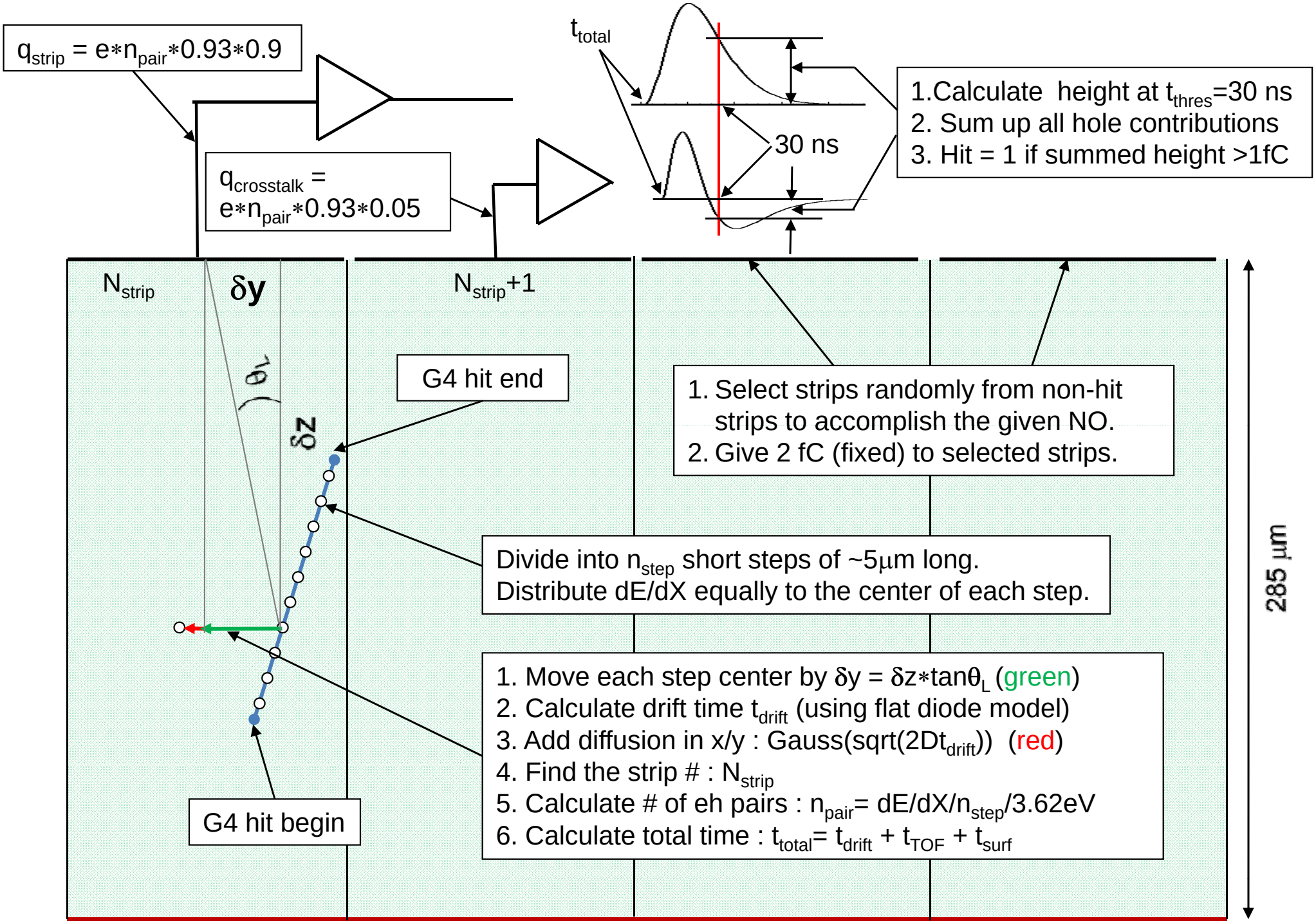
Issues of the SCT Digitization model

2nd meeting of SCT Digitization TF
2010.5.25
Taka Kondo (KEK)

1. Current SCT digitization scheme (updated)
2. Effects to be studied
3. Models of the bulk electric field
4. Timing of pulses
5. Quick summary



SCT Digitization model

Parameters user in SCT Digitization

parameters	Values	Variable names and their origins	calculation
depletionDepth $d_{depletion}$		SiLorentzAngleSvc.cxx #L457	Eq-1
meanElectricField E_{mean}		SiLorentzAngleSvc.cxx #L461	Eq-2
drift mobility μ_d	485.77 [cm^2/V/s]	SiliconProperties::calcHoleDriftMobility(T,E)	Eq-3
θ_{LA}	-3.9079^o	SiLorentzAngleSvc.cxx#L482	Eq-4
diffusion constant D	11.14 [cm^2/s]	SiliconProperties::calcDiffusionConstant	Eq-5
Drift time t_{drift}		SCT_SurfaceChargesGenerator::DriftTime(zhit)	Eq-6
Surface drift time t_{surf}		SCT_SurfaceChargesGenerator::SurfaceDriftTime(ysurf)	Eq-7
Diffusion σ		SCT_SurfaceChargesGenerator::DiffusionSigma(zhit)	Eq-8
Amplifier response a(t)		SCT_Amp::response(q, t_{thres})	Eq-9
Crosstalk function b(t)		SCT_Amp::crosstalk(q, t_{thres})	Eq-10
Correction factor C_1		SCT_Amp.cxx#L052, m_NormConstCentral	Eq-11
Correction factor C_2		SCT_Amp.cxx#L053-54, m_NormConstNeigh	Eq-12
dE/dX to eh pairs	3.62 eV	SiliconProperties.cxx #L015	
Threshold timing t_{thres}	30 ns	SCT_FrontEnd.cxx #L067	
Crosstalk factor $K_{neighbour}$	0.1	SCT_Amp.cxx#L21, m_CrossFactor2sides	
loss to backplane K_{back}	0.07	SCT_Amp.cxx#L22, m_CrossFactorBack	
Peaking time τ	21 ns	SCT_Amp.cxx#L23, m_PeakTime	

