E-TCT measurements with laser beam directed parallel to strips

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Introduction

- in usual E-TCT measurements focused laser beam is directed to the side of the detector perpendicular to the direction of strips

  - IR laser (λ = 1064 nm), attenuation length in Si ~1 mm
  - charge is generated below many strips
  - carriers drifting to the neighbor strips also induce current on the readout electrode

  → effective weighting field modified:

  ➢ instead of peaked weighting field of a strip detector the effective weighting field is approximately constant $E_w = 1/D$ as in pad detectors

  ✓ good for measurements of velocity profile: $I(y, t \sim 0) \approx q \cdot \frac{1}{D} \cdot [\bar{v}_e(y) + \bar{v}_h(y)]$;

  ➢ charge collection profile of **irradiated** detector is not as in detector application

- if laser beam is directed parallel to strips all carriers (in ideal case) generated along laser beam drift in the same electric and weighting field -> true charge collection profiles could be measured

  ➢ in reality laser beam divergence smears the measurement

- in this presentation some aspects of this measurement technique will be presented

Simulation

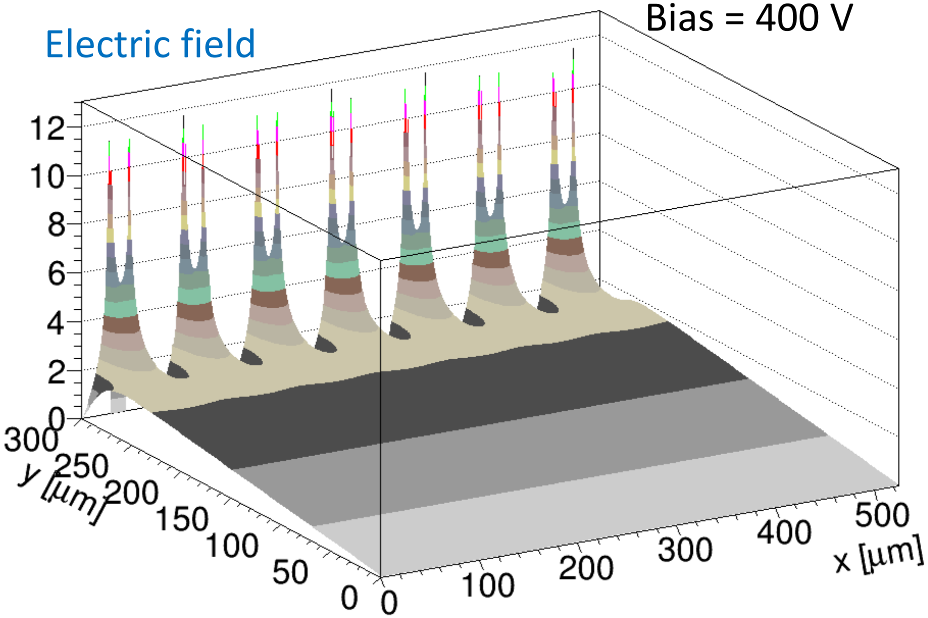
- KDetSim by G. Kramberger
- described in:

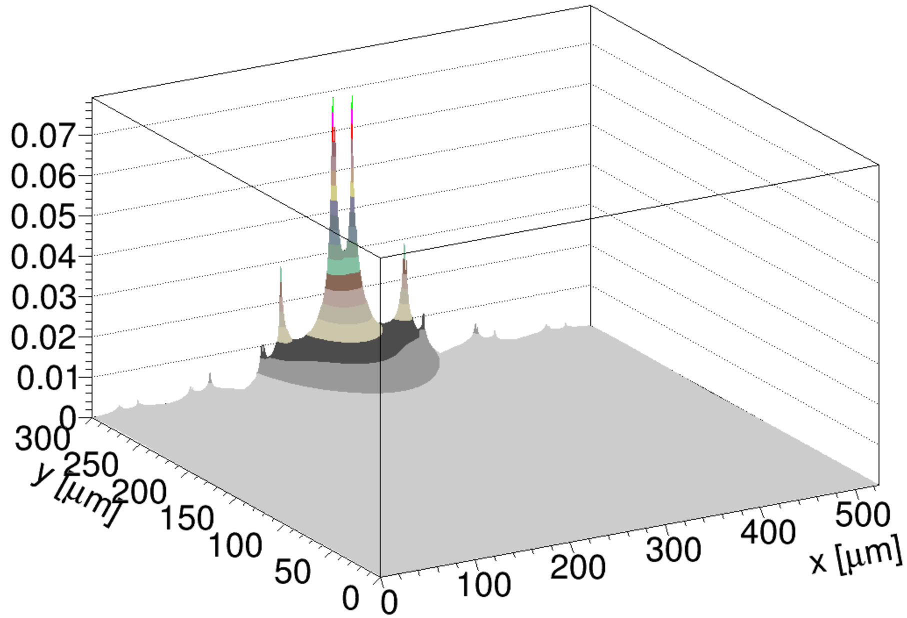
G. Kramberger et al., IEEE Trans.Nucl.Sci., Vol 49, (2002), 1717.
G. Kramberger et al., NIM A 457, pp-550-557,2001.
G. Kramberger et al., 2014 JINST 9 P10016

P-type strip detector, pitch 75 um, strip width 20 um
N_{eff} = 4.76e12 cm^{-3} (V_{fd} ~ 350 V)
(approx. Hamamatsu ATLAS12)

