

Understanding of timing resolution (basic)

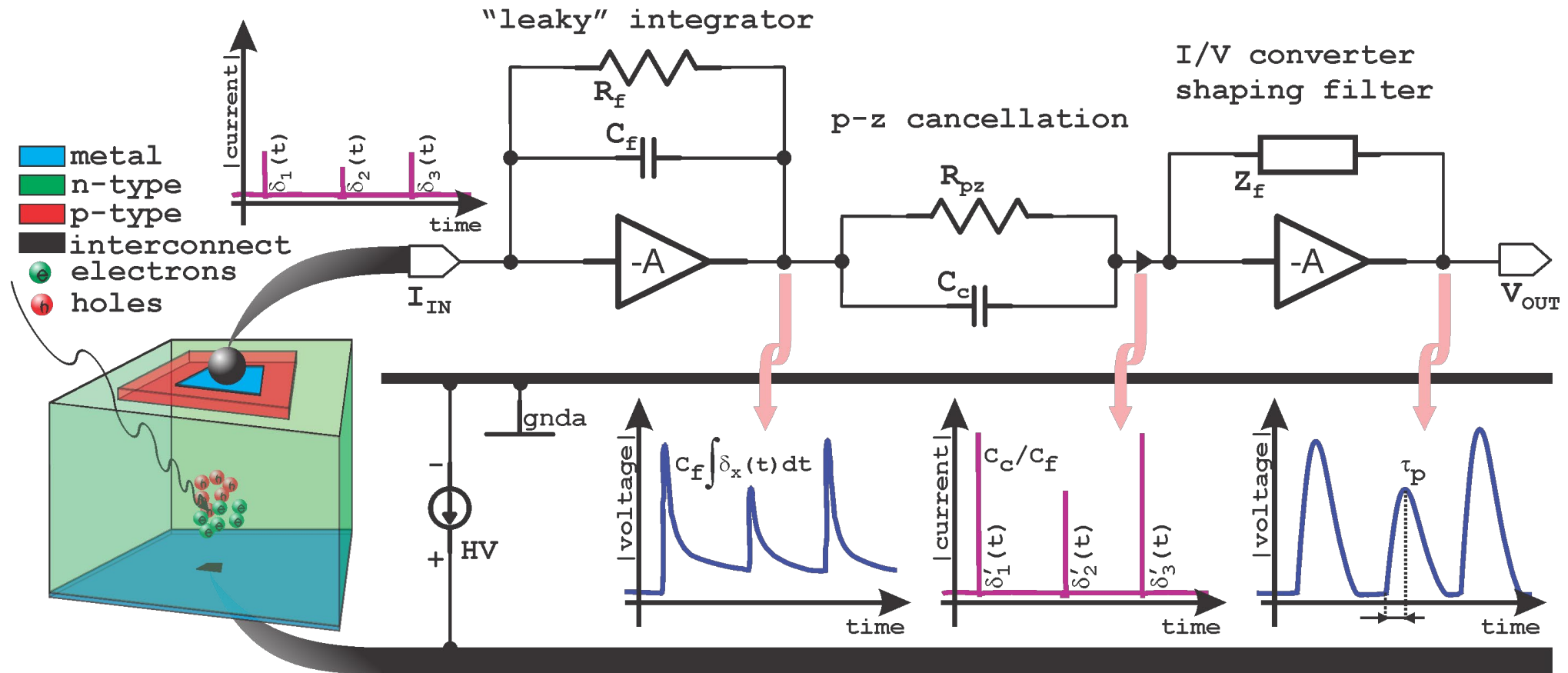
EIC-SC eRD113

EIC-SC general meeting: 03/14/2023



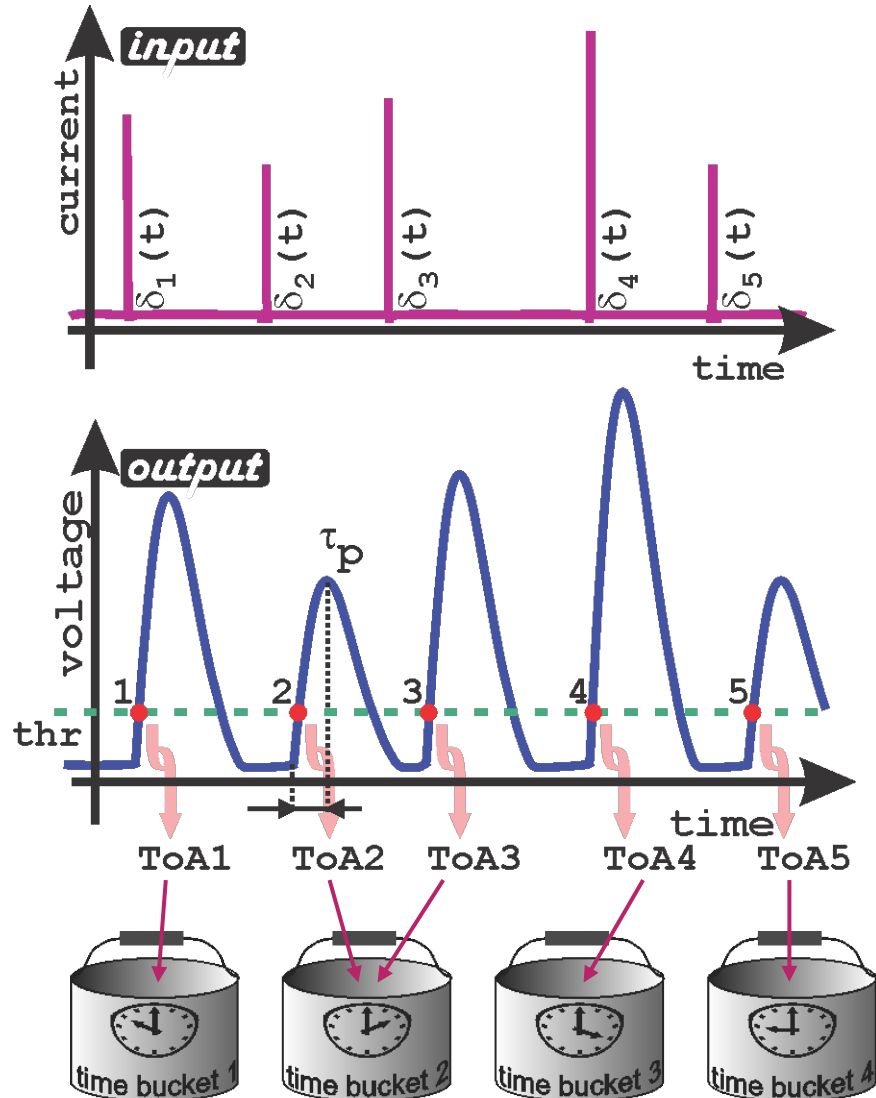
@BrookhavenLab

Typical Charge Processing Chain



ALPIDE/ALICE-ITS3 uses different / simpler scheme

Measurements of Time of Arrival (1)

