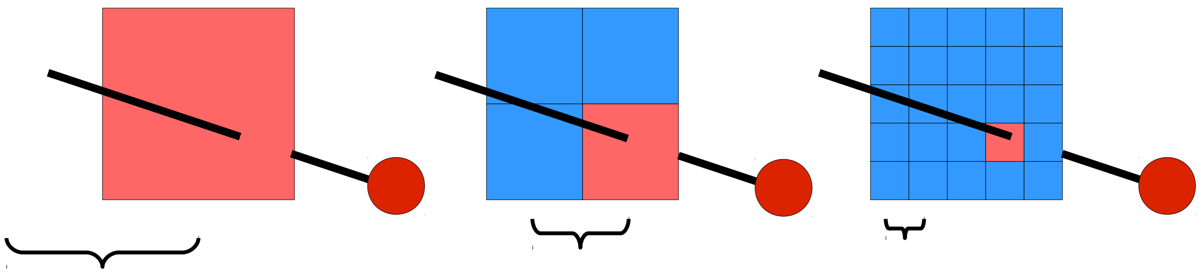
Concept of an enhanced later drift sensor

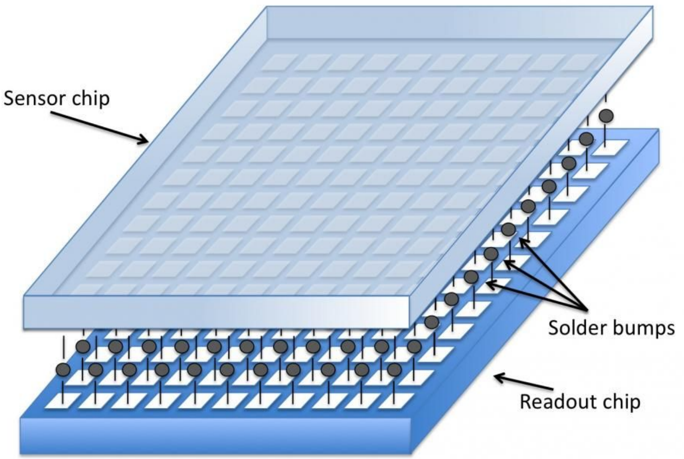
Manufacturing the bulk

Hendrik Jansen

How to archive high resolution?

- Accurate guess: make pitch smaller





→ Increases number of readout channels
→ Potentially higher band width from detectors
→ Less space on-chip per channel
→ Higher power dissipation

- Miniaturisation has limits

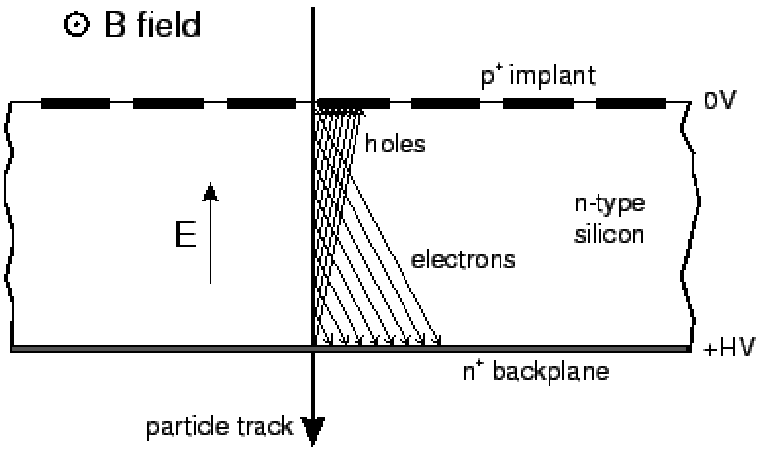
→ Size of bump bonds, wire bond pads, cross talk,
→ Minimum of logic/processing on-chip

→ Is there another solution?

Charge coll. at perpendicular incident

- Enable charge sharing by

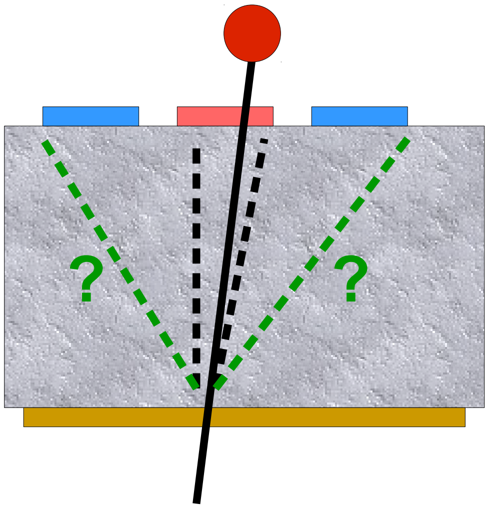
  B-field and/or tilting of sensor
  - increases effective area collecting charge
  - increases material budget in beam



- No tilt + no magnetic field:

  → Little to no charge sharing

- How can charges be spread laterally, left and right?

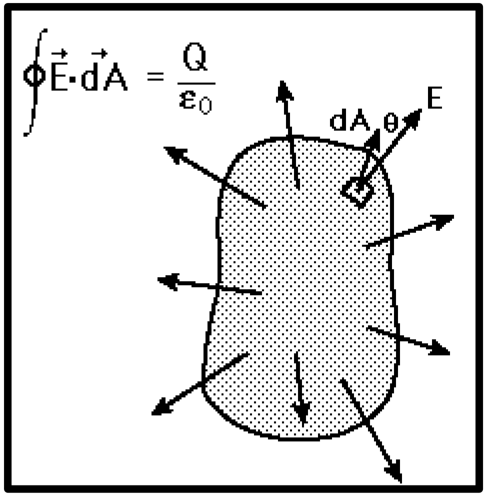


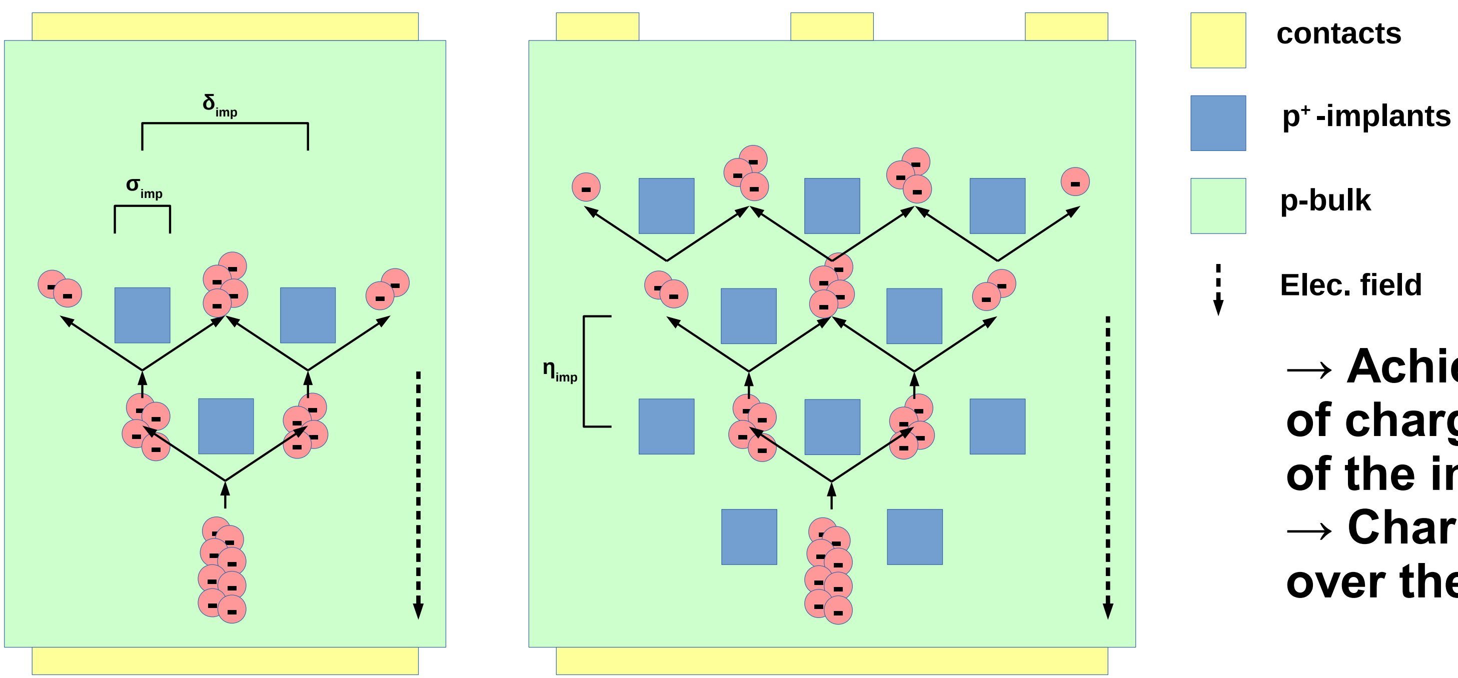
Manipulating the electric field

- Path of drifting charges follows the electric field lines
  → Local doping changes the electric field locally
  → Tailor electric field as needed!

