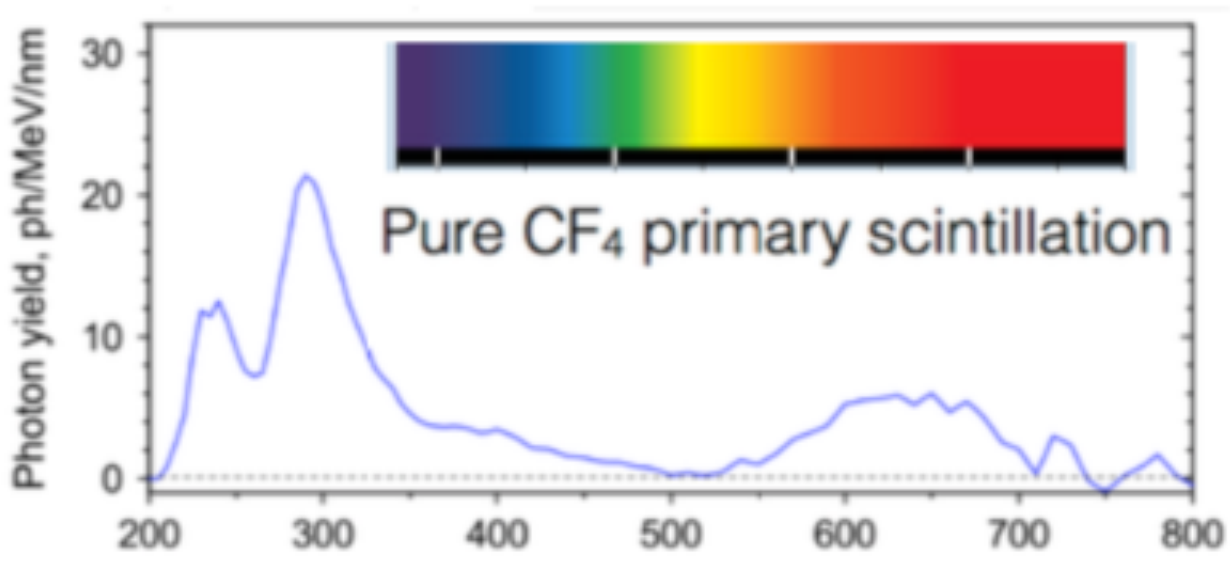
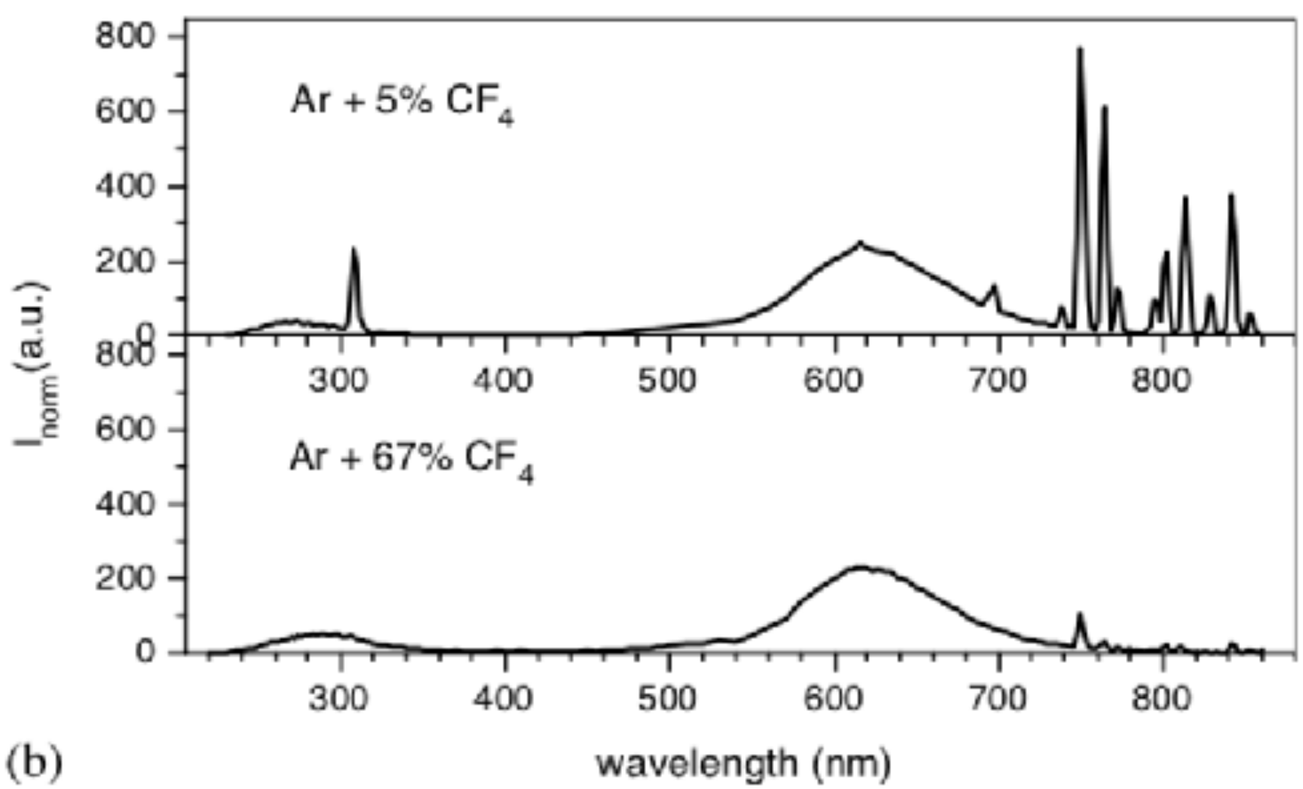
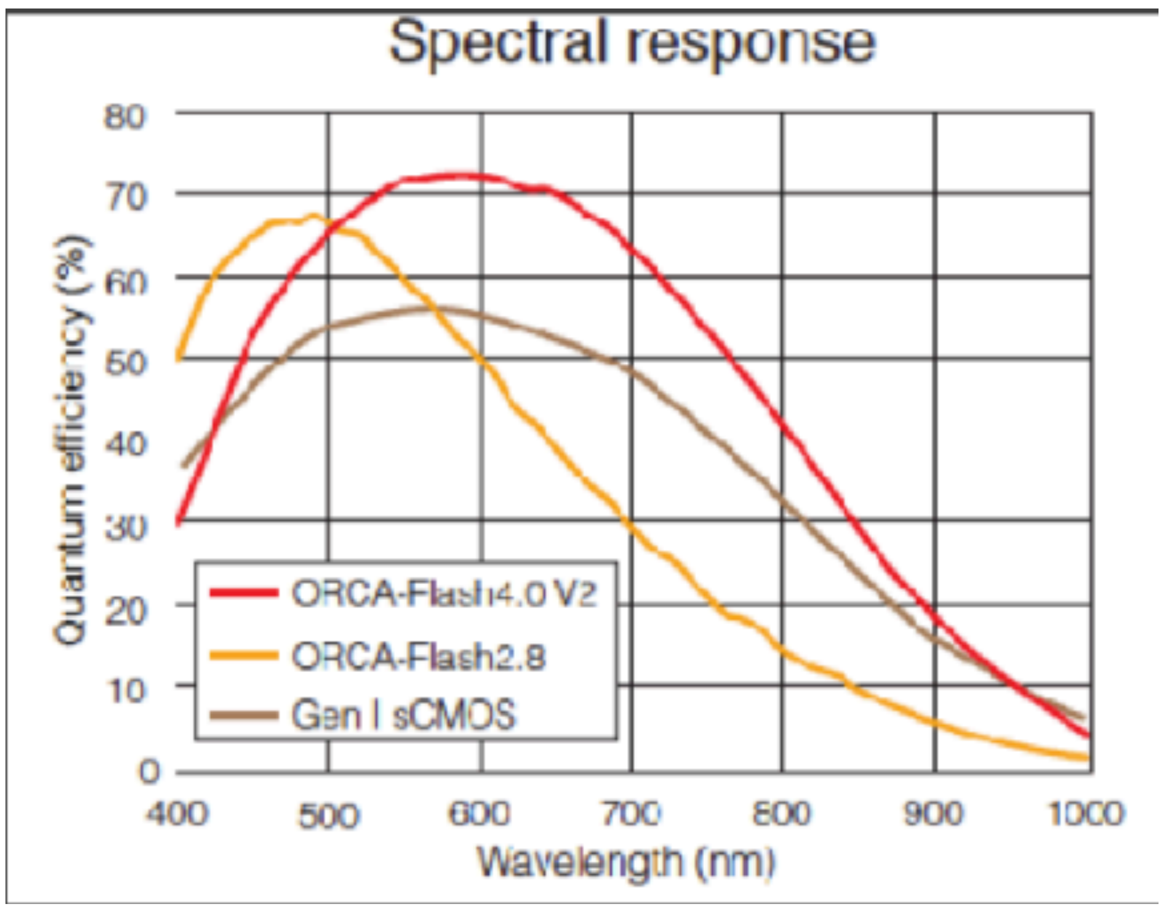
# CMOS Desiderata