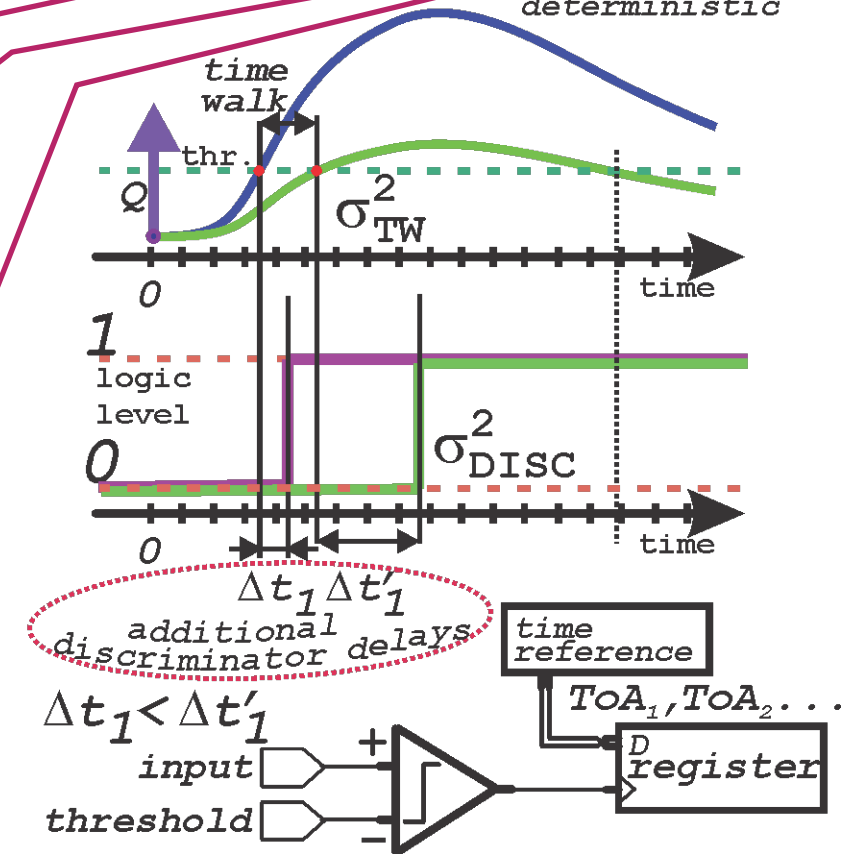


$$\sigma_{ToA} = \sqrt{\underbrace{\left(\alpha_f \frac{\tau_p}{S/N}\right)^2}_{\text{deterministic}} + \underbrace{\sigma_{TW}^2 + \sigma_{DISC}^2}_{\text{indeterministic}}}$$

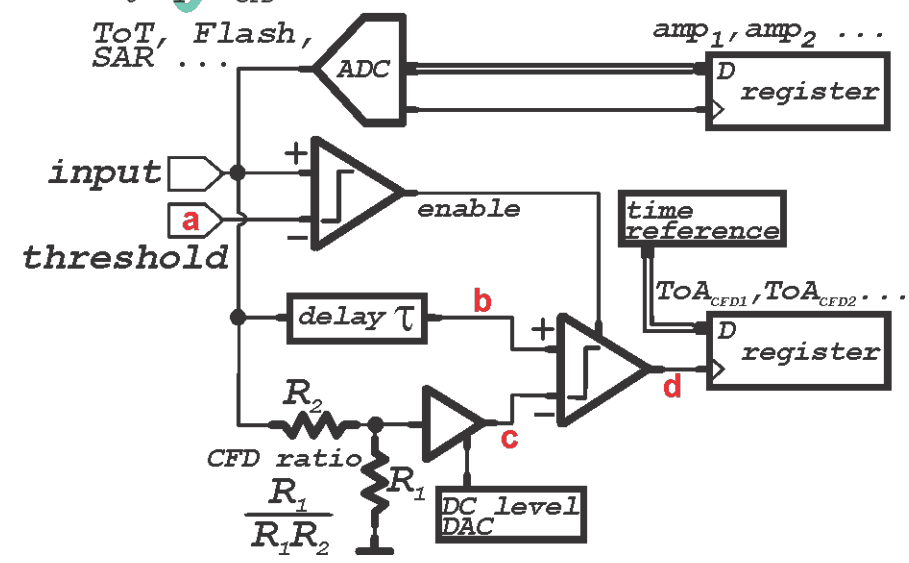
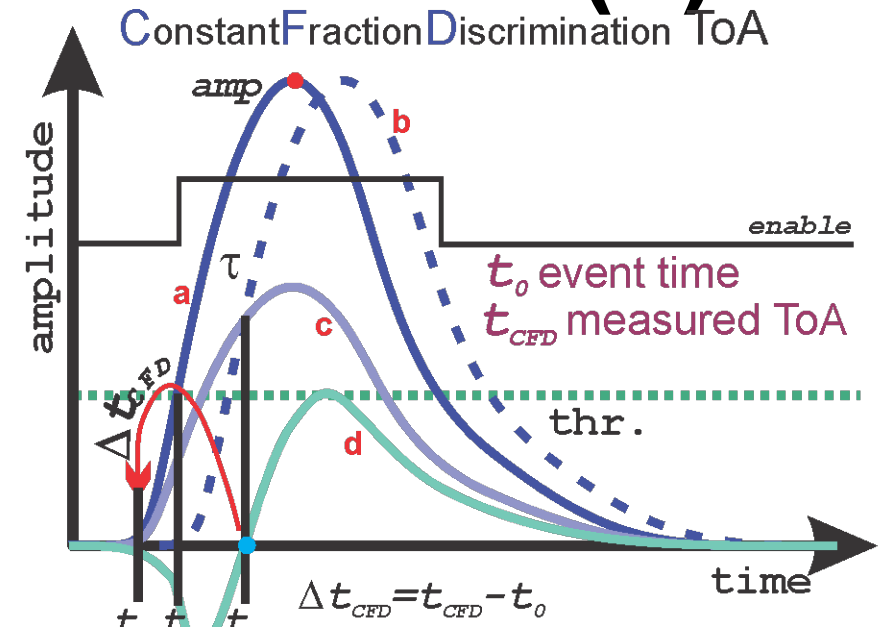
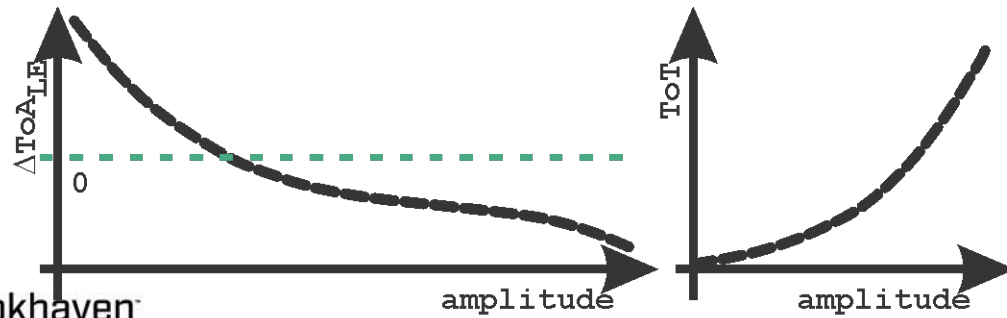
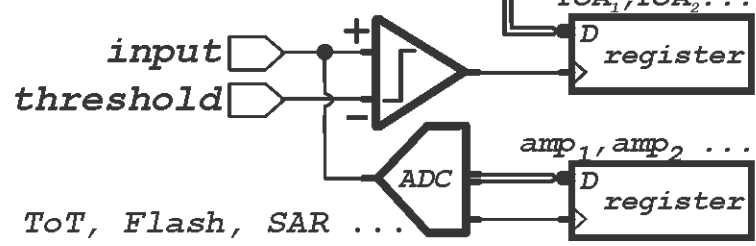
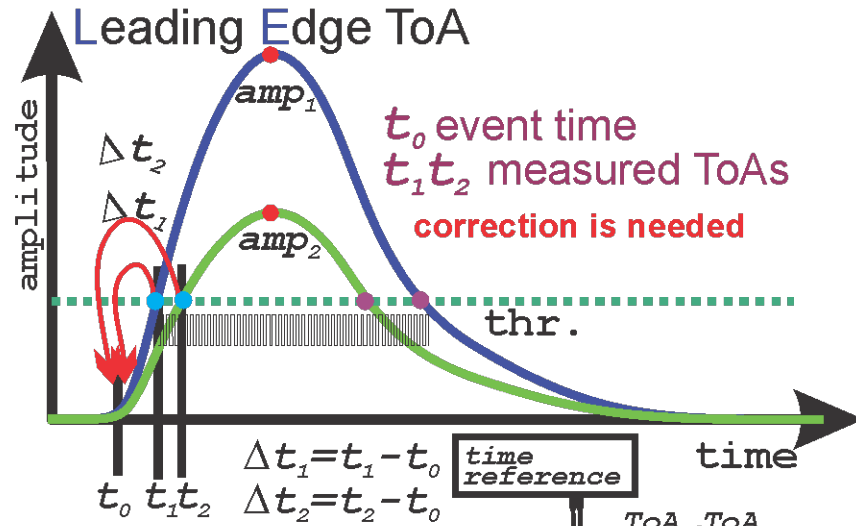
indeterministic term, depending on noise contained in signal

