Experimental investigation of the Charge Collection properties in pc-CVD under heavy ion irradiation

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Goal: A two-dimensional position sensitive Heavy Ion Detector

Detector capabilities:

- position resolution: $\frac{\Delta x}{x} \cong 0.2\,\text{mm}$ and $\frac{\Delta y}{y} \cong 0.2\,\text{mm}$
- time resolution: $0.5ns \le \frac{\Delta t}{t} \le 1ns$

count rate: $10^2\ s^{-1}mm^{-2}$ to $10^6\ s^{-1}mm^{-2}$

- active area: at least 80 mm x 40 mm
- radiation resistant
- UHV-compatible
- no window

comfortable handling and low cost

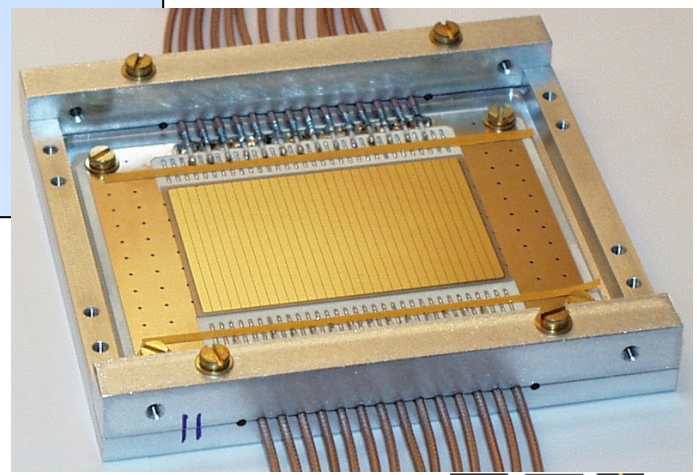
.....to detect primarily heavy ions with

Xe < Z_{ion}< U

4 MeV/u < E_{ion} < 100 MeV/u

Present detector status:

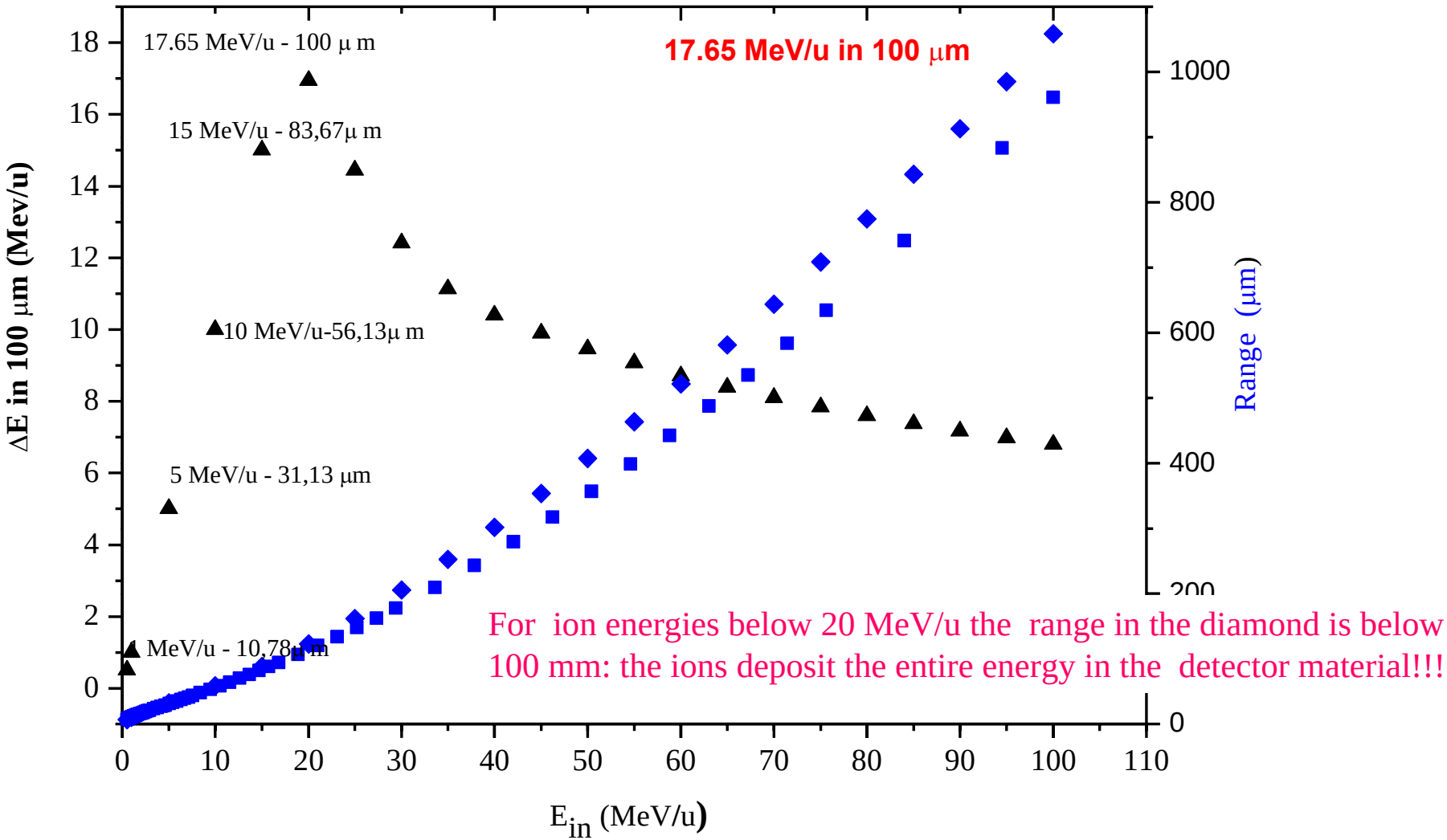
- one-dimensional sensitive: 32 Au-Ni stripes 1.8 mm, 2 mm pitch
- individual strip read-out
- active area: 60 mm x 40 mm, 0.2 mm thick pc-CVD diamond



HI in Diamond: Simulations

Uranium in Diamond

SRIM & ATIMA



For ion energies below 20 MeV/u the range in the diamond is below 100 mm: the ions deposit the entire energy in the detector material!!!