Bias = 400 V

Electric field



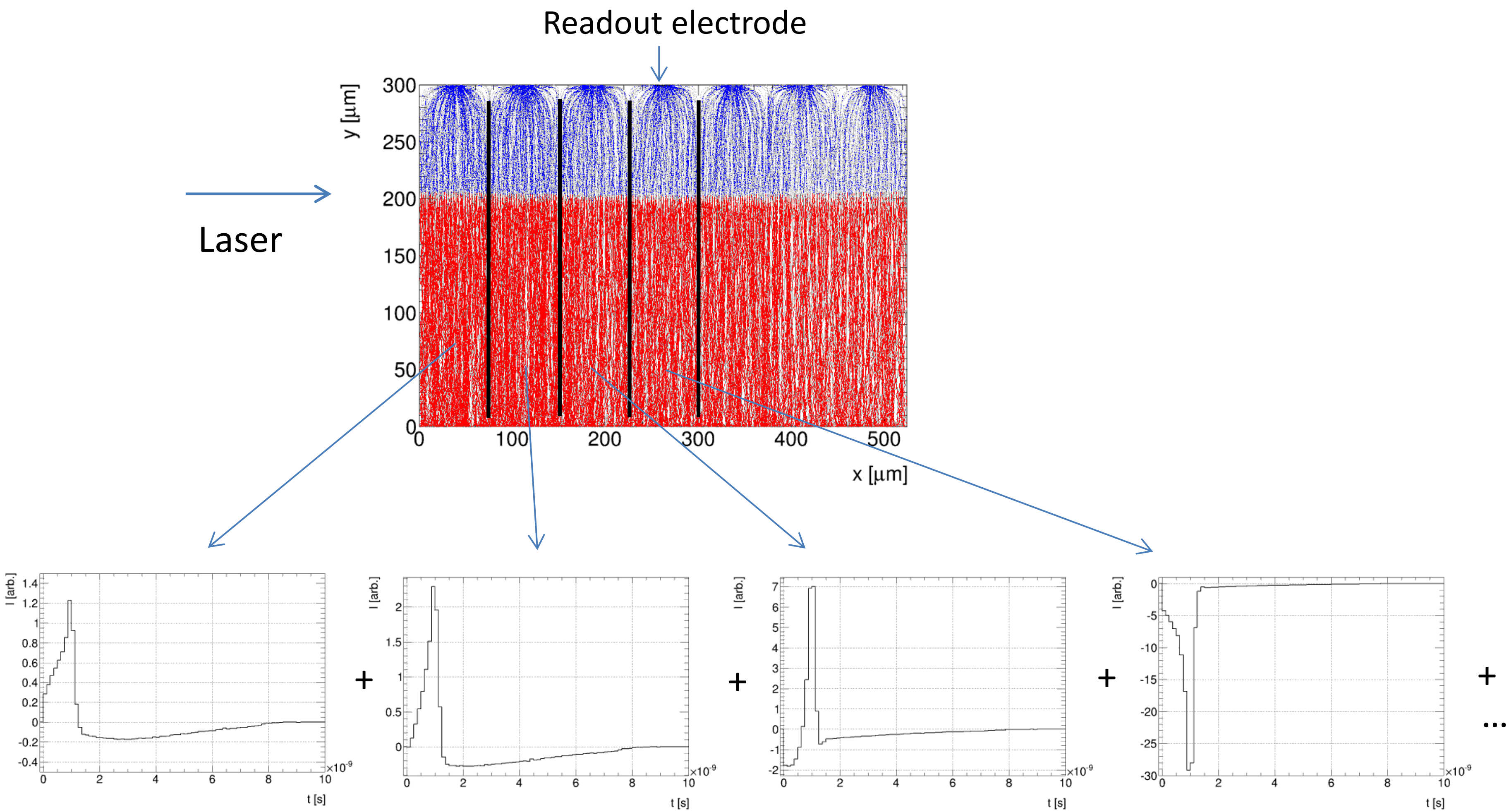


Weighting field

→strongly peaked at the readout strip

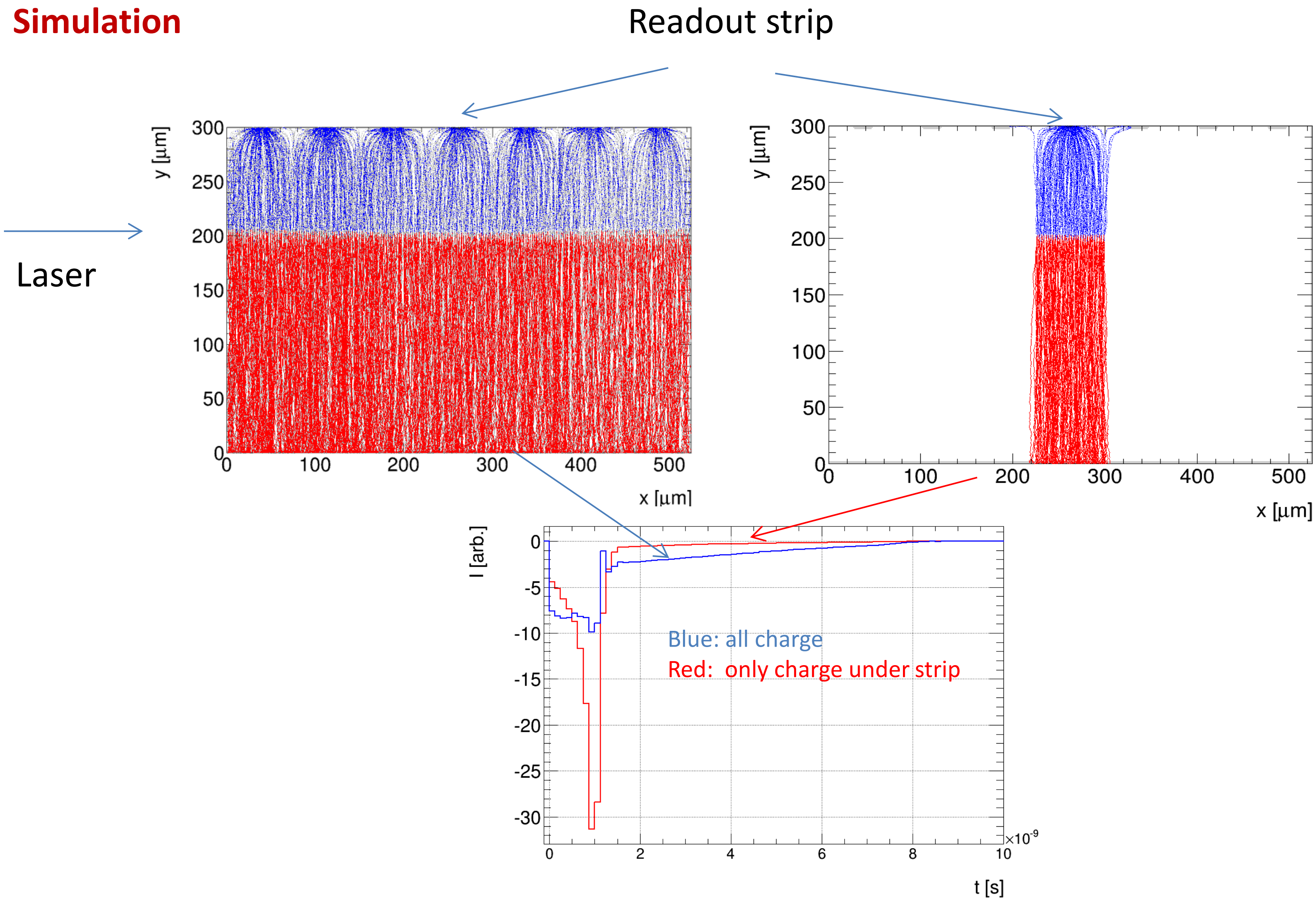
Simulation

- standard E-TCT



- current pulse on readout strip in E-TCT is induced also by charge drifting under neighbor strips
  → measured pulse is the sum of all contributions