term depending on slope of rising/falling edge resulting in delayed crossing of discriminator threshold – can be compensated knowing amplitude

term depending on slope of rising/falling edge giving overdrive of discriminator's input and resulting delayed response of discriminator – can be compensated knowing relation threshold-amplitude



Measurements of Time of Arrival (2)



Measurements of Time of Arrival (3)

Does LE or CFD determines timing in ALPIDE/ALICE-ITS3?

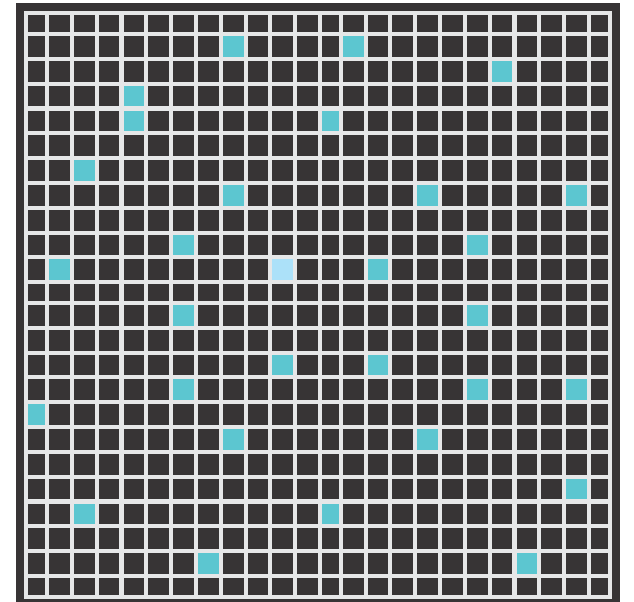
NO

in ALPIDE/ALICE-ITS3:

- no LE or CFD method for measuring time is used,
- there is no fast clock distributed to pixels with which LE or CFD threshold crossing could be compared;
- readout is static (aka snapshotted or framed), therefore no signals are transferred to periphery upon LE or CFD threshold could occurs in pixel;
- frames are generated by STROBE that tests discriminators in pixels at given time.

precision of time measurement of ALPIDE/ALICE-ITS3 cannot be better than time between STROBES; but if STROBES are sent too often, same hits will be reported multiple times

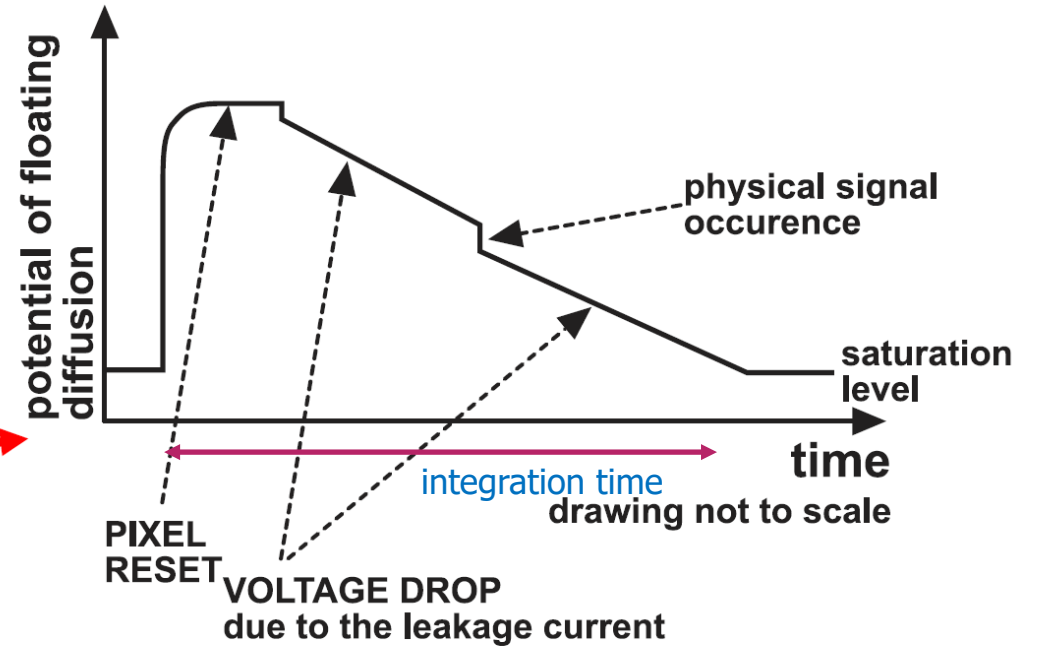
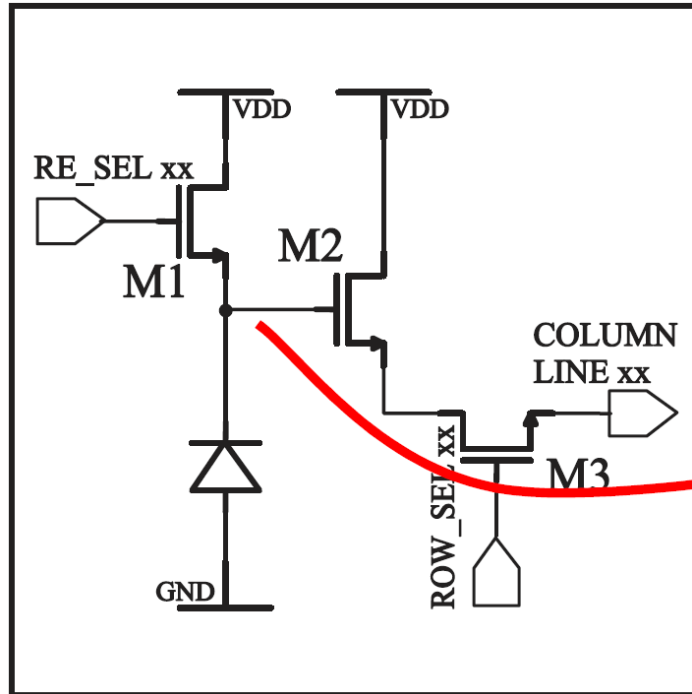
STROBE freezes state of matrix and shifts it to readout



