ADAMAS meeting

Diamond transmission detector for external microbeams

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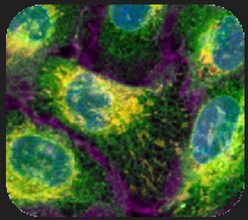
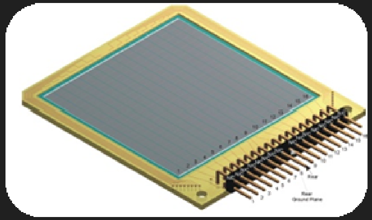
4. JAEA, Takasaki

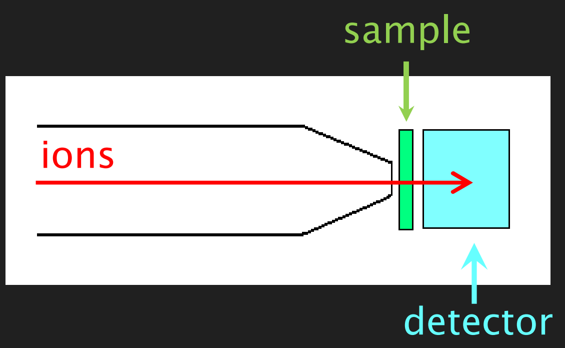
Introduction

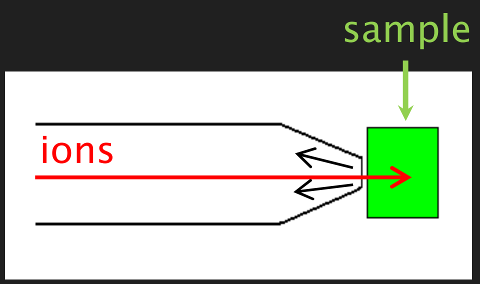
- in some microprobe applications the sample can't be mounted inside the vacuum chamber
  - properties of the sample could change (cell irradiation)
  - size of the sample (large nuclear physics detectors)





- requirements for the external (micro)beam:
  - exit vacuum window
  - additionally: **efficient hit detection system and/or fast trigger**





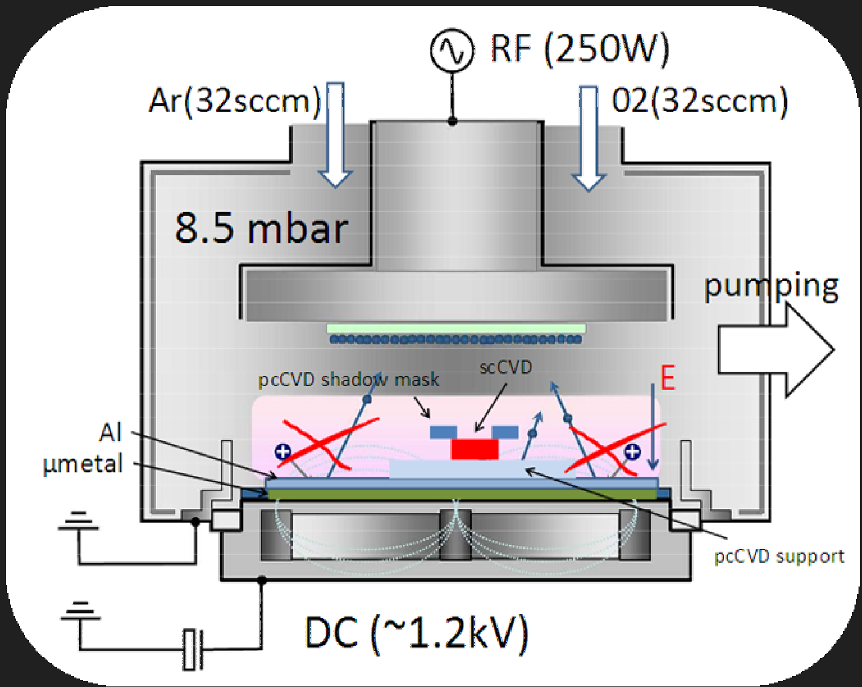
- secondary electrons
- hit detection efficiency???

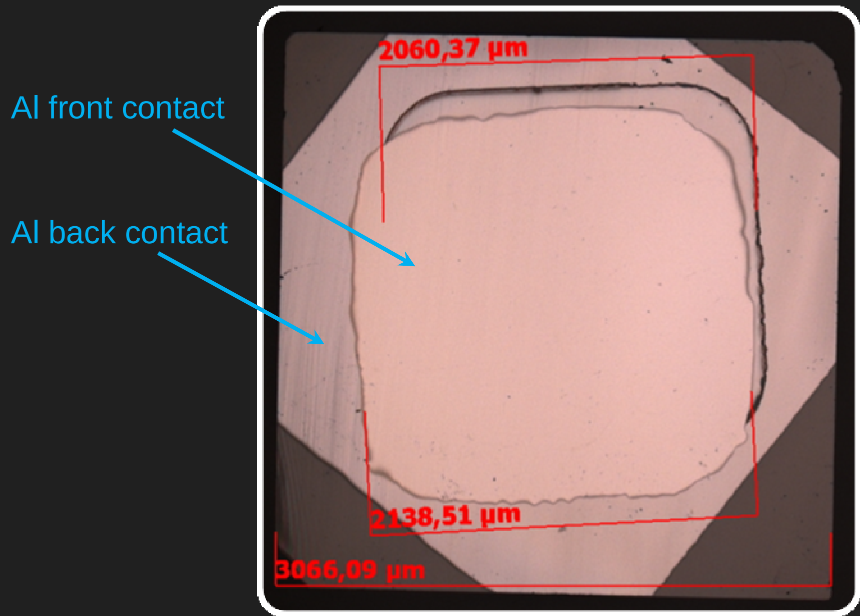
- solution: thin diamond membrane → transmission detector and vacuum window

