Triggerable and time-tagged X-ray generator

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on behalf of the GDD team

RD-51 Mini Week - Precise Timing Workshop - CERN - 22/2/2017

X-ray generator

Idea from Patent US 20140044239 A1

One new feature: time tagging of the X-ray production

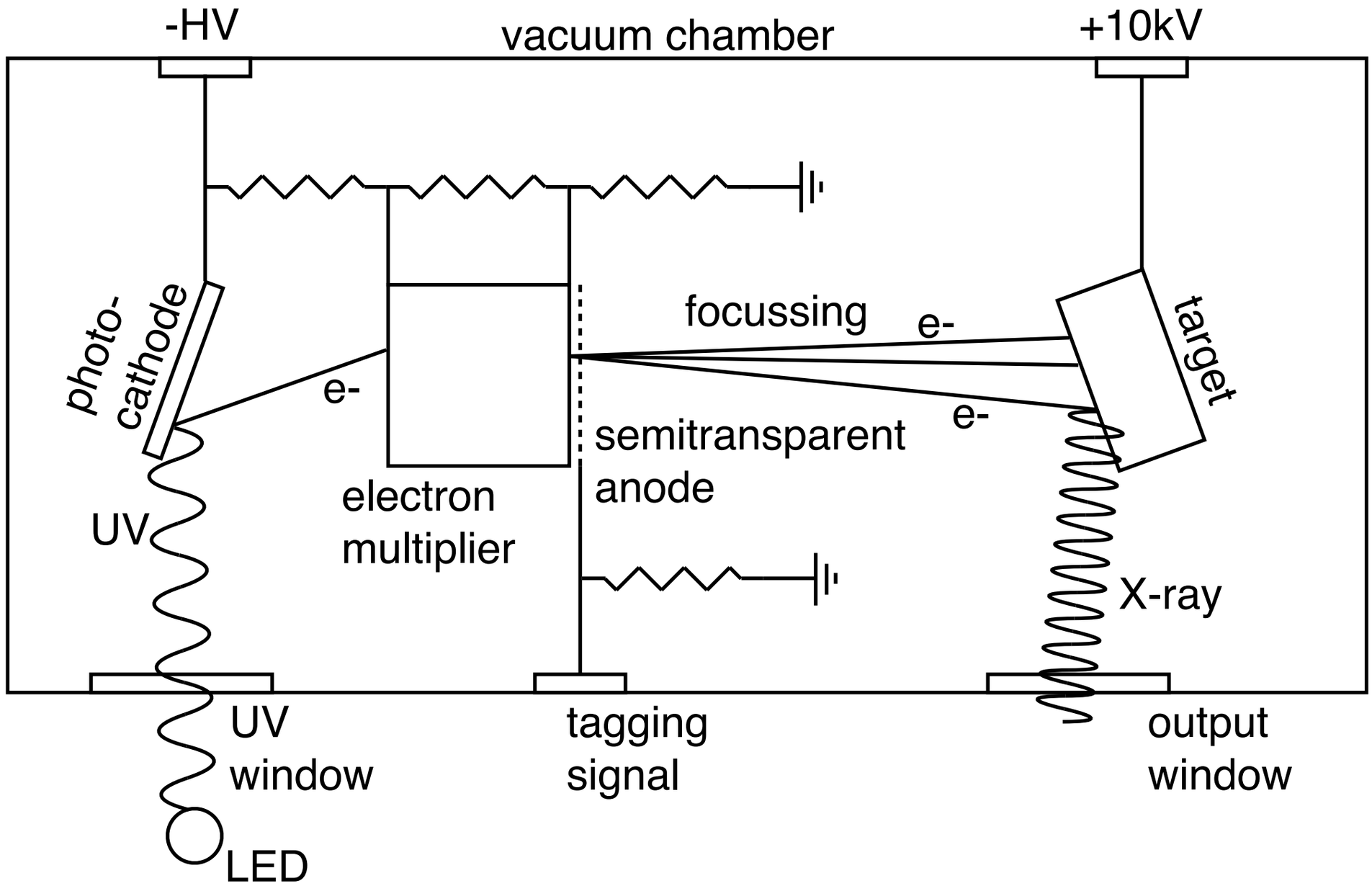
Possible usage:

- triggerable and modulated X-ray generator

- precise time tagging of X-rays

- low quantum efficiency (but fast) UV PMT

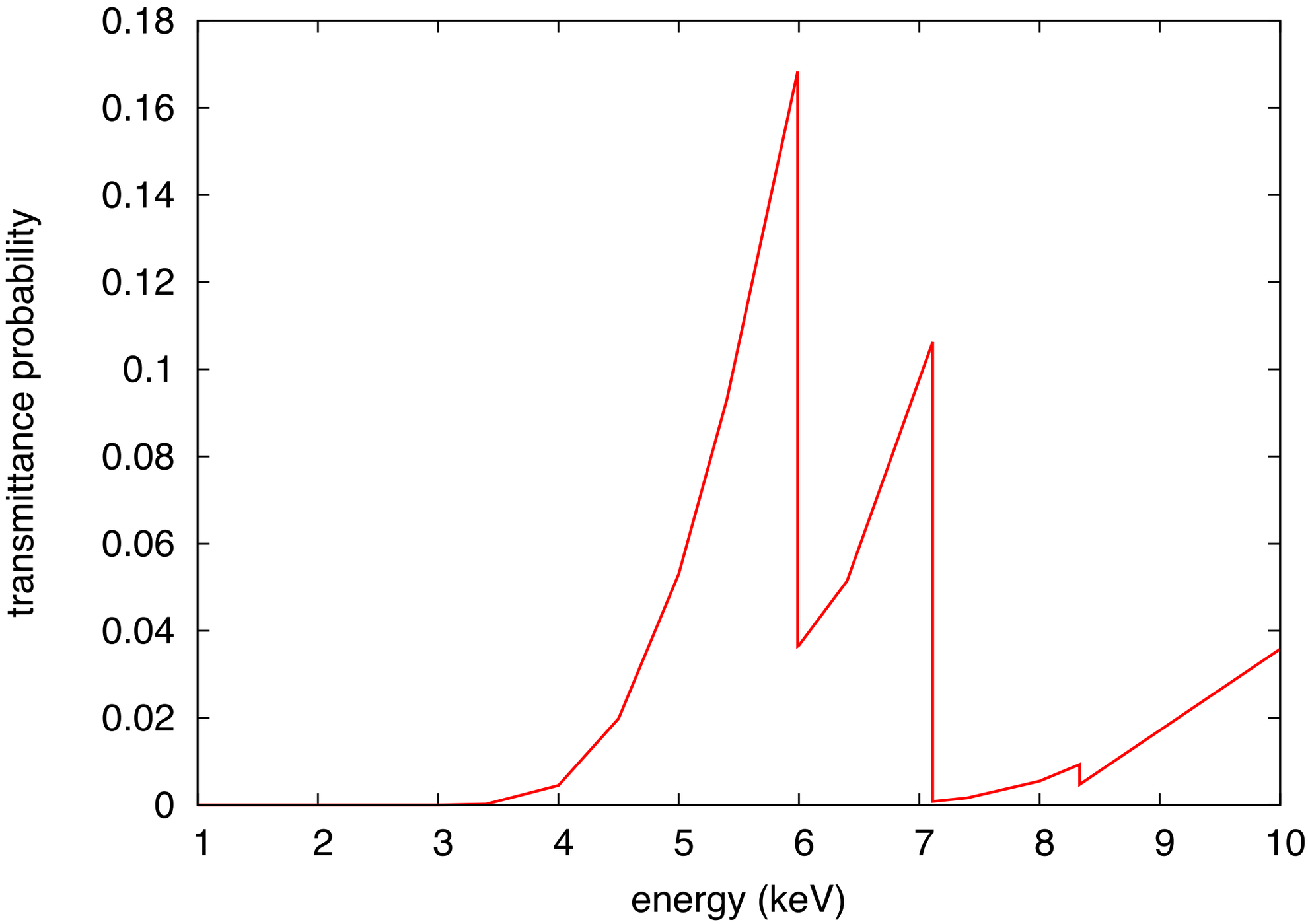
WLS: from UV to X-ray



LED: UVTOP 240
UV window: CaF_2
Photocathode: Au

Electron multiplier: MCP
Target: Cr (5.4 keV)
Output window: SS 25 um

The X-ray window



The target

Target	Transition	Energy (keV)	Efficiency (sr	After attenuation
Ti	K	4.5	6.7x10	1.3x10
Cr	K	5.4	3.5x10	3.1x10
Fe	K	6.4	1.5x10	7.5x10
Ni	K	7.4		
Cu	K	8.0	1.2x10	6.0x10
Ag	L	3.4		
Pt	M	2.2	2.4x10	/
Au	M	2.3	3.9x10	/
Pb	M	2.4	2.4x10	/

The MCP

- Gain > 10^6
measure single photoelectrons
about the same order of UV input and X-ray output

