Trace alpha-particle detection system for water networks: from direct detection in liquid phase to element identification

αctiFind

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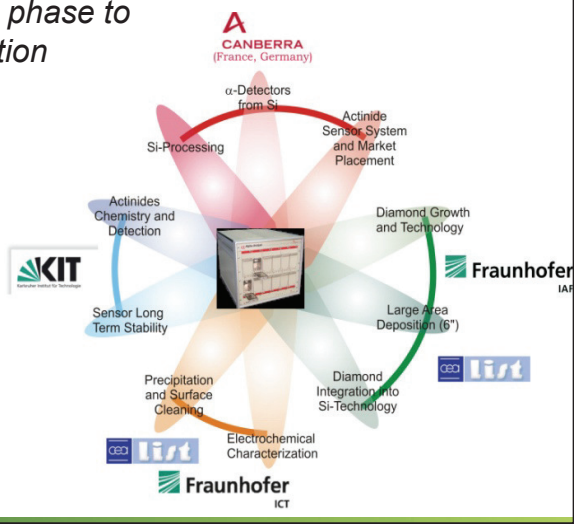
M. Pomorski,
P. Bergonzo



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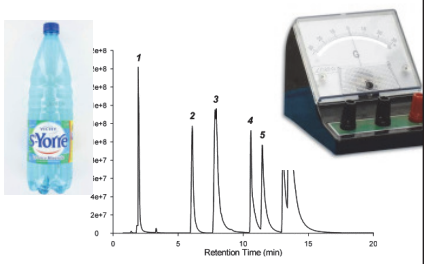
CONTEXT

In emergency situations : how to identify and probe water contamination from alpha emitters?

We want

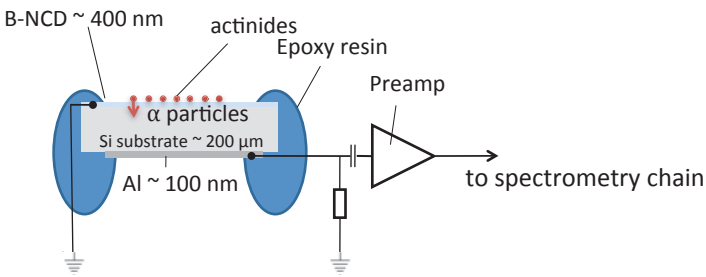
- A reliable and reusable device
- Cleanable
- Enabling spectroscopy at high resolution
- Fast (max a few 10s of minutes)
- Enabling quantification of actinides
- Available for water, but also drinks
- Low energy, a field trial device.

Several actinides are solely alpha emiters



APPROACH

Electrochemistry on top of a silicon detector

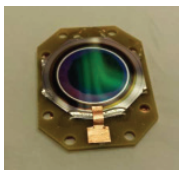


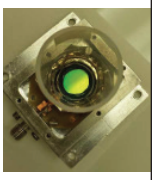
Patented WO 2012045872 (2010)

Devices

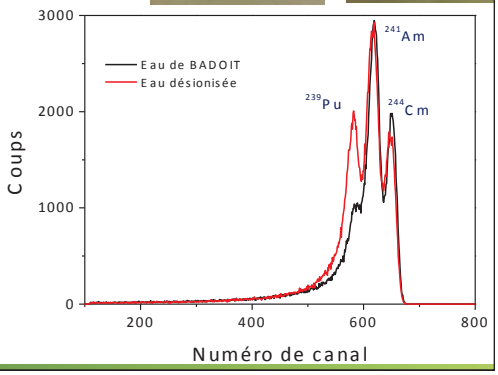
BDD diamond is grown on Si from a Canberra PIPS

- 1/ Preconcentration of actinides
  2/ Counting time.
  → Typ 30Bq/l detected in 10 min





- The detection limits only depends from the acquisition time
- Identification of the traces possible
- Cleaning of the sensor is automatic at the end of the measurement



→ Thank you for your attention…

… Little time to discuss signal issues in polyX…

Probing the transient response of poly-X diamond to improve the stability of diamond devices under pulsed periodic excitation.

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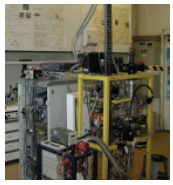
MRS 2007 FALL MEETING
November 26-30
HYNES CONVENTION CENTER
BOSTON, MA

Requirements

- OK SC CVD should be close to ideal,
  (but unfortunately not defect free !)

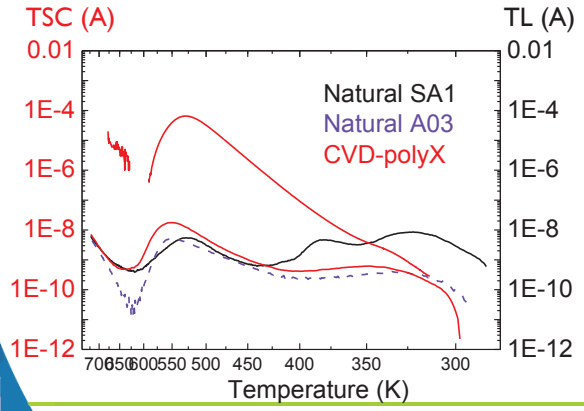
- But … what about
  - large area
  - availability
  - very thin layers
    e.g. for alpha detection or membranes for synchrotrons
  - cost
  - Autonomy for production

→Still a chance for polyX materials ?
→ Essentially very uniform over large areas !



The role of defects

☞ CVD materials, as well as high quality IIa type diamonds inherently exhibit defect levels

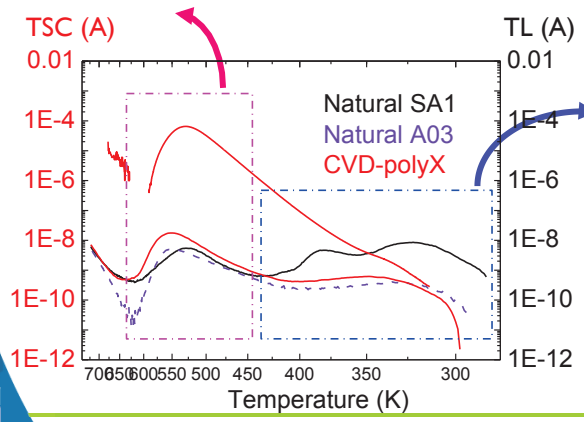


The role of defects

☞ CVD materials, as well as high quality IIa type diamonds inherently exhibit defect levels

- of interest for TL dosimetry
- stable at RT

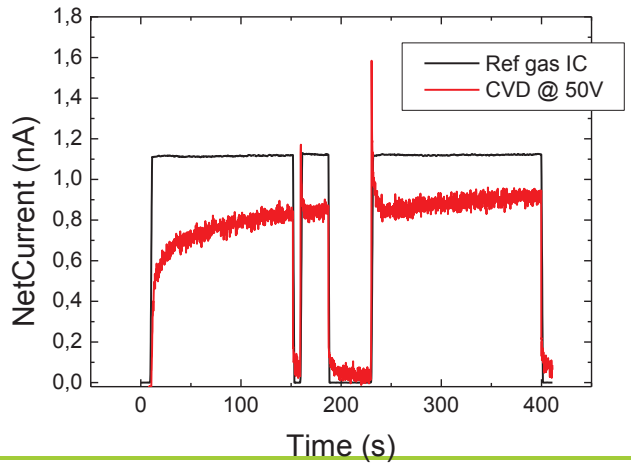
Lot of literature available…
Impurities, Dislocations, Vacancies etc