Detector production

1. start: 300μm thick 3×3 mm² optical grade scCVD diamond crystal (purchased from E6)
2. laser cutting to get approximately 30μm thick plates (Deleware Diamond Knives, Inc)
3. etching 2×2 mm² area in Ar-O_2 plasma
4. metallization with Al

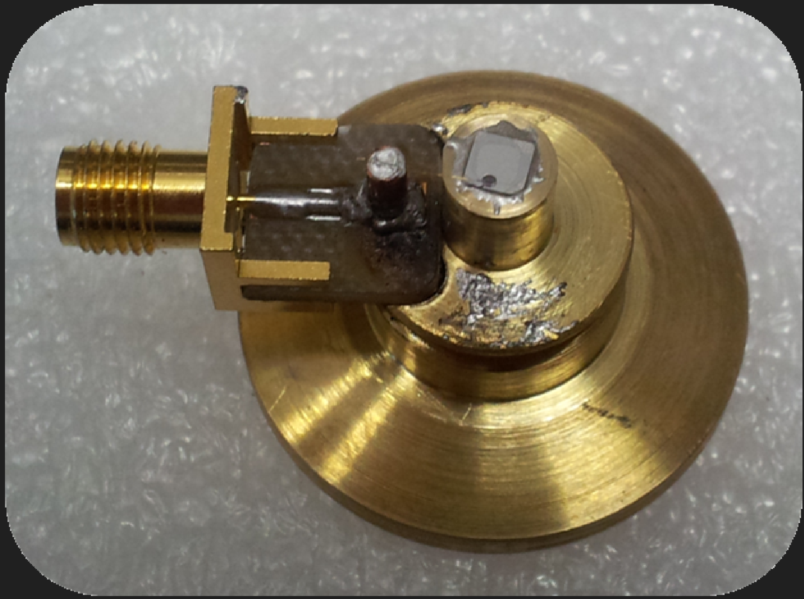
(3–4) done at CEA, Saclay





Detector production

5. mounting the membrane on the brass stage
   - back electrode is grounded over the stage through the conductive epoxy
   - front electrode is connected to the PCB which is soldered on the stage



