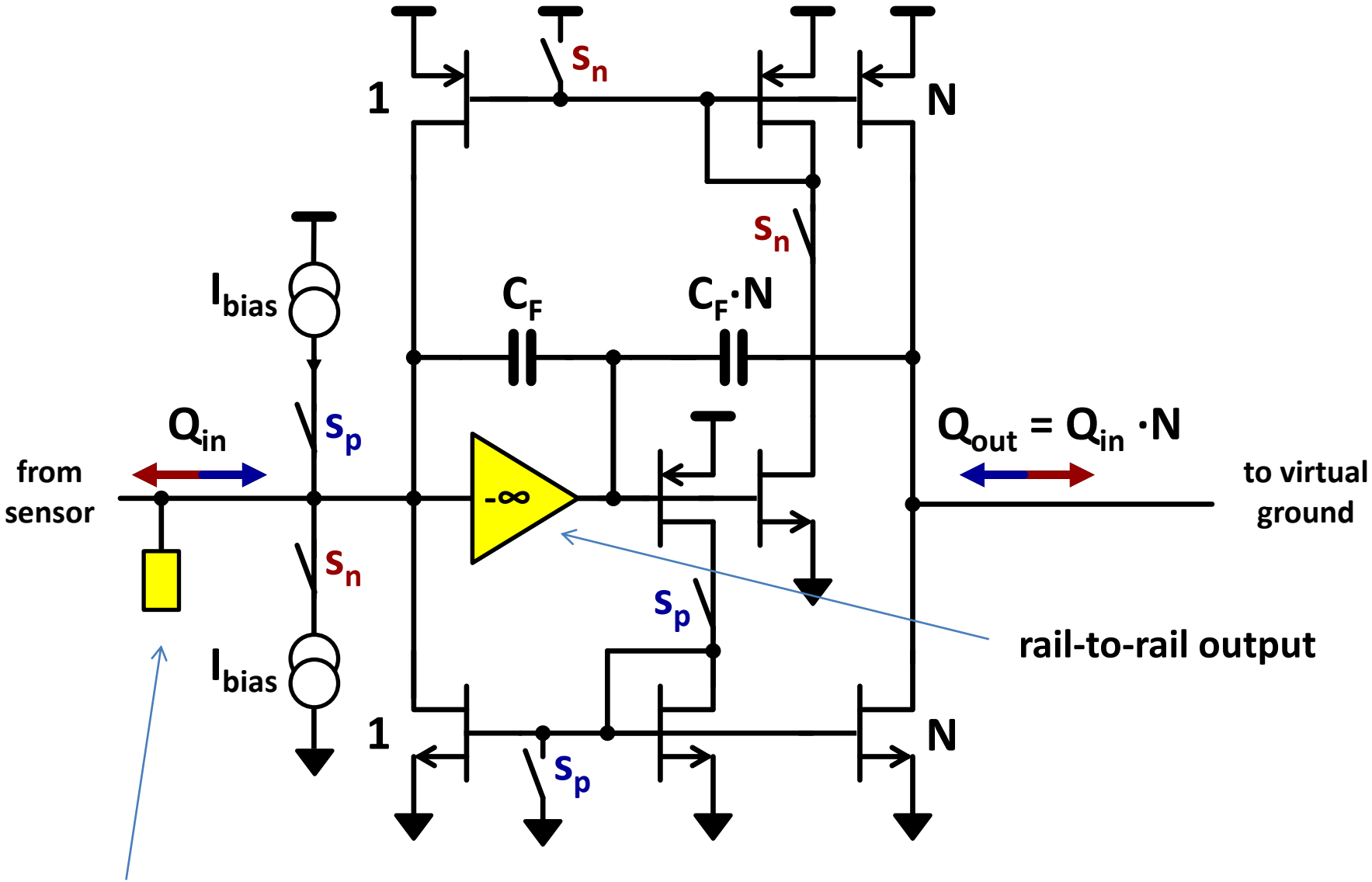
Nachman Lupu (Technion Haifa, Israel)

Howard Gordon and Craig Woody (BNL, USA)

ATLAS review team (J. Oliver, M. Newcomer, R. Richter, P. Farthouat)