- Intrinsic time resolution << 100 ps

- Dark current << Hz

- Operative at pressure < 10^{-4} mbar

- Compact size

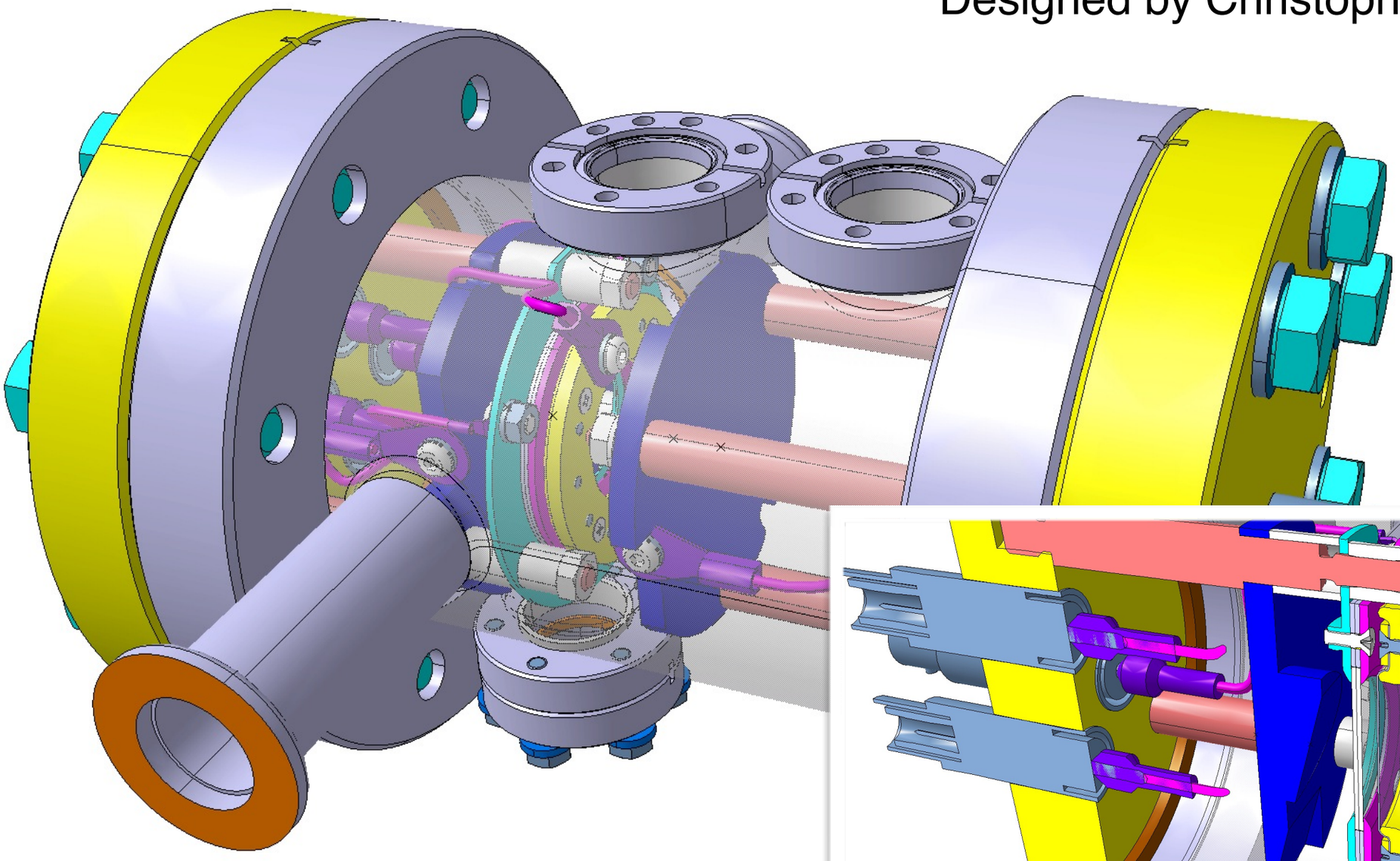
Operation modes

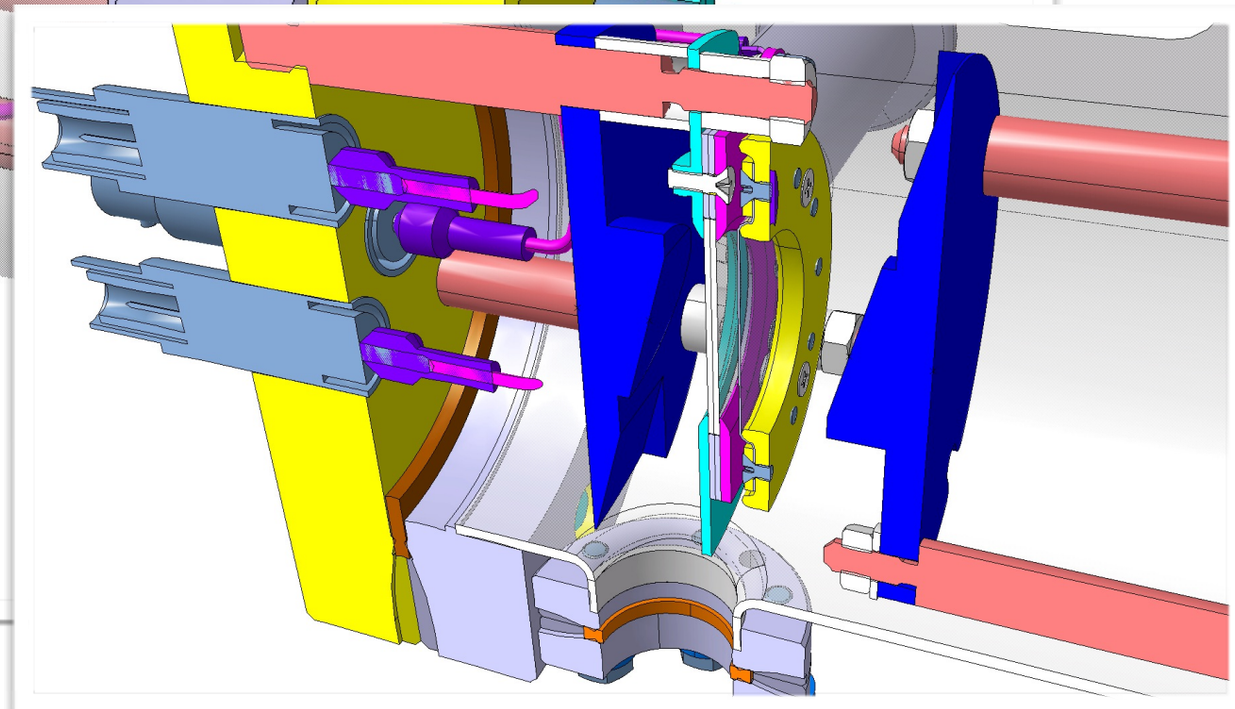
“Amplitude and time modulation”:
- several X-rays out every UV bunch in
- time resolution limited by the UV source

“Low intensity”:
- X-Ray out < 1 every UV bunch in
- time resolution given by the tagging signal

