ADAMAS 2015

Degradation of charge collection in irradiated thin diamond detectors

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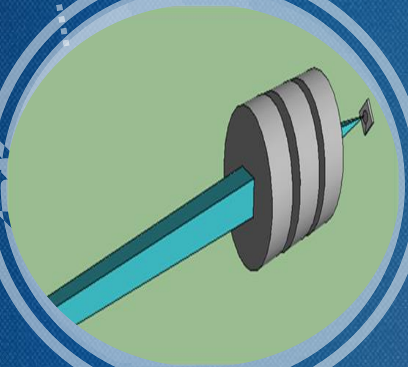
Outline

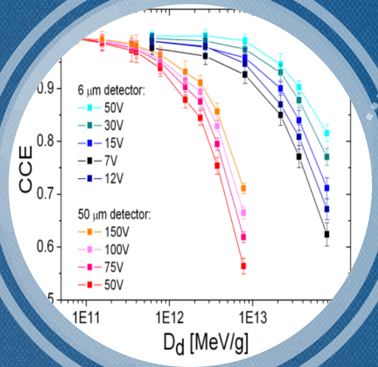
Short intro

- defining the aim of radiation hardness test

Samples and methods

- description of detectors used
- irradiation procedure





Results and modelling

- CCE degradation model
- specification of damage parameter
- polarization issues

Introduction

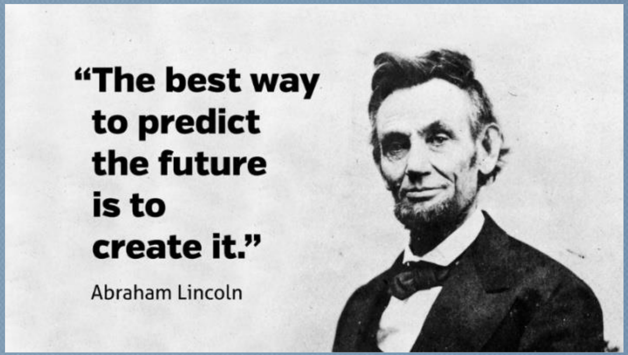
Defining the problem

Main goal:

- predicting the future of a detector exposed to damaging radiation

Common procedure:

- radiation hardness test and calculation of damage coefficients



$$CCE = 1 - K_{ef} \times D_d$$

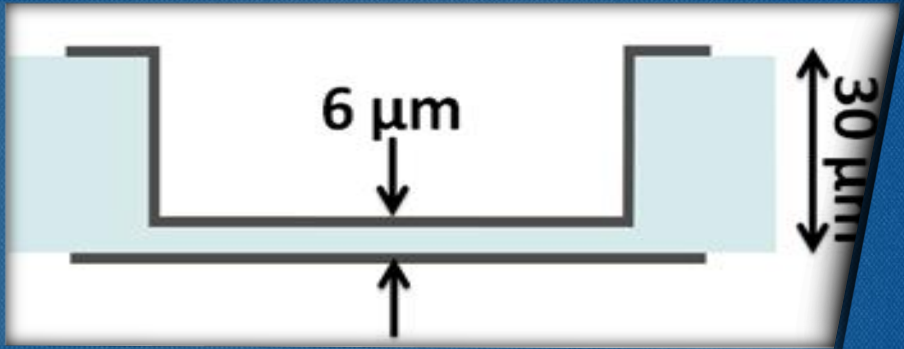
D_d = fluence × NIEL

K_{ef} is NOT a material property

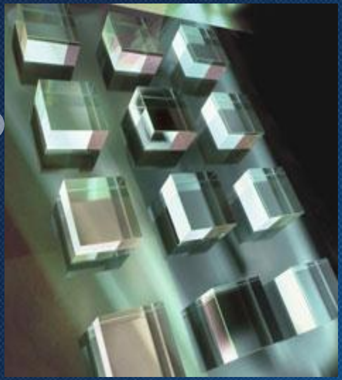
Samples

50 μm scCVD from DDL

6 μm scCVD membrane

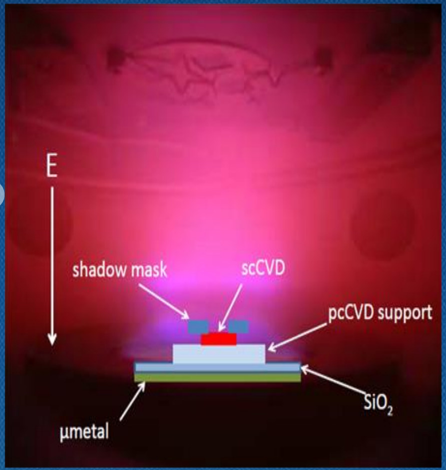


Membrane detector



scCVD

- Element Six
- Thickness: 300 µm
- [N]< 1 ppm

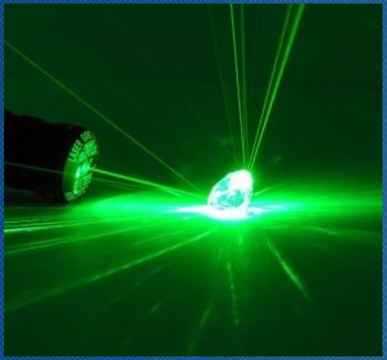


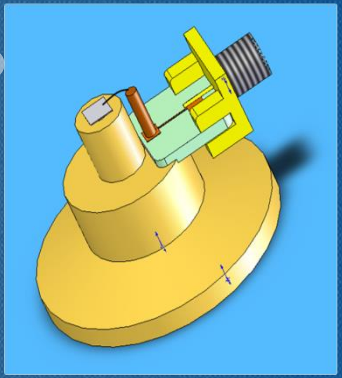
Plasma etching

- Magnetron sputtering device PVD - PLASSYS
- Ar/O_2 plasma

Laser cutting

- wedge ~ 1 µm





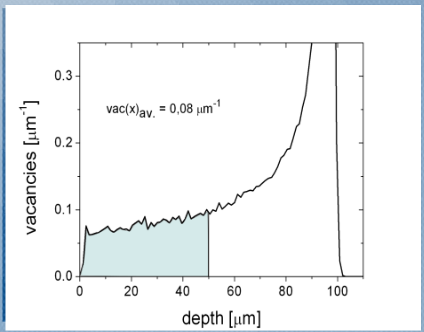
Contacts

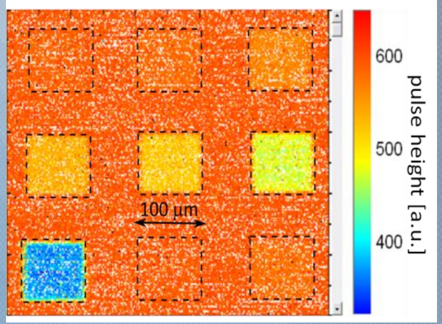
- sputtered Al (around 300 nm)

Irradiation

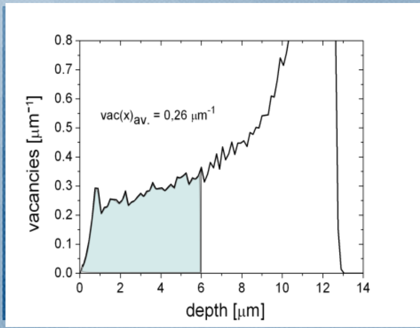
Several areas in both detectors irradiated by proton microbeams