**N.B. we do not know our wavelength**
**and our is He:$CF_4$**

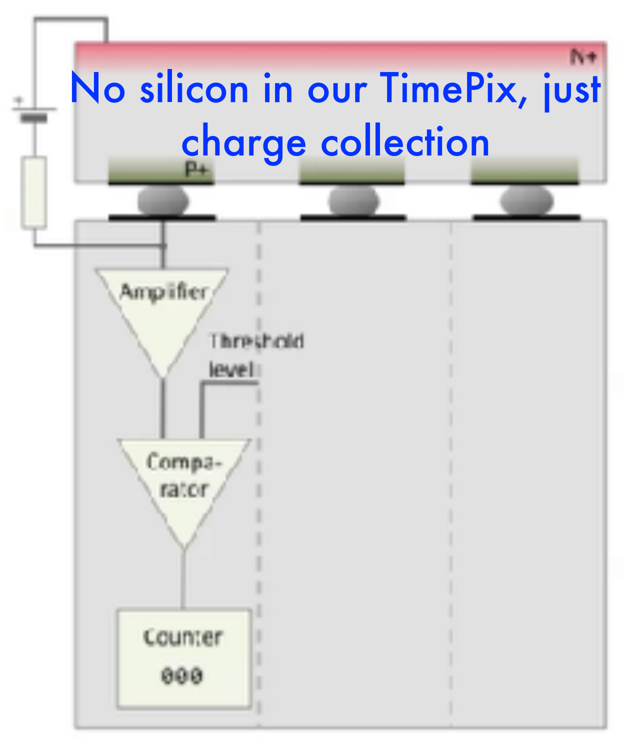


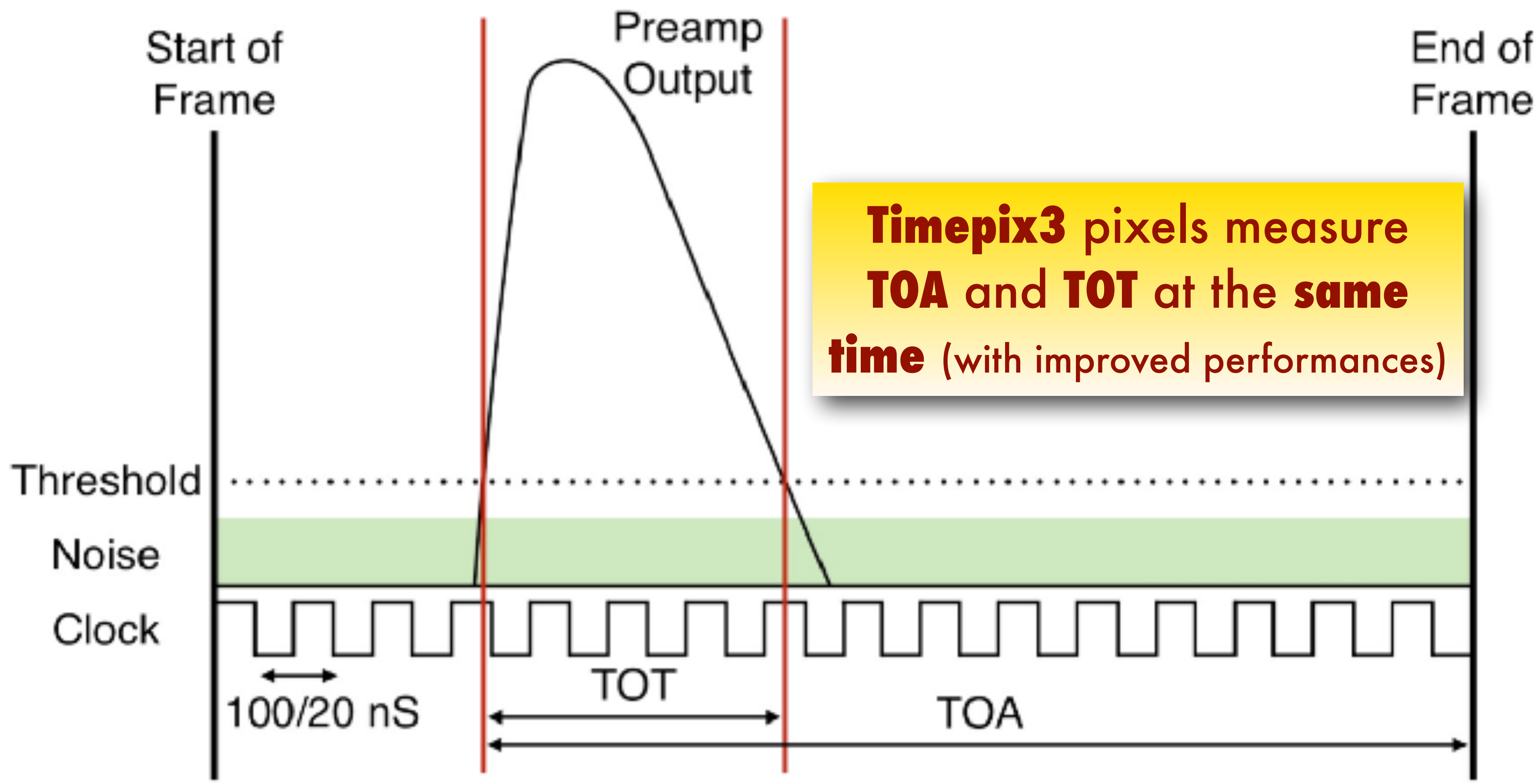



# TimePix

- TimePix is a pixelated CHARGE silicon detector developed by MediPix2 collaboration
- We use a 2x2 array for a total of 512x512 pixel of 55 um side WITHOUT silicon sensors
- Processing electronics, including preamplifiers, discriminator threshold and pseudo-random counter fit inside the footprint of the overlying semiconductor pixel.
- Can be operated in counting TOA, TOA and TOT mode but also **TOA/TOT MIXED mode**



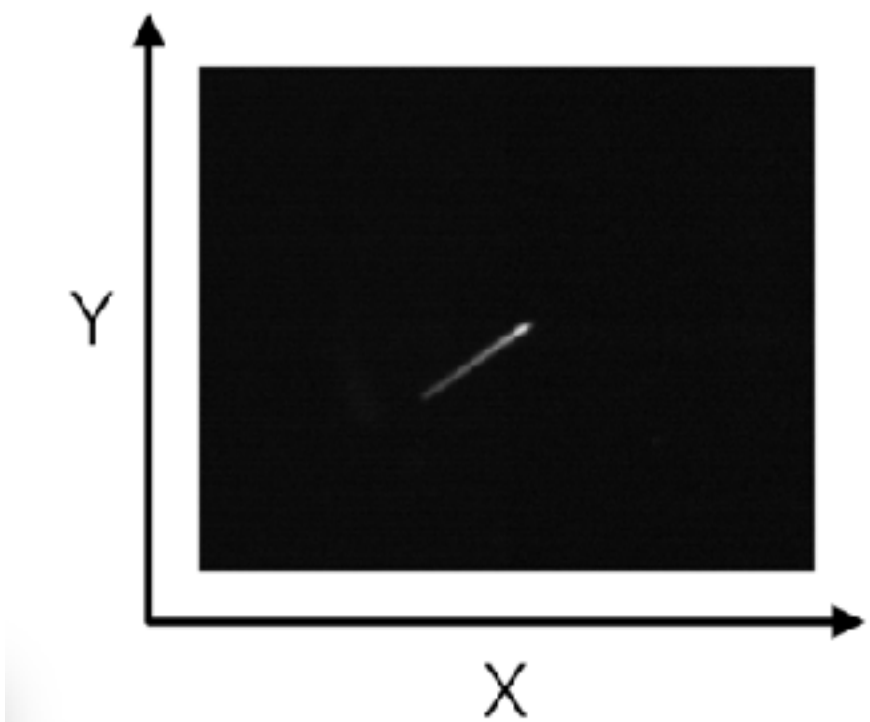




**Timepix3** pixels measure **TOA** and **TOT** at the **same time** (with improved performances)

- Timepix clock can run from <1 MHz up to 100 MHz
- Timepix counter depth is 11810 —> limits total acquisition time —> ok for negative ion slow drift as well

# sCMOS with fast acquisition can become a 3D readout just like charge pixels!!!

Florian M. Brunbauer
on behalf of the CERN EP-DT-DD GDD team




**Already doable with existing fast cameras and low drift fields, i.e. low electron drift velocity**

**Even better with faster sCMOS sensors and/or negative ion drift**

At **very low drift fields**, the arrival time of primary electrons at the GEM in a TPC setup can be resolved in **individual image frames**

From the known time difference between frames, the depth of interaction at a certain 2D location can be determined