readout occurs with a built in-order, i.e. priorities

Integration

Classical integration is present in CCD or 3T MAPS sensors



- during integration time (exposure time) events are accumulated;
- at the end of integration time, total signal, being sum of all event, is seen;
- with filtering (CDS) at low noise and monoenergetic individual contribution, one can say how many events has occurred.

Timing in ALPIDE/ALICE-ITS3

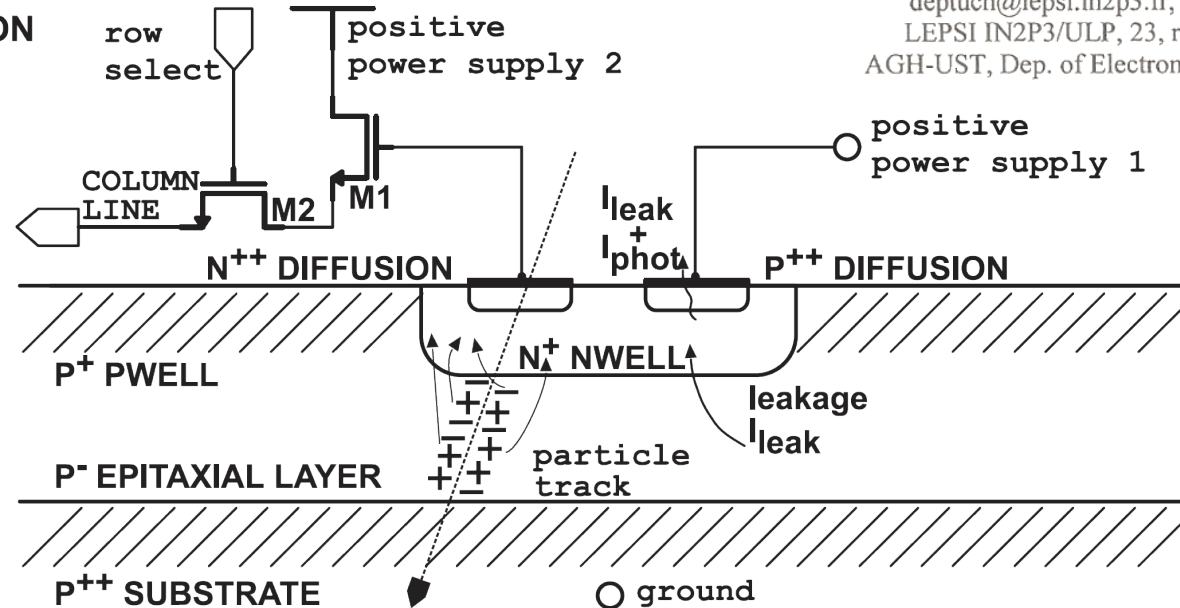
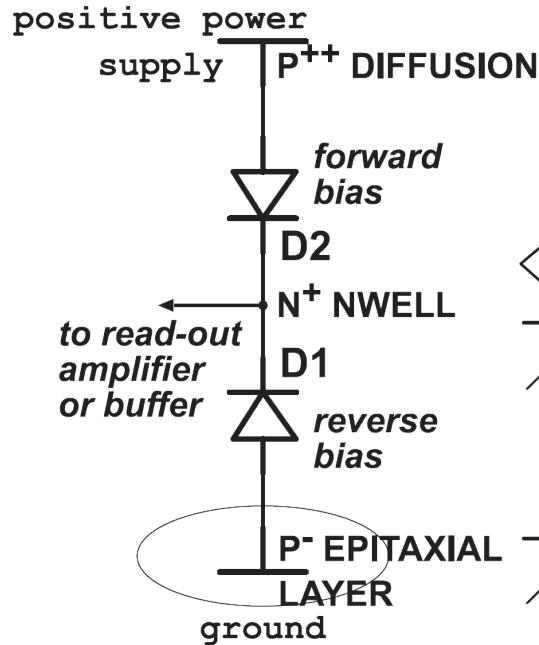
IISW 2003, Schloss Elmau, Germany

Timing related to SB diode

Charge Sensitive Elements Optimised for Particle Tracking

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charge collecting diode remains a n-well/p-epi junction.

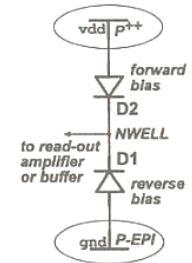
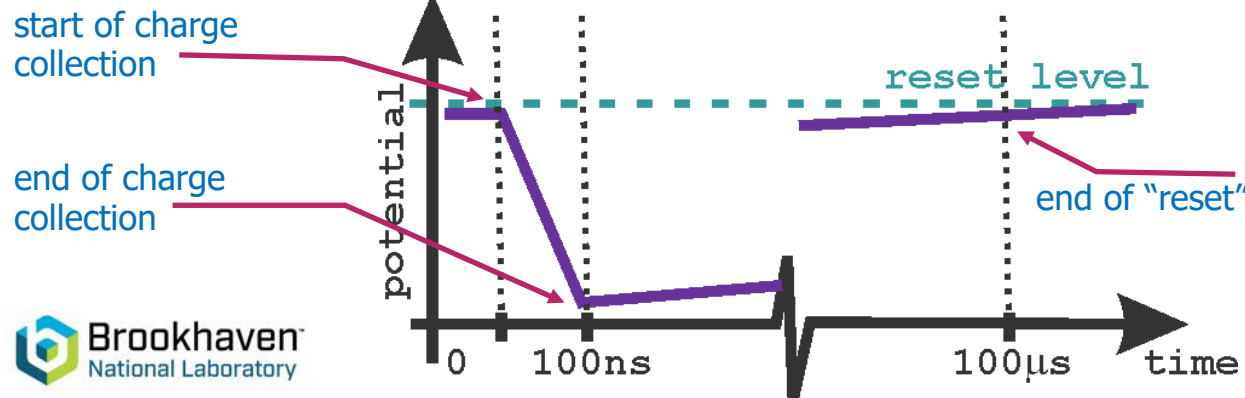


Fig. 1: Two-diode configuration providing logarithmic pixel characteristics.