$$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\epsilon_o}$$

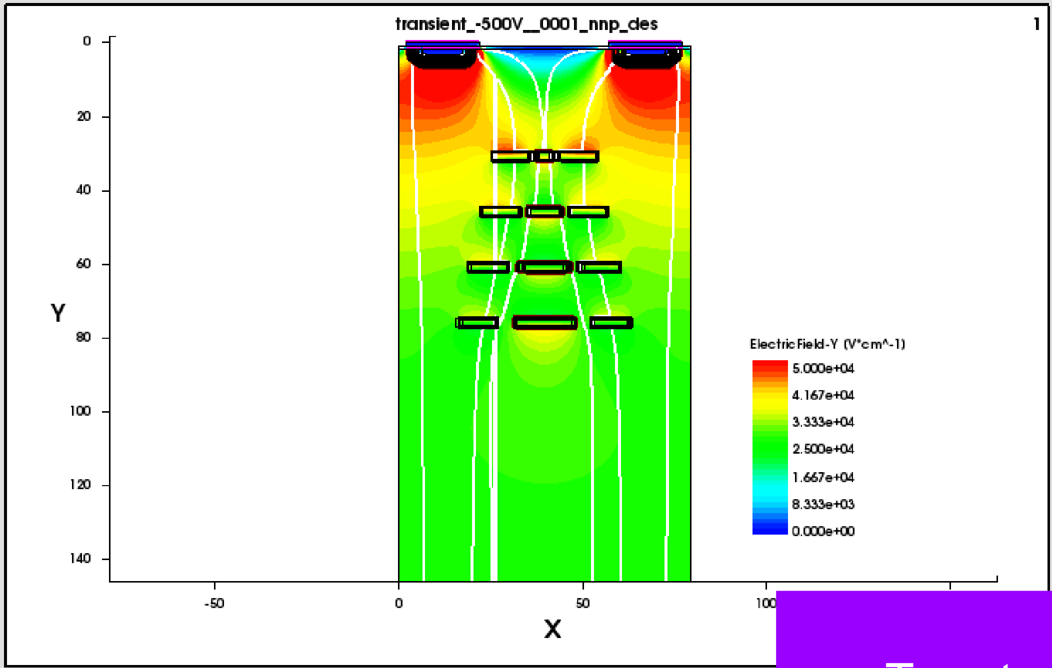
- If approached head-on, repulsive areas split the charge cloud 50-50.
  → Apply this layer-wise.

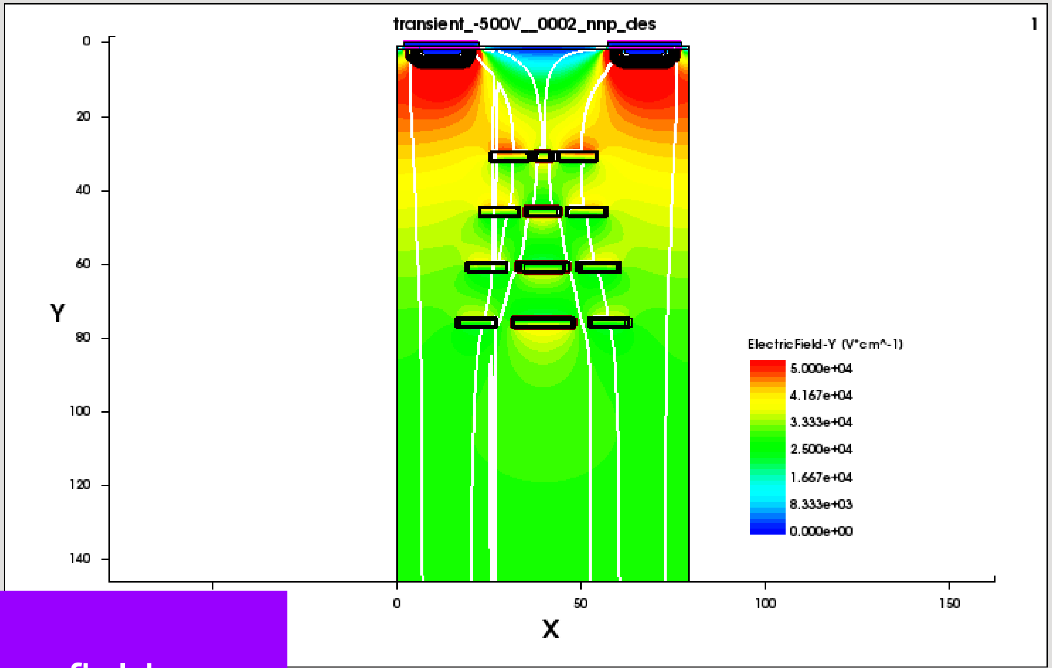


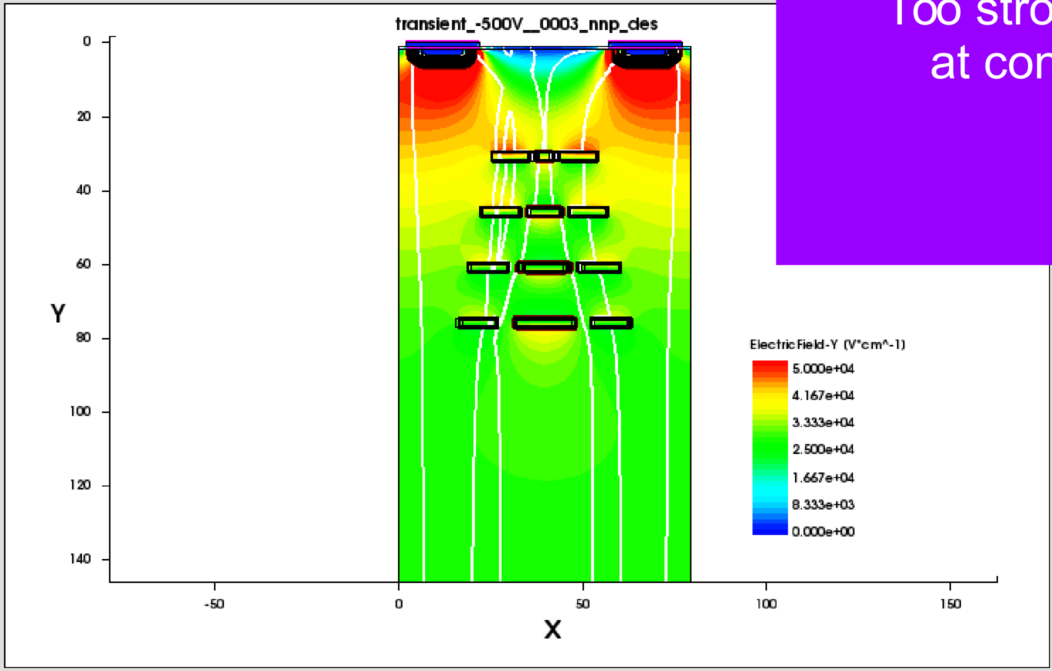


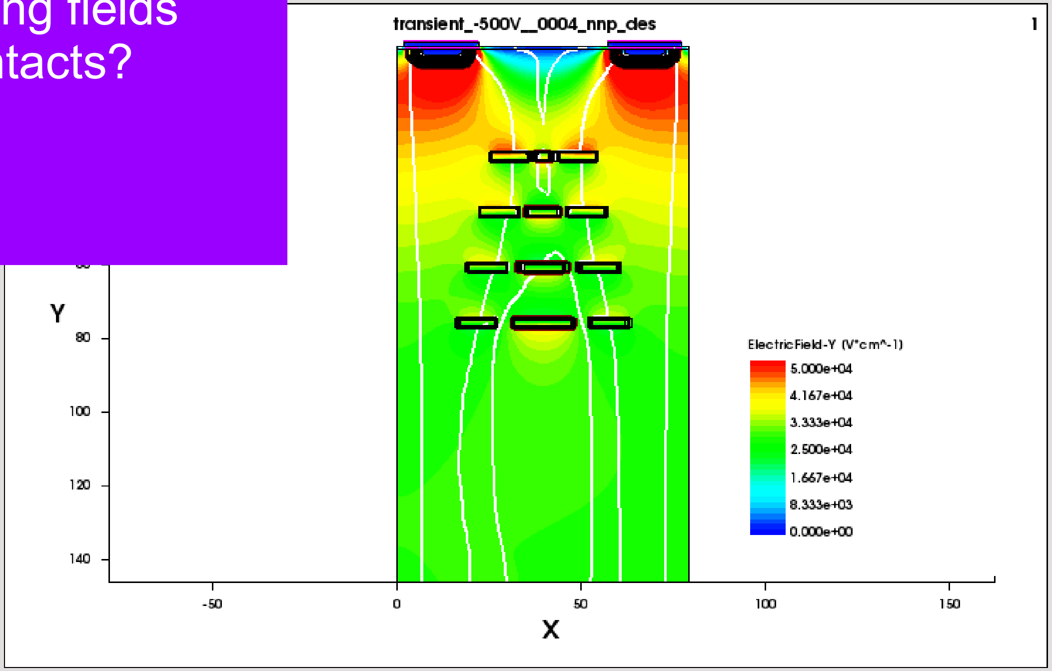
→ Achieve lateral enlargement of charge cloud independent of the incident position
→ Charge weighting enabled over the entire pitch length