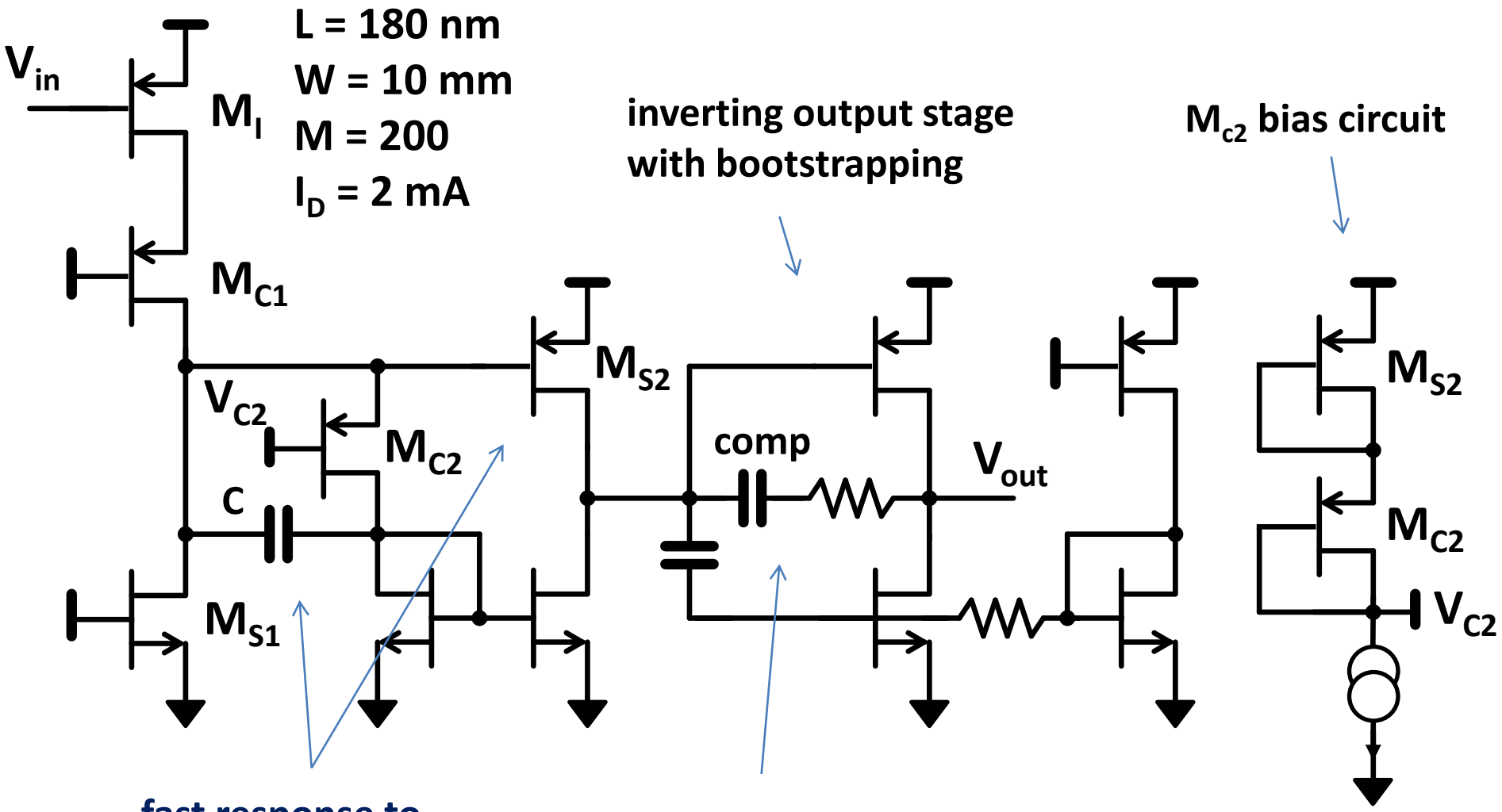
Backup slides

Dual polarity charge amplifier



ESD protection - ***issue: excessive leakage (few nA)***

Front-end voltage amplifier



