BeamCal electronics update

Angel Abusleme

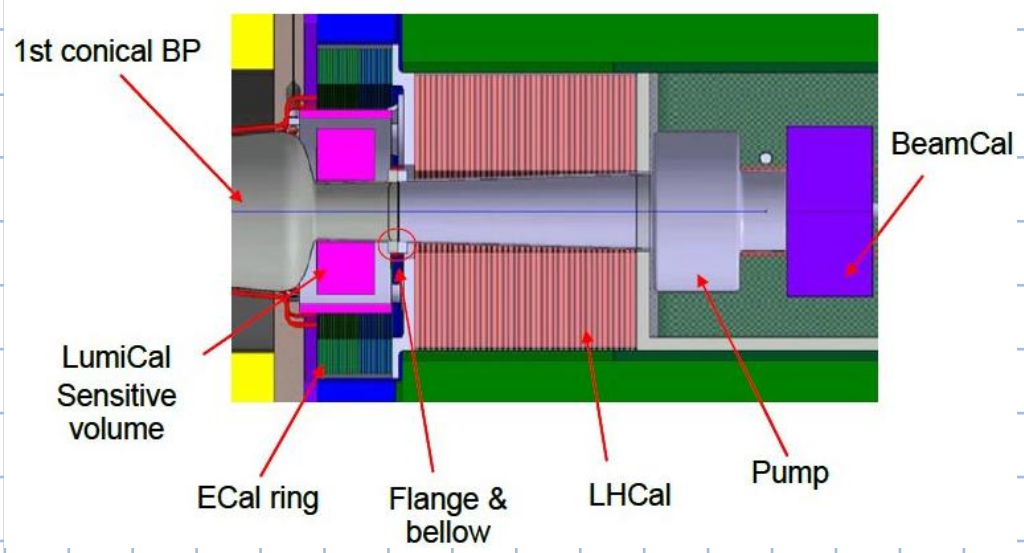
31st FCAL collaboration meeting

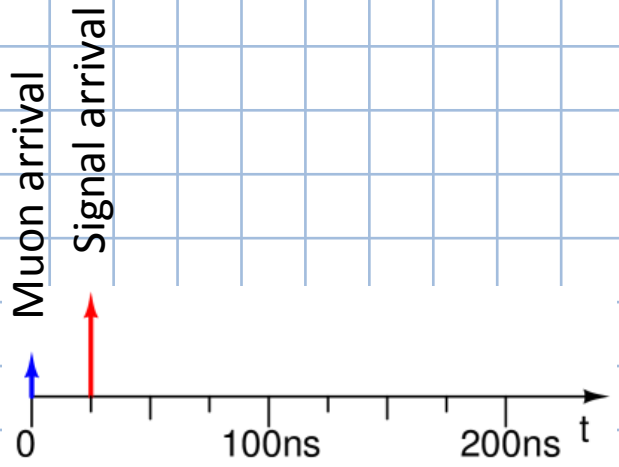
VINCA Belgrade, September 4th 2017

Halo calibration concept

this is a tentative, **non-official** idea

- We want to see MIPs in order to calibrate the detector
- We could use halo muons





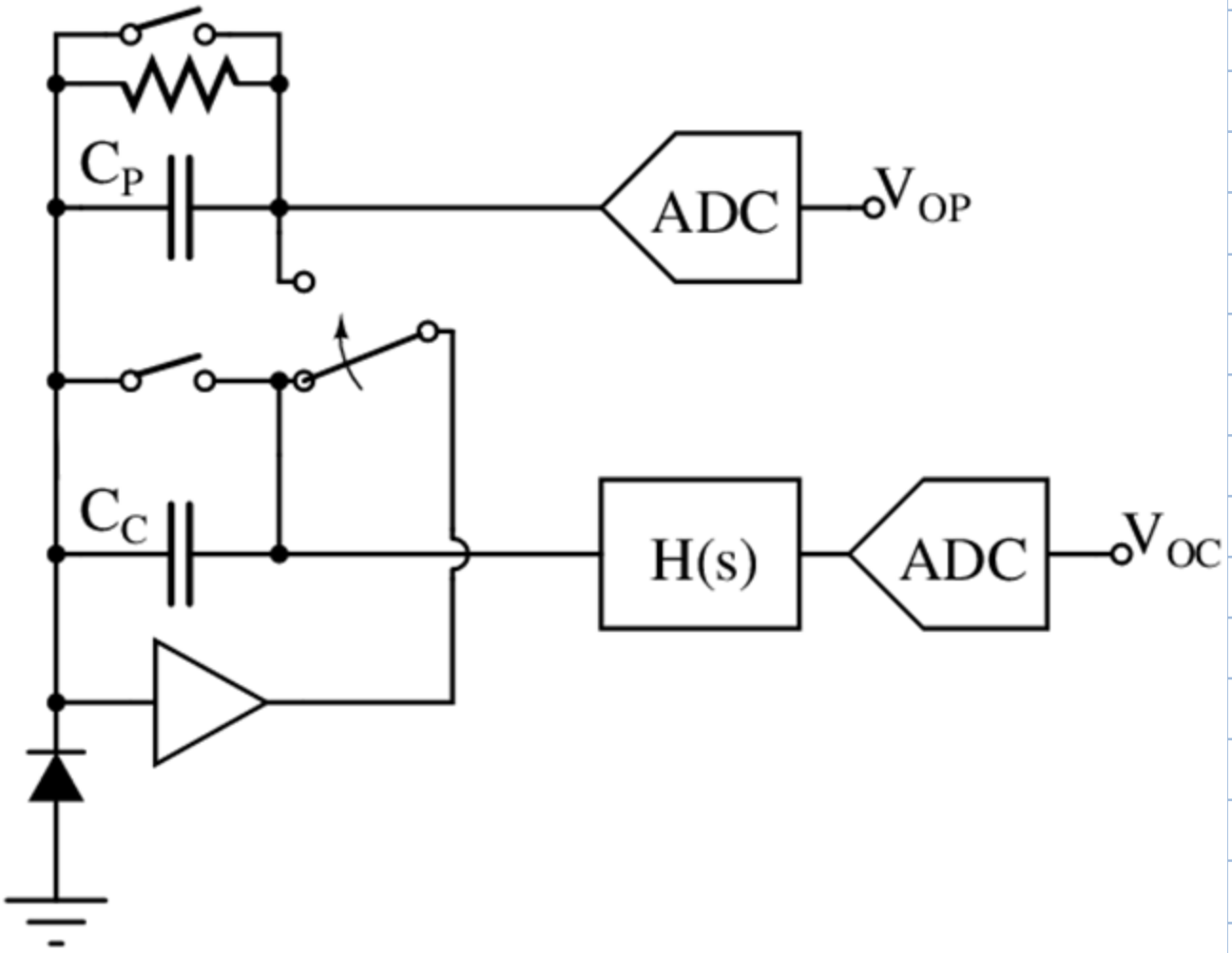
- Assuming **original detector layout**
  - MIP charge deposition: 550e
  - Noise target: ~390e (about half the power of a MIP)