Engineering design

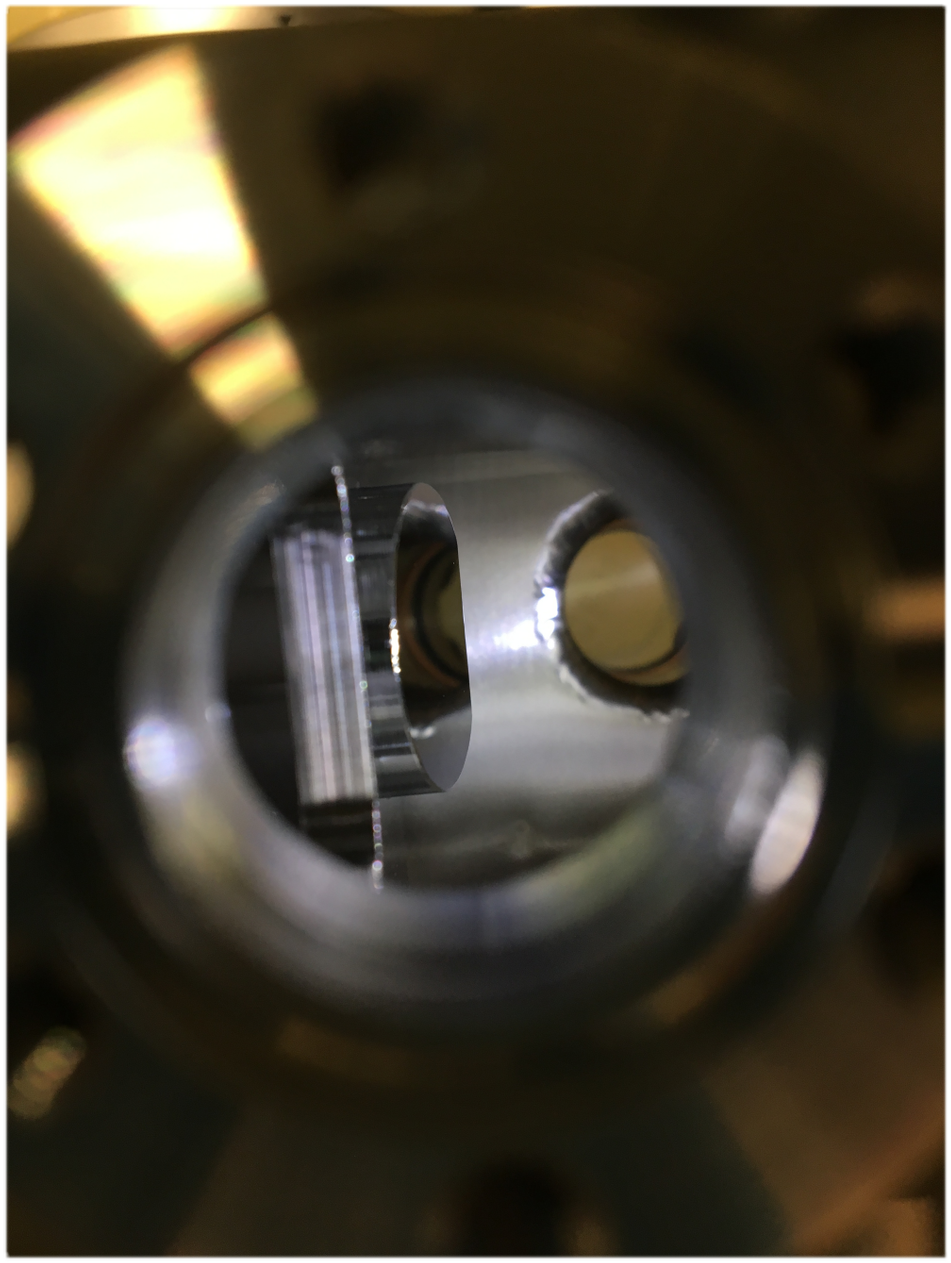
Designed by Christophe Bault



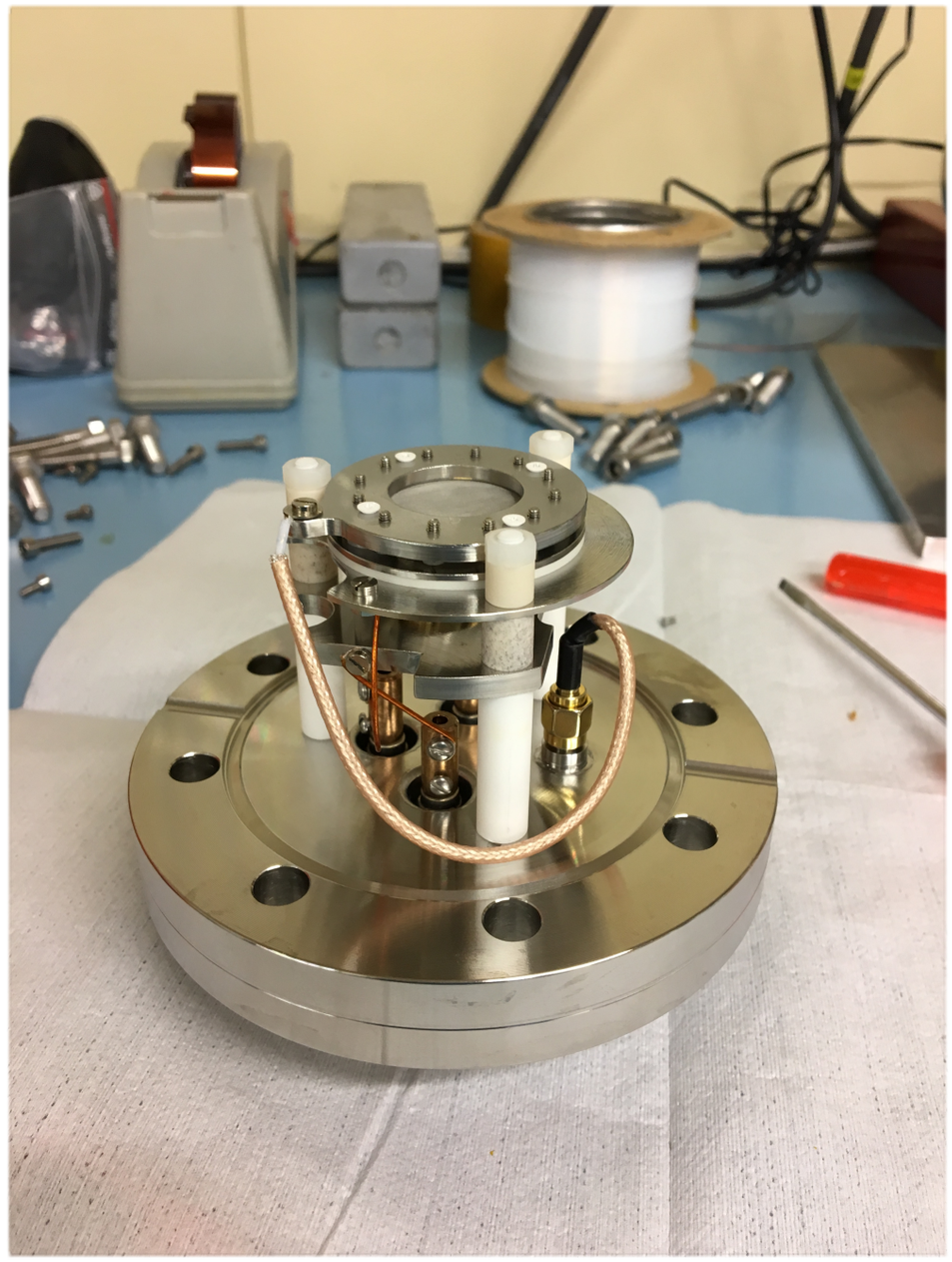


Assembly

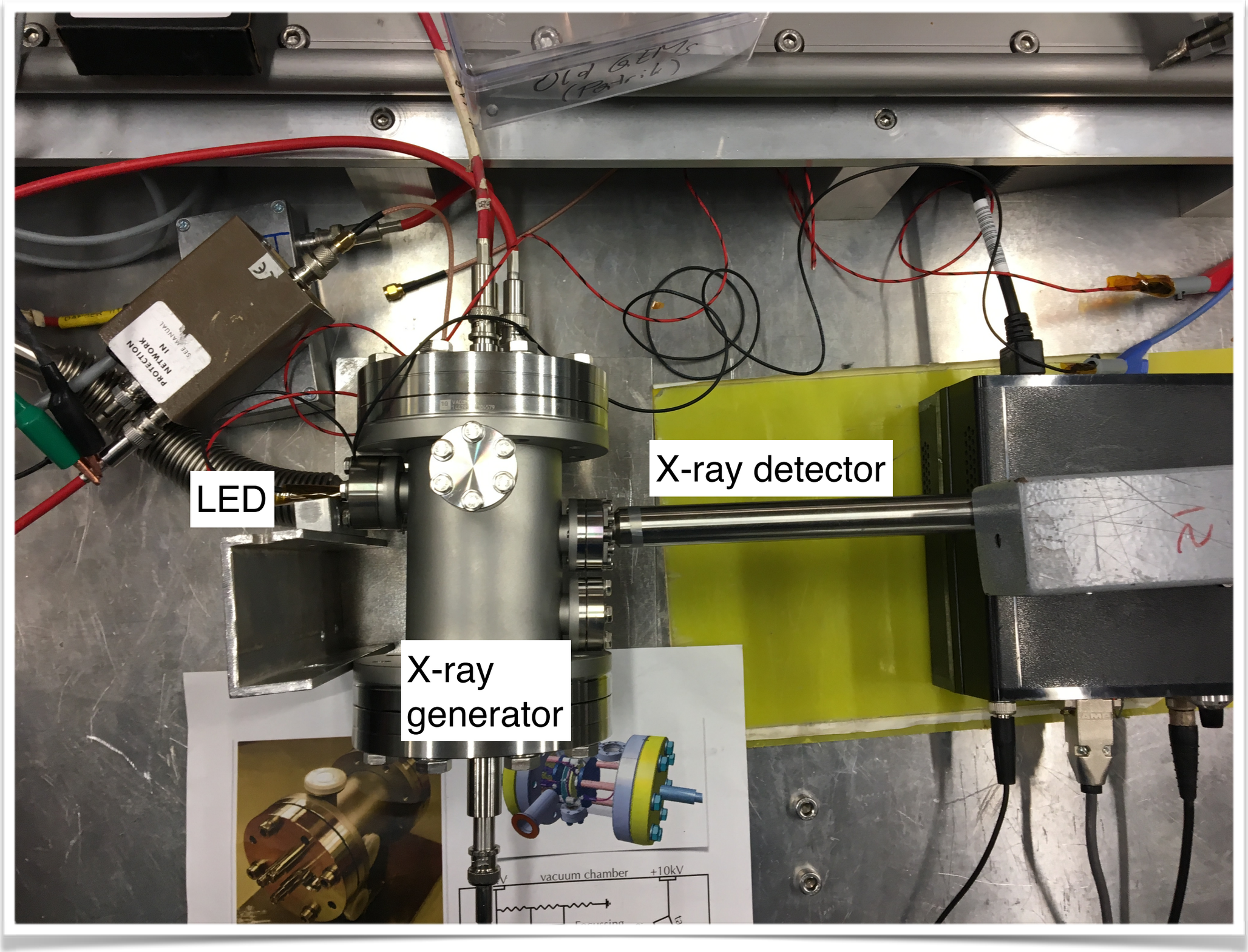
Target



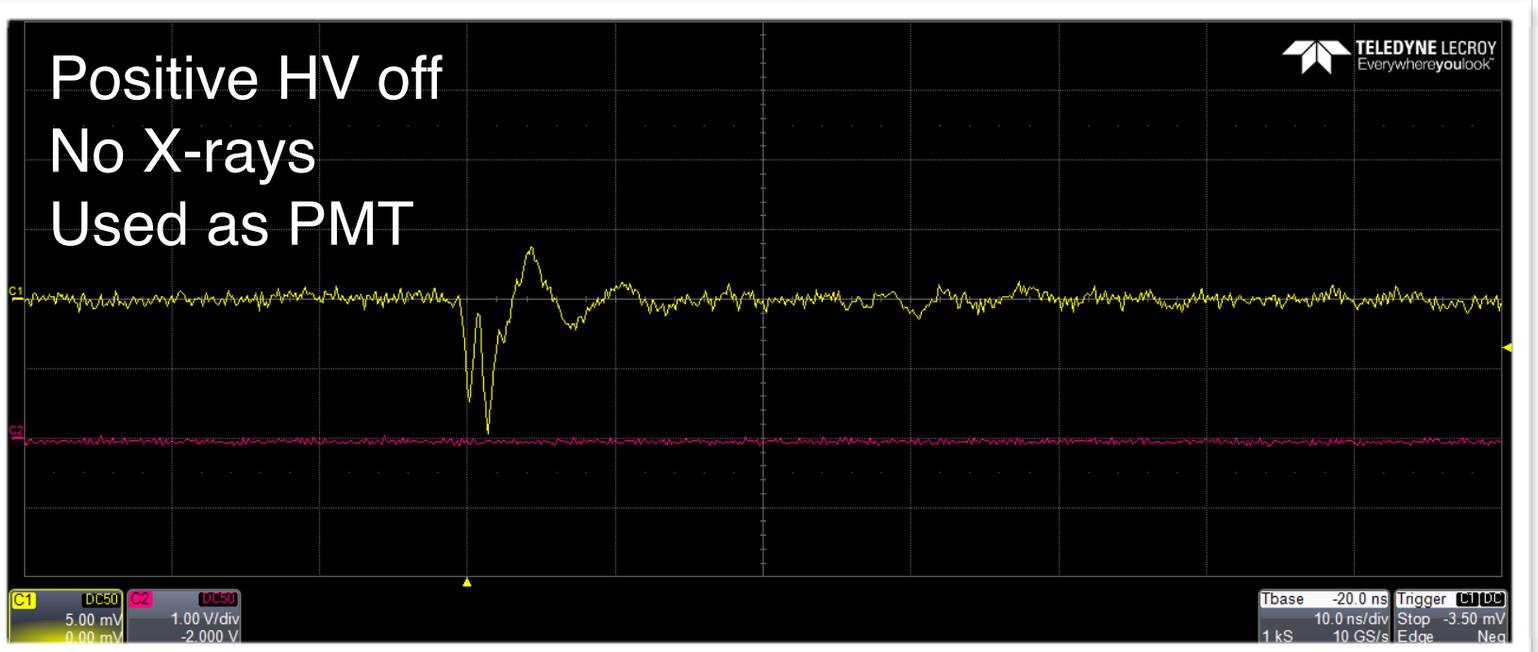
Cathode side



Assembled


Old GEMs (Part 1)
PROTECTION NETWORK IN
LED
X-ray detector
X-ray generator
vacuum chamber
+10kV