Equations used in SCT digitization

[Eq-1] $d_{depletion} = d_{thick}$, if($|V_B| < |V_D|$) $d_{depletion} = \sqrt{|V_B / V_D|}$

[Eq-2] $E_{mean} = V_B / d_{depletion}$

[Eq-3] $\mu_d = (v_s / E_C) \Big/ \left[1 + (E_{mean} / E_C)^{\beta}\right]^{1/\beta}$

[Eq-4] $\tan\theta_L = \mu_H B_{\perp}$

[Eq-5] $D = -k_B \cdot T \cdot \mu_d / e$

[Eq-6] $t_{drift} = \log\{(V_D + V_B)/(V_D + V_B - (2 \cdot z \cdot V_D / d))\} \cdot d^2 / (2 \cdot \mu_d \cdot V_D)$

[Eq-7] $t_{surf} = t_{surfmax} \cdot 8 \cdot \delta y^2$ (for $\delta y < 0.25$)

$t_{surf} = t_{surfmax} \cdot (-1 + 8\delta y - 8\delta y^2)$ (for $0.25 < \delta y < 0.5$)

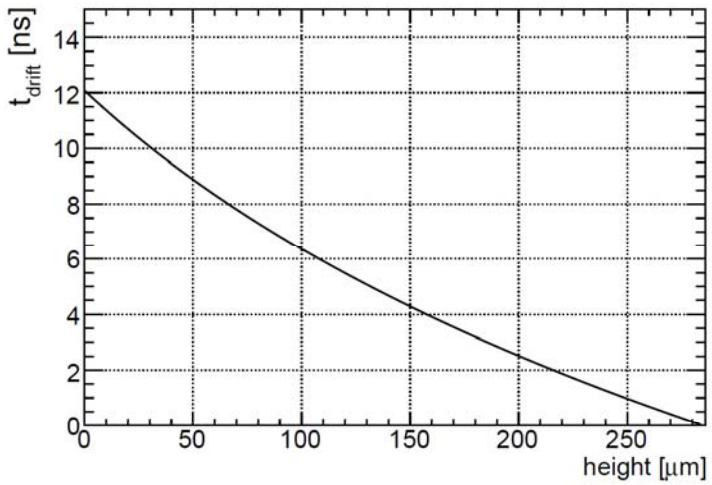
[Eq-8] $\sigma_{diffusion} = \sqrt{2 \cdot D \cdot t_{drift}}$

[Eq-9] $a(t) = C_1 (t/\tau)^3 e(-t/\tau)$

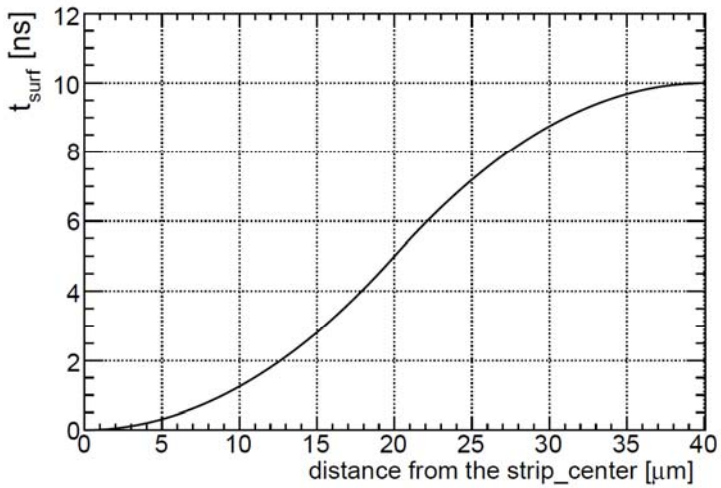
[Eq-10] $b(t) = C_2 (t/\tau)^2 \times (3 - t/\tau) \exp(-t/\tau)$

[Eq-11] $C_1 = \exp(3)/27 \times (1 - K_{neighbour}) \times (1 - K_{back})$

[Eq-12] $C_2 = \exp(3 - \sqrt{3})/(6 * (2 * \sqrt{3} - 3)) \times (K_{neighbour} / 2) \times (1 - K_{back})$



[Eq-6] t_{drift}



[Eq-7] t_{surf}

2. Effects to be studied

Electric field:

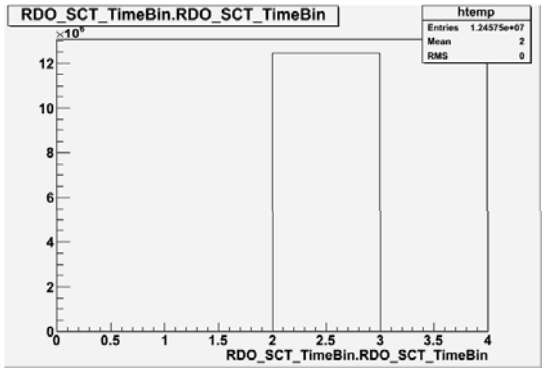
Current SCT digitization model assumes uniform Electric field in the bulk. Actual Electric field is non-uniform due to the presence of positive charges (doping concentration) in the depleted region. Also the discrete structure of strips creates distorted field shapes near the strips.

Charges:

Current SCT digitization model handles only hole charges arriving at the strip electrodes. Even before reaching the strips, charges are excited due to induction. Motion of electrons gives certain contribution in the induced charges.

Timing of threshold:

Current SCT model has a fixed time of threshold at 30 ns. This may have large effects in cluster size. There is no mechanism to give Tbin information.



MC gives always 010.

A strategy of study

(1) Construct a program to simulate the electron/hole transportation in order to estimate quantitatively how close (or how far) the current SCT digitization model is.

(2) In order to simulate as realistic as possible, the new program should include:

(a) realistic electric field distribution,

(b) effects of induced charge (instead of arriving hole charge) .