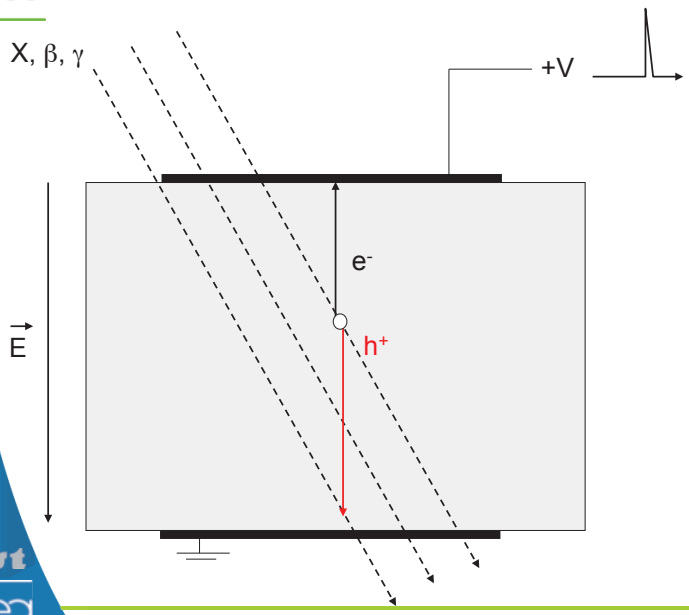
- highly detrimental for IC
- → unstability

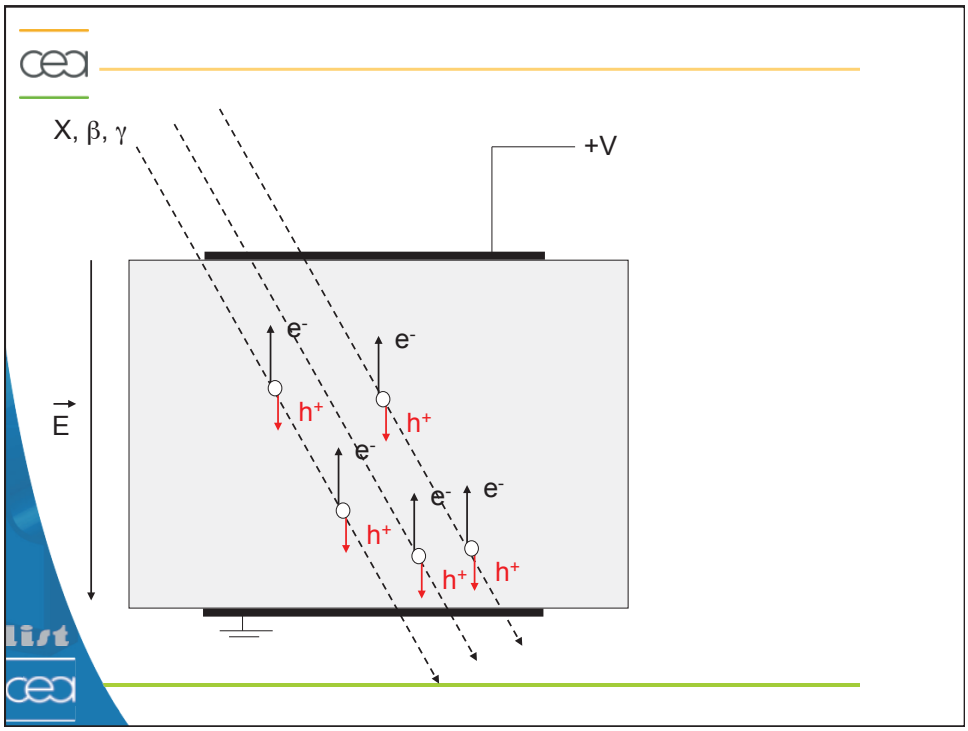
polyX materials characteristics

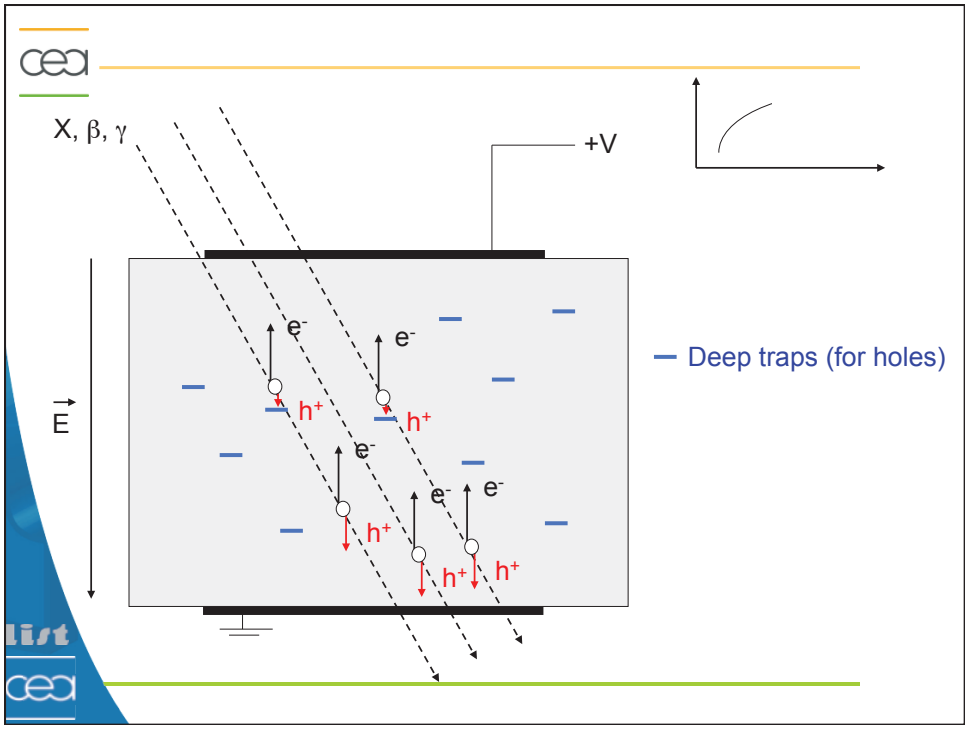
Experiments performed under 6 MeV photon beams (medical accelerator)
Comparing a diamond device to a reference gas ionisation chamber
Typ. dose rate is = 3Gy/min