Field Y



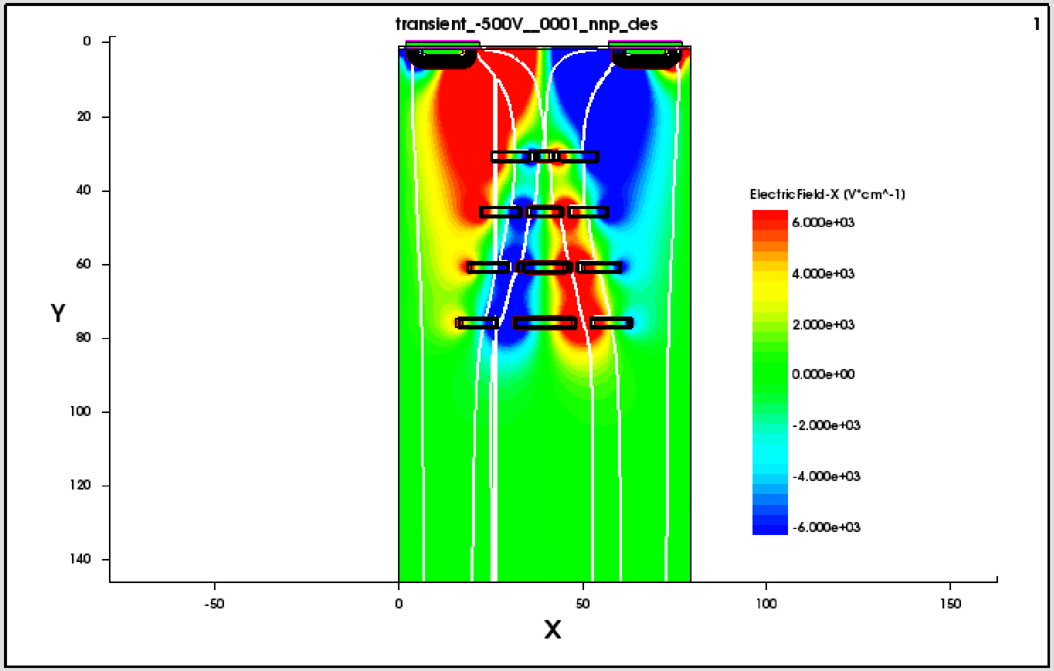


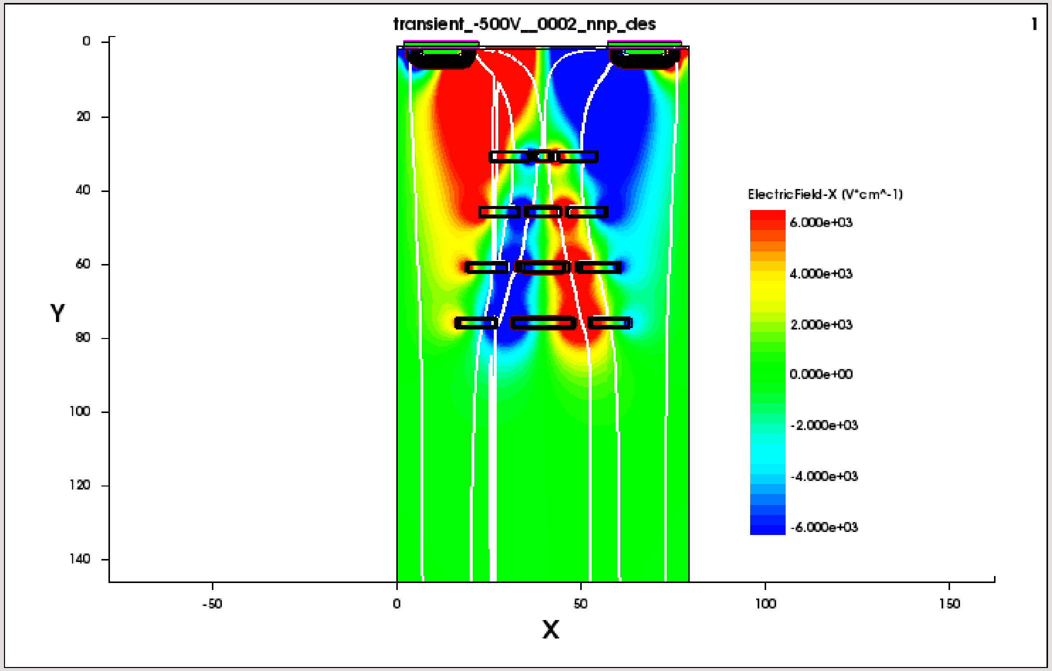


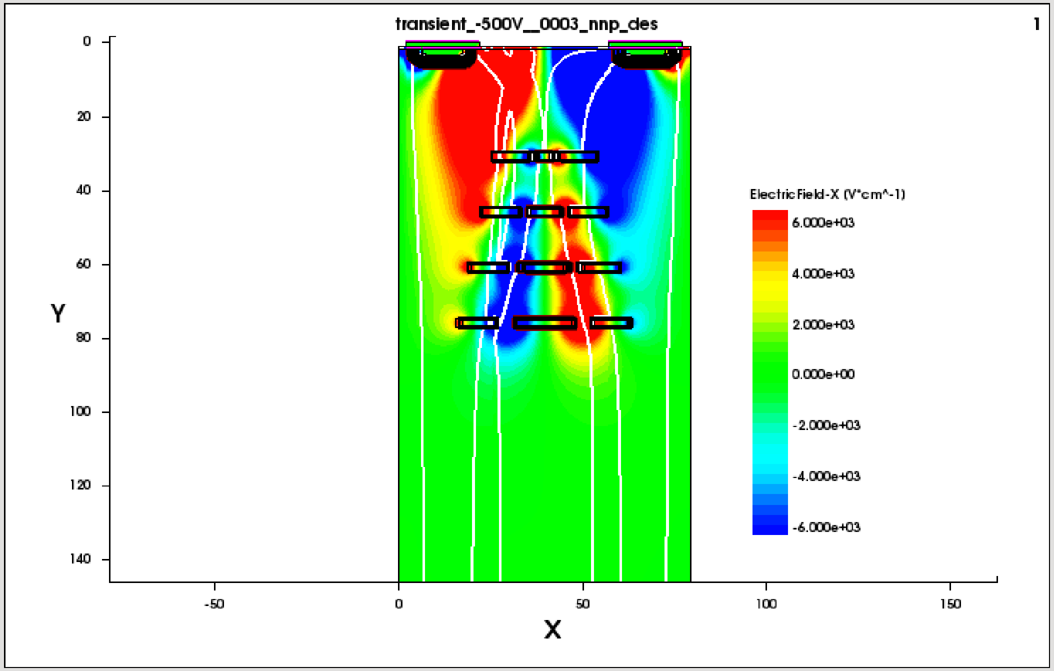


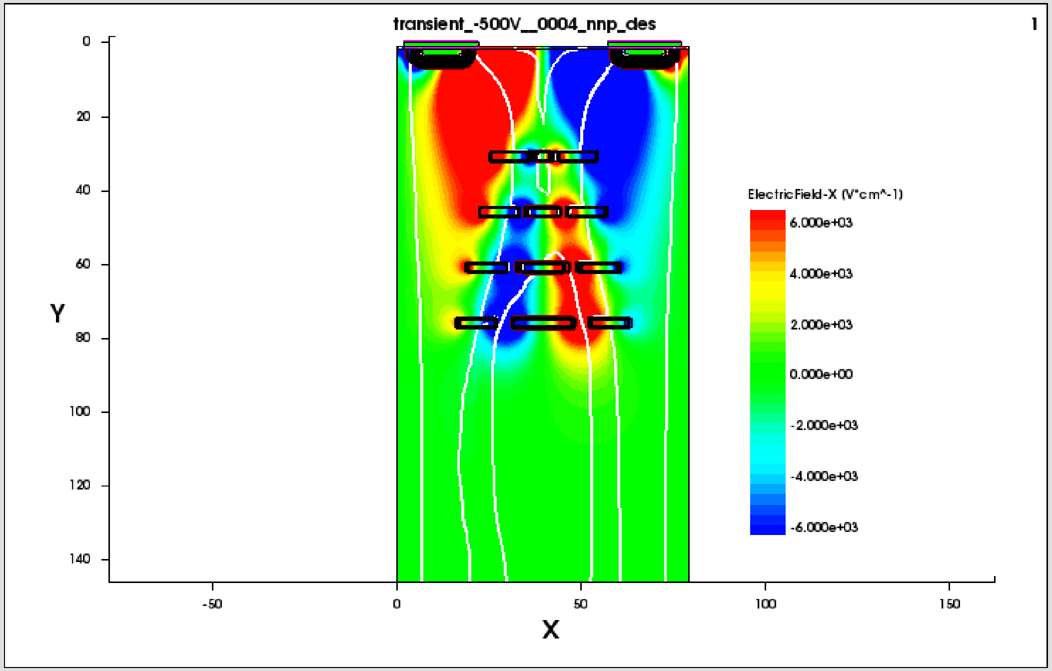
Too strong fields
at contacts?