This is not important for timing, as one can consider change of voltage on CSE node as a step, however "reset" is faster after irradiation and when more hits are accumulated

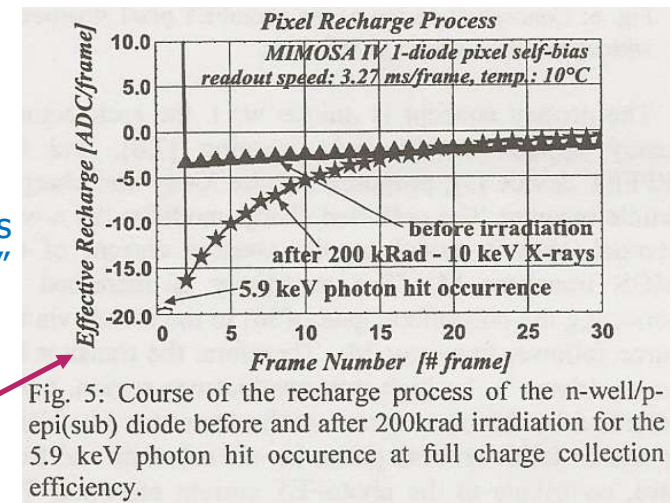


Fig. 5: Course of the recharge process of the n-well/p-epi(sub) diode before and after 200krad irradiation for the 5.9 keV photon hit occurrence at full charge collection efficiency.

ALPIDE/ALICE-ITS3 Pixel Circuit

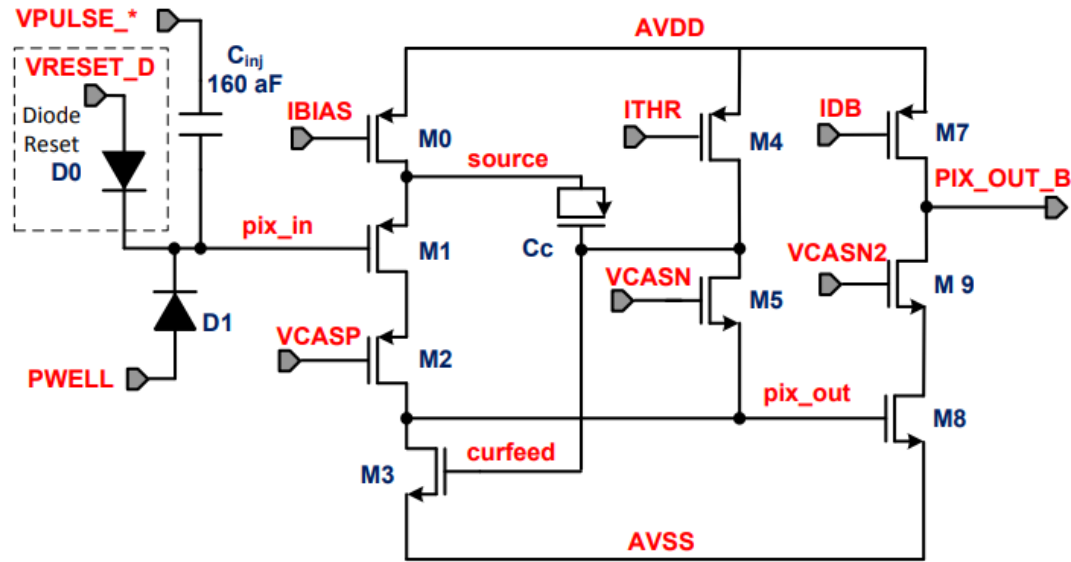


Figure 4.1: ALPIDE Front-end scheme

ALPIDE is voltage amplifier using independent bias of charge collecting diode, i.e. self-bias;
 following every hit, amplifier finds new operating point;