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# Frame rate

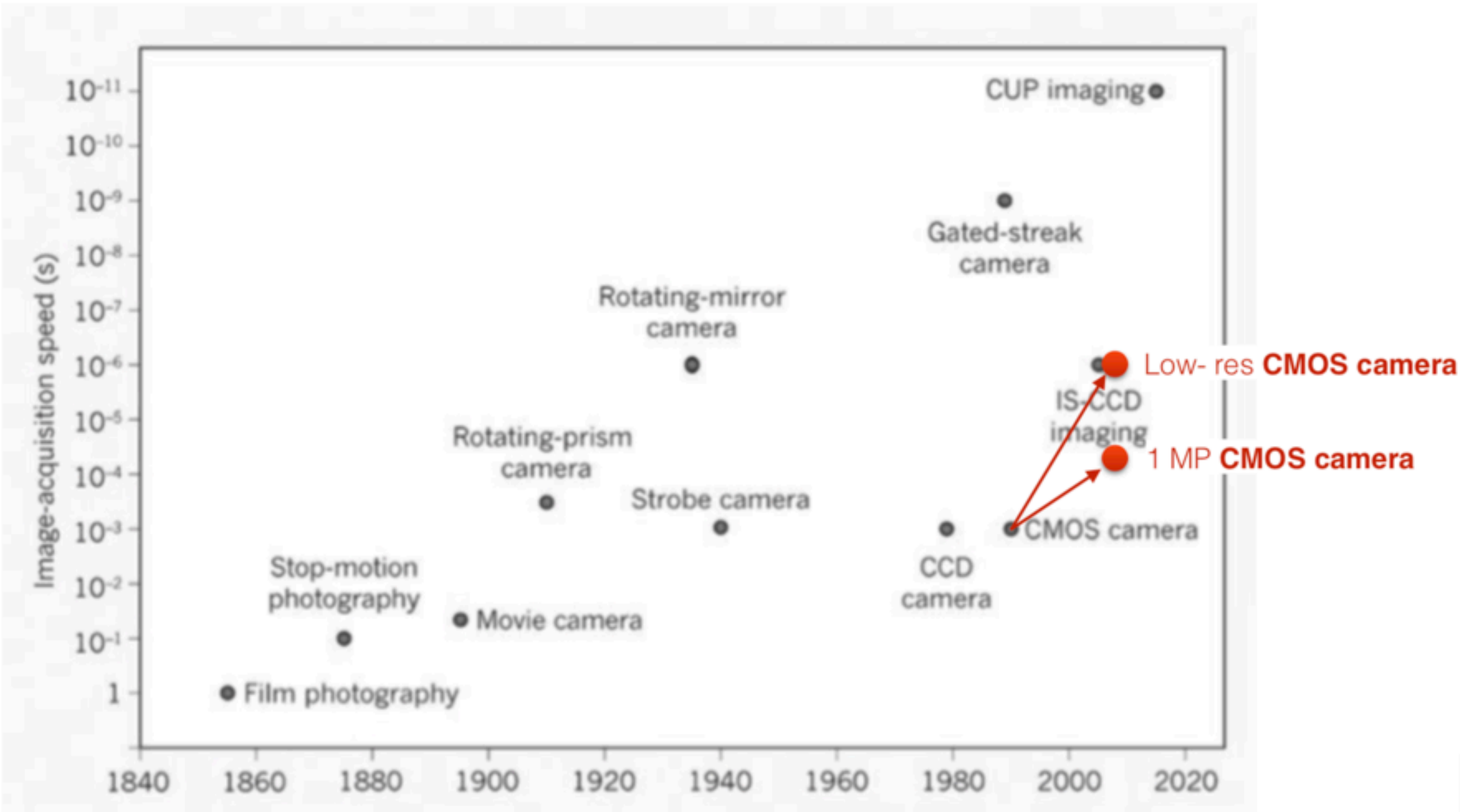


Image adapted from: B. Pogue, Nature 516 (2014) 46–47

**Florian M. Brunbauer**
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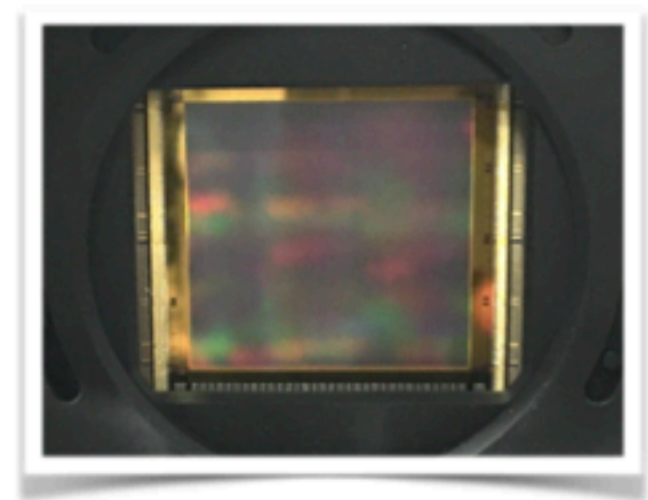
# High-speed CMOS cameras

## Photron FASTCAM SA-Z

- 1 megapixel CMOS sensor
- 12 bit depth