Field X

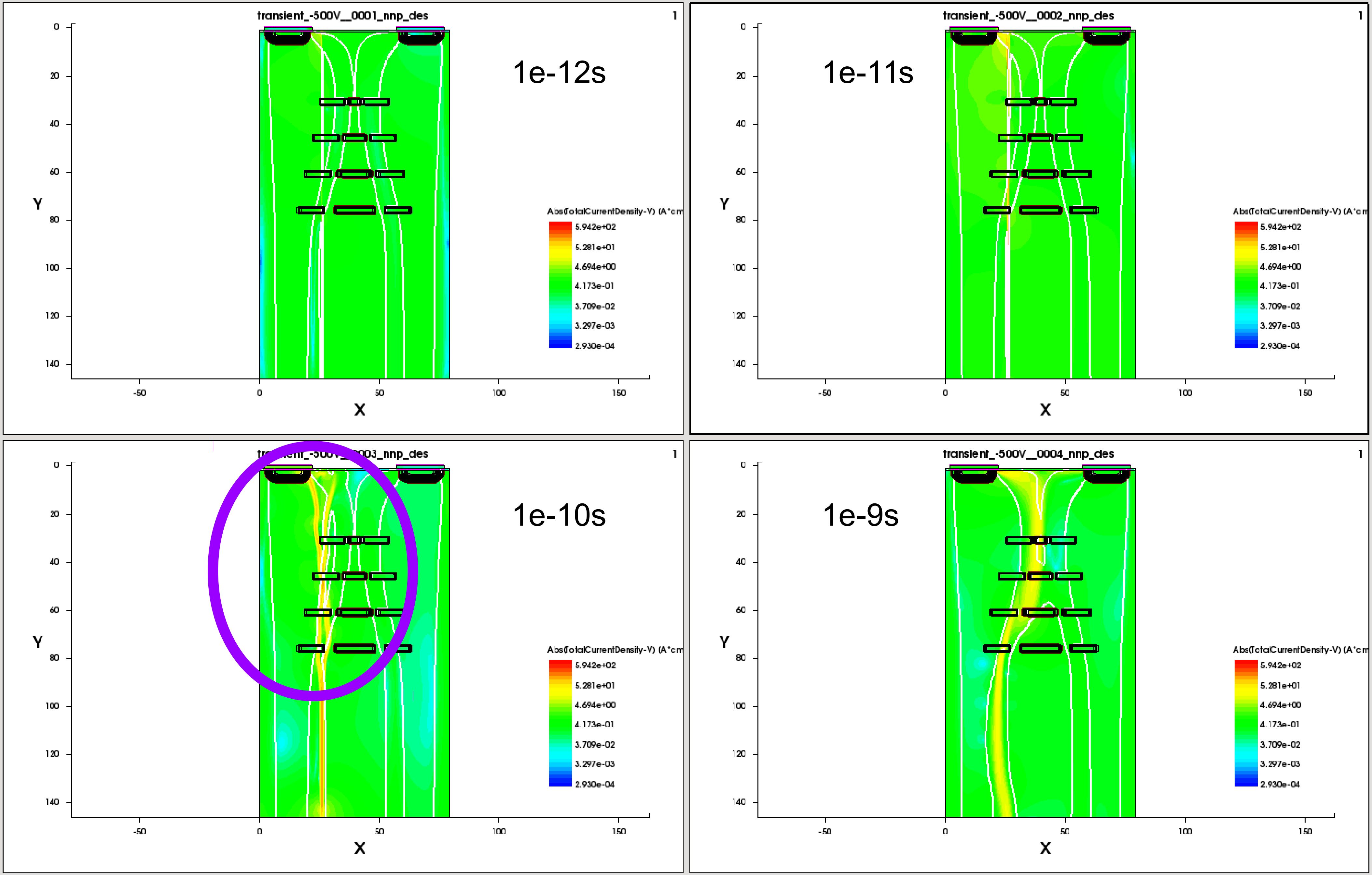

transient_-500V__0001_nnp_des
ElectricField-X (V*cm^-1)
6.000e+03
4.000e+03
2.000e+03
0.000e+00
-2.000e+03
-4.000e+03
-6.000e+03
X
Y


transient_-500V__0002_nnp_des
ElectricField-X (V*cm^-1)
6.000e+03
4.000e+03
2.000e+03
0.000e+00
-2.000e+03
-4.000e+03
-6.000e+03
X
Y

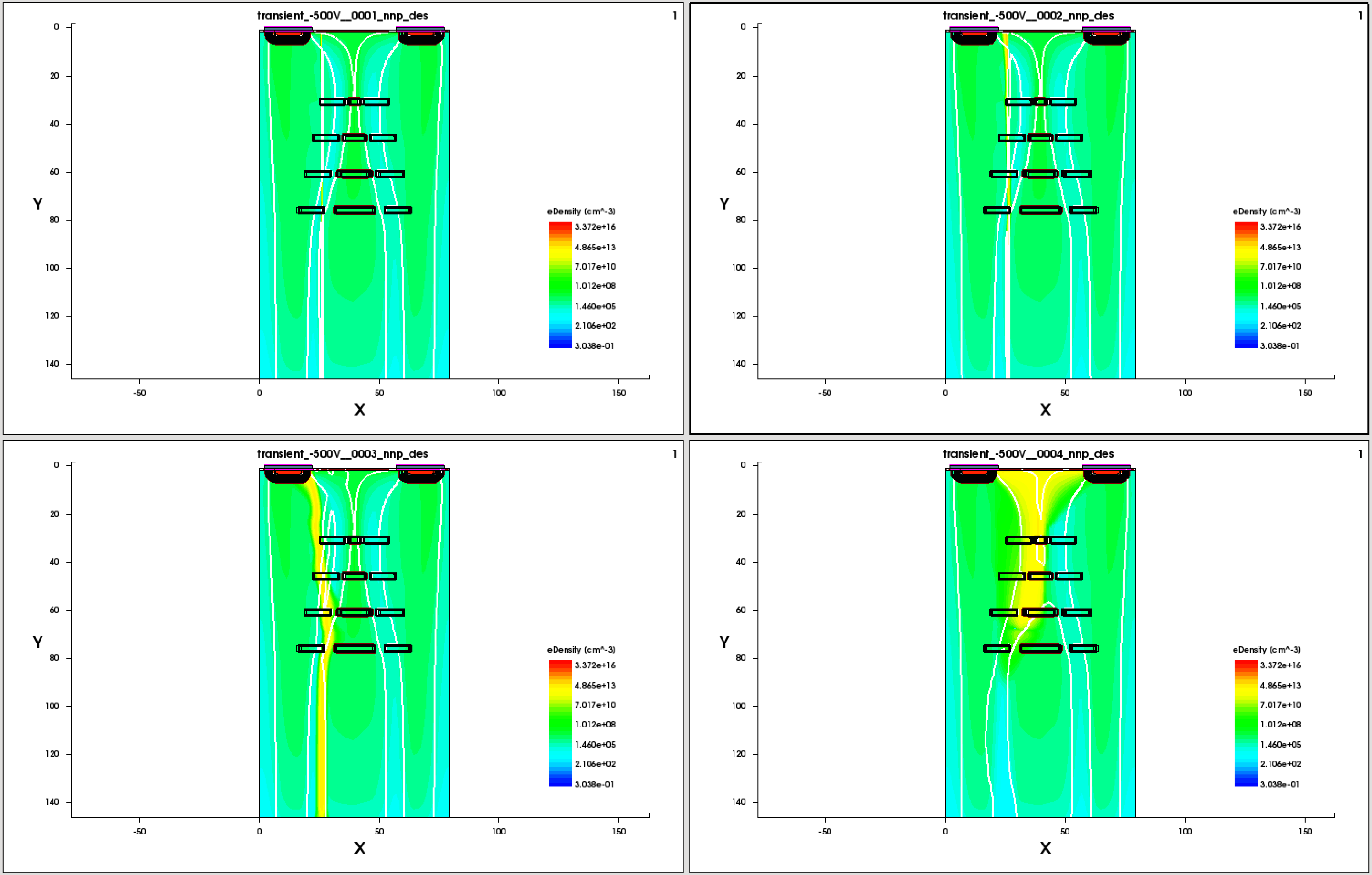

transient_-500V__0003_nnp_des
ElectricField-X (V*cm^-1)
6.000e+03
4.000e+03
2.000e+03
0.000e+00
-2.000e+03
-4.000e+03
-6.000e+03
X
Y


transient_-500V__0004_nnp_des
ElectricField-X (V*cm^-1)
6.000e+03
4.000e+03
2.000e+03
0.000e+00
-2.000e+03
-4.000e+03
-6.000e+03
X
Y