(3) Compare the results with real SCT data by optimizing contributing parameters.

(4) Find ways to improve the SCT digitization model based on the studies. For example, develop an optimized installation of Tbin information.

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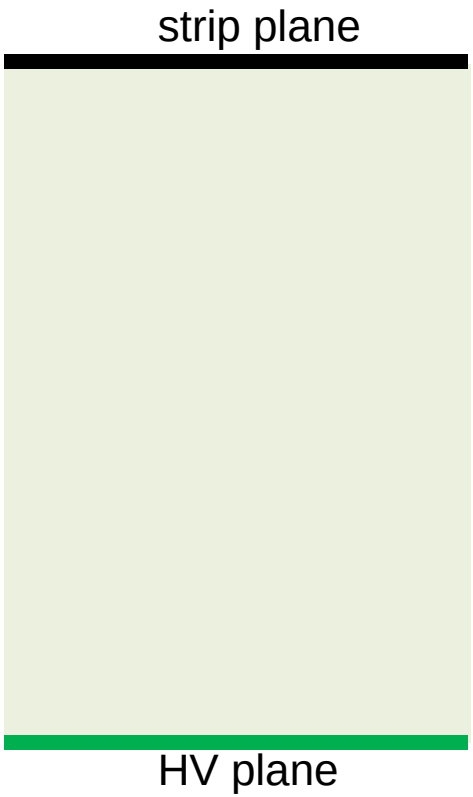
3. Models of the bulk electric field