EXPERIMENT

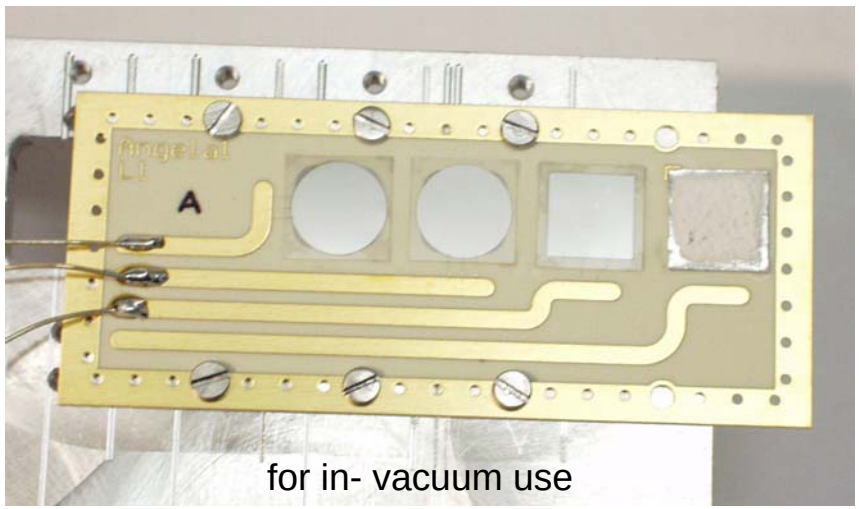
pc-CVD samples:

Diamond Materials: 70 μm, 100 μm, 200 μm, 165 μm, 325 μm, 430 μm; area 1 cm^2, both sided polished, Al metallization

element six: 93 μm, area 1 cm^2; 300 μm, 500 μm, area 4 cm^2; as grown, Au-Cr metallization

Sample preparation: GSI Target Lab and GSI Detector Lab, GANIL

- cleaning with H_2SO_4 and HNO_3 at 250° C
- metallization with 100 nm thick Al layer, 8 mm diameter pad
- bonding on a ceramic substrate



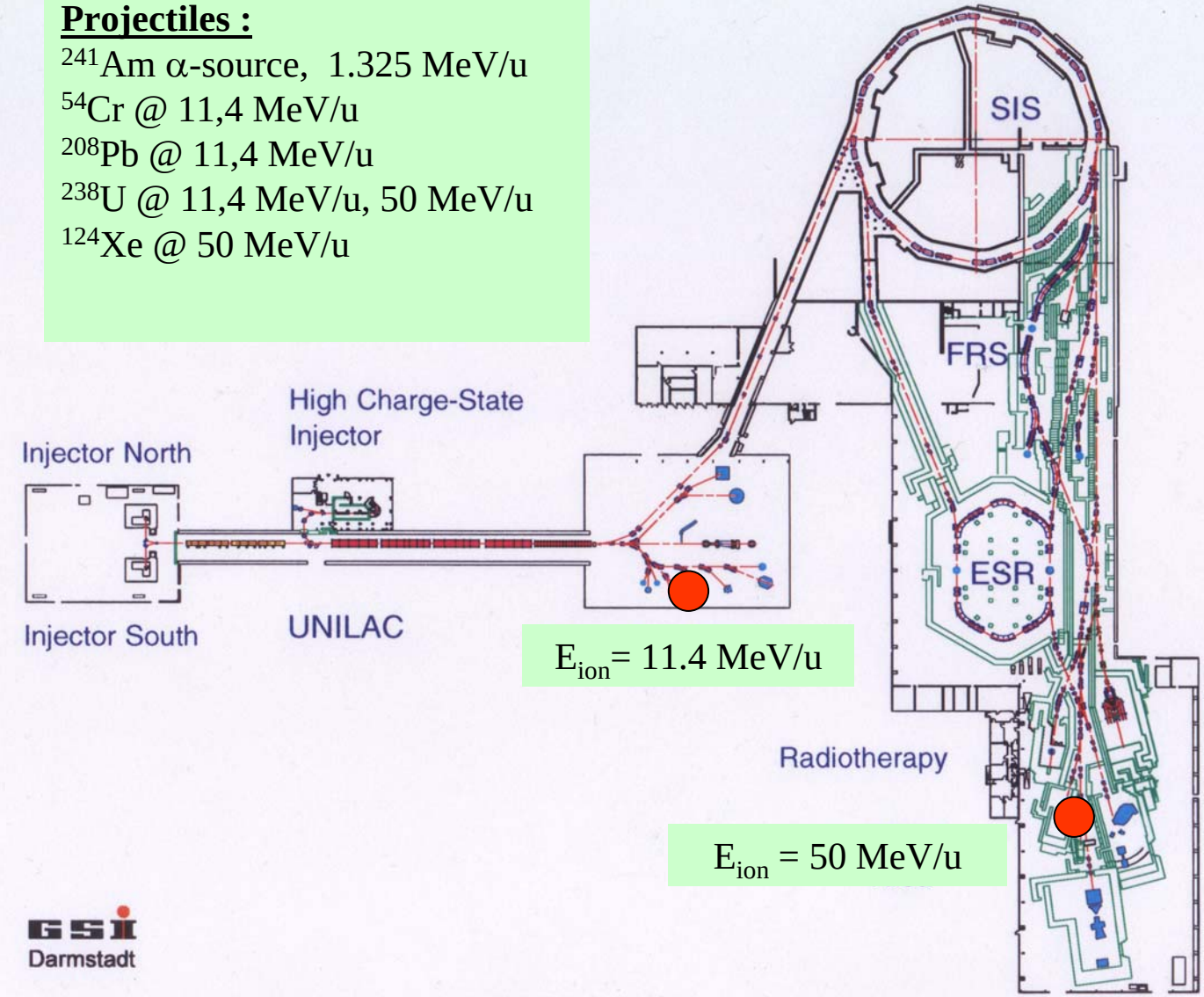
for in- vacuum use


for in-air use

EXPERIMENT

Projectiles :

