

# CCE and E-TCT measurements with ATLAS12 and ATLAS07 mini strip detectors

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Work within ATLAS Upgrade (ITK-strips) program

## Setup

CCE:

- Alibava readout system
- Keithley 2410 HV unit
- $^{90}\text{Sr}$  source
- only detector cooled with Peltier element, not the readout chip

More details in: <https://indico.cern.ch/event/292247/>

E-TCT measurement system:

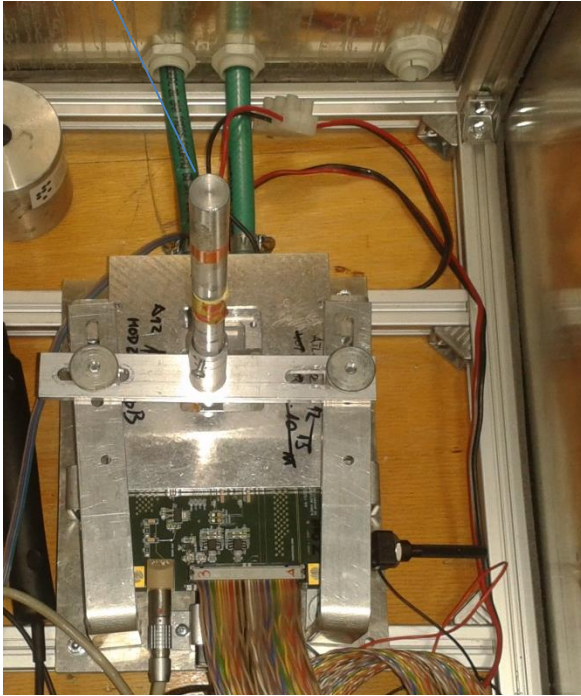
- G. Kramberger, et al., IEEE Trans. Nucl. Sci. NS-57 (2010) 2294.
- G. Kramberger et al., PoS - Proceedings of Science (Vertex 2013) 022.

## Two batches of detectors n-p were produced by Hamamatsu

- A07 FDV  $\approx$  170V
- A12 FDV  $\approx$  370 V
- THICKNESS 320  $\mu\text{m}$
- pitch 75 microns
- A12 irradiated with neutrons : 5e14, 1e15, 2e15, 5e15
- A12 irradiated with 70 MeV protons at KEK: 1.8e15, 2.5e15
- A12 irradiated with 26 MeV protons at Birmingham: 1e15
- A07 irradiated with neutrons: 5e14, 1e15