Dual readout concept - Motivation

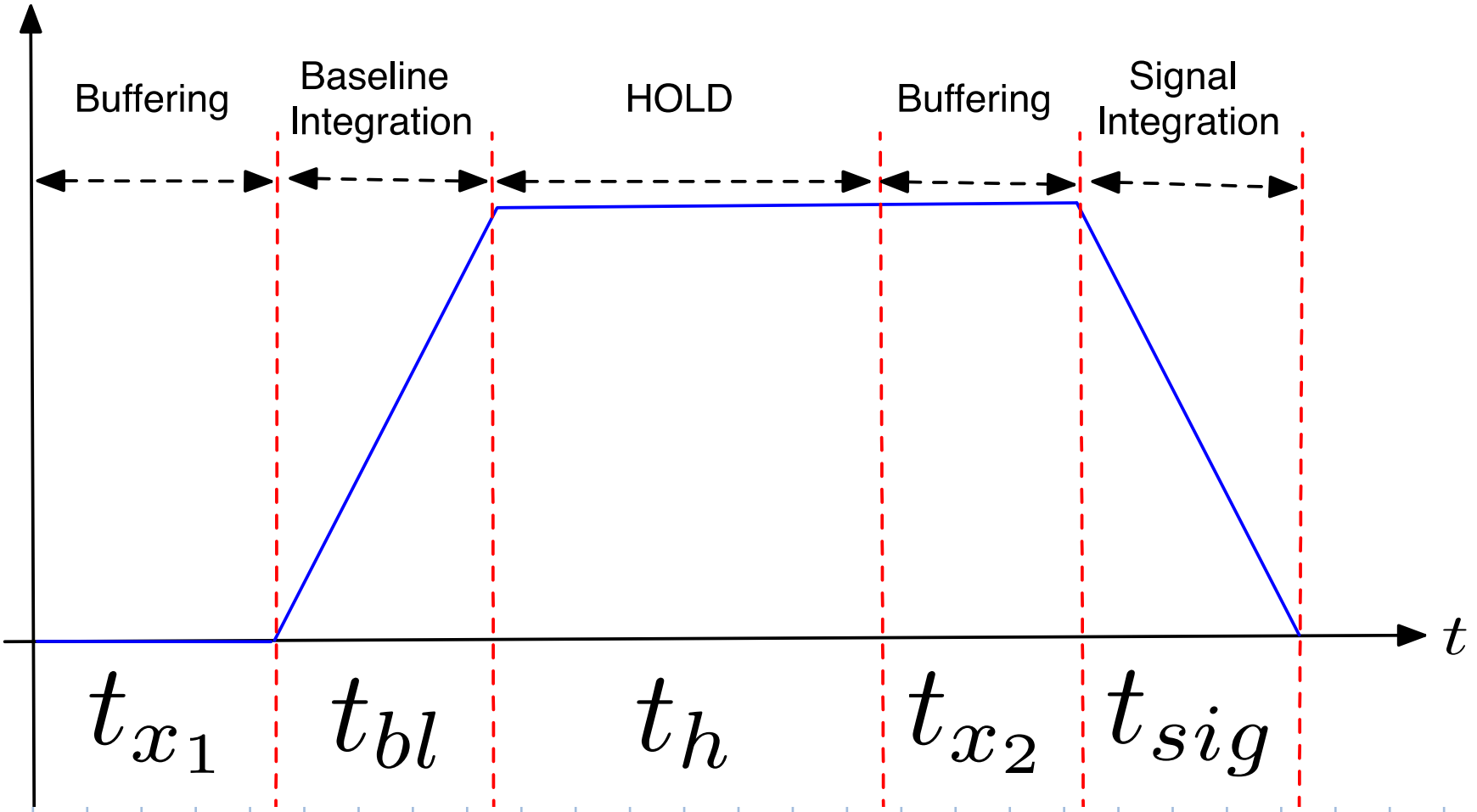
- How to read out such a small signal in short time?
  - Small signals (MIPs) are noisy
    - Could improve by increasing CSA current to **> 5mA** – this is not efficient
  - Processing time required for filtering (integration)
    - Cannot simply digitize CSA output
  - **25 ns** is not enough processing time before arrival of standard data taking signals
  - Need weighting function with smooth slopes…