^{241}Am α-source, 1.325 MeV/u
^{54}Cr @ 11,4 MeV/u
^{208}Pb @ 11,4 MeV/u
^{238}U @ 11,4 MeV/u, 50 MeV/u
^{124}Xe @ 50 MeV/u



E_{ion}= 11.4 MeV/u

E_{ion} = 50 MeV/u

Ion beams

UNILAC:

3.5 Hz, 1.2ms macro pulse, low intensity, poor statistics

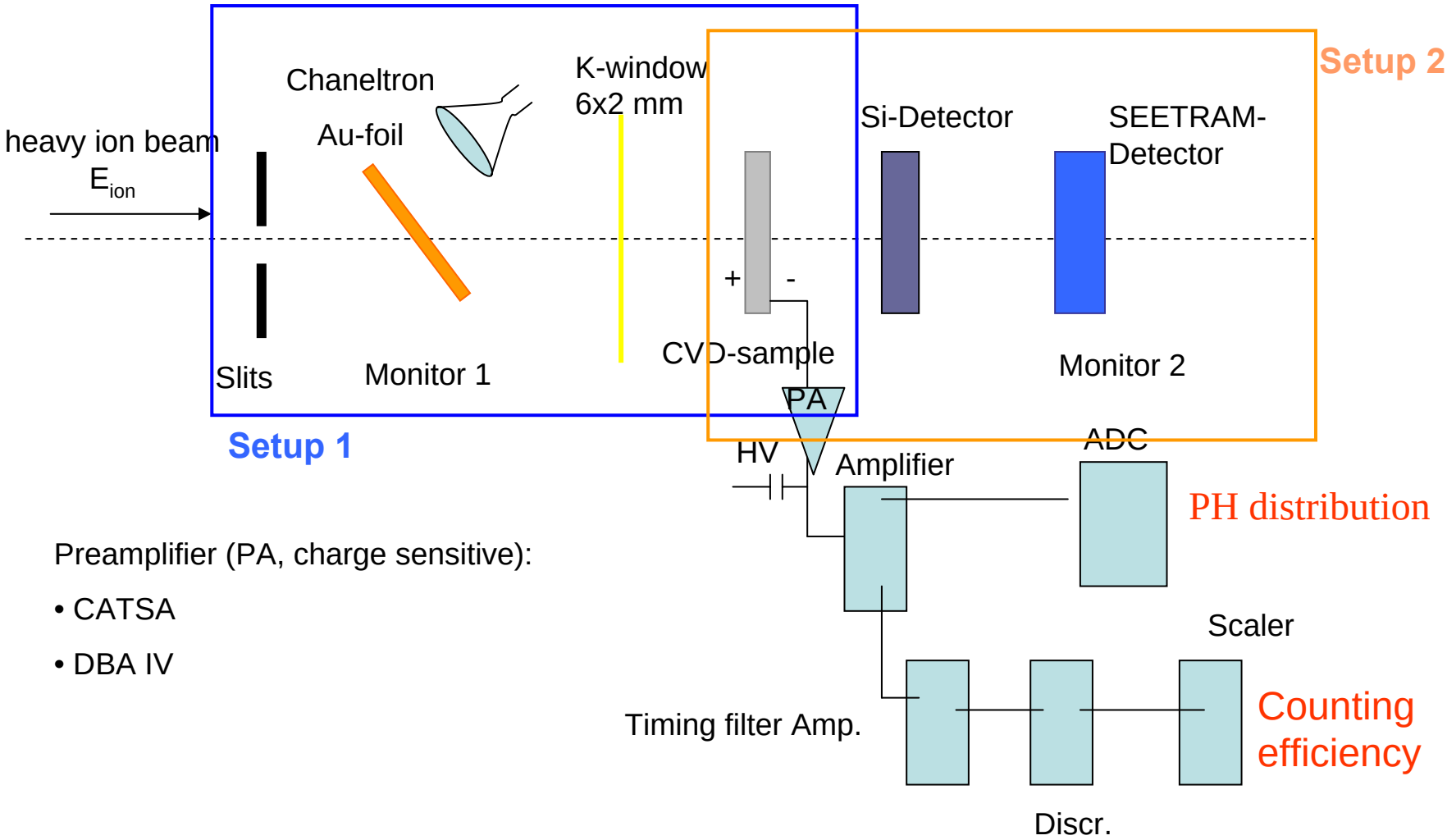
counting rates below 100 Hz

SIS:

1,5 x 10^7 ions/spill, slow extraction, ~ 10 sec.