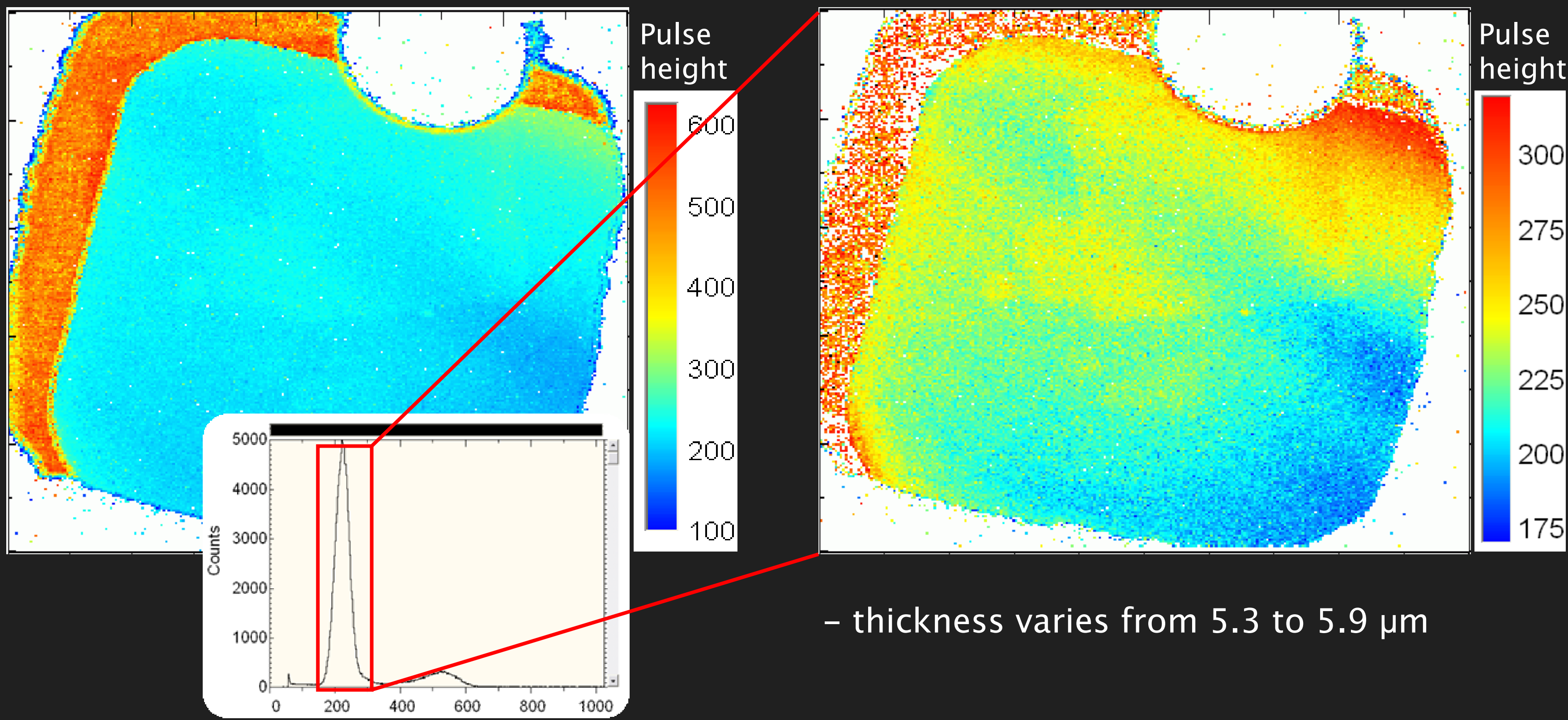
Detector performances

a) Membrane thickness

- the detector is connected to the electronic chain
  (charge sensitive preamplifier → shaping amplifier → ADC MCA → SPECTOR)

- IBIC imaging with 1.3 MeV protons (energy loss in membrane ≈ 430 keV)