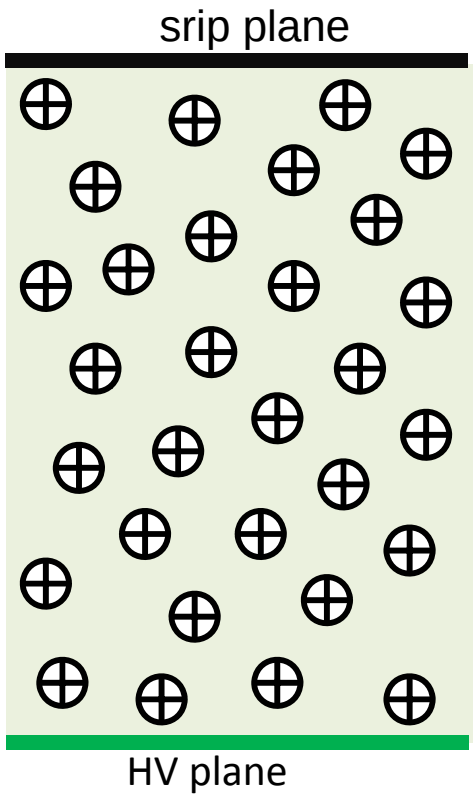
Uniform field model



Neglect depleted charges
Flat electrodes

$$E = \frac{V_B}{d}$$

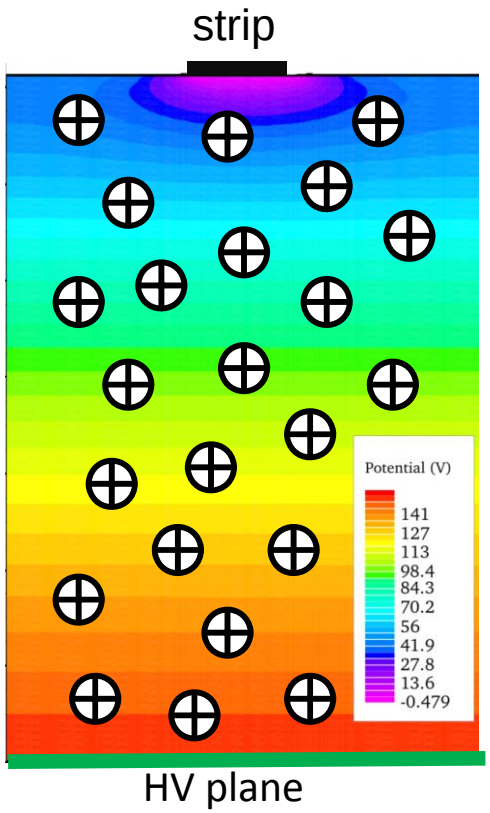
Flat diode model



Depleted charges
Flat electrodes

$$E = \frac{V_B + V_D}{d} - \frac{2 \cdot V_D \cdot y}{d^2}$$

FEM field model

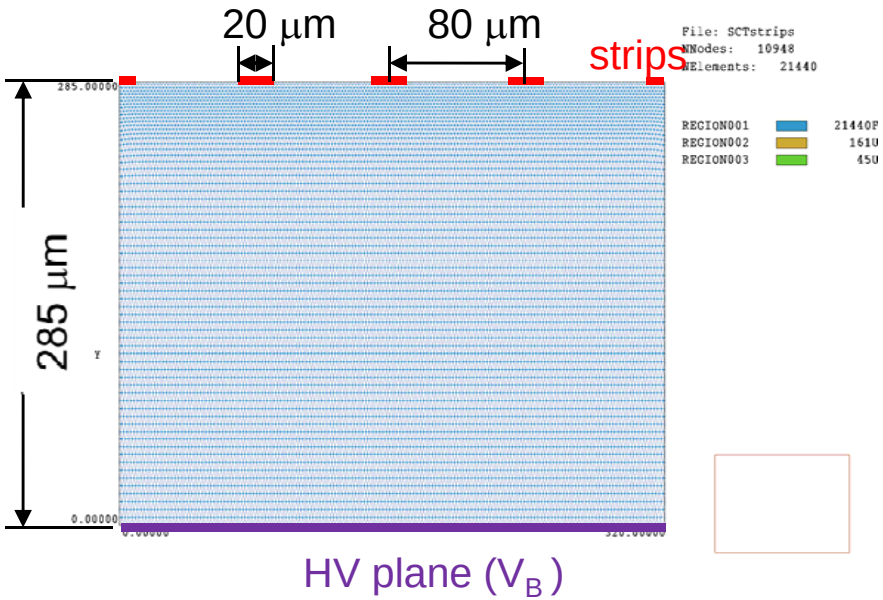


Depleted charges
Discrete strip
electrodes

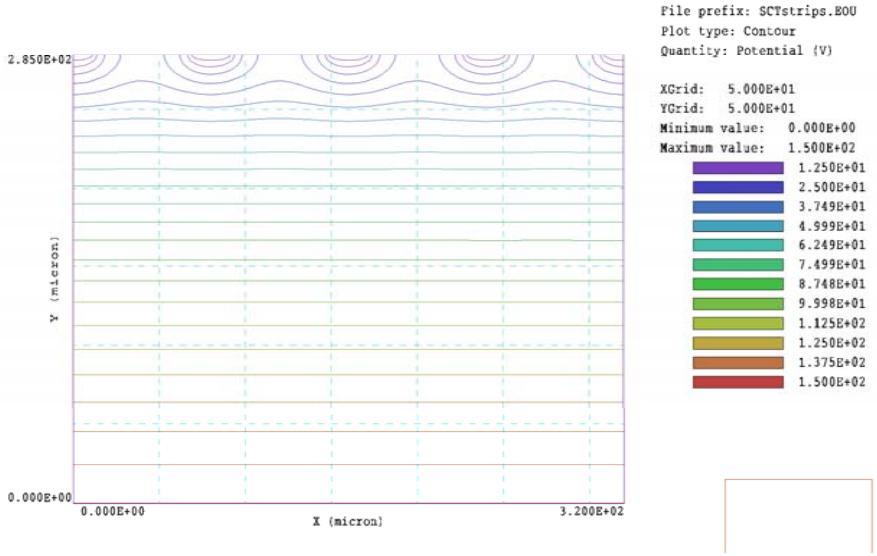
E field by FEM solution

Using 2-dimensional Finite Element Method (FEM)

(http://www.fieldp.com/sate.html, free soft)



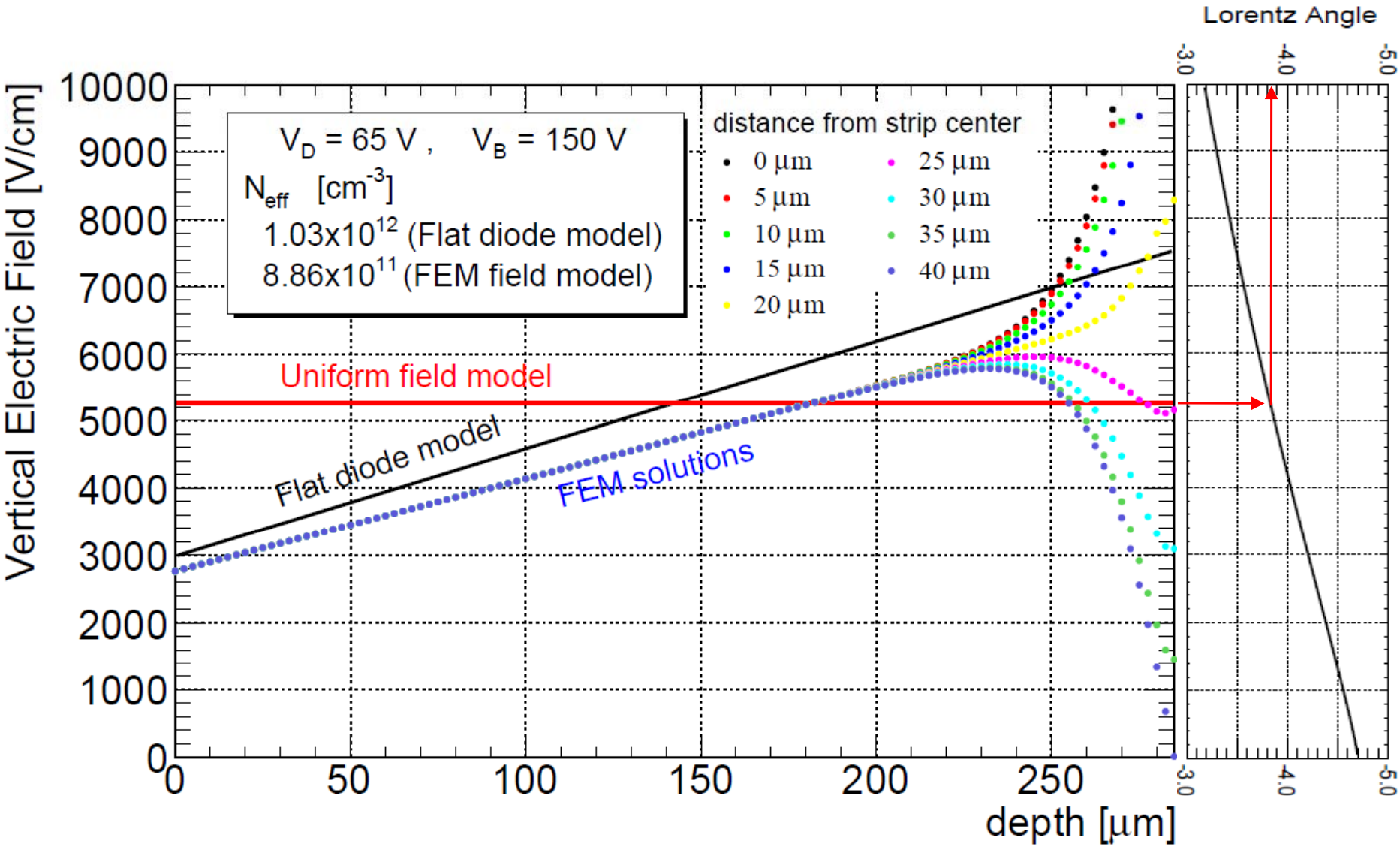
Geometry and meshes



Potential at V_B=150V

Effective doping concentration N_{eff} is adjusted to achieve the full depletion at V_B=65V.