40 kHz to 250 kHz detector rate

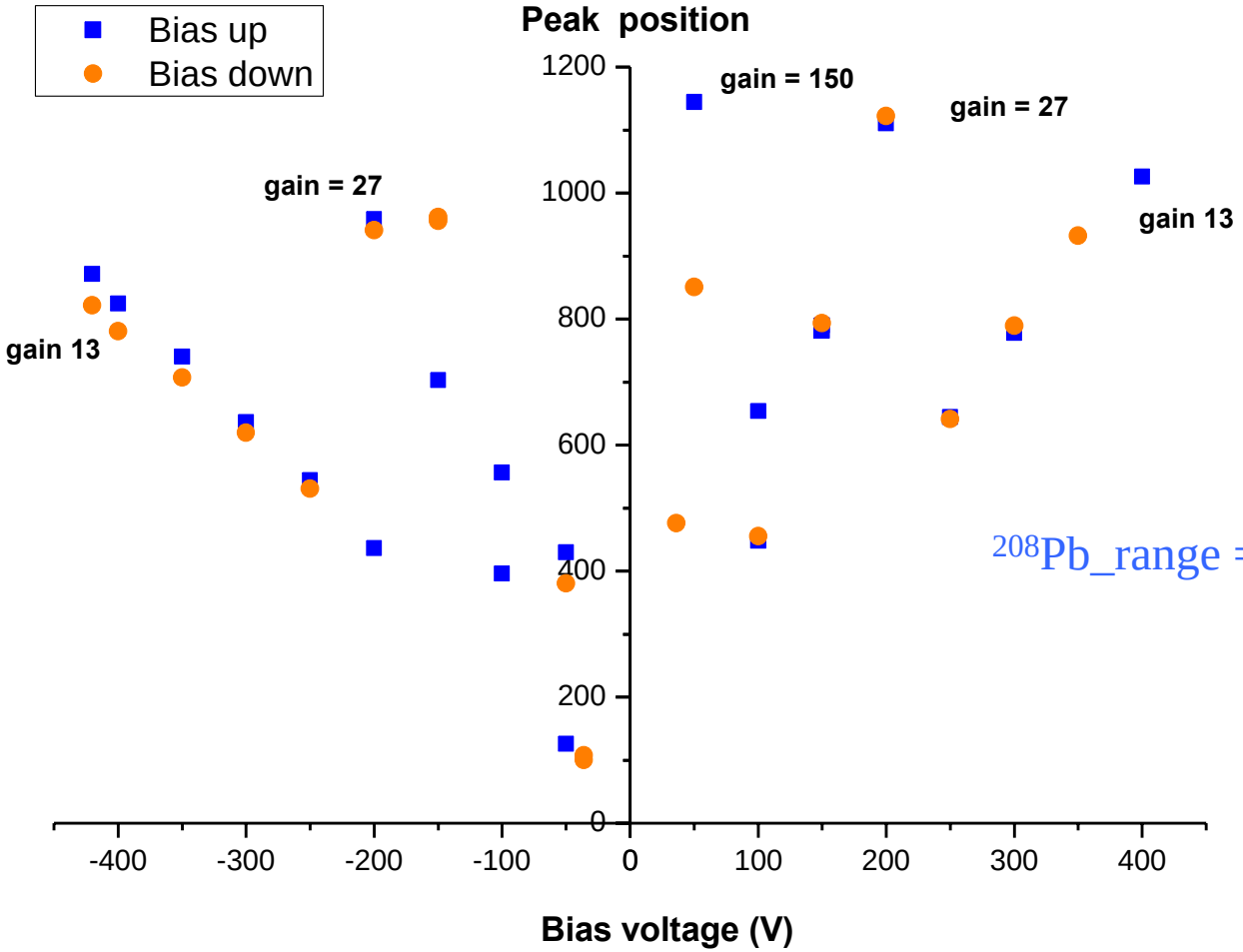
Experimental setup



Preamplifier (PA, charge sensitive):