# Setup

$^{90}\text{Sr}$  source holder



Cooling block

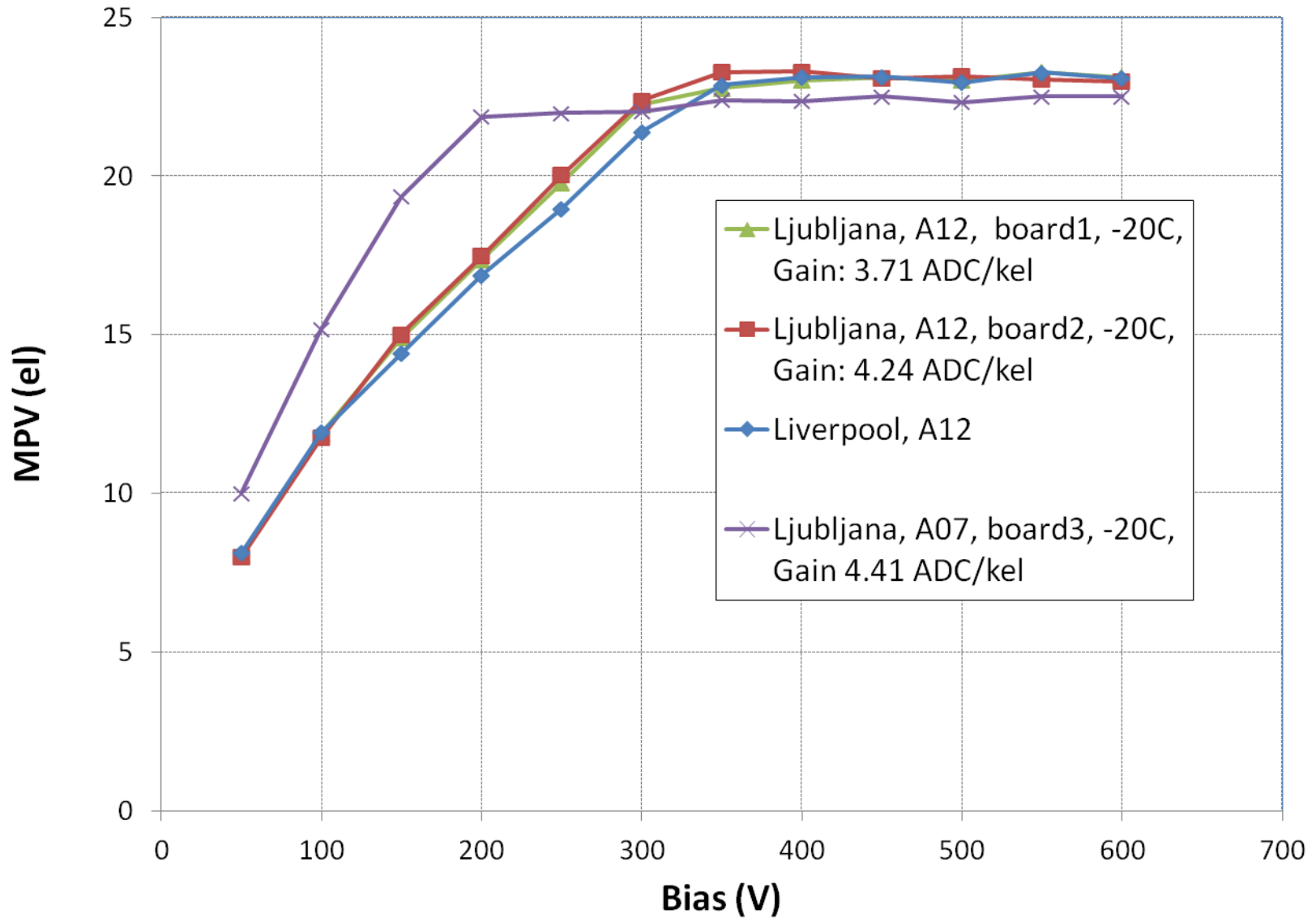
PM



Detector



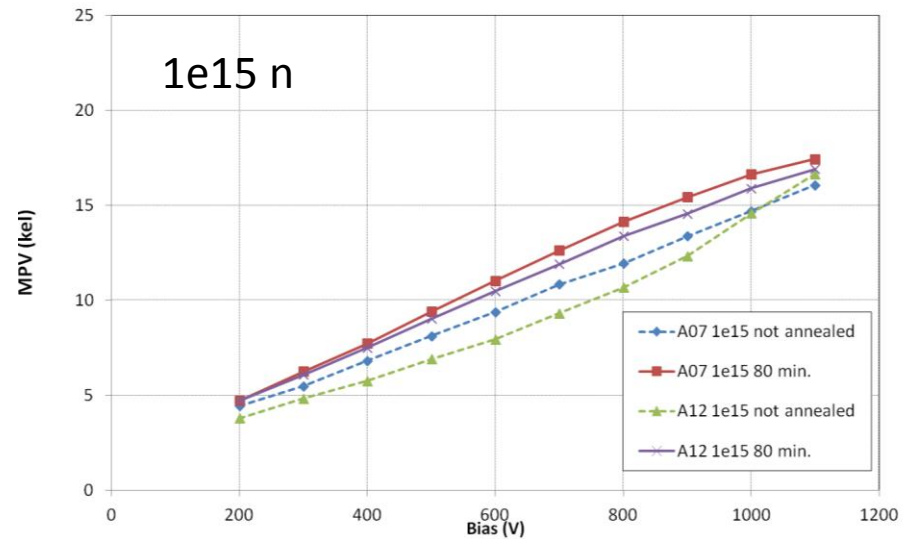
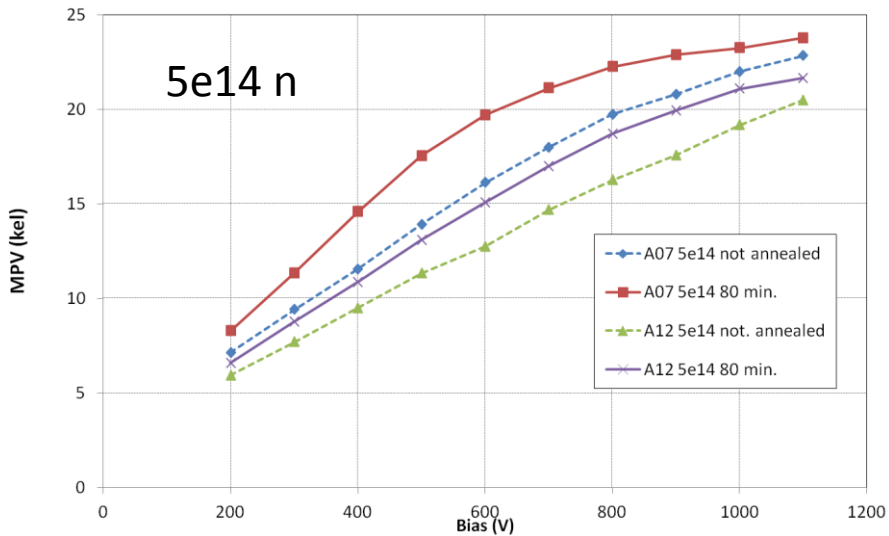
Al support in thermal contact with cooling block



## ATLAS12 / ATLAS07 comparison

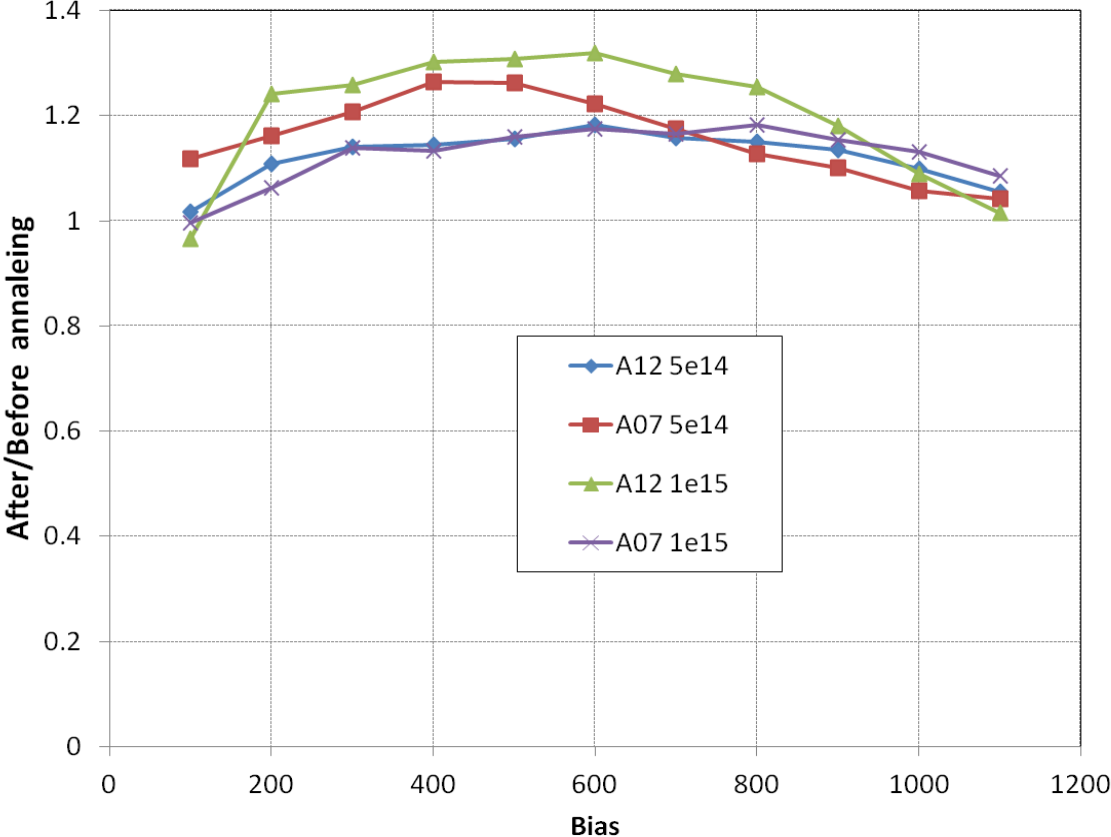
- A07 and A12 irradiated with neutrons in **same irradiation** → fluences are the same
- detectors irradiated together measured with same Beetle chip → chip gain the same