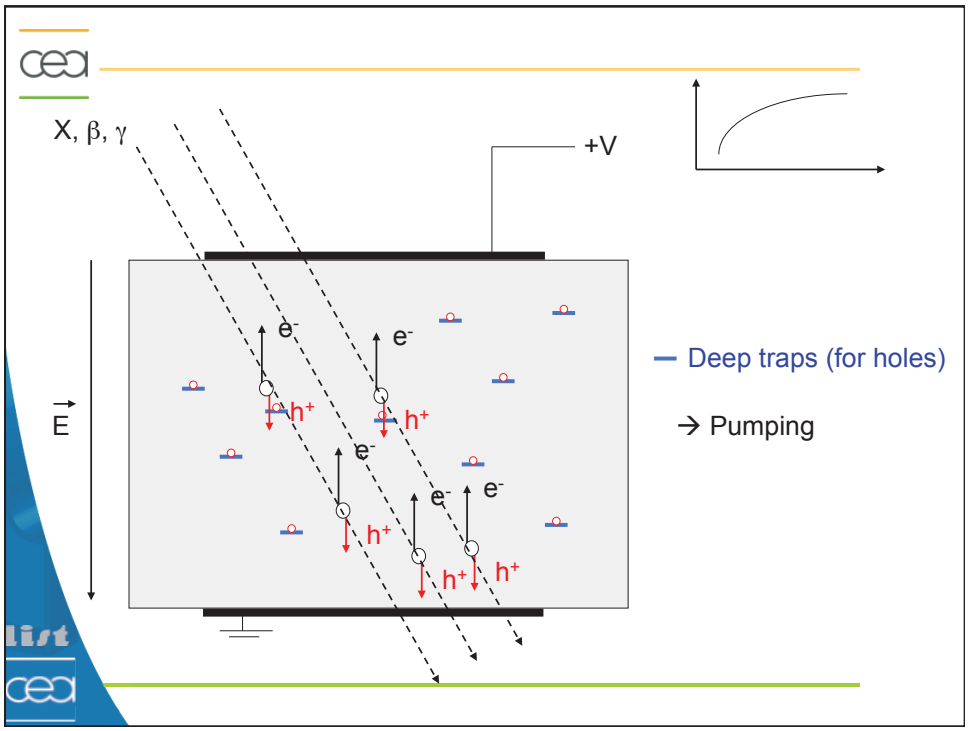


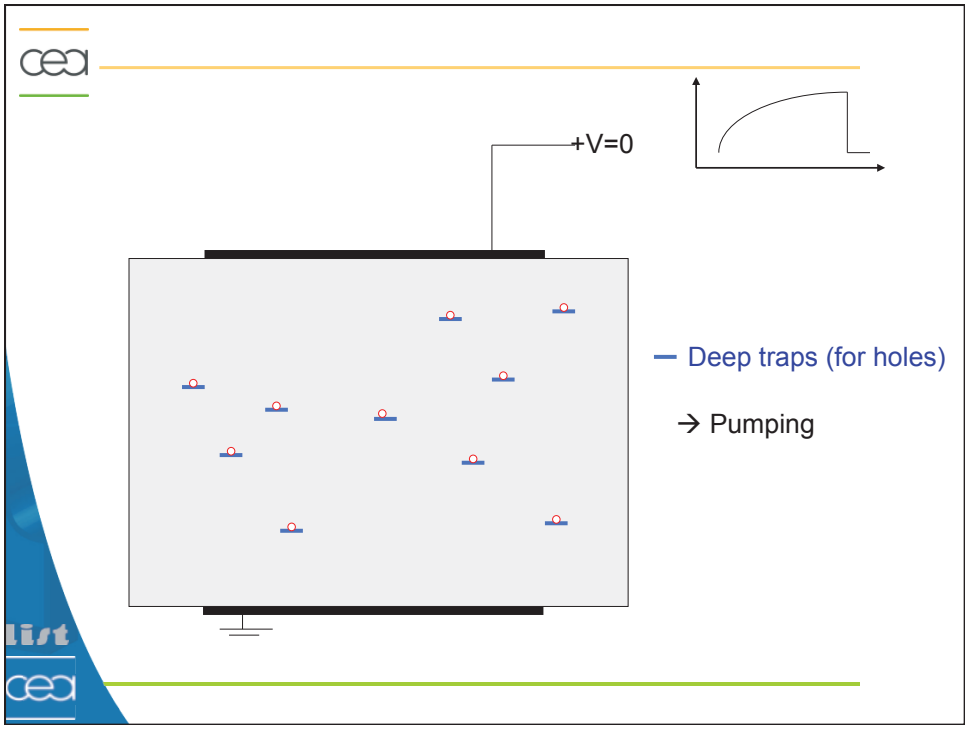
Basics of signal formation

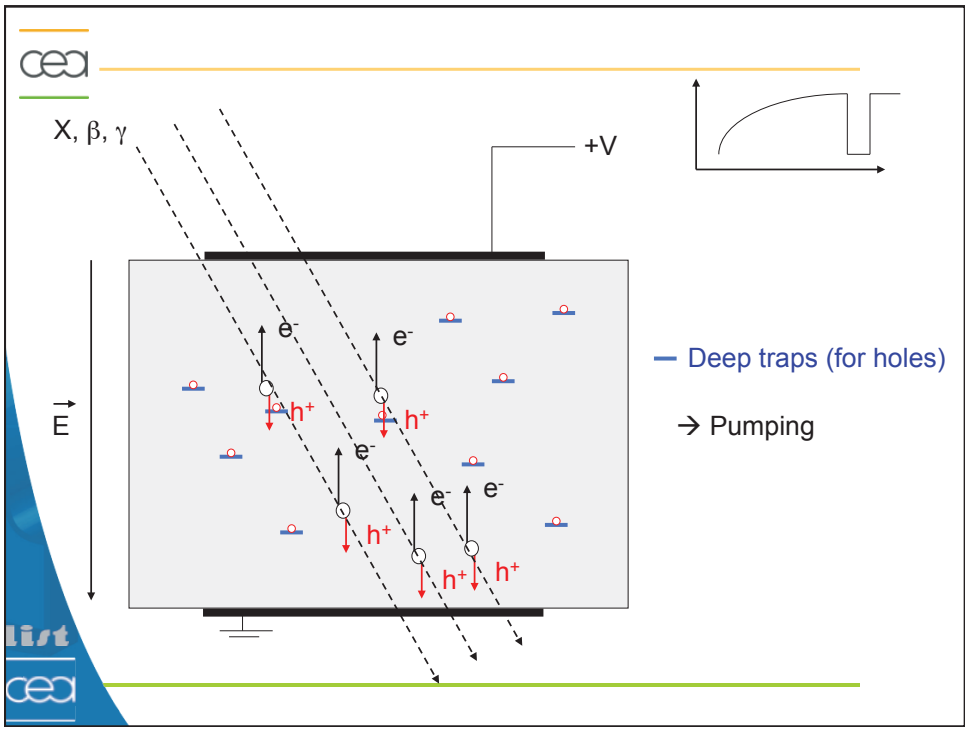