- CATSA
- DBA IV

208 Pb @ 11,4 MeV/u in 70 µm pc-CVD (Dia. Mat.)

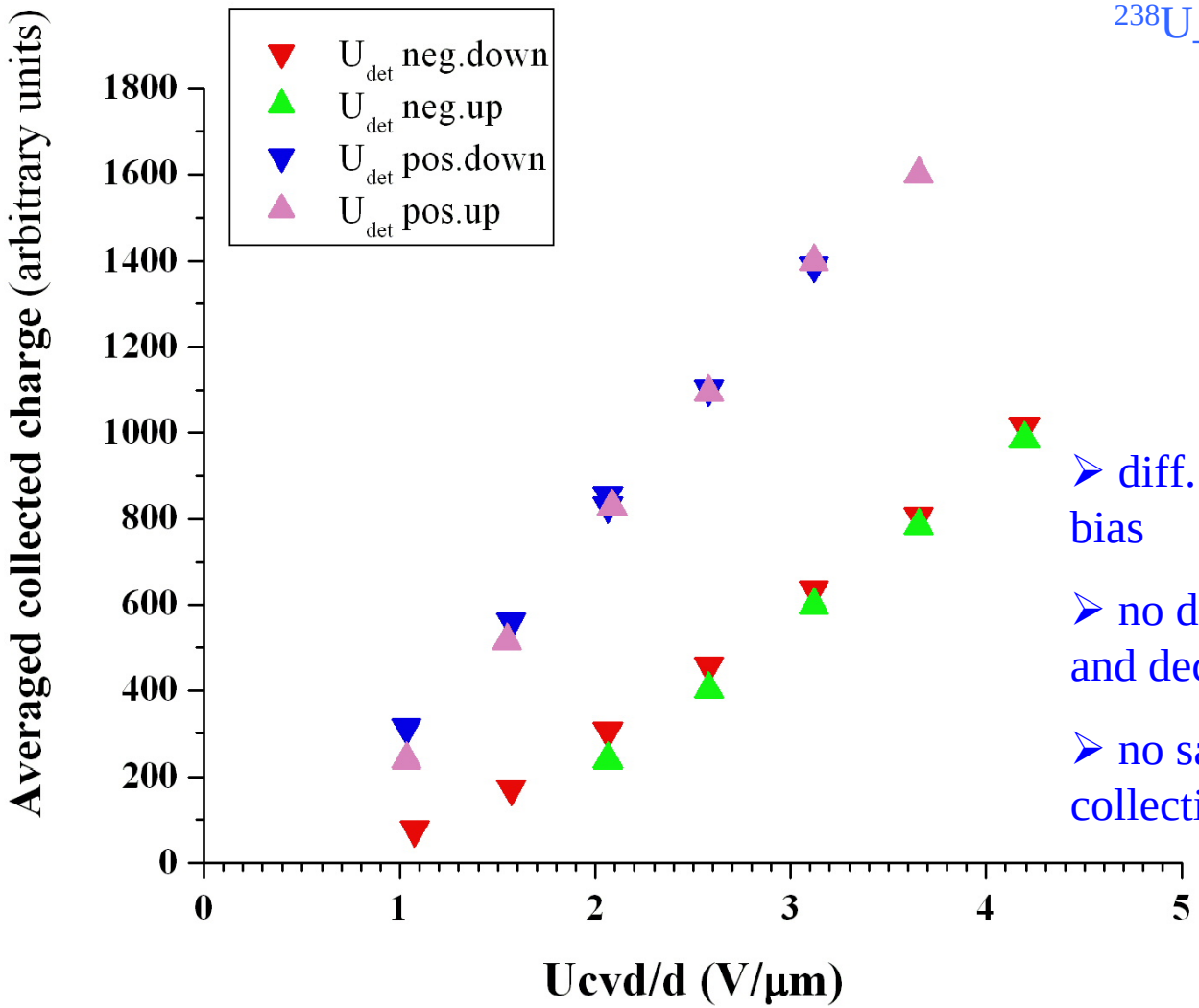


^{208}Pb_range = ~ 66 ÷ 72 µm

similar measurements for the 100 µm and 165 µm samples at 11.MeV/u and

for the 70, 100 , 165, 325 and 430 µm samples with ^{124}Xe @ 50 MeV/u

The 93 μm sample (E6): ^{238}U @ 11,4 MeV/u

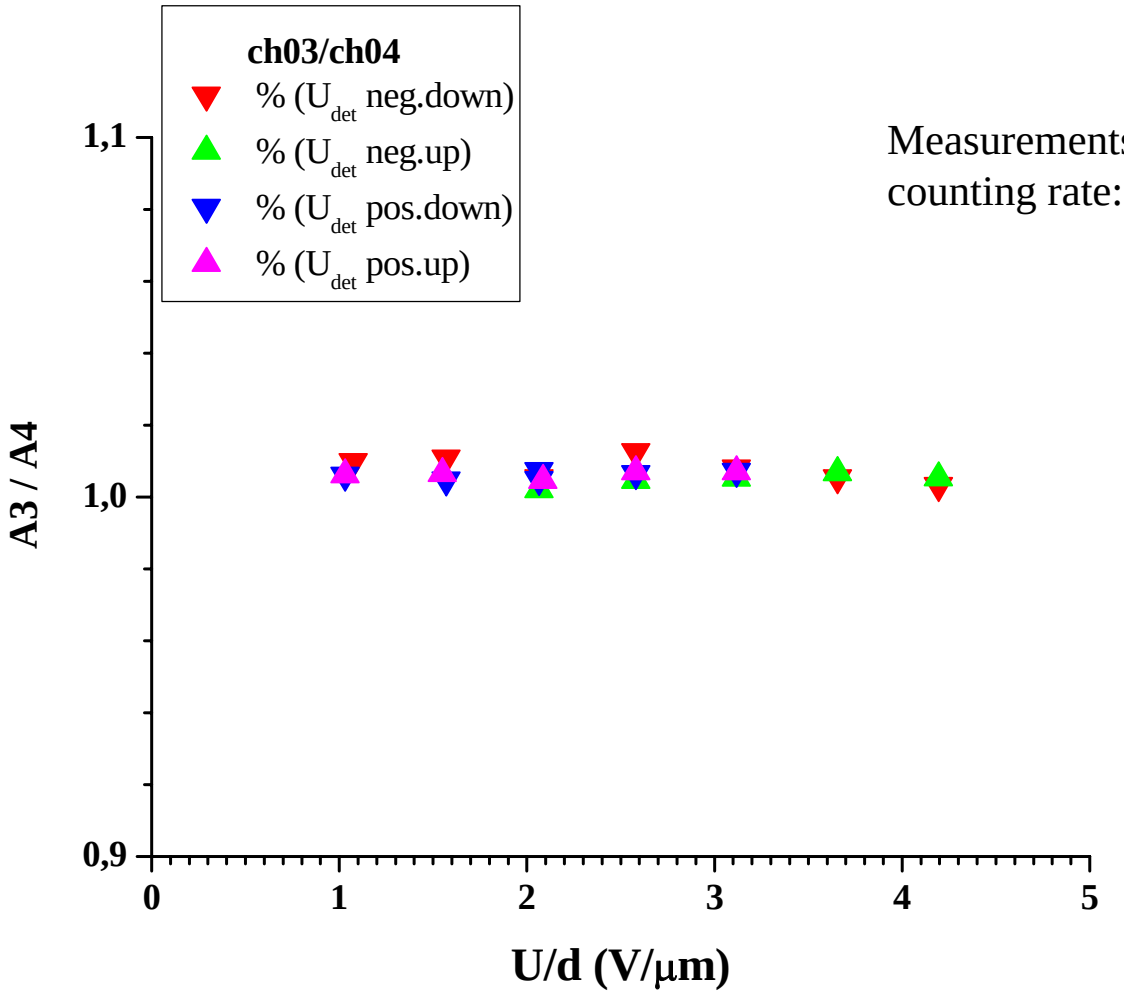


^{238}U_range = ~ 63 ÷ 69 μm

- diff. between positive and negative bias
- no difference between increasing and decreasing the bias voltage
- no saturation of the charge collection