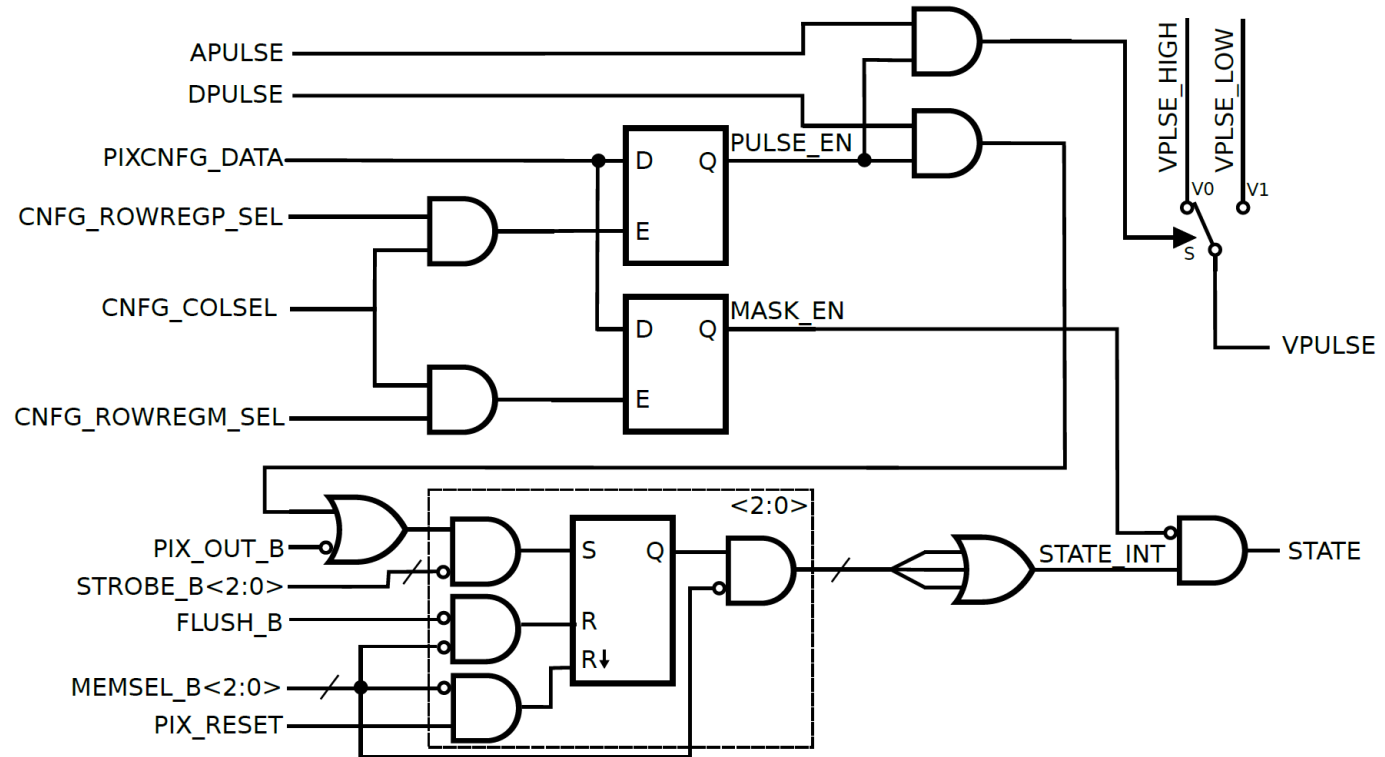


Figure 4.2: Functional diagram of the pixel logic

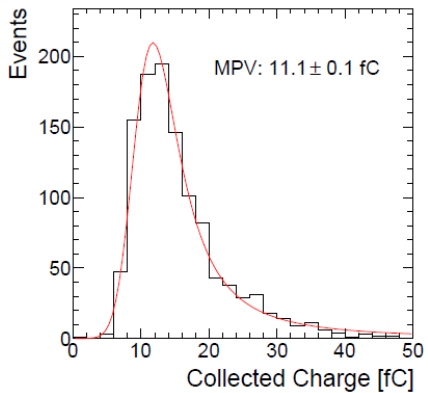
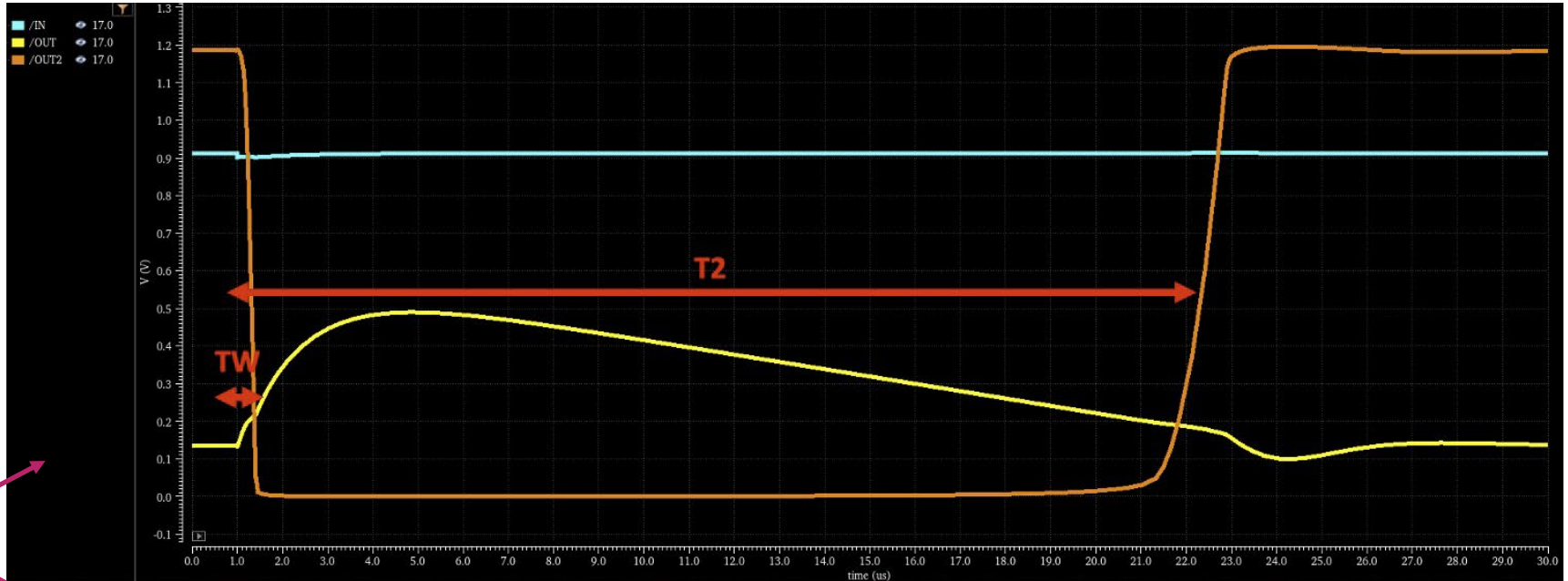
STROBE selects 1 out of 3 latches to store state of discriminator;
 then MEMSEL allow reading out 1 out of 3 latches through priority encoder

ALPIDE/ALICE-ITS3 FE-DISC-STROBE

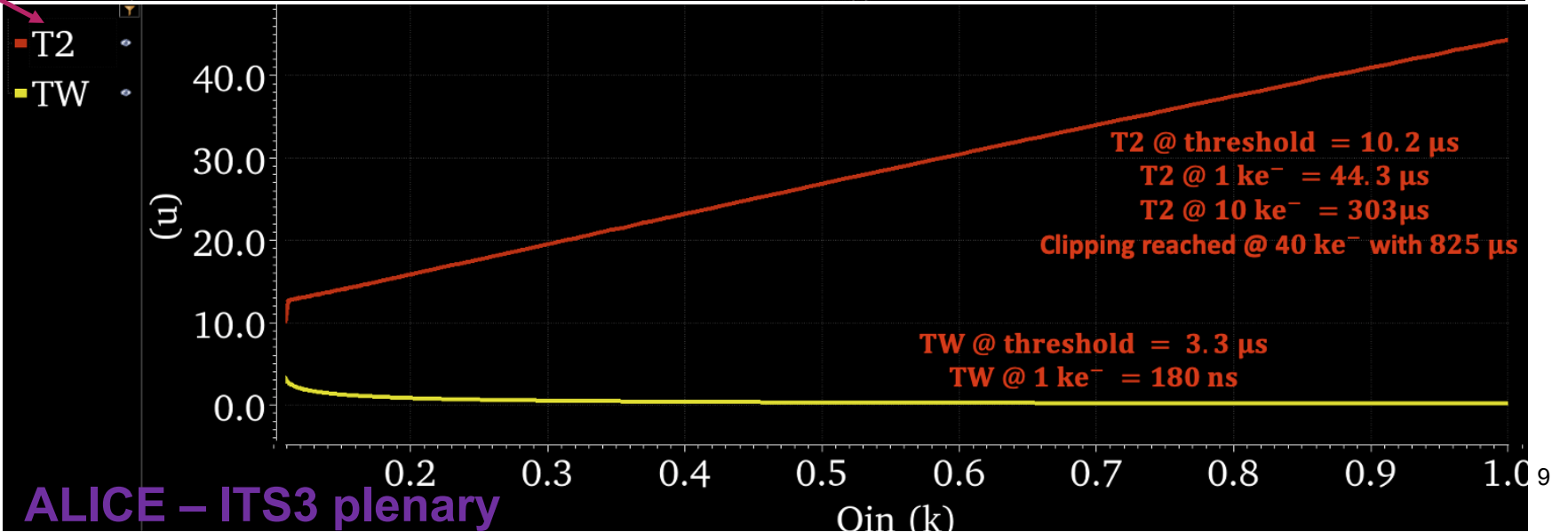
- assuming 50 μm thick active sensor layer \Rightarrow 1 MIP produces MPV = 4 ke^-/h^+ and e^- are collected;
- charge sharing in corner impact splits collected charge to MPV = 4 \times 1 k e^- ;
- taking Landau distribution max - min signals \in (0.3 MPV, 3 MPV) \Rightarrow \sim (0.3 ke^- , 15 ke^-)