First operation

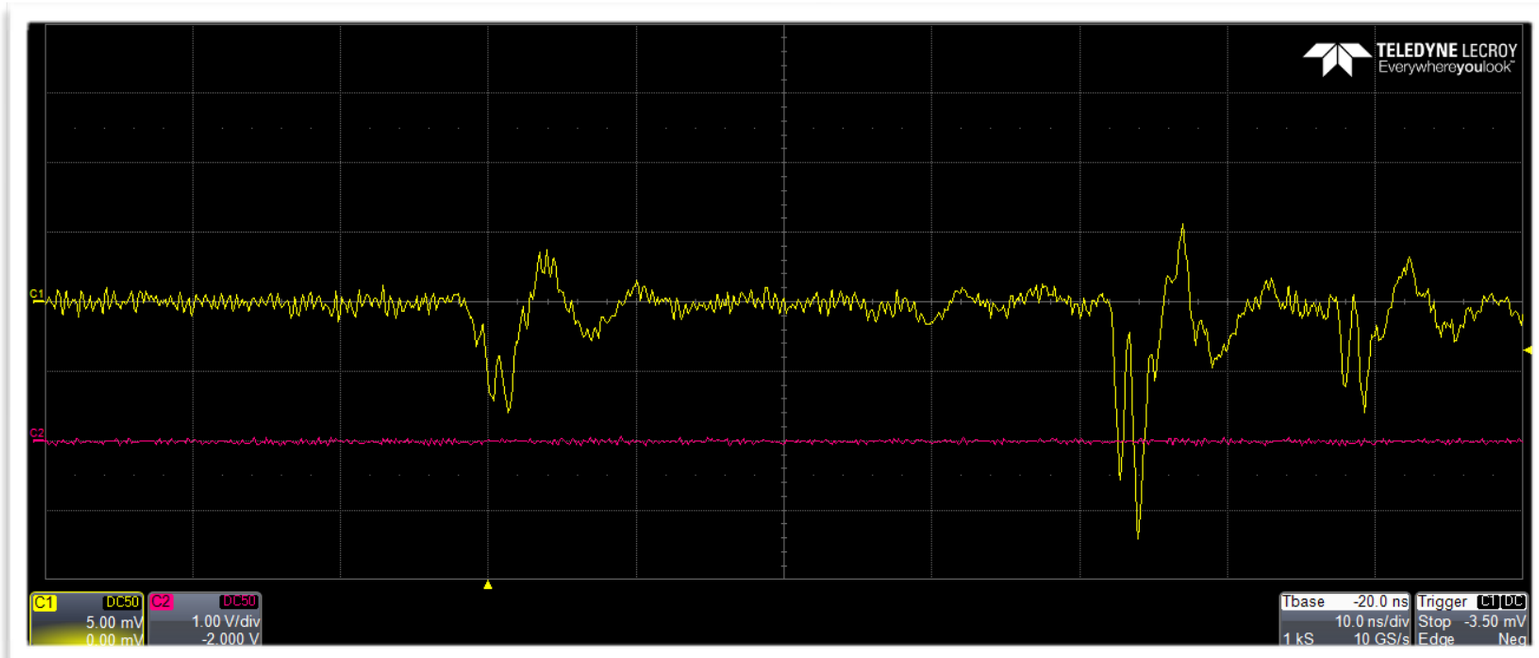


Single photoelectrons
MCP gain of about 3×10^5

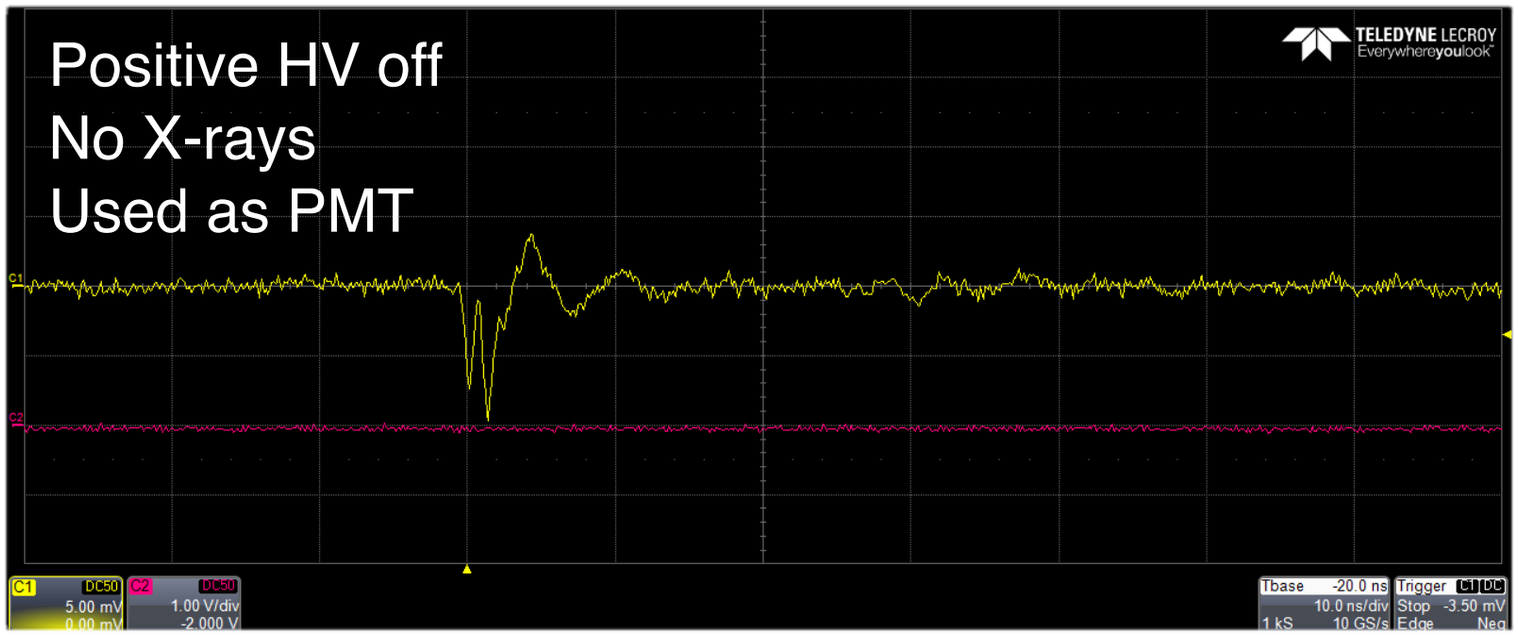
Reflections caused by
non-ideal signal routing
(improved but improvable)

Anyway rise-time < 500 ps

After-pulses due to ion feedback
Improvements already done on:
- MCP chevron configuration
- residual gas



First operation



Single photoelectrons
MCP gain of about 3×10^5

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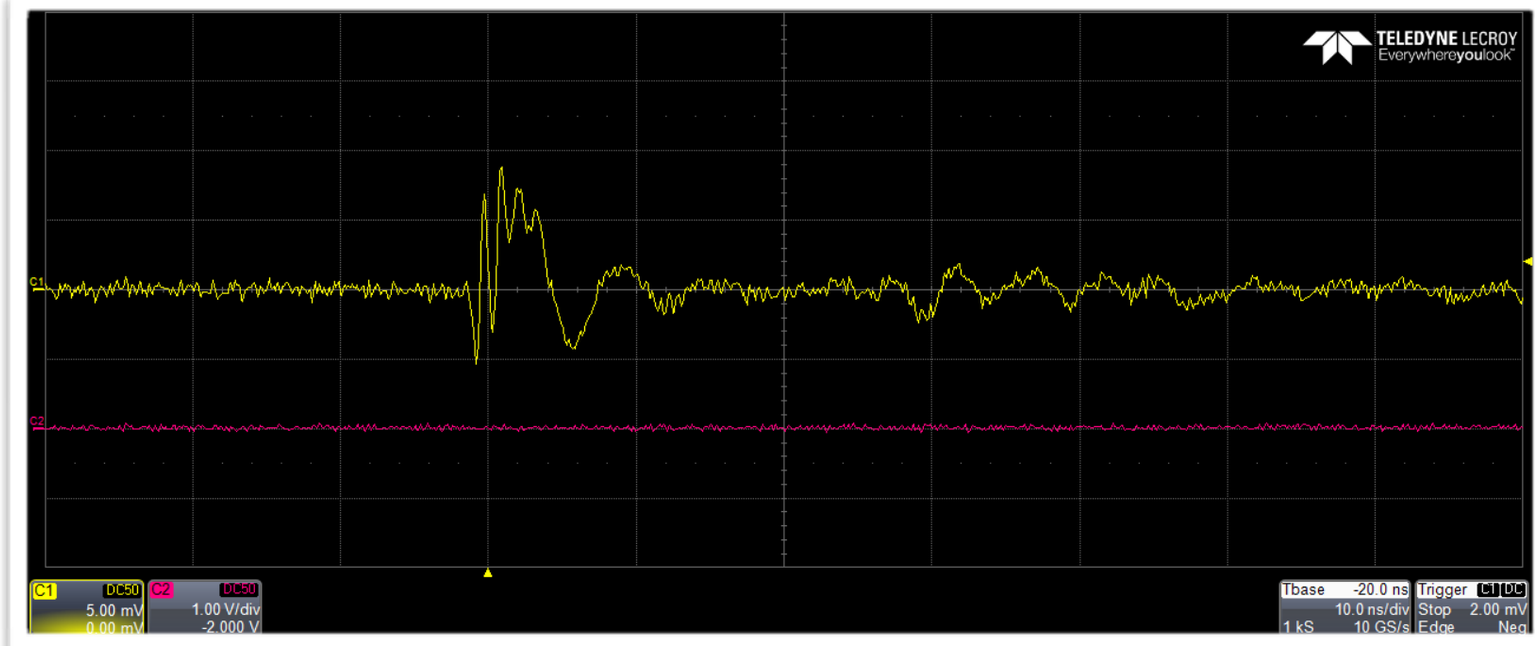
Anyway rise-time < 500 ps

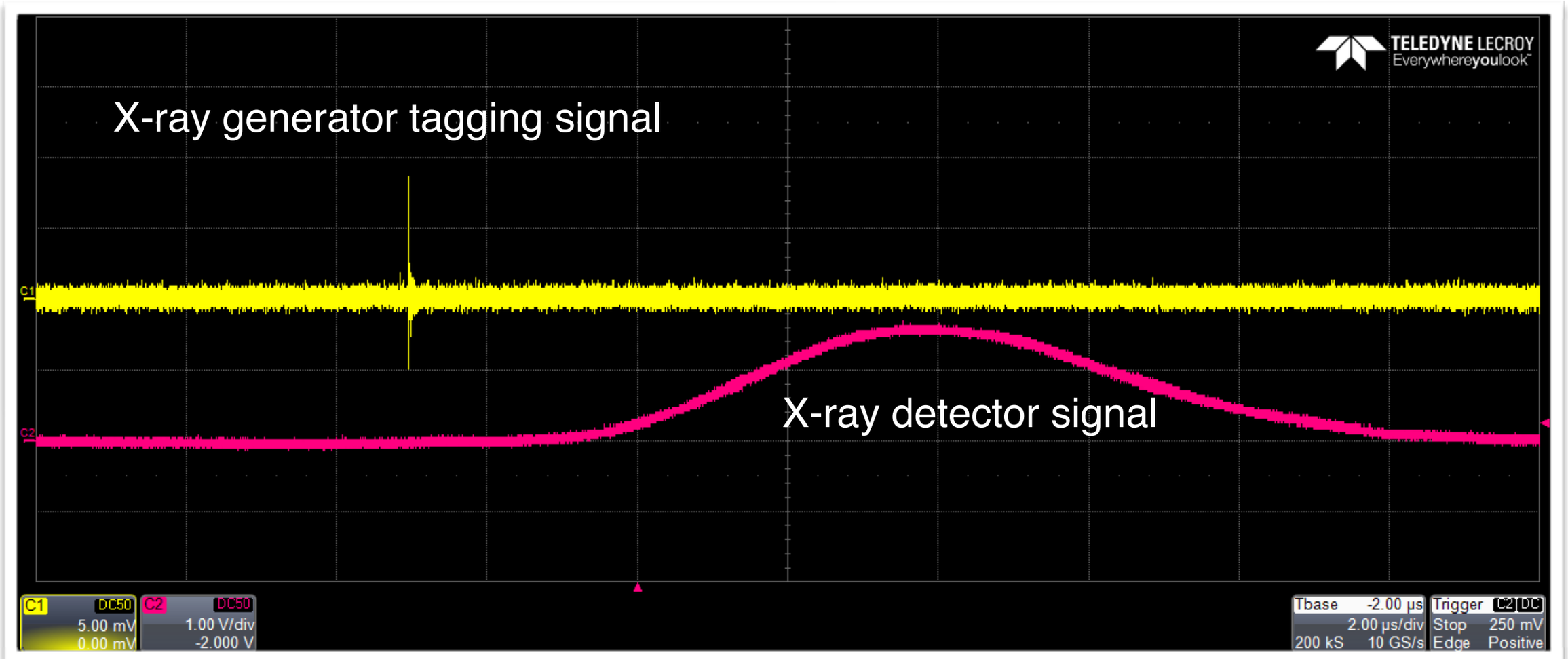
When positive HV is on
signals change sign and shape

Not all electrons are collected
on the semi-transparent anode
and electrons move away from it