Simulation



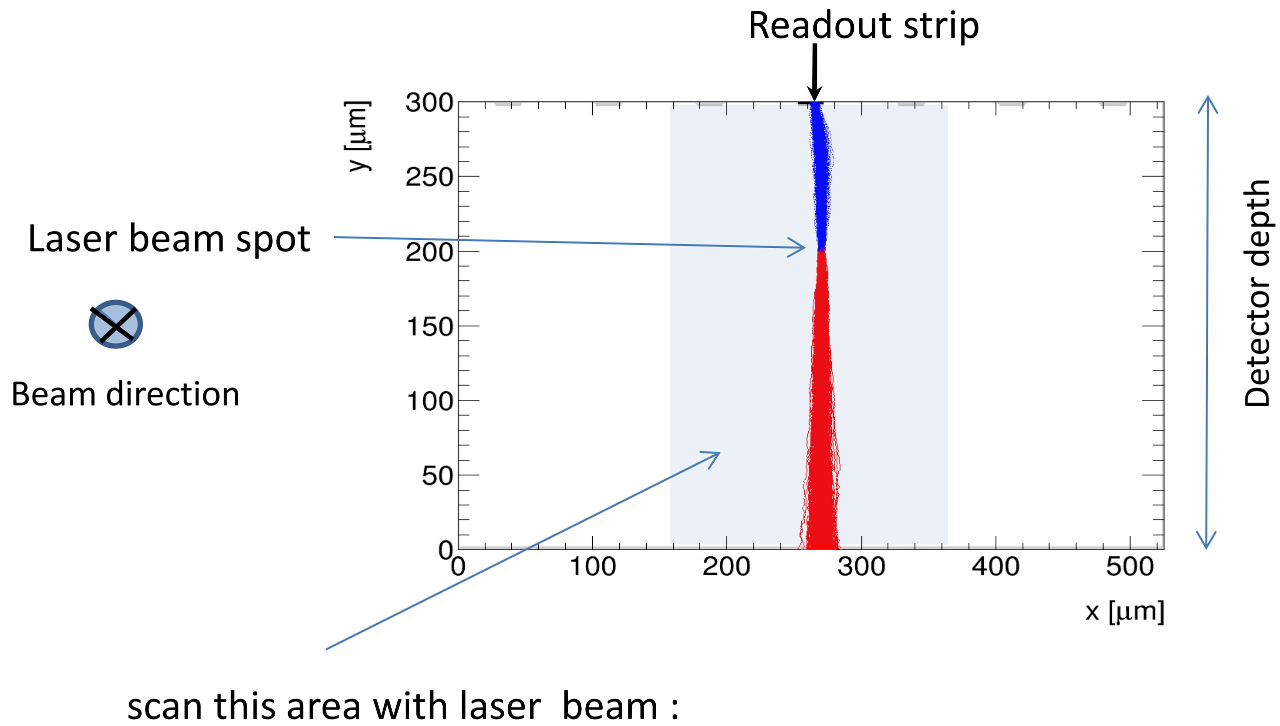
- pulses different because of carriers drifting to other strips ➔ reason for effective E_w = 1/D in E-TCT
- charge (integral of the pulse) same for **blue** and **red** pulse before irradiation
  - ➔ in irradiated detector carriers do not drift over whole weighting field because of trapping
  - ➔ charge is not the same for the two cases

Simulation

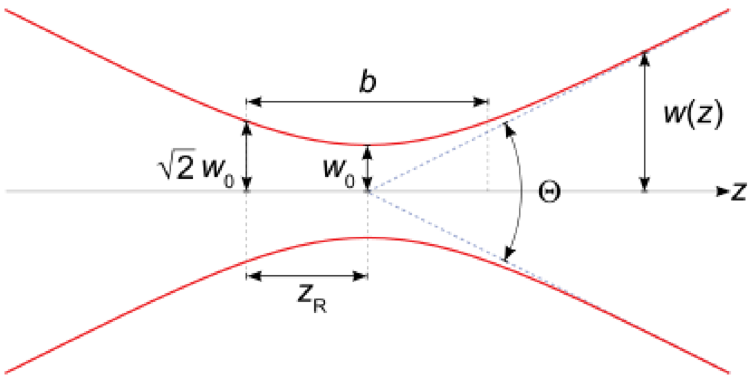
• laser beam in the direction of strips:

→ "real" strip weighting field
→ "real" charge collection profiles in irradiated strip detectors could be measured

Problem: laser beam divergence



Gaussian beam



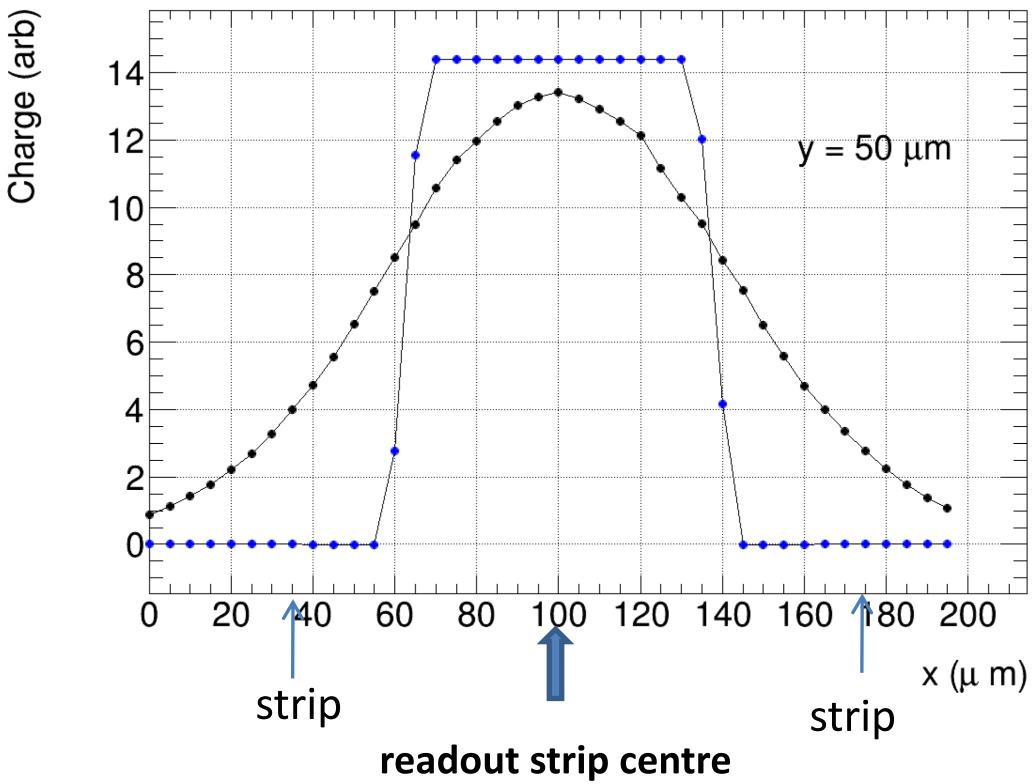
- Gaussian beam spot size: $w = w_0 \cdot \sqrt{(1+(\frac{z}{z_R})^2)}$, $\quad z_R = \frac{\pi w_0^{\;2}}{\lambda}$, $\quad z_R = 168\mu m$