Dual readout concept – block diagram

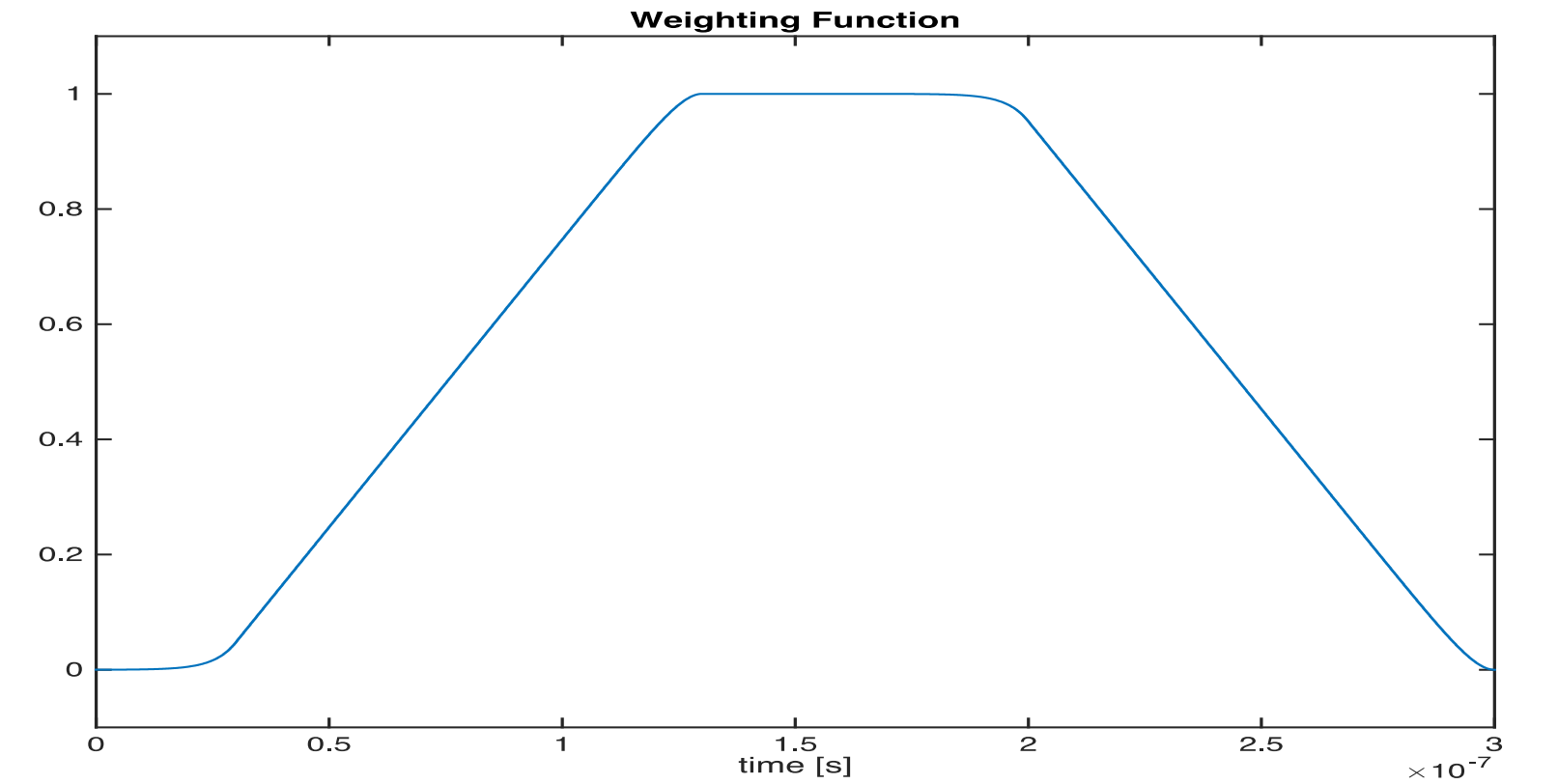
as presented in the 29th FCAL meeting, TAU 2016