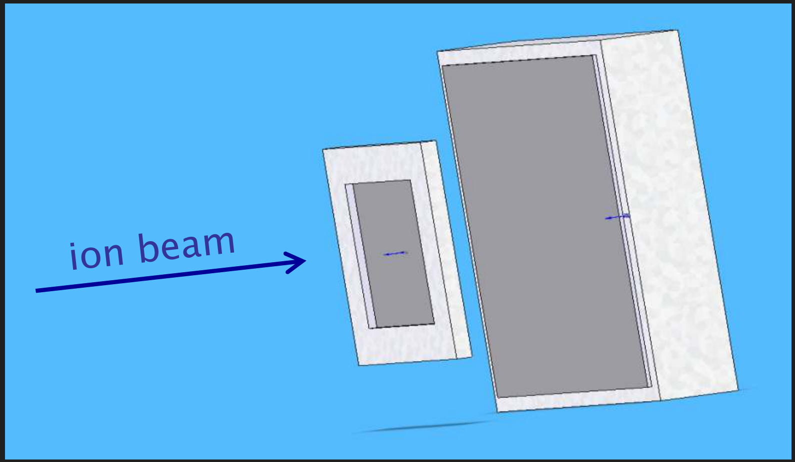
finer scale



- thickness varies from 5.3 to 5.9 μm

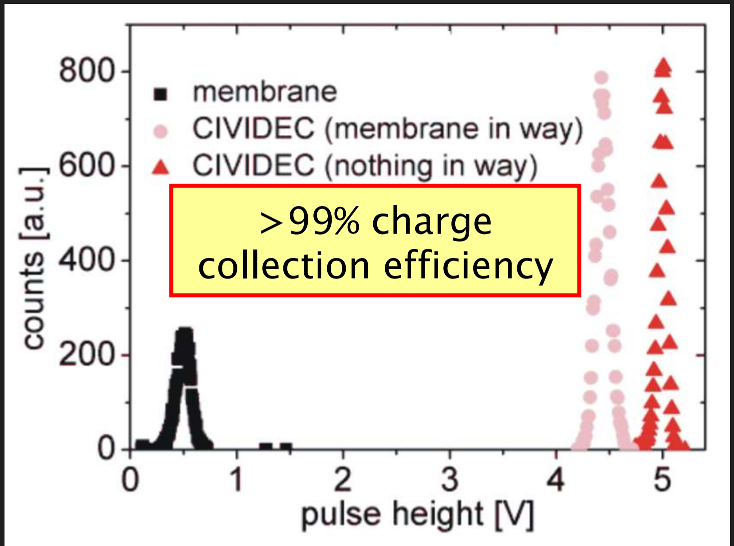
Detector performances

b) Charge collection efficiency

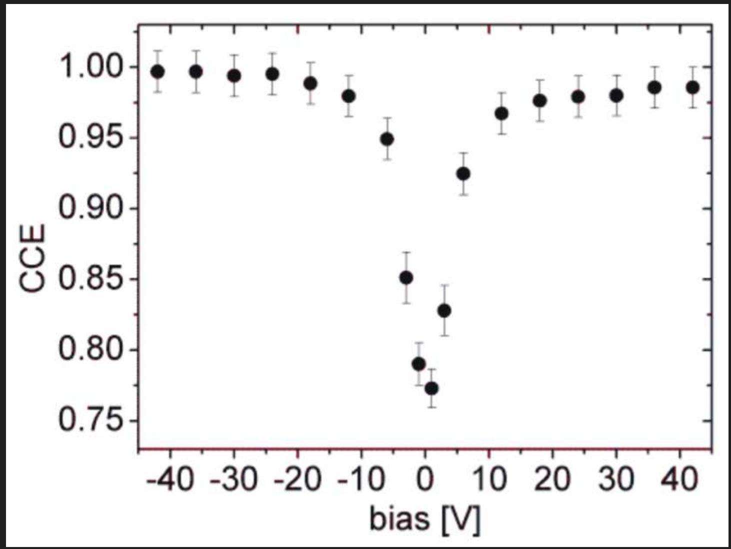


In coincidence:

- diamond membrane
- commercial diamond detector (300µm CIVIDEC)

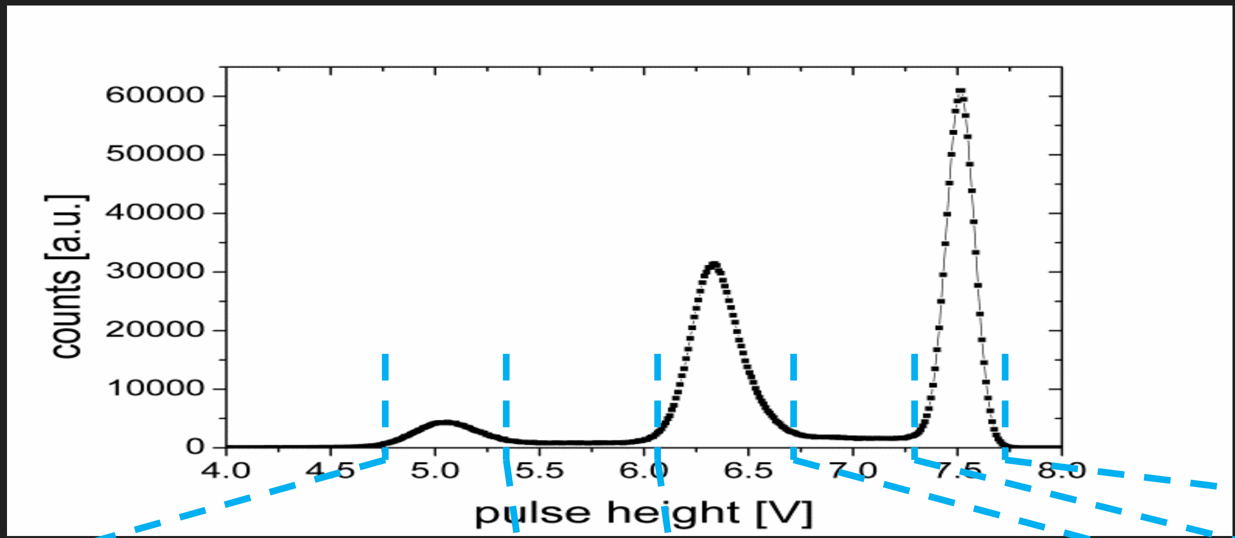


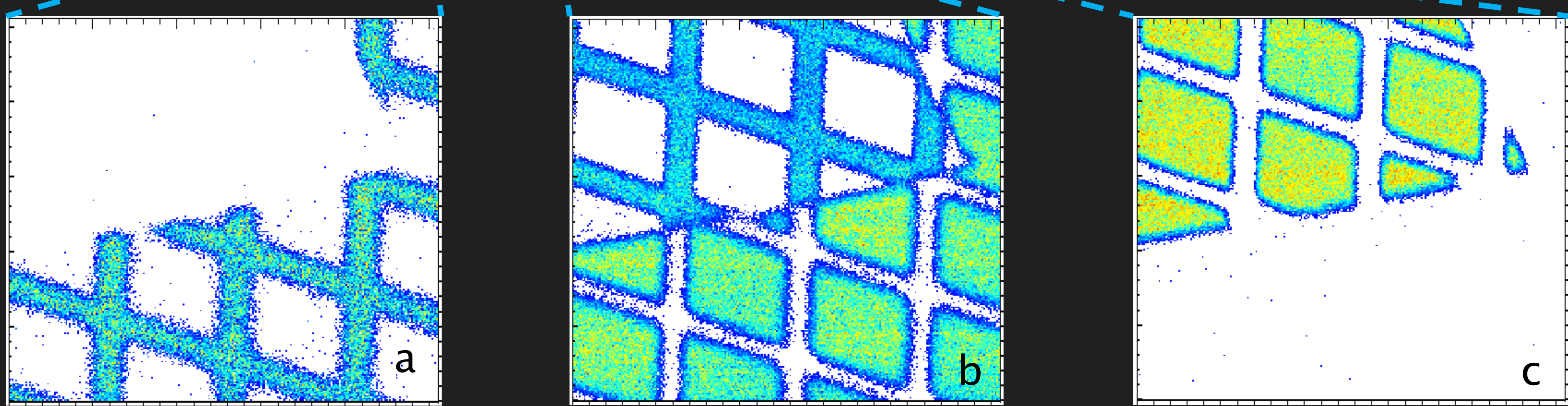
CCE vs. bias:

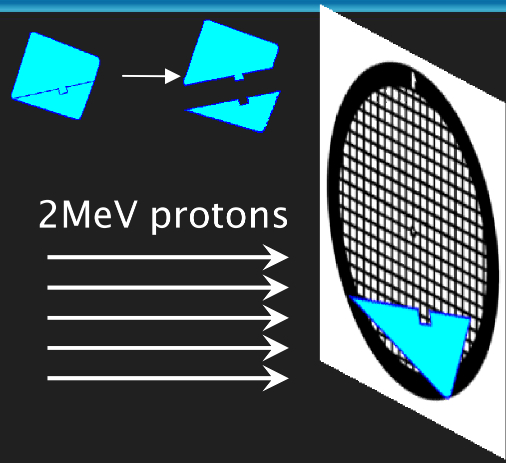


Detector performances

c) Beam broadening



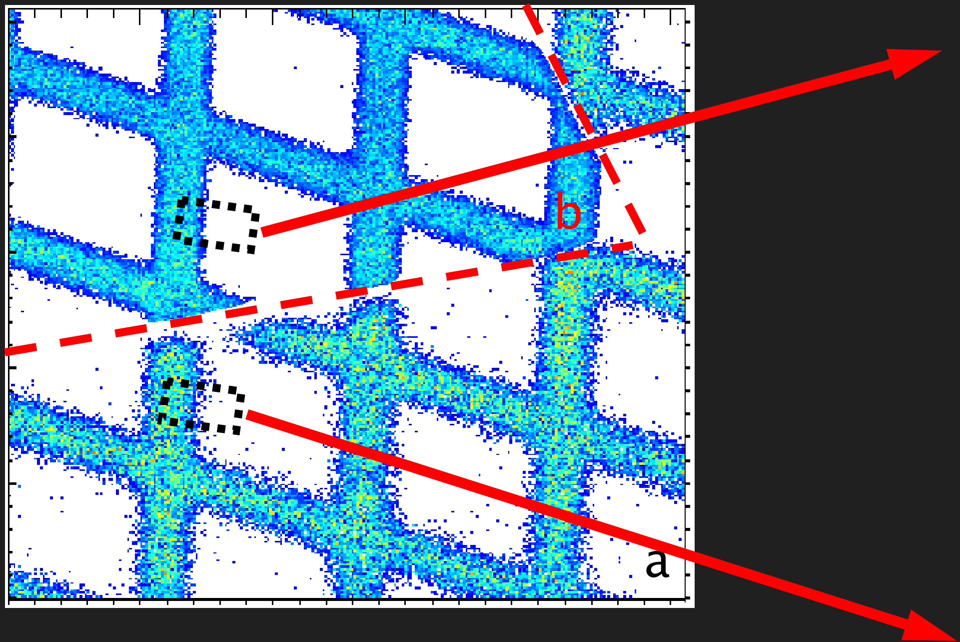


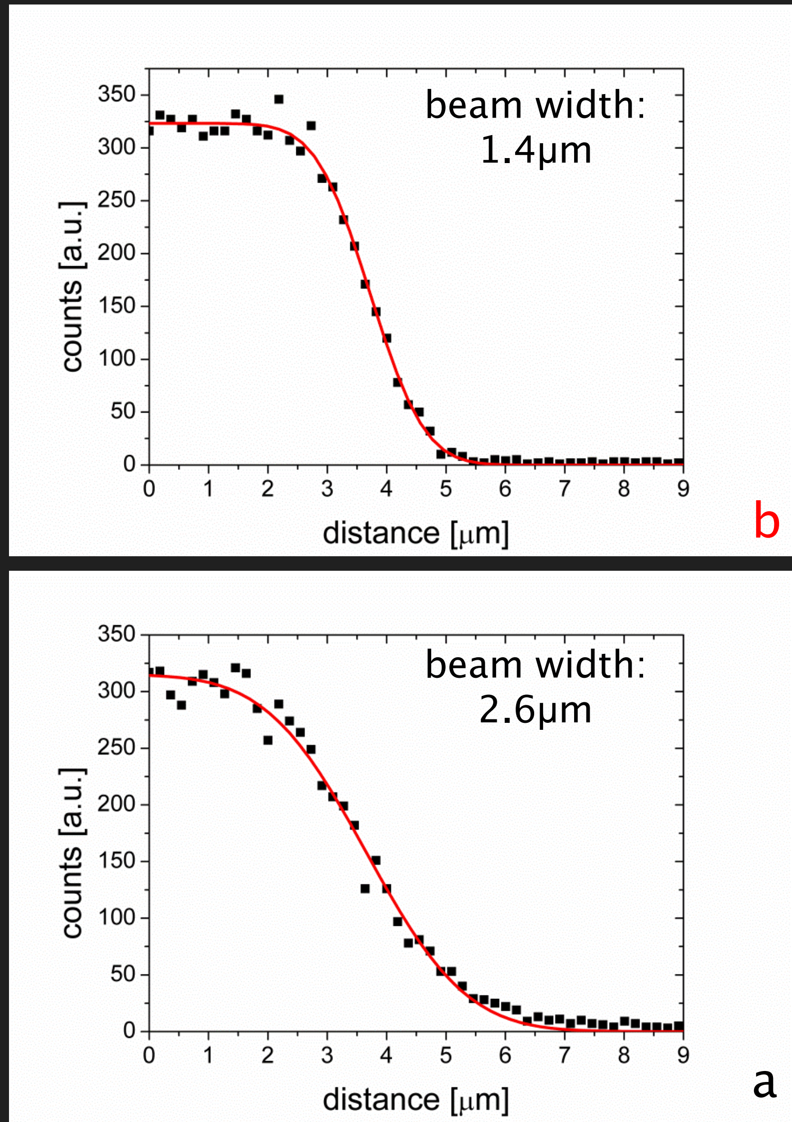


- Distance between the mesh and the membrane is around 150 µm

Detector performances

c) Beam broadening

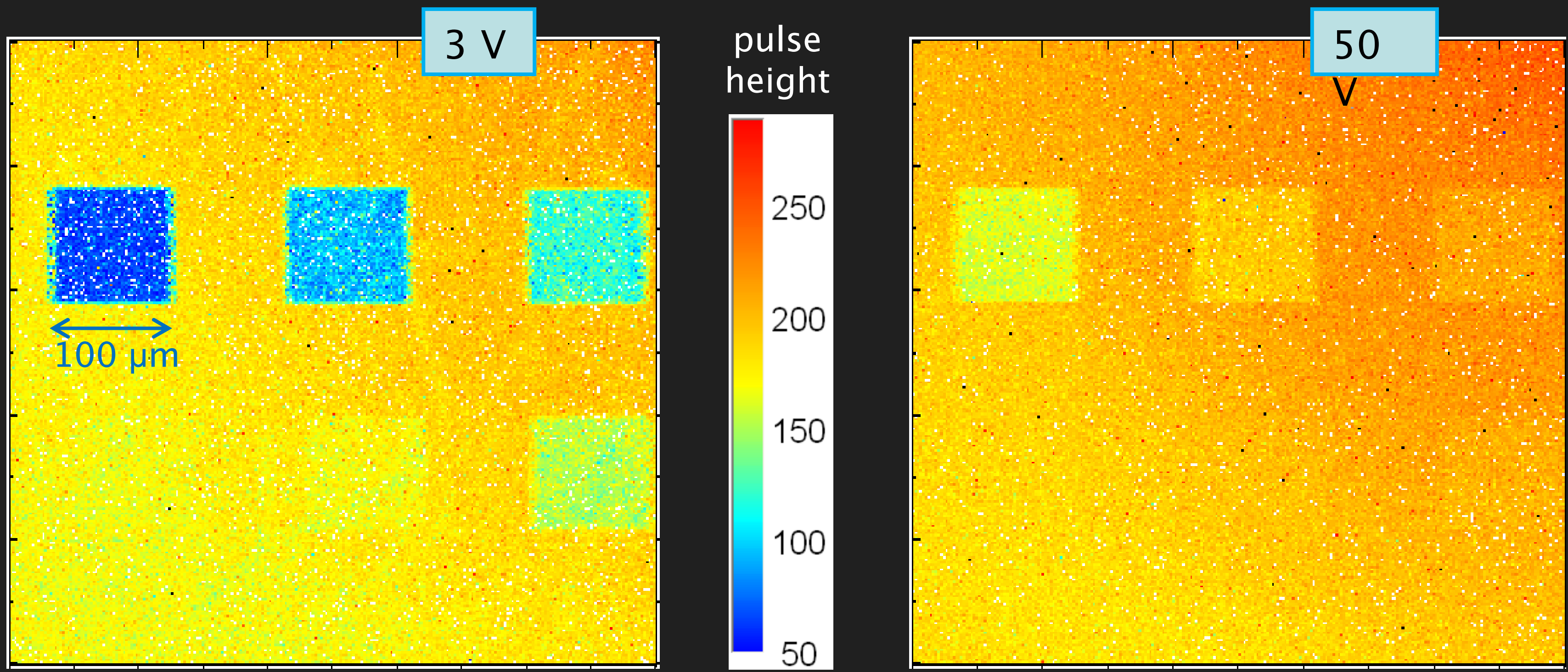