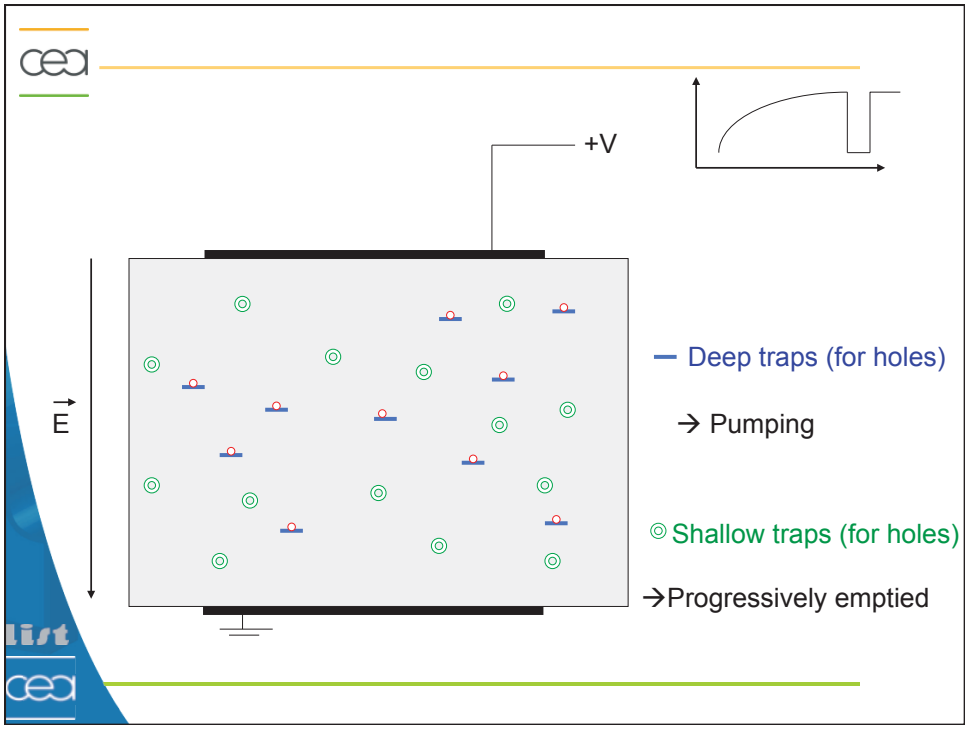

X, β, γ
+V
E
e-
h+

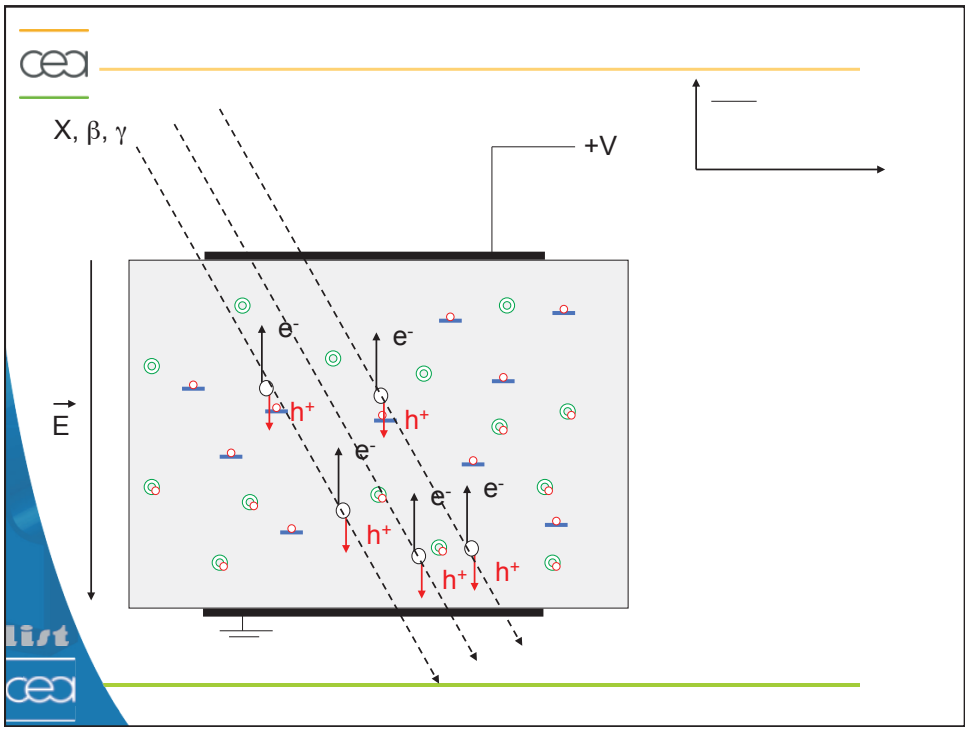

X, β, γ
+V
E
e-
h+
Deep traps (for holes)