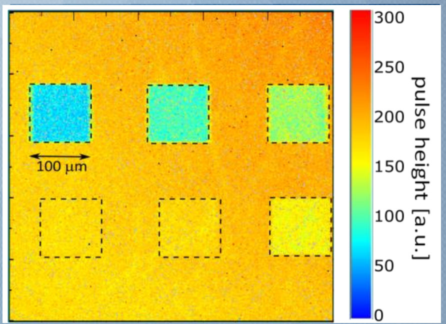
4.5 MeV protons





1.3 MeV protons





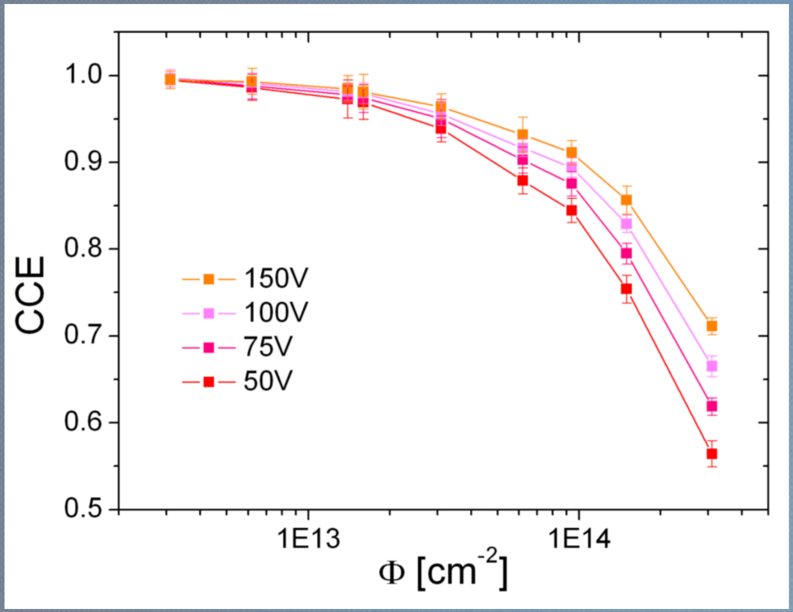
IBIC analysis

Detectors connected to “standard” electronic chain

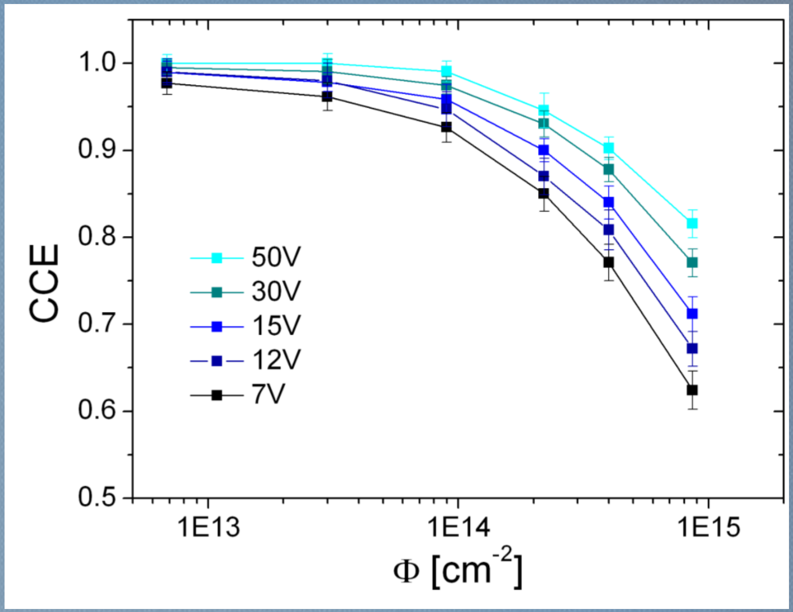
CCE degradation

Dependance on the total irradiated fluence

50 um DDL detector



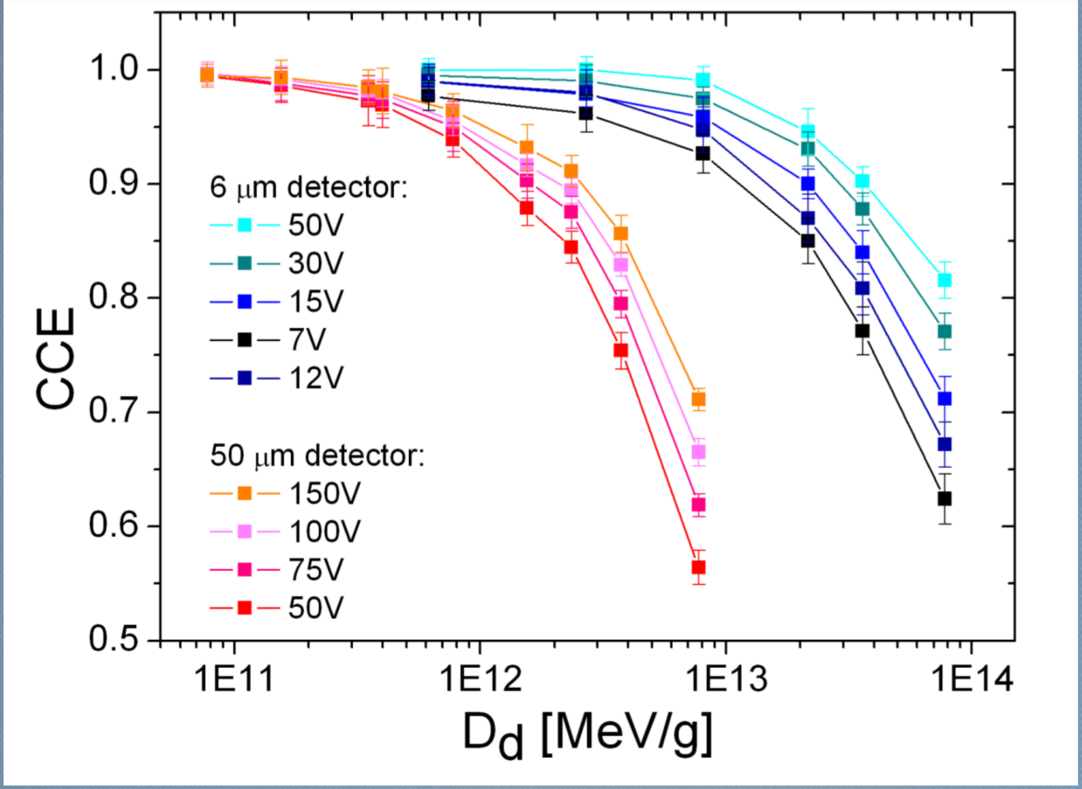
Membrane detector



CCE degradation

Dependance on the damage dose, $D_d = \Phi \times NIEL$

Combined data for both detectors



CCE degradation

Modelling

Start

weak point of the model

- SRH result for the lifteme:

$$\tau(x,\Phi) = \frac{\tau_0(x)}{1 + k\cdot\sigma\cdot vac(x)\cdot v_{th}\cdot\Phi\cdot\tau_0} \qquad k = \frac{N\_of\_el.\_active\_traps}{N\_of\_vacancies}$$

- CCE profile is the solution to adjoint equations:

$$\eta(x,\Phi) = \frac{\int_x^d dy\cdot E_w(y)\cdot\exp\left[-\int_x^y \frac{dz}{v_e(z)\cdot\tau_e(z,\Phi)}\right] + \int_0^x dy\cdot E_w(y)\cdot\exp\left[-\int_y^x \frac{dz}{v_h(z)\cdot\tau_h(z,\Phi)}\right]}{\int_x^d