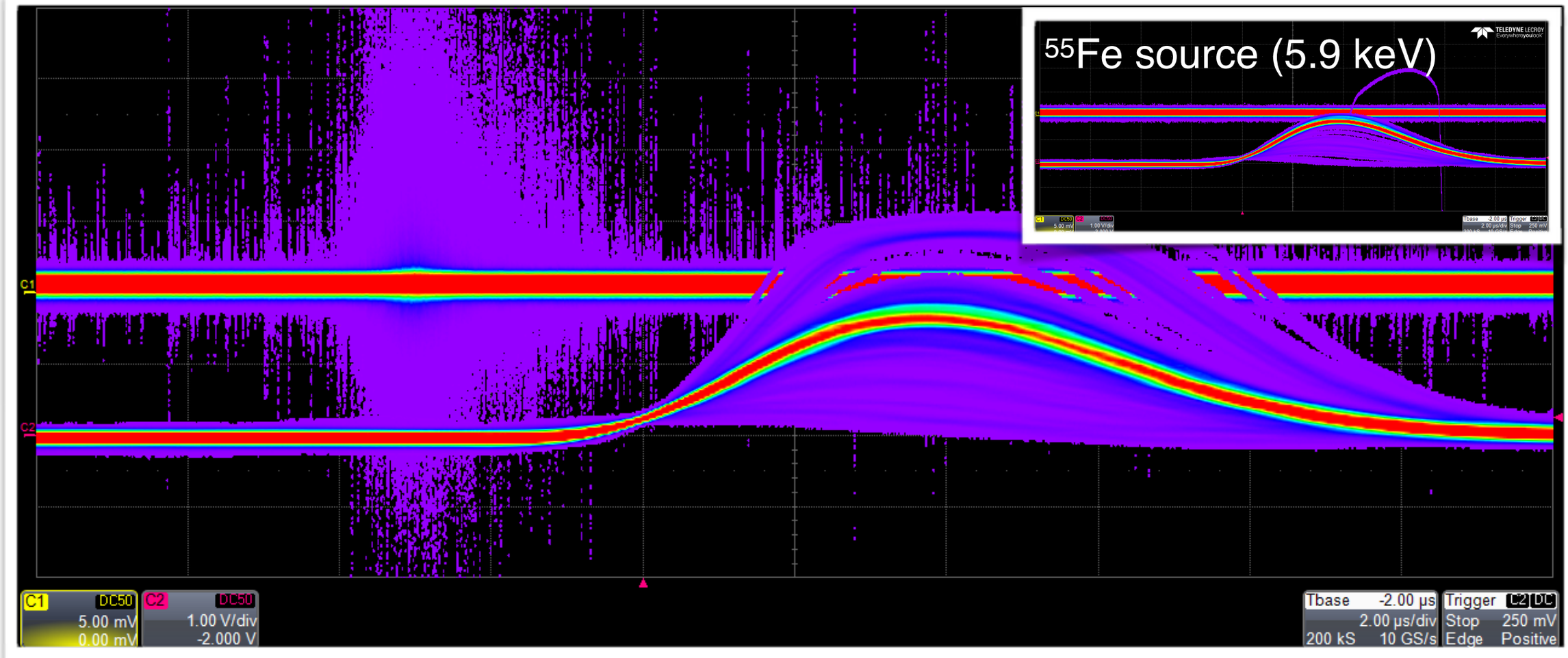
First operation

And X-rays are produced



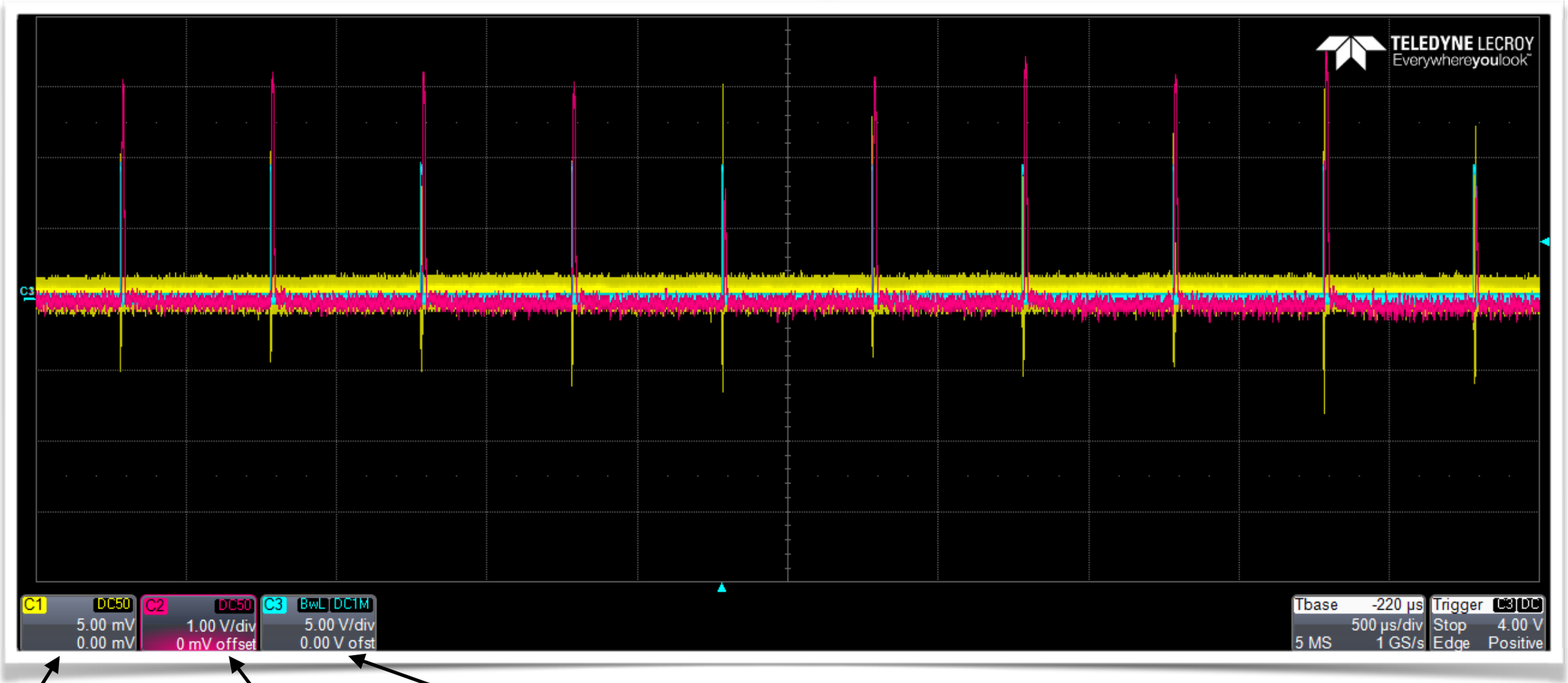
First operation

Of the right energy (5.4 keV)