Detector performances

d) Radiation hardness

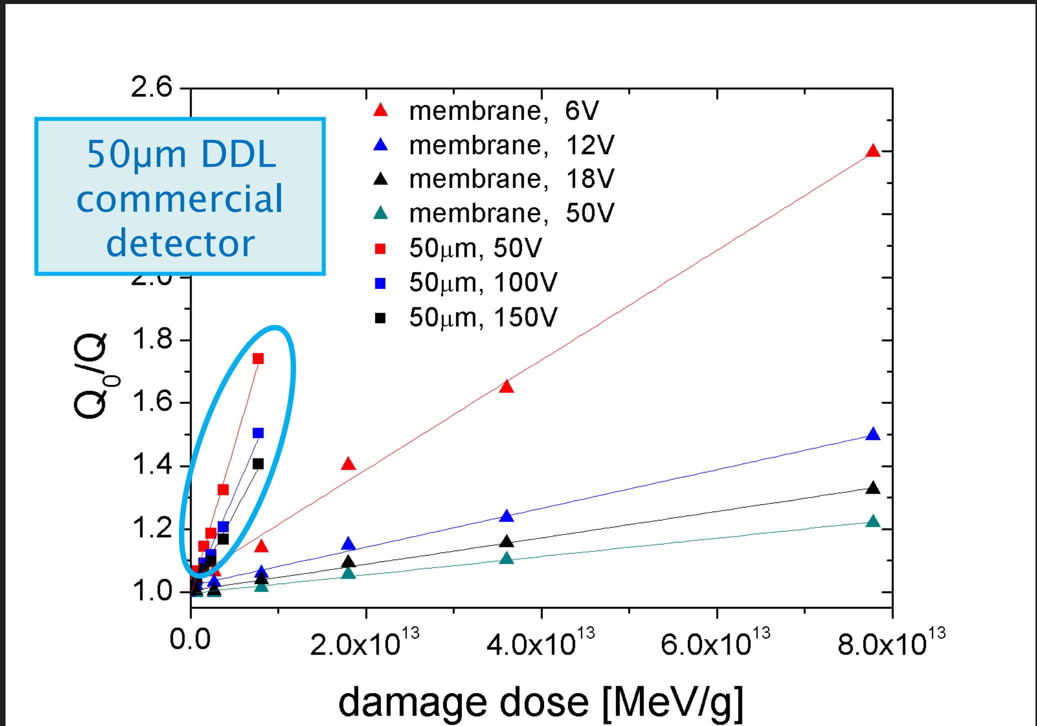
- 6 areas (100×100μm²) were irradiated on the microprobe line with different fluences
- ion beam: 1.3 MeV protons
- fluence range: from 6.8×10^{12} up to 8.7×10^{14} ion/cm²
- IBIC analysis also done with 1.3 MeV protons



Detector performances