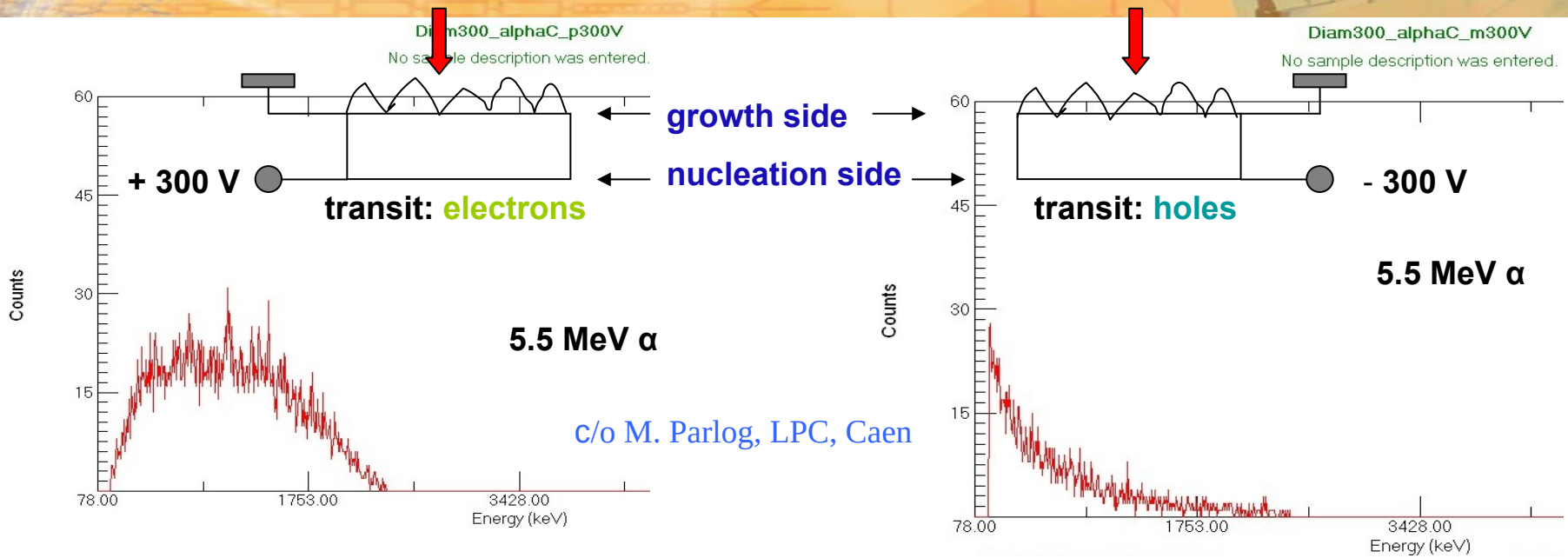
238 U @ 11,4 MeV/u in 93 μm pc-CVD (E6)

Counting rate ratio CVD / Channeltron

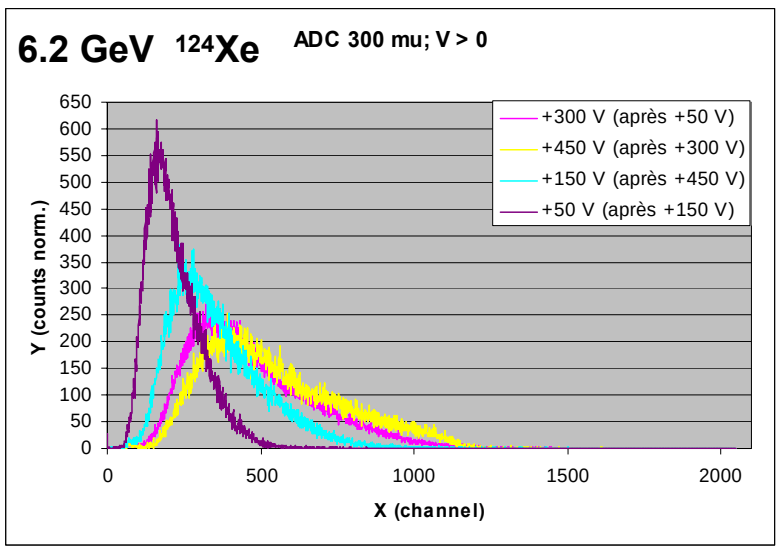


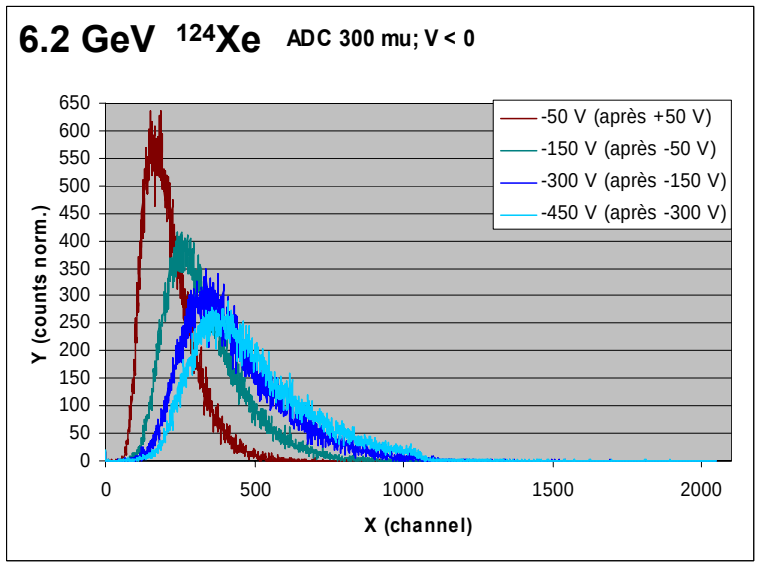
Measurements performed at low counting rate: ~ 100 Hz

Irradiation response of the 300 μm pc-CVD sample (E6)