transient FE + disc

TW and ToT vs. signal



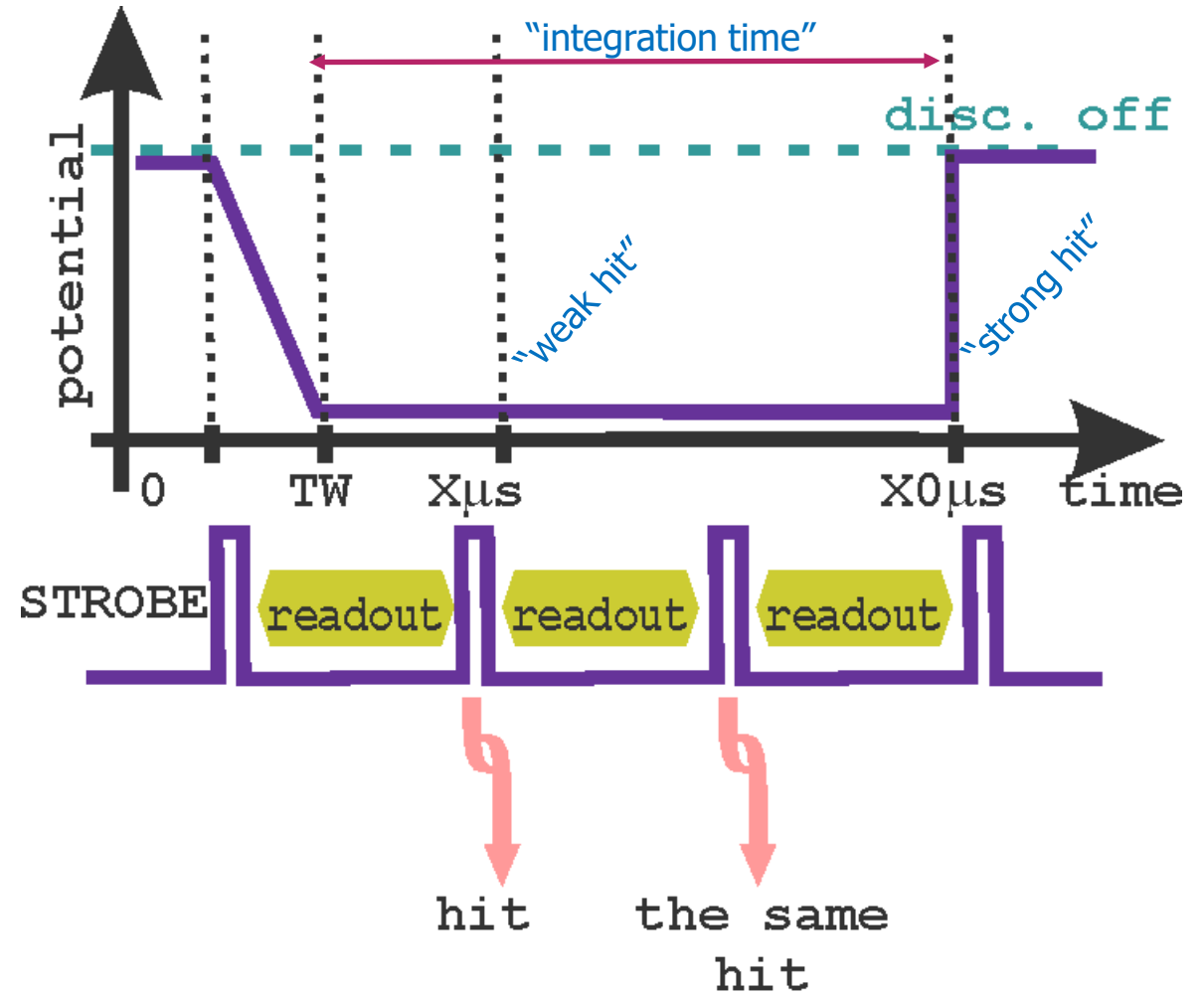
measured with LGAD 50 μm thick



Summary (1)

Two readout mods in ALPIDE/ALICE-ITS3:

- **Triggered,**
 - where stobes are sent upon a trigger and current state of pixel matrix is snapshotted and presented to readout.
 - ❖ up to 3 snapshots can be taken in burst,
 - ❖ each snapshot can be read slower (max RO time = all hits fished out), but leading to dead time.
- **Continuous,**
 - where stobes are sent continuously.
 - ❖ minimum frequency of stobes given by duration of discriminator staying active for "weak hits",
 - ❖ maximum frequency of stobes given by avoiding reading our same hit multiple times and clogging readout (repeated hits can a priori be eliminated offline because of low probability of double hits)