First operation

And only when the UV light is on



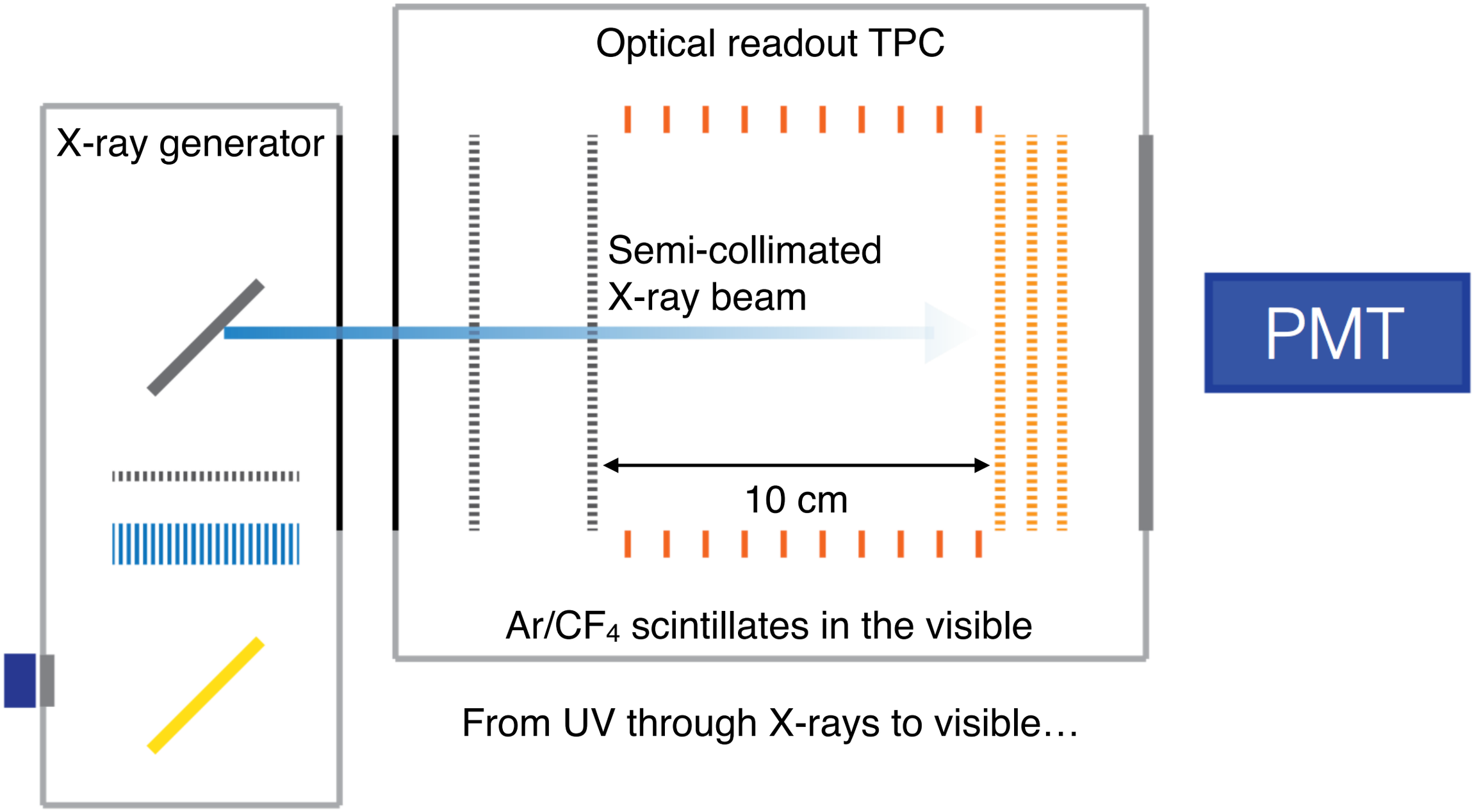
X-ray generator

X-ray detector

LED pulser

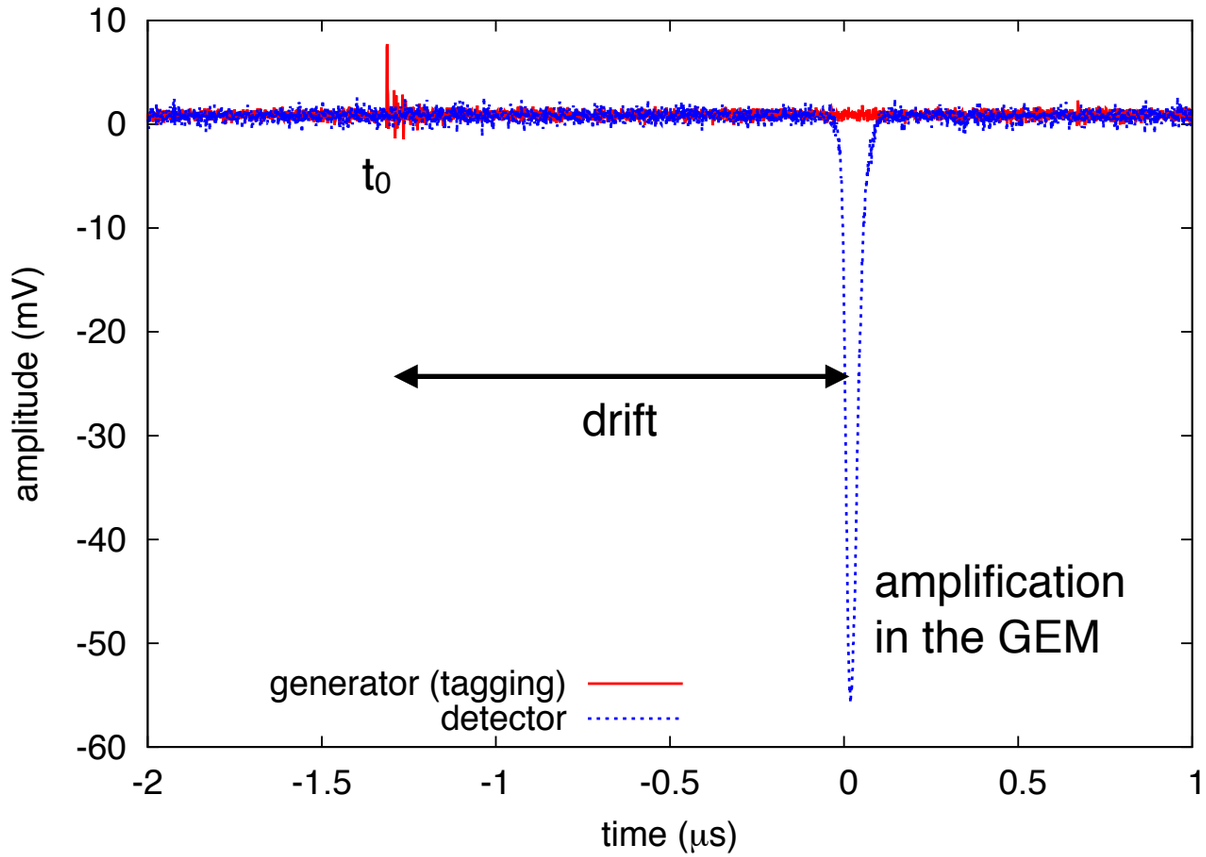
Original use of the device:
time structure and intensity of X-rays reflect the ones of UV light

A twist in the WLS story

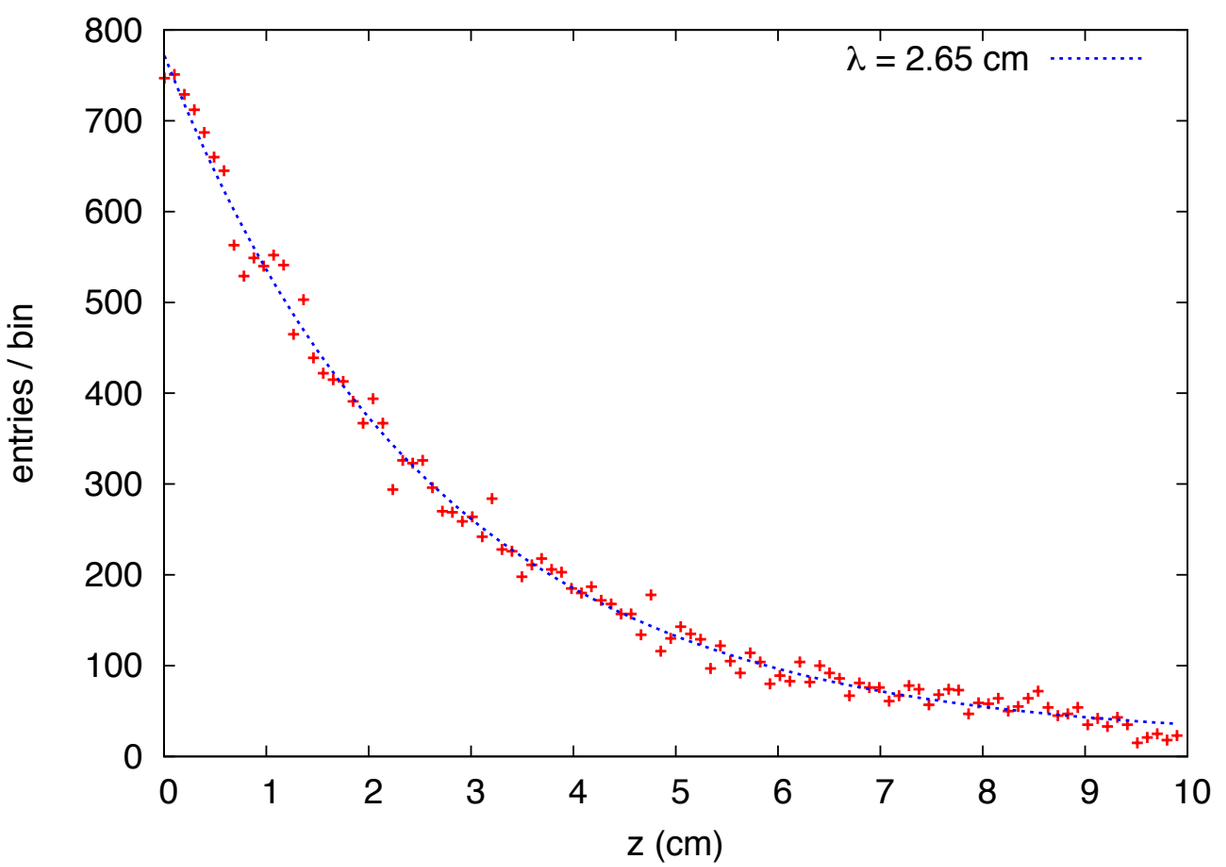


From UV through X-rays to visible…

Depth of interaction



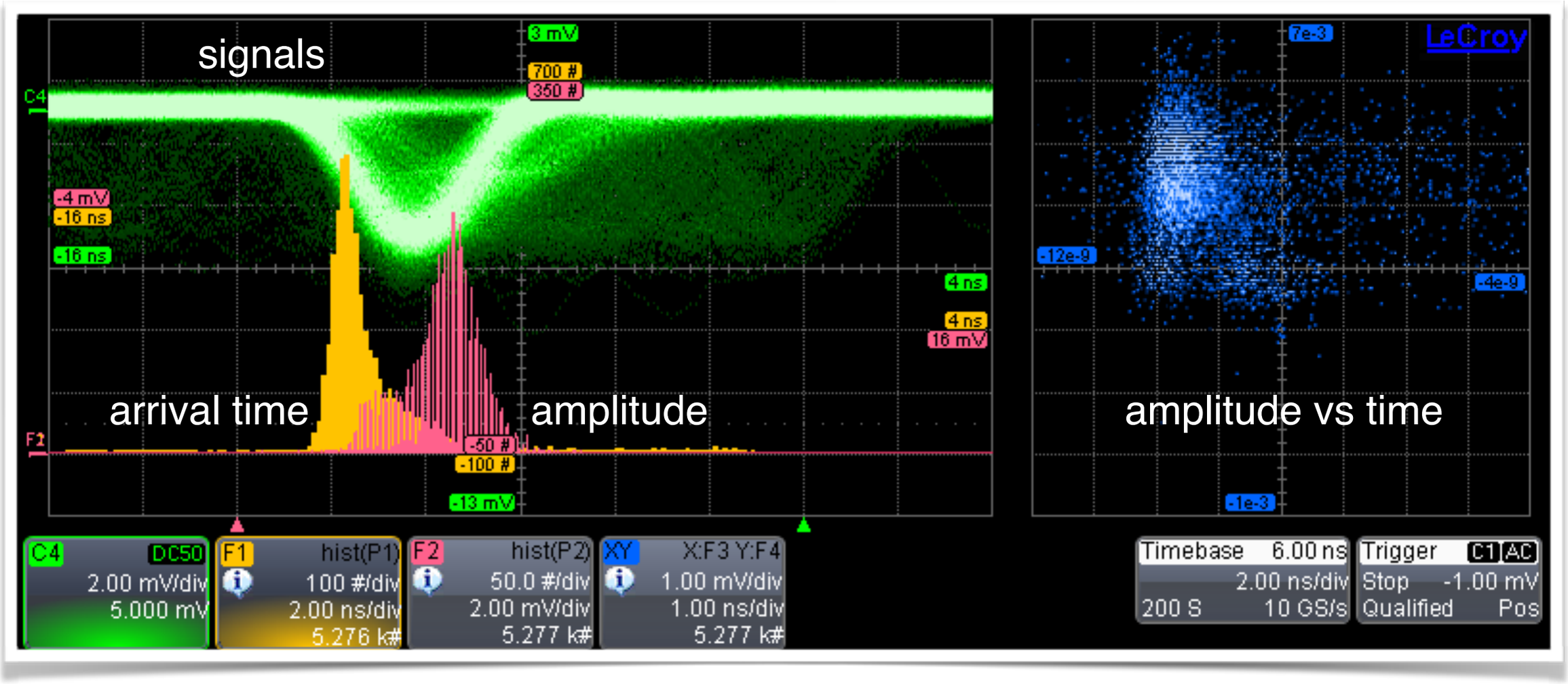
Examples of applications:
- amplitude vs drift time
(electronegative impurities)
- absorption length
(gas composition)



And also (for instance):
- depth of interaction studies
in dense and thin materials

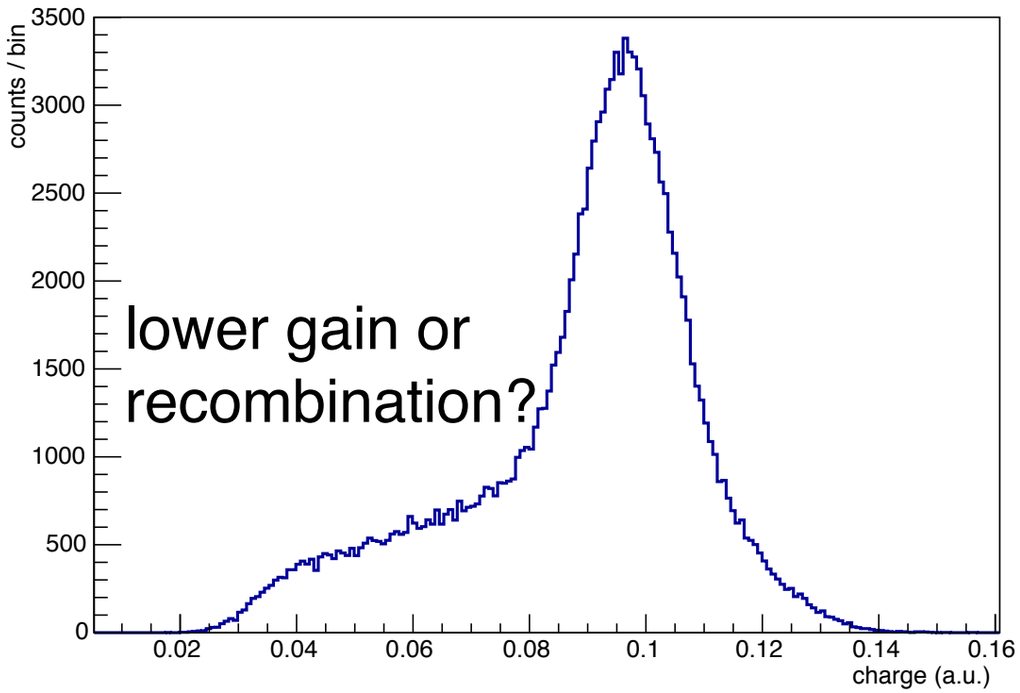
Like silicon (detector)