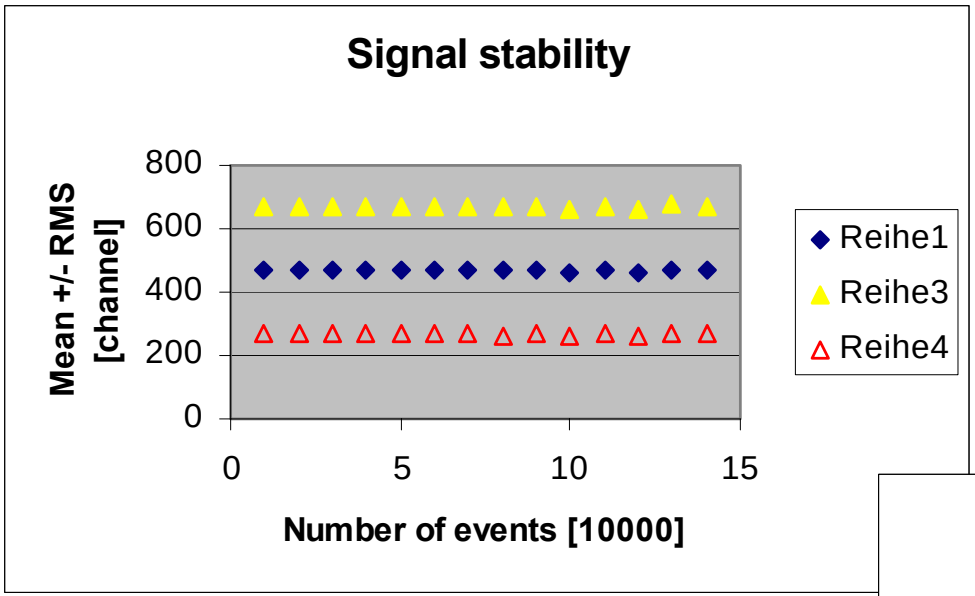


c/o M. Parlog, LPC, Caen



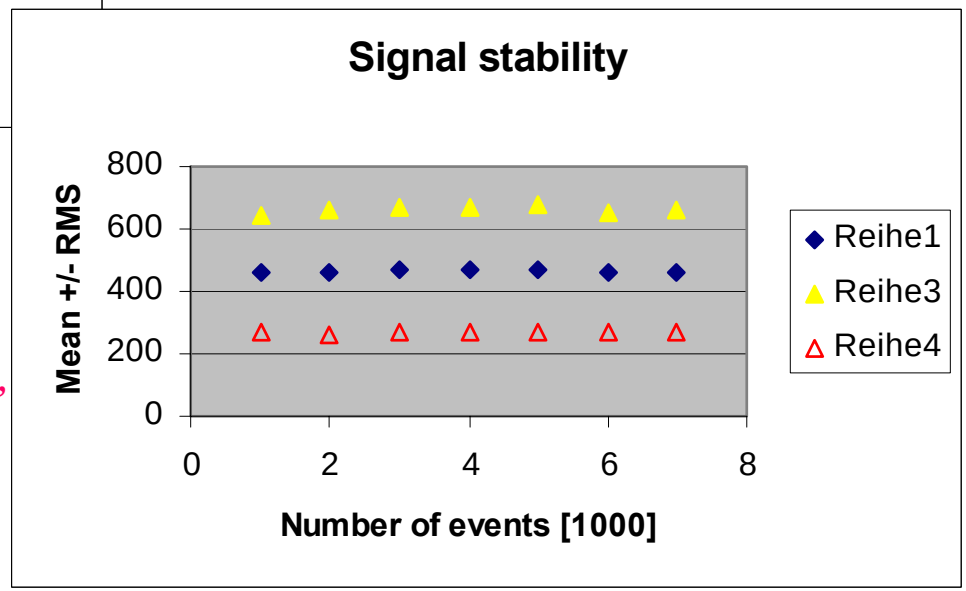


Time dependent evolution of the PH height distribution



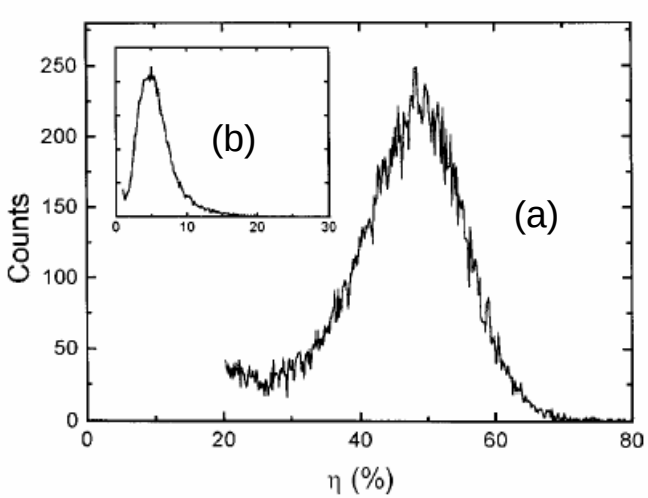
Sample: 300 µm pc-CVD (E6) irradiated with ^{124}Xe @ 50 MeV/u

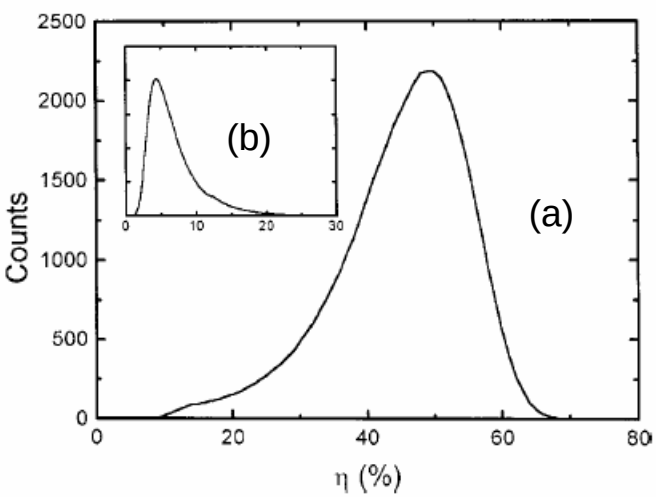
U_{bias}=



For irradiation over ~ 300 sec. with counting rates of 80 kHz the maximum of the pulse height distribution does not move → stable operation, no indication of polarization

The Priming Mechanism as response enhancement for the pc-CVD Detectors





- Preirradiation by ionizing radiation improves the **Detection Efficiency** in the pc-CVD diamond detectors