dy\cdot E_w(y)\cdot\exp\left[-\int_x^y \frac{dz}{v_e(z)\cdot\tau_e(z,0)}\right] + \int_0^x dy\cdot E_w(y)\cdot\exp\left[-\int_y^x \frac{dz}{v_h(z)\cdot\tau_h(z,0)}\right]}$$

- total CCE is the convolution of $\eta(x,\Phi)$ and ionization profile of the probing ion $\Gamma(x)$:

$$CCE(\Phi) = \int_0^d \Gamma(x)\cdot\eta(x,\Phi)\cdot dx$$

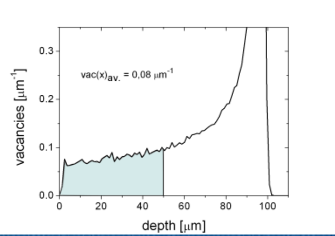
CCE degradation

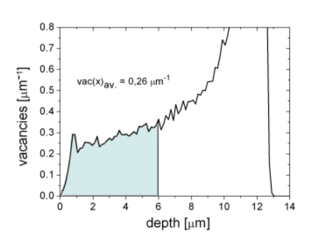
Modelling

Assumptions and inputs

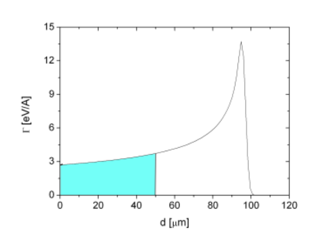
- low damage regime, $v_d \times \tau > d$
- nearly homogeneous vacancy profile of damaging ion
- homogeneous ionization profile of probing ion
- similar probability for electron and hole trapping

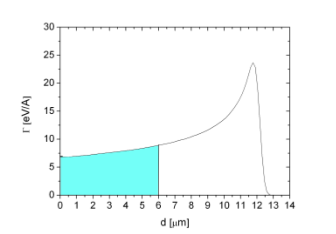
vacancies:





ionization:



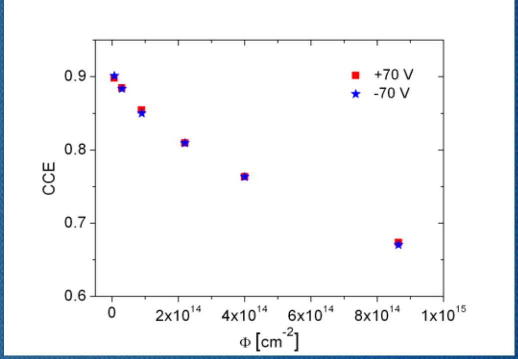


Analitical solution

$$\mathrm{CCE}(\Phi) = 1 - \boxed{\Phi \cdot \frac{\overline{\mathrm{vac}} \cdot d}{6} \cdot \left(\frac{v_{th,e}}{v_e} + \frac{v_{th,h}}{v_h} \right)} k\sigma$$