Dual readout concept – timing diagram



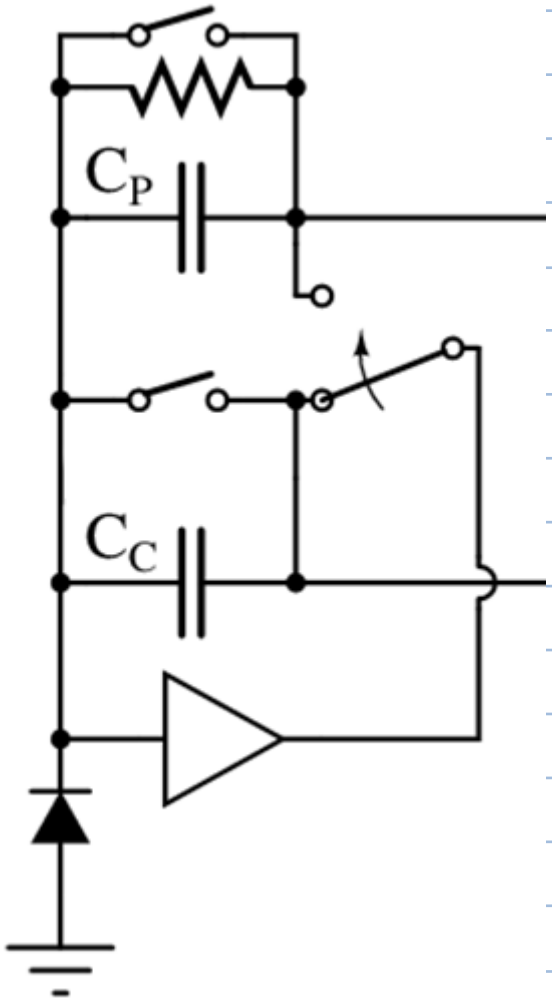
Intended weighting function (behavioral simulation)



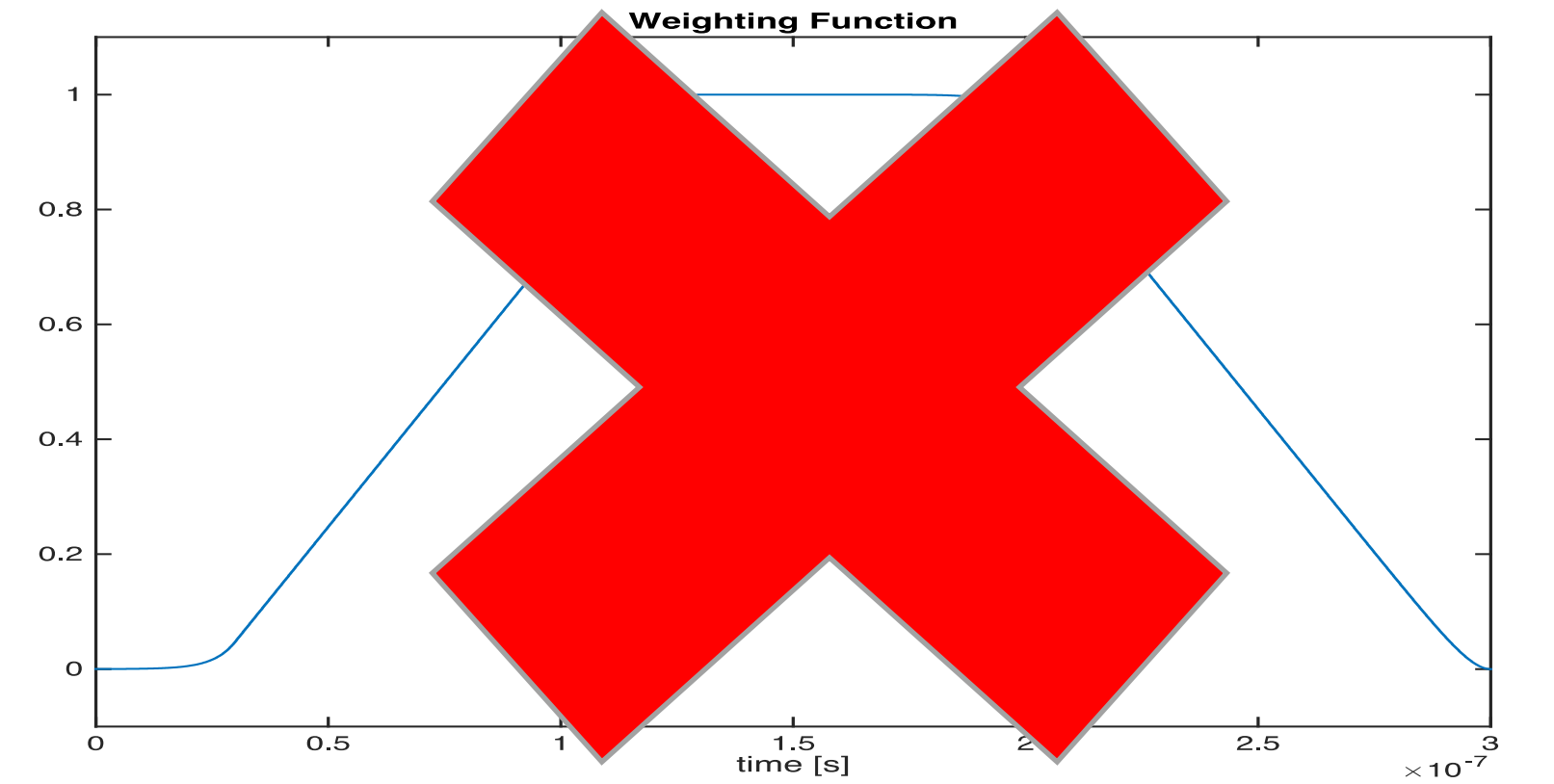
This weighting function does not take into account the **sampled noise** when switching capacitances, and this effect may add a considerable amount of noise.

How bad is the **sampled noise**?

- Opening the feedback switch will sample the output noise
- This sampled noise cannot be distinguished from the signal
  - … and its RMS value is huge!