- **20 kfps** at 1024x1024
- **2.1 Mfps** at 128x8
- ISO 50,000 sensitivity

## Phantom v2512



CMOS sensor

- 1 megapixel CMOS sensor
- **25 kfps** at 1280 x 800
- **1 Mfps** at 128x32

- 35.8 x 22.4 $mm^2$ sensor
- 28 μm pixel size
- 12 bit depth
- ISO 100,000 sensitivity

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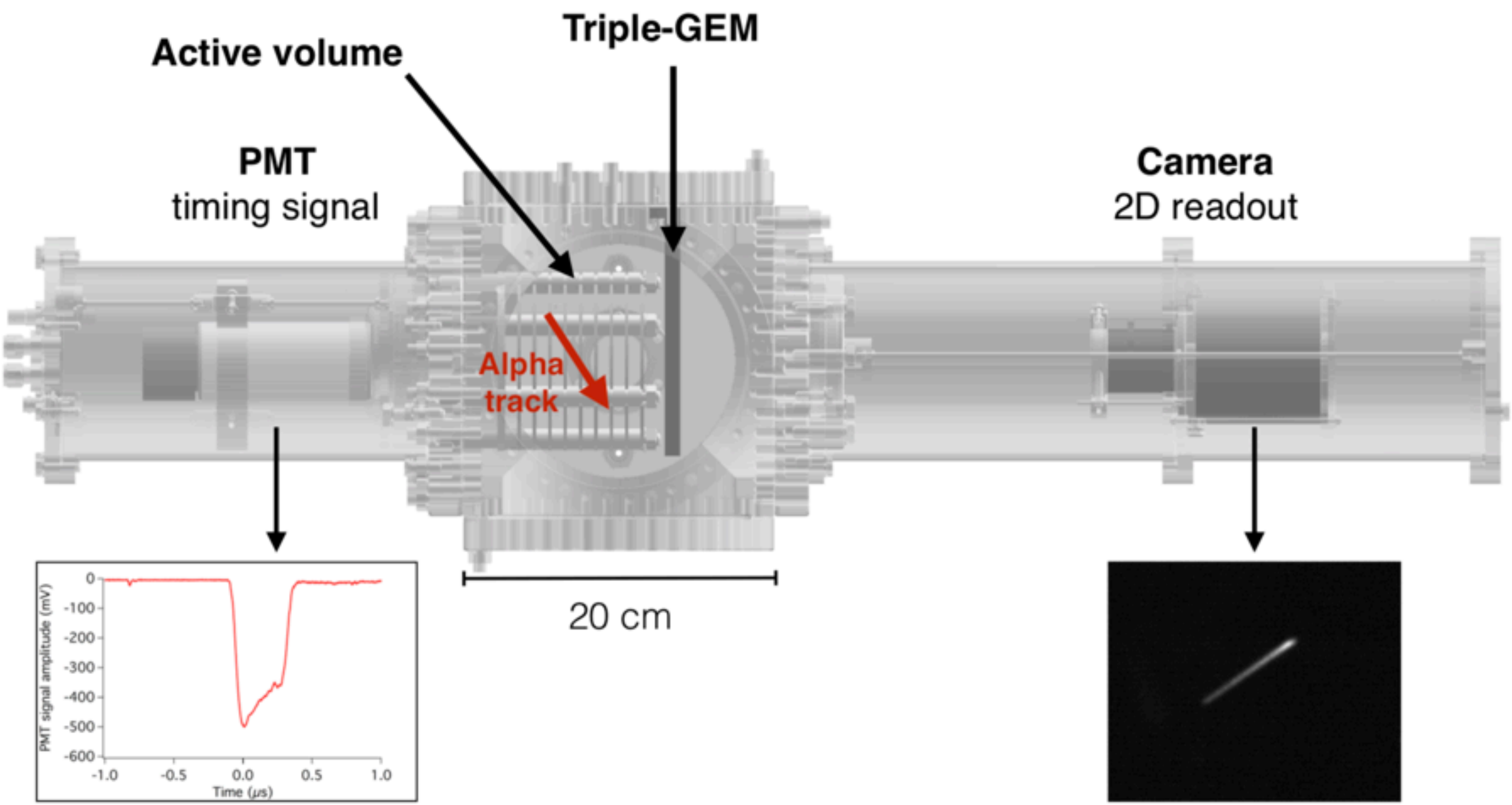
# Optically read out TPC