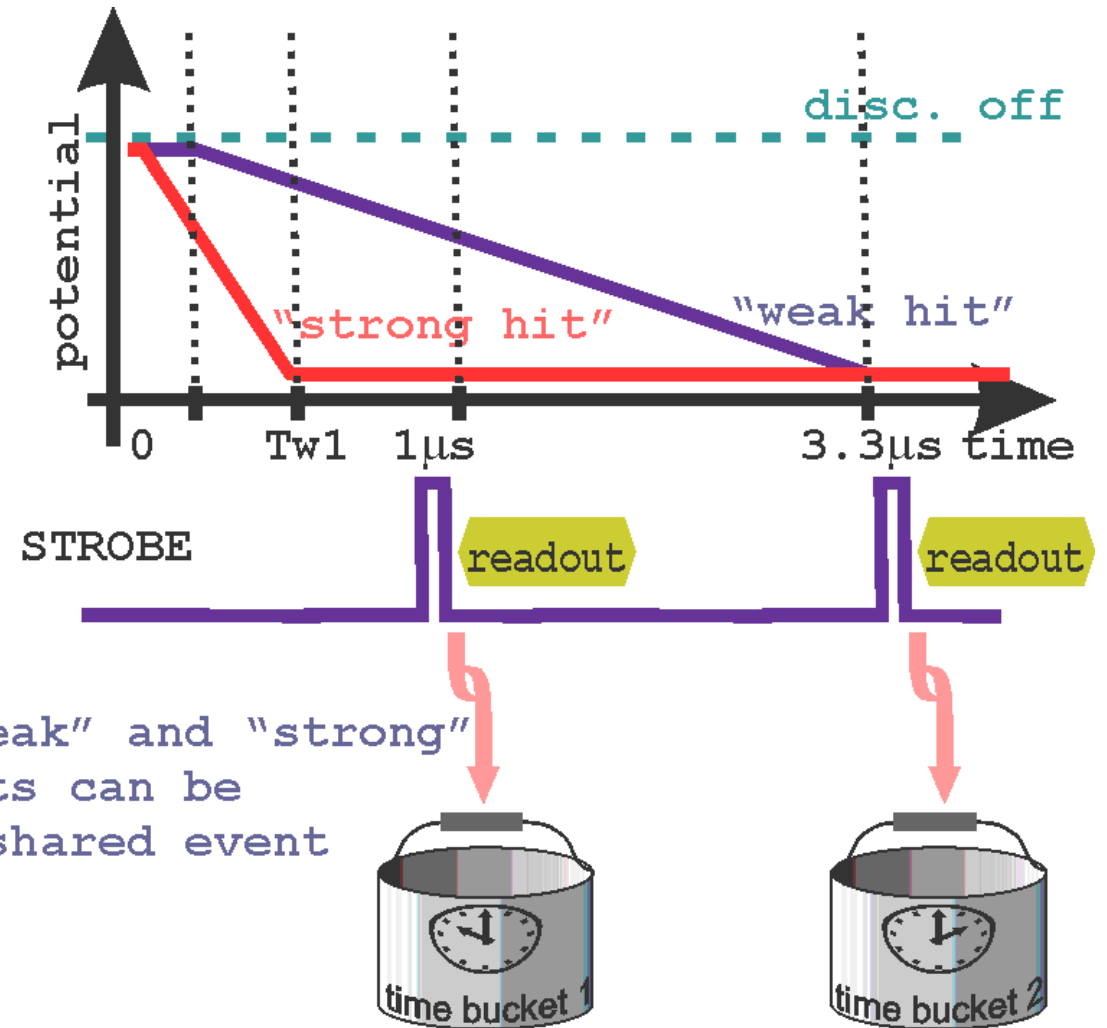
best time binning is given by duration discriminator stay active for "weak hits", i.e. 5-10μs

Summary (2)

Impact of TW on assigning hits to frames

(RO mode agnostic):

- "weak hits" and "strong hits" can be mistimed (assigned to consecutive frames-buckets) – having time difference of $X \mu\text{s}$),
 - there is no obvious way of assigning back hits to their time frames;
 - out-of-time hits are present in CMS/ATLAS pixels but they may be shifted maximally by 1BX;
 - effect of TW is intrinsic to priority encoder – snapshotted readout.



Summary (3)

- Timing resolution is to be expected a few microseconds:
 - Granularity of snapshotted readout;
 - Out of time, incl. fake fractional signals, hits;
 - Duplicated hits.
- Deeper studies, including system modeling and simulations are required;
- Testing with a laser may not be sufficient – difficult to recreate occupancy;
- Help from ALPIDE/ALICE-ITS3 and/or access to design database and develop model fed by representative data (amplitude, q-sharing, occupancy, timing and geometrical patterns if any) - proposed as part of eRD113;
- improvement may be paid for by increasing the dissipated power / design mods (💣? needed?).

Reserve Slides



E

Priority Encoder Readout

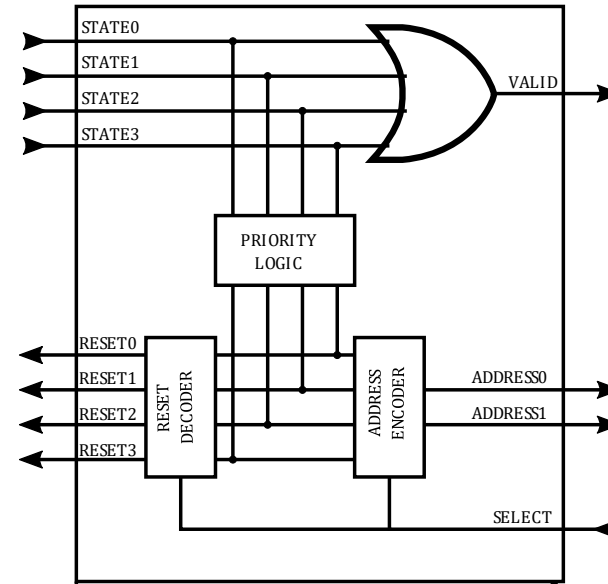
Priority encoder:

- suited only to framed (snapshoted) readouts;
- frame occupancy at least by one hit is detected,
- address of read out channel can be automatically constructed;

Static "image" must be presented to priority encoder readout;

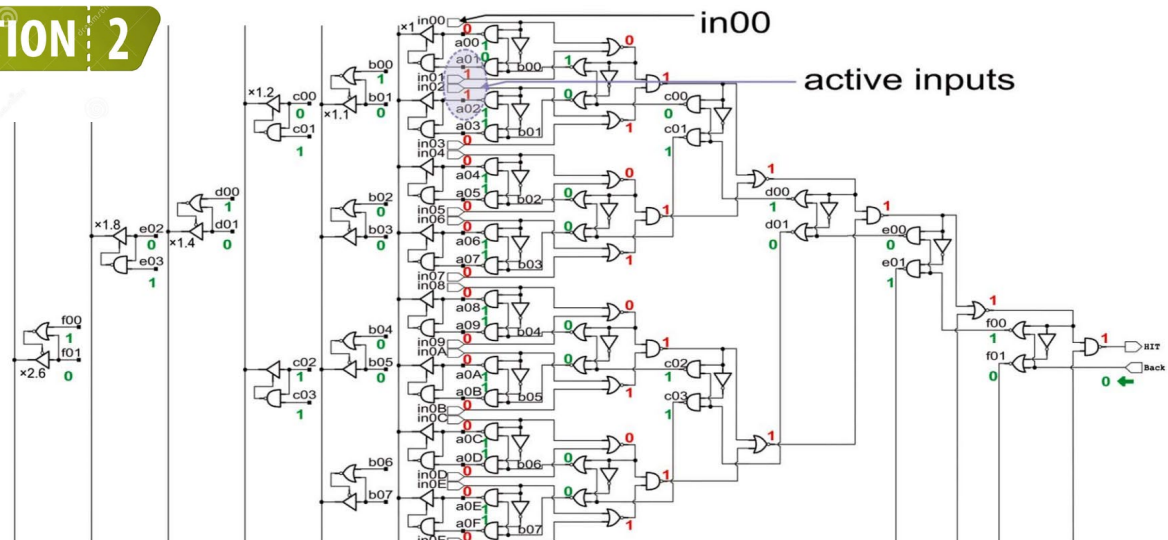
If "dynamic", possible to handle in event driven readout, pointers to channels will be jumping to these higher in priority order not finishing actual readout of these lower in priority.

OPTION 1



AERD

OPTION 2



Peter Fischer's
Mephisto-like