- at  $5e14$  A07 significantly more charge than A12  
→ difference expected because of different initial  $V_{fd}$
- at  $1e15$  smaller difference between A07 and A15



# ATLAS12 / ATLAS07 comparison

Comparison of after/before 80 minutes at 60°C annealing factors

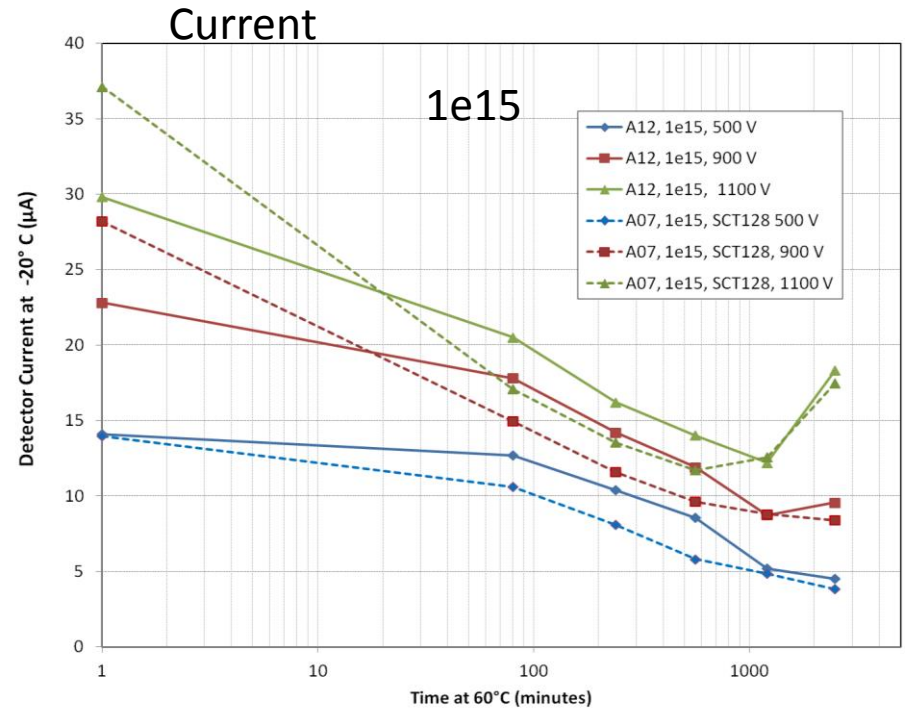
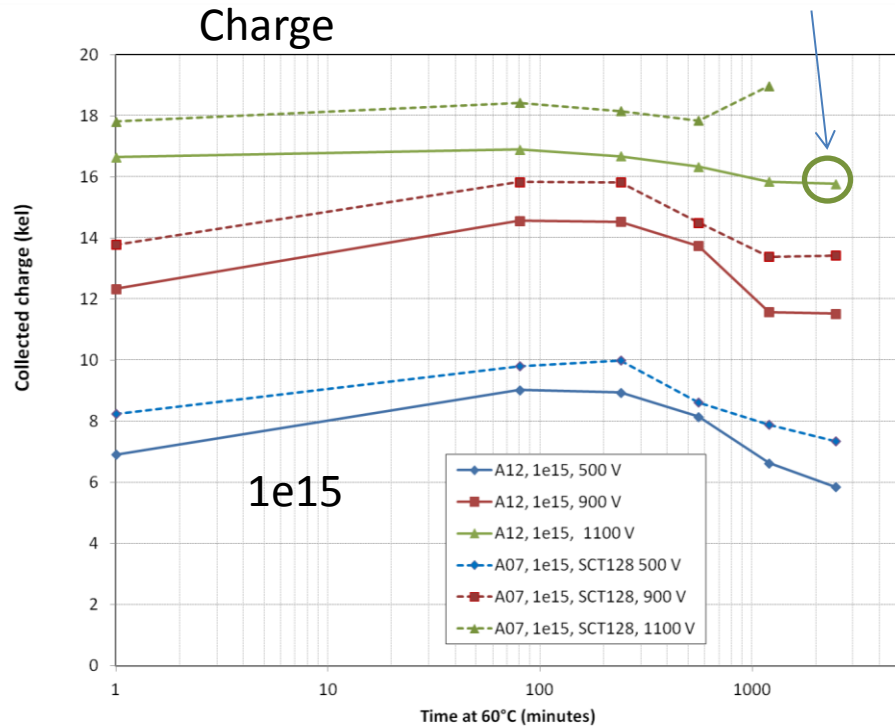


## Long term annealing at 60°

- A12, 1e15 neutrons
- A07, 1e15 neutrons (**dashed line**) measured with SCT128 (old data: I. Mandic et al., NIMA 629 (2011) 101)

- A12 and A07 annealing very similar at this fluence
- charge multiplication starts at same bias, time point