F.M. Brunbauer et al. NIM A (886) 2018.

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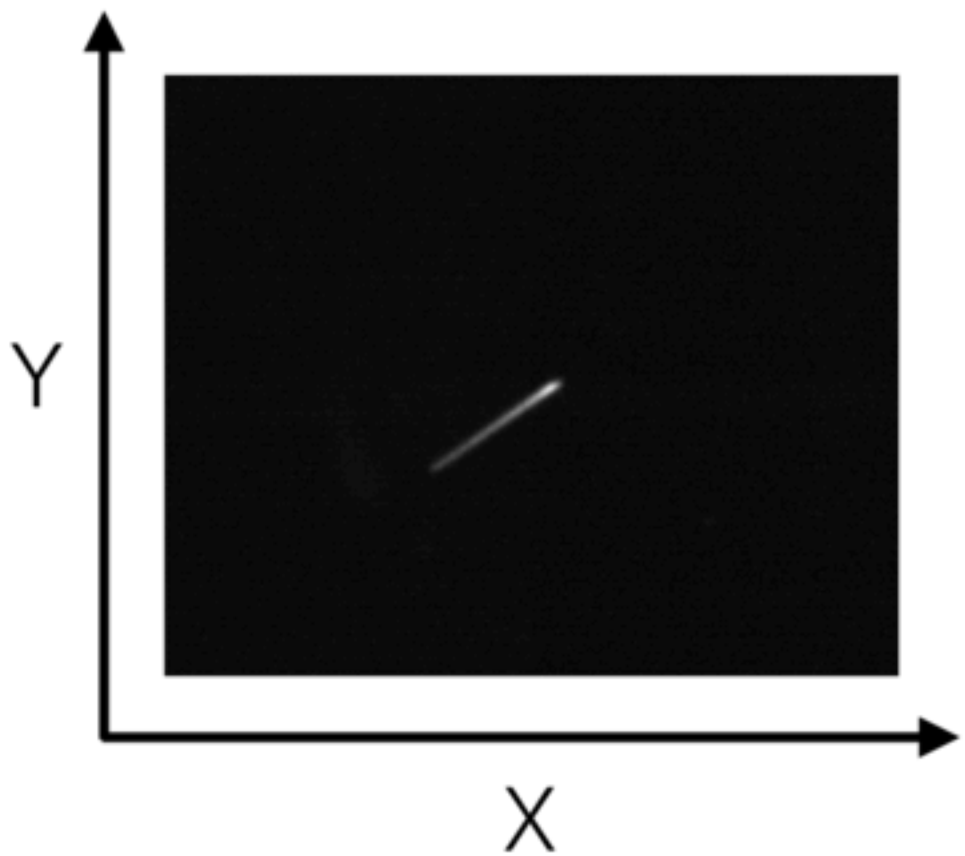
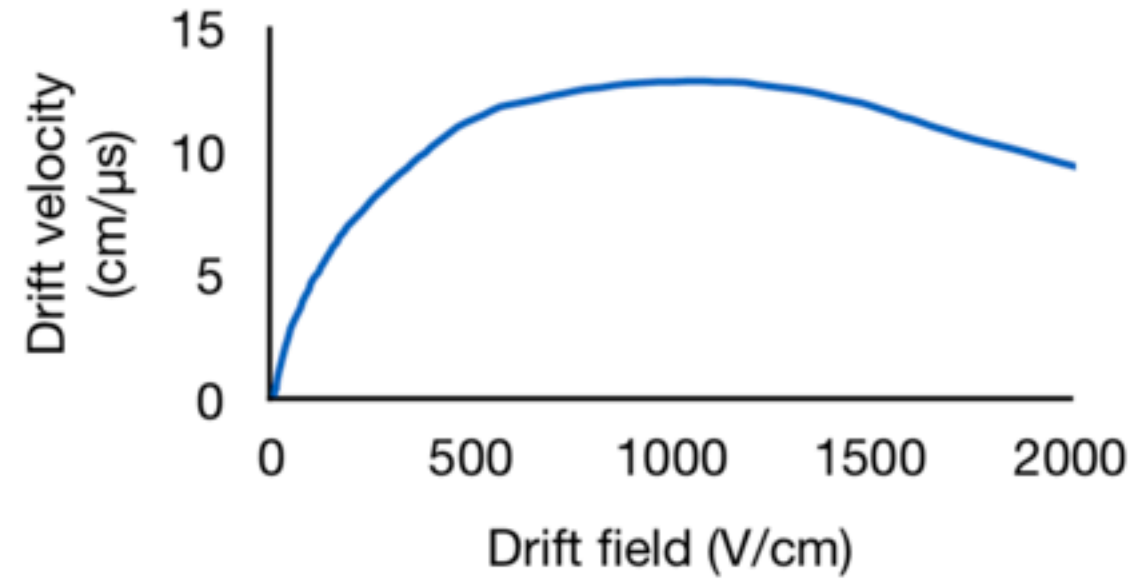