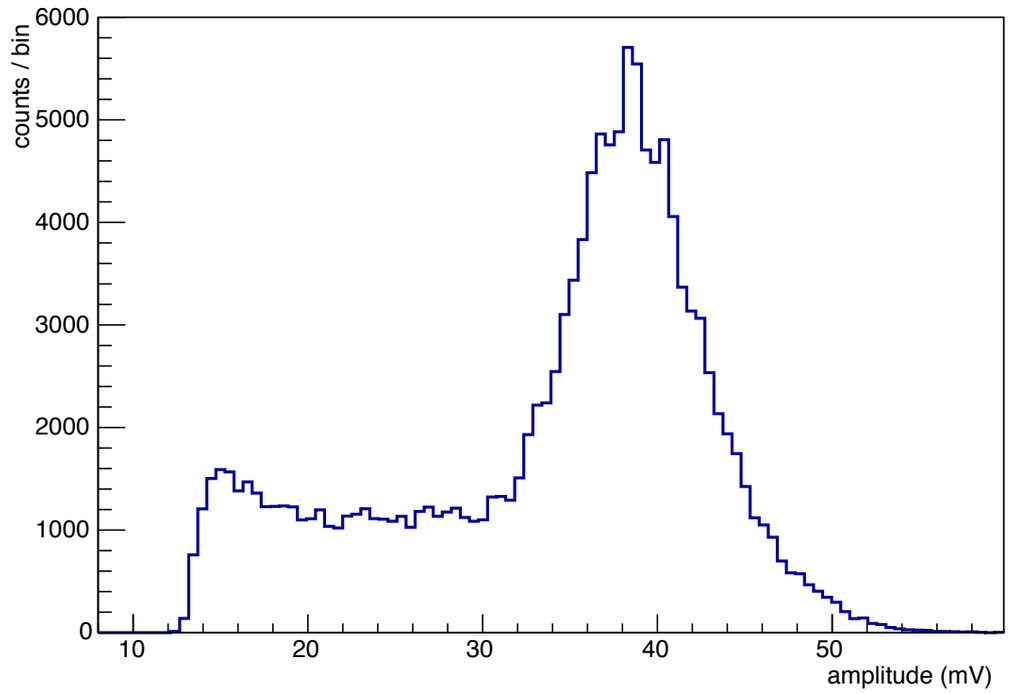
Again t_0 is set by the X-ray tagging signal.
Preliminary depth of interaction study (timing, charge, and signal shape)
in high-gain 'Hyper-fast' silicon detector with trans-impedance preamplifier