→ initial beam spot radius w_0 = 4 µm ➔ at z = 2 mm radius already w = 48 µm

→ absorption length ~ 1 mm, contribution gets smaller as beam spot grows

Simulation

- compare collected charge - time integral of the induced current pulse (at depth y = 50 μm) **with** and **without** beam divergence

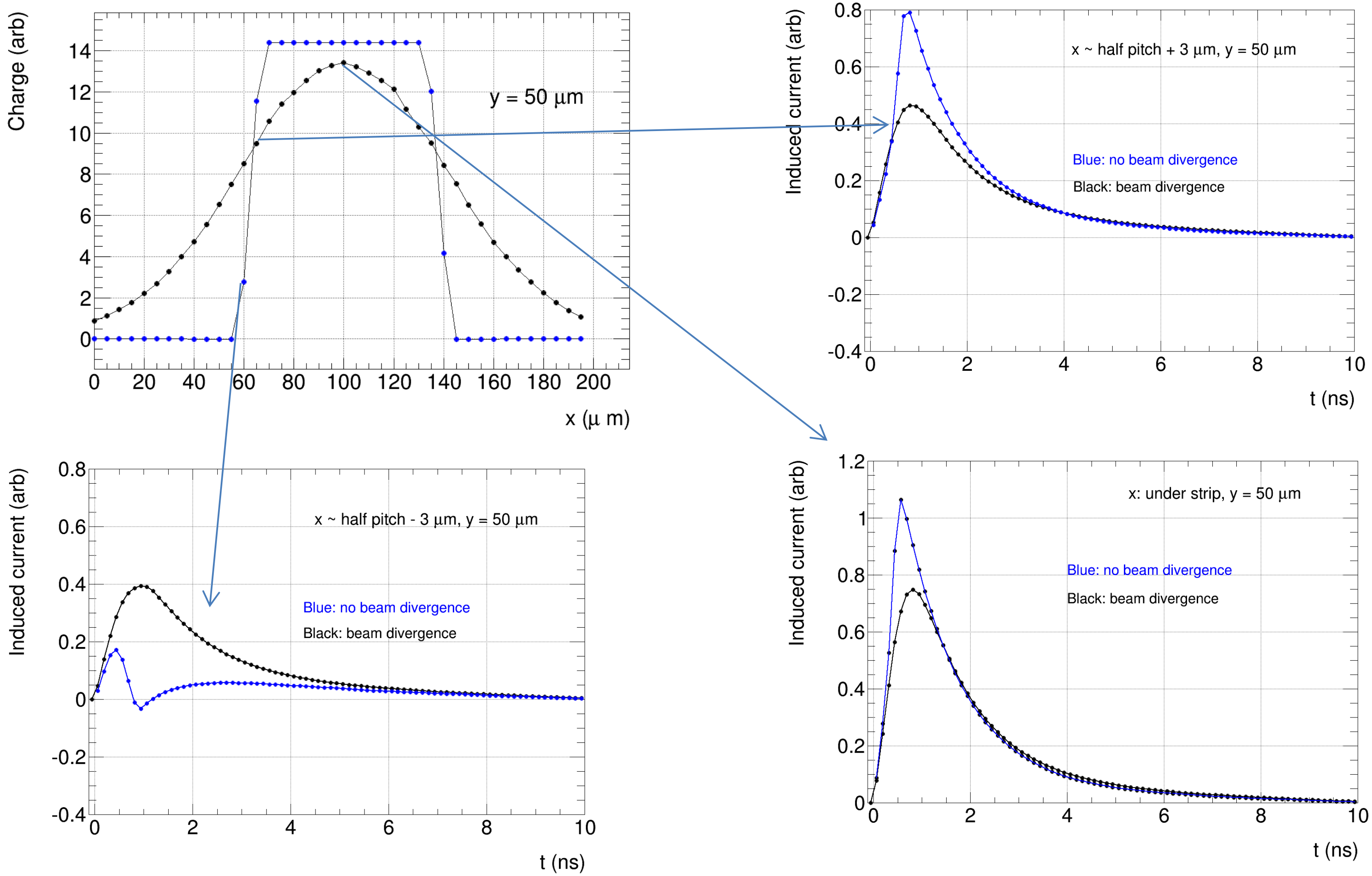


Blue: no divergence
Black: beam divergence

- more than half pitch (35 μm) from the strip centre large effect of beam divergence

Simulation

- compare induced current pulses with and without beam divergence



→below readout strip, less than half pitch from the strip centre, differences not dramatic

→ further away carriers released by diverged beam drifting to the readout strip dominate the pulses

Simulation:

- E-TCT measurements with laser beam parallel to strips can be done in the area under strip
  → not too sensitive to beam divergence

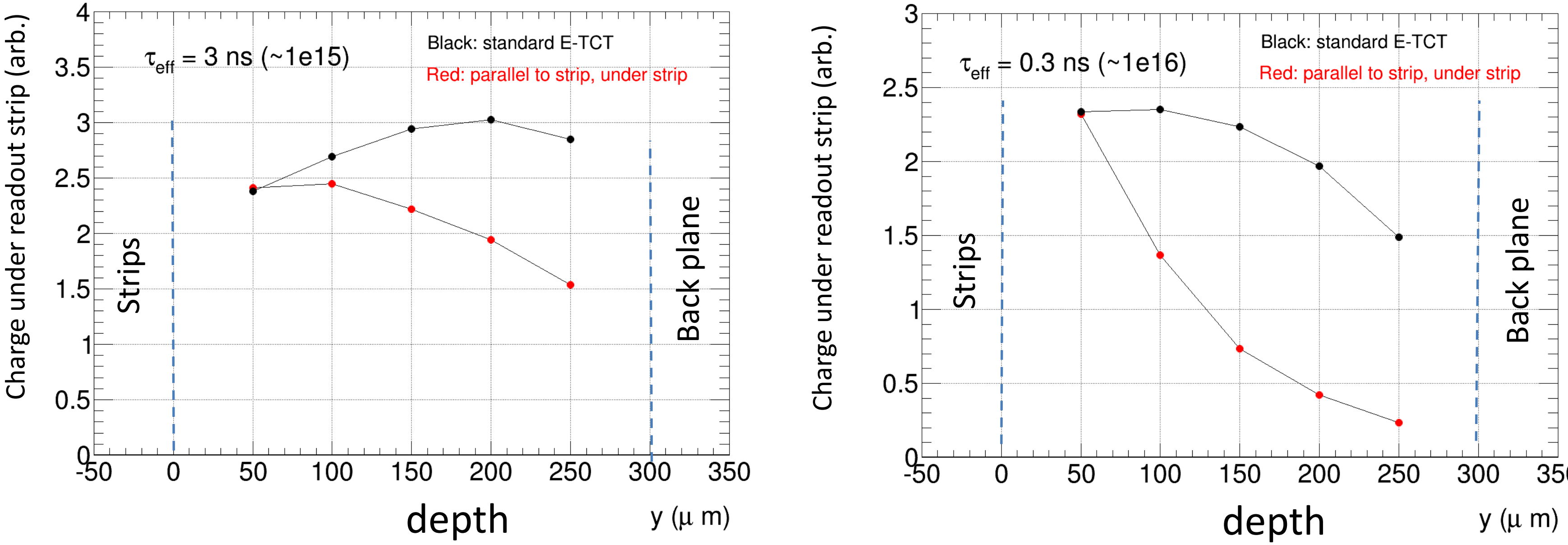
- compare **standard** E-TCT and **parallel** with strips