Electron drift velocity in Ar/CF$_4$ 80/20%

Christophorou et al., 1979

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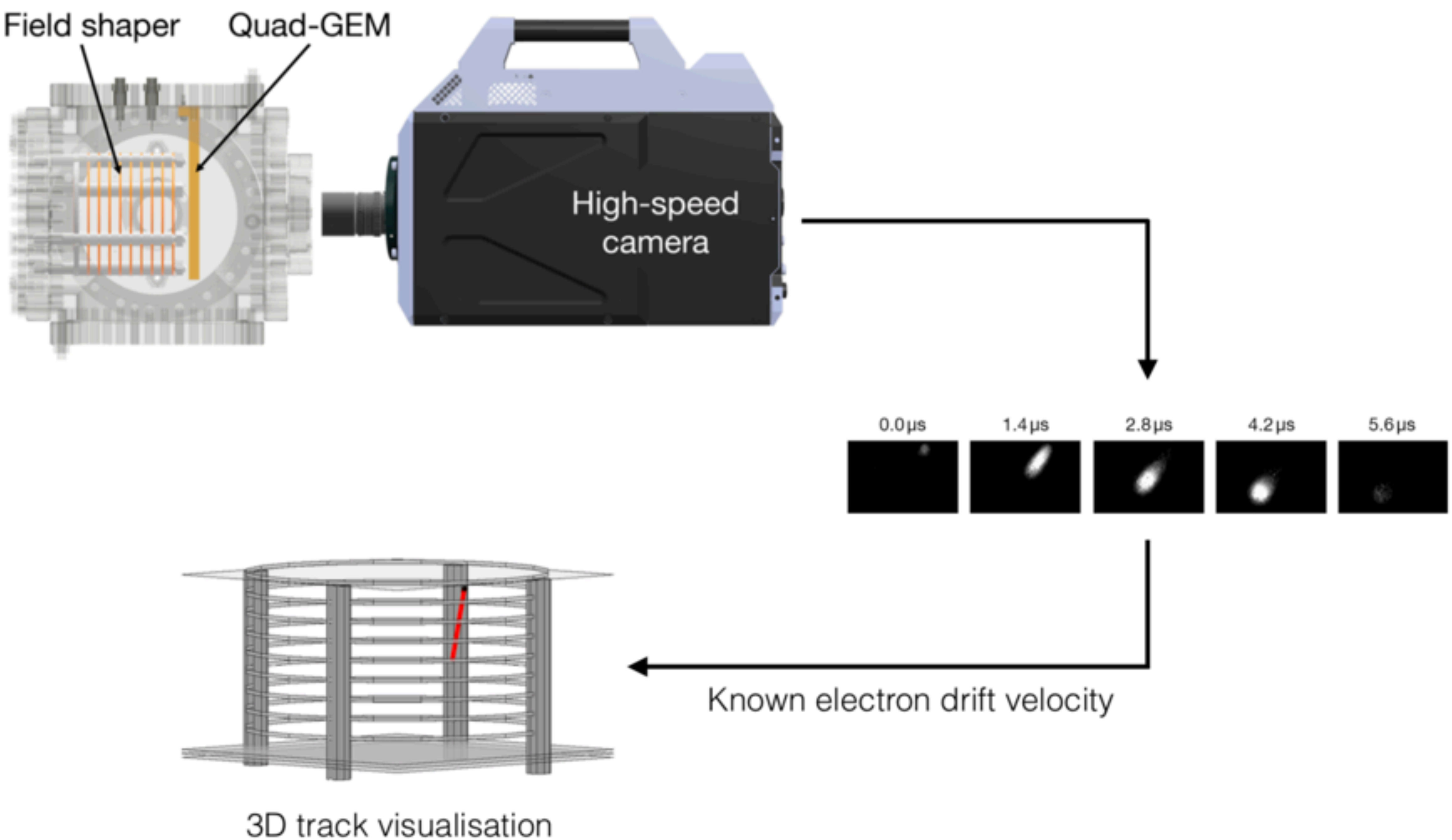
# 3D alpha track reconstruction



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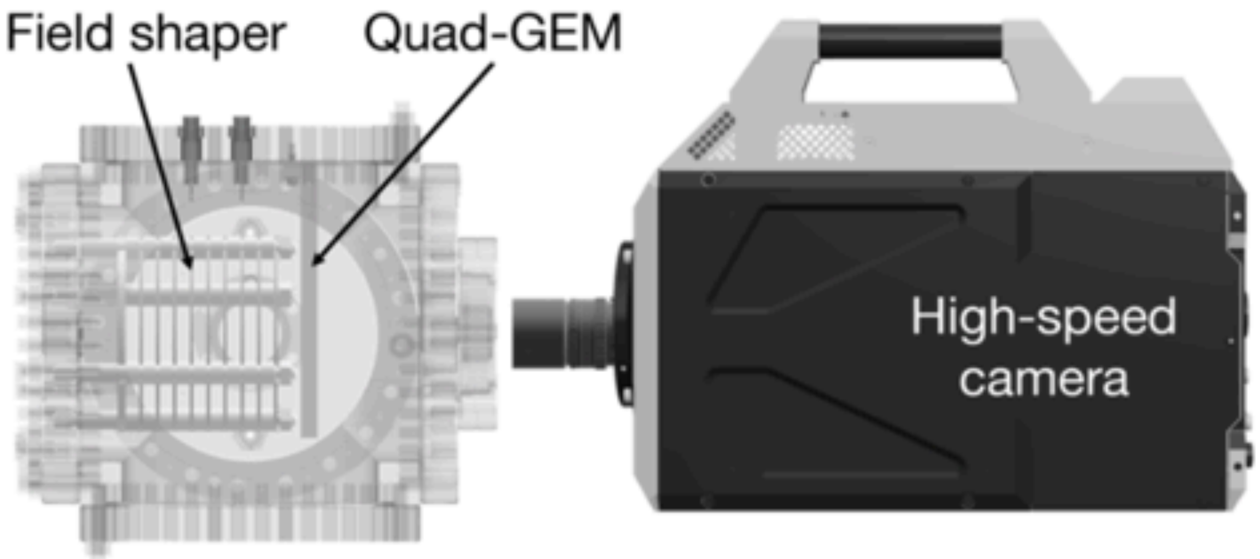
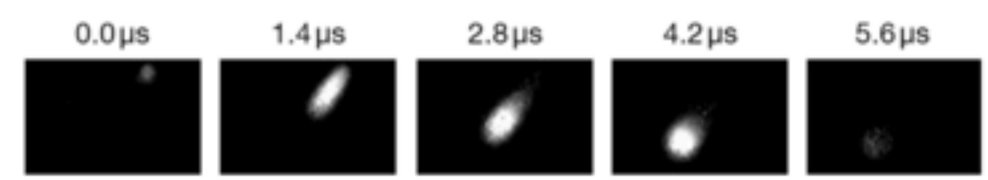
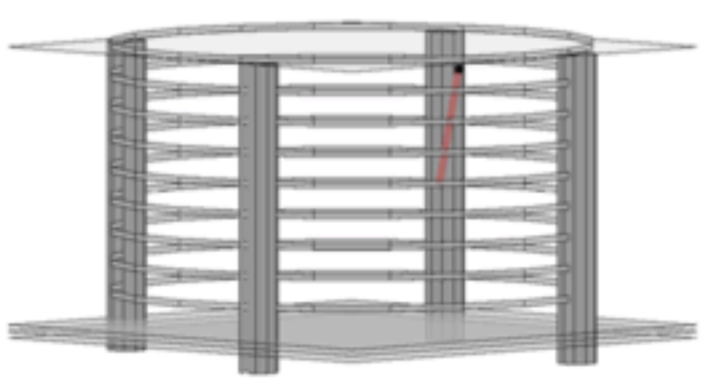