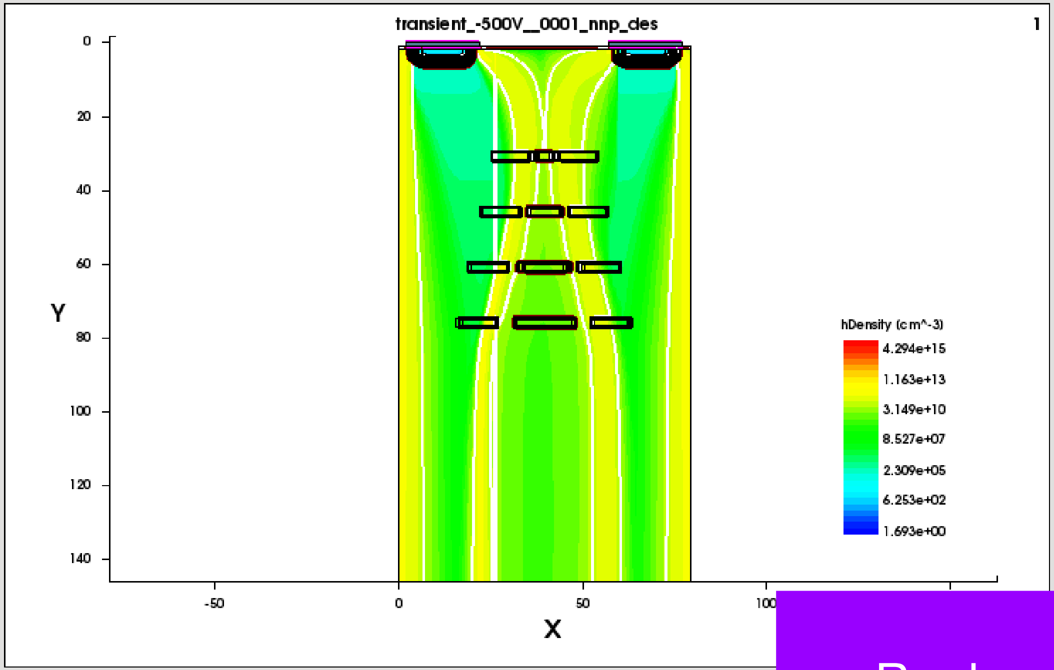
Absolute current

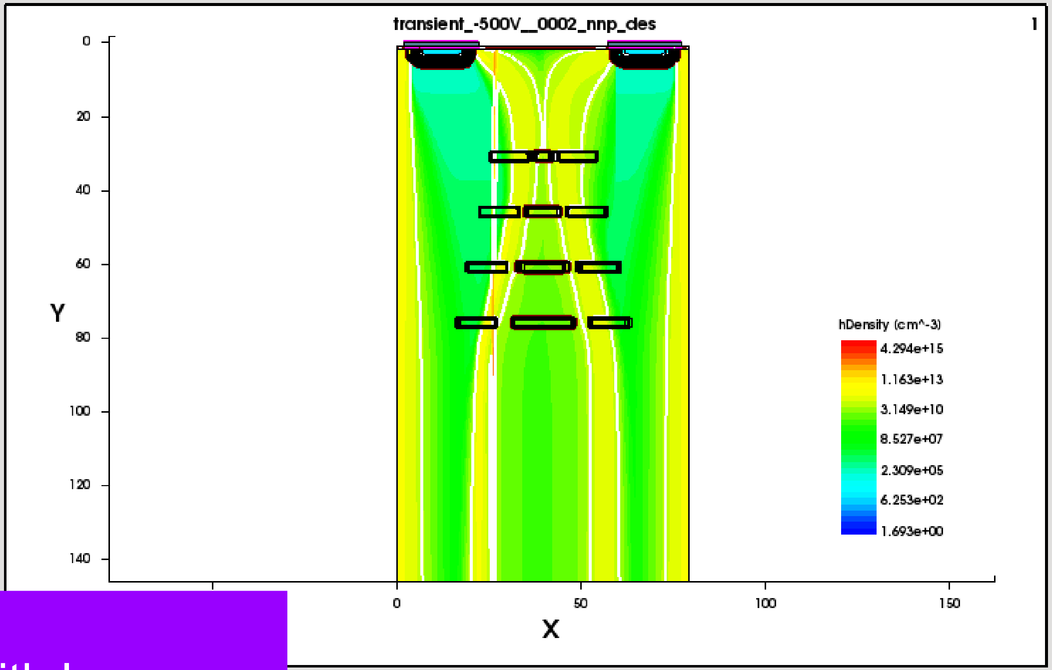


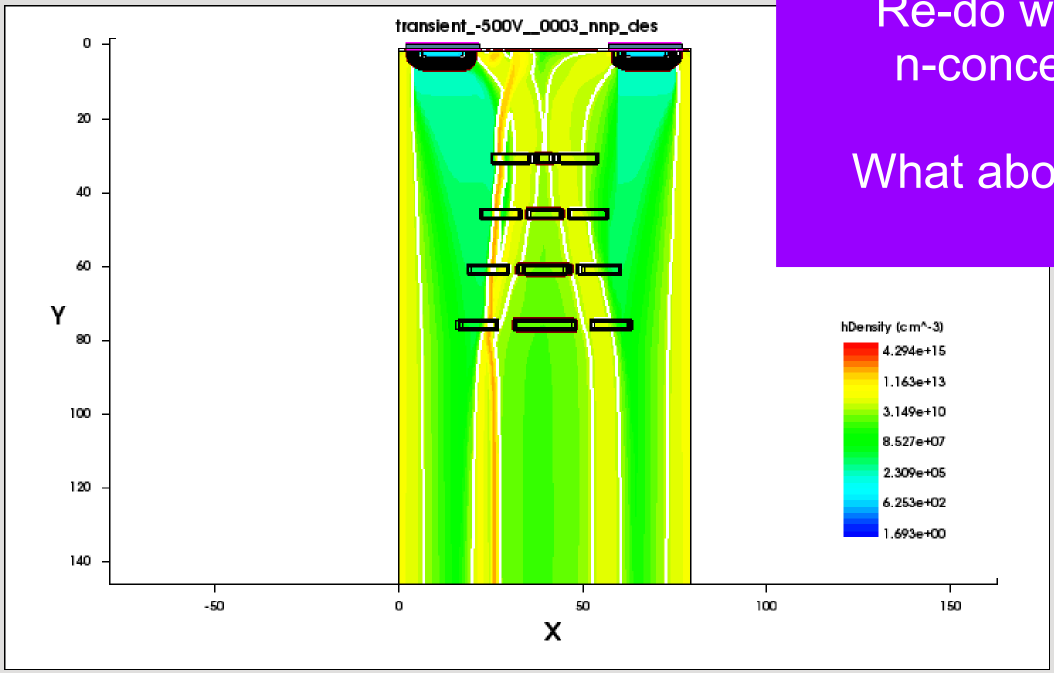
Electrons

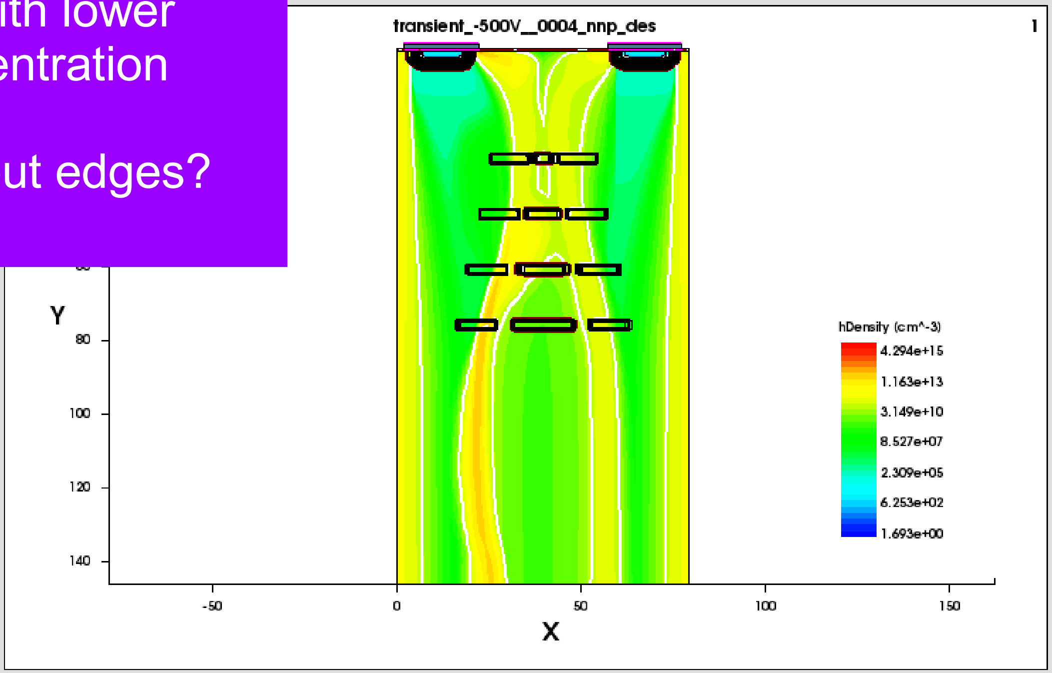

transient_-500V__0001_nnp_des
transient_-500V__0002_nnp_des
transient_-500V__0003_nnp_des
transient_-500V__0004_nnp_des
eDensity (cm^-3)
3.372e+16
4.865e+13
7.017e+10
1.012e+08
1.460e+05
2.106e+02
3.038e-01
X
Y

Holes - problematic









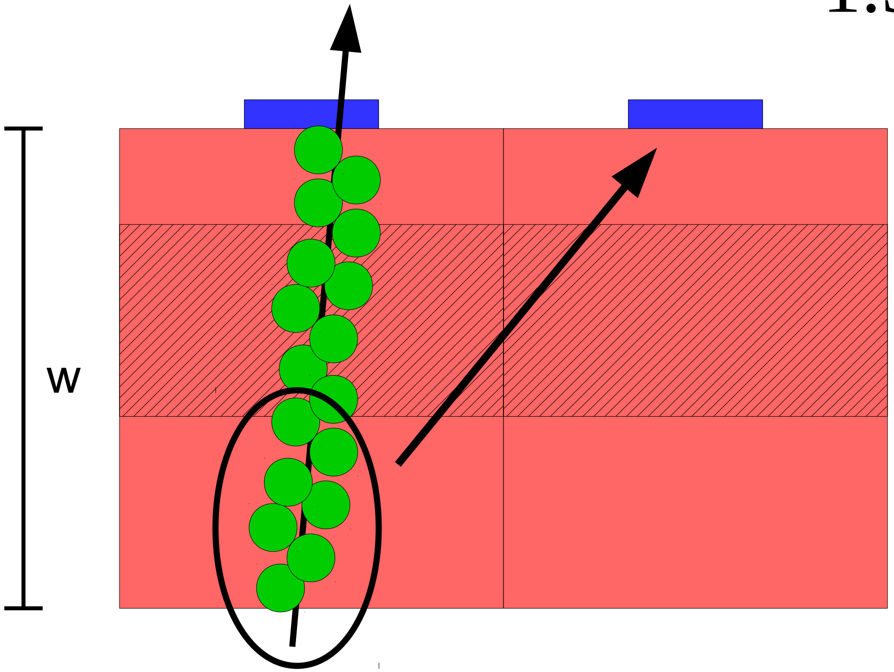
Re-do with lower n-concentration

What about edges?

Pascalian Lateral Drift Detector II

- Analogue resolution at 55 um pitch ("rule of thumb"):

$$\sigma_{analogue} \approx \frac{d}{1.5 \cdot (S/N)}$$



150 um *80 e/um = 12 ke
~5 ke in last 2/5
Try to get 50% into neighbour → 2.5ke