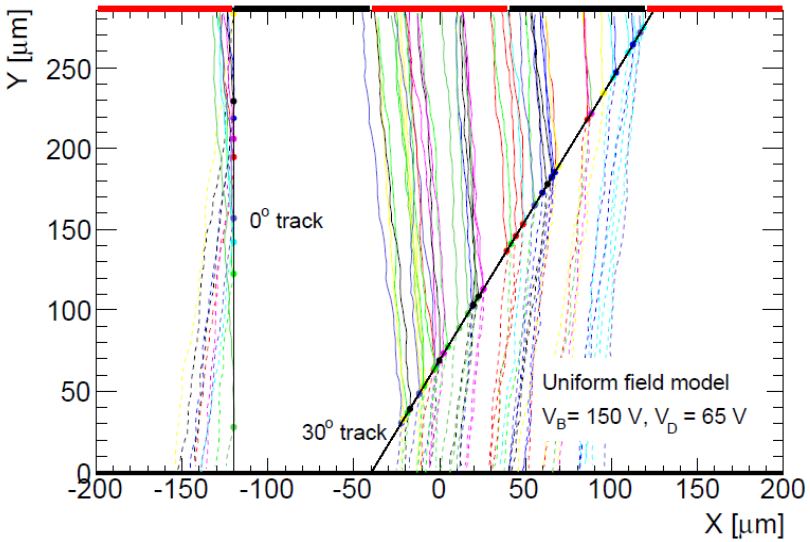
E field and Lorentz Angle at B= 2 Tesla, T = 273 K



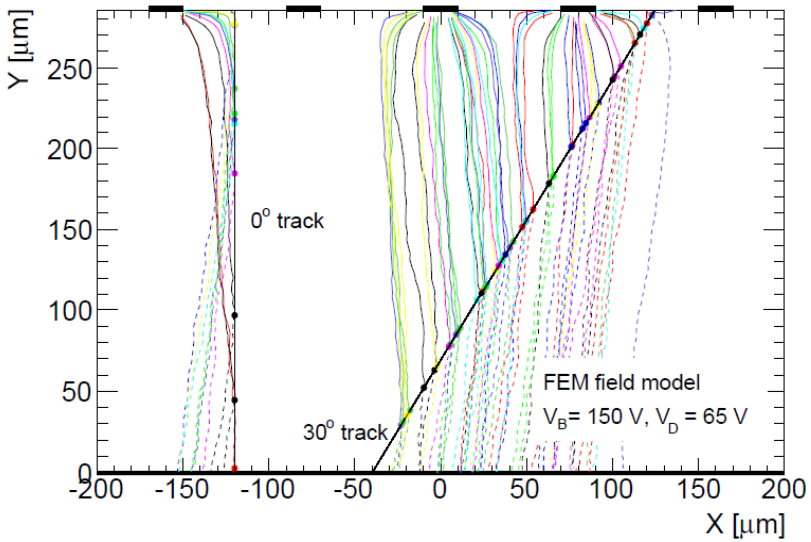
Thus the "measured LA" is a mixture of various local LA values.

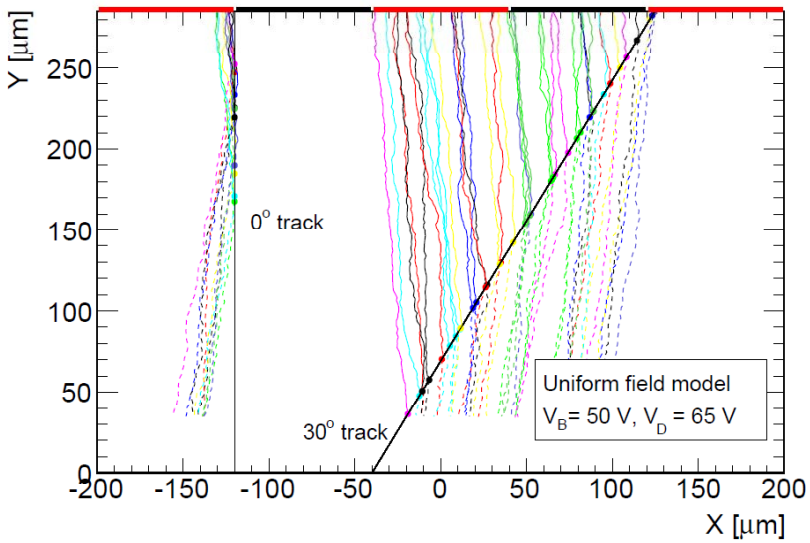
In addition, it may be affected by e/h trajectory distortion in the bulk.