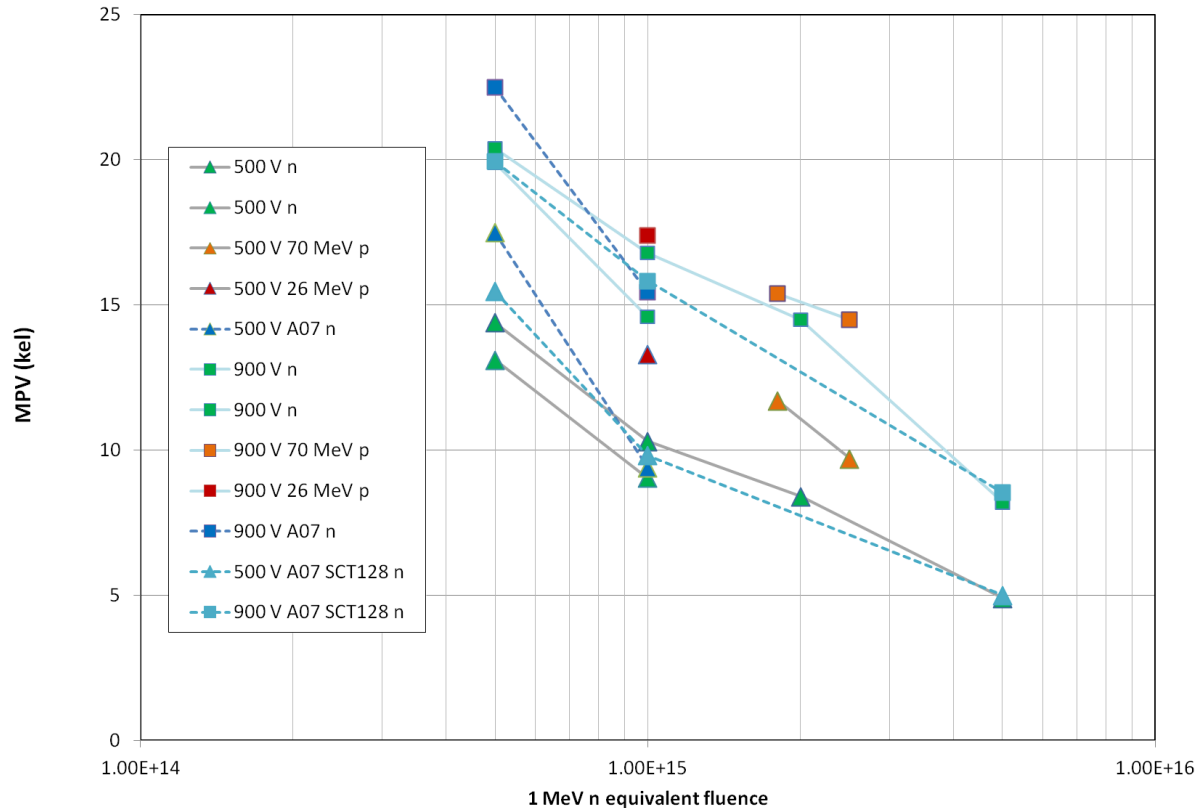
Large noise, near breakdown  
→ also A07 broke down at this point



# Summary plot of CCE measurements

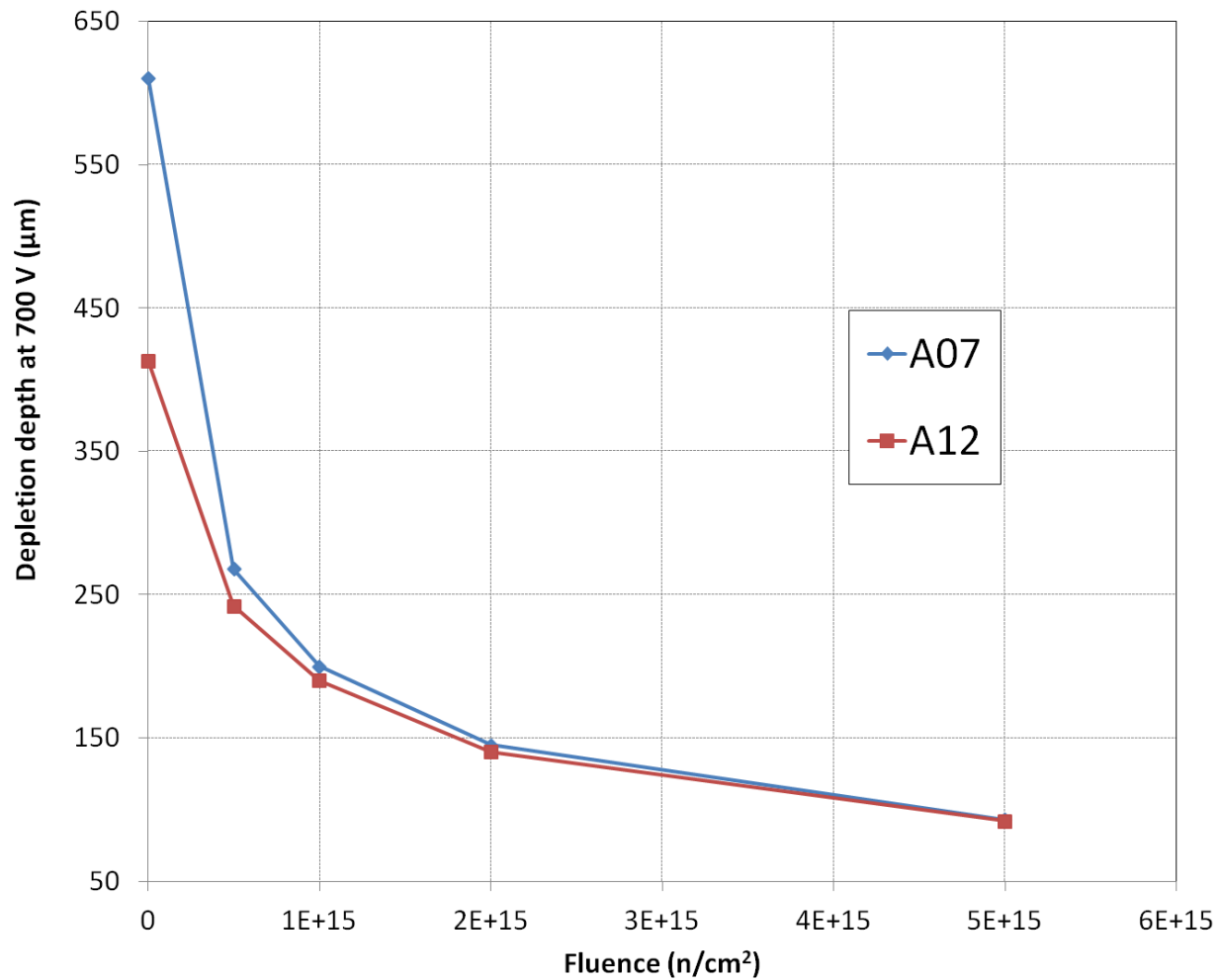
- Charge vs. fluence **after 80 minutes annealing** at 60 C at 500 V and 900 V
- A12 full lines, A07 dashed lines

→ at lower bias is CCE after proton irradiation larger than after neutron irradiation  
→ 5e14 A07 larger charge than A12