d) Radiation hardness

- 1/CCE vs. fluence:
- simple modelling: $Q_0/Q=1+K_d*\Phi_d$



* damage dose = fluence × NIEL

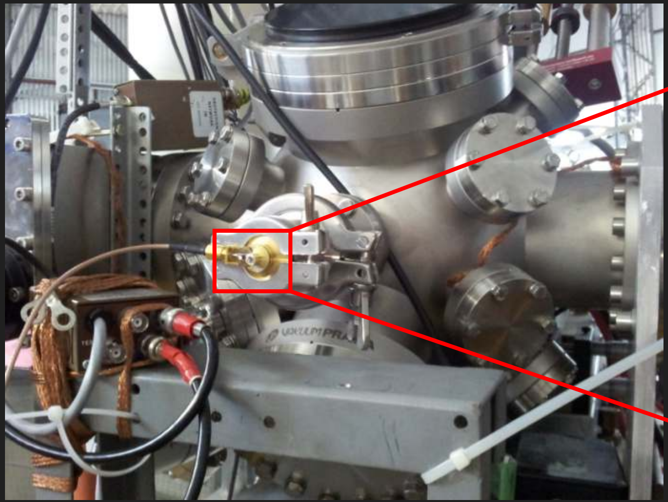
- strong bias dependance

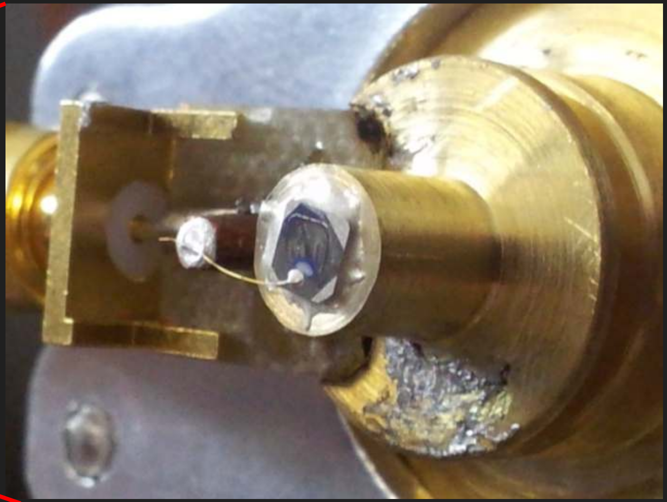
- increased radiation hardness is expected because of a very short collection distance