Intended weighting function (behavioral simulation)



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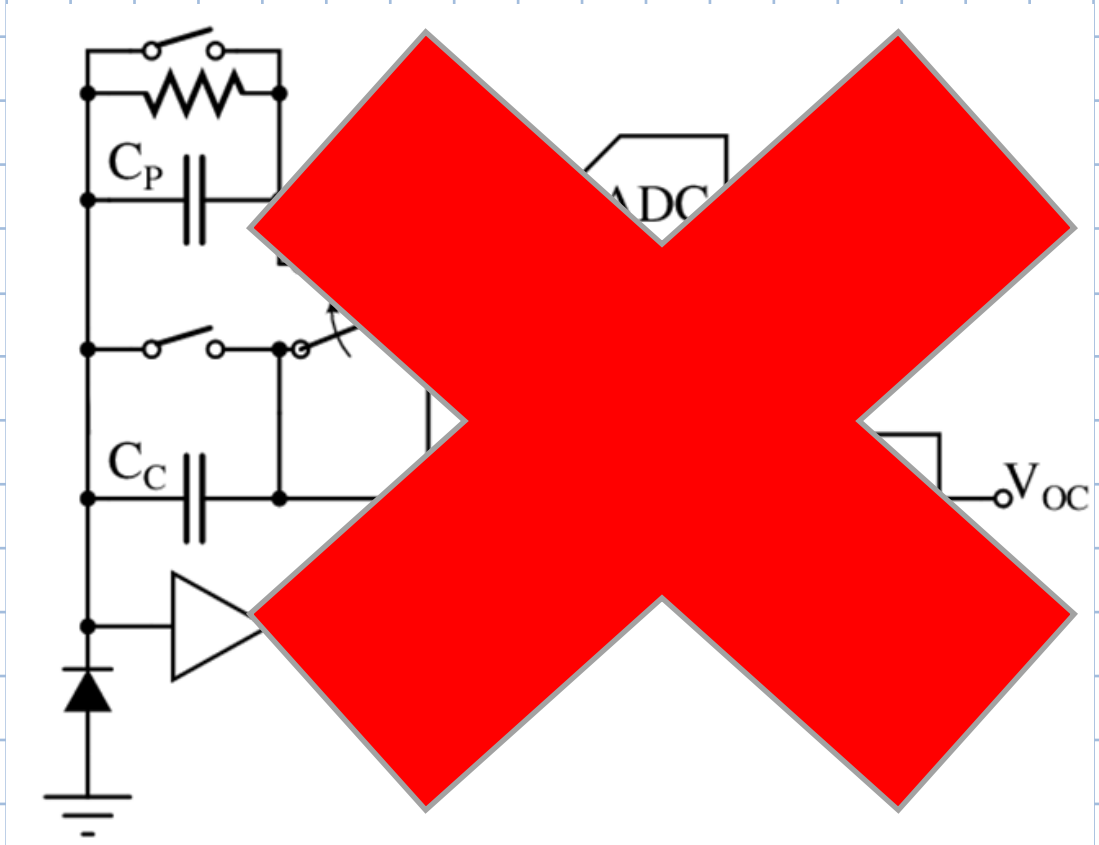
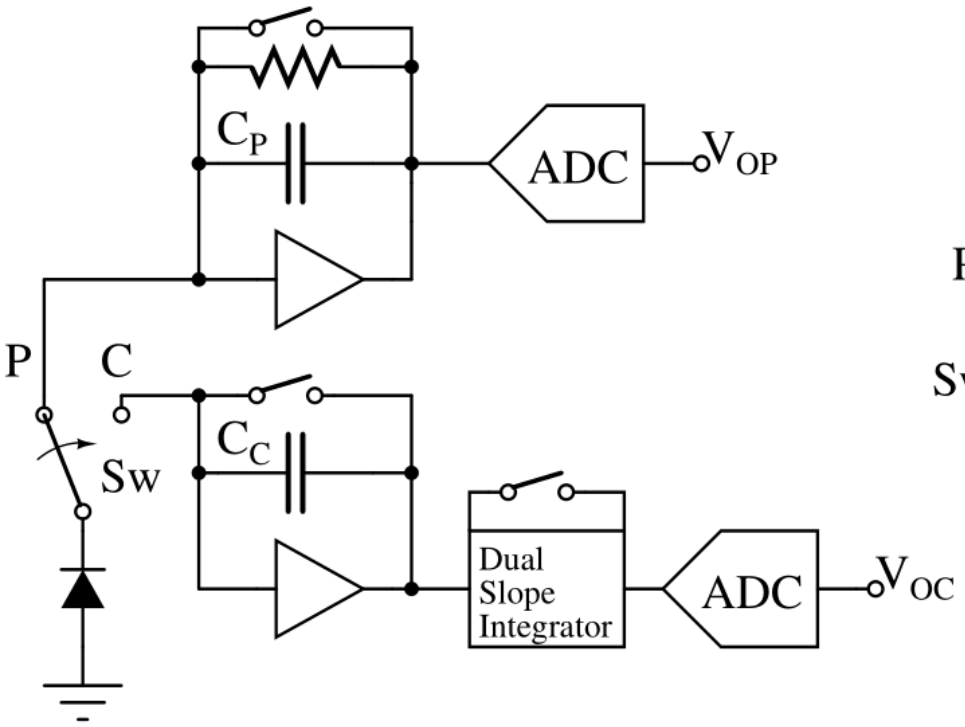
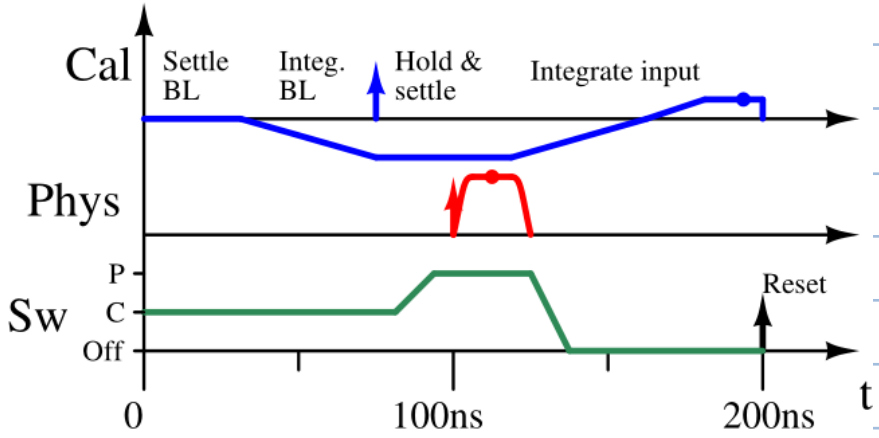