- some slides at the end of this presentation

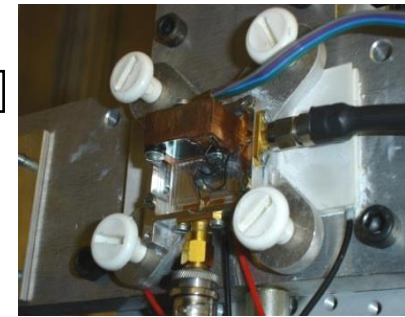
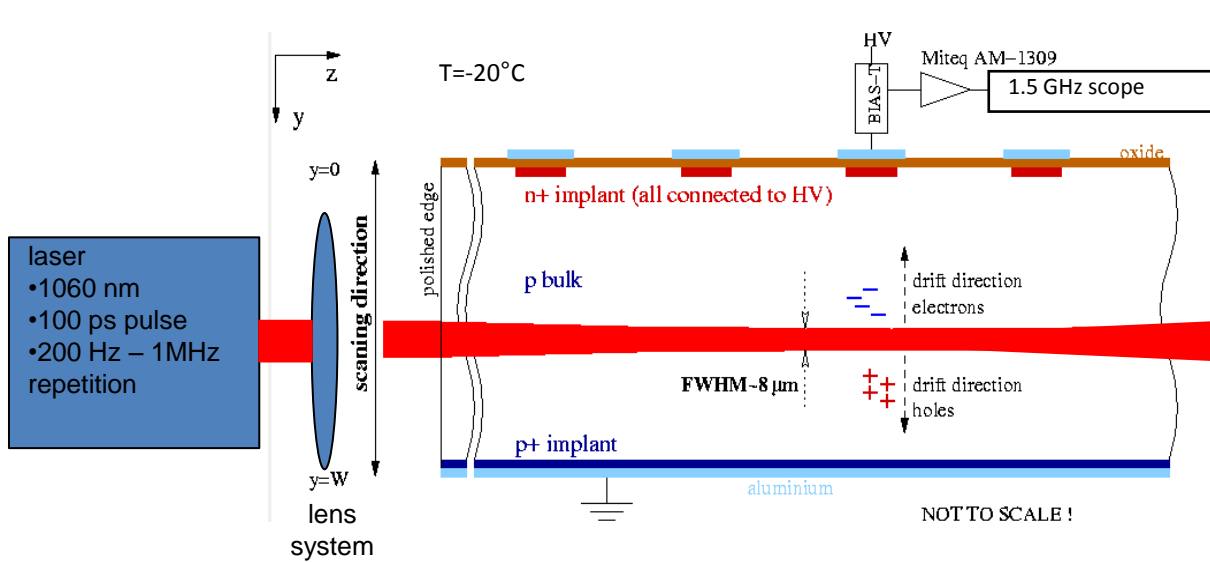




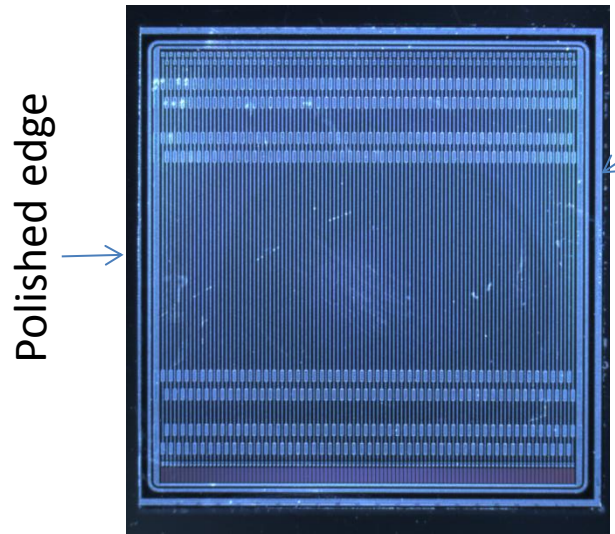
Hamburg model, annealing 80 minutes at 60C.

Parameters: taken from V. Cindro et al. NIM 599 (2009) 60-65

# Edge-TCT



detectors on a Peltier cooled support in dry air atmosphere (down to -20°C)



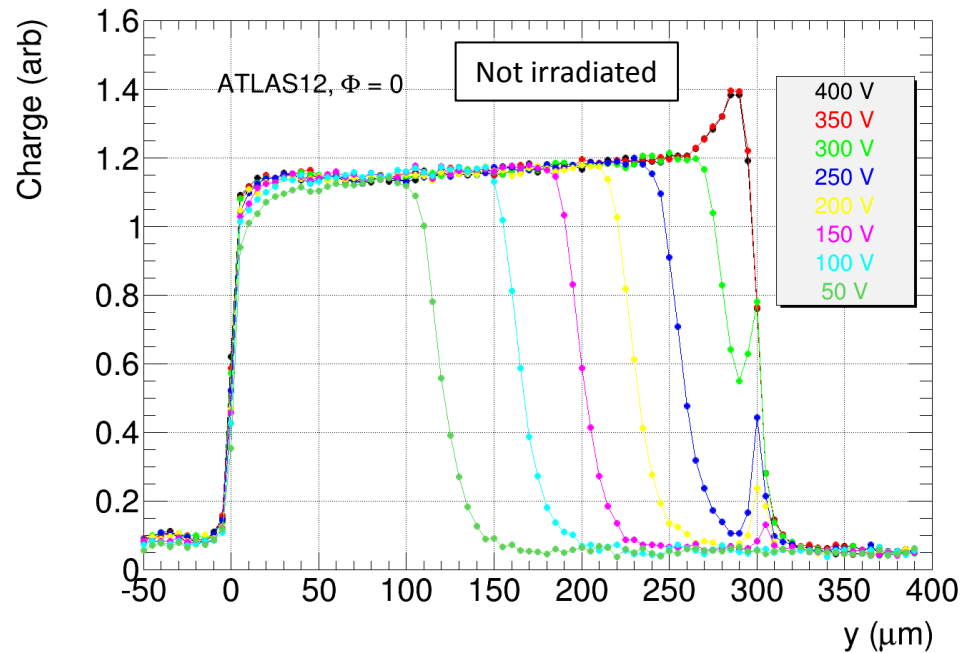
ATLAS12 slim cut  
max bias ~ 400 V before 5e14 n, ~ 750 V after

- Compare with E-TCT measurements with ATLAS07 from 2011 (by M. Milovanović et al.)