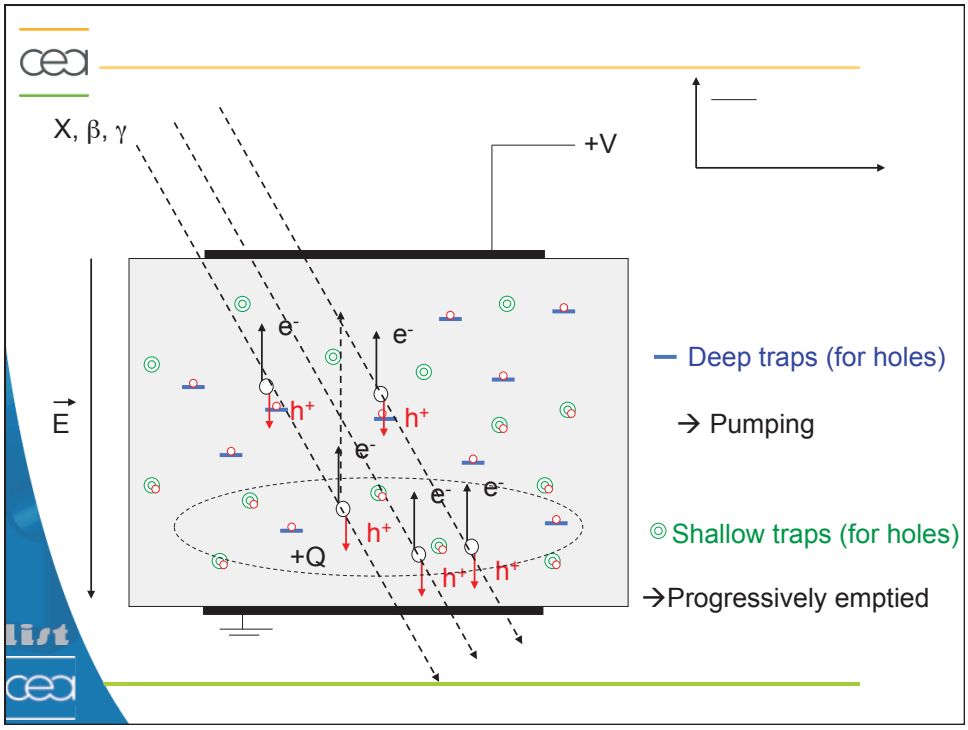

X, β, γ
+V
E
e-
h+
Deep traps (for holes)
→ Pumping

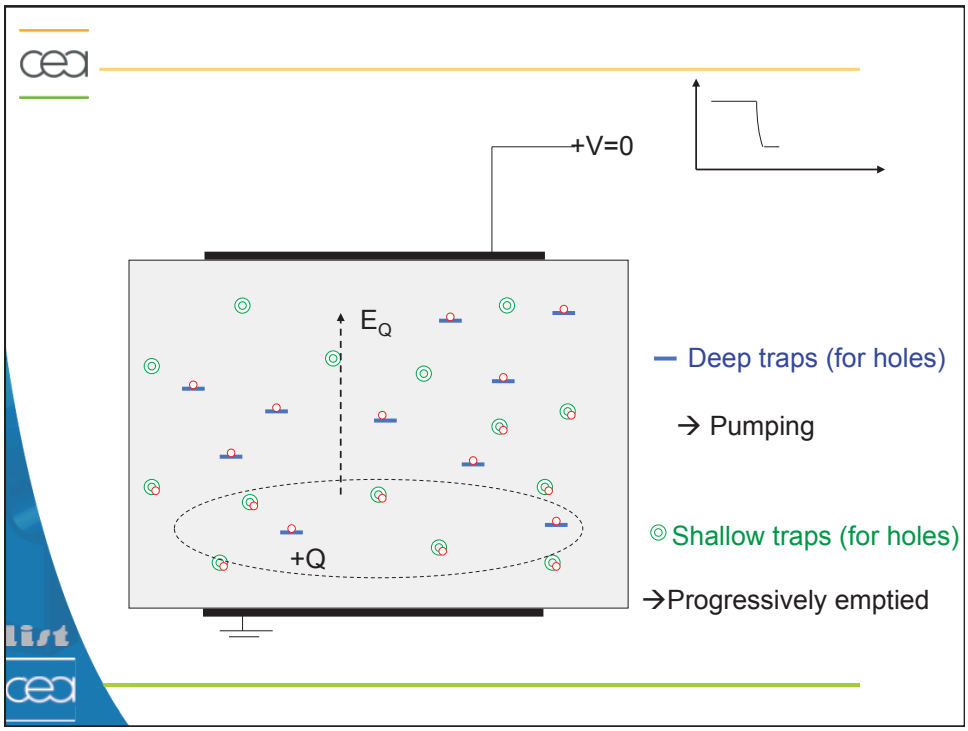

+V=0
Deep traps (for holes)
→ Pumping

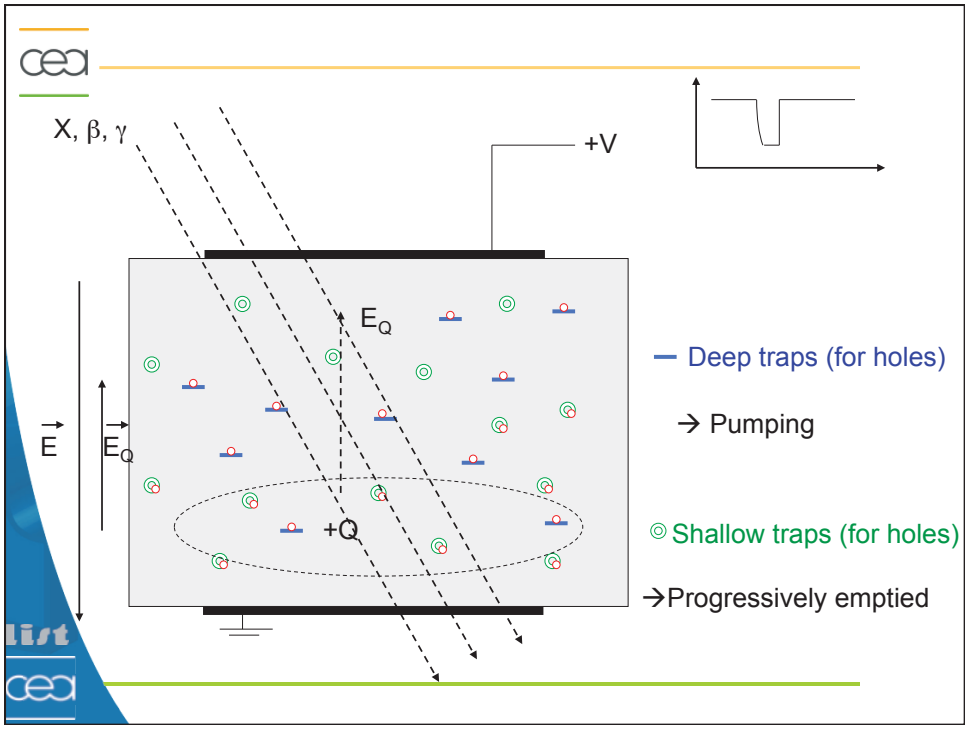

X, β, γ
+V
E
e-
h+
Deep traps (for holes)
→ Pumping

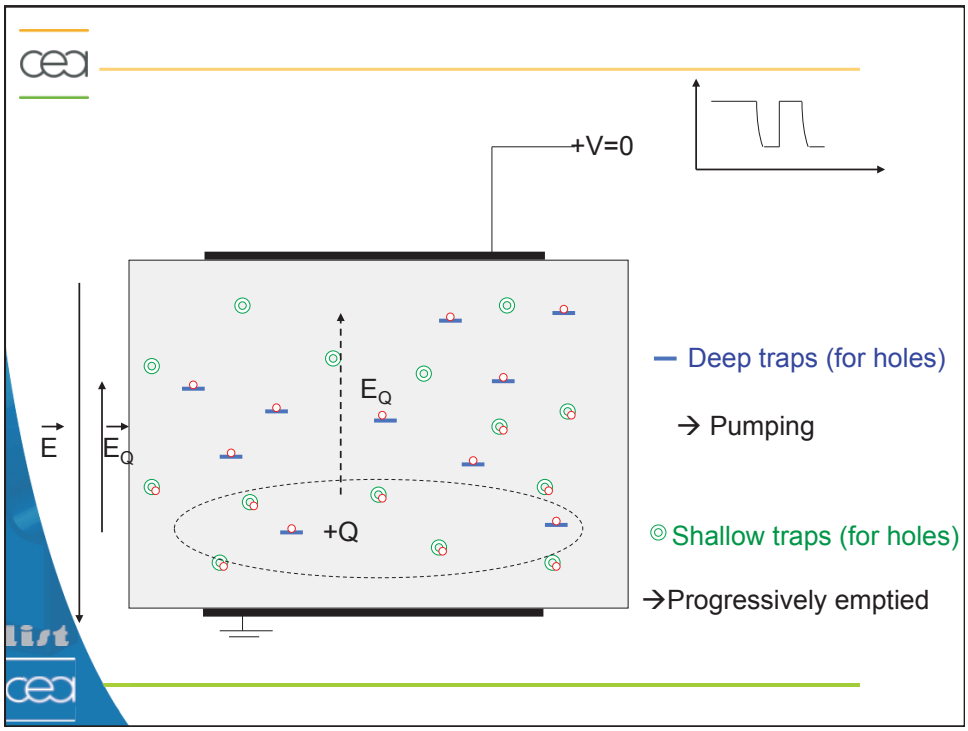

+V
E
Deep traps (for holes)
→ Pumping
Shallow traps (for holes)
→Progressively emptied