D* - efective fluence

Short range probe, 1.8 MeV C:

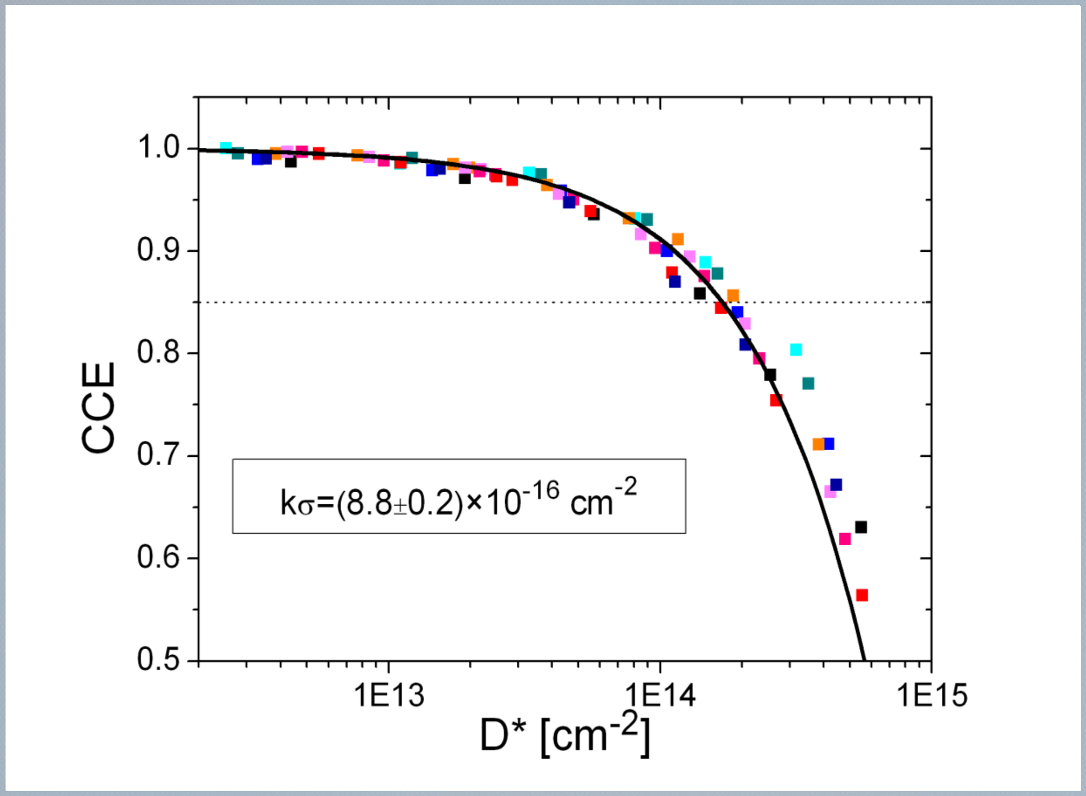


CCE degradation

Dependance on the effective flunce, D*

Damage report

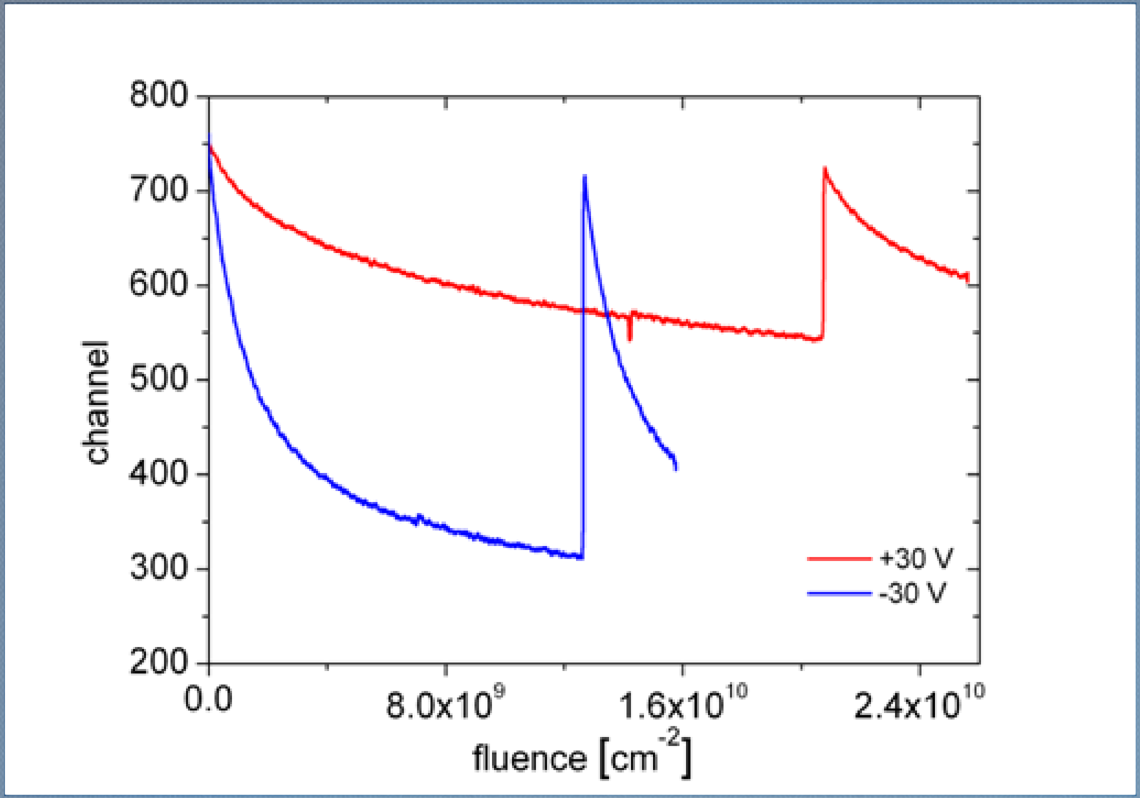
Modelling approach



Polarization issues