  → E-TCT **parallel** with strip: information about charge collection profile in irradiated strip detectors

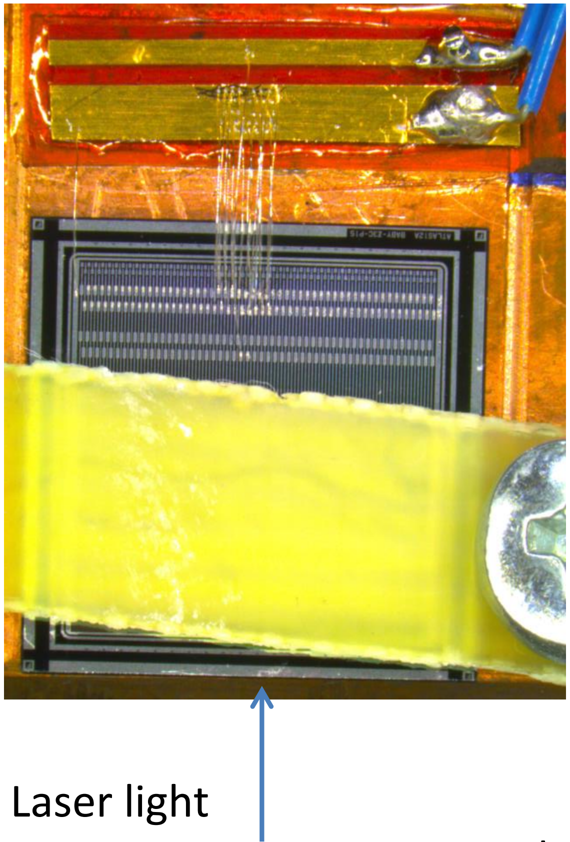
  → **standard** E-TCT: weighting field not realistic, overestimated contribution of charge from larger detector depths

Trapping: multiply induced current pulses with *exp(-t/τ_{eff})* and integrate to get the charge:

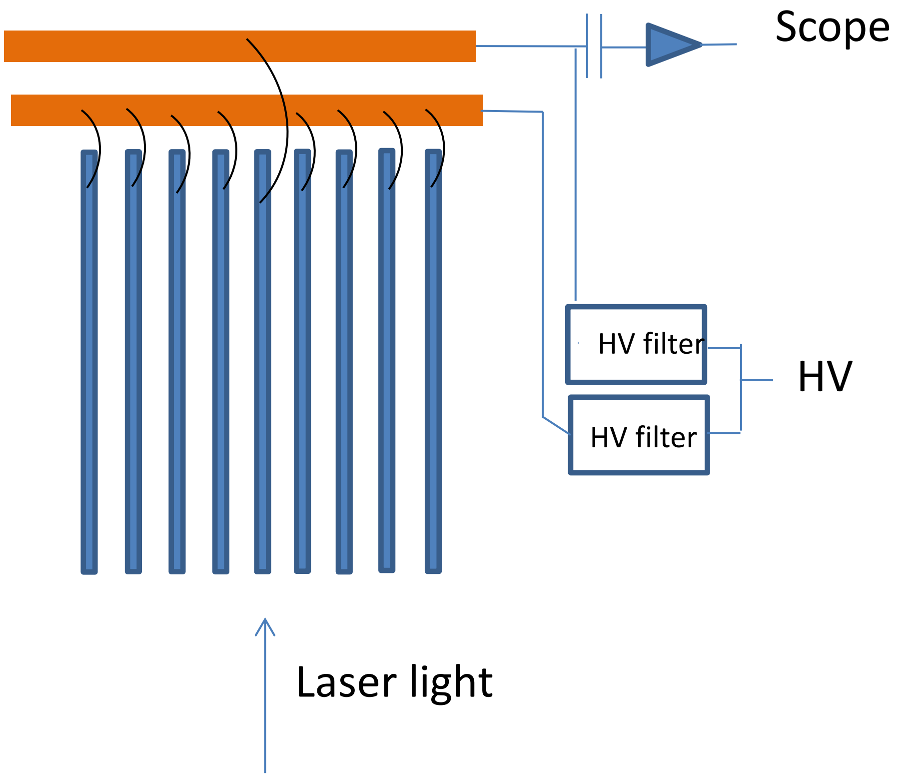
Warning: electric field here is not realistic and is the same for both trapping time