This switching scheme adds a considerable amount of noise. Need another idea.

Another switching scheme: 2 signal paths, 2 charge amplifiers

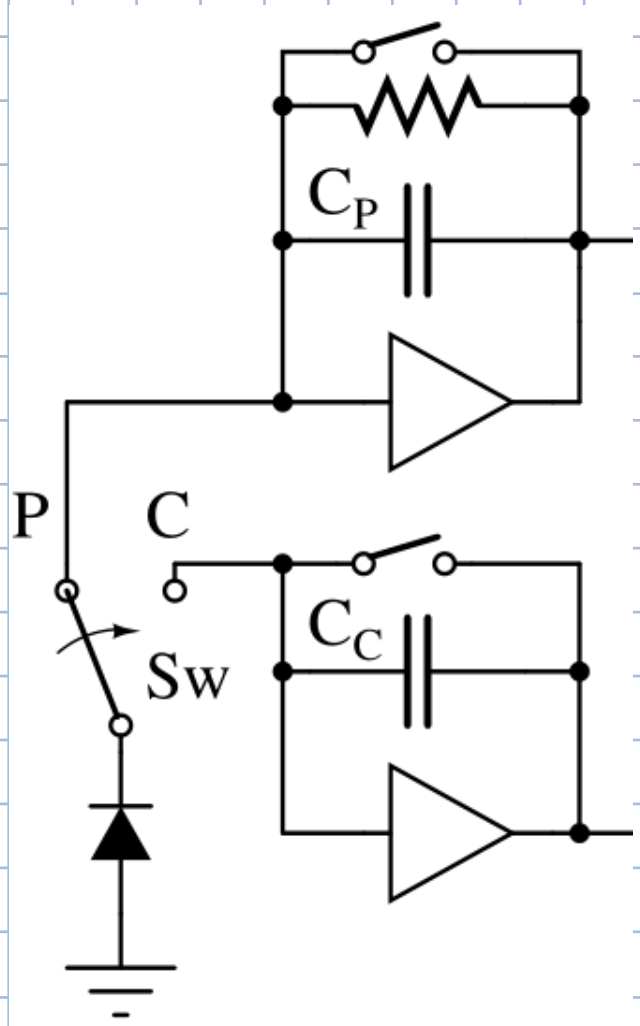




How to avoid a weighting function discontinuity when switching? Here we see two choices

Choice 1: time-share the detector

- First the detector is connected to muon signal path (C)
- Baseline is integrated
- After muon measurement, detector is switched to the physics CSA (P)
- After signal is measured, detector is switched back to the muon CSA
- Finally the signal is filtered



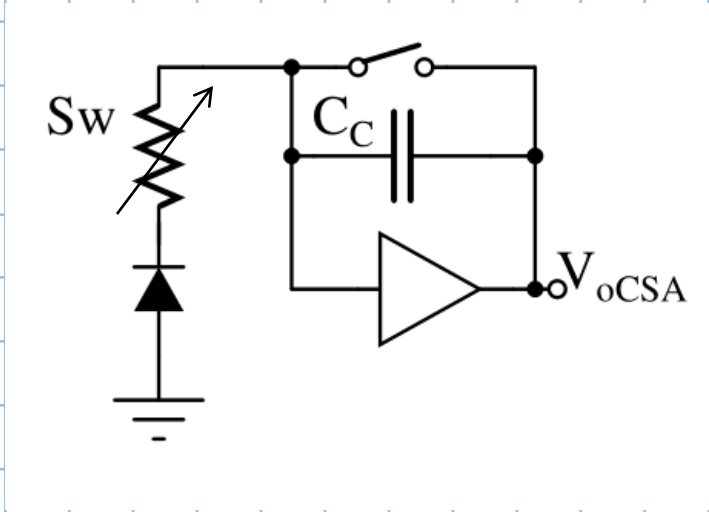
Choice 2: use the detector only when injecting signals

- First the detector is connected to muon signal path (C)
- Baseline is integrated
- After muon measurement, detector is **slowly switched** to the physics CSA (P)
- After signal is measured, detector is **slowly left floating**
- Calibration signal is filtered with a floating input (!)