1. Shallow probe (1.8 MeV C)

scanning area:
$200 \times 200\ \mu m^2$

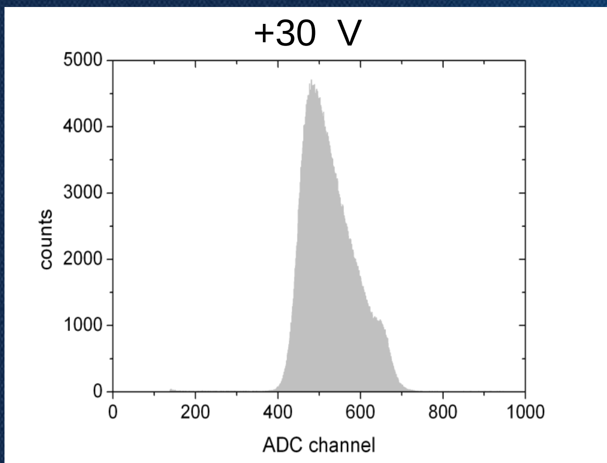


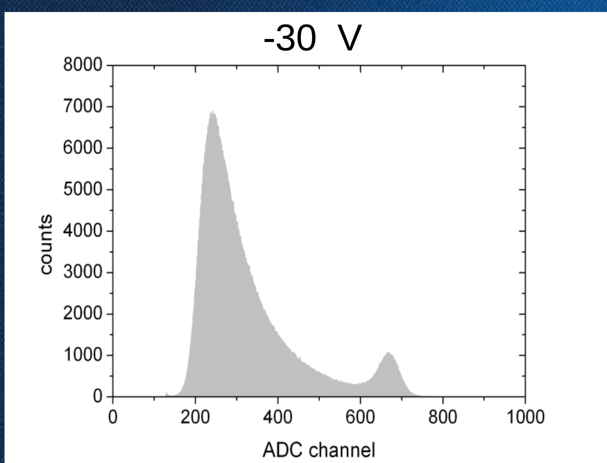
detector grounded for 50 sec, beam ON
detector grounded for 30 min, beam OFF