Use chip with ~125e noise → S/N = 20
In case of ~250e noise → S/N = 10

→ Resolution @125e is 55 / 30 = 1.8 um
@250e is 55 / 15 = 3.7 um

Production

- Let’s lave a look on the other PDF.

Pros and Cons

Pros

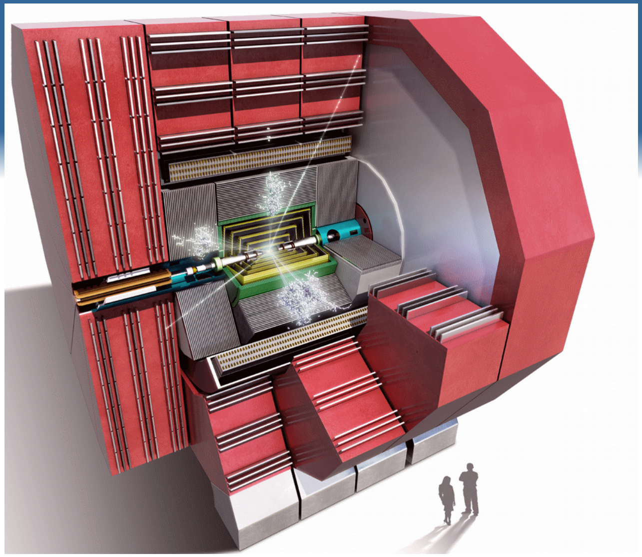
- Disentangle occupancy from resolution
- Higher resolution for same pitch size (clustersize 2)
- Higher resolution w/o B-field or tilted sensors
- Maintain fast signal (no coupling of read-out entities)

Cons:

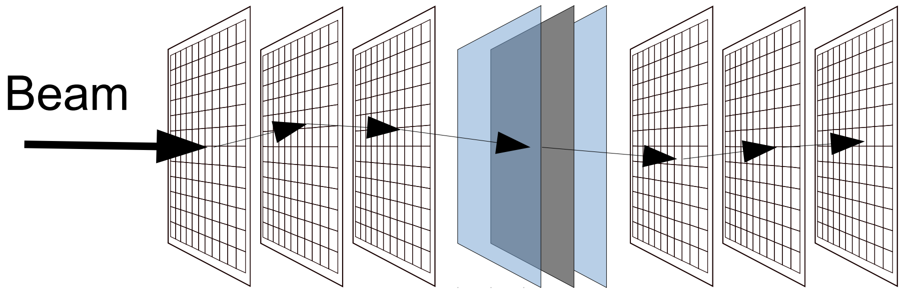
- Production will be “interesting” (no one tried this before)
- How well can one grow silicon on implanted silicon?
- Costly due to multilayer processes

Future applications

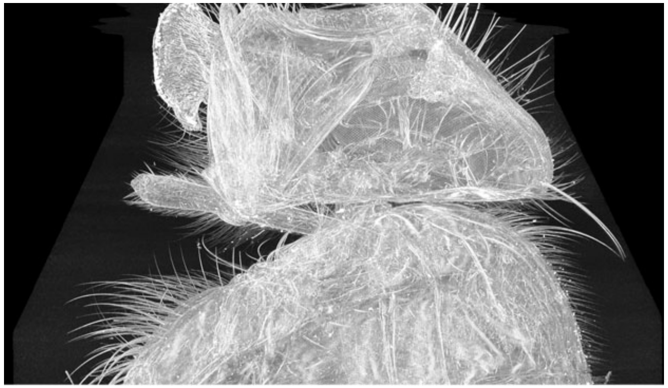
- (?) Clic / ILC



- Fast, high resolution beam telescopes:



- (?) Soft X-Ray CT of small objects with um resolution requirement



Conclusion

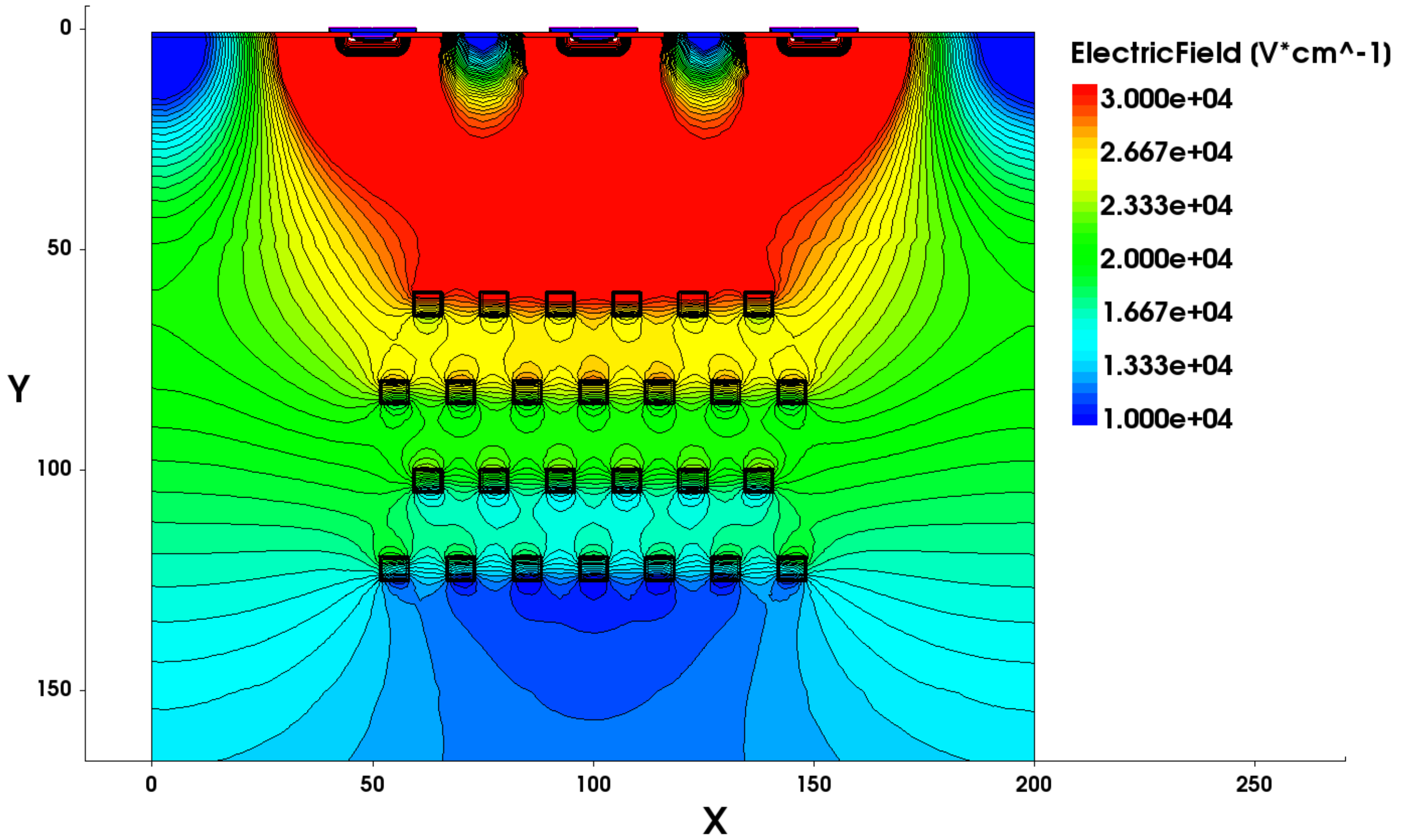
- Trying to break the small pitch dogma
- Charge sharing by lateral spread of charges
- Lateral spread enabled by charge guiding implants

- Simulations so far do not rule this idea out
- More simulations in the next months
- PIER grant for sensor production
- Patent submitted
- PhD student started with non-TCAD tool, now switches to TCAD

Back-up

TCAD Simulation

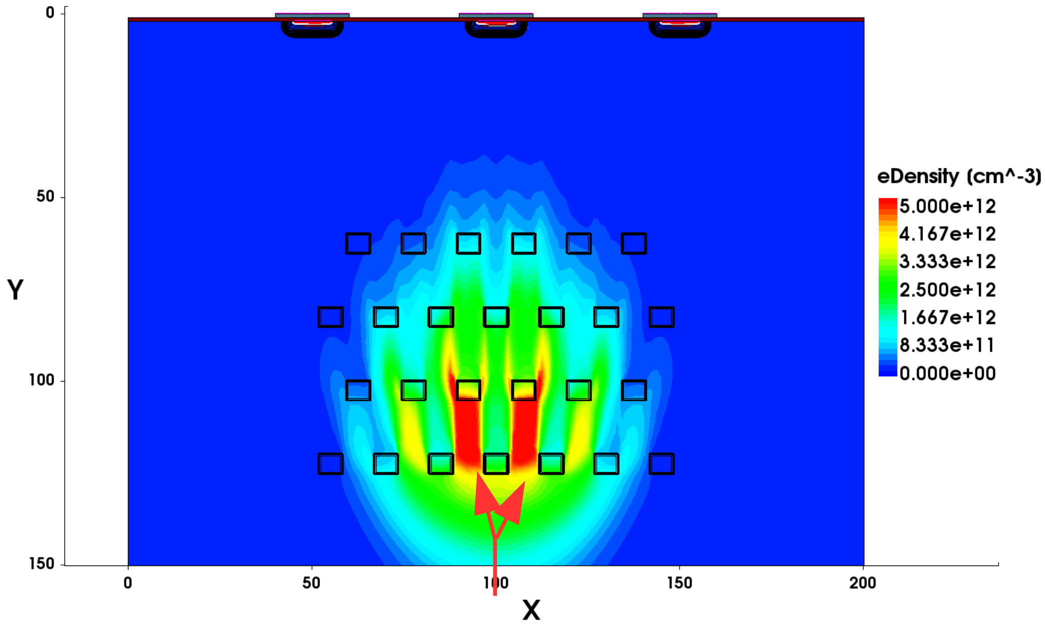
- Simulation of E-field using TCAD tools:

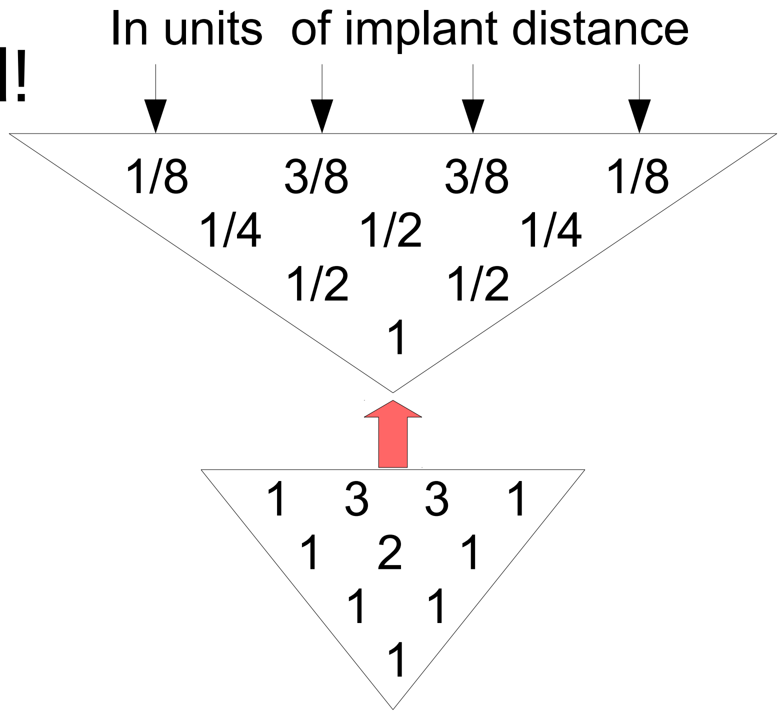


… and simulation of charge drift → next slide

Pascalian Lateral Drift Detector I

- Lateral increase of charge cloud!





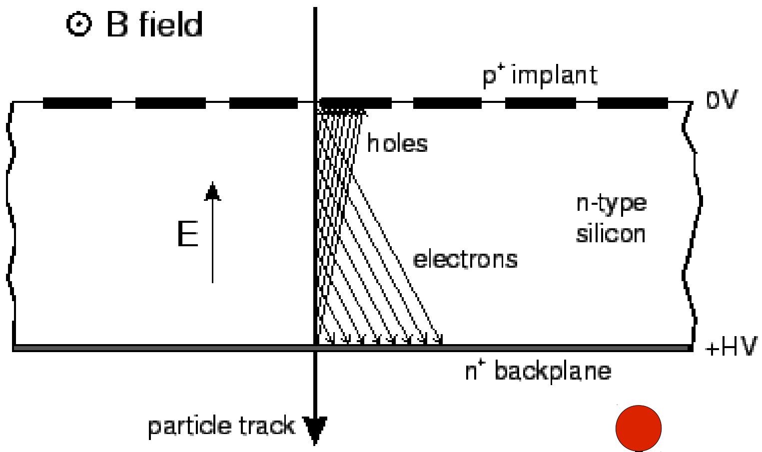
- 50-50 splitting as in normalised Pascal's triangle
- For 50 um pitch (bin. res. = 14.4 um),

what is achievable in terms of resolution?