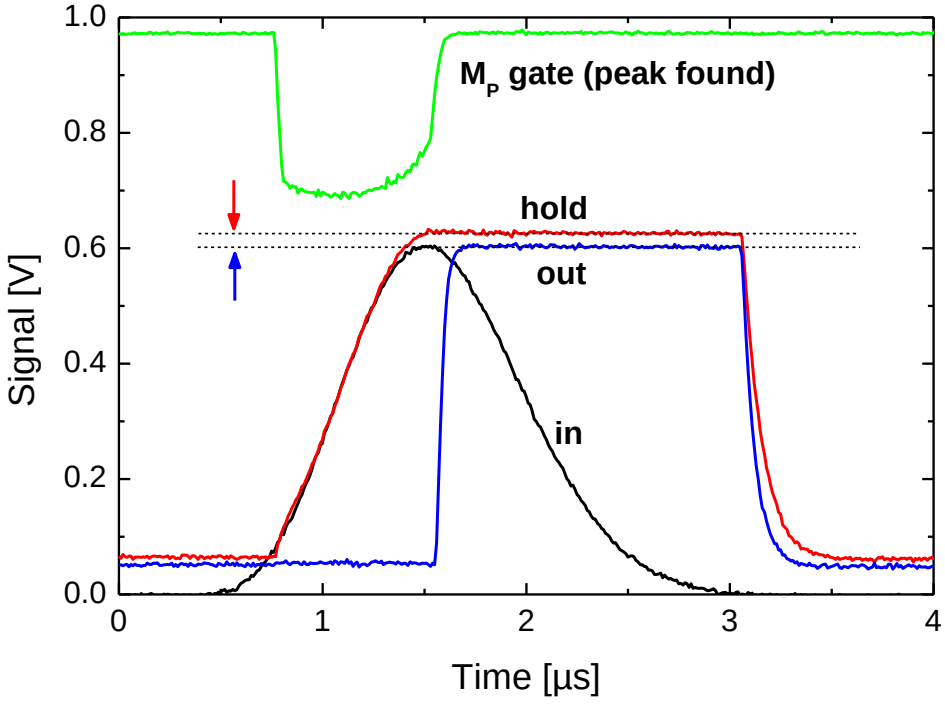
fast response to positive charge

switchable compensation

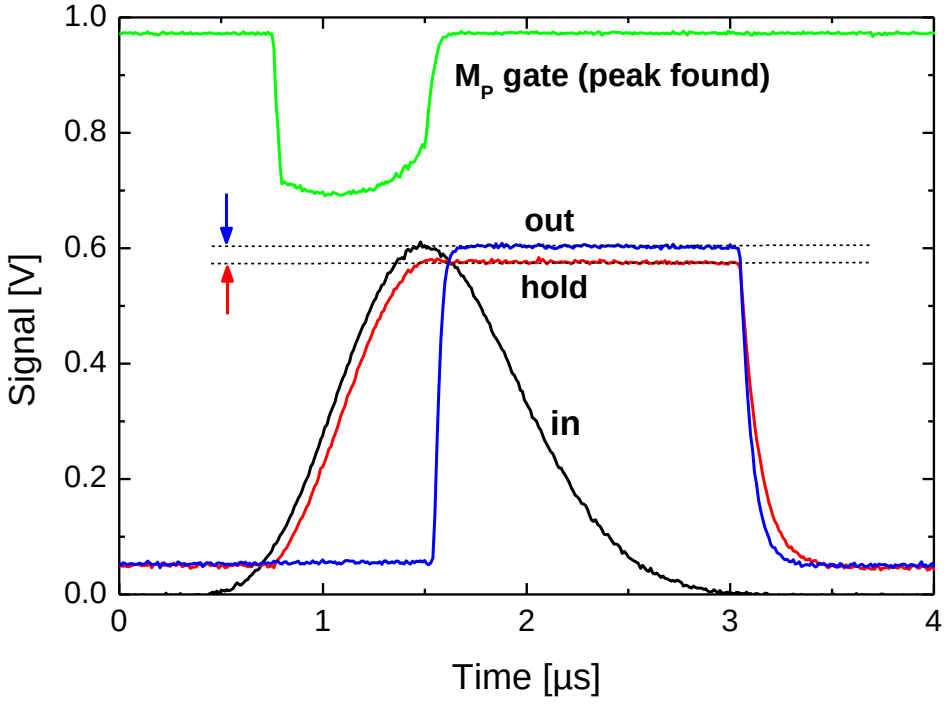
- issue: unstable when set for large caps