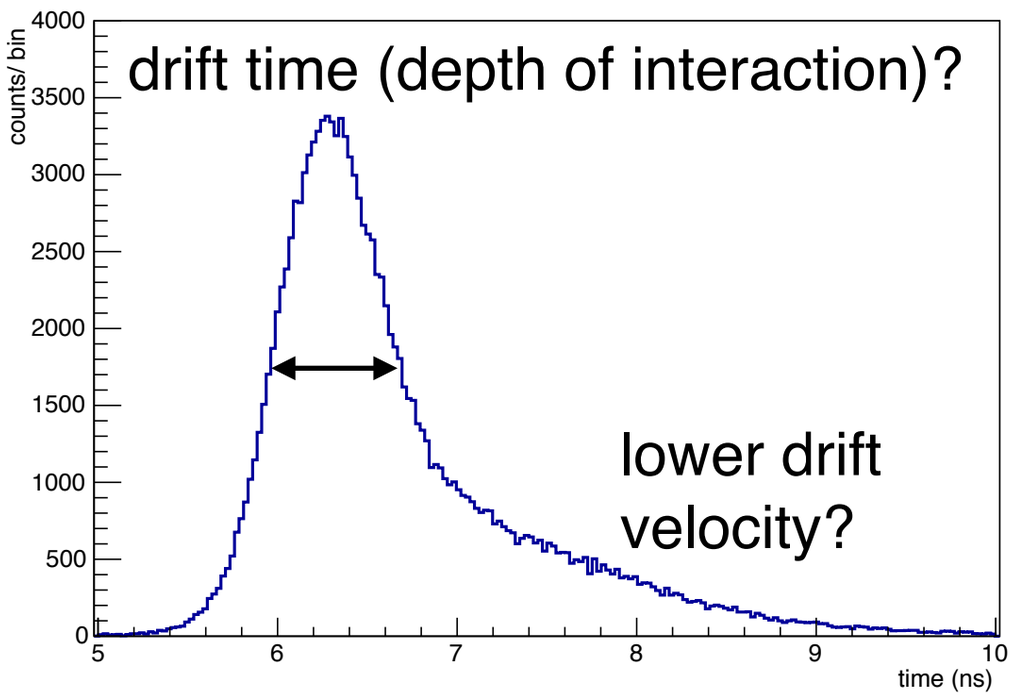


Mean free path of 5.4 keV X-rays in silicon (~1500 e^-/h^+): ~20 um

Offline data

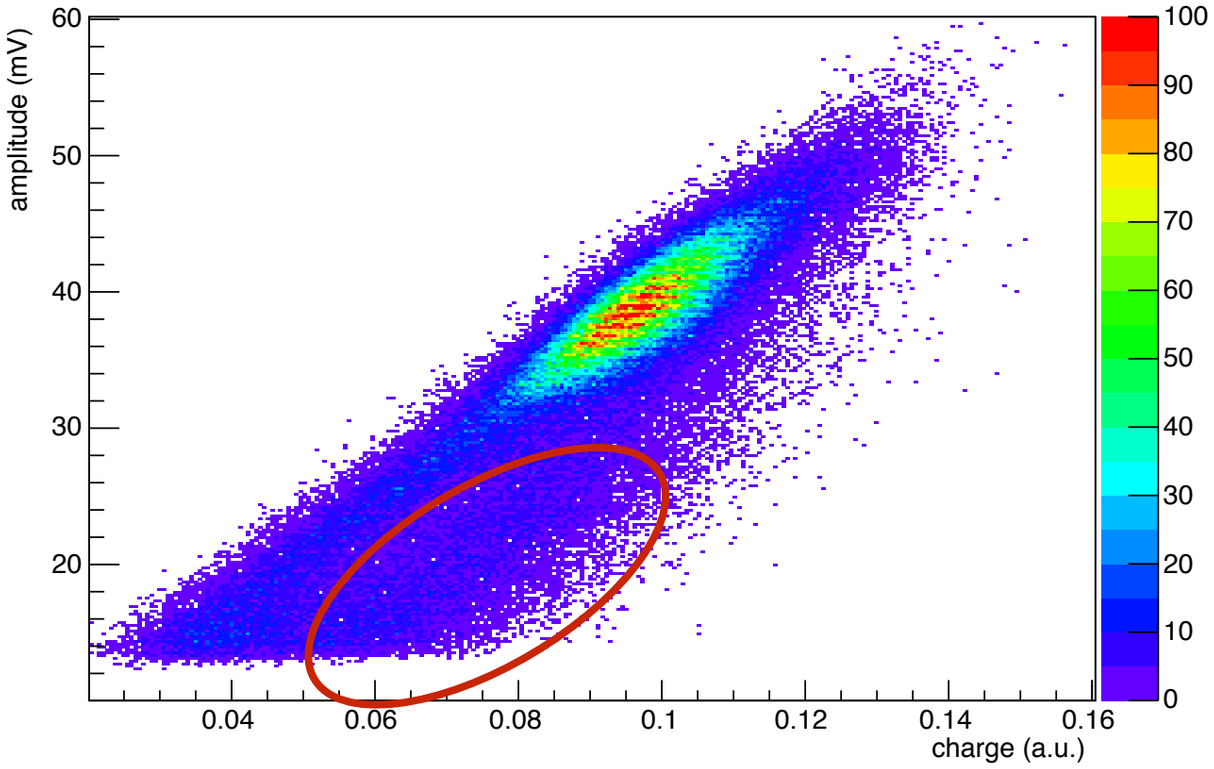




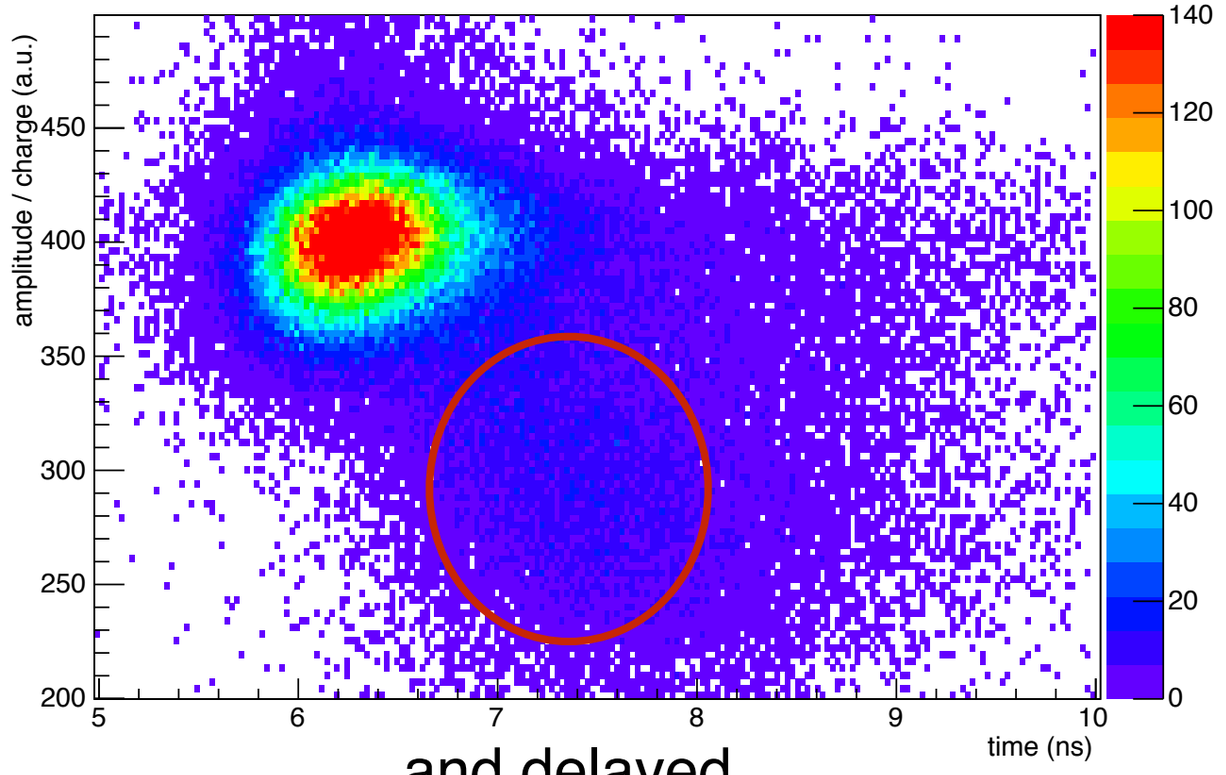


Offline data

First two interesting features

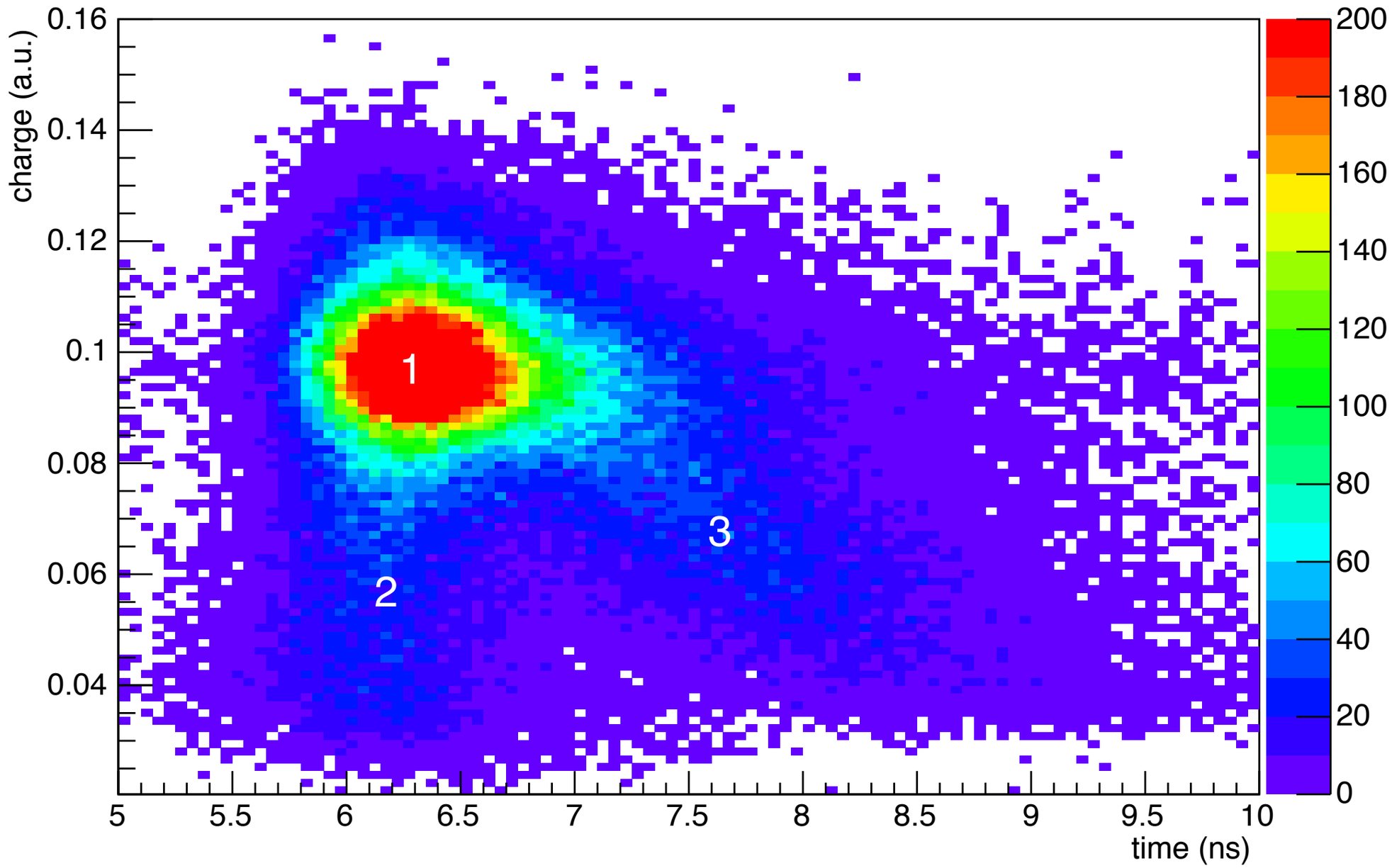


slower
(same charge
lower amplitude)



and delayed

Offline data



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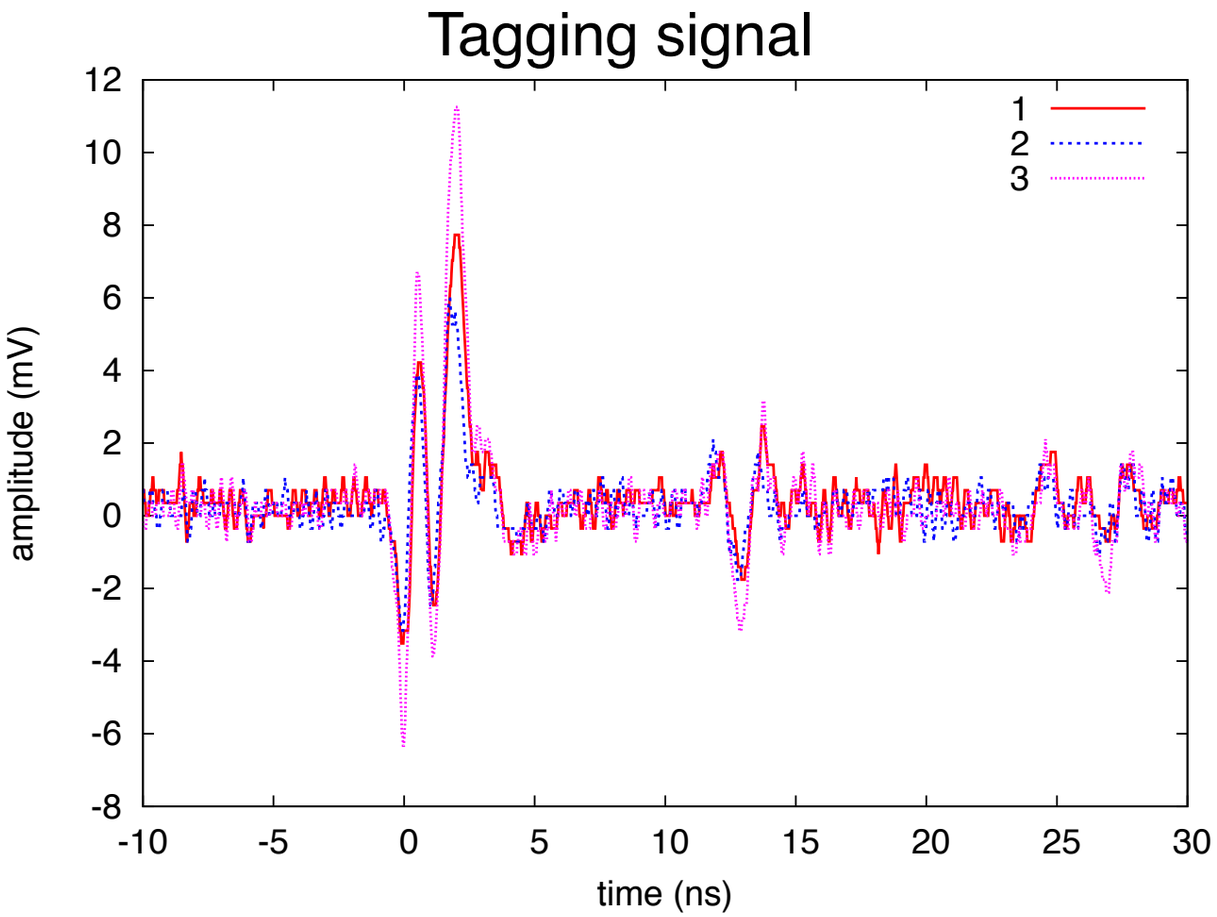

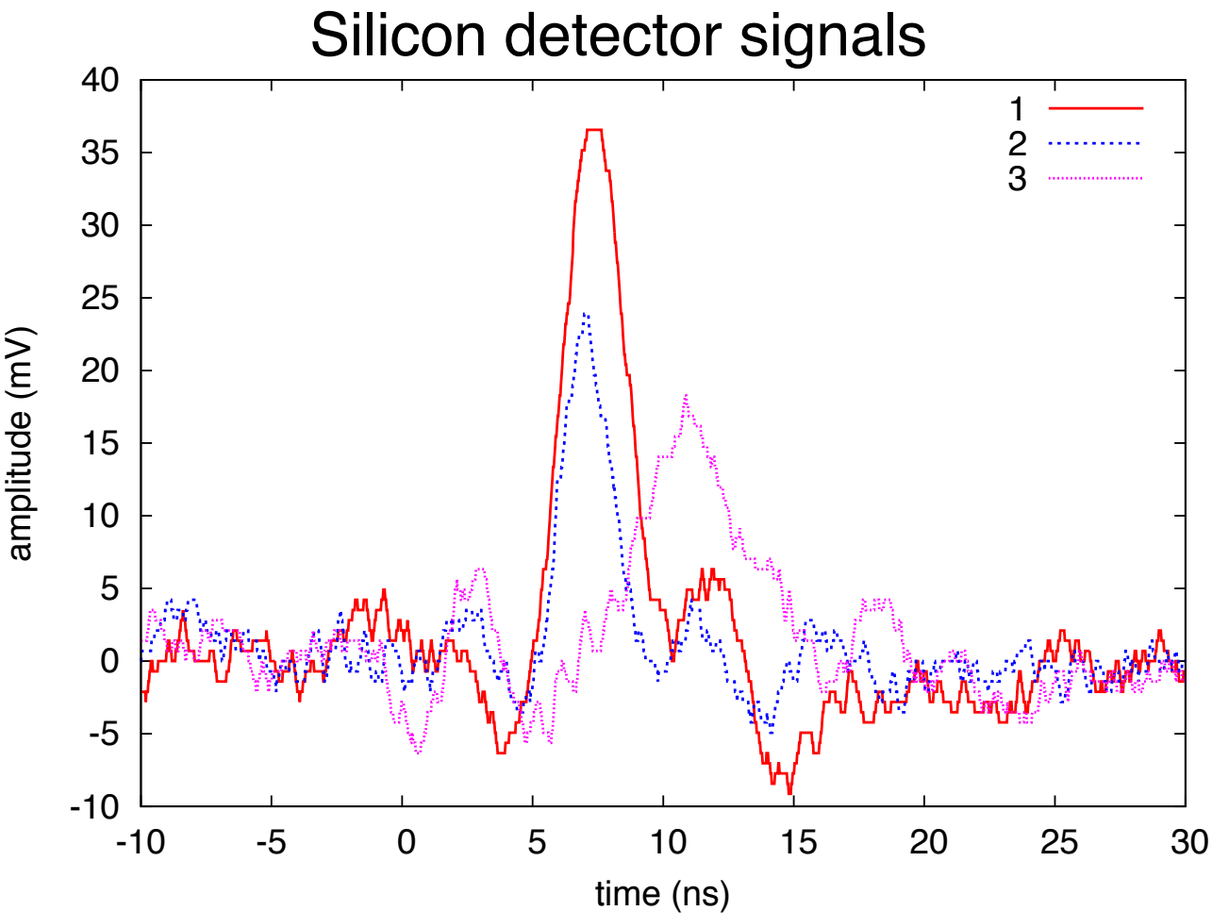

In the process of understanding these features

Summary and outlook

Summary:

- Time-tagging of the X-ray generation is established

- Ultimate time resolution is expected to be << 100 ps

- The device can be used as a very fast UV-PMT

- Depth of interaction studies is only one of the possible usages

Outlook:

- Several things understood and few things to be improved (signal)

- Use a very fast LED driver (several X-rays in few tens ps)

- Start using it as a tool to study detectors