Electron drift velocity limits number of frames and consequently Z-resolution

**May be overcome by novel imaging sensors or technologies**



3D track visualisation

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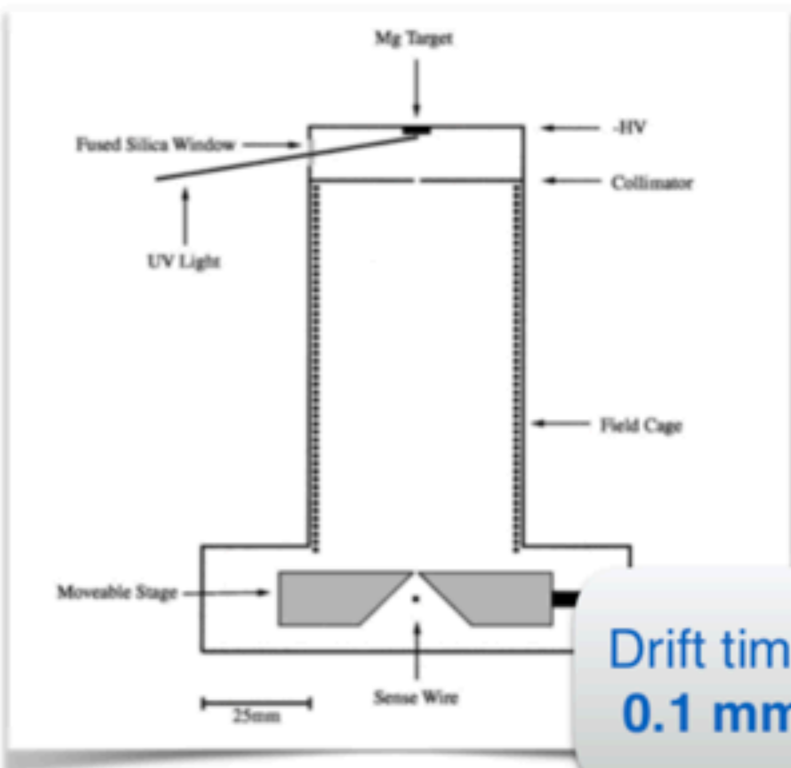
# Negative ion TPCs




Drift times on the order of **0.1 mm/μs** at 1bar in Xe

Martoff et al., NIM A 440, 355 (2000)
Nygren, Journal of Physics: Conference Series 65 (2007) 012003

The **low drift velocity** of ions in negative ion TPCs makes optical readout for 3D track reconstruction with existing CMOS-based cameras feasible and **high Z-resolution** may be achieved

## Possible applications

**Directional dark matter experiments**

N.S. Phan et al 2017 JINST 12 P02012

**Nuclear recoil detection in WIMP searches**

Nygren, Journal of Physics: Conference Series 65 (2007) 012003

**X-ray polarimetry**

Prieskorn, IEEE Trans.Nucl.Sci. 58 (2011) 2055-2059

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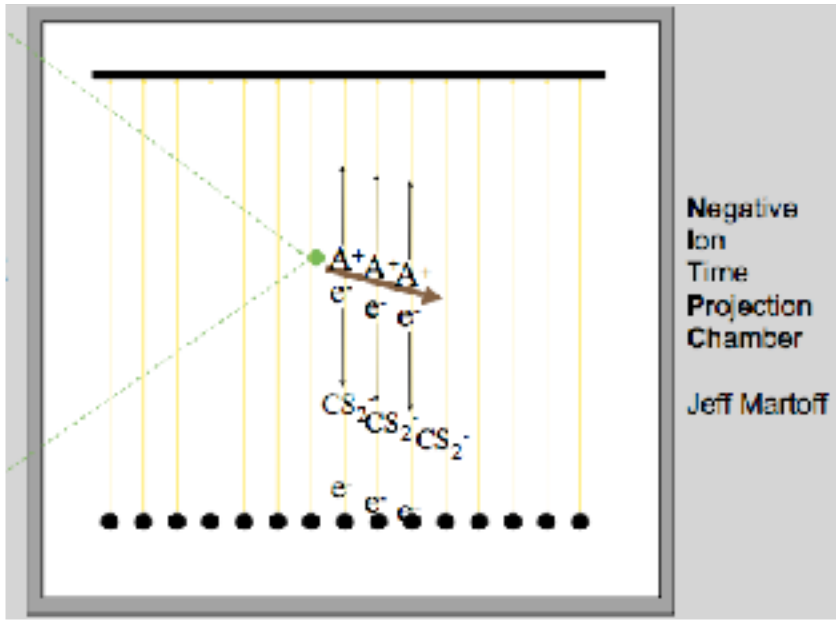
# Negative ion drift concept