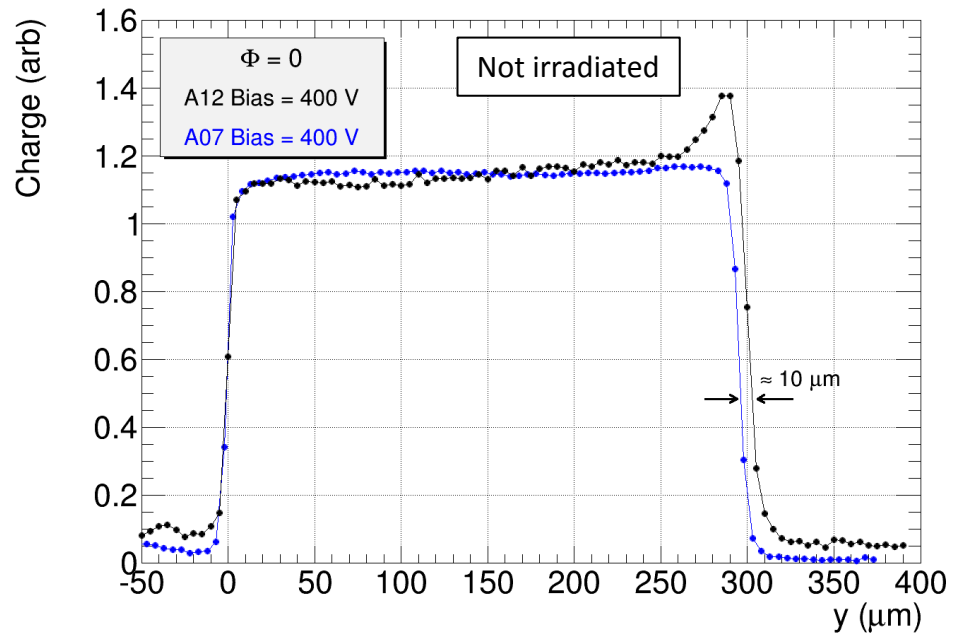
## E-TCT

### Charge vs. depth

- A12 detector depleted at 350 V



- active depth  $\sim 300$   $\mu\text{m}$
- A12 about 10  $\mu\text{m}$  more than A07  
→ as expected

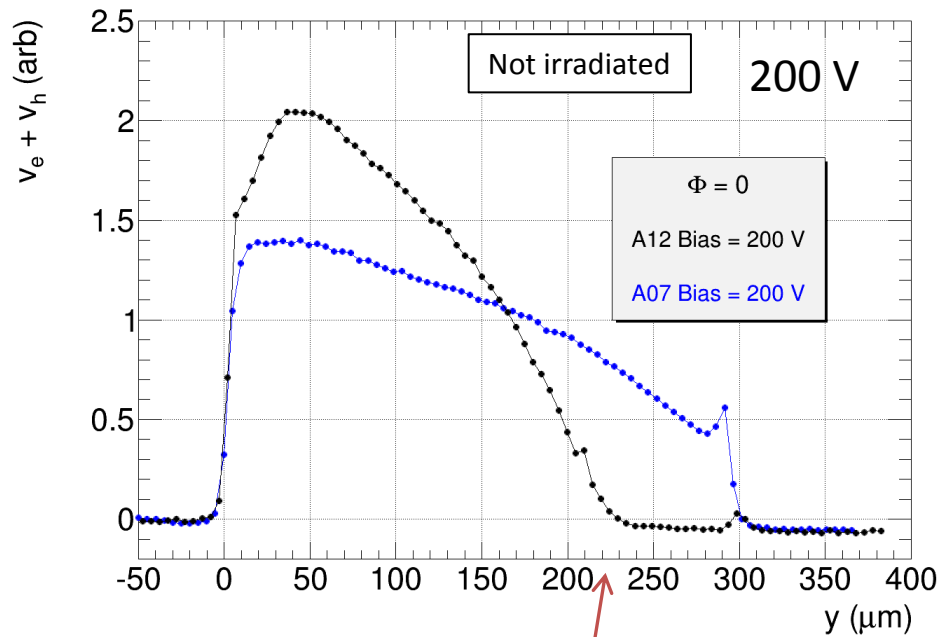


## Velocity profile

$$I(y, t \sim 0) \approx qE_w [\bar{v}_e(y) + \bar{v}_h(y)]; \quad \bar{v}_e(y) + \bar{v}_h(y) \propto E$$

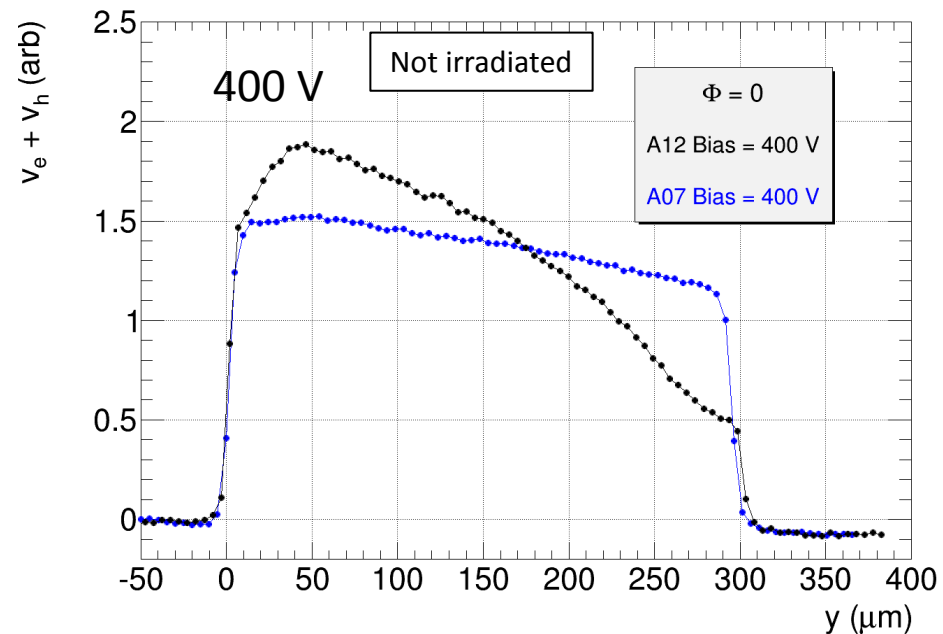
- induced current at  $t \sim 0$  proportional to carrier velocity at laser spot location
- if  $E$  not too large,  $I$  proportional to  $E$  ( $E_w \sim \text{constant}$  (see: G. Kramberger, et al., IEEE Trans. Nucl. Sci. NS-57 (2010) 2294.))
- plots normalized to same integral from 0-300  $\mu\text{m}$  (because  $\int E dx = \text{Bias}$ )

- at 200 V A07 depleted, A12 not



→ expected depletion depth for A12 at 200 V 220  $\mu\text{m}$ !