Transporting electrons and holes at B = 2 Tesla

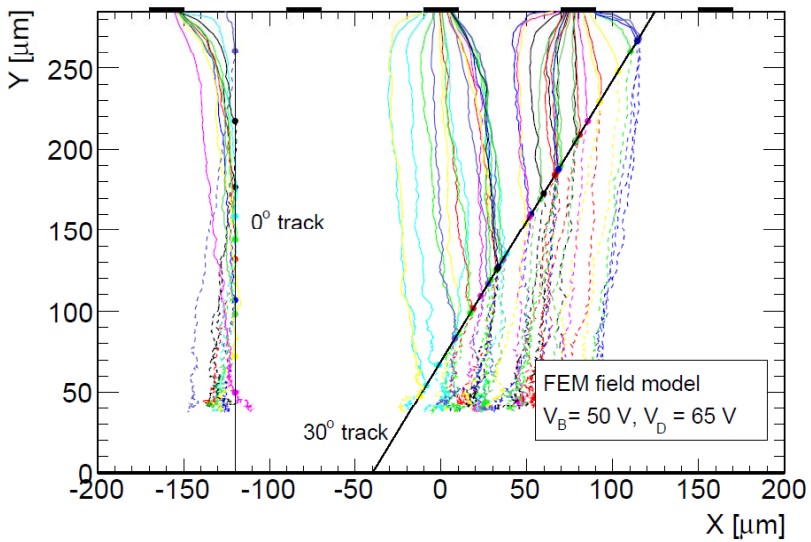


V_B=150V





V_B=50V

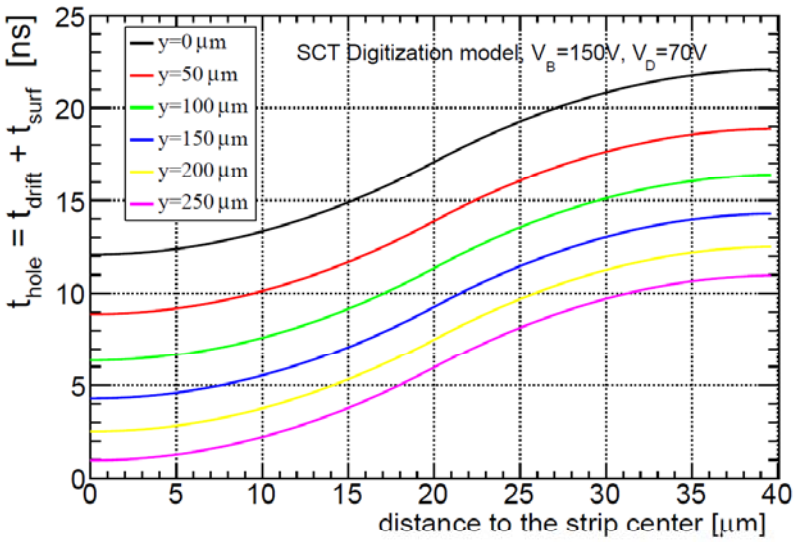


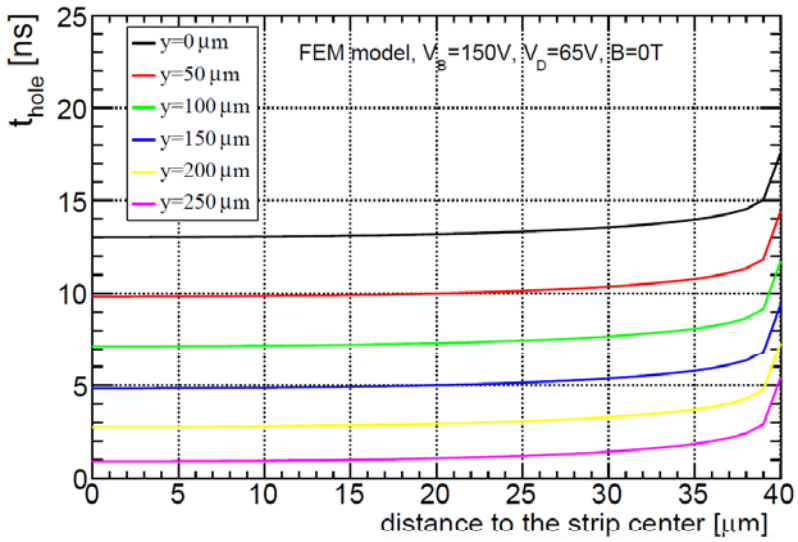
Uniform field model
used in current SCT digitization

FEM field model

4. Timing of pulses

Current SCT digitization model handles only holes arriving at the strips. The timing of arrival is calculated using certain formulae.