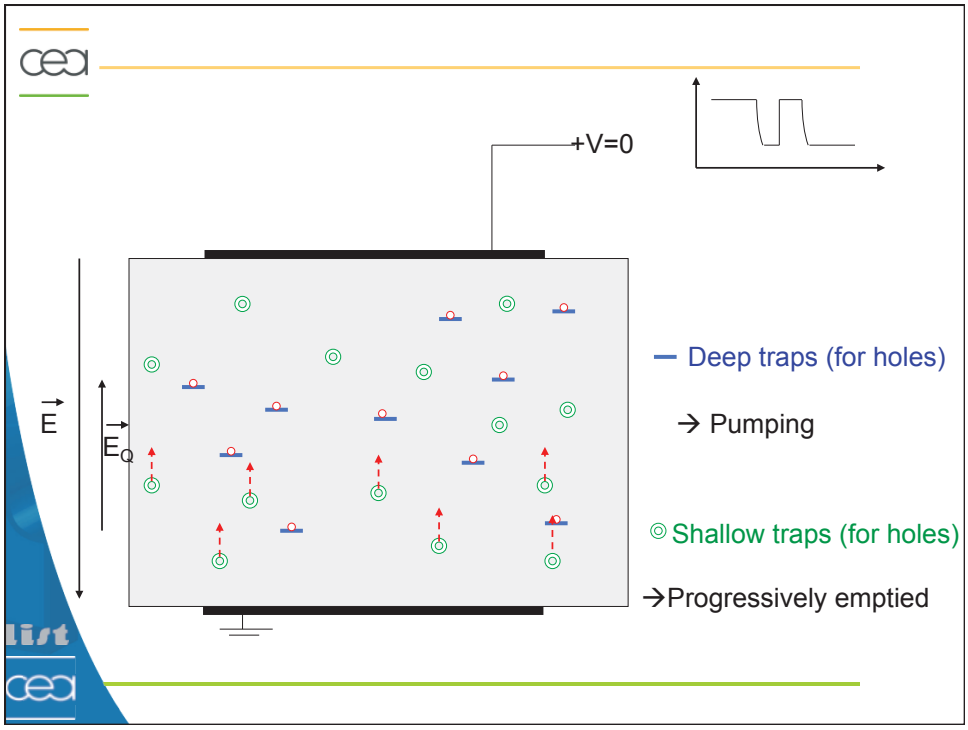

X, β, γ
+V
E
e-
h+

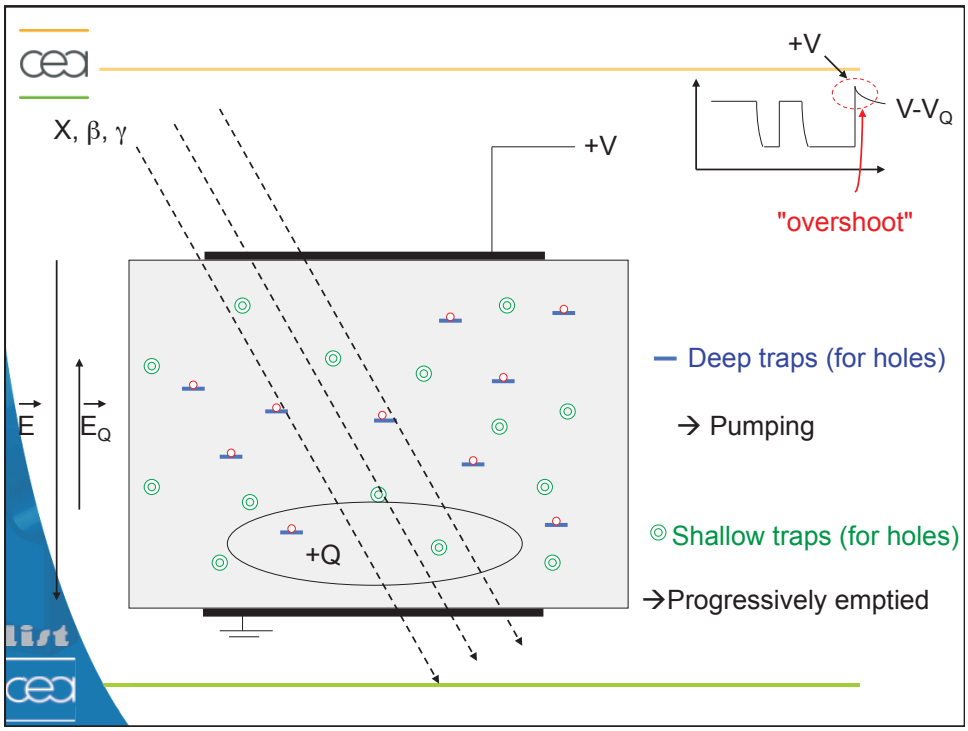

X, β, γ
+V
E
e-
h+
+Q
Deep traps (for holes)
→ Pumping
Shallow traps (for holes)
→Progressively emptied

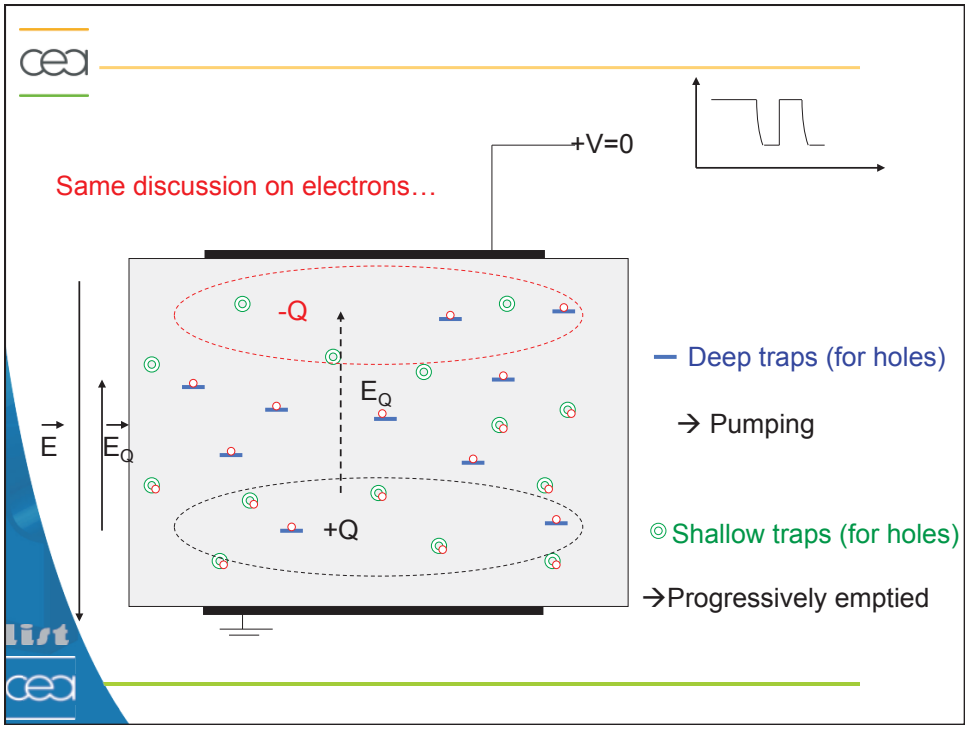

+V=0
E_Q
+Q
— Deep traps (for holes)
→ Pumping
◎ Shallow traps (for holes)
→Progressively emptied


X, β, γ
+V
E_Q
$\vec{E}$
$\vec{E_Q}$
+Q
— Deep traps (for holes)
→ Pumping
◎ Shallow traps (for holes)
→Progressively emptied


+V=0
E
E_Q
E_Q
+Q
— Deep traps (for holes)
→ Pumping
◎ Shallow traps (for holes)
→Progressively emptied


+V=0
E
E_Q
— Deep traps (for holes)
→ Pumping
◎ Shallow traps (for holes)
→Progressively emptied


+V
V-V_Q
"overshoot"
X, β, γ
+V
E
E_Q
+Q
— Deep traps (for holes)
→ Pumping
◎ Shallow traps (for holes)
→Progressively emptied


+V=0
Same discussion on electrons…
-Q
E_Q
E
E_Q
+Q
— Deep traps (for holes)
→ Pumping
◎ Shallow traps (for holes)
→Progressively emptied

It comes :

- The ON state is related to an equilibrium between carrier trapping and de-trapping :

- Sensitivity is strongly affected by transiting charges
  → Thus to fluency !