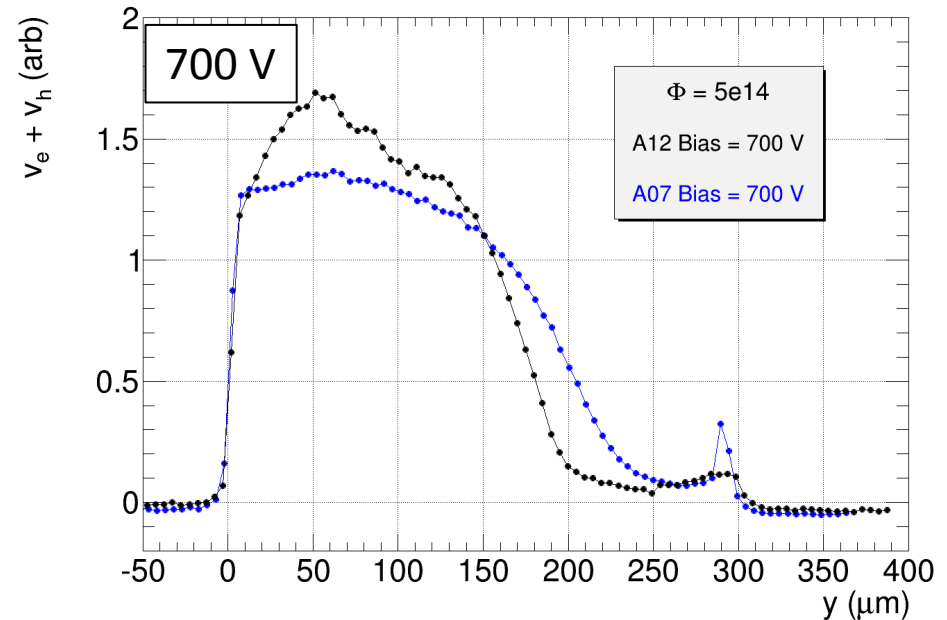
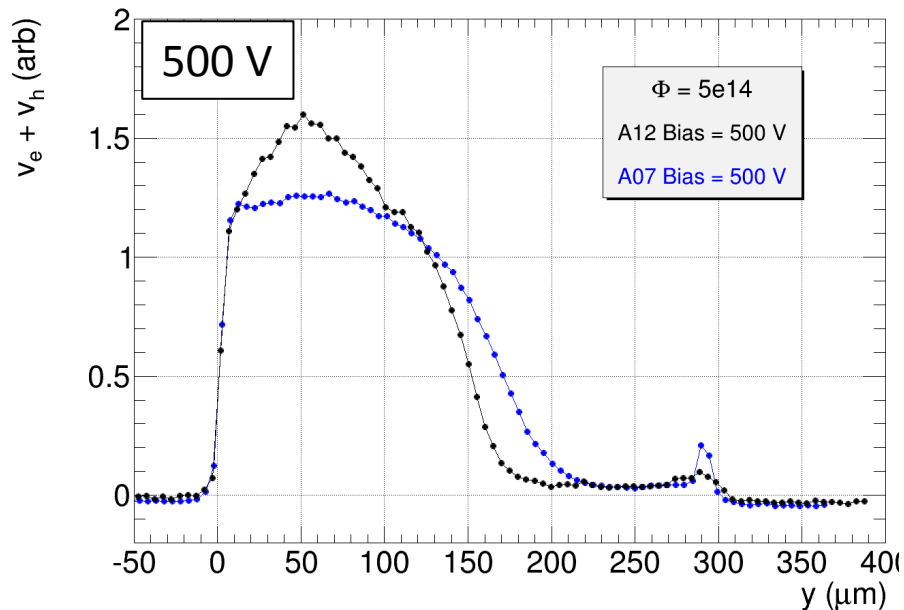
- at 400 V both depleted



## After irradiation with $5e14$ neutrons

### Before annealing:

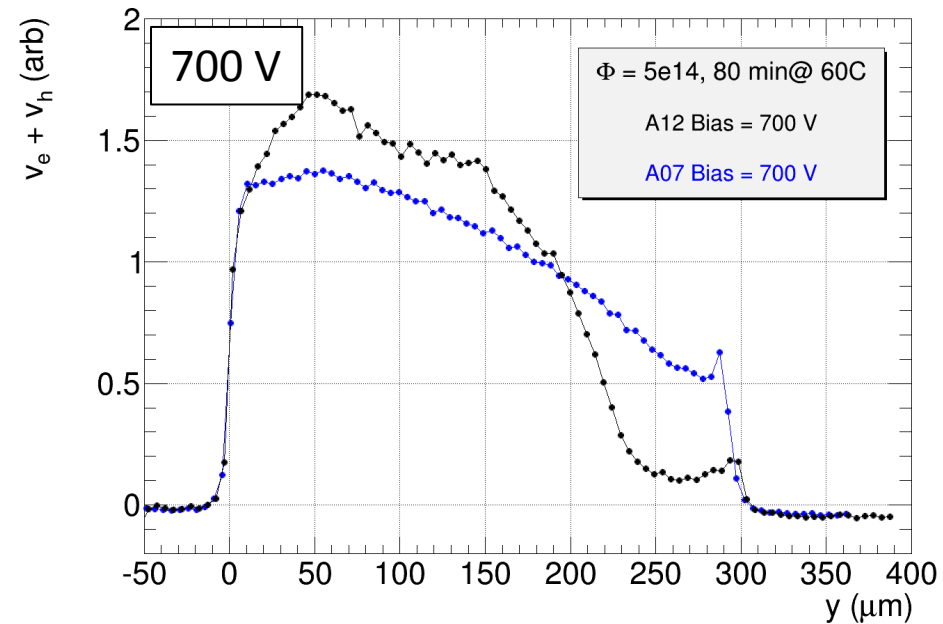
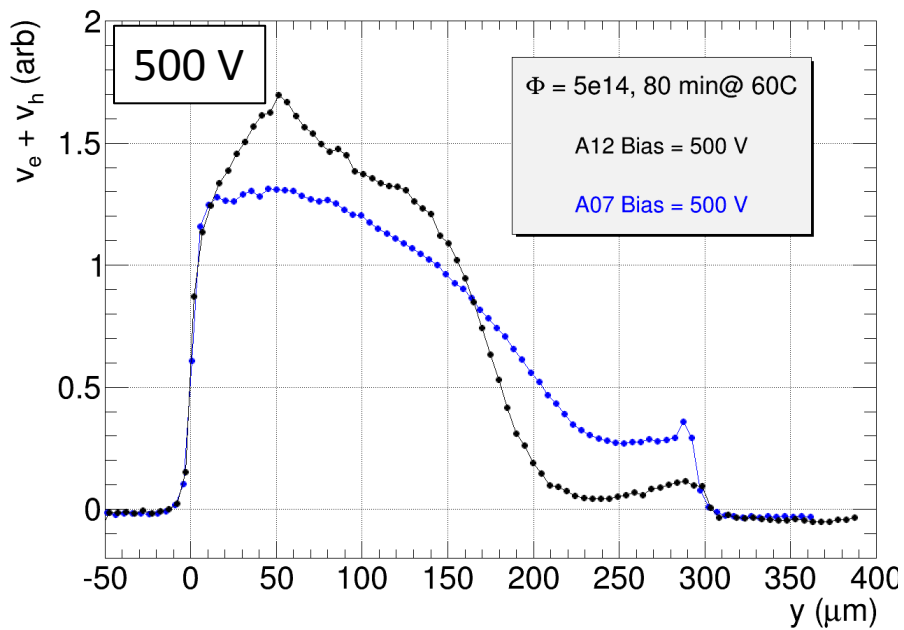
- larger active region in A07
  - roughly in agreement with expectation because of different initial resistivities ( “standard” (Hamburg model) introduction rates and annealing parameters for neutrons)