We cannot do a standard weighting function analysis because not only the transfer function, but also **the noise psd is time-variant**

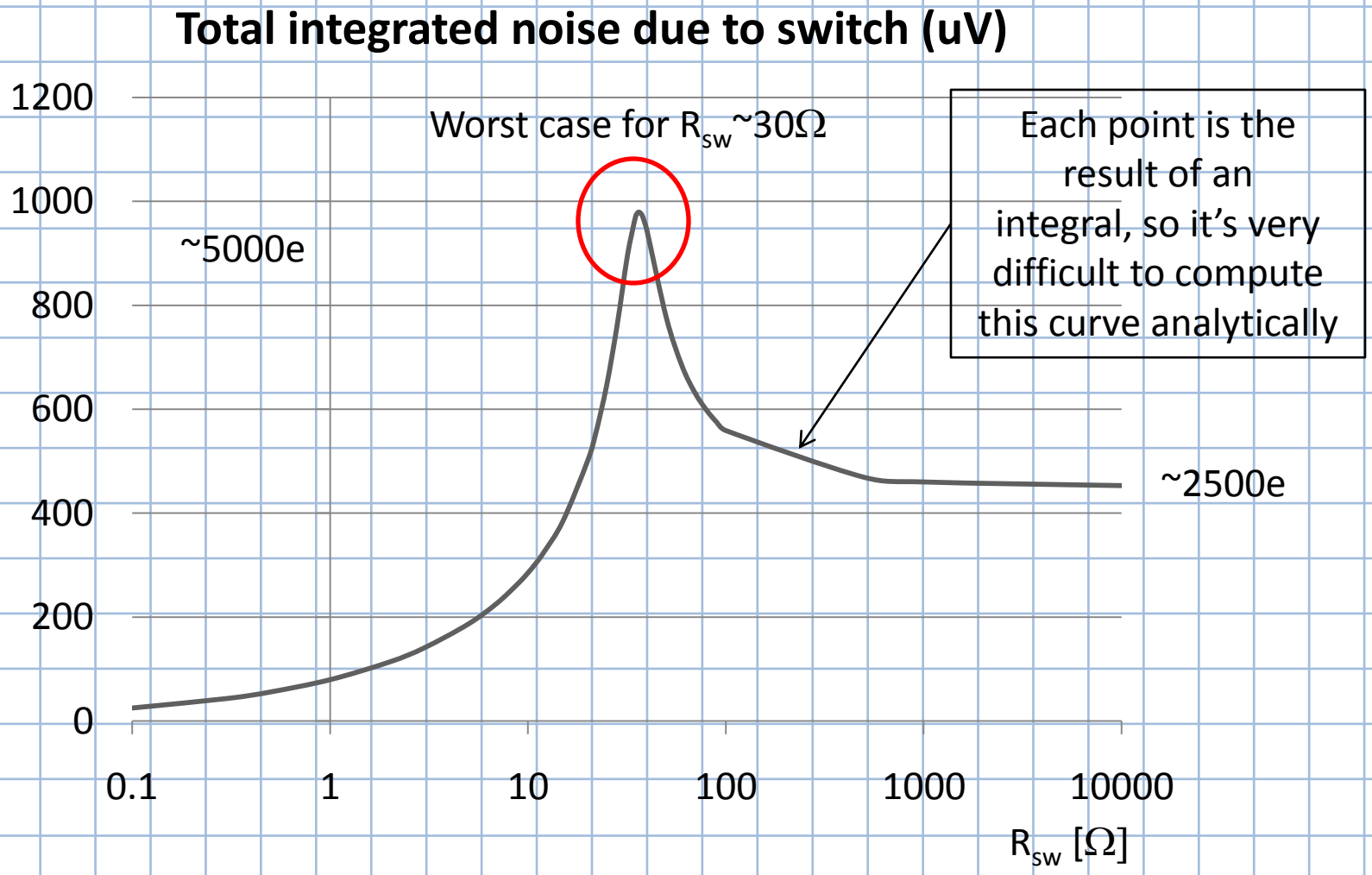
Let's zoom into the switch…

- The switch is like a variable resistor:



- When opening (slowly), R ↑ then CSA becomes a buffer
  - This should reduce the amplifier RMS noise at output
- Switching will inject unintended charge into CSA…
  - This charge does not depend on signal, can be compensated
- There is also extra noise from the switch itself… How bad?

Switch noise at CSA output
(this is **BEFORE filtering)**



How much reduction by filtering?

- Continuous-time integration is like averaging when the sampling period $\rightarrow 0$
  - But since the pre-filter noise is colored, there is some correlation between samples
  - Therefore, noise reduction converges to an equivalent of ~4.5 samples (current specs)
- Then the ENC from the resistor will be about 1200 electrons, still too much!