Measurements



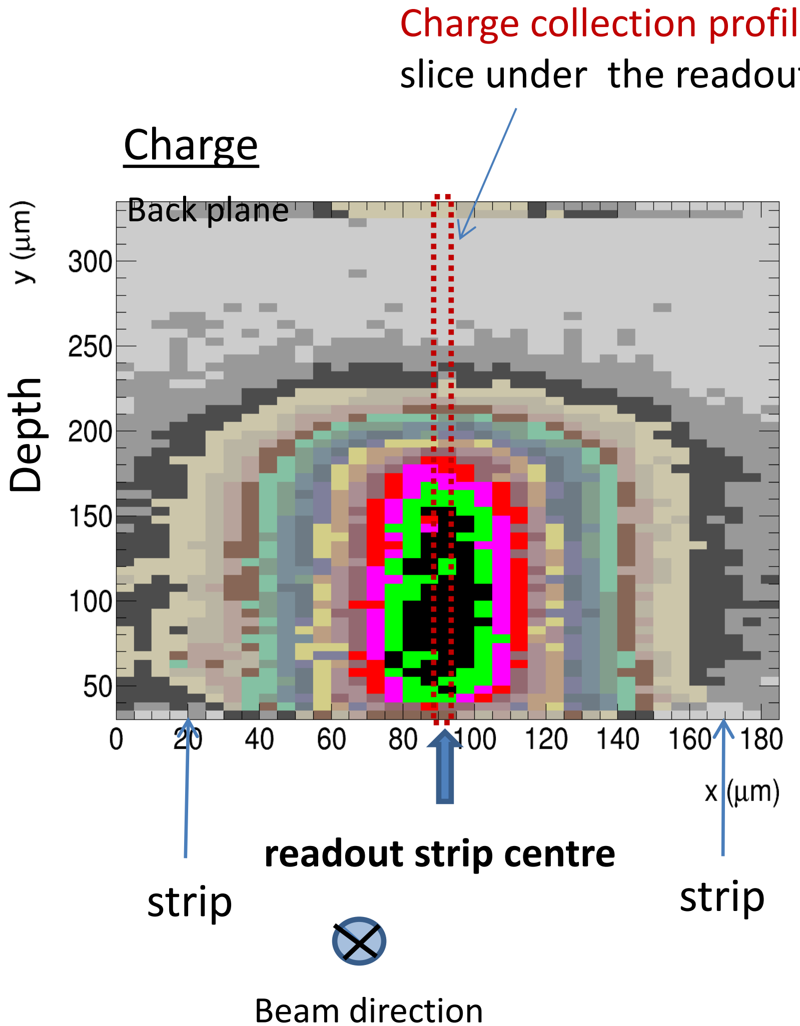
Laser light

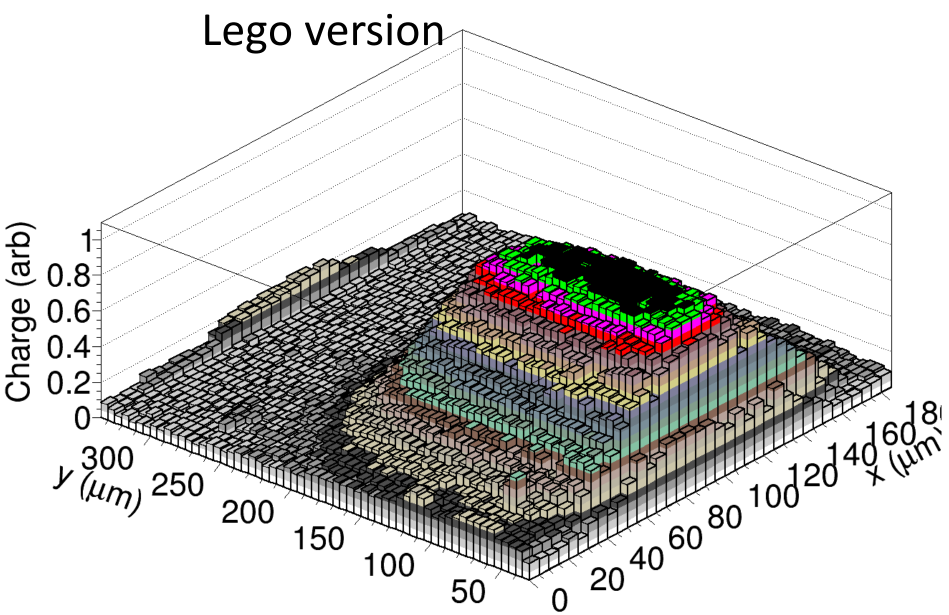


- Atlas12 mini strip detector
- n-in-p
- pitch 75 µm
- V_{fd} ~ 370 V

Measurements

- charge before irradiation, Bias = 100 V (not fully depleted)