- no polarization at bias > 1 V

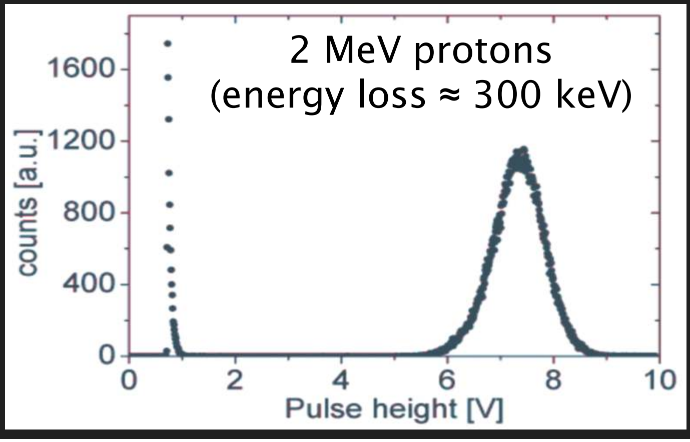
Detector performances

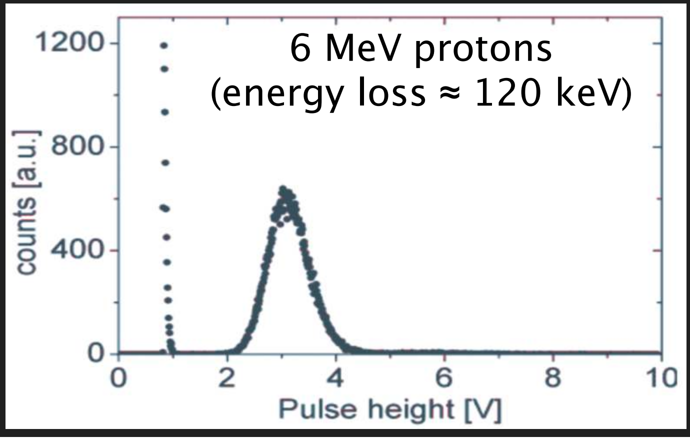
e) Vacuum window/tranmission detector





➢ Response to different proton beams (bias 42V, CoolFET):





References

APPLIED PHYSICS LETTERS **103**, 112106 (2013)

Super-thin single crystal diamond membrane radiation detectors

Michal Pomorski, Benoit Caylar, and Philippe Bergonzo
CEA-LIST, Diamond Sensors Laboratory, Gif-sur-Yvette F-91191, France

(Received 19 July 2013; accepted 28 August 2013; published online 12 September 2013)

We propose to use the non-electronic grade (nitrogen content 5 ppb < [N] < 5 ppm) single crystal (sc) chemical vapour deposited (CVD) diamond as a thin-membrane radiation detector. Using deep Ar/O_2 plasma etching it is possible to produce self-supported few micrometres thick scCVD membranes of a size approaching 7 mm × 7 mm, with a very good surface quality. After metallization and contacting, electrical properties of diamond membrane detectors were probed with 5.486 MeV α-particles as an ionization source. Despite nitrogen impurity, scCVD membrane detectors exhibit stable operation, charge collection efficiency close to 100%, with homogenous response, and extraordinary dielectric strength up to 30 V/μm. © *2013 AIP Publishing LLC.* [http://dx.doi.org/10.1063/1.4821035]

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An ultra-thin diamond membrane as a transmission particle detector and vacuum window for external microbeams

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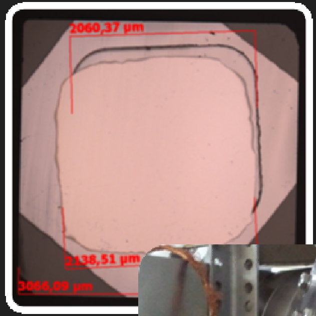
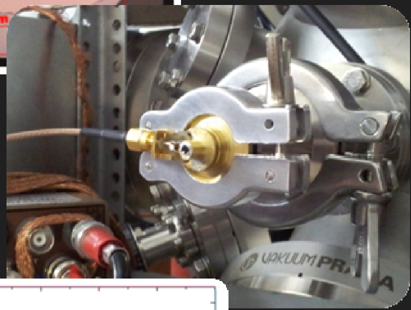
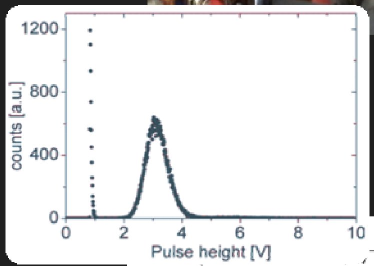
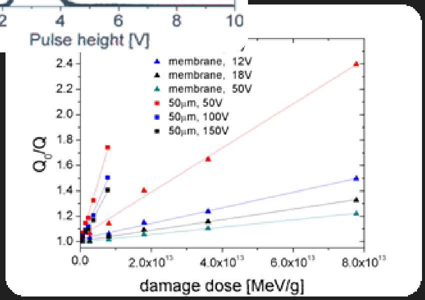
Conclusions









- 6 μm thick diamond membrane was produced at CEA Saclay
- the membrane can withstand high vacuum conditions and simultaneously act as a transmission detector
- high detection efficiency (close to 100%) even for protons
- excellent radiation hardness (no polarization was noticed)
- applications, future???

Thank you for attention!