More on *switching out* the detector

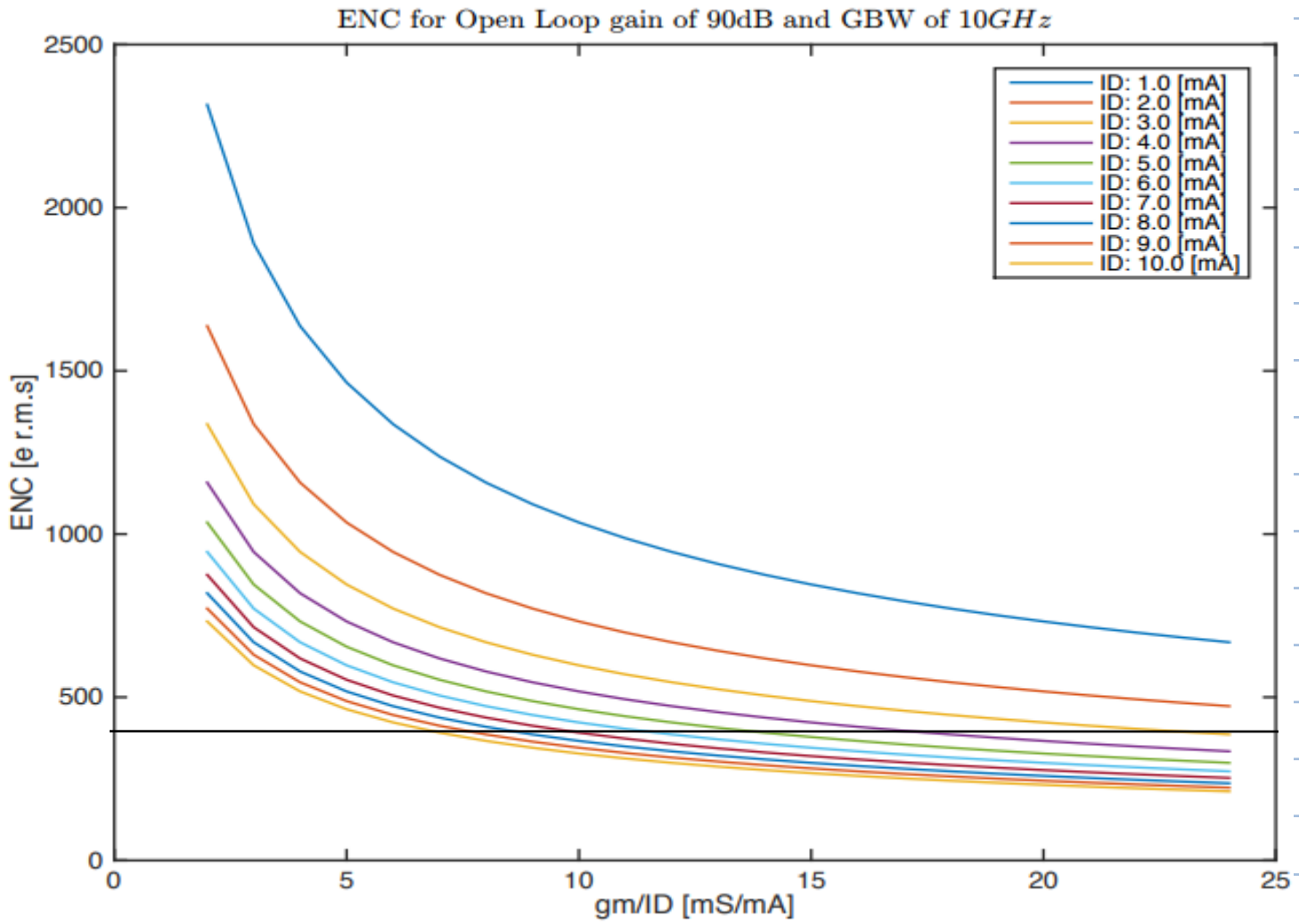
- Use the detector only to inject the signal
- Disconnect when not in use
  - This improves feedback ratio and reduces amplifier noise
  - This also reduces parallel noise from dark current
  - If switching is done slowly, the effect on amplifier series noise could be minimized
  - If we avoid integrating while R_{sw}~30Ω, then the large noise due to the switch can be reduced, **but still not negligible**
- This is becoming too complicated…

Noise simulations (amplifier noise only)

Considerations:

- 90-dB open loop gain
- GBW = 10GHz
- Buffering time $t_{x1} = t_{x2} = 30ns$
- Integration (peaking) time $t_{bl} = t_{sig} = 100ns$
- Hold time $t_h = 40ns$
- Detector Capacitance $C_D = 40pF$
- Input cap C_{GS} ~ 1pF (depends on inversion coefficient)
- Feedback capacitor for MIP calibration $C_C = 0.9pF$

Noise simulations results
(amplifier noise only, noiseless resistor)



Conclusion: in-frame halo measurement studies

- Is it feasible?
  - Doesn't look too good, several issues
- What are the risks?
  - Switch noise is high, longer filtering time is required
  - The idea is kind of novel, possibly publishable

But maybe it's safer to aim for a **working prototype** for testbeam campaign, and think of a calibration scheme after the specifications are fully settled

Proposed timeline

- Design **simple IC** (250nm) for testbeam campaign, minimum functionality
- Submit for fabrication by March 2018
- Electronics tests done in a year from now
- Testbeam campaign 2019?

Some news from Chile

- Got funded!!!
  - 4-years, April 2017 – March 2021
  - $$ for IC fabrication at least one 250-nm run per year
  - No funding for workshop, though…
- Got a MSc student to work on FCAL, Matías Henríquez
  - Just begun working on this
  - Already broke the noise calculation entry barrier
  - He seems to enjoy what he's doing

Thanks for your attention