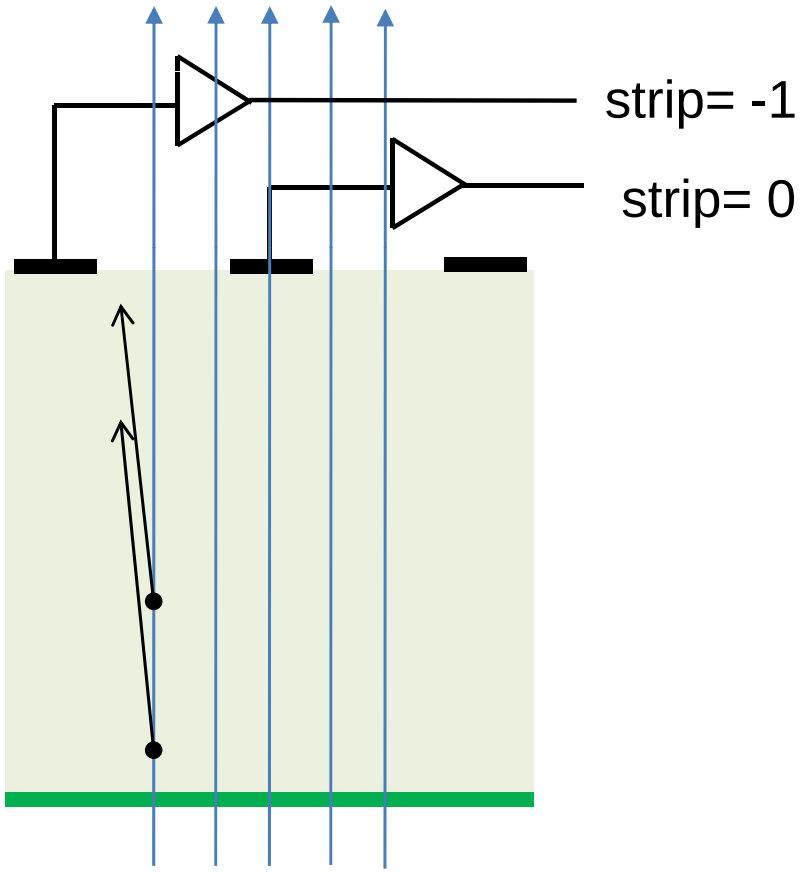
SCT digitization model

$$t_{hole} = t_{drift} + t_{surf}$$

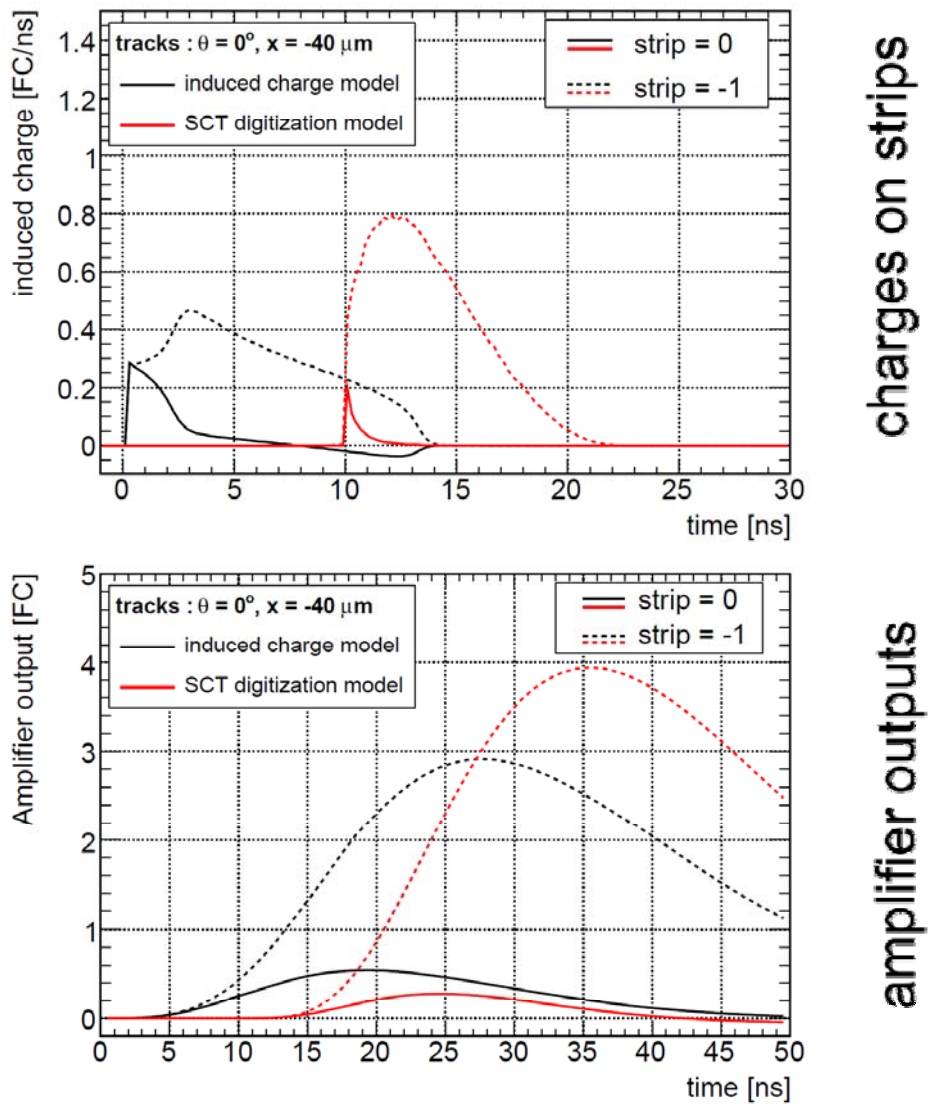
t_{hole} obtained by tracing holes in the FEM field model.

Time distribution of charges and amplifier outputs (1)