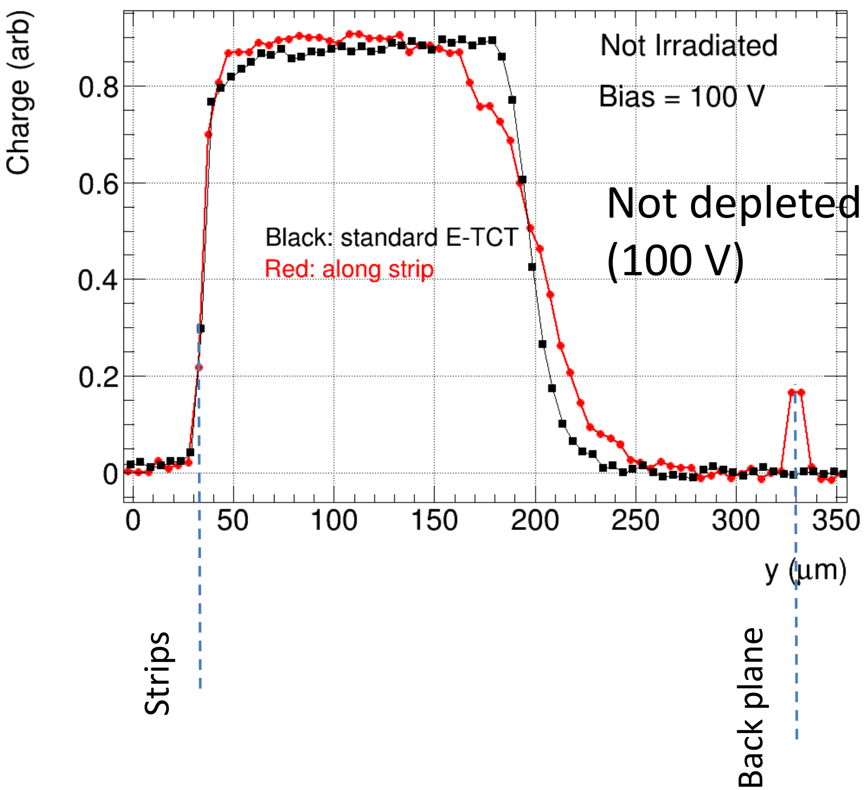


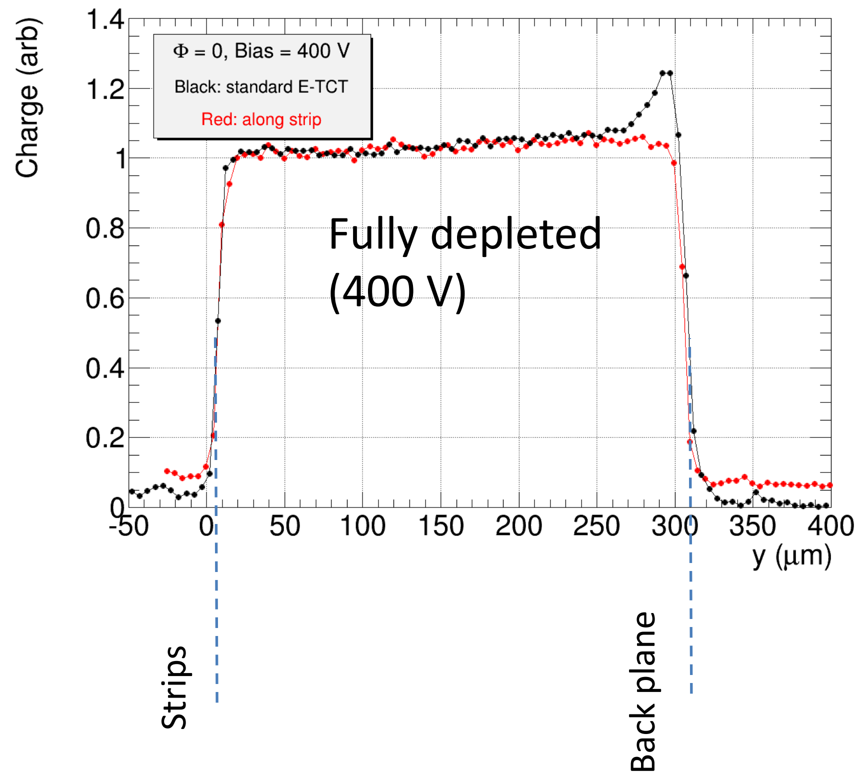


Measurements

- compare charge collection profiles measured with standard E-TCT and with laser parallel to strip:

  → charge collection profiles under strip before irradiation similar
  → beam spread influences also resolution in *y* direction

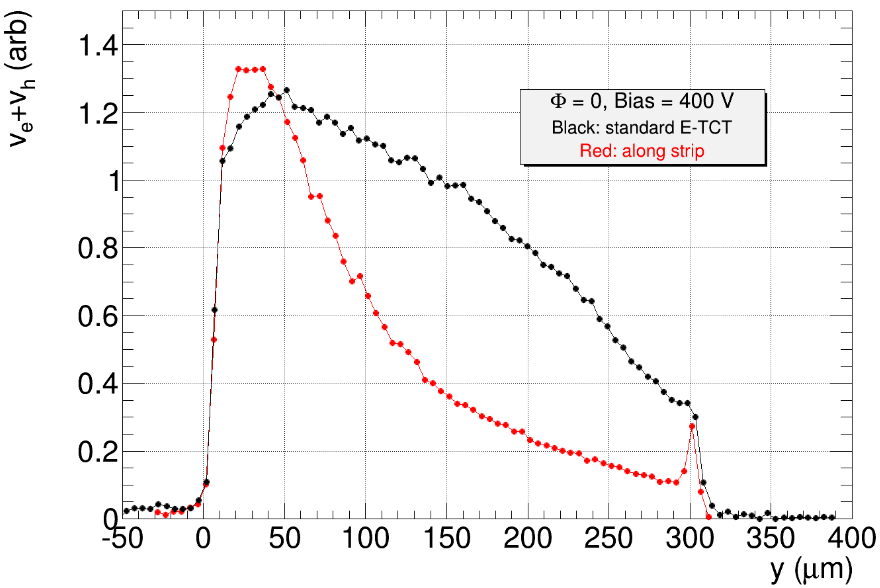




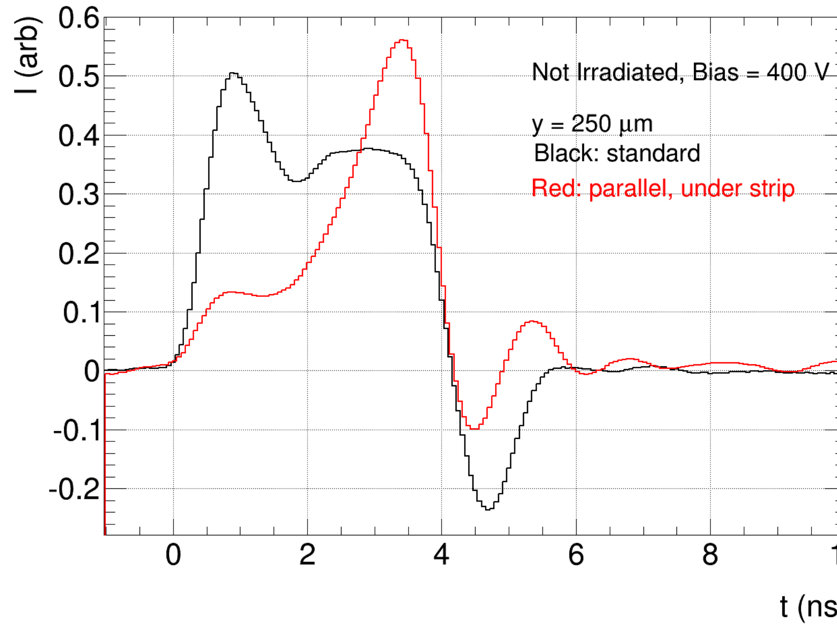
Measurements

• velocity profiles and pulses different:

Velocity profile



Pulses at *y* = 250 μm deep (near backplane)