**Reduced diffusion & improved tracking**

- Primary ionization electrons are captured by the electronegative gas molecules at tens of um
- Anions drift to the anode acting as the effective image carrier instead of the electrons
- At the amplification stage, anions are stripped of the additional electron and common electron avalanche is generated
- This effectively reduces both longitudinal and transverse diffusion to thermal limit

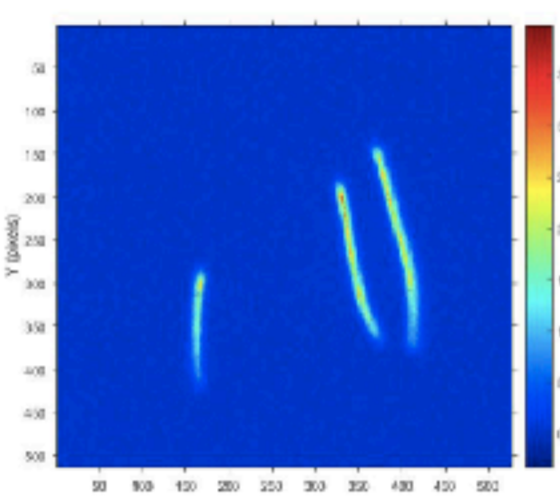
- Diffusion is ~ thermal (both transverse and longitudinal)

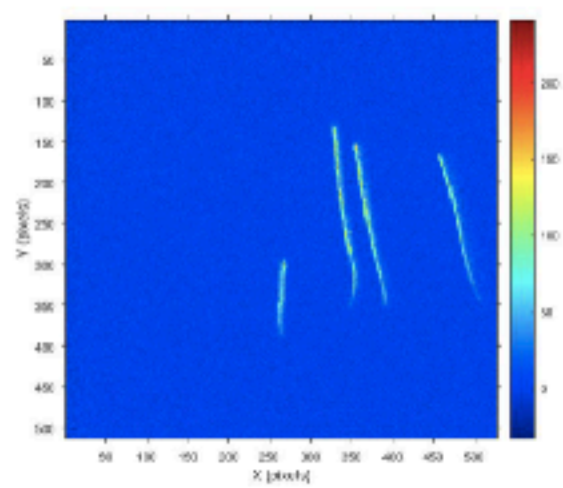
$$\sigma = \sqrt{\frac{2kTL}{eE}} = 0.7\,\mathrm{mm}\left(\frac{T}{300\,\mathrm{K}}\right)^{1/2}\left(\frac{580\,\mathrm{V/cm}}{E}\right)^{1/2}\left(\frac{L}{50\,\mathrm{cm}}\right)^{1/2}$$

low diffusion increases active volume per readout area

- Drift speeds are ~5 cm/ms or ~20 us/mm

$$v = \mu\frac{E}{P}$$





T. Ohnuki et al., NIM A 463

J. Martoff et al., NIM A 440 355

“sampling” frequency requirement for
electron drift ± 10 ns, for negative ion drift ± 10 us

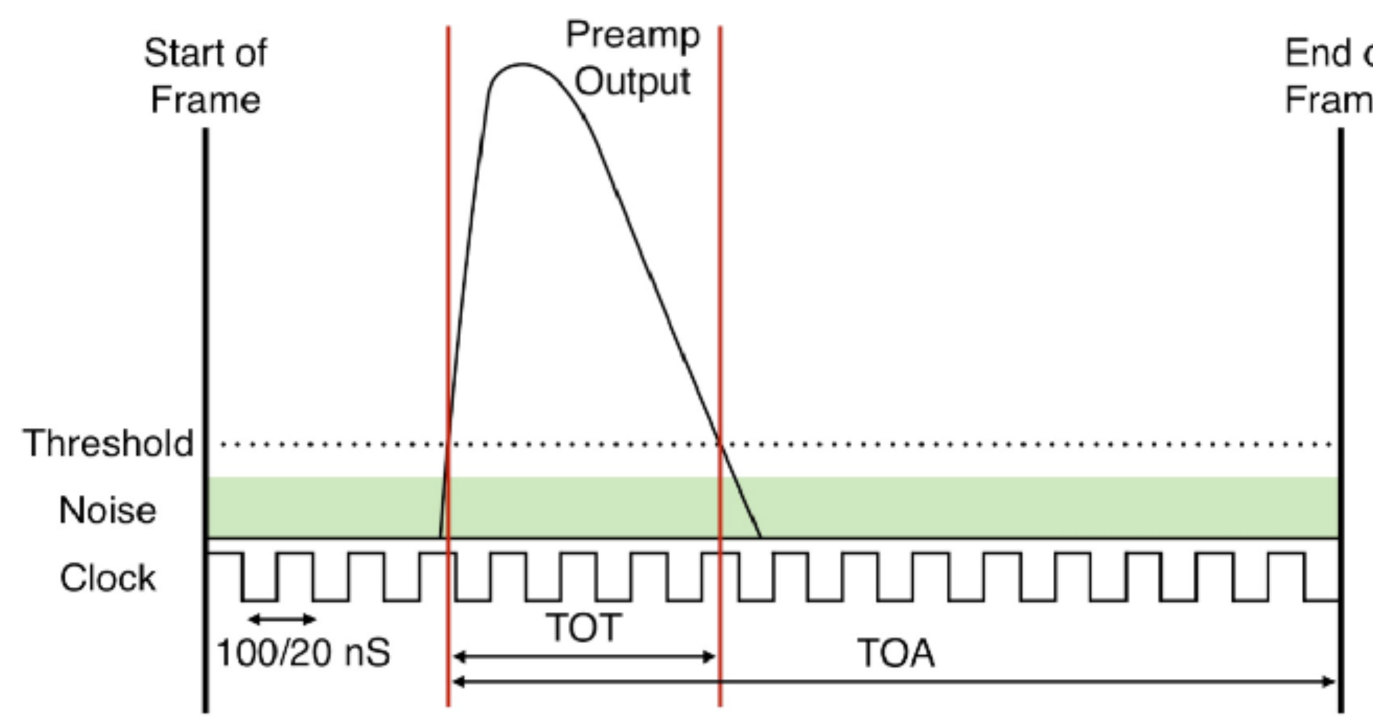
# ISSUE

## Optical

**Each of the light sampling will collect very few photons compared to an integrated acquisition**

**We want low threshold and we kind already limited with integrated light acquisition**

## Charge




**Charge sampling works with clocks, so it does not matter if each clock measure a charge lower than threshold...is it possible to do something similar with CMOS?**