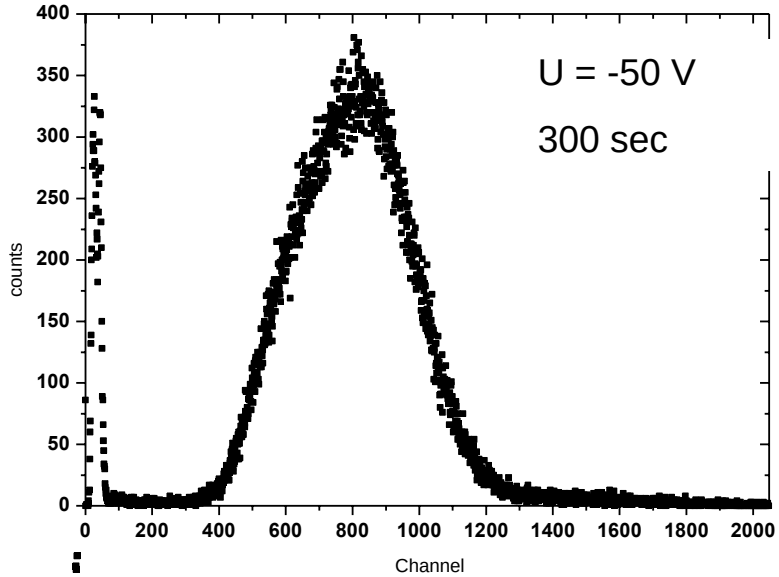
α-particle (Am^{241}) spectra from an 115 μm thick pc-CVD ' as grown' sample in primed (a) (^{90}Sr) and unprimed (b) state;

Monte Carlo simulation of the α-particle spectra in primed (a) and unprimed (b) state

The preirradiation of the sample deactivates only the in-grain defects (uniformly distributed over the sample thickness) but leaves the grain boundaries (concentrated on the nucleation side) unaffected.

M. Marinelli et al., Applied . Phys. Lett, Vol 75, 20 (1999), 3216

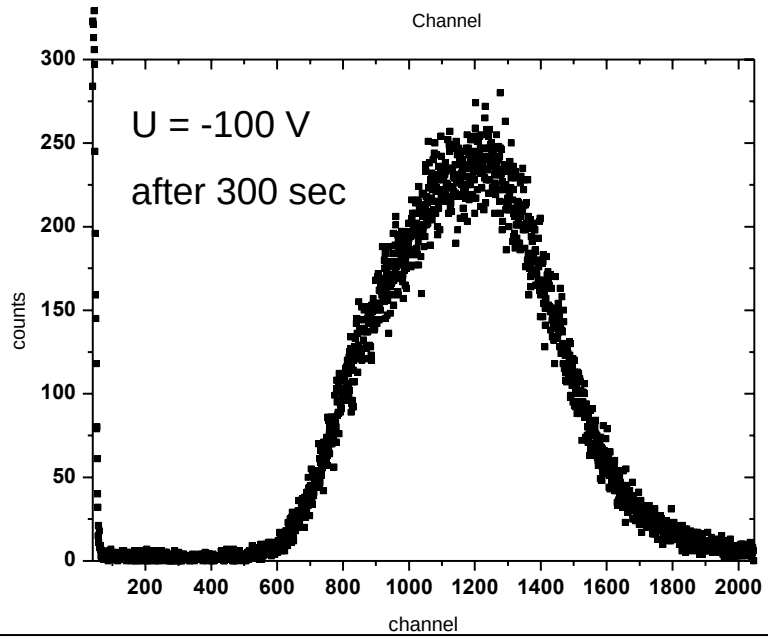
^{124}Xe@ 50 MeV/u in 100 μm pc-CVD (Dia. Mat.)

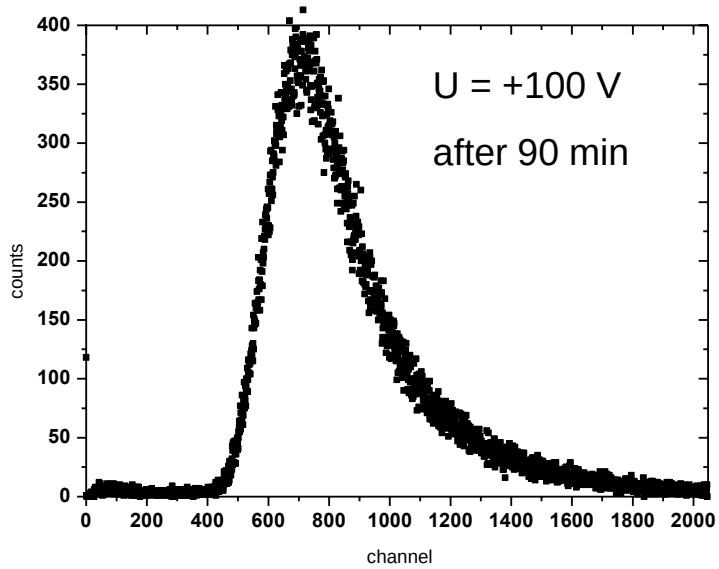


Range ^{124}Xe @ 50 MeV/u = ~ 420 μm

Counting rate: ~150 kHz

Modification of the bias voltage, induces changes in the charge collection efficiency : peak position and form change.





Closing remarks

1. instable operation in the Bragg peak region: polarization effects clearly observed when $Range_{ion} <$ Sample thickness
2. 'priming' not clearly observed in the PH distribution
3. material differences: sample handling / production; the 165 μm sample performed unexpected poor
4. the primary data analysis is closed but a more careful analysis and cross-checks are still on-going

Open Questions:

- can we overcome the limitation due to the polarization and how?
- where is the limit of radiation hardness of CVD when irradiated with heavy ions ?

Collaboration team

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Thanks for the sustained collaboration !!!