Charge collection at low angle

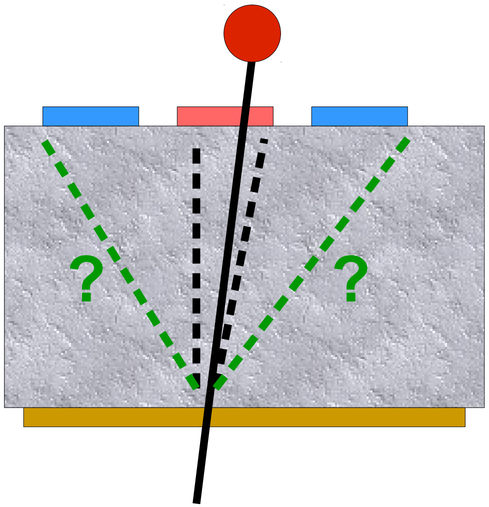
- Enable charge sharing by

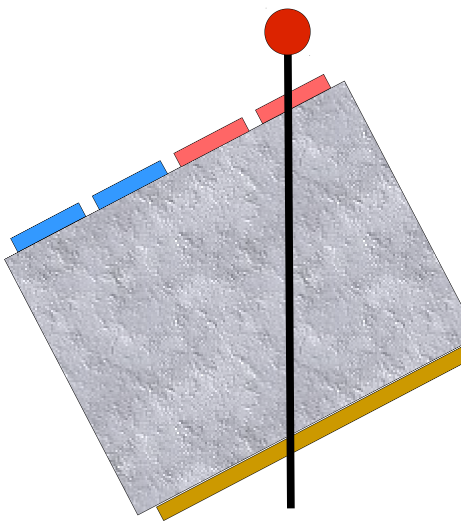
  B-field and/or tilting of sensor
  - increases effective area collecting charge
  - increases material budget in beam



- No tilt + no magnetic field:
  → Little to no charge sharing

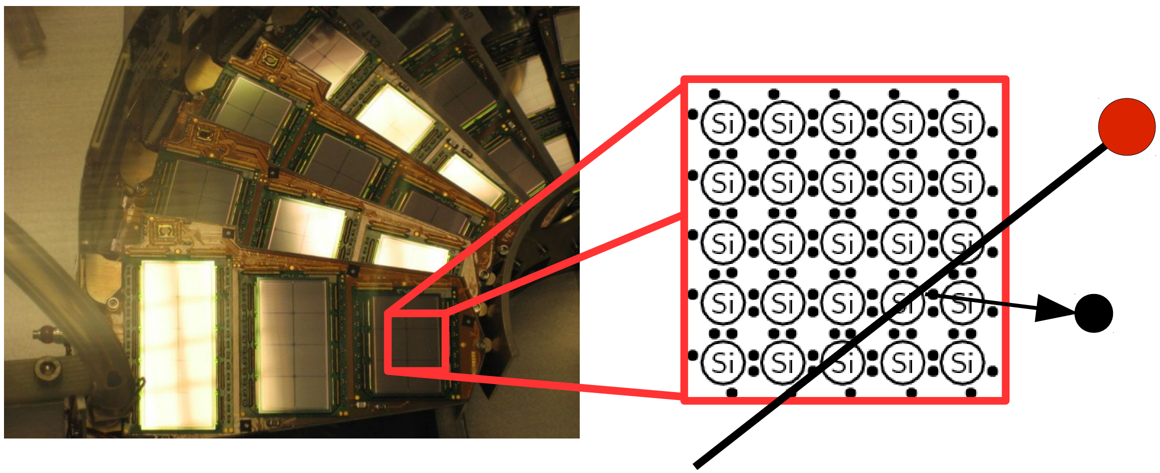
- How can charges be spread laterally, left and right?





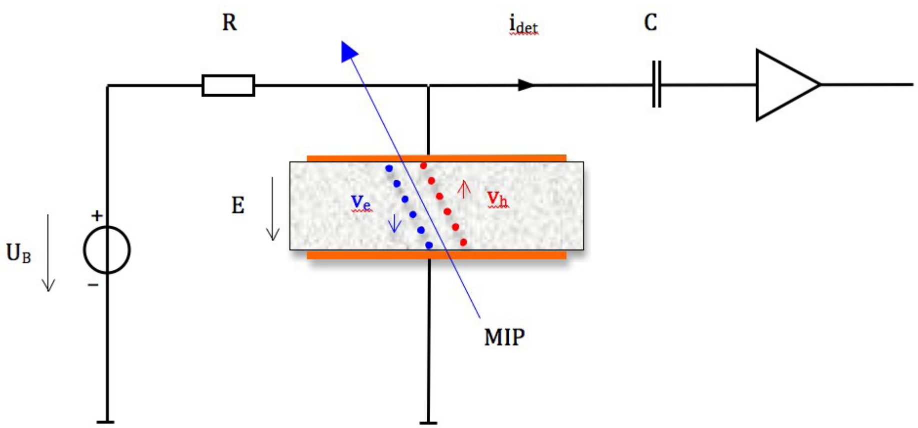
How to detect (charged) particles?

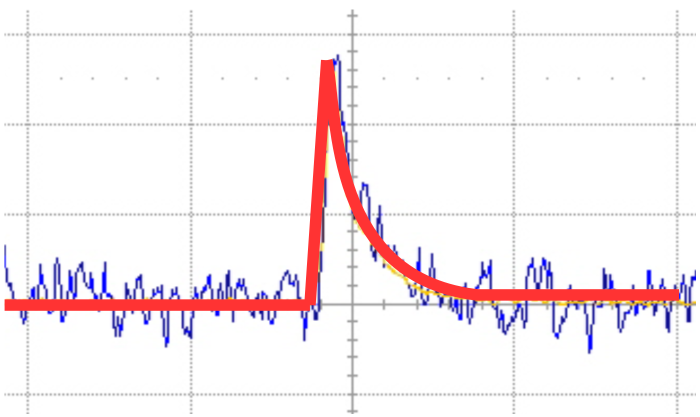
- Detect the energy transferred to the traversed medium



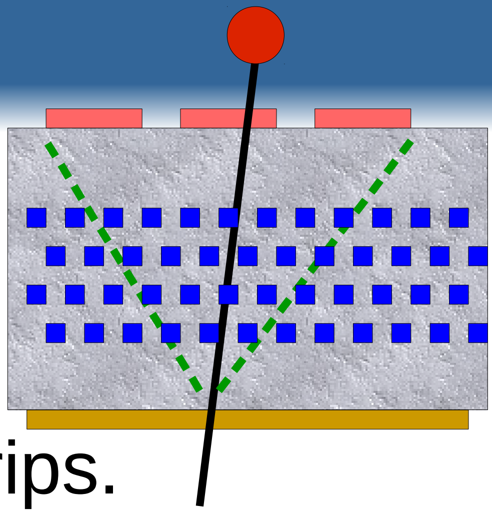
Traversing particle creates free electrons and holes that are accelerated by an external electric field

- Apply external electric field, amplify and read current





Challenges

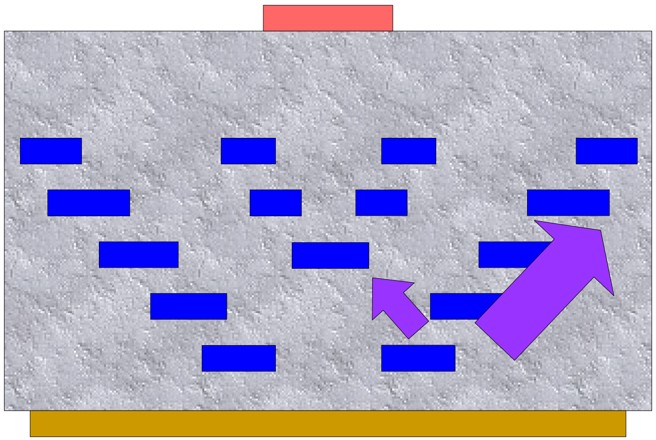


- Binomial with p = 0.5 tends towards Gauss for high n
  → $\sigma = \text{sqrt}(npq)*\delta_{imp} \approx 1*\delta_{imp}$.
  Not enough charge on the neighbouring strips.

Solution?

- Tweak position of implants:
  "directional pLAD" sensor

  → p = 4/5 towards neighbour
  → $Q_{nb} = (4/5)^6 = 0.26$



Parameters in simulation

- Structure can be modified with respect to
  - Width, depth, concentration of implants
  - distance within/to next layer
  - position/shift to neighbouring layer
  - number of layers
  - possible defined by implantation
  - …
- Parameters need to be tuned to
  - choice of read-out: pixel or strip
  - its threshold and pitch