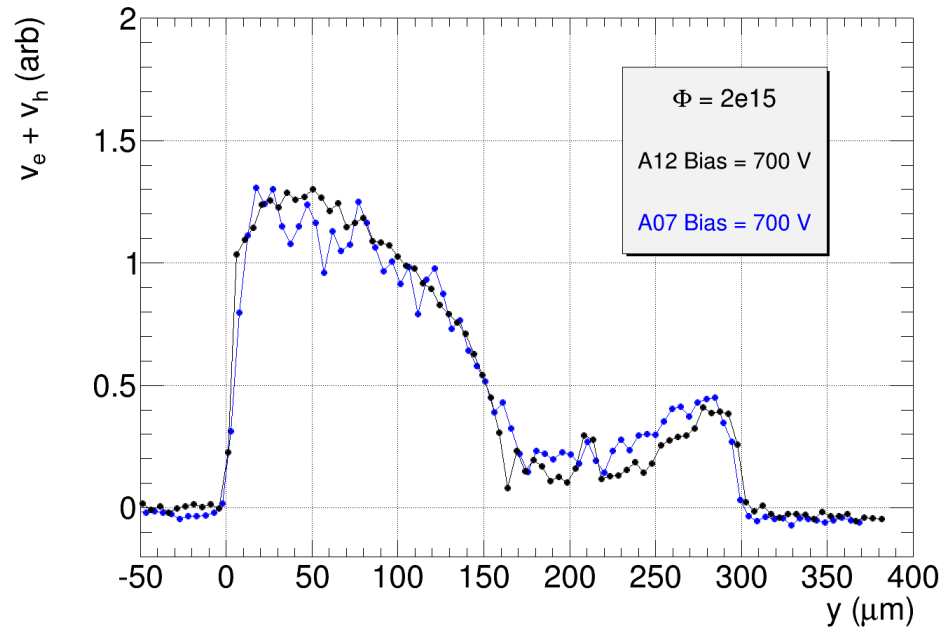
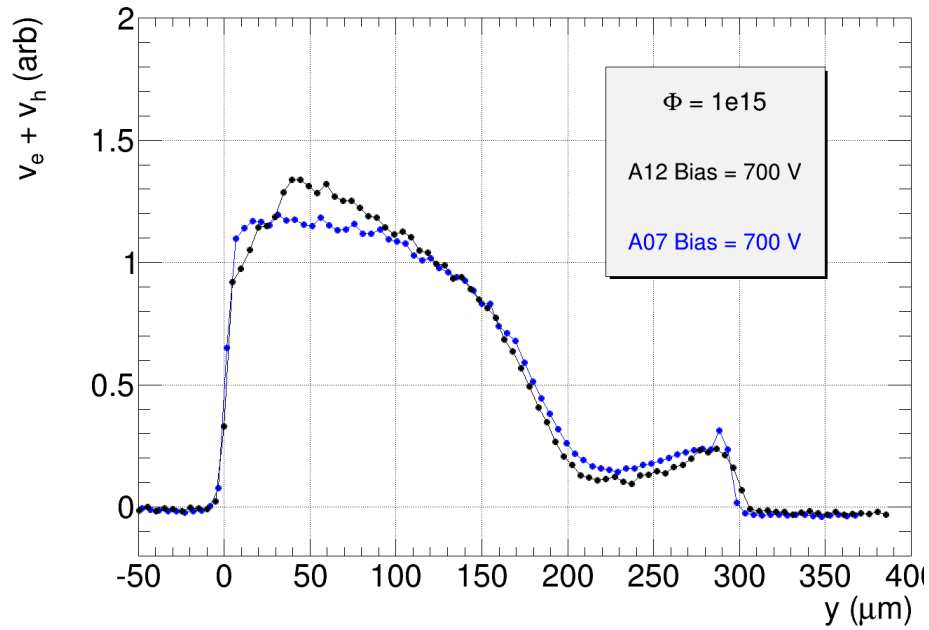
## After irradiation with $5e14$ neutrons

### After annealing for 80 minutes at 60 C

- in A07 significant field at back side already at 500 V
- effect in A12 as expected



# Velocity profiles, A07 A12, annealed 80 min



# Conclusions

- A12 detectors measured after irradiation with neutrons and protons
  - **at lower bias voltages ( $\sim 500\text{V}$ ) collected charge larger after protons then after neutrons**
- comparison A07-A12
  - **after  $5\text{e}14$  neutrons, at  $500\text{ V}$ , more charge measured with A07 than with A12**
    - difference expected because of different initial  $V_{fd}$
  - after  $1\text{e}15$  neutrons no significant difference
  - **at  $1\text{e}15$  very similar long term annealing for A07 and A12, multiplication onset at the same time, voltage point**
- Edge-TCT
  - **active depth of A12 detector  $\sim 300\ \mu\text{m}$**
  - **A12  $\sim 10\ \mu\text{m}$  more active depth than A07**
  - **initial difference in electric field disappears at fluences higher than  $1\text{e}15$**

## Future work:

- irradiation with  $23\text{ MeV}$  protons in Karlsruhe and CCE and E-TCT after that
- 2 A12 detectors sent to PSI irradiation