- Equilibrium also varies with dose levels
  → Non linearities !

- Stability is strongly varying with the device temperature :

  → This is one way to improve the signal stability : work at temperatures at which shallow levels are emptied.
  → OK but not always applicable

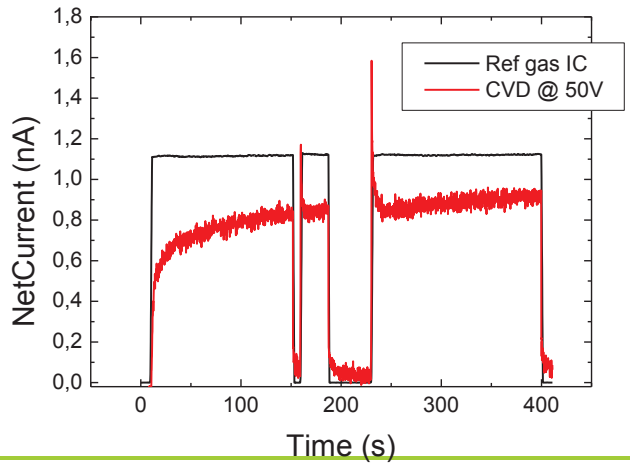
Illustrative case

Probing the response under a medical accelerator :

- 6 MeV photon beam
- Polycrystalline diamond (very defective !)
- Dose rate is 3Gy/min

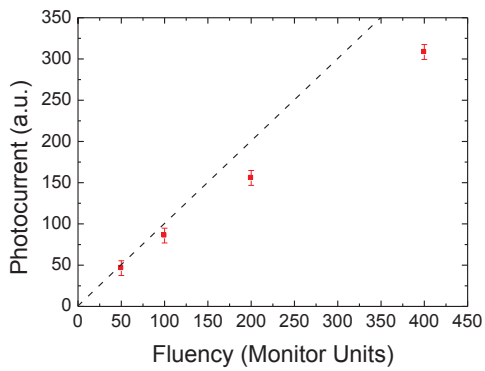
Explaining the poor device characteristics ?

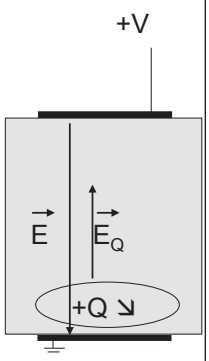
Experiments performed under 6 MeV photon beams.
Comparing a diamond device to a reference gas ionisation chamber
Typ. dose rate is = 3Gy/min



And sub-linearities ?

E_Q is only created by the carriers transiting through the device
→ Therefore the greater the signal the greater E_Q

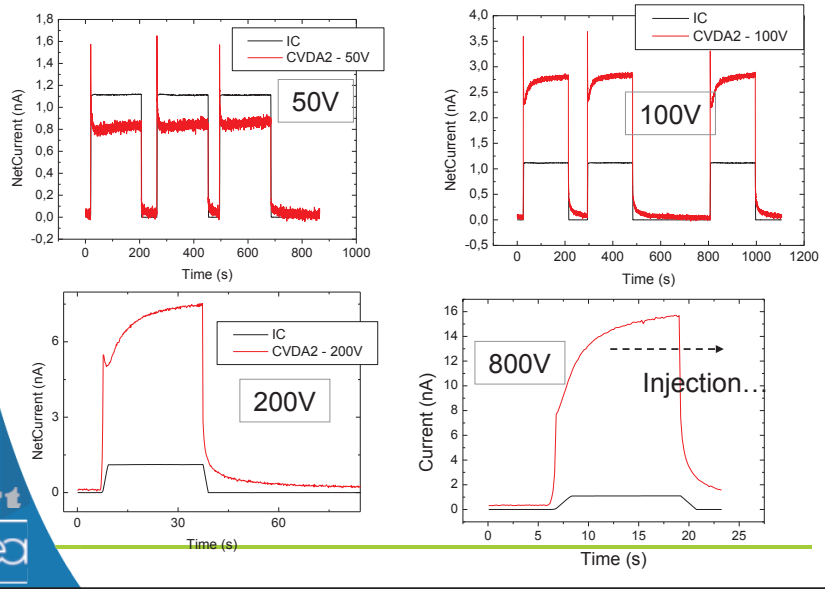


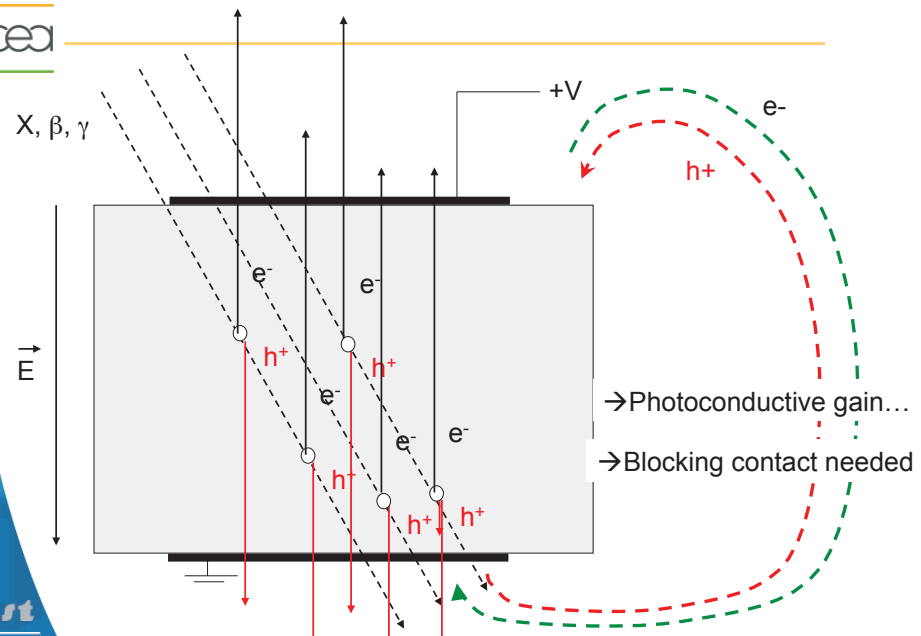


→The lower the fluency, the lower the signal :
→ the lower the trapped charge,
→ higher signals after stabilisation (E_Q vanishes)

Effect of the E field

At low E fields, the overshoot is predominant, and vanishes at high E fields

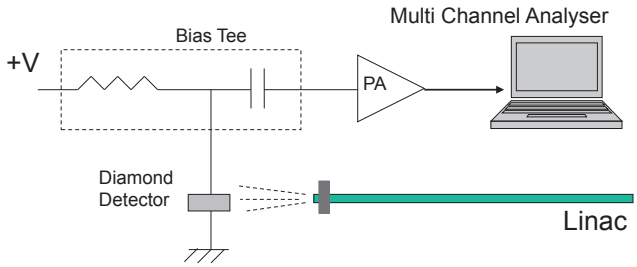




See A. Rose, Concepts in Photoconductivity (1963)