5 MIP (108 eh /μm) tracks penetrates with different incoming positions relative to the strip center.

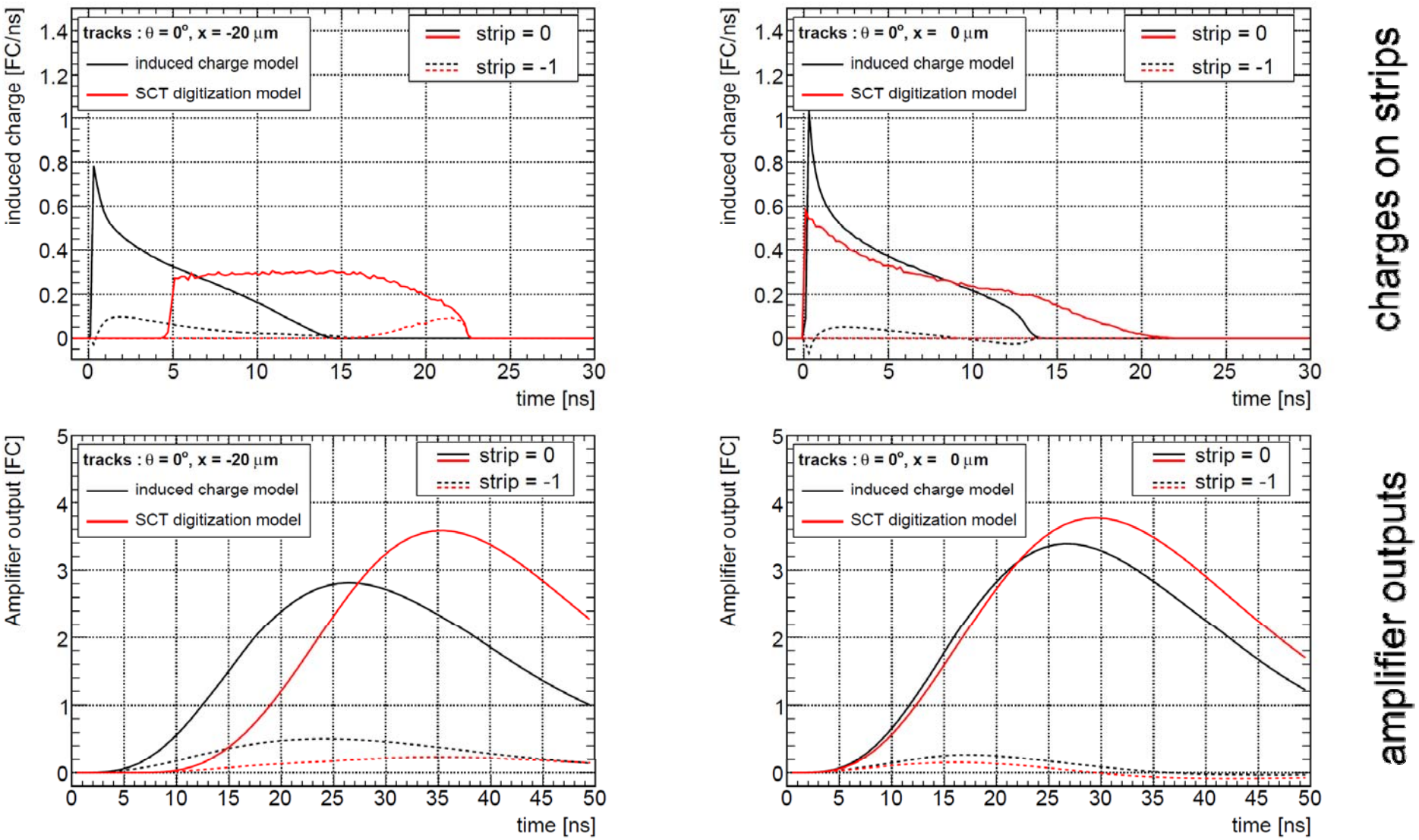


x_{in} = -40, -20, 0, 20, 40 μm



x_{in} = -40 μm

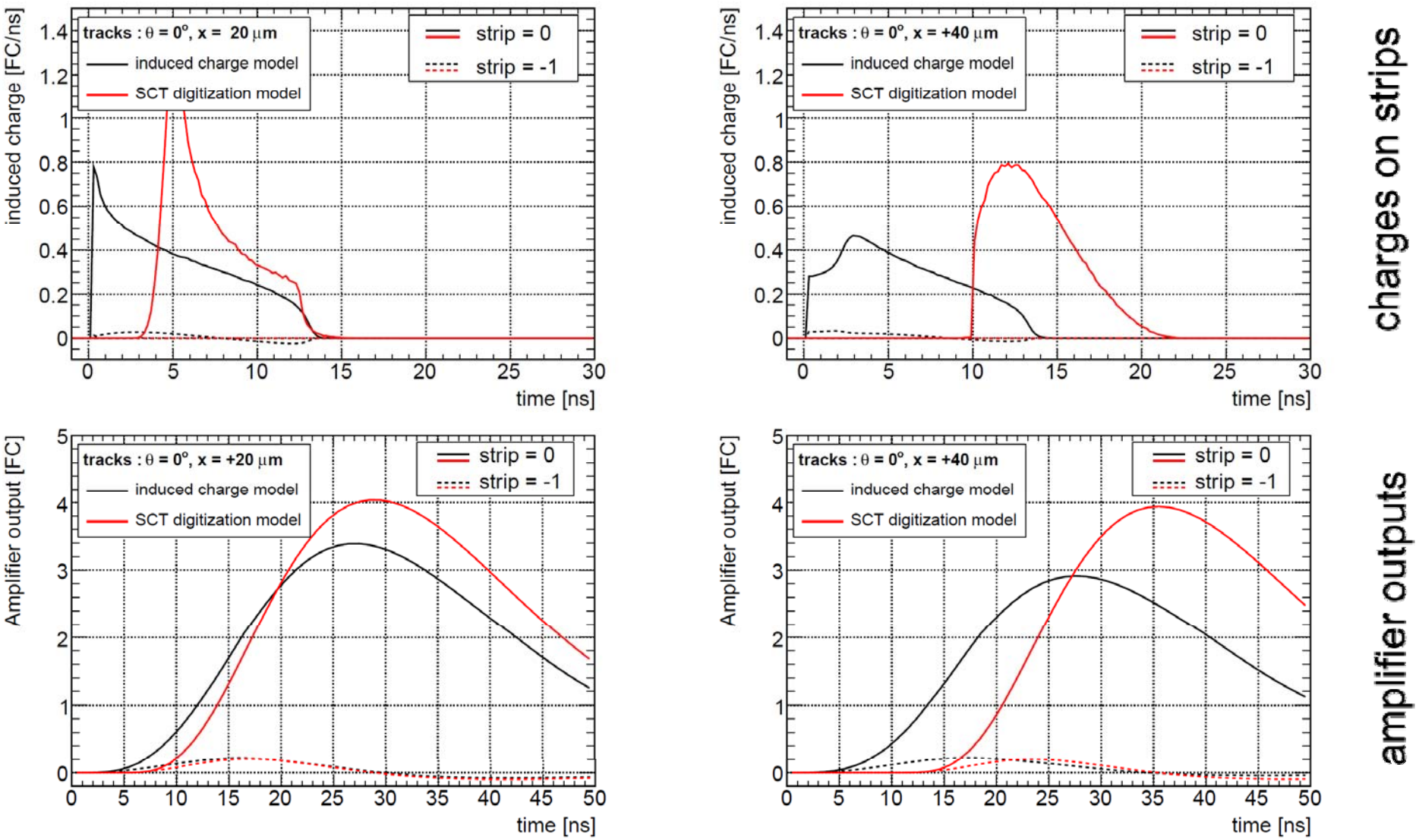
Time distribution of charges and amplifier outputs (2)



x_{in} = -20 μm

x_{in} = 0 μm

Time distribution of charges and amplifier outputs (3)



x_{in} = +20 μm

x_{in} = +40 μm

5. Quick summary

(1) The Current SCT digitization model was digested by going through the SCT digitization code, though not completed yet.

(2) Realistic electric field is calculated using 2 dimensional FEM, showing the “measured LA” is a mixture of various local LAs.

(3) An e/h transportation program is being developed including the induced charge effects.

(4) An initial comparison with the current SCT digitization model shows some (but not large) differences in time dependence as well as pulse heights.