Polarization issues

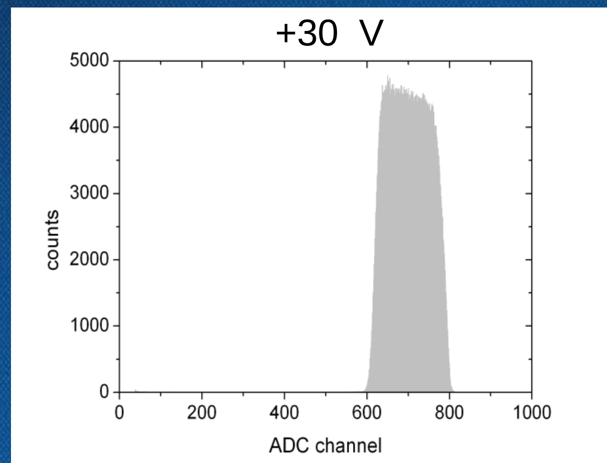
2. Varying the range of ions...

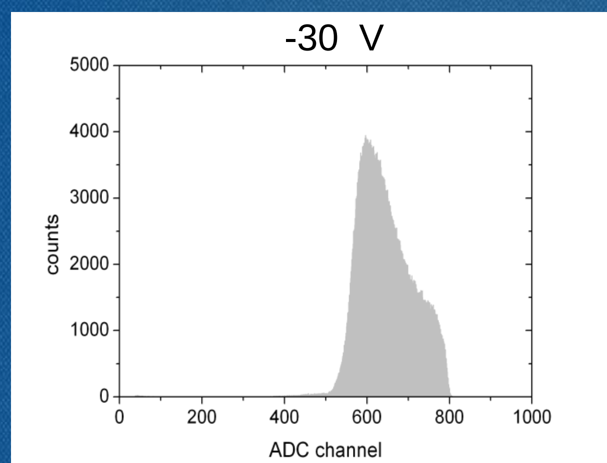
1.8 MeV C, range = 1.13 μm



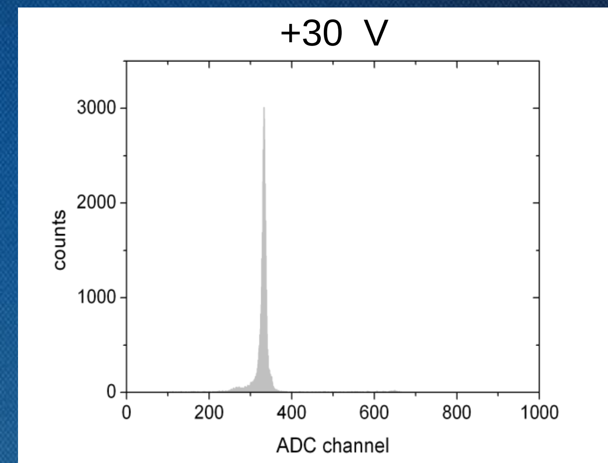


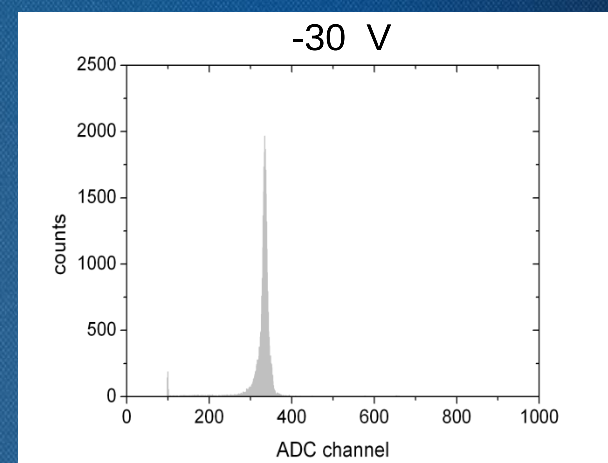
7.2 MeV C, range = 3.25 μm





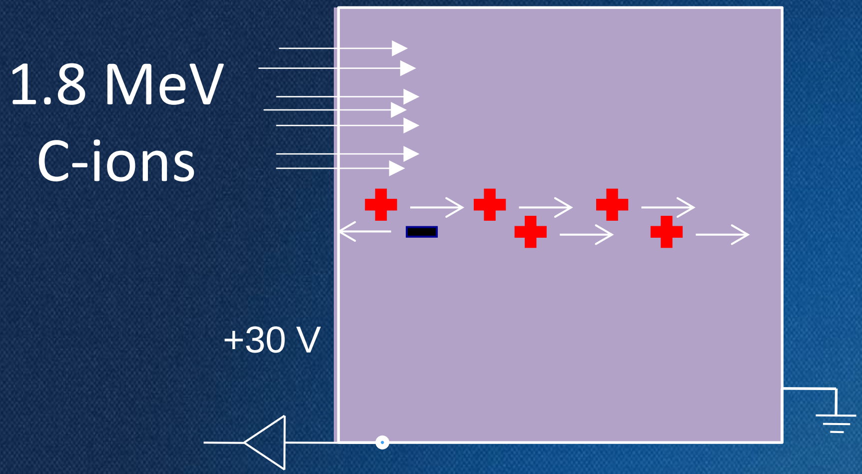
12 MeV C, range = 5.36 μm

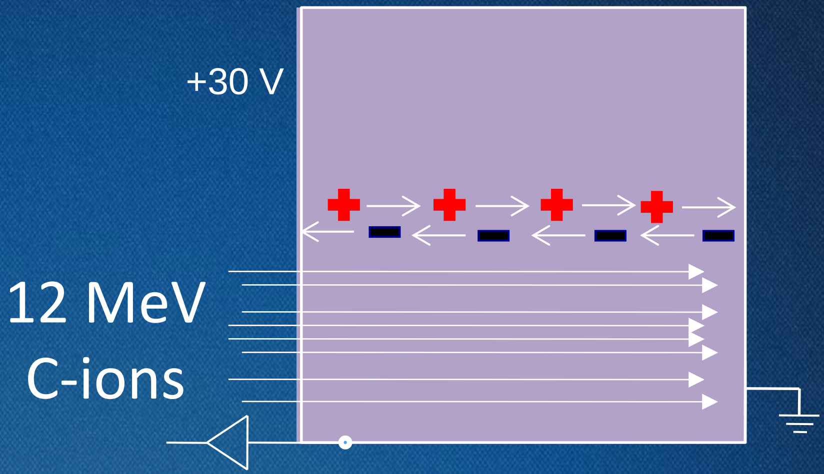




Polarization issues

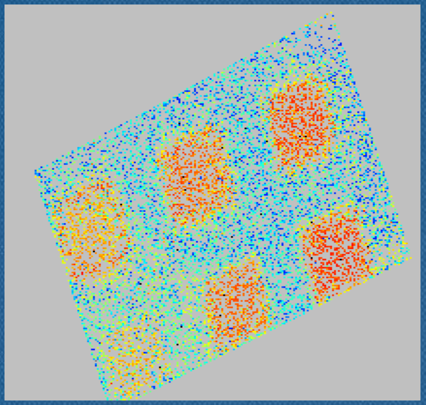
2. Varying the range of ions...

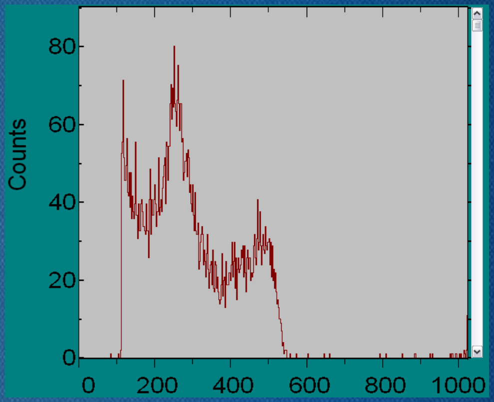




3. Pronounced polarization in damaged areas...

- detector polarized by 1.8 MeV C on +30 V
- signal recorded with 0 V bias and opposite polarity on shaping amplifier

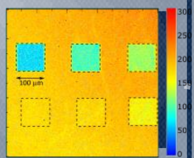


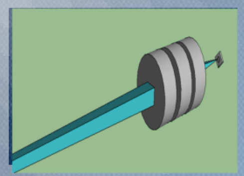


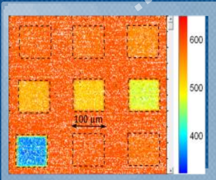
Collaborators

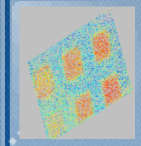
Many many thanks to:

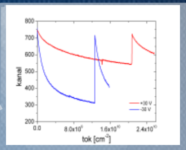
Thank you!

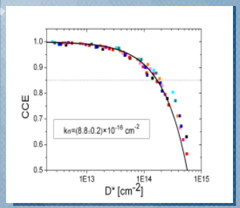


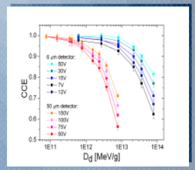












Extra slides