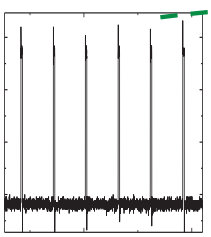
Response to a pulsed excitation

Tests on the SAPHIR accelerator (Saclay)
Pulsed X-rays, 17MV accelerator
Pulses are 2µs long, at 25 Hz

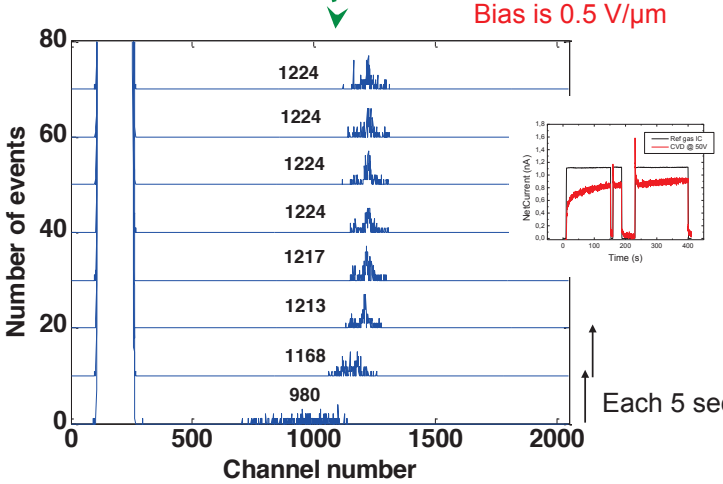


Pulsed height spectra under DC bias

(= Histograms of the voltage pulses)



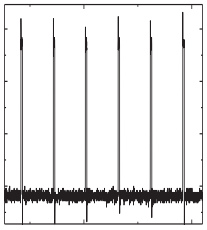
Bias is 0.5 V/µm

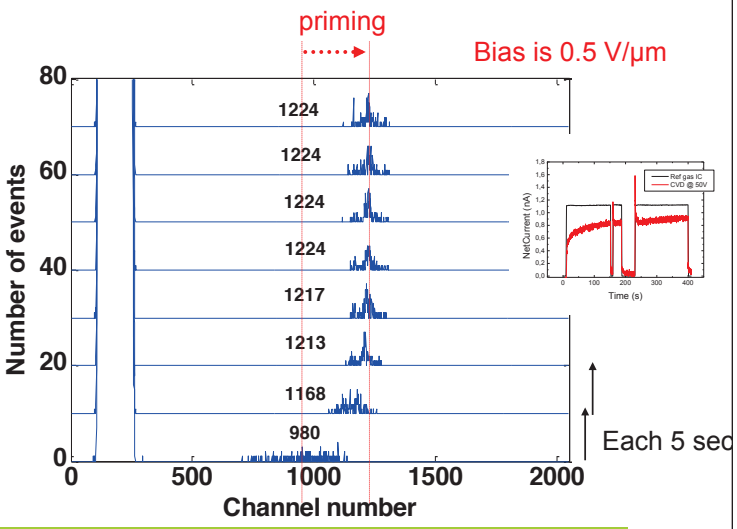


Each 5 sec

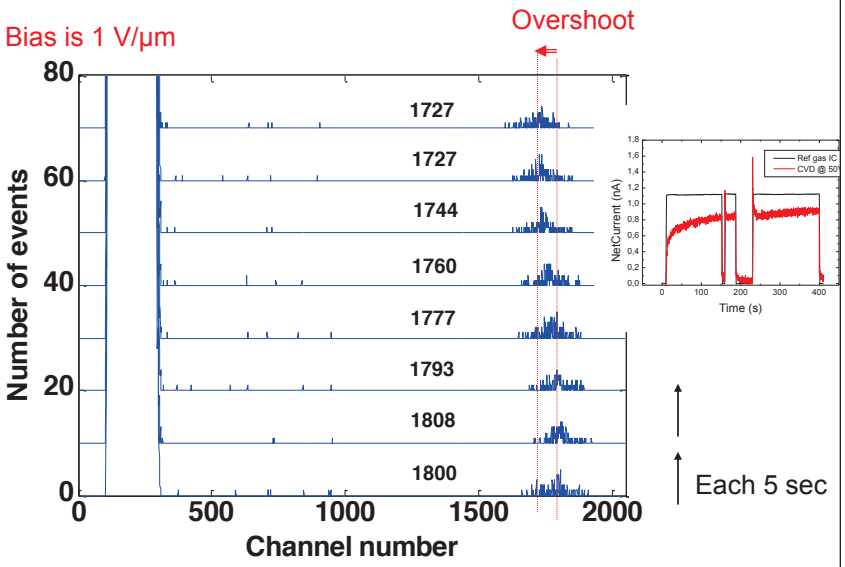
Pulsed height spectra under DC bias

(= Histograms of the voltage pulses)



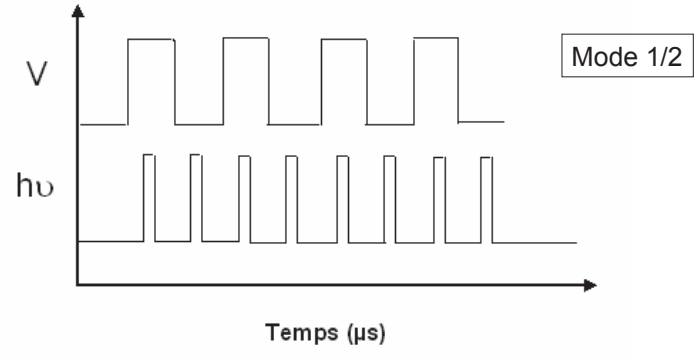


Pulsed height spectra under DC bias

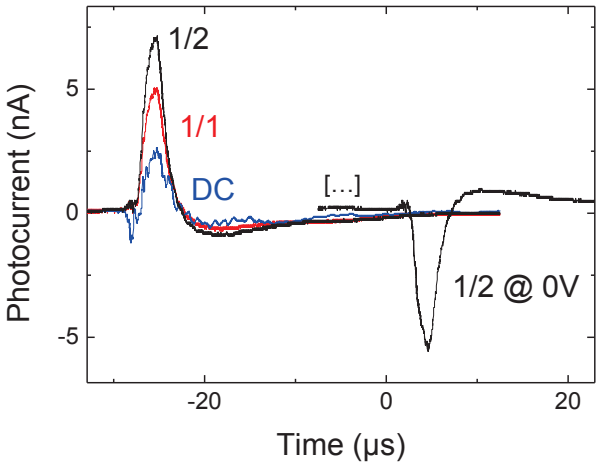


Emptying defects at 0V bias

Pulsing the bias → Using one "lost" pulse to further empty traps



Emptying defects at 0V bias



It comes :

→ Unstable effects are *very* commonly observed in polyX devices

→ The most determinant influence of shallow defect levels (typ 0.3 to 0.6 eV : the ones emptied close to RT)

→ They affect all materials ! (from 1E8 to 1E13 defects/cm$^{3)}$

→ Solutions proposed :

- Heat the device (Patent WO2006024661)
- Use light to detrap shallow carriers between events
- 0V-bias the device and irradiate between two events (most convincing) (Patent FR243507 D25440 AV)

→ Thank you for your attention…

(I stop now…)