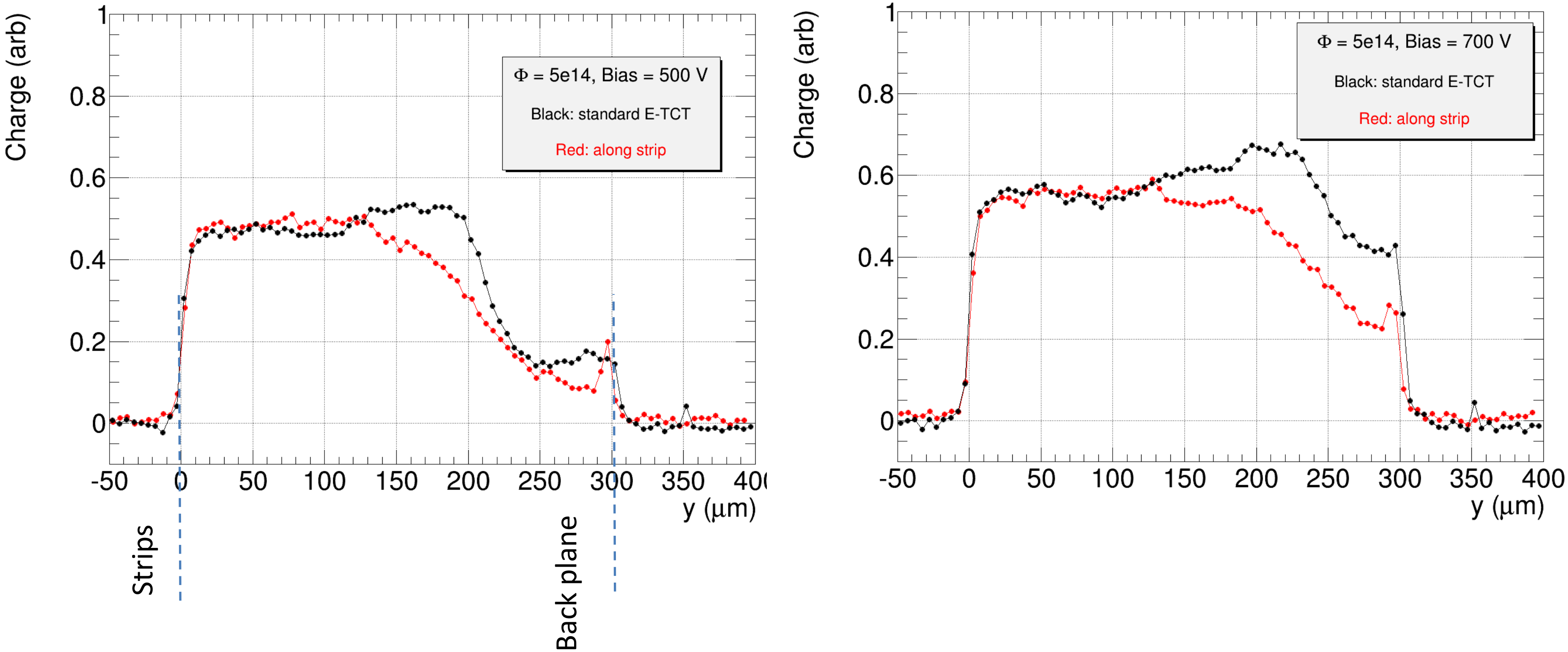


E_w different:

$$I(y, t \sim 0) \approx q \cdot E_w \cdot [\bar{v}_e(y) + \bar{v}_h(y)];$$

Measurements

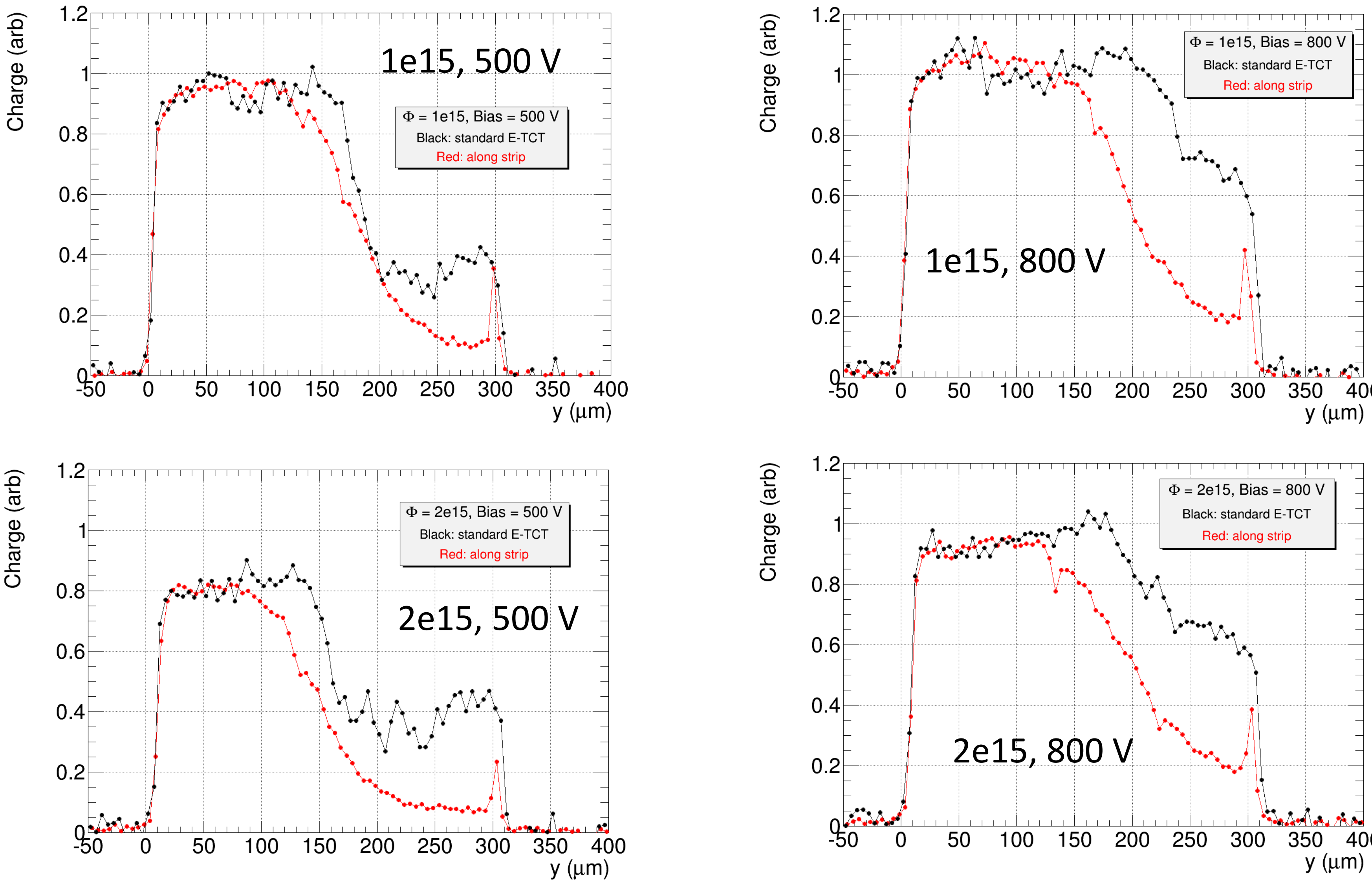
- irradiated detector Φ = 5e14 n/cm^2
- normalize to same charge at y = 0 µm for standard and parallel (along strip)



- less charge than with standard E-TCT measured near back plane

Measurements

- higher fluences



Conclusions

- E-TCT with laser light parallel to strips can be used to better estimate charge collection profiles in irradiated strip detectors compared to standard E-TCT

  → standard E-TCT overestimates contribution of the back side of the detector
  → standard E-TCT good for velocity profiles

- because of divergence of laser beam in the detector only limited spatial resolution can be reached

Future work:

- try with laser light with shorter penetration depth to get better resolution

- measure charge collection profiles with detectors irradiated with 26 GeV protons or pions where strong double peak field was observed with standard e-TCT:

Example: standard E-TCT charge collection profile measured with ATLAS07 detector irradiated with PSI pions to Φ_{eq} = 1.6e15 n/cm2

M. Milovanović, 18thRD50 meeting, Liverpool 2011