Multi-phase peak detection

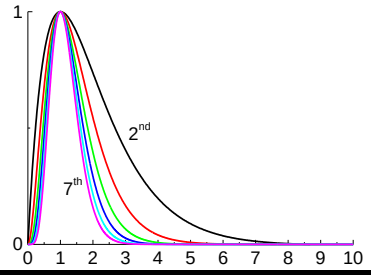
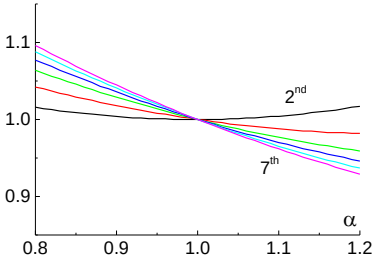
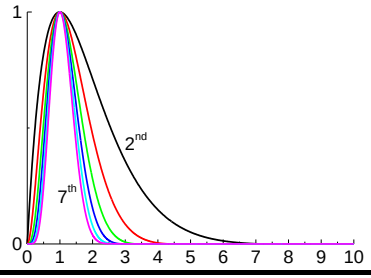
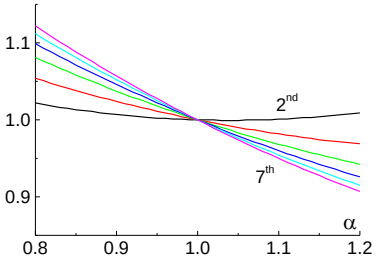
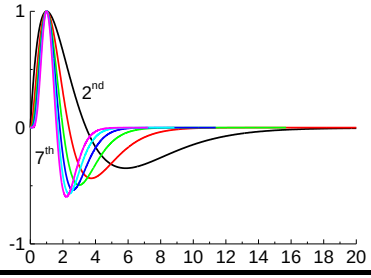
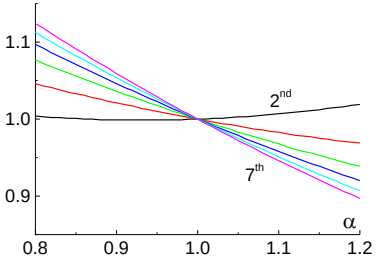
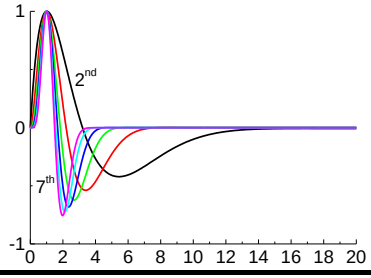
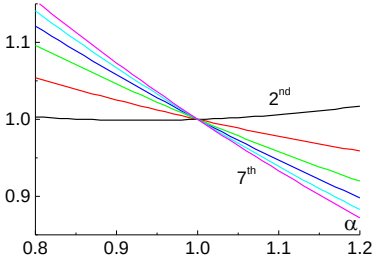
Chip 1 - negative offset



Chip 2 - positive offset



ENC and timing coefficients for various shapers

Filter	Shape	a_w	$a_f(1)$	a_p	$\rho_f(\alpha_f)=a_f(\alpha_f)/a_f(1)$	τ_w/τ_p	$-\rho_p$	η_p	λ_p
RU-2		0.92	0.59	0.92		7.49	0.98	-	-
RU-3		0.82	0.54	0.66		5.04	1.85	0.30	1.64
RU-4		0.85	0.53	0.57		4.17	2.50	0.44	1.60
RU-5		0.89	0.52	0.52		3.72	3.01	0.52	1.60
RU-6		0.92	0.52	0.48		3.46	3.40	0.57	1.61
RU-7		0.94	0.51	0.46		3.28	3.74	0.61	1.62
CU-2		0.93	0.59	0.88		6.17	1.05	-	-
CU-3		0.85	0.54	0.61		3.92	2.07	0.31	1.59
CU-4		0.91	0.53	0.51		3.16	2.95	0.48	1.57
CU-5		0.96	0.52	0.46		2.84	3.65	0.58	1.58
CU-6		1.01	0.52	0.42		2.66	4.22	0.63	1.60
CU-7		1.04	0.52	0.40		2.55	4.71	0.65	1.62
RB-2		1.03	0.75	1.01		16.6	0.34	0.29	-
RB-3		1.11	0.78	0.76		9.87	0.69	0.41	-
RB-4		1.30	0.81	0.66		7.67	0.98	0.47	-
RB-5		1.47	0.85	0.62		6.61	1.20	0.51	-
RB-6		1.61	0.87	0.59		5.96	1.39	0.54	-
RB-7		1.74	0.90	0.57		5.53	1.55	0.56	-
CB-2		1.08	0.80	1.02		12.9	0.47	0.33	-
CB-3		1.27	0.86	0.76		7.29	0.91	0.45	-
CB-4		1.58	0.93	0.67		5.58	1.32	0.52	-
CB-5		1.87	0.98	0.62		4.80	1.66	0.56	-
CB-6		2.10	1.03	0.60		4.39	1.92	0.58	-
CB-7		2.33	1.06	0.57		4.10	2.15	0.61	-

G. De Geronimo, in "Medical Imaging" by Iniewski